# Management Flows for Aquatic Ecosystems in Kaihiku Stream

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# Overview

Kaihiku Stream is a tributary of the lower Clutha River that drains a small agricultural catchment near Balclutha.

### *Why was this study done?*

This report is intended to inform flow management in the Kaihiku Stream catchment. It considers the following:

- The hydrology and existing water allocation in Kaihiku Stream
- The aquatic values of Kaihiku Stream
- The flows that will maintain aquatic ecological values in Kaihiku Stream

### *What did this study find?*

- Hydrological analysis conducted as part of this study estimated the 7-day mean annual low flow (MALF) for the Kaihiku Stream at the Clutha confluence at 62 l/s.
- Kaihiku Stream provides spawning habitat for trout and provides a resident trout fishery. It also provides habitat for lamprey, longfin eel, lower Clutha galaxias and upland bully.
- Lamprey are classified as "nationally vulnerable", longfin eel and lower Clutha galaxias are classified as "declining", while upland bully is classified as "not threatened".
- There is a single permitted water take in the lower Kaihiku Stream (maximum instantaneous rate = 37.3 l/s), meaning that the Kaihiku catchment is over-allocated based on the default allocation limited 50% of the 7-d MALF (31 l/s) in Policy 6.4.2.
- Instream habitat modelling was conducted to determine how changes in flow affect habitat for the fish species present in Kaihiku Stream. The flows recommended to maintain fish and food producing (invertebrate) habitat in Kaihiku Stream are summarised below:

| Section | 7-d MALF (l/s) | Recommended flow (l/s) | Reason |
|---|---|---|---|
| Upper (upstream of gorge) | 15 | 12 | Food producing, brown trout |
| Lower (Clifton Road) | 57 | 44 | Food producing, brown trout |

- The results of this investigation will be used to inform assessments of residual flows on future applications to take water from the Kaihiku Stream catchment.

# Technical summary

Kaihiku Stream is a small stream draining an agricultural catchment near Balclutha. The headwaters of the catchment are in the Kaihiku Range where the catchment is dominated by exotic forestry and agriculture, while most of the remaining catchment is intensively farmed. There is currently a single consented water take in the Kaihiku catchment, but water demand in south Otago has risen in recent times and the Kaihiku catchment is unlikely to be an exception.

The objectives of this report were to:

- Present information on Kaihiku Stream that is relevant to determining the flows required to sustain the river's aquatic habitat, including freshwater values, flow statistics, the distribution of water resources within the catchment and the results of in-stream habitat modelling.
- Assess the aquatic values of Kaihiku Stream
- To present and interpret the results of these analyses to recommend flows required to maintain aquatic ecological values.

Kaihiku Stream provides spawning habitat for trout and provides an resident trout fishery and may contribute to recruitment to the lower Clutha River. It also provides habitat for lamprey, longfin eel, lower Clutha galaxias and upland bully. Lamprey are classified as "nationally vulnerable", while longfin eel and lower Clutha galaxias are classified as "declining", and upland bully is classified as "not threatened" (Goodman *et al.* 2014).

There is a single permitted water take in the lower Kaihiku Stream (maximum instantaneous rate = 37.3 l/s), meaning that the Kaihiku catchment is over-allocated based on the default allocation limited 50% of the 7-d MALF (31 l/s) in Policy 6.4.2.

The flows recommended to maintain fish and food producing (invertebrate) habitat in Kaihiku Stream are summarised below:

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# 1. Introduction

The Regional Plan: Water for Otago (2013; 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 of achieving this objective, the Water Plan provides for the setting of minimum flows in Otago's rivers[2].

Kaihiku Stream is a small stream draining an agricultural catchment near Balclutha. The headwaters of the catchment are in the Kaihiku Range where the catchment is dominated by exotic forestry and agriculture, while most of the remaining catchment is intensively farmed. There is currently a single consented water take in the Kaihiku catchment, but water demand in south Otago has risen in recent times and the Kaihiku catchment is unlikely to be an exception.

Schedule 1A of the Water Plan[3] identifies the ecosystem values that must be sustained in Otago catchments. In Kaihiku Stream, these include spawning and juvenile rearing and adult habitat for trout and significant habitat for eels. Further to these values, Kaihiku Stream also supports populations of the lower Clutha galaxias, an undescribed species of non-migratory galaxias.

## 1.1. Objectives

This report presents information on Kaihiku Stream that is relevant to determining the flows required to sustain the river's aquatic habitat. This includes freshwater values, flow statistics and the distribution of water resources within the catchment in addition to the results of in-stream habitat modelling.

[1] [1] Objective 6.3.1 of the Regional Plan: Water for Otago (2013), p. 6–7
[2] Policies 6.4.1 – 6.4.11 of the Regional Plan: Water for Otago (2013), pp 6–13 to pp 6–26
[3] Schedule 1A of the Regional Plan: Water for Otago (2013), p. 20–6

# 2. The Kaihiku catchment

Kaihiku Stream drains a catchment of 170 $km^2$, approximately 6 km from Balclutha, before entering the Clutha River 10 km upstream of the Balclutha Bridge (Figure 2.1). The highest point in the catchment is Kaihiku (676 m), although much of the catchment is at elevations of less than 100 m.

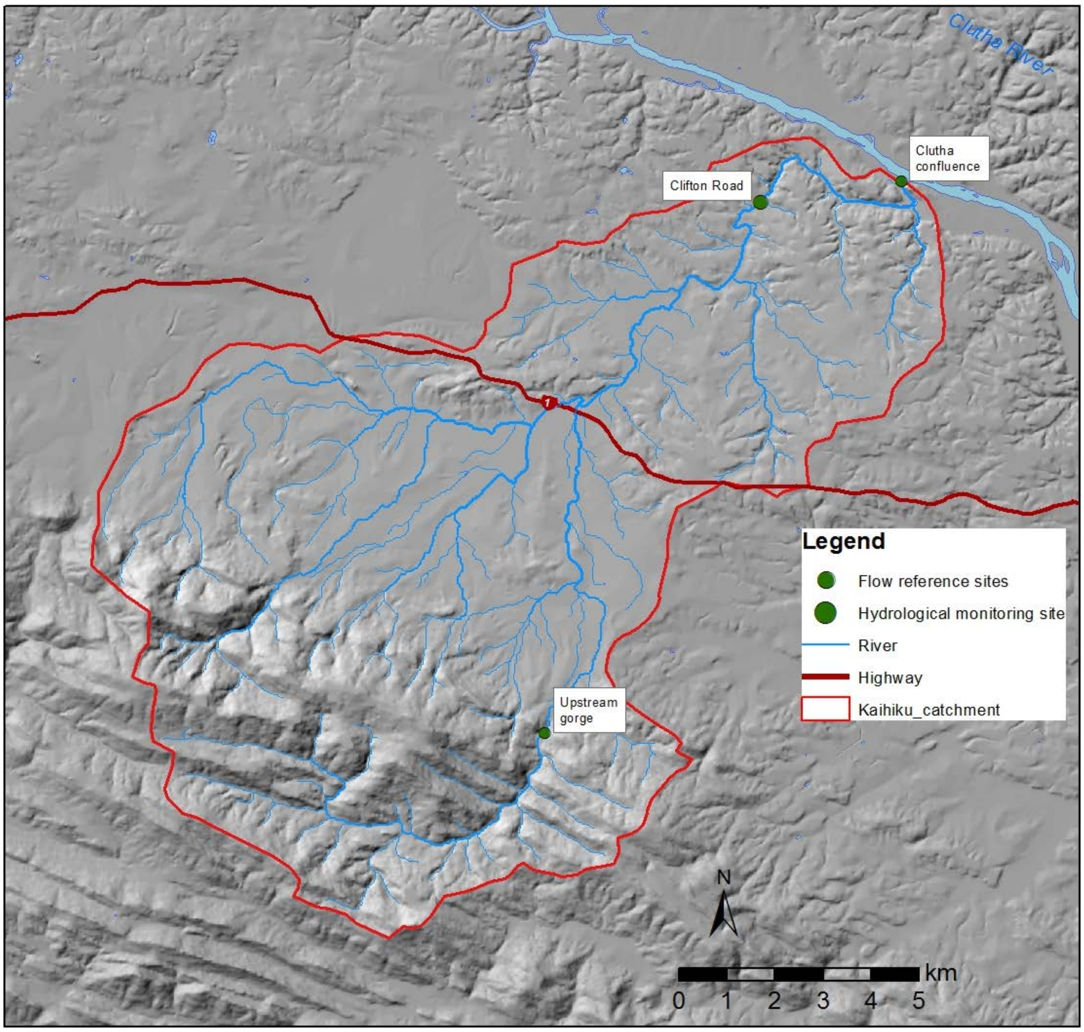


**Figure 2.1** **The Kaihiku Stream catchment showing the location of the hydrological monitoring site (Clifton Road) and flow reference sites.**

## 2.1. Vegetation & land use

The dominant land-use in the Kaihiku catchment is intensive agriculture, although there are also substantial portions in extensive agriculture, cropping and exotic forestry (Table 2.1).

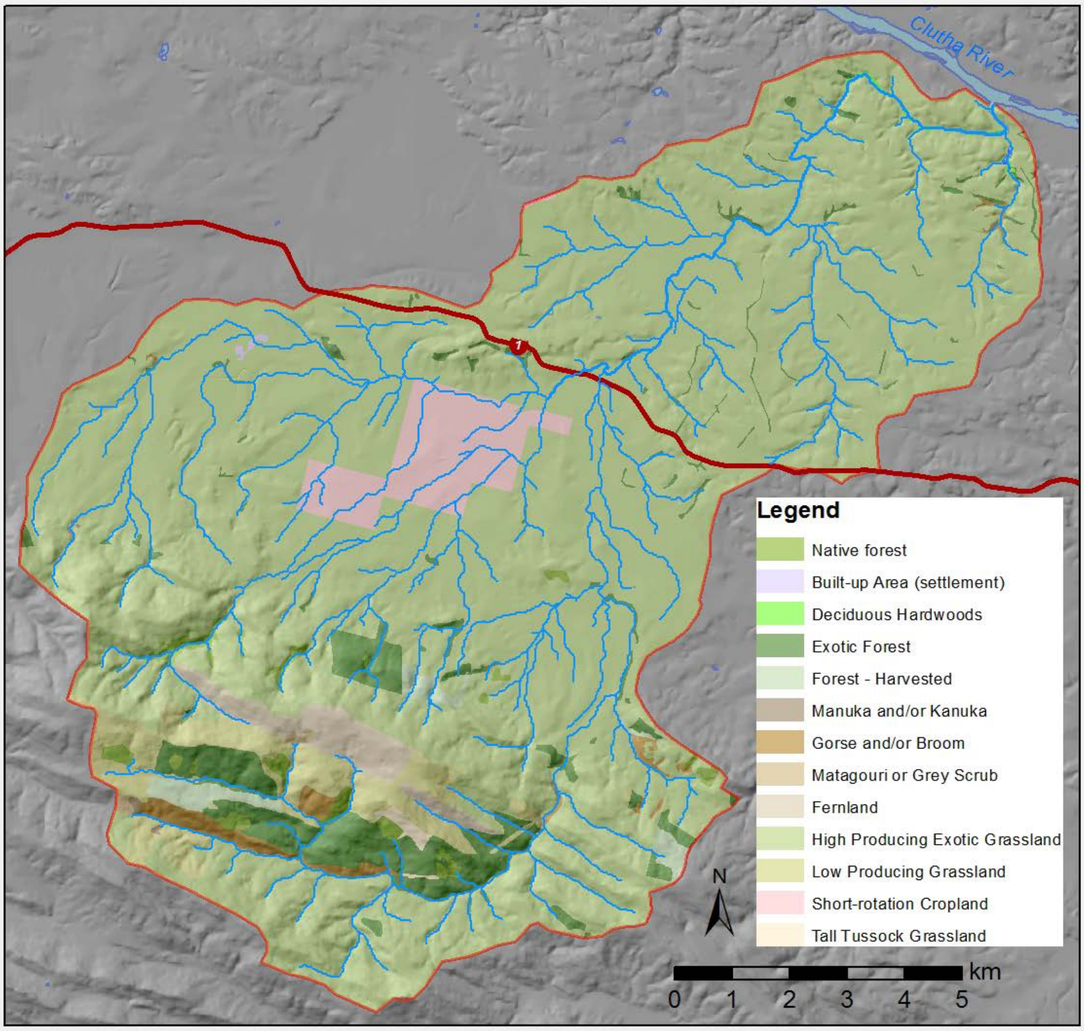


**Figure 2.2** **Landcover in the Kaihiku Stream catchment based on Land Cover Database version 4.0 (LCDB v.4).**

**Table 2.1** **Land cover types in the Kaihiku Stream catchment based on LCDB v.4.**

| Landuse type | Area (ha) | % |
|---|---|---|
| High Producing Exotic Grassland | 13,029 | 77% |
| Low Producing Grassland | 624 | 4% |
| Short-rotation Cropland | 563 | 3% |
| Indigenous Forest | 176 | 1% |
| Exotic Forest | 1026 | 6% |
| Other | 1551 | 9% |

## 2.2. Rainfall patterns in the Kaihiku catchment

The upper reaches of Kaihiku Stream receives the greatest amount of rainfall in the Kaihiku catchment (>1150 mm). The lower parts of the catchment receive less than 750 mm annually (Figure 2.3).

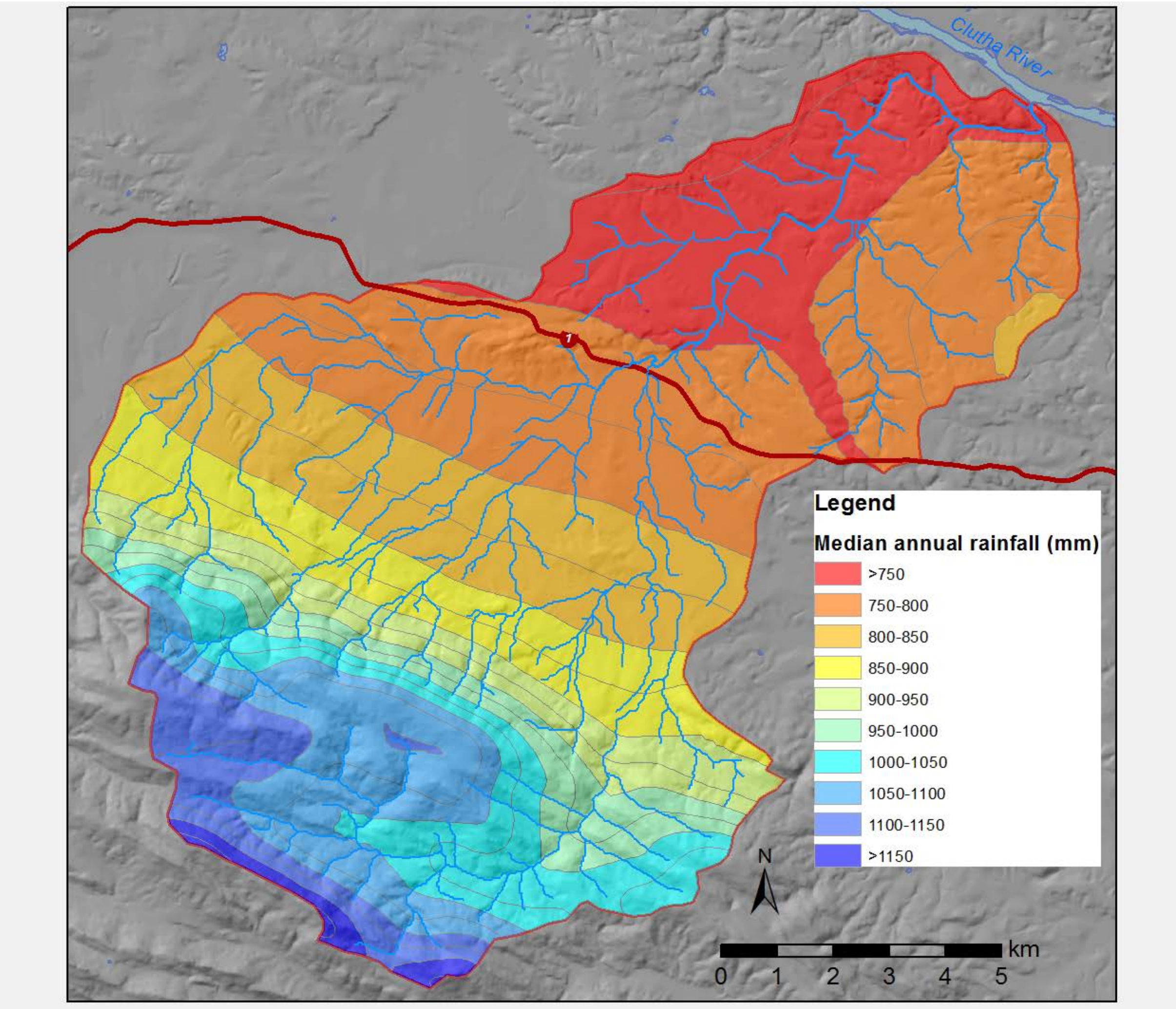


**Figure 2.3 Median annual rainfall in the Kaihiku Stream catchment (from Grow Otago).**

# 3. River hydrology

## 3.1. Comparison of the Kaihiku Stream with the Waipahi catchment

Flows in the Kaihiku Stream were measured at a temporary flow recorder (Figure 2.1) between 9 October 2013 and 9 September 2014. The purpose of this temporary flow site was to establish a flow record for comparison with another nearby permanent flow site to estimate flow statistics for the catchment. The flow site chosen for this comparison was the Waipahi River at Waipahi. The upstream catchment area from Waipahi at Waipahi is about double size of that from Kaihiku Stream at Clifton Road (Table 3.1, Figure 3.1).

**Table 3.1 Comparison between the upstream catchments from Kaihiku Stream at Clifton Road and Waipahi at Waipahi**

| | Kaihiku Stream at Clifton Road | Waipahi at Waipahi |
|---|---|---|
| Catchment area ($km^2$) | 146 | 300 |
| Elevation (m) | 38 - 660 | 118 - 617 |
| Rainfall (mm) | 700 - 1200 | 825 - 1300 |
| Records | 9 Oct 2013 – 9 Sep 2014 | 4 Jul 1996 - present |

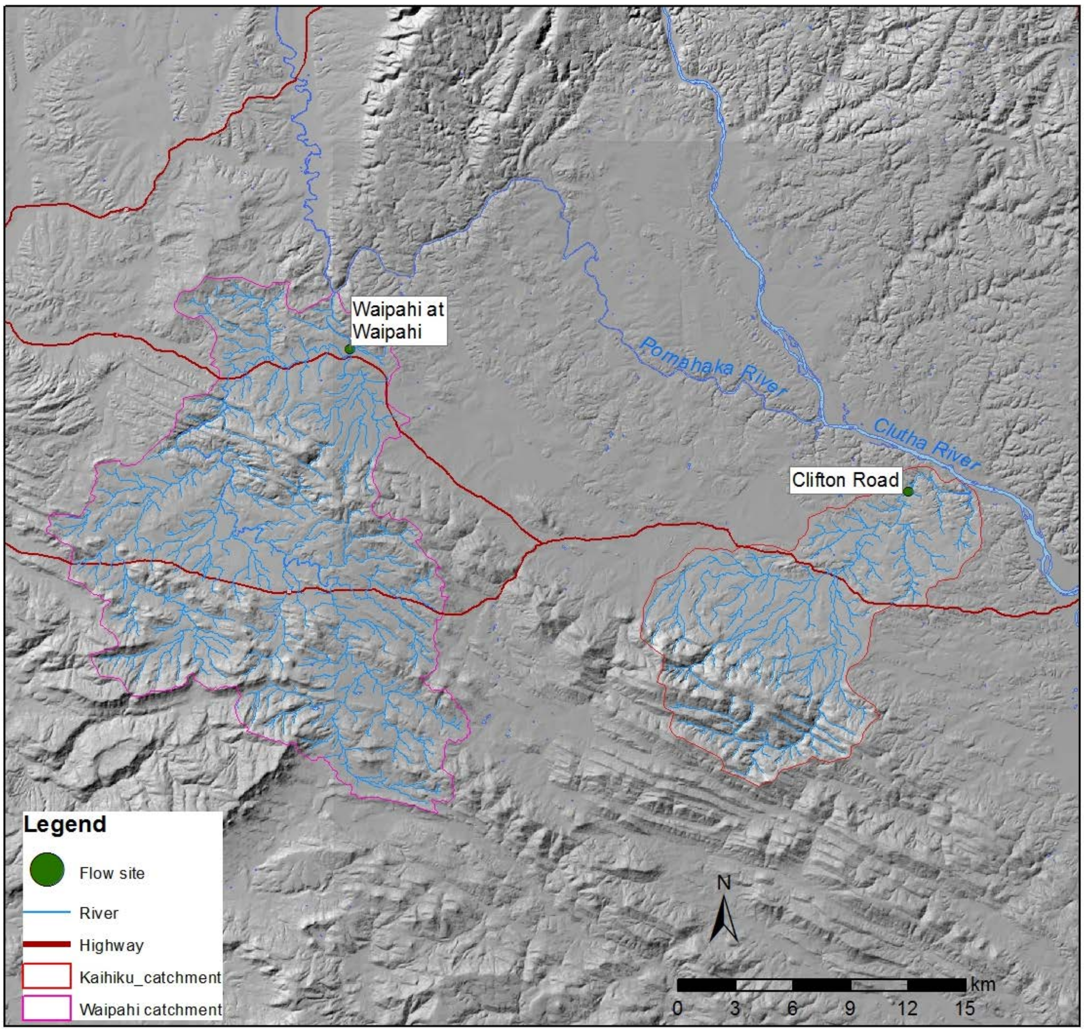


**Figure 3.1 Location of the Kaihiku and Waipahi catchments.**

There was a relatively strong relationship between flows in the Waipahi River with those in Kaihiku Stream, with different relationship between flows at the two sites above and below 5,000 l/s in the Waipahi River (Figure 3.2). The relationship between flows at these two flow sites at low flows (i.e. when flows in the Waipahi < 5,000 l/s) was best described by the power-function:

$$Q_{Kaihiku} = 0.1084*Q_{Waipahi}^{1.5495}$$

A linear function under-predicted values at very low flows. The fit of the various functions considered were also tested against low-flow gaugings available to determine which best fitted the lower end of the flow range.

At high flows (i.e. when flows in the Waipahi > 5,000 l/s) the relationship was best described by the exponential-function:

$$Q_{Kaihiku} = 0.9461*e^{0.072*QWaipahi}$$

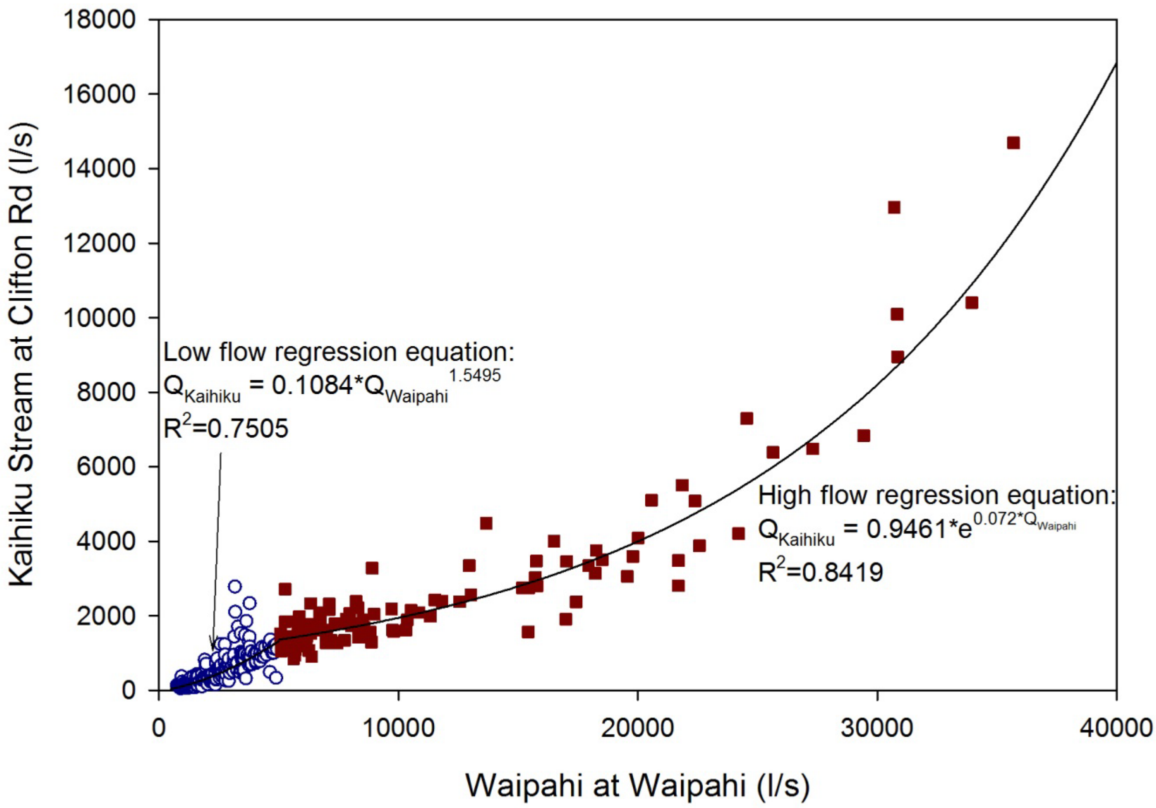


**Figure 3.2** **Relationship between flows in the Waipahi River at Waipahi and flows in Kaihiku Stream at Clifton Road between 9 October 2013 and 9 September 2014**

## 3.2. Estimated flow statistics for Kaihiku Stream

Flow statistics for Kaihiku Stream were estimated by generating a synthetic flow data set based on the relationships presented in Section 3.1. These flow statistics are presented in Table 3.2.

**Table 3.2 Flow statistics for various sites in Kaihiku Stream and the Waipahi River at Waipahi. Flow statistics for Kaihiku Stream were estimated based on the relationships presented in Section 3.1**

| Site | Mean flow | Median flow | 7-day MALF (l/s) | | Catchment area | Catchment yield at MALF |
|---|---|---|---|---|---|---|
| | (l/s) | (l/s) | Hydro year (Jul-Jun) | Irrigation season (Oct-Apr) | (ha) | (l/s/ha) |
| Kaihiku Stream at Clifton Road | 2,173 | 572 | 49 | 57 | 14578 | 0.0039 |
| Kaihiku Stream at Clutha Confluence | 2,335 | 615 | 52 | 62 | 15839 | 0.0039 |
| Kaihiku Stream at upstream gorge | 559 | 147 | 13 | 15 | 3111 | 0.0048 |
| Waipahi River at Waipahi | 5,201 | 2.921 | 600 | 651 | 30040 | 0.0217 |

The estimated 7-day Mean Annual Low Flow (7dMALF) for the Kaihiku Stream at Clifton Road during the irrigation season is 57 l/s with a corresponding value of 62 l/s at the Clutha Confluence and 15 l/s in the upper reach used in the instream habitat modelling (Table 6.7).

# 4. Water allocation

There is a single permit to take water from the Kaihiku catchment, with a maximum consented instantaneous rate of take of 37.3 l/s (Figure 4.1). This consent is held by Landcorp Farming Ltd for the purpose of irrigation.

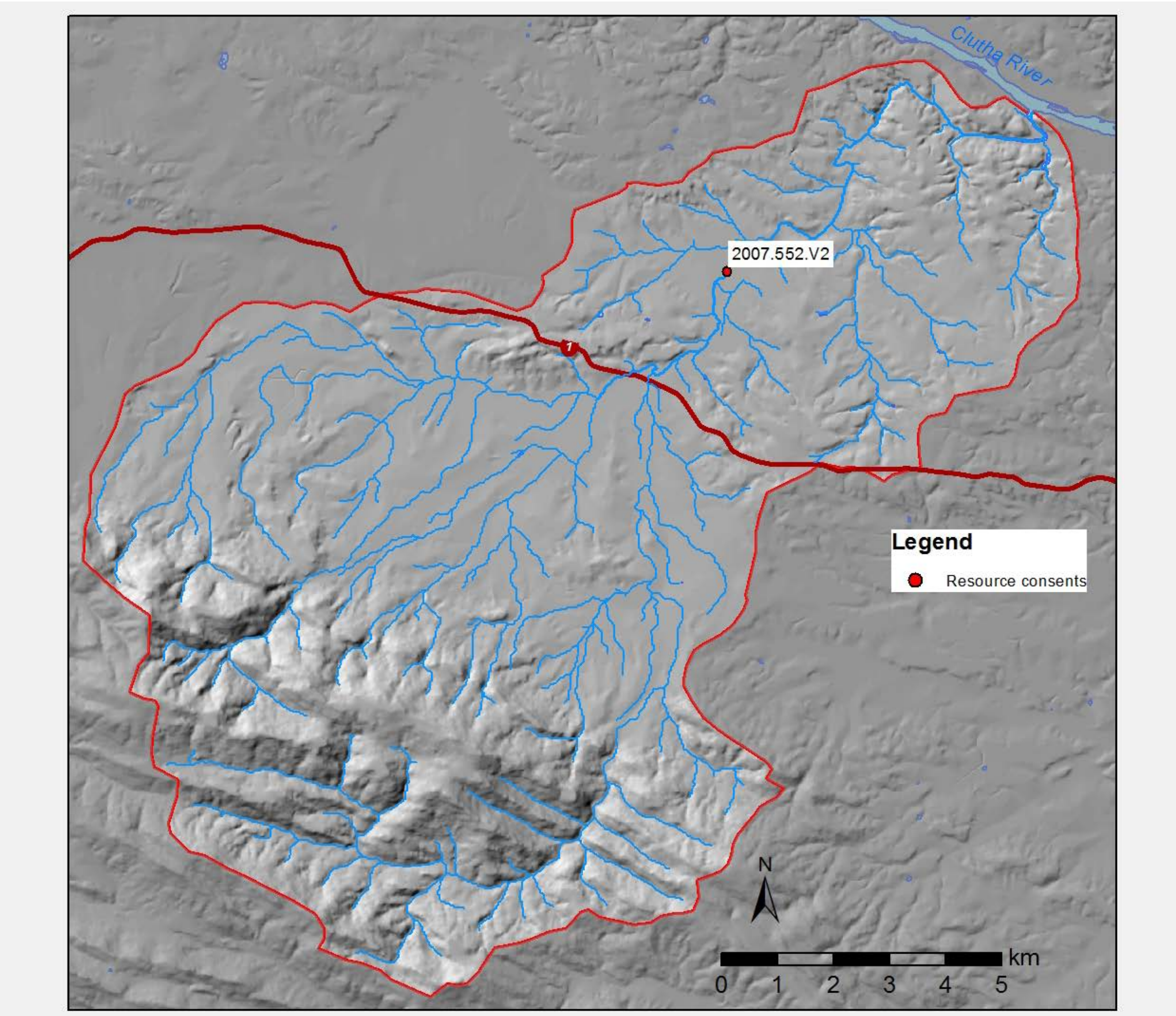


**Figure 4.1 Consented surface water takes in the Kaihiku catchment**

# 5. Values of the Kaihiku catchment

## 5.1. Freshwater fish

Five fish species in addition to koura (freshwater crayfish) have been recorded from the Kaihiku catchment: longfin and shortfin eels, lower Clutha galaxias, upland bully and brown trout (Figure 5.1). In addition to the species above, lamprey are present in the Kaihiku catchment, with Kaihiku Falls a traditional site for harvesting lamprey. Of these, longfin eels and koura are listed as "at risk, declining" in the most recent threat classification publications, while lamprey are listed as "Threatened, national vulnerable" and shortfin eel and upland bully are listed as "not threatened" (Goodman *et al.* 2014, Granger *et al.* 2014). The taxonomic status of the lower Clutha galaxias is uncertain, and they are currently listed as "data deficient" (Goodman *et al.* 2014).

Brown trout have been recorded throughout the Kaihiku catchment (Figure 5.1).

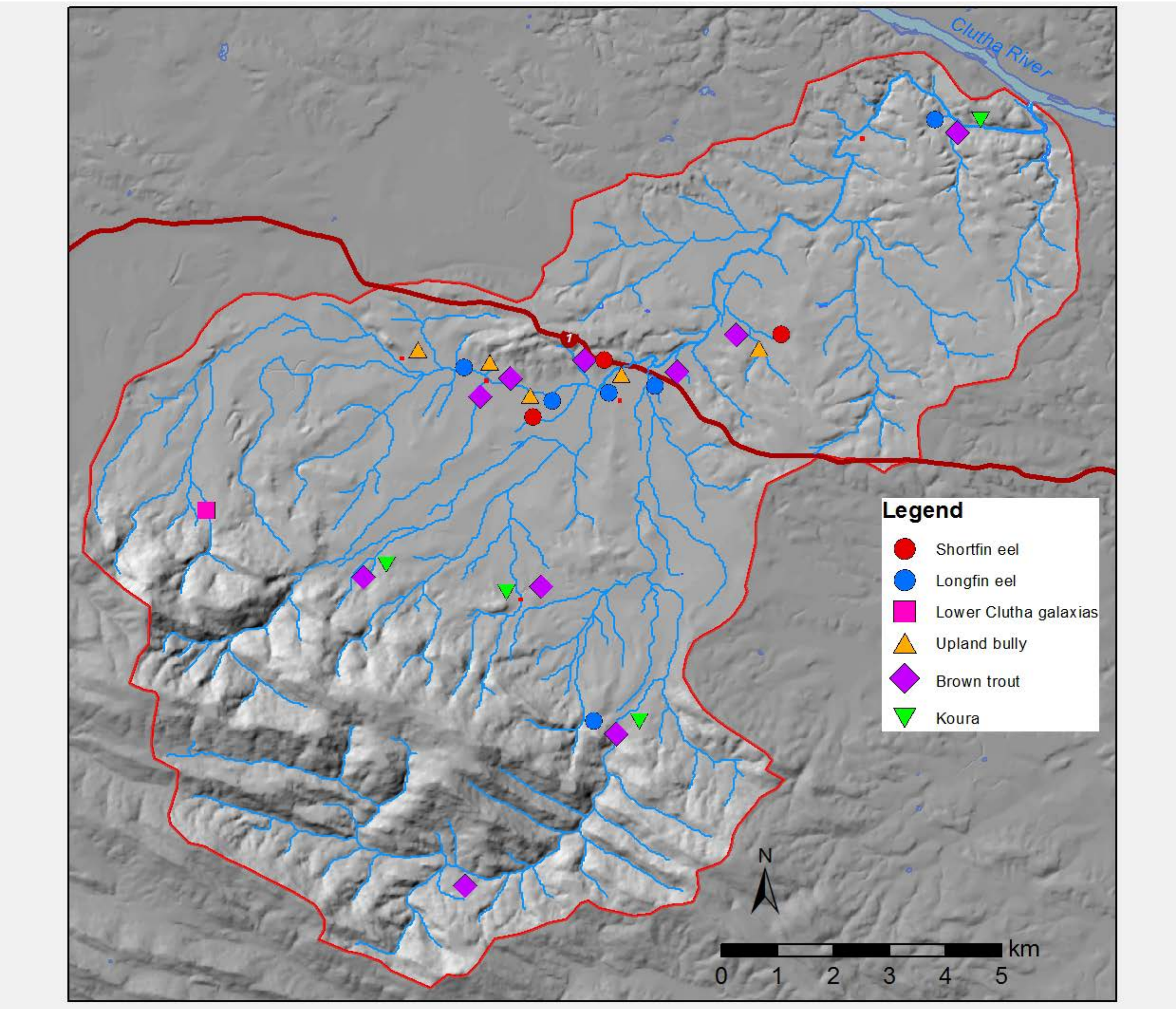


**Figure 5.1** **Distribution of fish species in the Kaihiku Stream catchment based on records in the New Zealand Freshwater Fish Database.**

## 5.2. Recreational values

While Kaihiku Stream supports a population of brown trout, it does not receive much use by anglers, with no angler use recorded in both the 2007/2008 or 2001/2002 seasons and only 20 angler days recorded for the 1994/1995 season (Unwin 2009). The Kaihiku Stream does support recreational game bird hunting, especially in the lower reaches.

# 6. Physical habitat

The Otago Regional Council contracted the Golder Associates to carry out a study to determine the flows required to maintain acceptable habitat for the fish species present in Kaihiku Stream. The in-stream habitat modelling conducted by Golder Associates (2009) forms the basis for the analyses presented in this section.

## 6.1. In-stream habitat modelling

In-stream habitat modelling is a means of considering the effects of changes in flow on in-stream values, such as river morphology, physical habitat, water temperature, water quality and sediment processes. As the habitat methods used are based on quantitative biological principles, they are considered more reliable and defensible than assessments made in other ways. The strength of in-stream habitat modelling lies in its ability to quantify the loss of habitat caused by changes in the natural flow regime, which helps to evaluate alternative flow proposals (Jowett, 2005).

Assessing suitable physical habitat for aquatic organisms that live in a river is the aim of in-stream habitat modelling. Habitat methods allow for a more focused flow assessment and can potentially result in improved allocation of resources (Jowett, 2005). However, it is essential to consider all factors that may affect the organism(s) of interest, such as food, shelter and living space, and to select appropriate habitat suitability curves, for an assessment to be credible. Habitat modelling does not take a number of other factors into consideration including biological interactions (such as predation) which can have a significant influence on the distribution of fish species.

## 6.2. Habitat preferences and suitability curves

In-stream habitat modelling 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 a given species, then they cannot exist (Jowett, 2005). However, if there is physical habitat available for that species, then it 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, 2005).

In-stream habitat is expressed weighted usable area (WUA), a measure of the total area of suitable habitat per metre of stream length. It is expressed as square metres per metre ($m^2/m$).

Habitat suitability curves were not available for lamprey, although flows sufficient to provide habitat for large longfin eels are expected to be sufficient to protect habitat for lamprey.

## 6.3. In-stream habitat modelling for Kaihiku Stream

In-stream habitat modelling was undertaken for two reaches of Kaihiku Stream (Figure 6.1) using the hydraulic and in-stream habitat model RHYHABSIM (Jowett 1989, Golder Associates 2009).

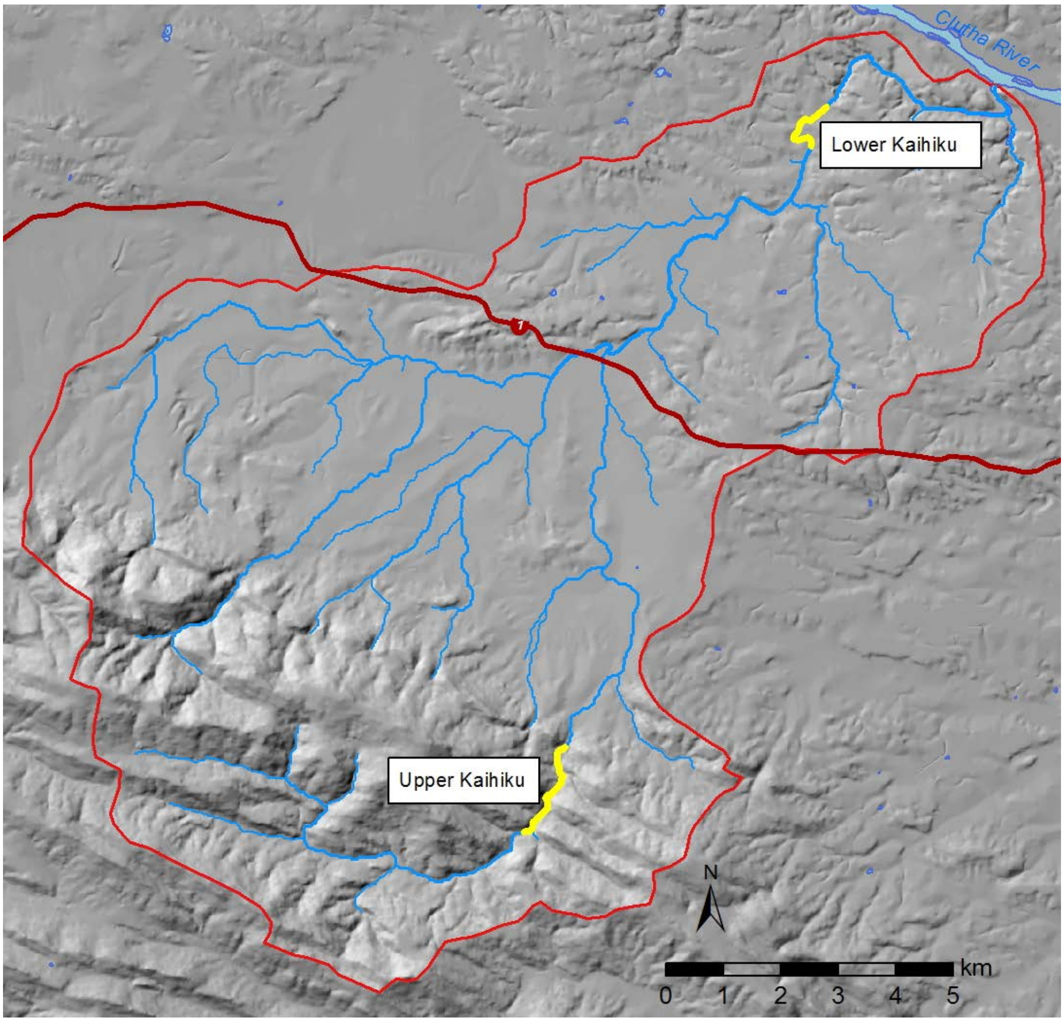


**Figure 6.1 Locations of the reaches of Kaihiku Stream where IFIM surveys were carried out in 2008**

The lower Kaihiku survey reach extended both upstream and downstream of Clifton Rd, with stream width averaging 6 m and a substrate dominated by bedrock in the lower reach and boulders and cobbles in the upper end of the section. Gravels, sands and finer sediments were uncommon throughout the lower study reach.

Kaihiku Falls, located at the downstream end of the survey reach, is expected to substantially limit fish migration from the Clutha, though it is likely that eels would be able to navigate this barrier without too much difficulty.

The upper survey reach flows through a gorge section as the steam cuts through the Kaihiku Range. This gorge section confines the stream flow to a narrow channel with no flood plain. Riffle run and pool habitat was present in equal measure with a mixed substrate including bedrock, cobbles and gravel.

## 6.4. Upper Kaihiku Stream

### 6.4.1. Physical habitat

The hydraulic component of instream habitat modelling predicts how water depth, channel width and water velocity change with changes in flow (Figure 6.2). In the upper Kaihiku Stream, the relationships between average channel width, depth and velocity with flow are relatively linear down to the MALF, below which the decline in width, depth and velocity with declining flow is steeper (Figure 6.2).

These results suggest that changes in the physical characteristics of the upper Kaihiku will be relatively consistent as flows drop between 200 l/s and 10 l/s.

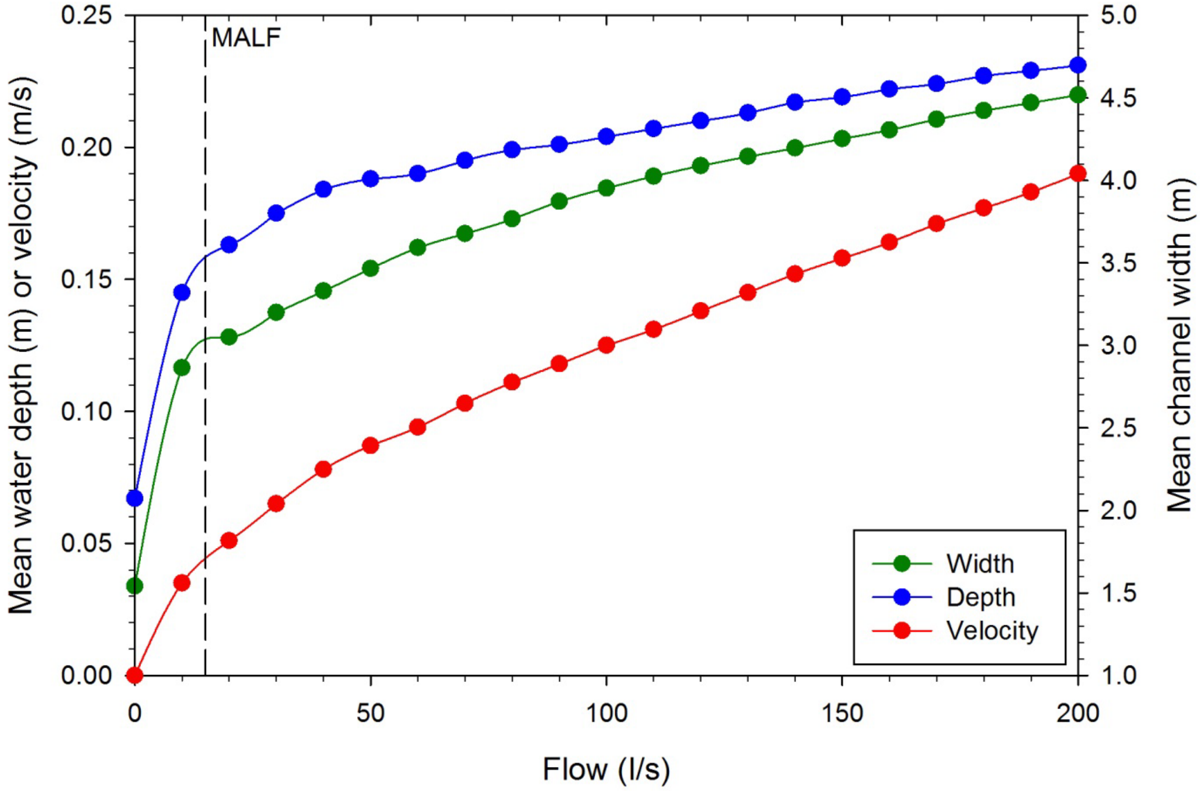


**Figure 6.2** **Changes in mean channel width, mean water depth and mean water velocity with changes in flow in the survey reach in the upper Kaihiku Stream**

### 6.4.2. Native fish habitat

Habitat for longfin eel increased with increasing flows with no clear optimum flow within the modelled range (up to 200 l/s, Figure 6.3, Table 6.1). Flows of approximately 130 l/s were predicted to provide the greatest amount of available habitat for lower Clutha galaxias[4], whilst habitat was predicted to decline rapidly below 30 l/s (Figure 6.3, Table 6.1). Habitat for upland bullies was relatively insensitive to flow, with optimal habitat at approximately 90 l/s, whilst habitat was predicted to decline rapidly below 10 l/s (Figure 6.3, Table 6.1).

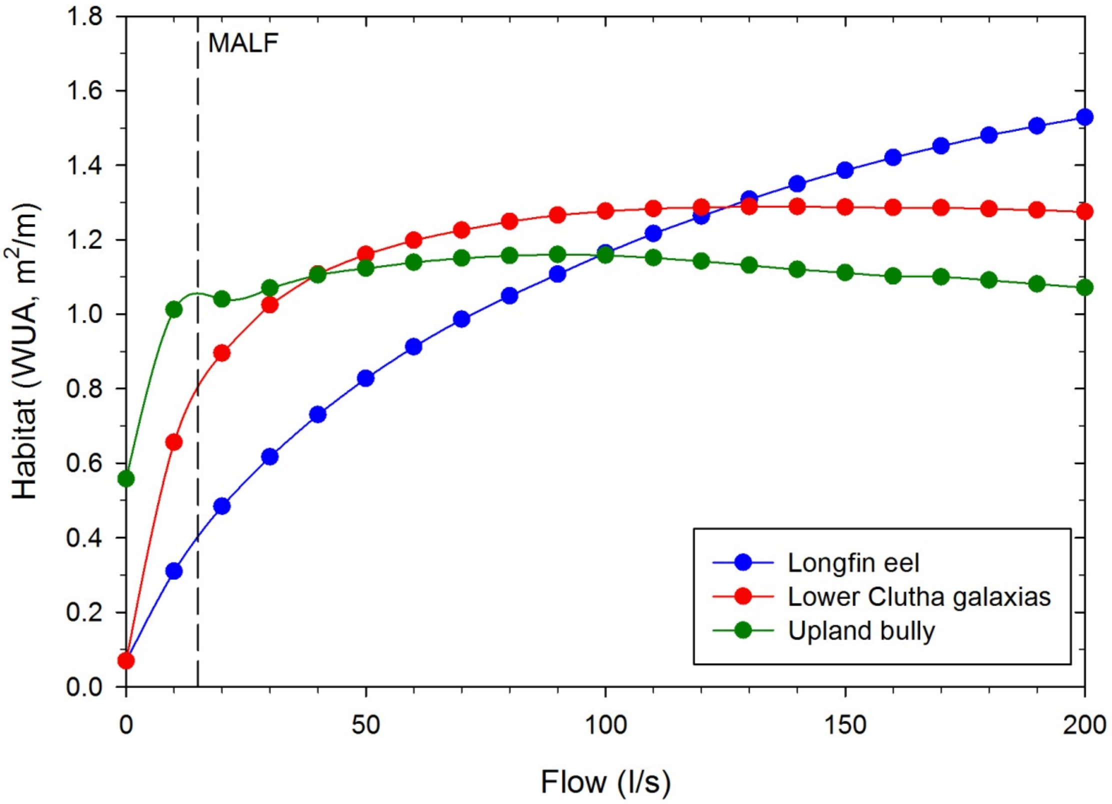


**Figure 6.3** **Variation in instream habitat for native fish with changes in flow in the survey reach in the upper Kaihiku Stream**

**Table 6.1** **Flow requirements for native fish habiat in the upper reaches of Kaihiku Stream based on instream habitat modelling by Golder Associates (2009)**

| Species/life stage | Optimum flow (l/s) | Flow below which habitat rapidly declines (l/s) | Flow at which % habitat retention occurs (l/s) | | | |
|---|---|---|---|---|---|---|
| | | | 60% | 70% | 80% | 90% |
| Longfin eel | >200 | - | 7 | 9 | 10 | 13 |
| Lower Clutha galaxias | 130 | 30 | 7 | 8 | 9 | 12 |
| Upland bully | 90 | <10 | 1 | 4 | 6 | 8 |

[4] Habitat suitability curves were not available for lower Clutha galaxias at the time of writing. Instead, habitat suitability curves for adult roundhead and flathead galaxias (Jowett & Richardson 2008) were used and the average of the habitat prediction of these two curves was used to estimate habitat for lower Clutha galaxias at each flow.

### 6.4.3. Brown trout habitat

Habitat for adult trout in the upper Kaihiku Stream was predicted to increase with increasing flows, with no clear changes in the nature of this relationship across the modelled flow range (0-200 l/s) (Figure 6.4). The relationship between flow and habitat for juvenile brown trout in the upper Kaihiku Stream was relatively consistent at the higher end of the modelled flow range (100-200 l/s), but decreased more rapidly with decreasing flows below 65 l/s (Figure 6.4, Table 6.2). Habitat modelling predicts that there will be no suitable brown trout spawning habitat at flows of less than 40 l/s (Figure 6.4). Given this, it is not possible to calculate habitat retention as a percentage of MALF, since there is predicted to be no suitable spawning habitat at MALF (Figure 6.4, Table 6.2).

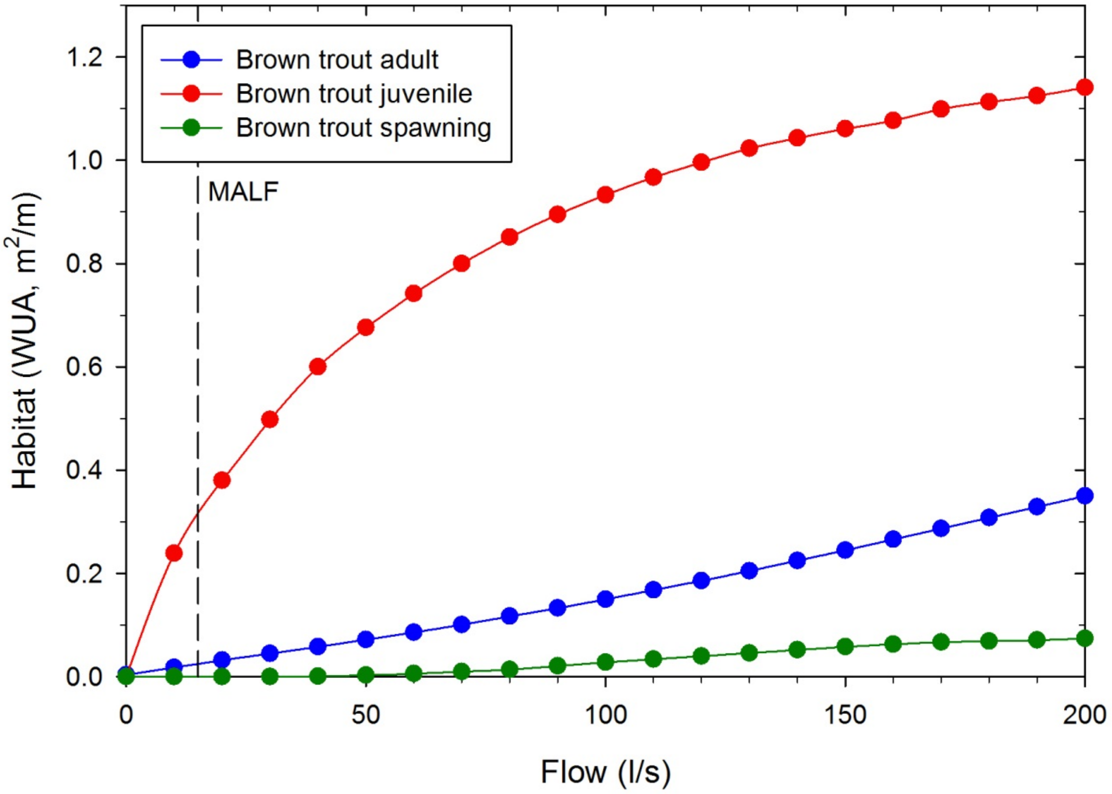


**Figure 6.4** **Variation in instream habitat for different life-stages of brown trout with changes in flow in the survey reach in the upper Kaihiku Stream**

**Table 6.2** **Flow requirements for trout habiat in the upper reaches of Kaihiku Stream based on instream habitat modelling by Golder Associates (2009)**

| Species/life stage | Optimum flow (l/s) | Flow below which habitat rapidly declines (l/s) | Flow at which % habitat retention occurs (l/s) | | | |
|---|---|---|---|---|---|---|
| | | | 60% | 70% | 80% | 90% |
| Brown trout adult | >200 | - | 8 | 10 | 11 | 13 |
| Brown trout juvenile | >200 | 65 | 8 | 9 | 11 | 13 |
| Brown trout spawning | >200 | - | - | - | - | - |

### 6.4.4. Food producing (invertebrate) habitat

Food producing habitat increased with increasing flows with no clear optimum flow within the modelled range (up to 200 l/s, Figure 6.5, Table 6.3).

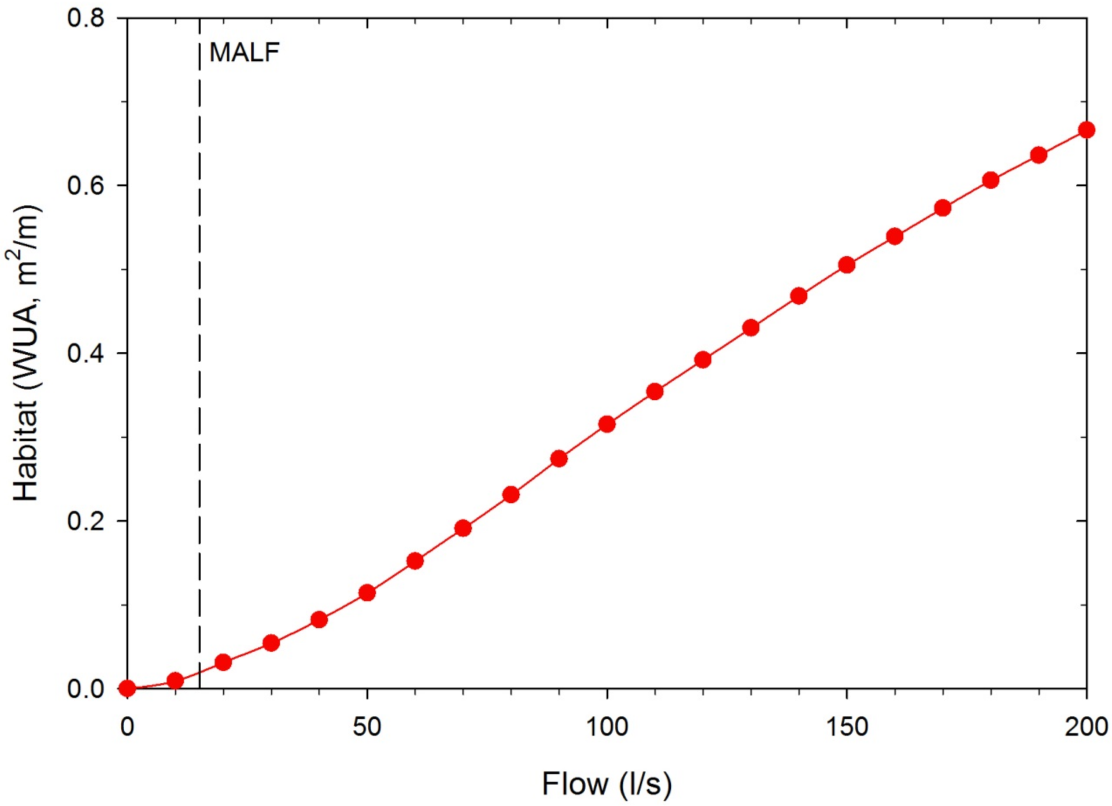


**Figure 6.5** **Variation in food producing (invertebrate) habitat with changes in flow in the survey reach in the upper Kaihiku Stream**

**Table 6.3** **Flow requirements for food producing (invertebrate) habitat in the upper reaches of Kaihiku Stream based on instream habitat modelling by Golder Associates (2009)**

| Species/life stage | Optimum flow (l/s) | Flow below which habitat rapidly declines (l/s) | Flow at which % habitat retention occurs (l/s) | | | |
|---|---|---|---|---|---|---|
| | | | 60% | 70% | 80% | 90% |
| Food producing | >200 | - | 11 | 12 | 13 | 14 |

## 6.5. Lower Kaihiku Stream

### 6.5.1. Physical habitat

The hydraulic component of instream habitat modelling predicts how water depth, channel width and water velocity change with changes in flow (Figure 6.6). In the lower Kaihiku Stream, the relationship between average channel width and flow is relatively linear down to 80 l/s, with the average width declining more quickly with flow below 80 l/s (Figure 6.6). Water depth is not predicted to change markedly across the modelled flow range (0-300 l/s) while water velocities increased linearly with increasing flow across the modelled flow range (Figure 6.6).

These results suggest that the physical characteristics of the lower Kaihiku Stream will change subtly between 80 l/s and 300 l/s, but that at flows below 80 l/s, the channel will become noticeably narrower and water velocities slower as flows drop, with little change in water depth.

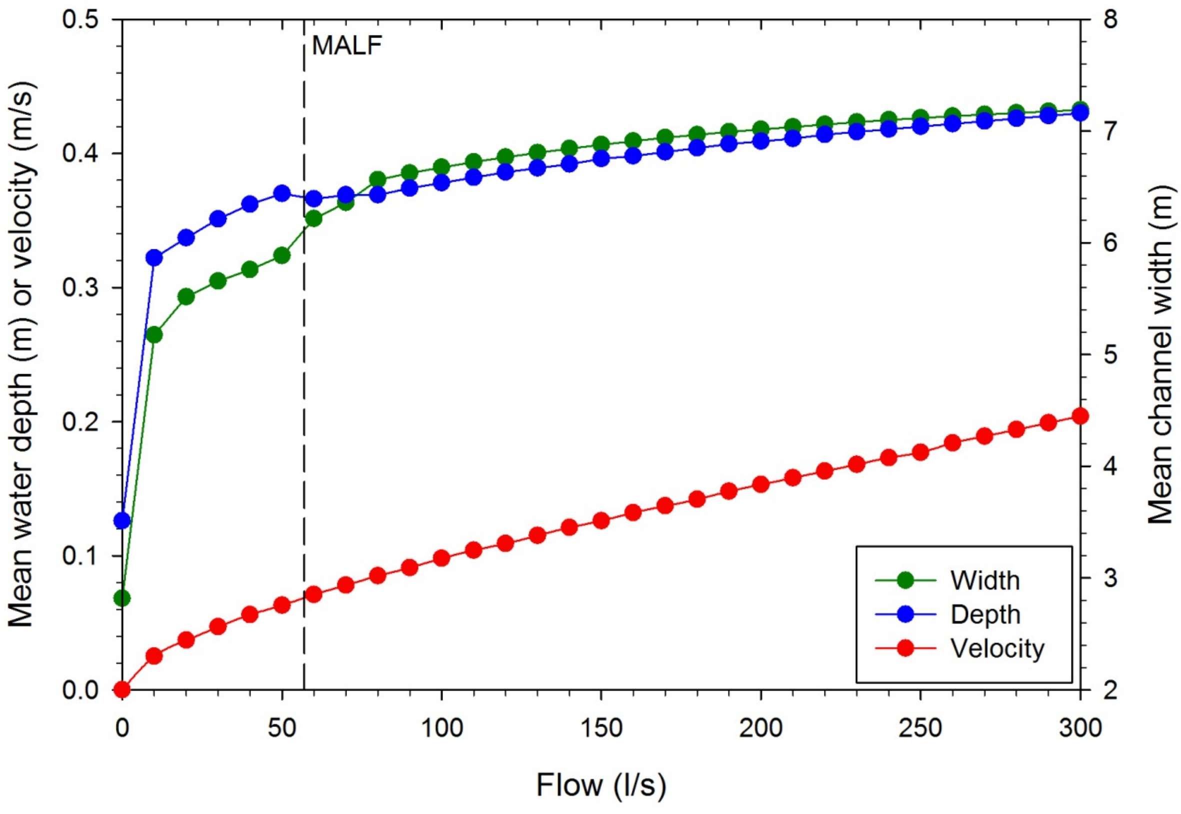


**Figure 6.6 Changes in mean channel width, mean water depth and mean water velocity with changes in flow in the survey reach in the lower Kaihiku Stream**

### 6.5.2. Native fish habitat

Habitat for longfin eels in the lower reaches of Kaihiku Stream is predicted to change relatively consistently with changes in flows across the modelled flow range (10-300 l/s), while habitat for upland bullies is expected to be relatively unaffected by changes in flow over the modelled range (Figure 6.7). However, habitat for lower Clutha galaxias is expected to decline as flow declines below about 100 l/s, with the rate of decline increasing below 40 l/s (Figure 6.7, Table 6.4).

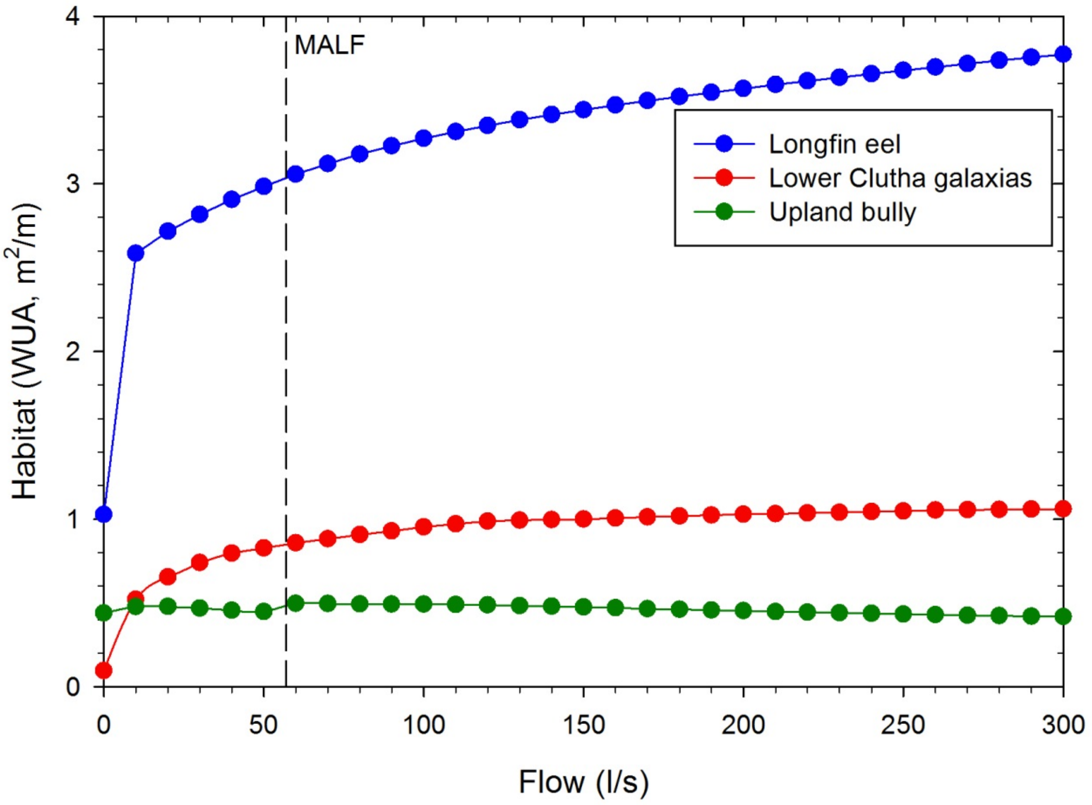


**Figure 6.7** **Variation in instream habitat for native fish with changes in flow in the survey reach in the lower Kaihiku Stream**

**Table 6.4** **Flow requirements for native fish habiat in the lower reaches of Kaihiku Stream based on instream habitat modelling by Golder Associates (2009)**

| Species/life stage | Optimum flow (l/s) | Flow below which habitat rapidly declines (l/s) | Flow at which % habitat retention occurs (l/s) | | | |
|---|---|---|---|---|---|---|
| | | | 60% | 70% | 80% | 90% |
| Longfin eel | >300 | 10 | 5 | 7 | 9 | 22 |
| Lower Clutha galaxias | >300 | 40 | 10 | 15 | 23 | 34 |
| Upland bully | - | - | <5 | <5 | <5 | <5 |

### 6.5.3. Brown trout habitat

Habitat for adult trout in the lower Kaihiku Stream was predicted to increase with increasing flows, with no clear changes in the nature of this relationship across much of the modelled flow range (10-200 l/s) (Figure 6.8). The relationship between flow and habitat for juvenile brown trout in the upper Kaihiku Stream was relatively consistent at the higher end of the modelled flow range (120-300 l/s), but decreased more rapidly with decreasing flows below 100 l/s (Figure 6.8, Table 6.5). Habitat modelling predicts that there will be no suitable brown trout spawning habitat at flows of less than 90 l/s (Figure 6.8). Given this, it is not possible to calculate habitat retention as a percentage of MALF, since there is predicted to be no suitable spawning habitat at MALF (Figure 6.8, Table 6.5).

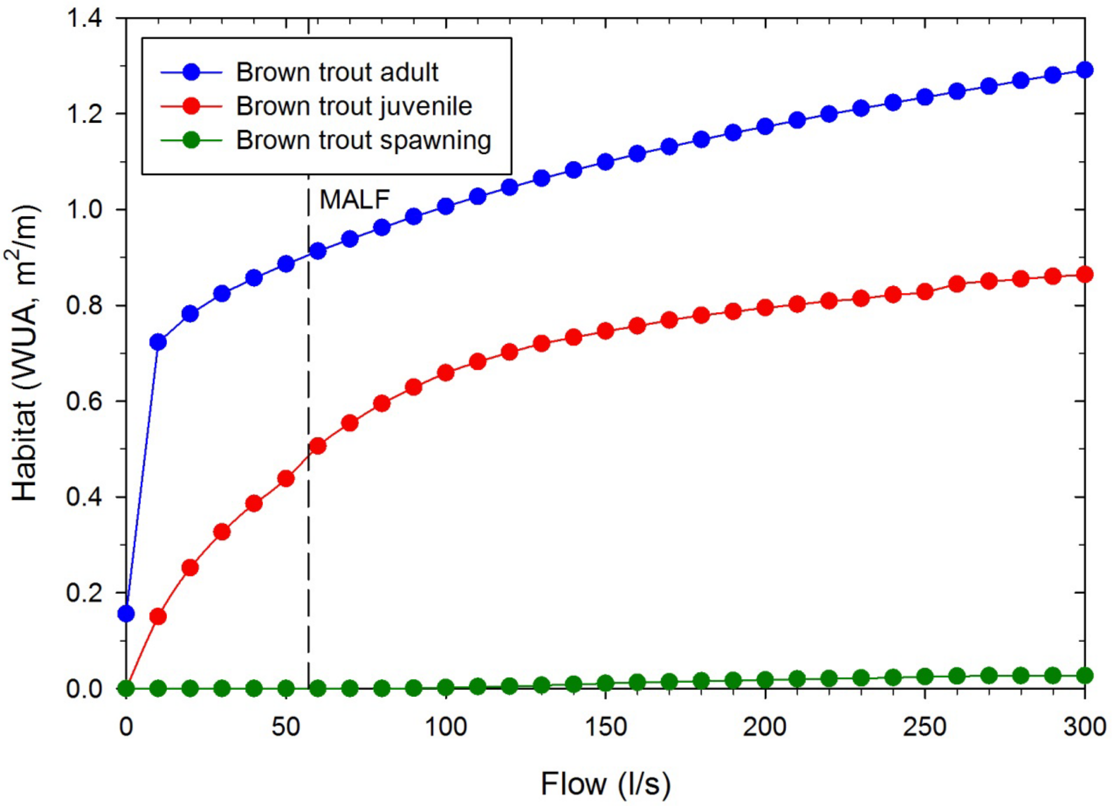


**Figure 6.8** **Variation in instream habitat for different life-stages of brown trout with changes in flow in the survey reach in the lower Kaihiku Stream**

**Table 6.5** **Flow requirements for trout habiat in the lower reaches of Kaihiku Stream based on instream habitat modelling by Golder Associates (2009)**

| Species/life stage | Optimum flow (l/s) | Flow below which habitat rapidly declines (l/s) | Flow at which % habitat retention occurs (l/s) 60% | 70% | 80% | 90% |
|---|---|---|---|---|---|---|
| Brown trout adult | >300 | - | 7 | 8 | 10 | 28 |
| Brown trout juvenile | >300 | 100 | 25 | 32 | 40 | 50 |
| Brown trout spawning | >300 | - | - | - | - | - |

### 6.5.4. Food producing (invertebrate) habitat

Food producing habitat increased with increasing flows with no clear optimum flow within the modelled range (up to 300 l/s, Figure 6.9, Table 6.6 ).

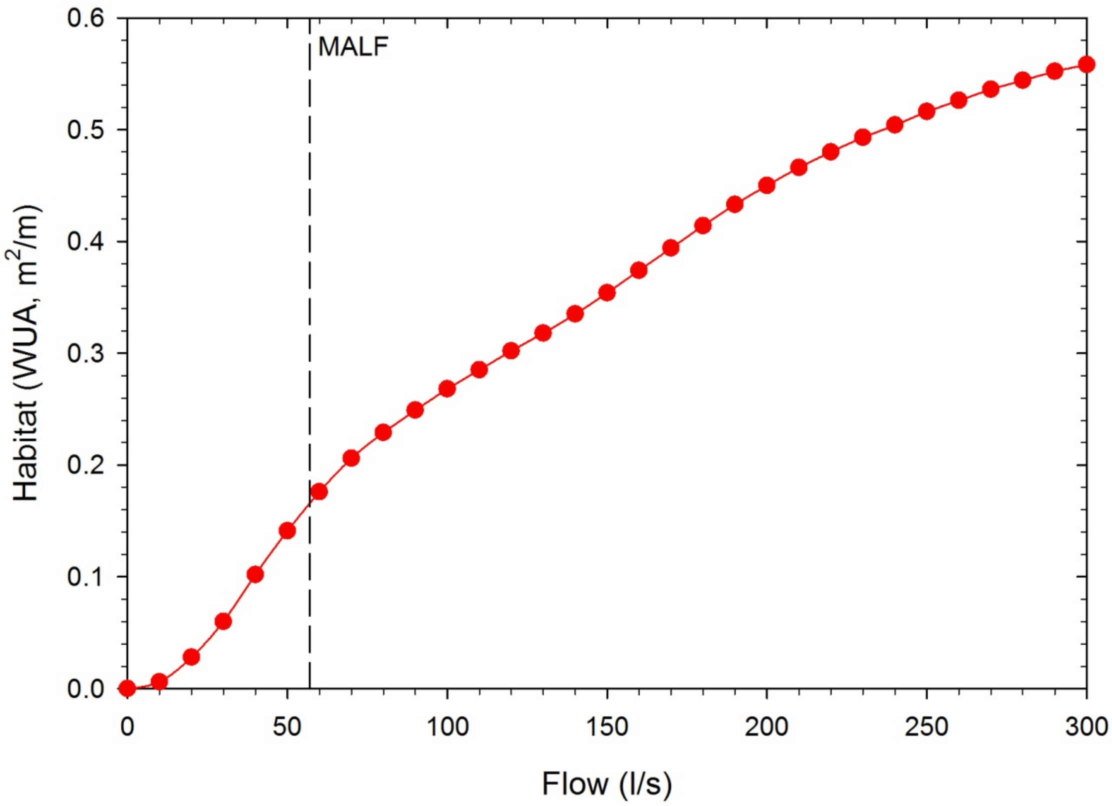


**Figure 6.9** **Variation in food producing (invertebrate) habitat with changes in flow in the survey reach in the lower Kaihiku Stream**

**Table 6.6** **Flow requirements for food producing (invertebrate) habiat in the lower reaches of Kaihiku Stream based on instream habitat modelling by Golder Associates (2009)**

| Species/life stage | Optimum flow (l/s) | Flow below which habitat rapidly declines (l/s) | Flow at which % habitat retention occurs (l/s) | | | |
|---|---|---|---|---|---|---|
| | | | 60% | 70% | 80% | 90% |
| Food producing | >200 | - | 39 | 44 | 48 | 52 |

## 6.6. Summary of in-stream habitat modelling

Values assessment is an important part of the flow-setting process and can be used to determine the level of protection required for different values based on their significance within the catchment. Flow-dependent values were assessed for Kaihiku Stream and appropriate levels of protection were assigned following the approach of Jowett & Hayes (2004). The outcome of these assessments is summarised in Table 6.7.

The trout fishery in Kaihiku Stream is limited, although brown trout are distributed throughout the catchment.

**Table 6.7 Assessment of instream habitat values at sites in the Kaihiku River with recommended levels of habitat retention (based on the approach of Jowett & Hayes 2004).**

| Value | Significance | Habitat retention | Flow (l/s) | |
|---|---|---|---|---|
| | | | Upper | Lower |
| Brown trout adult | Locally significant† | 70% | 10 | 8 |
| Brown trout juvenile | Locally significant ɣ | 70% | 9 | 32 |
| Upland bully | Low conservation value‡ | 70% | 4 | <5 |
| Lower Clutha flathead galaxias adult | Declining‡ | 80% | 9 | 23 |
| Longfin eel | Declining‡ | 80% | 10 | 9 |
| Food producing | Life supporting capacity | 70% | 12 | 44 |

† Based on the assessment in Otago Fish & Game Council (2003)
‡ Based on Goodman *et al.* (2014)

# 7. Conclusions: Flow requirements for aquatic ecosystems in Kaihiku Stream

Under the Regional Plan: Water Otago, residual flows can be imposed on resource consents to provide for the maintenance of aquatic ecosystems and natural character under low flow conditions. The purpose of this report is to provide information that assists in setting such residual flows, including the values present in the Kaihiku catchment, the existing use of water resources and the flows required to maintain in-stream habitat based on habitat modelling.

Kaihiku Stream provides spawning habitat for trout and provides an resident trout fishery. It also provides habitat for lamprey, longfin eel, lower Clutha galaxias and upland bully. Lamprey are classified as "nationally vulnerable", longfin eel and lower Clutha galaxias are classified as "declining" in the most recent assessment of the conservation status of New Zealand freshwater Fish, while upland bully were classified as "not threatened" (Goodman *et al.* 2014).

Instream habitat modelling predicts that flows to protect food producing habitat in the upper (12 l/s) and lower Kaihiku Stream (44 l/s) during the period December-April will also provide an appropriate level of protection for the fish species present in Kaihiku Stream, including adult trout. Protection of spawning habitat during winter and spring (May-November) would require higher flows (120 l/s).

The hydrological analysis conducted as part of this study estimated the MALF for the Kaihiku Stream at the Clutha confluence of 62 l/s. There is a single permitted water take in the lower Kaihiku Stream (maximum instantaneous rate = 37.3 l/s), meaning that the Kaihiku catchment is over-allocated based on the default allocation limited 50% of the 7-d MALF (31 l/s) in Policy 6.4.2.

While habitat suitability curves were not available for lamprey, flows sufficient to provide habitat for large longfin eels are expected to be sufficient to protect habitat for lamprey.

The results of this investigation will be used to inform assessments of residual flows on future applications to take water from the Kaihiku Stream catchment.

# 8. Glossary

**Abstraction**
See water abstraction.

**Allocation limit or allocation volume**
The maximum flow or quantity of water in a water body, which is able to be allocated to resource consents for taking.

**Catchment**
The area of land drained by a river or body of water.

**Consumptive use**
Use of water that results in a net loss of water from the water body.

**Instream Flow Incremental Methodology (IFIM)**
An instream habitat model used to assess the relationship between flow and available habitat for fish and invertebrates.

**Instantaneous take**
All takes of water occurring at a particular time.

**Irrigation**
The artificial application of water to the soil, usually for assisting the growing of crops and pasture.

**Main stem**
The principal course of a river (i.e., does not include tributaries).

**Mean Annual Low Flow (MALF)**
The average of the lowest seven-day low flow period for every year of record (see also seven-day low flow).

**Mean flow**
The average flow of a watercourse (i.e., the total volume of water measured divided by the number of sampling intervals).

**Minimum flow**
The flow below which the holder of any resource consent to take water must cease taking water from that river.

**Non-consumptive**
A water use that returns all water to the catchment it was taken from.

**Point of inflection**

The point at which there is a sharp decrease in the available habitat relative to flow in an IFIM habitat curve.

**Primary allocation**
The volume of water established under Policy 6.4.2 of the RPW that is able to be taken, subject to a primary allocation minimum flow.

**Reach**
A specific section of a stream or river.

**Return period**
An estimate of the average interval of time between events (e.g., flood or low-flow event).

**River**
A continually or intermittently flowing body of fresh water that includes a stream and modified watercourse, but does not include any artificial watercourse (such as an irrigation canal, water supply race or canal for the supply of water for electricity power generation and farm drainage canal).

**Seven-day low flow**
The lowest seven-day low flow in any year is determined by calculating the average flow over seven consecutive days for every seven consecutive day period in the year and then choosing the lowest.

**Stock water**
Water used as drinking water for livestock.

**Taking**
The taking of water is the process of extracting the water for any purpose and for any period of time.

**Vegetation**
Plant cover, including trees, shrubs, plants or grasses.

**Water abstraction**
The extraction of water from a water body (including aquifers).

**Water body**
Fresh water or geothermal water in a river, lake, stream, pond, wetland or aquifer, or any part thereof, which is not located within the coastal marine area.

**Water permit**
A permit granted under the Resource Management Act (1991) to take water.

# 9. References

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# Appendix A

## Habitat suitability curves used in instream habitat modelling presented in this report

| Species | Habitat suitability curve |
|---|---|
| Brown trout adult | Hayes & Jowett 1994 |
| Brown trout yearling | Jowett & Richardson 2008 |
| Brown trout spawning | Shirvell & Dungey 1983 |
| Longfin eel (>300 mm) | Jowett & Richardson 2008 |
| Upland bully | Jowett & Richardson 2008 |
| Flathead galaxias adult | Jowett & Richardson 2008 |
| Roundhead galaxias adult | Jowett & Richardson 2008 |
| Food producing | Waters 1976 |

Note: Habitat suitability curves were not available for lower Clutha galaxias at the time of writing. Instead, habitat suitability curves for adult roundhead and flathead galaxias (Jowett & Richardson 2008) were used and the average of the habitat prediction of these two curves was used to estimate habitat for lower Clutha galaxias at each flow.