



Toitū Te Hikapupu/Pleasant River Restoration Project

Year 4 Monitoring Report - to June 30, 2025

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Whirika Consulting
PO Box 1320
Dunedin 9054

Level 3
2 Dowling Street
Dunedin 9016

(03) 742 1093
kiaora@whirika.co.nz
whirika.co.nz

Report prepared for client by:

Dr Solis Norton Whirika Consulting, Associate Professor Marc Schallenberg, Department of Zoology, University of Otago, Matt Dale, WaterScape Connections Limited & Sally Dicey, Whirika Consulting.

Report reviewed by S Norton & S Dicey

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© Whirika Consulting Limited
2 Dowling Street
Dunedin 9016
New Zealand

kiaora@whirika.co.nz
whirika.co.nz

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1 Executive summary

The Toitū Te Hākapupu/Pleasant River Restoration Project (“Toitū Te Hākapupu project”) is a four-year (2021-2025) project with the objective of improving water quality in Te Hākapupu/Pleasant River catchment while also enhancing conservation, cultural, and community values.

The project is being delivered by the Otago Regional Council in partnership with Kāti Huirapa Rūnaka ki Puketeraki and includes development of an overarching Catchment Action Plan.

The catchment is 13,000 hectares in size and situated 50 kilometres north of Dunedin. It contains Te Hākapupu/Pleasant River Estuary Wetland Complex, a predominantly estuarine system about 84 hectares in size noted as rare, vulnerable, and in fair to poor condition (Roberts et. al, 2022). This is the largest wetland in the North Otago Freshwater Management Unit. Land use in the catchment is mainly commercial forestry (50%) and medium to low intensity farming (43%) (Norton, Dicey and Mohan, 2023). Commercial forestry has only emerged in the catchment as a land use since the 1990s. The catchment is sparsely populated, contains no towns, and has a low annual rainfall of around 650mm. In-stream discharge (flow) can be low during the summer and autumn months, reducing the main tributaries (Te Hākapupu/Pleasant River, Trotters Creek, and Watkin Creek) from steady flow to a series of isolated pools.

A range of water and ecological monitoring methods have been utilised in this project to establish baseline information about water quality and the ecological health of waterways in the catchment, as well as to identify any potential issues related to these. They have been developed with guidance from Kāti Huirapa Rūnaka ki Puketeraki and the local community.

The objective of this report is to describe the results of this monitoring, which occurred from March 2023 to June 2025. Annual iterations of this report in 2023 and 2024 were also used throughout the project to recommend changes to monitoring methods and to identify potential considerations for a catchment action plan.

A total of 34 different metrics were used. They range from high frequency data logging to temporally discrete sampling and measurements. They cover water quality, sediment flux, environmental DNA, stream habitat scoring, ecological assessment, and an assessment of barriers to fish passage. Key outcomes are summarised below.

The nature of waterways in Te Hākapupu/Pleasant River catchment

Hydrological discharge in the catchment is ‘flashy’ in nature, meaning that it is subject to sudden, large increases in flow. It also has periods of no discharge (flow) which may last for months on end. For example, for Te Hākapupu/Pleasant River at the Patterson Road ford, the mid-point (median) discharge was 0.04 cumecs, while the peak discharge was 1,050 times higher (42 cumecs).

Water quality measured using grab samples

Monthly monitoring using grab sampling (only undertaken when flow was visible) indicated that turbidity was above the ORC Water Quality Schedule 15 (80th percentile) threshold for Te Hikapupu/Pleasant River and Watkin Creek, but not for Trotters Creek. It also showed that nitrate and nitrite nitrogen (NNN) was above the ORC (80th percentile) threshold for all three tributaries. Te Hikapupu/Pleasant River was also above the NPSFM national bottom line for NNN (95th percentile).

These thresholds are for continuously flowing waterways based on at least five years of data. Hence, they are not strictly applicable to waterways in this catchment which are ephemeral and which have been sampled over only two years thus far. However, most of the sampling occurred at comparatively low levels of discharge and the comparison is made for illustrative purposes.

Sediment flux

Annual flux of sediment in Te Hikapupu/Pleasant River at the Patterson Road ford was estimated at 358 tonnes in 2023/24 and 987 tonnes in 2024/25. Monthly flux values ranged from 0 to 924 tonnes. This site receives discharge from Te Hikapupu/Pleasant River and Trotters Creek but not from Watkin Creek, which drains approximately 20% of the catchment. Thus, additional sediment will be entering the estuary from Watkin Creek and from run-off into Te Hikapupu/Pleasant River between Patterson Road ford and the estuary.

Sediment flux varied by a factor 2.76 in the two years monitored and will be influenced by climatic and land management factors from year to year. It is recommended that at least 10 years of annual flux estimates be obtained to better derive a mean annual sediment flux and to understand the magnitude and drivers of interannual variability in sediment flux.

The establishment, harvest and replanting of commercial forestry, plus the construction of roads within the forest estate, as well as agricultural practices such as winter grazing all represent significant risks to sedimentation of the catchment's waterways and estuary. Effective management of these land uses could contribute significantly to supporting the other activities undertaken within the project such as the fencing of 39 kilometres of waterways, the planting of 92,000 native plants, and the improvement of fish passage at five sites to help Kāti Huirapa Rūnaki Puketeraki, the community, and Otago Regional Council meet the aspirations for this catchment described in the catchment action plan.

Ecological baseline monitoring

Ecological baseline monitoring at ten sites throughout the catchment involved scoring stream habitat against nine criteria, in addition to measuring re-suspendable sediment (five replicates per site) and macroinvertebrate abundance. Habitat scores were 'poor' at two sites, 'fair' at six sites, and 'good' at two sites. No sites were scored as 'excellent'. The two 'good' sites were in the upper reaches of the waterways, and the lowest scores were consistently from the lower reaches of both Watkin Creek and Trotters Creek.

The Paru site in Watkin Creek had levels of deposited sediment about three times higher than at the other sites in the three tributaries. This difference had also been noted in the years preceding monitoring. It may have been caused by upstream erosion due to the clearing of land for commercial forestry planting in 2019.

Macroinvertebrate abundance followed a similar trend to habitat scores.

The combination of low discharge and low oxygen levels, due to the combination of groundwater seeps and higher water temperatures, is likely to be impacting stream health along some stretches of the catchment's waterways.

Localised areas of turbidity

Areas of episodic localised turbidity have been observed in the catchment's waterways. These may occur when groundwater with low dissolved oxygen and high iron concentrations meets surface water with higher oxygen concentrations. This can lead to chemical precipitation of iron oxides and other minerals, which result in localised high turbidity. Our observations indicate that such seeps are most noticeable for short periods of time, when shallow groundwater flow is sufficient to discharge into the rivers. These turbid zones are not visible when river flows are high (perhaps due to dilution) or when groundwater flow to the river is restricted due to dry conditions. When the groundwater seeps impact the streams, dissolved oxygen levels in the streams are potentially depleted due to chemical oxidation.

Efforts during the project to investigate these seeps were unsuccessful due to their episodic occurrence and our initial lack of knowledge about how the seeps are affected by soil moisture and river flow. When seeps again become conspicuous in future, their ecological impacts could be investigated either as part of the catchment action plan, or as an independent research project.

Fish species

Across the six sites sampled for fish using eDNA analysis, including the estuary, the following freshwater species detected are considered threatened; bluegill bully (*Gobiomorphus hubbsi*), inaka/inanga (*Galaxias maculatus*) and tuna (New Zealand longfinned eel, *Anguilla dieffenbachia*). In addition, four are considered mahika kai species; banded kokopu (*Galaxias fasciatus*), inaka, longfinned eel, and shortfin eel (*Anguilla australis*). No non-migratory galaxids were detected.

Fish monitoring revealed fair numbers of tuna (eels) as well as inaka, common bully (*Gobiomorphus cotidianus*) and European perch (*Perca fluviatilis*) at the freshwater sites. Sand flounder (*Rhombosolia plebeia*) was the single species caught at the estuary site, however the presence of three other mahika kai species was indicated by eDNA sampling; kahawai (*Arripis trutta*), skate (*Rajidae* spp.) and yellow eyed mullet (*Aldricheta forsteri*).

Stress was evident on the common bully population in Watkin Creek. This may have been related to the high density of fish recorded there and to low levels of dissolved oxygen. Further

investigation of the cause of this stress is recommended, either as part of the Catchment Action Plan or as unrelated research.

Fish passage

A fish passage assessment of the catchment's waterways identified seven priority sites where barriers existed to the movement of fish. These barriers comprised fords, flap gates, and culverts in fords. Their full removal and reconstruction were recommended.

In response the Toitū Te Hākapupu project has established a rock ramp at the Brooklands and Patterson Road fords and has facilitated three additional farm culvert replacements. These improvements have resulted in a marked increase in fish passage in the lower Hākapupu catchment.

The fish passage assessment was an important step in prioritising action to improve the access of native fish from the sea into the catchment. Remedial actions to date based on this prioritisation have shown great results and more gains stand to be made.

High frequency water quality monitoring with Aquawatch waka

High frequency water quality monitoring showed that dissolved oxygen in the rivers can drop to concentrations below 5mg/ml (recommended threshold for aquatic health) during dry periods. Trotters Creek and Watkin Creek were below 5mg/ml for 23% and 22% of the monitoring period respectively.

Turbidity data collected by the waka differed at times to grab-sampling data collected concurrently. Waka data also contained anomalies that could not be readily explained, leading to uncertainties in the interpretation of this information. The combination of some apparently anomalous data and the fact that discharge data was available only for Te Hākapupu/Pleasant River led to the decision to use grab sample data for this river at the Patterson Road ford to estimate sediment flux.

Monitoring turbidity upstream and downstream of a sub-catchment with active erosion on farmland and with an area of recently harvested commercial forest did not clearly identify increased sediment flux from this area entering Te Hākapupu/Pleasant River. In addition, no clear turbidity spike was evident in the river when rain fell upon earthworks in this area, where sediment traps had recently been constructed.

One conclusion from the waka data is that the larger refuge pools (pools that remain when continuous discharge stops) are likely to be important for the health of aquatic organisms when dissolved oxygen levels drop to stressful levels. The protection and enhancement of these pools achieved during the project through riparian plantings and fencing to exclude livestock has been a major success. There are likely to be opportunities to extend this work to other parts of the catchment in future.

A second conclusion is that the waka provide a unique opportunity for data recording and visualisation in a community science setting. The web-based dashboard is an excellent way to communicate the data in real-time. For detailed analysis of those data, regular observation of the upstream and surrounding area, together with regular servicing of the waka is important for providing supporting information and for ensuring the collection of reliable data. Even with this input, anomalies may result that require expert input into data quality control.

Final recommendations

- Investigate the cause of elevated sediment levels at the Paru site and consider this site for sediment mitigation actions.
- Investigate the impact of stress on fish health, the common bully in particular, in Watkin Creek. For example, examine fish condition, fish density, water quality and environmental stressors.
- Continue remedial work on obstructions to fish passage.

2 Introduction

The health of our waterways is intrinsically linked to the wellbeing of Aotearoa/New Zealand, both from the perspective of the species and ecosystems that they support, as well as the cultural, social, and economic benefits that they provide. The National Policy Statement for Freshwater 2020 (NPSFM) directs local authority management of freshwater under the Resource Management Act 1991.

Te Mana o te Wai is the fundamental concept underpinning the management of freshwater in Aotearoa/New Zealand under the National Policy Statement for Freshwater Management (NPSFM). Te Mana o te Wai is defined as:

“a concept that refers to the fundamental importance of water and recognises that protecting the health of freshwater protects the health and well-being of the wider environment. It protects the mauri of the wai. Te Mana o te Wai is about restoring and preserving the balance between the water, the wider environment, and the community.”
(clause 1.3)

The NPSFM sets out a hierarchy of obligations, so that natural and physical resources are managed in a way that prioritises:

- First, the health and well-being of water bodies and freshwater ecosystems
- Second, the health needs of people
- Third, the ability for people and communities to provide for social, economic and cultural well-being, now and in the future.

To understand the health and well-being of waterways, and to design and implement effective interventions if required, it is important to understand the state and trends of the health of our waterways.

The Toitū Te Hākapupu/Pleasant River Restoration Project (“Toitū Te Hākapupu Project”) is a four-year (2021-2025) project funded by the Ministry for the Environment Jobs for Nature Fund. Its objective is to work with Kāti Huirapa Rūnaka ki Puketeraki and the community to create enduring improvement in the catchment’s water quality, particularly in relation to sediment, while also enhancing conservation, cultural, and community values. It is being delivered by the Otago Regional Council with science and planning support from Whirika Consulting.

For consistency in this report the project is referred to as the Toitū Te Hākapupu Project, the river as Te Hākapupu/Pleasant River and the estuary as Te Hākapupu/Pleasant River estuary. Also, the tributary within the catchment known as Trotters Creek or Owhakaoho is referred to as Trotters Creek.

Te Hākapupu/Pleasant River catchment is located 50km north of Dunedin and has a total catchment area of 13,000ha. It sits within the rohe of Kāti Huirapa Rūnaka ki Puketeraki and has three main tributaries; Watkin Creek, Trotters Creek, and the main stem; Te Hākapupu/Pleasant

River.

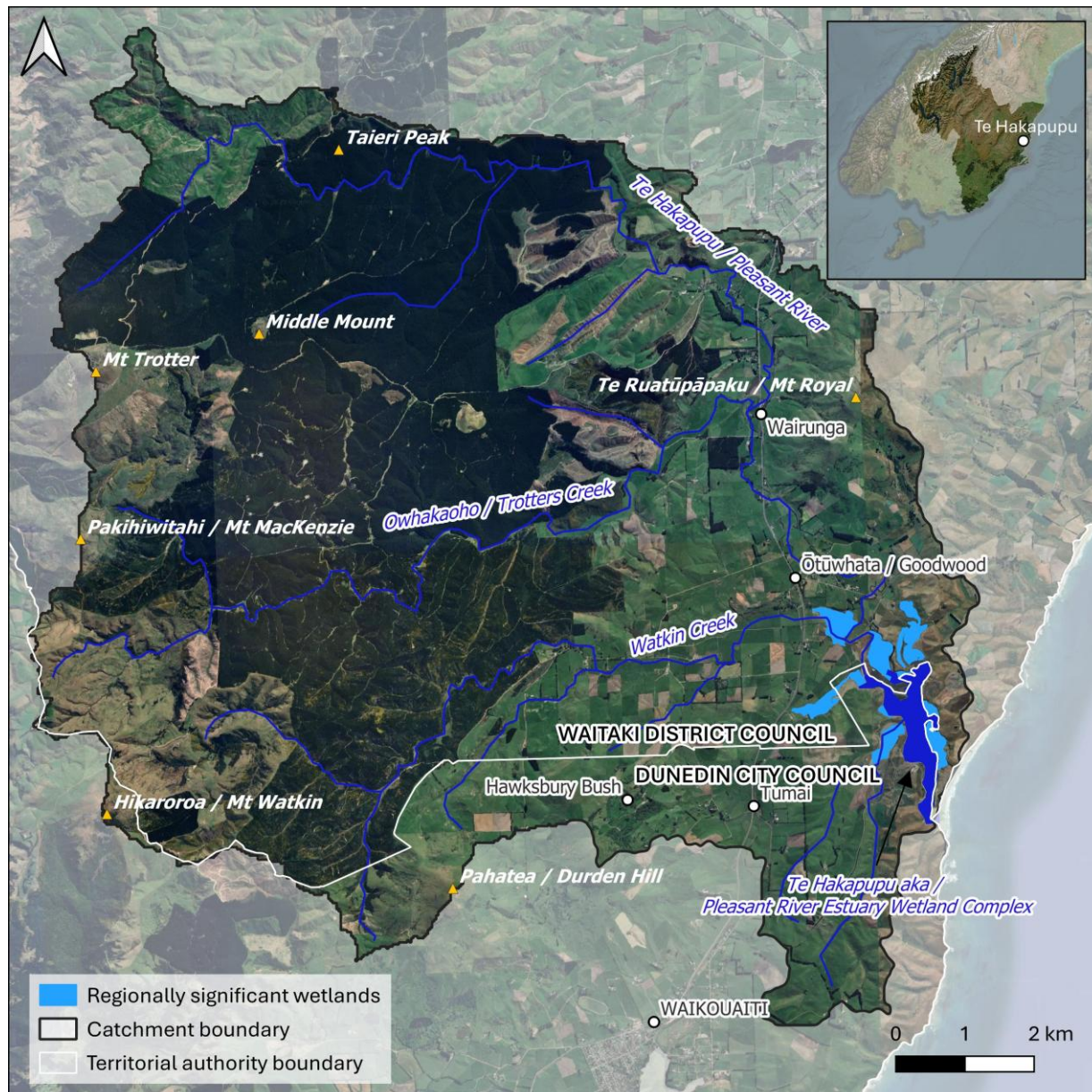


Figure 1).

Land use across approximately 50% of the catchment, mainly in its upper reaches, is commercial forestry. Much of the remainder (44%) is moderate to low intensity sheep, beef and deer farming in the mid to lower catchment. Gorse and broom represent 2% of the catchment (Norton, Dicey and Mohan, 2023).

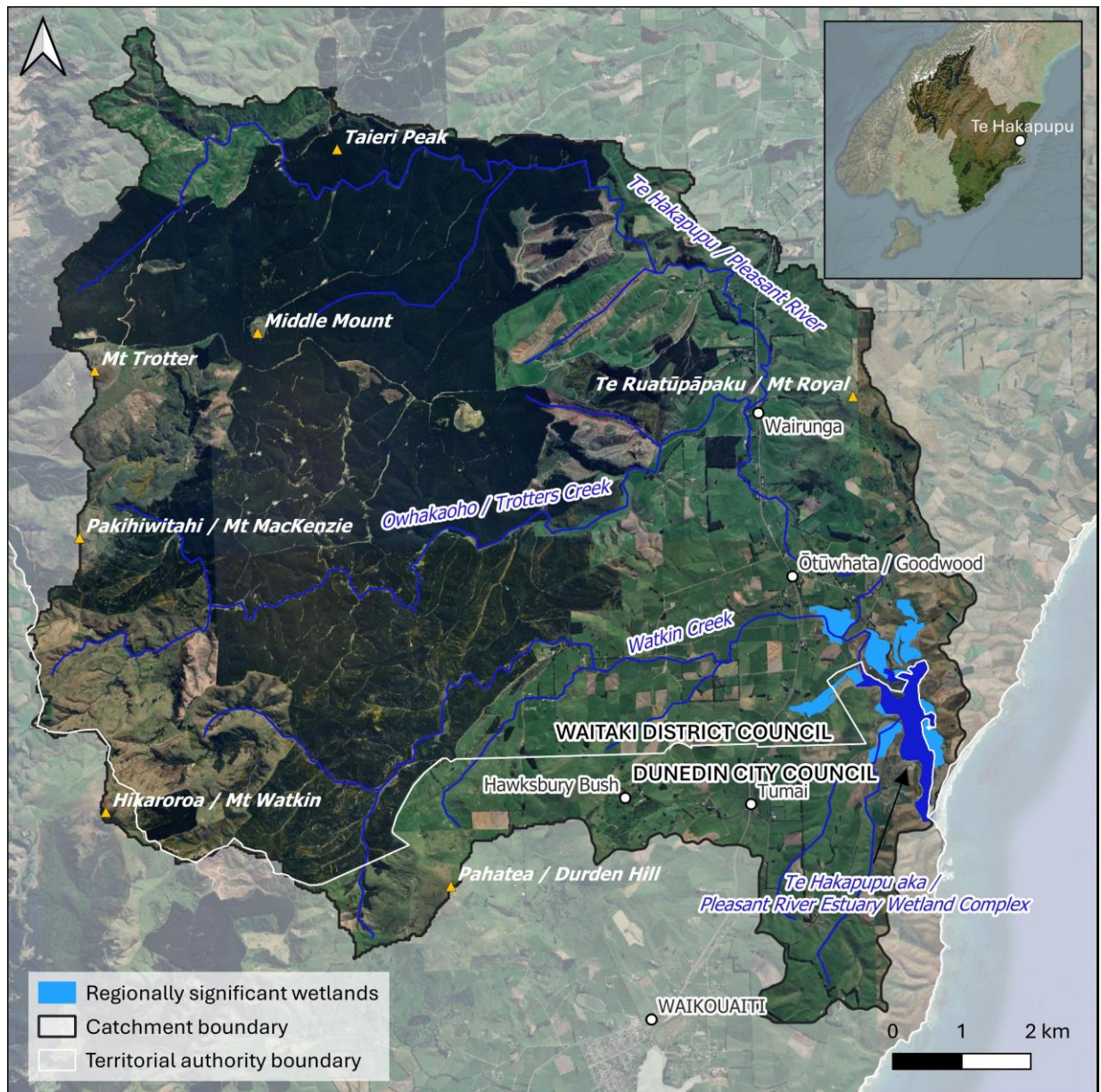


Figure 1. Te Hākapupu/Pleasant River catchment in Otago.

Erosion and the deposition of fine sediment into the streams and estuary of Te Hākapupu/Pleasant River catchment have been raised as a potential issue by the Otago Regional Council, Kāti Huirapa Rūnaka ki Puketeraki and the local community.

Understanding the nature and quality of the catchment's water and waterways is a key part of the wider catchment plan. With this knowledge, Rūnaka and the community can tailor their objectives to meet both the social and natural values of the catchment. On-going monitoring will also support an evaluation of any mitigations, and progress towards outcomes for the catchment.

More detailed information about the catchment is available in the Toitū Te Hākapupu/Pleasant River Restoration Project's Context Analysis (Norton et. al, 2024).

This report describes monitoring undertaken as part of Whirika Consulting's part in the Toitū Te Hākapupu Project from 1 January 2023 to 30 June 2025 and makes recommendations for catchment interventions and adaptations based on the results of:

- Water level and discharge monitoring
- Monthly water quality monitoring
- Environmental DNA
- Ecological baseline monitoring
- Real-time telemetered water quality monitoring.

3 Te Hākapupu/Pleasant River discharge

A telemetered discharge site administered by the Otago Regional Council is located immediately downstream of the confluence of Trotters Creek and Te Hākapupu/Pleasant River at the Patterson Road ford. Discharge data between March 2023 and March 2025 are shown in Figure 2.

The monitoring period was characterised by long periods of low, or no, discharge interspersed with several high discharge events. Discharge was less than 0.5 cumecs 94% of the time, and there were only 5 instances when it was higher than 10 cumecs. Thus, the river can be defined as having a 'flashy'/ephemeral nature, highlighted in Figure 6. Median discharge was 0.04 cumecs, mean discharge was 0.25 cumecs, minimum discharge was 0 cumecs and maximum discharge was 42.19 cumecs.

The total annual hydrological discharge was calculated over two years; March 2023 – February 2024, and March 2024 – February 2025. March was chosen as the starting point for the hydrological year because it is typically the driest time of year and discharge was either extremely low (less than 5 litres per second) or had stopped completely. Total annual hydrological discharge at the Patterson Road ford was estimated to be 5.957 million cubic metres in 2023/24 and 8.563 million cubic metres in 2024/25.

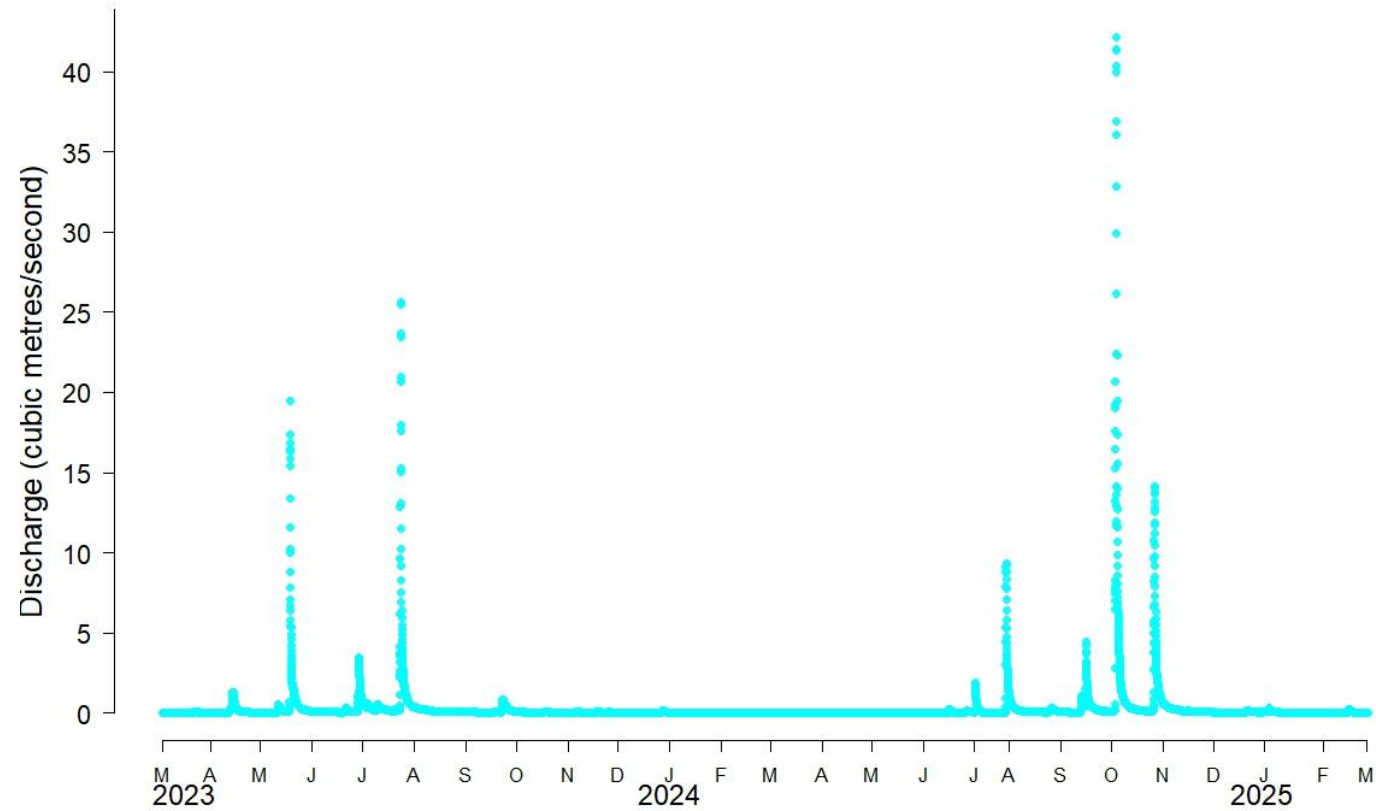


Figure 2. Discharge monitoring data measured by the Otago Regional Council in cubic metres per second for Te Hikapupu/Pleasant River at Patterson Road from March 2023 to March 2025, showing an extended period of low, or no, discharge from August 2023 to May 2024.

3.1 Interpretation

The hydrological discharge in Te Hikapupu/Pleasant River at the Patterson Road ford has a 'flashy' nature which indicates that discharge can rise rapidly to high levels. It has periods of no discharge which may last for months. To illustrate, the mid-point (median) of discharge was 0.04 cumecs, while the peak was 1,050 times higher (42 cumecs). This is an important hydrological and ecological characteristic of the catchment's waterways.

4 Water quality monitoring using grab samples

Based on feedback from a community hui in February 2023, sites 2, 4 and 5 (Figure 3) were selected for regular water quality monitoring using grab samples. Water samples were taken monthly, if flow was visible. Samples were chilled immediately following collection and sent to Hill Laboratories in Christchurch for analysis within 24 hours of collection. Monthly sampling began in May 2023 and finished in March 2025.

The first sampling event also included sweep net samples for invertebrates. The chosen sampling sites often contained thick growths of macrophytes and lacked gravels. This indicated that monitoring of the macroinvertebrate community index for stream health was not going to be informative at these lowland sites. Monitoring of macroinvertebrates at these sites was therefore not progressed.

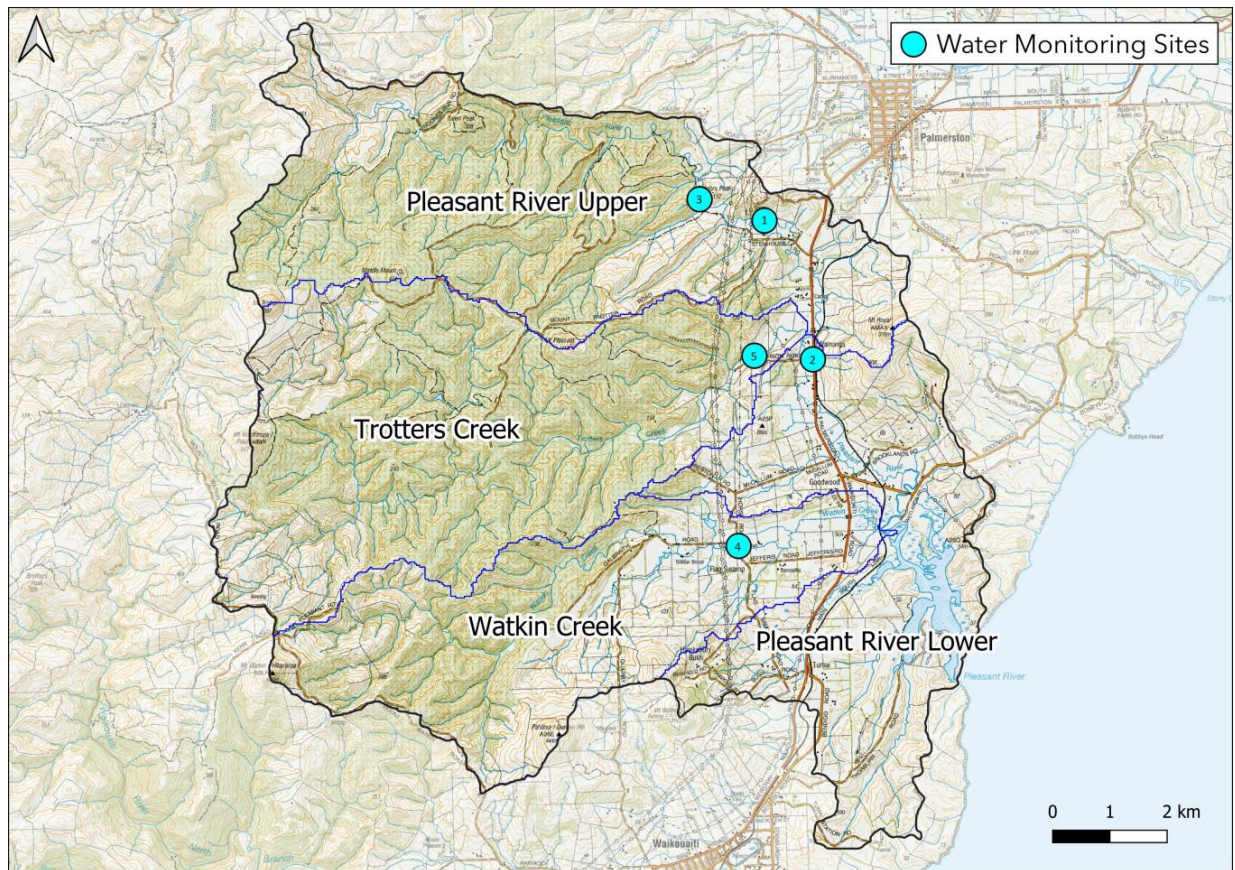


Figure 3. Water quality monitoring sites; sites 2, 4, and 5 were used for monthly grab samples, sites 2 and 4 were used for grab sampling during high discharge events, sites 1 and 3 had an Aquawatch waka installed and were not grab sampled (see section 13.1.3).

4.1 Results

4.1.1 Monthly grab sampling

Water quality results for the three main tributaries from monthly grab sample data are shown in Table 1, Table 2, and Table 3. Some sample values for total suspended solids (TSS), total oxidised nitrogen (NNN) and dissolved reactive phosphorous (DRP) were below analytical detection limits. For these, a value of half the detection limit was used in the analysis.

The medians, 95th percentiles and 80th percentiles are also presented to allow tentative comparison with water quality guidelines provided in the National Policy Statement for Freshwater Management and in Schedule 15 of the Otago Water Plan Change 6a. For this comparison green shading indicates the value meets NOF Band A. NOF is the National Objectives Framework, which is part of the National Policy Statement for Freshwater Management (NPS-FM) 2020, and used by the Otago Regional Council to set water quality metrics.

Most of the sampling occurred at comparatively low levels of discharge. For example, at Te Hikapupu/Pleasant River 5 of 16 samples were taken at or below median discharge (0.04 cumecs) and 12 of 16 samples were taken at or below average discharge (0.25 cumecs). All samples were

collected while discharge was less than one cumec, relative to maximum discharge of 42.19 cumecs.

Turbidity was above the ORC Water Quality Schedule 15 (80th percentile) threshold for Te Hākapupu/Pleasant River and Watkin Creek, but not for Trotters Creek.

Total oxidised nitrogen (NNN) was above the ORC Water Quality Schedule 15 (80th percentile) threshold for all three tributaries. Te Hākapupu/Pleasant River was also above the NPSFM threshold (95th percentile).

The National Objectives Framework (NOF) within the National Policy Statement for Freshwater Management (NPSFM) provides guidelines for dissolved reactive phosphorus (DRP; medians and 95th percentiles), which is related to the risk of periphyton proliferation as well as an indicator of the health of invertebrate, fish and ecosystem processes in rivers and streams. The DRP data suggest that these rivers do not exceed the national bottom line for DRP concentrations, although a full assessment requires more samples.

Table 1. Water quality data and discharge for Te Hikapupu/Pleasant River at site 2 (see Figure 3) from monthly grab samples. Turb is turbidity in NTU; TSS is total suspended solids in mg/L; TN is total nitrogen in mg/L; NNN is nitrate and nitrite nitrogen in mg/L; DRP is dissolved reactive phosphorus in mg/L; TP is total phosphorus in mg/L; Discharge is the associated discharge measured by the Otago Regional Council at the Patterson Road ford site in cubic meters per second (cumecs; m³/s). Red shading indicates value is either below the NOF bottom line or fails the Otago Regional Council guideline value. Gray shading indicates the measurement was below analytical detection limits and a value of half that limit has been used. **Note: the data from Te Hikapupu/Pleasant River represent only interim calculations for comparisons with the guideline values. Five years of monthly sampling is required to calculate the statistics required to compare to the guidelines. In addition, some samples were collected when discharge was above the median flow.**

Date	Time	Turb	TSS	TN	NNN	DRP	TP	Discharge
15 May 2023	4:00:00 PM	4.0	27.0	0.54	0.001	0.008	0.029	0.110
30 July 2023	4:30:00 PM	10.3	1.5	1.88	1.250	0.007	0.037	0.500
1 October 2023	1:30:00 PM	3.9	1.5	0.58	0.014	0.007	0.024	0.098
29 October 2023	5:23:00 PM	2.2	3.0	0.47	0.003	0.007	0.025	0.024
6 December 2023	4:18:00 PM	1.9	1.5	0.53	0.001	0.002	0.020	0.014
27 December 2023	7:06:00 PM	2.6	1.5	0.72	0.001	0.005	0.032	0.149
4 July 2024	1:00:00 PM	21.0	8.0	4.4	3.500	0.002	0.052	0.262
1 August 2024	12:40:00 PM	30.0	20.0	5.1	4.000	0.006	0.082	0.972
29 August 2024	11:45:00 AM	6.4	3.0	0.75	0.310	0.002	0.027	0.137
30 September 2024	11:38:00 AM	3.1	1.5	1.62	0.069	0.002	0.021	0.084
3 November 2024	5:20:00 PM	10.6	1.5	1.25	0.560	0.007	0.044	0.377
28 November 2024	7:00:00 PM	2.0	1.5	0.56	0.012	0.009	0.025	0.058
6 January 2025	1:20:00 PM	9.2	54.0	0.52	0.001	0.005	0.060	0.089
2 February 2025	6:00:00 PM	2.0	3.00	0.55	0.001	0.002	0.016	0.007
3 March 2025	4:00:00 PM	1.7	3.00	0.61	0.003	0.002	0.013	0.013
30 March 2025	5:00:00 PM	1.4	3.00	0.52	0.002	0.002	0.026	0.028
ORC 80th*		10.30	8.00	1.62	0.560	0.007	0.044	
NPSFM Median		3.50	3.00	0.60	0.008	0.005	0.027	
NPSFM 95th		23.25	33.75	4.58	3.625	0.008	0.066	

Table 2. Water quality data for Trotters Creek at site 5 (see Figure 3) from monthly grab samples (see Table 1 for detailed explanation of metrics and units).

Date	Time	Turb	TSS	TN	NNN	DRP	TP
15 May 2023	3:00:00 PM	3.80	9.0	0.63	0.24	0.002	0.036
30 July 2023	4:30:00 PM	4.30	1.5	2.1	1.64	0.004	0.016
1 October 2023	12:55:00 PM	2.40	1.5	0.47	0.025	0.002	0.013
29 October 2023	4:23:00 PM	2.30	1.5	0.32	0.007	0.002	0.014
6 December 2023	3:56:00 PM	4.90	9.0	0.4	0.001	0.002	0.020
27 December 2023	6:44:00 PM	5.00	4.0	0.53	0.027	0.007	0.027
4 July 2024	11:30:00 AM	7.80	4.0	2.5	1.83	0.002	0.035
1 August 2024	11:40:00 AM	8.00	6.0	2.9	2.3	0.002	0.049
29 August 2024	10:46:00 AM	1.86	1.5	0.78	0.460	0.002	0.013
30 September 2024	10:15:00 AM	1.38	1.5	0.51	0.113	0.002	0.013
3 November 2024	4:50:00 PM	3.20	1.5	0.85	0.440	0.002	0.017
28 November 2024	6:30:00 PM	2.40	1.5	0.47	0.068	0.005	0.014
6 January 2025	12:12:00PM	2.60	1.5	0.43	0.001	0.002	0.019
2 February 2025	6:00:00 PM	4.20	14.0	0.46	0.001	0.002	0.019
3 March 2025	3:00:00 PM	3.10	3.0	0.48	0.001	0.002	0.020
30 March 2025	5:00:00 PM	4.80	4.0	0.46	0.001	0.002	0.020
ORC 80th*		7.88	11.00	2.44	1.382	0.006	0.041
NPSFM Median		4.20	4.00	0.53	0.113	0.002	0.020
NPSFM 95th		120.35	132.50	2.96	1.895	0.056	0.394

Table 3. Water quality data for Watkin Creek at site 4 (see Figure 3) from monthly grab samples. (see Table 1 for detailed explanation of metrics and units).

Date	Time	Turb	TSS	TN	NNN	DRP	TP
15 May 2023	1:00:00 PM	2.8	1.5	0.34	0.007	0.004	0.014
30 July 2023	5:00:00 PM	8.4	1.5	1.55	1.000	0.009	0.034
1 October 2023	11:30:00 AM	7.2	1.5	0.5	0.049	0.009	0.032
29 October 2023	3:52:00 PM	9.5	1.5	0.32	0.004	0.002	0.017
6 December 2023	3:12:00 PM	6.2	1.5	0.34	0.001	0.002	0.021
27 December 2023	4:02:00 PM	7.5	1.5	0.39	0.002	0.008	0.029
4 July 2024	9:45:00 AM	12.9	7	1.47	0.810	0.002	0.055
1 August 2024	11:00:00 AM	11.3	7	2.2	1.410	0.008	0.074
29 August 2024	10:20:00 AM	5	1.5	0.47	0.450	0.002	0.022
30 September 2024	10:15:00 AM	4.2	1.5	0.46	0.005	0.000	0.017
3 November 2024	4:15:00 PM	5.4	1.5	0.97	0.200	0.011	0.036
28 November 2024	6:00:00 PM	6.7	1.5	0.51	0.057	0.003	0.022
6 January 2025	10:15:00AM	7.6	4	0.73	0.010	0.005	0.040
2 February 2025	6:00:00 PM	2.2	1.5	0.4	0.001	0.002	0.016
3 March 2025	4:00:00 PM	7.4	16	0.51	0.001	0.002	0.036
30 March 2025	5:00:00 PM	4	3	0.45	0.001	0.002	0.021
ORC 80th*		8.40	4.00	0.97	0.450	0.008	0.036
NPSFM Median		6.95	1.50	0.49	0.009	0.002	0.026
NPSFM 95th		11.70	9.25	1.71	1.103	0.010	0.060

4.1.2 Event sampling

Water quality results for Te Hikapupu/Pleasant River and Watkin Creek across the range of discharge levels that occurred during the monitoring period are shown in Table 4 and Table 5. Trotters Creek was inaccessible during periods of high discharge so was not sampled at those times.

Turbidity and total suspended solids values increased with increasing discharge (see section 5.2.2). Similarly, the average of NNN values in samples collected during high discharge events was approximately double that of the average of the samples collected monthly.

Discharge levels for high discharge event sampling ranged from 0.747 cumecs to 40.377 cumecs. These compare with median discharge for the monitoring period of 0.041 cumecs and maximum discharge of 42.190 cumecs.

Table 4. Water quality data for Te Hikapupu/Pleasant River at site 2 (see Figure 3) from grab samples taken during high discharge events (see Table 1 for detailed explanation of metrics and units).

Date	Time	Turb	TSS	TN	NNN	DRP	TP	Discharge
30 July 2024	3:55:00 PM	88.0	77	4.7	3.20	0.011	0.182	7.771
31 July 2024	11:44:00 AM	30.0	25	4.6	3.40	0.01	0.010	1.775
3 October 2024	6:08:00 PM	82.0	84	3.1	0.57	0.057	0.300	7.713
4 October 2024	11:50:00 AM	400.0	460	3.9	1.45	0.029	0.620	40.377
4 October 2024	10:30:00 PM	175.0	148	3.3	2.00	0.018	0.220	15.569
9 October 2024	9:30:00 AM	10.6	8	2.1	1.43	0.005	0.039	0.747
26 October 2024	8:30:00 PM	41.0	50	1.4	0.24	0.031	0.173	4.984
27 October 2024	2:15:00 AM	153.0	92	2.3	0.65	0.017	0.230	10.765
27 October 2024	4:11:00 AM	140.0	133	2.7	0.82	0.026	0.330	12.788
27 October 2024	11:40:00 AM	147.0	109	3	0.98	0.033	0.230	11.899
27 October 2024	4:25:00 PM	122.0	72	2.7	1.09	0.021	0.171	8.484

Table 5. Water quality data for Watkin Creek at site 4 (see Figure 3) from grab samples taken during high discharge events (see Table 1 for detailed explanation of metrics and units).

Date	Time	Turb	TSS	TN	NNN	DRP	TP
30 July 2024	3:44:00 PM	64	57	3.3	1.86	0.024	0.230
31 July 2024	11:34:00 AM	19.8	11	2.8	1.84	0.02	0.097
3 October 2024	5:44:00 PM	105	132	2	0.199	0.043	0.400
4 October 2024	1:30:00 PM	400	430	3.6	0.73	0.054	0.630
4 October 2024	10:20:00 PM	117	116	2.8	1.21	0.048	0.280
9 October 2024	9:20:00 AM	7.4	5	1.32	0.63	0.007	0.048
26 October 2024	8:20:00 PM	24	40	1.48	0.23	0.024	0.178
27 October 2024	2:05:00 AM	48	54	1.88	0.39	0.055	0.250
27 October 2024	4:02:00 AM	73	77	2.4	0.4	0.063	0.380
27 October 2024	11:30:00 AM	86	59	2.5	0.65	0.071	0.260
27 October 2024	4:18:00 PM	61	35	2.3	0.72	0.055	0.230

4.2 Interpretation

Two points should be considered when interpreting these results. Firstly, the NOF and ORC Regional Water Plan Schedule 15 give no specific guidance for monitoring of ephemeral streams, such as the ones in Te Hikapupu/Pleasant catchment. Therefore, it is unclear whether it is valid to compare the data collected from these streams with the limits/targets set out in these guidance documents. The comparison is made here for illustrative purposes.

Secondly, Schedule 15 of the ORC Regional Water Plan lists guidelines for DRP, nitrate and turbidity, indicating inferences are based on the 80th percentile of five years of monthly samples collected at discharge less than median discharge. Median discharge in Te Hikapupu / Pleasant River during the study period was 0.04 cumecs and monthly grab samples were collected at discharges (shown in Table 1) ranging from 0.01 to 0.97 cumecs (average discharge across sampling dates was 0.18 cumecs). Given that grab samples were sometimes collected at higher than median discharge and that sampling occurred over two years, compared to ORC's guideline of five years, the comparison with ORC guidelines provides some insight regarding compliance with the guidelines, but the data is not strictly aligned with the methodology that ORC set out.

Consequently, the short duration of the project plus the ephemeral nature of the tributaries constrains our ability to assess waterway health against bottom lines and limits/targets because the regulatory documents refer to flowing water bodies assessed over five years or more.

The period of extremely low discharge occurring between February and May 2023 may have been a result of the change in the El Niño-Southern Oscillation (ENSO), which changed from a weak La Niña in 2022/23 to a strong El Niño in 2023/24 (Figure 4).

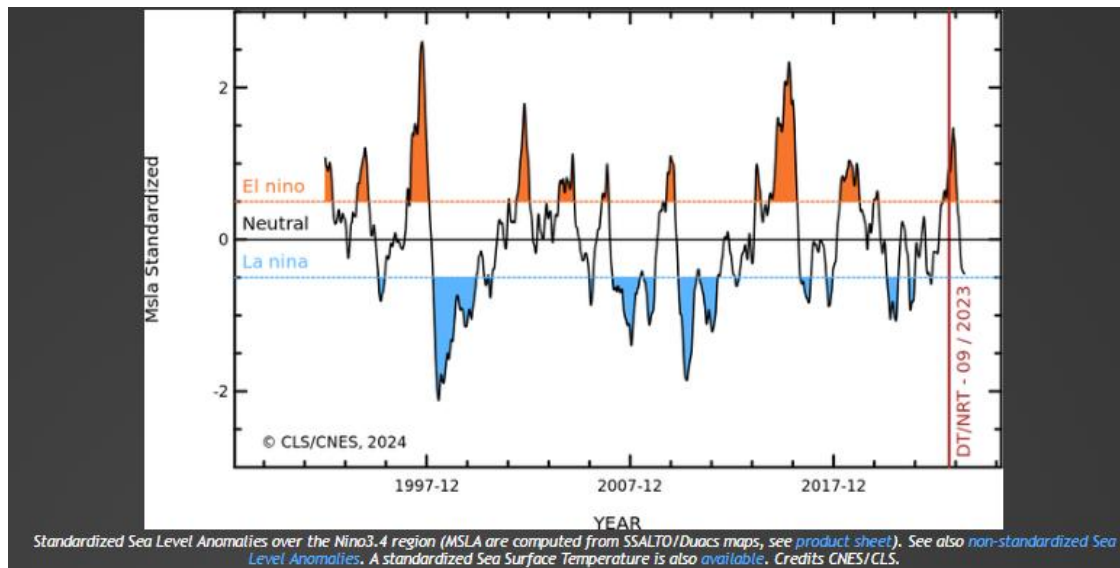


Figure 4. A screen shot of the El Niño Southern Oscillation index showing the change from a weak La Niña in 2022/23 to a strong El Niño in 2023/24.

The plan had also been to assess stream health at the three tributary monitoring sites with monthly sampling of invertebrates (to determine the macroinvertebrate community index, MCI). However, the first sampling of these sites revealed that the stream bed was covered in thick growths of macrophytes, which turned out to be not uncommon at these lowland sites. Furthermore, the stream bottoms generally consisted of soft substrate, composed of fine materials (e.g., silt and mud, with few gravels). The MCI stream health index is designed to sample invertebrates from gravelly river runs, not from sites covered in macrophytes. There is a soft bottom MCI, which is more suitable for soft bottom sites, but the thick macrophyte growths precluded us from being able to sample macroinvertebrates on the stream bed. Due to this, it was decided not to assess stream health at the water quality monitoring sites using macroinvertebrates. However, the MCI has been used at the ecological monitoring sites in more appropriate reaches, located further upstream.

5 Suspended sediment flux

An important driver for the Toitū Te Hākapupu/Pleasant River Restoration Project was concern from Kāti Huirapa Rūnaka ki Puketeraki and the Otago Regional Council (ORC) regarding the sources and levels of sediment movement through the catchment's tributaries, accumulating in the estuary and impacting the marine environment. A Catchment Action Plan¹ was developed as part of the project to help understand risks and priorities for the catchment and to set out actions

¹ <https://www.orc.govt.nz/get-involved/projects-in-your-area/toitu-te-hakapupu-the-pleasant-river-catchment-project/toitu-te-hakapupu-pleasant-river-catchment-action-plan/>

that could be taken to mitigate those risks, enabling the community to meet its aspirations for this area.

This rural catchment has been highly modified by human activity and has, furthermore, undergone a significant recent change in land use since the 1990s with the emergence and expansion of commercial forestry. Commercial forestry now covers 50% of the catchment's area, mostly in the upper parts of the catchment which are steeper and thus more prone to erosion, where it has displaced agriculture. Forest harvest and re-establishment brings risks for erosion and its effect on water quality (Marden, Rowe and Rowan, 2007), so understanding the current status of the catchment's waterways is important as a benchmark against which change can be measured.

Knowledge about sediment levels in the catchment has emerged from recent research. Levels of deposited sediment in the catchment's tributaries were assessed in 2023, revealing stream bank erosion as an important sediment source (Swales *et al.*, 2023). Comparatively high amounts of sediment from the small area of recently harvested commercial forest were also highlighted in that study.

In the estuary, the annual sedimentation rate was compared between 2021 and 2022 at two sites (Forrest, Roberts and Stevens, 2022). At one site there was an annual accrual of 2.7mm; at the other site sediment level had declined by 1.7mm. The national guideline for sediment deposition in estuaries is 2mm/yr (Townsend and Lohrer, 2015) and a trend of at least five years is recommended for assessing change in sedimentation rate.

Sediment loss from the catchment reduces water clarity in the coastal marine environment. This impact on water clarity exacerbates the loss of giant kelp (*Macrocystis pyrifera*) which has been documented during marine heat waves along the East Otago coastline (Tait *et al.*, 2021).

Suspended sediment levels in rivers and streams increase markedly during flood events (Fransen, Phillips and Fahey, 2001). There are several reasons for this. Firstly, as the level of discharge increases, a river moves above and beyond its usual channel, scouring sediment from areas not usually exposed to water flow. Secondly, flood waters are typically fast flowing and turbulent, generating a high erosive force which mobilises sediment from the sides and bottom of the waterway. Thirdly, heavy rainfall generates overland flow which mobilises soils (especially exposed soils), transferring soil particles into the river. In these ways, large amounts of sediment can be mobilised from erosion-prone areas and from land uses which expose the topsoil, such as winter grazing of crops on farmland, and from areas of recently harvested forestry and earthworks.

Calculation of the flux and load of sediment measured in Te Hakapupu/Pleasant River at the Paterson Road ford is described in the following sections.

5.1 Methods

- The location was Te Hakapupu/Pleasant River at the Patterson Road ford (site 2 in Figure 3).

- The observation period was from March 2023 to March 2025.
- Suspended sediment was measured in Te Hākapupu/Pleasant River using 15 grab samples collected at monthly intervals (when flow was visible) and 11 grab samples taken during periods of high discharge (see section 3.1). Overall, grab samples were taken at discharge volumes ranging from 0.007 to 40.3 cumecs.
- Discharge (see section 3) was estimated at 15-minute intervals at the Patterson Road ford (site 2) and averaged to hourly intervals for analysis.² There were 17,317 data points for discharge.
- Sediment flux (the amount of sediment in Te Hākapupu/Pleasant River passing the Patterson Road ford site monthly and annually) was calculated by combining the discharge data with suspended sediment values from grab sample data in a 'rating curve' (statistical model).

5.2 Results

5.2.1 Discharge and grab sampling

Grab samples were taken across the full range of discharge volumes observed during the monitoring period (Figure 5). An illustration of this range is shown in Figure 6 with photographs taken from the bridge on Stenhouse road.

² <https://envdata.orc.govt.nz/AQWebPortal/Data/Location/Summary/Location/FH844/Interval/Latest>

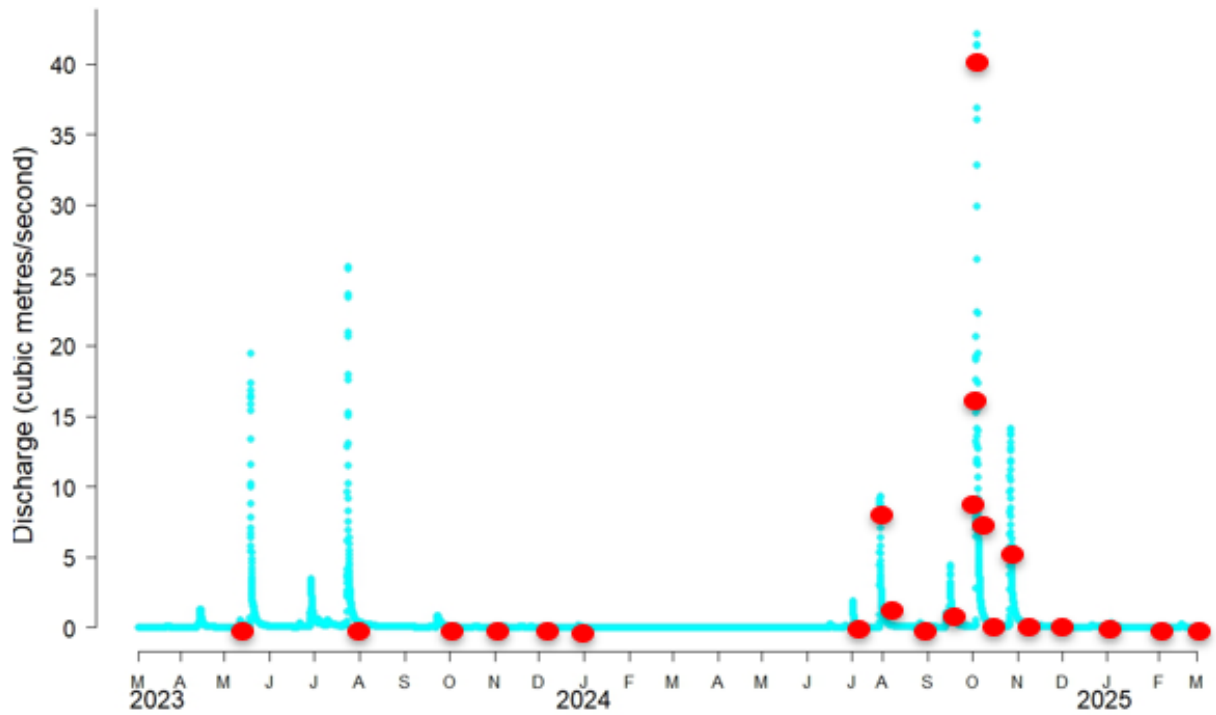


Figure 5. Discharge in Te Hikapupu/Pleasant River between March 2023 and March 2025 measured at the Patterson Road ford. Red dots indicate times of grab sampling for water quality (both monthly grab sampling and ‘event sampling’ during periods of high discharge).



Figure 6. Te Hikapupu/Pleasant River at the Stenhouse Road bridge at low discharge in November 2023 (left) and at high discharge in October 2024 (right).

5.2.2 Suspended sediment levels relative to discharge

Discharge level has a massive impact on sediment transit through the catchment's waterways. At or below median discharge, the mass of suspended sediment passing the Patterson Road ford was estimated at 0.43 kg/hr. In contrast, near the peak discharge at the same site (at 40 cumecs), it was estimated at 66,200 kg/hr. The mass of suspended solids at these opposite ends of the discharge spectrum differs by approximately 150,000 times, as illustrated in Figure 7.

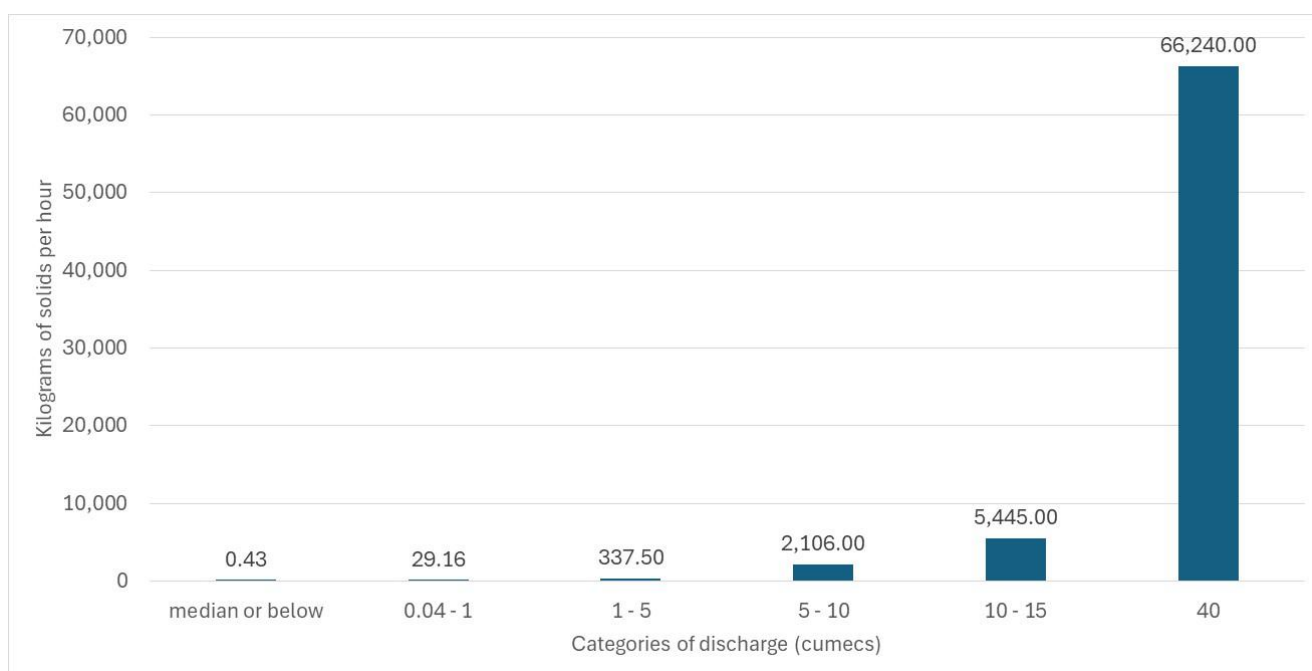


Figure 7. Kilograms per hour of suspended solids passing the Patterson Road ford (site 2) at different levels of discharge.

The level of suspended sediment at or below median discharge observed during the project ($\leq 3 \text{ g/m}^3$) was similar to this same metric (3.9 g/m^3) in a larger dataset collected by ORC over seven years at the same site.

5.2.3 Rating curve

The rating curve (Figure 8) describes the relationship between discharge (cumecs) and total suspended solids concentration (g/m^3). The fit of the model to the data is very good when a second order polynomial is used ($R^2 = 0.98$), providing confidence in this method of estimating sediment flux at this site.

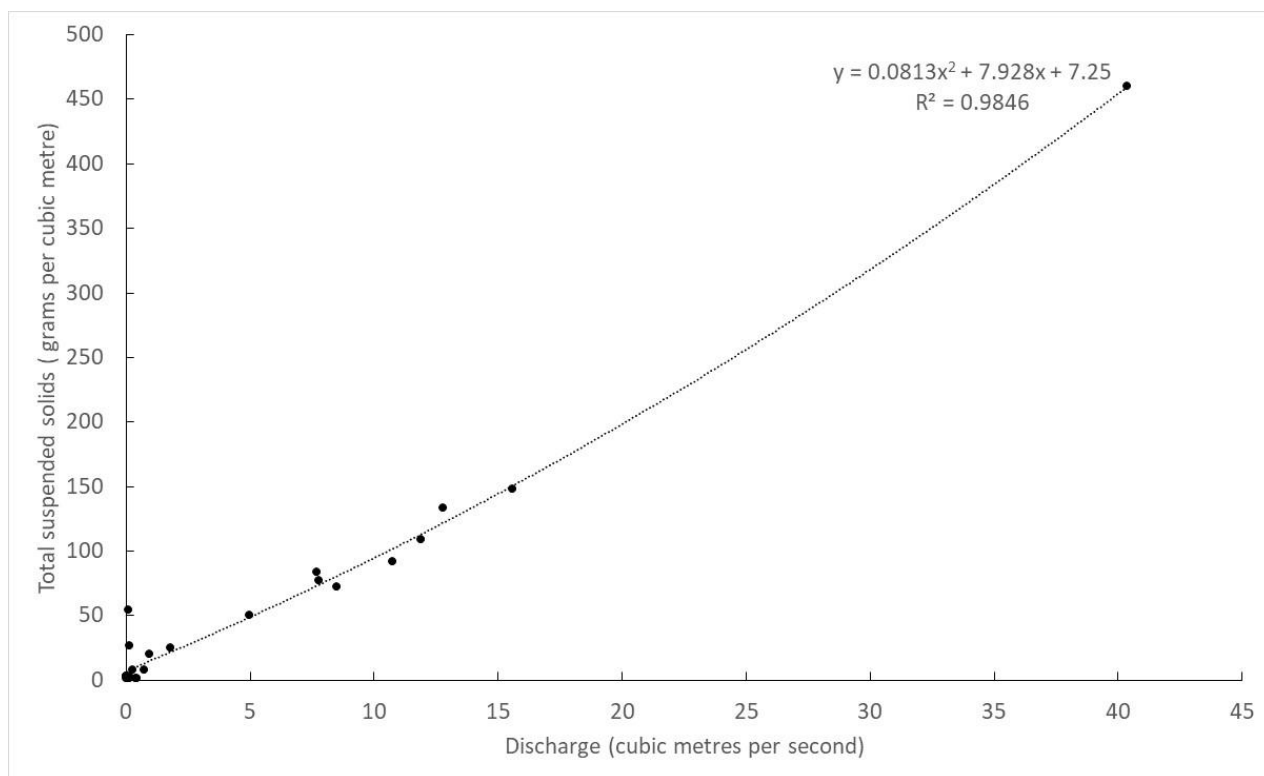


Figure 8. Rating curve for the Te Hikapupu River/Pleasant River at the Patterson Road ford using grab samples of total suspended solids (TSS, g/m³). Discharge is in cumecs, from the Otago Regional Council gauging site. The period is May 2023 to March 2025. The rating curve is a 2nd order polynomial, explaining 98% of the variation in the relationship.

5.2.4 Sediment flux

The total annual sediment flux was estimated for 2023/24 (Figure 9) at 358 tonnes, and for 2024/25 at 987 tonnes (Figure 10). The monthly sediment flux was estimated to vary between 0 tonnes and 924 tonnes (Figure 9 and Figure 10) illustrating the highly variable nature of discharge from Te Hikapupu/Pleasant River from month to month.

In 2023/24, the main sediment fluxes occurred in May and July (Figure 9), when two floods occurred (Figure 5). In 2024/25, most of the annual sediment flux and discharge occurred in October 2024 (Figure 10), as a result of a single large flood (Figure 5). No sediment flux occurred when there was no measurable discharge.

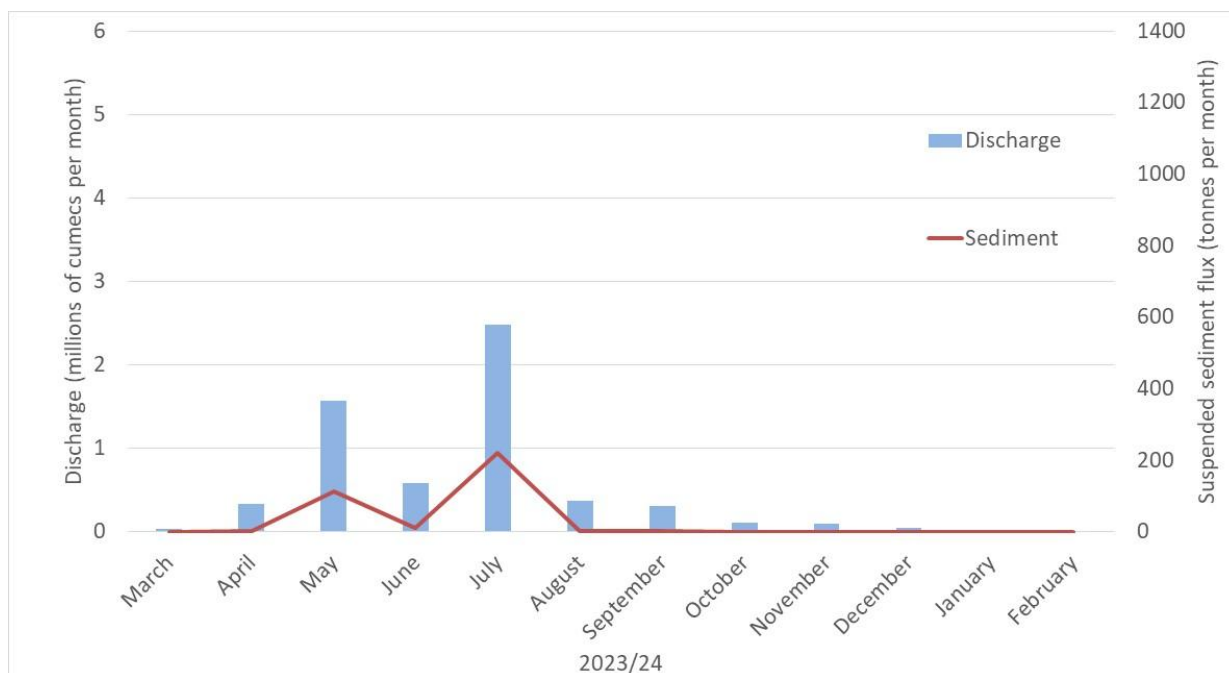


Figure 9. Monthly discharge in 2023/24 (millions of cubic metres, blue bars) and suspended sediment flux (brown line) from Te Hakapupu/Pleasant River at Patterson Road ford during the first year of monitoring in the Toitū Te Hakapupu project.

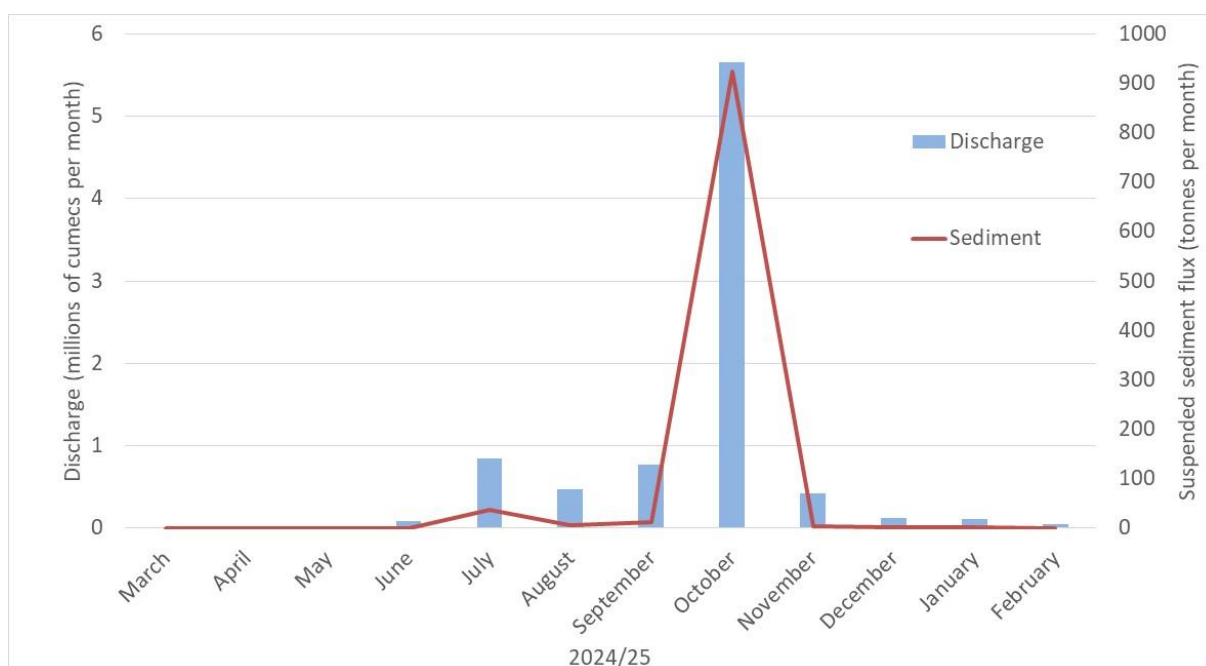


Figure 10. Monthly discharge in 2024/25 (millions of cubic metres, blue bars) and suspended sediment flux (brown line) from Te Hākapupu/Pleasant River at Patterson Road ford during the second year of monitoring in the Toitū Te Hākapupu project.

5.3 Interpretation

The amount of sediment flux reaching the estuary will be higher than the estimate in our analysis for two reasons. Firstly, the Patterson Road ford (site 2, Figure 3) includes discharge from Te Hākapupu/Pleasant River and Trotters Creek but not from the third main tributary in the catchment, Watkin Creek which represents approximately 20% of the total catchment area and enters the estuary at a different location. Secondly, because additional sediment will enter Te Hākapupu/Pleasant River as run-off between the Patterson Road ford and the estuary.

A range of factors related to climatic conditions will markedly affect annual sediment flux from year to year. For example, in this study, the flux estimate in 2024/25 was 2.76 times higher than that in 2023/24. Because of this variation, it is recommended that at least 10 years of annual flux estimates be obtained before attempts are made to estimate an average annual yield of suspended sediment from the catchment.

These results highlight the impact of the length of a drought period and the frequency and severity of floods in determining the timing and magnitudes of major sediment fluxes in this system. That is, during drought when there is no discharge, there is no movement of sediment, but then during floods large amounts of suspended sediment move along the rivers. To illustrate this, the flux of suspended solids varied by approximately 150,000 times between low discharge conditions (0.43kg/hr) and peak discharge of 40 cumecs (66,400 kg/hr).

In addition, annual flux of sediment will vary in response to management of the erosion risk from agriculture and commercial forestry in this highly modified catchment. These land uses represent the greatest risk to sedimentation of the catchment's waterways and estuary. Effective management of these land uses will help reduce sediment inputs to the waterways and the estuary.

The level of suspended sediment at or below median flow was very similar between data collected during the project (2023 – 2025) and data collected over a longer time period (2018 – 2025) by ORC. This indicates that the results from the analysis described here would reasonably reflect the nature of the river in at least the preceding five years.

6 Localised areas of turbidity

Areas of temporary localised turbidity occur in Te Hākapupu/Pleasant River (Figure 11). The colouration potentially comes from iron oxide (essentially rust) produced by iron-oxidising bacteria as part of their biological process and occurs when groundwater with low-oxygen and high iron content meets surface water with higher oxygen concentrations (Blöthe and Roden, 2009). It may also be related to the type of base rock, which has high levels of iron.



Figure 11. Examples of water discolouration associated with groundwater seeps and microbial iron oxidation in Te Hākapupu/Pleasant River.

Under low discharge conditions, it is possible that the ratios of groundwater to surface water are high enough that there is insufficient oxygen to support many aquatic species including invertebrates. Similar levels of discolouration (and likely low dissolved oxygen) have been observed in several reaches of Watkin Creek and Trotters Creek.

The chemically reduced substances that enter the tributaries at groundwater seepage sites potentially affect the suitability of habitats for fish and other aquatic life. The risk of low oxygen events is exacerbated when discharge is low which increases the ratio of groundwater to surface water. Te Hākapupu/Pleasant catchment has a low annual rainfall of around 650mm and low discharge conditions are common. A substantial increase in the amount of commercial forestry in the catchment over the last 30 years may also reduce catchment water yield (Fahey & Payne 2017, Fahey & Watson 1991, Buytaert, Iñiguez, & De Bièvre 2007).

Several attempts to sample the seeps in 2024 were unsuccessful as the typical turbid water previously observed at the sites was not apparent. This may have been due to lack of groundwater inputs to the sites as a result of the prolonged period of low rainfall. Our observations indicate that such seeps are most noticeable for short periods of time, when shallow groundwater flow is sufficient to discharge into the rivers. These turbid zones are not visible when river flows are high (perhaps due to dilution) or when groundwater flow to the river is restricted due to dry conditions. When the groundwater seeps impact the streams, dissolved oxygen levels in the streams may be somewhat depleted due to chemical oxidation.

7 eDNA

eDNA monitoring provides a simple, cost-effective method of understanding broad scale community composition of living organisms from the catchment upstream of the sampling site.

This information can be used to guide more detailed monitoring such as fish surveys, as well as identify parts of the catchment where migration barriers may be affecting fish passage. This information can also be used to assess the general ecological health of a segment of river by comparing it to a wide range of other New Zealand sites across a spectrum from pristine to degraded. An eDNA-based index known as the Taxon Independent Community Index (TICI) was developed in the early 2020s using data from 53 rivers and streams across New Zealand.³

eDNA monitoring was undertaken at the six He Pātaka Wai Ora (cultural monitoring) sites (Figure 12) by the East Otago Catchment Group and the Otago Regional Council. Although this monitoring was undertaken separately to the baseline monitoring undertaken by Whirika Consulting, it does provide useful context and supporting information for the other monitoring methods used during the 2022/23 field season.

7.1 Results

A summary of the fish species detected is presented in Table 6. Ten species of freshwater fish, and seven estuarine/marine species were detected. Of the freshwater species, bluegill bully (*Gobiomorphus hubbsi*), inaka/inanga (*Galaxias maculatus*) and tuna (New Zealand longfin eel, *Anguilla dieffenbachia*) are considered threatened (at risk – declining), and four are considered mahika kai species: banded kokopu (*Galaxias fasciatus*), inaka, longfin eel, and short-finned eel (*Anguilla australis*). Of the estuarine fish species detected, four are considered mahika kai species: kahawai (*Arrapis trutta*), sand flounder (*Rhombosolia plebeia*), skate (*Rajidae* spp.) and yellow eyed mullet (*Aldricheta forsteri*).

³ <https://www.wilderlab.co.nz/tici>

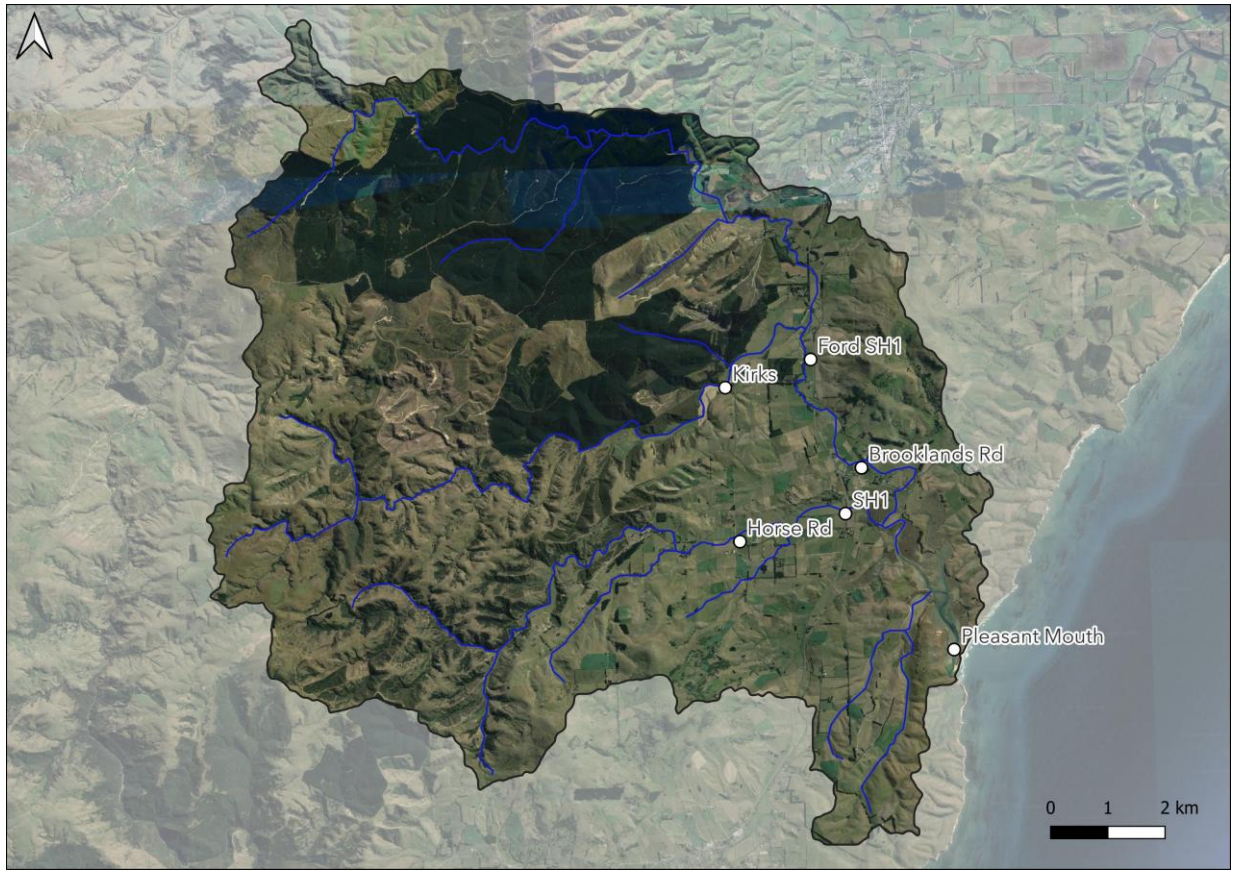


Figure 12. Location of eDNA monitoring sites in Te Hikapupu/Pleasant River catchment sampled in autumn 2023.

Table 6. Summary of fish species detected in eDNA samples from the lower Hapakupu/Pleasant River catchment.

	Site	Te Hapakupu at Brooklands Rd	Te Hapakupu at Patterson Rd	Trotters Creek at Patterson Rd	Watkin Creek at Horse Rd	Watkins Creek at SH1	Lower estuary
Freshwater migratory	Banded kokopu						
	Bluegill bully						
	Common bully						
	Inaka (inanga)						
	Longfin eel						
	Redfin bully						
	Shortfin eel						
Freshwater non- Migratory	Upland bully						
	Brown trout						
	European perch						
Marine/Estuarine	Estuary clingfish						
	Kahawai						
	Sand flounder						
	New Zealand smooth skate						
	Spotty						
	Thornfish						
	Yelloweye mullet						

The Taxon Independent Community Index (TICI index) rating index (Table 7) was 'poor' for four sites, 'average' for one.

Table 7. Taxon Independent Community Index rating for eDNA samples from six sites in Te Hākapupu/Pleasant River catchment.

	Te Hākapupu at Brooklands Rd	Te Hākapupu at Patterson Rd	Trotters Creek at Patterson Rd	Watkin Creek at Horse Rd	Watkins Creek at SH1
TICI score	84.13	89.33	94.47	88.25	85.44
TICI rating	Poor	Poor	Average	Poor	Poor

7.2 Interpretation

The presence of a high proportion of migratory fish highlights the importance of maintaining fish passage throughout the lower and middle reaches of the catchment. An assessment of fish passage is described in section 14.

Furthermore, the presence of inaka indicate that significant biodiversity gains can be made through riparian fencing and planting of spawning habitat in the lower reaches of Te Hākapupu/Pleasant River. Previous work undertaken by the Department of Conservation (Clucas, 2019) mapped spawning sites in the catchments and should be used to inform targeted planting of species suited to the enhancement of whitebait spawning at these sites. The need for a more up to date inaka spawning survey should also be considered.

Although the 2022/23 eDNA surveys provide a good understanding of population assemblages in the lower reaches of the three tributaries, the low discharge and high residence times of these reaches mean that these samples offer little information on the middle and upper reaches of the catchment. We estimated that it is unlikely that an eDNA sample would be detecting eDNA from more than 1 to 2 kilometres upstream of the sampling sites. To gain a more comprehensive picture of the entire catchment an initial recommendation (made in 2023) to undertake further eDNA sampling in the mid and upper ecological monitoring sites for each tributary was instead actioned by fish sampling described in section 7.

8 Freshwater fish monitoring

Kāti Huirapa Rūnaka ki Puketeraki undertook fish surveys in March 2024 to compliment the ecological monitoring undertaken in the previous year. River discharge at the time was low, with no surface flow connection through much of the mid to lower catchment and habitat was restricted to isolated pools. Monitoring was undertaken at four freshwater sites and one estuary site in Te Hākapupu catchment

(Figure 13) using hīnaki (fyke nets) in the river and drag nets in the estuary. Three hīnaki were set overnight at each site and baited with paua offal, while drag nets were dragged in 100m runs on an incoming tide.



Figure 13. Locations of fish monitoring sites in Te Hākapupu/Pleasant River catchment.

All tuna (eels) captured were measured and weighed (Figure 14), while smaller species were identified to the species level and measured.



Figure 14. Rūnaka members measuring and weighing tuna at the Otutahanga (Paterson Road) monitoring site.

8.1 Results

The catchment hydrology is such that flows are disconnected throughout much of the catchment through summer and autumn, and freshwater fish habitat consists of a series of “refuge pools” and setting hīnaki is more likely a reflection of the quality of the “refuge pool” in which the net is located rather than the wider reach of the waterway. This is not necessarily an issue when undertaking baseline monitoring such as being undertaken here, however it does limit the ability to draw meaningful comparisons of fish abundance between years, if the exact same pools are not monitored on every sampling occasion.

Longfin tuna were present at all four freshwater sites, while shortfin tuna were present at the Lower Trotters Creek and mid-Hakapupu sites alongside small numbers of inaka (Figure 15). Kōkopu (common bully) were present at the lower three sites, with particularly high numbers (365) in lower Watkin Creek.

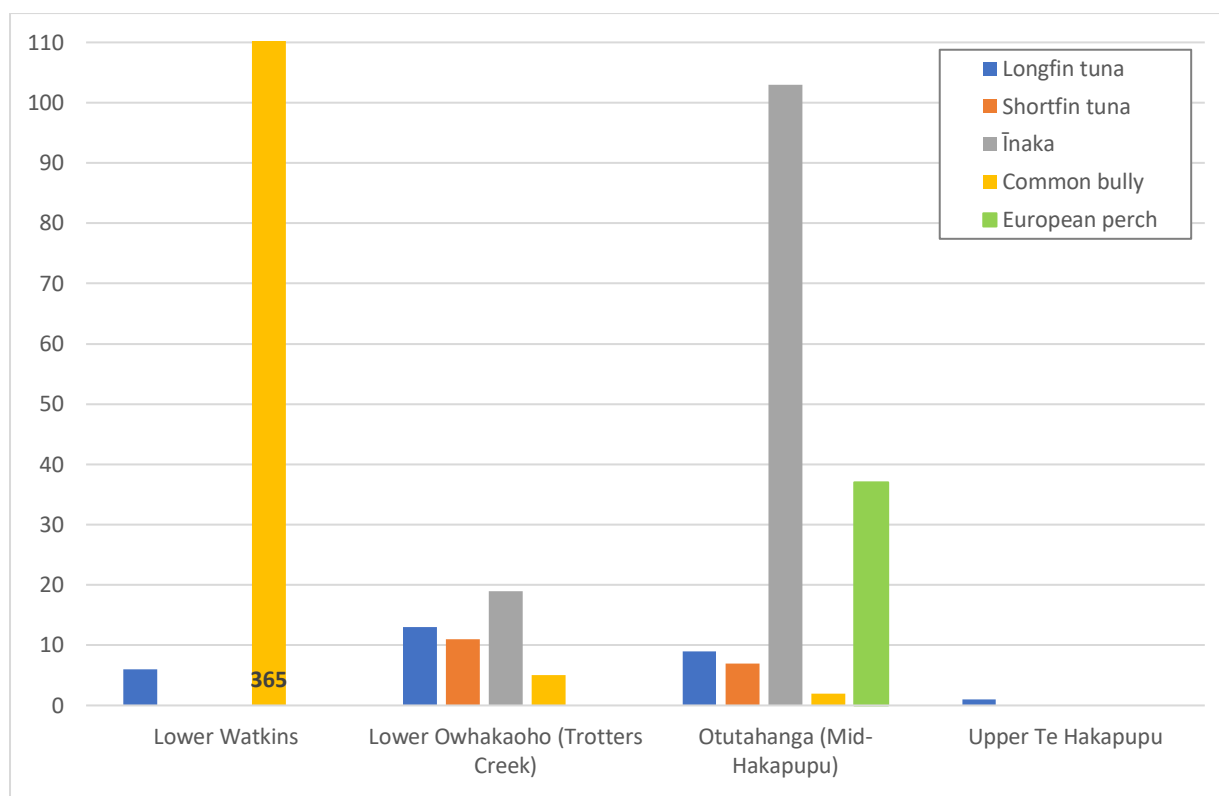


Figure 15. Total fish numbers from the 2024 Te Hakapupu/Pleasant River catchment baseline monitoring survey.

The record of large numbers of juvenile European perch corroborates the 2023 eDNA results that indicated their presence and represents the first time this species has been recorded in the catchment.

Several upland bully (*Gobiomorphus breviceps*) were also observed at the Upper Hakapupu site, but unfortunately the hinaki set in the main pool there was stolen overnight, which also contributed to the low numbers of tuna captured.

Overall, a total of 29 longfin tuna and 18 shortfin tuna were captured across the four sites, as well as 122 inaka, 372 common bully, and 37 perch (Table 8).

Table 8. Summary of fish captured for the 2024 Te Hakapupu/Pleasant River catchment fish survey.

Site	Species				
	Longfin tuna	Shortfin tuna	Inaka	Common bully	European perch
Lower Watkin	6			365	
Trotters Creek	13	11	19	5	
Mid Te Hakapupu/Pleasant River	9	7	103	2	37
Upper Te Hakapupu/Pleasant River	1				
Total	29	18	122	372	37

Tuna length frequency data across all sites shows that there was significant overlap in the size range of both species, with an absence of juvenile tuna (less than 400mm) (Figure 16). Most of the tuna captured were within the size range considered suitable for mahika kai, which is usually between 600-900mm.

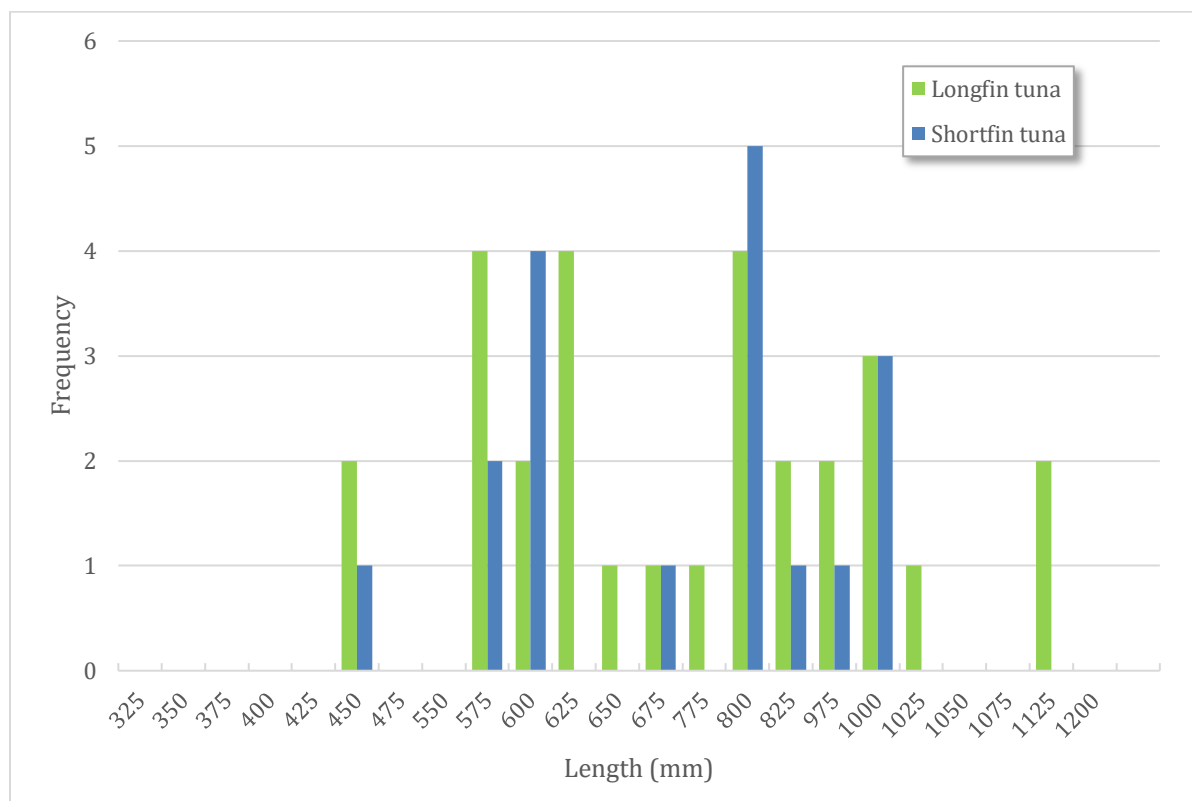


Figure 16. Size distribution of tuna in Te Hākapupu/Pleasant River catchment sampled in March 2024.

8.2 Interpretation

The baseline fish monitoring did not pick up any additional species that were not identified in the eDNA survey. Although eDNA monitoring indicated the presence of bluegill bully, banded kōkopu, brown trout and redfin bully, these were not captured as part of this survey. Due to their preference for fast flowing shallow water, it would not be expected that bluegill bully would be captured using hīnaki, which are set in deeper slow flowing pools. The low oxygen levels throughout most of the mid/lower reaches of Te Hākapupu catchment and its tributaries are likely to restrict trout to the upper reaches of the three sub-catchments as well as the estuary. This is supported by earlier work undertaken by Kāti Huirapa Rūnaka ki Puketeraki, who undertook electrofishing throughout Watkins Creek and Trotters Creek and found that trout were only present in the upper reaches of Trotters Creek.

The absence of inaka at the lower Watkin Creek site may be an indicator of poor fish passage in the downstream reach, which is supported by the results of the fish passage assessment discussed in section 14.

Many of the common bully found at the Lower Watkins Creek site exhibited extremely high parasite loads of the protozoan *Ichthyophthirius multifiliis*, also known as “white spot”. While this parasite is common throughout New Zealand, it is very rare to see infections of this scale and severity. One of the major factors contributing to the susceptibility of fish to white spot is environmental stress, and in this case, it is likely that a combination of low dissolved oxygen, high temperatures, and overcrowding in refuge pools over summer all play a part. AquaWatch waka data (see section 13) indicate that dissolved oxygen levels could drop to very low levels during summer, well below the recommended minimum for fish of 5 mg/L.

This parasitism was also observed at this site by mana whenua in 2017/18 and was one of the major factors behind the Rūnaka request for intervention in the catchment which led to the Toitū te Hākapupu Restoration Project.

9 Estuarine fish monitoring

Drag netting was undertaken in Te Hākapupu/Pleasant River Estuary in March 2024 using a 40m drag net on an incoming tide. Two drags of 100m each were taken in the lower estuary, and any fish caught were identified to the species level and measured.

9.1 Results

From the 6,000m² of habitat sampled, a total of five pātiki (sand flounder, *Rhombosolea plebeia*) were captured that measured between 27 and 30cm (Figure 17).



Figure 17. Pātiki (sand flounder) captured in Te Hākapupu/Pleasant River estuary.

9.2 Interpretation

Pātiki (sand flounder) are considered an important mahika kai species for Kāi Tahu, and their presence in the lower estuary is an encouraging sign.

10 Ecological baseline monitoring

Ecological baseline monitoring was undertaken using a variety of methods designed to be easily replicated and adopted by the community during and beyond the life of the project. Many of these methods are taken from the Stream Health Monitoring and Assessment Kit (SHMAK), while others such as the Quorer method have been adapted from national monitoring guidelines. This monitoring has been designed in a manner that anticipates community involvement in the monitoring programme in the longer term.

A total of 10 sites were monitored across the 2022/23 field season (Figure 18), with five being monitored through an existing programme run by Kāti Huirapa Rūnaka ki Puketeraki/Ngāi Tahu Forestry, and the other five being directly supported by the Toitū Te Hākapupu project. Kāti Huirapa Rūnaka ki Puketeraki has agreed to share its Ngāi Tahu Forestry monitoring data as part of its support for the Toitū Te Hākapupu project.

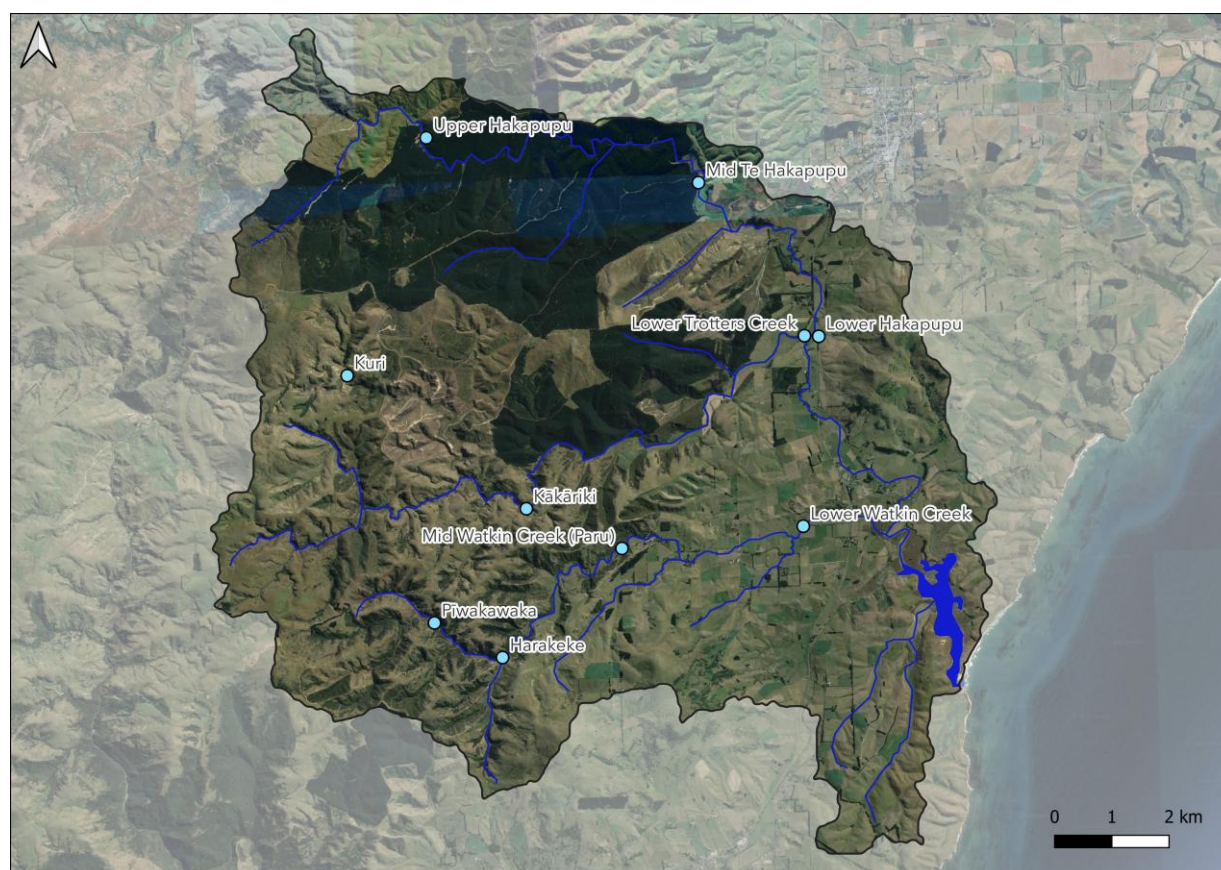


Figure 18. Annual ecological baseline monitoring sites for 2022/23 in Te Hākapupu/Pleasant River catchment.

The assessment of sediment focussed on re-suspendable sediment using the Quorer method (Clapcott *et al.*, 2011), which is the fine sediment that is sitting on top of and between the river substrate but can be suspended in the water column during high flows and/or bed disturbance.

The sample is collected by re-suspending sediment in the water column within a tube sealed to the bed of the stream and then collecting a 50 mL sample from the water within the tube (Figure 19). The total

volume of water within the tube is calculated so that each sediment sample can be volume-adjusted to account for the depth of water from which the sample was taken.



Figure 19. Photos of sample collection using the Quorer method.

At least five replicates are taken from each site, and water in each sampling tube is allowed to settle for 24 hours before measuring the total volume of sediment in each tube (Figure 20). For a more detailed sediment analysis, samples can be sent to a laboratory to assess the amounts of organic and inorganic sediment within each sample. The volumetric Quorer method is simpler, quicker, and less cost compared to the weight-based assessment that requires specialist equipment and laboratory analysis.



Figure 20. Sediment samples taken using the Quorer method.

The advantage of measuring re-suspendable sediment is that it provides an indication of what has been deposited in the stream bed over time, rather than what is in the water column at the time of measurement. It is also this sediment that smothers invertebrate and fish habitat and has the biggest impact on stream health.

10.1 Results

Quorer results were divided into the three sub-catchments and displayed from upstream to downstream (Figure 21).

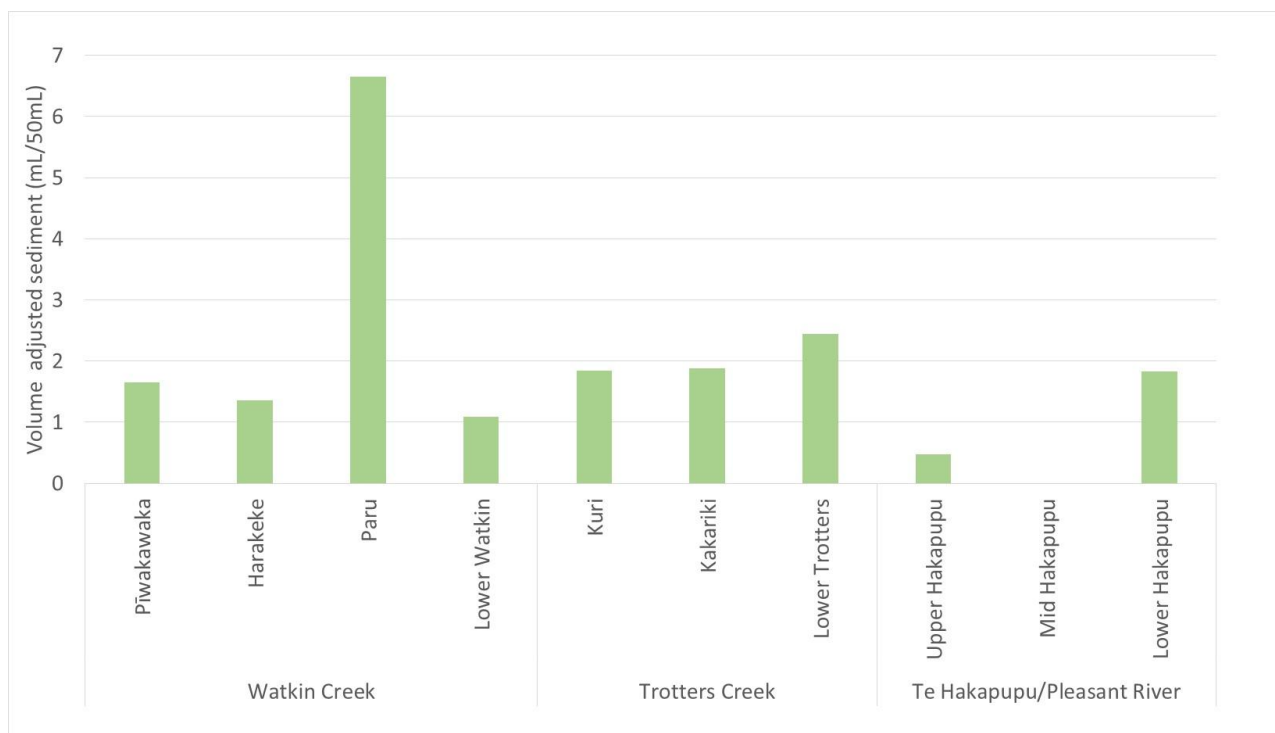


Figure 21. Volume adjusted re-suspendable sediment levels measured at nine sites in Te Hikapupu/Pleasant catchment in the autumn of 2023.

The results show that sediment volumes are relatively consistent across the catchment with the exception of the “Paru” site in the middle reaches of Watkin Creek. Trotters Creek experienced a slight increase in sediment volume with distance downstream, but unfortunately the same comparison for Te Hikapupu/Pleasant River cannot be made for 2023 due to damage to the samples from this site while in transit.

10.2 Interpretation

The results for the “Paru” site were consistent with results from the previous year from sampling undertaken by Kāti Huirapa Rūnaka ki Puketeraki and Ngāi Tahu Forestry. Although the previous years’ work used sediment weight instead of volume (Figure 22), there is still clearly significant sedimentation issues in this part of the catchment.

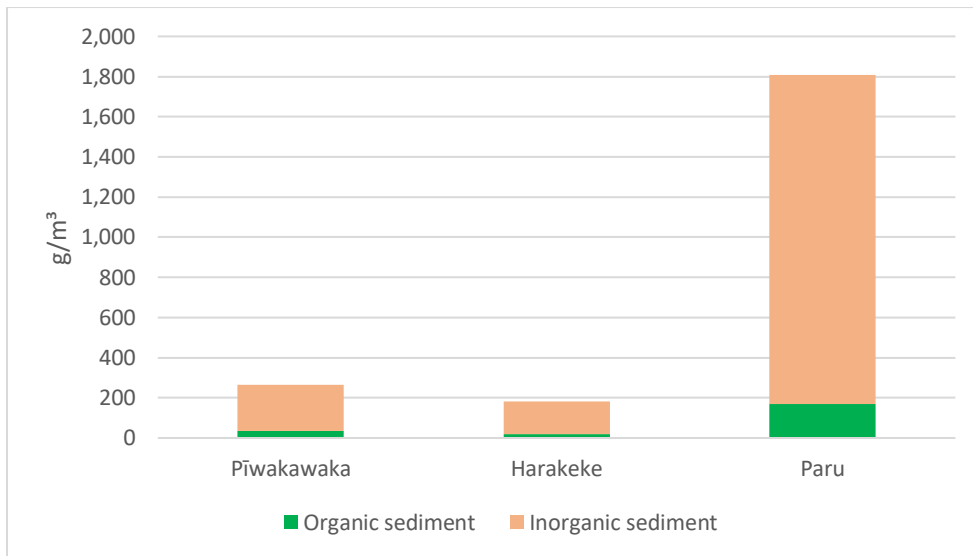


Figure 22. Suspendable sediment concentrations from the upper and middle reaches of Watkin Creek sampled during the 2021/22 field season.

Observations made during the 2021/22 monitoring suggest the high levels of sediment may have been due to erosion caused by the aerial spraying of land near the Paru site in preparation for planting forestry. There is evidence of erosion in satellite imagery in the years preceding the project of the hills on the true right of Watkin Creek, upstream of the Paru site (Figure 23).



Figure 23. Time series photos of changes in vegetation cover and resulting erosion at the Harakeke monitoring site following aerial spraying in 2017 in preparation for planting of commercial forestry.

Forestry provides a full canopy cover and land stabilisation much of the time to reduce the risk of erosion on fragile soils, however good management in relation to the ‘window of vulnerability’ is important to sustain these benefits. The window of vulnerability relates to the period when this canopy is not present

and bare soil is likely to be present, through the preparation of land for planting, or during the harvest and re-planting process.

Observations during the 2022/23 field season indicate that the total depth of sediment has decreased marginally in some areas at the Paru monitoring site but is still much higher than found at any other location in the catchment. We have not investigated in detail whether the high level of sediment we recorded at the Paru site is associated with the erosion and activity shown in Figure 17, or from another source such as streambank erosion.

State of the Environment (SOE) monitoring at the Patterson Road Ford site is in the “A” band of the National Policy Statement for Freshwater Management (NZPSFM) attribute table for suspended fine sediment (Ozanne, 2022). This differs from our results. This difference is largely due to SOE monitoring occurring monthly at or below median discharge. Most sediment enters the water during medium and high discharge associated with heavy rainfall, which is not when SOE monitoring occurs. Also, the low discharge and low water velocities common in the catchment mean sediment entering the upper parts of the catchment may settle out there, rather than being flushed down to where the SOE monitoring occurs, into the estuary, or out to sea.

Comparing the Quorer results across the three sub-catchments showed broadly similar sediment levels in Trotters Creek, Watkin Creek, and Te Hikapupu/Pleasant River. These results, which relate to sediment present at the time of sampling, add another perspective to the recent modelling study of past sources of sediment in Te Hikapupu/Pleasant River estuary systems which indicated 77% of the long term suspended sediment load comes from Trotters Creek (Swales et. Al, 2023).

The Quorer method applied at intervals throughout the length of a waterway can indicate levels of deposited sediment across the entire discharge regime. It can also assist in identifying whether sediment is having a direct ecological impact at the monitoring site and can track sediment as it moves down the catchment. When combined with the continuous turbidity monitoring being undertaken by the AquaWatch waka units, this provides a more detailed picture of instream sediment dynamics within the catchment.

This is not a criticism of the methodology for measuring suspended fine sediment in SOE networks at a regional and national scale, as it is suited to this purpose. It should, however, serve to highlight the importance of using alternative methods appropriate for reach and catchment scale monitoring across the entire discharge regime when informing detailed catchment management processes.

During monitoring at the mid Hikapupu site it was observed that there was significant water discolouration immediately upstream in the absence of any noticeable inputs from surface discharge (Figure 11). The discolouration occurred over approximately 50m, with the orange colour indicating the presence of oxidising bacteria (see section 5).

11 Stream habitat score

Stream habitat is defined as the whole stream environment including the stream bed, stream banks and land use in the immediate vicinity of the stream (riparian zone).

The type and quality of this physical habitat have a significant influence on the stream plants and animals because each species needs a suitable “living space” (habitat) to survive. Each species prefers different habitat conditions (e.g., some species prefer fast moving water, others quiet pools).

The stream habitat assessment helps to describe the impact of various human activities or natural processes that may have degraded stream habitat. Identifying which habitat features could be affecting stream health is essential to help set goals for restoring stream health. Monitoring stream habitat over time can also help evaluate the success of restoration efforts.

The main components covered by the stream habitat score are;

- Sediment
- Habitat for aquatic animals
- Water clarity
- Discharge types
- Bank stability and erosion
- Bank vegetation
- Riparian buffer
- Shade
- Channel alteration

Each of these categories is given an individual score based on what can be observed at the monitoring site, which are then combined to give an overall score (Table 9).

Table 9. Stream habitat health scores and categories.

Habitat health score	Category
<24	Poor
24-39	Fair
40-55	Good
>55	Excellent

11.1 Results

Stream habitat score results are shown in Figure 24, with the colour shading for each site corresponding to the ecosystem health category in Table 9.

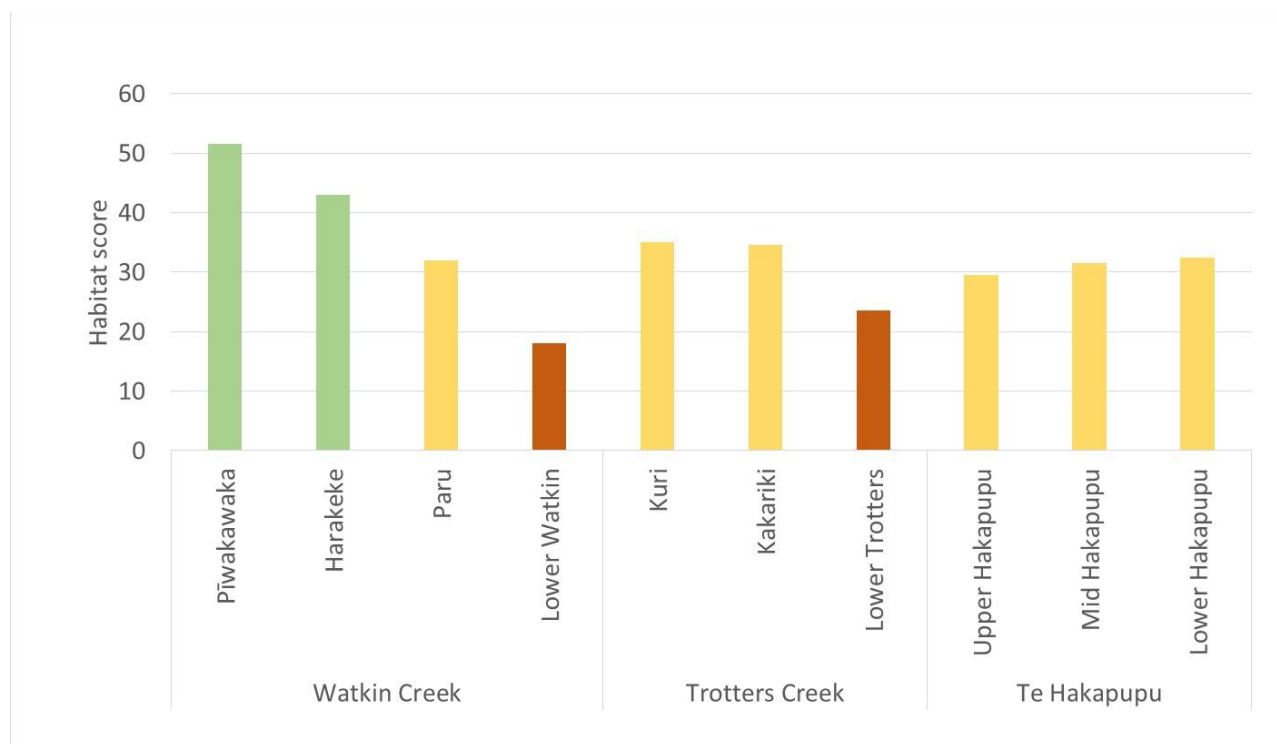


Figure 24. Stream habitat scores for ten sites in Te Hikapupu/Pleasant catchment in autumn, 2023, green = good, yellow = fair, red = poor.

The high habitat scores for Piwakawaka and Harakeke in the upper reaches of Watkin Creek were driven largely by habitat and discharge diversity as well as a lack of channel alteration. The lower scores observed in the Lower Watkin and Lower Trotters were largely driven by channel modification, a lack of riparian vegetation, little shade, and higher amounts of stream bank erosion.

11.2 Interpretation

The habitat scores (Figure 24) provide a baseline across the catchment. Re-scoring these sites in the years following the Toitū Te Hikapupu/Pleasant River Restoration Project will help to show the positive impacts of the project and further work undertaken after the project based on the catchment action plan. At present there is no comparable data to indicate whether these results reflect habitat quality elsewhere in the catchment, or in nearby catchments.

12 Macroinvertebrates (Macroinvertebrate Abundance Index)

Benthic macroinvertebrates are animals that live at the bottom (benthic) of streams and lakes, are large enough to be seen with the naked eye (macro) and lack a backbone (invertebrate).

Among insects, the term macroinvertebrate also includes crustaceans such as kōura/crayfish, amphipods and shrimps, as well as snails, worms and leeches. These animals are a key part of stream food webs, feeding on periphyton, macrophytes, dead wood or each other. The aquatic larvae of some macroinvertebrate species are an important food source for fish and the winged adults are often eaten by birds.

Macroinvertebrate communities are useful indicators of stream health as they persist in a river over long periods of time, and the makeup of the community can be a strong indicator of the health of the river. The presence of pollution sensitive macroinvertebrates such as mayflies, stoneflies and caddis flies can indicate a healthy ecosystem, while the dominance of pollution tolerant species such as worms and aquatic snails may indicate a more stressed system.

The Macroinvertebrate Abundance Index (MAI) has been developed as part of the Stream Health Monitoring and Assessment Kit (SHMAK) and is calculated by multiplying the number of each type of macroinvertebrate found in the sample by its sensitivity score (Biggs *et al*, 2002). The more sensitive a particular macroinvertebrate is to pollution the higher its sensitivity score, so a site with more pollution sensitive species will have a higher overall score (Table 10).

Table 10. Ecosystem health categories for the Macroinvertebrate Abundance Index

MAI Range	Ecosystem Health
0 - 1.9	Very Degraded
2 - 3.9	Degraded
4 - 5.9	Slightly to moderately degraded
6 - 7.9	Moderately healthy
8 - 10	Healthy

12.1 Interpretation

Overall, there is a positive relationship between the habitat and MAI categories across the ten sites. The exception to this is the significant difference between Habitat and MAI scores at the mid Hakapupu site (Table 11).

Table 11. Comparison of habitat and macroinvertebrate abundance scores in Te Hikapupu/Pleasant catchment based on data from autumn, 2023.

		Habitat score	MAI
Watkin Creek	Piwakawaka	51.50	6.74
	Harakeke	43.00	7.59
	Paru	32.00	4.20
	Lower Watkin	18.00	3.90
Trotters Creek	Kuri	35.00	4.28
	Kakariki	34.50	4.71
	Lower Trotters	23.50	3.31
Te Hikapupu/Pleasant River	Upper	29.50	
	Mid	31.50	2.38
	Lower	32.50	4.78

The low MAI score at mid Hikapupu was driven by a high abundance of segmented worms, which are extremely tolerant of fine sediment and low dissolved oxygen.

Periphyton is made up of a variety of organisms (algae, bacteria, and fungi) that live attached to underwater surfaces. These organisms are essential for ecosystem functioning but under certain circumstances can proliferate, causing freshwater management problems such as degrading aesthetic, recreational and biodiversity values.

Proliferation may cause the water to become tainted or toxic and may also clog water abstraction intakes.

Percentage cover of periphyton was measured where possible in the upper reaches of the three main tributaries, however the depth, channel morphology and substrate type at most mid and lower sites was not conducive to periphyton growth (or monitoring) and no meaningful comparative data could be collected.

12.2 Results

The MAI results for Te Hikapupu/Pleasant catchment are shown in Figure 25, with the colour shading for each site corresponding to the ecosystem health category in Table 10.

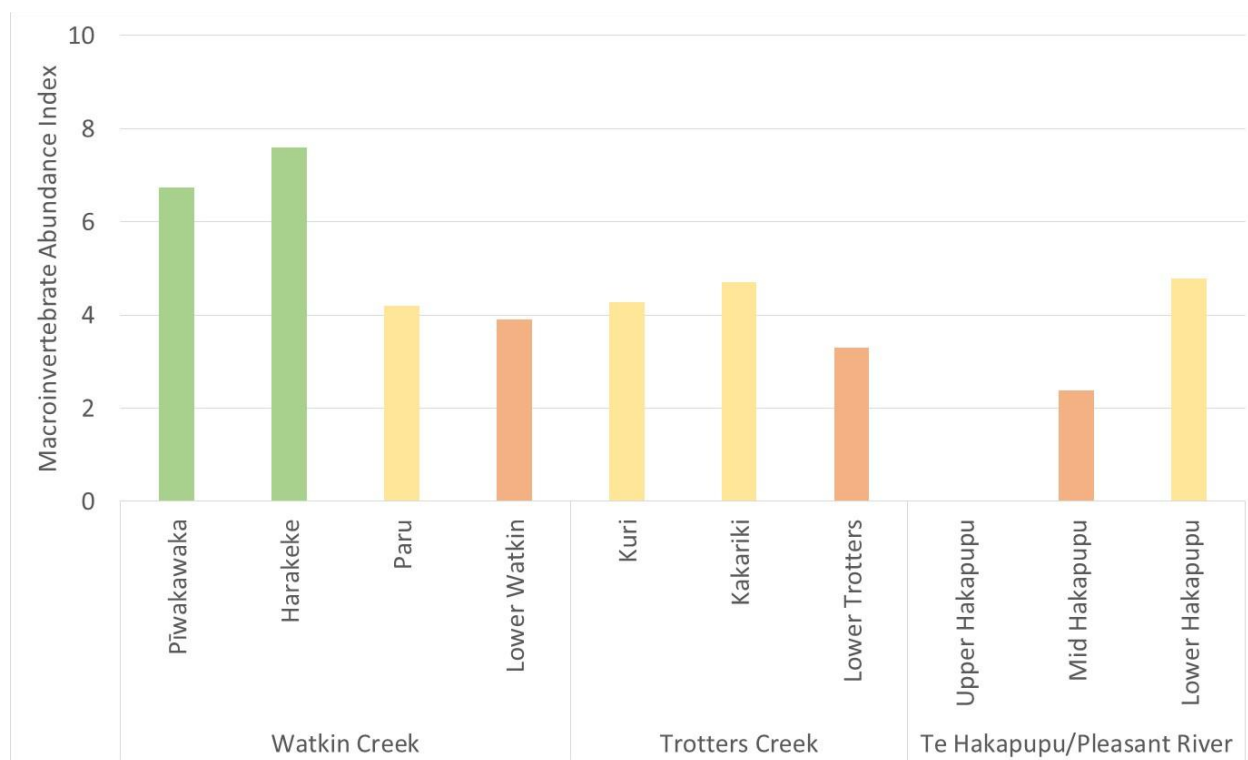


Figure 25. Macroinvertebrate Abundance Index measured at nine sites in Te Hikapupu/Pleasant catchment in autumn 2023, green = moderately healthy, yellow = slightly to moderately degraded, orange = degraded.

The MAI for 2022/23 show that the highest ecosystem health was recorded in the upper Watkin Creek (Pīwakawaka and Harakeke sites), although a meaningful catchment comparison cannot be made until further information is available for the Upper Hikapupu site. MAI scores for most other sites sit around the boundary between “slightly to moderately degraded” and “degraded”.

13 Aquawatch waka high-frequency water quality monitoring

Aquawatch ‘Waka’ (Figure 26) are a recently developed technology that enables high-frequency water quality monitoring. The waka relay results for turbidity, dissolved oxygen, temperature, pH, and conductivity at fifteen-minute intervals to a website. The data is checked by Aquawatch and is made available through the dashboard on their website, where it can be viewed as a time series for each analyte.



Figure 26. Aquawatch 'Waka' in Te Hikapupu/Pleasant River (left) and showing the water quality sensors (right).

A waka was initially deployed in February 2023 in a trial period on each of the three main tributaries at locations identified during community consultation. The trial revealed challenges with connectivity and some aspects of the waka design. The waka were returned to Aquawatch for upgrades in June 2023.

Five waka were re-deployed from February 2024 to January 2025 (Figure 27). Three (sites 2, 4 and 5 in Figure 21) were deployed at the same locations on the main tributaries as during the initial trial. The remaining two (sites 1 and 3 in Figure 21) were located upstream and downstream of an erosion prone sub-catchment (Figure 31) that discharges into Te Hikapupu/Pleasant River near the western end of Stenhouse road. This deployment was expected to capture erosion from an adjacent recently harvested forestry block and a nearby site where sediment traps had been installed by the project to minimise sediment loss from historical yet active erosion on that property.

Maintenance of the wakas was conducted approximately fortnightly, as recommended by Aquawatch, to clean the waka sensors and check that the devices were positioned correctly in the rivers.

Raw data from the waka was screened for errors by Aquawatch and the screened dataset was utilised in this analysis.

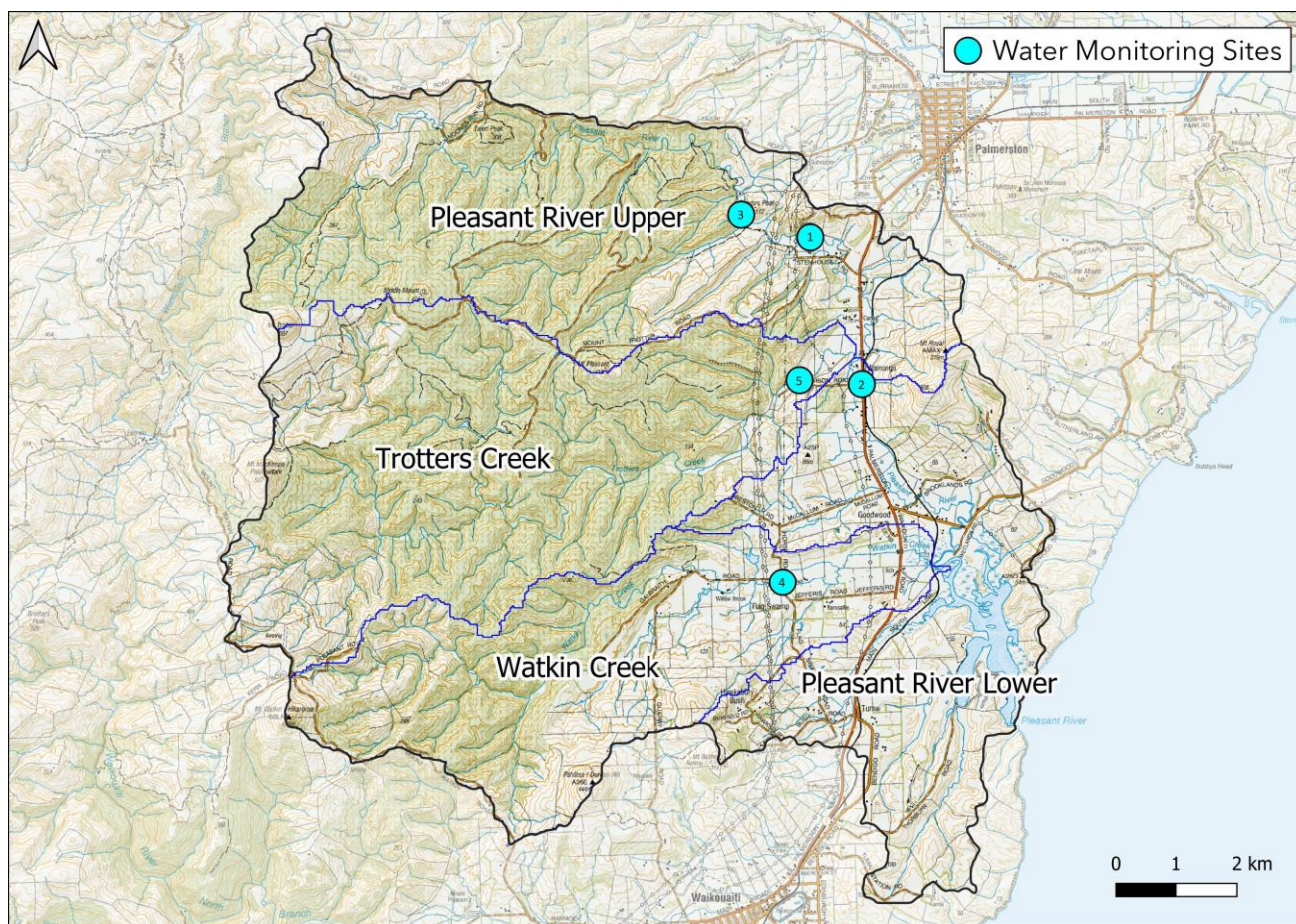


Figure 27. Locations of Aquawatch waka installed from February 2024 to January 2025 for sites 2, 4 and 5, and from May to December in 2024 for sites 1 and 3.

13.1 Results

13.1.1 Water quality assessment by waka

Summary statistics for temperature, electrical conductivity, pH and dissolved oxygen are presented in Table 12. This monitoring indicates that the levels of these attributes were acceptable for aquatic health, with the exception of dissolved oxygen which dropped to levels likely to stress aquatic organisms.

Electrical conductivity values sat within the normal range⁴ for most rivers of 200 – 1000 mS/cm. We did not identify any clearly anomalous data from this sensor.

⁴ <https://www.gov.nt.ca/sites/ecc/files/conductivity.pdf>

Table 12. Summary information for water quality attributes from Aquawatch Waka in the three main tributaries of Te Hākapupu/Pleasant River catchment between March 2024 and January 2025.

	Te Hākapupu / Pleasant River (site 2)	Trotters Creek (site 5)	Watkin Creek (site 4)
Electrical conductivity (mS/cm)			
Median	326	329	431
Inter-quartile range	267 - 390	244 – 701	374 - 462
Dissolved oxygen (mg/L)			
Median	10.8	6.8	9.3
Inter-quartile range	9.4 – 11.9	5.0 – 9.2	5.6 – 10.7
Percent of time below 5 mg/L	6	23	22
pH			
Median	7.3	7.1	7.2
Inter-quartile range	7.0 – 7.4	6.9 – 7.2	7.1 – 7.4
Temperature (C)			
Median	7.7	12.2	9.2
Inter-quartile range	6.4 – 13.5	8.8 – 15.3	6.4 – 13.0
Percent of time above 20 degrees C	1.5	1.4	0.6
Turbidity (NTU)			
Median	15	28	24
Inter-quartile range	5 - 41	10- 96	9 – 77
Data points	18,021	25,656	26,437

Dissolved oxygen levels sometimes decreased to hypoxic and anoxic levels in both Watkin Creek and Trotters Creek. This occurred when discharge was absent, indicating that stagnant waters could eventually become anoxic. Low levels of dissolved oxygen were common; concentrations below 5 mg/L were recorded at both sites for almost 25% of the monitoring period (a part of the study period is shown in Figure 28 showing dissolved oxygen levels below 5 mg/L commonly occurring from March to June in 2024). This suggests stress on oxygen-sensitive organisms, including fish, occurs during these periods at these sites. Dissolved oxygen stress in Te Hākapupu/Pleasant River at the Patterson Road ford was less severe, with only 6% of the data reported as below 5 mg/L.

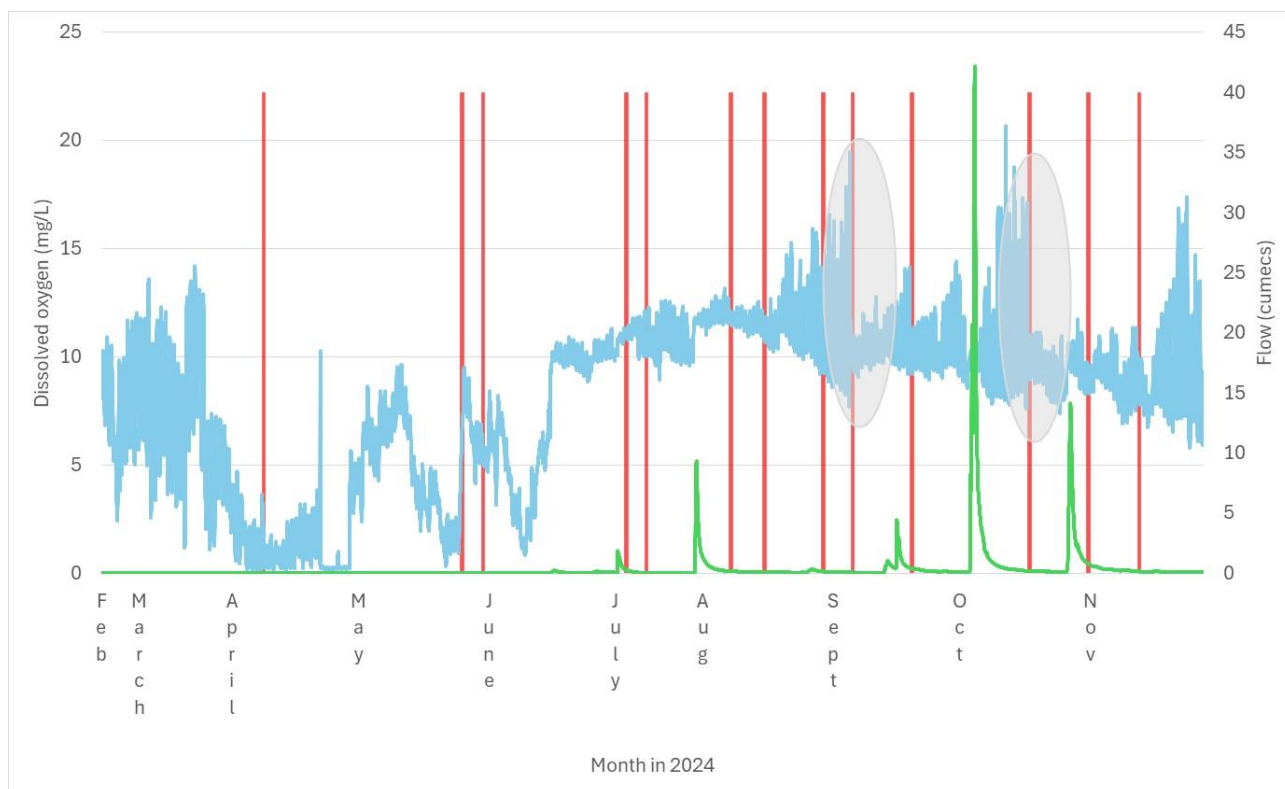


Figure 28. Dissolved oxygen levels in Trotters Creek recorded by the waka (blue line). Waka maintenance events are shown by red lines. Discharge in Te Hikapupu/Pleasant River is shown by the green line. Two extreme examples of the dissolved oxygen anomaly are shown by the ellipses.

Dissolved oxygen data from the waka should be interpreted with caution. The time series in Figure 28 shows that the dissolved oxygen sensors were sensitive to biofouling over time. Consequently, recorded levels of dissolved oxygen could change markedly (grey ellipses in Figure 28) in response to sensor cleaning (shown as the red lines in Figure 28). When the sensor was malfunctioning, daily variation appeared to be as high as 12 mg/L, but after cleaning, the daily variation was usually approximately 4 mg/L, or less.

The summary data for both temperature and pH indicate that these attributes were of no ecological concern in the rivers and that the sensors operated without apparent anomalies.

13.1.2 Relationship between waka turbidity data and total suspended solids

The relationship between turbidity data collected by the waka and by grab sampling differed between the sites. This difference is described below and contributed to our decision to analyse sediment flux using grab sample data rather than real-time turbidity data.

13.1.2.1 Te Hikapupu/Pleasant River

At the Patterson Road ford site turbidity readings from the waka generally correlated with total suspended solids and turbidity measured by grab samples at low to medium discharge (Figure 29). However, at discharge levels above approximately 8 cumecs, the turbidity values recorded by the waka dropped substantially below the grab sample turbidity values. The underestimates by the waka were

confirmed by the total suspended solids concentrations from the grab samples, which tended to increase with increasing discharge. This indicates that the waka turbidity sensor at this site malfunctioned at discharges above 8 cumecs. It is unclear how or why this sensor malfunctioned.

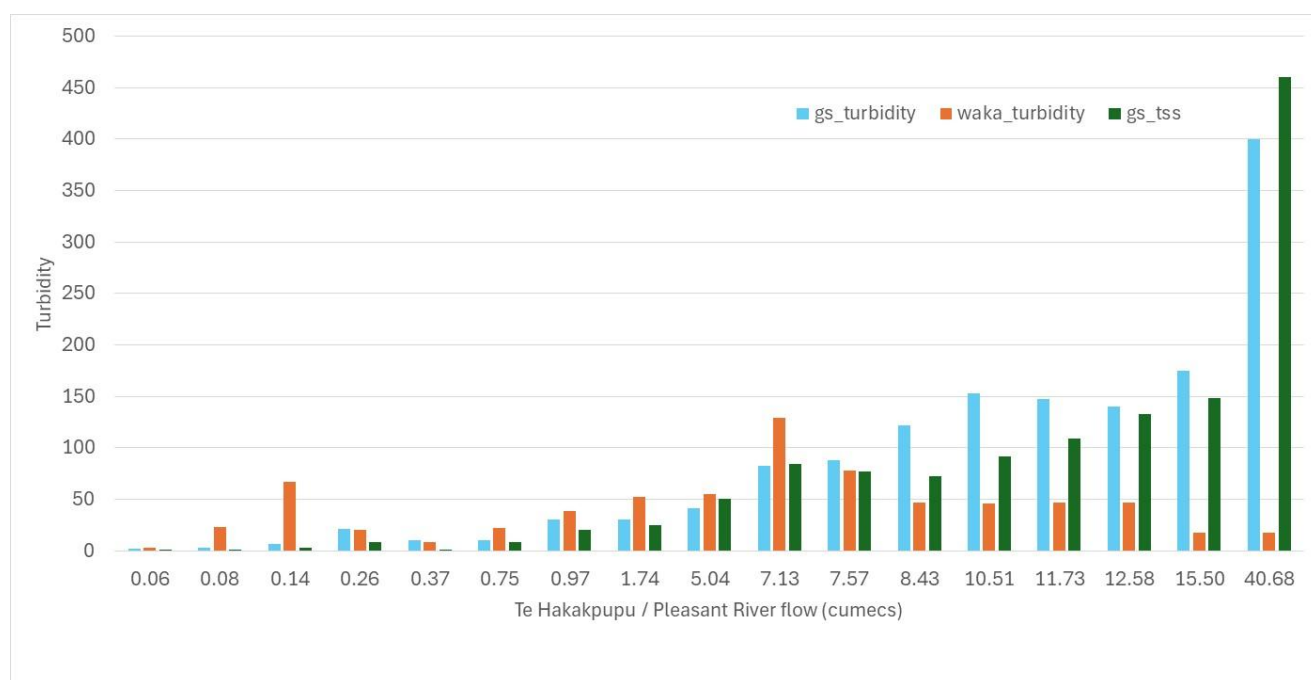


Figure 29. Turbidity measured by the waka (NTU, orange bars) compared to grab sample turbidity (NTU, light blue bars) and total suspended solids g/m^3 , green bars) for Te Hakapupu / Pleasant River at Patterson Road ford between July and November 2024.

The correlation coefficient between waka turbidity values and total suspended solids values measured from grab samples at the Patterson Road ford site was -0.052. In contrast turbidity and total suspended solids from grab samples were tightly correlated at the site (correlation coefficient 0.97).

13.1.2.2 Watkin Creek

At the Watkin Creek site the relationship between waka turbidity and grab sample turbidity was generally much closer. Yet some of the turbidity readings at low discharge appeared to be anomalous (Figure 30). In terms of estimating suspended sediment fluxes or loads, these anomalies are not as problematic as anomalies at high discharge because the contribution of suspended sediment at low discharges to the overall sediment flux are minor.

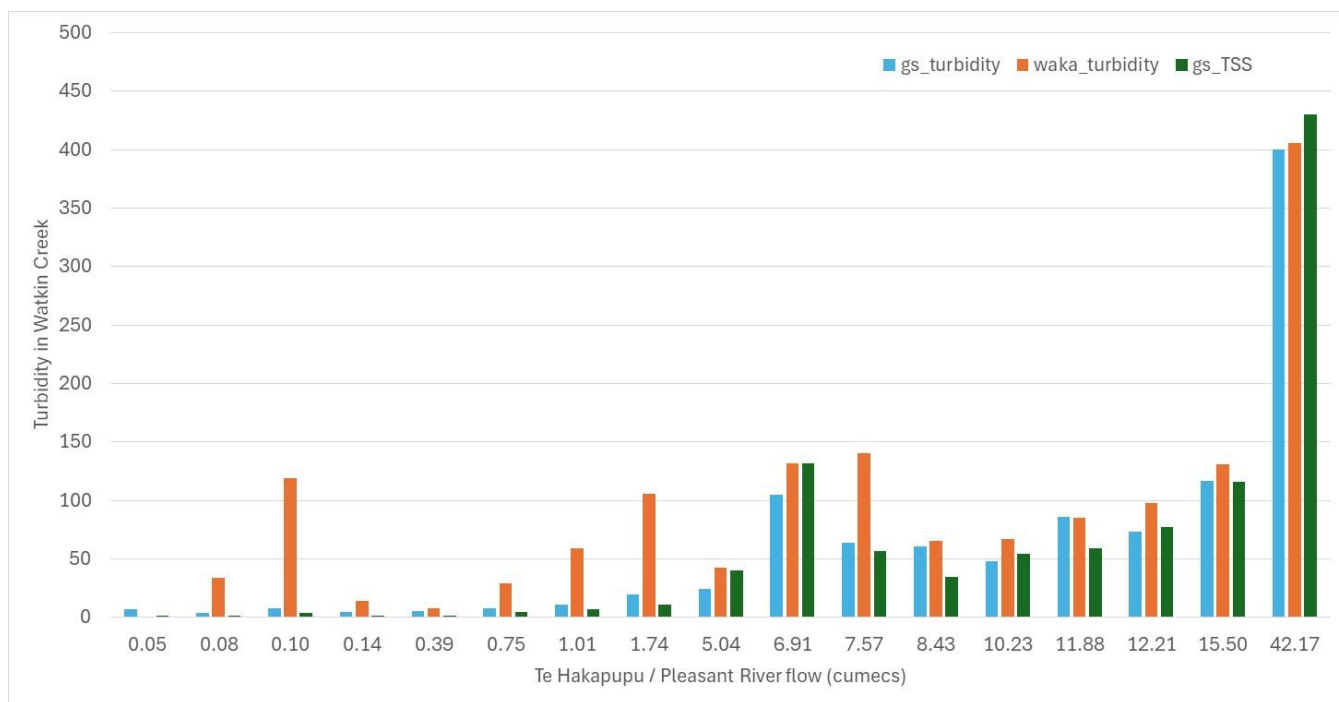


Figure 30. Turbidity measured by the waka (NTU, orange bars) compared to turbidity measured in grab samples (NTU, light blue bars) and total suspended solids (g/m³, green bars) in Watkin Creek between July 2024 and November 2025.

The correlation coefficient between turbidity values from the waka and total suspended solids from grab samples at the Watkin Creek site was 0.97, after removing two anomalous turbidity estimates (at 0.08 and 0.1 cumeecs) at low discharge.

The correlation coefficient within grab sample data between turbidity and total suspended solids was 0.99.

It was not possible to estimate sediment flux in Watkin Creek using the high-frequency waka data, despite the data's close relationship with the grab sample data, because discharge was not quantified for this tributary.

13.1.3 Instream turbidity levels above and below erosion risk areas

The contribution of a sub-catchment area with high erosion risk to sediment in Te Hākapupu/Pleasant River (Figure 31) was assessed by comparing turbidity data from wakas upstream (site 3) and downstream (site 1) of this area. The risk stemmed from both active erosion on farmland and from an adjacent area of recently harvested commercial forest. The distance between the wakas was 1.2 km. Turbidity levels were monitored from May to December, 2024.

A series of sediment traps (example shown in Figure 32) were installed in June 2024, midway through the monitoring period, along this erosion prone gully on farmland (indicative locations indicated by blue ovals in Figure 31). A total of 1,082m³ of sediment was removed from the traps in April 2025, after the end of the monitoring period. The sediment traps would have reduced the amount of sediment that eroded from this sub-catchment into the river.



Figure 31. The sub-catchment area with recent commercial forest harvest and area of active erosion on adjacent farmland (including indicative locations of sediment traps) established in 2023 from which discharge into Te Hikapupu/Pleasant River was monitored with Aquawatch waka. Site 3 is upstream of the erosion-prone sub-catchments and site 1 is downstream of the sub-catchments.



Figure 32. One of the series of sediment traps (shown by the blue ovals in Figure 31) established in June 2024, part way through the monitoring period, in the watercourse within an erosion prone gully on farmland discharging into Te Hikapupu/Pleasant River.

During the period of monitoring there were three high discharge events. It was anticipated that these would cause sediment mobilisation from this sub-catchment, creating a measurable difference in turbidity upstream (site 3) and downstream (site 1) of where it entered Te Hikapupu/Pleasant River. In addition, a spike in turbidity downstream (site 1) was also expected due to the earthworks associated with the construction of the sediment traps. The anticipated erosion from the earthworks would most likely occur with the first rainfall following construction in June 2024 and this is what was observed (Figure 33). That rainfall created initial turbidity spikes of similar magnitude (400 – 450 NTU) both upstream and downstream of where discharge from the area with sediment traps entered Te Hikapupu/Pleasant River, however the downstream spike persisted several days longer.

Contrary to expectation, turbidity values were generally quite similar at the two sites over the period of deployment (Table 13).

The similarity in turbidity values could be caused by two factors, either independently or in combination. Firstly, the level of suspended sediment discharging from the erosion-prone sub-catchments may have been similar to the level of suspended sediment already present in Te Hikapupu/Pleasant River (i.e., at the upstream site). This could have resulted from the new sediment traps intercepting mobilised sediment and from natural re-vegetation of the recently harvested area of forest. The second factor is

that variability (“noise”) in the data reported by the waka at these sites swamped the more subtle changes in suspended sediment concentration between the sites.

Table 13. Summary statistics for turbidity (NTU) data collected from Te Hikapupu/Pleasant River from May to December 2024 upstream (site 3) and downstream (site 1) of an erosion prone sub-catchment.

	Upper Stenhouse Road (site 3)	Lower Stenhouse Road (site 1)
Mean	48	40
Median	8	8
Range	1 – 1,320	1 – 1,363
Standard deviation	129	83

Spikes in turbidity were evident at both site 1 and site 3 (Figure 33), some coinciding with high discharge events and others not. The latter were most often observed only at the upstream site and were possibly due vehicles or livestock disturbing the bed of the waterway above site 3. Fortnightly observation of these sites while servicing the waka did not identify any events or other factors that seemed likely to have contributed to the spikes in turbidity.

Turbidity values at the two sites did not follow a similar trend over time. This is indicated by their low correlation value of 0.12. This poor correlation was related to the apparently anomalous turbidity spikes, usually at site 3, which occurred periodically, especially in September and November 2024.

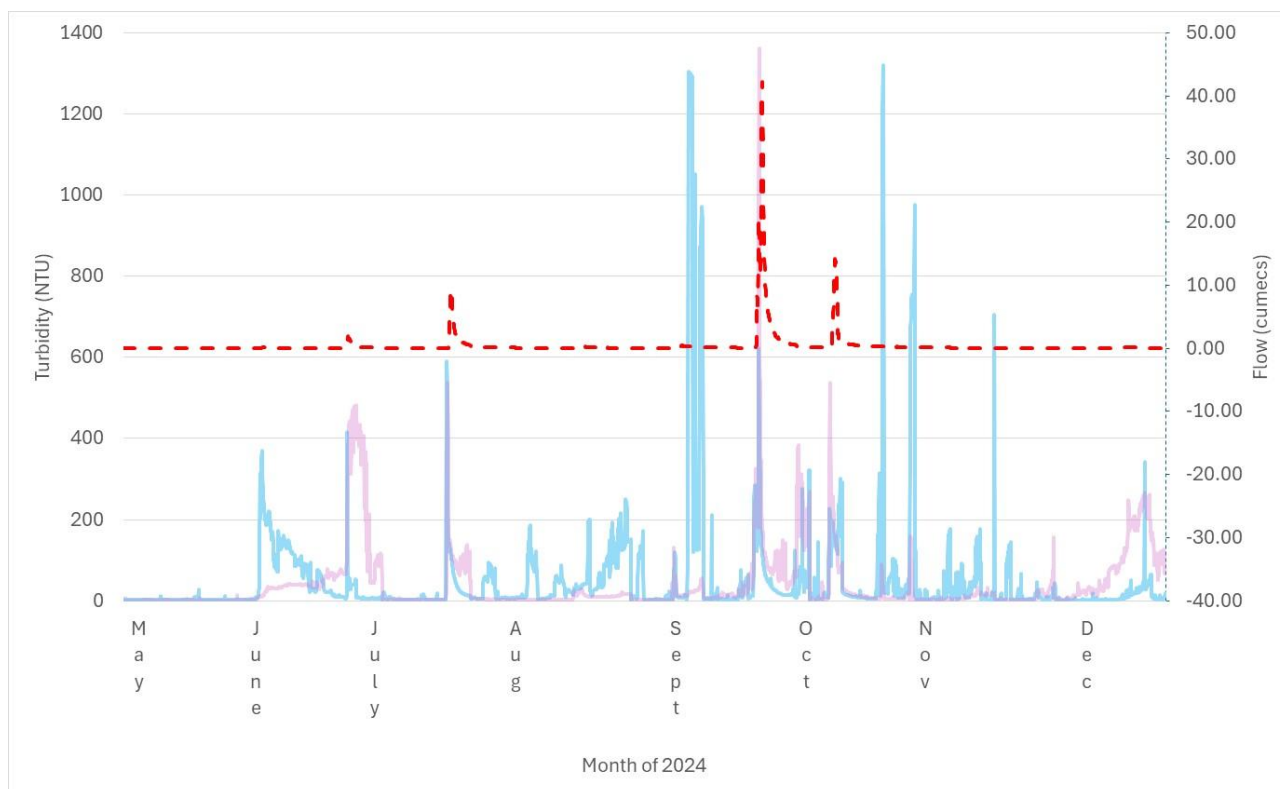


Figure 33. Turbidity (NTU) measured at the Upper Stenhouse Road site (site 3, blue line) upstream of the erosion risk areas and the Lower Stenhouse Road site (site 1, purple line) which is downstream of the erosion risk areas, discharge is shown as the red dashed line.

13.2 Interpretation

Waka data showed that during periods of low discharge, levels of dissolved oxygen dropped well below thresholds consistent with conditions promoting fish health. Prioritising the enhancement of pools to provide good refugia habitat for fish may be an effective means of supporting aquatic health in the rivers.

Waka data also showed large fluctuations in turbidity over time, some of which were related to high discharge and some of which were not. These results highlight the importance of careful visual assessment of the areas upstream and in the vicinity of the waka. In addition, timely servicing of the waka is also necessary to help understand the drivers of change in turbidity within the river.

The volume of material removed from the sediment traps highlights the contribution these structures can make to retaining suspended sediment moving from this high-risk sub-catchment toward the river. Earthworks for sediment trap construction appeared to prolong the spike in turbidity in the initial rainfall following installation of the traps (see late June in Figure 33). However, after this, the waka data did not show consistent evidence that increased sediment was being lost from this high-risk sub-catchment relative to the levels of sediment already present in Te Hikapupu/Pleasant River, suggesting the sediment traps were assisting in sediment retention.

The ability of the project team and the community to view the high-frequency waka data on a website was a valuable characteristic of this approach to water quality monitoring.

The waka require time and expertise from users to maintain them and keep them recording accurate data.

14 Fish passage

Many of Aotearoa's fish species undertake significant migrations as part of their life cycle, including many iconic freshwater species such as tuna (eel) and our five whitebait species. Most migratory (diadromous) freshwater fish species fall into two categories:

- Amphidromous species that are born in freshwater/estuaries, then drift into the ocean as larvae before migrating back into freshwater to grow into adults and spawn, e.g., inaka.
- Catadromous species that are born in saltwater, then migrate into freshwater as juveniles where they grow into adults before migrating back into the ocean to spawn, e.g. tuna.

Instream infrastructure, such as culverts, weirs, and dams can have significant impacts on freshwater migratory species by preventing them from moving between their breeding, juvenile and adult habitats. In many cases, this can lead to certain species only being able to access a fraction of the habitat that would naturally be available in a river catchment. In some cases, this can lead to the complete local extinction of some species.

The effect of migration barriers varies between species, largely due to their different climbing and swimming abilities. Some species such as tuna, koaro, and kōkopu have excellent climbing abilities and are able to move through or around most structures that impede fish passage. However, species such as inaka (inanga), smelt, and pātiki (black flounder) are less able to do so and can be impeded by relatively small barriers.

Kāti Huirapa Rūnaka ki Puketeraki was contracted as part of the project to assess potential fish passage barriers in Te Hākapupu/Pleasant River catchment and make recommendations on actions to be taken where barriers have been identified (Dale & Rata te Raki, 2024). Potential fish passage barriers were assessed using the New Zealand Fish Passage Assessment Tool (Table 14).

Table 14. Qualitative descriptions of the different fish passage risk classes (Franklin, 2018).

Risk class	Description
Very high	Very high chance that most or all fish species will be blocked most or all of the time.
High	High chance that the movements of many fish species and life stages will be restricted for much of the time.
Moderate	Moderate chance that the movements of some fish species and life stages are commonly restricted.
Low	Some chance that movements of weaker swimming species are restricted some of the time.
Very Low	Movements are unimpeded for most or all fish species and life stages for most or all of the time.
Not assessed	Select this if you are not confident or do not have the right knowledge to determine the likely risk.

14.1 Results

Twenty instream structures were assessed for fish passage across the four sub-catchments in 2024 (Figure 34). The structures were prioritised on a scale from very low risk to very high risk.

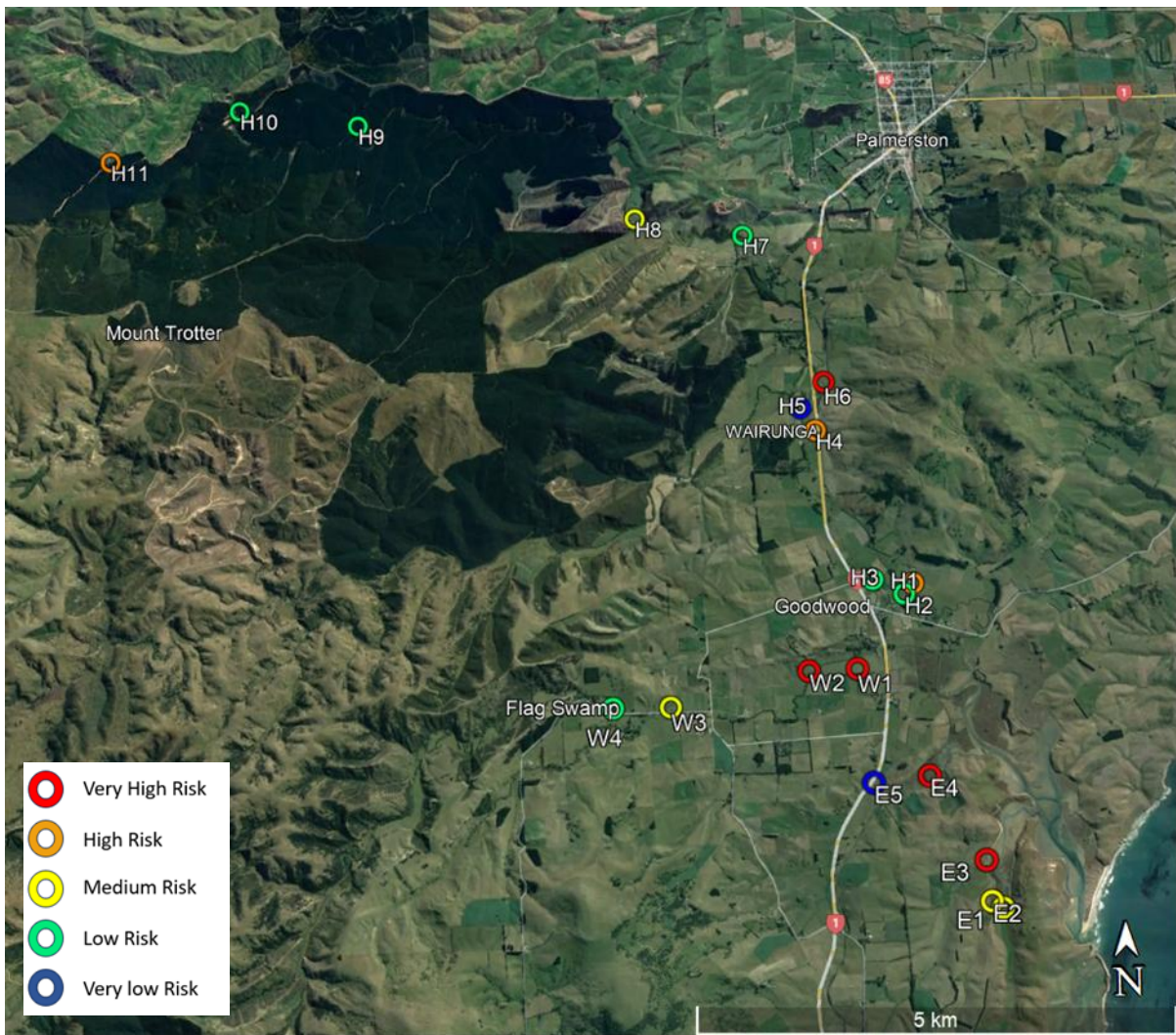


Figure 34. Potential fish passage barriers in Te Hikapupu/Pleasant River catchment.

Of these twenty, seven (Figure 34) were considered high or very high priority for replacement or remediation. In all cases, complete removal and replacement of the existing structures was recommended, although some temporary remediation measures may be appropriate while more permanent solutions were progressed.

Five of the seven sites are privately owned and the Otago Regional Council is currently working with three landowners to provide funding and support for improvements at three of these sites. A further two sites are managed by the Waitaki District Council.

Table 15. Summary of high priority structures for fish passage remediation work in Te Hākapupu/Pleasant River catchment shown in Figure 34.

Site name	Database ID	Structure type	Recommended action
E3	177868	Flap gate with culvert	Removal of flap gate, installation of fish friendly gate if this is not possible
E4	177866	Flap gate with culvert	Removal of flap gate, installation of fish friendly gate if this is not possible
W1	177872	Ford with culvert	Complete removal and replacement with large diameter culvert imbedded in stream bed
W2	177871	Culvert	Complete removal and replacement with large diameter culvert imbedded in stream bed
H1	177857	Ford with culvert	Removal and replacement with bridge or large box culvert. Rock ramp as a short-term alternative
H4	177855	Ford with culvert	Removal and replacement with bridge or large box culvert. Rock ramp as a short-term alternative
H6	177863	Culvert	Complete removal and replacement with large diameter culvert imbedded in stream bed

Three farm culverts and two public road fords had received remedial action by the end of the project in July 2025. For example, a rock ramp was installed at the Brooklands Road ford (Figure 35 and Figure 36).



Figure 35. The Brooklands Road ford before (left image) and during (right image) construction of a rock ramp to improve fish passage.



Figure 36. The established rock ramp at Brooklands Road ford.

To test the effectiveness of this rock ramp, Kāti Huirapa Rūnaka ki Puketeraki monitored whitebait numbers before and after its installation – from September to December, 2024. Whitebait nets were set for 3-5 days per month, for one tidal cycle per day. The catch from each day was counted and then released back into the river.

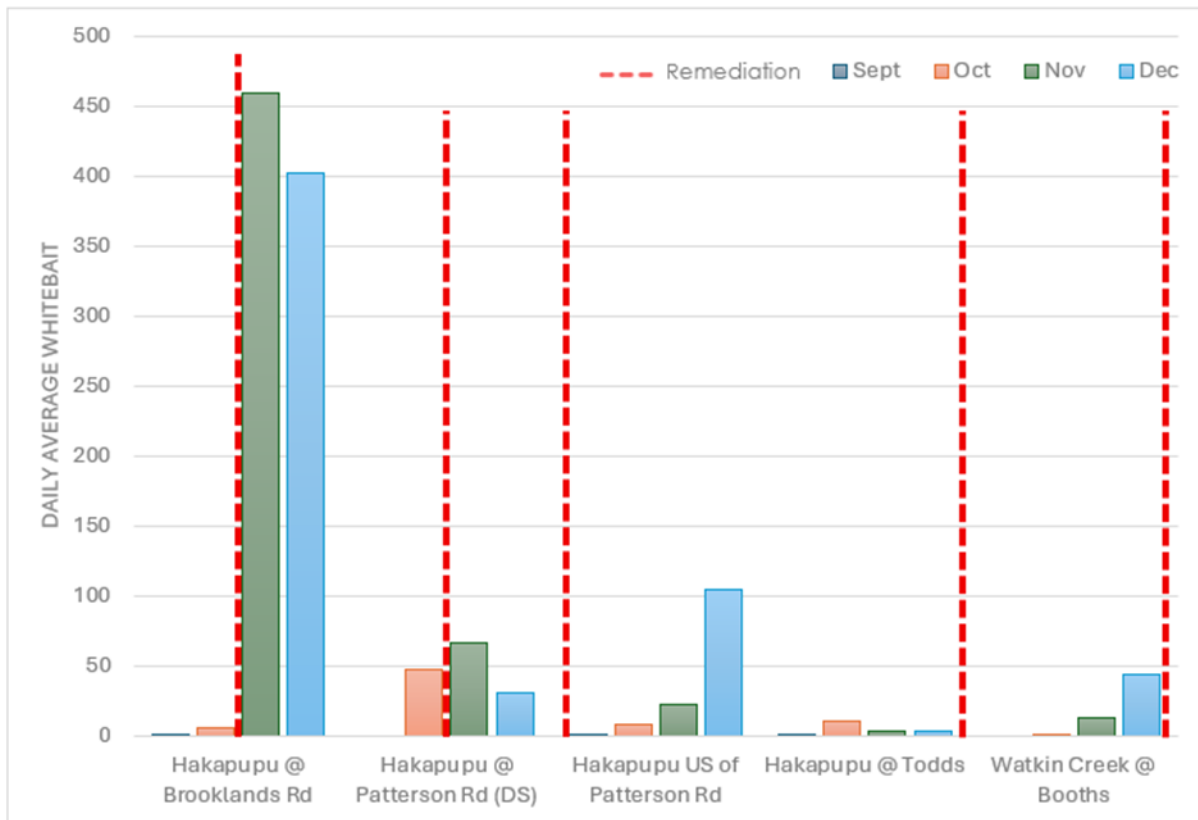


Figure 37. Average daily whitebait catches from September to December in Te Hākapupu catchment. Red dotted lines indicate when fish passage remediation was undertaken for each site.

Prior to installing the ramp, an average of less than 10 whitebait per tidal cycle were recorded. Afterward, an average of over 400 whitebait were recorded per tidal cycle in each of the following two months.

14.2 Interpretation

Work at Brooklands Road ford shows how effective well-designed fish passage remediation can be. It also highlights the importance of providing fish passage in our coastal catchments.

Critically, the Brooklands Road ford is very close to where the Te Hākapupu/Pleasant River discharges into the estuary. Consequently, the remedial work there has enabled fish access to the vast majority of the rest of the catchment, other barriers notwithstanding.

Following on from this work, the Otago Regional Council, Kāti Huirapa Rūnaka ki Puketeraki and the East Otago Catchment Group continue to work with local landowners to replace culverts on farms that are also preventing fish passage further up the catchment. At the completion of the project, two road crossing had been remediated, and three farm culverts had been replaced, opening up fish passage to over 90% of the catchment.

15 Summary of monitoring methods

A substantial amount of scientific information has been collated describing the ecological health and quality of the water and waterways in Te Hikapupu/Pleasant River catchment as part of the Toitū Te Hikapupu/Pleasant River Restoration Project.

Six approaches were used and across these a total of 34 different metrics were assessed:

- Hydrological discharge in Te Hikapupu/Pleasant River
- Sediment load in Te Hikapupu/Pleasant River
- Sediment flux in Te Hikapupu/Pleasant River
- Real-time telemetered water quality information with the Aquawatch Waka
- Turbidity
- Temperature
- Dissolved oxygen
- Electrical conductivity
- pH
- Water level and flow monitoring by the Otago Regional Council
- Monthly water quality monitoring using grab sampling at key locations in the catchment
- Water quality monitoring using grab samples during periods of high discharge
- Turbidity
- Total dissolved solids
- Total nitrogen
- Nitrite + Nitrite N
- Dissolved reactive phosphorous
- Total phosphorous
- Environmental DNA analysis of the types of freshwater and estuarine fish species
- Fish passage assessment
- Fish diversity and abundance
- Annual ecological baseline assessment which involves;
- Stream habitat score (made up of nine variables listed below)
- Sediment level measurement (Quorer method)

- Periphyton measurement
- Macro invertebrate abundance index

The stream habitat score is made up of

- Habitat for aquatic animals
- Water clarity
- Flow types
- Bank stability and erosion
- Bank vegetation
- Riparian buffer
- Shade
- Channel alteration

The collective application of these methods has established a valuable baseline for the catchment. For most methods repeated sampling over longer periods will build up a body of data robust enough to enable trend analysis. Some of these methods will be suited to continuation by the community in the catchment as part of work carried out under the Catchment Action Plan. Methods involving the community that are able to demonstrate the project's success in reducing sediment loads, improving water quality, and enhancing other related biodiversity and catchment values would be particularly valuable.

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Bibliography

Biggs, B.J.F., Kilroy, C., Mulcock, C.M., Scarsbrook, M.R., Ogilvie, S.C. 2002: New Zealand Stream Health Monitoring and Assessment Kit. Stream Monitoring Manual. Version 2K – A Tool for Kaitiaki. NIWA Technical Report 111-1. 190 p

Blöthe, M. and Roden, E. (2009) 'Microbial Iron Redox Cycling in a Circumneutral-pH Groundwater Seep', *Applied Environmental Microbiology*, 75. Available at: <https://doi.org/10.1128/AEM.01817-08>.

Buytaert. W., Iñiguez. V., De Bièvre. B., 2007, The effects of afforestation and cultivation on water yield in the Andean páramo, *Forest Ecology and Management*, Volume 251, Issues 1–2, Pages 22-30, ISSN 0378-1127,

Clapcott. J., Young. R., Harding. J., Matthaei. C., Quinn. J., Death. R., 2011, *Sediment Assessment Methods Protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values*, Cawthron Institute, ISBN: 978-0-473-20106-7

Clucas, R. (2019) *Delimitation of inaka (whitebait) spawning in coastal Otago Rivers - DRAFT*. Department of Conservation, p. 18. Available at: <https://www.orc.govt.nz/media/152nb10v/delimitation-of-inaka-whitebait-spawning-in-coastal-otago-rivers-2019-draft.pdf>. Blöthe, M. and Roden, E. (2009) 'Microbial Iron Redox Cycling in a Circumneutral-pH Groundwater Seep', *Applied Environmental Microbiology*, 75. Available at: <https://doi.org/10.1128/AEM.01817-08>.

Clucas, R. (2019) *Delimitation of inaka (whitebait) spawning in coastal Otago Rivers - DRAFT*. Department of Conservation, p. 18. Available at: <https://www.orc.govt.nz/media/152nb10v/delimitation-of-inaka-whitebait-spawning-in-coastal-otago-rivers-2019-draft.pdf>.

Forrest, B., Roberts, K. and Stevens, L. (2022) *Fine scale intertidal monitoring of Pleasant River (Te Hākapupu) estuary*. Salt Ecology Report 093. Salt Ecology, p. 29. Available at: https://www.orc.govt.nz/media/15864/pleasant-river-cssi_sediment-source-tracking-report-2023.pdf.

Fransen, P., Phillips, C. and Fahey, B. (2001) 'Forest road erosion in New Zealand: overview', *Earth Surface Processes and Landforms*, 26(2), pp. 165–174.

Marden, M., Rowe, L. and Rowan, D. (2007) 'Slopewash erosion following plantation harvesting in pumice terrain and its contribution to stream sedimentation, Pokairoa catchment, North Island', *Journal of Hydrology (NZ)*, 46(2), pp. 73–90.

Norton, S., Dicey, S. and Mohan, R. (2023) *Te Hākapupu/Pleasant River catchment restoration project context analysis to inform catchment plan*. 230807-05013–4A. Whirika Consulting Limited, p. 80.

Ozanne, R. (2022) *State and trends of river and lake water quality in the Otago region 2000 - 2020*. Otago Regional Council, p. 135. Available at: <https://www.orc.govt.nz/media/9781/state-and-trends-of-lake-and-river-water-quality-in-the-otago-region-2000-to-2020.pdf>.

Swales, A. et al. (2023) *Sources of sediment deposition in the Pleasant River (Te Hākapupu) catchment and estuary*. 2023175HN. NIWA, p. 96. Available at: https://www.orc.govt.nz/media/15864/pleasant-river-cssi_sediment-source-tracking-report-2023.pdf.

Tait, L. et al. (2021) 'Loss of giant kelp (*Macrocystis pyrifera*) driven by marine heat waves and exacerbated by poor water quality in New Zealand', *Frontiers in Marine Science*, 8, p. 13.

Townsend, M. and Lohrer, D. (2015) *ANZECC guidance for estuary sedimentation*. HAM2015-096. National Institute of Water and Atmospheric Research, p. 45. Available at: <chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://environment.govt.nz/assets/publications/niwa-anzecc-estuary-sedimentation-final.pdf>.

Macara, G. (2015) *The climate and weather of Otago*. 2nd edition. National Institute of Water and Atmospheric Research, p. 44.

Marden, M., Rowe, L. and Rowan, D. (2007) 'Slopewash erosion following plantation harvesting in pumice terrain and its contribution to stream sedimentation, Pokairoa catchment, North Island', *Journal of Hydrology (NZ)*, 46(2), pp. 73–90.

Norton, S., Dicey, S. and Mohan, R., 2023, *Te Hākapupu/Pleasant River catchment restoration project context analysis to inform catchment plan*. 230807-05013–4A. Whirika Consulting Limited, p. 80.

Norton, S., Dicey, S., Mohan, R., Millar, R., 2024, Context analysis – reference information to support the Toitū Te Hākapupu/Pleasant River Catchment Action Plan, Whirika client report number 230807-05013-4A

Olsen, D. and Ozanne, R. (2013) *Water quality study; Waianakarua river catchment*. Otago Regional Council, p. 57. Available at: [chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.orc.govt.nz/media/6184/waianakarua-water-quality-report-2013.pdf](https://www.orc.govt.nz/media/6184/waianakarua-water-quality-report-2013.pdf).

Olsen, D. and Ozanne, R. (2014) *Shag River/Waihemo catchment: water quality and ecosystem*. Otago Regional Council, p. 88. Available at: [chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.orc.govt.nz/media/6178/shag-river-waihemo-catchment-water-quality-and-ecosystem-health-report.pdf](https://www.orc.govt.nz/media/6178/shag-river-waihemo-catchment-water-quality-and-ecosystem-health-report.pdf).

Ozanne, R. (2022) *State and trends of river and lake water quality in the Otago region 2000 - 2020*. Otago Regional Council, p. 135. Available at: <https://www.orc.govt.nz/media/9781/state-and-trends-of-lake-and-river-water-quality-in-the-otago-region-2000-to-2020.pdf>.

Roberts KL, Stevens LM, Forrest BM, (2022) Broudscale intertidal habitat mapping of Pleasant River (Te Hākapupu) estuary. Salt Ecology, prepared for Otago Regional Council.

Schallenberg, M. et al. (2024) *Toitū Te Hākapupu / Pleasant River Restoration Project - Monitoring Report to June 30, 2024*. 05013–3B & 3A. Whirika Consulting Limited, p. 59.

Swales, A. et. al, 2023, Sources of sediment depositing in the Pleasant River (te Hākapupu) catchment and estuary. National Institute of Water and Atmospheric Research. [NIWA Client report \(orc.govt.nz\)](#)

Tait, L. et al. (2021) 'Loss of giant kelp (*Macrocystis pyrifera*) driven by marine heat waves and exacerbated by poor water quality in New Zealand', *Frontiers in Marine Science*, 8, p. 13.

Townsend, M. and Lohrer, D. (2015) *ANZECC guidance for estuary sedimentation*. HAM2015-096. National Institute of Water and Atmospheric Research, p. 45. Available at: [chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://environment.govt.nz/assets/publications/niwa-anzecc-estuary-sedimentation-final.pdf](https://environment.govt.nz/assets/publications/niwa-anzecc-estuary-sedimentation-final.pdf).