

Management Flows for Aquatic Ecosystems in the Waianakarua River

SURFACE WATER



**Management Flows for Aquatic Ecosystems
in the
Waianakarua River**

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Foreword

The future development and prosperity of Otago depends on water. However, much of Otago has long been recognised as a water-short area and, consequently, Otago is constantly at the forefront of water management in New Zealand. In many cases, irrigation, particularly in these drier areas, is critical to the continued well being of the people and communities who rely on the primary production it supports.

The Regional Policy Statement provides the overall framework for the future management of water in Otago. The Water Plan provides the direction for better utilisation and protection of water so that the values, opportunities and needs of Otago's communities can be reasonably met.

A key thrust of the Water Plan is its emphasis on the progressive implementation of minimum flow regimes for streams and rivers throughout the region. The goal of these minimum flows is to maintain the stream's aquatic ecosystem and natural character during periods of low flow. Furthermore, setting appropriate allocation limits and promoting water use efficiency are integral for ensuring reliable access to the water resource.

In Otago, surface water supplies are heavily allocated. Over-abstraction can result in degradation of a stream's natural values and character. Therefore, careful management is required to keep rates of taking sustainable. The best way forward is to use this valuable water resource to our advantage and to implement allocation limits and minimum flows so that over-abstraction does not occur.

The Waianakarua River contains a limited brown trout fishery and several species of native fish of conservation importance. Currently, there are 10 water takes from the catchment that are used to irrigate approximately 652ha. Primary allocation for the catchment is considered fully allocated. Clearly there is a need to manage the stream for its natural values while allowing access to the water resource for the local community.

Executive Summary

The purpose of this report is to investigate the flows required to maintain acceptable habitat for the fish species found in the Waianakarua River.

Flow statistics such as the 7-day mean annual low flow (MALF) and 7-day 10 year low flow (Q_{710}) have been calculated to give an indication of the low flows experienced by that part of the catchment. Rainfall data have also been summarised to give an indication of annual rainfall and seasonal distributions.

Biodiversity and angling information has been obtained from both the Department of Conservation and Fish and Game Otago. This information has been incorporated into this report along with fisheries and climate data collected by Otago Regional Council.

Instream habitat surveys were carried out in the Waianakarua River and flow requirements for all the known resident fish species assessed by examining the relationships between flow and suitable habitat using instream habitat modelling. Habitat suitability was determined from general habitat suitability curves developed from studies in other rivers.

The Waianakarua River contains a limited brown trout fishery along with 13 species of native fish. The habitat information showed that maximum habitat for common bullies and redfin bullies is provided by a flow of $0.4 \text{ m}^3/\text{s}$, with habitat declining sharply as flows fall below $0.15 \text{ m}^3/\text{s}$. Maximum inanga habitat is provided by a flow of $0.15 \text{ m}^3/\text{s}$. Maximum habitat for bluegill bullies is provided by a flow of $0.8 \text{ m}^3/\text{s}$, and there is a gradual decline in the amount of bluegill habitat as flows reduced below $0.8 \text{ m}^3/\text{s}$. Maximum habitat is provided for koaro at $1.8 \text{ m}^3/\text{s}$ with habitat declining sharply as flows fall below $0.6 \text{ m}^3/\text{s}$. Maximum habitat for torrentfish is provided by a flow of $4.8 \text{ m}^3/\text{s}$, with habitat declining sharply as flows fall below $1.0 \text{ m}^3/\text{s}$. Maximum habitat for Canterbury galaxias (common river galaxiid) is provided by a flow of $0.4 \text{ m}^3/\text{s}$, with habitat declining sharply as flows fall below $0.2 \text{ m}^3/\text{s}$. Maximum habitat for adult brown trout is provided by a flow of $4.2 \text{ m}^3/\text{s}$, with habitat declining sharply as flows fall below $3.0 \text{ m}^3/\text{s}$.

The selection of an appropriate minimum flow depends on the fish species present and the flow management objectives that balance the degree of environmental protection against the value of water for other uses. This report focuses on the Waianakarua River's natural values which have been taken from Schedule 1A of the Regional Plan: Water for Otago (ORC 2004) (the Water Plan).

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1. Introduction

The Regional Plan: Water for Otago (ORC 2004) (the Water Plan) sets out as one of its objectives “to retain flows in rivers sufficient to maintain their life-supporting capacity for aquatic ecosystems and their natural character”¹. As a means to achieve this objective, the Water Plan provides for the setting of minimum flows in Otago rivers².

The purpose of this report is to provide information on the Waianakarua River that is relevant to determining the flows desirable for sustaining aquatic habitat. Hydrological data are summarised and analysed to determine low flow return periods for the Waianakarua River. Rainfall data are provided to show the variation in rainfall throughout the catchment. A brief overview of the topography, vegetation, land use and environmental concerns within the catchment is provided along with a summary of the recreational and biodiversity values of the Waianakarua River. A physical habitat study (the Instream Flow Incremental Methodology or IFIM) has also been carried out to determine the flow requirements for both native fish and introduced sports fish found within the catchment.

1.1 Focus of document

In order to manage a stream for aquatic ecosystems there needs to be a clear focus on what the management objective is. Schedule 1A of the Water Plan³ identifies the ecosystem values that must be sustained, and a key value that requires sufficient flow is the presence of a significant range of indigenous fish species. IFIM data are discussed with a focus on the management objective and the natural low flow regime of the Waianakarua River. Flows to sustain these aquatic ecosystem values in the Waianakarua River are suggested.

¹ Objective 6.3.1 of the Water Plan, pg 55.

² Policies 6.4.1 – 6.4.11 of the Water Plan, pp 58-69.

³ Schedule 1A of the Water Plan, pg 296.

2. The Waianakarua catchment

The Waianakarua catchment is found in North Otago, extends for approximately 33 km and has an area of approximately 260km². The Waianakarua River is relatively short and is divided into two branches that merge about 1km below the State Highway 1 bridge. The South Branch flows from the Horse Range while the North Branch drains the Kakanui Mountains. The upper Waianakarua catchment is made up of a mixture of tussock and native forest and has a reliable rainfall. It flows in an easterly direction and joins the Pacific Ocean south of Oamaru (Figure 2.1).



Figure 2.1 The Waianakarua catchment, Otago, New Zealand

2.1 Vegetation

Original vegetation of the catchment consisted of snow tussock, manuka and native bush. The native plant population has been modified with the spread of introduced plants and over-sowing of introduced pasture grasses. A large area of the catchment is also used for forestry (Reid & Keller, 1975).

2.2 Land use

The upper catchment of the Waianakarua is primarily used for extensive sheep and beef grazing. The mid reaches of the catchment contain extensive areas of production forestry. The land downstream of the main highway is mainly used for intensive sheep farming with some cropping and dairy production.

2.3 Topography and soils

The Waianakarua catchment is bounded by the Kakanui Mountains in the northwest and the Horse Range in the south (Figure 2.1). Templeton shallow silt loam dominates the generally flat lower catchment. The adjacent rolling topography is classed as silt loam, imperfectly drained with the soil structure susceptible to erosion. The upper catchment has soils of the stepland phase of the Kaikoura-Dunstan upland and high country yellow-brown earths, with a band of Arrow-Tengaura yellow-grey earths along the Horse Range ridge (Reid & Keller, 1975).

2.4 Rainfall

The Waianakarua area is protected from south and westerly weather patterns by the high country. However, it is affected by cool northeasterly sea breezes. Shelter from northwest winds also means that evapotranspiration is lower than on the more open valleys and plains further north (Reid & Keller, 1975). Due to the topography of the catchment, rainfall increases with distance from the coast. This can be seen in Figure 2.2 where the Glenrowan site is representative of rainfall for the lower catchment near the coast, while The Dasher represents the higher altitude upper catchment (refer to Figure 2.3).

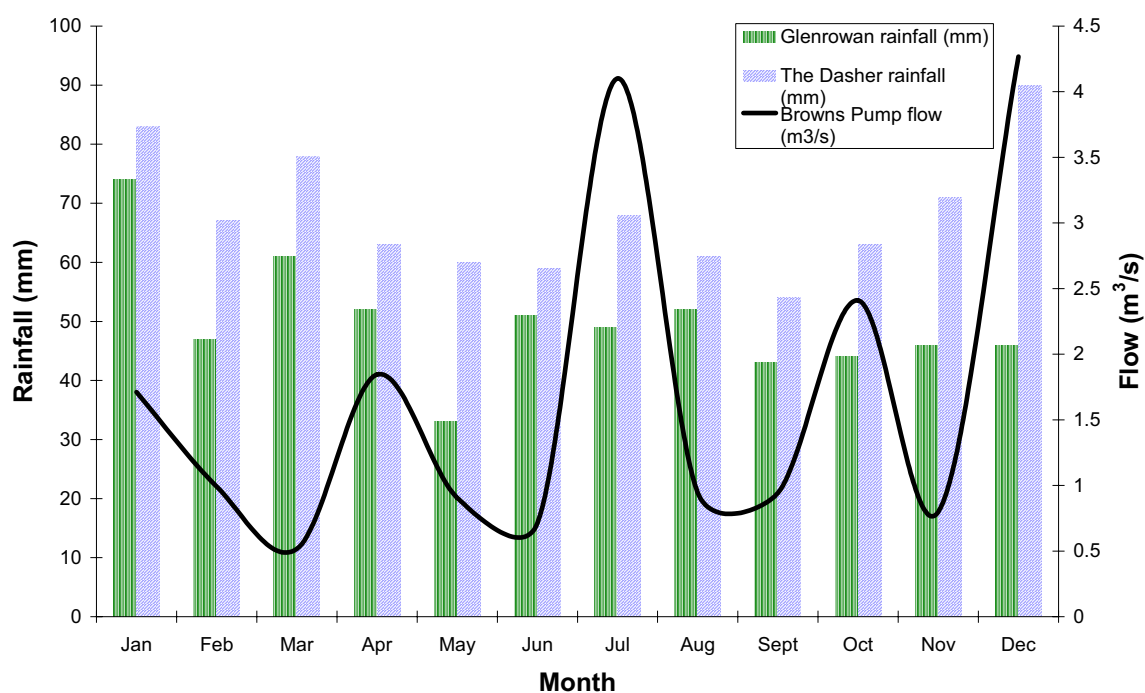


Figure 2.2 Mean monthly rainfall and recorded river flows for the Waianakarua catchment. Glenrowan represents the lower Waianakarua catchment while The Dasher is representative of the higher yielding upper catchment

2.5 Hydrology

Several sites within the Waianakarua catchment have been analysed to provide information about the long-term statistics of stream flows within the catchment (Figure 2.3). It should be noted that a permanent flow recorder was not installed in the lower Waianakarua until April 2005. As a result, flow records are short and need to be treated with some caution. Prior to 2005, all flow data that have been collected were one-off gaugings. Also, at times of low flows, recorded flows are influenced by irrigation takes.

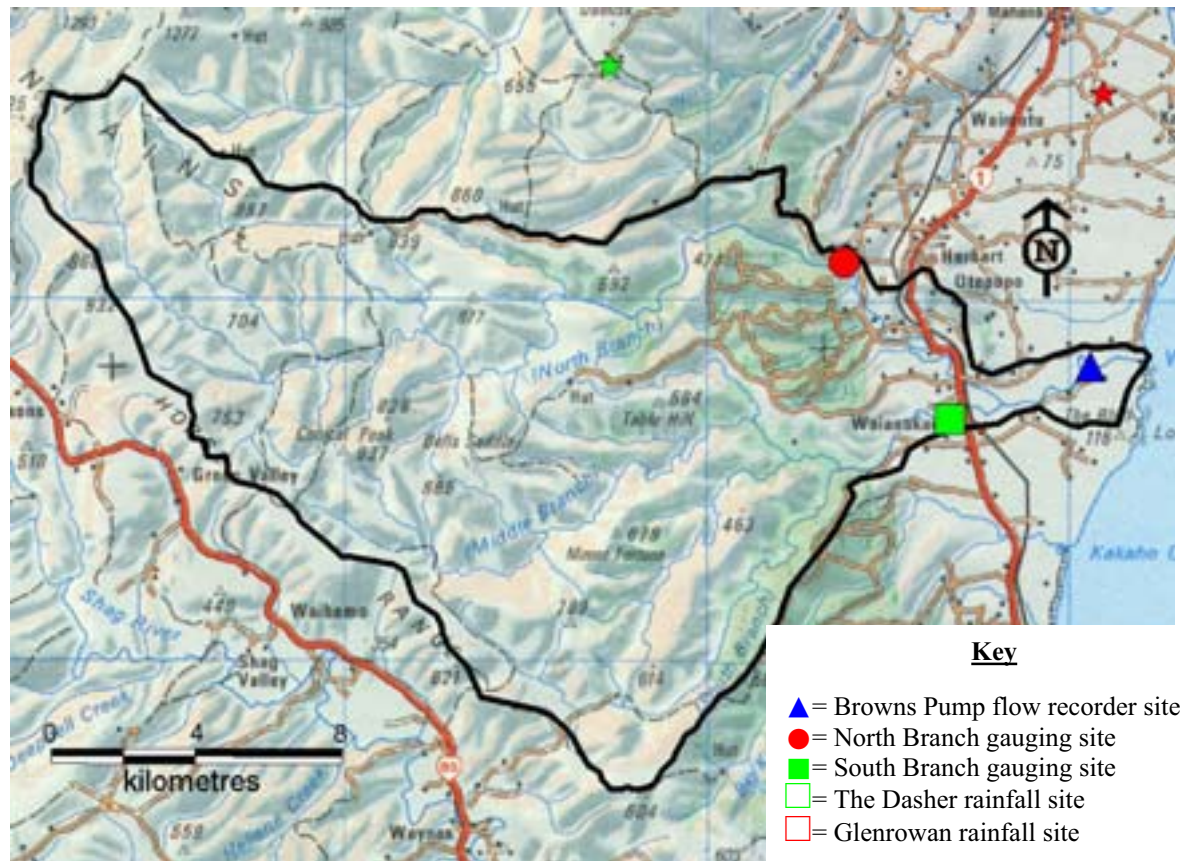


Figure 2.3 Gauging and rainfall recorder sites used for the Waianakarua River

2.6 Calculating the mean annual 7-day low flow (MALF) for the Waianakarua River

The 7-day Mean Annual Low Flow⁴ (MALF) was calculated in order to determine the primary allocation limit for the Waianakarua catchment⁵ and to get an indication of the average natural low flow experienced by the river. This was complicated by numerous factors, including: the permanent flow recorder in the Waianakarua catchment at Browns Pump is relatively new (records start in April 2005), the Waianakarua has two main branches that yield significantly different volumes of

⁴ The mean of the lowest 7-day average flow for each hydrological year of record.

⁵ Policy 6.4.2 of the Water Plan, pg 59.

water and different techniques for 7-day MALF estimation can produce differing results.

Appendices 1 – 4 provide the details of the different techniques used to estimate the 7-day MALF. Below is the 7-day MALF value used for the Waianakarua River in this report and the rationale behind its use in the absence of long-term continuous flow data.

2.7 Mean annual 7-day low flow (MALF) for the Waianakarua River

Table 2.1 shows the predicted 7-day MALF values for the two methods used, the regression method and catchment area/rainfall method. Both methods for estimating 7-day MALF values have predicted values that are very similar (Table 2.1). The mean of the summer flow gaugings for the period January to April at each site has also been shown along with the actual recorded 7-day MALF at Browns Pump. In calculating the mean summer gauging values, records of flows higher than would be expected during low flow condition were removed.

Table 2.1 Summary of the two methods used to estimate the 7-day MALF for the Waianakarua River in relation to the mean gauged flows at each site from January to April and actual recorded flow at Browns Pump

Site	Regression method MALF (m ³ /s)	Catchment/rainfall method MALF (m ³ /s)	Mean summer gaugings for January to April (m ³ /s)	Recorded 7-day MALF (m ³ /s)
North Branch	0.192	0.197	0.183	N/A
South Branch	0.077*	0.080	0.089*	N/A
Browns Pump	0.286*	0.312	0.250*	0.213*

* Affected by irrigation takes

It can be seen that the catchment/rainfall method for predicting MALF produces a value which is higher than other MALF values (Table 2.1). This is due to upstream irrigation takes affecting the flows expected and/or recorded by the other methods.

Times of low flow tend to correspond with high water demand, thus low flow gaugings are often affected by irrigation takes. In the Waianakarua catchment there is a total of **0.189 m³/s** of primary allocation allocated. Therefore, when the river is at MALF, if a fraction of the primary allocation is taken, flows can drop significantly.

It is more than likely that the mean of the summer flow gaugings for the period January to April at the Browns Pump site is reflecting an irrigation influence as is the recently installed Browns Pump flow recorder. The mean of the summer flow gaugings at the North Branch site is slightly lower than the MALF predicted by both methods. This may be due to the fact that many of the gaugings at this site were done in the 1999 and 2004 droughts. Hence, it is likely that recorded flows at the North Branch site do not reflect average conditions.

The 7-day MALF values at Browns Pump seem to represent best and worst case figures (Table 2.1). Actual gauged and recorded flows would appear to be too low

due to the influence of irrigation takes. MALF values predicted by the catchment/rainfall method may be a little generous, as it appears to be assuming flow contribution from the drier coastal section of catchment is more significant than would be expected. The regression method is predicting values slightly lower than those of the catchment/rainfall method but this prediction is also influenced by irrigation takes so it is expected that it would be slightly low.

A 7-day MALF of **0.3 m³/s** has been chosen as this represents a compromise between the two methods used to predict MALF and the measured flows at Browns Pump (Table 2.1).

2.7.1 Annual 7-day low flows and their frequency analyses

Mean annual 7-day low flows (MALF or $Q_{7,m}$ in m³/s) and the corresponding specific MALF⁶ (SMALF or $SQ_{7,m}$ in l/s/km²) are provided in Table 2.2 for the three flow gauging sites in the Waianakarua catchment.

Table 2.2 Low flows for three gauging sites in the Waianakarua catchment

Site	Location	Min. (m ³ /s)	MALF (m ³ /s)	Area (km ²)	SMALF (l/s/km ²)
Camp Iona	North Branch	0.112	0.192	116	1.66
Gravel Pit*	South Branch	0.013	0.077	107	0.72
Browns Pump*	Lower Waianakarua	0.13	0.3	260	1.15

*Affected by upstream irrigation intakes

The specific MALF for the North Branch of the Waianakarua is significantly higher than that of the South Branch, while the Browns Pump gauging site at the bottom of the catchment is intermediate between the two branches (Table 2.2). The higher specific yield in the North Branch of the Waianakarua River is more than likely due to a combination of high water yielding vegetation and higher rainfall due to topography.

Low flow return periods in Table 2.3 were calculated using the same regression procedure (Appendix 1 to Appendix 3) as was used to derive the 7-day MALF for the Waianakarua River. Return periods were then converted, based on the chosen MALF of 0.3 m³/s at the Browns Pump gauging site (Table 2.3).

Table 2.3 Low flows for selected return periods in the Waianakarua catchment

Site	Min. (m ³ /s)	MALF (m ³ /s)	Q ₇₅ (m ³ /s)	Q ₇₁₀ (m ³ /s)	Q ₇₂₀ (m ³ /s)	Q ₇₅₀ (m ³ /s)	Q ₇₁₀₀ (m ³ /s)
Nth Branch at Camp Iona	0.112	0.192	0.125	0.107	0.095	0.084	0.077
Sth Branch at Gravel pit*	0.013*	0.077	0.050	0.043	0.038	0.034	0.031
Browns Pump* (Regression Method)	0.13*	0.286	0.185	0.159	0.141	0.125	0.114
Browns Pump (Chosen MALF)	0.13*	0.3	0.194	0.164	0.148	0.131	0.12

*Affected by upstream irrigation intakes

⁶ Specific discharge from one unit catchment area at times of the 7-day mean annual low flow.

Table 2.3 shows that the gauged minimum flows vary in intensity between sites. The South Branch has recorded flows which are less than would be expected in a 7-day 100-yr low flow (Q_{7100}). Similarly, the Browns Pump site has recorded flows less than those expected in a 7-day 50-yr low flow (Q_{750}). Both these sites are affected by irrigation takes. In contrast, the North Branch is unaffected by irrigation takes and its lowest gauged flow is intermediate between a 7-day 5-yr low flow (Q_{75}) and a 7-day 10-yr low flow (Q_{710}). It must be noted that, as the Waianakarua is a relatively small stream, there is little difference between a Q_{750} low flow and a Q_{710} low flow. For example, the difference between a normally relatively benign Q_{710} low flow and a typically much more severe Q_{750} low flow on the South Branch of the Waianakarua River is only $0.009 \text{ m}^3/\text{s}$ (Table 2.3). This highlights the fact that irrigation takes on small streams can magnify the effects of low flows significantly in comparison to larger rivers.

To provide comparison between the predicted flows for the Waianakarua catchment, summary statistics for the relatively new Browns Pump flow recorder have been provided (Table 2.4).

Table 2.4 Recorded flows for the Waianakarua River at Browns Pump flow site

Site	Min	Mean	Maximum	7-day MALF
<i>Browns Pump</i>	<i>0.155</i>	<i>1.713</i>	<i>88.524</i>	<i>0.213</i>

Table 2.4 shows actual recorded flows from April 2005 to June 2006. The flows recorded at Browns Pump are affected by upstream irrigation takes.

2.8 The Waianakarua's fish species

The Waianakarua River supports a diverse fishery, with 14 species of fish listed as being present in the catchment (NIWA freshwater fish database; ORC observations) (Figure 2.4). Brown trout (*Salmo trutta*) is the only species of introduced sports in the Waianakarua catchment. Thirteen species listed by the NIWA fish database are native. Many sampling sites within the catchment have a diverse fish community with up to 9 species of fish found at a single site. Fish diversity is considered the ecosystem value requiring the greatest consideration in setting a flow regime.

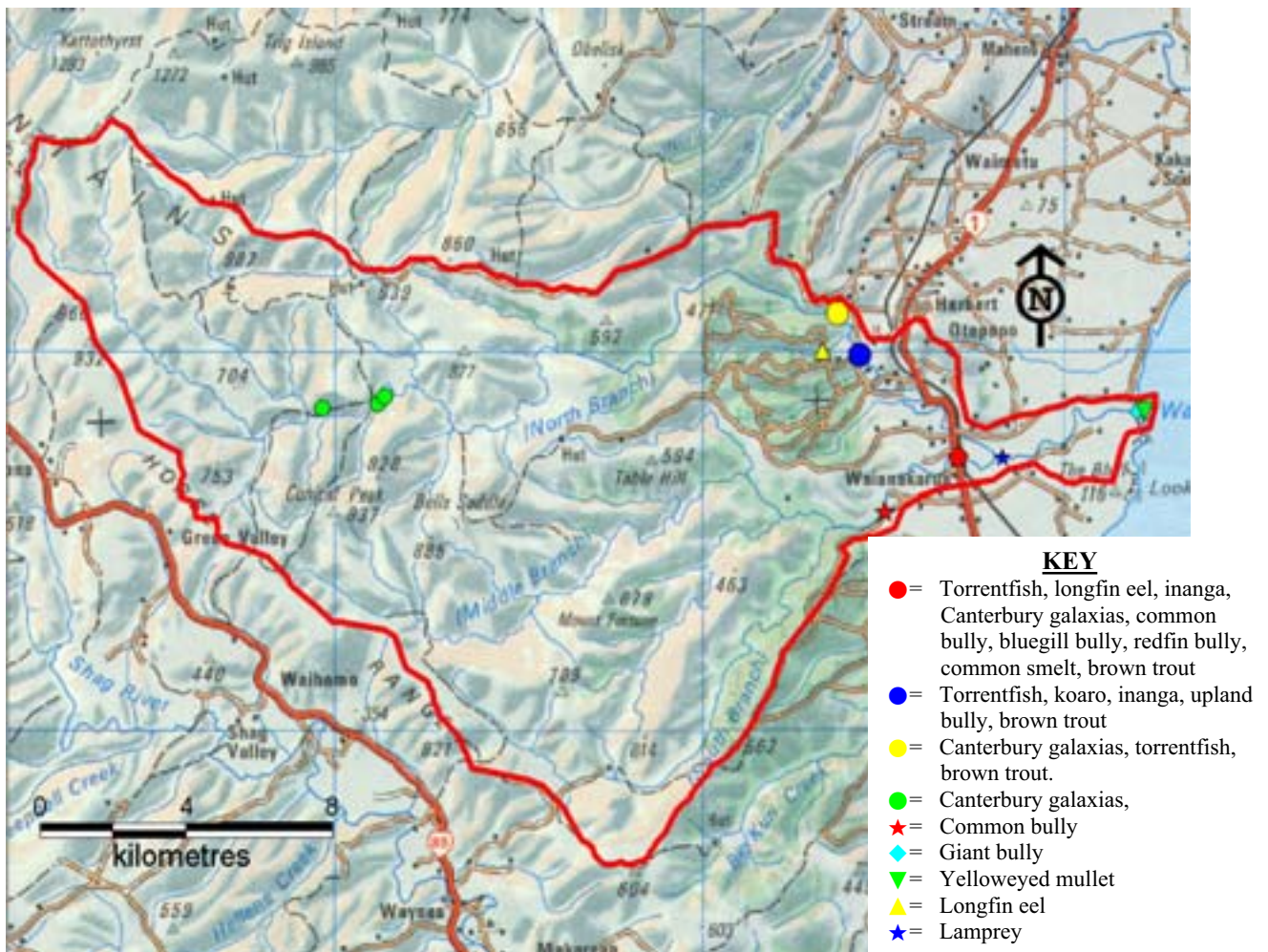


Figure 2.4 Sites where fish species have been recorded in the Waianakarua catchment. Data are from the NIWA freshwater fish database and ORC observations

3. Recreational and biodiversity values

The Waianakarua River is a small coastal stream in North Otago, and has many recreational and biodiversity values that make it of interest to the community of Otago. Below is a summary of information available on the Waianakarua catchment with information incorporated from agencies that have an interest in the flow regime of the Waianakarua River.

3.1 Recreational values

The National Angling Survey 1994/1996 by Unwin and Brown (1998) does not mention the Waianakarua River as a significant sports fishery. Further information submitted by Fish and Game Central South Island recognises that the Waianakarua River is a limited sports fishery due to lack of cover and low flows (Pringle 2003). The lower section of river downstream of the State Highway 1 bridge holds a few sports fish in the deeper pools and, depending on access, some anglers utilise this. It is believed that the trout fishery is heavily dependent on the sea run component (Pringle 2003). Further recreational pursuits such as whitebaiting and swimming also occur in the Waianakarua River.

3.2 Biodiversity values

The Water Plan⁷ lists many natural values for the Waianakarua, including significant habitat for the native fish koaro (*Galaxias brevipinnis*), high native fish diversity and a high degree of naturalness above the afforested areas of the catchment. According to the Department of Conservation Otago, there is a recognised inanga (*Galaxias maculatus*) spawning site 500 metres upstream from the mouth of the Waianakarua River and variable oystercatchers are present at and near the mouth of the river.

⁷ Schedule 1A of the Water Plan, pg 296.

4. Physical habitat survey

The Otago Regional Council contracted NIWA to carry out a study to determine the flows required to maintain acceptable habitat for the fish species present in the Waianakarua River.

The primary aims of this study were to:

- Conduct instream habitat surveys in critical reaches of the Waianakarua River.
- Conduct a hydraulic analysis in the above streams using RHYHABSIM (Jowett 1989) to determine how weighted usable area (WUA) for brown trout and native fish habitat varies with flow.
- Assess flow requirements for the Waianakarua based on the habitat requirements of the native and introduced fish species.

4.1 Instream flow incremental methodology (IFIM) summary

The IFIM (Bovee 1982) is an example of a holistic way to determine an appropriate flow regime by considering the effects of flow changes on instream values, such as river morphology, physical habitat, water temperature, water quality, and sediment processes. As habitat methods are based on quantitative biological principles, they are considered more reliable and defensible than assessments made in other ways (White 1976; Annear & Conder 1984; Dunbar et al. 1998; Tharme 1996; Annear et al. 2002). Their strength lies in their ability to quantify the loss of habitat caused by changes in the natural flow regime, which helps the evaluation of alternative flow proposals (Jowett 2004).

Providing or retaining suitable physical habitat for aquatic organisms that live in a river is the ecological aim of IFIM assessments. Habitat methods allow for a more focused flow assessment and can potentially result in improved allocation of resources (Jowett 2004). However, it is essential to consider all aspects such as food, shelter, and living space and to select appropriate habitat suitability curves for an assessment to be credible (Orth 1987; Jowett 1995; Biggs 1996).

4.1.1 Habitat preferences and suitability curves

The aim of the IFIM is to maintain, or even improve, the physical habitat for instream values. The IFIM requires detailed hydraulic data, as well as knowledge of the ecosystem and the physical requirements of stream biota. The basic premise of habitat methods is that if there is no suitable physical habitat for the given species, then they cannot exist. However, if there is physical habitat available for a given species, then that species may or may not be present in a survey reach, depending on other factors not directly related to flow, or to flow related factors that have operated in the past (e.g., floods). In other words, habitat methods can be used to set the outer envelope of suitable living conditions for the target biota (Jowett 2004).

Biological information is supplied in terms of habitat suitability curves for a particular species and life stage (Jowett 2004). A suitability value is a quantification of how well suited a given depth, velocity or substrate is for the particular species and life stage (Jowett 2004). The result of an instream habitat analysis is strongly influenced by the habitat criteria that are used. If these criteria specify deep water and high velocity requirements, maximum habitat will be provided by a relatively high flow.

Conversely, if the habitat requirements specify shallow water and low velocities, maximum habitat will be provided by a relatively low flow and habitat will decrease as the flow increases. The suitability curves developed in New Zealand for large, feeding adult brown trout (Hayes & Jowett 1994) specify higher depth and velocities than curves for adult brown trout developed in the U.S. (Raleigh et al. 1986). Whether this is due to differences in the sizes of fish has not been clarified. However, it is clear that it is important to use suitability curves that are appropriate to the river and were developed for the same size and life stage of fish, and behaviour, as those to which they are applied.

Generally, native fish are found in similar habitats over a wide range of rivers. McDowall (1990) has described these habitats in descriptive terms. The quantitative approach taken in New Zealand has been to develop general habitat suitability criteria for species of interest by using data collected from several rivers. To date, general habitat suitability curves have been developed for several native fish species, some of it published (e.g., Jowett & Richardson 1995) and some of it unpublished.

4.2 IFIM for the Waianakarua River

The Waianakarua River has two main branches: the South Branch flows from the Horse Range while the North Branch drains the Kakanui Mountains. The upper and mid reaches of both branches are confined by a series of steep gorges. The lower Waianakarua River remains entrenched while flowing through relatively flat land. The lower Waianakarua River contains shallow riffles and runs, with some large pools.

The instream habitat survey was carried out at a flow of 0.28 m³/s in the lower Waianakarua River upstream of Browns Pump and calibration measurements for depth/flow relationships at each cross-section were made at flows of 0.21 m³/s and 0.130 m³/s. At the survey flow of 0.28 m³/s, the average river width was 13.1 m, the depth 0.23 m, and velocity 0.11 m/s. The substrate comprised mainly cobble (27%), gravel (34%) and fine gravel (12%), with cobbles dominating riffles and gravel/fine gravel in runs and pools.

Maximum habitat for common bullies (*Gobiomorphus cotidianus*) and redfin bullies (*Gobiomorphus huttoni*) is provided by a flow of 0.4 m³/s, with habitat declining sharply as flows fell below 0.15 m³/s. Maximum inanga habitat is provided by a flow of 0.15 m³/s, although generally the river would not provide sufficient cover for inanga (Jowett & Wilding 2003) except in the lower reaches. Maximum habitat for bluegill bullies (*Gobiomorphus hubbsi*) is provided by a flow of 0.8 m³/s, and there is a gradual decline in the amount of bluegill habitat as flows reduce below 0.8 m³/s. Maximum habitat is provided for koaro at 1.8 m³/s with habitat declining sharply as flows fall below 0.6 m³/s. Maximum habitat for torrentfish (*Cheimarrichthys fosteri*) is provided by a flow of 4.8 m³/s, with habitat declining sharply as flows fall below 1.0 m³/s. Maximum habitat for Canterbury galaxias (*Galaxias vulgaris*) is provided by a flow of 0.4 m³/s, with habitat declining sharply as flows fall below 0.2 m³/s. Optimum habitat for adult brown trout is provided by a flow of 4.2 m³/s, with habitat declining steadily as flows fall below 3.0 m³/s (Table 4.1 and Figure 4.1).

Table 4.1 Flow requirements for fish species using IFIM in the lower Waianakarua River

Fish species	Optimum flow (m ³ /s)	Flow below which habitat declines sharply (m ³ /s)
Redfin bully	0.4	0.15
Common bully	0.4	0.15
Inanga	0.15	0.05
Bluegill bully	0.8	-
Longfin eel	0.9	-
Koaro	1.8	0.6
Canterbury galaxias	0.4	0.2
Torrentfish	4.8	1.0
Adult brown trout	4.2	3.0
Juvenile brown trout	2.6	0.6

7-day MALF = 0.3 m³/s

4.3 Discussion – IFIM and management objective

The IFIM data provide an overview of the flow requirements of different fish species to maintain their preferred habitat requirements (Figure 4.1). Flow requirements can be selected so that they provide optimum habitat, or selected so that they prevent a serious decline in fish habitat. The flow below which habitat declines significantly is known as the point of inflection. It is a point of diminishing return, where proportionately more habitat is lost with decreasing flow than is gained with increasing the flow by the same increment. Different species of fish and even different size classes of fish have different points of inflection. Ecologically, the point of inflection represents the flow below which there is serious risk of losing sufficient habitat to maintain a species of fish or size class.

Clear management objectives for aquatic ecosystems are necessary when applying IFIM data (Hudson et al. 2003; Jowett & Wilding 2003). In the National Angling Survey 1994/1996 by Unwin and Brown (1998), the Waianakarua River is not mentioned as a significant sports fishery. Information submitted by Central South Island Fish and Game supports this. Therefore, the recommended management objective for the Waianakarua River is to sustain the diverse native fish community in the lower reaches in accordance with Schedule 1A of the Water Plan⁸.

⁸ Schedule 1A of the Water Plan, pg 296.

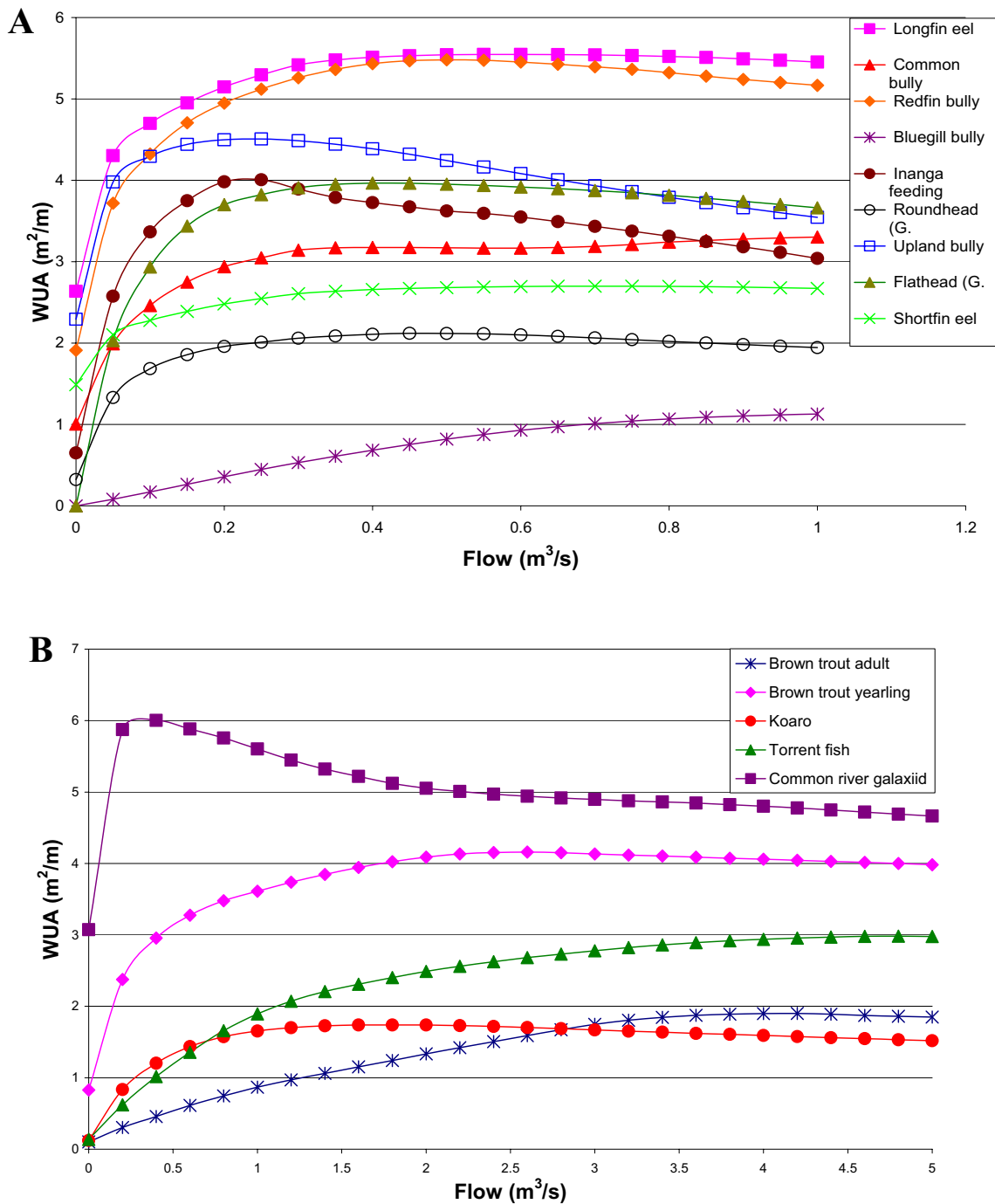


Figure 4.1 Variation of instream habitat for the Waianakarua River for fish species preferring low flows (A) and fish species preferring higher flows (B)

5. Flow requirements: Discussion and suggested management flows for aquatic habitat

Under the Water Plan⁹, Otago rivers will have minimum flows set to provide for the maintenance of aquatic ecosystems and natural character under low flow conditions. Under the Water Plan¹⁰, when minimum flow levels are reached all consents that are subject to that minimum flow are to cease taking.

5.1 Waianakarua River flows discussion based on technical information

The Waianakarua catchment is a relatively small catchment with most water use restricted to the lower reaches. Therefore, it is recommended that there be one minimum flow site on the Waianakarua River.

The flows required to maintain introduced sports fish such as trout are generally much greater than those required by native fish. Often the optimum flow range is far greater than the flows required to simply maintain habitat for a particular size class or fish species. For the Waianakarua River, optimum flows (Table 4.1) for the different native fish species vary from 0.15 m³/s for inanga to 4.8 m³/s for torrentfish (Jowett & Wilding 2003). Optimum habitat for adult brown trout is provided by flows of 4.2 m³/s. Habitat declines sharply for native fish in flows ranging from 0.05 m³/s for inanga to 1.0 m³/s for torrentfish (Jowett & Wilding 2003). Two species of the five assessed using IFIM did not show a clear point of inflection (flows below which habitat declines sharply) but rather a gradual decline in habitat as flows reduce. Adult brown trout habitat declines steadily once flows fall below 3.0 m³/s (Figure 4.1).

Jowett (1990; 1992) found that the percentage of adult trout habitat at the 7-day MALF acts as a bottleneck to trout density. A flow of 0.3 m³/s (MALF) provides only 0.38 m²/m WUA for adult brown trout, and when flows are reduced to 0.2 m³/s, usable habitat falls to 0.3 m²/m WUA (Figure 4.1). Therefore, it would appear that the natural low flows of the Waianakarua River are restricting the trout fishery.

The Waianakarua River contains a variety of fish species and the management objective for the river is to maintain the native fish diversity (Schedule 1A¹¹). There will be a flow that represents a compromise between the needs of the native fish that prefer high and low velocity environments. It is necessary to identify that flow for maintaining native fish diversity.

From the IFIM data, the difference between the amount of habitat available at 0.2 m³/s and the optimum for each of the native species is negligible with the exception of bluegill bullies, torrentfish and koaro (Figure 4.1). At 0.2 m³/s, bluegill bullies, torrentfish and koaro have significantly less habitat than the other native species assessed by the IFIM. The MALF (0.3 m³/s) also restricts the habitat available for bluegill bullies, torrentfish and koaro. Hence, there is no significant habitat difference for these species at flows of 0.3 m³/s compared to 0.2 m³/s (Figure 4.1).

⁹ Schedule 2A of the Water Plan, pg 314.

¹⁰ Policy 6.4.11 of the Water Plan, pg 69

¹¹ Schedule 1A of the Water Plan, pg 296.

Long duration low flows with little flow variability can promote excessive periphyton growth, lower invertebrate diversity and contribute to increased water temperatures which may impact on fish (Jowett 1990; Jowett 1992; Suren et al. 2003a; Suren et al. 2003b). From the recorded flows on the Waianakarua River, it can be seen that considerable flow variability occurs throughout the year (Figure 2.2). It is worth noting that the current amount of water allocated from the Waianakarua is close to 50% of its 7-day MALF. This is of interest when considering flow as the amount of water allocated is as important as the actual minimum flow set. That is, if the amount of water allocated is large relative to the natural flow of the stream, a large portion of the stream flow variability can be removed. The continuous flow data suggest that the primary allocation limit of 50% MALF would continue to provide a significant amount of annual flow variation (Figure 2.2). Flow variation is seen as important for numerous ecological reasons including removing algal growth, lowering water temperatures and providing for fish migration.

5.2 Suggested management flows for aquatic ecosystems

From the IFIM data, it has been shown that the difference between the amount of habitat available at 0.2 m³/s and the optimum for each of the native species is negligible with the exception of bluegill bullies, torrentfish and koaro (Figure 4.1). However, as is the case for adult brown trout, the natural low flow of the Waianakarua is restricting habitat for bluegill bullies, torrentfish and koaro.

Seasonal management flows of **0.2 m³/s** and **0.4 m³/s** are suggested for the Waianakarua catchment. Although there are no clear seasonal patterns with the flow regime of the Waianakarua River, lower flows are expected to occur from October to April (Figure 2.2). By implementing higher management flows during the period when there is naturally high flows in the river (May to September), some seasonal flow variation is provided for. Brown trout migration and spawning tends to occur over the winter period when flows are naturally higher, allowing for upstream migration.

A flow of **0.4 m³/s** at the Browns Pump gauging site is likely to ensure the sustainability of the diverse indigenous fish community in the Waianakarua River during the high flow period May to September (inclusive). A flow of **0.2 m³/s** at the Browns Pump flow recorder site is likely to ensure the sustainability of the diverse indigenous fish community in the Waianakarua River during the lower flow period October to April (inclusive), and it is suggested that flows should not be allowed to drop below those outlined above due to consumptive use.

The management flow for the low flow period of **0.2 m³/s** is well below the point of inflection indicated by the IFIM survey for adult brown trout, juvenile brown trout, torrentfish and koaro (Table 4.1). As shown earlier for adult brown trout, the MALF (0.3 m³/s) also restricts the habitat available for bluegill bullies, torrentfish and koaro, hence there is no significant habitat difference for these species at flows of 0.3 m³/s compared to 0.2 m³/s (Figure 4.1).

The high flow period (May to September inclusive) management flow of **0.4 m³/s** represents the flow that provides optimum redfin bully, common bully and Canterbury galaxiid habitat indicated by the IFIM (Table 4.1).

6. Acknowledgements

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8. Glossary of terms

7-Day MALF	The mean of the lowest 7-day average flow for each hydrological year of record (MALF).
Q₇10	The 7-day low flow with the likelihood of occurring once in a 10 year period.
Pool	Aquatic habitat characterised by slow flowing, deep water with an unbroken surface.
Return Period	Sometimes called the recurrence interval. Return period is the means of expressing the statistical likelihood of a low or flood flow occurring.
Riffle	Aquatic habitat characterised by shallow, stony, fast flowing (where the surface of the water is broken) conditions, favoured by most aquatic invertebrates.
Run	Aquatic habitat characterised by obvious flow, but without the rapid, broken surface conditions of a riffle.
SMALF	Specific discharge from one unit catchment area at times of the 7-day mean annual low flow (MALF).
Weighted Usable Area (WUA)	WUA (m ² /m) is the measure of the total area of suitable habitat per metre of stream.

Appendix 1 - The flow relationship between the Kakanui River at Clifton Falls and the North Branch of the Waianakarua River

The North Branch of the Waianakarua River has been gauged at Camp Iona and is unaffected by irrigation takes thus recorded flows are natural. Recorded flows in the Kakanui River at Clifton Falls are also considered very close to natural. Figure A. 1 compares these flows. The Waianakarua North Branch catchment is also relatively close to the long-term continuous recorder site at Clifton Falls on the Kakanui, with similar land use, rainfall and topography.

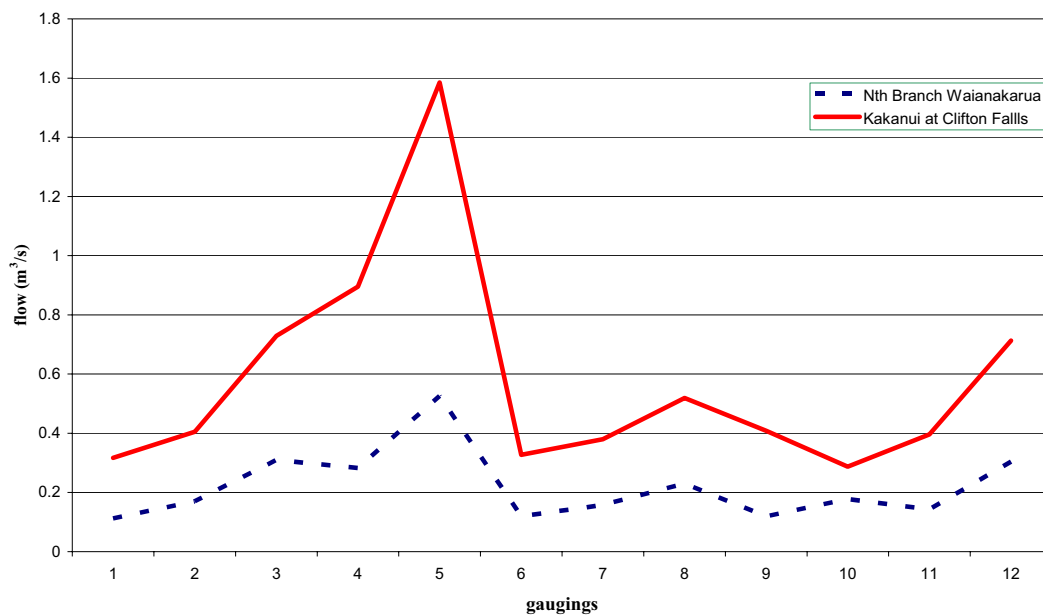


Figure A. 1 Gauged flows for the North Branch of the Waianakarua River compared to daily mean flow recorded at Clifton Falls on the Kakanui River

Regression analysis was carried out on these data resulting in an R^2 of 0.8913 (Figure A. 2). This suggests a strong relationship between flows in the North Branch of the Waianakarua River and recorded flows in the Kakanui River at Clifton Falls (Figure A. 2).

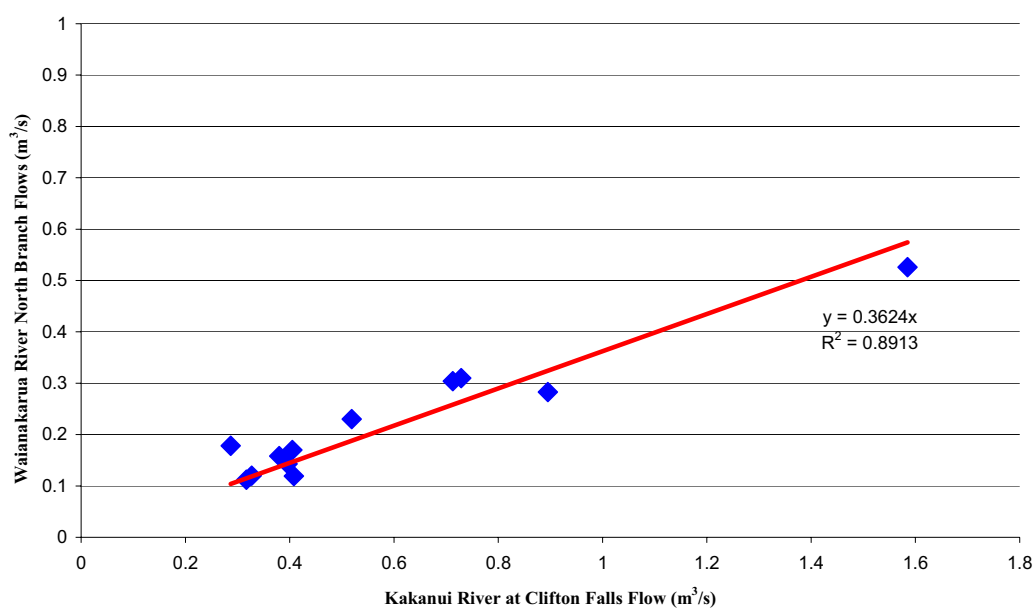


Figure A. 2 Regression analysis comparing flows in the North Branch of the Waianakarua River and daily mean flow recorded at Clifton Falls on the Kakanui

As the linear relationship between flows in the North Branch of the Waianakarua and the Kakanui at Clifton Falls is relatively strong it can be used to get an idea of MALF for the North Branch of the Waianakarua River. MALF for the Kakanui at Clifton Falls is $0.530 \text{ m}^3/\text{s}$. Therefore using the regression equation from Figure A. 2, $Y = 0.3624X$ (where Y = North Branch flows and X = flows at Clifton Falls) we can see that the corresponding MALF value for the North Branch of the Waianakarua River is $0.192 \text{ m}^3/\text{s}$ ($Y = 0.3624 \times 0.530$).

Appendix 2 - The flow relationship between the North Branch of the Waianakarua and the South Branch of the Waianakarua

The North and South Branches of the Waianakarua River show the same trends in flow regime at times of low flow when gauged flows for the same day are plotted against each other (Figure A. 3). From the gauging data it is clear that the South Branch yields significantly less water during low flows. This is likely due to the lower rainfall and the influence of irrigation takes in the South Branch.

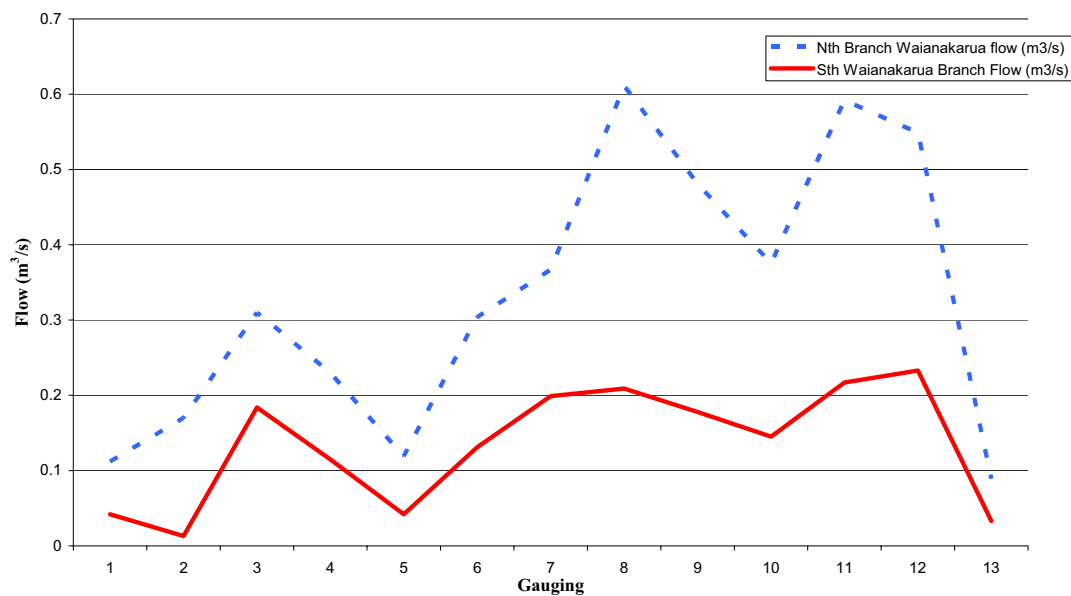


Figure A.3 Gauged flows for the North and South Branches of the Waianakarua River

Regression analysis was carried out on these data resulting in an R^2 of 0.8352 (Figure A. 4). This suggests a good linear relationship between flows in the North and South Branches of the Waianakarua River (Figure A. 4).

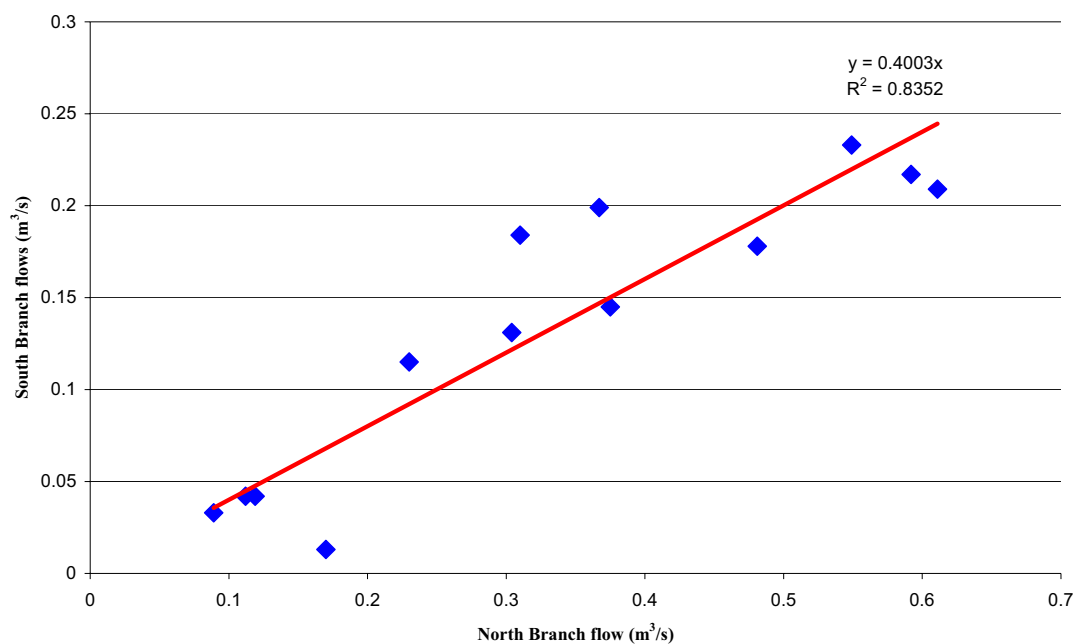


Figure A.4 Regression analysis comparing flows in the North and South Branches of the Waianakarua River

MALF for the North Branch has been determined earlier (Appendix 1) and the relationship between flows in the North Branch and the South Branch of the Waianakarua River is relatively strong (R^2 of 0.8352). Therefore, using the regression equation from Figure A. 4, $Y = 0.4003X$ (where Y = South Branch flows and X = North Branch flows) it can be seen that the corresponding MALF value for the South Branch of the Waianakarua River is $0.077 \text{ m}^3/\text{s}$ ($Y = 0.4003 \times 192$).

Appendix 3 - North and South Branch Flow relationship with the Browns Pump site

When gauged flows from the North and South Branches of the Waianakarua River are added and plotted against gauged flows at Browns Pump (bottom of the catchment) there is a distinct relationship (Figure A. 5).

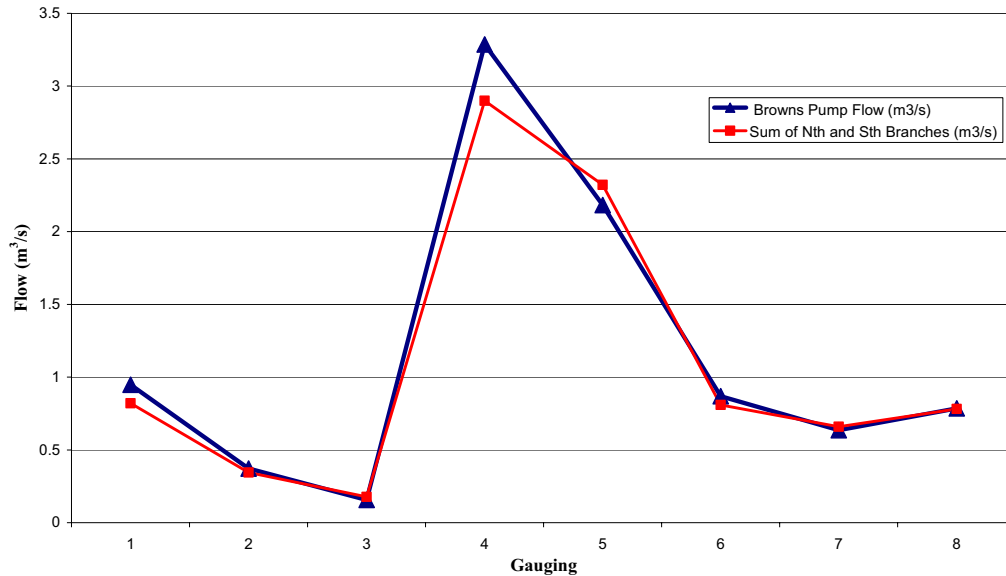


Figure A. 5 Combined gauged flows of the North and South Branches of the Waianakarua River compared to gauged flows at Browns Pump

Regression analysis was carried out on these data resulting in an R^2 of 0.9828 (Figure A. 6). This suggests a strong relationship between the sum of flows in the North Branch and South Branch of the Waianakarua and the flows gauged at Browns Pump (Figure A. 6).

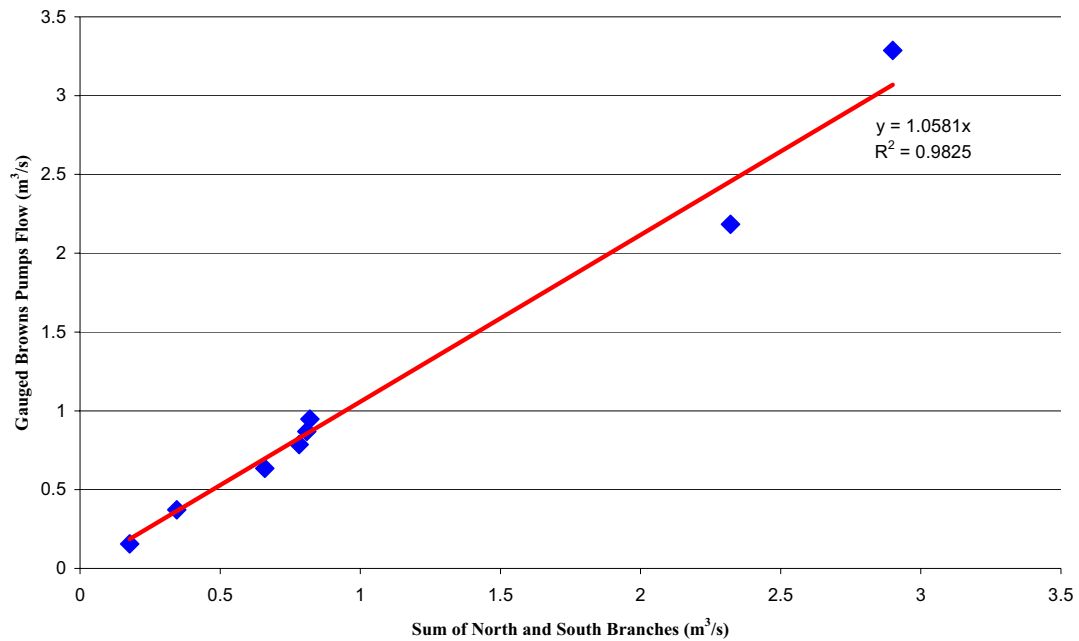


Figure A. 6 Regression analysis comparing the sum of flows in the North and South Branches of the Waianakarua River versus gauged flows at Browns Pump

The relationship between the North Branch and South Branch flows summed and the gauged flow at Browns Pump is very strong (R^2 of 0.9825). Therefore using the regression equation from Figure A. 6, $Y = 1.0581X$ (where Y = North Branch and South Branch flows summed and X = flows at Browns Pump) it can be seen that the corresponding MALF value for Browns Pump site on the Waianakarua River is 0.286 m³/s ($Y = 1.0581, x = 269$).

Appendix 4 - Mean annual 7-day low flow based on catchment area and rainfall

Catchment area and rainfall relationships are often used to determine 7-day MALF values. Table A: 1, Table A: 2 and Table A: 3 are the MALF values calculated using the available rainfall and catchment data for the Waianakarua catchment. Table A: 1, Table A: 2 and Table A: 3- 8 also provide some justification as to why certain values were chosen.

Table A: 1 7-day MALF value for the Waianakarua River South Branch at the Gravel pit gauging site

Location	J42: 366-467
Site Description	South Branch at gravel pit site
Basin Area (km ²)	107
Precipitation (m/yr.)	0.731 (from rainfall contour maps 1:250,000)
SMALF Q _{7,m} (l/s/km ²):	
Pearson's Contours	0.5 – 1.0 (NIWA's Package)
Pearson's Regression	0.5 – 2.0 (NIWA's Package)
Otago's Regression	$1.58 P^{3.618} = 0.51$
Actual Observations	
1977 observations	2.82 (3 gaugings in January)
1999 observations	0.48 (2 gaugings in March and 1 in April)
2001 observations	0.73 (1 gaugings in February and 1 in April)
Kauru River at Ewings	1.50 (3yrs record) (MALF of 187 l/s)
Clifton Falls	1.85 (MALF 530 l/s)
Nominated SMALF	0.75
Justification	Catchment area, land use and rainfall is almost exactly the same as the north branch of the Waianakarua. Gauging suggest the Sth Branch yields significantly less water than the Nth Branch. The Gravel pit site SMALF values above are heavily affected by irrigation takes upstream during the low flow period, thus the nominated SMALF is much lower than that of the Nth Branch.
MALF Q _{7,m} (l/s)	80 l/s

Table A: 2 7-day MALF value for the Waianakarua North Branch at Camp Iona gauging site

Location	J42: 337- 508
Site Description	North Branch at Camp Iona
Basin Area (km ²)	116
Precipitation (m/yr.)	0.796 (from rainfall contour maps 1:250,000)
SMALF Q _{7,m} (l/s/km ²):	
Pearson's Contours	0.5 – 1.0 (NIWA's Package)
Pearson's Regression	0.5 – 2.0 (NIWA's Package)
Otago's Regression	$1.58 P^{3.618} = 0.69$
Actual Observations	
1999 observations	1.62 (3 gaugings in March)
2001 observations	1.67 (1 gaugings in February and 1 in March)
2003 observations	1.03 (1 gaugings in February)
2004 observations	1.38 (2 gaugings in January)
Kauru River at Ewings	1.50 (3yrs record) (MALF of 187 l/s)
Clifton Falls	1.85 (MALF 530 l/s)
Nominated SMALF	1.7
Justification	The average SMALF over the low flow period from 1999-2004, which covered two significant droughts, is 1.43. Thus the nominated SMALF is slightly higher to take into account the extreme low flows. Kakanui at Clifton Falls nearby has a SMALF value of 1.85. The SMALF estimates also fall within the NIWA estimates.
MALF Q _{7,m} (l/s)	197 l/s

Table A: 3 7-day MALF value for the Waianakarua River at Browns Pump gauging site

Location	J42:403-484
Site Description	Waianakarua at Browns Pump
Basin Area (km ²)	260
Precipitation (m/yr.)	0.736 (from rainfall contour maps 1:250,000)
SMALF Q _{7,m} (l/s/km ²):	
Pearson's Contours	0.5 – 1.0 (NIWA's Package)
Pearson's Regression	0.5 – 2.0 (NIWA's Package)
Otago's Regression	1.58 P ^{3.618} = 0.51
Actual Observations	
1978 observations	1.47 (8 gaugings Jan – Mar)
1979 observations	1.87 (5 gaugings Jan – Feb)
1985 observations	0.76 (8 gaugings Feb-Apr)
2001 observations	0.99 (3 gaugings Jan – Mar)
2004 observations	1.22 (3 gaugings January)
Kauru River at Ewings	1.51 (3yrs record) (MALF of 187 l/s)
Clifton Falls	1.85 (MALF 530 l/s)
Nominated SMALF	1.2
Justification	The average SMALF over the low flow period is 1.26. Thus the nominated SMALF is slightly conservative. All observed SMALF values have the potential to be slightly lower than would be expected under natural conditions due to irrigation takes. The SMALF estimates also fall within the NIWA estimates.
MALF Q _{7,m} (l/s)	312 l/s

