Management Flows for Aquatic Ecosystems in the Tokomairiro River

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Otago Regional Council
Private Bag 1954, Dunedin 9054
70 Stafford Street, Dunedin 9016
Phone 03 474 0827
Fax 03 479 0015
Freephone 0800 474 082
www.orc.govt.nz

ISBN [get from Comms Team]

Report writer: Dean Olsen, Resource Scientist
Reviewed by: Matt Dale, Resource Scientist

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Overview

Background

One of the objectives of the Regional Plan: Water for Otago (2013; Water Plan) is 'to retain flows in rivers sufficient to maintain their life-supporting capacity for aquatic ecosystems and their natural character. As a means of achieving this objective, the Water Plan provides for the setting of minimum flows in Otago's rivers.

The Tokomairiro River has a catchment area of 403 km^2 and is located approximately 48 km southwest of Dunedin. For much of its length, the river consists of two branches: the East Branch (139 km^2) and West Branch (201 km^2). The two branches join at Milton and the river flows a further 21 km to the sea.

Why was this study done?

This report is intended to inform the minimum flow setting and flow allocation processes for the Tokomairiro catchment. It considers the following:

- The hydrology and existing water allocation in the Tokomairiro catchment.
- The aquatic values of the Tokomairiro catchment.
- The flows that will maintain aquatic ecological values in the Tokomairiro catchment.

What did this study find?

- The Tokomairiro catchment supports high ecological values including several threatened native fish species including Eldon's galaxias (nationally endangered), Clutha flathead galaxias (nationally vulnerable), longfin eels, lamprey, inanga and redfin bullies (declining). In addition, it supports a locally significant trout fishery.
- Existing allocation in the Tokomairiro is relatively modest, with current consents accounting for less than half (147.59 l/s) of the total available primary allocation limit (514.5 l/s), although the majority of allocation (142.3 l/s, 96% of the total) is from the East Branch.

- In-stream habitat modelling was conducted to determine how changes in flow affect the availability for a range of fish species. Habitat for adult brown trout was the most flow-sensitive in-stream value during the irrigation season, while trout spawning was the critical value in the two branches during winter. The flows recommended to maintain ecological values in the Tokomairiro catchment are presented in the table below:

Site	Season	7-d MALF (l/s)	7-d Winter low flow (l/s)	Recommended flow at modelled location (l/s)	Equivalent flow at confluence (l/s)	Reason
West Branch at SH8	**Summer**	162		72	206	Brown trout adult habitat
	Winter		260	260	741	Trout spawning habitat (maintain existing)
East Branch at Lisnatunny	**Summer**	130		80	169	Brown trout adult habitat
	Winter		311	250	528	Trout spawning habitat (optimum)
Main stem at Coal Gully Road	**All year**	1029	-	600	-	Brown trout habtiat – juvenile (optimal) and adult (76% retention of habitat at MALF)

- The availability of water for abstraction under the suggested management flows was considered and the suggested management flows would not significantly reduce the security of supply for water users.

Technical summary

The Tokomairiro River has a catchment area of 403 km^2 and is located approximately 48 km southwest of Dunedin. The two branches (the East and West branches) join at Milton and the river flows a further 21 km to the sea. The East Branch has a catchment area of 139 km^2 while the West Branch, drains a catchment of 201km^2.

The objectives of this report were:

- To summarise the hydrology and existing water allocation in the Tokomairiro catchment.
- To assess the aquatic values of the Tokomairiro catchment.
- To present and interpret in-stream habitat assessment maintain aquatic ecological values in the Tokomairiro catchment. Because of physical differences between the West Branch, East Branch and mainstem of the Tokomairiro River, the flows required to maintain aquatic values in each are considered separately.

The Tokomairiro catchment supports high ecological values including several threatened native fish species including Eldon's galaxias (nationally endangered), Clutha flathead galaxias (nationally vulnerable), longfin eels, lamprey, inanga and redfin bullies (declining). In addition, it supports a locally significant trout fishery.

Existing allocation in the Tokomairiro is relatively modest, with current consents accounting for less than half (147.59 l/s) of the total available primary allocation limit (514.5 l/s), although the majority of allocation (142.3 l/s, 96% of the total) is from the East Branch. Two of the largest takes (combined maximum consented take: 102 l/s) are located a short distance upstream of the confluence, meaning that the reach affected by these takes is relatively short and that flow variability in the main stem will be maintained by flows from the West Branch, which has a very low level of allocation.

In all cases, habitat for adult brown trout was the most flow-sensitive in-stream value during the irrigation season, while trout spawning was the critical value in the two branches during winter. These results of in-stream habitat modelling indicate that flows to maintain habitat for adult brown trout in summer and trout spawning in winter months (May-September) will also maintain other fish values.

The flows recommended to maintain ecological values in the Tokomairiro catchment are presented in the table below:

Site	Season	7-d MALF (l/s)	7-d Winter low flow (l/s)	Recommended flow at modelled location (l/s)	Equivalent flow at confluence (l/s)	Reason
West Branch at SH8	**Summer**	162		72	206	Brown trout adult habitat
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	Winter		311	250	528	Trout spawning habitat (optimum)
Main stem at Coal Gully Road	**All year**	1029	-	600	-	Brown trout habtiat – juvenile (optimal) and adult (76% retention of habitat at MALF)

The effect of these flows on the availability of water for abstraction was considered and the results are summarised in the following table:

Site	Season	Recommended flow (l/s)	Percentage of time below recommended flow	Number of days
West Branch at SH8	**Summer**	72	0.6	2
	Winter	260	7.4	11
East Branch at Lisnatunny	**Summer**	80	0.6	1
	Winter	250	4.7	7
Main stem at Coal Gully Road	**All year**	600	1.6	6

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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].

The Tokomairiro River rises in two branches in the rolling hills to the northwest of the town of Milton in south Otago. These two branches join near Milton before flowing to the sea a further 21 km downstream. At present, there is little irrigation in the Tokomairiro catchment, although there are several takes for dairy shed and stock water supply. However, the largest takes in the catchment are from the East Branch including the town water supply for Milton (39 l/s) and an industrial water take (77 l/s) in Milton.

Schedule 1A of the Water Plan[3] identifies the ecosystem values that must be sustained in Otago catchments. In the Tokomairiro catchment these include spawning habitat for eels, trout and significant habitat for galaxiids and lamprey. Further to these values, the Tokomairiro River also supports populations of several threatened native fish species including Eldon's galaxias, Clutha flathead galaxias, longfin eels, lamprey, inanga and redfin bully.

1.1. Objectives

This report presents information on the Tokomairiro River that is relevant to determining the flows required to sustain the river's aquatic habitat including 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 Tokomairiro catchment

The Tokomairiro River has a catchment area of 403 km^2 and is located approximately 48 km southwest of Dunedin. The catchment has indistinct boundaries, with no dividing mountain ranges between it and its neighbouring catchments. It is bordered to the east by tributaries of the Waihola-Waipori Wetland Complex (including Meggat Burn and Boundary Creek) and a number of coastal tributaries (including Akatore Creek) (Figure 2.1). The Waitahuna River borders the Tokomairiro catchment to the north, while it is bordered to the west by tributaries of Lake Tuakitoto (such as Lovells Creek) and Rocky Valley Creek, which enters the Pacific Ocean just south of Toko Mouth (Figure 2.1).

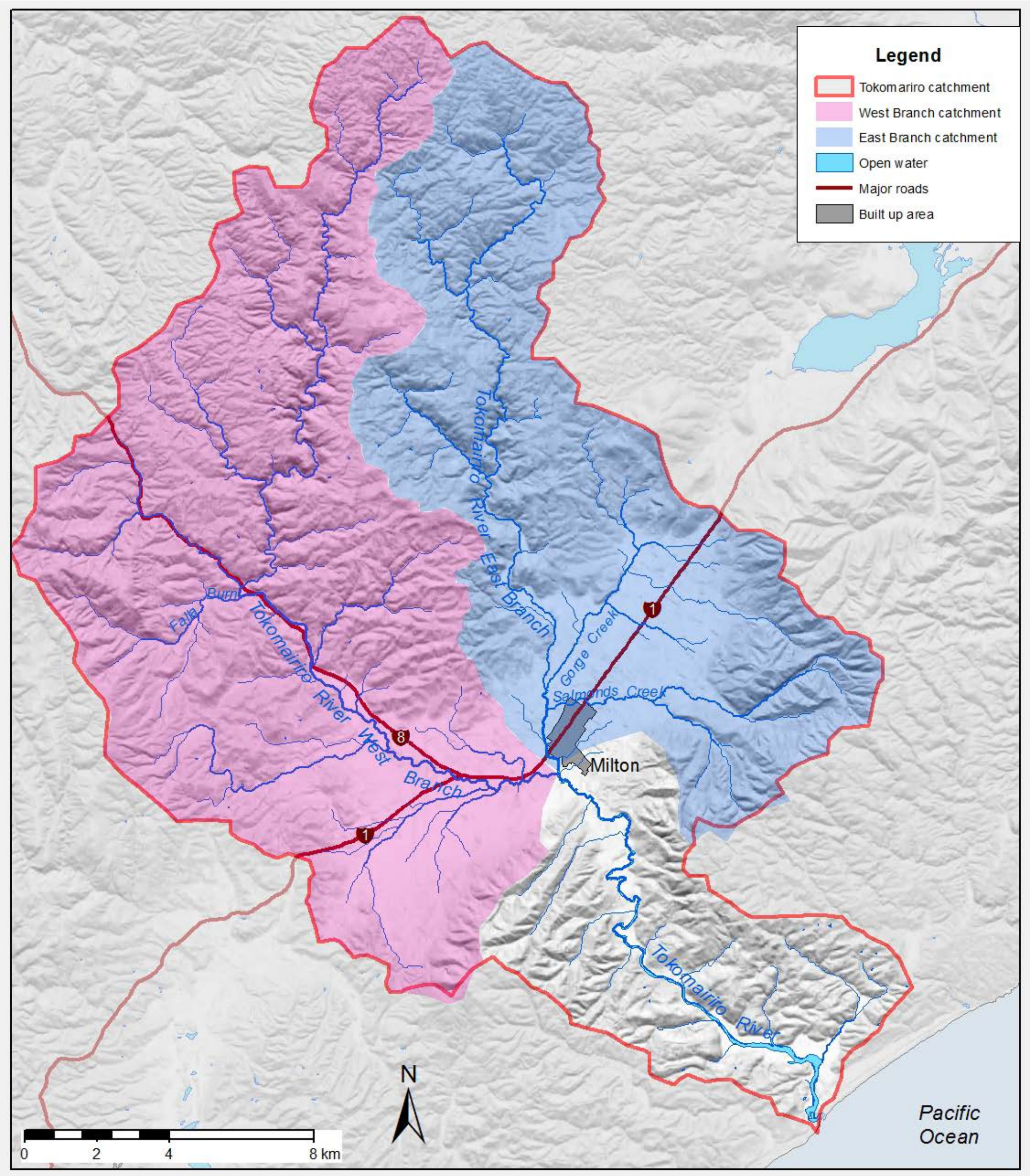

Figure 2.1 The Tokomairiro catchment

The Tokomairiro River splits into two branches (East and West Branch), at the township of Milton before flowing for 21 km to the sea. The East Branch has a catchment area of 139 km^2 while the West Branch, drains a catchment of 201 km^2.

Milton is located in the centre of the Milton Plain and had a population of 1929 people at the time of the 2013 Census (Statistics New Zealand). Industries in the Milton area include construction, boat building, woollen mill, limeworks and forestry (including sawmilling). The township and surrounding area are prone to flooding and a plan for mitigating that hazard is being implemented (Milton 2060 - REF)

2.1. Vegetation

Prior to European settlement, parts of the Tokomairiro Plain were a wetland complex, although northern and eastern portions of the plain were dry grasslands (Otago Catchment Board and Regional Water Board 1984). However, swampy parts of the plain were drained to allow for pasture development (Otago Catchment Board and Regional Water Board 1984). To facilitate farming on the heavy peat soils, tile-mole drains are used extensively in the catchment.

The Tokomairiro catchment is dominated by high- and low-producing grasslands on the Tokomairiro Plain and much of the surrounding hill country (Figure 2.2). There are also substantial areas of exotic forestry, with large tracts in the upper reaches of both branches and in the coastal ranges (Figure 2.2). Several small tracts of native are scattered within the Tokomairiro catchment (Figure 2.2).

2.2. Land use

Sheep and beef farming is the dominant land use in the Tokomairiro catchment, although there is substantial dairying on the Tokomairiro Plain (Figure 2.2). There are also substantial areas of forestry in the catchment: both branches flow out of Berwick Forest, while the lower river is flanked by forestry and some tributaries of the East Branch (including Narrowdale Stream) flow from Otago Coast Forest (Figure 2.2). There is only a small amount of conservation land (56 ha) in the Tokomairiro catchment (Figure 2.2).

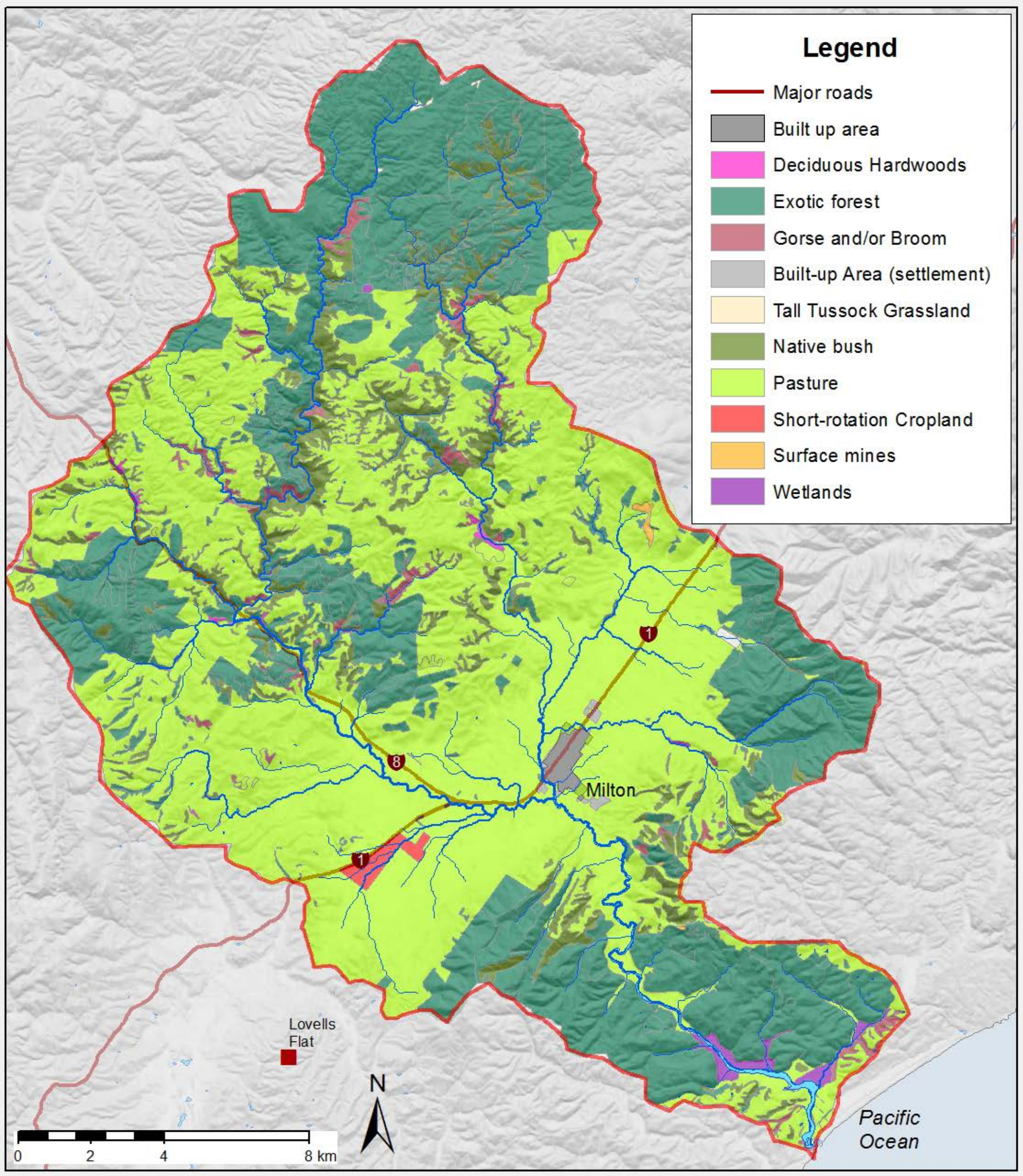

Figure 2.2 Land use in the Tokomairiro catchment.

2.2.1. Point source discharges

The Milton Wastewater Treatment Plant (WTP) discharges into the main stem of the Tokomairiro River, at the confluence of the East and West Branches. The Clutha District Council has two discharge permits associated with the operation of the Milton WTP – Resource Consent 2007.090.V1 allows for the discharge of up to 1,625 m^3 of treated waste water per day to the Tokomairiro River. Meanwhile, Resource Consent 2002.369 allows for the discharge of up to 9,150 m^3 of untreated waste water per day from the Milton WTP to the Tokomairiro River during heavy rainfall events.

2.3. Rainfall and flow patterns in the Tokomairiro catchment

2.3.1. Rainfall patterns

The Tokomairiro catchment has a cool-dry climate, with a mean annual temperature of less than 12°C and mean annual effective precipitation of ≤500 mm (River Environment Classification, Ministry for the Environment & National Institute of Water and Atmospheric Research). The mean daily temperature at Milton is 10°C with monthly mean minimum of 0.3°C in July and a monthly maximum of 20.4°C in February (Table 1.1). Annual rainfall at Lovells Flat on the southwestern border of the Tokomairiro catchment is approximately 750 mm with a tendency for more rainfall in summer months (Table 1.2). Greater amounts of rainfall occur on the coastal hills and in Berwick Forest in the headwaters of both branches of the Tokomairiro River (Figure 2.3).

Table 2.1 Mean monthly temperature (°C), mean daily minimum air temperature (°C) and mean daily maximum air temperature (°C) at the Milton weather station (1971-2000).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	14.8	14.8	13.0	10.4	7.6	5.2	4.8	6.2	8.4	10.4	11.9	13.8	10.1
Minimum	9.4	9.2	7.5	5.1	2.9	0.9	0.3	1.3	3.3	5.3	6.6	8.6	5.0
Maximum	20.2	20.4	18.5	15.8	12.3	9.6	9.2	11.0	13.5	15.5	17.2	19.0	15.2

Table 2.2 Mean monthly rainfall (mm) at Lovells Flat weather station (1981-2010). The location of the Lovells Flat weather station is shown in Figure 2.3.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
70	74	63	54	70	63	56	49	53	64	58	79	752

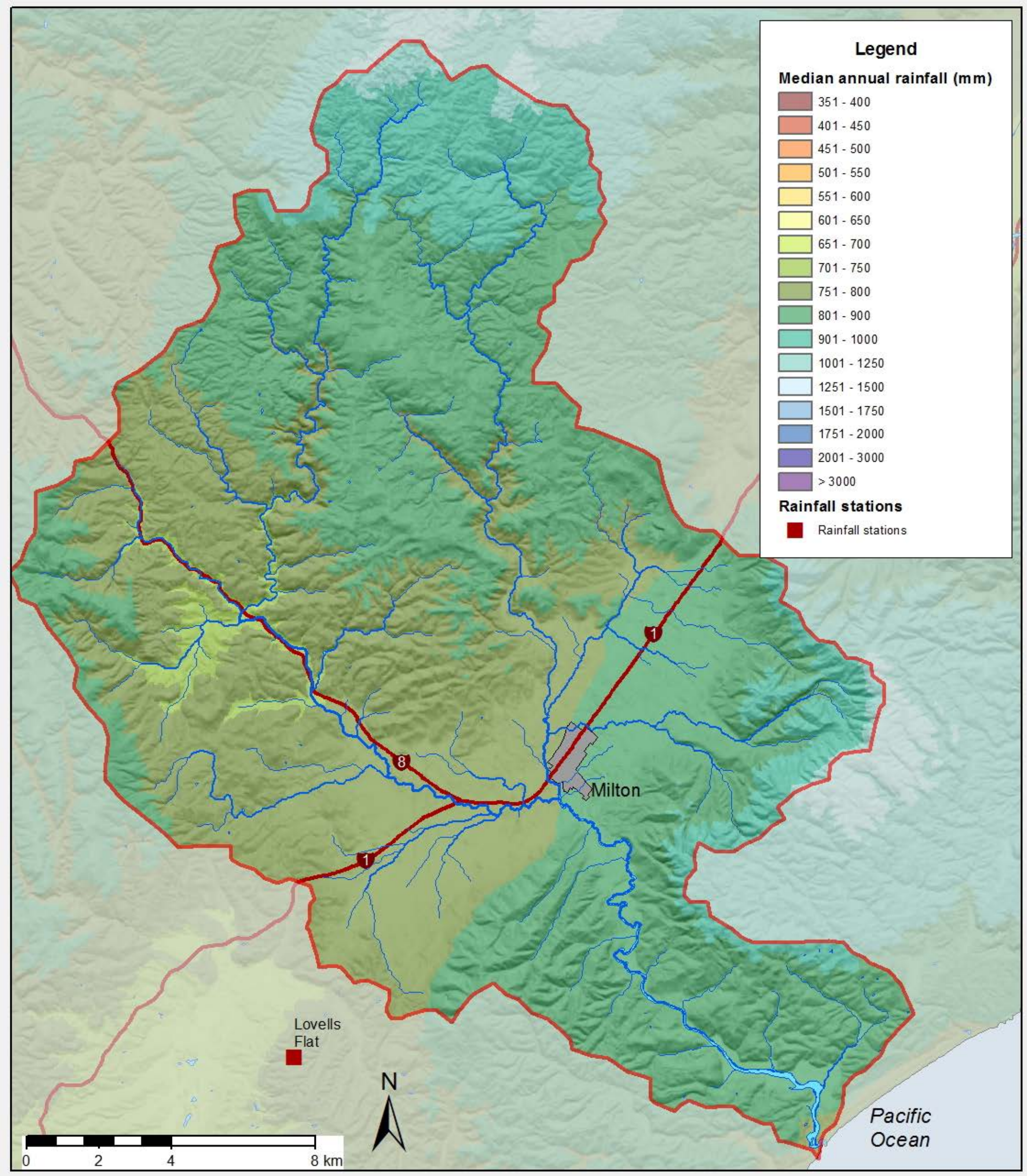

Figure 2.3 **Median annual rainfall over the Tokomairiro catchment (from growOtago).**

2.4. River hydrology

A continuous flow recorder is located in the West Branch at the State Highway 8 bridge, approximately 15 km above the confluence (Figure 2.4). This site captures 34% of the catchment area of the West Branch and has been in place since December 1981.

As part of this study, flow recorders were established at two sites in the East Branch (Fletts Road and Lisnatunny), two sites in the West Branch (SH8 bridge and SH1 bridge at Clarkesville), and in two tributaries (Falla Burn and Salmonds Creek) (Figure 2.4, Table 2.3).

In addition, synthetic flow records were calculated for sites in the East and West Branches immediately upstream of the confluence, the main stem at Coal Gully Road and for Gorge Creek (Table 2.3).

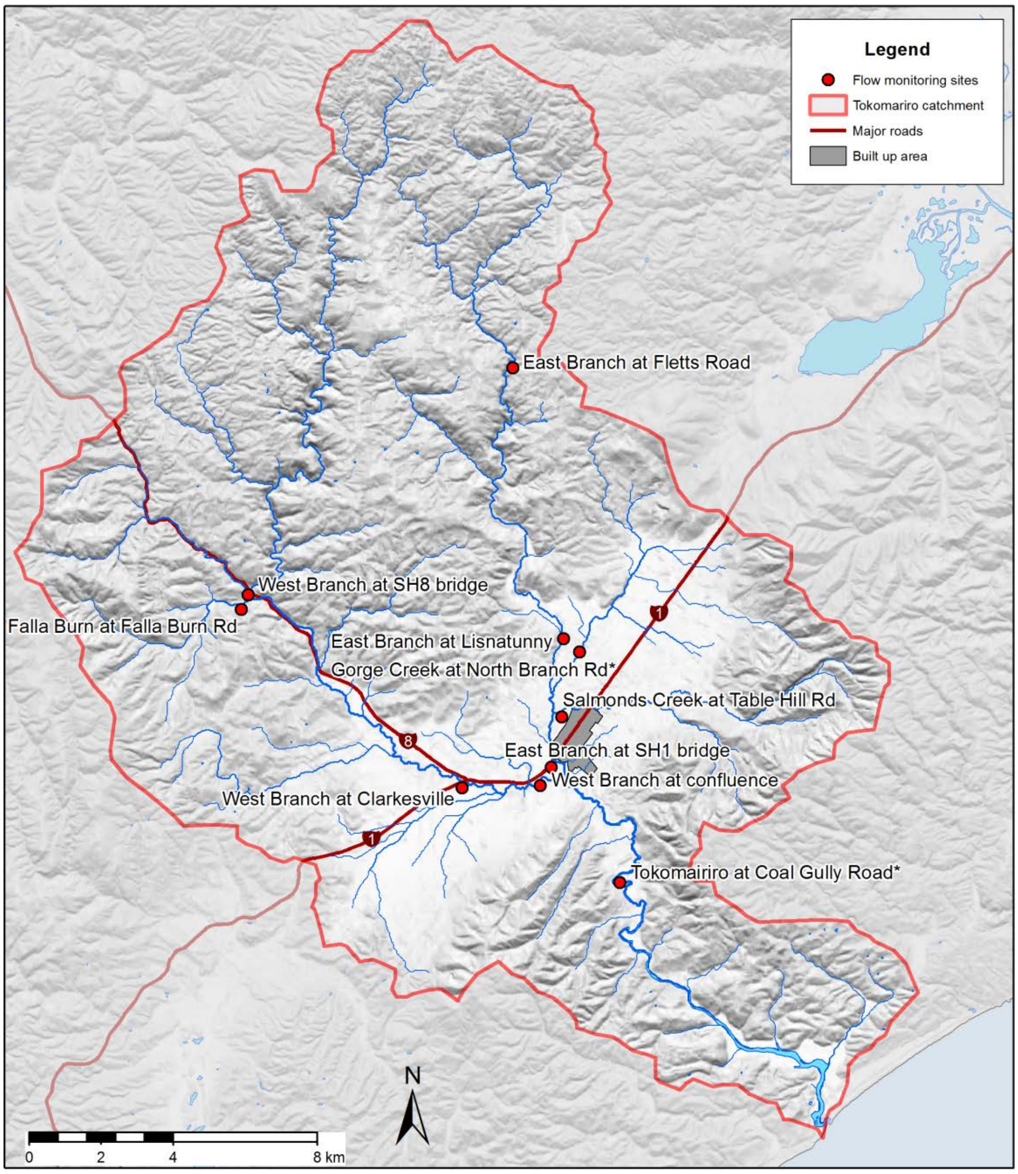

Figure 2.4 **Flow monitoring sites in the Tokomairiro catchment.**

Table 2.3 **Descriptions of the flow recorder sites in the Tokomairiro River used in this study. Sites marked with an asterisk (*) represent sites for which synthetic flow records were calculated.**

Site name	Upstream Catchment area (ha)	2011/2012 hydrological year				
		Minimum flow (l/s)	Min 7-day low flow (l/s)	Catchment yield at min 7-day low flow (l/s/ha)	Median flow (l/s)	Mean flow (l/s)
East Branch at Fletts Road	3576	98	132	0.037	328	671
East Branch at Lisnatunny	6532	90	134	0.021	436	610
East Branch at SH1 bridge	13530	239	282	0.021	1022	1283
West Branch at SH8 Bridge	6851	102	120	0.018	436	568
West Branch at Clarkesville	15303	125	145	0.009	578	1121
West Branch at confluence	19504	133	155	0.008	628	1408
Tokomairiro at Coal Gully Road*	35086	562	662	0.019	2408	3081
Falla Burn at Falla Burn Rd	1934	2	3	0.002	45	118
Salmonds Creek at Table Hill Rd	2021	1	2	0.001	19	119
Gorge Creek at North Branch Rd*	3625	3	6	0.002	57	357

Table 2.4 **Long-term flow statistics for the Tokomairiro River at the West Branch SH8 bridge flow recorder (1981-2013).**

Minimum flow (l/s)	7-day MALF (l/s)	Catchment yield at 7-day MALF (l/s/ha)	Median flow (l/s)	Mean flow (l/s)
44	162	0.024	450	786

2.4.1. Synthetic flow record for the Tokomairiro River, downstream of the confluence

A synthetic flow record was calculated for the main stem of the Tokomairiro River at Coal Gully Road, 6.4 km downstream of the confluence and just upstream of the tidal influence. The period of the synthetic flow record is 18 December 1981 to 19 August 2013. The method used to calculate this synthetic record is outlined in Appendix 1.

2.4.2. Flow statistics of the Tokomairiro River

Using the synthetic flow described above, general flow statistics have been calculated for the Tokomairiro River at the Coal Gully Road bridge on the main stem (Table 2.5).

Table 2.5 Flow statistics for the Tokomairiro River at Coal Gully Road based on a synthetic flow record for the period 18 December 1981 to 19 August 2013. Mean and median flows are daily averages, while the minimum and maximum flows are instantaneous flows.

Min (l/s)	Max (l/s)	Mean (l/s)	Median (l/s)	7-day MALF (l/s)	Catchment area (ha)	Catchment yield at MALF (l/s/ha)
244	753,409	4,288	2,524	1,029	35,090	0.029

The 7-day Mean Annual Low Flow (MALF[4]) for the Tokomairiro River at the Coal Gully Road bridge was estimated to be 1,029 l/s, while the 7-day MALF in the West Branch at SH8 was 162 l/s. The lowest recorded mean daily flow in the West Branch at the SH8 bridge was 48 l/s, which was recorded on 18 January 2004.

Table 2.6 shows the estimated 7-day and instantaneous low-flow return periods for the Tokomairiro River at Coal Gully Road.

Table 2.6 Return period analysis of 7-day and instantaneous low flows for the Tokomairiro River at the Coal Gully Road bridge

Return period	7-day low flow (l/s)	Instantaneous flow (l/s)
1:5 year low flow (l/s)	648	485
1:10 year low flow (l/s)	543	418
1:20 year low flow (l/s)	474	374
1:50 year low flow (l/s)	410	334

[4] The seven-day MALF is the average of the lowest seven-day moving average flows for every year of record.

3. Water allocation

There are currently four consented consumptive surface water takes and three consented consumptive groundwater takes in the Tokomairiro catchment (Table 3.1, Figure 3.1). A single surface water take and two groundwater takes are taken from the West Branch (maximum total instantaneous abstraction: 5.29 l/s) while three surface water takes and one groundwater take are taken from the East Branch (maximum total instantaneous abstraction: 142.3 l/s; Table 3.1, Figure 3.1). The current total primary allocation limit for the catchment is 514.5 l/s (50% of MALF), meaning that 366.9 l/s remain unallocated.

Table 3.1 Consented consumptive water takes in the Tokomairiro catchment. *= Bracketed daily volumes consented, monthly volume calculated by multiplying daily volume by 31.

Consent no.	Expiry date	Location	Type	100 m rule	Purpose	Maximum rate (l/s)	Volume (m^3/month)
98051	1/2/2018	Glenore	SW	-	Dairy shed/stockwater	2.4	5,580 (180 m^3/day)
2000.417.V1	1/2/2031	Lisnatunny	SW	-	Milton town water supply	39	104,160 (3,360 m^3/day)
2004.377	1/8/2024	Milton	SW	-	Irrigation	25	66,960
2004.942	1/3/2025	Milton	SW	-	Industrial	77	15500 (500 m^3/day)
RM12.115.01	1/6/2047	Moneymore Rd	GW	F	Dairy shed/stockwater	1.5	3,705
2008.313	1/6/2047	Moneymore Rd	GW	F	Single houshold/dairy shed/stockwater	1.39	2,418 (78 m^3/day)
2005.104	30/3/2030	Milburn Correction Facility	GW	F	Construction & grounds maintenance	1.3	1,680
		Existing total consented primary allocation				**147.59**	**200,003**

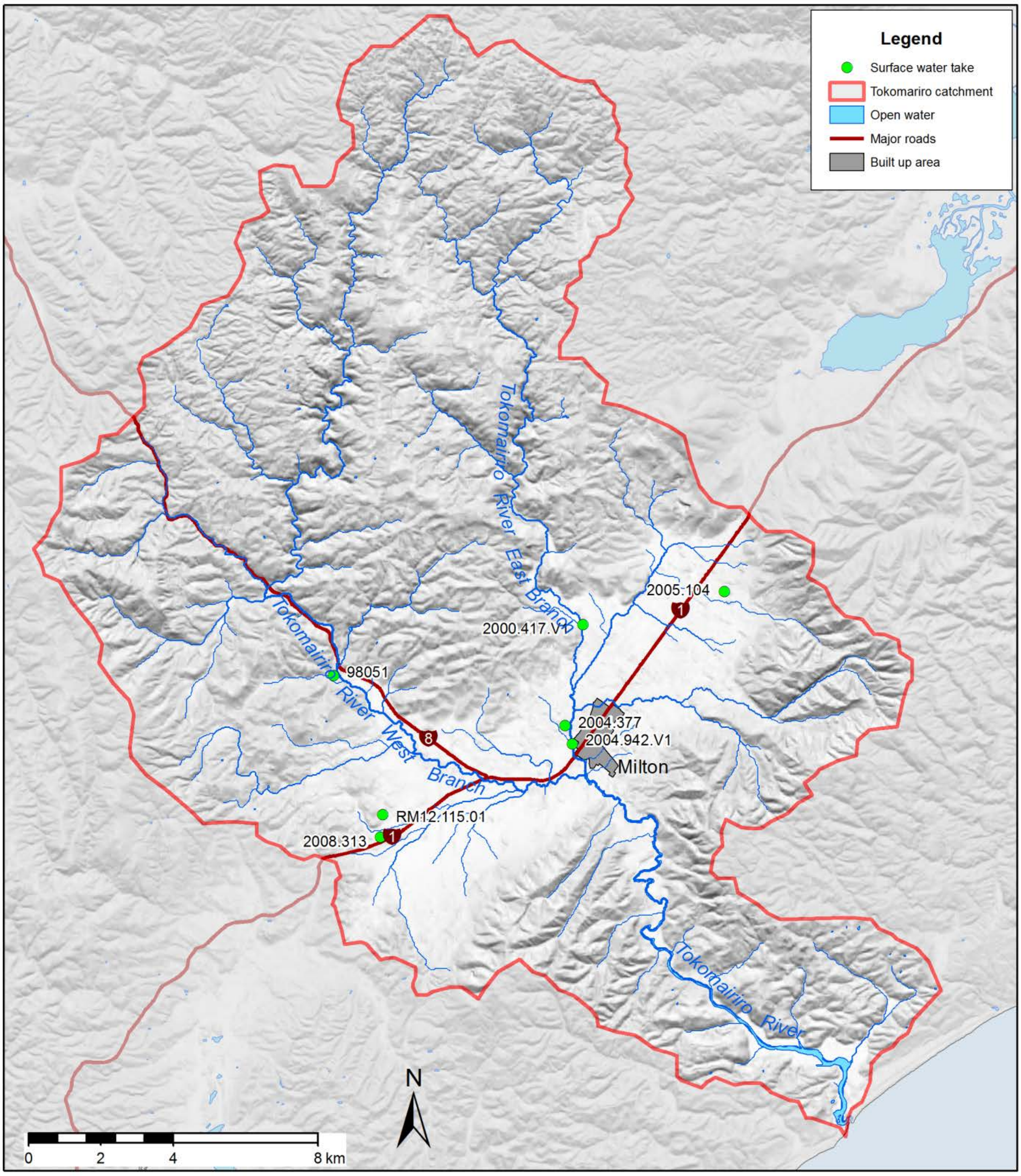

Figure 3.1 Consented surface water and groundwater takes in the Tokomairiro catchment

The Clutha District Council (CDC) take from the East Branch at Lisnatunny is listed in Schedule 1B of the Water Plan as a community take and will not be subject to any minimum flow implemented for the Tokomairiro catchment.

4. Values of the Tokomairiro catchment

4.1. Freshwater fish

Thirteen fish species are present in the Tokomairiro catchment, of which 12 are native (Table 4.1). The only introduced fish is brown trout. Of the native fish, six species are listed as endangered, with the most critical being Eldon's galaxias, which is classified as 'nationally endangered' and Clutha flathead galaxias which is classified as 'nationally vulnerable', while longfin eel, lamprey, inanga and redfin bully are all listed as 'declining' (Table 4.1).

The Upper Tokomairiro River (including East and West Branches) is listed in Schedule 1A of the Water Plan, with eels and trout are listed as 'significant ecosystem values', and the area is considered to be an important habitat for trout spawning and juvenile trout (ORC, 2004). An unnamed tributary of Fishers Stream, a tributary of the East Branch, (NZTM E1360826 N4902777) and an unnamed tributary of the West Branch (NZTM E1359524 N4903775) are listed as providing significant habitat for Eldon's galaxiid. An unnamed tributary of the Tokomairiro River West Branch, also known as Nuggety Gully, provides significant habitat for Clutha flathead galaxias (Table 4.1).

Table 4.1 Fish species present within the Tokomairiro catchment (Sources: New Zealand Freshwater Fish Database, ORC records and Fish and Game Otago records). Conservation status is based on Allibone *et al*. (2010).

Common name	Species name	Conservation status
Brown trout	*Salmo trutta*	Introduced and naturalised
Longfin eel	*Angullia dieffenbachii*	Declining
Shortfin eel	*Angullia australis*	Not threatened
Lamprey	*Geotria australis*	Declining
Common smelt	*Retropinna retropinna*	Not threatened
Inanga	*Galaxias maculatus*	Declining
Eldon's galaxias	*Galaxias eldoni*	Nationally endangered
Clutha flathead galaxias	*Galaxias* sp. D	Nationally vulnerable
Redfin Bully	*Gobiomorphus huttoni*	Declining
Common Bully	*Gobiomorphus cotidianus*	Not threatened
Upland Bully	*Gobiomorphus breviceps*	Not threatened
Black flounder	*Rhombosolea retiaria*	Not threatened
Yellow-eyed mullet	*Aldrichetta forsteri*	Not threatened

Longfin eels are widely distributed in the West Branch and have been recorded from the lower East Branch and lower reaches of the main stem, while shortfin eels have been recorded from near the mouth and at the SH8 bridge in the West Branch (Figure 4.2).

Eldon's galaxias is found in small tributaries in the upper East and West Branches (Figure 4 1) and Clutha flathead galaxias have been recorded from two tributaries of the West Branch: Manuka Stream and Nuggety Gully (Figure 4.1). Lamprey have been recorded from both the East and West Branches of the Tokomairiro River (Figure 4.2). Black flounder and common smelt have been collected in the lower river (Figure 4.2), while inanga (adult whitebait) and yellow-eyed mullet have been recorded from the main stem almost as far upstream as the confluence (Figure 4.1, Figure 4.2). Several inanga spawning sites have been identified in the lower reaches of the Tokomairiro River (P. Ravenscroft, pers. comm.).

Common bullies have been found upstream as far as the lower reaches of both branches, while redfin bullies have been recorded from the lower reaches of the East Branch (Figure 4.2). Upland bullies have been recorded from various sites in the lower East Branch and at some sites in the Falla Burn and at the SH8 Bridge in the West Branch catchment (Figure 4.2).

Brown trout are distributed throughout much of the Tokomairiro catchment, while there is a single record of perch from the lower river (Figure 4.3).

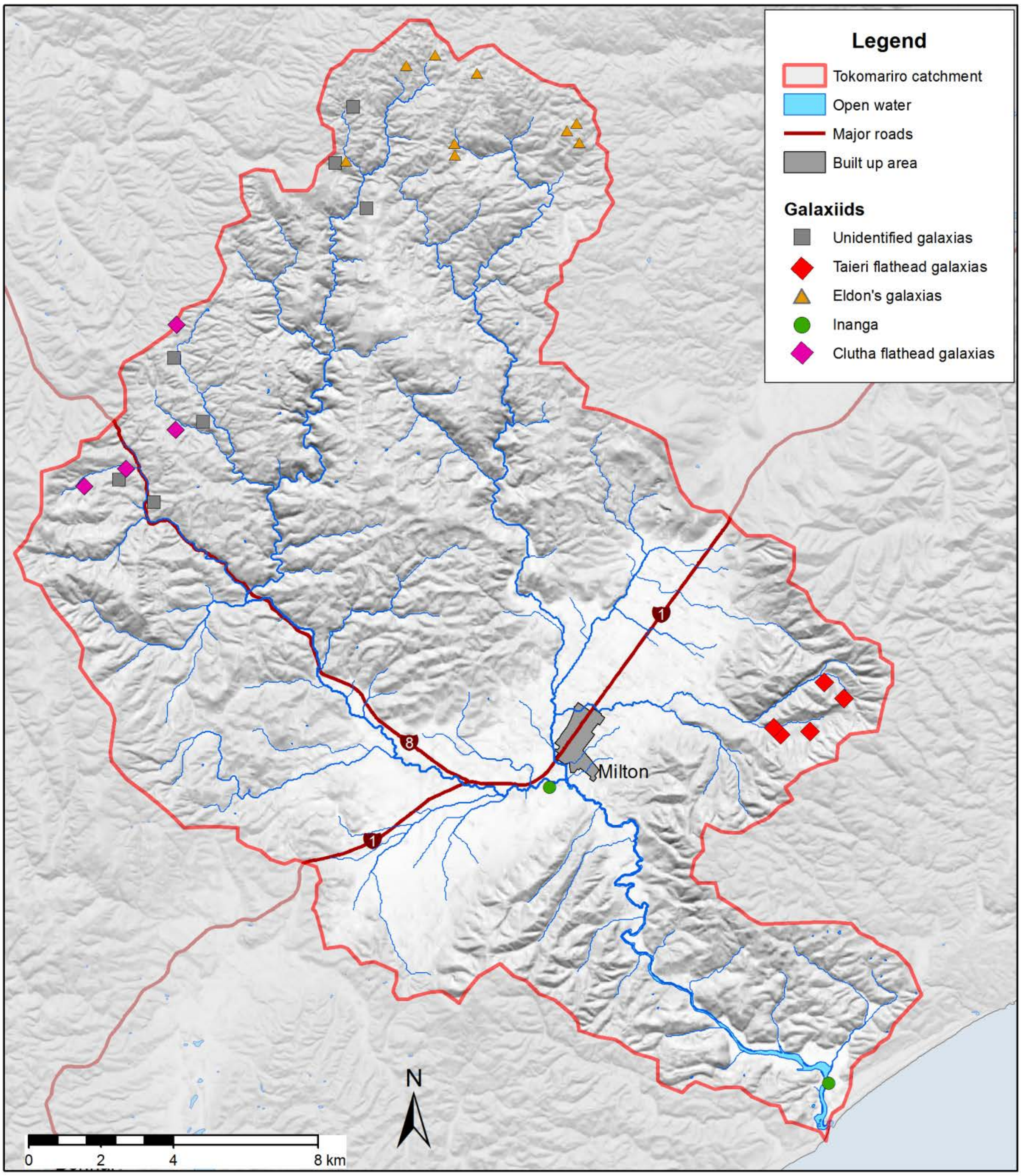

Figure 4.1 **Distribution of galaxiid species in the Tokomairiro catchment.**

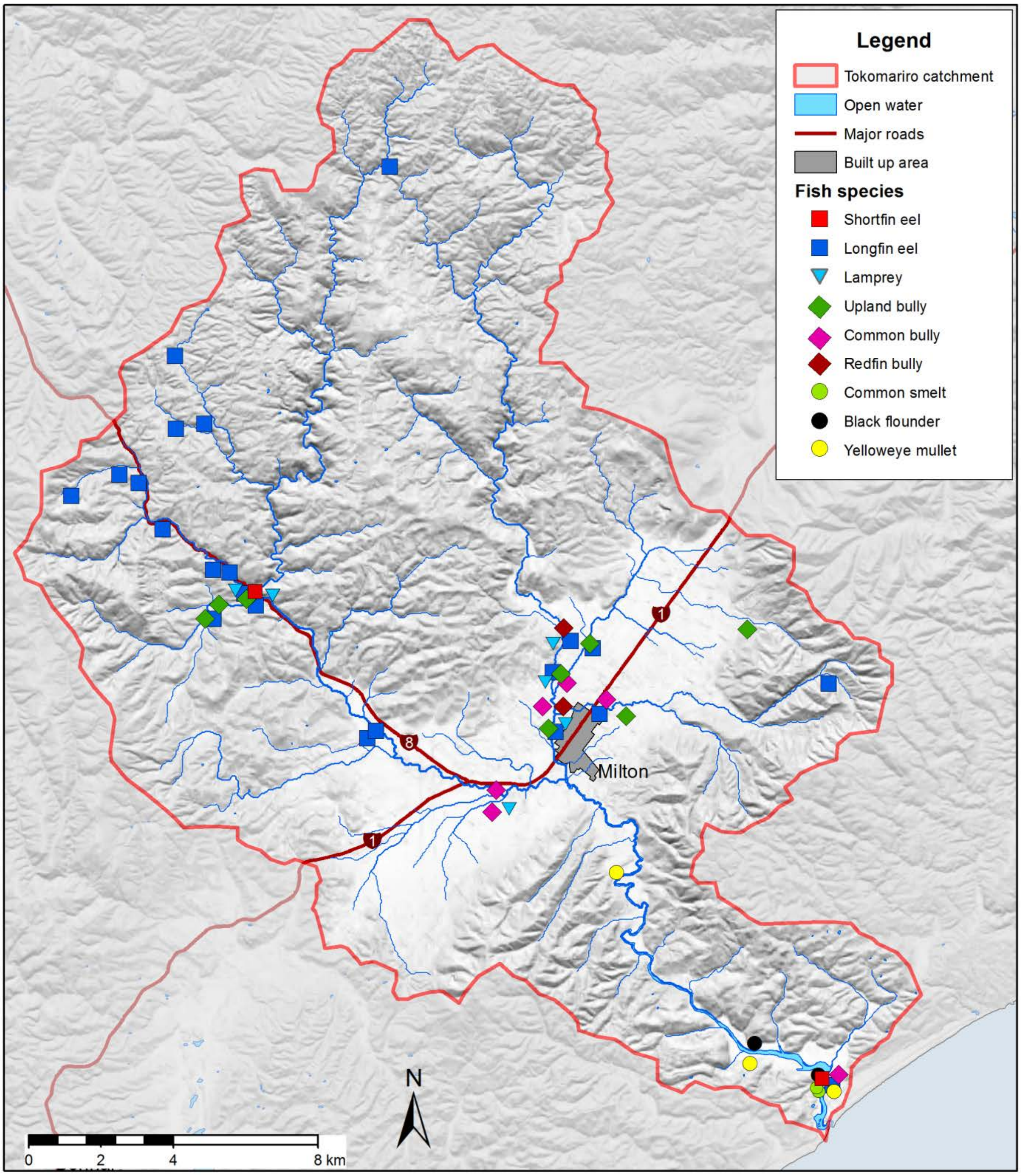

Figure 4.2 Distribution of native fish species (except galaxiids) in the Tokomairiro catchment.

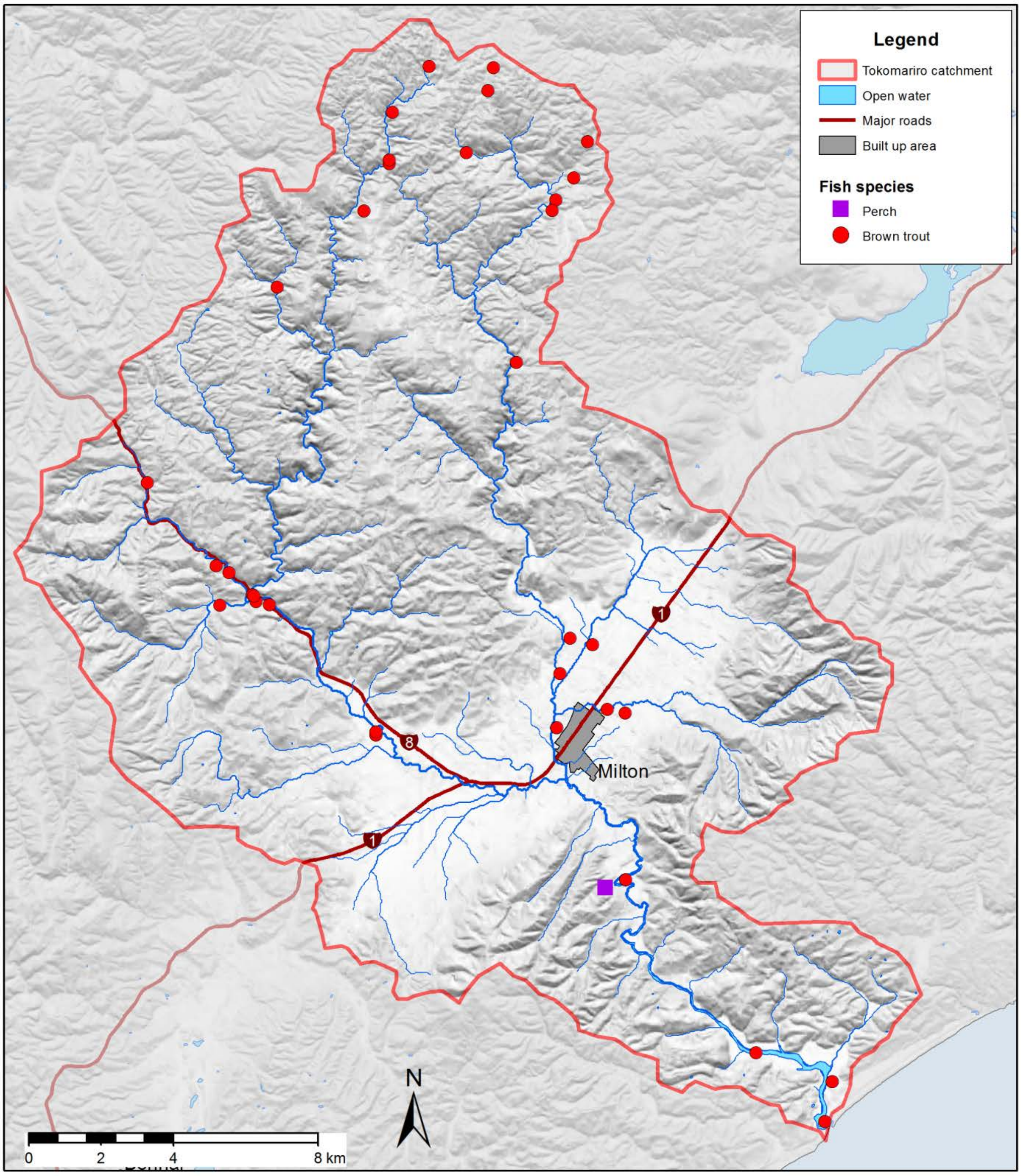

Figure 4.3 Distribution of sports fish species in the Tokomairiro catchment.

4.2. Recreational values

The lower reaches and adjacent wetlands of the Tokomairiro River (Figure 2.2) have been recognised by the Otago Fish and Game Council as a regionally important wildlife habitat for gamebirds and protected species (Otago Fish & Game Council 2003). Several wetlands in the lower Tokomairiro catchment have some protection, either by QEII covenants (27.5 ha) or by being owned by the Otago Fish & Game Council (Nobleburn, 46 ha).

The Tokomairiro catchment also supports a brown trout fishery and angling is common on the West Branch and in the lower reaches, including the estuary. Benfield (1948) reported that the Tokomairiro River was "well stocked with brown trout that range from one to three or four pounds" while Turner (1983) reported that "It is well stocked with brown trout averaging just under 1 kg". A user survey for the 2007/2008 fishing year estimated that there were 520 angler days on the Tokomairiro River (Table 4 2). This number is well down on the estimated angler useage in 2001/2002 and 1994/1995 fishing season, although the estimate for the 2001/02 season may be anomolous (Unwin, 2009).

The Tokomairiro River is a popular whitebaiting area, with the season running between August and November.

Table 4.2 Estimated angler usage in the Tokomairiro catchment from national angler surveys (Unwin 2009).

	Estimated useage (angler days ± 1 standard error)		
	1994/95	2001/02	2007/08
Tokomairiro River	850±270	4090±1680	520±330

4.3. Summary of values

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 the two branches and lower (main stem) of the Tokomairiro catchment and appropriate levels of protection were assigned following the approach of Jowett & Hayes (2004). The outcome of these assessments is summarised in Table 4 3.

The highest ecosystem value that is relevant to the setting of minimum flows was habitat for Clutha flathead galaxiids, which are classified as 'Nationally vulnerable' (see Table 4 1). Eldon's galaxias, which are classified as 'Nationally endangered' (see Table 4 1) were not included in this assessment, as the populations of Eldon's galaxias are limited to the upper portions of the East and West Branches where water abstraction is minimal. Habitat for eels, inanga and juvenile lamprey were assessed as moderate due to these species being classed as 'declining' (see Table 4 1). Habitat for other native fish (mainly bullies) was assessed as having low conservation or fishery value.

The trout fishery in Tokomairiro catchment is locally significant (Otago Fish & Game Council 2003), but given the limited availability of suitable spawning habitat for trout in the Tokomairiro catchment, higher levels of protection for trout spawning is recommended for the upper West and East Branches during the winter months (Table 4 3).

Table 4.3 **Assessment of instream habitat values at sites in the Tokomairiro River with recommended levels of habitat retention (based on the approach of Jowett & Hayes 2004).**

Site	Critical value	Fishery or conservation value	Recommended % habitat retention
West Branch at SH8	Large adult trout - perennial fishery	Locally significant*	70
	Trout - juvenile rearing	Locally significant*	70
	Trout spawning	Locally significant*†	80
	Eel habitat	Moderate (declining‡)	70
	Bully habitat	Low	60
	Lamprey - juvenile habitat	Moderate (declining‡)	70
	Clutha flathead galaxias	High (nationally vulnerable‡)	90
East Branch at Lisnatunny	Large adult trout - perennial fishery	Locally significant*	70
	Trout - juvenile rearing	Locally significant*	70
	Trout spawning	Locally significant*†	80
	Eel habitat	Moderate (declining‡)	70
	Bully habitat	Low	60
	Lamprey - juvenile habitat	Moderate	70
Main stem at Coal Gully Rd	Large adult trout - perennial fishery	Locally significant*	70
	Eel habitat	Moderate (declining‡)	70
	Bully habitat	Low	60
	Inanga habitat	Moderate (declining‡)	70
	Lamprey - juvenile habitat	Moderate (declining‡)	70

* Based on Otago Fish & Game Council (2003)

† A value of 80% habitat retention used based on the limited availability of suitable spawning substrate in catchment. This would apply during the brown trout spawning season (May-September).

‡ Based on the NewZealand threat classification of Allibone *et al.* (2010).

5. Physical habitat survey

The Otago Regional Council contracted the National Institute for Water and Atmospheric research (NIWA) to carry out a study to determine the flows required to maintain an acceptable habitat for the fish species present in the Tokomairiro catchment. The in-stream habitat modelling conducted by NIWA (Jowett 2005) forms the basis for most of the analyses presented in this section.

5.1. 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, 2004).

Assessing suitable physical habitat for aquatic organisms that live in a river is the aim of in-stream habitat modelling. The consequences of loss of habitat are well documented; the environmental bottom line is that if there is no suitable habitat for a species, it will cease to exist (Jowett, 2004). 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 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, especially non-migratory galaxiids.

5.2. 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. 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, 2004).

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).

5.3. In-stream habitat modelling for the Tokomairiro River

In-stream habitat modelling was undertaken for three reaches in the Tokomairiro River: East Branch near Lisnatunny, West Branch at SH8 bridge and the main stem at Coal Gully Road using the hydraulic and in-stream habitat model RHYHABSIM (Jowett 2005). At two sites (East Branch at Lisnatunny, Main stem at Coal Gully Road), surveys were undertaken at two calibration flows in addition to the initial survey flow, while at the site in the West Branch, surveys were undertaken at three calibration flows in addition to the initial survey flow (Table 5.1). Jowett (2005) presents more details of the methods employed in these surveys and the results of these analyses.

Table 5.1 Survey flows, calibration flows and average physical characteristics of reaches at the survey flow of instream habitat modelling sites (Jowett 2005).

Reach	Survey flow (l/s)	Callibration flow 1 (l/s)	Callibration flow 2 (l/s)	Callibration flow 3 (l/s)	Mean width (m)	Mean depth (m)	Mean velocity (m/s)
East Branch at Lisnatunny	470	331	1,019		4.1	0.48	0.28
West Branch at SH8	411	390	290	1,040	5.8	0.33	0.29
Main stem at Coal Gully Road	862	800	4,970		10.0	0.74	0.12

5.3.1. Instream habitat

The survey reach in East Branch was dominated by run habitat, while the survey reach in the West Branch had a more even balance of run, riffle and pool habitats and the survey reach in the lower river was dominated by pool habitat, with some run habitat (Table 5.2). The sediment composition in the West Branch site was markedly different to the two other sites, with much coarser substrate with bedrock, boulders and cobble present in addition to gravel, whereas the East Branch site was dominated by gravel and fine gravels (Table 5.2). In contrast, the main stem site had abundant macrophytes and a bed composed primarily of gravels and fine gravels (Table 5.2).

Table 5.2 Habitat characteristics at the three habitat survey sites including meso-habitat types and substrate composition (Jowett 2005).

Reach	Habitat (%)			Substrate (%)							
	Pool	Run	Riffle	Bedrock	Boulder	Cobble	Gravel	Fine gravel	Sand	Mud	Veg.
East Branch at Lisnatunny	8	85	7	1	0	0	31	41	16	8	3
West Branch at SH8	24	43	33	25	12	18	26	11	1	4	4
Main stem at Coal Gully Road	90	10	0	0	0	10	25	25	5	0	35

The hydraulic modelling component of in-stream habitat modelling made predictions over how water depth, channel width and water velocity will change with changes in flow at each of the three sites. As expected, water depth, channel width and water velocity all increase with increasing flow at the three sites, although the pattern of change differs depending on channel morphology (including channel gradient, channel profile) (Figure 5.1).

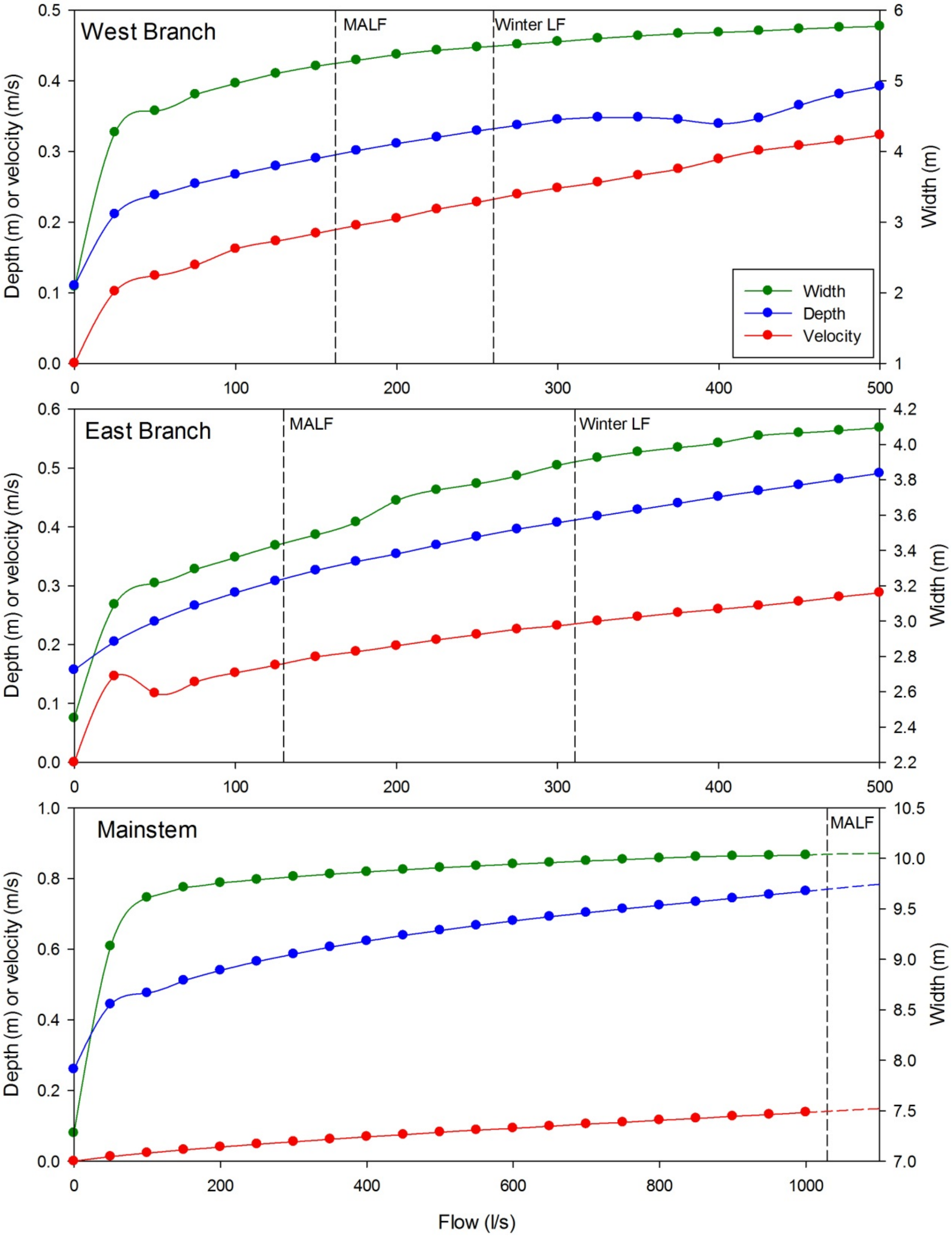

Figure 5.1 Changes in mean channel width, mean water depth and mean water velocity with changes in flow at three sites in the Tokomairiro catchment. Habitat-flow curves for the main stem site were extrapolated to the mean annual low flow (dashed lines).

5.3.2. Native fish habitat

Habitat for seven native fish species was modelled across the three sites in the Tokomairiro catchment, based on the distribution of species within the catchment.

Of the native fish species considered in the West Branch, habitat for longfin and shortfin eels increased only modestly with increasing flow above 50 l/s and did not show a distinct optimum across the modelled range (Figure 5.2). Common and upland bullies and Clutha flathead galaxias had distinct peaks in habitat within the modelled flow range (Figure 5.2, Table 5.3). A flow of 225 l/s was predicted to provide optimum habitat for common bullies, while optimum for upland bullies was predicted at flows of between 75-100 l/s(Figure 5.2, Table 5.3). Optimal habitat for Clutha flathead galaxias was predicted to occur at 175-200 l/s (Figure 5.2). Habitat for juvenile lamprey increased across the modelled range (Figure 5.2).

In the East Branch, habitat for longfin and shortfin eels was insensitive to flow across the modelled range, except below 25 l/s (Figure 5.2). Habitat for upland bullies decreased with increasing flow across the flow range 50-500 l/s, while habitat for redfin bullies peaked at 100 l/s (Figure 5.2). In contrast, habitat for common bullies was optimum at 200-225 l/s (Figure 5.2). Habitat for juvenile lamprey increased across the modelled range (Figure 5.2).

In the main stem, habitat for longfin and shortfin eels, common bullies and juvenile lamprey decreased with increasing flow across the modelled flow range (Figure 5.2). Habitat for inanga was predicted to peak at between 150 and 200 l/s (Figure 5.2).

Table 5.3 gives the optimum flows and points of inflection of available habitat for native fish in the Tokomairiro River. If the point of inflection or optimum flow is above MALF for a site, this suggests that the available habitat is limited naturally by low flows. Another way of considering the effects of flow alteration is to consider the flow that provides a percentage of the habitat available at MALF, where the percentage of habitat retention was dependent on the relative ecological/recreational values of the species, as assessed in Section 4.3 (Table 4.3).

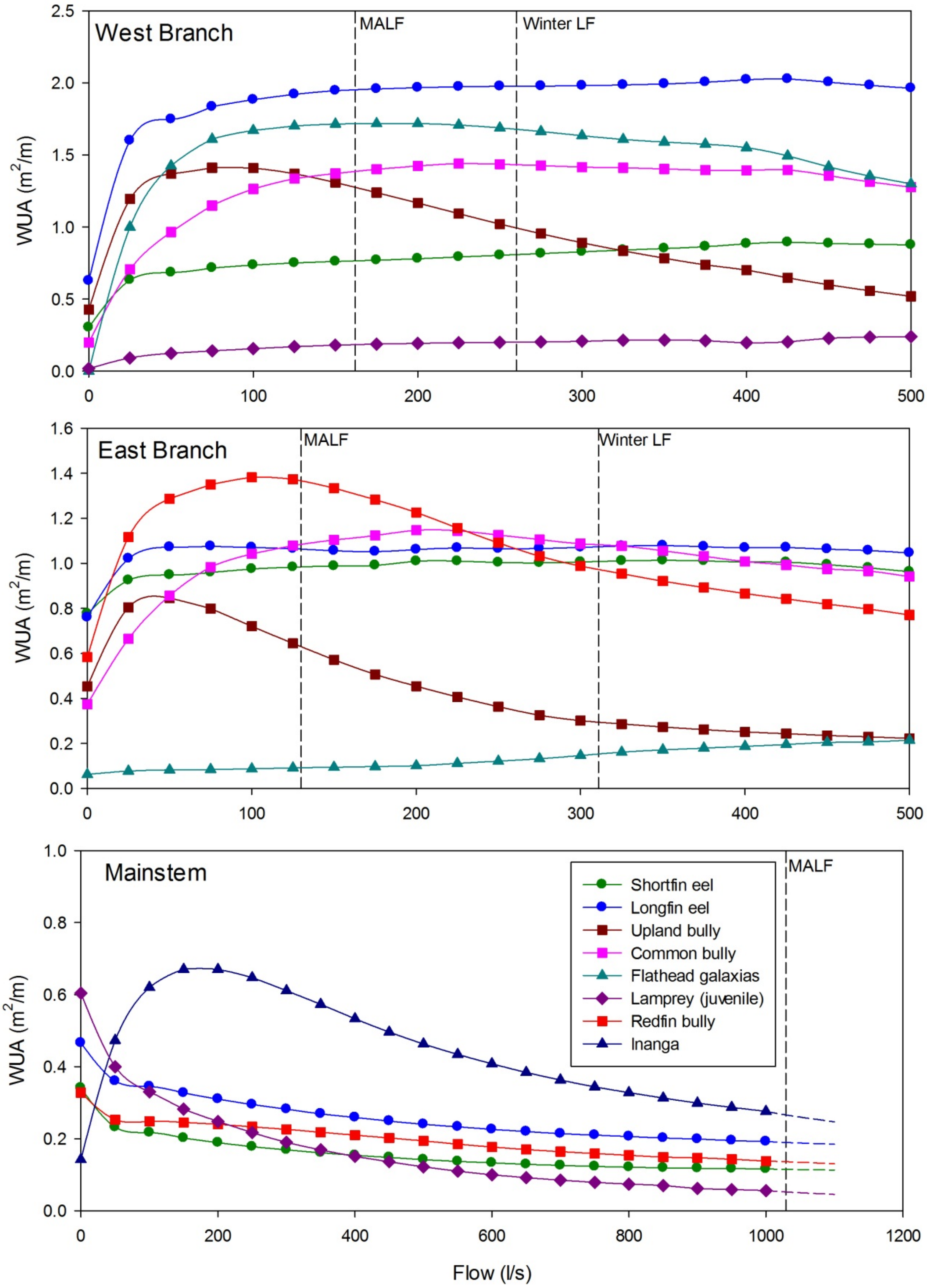

Figure 5.2 **Variation in in-stream habitat of native fish, in relation to flow, in the lower Tokomairiro River. Habitat-flow curves for the main stem site were extrapolated to the mean annual low flow (dashed lines).**

Table 5.3 **Recommended flows requirements for native fish habitat in the Tokomairiro River, based on the IFIM analysis of Jowett (2005).**

Species	Optimum flow (l/s)	Point of inflection (l/s)	Flow at which the recommended % habitat retention occurs (l/s)
West Branch at SH8			
Shortfin eel	-	25	<25
Longfin eel	-	25	<25
Upland bully	75-100	37	<25
Common bully	225	105	37
Flathead galaxias	175-200	75	103
Lamprey (juvenile)	-	-	85
East Branch at Lisnatunny			
Shortfin eel	325-375	-	<25
Longfin eel	325-350	-	<25
Upland bully	50	31	<25
Common bully	200-225	113	<25
Redfin bully	100	48	<25
Lamprey (juvenile)	-	-	<25
Main stem at Coal Gully Road			
Shortfin eel	<50	-	-
Longfin eel	<50	-	-
Redfin bully	<50	-	-
Inanga	150-200	73	-
Lamprey (juvenile)	<50	-	-

5.3.3. Brown trout habitat

Brown trout adult, juveniles and spawning habitat was modelled for the three sites. However, given the physical nature of the main stem site (including fine substrate, macrophytes), spawning habitat was not considered for this site.

In the West and East Branches, habitat for adult and juvenile brown trout increased across the modelled flow range (Figure 5.3a & b). Spawning habitat was highest at 375-400 l/s in the West Branch (Figure 5.3a) and peaked at 225-275 l/s in the East Branch (Figure 5.3b). In the main stem at Coal Gully Road, adult habitat increased across the modelled flow range, while juvenile habitat peaked at 600-750 l/s, with little change in predicted habitat over the range 500-1000 l/s (Figure 5.3).

Recommended flows for each of the three locations in the Tokomairiro catchment were determined based on the results of in-stream habitat modelling. Table 5.4 gives the optimum flows and points of inflection of available habitat for brown trout in the Tokomairiro River.

For both branches of the Tokomairiro River, a higher minimum flow is recommended for the brown trout spawning season (1 May-30 September) than for the irrigation season (1 October-31 April). This reflects the seasonal variation in flows observed in the catchment, with low flows typically observed in summer or autumn (7-day MALF c.f. 7-d winter low flows in Table 5.5). Habitat retention for brown trout spawning was assessed relative to the 7-day mean winter low flow (260 l/s for the West Branch at SH8 and 311 l/s for the East Branch at Lisnatunny).

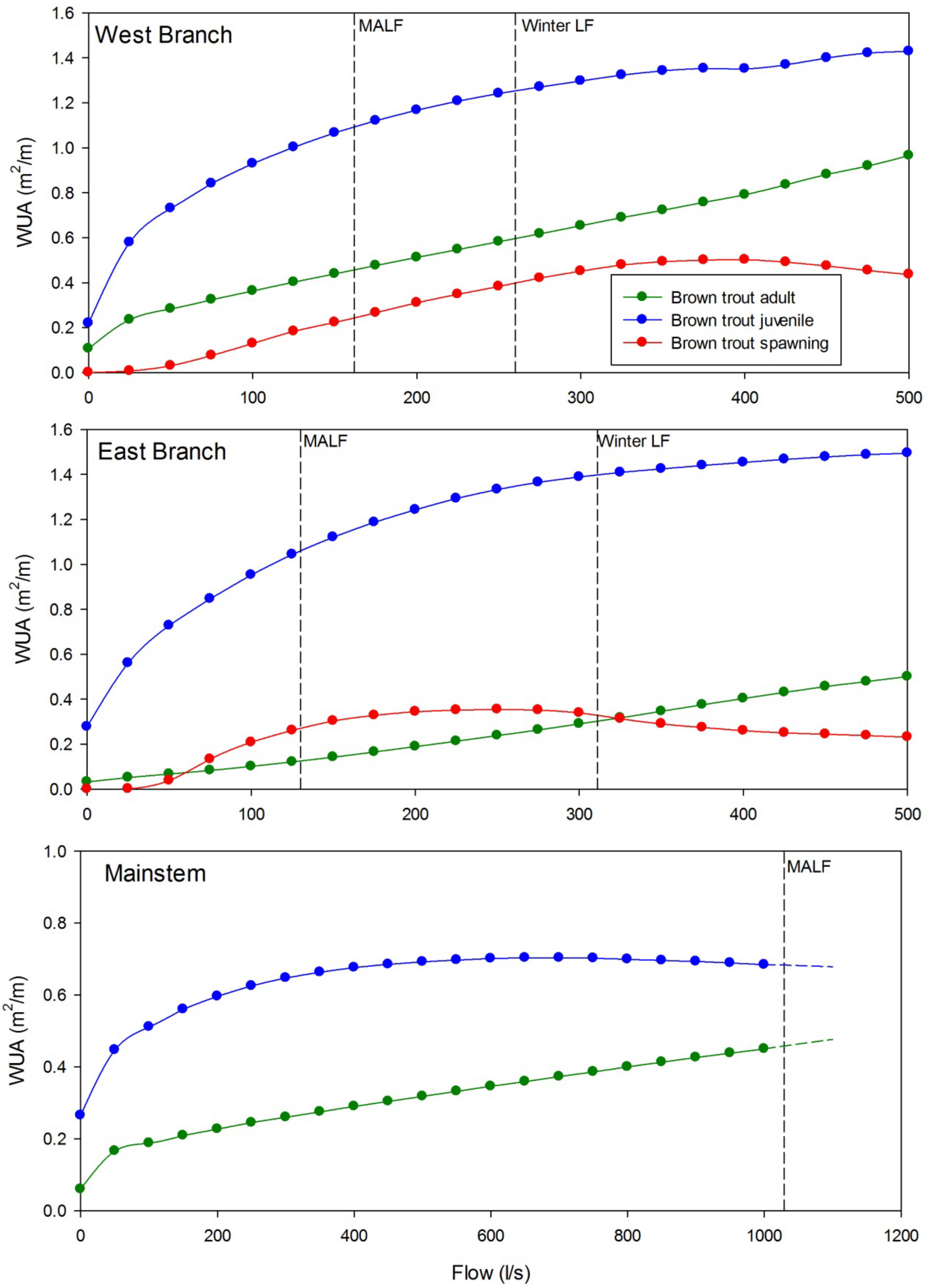

Figure 5.3 **Variation in instream habitat of various life-stages of brown trout, relative to flow, in the Tokomairiro River. Dotted lines represent the 7-d mean annual low flow (MALF) and 7-d winter mean low flow (Winter LF) for each site. Habitat-flow curves for the main stem site were extrapolated to the mean annual low flow (dashed lines).**

Table 5.4 Recommended flow requirements for brown trout habitat in the Tokomairiro River, based on the IFIM analysis of Jowett (2005). Values marked with an asterisk (*) indicates that percent habitat retention for spawning was assessed relative to habitat availability at the mean winter (May-September) low flow.

Species	Optimum flow (l/s)	Point of inflection (l/s)	Flow at which the recommended % habitat retention occurs (l/s)
West Branch at SH8			
Adult habitat	-	-	72
Juvenile habitat	-	-	38
Spawning habitat	375-400	310	205*
East Branch at Lisnatunny			
Adult habitat	-	-	81
Juvenile habitat	-	210	53
Spawning habitat	225-275	110	126*
Main stem at Coal Gully Road			
Adult habitat	-	-	507
Juvenile habitat	600-750	285	73

5.3.4. Dissolved oxygen

In addition to modelling the effect of flow on habitat availability for various species of fish, Jowett (2005) also considered the effect of flow on dissolved oxygen concentrations in the lower Tokomairiro River, due to concerns that the high biomass of macrophytes could result in dissolved oxygen dropping below the recommended limit for salmonids (6 mg/l).

A dissolved oxygen model parameterised based on data collected from the lower Tokomairiro River indicated that dissolved oxygen concentrations would not fall below 6 mg/l until flows were below 80 l/s (Jowett 2005).

5.4. Summary of instream habitat modelling

For both branches of the Tokomairiro River, a higher minimum flow is recommended for the brown trout spawning season (1 May-30 September) than for the irrigation season (1 October-31 April).

In the West Branch at SH8, a minimum flow of 72 l/s (206 l/s at the confluence) during the irrigation season would adequately protect the brown trout fishery. The optimal flow for spawning habitat (375-400 l/s) exceeded the 7-d winter low flow (260 l/s) and given the limited availability of suitable spawning habitat in the Tokomairiro catchment, it is recommended that during the trout spawning season, flow abstraction should cease when flows drop to below 260 l/s (Table 5.5).

In the East Branch during the irrigation season a minimum flow of 80 l/s would maintain 70% of the brown trout adult habitat available at MALF (Table 5.5). The optimal flow for spawning habitat was 225-275 l/s and given the limited availability of suitable spawning habitat in the Tokomairiro catchment, it is recommended that during the trout spawning season, flow abstraction should cease when flows drop below 250 l/s (Table 5.5).

In the main stem, it is recommended that a minimum flow of 600 l/s would provide optimum habitat for juvenile brown trout (Table 5.5).

Table 5.5 Recommended flows to maintain fish habitat in the Tokomairiro River, based on the IFIM analysis of Jowett (2005).

Site	Season	7-d MALF (l/s)	7-d Winter low flow (l/s)	Recommended flow at modelled location (l/s)	Equivalent flow at confluence (l/s)	Reason
West Branch at SH8	**Summer**	162		72	206	Brown trout adult habitat
	Winter		260	260	741	Trout spawning habitat (maintain existing)
East Branch at Lisnatunny	**Summer**	130		80	169	Brown trout adult habitat
	Winter		311	250	528	Trout spawning habitat (optimum)
Main stem at Coal Gully Road	**All year**	1029	-	600	-	Brown trout habtiat – juvenile (optimal) and adult (76% retention of habitat at MALF)

5.5. Flow distributions analysis

The recommended flows required to maintain fish habitat have been compared to the flow distribution for the three sites in the Tokomairiro River. Flow distributions were calculated for the irrigation season (October to April, inclusive) and the non-irrigation season (May to September).

Table 5.6 shows the percentage of time and the average number of days that flows in the Tokomairiro River drop below the flows recommended to protect in-stream values.

On average, flows in the East and West Branches are expected to drop below recommended summer environmental flows on fewer than 5 days per irrigation season (Table 5.6). This suggests that the implementation of these recommended environmental flows would have a limited effect on water availability during the irrigation season. Higher recommended environmental flows during the trout spawning season would have a greater effect on the availability of water (Table 5.6), although water demand is expected to be low during this period and any environmental flows would not apply to stock water or household supply.

Flows in the main stem are expected to drop below the recommended environmental flow on thirteen days per year, on average (Table 5.6).

Table 5.6 Comparison of the amount of time that flows are below those recommended to maintain habitat for fish species in the Tokomairiro River

Site	Season	Recommended flow (l/s)	Percentage of time minimum flow exceeded	Number of days
West Branch at SH8	**Summer**	72	99.4	2
	Winter	260	92.6	11
East Branch at Lisnatunny	**Summer**	80	99.4	1
	Winter	250	95.3	7
Main stem at Coal Gully Road	**All year**	600	98.4	6

6. Conclusions: Flow requirements for aquatic ecosystems in the Tokomairiro River

Under the Regional Plan: Water Otago, rivers will have minimum flows set to provide for the maintenance of aquatic ecosystems and natural character under low flow conditions. Furthermore, under the Plan, when minimum flow levels are reached, all consent holders subject to the minimum flow are to cease taking . The purpose of this report is to support policy development by providing information on the values present in the Tokomairiro catchment, the existing use of water resources and the flows required to maintain in-stream habitat based on in-stream habitat modelling.

The Tokomairiro catchment supports high ecological values including several threatened native fish including Eldon's galaxias (nationally endangered – Allibone et al., 2010), Clutha flathead galaxias (nationally vulnerable – Allibone et al., 2010), longfin eels, lamprey, inanga and redfin bullies (declining – Allibone et al., 2010). In addition, it supports a locally significant trout fishery (Otago Fish & Game Council, 2003).

In all cases, habitat for adult brown trout was the most flow-sensitive in-stream value during the irrigation season, while trout spawning was the critical value in the two branches during winter. The results of in-stream habitat modelling indicate that flows to maintain habitat for adult brown trout in summer and trout spawning in winter months (May-September) will also maintain other fish values.

Existing allocation in the Tokomairiro is relatively modest, with 147.59 l/s allocated, compared with an allocation limit of 514.5 l/s. This current level of allocation is unlikely to have an impact on flushing flows. However, the majority of allocation (142.3 l/s, 96% of the total) is from the East Branch, meaning that allocation is much higher in this branch. However, two of the largest takes (combined maximum consented take: 102 l/s) are located a short distance upstream of the confluence, meaning that the reach affected by these takes is relatively short and that flow variability in the main stem will be maintained by flows from the West Branch, which has a very low level of allocation.

7. 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 drained by a river or body of water.

Consumptive use
A use 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.

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Appendix 1

Synthetic flow record for the Tokomairiro River, downstream of the confluence

A synthetic flow record was calculated for the main stem of the Tokomairiro River at Coal Gully Road, 6.4 km downstream of the confluence. The flow in the West Branch at the confluence was calculated by time-shifting the flow record at the West Branch bridge recorder by 5 h and scaling-up flows based on the ratio of the total catchment area of the West Branch to the catchment area upstream of the West Branch bridge (ratio=2.85). A synthetic dataset for the East Branch at Lisnatunny was calculated using the following regression between flows at the West Branch bridge flow recorder and 5 h time-shifted flows at the Lisnatunny recorder between 8 February 2012 and 24 February 2012:

$$Lisnatunny = -0.0166(West\ Branch\ Bridge)^2 + 1.1393((West\ Branch\ Bridge)$$

This equation applies to flows at the West Branch Bridge up to 35 m^3/s. This synthetic dataset was then scaled-up based on the ratio of the total catchment area of the East Branch to the catchment area upstream of the Lisnatunny recorder (ratio=2.11).

The synthetic flow record was calculated for the main stem of the Tokomairiro River at Coal Gully Road by combining the calculated flows of both branches and scaling-up this flow based on the ratio of total catchment area upstream of the Coal Gully Road bridge to the catchment area upstream of the confluence (ratio = 1.05).

Appendix 2

Guidelines for habitat retention required for instream values (Jowett & Hayes, 2004).

Critical value	Fishery value	Significance ranking	Recommended % of habitat retention
Large adult trout - perennial fishery	High	1	90
Diadromous galaxiid	High	1	90
Non-diadromous galaxiid	-	2	80
Trout spawning/juvenile rearing	High	3	70
Large adult trout - perennial fishery	Low	3	70
Diadromous galaxiid	Low	3	70
Trout spawning/juvenile rearing	Low	5	60
Bully species	-	5	60