AN ASSESSMENT OF ENVIRONMENTAL FLOW REQUIREMENTS FOR THE DIAMOND CREEK CATCHMENT

for
Melbourne Water
Waterways and Drainage

by

Brenton Zampatti
&
Jason Lieschke

Natural Resources and Environment

AGRICULTURE
RESOURCES
CONSERVATION
LAND MANAGEMENT

Freshwater Ecology
Parks, Flora and Fauna
March 1999

SUMMARY

Melbourne Water, being the authority responsible for waterway management in the Yarra catchment, is undertaking the development of a Streamflow Management Plan (SMP) for Diamond Creek to enable the formulation of guidelines for the effective management of the system. The guidelines will include the establishment of flow regimes that will protect the environmental values of the system. This report documents the environmental values of the Diamond Creek system, outlines necessary environmental management objectives, and also recommends environmental flows that will protect the fish fauna and associated values of the system.

Demand for water from the Diamond Creek system is year round, with direct irrigation diversions over the summer/autumn low flow period (January to May) and off-stream dam diversions (winter-fill) over the higher flow winter/spring period (May to December). Consequently, two issues have been addressed in this study: 1) the need for a minimum environmental flow over the summer/autumn low flow period and 2) a maximum extraction rate over the winter-fill period. The recommendations for both periods are such that they will support the environmental management objectives that have been recommended for the system.

Environmental Values

Data on the environmental values of the Diamond Creek system was obtained from relevant literature, the Victorian Fish Database, the Atlas of Victorian Wildlife and from recent fish surveys in the system.

The fauna of the Diamond Creek system represents a diverse biological community that is reliant upon the instream and riparian zones of the creeks in the catchment. The pouched lamprey (*Geotria australis*), spotted galaxias (*Galaxias truttaceus*), mountain galaxias (*Galaxias olidus*) and river blackfish (*Gadopsis marmoratus*) which occur in the Diamond Creek system are considered threatened in Victoria (CNR, 1995a). The system may also provide habitat for another threatened species, namely the Australian grayling (*Prototroctes maraena*), which may recolonise Diamond Creek by means of the Dights Falls fishway on the Yarra River.

Other threatened vertebrates which rely on instream and riparian zones and may occur in the catchment include the large-footed myotis (*Myotis adversus*) and the broad-shelled tortoise (*Chelodina expansa*). Common species that occur in the catchment include the platypus (*Ornithorhynchus anatinus*) and the water rat (*Hydromys chrysogaster*).

None of the aquatic invertebrates that occur in the Diamond Creek catchment are considered threatened. Nevertheless, aquatic macroinvertebrates provide an integral part of the food chain in aquatic systems and are in turn dependent on the provision of sufficient flows to maintain riffle areas, and diverse and complex riparian habitat. Of the species of riparian flora that occur in the catchment, the netted brake (*Pteris comans*) and the swamp bush-pea (*Pultenaea weindorferi*) are classified as rare in Victoria.

Hydrology of the Diamond Creek System

In general, the lower reaches of Diamond Creek, downstream of the confluence of Arthurs Creek, are subject to low flows from January to May. Flows increase during June with maximum flow occurring from July to October. During the low flow period (January to May) 80 % of flows at Station 229223A (Diamond Creek at Diamond Creek) exceed approximately 0.5 ML/d. Analysis of flow data suggests that median flows at this gauging station may have been approximately 1-2 ML/d greater prior to water abstraction.

The mid to upper reaches of Diamond and Arthurs Creek, above the confluence of the two creeks, may be ephemeral. Data from gauging station 229620 (Arthurs Creek at Arthurs Creek) suggest that from January to May flows may be zero at this site for up to 50 % of the time. In addition, recent fish surveys at a number of sites in the mid to upper reaches of these creeks revealed an absence of fish or low numbers of fish in comparison to lower sites, thus suggesting that these reaches of the creeks may be subject to prolonged periods of no flow (Lieschke and Raadik, 1999).

Stream Condition

In general, the lower reaches of Diamond Creek and Arthurs Creek were characterised by cleared riparian zones, exotic riparian vegetation, considerable amounts of urban rubbish, a lack of diverse instream habitat and obvious siltation. Mid to upper reaches were more likely to have a greater area of intact native riparian vegetation, more complex instream habitat in the form of woody debris, bank overhang etc., and more diverse substrates with less siltation.

Habitat Availability and Environmental Flow Recommendations

Minimum environmental flows for the summer/autumn low flow period were determined using an adaptation of the Instream Flow Incremental Method (IFIM). Field measurements of potential habitat availability for river blackfish (juveniles and adults) and mountain galaxias were conducted at varying flows. Potential habitat availability was measured at three sites on Arthurs Creek and three sites on Diamond Creek, and calculated using the RHABSIM hydraulic and habitat simulation system.

Habitat availability was measured at three flows (corresponding to 0.9, 7.7 and 31.4 ML/d at the lowest site in the system). At sites on Diamond Creek the amount of habitat potentially available to river blackfish varied little with flow due to the high proportion of pools at these sites. At sites on Arthurs Creek less habitat was available at low flows as riffles and shallow run areas were exposed.

From an analysis of hydrological data and habitat availability the following minimum environmental flows have been recommended for sites in the Diamond Creek system. Due to the likely ephemeral nature of the mid to upper reaches of the system, sites S3 and S6 are not always expected to flow throughout the summer/autumn period.

Recommended minimum environmental flows for six locations in the Diamond Creek system

Site	Location	Minimum Flow (ML/d)
S1	Diamond Creek at Diamond Creek	1.5
S2	Diamond Creek at Hurstbridge (u/s Arthurs Creek)	0.5
S3	Diamond Creek at St Andrews	0.3*
S4	Arthurs Creek upstream of Diamond Creek confluence	1.0
S5	Arthurs Creek upstream of Nutfield	0.5
S6	Arthurs Creek at Strathewen	0.3*

*or natural (whichever is least)

With regards to winter-fill diversions, high flow events during this period (May to December) stimulate spawning and migration in a number of native fish species, and are essential for stream forming processes (e.g. silt removal). Whilst it is not possible to quantify the required magnitude of these flows using fish habitat availability, a precautionary approach that maintains flow magnitude and variability can be used.

It is recommended that winter-fill diversions may only commence once the 80th percentile daily exceedence flow for any given month (May to December inclusive) has been attained at site 229223A (Diamond Creek at Diamond Creek). At any flow above this level only 20% of the daily flow rate may be diverted for winter-fill dams. In the Diamond Creek system flows during May appear relatively low and a considerable proportion of flow may be committed to winter-fill. Consequently, it is recommended that May is regarded as a low flow month and that provision for winter-fill diversions during this month be reviewed. Winter-fill diversion rates during June may also need to be reviewed, with the possibility of allowing higher extraction rates from August to October inclusive.

Environmental Management Objectives

The primary environmental management objectives for the Diamond Creek system should include the following:

1. *Maintain the existing species diversity and populations of aquatic fauna, and where possible, provide conditions that will encourage recolonisation of the Diamond Creek system by migratory native fish species that can now utilise the Yarra system by means of the Dights Falls fishway*
.
2. *Maintain water quality in accordance with SEPP (Waters of Victoria) - draft Schedule F7 Waters of the Yarra Catchment (EPA, 1995).*

3. *Maintain, and where possible, restore diverse and complex instream habitat (e.g. woody debris).*

4. *Maintain remnants, and rehabilitate degraded areas, of indigenous riparian vegetation along Diamond and Arthurs Creek and their tributaries. In addition, ensure adequate buffer strips between cleared land and the creeks.*

5. *Maintain suitable river blackfish and mountain galaxias habitat from January to May through the provision of environmental flows of the magnitude specified in this report.*

6. *Ensure that winter-fill diversions are set at a level that does not impact upon migration and spawning of native fish species or essential stream forming processes such as channel scouring and silt removal.*

A number of actions pertaining to the environmental management objectives have also been recommended.

Table of Contents

1. INTRODUCTION

Development of a Streamflow Management Plan (SMP) for the Diamond Creek system is required as part of the State Environment Protection Policy (Waters of Victoria) Draft Schedule F7 (Waters of the Yarra Catchment). Melbourne Water, being the authority responsible for waterway management in the Yarra catchment, is undertaking the development of a SMP for Diamond Creek to enable the formulation of guidelines for the effective management of the system. These guidelines will include the establishment of flow regimes that will protect the environmental values of the system.

The development of a SMP for the Diamond Creek system will enable Melbourne Water to address issues such as the following:

- clarification of rights to water resources;
- ensure the long term sustainability of the river system by reaching a balance between environmental requirements and consumptive uses of the water;
- provide a framework of rules to operate the river system to meet agreed water management objectives ; and
- ensure that future development does not have a negative impact on existing water users and the environment.

As a component of the SMP for Diamond Creek, the Freshwater Ecology Division of the Department of Natural Resources and Environment (DNRE) has been contracted to assess the environmental values of the Diamond Creek system, determine environmental management objectives for the system and investigate the environmental flow requirements of Diamond and Arthurs Creek. The specific objectives of the study are to:

- identify significant environmental values that need to be protected by adequate flows;
- identify other significant impacts on environmental values;
- recommend environmental management objectives; and
- recommend environmental flows at a number of specified points on Diamond and Arthurs Creek.

2. STUDY AREA

Diamond Creek is a major tributary of the Yarra River, it rises on the Kinglake Plateau at an altitude of approximately 600 m and flows in a south-westerly direction past the townships of St Andrews, Hurstbridge, Diamond Creek and Eltham. The catchment covers an area of 311 km^2 and includes two main tributaries, namely Running Creek and Arthurs Creek (Figure 3-1).

The basin is predominantly rural in character with a shift to an urban environment in the lower reaches around Diamond Creek and Eltham. The upper most parts of the catchment are situated in Kinglake National Park. Landuse in the mid to lower reaches of the catchment is predominantly grazing with some horticulture.

There are a total of 26 licensed diverters in the Diamond Creek catchment. Of these, 16 are situated on Diamond Creek, eight on Arthurs Creek and one each on Running Creek and Peters Creek. Water is diverted for stock and domestic use, irrigation and off-stream dam filling. Off-stream dam filling (winter-fill) is conducted during the higher flow months from May to December. A total volume of 563 ML is allocated annually to diverters of which 258 ML is winter-fill.

Flow data for the Diamond Creek system is available from a number of gauges, however, ratings for most of the gauges have not been revised for the last 10 years. Consequently, considerable error (up to 300%) may be involved in readings from these gauges (Peter Dowland, Melbourne Water, pers comm). For the purpose of this environmental flow study historical flow data from stations 229216 (Diamond Creek at Hurstbridge), 229223A (Diamond Creek at Diamond Creek) and 229618 (Diamond Creek at Bridge St Eltham) was used (Figure 3-1).

3. ENVIRONMENTAL VALUES OF THE DIAMOND CREEK CATCHMENT

A review was undertaken of significant species of fauna and flora that occur in the Diamond Creek region. Data was obtained from relevant literature, the Victorian Fish Database (Department of Natural Resources and Environment - DNRE) and the Atlas of Victorian Wildlife (DNRE). Only species that may be dependent on the instream environment have been discussed.

3.1 Fish

Fourteen species of fish have been recorded in the Diamond Creek system (Victorian Fish Base; Lieschke and Raadik, 1999) (Table 3-1). Nine of these are native and five are acclimatised exotic species. Of the native species previously recorded, four are considered threatened in Victoria: the pouched lamprey (*Geotria australis*) and the spotted galaxias (*Galaxias truttaceus*) are rare, while the river blackfish (*Gadopsis marmoratus*) and mountain galaxias (*Galaxias olidus*) are considered as insufficiently known[1]. No species are listed on the Victorian *Flora and Fauna Guarantee Act* 1988.

[1] suspected Rare, Vulnerable or Endangered.

Figure 3-1. Location of habitat availability survey sites and gauging stations in the Diamond Creek catchment.

Table 3-1 Native and acclimatised exotic fish species recorded from the Diamond Creek system, including their conservation status (CNR, 1995a).(+migratory species)

Specific Name	Common Name	Conservation Status
Native species		
Geotria australis+	Pouched lamprey	Rare
Anguilla australis+	Short-finned eel	Common
Galaxias brevipinnis+	Broad finned galaxias	Common
*Galaxias truttaceus**+	Spotted Galaxias	Rare
*Galaxias maculatus**+	Common Galaxias	Common
Galaxias olidus	Mountain galaxias	Insufficiently known
Gadopsis marmoratus	River blackfish	Insufficiently known
Nannoperca australis	Southern pygmy perch	Common
Retropinna semoni	Australian smelt	Common
Exotic species		
Salmo trutta	Brown trout	-
*Gambusia holbrooki**	Eastern gambusia	-
Carassius auratus	Goldfish	-
Rutilus rutilus	Roach	-
*Misgurnus anguillicaudatus**	Oriental weatherloach	-

* species previously unrecorded in the Diamond Creek system (Lieschke and Raadik, 1999).

Five of the native fish species collected in the catchment are migratory (Table 3-1), two of these species (spotted and common galaxias) only being recorded in recent surveys of the Diamond Creek system (Lieschke and Raadik, 1999).

In the past Dights Falls has represented a major barrier to fish movement in the Yarra River. A fish ladder has now been incorporated into this structure to facilitate upstream movement and it is likely that a number of native species that have been restricted from the Yarra River and its tributaries for many years may be able to recolonise this area (Table 3-2). The presence of small common galaxias and spotted galaxias in the Diamond Creek system suggests that these species are utilising the Dights Falls fish ladder.

Other fish which may recolonise the system include the Australian grayling (*Prototroctes maraena*) which is considered vulnerable in Victoria and Australia, and is listed on the Victorian *Flora and Fauna Guarantee Act* 1988 and the Commonwealth *Endangered Species Protection Act* 1992. It is possible that broad-finned galaxias (*Galaxias brevipinnis*) and tupong (*Pseudaphritis urvillii*), may also move into the Diamond Creek system as their numbers increase in the Yarra River. Consequently, it is important that the life history requirements of all migratory species are also taken into account when determining environmental flows for the Diamond Creek system.

Table 3-2 Native fish species that may increase in numbers or re-establish in Diamond Creek as a result of the Dights Falls fish ladder, including their conservation status (CNR, 1995a).

Scientific Name	Common Name	Conservation Status
Galaxias brevipinnis	Broad-finned galaxias	Common
*Galaxias maculatus**	Common galaxias	Common
*Galaxias truttaceus**	Spotted galaxias	Rare
Prototroctes maraena	Australian grayling	Vulnerable, FFG Act listed
Pseudaphritis urvillii	Tupong	Common

*species recently collected in Diamond Creek (Lieschke and Raadik, 1999).

3.2 Aquatic Macroinvertebrates

Numerous macroinvertebrate surveys have been conducted in Diamond Creek and its tributaries, including studies by Cameron and Vertessy (1995), Cameron and Vertessy (1998) (draft) and Campbell *et al*. (1982). These studies have shown that the diversity and composition of macroinvertebrate populations in the Diamond Creek catchment vary throughout the system, with a general trend to more depauperate communities towards the lower sections of the system.

Diverse macroinvertebrate populations and significant macroinvertebrate habitat are found above regulatory structures in the upper Diamond Creek catchment with a decline in the number of species and abundance in a downstream direction (Cameron and Vertessy, 1995). Previous studies in the Yarra catchment have shown that below regulatory structures, downstream of towns, and in areas with degraded riparian vegetation, the invertebrate fauna is often dominated by taxa that are tolerant to disturbance and nutrient enrichment (Campbell, 1982; Pettigrove, 1989; Doeg and Saddlier, 1992).

The distribution of freshwater crayfish in the genus *Euastacus* and *Engaeus* in Victoria is discussed by Morgan (1986) and Horwitz (1990). Of the species occurring in the Diamond Creek system none are considered threatened.

Whilst none of the aquatic invertebrates occurring in Diamond Creek and its tributaries are considered threatened, it is important to recognise their environmental requirements and value. Many macroinvertebrates inhabit structurally complex areas of the stream, such as riffles or riparian vegetation. Consequently, the preservation of riparian habitat and the provision of sufficient flows to maintain riffle areas is important. In addition, many animals higher in the food chain are reliant on aquatic invertebrates as a food source (e.g. platypus and fish).

3.3 Reptiles and Amphibians

Numerous frogs have been recorded in the Diamond Creek catchment including Lesueur's (Rocky River) tree frog (*Litoria lesueuri*). Within the Yarra catchment (including Diamond Creek) this frog is only found in the upper reaches where its tadpoles are dependent on running water (CNR, 1995b). The broad-shelled tortoise (*Chelodina*

expansa) has also been found in the Diamond Creek catchment and is classified as insufficiently known in Victoria (DNRE, 1997).

3.4 Other Vertebrates

The platypus (*Ornithorhynchus anatinus*) and the water rat (*Hydromys chrysogaster*) have both been recorded in the Diamond Creek catchment (DNRE, 1997). These animals rely directly on the instream environment for their survival and, as such, need to be considered in the determination of environmental flows. The large-footed myotis (*Myotis adversus*) has also been recorded throughout the eastern side of the Diamond Creek catchment (Smiths Gully and Panton Hill), and is classified as rare in Victoria. The large-footed myotis depends on the instream environment for aquatic macroinvertebrates and small fish that comprise a large part of its diet (Richards, 1993 in CNR, 1995b).

3.5 Instream and Riparian Flora

Of the species of riparian flora that occur in the Diamond Creek catchment, two are considered threatened in Victoria (CNR, 1995b). The netted brake (*Pteris comans*) and the swamp bush-pea (*Pultenaea weindorferi*) are both classified as rare in Victoria. Instream and riparian flora provide essential habitat for fish and macroinvertebrates. Therefore, it is important that the flow requirements of aquatic and riparian flora present in the Diamond Creek catchment are considered when determining the magnitude and timing of environmental flows.

4. HYDROLOGY OF THE DIAMOND CREEK SYSTEM

In general, the lower reaches of Diamond Creek, downstream of the confluence of Arthurs Creek, are subject to low flows from January to May. Flows increase during June with maximum flow occurring from July to October (Figure 4-1). During the low flow period (January to May) 80 % of flows at Station 229223A (Diamond Creek at Diamond Creek) exceed approximately 0.5 ML/d. This site is likely to be the most accurate flow gauging site in the Diamond Creek catchment as it was designed to measure both low and high discharges. Most of the other gauging sites in the catchment are used by Melbourne Water as flood warning sites and are not calibrated to measure low flows which are of primary concern during the summer/autumn low flow period.

The mid to upper reaches of Diamond and Arthurs Creek, above the confluence of the two creeks, may be ephemeral, although this is difficult to verify given available flow data. Data from gauging station 229620 (Arthurs Creek at Arthurs Creek) suggest that from January to May flows may be zero at this site for up to 50 % of the time. In addition, recent fish surveys at a number of sites in the mid to upper reaches of these creeks revealed an absence of fish or low numbers of fish in comparison to lower sites, thus suggesting that these reaches of the creeks may be subject to prolonged periods of no flow (Lieschke and Raadik, 1999). The dry nature of the system is also supported by the freshwater mussel fauna which consists only of *Velesunio ambiguus* a species adapted to periods of low flows (Lieschke and Raadik, 1999).

In order to provide an indication of the approximate magnitude of median natural flows over the summer/autumn low flow period, daily diversion rates (only those above Diamond Creek township) have been added to the median (50th percentile) flow for each month at Station 229223A (Diamond Creek at Diamond Creek) (Figure 4-1). This data indicates that without abstractions the median flows over the low flow period may have been 1-2 ML/d greater than those that occur now.

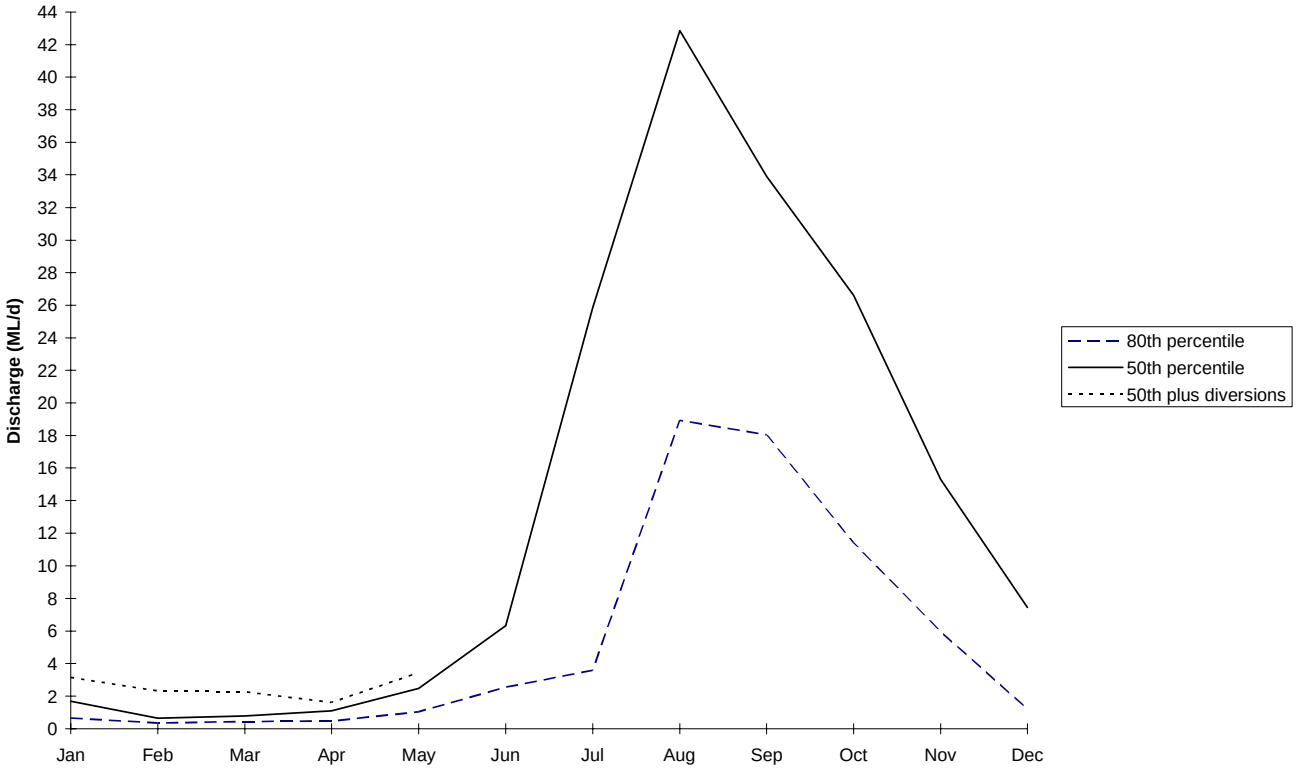

Figure 4-1. 50th and 80th percentile exceedence flows, including 50th percentile plus diversions, at Station 229223A (Diamond Creek at Diamond Creek).

5. METHODOLOGY FOR ENVIRONMENTAL FLOW STUDIES

A habitat availability technique has been used only to recommend environmental flows over the summer/autumn low flow period (January - April/May) in the Diamond Creek system. The issue of environmental flows with regards to the winter-fill period (May - December) is discussed in Section 6.4.

An adaptation of the instream flow incremental method (IFIM) (Bovee, 1982) was used to determine the availability of fish habitat at a range of flows in Diamond and Arthurs Creek. The decision to base our method on the IFIM was driven by the need for a quantifiable and defensible method for assessing environmental flows. Our method employs the IFIM along with historical flows and expert knowledge to determine environmental flow recommendations for the diamond creek system.

Implementation of the IFIM method and the construction of suitability of use curves requires a sound knowledge of the flow and habitat requirements of the fish species of concern. This type of information is lacking for many species of Australian native fish and, although recognised for many years (Jackson, 1986; Koehn, 1986 and Arthington *et al*, 1991), little new data is available.

In order to determine habitat availability for native fish species in the Diamond Creek system, river blackfish and mountain galaxias were selected as key species. River blackfish are the deepest bodied native fish species found in the Diamond Creek system and it is assumed that providing a suitable amount of potential habitat for river blackfish will also provide habitat for smaller native species. River blackfish have been used to model habitat availability at all sites except the uppermost site on Arthurs Creek at Strathewen, where only mountain galaxias have been found to occur (Lieschke and Raadik, 1999).

The depth and velocity requirements of river blackfish have been derived from a study by Koehn *et al.* (1994) on the habitat preferences of this species in Armstrong Creek, a tributary of the upper Yarra River. Additional information was obtained from observations made by experienced field staff from the Freshwater Ecology Division, DNRE in previous field studies. The habitat requirements of river blackfish were divided into two life stages, juveniles (fish < 150 mm in length) and adults (fish > 150 mm in length) (Table 5-1). The depth and velocity requirements for mountain galaxias were based on observations made by experienced field staff from the Freshwater Ecology Division, DNRE and extensive previous work on streams throughout Victoria, particularly the Yarra River system (Table 5-1).

Table 5-1. Depth and velocity requirements of river blackfish and mountain galaxias.

Species	Life Stage	Depth (m)	Velocity (m/s)
River Blackfish	Juvenile	>0.1	<0.2
	Adult	>0.2	<0.2
Mountain Galaxias	All	>0.1	<0.3

Unlike previous Victorian studies, we have not divided habitat requirements into rearing, resting, passage and spawning requirements (Tunbridge and Glenane, 1988; Hall, 1989). The current scientific data available for the depth and velocity requirements of river blackfish and mountain galaxias is not comprehensive enough to enable the modelling of habitat availability with regards to all requirements. The habitat requirements we have used encompass both rearing and resting activities. This habitat covers the largest component of stream area and is considered the most important habitat over the low flow period.

The flows that are suggested as maintaining blackfish and mountain galaxias habitat during the summer/autumn low flow period will also maintain habitat for other fish species (currently present or likely to occur in the future), invertebrates and aquatic vegetation in the Diamond Creek system. The flows may not provide enough water for fish passage, although during the summer period migration is generally not an issue and only localised movements will occur.

5.1 Field measurements of hydraulic parameters and habitat

Six sites were selected in the Diamond Creek system to establish reaches where habitat availability could be measured at a range of flows (Figure 3-1, Table 5-2). Three sites were located on Diamond Creek and three sites on Arthurs Creek, thus providing detailed information on discharge and habitat availability throughout the catchment.

Table 5-2 Location of habitat availability survey sites on Diamond and Arthurs Creek (see also Figure 3-1).

Site Number	Location
S1	Diamond Creek downstream of Gipson St at Diamond Creek
S2	Diamond Creek upstream of Arthurs Creek confluence at Hurstbridge
S3	Diamond Creek upstream of Haffenden Lane at St Andrews
S4	Arthurs Creek upstream of Diamond Creek confluence opposite 'Nihill'
S5	Arthurs Creek at reserve upstream of Nutfield
S6	Arthurs Creek upstream Chads Creek Rd at Strathewen

At each flow site a series of transects was established in areas of habitat that were representative of that particular reach of river. The number of transects (13 to 20) was determined by the number required to provide a representative sample of all habitat types and associated hydrological characteristics. Transects were placed perpendicular to the channel (from bank to bank), each end being identified by a permanent marker to facilitate future measurements at a range of flow conditions. A measuring tape was extended across the stream and, depending on the width and uniformity of the stream, velocity (m/s), depth (m) and substrate type were measured at 0.1 to 0.6 m intervals. Depth was measured to the nearest 0.01 m using a 1 m steel ruler and velocity was measured using a Hydrological Services OSS PC-1 current meter with a CMC 20 digital counter.

5.2 Modelling using RHABSIM

The amount of habitat available to river blackfish and mountain galaxias, at a range of flows, was calculated using the RHABSIM hydraulic and habitat simulation system (Payne and Associates, 1994). Criteria curves were constructed for adult and juvenile river blackfish and mountain galaxias. The habitat preferences for these species were not weighted (Mathur *et al.*, 1985). Instead a binary approach was used and habitat was classified as being present or absent. When combined with the hydraulic characteristics of the stream section this approach predicts how much habitat (user defined) will be potentially available to a particular species. It is important to note that predictions made with RHABSIM do not suggest that system productivity will be altered through changes in habitat availability.

Changes in habitat availability at a range of flows were measured in the field rather than by hydraulic simulation. Due to an absence of accurate stage/discharge data for most sites in the Diamond Creek system, it was considered impractical to calibrate a hydraulic simulation model of the stream sections. In addition, the structural complexity (woody debris, aquatic vegetation etc.) of the stream reaches, may have resulted in inaccurate hydraulic calibration of a model (Gordon *et al.*, 1992; Courot, 1989).

6. RESULTS AND RECOMMENDATIONS

6.1 Site Descriptions

S1. Diamond Creek downstream of Gipson St at Diamond Creek

This site was located behind the football oval downstream of Gipson St, Diamond Creek. The site the lowest in the Diamond Creek system and situated in the most urbanised area, consequently disturbance was high. The banks of the creek were steep (approximately 10 m high) and riparian vegetation was predominantly *Acacia* sp, along with introduced grasses, blackberries and willows. The survey reach consisted primarily of long, wide (approximately 5m) pools interspersed with narrow rocky riffles. Large piles of willow debris were present in some pools and urban rubbish (plastics, bikes, supermarket trolleys etc.) was abundant. Substrate was predominantly clay with small areas of cobble/pebble in riffles. Aquatic vegetation was restricted to small patches of common reed (*Phragmites australis*) and water ribbon (*Triglochin procerum*). Willows were also present instream.

S2. Diamond Creek upstream of Arthurs Creek confluence at Hurstbridge

This site was located upstream of the footbridge in Fergusons Paddock, Hurstbridge, immediately upstream of the Arthurs Creek confluence. The creek was relatively narrow being approximately 2m wide. The site was located in a shrubland reserve, although disturbance was relatively high, with erosion and urban rubbish obvious. Riparian vegetation consisted of silver wattle (*Acacia dealbata*), eucalypts, bracken, grasses and a small amount of blackberry. The survey reach comprised pools with a clay substrate, interspersed with short riffles with gravel/sand substrate. Instream habitat consisted of large areas of slender knotweed (*Persicaria decipiens*) and areas of woody debris and

smaller organic debris in pools. Slender knot weed is summer growing and an indication of low flows, it is likely that this macrophyte would die-back during winter.

S3. Diamond Creek upstream of Haffenden Lane at St Andrews

This was the least disturbed site on Diamond Creek. Riparian vegetation was relatively intact and extended at least 20 m from the waters edge. Native vegetation was dominant (manna gums (*Eucalyptus viminalis*), messmate (*Eucalyptus obliqua*), silver wattle and blackwood (*Acacia melanoxylon*)) although exotic willows and blackberries were also present. Over the summer period this site was comprised of a series of unconnected pools. Substrate was predominantly clay, and instream habitat comprised a small amount of woody debris, vegetation overhang and leaves/organic debris.

S4. Arthurs Creek upstream of Diamond Creek confluence opposite 'Nihill'

This site was located upstream of the Arthurs Creek/Diamond Creek confluence. The site was highly disturbed with a cleared riparian zone, considerable erosion and cattle grazing to the waters edge on both banks. Riparian vegetation was dominated by willows and pasture grasses with small areas of *Acacia* spp and eucalypts upstream. Flow type was predominantly pool separated by glides or riffles over willow roots. Instream habitat was scarce and was comprised mainly of woody debris from willows and willow roots, substrate was clay and silt.

S5. Arthurs Creek at reserve upstream of Nutfield

This site was located in a roadside reserve approximately 2 km upstream of Nutfield. The banks of the creek were steep (3-4 m high) and disturbance was moderate with pasture and clearing of riparian vegetation on the left hand bank. Riparian vegetation on the right hand bank was relatively intact with manna gum, silver wattle, blackwood and woolly tea tree (*Leptospermum lanigerum*). During summer the creek at this location was a series of pools with minimal flow (< 0.5 ML/d) over a number of shallow runs. Stream width varied from 0.3 to 1.0 m and most of the pools and runs contained abundant water ribbon and slender knot weed. Woody debris, leaf packs and aquatic vegetation provided diverse instream habitat and substrate was comprised of sand, silt and clay.

S6. Arthurs Creek upstream Chads Creek Rd at Strathewen

This site was located immediately upstream of the bridge on Chads Creek Rd at Strathewen and was dry over summer. The channel was deeply incised (3-4 m) and approximately 2 m wide. Upstream of the site there had been some temporary alteration (redirection) to the low flow channel. Riparian vegetation was relatively intact on the left hand bank although the right hand bank had been cleared. Riparian vegetation consisted of manna gum, silver wattle, blackwood and numerous native understory shrubs. Exotic blackberries were also evident. By June there was a flow of approximately 1 ML/d and most of the section was comprised of pools and glides. Instream habitat in the form of woody debris, bank overhang and tree roots, was abundant and substrate was diverse, ranging from clay and silt through to gravel and boulder.

6.1.1 Summary of Stream Condition

In general, the lower sites in the Diamond Creek and Arthurs Creek were characterised by cleared riparian zones, exotic riparian vegetation, considerable amounts of urban rubbish, a lack of diverse instream habitat and obvious siltation. Sites that were higher in the catchment were more likely to have a greater area of intact native riparian vegetation, more complex instream habitat in the form of woody debris, bank overhang etc., and more diverse substrates with less siltation.

These observations are reflected in the distribution, richness and abundance of fish in Diamond Creek catchment (Lieschke and Raadik, 1999). In general, expected native species richness was only high towards the headwaters of each creek. In the lower sections of each creek expected native fish species richness was low and exotic species richness and abundance was high. The change in fish fauna from the upper to lower reaches of the creeks is most likely associated with increasing land use and urbanisation.

Low native fish abundance at some sites in the mid to upper reaches of Diamond and Arthurs Creek may also be related to the ephemeral nature of the creeks. During dry periods fish would be restricted to pools, recolonising other areas when flows increase in late autumn. Recolonisation of some fish species may be slow due to their non-migratory nature and limited home range (e.g. river blackfish). Water abstractions in the Diamond Creek system may also, at times, prolong the dry period and interfere with the very low baseflow that possibly maintains water quality in remnant pools.

6.2 Habitat Availability

Habitat availability for river blackfish and mountain galaxias was measured at three distinct flows in Diamond and Arthurs Creek. Flows ranged from 0.9 to 31.4 ML/d at the lowest site on Diamond Creek (S1), from 0 to 4.2 ML at the highest site on Diamond Creek (S3) and 1.1 to 9.3 ML/d at the highest site on Arthurs Creek (S6) (Table 6-1).

Table 6-1 Total area of stream reach (m^2) and area of reach available as potential habitat to juvenile and adult river blackfish (sites S1 to S5) and mountain galaxias (site S6)

			Area of reach available as habitat		
Site	Flow (ML/d)	Total Area (m^2)	Juvenile Blackfish	Adult Blackfish	Mountain Galaxias
S1	0.9	440.1	342.7	255.9	-
	7.7	471.8	358.3	307.4	-
	31.4	530.3	375.5	343.6	-
S2	0.2	41.0	30.7	22.9	-
	0.5	37.6	27.2	17.3	-
	6.1	53.6	40.6	33.4	-
S3	0	107.4	92.0	61.4	-
	0.6	106.5	91.8	61.3	-
	4.2	111.3	95.7	82.4	-
S4	0.3	175.3	98.9	70.9	-
	5.2	273.1	156.9	112.3	-
	22.2	295.9	261.6	222.6	-
S5	0.1	31.4	23.1	12.8	-
	6.4	51.7	36.9	28.5	-
	22.4	67.7	37.7	32.5	-
S6	1.1	88.4	-	-	62.5
	3.8	93.6	-	-	72.9
	9.3	117.4	-	-	101.9

At site S1 (Diamond Creek at Diamond Creek) total stream area and the area of habitat potentially available to both juvenile and adult blackfish varied little with flow (Figure 6-1). This is most likely due to this site being comprised primarily of pools that retain potential habitat even during low flows.

At site S2 (Diamond Creek upstream of Arthurs Creek confluence) total stream area and the area of habitat potentially available to juvenile and adult river blackfish decreased by 20-25% when flow decreased from approximately 6 ML/d to less than 1 Ml/d (Figure 6-2). Consequently, at least 75% of potentially available habitat remained at flows of less than 1 ML/d.

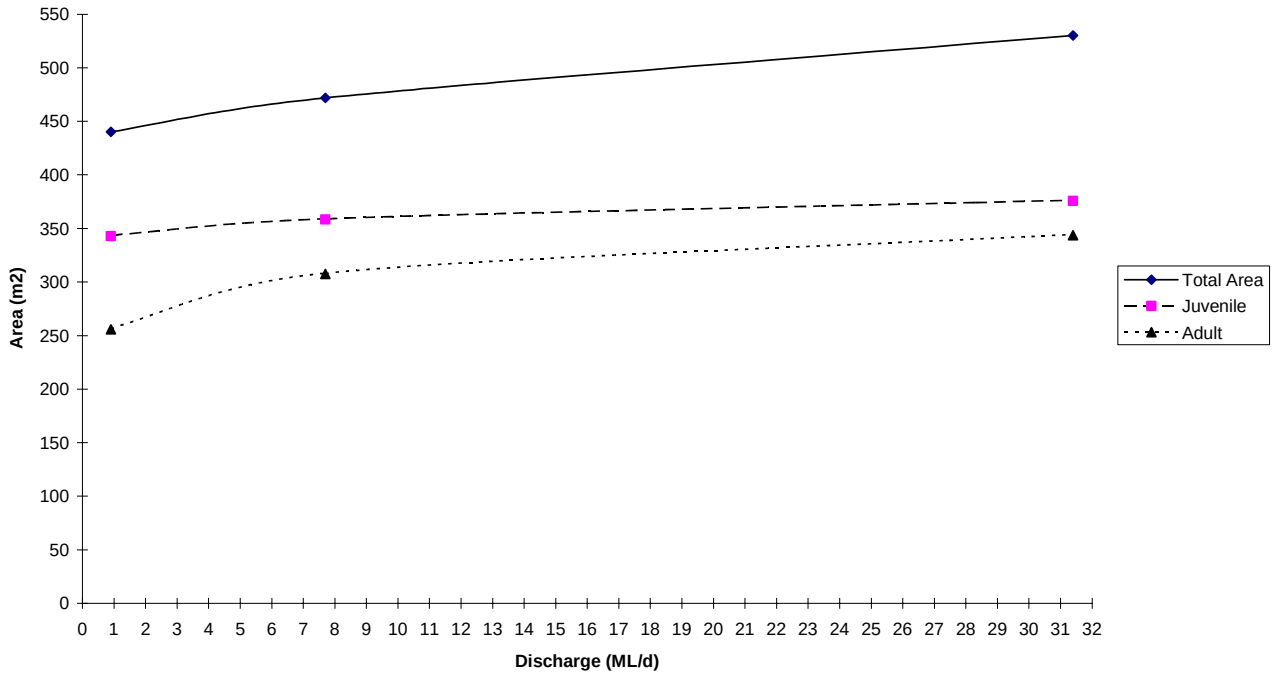

Figure 6-1. Total area and area of habitat potentially available to juvenile and adult river blackfish at a range of flows at site S1.

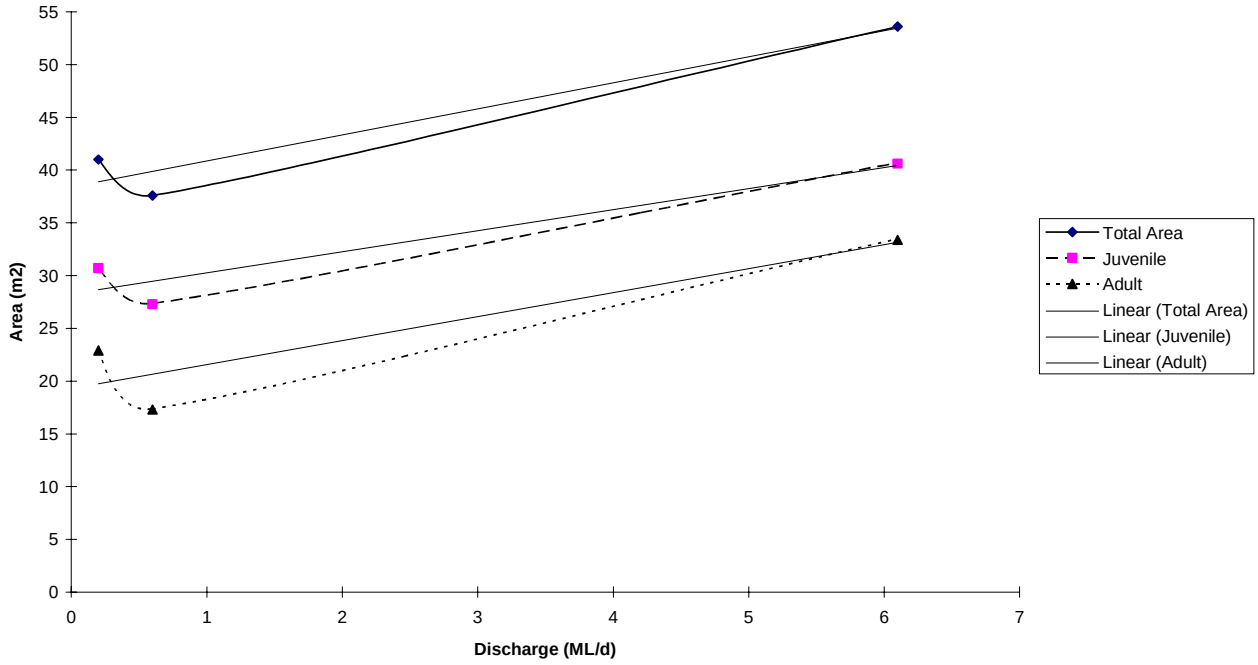

Figure 6-2. Total area and area of habitat potentially available to juvenile and adult river blackfish at a range of flows at site S2. A linear line of best fit has been fitted to the data points due to a discrepancy in habitat measurements at low flows.

Total stream area and the area of habitat potentially available to juvenile and adult river blackfish at site S3 (Diamond creek at St Andrews) remained relatively constant at flows from 0-4 ML/d (Figure 6-3). Like site S1, this site was comprised primarily of pools which retained habitat even at zero flows. When first observed in April 1998, this site was dry.

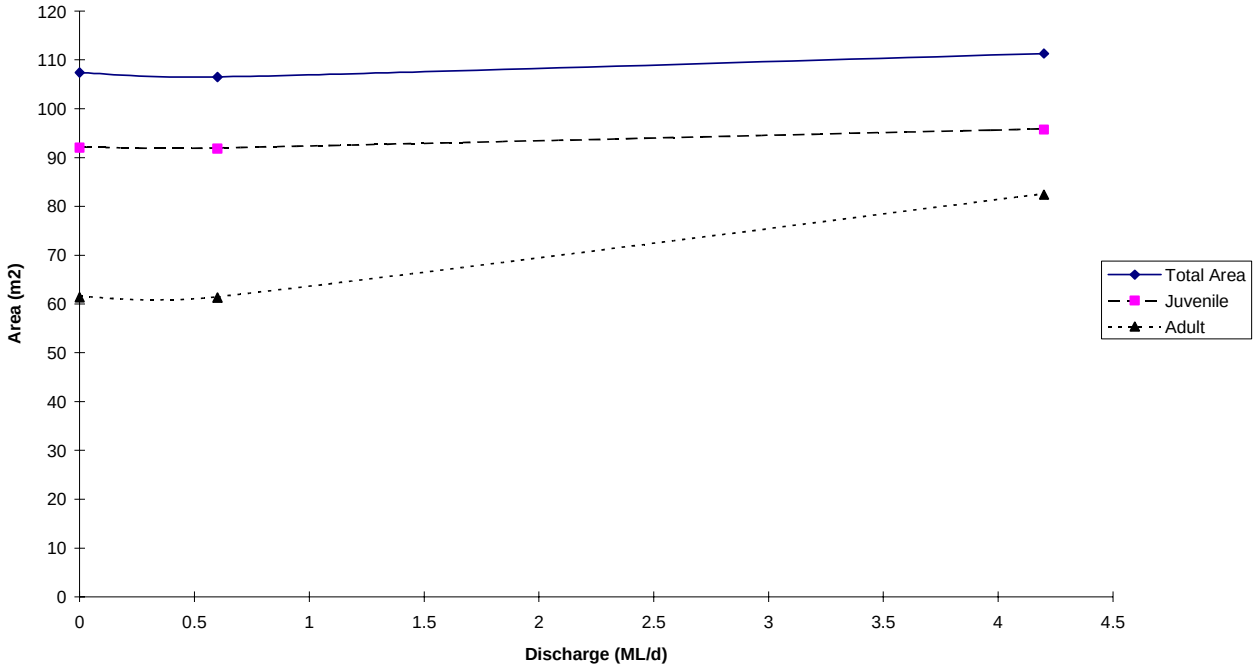

Figure 6-3. Total area and area of habitat potentially available to juvenile and adult river blackfish at a range of flows at site S3.

At site S4 (Arthurs Creek opposite 'Nihill') the area of habitat potentially available to juvenile and adult blackfish doubled as flows increased from near zero to 22 ML/d (Figure 6-4). This site had a greater area of glide/riffle than sites on Diamond Creek and hence stream area decreased substantially as flow decreased, particularly below 5 ML/d (Figure 6-4).

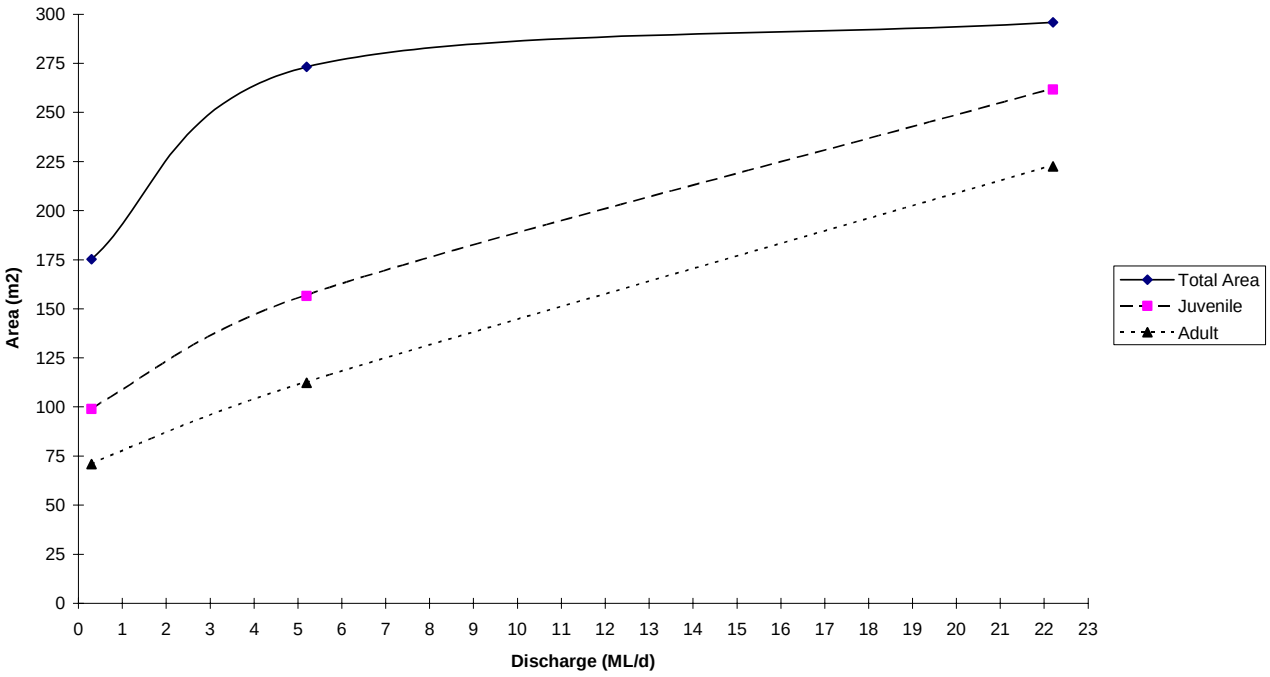

Figure 6-4. Total area and area of habitat potentially available to juvenile and adult river blackfish at a range of flows at site S4.

At site S5 (Arthurs Creek upstream of Nutfield) the area of habitat potentially available to juvenile and adult river blackfish remained relatively constant at flows between 6 and 22 ML/d but decreased by up to 50% as flows neared 0 ML/d (Figure 6-5). Like site S4 this site had considerably more shallow run areas and less pool area than sites on Diamond Creek.

At site S6 (Arthurs Creek at Strathewen) potential habitat availability was determined for mountain galaxias due to an absence of river blackfish in the upper reaches of Arthurs Creek. The site was dry when first observed in April 1998. The area of potential habitat was greatest at the highest measured flow (9.3 ML/d) but decreased by approximately 40% at a flow of 1 ML/d (Figure 6-6).

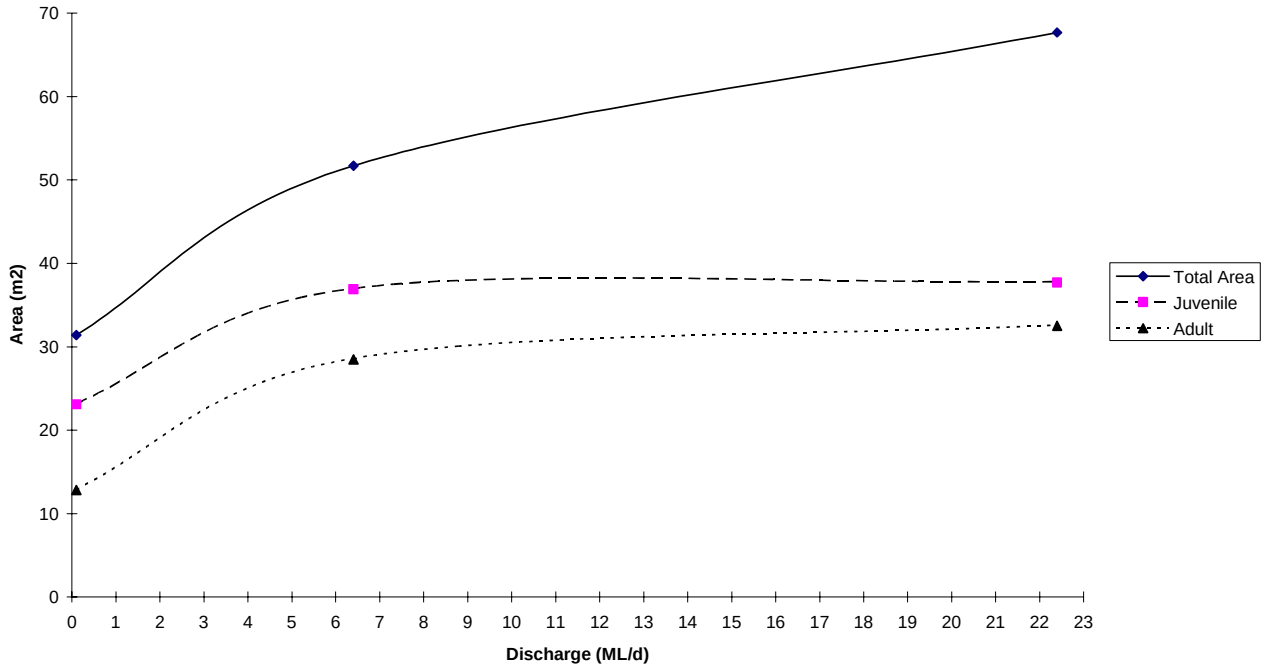

Figure 6-5. Total area and area of habitat potentially available to juvenile and adult river blackfish at a range of flows at site S5.

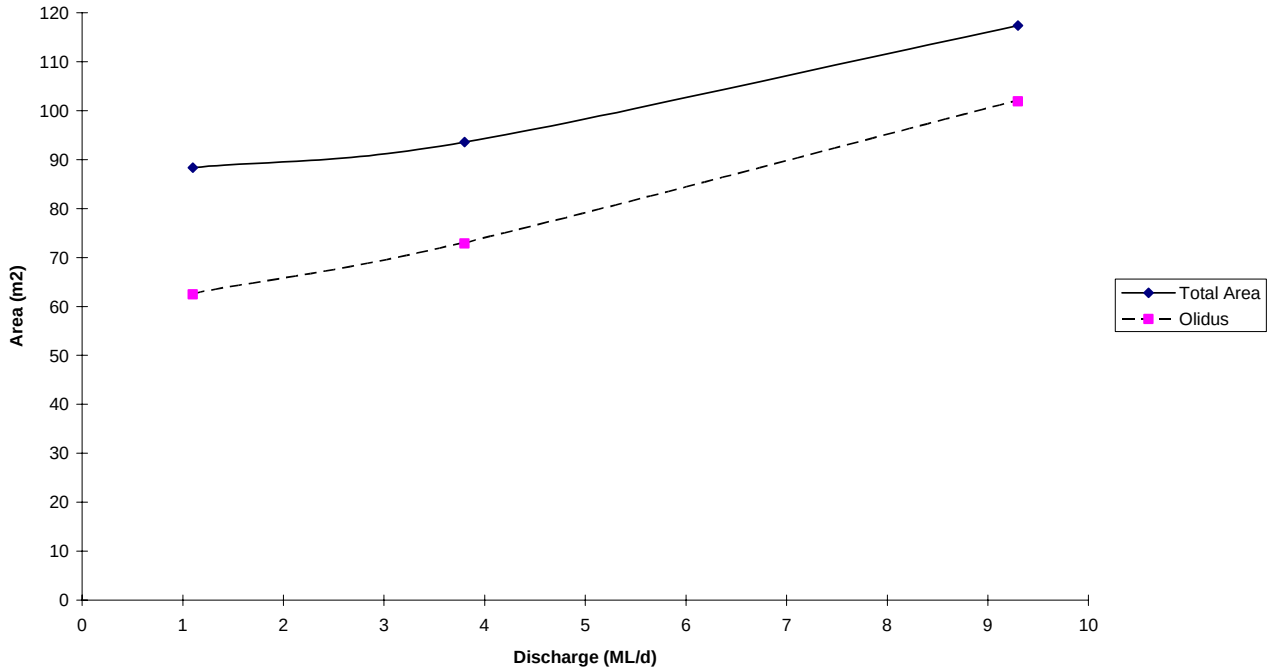

Figure 6-6. Total area and area of habitat potentially available to mountain galaxias at a range of flows at site S6.

6.3 Environmental Flow Recommendations (January - May)

Due to the possible ephemeral nature of the mid to upper reaches of Diamond and Arthurs Creek, and a lack of accurate gauging station information, it is difficult to recommend minimum environmental flows for sites S3 and S6. Nevertheless, a flow of 0.3 ML/d will maintain adequate potential habitat for river blackfish at site S3 and for mountain galaxias at site S6. The recommended flow for these sites is 0.3 ML/d or natural (i.e. flow above the first diverter in the system), whichever is least.

At sites S2 and S5, a minimum flow of 0.5 ML/d is recommended (Table 6-2). A flow of this magnitude will maintain much of the potentially available river blackfish habitat at site S2 and will retain an acceptable area of habitat at site S5. Gauging stations are not located at either site but the recommended flow appears to be within the natural regime for the summer/autumn low flow period.

At site S4 a minimum flow of 1.0 ML/d is recommended (Table 6-2). This site is the lowest site on Arthurs Creek and is downstream from the Running Creek confluence. Consequently, slightly higher flows than occur at site S5 would be expected to occur at this site over the summer/autumn low flow period. The recommended flow maintains an acceptable area of potential river blackfish habitat for what would naturally be a low flow period.

Site S1 is the lowest in the Diamond Creek system and is situated immediately downstream of gauging station 229223A. Flow records indicate that median flows for the period January to February range from 0.6 to 2.5 ML/d, however without diversions median flows may have ranged from approximately 2 to 3.5 ML/d (see section 4). Consequently, a minimum flow of 1.5 ML/d is recommended for this site (Table 6-2). This flow will retain a large proportion of potentially available river blackfish habitat and possibly help maintain or improve water quality in the large pools in this reach of Diamond Creek.

Table 6-2. Recommended minimum environmental flows for six locations in the Diamond Creek system

Site	Location	Minimum Flow (ML/d)
S1	Diamond Creek at Diamond Creek	1.5
S2	Diamond Creek at Hurstbridge (u/s Arthurs Creek)	0.5
S3	Diamond Creek at St Andrews	0.3*
S4	Arthurs Creek upstream of Diamond Creek confluence	1.0
S5	Arthurs Creek upstream of Nutfield	0.5
S6	Arthurs Creek at Strathewen	0.3*

*or natural (whichever is least)

The environmental flow recommendations for the Diamond Creek system have been determined using available biological and hydrological data. Ongoing biological monitoring and habitat availability assessment should be undertaken to assess the suitability of these flows. As new data becomes available it may be necessary to modify the recommended flows.

6.4 Winter-Fill Diversions

Water abstraction for winter-fill dams is conducted in the Diamond Creek system from May to December inclusive. Median flows during this period, at station 229223A (Diamond Creek at Diamond Creek) range from 2.5 ML/d during May to 42.9 ML/d during August (Figure 4-1). Although flows are generally of a larger magnitude during these periods, alterations to the natural flow regime through water abstraction may have adverse effects on aquatic fauna and flora.

Many species of native fish require specific seasonal flow events to stimulate life history processes such as spawning and migration. For example, the threatened Australian grayling spawns during the first high flow events at the end of Autumn and juveniles migrate upstream during the high flow period of October to November (Koehn and O'Connor, 1990). It is likely that a number of migratory fish species previously restricted from the Diamond Creek system (e.g. Australian grayling and tupong) may now recolonise the system by means of the Dights falls fish way. Consequently, the recommended environmental flow regime for the Diamond creek system must protect the requirements of these species.

In order to protect the environmental values of the Diamond Creek system and ensure that essential stream forming processes occur (e.g. channel scouring, silt removal etc.) flows of a large magnitude are essential during the May to December period. It is not possible to quantify these flows using fish habitat availability, however a precautionary approach that maintains flow magnitude and variability during this important period may be used.

It is recommended that winter-fill diversions may only commence once the 80th percentile daily exceedence flow for any given month (May to December inclusive) has been attained at site 229223A (Diamond Creek at Diamond Creek). At any flow above this level only 20% of the daily flow rate may be diverted for winter-fill dams.

Table 6-3. 80th and 50th percentile exceedence flows at station 229223A and daily winter-fill extraction rates (diversions upstream of Gipson St Diamond Creek).

	May	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
80th percentile flow (ML/d)	1.0	2.5	3.6	18.9	18.0	11.4	6.0	1.2
50th percentile flow (ML/d)	2.5	6.3	25.9	42.9	33.9	26.6	15.3	7.4
Extraction rate (ML/d)	0.8	0.9	1.2	1.2	1.7	1.7	0.4	0.4

At present in the Diamond Creek system the approximate daily rate for winter-fill diversions during May is 0.8 ML/d (Table 6-3), this is 80% of the 80th percentile exceedence flow and 35% of the median exceedence flow. This exceeds the recommendation of 20% of the daily flow at flows greater than the 80th percentile exceedence flow.

As mentioned, the first high flows following the low flow summer/autumn period are important for spawning and migratory cues for a number of native fish. In the Diamond Creek system flows during May appear relatively low (Figure 4-1 and Table 6-3) and a considerable proportion of flow may be commited to winter-fill. Consequently, it is

recommended that May is regarded as a low flow month and that provision for winter-fill diversions during this month be reviewed. Winter-fill diversion rates during June may also need to be reviewed, with the possibility of allowing higher extraction rates from August to October inclusive.

6.5 Instream Barriers

The only large barrier found in the Diamond Creek system was a natural rock bar in the lower reaches of Diamond Creek, adjacent to Antoinette Ave., Eltham. This structure does not appear to be restricting the upstream movement of fish, as migratory common galaxias and spotted galaxias were both collected further upstream by Lieschke and Raadik (1999).

Other smaller rock structures and artificial riffles have been constructed in the Diamond Creek system, although these are not considered to restrict fish passage. In some parts of the system willow roots have created vertical drops that may restrict passage for smaller migratory species during low flow periods but under higher flows passage would be available. Similar passage restrictions would occur in the mid to upper reaches of Diamond and Arthurs creek where, due to the possible ephemeral nature of the creeks, fish would be restricted to disjunct pools during some years.

6.6 Environmental Management Objectives

The primary environmental management objectives for the Diamond Creek system should include the following:

1. Maintain the existing species diversity and populations of aquatic fauna, and where possible, provide conditions that will encourage recolonisation of the Diamond Creek system by migratory native fish species that can now utilise the Yarra system by means of the Dights Falls fishway.

2. Maintain water quality in accordance with SEPP (Waters of Victoria) - draft Schedule F7 Waters of the Yarra Catchment (EPA, 1995).

3. Maintain, and where possible, restore diverse and complex instream habitat (e.g. woody debris).

4. Maintain remnants, and rehabilitate degraded areas, of indigenous riparian vegetation along Diamond and Arthurs Creek and their tributaries. In addition, ensure adequate buffer strips between cleared land and the creeks.

5. Maintain suitable river blackfish and mountain galaxias habitat from January to May through the provision of environmental flows of the magnitude specified in this report.

6. Ensure that winter-fill diversions are set at a level that does not impact upon migration and spawning of native fish species or essential stream forming processes such as channel scouring and silt removal.

6.7 Actions

With regards to the environmental management objectives, the following actions are recommended:

- Ongoing biological monitoring and habitat assessment should be undertaken to assess the suitability of the recommended environmental flows. This should include an annual survey of fish populations in the Diamond Creek system to determine their composition and recruitment success. As new data becomes available it may be necessary to modify the environmental flow recommendations.

- Buffer strips of approximately 30 m in width are recommended between cleared land and the creeks (Dignan *et al*., 1996). Riparian vegetation should also be adequately fenced to prevent cattle access. Whilst most sites surveyed had some riparian vegetation, a number of areas, particularly the lower reaches of Arthurs Creek and Diamond Creek, had a paucity of riparian vegetation or an abundance of exotic species such as willows. These areas should be rehabilitated with suitable endemic vegetation and fenced.

- The diversion rates for winter-fill extraction during the months of May and June should be reviewed so as to minimise possible adverse effects on instream biota. It would be preferable to commence winter-fill diversion in August and possibly increase the level of diversion during the period from August to October inclusive.

7. ACKNOWLEDGEMENTS

Thankyou to Stephen Nicol (Melbourne Water) for background and diversion information on the Diamond Creek system. Thanks also to the following staff from the Freshwater Ecology Division (DNRE) who assisted with field measurements and data analysis: Louise Grgat, Peter Fairbrother, Tarmo Raadik and Terry Glenane. Flow information for gauging stations on Diamond and Arthurs Creek was kindly provided by Peter Dowland (Melbourne Water) and Barbara Dworakowski (Thiess Environmental).

8. REFERENCES

Arthington, A.H., King, J.M., O'Keeffe, J.H., Bunn, S.E., Day, J.A., Pusey, B.J., Bludhorn, D.R. and Tharme, R. (1992) Development of an Holistic Approach for Assessing Environmental Flow Requirements of Riverine Ecosystems. In Pigram, J.J. and Hooper, B.P. (Eds) *Water Allocation for the Environment - Proceedings of an International Seminar and Workshop*.

Bovee, K.D. (1982) *A Guide to Stream Habitat Analysis Using the Instream Flow Incremental Methodology*. Instream Flow Information Paper 12. U.S.D.I. Fish and wildlife Service, Office of Biological Services. FWS/OBS-82/26. 248pp.

Cameron, A. and Vertessy, D. (1995) *Macroinvertabrate survey of the Diamond Creek basin and Stony Creek*. Water Ecoscience Scientific Report 11060095.

Cameron, A. and Vertessy, D. (1998) *Aquatic macroinvertebrate survey of the Diamond Creek basin, interim data report*. Water Ecoscience Report No. 227/98.

Campbell, I.C., MacMillan, L.A., Smith, A.J. and McKaige, M.E. (1982) *The Benthic Macroinvertebrates of the Yarra River and its Tributaries*. Environmental Studies Series Publication No. 362. Ministry for conservation, Victoria.

Courot, A. (1989) Determination of hydraulic parameters for instream flow assessments. *Regulated Rivers: Research and Management,* **3**: 337-344.

CNR (1995a) *Threatened Fauna in Victoria* - 1995. Department of Conservation and Natural Resources, Victoria.

CNR (1995b) *Yarra River Basin Overview Report - Environmental Input into the Bulk Entitlement Conversion Process* (Draft). Department of Conservation and Natural Resources.

Dignan, P., Kefford, B., Smith, N., Hopmans, P. and Doeg, T. (1996) *The Use of Buffer Strips for the Protection of Streams and Stream Dependent Biota in Forested Ecosystems*. Centre for Forest tree Technology, Department of Natural Resources and Environment, Victoria.

DNRE (1997) *Atlas of Victorian Wildlife*. Department of Natural Resources and Environment, Victoria.

Doeg, T.J. and Saddlier, S.R. (1992) *The Fish and Macroinvertebrate Fauna and Habitats of the Yarra River in Relation to the Upper Yarra Reservoir*. Department of Conservation and Natural Resources, Victoria.

EPA (1995) *Protecting Water Quality in the Yarra Catchment. State environment protection policy (Waters of Victoria) draft Schedule F7 (Waters of the Yarra Catchment) and draft Policy Impact Assessment*. Environment Protection Authority, Publication No. 471.

Gordon, N.D., McMahon, T.A. and Finlayson, B.L. (1992) *Stream Hydrology - An Introduction for Ecologists*. John Wiley & Sons, Chichester.

Hall, D.N. (1989) *Preliminary Assessment of Daily Flows Required to Maintain Habitat for Fish Assemblages in the Latrobe, Thompson, Mitchell and snowy rivers, Gippsland*. Arthur Rylah Institute for Environmental Research: Conservation Forests and lands technical report Series No. 85.

Horwitz, P. (1990) A taxonomic revision of species in the freshwater crayfish genus *Engaeus* Erichson (Decapoda : Parastacidae). *Invertebrate Taxonomy,* **4**: 427-614.

Jackson, P.D. (1986) Determination of Streamflow Allocations for Fishes: Developments and Inadequacies in Victoria. In Choon-Hui Teoh (Ed) *Proceedings of the Specialist Workshop on Instream Needs and Water Uses*. Australian Government Publishing Service, Canberra.

Koehn, J. (1986) Approaches to determining flow and habitat requirements for freshwater native fish in Victoria. In Campbell, I.C. (ed.) *Stream Protection: The Management of River and Instream Uses*. Water Studies Centre, Chisolm Institute of Technology, Australia.

Koehn, J.D. and O'Connor, W.G. (1990) *Biological Information for Management of Native Freshwater Fish in Victoria*. Dept of Conservation and Environment, Freshwater Fish Management Branch, Arthur Rylah Institute for Environmental Research.. Government Printer, Melbourne.

Koehn, J.D., O'Connor, N.A. and Jackson, P.D. (1994) Seasonal and size-related variation in microhabitat use by a southern Victorian stream fish assemblage. *Australian journal of Marine and Freshwater Research*, 45: 1353-1366.

Lieschke, J. and Raadik, T.A. (1999) *An assessment of aquatic biota at selected sites in the Diamond Creek system*. Freshwater Ecology Research Section, Dept of Natural Resources and Environment, Victoria.

Mathur, D., Bason, W.H., Purdy, E,J. and Silver, C.A. (1985) A critique of the instream flow incremental methodology. *Canadian Journal of Fisheries and Aquatic Science,* **42**: 825-831.

Morgan, G.J. (1986) Freshwater crayfish of the genus *Euasatacus* Clark (Decapoda : Parastacidae) from Victoria. *Memoirs of the Museum of Victoria,* **47** (1): 1-57.

Payne, T.R. and Associates (1994) *RHABSIM 1.1 for DOS*. Arcata, California.

Pettigrove, V.J. (1989) *Biological Monitoring of the Yarra River using Macroinvertebrates*. Scientific Series SRS 88/014. Environmental Protection Authority, Victoria.

Tunbridge, B.R. and Glenane, T.J. (1988) A *Study of Environmental Flows Necessary to Maintain Fish Populations in the Gellibrand River and Estuary*. Dept. of Conservation Forests and Lands, Arthur Rylah Institute for Environmental Research, Victoria.