State of the Environment
Surface Water Quality in Otago

2006 to 2017

Manuherikia River at Ophir

Catlins River at Houipapa

Dunstan Creek at Beattie Road

Kakanui River at Clifton Falls

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Executive summary

This report summarises compliance with Schedule 15 of the Regional Plan: Water for Otago (Water Plan), National Policy Statement for Freshwater Management 2014 (NPS-FM 2014) National Objectives Framework (NOF) attribute bands, and state and trends of water quality across Otago Regional Council's State of Environment (SoE) lake, river and stream monitoring sites for the period July 2006 to June 2017.

SoE surface water quality reporting helps identify areas in Otago where land-use and land management practices are putting pressure on water quality and river ecosystem health.

The report provides a detailed review of water quality state and trends across the region and is an update on the 5-yearly report that covered the period 2006 to 2011 (Ozanne, 2012).

The report has been split into 'water quality reporting regions' that follow logical catchment and geographical boundaries and align closely with Schedule 15 (Water Plan) Receiving Water Group water management zones. The reporting regions include:

- North Otago;
- Dunedin / Southern Coastal;
- Taieri;
- Upper Clutha;
- Middle Clutha / Central Otago;
- Lower Clutha / Pomahaka;
- Otago Lakes.

To best represent current conditions, state analysis is based on water quality samples collected over a five year period running from July 2012 to June 2017. Trend analysis was carried out on data collected over an eleven year period running July 2006 to June 2017. An eleven year period was required to provide adequate data for robust trend analysis.

Up to June 2013, Otago Regional Council (ORC) collected surface water quality samples on a bi-monthly basis. From July 2013, sampling frequency increased to monthly sampling in line with current good practice approaches to routine water quality sampling in New Zealand.

Long-term SoE lake monitoring sites consist of a mix of lake-outlet (lakes Wanaka, Wakatipu and Hawea) and lake-shore (lakes Dunstan, Johnson, Onslow, Waihola and Tuakitoto) sampling sites. More detailed lake monitoring occurs at a subset of these lakes as part of ORC's Trophic Lake Sampling Program. The results of the Trophic Lake Sampling Program are presented independently of this report.

Assessments of riverine ecological health are based solely on aquatic macroinvertebrates collected from 36 river and stream sites across the region. Results are analysed and presented for the period running January 2011 to July 2017.

Data analysis includes an assessment of spatial variation on a region-wide basis against compliance with Schedule 15 (Water Plan) limits; National Objectives Framework (NOF) bands; and national water quality guidelines (ANZECC) along with an assessment of water quality trends. Included are regional rankings of sites to allow for a wider regional context of site specific water quality.

ORC do not routinely measure sediment cover, water clarity or periphyton (algal) cover or biomass at their SoE monitoring sites. No results are presented for these parameters.

Overall, water quality across Otago is variable, with some areas such as the Upper Clutha and the Taieri having excellent water quality, with other areas, such as urban streams in the Dunedin locale, intensified catchments in North Otago and some tributaries of the Pomahaka having poor water quality. The sites with the worst water quality overall includes the Waiareka Creek (North Otago); the Kaikorai Stream (Dunedin / Southern Coastal); the Owhiro Stream (Taieri); and the Heriot Burn, Crookston Burn, Waikoikoi Stream and the Wairuna River (Lower Clutha / Pomahaka). Of the lowland sites with the best water quality, the Waikouaiti River was clearly the frontrunner.

As has been previously reported (Ozanne, 2012), water quality in rivers across Otago show a clear spatial pattern related to land cover and land use. Water quality is best at river and stream reaches located at high or mountainous elevations under predominantly native cover. These sites tend to be associated with the upper catchments of larger rivers (e.g. Clutha River/Matau-Au, Taieri River and Lindis River) and the outlets from large lakes (e.g. Hawea, Wakatipu and Wanaka). Water quality is generally poorer at sites located on smaller, low-elevation streams that drain pastoral or urban catchments.

Trend analysis was undertaken on ammoniacal nitrogen (NH_4-N), total nitrogen (TN), nitrite-nitrate nitrogen (NNN), total phosphorus (TP), *Escherichia coli* (*E.coli*) and turbidity from each of the 69 core water quality monitoring sites providing 483 independent trend assessments. The analysis returned a mix of results for the different reporting regions. In nearly all cases, in instances where trends were confidently identified, there were a greater number of increasing or degrading trends than decreasing or improving trends; this held for each given reporting region and regionally overall. The worst performing variable was *E. coli* where 30% of sites had a probable or significant increasing (degrading) trend versus 7% of sites that had either stable or decreasing (improving) trends. For *E. coli* 63% of sites were either indeterminate (51%) or had too many results that were less than detect (8%). For these sites, in all likelihood trends would be present, but limitations in the data do not allow the trend to be confidently identified. This point is highly relevant when looking at the pattern of trends across the region as for all water quality variables; there were far greater numbers of sites that returned 'indeterminate' trend results than those that returned a confident trend result. This highlights limitations in the historical data set held by Otago Regional Council and constrains Council's ability to confidently assess trends.

There is a lack of detailed information held by Otago Regional Council on local or catchment scale land use change or land management practice changes. This severely limits Council's ability to comment on drivers of trends evident across Otago. To better interpret the reasons for improvements or degradation in water quality, information on the following is required:

- Changes in irrigation practice – flood to pivot;
- Changes in farm type or stocking rate;
- The level of stream protection afforded to streams and rivers, and the width of setbacks;
- Mitigation measures to address critical source areas.
- Physiographic Environments in Otago[1]

Collection of this type of information in a robust and repeatable manner would allow for better interpretation of the drivers of water quality changes evident across Otago.

[1] The Physiographic Environments of New Zealand (PENZ) is a three-year project that links fresh water to the land

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1. Introduction

1.1. Otago's rivers and lakes

The Otago region covers a land area of 32,000 km^2: from the Waitaki River in the north to Brothers Point in the south, and inland to Lake Wakatipu, Queenstown, Hawea, Haast Pass and Lindis Pass.

The distinctive and characteristic landscape of Otago includes the Southern Alps and alpine lakes; large high country stations; dry central areas, with tussock grassland and tors; and dramatic coastlines around the Otago Peninsula and the Catlins. Lowland pasture country is common in the west. The character of the region's water bodies is diverse, reflecting the variation in environmental conditions throughout the region.

The Clutha River/Mata-Au drains much of the Otago region. Its catchment area totals 21,000 km^2, and 75% of the total flow of the river at Balclutha comes from the outflows of Lakes Hawea, Wanaka and Wakatipu. Larger rivers feeding into the Clutha catchment include the Cardrona, Lindis, Shotover, Nevis, Fraser, Manuherikia, Teviot, Pomahaka, Waitahuna and Waiwera rivers.

The Clutha and its principal tributary, the Kawarau River, pass through gorges, two of which are dammed for hydro-electricity generation. One of the larger tributaries of the Clutha, in its lower reaches, is the Pomahaka River, which rises in the mountains above Tapanui.

The second largest catchment in Otago is the Taieri River (5,060 km^2). It rises in the uplands of Central Otago and meanders among the block mountain ranges before passing through an incised gorge and crossing the Taieri Plain, where it joins the waters of the Lake Waipori and Waihola catchments and becomes tidal before making its way through another gorge to the sea at Taieri Mouth.

Other significant Otago rivers drain the coastal hills in catchments of varying character. In the north, the Kakanui, Waianakarua, Shag and Waikouaiti rivers rise in high country and pass through mainly dry downlands. The Tokomairiro River, which flows through Milton, south of Dunedin, drains rolling country between the Taieri and Clutha catchments. Rivers to the south of Otago, particularly the Catlins area, emerge from wetter, often forested hills.

The environmental context in which Otago's water bodies exist is characterised by high rainfall in the Southern Alps and occasional very low rainfall in the semi-arid central Otago valleys. Despite the large water volumes in the region, parts of Otago are among the driest areas in New Zealand. Several rivers are characterised as 'water-short', including the Lindis, Manuherikia, Taieri, Shag and Kakanui rivers and their tributaries (Regional Plan: Water 2004).

1.2. State of Environment monitoring and reporting

1.2.1. Overall objectives

River water quality sampling is carried out across New Zealand for many purposes. Water quality measurements help in our understanding of ecosystem health and also provide important information on the suitability of rivers and streams for specific uses, such as irrigation, stock watering, recreation and mahinga kai (food gathering) (DWQ NEMS, 2017).

Otago Regional Council (ORC) operates a long-term State of Environment (SoE) water quality monitoring network in lakes, rivers and streams throughout the region. Its objectives include providing information that underpins SoE reporting according to obligations under s35 of the Resource Management Act (1991). This monitoring is important as it improves the efficiency of Council policy initiatives and strategies, provides information on the effectiveness of Council's plans, as well as helping to identify the large-scale and/or cumulative impact of contaminants associated with varying land uses and disturbance regimes.

To meet Council's reporting obligations under s35 of the Resource Management Act (1991), ORC provides annual summaries of monitoring site compliance with the Water Plan as well as more detailed analysis of general state and long-term trends every 5 years. ORC conducted the last analysis of general state and trends (for the period 2006 to 2011) in 2012. The primary aim of this report is to repeat this analysis.

To best represent current conditions, state analysis is based on water quality samples collected over a five year period running from July 2012 to June 2017. Trend analysis was carried out on data collected over an eleven year period running July 2006 to June 2017. An eleven year period was required to provide adequate data for robust trend analysis. A total of 60 river and stream monitoring sites and 9 lake shore and lake outlet monitoring sites are included in the analysis.

Up to June 2013, Otago Regional Council (ORC) collected surface water quality samples on a bi-monthly basis. From July 2013, sampling frequency increased to monthly sampling in line with current good practice approaches to routine water quality sampling in New Zealand.

Long-term SoE lake monitoring sites consist of a mix of lake-outlet (lakes Wanaka, Wakatipu and Hawea) and lake-shore (lakes Dunstan, Hayes, Johnson, Onslow, Waihola and Tuakitoto) sampling sites. More detailed lake monitoring occurs at a subset of these lakes as part of ORC's Trophic Lake Sampling Program. The results of the Trophic Lake Sampling Program are presented independently of this report.

Assessments of riverine ecological health are based on aquatic macroinvertebrate collected (only) from 36[2] river and stream sites across the region. Results are analysed and presented for the period running January 2011 to July 2017.

The aims of this report are to:

- Report on the state of water quality and ecology indicators in rivers, streams and lakes across sub-regions and water management zones of Otago;
- Assess the spatial variation of water quality on a region-wide basis against compliance with Schedule 15 (Water Plan) limits; National Objectives Framework (NOF) bands; and national water quality guidelines (ANZECC);
- Identify significant trends in water quality. I.e. are water quality indicators degrading or improving over time?
- Meet Council's RMA obligations on reporting on State of the Environment of Otago's rivers and lakes.

1.2.2. Long-term SoE monitoring sites

The ORC SoE water quality programme has 52 core river and stream water quality monitoring sites spread throughout Otago. NIWA, until recently, monitored 8 sites in the Otago region as part of the National River Water Quality Network (NRWQN). These 60 river sampling sites span a range of geographical, source of flow and catchment land uses types. Figure 1 shows the location of the river

[2] Otago regional Council currently collect annual macroinvertebrate samples from 29 sites; NIWA collect annual macroinvertebrate samples from 7 sites in Otago. This brings the total number of sites with more than 5 years of macroinvertebrate samples to 36.

and stream monitoring sites covered in this report. Included in Figure 1 are the Receiving Water group boundaries identified in ORC's Water Plan.

ORC also monitors 9 lake sites. Long-term SoE lake monitoring sites consist of a mix of lake-outlet (lakes Wanaka, Wakatipu and Hawea) and lake-shore (lakes Dunstan, Hayes, Johnson, Onslow, Waihola and Tuakitoto) sampling sites. Figure 2 shows the location of the long-term SoE lake monitoring sites covered in this report. More detailed lake monitoring occurs at a subset of these lakes as part of ORC's Trophic Lake Sampling Program. The results of Trophic Lake Sampling Program are presented independently of this report.

Appendix A provides site metadata information for all sites; including the reporting or geographical region; ORC SoE reporting name; location (Easting/Northing); the Water Plan Receiving Water group (RWG); the River Environment Classification (REC) class; the Freshwater Environments of New Zealand (FENZ) class; the organisation responsible for sampling the site (ORC or NIWA); the site elevation; and if the site is classed as an ANZECC Upland (> 150m ASL) or Lowland site (< 150m ASL).

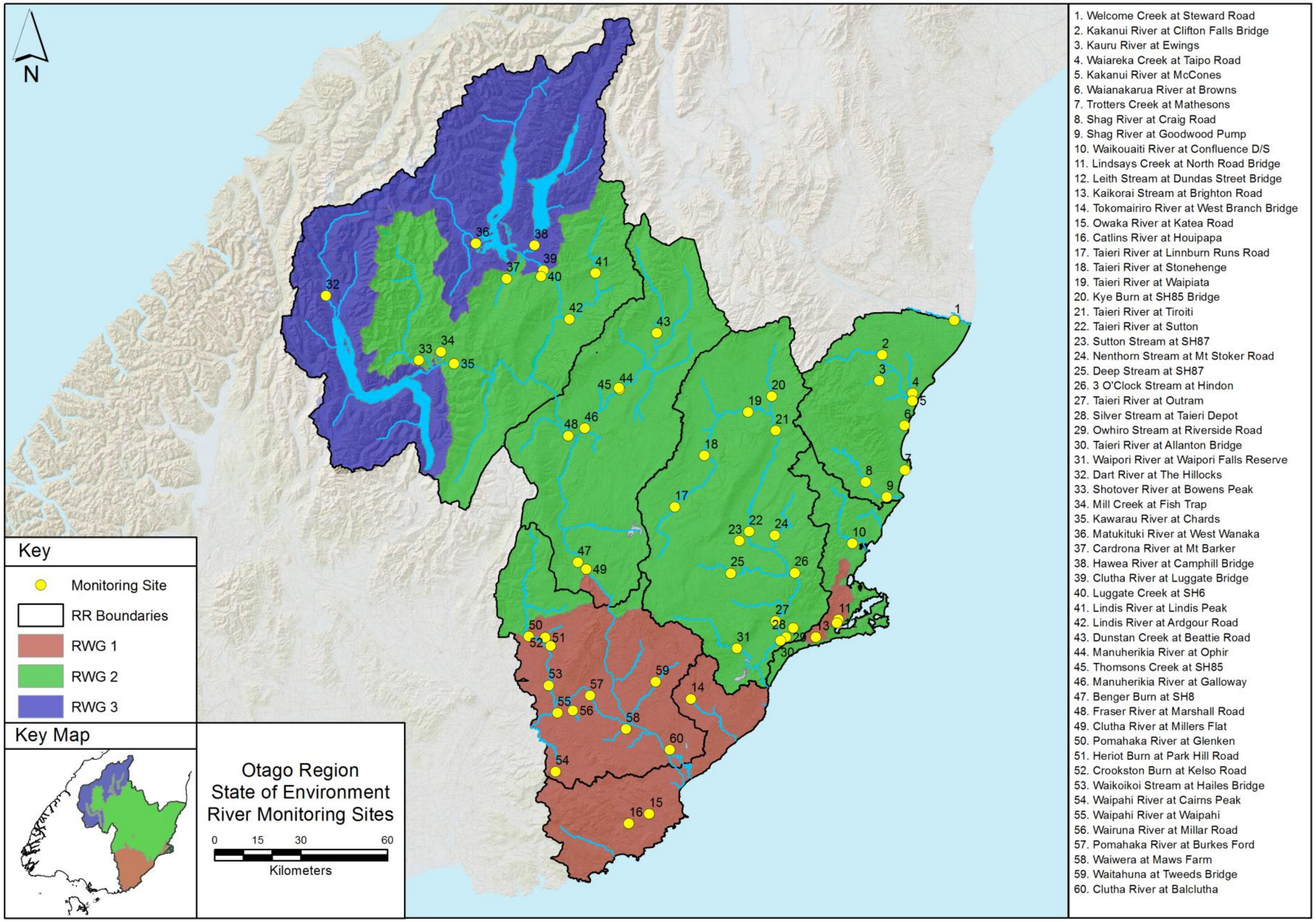

Figure 1: Location of long-term State of Environment river monitoring sites covered in this report. (For Group 4 see Figure 2)

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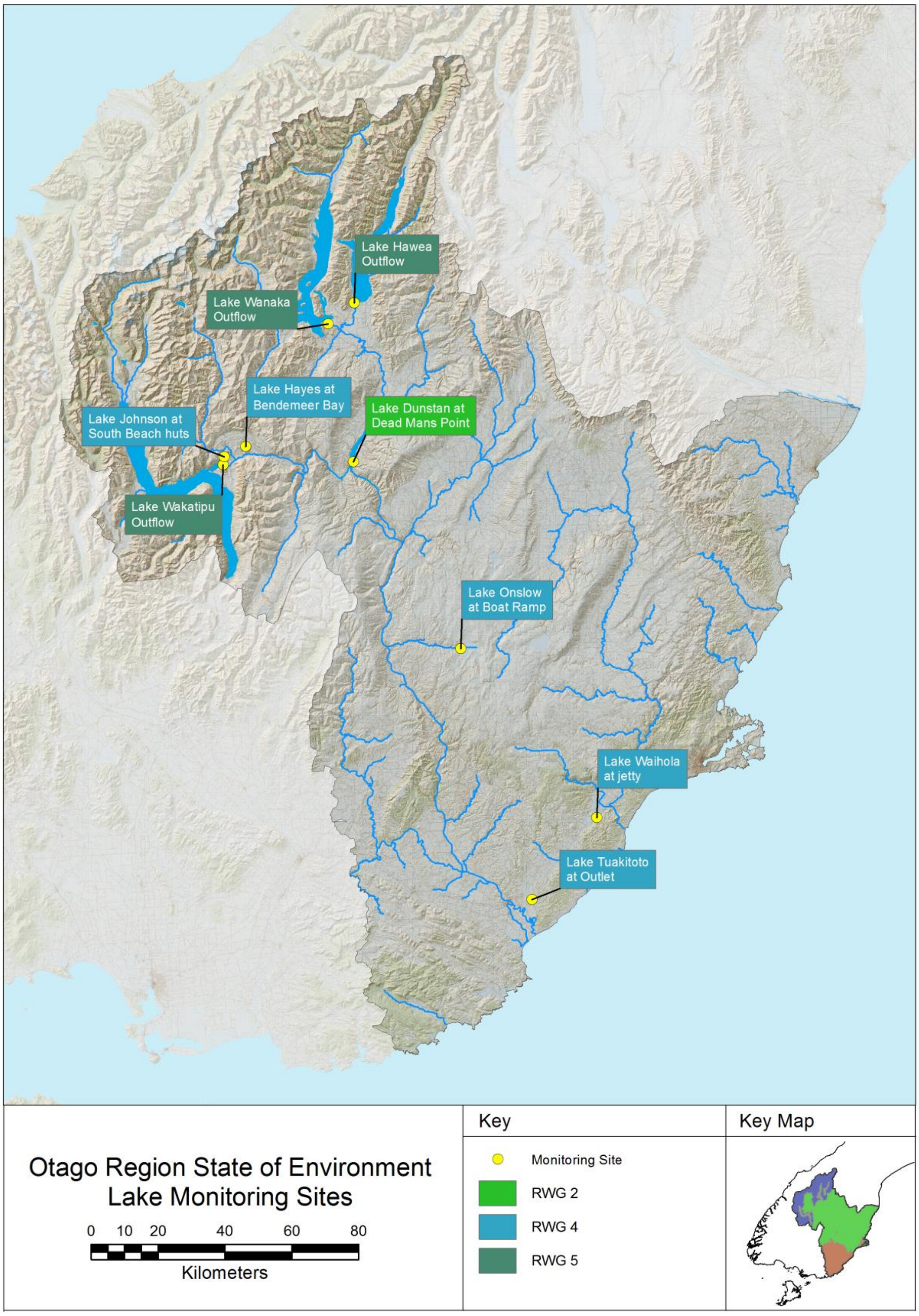

Figure 2: Location of long-term State of Environment lake monitoring sites covered in this report.

1.2.3. What we measure

Water quality parameters routinely measured at SoE monitoring sites include the following field-based measurements:

- Turbidity (NTU)
- Dissolved oxygen (mg/l)
- Conductivity (μS/cm)
- pH
- Water temperature (^{o}C)

Water samples are collected at each site and kept in chilled containers while being freighted overnight to the laboratory and analysed for total and dissolved nutrients (nitrogen and phosphorus), suspended solids, and faecal bacteria (as *E. coli*).

Nitrite-nitrate nitrogen (NNN) and dissolved reactive phosphorus (DRP) are dissolved inorganic forms of the nutrients nitrogen (N) and phosphorus (P) respectively. N and P are the two key nutrients required for growth of plants and algae. DRP includes phosphate. Although numerous other forms of nitrogen and phosphorus exist and are commonly referred to in the field of water quality (e.g., organic and particulate forms), it is the dissolved forms that are most readily available for uptake by plants and are thus most relevant for assessing effects on nuisance growths in rivers. The terms total nitrogen (TN) and total phosphorus (TP) refer to the sum total of all forms of N and P respectively in a sample. TN and TP are most relevant for assessments in lakes and coastal waters. At sufficiently elevated concentrations, nitrate and ammonia forms of nitrogen have toxic effects on aquatic biota (and on humans in the case of nitrate). This effect is independent of their significance as plant nutrients (Norton, 2012).

Visual periphyton cover and biomass estimates (as chlorophyll-*a*); visual clarity (as black disk sighting distance) and fine deposited sediment cover are not currently taken. No results are presented for these parameters.

1.2.4. Schedule 15 (Water Plan) limits

The Water Plan was approved on 26 March 2014 and made provision for controlling contaminants and sediment coming off rural properties into waterways from runoff, leaching and drains (non-point sources). The rules covering these areas aim to ensure good quality water in rivers, lakes, wetlands and aquifers.

Schedule 15 (Water Plan) describes and sets out the characteristics, contaminant concentration limits, and targets for good quality surface water in Otago rivers and lakes, as required by the National Policy Statement for Freshwater Management. Table 15.1 and Table 15.2 of the Water Plan (water quality) are reproduced as Table 1 and Table 2 below.

Table 1: 'Table 15.1' of the Water Plan 'Characteristics of good quality water'

Characteristic	Description
Clarity	Water is clear: able to easily and clearly see the bed when standing in knee-deep water. Naturally occurring scums and foams only.
Colour	Water is colour-free, however, some rivers are naturally tannin-stained e.g. The Catlin, Taieri, Waitahuna and Tokomairiro Rivers.
Algae	Healthy levels of algae: ▪ Do not cover more than 30% of the bed. ▪ Strands are less than 20 mm in length. ▪ No slime on the surface of the water.
Sediment	Riffles and runs are free of obvious mud and silt deposits. Walking across a riffle or run should not produce an obvious plume. However, some rivers are naturally high in sediment e.g. the Dart and Shotover Rivers.
Smell	Water is odourless, however, water in some wetlands may have a naturally earthy smell.
Bank	Functioning riparian margins: ▪ Vegetation is healthy and not stripped bare. ▪ Banks are stable with no obvious livestock disturbance.

Table 2 summarises the Schedule 15 (Water Plan) numerical limits (or numerical objectives under the NPSFM, 2014 nomenclature) for acceptable water quality for all receiving water 'Groups' throughout catchments in the Otago region. The receiving water numerical limits (outlined in Table 2) are applied as five-year, 80th percentiles, when flows are at or below median flow at the relevant flow reference site.

Table 2: 'Table 15.2' of the Water Plan. Receiving water numerical standards by surface water catchment group for good quality water (five-year, 80th percentiles, when flows are at or below median flow).

Schedule 15[3]	NNN (mg/L)	DRP (mg/L)	NH_4-N (mg/L)	*E. coli* (CFU/100 ml)	Turbidity NTU	TN (mg/L)	TP (mg/L)
Group 1	0.444	0.026	0.10	260	5		
Group 2	0.075	0.010	0.10	260	5		
Group 3	0.075	0.005	0.01	50	3		
Group 4			0.10	126	5	0.55	0.033
Group 5			0.01	10	3	0.10	0.005

Field data is not collected to assess SoE site compliance against the Schedule 15 (Water Plan) narratives for 'Characteristics of Good Water Quality' as outlined in Table 1. A review of the ORC SoE monitoring

[3] NNN = oxides of nitrogen or nitrate/nitrite- nitrogen; DRP= dissolved reactive phosphorus; NH4-N = Ammonical nitrogen; *E. coli* = faecal bacteria levels measured as *E. coli* in colony forming units (CFU) / 100ml; TN = total nitrogen; TP = total phosphorus

program currently being undertaken by NIWA should help address this should it be identified as a critical gap in the monitoring program.

The boundaries of the different receiving water 'Groups' or RWG's identified under the Water Plan are shown in Figure 1 for the river monitoring sites and in Figure 2 for the lake monitoring sites.

Compliance with Schedule 15 (Water Plan) numerical standards (Table 2) are summarised for all river and lake monitoring sites in the respective reporting sections. Should different Receiving Water 'Group' standards apply across a reporting region, the different standards that apply are clearly highlighted in the summary tables.

1.2.5. National Objective Framework (NOF) Attribute Bands under the NPS-FM (2014)

The National Policy Statement for Freshwater Management 2014 (NPS-FM 2014) sets out the objectives and policies for freshwater management under the Resource Management Act 1991. The NPS-FM 2014 came into effect on 1 August 2014 and is one of the initiatives developed as part of the Government's Fresh Start for Fresh Water programme of water reform.

The NPS-FM 2014 includes a National Objectives Framework (NOF) aimed at providing "an approach to establish freshwater objectives and national values, and any other values that: a) is nationally consistent; and b) recognises regional and local circumstances." (Objective CA1).

The government has recently amended the 2014 National Policy Statement for Freshwater Management in a 2017 Amendment to include a Clean Water Package. It sets national targets relating to 'swimmability' for New Zealand's rivers and lakes. The Clean Water Package includes numerous other changes to the NPSFM such as provisions for stock exclusion, and requirements for regional councils to monitor the ecological health of our rivers and lakes. The changes can be viewed online at the MfE website[4].

Appendix 2[5] of the NOF outlines several attribute tables. An attribute "is a measureable characteristic of freshwater, including physical, chemical and biological properties, which supports particular values". The NOF includes river-related attributes for periphyton (as chlorophyll *a*/m^2), nitrate-nitrogen (mg/L), ammoniacal-nitrogen (mg/L), dissolved oxygen (mg/L – applicable to downstream of point-source discharges only), and *E. coli* (as listed in the 2017 Clean Water Package and NPS 2017 amendments); and lake–related attributes for TP (mg/L), TN (mg/L) and phytoplankton biomass (ug/L).

Targets have been proposed within the NOF attributes that include "national bottom lines" (D band) – thresholds of water quality attributes that good management should prevent waterways from crossing. A "bottom line" is the minimum water quality level that all water bodies must achieve. Therefore the boundary between C and D describes the minimum acceptable state to provide for that value.

Each attribute table sets out the attribute and the unit in which it is to be measured (refer to Appendix B of this report titled NPSFM (2014) NOF Attribute Tables. It then sets out A, B, C and D bands and defines these in narrative and numeric terms, with "A" being the highest/best quality and "D" being below the national bottom line.

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4 https://www.mfe.govt.nz/sites/default/files/media/npsfm-showing-changes_0.pdf

5 https://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/nps-freshwater-management-jul-14.pdf

Escherichia coli Attribute – primary contact recreation

Microbial pathogens such as *Campylobacter* in fresh water primarily come from faecal contamination. It is difficult to detect pathogens in water samples obtained from freshwater sites. Methods for detecting and identifying viruses or parasites are either very difficult and/or expensive. Because of this, the main approach for assessing the presence of pathogens is to use 'indicator organisms' – organisms whose presence in the water is an indication of faecal contamination and therefore the potential that other pathogens might be present. *E.coli* are bacteria commonly found in the gut of warm blooded animals. *E. coli* survives outside the body and can survive for up to four to six weeks in fresh water making it a useful indicator of faecal presence and therefore of disease-causing organisms that may be present in faecal matter. *E. coli* is relatively straightforward and inexpensive to measure. MfE (2017).

The NPS (2014) defines attribute states for primary contact recreation based on *E. coli* levels as a faecal indicator to assess the risk of pathogenic infection from contact with water. "Primary contact" means people's contact with fresh water that involves immersion in water, including swimming.

Compulsory national values in the NPSFM (2014) for Human Health for Recreation state that "In a healthy waterbody, people are able to connect with the water through a range of activities such as swimming, waka, boating, fishing, mahinga kai and water-skiing, in a range of different flows.

Matters to take into account for a healthy waterbody for human use include pathogens, clarity, deposited sediment, plant growth (from macrophytes to periphyton to phytoplankton), cyanobacteria and other toxicants."

There are many factors that can affect whether a water body is suitable for swimming, such as water clarity, but the government has decided that swimmability will be assessed on potential health risks. This will be determined by *E. coli* concentrations (faecal indicator bacteria sourced from warm-blooded animals) in rivers; and toxic algae bio-volumes in lakes. A swimmable river is one with low levels of *E. coli* and a swimmable lake is one with low levels of toxic algae.

Clean Water Package 2017 - National Swimmability Targets

The government has recently amended the 2014 National Policy Statement for Freshwater Management (NPSFM). It sets national targets relating to 'swimmability' for New Zealand's rivers and lakes. The Clean Water Package included numerous other changes to the NPSFM such as provisions for stock exclusion, and requirements for regional councils to monitor the ecological health of our rivers and lakes. The changes can be viewed online at the MfE website[6].

The Government has set a national target of making 90 percent of New Zealand's rivers (fourth order or greater) and lakes (with perimeters greater than 1.5 km) swimmable by 2040. The stream order describes the relative size of streams. Streams with no tributaries are "first order", streams with two first order tributaries are second order, and with two second order tributaries arethird order and so on. Examples of fourth order streams in the Dunedin locale include the Water of Leith alongside the University of Otago, the Silverstream at Mosgiel and the Kaikorai Stream at State Highway 1. The Manuherikia River at Alexandra is seventh order and Otago's biggest river, the Clutha at Balclutha, is eighth order. Around 90 percent of New Zealand's catchments flow into rivers that are fourth order or bigger (MfE website).

The NPSFM grading proposals are based on a grading system that uses four statistical measures of *E.coli* concentrations when assessing river swimmability; and one statistical measure for toxic algae bio-volumes when assessing lake swimmability. The four statistical measures of river *E.coli* data are

[6] https://www.mfe.govt.nz/sites/default/files/media/npsfm-showing-changes_0.pdf

presented in the *E. coli* attribute table in Appendix B. As stated in the footnote to the table, "Attribute state must be determined by satisfying all numeric attribute states".

Otago Regional Council has set targets for *E. coli* for the region in The Water Plan under Schedule 15 (Water Plan) (Table 2). Comparison of Schedule 15 (Water Plan) limits of *E. coli* data collected throughout the region from the State of Environment monitoring network to the 4 separate statistical tests within the NPSFM has shown (Appendix H):

- That the *E. coli* limits set in Schedule 15 (Water Plan) for Receiving Water Group 3 (Upper Clutha upstream of the Southern Great Lakes) provides compliance against the four separate statistical tests in the NPSFM and as a minimum, will provide a blue (A grade) or green (B grade) swimmability category. The minimum requirement is a yellow or C grade.
- With the exception of some catchments in the Pomahaka catchment, the *E. coli* limits set in Schedule 15 (Water Plan) for Receiving Water Group 1 and 2 (that covers the remainder of the Otago region), will provide good compliance against the four separate statistical tests in the NPSFM, and as a minimum, will provide a blue (A grade), green (B grade) or in some cases an yellow (C grade) category. The yellow, C grade category being the minimum requirement.
- For Receiving Water Groups 4 and 5 that relate to the lakes throughout Otago, the *E. coli* limits set in Schedule 15 (Water Plan) provides compliance against the four separate statistical tests in the NPSFM and as a minimum, will provide a blue (A grade) or green (B grade) swimmability category. The minimum requirement is a yellow or C grade.

In the case of the Pomahaka catchment, monitoring sites in some catchments return high 95th percentiles at all flows, even though they may be compliant with the Schedule 15 (Water Plan) limit. This is believed to be due to effluent storage issues and a prevalence of mole and tile drains through areas of the catchment resulting in very high *E. coli* peaks under high flow conditions and elevated *E. coli* concentrations at low to moderate flows. ORC are working actively throughout the Pomahaka catchment with groups such as the Pomahaka Watercare Trust, the Landcare Trust and the Clutha Development Trust to address water quality issues. A large part of this effort is focused on improving bacterial water quality.

Toxicity and the Nitrate and Ammonia Attributes

The NOF nitrate and ammonia attributes help assess chronic toxicity risk for aquatic animals. Chronic exposure typically includes a biological response of relatively slow progress and long continuance, often affecting a life stage (Hickey, 2013). Such a response may be reduced growth rate or reduced gonad development when compared to optimum growth conditions (a control). It does not relate to acute toxicity effects that result in the death of an animal. The narratives for each ammonia and nitrate attribute band are included in Appendix B of this report titled NPSFM (2014) NOF Attribute Tables.

Regime shifts and the Total Phosphorus, Total Nitrogen and Phytoplankton (Trophic state) attributes for lakes

The NOF TN and TP attributes aim to manage against the risk of increased and excessive growth of algae and plants arising from elevated levels of nutrients above natural background levels.

Similarly the phytoplankton (Trophic state) attribute provides bands to assess the risk against 'lake ecological communities undergoing a regime shift to a persistent, degraded state, due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes' (NPSFM, 2014). The TN and TP attribute states are listed in Appendix B.

Reporting against NOF Attributes

Compliance of dissolved oxygen and periphyton biomass against attribute bands could not be assessed because there is presently insufficient monitoring data.

For rivers, where adequate monitoring data existed for *E. coli*, NNN and NH_4-N concentrations, NOF attribute states were calculated at each monitoring site and presented in summary tables in each respective reporting region section.

For lakes, where adequate monitoring data existed for TP, TN and phytoplankton (chlorophyll *a*) concentrations, NOF attribute states were calculated and presented in tables in the 'Otago Lakes' reporting section.

1.2.6. General Water Quality Guidelines

Environmental guidelines are often used to describe the general state of a natural resource, even though they may not be directly applicable in a regulatory context.

Table 3 outlines several relevant 'trigger values' and guidelines that are included in graphical summaries throughout this report. The various trigger values, guidelines and limits are discussed in the following paragraphs.

The ANZECC (2000) guidelines are used to indicate environmental conditions in "baseline" (essentially unaffected) or "pseudo-baseline" (lightly impacted) catchments (Davies-Colley, 2000). The 'trigger' values are based on water quality conditions taken from sites from the NIWA National River Water Quality Monitoring Network (NRWQMN) (Davies-Colley, 2000). The trigger values relate to 80th percentile or 20th percentile values for the data range taken from the NRWQMN.

In the development of the ANZECC (2000) trigger values, Davies-Colley (2000) states: 'running medians of water quality data measured in monitoring programmes may be compared with these trigger values. If the median value of a water quality variable for a particular site exceeds the trigger value, then it is intended to "trigger" a response on the part of water managers, which might be to initiate special sampling or carry out an investigation of reasons for the degraded water quality.'

The development of Schedule 15 (Water Plan) numerical limits were based, in part, on the ANZECC guidelines. The difference being that the adopted Schedule 15 (Water Plan) limits are assessed as 80th percentiles at times that flows are below median flow for the reference river flow site in question. ANZECC (2000) on the other hand compares median values at all flows to the suggested trigger values.

Hay *et al.* (2006) identified several limits for the protection of trout fisheries in their report 'Water quality guidelines to maintain trout fishery values'. The report was produced on behalf of Horizons Regional Council in the development of their One Plan.

The MfE/MoH (2003) 'microbiological water quality guidelines for marine and freshwater areas' are used extensively to assess 'risk' in relation to contact recreation and exposure to bacteria present in aquatic environments. The RMA (1991) outlines a dissolved oxygen saturation limit for the protection of trout fisheries.

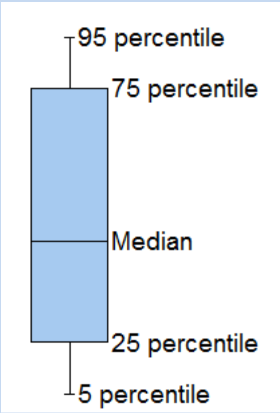
Table 3: Relevant general water quality guidelines referenced in this report.

Variable[7]	Trigger / Limit	Source
NH_4-N – ANZECC Lowland	0.021 mg/L	ANZECC (2000)
NH_4-N – ANZECC Upland	0.010 mg/L	ANZECC (2000)
DIN/NNN – ANZECC Lowland	0.444 mg/L	ANZECC (2000)
DIN/NNN – ANZECC Upland	0.167 mg/L	ANZECC (2000)
TN – ANZECC Lowland	0.614 mg/L	ANZECC (2000)
TN – ANZECC Upland	0.295 mg/L	ANZECC (2000)
DRP – ANZECC Lowland	0.010 mg/L	ANZECC (2000)
DRP – ANZECC Upland	0.009 mg/L	ANZECC (2000)
TP – ANZECC Lowland	0.033 mg/L	ANZECC (2000)
TP – ANZECC Upland	0.026 mg/L	ANZECC (2000)
Turbidity – ANZECC Lowland	< 5.6 NTU	ANZECC (2000)
Turbidity – ANZECC Upland	< 4.1 NTU	ANZECC (2000)
E. coli – Contact recreation (health) Red alert	> 550 (CFU/100ml)	MfE/MoH (2003)
E. coli – Contact recreation (health) Amber alert	> 260 (CFU/100ml)	MfE/MoH (2003)
MCI 'Outstanding' trout fishery; Excellent quality	> 120	Hay and Hayes (2006); Stark and Maxted (2007)
MCI 'Significant' trout fishery; Good quality	> 100	Hay and Hayes (2006); Stark and Maxted (2007)
MCI Poor quality	>80	Stark and Maxted (2007)
MCI Degraded quality	<80	Stark and Maxted (2007)

1.2.7. Data analysis and presentation

Box plots have been used throughout the report to summarise water quality data. The sites are ordered from right to left in ascending order based on distance from the sea along the river channel and north to south for the differing river catchments that may be included across a reporting region.

Box plots graph data as a box representing statistical values. The lower boundary of each box indicates the 25th percentile, a line within the box marks the median, and the higher boundary of each box indicates the 75th percentile. The line at the end of the whiskers (error bars) above and below the box indicate the 95th and 5th percentiles respectively.



[7] TN = total nitrogen; TP = total phosphorus; NNN = oxides of nitrogen or nitrate/nitrite- nitrogen; DRP= dissolved reactive phosphorus; *E. coli* = faecal bacteria levels measured as *E. coli* in colony forming units (CFU) / 100ml; MCI = Macroinvertebrate Community Index.

Numerous sites had insufficient data to allow for robust trend analysis of some water quality parameters. The two main reasons being too many observations returned from the laboratory that were below method detection level; and sites with intermittent observations over the 11 year analysis period; or a combination of the two. The trend analysis for NH_4-Nis a good example of this where many sites across Otago frequently have NH_4-N concentrations that are below the laboratory detection level. Should this occur then the trend analysis summary tables list the result as “<DL” reflecting that too many observations were received from the laboratory that were below detection level.

For future analysis and reporting, the occurrence of this will be markedly lower due to improvements in laboratory method detection levels that have occurred in recent years.

Compliance against Schedule 15 (Water Plan) limits; NPSFM (2014) NOF attribute bands; and box plot summaries that include generic water quality guidelines are based on the last 5 years of data to best represent current conditions whilst maintaining an adequate number of data points to calculate the required statistics.

Trend analysis

Trend analysis of environmental monitoring data is important because environmental features may exhibit trends which indicate particular issues are changing over time. For example, if bacteria levels are increasing or decreasing at a particular site, the cause and significance of these changes may need to be identified.

In this report trend analysis was carried out using the Time Trends (V6.30) software (Jowett Consulting). The approach takes into account a number of challenges and limitations that exist with the long-term SoE data set held by ORC. Such challenges include:

- Changes in laboratory supplier over the analysis period that can introduce ‘step changes’ in the data set. This was evident for TP and DRP with a change in laboratory supplier that occurred mid-2011;
- Changes in method Detection Levels (DL) for a given analyte over time;
- Changes in sampling frequency, bimonthly pre 2013, monthly post 2013;
- The availability of flow data for all sites to allow consistent flow adjustment of trends for flow effected variables (eg turbidity, *E. coli* and TP). At present ORC measures flow continuously at 25 of the 60 SoE river monitoring sites;
- Intermittent periods of sampling for some sites (eg. monthly for twelve months, then no sampling for three years, then bi-monthly for three years and then monthly);
- Rounding of laboratory results resulting in very little variation between sampling dates for sites with very low nutrient levels (eg. Lake Hawea Outflow and DRP).

These challenges are not atypical of long-term New Zealand regional council SoE data sets.

For future analysis, improvements in laboratory detection levels and commitment from ORC to move from bi-monthly to monthly sampling in 2013 will remove some of these confounding factors.

Trend analysis employed either a Mann-Kendall or Seasonal Kendall trend test. Both trend analysis methods are non-parametric and calculate the Kendall Statistic. Mann-Kendall is used when there is no seasonal trend in the data, so that data values in a season are compared with all other seasons. The Seasonal Kendall test is used when there is seasonality in the data, so that data values are only compared within the season. If Mann-Kendall is used with seasonally varying data, it will be less likely to determine a significant trend than the Seasonal Kendall. Mann-Kendall is more powerful if there is no seasonal variation because it makes more comparisons (Jowett, 2017).

A Kruskal-Wallis (non-parametric ANOVA) test was applied to the data to test for seasonality. If the Kruskal-Wallis test showed statistically significant seasonality, then a Seasonal Kendall trend test was used. If there was no seasonality present in the data, a Mann-Kendall trend test was used.

To estimate the strength of trends over time, a Sen slope estimator was used. This non-parametric approach involves computing slopes for all the pairs of ordinal time points and then using the median of these slopes as an estimate of the overall slope. As such, it is insensitive to outliers and can handle a moderate number of values below the detection limit and missing values.

The Sen slope can be used to estimate Percent Annual Change (PAC). A trend with a PAC of greater than 1% per year was considered meaningful.

All sites had monthly data from January 2013. Prior to this date, for ORC managed SoE sites, samples were collected on a bi-monthly basis. For ORC data, so as to not bias the analysis, a bi-monthly sampling period was chosen for the whole data record to avoid biasing the analysis to the latter part of the period. July was used as the 'start' month, i.e. the sampling interval was bi-monthly for Jul-Aug; Sept-Oct, Nov-Dec; etc. over the ten year analysis period.

Cumulative sum analysis in Time Trends (V6.30) identified significant step changes in TP and DRP data that occurred mid-2011. This date coincides with ORC changing their laboratory service provider and is evidence of a step-change brought on by this change. The presence of a step change mid-way through the time-series data (July 2006 to June 2017) significantly affected the trend analysis for these two variables and introduced a significant number of 'decreasing' trends that were driven by laboratory step changes as opposed to environmental changes. To control for this, trend analysis for TP and DRP was undertaken on data collected from August 2011 to June 2017.

The majority of ORC's SoE monitoring sites do not have flow recorders located at the monitoring site. It is therefore not possible to obtain accurate estimates of flow for all SoE sites. 25 sites have continuous flow recorders located in a proximity that allows for accurate estimates of flow to be made at the water quality sample site. Flow adjustment in the trend analysis was undertaken at these sites. All other sites were not flow adjusted. Appendix C lists the ORC SoE sites that have flow recorders and that flow adjustment of trends was possible.

A number of variables had differing method detection levels (DL) over the trend analysis time period. This introduced a bias towards detecting false 'decreasing' trends where the detection level was reduced over time. To control for this all measurements that were below the highest method detection level were made to be equal to that method detection level. For example, DRP had a historic DL of 0.004 mg/L; recently this was reduced to 0.001 mg/L. This introduced a significant bias of detecting false decreasing trends towards the latter period of the times series. To control for this all observations in the data set that were < 0.004 mg/L were made equal to 0.004 mg/L. This was done after consultation with Jowett Consulting, the creator of the Time Trends software.

Trend analysis was carried out on 7 core water quality variables, these being NH_4-N; NNN; TN; DRP; TP; Turbidity and *E. coli.* Analysis was carried out on data collected at 60 river sites and 9 lake shore/outlet sites giving a total of 490 individual trend analysis. For each individual analysis, time series plots were examined to assess if the following was evident:

- Step changes in the time series due to analytical methods or laboratory changes;
- Spurious results affecting the analysis;
- The extent of patchy or missing data;

- The presence of rounding or resolution effecting the capacity to detect variation in the time series (DRP being an example for sites with very low concentrations);
- 'Indeterminate' trends or obvious anomalies in data series effecting results;
- Excessive numbers of results below laboratory detection level (as is the case for NH_4-N at many sites).

Taking these factors into account, and with the time-series plots on hand, the existence of a trend in the time series was assessed based on both the Kendall statistic P-value and the probability of the Sen slope being less than or greater than zero, that is the confidence interval of the slope does not straddle zero (or no slope/no change over time).

The strength or 'significance' of the trend was assessed as being SIGNIFICANT or PROBABLE based on the following -

- Should the Kendall statistic P-value be <0.05; the Probability that the Sen Slope is less than or greater than 0 be 1.0 to 0.95; and the Percent Annual Change in the Sen Slope is > 1%; label "**SIGNIFICANT"**;
- Should the Kendall statistic P-value be 0.05 to 0.10; the Probability that the Sen Slope is less than or greater than 0 be 0.9 to 0.95; and the Percent Annual Change in the Sen Slope is > 1%; label "**PROBABLE"**;
- Where the P-value is > 0.10 and the Probability > 0.5 but less < 0.9, and the trend is obviously not 'Stable' over time; and the analysis is limited by power, identify as **INDETERMINATE or "?"** in the trend summary tables. In this case a trend is likely present but the data set does not allow this to be confidently identified. With more observations, a trend may become evident over time but at this stage, confidence is low.
- Where the P-value ~ 1; the Probability ~ 0.5; and the Sen Slope ~ 0; label "**STABLE".** This identifies that there is no trend evident in the times series and apart from typical seasonal and temporal variation, the overall trend is flat or 'stable' over time.
- Where there is not enough data, such as > 40% of samples returned a result from the laboratory that was 'less than detect', or there are other constraints/limitations in the data such as lo ow numbers if observations, highlight as "**NOT ENOUGH DATA"** or **"<DL"** in the trend summary tables**.**

So in summary, the analysis was broken down according to the following 'trend' categories (also refer to Figure 3):

SIGNIFICANT – A trend has been confidently identified, has a significant P-value < 0.05 and the Probability that the slope confidence intervals do not cross 0 is very high at > 0.95. Time-series plot shows an obvious trend.

PROBABLE – It is highly probable that a trend is present but the P-value for the Kendall statistic is > 0.05 but < 0.10. There is a high Probability that the trend line slope is positive or negative at > 0.90. The Timeseries plot shows evidence that a trend is present.

STABLE – There no discernible change over time and the time series plots reflect a this. The Sen slope is ~ 0, the P-value is high (approaching 1) and the Probability is close to 0.5. Also the confidence intervals around the slope are very close to 0.

INDETERMINATE (STABLE/NO CHANGE) – There is no obvious trend but with more data a trend may become evident. The statistics do not reflect a 'stable trend' nor a 'significant' or 'probable' trend.

NOT ENOUGH DATA – Where the data is patchy, limited by too many non-detects or missing data (> 40% of observations).

Trends have been summarised in table form as outlined in Figure 3.

Symbol	Trend result
↑↑↑	Increasing Significant
↑↑	Increasing Probable
→	Stable
↓↓	Decreasing Probable
↓↓↓	Decreasing Significant
?	Indeterminate / Not Enough Data
< DL	More than 40% of data below detection level

Figure 3: Summary of symbols used for trend result summary tables.

1.2.8. Land Use capability

The LUC[8] is a system in use in New Zealand since the 1950s that classifies all of New Zealand's rural land into one of eight classes, based on its physical characteristics and attributes. The LUC maps are created to represent the potential uses of a "unit" of land. They are measured using various indicators, although the most common are five physical factors (rock type, soil type, slope, erosion degree and type, and vegetation). Class 1 land is the most versatile and can be used for a wide range of land uses. Class 8 land has a lot of physical limitations; it may be extremely steep, and not generally suitable for arable, pastoral or commercial forestry use. Land use capability maps must not be confused with land use maps. The former shows the potential uses (usually in relation to farming) whilst the latter shows the actual use for the land at the present time.

[8] https://www.landcareresearch.co.nz/publications/books/luc

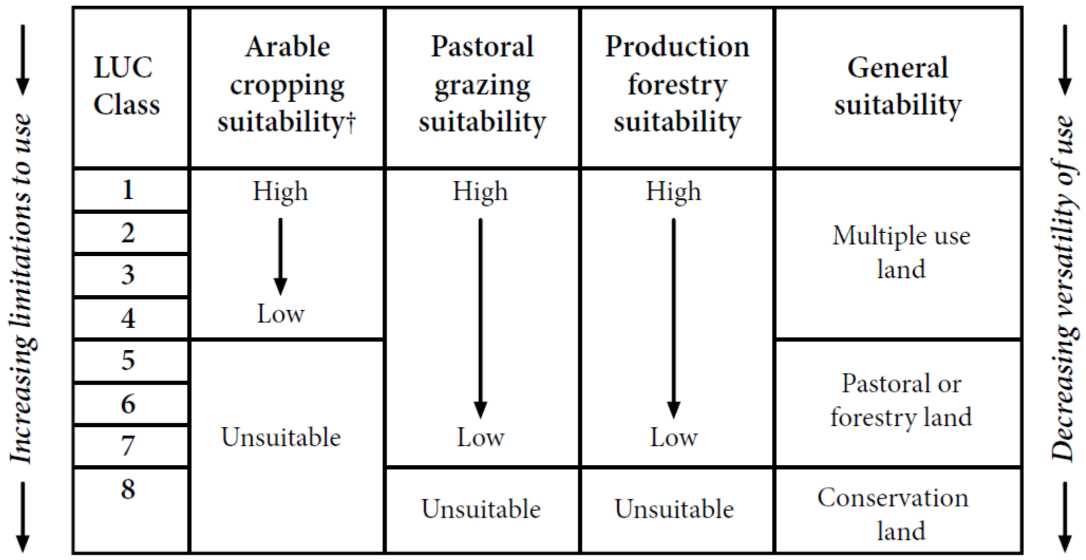


Figure 4: Increasing limitations to use and decreasing versatility of use from LUC Class 1 to LUC Class 8. *Source[9]: Figure 2, page 9, Lynn et al. (2009).*

Table 4: LUC Class descriptions (Lynn et al. 2009).

LUC Class	LUC Description
Class 1	Versatile arable land for multiple land-uses
Class 2	Arable land with only slight physical limitations to land-uses
Class 3	Arable land with moderate physical limitation to land-uses
Class 4	Arable land with severe physical limitation to land-uses
Class 5	High-producing land for pasture or forestry with minimal physical limitations
Class 6	Moderate-producing pastoral or forestry with moderate physical limitations
Class 7	Low-producing land for pastoral or forestry with severe physical limitations
Class 8	Severe to extreme physical limitations, unsuitable for arable, pastoral or forestry land-uses
River /Town/Lake	River open water and urban areas unsuitable for arable land-uses, pasture or forestry.

[9] https://www.landcareresearch.co.nz/__data/assets/pdf_file/0017/50048/luc_handbook.pdf

2. Water quality of Otago

Due to the size of the Otago region, discussion of water quality characteristics, state and trends has been separated into logical geographical and catchment areas. The different regions identified in this report being:

- North Otago
- Dunedin / Southern Coastal
- Taieri
- Upper Clutha
- Middle Clutha (including the Manuherikia catchment)
- Lower Clutha / Pomahaka
- Lakes

Each section includes a brief introduction of the general characteristics of the reporting region including dominant land-use, river characteristics, land vegetation cover information and a Land Use Capability (LUC) summary.

Following a summary of general characteristics of the reporting region in question, the state and trends of water quality are discussed for each region in relation to:

- Compliance with Schedule 15 (Water Plan) numerical limits;
- The NPSFM (2014) NOF attribute bands for water quality parameters that data is available to assess against the NOF;
- Box plot summaries of key water quality variables with inclusion of ANZECC general water quality guidelines;
- The results of the trend analysis.

Appendix E shows Otago wide boxplot summaries of key water quality variables discussed in regional reporting section and Appendix G provides a ranking of site 'medians'. The Otago wide summaries help put individual sites and the wider reporting regions into an Otago wide context.

2.1. North Otago river catchments overview

The North Otago reporting region spans an area of 2202 km^2 (220208 hectares) and encompasses parts of the lower Waitaki Plains (Welcome Creek); the Kakanui catchment that includes the Kakanui River, Kauru River and Waiareka Creek; the Waianakarua Stream and Trotters Creek with catchments that drain independently to the sea; and to the south, the Shag River.

The Kakanui River catchment has an area of 894 km^2. The catchment is bordered by the Kakanui Mountains and Pisgah Spur to the west and south and is separated from the Waitaki catchment to the north by rolling hill country. The main tributaries of the Kakanui River are the Kauru River (catchment area 143 km^2), Island Stream (122 km^2) and Waiareka Creek (213 km^2) (Ozanne and Wilson, 2013).

From its source in the Kakanui Mountains, the Kakanui River flows north-east for about 40 km, through gorges incised in rolling or downland country, before emerging onto plains at Clifton. It then flows south-eastwards at a gentler gradient through highly developed pastures to be joined further down the widening valley by the broad, gravel-bedded Kauru River (Ozanne and Wilson, 2013).

The Kakanui River's water resource is heavily used for irrigation. In recent times concern has been expressed about agricultural intensification and subsequent degradation of the water quality. Over the past twenty years, land use in the Kakanui catchment has intensified. The lower Kakanui River and Waiareka Creek are dominated by a mixture of beef/sheep/deer/cropping and, in recent times, dairy farming, particularly since the introduction of irrigation water into the Waiareka Creek catchment by the NOIC irrigation scheme. This is in contrast to land use in the Kauru and upper Kakanui which are typified by red tussock, native forest, plantation forestry or pasture for red deer, sheep and beef. The water quality in the alluvial gravels of the Kauru River and the main-stem Kakanui River, particularly upstream of Gemmels Crossing, is influenced by groundwater surface water interaction. There is very little groundwater surface water interaction in Waiareka Creek (Ozanne and Wilson, 2013).

During February 2002, the North Otago Downlands Water Company (now North Otago Irrigation Company Ltd or NOIC) was granted a resource consent by Environment Canterbury to take 8 cumecs (8000 L/s) of water from the Waitaki River and use the water for spray and trickle irrigation across the Waiareka Creek, Kakanui River and Island Stream catchments in Otago. The NOIC scheme pumps water from the Waitaki River up to a head pond near Ngapara. The water is then gravity fed into the Waiareka Valley. Pressurised water is delivered to the farm gate via NOIC's piped network. Some water is also discharged into the Waiareka Creek. NOIC currently delivers over 4 cumecs (4000 L/s) of water to approximately 14,000ha[10]. A condition of ORC Consent 2001.658 was for the irrigation company to maintain a minimum flow of at least 100 L/s in Waiareka Creek at its confluence with the Kakanui River.

In 2011, ORC initiated a ten-month water quality sampling programme to gain a better understanding of water quality and ecological values in the Kakanui catchment. The results of the study are reported in Ozanne and Wilson (2013). An additional intensive water quality sampling program was carried out between April 2014 and April 2017. The aim of the more recent study was to better understand groundwater-surface water interactions in the catchment. The data from this study being used to develop a groundwater- surface water quality model that will support Otago Regional Council in identifying a sustainable nitrogen leaching threshold for the Kakanui Catchment to meet Schedule 15 (Water Plan) limits and protect the values of the Kakanui Estuary.

The Waianakarua River is a small river with a catchment area of 262 km^2 which rises in the Horse Range and Kakanui Mountains in North Otago. Much of the catchment consists of extensively grazed grasslands and scrub, native forest and plantation forestry. However, the intensification of land use in the lower catchment, with two dairy farms operating near the mouth of the river and proposals for further intensification of land use in areas upstream of State Highway 1 (SH1), has previously been identified as having the capacity to affect water quality in the lower part of the river (Olsen, 2013). Previously ORC have undertaken and reported on an intensive catchment study of the Wainakarua River (Olsen, 2013).

The Shag River catchment covers an area of 550 km^2. The Shag River is a medium sized river with its headwaters originating on the south-western slopes of Kakanui Peak in the Kakanui Mountains. From here it flows 90km in a south-easterly direction past the township of Palmerston before entering the Pacific Ocean to the south of Shag Point. The Shag River supports high values including a high diversity of native fish, habitat for waterfowl, and regionally significant trout and whitebait fisheries. The Shag catchment is dominated by extensive agriculture and forestry with some short-rotation cropping in the lower catchment. There is currently no dairy farming in the Shag catchment, although some farms are used for dairy support (Olsen, 2014).

In parts of the Shag River catchment, Oceana Gold Ltd. operates a hard-rock goldmine at Macraes Flat. The mining operation includes several open pit mines as well as underground mining. The Macraes open pit mine has been in operation since 1990. Overall the Macraes gold mining operation has produced over 3 million ounces of gold to date. Within the Shag River catchment, the existing mine

[10] http://www.noic.co.nz/docs/NOIC%202015%20FAQ.pdf

operation discharges water and associated contaminants to the Deepdell Creek catchment (Olsen, 2014). This current report does not consider the effects of the mining operation on Shag River water quality. The operation of the Oceana Gold Macraes Flat gold mine is covered by numerous consents that include extensive monitoring and reporting requirements. Reports on the results of the monitoring are available on request through Oceana Gold.

2.1.1. North Otago river and land cover characteristics

Table 5 summarises characteristics of the North Otago reporting region based on the River Environment Classification (refer Appendix F for a detailed overview of the REC); land-cover (based on the Land Cover Database Version 4; condensed with the approach summarised in Appendix D); and the Land Use Capability (LUC) classes (see Section 1.2.8 for the LUC definition).

According to the River Environment Classification (REC), The North Otago reporting region is dominated by rivers and streams with catchments that receive very low rainfall (less than 500mm annual average rainfall) and are predominantly Cool/Dry low elevation rivers (63%) and Cool/Dry Hill rivers (34%) (Table 5). The predominantly dry climate combined with significant areas of low relief land typical of the lower Waitaki Plains (Welcome Creek); the Kakanui River and Waiareka Creek catchments; and the lower Shag River catchment, provides opportunity for irrigation and provide for areas of cropping (total cropping area 2.7 % or approximately 6000 hectares; Table 5, Figure 5). More intensive land-uses associated with irrigated pasture and cropping can add pressure to water resources and water quality.

The predominant land cover throughout the North Otago reporting region is high producing grassland (51%). High producing grassland reflects areas that are actively managed and grazed for wool, lamb, beef, dairy or deer production (Table 5, Appendix D). This land cover dominates the Kakanui and Shag River catchments (Figure 5).

The upper reaches of the Kakanui, Wainakarua and Shag River catchments sit in the Kakanui Mountains and Horse Range. These areas have LUC classes of 6 and greater and are less suitable for intensive grazing. These areas are dominated by low producing grassland, production forestry and native cover. A significant proportion of the upper Wainakarua catchment is dominated by native cover (Figure 5). 'Low Producing Grassland' includes exotic and indigenous grasslands grazed for wool, sheep or beef and are usually found on steep hill country (Appendix D). These low intensity land-uses typically leach low levels of nutrients and provide for good water quality.

Rivers with low water yield (those on dry areas) have reduced dilution and flushing capacity. They tend to be more susceptible to elevated nutrients should intensive land-uses fall within their catchments.

Table 5: Characteristics of the North Otago reporting region (220,280 hectares). Source of flow, Land Cover Area and Land-use Capability.

Source of flow (REC)		Land Cover Area (LCDB4)		Land-use Capability Class (LUC)	
Cool-Dry / Hill	34.1%	Cropping	2.7%	Class 2	8.2%
Cool-Dry / Low-Elevation	62.5%	High producing grassland	50.5%	Class 3	19.1%
Cool-Dry / Mountain	0.7%	Low producing grassland	20.9%	Class 4	19.5%
Cool-Wet / Lake	0.1%	Native Cover	15.1%	Class 5	0.1%
Cool-Wet / Mountain	2.6%	Orchards/Vineyards	0.04%	Class 6	39.3%
		Plantation forestry	7.9%	Class 7	11.5%
		Unaccounted	2.1%	Class 8	0.7%
		Urban areas	0.8%	River	1.2%
				Town	0.4%

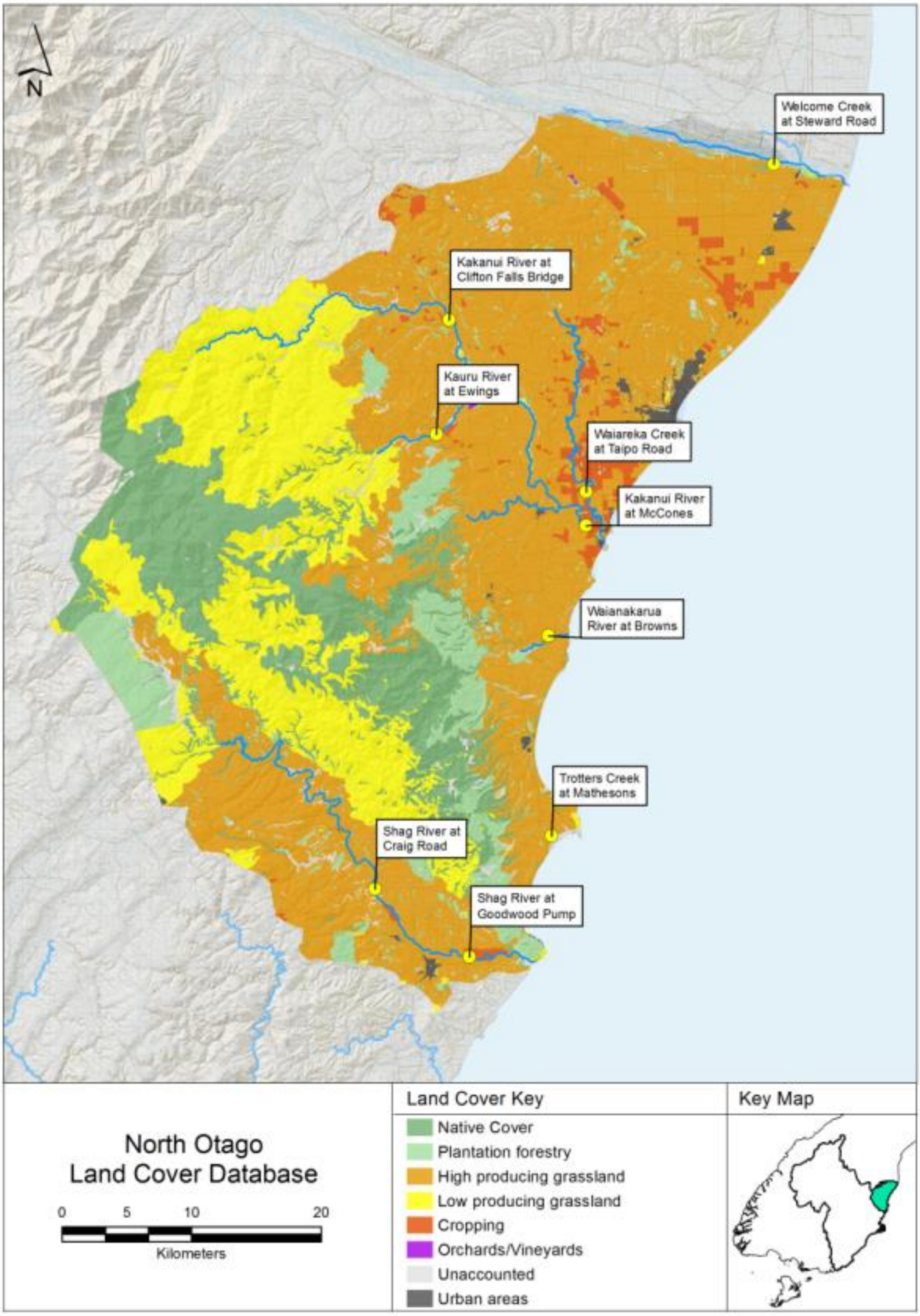


Figure 5: Map showing broad land cover categories of the North Otago reporting region based on the LCDB Version 4 database.

2.1.2. North Otago water quality

The following section provides a summary of the North Otago reporting regions' water quality based on:

- Compliance with Schedule 15 (Water Plan) numerical limits ;
- National Policy Statement for Freshwater Management (NPSFM 2014) National Objectives Framework Attribute bands (NOF bands);
- Summary boxplots of key water quality indicators with the inclusion of general water quality guidelines such as ANZECC (2000);
- A summary of trends (degrading/improving) that may (or may not) be evident in the data.

Schedule 15 compliance

Table 6 summarises compliance for SoE monitoring sites throughout the North Otago reporting region with Schedule 15 (Water Plan) limits. For this section, all '80th percentile concentrations' are calculated from data collected when flows are below median flow at the relevant flow reference site.

All sites are compliant for NH_4-N and have 80th percentile concentrations below at least half of the Schedule 15 limit of 0.100 mg/L. Ammonia is toxic to aquatic life. In the environment, NH_4-N is quickly converted to nitrate-nitrogen by bacteria. The presence of elevated NH_4-N in a stream or river typically reflects direct contamination from a source that is high in this contaminant, an example being effluent. The combined presence of high NH_4-N, dissolved reactive phosphorus and faecal bacteria such as *E. coli* provides further evidence of this type of contamination, and would be expected to be present should significant amounts of effluent be reaching a stream or river.

Looking across all variables, the Kauru River at Ewings, and Kakanui River at Clifton Falls are the only two monitoring sites in the North Otago reporting region that are fully compliant with Schedule 15 Schedule 15 (Water Plan) limits. Both of these sites have upstream catchments dominated by low-producing grasslands made up of exotic and indigenous grasslands, with some areas of native cover (Figure 5). The higher elevation areas in the upper catchments also have higher water yields due to increased rainfall (Ozanne and Wilson, 2013), this coupled with low-intensity land-uses typical of the upper catchment of these two sites combine to provide water quality with low levels of contaminants.

The next most compliant site is the Shag River at Craig Road that is only marginally non-compliant for NNN with an 80th percentile concentration of 0.087 mg/L compared with the Water Plan limit of 0.075 mg/L.

All remaining sites are non-compliant and are well above the Water Plan NNN limit with the two worst sites, the Waiareka Creek at Taipo Road being five times; and Welcome Creek at Steward Road being 18 times the NNN limit.

DRP and *E. coli* compliance across sites is fair with 3 out of 9 sites being non-compliant for both. For DRP, Waiareka Creek is excessively high with an 80th percentile of more than 14 times the Water Plan limit. This coupled with poor NNN and *E. coli* compliance is of particular concern.

The Kakanui at Clifton Falls elevated *E. coli* concentration, past and present, is attributed to a colony of black-billed gulls that live upstream of the monitoring site. The *E. coli* bacteria are derived from this population and not related to land-use or poor land-management practices. The black-billed gull is endemic to New Zealand and has a conservation status of 'Nationally Critical'. The presence of a colony of these birds in Kakanui River catchment is an asset to the Otago region.

Table 6: 80th percentile values for water quality variables identified in Schedule 15. Values are calculated from samples taken when flows are below median flow. The orange cells show where the 80th percentile exceeds the Schedule 15 limit.

Variable	NNN	NH_4-N	DRP	*E. coli*	Turbidity
Schedule 15 limit when flows < median flow	0.075 mg/L	0.100 mg/L	0.010 mg/L	260 CFU	5.00 NTU
SoE reporting name					
Welcome Creek at Steward Road	1.400	0.020	0.033	454	0.73
Kakanui River at Clifton Falls Bridge	0.037	0.009	0.003	324	0.63
Kauru River at Ewings	0.025	0.009	0.004	138	0.42
Kakanui River at McCones	0.187	0.022	0.004	160	0.76
Waiareka Creek at Taipo Road	0.410	0.039	0.140	460	1.80
Waianakarua River at Browns	0.248	0.007	0.007	130	0.40
Trotters Creek at Mathesons	0.228	0.016	0.008	120	2.16
Shag River at Craig Road	0.086	0.007	0.006	138	0.55
Shag River at Goodwood Pump	0.260	0.011	0.011	240	0.70

Nitrate and ammonia toxicity and NOF compliance

It is important to note that the NOF nitrate and NH_4-N attributes focus on protection of ecosystem health and life supporting capacity by providing protection against toxicity effects. Toxicity effects occur if concentrations of these contaminants reach high levels (refer Section 1.2.5). It is important to realise that toxicity effects occur at concentrations *far* greater than those that stimulate algal growth and eutrophication[11] effects. The limits identified in the Water Plan for NNN and the generic ANZECC trigger levels discussed in the following section, are more closely aligned with those necessary to guard against eutrophication of our waterways.

NOF attribute bands for nitrate are summarised in Table 7. With the exception of Welcome and Waiareka creeks, all sites are in the "A band". If a site falls in the A band then there is "unlikely to be [toxicity] effects even for sensitive species". This shows, for these sites at current concentrations, there to be a high level of protection against nitrate toxicity.

Both elevated median and 95th percentile nitrate concentrations push Welcome Creek into the 'B' band, for Waiareka Creek, the 95th percentile concentration is also in the B band; however for this site, the median concentration is more than half that of the A band cutoff of 1.0 mg/L. Based on nitrate concentration peaks (95th percentile concentrations), both sites can be categorised as being in the "B band" for the NOF nitrate attribute. The B-band reflects an environment that may have "some growth effect on up to 5% of species" in regards to a chronic nitrate toxicity effect (Appendix B). This provides for a good level of protection with some minor effects on growth rate of the most sensitive species (Hickey, 2013).

NOF attribute bands for NH_4-N are summarised in Table 8. With the exception of Waiareka Creek and the 95th percentile NH_4-N concentration, all sites are graded as being in the "A band" and reflect an environment where there is "no observed [toxicity] effect on any species tested" and provide a 99% species protection level (Appendix B), being the highest protection banding. The 95th percentile NH_4-N concentration for Waiareka Creek pushes this site into the "B band". The B band reflects an

[11] Eutrophication is the term used to describe enrichment of a water body with nutrients, usually an excess amount of nutrients that induces growth of plants and algae to nuisance levels.

environment where NH_4-N concentrations "start impacting occasionally on the 5% most sensitive species" (Appendix B).

Both the A and B bands provide a good level of protection against toxicity effects and in the case of nitrate and NH_4-N, it is highly unlikely that there would be any chronic toxicity effects on aquatic species present at these sites.

Table 7: NOF compliance summary for Nitrate (estimated from NNN). Included are median and 95^{th} percentile values for the period July 2012 to June 2017 and the corresponding NOF attribute bands.

Variable	Nitrate as NNN		NOF Band	
SoE reporting name	Median (mg/L)	95^{th} Percentile (mg/L)	Median	95^{th} Percentile
Welcome Creek at Steward Road	1.463	2.146	B	B
Kakanui River at Clifton Falls Bridge	0.018	0.091	A	A
Kauru River at Ewings	0.013	0.079	A	A
Kakanui River at McCones	0.267	0.600	A	A
Waiareka Creek at Taipo Road	0.480	1.747	A	B
Waianakarua River at Browns	0.193	0.520	A	A
Trotters Creek at Mathesons	0.560	1.432	A	A
Shag River at Craig Road	0.104	0.496	A	A
Shag River at Goodwood Pump	0.219	0.649	A	A

Table 8: NOF compliance summary for NH_4-N. Included are median and maximum values for the period July 2012 to June 2017 and the corresponding NOF attribute bands.

Variable	Ammoniacal nitrogen (unadjusted)		NOF Band	
SoE reporting name	Median (mg/L)	Maximum (mg/L)	Median	Maximum
Welcome Creek at Steward Road	0.008	0.024	A	A
Kakanui River at Clifton Falls Bridge	0.005	0.018	A	A
Kauru River at Ewings	0.004	0.011	A	A
Kakanui River at McCones	0.007	0.019	A	A
Waiareka Creek at Taipo Road	0.024	0.106	A	B
Waianakarua River at Browns	0.005	0.014	A	A
Trotters Creek at Mathesons	0.012	0.025	A	A
Shag River at Craig Road	0.005	0.011	A	A
Shag River at Goodwood Pump	0.006	0.016	A	A

E. coli, swimmability and NOF compliance

Table 9 summarises compliance for *E. coli* against the four statistical tests of the NOF *E. coli* attribute.

With the exception of Waiareka Creek, and to a lesser extent Welcome Creek, all sites have a high level of compliance and return an A (blue) or green (B) attribute state. This is a great result for the North Otago reporting region and shows sites to have good water quality in regards to swimmability. The high 95th percentile for Welcome Creek pushes it into the upper C band; the threshold from a C band to a D band is 1200 CFU/100ml (Appendix B) so Welcome Creek, should *E. coli* peaks increase, will go from an acceptable C band to an unacceptable D band.

Waiareka Creek fails all attribute states returning a 'D' band for all. This aligns with Waiareka Creek failing Schedule 15 (Water Plan) *E. coli* compliance (Table 6) and highlights issues with bacterial contamination in the catchment.

The overall attribute state is based on the worst grading with the national bottom line being an orange "D" band; all sites must return a minimum of a "C" band.

Table 9: NOF compliance summary for *E. coli* for the the period July 2012 to June 2017. The overall grading band is determined by the lowest (worst) ranked Numeric Attribute State as it relates to the four.

	Numeric Attribute State				Overall attribute state	
Site	Median grade (CFU/100ml)	95th percentile grade (CFU/100ml)	% over 260 CFU/100ml grade (%)	% over 540 CFU/100ml grade (%)	Grading attribute state	Overall Pass/Fail
Welcome Creek at Steward Road	A (50)	C (1156)	A (14%)	C (11%)	C	PASS
Kakanui River at Clifton Falls Bridge	A (70)	B (818)	B (23%)	A (5%)	B	PASS
Kauru River at Ewings	A (42)	A (393)	A (10%)	A (3%)	A	PASS
Kakanui River at McCones	A (88)	A (454)	A (12%)	A (3%)	A	PASS
Waiareka Creek at Taipo Road	**D (230)**	**D (1595)**	**D (40%)**	**D (24%)**	**D**	**FAIL**
Waianakarua River at Browns	A (33)	A (308)	A (5%)	A (2%)	A	PASS
Trotters Creek at Mathesons	A (80)	B (708)	A (19%)	B (7%)	B	PASS
Shag River at Craig Road	A (48)	A (445)	A (9%)	A (2%)	A	PASS
Shag River at Goodwood Pump	A (66)	A (308)	A (10%)	A (2%)	A	PASS

Ammoniacal nitrogen

With the exception of the Waiareka Creek, NH_4-N concentrations are low across all North Otago SoE monitoring sites, with median and most 95th percentile values being well below the ANZECC trigger level of 0.021 mg/L (Figure 6). In Waiareka Creek NH_4-N are mildly elevated above ANZECC (2000) trigger levels and reflect some enrichment of NH_4-N above typical natural background levels.

Ammoniacal nitrogen trend analysis (Table 10) reveals significant increasing trends for both the Waiareka Creek and Trotters Creek monitoring sites. These two sites also have the highest NH_4-N concentrations of the North Otago reporting regions.

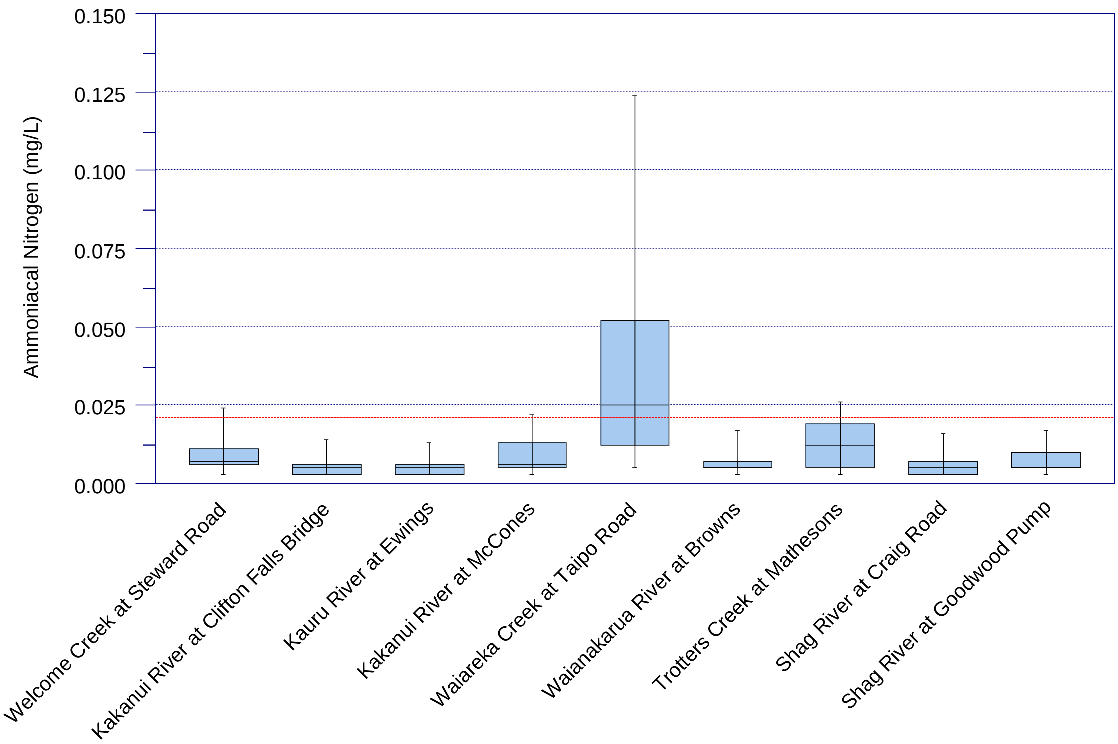


Figure 6: Boxplot summary of NH_4-N concentrations at SoE monitoring sites throughout North Otago. The **red** dashed line corresponds to the lowland ANZECC guideline of 0.021 mg/L.

Table 10: Trend summary of Ammonical Nitrogen (NH_4-N) concentrations for the North Otago reporting region.

Site	Welcome Creek at Steward Road	Kakanui River at Clifton Falls Bridge	Kauru River at Ewings	Kakanui River at McCones	Waiareka Creek at Taipo Road	Waianakarua River at Browns	Trotters Creek at Mathesons	Shag River at Craig Road	Shag River at Goodwood Pump
Ammoniacal Nitrogen	< DL	< DL	< DL	< DL	↑↑↑	< DL	↑↑↑	< DL	< DL

Nitrite/Nitrate nitrogen

Nitrite/nitrate nitrogen levels are elevated above the ANZECC trigger level of 0.444 mg/L for three sites across the North Otago reporting region, including Welcome Creek (the highest), Waiareka Creek (second highest) and Trotters Creek (Figure 7). This aligns with Schedule 15 (Water Plan) 'non-compliance' for these three sites.

On a regional standing, Welcome Stream has very elevated levels of NNN with the second highest median concentration for the wider Otago region (Appendix E). Welcome Creek is a spring-fed stream located in the lower Waitaki Plains and lies in an area where groundwater is known to be enriched with nitrate (Rajanayaka, 2012).

Nitrite/nitrate nitrogen trend analysis (Table 11) reveals significant increasing trends for three sites including Waiareka and Trotters creeks, and the Kakanui River at McCones.

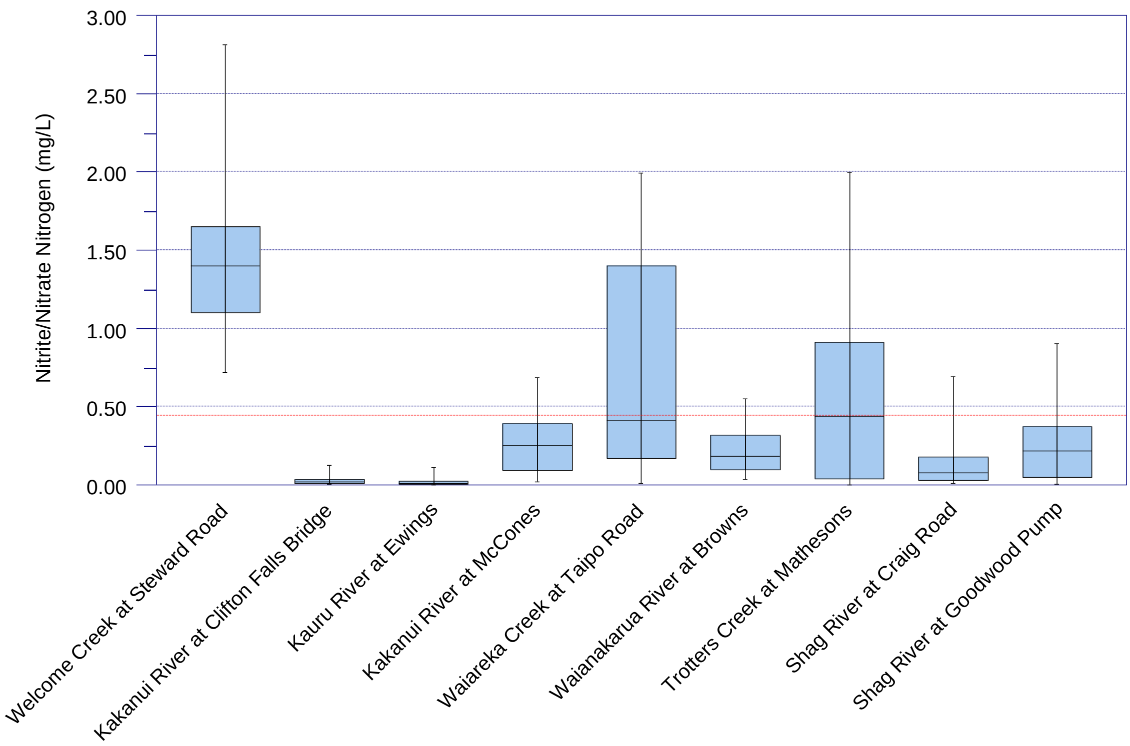


Figure 7: Nitrite/nitrate nitrogen (NNN) concentrations at SoE monitoring sites throughout North Otago. The red dashed line corresponds to the lowland ANZECC guideline of 0.444 mg/L.

Table 11: Trend summary of Nitrite/nitrate nitrogen (NNN) concentrations for the North Otago reporting region.

Site	Welcome Creek at Steward Road	Kakanui River at Clifton Falls Bridge	Kauru River at Ewings	Kakanui River at McCones	Waiareka Creek at Taipo Road	Waianakarua River at Browns	Trotters Creek at Mathesons	Shag River at Craig Road	Shag River at Goodwood Pump
Nitrite / Nitrate Nitrogen	?	?	→	↑↑↑	↑↑↑	?	↑↑↑	?	↓↓

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Total Nitrogen

Total nitrogen concentrations follow similar patters to nitrite/nitrate nitrogen (NNN) for the North Otago reporting region, with concentrations elevated above the ANZECC trigger level of 0.614 mg/L for three sites, including Welcome Creek (second highest), Waiareka Creek (highest), and Trotters Creek (Figure 8). Waiareka Creek has higher TN concentrations than Welcome Creek, being the opposite of that seen for NNN. This reflects the difference in NH_4-N contribution to the TN pool between the two sites with the high NH_4-N of Waiareka Creek elevating the TN above that of Welcome Stream.

TN trend analysis (Table 12) follows a similar pattern as NNN, with increasing trends for three sites, including significant increasing trends for the Waiareka and Trotters creeks; and a probable increasing trend for the Kakanui River at McCones.

When considering effects on sensitive downstream receiving environments, such as estuarine and lake environments, we are typically more interested in TN than NNN due to the extended water residence times in these environments. This increases the opportunity for nutrient cycling and conversion of organic nutrients or organic nitrogen that typically aren't readily available for plant and algal growth, into inorganic nutrients, or in the case of nitrogen, NNN, that are readily available for algal and plant growth.

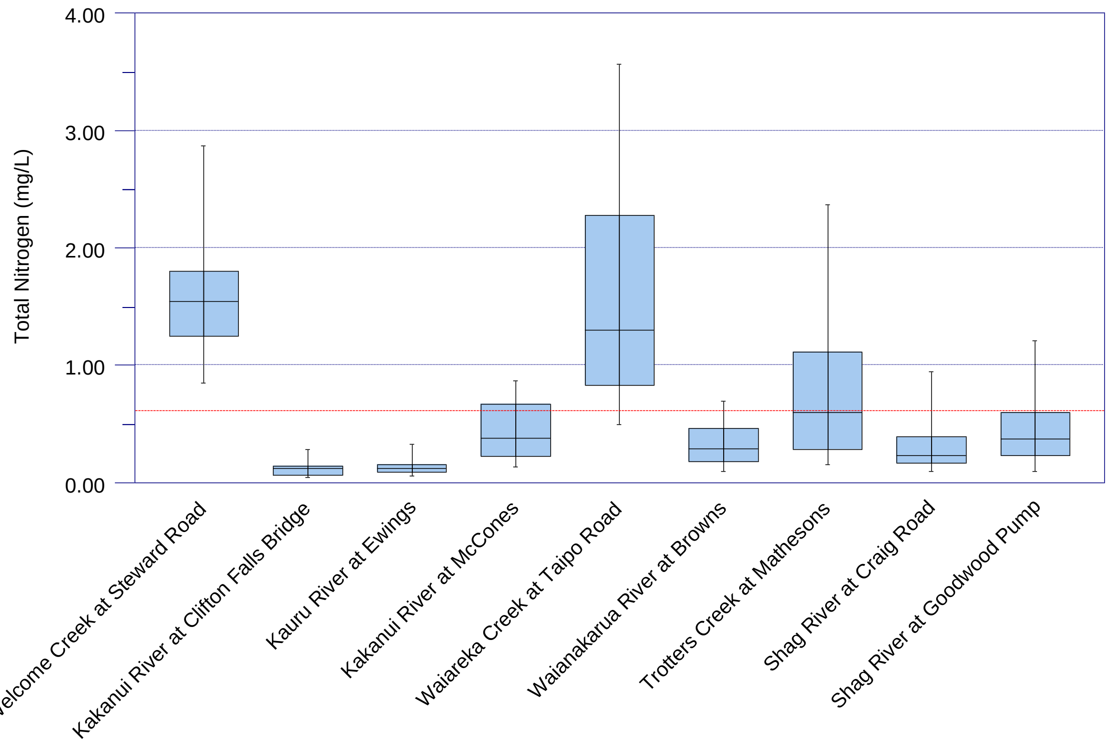

Figure 8: Boxplot summary of TN concentrations at SoE monitoring sites throughout North Otago. The red dashed line corresponds to the lowland ANZECC guideline of 0.614 mg/L.

Table 12: Trend summary of TN concentrations for the North Otago reporting region.

Site	Welcome Creek at Steward Road	Kakanui River at Clifton Falls Bridge	Kauru River at Ewings	Kakanui River at McCones	Waiareka Creek at Taipo Road	Waianakarua River at Browns	Trotters Creek at Mathesons	Shag River at Craig Road	Shag River at Goodwood Pump
Total Nitrogen	?	?	→	↑↑	↑↑↑	?	↑↑↑	?	?

Dissolved Reactive Phosphorus

With the exception of the Waiareka Creek, dissolved reactive phosphorus (DRP) concentrations are low across all North Otago SoE monitoring sites, with median and most 95th percentile values being well below the ANZECC trigger level of 0.010 mg/L (Figure 9). DRP concentrations in Waiareka Creek are highly elevated, being 10 to 20 times those of the ANZECC trigger value and well above Schedule 15 (Water Plan) limits.

On a regional standing, the Waiareka Creek has the highest recorded DRP concentrations of any site across Otago (Appendix E), further demonstrating the highly degraded water quality that is typical of this site at the present time.

DRP trend analysis (Table 13) reveals no significant increasing trends. The Waianakarua River has a significant decreasing trend for DRP which is promising, particularly given the already low DRP concentrations measured at this site.

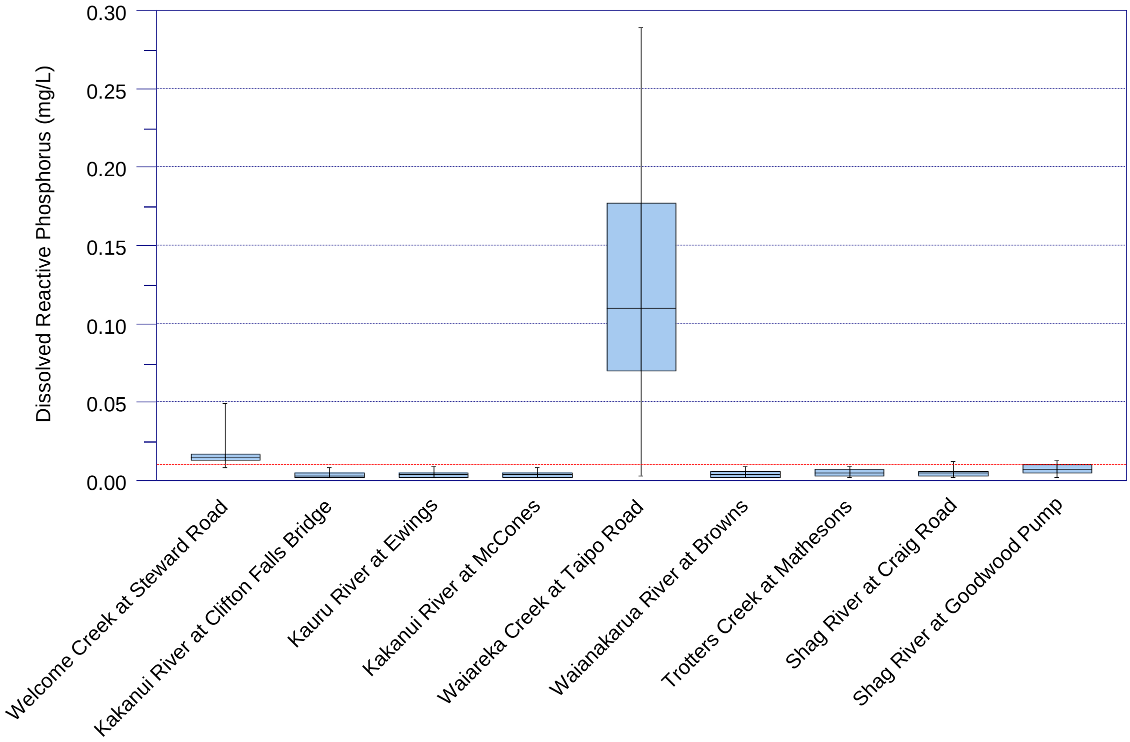

Figure 9: Boxplot summary of Dissolved Reactive Phosphorus (DRP) concentrations at SoE monitoring sites throughout North Otago. The **red** dashed line corresponds to the lowland ANZECC guideline for DRP of 0.010 mg/L.

Table 13: Trend summary of Dissolved Reactiver Phosphorus (DRP) concentrations for the North Otago reporting region.

Site	Welcome Creek at Steward Road	Kakanui River at Clifton Falls Bridge	Kauru River at Ewings	Kakanui River at McCones	Waiareka Creek at Taipo Road	Waianakarua River at Browns	Trotters Creek at Mathesons	Shag River at Craig Road	Shag River at Goodwood Pump
Dissolved Reactive Phosphorus	?	< DL	< DL	< DL	?	↓↓↓	?	?	?

Total Phosphorus

With the exception of Waiareka Creek, and to a limited extent Welcome Creek, TP concentrations are low across all North Otago SoE monitoring sites, with median and most 95th percentile values being well below the ANZECC trigger level of 0.033 mg/L (Figure 10).

The high concentrations of DRP in Waiareka Creek contribute to the TP pool at this site, and result in highly elevated TP concentrations. TP concentrations in Waiareka Creek are 5 to 10 times those of the ANZECC trigger value.

With the exception of the Dart River that carries a very high sediment and associated particulate phosphorus load, on a regional standing, the Waiareka Creek has the highest recorded TP concentrations of any site across Otago that can be attributed to anthropogenic (human) sources (Appendix E), again demonstrating the degraded water quality that is typical of this site at the present time.

TP trend analysis (Table 14) reveals a number of significant increasing (degrading) trends, including the Kauru at Ewings, Trotters Creek and the Shag River at Craig Road. ORC do not have information on changes in land-use or land management practices so it is not possible to comment on the cause of the degrading trends at these sites.

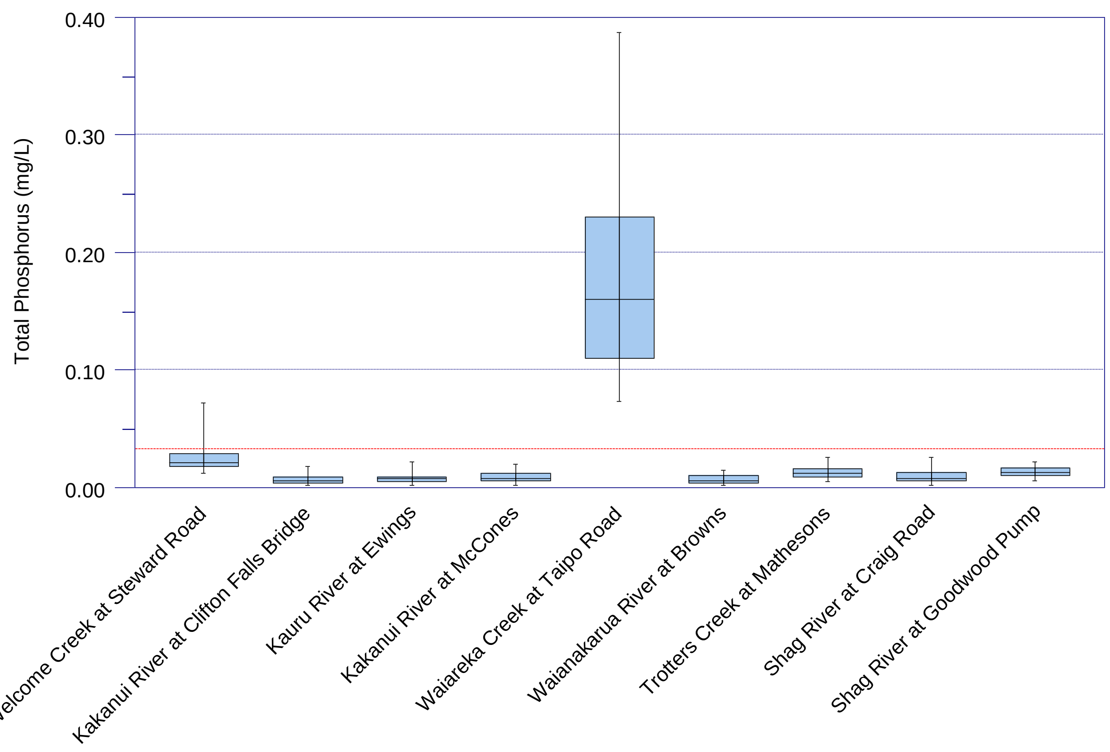

Figure 10: Boxplot summary of TP concentrations at SoE monitoring sites throughout North Otago. The red dashed line corresponds to the lowland ANZECC guideline for TP of 0.033 mg/L.

Table 14: Trend summary of TP concentrations for the North Otago reporting region.

Site	Welcome Creek at Steward Road	Kakanui River at Clifton Falls Bridge	Kauru River at Ewings	Kakanui River at McCones	Waiareka Creek at Taipo Road	Waianakarua River at Browns	Trotters Creek at Mathesons	Shag River at Craig Road	Shag River at Goodwood Pump
Total Phosphorus	?	?	↑↑↑	?	?	?	↑↑↑	↑↑↑	?

Escherichia coli

E.coli concentrations are relatively low across the majority of sites for the North Otago reporting region. The exceptions being peak concentrations (95th percentiles; represented by the upper whiskers on the Figure 11 boxplots) for Welcome Creek, the Kakanui River at Clifton Falls, Waiareka Creek and Trotters Creek (Figure 11). The 95th percentile concentrations at these sites are above the red alert level of 550 CFU/100ml and represent an unacceptable risk to human health at such times.

Swimmability and compliance of *E. coli* concentrations for the North Otago reporting region with The Water Plan and NPSFM NOF attribute limits are discussed in the previous section.

Waiareka Creek has the worst bacterial water quality for the North Otago reporting region with both elevated median and peak concentrations. This shows bacteria levels at this site to typically be above guideline levels and poses an unacceptable risk to human health for primary contact recreation (full immersion) activities. Previous discussion of compliance with the NOF *E. coli* attribute placed the Waiareka Creek in the orange (D band), or exceeding the national bottom line.

As discussed previously, bacterial levels at the Kakanui at Clifton Falls is naturally elevated due to the presence of a black-billed gull colony located upstream of the monitoring site (Ozanne and Wilson, 2013). There are no appropriate interventions or mitigation measures available that can reduce bacteria sourced from the gull colony.

E. coli trend analysis (Table 15) reveals a number of significant increasing (degrading) trends for some sites, including the Kakanui at McCones, Waiareka Creek, the Waianakarua River and Trotters Creek. The degrading trends for the Kakanui at McCones and Waianakarua River are of concern given the currently good bacterial water quality at these two sites. The Waianakarua River has the lowest recorded bacterial levels for the North Otago reporting region.

ORC do not have information on changes in land-use or land management practices so it is not possible to comment on the cause of the degrading trends at these sites.

Looking across Otago, The North Otago reporting region has bacterial water quality that is midway across reporting regions (Appendix E).

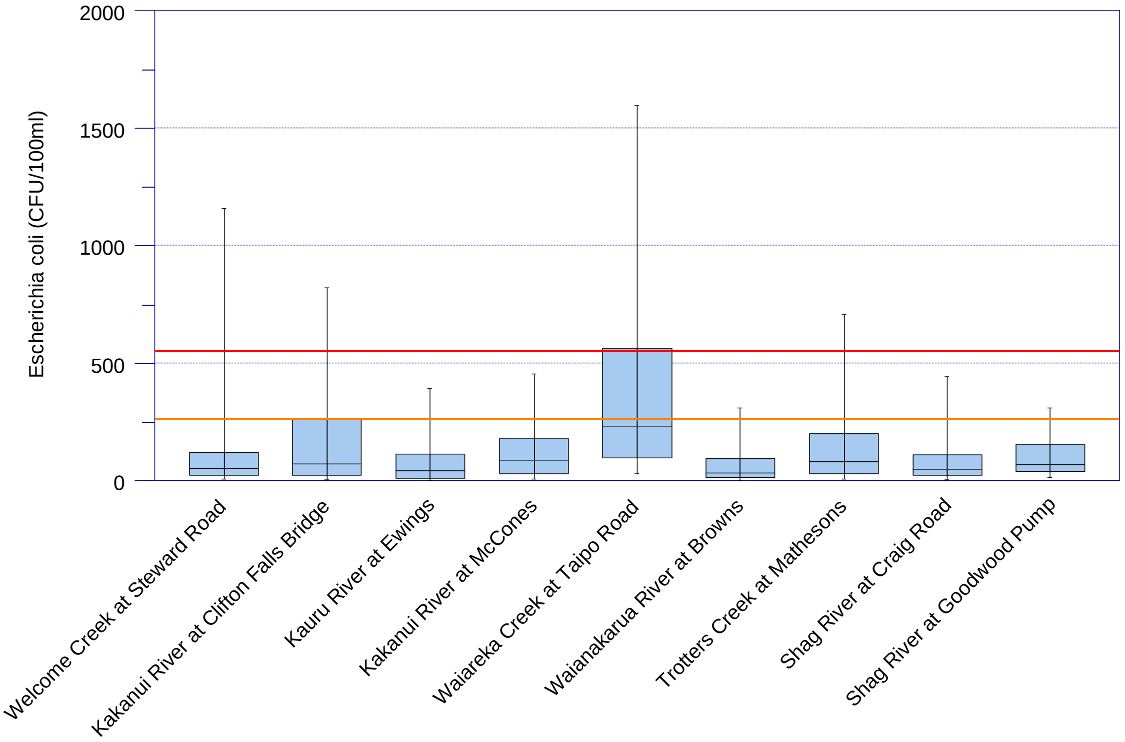

Figure 11: Boxplot summary of *E coli* concentrations at SoE monitoring sites throughout North Otago. The amber line corresponds to the amber alert level of 260 CFU/100ml; the **red** line to the red alert level of 550 CFU/100ml.

Table 15: Trend summary of *E. coli* concentrations for the North Otago reporting region.

Site	Welcome Creek at Steward Road	Kakanui River at Clifton Falls Bridge	Kauru River at Ewings	Kakanui River at McCones	Waiareka Creek at Taipo Road	Waianakarua River at Browns	Trotters Creek at Mathesons	Shag River at Craig Road	Shag River at Goodwood Pump
Escerichia coli	?	?	?	↑↑↑	↑↑↑	↑↑↑	↑↑↑	?	?

Turbidity

Turbidity levels are low across all North Otago SoE monitoring sites with median and 95th percentile values being well below the ANZECC lowland guideline value of 5.6 NTU (Figure 12). The exception is Waiareka Creek, which returns elevated turbidity levels when compared to other monitoring sites.

Turbidity trend analysis (Table 16) reveals significant increasing trends for both the Kauru River and Waiareka Creek monitoring sites. The Kauru River has very low turbidity levels and the increasing trend is of concern. The elevated turbidity levels of Waiareka Creek, combined with a significant increasing trend, are of particular concern. The Waianakarua River returned a 'probable' increasing trend and warrants further scrutiny of monitoring data as it comes to hand.

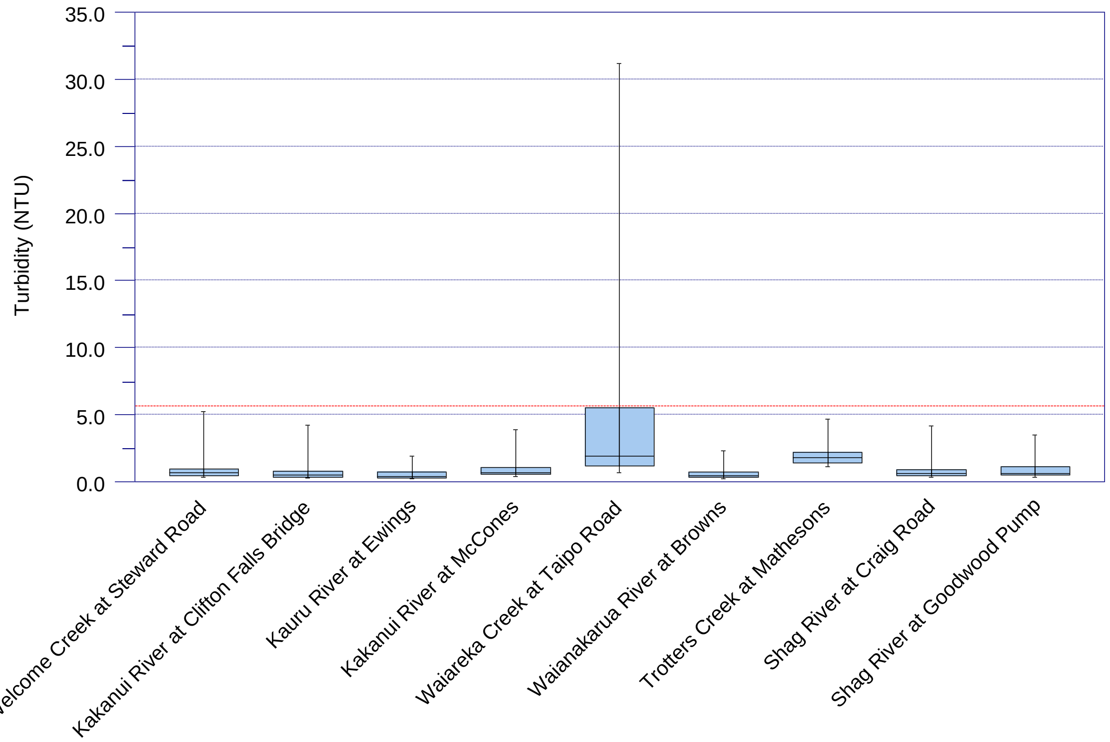

Figure 12: Boxplot summary of Turbidity at SoE monitoring sites throughout North Otago. The **red** dashed line corresponds to the lowland ANZECC guideline for Turbidity of 5.6 NTU.

Table 16: Trend summary of Turbidity levels for the North Otago reporting region.

Site	Welcome Creek at Steward Road	Kakanui River at Clifton Falls Bridge	Kauru River at Ewings	Kakanui River at McCones	Waiareka Creek at Taipo Road	Waianakarua River at Browns	Trotters Creek at Mathesons	Shag River at Craig Road	Shag River at Goodwood Pump
Turbidity	?	?	↑↑↑	?	↑↑↑	↑↑	?	?	?

Stream Health and the Macroinvertebrate Community Index

Macroinvertebrate Community Index (MCI) scores provide an integrated indicator of the general state of water quality and aquatic ecosystem health at a site.

Figure 13 summarises MCI scores for sites monitored for aquatic macroinvertebrates throughout the North Otago reporting region. The summary includes annual samples, where available, collected from 2008 to 2017 (8 years).

There is considerable variation in MCI scores across monitoring sites that follow similar patterns to key water quality indicators. Sites with good water quality, such as the Kakanui at Clifton Falls, the Kauru at Ewings, and the Waianakarua at Browns return the highest scores with an MCI of over 100, reflecting a macroinvertebrate community representative of water in 'good' condition. In a regional context (refer to regional boxplot summaries for MCI in Appendix E), the Kauru at Ewings is in the top three of all Otago sites monitored for MCI.

The remaining sites, with the exception of the Waiareka Creek, return MCI scores between 80 and 100. This reflects stream health in 'poor' condition with a macroinvertebrate community that has reduced numbers of pollution sensitive taxa and a prevalence of pollution tolerant taxa.

The Waiareka Creek site returns an MCI score in a much 'degraded' state and well below the red 'degraded' band threshold of 80. This follows the degraded nature of overall water quality at this site but is also a reflection of the soft substrate. In a regional context (Appendix E), the Waiareka Creek has the second lowest MCI scores for sites across Otago, and is only very slightly above the Kaikorai Stream. Recent amendments to the NPSFM require councils to actively investigate reasons for a site returning an MCI below 80 (Policy CB3). The low MCI score for Waiareka Creek has been reported on previously by Ozanne and Wilson (2013).

By way of contrast for the North Otago reporting region, the Kauru at Ewings returns a median MCI that is equal first on a regional basis with Dunstan Creek; contrast this with the Waiareka Creek that returns median MCI that is ranked as the second worst for the region (Appendix G).

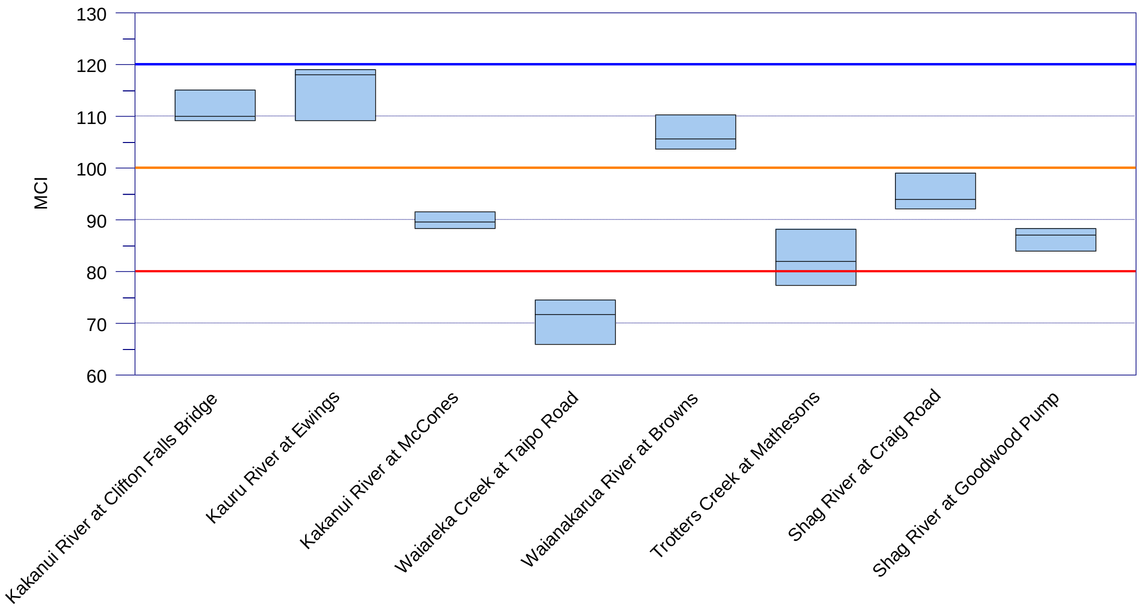

Figure 13: Boxplot summary of Macroinvertebrate Community Index (MCI) scores at SoE monitoring sites throughout North Otago where macroinvertebrate samples are routinely collected. Above the **blue** line corresponds to the 'Excellent' quality threshold; between the **orange** and blue line the 'Good' quality threshold; betwene the **red** and orange line 'Poor' quality threshold; below the red line the 'Degraded' threshold.

North Otago Water Quality Summary and Conclusions

Despite relatively good water quality across most monitoring sites of the North Otago reporting region, there is a considerable number of sites with degrading water quality trends, as shown in Table 17 which summarises trend results across all sites. There are a total of 63 results reported in the table; 29% return significant or probable degrading trends; 3% are stable; and 3% return significant or probable improving trends. Overall 35% of sites have either indeterminate trends (reported as "?"); or too many observations being 'less than detect' (<DL) for results returned from the laboratory.

In summary:

- The Kakanui at Clifton Falls, the Kauru at Ewings, the Wainakarua at Browns, and the Shag at Craig Road have the best water quality for sites monitored across the North Otago reporting region;
- Compliance with the Schedule 15 (Water Plan) NNN limit is poor for the majority of North Otago sites. The exceptions being the Kakanui at Clifton Falls and the Kauru at Ewings that have low NNN concentrations reflecting the low intensity land-use and low nitrogen leaching rates typical of the upstream catchments of these sites;
- Compliance with the NOF *E. coli* attribute is high for all sites returning either an "A band" (4 of 9 sites) or "B band" (4 of 9 sites). This reflects very good to excellent swimmability based on bacterial water quality and good protection for human health for primary recreation activities. The exception is the Waiareka Creek that returns both elevated median and 95th percentile concentrations placing it in the "D" band;

- Water quality and instream health (based on MCI) of the Waiareka Creek is highly degraded. This is likely a combination of soft substrate along with generally poor water quality (and significant degrading trends for the majority of water quality parameters measured at this site. The Waiareka Creek discharges to the Kakanui Estuary and has been identified as a significant source of nutrient loading to the estuary in past studies (Ozanne and Wilson, 2013).

Previous reports have identified land-use intensification as a driver of poor water quality in the Kakanui River and Waiareka Creek catchments (Ozanne and Wilson, 2013). Presently, ORC do not collect detailed information on land-use, land management practices or changes in either of the two that allow for inference as to the drivers of degrading or improving trends in water quality.

A targeted catchment study is currently underway in the Waiareka Creek catchment. This work will help to identify hotspots in the catchment and ideally should help isolate the causes of already degraded and deteriorating water quality.

Table 17: Trend summary for the North Otago reporting region.

Site	Ammoniacal Nitrogen	Nitrite/Nitrate Nitrogen	Total Nitrogen	Dissolved Reactive Phosphorus	Total Phosphorus	*Escherichia coli*	Turbidity
Welcome Creek at Steward Road	< DL	?	?	?	?	?	?
Kakanui River at Clifton Falls Bridge	< DL	?	?	< DL	?	?	?
Kauru River at Ewings	< DL	→	→	< DL	↑↑↑	?	↑↑↑
Kakanui River at McCones	< DL	↑↑↑	↑↑	< DL	?	↑↑↑	?
Waiareka Creek at Taipo Road	↑↑↑	↑↑↑	↑↑↑	?	?	↑↑↑	↑↑↑
Waianakarua River at Browns	< DL	?	?	↓↓↓	?	↑↑↑	↑↑
Trotters Creek at Mathesons	↑↑↑	↑↑↑	↑↑↑	?	↑↑↑	↑↑↑	?
Shag River at Craig Road	< DL	?	?	?	↑↑↑	?	?
Shag River at Goodwood Pump	< DL	↓↓	?	?	?	?	?

2.2. Dunedin/Southern coastal river catchments overview

The Dunedin/Southern Coastal reporting region spans an area of 3096 km^2 (309642 hectares) encompassing the catchments of the Waikouaiti River to the north; Lindsays Creek, the Leith Stream and the Kaikorai Stream in the Dunedin City area; and the Tokomairiro, Owaka and Catlins rivers to the south.

The Waikouaiti catchment area covers 421 km^2, the river has two main branches, the 'North Branch' and 'South Branch'. The North Branch has a catchment area of 283 km^2 and the South Branch a catchment area of 86 km^2. The remaining 52 km^2 includes the area downstream of the confluence of the two main branches along with the Waikouaiti Estuary. The headwaters of the north branch originate in the Macraes Flat area, whereas the south branch drains the northern slopes of the Silver Peaks. The Waikouaiti Estuary is both locally and regionally significant and is listed as a significant wetland in Schedule 9 of the Regional Plan: Water. The estuary contains Otago's largest salt marsh. The estuary is a high use estuary that is valued for its cultural, recreational, scientific and aesthetic appeal, with rich biodiversity, shellfish collection, bathing, white-baiting, fishing, boating, surfing, and walking values. In the Otago Regional Plan: Water, the Waikouaiti Estuary is listed as a coastal protection area with Kai Tahu cultural and spiritual values (Robertson et al., 2017a). The health of the upper estuary is affected by nutrient and sediment input, intensity and duration of low flows, and frequency and size of flushing flows.

The Leith Stream catchment covers an area of 42 km^2. The headwaters of the Leith Stream originate at the saddle between Mount Cargill and Swampy Hill and flow for 12 km in a south-easterly direction to discharge direct to the Otago Harbour, Dunedin. The total fall in the river is approximately 365 m and, for a considerable distance, the Leith flows in a narrow valley with steep slopes rising to the hills, Mount Cargill (elevation 680 m) to the east, Flagstaff Hill (668 m) and Swampy Spur (665 m) to the west. There are numerous tributary streams to the Leith, the principal of which are West Branch, Morrison's, Cedar, Nichol's and Ross Creeks entering the true right bank; and Cargill, Pine Hill and Lindsays Creeks entering on the true left bank (ORC, 2008). Lindsays Creek is the main tributary of the Leith Stream, with headwaters draining the upper eastern slopes of Mount Cargill. Lindsays Creek flows for 7 km to its junction with the Leith Stream at the Dunedin Botanical Gardens, approximately 2 km upstream of the mouth of the Leith Stream and the Otago Harbour. Significant areas of the lower catchment of the Leith Stream and Lindsays Creek flow through urban areas of the Dunedin City. Both the Leith Stream and Lindsays Creek are prone to sudden extreme floods due to the character of their catchment areas (ORC, 2008).

The Kaikorai Stream has a total catchment area of 55 km^2 and flows in a south westerly direction for approximately 15 km down the Kaikorai Valley into Kaikorai Estuary, where it discharges to the Pacific Ocean near Waldronville (approximately 10 km south of the Dunedin city centre). The headwaters originate in the Kaikorai Hills to the north; and to the west lie Abbot's Hill, the Chain Hills and Saddle Hill. The catchment includes the western flanks of Dunedin city and all of Green Island. The remaining area includes the communities of Fairfield and Waldronville (ORC, 2008). Fraser's Stream is a major tributary of the Kaikorai Stream and the Dunedin City Council discharges up to 560 litres per second of high-quality water from the Mt Grand Water Treatment Plant to MacLeod's Creek (a tributary of Fraser's Stream). This flow significantly improves the water quality and instream values of the Kaikorai Stream downstream of the discharge point (ORC, 2008).

The Tokomairiro River is located about 48 km south-west of Dunedin and has a catchment area of 403 km^2. The catchment has indistinct boundaries, with no dividing mountain ranges between it and neighbouring catchments. It is bordered to the east by tributaries of the Waihola-Waipori wetland complex (including Meggat Burn and Boundary Creek) and a number of coastal tributaries (including

Akatore Creek). The Waitahuna River borders the catchment to the north, while to the west; it is bordered by tributaries of Lake Tuakitoto (such as Lovells Creek) and Rocky Valley Creek. The Tokomairiro River enters the Pacific Ocean south of Toko Mouth (Olsen, 2013b).

The Catlins River catchment covers an area of 415 km^2 that includes its main tributary, the Owaka River. Both rivers discharge to the Catlins Estuary (or Catlins Lake) (Robertson et al., 2017b). The river's source is to the west of Mt Rosebery, 15 km southwest of Clinton where the headwaters flow from the Beresford Range to the south-west, and the Rata Range to the north-east. The river flows south-eastward for 42 km where it meets the Catlins Lake and shares an estuary with the Owaka River. The Catlins Lake discharges to the Pacific Ocean at Pounawea, 28 km south of Balclutha. The Owaka River is 30 km long and flows south-east. Its source is on the slopes of Mt Rosebery. The Catlins rivers' are recognised for many natural values, including high fish and macroinvertebrate diversity, rare fish, trout spawning and rearing habitat and a significant presence of eels (Ozanne, 2011).

2.2.1. Dunedin /Southern coastal river and land cover characteristics

Table 18 summarises characteristics of the Dunedin /Southern coastal reporting region based on the River Environment Classification (refer Appendix F for a detailed overview of the REC); land-cover (based on the Land Cover Database Version 4; condensed with the approach summarised in Appendix D); and the Land Use Capability (LUC) classes (see Section 2.0 for the LUC definition).

According to the River Environment Classification (REC), The Dunedin/Southern coastal reporting region is dominated by rivers and streams that are predominantly Cool/Dry low elevation rivers (73%) and Cool/Dry Hill rivers (9%). Cool/Wet Hill Rivers (4%) and Cool/Wet low elevation rivers (12%) also feature widely (Table 18).

The predominant land cover throughout the Dunedin/Southern coastal reporting region is high producing grassland (62%) that reflect areas actively managed and grazed for wool, lamb, beef, dairy or deer production (Table 18, Appendix D). This land cover dominates the Dunedin/Southern coastal reporting region (Figure 14). Areas of forestry (16%) and native cover (15%) are also widespread. Of all the areas covered in this report, the Dunedin/Southern coastal reporting region has the highest percentage cover of urban areas (2%). There is a significant proportion of LUC Class 6 land throughout the Dunedin/Southern coastal reporting region (47%). Class 6 land represents land that is steeper and less suited to arable land uses and more suitable to forestry.

The Waikouaiti catchment is an agricultural dominated catchment with high producing grasslands that support primarily extensive sheep and beef farming. Some dairy production (total of 750 milking cows) is occurring in the lower catchment bordering the estuary and is aided by irrigation from the main stem of the river (Robertson et al., 2017a).

The Leith Stream catchment has an upper catchment covered in indigenous hardwoods, production forest, manuka/kanuka, and native grassland. While in the lower catchment the bottom and side slopes of the valley are occupied to a large degree by streets and buildings, parks and open spaces (ORC, 2008).

The upper catchment of the Kaikorai Stream is dominated by a mix of kanuka/manuka scrubland and native forest; as well as areas of high producing grassland. The lower catchment has similar characteristics to the Leith Stream in as much as it flows through urban and industrial areas (Kaikorai Valley) before entering the Kaikorai Estuary and discharging to the Pacific Ocean at Waldronville.

The Tokomairiro Plains comprise sheep and beef farming as well as some cropping. Dairy conversion from sheep and beef has occurred over the past decade and there are currently 19 dairy farms in the catchment. Much of the hill country surrounding the Tokomairiro Plain has a high proportion of forestry. Prior to European land clearance, the Tokomairiro Plain would have been a wetland complex. However, the Plain has been drained to allow for pasture development. To facilitate farming on the heavy peat soils, tile-mole drains are extensively used in the catchment (Olsen, 2013b).

The Catlins River catchment consists of undulating or lower hill-country. Forested ridges provide a contrast to cleared valleys, where pastoral activities are concentrated. There is little flatland in the catchment, except in the lower reaches. Until recently, farming in the area has traditionally been sheep and beef grazing; however, land-use is changing and more intensive farming is now prevalent in the Owaka catchment and is likely to expand (Ozanne, 2011).

Table 18: Characteristics of the Dunedin/Southern coastal reporting region (309,642 hectares). Source of flow, Land Cover Area and Land-use Capability.

Source of flow (REC)		Land Cover Area (LCDB4)		Land-use Capability Class (LUC)	
Cool-Dry / Hill	8.9%	Cropping	0.3%	Class 2	3.5%
Cool-Dry/Low-Elevation	73.3%	High producing grassland	61.9%	Class 3	18.8%
Cool-Dry/Lake	0.1%	Low Producing Grassland	1.8%	Class 4	20.2%
Cool-Wet/ Hill	4.3%	Native Cover	14.7%	Class 5	6.2%
Cool-Wet/Low-Elevation	12.0%	Orchards/Vineyards	0.0%	Class 6	47.0%
Cool-Wet/Lake	1.4%	Plantation forestry	15.5%	Class 7	1.8%
		Unaccounted	3.4%	Class 8	0.02%
		Urban areas	2.3%	Town	1.6%

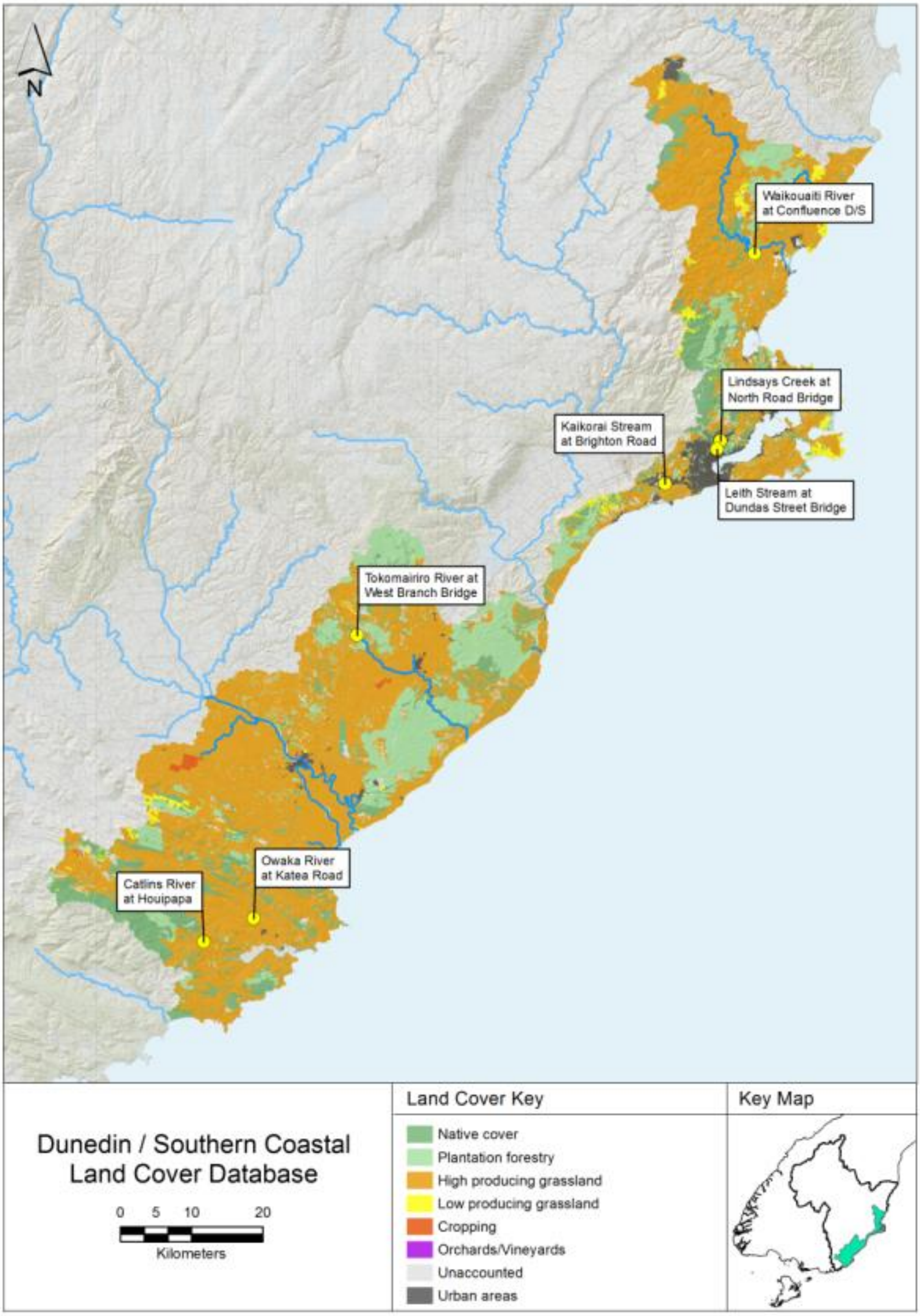

Figure 14: Map showing broad land cover categories of the Dunedin/Southern coastal reporting region based on the LCDB4 databse.

2.2.2. Dunedin /Southern coastal water quality

The following section provides a summary of the Dunedin/Southern coastal reporting region water quality based on:

- Compliance with Schedule 15 (Water Plan) numerical limits;
- National Policy Statement for Freshwater Management (NPSFM 2014) National Objectives Framework Attribute bands (NOF bands);
- Summary boxplots of key water quality indicators with the inclusion of general water quality guidelines such as ANZECC (2000);
- A summary of trends (degrading/improving) that may (or may not) be evident in the data.

Schedule 15 compliance

Table 19 summarises compliance for SoE monitoring sites throughout the Dunedin/Southern coastal reporting region with Schedule 15 (Water Plan) limits. For this section, all '80th percentile concentrations' are calculated from data collected when flows at the relevant flow reference site are below median flow.

All sites are compliant for NH_4-N and have 80th percentile concentrations below one-quarter of the Schedule 15 limit of 0.100 mg/L. Ammonia is toxic to aquatic life. In the environment, NH_4-N is quickly converted to nitrate-nitrogen by bacteria. The presence of elevated NH_4-N in a stream or river typically reflects direct contamination from a source that is high in this contaminant, an example being effluent. The combined presence of high NH_4-N, dissolved reactive phosphorus and faecal bacteria such as *E. coli* provides further evidence of this type of contamination, and would be expected to be present should significant amounts of effluent be reaching a stream or river.

Looking across all variables, the Waikouaiti River and Catlins River monitoring sites are the only two sites that are fully compliant with Schedule 15 (Water Plan) limits. The catchment upstream of the Catlins River monitoring site is dominated by native vegetation, production forestry and some limited high producing grassland (Figure 14). Native vegetation and production forest typically leach very low level of nutrients and would help this site in meeting the Water Plan limits. The Waikouaiti River monitoring site returns <u>very</u> low 80th percentile concentrations for all The Water Plan water quality variables showing an excellent level of compliance. This is very positive given the highly sensitive estuarine downstream receiving environment. Also worth noting for the Waikouaiti catchment are the lower Schedule 15 (Water Plan) limits for RWG 2 under The Water Plan (Table 19), with an NNN limit of 0.075 mg/L as opposed to 0.444 mg/L for RWG 1; and a DRP limit of 0.010 mg/L as opposed to 0.026 mg/L.

The Tokomairiro River and Kaikorai Streams are the next most compliant sites being compliant for nutrients and turbidity. They fail the Schedule 15 (Water Plan) *E. coli* limits.

The Owaka River returns very high 80th percentiles for NNN, around three times the Schedule 15 (Water Plan) limit. DRP 80th percentiles are close to being non-compliant, returning an 80th percentile of 0.025 mg/L compared with the Schedule 15 (Water Plan) limit of 0.026 mg/L.

With the exception of the Waikouaiti River and to a limited extent the Catlins River, *E. coli* compliance for the Dunedin/Southern coastal reporting region is very poor, with all remaining sites being non-compliant.

Table 19: 80th percentile values for water quality variables identified in Schedule 15 for the Dunedin/Southern coastal reporting region. Values are calculated from samples taken when flows are below median flow. The orange cells show where the 80th percentile exceeds the Schedule 15 limit. Numbers underlined in italics have lower limits under Schedule 15.

Variable	NNN	NH_4-N	DRP	*E. coli*	Turbidity
Schedule 15 limit when flows < median flow	0.444 mg/L *0.075 mg/L*	0.100 mg/L	0.026 mg/L *0.010 mg/L*	260 CFU	5.0 NTU
SoE reporting name					
Waikouaiti River at Confluence D/S	*0.015*	0.013	*0.003*	80	1.11
Lindsays Creek at North Road Bridge	0.664	0.023	0.024	1004	3.32
Leith Stream at Dundas Street Bridge	0.470	0.014	0.028	626	2.22
Kaikorai Stream at Brighton Road	0.232	0.014	0.012	916	2.92
Tokomairiro River at West Branch Bdg	0.272	0.016	0.015	288	2.94
Owaka River at Katea Road	1.200	0.022	0.025	380	2.70
Catlins River at Houipapa	0.420	0.016	0.016	250	4.00

Nitrate and ammonia toxicity and NOF compliance

NOF attribute bands for nitrate are summarised in Table 20. With the exception of the Owaka River, all sites are in the “A band”. If a site falls in the A band then there is “unlikely to be [toxicity] effects even for sensitive species”. This shows, for these sites at current concentrations, there to be a high level of protection against nitrate toxicity.

Both elevated median and 95th percentile nitrate concentrations push the Owaka River into the ‘B’ band. The B-band reflects an environment that may have “some growth effect on up to 5% of species” in regards to a chronic nitrate toxicity effect (Appendix B). This provides for a good level of protection with some minor effects on growth rate of the most sensitive species (Hickey, 2013).

NOF attribute bands for NH_4-N are summarised in Table 21. For median concentrations, all sites fall within the ‘A’ band. This shows a good level of protection against ammonia toxicity effects for typical concentrations encountered in the rivers and streams. Concentration ‘peaks’ (maximum recorded values) push a number of sites into the ‘B’ band, including the Leith and Kaikorai Streams, and the Catlins River. If a site falls in the ‘A’ band then there is “no observed [toxicity] effect on any species tested”. The A band provides a 99% species protection level (Appendix B), being the highest protection banding. The B band reflects an environment where NH_4-N concentrations “start impacting occasionally on the 5% most sensitive species” (Appendix B). For the sites with high peak concentrations, there may be a chance of chronic ammonia toxicity effects on the most sensitive species at times that concentrations are elevated at these sites.

Both the A and B bands provide a good level of protection against toxicity effects and in the case of nitrate and NH_4-N, it is highly unlikely that there would be any chronic toxicity effects on aquatic species present at these sites.

Table 20: NOF compliance summary for Nitrate (estimated from NNN) toxicity for the Dunedin/Southern coastal reporting region. Included are median and 95th percentile values for the the period July 2012 to June 2017 and the corresponding NOF attribute band.

Variable	Nitrate as NNN		NOF Band	
SoE reporting name	Median (mg/L)	95th Percentile (mg/L)	Median	95th Percentile
Waikouaiti River at Confluence D/S	0.012	0.316	A	A
Lindsays Creek at North Road Bridge	0.692	1.221	A	A
Leith Stream at Dundas Street Bridge	0.508	0.891	A	A
Kaikorai Stream at Brighton Road	0.293	0.783	A	A
Tokomairiro River at West Branch Bdg	0.307	0.901	A	A
Owaka River at Katea Road	1.173	1.908	B	B
Catlins River at Houipapa	0.435	0.779	A	A

Table 21: NOF compliance summary for NH_4-N toxicity for the Dunedin/Southern coastal reporting region. Included are median and maximum values for the the period July 2012 to June 2017 and the corresponding NOF attribute band.

Variable	Ammoniacal nitrogen (unadjusted)		NOF Band	
SoE reporting name	Median (mg/L)	Maximum (mg/L)	Median	Maximum
Waikouaiti River at Confluence D/S	0.005	0.020	A	A
Lindsays Creek at North Road Bridge	0.011	0.039	A	A
Leith Stream at Dundas Street Bridge	0.010	0.056	A	B
Kaikorai Stream at Brighton Road	0.010	0.095	A	B
Tokomairiro River at West Branch Bdg	0.010	0.027	A	A
Owaka River at Katea Road	0.013	0.034	A	A
Catlins River at Houipapa	0.014	0.119	A	B

E. coli, swimmability and NOF compliance

Table 22 summarises compliance for *E. coli* against the four statistical tests of the NOF *E. coli* attribute.

With the exception of the Waikouaiti River that has excellent bacterial water quality against all four attribute states; all sites fail the national bottom line (D band).

For the urban streams, being Lindsay Creek, Leith Stream and Kaikorai Stream, all attribute states are exceeded to a large degree reflecting highly degraded bacterial water quality.

The Owaka and Catlins rivers have low 95th percentiles (B band) showing peak concentrations of *E. coli* aren't such an issue, but the sites have elevated median concentrations that place the sites in the unacceptable "D" band. A high median *E. coli* value shows there to be elevated background concentrations of bacteria in the stream more often than not.

The Tokomairiro returns a "D" band for three of the four attribute states with elevated median, high 'peak' concentrations (95th percentiles) and an unacceptable percentage of exceedances over 540 CFU/100ml; this places the site in the "D" band.

Overall compliance with the *NOF E.coli* attribute for the Dunedin/Southern coastal reporting region is very poor. The overall attribute state is based on the worst grading with the national bottom line being an orange "D" band; all sites must return a minimum of a "C" band.

Table 22: NOF compliance summary for *E. coli* for the the period July 2012 to June 2017. The overall grading band is determined by the lowest (worst) ranked Numeric Attribute State as it relates to the four separate states**.**

	Numeric Attribute State				Overall attribute state	
Site	Median conc. grade	95th percentile conc.grade	% over 260 CFU/100ml grade	% over 540 CFU/100ml grade	Grading attribute state	Overall Pass/Fail
Waikouaiti River at Confluence D/S	A (31)	A (345)	A (7%)	A (2%)	A	PASS
Lindsays Creek at North Road Bridge	**E (450)**	**D (2740)**	**E (68%)**	**E (39%)**	**E**	**FAIL**
Leith Stream at Dundas Street Bdg	**E (480)**	**D (4440)**	**E (70%)**	**E (41%)**	**E**	**FAIL**
Kaikorai Stream at Brighton Road	**E (450)**	**D (3300)**	**E (66%)**	**E (36%)**	**E**	**FAIL**
Tokomairiro River at West Branch Bdg	**D (140)**	**D (2760)**	C (32%)	**D (22%)**	**D**	**FAIL**
Owaka River at Katea Road	**D (170)**	B (768)	C (33%)	C (12%)	**D**	**FAIL**
Catlins River at Houipapa	**D (145)**	B (591)	B (27%)	B (7%)	**D**	**FAIL**

Otago Regional Council

Ammoniacal nitrogen

With the exception of the Catlin River at Houipapa, NH_4-N concentrations are low across all Dunedin/Southern coastal SoE monitoring sites, with median and 75th percentile (represented by the upper boundary of the 'box' in the boxplots) being below the ANZECC trigger level of 0.021 mg/L (Figure 15). In the Catlins River NH_4-N are elevated above ANZECC (2000) trigger levels and reflect some enrichment of NH_4-N above typical natural background levels.

Trend analysis results (Table 10) reveal no significant increasing or decreasing trends for NH_4-N. The very low concentrations in the Waikouaiti River return too many '<DL' (less than laboratory detection level) values for a meaningful trend analysis to be carried out. There is a stable trend for Lindsays Creek reflecting no change over time. Trend results for all remaining sites are indeterminate.

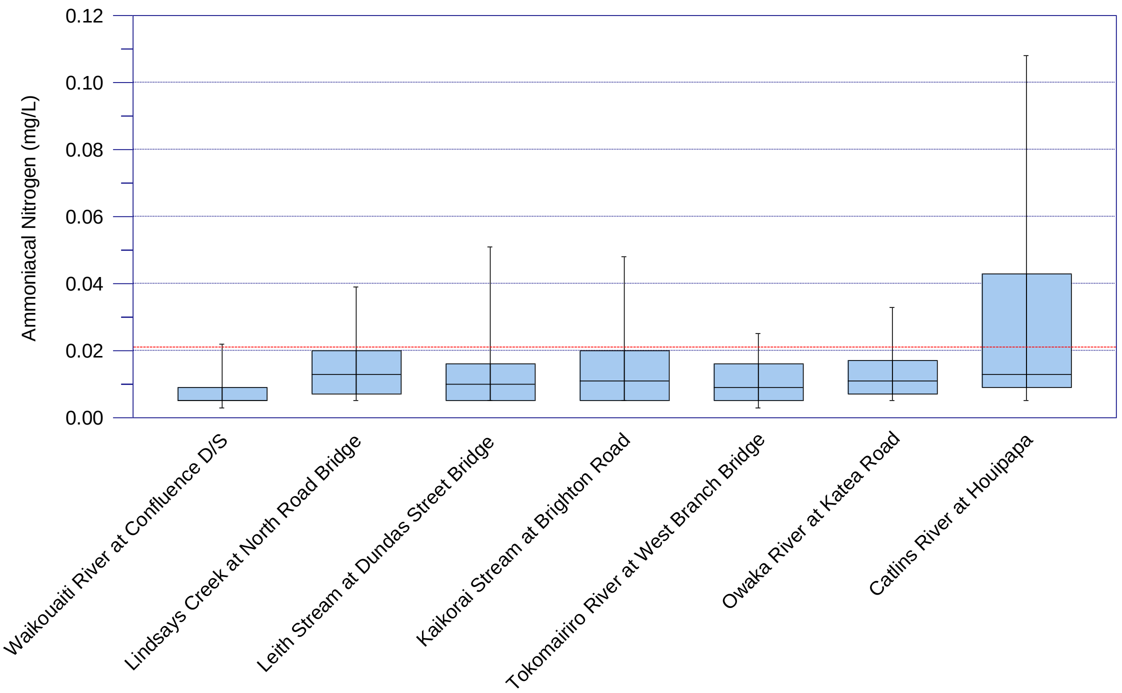

Figure 15: Boxplot summary of NH_4-N concentrations at SoE monitoring sites throughout the Dunedin/Southern coastal reporting region. The **red** dashed line corresponds to the lowland ANZECC guideline for NH_4-N of 0.021 mg/L.

Table 23: Trend summary of ammonical nitrogen concentrations for the Dunedin/Southern coastal reporting region.

Site	Waikouaiti River at Confluence D/S	Lindsays Creek at North Road Bridge	Leith Stream at Dundas Street Bridge	Kaikorai Stream at Brighton Road	Tokomairiro River at West Branch Bridge	Owaka River at Katea Road	Catlins River at Houipapa
Ammoniacal Nitrogen	< DL	→	?	?	?	?	?

Nitrite/Nitrate nitrogen

Nitrite/nitrate nitrogen (NNN) levels are elevated above the ANZECC trigger level of 0.444 mg/L for Lindsays Creek and the Owaka River; and to a lesser extent, the Leith Stream and Catlins River (Figure 16). This aligns with Schedule 15 (Water Plan) 'non-compliance' for three of four of these sites. All other sites have NNN concentrations that are typically below the ANZECC lowland trigger value.

On a regional standing, the Owaka River has quite elevated levels of NNN (Appendix E), being comparable to catchments in the Pomahaka River that have previously been identified as having high NNN levels due to land-use effects on water quality (ORC, 2011). By contrast, the Waikouaiti River returns very low concentrations of NNN which is an excellent result for this site.

Nitrite/nitrate nitrogen trend analysis (Table 24) reveals a significant decreasing trend for NNN in the Waikouaiti River. This is an excellent result given the already low levels of NNN at this site (Figure 16) and provides confidence for ongoing protection of instream values against eutrophication that may occur should NNN increase; also further safeguarding the downstream Waikouaiti Estuary from effects of elevated NNN loads.

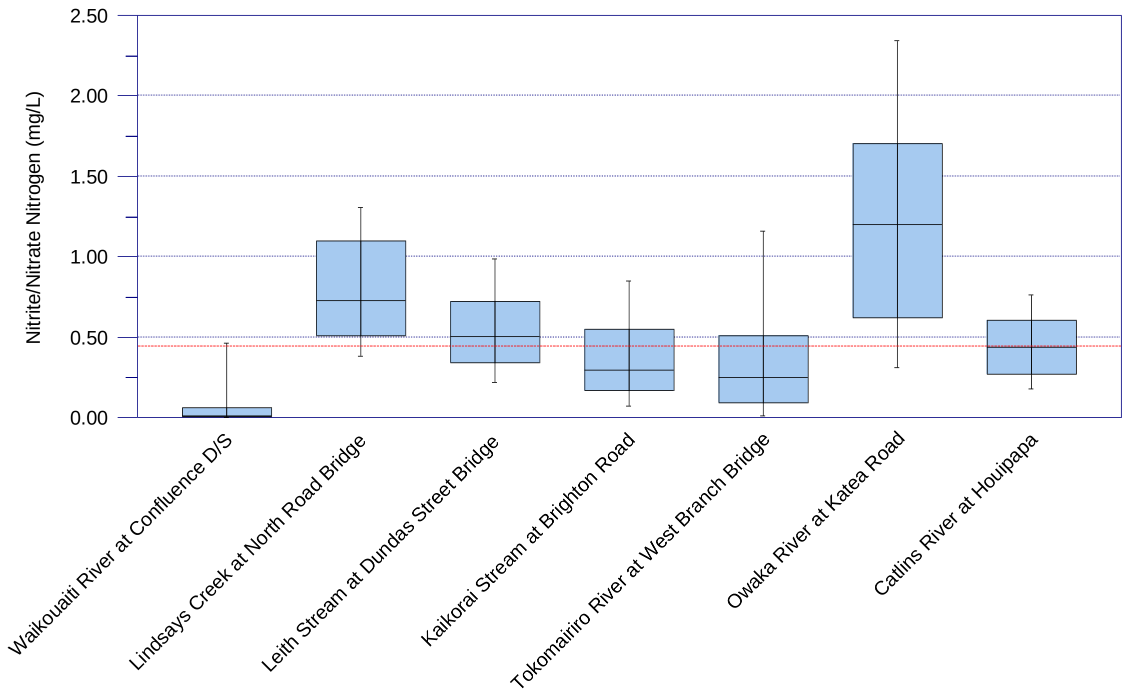

Figure 16: Nitrite/nitrate nitrogen (NNN) concentrations at SoE monitoring sites throughout the Dunedin/Southern coastal reporting region. The red dashed line corresponds to the lowland ANZECC guideline for NNN of 0.444 mg/L.

Table 24: Trend summary of nitrate/nitrite nitrogen (NNN) concentrations for the Dunedin/Southern coastal reporting region.

Site	Waikouaiti River at Confluence D/S	Lindsays Creek at North Road Bridge	Leith Stream at Dundas Street Bridge	Kaikorai Stream at Brighton Road	Tokomairiro River at West Branch Bridge	Owaka River at Katea Road	Catlins River at Houipapa
Nitrite / Nitrate Nitrogen	↓↓↓	?	?	?	?	?	↑↑↑

Total Nitrogen

Total nitrogen concentrations follow similar patters to nitrite/nitrate nitrogen (NNN) for the Dunedin/Southern coastal reporting region, with median concentrations elevated above the ANZECC trigger level of 0.614 mg/L for TN for four sites, including Lindsays Creek and the Owaka River; and to a lesser extent, the Leith Stream and Catlins River.

TN concentrations are almost directly comparable to NNN concentrations for all sites reflecting a high contribution of inorganic N to the TN pool.

Total nitrogen trend analysis (Table 25) follows similar patterns as NNN, with a significant decreasing trend for the Waikouaiti River. This is an excellent result given the already low levels of TN at this site (Figure 16).

When considering effects on sensitive downstream receiving environments, such as estuarine and lake environments, we are typically more interested in TN than NNN due to the extended water residence times increasing the opportunity for nutrient cycling and conversion of organic nutrients or organic nitrogen that typically aren't readily available for plant and algal growth, into inorganic nutrients, or in the case of nitrogen, NNN, that is readily available for algal and plant growth.

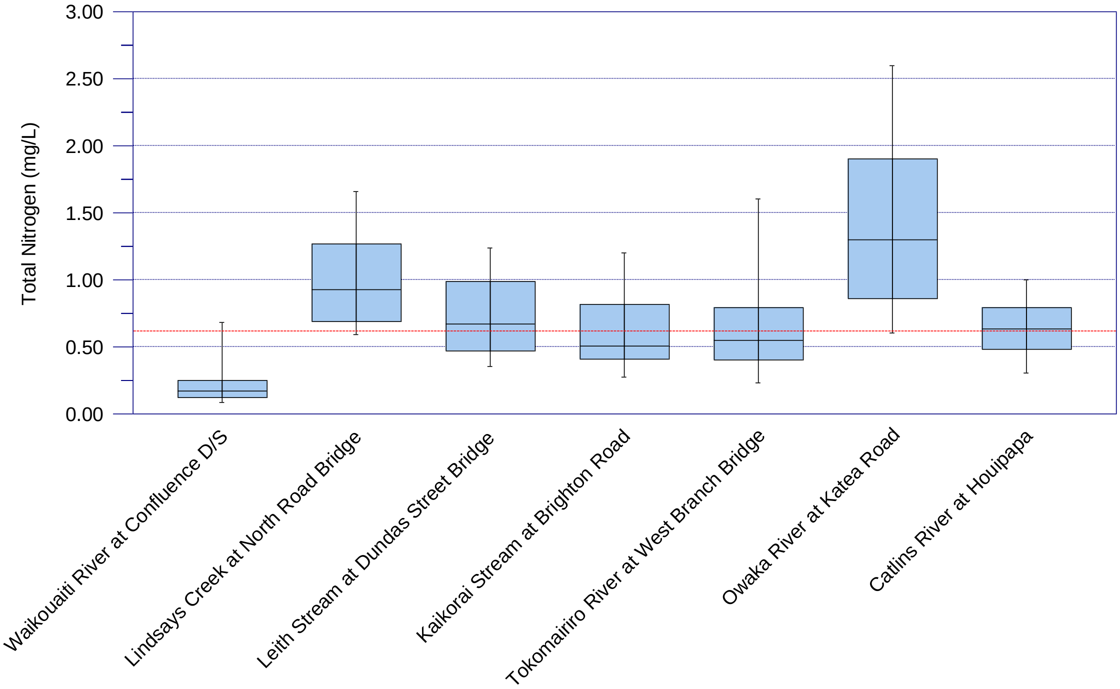

Figure 17: Boxplot summary of TN concentrations at SoE monitoring sites throughout the Dunedin/southern coastal reporting region. The **red** dashed line corresponds to the lowland ANZECC guideline for TN of 0.614 mg/L.

Table 25: Trend summary of Total Nitrogen (TN) concentrations for the Dunedin/Southern coastal reporting region.

Site	Waikouaiti River at Confluence D/S	Lindsays Creek at North Road Bridge	Leith Stream at Dundas Street Bridge	Kaikorai Stream at Brighton Road	Tokomairiro River at West Branch Bridge	Owaka River at Katea Road	Catlins River at Houipapa
Total Nitrogen	↓↓↓	?	?	?	?	?	↑↑↑

Dissolved Reactive Phosphorus

With the exception of the Waikouaiti River, median dissolved reactive phosphorus (DRP) concentrations are elevated across all Dunedin/Southern coastal monitoring sites, with median concentrations being equal to or well above the ANZECC trigger level of 0.010 mg/L (Figure 18). Promisingly, median DRP concentrations in the Kaikorai Stream are equal to the ANZECC trigger value, and reflect relatively low levels of phosphorus enrichment for this urban stream.

Quite alarmingly, DRP trend analysis (Table 26) reveals significant increasing trends across five of the seven sites. The two exceptions being the Waikouaiti River, that returns too many results below detection levels (<DL) to undertake a meaningful analysis; and the Owaka River that returned an indeterminate trend analysis result.

ORC does not have information on changes in land-use or land management practices so it is not possible to comment on the cause of the degrading trends at these sites.

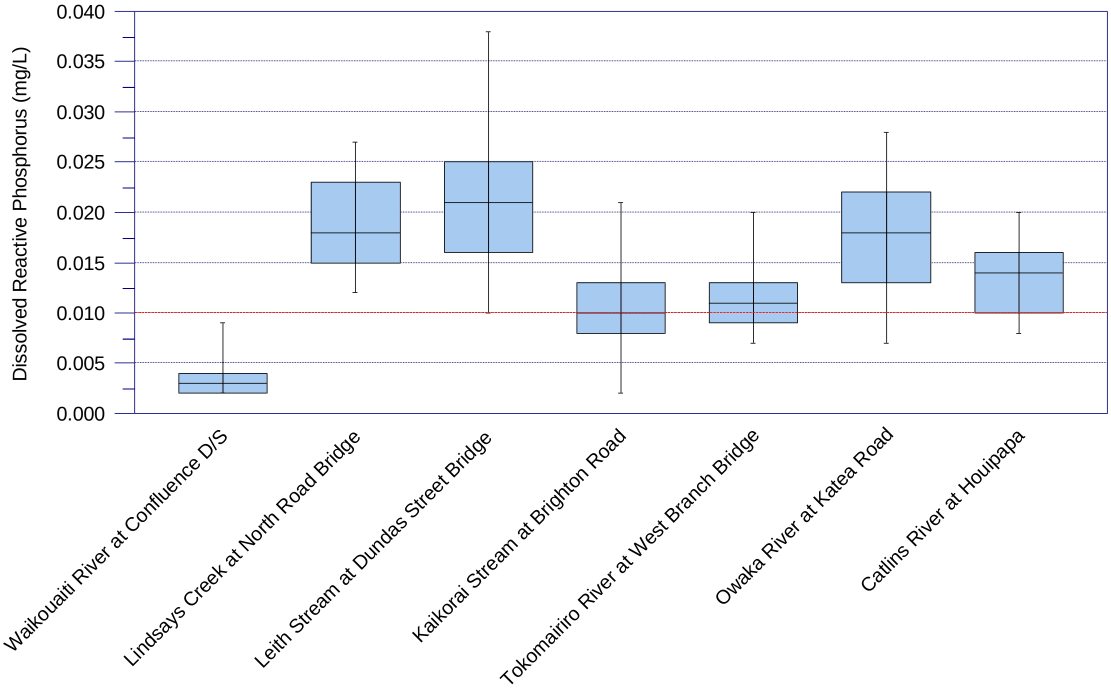

Figure 18: Boxplot summary of Dissolved Reactive Phosphorus (DRP) concentrations at SoE monitoring sites throughout the Dunedin/Southern coastal reporting region. Full scale. The **red** dashed line corresponds to the lowland ANZECC guideline for DRP of 0.010 mg/L.

Table 26: Trend summary of Dissolved Reactive Phosphorus (DRP) concentrations for the Dunedin/Southern coastal reporting region.

Site	Waikouaiti River at Confluence D/S	Lindsays Creek at North Road Bridge	Leith Stream at Dundas Street Bridge	Kaikorai Stream at Brighton Road	Tokomairiro River at West Branch Bridge	Owaka River at Katea Road	Catlins River at Houipapa
Dissolved Reactive Phosphorus	< DL	↑↑↑	↑↑↑	↑↑↑	↑↑↑	?	↑↑↑

Total Phosphorus

In contrast to elevated median DRP concentrations typical of the Dunedin/Southern coastal reporting region monitoring sites, median TP concentrations are below the ANZECC trigger level of 0.033 mg/L (Figure 19).

With the exception of the Waikouaiti River that returns 95th percentile TP concentrations well below the ANZECC trigger level; all other sites have concentration peaks well above trigger levels, being driven by high flow events and increased sediment loading that is typical of streams in modified catchments.

TP trend analysis (Table 26) shows similar patterns to DRP trend analysis, with most site shaving significant increasing (degrading) trends; the exceptions being the Waikouaiti, Owaka and Catlins rivers, which return indeterminate trend analysis results.

ORC do not have information on changes in land-use or land management practices so it is not possible to comment on the cause of the degrading trends at these sites.

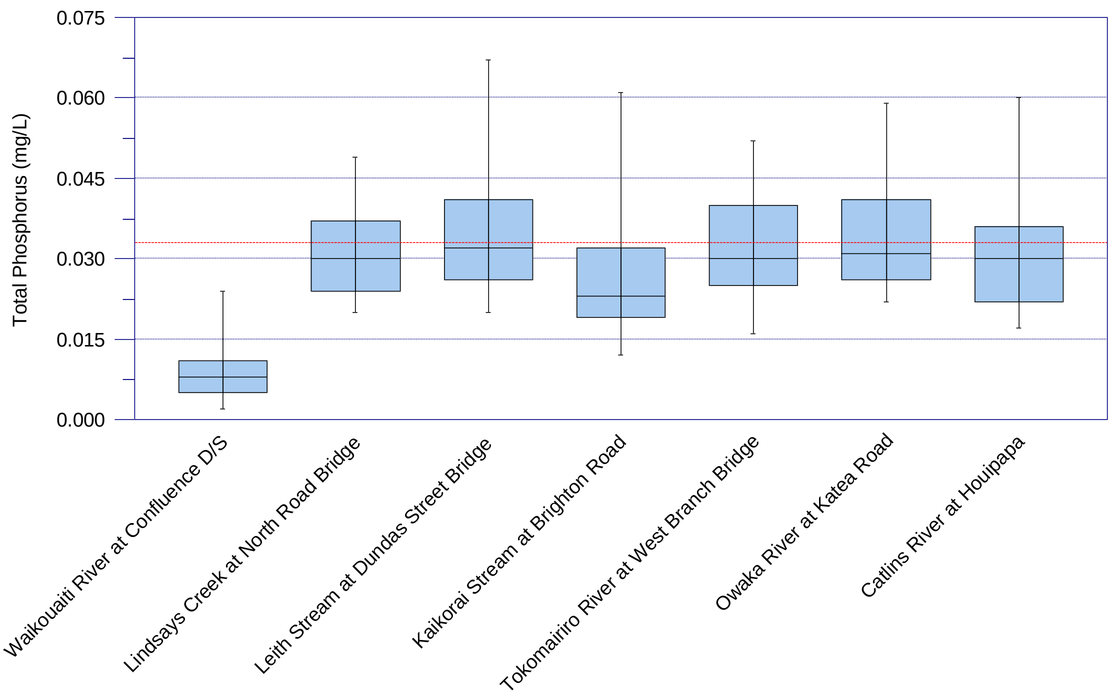

Figure 19: Boxplot summary of TP concentrations at SoE monitoring sites throughout the Dunedin/Southern coastal reporting region. The **red** dashed line corresponds to the lowland ANZECC guideline for TP of 0.033 mg/L.

Table 27: Trend summary of TP concentrations for the Dunedin/Southern coastal reporting region.

Site	Waikouaiti River at Confluence D/S	Lindsays Creek at North Road Bridge	Leith Stream at Dundas Street Bridge	Kaikorai Stream at Brighton Road	Tokomairiro River at West Branch Bridge	Owaka River at Katea Road	Catlins River at Houipapa
Total Phosphorus	?	↑↑↑	↑↑↑	↑↑↑	↑↑↑	?	?

Escherichia coli

The Waikouaiti River has very low levels of *E.coli* reflecting excellent bacterial water quality. This is a great result for a site that has a high degree of agriculture in the upstream catchment. This site is also fully Water Plan compliant and has an 'A' band status for the four separate NOF *E. coli* statistics further demonstrating excellent bacterial water quality.

The three monitoring sites with urbanised catchments have elevated *E. coli* concentrations; these being Lindsays Creek, the Water of Leith and the Kaikorai Stream. These streams do not have high primary contact recreational value but can contribute elevated bacteria levels to downstream receiving environments that do. Most notably being the upper Otago harbour that receives water from the Leith Stream and is popular for wind and kite surfing, kayaking and sailing. These three sites are in the top (worst) ten of all regional sites for returning high *E. coli* concentrations (Appendix E; Appendix G). Recent reporting by the Ministry for Environment (MfE) and Stats NZ found streams with urban upstream catchments to have the highest *E. coli* concentrations when compared to other land-cover types and concluded "the highest *E. coli* median concentrations were at sites in the urban land-cover class, followed by sites in the pastoral, exotic forest, or native land-cover class over the 2009–13 period"[12].

The Tokomairiro River also has high elevated bacteria levels that are often above the amber 260 CFU/100ml and red 550 CFU/100ml alert levels; although *E. coli* concentrations at this site are not as high as the urban sites. The Tokomairoro catchment has been identified in previous studies as suffering from bacterial enrichment that, for the wider catchment has been attributed to a number of sources, including extensive sheep and beef farming, dairying and for areas downstream of Milton, bacterial loading from the Milton wastewater treatment plant (WWTP) (Olsen, 2013). The Tokomairiro River at West Branch Bridge monitoring site reported on here lies well upstream of Milton, so is not affected by discharges from the WWTP. Land-use in the catchment upstream of this site is dominated by extensive sheep and beef farming and to a lesser extent, forestry.

For the four sites discussed above, 95th percentile *E. coli* concentrations exceed 2000 CFU/100ml and reflect high bacteria contamination levels at times. These periods would occur during high flow events. Both the Owaka River and Catlins River monitoring sites return elevated median *E. coli* concentrations of 170 and 140 CFU/100ml respectively (Appendix G).

[12] http://www.stats.govt.nz/browse_for_stats/environment/environmental-reporting-series/environmental-indicators/Home/Fresh%20water/river-water-quality-bacteria-ecoli.aspx

E. coli trend analysis (Table 28) returns significant trends for two sites only. These being an improving (decreasing trend) for the Owaka River and a degrading (increasing) trend for Lindsays Creek. The improving trend for the Owaka River is promising, particularly given the history of poor water quality across the wider catchment (Ozanne, 2011). All remaining sites have 'indeterminate' trends.

ORC do not have information on changes in land-use or land management practices so it is not possible to comment on the cause of the degrading trends at these sites.

Looking across Otago, the Dunedin/Southern coastal reporting region, with the exception of the Waikouaiti River, has quite poor bacterial water quality (Appendix E).

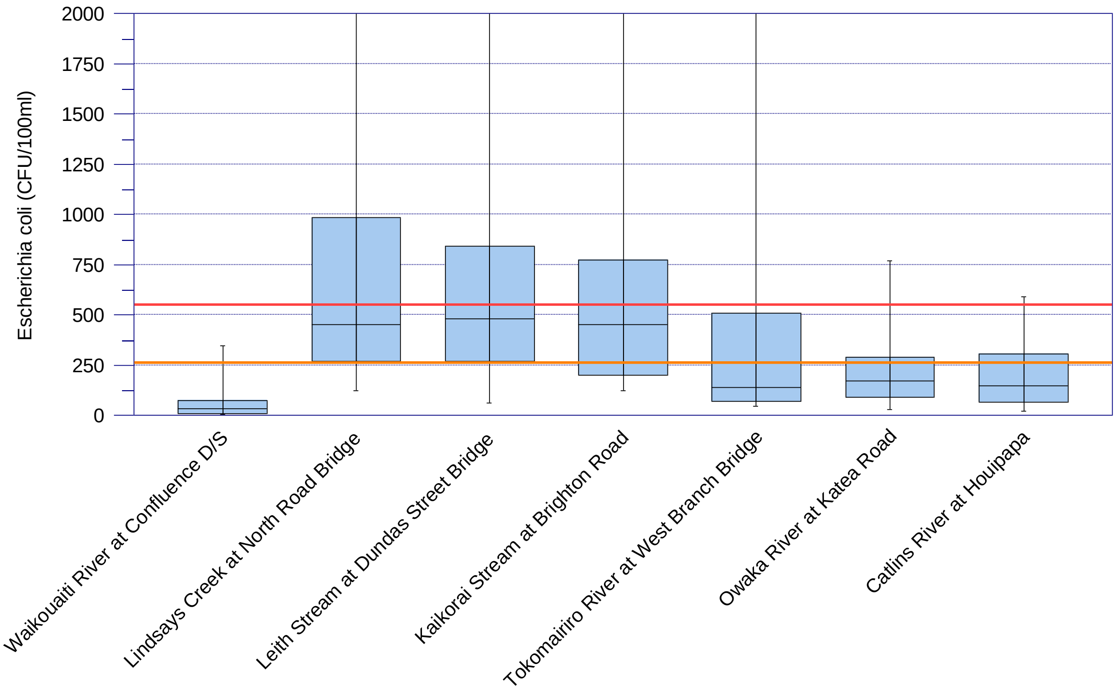

Figure 20: Boxplot summary of *E coli* concentrations at SoE monitoring sites throughout the Dunedin/Southern coastal reporting region. The amber line corresponds to the amber alert level of 260 CFU/100ml; the red line to the red alert level of 550 CFU/100ml.

Table 28: Trend summary of *E. coli* concentrations for the Dunedin/Southern coastal reporting region.

Site	Waikouaiti River at Confluence D/S	Lindsays Creek at North Road Bridge	Leith Stream at Dundas Street Bridge	Kaikorai Stream at Brighton Road	Tokomairiro River at West Branch Bridge	Owaka River at Katea Road	Catlins River at Houipapa
Escerichia coli	?	↑↑↑	?	?	?	↓↓↓	?

Turbidity

Turbidity levels are low across all Dunedin/Southern coastal monitoring sites with median and 75th percentile values (shown as the upper boundary of the box in the boxplots in Figure 21) being well below the ANZECC lowland guideline level of 5.6 NTU. Again with the exception of the Waikouaiti River, 95th percentile turbidity levels exceed the ANZECC lowland trigger levels at times, but are still very low when compared across the region (Appendix E).

Turbidity trend analysis (Table 29) reveals a significant decreasing trend for the Owaka River. This aligns with the decreasing trend for *E. coli* and again, is a promising result for this monitoring site. Previous intensive surveys of the Owaka River catchment identified high levels of deposited sediment throughout the catchment (Ozanne, 2011). The decreasing trend in turbidity would reflect a long-term reduction in sediment load being transported down the river and should help to improve issues of sedimentation.

The Tokomairiro River returned a probable increasing (degrading) trend for turbidity and warrants further scrutiny as more monitoring data comes to hand.

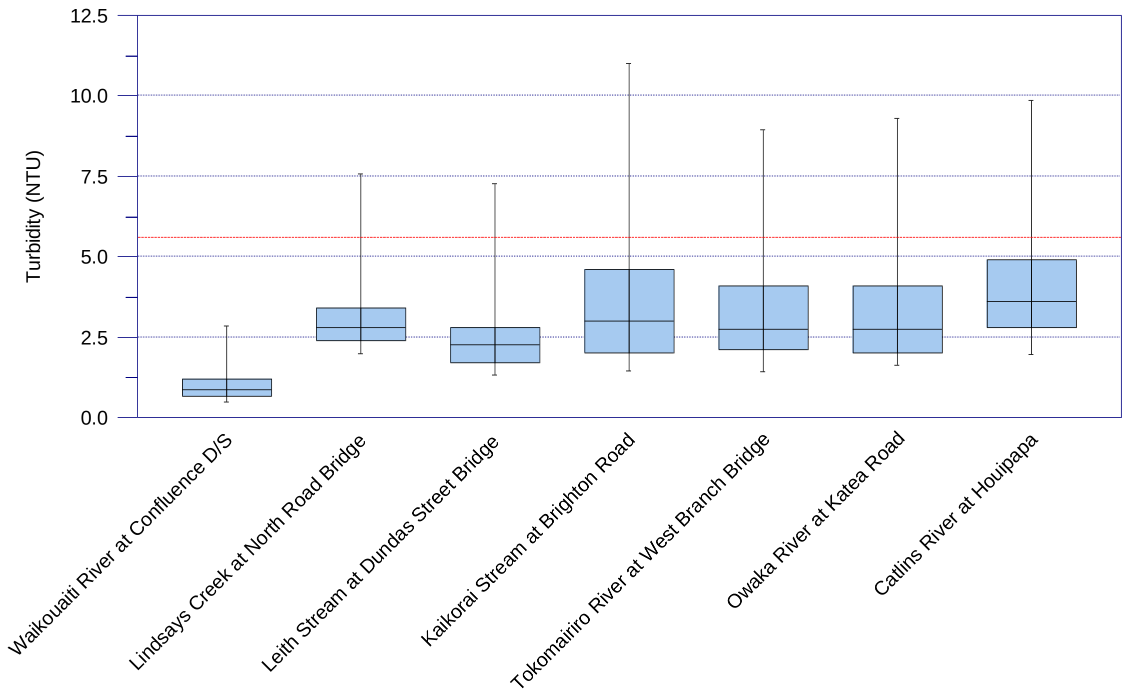

Figure 21: Boxplot summary of turbidity at SoE monitoring sites throughout the Dunedin/Southern coastal reporting region. The red dashed line corresponds to the lowland ANZECC guideline for Turbidity of 5.6 NTU.

Table 29: Trend summary of turbidity levels for the Dunedin/Southern coastal reporting region.

Site	Waikouaiti River at Confluence D/S	Lindsays Creek at North Road Bridge	Leith Stream at Dundas Street Bridge	Kaikorai Stream at Brighton Road	Tokomairiro River at West Branch Bridge	Owaka River at Katea Road	Catlins River at Houipapa
Turbidity	?	?	?	?	↑↑	↓↓↓	?

Stream Health and the Macroinvertebrate Community Index

Macroinvertebrate Community Index (MCI) scores provide an integrated indicator of the general state of water quality and aquatic ecosystem health at a site.

Figure 23 summarises MCI scores for sites monitored for aquatic macroinvertebrates throughout the Dunedin/southern coastal reporting region. The summary includes annual samples collected from 2008 to 2017 (8 years) where available. Not all sites monitored for water quality have macro-invertebrate samples taken. In the case of the Dunedin/Southern coastal reporting region, the Owaka River is such a site.

There is considerable variation in MCI scores across monitoring sites that, to a limited extent follow similar patterns to key water quality indicators.

MCI results for the Waikouaiti River monitoring site should be treated with caution. For a number of years the location of the site was 1.5 km downstream of the water quality monitoring site and located in a river reach affected intermittently by salt wedge intrusion from the estuary. At such times the freshwater macro-invertebrate community would be impacted intermittently by elevated salinities. From early 2017, the bio-monitoring site was moved upstream to the same location as the water quality monitoring site. However, the MCI score for 2017 was still very low at 83. The reasons for the low MCI remain unclear. For March 2017, during bio-monitoring, site assessments for the Waikouaiti River downstream (D/S) of the confluence show habitat to be marginal for invertebrates with some smothering of the bed by fine sediment and sand; also present is a moderate to high cover of periphyton (approximately 50% bed cover; ORC unpublished data). These factors would negatively impact the MCI and may explain the low scores for this site for the 2017 sampling round.

The highest scores recorded were for the Tokomairiro River and Catlins River monitoring sites with MCI's typically being above 110 representing a community in 'good' health. These two sites rank in the top five of all sites monitored for MCI across Otago (Appendix G), and show overall water and habitat quality to be supporting the existence of a healthy invertebrate community.

The three urban streams, despite having comparable water quality returned very different MCI scores. The Leith Stream and Lindsays Creek returned MCI scores around 90, with the Leith Stream having moderately higher MCI scores than Lindsays Creek (Figure 23), reflecting a stream with an invertebrate community in 'poor' health, a result not unexpected for these two sites. The big difference lies between these two sites and the Kaikorai Stream that returns very low MCI scores, with a median of 68. This reflects an invertebrate community in an extremely degraded state.

In a regional context (Appendix E), the Kaikorai Stream has the lowest MCI scores for sites across Otago and sits well below the 'degraded' threshold of 80. The measured core water quality variables show the Kaikorai Stream to have better water quality than the Leith Stream and Lindsays Creek. Despite this, the invertebrate community is severely impacted. Stream assessments carried out as part of the bio-monitoring program of 2017 show deposited sediment levels to be low and invertebrate habitat diversity to be high. However, habitat availability for Ephemeroptera/Plecoptera/Trichoptera (EPT) taxa that return high MCI scores was very low, with their preferred riffle/run habitat being absent from the site (Figure 22). This combined with high algal cover (99% stream bed cover for the 2017 sampling) would negatively affect MCI scores. However, this does not necessarily explain the extremely low MCI for this site and suggests other stressors to be impacting the site. Given the high degree of industrial activity upstream of the monitoring site, it is likely that stormwater as well as intermittent discharges of contaminants adversely affect the invertebrate community.

Recent amendments to the NPSFM require councils to actively investigate reasons for a site returning an MCI below 80 (Policy CB3). The low MCI score for the Kaikorai Stream has been reported on previously (ORC, 2008).

Figure 22: The Kaikorai Stream at Brighton Road monitoring site.

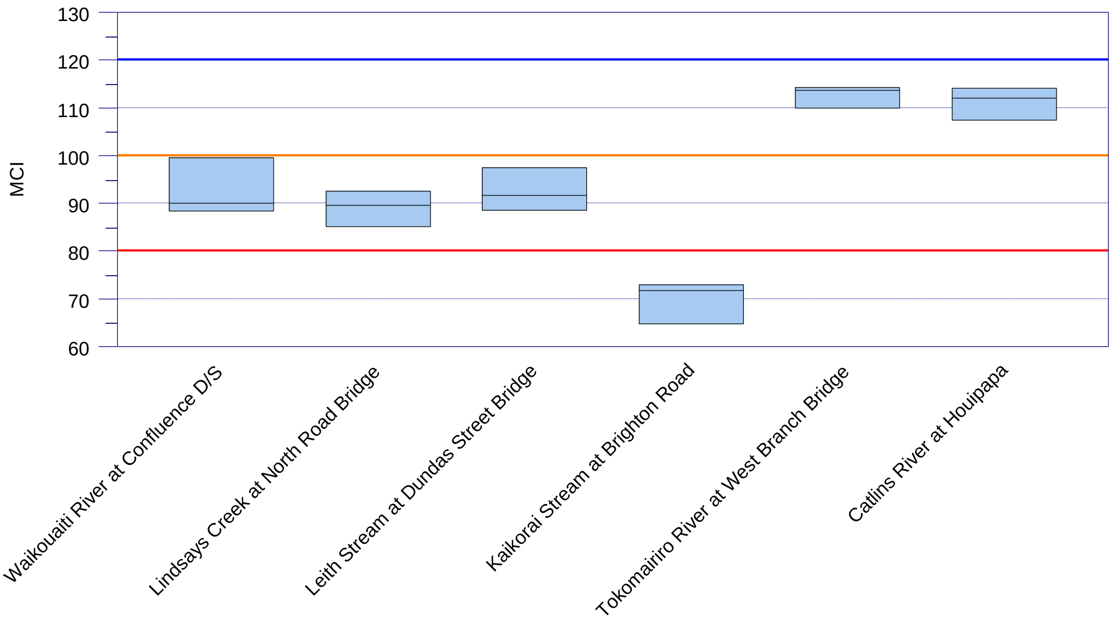

Figure 23: Boxplot summary of Macroinvertebrate Community Index (MCI) scores at SoE monitoring sites throughout North Otago where macroinvertebrate samples are routinely collected. Above the **blue** line corresponds to the 'Excellent' quality threshold; between the **orange** and blue line the 'Good' quality threshold; between the **red** and orange line 'Poor' quality threshold; below the red line the 'Degraded' threshold.

Dunedin/Southern coastal Water Quality Summary and Conclusions

Across the Dunedin/Southern coastal reporting region there are a considerable number of sites with degrading water quality trends, as shown in Table 30, which summarises trend results across all sites. There are a total of 49 results reported in the table; 27% return significant or probable degrading trends; 2% are stable; and 8% return significant or probable improving trends. Overall 63% of sites have either indeterminate trends (reported as "?"); or too many observations being 'less than detect' (<DL) for results returned from the laboratory.

Phosphorus is by far the worst performing variable with five of seven sites having increasing (degrading) trends for DRP. The reasons for this are unclear, particualry given the differences in land cover upstream of the monitoring sites in question, with the the local Dunedin City sites having a high degree of urbanisation versus the rural sites with a prevalence of extensive sheep and beef. These land cover types would have very different sources and transport mechanisms for DRP.

The Waikouaiti River monitoring site returned the best water quality for all measured variables (excluding MCI). This combined with decreasing trends for NNN and TN, and many results as being 'less than detection level' for NH_4-N and DRP, shows risk of eutrophication to be low. The low *E. coli* levels (full 'A' grade compliance under the NOF *E. coli* attribute) is an excellent result. This is good news for the Waikouaiti River and the vulnerable estuary downstream in relation to nutrient and bacteria loading.

Water quality for the Tokomairiro and Catlins rivers was generally moderate to good, with some minor exceedances of ANZECC trigger values for nutrients. Both sites had good MCI scores above 110 representing an invertebrate community in 'good' health. These two sites rank in the top five of all sites monitored for MCI across Otago (Appendix G), and show overall water and habitat quality to be supporting the existence of a healthy invertebrate community. Elevated *E. coli* concentrations are the biggest challenge for the Tokomairiro site.

In the case of the Owaka River, in a regional context, the river is quite eutrophic, with it being ranked in the top 5% of sites for elevated NNN and TN concentrations, sitting midway for DRP and TP and in the top 25% for elevated *E. coli.* River health is fair with MCI's fluctuating between 80 and 90 (the higher the better). The NPSFM identifies an MCI bottom line of 80. River physical habitat is poor to fair (ORC unpublished data). The high nitrogen load leaving the Owaka River catchment and entering the downstream estuary and Catlins Lake poses a significant eutrophication risk to these sensitive downstream receiving environments. What is promising is a decreasing (improving) trend in both *E. coli* and turbidity for the Owaka River monitoring site.

In summary:

- The Waikouaiti River has the best water quality for sites monitored across the Dunedin/Southern coastal reporting region;
- The Owaka River has poor water quality and is particularly enriched with NNN. There is evidence of an improving trend for *E. coli* and turbidity for this site;
- Compliance with the NOF *E. coli* attribute for 'median' concentrations is poor for all sites with the exception of the Waikouaiti River; with 6 out of 7 sites failing the national bottom line; 4 of the 7 are in the "E" band and 2 of the 7 in the "D" band. This reflects unacceptable levels of *E. coli* for more than half of samples taken at these sites;
- Water quality and instream health (based on MCI) of the Kaikorai Stream is highly degraded. Further investigation for the reasons driving this is needed.

Previous reports have identified stock access as a likely driver of poor water quality in the Owaka River, particularly in regards to the high fine sediment load delivered to the river and deposited on the stream bed (Ozanne, 2011). Ozanne (2011) concluded 'that riparian vegetation is largely absent from the [Owaka] River. Riparian vegetation is vital as a mechanism to control sediment input. Most rivers in the Catlins are used to provide stock water. Allowing stock access to rivers obviously accelerates bank erosion and degrades riparian vegetation'. Stock accessing streams also leads to increased bacterial loading.

Presently, ORC do not collect detailed information on land-use, land management practices or changes in either of the two that allow for inference as to the drivers of degrading or improving trends in water quality.

Table 30: Trend summary for the Dunedin/Southern coastal reporting region

Site	Ammoniacal Nitrogen	Nitrite/Nitrate Nitrogen	Total Nitrogen	Dissolved Reactive Phosphorus	Total Phosphorus	*Escherichia coli*	Turbidity
Waikouaiti River at Confluence D/S	< DL	↓↓↓	↓↓↓	< DL	?	?	?
Lindsays Creek at North Road Bridge	→	?	?	↑↑↑	↑↑↑	↑↑↑	?
Leith Stream at Dundas Street Bridge	?	?	?	↑↑↑	↑↑↑	?	?
Kaikorai Stream at Brighton Road	?	?	?	↑↑↑	↑↑↑	?	?
Tokomairiro River at West Branch Bridge	?	?	?	↑↑↑	↑↑↑	?	↑↑
Owaka River at Katea Road	?	?	?	?	?	↓↓↓	↓↓↓
Catlins River at Houipapa	?	↑↑↑	↑↑↑	↑↑↑	?	?	?

2.3. Taieri

The Taieri River catchment has an area of 5650 km^2 and is Otago's second largest catchment after the Clutha River/Mata-Au. The Taieri River originates in the Lammerlaw and Lammermoor Ranges (1150 m above sea level) and the Rock and Pillar Ranges (1450 m above sea level) of Central Otago. From here it meanders in a north-easterly direction across the Upper Taieri River Scroll Plain, a unique wetland system with nationally and regionally significant values.

The Upper Taieri River Scroll Plain (Figure 24) is a large natural wetland in the centre of the Maniototo and Styx Basins, with nationally and regionally significant landscape and biodiversity values. A scroll plain is a flood plain with a meandering river that changes its course during flooding, leaving ox-bow lakes and depressions that hold water for varying periods of time. The Upper Taieri River Scroll Plain is New Zealand's best example of such a meandering river. The Styx Basin wetlands consist of a scroll-plain landform of meanders, oxbows, old braids, backwaters and cut-offs, stretching from near Paerau to Canadian Hut. The area includes the 136 ha Serpentine Wildlife Management Reserve. The Maniototo Basin Wetlands, downstream of the Styx Wetlands, are of similar landform. They include the 37.5 ha Eden Creek Wildlife Management Reserve and the 44 ha Halls Road Wildlife Management Reserve. The Taieri Lake Wetlands lie adjacent to the Taieri River, downstream of the Maniototo Wetlands. They encompass part of the 187 ha Taieri Lake Recreation Reserve.

The Upper Taieri has two major catchments that are greater than 1000 km^2 in size; the Logan Burn that originates in the Rock and Pillar and Lammermoors ranges; and the Kye Burn that originates in the Ida Range and Kakanui Mountains. The Ida Range and Kakanui Mountains have the highest elevations in the catchment and are snow-capped for several months. Mount Ida is 1691 m above sea level and Mount Pisgah in the Kakanui Range is 1643 m above sea level. To the east, the Rock and Pillar Range, a prominent feature in the catchment, divides the Upper Taieri and the Strath Taieri. The Taieri River collects tributaries from its western, northern and eastern slopes. The range extends north-east from the Lammermoors for about 45 km, is about 20 km in width and reaches 1450 m above sea level at Summit Rock (Kitto, 2012).

Many tributaries from the surrounding ranges flow through gorges and down alluvial fans on the Maniototo Plain to the Taieri River, including the Linn Burn and Totara Creek, from Rough Ridge, in the west; the Logan Burn, Sow Burn and Pig Burn, from the Rock and Pillar Range, in the south; the Wether Burn and Hog Burn, from the Ida Range, in the north; and the Kye Burn, from the Ida Range, in the north, and the Swin Burn, from the Kakanui Mountains, in the north-east (Kitto, 2012).

From the Maniototo, the river passes through an incised gorge and crosses the Taieri Plain, where it joins the waters of the Lake Waipori and Waihola catchments and becomes tidal before making its way through another gorge to the sea at Taieri Mouth. Rainfall throughout the Taieri catchment is highly variable and is especially low in Central Otago due to the rain shadow effect of the Alps.

The river flows for a total length of 318 km to reach the Pacific Ocean 30 km south of Dunedin.

Figure 24: The Taieri Scroll Plain.

2.3.1. Taieri River and land cover characteristics

Table 31 summarises characteristics of the Taieri River reporting region based on the River Environment Classification (refer Appendix F for a detailed overview of the REC); land-cover (based on the Land Cover Database Version 4; condensed with the approach summarised in Appendix D); and the Land Use Capability (LUC) classes (see Section 2.0 for the LUC definition).

According to the River Environment Classification (REC), The Taieri River reporting region is dominated by rivers and streams with catchments that receive very low rainfall (less than 500 mm annual average rainfall) and are predominantly Cool/Dry low elevation rivers (19%) and Cool/Dry Hill rivers (65%) (Table 31).

The predominantly dry climate combined with significant areas of low relief land typical of the Upper Taieri Plain, the Maniototo Plain and the Strath Taieri Plain provides good opportunities for irrigation. More intensive land-uses associated with irrigated pasture can add pressure to water resources and water quality.

The predominant land cover throughout the Taieri River reporting region is high producing grassland (49%). High producing grassland represents areas that are actively managed and grazed for wool, lamb, beef, dairy or deer production (Table 31, Appendix D).

The upper reaches of the Logan Burn sit in the Lammerlaw and Lammermoor Ranges to the west and the Rock and Pillar Range to the east; the upper reaches of the Kye Burn catchment sit in the Ida Range and Kakanui Mountains to the east. These areas are steep and represent the high percentage of Class 6 (37%) and Class 7 (21%) land present in the Taieri catchment (Table 31, Appendix D). These areas have moderate to severe physical limitations for arable cropping activity and are dominated by low producing grassland and native cover. A significant proportion of the upper Taieri catchment in the Lammerlaw, Lammermoor and Rock and Pillar Ranges are dominated by native cover (Figure 25). The total area of native cover area in the catchment is 29% or 1650 km^2. 'Low Producing Grassland' includes exotic and indigenous grasslands, grazed for wool, sheep or beef and are usually found on steep hill country (Appendix D). There is approximately 740 km^2 of low producing grassland throughout the Taieri catchment. These low intensity land-uses leach low levels of nutrients and provide for good water quality.

This contrasts with the Upper Taieri Plain, the Maniototo Plain, the Strath Taieri Plain and the lower Taieri Plain that are low relief areas of Class 2, 3 and 4 land making up a total of 38% or 2170 km^2 of the total catchment area. These classes of land are more suited to arable cropping and intensive land use.

The Upper Taieri is one of the driest, coldest and hottest areas in New Zealand. Maximum temperatures over 30ºC are common in summer, and minimum temperatures of minus 15°C have been recorded near Naseby in the north of the Taieri River catchment. Throughout the catchment Patearoa has the lowest mean annual rainfall of 396 mm per year. In contrast, Dansey's Pass, which is influenced by orographic rainfall from the east, has a mean annual rainfall of 758 mm. The lowest rainfall experienced in any year was 262 mm, recorded at Patearoa in 1997. All sites tend to experience their lowest mean monthly rainfall during winter and early spring. The highest rainfall months occur in December, while Dansey's Pass gets most of its annual rain in summer, between November and February (Kitto, 2012).

Rivers with low water yield (those on dry areas) have reduced dilution and flushing capacity. They tend to be more susceptible to elevated nutrients should intensive land-uses fall within their catchments.

A report recently compiled by Ozanne (2017) provides a good summary of the water quality and surrounding catchment land-use of Lakes Waihola and Waipori located in the lower Taieri reporting region. Most of the farming in the vicinity of Lake Waipori on the Lower Taieri Plain takes place on poorly drained soils that would not be possible without the construction of extensive artificial drainage (pumped drainage schemes such as the Main Drain) to lower the underlying groundwater table (Ozanne, 2017).

Table 31: Characteristics of the Taieri reporting region. Source of flow, Land Cover Area and Land-use Capability.

Source of flow (REC)		Land Cover Area (LCDB4)		Land-use Capability Class (LUC)	
Cool-Dry / Hill	65.1%	Cropping	0.3%	Class 1	0.5%
Cool-Dry/Low-Elevation	18.8%	High producing grassland	49.3%	Class 2	1.3%
Cool-Dry/Lake	0.5%	Low Producing Grassland	13.0%	Class 3	10.2%
Cool-Dry/ Mountain	4.1%	Native Cover	29.1%	Class 4	26.7%
Cool-Wet/ Hill	4.2%	Orchards/Vineyards	0.02%	Class 5	0.6%
Cool-Wet/Low-Elevation	0.1%	Plantation forestry	6.0%	Class 6	37.3%
		Unaccounted	2.1%	Class 7	21.0%
		Urban areas	0.3%	Class 8	1.6%
				Lake	0.5%

The Taieri reporting region covers 570 578 hectares

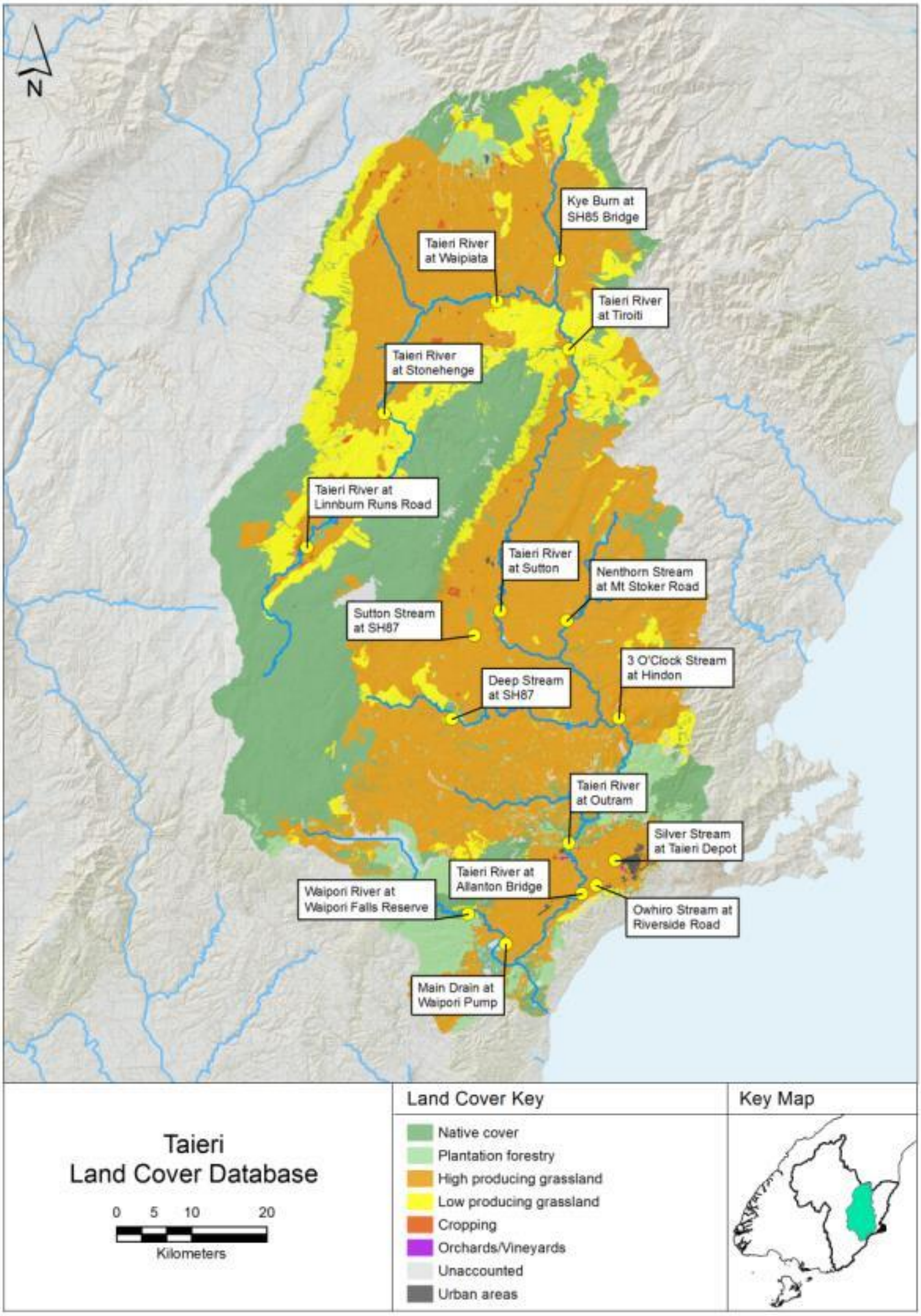

Figure 25: Map showing broad land cover categories of the Taieri reporting region based on the LCDB4databse.

2.3.2. Taieri water quality

The following section provides a summary of the Taieri reporting region water quality based on:

- Compliance against Schedule 15 (Water Plan) water quality limits;
- National Policy Statement for Freshwater Management (NPSFM 2014) National Objectives Framework Attribute bands (NOF bands);
- Summary boxplots of key water quality indicators with the inclusion of general water quality guidelines such as ANZECC (2000);
- A summary of trends (degrading/improving) that may (or may not) be evident in the data.

Schedule 15 compliance

Table 32 summarises compliance for SoE monitoring sites throughout the Taieri River reporting region with Schedule 15 (Water Plan) limits. For this section, all '80th percentile concentrations' are calculated from data collected when flows at the relevant flow reference site are at or below median flow.

There are a total 15 SoE monitoring sites throughout the Taieri River reporting zone with a good spread of sites across main-stem river and tributary stream sites from the upper to lower catchment. NIWA currently monitor two sites in the Taieri River, the Taieri River at Tiroiti and Sutton Stream at SH87 (Appendix A). Historically NIWA monitored the Taieri River at Outram, but in recent years monitoring of this site has been taken over by ORC.

The Owhiro Stream in the lower Taieri catchment has the worst level of compliance against Schedule 15 (Water Plan) limits of any site across the Taieri River reporting region and in fact, the wider Otago region. This site fails all Schedule 15 (Water Plan) limits (Figure 25).

For remaining sites, all are compliant for NH_4-N and have 80th percentile concentrations below at least one-quarter of the Schedule 15 limit of 0.100 mg/L (Table 32). Ammonia is toxic to aquatic life. In the environment, NH_4-N is quickly converted to nitrate-nitrogen by bacteria. The presence of elevated NH_4-N in a stream or river typically reflects direct contamination from a source that is high in this contaminant, an example being effluent. The combined presence of high NH_4-N, dissolved reactive phosphorus and faecal bacteria such as *E. coli* provides further evidence of this type of contamination, and would be expected to be present should significant amounts of effluent be reaching a stream or river.

Looking across all variables, 4 sites are fully compliant with Schedule 15 (Water Plan) limits, these sites being the Taieri River at Stonehenge, Deep Stream at SH87, the Taieri River at Outram and the Waipori River at Waipori Falls Reserve.

Generally all sites across the Taieri River catchment return low concentrations of NNN that are well below the Schedule 15 (Water Plan) limit of 0.075 mg/L. The exceptions being the Silver Stream and Owhiro Stream; both located in the lower Taieri catchment. The Silver Stream flows through Mosgiel and is influenced to some extent by the Mosgiel township. The Owhiro Stream has areas of intensive agriculture in its catchment that would increase NNN concentrations in the stream. The very low concentrations of NNN for the remaining sites throughout the catchment is very promising as the levels are very low and would be limiting both algae and cyanobacteria (phormidium) growth in the streams. The elevated NNN concentrations in the Silver Stream combined with the very low DRP concentrations provide ideal conditions for phormidium as this species of cyanobacteria can outcompete other algae in streams where these conditions prevail. Should NNN concentrations become elevated above 0.150 mg/L at other sites, then phormidium growth may become more of a risk.

E. coli compliance across sites is moderate with 8 sites failing and 7 sites passing the Schedule 15 (Water Plan) 80th percentile limit of 260 CFU/100ml. Stock access levels are high throughout the catchment and may be contributing to the elevated *E. coli* concentrations measured at some sites.

Table 32: 80th percentile values for water quality variables identified in Schedule 15 for the Taieri. Values are calculated from samples taken when flows are below median flow. The orange cells show where the 80th percentile exceeds the Schedule 15 limit.

Variable	NNN	NH_4-N	DRP	*E. coli*	Turbidity
Schedule 15 limit when flows < median flow	0.075 mg/L	0.100 mg/L	0.010 mg/L	260 CFU	5.00 NTU
SoE reporting name					
Taieri River at Linnburn	0.004	0.010	0.005	304	1.58
Taieri River at Stonehenge	0.008	0.009	0.009	156	2.16
Taieri River at Waipiata	0.016	0.014	0.047	480	3.38
Kye Burn at SH85 Bridge	0.030	0.011	0.006	294	1.62
Taieri River at Tiroiti	0.033	0.007	0.019	330	4.27
Taieri River at Sutton	0.020	0.013	0.014	512	2.78
Sutton Stream at SH87	0.008	0.009	0.006	308	2.07
Nenthorn Stream at Mt Stoker Road	0.002	0.019	0.017	68	1.80
Deep Stream at SH87	0.001	0.010	0.005	178	1.10
3 O'Clock Stream at Hindon	0.051	0.007	0.004	33	0.85
Taieri River at Outram	0.039	0.009	0.009	130	3.40
Silver Stream at Taieri Depot	0.360	0.015	0.007	230	2.10
Owhiro Stream at Riverside Road	0.340	0.140	0.048	870	21.00
Taieri River at Allanton Bridge	0.048	0.022	0.015	466	5.34
Waipori River at Waipori Falls Rsv	0.014	0.007	0.003	45	1.85

Nitrate and ammonia toxicity and NOF compliance

NOF attribute bands for nitrate (measured as NNN) and NH_4-N toxicity (Table 33 and Table 34 respectively) show excellent protection levels against toxicity risk for all Taieri monitoring sites with all sites returning an 'A' band (highest level of protection) for NNN and all sites returning an 'A' band for NH_4-N; with the exception of the Owhiro Stream that returns a 'B' band for NH_4-N.

The elevated median and maximum concentrations for NH_4-N for the Owhiro Stream push this site up into the B-band with the upper thresholds of < 0.03 and < 0.05 mg/L for the median and maximum NH_4-N concentrations. The 'B' band still provides for a good level of protection against ammonia toxicity but 'starts impacting occasionally on the 5% most sensitive species' (Appendix B). Some species of freshwater mollusc can be sensitive to ammonia toxicity.

Table 33: NOF compliance summary for Nitrate (estimated from NNN) toxicity for the Taieri reporting region. Included are median and 95th percentile values for the the period July 2012 to June 2017 and the corresponding NOF attribute band.

Variable	Nitrate as NNN		NOF Band	
SoE reporting name	Median (mg/L)	95th Percentile (mg/L)	Median	95th Percentile
Taieri River at Linnburn Runs Road	0.003	0.009	A	A
Taieri River at Stonehenge	0.007	0.045	A	A
Taieri River at Waipiata	0.019	0.075	A	A
Kye Burn at SH85 Bridge	0.039	0.134	A	A
Taieri River at Tiroiti	0.035	0.106	A	A
Taieri River at Sutton	0.032	0.175	A	A
Sutton Stream at SH87	0.010	0.114	A	A
Nenthorn Stream at Mt Stoker Road	0.001	0.028	A	A
Deep Stream at SH87	0.001	0.118	A	A
3 O'Clock Stream at Hindon	0.038	0.121	A	A
Taieri River at Outram	0.059	0.230	A	A
Silver Stream at Taieri Depot	0.330	0.553	A	A
Owhiro Stream at Riverside Road	0.367	0.831	A	A
Taieri River at Allanton Bridge	0.067	0.235	A	A
Waipori River at Waipori Falls Rsv.	0.003	0.009	A	A

Table 34: NOF compliance summary for NH_4-N. Included are median and maximum values for the the period July 2012 to June 2017 and the corresponding NOF attribute band.

Variable	Ammoniacal nitrogen (unadjusted)		NOF Band	
SoE reporting name	Median (mg/L)	Maximum (mg/L)	Median	Maximum
Taieri River at Linnburn Runs Road	0.006	0.023	A	A
Taieri River at Stonehenge	0.006	0.013	A	A
Taieri River at Waipiata	0.008	0.032	A	A
Kye Burn at SH85 Bridge	0.005	0.010	A	A
Taieri River at Tiroiti	0.006	0.015	A	A
Taieri River at Sutton	0.007	0.026	A	A
Sutton Stream at SH87	0.006	0.010	A	A
Nenthorn Stream at Mt Stoker Road	0.010	0.026	A	A
Deep Stream at SH87	0.005	0.020	A	A
3 O'Clock Stream at Hindon	0.006	0.011	A	A
Taieri River at Outram	0.006	0.014	A	A
Silver Stream at Taieri Depot	0.007	0.060	A	B
Owhiro Stream at Riverside Road	0.091	0.227	B	B
Taieri River at Allanton Bridge	0.013	0.031	A	A
Waipori River at Waipori Falls Rsv.	0.005	0.023	A	A

E. coli, swimmability and NOF compliance

Table 35 summarises compliance for *E. coli* against the four statistical tests of the NOF *E. coli* attribute.

There is quite a mix of compliance levels across the Taieri reporting region with 12 sites being compliant with a C band or better; and 3 sites failing with a D or E band. The Owhiro Stream has the worst level of compliance returning an E band for 3 of the 4 statistical tests. The other sites with poor bacterial water quality that are non-compliant with the national bottom line include the Taieri River at Waipiata and the Silver Stream at Taieri Depot. In the case of the Taieri at Waipiata, it is the 95th percentile concentration being slightly elevated above the “C” band threshold of 1200 CFU/100ml that pushes this site from an acceptable “C” band to the unacceptable “D” band. Should peak *E. coli* concentrations drop over time, then this site would be compliant.

The overall attribute state is based on the worst grading with the national bottom line being an orange “D” band; all sites must return a minimum of a “C” band.

Table 35: NOF compliance summary for *E. coli* for the the period July 2012 to June 2017. The overall grading band is determined by the lowest (worst) ranked Numeric Attribute State as it relates to the four separate states.

	Numeric Attribute State				Overall attribute state	
Site	Median grade (CFU/100ml)	95th percentile grade (CFU/100ml)	% over 260 CFU/100ml grade (%)	% over 540 CFU/100ml grade (%)	Grading attribute state	Overall Pass/Fail
Taieri River at Linnburn Runs Rd.	A (43)	B (894)	B (24%)	B (9%)	B	PASS
Taieri River at Stonehenge	A (41)	A (405)	A (7%)	A (3%)	A	PASS
Taieri River at Waipiata	A (74)	**D (1250)**	B (25%)	C (13%)	**D**	**FAIL**
Kye Burn at SH85 Bridge	A (29)	A (500)	A (14%)	A (2%)	A	PASS
Taieri River at Tiroiti	A (104)	B (703)	A (18%)	B (5%)	B	PASS
Taieri River at Sutton	A (105)	B (766)	B (21%)	C (10%)	C	PASS
Sutton Stream at SH87	A (122)	C (1072)	B (22%)	B (9%)	C	PASS
Nenthorn Stream at Mt Stoker Road	A (22)	A (105)	A (3%)	A (0%)	A	PASS
Deep Stream at SH87	A (54)	A (315)	A (8%)	A (0%)	A	PASS
3 O'Clock Stream at Hindon	A (13)	A (130)	A (4%)	A (2%)	A	PASS
Taieri River at Outram	A (63)	C (1055)	A (14%)	B (7%)	C	PASS
Silver Stream at Taieri Depot	**D (145)**	**D (2190)**	B (25%)	B (9%)	**D**	**FAIL**
Owhiro Stream at Riverside Road	**E (650)**	**D (4805)**	**E (81%)**	**E (57%)**	**E**	**FAIL**
Taieri River at Allanton Bridge	A (120)	B (834)	B (25%)	C (10%)	C	PASS
Waipori River at Waipori Falls Rsv.	A (13)	A (54)	A (0%)	A (0%)	A	PASS

Ammoniacal nitrogen

With the exception of the Owhiro Stream, NH_4-N concentrations are low across all Taieri reporting region SoE monitoring sites, with median and 75th percentile (represented by the upper boundary of the 'box' in the boxplots) being below the ANZECC trigger level of 0.021 mg/L (Figure 26). In the Owhiro Stream NH_4-N are elevated above ANZECC (2000) trigger levels and reflect some enrichment of NH_4-N above typical natural background levels. On a regional scale, the Owhiro Stream returns the highest NH_4-N concentrations of any SoE monitoring site across Otago (Appendix E).

Trend analysis results (Table 36) reveals a number of increasing (degrading) trends for NH_4-N. With the Taieri River at Tiroiti, the Owhiro Stream (already with elevated NH_4-N concentrations), and the Taieri River at Allanton all having significant degrading trends.

At 10 of the 15 monitoring sites, the very low concentrations return too many '<DL' (less than laboratory detection level) results for a meaningful trend analysis to be carried out.

There is a stable trend for Sutton Stream with no change over time. Trend results for the Taieri River at Outram are indeterminate.

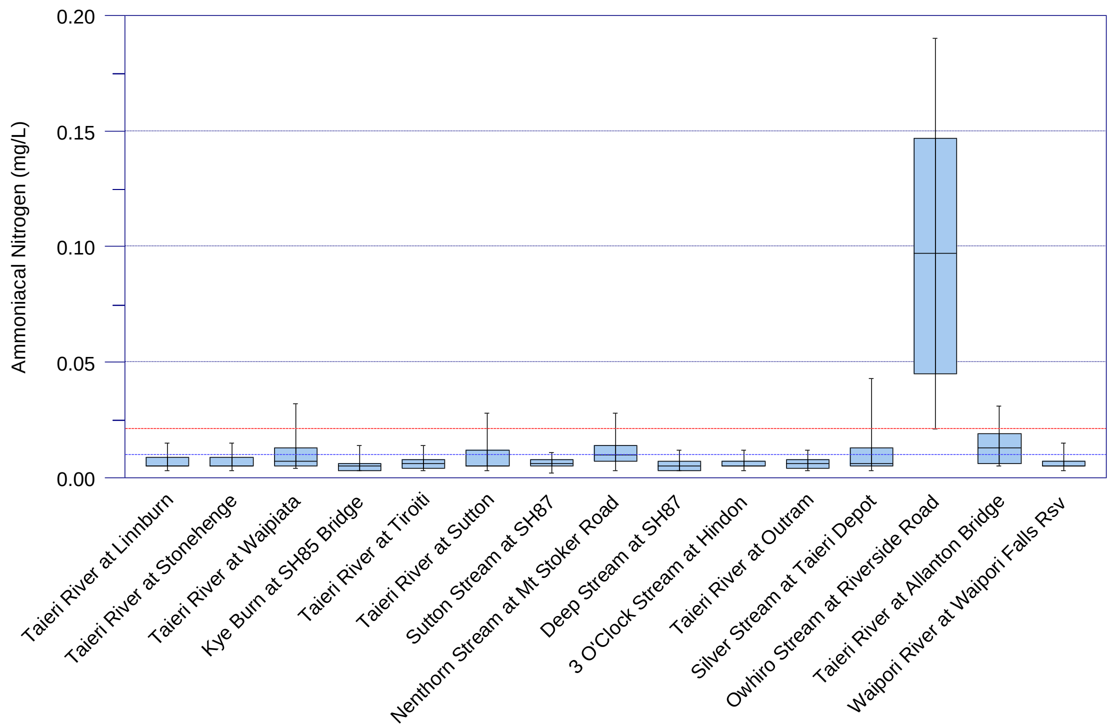

Figure 26: Boxplot summary of NH_4-N concentrations at SoE monitoring sites throughout the Taieri. Full scale. The **red** dashed line corresponds to the ANZECC lowland guideline for NH_4-N of 0.021 mg/L; the **blue** dashed line the upland guideline of 0.010 mg/L.

Table 36: Trend summary of ammonical nitrogen concentrations for the Taieri reporting region.

Site	Taieri River at Linnburn	Taieri River at Stonehenge	Taieri River at Waipiata	Kye Burn at SH85 Bridge	Taieri River at Tiroiti	Taieri River at Sutton	Sutton Stream at SH87	Nenthorn Stream at Mt Stoker Road	Deep Stream at SH87	3 O'Clock Stream at Hindon	Taieri River at Outram	Silver Stream at Taieri Depot	Owhiro Stream at Riverside Road	Taieri River at Allanton Bridge	Waipori River at Waipori Falls Rsv
Ammoniacal Nitrogen	< DL	< DL	< DL	< DL	↑ ↑ ↑	< DL	→	< DL	< DL	< DL	?	< DL	↑ ↑ ↑	↑ ↑ ↑	< DL

Nitrite/Nitrate nitrogen

Nitrite/nitrate nitrogen (NNN) concentrations are very low across all Taieri reporting region monitoring sites with the exception of the Owhiro Stream that has 75^{th} and 95^{th} percentile concentrations above the ANZECC (2000) lowland trigger value of 0.444 mg/L. The Silver Stream has a median concentration well below, and a 75^{th} percentile (represented by the upper box boundary) equal to the lowland trigger value of 0.444 mg/L reflecting some mild NNN enrichment (Figure 27).

All other sites have NNN concentrations that are well below the ANZECC upland trigger value of 0.167 mg/L reflecting very low levels of NNN - which is an excellent result.

On a regional standing, the Taieri River reporting zone has very low NNN concentrations comparable to the pristine monitoring sites of the Upper Clutha (Appendix G) which is an excellent result for catchment.

Of some concern is the NNN trend analysis (Table 37) that reveals a number of significant increasing (degrading) trends for NNN including the Taieri at Stonehenge, the Taieri at Sutton and the Taieri at Allanton. The Taieri at Tiroiti returns a probable increasing (degrading) trend. This is of particular concern given the current low NNN concentrations that are typically recorded at these sites. Increasing NNN concentration could increase the risk of toxic phormidium growth and nuisance algal blooms.

A number of tributary streams, namely the Sutton Stream, the 3'Oclock Stream and the Waipori River return significant decreasing (improving) trends (Table 37).

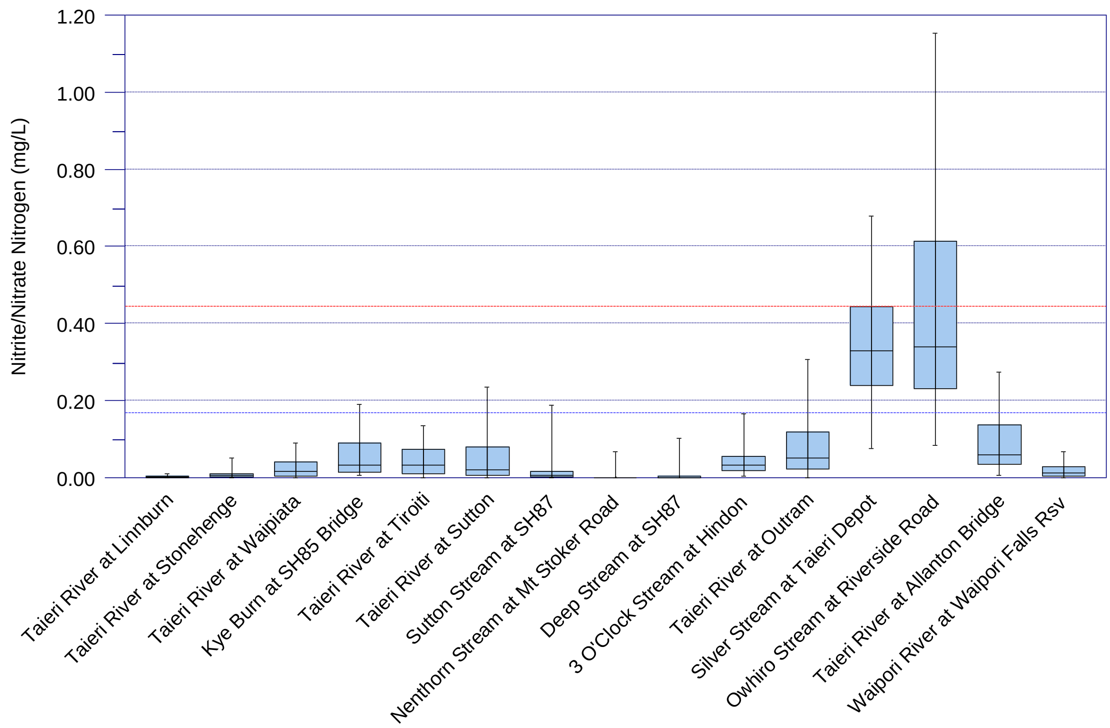

Figure 27: Nitrite/nitrate nitrogen (NNN) concentrations at SoE monitoring sites throughout the Taieri. The **red** dashed line corresponds to the ANZECC lowland guideline for NNN of 0.444 mg/L; the **blue** dashed line the upland guideline of 0.167 mg/L.

Table 37: Trend summary of nitrite/nitrate nitrogen (NNN) concentrations for the Taieri reporting region.

Site	Taieri River at Linnburn	Taieri River at Stonehenge	Taieri River at Waipiata	Kye Burn at SH85 Bridge	Taieri River at Tiroiti	Taieri River at Sutton	Sutton Stream at SH87	Nenthorn Stream at Mt Stoker Road	Deep Stream at SH87	3 O'Clock Stream at Hindon	Taieri River at Outram	Silver Stream at Taieri Depot	Owhiro Stream at Riverside Road	Taieri River at Allanton Bridge	Waipori River at Waipori Falls Rsv
NNN	< DL	↑↑↑	?	?	↑↑	↑↑↑	↓↓↓	< DL	< DL	↓↓↓	?	?	?	↑↑↑	↓↓↓

Total Nitrogen

Total nitrogen concentrations (Figure 28) are elevated compared to NNN concentrations (Figure 27) and show a significant amount of the nitrogen pool to be present in the stream as organic nitrogen. Organic nitrogen is not readily available for plant and algae growth but will be converted by in-stream processes to inorganic, bio-available nitrogen at a later date (termed nutrient spiralling).

Overall TN concentrations are below ANZECC trigger values (Figure 28).

In regards to decreasing (improving) trends, there is present similar pattern to NNN, with a number of tributary streams including the Kye Burn, the Sutton Stream, the 3'Oclock Stream and the Waipori River returning significant or probable decreasing (improving) trends for TN (Table 38).

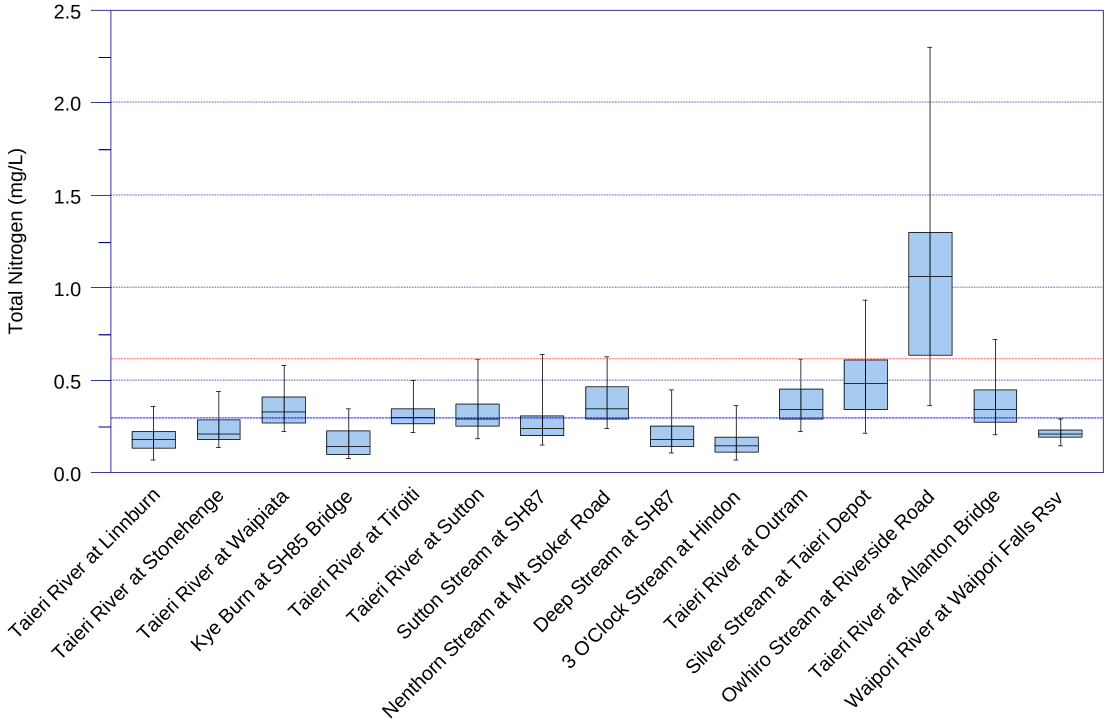

Figure 28: Boxplot summary of TN concentrations at SoE monitoring sites throughout the Taieri. The **red** dashed line corresponds to the ANZECC lowland guideline for TN of 0.614 mg/L; the **blue** dashed line the upland guideline of 0.295 mg/L.

Table 38: Trend summary of TN concentrations for the Taieri reporting region.

ite	Total Nitrogen
Taieri River at Linnburn	↑↑
Taieri River at Stonehenge	→
Taieri River at Waipiata	?
Kye Burn at SH85 Bridge	↓↓
Taieri River at Tiroiti	?
Taieri River at Sutton	?
Sutton Stream at SH87	↓↓↓
Nenthorn Stream at Mt Stoker Road	?
Deep Stream at SH87	?
3 O'Clock Stream at Hindon	↓↓
Taieri River at Outram	?
Silver Stream at Taieri Depot	?
Owhiro Stream at Riverside Road	?
Taieri River at Allanton Bridge	?
Waipori River at Waipori Falls Rsv	↓↓↓

Dissolved Reactive Phosphorus

Dissolved Reactive Phosphorus (DRP) concentrations are elevated across a number of sites throughout the Taieri River reporting region (Figure 29). In the upper catchment, the Taieri at Waipiata returns very high DRP concentrations. This is concerning as any increase in nitrogen concentration that are currently low, alongside the elevated DRP will result in significant increases in algal growth rate and a high risk of problematic algal blooms. The Taieri at Waipiata and the Owhiro Stream are in the top 10 sites for all of Otago for elevated DRP concentrations (Appendix E). In the upper catchment, the Taieri River at Tiroiti, the Taieri River at Sutton and the Nenthorn Stream all return elevated DRP concentrations above ANZECC upland trigger values. In the lower catchment, besides the Owhiro Stream that has already been discussed, the Taieri at Allanton has DRP concentrations above ANZECC (2000) trigger values. In the case of the Taieri at Allanton, the very low NNN concentrations at this site would result in strong nitrogen limitation of algae and plant growth. Given the elevated DRP at this site, it is important that NNN concentrations remain low or the risk of problematic algae growth will increase significantly.

The Taieri at Outram returns a significant decreasing (improving) trend whereas the Taieri at Allanton returns a significant increasing (degrading) trend (Table 39). The cause of the increase in DRP concentrations between Outram and Allanton is unclear. This could be changes in land-use or land-management practices, or it could be another stream discharging to the Taieri upstream of Allanton, such as the Silver Stream, which also returns a significant increasing (degrading) trend for DRP. Three of 15 sites return significant decreasing (improving) trends and include the Taieri at Tiroiti, the Sutton Stream and the Taieri at Outram. Three sites of 15 return a stable trend or no change over time.

Only two sites have too many ‘<DL’ results to allow a robust trend analysis to be carried out, these sites include the top-most Taieri River site, the Taieri at Linnburn; and in the lower catchment, the Waipori River. Both these sites have very low DRP concentrations.

ORC does not have detailed information on changes in land-use or land management practices that would allow comment to be made on the cause of the degrading or improving trends at these sites.

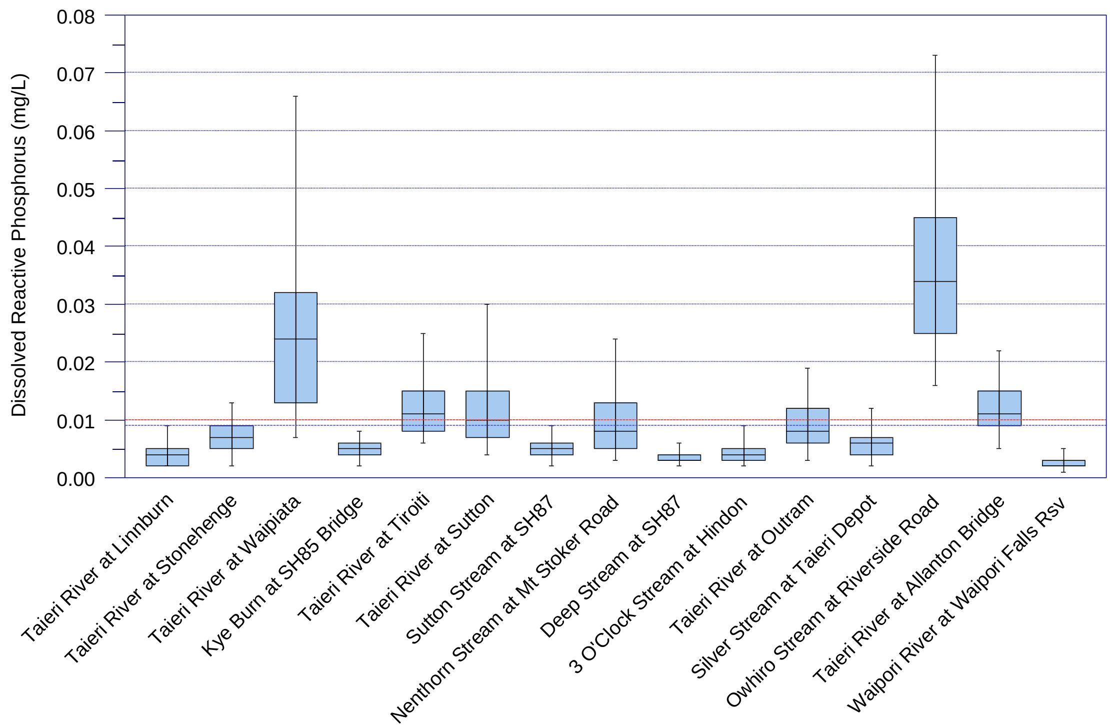

Figure 29: Boxplot summary of Dissolved Reactive Phosphorus (DRP) concentrations at SoE monitoring sites throughout the Taieri. Full scale. The **red** dashed line corresponds to the ANZECC lowland guideline for DRP of 0.010 mg/L; the **blue** dashed line the upland guideline of 0.009 mg/L.

Table 39: Trend summary of Dissolved Reactive Phosphorus (DRP) concentrations for the Taieri reporting region.

Site	DRP
Taieri River at Linnburn	< DL
Taieri River at Stonehenge	↑↑↑
Taieri River at Waipiata	?
Kye Burn at SH85 Bridge	→
Taieri River at Tiroiti	↓↓↓
Taieri River at Sutton	?
Sutton Stream at SH87	↓↓↓
Nenthorn Stream at Mt Stoker Road	?
Deep Stream at SH87	→
3 O'Clock Stream at Hindon	→
Taieri River at Outram	↓↓↓
Silver Stream at Taieri Depot	↑↑↑
Owhiro Stream at Riverside Road	?
Taieri River at Allanton Bridge	↑↑
Waipori River at Waipori Falls Rsv	< DL

Total Phosphorus

Total phosphorus concentrations across the Taieri reporting region (Figure 30) follow similar patterns to DRP with sites generally being below ANZECC trigger values. The exception being the Taieri at Waipiata and the Owhiro Stream, that return elevated TP levels.

The majority of sites return median TP concentrations well below the ANZECC trigger values for upland and lowland sites, with the exception of the Taieri at Tiroiti and Taieri at Sutton that have median TP concentrations above the ANZECC upland trigger value of 0.026 mg/L that is applicable to these two sites.

TP trend analysis (Table 40) returned indeterminate trends for all sites.

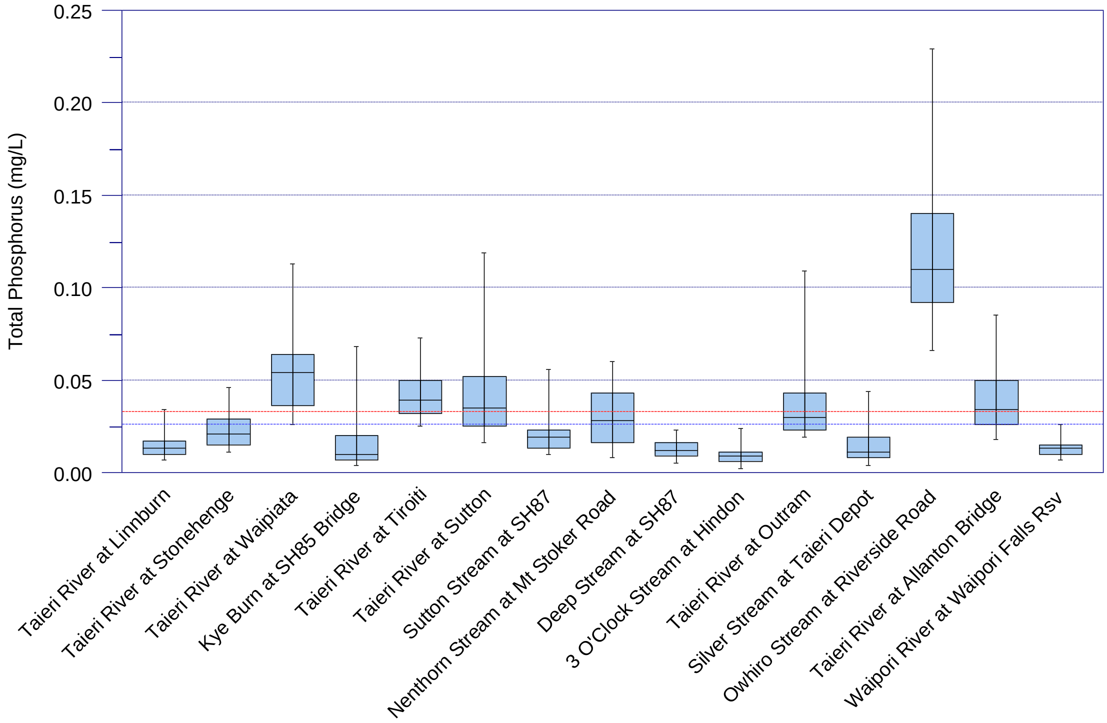

Figure 30: Boxplot summary of TP concentrations at SoE monitoring sites throughout the Taieri. The **red** dashed line corresponds to the ANZECC lowland guideline for TP of 0.033 mg/L; the **blue** dashed line the upland guideline of 0.026 mg/L.

Table 40: Trend summary of TP concentrations for the Taieri reporting region.

Site	Taieri River at Linnburn	Taieri River at Stonehenge	Taieri River at Waipiata	Kye Burn at SH85 Bridge	Taieri River at Tiroiti	Taieri River at Sutton	Sutton Stream at SH87	Nenthorn Stream at Mt Stoker Road	Deep Stream at SH87	3 O'Clock Stream at Hindon	Taieri River at Outram	Silver Stream at Taieri Depot	Owhiro Stream at Riverside Road	Taieri River at Allanton Bridge	Waipori River at Waipori Falls Rsv
Total Phosphorus	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?

Escherichia coli

Figure 31 shows *E. coli* concentrations for all SoE monitoring sites across the Taieri River reporting region. All sites have median and 75th percentile (upper bound of boxplots) equal to or below the amber alert level of 260 CFU/100ml; the exception is the Owhiro Stream that has highly elevated bacteria levels with a median and 75th percentile levels well above the red alert level of 550 CFU/100ml. The Owhiro also returns a significant increasing (degrading) trend (Table 41) showing this already heavily degraded site with respect to bacterial water quality, to be getting worse.

Nearly all sites return elevated 95th percentile concentrations (shown as the upper whisker in the boxplots) well above the red alert level. These peaks typically occur during times of elevated flow when surface runoff from the catchment transports bacteria to the stream and river sites. Having elevated bacteria levels during such times in a farmed catchment is not uncommon.

The Taieri River at Stonehenge, the Kyeburn, Nenthorn, 3 O'clock and Deep streams, and the Waipori River all have very low *E. coli* concentrations with 95th percentiles well below the 550 CFU/100ml red alert threshold. This shows these sites to have excellent bacterial water quality, even at times of elevated flow.

Trend analysis returns some concerning results with 6 of 15 sites having a significant or probable increasing (degrading) trend for *E. coli*. These sites include the upper catchment Taieri River sites at Linnburn, Stonehenge, Waipiata and Sutton, and the Taieri River at Allanton Bridge in the lower catchment. The other degrading trend is found in the Owhiro Stream (discussed previously).

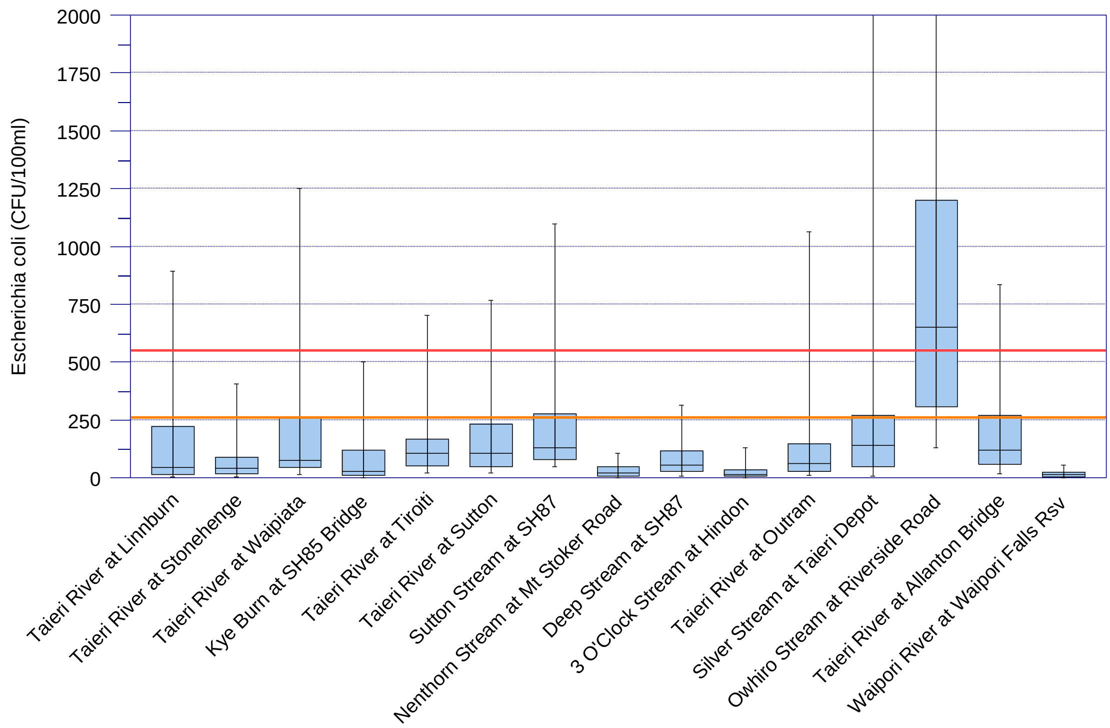

Figure 31: Boxplot summary of *E coli* concentrations at SoE monitoring sites throughout the Taieri. The amber line corresponds to the amber alert level of 260 CFU/100ml; the **red** line to the red alert level of 550 CFU/100ml.

Table 41: Trend summary of *Escerichia coli* (*E. coli*) concentrations for the Taieri reporting region.

Site	Taieri River at Linnburn	Taieri River at Stonehenge	Taieri River at Waipiata	Kye Burn at SH85 Bridge	Taieri River at Tiroiti	Taieri River at Sutton	Sutton Stream at SH87	Nenthorn Stream at Mt Stoker Road	Deep Stream at SH87	3 O'Clock Stream at Hindon	Taieri River at Outram	Silver Stream at Taieri Depot	Owhiro Stream at Riverside Road	Taieri River at Allanton Bridge	Waipori River at Waipori Falls Rsv
E. coli	↑↑↑	↑↑	↑↑↑	?	?	↑↑	?	→	?	?	?	< DL	↑↑↑	↑↑↑	?

Turbidity

Turbidity levels for SoE monitoring sites across the Taieri River reporting region are typically low (Figure 32) with 9 of the 15 sites monitored having turbidity concentrations that are well below the ANZECC upland and lowland guideline trigger levels of 4.1 NTU and 5.6 NTU respectively. The exceptions to this are the Kye Burn and Taieri at Tiroiti and Taieri at Sutton in the upper catchment; and the Taieri River at Outram, Owhiro Stream and to a lesser extent, the Taieri at Allanton in the lower catchment. These sites have turbidity levels that are often above guideline levels. In fact the Owhiro Stream returns the highest median turbidity for all Otago SoE sites (Appendix G).

For the Kyeburn, Taieri River at Tiroiti and the Taieri River at Sutton, historic gold workings have been hypothesised as affecting instream turbidity and suspended sediment levels (Kitto, 2012).

Trend analysis (Table 42) shows a number of sites to have significant and probable increasing (degrading) trends for turbidity, these being the Taieri River at Tiroiti and Sutton Stream at SH87 in the upper catchment; and the Taieri at Outram, Owhiro Stream and Taieri at Allanton in the lower catchment. The reasons for these trends is not evident as ORC do not have detailed information on changes in land-use or land management practices, so it is not possible to comment on the cause of the degrading trends at these sites.

Two sites have probable or significant decreasing (improving) trends for turbidity; this includes the Nenthorn Stream that already has very low turbidity; and the Waipori River.

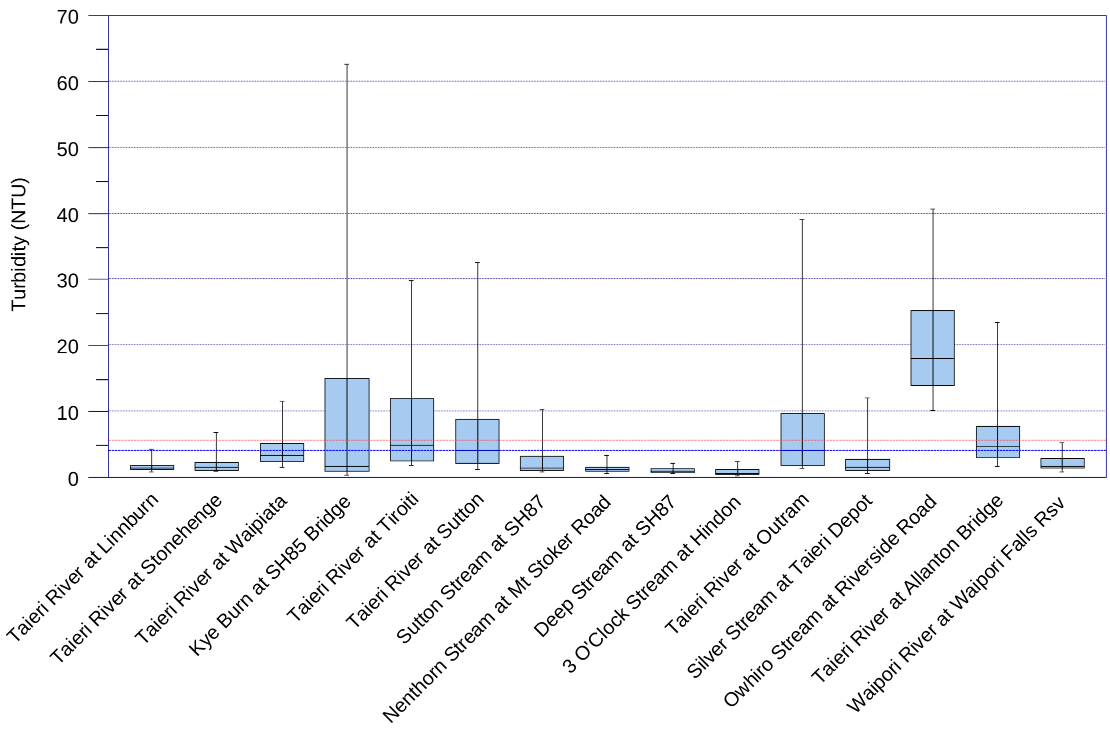

Figure 32: Boxplot summary of Turbidity at SoE monitoring sites throughout the Taieri. The **red** dashed line corresponds to the ANZECC lowland guideline for Turbidity of 5.6 NTU; the **blue** dashed line the upland guideline of 4.1 NTU.

Table 42: Trend summary of Turbidity levels for the Taieri reporting region.

Site	Turbidity
Taieri River at Linnburn	?
Taieri River at Stonehenge	?
Taieri River at Waipiata	?
Kye Burn at SH85 Bridge	?
Taieri River at Tiroiti	↑↑↑
Taieri River at Sutton	?
Sutton Stream at SH87	↑↑
Nenthorn Stream at Mt Stoker Road	↓↓
Deep Stream at SH87	?
3 O'Clock Stream at Hindon	?
Taieri River at Outram	↑↑↑
Silver Stream at Taieri Depot	?
Owhiro Stream at Riverside Road	↑↑↑
Taieri River at Allanton Bridge	↑↑↑
Waipori River at Waipori Falls Rsv	↓↓↓

Stream Health and the Macroinvertebrate Community Index

Macroinvertebrate Community Index (MCI) scores provide an integrated indicator of the general state of water quality and aquatic ecosystem health at a site.

Figure 33 summarises MCI scores for sites monitored for aquatic macroinvertebrates throughout the Taieri River reporting region. The summary includes annual samples collected from 2008 to 2017 (8 years) where data is available. Not all sites monitored for water quality have macro-invertebrate samples taken. Of the 15 sites monitored for water quality, 6 sites are sampled annually for macro-invertebrates.

MCI scores are somewhat comparable across sites with five of the six monitored sites returning comparable MCI scores that fall between 100 and 115; reflecting a macroinvertebrate community in 'good' condition. The exception is the Silver Stream monitoring site that returns a score of around 90, representing a macroinvertebrate community in 'poor' condition.

In a regional context, with the exception of the Silver Stream that is degraded, the Taieri River reporting region macroinvertebrate monitoring sites generally rank favourably against sites across Otago (Appendix G), and show overall water and habitat quality to be supporting the existence of a healthy invertebrate community.

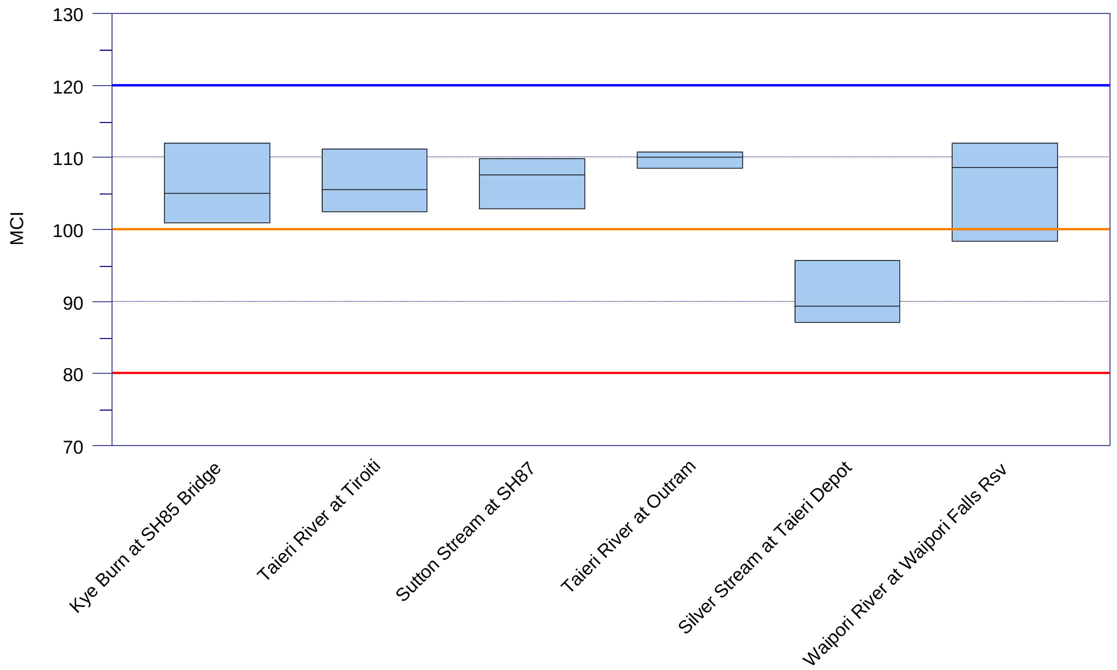

Figure 33: Boxplot summary of Macroinvertebrate Community Index (MCI) scores at SoE monitoring sites throughout North Otago where macroinvertebrate samples are routinely collected. Above the **blue** line corresponds to the 'Excellent' quality threshold; between the **orange** and blue line the 'Good' quality threshold; betwene the **red** and orange line 'Poor' quality threshold; below the red line the 'Degraded' threshold.

Taieri Water Quality Summary and Conclusions

Across the Taieri River reporting region there are a moderate number of sites with degrading water quality trends, as shown in Table 43, which summarises trend results across all sites. There are a total of 105 results reported in the table; 22% return significant or probable degrading trends; 5% are stable; and 11% return significant or probable improving trends. Overall 62% of sites have either indeterminate trends (reported as "?"); or too many observations being 'less than detect' (<DL) for results returned from the laboratory.

Despite relatively good bacterial water quality throughout the reporting region, *E. coli* is the worst performing variable with six of 15 sites having increasing (degrading) trends for *E. coli*. The reasons for this are unclear, but could be due to changes in irrigation practices as some types of irrigation, such as flood or border-dyke irrigation, have been identified in the past as a signifcant contributor to elevated *E. coli* levels instream (Kitto, 2012). Having accurate information on changes in land management practice, in particular irrigation practices, would help in identifying drivers of change evident with some water quality variables.

In summary:

- Risk to ammonia and nitrate toxicity is negligible across the Taieri River reporting region;
- Swimmability and *E. coli* bacteria levels are moderate with four of 15 sites failing the national bottom line. For the most part, Swimmability and bacterial water quality is good;
- The Owhiro Stream in the lower Taieri catchment has the worst level of compliance against Water Plan limits of any site across the Taieri River reporting region and in fact, the wider Otago region. This is the only site across the region that fails all Water Plan limits;
- The Owhiro Stream has the highest median *E. coli* and turbidity levels of all Otago SoE monitoring sites;
- Nitrite/nitrate nitrogen concentrations in the Taieri River are some of the lowest of those measured across Otago;
- Total Nitrogen concentrations are moderate across the Taieri River reporting region. This combined with the very low NNN concentrations shows organic nitrogen to dominate the TN pool;
- Dissolved Reactive Phosphorus concentraitons are elevated at more sites than not. This combined with the very low NNN concentrations shows that at most sites, algal growth would be very strongly nitrogen limited;
- For the Taieri River where macroinvertebrate monitoring takes place, Macroinvertebrate Community Health estimated by the MCI is typically good; the exception is the Silver Stream that has a macroinvertbrate community in 'poor' health.

Table 43: Trend summary for the Taieri reporting region.

Site	Ammoniacal Nitrogen	Nitrite/Nitrate Nitrogen	Total Nitrogen	Dissolved Reactive Phosphorus	Total Phosphorus	*Escherichia coli*	Turbidity
Taieri River at Linnburn	< DL	< DL	↑↑	< DL	?	↑↑↑	?
Taieri River at Stonehenge	< DL	↑↑↑	→	↑↑↑	?	↑↑	?
Taieri River at Waipiata	< DL	?	?	?	?	↑↑↑	?
Kye Burn at SH85 Bridge	< DL	?	↓↓	→	?	?	?
Taieri River at Tiroiti	↑↑↑	↑↑	?	↓↓↓	?	?	↑↑↑
Taieri River at Sutton	< DL	↑↑↑	?	?	?	↑↑	?
Sutton Stream at SH87	→	↓↓↓	↓↓↓	↓↓↓	?	?	↑↑
Nenthorn Stream at Mt Stoker Road	< DL	< DL	?	?	?	→	↓↓
Deep Stream at SH87	< DL	< DL	?	→	?	?	?
3 O'Clock Stream at Hindon	< DL	↓↓↓	↓↓	→	?	?	?
Taieri River at Outram	?	?	?	↓↓↓	?	?	↑↑↑
Silver Stream at Taieri Depot	< DL	?	?	↑↑↑	?	< DL	?
Owhiro Stream at Riverside Road	↑↑↑	?	?	?	?	↑↑↑	↑↑↑
Taieri River at Allanton Bridge	↑↑↑	↑↑↑	?	↑↑	?	↑↑↑	↑↑↑
Waipori River at Waipori Falls Rsv	< DL	↓↓↓	↓↓↓	< DL	?	?	↓↓↓

2.4. Upper Clutha

The Clutha River/Mata-Au originates in the headwaters of lakes Wakatipu, Wanaka and Hawea and drains much of the Otago region with a catchment area totalling 21 022 km^2. The Clutha River is the second longest river in New Zealand and the longest river in the South Island flowing for a total distance of 322 km from its furthest point to the north-west in the headwaters of the Makarora River, to where it discharges downstream of Balclutha to the Pacific Ocean. The Clutha River has a mean annual flow of 575 m^3/s. 75% of the total river flow measured at Balclutha upstream of where the river meets the Pacific Ocean, comes from the combined outflows of lakes Wakatipu, Wanaka and Hawea (Ozanne, 2012; LAWA[13]).

The Upper Clutha reporting region encapsulates (from upstream to downstream by confluence) the Makarora River (745 km^2), Matukituki River (801 km^2), Hunter River (1473 km^2), Cardrona River (347 km^2), Luggate Creek (123 km^2), Lindis River (1039 km^2), Dart River (631 km^2), Rees River (405 km^2), Shotover River (1091 km^2) and Mill Creek (14 km^2). The iconic Southern Great Lakes, Lake Wakatipu, Lake Wanaka and Lake Hawea are central to the region. Of these larger lakes, Wanaka and Wakatipu are unimpounded and Hawea is regulated (LAWA).

The Clutha and its principal tributary, the Kawarau River, pass through gorges, two of which are dammed for hydro-electricity generation forming lakes Dunstan and Roxsburgh, with lakes Roxsburgh being downstream of the Upper Clutha reporting region.

The headwaters of the catchment are predominantly in rugged, steep terrain with the highest point, Mt. Aspiring, reaching 3027 m. Numerous headwater streams such as the Dart River and Matukituki River originate along the eastern boundary of the Southern Alps and are fed by permanent glaciers (LAWA).

2.4.1. Upper Clutha geographical and land cover characteristics

Table 44 summarises characteristics of the Upper Clutha reporting region based on the River Environment Classification (refer Appendix F for a detailed overview of the REC); land-cover (based on the Land Cover Database Version 4; condensed with the approach summarised in Appendix D); and the Land Use Capability (LUC) classes (see Section 2.0 for the LUC definition). The Upper Clutha reporting region covers an area of 11974 km^2 representing approximately 57% of the total Clutha River/Mata-Au catchment.

According to the River Environment Classification (REC), rivers and streams of the Upper Clutha reporting region cover a broad range of river types with cool/wet (36.9%) and cool/extremely wet (9.9%) rivers being a significant contributor to total river length throughout the region. The REC classes wet rivers as having a mean annual rainfall of 500 mm to 1500 mm; extremely wet rivers are classed as having a mean annual rainfall greater than 1500 mm. Water yields from these streams and rivers is high. This is the highest percentage of wet and extremely wet rivers of any region covered in this report. Also of significance is the proportion of glacial fed (6.9%) and lake fed (23.5%) rivers (Table 44).

The predominant land cover throughout the Upper Clutha reporting region is native cover (63%, 7544 km^2) followed by low producing grassland (14.7%, 1760 km^2). 'Low producing grassland' includes "exotic and indigenous grasslands, grazed for wool, sheep or beef. Usually found on steep hill country" (Table 44, Appendix D). The high proportion of native cover in the upper catchments of the large lakes falls in areas of high to very high rain and snowfall. This provides large volumes flowing from pristine catchments of exceptional quality that feeds the Southern Great Lakes.

[13] https://www.lawa.org.nz/explore-data/otago-region/river-quality/clutha-river/

LUC Class 6 to 8 lands dominate the Upper Clutha reporting region with 86.7% (10381 km^2) of the total land area made of this steep terrain typical of the mountain ranges surrounding the Southern Great Lakes.

Table 44: Zone characteristics of the Upper Clutha reporting region. Land cover area and land-use capability.

Source of flow (REC)		Land Cover Area (LCDB4)		Land-use Capability Class (LUC)	
Cool-Dry / Hill	13.2%	Cropping	0.2%	Class 2	0.3%
Cool-Dry / Low-Elevation	3.5%	High producing grassland	6.0%	Class 3	2.3%
Cool-Dry / Lake	15.0%	Low Producing Grassland	14.7%	Class 4	4.0%
Cool-Dry / Mountain	2.7%	Native Cover	63.1%	Class 5	0.4%
Cool-Wet / Glacial-Mountain	0.02%	Orchards/Vineyards	0.2%	Class 6	19.0%
Cool-Wet / Hill	7.3%	Plantation forestry	0.6%	Class 7	34.4%
Cool-Wet / Low-Elevation	1.2%	Unaccounted	14.8%	Class 8	33.3%
Cool-Wet / Lake	7.6%	Urban areas	0.3%	Lake	5.5%
Cool-Wet / Mountain	22.0%				
Cool-Extremely-Wet / Glacial-Mountain	6.7%				
Cool-Extremely-Wet / Hill	3.2%				
Cool-Extremely-Wet / Low-Elevation	0.1%				
Cool-Extremely-Wet / Lake	0.9%				
Cool-Extremely-Wet / Mountain	16.7%				

The Upper Clutha reporting region covers 1 197 398 hectares

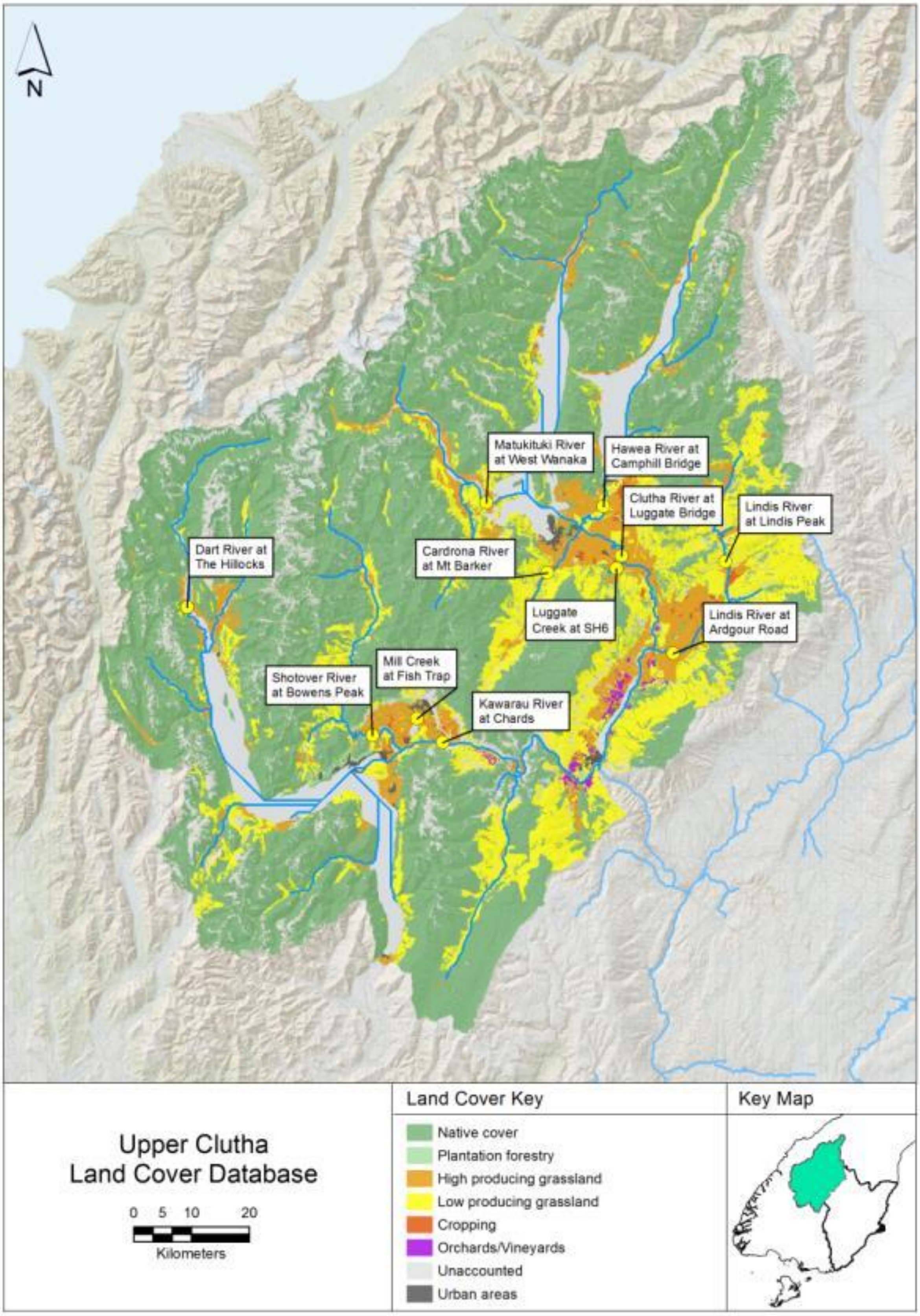

Figure 34: Map showing broad land cover categories of the Upper Clutha reporting region based on the LCDB4 databse.

2.4.2. Upper Clutha water quality

The following section provides a summary of the Upper Clutha reporting region water quality based on:

- Compliance against Schedule 15 (Water Plan) water quality limits;
- National Policy Statement for Freshwater Management (NPSFM 2014) National Objectives Framework Attribute bands (NOF bands);
- Summary boxplots of key water quality indicators with the inclusion of general water quality guidelines such as ANZECC (2000);
- A summary of trends (degrading/improving) that may (or may not) be evident in the data.

Schedule 15 compliance

Table 45 summarises compliance for SoE monitoring sites throughout the Upper Clutha reporting region with Schedule 15 (Water Plan) limits. For this section, all ‘80th percentile concentrations’ are calculated from data collected when flows at the relevant flow reference site are below median flow.

There are a number of SoE monitoring sites in the Upper Clutha reporting region that fall in RWG 3 (Figure 1). These sites have the most stringent water quality limits under Schedule 15 (Water Plan) and are delineated in Table 45 as underlined numbers in italics.

All sites in RWG2 are compliant with respect to the Schedule 15 (Water Plan) NH_4-N limit of 0.100 mg/L. For the RWG 3 sites, a number fail the more stringent Schedule 15 (Water Plan) limit of 0.010 mg/L, including the Dart, Matukituki and Kawarau rivers. In the case of the Dart and Matukituki rivers, the upstream catchments are relatively untouched and elevated NH_4-N would in all likelihood be derived from natural sources. In the case of the Kawarau, the Project Shotover WWTP discharging to the Shotover River appears to elevate NH_4-N concentrations downstream, as shown by Figure 35 that compares two SoE sampling sites upstream of Project Shotover to the non-compliant SoE monitoring site downstream.

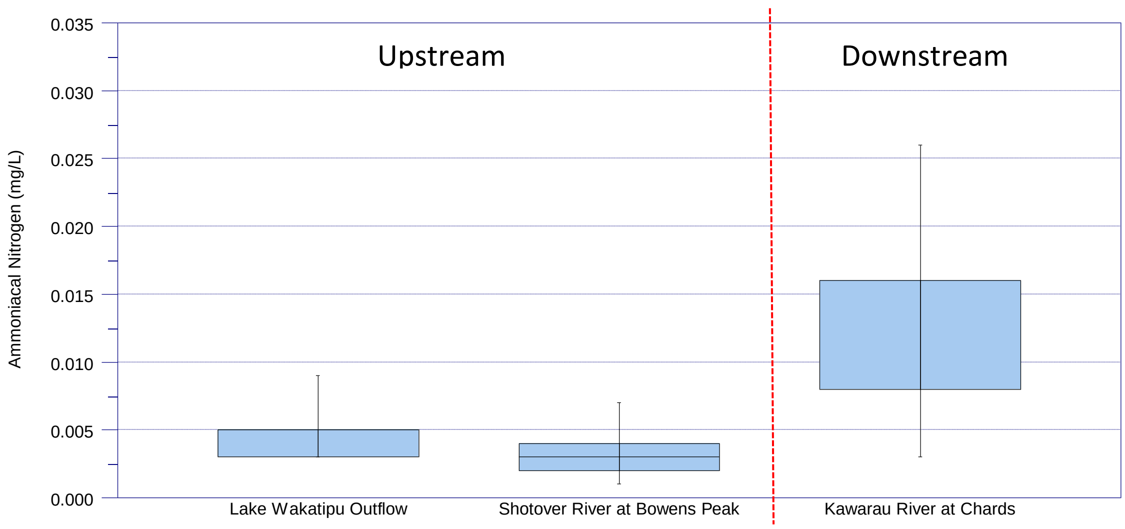

Figure 35: Comparison of in-stream NH_4-N concentrations upstream and downstream of the Project Shotover Waste Water Treatment Plant.

Both RWG 2 and RWG 3 share the same Water Plan limit of 0.075 mg/L for NNN. The majority of sites across the Upper Clutha reporting region are compliant with this limit. The exceptions being the Cardrona River at Mt Barker, the Lindis River at Ardgour; and Mill Creek at the Fish Trap. The Cardrona is only marginally non-compliant but the Lindis River, and in particular Mill Creek monitoring sites exceed the 0.075 mg/L limit by a significant amount. In the case of Mill Creek, the NNN concentration is over 5 times the Water Plan limit. This is particularly concerning given Mill Creek is the dominant tributary discharging to Lake Hayes.

Dissolved Reactive Phosphorus compliance is generally excellent with all sites except the Luggate Creek at SH6 being Schedule 15 (Water Plan) compliant. In the case of turbidity, the only non-compliant sites are those that have a high degree of glacial flour present in the river, such as the Dart, that returns very high turbidity (and suspended sediment) levels despite this river being a natural, pristine river. Turbidity limits in the Water Plan do recognize that some rivers such as the Dart and Shotover can be influenced by natural glacial outflows.

E. coli compliance for most sites is good, the exception being Mill Creek that returns a very high 80th percentile concentration of *E. coli* of 420 CFU/100ml, compared with the Water Plan limit for RWG 2 of 260 CFU/100ml. understanding the source of the high *E. coli* in Mill Creek is important given the value of this Creek for primary recreation activities in the area that it flows into Lake Hayes.

Table 45: 80th percentile values for water quality variables identified in Schedule 15. Values are calculated from samples taken when flows are below median flow. The orange cells show where the 80th percentile exceeds the Schedule 15 limit. Numbers underlined in italics have lower limits under Schedule 15.

Variable	NNN	NH_4-N	DRP	*E. coli*	Turbidity
Schedule 15 limit when flows < median flow	0.075 mg/L	0.100 mg/L *0.010 mg/L*	0.010 mg/L *0.005 mg/L*	260 CFU *50 CFU*	5.0 NTU *3.0 NTU*
SoE reporting name					
Dart River at The Hillocks	0.033	*0.024*	*0.003*	*10*	*11.40*
Shotover River at Bowens Peak	0.012	0.004	0.001	6	4.20
Mill Creek at Fish Trap	0.390	0.014	0.008	420	3.90
Kawarau River at Chards	0.032	*0.025*	*0.002*	*42*	*3.90*
Matukituki River at West Wanaka	0.070	*0.011*	*0.004*	*66*	*2.08*
Cardrona River at Mt Barker	0.084	0.010	0.004	80	0.70
Hawea River at Camphill Bridge	0.019	0.006	0.003	8	0.62
Clutha River at Luggate Bridge	0.041	*0.004*	*0.001*	*4*	*1.09*
Luggate Creek at SH6	0.003	0.009	0.015	228	1.32
Lindis River at Lindis Peak	0.011	0.008	0.005	60	1.19
Lindis River at Ardgour Road	0.170	0.011	0.004	70	1.02

Nitrate and ammonia toxicity and NOF compliance

NOF attribute bands for nitrate (measured as NNN) and NH_4-N toxicity (Table 46 and Table 47 respectively) show excellent protection levels against toxicity risk for all Upper Clutha SoE monitoring sites, with all sites returning an 'A' band (highest level of protection) for NNN; and all sites returning an 'A' band for NH_4-N. There is present some slightly elevated NH_4-N concentrations in the Dart River at times that are approaching the upper 'A' band boundary of 0.05 mg/L. As discussed previously, the Dart River catchment is predominantly a native catchment so elevated NH_4-N is sourced from natural sources.

Table 46: NOF compliance summary for Nitrate (estimated from NNN). Included are median and 95^{th} percentile values for the the period July 2012 to June 2017 and the corresponding NOF attribute band.

Variable	Nitrate as NNN		NOF Band	
SoE reporting name	Median (mg/L)	95^{th} Percentile (mg/L)	Median	95^{th} Percentile
Dart River at The Hillocks	0.021	0.037	A	A
Shotover River at Bowens Peak	0.015	0.030	A	A
Mill Creek at Fish Trap	0.317	0.452	A	A
Kawarau River at Chards	0.024	0.032	A	A
Matukituki River at West Wanaka	0.048	0.074	A	A
Cardrona River at Mt Barker	0.056	0.127	A	A
Hawea River at Camphill Bridge	0.013	0.023	A	A
Clutha River at Luggate Bridge	0.033	0.043	A	A
Luggate Creek at SH6	0.002	0.016	A	A
Lindis River at Lindis Peak	0.019	0.072	A	A
Lindis River at Ardgour Road	0.064	0.144	A	A

Table 47: NOF compliance summary for NH_4-N. Included are median and maximum values for the the period July 2012 to June 2017 and the corresponding NOF attribute band.

Variable	Ammoniacal nitrogen (unadjusted)		NOF Band	
SoE reporting name	Median (mg/L)	Maximum (mg/L)	Median	Maximum
Dart River at The Hillocks	0.014	0.041	A	A
Shotover River at Bowens Peak	0.003	0.006	A	A
Mill Creek at Fish Trap	0.008	0.027	A	A
Kawarau River at Chards	0.014	0.024	A	A
Matukituki River at West Wanaka	0.007	0.016	A	A
Cardrona River at Mt Barker	0.005	0.018	A	A
Hawea River at Camphill Bridge	0.004	0.012	A	A
Clutha River at Luggate Bridge	0.002	0.006	A	A
Luggate Creek at SH6	0.004	0.014	A	A
Lindis River at Lindis Peak	0.004	0.011	A	A
Lindis River at Ardgour Road	0.004	0.011	A	A

E. coli, swimmability and NOF compliance

Table 48 summarises compliance for *E. coli* against the four statistical tests of the NOF *E. coli* attribute. Compliance is generally excellent across the Upper Clutha reporting district with all sites except Mill Creek returning bacterial water quality that is acceptable to the recently amended NPSFM (2014).

The high background *E. coli* concentrations in Mill Creek (determined by the 'median' concentration grade) push this site from an acceptable 'C' band to an unacceptable 'D' band by 10 CFU/100ml. Interestingly the peaks in *E. coli* in Mill Creek are minor and are below 600 (discussed in the next section), however the 'median' or background concentrations are elevated. This indicates an *E. coli* source that is affecting water quality even under low flow conditions, such as water fowl or stock often being present in the stream above the sampling location. Faecal Source Tracking (FST) is a technique that uses steroid and DNA markers to determine the source or type of animal that the *E. coli* is derived from. It is ORC's intention to undertake FST analysis on Mill Creek over the 2017/18 and 2018/19 financial years to better understand the drivers of poor bacterial water quality at this site (Ozanne, ORC, pers. comm.).

The overall attribute state is based on the worst grading with the national bottom line being an orange "D" band; all sites must return a minimum of a "C" band.

Table 48: NOF compliance summary for *E. coli* for the the period July 2012 to June 2017. The overall grading band is determined by the lowest (worst) ranked Numeric Attribute State as it relates to the four separate states.

	Numeric Attribute State				Overall attribute state	
Site	Median grade (CFU/100ml)	95th percentile grade (CFU/100ml)	% over 260 CFU/100ml grade (%)	% over 540 CFU/100ml grade (%)	Grading attribute state	Overall Pass/Fail
Dart River at The Hillocks	A (8)	A (340)	A (10%)	A (4%)	A	**Pass**
Shotover River at Bowens Peak	A (4)	A (55.4)	A (0%)	A (0%)	A	**Pass**
Mill Creek at Fish Trap	**D (140)**	B (593)	B (29%)	B (7%)	**D**	**FAIL**
Kawarau River at Chards	A (7)	A (95)	A (0%)	A (0%)	A	**Pass**
Matukituki River at West Wanaka	A (23)	C (1200)	A (15%)	B (7%)	C	**Pass**
Cardrona River at Mt Barker	A (38)	A (276)	A (5%)	A (3%)	A	**Pass**
Hawea River at Camphill Bridge	A (2)	A (32)	A (2%)	A (0%)	A	**Pass**
Clutha River at Luggate Bridge	A (1)	A (22)	A (0%)	A (0%)	A	**Pass**
Luggate Creek at SH6	A (25)	A (364)	A (5%)	A (2%)	A	**Pass**
Lindis River at Lindis Peak	A	A	A	A	A	**Pass**
Lindis River at Ardgour Road	A	A	A	A	A	**Pass**

Ammoniacal nitrogen

With the exception of the Kawarau River at Chards, NH_4-N concentrations are relatively low across all Upper Clutha reporting region SoE monitoring sites; with median concentrations being below the ANZECC upland trigger level of 0.010 mg/L (Figure 36).

For the Dart River and Mill Creek monitoring sites, the 75th percentile (represented by the upper boundary of the 'box' in the boxplots) exceeds the upland ANZECC trigger level of 0.010 mg/L; but overall concentrations are still relatively low, and do not pose any real concerns. As discussed previously, the Dart River catchment is dominated by native vegetation cover and is in pristine condition. The elevated concentrations in this catchment are in all likelihood derived from natural sources such as the decomposition or breakdown of organic vegetation matter.

On a regional scale, the Dart and Mill Creek have median concentrations that are pretty typical of Otago's rivers (Appendix E and Appendix G). The Kawarau River by contrast has a slightly elevated median concentration that is double that of the Dart River. This monitoring site also returns the only significant increasing (degrading) trend for NH_4-N for the Upper Clutha reporting region. As discussed briefly in the section summarising compliance with the Water Plan limits, water quality monitoring upstream of the Project Shotover WWTP returns NH_4-N concentrations that are very low, whereas the downstream monitoring site on the Kawarau River at Chards shows an enrichment of NH_4-N (Figure 35).

At eight of the 11 monitoring sites, the very low concentrations typical of the sites, return too many '<DL' (less than laboratory detection level) for a meaningful trend analysis to be carried out.

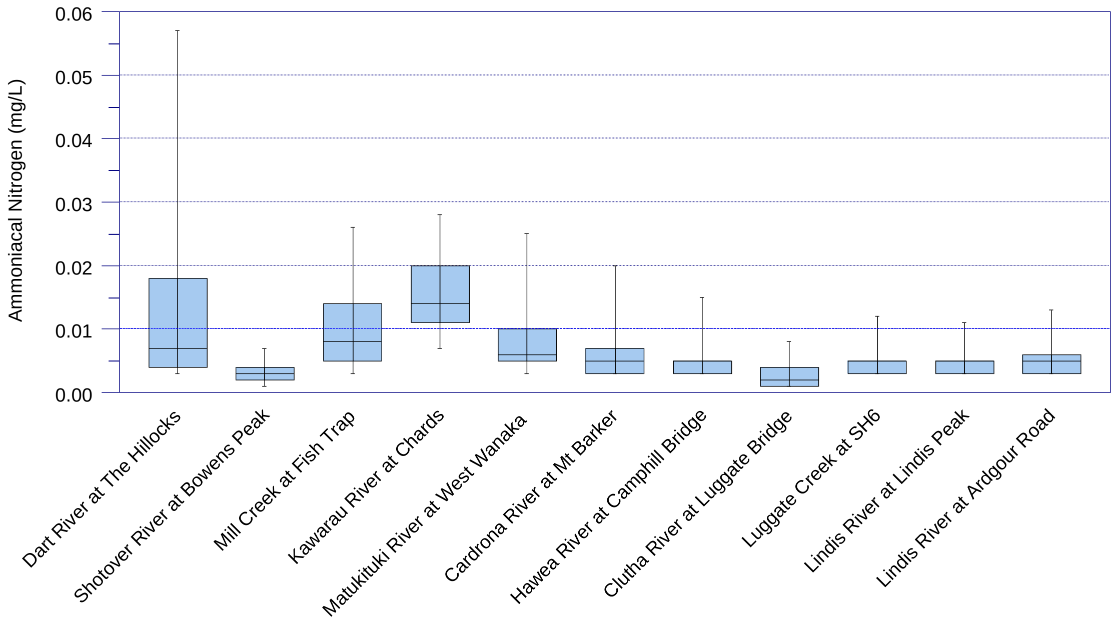

Figure 36: Boxplot summary of NH_4-N concentrations at SoE monitoring sites throughout Upper Clutha. The **blue** dashed line corresponds to the upland ANZECC NH_4-N guideline of 0.010 mg/L.

Table 49: Trend summary of ammonical nitrogen concentrations for the Upper Clutha reporting region.

Site	Dart River at The Hillocks	Shotover River at Bowens Peak	Mill Creek at Fish Trap	Kawarau River at Chards	Matukituki River at West Wanaka	Cardrona River at Mt Barker	Hawea River at Camphill Bridge	Clutha River at Luggate Bridge	Luggate Creek at SH6	Lindis River at Lindis Peak	Lindis River at Ardgour Road
NH_4-N	< DL	?	< DL	↑↑↑	< DL	< DL	< DL	?	< DL	< DL	< DL

Nitrite/Nitrate nitrogen

Nitrite/nitrate nitrogen concentrations are very low across all Upper Clutha reporting region monitoring sites with the exception of Mill Creek that has a median NNN concentration well above the ANZECC (2000) upland trigger value of 0.167 mg/L (Figure 37).

All other sites have NNN concentrations that are well below the ANZECC upland trigger value of 0.167 mg/L reflecting very low levels of NNN - which is an excellent result.

On a regional standing, the Upper Clutha reporting region returns very low NNN concentrations with a number of sites recording the lowest median concentrations of NNN for all of Otago (Appendix G).

Despite having extremely low NNN concentrations, two sites return significant increasing (degrading) trends for NNN, these being the Hawea River at Camphill Bridge and the Clutha River at Luggate Bridge (Table 50). The reasons for this are unknown. Increasing NNN concentration could increase the risk of toxic phormidium growth and nuisance algal blooms, particularly if levels exceeded guideline levels.

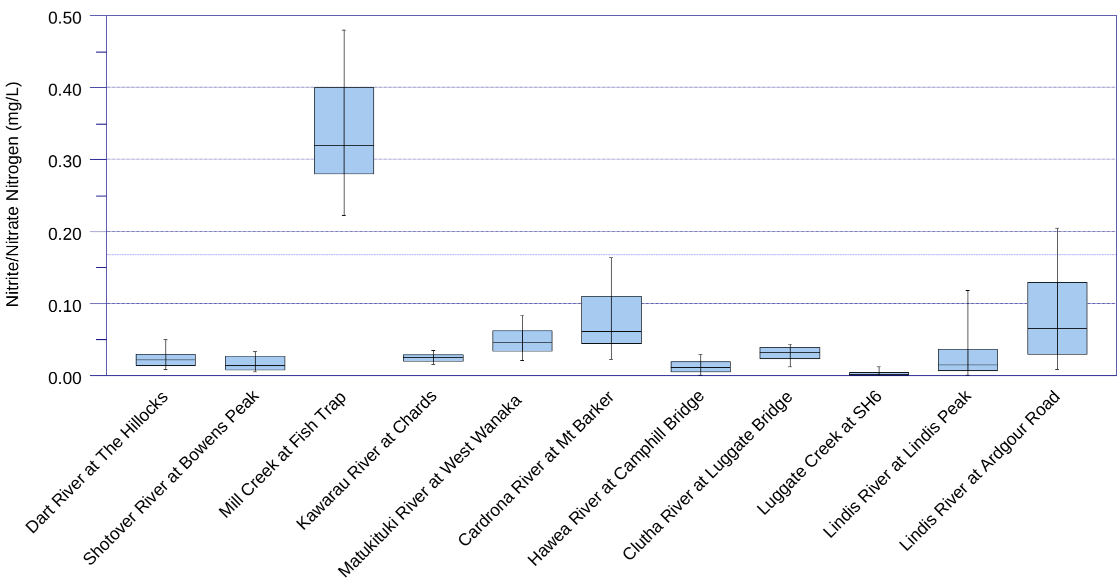

Figure 37: Nitrite/nitrate nitrogen (NNN) concentrations at SoE monitoring sites throughout Upper Clutha. The **blue** dashed line corresponds to the upland ANZECC guideline for NNN of 0.167 mg/L.

Table 50: Trend summary of nitrite/nitrate nitrogen (NNN) concentrations for the Upper Clutha reporting region.

Site	Dart River at The Hillocks	Shotover River at Bowens Peak	Mill Creek at Fish Trap	Kawarau River at Chards	Matukituki River at West Wanaka	Cardrona River at Mt Barker	Hawea River at Camphill Bridge	Clutha River at Luggate Bridge	Luggate Creek at SH6	Lindis River at Lindis Peak	Lindis River at Ardgour Road
NNN	?	?	?	?	?	?	↑↑↑	↑↑↑	< DL	?	?

Total Nitrogen

Total nitrogen concentrations (Figure 38) are slightly elevated compared to NNN concentrations (Figure 37) and show a significant amount of the nitrogen pool to be present in the stream as organic nitrogen. Organic nitrogen is not readily available for plant and algae growth but will be converted by in-stream processes to inorganic, bio-available nitrogen at a later date.

Overall TN concentrations are very low across the Upper Clutha reporting region and are well below the ANZECC upland trigger value of 0.295 mg/L; with the exception of Mill Creek that is well above this threshold (Figure 38). On a regional scale, the Upper Clutha reporting region returns eight sites with the lowest recorded median TN concentrations for Otago, reflecting the pristine nature of water quality for the majority of sites monitored. In regards to trends, there is present two sites with increasing (degrading) trends; these sites being the Kawarau at Chards and the Clutha at Luggate (Table 38). In the case of the Kawarau, the increasing trend in NH_4-N that forms part of the TN pool may be driving the increasing trend at this site. In the case of the Clutha River at Chards, the significant increasing trend in NNN may be driving the increase in TN.

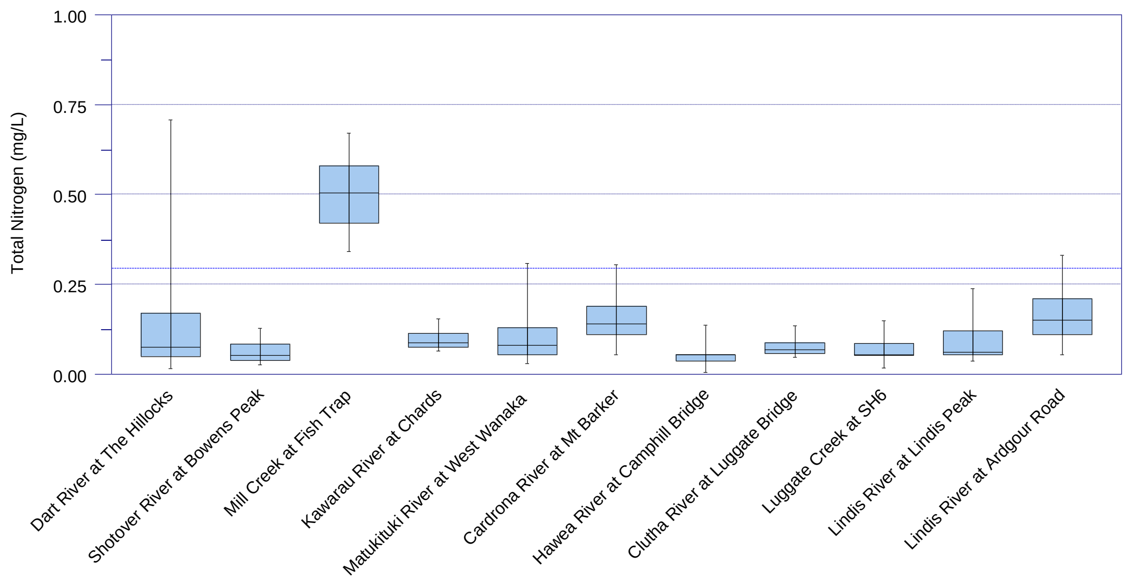

Figure 38: Boxplot summary of TN concentrations at SoE monitoring sites throughout Upper Clutha. The **blue** dashed line corresponds to the upland ANZECC (2000) guideline for TN of 0.295 mg/L.

Table 51: Trend summary of TN concentrations for the Upper Clutha reporting region.

Site	Dart River at The Hillocks	Shotover River at Bowens Peak	Mill Creek at Fish Trap	Kawarau River at Chards	Matukituki River at West Wanaka	Cardrona River at Mt Barker	Hawea River at Camphill Bridge	Clutha River at Luggate Bridge	Luggate Creek at SH6	Lindis River at Lindis Peak	Lindis River at Ardgour Road
TN	< DL	?	?	↑↑↑	< DL	?	< DL	↑↑↑	< DL	< DL	?

Dissolved Reactive Phosphorus

Dissolved Reactive Phosphorus concentrations are very low across the majority of sites throughout the Upper Clutha reporting region and are well below the ANZECC upland trigger value of 0.009 mg/L (Figure 39). As with NNN and TN, this reflects the extremely low concentrations of nutrients typical of sites across the area. The only site with elevated DRP above the ANZECC trigger value is Luggate Creek at SH6. The reasons for the slight elevation in DRP at this site are unknown. Only one site returned a significant increasing (degrading) trend for DRP, this being the Mill Creek monitoring site (Table 52). This is quite alarming as poor water quality in Lake Hayes has historically been attributed to phosphorus enrichment. Increasing DRP loads to Lake Hayes combined with the high NNN and TN concentrations already present in Mill Creek will only degrade water quality in the lake further. Over half of the sites monitored returned too many '<DL' results to allow a robust trend analysis to be carried out.

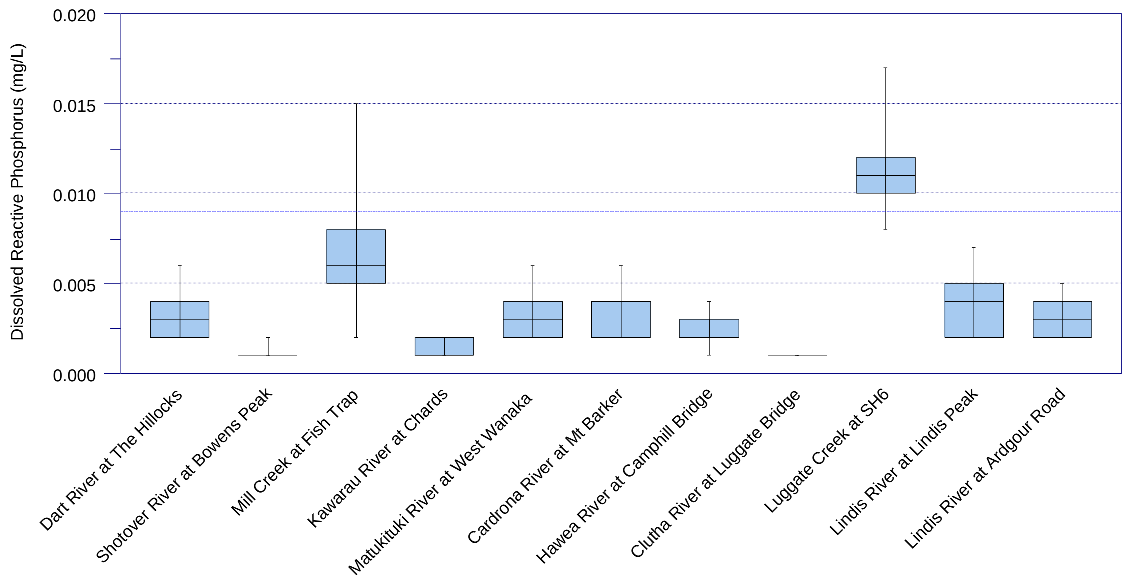

Figure 39: Boxplot summary of Dissolved Reactive Phosphorus (DRP) concentrations at SoE monitoring sites throughout Upper Clutha. The **blue** dashed line corresponds to the upland ANZECC (2000) guideline for DRP of 0.009 mg/L.

Table 52: Trend summary of Dissolved Reactive Phosphorus concentrations for the Upper Clutha reporting region.

Site	Dart River at The Hillocks	Shotover River at Bowens Peak	Mill Creek at Fish Trap	Kawarau River at Chards	Matukituki River at West Wanaka	Cardrona River at Mt Barker	Hawea River at Camphill Bridge	Clutha River at Luggate Bridge	Luggate Creek at SH6	Lindis River at Lindis Peak	Lindis River at Ardgour Road
DRP	< DL	?	↑↑↑	?	< DL	< DL	< DL	?	?	< DL	< DL

Total Phosphorus

Patterns in TP concentrations across the Upper Clutha reporting region (Figure 40) are quite different to those of DRP, with a number of rivers with glaciers in their upper catchment resulting in high sediment load from glacial flour, such as the Dart and Shotover rivers. These sites return extremely high TP concentrations at times due to the high sediment loads and associated phosphorus that is bound to these naturally derived sediments. This can be regarded as an anomaly and one that is a natural process. The Kawarau River at Chards site is downstream of the Shotover and is influenced by the elevated sediment load discharged from the Shotover during winter snow melt and high flow events.

TP trend analysis (Table 53) returned a significant decreasing (improving) trend for the Dart River. A probable increasing (degrading) trend is present for the Luggate Creek. All other trends are indeterminate with the exception of one '<DL'.

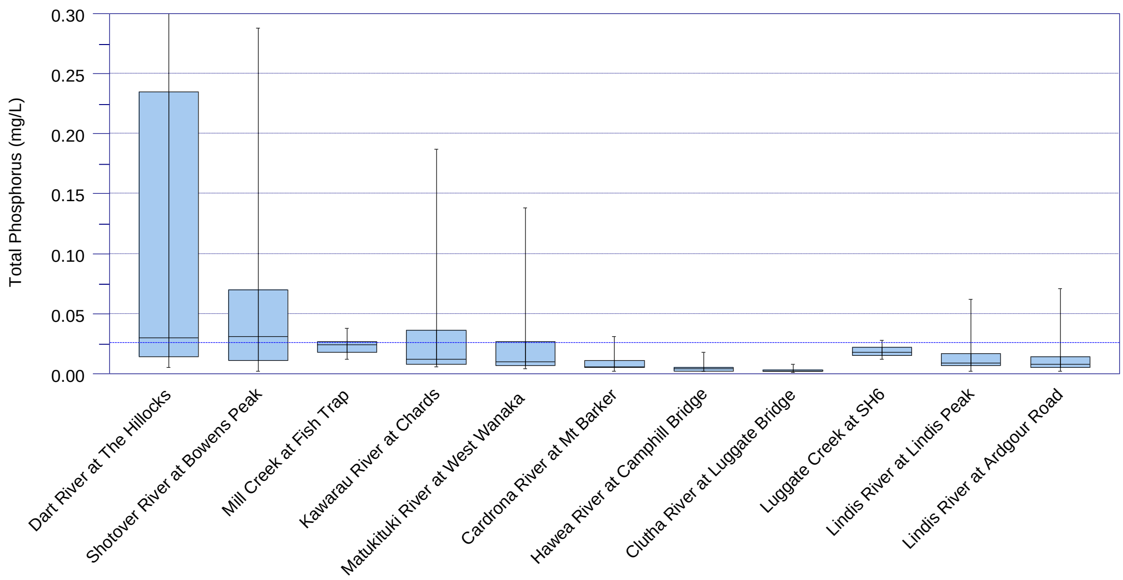

Figure 40: Boxplot summary of TP concentrations at SoE monitoring sites throughout Upper Clutha. The **blue** dashed line corresponds to the upland ANZECC (2000) guideline for TP of 0.026 mg/L.

Table 53: Trend summary of TP concentrations for the Upper Clutha reporting region.

Site	Dart River at The Hillocks	Shotover River at Bowens Peak	Mill Creek at Fish Trap	Kawarau River at Chards	Matukituki River at West Wanaka	Cardrona River at Mt Barker	Hawea River at Camphill Bridge	Clutha River at Luggate Bridge	Luggate Creek at SH6	Lindis River at Lindis Peak	Lindis River at Ardgour Road
TP	↓↓↓	?	?	?	?	?	< DL	?	↑↑	?	?

Escherichia coli

Figure 41 shows *E. coli* concentrations for all SoE monitoring sites across the Upper Clutha reporting region. All sites have median and 75th percentile (upper bound of boxplots) concentrations well below the amber alert level of 260 CFU/100ml; the exception is Mill Creek that has a 75th percentile that exceeds the amber alert level of 260 CFU/100ml but remains below the red alert level of 550 CFU/100ml. This shows *E. coli* levels across all sites except Mill Creek to be low and of good quality.

Trend analysis returns some concerning results with four of 11 sites having a significant or probable increasing (degrading) trend for *E. coli*. These sites include the Dart, Shotover, Kawarau and Cardrona rivers; all sites that typically return very low concentrations of *E. coli* and have good bacterial water quality. All other trends are indeterminate, with the exception of one '<DL' for the Hawea River at Camphill Bridge.

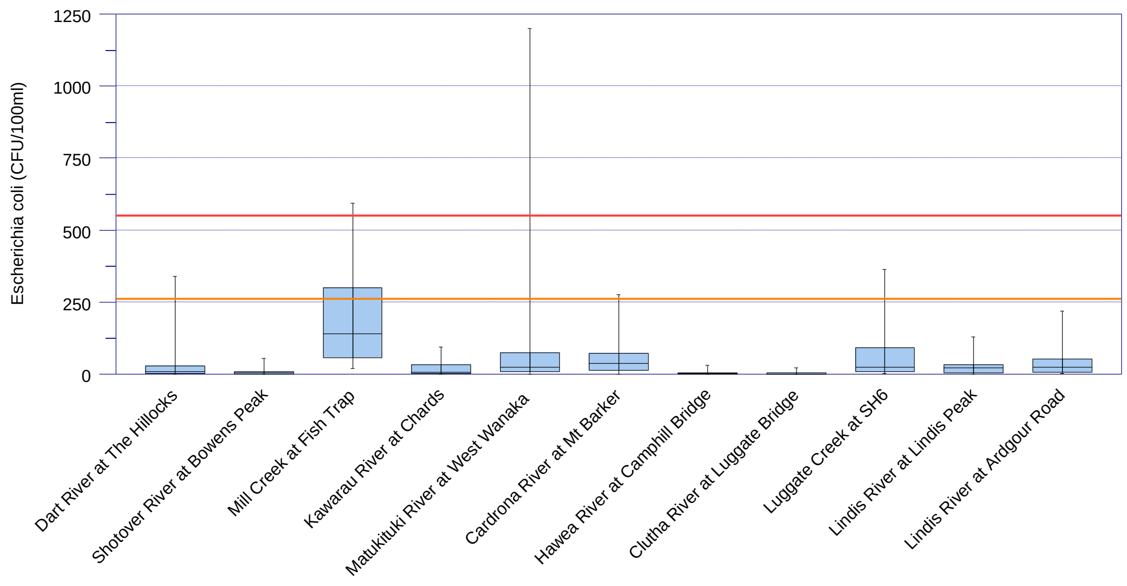

Figure 41: Boxplot summary of *E coli* concentrations at SoE monitoring sites throughout Upper Clutha. The **amber** line corresponds to the amber alert level of 260 CFU/100ml; the **red** line to the red alert level of 550 CFU/100ml.

Table 54: Trend summary of *Escerichia coli* concentrations for the Upper Clutha reporting region.

Site	Dart River at The Hillocks	Shotover River at Bowens Peak	Mill Creek at Fish Trap	Kawarau River at Chards	Matukituki River at West Wanaka	Cardrona River at Mt Barker	Hawea River at Camphill Bridge	Clutha River at Luggate Bridge	Luggate Creek at SH6	Lindis River at Lindis Peak	Lindis River at Ardgour Road
E. coli	↑↑↑	↑↑	?	↑↑↑	?	↑↑	< DL	?	?	?	?

Turbidity

Turbidity levels for SoE monitoring sites across the Upper Clutha reporting region, with the exception of sites affected by high sediment loads from glacial flour, are typically low (Figure 42) with nine of the 11 sites monitored having median turbidity levels that are well below the ANZECC upland guideline trigger level of 4.1 NTU. The exceptions to this are the Dart and Shotover Rivers that return some exceptionally high turbidity levels at times of high flow (Appendix G).

Trend analysis (Table 55) shows a high number of sites to have significant and probable increasing (degrading) trends for turbidity, these being the Shotover River, Mill Creek, Kawarau River, Matukituki River, Hawea River and Luggate Creek. The catchments of these monitoring sites are very diverse with little commonality to explain the drivers of the increasing trends.

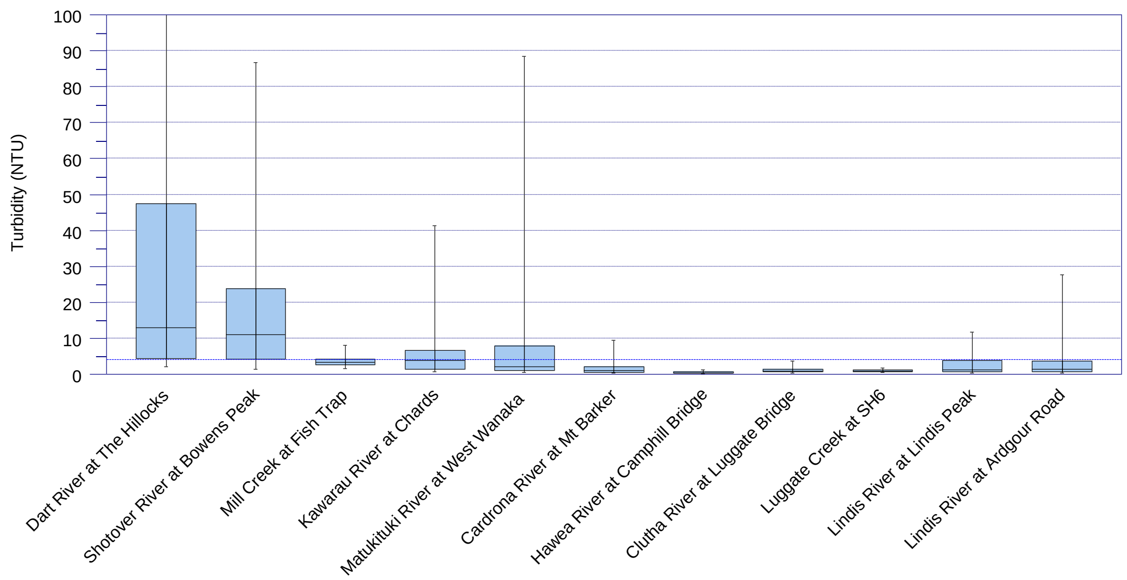

Figure 42: Boxplot summary of Turbidity at SoE monitoring sites throughout Upper Clutha. The **blue** dashed line corresponds to the upland ANZECC (2000) guideline for Turbidity of 4.1 NTU**.**

Table 55: Trend summary of turbidity levels for the Upper Clutha reporting region.

Site	Dart River at The Hillocks	Shotover River at Bowens Peak	Mill Creek at Fish Trap	Kawarau River at Chards	Matukituki River at West Wanaka	Cardrona River at Mt Barker	Hawea River at Camphill Bridge	Clutha River at Luggate Bridge	Luggate Creek at SH6	Lindis River at Lindis Peak	Lindis River at Ardgour Road
Turbidity	??	↑↑	↑↑	↑↑↑	↑↑↑	?	↑↑↑	?	↑↑↑	?	?

Stream Health and the Macroinvertebrate Community Index

Macroinvertebrate Community Index (MCI) scores provide an integrated indicator of the general state of water quality and aquatic ecosystem health at a site.

Figure 43 summarises MCI scores for sites monitored for aquatic macroinvertebrates throughout the Upper Clutha reporting region. The summary includes annual samples collected from 2008 to 2017 (8 years) where data is available. Not all sites monitored for water quality have macro-invertebrate samples taken. Of the 11 sites monitored for water quality, seven sites are sampled annually for macro-invertebrates.

MCI scores are somewhat comparable across sites with five of the seven monitored sites returning comparable MCI scores that fall between 100 and 110; reflecting a macroinvertebrate community in 'good' condition. The exception is Mill Creek and the Clutha River at Luggate Bridge monitoring sites that return a score of around 90, representing a macroinvertebrate community in 'poor' condition. MCI is not well suited to large rivers so for Clutha River at Luggate Bridge, the 'poor' MCI value may be driven more by habitat constraints and the ability to sample macroinvertebrates from riffles that are present in the middle of the river and better representative of the wider river condition. In the case of Mill Creek, the 'poor' MCI value that at times approaches 80, would be driven by water and habitat quality and shows this site to be in a somewhat degraded state.

In a regional context, with the exception of Mill Creek that is 'poor', the Upper Clutha reporting region macroinvertebrate monitoring sites generally rank favourably against sites across Otago (Appendix G), and show overall water and habitat quality to be supporting the existence of healthy invertebrate communities.

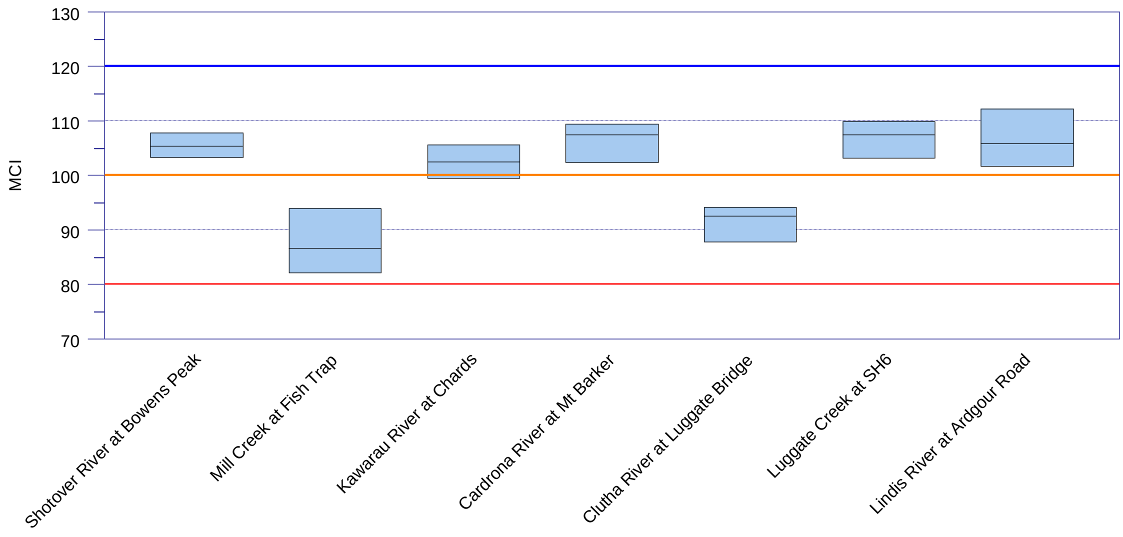

Figure 43: Boxplot summary of Macroinvertebrate Community Index (MCI) scores at SoE monitoring sites throughout North Otago where macroinvertebrate samples are routinely collected. Above the **blue** line corresponds to the 'Excellent' quality threshold; between the **orange** and blue line the 'Good' quality threshold; betwene the **red** and orange line 'Poor' quality threshold; below the red line the 'Degraded' threshold.

Upper Clutha Water Quality Summary

Across the Upper Clutha reporting region there are a moderate number of sites with degrading water quality trends, as shown in Table 56, which summarises trend results across all sites. There are a total of 77 results reported in the table; 22% return significant or probable degrading trends; and 1% return significant or probable improving trends. Overall 77% of sites have either indeterminate trends (reported as "?"); or too many observations being 'less than detect' (<DL) for results returned from the laboratory.

Turbidity is the worst performing indicator with six of 11 sites returning a degrading trend. The reasons for this are unclear as ORC do not collect any information on changes in land use or land management practices that would allow for confident assessment of drivers of increased turbidity and sediment in our waterways.

Despite relatively good bacterial water quality throughout the reporting region, *E. coli* is the second worst performing variable with four of 11 sites having increasing (degrading) trends. Again the reasons for this are unclear, particularly given the disparity between sites with degrading turbidity and *E. coli* trends with an increase in one possibly correlating with an increase in the other as sediment and E. coli follow similar flow paths to streams and rivers. Only two sites have a degrading trend in both; the Shotover at Bowens and the Kawarau at Chards. As discussed earlier with NH_4-N and the Kawarau River monitoring site, there is a chance that Project Shotover is influencing *E. coli* levels downstream in the Kawarau River. Either way, for the four sites with degrading *E. coli* trends, the actual *E. coli* levels instream are very low and well below any alert levels that would impact on contact recreation value.

As stated previously, having accurate information on changes in land use and land management practice would help in identifying drivers of change evident with some water quality variables.

In summary:

- For the majority of sites across the Upper Clutha reporting region, water quality is excellent and the best in Otago;
- Bacterial water quality is excellent across all sites, with the exception of Mill Creek;
- Mill Creek has elevated NNN and TN, as well as significant increasing trends in DRP; has elevated background *E. coli* concentrations that fail the national bottom line; and a macroinvertebrate community in 'poor' condition reflecting an overall degraded state in regards to water quality;
- The Kawarau River at Chards appears to be influenced by slight ammonia enrichment coming from the Project Shotover WWTP;
- The Cardrona River shows some enrichment of NNN in the lower reaches, likely linked to slightly enirched groundwater contributing to surface flows in the lower reaches. The enrichment of groundwater with nitrogen comes from more intensive land-use asociated with irrigation in the lower Cardrona. These areas leach higher amounts of N than low-intensity, non-irrigated land.

As has been previously reported (Ozanne, 2012), water quality in rivers across Otago show a clear spatial pattern related to land cover. Water quality is best at river and stream reaches located at high or mountainous elevations under predominantly native cover. These sites tend to be associated with the upper catchments of larger rivers (e.g. Clutha River/Matau-Au, Taieri River and Lindis River) and the outlets from large lakes (e.g. Hawea, Wakatipu and Wanaka).

Table 56: Trend summary for the Upper Clutha reporting region.

Site	Dart River at The Hillocks	Shotover River at Bowens Peak	Mill Creek at Fish Trap	Kawarau River at Chards	Matukituki River at West Wanaka	Cardrona River at Mt Barker	Hawea River at Camphill Bridge	Clutha River at Luggate Bridge	Luggate Creek at SH6	Lindis River at Lindis Peak	Lindis River at Ardgour Road
Ammoniacal Nitrogen	< DL	?	< DL	↑↑↑	< DL	< DL	< DL	?	< DL	< DL	< DL
Nitrite/Nitrate Nitrogen	?	?	?	?	?	?	↑↑↑	↑↑↑	< DL	?	?
Total Nitrogen	< DL	?	?	↑↑↑	< DL	?	< DL	↑↑↑	< DL	< DL	?
Dissolved Reactive Phosphorus	< DL	?	↑↑↑	?	< DL	< DL	< DL	?	?	< DL	< DL
Total Phosphorus	↓↓↓	?	?	?	?	?	< DL	?	↑↑	?	?
Escherichia coli	↑↑↑	↑↑	?	↑↑↑	?	↑↑	< DL	?	?	?	?
Turbidity	?	↑↑	↑↑	↑↑↑	↑↑↑	?	↑↑↑	?	↑↑↑	?	?

2.5. Middle Clutha / Central Otago

The Middle Clutha reporting region runs from the outflow of Lake Dunstan at the township of Clyde, downstream to the small settlement of Beaumont, where State Highway 8 crosses the Clutha River / Mata-Au. The Middle Clutha reporting region includes the catchments of the Fraser River (327 km^2), the Manuherikia River (3033 km^2; the largest tributary by catchment area of the Clutha River Mata-Au), the Teviot River (332 km^2) and the Benger Burn (131 km^2). The Middle Clutha reporting region, in contrast to the Upper Clutha reporting region, is dominated by rivers and streams with relatively broad valleys dissected by rolling, block mountains ranging from 1000 m to 1600 m above sea level (LAWA).

The Manuherikia River is the largest catchment of the Middle Clutha reporting region covering over 94% of the reporting region's catchment area. The Manuherikia River flows for approximately 64 km and has a catchment area of 3033 km^2. The catchment includes two major depressions, the Manuherikia Valley and the Ida Valley. These are connected by the Pool Burn Gorge. The Manuherikia catchment is one of the driest in New Zealand, and irrigation water is in high demand (Kitto, 2011). The river's headwaters originate in the Hawkdun and Saint Bathans Ranges and Dunstan Mountains, before flowing in a south-west direction to join the Clutha River at the township of Alexandra. The climate of the Manuherikia catchment is considered to be the most continental type in the country and is characterised by cold winters and warm dry summers. The Manuherikia valley floor is classified as semi-arid as it receives between 350 mm and 500 mm rainfall (Olsen et al., 2016).

2.5.1. Middle Clutha / Central Otago geographical and land cover characteristics

Table 57 summarises characteristics of the Middle Clutha reporting region based on the River Environment Classification (refer Appendix F for a detailed overview of the REC); land-cover (based on the Land Cover Database Version 4; condensed with the approach summarised in Appendix D); and the Land Use Capability (LUC) classes (see Section 2.0 for the LUC definition). The Middle Clutha reporting region covers an area of 3214 km^2 representing approximately 15% of the total Clutha River/Mata-Au catchment.

According to the River Environment Classification (REC), rivers and streams of the Middle Clutha reporting region are dominated by cool-dry/hill (69.3%) and cool-dry/low elevation (20.1%) rivers that receive very low rainfall (less than 500mm annual average rainfall).

The predominant land cover throughout the Middle Clutha reporting region is low producing grassland (43%, 1382 km^2) followed by near-equal parts of high producing grassland (27%, 868 km^2) and native cover (23%, 739 km^2). 'Low producing grassland' includes "exotic and indigenous grasslands, grazed for wool, sheep or beef. Usually found on steep hill country" (Table 57, Appendix D). Orchards are prevalent along the river terraces of the Clutha River/Mata-Au in the vicinity or Earnscleugh, Roxburgh and Ettrick (Figure 44).

There is an interesting mix of LUC class land through the Middle Clutha reporting region, dominated largely by land characteristics of the Manuherikia catchment and the ranges to the east and west of Roxburgh. Areas of relatively flat, rolling LUC Class 3 and 4 land (20%, 643 km^2) exists through the Manuherikia and Ida Valleys. These areas are where the majority of irrigation occurs through the Middle Clutha reporting region. This contrasts with steeper LUC Class 6 and 7 land (77%, 2484 km^2) that is typical of the ranges bordering the Clutha River/Mata-Au around Roxburgh and the ranges encircling the Manuherikia catchment.

The Manuherikia River catchment, the largest of the Middle Clutha reporting region at over 94% of the reporting region land area, has a dominant land-use of agriculture, with pasture grasslands dominating the catchment (Figure 44). The level of production (agricultural intensity) is largely dependent on the availability of water for irrigation, with high producing pastures mainly found at lower elevations in the Manuherikia and Ida Valleys where irrigation predominates (Olsen et al., 2016).

The original vegetation of the Manuherikia catchment can still be seen in many of the headwater tributaries and in parts above Falls Dam where tussock grassland dominates the river and creek terraces with snow tussock occupying the higher mountain faces. There has been a relatively small amount of land use change in the Manuherikia catchment over the period 1996-2012, with the majority of this change being the conversion of low producing grassland to high producing exotic grassland (68 ha) and harvest of exotic forest (44 ha), of which almost half was converted to high producing exotic grassland (18 ha) (Olsen et al., 2016).

Table 57: Zone characteristics of the Middle Clutha / Central Otago reporting region. Land cover area and land-use capability.

Source of flow (REC)		Land Cover Area (LCDB4)		Land-use Capability Class (LUC)	
Cool-Dry / Hill	69.3%	Cropping	0.4%	Class 2	0.1%
Cool-Dry/Low-Elevation	20.1%	High producing grassland	26.6%	Class 3	6.9%
Cool-Dry/Lake	1.3%	Low Producing Grassland	42.9%	Class 4	13.1%
Cool-Dry/ Mountain	2.3%	Native Cover	23.3%	Class 5	0.01%
Cool-Wet/ Hill	1.3%	Orchards/Vineyards	1.0%	Class 6	41.4%
Cool-Wet/Lake	1.7%	Plantation forestry	1.8%	Class 7	35.9%
Cool-Wet/ Mountain	4.3%	Unaccounted	3.5%	Class 8	1.8%
		Urban areas	0.4%	Lake	0.4%
				River	0.5%
				Town	0.1%

The Middle Clutha / Central Otago Reporting Region covers 321 416 hectares

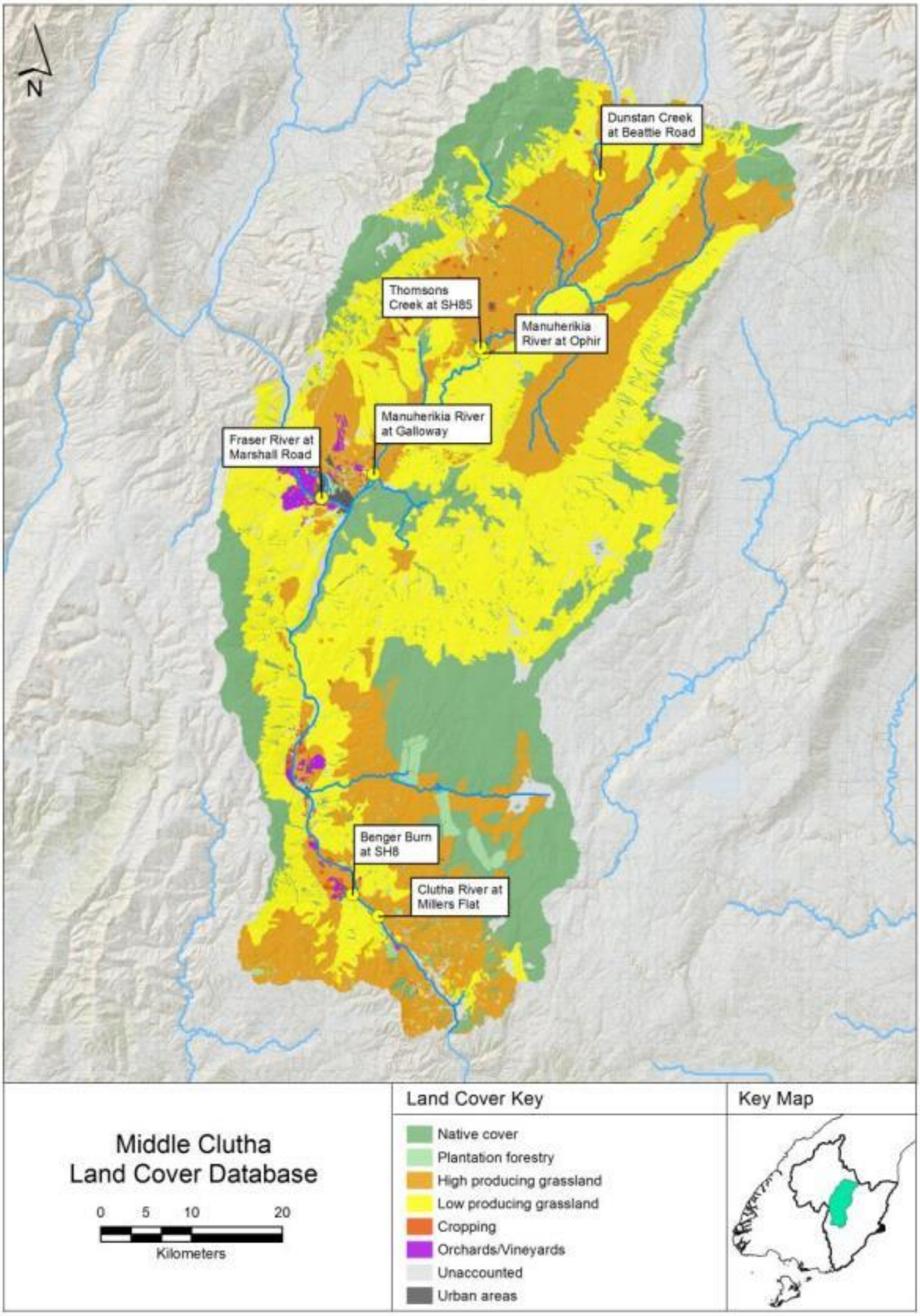

Figure 44: Map showing broad land cover categories of the Middle Clutha / Central Otago reporting region based on the LCDB4 databse.

2.5.2. Middle Clutha / Central Otago water quality

The following section provides a summary of the Middle Clutha reporting region water quality based on:

- Compliance against Schedule 15 (Water Plan) water quality limits;
- National Policy Statement for Freshwater Management (NPSFM 2014) National Objectives Framework Attribute bands (NOF bands);
- Summary boxplots of key water quality indicators with the inclusion of general water quality guidelines such as ANZECC (2000);
- A summary of trends (degrading/improving) that may (or may not) be evident in the data.

There are a total 7 SoE monitoring sites throughout the Middle Clutha reporting zone with a good spread of sites across main-stem river and tributary stream sites from the upper to lower catchment. NIWA currently monitors one site, being the Clutha River at Millers Flat.

Schedule 15 compliance

Table 58 summarises compliance for SoE monitoring sites throughout the Middle Clutha reporting region with Schedule 15 (Water Plan) limits. For this section, all '80th percentile concentrations' are calculated from data collected when flows at the relevant flow reference site are below median flow. All SoE monitoring sites in the Middle Clutha reporting region fall in Receiving Water Group (RWG) 2 (refer Figure 1 for RWG boundaries).

Three of the 7 Middle Clutha monitoring sites are fully compliant with the Schedule 15 (Water Plan) limits, these sites being Dunstan Creek, Fraser River and the Clutha River at Millers Flat. Of the seven sites, Thomsons Creek has the worst level of compliance, with exceedances for NNN (over two times the limit of 0.075 mg/L); very high exceedances for DRP (over seven times the limit of 0.010 mg/L); and very high exceedances for *E. coli* (over four times the limit of 260 CFU/100ml). Compliance wise, Benger Burn is a close second, with similar exceedances for NNN, DRP and *E. coli* (Table 58).

All sites are compliant with respect to the Water Plan NH_4-N limit of 0.100 mg/L. Overall, compliance is generally excellent for NNN, with the exception of Thomsons Creek and Benger Burn (Table 58).

DRP is the worst performing water quality variable with respect to Schedule 15 limits, with four of the seven sites exceeding the 80th percentile limit of 0.010 mg/L (Table 58).

Table 58: 80th percentile values for water quality variables identified in Schedule 15. Values are calculated from samples taken when flows are below median flow. The orange cells show where the 80th percentile exceeds the Schedule 15 limit.

Variable	NNN	NH_4-N	DRP	*E. coli*	Turbidity
Schedule 15 limit when flows < median flow	0.075 mg/L	0.100 mg/L	0.010 mg/L	260 CFU	5.00 NTU
SoE reporting name					
Dunstan Creek at Beattie Road	0.052	0.008	0.005	82	0.93
Manuherikia River at Ophir	0.067	0.019	0.037	320	3.70
Thomsons Creek at SH85	0.178	0.024	0.077	1100	5.60
Manuherikia River at Galloway	0.025	0.010	0.018	170	2.80
Benger Burn at SH8	0.200	0.014	0.024	960	2.10
Fraser River at Marshall Road	0.048	0.005	0.004	44	1.11
Clutha River at Millers Flat	0.040	0.004	0.001	18	2.32

Nitrate and ammonia toxicity and NOF compliance

NOF attribute bands for nitrate (measured as NNN) and NH_4-N toxicity (Table 59 and Table 60 respectively) show excellent protection levels against toxicity risk for all Middle Clutha monitoring sites with all sites returning an 'A' band (highest level of protection) for NNN and all sites returning an 'A' band for NH_4-N; with the exception of Thomsons Creek that returns a 'B' band for the maximum recorded concentration of NH_4-N.

The elevated maximum concentrations for NH_4-N for Thomsons Creek push this site up into the B-band by marginally exceeding the upper maximum concentration threshold of 0.05 mg/L for the A- band. The 'B' band still provides for a good level of protection against ammonia toxicity but 'starts impacting occasionally on the 5% most sensitive species' (Appendix B). Some species of freshwater mollusc can be sensitive to ammonia toxicity.

Table 59: NOF compliance summary for Nitrate (estimated from NNN). Included are median and 95th percentile values for the the period July 2012 to June 2017 and the corresponding NOF attribute band.

Variable	Nitrate as NNN		NOF Band	
SoE reporting name	Median (mg/L)	95th Percentile (mg/L)	Median	95th Percentile
Dunstan Creek at Beattie Road	0.041	0.136	A	A
Manuherikia River at Ophir	0.053	0.190	A	A
Thomsons Creek at SH85	0.132	0.421	A	A
Manuherikia River at Galloway	0.030	0.175	A	A
Benger Burn at SH8	0.276	1.057	A	A
Fraser River at Marshall Road	0.026	0.043	A	A
Clutha River at Millers Flat	0.028	0.057	A	A

Table 60: NOF compliance summary for NH_4-N. Included are median and maximum values for the the period July 2012 to June 2017 and the corresponding NOF attribute band.

Variable	Ammoniacal nitrogen (unadjusted)		NOF Band	
SoE reporting name	Median (mg/L)	Maximum (mg/L)	Median	Maximum
Dunstan Creek at Beattie Road	0.006	0.024	A	A
Manuherikia River at Ophir	0.009	0.037	A	A
Thomsons Creek at SH85	0.009	0.055	A	B
Manuherikia River at Galloway	0.006	0.020	A	A
Benger Burn at SH8	0.010	0.023	A	A
Fraser River at Marshall Road	0.004	0.009	A	A
Clutha River at Millers Flat	0.003	0.008	A	A

E. coli, swimmability and NOF compliance

Table 61 summarises compliance for *E. coli* against the four statistical tests of the NOF *E. coli* attribute.

Compliance is moderate across the Middle Clutha reporting district with four of the seven sites returning bacterial water quality that is acceptable to the recently amended NPSFM (2014). Two sites, Dunstan Creek and the Clutha River at Millers Flat have excellent bacterial water quality with an 'A' band for the four statistical tests.

Three sites fail the national bottom line including the Manuherikia at Ophir, Thomsons Creek and the Benger Burn. Thomsons Creek is the worst performing site with three of the four statistical tests returning a highly degraded 'E' band. The remaining statistical test returns a 'D' band that still exceeds the national bottom line. The Benger Burn returns a 'D' band for all tests and therefore fails the national bottom line. Both Thomsons Creek and the Benger Burn would have limited recreational value given the small size and relative inaccessibility of the streams. However both are 4^{th} order streams and therefore the NOF *E. coli* attribute limits apply.

In the case of the Manuherikia at Ophir, the high background *E. coli* concentrations represented by a high 'median' value push this site from an acceptable 'C' band to an unacceptable 'D' band. The Manuherikia River at Ophir is an important river with high primary contact recreation value. The failure of this site in relation to the NOF *E. coli* attribute is disappointing, and warrants further work to determine the source of bacteria. The monitoring site is in the immediate vicinity of both the outflow of the bacteria enriched Thomsons Creek and Omakau Waste Water Treatment Plant that discharges treated sewage direct to the Manuherikia River. Both of these sources are significant contributors of bacteria to the Manuherikia River and could be leading to the elevated background concentrations of *E. coli*.

The overall attribute state is based on the worst grading with the national bottom line being an orange "D" band; all sites must return a minimum of a "C" band.

Table 61: NOF compliance summary for *E. coli* for the the period July 2012 to June 2017. The overall grading band is determined by the lowest (worst) ranked Numeric Attribute State as it relates to the four separate states.

	Numeric Attribute State				Overall attribute state	
Site	Median grade (CFU/100ml)	95th percentile grade (CFU/100ml)	% over 260 CFU/100ml grade (%)	% over 540 CFU/100ml grade (%)	Grading attribute state	Overall Pass/Fail
Dunstan Creek at Beattie Road	A (27)	A (392)	A (5%)	A (3%)	A	PASS
Manuherikia River at Ophir	A (96)	C (1194)	B (26%)	C (12%)	C	PASS
Thomsons Creek at SH85	**E (310)**	**D (1705)**	**E (51%)**	**E (33%)**	**E**	**FAIL**
Manuherikia River at Galloway	A (44)	B (770)	A (13%)	B (8%)	B	PASS
Benger Burn at SH8	**D (175)**	**D (7450)**	**D (38%)**	**D (23%)**	**D**	**FAIL**
Fraser River at Marshall Road	A (18)	B (736)	A (7%)	B (6%)	B	PASS
Clutha River at Millers Flat	A (12)	A (61)	A (0%)	A (0%)	A	PASS

Ammoniacal nitrogen

Of the sites included in the Middle Clutha reporting region, Dunstan Creek, Thomsons Creek and the Manuherikia at Ophir are classed as 'Upland' sites according to the ANZECC (2000) altitude cut-off of 150 m. The remaining sites are classed as 'lowland' sites.

Generally sites throughout the Manuherikia, being Dunstan, Thomsons and the two mainstem Manuherikia monitoring sites, show a slight elevation of NH_4-N above background concentrations. Of the three upland sites, only the median concentration of NH_4-N for the Manuherikia at Ophir exceeds the ANZECC upland trigger value. However this site is only slightly elevated above the threshold. All remaining sites have median concentrations below the ANZECC trigger values, with the Fraser and Clutha river sites having concentrations at near natural background levels.

At five of the seven monitoring sites, the very low concentrations typical of the sites return too many '<DL' (less than laboratory detection level) results for a meaningful trend analysis to be carried out. The two remaining sites return an indeterminate trend result (Table 62).

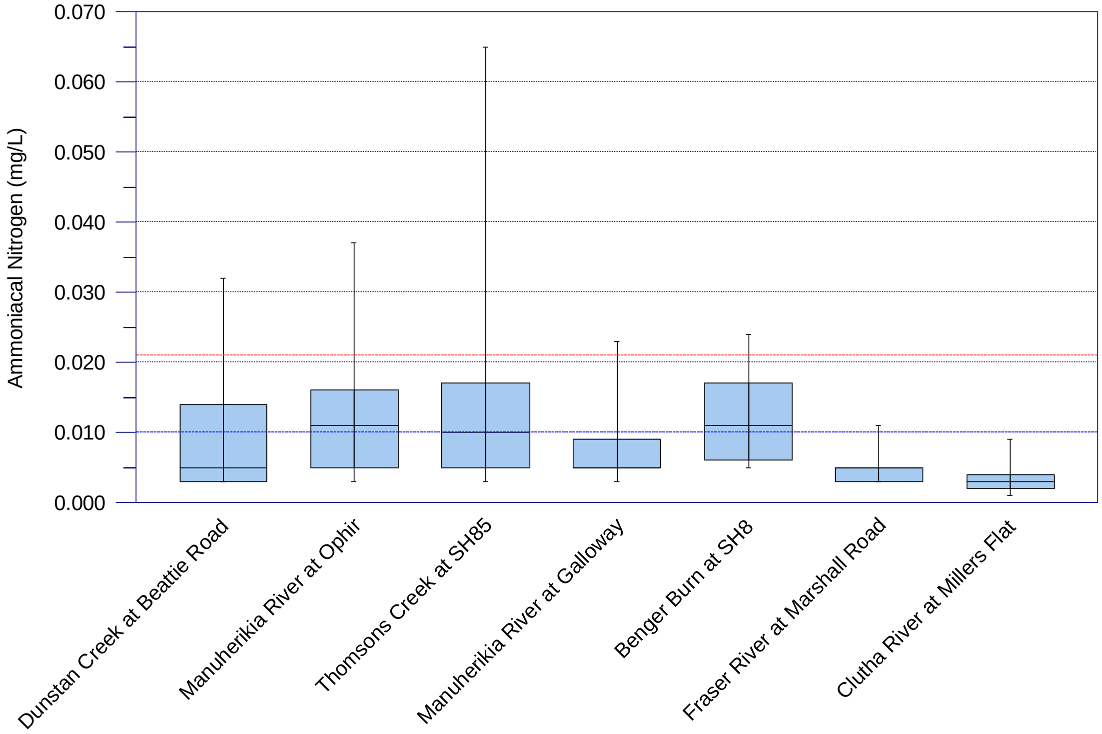

Figure 45: Boxplot summary of NH_4-N concentrations at SoE monitoring sites throughout Middle Clutha / Central Otago. The **red** dashed line corresponds to the ANZECC lowland guideline for NH_4-N of 0.021 mg/L; the **blue** dashed line the upland guideline of 0.010 mg/L.

Table 62: Trend summary of NH_4-N concentrations for the Middle Clutha reporting region.

Site	Dunstan Creek at Beattie Road	Manuherikia River at Ophir	Thomsons Creek at SH85	Manuherikia River at Galloway	Benger Burn at SH8	Fraser River at Marshall Road	Clutha River at Millers Flat
NH_4-N	< DL	< DL	?	< DL	< DL	< DL	?

Nitrite/Nitrate nitrogen

Nitrite/nitrate nitrogen (NNN) concentrations are very low at near natural levels for five of the seven Middle Clutha reporting region monitoring sites. The remaining two sites, Thomsons Creek and Benger Burn, show some mild NNN enrichment (Figure 46). For Thomsons Creek, the median NNN concentration remains below the ANZECC upland trigger value of 0.167 mg/L, but concentrations are slightly elevated at times, with the 75th percentile NNN concentration (represented by the upper boundary of the box in the boxplots) being close to 0.25 mg/L. Similarly with the Benger Burn, a lowland site by ANZECC definition, the median concentration remains below the ANZECC lowland trigger value of 0.444 mg/L, but concentrations are elevated at times with the 75th percentile being above 0.5 mg/L and the 95th percentile concentration (represented by the upper bound of the whisker) approaching 1.5 mg/L.

On a regional standing, Thomsons Creek and Benger Burn have moderately low NNN levels when compared to sites with elevated NNN concentrations, such as those present in parts of the North Otago reporting region and the Pomahaka (Appendix E).

Trend analysis returns indeterminate trends for all sites in the Middle Clutha reporting region (Table 63), so it is not possible to confidently state if NNN concentrations are stable, or are increasing or decreasing.

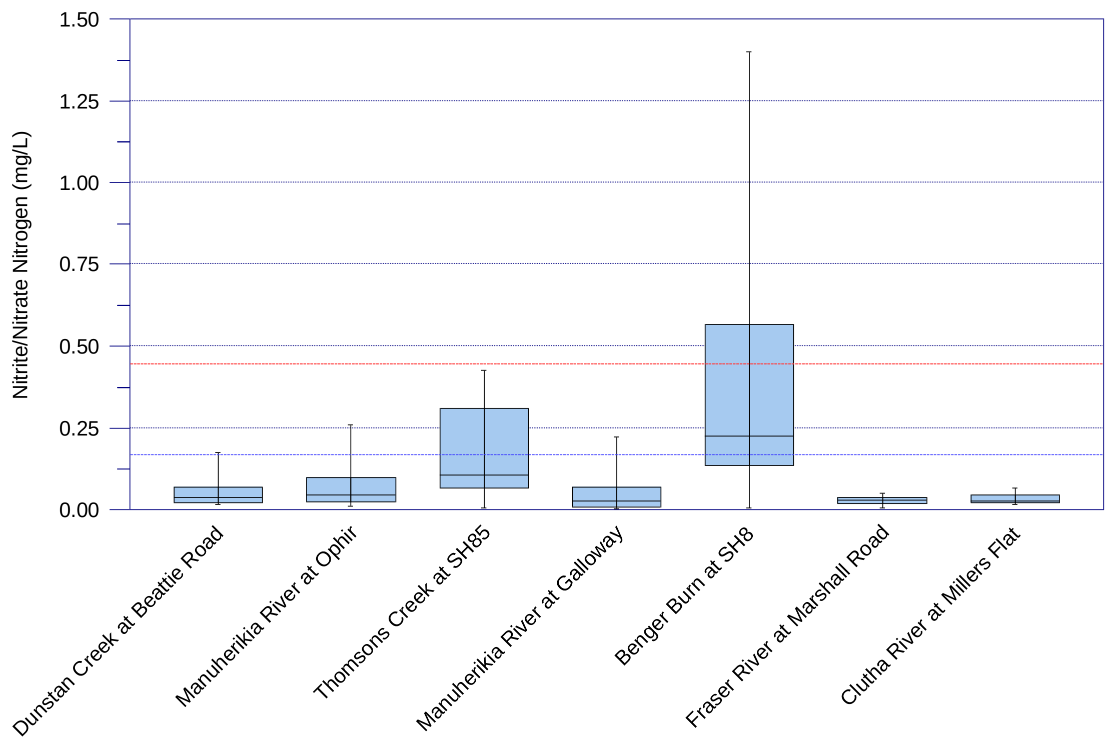

Figure 46: Nitrite/nitrate nitrogen (NNN) concentrations at SoE monitoring sites throughout Middle Clutha / Central Otago . The **red** dashed line corresponds to the ANZECC lowland guideline for NNN of 0.444 mg/L; the **blue** dashed line the upland guideline of 0.167 mg/L

Table 63: Trend summary of nitrite/nitrate nitrogen (NNN) concentrations for the Middle Clutha reporting region.

Site	Dunstan Creek at Beattie Road	Manuherikia River at Ophir	Thomsons Creek at SH85	Manuherikia River at Galloway	Benger Burn at SH8	Fraser River at Marshall Road	Clutha River at Millers Flat
NNN	?	?	?	?	?	?	?

Total Nitrogen

Total nitrogen concentrations (Figure 47) follow similar patterns to NNN concentrations (Figure 46), with five of the seven monitoring sites returning low TN concentrations below ANZECC trigger values. The remaining two sites, Thomsons Creek and Benger Burn, have elevated TN levels above natural background levels, as is the case with NNN.

Trend analysis of the TN data returned a number of significant trends with two sites, the Manuherikia at Ophir and the Clutha at Millers Flat, returning probable and significant increasing (degrading) trends respectively (Table 64). In the case of the Clutha River, that has very low background levels of TN, an increasing trend is of concern and warrants close scrutiny moving forward. This site is monitored by NIWA and the data that the analysis is based on is of high quality. The Fraser River returned a stable trend.

As with NNN, on a regional scale, Thomsons Creek and Benger Burn have moderately low TN levels when compared to sites with elevated TN concentrations, such as those present in parts of the North Otago reporting region, The Dunedin/Southern coastal reporting region and the Lower Clutha reporting region (Appendix E).

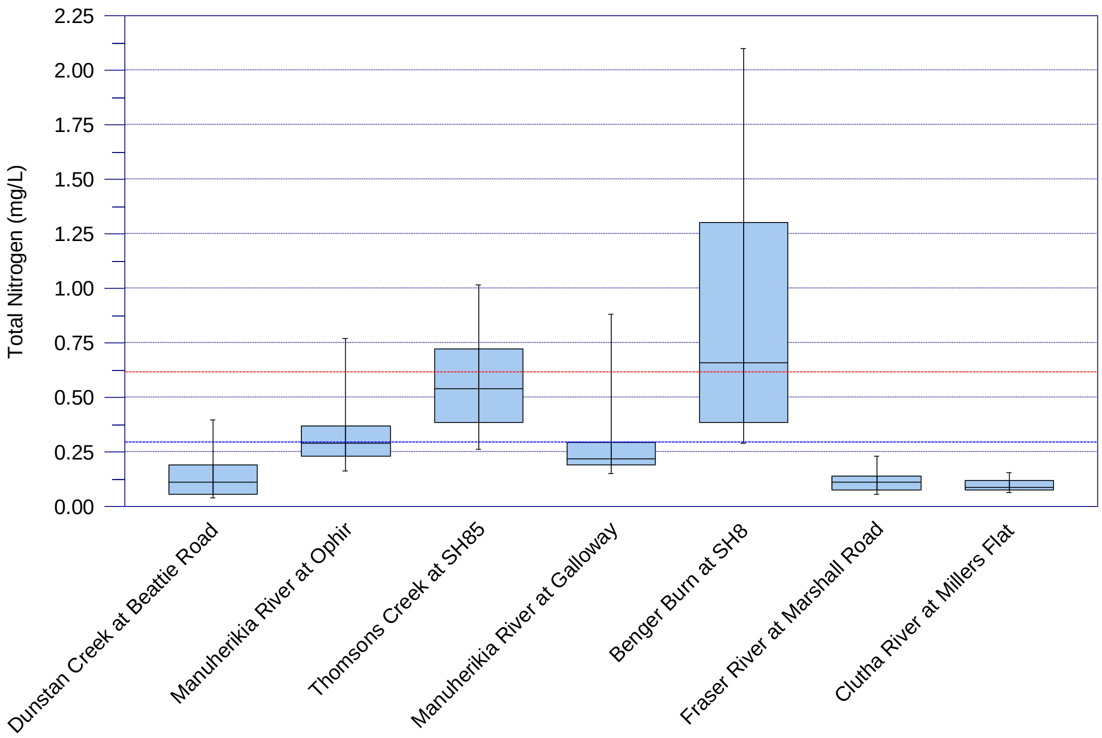

Figure 47: Boxplot summary of TN concentrations at SoE monitoring sites throughout Middle Clutha / Central Otago. The **red** dashed line corresponds to the ANZECC lowland guideline for TN of 0.614 mg/L; the **blue** dashed line the upland guideline of 0.295 mg/L.

Table 64: Trend summary of TN concentrations for the Middle Clutha reporting region.

Site	Dunstan Creek at Beattie Road	Manuherikia River at Ophir	Thomsons Creek at SH85	Manuherikia River at Galloway	Benger Burn at SH8	Fraser River at Marshall Road	Clutha River at Millers Flat
TN	?	↑↑	?	?	?	→	↑↑↑

Dissolved Reactive Phosphorus

Dissolved Reactive Phosphorus (DRP) concentrations are very low at three of the Middle Clutha monitoring sites, these sites being Dunstan Creek, the Fraser River and the Clutha River at Millers Flat (Figure 48). The remaining sites show moderate to high levels of DRP, with the most enriched site being Thomsons Creek. This site has very high concentrations of DRP well above those that would be seen in slightly impacted sites. On a regional scale, Thomsons Creek sits in the top ten of sites with elevated DRP concentrations (Appendix G).

Trend analysis of the DRP data set returns only one significant increasing (degrading) trend, that being for the Manuherikia at Galloway. This site currently has moderate DRP concentrations with a median slightly above the ANZECC lowland trigger value of 0.010 mg/L. Kitto (2012) identified increasing trends for DRP at this site as well as highly elevated nutrients in many of the Manuherikia tributary streams.

Over 2017 and 2018, ORC are undertaking a detailed study of the Thomsons Creek catchment that will allow identification of hotspots and assessment of reasons for the elevated DRP.

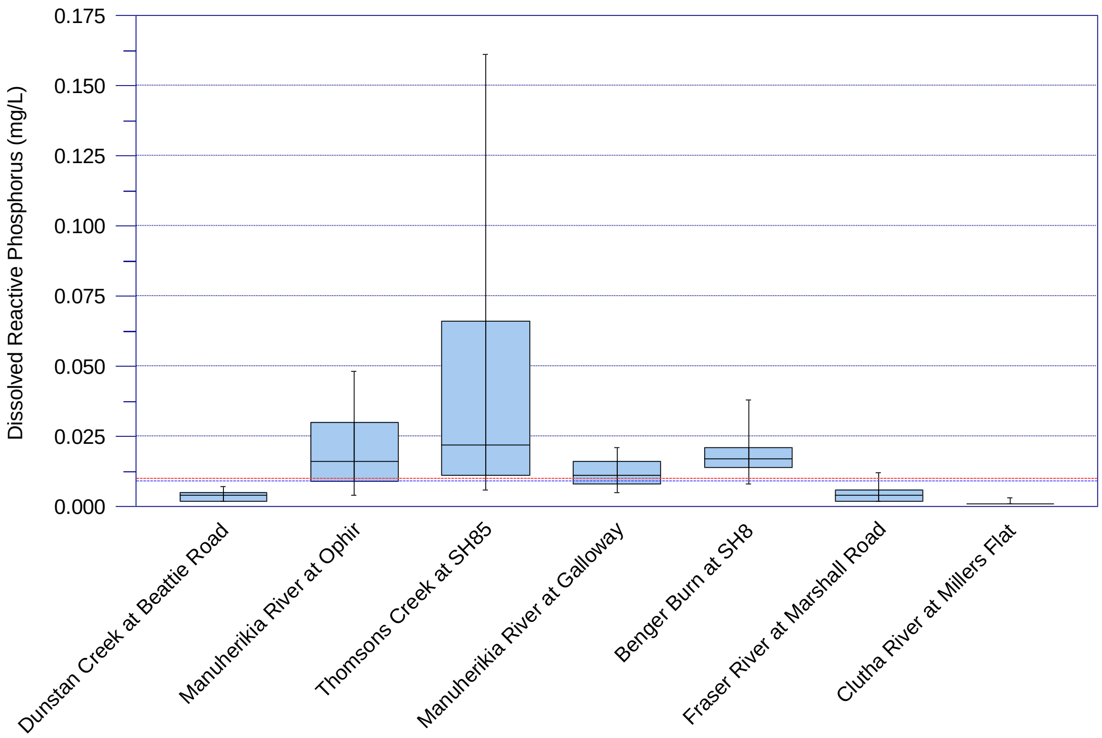

Figure 48: Boxplot summary of Dissolved Reactive Phosphorus (DRP) concentrations at SoE monitoring sites throughout Middle Clutha / Central Otago. The **red** dashed line corresponds to the ANZECC lowland guideline for DRP of 0.010 mg/L; the **blue** dashed line the upland guideline of 0.009 mg/L.

Table 65: Trend summary of Dissolved Reactive Phosphorus (DRP) concentrations for the Middle Clutha reporting region.

Site	Dunstan Creek at Beattie Road	Manuherikia River at Ophir	Thomsons Creek at SH85	Manuherikia River at Galloway	Benger Burn at SH8	Fraser River at Marshall Road	Clutha River at Millers Flat
DRP	→	?	?	↑↑↑	?	→	?

Total Phosphorus

Site variations in TP compare closely to those of DRP, with three sites returning very low TP levels, these sites being Dunstan Creek, the Fraser River and the Clutha River at Millers Flat (Figure 49). The remaining sites show moderate to very high levels of TP, with the most enriched site being Thomsons Creek. As with DRP, this site has concentrations of TP well above those that would be seen in slightly impacted sites. On a regional scale, Thomsons Creek sits in the top five of sites with elevated TP concentrations. The levels seen are well above natural backgournd levels and are derived from human (anthropogenic) activities (Appendix G). Trend analysis of the TP data (Table 66) returned indeterminate trends for all sites.

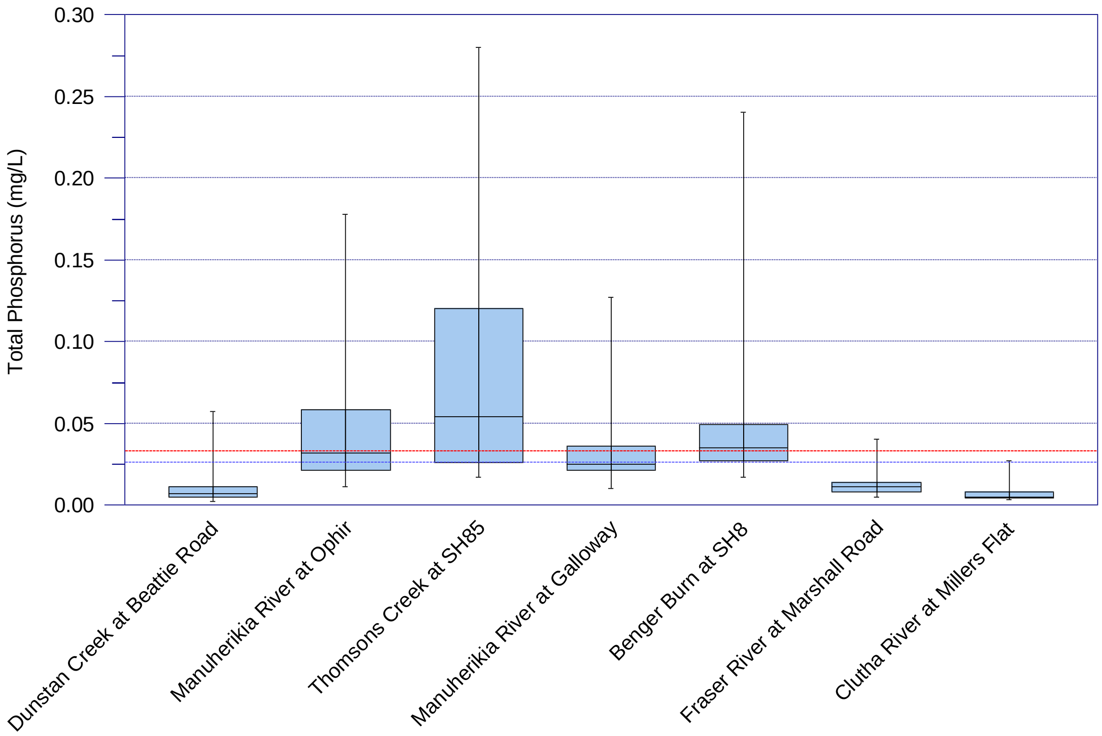

Figure 49: Boxplot summary of TP concentrations at SoE monitoring sites throughout Middle Clutha / Central Otago. The **red** dashed line corresponds to the ANZECC lowland guideline for TP of 0.033 mg/L; the **blue** dashed line the upland guideline of 0.026 mg/L.

Table 66: Trend summary of TP concentrations for the Middle Clutha reporting region.

Site	Dunstan Creek at Beattie Road	Manuherikia River at Ophir	Thomsons Creek at SH85	Manuherikia River at Galloway	Benger Burn at SH8	Fraser River at Marshall Road	Clutha River at Millers Flat
TP	?	?	?	?	?	?	?

Escherichia coli

Figure 50 shows *E. coli* concentrations at SoE monitoring sites across the Middle Clutha reporting region. Four of the seven sites return low levels of *E. coli*, with median and 75th percentile (upper boundary of the box on the boxplots) concentrations being well below the amber alert level of 260 CFU/100ml; these sites being Dunstan Creek, the Manuherikia at Galloway, Fraser River and the Clutha River at Millers Flat. The remaining three sites have varying levels of elevated *E. coli* concentrations with numbers being above the amber alert level. In the case of Thomsons Creek, *E. coli* levels are typically above the red alert level of 550 CFU/100ml.

Interestingly the Manuherikia at Galloway located well downstream of Ophir has better bacterial water quality than the Manuherikia at Ophir. This may reflect the influence of the Omakau Waste Water Treatment plant discharge and Thomson's Creek on the bacteria levels at the Ophir site.

Trend analysis of the *E. coli* data shows two of the seven sites to have significant increasing (degrading) trends (Table 67). One of these sites, Dunstan Creek, currently has very good water quality so an increasing trend is disappointing. The remaining site, the Manuherikia at Ophir currently has marginal bacterial water quality. An increasing trend at this site is alarming given the high primary contact recreation interest on the river in this area. Increasing A trend of increasing levels of bacteria at this site given that already has elevated *E. coli* above the national bottom line is of concern.

A positive result is a significant decreasing trend in *E. coli* for Thomsons Creek. This is a good result given the already elevated concentrations at this site.

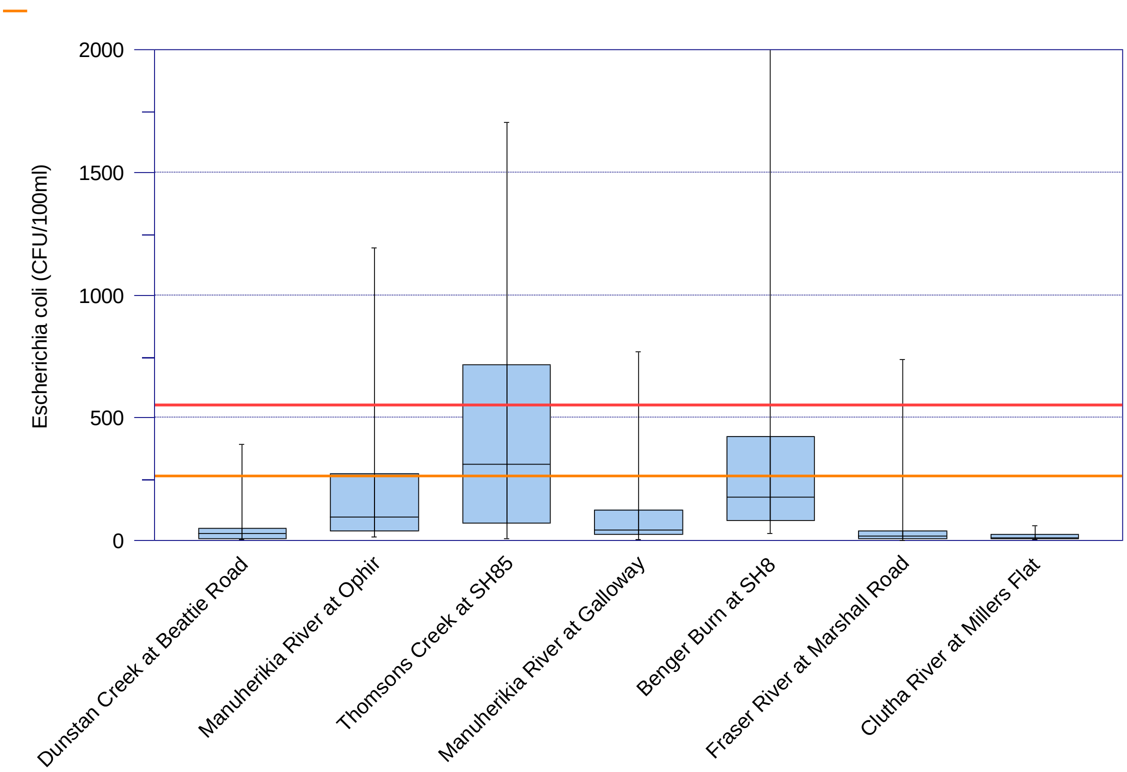

Figure 50: Boxplot summary of *E. coli* concentrations at SoE monitoring sites throughout Middle Clutha / Central Otago. The amber line corresponds to the amber alert level of 260 CFU/100ml; the red line to the red alert level of 550 CFU/100ml.

Table 67: Trend summary of *Escerichia coli* (*E. coli*) concentrations for the Middle Clutha reporting region.

Site	Dunstan Creek at Beattie Road	Manuherikia River at Ophir	Thomsons Creek at SH85	Manuherikia River at Galloway	Benger Burn at SH8	Fraser River at Marshall Road	Clutha River at Millers Flat
E. coli	↑↑↑	↑↑↑	↓↓↓	?	?	?	?

Turbidity

Turbidity levels at SoE monitoring sites across the Middle Clutha reporting region are typically low (Figure 51) with all sites monitored having median turbidity levels that are well below the ANZECC trigger levels for both upland and lowland sites. As would be expected, at times of high flow turbidity levels increase, as reflected by the 'whiskers' representing the 95th percentile turbidity levels at the sites.

Trend analysis (Table 68) shows three of the seven sites to have a probable increasing trend, these sites being Dunstan Creek, the Manuherikia at Galloway and the Clutha River at Millers Flat. The reasons for the increasing trends are unclear as Otago Regional Council do not collect data on land use change nor changes in land management practice that would allow for inference as to the reasons for increases in turbidity at these sites. Thomsons Creek is the only site that returns a decreasing (improving) trend. This is a good result given water quality at this site is degraded.

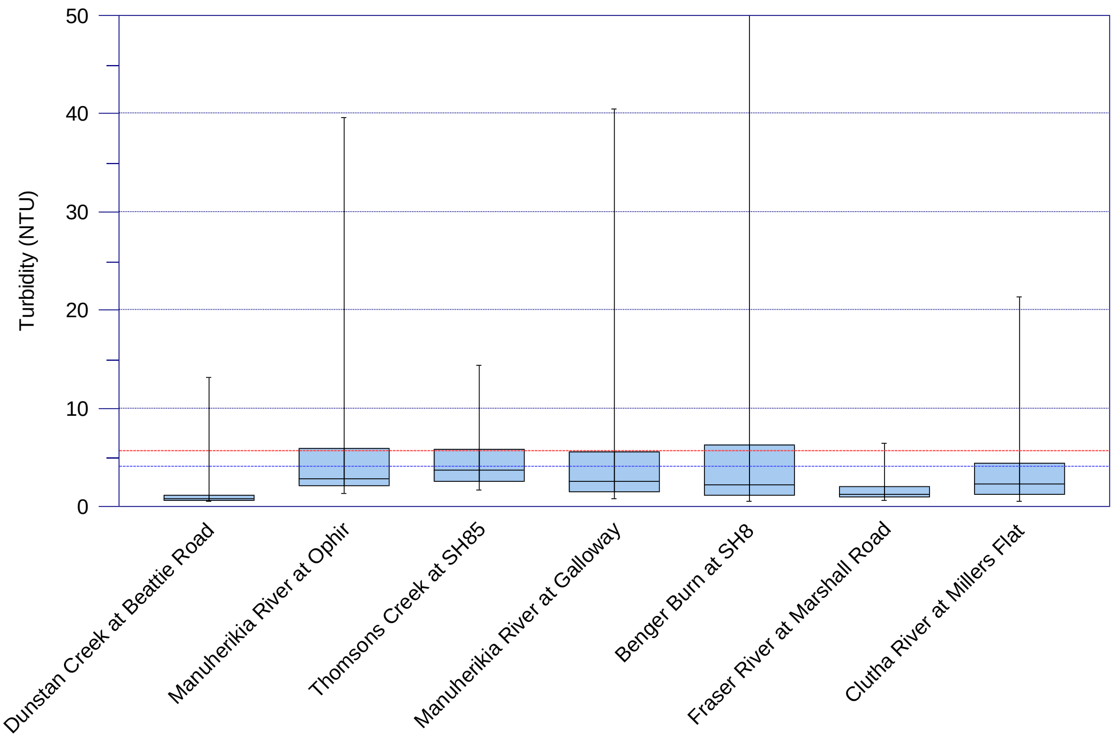

Figure 51: Boxplot summary of Turbidity at SoE monitoring sites throughout Middle Clutha / Central Otago. The **red** dashed line corresponds to the ANZECC lowland guideline for Turbidity of 5.6 NTU; the **blue** dashed line the upland guideline of 4.1 NTU.

Table 68: Trend summary of Turbidity levels for the Middle Clutha reporting region.

Site	Dunstan Creek at Beattie Road	Manuherikia River at Ophir	Thomsons Creek at SH85	Manuherikia River at Galloway	Benger Burn at SH8	Fraser River at Marshall Road	Clutha River at Millers Flat
Turbidity	↑↑	?	↓↓↓	↑↑	?	?	↑↑

Stream Health and the Macroinvertebrate Community Index

Macroinvertebrate Community Index (MCI) scores provide an integrated indicator of the general state of water quality and aquatic ecosystem health at a site.

Figure 52 summarises MCI scores for sites monitored for aquatic macroinvertebrates throughout the Middle Clutha reporting region. The summary includes annual samples collected from 2008 to 2017 (8 years) where data is available. Not all sites monitored for water quality have macro-invertebrate samples taken. Of the seven sites monitored for water quality, three sites are sampled annually for macro-invertebrates.

Dunstan Creek returns the highest MCI score for the rivers monitored across the Middle Clutha reporting region, and in fact on a regional standing, is equal first for the highest median MCI score of 118 (Appendix G). This shows the macroinvertebrate community to be in excellent health with overall water quality conditions supporting a diverse and pollution sensitive macroinvertebrate community.

The Manuherikia at Ophir has an MCI score that reflects a macroinvertebrate community in 'good' condition. This shows the slightly degraded water quality at this site not to be impacting too heavily on the macroinvertebrate community.

The Clutha River at Millers Flat has a low MCI score below 90. MCI is not well suited to large rivers so for the Clutha River at Miller Flat, the 'poor' MCI value may be driven more by habitat constraints and the ability to sample macroinvertebrates from riffles representative of the wider river.

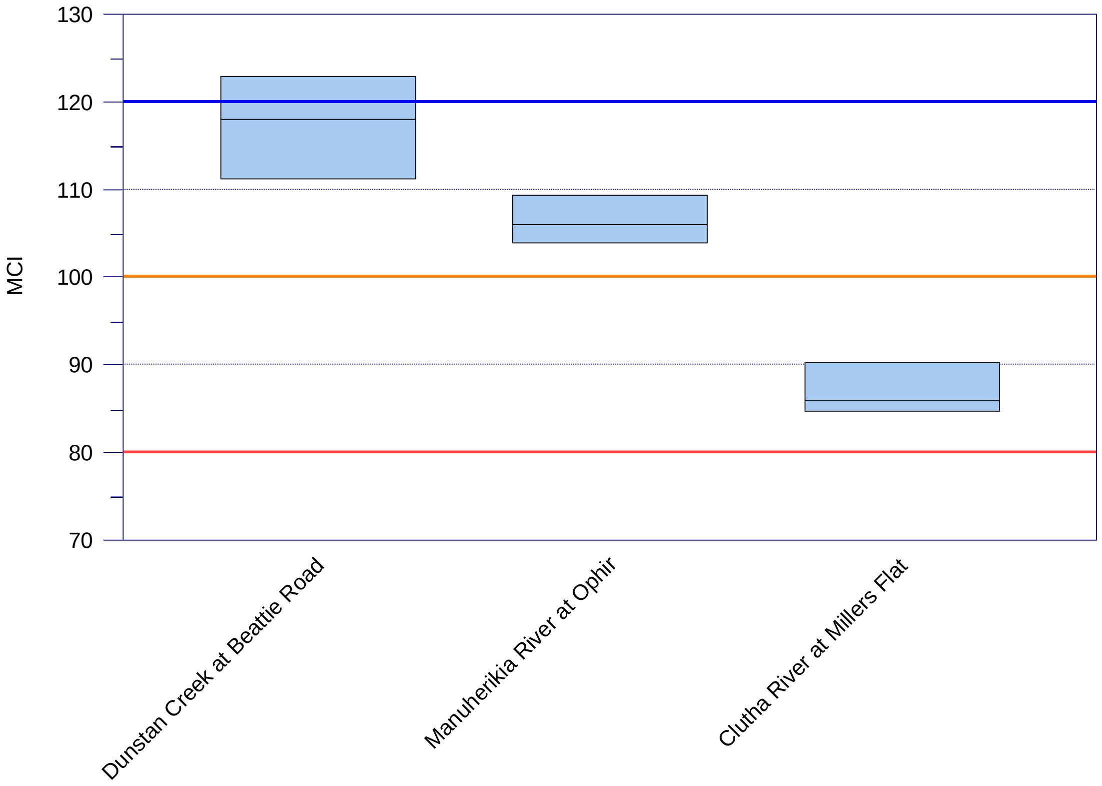

Figure 52: Boxplot summary of Macroinvertebrate Community Index (MCI) scores at SoE monitoring sites throughout the Middle Clutha / Central Otago reporting region where macroinvertebrate samples are routinely collected. Above the **blue** line corresponds to the 'Excellent' quality threshold; between the **orange** and blue line the 'Good' quality threshold; betwene the **red** and orange line 'Poor' quality threshold; below the red line the 'Degraded' threshold.

Middle Clutha Water Quality Summary

Across the Middle Clutha reporting region there are a moderate number of sites with degrading water quality trends, as shown in Table 69, which summarises trend results across all sites. There are a total of 49 results reported in the table; 16% return significant or probable degrading trends; and 4% return significant or probable improving trends; 6% return stable trends. Overall 74% of sites have either indeterminate trends (reported as "?"); or too many observations being 'less than detect' (<DL) for results returned from the laboratory.

Water quality across the Manuherikia catchment is variable, as was found by the Kitto (2012) study, with impacted water quality in the tributary streams of the Manuherikia likely impacting on the water quality of the main-stem river.

As stated previously, having accurate information on changes in land use and land management practice would help in identifying the reasons for degarded water quality and drivers of change evident with some water quality variables.

In summary:

- For four of seven sites monitored across the Middle Clutha reporting region, water quality is excellent overall. These sites include Dunstan Creek, the Manuherikia at Galloway, Fraser River and the Clutha at Millers Flat;
- Bacterial water quality is excellent in Dunstan Creek, the Manuherikia at Galloway, Fraser River and the Clutha at Millers Flat. The remaining three sites, Thomsons Creek, the Manuherikia at Galloway, and Benger Burn, all fail the national bottom line for *E. coli* and have unacceptable bacterial water quality. Thomsons Creek is particulalry degraded;
- Thomsons Creek, and to a lesser extent Benger Burn, have degraded water quality, returning elevated levels of phosphorus, nitrogen and bacteria;
- The Manuherikia at Ophir appears to be influenced by treated sewage being discharged from the Omakau WWTP. Further work is needed to understand the effects of this discharge on the river receiving environment;
- Water quality improves in the Manuherikia River as one travels downstream from Ophir to Galloway.

Table 69: Trend summary for the Middle Clutha reporting region.

Site	Dunstan Creek at Beattie Road	Manuherikia River at Ophir	Thomsons Creek at SH85	Manuherikia River at Galloway	Benger Burn at SH8	Fraser River at Marshall Road	Clutha River at Millers Flat
Ammoniacal Nitrogen	< DL	< DL	?	< DL	< DL	< DL	?
Nitrite/Nitrate Nitrogen	?	?	?	?	?	?	?
Total Nitrogen	?	↑↑	?	?	?	→	↑↑↑
Dissolved Reactive Phosphorus	→	?	?	↑↑↑	?	→	?
Total Phosphorus	?	?	?	?	?	?	?
Escherichia coli	↑↑↑	↑↑↑	↓↓↓	?	?	?	?
Turbidity	↑↑	?	↓↓↓	↑↑	?	?	↑↑

Otago Regional Council

2.6. Lower Clutha / Pomahaka

The Lower Clutha/Pomahaka reporting region runs from the small settlement of Beaumont, where State Highway 8 crosses the Clutha River/Mata-Au, downstream to the Pacific Ocean where the Clutha River/Mata-Au discharges to the sea near Balclutha. The Lower Clutha/Pomahaka reporting region includes the catchments of the Tuapeka River (249 km^2), Pomahaka River (2060 km^2), Waipahi River (339 km^2), Waiwera River (208 km^2) and the Waitahuna River (406 km^2). The Lower Clutha/Pomahaka reporting region, in contrast to the Upper and Middle Clutha reporting regions, is dominated by alluvial plains, rolling hill country and lowlands.

The Pomahaka River is the largest catchment of the Lower Clutha/Pomahaka reporting region covering over 57% of the reporting area's 3600 km^2. The upper reaches of the Pomahaka catchment are steep and dominated by tussock, while the lower reaches are primarily flowing through pastoral rolling hill country. The headwaters originate in the Umbrella Range and flow in a south-west direction to its junction with the Clutha River/Mata-Au near Clydevale. A small section of the Pomahaka catchment, the Kaiwera Stream, is not within the Otago Region. The Pomahaka catchment climate is considered mild, with consistent rainfall throughout the year. Annual rainfall for the Pomahaka catchment generally varies from around 700 mm in the low altitude parts of the catchment to 1400 mm in the Blue Mountains and Umbrella Mountains. This rainfall contributes to higher river flows in the Pomahaka, including, in particular, numerous flushing flows. The lowest flow recorded in the Pomahaka River at Glenken (upper catchment) was 0.8 m^3/s, while the maximum discharge recorded at the same site was 480 m^3/s. The Pomahaka River typically experiences about eight flushing flows each year. These larger flows are important for removing algae, flushing nutrients and moving sediment. Streams with a low frequency of flushing flows are susceptible to algal proliferations, particularly if they contain high nutrient levels. Relative to North or Central Otago streams, the Pomahaka River has a high frequency of flushing flows. Soil profiles vary primarily by topography and elevation, with the rolling hill country of the lower catchment being dominated by insoluble organic, pallic and grey soils, and the more mountainous areas of the catchment having primarily semi-arid soils. The river supports a regionally significant brown trout fishery (ORC, 2011).

2.6.1. Lower Clutha / Pomahaka geographical and land cover characteristics

Table 70 summarises characteristics of the Lower Clutha/Pomahaka reporting region based on the River Environment Classification (refer Appendix F for a detailed overview of the REC); land-cover (based on the Land Cover Database Version 4; condensed with the approach summarised in Appendix D); and the Land Use Capability (LUC) classes (see Section 2.0 for the LUC definition). The Lower Clutha/Pomahaka reporting region covers an area of 3600 km^2 representing approximately 17% of the total Clutha River/Mata-Au catchment.

According to the River Environment Classification (REC), rivers and streams of the Lower Clutha/Pomahaka reporting region are dominated by cool-dry/hill (10.9%) and cool-dry/low elevation (77.9%) rivers that receive low rainfall (less than 500 mm annual average rainfall). Cool/wet hill (6.8%) and cool/wet low elevation (2.7%) rivers and streams are also a feature of the reporting region and are typical of areas of the Pomahaka catchment.

The predominant land cover throughout the Lower Clutha/Pomahaka reporting region is high producing grassland (72.4%, 2606 km^2) followed by plantation forestry (12.8%, 461 km^2) and native cover (8.7%, 313 km^2) (Table 70, Figure 53). 'High producing grassland' includes "land that is intensively managed and grazed for wool, lamb, beef, and dairy or deer production" (Appendix D).

There is an interesting mix of LUC class land through the Lower Clutha/Pomahaka reporting region, dominated largely by land characteristics of the Pomahaka catchment and the Blue Mountains to the west. Areas of relatively flat, rolling LUC Class 3 and 4 land (57%, 2050 km^2) exists through the middle and lower Pomahaka catchment and the river terraces bordering the Clutha River/Mata-Au. These areas are where the majority of intensive agriculture occurs throughout the Lower Clutha/Pomahaka reporting region. This contrasts with steeper LUC Class 6 and 7 land (34%, 1228 km^2) that is typical of the ranges bordering the Pomahaka catchment.

Land-use changes in the Pomahaka catchment have been significant over recent decades. ORC (2011) reported that between 1999 and 2008, the number of dairy farms increased from 38 to 105. At the time, anecdotal evidence suggested that the intensity of the farming had also increased. The conversions typically occurred in the middle and lower areas of the Pomahaka catchment, in particular around Tapanui, Heriot and Clydevale. Due to most farms being located in relatively low-lying areas with poor draining soils, farming in the Pomahaka catchment relies on artificial drainage predominantly in the form of tile drains. Unfortunately, subsurface drainage has been identified as a significant source of contaminants from grazed pastures to waterways (Wilcock et al., 1999; Monaghan et al. 2002). If inappropriately managed, these tile and mole drains accelerate water and associated contaminant flows of nitrogen, phosphorous and bacteria to local watercourses and the tile drains also allow riparian zones to be bypassed (Nguyen, et al. 2002).

Table 70: Zone characteristics of the Lower Clutha reporting region. Source of flow, land cover area and land-use capability class.

Source of flow (REC)		Land Cover Area (LCDB4)		Land-use Capability Class (LUC)	
Cool-Dry / Hill	10.9%	Cropping	0.5%	Class 2	3.1%
Cool-Dry / Low-Elevation	77.9%	High producing grassland	72.4%	Class 3	40.1%
Cool-Dry / Lake	0.01%	Low Producing Grassland	2.8%	Class 4	17.1%
Cool-Wet / Hill	6.8%	Native Cover	8.7%	Class 5	4.8%
Cool-Wet / Low-Elevation	2.7%	Orchards/Vineyards	0.02%	Class 6	31.6%
Cool-Wet / Lake	1.8%	Plantation forestry	12.8%	Class 7	2.5%
		Unaccounted	2.6%	Lake	0.1%
		Urban areas	0.3%	River	0.8%
				Town	0.1%

Lower Clutha reporting region covers 360 030 hectares

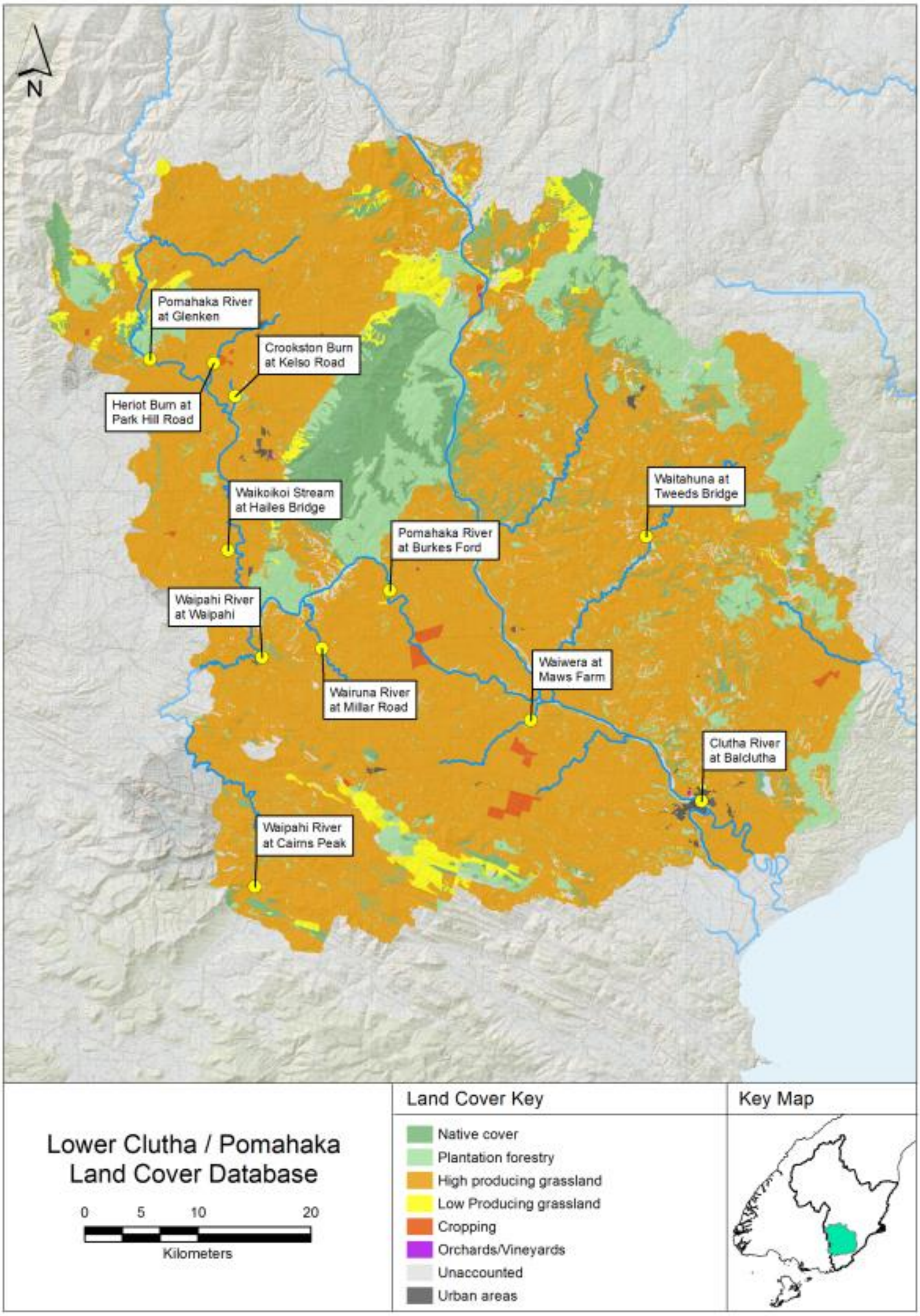

Figure 53: Map showing broad land cover categories of the Lower Clutha / Pomahaka reporting region based on the LCDB4 databse.

2.6.2. Lower Clutha / Pomahaka water quality

The following section provides a summary of the Lower Clutha/Pomahaka reporting region water quality based on:

- Compliance against Schedule 15 (Water Plan) water quality limits;
- National Policy Statement for Freshwater Management (NPSFM 2014) National Objectives Framework Attribute bands (NOF bands);
- Summary boxplots of key water quality indicators with the inclusion of general water quality guidelines such as ANZECC (2000);
- A summary of trends (degrading/improving) that may (or may not) be evident in the data.

There are a total 11 SoE monitoring sites throughout the Lower Clutha/Pomahaka reporting zone with a good spread of sites across river and tributary stream sites. 8 of the 11 sites are located in the Pomahaka catchment. NIWA currently monitor one site being the Clutha River at Balclutha.

Schedule 15 compliance

10 of the 11 SoE monitoring sites in the Lower Clutha/Pomahaka reporting region are located in Receiving Water Group 1; the remaining site, the Pomahaka River at Glenken located in the upper Pomahaka catchment, is in Receiving Water Group 2. RWG2 has more stringent limits for NNN and DRP under Schedule 15 (Water Plan). These are outlined in Table 71.

Ammoniacal nitrogen compliance against Schedule 15 (Water Plan) limits is good, with all sites across the Lower Clutha/Pomahaka reporting region returning 80th percentile concentrations that are typically less than half the Schedule 15 (Water Plan) limit of 0.10 mg/L.

For sites that fall in RWG 1, compliance with the nitrite/nitrate nitrogen (NNN) Schedule 15 (Water Plan) limit of 0.444 mg/L is poor, with eight out of 10 sites exceeding the limit. Sites in the Pomahaka exceed the limit by varying degrees but in the case of the Heriot Burn, Crookston Burn, Waipahi River at Waipahi, and the Wairuna Stream, the limit is exceeded by two to four times.

The Heriot Burn, Crookston Burn, Waikoikoi Stream and the Wairuna River monitoring sites have the worst compliance with Schedule 15 (Water Plan) limits failing four of the five water quality limits.

E. coli compliance is poor, with eight of 11 sites failing. In some cases, again with the Heriot Burn, Crookston Burn, Waikoikoi Stream and the Wairuna River, the 80th percentile *E. coli* concentrations are very high, exceeding the limit by four to eight times. This reflects extremely high *E. coli* bacteria concentrations at these sites and a high degree of faecal contamination.

Table 71: 80th percentile values for water quality variables identified in Schedule 15. Values are calculated from samples taken when flows are below median flow. The orange cells show where the 80th percentile exceeds the Schedule 15 limit. Numbers underlined in italics have lower limits under Schedule 15.

Variable	NNN	NH_4-N	DRP	*E. coli*	Turbidity
Schedule 15 limit when flows < median flow	0.444 mg/L *0.075 mg/L*	0.100 mg/L	0.026 mg/L *0.010 mg/L*	260 CFU	5.0 NTU
SoE reporting name					
Pomahaka River at Glenken	*0.032*	0.012	*0.010*	508	2.44
Heriot Burn at Park Hill Road	1.576	0.036	0.052	2180	5.90
Crookston Burn at Kelso Road	1.604	0.036	0.045	2000	5.04
Waikoikoi Stream at Hailes Bridge	0.448	0.023	0.038	1140	5.64
Waipahi River at Cairns Peak	0.742	0.035	0.019	884	8.16
Waipahi River at Waipahi	1.174	0.016	0.021	218	2.64
Wairuna River at Millar Road	1.268	0.059	0.100	1220	11.62
Pomahaka River at Burkes Ford	0.564	0.018	0.014	156	3.36
Waiwera at Maws Farm	0.858	0.020	0.031	380	3.92
Waitahuna at Tweeds Bridge	0.132	0.015	0.018	388	4.00
Clutha River at Balclutha	0.101	0.005	0.002	101	3.77

Nitrate and ammonia toxicity and NOF compliance

NOF attribute bands for nitrate (measured as NNN) and NH_4-N toxicity (Table 72 and Table 73 respectively) provide good protection against toxicity risk for all Lower Clutha/Pomahaka monitoring sites with four of 11 sites returning an ‘A’ band (highest level of protection), and seven of 11 sites returning a ‘B’ band for NNN. The B-band reflects an environment that may have “some growth effect on up to 5% of species” in regards to a chronic nitrate toxicity effect (Appendix B). This provides for a good level of protection with some minor effects on growth rate of the most sensitive species (Hickey, 2013). So despite elevated NNN concentrations at a number of Pomahaka River tributary sites, the risk of nitrate toxicity effects on in-stream biota remains relatively low.

In the case of NH_4-N, seven of 11 sites return an ‘A’ band, and four of 11 sites return a ‘B’ band. The ‘B’ band still provides for a good level of protection against ammonia toxicity but ‘starts impacting occasionally on the 5% most sensitive species’ (Appendix B). Some species of freshwater mollusc can be sensitive to ammonia toxicity.

Table 72: NOF compliance summary for Nitrate (estimated from NNN). Included are median and 95th percentile values for the the period July 2012 to June 2017 and the corresponding NOF attribute band.

Variable	Nitrate as NNN		NOF Band	
SoE reporting name	Median (mg/L)	95th Percentile (mg/L)	Median	95th Percentile
Pomahaka River at Glenken	0.050	0.298	A	A
Heriot Burn at Park Hill Road	1.320	2.156	B	B
Crookston Burn at Kelso Road	1.333	2.265	B	B
Waikoikoi Stream at Hailes Bridge	0.742	2.192	A	B
Waipahi River at Cairns Peak	0.788	1.658	A	B
Waipahi River at Waipahi	1.068	2.073	B	B
Wairuna River at Millar Road	1.306	3.047	B	B
Pomahaka River at Burkes Ford	0.558	1.452	A	A
Waiwera at Maws Farm	0.872	2.019	A	B
Waitahuna at Tweeds Bridge	0.184	0.779	A	A
Clutha River at Balclutha	0.063	0.190	A	A

Table 73: NOF compliance summary for NH_4-N. Included are median and maximum values for the the period July 2012 to June 2017 and the corresponding NOF attribute band.

Variable	Ammoniacal nitrogen (unadjusted)		NOF Band	
SoE reporting name	Median (mg/L)	Maximum (mg/L)	Median	Maximum
Pomahaka River at Glenken	0.007	0.014	A	A
Heriot Burn at Park Hill Road	0.029	0.070	A	B
Crookston Burn at Kelso Road	0.053	0.143	B	B
Waikoikoi Stream at Hailes Bridge	0.028	0.080	A	B
Waipahi River at Cairns Peak	0.022	0.048	A	A
Waipahi River at Waipahi	0.011	0.039	A	A
Wairuna River at Millar Road	0.048	0.187	B	B
Pomahaka River at Burkes Ford	0.013	0.043	A	A
Waiwera at Maws Farm	0.013	0.034	A	A
Waitahuna at Tweeds Bridge	0.011	0.026	A	A
Clutha River at Balclutha	0.003	0.014	A	A

E. coli, swimmability and NOF compliance

Table 74 summarises compliance for *E. coli* against the four statistical tests of the NOF *E. coli* attribute.

The lower Clutha/Pomahaka reporting region returns the worst NOF *E. coli* compliance of any reporting region across Otago. With 10 of the 11 sites failing the NPSFM (2014) NOF national bottom line and returning a 'D' band or worse, an 'E' band.

The Heriot Burn, Crookston Burn, Waikoikoi Stream, Waipiahi River at Cairns and the Wairuna River at Millers Road have excessive levels of *E. coli* and fail all tests by a significant margin when compared to the acceptable 'C' band threshold (Appendix B). In recent years significant work has been occurring by catchment groups and the community in these catchments, in efforts to improve bacterial water quality.

The only site with acceptable bacterial water quality is the Clutha River at Balclutha that is fully compliant with 'A' bands for the four individual tests.

The overall attribute state is based on the worst grading with the national bottom line being an orange 'D' band; all sites must return a minimum of a 'C' band.

Table 74: NOF compliance summary for *E. coli* for the the period July 2012 to June 2017. The overall grading band is determined by the lowest (worst) ranked Numeric Attribute State as it relates to the four separate states**.**

	Numeric Attribute State				Overall attribute state	
Site	Median grade (CFU/100ml)	95th percentile grade (CFU/100ml)	% over 260 CFU/100 ml grade (%)	% over 540 CFU/100 ml grade (%)	Grading attribute state	Overall Pass/Fail
Pomahaka River at Glenken	**D (210)**	**D (2465)**	**D (43%)**	**D (20%)**	**D**	**FAIL**
Heriot Burn at Park Hill Road	**E (600)**	**D (5695)**	**E (74%)**	**E (48%)**	**E**	**FAIL**
Crookston Burn at Kelso Road	**E (500)**	**D (7890)**	**E (74%)**	**E (46%)**	**E**	**FAIL**
Waikoikoi Stream at Hailes Bridge	**E (590)**	**D (14285)**	**E (8%)**	**E (52%)**	**E**	**FAIL**
Waipahi River at Cairns Peak	**D (235)**	**D (5980)**	**D (45%)**	**E (31%)**	**E**	**FAIL**
Waipahi River at Waipahi	A (120)	**D (4400)**	B (23%)	C (15%)	**D**	**FAIL**
Wairuna River at Millar Road	**E (620)**	**D (6000)**	**E (69%)**	**E (52%)**	**E**	**FAIL**
Pomahaka River at Burkes Ford	A (92)	**D (5240)**	B (28%)	C (18%)	**D**	**FAIL**
Waiwera at Maws Farm	**D (190)**	**D (1385)**	**D (38%)**	C (17%)	**D**	**FAIL**
Waitahuna at Tweeds Bridge	**E (290)**	**D (4450)**	**E (51%)**	C (18%)	**E**	**FAIL**
Clutha River at Balclutha	A (32)	A (447)	A (9%)	A (4%)	A	PASS

Otago Regional Council

Ammoniacal nitrogen

A number of sites throughout the Pomahaka catchment, namely the Heriot Burn, Crookston Burn, Waikoikoi Stream, Wairuna River at Millers Road, and to a lesser extent, the Waipahi River at Cairns have elevated NH_4-N concentrations that are above ANZECC trigger values. In a regional context, these sites have highly elevated NH_4-N concentrations with the Heriot Burn, Crookston Burn, Waikoikoi Stream, Wairuna River at Millers Road being in the top five regional sites for elevated median NH_4-N concentrations (Appendix E and Appendix G).

This reflects a degree of ammonia enrichment over and above levels that would be expected of non-impacted sites or natural background levels. All other sites have concentrations that fall below ANZECC trigger levels.

Only one site returned a trend result, and that was a probable increasing trend for the Waipahi River at Cairns Peak (Table 75). All remaining sites returned an indeterminate trend, or in the case of the Pomahaka River at Glenken, had too many results returned from the laboratory as being less than detect (<DL).

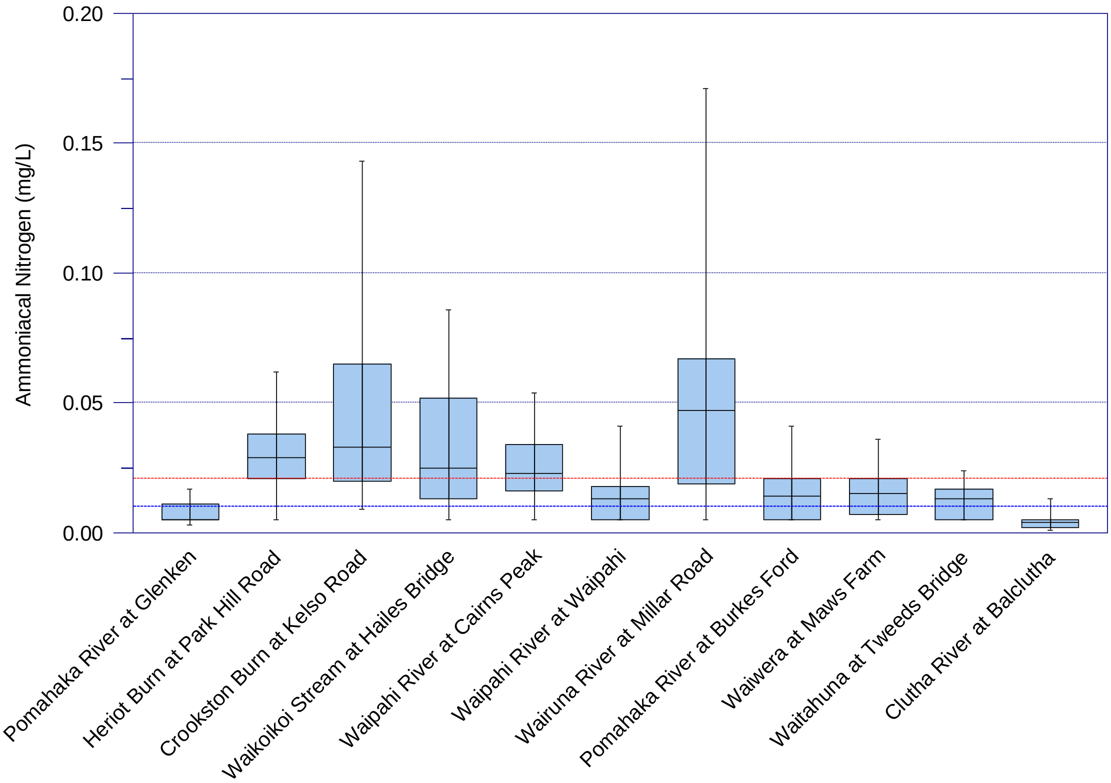

Figure 54: Boxplot summary of NH_4-N concentrations at SoE monitoring sites throughout Lower Clutha / Pomahaka. The **blue** dashed line corresponds to the upland ANZECC NH_4-N guideline of 0.010 mg/L. The **red** dashed line corresponds to the lowland ANZECC guideline of 0.021 mg/L.

Table 75: Trend summary of NH_4-N concentrations for the Lower Clutha / Pomahaka reporting region.

Site	Pomahaka River at Glenken	Heriot Burn at Park Hill Road	Crookston Burn at Kelso Road	Waikoikoi Stream at Hailes Bridge	Waipahi River at Cairns Peak	Waipahi River at Waipahi	Wairuna River at Millar Road	Pomahaka River at Burkes Ford	Waiwera at Maws Farm	Waitahuna at Tweeds Bridge	Clutha River at Balclutha
NH_4-N	< DL	?	?	?	↑↑	?	?	?	?	?	?

Nitrite/Nitrate nitrogen

Eight of the 11 sites monitored in the Lower Clutha/Pomahaka reporting region have elevated NNN levels with median concentrations above ANZECC (2000) trigger levels. In the case of the Pomahaka catchment monitoring sites, namely the Heriot Burn, Crookston Burn, Waikoikoi Stream, Wairuna River and the Waipiahi River; and next door to the Pomahaka catchment, the Waiwera River, NNN concentrations are some of the highest recorded across Otago (Appendix E and Appendix G). This reflects a high degree of NNN enrichment over and above levels that would be expected of non-impacted sites or natural background levels.

Only the upper Pomahaka River monitoring site at Glenken, the Waitahuna River on the opposite side of the Clutha to the Pomahaka, and the Clutha River at Balclutha have median NNN concentrations below ANZECC trigger levels.

Trend analysis returned two increasing (degrading) trends for NNN, this being a probable increasing trend for the Heriot Burn; and a significant increasing trend for the Waipahi River at Cairns. As stated previously, ORC do not have information on changes in land-use or land management practices that allows for inference as to the reasons for degraded water quality or the cause of the degrading trends at these sites.

All remaining sites returned an indeterminate trend (Table 75).

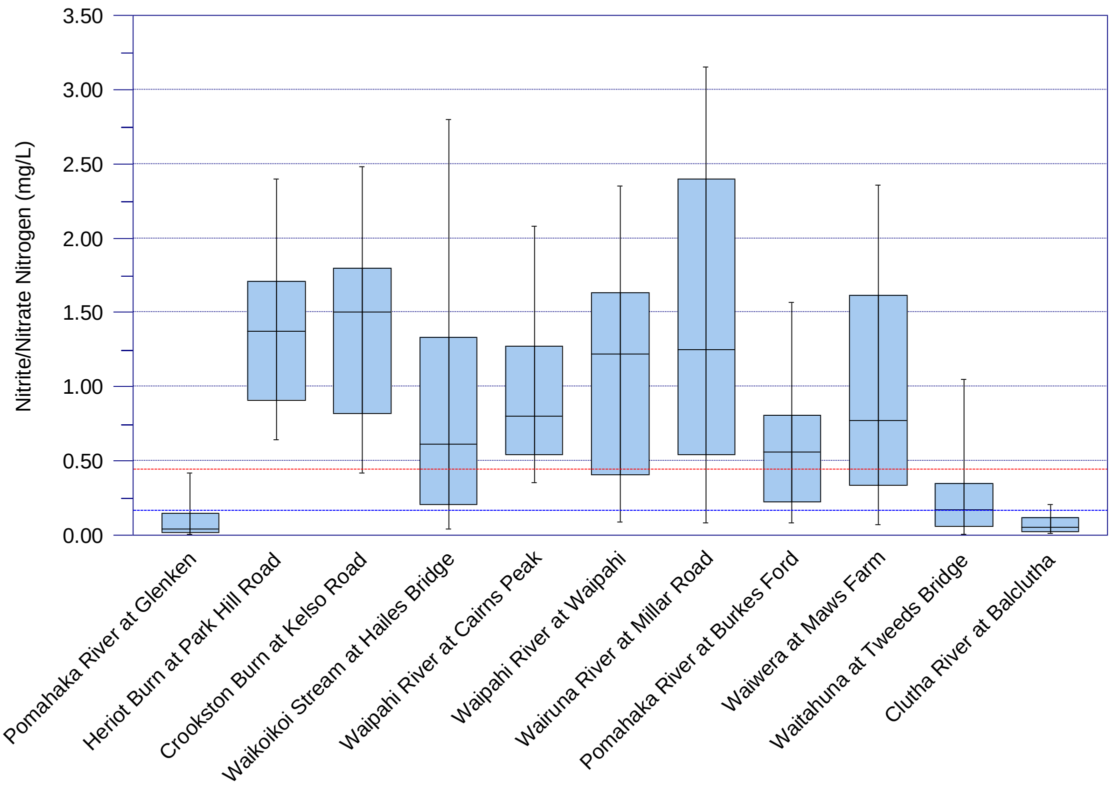

Figure 55: Nitrite/nitrate nitrogen (NNN) concentrations at SoE monitoring sites throughout Lower Clutha / Pomahaka. The **red** dashed line corresponds to the ANZECC lowland guideline for NNN of 0.444 mg/L; the **blue** dashed line the upland guideline of 0.167 mg/L.

Table 76: Trend summary of Nitrite/Nitate Nitrogen (NNN) concentrations for the Lower Clutha / Pomahaka reporting region.

Site	Pomahaka River at Glenken	Heriot Burn at Park Hill Road	Crookston Burn at Kelso Road	Waikoikoi Stream at Hailes Bridge	Waipahi River at Cairns Peak	Waipahi River at Waipahi	Wairuna River at Millar Road	Pomahaka River at Burkes Ford	Waiwera at Maws Farm	Waitahuna at Tweeds Bridge	Clutha River at Balclutha
NNN	?	↑↑	?	?	↑↑↑	?	?	?	?	?	?

Total Nitrogen

Total nitrogen concentrations (Figure 56) follow similar patterns to NNN concentrations (Figure 55), with eight of the 11 sites having elevated TN levels with median concentrations well above ANZECC (2000) trigger levels.

As is seen with NNN, in the case of the Pomahaka catchment monitoring sites, namely the Heriot Burn, Crookston Burn, Waikoikoi Stream, Wairuna River and the Waipahi River; and next door to the Pomahaka catchment, the Waiwera River, TN concentrations are some of the highest recorded across Otago (Appendix E and Appendix G). This reflects a high degree of nitrogen enrichment in the upstream catchments of these monitoring sites over those of natural background levels. As was the case for NNN, only the upper Pomahaka River monitoring site at Glenken, the Waitahuna River on the opposite side of the Clutha to the Pomahaka, and the Clutha River at Balclutha have median TN concentrations below ANZECC trigger levels.

Trend analysis of TN data returned a number of significant trends with one site, the Waipahi at Cairns, returning a significant increasing (degrading) trend. Two sites returned significant decreasing (improving) trends; the Wairuna River with a significant improving trend, and the Waiwera River with a probable improving trend. This is a promising result for these two sites given the elevated TN concentrations that are currently present.

ORC do not have information on changes in land-use or land management practices so it is not possible to comment on the cause of degrading or improving trends at these sites.

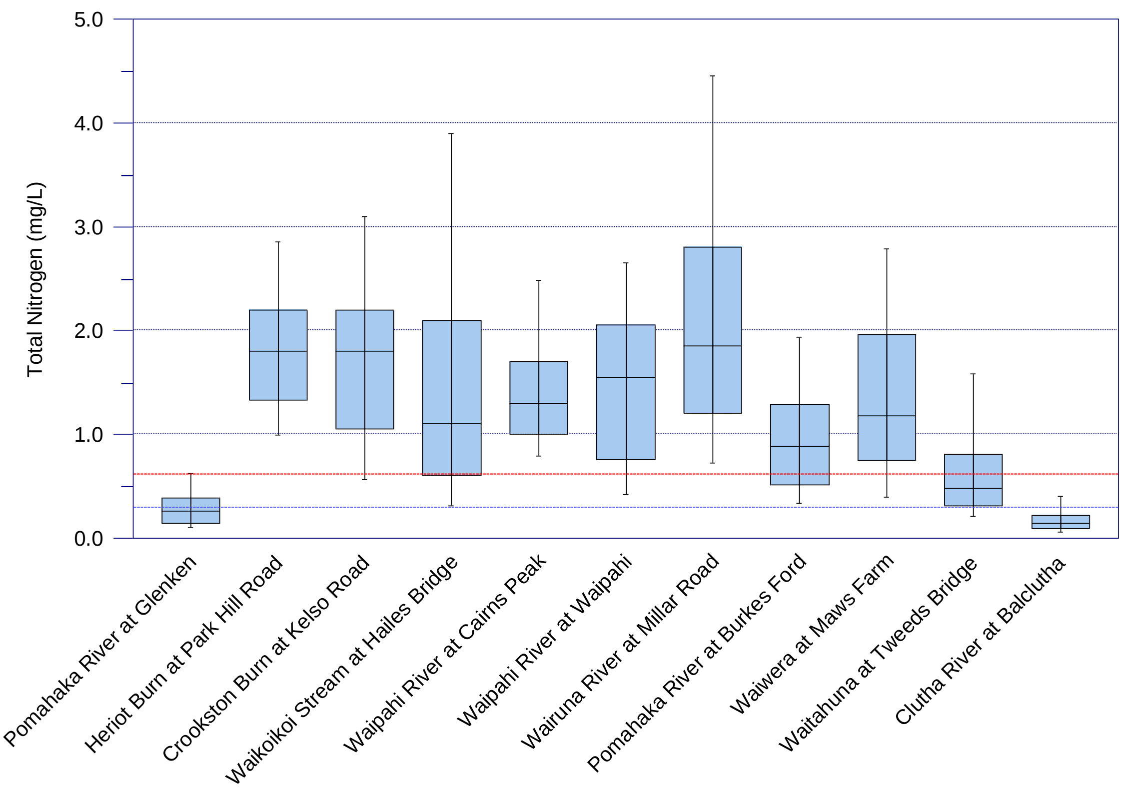

Figure 56: Boxplot summary of TN concentrations at SoE monitoring sites throughout Lower Clutha / Pomahaka. The **red** dashed line corresponds to the ANZECC lowland guideline for TN of 0.614 mg/L; the **blue** dashed line the upland guideline of 0.295 mg/L.

Table 77: Trend summary of TN concentrations for the Lower Clutha / Pomahaka reporting region.

Site	Pomahaka River at Glenken	Heriot Burn at Park Hill Road	Crookston Burn at Kelso Road	Waikoikoi Stream at Hailes Bridge	Waipahi River at Cairns Peak	Waipahi River at Waipahi	Wairuna River at Millar Road	Pomahaka River at Burkes Ford	Waiwera at Maws Farm	Waitahuna at Tweeds Bridge	Clutha River at Balclutha
TN	?	?	?	?	↑↑↑	?	↓↓↓	?	↓↓	?	?

Dissolved Reactive Phosphorus

Dissolved Reactive Phosphorus (DRP) concentrations exceed ANZECC (2000) trigger values at nine of the 11 monitoring sites across the Lower Clutha/Pomahaka reporting region and (Figure 57). In the case of the Heriot Burn, Crookston Burn, Waikoikoi Stream and Wairuna River, concentrations are highly elevated above those of non-impacted sites, with these streams sitting in the top six sites across Otago for elevated DRP (Appendix G). The patterns in DRP follow those of NNN and TN, with the same sites returning elevated concentrations for all.

Trend analysis of DRP data returns four increasing (degrading) trends; these being a significant degrading trend for the Pomahaka at Glenken, a site currently with good water quality; significant degrading trends for the Waikoikoi and Waitahuna rivers; and a probable degrading trend for the Waipahi River at Cairns.

A significant decreasing (improving) trend was returned for the Clutha River at Balclutha, a site currently with excellent water quality.

ORC do not have information on changes in land-use or land management practices so it is not possible to comment on the cause of the degrading trends at these sites.

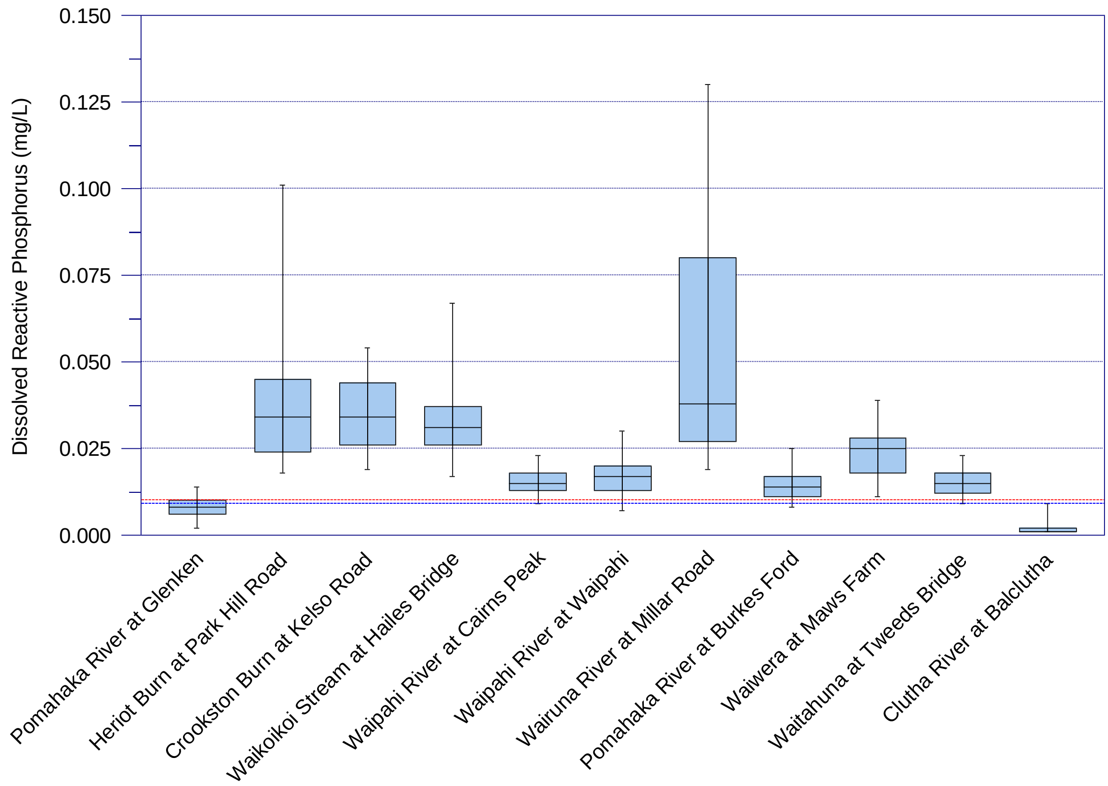

Figure 57: Boxplot summary of Dissolved Reactive Phosphorus (DRP) concentrations at SoE monitoring sites throughout Lower Clutha / Pomahaka. Full scale. The **red** dashed line corresponds to the ANZECC lowland guideline for DRP of 0.010 mg/L; the **blue** dashed line the upland guideline of 0.009 mg/L.

Table 78: Trend summary of Dissolved Reactive Phosphorus (DRP) concentrations for the Lower Clutha / Pomahaka reporting region.

Site	Pomahaka River at Glenken	Heriot Burn at Park Hill Road	Crookston Burn at Kelso Road	Waikoikoi Stream at Hailes Bridge	Waipahi River at Cairns Peak	Waipahi River at Waipahi	Wairuna River at Millar Road	Pomahaka River at Burkes Ford	Waiwera at Maws Farm	Waitahuna at Tweeds Bridge	Clutha River at Balclutha
DRP	↑↑↑	?	?	↑↑↑	↑↑	?	?	?	?	↑↑↑	↓↓↓

Total Phosphorus

As was seen with DRP, TP concentrations exceed ANZECC (2000) trigger values at nine of the 11 monitoring sites across the Lower Clutha/Pomahaka reporting region (Figure 58); although the median TP for the Pomahaka at Burkes Ford is only marginally above the ANZECC lowland trigger level of 0.033 mg/L. The Wairuna River returns the second highest median TP concentration of all Otago sites, second to the Waiareka Creek in North Otago (Appendix G).

Trend analysis of TP data returns two increasing (degrading) trends; these being a probable increasing trend for the Pomahaka at Glenken (as was the case with DRP) and the Heriot Burn. All remaining sites return 'indeterminate' trends with the exception of the Waipahi at Cairns which is stable (Table 79).

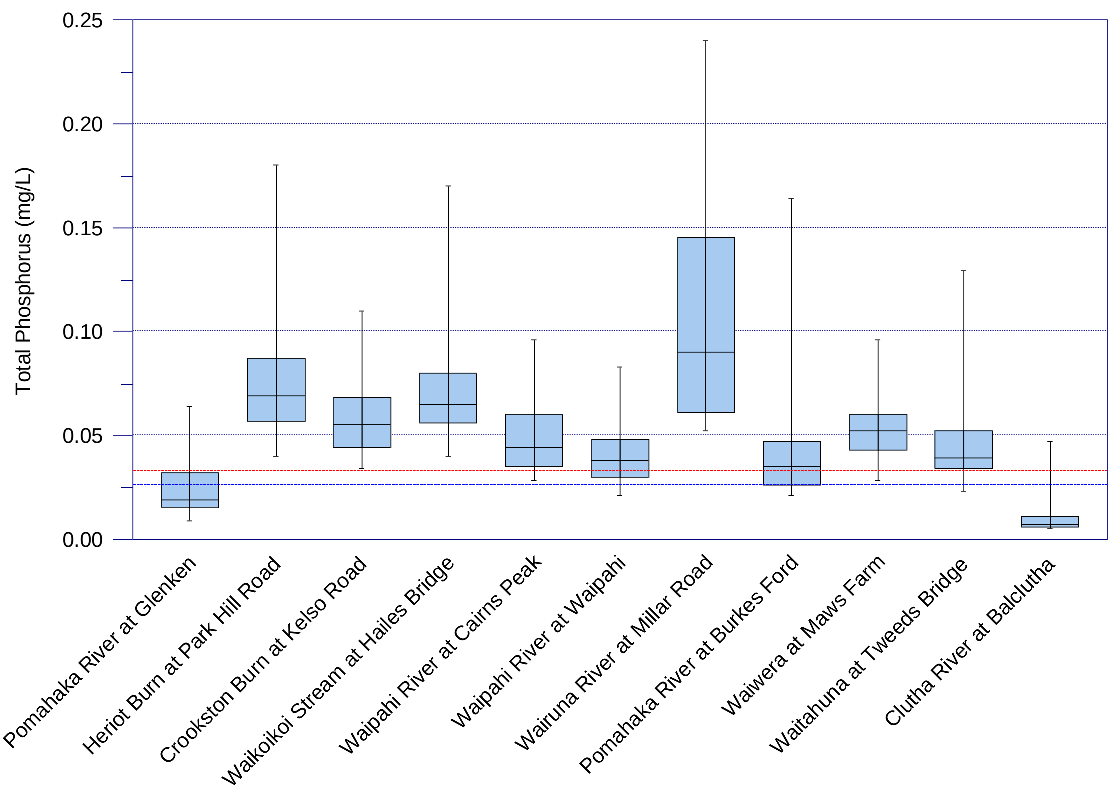

Figure 58: Boxplot summary of TP concentrations at SoE monitoring sites throughout Lower Clutha / Pomahaka. The **red** dashed line corresponds to the ANZECC lowland guideline for TP of 0.033 mg/L; the **blue** dashed line the upland guideline of 0.026 mg/L.

Table 79: Trend summary of TP concentrations for the Lower Clutha / Pomahaka reporting region.

Site	Pomahaka River at Glenken	Heriot Burn at Park Hill Road	Crookston Burn at Kelso Road	Waikoikoi Stream at Hailes Bridge	Waipahi River at Cairns Peak	Waipahi River at Waipahi	Wairuna River at Millar Road	Pomahaka River at Burkes Ford	Waiwera at Maws Farm	Waitahuna at Tweeds Bridge	Clutha River at Balclutha
TP	↑↑	↑↑	?	?	→	?	?	?	?	?	?

Escherichia coli

As discussed previously with the NOF *E. coli* compliance, many sites monitored across the Lower Clutha/Pomahaka reporting region have elevated *E. coli* concentrations with four sites being in the top five sites regionally for elevated *E. coli* levels, these sites again being the Heriot Burn, Crookston Burn, Waikoikoi Stream and the Wairuna River (Appendix G).

Trend analysis returned probable degrading trends for the Pomahaka at Glenken, the Heriot Burn and the Waitahuna River. Probable improving trends were evident for the Waipahi at Cairns and the Waiwera at Maws Farm (Table 80).

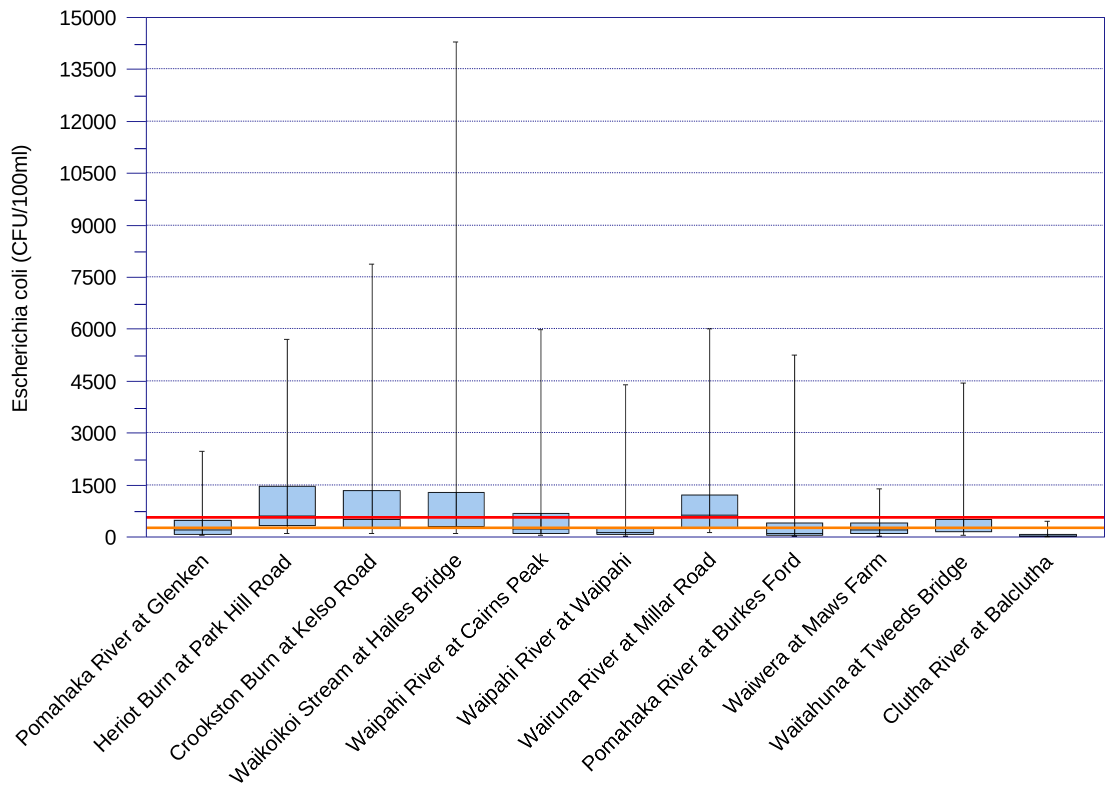

Figure 59: Boxplot summary of *E coli* concentrations at SoE monitoring sites throughout Lower Clutha / Pomahaka. The amber line corresponds to the amber alert level of 260 CFU/100ml; the **red** line to the red alert level of 550 CFU/100ml.

Table 80: Trend summary of *Escerichia coli* (*E. coli*) levels for the Lower Clutha/Pomahaka reporting region.

Site	Pomahaka River at Glenken	Heriot Burn at Park Hill Road	Crookston Burn at Kelso Road	Waikoikoi Stream at Hailes Bridge	Waipahi River at Cairns Peak	Waipahi River at Waipahi	Wairuna River at Millar Road	Pomahaka River at Burkes Ford	Waiwera at Maws Farm	Waitahuna at Tweeds Bridge	Clutha River at Balclutha
E. coli	↑↑	↑↑↑	?	?	↓↓	?	?	?	↓↓	↑↑	?

Turbidity

Turbidity levels generally compare favourably with the ANZECC (2000) trigger levels, with all sites except the Heriot Burn and the Wairuna River being below ANZECC (2000) trigger values (Figure 60). This is a good result given the marginal compliance with nutrient and bacterial indicators.

Trend analysis returns a number of increasing (degrading) trends, these being significant increasing trends for the Heriot Burn and the Waitahuna River; and a probable increasing trend for the Clutha River at Balclutha. Improving trends were evident for the Waipahi at Cairns and Waiwera at Maws Farm (Table 81).

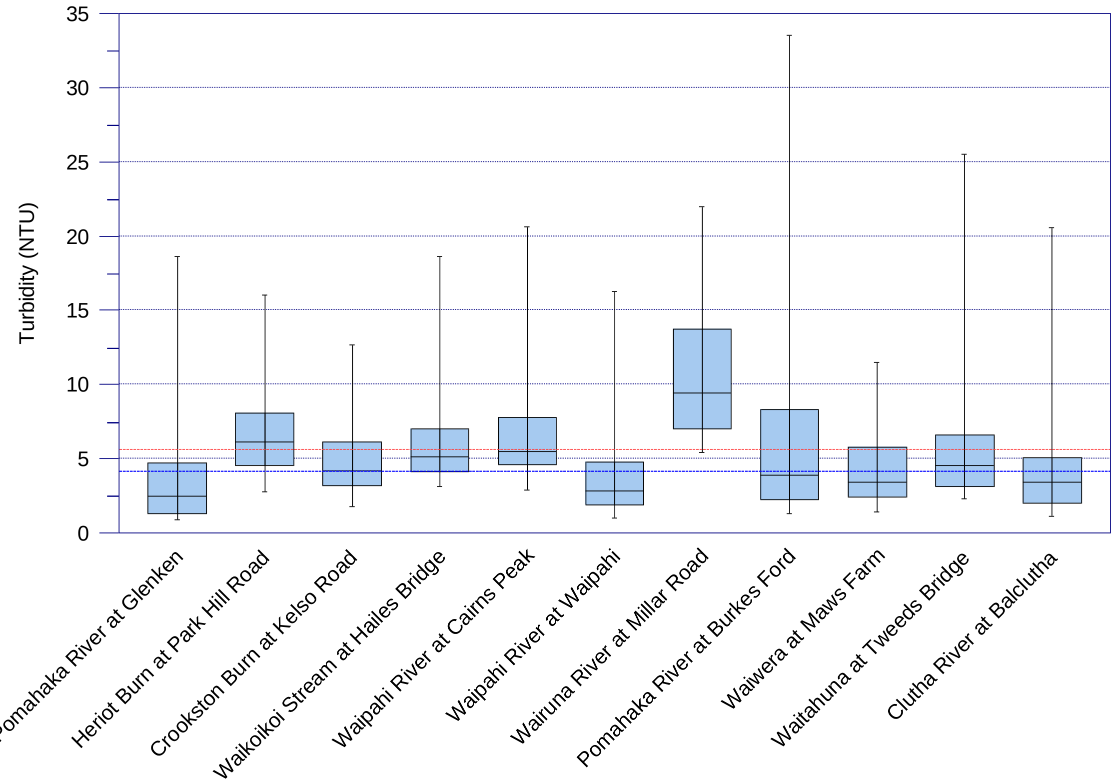

Figure 60: Boxplot summary of Turbidity at SoE monitoring sites throughout Lower Clutha / Pomahaka. The **red** dashed line corresponds to the ANZECC lowland guideline for Turbidity of 5.6 NTU; the **blue** dashed line the upland guideline of 4.1 NTU.

Table 81: Trend summary of Turbidity levels for the Lower Clutha / Pomahaka reporting region.

Site	Pomahaka River at Glenken	Heriot Burn at Park Hill Road	Crookston Burn at Kelso Road	Waikoikoi Stream at Hailes Bridge	Waipahi River at Cairns Peak	Waipahi River at Waipahi	Wairuna River at Millar Road	Pomahaka River at Burkes Ford	Waiwera at Maws Farm	Waitahuna at Tweeds Bridge	Clutha River at Balclutha
Turbidity	?	↑↑↑	?	?	↓↓	?	?	?	↓↓↓	↑↑↑	↑↑

Stream Health and the Macroinvertebrate Community Index

Macroinvertebrate Community Index (MCI) scores provide an integrated indicator of the general state of water quality and aquatic ecosystem health at a site.

Figure 61 summarises MCI scores for sites monitored for aquatic macroinvertebrates throughout the Lower Clutha/Pomahaka reporting region. The summary includes annual samples collected from 2008 to 2017 (eight years) where data is available. Not all sites monitored for water quality have macro-invertebrate samples taken. Of the 11 sites monitored for water quality, six sites are sampled annually for macro-invertebrates.

The Waitahuna River returns the highest MCI scores for sites monitored across the Lower Clutha/Pomahaka reporting region with MCI's exceeding 120, representing a macroinvertebrate community in excellent health. Based on the median MCI, this site is ranked fifth highest of all Otago sites (Appendix G), where the higher the value the better the result.

The remaining sites have mixed MCI scores, with the Waipahi River at Cairns retuning MCI scores typically around 110. This site is ranked ninth regionally for median MCI's.

The remaining sites have MCI's that are representative of macroinvertebrate communities in poor health, with the Heriot Burn, Waipahi River at Waipahi, the Wairuna River and Waiwera at Maws Farm all having MCI scores below 100, with the latter three site having MCI's below 90. These results follow similar patterns to other water quality indicators.

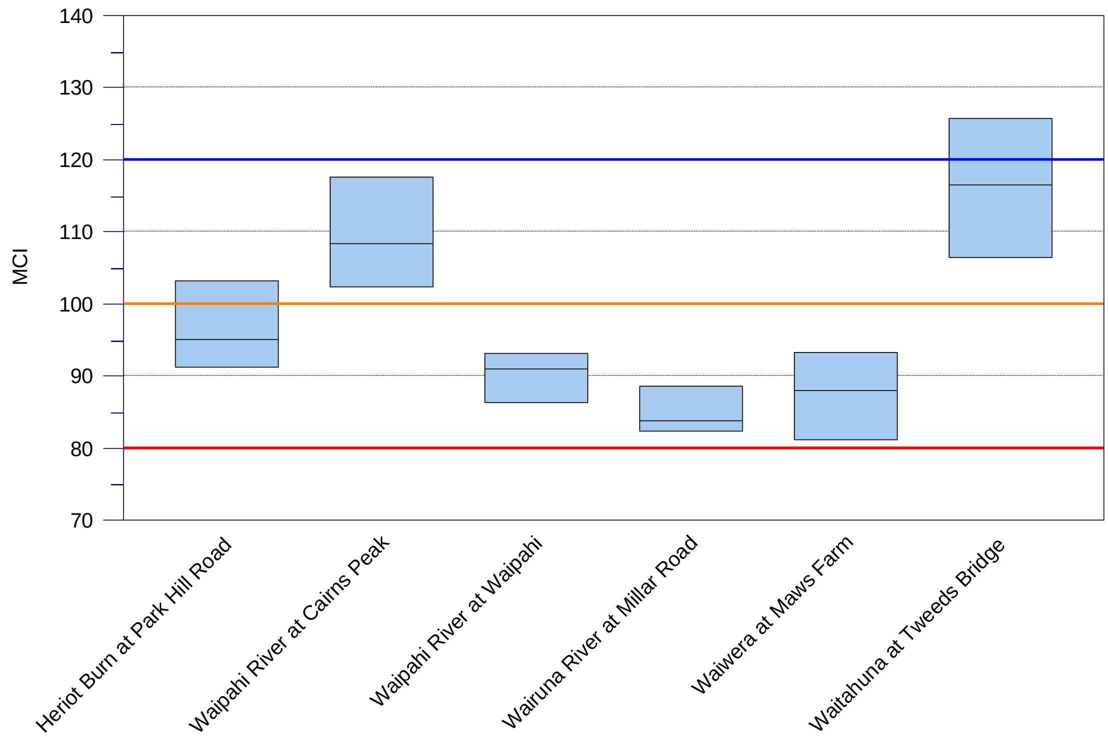

Figure 61: Boxplot summary of Macroinvertebrate Community Index (MCI) scores at SoE monitoring sites throughout the Lower Clutha / Pomahaka reporting region where macroinvertebrate samples are routinely collected. Above the **blue** line corresponds to the 'Excellent' quality threshold; between the **orange** and blue line the 'Good' quality threshold; betwene the **red** and orange line 'Poor' quality threshold; below the red line the 'Degraded' threshold.

Lower Clutha / Pomahaka Water Quality Summary

Across the Lower Clutha/Pomahaka reporting region there are a moderate number of sites with degrading water quality trends, as shown in Table 82, which summarises trend results across all sites. There are a total of 77 results reported in the table; 21% return significant or probable degrading trends; and 9% return significant or probable improving trends; 1% return stable trends. Overall 69% of sites have either indeterminate trends (reported as "?"); or too many observations being 'less than detect' (<DL) for results returned from the laboratory.

Water quality at SoE monitoring sites across the Lower Clutha/Pomahaka reporting region is typically degraded, as was found by previous State of Environment monitoring reports published by ORC (Ozanne, 2012).

Previous work has identified water quality in the lower Pomahaka catchment to be degrading for a number of years, while land use has intensified. The Pomahaka catchment has poor draining pallic soils, which has resulted in tile-and mole drainage being installed to improve grazing land-use. The deterioration in water quality has been largely caused by the management practices employed on this tile-and-mole drainage network (ORC, 2010; 2011). The results presented here summarise monitoring results collected over the last five years, and trend results over the last 11 years. ORC are working actively throughout the Pomahaka catchment with groups such as the Pomahaka Watercare Trust, the Landcare Trust and the Clutha Development Trust to address water quality issues. A large part of this effort is focused on improving bacterial water quality. Recent work by landowners across a number of these catchments is likely resulting in improvements to overall water quality that aren't currently being reflected in this data set.

As stated previously, having accurate information on changes in land use and land management practice would help in identifying drivers of change evident with some water quality variables.

In summary:

- For two of 11 sites monitored across the Lower Clutha/Pomahaka reporting region, water quality is excellent. These two sites are the upper Pomahaka River at Glenken, and the Clutha River at Balclutha. All remaining sites have varying degrees of degraded water quality;
- Bacterial water quality is severely degraded at nearly all monitoring sites with 10 of the 11 sites failing the NPSFM (2014) national bottom line. A number of sites return the worst bacteria levels of all sites monitored across Otago;
- Heriot Burn, Crookston Burn, Waikoikoi Stream and the Wairuna River monitoring sites are the worst performing sites of the Lower Clutha/Pomahaka reporting region. On a regional standing, these sites are in the top five for degraded water quality (Appendix E and Appendix G);
- Water quality degrades from the upper Pomhaka River at Glenken to the lower Pomahaka River at Burkes Ford. In the case of the Pomahaka, as identified from prevoius studies, it appears that degraded water quality in the tributary streams impacts on water quality of the main-stem river.

Table 82: Trend summary for the Lower Clutha / Pomahaka reporting region.

Site	Pomahaka River at Glenken	Heriot Burn at Park Hill Road	Crookston Burn at Kelso Road	Waikoikoi Stream at Hailes Bridge	Waipahi River at Cairns Peak	Waipahi River at Waipahi	Wairuna River at Millar Road	Pomahaka River at Burkes Ford	Waiwera at Maws Farm	Waitahuna at Tweeds Bridge	Clutha River at Balclutha
Ammoniacal Nitrogen	< DL	?	?	?	↑↑	?	?	?	?	?	?
Nitrite/Nitrate Nitrogen	?	↑↑	?	?	↑↑↑	?	?	?	?	?	?
Total Nitrogen	?	?	?	?	↑↑↑	?	↓↓↓	?	↓↓	?	?
Dissolved Reactive Phosphorus	↑↑↑	?	?	↑↑↑	↑↑	?	?	?	?	↑↑↑	↓↓↓
Total Phosphorus	↑↑	↑↑	?	?	→	?	?	?	?	?	?
Escherichia coli	↑↑	↑↑↑	?	?	↓↓	?	?	?	↓↓	↑↑	?
Turbidity	?	↑↑↑	?	?	↓↓	?	?	?	↓↓↓	↑↑↑	↑↑

2.7. Otago Lakes

Otago has some of New Zealand's largest and most pristine lakes, which are a recreational haven for boaties, fishermen, tourists, and swimmers. Some also provide hydro-electric power and support Otago's agricultural industries with water for irrigation[14]. The lakes of Otago are diverse, ranging from lowland, shallow coastal lagoons such as Tomahawk Lagoon and Lake Waihola to the deep, glacial Southern Great Lakes that include the iconic Lakes Wanaka, Wakatipu and Hawea.

There are 63 lakes in Otago that are 10 hectares in size or larger (Figure 63; Milne et al., 2017). Of the 63 lakes, ORC monitors nine on a monthly basis as part of their core, long-term State of Environment monitoring program. These lakes being Lake Wanaka, Lake Wakatipu, Lake Hawea, Lake Dunstan, Lake Hayes, Lake Johnson, Lake Onslow, Lake Waihola and Lake Tuakitoto. Figure 2 (located at the beginning of the report) shows the geographical location of the SoE monitored lakes; Table 83 summarises the main characteristics of the lakes.

Overall, the characteristics of the nine lakes monitored as part of the long-term SoE program incorporate a range of (Table 83; Milne et al., 2017):

- sizes and depths, from very shallow lakes through to several of the deepest (and largest) lakes in the country;
- lake types and elevations – from high country glacial lakes to reservoirs and lowland coastal lakes;
- natural and pastoral landcover combinations in the upstream catchments; and
- trophic states on the Trophic Lake Index (TLI) scale, from microtrophic to supertrophic.

The nine lakes included in the program provide a good representation of lake types and lake catchment land-uses across Otago (Milne et al., 2017).

Long-term SoE lake monitoring sites consist of a mix of lake-outlet (lakes Wanaka, Wakatipu and Hawea) and lake-shore (lakes Dunstan, Hayes, Johnson, Onslow, Waihola and Tuakitoto) sampling sites. Shore sites are usually affected by littoral shallow water conditions, including local nutrient run off, and sediment disturbance. Nutrient concentrations are usually higher and phytoplankton and zooplankton species composition and abundance usually differ from mid-lake monitoring sites. Moreover, Secchi depth measurements cannot be made at shore sites (Milne et al., 2017). To address this ORC undertakes a more detailed 'Trophic Lake Sampling Program' (TLSP) that focusses on mid-water, boat based sampling with a more comprehensive suite of water quality measurements (including Secchi depth), as well as depth profiles of dissolved oxygen and temperature (amongst other variables). This work is carried out on a subset of these lakes.

The results of TLSP work carried out in recent years are presented independently of this report. For examples see Ozanne (2009) for TLSP work carried out on Wanaka, Wakatipu, Hayes, Johnson and Onslow between the years 2006 to 2008; and Ozanne (2017) for TLSP work carried out on lakes Waihola and Waipori between the years 2014 and 2016. At present, detailed TLSP work is underway on lakes Wanaka, Hawea, Wakatipu, Hayes and Onslow.

A number of ORC publications exist that provide detailed summaries of the characteristics of Otago's monitored lakes, namely Ozanne (2009; 2017).

[14] https://www.lawa.org.nz/explore-data/otago-region/lakes/

Figure 62: Lake Onslow and surrounds. *Photo courtesy N. Manning, ORC.*

While there are numerous other lakes in Otago that could be monitored, most are small (< 10 ha), with many located within or near conservation areas where pressures are low and access for regular water quality monitoring is difficult (e.g., Diamond Lake, Moke Lake and Lakes Alta, Dispute, Harris, Kirkpatrick, Luna, Lochnagar and Sylvan). The remaining lakes are manmade, including reservoirs of small to moderate size (e.g., Fraser's Dam, Falls Dam, Butcher's Dam, Blue Lake, Poolburn Reservoir, West Eweburn Dam, Manorburn Dam, Greenland Reservoir, Loganburn Reservoir and Lake Mahinerangi) that support water/power supply and/or recreational values (Milne et al., 2017).

Despite small and shallow lakes being more common in Otago (Figure 63), the townships of Queenstown, Wanaka, Hawea and Cromwell are all located adjacent to large and popular lakes. Therefore, it is appropriate that the proportion of large (and deep) lakes among those that are monitored exceeds their proportion of all lakes in the region (Milne et al., 2017).

Table 83: Characteristics of lakes currently monitored by ORC. The 'Natural' landcover is a combination of the Bare, Indigenous Forest, Tussock, Scrub, Wetland and Miscellaneous classes of the River Environment Classification (REC). Table sourced from Milne et al., (2017).

Lake	Maximum depth (m)	Surface area (ha)	Elevation (m)	TLI	Upstream landcover (%)		Lake type
					Natural	Pasture	
Hawea	384	15 171	334	1.6	97.1	0.2	Glacial
Wanaka	311	19 886	278	2.1	96.0	1.0	Glacial
Wakatipu	380	29 542	317	1.9	94.1	2.0	Glacial
Hayes	33	274	335	4.9	54.3	42.0	Glacial
Johnson	27	26	334	5.0	97.6	0.4	Glacial
Dunstan	30	2 282	149	2.2	95.1	1.0	Reservoir
Onslow	9.5	1 125	678	3.9	93.1	5.0	Reservoir
Tuakitoto	3	130	15	4.9	9.7	80.0	Riverine
Waihola	2.2	604	5	4.5	46.0	29.0	Riverine

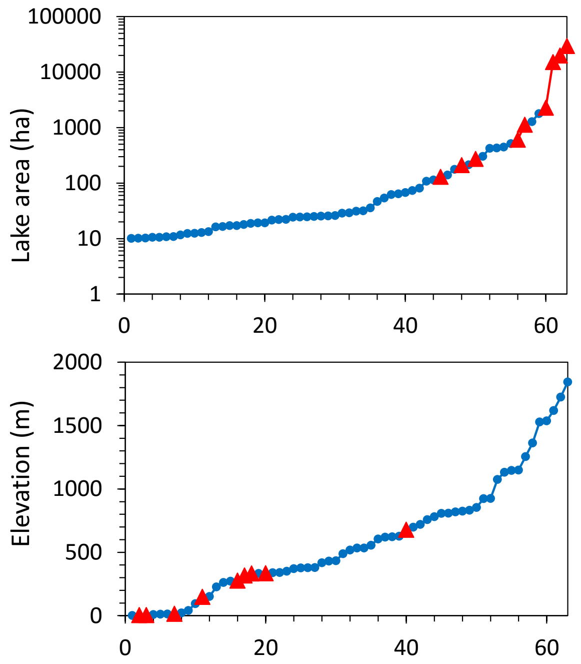

Figure 63: Distribution of lake area (top) and elevation (bottom) of 63 lakes that are larger than 10 ha in the Otago region. Monitored lakes (Table 83) are indicated by red triangles. Note the logarithmic scale for the top plot. *Figure reproduced from Milne et al., (2017)*.

2.7.1. Water quality and trophic status of Otago Lakes monitored as part of the long-term SoE monitoring program

The following section provides a summary of the Otago lakes' water quality based on:

- Compliance against Schedule 15 (Water Plan) water quality limits;
- National Policy Statement for Freshwater Management (NPSFM 2014) National Objectives Framework Attribute bands (NOF bands);
- Summary boxplots of chlorophyll a, TP, TN and the Trophic Lake Index.

Trophic status is a common method for describing the health of lakes and an indicator of how much growth or productivity occurs in the lake, productivity being directly related to the availability of nutrients. Lakes in pristine condition typically have very low nutrient and algal biomass levels. As lakes become more enriched due to changes in land-use and land management practices, lake nutrient levels and algal productivity increases, lakes become murky and there health is compromised.

The Schedule 15 (Water Plan) water quality limits and the NPSFM (2014) NOF attributes, with the exception of bacterial water quality (*E. coli* levels), focus on keeping nutrients and algal biomass at trophic levels that maintain healthy lake ecosystems and support the life supporting capacity of lakes.

Figure 64: Lake Hayes. *Photo courtesy N. Manning, ORC*

Schedule 15 compliance

The Water Plan lake water quality limits (Receiving Water Groups 4 and 5; Table 2) identify different limits for Otago's large, microtrophic[15] Great Southern Lakes and all other lake across the region. This was done in recognition that the Great Southern Lakes need added protection for their pristine, iconic status and under present conditions have extremely low levels of nutrients and algal productivity. The Great Southern lakes fall within RWG 5, whereas all other lakes are RWG 4.

Note, for the purpose of this report, Lake Dunstan has been assessed against the more stringent RWG 5 limits. In ORC's Water Plan, Lake Dunstan, along with Lake Roxburgh, sits in the rivers RWG 2.

Table 84 (NH_4-N), Table 85 (*E. coli*), Table 86 (TP), Table 87 (TN), and Table 88 (turbidity) summarises compliance against Schedule 15 (Water Plan) limits that relate to lake Receiving Water Groups 4 and 5 for all SoE lake monitoring sites. Compliance is based on a comparison of 80th percentile concentrations for a given variable against the Schedule 15 (Water Plan) limits for the respective RWG's.

With the exception of Lake Johnson, all sites are compliant with Schedule 15 (Water Plan) limits for NH_4-N and have 80th percentile concentrations below the 0.010 mg/L limit for RWG 5 lakes and 0.100 mg/L for RWG 4 lakes. In the case of Lake Johnson, summer thermal stratification results in anoxia (no oxygen) in the bottom waters (hypolimnion) of this lake. During such times, NH_4-N concentrations build up. At the onset of winter, the surface waters of the lake cool to a point that the lake becomes fully mixed. This results in increased concentrations of NH_4-N in the surface water over July, August and September. This is illustrated in Figure 65 that shows the high concentrations recorded in surface waters during the winter turnover period. This phenomena results in high 80th percentile concentrations of NH_4-N and non-compliance with the Schedule 15 (Water Plan) RWG 4 limit of 0.100 mg/L. High ammonia concentrations are a concern as ammonia is toxic to aquatic life, particularly at times of elevated pH. In the case of Lake Johnson, the maximum recorded concentration 0.560 mg/L recorded in August 2014 (Figure 65) places the site in lower end of the NOF 'C' band for ammonia toxicity. This band provides for an 80% species protection level and reflects an increased chance of

[15] 'Microtrophic' is a term given to lakes with extremely low nutrient concentrations, very low algal productivity levels and very good water clarity

chronic toxicity effects (not acute) for sensitive species during times of concentration peaks. For other years the concentration peaks are less pronounced and the NOF attribute band would be a 'B' band.

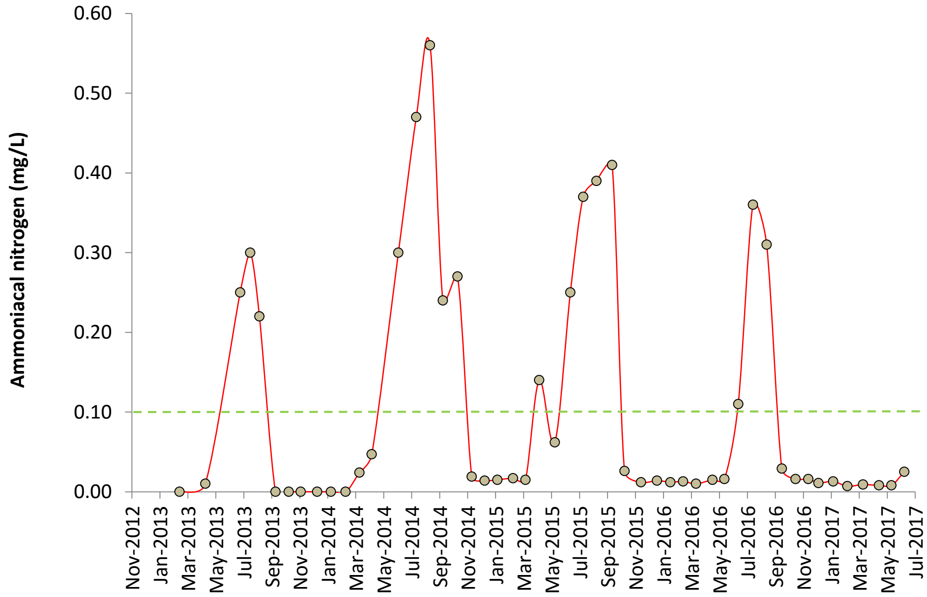

Figure 65: Ammoniacal nitrogen concentrations in Lake Johnson. The dashed green line corresponds to the Schedule 15 (Water Plan) limit for RWG 4.

Table 84: 80th percentile values for ammonical nitrogen and comparison to limits identified in Schedule 15. The orange cells show where the 80th percentile exceeds the Schedule 15 limit.

SoE reporting name	RWG	NH_4-N limit (80th percentile)	NH_4-N 80th percentile	Pass/Fail
Lake Wanaka Outflow	5	0.010	0.006	Pass
Lake Hawea Outflow	5	0.010	0.005	Pass
Lake Dunstan at Dead Man's Pt	5	0.010	0.005	Pass
Lake Wakatipu Outflow	5	0.010	0.005	Pass
Lake Hayes at Bendemeer Bay	4	0.100	0.033	Pass
Lake Johnson at Sth Beach huts	4	0.100	0.188	Fail
Lake Onslow at Boat Ramp	4	0.100	0.010	Pass
Lake Waihola at jetty	4	0.100	0.015	Pass
Lake Tuakitoto at Outlet	4	0.100	0.064	Pass

Compliance against the *E. coli* Schedule 15 (Water Plan) limit is good across all sites with the exception of Lake Tuakitoto (Table 85). This site fails as the 80th percentile concentration of *E. coli* is 180 CFU/100ml and above the Water Plan limit of 126 CFU/100ml. Lake Tuakitoto is renowned for its birdlife due to the high value fringing wetlands surrounding the lake, the elevated *E. coli* levels could be sourced from birds.

Table 85: 80th percentile values for *E. coli* and comparison to limits identified in Schedule 15. The orange cells show where the 80th percentile exceeds the Schedule 15 limit.

SoE reporting name	RWG	*E. coli* limit (80th percentile)	*E. coli* 80th percentile	Pass/Fail
Lake Wanaka Outflow	5	10	1.6	Pass
Lake Hawea Outflow	5	10	1.0	Pass
Lake Dunstan at Dead Man's Pt	5	10	4.0	Pass
Lake Wakatipu Outflow	5	10	4.9	Pass
Lake Hayes at Bendemeer Bay	4	126	15	Pass
Lake Johnson at Sth Beach huts	4	126	10	Pass
Lake Onslow at Boat Ramp	4	126	3.3	Pass
Lake Waihola at jetty	4	126	81	Pass
Lake Tuakitoto at Outlet	4	126	180	Fail

Compliance against the TP Schedule 15 (Water Plan) limit is very poor for RWG 4 lakes with all failing. In the case of Lake Johnson and Tuakitoto, TP 80th percentiles are three to four times the Schedule 15 (Water Plan) limit. This reflects high levels of phosphorus enrichment at these lakes well above those identified in the plan. Assessing TP compliance for RWG 5 lakes is difficult due to a laboratory method detection limit of 0.004 mg/L being close to the Schedule 15 (Water Plan) limit of 0.005 mg/L. Added to this is the reporting of TP from the laboratory to be provided to three significant figures only (0.001). This causes numerous results to be either <0.004 mg/L, 0.004 mg/L or 0.005 mg/L for the microtrophic lakes. And when calculating an 80th percentile for Wanaka, Hawea and Wakatipu, returns a number equal to the Schedule 15 (Water Plan) limit. The TP concentrations for these lakes are likely much lower than 0.005 mg/L. As demonstrated by work presently underway as part of the Trophic Lake Sampling Program, that is sending samples for phosphorus analysis to a laboratory that offers detection limits of 0.001 mg/L. For samples taken over the last twelve months, the 80th percentile concentrations are closer to 0.001 mg/L (ORC unpublished data) as opposed to 0.005 mg/L, as calculated from the data set used in this report.

Table 86: 80th percentile values for TP and comparison to limits identified in Schedule 15. The orange cells show where the 80th percentile exceeds the Schedule 15 limit.

SoE reporting name	RWG	TP limit (80th percentile)	TP 80th percentile	Pass/Fail
Lake Wanaka Outflow	5	0.005	*0.005*[16]	*Pass*
Lake Hawea Outflow	5	0.005	*0.005*	*Pass*
Lake Dunstan at Dead Man's Pt	5	0.005	0.009	Fail
Lake Wakatipu Outflow	5	0.005	*0.005*	*Pass*
Lake Hayes at Bendemeer Bay	4	0.033	0.057	Fail
Lake Johnson at Sth Beach huts	4	0.033	0.090	Fail
Lake Onslow at Boat Ramp	4	0.033	0.037	Fail
Lake Waihola at jetty	4	0.033	0.079	Fail
Lake Tuakitoto at Outlet	4	0.033	0.144	Fail

Compliance against the TN Schedule 15 (Water Plan) limit is slightly better for RWG 4 lakes than was the case for TP, with 3 of 5 lakes failing (Table 87). Again Lake Johnson and Lake Tuakitoto are the two worst lakes compliance wise with 80th percentile TN concentrations being at least twice that of the Schedule 15 (Water Plan) limit of 0.55 mg/L TN. This combined with the high TP concentrations for these two lakes shows both lakes are nutrient enriched and eutrophic.

For RWG 5 lakes, TN compliance is good with all lakes 80th percentile concentrations being well below the Schedule 15 (Water Plan) limit of 0.10 mg/L (Table 87).

Table 87: 80th percentile values for TN and comparison to limits identified in Schedule 15. The orange cells show where the 80th percentile exceeds the Schedule 15 limit.

SoE reporting name	RWG	TN limit (80th percentile)	TN 80th percentile	Pass/Fail
Lake Wanaka Outflow	5	0.100	0.080	Pass
Lake Hawea Outflow	5	0.100	0.050	Pass
Lake Dunstan at Dead Man's Pt	5	0.100	0.084	Pass
Lake Wakatipu Outflow	5	0.100	0.080	Pass
Lake Hayes at Bendemeer Bay	4	0.550	0.430	Pass
Lake Johnson at Sth Beach huts	4	0.550	1.200	Fail
Lake Onslow at Boat Ramp	4	0.550	0.290	Pass
Lake Waihola at jetty	4	0.550	0.664	Fail
Lake Tuakitoto at Outlet	4	0.550	1.416	Fail

[16] NOTE: the detection level for TP is 0.004 mg/L and the resolution is 0.001 mg/L. The actual concentrations of TP in Wakatipu, Wanaka and Hayes are likely well below the Schedule 15 limits but the limitations with laboratory detection limits do not allow us to recognise this.

Compliance against the Schedule 15 (Water Plan) limit for turbidity (Table 88) is excellent for the RWG 5 lakes with 80th percentile turbidity levels being less than one-third of the limit. This reflects the good levels of water clarity and low turbidity typical of lakes Wanaka, Hawea, Wakatipu and Dunstan.

In the case of the RWG 4 lakes, Lake Waihola and Lake Tuakitoto return 80th percentiles for turbidity two to three times the Schedule 15 (Water Plan) limit of 5.0 NTU (Table 88). Both these lakes are very shallow and susceptible to sediment resuspension from wind-driven waves. At such times turbidity levels become elevated and may remain so for a number of days. This could be argued as being a natural characteristic of very shallow lakes. The challenge is identifying the drivers of elevated turbidity, is it sediment resuspension, high algal biomass in the water column, or both?

Table 88: 80th percentile values for turbidity and comparison to limits identified in Schedule 15. The orange cells show where the 80th percentile exceeds the Schedule 15 limit.

SoE reporting name	RWG	Turbidity limit (80th percentile)	Turbidity 80th percentile	Pass/Fail
Lake Wanaka Outflow	5	3.0	0.6	Pass
Lake Hawea Outflow	5	3.0	0.7	Pass
Lake Dunstan at Dead Man's Pt	5	3.0	1.2	Pass
Lake Wakatipu Outflow	5	3.0	0.7	Pass
Lake Hayes at Bendemeer Bay	4	5.0	2.2	Pass
Lake Johnson at Sth Beach huts	4	5.0	6.0	Fail
Lake Onslow at Boat Ramp	4	5.0	5.7	Fail
Lake Waihola at jetty	4	5.0	18.5	Fail
Lake Tuakitoto at Outlet	4	5.0	12.5	Fail

Figure 66: Lake Wakatipu and the Frankton Arm. *Photo courtesy N. Manning, ORC.*

NOF compliance

The NPS FM (2014) NOF attributes for lakes cover algal biomass (Chl*a*), TN, TP, *E. coli*, and cyanobacteria. The Chl*a*, TN and TP attributes focus on managing the life supporting capacity of lakes and guarding against eutrophication and algal blooms that impact on lake ecological communities. The *E. coli* and cyanobacteria attributes focus on managing risk to human health for people undertaking primary contact (full immersion) activities.

ORC do not routinely measure cyanobacteria as part of their SoE monitoring program so no assessment is made as to compliance against the NOF cyanobacteria bio-volume attribute. Historically, with the rare exceptions for Lake Hayes, Lake Tuakitoto and Lake Waihola, cyanobacteria levels across the SoE lakes monitored are very low.

Table 89 summarises compliance for the algal biomass (chlorophyll *a*) NOF attribute. Lakes in RWG 5 record very low levels of algal biomass with median and maximum concentrations being at least half of the upper 'A' band threshold. This reflects chl*a* concentrations in these lakes to provide for 'lake ecological communities that are healthy and resilient, similar to natural reference conditions' (Appendix B).

For the remaining lakes the level of compliance varies. Lake Johnson fails the national bottom line with a median Chl*a* concentration above the national bottom line of 12 ug/L. Maximum's for Lake Johnson are elevated but are below the national bottom line of 60 ug/L. The 'D' band rating for this lake reflects Chl*a* or algal biomass levels that threaten lake ecological communities and pose an unacceptable risk of a regime shift to a persistent, degraded state (see Appendix B for NOF band definitions for Chl*a*).

Median and maximum Chl*a* concentrations for Lake Hayes and Lake Waihola are both elevated and place these two lakes into a 'C' band. This reflects chl*a* biomass levels that are 'moderately impacted by additional plant and algae growth arising from nutrient levels that are elevated well above natural, reference conditions' (Appendix B).

Interestingly, Lake Tuakitoto that typically returns very high TN and TP concentrations has quite low algal biomass levels (Chl*a* concentrations) that place it in the 'B' band. The 'B' band narrative states that the Chl*a* levels provide for 'lake ecological communities that are slightly impacted by additional plant and algae growth' (Appendix B).

For Lake Onslow, the median Chl*a* concentration of 2.2 ug/L edges this lake from being in the 'A' band to being in a 'B' band. The maximum Chl*a* concentration for this lake has it sitting well within the 'A' band.

Table 89: NOF lake compliance summary for Chlorophyll a. Included are median and maximum values for the period July 2012 to June 2017 and the corresponding NOF attribute band.

Variable	Chlorophyll a		NOF Band	
SoE reporting name	Median (ug/L)	Maximum (ug/L)	Median Band	Maximum Band
Lake Wanaka Outflow	1.0	1.5	A	A
Lake Hawea Outflow	0.9	1.3	A	A
Lake Dunstan at Dead Man's Pt	1.1	1.6	A	A
Lake Wakatipu Outflow	1.0	1.8	A	A
Lake Hayes at Bendemeer Bay	10.8	30.2	C	C
Lake Johnson at Sth Beach huts	**14.1**	45.4	**D**	C
Lake Onslow at Boat Ramp	2.2	3.9	B	A
Lake Waihola at jetty	7.5	25.6	C	C
Lake Tuakitoto at Outlet	4.8	17.2	B	B

Table 90 summarises compliance for the total TN NOF attribute. Lakes in RWG 5 record very low levels of TN with median concentrations being at least half of the upper 'A' band threshold. This reflects TN concentrations in these lakes to provide for 'lake ecological communities that are healthy and resilient, similar to natural reference conditions' (Appendix B). Lake Onslow, Lake Hayes and Lake Waihola have median TN concentrations that place these lakes in the 'B' band . Lake Hayes and Lake Onslow both seasonally stratify, compared to the shallow Lake Waihola that is permanently mixed (polymictic). Seasonally stratified and polymictic lakes have different TN thresholds for the NOF TN attribute (Appendix B). Lake Johnson and Lake Tuakitoto have median TN concentrations that place them in the 'D' band and therefore fail the national bottom line. This reflects an unacceptable level of nitrogen enrichment that poses a high risk of a permanent regime shift to an undesirable algal dominated state and one that would threaten the ecological communities of these lakes.

Table 90: NOF lake compliance summary for TN. Included are median values for the period July 2012 to June 2017 and the corresponding NOF attribute band.

SoE reporting name	Lake type	Total Nitrogen (mg/L)	
		Median (mg/L)	Band
Lake Wanaka Outflow	Seasonally stratified	0.064	A
Lake Hawea Outflow	Seasonally stratified	0.038	A
Lake Dunstan at Dead Man's Pt	Seasonally stratified	0.065	A
Lake Wakatipu Outflow	Seasonally stratified	0.066	A
Lake Hayes at Bendemeer Bay	Seasonally stratified	0.319	B
Lake Johnson at Sth. Beach huts	Seasonally stratified	**0.881**	**D**
Lake Onslow at Boat Ramp	Seasonally stratified	0.248	B
Lake Waihola at jetty	Polymictic	0.492	B
Lake Tuakitoto at Outlet	Polymictic	**1.024**	**D**

Figure 67: Lake Wanaka and the Stevenson Arm. *Photo courtesy N. Manning, ORC.*

Table 91 summarises compliance for the TP NOF attribute. Lakes in RWG 5 (lakes Wanaka, Hawea and Wakatipu) record very low levels of TP with median concentrations being less than half of the upper 'A' band threshold. Lake Dunstan also records low TP concentrations and is in the 'A' band. This reflects TP concentrations in these lakes to provide for 'lake ecological communities that are healthy and resilient, similar to natural reference conditions' (Appendix B).

Lake Hayes and Lake Onslow have elevated TP concentrations that are elevated 'well above natural reference conditions' (Appendix B). TP concentrations at these levels pose additional risk to a potential regime shift to an algal dominated state that would impact on the ecological health of the lakes.

Lake Johnson, Lake Waihola and Lake Tuakitoto have median TP concentrations that place these lakes in the 'D' band and therefore fail the national bottom line. This reflects an unacceptable level of phosphorus enrichment that poses a high risk of a permanent regime shift to an undesirable algal dominated state and one that would threaten the ecological communities (and health) of these lakes.

Table 91: NOF lake compliance summary for TP. Included are median values for the period July 2012 to June 2017 and the corresponding NOF attribute band.

Variable	Total Phosphorus	
SoE reporting name	Median (mg/L)	Band
Lake Wanaka Outflow	0.002	A
Lake Hawea Outflow	0.005	A
Lake Dunstan at Dead Man's Pt	0.007	A
Lake Wakatipu Outflow	0.003	A
Lake Hayes at Bendemeer Bay	0.036	C
Lake Johnson at Sth Beach huts	**0.060**	**D**
Lake Onslow at Boat Ramp	0.026	C
Lake Waihola at jetty	**0.052**	**D**
Lake Tuakitoto at Outlet	**0.101**	**D**

Table 92 summarises compliance for *E. coli* against the four statistical tests to determine the NOF attribute band. With the exception of Lake Tuakitoto, all lake monitoring sites have a high level of compliance and return an 'A' band (blue) attribute state. This is a great result and shows the lake monitoring sites to have good water quality in regards to swimmability and *E. coli* concentrations. Lake Tuakitoto has elevated peak concentrations with a 95th percentile of 575 CFU/100ml. This places this lake in the 'B' band which is still compliant with the NPS FM Swimmability guidelines.

Table 92: NOF lake compliance summary for *E. coli* for the the period July 2012 to June 2017. The overall grading band is determined by the lowest (worst) ranked Numeric Attribute State as it relates to the four separate states**.**

	Numeric Attribute State (NOF Band)				**Overall attribute state**	
Site	Median *E. coli* (CFU/100ml)	95th percentile *E. coli* (CFU/100ml)	% over 260 CFU/100m	% over 540 CFU/100m l	Grading attribute state	Overall Pass/Fai l
Lake Wanaka Outflow	1 (A)	28 (A)	0% (A)	0% (A)	A	**Pass**
Lake Hawea Outflow	1 (A)	2 (A)	0% (A)	0% (A)	A	**Pass**
Lake Dunstan at Dead Man's Pt	2 (A)	28 (A)	1% (A)	1% (A)	A	**Pass**
Lake Wakatipu Outflow	1 (A)	16 (A)	0% (A)	0% (A)	A	**Pass**
Lake Hayes at Bendemeer Bay	2 (A)	97 (A)	2% (A)	0% (A)	A	**Pass**
Lake Johnson at Sth Beach huts	2 (A)	36 (A)	0% (A)	0% (A)	A	**Pass**
Lake Onslow at Boat Ramp	1 (A)	21 (A)	0% (A)	0% (A)	A	**Pass**
Lake Waihola at jetty	26 (A)	185 (A)	2% (A)	2% (A)	A	**Pass**
Lake Tuakitoto at Outlet	61 (A)	885 (B)	14% (A)	8% (A)	B	**Pass**

The Trophic Lake Index and trophic status of lakes monitored as part of the long-term SoE program

In its simplest terms, the trophic state of a lake can be defined as the *life-supporting capacity per unit volume of a lake* (Burns, et al., 2000). Trophic state provides a measure of the nutrient status and productivity of a body of water (Burns et al., 2000). Water quality information on nutrients (TN and TP), algal productivity (estimated from chlorophyll *a* concentration) and, if available, water clarity (as Secchi depth[17]) is used to calculate a Trophic Lake Index (TLI) score for each of these parameters; and is then summarised into a single overall TLI score for the lake. The calculations follow a standard set of

[17] Secchi depth is the depth of disappearance that a 20 cm diameter disc painted in black and white quadrants is lost from view when lowered over the side of a boat.

protocols developed by Burns et al., (2000) for New Zealand that are based loosely on the Carlson Trophic State Index employed overseas but adapted to New Zealand conditions.

The overall TLI score is categorised into seven trophic states (Table 93) indicating progressively more nutrient enrichment, more algal productivity and reduced water clarity (Hamill, 2006).

Total nitrogen and total phosphorous are nutrients that stimulate algae and plant growth. They are often called the 'growth limiting nutrients' when referring to aquatic ecosystems. Large amounts of these nutrients encourage the growth of algae which can lead to poor water quality, unhealthy fluctuations in dissolved oxygen and reduced clarity.

Table 93: Summary of water quality concentrations and Secchi disk depths corresponding to different lake trophic levels.

Lake Type	Trophic Lake Index (TLI)	Chla (ug/L)	TP (mg/L)	TN (mg/L)	Secchi depth (m)*
Ultra-microtrophic	0.0 - 1.0	0.13 - 0.33	0.0008 - 0.0018	0.016 - 0.034	33 - 25
Microtrophic	1.0 - 2.0	0.33 - 0.82	0.0018 - 0.0041	0.034 - 0.073	25 - 15
Oligotrophic	2.0 - 3.0	0.82 - 2.0	0.0041 - 0.009	0.073 - 0.157	15 - 7
Mesotrophic	3.0 - 4.0	2.0 - 5.0	0.009 - 0.020	0.157 - 0.337	7 - 2.8
Eutrophic	4.0 - 5.0	5.0 - 12	0.020 - 0.043	0.337 - 0.725	2.8 - 1.1
Supertrophic	5.0 - 6.0	12 - 31	0.043 - 0.096	0.725 - 1.558	1.1 - 0.4
Hypertrophic	6.0 - 7.0	> 31	> 0.096	> 1.558	< 0.4

***NOTE: Secchi depth is not used in the calculation of the TLI for the lake shore based SoE monitoring results.**

The TLI gives an indication of lake water quality. Each range of numbers translates into a scientific description as explained below (Burns et al., 2000; Ozanne, 2009; LAWA[18]):

- Microtrophic lakes are clear and blue with very extremely low levels of nutrients and algae;
- Oligotrophic lakes are clear and blue, with low levels of nutrients and algae;
- Mesotrophic lakes have moderate levels of nutrients and algae;
- Eutrophic lakes are green and murky, with higher amounts of nutrients and algae;
- Supertrophic lakes are fertile and saturated in phosphorus and nitrogen, and have very high algae growth with problematic algal blooms at times;
- Hypertrophic lakes are highly fertile and supersaturated in phosphorus and nitrogen. They are rarely suitable for recreation and habitat for desirable aquatic species is limited.

[18] https://www.lawa.org.nz/learn/factsheets/lake-trophic-level-index/

As lake monitoring is shore based for the long-term SoE monitoring program, there is a lack of Secchi depth or water clarity data, as these measurements need to be made from a boat or suitable platform with enough water depth to lower a Secchi depth to a depth where it is lost from view (up to 25 metres at times in Otago's Southern Great Lakes).

In the following sections, the TLI index is calculated based on three variables, Chl*a*, TN and TP. This approach has been used in the past by Verburg et al., (2010) where Secchi depth data was not available. Verburg et al., (2010) demonstrated good agreement between TLI3 (excluding Secchi depth) and TLI4 (including Secchi depth) (Figure 69).

Figure 68: Lake Hawea from the neck. Photo courtesy N. Manning, ORC**.**

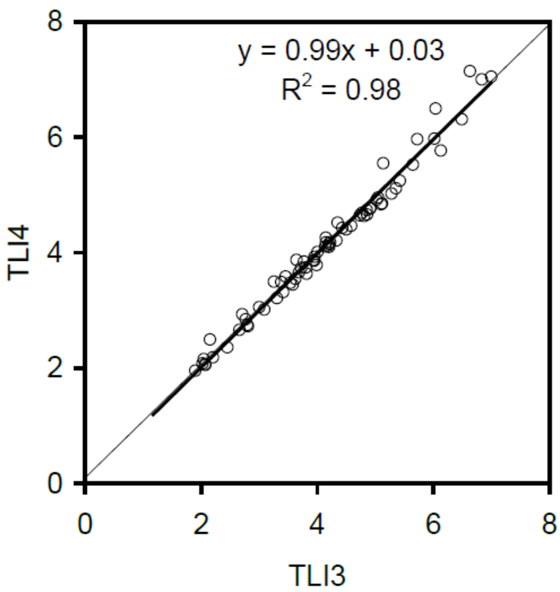

Figure 69: Comparison of TLI4 versus TLI3. The 1:1 line is shown. Note the regression fit between TLI4 and TLI3 is almost inditnguishalble to the 1:1 line reflecting almost perfect agreement. *Reproduced from Verburg et al., (2010).*

Chlorophyll a

Concentrations of chlorophyll-*a* (Chl*a*) are used to assess primary productivity in our lakes and as an indicator of algal biomass. The more algae present in a lake, the higher the Chl*a* concentration. A high concentration of algae is undesirable as it causes increased turbidity, discolours the water, can form surface scums, drives large fluctuations in dissolved oxygen and pH that causes stress on aquatic animals, and can lead to odours. Some species of algae, particularly cyanobacteria (blue-green algae) can produce toxins that are a significant human health issue. Elevated algae in a lake is driven by increases in nitrogen and phosphorus, the growth limiting nutrients.

Figure 70 and Figure 71 summarise Chl*a* concentrations (ug/L) and the Trophic Lake Index for Chl*a* (TLIc) for all SoE monitored lakes. The figures highlight extreme differences in chlorophyll *a* concentrations typical of Otago lakes, with the iconic Southern Great Lakes, Wanaka, Hawea, Wakatipu and Dunstan, recording extremely low concentrations of Chl*a* due to their pristine condition, with very low levels of nutrients that results in very low levels of algal productivity. The median concentration for these four lakes is typically around 1 ug/L; and the maximum concentration is below 2 ug/L. This places the lakes in the 'oligotrophic' TLIc.

This contrasts with Lake Hayes and Lake Johnson that have medians of 11 and 14 ug/L; and maximums of 30 and 45 ug/L respectively. These are the most productive of the 9 lakes sampled by ORC, and have both sitting in the hypertrophic to supertrophic TLIc bands (Figure 71). This reflects a high degree of enrichment with the lakes displaying a very high algal biomass that would impact on the overall water quality and ecosystem health of the lakes.

Lake Onslow has slightly elevated algal biomass levels when compared to Wanaka, Hawea and Wakatipu and is classed as 'mesotrophic'. Lake Waihola and Lake Tuakitoto sit midway between the Lake Onslow and lake Hayes and Johnson. Lake Tuakitoto is interesting as previous work has identified the high densities of kakahi (freshwater mussels) living in the lake as exerting high algae grazing rates that limit the algal biomass. This certainly appears to be the case and is discussed in more detail in the following sections.

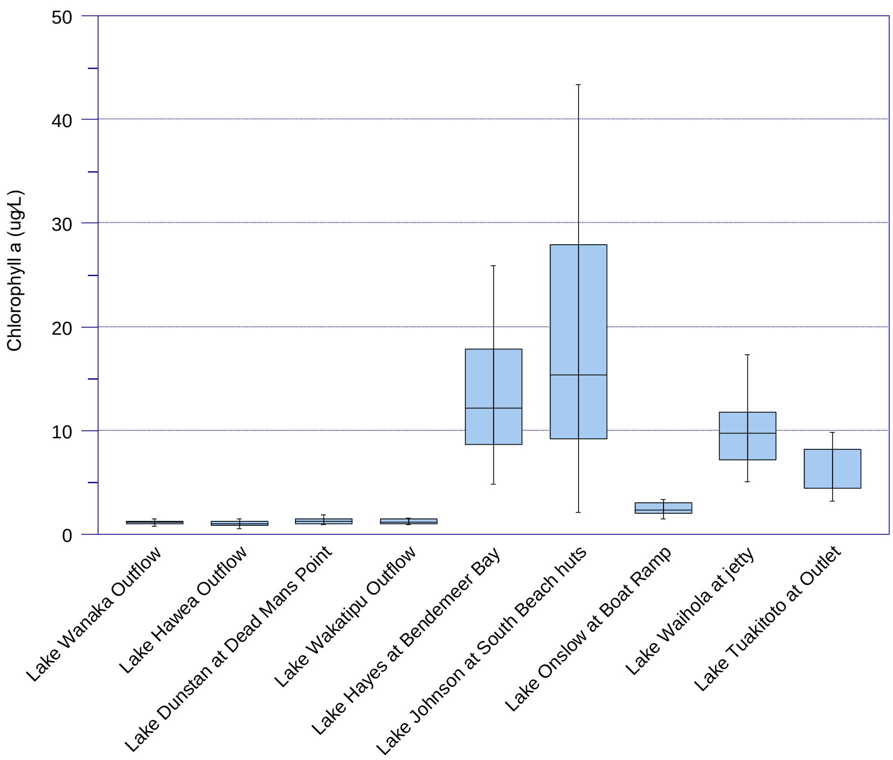

Figure 70: Boxplot summary of Chlorophyll a concentrations at lake SoE monitoring sites throughout Otago.

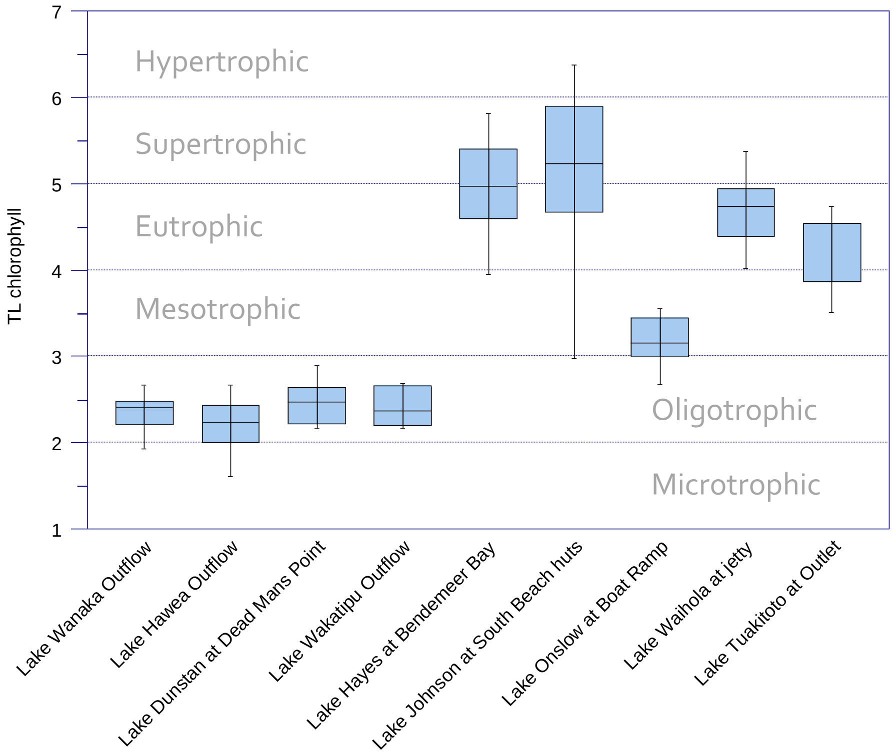

Figure 71: Boxplot summary of the Trophic Lake chlorophyll a index at lake SoE monitoring sites throughout Otago.

Total Phosphorus

Phosphorus, like nitrogen, are key 'growth' limiting nutrients that influence the growth rate and biomass of algae (or periphyton) and plants. Low availability of these two nutrients often limits algal and plant growth rate and biomass (Mathieson et al., 2012). High levels of phosphorus in water can come from either waste water or, more often, runoff from agricultural land. Agricultural sources of phosphorus include waste from animals and fertiliser (eg. super phosphate). Phosphorus is often transported from the wider catchment attached to sediment. The sediment and attached phosphorus settles to the lake bed where it can be recycled over years to decades. In this way, historic land management practices, such as top-dressing with super-phosphate, can affect phosphorus cycling in a lake for many, many years. This is the case for Lake Hayes that has high amounts of legacy phosphorus present in the lake bed sediments (Schallenberg and Schallenberg, 2017). Elevated phosphorus levels in a lake increase the risk of algae and cyanobacteria blooms.

Total Phosphorus is used as the primary indicator of phosphorus enrichment in lakes, and is one of the key TLI variables. Figure 72 and Figure 73 summarise TP concentrations (mg/L) and the Trophic Lake Index for TP (TLIp) for all SoE monitored lakes respectively. The figures show there to be extreme differences in TP concentrations across Otago's lakes. The iconic Southern Great Lakes, Lake Wanaka, Lake Hawea and Lake Wakatipu, record extremely low TP concentrations typically below 0.005 mg/L. At present, a major challenge is being able to reliably measure the actual concentration of phosphorus in these lakes. New Zealand commercial laboratories typically report down to a minimum of 0.004 mg/L for TP. As the concentrations of TP are often below 0.004 mg/L for these lakes (and including Lake Dunstan), this results in over 90% samples being reported as less than detection level and severely limits our ability to comment on the actual concentration of TP in these lakes. The TLIp for these three lakes have them sitting on the boundary between microtrophic and oligotrophic. Given the challenges with reliability of TP analysis at very low concentrations, in all likelihood the TLIp for these three lakes would be well below the 'oligotrophic' boundary. Either way, phosphorus concentrations are extremely low and would be at levels that would severely limit algal growth.

Lake Dunstan also returns very low concentrations of TP, but is slightly elevated when compared to lakes Wanaka, Hawea and Wakatipu. This isn't too surprising given Dunstan's location farther down the catchment with agriculture being more prevalent that than the upstream catchments of lakes Wanaka, Hawea and Wakatipu. Even with slightly elevated TP, the TLIp for Lake Dunstan has it sitting in the middle of the 'oligotrophic' band, reflecting extremely good water quality in regards to TP concentrations.

Lake Hayes has a history of elevated phosphorus sourced from the upstream catchment and driven by past catchment land-management practices and point-source discharges (Schallenberg and Schallenberg, 2017). This is evident with reference to Figure 72 with TP concentrations typically being around 0.040 mg/L. This would be well above those you would expect from a slightly impacted lake. The TLIp categorises Hayes as being on the upper boundary of 'eutrophic' and has it edging into the 'supertrophic' category. This reflects a lake with a high degree of enrichment of TP that would provide for extremely high levels of algal growth that would impact on the overall water quality and ecosystem health of the lakes. Promisingly, recent work by Schallenberg and Schallenberg (2017) has concluded that TP concentrations in the bottom waters of Lake Hayes appear to be declining in recent years. This has also coincided with a number of years of good water clarity in the lake over summer. Schallenberg and Schallenberg (2017) concluded that the legacy TP of Lake Hayes may be having less of an impact in lake productivity and algal blooms and there to be a chance that the lake is slowly rehabilitating. If this is the case then the focus needs to shift to wider catchment land management practices and critical source areas to further reduce phosphorus (and nitrogen) loads to the lake.

Lake Onslow has slightly elevated TP concentrations and sits mid-way between Lake Dunstan and Lake Hayes. Lake Onslow is classed as being 'mesotrophic' reflecting mild enrichment of phosphorus above natural background levels and a slight increase in the risk of algal growth. Mesotrophic lakes still typically have good water quality and very few issues with algal blooms.

Lake Johnson has even higher TP concentrations than Lake Hayes with a TLIp banding of 'supertrophic'. This reflects a lake with a very high level of phosphorus enrichment to a level that reflects extremely degraded water quality in respect to phosphorus. This provides the opportunity for very high levels of algal growth and algal blooms, as is evident when looking at chlorophyll a levels (discussed in the previous section). As discussed in the previous section, Lake Johnson fails the national bottom line for TP under the NPSFM (2014).

Lake Waihola sits alongside Lake Johnson with a 'supertrophic' TLIp banding. Lake Waihola has had past issues with algae and cyanobacteria blooms. The lake is shallow and often stirred up by wind-driven waves. The high water column sediment loading coupled with phosphorus enriched sediment would result in increased TP concentrations in water samples at such times. Either way, the TP concentrations of Lake Waihola reflect a highly enriched state that fails the national NPSFM bottom line (see previous section on lake NOF compliance). A recent report by Ozanne (2017) summarised the water quality and trophic status of Lake Waihola at the conclusion of a two year intensive study that collected water samples from the main basin of the lake at three sites. The TP concentrations of Lake Waihola recorded over this time period were comparable to those recorded at the shoreline SoE monitoring site and were highly elevated. Currently Clutha District Council has a consent to discharge treated phosphorus enriched waste water to the Lake Waihola outflow channel from the township of Waihola (Ozanne, 2017).

Lake Tuakitoto has extremely elevated TP concentrations well in excess of any other Otago lake. The TLIp category for the lake is the highest possible, being 'hypertrophic' and reflects a highly enriched state. The TP concentrations are more than double the NPSFM bottom line (see previous section on lake NOF compliance). As is the case with Lake Waihola, Lake Tuakitoto is a shallow lake that can experience sediment resuspension from wind-driven waves. This would affect TP concentrations at the outflow at such times. Despite this the lake remains highly enriched well above levels that would be expected of a shallow lake with a catchment dominated by native vegetation. Shallow New Zealand lakes have in the past been identified as having higher TP concentrations than deeper lakes. For example, Verburg et al., (2000) reported on water quality for 112 lakes throughout New Zealand and found shallow lakes (<10m depth) to have TP concentrations of 0.078 mg/L; this compares to the average TP concentration of deeper lakes of 0.018 mg/L. The average TP concentration of Lake Tuakitoto for the period July 2012 to June 2017 was 0.098 mg/L, with TP peaks reaching 0.200 mg/L.

A previous report by Ozanne (2014) on water quality across the Lake Tuakitoto catchment identified elevated TP concentrations on a number of the catchment streams. There are presently no point-source discharges that would help explain the highly enriched state of the lake. From the Ozanne (2014) report it is highly likely that the phosphorus present in the sediments in Lake Tuakitoto is a legacy of past and present catchment land management practices.

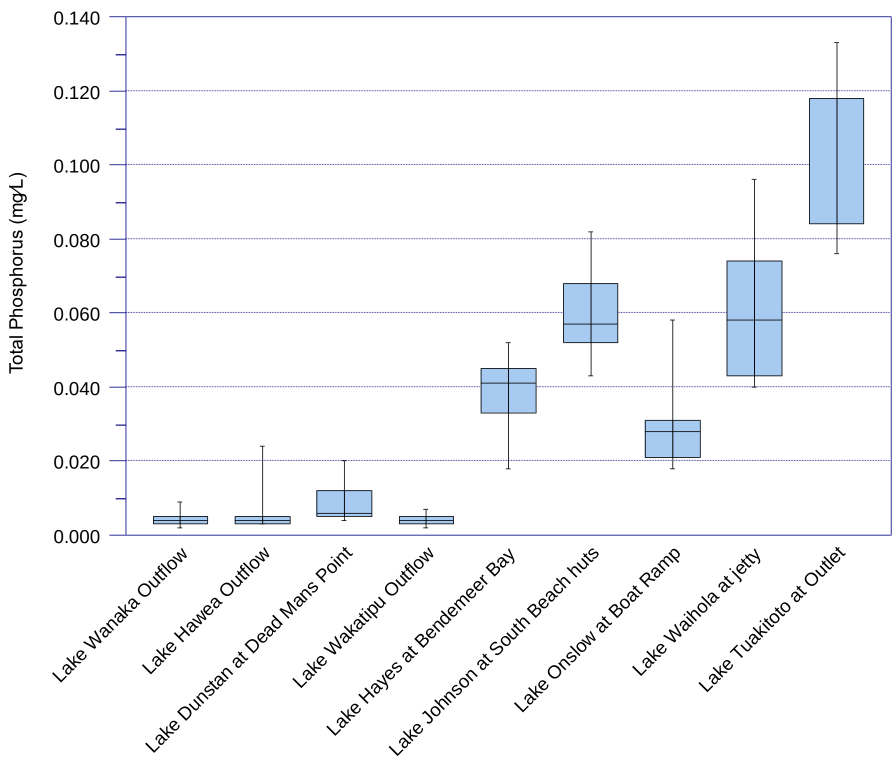

Figure 72: Boxplot summary of TP concentrations at lake SoE monitoring sites throughout Otago.

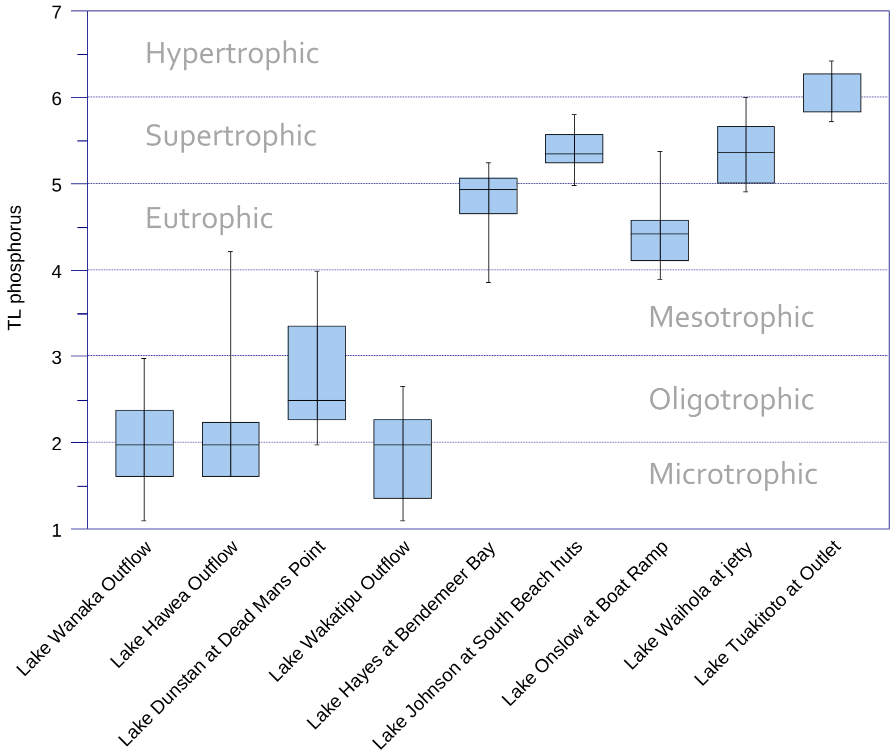

Figure 73: Boxplot summary of the Trophic Lake phosphorus index at lake SoE monitoring sites throughout Otago.

Total Nitrogen

Total Nitrogen (TN) is used as the primary indicator of nitrogen enrichment in lakes, and is one of the key TLI variables. TN is the sum of all nitrogen forms, including NH_4-N, nitrate and nitrite nitrogen (NNN), and organic nitrogen from plant tissues and algae. Nitrogen, like phosphorus, are key 'growth' limiting nutrients that influence the growth rate and biomass of algae (or periphyton) and plants. Low availability of these two nutrients often limits algal growth rate (Mathieson et al., 2012). High levels of nitrogen in water can come from waste-water or, more often, sub-surface flows, groundwater inputs and surface run-off from agricultural land.

Figure 74 and Figure 75 summarise TN concentrations (mg/L) and the Trophic Lake Index for TN (TLIn) respectively for all SoE monitored lakes.

TN concentrations follow a very similar pattern to TP, with the Southern Great Lakes returning extremely low levels of TN that place these lakes in the microtrophic to oligotrophic TLIn band. Lake Hawea returns the lowest TN concentration of all lakes and has a significantly lower TLIn, straddling the ultra-microtrophic TLIn band. This would be some of the lowest recorded TN concentrations for a New Zealand lake. The Lake Hawea catchment is relatively free of intensive land-use and is dominated by native vegetation cover. This lake provides an excellent reference lake to assess what water quality would be like under near-natural conditions. The slightly elevated TN concentrations of Lake Wanaka and Wakatipu compare closely with those recorded for Lake Dunstan, and place these lakes in the microtrophic to oligotrophic band, reflecting excellent water quality in relation to TN concentrations.

Lake Hayes and Lake Onslow have TN concentrations that are 4 to 5 times higher than the Southern Great Lakes but still relatively low when compared to the remaining lakes monitored across Otago (Figure 74). Lake Hayes is classed as meso to eutrophic with respect to TLIn. This compares to the eutrophic to supertrophic TLIp banding of Lake Hayes. Bayer etal., (2008) and Ozanne (2012) reported on nutrient ratios in Lake Hayes and found the lake to be nitrogen limited in relation to overall available nutrients and algal growth. The difference between the TLIn and TLIp for Lake hayes supports this also. Based on this, further increases in nitrogen in Lake Hayes would stimulate algal growth and elevate the risk of problematic algae blooms considerably.

Verburg et al., (2010) found average TN concentrations for deeper lakes across New Zealand to be 0.309 mg/L. This compares with an average TN concentration of 0.334 mg/L for Lake Hayes and 0.239 mg/L for Lake Onslow showing TN concentrations to be about 'average' for deep New Zealand lakes.

Lake Johnson is highly enriched with TN and returns the highest concentrations of all monitored lakes across Otago, with a maximum TN of 2.4 mg/L being recorded in March 2014 (Figure 76). Interestingly, in April 2013, TN concentrations in Lake Johnson increased markedly over a twelve month period. What caused this 'spike' in TN remains unknown, as the surrounding catchment has no obvious point source discharges, inflows, or farming activities that could cause such a jump in TN. Concentrations have reduced since this time but are still elevated when compared to levels present in the lake prior to 2013.

Lake Waihola has quite low TN concentrations for a lowland, shallow lake returning an average TN concentration of 0.49 mg/L for the period July 2012 to June 2017; and a 'mesotrophic' TLIn band. This compares favourably with the New Zealand 'shallow lake' average reported by Verburg et al., (2000) of 1.09 mg/L TN, and shoes on average, that Lake Waihola has relatively low levels of TN.

Lake Tuakitoto has TN levels comparable to Lake Johnson with an average TN concentration of 1.00 mg/L and a TLIn band of 'supertrophic'. This combined with its 'supertrophic' status for TP shows the lake to possess a highly enriched nutrient environment.

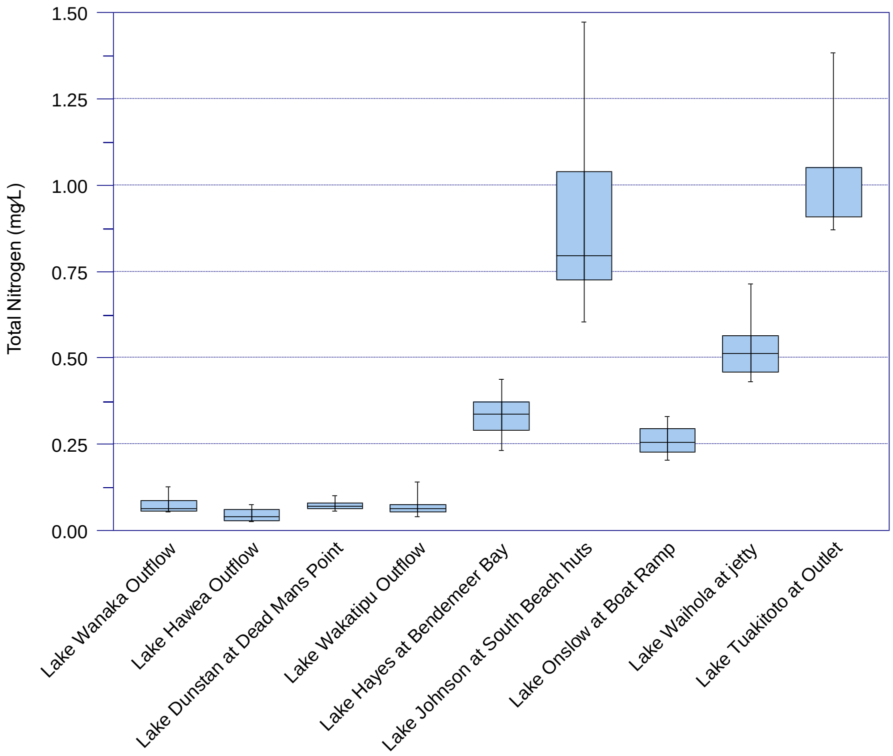

Figure 74: Boxplot summary of Total Nitrogen concentrations at lake SoE monitoring sites throughout Otago.

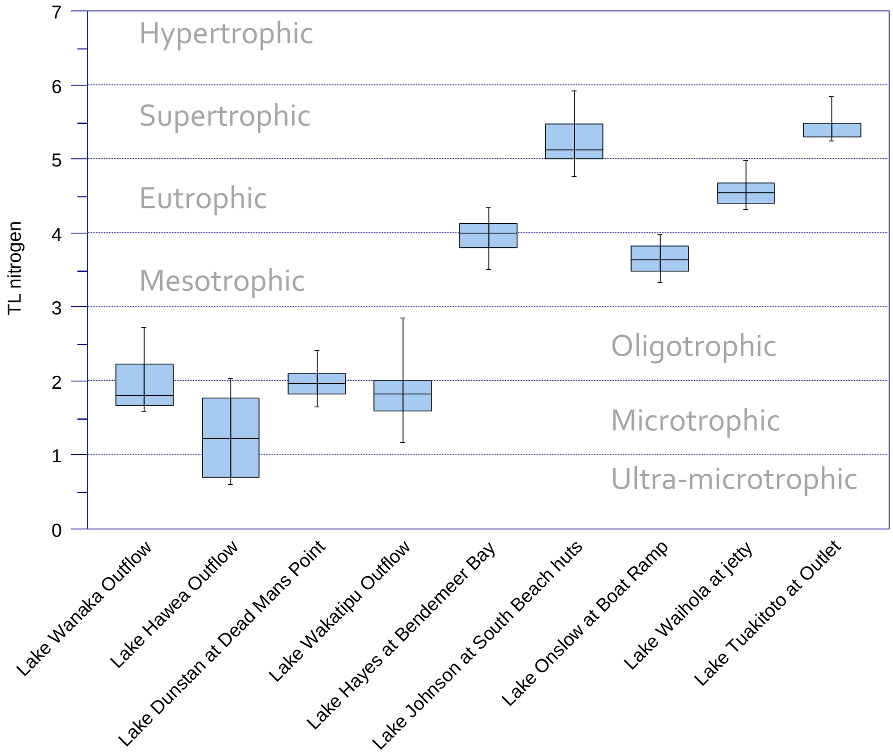

Figure 75: Boxplot summary of the Trophic Lake nitrogen index at lake SoE monitoring sites throughout Otago.

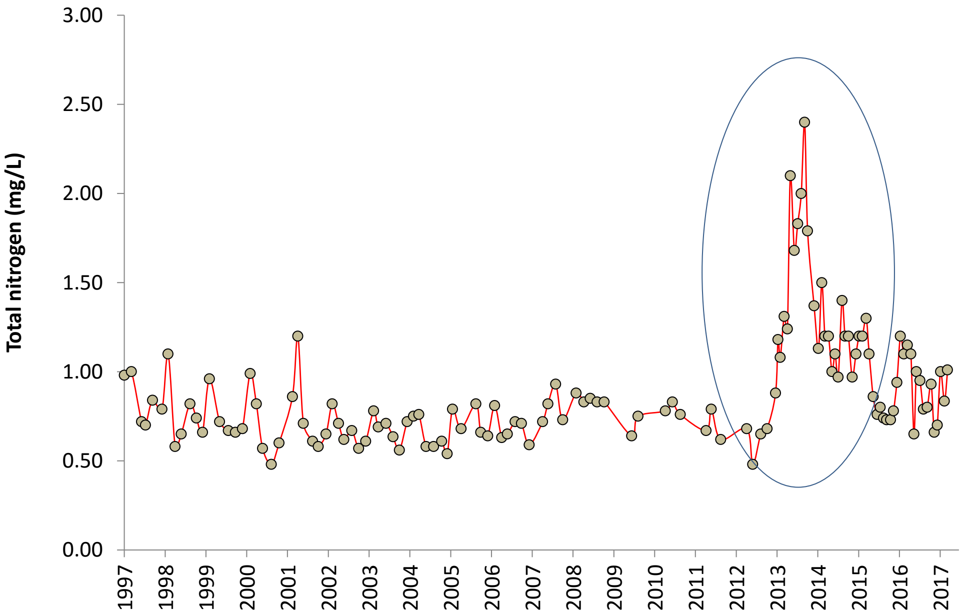

Figure 76: Total nitrogen concentrations in Lake Johnson. The blue circle encompasses a signifcant period of nitrogen enrichment for Lake Johnson that occurred early in 2013.

Figure 77: Lake Hawea. *Photo courtesy N. Manning, ORC.*

Trophic Lake Index 3 – TLI3

TLI3 provides a summary of the overall trophic lake index of a lake based on the integrated scores for TLI (chl*a*), TLI (TP) and TLI (TN). A more detailed discussion of the TLI3 is provided in the introduction to this report section. Table 94 provides a summary of TLI3 scores across lakes with lakes ordered from the lowest (cleanest) to the highest (most enriched). The TLI3 bands are based on those listed in Table 93. Figure 78 provides boxplot summaries of the annual TLI3 scores for the 9 SoE monitored lakes.

It is important to consider the limitations of TLI3 estimates for Wanaka, Hawea, Wakatipu and Dunstan that are affected by many data points being 'less than detect'. This artificially inflates the TLI scores, as the estimates do not take into account that many samples returned lower than measureable concentrations of chlorophyll a, phosphorus and nitrogen. Additionally, samples for all lakes covered in this chapter have samples collected from outflow and shoreline monitoring sites. These sites can be impacted by edge effects, such as disturbance of shoreline areas by waves generated from wind and boat-wake, as well as localised concentrations of algae in the shallows of a lake shore that can occur under certain conditions, such as when wind is blowing onto the shore. Samples may therefore not be representative of overall lake condition. This highlights the value of sampling lake water quality at mid-lake sampling stations – although at significantly higher cost and effort. This sampling is occurring at present on lakes Wanaka, Hawea, Wakatipu and Hayes. The results will provide accurate estimates of TLI and also allow for incorporation of water clarity (Secchi depth) into the TLI calculation (TLI4).

Overall the TLI3 analysis presented here does provide a representative summary of lake nutrient status and productivity levels and aligns well with our understanding of the health of each lake.

Hawea returns the lowest overall TLI3, due to very low TLIc and TLIn scores. Wanaka and Wakatipu follow on from Hawea and are directly comparable to one another. The slight increase in TLIn for these two lakes places the TLI3 score on the boundary of micro and oligotrophic. This TLI3 score represents lakes with exceptionally good water quality. The slightly higher TLIp score for Lake Dunstan increases the TLI3 to be in the middle of the oligotrophic band; a trophic level representing extremely good water quality, with low nutrients and low algal productivity levels. Lake Onslow is slightly enriched compared to these 4 lakes with higher TLIc, TLIp and TLIn scores giving it an overall 'mesotrophic' banding. Mesotrophic lakes still have good water quality and are healthy, but are typically more productive than oligotrophic lakes. Lake Hayes and Lake Waihola are both productive lakes with increased levels of nutrients and algae over those that would be expected under natural or near natural conditions. Both lakes have issues with episodic algal blooms. Lake Johnson and Lake Tuakitoto are classed as supertrophic, a dubious banding reflecting a highly enriched lake environment. Supertrophic lakes are fertile and saturated in phosphorus and nitrogen, and have very high algae growth with problematic algal blooms at times.

Table 94: Summary of average TLI3 scores for SoE monitored lakes ordered from lowest to highest.

Lake	Average TLI 3 2006 to 2017	TLI3 band
Hawea	1.88	Microtrophic
Wakatipu	2.03	Oligotrophic
Wanaka	2.08	Oligotrophic
Dunstan	2.40	Oligotrophic
Onslow	3.76	Mesotrophic
Hayes	4.57	Eutrophic
Waihola	4.87	Eutrophic
Tuakitoto	5.24	Supertrophic
Johnson	5.25	Supertrophic

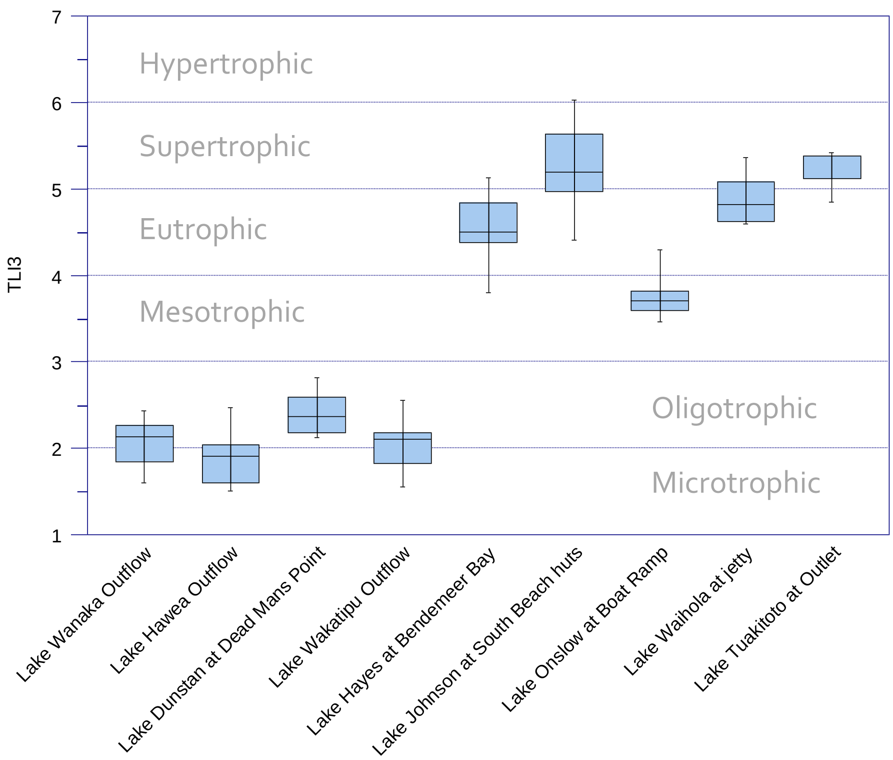

Figure 78: Boxplot summary of the Trophic Lake Index 3 (TLI3) at lake SoE monitoring sites throughout Otago.

Trend analysis

Table 95 summarises trend results for water quality parameters monitored as part of the lakes SoE monitoring program. For discrete water quality parameters, there are a total of 81 results reported in the table; 12% return significant or probable degrading trends; 4% are stable; and 6% return significant or probable improving trends. Overall 26% of sites have indeterminate trends (reported as "?"). Of the 81, 39 (48%) had too many results returned from the laboratory that were less than detection levels. This is driven by historic method detection levels that need to be applied across the entire time-series to eliminate the calculation of false trends (See Section 1.2.7 for a more detailed explanation). For the current analysis period, this severely limits our capacity to detect trends at sites with low levels of nutrients and chlorophyll *a*, as is typical of lakes Wanaka, Hawea, Wakatipu and Dunstan. Improved laboratory techniques and lower method detection levels that have become available in recent years will help eliminate this for future analysis, particularly with respect to NNN, TN and Chl*a*. Method detection limits for phosphorus, both DRP and TP, still result in the majority of results being returned from the laboratory as below detection level (<DL). There is a considerable challenge for laboratories to develop and offer IANZ accredited, improved detection levels for phosphorus in water.

For both Lake Wanaka and Lake Hawea, there are significant increasing trends for turbidity. The reasons for this are unknown but are of concern, particularly given the high intrinsic value of water clarity in these two lakes. There is a chance that the trend may be due to changes in laboratory service providers over the time period analysed. Different laboratories use different turbidity measuring equipment that doesn't necessarily return comparable results. This is particularly the case at the extremely low turbidity levels (< 0.5 NTU) typical of these lakes.

Of the lakes monitored, Lake Johnson returns three significant and three probable increasing trends for the 9 trend analyses. This shows Lake Johnson, which is already supertrophic with severely degraded water quality, to be getting worse over time.

There is a probable increasing trend for NNN in Lake Hawea. This is of concern given the extreme low nutrient levels typical of this lake. Current TN levels are the lowest of all lakes monitored and have it classed as 'microtrophic' (Figure 75), the second lowest possible trophic level for nitrogen. The source of increasing NNN is unknown. The sampling site is located at the dam wall in the vicinity of the Hawea township. To confidently identify if the source of increasing NNN is derived from the wider catchment or the area directly adjacent to the sampling location is difficult. The Trophic Lake Monitoring Program (TLMP) currently underway has an offshore monitoring site. The data collected as part of the TLMP will allow comparison of open-water water quality to shore-based water quality data. If the two compare closely then the trend is likely more driven by an overall shift in NNN concentrations in the lake.

Lake Tuakitoto returns significant increasing (degrading) trends for NH_4-N and dissolved reactive phosphorus. These two forms of nutrients may be entering the lake from the catchment or they could be released from lake sediments under anoxic conditions (internal loading). Both are bio-available for plant and algae growth and ongoing increases in their concentrations will increase the risk of significant algal blooms. Presently Lake Tuakitoto is classed as supertrophic for nitrogen and hypertrophic for phosphorus reflecting the highly enriched nutrient environment of the lake. Despite extremely high nutrient concentrations being recorded in the lake, the algal biomass levels are relatively low, particularly when compared to lakes Johnson, Hayes and Waihola. Previous studies identified the resident kakahi (freshwater mussel) population to have the capacity to filter the entire lake volume once every 32 hours (Ogilvie and Mitchell, 1995). The Ogilvie and Michell (1995) Lake Tuakitoto mussel study concluded "mussel grazing may account for the observed suppression of chlorophyll-a concentrations to about 10 % of those predicted by phosphorus-chlorophyll relationships in this lake… These results suggest that *Hyridella* [kakahi] has potential as a biomanipulation tool for control of phytoplankton in eutrophic lakes".

Of concern is that in recent years a reduction in the mussel population has been recorded, with a resulting reduction in algal filtration rate (Ozanne 2014). Either way, the kakahi population in Lake

Tuakitoto is extremely important in controlling algal biomass in this lake[19] and does explain the supressed algal biomass when compared to other lakes of a similar, highly enriched nutrient status. Protection and management of the kakahi population is a top priority, as the loss of this alga bio-control would lead to increased algal biomass and the possibility of a switch to a highly undesirable turbid, phytoplankton dominated state. Despite the degrading trends in Lake Tuakitoto for NH_4-N and DRP, trend analysis for *E. coli* returned a significant decreasing (improving) trend (Table 95). The reasons for this are unclear and may be driven by shifts in waterfowl numbers or reduced stock access to the lake.

For TP, Lake Hayes returned a probable decreasing (improving) trend. This is a very encouraging result given the issue of legacy phosphorus release from lake bed sediments fuelling algal blooms in the lake in past. Any reduction in phosphorus concentration overall is encouraging. As more data comes to hand, revisiting the trend analysis will hopefully provide more certainty as to the significance of the improving trend.

Significant decreasing (improving) trends were also recorded for Lake Onslow and TP and turbidity. The reduction in TP has also increased the TN/TP ratio reflecting stronger potential P-limitation of algal growth. The reduction in both turbidity and TP points towards a reduction in particulates as driving the trends.

NNN concentrations in the Lake Wanaka outflow have been dropping significantly overtime. This is in contrast to the Lake Hawea NNN trend that returned a probable increasing trend. The Lake Wanaka outflow sampling site is located adjacent to the Stevenson Arm and integrates all localised and catchment scale land-uses in the area, including any effects of Wanaka township. As with Lake Hawea, there is a chance localised land-use effects could influence the nutrient levels recorded at this site. Either way, having a significant decreasing trend for NNN is a good result.

Trend analysis of the TLI water quality variables and the overall summary TLI3 index score return some interesting results. A total of 36 trends are presented for the TLI (Table 95). 29 of 36 (81%) are indeterminate; 4 (11%) return decreasing or improving trends; and 3 (8%) return increasing or degrading trends.

The results of the analysis for lakes Wanaka, Hawea, Dunstan and Wakatipu need to be treated with caution as the calculation of individual TLI numbers for Chla, TP and TN are heavily confounded by the presence of numerous laboratory data records of being less than detection level or "< DL".

The high number of indeterminate trends is in part due to the analysis being carried out on annual average TLI numbers. This provides a total of 11 independent TLI estimates over the 11 years of sampling and is therefore a limited data set for carrying out trend analysis.

Of concern is the significant increasing trend for TLIn for Lake Hawea. As discussed previously, due to the location of the sampling site it is difficult to confidently conclude if this represents and overall increase in TLIn for the lake or is impacted by localised activities in the vicinity of the sampling site. The current boat-based Trophic Lake Sampling program will better inform the veracity of the shoreline sampling site for Lake Hawea and how representative this is of overall lake water quality.

Lake Dunstan returned a significant increasing trend for TLIc or chlorophyll a. This needs to be treetd with caution given the high number of chla samples submitted to the laboratory for this lake that returned "<DL" results. Lower chlorophyll a detection levels offered in recent years will remove this limitation in future analysis.

[19] http://www.stuff.co.nz/nelson-mail/news/81130292/unlocking-secrets-to-saving-our-native-freshwater-mussels

Lake Wakatipu returned three significant decreasing (improving) trends; two for TLIn and TLIp; and one for TLI3. The improving trends for TLIn and TLIp would combine to provide the improvement in TLI3. Despite this there was a probable increasing (degrading) trend for TLIc. As discussed, the high number of "<DL's" for the Great Southern Lakes does reduce the reliability of the trend analysis.

Lake Onslow returned a significant decreasing (improving) trend for TLIp which is promising. Currently the TLIp for Onslow is elevated and sitting in the eutrophic band. Any improvement in this will be welcome.

Table 95: Trend summary for the SoE monitored lakes

Site	Lake Wanaka Outflow	Lake Hawea Outflow	Lake Dunstan at Dead Mans Point	Lake Wakatipu Outflow	Lake Hayes at Bendemeer Bay	Lake Johnson at South Beach huts	Lake Onslow at Boat Ramp	Lake Waihola at jetty	Lake Tuakitoto at Outlet
Escherichia coli	< DL	< DL	< DL	< DL	< DL	↑↑↑	< DL	??	↓↓↓
Ammoniacal Nitrogen	< DL	< DL	< DL	< DL	< DL	< DL	< DL	< DL	↑↑↑
Nitrite/Nitrate Nitrogen	??	↑↑	→	↓↓↓	< DL	< DL	< DL	< DL	??
Total Nitrogen	< DL	< DL	< DL	< DL	??	↑↑↑	??	??	??
Dissolved Reactive Phosphorus	< DL	< DL	< DL	< DL	→	??	< DL	→	↑↑↑
Total Phosphorus	< DL	< DL	< DL	< DL	↓↓	↑↑	↓↓↓	??	??
TN/TP	< DL	??	??	??	↑↑↑	↑↑	↑↑↑	??	??
Turbidity	↑↑↑	↑↑↑	??	??	??	↑↑	↓↓↓	??	??
Chlorophyll *a*	< DL	< DL	< DL	< DL	??	↑↑↑	< DL	< DL	< DL
TLI chlorophyll	??	??	↑↑↑	↑↑	??	??	??	??	??
TLI phosphorus	??	??	??	↓↓↓	??	??	↓↓↓	??	??
TLI nitrogen	??	↑↑↑	??	↓↓↓	??	??	??	??	??
TLI3	??	??	??	↓↓↓	??	??	??	??	??

Otago Lakes' Water Quality Summary and Conclusions

The lakes monitored as part of the SoE lake monitoring program incorporate a range of:

- sizes and depths, from very shallow lakes through to several of the deepest (and largest) lakes in the country;

- lake types and elevations – from high country glacial lakes to reservoirs and lowland coastal lakes;
- natural and pastoral landcover combinations in the upstream catchments; and
- trophic states on the Trophic Lake Index (TLI) scale, from microtrophic to supertrophic.

The nine lakes included in the SoE program provide a good representation of lake types and lake catchment land-uses across Otago (Milne et al., 2017).

Analysis of water quality data from the monitoring program returns some stark contrasts across the lakes with the Southern Great Lakes and Lake Dunstan having exceptionally good water quality. The remaining lakes have water quality of varying degrees of nutrient enrichment and algal productivity.

In relation to Schedule 15 (Water Plan) compliance:

- Lake Johnson fails for NH_4-N;
- Lake Tuakitoto fails for *E. coli;*
- Lake Johnson, Tuakitoto and Waihola fail for TN; and
- Lake Johnson, Tuakitoto, Waihola and Onslow fail for turbidity.

In relation to the national bottom lines in the NPSFM (2014) for lakes;

- Lake Johnson fails for chlorophyll a, TN and TP;
- Lake Tuakitoto fails for TN and TP;
- Lake Waihola fails for TP.

In relation to compliance with the NPSFM (2014) *E. coli* swimmability attribute, all lakes return an A band for all attribute states with the exception of Lake Tuakitoto, which returns a B band for one. This reflects good to excellent bacterial water quality and a high level of protection for primary contact activities across all monitored lakes in regards to bacterial contact risk. Note, this is for *E. coli* only, NOT cyanobacteria. As ORC do not routinely measure cyanobacteria abundance and associated bio-volumes, it is not possible to comment on Swimmability against the lake cyanobacteria attribute.

TLI scores span all bands from Microtrophic to Supertrophic with lakes, based on the TLI3 being ordered as

- MICROTROPHIC **Hawea** < OLIGOTROPHIC **Wakatipu** < **Wanaka** < **Dunstan** < MESOTROPHIC **Onslow** < EUTROPHIC **Hayes** < **Waihola** < SUPERTROPHIC **Tuakitoto** < **Johnson**.

The historic data series for the SoE lake monitoring sites, particularly for the Southern Great Lakes Wanaka, Wakatipu and Hawea; and Lake Dunstan, has very high numbers of “less than detects” reflecting nutrient and algal concentrations below those that are able to be measured by the laboratory. This severely limits some analysis that can be carried out on the data; as well as artificially increasing the perception of elevated nutrient and algal concentrations over what is actually present. Improved laboratory techniques that have been made available in recent years will eliminate this for future analysis.

The Trophic Lake Sampling program that is currently underway on lakes Wanaka, Hawea, Wakatipu and Hayes will provide an accurate estimate of the actual TLI of these lakes and will be free of “ less than detects” for TN and Chla further increasing the accuracy and validity of the TLI estimate.

3. Summary and Conclusions

Overall, water quality across Otago is variable, with some areas such as the Upper Clutha and the Taieri having excellent water quality, with other areas, such as urban streams in the Dunedin locale, intensified catchments in North Otago and some tributaries of the Pomahaka having poor water quality.

As has been previously reported (Ozanne, 2012), water quality in rivers across Otago show a clear spatial pattern related to land cover and land use. Water quality is best at river and stream reaches located at high or mountainous elevations under predominantly native cover. These sites tend to be associated with the upper catchments of larger rivers (e.g. Clutha River/Matau-Au, Taieri River and Lindis River) and the outlets from large lakes (e.g. Hawea, Wakatipu and Wanaka).

Trend analysis returned a mix of results for the different reporting regions. In nearly all cases, in instances where trends were able to be confidently identified, there were a greater number of increasing or degrading trends than decreasing or improving trends for a given reporting region and overall, as shown in Table 96 and Table 97. The worst performing variable was *E. coli* where 30% of sites had a probable or significant increasing (degrading) trend versus 7% of sites that had either stable or decreasing (improving) trends (Table 97). For *E. coli* 63% of sites were either indeterminate (51%) or had too many results that were less than detect (8%). For these sites, in all likelihood trends would be present, but limitations in the data do not allow the trend to be confidently identified. This point is highly relevant when looking at the pattern of trends across the region as for all water quality variables, there were far greater numbers of sites that returned 'indeterminate' or '<DL' results than those that returned a confident trend result (Table 98). This highlights the severe limitations in the historical data set and constrains Council's ability to confidently assess trends.

Table 96: Regional trend summary for all ORC and NIWA SoE monitoring sites across Otago. The table includes trend results for lake monitoring sites.

Trend direction / significance	NH_4-N	NNN	TN	DRP	TP	*E. coli*	Turbidity
Indeterminate	19	40	39	28	52	35	38
Increasing Significant	7	10	8	12	7	15	14
Increasing Probable	1	3	3	2	3	6	10
Stable	2	2	3	5	1	1	0
Decreasing Probable	0	1	3	0	0	2	2
Decreasing Significant	0	5	4	5	2	2	5
< DL	40	8	9	17	4	8	0
Total	69	69	69	69	69	69	69

Table 97: Regional trend summary for all ORC and NIWA SoE monitoring sites across Otago. The table includes trend results for lake monitoring sites.

Trend direction	NH_4-N	NNN	TN	DRP	TP	*E. coli*	Turbidity
Indeterminate	28%	58%	57%	41%	75%	51%	55%
Increasing	12%	19%	16%	20%	14%	30%	35%
Stable	3%	3%	4%	7%	1%	1%	0%
Decreasing	0%	9%	10%	7%	3%	6%	10%
< DL	58%	12%	13%	25%	6%	12%	0%
Total	69	69	69	69	69	69	69

Table 98: Regional summary of percentage of trend analysis that were unable to be confidently idenitifed versus those that were.

Trend direction	NH_4-N	NNN	TN	DRP	TP	*E. coli*	Turbidity
Data limited to confidently identify trends	85%	69%	70%	66%	82%	63%	55%
Trend confidently identified	15%	31%	30%	34%	18%	37%	45%

The weaknesses in historic SoE data held by ORC are due to a number of unavoidable challenges and limitations. These weaknesses limit our capacity to undertake robust trend analysis. The reasons for these limitations include:

- Changes in laboratory supplier over the analysis period that can introduce 'step changes' in the data set. This was evident for TP and DRP for the change in laboratory supplier that occurred mid-2011;
- Changes in method Detection Levels (DL) for a given analyte over time;
- Changes in sampling frequency, bimonthly pre 2013, monthly post 2013;
- The availability of flow data for all sites to allow consistent flow adjustment of trends for flow effected variables (eg suspended solids, *E. coli* and TP). At present ORC measures flow continuously at 25 of the 60 SoE river monitoring sites;
- Intermittent periods of sampling for some sites (eg. monthly for twelve months, then no sampling for three years, then bi-monthly for three years and then monthly);
- Rounding of laboratory results resulting in very little variation between sampling dates for sites with very low nutrient levels (eg. Lake Hawea Outflow).

These challenges are not atypical of long-term regional council SoE data sets. Improvements in laboratory detection levels and commitment from ORC to move from bi-monthly to monthly sampling in 2013 will remove some of these confounding factors in future analysis.

In nearly all cases, sites that have been identified as being degraded in previous reports and targeted catchment studies remain degraded. There is evident very little change in the pattern of water quality throughout Otago from the previous 5 yearly SoE report published in 2012, nor from annual SoE updates provided in recent years.

The lack of detailed information on local or catchment scale land use change or land management practice changes severely limits our ability to comment on drivers of trends evident in the data set. To better interpret the reasons for improvements or degradation in water quality, information on the following is required:

- Changes in irrigation practice – flood to pivot;
- Changes to farm type or stocking rate;
- The level of stream protection afforded to streams and rivers, and the width of setbacks;
- Mitigation measures to address critical source areas.

Collection of this type of information in a robust and repeatable manner would allow for better interpretation of the drivers of water quality changes evident across Otago. The lack of this information severely limits ORC's capacity to comment on drivers of water quality change.

Monitoring by ORC is focused on the collection of numeric information on a limited number of water quality variables that is focussed heavily on nutrients and bacteria. Very little integrated information is collected that allows for confident assessments of overall stream and river health. For example, visual periphyton cover and biomass estimates (as chlorophyll-*a*); visual clarity (as black disk sighting distance) and fine deposited sediment cover are not measured. This limits our ability to comment on the overall effects of high nutrients and bacteria, or elevated turbidity on the overall health of a river or stream. Currently ecosystem health assessment is limited to the Macroinvertebrate Community Index (MCI) that is measured at limited number of SoE monitoring sites.

During 2017, Otago Regional Council commissioned an independent review of their river and lake State of Environment monitoring programs by NIWA. The scope of the NIWA review included:

- Assessment of the appropriateness of the river monitoring network;
- Critique of the lake monitoring program;
- Variables, or lack thereof, measured across the river and lake monitoring programs;
- Linkages between river and lake monitoring (and other domains such as estuaries);
- Key out-of-stream pressures (land use/land management) to measure to better interpret state and change sin water quality and ecological health.

The review found the existing program to over-represent pastoral sites and under-represent natural sites, with few sites present in RWG 3. The program also strongly focusses on water quality and would benefit from the inclusion of additional measures of ecosystem health across a greater number of (wadeable) sites, including:

- Monthly assessments of periphyton cover;
- Annual monitoring of macroinvertebrates; and
- Annual assessments of stream habitat.

Additional recommendations included:

- Monthly assessments of periphyton biomass and deposited sediment cover at a selection of sites, with both current and potential future land use pressures considered when identifying these sites;
- Supplementing the existing annual biomonitoring programme with continuous measurements of water temperature and dissolved oxygen for periods of 1-2 weeks during the warmest months of year, prioritising monitoring at sites with poor riparian shading; and
- Making estimates of flow at the time of sampling ('flow stamping') at all water quality sites that lack regular flow monitoring.

In the case of the lake monitoring program, the NIWA review that the lakes monitored by ORC covered a range of depths, lake type, trophic state, and upstream catchment landcover. It was concluded that while more of the 60+ lakes in Otago could be monitored, a higher priority is to establish representative open water monitoring sites across the monitored lakes, where possible.

The review recommended:

- Ongoing monitoring of open water sites on Lakes Wakatipu, Wanaka and Hawea;
- Establishing an open water monitoring site on each of Lake Onslow and Lake Tuakitoto that is monitored monthly for at least two years to verify the monitoring results obtained from outlet monitoring to date; and
- Reducing the return interval for monitoring open water sites on Lakes Waihola and Waipori from 10 to 5 years to improve the ability for timely detection of changes in lake condition.

It was also concluded that while monitoring lake shore sites in bays or outlets is not recommended as a replacement for monitoring open water sites, shore sampling is preferred to no sampling at all.

The findings of the NIWA review align with some of the limitations in the current program identified in this report. Should the findings be incorporated into the ORC SoE monitoring program, then future analysis and reporting would greatly benefit.

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Appendix A – Site metadata

Reporting region	SoE reporting name	Easting	Northing	River/Lake	ORC RWG	REC class	FENZ class	ORC / NIWA	Elevation (mASL)	Upland / Lowland
North Otago	Welcome Creek at Steward Road	1447988	5023090	River	2	CD/L/P	A	ORC	18	Lowland
	Kakanui River at Clifton Falls Bridge	1422937	5011060	River	2	CD/H/P	C	ORC	91	Lowland
	Kauru River at Ewings	1421935	5002223	River	2	CD/H/P	C	ORC	104	Lowland
	Kakanui River at McCones	1433513	4995180	River	2	CD/H/P	C	ORC	7	Lowland
	Waiareka Creek at Taipo Road	1433510	4997780	River	2	CD/L/P	A	ORC	12	Lowland
	Waianakarua River at Browns	1430610	4986676	River	2	CD/H/P	C	ORC	7	Lowland
	Trotters Creek at Mathesons	1430827	4971209	River	2	CD/L/P	A	ORC	6	Lowland
	Shag River at Craig Road	1417203	4967124	River	2	CD/H/P	G	ORC	28	Lowland
	Shag River at Goodwood Pump	1424508	4961853	River	2	CD/L/P	G	ORC	7	Lowland
Dunedin / Southern Coastal	Waikouaiti River at Confluence D/S	1412607	4945796	River	2	CD/H/P	G	ORC	4	Lowland
	Lindsays Creek at North Road Bridge	1407755	4919443	River	1	CD/L/U	G	ORC	27	Lowland
	Leith Stream at Dundas Street Bridge	1407297	4918262	River	1	CW/L/U	G	ORC	16	Lowland
	Kaikorai Stream at Brighton Road	1400015	4913355	River	1	CD/L/U	G	ORC	4	Lowland
	Tokomairiro River at West Branch Bdge	1356633	4892026	River	1	CD/L/P	G	ORC	31	Lowland
	Owaka River at Katea Road	1342116	4852225	River	1	CW/L/P	G	ORC	10	Lowland
	Catlins River at Houipapa	1335133	4848930	River	1	CW/L/P	G	ORC	21	Lowland

Reporting region	SoE reporting name	Easting	Northing	River/Lake	ORC RWG	REC class	FENZ class	NIWA/ORC	Elevation (mASL)	Upland / Lowland
Taieri	Taieri River at Linnburn Runs Road	1351010	4958393	River	2	CD/H/N	H	ORC	560	Upland
	Taieri River at Stonehenge	1361322	4976302	River	2	CD/H/N	D	ORC	381	Upland
	Taieri River at Waipiata	1376400	4991252	River	2	CD/H/P	D	ORC	354	Upland
	Kye Burn at SH85 Bridge	1384708	4996733	River	2	CD/H/P	C	ORC	376	Upland
	Taieri River at Tiroiti	1385941	4984856	River	2	CD/H/P	C	NIWA	315	Upland
	Taieri River at Sutton	1376859	4949913	River	2	CD/H/P	G	ORC	184	Upland
	Sutton Stream at SH87	1373364	4946708	River	2	CD/H/P	G	NIWA	221	Upland
	Nenthorn Stream at Mt Stoker Road	1385683	4948654	River	2	CD/H/P	G	ORC	245	Upland
	Deep Stream at SH87	1370377	4935501	River	2	CD/H/P	G	ORC	342	Upland
	3 O'Clock Stream at Hindon	1392681	4935632	River	2	CD/H/P	G	ORC	111	Lowland
	Taieri River at Outram	1385927	4918942	River	2	CD/H/P	G	NIWA	15	Lowland
	Silver Stream at Taieri Depot	1392170	4916608	River	2	CD/L/P	G	ORC	12	Lowland
	Owhiro Stream at Riverside Road	1389614	4913325	River	2	CD/L/P	A	ORC	5	Lowland
	Taieri River at Allanton Bridge	1387685	4912202	River	2	CD/H/P	A	ORC	1	Lowland
	Waipori River at Waipori Falls Reserve	1372537	4909488	River	2	CD/Lk/N	G	ORC	12	Lowland
Upper Clutha	Dart River at The Hillocks	1230044	5031514	River	3	CX/GM/N	C	ORC	346	Upland
	Shotover River at Bowens Peak	1262216	5009225	River	2	CW/M/N	E	NIWA	330	Upland
	Mill Creek at Fish Trap	1269921	5012135	River	2	CD/H/P	D	ORC	330	Upland
	Kawarau River at Chards	1274430	5008034	River	3	CW/Lk/N	E	NIWA	327	Upland
	Matukituki River at West Wanaka	1282005	5049680	River	3	CX/GM/N	E	ORC	277	Upland
	Cardrona River at Mt Barker	1292623	5037476	River	2	CD/H/N	D	ORC	393	Upland
	Hawea River at Camphill Bridge	1302363	5049022	River	2	CX/Lk/N	E	ORC	313	Upland
	Clutha River at Luggate Bridge	1305473	5040410	River	3	CX/Lk/N	E	NIWA	271	Upland
	Luggate Creek at SH6	1304632	5038216	River	2	CW/M/N	D	ORC	282	Upland
	Lindis River at Lindis Peak	1323545	5039400	River	2	CD/H/N	D	ORC	357	Upland
	Lindis River at Ardgour Road	1314455	5023467	River	2	CD/H/N	D	ORC	234	Upland

Spatial area name	SoE reporting name	Easting	Northing	River/Lake	ORC RWG	REC class	FENZ class	NIWA/ORC	Elevation (mASL)	Upland / Lowland
Middle Clutha / Central Otago	Dunstan Creek at Beattie Road	1344753	5018685	River	2	CD/M/N	D	ORC	429	Upland
	Manuherikia River at Ophir	1331884	4999082	River	2	CD/H/P	D	ORC	298	Upland
	Thomsons Creek at SH85	1331613	4999632	River	2	CD/H/P	D	ORC	297	Upland
	Manuherikia River at Galloway	1319790	4985701	River	2	CD/H/P	D	ORC	143	Lowland
	Benger Burn at SH8	1317447	4939327	River	2	CD/H/P	C	ORC	72	Lowland
	Fraser River at Marshall Road	1314057	4983106	River	2	CD/M/P	D	ORC	140	Lowland
	Clutha River at Millers Flat	1320354	4936929	River	2	CW/Lk/N	E	NIWA	66	Lowland
Lower Clutha / Pomahaka	Pomahaka River at Glenken	1300423	4913601	River	2	CD/H/P	G	ORC	172	Upland
	Heriot Burn at Park Hill Road	1306049	4913250	River	1	CD/L/P	A	ORC	149	Lowland
	Crookston Burn at Kelso Road	1307953	4910330	River	1	CD/L/P	A	ORC	142	Lowland
	Waikoikoi Stream at Hailes Bridge	1307309	4896680	River	1	CD/L/P	A	ORC	108	Lowland
	Waipahi River at Cairns Peak	1309698	4866864	River	1	CD/L/P	G	ORC	219	Upland
	Waipahi River at Waipahi	1310329	4887179	River	1	CD/L/P	G	ORC	106	Lowland
	Wairuna River at Millar Road	1315641	4887960	River	1	CD/L/P	G	ORC	97	Lowland
	Pomahaka River at Burkes Ford	1321675	4893104	River	1	CD/L/P	A	ORC	49	Lowland
	Waiwera at Maws Farm	1334153	4881621	River	1	CD/L/P	G	ORC	36	Lowland
	Waitahuna at Tweeds Bridge	1344378	4897887	River	1	CD/L/P	G	ORC	87	Lowland
	Clutha River at Balclutha	1349274	4874447	River	1	CW/Lk/P	E	NIWA	6	Lowland

Lake SoE metadata

Spatial area name	SoE reporting name	Easting	Northing	River/Lake	ORC RWG	NIWA/ORC	Elevation (mASL)	Upland / Lowland
Upper Clutha	Lake Wanaka Outflow	1294718	5047186	Lake	5	ORC	275	Upland
	Lake Hawea Outflow	1302520	5053536	Lake	5	ORC	346	Upland
	Lake Dunstan at Dead Man's Point	1302216	5005918	Lake	5	ORC	198	Upland
	Lake Wakatipu Outflow	1263310	5005041	Lake	5	ORC	308	Upland
	Lake Hayes at Bendemeer Bay	1270123	5010533	Lake	4	ORC	331	Upland
	Lake Johnson at South Beach huts	1263618	5007424	Lake	4	ORC	397	Upland
Middle Clutha / Central Otago	Lake Onslow at Boat Ramp	1334382	4950057	Lake	4	ORC	685	Upland
Taieri	Lake Waihola at jetty	1375024	4899520	Lake	4	ORC	1	Lowland
Dunedin / Southern Coastal	Lake Tuakitoto at Outlet	1355609	4874931	Lake	4	ORC	2	Lowland

Appendix B – NPSFM (2014) NOF Attribute Tables

Periphyton NOF attribute table

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	Periphyton (Trophic state)		
Attribute Unit	mg chl-a/m^2 (milligrams chlorophyll-a per square metre)		
Attribute State	**Numeric Attribute State (Default Class)**	**Numeric Attribute State (Productive Class[1])**	**Narrative Attribute State**
	Exceeded no more than 8% of samples[2]	**Exceeded no more than 17% of samples[2]**	
A	≤50	≤50	Rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat.
B	>50 and ≤120	>50 and ≤120	Occasional blooms reflecting low nutrient enrichment and/ or alteration of the natural flow regime or habitat.
C	>120 and ≤200	>120 and ≤200	Periodic short-duration nuisance blooms reflecting moderate nutrient enrichment and/or alteration of the natural flow regime or habitat.
National Bottom Line	**200**	**200**	
D	>200	>200	Regular and/or extended-duration nuisance blooms reflecting high nutrient enrichment and/or significant alteration of the natural flow regime or habitat.

1. Classes are streams and rivers defined according to types in the River Environment Classification (REC). The Productive periphyton class is defined by the combination of REC "Dry" Climate categories (i.e. Warm-Dry (WD) and Cool-Dry (CD)) and REC Geology categories that have naturally high levels of nutrient enrichment due to their catchment geology (i.e. Soft-Sedimentary (SS), Volcanic Acidic (VA) and Volcanic Basic (VB)). Therefore the productive category is defined by the following REC defined types: WD/SS, WD/VB, WD/VA, CD/SS, CD/VB, CD/VA. The Default class includes all REC types not in the Productive class.

2. Based on a monthly monitoring regime. The minimum record length for grading a site based on periphyton (chl-a) is 3 years.

Nitrate NOF attribute table

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	Nitrate (Toxicity)		
Attribute Unit	mg NO_3-N/L (milligrams nitrate-nitrogen per litre)		
Attribute State	Numeric Attribute State		Narrative Attribute State
	Annual Median	Annual 95th Percentile	
A	≤1.0	≤1.5	High conservation value system. Unlikely to be effects even on sensitive species
B	>1.0 and ≤2.4	>1.5 and ≤3.5	Some growth effect on up to 5% of species.
C	>2.4 and ≤6.9	>3.5 and ≤9.8	Growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects.
National Bottom Line	6.9	9.8	
D	>6.9	>9.8	Impacts on growth of multiple species, and starts approaching acute impact level (ie risk of death) for sensitive species at higher concentrations (>20 mg/L)

Ammonia NOF attribute table

Value	Ecosystem health		
Freshwater Body Type	Lakes and rivers		
Attribute	Ammonia (Toxicity)		
Attribute Unit	mg NH_4-N/L (milligrams ammoniacal-nitrogen per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual Median*	**Annual Maximum***	
A	≤0.03	≤0.05	99% species protection level: No observed effect on any species tested
B	>0.03 and ≤0.24	>0.05 and ≤0.40	95% species protection level: Starts impacting occasionally on the 5% most sensitive species
C	>0.24 and ≤1.30	>0.40 and ≤2.20	80% species protection level: Starts impacting regularly on the 20% most sensitive species (reduced survival of most sensitive species)
National Bottom Line	**1.30**	**2.20**	
D	>1.30	>2.20	Starts approaching acute impact level (ie risk of death) for sensitive species

* Based on pH 8 and temperature of 20°C.

Compliance with the numeric attribute states should be undertaken after pH adjustment.

Dissolved Oxygen NOF attribute table

Value	Ecosystem health		
Freshwater Body Type	Rivers (below point sources)		
Attribute	Dissolved Oxygen		
Attribute Unit	mg/L (milligrams per litre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	7-day mean minimum[1] (Summer Period: 1 November to 30th April)	1-day minimum[2] (Summer Period: 1 November to 30th April)	
A	≥8.0	≥7.5	No stress caused by low dissolved oxygen on any aquatic organisms that are present at matched reference (near-pristine) sites.
B	≥7.0 and <8.0	≥5.0 and <7.5	Occasional minor stress on sensitive organisms caused by short periods (a few hours each day) of lower dissolved oxygen. Risk of reduced abundance of sensitive fish and macroinvertebrate species.
C	≥5.0 and <7.0	≥4.0 and <5.0	Moderate stress on a number of aquatic organisms caused by dissolved oxygen levels exceeding preference levels for periods of several hours each day. Risk of sensitive fish and macroinvertebrate species being lost.
National Bottom Line	**5.0**	**4.0**	
D	<5.0	<4.0	Significant, persistent stress on a range of aquatic organisms caused by dissolved oxygen exceeding tolerance levels. Likelihood of local extinctions of keystone species and loss of ecological integrity.

1. The mean value of 7 consecutive daily minimum values.

2. The lowest daily minimum across the whole summer period.

Escherichia coli NOF attribute table

Value	Human health for recreation				
Freshwater Body Type	Lakes and rivers				
Attribute	*Escherichia coli (E. coli)*				
Attribute Unit	*E. coli*/100 mL (number of *E. coli* per hundred millilitres)				
Attribute State[1 2]	**Numeric Attribute State**				**Narrative Attribute State**
	% exceedances over 540 cfu/100 mL	% exceedences over 260 cfu/100 mL	Median concentration (cfu/100 mL)	95th percentile of *E. coli*/100 mL	Description of risk of Campylobacter infection (based on *E. coli* indicator)
A (Blue)	<5%	<20%	≤130	≤540	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 1%*
B (Green)	5-10%	20-30%	≤130	≤1000	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 2%*
C (Yellow)	10-20%	20-34%	≤130	≤1200	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 3%*
D (Orange)	20-30%	>34%	>130	>1200	20-30% of the time the estimated risk is ≥50 in 1000 (>5% risk) The predicted average infection risk is >3%*

E (Red)	>30%	>50%	>260	>1200	For more than 30% of the time the estimated risk is ≥50 in 1000 (>5% risk) The predicted average infection risk is >7%*

* The predicted average infection risk is the overall average infection to swimmers based on a random exposure on a random day, ignoring any possibility of not swimming during high flows or when a surveillance advisory is in place (assuming that the *E. coli* concentration follows a lognormal distribution). Actual risk will generally be less if a person does not swim during high flows.

[1] Attribute state should be determined by using a minimum of 60 samples over a maximum of 5 years, collected on a regular basis regardless of weather and flow conditions. However, where a sample has been missed due to adverse weather or error, attribute state may be determined using samples over a longer timeframe.

[2] Attribute state must be determined by satisfying all numeric attribute states.

Total Nitrogen (Lakes) NOF attribute table

Value	Ecosystem health		
Freshwater Body Type	Lakes		
Attribute	Total Nitrogen (Trophic state)		
Attribute Unit	mg/m^3 (milligrams per cubic metre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual Median	Annual Median	
	Seasonally Stratified and Brackish*	Polymictic	
A	≤160	≤300	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
B	>160 and ≤350	>300 and ≤500	Lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrients levels that are elevated above natural reference conditions.
C	>350 and ≤750	>500 and ≤800	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions
National Bottom Line	**750**	**800**	
D	>750	>800	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state, due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

* Intermittently closing and opening lagoons (ICOLs) are not included in brackish lakes.

Total Phosphorus (Lakes) NOF attribute table

Value	Ecosystem health	
Freshwater Body Type	Lakes	
Attribute	Total Phosphorus (Trophic state)	
Attribute Unit	mg/m³ (milligrams per cubic metre)	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
	Annual Median	
A	≤10	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
B	>10 and ≤20	Lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrients levels that are elevated above natural reference conditions.
C	>20 and ≤50	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions.
National Bottom Line	**50**	
D	>50	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state, due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

Phytoplankton (Lakes) NOF attribute table

Value	Ecosystem health		
Freshwater Body Type	Lakes		
Attribute	Phytoplankton (Trophic state)		
Attribute Unit	mg/m^3 (milligrams chlorophyll-a per cubic metre)		
Attribute State	**Numeric Attribute State**		**Narrative Attribute State**
	Annual Median	Annual Maximum	
A	≤2	≤10	Lake ecological communities are healthy and resilient, similar to natural reference conditions.
B	>2 and ≤5	>10 and ≤25	Lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrients levels that are elevated above natural reference conditions.
C	>5 and ≤12	>25 and ≤60	Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrients levels that are elevated well above natural reference conditions.
National Bottom Line	**12**	**60**	
D	>12	>60	Lake ecological communities have undergone or are at high risk of a regime shift to a persistent, degraded state, due to impacts of elevated nutrients leading to excessive algal and/or plant growth, as well as from losing oxygen in bottom waters of deep lakes.

Appendix C – River SoE sites with continuous flow recorders

Otago Regional Council State of Environment monitoring sites with continuous flow recorders

- Benger Burn at SH8
- Cardrona River at Mt Barker
- Catlins River at Houipapa
- Dart River at The Hillocks
- Kakanui River at Clifton Falls Bridge
- Leith Stream at Dundas Street Bridge
- Lindis River at Ardgour Road
- Lindis River at Lindis Peak
- Manuherikia River at Ophir
- Matukituki River at West Wanaka
- Mill Creek at Fish Trap
- Pomahaka River at Burkes Ford
- Pomahaka River at Glenken
- Shag River at Craig Road
- Shotover River at Bowens Peak
- Silver Stream at Taieri Depot
- Taieri River at Outram
- Taieri River at Sutton
- Taieri River at Tiroiti
- Taieri River at Waipiata
- Tokomairiro River at West Branch Bridge
- Waianakarua River at Browns
- Waikouaiti River at Confluence D/S
- Waitahuna at Tweeds Bridge
- Waiwera at Maws Farm

Appendix D – Land Cover Descriptions (LCDB4)

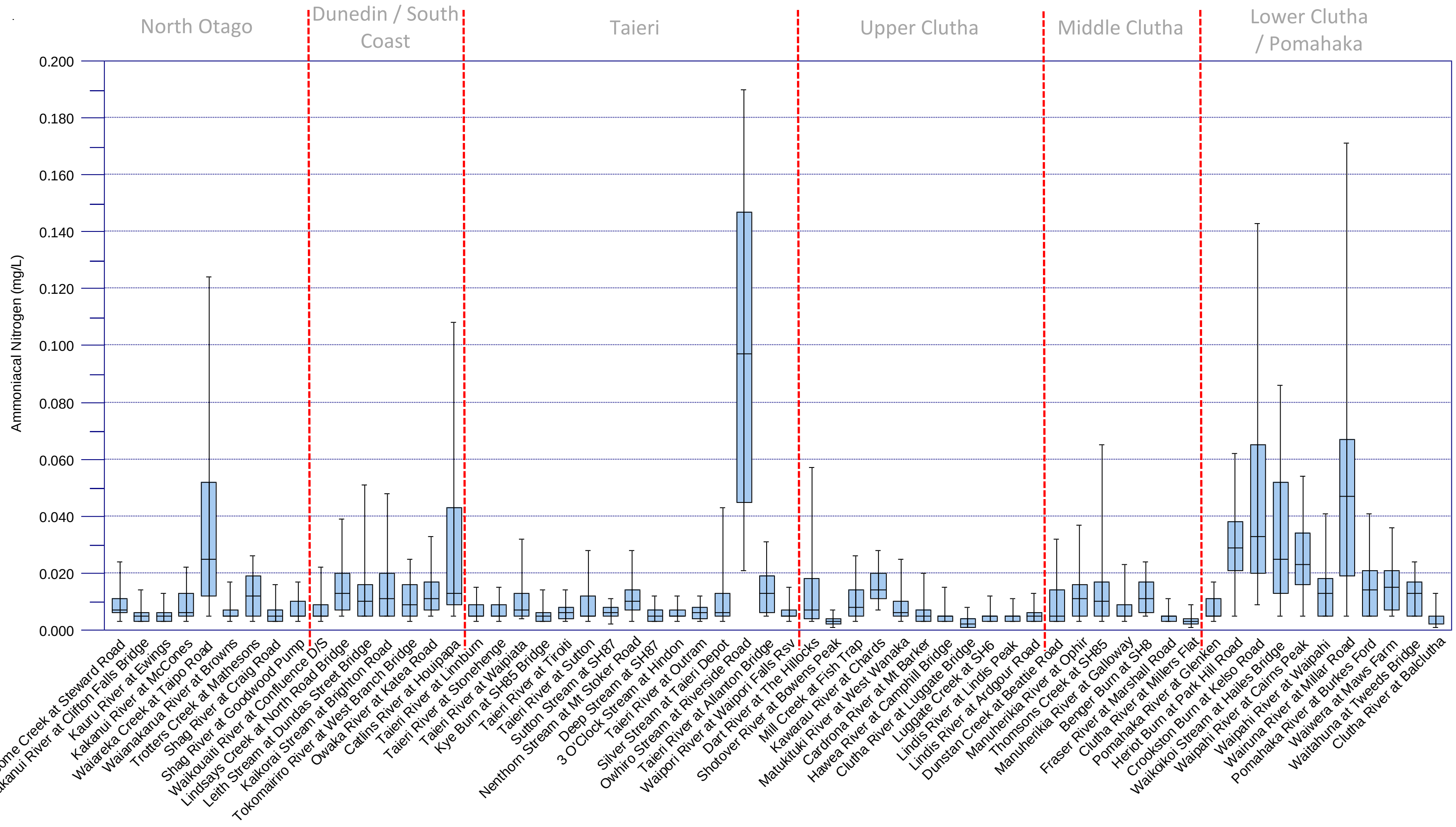
Table D -1: LCDB4 land cover categories and summary principle land cover categories. SOURCE: The principal land cover categories have been adapted from Thompson et al 2003 and Walker et al 2007. (Thompson S, Grüner I, Gapare N, Ministry for the Environment 2003. New Zealand Land Cover Database Version 2, Illustrated Guide to Target Classes. Walker S, Ciegaard E, Grove P, Lloyd K, Myers S, Park T, Porteous T 2007. Guide for the Users of the Threatened Environment Classification Version 1.1, August 2007. Landcare Research Manaaki Whenua (p 35). ***Adapted from the approach taken by Hawke's Bay Regional Council.***

Principal land-cover category	LCDB4 Land-use Category Name	Comment
Native Cover	Broadleaved Indigenous Hardwoods Depleted Grassland Fernland Herbaceous Freshwater Vegetation Herbaceous Saline Vegetation Indigenous Forest Manuka and/or Kanuka Matagouri or Grey Scrub Sub Alpine Shrubland Tall Tussock Grassland	These LCDB4 land-use categories have all been classified as indigenous (Walker et al 2007). The assessment whether a land cover class is indigenous or exotic is based on a subjective examination of vegetation cover and whether it is mainly exotic or indigenous. Many of the cover classes, such as depleted grassland, contain a mixture of exotic and indigenous species (Walker et al 2007). For the purposes of this report, depleted grassland has been classified as indigenous.
Plantation forestry	Deciduous Hardwoods Exotic Forest Forest - Harvested	As well as including willow and poplar species, deciduous hardwoods have been included in this category, as this class, also includes planted exotic hardwoods (Thompson et al 2003)
High producing grassland	High Producing Exotic Grassland	Land that is intensively managed and grazed for wool, lamb, beef, dairy or deer production.
Low producing grassland	Low Producing Grassland	Exotic and indigenous grasslands, grazed for wool, sheep or beef. Usually found on steep hill country.
Orchards/Vineyards	Orchard, Vineyard or Other Perennial Crop	Land used for perennial vines, areas cultivated less than annually and tree crops such as pip,

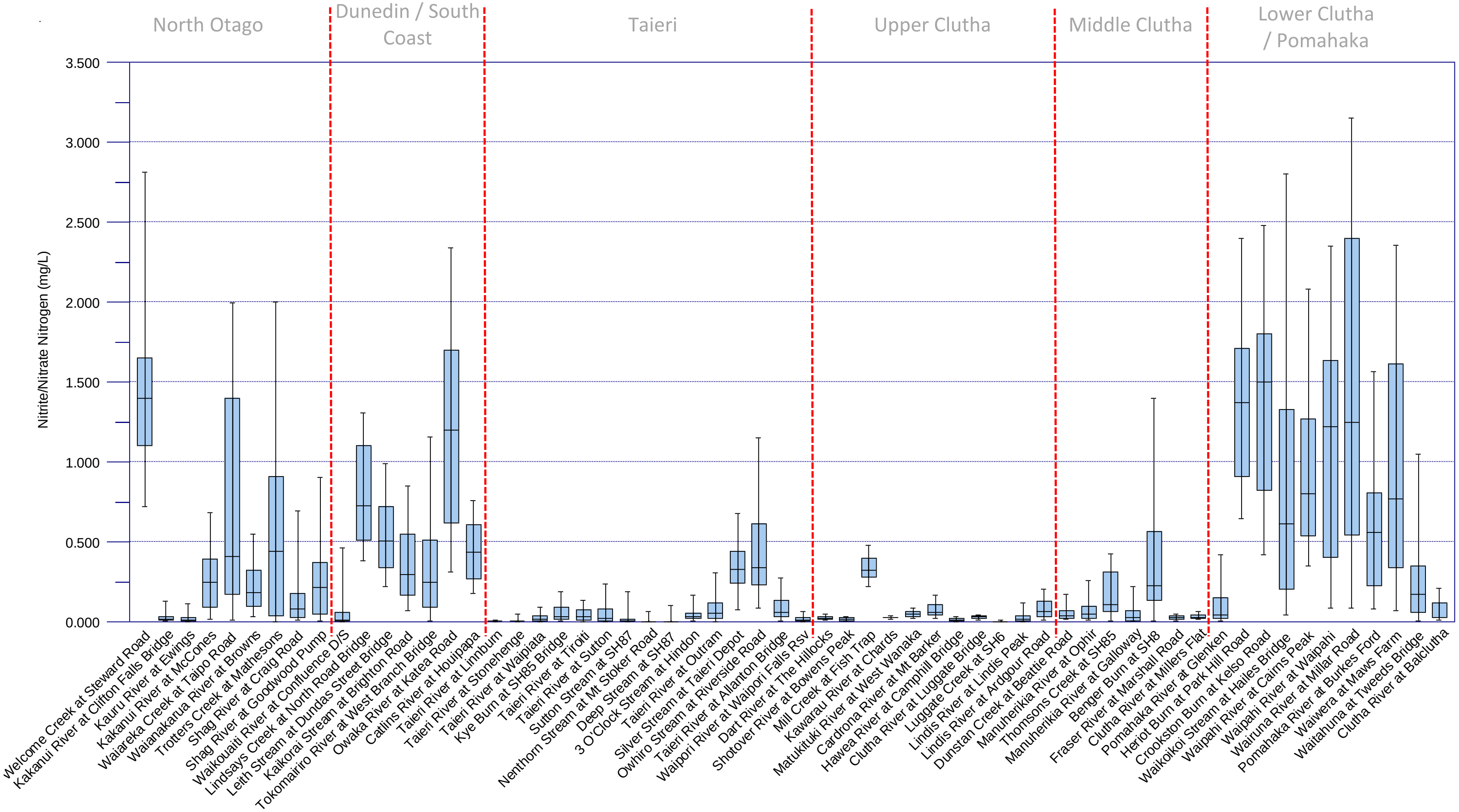
Principal land-cover category	LCDB4 Land-use Category Name	Comment
		stone and citrus fruit, olives and nuts as well as climbing plants such as berries, and kiwifruit.
Cropping	Short-rotation Cropland	Includes land used for cereal, root, annual seed and annual vegetable crops, hops, strawberries, flower crops and open ground nurseries.
Urban areas	Built-up Area (settlement) Transport Infrastructure Urban Parkland/Open Space Surface Mine or Dump	Surfaces with high run off rates. Includes land associated with hard urban manmade surfaces, infrastructure and mown grass, and bare surfaces associated with gravel pits, quarries and dumps.
Unaccounted, <1% of total catchment area	Estuarine Open Water Gorse and/or Broom Gravel or Rock Lake or Pond Landslide Mixed Exotic Shrubland River Sand or Gravel	These categories have not been included in the land-use summary tables in this report. They account for less than 1% of total catchment area and are perceived to have little or no contribution to eutrophication of water bodies.

Appendix E – Regional boxplot summary

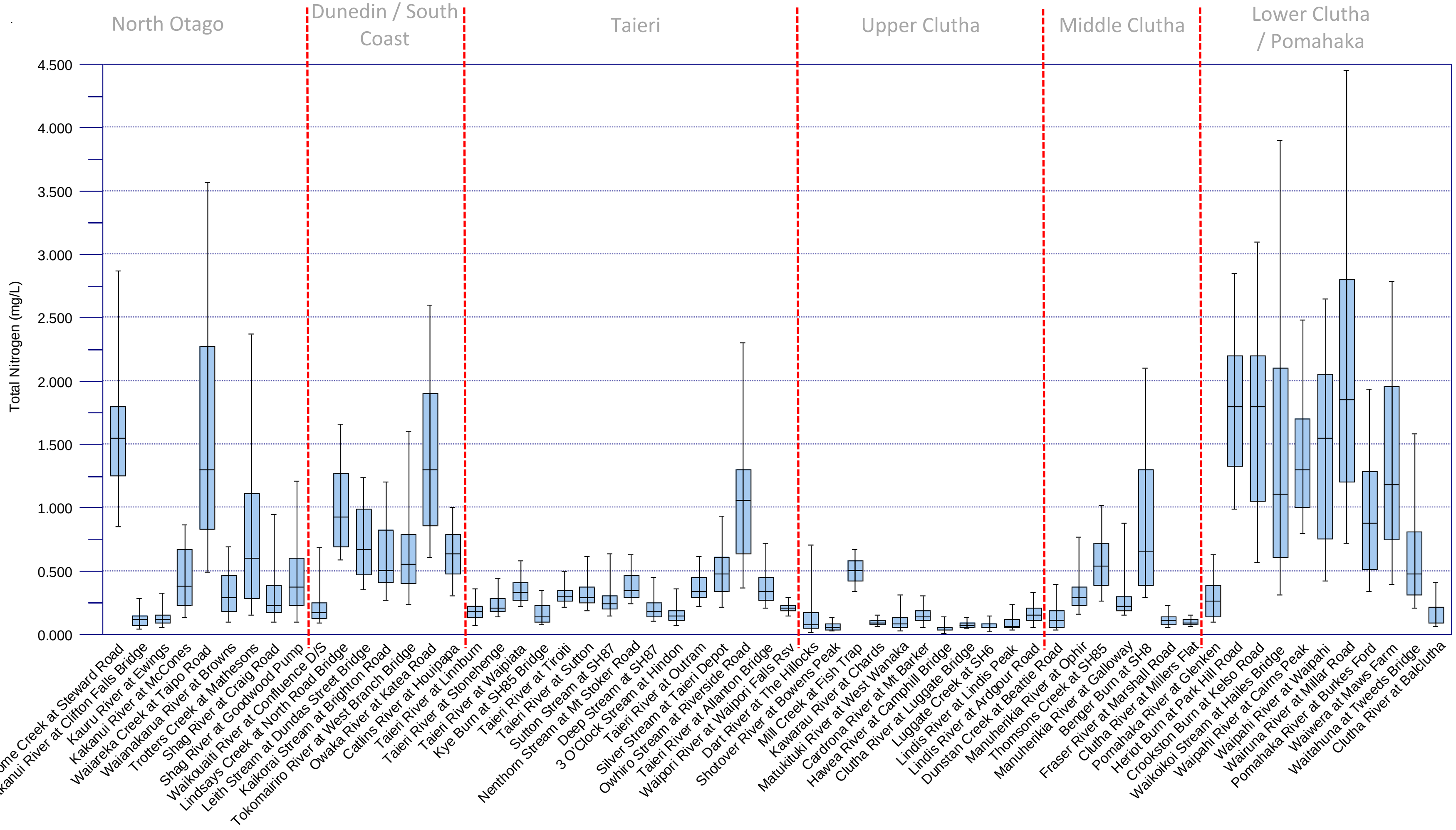
Ammoniacal Nitrogen



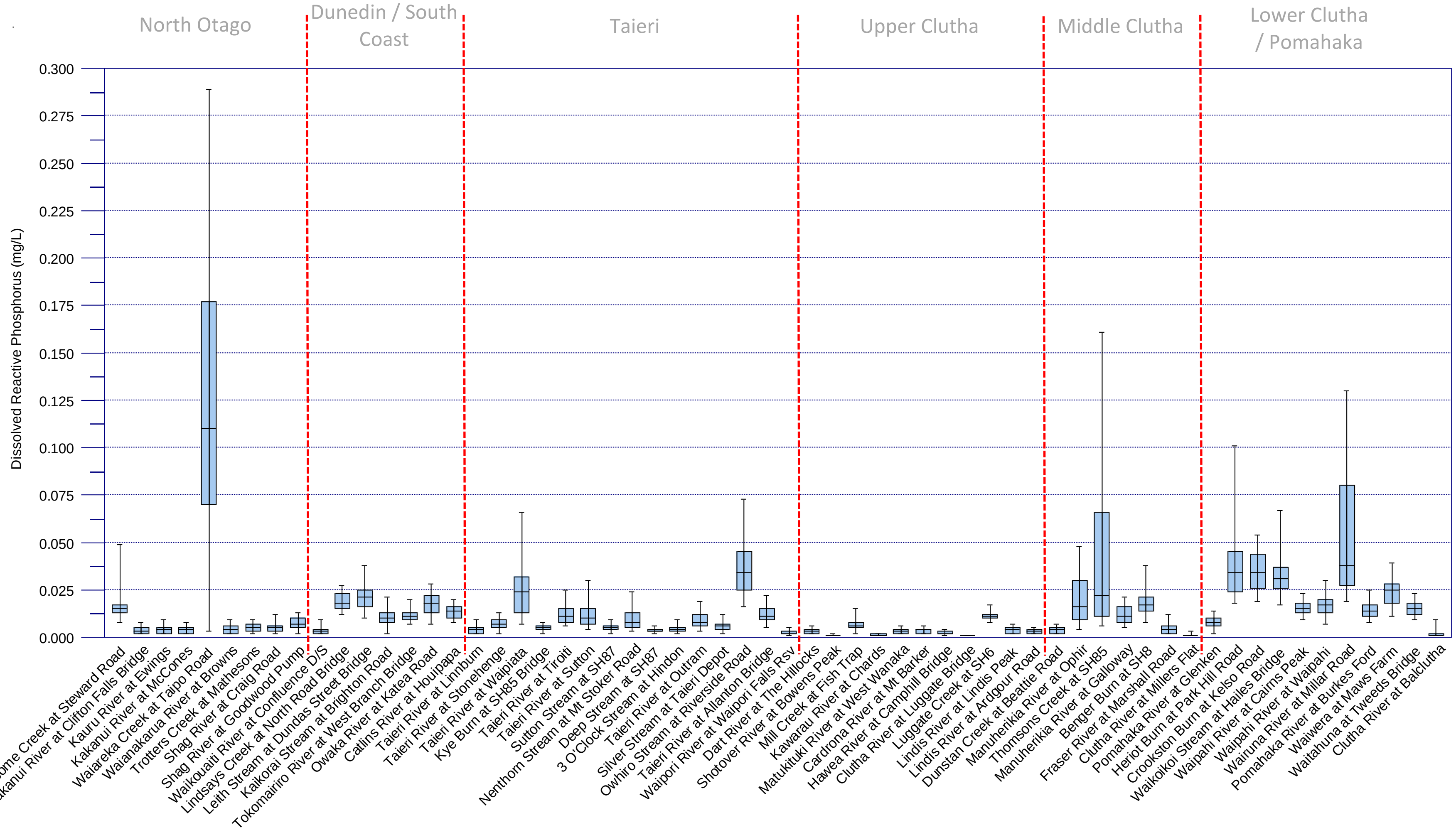
Nitrite/Nitrate Nitrogen



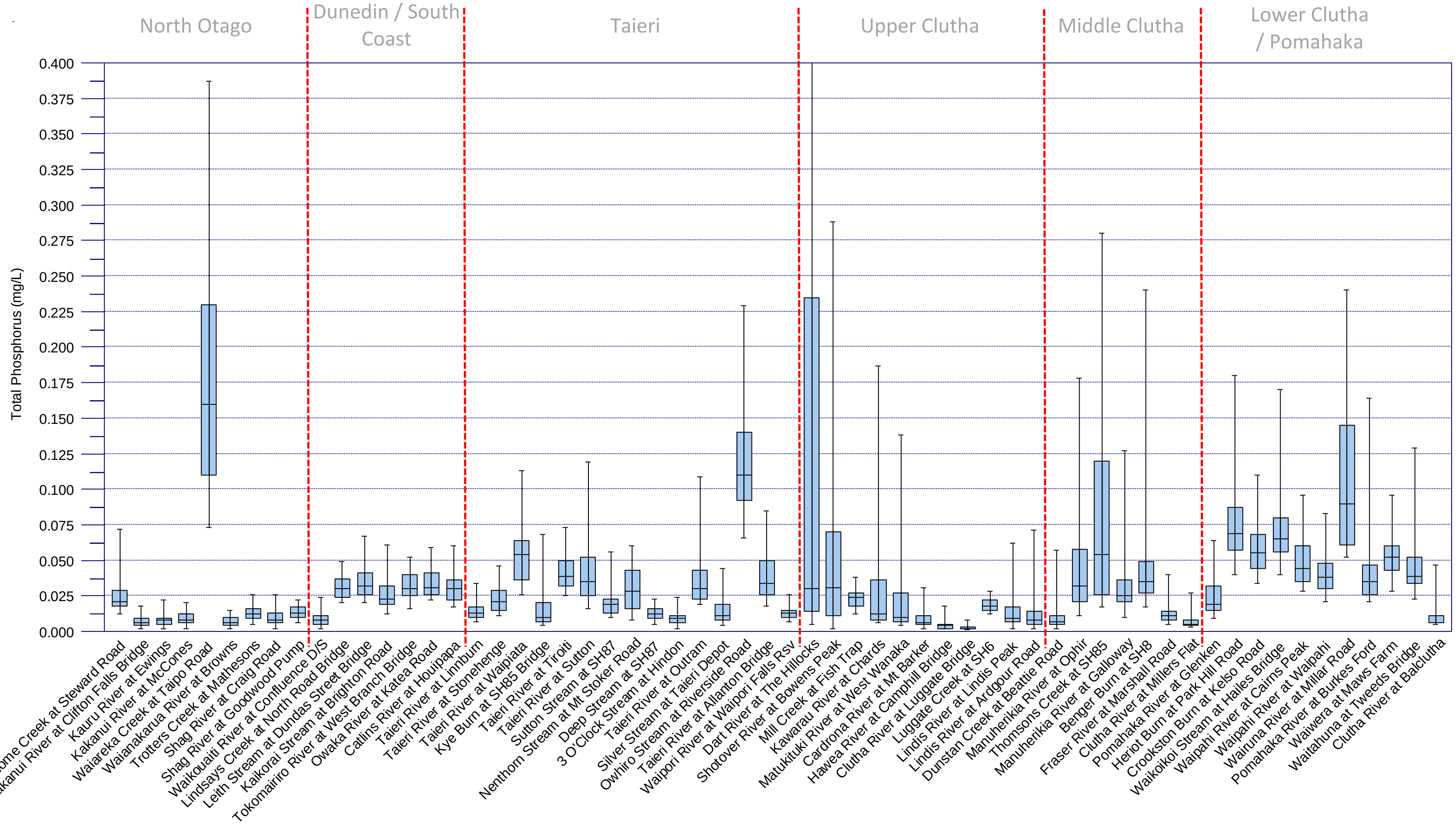
Total Nitrogen



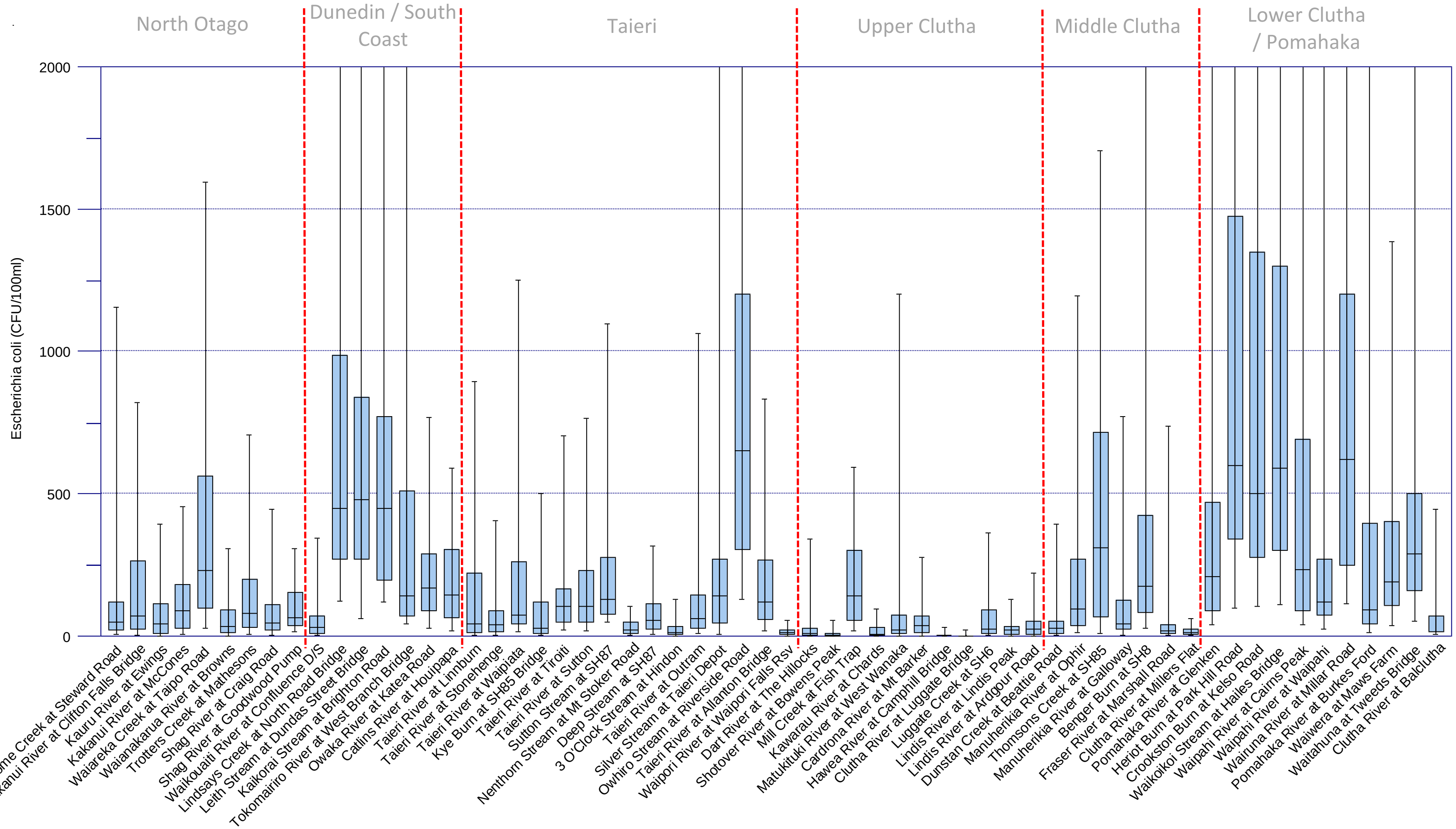
Dissolved Reactive Phosphorus



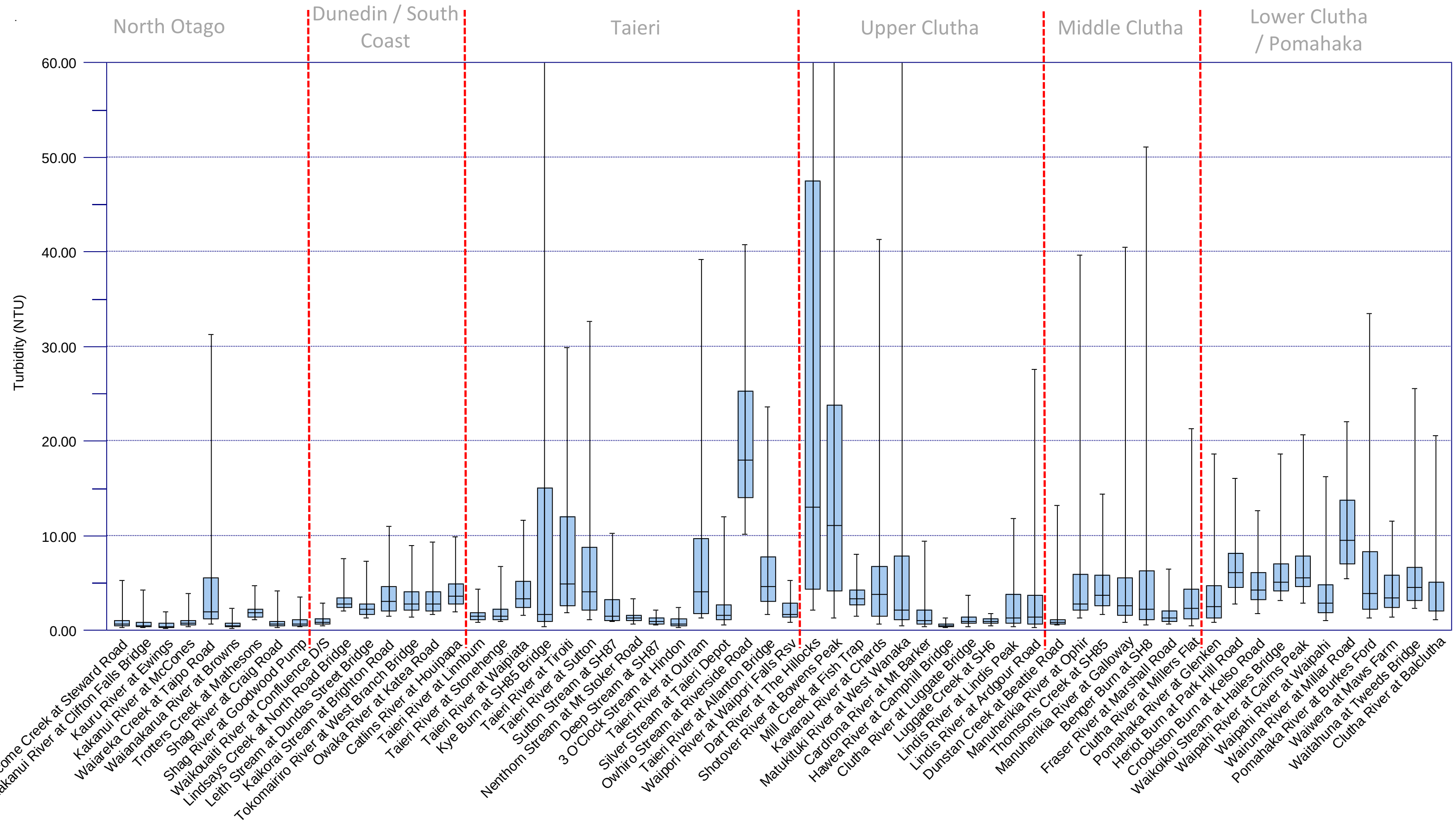
Total Phosphorus



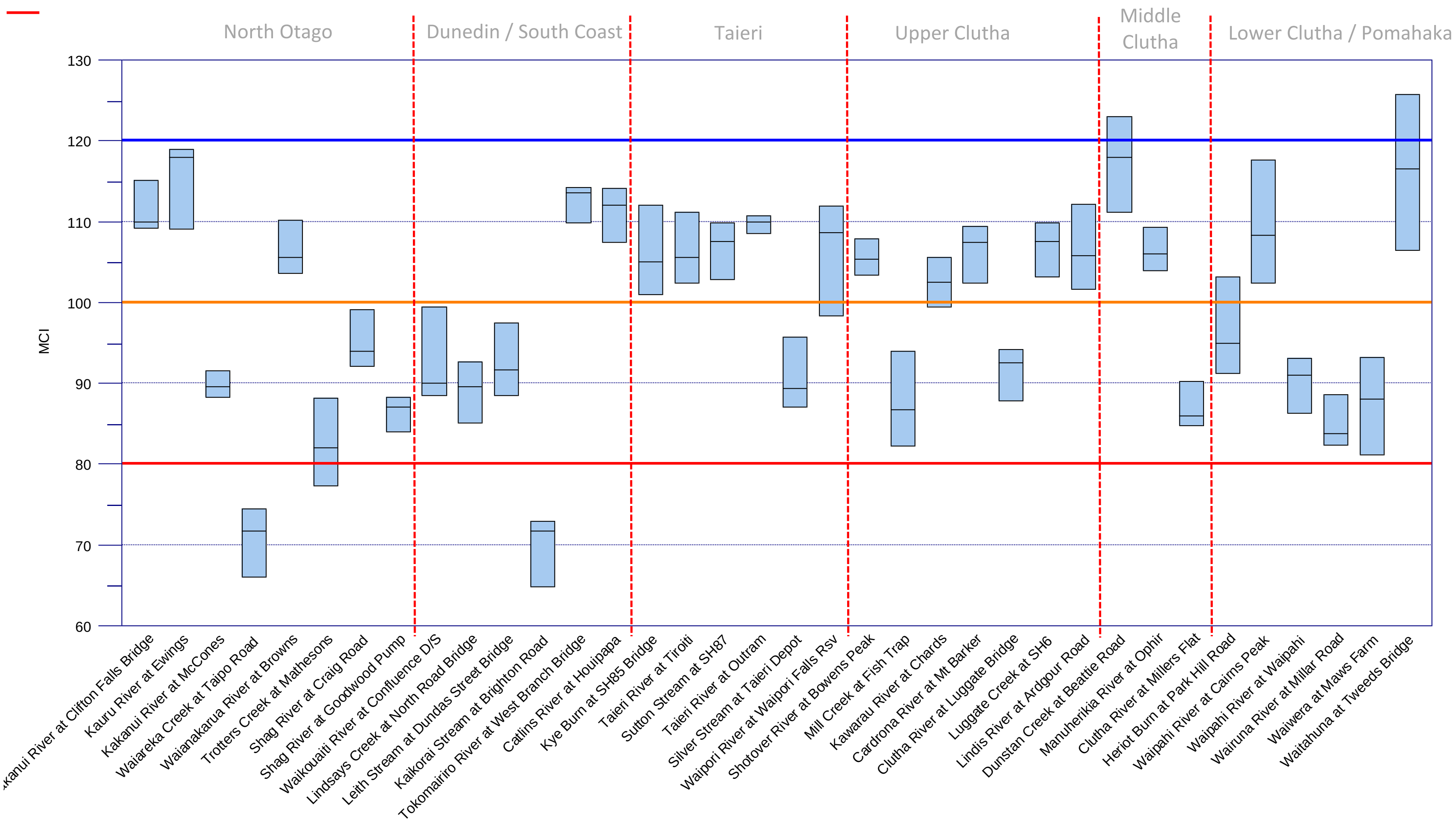
Escherichia coli



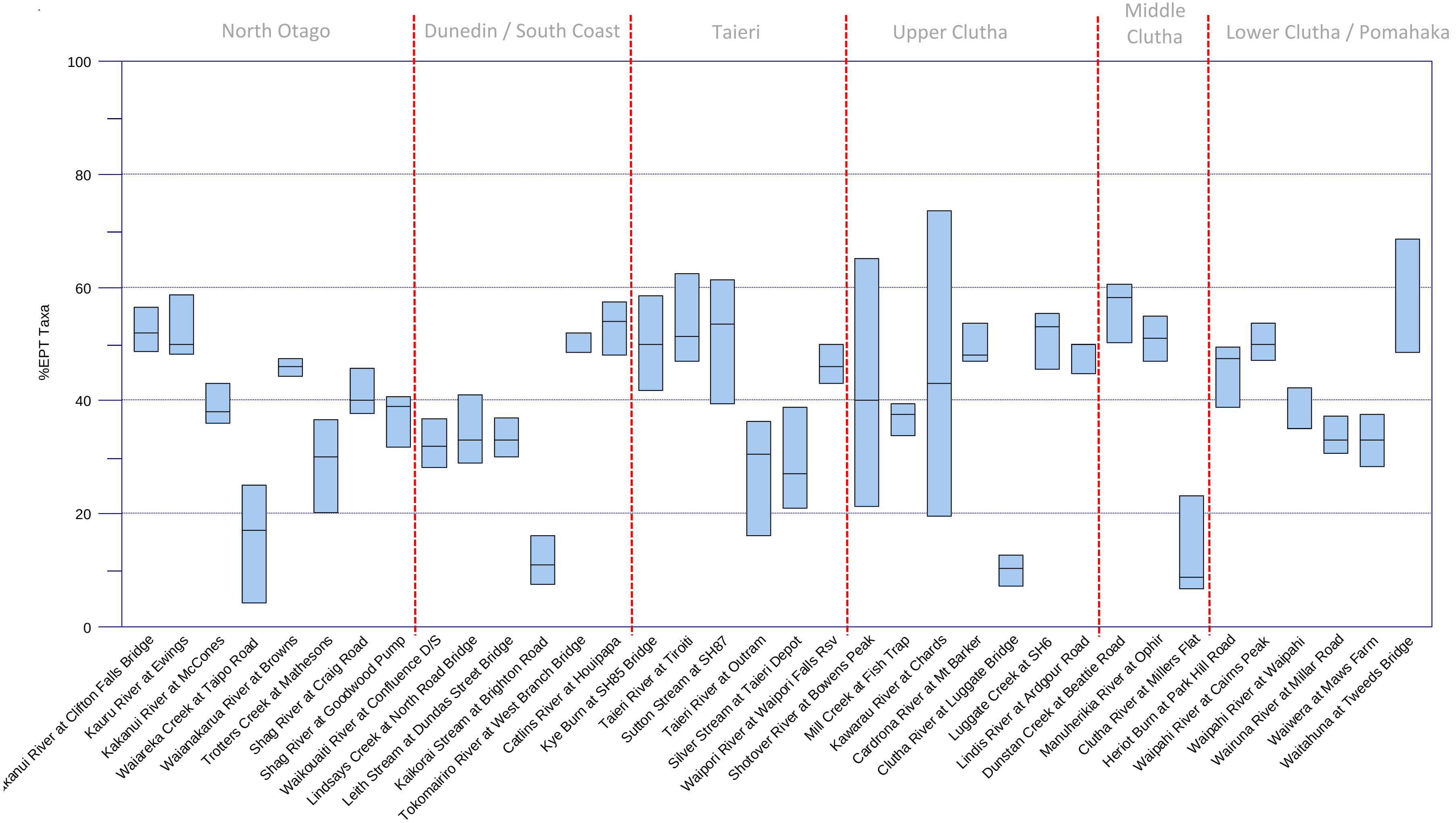
Turbidity


North Otago
Dunedin / South Coast
Taieri
Upper Clutha
Middle Clutha
Lower Clutha / Pomahaka
Turbidity (NTU)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Welcome Creek at Steward Road
Kakanui River at Clifton Falls Bridge
Kauru River at Ewings
Kakanui River at McCones
Waiareka Creek at Taipo Road
Waianakarua River at Browns
Trotters Creek at Mathesons
Shag River at Craig Road
Shag River at Goodwood Pump
Waikouaiti River at Confluence D/S
Lindsays Creek at North Road Bridge
Leith Stream at Dundas Street Bridge
Kaikorai Stream at Brighton Road
Tokomairiro River at West Branch Bridge
Owaka River at Katea Road
Catlins River at Houipapa
Taieri River at Linnburn
Taieri River at Stonehenge
Taieri River at Waipiata
Kye Burn at SH85 Bridge
Taieri River at Tiroiti
Taieri River at Sutton
Sutton Stream at SH87
Nenthorn Stream at Mt Stoker Road
Deep Stream at SH87
3 O'Clock Stream at Hindon
Taieri River at Outram
Silver Stream at Taieri Depot
Owhiro Stream at Riverside Road
Taieri River at Allanton Bridge
Waipori River at Waipori Falls Rsv
Dart River at The Hillocks
Shotover River at Bowens Peak
Mill Creek at Fish Trap
Kawarau River at Chards
Matukituki River at West Wanaka
Cardrona River at Mt Barker
Hawea River at Camphill Bridge
Clutha River at Luggate Bridge
Luggate Creek at SH6
Lindis River at Lindis Peak
Lindis River at Ardgour Road
Dunstan Creek at Beattie Road
Manuherikia River at Ophir
Thomsons Creek at SH85
Manuherikia River at Galloway
Benger Burn at SH8
Fraser River at Marshall Road
Clutha River at Millers Flat
Pomahaka River at Glenken
Heriot Burn at Park Hill Road
Crookston Burn at Kelso Road
Waikoikoi Stream at Hailes Bridge
Waipahi River at Cairns Peak
Waipahi River at Waipahi
Wairuna River at Millar Road
Pomahaka River at Burkes Ford
Waiwera at Maws Farm
Waitahuna at Tweeds Bridge
Clutha River at Balclutha

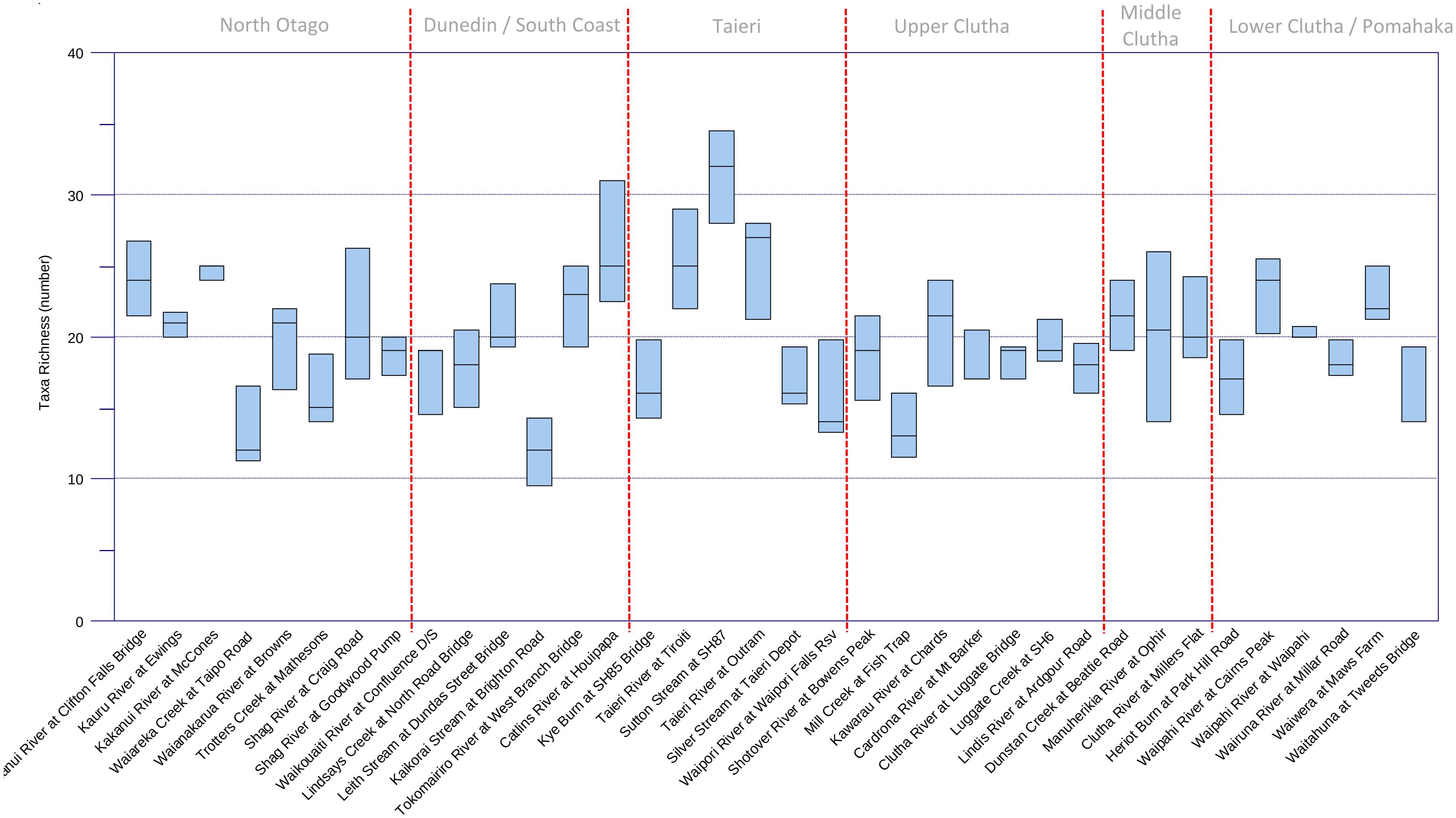
Macroinvertebrate Community Index



Percent EPT Taxa



Taxa Richness



Appendix F – River Environment Classification System (REC)

The Ministry for the Environment, in conjunction with NIWA developed the New Zealand River Environment Classification (REC) system (Snelder et al., 2004). The REC system characterises river environments at six hierarchical levels, according to their climate (1), source of flow (2), geology (3), land cover (4), network position (5) and valley landform (6), and within each level are a series of categories that are used to describe reaches of rivers throughout New Zealand (Table ***).

Table Appendix E – 1: REC classification levels, classes and criteria used to assign river segments to REC classes (from Snelder, 2004). Only the factors highlighted have been analysed in this section.

Factor	Climate	Code	Criteria
1. Climate	Warm extremely wet	WX	*Mean annual temperature:*
	Warm wet	WW	Warm: ≥12ºC
	Warm dry	WD	Cool: ≥12ºC
	Cool extremely wet	CX	*Mean annual effective precipitation:*
	Cool wet	CW	Extremely wet: ≥1500mm
	Cool dry	CD	Wet: 500 to 1500 mm, Dry: ≤ 500mm
2. Source of Flow	Glacial mountain	GM	*% permanent ice:*
	Mountain	M	Glacial Mountain: >1.5%
	Hill	H	*Rainfall volume in elevation categories:*
	Low elevation	L	Mountain: >50% above 1000 m
	Lake	Lk	Hill: 50% between 400 to 1000 m
	Spring	Sp	Low elevation: 50% below 400 m
	Regulated	R	*Lake influence index*
	Wetland	W	*Others manually assigned*
3. Geology	Alluvium	Al	*Spatially dominant geology category, unless:*
	Hard sedimentary	HS	Soft sedimentary >25%, then classified as sedimentary
	Soft sedimentary	SS	
	Volcanic basic	VB	
	Volcanic acidic	VA	
	Plutonic	Pl	
	Miscellaneous	M	
4. Land cover	Bare	B	*Spatially dominant land cover class, unless:*
	Native forest	IF	Pasture: >25%, then classified as pasture
	Pastoral	P	Urban: >15% then classified as urban
	Tussock	T	
	Scrub	S	
	Exotic forest	EF	

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	Wetland Urban	W U	
5. Network position	Low order Middle order High order	L M H	*Stream Order:* Low: 1 and 2 Medium: 3 and 4 High: >5
6. Valley landform	High gradient Medium gradient Low gradient	H M L	Valley slope: High: >0.04 Medium: 0.02 to 0.04 Low: <0.02

Only factors 1 and 2 are included in the REC summaries of this report.

Appendix G – Water quality regional ranking tables

Median Regional Ranking Tables – Ammoniacal Nitrogen

WQ Reporting zone	Reporting name	Median NH_4-N (mg/L)	Ranking		
Upper Clutha	Clutha River at Luggate Bridge	0.002	Ranked	1	out of 20 discrete levels
Upper Clutha	Shotover River at Bowens Peak	0.003	Ranked	2	out of 20 discrete levels
Middle Clutha / Central Otago	Clutha River at Millers Flat	0.003	Ranked	2	out of 20 discrete levels
Lower Clutha / Pomahaka	Clutha River at Balclutha	0.004	Ranked	3	out of 20 discrete levels
North Otago	Kakanui River at Clifton Falls Bridge	0.005	Ranked	4	out of 20 discrete levels
North Otago	Kauru River at Ewings	0.005	Ranked	4	out of 20 discrete levels
North Otago	Waianakarua River at Browns	0.005	Ranked	4	out of 20 discrete levels
North Otago	Shag River at Craig Road	0.005	Ranked	4	out of 20 discrete levels
North Otago	Shag River at Goodwood Pump	0.005	Ranked	4	out of 20 discrete levels
Dunedin / Southern Coastal	Waikouaiti River at Confluence D/S	0.005	Ranked	4	out of 20 discrete levels
Taieri	Taieri River at Linnburn	0.005	Ranked	4	out of 20 discrete levels
Taieri	Taieri River at Stonehenge	0.005	Ranked	4	out of 20 discrete levels
Taieri	Kye Burn at SH85 Bridge	0.005	Ranked	4	out of 20 discrete levels
Taieri	Taieri River at Sutton	0.005	Ranked	4	out of 20 discrete levels
Taieri	Deep Stream at SH87	0.005	Ranked	4	out of 20 discrete levels
Taieri	3 O'Clock Stream at Hindon	0.005	Ranked	4	out of 20 discrete levels
Taieri	Waipori River at Waipori Falls Rsv	0.005	Ranked	4	out of 20 discrete levels
Upper Clutha	Cardrona River at Mt Barker	0.005	Ranked	4	out of 20 discrete levels
Upper Clutha	Hawea River at Camphill Bridge	0.005	Ranked	4	out of 20 discrete levels
Upper Clutha	Luggate Creek at SH6	0.005	Ranked	4	out of 20 discrete levels
Upper Clutha	Lindis River at Lindis Peak	0.005	Ranked	4	out of 20 discrete levels
Upper Clutha	Lindis River at Ardgour Road	0.005	Ranked	4	out of 20 discrete levels
Middle Clutha / Central Otago	Dunstan Creek at Beattie Road	0.005	Ranked	4	out of 20 discrete levels
Middle Clutha / Central Otago	Manuherikia River at Galloway	0.005	Ranked	4	out of 20 discrete levels
Middle Clutha / Central Otago	Fraser River at Marshall Road	0.005	Ranked	4	out of 20 discrete levels
Lower Clutha / Pomahaka	Pomahaka River at Glenken	0.005	Ranked	4	out of 20 discrete levels
North Otago	Kakanui River at McCones	0.006	Ranked	5	out of 20 discrete levels
Taieri	Taieri River at Tiroiti	0.006	Ranked	5	out of 20 discrete levels
Taieri	Sutton Stream at SH87	0.006	Ranked	5	out of 20 discrete levels
Taieri	Taieri River at Outram	0.006	Ranked	5	out of 20 discrete levels
Taieri	Silver Stream at Taieri Depot	0.006	Ranked	5	out of 20 discrete levels
Upper Clutha	Matukituki River at West Wanaka	0.006	Ranked	5	out of 20 discrete levels
North Otago	Welcome Creek at Steward Road	0.007	Ranked	6	out of 20 discrete levels
Taieri	Taieri River at Waipiata	0.007	Ranked	6	out of 20 discrete levels
Upper Clutha	Dart River at The Hillocks	0.007	Ranked	6	out of 20 discrete levels
Upper Clutha	Mill Creek at Fish Trap	0.008	Ranked	7	out of 20 discrete levels
Dunedin / Southern Coastal	Tokomairiro River at West Branch Bridge	0.009	Ranked	8	out of 20 discrete levels
Dunedin / Southern Coastal	Leith Stream at Dundas Street Bridge	0.010	Ranked	9	out of 20 discrete levels
Taieri	Nenthorn Stream at Mt Stoker Road	0.010	Ranked	9	out of 20 discrete levels
Middle Clutha / Central Otago	Thomsons Creek at SH85	0.010	Ranked	9	out of 20 discrete levels
Dunedin / Southern Coastal	Kaikorai Stream at Brighton Road	0.011	Ranked	10	out of 20 discrete levels
Dunedin / Southern Coastal	Owaka River at Katea Road	0.011	Ranked	10	out of 20 discrete levels
Middle Clutha / Central Otago	Manuherikia River at Ophir	0.011	Ranked	10	out of 20 discrete levels
Middle Clutha / Central Otago	Benger Burn at SH8	0.011	Ranked	10	out of 20 discrete levels
North Otago	Trotters Creek at Mathesons	0.012	Ranked	11	out of 20 discrete levels
Dunedin / Southern Coastal	Lindsays Creek at North Road Bridge	0.013	Ranked	12	out of 20 discrete levels
Dunedin / Southern Coastal	Catlins River at Houipapa	0.013	Ranked	12	out of 20 discrete levels
Taieri	Taieri River at Allanton Bridge	0.013	Ranked	12	out of 20 discrete levels
Lower Clutha / Pomahaka	Waipahi River at Waipahi	0.013	Ranked	12	out of 20 discrete levels
Lower Clutha / Pomahaka	Waitahuna at Tweeds Bridge	0.013	Ranked	12	out of 20 discrete levels
Upper Clutha	Kawarau River at Chards	0.014	Ranked	13	out of 20 discrete levels
Lower Clutha / Pomahaka	Pomahaka River at Burkes Ford	0.014	Ranked	13	out of 20 discrete levels
Lower Clutha / Pomahaka	Waiwera at Maws Farm	0.015	Ranked	14	out of 20 discrete levels
Lower Clutha / Pomahaka	Waipahi River at Cairns Peak	0.023	Ranked	15	out of 20 discrete levels
North Otago	Waiareka Creek at Taipo Road	0.025	Ranked	16	out of 20 discrete levels
Lower Clutha / Pomahaka	Waikoikoi Stream at Hailes Bridge	0.025	Ranked	16	out of 20 discrete levels
Lower Clutha / Pomahaka	Heriot Burn at Park Hill Road	0.029	Ranked	17	out of 20 discrete levels
Lower Clutha / Pomahaka	Crookston Burn at Kelso Road	0.033	Ranked	18	out of 20 discrete levels
Lower Clutha / Pomahaka	Wairuna River at Millar Road	0.047	Ranked	19	out of 20 discrete levels
Taieri	Owhiro Stream at Riverside Road	0.097	Ranked	20	out of 20 discrete levels

Median Regional Ranking Tables – Nitrite/nitrate nitrogen (NNN)

WQ Reporting zone	Reporting name	Median NNN (mg/L)	Ranking		
Taieri	Nenthorn Stream at Mt Stoker Road	0.001	Ranked	1	out of 51 discrete levels
Taieri	Deep Stream at SH87	0.001	Ranked	1	out of 51 discrete levels
Upper Clutha	Luggate Creek at SH6	0.002	Ranked	2	out of 51 discrete levels
Taieri	Taieri River at Linnburn	0.003	Ranked	3	out of 51 discrete levels
Taieri	Taieri River at Stonehenge	0.006	Ranked	4	out of 51 discrete levels
Taieri	Sutton Stream at SH87	0.007	Ranked	5	out of 51 discrete levels
Dunedin / Southern Coastal	Waikouaiti River at Confluence D/S	0.009	Ranked	6	out of 51 discrete levels
North Otago	Kauru River at Ewings	0.011	Ranked	7	out of 51 discrete levels
Upper Clutha	Hawea River at Camphill Bridge	0.011	Ranked	7	out of 51 discrete levels
Taieri	Waipori River at Waipori Falls Rsv	0.013	Ranked	8	out of 51 discrete levels
Upper Clutha	Shotover River at Bowens Peak	0.014	Ranked	9	out of 51 discrete levels
Upper Clutha	Lindis River at Lindis Peak	0.015	Ranked	10	out of 51 discrete levels
North Otago	Kakanui River at Clifton Falls Bridge	0.017	Ranked	11	out of 51 discrete levels
Taieri	Taieri River at Waipiata	0.017	Ranked	11	out of 51 discrete levels
Taieri	Taieri River at Sutton	0.021	Ranked	12	out of 51 discrete levels
Upper Clutha	Dart River at The Hillocks	0.022	Ranked	13	out of 51 discrete levels
Upper Clutha	Kawarau River at Chards	0.025	Ranked	14	out of 51 discrete levels
Middle Clutha / Central Otago	Manuherikia River at Galloway	0.027	Ranked	15	out of 51 discrete levels
Middle Clutha / Central Otago	Clutha River at Millers Flat	0.027	Ranked	15	out of 51 discrete levels
Middle Clutha / Central Otago	Fraser River at Marshall Road	0.029	Ranked	16	out of 51 discrete levels
Taieri	Kye Burn at SH85 Bridge	0.032	Ranked	17	out of 51 discrete levels
Upper Clutha	Clutha River at Luggate Bridge	0.032	Ranked	17	out of 51 discrete levels
Taieri	Taieri River at Tiroiti	0.033	Ranked	18	out of 51 discrete levels
Taieri	3 O'Clock Stream at Hindon	0.033	Ranked	18	out of 51 discrete levels
Middle Clutha / Central Otago	Dunstan Creek at Beattie Road	0.037	Ranked	19	out of 51 discrete levels
Lower Clutha / Pomahaka	Pomahaka River at Glenken	0.043	Ranked	20	out of 51 discrete levels
Upper Clutha	Matukituki River at West Wanaka	0.046	Ranked	21	out of 51 discrete levels
Middle Clutha / Central Otago	Manuherikia River at Ophir	0.046	Ranked	21	out of 51 discrete levels
Taieri	Taieri River at Outram	0.052	Ranked	22	out of 51 discrete levels
Lower Clutha / Pomahaka	Clutha River at Balclutha	0.052	Ranked	22	out of 51 discrete levels
Taieri	Taieri River at Allanton Bridge	0.060	Ranked	23	out of 51 discrete levels
Upper Clutha	Cardrona River at Mt Barker	0.061	Ranked	24	out of 51 discrete levels
Upper Clutha	Lindis River at Ardgour Road	0.066	Ranked	25	out of 51 discrete levels
North Otago	Shag River at Craig Road	0.078	Ranked	26	out of 51 discrete levels
Middle Clutha / Central Otago	Thomsons Creek at SH85	0.105	Ranked	27	out of 51 discrete levels
Lower Clutha / Pomahaka	Waitahuna at Tweeds Bridge	0.173	Ranked	28	out of 51 discrete levels
North Otago	Waianakarua River at Browns	0.181	Ranked	29	out of 51 discrete levels
North Otago	Shag River at Goodwood Pump	0.215	Ranked	30	out of 51 discrete levels
Middle Clutha / Central Otago	Benger Burn at SH8	0.225	Ranked	31	out of 51 discrete levels
North Otago	Kakanui River at McCones	0.250	Ranked	32	out of 51 discrete levels
Dunedin / Southern Coastal	Tokomairiro River at West Branch Bridge	0.250	Ranked	32	out of 51 discrete levels
Dunedin / Southern Coastal	Kaikorai Stream at Brighton Road	0.295	Ranked	33	out of 51 discrete levels
Upper Clutha	Mill Creek at Fish Trap	0.320	Ranked	34	out of 51 discrete levels
Taieri	Silver Stream at Taieri Depot	0.330	Ranked	35	out of 51 discrete levels
Taieri	Owhiro Stream at Riverside Road	0.340	Ranked	36	out of 51 discrete levels
North Otago	Waiareka Creek at Taipo Road	0.410	Ranked	37	out of 51 discrete levels
Dunedin / Southern Coastal	Catlins River at Houipapa	0.435	Ranked	38	out of 51 discrete levels
North Otago	Trotters Creek at Mathesons	0.440	Ranked	39	out of 51 discrete levels
Dunedin / Southern Coastal	Leith Stream at Dundas Street Bridge	0.505	Ranked	40	out of 51 discrete levels
Lower Clutha / Pomahaka	Pomahaka River at Burkes Ford	0.560	Ranked	41	out of 51 discrete levels
Lower Clutha / Pomahaka	Waikoikoi Stream at Hailes Bridge	0.615	Ranked	42	out of 51 discrete levels
Dunedin / Southern Coastal	Lindsays Creek at North Road Bridge	0.725	Ranked	43	out of 51 discrete levels
Lower Clutha / Pomahaka	Waiwera at Maws Farm	0.770	Ranked	44	out of 51 discrete levels
Lower Clutha / Pomahaka	Waipahi River at Cairns Peak	0.800	Ranked	45	out of 51 discrete levels
Dunedin / Southern Coastal	Owaka River at Katea Road	1.200	Ranked	46	out of 51 discrete levels
Lower Clutha / Pomahaka	Waipahi River at Waipahi	1.220	Ranked	47	out of 51 discrete levels
Lower Clutha / Pomahaka	Wairuna River at Millar Road	1.250	Ranked	48	out of 51 discrete levels
Lower Clutha / Pomahaka	Heriot Burn at Park Hill Road	1.370	Ranked	49	out of 51 discrete levels
North Otago	Welcome Creek at Steward Road	1.400	Ranked	50	out of 51 discrete levels
Lower Clutha / Pomahaka	Crookston Burn at Kelso Road	1.500	Ranked	51	out of 51 discrete levels

Median Regional Ranking Tables – Total Nitrogen

WQ Reporting zone	Reporting name	Median Total N (mg/L)	Ranking		
Upper Clutha	Shotover River at Bowens Peak	0.053	Ranked	1	out of 46 discrete levels
Upper Clutha	Hawea River at Camphill Bridge	0.055	Ranked	2	out of 46 discrete levels
Upper Clutha	Luggate Creek at SH6	0.055	Ranked	2	out of 46 discrete levels
Upper Clutha	Lindis River at Lindis Peak	0.062	Ranked	3	out of 46 discrete levels
Upper Clutha	Clutha River at Luggate Bridge	0.068	Ranked	4	out of 46 discrete levels
Upper Clutha	Dart River at The Hillocks	0.075	Ranked	5	out of 46 discrete levels
Upper Clutha	Matukituki River at West Wanaka	0.081	Ranked	6	out of 46 discrete levels
Upper Clutha	Kawarau River at Chards	0.088	Ranked	7	out of 46 discrete levels
Middle Clutha / Central Otago	Clutha River at Millers Flat	0.088	Ranked	7	out of 46 discrete levels
Middle Clutha / Central Otago	Dunstan Creek at Beattie Road	0.110	Ranked	8	out of 46 discrete levels
Middle Clutha / Central Otago	Fraser River at Marshall Road	0.110	Ranked	8	out of 46 discrete levels
North Otago	Kakanui River at Clifton Falls Bridge	0.120	Ranked	9	out of 46 discrete levels
North Otago	Kauru River at Ewings	0.120	Ranked	9	out of 46 discrete levels
Taieri	Kye Burn at SH85 Bridge	0.140	Ranked	10	out of 46 discrete levels
Upper Clutha	Cardrona River at Mt Barker	0.140	Ranked	10	out of 46 discrete levels
Lower Clutha / Pomahaka	Clutha River at Balclutha	0.144	Ranked	11	out of 46 discrete levels
Taieri	3 O'Clock Stream at Hindon	0.145	Ranked	12	out of 46 discrete levels
Upper Clutha	Lindis River at Ardgour Road	0.150	Ranked	13	out of 46 discrete levels
Dunedin / Southern Coastal	Waikouaiti River at Confluence D/S	0.170	Ranked	14	out of 46 discrete levels
Taieri	Taieri River at Linnburn Runs Road	0.180	Ranked	15	out of 46 discrete levels
Taieri	Deep Stream at SH87	0.180	Ranked	15	out of 46 discrete levels
Taieri	Taieri River at Stonehenge	0.210	Ranked	16	out of 46 discrete levels
Taieri	Waipori River at Waipori Falls Reserve	0.210	Ranked	16	out of 46 discrete levels
Middle Clutha / Central Otago	Manuherikia River at Galloway	0.220	Ranked	17	out of 46 discrete levels
North Otago	Shag River at Craig Road	0.230	Ranked	18	out of 46 discrete levels
Taieri	Sutton Stream at SH87	0.239	Ranked	19	out of 46 discrete levels
Lower Clutha / Pomahaka	Pomahaka River at Glenken	0.260	Ranked	20	out of 46 discrete levels
North Otago	Waianakarua River at Browns	0.290	Ranked	21	out of 46 discrete levels
Taieri	Taieri River at Sutton	0.290	Ranked	21	out of 46 discrete levels
Middle Clutha / Central Otago	Manuherikia River at Ophir	0.290	Ranked	21	out of 46 discrete levels
Taieri	Taieri River at Tiroiti	0.300	Ranked	22	out of 46 discrete levels
Taieri	Taieri River at Waipiata	0.330	Ranked	23	out of 46 discrete levels
Taieri	Taieri River at Outram	0.339	Ranked	24	out of 46 discrete levels
Taieri	Taieri River at Allanton Bridge	0.340	Ranked	25	out of 46 discrete levels
Taieri	Nenthorn Stream at Mt Stoker Road	0.345	Ranked	26	out of 46 discrete levels
North Otago	Shag River at Goodwood Pump	0.370	Ranked	27	out of 46 discrete levels
North Otago	Waiareka Creek at Taipo Road	0.380	Ranked	28	out of 46 discrete levels
Taieri	Silver Stream at Taieri Depot	0.480	Ranked	29	out of 46 discrete levels
Lower Clutha / Pomahaka	Waitahuna at Tweeds Bridge	0.480	Ranked	29	out of 46 discrete levels
Dunedin / Southern Coastal	Kaikorai Stream at Brighton Road	0.505	Ranked	30	out of 46 discrete levels
Upper Clutha	Mill Creek at Fish Trap	0.505	Ranked	30	out of 46 discrete levels
Middle Clutha / Central Otago	Thomsons Creek at SH85	0.540	Ranked	31	out of 46 discrete levels
Dunedin / Southern Coastal	Tokomairiro River at West Branch Bridge	0.550	Ranked	32	out of 46 discrete levels
North Otago	Trotters Creek at Mathesons	0.600	Ranked	33	out of 46 discrete levels
Dunedin / Southern Coastal	Catlins River at Houipapa	0.635	Ranked	34	out of 46 discrete levels
Middle Clutha / Central Otago	Benger Burn at SH8	0.660	Ranked	35	out of 46 discrete levels
Dunedin / Southern Coastal	Leith Stream at Dundas Street Bridge	0.670	Ranked	36	out of 46 discrete levels
Lower Clutha / Pomahaka	Pomahaka River at Burkes Ford	0.880	Ranked	37	out of 46 discrete levels
Dunedin / Southern Coastal	Lindsays Creek at North Road Bridge	0.925	Ranked	38	out of 46 discrete levels
Taieri	Owhiro Stream at Riverside Road	1.060	Ranked	39	out of 46 discrete levels
Lower Clutha / Pomahaka	Waikoikoi Stream at Hailes Bridge	1.105	Ranked	40	out of 46 discrete levels
Lower Clutha / Pomahaka	Waiwera at Maws Farm	1.180	Ranked	41	out of 46 discrete levels
North Otago	Kakanui River at McCones	1.300	Ranked	42	out of 46 discrete levels
Dunedin / Southern Coastal	Owaka River at Katea Road	1.300	Ranked	42	out of 46 discrete levels
Lower Clutha / Pomahaka	Waipahi River at Cairns Peak	1.300	Ranked	42	out of 46 discrete levels
North Otago	Welcome Creek at Steward Road	1.545	Ranked	43	out of 46 discrete levels
Lower Clutha / Pomahaka	Waipahi River at Waipahi	1.550	Ranked	44	out of 46 discrete levels
Lower Clutha / Pomahaka	Heriot Burn at Park Hill Road	1.800	Ranked	45	out of 46 discrete levels
Lower Clutha / Pomahaka	Crookston Burn at Kelso Road	1.800	Ranked	45	out of 46 discrete levels
Lower Clutha / Pomahaka	Wairuna River at Millar Road	1.855	Ranked	46	out of 46 discrete levels

Median Regional Ranking Tables – Dissolved Reactive Phosphorus (DRP)

WQ Reporting zone	Reporting name	Median DRP (mg/L)	Ranking		
Upper Clutha	Shotover River at Bowens Peak	0.001	Ranked	1	out of 23 discrete levels
Upper Clutha	Kawarau River at Chards	0.001	Ranked	1	out of 23 discrete levels
Upper Clutha	Clutha River at Luggate Bridge	0.001	Ranked	1	out of 23 discrete levels
Middle Clutha / Central Otago	Clutha River at Millers Flat	0.001	Ranked	1	out of 23 discrete levels
Lower Clutha / Pomahaka	Clutha River at Balclutha	0.001	Ranked	1	out of 23 discrete levels
Taieri	Waipori River at Waipori Falls Rsv	0.002	Ranked	2	out of 23 discrete levels
Upper Clutha	Hawea River at Camphill Bridge	0.002	Ranked	2	out of 23 discrete levels
North Otago	Kakanui River at Clifton Falls Bridge	0.003	Ranked	3	out of 23 discrete levels
Dunedin / Southern Coastal	Waikouaiti River at Confluence D/S	0.003	Ranked	3	out of 23 discrete levels
Taieri	Deep Stream at SH87	0.003	Ranked	3	out of 23 discrete levels
Upper Clutha	Dart River at The Hillocks	0.003	Ranked	3	out of 23 discrete levels
Upper Clutha	Matukituki River at West Wanaka	0.003	Ranked	3	out of 23 discrete levels
Upper Clutha	Lindis River at Ardgour Road	0.003	Ranked	3	out of 23 discrete levels
North Otago	Kauru River at Ewings	0.004	Ranked	4	out of 23 discrete levels
North Otago	Kakanui River at McCones	0.004	Ranked	4	out of 23 discrete levels
North Otago	Waianakarua River at Browns	0.004	Ranked	4	out of 23 discrete levels
Taieri	Taieri River at Linnburn	0.004	Ranked	4	out of 23 discrete levels
Taieri	3 O'Clock Stream at Hindon	0.004	Ranked	4	out of 23 discrete levels
Upper Clutha	Cardrona River at Mt Barker	0.004	Ranked	4	out of 23 discrete levels
Upper Clutha	Lindis River at Lindis Peak	0.004	Ranked	4	out of 23 discrete levels
Middle Clutha / Central Otago	Dunstan Creek at Beattie Road	0.004	Ranked	4	out of 23 discrete levels
Middle Clutha / Central Otago	Fraser River at Marshall Road	0.004	Ranked	4	out of 23 discrete levels
North Otago	Trotters Creek at Mathesons	0.005	Ranked	5	out of 23 discrete levels
North Otago	Shag River at Craig Road	0.005	Ranked	5	out of 23 discrete levels
Taieri	Kye Burn at SH85 Bridge	0.005	Ranked	5	out of 23 discrete levels
Taieri	Sutton Stream at SH87	0.005	Ranked	5	out of 23 discrete levels
Taieri	Silver Stream at Taieri Depot	0.006	Ranked	6	out of 23 discrete levels
Upper Clutha	Mill Creek at Fish Trap	0.006	Ranked	6	out of 23 discrete levels
North Otago	Shag River at Goodwood Pump	0.007	Ranked	7	out of 23 discrete levels
Taieri	Taieri River at Stonehenge	0.007	Ranked	7	out of 23 discrete levels
Taieri	Nenthorn Stream at Mt Stoker Road	0.008	Ranked	8	out of 23 discrete levels
Taieri	Taieri River at Outram	0.008	Ranked	8	out of 23 discrete levels
Lower Clutha / Pomahaka	Pomahaka River at Glenken	0.008	Ranked	8	out of 23 discrete levels
Dunedin / Southern Coastal	Kaikorai Stream at Brighton Road	0.010	Ranked	9	out of 23 discrete levels
Taieri	Taieri River at Sutton	0.010	Ranked	9	out of 23 discrete levels
Dunedin / Southern Coastal	Tokomairiro River at West Branch Bridge	0.011	Ranked	10	out of 23 discrete levels
Taieri	Taieri River at Tiroiti	0.011	Ranked	10	out of 23 discrete levels
Taieri	Taieri River at Allanton Bridge	0.011	Ranked	10	out of 23 discrete levels
Upper Clutha	Luggate Creek at SH6	0.011	Ranked	10	out of 23 discrete levels
Middle Clutha / Central Otago	Manuherikia River at Galloway	0.011	Ranked	10	out of 23 discrete levels
Dunedin / Southern Coastal	Catlins River at Houipapa	0.014	Ranked	11	out of 23 discrete levels
Lower Clutha / Pomahaka	Pomahaka River at Burkes Ford	0.014	Ranked	11	out of 23 discrete levels
North Otago	Welcome Creek at Steward Road	0.015	Ranked	12	out of 23 discrete levels
Lower Clutha / Pomahaka	Waipahi River at Cairns Peak	0.015	Ranked	12	out of 23 discrete levels
Lower Clutha / Pomahaka	Waitahuna at Tweeds Bridge	0.015	Ranked	12	out of 23 discrete levels
Middle Clutha / Central Otago	Manuherikia River at Ophir	0.016	Ranked	13	out of 23 discrete levels
Middle Clutha / Central Otago	Benger Burn at SH8	0.017	Ranked	14	out of 23 discrete levels
Lower Clutha / Pomahaka	Waipahi River at Waipahi	0.017	Ranked	14	out of 23 discrete levels
Dunedin / Southern Coastal	Lindsays Creek at North Road Bridge	0.018	Ranked	15	out of 23 discrete levels
Dunedin / Southern Coastal	Owaka River at Katea Road	0.018	Ranked	15	out of 23 discrete levels
Dunedin / Southern Coastal	Leith Stream at Dundas Street Bridge	0.021	Ranked	16	out of 23 discrete levels
Middle Clutha / Central Otago	Thomsons Creek at SH85	0.022	Ranked	17	out of 23 discrete levels
Taieri	Taieri River at Waipiata	0.024	Ranked	18	out of 23 discrete levels
Lower Clutha / Pomahaka	Waiwera at Maws Farm	0.025	Ranked	19	out of 23 discrete levels
Lower Clutha / Pomahaka	Waikoikoi Stream at Hailes Bridge	0.031	Ranked	20	out of 23 discrete levels
Taieri	Owhiro Stream at Riverside Road	0.034	Ranked	21	out of 23 discrete levels
Lower Clutha / Pomahaka	Heriot Burn at Park Hill Road	0.034	Ranked	21	out of 23 discrete levels
Lower Clutha / Pomahaka	Crookston Burn at Kelso Road	0.034	Ranked	21	out of 23 discrete levels
Lower Clutha / Pomahaka	Wairuna River at Millar Road	0.038	Ranked	22	out of 23 discrete levels
North Otago	Waiareka Creek at Taipo Road	0.110	Ranked	23	out of 23 discrete levels

Median Regional Ranking Tables – Total Phosphorus

WQ Reporting zone	Reporting name	Median Total P (mg/L)	Regional Ranking		
Upper Clutha	Clutha River at Luggate Bridge	0.002	Ranked	1	out of 34 discrete levels
Upper Clutha	Hawea River at Camphill Bridge	0.004	Ranked	2	out of 34 discrete levels
Middle Clutha / Central Otago	Clutha River at Millers Flat	0.005	Ranked	3	out of 34 discrete levels
North Otago	Kakanui River at Clifton Falls Bridge	0.006	Ranked	4	out of 34 discrete levels
North Otago	Waianakarua River at Browns	0.006	Ranked	4	out of 34 discrete levels
Upper Clutha	Cardrona River at Mt Barker	0.006	Ranked	4	out of 34 discrete levels
Middle Clutha / Central Otago	Dunstan Creek at Beattie Road	0.007	Ranked	5	out of 34 discrete levels
Lower Clutha / Pomahaka	Clutha River at Balclutha	0.007	Ranked	5	out of 34 discrete levels
North Otago	Kauru River at Ewings	0.008	Ranked	6	out of 34 discrete levels
North Otago	Kakanui River at McCones	0.008	Ranked	6	out of 34 discrete levels
North Otago	Shag River at Craig Road	0.008	Ranked	6	out of 34 discrete levels
Dunedin / Southern Coastal	Waikouaiti River at Confluence D/S	0.008	Ranked	6	out of 34 discrete levels
Upper Clutha	Lindis River at Ardgour Road	0.008	Ranked	6	out of 34 discrete levels
Taieri	3 O'Clock Stream at Hindon	0.009	Ranked	7	out of 34 discrete levels
Upper Clutha	Lindis River at Lindis Peak	0.009	Ranked	7	out of 34 discrete levels
Taieri	Kye Burn at SH85 Bridge	0.010	Ranked	8	out of 34 discrete levels
Upper Clutha	Matukituki River at West Wanaka	0.010	Ranked	8	out of 34 discrete levels
Taieri	Silver Stream at Taieri Depot	0.011	Ranked	9	out of 34 discrete levels
Middle Clutha / Central Otago	Fraser River at Marshall Road	0.011	Ranked	9	out of 34 discrete levels
North Otago	Trotters Creek at Mathesons	0.012	Ranked	10	out of 34 discrete levels
Taieri	Deep Stream at SH87	0.012	Ranked	10	out of 34 discrete levels
Upper Clutha	Kawarau River at Chards	0.012	Ranked	10	out of 34 discrete levels
North Otago	Shag River at Goodwood Pump	0.013	Ranked	11	out of 34 discrete levels
Taieri	Taieri River at Linnburn	0.013	Ranked	11	out of 34 discrete levels
Taieri	Waipori River at Waipori Falls Rsv	0.013	Ranked	11	out of 34 discrete levels
Upper Clutha	Luggate Creek at SH6	0.018	Ranked	12	out of 34 discrete levels
Taieri	Sutton Stream at SH87	0.019	Ranked	13	out of 34 discrete levels
Lower Clutha / Pomahaka	Pomahaka River at Glenken	0.019	Ranked	13	out of 34 discrete levels
North Otago	Welcome Creek at Steward Road	0.021	Ranked	14	out of 34 discrete levels
Taieri	Taieri River at Stonehenge	0.021	Ranked	14	out of 34 discrete levels
Dunedin / Southern Coastal	Kaikorai Stream at Brighton Road	0.023	Ranked	15	out of 34 discrete levels
Upper Clutha	Mill Creek at Fish Trap	0.024	Ranked	16	out of 34 discrete levels
Middle Clutha / Central Otago	Manuherikia River at Galloway	0.025	Ranked	17	out of 34 discrete levels
Taieri	Nenthorn Stream at Mt Stoker Road	0.028	Ranked	18	out of 34 discrete levels
Dunedin / Southern Coastal	Lindsays Creek at North Road Bridge	0.030	Ranked	19	out of 34 discrete levels
Dunedin / Southern Coastal	Tokomairiro River at West Branch Bridge	0.030	Ranked	19	out of 34 discrete levels
Dunedin / Southern Coastal	Catlins River at Houipapa	0.030	Ranked	19	out of 34 discrete levels
Taieri	Taieri River at Outram	0.030	Ranked	19	out of 34 discrete levels
Upper Clutha	Dart River at The Hillocks	0.030	Ranked	19	out of 34 discrete levels
Dunedin / Southern Coastal	Owaka River at Katea Road	0.031	Ranked	20	out of 34 discrete levels
Upper Clutha	Shotover River at Bowens Peak	0.031	Ranked	20	out of 34 discrete levels
Dunedin / Southern Coastal	Leith Stream at Dundas Street Bridge	0.032	Ranked	21	out of 34 discrete levels
Middle Clutha / Central Otago	Manuherikia River at Ophir	0.032	Ranked	21	out of 34 discrete levels
Taieri	Taieri River at Allanton Bridge	0.034	Ranked	22	out of 34 discrete levels
Taieri	Taieri River at Sutton	0.035	Ranked	23	out of 34 discrete levels
Middle Clutha / Central Otago	Benger Burn at SH8	0.035	Ranked	23	out of 34 discrete levels
Lower Clutha / Pomahaka	Pomahaka River at Burkes Ford	0.035	Ranked	23	out of 34 discrete levels
Lower Clutha / Pomahaka	Waipahi River at Waipahi	0.038	Ranked	24	out of 34 discrete levels
Taieri	Taieri River at Tiroiti	0.039	Ranked	25	out of 34 discrete levels
Lower Clutha / Pomahaka	Waitahuna at Tweeds Bridge	0.039	Ranked	25	out of 34 discrete levels
Lower Clutha / Pomahaka	Waipahi River at Cairns Peak	0.044	Ranked	26	out of 34 discrete levels
Lower Clutha / Pomahaka	Waiwera at Maws Farm	0.052	Ranked	27	out of 34 discrete levels
Taieri	Taieri River at Waipiata	0.054	Ranked	28	out of 34 discrete levels
Middle Clutha / Central Otago	Thomsons Creek at SH85	0.054	Ranked	28	out of 34 discrete levels
Lower Clutha / Pomahaka	Crookston Burn at Kelso Road	0.055	Ranked	29	out of 34 discrete levels
Lower Clutha / Pomahaka	Waikoikoi Stream at Hailes Bridge	0.065	Ranked	30	out of 34 discrete levels
Lower Clutha / Pomahaka	Heriot Burn at Park Hill Road	0.069	Ranked	31	out of 34 discrete levels
Lower Clutha / Pomahaka	Wairuna River at Millar Road	0.090	Ranked	32	out of 34 discrete levels
Taieri	Owhiro Stream at Riverside Road	0.110	Ranked	33	out of 34 discrete levels
North Otago	Waiareka Creek at Taipo Road	0.160	Ranked	34	out of 34 discrete levels

Median Regional Ranking Tables – Escerichia coli (CFU/100ml)

WQ Reporting zone	Reporting name	Median *E. coli* (CFU/100ml)	Ranking		
Upper Clutha	Clutha River at Luggate Bridge	1	Ranked	1	out of 54 discrete levels
Upper Clutha	Hawea River at Camphill Bridge	2	Ranked	2	out of 54 discrete levels
Upper Clutha	Shotover River at Bowens Peak	4	Ranked	3	out of 54 discrete levels
Upper Clutha	Kawarau River at Chards	7	Ranked	4	out of 54 discrete levels
Upper Clutha	Dart River at The Hillocks	8	Ranked	5	out of 54 discrete levels
Middle Clutha / Central Otago	Clutha River at Millers Flat	12	Ranked	6	out of 54 discrete levels
Taieri	3 O'Clock Stream at Hindon	13	Ranked	7	out of 54 discrete levels
Taieri	Waipori River at Waipori Falls Rsv	13	Ranked	7	out of 54 discrete levels
Middle Clutha / Central Otago	Fraser River at Marshall Road	18	Ranked	8	out of 54 discrete levels
Taieri	Nenthorn Stream at Mt Stoker Road	22	Ranked	9	out of 54 discrete levels
Upper Clutha	Lindis River at Lindis Peak	22	Ranked	9	out of 54 discrete levels
Upper Clutha	Matukituki River at West Wanaka	23	Ranked	10	out of 54 discrete levels
Upper Clutha	Lindis River at Ardgour Road	24	Ranked	11	out of 54 discrete levels
Upper Clutha	Luggate Creek at SH6	25	Ranked	12	out of 54 discrete levels
Middle Clutha / Central Otago	Dunstan Creek at Beattie Road	27	Ranked	13	out of 54 discrete levels
Taieri	Kye Burn at SH85 Bridge	29	Ranked	14	out of 54 discrete levels
Dunedin / Southern Coastal	Waikouaiti River at Confluence D/S	31	Ranked	15	out of 54 discrete levels
Lower Clutha / Pomahaka	Clutha River at Balclutha	32	Ranked	16	out of 54 discrete levels
North Otago	Waianakarua River at Browns	33	Ranked	17	out of 54 discrete levels
Upper Clutha	Cardrona River at Mt Barker	38	Ranked	18	out of 54 discrete levels
Taieri	Taieri River at Stonehenge	41	Ranked	19	out of 54 discrete levels
North Otago	Kauru River at Ewings	42	Ranked	20	out of 54 discrete levels
Taieri	Taieri River at Linnburn	43	Ranked	21	out of 54 discrete levels
Middle Clutha / Central Otago	Manuherikia River at Galloway	44	Ranked	22	out of 54 discrete levels
North Otago	Shag River at Craig Road	48	Ranked	23	out of 54 discrete levels
North Otago	Welcome Creek at Steward Road	50	Ranked	24	out of 54 discrete levels
Taieri	Deep Stream at SH87	54	Ranked	25	out of 54 discrete levels
Taieri	Taieri River at Outram	61	Ranked	26	out of 54 discrete levels
North Otago	Shag River at Goodwood Pump	66	Ranked	27	out of 54 discrete levels
North Otago	Kakanui River at Clifton Falls Bridge	70	Ranked	28	out of 54 discrete levels
Taieri	Taieri River at Waipiata	74	Ranked	29	out of 54 discrete levels
North Otago	Trotters Creek at Mathesons	80	Ranked	30	out of 54 discrete levels
North Otago	Kakanui River at McCones	88	Ranked	31	out of 54 discrete levels
Lower Clutha / Pomahaka	Pomahaka River at Burkes Ford	92	Ranked	32	out of 54 discrete levels
Middle Clutha / Central Otago	Manuherikia River at Ophir	96	Ranked	33	out of 54 discrete levels
Taieri	Taieri River at Tiroiti	104	Ranked	34	out of 54 discrete levels
Taieri	Taieri River at Sutton	105	Ranked	35	out of 54 discrete levels
Taieri	Taieri River at Allanton Bridge	120	Ranked	36	out of 54 discrete levels
Lower Clutha / Pomahaka	Waipahi River at Waipahi	120	Ranked	36	out of 54 discrete levels
Taieri	Sutton Stream at SH87	128	Ranked	37	out of 54 discrete levels
Dunedin / Southern Coastal	Tokomairiro River at West Branch Bridge	140	Ranked	38	out of 54 discrete levels
Taieri	Silver Stream at Taieri Depot	140	Ranked	38	out of 54 discrete levels
Upper Clutha	Mill Creek at Fish Trap	140	Ranked	38	out of 54 discrete levels
Dunedin / Southern Coastal	Catlins River at Houipapa	145	Ranked	39	out of 54 discrete levels
Dunedin / Southern Coastal	Owaka River at Katea Road	170	Ranked	40	out of 54 discrete levels
Middle Clutha / Central Otago	Benger Burn at SH8	175	Ranked	41	out of 54 discrete levels
Lower Clutha / Pomahaka	Waiwera at Maws Farm	190	Ranked	42	out of 54 discrete levels
Lower Clutha / Pomahaka	Pomahaka River at Glenken	210	Ranked	43	out of 54 discrete levels
North Otago	Waiareka Creek at Taipo Road	230	Ranked	44	out of 54 discrete levels
Lower Clutha / Pomahaka	Waipahi River at Cairns Peak	235	Ranked	45	out of 54 discrete levels
Lower Clutha / Pomahaka	Waitahuna at Tweeds Bridge	290	Ranked	46	out of 54 discrete levels
Middle Clutha / Central Otago	Thomsons Creek at SH85	310	Ranked	47	out of 54 discrete levels
Dunedin / Southern Coastal	Lindsays Creek at North Road Bridge	450	Ranked	48	out of 54 discrete levels
Dunedin / Southern Coastal	Kaikorai Stream at Brighton Road	450	Ranked	48	out of 54 discrete levels
Dunedin / Southern Coastal	Leith Stream at Dundas Street Bridge	480	Ranked	49	out of 54 discrete levels
Lower Clutha / Pomahaka	Crookston Burn at Kelso Road	500	Ranked	50	out of 54 discrete levels
Lower Clutha / Pomahaka	Waikoikoi Stream at Hailes Bridge	590	Ranked	51	out of 54 discrete levels
Lower Clutha / Pomahaka	Heriot Burn at Park Hill Road	600	Ranked	52	out of 54 discrete levels
Lower Clutha / Pomahaka	Wairuna River at Millar Road	620	Ranked	53	out of 54 discrete levels
Taieri	Owhiro Stream at Riverside Road	650	Ranked	54	out of 54 discrete levels

Median Regional Ranking Tables – Turbidity (NTU)

WQ Reporting zone	Reporting name	Median Turbidity (NTU)	Regional Ranking		
North Otago	Kauru River at Ewings	0.4	Ranked	1	out of 57 discrete levels
Upper Clutha	Hawea River at Camphill Bridge	0.4	Ranked	2	out of 57 discrete levels
North Otago	Waianakarua River at Browns	0.5	Ranked	3	out of 57 discrete levels
North Otago	Kakanui River at Clifton Falls Bridge	0.5	Ranked	4	out of 57 discrete levels
North Otago	Shag River at Craig Road	0.6	Ranked	5	out of 57 discrete levels
North Otago	Shag River at Goodwood Pump	0.6	Ranked	6	out of 57 discrete levels
Taieri	3 O'Clock Stream at Hindon	0.6	Ranked	7	out of 57 discrete levels
North Otago	Welcome Creek at Steward Road	0.7	Ranked	8	out of 57 discrete levels
North Otago	Kakanui River at McCones	0.7	Ranked	9	out of 57 discrete levels
Middle Clutha / Central Otago	Dunstan Creek at Beattie Road	0.8	Ranked	10	out of 57 discrete levels
Dunedin / Southern Coastal	Waikouaiti River at Confluence D/S	0.9	Ranked	11	out of 57 discrete levels
Taieri	Deep Stream at SH87	0.9	Ranked	12	out of 57 discrete levels
Upper Clutha	Clutha River at Luggate Bridge	0.9	Ranked	13	out of 57 discrete levels
Upper Clutha	Luggate Creek at SH6	1.0	Ranked	14	out of 57 discrete levels
Upper Clutha	Cardrona River at Mt Barker	1.0	Ranked	15	out of 57 discrete levels
Taieri	Nenthorn Stream at Mt Stoker Road	1.3	Ranked	16	out of 57 discrete levels
Middle Clutha / Central Otago	Fraser River at Marshall Road	1.3	Ranked	16	out of 57 discrete levels
Upper Clutha	Lindis River at Lindis Peak	1.3	Ranked	17	out of 57 discrete levels
Upper Clutha	Lindis River at Ardgour Road	1.4	Ranked	18	out of 57 discrete levels
Taieri	Sutton Stream at SH87	1.4	Ranked	19	out of 57 discrete levels
Taieri	Taieri River at Linnburn	1.5	Ranked	20	out of 57 discrete levels
Taieri	Taieri River at Stonehenge	1.5	Ranked	21	out of 57 discrete levels
Taieri	Silver Stream at Taieri Depot	1.6	Ranked	22	out of 57 discrete levels
Taieri	Kye Burn at SH85 Bridge	1.6	Ranked	23	out of 57 discrete levels
Taieri	Waipori River at Waipori Falls Rsv	1.7	Ranked	24	out of 57 discrete levels
North Otago	Trotters Creek at Mathesons	1.8	Ranked	25	out of 57 discrete levels
North Otago	Waiareka Creek at Taipo Road	1.9	Ranked	26	out of 57 discrete levels
Upper Clutha	Matukituki River at West Wanaka	2.1	Ranked	27	out of 57 discrete levels
Middle Clutha / Central Otago	Benger Burn at SH8	2.2	Ranked	28	out of 57 discrete levels
Dunedin / Southern Coastal	Leith Stream at Dundas Street Bridge	2.3	Ranked	29	out of 57 discrete levels
Middle Clutha / Central Otago	Clutha River at Millers Flat	2.3	Ranked	30	out of 57 discrete levels
Lower Clutha / Pomahaka	Pomahaka River at Glenken	2.5	Ranked	31	out of 57 discrete levels
Middle Clutha / Central Otago	Manuherikia River at Galloway	2.6	Ranked	32	out of 57 discrete levels
Dunedin / Southern Coastal	Tokomairiro River at West Branch Bridge	2.8	Ranked	33	out of 57 discrete levels
Dunedin / Southern Coastal	Owaka River at Katea Road	2.8	Ranked	33	out of 57 discrete levels
Dunedin / Southern Coastal	Lindsays Creek at North Road Bridge	2.8	Ranked	34	out of 57 discrete levels
Middle Clutha / Central Otago	Manuherikia River at Ophir	2.8	Ranked	34	out of 57 discrete levels
Lower Clutha / Pomahaka	Waipahi River at Waipahi	2.9	Ranked	35	out of 57 discrete levels
Dunedin / Southern Coastal	Kaikorai Stream at Brighton Road	3.0	Ranked	36	out of 57 discrete levels
Taieri	Taieri River at Waipiata	3.3	Ranked	37	out of 57 discrete levels
Upper Clutha	Mill Creek at Fish Trap	3.4	Ranked	38	out of 57 discrete levels
Lower Clutha / Pomahaka	Waiwera at Maws Farm	3.4	Ranked	39	out of 57 discrete levels
Lower Clutha / Pomahaka	Clutha River at Balclutha	3.4	Ranked	40	out of 57 discrete levels
Dunedin / Southern Coastal	Catlins River at Houipapa	3.6	Ranked	41	out of 57 discrete levels
Middle Clutha / Central Otago	Thomsons Creek at SH85	3.7	Ranked	42	out of 57 discrete levels
Upper Clutha	Kawarau River at Chards	3.8	Ranked	43	out of 57 discrete levels
Lower Clutha / Pomahaka	Pomahaka River at Burkes Ford	3.9	Ranked	44	out of 57 discrete levels
Taieri	Taieri River at Outram	4.1	Ranked	45	out of 57 discrete levels
Taieri	Taieri River at Sutton	4.1	Ranked	46	out of 57 discrete levels
Lower Clutha / Pomahaka	Crookston Burn at Kelso Road	4.2	Ranked	47	out of 57 discrete levels
Lower Clutha / Pomahaka	Waitahuna at Tweeds Bridge	4.6	Ranked	48	out of 57 discrete levels
Taieri	Taieri River at Allanton Bridge	4.6	Ranked	49	out of 57 discrete levels
Taieri	Taieri River at Tiroiti	4.9	Ranked	50	out of 57 discrete levels
Lower Clutha / Pomahaka	Waikoikoi Stream at Hailes Bridge	5.1	Ranked	51	out of 57 discrete levels
Lower Clutha / Pomahaka	Waipahi River at Cairns Peak	5.5	Ranked	52	out of 57 discrete levels
Lower Clutha / Pomahaka	Heriot Burn at Park Hill Road	6.1	Ranked	53	out of 57 discrete levels
Lower Clutha / Pomahaka	Wairuna River at Millar Road	9.5	Ranked	54	out of 57 discrete levels
Upper Clutha	Shotover River at Bowens Peak	11.1	Ranked	55	out of 57 discrete levels
Upper Clutha	Dart River at The Hillocks	13.0	Ranked	56	out of 57 discrete levels
Taieri	Owhiro Stream at Riverside Road	18.0	Ranked	57	out of 57 discrete levels

Median Regional Ranking Tables – MCI (Unitless)

WQ Reporting zone	Reporting name	Median MCI (Unitless)	Ranking		
North Otago	Kauru River at Ewings	118.0	Ranked	1	out of 33 discrete levels
Middle Clutha / Central Otago	Dunstan Creek at Beattie Road	118.0	Ranked	1	out of 33 discrete levels
Dunedin / Southern Coastal	Tokomairiro River at West Branch Bridge	113.9	Ranked	2	out of 33 discrete levels
North Otago	Kakanui River at Clifton Falls Bridge	113.6	Ranked	3	out of 33 discrete levels
Dunedin / Southern Coastal	Catlins River at Houipapa	112.0	Ranked	4	out of 33 discrete levels
Lower Clutha / Pomahaka	Waitahuna at Tweeds Bridge	111.4	Ranked	5	out of 33 discrete levels
Taieri	Taieri River at Outram	109.6	Ranked	6	out of 33 discrete levels
Taieri	Waipori River at Waipori Falls Rsv	108.6	Ranked	7	out of 33 discrete levels
Upper Clutha	Luggate Creek at SH6	108.4	Ranked	8	out of 33 discrete levels
Lower Clutha / Pomahaka	Waipahi River at Cairns Peak	108.3	Ranked	9	out of 33 discrete levels
Upper Clutha	Cardrona River at Mt Barker	107.6	Ranked	10	out of 33 discrete levels
Taieri	Taieri River at Tiroiti	107.1	Ranked	11	out of 33 discrete levels
Middle Clutha / Central Otago	Manuherikia River at Ophir	106.1	Ranked	12	out of 33 discrete levels
North Otago	Waianakarua River at Browns	105.6	Ranked	13	out of 33 discrete levels
Taieri	Kye Burn at SH85 Bridge	105.0	Ranked	14	out of 33 discrete levels
Upper Clutha	Shotover River at Bowens Peak	104.2	Ranked	15	out of 33 discrete levels
Upper Clutha	Lindis River at Ardgour Road	103.2	Ranked	16	out of 33 discrete levels
Taieri	Sutton Stream at SH87	100.3	Ranked	17	out of 33 discrete levels
Upper Clutha	Kawarau River at Chards	99.5	Ranked	18	out of 33 discrete levels
North Otago	Shag River at Craig Road	98.7	Ranked	19	out of 33 discrete levels
Upper Clutha	Clutha River at Luggate Bridge	93.1	Ranked	20	out of 33 discrete levels
Lower Clutha / Pomahaka	Heriot Burn at Park Hill Road	92.9	Ranked	21	out of 33 discrete levels
North Otago	Kakanui River at McCones	90.0	Ranked	22	out of 33 discrete levels
Dunedin / Southern Coastal	Leith Stream at Dundas Street Bridge	90.0	Ranked	22	out of 33 discrete levels
Lower Clutha / Pomahaka	Waipahi River at Waipahi	90.0	Ranked	22	out of 33 discrete levels
Dunedin / Southern Coastal	Lindsays Creek at North Road Bridge	89.5	Ranked	23	out of 33 discrete levels
Taieri	Silver Stream at Taieri Depot	89.4	Ranked	24	out of 33 discrete levels
Dunedin / Southern Coastal	Waikouaiti River at Confluence D/S	88.6	Ranked	25	out of 33 discrete levels
Lower Clutha / Pomahaka	Wairuna River at Millar Road	87.8	Ranked	26	out of 33 discrete levels
North Otago	Trotters Creek at Mathesons	87.4	Ranked	27	out of 33 discrete levels
Upper Clutha	Mill Creek at Fish Trap	86.7	Ranked	28	out of 33 discrete levels
North Otago	Shag River at Goodwood Pump	86.0	Ranked	29	out of 33 discrete levels
Middle Clutha / Central Otago	Clutha River at Millers Flat	85.0	Ranked	30	out of 33 discrete levels
Lower Clutha / Pomahaka	Waiwera at Maws Farm	84.5	Ranked	31	out of 33 discrete levels
North Otago	Waiareka Creek at Taipo Road	71.7	Ranked	32	out of 33 discrete levels
Dunedin / Southern Coastal	Kaikorai Stream at Brighton Road	68.3	Ranked	33	out of 33 discrete levels

Appendix H – Comparison of Schedule 15 (Water Plan) E. coli limits to the 2017 amended NPSFM (2014) NOF Swimmability limits.

The government has recently amended the 2014 National Policy Statement for Freshwater Management (NPSFM). It sets national targets relating to 'swimmability' for New Zealand's rivers and lakes. The Clean Water Package includes numerous other changes to the NPSFM such as provisions for stock exclusion, and requirements for regional councils to monitor the ecological health of our rivers and lakes. The changes can be viewed online at the MfE website[20].

The Government has set a national target of making 90 percent of New Zealand's rivers (fourth order or greater) and lakes (with perimeters greater than 1.5 km) swimmable by 2040. The stream order describes the relative size of streams. Streams with no tributaries are "first order", streams with two first order tributaries are second order, and with two second order tributaries are third order and so on. Examples of fourth order streams in the Dunedin locale include the Water of Leith alongside the University of Otago, Silverstream at Mosgiel and the Kaikorai Stream at State Highway 1. The Manuherikia River at Alexandra is seventh order and Otago's biggest river, the Clutha at Balclutha, is eighth order. Around 90 percent of New Zealand's catchments flow into rivers that are fourth order or bigger (MfE website).

The NPSFM grading proposals are based on a "sophisticated" grading system that uses four statistical measures of *E.coli* concentrations when assessing river swimmability; and one statistical measure for toxic algae bio-volumes when assessing lake swimmability. The four statistical measures of river *E.coli* data are presented in the *E. coli* attribute table in Appendix H Table 1; and Appendix H Table 3. As stated in the footnote to the Appendix H Table 3, "Attribute state must be determined by satisfying all numeric attribute states".

Otago Regional Council has set targets for *E. coli* for the region in Schedule 15 (Water Plan) (Appendix H Table 2). A key question for Council is whether the Schedule 15 (Water Plan) limits for *E. coli* for each Receiving Water Group (RWG) meet the requirements or 'bottom line acceptable state' of the NPSFM (2014).

For each ORC State of Environment monitoring site, it is possible to calculate both the Schedule 15 (Water Plan) 80th percentile *E. coli* concentrations when flows are at or below median flow (at the relevant flow reference site); as well as the four separate NOF *E.coli* attribute statistics that are calculated from *E. coli* data collected at all flows (summarised in Appendix H Table 1). These values can then be compared, as illustrated in Appendix H Figures 1 through 4. Using regression analysis, it is possible to predict the 'likely' NOF E. coli attribute state for each RWG under Scehdule 15. This has been done based on the regression relationships shown in Appendix H Figures 1 through 4 and presented in Appendix H Table 2.

Comparison of Schedule 15 (Water Plan) limits to the 4 separate statistical tests within the NPSFM has shown (Appendix H Table 2):

- That the *E. coli* limits set in Schedule 15 (Water Plan) for Receiving Water Group 3 (Upper Clutha upstream of the Southern Great Lakes) provides compliance against the four separate statistical tests in the NPSFM and as a minimum, will provide a blue (A grade) swimmability category. The minimum requirement is a yellow or C grade.

[20] https://www.mfe.govt.nz/sites/default/files/media/npsfm-showing-changes_0.pdf

- With the exception of some catchments in the Pomahaka catchment, the *E. coli* limits set in Schedule 15 (Water Plan) for Receiving Water Group 1 and 2 (that covers the remainder of the Otago region), will provide good compliance against the four separate statistical tests in the NPSFM, and as a minimum, will provide a blue (A grade), green (B grade) or in some cases an yellow (C grade) category. The yellow, C grade category being the minimum requirement.\
- For Receiving Water Groups 4 and 5 that relate to the lakes throughout Otago, the *E. coli* limits set in Schedule 15 (Water Plan) provides compliance against the four separate statistical tests in the NPSFM and as a minimum, will provide a blue (A grade) or green (B grade) swimmability category. The minimum requirement is a yellow or C grade.

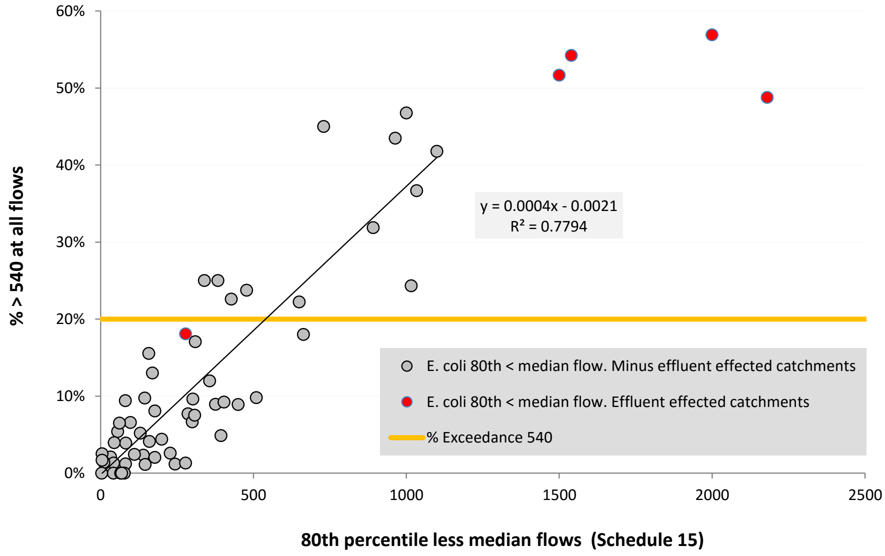
In the case of the Pomahaka catchment, monitoring sites in some catchments return high 95th percentiles at all flows, even though they may be compliant with the Schedule 15 (Water Plan) limit. This is believed to be due to effluent storage issues and a prevalence of mole and tile drains through areas of the catchment resulting in very high *E. coli* peaks under high flow conditions and elevated *E. coli* concentrations at low to moderate flows. The sub-catchments this relates to include the Heriot Burn, Crookston Burn, Waikoikoi Stream, Wairuna River and the lower Waipahi River. These sites have been excluded from the regression analysis described above, as they are outliers in the data set and have unique circumstances that differ from the wider Otago Region. To address issues of high *E. coli* in these catchments, ORC are working actively throughout the Pomahaka catchment with groups such as the Pomahaka Watercare Trust, the Landcare Trust and the Clutha Development Trust to address water quality issues. A large part of this effort is focused on improving bacterial water quality.

Appendix H Table 1: NPSFM (2014) NOF *E. coli* attribute states.

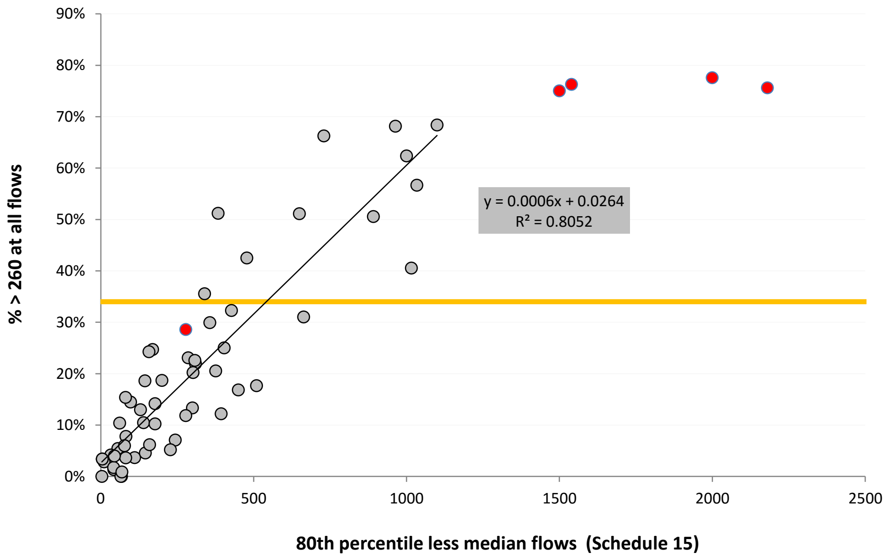
Attribute state	Median concentration (CFU/100ml)	95th percentile (CFU/100ml)	% Exceedances over 260 CFU/100ml	% Exceedances over 540 CFU/100ml
A (Blue)	<= 130	<= 540	< 20%	< 5%
B (Green)	<= 130	<= 1000	20 - 30%	5 - 10%
C (Yellow)	<= 130	<= 1200	20 - 34%	10 - 20%
D (Orange - Exceeded)	> 130	>1200	> 34%	20 - 30%
E (Red - Exceeded)	> 260	> 1200	> 50%	> 30%

Appendix H Table 2: Predicted states for NOF *E. coli* attributes states when compared to the Plan Schedule 15 (Water Plan) *E. coli* limits for the different RWG's.

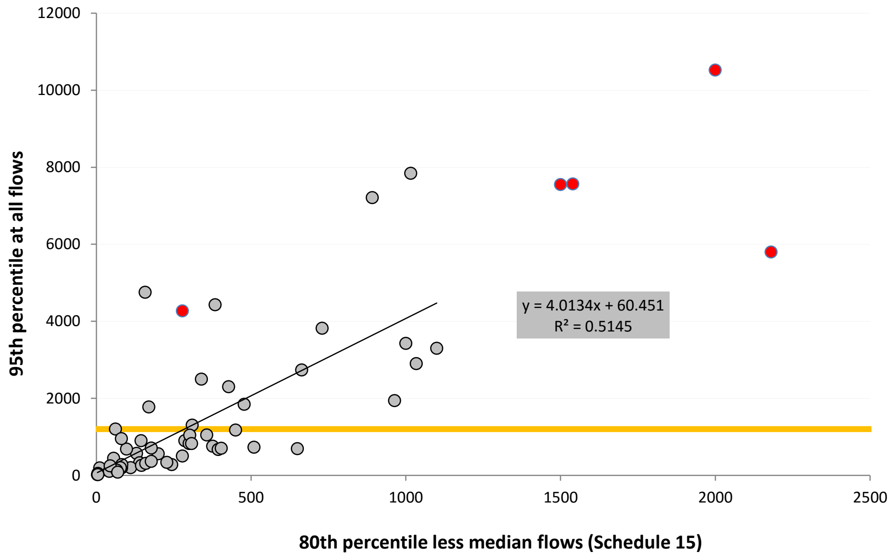
ORC Schedule 15 Receiving Water Group (RWG)	ORC Schedule 15 limit 80th percentile less median flow	Estimated median all flows	Estimated 95th percentile all flows	Estimated % exceedances > 260 all flows	Estimated % exceedances > 540 all flows
Group 1/2	260	(A) 89	(C) 1104	(A) 18%	(B/C) 10%
Group 3	50	(A) 10	(A) 261	(A) 6%	(A) 2%
Group 4	126	(A) 39	(B) 566	(A) 10%	(A/B) 5%
Group 5	10	(A) 1	(A) 101	(A) 3%	(A) 0%



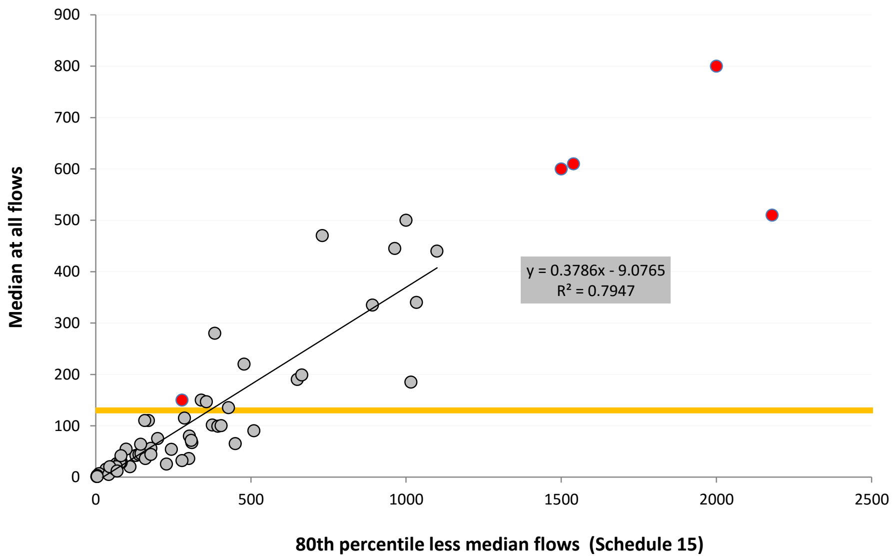
Appendix H Figure 1: % of *E. coli* data > 540 versus the 80th percentile *E. coli* at flows less than median flow for all ORC SoE monitoring sites. *The grey circles are used in the regression analysis; the red circles have been excluded from the regression analysis (see text for reasoning)*.



Appendix H Figure 2: % of *E. coli* data > 260 versus the 80th percentile *E. coli* at flows less than median flow for all ORC SoE monitoring sites. *The grey circles are used in the regression analysis; the red circles have been excluded from the regression analysis (see text for reasoning)*.



Appendix H Figure 3: 95th percentile *E. coli* at all flows versus the 80th percentile *E. coli* at flows less than median flow for ORC SoE monitoring sites. *The grey circles are used in the regression analysis; the red circles have been excluded from the regression analysis (see text for reasoning)*.



Appendix H Figure 4: Median *E. coli* at all flows versus the 80th percentile *E. coli* at less than median flow for all ORC SoE monitoring sites. *The grey circles are used in the regression analysis; the red circles have been excluded from the regression analysis (see text for reasoning)*.

Appendix H Table 3: NPSFM (2014) NOF *E. coli* attribute states.

Value	Human health for recreation				
Freshwater Body Type	Lakes and rivers				
Attribute	*Escherichia coli (E. coli)*				
Attribute Unit	*E. coli*/100 mL (number of *E. coli* per hundred millilitres)				
Attribute State[1 2]	Numeric Attribute State				Narrative Attribute State
	% exceedances over 540 cfu/100 mL	% exceedences over 260 cfu/100 mL	Median concentration (cfu/100 mL)	95th percentile of *E. coli*/100 mL	Description of risk of Campylobacter infection (based on *E. coli* indicator)
A (Blue)	<5%	<20%	≤130	≤540	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 1%*
B (Green)	5-10%	20-30%	≤130	≤1000	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 2%*
C (Yellow)	10-20%	20-34%	≤130	≤1200	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 3%*
D (Orange)	20-30%	>34%	>130	>1200	20-30% of the time the estimated risk is ≥50 in 1000 (>5% risk) The predicted average infection risk is >3%*
E (Red)	>30%	>50%	>260	>1200	For more than 30% of the time the estimated risk is ≥50 in 1000 (>5% risk) The predicted average infection risk is >7%*

* The predicted average infection risk is the overall average infection to swimmers based on a random exposure on a random day, ignoring any possibility of not swimming during high flows or when a surveillance advisory is in place (assuming that the *E. coli* concentration follows a lognormal distribution). Actual risk will generally be less if a person does not swim during high flows.

[1] Attribute state should be determined by using a minimum of 60 samples over a maximum of 5 years, collected on a regular basis regardless of weather and flow conditions. However, where a sample has been missed due to adverse weather or error, attribute state may be determined using samples over a longer timeframe.

[2] Attribute state must be determined by satisfying all numeric attribute states.