Management Flows for Aquatic Ecosystems in the Poumāhaka River

October 2024

Otago Regional Council

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

Report writer: Dean Olsen, Freshwater Scientist, Otago Regional Council
External reviewer: Bridget Bosworth, Gisborne District Council.
Internal reviewer: Jason Augspurger, Senior Scientist, Otago Regional Council.

Published October 2024

Acknowledgements
The author would like to thank the ORC Environmental Monitoring team for the collection and verification of the hydrological data used in this report.

Otago Regional Council

Executive summary

The Poumāhaka[1] River is a medium-sized river (catchment area: 2,060 km^2), which rises in the Kōpūwai (the Old Man Range) in south-west Otago. The upper catchment consists of tussock grasslands and extensively grazed grasslands, while land use in the middle and lower reaches is more intensive, with more than 120 dairy farms in the catchment.

The Poumāhaka catchment is within the Lower Clutha Rohe within the Clutha/Mata-Au Freshwater Management Unit (FMU). The current minimum flow and allocation in the Poumāhaka catchment was added to the Regional Plan: Water by Plan Change 3B, which was notified on 16 August 2014 and became operative on 1 June 2015. Schedule 2A of the RPW specifies a minimum flow for primary allocation at Burkes Ford of 3,600 l/s (1 October to 30 April) or 7,000 l/s (1 May to 30 September). The primary allocation limit specified for the Poumāhaka catchment in Schedule 2A is 1,000 l/s.

The purpose of this report is to present information to inform water management decision-making in the Poumāhaka catchment. This includes hydrological information (including flow naturalisation and flow statistics), data on aquatic values (including the distribution of indigenous fish), application of instream habitat modelling to guide flow-setting processes, and consideration of the current state of the Poumāhaka River compared to the proposed objectives for the Lower Clutha Rohe set out in the proposed Otago Land and Water Regional Plan.

The flow statistics based on the analysis of Lu (2023) are summarised below:

Site		Flow statistics (m^3/s)			Low flow return interval analysis (7-day moving average) (m^3/s)	
		Mean	Median	7d MALF (Jul-Jun)	5-year ($Q_{7,5}$)	10-year ($Q_{7,10}$)
Pomahaka at Burkes Ford	Naturalised flows	25.376	16.540	3.521	2.583	2.474
	Observed flows	25.255	16.411	3.455	-	-
	Otago Regional Council 2006	26.9	-	4.3	-	-
Waipahī at Waipahī	Naturalised flows	4.778	2.521	0.547	-	-
	Observed flows	4.774	2.518	0.540	-	-

There are twenty-nine permits for primary allocation in the Poumāhaka River (Table 4). The purpose of twelve of these permits includes irrigation, along with stock water, dairy shed water, frost fighting and domestic use in some cases (combined maximum consented rate of take = 1,247.5 l/s). There are four permits for town or rural water supply schemes (combined maximum consented rate of take = 114.3 l/s), ten permits for dairy shed and stock water (combined maximum consented rate of take = 20.2 l/s) and

[1] https://kahurumanu.co.nz/atlas

three non-consumptive[2] takes for the purpose of operating gold-mining equipment (sluices) in the Poumāhaka catchment (combined maximum consented rate of take = 59.5 l/s).

Periphyton cover in the upper Poumāhaka at Aitchison Runs Road has typically been low, typically dominated by thin to medium light brown and dark brown/black films/mats, likely composed of diatoms and benthic cyanobacteria. Cover by thick mats and/or filamentous algae has typically been low at this site. The periphyton community in the Waipahī at Waipahī has been variable, but thin to medium light brown and dark brown/black films/mats (likely diatoms and benthic cyanobacteria) have typically had the highest cover. High cover by filamentous algae has been observed on several occasions, although it has only exceeded 30% on one occasion. Chlorophyll a concentrations in the upper Poumāhaka at Aitchison Runs Road were consistently low (A-band) with the exception of a single occasion which was close to the upper limit of B-band, placing this site in A-Band. Chlorophyll *a* concentrations in the Waipahī at Waipahī were low (A-band) but several periods of high biomass were observed in the 2021 and 2022 seasons, with several values in excess of 150 mg/m^2 observed over this period. Observed chlorophyll a concentrations in the Waipahī at Waipahī place this site in D-band (below the national bottom line).

The cased caddis fly (*Pycnocentrodes*), and the mudsnail *Potamopyrgus* were the most abundant taxa collected in the Poumāhaka at Burkes Ford, while riffle beetles (Elmidae), the cased caddis fly (*Pycnocentrodes*), the common mayfly *Deleatidium* and the net-spinning caddis fly *Hydropsyche* (*Aoteapsyche*) were among the most abundant macroinvertebrate taxa collected in the Poumāhaka at Glenken. The common mayfly *Deleatidium* and riffle beetles (Elmidae) were among the most abundant macroinvertebrate taxa collected in the Upper Poumāhaka at Aitchison Runs Road. MCI scores based on the limited sampling available for Burkes Ford put this site in C-band of the National Objectives Framework (NOF), while scores for Glenken and Aitchison Runs Road put this site in B-band of the NOF. SQMCI scores for Burkes Ford put this site in D-band of the NOF and below the national bottom line, while SQMCI scores for Glenken and Aitchison Runs Road put this site in B-band of the NOF.

MCI and SQMCI scores for Waipahī at Waipahī and Cairns Peak put these sites in C-band of the NOF.

Six species of indigenous freshwater fish have been recorded from the Poumāhaka catchment including three species that are at risk or threatened – longfin eel (at risk – declining), Pomahaka galaxias (threatened – nationally vulnerable), and kanakana/lamprey (threatened – nationally vulnerable). Recent genetic studies have identified two distinct lineages of non-migratory galaxias in the Poumāhaka catchment – a flathead species (referred to as *G.* “Pomahaka”) and a new roundhead lineage (*Galaxias* “species Z”). Brown trout, rainbow trout and chinook salmon have also been collected from the Poumāhaka catchment. The Poumāhaka River supports a regionally important sport fishery for both resident and sea run brown trout, while the upper Poumāhaka River has backcountry characteristics and the Waipahī River is recognised as a regionally important brown trout fishery.

The updated hydrological analysis of Lu (2023) estimates the 7-d MALF at 3.5 m^3/s, suggesting that the current minimum flow is set at a value very close to the 7-d MALF. Thus, it will result in habitat retention levels that are very close to those at the natural 7-d MALF for all species considered. Given this and the low level of actual water usage in the Poumāhaka catchment it appears that the water allocation is

[2] Where water taken is immediately returned to the source water body

unlikely to contribute to the observed exceedances of aquatic ecology and water quality objectives in the Poumāhaka catchment.

The existing minimum flow and allocation limit are predicted to result in a hydrograph that is unimpacted relative to naturalised flows (based on the DHRAM score). However, periphyton biomass in the Waipahī at Waipahī exceeds both the LWRP objectives for the Lower Clutha Rohe and the national bottom line (based on Table 2 of the NOF; NPSFM 2022). Water abstraction can affect periphyton accrual and may contribute to high periphyton biomass and exceedance of periphyton targets. However, given the very low level of actual use in the Waipahī sub-catchment, water allocation is unlikely to have contributed meaningfully to the high biomasses observed in the Poumāhaka catchment.

Contents

Otago Regional Council

List of figures

List of tables

Glossary

Catchment	The area of land drained by a river or body of water.
Existing flows	The flows observed in a river under current water usage and with current water storage and transport.
Habitat suitability curves (HSC)	Representations of the suitability of different water depths, velocities and substrate types for a particular species or life-stage of a species. Values vary from 0 (not suitable) to ideal (1). HSC are used in instream habitat modelling to predict the amount of suitable habitat for a species/life-stage.
Instream habitat modelling	An instream habitat model used to assess the relationship between flow and available physical habitat for fish and invertebrates.
Irrigation	The artificial application of water to the soil, usually for assisting the growing of crops and pasture.
7-d Mean Annual Low Flow (7-d MALF)	The average of the lowest seven-day low flow for each year of record
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.
Natural flows	The flows that occur in a river in the absence of any water takes or any other flow modification.
Naturalised flows	Synthetic (calculated) flows created to simulate the natural flows of a river by removing the effect of water takes or other flow modifications.
Reach	A specific section of a stream or river.
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.

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

1 Introduction

The Poumāhaka[3] River is a medium-sized river (2,060 km^2), which rises in the Kōpūwai (the Old Man Range) in south-west Otago. The upper catchment consists of tussock grasslands and extensively grazed grasslands, while land use in the middle and lower reaches is more intensive, with many dairy farms.

The Poumāhaka catchment is within the Lower Clutha Rohe within the Clutha/Mata-Au Freshwater Management Unit (FMU). The current minimum flow and allocation in the Poumāhaka catchment was added to the Regional Plan Water (RPW) by Plan Change 3B, which was notified on 16 August 2014 and became operative on 1 June 2015. Schedule 2A of the RPW specifies a minimum flow for primary allocation at Burkes Ford (Figure 1) of 3,600 l/s (1 October to 30 April) or 7,000 l/s (1 May to 30 September). The primary allocation limit specified for the Poumāhaka catchment in Schedule 2A is 1,000 l/s (at the time of writing the actual primary allocation is 1.25955 m^3/s – see Section 4.1.1).

The Poumāhaka River is significant to local iwi for mahika kai and other cultural values and is a Statutory Acknowledgement area under the Ngai Tahu Claims Settlement Act 1998 (Schedule 52), providing for the special association of Ngati Mamoe and Ngai Tahu kainga (settlements) in the Catlins and Tautuku areas, with the river.

Water abstraction in the upper Poumāhaka catchment consists of permits for suction dredging for gold mining and rural water supply schemes (Moa Flat and Glenkenich Rural Water Supply Schemes), while takes from tributaries in the middle and lower reaches are for irrigation, stock water, dairy shed supply and town supply.

Degrading trends in water quality in the lower Poumāhaka catchment were recognised in the early 2000's and attributed to land use intensification including conversion of historical sheep farms to dairy farms on poorly draining soils drained by tile and mole drains (Otago Regional Council 2010). The Pomahaka Water Care Group (https://www.pwcg.co.nz/) was formed in 2014 to address degrading water quality. While long-term trends (20-year) continue to indicate that water quality has declined, short-term trends (10-year) in water quality in the lower Pomahaka indicate that many of the water quality variables are improving (Ozanne et al. 2023).

1.1 Purpose of the report

The purpose of this report is to present information to inform water management decision-making in the Poumāhaka catchment. This includes hydrological information (including flow naturalisation and flow statistics), data on aquatic values (including the distribution of indigenous fish), application of instream habitat modelling to guide flow-setting processes, and consideration of the current state of the Poumāhaka River compared to the proposed objectives for the Lower Clutha Rohe set out in the proposed Otago Land and Water Regional Plan (LWRP).

[3] https://kahurumanu.co.nz/atlas

2 Background information

2.1 Catchment description

The Poumāhaka River flows for approximately 98 km from the Kōpūwai (Old Man Range) to enter the Clutha River/Mata-Au approximately 6 km downstream of Clydevale and 16 km upstream of Balclutha/Iwikatea. The catchment has a total area of 2,060 km^2 (Figure 1). Major tributaries include the Waipahī, Heriot Burn, Wairuna Stream, Waikoikoi Creek, Spylaw Burn and Leithen Burn.

2.1.1 Climate

The climate within the Poumāhaka catchment is classified as either 'cool-dry' (mean annual temperature <12°C, mean annual effective precipitation ≤500 mm) or 'cool-wet' (mean annual temperature <12°C, mean annual effective precipitation 500-1500 mm) (River Environment Classification, Ministry for the Environment & NIWA, 2004). There is a strong gradient in rainfall within the catchment, with more than a metre of rain falling in the higher elevation areas in the upper catchment (1001-1250 mm; Umbrella Mountains and Black Umbrella Range) and Blue Mountains (1251-1500 mm), while mean annual rainfall in the lower catchment is as low as 650-700 mm (Figure 2).

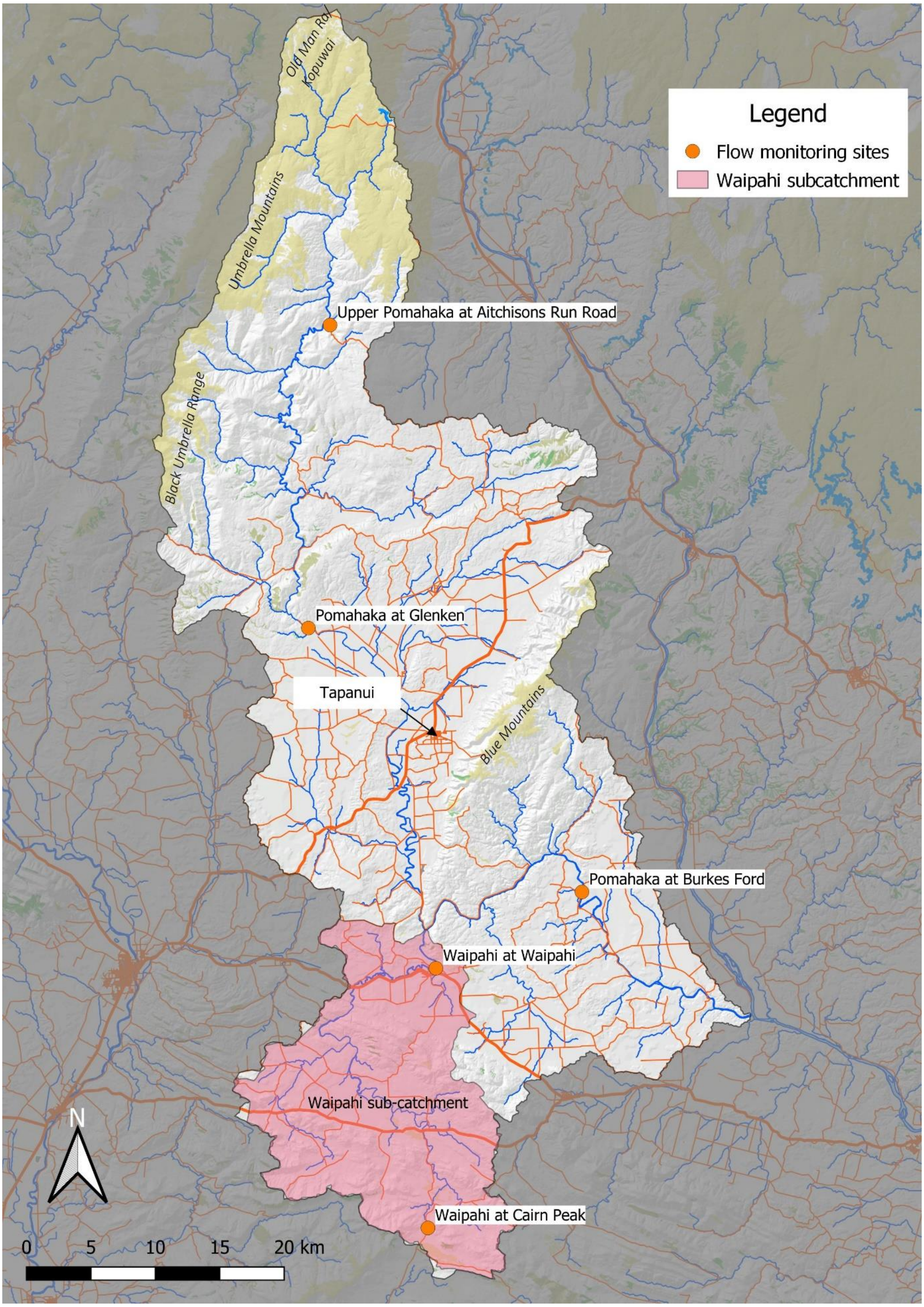

Figure 1 Map of the Poumāhaka catchment showing the sub-catchments and flow recorder site.

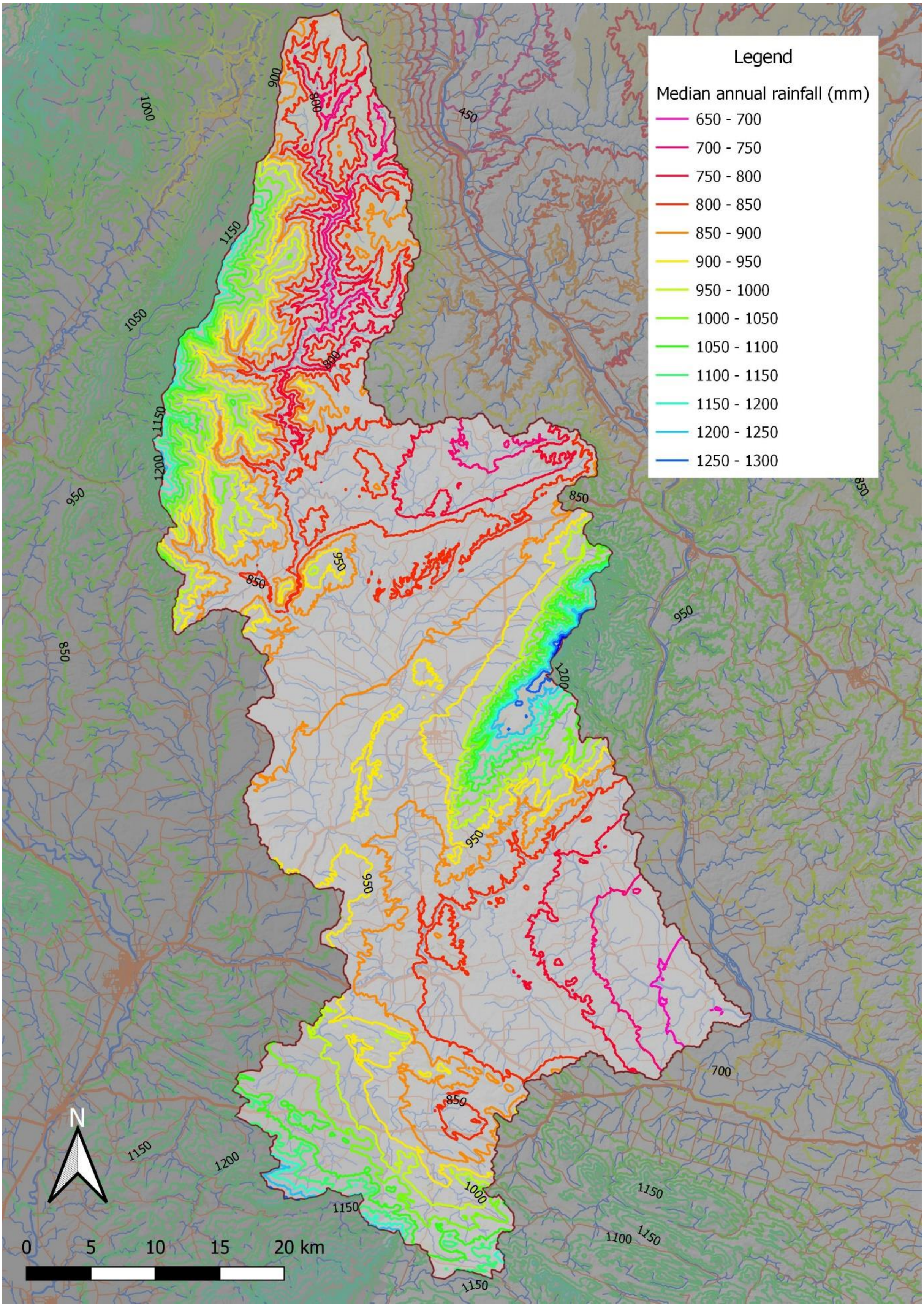

Figure 2 Distribution of rainfall (annual median rainfall) in the Poumāhaka catchment.

2.1.2 Geological setting

The geology of much of the upper Poumāhaka catchment consists mainly of semischist, the middle reaches dominated by quaternary sediments, while the geology of the lower catchment is complex, with the Southland Syncline and multiple faults (including the Hillfoot and Livingstone Faults) crossing the Waipahī catchment in a northwest-southeast direction (Forsyth 2001). The basement rock in much of the lower catchment is composed of sandstones, siltstones, and mudstones of the Dun Mountain-Maitai, Murihiku and Caples (Schist) Terranes (Turnbull & Allibone 2003).

The upper Poumāhaka River consists of confined channels cutting into schist bedrock, with a mixed gravel and bedrock bed. The middle reaches of the Poumāhaka River is a dynamic system where flood events and sediment transport regularly cause changes in riverbed morphology and changes in the longitudinal profile of the riverbed occur due to aggradation and degradation along the channel, and as a result of lateral bank erosion (Williams 2016).

2.1.3 Vegetation and land use

Vegetation cover in the upper Poumāhaka catchment is mainly tussock and low producing pasture, much of which is extensively grazed with some indigenous forest in the Leithenburn catchment and some exotic forestry in the Leithen Burn catchment and Dusky Forest (Figure 3). The middle and lower reaches of the catchment are dominated by high producing pastures, with areas of indigenous and exotic forest in the Blue Mountains (Figure 3).

Land use in the upper catchment is dominated by sheep and beef farming, while dairy farming dominates much of the lower catchment (Figure 4).

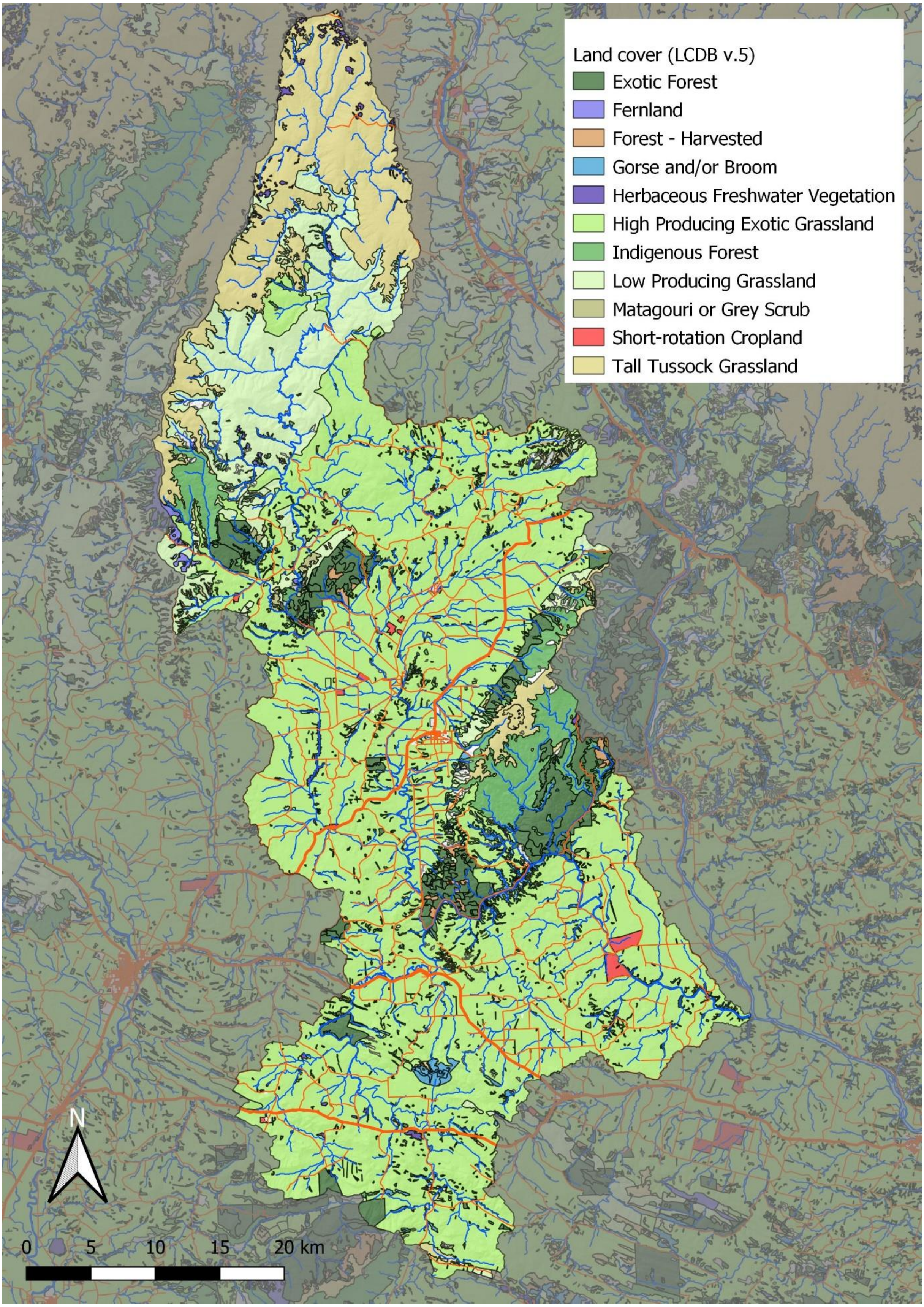

Figure 3 Land cover in the Poumāhaka catchment.

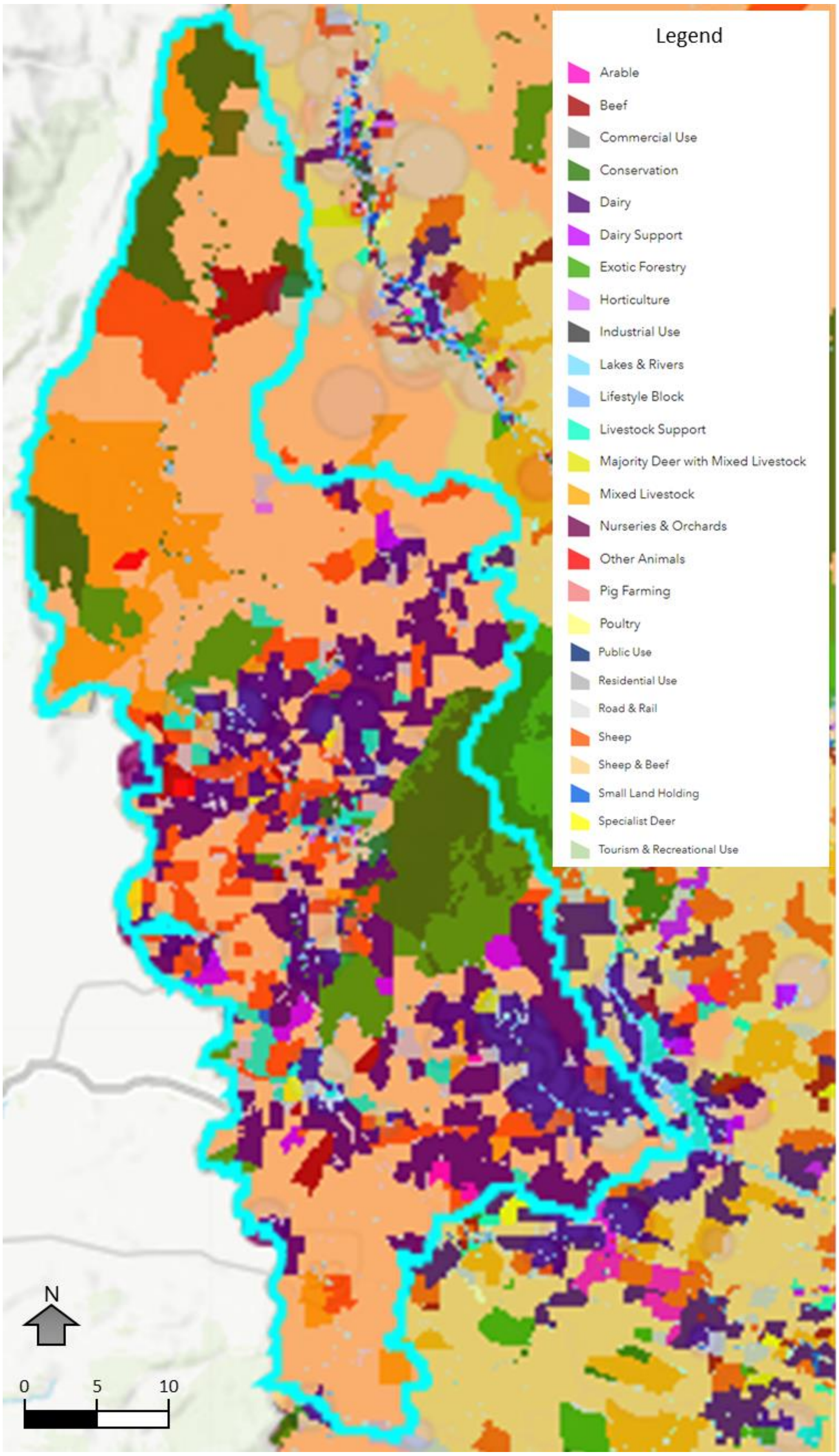

Figure 4 Farm types in the Poumāhaka River catchment based on Agribase[4] (March 2023). Cyan outline is the Poumāhaka catchment boundary.

[4] https://www.asurequality.com/services/agribase/

3 Regulatory setting

3.1 Regional Plan: Water (RPW)

The current minimum flow and allocation in the Poumāhaka catchment was added to the RPW by Plan Change 3B, which was notified on 16 August 2014 and became operative on 1 June 2015.

Schedule 2A of the RPW specifies a minimum flow for primary allocation at Burkes Ford of 3.6 m^3/s (1 October to 30 April) or 7 m^3/s (1 May to 30 September). The primary allocation limit specified for the Poumāhaka catchment in Schedule 2A is 1,000 l/s. Primary allocation at the time of writing is 1.260 l/s (see Section 4.1.1).

In addition, Schedule 2B of the RPW specifies a minimum flow for the first supplementary allocation block of 13 m^3/s at Burkes Ford, with a supplementary allocation block size of 0.5 m^3/s. At the time of writing, there are no resource consents for supplementary takes from the Poumāhaka catchment.

3.2 Proposed Land and Water Plan

The ORC has undertaken a full review of the RPW, and the results of this review will be incorporated into a new Land and Water Regional Plan (LWRP). As part of consultation for the LWRP, objectives have been developed for the Lower Clutha Rohe, which includes the Poumāhaka catchment. The proposed objectives, valid at the time of writing, are presented in Table 1 and Table 2.

Table 1 Baseline state and target attribute states for the state of the environment monitoring sites in the Poumāhaka River. Values in brackets indicate the range of baseline states based on rollling averages.

Attribute		Pomahaka at Burkes Ford		Pomahaka at Glenken		Upper Pomahaka at Aitchison Runs Road	
		Baseline State	Target 2050	Baseline State	Target 2050	Baseline State	Target 2050
Periphyton Biomass						A	A
Periphyton TN		D	C	C	C		
Periphyton TP		D	C	D	C		
Ammonia - median		A	A	A	A		
Ammonia - 95th Percentile		A	A	A	A		
NNN - median		A	A	A	A		
NNN - 95th percentile		B	A	A	A		
Suspended fine sediment		D	C	D (D - C)	C		
E. coli	% exceed 260 cfu/100 mL	B (B - C)	C	D (C - D)	C		
	% exceed 540 cfu/100 mL	C	C	C (B - C)	C		
	Median	A	A	D	C		
	95th percentile	D	C	D (B - D)	C		
Fish IBI				C (D - C)	C (D - C)		
MCI							
ASPM							
DRP-median		C	C	B (A - B)	B		
DRP 95th percentile		B	B	A	A		

Otago Regional Council

Table 2 Baseline state and target attribute states for the state of the environment monitoring sites in the Waipahī sub-catchment.

Attribute		Waipahī at Cairns Peak		Waipahī at Waipahī	
		Baseline State	Target 2050	Baseline State	Target 2050
Periphyton Biomass				D	C
Periphyton TN		D	C	D	C
Periphyton TP		D	C	D	C
Ammonia - median		A	A	A	A
Ammonia - 95th Percentile		A	A	A	A
NNN - median		A	A	B	A
NNN - 95th percentile		B	A	B	A
Suspended fine sediment		C C - B)	C	A	A
E. coli	% exceed 260 cfu/100 mL	D	C	B (B - D)	C
	% exceed 540 cfu/100 mL	E (D - E)	C	C (B - C)	C
	Median	D	C	A (A - D)	A
	Q95	D	C	D (B - D)	C
Fish IBI		No data			
MCI		C (C - B)	C	D	C
ASPM		B (C - B)	C	D	C
DRP-median		C	C	C	C
DRP Q95		B (B - C)	B	C (B - C)	C

4 Hydrology

4.1 Flow statistics

A continuous flow recorder has been in place in the Poumāhaka River at Burkes Ford since August 1961. This site is located approximately 23.5 km upstream of where it enters the Clutha River/Mata-Au. Another long-term hydrological monitoring site on the mainstem is located at Glenken (June 1992 to present) and at Hamilton Flat (November 1995-November 1996).

Lu (2023) used available flow data for the Poumāhaka River at Burkes Ford and water use data to produce a naturalised flow time-series for the period 1 July 2013 to 24 June 2023. The flow statistics based on the analysis of Lu (2023) are summarised in Table 3.

The naturalised 7-d MALF calculated for the Poumāhaka River at Burkes Ford by Lu (2023) is considerably lower (-19%) than that estimated by ORC (2006). The estimates presented in ORC (2006) were based on 34 years of record, suggesting that the records used in these calculations spanned from the early 1970's to 2006. The accuracy of flow records prior to the 1990's, especially the low flow ratings, are questionable meaning that at least 20 years of the 34-year record used by ORC (2006) is of unknown quality (Stewart 2023).

Table 3 Flow statistics for the Poumāhaka River at Burkes Ford from Lu (2023).

Site		Flow statistics (m^3/s)			Low flow return interval analysis (7-day moving average) (m^3/s)	
		Mean	Median	7d MALF (Jul-Jun)	5-year ($Q_{7,5}$)	10-year ($Q_{7,10}$)
Pomahaka at Burkes Ford	Naturalised flows	25.376	16.540	3.521	2.583	2.474
	Observed flows	25.255	16.411	3.455	-	-
	ORC 2006	26.9	-	4.3	-	-
Waipahī at Waipahī	Naturalised flows	4.778	2.521	0.547	-	-
	Observed flows	4.774	2.518	0.540	-	-

The average number of events per year that exceed three times the median flow (FRE3) in the Poumāhaka River at Burkes Ford is 7.8 events per year (Lu 2023).

4.1.1 Water allocation

Primary allocation

There are twenty-nine permits for primary allocation in the Poumāhaka River (Table 4). The purpose of twelve of these permits includes irrigation, along with stock water, dairy shed water, frost fighting and domestic use in some cases (combined maximum consented rate of take = 1,247.5 l/s). There are four permits for town or rural water supply schemes (combined maximum consented rate of take = 114.3 l/s), ten permits for dairy shed and stock water (combined maximum consented rate of take = 20.2 l/s) and three non-consumptive[5] takes for the purpose of operating gold-mining equipment (sluices) in the Poumāhaka catchment (combined maximum consented rate of take = 59.5 l/s).

Water use in the Poumāhaka catchment is relatively consistent through the year, although it is typically highest between September and March (Figure 5). The actual take represents a small proportion (<15%) of the consented maximum rate of take (Figure 5). The lack of a clear seasonal pattern in water use in the Poumāhaka catchment is unusual compared to many other catchments in Otago, which exhibit strong seasonal variation. The pattern of water use in the Poumāhaka catchment likely reflects the mix of uses (e.g. dairy shed water, stock water and rural water supply) provided for by many of the consents in the catchment as well as variable demand for irrigation water due to the typically consistent, high rainfall in the Poumāhaka catchment (Macara 2015).

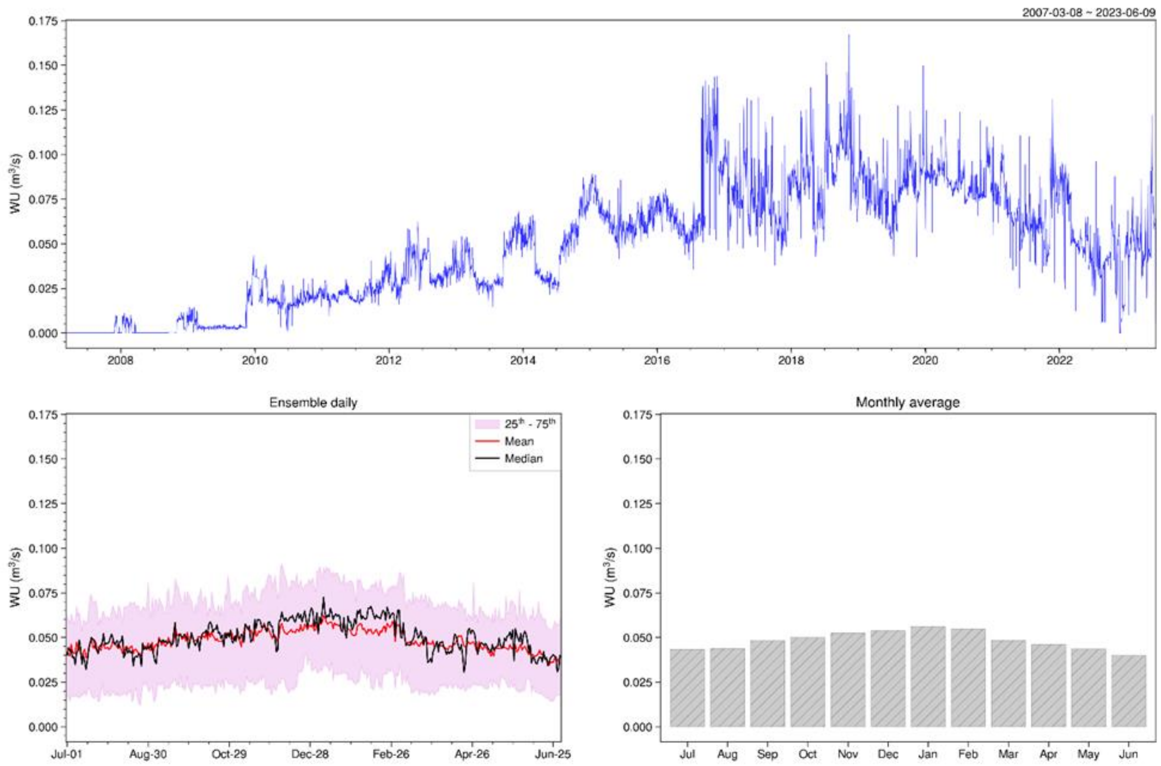

Figure 5 **Total water abstraction upstream of the Poumāhaka River at Burkes Ford. The lower, left plot presents the mean, median and inter-quartile range in daily water use across the hydrological year. Lower right plot presents the monthly mean water use. Reproduced from Lu (2023).**

[5] Where water taken is immediately returned to the source water body

Table 4 Active resource consents in the Poumāhaka catchment.

Consent Number	Expiry Date	Max rate (l/s)	Monthly volume (m³)	Annual volume (m³)	Activity	Source
2004.978.V2	1/09/2030	20		196,416	Irrigation	Dredge ponds within the Pomahaka catchment
2007.621.V1	1/06/2035	1	2170	25550	Dairy shed and stock water supply	Unnamed tributary of the Wairuna Stream
2008.458.V1	5/11/2038	2.5	3,920	35,280	Dairy shed and stock water supply	Pomahaka River
2009.224.V2	29/10/2034	2.3	5,400	65,700	Dairy shed and stock water supply	Unnamed tributary of the Pomahaka River
RM12.071.01	23/05/2042	4.55	7,084	31,193	Irrigation and frost fighting	Unnamed tributary of the Pomahaka River locally known as Pattersons Creek
RM12.346.01.V3	24/10/2047	81	188,055	893,261	Irrigation, stock water, dairy shed water	Pomahaka River
RM13.054.01.V1	1/06/2030	120	190,200	968,280	Irrigation, stock water, dairy shed water	Pomahaka River
RM13.264.01.V2	8/07/2038	160	193,184	885,478	Irrigation, stock water, dairy shed water	Pomahaka River
RM13.314.01.V1	26/08/2043	1.7	2,976	35,040	Dairy shed and stock water supply	Pomahaka River
RM13.333.01	9/10/2038	1.2	1,628	19,163	Dairy shed and stock water supply	Unnamed tributary of the Pomahaka River, locally known as Black Gully Stream
RM13.484.01.V1	6/05/2039	145	192,630	925,582	Irrigation, stock water, dairy shed water	Pomahaka River
RM13.487.01.V2	6/05/2039	109	147,908	710,742.50	Irrigation, stock water, dairy shed water	Pomahaka River
RM14.078.01.V1	24/04/2039	69	180,000	855,000	Irrigation	Pomahaka River
RM14.092.01.V1	2/07/2049	1.3	2,194.80	25,482	Stock water supply & storage	Unnamed tributary of Flodden Creek
RM14.163.01.V1	12/08/2039	40	59,400	297,000	Irrigation	Pomahaka River
RM14.175.01	20/11/2039	135	175,275	840,732	Irrigation, stock water, dairy shed water	Waipahī River
RM18.317.01	30/11/2028	6	2562	23058	Dairy shed and stock water supply	Pomahaka River
RM18.317.02	24/10/2047	107	234,000	1,111,500	Irrigation	Pomahaka River
RM19.033.01	1/12/2043	2.5	2,250	16,500	Dairy shed and stock water supply	Pomahaka River
RM20.324.01	25/02/2046	0.7		10,320		Unnamed tributary of the Pomahaka River
RM21.065.01	7/06/2028	83	145,326	873,259	Domestic use, irrigation and stockwater	Bullock Creek
RM21.565.01	3/02/2028	1	1800	21,600	Dairy shed and stock water supply	Pomahaka River
2000.418.V1	1/11/2030	17			Town water supply	Whisky Gully Recreation reserve,
2005.283.V2	12/07/2040	36			Rural Water Supply scheme	Pomahaka River
2009.142.V2	10/08/2045	15	40,176	473,040	Rural Water Supply scheme	Waipahī River
RM18.196.01	16/12/2028	46.3	4000	1460000	Rural Water Supply scheme	Timber Creek
RM15.330.02	22/01/2026	15.5	4017.6		Gold mining	Pomahaka River and Little Pomahaka
RM21.243.02	3/06/2033	22			Gold mining	Pomahaka River
RM21.431.03	22/07/2031	22			Gold mining	Pomahaka River

5 Water temperature

Water temperature is a fundamental factor affecting all aspects of stream systems. It can directly affect fish populations by influencing survival, growth, spawning, egg development and migration. It can also affect fish populations indirectly, through effects on physicochemical conditions and food supplies (Olsen et al., 2012). Of all the fish in the Poumāhaka catchment, brown trout (*Salmo trutta*) are likely to be the most sensitive to high water temperatures. Their thermal requirements are relatively well understood, and Todd *et al*. (2008) calculated acute and chronic thermal criteria for this species. The objective of acute criteria is to protect species from the lethal effects of short-lived high temperatures. In this case, acute criteria are applied as the highest two-hour average water temperature measured within any 24-hour period (Todd et al., 2008). In contrast, the intent of chronic criteria is to protect species from sub-lethal effects of prolonged periods of elevated temperatures. In this study, chronic criteria are expressed as the maximum weekly average temperature (Todd et al., 2008).

Water temperatures in the Poumāhaka River at Burkes Ford between 28 April 2004 and 19 September 2023 are presented in Figure 6 and Figure 7. Water temperatures in the Poumāhaka River at Burkes Ford exceeded acute (14% of years) and chronic thermal criteria (81% of years) for brown trout (Table 5). Of the indigenous species present in the Poumāhaka catchment, temperatures in exceeded acute criteria for the common mayfly *Deleatidium*, common bully, longfin eels and the sand-cased caddis fly *Pycnocentria* (Table 5).

Water temperatures in the Poumāhaka River at Glenken between 8 November 1995 – 26 June 1997; 29 April 2004 – 12 January 2011 are presented in Figure 6 and Figure 7. Water temperatures in the Poumāhaka River at Burkes Ford exceeded acute (20% of years) and chronic thermal criteria (30% of years) for brown trout (Table 5). Of the indigenous species present in the Poumāhaka catchment, temperatures in exceeded acute criteria for the common mayfly *Deleatidium*, common bully, longfin eels and the sand-cased caddis fly *Pycnocentria* (Table 5).

Water temperatures in the Waipahī River at Waipahī between; 19 December 2017 – 15 August 2023 are presented in Figure 10. Water temperatures in the Waipahī River at Waipahī exceeded acute (58% of years) and chronic thermal criteria (83% of years) for brown trout (Table 5). Of the indigenous species present in the Poumāhaka catchment, temperatures in exceeded acute criteria for the common mayfly *Deleatidium*, common bully, longfin eels and the sand-cased caddis fly *Pycnocentria* (Table 5).

These data suggest that the thermal environment of the Poumāhaka River at Burkes Ford and Glenken may be unsuitable at times for several of the indigenous and introduced fish species found in the catchment. Similarly, the thermal environment of the Waipahī River at Waipahī may also be unsuitable at times for several of the indigenous and introduced fish species found in the Waipahī River.

Table 5 Number of exceedances of thermal criteria at monitoring sites in the Poumāhaka catchment.

Site	Thermal criteria	Number of exceedances		Years with no exceedances	Total number of years
		Mean	Max		
Pomahaka at Burkes Ford (28 Apr 04 – 19 Sep 23)	Brown trout acute (>24.6°C)	1	19	18	21
	Deleatidium acute (21°C)	12	56	4	21
	Common bully, *Paracalliope* acute (22°C)	7	47	8	21
	Longfin eel, *Pycnocentria* acute (23°C)	4	34	11	21
	Aoteapsyche acute (24°C)	2	24	16	21
	Shortfin eel acute (26°C)	1	14	18	21
	Brown trout chronic (>19.6°C)	12	56	4	21
Pomahaka at Glenken (8 Nov 95-26 Jun 97; 29 Apr 04 – 12 Jan 11)	Brown trout acute (>24.6°C)	0	2	8	10
	Deleatidium acute (21°C)	8	25	3	10
	Common bully, *Paracalliope* acute (22°C)	4	13	3	10
	Longfin eel, *Pycnocentria* acute (23°C)	2	8	5	10
	Aoteapsyche acute (24°C)	1	5	8	10
	Shortfin eel acute (26°C)	0	1	9	10
	Brown trout chronic (>19.6°C)	2	6	7	10
Waipahī at Waipahī (19 Dec 17 – 15 Aug 23)	Brown trout acute (>24.6°C)	3	21	5	12
	Deleatidium acute (21°C)	23	65	1	12
	Common bully, *Paracalliope* acute (22°C)	14	49	1	12
	Longfin eel, *Pycnocentria* acute (23°C)	8	36	3	12
	Aoteapsyche acute (24°C)	5	28	4	12
	Shortfin eel acute (26°C)	1	10	9	12
	Brown trout chronic (>19.6°C)	14	56	2	12

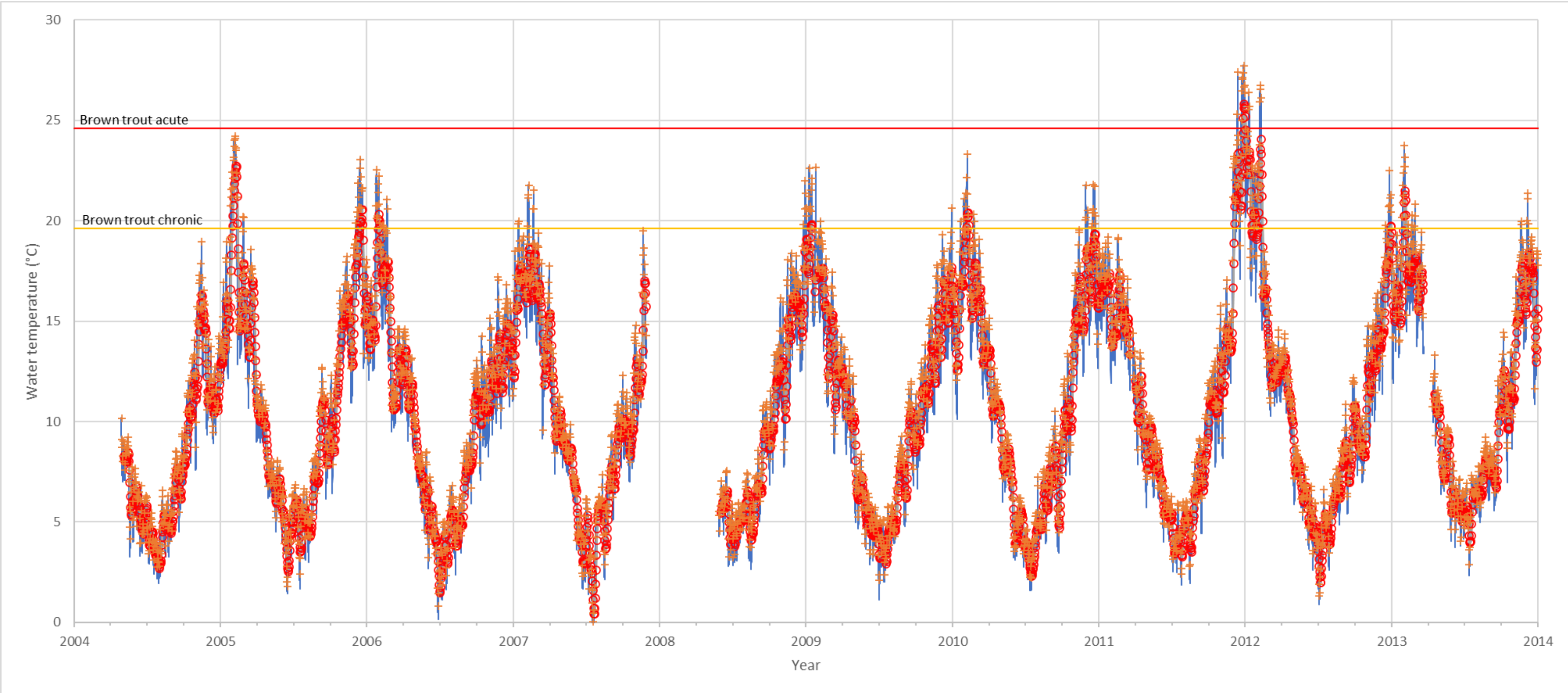

Figure 6 Water temperature in the Poumāhaka River at Burkes Ford between April 2004 and December 2013. Orange crosses are the maximum 2-h average water temperature for comparison with acute thermal criteria. Red circles are the seven-day average of mean daily temperatures for comparison with chronic thermal criteria.

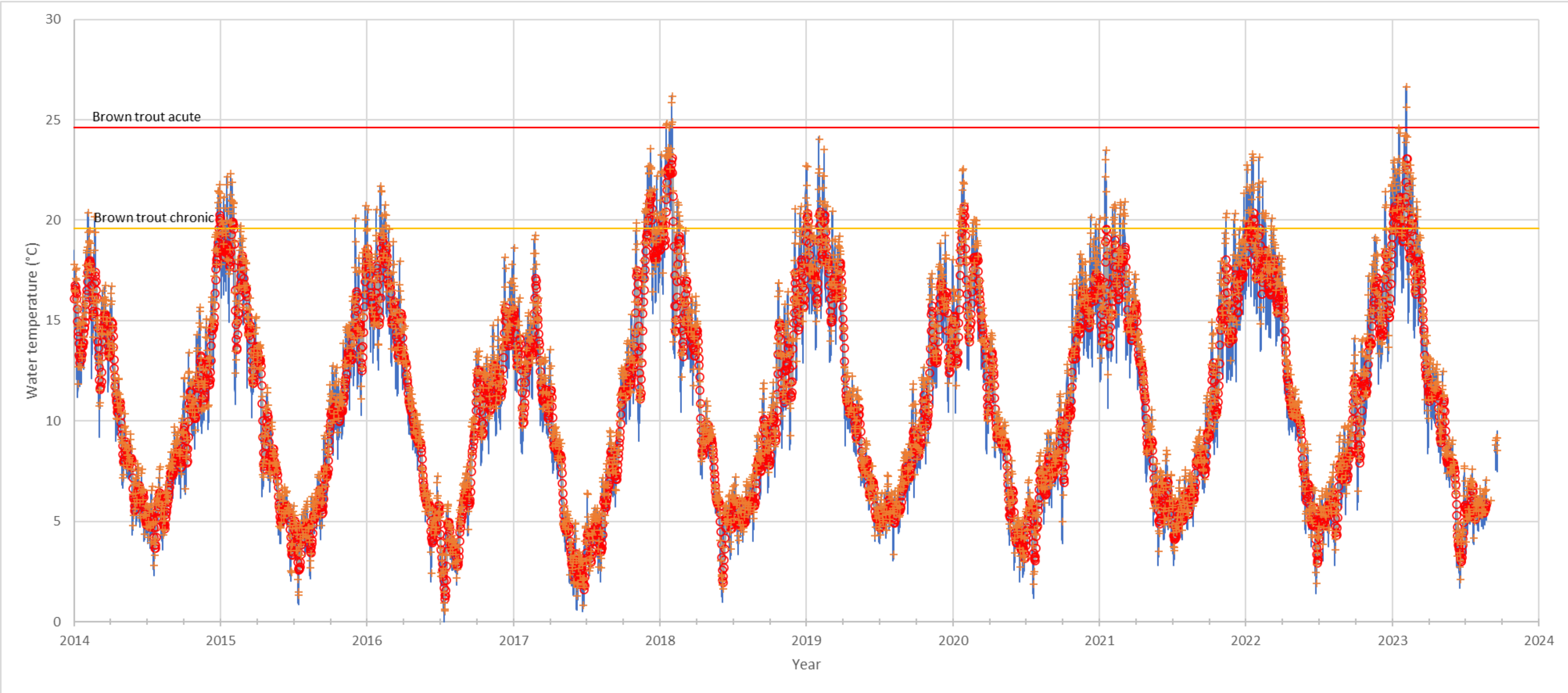

Figure 7 Water temperature in the Poumāhaka River at Burkes Ford between January 2014 and September 2023. Orange crosses are the maximum 2-h average water temperature for comparison with acute thermal criteria. Red circles are the seven-day average of mean daily temperatures for comparison with chronic thermal criteria.

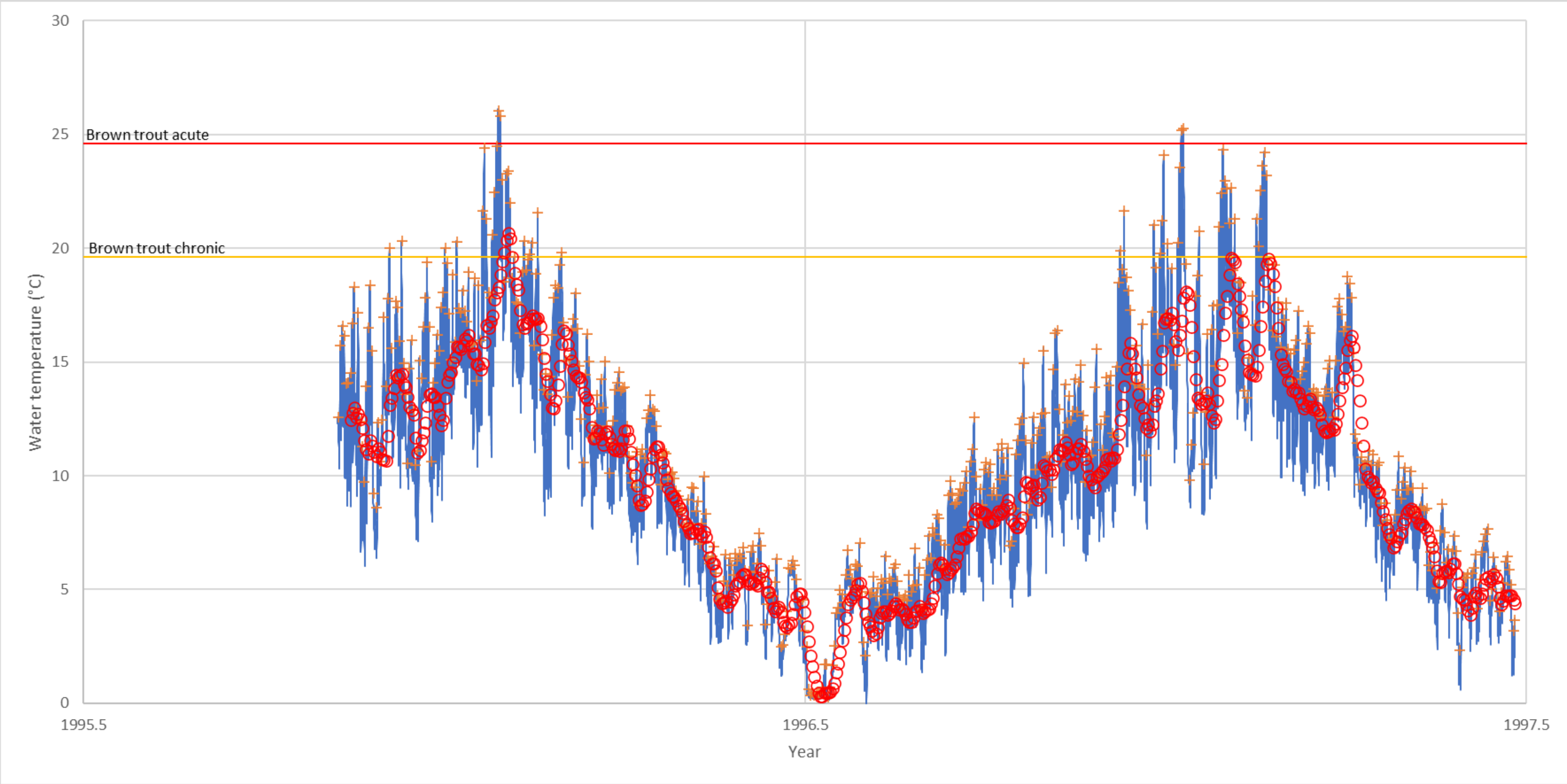

Figure 8 **Water temperature in the Poumāhaka River at Glenken between November 1995 and June 1997. Orange crosses are the maximum 2-h average water temperature for comparison with acute thermal criteria. Red circles are the seven-day average of mean daily temperatures for comparison with chronic thermal criteria.**

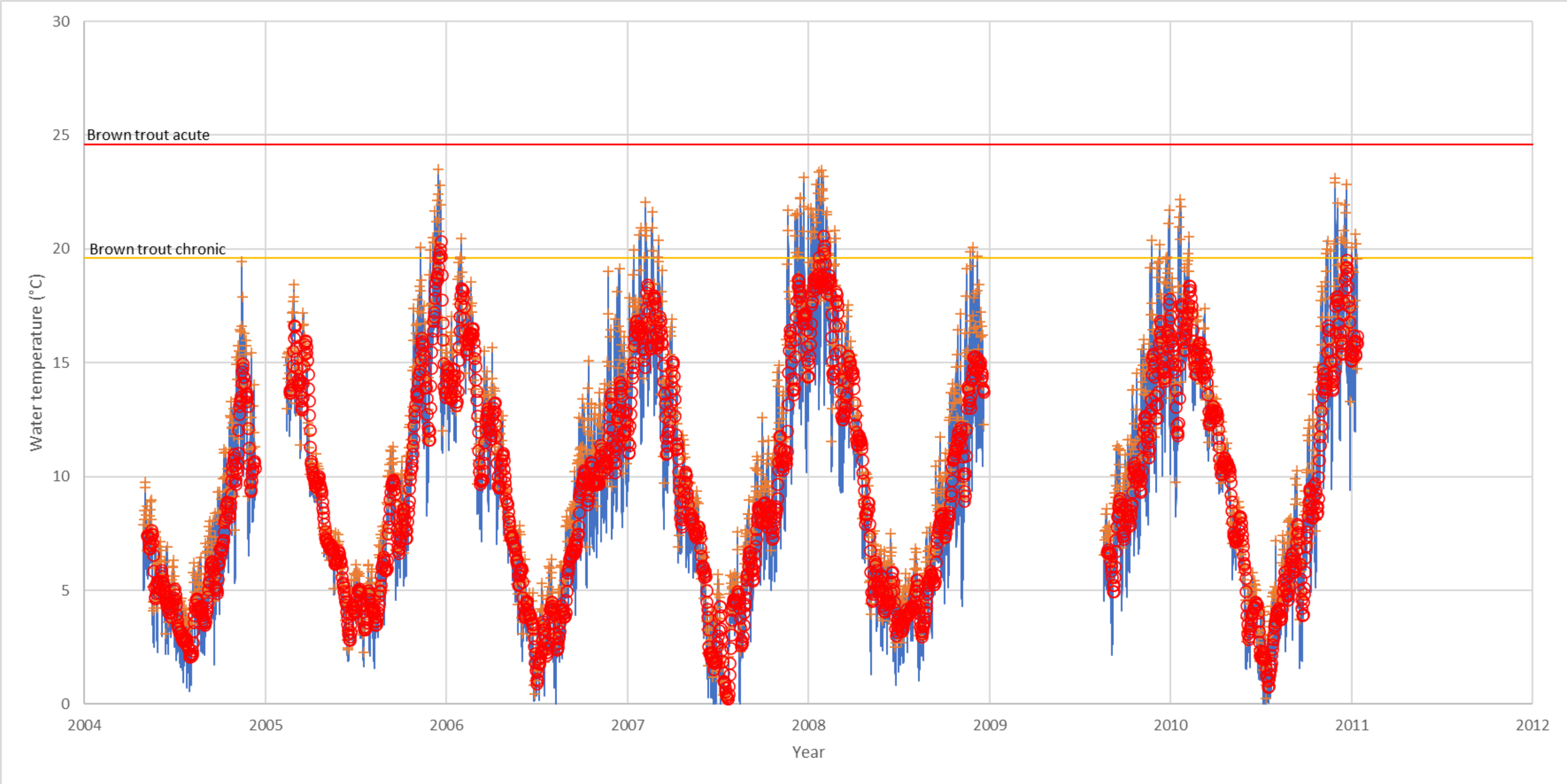

Figure 9 Water temperature in the Poumāhaka River at Glenken between April 2004 and January 2011. Orange crosses are the maximum 2-h average water temperature for comparison with acute thermal criteria. Red circles are the seven-day average of mean daily temperatures for comparison with chronic thermal criteria.

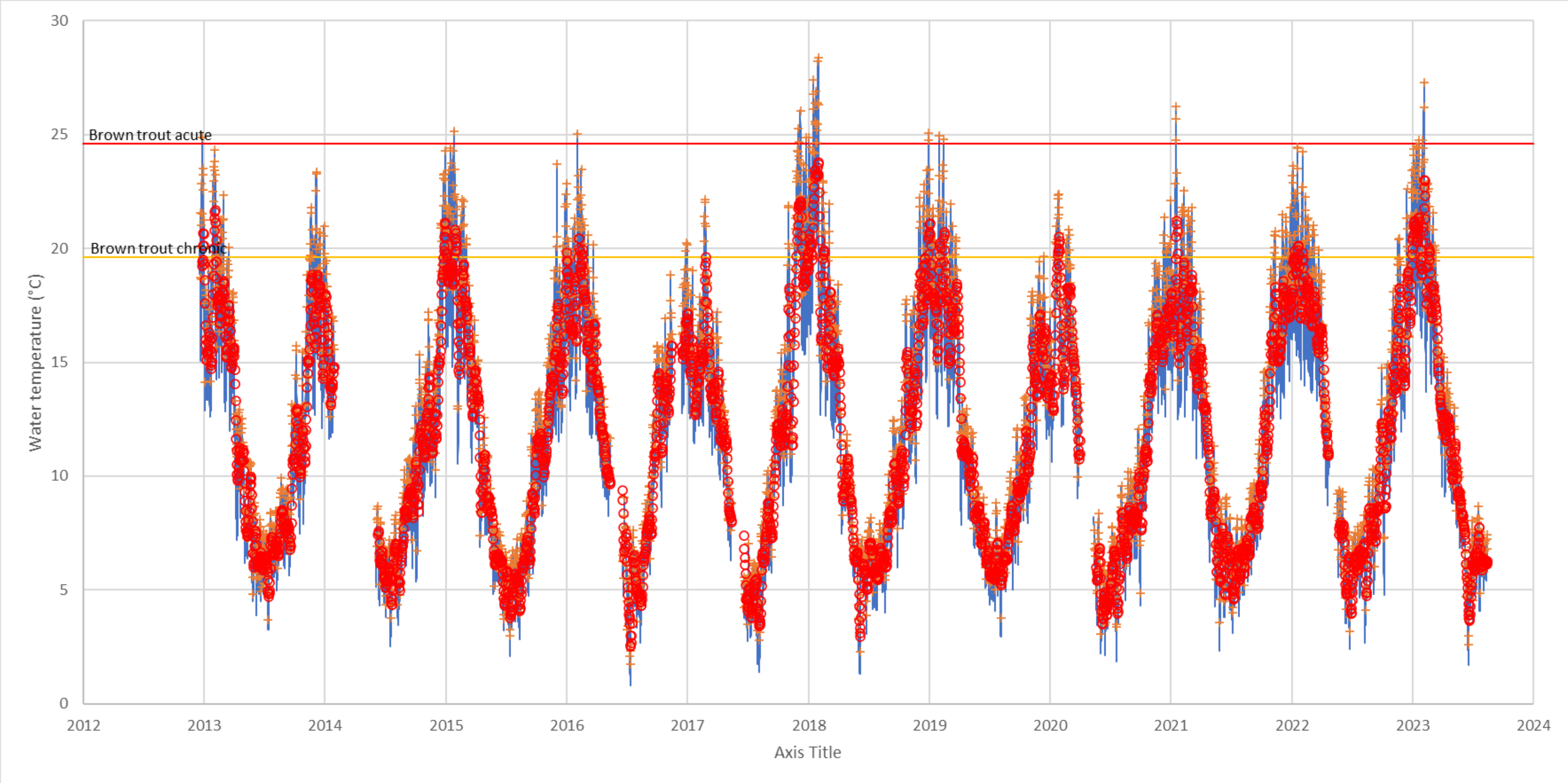

Figure 10 Water temperature in the Waipahī River at Waipahī between December 2012 and December 2022. Orange crosses are the maximum 2-h average water temperature for comparison with acute thermal criteria. Red circles are the seven-day average of mean daily temperatures for comparison with chronic thermal criteria.

6 The aquatic ecosystem of the Poumāhaka catchment

6.1 Periphyton

The periphyton community forms the slimy coating on the surface of stones and other substrates in freshwaters and can include a range of different types and forms. Periphyton is an integral part of the food web of many rivers; it captures energy from the sun and converts it, via photosynthesis, to energy sources available to macroinvertebrates, which feed on it. These, in turn, are fed on by other invertebrates and fish.

However, periphyton can form nuisance blooms that can detrimentally affect other instream values, such as aesthetics, biodiversity, recreation (swimming and angling), water-takes (irrigation, stock/drinking water and industrial) and water quality. Some types of cyanobacteria may produce toxins that pose a health risk to humans and animals. These include toxins that affect the nervous system (neurotoxins), liver (hepatotoxins), and dermatotoxins that can cause severe irritation of the skin.

The presence of potentially toxic cyanobacteria is undesirable as it can affect the suitability of a waterway for drinking, recreation (swimming), dogs, stock drinking water and food-gathering (by affecting palatability or through accumulation of toxins in organs such as the liver). Cyanobacteria-produced neurotoxins have been implicated in the deaths of numerous dogs in New Zealand (Hamill, 2001; Wood et al., 2007).

Periphyton cover in the upper Poumāhaka at Aitchison Runs Road has typically been low, typically dominated by thin to medium light brown and dark brown/black films/mats, likely diatoms and benthic cyanobacteria films and mats. Cover by thick mats and/or filamentous algae has typically been low. The periphyton community in the Waipahī at Waipahī has been variable, but thin to medium light brown and dark brown/black films/mats (likely diatoms and benthic cyanobacteria) have typically had the highest cover. High cover by filamentous algae has been observed on several occasions, although it has only exceeded 30% on one occasion (18 October 2022).

Chlorophyll *a* concentrations in the upper Poumāhaka at Aitchison Runs Road were consistently low (A-band) over the June 2019 – 2022 period with the exception of the reading on 21 April 2022 which was close to the upper limit of B-band (Figure 11a), placing this site in A-Band of the National Objective Framework of the NPS-FM (NOF). Chlorophyll *a* concentrations in the Waipahī at Waipahī were low (A-band) over the June 2019 – December 2020 period but several periods of high biomass were observed in the 2021 and 2022 seasons, with several values in excess of 150 mg/m^2 observed over this period (Figure 11b). Based on the available data, the chlorophyll *a* concentrations in the Waipahī at Waipahī place this site in D-band of the NOF.

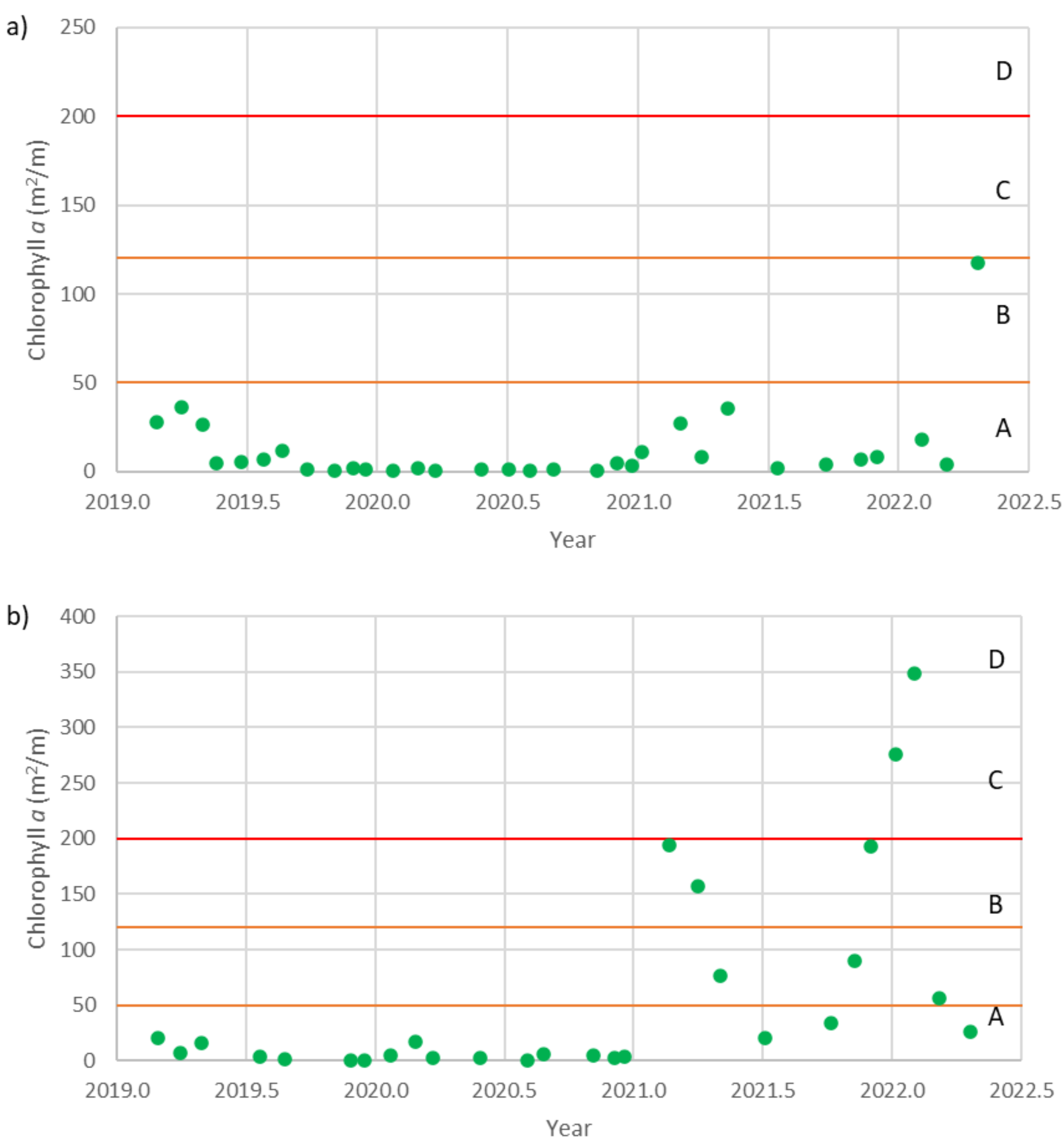

Figure 11 Chlorophyll *a* concentrations in a) Upper Poumāhaka River at Aitchison Runs Road and b) Waipahī at Waipahī over the period 2019-2022. The periphyton biomass attribute is applied such that no more than three values can exceed the numeric attribute state in any three-year period (8% exceedence, based on monthly sampling over a 3-year period).

6.2 Macroinvertebrates

Macroinvertebrates are an important part of stream food webs, linking primary producers (periphyton and terrestrial leaf litter) to higher trophic levels (fish and birds). Macroinvertebrates have long been used as indicators of ecosystem health and, conversely, the impacts of pollutants (e.g. Hilsenhoff 1977, 1987; Stark 1985). The Macroinvertebrate Community Index and its variants have been widely used in New Zealand to assess the effects of nutrients and sediment (Wagenhoff et al. 2016).

Macroinvertebrate samples were collected from the Poumāhaka River at Burkes Ford and Glenken between 2001 and 2004, then again in 2022, while samples have been collected from the upper Poumāhaka at Aitchison Runs Road between 2020 and 2022. Macroinvertebrate samples have been collected from two sites in the Waipahī – Waipahī at Waipahī (2001-2004 and 2007-2022) and Waipahī at Cairns Peak (2003-2004, 2008-2018 and 2022).

The cased caddis fly (*Pycnocentrodes*), and the mudsnail *Potamopyrgus* were the most abundant taxa collected in the Poumāhaka at Burkes Ford, with oligochaete worms, the net-spinning caddis fly *Hydropsyche* (*Aoteapsyche*), the cased caddis fly (*Pycnocentria*) and chironomid larvae (*Maoridiamesa*, Chironomidae and Orthocladiinae) also among the most abundant taxa on occasion.

Riffle beetles (Elmidae), the cased caddis fly (*Pycnocentrodes*), the common mayfly *Deleatidium* and the net-spinning caddis fly *Hydropsyche* (*Aoteapsyche*) were among the most abundant macroinvertebrate taxa collected in the Poumāhaka at Glenken, with oligochaete worms, the spiral-cased caddisfly *Helicopsyche*, the mudsnail *Potamopyrgus*, and chironomid larvae (*Maoridiamesa* and Orthocladiinae) also among the most abundant taxa on occasion.

The common mayfly *Deleatidium* and riffle beetles (Elmidae) were among the most abundant macroinvertebrate taxa collected in the Upper Poumāhaka at Aitchison Runs Road, with oligochaete worms, crane fly larvae (*Aphrophila*), the cased caddis fly (*Olinga*), chironomid larvae (Orthocladiinae) and the purse-cased caddis fly *Oxyethira*.

MCI scores[6] for Burkes Ford (Range: 87-94, median = 90, N=5) put this site in C-band of the NOF, while scores for Glenken (Range: 101-123, median = 112, N=5) and Aitchison Runs Road (Range: 116-127, median = 122, N=3) put this site in B-band of the NOF (Figure 12a). SQMCI scores for Burkes Ford (Range: 3.24-4.92, median = 4.07, N=5) put this site in D-band of the NOF and below the national bottom line, while SQMCI scores for Glenken (Range: 3.53-6.79, median = 5.64, N=5) and Aitchison Runs Road (Range: 5.30-7.36, median = 6.41, N=3) put this site in B-band of the NOF (Figure 12b).

MCI scores for Waipahī at Waipahī (Range: 78-114, median = 90, N=20) and Cairns Peak (Range: 90-120, median = 101, N=14) put these sites in C-band of the NOF (Figure 13a). Similarly, SQMCI scores for Waipahī at Waipahī (Range: 3.47-6.17, median = 4.57, N=20) and Cairns Peak (Range: 3.65-6.54, median = 5.01, N=14) put these sites in C-band of the NOF (Figure 13b).

[6] Calculated following the method of Stark & Maxted (2007), as per Table 14 of the NPSFM.

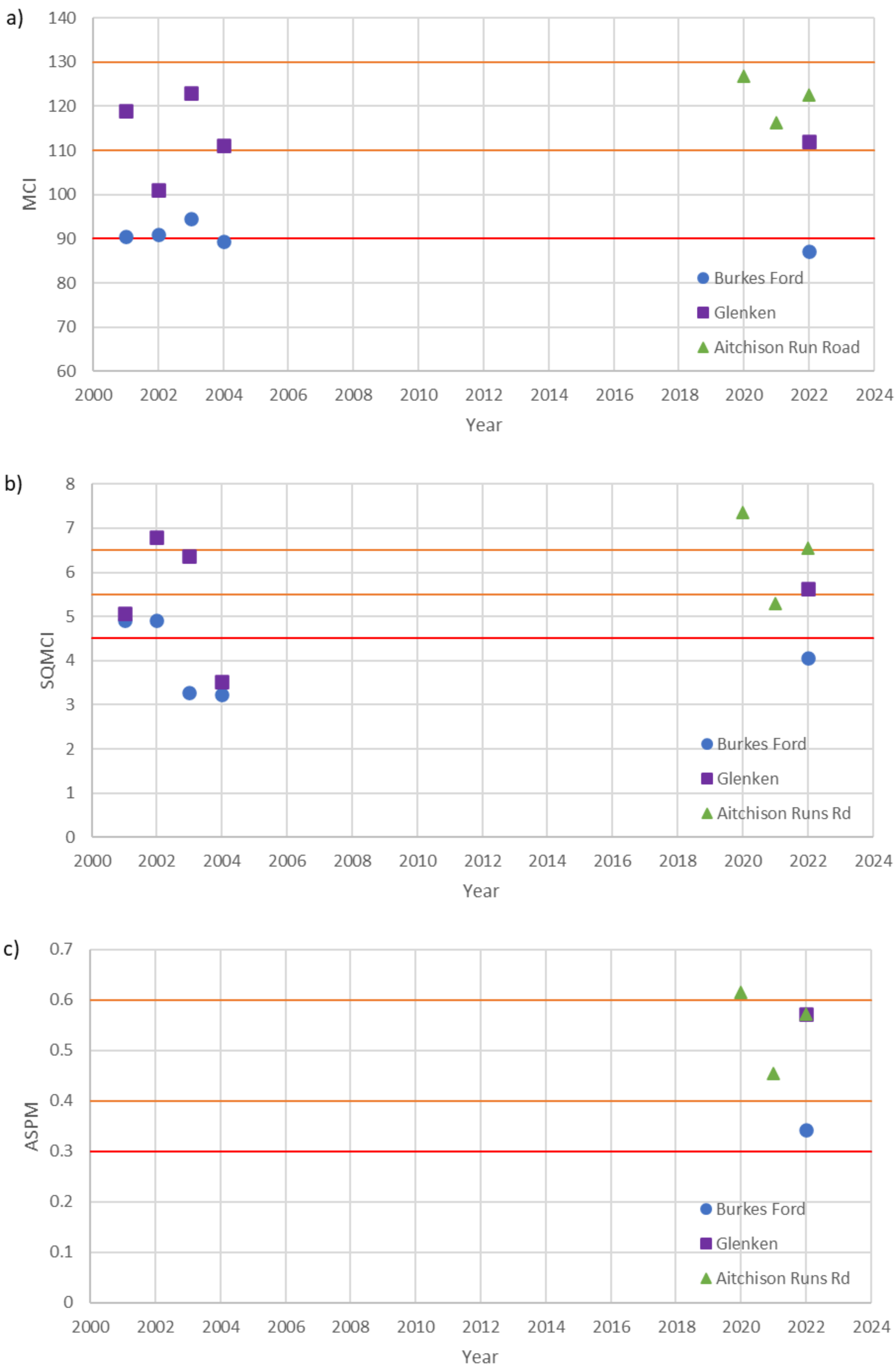

Figure 12 Macroinvertebrate indices for the Poumāhaka River at Burkes Ford, Glenken and Aitchison Runs Road between 2000 and 2021. a) Macroinvertebrate community index (MCI), b) semi-quantitative MCI (SQMCI) and c) average score per metric (ASPM). Each plot includes thresholds for attribute states based on Tables 14 and 15 of the National Objectives Framework (based on 5-year medians).

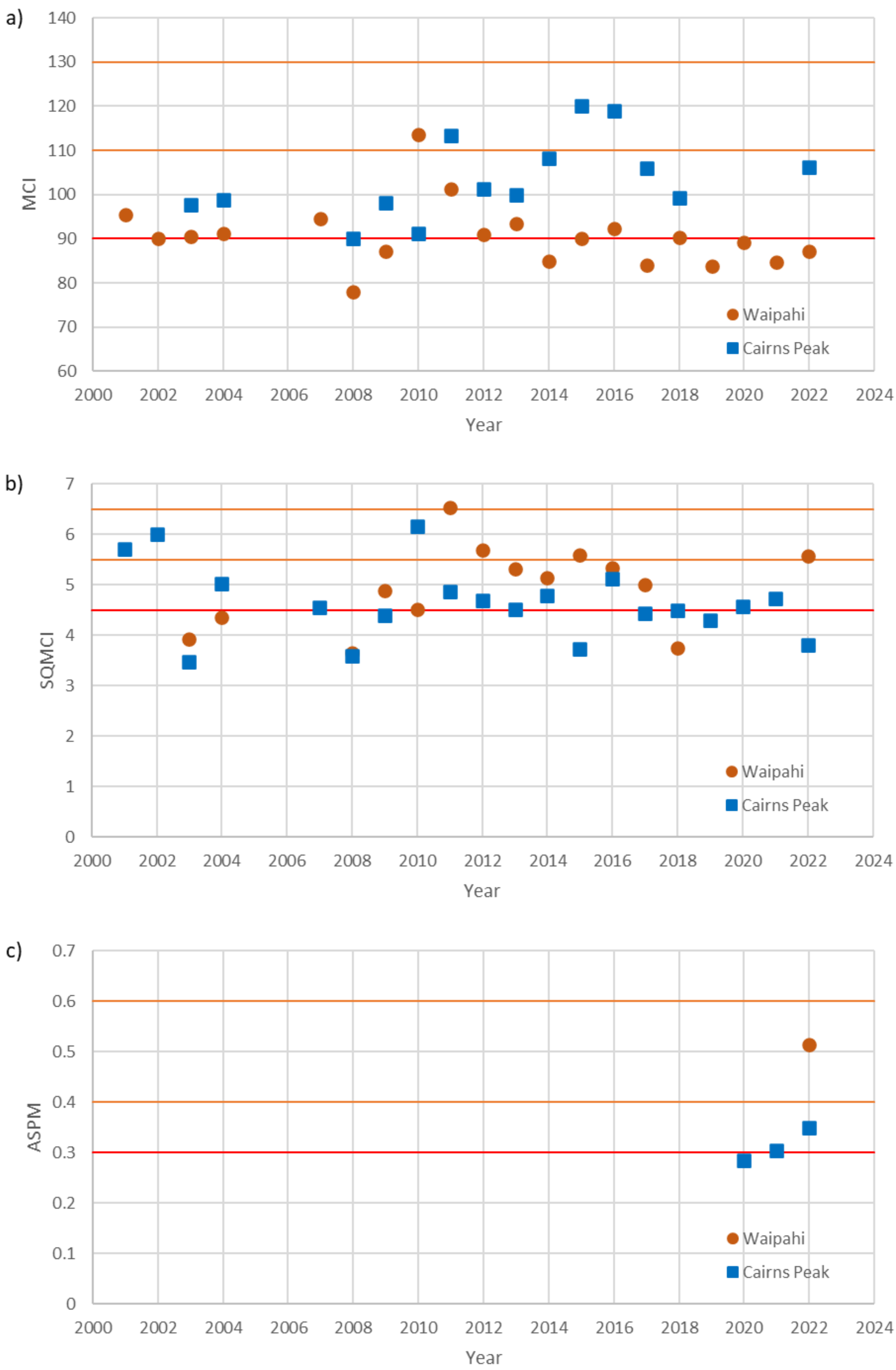

Figure 13 Macroinvertebrate indices for the Waipahī at Waipahī between 2000 and 2021. a) Macroinvertebrate community index (MCI), b) semi-quantitative MCI (SQMCI) and c) average score per metric (ASPM). Each plot includes thresholds for attribute states based on Tables 14 and 15 of the National Objectives Framework (note that these thresholds are based on 5-year medians).

Table 6 Trends in macroinvertebrate metrics in the Waipahī River at Waipahī state of the environment monitoring site between 2007 and 2022. Analysis from Ozanne et al. (2023). The Z-statistic indicates the direction of any trend detected. Trends with a *P*-value of 0.05 or less (highlighted red) are considered to be statistically significant.

Metric	Z	P	Trend
MCI	-1.40	0.16	Very unlikely improving
SQMCI	1.40	0.16	Very likely improving
ASPM	0.18	0.18	As likely as not improving

6.3 Fish

6.3.1 Indigenous fish

Seven species of indigenous freshwater fish have been recorded from the Poumāhaka catchment (Table 8; Figure 14). The species present include several species that are at risk or threatened – tuna/longfin eel are classified as at risk – declining, while Pomahaka galaxias and kanakana/lamprey are both classified as threatened – nationally vulnerable (Dunn et al. 2017).

Recent studies by Campbell (2022) have identified two distinct lineages of non-migratory galaxias in the Poumāhaka catchment – a flathead species (referred to as *G.* "Pomahaka") that is phylogenetically distinct from the Clutha flathead galaxias (*Galaxias* "species D"), which is found in the upper Clutha catchment and a new roundhead lineage (*Galaxias* "species Z"). Specimens of *G*. "species D" were collected from Parasol Creek and Valley Creek, while *G.* "species Z" was collected from Thompsons Creek, Flodden Creek, Heriot Burn, and widely in the Waipahi catchment (Campbell 2022). These findings will undoubtedly affect the threat status of the non-migratory galaxiids found in the Poumāhaka catchment in future threat rankings.

6.3.2 Introduced fish

Brown trout, rainbow trout and chinook salmon have been collected from the Poumāhaka catchment (Table 8; Figure 14).

The Poumāhaka River supports a regionally important sport fishery for both resident and sea run brown trout, while the upper Poumāhaka River has backcountry characteristics (Otago Fish & Game Council 2015). The Waipahī River is also recognised as a regionally important brown trout fishery (Otago Fish & Game Council 2015). Table 7 presents angler effort in the Poumāhaka River, recorded during National Angler Surveys conducted in 1994/95, 2007/08 and 2014/15. Overall angler usage in the Poumāhaka catchment is relatively high, with most of the angling effort (46%) occurring in December-January (Unwin, 2016).

Table 7 Angler effort[7] on the Poumāhaka River based on the National Angler Survey (Unwin, 2016). Angler usage is presented as angler days ± standard error.

	National Angler Survey			
Catchment	**1994/95**	**2001/02**	**2007/08**	**2014/15**
Poumāhaka	6,780 ± 1,210	6,000 ± 1,440	3,630 ± 970	3,020 ± 840
Waipahī	2,370 ± 630	1,810 ± 490	840 ± 400	150 ± 140
Kaiwera	100 ± 70	70 ± 70	260 ± 260	
Waikoikoi		3400 ± 310	50 ± 50	
Leithen Burn				390 ± 350

Table 8 Fish species recorded from the Poumāhaka River catchment.

Family	Common name	Species	Threat classification
Anguillidae	Shortfin eel	*Anguilla australis*	Not threatened
	Longfin eel	*Anguilla dieffenbachii*	Declining
Eleotridae	Upland bully	*Gobiomorphus breviceps*	Not threatened
	Common bully	*Gobiomorphus cotidianus*	Not threatened
Galaxidae	Pomahaka flathead galaxias	*Galaxias* sp. D (lower Clutha)	Nationally vulnerable
	Pomahaka roundhead galaxias	*Galaxias* sp. Z "Pomahaka"	Nationally vulnerable
Geotriidae	Lamprey	*Geotria australis*	Nationally vulnerable
Percidae	Perch	*Perca fluviatilis*	Introduced and naturalised
Salmonidae	Brown trout	*Salmo trutta*	Introduced and naturalised
	Rainbow trout	*Oncorhynchus mykiss*	Introduced and naturalised
	Chinook salmon	*Oncorhynchus tshawytscha*	Introduced and naturalised

[7] Angler effort is a measure of the level of usage of a fishery. In the National Angler Survey, angler effort has been estimated as angler days, the number of days that a fishery was visited by an individual angler.

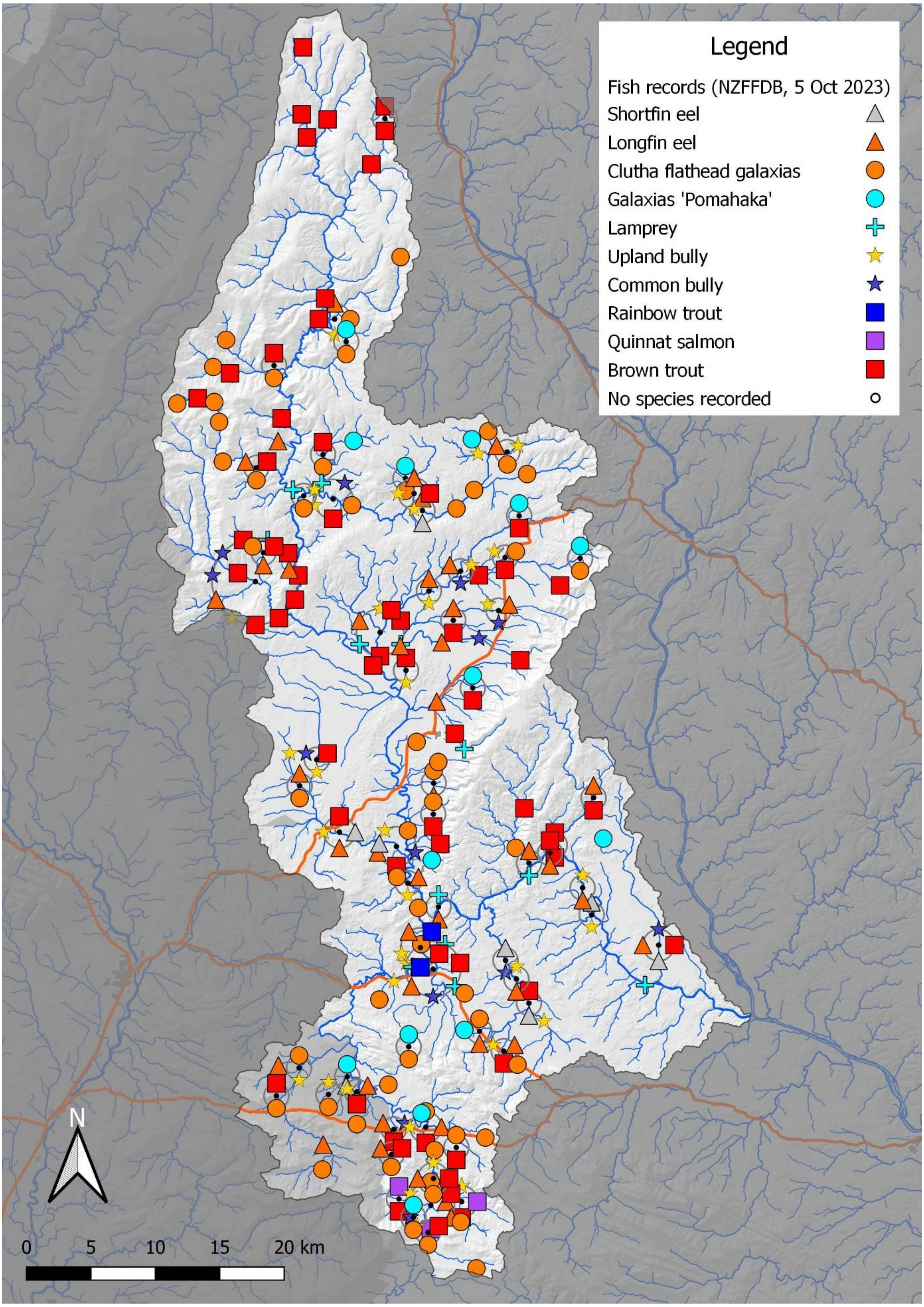

Figure 14 Fish distribution within the Poumāhaka catchment. Simplified (for clarity) from records from the NZ Freshwater Fish Database, downloaded on 5 October 2023.

6.4 Current ecological state

The current minimum flow and allocation in the Poumāhaka catchment was added to the RPW by Plan Change 3B, which became operative on 1 June 2015. Thus, the current minimum flow and allocation limit have been in effect for several years and is reflected in the current state of the Poumāhaka River. Therefore, comparison of the current state of the Poumāhaka River with objectives for the Lower Clutha FMU provide insight into whether the current minimum flow and allocation regime are consistent with the objectives proposed in the Land & Water Regional Plan.

At the time of writing, the proposed objectives for the Lower Clutha FMU include the following narrative objectives: *"Freshwater bodies within the Lower Clutha FMU support healthy ecosystems with thriving habitats for a range of indigenous species, and the life stages of those species, that would be expected to occur naturally"* and *"This is achieved where the target attribute state for each biophysical component (as set in table) are reached.".* The table referred to is presented in Table 9 below.

6.4.1 Ecosystem health

In addition to the ecosystem health and human contact values identified in Table 9, the proposed objectives for fishing, animal drinking water, cultivation and production of food and beverages and fibre, commercial and industrial use, drinking water supply are measured by the target attribute states for ecosystem health and human contact presented in Table 9. Attributes for natural form and character and threatened species within the Lower Clutha FMU are under development, so it is not possible to consider the current state of the Poumāhaka catchment relative to these attributes.

Table 9 presents the current attribute state for Burkes Ford, Glenken, the upper river at Aitchison Runs Road (limited attributes) and for the Waipahī at Cairns Peak and Waipahī and compares the current state to the proposed target attribute state for the Lower Clutha Rohe.

Attributes for Ecosystem Health – Aquatic life meet the target states for macroinvertebrates attributes at both Waipahī sites, but periphyton biomass in the Waipahī at Waipahī exceeds the national bottom line (≤8% of values exceeding 200 mg/m^2), while periphyton biomass in the upper Poumāhaka at Aitchison Runs Road meets the target for this site (A-band; Table 9).

6.4.2 Water quality

Most water quality parameters considered were consistent with the baseline and target attribute state for each site (Table 9). However, median and 95th percentile of nitrate concentrations and *E. coli* concentrations (number of exceedances of 260 cfu/100 mL and 95th percentile) in the Poumāhaka at Burkes Ford exceeded the 2050 target attribute state (Table 9). In comparison, *E. coli* concentrations in the Poumāhaka at Glenken were above the national bottom line for the number of exceedances of 260 cfu/100 mL and median concentrations (Table 9). Water quality in the upper Poumāhaka at

Aitchison Runs Road was very good, with the water attributes considered in A-band of the NOF (Table 9).

The 95th percentile of nitrate concentrations and *E. coli* concentrations (number of exceedances of 260 cfu/100 mL, median and 95th percentile) in the Waipahī at Waipahī exceeded the 2050 target attribute state (Table 9). Similarly, the 95th percentile of nitrate concentrations and *E. coli* concentrations (number of exceedances of 260 cfu/100 mL, number of exceedances of 540 cfu/100 mL, median and 95th percentile) in the Waipahī at Cairns Peak exceeded the 2050 target attribute state (Table 9).

Table 9 Comparison of the current attribute state at four sites in the Poumāhaka River with baseline state(2017) and the proposed target state (by 2050) based on State of the Environment data collected between 1 July 2017 and 30 June 2022 (Ozanne, Borges & Levy, 2023). Values in brackets indicate the range of baseline states based on rollling averages.

Attribute		Pomahaka at Burkes Ford			Pomahaka at Glenken			Upper Pomahaka at Aitchison Runs Rd			Waipahī at Cairns Peak			Waipahī at Waipahī		
		Baseline State	Target 2050	Current state	Baseline State	Target 2050	Current state	Baseline State	Target 2050	Current state	Baseline State	Target 2050	Current state	Baseline State	Target 2050	Current state
Periphyton Biomass								A	A	A				D	C	D
Periphyton TN		D	C		C	C					D	C		D	C	
Periphyton TP		D	C		D	C					D	C		D	C	
Ammonia - median		A	A	A	A	A	A			A	A	A	A	A	A	A
Ammonia - 95th Percentile		A	A	A	A	A	A			A	A	A	A	A	A	A
NNN - median		A	A	A	A	A	A			A	A	A	A	B	A	B
NNN - 95th percentile		B	A	B	A	A	A			A	B	A	B	B	A	B
Suspended fine sediment		D	C	C	D (D - C)	C	C			A	C (C - B)	C	D	A	A	A
E. coli	% exceed 260 cfu/100 mL	B (B - C)	C	B	D (C - D)	C	D			A	D	C	D	B (B - D)	C	D
	% exceed 540 cfu/100 mL	C	C	C	C (B - C)	C	B			A	E (D - E)	C	D	C (B - C)	C	C
	Median	A	A	A	D	C	D			A	D	C	D	A (A - D)	A	D
	Q95	D	C	D	D (B - D)	C	B			A	D	C	D	D (B - D)	C	D
Fish IBI					C (D - C)	C (D - C)							B			B
MCI				D*			B			B	C (C - B)	C	C	D	C	D
ASPM							B			B	B (C - B)	C	C	D	C	D
DRP-median		C	C	C	B (A - B)	B	A			A	C	C	C	C	C	C
DRP Q95		B	B	B	A	A	A			A	B (B - C)	B	C	C (B - C)	C	C

6.4.3 Contribution of flows to ecological outcomes

The assessment of the current ecological state in the Poumāhaka catchment with the target attribute state in the proposed LWP indicates that the current state for several attributes do not meet the target attribute state for the Lower Clutha FMU and/or national bottom lines (Table 9). The poor water quality in the lower Poumāhaka River has been long recognised. Given the low level of actual water usage in the Poumāhaka catchment (Section 4.1.1), the contribution of water allocation to these exceedances is likely to be minor.

There is a risk that an increase in water use in the future (within the current allocation limit set out in the RPW) may contribute to additional exceedances of some water quality attributes. For many of these attributes, the main effect of water abstraction will be reduced dilution of contaminants. However, more direct action to reduce catchment loads of nutrients and sediment will be essential to address the current state of water quality in the Poumāhaka catchment.

Of the water quality parameters considered, the relationship between *E. coli* and flow is expected to be particularly complex. Faecal microbes such as *E. coli* are mobilised from land and channel sources during storm flows and high flows, greater water depths, and reduced water clarity during such events will reduce microbial die-off resulting from exposure to UV light (Wilkinson et al. 2011). In contrast, during periods of low flows, there is little transport of microbes and shallow water depths, clear water and low water velocities favour die-off of microbes (Wilkinson et al. 2011). On this basis, with all other factors held constant, the reduction of flows resulting from water abstraction is expected to increase microbial die-off and reduce mobilisation and transport of in-channel stores. Thus, it is considered that water abstraction is unlikely to contribute to the observed exceedance of *E. coli* attributes in the Poumāhaka catchment and direct action to address local sources of faecal contamination (e.g. land use controls, fencing/stock exclusion, tile drain will be essential to address concentrations of *E. coli* observed in the Poumāhaka catchment.

Periphyton biomass at a point in time reflects the balance of two opposing processes – biomass accrual and biomass loss. The rate of biomass accrual is driven by the rate of cell division which is, in turn, affected by factors such as the supply of resources (nutrients and light) and water temperature, while biomass loss is driven by two main mechanisms: disturbance caused by high flows (resulting in high water velocities, substrate instability and/or abrasion caused by suspended or saltating sediments) and physical removal by grazing my macroinvertebrates (Biggs 2000). Nutrient concentrations in the Waipahī River are favourable to the development of high periphyton biomasses (Ozanne et al. 2023). There has been limited water take from the Waipahī sub-catchment, suggesting that to date water abstraction is unlikely to have contributed to the high periphyton biomass observed in the Waipahī at Waipahī.

7 Instream habitat modelling in Poumāhaka River

Instream habitat modelling is a method that can be used to consider the effects of changes in flow on instream values, such as physical habitat, water temperature, water quality and sediment processes. The strength of instream habitat modelling lies in its ability to quantify the loss of habitat caused by changes in the flow regime, which helps to evaluate alternative flow proposals. 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 the disturbance and mortality caused by flooding as well as biological interactions (such as predation), which can have a significant influence on the distribution of aquatic species.

An instream habitat model has previously been developed for 3 sections of the Poumāhaka River by Jowett & Wilding (2003). This model was used to inform the minimum flow setting process for the Poumāhaka (Plan Change 3B). The model presented by Jowett & Wilding (2003) was based on data collected by Young & Hayes (1999) and ORC (2000) and was compiled into models for two reaches: Glenken and Burkes Ford.

The modelling to support Plan Change was analysed in ORC (2006) and at the time of the plan change, a flow of 3.6 m^3/s was thought to maintain 90% of the adult brown trout habitat available at the naturalised 7-d MALF at Burkes Ford (4.3 m^3/s, from ORC 2006). The recent analysis of Lu (2023) suggests that the naturalised 7-d MALF at Burkes Ford is 3.521 m^3/s, meaning that the current minimum flow (3.6 m^3/s is set above the naturalised 7-d MALF). Anecdotally, this is confirmed by the length of the irrigation season when water restrictions are in place in the Poumāhaka catchment, despite the relatively low level of water use (Section 4.1.1).

Given the age of the physical surveys that underpin the modelling undertaken for the Poumāhaka River (some of which were undertaken in the 1990's), along with the very conservative level of the minimum flow (set at approximately at the naturalised 7-d MALF), it was decided that there was little merit in re-analysing the existing instream habitat model for the Poumāhaka River. If the catchment minimum flow is to be revisited in the future, it is recommended that a new instream habitat model (or alternative such as bioenergetics modelling) be undertaken for the Poumāhaka River.

8 Assessment of alternative minimum flows and allocation limits

Three minimum flows were considered representing different proportions of the 7-day MALF (including the existing minimum flow of ~100% of the 7-d MALF) along with four allocation limits (Table 10). To consider the hydrological effects of the various combinations of minimum flow/allocation, simulations were run for the period 1 July 2013 – 29 June 2023 using naturalised flows estimated by adding measured water take (based on water metering data for water users in the upstream of the Burkes Ford flow monitoring site) back onto the observed flows in the Poumāhaka River at Burkes Ford. Supplementary allocation blocks were not considered in these simulations given the lack of supplementary takes in the Poumāhaka catchment.

Table 10 Minimum flow and allocation limits considered in this analysis.

Minimum flow		Allocation limit		
Option	**% 7-d MALF**	**Option**	**% 7-d MALF**	**Description**
3.6 m³/s (current minimum flow)	102%	1.26 m³/s	36% (current allocation)	Current minimum flow and current allocation limit (36% of MALF).
		0.7 m³/s	20%	Current minimum flow and allocation at 20% of MALF.
		0.24 m³/s	7%	Current minimum flow and current combined maximum observed rates of take[8] (7% of MALF).
		0.15 m³/s	4%	Current minimum flow and current maximum observed cumulative rate of take[9] (4% of MALF).
2.8 m³/s	80%	1.26 m³/s	36%	Minimum flow 80% of the naturalised 7-d MALF and current allocation limit (36% of MALF).
		0.7 m³/s	20%	Minimum flow 80% of the naturalised 7-d MALF and allocation at 20% of MALF.
		0.24 m³/s	7%	Minimum flow 80% of the naturalised 7-d MALF and current current combined maximum observed rates of take (XX% of MALF).
		0.15 m³/s	4%	Minimum flow 80% of the naturalised 7-d MALF and current maximum observed cumulative rate of take (4% of MALF).
3.2 m³/s	90%	1.26 m³/s	36%	Minimum flow 90% of the naturalised 7-d MALF and current allocation limit (36% of MALF).
		0.7 m³/s	20%	Minimum flow 90% of the naturalised 7-d MALF and allocation at 20% of MALF.
		0.24 m³/s	7%	Minimum flow 90% of the naturalised 7-d MALF and current current combined maximum observed rates of take (XX% of MALF).
		0.15 m³/s	4%	Minimum flow 90% of the naturalised 7-d MALF and current maximum observed cumulative rate of take (4% of MALF).

[8] The sum of the maximum observed rate of take for each consent
[9] The maximum of the observed combined rate of take at any point in time

The degree of hydrological alteration resulting from each of the minimum flow/allocation scenarios was assessed using the Dundee Hydrological Regime Assessment Method (DHRAM) (Black et al. 2005). This method involves the calculation of 32 parameters relating to the seasonality of flows, magnitude and duration of annual extremes (high and low flow events), timing of annual extremes, frequency and duration of high and low pulses and the rate and frequency of change in flow (Black et al. 2005). For each parameter, the mean and co-efficient of variation[10] is calculated. The results of these simulations are presented in Table 12.

Table 11 DHRAM classes used in the assessment of alternative minimum flow/allocation

Class	Points range	Description
1	0	Un-impacted condition
2	1-4	Low risk of impact
3	5-10	Moderate risk of impact
4	11-20	High risk of impact
5	21-30	Severely impacted condition

All scenarios considered, including the existing minimum flow and allocation limit, are predicted to result in a hydrograph that is unimpacted relative to naturalised flows (based on the DHRAM score) (Table 12; Figure 15, Figure 16, Figure 17, and Figure 18).

[10] Coefficient of variation is a measure of the variability around the mean (average) value. At its simplest, the coefficient of variation is calculated as the standard deviation divided by the mean.

Table 12 Comparison of the hydrological effects of different minimum flow/allocation limit combinations in the Poumāhaka River.

Min flow	Allocation	Monthly		Min/max means		Date/timing		Pulse count/duration		Rate of change		Risk grade
		CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	
Observed		0	0	0	0	0	0	0	0	0	0	Unimpacted
3.6	1.26	0	0	0	0	0	0	0	0	0	0	Unimpacted
	1	0	0	0	0	0	0	0	0	0	0	Unimpacted
	0.7	0	0	0	0	0	0	0	0	0	0	Unimpacted
	0.24	0	0	0	0	0	0	0	0	0	0	Unimpacted
	0.15	0	0	0	0	0	0	0	0	0	0	Unimpacted
3.2	1	0	0	0	0	0	0	0	0	0	0	Unimpacted
	0.7	0	0	0	0	0	0	0	0	0	0	Unimpacted
	0.24	0	0	0	0	0	0	0	0	0	0	Unimpacted
	0.15	0	0	0	0	0	0	0	0	0	0	Unimpacted
2.8	1	0	0	0	0	0	0	0	0	0	0	Unimpacted
	0.7	0	0	0	0	0	0	0	0	0	0	Unimpacted
	0.24	0	0	0	0	0	0	0	0	0	0	Unimpacted
	0.15	0	0	0	0	0	0	0	0	0	0	Unimpacted

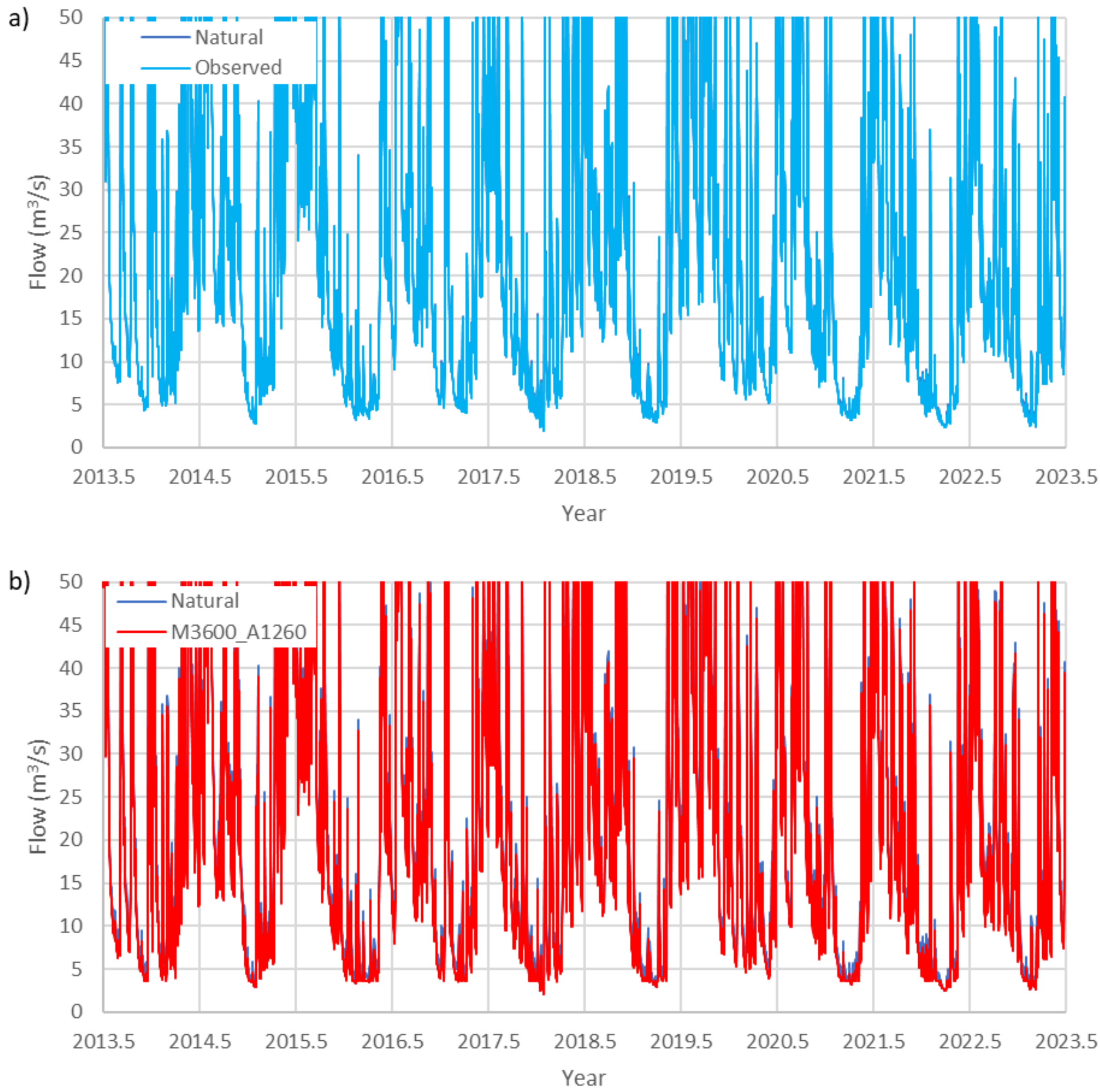

Figure 15 Hydrographs of a) naturalised flows compared to observed flows, b)a scenario with a minimum flow of 3.6 m^3/s and current consented allocation 1.26 m^3/s.

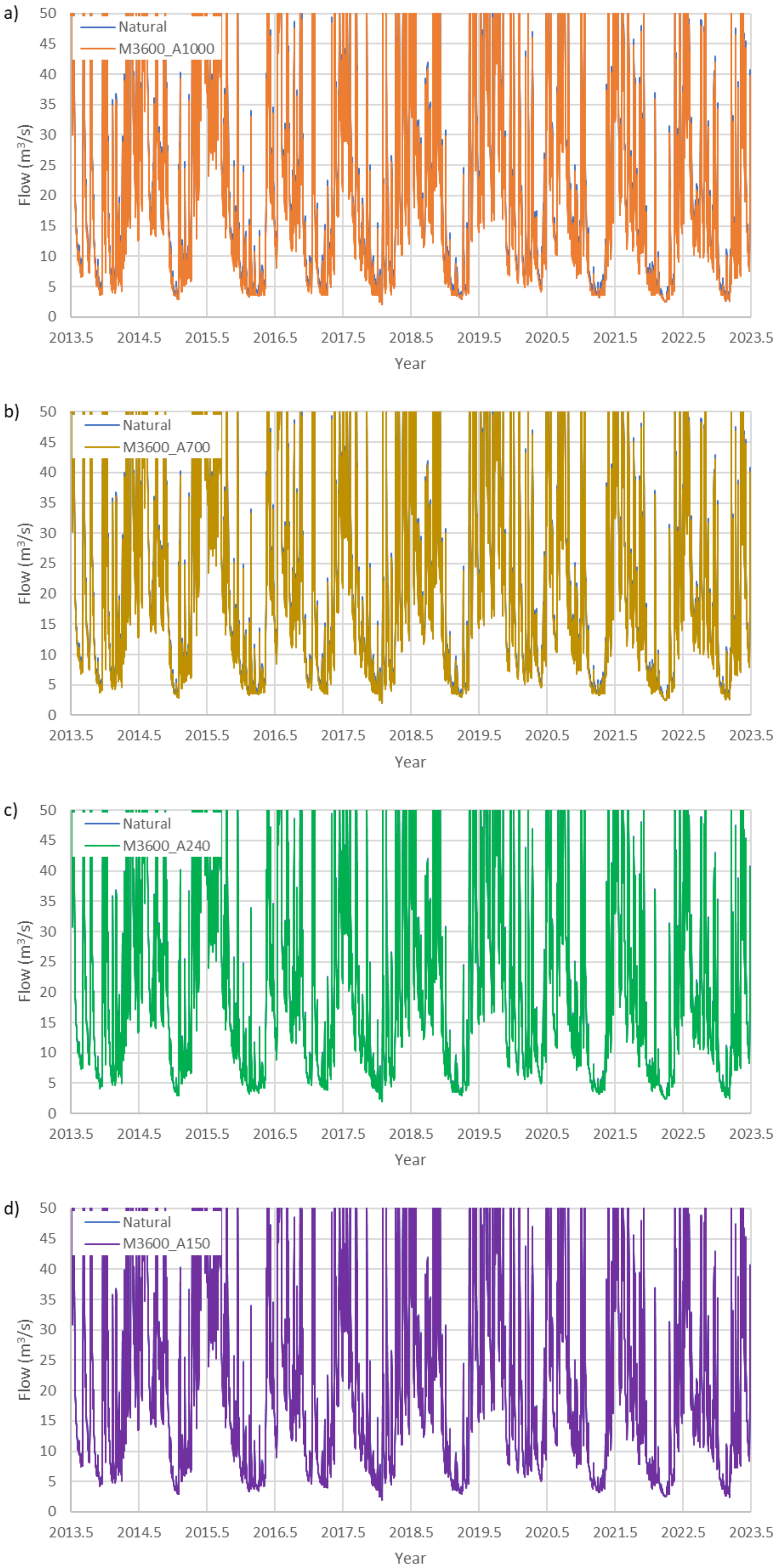

Figure 16 Hydrographs of allocation scenarios with a minimum flow of 3.6 m^3/s. a) Current allocation 1.26 m^3/s, b) allocation limit of 1 m^3/s, c) allocation limit of 0.7 m^3/s, d) allocation limit of 0.24 m^3/s, e) allocation limit of 0.15 m^3/s.

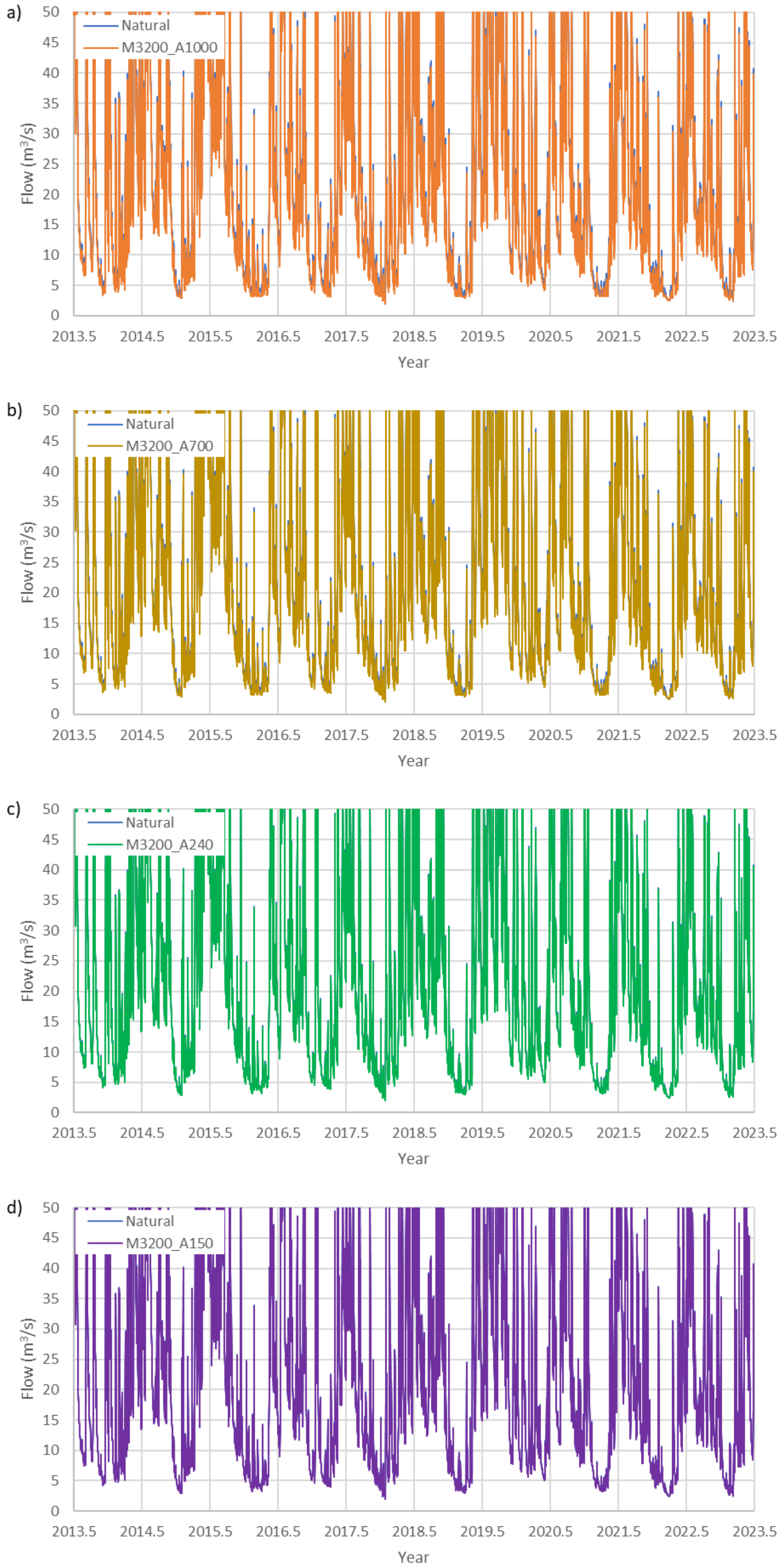

Figure 17 Hydrographs of allocation scenarios with a minimum flow of 3.2 m^3/s. a) Current allocation limit of 1 m^3/s, b) allocation limit of 0.7 m^3/s, c) allocation limit of 0.24 m^3/s, d) allocation limit of 0.15 m^3/s.

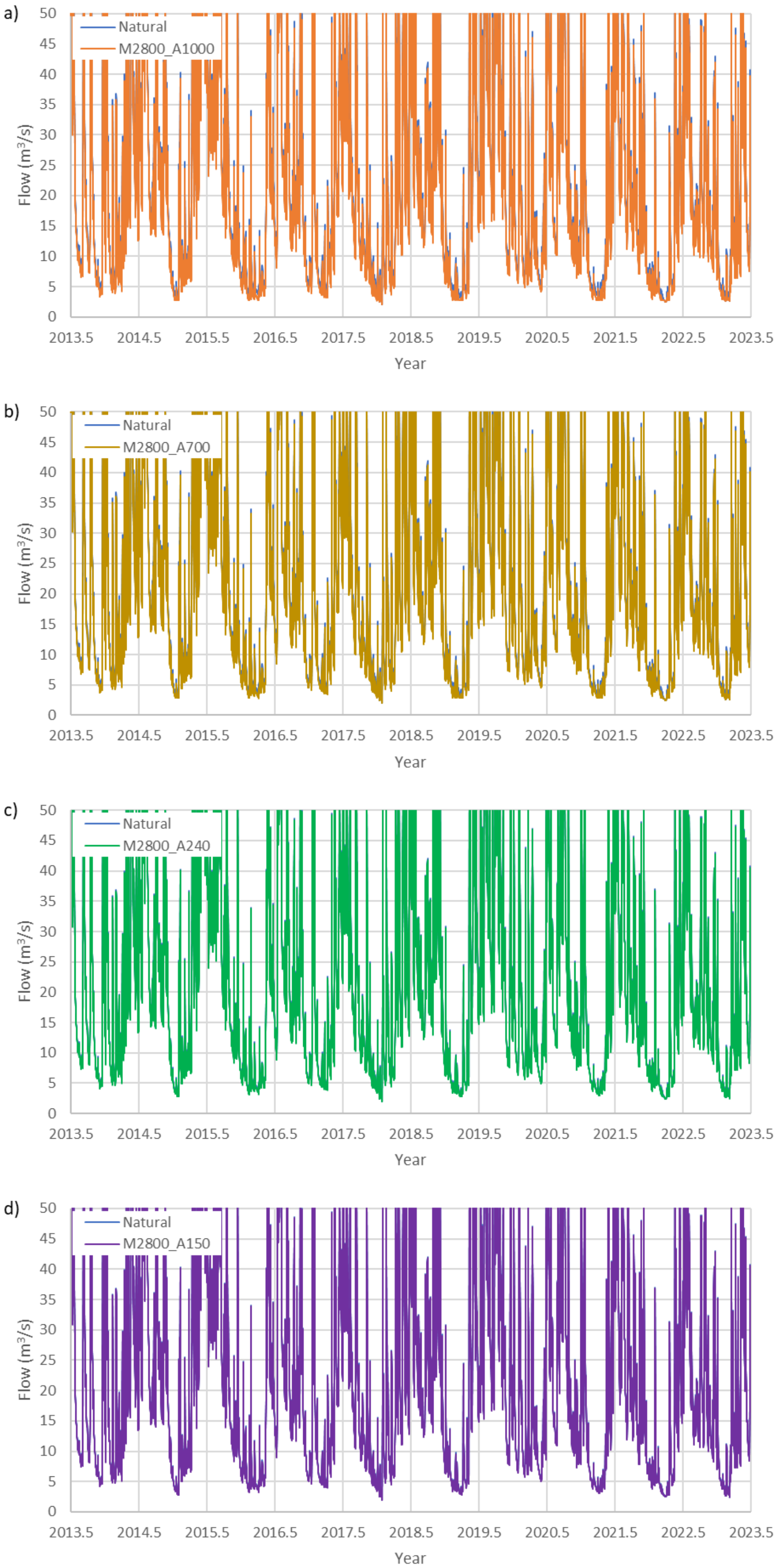

Figure 18 Hydrographs of allocation scenarios with a minimum flow of 2.8 m^3/s. a) Current allocation limit of 1 m^3/s, b) allocation limit of 0.7 m^3/s, c) allocation limit of 0.24 m^3/s, d) allocation limit of 0.15 m^3/s.

8.1 Consideration of existing minimum flows & allocation

The current minimum flow and allocation in the Poumāhaka catchment was added to the RPW by Plan Change 3B, which was notified on 16 August 2014 and became operative on 1 June 2015. Schedule 2A of the RPW specifies a minimum flow for primary allocation at Burkes Ford of 3.6 m^3/s (1 October to 30 April) or 7 m^3/s (1 May to 30 September). The primary allocation limit specified for the Poumāhaka catchment in Schedule 2A is 1 m^3/s, although at the time of writing the actual primary allocation is 1.260 m^3/s (see Section 4.1.1).

The current minimum flow of 3.6 m^3/s was 84% of the 7-d MALF based on the ORC (2006) report. The updated hydrological analysis of Lu (2023) estimates the 7-d MALF at 3.5 m^3/s, suggesting that the current minimum flow is set at a value very close to the 7-d MALF.

The existing minimum flow and allocation limit are predicted to result in a hydrograph that is unimpacted relative to naturalised flows (based on the DHRAM score). Water quality in the lower Poumāhaka River currently exceeds LWRP objectives and/or national bottom lines and given the low level of actual water usage in the Poumāhaka catchment (Section 4.1.1), it appears that the contribution of water allocation to these exceedances is likely to be minor.

8.2 Options for flow management in the Waipahī sub-catchment

The Waipahī River is a major tributary of the Poumāhaka. While the headwaters of the Poumāhaka rise at high altitudes in the Umbrella Mountains/Whitecoomb Range (maximum elevation 1485 m a.s.l.), the Waipahī sub-catchment is at much lower elevations (maximum elevation <620 m a.s.l.). Accordingly, flows in the Waipahī are poorly correlated with those in the upper Poumāhaka (based on flows at Glenken). The Waipahī also supports a highly valued, regionally significant brown trout fishery.

At present, the only major consent (RM14.175.01) in the Waipahī sub-catchment has a residual flow of 455 l/s (84% of 7-d MALF), although water metering data for this take indicates that the actual take rarely exceeds 2 l/s, the maximum consented rate of take is 135 l/s. Surface water allocation in the Waipahī is 150 l/s (27% of 7-d MALF). Introducing a minimum flow for the Waipahī sub-catchment at the existing Waipahī at Waipahī flow site would have little impact on environmental outcomes at present, as RM14.175.01 is downstream of the minimum flow site and the other take is for a rural water supply scheme (2009.142.V2) that is listed in Schedule 1B of the RPW, and is therefore exempt from minimum flows.

While introducing a minimum flow on the Waipahī would have little immediate benefit given the considerations above, it would provide protection for the specific values of the Waipahī sub-catchment and would provide consistency for water users in the Waipahī catchment. However, this would only be necessary if additional primary allocation became available in the Poumāhaka catchment.

8.3 Potential effects of climate change in the Poumāhaka catchment

The potential effects of future climate change are subject to considerable variation depending on future emission scenarios. This assessment is based on the assessment of Macara et al. (2019) using two scenarios (RCP[11]4.5 and RCP8.5) for the period 2031-2050.

The projected effects of climate change (from Macara et al. 2019) are not expected to significantly increase the probability, magnitude and duration of low flow events in the Poumāhaka catchment (Table 13) and are not expected to affect the achievability of in-stream objectives in the Poumāhaka catchment.

Table 13 Potential effects of climate change on the Waiwera River/Te Waiwhero catchment based on the assessment of Macara et al. (2019) using two scenarios (RCP4.5 and RCP8.5) for the period 2031-2050.

Variable	Projected effect	Potential effect on hydrology of Waiwera River/Te Waiwhero	Potential ecological consequences
Temperature	• Increased mean temperatures (0.5-1°C) • Increased annual mean maximum temperature (0.5-1.5°C) • No increase in number of hot days (>30°C) (increase of <1 days per annum) • Reduced frost days (5-10 fewer frost days per annum)	• Increased evapotranspiration • Faster flow recession • Slightly increased irrigation demand	• Higher water temperatures, reduced suitability for sensitive species • Faster accrual of periphyton biomass
Rainfall	• Little change in annual mean rainfall (0-5%) • Increased summer mean rainfall (-5% -+5%) • Slight increase in risk of low rainfall events • Small increase in heavy rain days	• Little change in likelihood and/or magnitude of low flow events • Little change in likelihood of high rainfall events	
Snow	• No change in snow days		
Hydrology	• No change to slight increase in Q95 flow (-5 - +10%) • Little change to slight increase in reliability for irrigators	• Little change in low flows	• Little change in habitat availability

[11] Future climate change projections are considered under four emission scenarios, called Representative Concentration Pathways (RCPs) by the IPCC. RCP 4.5 is a mid-range scenario where greenhouse gas concentrations stabilise by 2100, while RCP8.5 is a "business as usual" scenario with greenhouse gas emissions continuing at current rates.

9 Conclusions

A minimum flow for primary allocation of 3,600 l/s (1 October to 30 April) or 7,000 l/s (1 May to 30 September) applies at Burkes Ford. The primary allocation limit specified for the Poumāhaka catchment in Schedule 2A is 1,000 l/s.

The flow statistics based on the analysis of Lu (2023) are summarised below:

Site		Flow statistics (m^3/s)		
		Mean	Median	7d MALF (Jul-Jun)
Pomahaka at Burkes Ford	Naturalised flows	25.376	16.540	3.521
	Observed flows	25.255	16.411	3.455
	ORC 2006	26.9	-	4.3
Waipahī at Waipahī	Naturalised flows	4.778	2.521	0.547
	Observed flows	4.774	2.518	0.540

There are twenty-nine permits for primary allocation in the Poumāhaka River (Table 4). The purpose of twelve of these permits includes irrigation, along with stock water, dairy shed water, frost fighting and domestic use in some cases (combined maximum consented rate of take = 1,247.5 l/s). There are four permits for town or rural water supply schemes (combined maximum consented rate of take = 114.3 l/s), ten permits for dairy shed and stock water (combined maximum consented rate of take = 20.2 l/s) and three non-consumptive[12] takes for the purpose of operating gold-mining equipment (sluices) in the Poumāhaka catchment (combined maximum consented rate of take = 59.5 l/s).

Periphyton cover in the upper Poumāhaka at Aitchison Runs Road has typically been low, typically dominated by thin to medium light brown and dark brown/black films/mats, likely composed of diatoms and benthic cyanobacteria. Cover by thick mats and/or filamentous algae has typically been low at this site. The periphyton community in the Waipahī at Waipahī has been variable, but thin to medium light brown and dark brown/black films/mats (likely diatoms and benthic cyanobacteria) have typically had the highest cover. High cover by filamentous algae has been observed on several occasions, although it has only exceeded 30% on one occasion. Chlorophyll a concentrations in the upper Poumāhaka at Aitchison Runs Road were consistently low (A-band) with the exception of a single occasion which was close to the upper limit of B-band, placing this site in A-Band. Chlorophyll *a* concentrations in the Waipahī at Waipahī were low (A-band) but several periods of high biomass were observed in the 2021 and 2022 seasons, with several values in excess of 150 mg/m^2 observed over this period. Observed chlorophyll a concentrations in the Waipahī at Waipahī place this site in D-band (below the national bottom line).

The cased caddis fly (*Pycnocentrodes*), and the mudsnail *Potamopyrgus* were the most abundant taxa collected in the Poumāhaka at Burkes Ford, while riffle beetles (Elmidae), the cased caddis fly (*Pycnocentrodes*), the common mayfly *Deleatidium* and the net-spinning caddis fly *Hydropsyche* (*Aoteapsyche*) were among the most abundant macroinvertebrate taxa collected in the Poumāhaka at

[12] Where water taken is immediately returned to the source water body

Glenken. The common mayfly *Deleatidium* and riffle beetles (Elmidae) were among the most abundant macroinvertebrate taxa collected in the Upper Poumāhaka at Aitchison Runs Road. MCI scores based on the limited sampling available for Burkes Ford put this site in C-band of the NOF, while scores for Glenken and Aitchison Runs Road put this site in B-band of the NOF. SQMCI scores for Burkes Ford put this site in D-band of the NOF and below the national bottom line, while SQMCI scores for Glenken and Aitchison Runs Road put this site in B-band of the NOF.

MCI and SQMCI scores for Waipahī at Waipahī and Cairns Peak put these sites in C-band of the NOF.

Six species of indigenous freshwater fish have been recorded from the Poumāhaka catchment including three species that are at risk or threatened – longfin eel (at risk – declining), Pomahaka galaxias (threatened – nationally vulnerable), and kanakana/lamprey (threatened – nationally vulnerable). Recent genetic studies have identified two distinct lineages of non-migratory galaxias in the Poumāhaka catchment – a flathead species (referred to as *G.* "Pomahaka") and a new roundhead lineage (*Galaxias* "species Z"). Brown trout, rainbow trout and chinook salmon have also been collected from the Poumāhaka catchment. The Poumāhaka River supports a regionally important sport fishery for both resident and sea run brown trout, while the upper Poumāhaka River has backcountry characteristics and the Waipahī River is recognised as a regionally important brown trout fishery.

The updated hydrological analysis of Lu (2023) estimates the 7-d MALF at 3.5 m^3/s, suggesting that the current minimum flow is set at a value very close to the 7-d MALF. Thus, it will result in habitat retention levels that are very close to those at the natural 7-d MALF for all species considered. Given this and the low level of actual water usage in the Poumāhaka catchment it appears that the water allocation is unlikely to contribute to the observed exceedances of aquatic ecology and water quality objectives in the Poumāhaka catchment.

The existing minimum flow and allocation limit are predicted to result in a hydrograph that is unimpacted relative to naturalised flows (based on the DHRAM score). However, periphyton biomass in the Waipahī at Waipahī exceeds both the LWRP objectives for the Lower Clutha Rohe and the national bottom line (based on Table 2 of the NOF; NPSFM 2022). Water abstraction can affect periphyton accrual and may contribute to high periphyton biomass and exceedance of periphyton targets. However, given the very low level of actual use in the Waipahī sub-catchment, water allocation is unlikely to have contributed meaningfully to the high biomasses observed in the Poumāhaka catchment.

10 References

Dunn, N.R.; Allibone, R.M.; Closs, G.P.; Crow, S.K.; David, B.O.; Goodman, J.M.; Griffiths, M.; Jack, D.C.; Ling, N.; Waters, J.M.; Rolfe, J.R. 2018: Conservation status of New Zealand freshwater fishes, 2017. *New Zealand Threat Classification Series 24*. Department of Conservation, Wellington. 11 p.

Heath, M. W., Wood, S. A., Brasell, K. A., Young, R. G., & Ryan, K. G. (2013). Development of habitat suitability criteria and in-stream habitat assessment for the benthic cyanobacteria *Phormidium*. River Research and Applications, DOI: 10.1002/rra.2722.

Hilsenhoff, W. L. (1977). Use of Arthropods to Evaluate Water Quality of Streams. Wis. Dep. Nat. Resour. Technical Bulletin, 100.

Hilsenhoff, W.L. (1987). An Improved Biotic Index of Organic Stream Pollution. *Great Lakes Entomologist*, **20**, 31-39.

Jowett I & Wilding T (2003). Flow requirements for fish habitat in the Chatto, Lindis, Manuherikia, Pomahaka and Waianakarua Rivers. NIWA Client Report HAM2003-052. 29 p. plus appendix.

Lu X (2023). Flow naturalisation of the Pomahaka River. Otago Regional Council, Dunedin. 6 p. plus appendix.

Macara, GR (2015). The Climate and Weather of Otago. 2nd edition. NIWA Science and Technology Series Number 67.

Olsen, D. A., Tremblay, L., Clapcott, J., & Holmes, R. (2012). Water temperature criteria for native biota. Auckland Council Technical Report 2012/036, 80 p.

Ozanne R, Borges H & Levy A (2023). State and trends of river, lake, and groundwater quality in Otago – 2017-2022. Otago Regional Council, Dunedin.

Stark JD (1985). A macroinvertebrate community index of water quality for stony streams. *Water & Soil Miscellaneous Publication* 87. National Water and Soil Conservation Authority, Wellington, New Zealand), 53 p.

Stark JD & Maxted JR (2007). A user guide for the Macroinvertebrate Community Index. Cawthron Institute, Nelson. 48 p. + appendices.

Todd, A. S., Coleman, M. A., Konowal, A.M., May, M. K., Johnson, S., Vieira, N. K. M., & Saunders, J. F. (2008). Development of New Water Temperature Criteria to Protect Colorado's Fisheries. Fisheries, (33), pp. 433–443.

Turnbull, I.M., Allibone, A.H, 2003: Geology of the Murihiku area, Institute of Geological & Nuclear Sciences 1:250,000 geological map 20, 1 sheet and 74 p., Lower Hutt, New Zealand.

Unwin, M (2016). Angler usage of New Zealand lake and river fisheries: Results from the 2014/15 National Angling Survey. NIWA Client Report 2016021CH, 59 p., plus appendices. Prepared for Fish & Game New Zealand.

Wagenhoff A, Shearer K, Clapcott J (2016). A review of benthic macroinvertebrate metrics for assessing stream ecosystem health. Prepared for Environment Southland. Cawthron Report No. 2852. 49 p. plus appendices.

Williams J (2016). Pomahaka River morphology and riparian management strategy. Otago Regional Council, Dunedin. 40 p. plus appendices.

RJ Wilkinson, LA McKergow, RJ Davies-Colley, DJ Ballantine & RG Young (2011) Modelling storm-event *E. coli* pulses from the Motueka and Sherry Rivers in the South Island, New Zealand, New Zealand Journal of Marine and Freshwater Research, 45:3, 369-393, DOI: 10.1080/00288330.2011.592839

Wood, S. A., Selwood, A. I., Rueckert, A., Holland, P. T., Milne, J. R., Smith, K. F., Smits, B., Watts, L., & Cary, C. S. (2007). First report of homoanatoxin-a and associated dog neurotoxicosis in New Zealand. Toxicon, (50), pp. 292–301.

Appendix A

Flow naturalisation of the Poumāhaka River (Lu 2023)

Flow naturalisation of the Pomahaka River

Contents

Document Review

Name	Role	Date Completed
Xiaofeng Lu	Author	27/06/2023
Helen Manly	Reviewer	27/06/2023
Dave Stewart	Technical Reviewer	30/06/2023

This document describes how naturalised flow statistics at the current flow recorder on the Pomahaka River at Burkes Ford were derived.

Daily flow time series data for Pomahaka River

The daily flow time series data available in the Pomahaka catchment are listed in **Table 1**. The locations of the flow sites are shown in **Figure 1**. The current consents used for flow naturalisation (shown in **Figure 1**) are listed in **Table 3** in the HTML file in the **Appendix**.

Table 1: The daily flow time series data available for the analysis above the Burkes Ford flow site on the Pomahaka River.

Site	Start	End	Length (year)
Pomahaka at Burkes Ford	4/08/1961	24/06/2023	61.9
Pomahaka at Glenken	30/06/1992	24/06/2023	31.0
Pomahaka at Hamiltons Flat	7/11/1995	5/11/1996	1.0
Waipahi at Waipahi	4/07/1996	24/06/2023	27.0
Waikoikoi Creek at Conical Hill Road	15/07/2008	18/11/2009	1.3
Heriot Burn at Park Hill Road	25/10/2012	24/06/2023	10.7
Crookston Burn at Kelso Road	15/07/2008	17/11/2009	1.3
Leithen Burn at Leithen Road	17/09/2008	17/11/2009	1.2
Heriot Burn at SH90	17/09/2008	22/11/2011	3.2
Spylaw Burn at Hukarere Station Road	23/09/2008	17/11/2009	1.2
Wairuna at Millar Road	15/07/2008	24/06/2023	14.9
Washpool Stream at Kilhastie Road	15/07/2008	18/11/2009	1.3

Flow naturalisation of Pomahaka at Burkes Ford

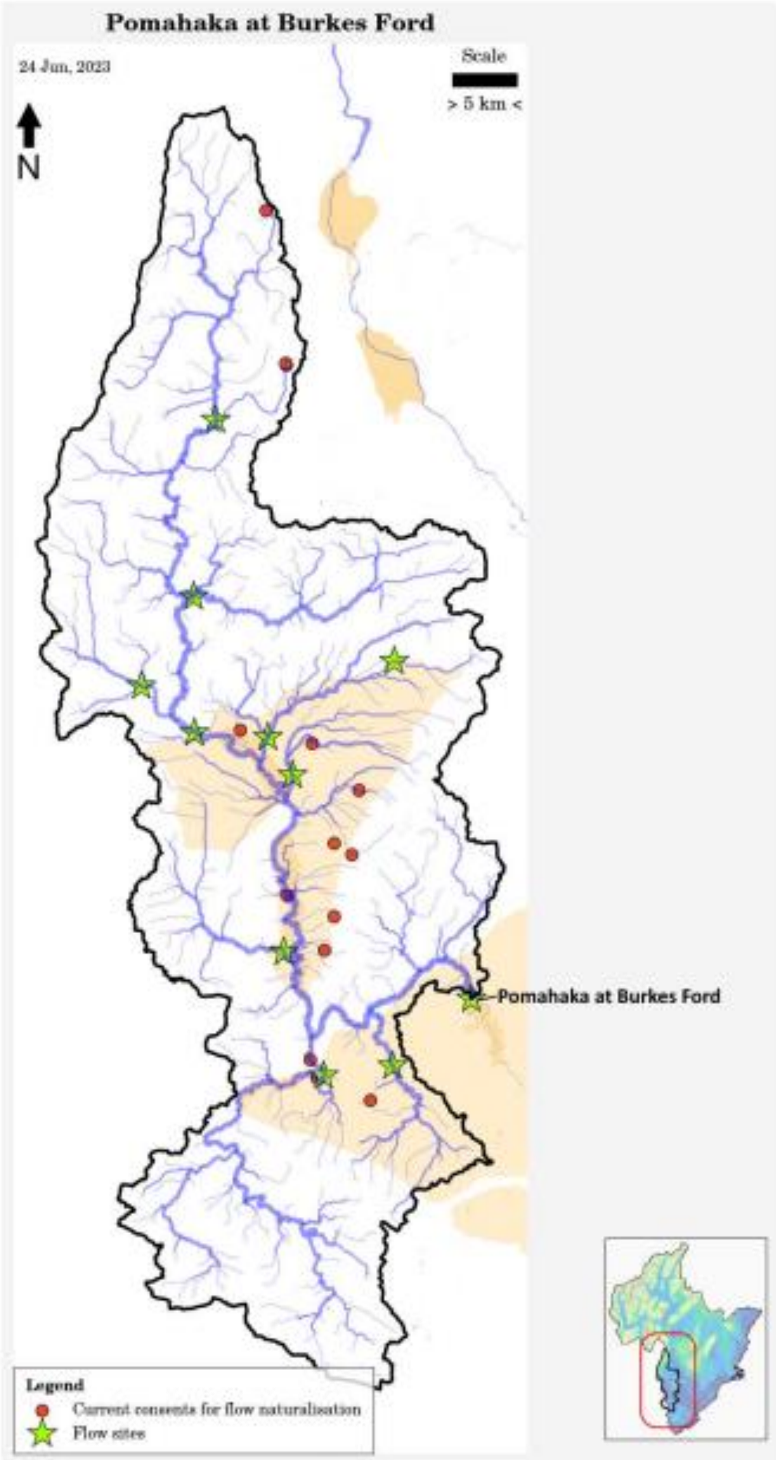

Figure 1: The location of flow recorders and current consents above the Burkes Ford flow site on the Pomahaka River.

Daily water use time series

Time series data of water use (WU) is used to naturalise the flow at the Burkes Ford flow recorder. All consents above the flow recorder must first be identified.

Total water use above the Burkes Ford recorder on the Pomahaka River

*Altogether 95 consents have been issued on the Pomahaka River above the Burkes Ford recorder. However, after removing consents which do not affect flow, 59[1] consents are used in the flow naturalisation process (See **Table 3** in the HTML file listed in the **Appendix**). As shown in the table, 16 are currently active. **Figure 2** shows the total water use (WU) regime above Burkes Ford.*

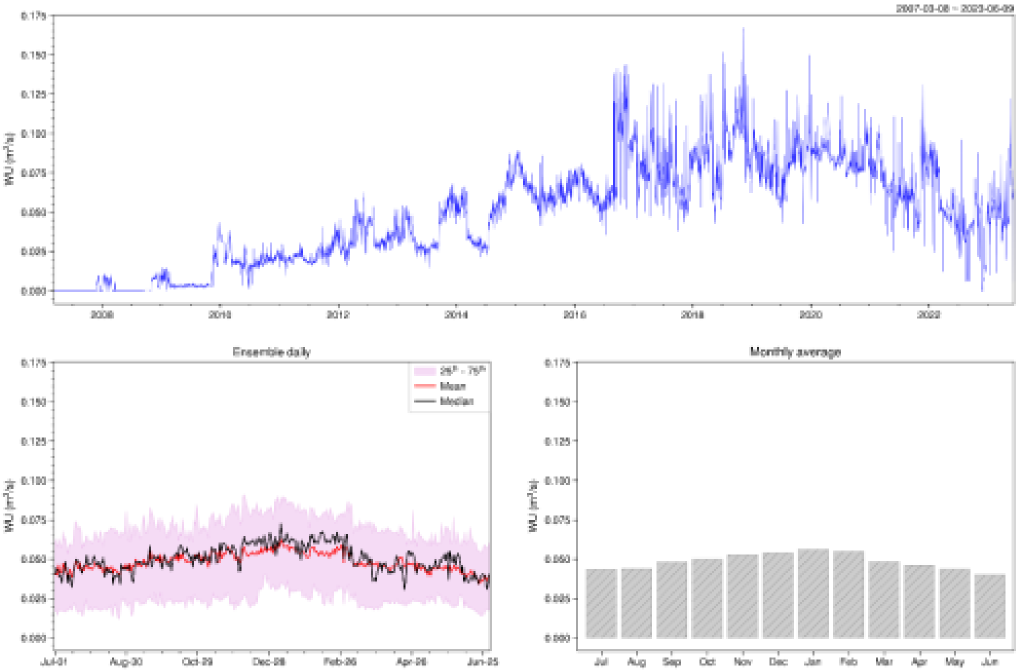

Figure 2: The total water use upstream of the recorder at Burkes Ford on the Pomahaka River.

As shown in **Figure 2**, the water is used across the whole year with various purposes, such as rural water supply, irrigation, domestic use, and stockwater. The pattern of

[1] 59 consents used in this study are listed in **Table 3** in the HTML file listed in the **Appendix**. They are the consents left by filtering out:

- Groundwater takes with no effect on the nearby water body (refer to the attribute of *Stream depletion rate*)
- Non-consumptive takes
- Retakes

water use in Figure 2 reflects the multi-use of the water in this catchment and water use is not dominated by irrigation abstraction.

The total WU time series after the water year 2013/14 is used in this study. Since 2013/14, the mean water use across the whole year is 69 L/s.

Flow naturalisation

This section describes how the naturalised flow statistics are estimated at the Burkes Ford flow recorder on the Pomahaka River.

Method

The naturalised flow time series can be estimated by adding the upstream total WU to the observed flow records.

This study's key goal is to produce long-term flow statistics, including the naturalised seven-day mean annual flow (7dMALF) and long-term median and mean flows for the flow recorder at Burkes Ford.

Naturalised flow Statistics

Basic flow statistics (Table 2).

Table 2: Naturalised flow statistics for the Burkes Ford recorder on the Pomahaka River (01/07/2013 - present).

Site	Mean (m^3/s)	Median (m^3/s)	FRE3[2] ($year^{-1}$)	7dMALF (m^3/s) (Jul - Jun)
Pomahaka at Burkes Ford (observed)	25.255	16.411	7.9	3.455
Pomahaka at Burkes Ford (naturalised)	25.376	16.540	7.8	3.521

[2] The frequency of events exceeding three times the median flow value. In this study, an independent event is defined by a minimal event interval of 7 days.

The naturalised mean annual 7-day moving average flows of 5- and 10-year return periods at Burkes Ford are estimated as $Q_{7,5}$ = 2.583 and $Q_{7,10}$ = 2.474 m^3/s, respectively.

It must be noted that the $Q_{7,5}$ and $Q_{7,10}$ values were estimated using a relatively shorter naturalised time series and they may vary dramatically when more data is available in the future. Using different distributions could also vary the results.

Appendix

The complete list of all consents used in this analysis can be found in **Table 3** in the HTML file.