WATERHOUSE COMMUNITY IRRIGATION DEVELOPMENT: AQUATIC ENVIRONMENTAL ASSESSMENT

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Freshwater Systems

Table of Contents

INTRODUCTION TO THIS DOCUMENT

This document details the assessment of aquatic environmental issues arising from the proposal for development of irrigation infrastructure in the catchments of the Boobyalla and Tomahawk rivers as part of the Waterhouse Community Irrigation Development (WCID) project.

Section1 ("Stage 1") reports on an initial assessment of values and issues for the WCID, and focuses largely on the areas to be inundated by the proposed dams on the Boobyalla, Tomahawk, Little Boobyalla and Wyniford rivers. The latter two rivers were subsequently excluded from further consideration within the WCID project.

Section 2 ("Stage 2") develops several of these themes further, makes a more detailed assessment of riverine aquatic environment values and issues, and assesses environmental flow requirements for the WCID in the Boobyalla and Tomahawk rivers.

SECTION 1:

STAGE 1 AQUATIC ENVIRONMENTAL SCREENING, ISSUES AND RISKS FOR THE WATERHOUSE IRRIGATION PROJECT

1. BACKGROUND

The ecology of the Wyniford, Little Boobyalla, Boobyalla and Tomahawk rivers and associated wetlands, both upstream and downstream of the proposed reservoir sites, was initially assessed in Stage 1 of this project by reviewing available literature and data on these and similar streams in the area. An initial inspection of sample sites was undertaken to assess existing ecosystem values.

The initial assessment included:

- An exploratory survey and inspection of aquatic habitats, plants and fish in the dam and reservoir (storage) ‘footprint’ areas, as well as downstream;

- Identification of key areas/habitats which may require specific environmental flow requirements and/or detailed assessment;

- Assessment of the likelihood of the presence of aquatic animal species listed under the Tasmanian *Threatened Species Protection Act* (TSP 1995) and the Federal *Environmental Protection and Biodiversity Conservation Act* (EPBC 1999);

- A broad assessment of likely environmental risks and environmental flow requirements (the latter using the DPIWE ‘desktop approach’ for minimum environmental flows);

- Identification of environmental issues associated with ‘Critical Review Points’ within the project.

2. METHODS

2.1 Field Inspection and Assessment

All four rivers in the vicinity of the dam sites were visited in early November 2001. A general inspection of the river was conducted at each location, and several sites were also sampled intensively for fish and macroinvertebrates, as well as having their habitats described and specimens of aquatic plants collected.

All sampled sites were electrofished using a backpack shocker for a standard 20 minute period (battery time). All fish were identified and counted and selected fish were also measured.

Sweep, kick and surber samples were taken of macroinvertebrates in a variety of habitats at all sampled sites. These are yet to be worked up (in Stage 2). Adult caddis and mayflies were observed and several specimens collected. Frogs were also identified where calls were heard.

Locations of sampled sites are listed in Table 2.1 below.

Table 2.1: Locations of Sites Intensively Sampled

River	Site	Comment	Easting	Northing
Wyniford	W1	Upstream from Argus Bridge	580500	5450750
	W2	Nr. Southern Cross Ck	580575	5449000
	W3	Trib. on 3 Notch Rd	581075	5450575
L. Boobyalla	LB1	U/s of Monarch Dam storage	547500	5460000
	LB2	Walpole Ck u/s & d/s dam outlfow	574150	5462100
Boobyalla	B1	600m u/s of dam site	568987	5461066
	B2	Off gravel-pit track from Banca Rd	569600	5458600
Tomahawk	T1	Tomahawk R., 'mid-storage'	563655	5460836
	T2	L. Tomahawk R.	563349	5460251

Note: grid references refer to the upstream end of each sampled reach.

2.2 Threatened Species Assessment

The Tasmanian Parks and Wildlife Service (DPIWE) GTSPOT database was inspected for the presence of threatened aquatic species in the areas of the dams and downstream. In addition, other collections from the area and related reports and publications were examined to assess the likely presence of rare species or species listed under the Tasmanian *Threatened Species Protection Act* (TSP) Act (1995) or the national *Environmental Protection and Biodiversity Conservation* (EPBC) Act (1999).

3. RESULTS AND ASSESSMENT

3.1 Wyniford River

3.1.1 Channel and habitats

The channel is dominated by highly mobile granitic sands, which form substantial bar and dune deposits throughout the lower and middle reaches. The channel is controlled by large granite boulder-bedrock formations that are frequently associated with pools. There is a substantial quantity of organic material, both as surficial deposits in backwaters of organic silts and debris (coarse particulate organic matter or CPOM), and as branch and log (snag) material.

The Wyniford is a blackwater river with a low conductivity (65 and 52 microS/cm at W1 and W2 respectively, on 7/11/01).

3.1.2 Biota

Fish

The river is almost devoid of finfish, containing moderate numbers of shortfin eel and juvenile lampreys. Only one brown trout was captured at the upper site despite intensive electrofishing, indicating a very low abundance. No native galaxiid fishes were captured or observed during this survey. No blackfish were captured associated with snag deposits, leafpacks or other CPOM. Brown trout have also been captured previously (1999/00) at two sites upstream of the abandoned mine, also in low densities (W Elvey, unpub. data). No other fish species were caught during these surveys.

Macroinvertebrates

The macroinvertebrate fauna on the dominant sand, boulder substrates is dominated by mayflies, caddis and amphipods. Large mobile oeniscigastrid and baetid mayflies and small diving beetles were highly abundant, indicating that the pressure from fish predation in this system is very low. The snag fauna is dominated by leptophlebiid mayflies and beetles. Overall, the fauna is abundant and indicative of both the dominant habitat types and of good water quality.

The upper river sections in the vicinity of sample site W2 were steeper and contained areas of granite cobble riffle with associated moss habitat. Active searching in these habitats, as well as on logs, failed to reveal the presence of any native freshwater snails, including the ecologically vulnerable *Beddomeia* genus.

Macrophytes

There were no significant stands of macrophytes in the main river channel. Site W3 contained extensive areas of macrophytes, dominated by the emergent *Eleocharis*.

Other records

No frogs were calling associated with the main channel. Site W3 included a wetland-creek complex, at which five species of frogs were identified: *Crinia tasmaniensis* (Tasmanian froglet), *C. signifera* (common froglet), *Geocrinia laevis* (smooth frog), *Lymnodynastes dumerili* (banjo frog) and *Litoria ewingi* (brown tree frog).

The IFS fish database, the PWSW GTSPOT database, other publications and raw data from previously conducted surveys in the area were reviewed. There are no previous fish records from the Wyniford River, and only *Astacopsis gouldi* has been recorded from the area (see below).

Threatened species

A single listed species is known to occur within the Wyniford and upper Ringarooma catchments – *Astacopsis gouldi*, the giant freshwater lobster. This species is listed under both relevant State and National acts (TSP and EPBC Acts) as vulnerable.

3.1.3 Issues and risks

There appear to be no significant threatened species issues in the Wyniford River dam area, or downstream in the Wyniford or in the reaches of the Ringarooma River just downstream of the Wyniford junction. More intensive surveys may be required to further confirm this, but it is deemed unlikely that a threatened aquatic species issue exists for this site.

All species observed during the survey were widespread and common. Further processing of survey samples is required to confirm this for the macroinvertebrates however (to be conducted under Stage 2 if required).

The proposed reservoir is apparently impacted by historical mine workings within this area and upstream which have caused some localised erosion. It is difficult to gauge the degree of impact from these workings on sediment delivery to the river. However, the instream fauna is in good condition and abundant and there is therefore no evidence of ongoing impacts on water quality of sufficient severity to cause major changes to the instream fauna.

The primary issue associated with the proposed dam is the presence of the *Eleocharis* wetland on the eastern tributary, which falls within the proposed inundation area. This wetland contains a diversity of aquatic plant species and is unusual in that it sustains populations of at least five species of frogs. While none of these are listed species, their co-occurrence at this one small location is relatively unusual at the state level. Also, this wetland is isolated within the catchment and represents a locally important focus for wetland species. We strongly recommend that any development at this site be limited so as not to inundate this wetland or affect its hydrology.

3.2 Little Boobyalla

3.2.1 Monarch dam and habitats

This storage is formed by the historical dam which, despite signs of leakage and substantial erosion of the spillway, is maintained with varying levels throughout the year. It is a degraded habitat with few natural features and was not surveyed in detail as part of this assessment.

3.2.2 Channel and habitats

The channel upstream of the Monarch storage is apparently typical of many of the medium sized creeks and streams of the area. It has an incised primary channel linked to several secondary channels and numerous backwaters, flood ways and wetland-swamp complexes. These are all sustained throughout the year and over long periods, as evidenced by the presence of distinct complex vegetation communities and fish populations with a wide range of size (and hence age) classes.

The primary channel is well shaded, meandering with a predominantly sand-gravel bed (with silt in backwaters), substantial woody debris, some instream macrophytes and dense overhanging vegetation.

The secondary channels and associated swamp-backwaters are intermittently deep (0.5 – 1.3 m) and shallow (< 10 cm), with much dense aquatic vegetation

Most of the habitat and channel features observed in the Little Boobyalla within the proposed dam area were also observed in Walpole Creek, a major tributary to the Little Boobyalla which is joined by the Monarch Dam spillway flows at the western end of the dam.

The Little Boobyalla is a clear, blackwater stream with moderate conductivity (132 micros/cm on 8/11/2001), comparable to that in Walpole Creek (156 microS/cm).

3.2.3 Biota

Fish

Four fish species were recorded during the survey in the following order of decreasing abundance – shortfin eel (*Anguilla australis*), mountain galaxias (*Galaxias truttaceus*), pygmy perch (*Nannoperca fluviatilis*) and the common jollytail (*Galaxias maculatus*). *A. australis* was highly abundant in the backwater swamps, with a wide range of size classes, and a particularly high abundance of elvers. *G. truttaceus* and *G. maculatus* were also represented by a range of size classes with several young of the year. This indicates that migration of these species is relatively unimpeded by the presence of the Monarch dam and its spillway.

All these species of fish were also present downstream of Monarch Dam. The sandy flathead (*Pseudaphritis urvillii*) was abundant downstream of the dam but absent upstream of the storage. It appears that the spillway and/or storage itself pose a barrier to upstream movement of this species. All of these fish species were also observed in Walpole Creek.

Macroinvertebrates

The macroinvertebrate fauna was characterised by mayflies and caddis associated with woody debris. Adult caddis were abundant during the survey and five species were recognised. At least one species of the burrowing crayfish *Engaeus* was present in the backwater-swam areas upstream of the Monarch storage. This was subsequently identified as *E. tayatea*, a species common and widespread in the area. A similar macroinvertebrate fauna was also observed in Walpole Creek.

Active searching for aquatic snails on rocks, logs and in moss failed to find any species from the ecologically vulnerable *Beddomeia* genus.

Two species of frog were identified during the survey from within the proposed dam area and downstream of the Monarch Dam – *Crinia tasmaniensis* and *C. signifera* – neither of which are rare or listed species.

Macrophytes

There were significant stands of macrophytes in the backwater swamps, dominated by *Triglochin striata*, *T. procera* and *Scirpus fluitans*, with occasional stands of *Alisma platago-aquatica* (water plantain). These macrophyte communities were also observed in Walpole Creek.

Other records

The IFS fish database, the PWS GTSPOT database, other publications and raw data from previously conducted surveys in the area were reviewed. There are no previous records of fish or macroinvertebrates or threatened aquatic species from the Little Boobyalla River.

Threatened species

There are no records of threatened aquatic species from the Little Boobyalla River either in the vicinity of the proposed dam site or downstream. The survey has revealed no listed species to date.

3.2.4 Issues and risks

The aquatic fauna and habitats of the Little Boobyalla do not appear to contain any threatened species. All species observed during the survey were widespread and common. Further processing of survey samples is required to confirm this for the macroinvertebrates however (to be conducted under Stage 2 if required). They do not appear to be unique to the section of the Little Boobyalla that would be affected by the proposed dam.

There appear to be no significant threatened species issues in the proposed Little Boobyalla River dam area, or in the immediate downstream river reaches.

3.3 Boobyalla River

3.3.1 Channel and habitats

The channel upstream of the proposed dam site is geomorphologically complex - characterised by a meandering, wide, deep and incised primary channel linked to several large and deep secondary channels and several wetland-swamp complexes.

The primary channel is well shaded with a sand-silt-clay bed overlain by substantial deposits of organic material and debris (CPOM) and numerous snags (20-25% by area). Further downstream toward the dam site, large granite boulders were also observed in the channel, occasionally forming short rapid-riffle sections, interspersed with long sand-silt pool-runs with some instream macrophytes.

The main secondary flood-way channels are frequently deep (0.5 – 2 m) and contain, dense aquatic vegetation.

The Boobyalla River is a turbid blackwater stream with moderate conductivity (132 micros/cm on 8/11/2001).

3.3.2 Biota

Fish

Due to problems with sampling equipment, electrofishing could only be conducted at the upstream site (B2). Only the shortfinned eel (*Anguilla australis*) was recorded.

Macroinvertebrates

Very high densities of macroinvertebrates were observed on woody debris at both sites, and this fauna was particularly diverse including a wide variety of mayflies, caddis, simuliids, beetle, snails, limpets and sponges. This macroinvertebrate fauna was numerically dominated by hydrobiosid caddis and leptophlebiid mayflies. Adult caddis were abundant during the survey and four species were recognised. At least one species of the burrowing crayfish *Engaeus* was present in the bank and backwater-swamp areas upstream of the dam site. This was subsequently identified as *E. tayatea*, a species common and widespread in the area.

Active searching for aquatic snails on rocks, logs and in moss failed to find any species from the ecologically vulnerable *Beddomeia* genus.

Macrophytes

There were significant stands of macrophytes in the backwater swamps, dominated by *T. procera* and *Scirpus fluitans*. *T. procera* was also observed in the main channel immediately upstream of the proposed dam site.

Other records

The IFS fish database, the PWS GTSPOT database, other publications and raw data from previously conducted surveys in the area were reviewed. Previous records include observations of *Astacopsis gouldi* (giant freshwater lobster), blackfish (*Gadopsis marmoratus*) and pygmy perch (*Nannoperca fluviatilis*). Both of these fish species are widespread and common.

Threatened species

Astacopsis gouldi (giant freshwater lobster), listed as vulnerable under both the Tasmanian TSP and national EPBC acts, occurs in the Boobyalla River in the vicinity of the proposed dam site and downstream. The survey has revealed no other listed species to date, although the presence of endemic *Beddomeia* snails is highly likely and requires further assessment.

3.3.2 Issues and risks

The aquatic fauna and habitats of the Boobyalla do not appear to contain any threatened species other than *Astacopsis gouldi*. All fish species recorded from the river are widespread and common. Further processing of survey samples is required to confirm this for the macroinvertebrates however (to be conducted under Stage 2 if required).

Astacopsis gouldi represents a potentially significant threatened species issue in the proposed Boobyalla River dam area and in the downstream river reaches.

3.4 Tomahawk River

3.4.1 Channel and habitats

The channel upstream of the proposed dam site is characterised by an alternately constrained and meandering incised primary channel within a small floodplain.

The channel is well shaded by a dogwood-blackwood-fern riparian complex. It has a sand-gravel bed overlain by deposits of organic silt and debris (CPOM) in small backwaters, and contains numerous snags (10-15% by area) and occasional granite boulders. Macrophytes are frequent within the main channel, dominated by *Triglochin procera*.

The Little Tomahawk River within the proposed dam area, a substantial tributary, is steeper, with short sandy runs interspersed with granite cobble-boulder riffles and chutes, and a low conductivity (36 microS/cm).

The Tomahawk River is a clear blackwater stream with low conductivity (46 microS/cm on 9/11/2001).

3.4.2 Biota

Fish

The Tomahawk and Little Tomahawk rivers contained highly abundant populations of *Galaxias truttaceus*, with at least five age classes including several young of the year. This indicates that recruitment from the coast into these populations is an unimpeded and annual event. Shortfinned eel, *Galaxias maculatus* and *G. brevipinnis* (the climbing galaxias) were also recorded from these sites, along with the sandy flathead (*Pseudaphritis urvillii*).

Macroinvertebrates

High densities of macroinvertebrates were observed on woody debris in the Tomahawk, including several species of leptophlebiid mayflies, caddis, simuliids, and beetle. Adult caddis were observed during the survey and two species were collected. At least one species of the burrowing crayfish, *Engaeus mairener*, was present along the bank upstream of the dam site. This species is common and widespread in the area. *Astacopsis gouldi* was recorded at both sampling locations during the survey.

Active searching for aquatic snails on rocks, logs and in moss failed to locate any species from the ecologically vulnerable *Beddomeia* genus.

Macrophytes

Stands of macrophytes were observed in the main channel, dominated by *Triglochin procera*.

Other records

The IFS fish database, the PWS GTSPOT database, other publications and raw data from previously conducted surveys in the area were again reviewed. Previous records include observations of *Astacopsis gouldi* (giant freshwater lobster) and pygmy perch (*Nannoperca fluviatilis*).

Threatened species

Astacopsis gouldi (giant freshwater lobster), listed as vulnerable under both the Tasmanian TSP and national EPBC acts, occurs in the Tomahawk in the vicinity of the proposed dam site and downstream. The survey has revealed no other listed species to date.

3.4.3 Issues and risks

The aquatic fauna and habitats of the Tomahawk River do not appear to contain any threatened species other than *Astacopsis gouldi*. All fish species recorded from the river are widespread and common. Further processing of survey samples is required to confirm this for the macroinvertebrates however (to be conducted under Stage 2 if required).

Astacopsis gouldi represents a potentially significant threatened species issue in the proposed Tomahawk River dam area, and in the downstream river reaches.

4. DOWNSTREAM ECOSYSTEMS

4.1 Rivers

No detailed field inspection was conducted in river reaches of the proposed dam sites for Stage 1 of this project (see Stage 2, Section 2 of this report). However, a number of aquatic faunal values were initially identified, namely:

1. The presence of the lobster, *Astacopsis gouldi*, at several locations within the lower Boobyalla and Tomahawk rivers, and presumably throughout these rivers;
2. The presence of the damselfly *Hemiphlebia mirabilis*, first recorded in the late 1980’s from the Ringarooma and Swansons Lagoon areas. Though it is also known from the Wilsons promontory area in Victoria, the species is both rare and vulnerable within the state. Its habitat is primarily still water in wetlands and floodplain pools;
3. The potential presence of the dwarf galaxias, *Galaxias pusilla*, currently listed as rare under the TSP Act (1995), usually found in shallow habitats dominated by macrophytes in river and wetland systems of the north east;
4. The presence of the grayling (*Prototroctes maraena*), listed as vulnerable under the TSP Act (1995), and historically known from the lower Ringarooma River, and highly likely to occur in both the lower Tomahawk and Boobyalla;
5. The presence of populations of a number of native fish species including the blackfish (*Gadopsis marmoratus*);
6. The likelihood of locally endemic *Beddomeia* freshwater snails, given the habitats observed within the Boobyalla and Tomahawk rivers.

Floodplain channels and pools in the lower reaches of the Tomahawk and Boobyalla, while not extensive or numerous, may well contain suitable habitats for *G. pusilla* and *H. mirabilis*.

4.2 Wetlands

A number of wetlands are found on the coastal plain which may be affected by the proposed development, mainly through the altered flow regime. Most noteable is the RAMSAR listed Lower Ringarooma Floodplain focused around Fosters Marshes, Bowlers Lagoon and the Chimneys. It is unlikely that changes in the Wyniford River will greatly affect values in these wetlands through changes to the Ringarooma River flow regime, but this requires further investigation. It should also be noted that this site includes the lower reach and estuary of the Boobyalla River. Two small wetlands lie adjacent to the Boobyalla at the upstream (eastern) boundary of the RAMSAR site.

These shallow coastal swale wetlands lie on quaternary sands, are frequently associated with peat deposits, are slightly to highly disturbed (by grazing and clearing and historical, sedimentary impacts of tin mining). They are used by waterbirds for feeding and nesting, contain a number of rare and/or vulnerable species and are considered important due to their diverse aquatic invertebrate fauna. The wetlands are dominated by scrub and tussock grasslands and included large areas of freshwater marsh.

These wetlands are situated on both private leasehold and Crown land, the latter including areas for which temporary grazing licenses are issued. No significant government management activities have taken place associated with this site to date.

5. SUMMARY OF ISSUES

A number of aquatic environmental issues have been identified, and were examined further in Stage 2 of the project (Section 2 of this report).

5.1 General Issues

All four rivers in the vicinity of the proposed dam sites are in good to fair environmental condition and contain a high diversity of native aquatic fauna and few exotic species. The Wyniford River has been impacted by historical mining operations, as well as associated ongoing erosion problems.

All rivers have potential issues with *Astacopsis gouldi* as a nationally and state-listed threatened species, with occurrences of that species confirmed for the Tomahawk, Boobyalla and Little Boobyalla. It is highly likely that these rivers also contain locally endemic *Beddomeia* freshwater snails, given their presence in neighbouring catchments.

Delivery of minimum environmental flows will be necessary for the maintenance of instream aquatic ecosystem health downstream of the proposed storages. Delivery of higher (flood) flows will also be necessary for channel maintenance in these sand-dominated river systems, as well as for maintenance of floodplain wetlands in the Tomahawk and Boobyalla systems.

Initial 'desktop' estimates for minimum environmental flows are unsatisfactory and must be further refined with:

- A risk assessment based on field data on habitat-discharge relationships; and
- The provision of flood-flow and base-flow requirements for channel, estuary and/or wetland maintenance.

4.2 Specific Issues and Initial Recommendations

We strongly recommend management to avoid flooding or other hydrological disturbance to the *Elodea* wetland within the proposed Wyniford dam footprint.

Both the Tomahawk and Boobyalla rivers upstream of the proposed dam sites appear to have high natural and potential conservation value, particularly the geomorphologically complex channel-floodplain complex of the Boobyalla system with its highly diverse and abundant macroinvertebrate community dependent on riparian-floodplain derived organic material. It is recommended that this system not be flooded if other alternatives exist.

SECTION 2:

WATERHOUSE COMMUNITY IRRIGATION DEVELOPMENT: AQUATIC ENVIRONMENTAL ASSESSMENT, STAGE 2.

5. Introduction

Stage 1 of the Aquatic Environmental Assessment of the Waterhouse Community Irrigation Development (WCID) DPEMP involved an initial assessment of the key issues associated with the proposed dam sites, including:

- An exploratory survey and inspection of aquatic habitats, plants and fish in the dam and storage 'footprint' areas, as well as downstream;
- Identification of key areas/habitats which may require specific environmental flow requirements and/or detailed assessment;
- Assessment of the likelihood of the presence of listed threatened aquatic species;
- A broad assessment of likely environmental risks and environmental flow requirements;
- Identification of environmental issues associated with 'Critical Review Points' within the project; and
- A listing of key issues which will require specific development or management actions, and/or further investigation under Stage 2.

The Stage 1 report concluded that the all the rivers within the WCID scope (the Boobyalla, Tomahawk, Little Boobyalla and Wyniford) were in good to excellent environmental condition and contain a high diversity of native aquatic fauna and few exotic species, and that the Tomahawk and Boobyalla Rivers contained the freshwater lobster *Astacopsis gouldi*, a nationally and state listed threatened species.

It also recommended delivery of minimum environmental flows for the maintenance of instream aquatic ecosystem health downstream of the proposed storages, as well as the delivery of higher (flood) flows for channel maintenance in these sand-dominated river systems.

Both the Tomahawk and Boobyalla rivers upstream of the proposed dam sites were identified as having high natural value, particularly the geomorphologically complex channel-floodplain complex of the Boobyalla system, with its highly diverse and abundant macroinvertebrate community dependent on riparian-floodplain derived organic material.

The WCID proposes to develop the Tomahawk and Boobyalla Rivers in two ways:

- Construction of a dam in the headwaters of each river to harvest and store flows for irrigation supply;
- Use of both river channels as routes of supply for irrigation water (in conjunction with related distributional infrastructure).

This report addresses both of these aspects of the WCID as they pertain to the downstream riverine environment.

The Stage 2 aquatic environmental assessment included:

- A detailed survey and sampling of representative riverine sites within the downstream area to be affected by the WCID, for aquatic biota.
- A minimum environmental flow assessment study, to include:
  - measurement of key hydraulic data for the assessment of minimum environmental flows within each river at a minimum of six representative locations;
  - derivation of habitat-preference curves for key taxa from the survey data;
  - hydraulic modelling of habitat-discharge relationships (using the RHYHAB simulation package);
  - a risk-assessment of habitat loss for key fish and macroinvertebrate taxa and platypus against a reference discharge;
  - recommendation of minimum environmental flows for maintenance of existing aquatic biota with no, or minimal, risk.

- An evaluation of the need for additional environmental flow components to ensure sustainability of downstream ecosystems, including:
  - timing and magnitude of flood flows;
  - rates of flow rise and fall associated with both natural and operational changes in flow;
  - duration of flooding events.

  For each river/dam the departure from natural flows to be evaluated and a proposed regime which minimises environmental risk proposed.
- Recommendation of an overall environmental flow regime for each river system, to include seasonal base and peak flows.
- Identification of ecological risks associated with inter-catchment transfers of water, following the field survey, particularly in relation to the potential for spread of alien plant and/or animal species, and of significant changes to the distribution of native plants and/or animals.
- Refinement of the assessment of fish migration requirements using the results of the field survey, and where fish passage is deemed to be a significant issue, preparation of design specifications for a fish passage structure.

Following a change in priorities within the WCID project, this Stage 2 report addresses the above tasks in relation to the Tomahawk and Boobyalla Rivers only, as both the Little Boobyalla and Wyniford reservoirs were removed from the proposal for a variety of reasons. Sampling intensity was therefore increased for the Tomahawk and Boobyalla rivers to ensure as adequate assessment as possible with the resources and time available.

Special Issue – Boobyalla River:

A key issue is the environmental condition of the Boobyalla River. During and subsequent to Stage 1 of this project, it became apparent that the Boobyalla River within the area proposed for inundation by the reservoir had very high ecological value, with:

- A particularly abundant and diverse aquatic macroinvertebrate community;
- An unusual riverine ecosystem completely dependent on coarse woody debris and particular organic matter (CPOM);

- A complex channel form, with meanders, oxbow lagoons and backwaters;
- A riparian zone with high plant diversity and community integrity.

This, coupled with the features identified during the vegetation assessment and the high quality of terrestrial faunal habitat, leads to the conclusion that the middle Boobyalla in the vicinity of the proposed reservoir has high conservation value at a regional and state level.

Surveys conducted during Stage 2 therefore also addressed the issue of whether the Boobyalla River downstream of the proposed dam site also had high conservation value.

6. Methods

6.1 Survey

A survey was conducted in late March-April 2002 of macrophytes, macroinvertebrates and fish in the Boobyalla and Tomahawk Rivers downstream of the proposed dam sites. Six sites were sampled quantitatively for fish and semi-quantitatively for macroinvertebrates, and assessed for the presence of aquatic plants (macrophytes).

Site locations are shown in Table 6.1, and illustrated in Figures 6.1 and 6.2.

Table 6.1. Location of aquatic biological survey and environmental flow assessment sites downstream of the proposed damsites in the Boobyalla and Tomahawk Rivers.

River	Site	Easting	Northing
Tomahawk	T1	562993	5470856
	T2	563926	5468518
	T3	563666	5467177
	T4	564179	5464887
	T5	564117	5463632
	T6	563727	5461626
Boobyalla	B1	572343	5469266
	B2	571060	5467204
	B3	570643	5466546
	B4	569290	5464886
	B5	568409	5463292
	B6	568255	5461587

Figure 6.1. Map of Boobyalla River showing location of sampling sites.

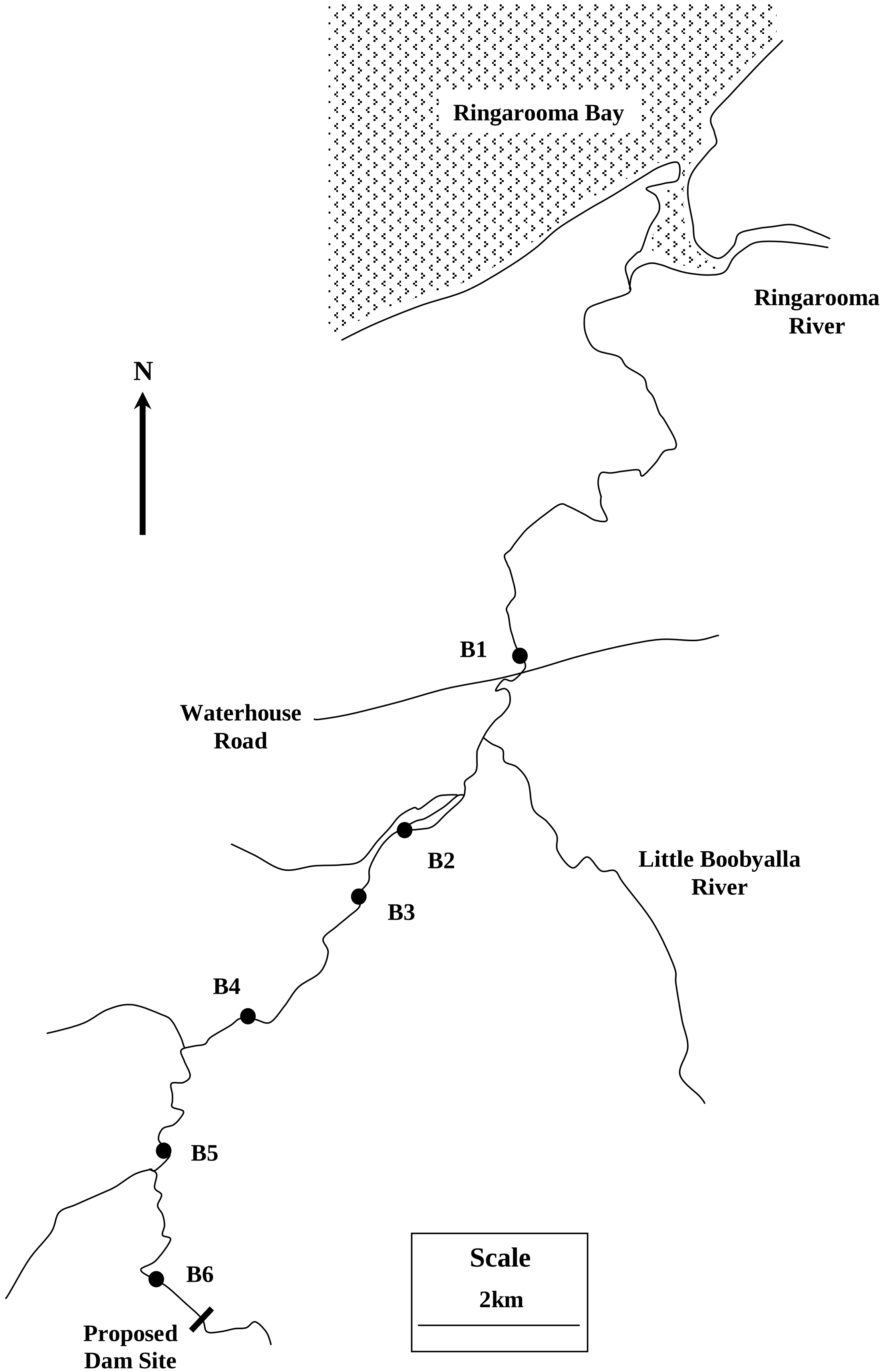
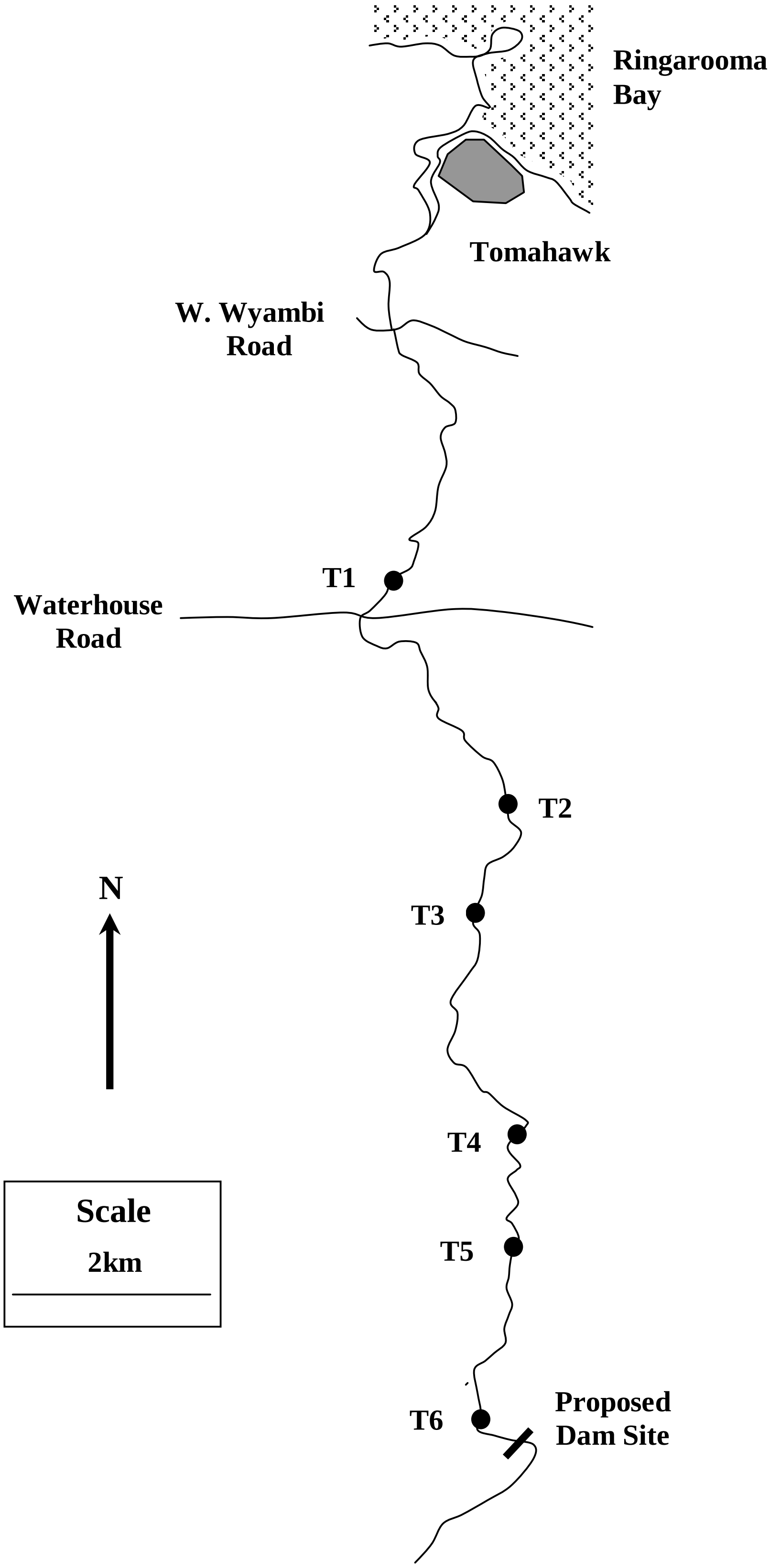


Figure 6.2. Map of Tomahawk River showing location of sampling sites.



Fish were sampled by 20 minutes of active electrofishing, with a Smith-Root backpack electrofisher, of all habitats at each site, with all captured fish counted, identified and measured (fork length) prior to release.

Macroinvertebrates were sampled in two ways:

Semi-quantitatively using standardised rapid bioassessment (RBA) kick sampling of riffle and edge habitats. At each site, one 10 m kick sample was collected from riffle habitat and one 10 m sweep sample was collected from the edge habitat. Riffle kick samples were live-picked using the standard Tasmanian AUSRIVAS live-picking protocol (Krasnicki et al. 2001). All edge and remaining riffle sample material was preserved with 10% formalin for later laboratory processing. All specimens were hand-sorted and identified to family level (with the exception of oligochaetes, Hydracarina, Turbellaria and nematodes which were not identified further, and of chironomids which were identified to sub-family). Further identification to species level was conducted for those groups known to contain listed threatened species, in selected samples.

Quantitatively using 30 x 30 cm surber samplers (with a 500 micron mesh), with individual samples collected to represent a wide range of habitat conditions within the channel (substrates, depths and velocities) across all study sites. A total of 58 samples were collected from the Boobyalla River and 45 from the Tomahawk River.

6.2 Environmental flow assessment - Minimum environment flows

6.2.1 Hydraulic data

Detailed hydraulic data was collected from the six survey sites located between the proposed dam site and the tidal limit in each of the Boobyalla and Tomahawk Rivers (see above for locations). One transect was established at each site, and located to represent the dominant habitat characteristics of each site. Each transect was established with a steel 'head' peg on the bank as a local datum from which all water surface elevations (stage) were measured. Each site was rated on at least three occasions, with stage and discharge measured over a range of flows.

In addition, at each site, the channel profile was surveyed, and velocities and depths measured at 0.5 - 1 m intervals from the head peg across the full width of the channel, including all side channels and backwaters. At each interval, substrate composition was recorded (as % of the following grain size classes/types – silt (<1 mm), sand (1 - 4 mm), gravel (4 - 16 mm), pebble (16 - 64 mm), cobble (64 - 256 mm), boulder (>256 mm), bedrock, as well as area of aquatic vegetation, woody debris and moss.

6.2.2 Habitat-preference curves

Habitat preference data were required for those native fish and macroinvertebrates observed in the Tomahawk and Boobyalla Rivers, as well as for platypus.

Macroinvertebrates:

Habitat preference data for macroinvertebrates had to be derived from instream sampling. Accordingly, the quantitative surber samples collected above were used, and sampling was accompanied by measurement of depth and substrate composition of the exact sampling location. In addition, mean water column (and near-bed) water velocity was measured at each location.

All surber samples from the Boobyalla River were processed in their entirety (with the exception of three large samples which were sub-sampled to 20 or 30%). Time constraints prevented processing of all 45 samples collected from the Tomahawk River, and samples were selected to include habitats not sampled in the Boobyalla. This yielded 58 sets of quantitative macroinvertebrate-habitat data for the Boobyalla and 19 for the Tomahawk, providing 77 in total. All macroinvertebrate samples were sorted and identified to family level only. The entire data set was used to derive a single set of habitat preference curves, as follows.

The abundance data for all macroinvertebrates encountered in each sample were entered into an Excel spreadsheet and screened. Only taxa which complied with minimal requirements for developing habitat preference curves (taxa occurring in > 10 samples with a total abundance > 15) were analysed further. Habitat preference curves were then prepared from the set of screened taxa abundance data, as well as substrate, velocity and depth data for each sample, in a standard manner (Bovee 1986, Stalnaker *et al.* 1995, Humphries *et al.* 1996).

These habitat preference curves were generated for the following taxa: Hydrozoa, Turbellaria, Sphaeriidae, Hydrobiidae, *Ferrissia*, Oligochaeta, Hydracarina, Ostracoda, Gripopterygidae, Notonemouridae, Leptophlebiidae, Caenidae, Baetidae, Chironominae, Orthocladiinae, Tanypodinae, Simuliidae, Tipulidae, Ceratopogonidae, Empididae, *Austrosimulium* pupae, Atriplectididae, Calocidae, Conoesucidae, Ecnomidae, Glossosomatidae, Helicophidae, Hydrobiosidae, Hydropsychidae, Hydroptilidae, Leptoceridae, Philorheithridae, adult Elmidae, larval Elmidae and larval Scirtidae.

In addition, curves were developed for the total number of taxa and the total abundance of all macroinvertebrates, the latter developed using data for all taxa in the sample set.

Fish and platypus:

Habitat preference data was used from existing sources for platypus (Davies and Cook 2001) and for the following native fish species shown to be present within the two catchments: shortfin eel (*Anguilla australis*), lamprey (*Geotria australis*) ammocoetes, common jollytail (*Galaxias maculatus*), spotted mountain galaxias (*Galaxias truttaceus*), blackfish (*Gadopsis marmoratus*), pygmy perch (*Nannoperca australis*). Habitat preference data for brown trout was not used due to the low observed abundance of this species in the catchment and the relative insignificance of these rivers as trout fisheries.

Aquatic vegetation:

Habitat preference curves were also developed for aquatic macrophytes, based on observations of the percentage of macrophyte cover (predominantly *Triglochin*), and matching depth, velocity and substrate data, from the transects at all sites. A total of 68 observations of macrophyte cover were made, within a total set of 206 point observations from all transects.

6.2.3 Habitat-flow analysis

Habitat-discharge (WUA-Q) curves were developed for all biological variables (macroinvertebrate and fish taxa, macroinvertebrate abundance and number of taxa, platypus, snags and macrophytes) for the 12 study sites. Hydraulic simulation was conducted over the flow range 0 - 2 and 0 - 1.5 cumec for the Boobyalla and Tomahawk respectively, using RHYHAB. Dry conditions prevented collection of high flow ratings necessary for simulation to higher discharges. The range of flows for which simulations could be conducted was sufficient, however, to include all monthly reference discharges.

6.2.4 Minimum flow risk analysis

In order to derive a minimum environmental flow regime for both rivers, the risk-assessment approach described by Davies and Humphries (1996) was used. This involved a risk assessment of habitat loss for the key biota, relative to a reference flow for each month of the year.

A 'reference' flow was required against which to assess changes in habitat and hence risks to biota. With the aim of maintaining instream habitat under the current conditions, a reference discharge was selected which represented median habitat conditions occurring over the last 35 years. A grand median mean daily flow was calculated for each month derived from the real and modeled flow record supplied by DPIWE, for the period 1965 to 2001. Average monthly flows unduly bias reference flows upwards and distort the analysis, therefore mean daily flows are used throughout this analysis. The grand median monthly flows for the Boobyalla and Tomahawk Rivers used as the basis for reference flows are shown in Table 2.2.

In addition to using a reference flow describing the 'median' flow condition, an assessment of EF requirements for dry or drought condition years was conducted. This recognises the need to provide minimum environmental flows which recognise the natural variability in low flows associated with dry conditions. The 20th percentile of mean daily flows for each month over the same period of record (1965-2001) was used as the reference flows for dry conditions (Table 6.2). The use of the 20th

percentile recognises the need to reduce baseflows in response to moderate rather than extreme dry conditions.

Table 6.2. Median and drought conditions reference flows used in the risk analysis for determining minimum environmental flows for the Tomahawk and Boobyalla Rivers.

	TOMAHAWK				BOOBYALLA			
	Median (cumecs)	20th Percentile (cumecs)	Median (ML/day)	20th Percentile (ML/day)	Median (cumecs)	20th Percentile (cumecs)	Median (ML/day)	20th Percentile (ML/day)
Jan	0.023	0.00468	2.0	0.4	0.078	0.049	6.8	4.2
Feb	0.0104	0.00009	0.9	0.01	0.032	0.014	2.8	1.3
Mar	0.014	0.00086	1.2	0.07	0.052	0.019	4.5	1.6
Apr	0.027	0.00769	2.4	0.7	0.076	0.044	6.6	3.8
May	0.091	0.026	7.9	2.3	0.224	0.107	19.4	9.3
Jun	0.243	0.082	21.0	7.1	0.568	0.253	49.1	21.9
Jul	0.450	0.224	38.9	19.3	1.251	0.575	108.1	49.6
Aug	0.537	0.260	46.4	22.4	1.319	0.714	113.9	61.7
Sep	0.373	0.168	32.2	14.5	1.210	0.510	104.5	44.0
Oct	0.234	0.086	20.2	7.4	0.810	0.243	70.0	21.0
Nov	0.108	0.043	9.3	3.7	0.351	0.158	30.3	13.6
Dec	0.061	0.022	5.3	1.9	0.182	0.098	15.7	8.5

Using the approach described by Davies and Humphries (1996), the following analysis was conducted for the entire lower Boobyalla and Tomahawk rivers:

1) Reference flow selection

The reference flow was selected for each month (Table 2.2).

2) Habitat change

A series of nominal flows at between 0.003 and 0.1 cumec intervals were selected for simulation.

The % deviation of habitat availability (WUA) at the nominal flow from the WUA at the reference flow for that month was then calculated using the following formula:

$$\%DelHA = 100*({}^{WUAQnom}/_{WUAQref})$$

where WUAQnom = WUA at the nominal discharge and WUAref = WUA at the reference flow.

This was done for all the biological 'values' listed above, including macroinvertebrates, platypus, macrophytes and fish.

Separate sets of %DelHA values were calculated for each month.

3) Risk categories

Each value of habitat deviation (%DelHA) was converted to a risk category according to the criteria established by Davies and Humphries (1996), as shown in Table 6.3. For this analysis, the risk being assessed is the risk of failure to maintain biota due to loss of habitat availability relative to reference flow conditions. Results for macroinvertebrate taxa were kept separate due to the low level of taxonomic resolution (mainly family). The same risk criteria were used for all biological values.

Table 6.3. Risk categories for all biological values in the Boobyalla and Tomahawk Rivers and corresponding values (criteria) for %DelHA i.e. % remaining WUA under nominal flow cf reference flow.

Value	**Risk Category**			
	I	**II**	**III**	**IV**
	Minimal risk or beneficial	**Moderate risk**	**High risk**	**Very high risk**
Habitat for macroinvertebrates, fish, platypus, macrophytes,	> 85% of habitat under reference flow	60 – 85% of habitat under reference flow	30 - 60% of habitat under reference flow	< 30% of habitat under reference flow

4) Overall risks and recommended minimum flows

A final risk assessment for each nominal discharge was conducted by taking the lowest risk score (lowest value of %DelHA across all biological variables) as the overall risk across all flows below the reference flow. This was done for each month of the year.

This is a deliberately conservative approach in order to minimise risk to the instream biota. All biological variables were treated equally in this approach. Trade-off between risk levels for different biological values in the absence of specific management targets favouring particular species/biotic groups is an inherently subjective and semi-arbitrary process and is avoided here. However, plots of %Del HA for the taxa with the lowest %DelHA values were made to illustrate their relative contribution to the overall risk assessment.

The lowest discharge associated with Risk Band I (minimal risk) is generally recommended as the minimum mean daily flow in each month. This recognises both:

- The desire for no additional environmental risk over and above the existing impacts from current levels of water abstraction and land use ; and
- The recognition that actual flows fall below this level in some years.

However, where the values associated with increasing risk at flows close to the reference flow are not deemed of particularly high value, consideration may be given to recommending flows that fall within Risk Band II (moderate risk). No choice between these is presented in this work, and results for both risk bands are reported. Results for severe or extreme risk (Bands III and IV) are not reported, as they are not considered appropriate for recommendation as minimum environmental flows due to the high risk of negative environmental impacts.

6.2.5 Upper limits on minimum environmental flows

The approach described above was used to develop minimum environmental flow thresholds considered to prevent significant harm occurring to the riverine fauna and flora. The recommended flows are relevant when considering abstractions or flow reductions in river systems. The WCID is also, however, considering using the river channel as a means of delivering irrigation flows to downstream users. This raises the issue of what are the maximum rates of flow delivery which can be supported without causing harm to the ecosystem. This recognises the fact that there are both lower and upper limits to the magnitude of flows within which a river ecosystem can be maintained in a sustainable state.

Upper limits to minimum flows were assessed using the results of the risk analysis described above, and applying the same criteria (in Table 6.3) for assessing deviations in habitat availability at flows above the reference flows for each month. This was done for both median and drought conditions.

6.3 Environmental flow assessment – high/flood flows

There is no comprehensive set of flow data at time steps suitable for a detailed assessment of the historical flood regime in either the Boobyalla or Tomahawk Rivers. DPIWE supplied a modeled hourly flow record for these rivers based on relationships between monthly flows at these sites and the North Esk River (at the Ballroom). An initial, descriptive assessment of the flood regime was conducted. However, detailed analysis was precluded by the lack of precision in the modelling, as high spatial and temporal variability in rainfall and storm events is a feature of the north-east region of Tasmania (eg Hughes 1988). Thus, the flood records modeled for the Boobyalla or Tomahawk should only be seen as broadly indicative and not be used as the basis for detailed analysis.

6.4 Ecological risks from inter-catchment transfers

Risks of interbasin transfers should be considered in the light of known distributions of fauna and flora within the rivers to be linked within the WCID, and the current knowledge of interactions between both native and exotic species. As resources were not available for a complete description of the macroinvertebrate fauna (to species), nor for sampling more vagile biota (such as algae and microcrustaceans), this assessment was fairly limited. It was also recognised that historical water transfer has occurred within the area for some years via series of water raceways.

7. Results

7.1 Survey

7.1.1 Boobyalla River

The Boobyalla River downstream of proposed dam site has a well developed, sand-gravel dominated channel, with a wide diversity of within-channel habitats. Several sections of the river are braided and have complex, anabranching backwater systems.

The Boobyalla River descends relatively quickly immediately downstream of the proposed dam site from an altitude of 70 m. The channel is 5-8 m wide and constrained by steep banks. The substrate for 4 km downstream of the dam site is predominantly boulder-bedrock, creating a series of riffles and pools. There is some aquatic vegetation throughout this reach, predominantly mosses on submerged bedrock and boulders, but also ribbonweed (*Triglochin procera*) in pools, and very little woody debris. The river is fringed by woolly tea-tree creating a canopy overhanging the main channel, and with a native grass and fern understorey. Beyond the immediate riparian zone (generally less than 3 m), the vegetation is relatively dry sclerophyll forest with an understorey of bracken and the occasional *Banksia* and *Acacia*.

By 5 km below the dam site, the river has dropped to 20 m altitude and its character changes. It is less steep, more meandering and has a pebble-dominated substrate. These features create a combination of riffles, pools and runs which shift with flow events. There is a moderate amount of larger woody debris in this reach, generally trunks and branches which form pools, and very little aquatic plant growth. The riparian zones are broader (approximately 20 m), consisting of thick tea-tree stands with a sparse understorey of native grasses. Beyond this zone is dry sclerophyll woodland with an understorey of *Banksia*, *Acacia*, *Xanthorrhoea* and native grasses. One wetland occurs in this reach near the main channel, whose water regime is controlled by a tributary stream. It supports extensive macrophyte growth (*Eleocharis sphacelata*) and associated biota including macroinvertebrates, amphibians, fish and waterfowl.

Downstream of this point, the river drops 15 m over 6-7 km. Over much of this length, the river is braided, often running through multiple channels between islands of tea-tree and swamp sections. This is a significant geomorphological feature of the Boobyalla and is considered relatively rare in lowland Tasmanian rivers. The substrate throughout this section is predominantly sand and gravel and can shift in larger flows. It supports some macrophyte (*Triglochin procera*) growth in slower flowing runs, and there is a moderate amount of woody debris, mostly tea-tree branches and leaf litter. This section also supports a population of the freshwater mussel *Hyridella narracanensis* (see below). The riparian zone (100 m including the river) consists of woolly tea-tree forest with a very thick canopy and an understorey of native grasses. The river is impacted by stock access from unfenced adjoining paddocks. Table 7.1 contains a description of key features of each survey site.

Table 7.1. Descriptions of study reaches and sites in the Boobyalla River, March 2002.

	Channel	Instream habitat	Riparian veg	Other features
B1	Channelised for 100m. Straight, steep banks. Silt/sand substrate. Shallow and meandering downstream, with sandy substrate. Approx 5m wide.	Moderate amount aquatic vegetation. Triglochin procera with some Potamogeton tricarinatus. Some large woody debris.	Riparian zones (>30m) of ti-tree. Tthick canopy overhanging main channel. Sparse understorey of native grasses. No evidence of stock access.	
B2	Very braided swampy section. Channels with gravel/sand substrate and separated by ti-tree root mats/islands. Widest section approx 2m. Run-riffle. Little pool habitat.	Very little aquatic vegetation, some Triglochin procera. Woody debris and small leaf litter packs in slow flows.	Wide ti-tree riparian zones (>20m). Dense canopy overhanging channel with grass understorey. Some Pampas grass present. Unfenced and impacted by stock access.	
B3	Wide (8m), shallow (<50cm), and meandering channel. Sandy substrate overlain by silt/algae. Mostly run, little riffle/pool habitat.	Very little aquatic veg. Mostly algae. Some woody debris.	Thick ti-tree forest, sparse grass understorey. Some Pampas grass and bracken. Wide riparian on right bank (>40m). Narrower on left (<10m) and unfenced allowing stock access.	
B4	Meandering channel approx 5m wide. Pebble/gravel substrate. Even mix of riffle/run/pool habitat. Pebble bars and beaches. Pools formed by fallen trunks.	No aquatic vegetation in main channel. Some woody debris and litter packs.	No stock access. Relatively unimpacted thick ti-tree forest (>40m) shading channel margins, with some Eucalyptus, dogwood, Acacia, and native grasses.	Wetland behind riparian vegetation on left bank (looking downstream), fed by tributary. Large pool (100x50m), mostly shallow (<20cm) with thick *Eleocharis sphacelata* , but deep pool in centre. Eels and pygmy perch present. Surrounding vegetation - dry scle
B5	40m downstream of weir and ford (old gauging station site). Narrow channel (5m) of granitic bedrock/boulder and cobble substrate. Mostly riffle/pool habitat associated with bouldery substrate.	Very little aquatic vegetation- mosses present on submerged rocks - and little woody debris.	Immediate narrow riparian zones of thick tea-tree (<2m), flanked by relatively steep inclines of open dry sclerophyll with an open understorey of bracken. Riparian vegetation overhangs main channel.	
B6	50m downstream of proposed dam site. Channel approx 8m wide , relatively straight. Boulder/bedrock substrate. Riffle/pool habitat.	Dense aquatic vegetation - mostly moss, submerged and emergent on boulders. Some Triglochin in pool/run areas. Little woody debris.	Relatively steep bank. Open dry sclerophyll with bracken understorey. Ti-tree fringe at water's edge. Thick overhanging vegetation shading channel. Recent bushfire impact.	

7.1.1.1 Fish fauna

Eight species of fish were recorded during the survey of the Boobyalla River. This fauna was characterised by:

- High densities of the native galaxiids *Galaxias maculatus* and *G. truttaceus*;
- The low abundance of brown trout (only 5 out of 283 fish captured) and the absence of other exotic fish species;
- Greatest diversity in the middle and lower reaches; with
- Declining diversity and abundance toward the proposed dam site.

The middle and downstream reaches of the Boobyalla have high densities of the jollytail (*G. maculatus),* and moderate abundances of pygmy perch (*Nannoperca australis*), sandies (*Pseudaphritis urvillii*) and the mountain galaxias (*G. truttaceus).* None of the fish species encountered in the survey were of particular conservation significance, and all are common and generally abundant in other rivers of the region. These reaches are, however, of some conservation value due to the presence of a native fish assemblage relatively unmodified by either the presence of exotic fish species, gross habitat disturbance or flow regulation.

Only blackfish and brown trout were encountered at the site just downstream of the dam site. In the Stage 1 survey, the shortfin eel (*Anguilla australis*) was also recorded at the proposed dam site. Overall, this indicates a low diversity and abundance of fish in the upper reaches of the Boobyalla.

Table 7.2 summarises the overall distribution and total abundance of fish surveyed. Inspection of the RFA-IFS fish database confirmed that pygmy perch, *G. maculatus*, sandies, shortfin eel (*A. australis*) and blackfish had been previously reported from the Boobyalla.

Abundance and size distributional data for fish is contained in Appendix 2.

Table 7.2. Number of species, total abundance and distribution (highlighted in grey) of fish species in the Boobyalla and Tomahawk Rivers, surveyed in March 2002.

River	Site	Number of species	Total abundance	*Galaxias maculatus*	*Galaxias truttaceus*	*Gadopsis marmoratus*	*Nannoperca australis*	*Pseudaphritis urvillii*	*Anguilla australis*	*Geotria australis*	*Salmo trutta*
Boobyalla	B1	5	33	■			■	■	■	■	
	B2	8	84	■	■	■	■	■	■	■	■
	B3	8	49	■		■	■	■	■	■	■
	B4	5	66	■		■		■	■	■	
	B5	6	40	■	■		■	■	■	■	
	B6	2	11			■					■
	All	*8*									
Tomahawk	T1	4	54	■	■		■	■			
	T2	4	39	■	■				■	■	
	T4	4	31	■	■			■		■	
	T6	4	41	■	■			■	■		
	All	6									

7.1.1.2 Macroinvertebrates

Both quantitative and semi-quantitative (RBA) sampling revealed a high density and diversity of macroinvertebrates in the Boobyalla River. Table 7.3 summarises the abundances of macroinvertebrates observed from the 69 quantitative surber samples taken across a range of habitat types, which contained a total of 33,000 individuals. A total of 56 taxa at family level were observed from this sample set. This highly diverse fauna was dominated by larval elmid beetles (19% of the total abundance), with leptophlebiid mayflies, orthoclad and chronomiid midges each accounting for 8-9% of total abundance each. This faunal composition is consistent with a stream in which:

- The dominant substrate is gravel and sand (high densities of midges and elmids);
- The dominant food source is particular organic matter (as above); and
- The water quality and flow regime are in good condition (high densities of leptophlebiids and elmids).

There was a substantial turnover of taxa between different habitat types, indicating that habitat diversity in the Boobyalla was a key aspect of the high level of macroinvertebrate diversity.

AUSRIVAS analysis of the RBA data revealed that the fauna was in an essentially undisturbed condition, equivalent in composition to unimpacted reference rivers within the region. As for the surber samples, the RBA sample fauna was dominated by elmids, leptophlebiids and chironomids (Table 7.4). A total of 36 taxa were present in the RBA samples, considerably less than in samples derived from the more effective, surber sampling. There was no strong trend in the diversity along the river, though the most downstream site had the lowest diversity. The river health index values derived using AUSRIVAS – O/E taxa - were all > 0.83, with all sites falling within or close to the boundary of the ‘equivalent to reference’ A band (Table 7.4). Thus overall, the sites are classified as being unaffected by any significant human impact.

A total of 983 hydrobiid snails were encountered in the Boobyalla surber samples. Further inspection of these revealed that a high proportion (24%) were of the genus *Beddomeia*. This represents a fairly high abundance of this genus, which is generally encountered only at low abundances in river habitats. The remaining hydrobiids were from the genus *Austropyrgus*, many of whose species are also locally endemic (and in the process of being described - W Ponder, National Museum, Sydney). All of the *Beddomeia* encountered were *B. briansmithi*, previously known only from Fern Creek, and listed as rare under the Tasmanian Threatened Species Protection Act (1995). This population is therefore of considerable conservation value.

15 families of caddisfly (Trichoptera) were encountered in the surber sample data set (Table 7.5). This is a high local diversity for a group that has a high degree of regional and local endemism within the state. Further identification of Trichoptera indicated that at least 35 species were observed in the Boobyalla. This high diversity, again reflective of a range of habitat conditions within the river system, is also of conservation significance. One of these species is the rare *Oxyethira mienica*, listed under the Tasmanian Threatened Species protection Act (1995), and previously known only from the Great Lake area. This species was found at nine locations in the middle Boobyalla River. These populations are also of potentially high conservation value at state level.

Eight adult specimens of a freshwater mussel, identified as *Hyridella narracanensis* (Family Hyriidae), were collected at site B2 on the Boobyalla River, as well as one juvenile in the surber samples from that site. Site B2 occurs in the 6-7 km river stretch of significant geomorphological interest - a braided, multiple channel system with islands of tea-tree and swamp sections.

There are only two species of freshwater mussel known from Tasmania, *H. narracanensis* being one, and all records to date are from rivers in the South Esk Basin. All current distributional records held by the Tasmanian Museum and Art Gallery, the Queen Victoria Museum, Launceston, and the National Museum in Sydney were reviewed. These records, as well as the formal review conducted by McMichael and Hiscock (1958), confirm the restricted distribution of both species. This is therefore a significant new distributional record.

H. narracanensis is also known from southern Victoria (McMichael and Hiscock 1958). However, given the lack of recent work on the taxonomy of southern Australian Hyriidae, the isolation of the Tasmanian fauna from the mainland and the high likelihood of undescribed species within the current known fauna (Smith, QVM, pers. comm.), this new record may also be significant taxonomically i.e. may be a new species. This finding is therefore of conservation significance. Further work is needed to evaluate the presence of mussels in other north-eastern Tasmanian rivers in order to assess the significance of this finding.

As reported in the Stage 1 report, *Astacopsis gouldi*, the Tasmanian freshwater lobster, is known from both the Tomahawk and Boobyalla Rivers, and was occasionally fished prior to the closure of the lobster fishery by the Inland Fisheries Service. No further sampling specifically for this species was conducted.

7.1.1.3 Macrophytes

The Boobyalla River contains moderate to dense stands of *Triglochin procera*, with *Potamogeton tricarinatus* also occurring, but only at the most downstream site (B1). No detailed survey for rare aquatic plants was conducted (being outside our brief). However, floristic diversity was very low, with most sites containing only *T. procera*.

7.1.1.4 Geomorphology

An assessment of the geomorphological character and significance of WCID rivers was not in this study's project brief. However, concerns were raised in our Stage 1 report about the high biological value of the aquatic ecosystem in the upper Boobyalla upstream of the proposed dam site, and within the area proposed to be flooded by the dam. An initial assessment of this area was conducted in December 2001 by a geomorphologist from DPIWE, confirming its significance. This report is attached at Appendix 1.

It is apparent that the unusual and diverse nature of the aquatic ecosystem in this area is linked to the unusual geomorphology of the channel upstream of the geological 'control' which is the favoured dam site. This geomorphological character determines the diversity of not only the aquatic ecosystem but also the riparian vegetation and terrestrial faunal habitats (see Stage 1 and 2 reports by other WCID technical consultants). We believe the Boobyalla floodplain complex within the proposed dam footprint to be of substantial environmental significance.

Table 7.2. Macroinvertebrates in surber samples from five habitats in the Boobyalla River, in March 2002. Abundances are N/0.09 m² of stream bed.

Order	Class	Family	Sand	Sand/Gravel	Pebble/Gravel	Bedrock	Boulder
		N samples:	**4**	**28**	**6**	**17**	**10**
Cnidaria	Hydrozoa			35	2	2	1
Platyhelminthes	Turbellaria		5	14	11	5	20
Nematoda				20	1	1	1
Mollusca	Bivalvia	Sphaeriidae	56	134	1	3	30
	Gastropoda	Hydrobiidae	392	455	82	20	55
		Ancylidae	21	14	53	580	115
Annelida	Oligochaeta		76	870	115	97	424
Arachnida	Hydracarina		27	27	3	67	55
Crustacea	Amphipoda	Paramelitidae	1				4
		Ceinidae		2			
	Copepoda			1		4	
	Decapoda	Atyidae	1				
		Janiridae			4		1
	Ostracoda		12	63	1	1	1
	Collembola			1			1
Insecta	Plecoptera	Gripopterygidae	19	105	6	39	23
		Notonemouridae	34	108		95	
	Ephemeroptera	Leptophlebiidae	1226	629	662	219	359
		Oniscigastridae				3	
		Caenidae	10	62	7	23	2
		Baetidae	21	377	340	192	132
	Hemiptera	Veliidae					3
		Corixidae		5			
	Mecoptera			1			
Diptera		Chironomidae:					
		Chironominae	338	319	64	1000	114
		Orthocladiinae	320	905	132	246	862
		Podonominae			3		
		Tanypodinae	60	171	21	43	15
		Simuliidae	96	279	134	20	31
		Tipulidae	5	37	11	6	
		Athericidae					6
		Ceratopogonidae	9	42	2	35	3
		Empididae	47	183	13	9	45
		Tanyderidae				2	
		Unid. pupae	31	212	143	139	80
	Trichoptera	Atriplectididae	8	14			
		Calocidae	31	29	8	2	
		Conoesucidae	22	55	74	205	669
		Ecnomidae		14		202	13
		Glossosomatidae		3	104	2	
		Helicophidae	152	88	42	109	169
		Helicopsychidae		2			1
		Hydrobiosidae	116	163	110	62	122
		Hydropsychidae	10	6	8	752	71
		Hydroptilidae	9	21		3	
		Kokiriidae					
		Leptoceridae	88	113	367	86	87
		Odontoceridae	6	20			
		Philorheithridae	15	164	2	8	2
		Polycentropodidae				9	
		Unid. pupae		1		1	9
	Coleoptera	Adult Elmidae	212	665	493	130	88
		Adult Dytiscidae	2				
		Larval Elmidae	686	3169	265	315	928
		Larval Scirtidae	135	676	170	75	10
		Larval Psephenidae		2			
		Mean N taxa	**21**	**22.5**	**24**	**25.1**	**20.8**
		Mean Total Abundance	**3670**	**367**	**576**	**283**	**455**

Table 7.3. Macroinvertebrates in RBA kick samples of riffle habitats at six sites in the Boobyalla River, in March 2002, along with AUSRIVAS O/E scores and assessment bands. Abundances are N/30 minute live pick from a 10m kick sample.

	B1	B2	B3	B4	B5	B6
Turbellaria						1
Sphaeridae						2
Hydrobiidae		2	1			1
Ancylidae						
Oligochaeta	1		2	8	2	7
Hydracarina	1	8	2	11	8	8
Paramelitidae						3
Phreatoicidae	3					
Ostracoda						
Copepoda						
Chydorid						
Eustheniidae						3
Gripopterygidae		1	1	2	15	10
Notonemouridae	3	3	1			
Leptophlebiidae	46	16	4	45	31	9
Oniscigastridae		2				
Baetidae		5	20	32	20	17
Telephlebiidae	1				4	
Veliidae	1					1
Gerridae				1		
Nannochoristidae						
Chironominae	10	6	5	2	3	4
Orthocladiinae	8	11	13	21	47	15
Tanypodinae		5	2	1	2	2
Simuliidae	10	4	9	23	11	7
Tipulidae	4	4		10		
Athericidae				1		
Ceratopogonidae						
Empididae		1		1		1
Atriplectidae		5	1			
Calocidae		2	4	9		2
Conoesucidae	7	2	9	8	9	14
Ecnomidae						
Glossosomatidae				1		
Helicophidae		3	3	8	15	14
Hydrobiosidae	7	19	10	36	6	11
Hydropsychidae	7		1	3	11	7
Hydroptilidae						1
Leptoceridae	3	11	18	35	18	8
Philorheithridae	2	2	9	1		1
Polycentropodidae						
Adult Elmidae	34	74	9	29	19	10
Larval Elmidae		5	4	21	3	18
Scirtidae		15	9	20		4
Psphenidae						
Adult Hydrophilidae						
Adult Dytiscidae						
N Taxa	**17**	**23**	**22**	**24**	**17**	**27**
O/E taxa	**0.83**	**0.86**	**0.93**	**1.03**	**0.84**	**1.09**
Band	**B**	**A**	**A**	**A**	**A**	**A**

Table 7.5. List of all caddis (Trichoptera) species found in 31 surber samples from a range of habitats in the Boobyalla River (excluding woody debris) in autumn 2002.

Family	Species
Atriplectididae	*Atriplectides dubius*
Calamoceratidae	*Anisocentropus latifascia*
Calocidae	*Tamasia variegata*
Conoesucidae	*Lingora aurata*
	Conoesucus nepotulus
	Conoesucus norelus
	Costora delora
Ecnomidae	*Ecnomus cygnitus*
	Ecnomus tillyardi
Glossosomatidae	*Agapetus sp. AV 1*
Helicophidae	*Alloecella grisea*
Hydrobiosidae	*Taschorema evansi*
	Taschorema ferrulum
	Taschorema sp. AV 4
	Taschorema sp. AV 2
	Ulmerochorema seona
	Ulmerochorema onychion
	Ulmerochorema lentum
	Ulmerochorema rubiconum grp.
	Moruya opora
	Moruya sp. AV 2
	Apsilochorema gisbum
Hydropsychidae	*Asmicridea sp. AV 1*
Hydroptilidae	*Oxyethira mienica*
	Hellyethira simplex
Leptoceridae	*Notalina sp. AV 1*
	Notalina sp. AV 7
	Notalina bifaria
	Triplectides similis
	Triplectides ciuskus ciuskus
	Triplectidina nigricornis
	Leptorussa darlingtoni
	Oecetis sp.
Odontoceridae	*Marilia fusca*
Philorheithridae	*Aphilorheithrus sp. AV 3*
	Austrheithrus sp.
Polycentropodidae	*Plectrocnemia sp. AV 1*

7.1.2 Tomahawk River

The Tomahawk River drops from 85 m altitude at the proposed dam site, relatively gradually over 10 km to 10 m altitude at Waterhouse Road. For the first 3-4 km below the dam site, the river is shallow and meandering (4 m wide) with a predominantly sandy substrate creating a series of runs and pools. These are interspersed occasionally with outcrops of bedrock which form small riffles. The river supports a moderate amount of aquatic plant growth, with ribbonweed (*Triglochin procera*) occurring in the runs and pools and some mosses on submerged rocks, and a moderate amount of woody debris. The riparian zone immediately downstream of the dam site is wet sclerophyll forest with an understorey of cutting grasses, ferns, dogwoods, and Acacia. By 2 km below the dam site the riparian vegetation has shifted to dry sclerophyll with an understorey of *Banksia*, *Acacia*, *Xanthorrhoea* and native grasses. The river runs through crown land for 5 km downstream of the dam site, and is largely unimpacted by vegetation clearing or stock access.

At 5 km downstream the river becomes steeper, with a cobble-boulder substrate creating a series of riffles and runs. Aquatic vegetation becomes relatively abundant, with a combination of macrophytes (*Triglochin procera*) in runs, and mosses and green filamentous algae on submerged rocks. Woody debris is sparse and the riparian zones (>50 m) are comprised of dry sclerophyll, *Banksia*, *Acacia*, *Kunzia*, some tea-tree and native grasses.

By 8 km downstream of the dam site the character of the river changes markedly. The banks incline relatively steeply to a main channel (4 m wide) with a predominantly bedrock-boulder substrate forming a series of fast-flowing riffles and pools. Macrophytes (*Triglochin procera*) occur in the pools with some green filamentous algae, and mosses are abundant on submerged rocks in the riffles. The riparian zones are mainly fenced off (>50 m) and are dominated by tea-tree and dry sclerophyll woodland.

By 10 km downstream of the dam site the river has flattened out again and is narrow (~2 m) and shallow with a sand-silt substrate. There is moderate macrophyte growth in the runs, and fenced riparian zones (<15 m) of thick woolly tea-tree

(*Leptospermum lanigerum*). This most downstream reach appears to be impacted by water level fluctuations, with pools and dewatered banks exposed at low flows.

Table 7.6 contains a description of each study site.

Table 7.6. Description of study reaches and sites in the Tomahawk River, March 2002.

	Channel	Instream habitat	Riparian veg
T1	Very narrow (<2m) channel with sand/silt substrate - mostly pool/run habitat. Water offtake upstream. Site fairly impacted by changing water levels - pools and dewatered banks occurring at low flows.	Relatively extensive macrophyte growth - mostly *Triglochin procera* with some *Potamogeton tricarinatus*. Some woody debris (tea-tree branches).	Intact Banksia and tea tree riparian zones (<30m). Fenced, preventing stock access.
T2	Steep granitic bedrock/boulder substrate. ~6m channel, wetted width <2m. Riffle/pool habitats with bedrock substrate.	Extensive aquatic vegetation - *Triglochin procera* in pools; moss-covered rocks in riffles. Moderate green filamentous algae growth on macrophytes and rocks. Woody debris.	Wide tea tree and Banksia riparian zones (> 50m) on both sides. Steep slopes with dry sclerophyll and Acacia - tea tree-Casuarina-Kunzea-native grass woodland. Large granitic boulders exposed on inclines. Fenced to prevent stock access.
T3	6m wide, straight channel with cobble/boulder substrate and riffle/pool habitat.	Moderate amount of aquatic vegetation - *Triglochin procera* in pool areas and moss on submerged rocks. Some filamentous green algae on cobbles. Some woody debris.	Broad (>50m), relatively open, with tea tree, Banksia, Eucalypt, Acacia, Kunzia and native grasses. Grass grazed by native animals and stock. Stock access to the water.
T4	Shallow meandering channel approx 5m wide with sand/gravel substrate. Predominantly run habitat with few riffles. This is the dominant habitat in the Tomahawk.	Some aquatic vegetation - *Triglochin procera* in slower flowing areas. Moderate amount of woody debris.	Crown land from here upstream. Broad riparian zones (>50m) of dry sclerophyll with an understorey of Banksias, Acacias and native grasses. tea tree fringing water's edge (~10m). Main channel is mostly shaded. Native grasses at water's edge. Unfenced, but n
T5	Very narrow channel (<2m) with heterogeneous substrate - small boulder/bedrock riffles interspersed with gravel/sand pools (<60cm deep).	Some aquatic vegetation - *Triglochin procera* in runs and pools. Algae and moss on submerged rocks. Little woody debris.	Very thick tea-tree (20m wide) shading the channel <1m from the water surface. Beyond 20m is open dry sclerophyll with Acacias, Banksias, *Xanthorrhoea*, bracken and patches of grazed grass.
T6	100m downstream of proposed damsite. Channel 5m wide, meandering, slow-flowing with sandy substrate. Runs the dominant habitat.	Moderate aquatic vegetation - all *Triglochin procera*. Some woody debris, many small leaf litter packs in backwaters	Broad riparian zones (>100m) of relatively unimpacted wet sclerophyll forest. Some tea tree and cutting grass, ferns, acacias, and dogwoods.

7.1.2.1 Fish fauna

Six species of fish were recorded during the survey of the Tomahawk River (Table 7.2). This fauna was characterised by:

- High densities of the native galaxiids *Galaxias maculatus* and *G. truttaceus* in the most downstream reaches (site T1);
- Sustained densities of the native *G. truttaceus* throughout the river;

- The absence or very low abundance of brown trout (none caught in the survey) and the absence of other exotic fish species;
- Greatest diversity in the middle and lower reaches.

No blackfish were observed during the survey, and were not recorded for the Tomahawk in the RFA-IFS fish distribution database. The database does include previous records of pygmy perch, *G. maculatus*, sandies and shortfin eel for the Tomahawk River.

The Tomahawk contains high densities of *G. truttaceus* throughout, from the most downstream survey site up to the proposed dam site (see Table 7.2). The Stage 1 survey also found *G. truttaceus* populations extending well upstream of the dam site, and including low densities of *G. brevipinnis*, the climbing galaxiid. Again, none of the fish species encountered in the survey were of particular conservation significance, and all are common and generally abundant in other rivers of the region. The Tomahawk is, however, of some conservation value due to the presence of a high-density of native populations unmodified by either the presence of exotic fish species, gross habitat disturbance or flow regulation.

Abundance and size distributional data for fish is contained in Appendix 2.

7.1.2.2 Macroinvertebrates

Both quantitative and semi-quantitative (RBA) sampling revealed a high density and diversity of macroinvertebrates in the Tomahawk River. Limited time prevented assessment of macroinvertebrates community composition from a range of habitats in the Tomahawk. A key habitat that distinguished the Tomahawk from the Boobyalla, boulder-bedrock, was therefore sampled. Table 7.7 summarises the abundances of macroinvertebrates observed from 18 quantitative surber samples taken from boulder-bedrock habitat, which contained over 11,000 individuals. A total of 49 taxa at family level were observed from this sample set. This diverse fauna was dominated by leptophlebiid mayflies, larval elmid beetles, orthoclad and chironomiid midges (accounting for 53% of total abundance). This faunal composition was similar to that found for a range of habitats in the Boobyalla River.

AUSRIVAS analysis of the RBA data revealed that the fauna was in an essentially undisturbed condition, equivalent in composition to unimpacted reference rivers within the region. As for the Boobyalla samples, the RBA sample fauna was dominated by leptophlebiids and chironomids, but also by leptocerid and hydrobiosid caddis (Table 7.8). A total of 41 taxa were present in the RBA samples. There was no strong trend in the diversity along the river, though the most downstream site had the lowest diversity. O/E taxa values were all > 0.73, with all sites falling within the 'equivalent to reference' A band (Table 7.7), except site T6 which had a slightly reduced diversity. Thus overall, the sites are classified as being unaffected by any significant human impact, with the exception of site T6.

Only one hydrobiid snail was encountered in the Tomahawk surber samples. It is possible that this habitat is not favoured by hydrobiid snails. However, the absence of hydrobiids in the RBA samples, when compared with the Boobyalla, suggest that hydrobiids are less abundant in the Tomahawk than in the Boobyalla.

12 families of caddisfly (Trichoptera) were encountered in the limited surber sample data set. This is a high local diversity for caddis which were only sampled from one habitat type.

No *Hyridella narracanensis* (Family Hyriidae) were observed in the Tomahawk River.

As reported in the Stage 1 report, *Astacopsis gouldi*, the Tasmanian freshwater lobster, is known from the Tomahawk River, and was occasionally fished prior to the closure of the lobster fishery. No further sampling was specifically conducted for this species.

Table 7.7. Macroinvertebrates in surber samples from bedrock-boulder habitat in the Tomahawk River, in March 2002. Abundances are N/0.09 m² of stream bed.

		Habitat:	**Bedrock-Boulder**
		N samples:	**18**
Order	**Class**	**Family**	**Total N**
Platyhelminthes	Turbellaria		3
Nematoda			3
Mollusca	Bivalvia	Sphaeriidae	41
	Gastropoda	Hydrobiidae	1
		Ancylidae	146
Annelida	Oligochaeta		337
Arachnida	Hydracarina		156
Crustacea	Amphipoda	Paramelitidae	9
		Eusiridae	1
	Copepoda		12
	Isopoda	Phreatoicidea	3
	Ostracoda		5
Insecta	Plecoptera	Gripopterygidae	85
		Notonemouridae	28
	Ephemeroptera	Leptophlebiidae	2169
		Caenidae	1
		Baetidae	25
	Odonata	Gomphidae	2
		Telephlebiidae	1
	Hemiptera	Veliidae	8
Diptera		Chironomidae:	
		Chironominae	1290
		Orthocladiinae	1658
		Tanypodinae	35
		Unid. chiron	8
		Simuliidae	38
		Ceratopogonidae	157
		Empididae	52
		Tanyderidae	6
		Unid. pupae	150
	Trichoptera	Atriplectididae	5
		Calocidae	10
		Conoesucidae	615
		Ecnomidae	110
		Helicophidae	2
		Helicopsychidae	72
		Hydrobiosidae	201
		Hydropsychidae	359
		Hydroptilidae	78
		Kokiriidae	1
		Leptoceridae	115
		Philorheithridae	4
		Unid. pupae	2
	Coleoptera	Adult Elmidae	197
		Adult Dytiscidae	2
		Adult Hydrophilidae	1
		Larval Elmidae	816
		Larval Scirtidae	34
		Larval Psephenidae	6
		Mean N Taxa	**22.4**
		Mean Total Abundance	**618.4**

Table 7.8. Macroinvertebrates in RBA kick samples of riffle habitats at six sites in the Tomahawk River, in March 2002, along with AUSRIVAS O/E scores and assessment bands. Abundances are N/30 minute live pick from a 10m kick sample.

	T1	T2	T3	T4	T5	T6
Turbellaria		1				
Sphaeridae	13					
Hydrobiidae						
Ancylidae			1			
Oligochaeta	1	2	6	1	4	2
Hydracarina	10	3	5		3	3
Paramelitidae	21		15	10	6	
Phreatoicidae					2	
Ostracoda	5					
Copepoda	1					
Chydorid	2					
Eustheniidae					9	
Gripopterygidae	1	5	16	4	16	20
Notonemouridae	2			1	3	7
Leptophlebiidae	16	21	48	35	33	40
Oniscigastridae		1		12	2	3
Baetidae		4	2			3
Telephlebiidae	2		1		1	
Veliidae	8	4	1			
Gerridae						
Nannochoristidae					1	2
Chironominae	32	3	19	9	12	4
Orthocladiinae	11	16	13	3	6	3
Tanypodinae	2		1	4	3	10
Simuliidae	11	7	9		12	2
Tipulidae	6	1		2	3	
Athericidae			1			1
Ceratopogonidae	8	1		3		5
Empididae						
Atriplectidae	9			1		7
Calocidae	11		1	7		1
Conoesucidae		14	8		2	1
Ecnomidae		4				2
Glossosomatidae						
Helicophidae						
Hydrobiosidae	35	13	22	10	18	10
Hydropsychidae		4	3		24	
Hydroptilidae						
Leptoceridae	22	15	39	9	4	31
Philorheithridae	12	6	1	19	1	13
Polycentropodidae						1
Adult Elmidae	4	4	19	1	9	
Larval Elmidae	2		1		1	
Scirtidae	3	1	7	1	7	
Psphenidae					1	
Adult Hydrophilida	1				1	
Adult Dytiscidae	1				1	
N Taxa	**28**	**21**	**23**	**18**	**27**	**22**
O/E taxa	**0.93**	**0.99**	**1.08**	**0.89**	**1.22**	**0.74**
Band	**A**	**A**	**A**	**A**	**X**	**B**

7.1.2.3 Macrophytes

The Tomahawk River contains moderate stands of *Triglochin procera*, with *Potamogeton tricarinatus* also occurring, but only at the most downstream site (T1). Floristic diversity was low, with most sites containing only *T. procera*.

7.1.3 Overall assessment

7.1.3.1 Boobyalla River

The Boobyalla River, both within the footprint of the proposed reservoir and downstream, has a number of features of conservation and management significance, including:

- A high diversity of macroinvertebrates;
- The presence of a particularly high diversity of Trichoptera;
- The presence of a substantial population of snails of the genus *Beddomeia*;
- The presence of *Astacopsis gouldi*;
- The presence of a freshwater mussel population in its middle reaches, which represents a new distributional record, and a potentially new species;
- The presence of a largely unmodified native fish population;
- Extensive areas of relatively or completely undisturbed riparian forest; and
- Habitat diversity and channel geomorphology which are rare both regionally and at state level for a lowland river system.

Overall, these features indicate that the Boobyalla River is a river of high aquatic ecological conservation significance and value.

7.1.3.2 Tomahawk River

The Tomahawk River, both within the footprint of the proposed reservoir and downstream, has a number of features of conservation and management significance, including:

- A high diversity of macroinvertebrates;
- The presence of *Astacopsis gouldi*;
- The presence of a largely unmodified population of *Galaxias truttaceus*;
- The near-absence and/or very low density of exotic fish species; and
- Extensive areas of relatively or completely undisturbed riparian forest.

Overall, these features indicate that the Tomahawk River is a river of moderate aquatic ecological conservation significance and value.

7.2 Environmental flow assessment - Minimum environmental flows

7.2.1 Habitat-discharge relationships

Transect hydraulic and habitat data is shown in Appendix 3, in standard RHYHAB format. Ratings were successfully developed for all sites, although the accuracy of curves at high flows (>0.5 cumec) could be improved by the addition of high flow gauging data (not possible during the dry conditions prevalent during the study). Curves were deemed reliable enough, however, to conduct simulation over the desired flow ranges with the exception of site T5. Problems with gauging accuracy and changing water levels could not be resolved within the time available, and this transect was not included in the hydraulic simulations.

Hydraulic simulations were successfully conducted over the desired flow ranges for all transects B1-B6 in the Boobyalla and T1-T4 and T6 in the Tomahawk.

Habitat preference curves developed for the macroinvertebrate taxa and macrophytes are shown in Appendix 4, along with the curves used for fish and platypus. A number of macroinvertebrate taxa showed marked velocity and/or depth preferences. Substrate preferences are strongly influenced by the dominance of sand-gravel substrates in both rivers.

7.2.4 Risk-assessment

Figure 7.1 shows plots of the relationships between minimum % Del HA (area of habitat area relative to that available at the reference flow) for each month for the Tomahawk River. It can be seen from these plots that:

- There is considerable difference between months (seasons) in the degree to which habitat availability is affected by changing flows;
- Changes around the reference flow for each month (at which %Del HA is always 100%) are very rapid during summer (January to April) compared with winter-spring.

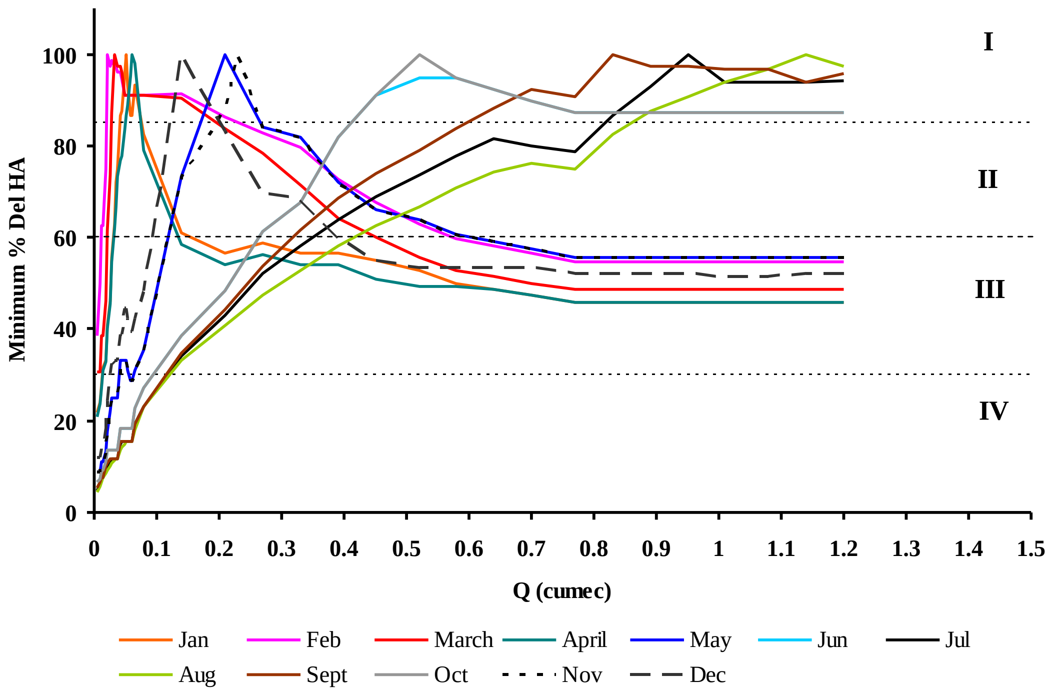


Figure 7.1. Plots of minimum % Del HA vs discharge for each month showing peak %Del HA at 100% at each month's reference discharge and trends on either side of the peak. These plots are for median conditions (i.e. using the median reference monthly flows) in the Tomahawk River. I to IV indicates risk bands, and horizontal lines indicate the risk band boundaries. Note the rapid change in Del HA around the peaks for the months of January to April.

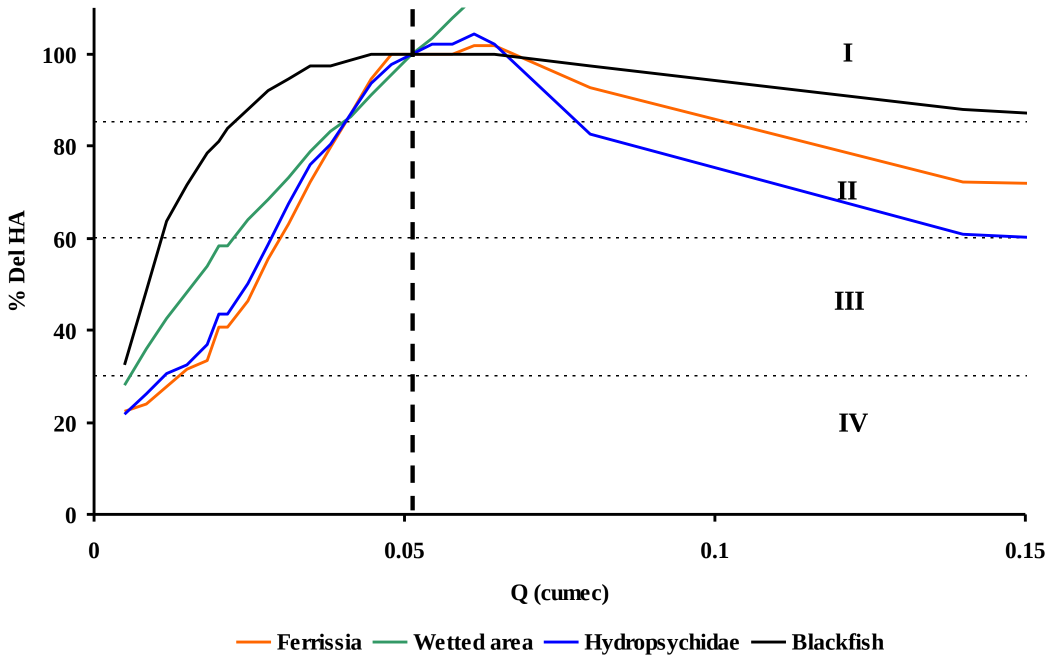


Figure 7.2. Example plots of changes in % Del HA vs discharge for three taxa and wetted area, showing rapid declines at flows lower than the reference discharge (indicated by the vertical dashed line). Data for median conditions, Tomahawk River.

This pattern is consistent across all four scenarios for which the risk assessment was conducted – Boobyalla median and drought conditions, Tomahawk median and drought conditions.

The sharpness of these curves indicates that there is a strong dependence on flow by a number of taxa. Figure 3.2 shows the detail for one of the curves in Figure 7.1 – for the month of January – for three of the 40 taxa/groups used in the assessment. The minimum %DelHA curves used in the risk assessment and shown in Figure 7.1 are developed from the responses of the most sensitive taxa at each discharge. Thus, the curve for January in the Tomahawk under median conditions is mainly developed by following the curve for *Ferrissia* (a freshwater limpet) - the taxon with the greatest rate of loss of habitat as flows fall below the reference flow. However, it can be seen that a number of taxa also lose habitat rapidly as flows fall below the reference flow, egg including Hydropsychid caddis and blackfish, as shown in Figure 7.2.

3.2.5 Minimum environmental flows

The lower thresholds for minimum environmental flows resulting, estimated from the risk assessment, are shown in Table 7.9 for the Boobyalla, and Table 7.10 for the Tomahawk. These flows are for the lowest margin of the minimal, moderate and significant risk bands (Bands I, II, and III) for each month of the year.

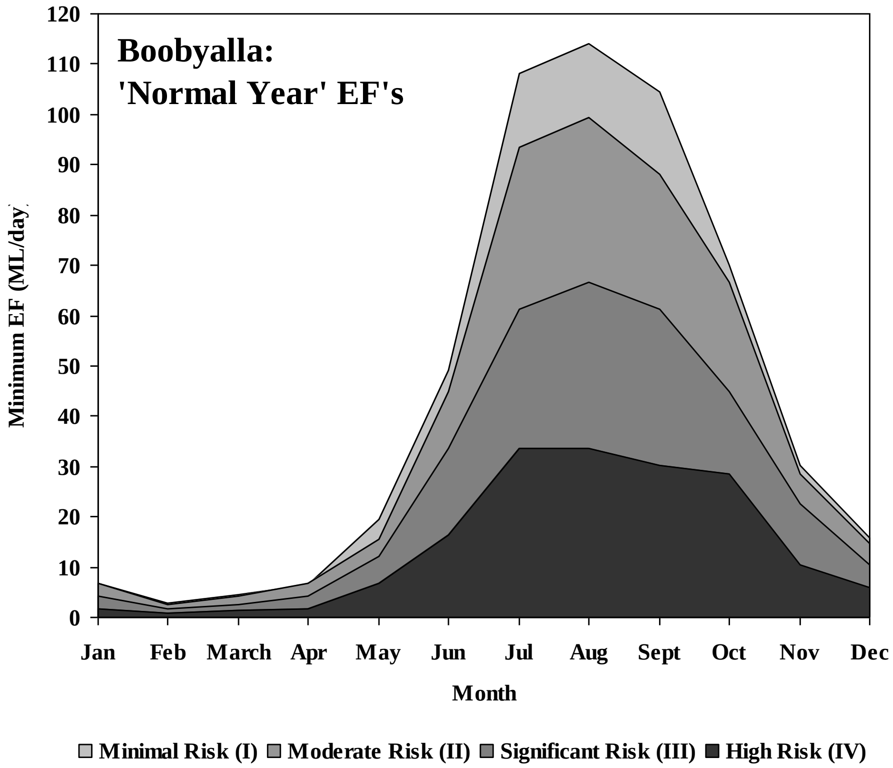
The environmental minimum flow ranges defined by these minimum flow thresholds are also plotted by month in Figures 7.3 and 7.4. Flows falling in Band I, between the reference flow and the lower boundary (the light grey areas in Figure 7.3 and 7.4), satisfy the criteria for minimal environment risk. Flows falling into the next lowest band (Band II) may cause moderate environmental risk, while flows falling lower than this (eg Band III) are deemed to cause significant to high risk to instream biota.

Table 7.9. Minimum environmental flow thresholds for three levels of risk (minimal, moderate, significant) for the Boobyalla River, as well as reference flows, for both 'normal' (median) and drought (20 percentile) conditions.

	Boobyalla Reference Flows				Boobyalla median						Boobyalla drought					
	Medians		Dry years (20 percentile)		Minimal risk I Boundary		Moderate risk II Boundary		Significant risk III Boundary		Minimal risk I Boundary		Moderate risk II Boundary		Significant risk III Boundary	
	cumec	ML/day	cumec	ML/day	cumec	ML/day	cumec	ML/day	cumec	ML/day	cumec	ML/day	cumec	ML/day	cumec	ML/day
Jan	0.078	6.77	0.049	4.19	0.0800	6.91	0.0500	4.32	0.0200	1.73	0.0480	4.15	0.0400	3.46	0.0130	1.12
Feb	0.032	2.80	0.014	1.25	0.0300	2.59	0.0200	1.73	0.0100	0.86	0.0139	1.20	0.0125	1.08	0.0025	0.22
March	0.052	4.49	0.019	1.63	0.0500	4.32	0.0300	2.59	0.0150	1.30	0.0169	1.46	0.0135	1.17	0.0070	0.61
Apr	0.076	6.58	0.044	3.79	0.0800	6.91	0.0500	4.32	0.0200	1.73	0.0419	3.62	0.0350	3.03	0.0100	0.86
May	0.224	19.36	0.107	9.26	0.1801	15.56	0.1400	12.10	0.0800	6.91	0.1036	8.95	0.0900	7.78	0.0400	3.46
Jun	0.568	49.07	0.253	21.89	0.5202	44.94	0.3901	33.71	0.1901	16.42	0.2567	22.18	0.2151	18.58	0.1000	8.64
Jul	1.251	108.13	0.575	49.66	1.0804	93.34	0.7102	61.37	0.3901	33.71	0.5475	47.30	0.4552	39.33	0.1901	16.42
Aug	1.319	113.97	0.714	61.73	1.1504	99.39	0.7703	66.55	0.3901	33.71	0.6774	58.52	0.5452	47.10	0.2301	19.88
Sept	1.210	104.55	0.510	44.06	1.0204	88.16	0.7102	61.37	0.3501	30.25	0.4501	38.89	0.3751	32.41	0.1801	15.56
Oct	0.810	70.00	0.243	21.01	0.7703	66.55	0.5202	44.94	0.3301	28.52	0.2257	19.50	0.2151	18.58	0.0850	7.35
Nov	0.351	30.33	0.158	13.64	0.3301	28.52	0.2601	22.47	0.1200	10.37	0.1540	13.30	0.1300	11.24	0.0600	5.19
Dec	0.182	15.75	0.098	8.48	0.1701	14.69	0.1200	10.37	0.0700	6.05	0.0961	8.30	0.0850	7.35	0.0300	2.59

Table 7.10. Minimum environmental flow thresholds for three levels of risk (minimal, moderate, significant) for the Tomahawk River, as well as reference flows, for both 'normal' (median) and drought (20 percentile) conditions.

	Tomahawk Reference Flows				**Tomahawk Median**						**Tomahawk Drought Year EF's**					
	Medians		**Dry years (20 percentile)**		**Minimal risk I Boundary**		**Moderate risk II Boundary**		**Significant risk III Boundary**		**Minimal risk I Boundary**		**Moderate risk II Boundary**		**Significant risk III Boundary**	
	cumec	**ML/day**	**cumec**	**ML/day**	**cumec**	**ML/day**	**cumec**	**ML/day**	**cumec**	**ML/day**	**cumec**	**ML/day**	**cumec**	**ML/day**	**cumec**	**ML/day**
Jan	0.018	1.52	0.00353	0.305	0.0170	1.47	0.0060	0.52	0.0040	0.35	0.0025	0.22	0.0020	0.17	0.0010	0.09
Feb	0.0078	0.68	0.00007	0.006	0.0060	0.52	0.0050	0.43	0.0025	0.22	0.0001	0.00	0.0000	0.00	0.0000	0.00
March	0.011	0.91	0.00065	0.056	0.0090	0.78	0.0060	0.52	0.0030	0.26	0.0001	0.01	0.0003	0.03	0.0000	0.00
Apr	0.021	1.79	0.00580	0.50	0.0150	1.30	0.0120	1.04	0.0040	0.35	0.0040	0.35	0.0030	0.26	0.0010	0.09
May	0.069	5.97	0.020	1.71	0.0620	5.36	0.0350	3.03	0.0149	1.29	0.0150	1.30	0.0110	0.95	0.0030	0.26
Jun	0.183	15.86	0.062	5.36	0.1801	15.56	0.1200	10.37	0.0400	3.46	0.0510	4.41	0.0310	2.68	0.0150	1.30
Jul	0.340	29.35	0.169	14.61	0.2701	23.34	0.2001	17.29	0.0750	6.48	0.1200	10.37	0.0900	7.78	0.0250	2.16
Aug	0.405	35.03	0.196	16.94	0.3501	30.25	0.2501	21.61	0.0800	6.91	0.1901	16.42	0.1200	10.37	0.0400	3.46
Sept	0.281	24.32	0.127	10.95	0.2301	19.88	0.1400	12.10	0.0700	6.05	0.1200	10.37	0.0900	7.78	0.0250	2.16
Oct	0.176	15.25	0.065	5.60	0.1501	12.96	0.1300	11.24	0.0400	3.46	0.0620	5.36	0.0350	3.03	0.0150	1.30
Nov	0.081	7.04	0.032	2.79	0.0700	6.05	0.0550	4.75	0.0180	1.56	0.0280	2.42	0.0200	1.73	0.0150	1.30
Dec	0.046	3.98	0.017	1.46	0.0400	3.46	0.0300	2.59	0.0165	1.43	0.0120	1.04	0.0080	0.69	0.0040	0.35



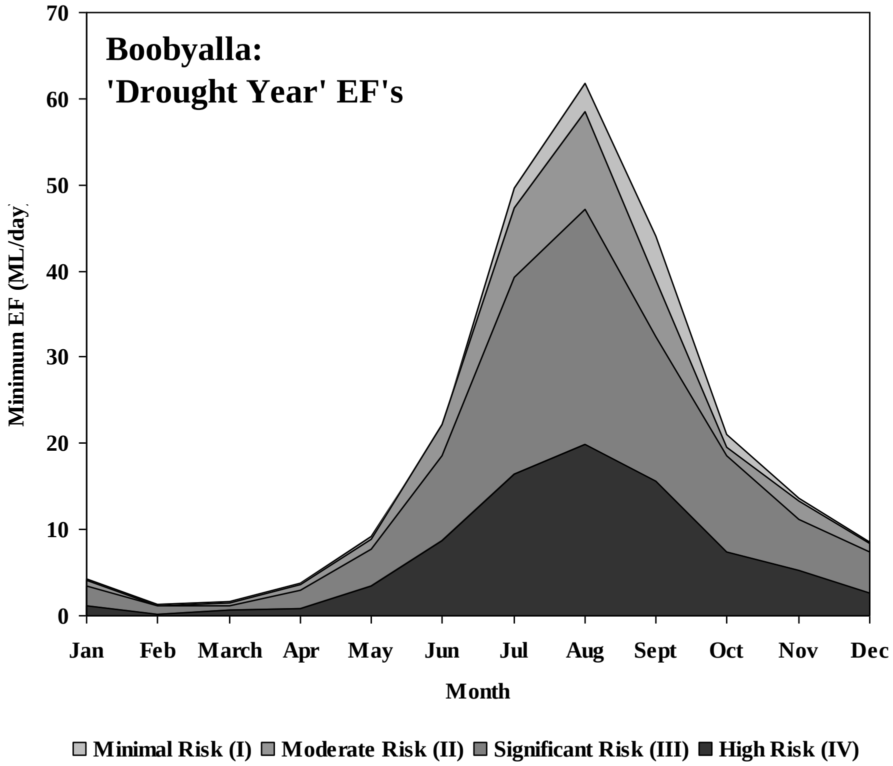
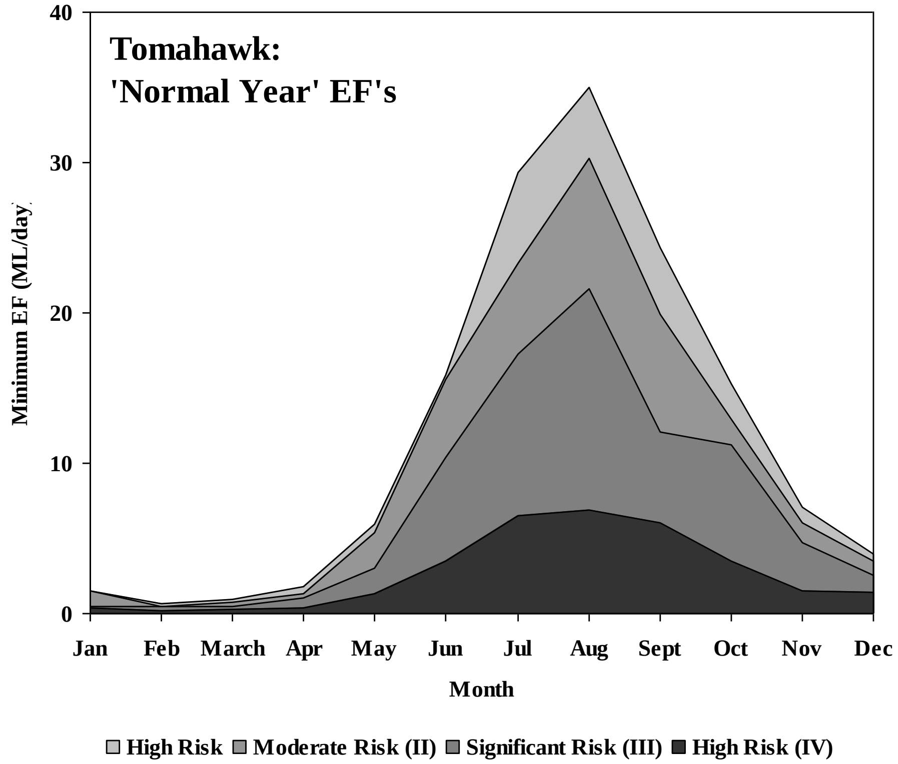


Figure 7.3. Plots of minimum environmental flow ranges for minimal, moderate, significant and high environmental risk under normal (median) and drought (20 percentile) conditions for the middle-lower Boobyalla River. Reference median and 20 percentile flows are also shown.



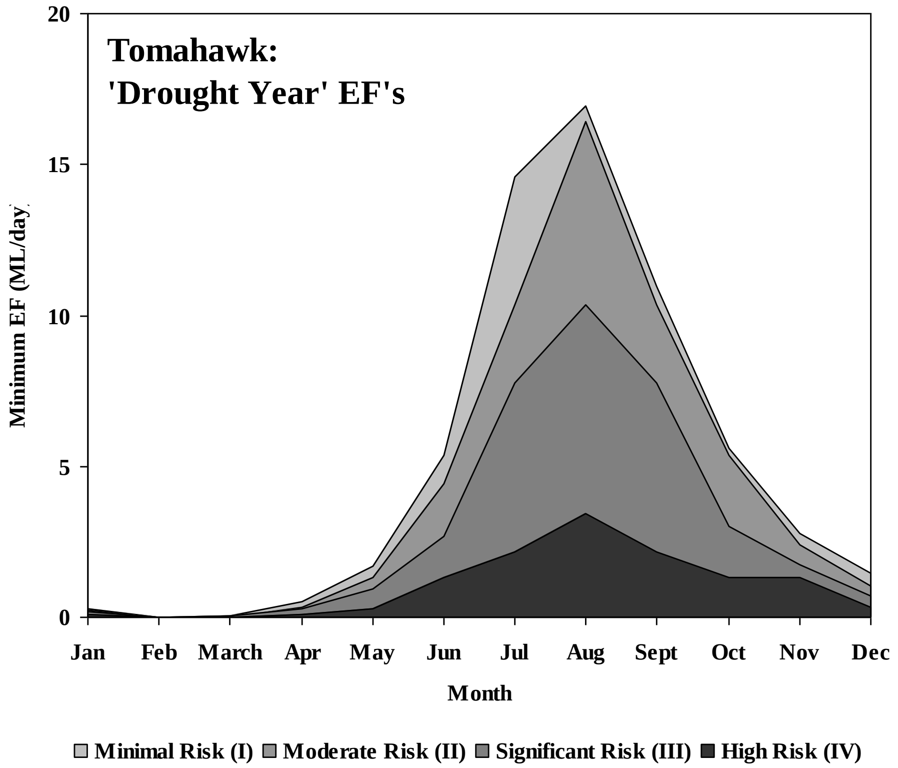


Figure 7.4. Plots of minimum environmental flow ranges for minimal, moderate, significant and high environmental risk under normal (median) and drought (20 percentile) conditions for the middle-lower Tomahawk River. Reference median and 20 percentile flows are also shown.

If the desired management goal for minimum environmental flows is minimal environmental risk then the values associated with Band I should be used. If moderate environmental risk as an accepted management goal, then the minimum environmental flows for Band II should be used. Minimum flows within the Band III range may cause significant environmental risk due to loss of instream habitat. Minimal risk (Band I) or moderate risk (Band II) flows are normally recommended in order to minimise risk to the instream environment.

7.2.6 Upper limits on minimum flows

The upper limits on minimum flows for the Boobyalla and Tomahawk derived from the risk analysis are shown in Table 7.10. Flow delivery downstream in the Boobyalla for irrigation at the levels proposed may to lead to slight risk of loss of habitat for instream biota through changes to the flow regime (though note the discussion below regarding the issue of impacts on sediment delivery and channel form and habitat availability). In the Tomahawk River, the risk associated with high delivery rates of irrigation flows may be significant during the irrigation season. It will also lead to loss of seasonal low flows in both rivers. The maximum flows shown in Table 7.10 place some restriction on the amount of water that can be delivered downstream for abstractive use without causing environmental impacts.

This indicates that flow delivery downstream in the both rivers may have to be constrained, and alternative routes of flow delivery sought where they exceed the thresholds in Table 7.11.

Table 7.11. Upper limits to minimum flows in the Tomahawk and Boobyalla Rivers deemed to present only moderate risk to instream biological values. Maximum values which are likely to be below peak irrigation delivery, and thus may cause a constraint on delivery downstream are highlighted in grey.

	Tomahawk Normal Year EF's		Tomahawk Drought Year EF's		Boobyalla Normal Year EF's		Boobyalla Drought Year EF's	
	Moderate risk		Moderate risk		Moderate risk		Moderate risk	
	A threshold		A threshold		A threshold		A threshold	
	cumec	ML/day	cumec	ML/day	cumec	ML/day	cumec	ML/day
Jan	0.07	6.1	0.01	0.9	0.26	22	0.25	22
Feb	0.05	4.3	0.01	0.4	0.20	17	0.20	17
March	0.07	6.1	0.01	0.4	0.25	22	0.25	22
Apr	0.10	10	0.01	0.9	0.30	26	0.30	26
May	0.15	13	0.03	2.6	0.50	43	0.35	30
Jun	0.26	22	0.08	6.9	0.75	65	0.50	43
Jul	0.40	35	0.16	14	1.50	130	0.75	65
Aug	0.52	45	0.21	18	1.70	147	0.80	69
Sept	0.35	30	0.14	12	1.50	130	0.65	56
Oct	0.26	22	0.08	6.9	0.95	82	0.50	43
Nov	0.18	16	0.06	5.2	0.50	43	0.45	39
Dec	0.12	10	0.03	2.6	0.40	35	0.30	26

7.3 Environmental flow assessment – high/flood flows

High flow and flood events are highly significant for maintaining environmental values in rivers and are becoming a key part of defining an environmental flow regime for water management. Flood events largely determine sediment transport within rivers, and interact with landforms to determine the pattern of channel and floodplain features, habitat types and diversity, and substrate characteristics of river channels. Floods are also vital in transporting organic material and as cues for key biological events. It is therefore vital that an environmental flow regime incorporates an appropriate pattern of floods which includes the magnitude, frequency and timing.

Figure 7.5 illustrates the dominant pattern of flows occurring in the Boobyalla and Tomahawk catchments. Flows are low to very low in summer-autumn. A strong peak in baseflows occurs in winter-spring, accompanied by a series of flood peaks which vary markedly in size. There is also marked interannual variation in flood frequency and magnitude.

No detailed assessment of flood sizes required to transport sediment was conducted in this study, and this should be assessed at least semi-quantitatively as part of a geomorphological assessment for these rivers (see discussion below). Nor was it possible to link specific floods/flood patterns with biological cues or channel forming processes, with the exception of native fish migration. Flooding in autumn and spring is known to stimulate movement of fish within the channel for spawning, and from the estuary into the lower river for galaxiid and other fish ('whitebait') and for elvers (juvenile eels) (e.g. Sloane 1984 a,b,c, Fulton and Pavuk 1988).

Overall, the assumption has been made in this study that the current channel form is in large part determined by the pattern of flood flows which have occurred over the last few decades to centuries, and that current habitat and biological features are also in part dictated by flood sequences that have occurred over the past few to tens of years. There is no evidence of major impacts caused by mining or agriculture on instream values/conditions.

Thus, the flood flow component of the environmental flow regime for these two rivers should essentially mimic the dominant annual pattern of flood flows that have occurred in the recent past. It has also been assumed in this study that extreme events (for which there are no reliable records) are unlikely to be affected greatly by the proposed dams, which are relatively small in storage capacity.

High flows and floods have been classified into four major types in this study, with differing roles, all of which are considered essential for the maintenance of the riverine/estuarine ecosystem (Table 7.12). Median floods are those floods with a 1 in 2 year average return interval, while annual floods are the average annual maximum floods. Both of these flood sizes play key roles in maintaining channel form, primarily though sediment transport, as well as key processes like meander migration. Annual floods also play a role in the transport of large woody debris (LWD). 'Trigger' high flows are flows considered essential of triggering key biological events. These flows are required in these rivers to initiate downstream migration of native fish for spawning (in autumn-early winter), as well as upstream migration of native fish juveniles (e.g. 'whitebait', which includes the juvenile forms of galaxiid fish and other species, and elvers – typically in spring). Trigger flows are also likely to play key short term roles in estuarine hydrodynamics, as well as in the transport of coarse organic material (CPOM) in river channels. Smaller, more regular 'freshes' are required for several purposes, most noteably maintenance of riparian and instream vegetation, local transport of fine particulate organic matter (FPOM) and flushing of algal biofilms.

The magnitude, duration and frequency of each of these high flow/flood types were determined for the Boobyalla and Tomahawk Rivers by examination of the hourly historical flow record, as well as relationships between catchment area and flood magnitude defined by Knighton (1987) for rivers of the north-east. The minimum sets of high flow/floods shown in Tables 7.13 and 7.14 are recommended as part of the overall environmental flow regime for these two rivers in all 'normal' years (annual rainfall between 20 and 80 percentiles).

We also recommend a reduced high flow/flood regime during drought years (annual rainfalls < 20 percentile), as shown in Table 7.15, with no annual or median flood events, and a reduced frequency of both trigger flows and freshes which mimics the pattern which occurred in drought years such as 1982 (Figure 7.5).

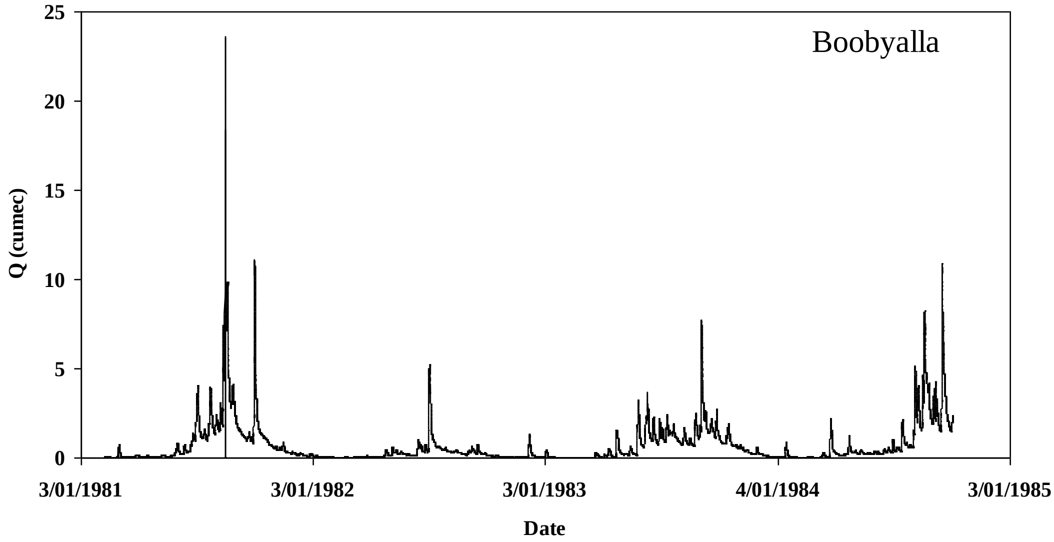


Figure 7.5. Example of Boobyalla River flow regime in the early 1980's, showing strongly seasonal pattern of base and flood flows, very low summer-autumn flows and the impact of drought (1982-83).

Table 7.12. Key environmental roles of four high flows/floods in the Boobyalla and Tomahawk Rivers.

Flood Type	Role
Median flood	Channel maintenance.
Annual flood	Channel maintenance, sediment and LWD transport, estuarine flushing.
Triggers	Downstream fish migration: sandies, shortfin eels, *G. maculatus*, *G. truttaceus*. Upstream fish migration: 'Whitebait', elvers. Also CPOM transport, estuarine mixing.
Freshes	Maintain riparian vegetation; flushing algae and FPOM; aquatic and riparian plant dispersal and germination.

Table 7.13. Recommended minimum set of high flow/flood events for maintaining environment values in the Boobyalla River.

Flood	Magnitude (cumec)	Months (inclusive)	Frequency	Duration (days)
Median	8.7	Aug-Sept	1 per 2 years	2
Annual	2.6	Aug-Sept	1 per year	1
Trigger	1.8	May-June	1 per autumn	1
	1.8	Sept-Oct	1 per spring	1
Freshes	0.5	May-Nov	1 per month	0.5

Table 7.14. Recommended minimum set of high flow/flood events for maintaining environment values in the Tomahawk River.

Flood	Magnitude (cumec)	Months (inclusive)	Frequency	Duration (days)
Median	8.4	Aug-Sept	1 per 2 years	2
Annual	3.4	Aug-Sept	1 per year	1
Trigger	1.5	May-June	1 per autumn	1
	1.5	Sept-Oct	1 per spring	1
Freshes	0.5	May-Nov	1 per month	0.5

Table 7.15. Recommended minimum set of high flow/flood events for maintaining environmental values in the Boobyalla and Tomahawk Rivers in drought years.

	Flood	Magnitude (cumec)	Months (inclusive)	Frequency	Duration (days)
Boobyalla	**Trigger**	1.8	Sept-Oct	1 per spring	1
	Freshes	0.5	May-June	1 per year	0.5
		0.5	Nov	1 per year	0.5
Tomahawk	**Trigger**	1.5	Sept-Oct	1 per spring	1
	Freshes	0.5	May-June	1 per year	0.5
		0.5	Nov	1 per year	0.5

These high flows/floods are recommended for release at the proposed dam sites. Release of these floods must be conducted so that:

- All high flows detailed in Tables 7.12 – 7.14 are released over and above the minimum flow releases;

- Flows are ramped up at 1 cumec/hr and down at 0.25 cumec/hr; and

- Trigger, annual and median flood flows are released coincident with major rainfall events.

Delivery of high and flood flows should in part mimic the natural pattern of flow variability. This is reflected in the difference in recommended high/flood flows for dry conditions. However, the annual environmental floods, trigger flows and freshes should be delivered every year since they are based on the long term, historical annual high flow pattern. Delivery of these flows may necessitate regular, specific releases, though with a proportion of annual floods provided by some spills at the dam.

Median floods should be delivered at the recommended average frequency of 1 in every 2 years. This does not necessitate delivery every second year, however, as the natural flood history is typified by clustered patterns of median and higher floods in wet and dry years. The aim should be to provide median floods with an average return interval of 1 every 2 years over a 5 year period.

7.4 Final Environmental Flow Regime

The final, recommended environmental flow regime for the two study rivers consists of the combination of the minimum baseflows plus a high/flood flow regime. Values for these flows are shown in Tables 7.9-10 and 7.13 – 7.15 for the two dam sites. Delivery of an appropriate environmental flow regime to the lower Boobyalla is dependent on releases of minimum and high/flood flows at the proposed dam, combined with unregulated inputs from lower catchment tributaries and/or groundwater inputs.

Delivery of an environment flow regime to the lower Tomahawk is more complex, due to the presence of inputs from the Boobyalla catchment combined with a regulated offtake for delivery of irrigation water to the west. It is recommended that an appropriate flow regime be delivered at the control weir downstream of the canal offtake. Minimum flows shown in Table 7.16 should be complied with, at the appropriate risk level, by flow control at that weir. High/flood flows should be assured by delivery of the recommended flows at the dam, combined with unregulated lower catchment inputs.

The typical pattern of environmental flows for both rivers is illustrated in Figures 7.6 and 7.7 for the 'normal' and 'drought' year cases, for baseflows based on no or minimal risk (Band I).

The drought year environmental flow regime should only be applied in cases where sustained drought conditions are experienced and/or forecast with high probability. Rules for identifying drought conditions must be agreed on, but it is suggested that they should include:

- Occurrence of sustained rainfall/natural flows (eg upstream of the proposed storage) that are less than the long-term 20 percentile mean; and
- A trigger based on quarterly rainfall/flow data.

These rules should be designed to avoid frequent switching from normal to drought flows based on short term rainfall deficits, where possible.

The flows detailed in Tables 7.10 and 7.11 and 7.13 - 7.15 are designed to released at the respective dam sites.

Compliance with these releases would obviously be assessed at the point of release. However, provision of adequate environmental flows throughout the river will require there to be no further substantial diversions/abstractions of yield from the lower part of the catchment. Thus, the proposed environmental flow releases will only be

Table 7.16. Minimum environment flow thresholds at two levels of risk (minimal and moderate) for the lower Tomahawk River at the proposed control weir and/or the Waterhouse Road for both 'normal' (median) and drought (20 percentile) conditions.

	Tomahawk Normal Year				Tomahawk Drought Year			
	Minimal risk		Moderate risk		Minimal risk		Moderate risk	
	I threshold		II threshold		I threshold		I threshold	
	cumec	ML/day	cumec	ML/day	cumec	ML/day	cumec	ML/day
Jan	0.0413	3.57	0.0314	2.71	0.0116	1.00	0.0083	0.72
Feb	0.02	1.73	0.0116	1.00	0.02	1.73	0.0116	1.00
March	0.0281	2.43	0.02	1.73	0.005	0.43	0.0015	0.13
Apr	0.0512	4.43	0.0314	2.71	0.0182	1.57	0.0083	0.72
May	0.18	15.56	0.14	12.10	0.0479	4.14	0.0314	2.71
Jun	0.45	38.89	0.27	23.34	0.17	14.69	0.14	12.10
Jul	0.83	71.74	0.39	33.71	0.39	33.71	0.27	23.34
Aug	0.89	76.92	0.45	38.89	0.45	38.89	0.33	28.52
Sept	0.64	55.32	0.33	28.52	0.35	30.25	0.27	23.34
Oct	0.45	38.89	0.27	23.34	0.18	15.56	0.14	12.10
Nov	0.18	15.56	0.14	12.10	0.0644	5.57	0.0512	4.43
Dec	0.14	12.10	0.1	8.64	0.0413	3.57	0.0314	2.71

effective at maintaining instream values throughout the river, as well as estuarine values, if they are augmented with unregulated and unaltered catchment inputs downstream of the dams. This will require effective metering and monitoring of all offtakes from the river channels, as well as controls on abstractions from tributaries.

The alternative is to impose both an environmental flow release strategy for the dams (as above) in addition to a flow regime at the downstream end of the catchments eg in the vicinity of the B52 Road. Matching these two regimes and assessing compliance is likely to prove problematic and this option is not currently recommended (though warrants further discussion).

This environmental flow regime has provided all the major elements of a flow regime for maintaining the values of the river and estuarine ecosystems - a seasonal pattern of baseflows along with high and moderate flood flows with defined frequency, timing, duration and rates of rise and fall. However one element which is known to be of ecological importance has not been recommended at this stage – cease-to-flow events. In situations where use of the river channel for irrigation supply leads to sustained, constant higher flows in summer-autumn, the provision of cease to flow events is problematic. Where this is not proposed to occur, e.g. in the Boobyalla, we recommend that when dam inflows fall below the drought minimum environmental flow, that the minimum environmental flow be equal to the inflow. Thus, when catchment yields are naturally very low and/or cease to flow conditions occur, the river downstream of the storage will also experience these conditions.

Extreme low flows and cessation of flow as been recorded for both the Boobyalla and Tomahawk Rivers, but is normally accompanied by a prolonged, slow drawdown allowing the biota to adjust to falling levels. Cessation of flows for short periods without sufficiently slow drawdown would not adequately mimic a natural event and is likely to cause significant deleterious impacts on the river ecosystem. Further evaluation of the use of extreme low flow/cease-to-flow events in regulated rivers in Tasmania is required.

Finally, it should be noted that the minimum flows recommended in this report should otherwise not be significantly interrupted or altered. Any reduction in releases below these levels that occurs due to accident or some other water management problem must be accompanied by supplementary flows to maintain the minimum. In cases where this is not possible, flow reductions must be managed to mimic natural rates of flow decline, to avoid the potentially serious and long-term impacts of abrupt dewatering and stranding events.

Compliance with the recommended environmental flow provisions should be assessed annually, with the median flood provision being fully reviewed very five years. Three points of compliance are recommended – immediately below the proposed Boobyalla and Tomahawk dams, and below the offtake channel in the Tomahawk River.

The relationship between the level of risk accepted for minimum environment flows and the catchment yield available for irrigation is explored in Tables 7.17 to 7.19. A significant to high level of environmental risk will have to be accepted in order to supply amounts of irrigation waters which fall within the design range proposed for the WCID. Tables 7.17 and 7.18 illustrate likely harvestable yields for several levels of environmental risk under median ('normal') and drought conditions. Table 7.19 provides an integrated estimate of the long term yield available for abstraction under four risk scenarios, by combining median and dry condition estimates.

While the yield figures may need more accurate calculation, they indicate that yields from the Boobyalla and Tomahawk in the range of 6,000 to 7000 ML/yr cannot be achieved without substantial loss of instream habitat and consequent impacts on instream fauna.

Data for the Boobyalla River on changes in habitat availability for aquatic fauna and flora over a range of flows at several levels of risk are shown in Table 7.20. A substantial number of native fish and macroinvertebrate taxa, macrophytes and platypus are projected to experience significant declines in habitat availability at high levels of abstraction (Risk Band III). This is further illustrated in plots of median and minimum annual habitat availability for the Boobyalla against % yield available for irrigation in Figure 7.8.

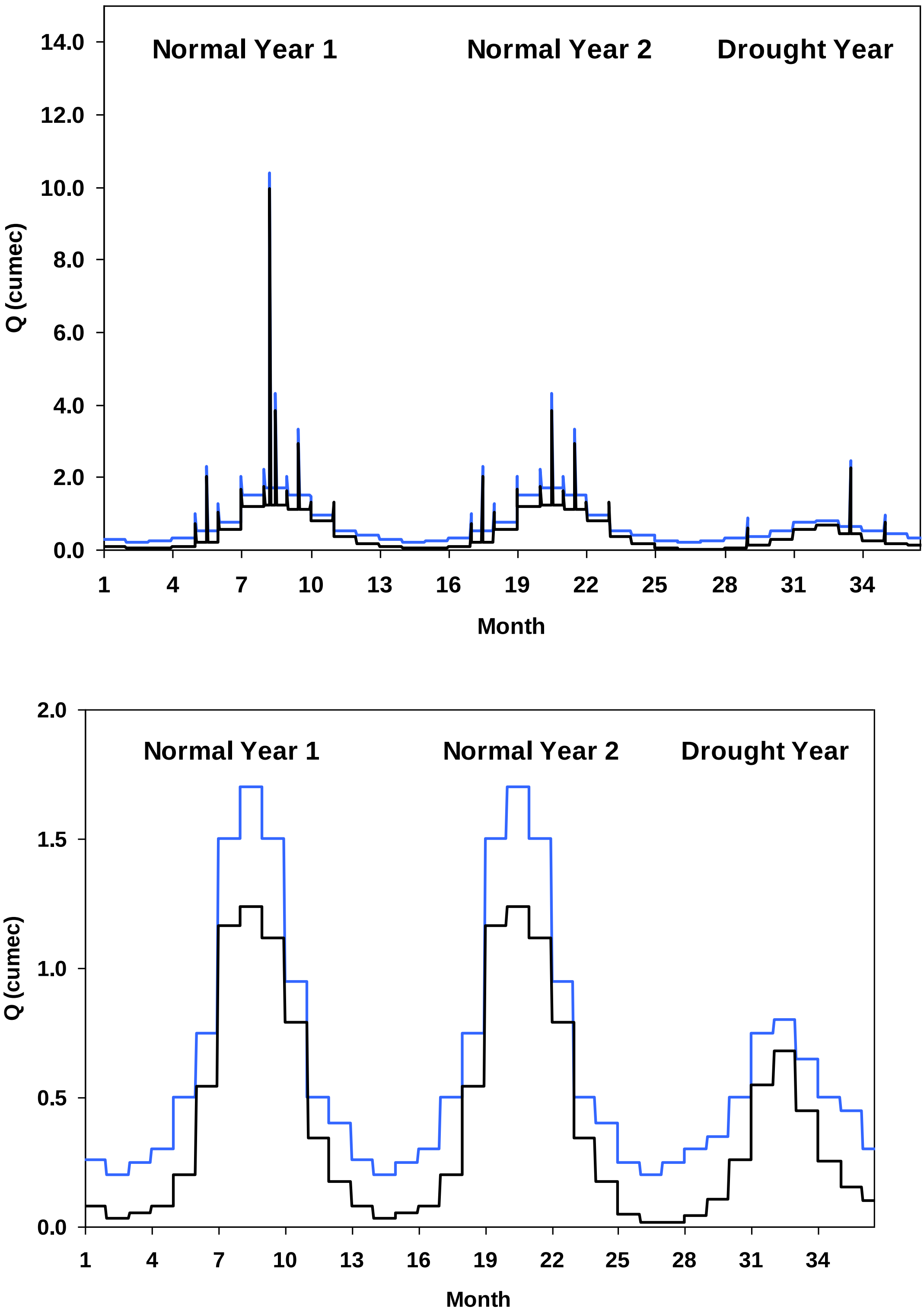
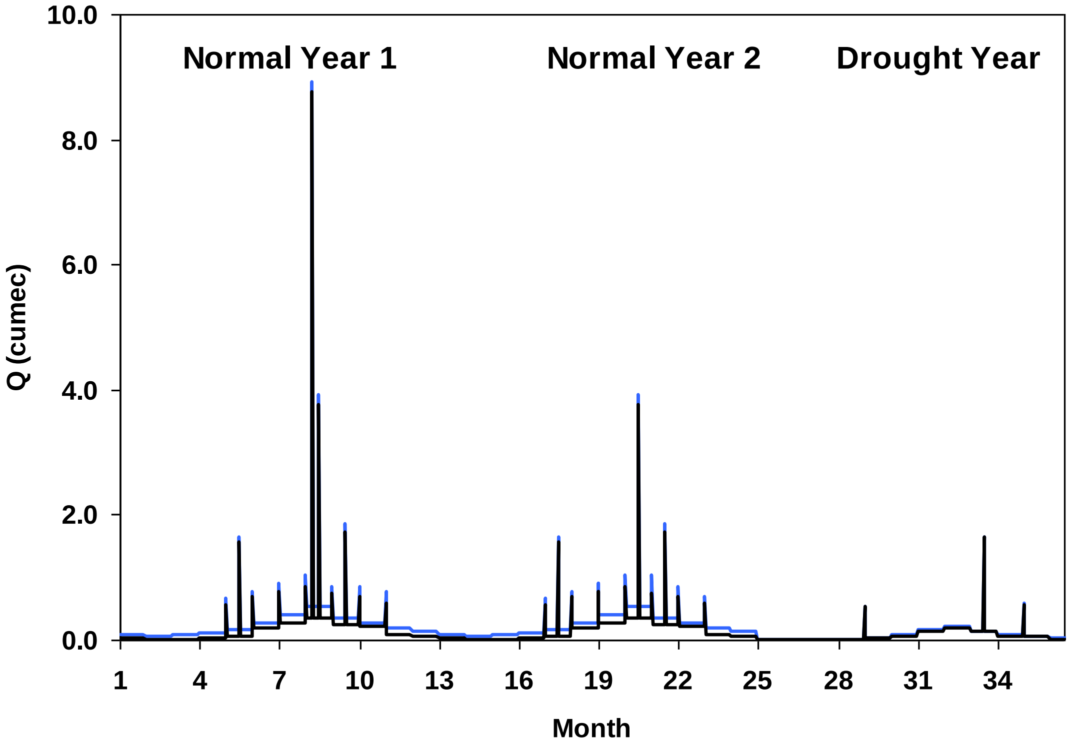


Figure 7.6. Pattern of Eflows for the Boobyalla River at the proposed dam site. Minimal risk Eflows are shown for 'normal years' - with and without the median flood release - as well as for a sample 'drought' year. Black and blue lines show minimum and maximum flows, respectively. Bottom plot shows baseflows only, to illustrate differences between minimum and maximum baseflow values.



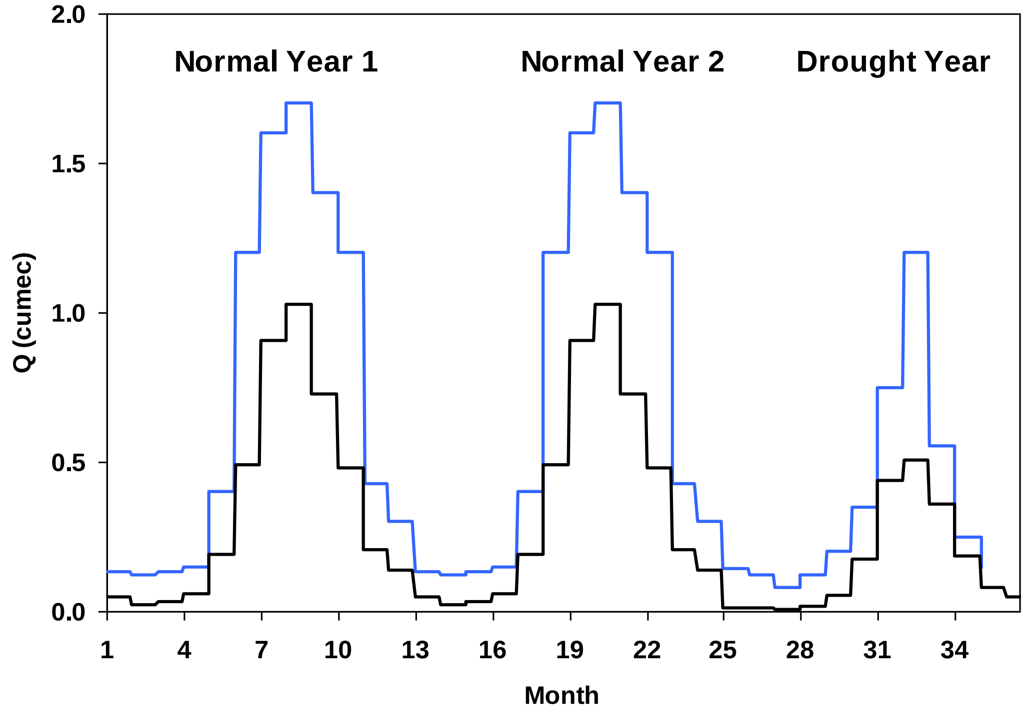


Figure 7.7. Pattern of Eflows for the Tomahawk River at the proposed dam site. Minimal risk Eflows are shown for 'normal years' - with and without the median flood release - as well as for a sample 'drought' year. Black and blue lines show minimum and maximum flows, respectively. Bottom plot shows baseflows only, to illustrate differences between minimum and maximum baseflow values.

For most taxa, habitat loss with abstraction is significantly greater in summer months. Values for January are shown in Table 7.21 for the Boobyalla River, and contrasted with annual values in Figure 7.9. For example, in January, when abstraction levels are equivalent to 62% of annual yield, both the area of wetted stream bed and of blackfish habitat fall to less than 40% of the value if no abstraction took place (Figure 7.9).

Some taxa do not show these responses, but these are the minority. Key species such as *Beddomeia* (the freshwater snail), blackfish and platypus all show substantial declines in habitat availability at abstraction levels greater than 50% of catchment yield.

Overall, risks associated with habitat loss are significant (>40% loss) to high (>60% loss) for the majority of aquatic fish and macroinvertebrate taxa, as well as for platypus and macrophytes, when minimum environmental flows are delivered so as to achieve >50% of catchment yield from either of the two storages. We would anticipate substantial changes to the instream fauna and flora if minimum flows are delivered below those shown in Tables 7.9 and 7.10 for Risk level III.

We would initially recommend that minimum environmental flows should fall above the band II band III boundary level to minimise risk to instream biota to an acceptable level.

Minimum environmental flows falling in Band III, ie between the lower boundaries of Bands II and III, run a significant risk of causing impacts on instream biota due to habitat loss.

Minimum environmental flows falling below the lower boundary of Band III run a high to severe risk of causing impacts on instream biota due to habitat loss.

Table 7.17. Mean daily minimum environmental flows (Eflows) and historical flows for the Boobyalla River at the proposed dam site under median and drought conditions. Minimum Eflows are shown for the lower boundary of three levels of environmental risk, by month. Sum of minimum and high/flood Eflows also shown. Along with the % of total catchment yield represented by Eflows and resulting median annual balance of yield available for abstraction.

	Boobyalla Normal Year Flows (ML/day)				Boobyalla Drought Year Flows (ML/day)			
	Minimum Environmental Flows			Historical Flows	Minimum Environmental Flows			Historical Flows
Month	Minimal risk Band I Boundary (85%)	Moderate risk Band II Boundary (60%)	Significant risk Band III Boundary (30%)	Median (Ref Q's)	Minimal risk Band I Boundary (85%)	Moderate risk Band II Boundary (60%)	Significant risk Band III Boundary (30%)	Median (Ref Q's)
Jan	6.9	4.3	1.7	6.77	4.2	3.5	1.1	4.19
Feb	2.6	1.7	0.9	2.80	1.2	1.1	0.2	1.25
March	4.3	2.6	1.3	4.48	1.5	1.2	0.6	1.63
Apr	6.9	4.3	1.7	6.58	3.6	3.0	0.9	3.78
May	15.6	12.1	6.9	19.35	8.9	7.8	3.5	9.25
Jun	44.9	33.7	16.4	49.05	22.2	18.6	8.6	21.89
Jul	93.3	61.4	33.7	108.09	47.3	39.3	16.4	49.64
Aug	99.4	66.6	33.7	113.93	58.5	47.1	19.9	61.71
Sept	88.2	61.4	30.3	104.51	38.9	32.4	15.6	44.05
Oct	66.6	44.9	28.5	69.98	19.5	18.6	7.3	21.00
Nov	28.5	22.5	10.4	30.32	13.3	11.2	5.2	13.64
Dec	14.7	10.4	6.1	15.75	8.3	7.3	2.6	8.48
Sum per annum (ML)	1817.1	6262.9	10958.6	16180.38	399.7	1504.0	4827.9	7320.39
E Flood flow total (ML/year)	950.0	950.0	950.0		163.0	163.0	163.0	
Total Eflows (ML/year)	15313.3	10867.5	6171.8		7083.7	5979.3	2655.5	
% Yield as Eflows	**94.6%**	**67.2%**	**38.1%**		**96.8%**	**81.7%**	**36.3%**	
Median balance as useable yield (ML/annum)	**867**	**5313**	**10009**		**237**	**1341**	**4665**	

Table 7.18. Mean daily minimum environmental flows (Eflows) and historical flows for the Tomahawk River at the proposed dam site under median and drought conditions. Minimum Eflows are shown for the lower boundary of three levels of environmental risk, by month. Sum of minimum and high/flood Eflows also shown. Along with the % of total catchment yield represented by Eflows and resulting median annual balance of yield available for abstraction.

	Tomahawk Normal Year Flows (ML/day)				Tomahawk Drought Year Flows (ML/day)			
	Minimum Environmental Flows			Historical Flows	Minimum Environmental Flows			Historical Flows
Month	Minimal risk Band I Boundary (85%)	Moderate risk Band II Boundary (60%)	Significant risk Band III Boundary (30%)	Median (Ref Q's)	Minimal risk Band I Boundary (85%)	Moderate risk Band II Boundary (60%)	Significant risk Band III Boundary (30%)	Median (Ref Q's)
Jan	1.5	0.5	0.3	1.52	0.2	0.2	0.1	0.31
Feb	0.5	0.4	0.2	0.68	0.0	0.0	0.0	0.006
March	0.8	0.5	0.3	0.91	0.0	0.0	0.0	0.06
Apr	1.3	1.0	0.3	1.79	0.3	0.3	0.1	0.50
May	5.4	3.0	1.3	5.97	1.3	1.0	0.3	1.71
Jun	15.6	10.4	3.5	15.85	4.4	2.7	1.3	5.36
Jul	23.3	17.3	6.5	29.34	10.4	7.8	2.2	14.60
Aug	30.3	21.6	6.9	35.02	16.4	10.4	3.5	16.93
Sept	19.9	12.1	6.1	24.31	10.4	7.8	2.2	10.95
Oct	13.0	11.2	3.5	15.25	5.4	3.0	1.3	5.60
Nov	6.1	4.8	1.6	7.03	2.4	1.7	1.3	2.79
Dec	3.5	2.6	1.4	3.98	1.0	0.7	0.3	1.46
Sum per annum (ML)	631.0	1709.6	3343.5	4311.30	243.5	754.7	1455.1	1834.08
E Flood flow total (ML pa)	939.0	939.0	939.0		146.0	146.0	146.0	
Total Eflows (ML pa)	4209.2	3540.7	1906.8		1736.6	1225.4	525.0	
% Yield as Eflows	**97.6%**	**82.1%**	**44.2%**		**94.7%**	**66.8%**	**28.6%**	
Median balance as useable yield (ML/annum)	**102**	**771**	**2404**		**97**	**609**	**1309**	

Table 7.19. Overall, long term estimates of % of catchment yield as EFlows and abstractable water for the Boobyalla and Tomahawk Rivers at the proposed dam sites, along with the long term, median abstractable yield. Values are shown for the lower boundaries of risk levels I to III, which correspond to the minimum environmental mean daily flows shown in Tables 7.9 and 7.10.

	Boobyalla Environmental Flows				Tomahawk Environmental Flows			
Risk:	**Minimal**	**Moderate**	**Significant**	**Significant**	**Minimal**	**Moderate**	**Significant**	**Significant**
Band:	**I**	**II**	**III**	**III**	**I**	**II**	**III**	**III**
	Boundary (85%)	**Boundary (60%)**	**Mid band (45%)**	**Boundary (30%)**	**Boundary (85%)**	**Boundary (60%)**	**Mid band (45%)**	**Boundary (30%)**
Long term % of Yield as EF's	95.1%	70.1%	54.2%	37.8%	97.0%	79.1%	60.9%	41.1%
Long term % of Yield as abstractions	4.9%	29.9%	46.0%	62.2%	3.0%	20.9%	39.1%	58.9%
Useable yield (long term average, ML pa)	741	4518	6700	8940	101	738	1455	2185

Table 7.20. Percent habitat available for all taxa in the Boobyalla River relative to reference conditions at four minimum flows representing differing levels of risk as the median over all months. Bold and underlined numerals indicate taxa with habitat loss > 15% (moderate risk) and 40% (significant risk) respectively.

		Risk Level			
		I	II	III mid	III
Wetted area		92.5	**72.2**	**<u>54.2</u>**	**<u>40.5</u>**
Macrophytes		96.8	**71.1**	**<u>55.1</u>**	**<u>37.8</u>**
Invertebrates	Hydrozoa	100.0	**83.9**	**78.3**	**62.8**
	Turbellaria	99.2	86.4	**73.8**	**<u>58.2</u>**
	Sphaeridae	97.8	**72.5**	**53.1**	**<u>39.8</u>**
	Hydrobiidae	100.0	87.1	**81.1**	**71.4**
	Ancylidae	100.0	102.9	104.0	105.9
	Oligochaetes	99.5	91.2	86.1	**81.9**
	Hydracraina	100.0	89.6	**80.9**	**68.3**
	Ostracoda	100.0	92.3	87.3	**81.3**
	Gripopterygidae	97.7	**84.4**	**76.6**	**63.6**
	Notonemouridae	98.7	**80.4**	**63.1**	**<u>52.2</u>**
	Leptophlebiidae	100.0	88.5	**82.7**	**68.7**
	Caenidae	99.2	92.0	**84.2**	**72.9**
	Baetidae	99.4	91.5	85.4	**76.4**
	Chironominae	97.1	89.0	**73.8**	**65.6**
	Orthocladiinae	100.0	91.5	86.8	**71.0**
	Tanypodinae	99.2	92.2	87.3	**76.1**
	Simuliidae	100.0	92.8	89.0	**78.6**
	Tipulidae	100.0	95.8	93.1	**84.4**
	Ceratopogonidae	97.3	88.4	**82.0**	**71.4**
	Empididae	100.0	93.5	90.5	**77.5**
	Dipteran Pupae	98.7	89.0	**75.6**	**65.8**
	Atriplectidae	100.0	88.9	**80.8**	**66.9**
	Calocidae	100.0	85.3	**75.3**	**65.7**
	Conoesucidae	100.0	97.3	94.8	89.2
	Ecnomidae	96.0	**81.7**	**63.3**	**<u>52.7</u>**
	Helicophidae	100.0	93.1	**84.0**	**75.4**
	Hydrobioisidae	100.0	91.0	86.1	**69.7**
	Hydropsychidae	101.1	105.9	111.8	115.9
	Hydroptilidae	100.0	98.1	96.2	86.7
	Leptoceridae	100.0	100.0	100.0	92.0
	Philorheithridae	100.0	93.7	**79.5**	**66.7**
	Elmidae (Adults)	100.0	90.8	86.2	**72.6**
	Elmidae (Larvae)	100.0	92.7	89.9	**74.8**
	Scirtidae	100.0	88.6	**74.1**	**68.1**
	N Taxa	100.0	91.7	**84.1**	**73.0**
	Total abundance	99.5	93.8	88.6	**80.9**
Native fish	Blackfish	100.0	91.8	86.1	**75.5**
	Shortfin eel	100.0	88.3	**81.0**	**75.0**
	Lamprey	100.0	88.7	**79.2**	**72.6**
	Jollytail	100.0	86.0	**71.5**	**<u>58.8</u>**
	Mountain galaxias	100.0	85.2	**71.6**	**<u>58.6</u>**
Platypus		99.7	86.4	**76.4**	**64.2**
N > 85%		**44**	**37**	**6**	**5**
N < 85%			**7**	**38**	**39**
N < 60%				**7**	**8**
% habitat loss					
Native fish	**Median**	0.0	13.0	20.8	29.1
	Minimum	6.7	34.5	53.2	66.7
Macroinvertebrates	**Median**	0.0	9.4	15.6	27.1
	Minimum	20.0	40.0	60.0	70.0

Table 7.21. Percent habitat available for all taxa in the Boobyalla River relative to reference conditions at four minimum flows representing differing levels of risk for January only. Bold and underlined numerals indicate taxa with habitat loss > 15% (moderate risk) and 40% (significant risk) respectively.

		Risk Level I	Risk Level II	Risk Level III mid	Risk Level III
		Mean daily Q			
	ML/day	**0.07**	**0.05**	**0.03**	**0.02**
	cumec	**6.048**	**4.32**	**2.592**	**1.728**
Wetted area		91.7	**73.8**	**53.6**	**40.5**
Macrophytes		93.5	96.8	100.0	106.5
Invertebrates	Hydrozoa	91.4	**72.4**	**53.4**	**46.6**
	Turbellaria	96.2	88.5	**76.9**	**65.4**
	Sphaeridae	**80.0**	**60.0**	**40.0**	**30.0**
	Hydrobiidae	91.1	**77.2**	**61.4**	**55.4**
	Ancylidae	100.0	100.0	92.9	80.4
	Oligochaetes	95.1	**84.7**	**72.9**	**72.9**
	Hydracraina	93.5	**81.8**	**70.1**	**61.0**
	Ostracoda	90.3	**77.4**	**67.7**	**71.0**
	Gripopterygidae	94.8	**83.1**	**70.1**	**63.6**
	Notonemouridae	88.9	**70.4**	**55.6**	**44.4**
	Leptophlebiidae	91.1	**77.2**	**62.0**	**55.7**
	Caenidae	94.6	86.8	**80.6**	**72.9**
	Baetidae	94.7	**84.0**	**73.4**	**64.9**
	Chironominae	91.7	**75.0**	**62.5**	**56.3**
	Orthocladiinae	94.1	**81.4**	**64.7**	**58.8**
	Tanypodinae	96.7	92.2	92.2	86.7
	Simuliidae	96.9	87.5	**62.5**	**50.0**
	Tipulidae	95.3	87.3	**80.0**	**78.7**
	Ceratopogonidae	92.1	**71.1**	**60.5**	**57.9**
	Empididae	93.5	**81.8**	**70.1**	**66.2**
	Dipteran Pupae	94.3	**79.2**	**66.0**	**58.5**
	Atriplectidae	90.3	**71.0**	**58.1**	**51.6**
	Calocidae	87.5	**66.1**	**46.4**	**41.1**
	Conoesucidae	96.9	90.6	**81.3**	**75.0**
	Ecnomidae	100.0	100.0	130.8	130.8
	Helicophidae	97.6	92.1	**77.2**	**60.6**
	Hydrobioisidae	94.5	**82.9**	**68.5**	**61.0**
	Hydropsychidae	100.0	96.1		74.5
	Hydroptilidae	92.9	85.7	**78.6**	**78.6**
	Leptoceridae	100.0	100.0	100.0	92.0
	Philorheithridae	87.5	**62.5**	**40.6**	**40.6**
	Elmidae (Adults)	93.5	**83.9**	**71.0**	**64.5**
	Elmidae (Larvae)	94.4	**82.5**	**69.1**	**63.9**
	Scirtidae	93.1	79.2	63.8	**60.0**
	N Taxa	95.2	**84.5**	**72.4**	**66.2**
	Total abundance	94.6	**82.8**	**69.2**	**63.3**
Native fish	Blackfish	95.7	**82.8**	**58.1**	**38.7**
	Shortfin eel	94.9	**83.9**	**68.6**	**62.7**
	Lamprey	93.9	**84.4**	**73.3**	**67.6**
	Jollytail	93.5	**79.5**	**65.1**	**56.5**
	Mountain galaxias	93.5	**79.8**	**65.7**	**56.5**
Platypus		93.9	**82.2**	**70.9**	**63.1**
N > 85%		**43**	**13**	**6**	**4**
N < 85%		**1**	**31**	**38**	**40**
N < 60%				**7**	**17**
% habitat loss					
Native fish	**Median**	5.7	17.9	33.8	43.6
	Minimum	6.5	20.5	41.9	61.3
Macroinvertebrates	**Median**	6.3	17.9	29.7	35.5
	Minimum	6.5	20.5	34.9	43.5

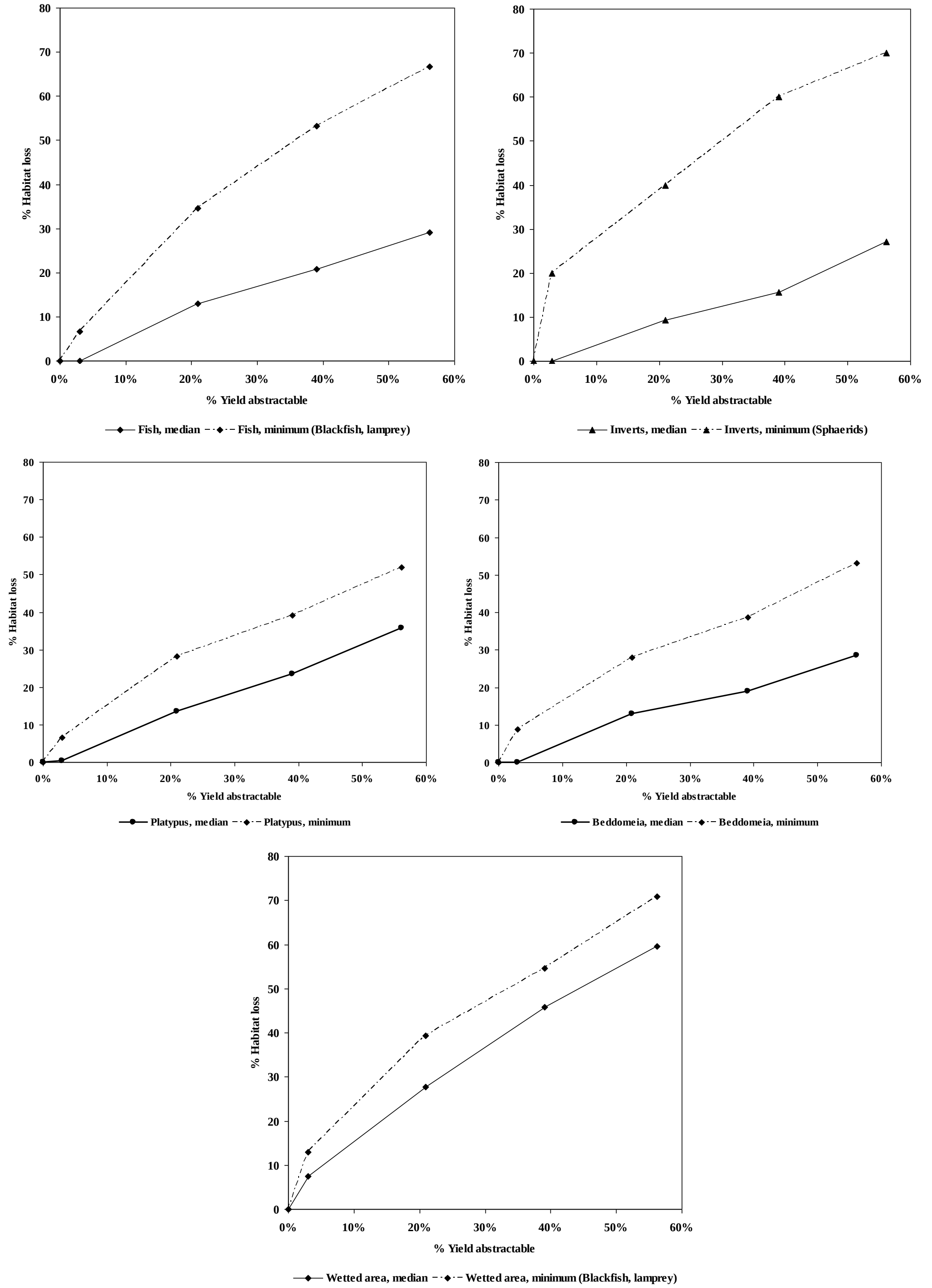
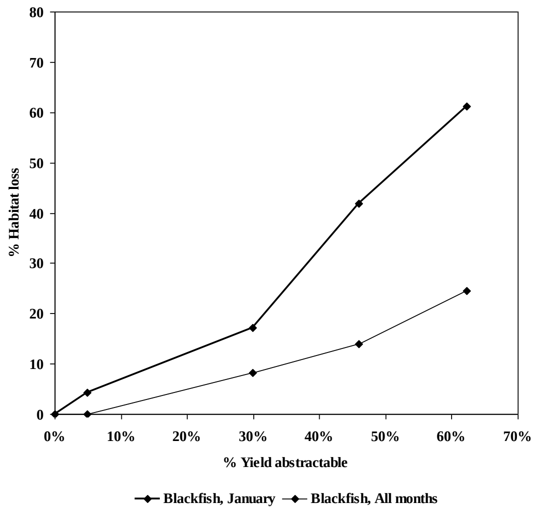
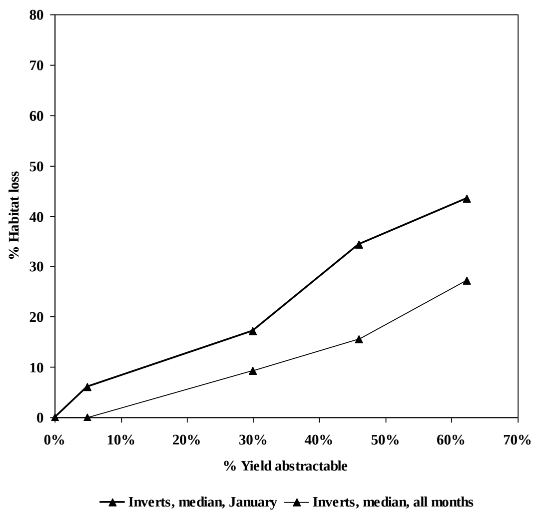


Figure 7.8. Percent habitat loss for key taxa, and as wetted area, over a range of levels of abstraction (as % of median catchment yield) in the Boobyalla River. Median and minimum values estimated over all months of the year (as well as over all taxa for native fish and macroinvertebrates).





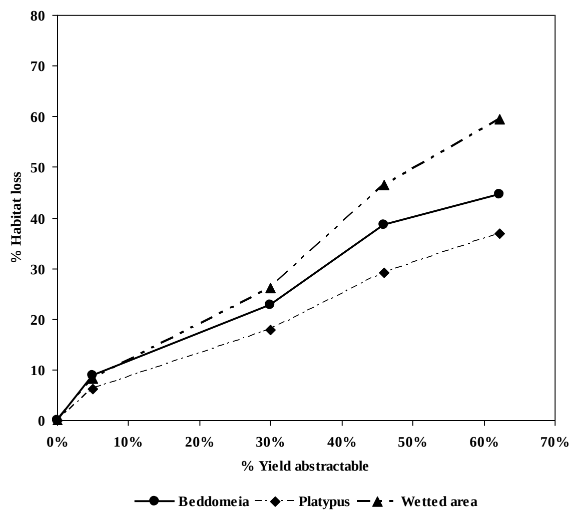


Figure 7.9. Comparison of percent habitat loss for blackfish and all macroinvertebrate taxa, estimated for January and as medians over all months over a range of levels of abstraction (as % of median catchment yield) in the Boobyalla River. January values only shown for *Beddomeia*, platypus and wetted area for comparison with Figure 7.8. Median values estimated over all taxa for macroinvertebrates.

7.5 Ecological risks from inter-catchment transfers

There are no major differences between the Tomahawk and Boobyalla in macroinvertebrate community composition. Based on the surber and RBA sample data sets, there are only two taxa that occur in the Boobyalla in any abundance which don't occur in the Tomahawk – hydrobiid snails (mainly *Beddomeia* and *Austropyrgus*), and helicophid caddis. Neither of these groups contain exotic species, could be deemed an environmental threat, or are likely to establish substantial new populations in the Tomahawk if the Boobyalla flows are re-directed into it. The absence of hydrobiid snails in the Tomahawk is probably related to habitat availability. The absence/low abundance of helicophids in the Tomahawk is also likely to be a habitat issue, since helicophid adults are likely to disperse between the two rivers at present. All taxa present in the Tomahawk which are not present in the Boobyalla samples are either highly mobile in their adult stage (and hence presumably have the opportunity to colonise at present), or have a low abundance.

There are some differences in the fish communities of the two rivers, in terms of relative dominance, but they share all species in common. There is therefore unlikely to be an issue with inter-basin transfer of fish. Brown trout occur in both catchments, and are likely to be limited by the dominance of sand in the stream substrate and the control this places on spawning success.

Risks associated with microcrustacean and/or algal transfer between the two rivers are unknown but are unlikely to be significant, as both rivers are highly likely to share common microcrustacean fauna and algal flora.

Overall, risks associated with inter-basin transfers of organisms are not deemed to be significant. Issues associated with interbasin transfers of water and resulting changes to the flow regime will be discussed below.

7.6 Fish migration requirements

Passage structures at dams are necessary where provision of passage would prevent a significant impact on a fish population or maintain linkages between key habitats.

For the Boobyalla River, the vast majority of migratory species within the catchment have been found below the dam, and the fish fauna at and upstream of the dam is limited to blackfish, brown trout and shortfin eels. None of these species or their populations are of particular conservation or commercial significance. Blackfish are largely non-migratory and are dependent on local habitat features and quality for maintaining a population (Davies 1994). Brown trout are not a significant feature of the catchment, and are likely to establish a population within the storage, as are blackfish. The population of shortfin eels upstream of the proposed dam site is not likely to be substantial or significant on a catchment or regional scale. There is therefore little evidence for a significant investment in fish passage at the proposed dam on the Boobyalla River. A small elver pass may be justified to enable eels to pass the dam.

A substantial and undamaged population of *Galaxias truttaceus* exists throughout the Tomahawk River. A significant portion of that population may be negatively impacted if passage is not made available at the dam wall, since this species is dependent on access to lower river/estuarine reaches for spawning and recruitment. In the absence of a fish pass at the dam, the population of both *G. truttaceus* and *G. brevipinnis* may decline. The degree to which this occurs will, however, be dependent on the degree to which the dam itself provides suitable rearing/spawning conditions for these two species, which are known to maintain sustainable landlocked populations in catchments adjacent to lakes. If large fluctuations in storage level are anticipated in the proposed Tomahawk storage, the quality of habitat for these two species will be poor, and a fish pass at the dam wall is recommended.

8. Discussion and Conclusions

8.1 Aquatic ecosystem values and significance

The Boobyalla River is a system with a high level of aquatic biological conservation significance, both on the regional and state levels. It contains threatened species, a high diversity of native macroinvertebrates and fish species, significant examples of native faunal and aquatic plant populations in an essentially undisturbed state, and a diversity of instream habitats of high quality. Macroinvertebrate bioassessment indicates that the entire river between the proposed dam site and downstream of the Waterhouse is in a largely unimpacted condition. Despite some local impacts, riparian vegetation has largely been protected over extensive areas due to the combination of Crown land status, streamside fencing and the low stock densities. This has helped maintain many of the natural values of this river system.

An assessment of the geomorphological features, values and processes within the Boobyalla River was not included in this study brief and has not been conducted. More importantly, an assessment of the geomorphological impacts of the presence of the proposed dam and its impact on sediment dynamics and erosion/alteration to the river channel downstream has not been conducted.

The proposal for a significant storage at the proposed site is likely to cause material harm to the aquatic environment in the area to be flooded and downstream of it. Flooding of the Boobyalla floodplain upstream of the dam site will result in permanent loss of a river reach of significant ecological value and significance. Values in the downstream reaches are unlikely to be maintained by the proposed environmental flow regime alone. It is our opinion that significant alteration to the downstream environment and habitats is highly likely to result from the proposed dam, which may result in negative consequences for the instream ecosystem.

The complex nature of the Boobyalla channel and its habitats downstream of the proposed dam site reflects the dominance by fine bed material (sands and gravels). The dynamics of this river will be strongly dependent on sediment transport combined with the pattern of flows. Prevention of downstream sediment supply due to storage at the dam site may have significant impacts on channel form downstream, which are unlikely to be controlled using environmental flows alone. This issue urgently needs assessment before further decisions are made regarding the WCID developments.

The Tomahawk River is a smaller river system. It has fewer significant natural features than the Boobyalla. However it is characterised by the presence of an unimpacted and dense population of the native spotted galaxias, *Galaxias truttaceus* throughout the river's length. The presence of such populations in the absence of brown trout and other disturbances is rare in Tasmania (the only other example on the Tasmanian northern and eastern coasts being Crayfish Creek near Port Latta). This is a value well worth maintaining. Consideration should be given to a fish ladder at the proposed dam site to maintain connectivity between the upper and lower catchment. In addition, the proposed storage on the Tomahawk River should not be stocked with trout or other exotic fish species.

Comments above regarding the impact of the proposed dam on the downstream river sediment dynamics, geomorphology and habitats also apply to the Tomahawk. The Tomahawk does not have a significant braided channel swamp or upper floodplain swamp forest features that occur on the Boobyalla River. However, the significant increase in baseflows resulting from transfer of water from the Boobyalla and irrigation delivery downstream may have significant deleterious impacts on the instream environment in the Tomahawk. A detailed geomorphological assessment is required to assess this issue, as for the Boobyalla River.

8.2 Environmental Flows

We recommend a set of minimum mean daily flows for each month which are required to maintain existing habitat for aquatic flora and fauna with a moderate level of risk, falling at the bottom of Band II, as shown in Tables 7.9, 7.10 and 7.16. Flows falling within or at the lower boundary of Band III (see those tables) may cause significant environmental harm through sustained loss of instream habitat under baseflow conditions.

In our analysis, risk is related to the risk of impact on faunal or macrophyte populations from loss of instream habitat. It should be re-iterated that the risks increase markedly if there are significant changes in riverine sediment dynamics affecting channel form, substrate type and habitat diversity as a result of the proposed dam (see comments above).

The set of minimum environmental flows includes provisions for 'normal' years (years experiencing flows not significantly different from the pattern of flows around the historical median). We also recommend flows for drought years, recognising the degree to which habitat availability fluctuates under these conditions naturally. This avoids unnecessary conflicts between users and natural values during droughts which may arise by the use of a single set of minimum environmental flows set using long term median/average conditions. The same recommendations in relation to flow bands apply, that is drought flow should not fall below the lower boundary of Band II. We also recommend once inflows to the proposed storages fall below the minimum flows for drought conditions, that minimum environment flow releases be equal to the storage inflows. This allows the rivers to experience very low and cease-to-flow events, conditions to which the instream biota are adapted, at a near-natural frequency.

A set of maximum values for daily minimum flows has also been recommended. This recognises the potential impact from downstream water supply envisioned within the WCID. It places a cap on the amount of water that can be distributed downstream via the river channel in any month, in order to avoid environmental impacts from these unnaturally high flows on the river ecosystem. It does not place any limits on the amounts of water to be distributed by other means (e.g. water races etc).

These caps do not impose significant constraints of delivery of irrigation water at the levels currently proposed in the Boobyalla or lower Tomahawk Rivers. The cap in the Tomahawk does, however, impose a major constraint on downstream water delivery between Tomahawk Dam and the canal offtake, some 6 km downstream of the dam. Irrigation season flows are projected to range between 12 and 80 ML/day, significantly above the proposed maxima for minimum environmental flows for all months of the irrigation season except for October. While not near bankfull and not anticipated to lead to major erosional problems, delivery of water at such rates in the mid Tomahawk is expected to have a substantial negative impact on the existing instream fauna and flora through decline in habitat suitability. This impact should be partially offset by provision of off-season minimum environmental flows with a low to moderate risk. Sustained flows during the season are expected to lead to a decline in diversity of macroinvertebrates and native fish, as well as in native macrophytes.

This study has also recommended a series of high/flood flow events for both rivers, which are aimed at maintaining the natural pattern of sediment movement, transport of organic material, channel change and cues for biological processes, such as fish spawning and migration. The degree to which sediment transport and channel form can be maintained by using these flow recommendations is however, dependent on the degree to which the dams themselves store and affect downstream sediment supply and transport (as discussed above). An assessment of this issue is required, which includes a review of the magnitude and frequency of the larger environmental flow events proposed here in relation to their potential for maintaining channel form with the reduced sediment supply below the proposed dams.

8.3 Main issues

The main aquatic environmental issues for the WCID project are as follows.

8.3.1 Boobyalla Dam Footprint

We believe that the floodplain which will be inundated by the Boobyalla Dam is of high ecological value and diversity and represents a unique example of a well developed floodplain-channel complex essentially undamaged by human impacts. Mining upstream does not appear to have caused any significant impact, and the well preserved riparian forest and floodplain channel complex is of regional and state significance. Flooding of this system is incompatible with its high conservation value.

8.3.2 Threatened species and Conservation values

A number of threatened species issues were detected in the Boobyalla River, with two listed species listed under Tasmanian legislation (one of which is listed under Federal legislation), and two potentially new and locally endemic species (the Beddomeid snail and freshwater mussel). Both the Boobyalla and Tomahawk contain an abundant native fish fauna, essentially unimpacted by alien or exotic species. The alien brown trout is very limited in abundance and distribution in these rivers, most likely due to limited amounts of spawning habitat of high quality. Management of the upper and middle Boobyalla River should focus on protecting the complex and relatively undisturbed instream habitats and their associated diverse biota from human impacts. Careful management of environmental flows is required to sustain the aquatic values of this system.

8.3.3 Water yield vs environmental flows

Constraints on the proportion of catchment yield available for irrigation use are required in order to provide adequate minimum environmental flows to minimise risks to instream flora and fauna. Pending further analysis, storage and abstraction should be limited to 50% or less of total catchment yield, in both river systems, to allow for an adequate level of environmental flow for protection of the downstream river ecosystem.

8.3.4 Middle Tomahawk River impacts

Proposed levels of irrigation water delivery between the proposed Tomahawk Dam and the canal offtake are much higher than caps on minimum environmental flow recommended for minimising the impact of high summer-autumn flows. Several management strategies are presented – use of the river to supply irrigation water downstream as proposed and allow the impact to occur; constraint of irrigation supply downstream in the river channel; and/or delivery of irrigation water downstream by an alternative route. We recommend adoption of a strategy which minimises risk to the instream biota, with flows not excessively exceeding the proposed caps recommended for each month.

8.3.5 Compliance with environmental flows

Environmental flows will need to be complied with at three locations – the proposed dam on the Boobyalla and on the Tomahawk Rivers, and downstream of the control weir in the middle Tomahawk River. This will necessitate the use of gauging stations at these locations.

9. References

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APPENDIX 1.

PRELIMINARY GEOMORPHOLOGICAL ASSESSMENT OF THE BOOBYALLA RIVER UPSTREAM OF THE PROPOSED WCID DAM SITE, CONDUCTED IN DECEMBER 2001.

KATH JERIE, FLUVIAL GEOMORPHOLOGIST (DPIWE TAS).

Tasmania

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<u>Assessment of the Boobyalla River proposed dam site near Little Mount Horror.</u>

Last year I spent a day investigating the geomorphology of the proposed Boobyalla dam site and inundated area, near Little Mount Horror, with a view to establishing its condition and regional significance. I looked at two sites: the dam site and the river immediately upstream (568900,5460900), and the river in the floodplain near the limit of inundation (near the gravel pit 569500,5458700). Such a short visit precludes a thorough investigation of the site, however, I have made the following observations.

The area is a long narrow floodplain, roughly half a kilometre wide and 3.5 km long. The plain is generally densely vegetated with an overstorey of mature eucalypts, a dogwood understorey and a ferny groundcover. The floodplain is grey/brown to dark brown silt. Toward the southern (upstream) end, the river has an irregular to tortuous meandering planform. The channel is fairly small, and is relatively narrow and deep. There is at least one abandoned channel on the western side of the floodplain, and another channel or backswamp to the east, that was flowing during field work. Moderate quantities of large woody debris were found in the main channel, and debris loads were high in the back channels.

This site looks like a good example of a lowland floodplain river. The meandering planform and the presence of secondary channels are typical of such systems. The low slope and fine sediments of the floodplain encourages the development of the meandering planform. Riparian and floodplain vegetation play an important role in stabilising such systems, by slowing the flow of water and by reinforcing river banks. Intact lowland floodplain rivers are generally very rare, because when cleared and drained they make very good farmland.

There are two possible causes of degradation of this site - changes to the vegetation and deposition of mine tailings. The large size of the overstorey eucalypts suggest that they at least are remnants of the pre-European vegetation. The aerial photo series, starting in 1952, shows that this section of the Boobyalla has not been cleared. There may have been some disturbance to the understorey, which appears to have increased in density during this time. However, it seems that the natural condition of the river has not been significantly impacted by vegetation clearance.

The story with mine tailings is not as clear. The Boobyalla River itself has not been mined upstream of the dam site. However, the Banca Mine, just south of Little Mount Horror, introduced sediment to the Boobyalla via Banca Creek and a small unnamed tributary. Some sediment was deposited by the unnamed tributary directly onto the area to be flooded by the proposed dam. However, the bulk of the tailings appear to have flowed down Banca Creek, which joins the Boobyalla less than a kilometre upstream of Banca road. The fan of mine tailings deposited at the confluence was large enough to partially dam the Boobyalla River, creating a wetland still present today. However, between here and the dam site, a constriction in the valley appears to have prevented large quantities of sediment from moving downstream.

If large volumes of sediment are introduced to a river, you expect deposition in the bed and floodplain to convert the river to a very shallow, wide and relatively straight channel surrounded by a silty and sandy floodplain. Once the supply of tailing stops, the channel usually incises the deposited sand, creating a gully of such size that flood frequency decreases because more water is held within the oversize channel, and the floodplains are now higher than natural because of the deposited tailings. This does not appear to be the case with the Boobyalla River. There is some evidence for sediment deposition on the floodplain, but it does not appear to be of any great depth, because the buttresses of old eucalypts are not buried. The meandering planform and stable nature of the channel also suggest that this has not been altered by a large influx of sediment.

There is a small section of channelised river at the upstream end of the floodplain. This does not appear to have affected the condition of the river downstream, although further investigation is required to confirm this.

In conclusion, the Boobyalla River at this site is an example of a lowland floodplain river in good condition. The site has been affected to some degree by mine tailings, and further field investigation are needed to confirm the extent of the impact. However, from field observations and examination of the available aerial photos, it appears that the sediments have not changed the geomorphic form or processes of the river or floodplain, and so have not significantly altered the geoconservation value of this site.

Although lowland floodplain rivers are very common, they are almost universally degraded by clearing and drainage works. I am not familiar enough with the region to be able to say how many similar river reaches exist in similar or better condition to this section of the Boobyalla. However, tin mining occurred throughout the region, and it appears that only an accident of topography has protected the Boobyalla from significant impact. It is possible that this is one of the best lowland floodplain sites in north eastern Tasmania. If this is the case it is an important site in a state wide context.

Kathryn Jerie
Fluvial Geomorphologist
Earth Science Section, DPIWE

APPENDIX 2.

FISH ABUNDANCE DATA FROM SURVEYS CONDUCTED IN THE BOOBYALLA AND TOMAHAWK RIVERS, 2002.

Boobyalla River

Site B1

Size (cm) :	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	30	40	50
Galaxias maculatus		+	+	+	+	+	+	+		+											
		+		+		+		+													
		+																			
Nannoperca australis	+	+																			
Pseudaphritis urvillii				+		+	+	+	+	+								+			
						+	+			+											
							+			+											
							+														
Anguilla australis																		+	+		+
																		+			
Geotria australis																			+		

Site B2

Size (cm) :	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	30	40	50
Galaxias maculatus		+	+	+	+	+	+	+	+												
			+	+	+	+	+	+													
			+	+	+	+	+	+													
			+	+	+	+	+														
			+	+	+	+	+														
				+	+	+															
				+	+	+															
				+	+	+															
				+	+	+															
				+	+	+															
				+	+																
				+	+																
				+																	
				12 +																	
Galaxias truttaceus				+	+	+	+														
					+																
					+																
Gadopsis marmoratus												+	+								
Nannoperca australis	+	+		+																	
	+	+		+																	
	+																				
	+																				
	+																				
	+																				
	+																				
	+																				
Pseudaphritis urvillii			+			+	+		+	+	+	+			+						
												+									
Anguilla australis																			+		
Geotria australis							+		+												
Salmo trutta								+											+		

Site B3

Size (cm) :	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**30**	**40**	**50**
Galaxias maculatus			+	+	+	+	+	+													
			+	+	+	+	+														
			+	+	+	+															
				+	+																
				+	+																
				+	+																
				+	+																
				+	+																
					+																
Gadopsis marmoratus																			+	+	
Nannoperca australis		+	+																		
		+	+																		
Pseudaphritis urvillii						+	+	+		+	+	+									
						+		+													
								+													
Anguilla australis											+							+			+
Geotria australis								+		+											
								+		+											
Salmo trutta																					+

Site B4

Size (cm) :	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**30**	**40**	**50**
Galaxias maculatus			+	+	+	+	+	+		+											
			+	+	+	+	+														
			+	+	+	+															
			+	+	+	+															
			+	+	+																
			+	+	+																
			+	+	+																
				+	+																
					+																
					+																
					+																
					+																
Gadopsis marmoratus		+													+	+	+	+	+		
																		+			
Pseudaphritis urvillii							+	+			+	+									
								+			+										
								+			+										
								+													
Anguilla australis						+	+	+	+	+	+		+			+		+			
							+						+					+			
Geotria australis										+									+		
										+											

Site B5

Size (cm) :	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	30	40	50
Galaxias maculatus			+	+	+	+															
			+	+	+	+															
			+	+	+	+															
			+	+	+																
			+	+	+																
			+	+	+																
			+	+																	
				+																	
				21+																	
Galaxias truttaceus							+														
Nannoperca australis				+																	
Pseudaphritis urvillii									+	+			+								
Anguilla australis							+	+		+			+					+			
								+										+			
								+										+			
																		+			
Geotria australis							+														

Site B6

Size (cm) :	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	30	40	50
Gadopsis marmoratus									+				+			+		+	+		
																		+			
																		+			
																		+			
																		+			
																		+			
Salmo trutta																		+			

Tomahawk River

Site T1

Size (cm) :	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	30	40	50
Galaxias maculatus		+	+	+	+	+	+	+	+	+											
		+	+		+		+		+	+											
		+			+		+		+	+											
					+		+		+	+											
					+		+		+												
Galaxias truttaceus				+	+	+			+	+	+										
				+	+	+			+												
				+	+	+															
					+	+															
					+																
					+																
					+																
					+																
Nannoperca australis	+	+																			
		+																			
		+																			
		+																			
		+																			
Pseudaphritis urvillii															+	+					

Site T2

Size (cm) :	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	30	40	50
Galaxias maculatus				+	+	+	+	+													
					+		+	+													
								+													
Galaxias truttaceus					+	+	+	+	+	+	+	+									
							+	+	+	+	+										
									+	+	+										
									+	+	+										
									+	+	+										
									+	+	+										
										+											
Anguilla australis													+								
Geotria australis						+	+														
							+														

Site T4

Size (cm) :	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	30	40	50
Galaxias maculatus						+		+		+											
						+				+											
						+				+											
Galaxias truttaceus				+	+	+		+	+	+		+									
					+			+	+	+		+									
					+			+	+	+		+									
								+		+											
										+											
										+											
										+											
Pseudaphritis urvillii														+							
Geotria australis								+													

Site T6

Size (cm) :	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	30	40	50
Galaxias maculatus									+												
Galaxias truttaceus			+	+	+		+	+	+	+	+										
				+	+		+	+	+	+	+										
				+				+	+	+	+										
								+	+	+	+										
								+	+	+	+										
								+	+	+											
								+	+	+											
								+													
								+													
								+													
Pseudaphritis urvillii										+											
Anguilla australis																			+		
																			+		

APPENDIX 3.

HYDRAULIC AND HABITAT DATA FROM STUDY TRANSECTS IN THE BOOBYALLA AND TOMAHAWK RIVER (IN STANDARD RHYHAB FILE FORMAT, SEE TEXT FOR TRANSECT LOCATIONS).

Boobyalla River
Transect B1

```
BED DATA 'Si' 'S' 'G' 'C' 'B' 'Be'

0.0 'B1' -1.746
GAU   -1.761      0.11702
GAU   -1.649      0.38172
SZF   -1.996
0     -1.609      0     100   0     0     0     0     0     0
1     -1.32 0     100   0     0     0     0     0     0
2     -1.104      0     100   0     0     0     0     0     0
4     -0.869      0     100   0     0     0     0     0     0
6     -0.668      0     100   0     0     0     0     0     0
7.5   -0.607      0     100   0     0     0     0     0     0
8     -0.41 0     100   0     0     0     0     0     0
8.4   -0.07 0     100   0     0     0     0     0     0
8.8   0     0     30    70    0     0     0     0     0
9.1   0.098 0     30    70    0     0     0     0     0
9.6   0.056 0     20    80    0     0     0     0     0
10    0     0     30    70    0     0     0     0     0
10.2  -0.062      0     30    70    0     0     0     0     0
10.6  -0.03 0     30    70    0     0     0     0     0
11    0     0     30    70    0     0     0     0     0
11.4  0.049 0.04  10    90    0     0     0     0     0
12    0.116 0.13  0     100   0     0     0     0     0
12.7  0.177 0.1   0     85    10    5     0     0     0
13.2  0.178 0.11  0     70    25    5     0     0     0
13.9  0.185 0.13  0     40    60    0     0     0     0
14.1  0.19  0.135 0     40    60    0     0     0     0
14.4  0.214 0.15  0     50    50    0     0     0     0
14.75 0.228 0.16  0     55    45    0     0     0     0
15    0.25  0.15  0     60    35    5     0     0     0
15.2  0.236 0.15  70    25    5     0     0     0     0
15.6  0.175 0.13  95    5     0     0     0     0     0
16    0.129 0.13  95    5     0     0     0     0     0
16.35 0     0     95    5     0     0     0     0     0
16.65 -0.124      0     95    5     0     0     0     0     0
16.8  -0.494      0     100   0     0     0     0     0     0
17.7  -0.628      0     90    10    0     0     0     0     0
18.7  -0.842      0     90    10    0     0     0     0     0
21    -0.856      0     95    5     0     0     0     0     0
END
100 'B1' -1.746
GAU   -1.761      0.11702
GAU   -1.649      0.38172
SZF   -1.996
0     -1.609      0     100   0     0     0     0     0     0
1     -1.32 0     100   0     0     0     0     0     0
2     -1.104      0     100   0     0     0     0     0     0
4     -0.869      0     100   0     0     0     0     0     0
6     -0.668      0     100   0     0     0     0     0     0
7.5   -0.607      0     100   0     0     0     0     0     0
8     -0.41 0     100   0     0     0     0     0     0
8.4   -0.07 0     100   0     0     0     0     0     0
8.8   0     0     30    70    0     0     0     0     0
9.1   0.098 0     30    70    0     0     0     0     0
9.6   0.056 0     20    80    0     0     0     0     0
10    0     0     30    70    0     0     0     0     0
10.2  -0.062      0     30    70    0     0     0     0     0
10.6  -0.03 0     30    70    0     0     0     0     0
11    0     0     30    70    0     0     0     0     0
```

```
11.4  0.049 0.04  10    90    0     0     0     0     0
12    0.116 0.13  0     100   0     0     0     0     0
12.7  0.177 0.1   0     85    10    5     0     0     0
13.2  0.178 0.11  0     70    25    5     0     0     0
13.9  0.185 0.13  0     40    60    0     0     0     0
14.1  0.19  0.135 0     40    60    0     0     0     0
14.4  0.214 0.15  0     50    50    0     0     0     0
14.75 0.228 0.16  0     55    45    0     0     0     0
15    0.25  0.15  0     60    35    5     0     0     0
15.2  0.236 0.15  70    25    5     0     0     0     0
15.6  0.175 0.13  95    5     0     0     0     0     0
16    0.129 0.13  95    5     0     0     0     0     0
16.35 0     0     95    5     0     0     0     0     0
16.65 -0.124      0     95    5     0     0     0     0     0
16.8  -0.494      0     100   0     0     0     0     0     0
17.7  -0.628      0     90    10    0     0     0     0     0
18.7  -0.842      0     90    10    0     0     0     0     0
21    -0.856      0     95    5     0     0     0     0     0
END
END
```

Transect B2

```
BED DATA 'Si' 'S' 'G' 'C' 'B' 'Be'

0 'B2' -0.380
GAU   -0.448      0.05634
GAU   -0.265      0.18185
SZF   -0.529
0     -0.278      0     80    20    0     0     0     0     0
1.3   -0.186      0     20    60    20    0     0     0     0
2.2   -0.377      0     80    20    0     0     0     0     0
5     -0.357      0     90    10    0     0     0     0     0
5.7   -0.349      0     90    10    0     0     0     0     0
6     0     0     40    10    50    0     0     0     0
6.3   0.055 0.01  0     30    70    0     0     0     0
6.75  0.017 0     0     50    50    0     0     0     0
7.4   0.03  0     0     80    20    0     0     0     0
8     0.117 0.28  0     15    85    0     0     0     0
8.12  0.149 0.19  0     10    90    0     0     0     0
8.24  0.106 0.26  0     10    90    0     0     0     0
8.36  0.091 0.29  0     10    90    0     0     0     0
8.48  0.082 0.35  0     10    90    0     0     0     0
8.6   0.088 0.4   0     10    90    0     0     0     0
8.72  0.095 0.37  0     10    90    0     0     0     0
8.84  0.111 0.32  0     10    90    0     0     0     0
8.96  0.115 0.33  0     5     95    0     0     0     0
9.08  0.116 0.33  0     5     95    0     0     0     0
9.2   0.077 0.3   0     5     95    0     0     0     0
9.32  0.058 0.3   0     5     95    0     0     0     0
9.44  0.062 0.32  0     5     95    0     0     0     0
9.56  0.05  0.24  0     10    90    0     0     0     0
9.66  0.04  0.11  0     15    85    0     0     0     0
9.8   0     0     0     10    90    0     0     0     0
10.35 -0.097      0     40    20    40    0     0     0     0
10.6  -0.513      0     70    5     25    0     0     0     0
14.1  -0.392      0     95    5     0     0     0     0     0
16    -0.199      0     95    5     0     0     0     0     0
18.6  -0.33 0     90    10    0     0     0     0     0
19.6  -0.103      0     5     90    5     0     0     0     0
20.1  0     0     0     85    15    0     0     0     0
20.4  0.084 0.13  0     50    50    0     0     0     0
```

```
20.7  0.099 0.12  0     40    60    0     0     0     0
21.05 0     0     10    30    60    0     0     0     0
22.5  -0.141      0     5     70    25    0     0     0     0
23.5  -0.062      0     10    30    60    0     0     0     0
24    -0.243      0     10    40    50    0     0     0     0
29    -0.295      0     60    30    10    0     0     0     0
32.3  -0.259      0     70    25    5     0     0     0     0
33    -0.056      0     50    40    10    0     0     0     0
34.4  -0.074      0     5     90    5     0     0     0     0
34.7  -0.063      0     5     90    5     0     0     0     0
36    -0.069      0     5     55    40    0     0     0     0
37.8  0     0     10    80    10    0     0     0     0
38.7  0.167 0     10    70    20    0     0     0     0
39.7  0.268 0     60    10    30    0     0     0     0
40.75 0     0     80    5     15    0     0     0     0
43.37 -0.212      0     95    5     0     0     0     0     0
46.3  -0.12 0     100   0     0     0     0     0     0
47.9  -0.077      0     100   0     0     0     0     0     0
48.5  -0.097      0     100   0     0     0     0     0     0
49.5  -0.145      0     100   0     0     0     0     0     0
51.5  -0.253      0     100   0     0     0     0     0     0
53.5  -0.299      0     100   0     0     0     0     0     0
55.5  -0.614      0     100   0     0     0     0     0     0
END
100 'B2' -0.380
GAU   -0.448      0.05634
GAU   -0.265      0.18185
SZF   -0.529
0     -0.278      0     80    20    0     0     0     0     0
1.3   -0.186      0     20    60    20    0     0     0     0
2.2   -0.377      0     80    20    0     0     0     0     0
5     -0.357      0     90    10    0     0     0     0     0
5.7   -0.349      0     90    10    0     0     0     0     0
6     0     0     40    10    50    0     0     0     0
6.3   0.055 0.01  0     30    70    0     0     0     0
6.75  0.017 0     0     50    50    0     0     0     0
7.4   0.03  0     0     80    20    0     0     0     0
8     0.117 0.28  0     15    85    0     0     0     0
8.12  0.149 0.19  0     10    90    0     0     0     0
8.24  0.106 0.26  0     10    90    0     0     0     0
8.36  0.091 0.29  0     10    90    0     0     0     0
8.48  0.082 0.35  0     10    90    0     0     0     0
8.6   0.088 0.4   0     10    90    0     0     0     0
8.72  0.095 0.37  0     10    90    0     0     0     0
8.84  0.111 0.32  0     10    90    0     0     0     0
8.96  0.115 0.33  0     5     95    0     0     0     0
9.08  0.116 0.33  0     5     95    0     0     0     0
9.2   0.077 0.3   0     5     95    0     0     0     0
9.32  0.058 0.3   0     5     95    0     0     0     0
9.44  0.062 0.32  0     5     95    0     0     0     0
9.56  0.05  0.24  0     10    90    0     0     0     0
9.66  0.04  0.11  0     15    85    0     0     0     0
9.8   0     0     0     10    90    0     0     0     0
10.35 -0.097      0     40    20    40    0     0     0     0
10.6  -0.513      0     70    5     25    0     0     0     0
14.1  -0.392      0     95    5     0     0     0     0     0
16    -0.199      0     95    5     0     0     0     0     0
18.6  -0.33 0     90    10    0     0     0     0     0
19.6  -0.103      0     5     90    5     0     0     0     0
20.1  0     0     0     85    15    0     0     0     0
20.4  0.084 0.13  0     50    50    0     0     0     0
```

```
20.7  0.099 0.12  0     40    60    0     0     0     0
21.05 0     0     10    30    60    0     0     0     0
22.5  -0.141      0     5     70    25    0     0     0     0
23.5  -0.062      0     10    30    60    0     0     0     0
24    -0.243      0     10    40    50    0     0     0     0
29    -0.295      0     60    30    10    0     0     0     0
32.3  -0.259      0     70    25    5     0     0     0     0
33    -0.056      0     50    40    10    0     0     0     0
34.4  -0.074      0     5     90    5     0     0     0     0
34.7  -0.063      0     5     90    5     0     0     0     0
36    -0.069      0     5     55    40    0     0     0     0
37.8  0     0     10    80    10    0     0     0     0

38.7  0.167 0     10    70    20    0     0     0     0
39.7  0.268 0     60    10    30    0     0     0     0
40.75 0     0     80    5     15    0     0     0     0
43.37 -0.212      0     95    5     0     0     0     0     0
46.3  -0.12 0     100   0     0     0     0     0     0
47.9  -0.077      0     100   0     0     0     0     0     0
48.5  -0.097      0     100   0     0     0     0     0     0
49.5  -0.145      0     100   0     0     0     0     0     0
51.5  -0.253      0     100   0     0     0     0     0     0
53.5  -0.299      0     100   0     0     0     0     0     0
55.5  -0.614      0     100   0     0     0     0     0     0
END
END
```

Transect B3

```
BED DATA 'Si' 'S' 'G' 'C' 'B' 'Be'

0 'B3' -0.872
GAU   -0.881      0.09332
GAU   -0.824      0.16901
SZF   -1.135
0     -0.765      0     100   0     0     0     0     0     0
2     -0.416      0     100   0     0     0     0     0     0
4.1   -0.367      0     100   0     0     0     0     0     0
4.4   0     0     100   0     0     0     0     0     0
5.25  0.172 0.04  100   0     0     0     0     0     0
6     0.263 0.03  10    50    40    0     0     0     0
6.75  0.256 0.03  0     70    30    0     0     0     0
7.5   0.238 0.02  20    40    40    0     0     0     0
8.25  0.224 0.01  0     30    70    0     0     0     0
9     0.195 0.02  0     10    90    0     0     0     0
9.75  0.198 0.03  0     10    90    0     0     0     0
10.5  0.172 0.01  0     10    90    0     0     0     0

11.25 0.152 0.02  0     20    80    0     0     0     0
12    0.139 0.02  0     20    80    0     0     0     0
12.75 0.181 0     0     20    80    0     0     0     0
13.5  0.156 0     0     10    90    0     0     0     0
14    0     0     0     20    80    0     0     0     0
14.3  -0.494      0     100   0     0     0     0     0     0
16    -0.587      0     100   0     0     0     0     0     0
17.2  -0.564      0     100   0     0     0     0     0     0
END
100 'B3' -0.872
GAU   -0.881      0.09332
GAU   -0.824      0.16901
SZF   -1.135
0     -0.765      0     100   0     0     0     0     0     0
```

```
2      -0.416       0      100    0      0      0      0      0      0
4.1    -0.367       0      100    0      0      0      0      0      0
4.4    0      0      100    0      0      0      0      0      0
5.25   0.172  0.04   100    0      0      0      0      0      0
6      0.263  0.03   10     50     40     0      0      0      0
6.75   0.256  0.03   0      70     30     0      0      0      0
7.5    0.238  0.02   20     40     40     0      0      0      0
8.25   0.224  0.01   0      30     70     0      0      0      0
9      0.195  0.02   0      10     90     0      0      0      0
9.75   0.198  0.03   0      10     90     0      0      0      0
10.5   0.172  0.01   0      10     90     0      0      0      0
11.25  0.152  0.02   0      20     80     0      0      0      0
12     0.139  0.02   0      20     80     0      0      0      0
12.75  0.181  0      0      20     80     0      0      0      0
13.5   0.156  0      0      10     90     0      0      0      0
14     0      0      0      20     80     0      0      0      0
14.3   -0.494       0      100    0      0      0      0      0      0
16     -0.587       0      100    0      0      0      0      0      0
17.2   -0.564       0      100    0      0      0      0      0      0
END
END
```

Transect B4

```
BED DATA 'Si' 'S' 'G' 'C' 'B' 'Be'

0 'B4' -0.672
GAU    -0.678       0.12513
GAU    -0.595       0.23894
SZF    -0.761
0      -0.532       0      100    0      0      0      0      0      0
3      -0.467       0      95     0      0      5      0      0      0
4.8    -0.345       0      40     0      15     45     0      0      0
5.1    -0.067       0      20     0      10     70     0      0      0
6      -0.046       0      0      0      10     90     0      0      0
6.4    0      0      0      0      45     55     0      0      0
6.65   0.024  0.03   0      0      45     55     0      0      0
6.9    0.031  0.13   0      0      40     60     0      0      0
7.15   0.054  0.3    0      0      40     60     0      0      0
7.4    0.069  0.39   0      0      30     70     0      0      0
7.65   0.069  0.36   0      0      30     70     0      0      0
7.9    0.075  0.48   0      0      30     70     0      0      0
8.15   0.089  0.2    0      0      30     70     0      0      0
8.4    0.077  0.35   0      0      30     70     0      0      0
8.65   0.067  0.26   0      0      30     70     0      0      0
8.9    0.048  0.18   0      0      30     70     0      0      0
9.15   0.033  0.33   0      0      30     70     0      0      0
9.4    0.031  0.33   0      0      40     60     0      0      0
9.75   0      0      0      5      40     55     0      0      0
10.1   -0.077       0      0      5      50     45     0      0      0
10.8   -0.15  0      0      0      30     70     0      0      0
12     -0.261       0      0      0      30     70     0      0      0
13.7   -0.22  0      0      0      20     80     0      0      0
END
100 'B4' -0.672
GAU    -0.678       0.12513
GAU    -0.595       0.23894
SZF    -0.761
0      -0.532       0      100    0      0      0      0      0      0
3      -0.467       0      95     0      0      5      0      0      0
4.8    -0.345       0      40     0      15     45     0      0      0
5.1    -0.067       0      20     0      10     70     0      0      0
```

```
6      -0.046       0      0      0      10     90     0      0      0
6.4    0      0     0      0      45     55     0      0      0
6.65   0.024 0.03   0      0      45     55     0      0      0
6.9    0.031 0.13   0      0      40     60     0      0      0
7.15   0.054 0.3    0      0      40     60     0      0      0
7.4    0.069 0.39   0      0      30     70     0      0      0
7.65   0.069 0.36   0      0      30     70     0      0      0
7.9    0.075 0.48   0      0      30     70     0      0      0
8.15   0.089 0.2    0      0      30     70     0      0      0
8.4    0.077 0.35   0      0      30     70     0      0      0
8.65   0.067 0.26   0      0      30     70     0      0      0
8.9    0.048 0.18   0      0      30     70     0      0      0
9.15   0.033 0.33   0      0      30     70     0      0      0
9.4    0.031 0.33   0      0      40     60     0      0      0
9.75   0      0     0      5      40     55     0      0      0
10.1   -0.077       0      0      5      50     45     0      0      0
10.8   -0.15 0      0      0      30     70     0      0      0
12     -0.261       0      0      0      30     70     0      0      0
13.7   -0.22 0      0      0      20     80     0      0      0
END
END
```

Transect B5

```
BED DATA 'Si' 'S' 'G' 'C' 'B' 'Be'

0 'B5' -0.667
GAU    -0.698       0.08952
GAU    -0.601       0.23136
SZF    -0.941
0      -0.484       0      40     0      0      0      0      60     0
1      -0.487       0      60     0      0      0      0      40     0
1.55   -0.406       0      20     0      0      0      0      80     0
1.6    0      0     0      0      5      10     0      85     0
1.65   0.043 0.5    0      0      15     15     0      70     0
2      0.056 0.24   0      0      15     15     0      70     0
2.2    0.002 0.01   0      0      15     15     0      70     0
2.25   0      0     0      0      15     15     0      70     0
2.4    -0.079       0      0      0      10     10     0      80     0
2.55   0      0     0      0      5      10     0      65     20
3      0.066 0.13   0      0      5      0      0      15     80
3.7    0.102 0.06   0      0      5      5      0      0      90
4.3    0.148 0.05   0      0      5      5      0      0      90
4.8    0.191 0.1    0      0      0      0      0      0      100
5.25   0.274 0.36   0      0      2      0      0      0      98
5.7    0.095 0.55   0      0      5      0      0      0      95
6.05   0.211 0.31   0      0      2      0      0      0      98
6.35   0.105 0.38   0      0      5      0      0      0      95
6.8    0.075 0.33   0      0      3      2      0      0      95
7.25   0      0     0      0      0      0      0      0      100
8.1    -0.057       0      5      0      0      0      0      0      95
8.6    -0.45 0      10     0      0      0      0      0      90
9.55   -0.596       0      100    0      0      0      0      0      0
10.2   -0.715       0      100    0      0      0      0      0      0
END
100 'B5' -0.667
GAU    -0.698       0.08952
GAU    -0.601       0.23136
SZF    -0.941
0      -0.484       0      40     0      0      0      0      60     0
1      -0.487       0      60     0      0      0      0      40     0
1.55   -0.406       0      20     0      0      0      0      80     0
```

```
1.6    0      0      0      0      5      10     0      85     0
1.65   0.043 0.5     0      0      15     15     0      70     0
2      0.056 0.24    0      0      15     15     0      70     0
2.2    0.002 0.01    0      0      15     15     0      70     0
2.25   0      0      0      0      15     15     0      70     0
2.4    -0.079        0      0      0      10     10     0      80     0
2.55   0      0      0      0      5      10     0      65     20
3      0.066 0.13    0      0      5      0      0      15     80
3.7    0.102 0.06    0      0      5      5      0      0      90
4.3    0.148 0.05    0      0      5      5      0      0      90
4.8    0.191 0.1     0      0      0      0      0      0      100
5.25   0.274 0.36    0      0      2      0      0      0      98
5.7    0.095 0.55    0      0      5      0      0      0      95
6.05   0.211 0.31    0      0      2      0      0      0      98
6.35   0.105 0.38    0      0      5      0      0      0      95
6.8    0.075 0.33    0      0      3      2      0      0      95
7.25   0      0      0      0      0      0      0      0      100
8.1    -0.057        0      5      0      0      0      0      0      95
8.6    -0.45 0       10     0      0      0      0      0      90
9.55   -0.596        0      100    0      0      0      0      0      0
10.2   -0.715        0      100    0      0      0      0      0      0
END
END
```

Transect B6

```
BED DATA 'Si' 'S' 'G' 'C' 'B' 'Be'

0 'B6' -0.885
GAU    -0.933        0.05116
GAU    -0.838        0.19449
SZF    -1.228
0      -0.804        0      100    0      0      0      0      0      0
1      -0.439        0      100    0      0      0      0      0      0
2      -0.389        0      100    0      0      0      0      0      0
2.8    -0.424        0      100    0      0      0      0      0      0

3.7    -0.309        0      95     0      5      0      0      0      0
4      -0.127        0      90     0      10     0      0      0      0
4.25   0      0      30     0      10     10     0      50     0
4.6    0.19  0.02    0      0      15     15     0      70     0
5      0.235 0.09    0      0      5      15     0      80     0
5.5    0.238 0.12    0      0      5      10     0      85     0
5.75   0.217 0.14    0      0      5      10     0      85     0
6      0.151 0.06    0      0      0      0      0      100    0
6.45   0.217 0       0      0      5      0      0      95     0
6.6    0.004 0       0      0      0      0      5      95     0
6.85   0.155 0.03    0      0      0      0      5      95     0
7.25   0.062 0.09    0      0      0      0      0      100    0
7.9    0.161 0.08    0      0      0      0      0      100    0
8.35   0.104 0.08    0      0      0      0      0      100    0
8.4    0      0      0      0      0      0      0      100    0
8.9    -0.061        0      0      0      0      0      0      100    0
9.1    0      0      0      0      0      0      0      100    0
9.25   0.274 0.11    0      0      0      0      0      100    0
9.65   0.343 0.16    0      0      0      5      0      95     0
10     0.253 0.16    0      0      10     0      0      90     0
10.4   0.299 0.18    0      0      5      0      0      95     0
10.9   0.188 0.01    0      0      5      0      0      95     0
11.1   0      0      0      0      5      0      0      40     55
11.3   -0.288        0      60     0      0      0      0      0      40
11.8   -0.483        0      90     0      0      0      0      0      10
```

```
12.3  -0.777      0     100   0     0     0     0     0     0
13    -1.023      0     100   0     0     0     0     0     0
END
100 'B6' -0.885
GAU   -0.933      0.05116
GAU   -0.838      0.19449
SZF   -1.228
0     -0.804      0     100   0     0     0     0     0     0
1     -0.439      0     100   0     0     0     0     0     0
2     -0.389      0     100   0     0     0     0     0     0
2.8   -0.424      0     100   0     0     0     0     0     0
3.7   -0.309      0     95    0     5     0     0     0     0
4     -0.127      0     90    0     10    0     0     0     0
4.25  0     0     30    0     10    10    0     50    0
4.6   0.19  0.02  0     0     15    15    0     70    0
5     0.235 0.09  0     0     5     15    0     80    0
5.5   0.238 0.12  0     0     5     10    0     85    0
5.75  0.217 0.14  0     0     5     10    0     85    0
6     0.151 0.06  0     0     0     0     0     100   0
6.45  0.217 0     0     0     5     0     0     95    0
6.6   0.004 0     0     0     0     0     5     95    0
6.85  0.155 0.03  0     0     0     0     5     95    0
7.25  0.062 0.09  0     0     0     0     0     100   0
7.9   0.161 0.08  0     0     0     0     0     100   0
8.35  0.104 0.08  0     0     0     0     0     100   0
8.4   0     0     0     0     0     0     0     100   0
8.9   -0.061      0     0     0     0     0     0     100   0
9.1   0     0     0     0     0     0     0     100   0
9.25  0.274 0.11  0     0     0     0     0     100   0
9.65  0.343 0.16  0     0     0     5     0     95    0
10    0.253 0.16  0     0     10    0     0     90    0
10.4  0.299 0.18  0     0     5     0     0     95    0
10.9  0.188 0.01  0     0     5     0     0     95    0
11.1  0     0     0     0     5     0     0     40    55
11.3  -0.288      0     60    0     0     0     0     0     40
11.8  -0.483      0     90    0     0     0     0     0     10
12.3  -0.777      0     100   0     0     0     0     0     0
13    -1.023      0     100   0     0     0     0     0     0
END
END
```

Tomahawk River (All transects)

```
BED DATA 'Si' 'S' 'G' 'C' 'B' 'Be'
0.0 'T1' -0.880
GAU   -0.788      0.00402
GAU   -0.793      0.04926
SZF   -1.028
0     -0.763      0     100   0     0     0     0     0     0
1     -0.656      0     100   0     0     0     0     0     0
1.6   -0.56 0     50    50    0     0     0     0     0
2     -0.351      0     0     100   0     0     0     0     0
2.2   -0.234      0     0     100   0     0     0     0     0
2.3   -0.039      0     0     100   0     0     0     0     0
2.44  0     0     0     90    10    0     0     0     0
2.55  0.032 0.01  0     55    40    0     5     0     0
2.65  0.052 0.02  0     55    40    0     5     0     0
2.75  0.075 0.01  0     55    40    0     5     0     0
2.85  0.078 0.01  0     55    40    0     5     0     0
2.95  0.077 0.04  0     55    40    0     5     0     0
3.05  0.077 0.02  0     55    40    0     5     0     0
3.15  0.079 0.01  0     55    40    0     5     0     0
3.25  0.084 0.07  0     55    40    0     5     0     0
3.35  0.089 0.04  0     60    40    0     0     0     0
3.45  0.067 0     0     60    40    0     0     0     0
3.55  0.08  0.02  0     60    40    0     0     0     0
3.65  0.086 0.05  0     60    40    0     0     0     0
3.75  0.095 0.04  10    55    35    0     0     0     0
3.85  0.1   0.01  20    50    30    0     0     0     0
3.95  0.121 0     30    45    25    0     0     0     0
4.05  0.148 0     40    40    20    0     0     0     0
4.15  0     0     50    35    15    0     0     0     0
4.3   -0.208      0     60    30    10    0     0     0     0
4.7   -0.358      0     100   0     0     0     0     0     0
5.3   -0.505      0     100   0     0     0     0     0     0
5.95  -0.686      0     100   0     0     0     0     0     0
END
100 'T2' -1.317
GAU   -1.3  0.03218
GAU   -1.229      0.02503
SZF   -1.762
0     -1.212      0     100   0     0     0     0     0     0
1     -0.972      0     100   0     0     0     0     0     0
2.1   -1.035      0     20    80    0     0     0     0     0
2.3   -0.251      0     5     45    0     0     0     35    15
2.8   -0.002      0     0     5     0     0     0     25    70
3.5   -0.095      0     0     0     0     0     0     0     100
4.6   0     0     0     0     0     0     0     10    90
5.2   0.043 0.32  0     0     0     0     0     0     100
5.8   0.22  0     0     0     0     0     0     0     100
6.4   0.232 0     0     0     0     0     0     0     100
7     0     0     0     0     0     0     0     15    85
7.6   -0.071      0     0     0     0     0     0     15    85
8.2   0     0     0     0     0     0     0     0     100
8.8   0.184 0     0     10    0     0     0     20    70
9.4   0.268 0.19  0     25    0     0     0     25    50
10    0.349 0     0     40    0     0     0     20    40
10.6  0.445 0     0     50    0     0     0     15    35
11.2  0.227 0     0     30    0     0     0     30    40
11.8  0.095 0     0     0     0     0     0     50    50
12.4  0.094 0     0     0     0     0     0     50    50
13    0.13  0     0     0     0     0     0     75    25
13.6  0.175 0     0     0     0     0     0     100   0
```

```
14.4   0      0      40     0      0      0      0      60     0
14.9   -0.11  0      85     0      0      0      0      15     0
15.6   -0.76  0      100    0      0      0      0      0      0
END
200 'T3' -1.135
GAU    -1.145        0.01903
GAU    -1.131        0.03992
SZF    -1.327
0      -0.983        0      95     0      0      0      5      0      0
0.7    -0.941        0      100    0      0      0      0      0      0
1.1    -0.61  0      95     0      0      0      5      0      0
1.9    -0.267        0      20     55     0      0      25     0      0
2.7    -0.112        0      0      50     0      10     40     0      0
3.7    0      0      0      30     25     10     35     0      0
4.05   0.046  0.06   0      15     25     20     40     0      0
4.3    0.1    0.03   0      5      25     20     50     0      0
4.55   0.097  0.07   0      0      20     5      75     0      0
4.8    0.078  0.07   0      0      20     5      70     5      0
5.05   0.067  0.07   0      0      10     5      80     5      0
5.3    0.064  0.16   0      0      5      5      70     20     0
5.55   0.126  0.23   0      0      10     5      60     25     0
5.8    0.165  0.14   0      0      10     5      65     20     0
6.05   0.17   0.16   0      0      5      10     60     25     0
6.3    0.174  0.21   0      0      10     10     55     25     0
6.55   0.192  0.14   0      0      10     10     50     30     0
6.8    0.025  0.05   0      0      5      5      50     40     0
7.05   0.107  0      0      0      5      5      50     40     0
7.3    0      0      0      0      5      5      50     40     0
7.95   -0.001        0      15     0      0      5      30     50     0
8.7    -0.072        0      50     0      0      5      15     30     0
9.4    -0.523        0      95     0      0      0      0      5      0
10.4   -0.652        0      100    0      0      0      0      0      0
11.4   -0.707        0      100    0      0      0      0      0      0
END
300 'T4' -1.364
GAU    -1.39 0.01842
GAU    -1.315        0.05666
SZF    -1.689
0      -1.22  0      0      100    0      0      0      0      0
0.8    -1.035        0      0      100    0      0      0      0      0
1.3    -0.852        0      0      100    0      0      0      0      0
1.8    -0.514        0      0      100    0      0      0      0      0
2.4    -0.605        0      30     70     0      0      0      0      0
2.85   0      0      30     70     0      0      0      0      0
3.1    0.068  0      0      100    0      0      0      0      0
3.3    0.113  0      0      100    0      0      0      0      0
3.5    0.165  0      0      100    0      0      0      0      0
3.7    0.163  0      0      100    0      0      0      0      0
3.9    0.198  0      0      100    0      0      0      0      0
4.1    0.235  0.02   0      100    0      0      0      0      0
4.3    0.25   0.1    0      100    0      0      0      0      0
4.5    0.288  0.14   0      100    0      0      0      0      0
4.7    0.279  0.05   0      95     0      0      0      5      0
4.9    0.32   0.01   0      95     0      0      0      5      0
5.1    0.313  0      0      95     0      0      0      5      0
5.3    0.325  0      0      95     0      0      0      5      0
5.5    0.295  0      0      100    0      0      0      0      0
5.7    0.283  0      0      100    0      0      0      0      0
5.9    0.233  0      0      100    0      0      0      0      0
6.1    0.183  0      0      100    0      0      0      0      0
6.3    0.137  0      10     90     0      0      0      0      0
```

```
6.55  0     0     25    75    0     0     0     0     0
6.8   -0.263      0     30    70    0     0     0     0     0
7.2   -0.425      0     25    75    0     0     0     0     0
7.9   -0.681      0     0     100   0     0     0     0     0
8.8   -0.625      0     0     100   0     0     0     0     0
9.7   -0.57 0     0     100   0     0     0     0     0
END
400 'T5' -1.244
GAU   -1.252      0.03651
GAU   -1.212      0.04468
SZF   -1.489
0     -1.055      0     0     100   0     0     0     0     0
1     -1.004      0     0     100   0     0     0     0     0
2     -1.096      0     0     100   0     0     0     0     0
3.1   -1.093      0     0     100   0     0     0     0     0
3.3   -0.464      0     0     100   0     0     0     0     0
3.5   -0.142      0     0     100   0     0     0     0     0
3.9   -0.044      0     0     50    0     0     0     0     50
4.45  -0.034      0     5     0     0     0     0     0     95
4.8   0     0     0     0     0     0     0     0     100
4.9   0.011 0.07  0     0     0     0     0     0     100
5     0.125 0.07  0     0     0     0     0     0     100
5.1   0.085 0.32  0     0     0     0     0     0     100
5.2   0.085 0.36  0     0     0     0     0     0     100
5.3   0.089 0.41  0     0     0     0     0     0     100
5.4   0.126 0.45  0     0     0     0     0     0     100
5.5   0.152 0.47  0     0     0     0     0     0     100
5.6   0.23  0.05  0     0     0     0     0     0     100
5.7   0.218 0.35  0     0     0     0     0     0     100
5.8   0.245 0.31  0     0     0     0     0     0     100
5.9   0.098 0.29  0     0     0     0     0     0     100
6     0.054 0.02  0     0     0     0     0     0     100
6.1   0.054 0.12  0     0     0     0     0     0     100
6.2   0.007 0     0     0     0     0     0     0     100
6.3   0     0     0     0     0     0     0     0     100
6.5   -0.03 0     0     0     0     0     0     0     100
7     -0.041      0     20    0     0     0     10    0     70
7.35  -0.17 0     95    0     0     0     5     0     0
7.5   -0.463      0     100   0     0     0     0     0     0
8.2   -0.65 0     100   0     0     0     0     0     0
8.7   -0.818      0     100   0     0     0     0     0     0
9.3   -0.815      0     100   0     0     0     0     0     0
END
500 'T6' -1.022
GAU   -1.033      0.02501
GAU   -0.973      0.03717
SZF   -1.443

0     -0.863      0     100   0     0     0     0     0     0
1     -0.559      0     100   0     0     0     0     0     0
1.7   -0.247      0     100   0     0     0     0     0     0
2.5   -0.13 0     100   0     0     0     0     0     0
3     0     0     100   0     0     0     0     0     0
3.25  0.073 0     90    10    0     0     0     0     0
3.65  0.034 0.04  20    75    5     0     0     0     0
4     0.07  0.03  20    75    5     0     0     0     0
4.3   0.082 0.05  40    45    15    0     0     0     0
4.6   0.099 0.04  40    45    15    0     0     0     0
4.9   0.08  0.04  35    45    20    0     0     0     0
5.2   0.038 0.02  35    45    20    0     0     0     0
5.5   0.048 0.01  15    60    25    0     0     0     0
```

```
5.8    0.134 0.01  15     60     25     0      0      0      0
6.1    0.292 0.01  90     5      5      0      0      0      0
6.4    0.421 0.01  75     5      20     0      0      0      0
6.8    0.288 0.02  80     5      15     0      0      0      0
7      0     0     95     5      0      0      0      0      0
7.3    -0.777      0      100    0      0      0      0      0      0
8      -1.125      0      100    0      0      0      0      0      0
9      -1.192      0      100    0      0      0      0      0      0
10     -1.202      0      100    0      0      0      0      0      0
END
END
```

APPENDIX 4.

HABITAT PREFERENCE DATA FOR INSTREAM BIOTA USED IN MINIMUM FLOW RISK ASSESSMENT FOR THE BOOBYALLA AND TOMAHAWK RIVERS, IN STANDARD RHYHAB .PRF FILE FORMAT.

Macroinvertebrates

```
'HYDROZOA'
Depth 0 0.03 0.085 0.175 0.3 0.425
Weight 0 0.193 0.128 0.233 1.000 0.120
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 1.000 0.700 0.300 0.300 0.400 0.400 0.500 0.500
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 1.000 0.225 0.338 0.000 0.024 0.517
END
'TURBEL'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.000 0.960 0.339 0.985 1.000
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.333 0.667 0.333 0.333 0.333 0.333 1.000 1.000
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.403 1.000 0.273 0.000 0.506 0.225
END
'SPHAERII'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.038 0.057 0.137 0.740 1.000
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.310 0.230 0.168 0.177 0.204 1.000 1.000 0.841
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.104 0.006 1.000 0.000 0.088 0.042
END
'GHYDROBI'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.360 0.205 0.319 1.000 0.251
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 1.000 0.978 0.170 0.178 0.141 0.385 0.422 0.326
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 1.000 0.432 0.949 0.000 0.064 0.279
END
'ANCYLID'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.113 0.608 1.000 0.247 0.340
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 1.000 0.948 0.665 0.716 0.748 0.703 0.581 0.594
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.027 0.158 0.009 0.000 0.182 1.000
END
'OLIGOCH'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 1.000 0.604 0.488 0.505 0.588
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.846 0.831 0.921 1.000 0.594 0.732 0.917 0.776
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.642 0.380 1.000 0.000 0.636 0.264
END
'HYDRACAR'
```

```
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.289 0.687 0.456 0.903 1.000
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.818 0.858 0.892 0.959 1.000 0.939 0.331 0.351
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.119 0.033 0.244 0.000 0.635 1.000
END
'OSTRACOD'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.414 0.374 0.081 1.000 0.295
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.364 0.364 0.227 0.227 0.136 0.545 1.000 1.000
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.870 0.051 1.000 0.000 0.066 0.109
END
'GRIPOPT'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.356 0.593 0.545 0.615 1.000
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.523 0.614 0.530 0.568 0.689 1.000 0.902 0.939
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.134 0.057 1.000 0.000 0.286 0.565
END
'NOTONEM'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.055 0.252 0.229 1.000 0.722
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.448 0.299 0.351 0.455 1.000 0.910 0.925 0.925
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.525 0.000 0.179 0.000 0.089 1.000
END
'LEPTOPHL'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.358 0.335 0.447 1.000 0.305
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 1.000 0.833 0.659 0.326 0.307 0.469 0.406 0.599
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.671 1.000 0.406 0.000 0.998 0.277
END
'CAENIDAE'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.000 0.867 0.600 1.000 0.980
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 1.000 0.667 0.667 0.842 0.912 0.965 1.000 0.982
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.426 0.191 0.490 0.000 0.018 1.000
END
'BAETIDAE'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.396 1.000 0.854 0.640 0.832
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.623 0.725 0.760 0.814 0.874 1.000 0.713 0.653
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.214 1.000 0.529 0.000 0.141 0.498
END
'CHIRONOM'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.479 0.866 0.380 1.000 0.956
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.350 0.388 0.531 0.693 1.000 0.948 0.814 0.908
Substrate 1 2 3 4 5 6 7 8
```

```
Weight 0.000 0.000 0.166 0.081 0.321 0.000 0.435 1.000
END
'ORTHOCLA'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.841 0.666 0.694 1.000 0.504
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.682 0.737 0.817 0.951 1.000 0.939 0.853 0.864
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.405 0.201 0.486 0.000 1.000 0.457
END
'TANYPOD'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.000 1.000 0.339 0.760 0.701
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.735 0.598 0.487 0.656 0.683 0.656 0.952 1.000
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.736 0.286 0.490 0.000 0.155 1.000
END
'SIMULID'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 1.000 0.590 0.329 0.505 0.082
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.143 0.571 0.571 0.571 0.429 0.714 0.714 1.000
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.633 1.000 0.582 0.000 0.127 0.076
END
'TIPULID'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.706 1.000 0.561 0.679 0.515
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.750 0.750 0.750 0.750 0.500 0.417 1.000 0.667
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.739 0.917 1.000 0.000 0.000 0.176
END
'CERATOPG'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.164 0.949 0.200 1.000 0.593
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.262 0.290 0.495 0.561 0.729 0.673 0.626 1.000
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.285 0.056 0.505 0.000 1.000 0.852
END
'EMPIDID'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.743 0.716 0.647 1.000 0.265
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.390 0.390 0.366 0.366 0.171 0.146 0.951 1.000
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 1.000 0.245 0.765 0.000 0.477 0.207
END
'DUNIDPUP'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.426 0.867 0.556 1.000 0.781
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.379 0.405 0.500 0.742 0.995 0.963 0.942 1.000
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.400 1.000 0.294 0.000 0.409 0.760
END
'ATRIPLEC'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.000 0.325 0.123 1.000 0.271
```

```
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.444 0.333 0.444 0.444 0.222 0.667 0.667 1.000
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.591 0.000 1.000 0.000 0.143 0.188
END
'CALOCID'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.088 0.147 0.080 1.000 0.110
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 1.000 0.800 0.300 0.400 0.500 0.500 0.500 0.500
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 1.000 0.590 0.885 0.000 0.174 0.260
END
'CONOESUC'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.393 0.580 1.000 0.582 0.595
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 1.000 0.559 0.627 0.475 0.475 0.525 0.288 0.492
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.039 0.186 0.075 0.000 1.000 0.399
END
'ECNOMID'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.009 0.794 0.149 0.028 1.000
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.571 0.407 0.571 0.794 1.000 0.750 0.632 0.850
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.006 0.000 0.085 0.000 0.152 1.000
END
'GLOSSOM'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.000 1.000 0.033 0.072 0.039
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.750 1.000 0.750 0.750 0.750 1.000 1.000 0.500
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.000 1.000 0.043 0.000 0.000 0.017
END
'HELICOPH'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.041 0.456 0.916 1.000 0.713
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 1.000 1.000 0.287 0.307 0.277 0.257 0.208 0.198
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.407 0.318 0.386 0.000 0.331 1.000
END
'HYDROBIO'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.562 0.659 0.765 1.000 0.448
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.951 0.927 0.829 0.829 0.829 1.000 0.854 0.976
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.574 1.000 0.559 0.000 0.779 0.417
END
'HYDROPSY'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.291 0.481 1.000 0.064 0.194
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.870 1.000 0.884 0.870 0.899 0.899 0.739 0.812
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.006 0.015 0.009 0.000 0.292 1.000
END
```

```
'HYDROPTI'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.474 1.000 0.435 0.941 0.164
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.167 0.167 0.167 0.167 0.033 0.067 0.067 1.000
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.379 0.000 0.436 0.000 1.000 0.123
END
'LEPTOCER'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.180 1.000 0.391 0.950 0.446
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 1.000 0.791 0.391 0.464 0.518 0.445 0.455 0.427
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.123 1.000 0.123 0.000 0.125 0.191
END
'PHILORHE'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.289 0.096 0.071 1.000 0.389
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.750 0.727 0.841 0.841 0.886 1.000 1.000 0.409
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.066 0.010 1.000 0.000 0.012 0.025
END
'ADTELMID'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.428 0.766 0.453 1.000 0.205
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.387 0.452 0.398 0.387 0.441 0.699 0.871 1.000
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.405 1.000 0.350 0.000 0.143 0.137
END
'LARELMID'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 1.000 0.752 0.973 0.958 0.561
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 1.000 0.867 0.880 0.906 0.726 0.702 0.939 0.714
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.770 0.248 1.000 0.000 0.437 0.334
END
'LARSCIRT'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.670 0.452 0.527 1.000 0.896
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.895 0.895 0.785 0.710 0.755 0.965 1.000 0.360
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.480 0.522 1.000 0.000 0.038 0.130
END
'Ntaxa'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.742 0.957 0.890 1.000 0.904
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.901 0.901 0.861 0.921 0.926 0.970 0.980 1.000
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.743 0.842 1.000 0.000 0.765 0.881
END
'T abund'
Depth 0.000 0.03 0.085 0.175 0.3 0.425
Weight 0.000 0.613 0.735 0.712 1.000 0.633
Velocity 0.025 0.08 0.15 0.25 0.35 0.45 0.575 0.725
Weight 0.808 0.764 0.767 0.860 0.980 1.000 0.956 0.976
```

```
Substrate 1 2 3 4 5 6 7 8
Weight 0.000 0.000 0.756 0.839 1.000 0.000 0.876 0.979
END
```

Boobyalla R Aquatic Vegetation

```
'Macrophytes'
Depth 0.005 0.03 0.075 0.125 0.2 0.3 0.4
Weight 0.298 0.1928 0.7801 0.3398 0.1328 0.08675 1
Velocity 0 0.015 0.03 0.075 0.15 0.25 0.35 0.45
Weight 0.4362 1 0.8382 0.3578 0.1771 0.01640 0.03936 0
Subs 1 2 3 4 5 6 7 8
Weight 1 0.4461 1 0.0334 0 0.09247 0.16326 0.15322
END
```

Platypus

```
Platypus
DEPTH 0 0.05 0.25 0.5 1 1.5 2 3 4
WEIGHT 0 1 1 1 1 0.7 0.3 0.1 0
VELOCITY 0 0.1 0.3 0.5 1 1.5 2
WEIGHT 1 1 1 0.6 0.1 0 0
SUBSTRATE 1 2 3 4 5 6 7 8
WEIGHT 1 1 1 1 0.7 0.5 0.1 0
END
```

Native fish

```
'Shortfin eel'
VELOCITY 0 0.15 0.35 0.55 0.85 1 1.5
WEIGHT 0.5 0.5 0.75 1 1 0.6 0
DEPTH 0 0.04 0.24 0.32 0.7 1
WEIGHT 0.8 1 1 0.5 0.1 0.1
SUBSTRATE 1 2 3 4 5 6 7 8
WEIGHT 1 0.5 0.5 1 0.6 0.2 0.05 0
END
'Lamprey (juv)'
VELOCITY 0 0.06 0.2 0.6
WEIGHT 1 1 0.2 0
DEPTH 0 0.4 0.8 1.5
WEIGHT 1 1 0.3 0
SUBSTRATE 1 2 3 4 5 6 7 8
WEIGHT 1 1 1 0.75 0.4 0.2 0 0
END
G. maculatus
VELOCITY 0 0.15 0.35 0.7 1
WEIGHT 0.65 1 1 0.2 0
DEPTH 0 0.05 0.15 0.3 0.7 2 3
WEIGHT 0 1 1 1 1 0.3 0
SUBSTRATE 1 2 3 4 5 6 7 8
WEIGHT 1 1 1 1 1 0.5 0.2 0
END
G. truttaceus

VELOCITY 0 0.15 0.35 0.7 1
WEIGHT 0.65 1 1 0.2 0
DEPTH 0 0.05 0.15 0.3 0.7 2 3
WEIGHT 0 1 1 1 1 0.3 0
SUBSTRATE 1 2 3 4 5 6 7 8
WEIGHT 1 1 1 0.7 0.7 0.5 0.2 0
END
```

Brown trout

```
'Brown trout fry (Bovee 1978)'
VELOCITY 0 0.34 0.6 1
WEIGHT 1 1 0.3 0
DEPTH 0 0.2 0.55 0.9 1.5
WEIGHT 0 1 1 0.35 0
SUBSTRATE 1 2 3 4 5 6 7 8
WEIGHT 0.2 0 0 0.5 1 0.9 0.2 0
END
'Brown trout juvenile (Bovee 1978)'
VELOCITY 0 0.1 0.73 1
WEIGHT 1 1 0.15 0
DEPTH 0 0.2 0.9 1 2
WEIGHT 0 1 1 0.35 0
SUBSTRATE 1 2 3 4 5 6 7 8
WEIGHT 0.2 0 0 0.5 1 1 0.1 0
END
Brown trout adult (Bovee 1978)
VELOCITY 0.25 0.6 1 1.2 2
WEIGHT 1 0.32 0.1 0.05 0
DEPTH 0.23 0.3 0.6 0.76
WEIGHT 0 0.6 0.72 1
SUBSTRATE 1 2 3 4 5 6 7 8
WEIGHT 0.3 0 0.95 1 1 1 0.15 0
END
Brown trout spawning (Shirvell & Dungey 1983)
VELOCITY 0.15 0.18 0.21 0.25 0.45 0.5 0.57 0.8
WEIGHT 0 0.25 0.5 1 1 0.5 0.25 0
DEPTH 0.06 0.08 0.135 0.17 0.2 0.32 0.33 0.375 0.55 1
WEIGHT 0 0.25 0.5 0.75 1 1 0.75 0.5 0.25 0
SUBSTRATE 1 2 3 4 5 6 7 8
WEIGHT 0 0 0 0 1 0 0 0
END
Brown trout adult (Raleigh et al. 1984)
VELOCITY 0 0.244 0.275 0.305 0.32 0.35 0.7 1.22 1.83
WEIGHT 1 1 0.98 0.91 0.81 0.68 0.23 0.05 0
DEPTH 0.228 0.259 0.29 0.32 0.67 0.717 0.748 0.762
WEIGHT 0 0.15 0.51 0.6 0.81 0.94 0.99 1
SUBSTRATE 1 2 3 4 5 6 7 8
WEIGHT 1 0 0 0.3 0.8 1 1 1
```

END