Traverse Environmental

Water quality in the Waikouaiti River catchment

Monitoring activities and findings

Prepared for: East Otago Catchment Group

March 2026

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Executive summary

The East Otago Catchment Group (EOCG) is helping facilitate farmer-led change towards the improvement of waterways and streams in the Waikouaiti River catchment, north of Dunedin. One of several focus areas for the EOCG is maintaining and improving water quality. This report has been prepared to support that work. Specifically, the report:

- outlines current and historical water quality monitoring, investigations and research carried out by different organisations,
- summarises what we know about water quality state and trends, based on an assessment of existing readily available reports and data, and
- identifies potential management considerations and information gaps.

This report focuses on water quality to support ecosystem health and human health for recreation. As water quality is only one component of a healthy stream, information on aquatic life (e.g. invertebrates and fish), physical habitat (e.g. riparian vegetation), ecosystem processes (e.g. nutrient cycling) and water quantity is also considered in this report.

Monitoring activities and information

Although the Waikouaiti River comprises two branches, the North Branch originating near Macraes township and the South Branch originating in the Silver Peaks Scenic Reserve, most of the information on water quality is limited to the North Branch and some of its tributaries in the uppermost areas of the catchment.

Routine monitoring of water quality in the Waikouaiti River began in the mid-1980s, by the Otago Catchment Board, the precursor to the Otago Regional Council (ORC). This monitoring focused on the lower catchment area, downstream of Bucklands Crossing. The ORC's current river state of the environment (SOE) monitoring programme includes monthly measurements of physical, chemical and microbiological water quality, and annual monitoring of invertebrate and fish communities, at one site on the river's mainstem above Orbells Crossing. In addition, over the summer months, concentrations of *E. coli* and enterococci indicator bacteria are tested weekly in the North Branch at Bucklands Crossing Recreation Reserve and Karitane Wharf swimming sites, respectively. Ecological health is also monitored at two sites within the Waikouaiti Estuary.

Other organisations collecting significant amounts of water quality information in the Waikouaiti River catchment on an ongoing basis are:

- the Dunedin City Council and Waitaki District Council in relation to raw water sourced from the river for drinking water supplies, upstream of Orbells Crossing and at Stoneburn, respectively, and
- OceanaGold in relation to discharges associated with its gold mining operation at Macraes.

In 2015/16 Kāti Huirapa Rūnaka ki Puketeraki (Kāti Huirapa) carried out monthly assessments of the health of five river and five estuary sites, incorporating a range of indicators and a mix of field and laboratory test methods. Kāti Huirapa continues to collect river health data on an annual basis, along with City Forests at a site on the South Branch, using the Stream Health Monitoring and Assessment Kit (SHMAK).

Key findings

River water quality and health

The available monitoring information indicates that water quality in the Waikouaiti River is 'very good' and compares favourably with the attribute[1] bands in the current (2020) National Policy Statement for Freshwater Management (NPS-FM). Based on the ORC's monitoring of the lower reaches over the five-year period ending

[1] An attribute essentially refers to a measurable form of an indicator (e.g. nitrate-nitrogen concentration).

June 2025, the river has very low median concentrations of suspended sediment and plant-available[2] nutrients, and significant faecal contamination is infrequent and limited to wet weather. However, the river often experiences extended periods of low flow and high water temperatures in summer, contributing to significant periphyton (i.e. algae) growth in some locations and, subsequently, an aquatic invertebrate fauna dominated by types that can tolerate these conditions. Despite this, sensitive mayflies, caddisflies and brown trout are present in the lower reaches. Native fish diversity is also high in the lower reaches, reflecting good access to the sea, which is required by many species to complete their life cycle. Regular electric fishing at Orbells Crossing since 2007 has recorded īnanga, longfin eel, shortfin eel, pouched lamprey, bluegill bully, common bully, black flounder, brown trout and – on occasion – torrentfish and flathead grey mullet. A small number of additional species were detected in a subset of eDNA samples collected in 2024 and 2025.

Recent ecological monitoring in the upper catchment of the North Branch carried out for OceanaGold shows Taieri flathead galaxias and both upland and common bullies are commonly recorded in the tributaries, along with koura (freshwater crayfish), freshwater shrimp and kākahi (freshwater mussels). However invertebrate community health is currently rated as ‘poor’ to ‘fair’, especially at sites downstream of the mine operation where there is high macrophyte (i.e. aquatic plant) cover. Long term data indicate macrophyte cover was lower, and invertebrate health better, when monitoring began in the early 2000s. As well as mine-related activities, low stream flows in summer and low-intensity farming in the area are likely contributing to the observed decline in stream health. In particular, stock access to stream margins and channels has been documented and is associated with localised bank damage and pugging at several sites.

The South Branch has far fewer invertebrate and fish records, but fish include brown trout, īnanga, longfin eel and common bully. Kōura have been recorded in the headwaters.

Estuary water quality and health

Waikouaiti Estuary is in a ‘moderate’ ecological condition. The Merton Arm has a high mud content and there are patches of nuisance algal growth on the flats in some locations. However, organic carbon, nutrient and metal concentrations in the surface sediments are low and, in the middle and lower areas of the estuary, there are well-oxygenated sands supporting a healthy invertebrate community.

Based on regular testing of enterococci indicator bacteria, the estuary at Karitane Wharf is suitable for swimming most of the time in summer but it can be compromised in wet weather. Collection of shellfish should also be avoided following rainfall.

Management considerations

Overall, monitoring to date suggests that the ecological health of the Waikouaiti River is impacted more by stable and frequently low flows than contaminant inputs from the surrounding catchment. However, the naturally low nutrient status of the river also means that even a small increase in nutrients could allow rapid changes in periphyton growth. This is especially the case if plant-available phosphorus, which is currently the nutrient that limits periphyton growth, were to increase in concentration. In terms of the estuary, nitrogen is the limiting nutrient. Therefore, both phosphorus and nitrogen need to be managed at the catchment scale, along with sediment, to safeguard ecological health. Most sediment will enter the estuary in wet weather.

Some information gaps exist, particularly in the South Branch for which considerably less monitoring has been carried out to date. Several suggestions have been made where further monitoring could be undertaken but consideration also needs to be given to the spatial scale at which farm planning and catchment management will operate.

[2] Plant available refers to dissolved reactive phosphorus and dissolved inorganic forms of nitrogen (principally present as nitrate-nitrogen).

Contents

1 Introduction

The East Otago Catchment Group (EOCG) was established in August 2019 to help facilitate farmer-led change towards the improvement of waterways in five freshwater catchments in the East Otago area. One of those catchments is the Waikouaiti River catchment, located around a 30-minute drive north of Dunedin City.

One of several focus areas for the EOCG is maintaining and improving water quality. There is a particular interest in better understanding current issues with, and potential future risks to, water quality so that this can inform identification of practical, effective on-the-ground management actions in freshwater farm plans (or their future equivalent). This report has been prepared to support that work.

1.1 Purpose and scope

The primary aim of this report is to collate what is known about water quality in the Waikouaiti River catchment to inform freshwater farm plan development and other activities, such as community-based monitoring and restoration. Specifically, the report:

- details current and historical water quality monitoring, investigations and research carried out by different organisations,
- summarises what we know about water quality state and trends, based on existing readily available reports and data, and
- identifies potential management considerations and information gaps.

1.2 What's in this report?

This report begins with a brief introduction to the Waikouaiti catchment and key features of relevant to water quality (section 2) followed by a description of the monitoring and research carried out to date by different organisations (section 3). Section 4 summarises the key findings from this work, drawing on both existing reports and interpretation of more recent and additional data and information. The Waikouaiti Estuary, as the primary receiving environment for river inputs, is considered alongside the Waikouaiti River in this section. Section 5 outlines management considerations and information gaps, and conclusions are presented in section 6.

1.3 Approach taken

This report focuses on water quality to support ecosystem health and human health for recreation, two compulsory values fresh waters must be managed for in New Zealand under the National Policy Statement for Freshwater Management 2020 (NPS-FM)[3]. While water quality that is suitable for ecosystem and human health is also suitable for most other purposes (e.g. irrigation and stock drinking water), this does not necessarily mean it is necessarily satisfactory for cultural use. Assessment of cultural and spiritual values rests with Kāti Huirapa Rūnaka ki Puketeraki as mana whenua of the Waikouaiti area, and is outside the scope of this report.

Water quality is only one component of a healthy stream; aquatic life (e.g. invertebrates and fish), physical habitat (e.g. riparian cover), ecosystem processes (e.g. nutrient cycling) and water quantity are also key components (Figure 1). These components are interrelated and so all are considered in this report.

[3] The NPS-FM and Resource Management Act are currently under review but the Government has signalled through the Natural Environment Bill that limits will be required to protect both ecosystem health and human health.

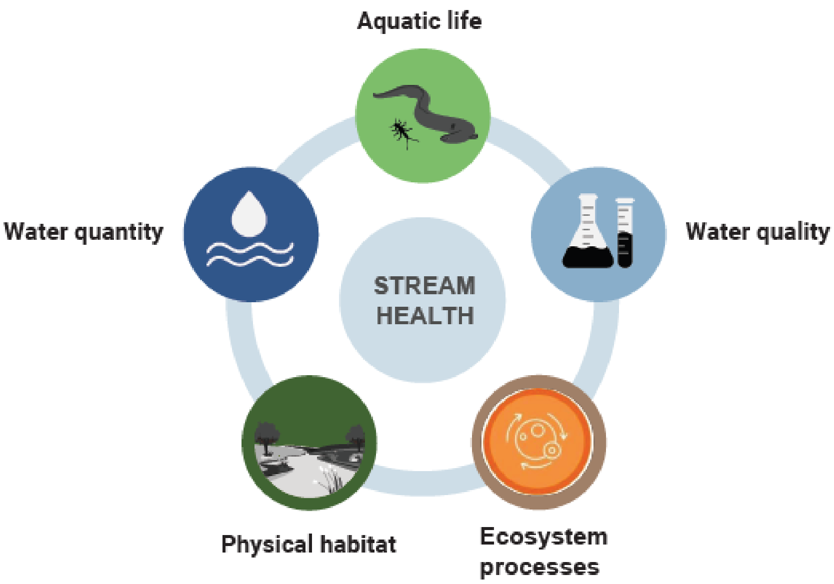

Figure 1: The five key components of freshwater ecosystem health recognised in the National Policy Statement for Freshwater Management 2020. Water quality itself is characterised by a range of physical (e.g. water temperature) chemical (e.g. nutrients) and – in this report – microbiological indicators (e.g. *E. coli*). Adapted from Milne et al. (2023).

1.4 Limitations

This report relies heavily on existing reports and collated or summarised data from third parties. Incomplete details, conflicting information and errors were followed up where possible, but it was beyond the scope of this project to re-examine the underlying data sets. Additional analyses of reported data were also out of scope but some recently collected, or previously unreported, data were assessed to better understand different aspects of water quality and wider ecosystem health.

With data provided from many different sources, there is a mix of monitoring methods, indicators and time periods monitored. While this prevents robust comparisons between sites and assessment of trends over time, it has allowed an understanding of catchment water quality to be pieced together that would not have been as comprehensive had only one organisation's data been relied upon.

Although water quality information associated with university research projects and resource consents is summarised, the search was not exhaustive and it is very likely that additional information exists.

2 Catchment overview

The Waikouaiti River is one of Otago's three major rivers draining to the coast north of Dunedin and rises in two branches (Figure 2). The North Branch is the larger of the two and originates near Macraes township, flowing south to join the South Branch 3.5 km downstream of Bucklands Crossing. The South Branch originates in the Silver Peaks Scenic Reserve and flows northwards. Following the joining of the two branches on the river flats northwest of Orbells Crossing, the river flows around 4.5 km before entering the Waikouaiti River Estuary. The river is tidal for much of this lower reach, with the tidal influence extending to just above Orbells Crossing.

Waikouaiti, located north of the estuary, is the most densely populated township, with a population of 1,320[4]. The smaller township of Karitane (population 440) is located on the southern side of the estuary where the river exits to the Pacific Ocean. Kāti Huirapa Rūnaka ki Puketeraki (hereafter Kāti Huirapa) are the mana whenua for the area.

The catchment covers an area of 425 km^2 and comprises landforms ranging from flat floodplains close to sea level, to plateau areas, steeplands and dissected hills inland with a maximum elevation of 700 m. High points in the catchment include Mt Hikaroroa/Watkin (615 m) and Mt Scott (664 m) in the north, and Mt Misery (714 m) and Silver Peak (767 m) in the south.

2.1 Climate

Most of the Waikouaiti catchment is classified as having a 'cool-dry' climate, based on an annual average temperature of <12°C and average effective[5] precipitation of 500 mm (Snelder Biggs and 2002). There is variation in annual rainfall across the catchment, ranging from around 500-550 mm in the upper North Branch catchment to 800-900 mm in high elevation areas of the South Branch catchment (Olsen 2024, Figure 3). Annual rainfall in the lower catchment area near the coast is around 650-700 mm.

Rainfall is distributed relatively evenly throughout the year, although inland areas experience larger totals in December from summer thunderstorms and rainfall is slightly lower in late autumn/winter in some areas (ORC 2008). There is a large variation in monthly rainfall between years, indicating rainfall is often sporadic and unreliable (ORC 2008).

2.2 Geology and soils

The base geology of the Waikouaiti catchment is dominated by Otago Schist, a hard metamorphic rock that controls much of the catchment's topography and drainage pattern (Forsyth 2001, Mortimer 2003). The schist is overlain by patches of younger marine sedimentary rocks near the coast, mainly sandstones, mudstones and limestones of the Caversham Formation and Goodwood Limestone, and by Quaternary alluvial and loess deposits along the river valley and floodplain (GNS Science QMAP, NZLRI 2020).

The schist-dominated hill country produces thin, stony soils and rapid runoff, while the younger sedimentary and alluvial materials in the lower catchment form more fertile but erodible soils on gentler slopes and along the river valley (NZLRI 2020). Together, these materials create a catchment with contrasting land stability and erosion risk.

The Otago Schist that underlies much of the catchment is hard and relatively impermeable, so groundwater is generally limited to small, shallow deposits in the lower Waikouaiti valley and estuarine area, with no significant aquifer systems identified (ORC 2018).

Most of the catchment comprises brown soils, with the South Branch characterised by orthic-brown soils and the North Branch consisting mainly of firm brown soils (NZLRI 2020). Pallic soils are found around Macraes and in the lower valley.

[4] As at June 2024: Stats NZ data.
[5] The amount of precipitation that contributes to soil moisture or usable water, after accounting for losses from evaporation, runoff, etc.

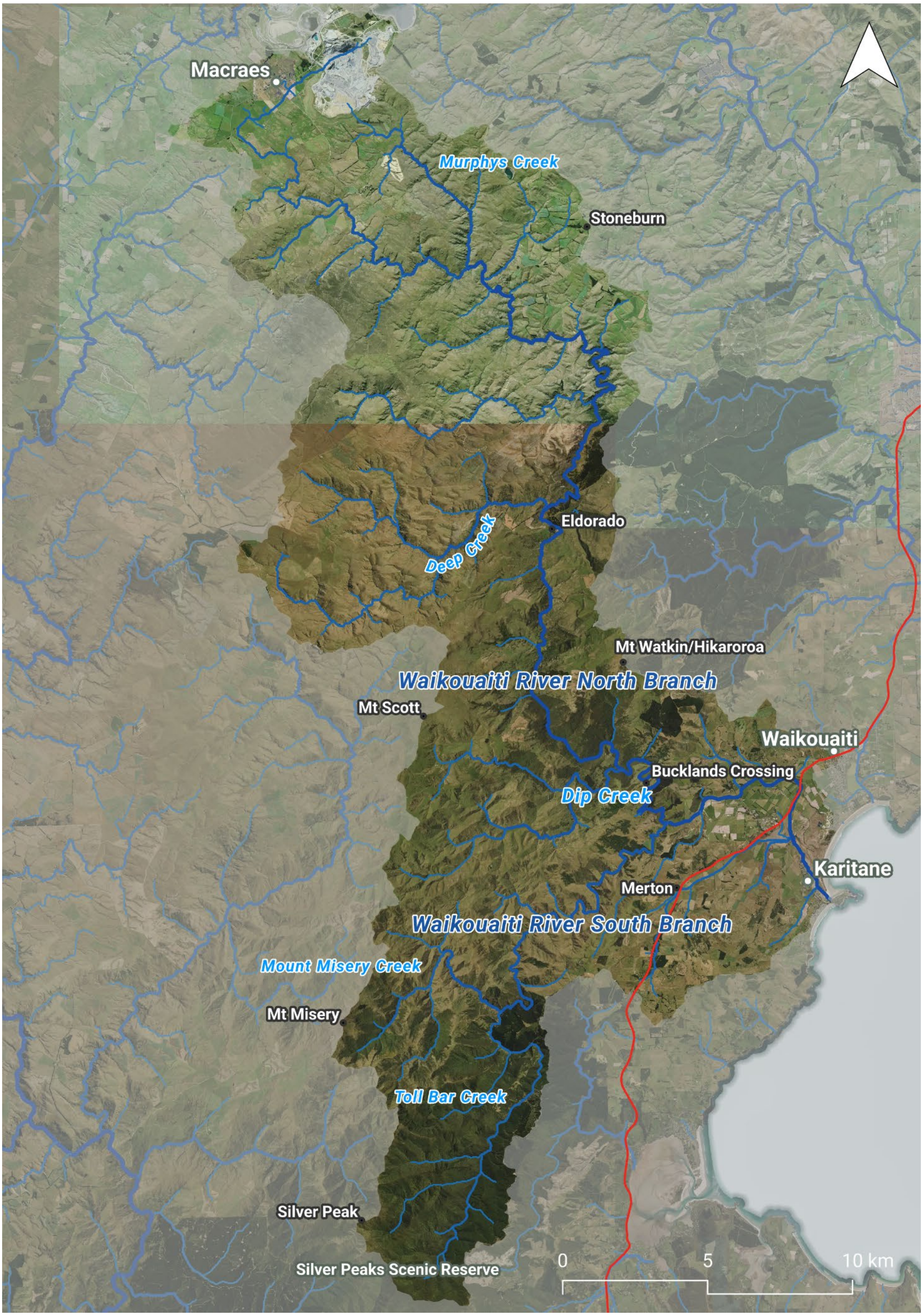

Figure 2: Overview of the Waikouaiti River catchment.

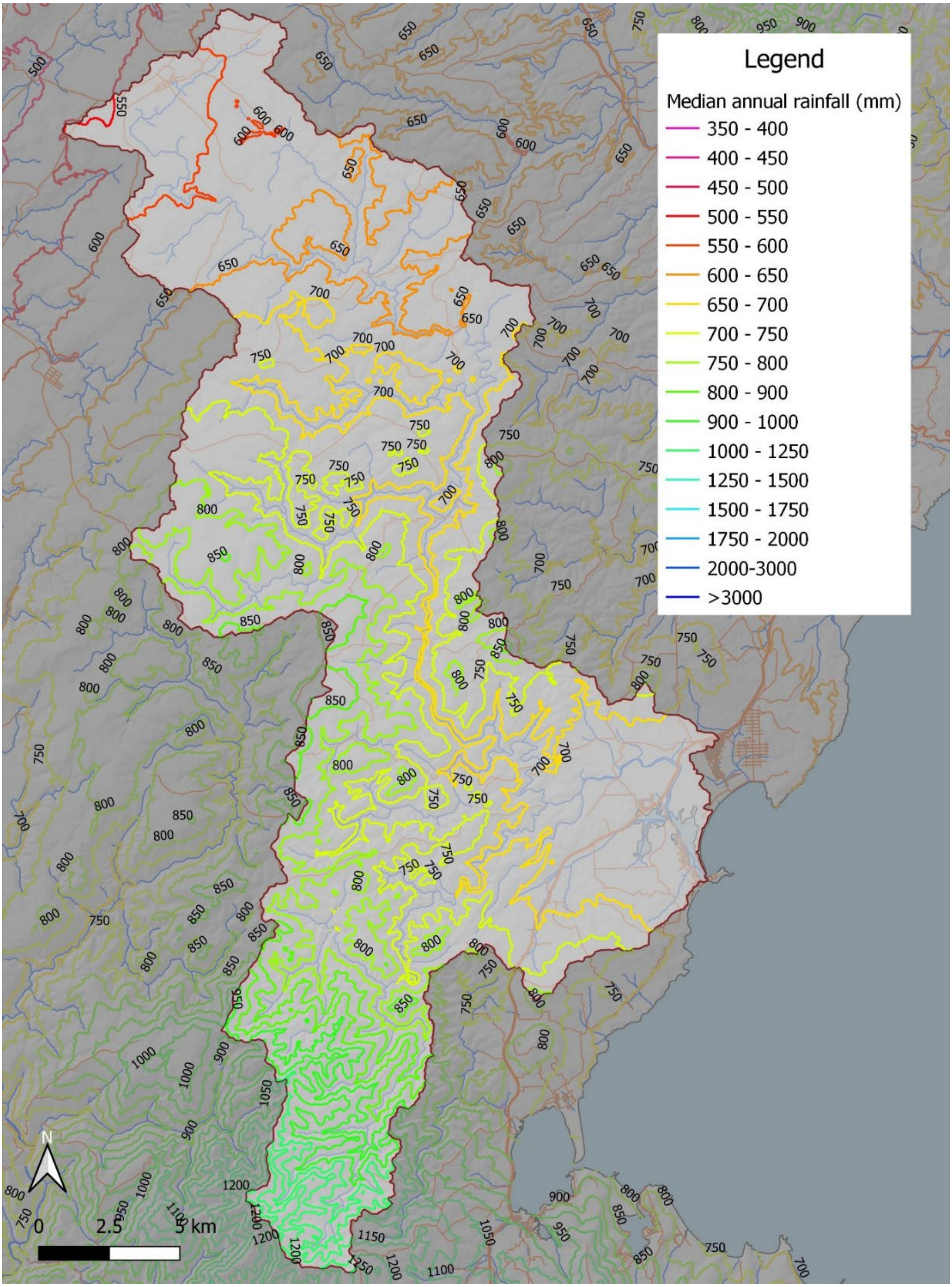

Figure 3: The distribution of rainfall across the Waikouaiti River catchment. Reproduced from Olsen (2024).

2.3 Hydrology

The Waikouaiti River generally has its highest flows in winter (June–August) and lower flows in late summer/autumn (January–March), reflecting the region's rainfall and evapotranspiration cycle. The river is prone to both extended low-flow periods and infrequent but significant flood events (ORC 2008).

Based on records from the ORC's flow monitoring site upstream of Orbells Crossing, the Waikouaiti River has a median and average flow of 0.99 m^3/s and 2.48 m^3/s, respectively (Lu 2023). On average, around two-thirds of the flow comes from the North Branch, with a mean flow of 1.96 m^3/s recorded at Bucklands Crossing. Both branches produce large floods at irregular intervals, with some years having two or more large floods and some none.

The mean annual flood flow for the main stem is estimated at ~187 m^3/s. Records from the ORC's Environmental Data Portal show that the highest flow recorded to date was 524 m^3/s on 2 January 2021 when a prolonged rain event hit much of the South Island's eastern and coastal areas. Records only date back to September 2014 for the current flow recorder site and higher flows will likely have occurred in earlier flood events. Olsen (2024) reports that, in any year, there is a 1% chance of a flood event of just under 1,000 m^3/s.

The lower 5 km of the river through the estuary is tidally influenced. The estuary itself is classified as a shallow, intertidal dominated estuary (SIDE), and discharges to the sea via a permanently open (but occasionally restricted) tidal mouth at Karitane. River inputs over the tidal cycle are small (under typical flow conditions) compared to the total volume of water in the estuary, with an estimated average river flow of ~3.5 m^3/s (Robertson et al. 2017). This indicates that hydrodynamic processes within the estuary are dominated by the tides. The small freshwater inputs also mean the main channel of the upper-mid estuary is poorly flushed during baseflows, which can result in a surface layer of lighter, low-salinity freshwater flowing over a layer of dense saline water at times (Robertson et al. 2017).

2.3.1 Water abstraction and use

The largest single abstraction of water from the Waikouaiti River is the Dunedin City Council's (DCC) potable water supply intake in the lower reaches upstream of Orbells Crossing. According to Beca (2024), for the period May 2022 to November 2023, the DCC's take ranged between zero and 2,788 m^3/day, with the median take being 1,264 m^3/day. Around 10% of this water is returned each day in the form of filter backwash from the Waikouaiti water treatment plant, although this process water now completely discharges to land and only reaches the river (via overland flow) if it does not first soak into the soil.

Other water takes include Waitaki District Council's (WDC) Stoneburn-Mt Pleasant community supply from the upper North Branch and one take for irrigation, dairy shed and stockwater use. OceanaGold also takes water as part of their operations at the Macraes gold mine, including for mining and mineral processing operations, post-mining rehabilitation and dewatering of tailings storage facilities. However, the water use is considered non-consumptive (Olsen 2024) as water is returned a short distance downstream of where it is taken.

The total consented water allocation in the Waikouaiti catchment is 129.2 L/s (Olsen 2024), against a median flow in the lower reaches of 990 L/s (0.99 m^3/s). The Regional Plan: Water for Otago (RPW) does not currently specify a minimum flow and/or allocation limit but the three main water takes are subject to residual flows that effectively serve as a default current minimum flow of 150 L/s (Olsen 2024).

2.4 Land cover and land use

The two branches of the Waikouaiti River have a different mix of land cover (Figure 4). Agricultural grasslands make up much of the catchment of the North Branch, although areas of tall tussock grassland remain, particularly at higher altitudes, and some indigenous forest and scrub occur upstream of Bucklands Crossing (Figure 4). In the catchment of the South Branch, land cover transitions from indigenous hardwoods and mānuka/kanuka scrub in the headwaters in Silver Peaks Scenic Reserve, through exotic forest and low producing grasslands. The lower catchment below the confluence of the two branches is dominated by high producing exotic grassland (Figure 4).

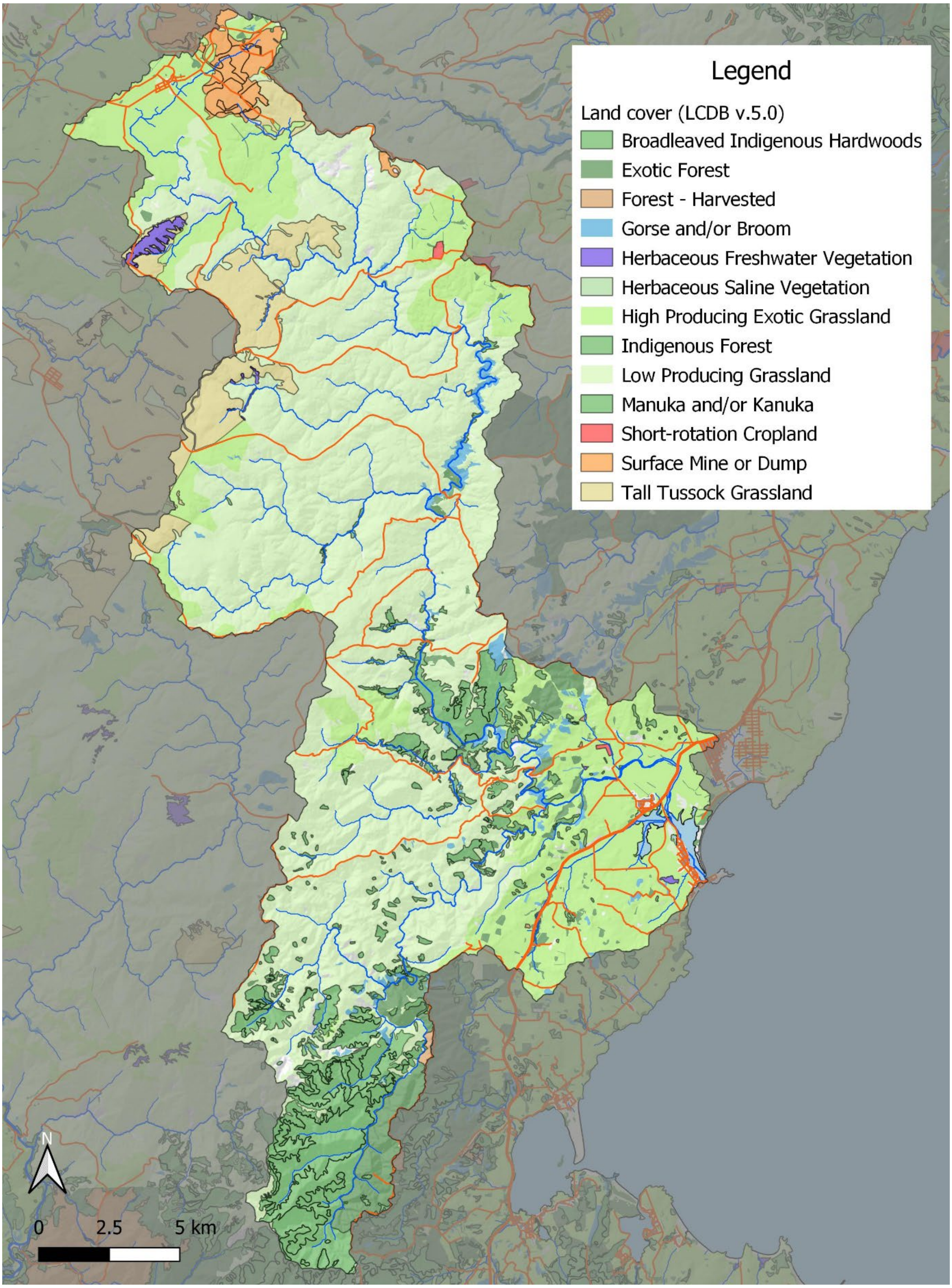

Figure 4: Land cover in the Waikouaiti catchment, based on aerial imagery from summer 2018/19 summarised in Land Cover Database (LCDB) Version 5.0. Map reproduced from Olsen (2024). The recently released LCDB Version 6, based on summer 2023/24 imagery, indicates there has since been a small increase in both the area of land under exotic forest and the area of harvested forest.

Sheep and beef farming and exotic forestry are the dominant land uses in the catchment. OceanaGold has a large gold mining operation near the headwaters of the North Branch at Macraes that has been operational since 1990. OceanaGold holds resource consents to take and discharge water and contaminants from tailings storage facilities to Murphys Creek, a tributary of the North Branch (as well as to tributaries of the Shag/Waihemo River). There are small pockets of dairy farming in the fertile lower plain around Orbells Crossing.

2.5 Freshwater values

As well as significant cultural and spiritual values (e.g. see Halderen et al. 2016), the Waikouaiti River is recognised in Schedule 1 of the RPW for a range of ecological values, including:

- indigenous fish species threatened with extinction,
- habitat for flathead galaxiid, hybrid galaxiid, banded kōkopu (North Branch) and kōaro,
- īnanga spawning in the lower reaches of the main stem upstream of SH 1,
- rare invertebrates in headwaters (North Branch),
- spawning areas for trout,
- areas for the development of juvenile fish,
- presence of eel and trout, and
- riparian vegetation (South Branch).

Downstream, the Waikouaiti Estuary supports the largest remnant saltmarsh system in Otago and is listed in Schedule 9 of the RPW as a scarce wetland type containing glasswort and jointed rush. The estuary is also important for coastal birds such as the eastern bar-tailed godwit and oystercatchers.

Schedule 1B of the RPW recognises the value of the Waikouaiti River as a potable supply for WDC's Mt Pleasant-Stoneburn and DCC's Waikouaiti community water supplies. The water drawn from the river for these supplies represents most of the total water abstracted for consumptive use (Olsen 2024).

Both the river and estuary support multiple recreational values:

- Bucklands Crossing and the Karitane Wharf are popular swimming sites,
- the Waikouaiti River supports a locally significant brown trout fishery and has a population of large sea-run brown trout in its lower reaches,
- the lower river is used extensively for whitebaiting between August and November, with īnanga, kōaro and banded kōkopu contributing to the whitebait catch (ORC 2011), and
- the estuary is popular for shellfish gathering, fishing, boating and walking.

3 Water quality monitoring – who, what and where?

Routine water quality monitoring in the Waikouaiti catchment began in the mid-1980s with the Otago Catchment Board, the precursor to the ORC. While the ORC has carried out most of the monitoring to date, the Dunedin City Council, Waitaki District Council and OceanaGold also carry out monitoring as part of regulatory requirements associated with drinking water and resource consents, and Kāti Huirapa and City Forests have ongoing river monitoring in place (Figure 5). This section presents a summary of these monitoring activities to date, with a focus on what each organisation or entity has monitored, where and when. Some relevant University of Otago research is also briefly outlined.

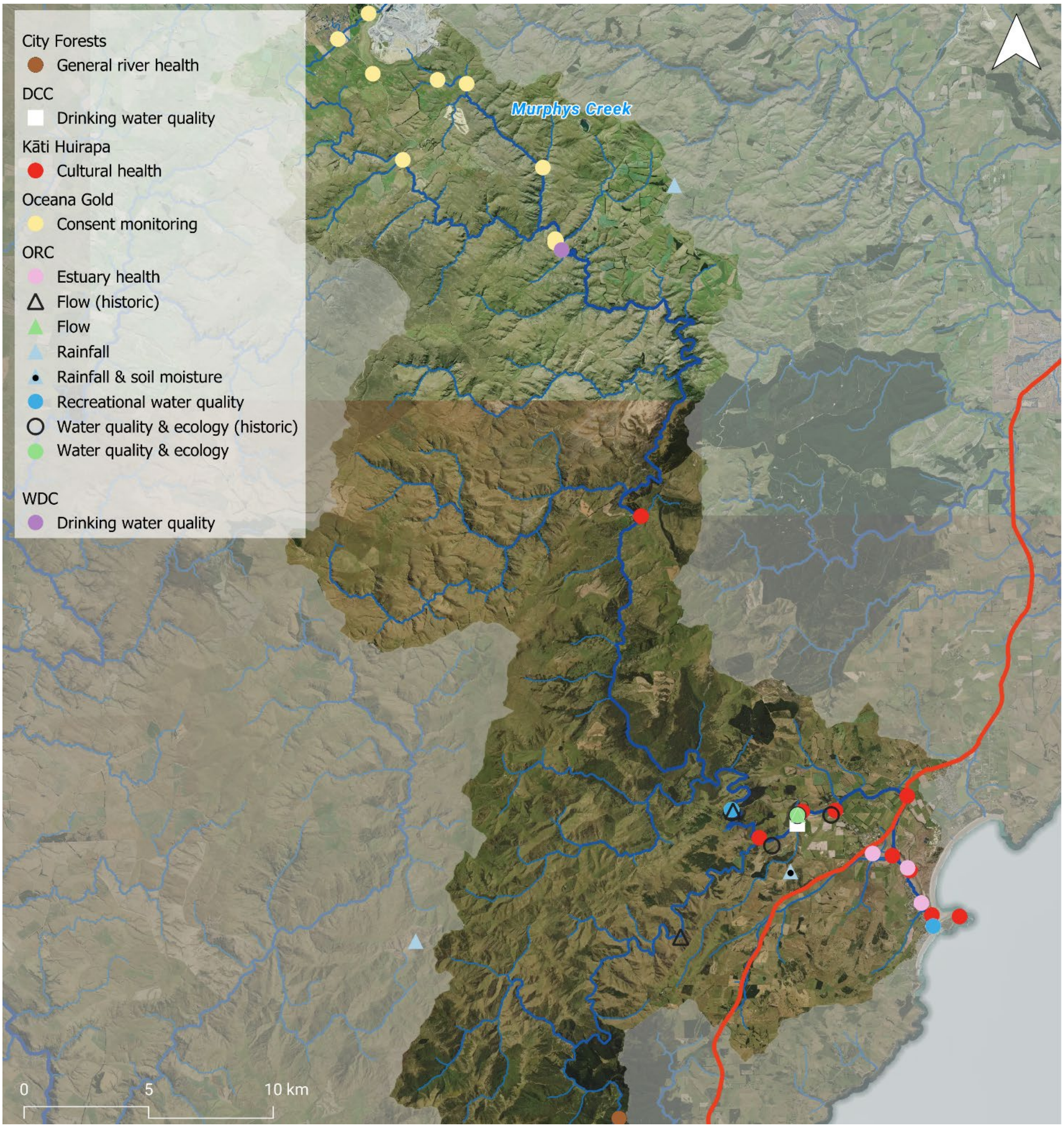

Figure 5: Summary of known monitoring locations within the Waikouaiti River and Estuary. The City Forests site on the South Branch is indicative only – different locations are sampled.

3.1 Otago Regional Council

3.1.1 River water quality and ecology

The ORC carries out both routine State of the Environment (SOE) and recreational water quality monitoring in the Waikouaiti River and estuary (Figure 5, Appendix A). Monitoring to date has focused on the lower reaches of the river and is currently based around a single SOE site located 200 m downstream of the Dunedin City Council's water supply intake. Originally the SOE site was located further downstream at Orbells Crossing, with monitoring dating back to July 1983. After a change in tidal dynamics, the site was relocated upstream to just below the confluence of the north and south branches in October 2010 before being shifted downstream to its current location in August 2018 to align it with the ORC's flow recorder (R. Ozanne, ORC, pers. comm).

Water samples are collected monthly and measured for water temperature, pH, turbidity and concentrations of dissolved oxygen, conductivity, plant-available nutrients (ammoniacal nitrogen, nitrate-nitrite nitrogen and dissolved reactive phosphorus), total nitrogen, total phosphorus and *E. coli* indicator bacteria. This measurement suite is similar to that adopted by most regional councils, the main difference being that most councils also routinely measure visual water clarity (as discussed later in this report, the ORC estimates this from turbidity measurements).

Once a year during stable river flows in late summer/early autumn, the riverbed invertebrate community (e.g. insects, snails and worms) is sampled and rapid assessments are made of physical habitat quality (e.g. bank stability, riparian vegetation, shade). In addition, electric fishing is carried out in most years near Orbells Crossing, and water temperature is monitored at high frequency (every 5-15 minutes) at the flow recorder site.

Some historical water quality data exist for a former SOE site on the North Branch at Bucklands Crossing (see Appendix A). Monitoring at this site was re-established in 2014 as part of the ORC's summer recreational water quality programme but is limited to weekly testing of *E. coli* levels between early December and mid-March. This monitoring occurs adjacent to a swimming hole in the Bucklands Recreation Reserve downstream of Bucklands Crossing.

3.1.2 Estuary water quality and ecology

Routine monitoring of water quality in the estuary is limited to weekly testing of enterococci levels at the Karitane Wharf during December to February as part of the ORC's summer recreational water quality monitoring programme.

The ecological health of the estuary is assessed using two types of monitoring:

- broad scale – estuary-wide mapping of the habitat types (e.g. sand, mud and vegetation) present and their condition, and
- fine scale – more detailed assessments of the near-surface sediments at three locations within the estuary to assess sediment quality (e.g. mud content and nutrient and metal contamination), sediment accumulation rates, and the macrofauna that live in and on the surface sediments.

Three broad-scale surveys have been carried out to date, in November 2006 (Stewart 2007), December 2016 (Stevens and Roberston 2017) and December 2023 (O'Connell-Milne et al. 2024a). Fine-scale monitoring following national estuary monitoring protocols commenced in December 2016 at two sites in the main channel and one site in the upper estuary, with further surveys carried out in December 2017 and January 2019 (O'Connell-Milne et al. 2024b) to establish an initial baseline of estuary condition. Some water quality assessments were also carried out with the first survey and, at two of the sites, plates were installed below the surface sediment to track the rate of fine sediment accumulation. The depth to these plates is measured annually (S. Thomas, ORC, pers. comm. 2025).

3.1.3 River flow/level and rainfall

Flow is continuously monitored at the SOE water quality site downstream of the DCC's water intake. Some historical data are also available for the North Branch at Cloverdowns and Bucklands Crossing, the lower reaches of the South Branch at Lawsons, and the mainstem below the confluence of the two branches (see Appendix A and Olsen 2024).

The ORC operates rainfall stations at Stoneburn (January 1985 to date), Mt Misery (since September 2007) and Karitane (since January 2023, Figure 5). Historical records are also available for a few sites near Macraes.

3.1.4 Soil moisture and quality

Soil moisture and temperature are monitored at Karitane (Figure 5) and the ORC's regional soil quality programme currently includes two sites within the Waikouaiti catchment: one site under drystock farming and one under native forest cover. Soil properties tested include soil acidity (pH), nutrient and organic carbon content, and two indicators of soil compaction (bulk density and macroporosity). Both sites have been sampled once to date in March 2022 (drystock site) and October 2024 (native forest site).

3.1.5 Targeted investigations and monitoring

The ORC has not carried out any specific investigations of water quality in the Waikouaiti catchment to date. However, it has completed several assessments on the availability and allocation of water from the Waikouaiti River (ORC 2008, ORC 2011, Olsen 2024) that are relevant for understanding the effects of water abstraction and low flows on water quality.

The ORC has also commissioned several investigations related to the estuary, including one by MetOcean Solutions (2016) to characterise its hydrodynamics and assess the influence of summer low flows on the estuary. In addition, the Waikouaiti Estuary has been included in regional modelling assessments of estimated nutrient and sediment loads entering Otago's estuaries (Plew 2021, Snelder and Fraser 2023).

3.2 Dunedin City Council

The Dunedin City Council (DCC) regularly monitors water quality in the lower Waikouaiti River to meet statutory requirements for drinking water supplies established by the Water Services Authority (Taumata Arowai 2022). As part of these requirements, the DCC monitors the quality of the raw water sourced for treatment and supply to Waikouaiti, Karitane and Hawksbury Village upstream of the ORC's SOE site. Current monitoring consists of:

- continuous monitoring of conductivity, pH and turbidity (i.e., using installed sensors),
- fortnightly monitoring of *E. coli* and nitrate-nitrogen,
- monthly monitoring of iron, manganese and colour, and
- six-monthly monitoring of total concentrations of heavy metals.

In addition to testing the river water sourced for treatment at the Waikouaiti Water Treatment Plant, in 2021 the DCC commissioned an ecological assessment to support a resource consent application for filter backwash and other discharges associated with a planned upgrade and the ongoing operation of the treatment plant (Beca 2024). This survey incorporated sampling of aquatic invertebrates and a survey of fish populations and river habitat at two locations in the vicinity of the WTP intake. The DCC also commissioned an updated hydrodynamic survey of the estuary.

3.3 Waitaki District Council

Similar to the DCC, the Waitaki District Council (WDC) monitors water quality for drinking water purposes. This includes monitoring of the upper reaches of the Waikouaiti River North Branch (near Philips Road) as the source water for the Stoneburn Water Supply (Figure 5). As this supply serves a population of less than 100 people, Taumata Arowai (2022) monitoring requirements for source waters are limited to a minimum of quarterly monitoring of *E. coli* and three-yearly monitoring of the concentrations of arsenic, boron, nitrate - nitrogen and manganese. Data provided by the WDC indicates the nitrate and metal tests have been performed more regularly, at six-monthly since November 2023.

3.4 OceanaGold

OceanaGold carries out both water quality and ecological monitoring at multiple river and stream sites as part of resource consent requirements to discharge contaminants from its gold monitoring operation at Macraes.[6] Ten sites monitored for water quality are located within the catchment of the North Branch, including two on Murphy's Creek, one on Golden Bar Creek (GB02, representing a control site) and five on the North Branch itself (Figure 5). Water samples are collected monthly and tested for pH, sulphate and a range of metals and nutrients. One site on the North Branch (Ross Ford) is also sampled quarterly for macroinvertebrates and annually for fish. A further four sites are sampled for fish on an annual basis.

3.5 City Forests

City Forests surveys the upper reaches of the South Branch of the Waikouaiti River along the edge of their property boundary, upstream of the Toll Bar Creek confluence, using the Stream Health Monitoring and Assessment Kit (SHMAK) developed by NIWA. This involves taking field measurements of water quality and recording the types of aquatic invertebrates present. Surveys date back to 2014 and have been carried out on a near-annual basis (see Appendix A).

3.6 Kāti Huirapa

In June 2015, Kāti Huirapa ki Rūnaka Puketeraki Kāti Huirapa (Rūnaka) commenced monthly surveys of river and estuary sites in the Waikouaiti catchment through their He Pātaka Wai Ora project. The year-long project provided the Rūnaka with an opportunity to identify river health issues and prioritise catchment restoration efforts (Halderen et al. 2016). The combination of five freshwater and five saline sites (Figure 5) and suite of indicators measured makes this the most comprehensive survey to date of catchment surface water quality and ecosystem health. Monitoring methods incorporated a mix of SHMAK, field meters and lab-based nutrient testing.

Although the He Pātaka Wai Ora project ended in April 2016, annual SHMAK assessments continue at the freshwater sites (M. Dale, pers. comm. 2025).

3.7 Other

MetService operates a rainfall station at Swampy Summit near the southern boundary of Waikouaiti catchment.

Fire and Emergency NZ has a weather station at Bucklands Crossing that measures air temperature, wind, rainfall and humidity. They also measure soil moisture and soil temperature at Macraes.

The Department of Conservation, Fish and Game Otago and other organisations have carried out fish surveys in parts of the Waikouaiti River catchment. Data are available on the National Freshwater Fish Database operated by Earth Science Research New Zealand (formerly NIWA).

The University of Otago has carried out research in the Waikouaiti catchment involving the collection and/or analysis of water quality, ecological and other data. Much of this research has focused on geology and the environmental impacts of mining operations in the Macraes area (e.g. Craw and Pope 2017, Blake et al. 2019, Weightman 2020). Two theses involving research on water quality were also found online:

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[6] Groundwater quality monitoring is also carried out to track the movement of contaminant plumes offsite.

- a Master of Science (MSc) thesis modelling the impacts of hypothetical land use change in the Waikouaiti catchment on flow regimes, water quality and cultural health (Reeves 2014), and
- a MSc thesis investigating faecal contamination in the waters and flesh of cockles and mussels from the Waikouaiti Estuary (Bell 2017).

4 Current state and trends

In this section, the results of monitoring and research carried out by various organisations are summarised and more recent data and information are assessed to provide an up-to-date picture of the current water quality and ecological condition (i.e. state) of the Waikouaiti River catchment. Trend information is also included but is limited to river water quality due to the shorter and sometimes intermittent record for ecological data available for current monitoring locations.

Assessing water quality and the NPS-FM

A range of targets, guidelines and standards exist for fresh water that are linked with protection of different values. This section uses those that are relevant to aquatic ecosystem health and human health for recreation; these are two values that regional councils have been directed to manage rivers and lakes for since the 2014 version of the National Policy Statement for Freshwater Management (NPS-FM) came into force.

The NPS-FM introduced the term **attributes.** An attribute is a measurable characteristic (e.g. nitrate-nitrogen or *E. coli* concentration) of a river or lake and is used to assess the extent to which a certain freshwater value (e.g. ecosystem health) is provided for. Measurements of each attribute are graded in bands from A to D, or A to E. The NPS-FM specifies a minimum acceptable state for different attributes of stream health, referred to as the national bottom line (NBL). In most cases the NBL is the boundary of bands C and D.

The NPS-FM 2020 requires regional councils to establish targets for mandatory freshwater attributes, called target attribute states. These targets must be set at a state that is no worse than attribute state was in 2017 (baseline attribute state). Where the baseline attribute state is below the NBL, measures need to be put in place to bring it above this line over a defined period of time. Councils must monitor current attribute state to track progress towards achieving targets.

Attribute bands can be thought of as a bit like a report card where A is the highest and D/E the lowest. However, a lower grade for a particular attribute does not always mean a river is in poor health. In some cases, a river's natural characteristics, such as geology, may mean that band A may be an unrealistic and unnecessary target. The NPS-FM also doesn't include bands for everything that may be monitored in rivers and streams. Examples are metal concentrations and stream habitat quality. In these cases, national guidelines (e.g. ANZG 2018, Clapcott 2015) can be used to interpret monitoring results. Guidelines are just that and exceeding them does not necessarily translate to an adverse environmental effect. Only standards have regulatory force and must be met.

In late 2024 the Government passed legislation that required regional councils to press 'pause' on notifying changes to regional plans to give effect to the NPS-FM 2020. Subsequent Government announcements have indicated that we can expect significant changes to the NPS-FM in 2026 as part of wider resource management reform. While this will result in changes to at least some future water quality targets at both the national and regional level, the targets, guidelines and standards used to interpret information in this section represent the most relevant currently available and allow the various data available to be assessed in a similar manner to the Otago Regional Council's existing river monitoring data.

4.1 River water quality and ecological health

4.1.1 Water quality, where monitored, is generally very good

The river typically runs clear

Although visual clarity is not measured by the ORC, turbidity and suspended fine sediment data from monthly sampling downstream of the DCC's water supply intake (over the five years ending June 2025; Table 1) indicate the river runs clear most of the time. Based on a conversion of turbidity measurements to estimates of visual clarity (Franklin et al. 2020), the current median visual clarity is 4.54 m. While there is potentially large uncertainty around this estimate, there is little doubt that median visual clarity sits in band A of the NPS-FM[7]. This is supported by historical black disc visual clarity measurements made at Orbells Crossing (median of 3.46 m, Aug 1998–Feb 2005).

Median turbidity values primarily represent base flow conditions so low median values do not necessary mean that sediment is not a problem at other times. The steep nature of the upper Waikouaiti catchment and current harvest of plantation forest in parts of the catchment increase the risk of fine sediment entering the river via overland flow in heavy rain events. The meandering course of much of the river also means that higher river flows during rainfall may increase bank erosion. Monthly 'spot' sampling rarely coincides with significant rain events when suspended sediment concentrations are highest.

The highest suspended sediment concentration recorded by the ORC to date is 21 mg/L on 6 September 2000 (at the former Orbell Crossing monitoring site), coinciding with a visual clarity measurement of 0.5 m. It was raining at the time of sampling and Stoneburn rainfall records indicate that over 35 mm of rain had already fallen in the 24 hours prior to that. No flow record is available to estimate the sediment load exiting the river into the estuary but a similar magnitude rain event on 23 July 2023 saw river flow in the lower reaches peak at 49.3 m^3/s.

Table 1: Summary of selected water quality indicators for the lower reaches of Waikouaiti River, 200 m downstream of the DCC's water intake, based on monthly data collected by the ORC over the five-years ending June 2025. The median values (shaded) summarise the current water quality state or condition.

	Turbidity (FNU)	Total Suspended Solids (mg/L)	Ammoniacal-N (mg/L)	Nitrate-N (mg/L)	Diss. inorganic N (mg/L)	Total N (mg/L)	Diss. reactive P (mg/L)	Total P (mg/L)	*E. coli* (MPN/100mL)
Min	0.35	<0.5	<0.005	0.004	0.007	0.096	<0.001	0.002	6
Median	0.67	0.7	<0.005	0.024	0.028	0.210	0.001	0.008	47
95^{th} percentile	2.4	2.5	0.009	0.349	0.350	0.630	0.038	0.019	445
Max	2.8	4.1	0.013	0.590	0.600	0.860	0.011	0.027	1,986
No. results	58	58	58	58	58	58	58	58	57

A review of the DCC's recent continuous turbidity record from the lower river offers some insights into the much higher sediment concentrations transported down the river in wet weather. Data collected in 2024 indicates there were several occasions where turbidity exceeded 200 NTU, much higher than the highest turbidity measurement recorded from monthly spot samples (Table 1). One of these occasions was on 4 October 2024 (Figure 6), following over 70 mm of rainfall in 48 hours when river flow peaked at 195 m^3/s.

[7] Visual clarity is used to assess the suspended fine sediment attribute in the NPS-FM. Visual clarity can also be estimated from turbidity using a national equation developed by Franklin et al. (2020) from the relationship between visual clarity and turbidity measurements at hundreds of river sites across the country. However, there is considerable scatter around the straight-line relationship used in the national equation. This, coupled with light brown tannin-staining in the Waikouaiti River add uncertainty to the estimate (because, while turbidity and visual clarity are usually closely correlated, visual clarity measurements (unlike turbidity) reflect both the concentration of suspended fine sediments and water colour; Franklin et al. 2019).

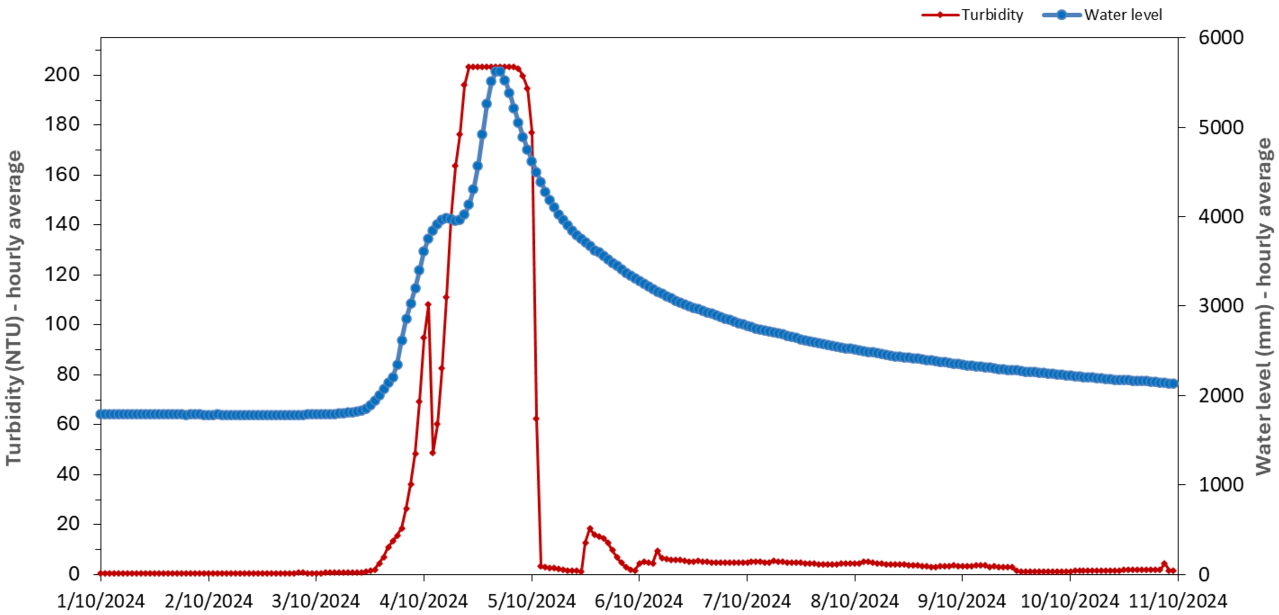

Figure 6: Continuous turbidity and water level measurements recorded by the DCC during an extended wet period in October 2024. Note the turbidity sensor appears to top out just over 200 NTU and the actual peak turbidity may have been higher.

Fine sediment suspended in the water column often settles out on the riverbed where it can infill the spaces in the cobbles and gravels that are important to invertebrates and fish. Little information is available on streambed sediment cover. Summary sediment scores for SHMAK habitat assessments provided by City Forests suggest that riverbed sediment cover is low in the upper South Branch. Habitat assessments carried out by Kāti Huirapa in 2016/17 only refer to fine sediment in the lower catchment reaches, suggesting that sediment is largely transported downstream into the estuarine reaches and estuary proper. However, surveys of tributary streambeds in the upper North Branch carried out for OceanaGold's consent monitoring indicate that fine sediment is also an issue at some locations and link this to stock access (SLR 2024 & 2025).

Plant-available forms of nutrients are very low

River water quality monitoring by all organisations to date points to very low concentrations of dissolved inorganic nutrients (DRP and DIN) that can, in sufficient concentrations, contribute to nuisance algal or plant growth (Figure 7 and Figure 8).[8] Concentrations of DRP at the ORC's SOE site on the lower reaches are frequently below or close to detection (Table 1), suggesting that phosphorus is the nutrient that limits or controls the extent of any nuisance plant growth. DIN, which is largely made up of nitrate-N, is present at higher concentrations than DRP but concentrations are still low across all sites when compared with those recorded in most other rural rivers in Otago, and nationally. This is evidenced by comparing the median nutrient concentrations in Table 1 with those from other monitored river sites in rural areas in New Zealand from the Land Air Water Aotearoa (LAWA) website; the Waikouaiti site sits comfortably inside the lowest (best) 25% of sites monitored across all forms of nitrogen and phosphorus monitored.

As is common in many hill-fed river systems, nitrate-N shows a strong seasonal cycle, with peak concentrations early in winter and the lowest concentrations recorded in summer (Figure 7). Monitoring by Kāti Huirapa in 2015/16 saw this pattern across all of their river monitoring sites, with a strong spike in nitrate-N in June (Halderen et al. 2016). This likely reflect a 'first flush' of nitrate through the soil profile after the drier summer period when more of the rain that falls makes its way into the river. In late summer-early autumn, soil moisture is depleted by high evapotranspiration (Dale 2011) and river flows remain low until sufficient rain soaks into the ground to cause saturated soils and 'throughflow' that contributes to river flow.

[8] One exception is the North Branch of Waikouaiti River just downstream of Golden Bar Creek (OceanaGold site NB03) where monthly sampling in the first half of 2019 returned nitrate-N concentrations between 0.882 and 2.81 mg/L. Results since then have been much lower (Ryder 2025).

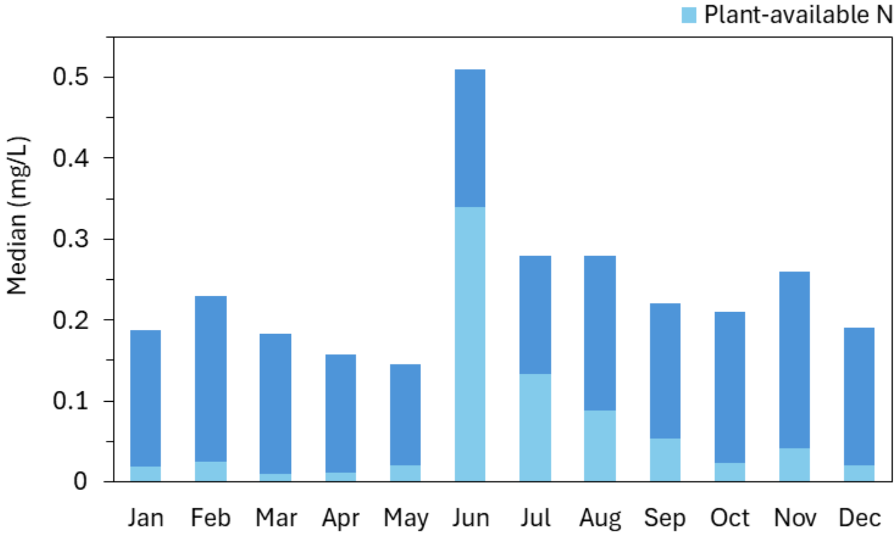

Figure 7: Median monthly concentrations of nitrogen in the Waikouaiti River below the DCC's water intake (ORC data, August 2018 to July 2025). The total height of each bar represents the total nitrogen concentration, with the dissolved inorganic component – primarily comprising nitrate-N – shown in light blue.

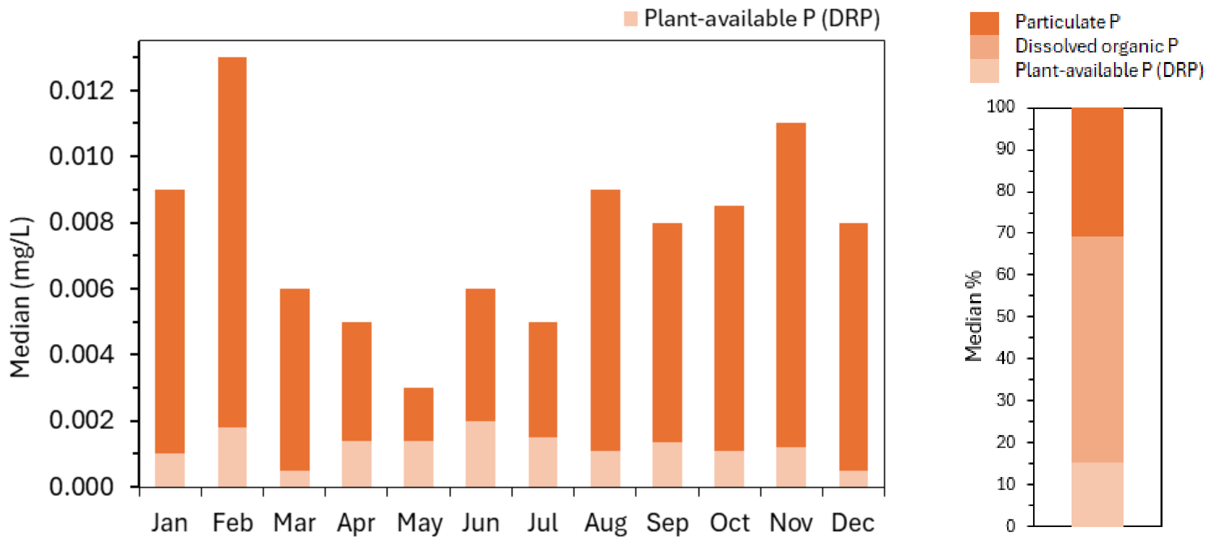

Figure 8: Left: Median monthly concentrations of phosphorus in the Waikouaiti River below the DCC's water intake (ORC data, August 2018 to July 2025). The total height of each bar represents the total phosphorus concentration, which is lowest in autumn and winter. **Right: Early ORC data for Bucklands Crossing suggests that dissolved organic phosphorus (DOP) is the dominant form of phosphorus present in river water samples.**

Although concentrations of DRP and DIN are low, the total concentrations of nitrogen and phosphorus are considerably higher (Figure 7, Figure 8). Most of this nutrient content is 'locked up' in organic matter, sediments or particles where it is not immediately available to plants. However, these nutrient stores can become available under the right conditions, such as during prolonged periods of low flows and very low dissolved oxygen concentrations – or downstream in the estuary where decomposition is faster and oxygen conditions differ.

Early ORC SOE monitoring at Bucklands Crossing included total dissolved phosphorus (TDP, representing DRP plus dissolved organic P) and the limited historical TDP data available indicate that this fraction typically makes up around 70% of the total phosphorus measured. Therefore, although DRP concentrations are very low, the fact that most phosphorus is dissolved in the water column means it is more readily converted into bioavailable forms than if it were largely bound to sediment or organic particles. Overall, the historical data suggest that phosphorus inputs to the river are dominated by soluble, organic-rich sources, with sediment-bound erosion contributing only around 30% of total phosphorus on average (Figure 8). With no known significant groundwater inputs or direct wastewater discharges to the Waikouaiti River, the likely sources of dissolved organic phosphorus are shallow leaching through cracked or porous soils during light rainfall, in-stream phosphorus recycling (via periphyton and microbial activity), and release from organic-rich riparian margins (e.g. as leaf litter and soil organic matter decompose).

Although organic sources of phosphorus (and nitrogen) dominate at base stream flows, the proportion of phosphorus delivered bound to sediment will be much higher in wet weather. Multiple New Zealand studies provide evidence of this. For example, McDowell et al. (2009) found that sediment-bound (i.e. particulate) phosphorus becomes increasingly significant in disturbed, high-flow scenarios and a Rotorua catchment study (Peryer-Fursdon et al. 2015) demonstrated that overland flow deposits mobilised during rainfall are rich in particulate phosphorus. Therefore, even in a low-nutrient catchment like the Waikouaiti, sediment-bound phosphorus pulses during wet events can substantially increase the load of phosphorus delivered to rivers. Much of this will be flushed downstream into the estuary where sediment and other particles more readily settle and can accumulate.

Faecal contamination is largely limited to wet weather

Routine monthly water quality monitoring in the lower reaches of the Waikouaiti River indicates that, most of the time, *E. coli* indicator bacteria are below levels that pose a significant risk to human health from contact recreation activities such as swimming and fishing, or to stock health if the river is used as a stock drinking water supply (Table 1). This is also the case further up the catchment, with quarterly monitoring on the North Branch between October 2022 and August 2025 (by WDC for the Stoneburn supply intake) only recording a single *E. coli* result over 200 MPN /100 mL. This occurred on 19 December 2022 and followed rainfall (4.5 mm recorded at Stoneburn) the day prior.

Based on five years of monthly monitoring to June 2025, the ORC's SOE site below the DCC's water intake falls into band A across all four metrics used to assess *E. coli* attribute under Table 9 of the NPS-FM. There are not many river sites in rural (or urban) areas of New Zealand that satisfy all four metrics to be graded band A. The 5-year median (47 *E. coli*/100mL) also meets the ANZG (2023) livestock drinking water guideline.

Bucklands Crossing is suitable for swimming most of the time

Weekly monitoring of *E. coli* concentrations since summer 2014/15 indicates that the Waikouaiti River at Bucklands Crossing only occasionally exceeds the red/action threshold of the national swimming guidelines (540 *E. coli*/100mL, equating to an unacceptable risk to human health) (Figure 9). In eight of the nine monitoring occasions that the red/action threshold has been exceeded to date, sampling coincided with rainfall during or prior to sampling when people were less likely to be swimming. This suggests overland runoff during rainfall is the primary source of faecal contamination and *E. coli* concentrations in fine weather don't generally pose a significant risk to human health.

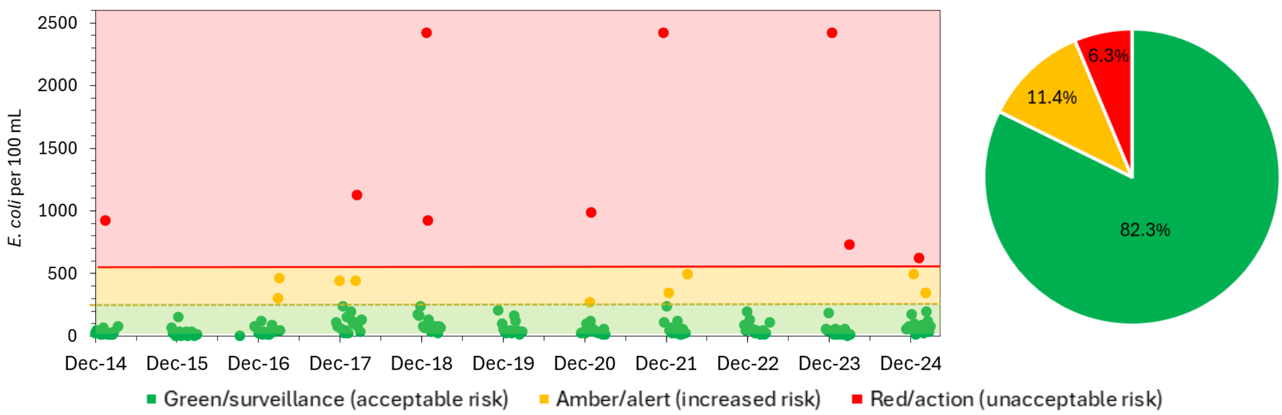

Figure 9: Left: *E. coli* concentrations recorded in the Waikouaiti River at Bucklands Crossing from approximately weekly summer sampling over last the ten summers to March 2025. Results are categorised according to MfE/MoH (2003) human health risk. Right: Summary of weekly results for the last five summers only. ORC data, downloaded from the LAWA website. Note that the three highest results (2,420 *E. coli*/100mL) represent the default upper 'measurement limit' associated with the lab test method and the actual *E. coli* counts may have been much higher.

Based on the five most recent summers, the 95th percentile is 676 *E. coli*/100 mL, equating to a long-term grade of 'poor' (see text box below). However, with removal of six of the eight action and alert level *E. coli* results that coincided with rainfall and high rivers flows when swimming was unlikely, the 95th percentile reduces to 40 *E. coli*/100 mL. This falls with the NPS-FM 'excellent' band and an estimated risk of Campylobacter infection of <0.1%, 95 percent of the time (in dry weather).

Why Bucklands Crossing has a current long-term grade of 'poor'

The national recreational water quality guidelines (MfE/MoH 2003) have two ways of assessing and communicating human health risks from swimming in fresh water – weekly water sampling test results and a long-term grade. The long-term grade (called a Microbial Assessment Category (MAC) in the guidelines) represents the 95th percentile or near-maximum *E. coli* count recorded from all routine weekly water samples taken over the most recent five summer monitoring periods. Both weekly test results and the long-term grade are displayed on the LAWA website.

Because water quality can vary rapidly, including over the course of a day if it rains, water levels rise or animals enter a river, the latest weekly test result does not necessarily represent the risk at the exact time someone wishes to swim. This is where the site's MAC is useful – if it is 'excellent' or 'good', then the public knows the site is likely to be suitable for swimming except following very heavy rain events. A site graded 'fair' or 'poor' is a warning to check what information exists about conditions that lead to water quality being unsuitable for swimming. Often in rural catchments, there can be a frequent dry-weather source of faecal contamination such as stock or wildfowl (Moriarty et al. 2019a-d). In the case of Bucklands Crossing, significant faecal contamination appears to be limited to wet weather and the wet weather samples are removed from the data set, the site's 95th percentile value gives a long-term grade of 'very good' (equivalent to the NPS-FM primary contact recreation band of 'excellent').

Microbial water quality, while critical for informing the risk to human health from pathogens, is only one measure of a river's suitability for contact recreation. Water clarity, depth and temperature, current strength, and the amount of nuisance weeds or algae and rubbish are also relevant (Milne et al. 2017). Based on estimates from turbidity measurements, visual clarity at the flows when people would be swimming easily meets the long established minimum guideline of 1.6 m (MfE 1994) but algae cover likely exceeds recreational use guidelines at times (see section 4.1.2).

The risk of contaminants causing toxic impacts on aquatic life is low

Both ammonia and nitrate can be toxic to aquatic life but ammonia concentrations in the Waikouaiti River are seldom above detection and nitrate is also well below levels that cause toxicity effects on sensitive aquatic species such as trout. Not surprisingly, the lower river sits within band A of the NPS-FM for both ammonia and nitrate toxicity.

Monitoring by OceanaGold in the upper North Branch and tributaries points to low concentrations of dissolved (i.e. bioavailable) arsenic, copper, cyanide, lead and zinc. Of these toxicants, only arsenic is consistently found in Murphy's Creek and the North Branch (median of 0.0024 and 0.0016 mg/L in 2024/25, respectively), likely reflecting weathering of naturally arsenic-rich Otago schist rock at Macraes (Blake et al. 2019). Based on 2024/25 monitoring results, dissolved concentrations of copper and zinc in Murphy's Creek were also above detection on occasion.

Monitoring of the lower Waikouaiti River by the DCC also indicates low (total) concentrations of toxicants, including copper, lead and zinc.

Although not a toxicant, sulphate is found in elevated concentrations in the North Branch of the Waikouaiti River downstream of Golden Bar Creek, relative to background levels (Ryder 2025). It is well established that high sulphate water is discharged from some parts of Macraes Mine but this is actively managed through consent conditions and current surface water concentrations are well below those that might potentially impact use of the water (e.g. for stock or irrigation purposes).

There are few strong directional trends in water quality in recent years

Identifying whether water quality is getting better or worse relies on a robust long-term monitoring record of at least five years or, ideally, 10 years of monthly data (McDowell et al. 2024). Owing to its SOE site being shifted twice, the ORC's data record for the current location is limited to just over seven years, precluding inclusion of trend information on the LAWA website. To inform this report, data from the complete seven-year period from August 2018 to July 2025 was assessed for trends, as per national guidance in Snelder et al. (2021). The results found an 'extremely likely' decreasing trend in conductivity, potentially indicating improving water quality. An increase in nitrate-N concentration of 9.1 and 13.4% per year (a deteriorating trend) was also found in the raw and seasonally, flow-adjusted data, as well as an increase in total phosphorus concentration of 4.4% per year in the seasonally, flow-adjusted data, but statistical confidence in these trends was low.

4.1.2 Ecological health is likely only 'fair' in some areas

Limited information suggests periphyton cover may be high at times

The amount (biomass) or bed cover of periphyton present in the Waikouaiti River is not routinely monitored by the ORC but there is some data to suggest it can be significant at times – despite the river having low nutrient concentrations. For example, weekly assessments made by the ORC on the North Branch near the Bucklands Crossing swimming site over summer 2023/24 estimated periphyton covered over 80% of the bed during parts of February and March. Cover that exceeds around 30% of the bed as long filaments or 60% as thick mats is considered a nuisance from an aesthetics and recreation perspective (MfE 2000). Thick cover of algae also reduces streambed habitat quality for sensitive invertebrates and fish.

Significant periphyton cover was also observed at Bucklands Crossing in September 2025 (author obs., Figure 10) and has been noted upstream at El Dorado (M. Dale, pers. comm.). Quarterly ecological assessments in the headwaters of the North Branch associated with the Macraes Mine indicate that macrophytes (aquatic plants) are more dominant than periphyton and plant cover across the channel exceeds recommended provisional national guidelines (Matheson et al. 2012) of 50%. An exception is the lower reaches of Murphys Creek where the bed is frequently covered with filamentous and mat algae (SLR 2024).

Figure 10: Thick cover of diatom mats – likely *Gomphonesis* or *Cymbella* – observed by the author in the North Branch of Waikouaiti River downstream of Bucklands Crossing on 9 September 2025. Aquatic macrophytes (plants) were also growing along the banks and below the water's surface in places.

High periphyton cover has also been recorded in the lower reaches of the river. A survey in the vicinity of the DCC's water take in autumn 2021 estimated riverbed periphyton cover at between 50 and 80% (Figure 11; Beca 2022). Mats of *Microcoleus* (formally known as *Phormidium*) cyanobacteria have also been recorded at the intake site with high concentrations of 2-methylisoborneol (2-MIB) that cause earthy, musty taste and odour problems in the water sourced for drinking supply (DCC nd). *Microcoleus* has been recorded growing elsewhere in the river too and, given it can produce toxins that can be deadly to dogs and harmful to humans (e.g. MfE/MoH 2024), the ORC now routinely surveys riverbed coverage at Bucklands Crossing over summer (H. Trotter, ORC. pers. comm.).

Little information is available about periphyton growth in the South Branch. Potentially higher base flows and greater streambed shading in the headwaters within the Silver Peaks Scenic Reserve may limit the extent of any blooms, although a few significant areas of organic matter (typically called 'sludge') were seen in the headwaters in September 2025 (author, pers. ob. Figure 12). This indicates that flow conditions are suitably stable to support algal growth.

Dominant periphyton taxa (i.e. types) identified from rock scrapings collected annually by the ORC between 2001 and 2018 at Orbells Crossing included the filamentous green algae *Mougeotia* and *Spirogyra*, and the diatoms *Didymosphenia (Didymo)*, *Fragilaria*, *Gomphoneis* and *Synedra* (Olsen 2024). Several of these taxa (e.g. *Didymo and Gomphoneis*) are characteristic of low-nutrient rivers such as the Waikouaiti River, indicating that even when plant-available nutrient concentrations are very low, substantial periphyton growth can still occur if other environmental conditions are favourable, including stable river flows and abundant sunlight.

The presence of *Didymo* is of some concern. As an invasive diatom, *Didymo* can spread rapidly and form thick mats on the riverbed, smothering aquatic habitat, altering invertebrate assemblages, and affecting aesthetic and recreational values (Kilroy and Unwin 2011). Didymo can be hard to distinguish by eye from the native diatom *Gomphonesis* but is fibrous and raspy, rather than slimy, to touch. Fishing gear and other equipment used in the river needs to be decontaminated after use to reduce spreading *Didymo* to other rivers.

Figure 11: Long strands of filamentous green periphyton seen in the Waikouaiti River in the vicinity of the DCC's water intake in April 2021. Photo: Beca (2022).

Figure 12: Shaded headwaters of the South Branch of the Waikouaiti River, 25 October 2025. Moss was present on many of the rocks. Elsewhere, in less shaded reaches, periphyton was observed on some rocks and macrophytes were growing at the water's edges. Photo: J Milne.

Invertebrate life reflects habitat more than water quality conditions

Macroinvertebrates are a direct measure of stream health

Aquatic macroinvertebrates include insects, crustaceans, snails, worms and other small critters that are large enough to see by the naked eye. They are an important part of the stream food web and good indicators of overall stream ecological health or condition. This is because as well as good water quality, a diverse macroinvertebrate community needs a range of microhabitats within the stream, including variation in streambed materials (substrate such as cobbles and gravel) and the types and amount of water flow (e.g. riffles, runs and pools).

Macroinvertebrate results are commonly reported as a series of **community health measures**:

Taxa richness – the number of different species (taxa) of invertebrates present in a sample. Generally, high taxa richness is considered good, but some streams with mild nutrient enrichment can support higher numbers of taxa than pristine streams. Taxa richness is therefore a very coarse indicator of stream health.

Macroinvertebrate Community Index (MCI) – the most widely used indicator of stream ecological health, based on the tolerance or sensitivity of the different species (taxa) present in a sample to organic pollution and nutrient enrichment. Most invertebrate taxa have been assigned a tolerance value ranging from 1 (very tolerant) to 10 (very sensitive). The MCI score is derived from the average tolerance value of all taxa present at a site, multiplied by 20. Higher MCI scores indicate better stream conditions at the sampled site.

The MCI and its variant, the QMCI (below), were designed originally for stony bed streams with riffle flow. This means caution is needed when interpreting scores for other stream types.

Quantitative Macroinvertebrate Community Index (QMCI) – a variation of the MCI that considers the relative abundance of each invertebrate taxa found in the sample. The QMCI is generally more sensitive to subtle changes in water quality and stream health because it responds to changes in the relative of proportions of different species rather than changes in what species are present or absent. A QMCI score ranges from 0 to 10.

Ephemeroptera (mayflies), Plecoptera (stoneflies) Trichoptera (caddisflies) (EPT) – aquatic insects that are sensitive to water pollution and degraded stream habitat (e.g. silted streambeds). A stream macroinvertebrate community that has a high abundance or percentage of EPT taxa generally indicates good stream health.

The NPS-FM 2020 also includes the **Average Score Per Metric (ASPM)**, calculated by combining information from the MCI and two measures of EPT.

Two common measures of aquatic invertebrate communities suggest that ecological health in the Waikouaiti River at the ORC's site on the lower reaches is 'fair' at best. This is based on median macroinvertebrate community index (MCI) and quantitative MCI (QMCI) scores of 86 and 4.0, respectively determined from annual macroinvertebrate sampling over the four summers ending in March 2025. Historical monitoring downstream at Orbells Crossing returned similar scores (Table 2).

Table 2: Median (and range) of common macroinvertebrate community health measures for the lower reaches of the Waikouaiti River. Source: ORC annual kick-net monitoring.

Monitoring site	Date range	MCI	QMCI	%EPT
200 m d/s	2022–2025 (4 samples)[1]	86 (80–98)	3.8 (2.4–4.7)	35 (30–42)
Orbells Crossing	2001–2018 (15 samples)	89 (81–105)	4.0 (1.5–5.0)*	37 (26-53)*
Bucklands Crossing	2001	92	5.9*	47*

[1] 2022–2024 for %EPT.

* QMCI value represents a semi-quantitative MCI (SMQCI) value and %EPT overestimated as includes pollution-insensitive Hydroptilidae.

The median MCI and QMCI scores equate to 'fair' and 'poor' quality under the long-established Stark and Maxted (2007) guidelines and band D (i.e. poor and below the minimum acceptable standard) under the current NPS-FM macroinvertebrate attribute bands. While invertebrate community health is degraded in the lower reaches, the description for band D in the NPS-FM that this is *"indicative of severe organic pollution or nutrient enrichment"* does not align with the available water quality data. Rather, the 'fair to poor' ecological health in the lower Waikouaiti River reflects the limited diversity of physical habitat on offer, with a bed composed mainly of gravels and water that flows in a straight run. Larger cobbles and riffle (i.e. broken water) areas are needed to support a greater abundance of the more sensitive invertebrates that contribute to higher MCI and QMCI scores. Overall, prolonged low flows likely result in water temperatures that are too warm to support large numbers of these taxa (see section 4.1.4), particularly where widespread algal cover develops on the riverbed.

The record of invertebrate taxa from ORC's sampling of the lower river reaches does frequently include good numbers of pollution-sensitive *Deleatidium* mayflies and several caddisflies (Figure 13). These insects are known food sources of brown trout, which are also present in the river, indicating that the river does support both pollution-sensitive invertebrates and fish (noting that trout are likely also sustained by access to downstream estuarine food sources). Overall, the low MCI and QMCI scores are driven by the presence and large numbers of lower-scoring taxa, particularly *Potamopyrgus* snails, *Paracalliope* amphipods, Elmidae riffle beetles, Orthocladiinae chironomid midges and oligochaete worms (Figure 12, Olsen 2024).

Invertebrate data collected in the headwaters of the North Branch and its tributaries as part of OceanaGold's consent monitoring also indicate 'poor' to 'fair' ecological health (Figure 14). Recent monitoring reports (SLR 2024 & 2025) document an increase in macrophyte cover over time at some sites, together with declines in mayfly numbers and QMCI scores (Figure 15). Although these negative trends may be influenced by mining activities, limited surface water during dry summer periods and farming activities may also be contributing factors (SLR 2024 & 2025). Stock have access to stream margins and channels at some sites, particularly in Murphys Creek, where this has caused bank damage and pugging (Figure 16).

Figure 13: The invertebrate taxa found in the highest numbers (>100 each) in the ORC's sampling of the lower Waikouaiti River in late January 2023. Left to right: *Deleatidium* mayfly larvae, *Husonema* caddisfly larvae, Elmidae riffle beetle, Orthocladiinae chironomid midge larvae, Oligochaete worm and *Potamopyrgus* snail. Photos: Stephen Moore, Landcare.

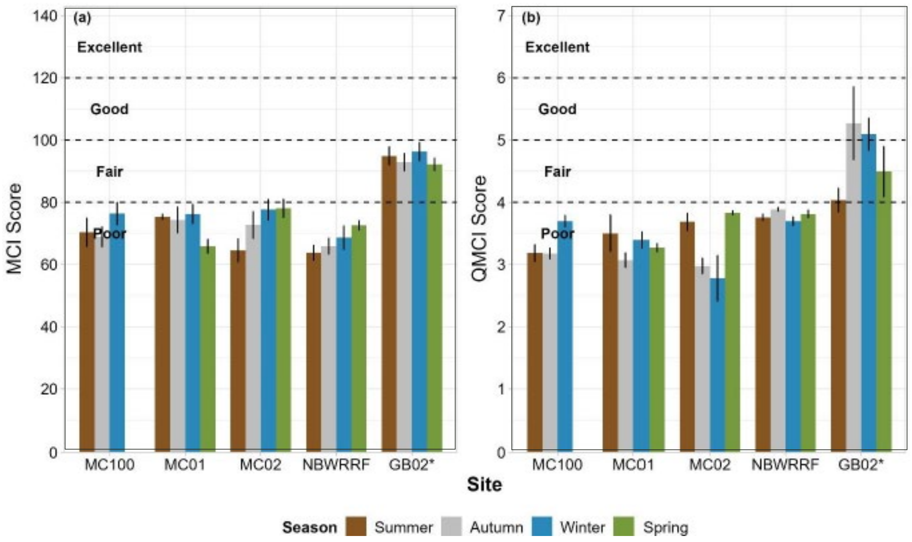

Figure 14: Average (± standard error) MCI (left) and QMCI (right) scores from stream sites sampled quarterly in 2023 in the upper reaches and tributaries of the North Branch of the Waikouaiti River. Golden Bar Creek (GB02) is the control site (see Appendix A for other site details). Few sites were able to be sampled in summer due to a lack of flow. The thresholds are based on guidance from Stark and Maxted (2007). Reproduced from Figure 31 in SLR (2024).

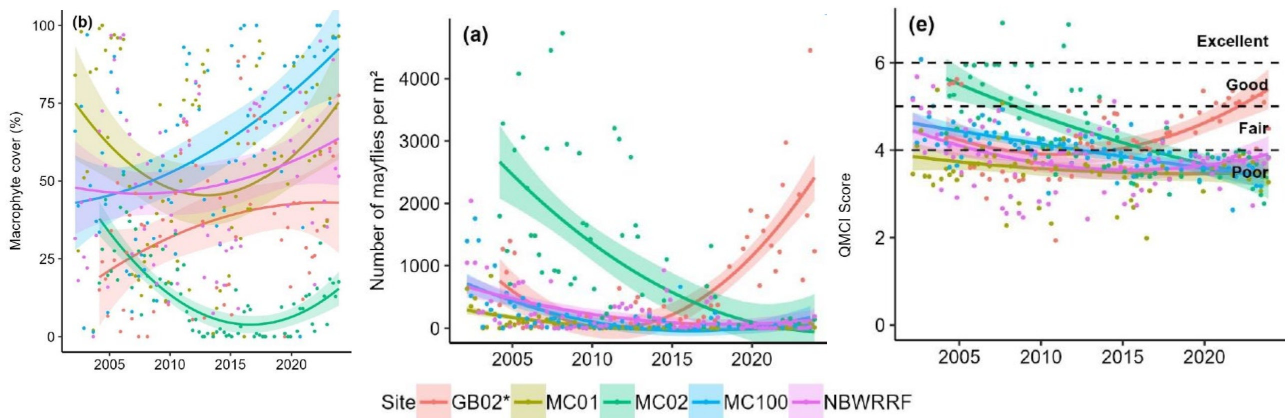

Figure 15: Long-term predicted trend (±95% confidence intervals) of seasonal average macrophyte (left) mayflues numbers (middle) and QMCI scores (rught) at Waikouaiti River catchment sites monitored by OceanaGold in the ~20 year period to June 2023. GB02 is the control site. Graphs reproduced from Figure 29 and Figure 31 in SLR (2024).

Figure 16: OceanaGold monitoring sites in the Waikouaiti River catchment in summer 2023. Stock access is evident in several photos and faecal deposits can be seen at site MC01 (Murphys Creek). Reproduced from Figure B.5 (SLR 2024).

Invertebrate habitat in the North Branch is better downstream at El Dorado and Bucklands Crossing, where assessments in January 2016 by Kāti Huirapa found a good proportion of caddisfly larvae and 'moderate' overall invertebrate health. Compared with further downstream, Bucklands Crossing has more diverse habitat, with occasional riffles and larger cobbles present. However, although early ORC monitoring at this site (ORC 2001) does show slightly higher proportions of EPT taxa than recorded at the current SOE site further downstream, MCI scores seldom exceeded 100 or 'fair' to 'good'. This suggests that, similar to downstream, water temperature and periphyton cover are sufficiently high at times to favour invertebrate taxa more tolerant of these conditions.

In contrast with the North Branch, summary scores from annual SHMAK invertebrate assessments by City Forests carried out between 2014 and 2025 suggest that the mid to upper reaches of the South Branch are in 'excellent' health, consistently supporting good numbers of sensitive mayfly, stonefly and caddisfly taxa – at least in winter when most of the assessments have been made. Kāti Huirapa's assessments at a site on the lower South Branch in January 2016 returned a lower SHMAK invertebrate community health score of 'moderate' (Halderen et al. 2016). Physical habitat quality is poorer in the lower reaches, where there is less diversity in riverbed composition and less riparian shade.

Overall, the Stark and Maxted (2007) quality classes appear to better describe macroinvertebrate community health than the current NPS-FM bands. However, both 'frameworks' present a 'one size fits all' set of numbers and a better approach is to compare the Waikouaiti invertebrate metrics against a national dataset that groups measurements made at hundreds of river sites according to their environmental 'type' (Clapcott et al. 2013). Type is determined using the first two classes of the River Environment Classification (Snelder & Biggs 2003): climate (e.g. warm-wet vs warm-dry) and source of flow (e.g. mountain-fed vs lowland). This comparison shows that the current median MCI for the lower Waikouaiti River of 86 (classified under REC as 'cool-dry upland' at ORC's monitoring site) is definitely below the average MCI (106.4) measured across river sites of the same type. The national dataset also includes average measured (and model-predicted) MCI scores for stream types that have minimal human influence in the upstream catchment areas to indicate what MCI scores could be expected at a river site under natural or low land use pressure conditions. The average measured MCI value for 'cool-dry upland' reference sites is 128.8 (Clapcott et al. 2013). This suggests that, based on current NPS-FM MCI bands, few, if any, parts of the Waikouaiti River catchment could realistically achieve better than band B (110–130).

Kōura/freshwater crayfish *(Paranephrops zealandicus,* Figure 17) are present in the tributaries of the upper North Branch (OceanaGold 2025) and along with freshwater shrimp *(Paratya)* and kākahi/freshwater mussel *(Echyridella* spp.*,* Figure 17*),* have been recorded elsewhere in the Waikouaiti catchment (Olsen 2024). Both kōura and kākahi are classified as 'at risk – declining' (Grainger et al. 2018) and were detected in an eDNA

Figure 17: Freshwater kōura/crayfish (left, DOC) and kākahi/mussels (right, NRC). Both are found in the Waikouaiti catchment and were detected in eDNA samples collected from the lower Waikouaiti River in 2024 and 2025.

Freshwater fish diversity is high

ORC monitoring at Orbells Crossing confirms a high diversity of native freshwater fish frequent this site, equating to band A (high biological integrity, indicating good habitat and access to the sea) in the current NPS-FM. In most of the 12 years that electric fishing has been carried out, īnanga, longfin eel (Figure 18), shortfin eel, pouched lamprey, bluegill bully (Figure 18), common bully, black flounder and brown trout have been recorded. Torrentfish and flathead grey mullet have also been recorded on occasion and some eDNA samples collected from the river in 2024 and 2025 also detected the presence of redfin bully, common bully, banded kokopu, Taieri flathead galaxiid and common smelt.[9]

Where sufficient water has been available to electric fish the upper reaches and tributaries of the North Branch, Taieri flathead galaxiids and both upland and common bullies have been recorded (SLR 2024 & 2025).

The South Branch has far fewer fish records but, according to the NZ Freshwater Fish Database, brown trout and kōura were recorded in the headwaters by DOC in February 2025. A year earlier, e3 Scientific recorded īnanga, longfin eel and common bully in the mid-reaches off Walker Road.

Figure 18: Longfin eel (photo: Rohan Wells, NIWA) and bluegill bully (photo © EOS Ecology) are regularly recorded in the lower Waikouaiti River in the vicinity of Orbells Crossing.

4.1.3 The river can get very warm

River water temperature, at least for short periods in summer, can get uncomfortably warm for some aquatic life. High frequency measurements at the ORC's SOE site on the lower Waikouaiti River indicates that water temperature at this location regularly exceeded 20°C for short periods during all summers since monitoring began (Figure 19). The highest water temperature recorded to date is 24.7°C early on the evening of 5 February 2023, following an extended period (starting in late December 2022) when peak daily water temperatures were almost always above 20°C.

In New Zealand, the Cox Rutherford Index (CRI) is commonly used to characterise summertime water temperatures and can be used to interpret the potential effects of water temperature on aquatic ecosystems. The CRI is the midpoint between the daily average and daily maximum temperatures and can be averaged over the five hottest days of a summer from a continuous water temperature record (Davies-Colley et al. 2013). For the five warmest days recorded during summer 2022/23, the CRI was calculated to be 21.4°C which places the site within a range Davies-Colley et al. (2013) describe as *"some thermal stress on occasion, with loss of certain sensitive insects and absence of certain sensitive fish."*[10] A scan of the remaining data records suggests that, in most summers, water temperatures would only cause *"minor thermal stress on occasion"*.

The ORC's historical (5 March 2024 to 4 October 2010) high frequency water temperature measurements for the lower South Branch at Lawsons also indicate water temperature exceeds 20°C at times in summer (Olsen 2024). On the North Branch, Kāti Huirapa recorded a peak spot measurement of 24.6°C at El Dorado in January 2016 (Figure 20).

[9] Koaro have also been detected in the catchment, being the only fish species found in eDNA sample collected from Hikaroroa Stream in April 2025.

[10] Davies-Colley et al. (2013) established recommended NPS-FM bands of A to D based for water temperature based on the CRI, but water temperature was not adopted as an attribute in the NPS-FM. A CRI of 21.4°C would equate to band C.

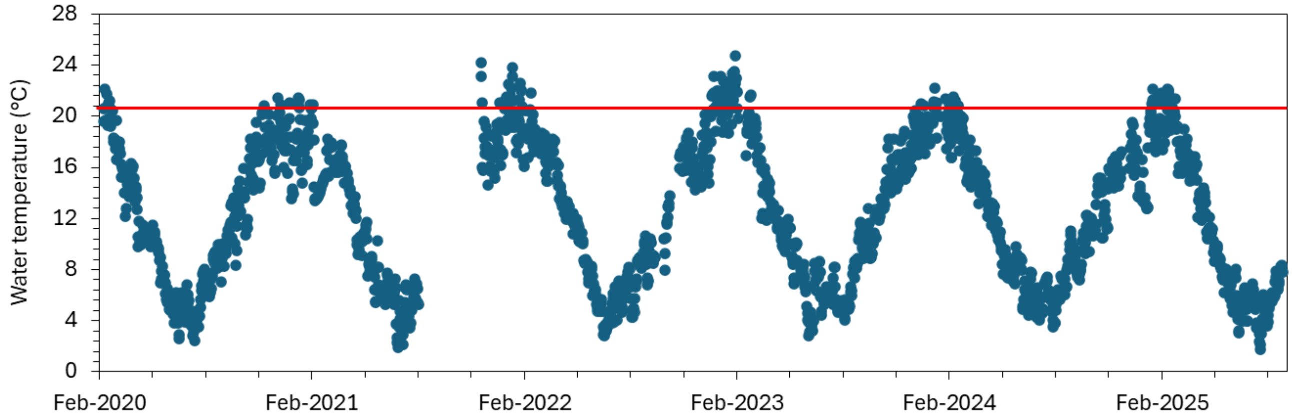

Figure 19: Maximum daily water temperature in the lower Waikouaiti River between 30 January and 10 February 2023, based on high frequency data from the ORC's Environmental Data Portal. The horizontal red line indicates a commonly accepted threshold of 21°C, above which acute thermal stress has been associated with mayflies (Olsen et al. 2012)[11].

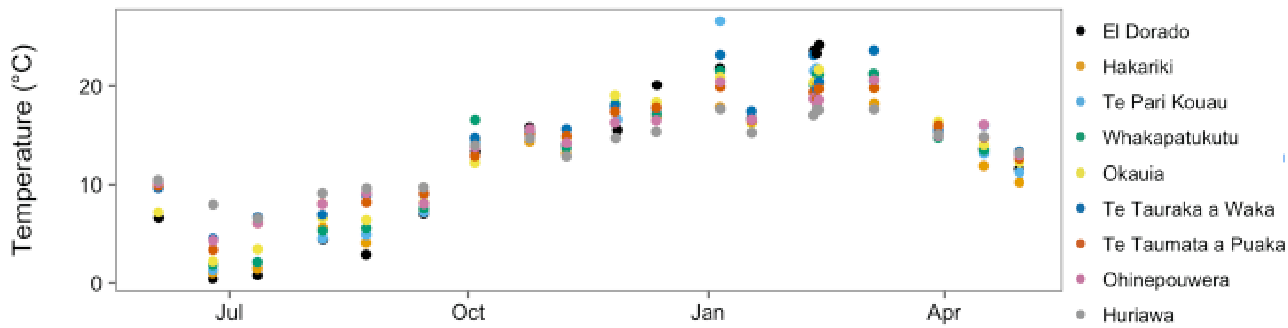

Figure 20: Spot water temperature measurements collected by Kāti Huirapa at nine locations between June 2015 and April 2016. Graph reproduced from Halderen et al. (2016).

One consequence of elevated stream temperatures can be lower levels of dissolved oxygen (DO) in the river (as warm water holds less oxygen). Based on spot summertime measurements taken by ORC in the lower reaches, very few measurements have dropped below critical minima (Figure 21) despite the high recorded water temperatures. The only period with multiple measurements between 4.5 and 6 mg/L – approaching stressful conditions for sensitive aquatic life – occurred in early 2008, 2009 and 2010 at Orbells Crossing. No flow data exist for this period to confirm but it is likely these occasions coincided with low flows. DO concentrations vary over the course of a day and high frequency measurements over summer would be needed to reliably identify whether there are extended periods of low DO.

[11] Thresholds for acute thermal stress vary across invertebrate and fish species and life stage. *Deleatidium* mayflies and brown trout are among the most sensitive invertebrates and fish, respectively.

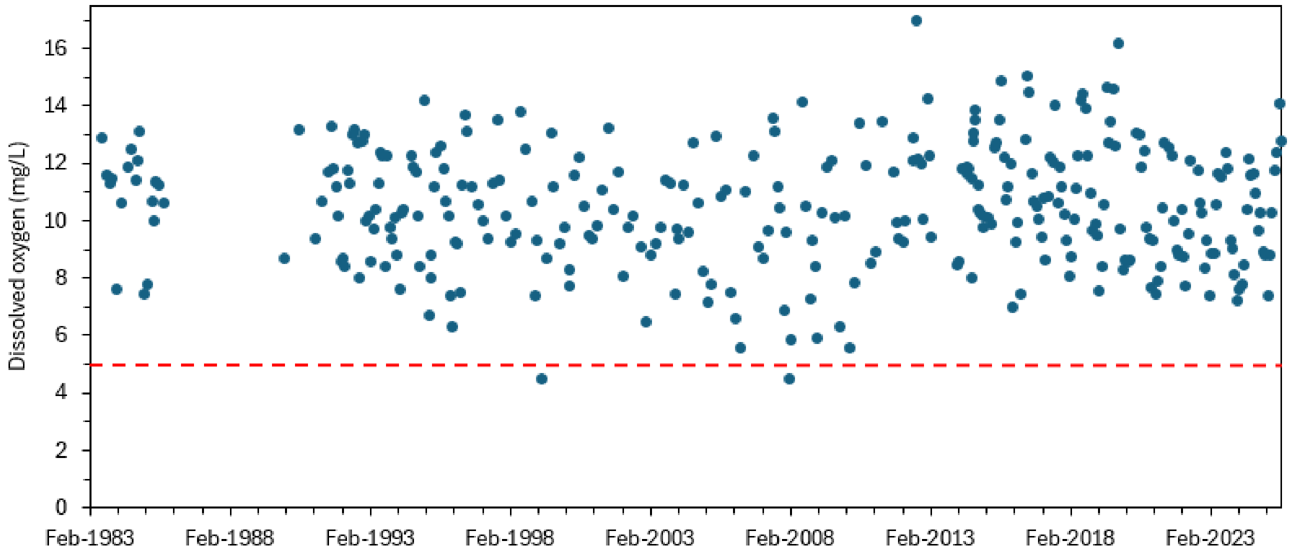

Figure 21: Dissolved oxygen (DO) concentrations from spot measurements by the ORC since monitoring began in the lower Waikouaiti River in 1983. Data have been combined from the three different long-term sites located at and upstream of Orbells Crossing (refer section 3.1.1) The horizontal red line indicates a minimum threshold; DO concentrations below this can be detrimental to aquatic life, particularly some fish. ORC data.

4.1.4 River flows are often low for extended periods

Continuous flow records for the Waikouaiti River downstream of the DCC's water intake indicate that flows are often low in the river for extended periods in summer and autumn. For the period since monitoring began at the current site in September 2014 and early 2023, flows above 3 times median (FRE3) occurred on average 6.4 times per year (Lu 2023). Although somewhat arbitrary, FRE3 is often used as coarse indicator of the magnitude of flow sufficient to 'flush' a riverbed free of algae, effectively 'resetting' the system (MfE 2000). With FRE3 events limited to six times per year, this means the river is hydrologically stable for periods of several months at a time, at times much longer (Figure 22) and coinciding with very low flows in summer (Table 3), sufficient for periphyton to persist and accumulate. The limited periphyton data available support this (refer section 4.1.2).

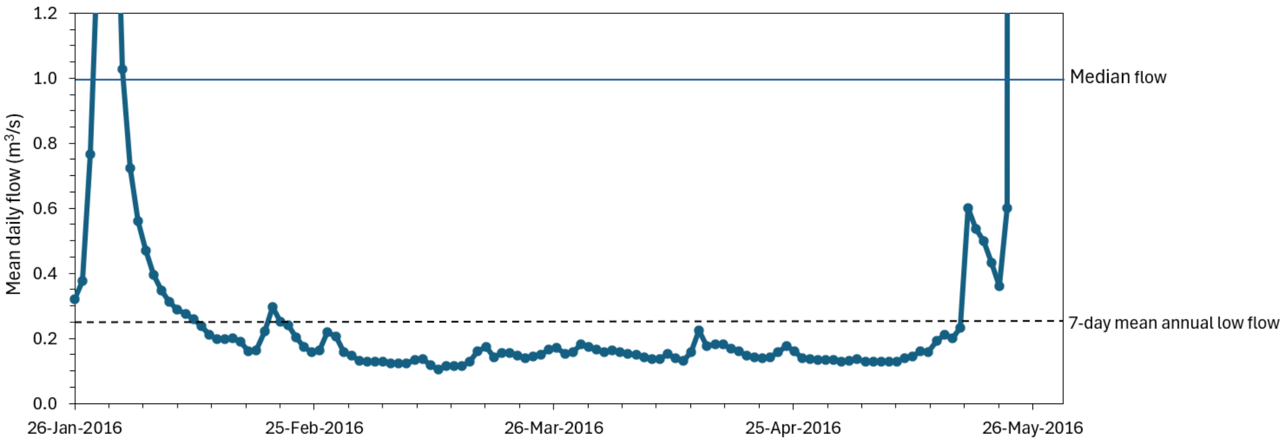

Figure 22: Average daily flows recorded by the ORC in the Waikouaiti River downstream of the DCC's water intake during an extended period of low flows in 2016. Flows did not return to above median (0.99 m^3/s) until late June. ORC data.

Table 3: Summary statistics of monthly mean flows (m³/s) in the lower reaches of the North Branch and South Branch of the Waikouaiti River, based on historical monitoring by the ORC. Reproduced from Table 4.3 of Dale (2011).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
South Branch at Lawsons (Feb 1991–Apr 2008)												
Median	0.46	0.35	0.25	0.43	0.37	0.47	0.81	0.94	0.58	0.54	0.55	0.68
Minimum	0.16	0.14	0.16	0.15	0.15	0.21	0.22	0.18	0.33	0.26	0.24	0.24
Mean	1.21	0.68	0.54	0.56	0.48	0.74	1.44	1.39	1.26	0.78	0.67	0.80
Max	9.06	3.08	2.78	1.67	0.96	3.13	5.62	5.33	9.25	1.95	1.87	2.24
North Branch at Bucklands (Jan 1991–Aug 1999)												
Median	0.40	0.30	0.26	0.37	0.74	1.19	2.36	2.06	1.12	0.81	0.81	0.65
Minimum	0.06	0.02	0.09	0.17	0.14	0.64	0.22	0.16	0.35	0.42	0.38	0.17
Mean	0.52	1.13	0.36	0.76	0.76	2.36	4.39	2.57	2.73	1.92	1.21	4.18
Max	1.27	4.76	1.17	3.07	1.28	7.81	21.1	9.25	8.36	5.20	3.15	28.4

4.2 Estuary water quality and ecological health

4.2.1 Karitane Wharf is suitable for swimming most of the time

Based on LAWA's record of enterococci indicator bacteria counts – the saline equivalent to *E. coli* in fresh waters – Waikouaiti Estuary at Karitane Wharf is suitable for swimming most of the time. On 70 sampling occasions over the five summers ending in March 2025, this site only exceeded the red/action threshold of the national swimming guidelines (>280 enterococci/100mL) twice and the amber/alert level (>140 enterococci/100mL) twice. This likely reflects the site's location near the estuary mouth, where strong tidal exchange with coastal waters rapidly dilutes and flushes any bacterial contamination entering from the upstream catchment or arising within the estuary itself (e.g. from waterfowl).

The 95th percentile enterococci count gives Karitane Wharf a current long-term grade of 'fair'. Similar to the results for Waikouaiti River at Bucklands Crossing, this grade is influenced by wet weather; removing the highest result to date (990 enterococci/100mL on 26 December 2023, which coincided with over 30 mm of rainfall at Karitane) reduces the 95th percentile from 171 to 124 enterococci/100mL and a shift in grade to 'good', more representative of the conditions when recreational water use will be greatest. A summertime grade of 'good' translates to risk of illness of less than 5% (MfE/MoH 2003).

4.2.2 Shellfish harvest should be delayed after rain

The only readily available information found on the suitability of the estuary for shellfish collection and consumption is a Masters thesis by Bell (2017) focused on the impact of rainfall-induced faecal contamination on cockles or tuaki (*Austrovenus stutchburyi*) and green-lipped mussels or kutai *(Perna canaliculus).* Weekly sampling of shellfish flesh over a 13-week period, and an additional three sampling events during rainfall, concluded marginal non-compliance with the New Zealand Food Safety Authority guidelines which state no more than 10% of samples shall exceed 700 *E. coli* per 100 g of shellfish flesh. Sampling of the water column for faecal coliform indicator bacteria was also undertaken but no correlation was found between bacterial concentrations in the water and shellfish flesh. This confirms what has been widely known for some time (e.g. Bolton-Ritchie et al. 2013), that monitoring of faecal indicator bacteria in shellfish-gathering waters is a poor indicator for identifying breaches of microbial safety in shellfish (Stott and Wood 2024).

Cockles and green-lipped mussels are filter feeders, meaning they filter food particles from the water column. Therefore, with faecal contamination in the Waikouaiti River and Estuary higher following rainfall, it is important that collection of these shellfish is avoided after heavy rain. Advice from MPI is to wait until after the water has run clear for five days. Cooking shellfish before eating can also help to avoid getting sick.

4.2.3 Estuary health is 'fair' to 'good'

Detailed assessments of the sediment, flora and fauna carried out annually between November 2016 and February 2019 indicate the ecological health of the estuary is 'good' in the mid to lower estuary. Sediments at representative locations in these areas have a high sand content with good oxygen, supporting a balanced macroinvertebrate community of crabs, cockles and other organisms (Robertson et al. 2017). This is despite the presence of moderate to dense surface cover of *Ulva intestinalis,* a green macroalgae, which has the potential to reduce the quality of sediments for macrofauna by trapping fine sediments and organic matter and by depleting oxygen within surface sediments when algal mats decay (Roberston et al. 2002).

The upper reaches of the estuary are characterised by a higher amount of mud, with the ORC's monitoring site in the Merton Arm recording around 30% mud content across all three surveys to date (O'Connell-Milne et al. 2024). This part of the estuary (together with the East Arm) acts as a depositional area for sediment entering the estuary from the upstream catchment and is not as well flushed as the middle and lower estuary areas. The higher mud content in the Merton Arm is reflected in low oxygen levels within the surface sediments, an absence of cockles and a macroinvertebrate community that is more tolerant of these conditions, including very high numbers of the polychaete *Scolecolepides benhami* in November 2016 survey. Blooms of red macroalgae *(Gracilaria chilensis)* have been recorded in the upper estuary in the past. Dense patches of macroalgae have also been recorded within the lower and middle areas of the estuary (Stevens and Roberston 2017, Figure 23). Odours associated with rotting algal blooms were lodged with the ORC's pollution hotline during the unusually dry period of 1997-99 (ORC 2001).

Figure 23: Green macroalgae blooms in the middle (left) and lower (right) reaches of the Waikouaiti Estuary near the main channel in December 2016. Photo from Stevens and Roberston (2017).

Annual estimates of sediment accumulation rates in the estuary up until December 2023 indicate average net erosion rates of -2.1 and -2.4 mm/year at sites in the lower and upper estuary and an accumulation of sediment at an average rate of 0.7 mm/year in the mid estuary (Rabel 2024). However, significant year-to-year variation in sediment depth has been recorded and this appears to reflect sediment erosion or accrual due to hydrodynamic processes rather than deposition of sediment from the upstream catchment (Forrest 2023).

Overall, monitoring results to date indicate that mud coverage and mud content pose the greatest risk to ecological health, particularly within the Merton Arm. Annual surveys between 2016 and 2018 consistently found low concentrations of sediment organic carbon, nutrients and metals across all three monitoring sites. In addition, one-off sampling of the surface and bottom waters in December 2016 found no evidence of stratification in the main channel. When present, stratification can result in poorly mixed bottom waters that are vulnerable to phytoplankton blooms, reduced dissolved oxygen levels and elevated nutrient concentrations. However, stratification — where incoming river water overlies denser estuarine water — has previously been observed in the upper estuary during summer low-flow conditions. This suggests that poorly flushed bottom waters may be intermittently present within the estuary (Robertson et al. 2017). Such conditions are most likely to occur in the upper estuary channel, or within the main estuary channel if flow at the estuary mouth becomes restricted.

Catchment sediment and nitrogen inputs pose the greatest risk to estuary health

With mud content in parts of the upper arm of the estuary already moderate to high, limiting further significant sediment inputs from the upstream catchment should be a priority. Current estuary sediment nutrient concentrations are low, suggesting that upstream nutrient inputs do not pose a significant risk to estuary health. While monitoring confirms the lower Waikouaiti River is characterised by low concentrations of plant-available nitrogen and, especially, phosphorus, in estuarine environments all forms of nitrogen and phosphorus have the potential to become available to fuel nuisance macroalgae growth and associated eutrophic (enrichment). Assessment of eutrophication risk for the estuary by Plew (2021) demonstrates that nitrogen is the limiting nutrient for plant growth and, therefore, increases in catchment nitrogen inputs have the potential to increase eutrophication risk in the estuary.

Current total nitrogen inputs to the estuary are estimated at 68.5 tonnes per year, compared with 5.2 tonnes per year for total phosphorus (Snelder and Fraser 2023). The estuary has several characteristics that help protect it from eutrophication, including high tidal exchange and a relatively short flushing time of 4.3 days. Overall, large blooms of algae on the sediment pose a greater risk than algal blooms in the water column (phytoplankton blooms) (Plew 2021).

4.3 Summary

The available monitoring information indicates that water quality in the Waikouaiti River is 'very good' and compares favourably with the current NPS-FM attribute bands. As well as high visual clarity at base flows and low concentrations of plant-available nutrients, significant faecal contaminant is infrequent. However, the river does suffer extended periods of low flow and high water temperatures in summer that appear to be the primary cause of significant periphyton growth at times and, subsequently, an invertebrate fauna dominated by taxa that can tolerate these conditions. pollution-sensitive mayflies, caddisflies and brown trout are present in the lower reaches. Native fish diversity is also high in the lower reaches, reflecting good access to the sea, which is required by many species to complete their life cycle.

Waikouaiti Estuary is in a 'moderate' ecological condition. The Merton Arm in the upper reaches has a high mud content and there are patches of nuisance macroalgal growth in some locations. However, organic carbon, nutrient and metal concentrations in the surface sediments are low and, in the middle and lower reaches, there are well-oxygenated sands supporting a healthy invertebrate community. Based on microbial water quality, the estuary at Karitane Wharf is suitable for swimming most of the time but it can be compromised in wet weather. Collection of shellfish should also be avoided following rainfall.

5 Management considerations and information gaps

Monitoring to date suggests that the ecological health of the Waikouaiti River is impacted more by stable and frequently low flows than contaminant inputs from the surrounding catchment. However, the naturally low nutrient status of the river also means that even a small increase in nutrients could results in rapid changes in periphyton growth. This is especially the case if plant-available phosphorus, which is currently the nutrient limiting (i.e. controlling) periphyton growth, were to increase in concentration. In terms of the estuary, nitrogen is the limiting nutrient, so both nutrients need to be managed at the catchment scale, along with sediment.

5.1 Sediment sources

Suspended fine sediment concentrations are consistently low at base flows in the lower reaches of the river but are not well quantified at higher flows (i.e. during rainfall). Monitoring data is limited elsewhere in the catchment but SLR (2024 & 2025) report disturbance of the bed and pugging by stock in some of the headwater tributaries. There is likely also localised bank erosion contributing to fine sediment into streams at base flows. For example, although City Forests' annual SHMAK assessments in the South Branch indicate that bed sediment cover is generally consistently low, the summary scores provided for this report suggest that fine sediment is sometimes present near the banks.

Plantation forestry cover has increased in some areas of the catchment in the last decade, in part to reduce hillslope erosion. However, some of the long-established forest, particularly in the South Branch, is progressively undergoing harvest (Figure 24) and this will need careful management to prevent sediment loss to surface water. With significant reaches of both branches bordered by steep-sided slopes that are in places considered at high risk of erosion (Figure 25), managing sediment loss, particularly in heavy rain events, may be a challenge.

Figure 24: Aerial photo (November 2023) looking down over the lower South Branch of the Waikouaiti River, with harvested forest in the foreground. Google Earth, accessed October 2025.

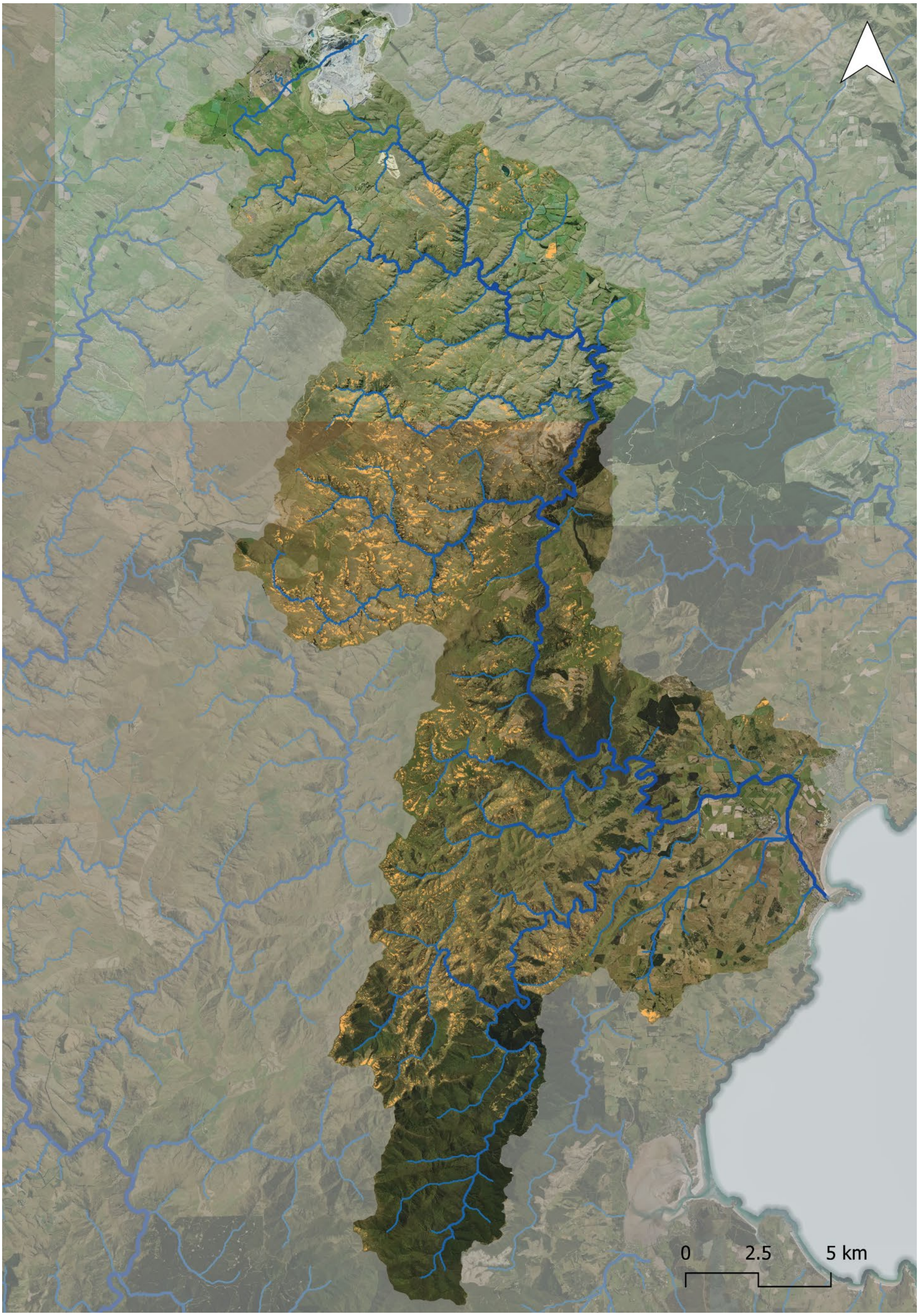

Figure 25: Pastoral land areas in the Waikouaiti River catchment most at risk (top 95%) of surficial erosion. Courtesy of Collaborations Ltd.

5.2 Nutrient sources

At base flows, it appears that most of the plant-available nutrients are sourced from cycling within the river system itself. Large pulses of nitrate-N are evident in early winter, reflecting a flush of nitrate once soil moisture levels, depleted over the summer, are replenished. The bulk of phosphorus inputs likely occur during rainfall events, via overland flow and bank erosion, with phosphorus transported attached to fine sediment particles.

There is some potential for nitrogen inputs to increase in the catchment. The proposed expansion of OceanaGold's mine at Macraes is predicted to increase instream nitrogen concentrations (Ryder 2024) and forestry harvest is an activity that has been linked with pulses of nitrogen loss to groundwater and connected streams (Wilkins et al. 2024, Davis 2014). Forestry harvest also increases the risk of sediment loss, which may provide an additional source of phosphorus during heavy rain events.

5.3 Faecal contaminant sources

The primary sources of faecal contamination in the catchment are stock (e.g. in the upper tributaries of the North Branch, as reported by SLR (2024 & 2025) and waterfowl. Monitoring in the lower river reaches and estuary to date shows that contamination – as assessed by concentrations of *E. coli* and enterococci indicator bacteria – only poses an unacceptable risk to human health in wet weather. This suggests that most faecal inputs enter the river and estuary from overland flow. It is also not uncommon in estuaries like the Waikouaiti for strong winds to resuspend pathogens entrained in the bottom sediments, increasing concentrations in the overlying water (Stott and Wood 2024).

5.4 Information gaps

Although there is a good amount of information on the condition of the lower reaches of the river, this is not the case in other parts of the catchment, particularly the South Branch where current monitoring is limited to annual SHMAK assessments by City Forests and Kāti Huirapa at one site each. This branch is likely to be in good health in its upper reaches but historical data assessed by Olsen (2024) suggest the lower reaches are prone to warm temperatures and low flows in summer. The river may also be prone to high sediment inputs in wet weather.

Some of the other information gaps identified include:

- <u>Sediment and nutrient concentrations under high rainfall</u> – spot monthly water sampling seldom coincides with the rain events that result in the greatest instream concentrations. The DCC's continuous monitoring of turbidity, if calibrated to a suspended sediment record, could provide important insights into the magnitude of wet weather sediment loads passing through the lower river into the estuary.
- <u>Nutrient losses from land use in the lower reaches</u> – due to the tidal influence in the lower river reach, the ORC's SOE site is located upstream of this and, consequently, upstream of some of the intensive dairying activity in the lower flats adjacent to SH 1. There could be value in monitoring a site further downstream for a few years to establish if there is any significant difference in nutrients at this point, particularly nitrogen. Sample collection would be best standardised to a mid-ebb (outgoing) tide to avoid backflow of (lower nutrient) estuarine water.
- <u>Nuisance plant growth</u> – the limited information available points to significant periphyton growth in the river at some locations as well as an increase in nuisance macrophyte growth in some tributaries of the upper reaches of the North Branch (SLR 2024 & 2025). Although the gravel-dominated bed at the ORC's monitoring site can be challenging for periphyton monitoring, it is possible to monitor both cover and biomass at gravel-bed sites. A monitoring site could also be established upstream, such as at Bucklands Crossing where periphyton growth may impact recreational water use and aesthetics; the ORC does already carry out cover assessments there as part of its summer recreational water quality monitoring programme.

- Low flows – low stream flows are a frequent occurrence in the catchment, particularly in the North Branch, where evapotranspiration often exceeds rainfall. SLR (2024 & 2025) report summer low flows as a potential contributing factor to the ‘poor’ to ‘fair’ ecological condition at sites downstream of OceanaGold’s mining operation. However, the information reviewed for this report does not address whether stream flows or overall water yield have changed over the approximately 20 years of monitoring, including whether mining activities may have influenced catchment hydrology. Irrespective of any long-term change in flow, low flow conditions can impose significant thermal stress on sensitive invertebrate and fish species, a stress that is likely to intensify given that average summer air temperatures in the inland Waikouaiti area are projected to increase by approximately 1°C by 2040 (Macara et al. 2019). Deployment of continuous water temperature and dissolved oxygen sensors during summer would help characterise the ecological risks associated with low flows. This monitoring might also improve understanding of the potential for organic nutrient sources to be mobilised into the water column if oxygen concentrations remain low for extended periods.

Overall, the need for additional information in part depends on the scale at which farm planning and catchment management will operate. The ORC’s current SOE site provides a useful bottom-of-catchment monitoring site against which any impacts of changes in upstream land use or management can be tracked. However, given the different climate conditions that exist in the catchments of the north and south branches and the more intensive land use present on the lower valley flats where these branches merge, there may be value in creating subcatchment areas with monitoring targeted to the information needs of each.

5.5 Other comments

The ORC and DCC monitor water quality in the lower Waikouaiti River in very close proximity to one another. Although the monitoring purposes and requirements differ, reflecting the different legislation behind them, there is overlap in the frequency of testing (monthly) and in many of the tests performed. This could present an opportunity for joining up some aspects of the current monitoring programmes, which might allow the resources saved to be redirected into implementing some of the targeted monitoring outlined in section 5.4 or supplementing the existing monitoring efforts of others in the catchment (e.g. lab identification of invertebrate samples collected by Kāti Huirapa and City Forests).

6 Conclusion

The available monitoring information indicates that water quality in the Waikouaiti River is 'very good' and compares favourably with the current NPS-FM attribute bands. Based on the ORC's monitoring of the lower reaches over the last five years, the river has very low median concentrations of suspended sediment and plant-available nutrients, and significant faecal contamination is infrequent and limited to wet weather. However, the river experiences extended periods of low flow and high water temperatures in summer, contributing to significant periphyton growth in some locations and, subsequently, an invertebrate fauna dominated by taxa that can tolerate these conditions. Despite this, pollution-sensitive mayflies, caddisflies and brown trout are present in the lower reaches. Native fish diversity is also high in the lower reaches, reflecting good access to the sea, which is required by many species to complete their life cycle.

Waikouaiti Estuary is in a 'moderate' ecological condition. The Merton Arm in the upper reaches has a high mud content and there are patches of nuisance macroalgal growth in some locations. However, organic carbon, nutrient and metal concentrations in the surface sediments are low and, in the middle and lower reaches, there are well-oxygenated sands supporting a healthy invertebrate community. Based on regular testing of enterococci indicator bacteria, the estuary at Karitane Wharf is suitable for swimming most of the time in summer but it can be compromised in wet weather. Collection of shellfish should also be avoided following rainfall.

Overall, monitoring to date suggests that the ecological health of the Waikouaiti River is impacted more by stable and frequently low flows than contaminant inputs from the surrounding catchment. However, the naturally low nutrient status of the river also means that even a small increase in nutrients could result in rapid changes in periphyton growth. This is especially the case if plant-available phosphorus, which is currently the nutrient that limits periphyton growth, were to increase in concentration. In terms of the estuary, nitrogen is the limiting nutrient so both nutrients need to be managed at the catchment scale, along with sediment, to safeguard ecological health. Most sediment will enter the estuary in wet weather.

Some information gaps exist, particularly in the South Branch for which considerably less monitoring has been carried out to date. Some suggestions have been made where further monitoring could be undertaken but consideration also needs to be given to the spatial scale at which farm planning and catchment management will operate.

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Appendix A Monitoring site information

ORC sites in bold indicate current monitoring sites.

Organisation	Site name	Site No.	Site type	Latitude	Longitude	Branch
City Forests	Waikouaiti South Branch (various points)	-	General river health	-45.693471	170.5315	South branch
DCC	Waikouaiti R source water (raw intake)	S00156	Drinking water quality	-45.611718	170.60687	Mainstem
Kāti Huirapa	Waikouaiti El Dorado	1	Cultural health	-45.52348	170.5478	North branch
Kāti Huirapa	Waikouaiti Hakariki	2	Cultural health	-45.61539	170.5914	South branch
Kāti Huirapa	Waikouaiti Te Pari Kouau	3	Cultural health	-45.60827	170.609	Mainstem
Kāti Huirapa	Waikouaiti Whakapatukutu (Orbell's Crossing)	4	Cultural health	-45.60832	170.6223	Mainstem
Kāti Huirapa	Waikouaiti Okauia	5	Cultural health	-45.60479	170.6514	Mainstem (estuarine)
Kāti Huirapa	Waikouaiti Te Tauraka a Waka	6	Cultural health	-45.62156	170.6447	Estuary
Kāti Huirapa	Waikouaiti Te Taumata a Puaka	7	Cultural health	-45.62586	170.6516	Estuary
Kāti Huirapa	Waikouaiti Ohinepouwera	8	Cultural health	-45.63867	170.6599	Estuary
Kāti Huirapa	Huriawa	9	Cultural health	-45.639308	170.67106	Saline
OceanaGold	Murphy's Creek tailings ford	MC01	Consent monitoring	-45.399742	170.48321	North branch
OceanaGold	Murphy's Ck d/s of junction with Clydesdale Ck	MC02	Consent monitoring	-45.424124	170.51274	North branch
OceanaGold	downstream of Murphys Creek Silt Pond	MC100	Consent monitoring	-45.398409	170.47159	North branch
OceanaGold	Golden Bar Creek upstream of junction with NBW	NB01	Consent monitoring	-45.444964	170.51709	North branch
OceanaGold	NBWR upstream of junction with Golden Bar Ck	NB02	Consent monitoring	-45.444441	170.51679	North branch
OceanaGold	NBWR downstream of junction with Golden Bar C	NB03	Consent monitoring	-45.445468	170.51672	North branch
OceanaGold	NBWR Gifford Road	NBWRGR	Consent monitoring	-45.379026	170.44483	North branch
OceanaGold	NBWR Redbank Road	NBWRRB	Consent monitoring	-45.385997	170.4322	North branch
OceanaGold	NBWR Ross Ford	NBWRRF	Consent monitoring	-45.420708	170.45668	North branch
OceanaGold	NBWR Tributary 01	NBWRTR	Consent monitoring	-45.396095	170.44574	North branch
ORC	**Waikouaiti R at 200m d/s DCC intake**	**EY527**	**State of the environment**	**-45.609338**	**170.60703**	**Mainstem**
ORC	Waikouaiti at Confluence d/s	EN394	State of the environment	-45.617717	170.59637	Mainstem
ORC	Waikouaiti R at Orbells	EW890	State of the environment	-45.60953	170.62057	Mainstem
ORC	**Waikouaiti North Branch at Bucklands**	**EM377**	**State of the environment**	**-45.608032**	**170.58059**	**North branch**
ORC	**Waikouaiti R at Bucklands**	**EM377**	**Recreational water quality**	**-45.60724**	**170.58057**	**North branch**
ORC	**Waikouaiti Estuary at Karitane Wharf**	**EV187**	**Recreational water quality**	**-45.641818**	**170.66032**	**Saline**
ORC	**Waikouaiti at Mt Misery**	**EM781**	**Rainfall**	**-45.641609**	**170.45188**	**-**
ORC	**Karitane soils**	**GT289**	**Rainfall & soil moisture**	**-45.625181**	**170.60357**	**-**
ORC	Waikouaiti South Branch at Lawsons	EM378	Flow	-45.642759	170.55856	South branch
ORC	**Waikouaiti Estuary - A**	**LAWA-103363**	**Estuary health**	**-45.635172**	**170.65583**	**Estuary**
ORC	**Waikouaiti Estuary - B**	**LAWA-103364**	**Estuary health**	**-45.625133**	**170.65071**	**Estuary**
ORC	**Waikouaiti Estuary - C**	**LAWA-103365**	**Estuary health**	**-45.620791**	**170.63682**	**Estuary**
ORC	**Shag at Stoneburn**	**EM379**	**Rainfall**	**-45.430231**	**170.56518**	**North branch**
ORC	Waikouaiti R at Cloverdowns	EM441	Flow	-45.444671	170.51731	**Mainstem**
ORC	Waikouaiti R at confluence	?	Flow	-45.612416	170.60609	Mainstem
WDC	Stoneburn source water	WADCPO-SB03	Drinking water quality	-45.447577	170.5192	North branch