Christchurch City Surface Water Quality Annual Report 2023

Prepared to meet the Requirements of CRC231955

Christchurch City Council

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Christchurch City Council

Internal Document Review

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Executive Summary

- The Christchurch City Council (Council) monitors the water quality of representative waterbodies within Christchurch and Banks Peninsula, as part of the Comprehensive Stormwater Network Discharge Consent (CSNDC; CRC231955).
- Monthly water samples were collected from 51 sites in Banks Peninsula (Stream Reserve Drain, Balguerie Stream, and Aylmers Stream), Ōtākaro-Avon River, Ōpāwaho-Heathcote River, Huritini-Halswell River, Pūharakekenui-Styx River, Ōtūkaikino River, Linwood Canal, and coastal water (Ihutai – Avon-Heathcote Estuary, Lyttelton Port, Cass Bay, and Akaroa Harbour) catchments. Eleven sites in the Pūharakekenui-Styx River catchment were monitored by the Styx Living Laboratory Trust. Two wet weather events were also monitored in the Pūharakekenui-Styx River catchment.
- Approximately 35,000 tests were conducted during 2021-2023 for the Council monthly monitoring, with over 26,000 of these allowing the assessment of each waterway site against relevant guideline levels.
- The priority parameters where issues were identified for freshwater sites include faecal indicator bacteria (as indicated by *Escherichia coli*), total suspended solids (TSS), dissolved copper, phosphorus (dissolved reactive phosphorus) and dissolved zinc and conductivity. The coastal sites generally had issues with dissolved copper and zinc contamination, as well as high turbidity and enterococci.
- Based on the average Water Quality Index (WQI) for each catchment or area, Banks Peninsula recorded 'poor' water quality, the Ōpāwaho-Heathcote River and Huritini-Halswell River catchments recorded 'fair' water quality, and the Ōtākaro-Avon River, Pūharakekenui-Styx, and Ōtūkaikino River catchments recorded 'good' water quality. The Ōtūkaikino River recorded the best overall water quality out of all the catchments. The best sites for water quality were jointly the Wairarapa Stream, Waimairi Stream, and Avon River at Mona Vale, followed by Ōtūkaikino at Scout Camp, and Avon River at Manchester St. The area recording the lowest average WQI worst water quality was the Banks Peninsula waterways, partly due to the stricter water quality standards that apply to protect ecological values, compared to the city waterways. The worst site for water quality was Curlett Stream at Motorway, followed by Curlett Stream upstream of Heathcote River, and Aylmers Stream.
- Trend analysis showed that water quality at the sites has mostly remained steady over time since monitoring began in the early to mid-2000s.
- Wet weather monitoring concentrations varied compared to the monthly monitoring. Of note, copper, lead, zinc and BOD_5 were higher in the wet weather monitoring.
- Twenty-five of the 50 sites (Lyttelton Port is not included in this assessment) triggered further investigations under the CSNDC, due to not meeting the Attribute

Target Levels for TSS, dissolved copper, or dissolved zinc. These sites are prioritised to three: Nottingham Stream at Candys Rd in the Huritini-Halswell River catchment; Heathcote River at Tunnel Rd and Heathcote River at Ferrymead Bridge in the Ōpāwaho-Heathcote River catchment. Some sites are the same sites prioritised for investigation for the last two years and therefore Condition 59 investigations are already under way.

- Several recommendations are provided in the report. In particular:
    - Nottingham Stream, Lower Heathcote River, Addington Brook and Curlett Stream are prioritised for contaminant source control and treatment.
    - Stormwater treatment in Banks Peninsula is prioritised and investigated as part of the Banks Peninsula Stormwater Management Plan.
    - Council and Environment Canterbury continue to investigate the increasing levels of *E. coli* and turbidity in the Ōtūkaikino River.
    - Construction of the Council stormwater wetlands in Belfast (Ōtūkaikino River catchment) is prioritised.
    - Erosion and sediment control measures continue to be implemented as a priority, and further investigations are carried out to determine how to mitigate discharges of loess sediment into the Ōpāwaho-Heathcote River (principally Cashmere Stream).
    - Investigations on sources of faecal and phosphorus contamination are carried out.
    - Tasks under the Action Plan for the Council Community Outcome for Healthy Water Bodies are implemented.
- If the recommendations in this report are implemented (at a bare minimum), surface water quality improvements are anticipated across the City. However, this would require significant financial investment which is not currently being allocated to these tasks. In addition, these changes may only occur over long time scales, due to the size of the issues and the lag time in observing reductions in contaminants within the environment.

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1. Introduction

The Christchurch City Council (Council) is required to monitor the water quality of representative waterbodies within Christchurch and Banks Peninsula, as part of the Comprehensive Stormwater Network Discharge Consent (CSNDC; CRC231955). In accordance with the CSNDC Environmental Monitoring Programme (EMP), monitoring was undertaken monthly at waterway and coastal sites. This report summarises the results of monthly monitoring for the 2023 calendar year and analyses trends over time since monitoring commenced. The report also analyses wet weather monitoring results from five sites in the Pūharakekenui-Styx River catchment in 2023. The results of community monitoring in the Pūharakekenui-Styx River catchment in 2023 by the Styx Living Laboratory Trust (SLLT) are also presented in this report.

2. Methods

2.1. Monitoring Sites

Water samples were collected from 47 sites from waterways within the catchments of Banks Peninsula (Stream Reserve Drain/Zephyr Stream, Balguerie Stream, and Aylmers Stream), Ōtākaro-Avon River, Ōpāwaho-Heathcote River, Huritini-Halswell River, Pūharakekenui-Styx River, Ōtūkaikino River, and Linwood Canal (Table 1; Figure 1). Samples were also taken from four coastal sites: Ihutai/Avon-Heathcote Estuary, Lyttelton Port, Cass Bay, and Akaroa Harbour (Table 1; Figure 1). An additional 11 sites in the Pūharakekenui-Styx River catchment were also monitored by the Styx Living Laboratory Trust (SLLT) (Table 1).

Seven of the waterway sites[1] and all four coastal sites were specifically chosen because they are in proximity to stormwater outfalls. However, it should be noted that there are hundreds of outfalls throughout the Christchurch City catchments and therefore many of the other sites are also located near stormwater discharge pipes.

2.2. Sampling and Testing Methods

Council has monitored most sites monthly since approximately 2007 (Table i, Appendix A). These samples were collected predominantly via grab sampling, with field testing of temperature and dissolved oxygen using a hand-held meter (YSI Pro ODO meter). Eight sites were in strongly tidal areas[2] (defined by having median 2020

[1] Avon River at Carlton Mill, Avon River at Avondale Rd, Heathcote River at Catherine St, Heathcote River at Mackenzie Ave, Haytons Stream, Curlett Stream at Motorway, and Balguerie Stream

[2] Avon River at Bridge St, Heathcote River at Ferrymead Bridge, Heathcote River at Tunnel Rd, Linwood Canal, Ihutai/Avon-Heathcote Estuary, Lyttelton Port, Cass Bay, and Akaroa Harbour

salinity values of ≥2.5), where sampling was undertaken at low tide (± 1 hour), with sampling within catchments starting at the most downstream site. The exceptions to this were the Ihutai/Avon-Heathcote Estuary and Cass Bay sites, which were sampled at high tide. The Cass Bay site was previously sampled at low tide, but as of June 2023 sampling was switched to high tide. As such, data prior to June 2023 has been excluded from analysis at this site. A comparison of pre- and post- June 2023 data changes may be included in next year's report if deemed relevant.

In all years COVID19 impacts and other logistical issues (e.g., locked gates and construction) meant that several sites were unable to be sampled. For the 2023 monitoring year these sites were Ōtūkaikino River at Groynes in March and April 2023 and Balguerie Stream in June, August, September and October 2023. For the previous 2021 and 2022 monitoring years this included, at the catchment level, Pūharakekenui-Styx River and Ōtūkaikino River catchments, Balguerie Stream and Aylmers Stream in January 2021; Linwood Canal and Ōtākaro-Avon River catchment in April 2021. At the site level this included Stream Reserve Drain, Balguerie Stream and Kā Pūtahi at Blakes Rd in March 2021; Styx River at Marshland Rd, Styx River at Harbour Rd and Wilsons Stream in May 2021; Ōtūkaikino River at Scout Camp and Curlett Stream at Motorway in July 2021; Stream Reserve Drain and Lyttelton Port in August 2021; Addington Brook and Riccarton Main Drain in December 2021; Ōtūkaikino River at Scout Camp in October 2022. Previous 2021 and 2022 monitoring years are important to note as the results discussed in this report are largely based on 3-years of rolling monitoring data. Incidental issues with field meters or laboratory errors resulted in 14 data points being removed from the dataset.

Wet weather samples were collected during 2023 at five sites in the Pūharakekenui-Styx River catchment: Smacks Creek at Gardiners Road, Styx River at Main North Road, Kā Pūtahi Creek at Blakes Rd, Kā Pūtahi Creek at Belfast Rd and Styx River at Marshlands Rd on 10th of July 2023 and 17th of October 2023. This sampling is a component of the 5-yearly catchment-based monitoring that also included ecological, sediment quality and mana whenua monitoring in the Pūharakekenui-Styx River catchment for 2023 (see the EMP for more details).

Wet weather samples were collected using Nalgene first flush sampler bottles (a sampling bottle used to collect a one litre grab sample of first flush stormwater runoff) in both rainfall events in the Pūharakekenui-Styx River catchment. However, during the first event water levels did not increase enough at the Smacks Creek at Gardiners Road site to fill the sampler. Therefore, a grab sample was collected for the second event at this site only. Sampling for all events was carried out to achieve as far as possible the following criteria:

- Minimum of a three-day dry period prior to sampling;
- Minimum of 3 mm total rainfall depth; and

- Catching of the “First Flush” (15-25mm), by sampling within 1 – 2 hours of the desired rainfall depth being achieved.

Monthly and wet weather samples were analysed at the Council International Accreditation New Zealand (IANZ) laboratory, for the parameters outlined in Table i in Appendix B. The exception to this was Dissolved Organic Carbon (DOC), which was analysed at Watercare in October 2023, due to the Council laboratory equipment needing repair. Field measurements of temperature, pH and dissolved oxygen were also undertaken using a hand-held meter (YSI Pro ODO or DSS meter) at the time of sampling. For the wet weather sampling using Nalgene bottles, these temperature and dissolved oxygen readings should be viewed with caution, as they were taken outside of the wet weather event when the Nalgene bottles were being retrieved.

The methods used to analyse each parameter, including laboratory Limits of Detection (LOD), are presented in Table i in Appendix C. Some of these methods have changed over time, as more advanced equipment has become available, and timeframes for changes are detailed in this table.

SLLT volunteers have analysed water in the field for pH (Eutech pH pocket testers 30), conductivity (Eutech Cybernetics TDScan 3), water clarity (clarity tube), and water temperature (glass spirit thermometer) since 2004. Water clarity results should be viewed with caution, as the clarity tube is only 1m long, so it is not possible to record a clarity measurement greater than this.

SLLT samples were aimed to be taken every third Saturday of the month, but as this was based on volunteer availability, the number of samples taken annually at each site for the entire dataset ranged from 7 – 12 in 2023. Of note:

- There was no data available for 2016;
- 2015, 2017, and 2022 had a small number of recordings at some sites; and
- pH readings changed from using test strips to a handheld meter in February 2010; therefore, pH data prior to this time have been excluded from this report.

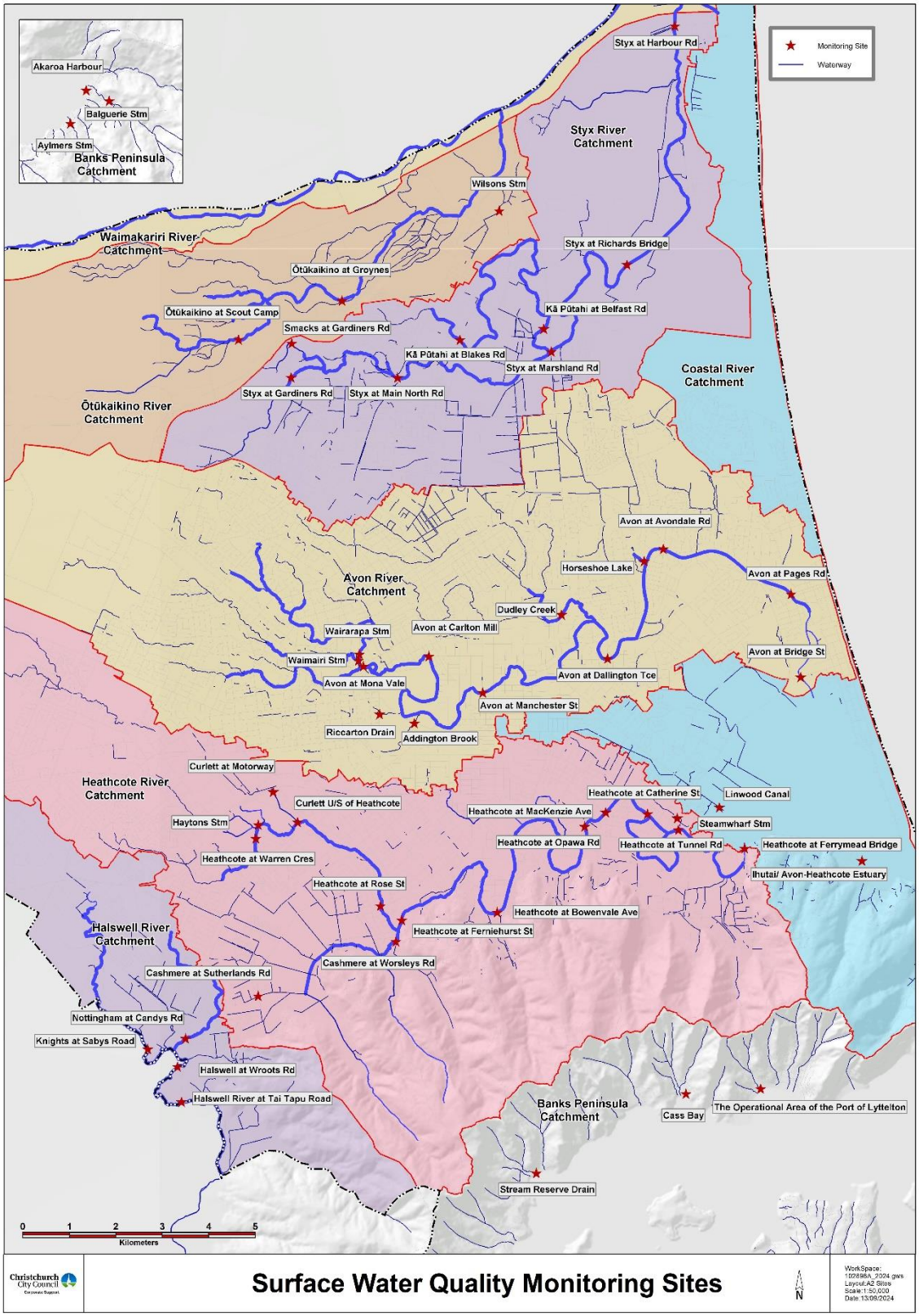

Figure 1. Location of Christchurch City Council surface water quality monitoring sites

Table 1. Christchurch City Council and Styx Living Laboratory Trust (SLLT) surface water quality monitoring sites, and associated waterway classifications under the Comprehensive Stormwater Network Discharge Consent Environmental Monitoring Programme to allow comparison to guideline levels.

Catchment	Site ID	Site	Easting (NZTM)	Northing (NZTM)	Waterway Classification
Ōtākaro-Avon	AVON01	Avon River at Pages/Seaview Bridge[3]	1577484	5182589	Spring-fed – plains – urban
	AVON02	Avon River at Bridge Street	1577691	5180813	Spring-fed – plains – urban
	AVON03	Avon River at Dallington Terrace/Gayhurst Road	1573560	5181210	Spring-fed – plains – urban
	AVON04	Avon River at Manchester Street	1570890	5180481	Spring-fed – plains – urban
	AVON05	Wairarapa Stream	1568250	5181303	Spring-fed – plains – urban
	AVON06	Waimairi Stream	1568233	5181172	Spring-fed – plains – urban
	AVON07	Avon River at Mona Vale	1568334	5181046	Spring-fed – plains – urban
	AVON08	Riccarton Main Drain	1568683	5180019	Spring-fed – plains – urban
	AVON09	Addington Brook	1569427	5179826	Spring-fed – plains – urban
	AVON10	Dudley Creek	1572574	5182150	Spring-fed – plains – urban
	AVON11	Horseshoe Lake Discharge	1574342	5183294	Spring-fed – plains – urban

[3] Strongly tidal waterway site

Catchment	Site ID	Site	Easting (NZTM)	Northing (NZTM)	Waterway Classification
	AVON12	Avon River at Carlton Mill Corner[4]	1569737	5181259	Spring-fed – plains – urban
	AVON13	Avon River at Avondale Road[4]	1574752	5183557	Spring-fed – plains – urban
Ōpāwaho-Heathcote	HEATH01	Heathcote River at Ferrymead Bridge[3]	1576491	5177150	Spring-fed – plains – urban
	HEATH02	Heathcote River at Tunnel Road[3]	1575074	5177543	Spring-fed – plains – urban
	HEATH03	Heathcote River at Opawa Road/Clarendon Terrace	1573071	5177615	Spring-fed – plains – urban
	HEATH04	Heathcote River at Bowenvale Avenue	1571198	5175780	Spring-fed – plains – urban
	HEATH05	Cashmere Stream at Worsleys Road	1569030	5175155	Banks Peninsula
	HEATH06	Heathcote River at Rose Street	1568701	5175918	Spring-fed – plains – urban
	HEATH07	Heathcote River at Ferniehurst Street	1569157	5175612	Spring-fed – plains – urban
	HEATH09	Haytons Stream at Retention Basin[4,5]	1566020	5177596	Spring-fed – plains – urban
	HEATH10	Curlett Road Stream Upstream of Heathcote River Confluence	1566928	5177711	Spring-fed – plains – urban
	HEATH11	Heathcote River at Catherine Street[4]	1574413	5177883	Spring-fed – plains – urban

[4] These sites are specifically located in proximity to stormwater outfalls
[5] This monitoring site was moved from the old outlet location to the new outlet location in May 2020.

Catchment	Site ID	Site	Easting (NZTM)	Northing (NZTM)	Waterway Classification
	HEATH12	Heathcote River at Mackenzie Avenue Footbridge[4]	1573520	5177917	Spring-fed – plains – urban
	HEATH14	Curlett Road Stream at Southern Motorway[4]	1566405	5178358	Spring-fed – plains – urban
	HEATH16	Cashmere Stream at Sutherlands Road	1566086	5173988	Banks Peninsula
	HEATH17	Steamwharf Stream upstream of Dyers Road	1575049	5177794	Spring-fed – plains – urban
	HEATH31	Heathcote River at Warren Crescent	1566034	5177359	Spring-fed – plains – urban
Pūharakekenui -Styx	STYX01	Smacks Creek at Gardiners Road near Styx Mill Road	1566804	5187956	Spring-fed – plains
	STYX02	Styx River at Gardiners Road	1566790	5187226	Spring-fed – plains
	STYX03	Styx River at Main North Road	1569066	5187219	Spring-fed – plains
	STYX04	Kā Pūtahi[6] Creek at Blakes Road	1570401	5188030	Spring-fed – plains
	STYX05	Kā Pūtahi[6] Creek at Belfast Road	1572194	5188267	Spring-fed – plains
	STYX06	Styx River at Marshland Road Bridge	1572358	5187778	Spring-fed – plains
	STYX07	Styx River at Richards Bridge	1573975	5189640	Spring-fed – plains
	STYX08	Styx River at Harbour Road Bridge	1574998	5194749	Spring-fed – plains
	SLLT01	Smacks Creek at Wilkinsons Road	1566478	5187459	Spring-fed – plains
	SLLT02	Styx River at Willowbank	1567218	5187641	Spring-fed – plains
	SLLT03	Styx River at Styx Mill Conservation Reserve	1567926	5187625	Spring-fed – plains
	SLLT04	Styx Drain at Redbrook Road	1568053	5187038	Spring-fed – plains
	SLLT05	Rhodes Drain at Hawkins Rd	1571548	5187060	Spring-fed – plains
	SLLT06	Horner's Drain at Hawkins Rd	1571569	5187095	Spring-fed – plains

[6] Previously known as Kaputone Creek.

Catchment	Site ID	Site	Easting (NZTM)	Northing (NZTM)	Waterway Classification
	SLLT07	Styx River at Radcliffe Road	1571720	5187413	Spring-fed – plains
	SLLT08	Kā Pūtahi Creek at Blakes Road	1570385	5188052	Spring-fed – plains
	SLLT09	Kā Pūtahi Creek at Ouruhia Domain	1571771	5190129	Spring-fed – plains
	SLLT10	Kā Pūtahi Creek at Everglades Golf Course	1571798	5189270	Spring-fed – plains
	SLLT11	Styx River at Brooklands	1575110	5193308	Spring-fed – plains
Huritini-Halswell	HALS03	Nottingham Stream at Candys Road	1564532	5173080	Spring-fed – plains
	HALS04	Halswell River at Akaroa Highway (Tai Tapu Road)	1564446	5171721	Spring-fed – plains
	HALS05	Knights Stream at Sabys Road	1563723	5172852	Spring-fed – plains
	HALS07	Halswell River at Wroots/Halswell Roads	1564359	5172477	Spring-fed - plains
Ōtūkaikino	OTUKAI01	Ōtūkaikino River at Groynes Inlet	1567878	5188869	Spring-fed – plains
	OTUKAI02	Wilsons Drain at Main North Road	1571241	5190793	Spring-fed – plains
	OTUKAI03	Ōtūkaikino Creek at Omaka Scout Camp	1565664	5188038	Spring-fed – plains
Linwood Canal	OUT01	Linwood Canal/City Outfall Drain3	1575952	5178026	Spring-fed – plains – urban
Stream Reserve Drain/Zephyr Stream	BP01	Stream Reserve Drain Above Outfall to Governors Bay	1572035	5170197	Banks Peninsula
Balguerie Stream	BP03	Balguerie Stream Downstream of Settlers Hill (road)[4]	1597748	5149578	Banks Peninsula
Aylmers Stream	BP04	Aylmers Stream Downstream of Rue Jolie, next to Bruce Terrace	1596920	5149096	Banks Peninsula

Catchment	Site ID	Site	Easting (NZTM)	Northing (NZTM)	Waterway Classification
Ihutai/Avon-Heathcote Estuary	CW01	Estuary of the Heathcote and Avon Rivers – Ihutai at the Eastern Tip by Beachville Road[4]	1579001	5176882	Coastal Contact Recreation Water
The Operational Area of the Port of Lyttelton	CW02	Lyttelton Port at the Small Wharf Opposite Voelas Road[4,7]	1576834	5172004	Coastal Aquatic Ecology Water
Cass Bay	CW03	Eastern Side of Cass Bay off the Cass Bay Walkway[4]	1575236	5171897	Coastal Contact Recreation Water
Akaroa Harbour	CW04	Akaroa Harbour at the Termination of Rue Balguerie[4]	1597257	5149806	Coastal Shellfish Gathering Water

[7] Site in location of stormwater outfall from an urban and industrial (i.e. port) catchment

2.3. Data Analysis

2.3.1. Summary Statistics and Graphs

Boxplots (for monthly data) were produced using the program RStudio (Version 4.3.3) for the most pertinent parameters (typically those with guideline levels). To allow graphing of monthly samples, concentrations less than the LOD were converted to half the detection limit. In some samples, monthly *E. coli* concentrations exceeded the maximum laboratory limit for counting (24,000 MPN/100ml) and these were graphed as 24,000, although concentrations may have been much higher than this. There were two *E. coli* samples in 2021, one in 2022 and one in 2023 that exceeded the maximum laboratory limit. Atypically high records which are presented in this report have been verified with the laboratory; however, as this was retrospective, sample analysis could not be re-run. New protocols are in place to ensure that samples are checked more frequently.

The dark lines in the boxes of the boxplots represent the medians, and the bottom and top lines of the boxes represent the 25th and 75th percentiles (the interquartile range), respectively. The T-bars that extend from the boxes approximate the location of 90% of the data (i.e., the 5th and 95th percentiles). The exception to this is for faecal coliforms where the T-bars represent the approximate location of 80% of the data (i.e., the 10th and 90th percentiles). This adjustment was necessary as faecal coliform guidelines refer to the 90th percentile. Additionally, the T-bars for turbidity and conductivity were altered to represent the approximate location of 60% of the data (i.e., the 20th and 80th percentiles) as the guidelines in this report refer to the 80th percentile. These percentiles were calculated using Hazen methodology (Ministry for the Environment, 2003). Circles represent outliers. In some cases, boxplots do not show all components, such as the percentiles, due to a lack of variation in the data, with some showing only the medians. This usually occurred where a large proportion of the data were below the laboratory limit of detection.

Graphs were created based on three years of rolling monitoring data. Additional graphs with data from the monitoring year (2023) alone were created for TSS, copper, lead and zinc. This was to allow an assessment for the CSNDC as to whether the Receiving Environment Objectives and Attribute Target Levels (these are consistent with the guideline levels) for these parameters are being met, or whether further investigations are triggered (in accordance with Condition 59).

2.3.1. Guideline Levels

The results of the monitoring were compared to guideline levels where these were available as outlined in Table i in Appendix B. This table also provides information on which parameters were assessed against percentiles (95th or 90th) versus medians, as required by the individual guidelines. Background on the environmental concern surrounding each parameter is also provided in this table. Comparisons to guideline levels for the wet weather monitoring must be viewed with caution, as these are based on individual samples, not datasets (i.e., not medians or percentiles).

Due to their salinity profiles, the strongly tidal waterway sites (Avon River at Bridge St, Heathcote River at Ferrymead Bridge, Heathcote River at Tunnel Rd, and Linwood Canal) are preferentially compared to estuarine guidelines. Where those are not available, coastal guidelines are used. If neither exist, then waterway guidelines are used. The exception to this is for conductivity where comparison to the guideline (116 µS/cm) would be inappropriate.

Dissolved lead and zinc guidelines for waterway sites were modified to account for water hardness (Warne et al., 2018; Appendix D). As required by the CSNDC, the toxicity modifiers for these guidelines are reviewed every five years. Although turbidity is now measured using Formazin Nephelometric Units (FNU) and not Nephelometric Turbidity Units (NTU), the NTU waterway and coastal guideline values are still used for direct comparison against this FNU data (Michele Stevenson, Environment Canterbury, personal communication, May 2020). Updated guidance refers to using medians for turbidity and conductivity, rather than 80th percentiles that have been used in this report. Caution should be used when viewing the results as it is likely there will be less exceedances when using medians. This will be updated and reflected in next years report. The turbidity and TSS guidelines for coastal sites were updated this year and calculated based on the 80th percentile of all available data (May 2020-December 2023), (Dudley et al. 2019) (Michele Stevenson and Melanie Burns, personal communication, May 2023). Turbidity and TSS guidelines for strongly tidal sites will be calculated next year. As the sample collection time for Cass Bay was changed from low to high tide, an interim guideline was calculated based on the available high-tide data (June 2023-December 2023).

2.3.2. Water Quality Index

A Water Quality Index (WQI) was developed in 2016 for the Council monthly monitoring sites, based on a Canadian WQI (CCME; Canadian Council of Ministers for the Environment, 2001). This index uses three factors to assess water quality: scope (the percentage of parameters not meeting the guideline on at least one occasion); frequency (the percentage of samples that did not

meet the guideline); and amplitude (the amount by which the guideline was not met). The WQI ranges from 0 – 100, with 100 representing high water quality. The user can choose which parameters to include and what guideline levels are appropriate to their system.

The parameters used in this Council WQI are dissolved copper, dissolved zinc, pH, TSS, dissolved oxygen (DO), temperature, BOD_5, total ammonia, nitrate, dissolved reactive phosphorus (DRP), and *E. coli*. Dissolved inorganic nitrogen (DIN) was not used in the WQI, as ammonia and nitrate form part of this parameter, and ammonia is already included in the index, so this may have potentially biased the results.

WQI scores could not be calculated at the four coastal sites as total ammonia, nitrate, and DRP are not collected. No TSS guideline exists for the strongly tidal sites, therefore WQI scores could also not be generated for these sites (Avon River at Bridge St, Heathcote River at Tunnel Rd, Heathcote River at Ferrymead Rd and Linwood Canal). Therefore, WQI scores were calculated for 43 of the 51 sites. Council is working on developing a WQI for coastal and tidal waterway sites, which will be presented in next year's annual report.

WQI scores were used to categorise the Council sites as being 'very poor' (0 – 39.99), 'poor' (40 – 69.99), 'fair' (70 – 79.99), 'good' (80 – 89.99), or 'very good' (90 – 100). The categories were selected based on local knowledge of water quality compared to other waterways nationally. These categorise Christchurch City waterways as expected. The WQI index was calculated for every year from 2016 (inclusive), to allow comparisons over time.

2.3.3. Temporal Trends

Temporal trends analysis was carried out on the monthly data, SLLT data, and both the site and catchment wide WQI, to determine whether water quality is declining, improving, or staying the same over time. Analyses on the monthly and SLLT data were undertaken on all data collected since monitoring began at each site (Appendix A, Table i). Trends in WQI were calculated from data collated from 2016-2023. As the SLLT dataset had low sample sizes for some years, this limits the ability of the software to identify significant changes. As such, these results should be viewed with caution.

Trends analysis was conducted using Time Trends Version 11.1, build 1 (NIWA, 2022). The Seasonal Kendall trend test was used to test the significance, magnitude and direction of the trends, providing an average annual percentage change. Data were treated as independent (i.e., all values were used instead of medians), as it was considered that the monthly samples at each site were independent of each other (i.e., the concentrations on any given month were not influenced by the concentrations in the previous month). A

change was considered meaningful when there was a statistically significant ($p \leq 0.05$) positive or negative result of greater than 1% (NIWA, 2022). Trend lines on graphs were fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method. This software requires three years of data to robustly analyse trends. As such, Time Trends could not be conducted on any parameters from the Cass Bay site as high tide sampling for this site began in June 2023. Several sites only just met the requirement of three years of data (see Appendix A, Table i) and are therefore likely to be more strongly influenced by small changes than the longer-term monitoring sites (i.e., changes in longer-term datasets are more likely reflective of sustained changes and are less sensitive to occasional peaks and short term trends). Time Trends accommodates for variable LODs and the option for using censored concentrations (records below the LOD) in Sen slope calculation was selected.

Concentrations of parameters may vary depending on flow rates at the time of sampling, due to variations in the level of dilution. Therefore, flow-adjusted data can be used in the Time Trends software to account for this potentially confounding factor. However, a flow recorder is only directly present at one of the sites (Heathcote River at Ferniehurst St). It is considered that extrapolation of this flow data to other locations, as well as the use of other flow gauges in Christchurch not directly at the monitoring sites, may bias the results through differences in stream habitat and additional discharge inputs. This may lead to inaccurate trend conclusions. Given the long period of monitoring, it is considered that variations in flow rates between sampling events will not strongly influence the trends analysis, as most events will have been conducted during base flow conditions. To ensure accurate comparisons between sites, the flow data for Heathcote River at Ferniehurst St was not used.

3. Results

3.1. Rainfall

- Rainfall in Christchurch City and Banks Peninsula during the monitoring year was assessed based on daily rainfall collected at the Christchurch Botanic Gardens and Akaroa, respectively, by the Council since the early 1960's.
- Over the last nine years Christchurch City rainfall has been variable, including dry years (2015, 2016, and 2020), wet years (2017, 2018, 2022 and 2023), and intermediate years (2019 and 2021) (Figure 2(a)).
- Above long-term normal rainfall was recorded in Christchurch for the 2023 year overall. January was the driest month, with 26 mm recorded

(61% of the January normal). Autumn and winter recorded the same rainfall volume (251 mm) which equated to 156% of the autumn normal, and 131% of winter normal.

- Overall, 23% of monthly samples were associated with rainfall.
- For the Council monthly data within the City, the Huritini-Halswell River catchment sites recorded the greatest number of sampling days affected by rain (35%) during 2023, followed by Ōpāwaho-Heathcote River catchment (33%), Ōtūkaikino River catchment (18%), Pūharakekenui-Styx River catchment (17%), and Ōtākaro-Avon River catchment (13%).
- For the Council monthly data on Banks Peninsula, Aylmers Stream and Zephyr Stream sites recorded the greatest number of sampling days affected by rain (42%), followed by Balguerie Stream and (38%). Coastal sites were affected by rain 8% of the time.
- These results are based on observations of the water quality samplers as to whether it had rained within the 24 hours prior to sampling. This means that it is a subjective assessment only and these results should be viewed with caution.

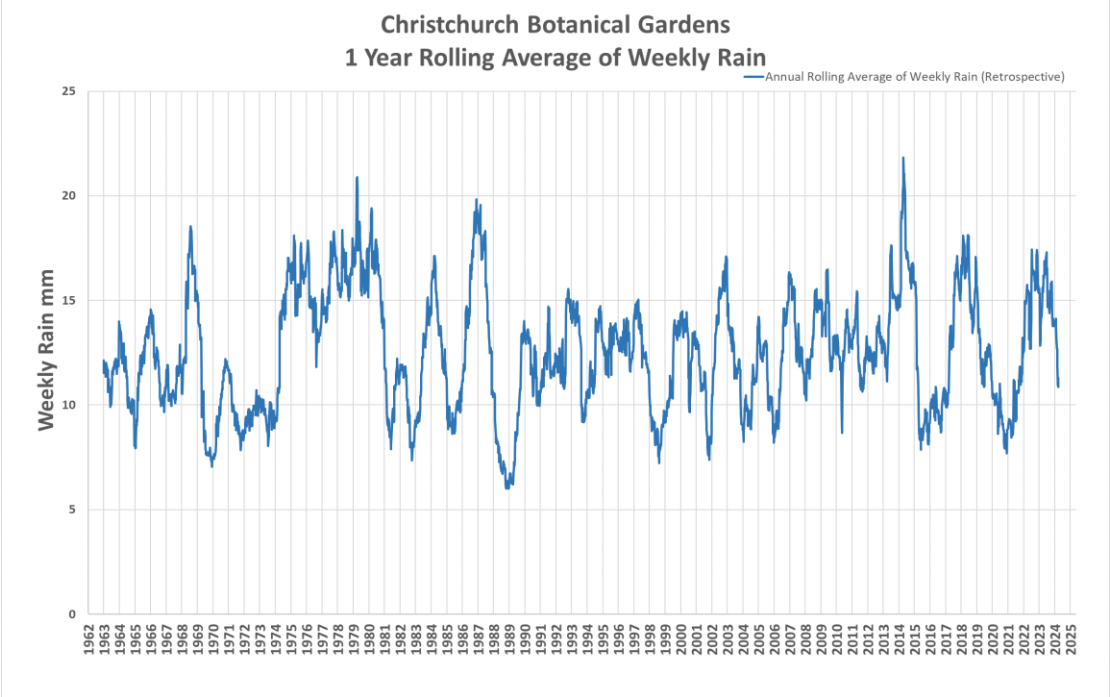

Figure 2(a). Annual rolling average of weekly rainfall at the Botanic Gardens in Hagley Park, Christchurch.

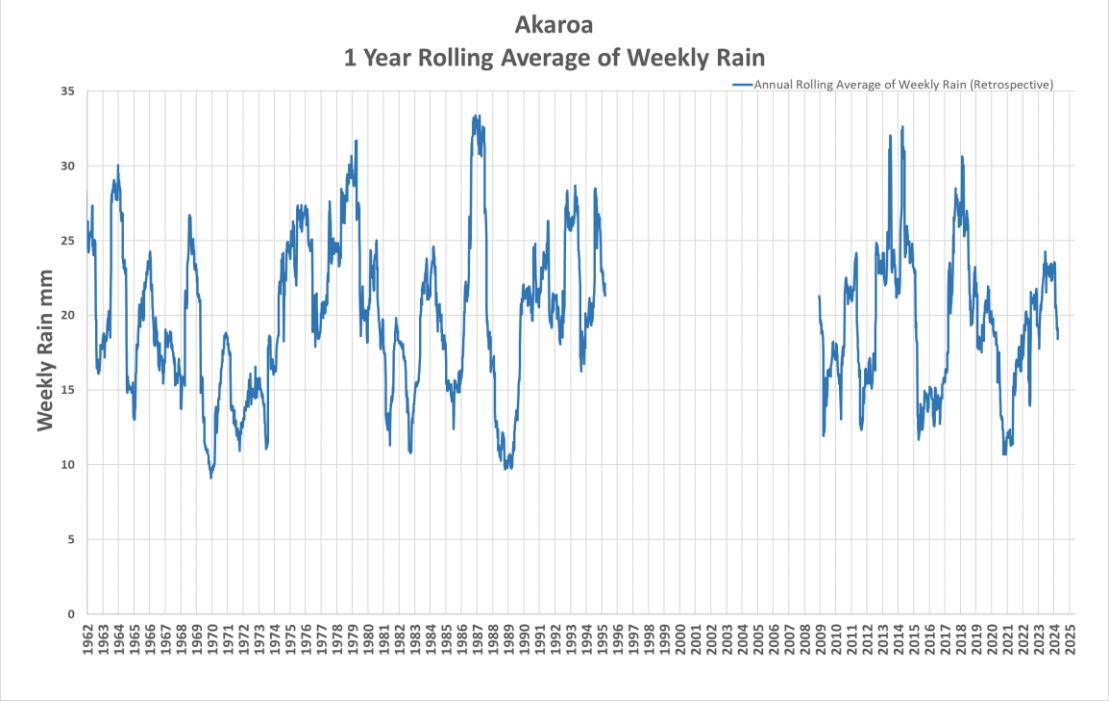

Figure 2(b). Annual rolling average of weekly rainfall in Akaroa. From approximately 1992 to 2008 no data was collected.

3.2. Water Quality Parameters

3.2.1. Summary

- 35,120 tests were conducted during 2021-2023 for the Council monthly monitoring, with 26,084 of these allowing the assessment of each waterway site against relevant guideline levels (Table 2).
- 51 of the 51 sites did not meet the guideline for at least one parameter (Table 2).
- Parameters that exceeded the guidelines at the most sites were turbidity (47 of 51 sites), *E. coli* (46 of 48 sites), and DRP (30 of 47 sites) (Table 2).
- Most parameters did not show a statistically significant change in concentration since monitoring began, with 443 (62%) parameter-site combinations recording no significant upwards or downwards trends in concentrations (Appendix F, Tables i–iv). However, 173 (24%) parameter-site combinations recorded a significant improvement in water quality, 71 (10%) parameter-site combinations recorded a significant decline in water quality, and 29 (4%) parameter-site combinations recorded a change that could indicate either an

improvement or decline in water quality (pH, conductivity and salinity). These results are generally similar to last year.

- The largest increases in parameter concentrations were all recorded from the short-term datasets (3.5 years). For example, TSS increased at Lyttleton Port (51%), Akaroa Harbour (46%) and Steamwharf Stream (27%). Turbidity increased at Lyttleton Port (56%) and Akaroa Harbour (27%). DIN increased at Balguerie Stream (32%) and Aylmers Stream (30%). A longer dataset is required to determine if these changes will be sustained over time, are due to climatic variations or other reasons; however, the increase in DIN at Aylmers Stream appears to be consistent over the last two years of monitoring (Figure 3; Table iii in Appendix F). Additional monitoring will help determine if these peaks are related to winter rainfall or groundwater inputs.
- For the longer-term datasets, a 12% and 8% increase in turbidity was recorded from Cashmere Stream at Sutherlands Rd and Wilsons Stream respectively (Figure 4 and Figure 5; Table ii and iv in Appendix F). Turbidity at the Cashmere Stream at Sutherlands Rd site has steadily increased over the last four years (11% increase last year), including increases in peak concentration; however, it is still low and meets the guideline level for now. Of interest, TSS showed no significant change and appears to be decreasing over the last two years. This may be a result of a changing sediment source, or as a result of the increasing residential development in the immediate catchment. Although Wilsons Stream continues to record an increasing trend, it is to a lesser extent than last year (11%). Wilsons Stream also recorded a 5% increase in TSS. This suggests a source of sediment into the catchment, likely due to rural land use (such as stock access), development, and/or bank erosion.
- For the longer-term datasets a 9% increase in *E. coli* at Wilsons Stream was recorded due to a steady increase over time and some peaks in 2022. However, 2023 concentrations were much lower than in 2022 and there were no peaks recorded. This is reflected in the trend, which increased to a lesser extent this year (12% in 2022) (Figure 6 and Table iv in Appendix F). The increase is likely due to faeces contamination from waterfowl and stock. This increase was accompanied by a 3% increase in DIN, which may be associated with faecal input, fertilisers, or contaminated groundwater. Ōtūkaikino at Scout Camp recorded a 6% increase in *E. coli* in 2023 however, 2023 concentrations were much lower than in 2022 due to no peaks being recorded. This is reflected in the increases being less than last year (11% in 2022).
- The largest decreases in parameter concentrations were:

  - 63%, 43% and 41% for dissolved lead at Avon River at Manchester St, Avon River at Avondale Road and Styx River at Harbour Rd due to a reduction in peak concentrations and an increase in data below the limit of detection (Figure 7-Figure 9; Table i and Table iv in Appendix F). There was a change in the Laboratory Limit of Detection in 2017, but the Time Trends software can account for this and there is still an obvious reduction in concentrations since that time. No trend was recorded at the Avon River at Avondale Rd site last year; however, Avon River at Manchester recorded a 32% decrease and Styx River at Harbour Rd a 37% decrease. Reductions in dissolved lead are directly attributable to the removal of lead in petrol in the 1990s.
  - 67% for salinity at Heathcote River at Tunnel Rd, due to a decrease in peak and baseline levels over time, with lower levels recorded since mid-2021 (Figure 10 and Figure 11; Table ii in Appendix F). While the trend was not reflected in the conductivity data which recorded a 2% increase, both measures show a decrease from around mid-2021. Salinity has only been monitored at this site for four years, but conductivity data has been collected since 2007. Examination of the conductivity data shows the rapid decrease in salinity (and co-varying decrease in conductivity) is likely a return to baseline conditions as data from 2019-2021 was atypically high. This highlights potential issues with short datasets.

- Decreasing trends for total ammonia, DIN, and DRP were recorded at many of the monitored sites (Appendix F). Other notable decreases included dissolved copper (at Avon River at Carlton Mill, Manchester St, Dallington Tce and Bridge St, Heathcote River at Warren Cres, Steamwharf Stream and Nottingham Stream), dissolved zinc (Wairarapa Stream, Horseshoe Lake, Avon River at Pages, Hayton Stream) and *E. coli* (Curlett u/s of Heathcote, Halswell at Wroots Rd). Plus turbidity at Halswell at Wroots Rd.

Table 2. Number of waterway and coastal sites monitored for each parameter (where guideline levels are available), the number of samples analysed, and the number of samples and sites (based on medians/80th, 90th or 95th percentiles, depending on the parameter) not meeting the guideline levels, during the monitoring period of January 2021 to December 2023.

Parameter	Guideline	Number of Sites Monitored	Number of Samples Analysed	Number of Sites Not Meeting Guideline
Turbidity	Varies depending on catchment, from 80th percentile ≤1.3 NTU to ≤22.3 NTU	51	1,754	47
Escherichia coli	95%th percentile ≤550/100ml	48	1,681	46
Conductivity	80th percentile ≤116 µS/cm for waterway sites only. Not relevant for tidal or coastal sites.	43	1,501	41
Dissolved Reactive Phosphorus	Varies depending on catchment, from median ≤0.016 mg/L to ≤0.025 mg/L	47	1,645	30
Dissolved zinc	Varies depending on catchment, from 95th percentile ≤0.00254 mg/L to ≤0.0396 mg/L	51	1,787	24
Dissolved copper	Varies depending on catchment, from 95th percentile ≤0.001 mg/L to ≤0.0018 mg/L	51	1,787	23
Dissolved oxygen	Varies depending on catchment, from median ≥70% to ≥90%	51	1,784	19
Dissolved Inorganic Nitrogen	Varies depending on catchment, from median ≤0.09 mg/L to ≤1.5 mg/L	47	1,645	18
Enterococci	Single samples < 140 MPN/100ml	8	345	7
Nitrate	Varies depending on catchment, from median ≤1.0 mg/L to ≤2.4 mg/L and/or 95%ile ≤1.5 mg/L to ≤3.5 mg/L	47	1,645	6
Dissolved lead	Varies depending on catchment, from 95th percentile ≤0.00109 mg/L to ≤0.02388 mg/L	51	1,787	1
Faecal coliforms	Median ≤14MPN/100ml and/or 90th percentile ≤43 MPN/100 ml	1	34	1
Total ammonia	Varies depending on catchment, from 95th percentile ≤0.32 mg/L to ≤2.38 mg/L	47	1,645	1
pH	Varies depending on catchment, from median 6.5 to 8.5, to 8.0 to 8.4	51	1,785	1
Total Suspended Solids	Varies depending on catchment, from median ≤13 mg/L to 29.7 mg/L.	51	1,787	0
Biochemical Oxygen Demand	Median ≤2 mg/L	50	1,739	0

Parameter	Guideline	Number of Sites Monitored	Number of Samples Analysed	Number of Sites Not Meeting Guideline
Water temperature	Varies depending on catchment, from median ≤20°C to ≤25°C	51	1,783	0
Total	-	51	26,084	51 of 51 (for at least one parameter)

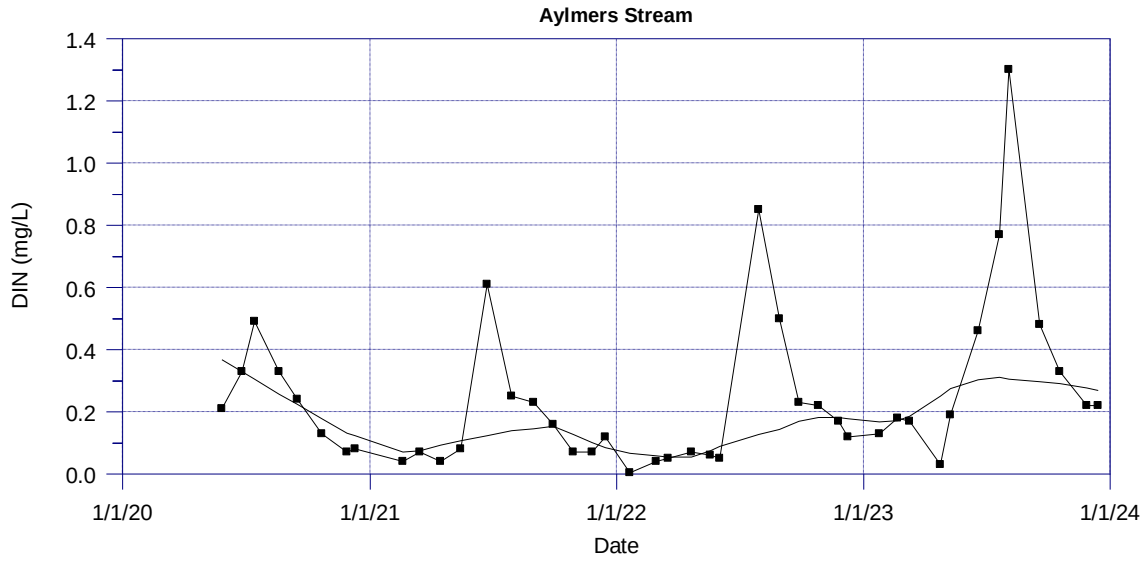

Figure 3. DIN concentrations at Aylmers Stream for the monitoring period May 2020 to December 2023. Squares indicate individual sampling events. An increasing trend of 30% was recorded over the sampling period.

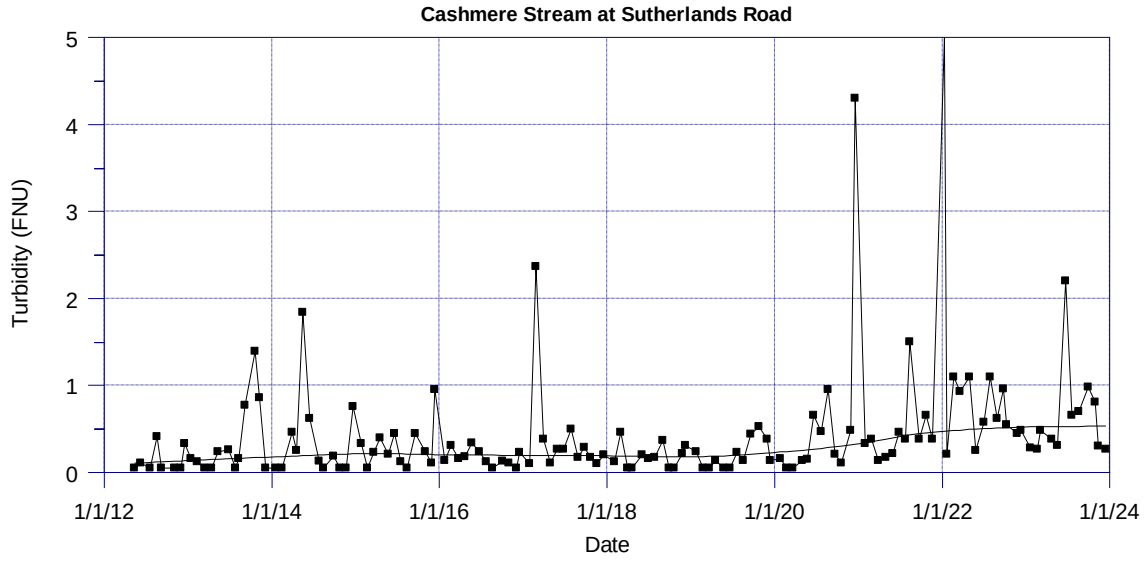

Figure 4. Turbidity at Cashmere Stream at Sutherlands Rd for the monitoring period December 2010 to December 2023. Squares indicate individual sampling events. An increasing trend of 12% was recorded over the sampling period.

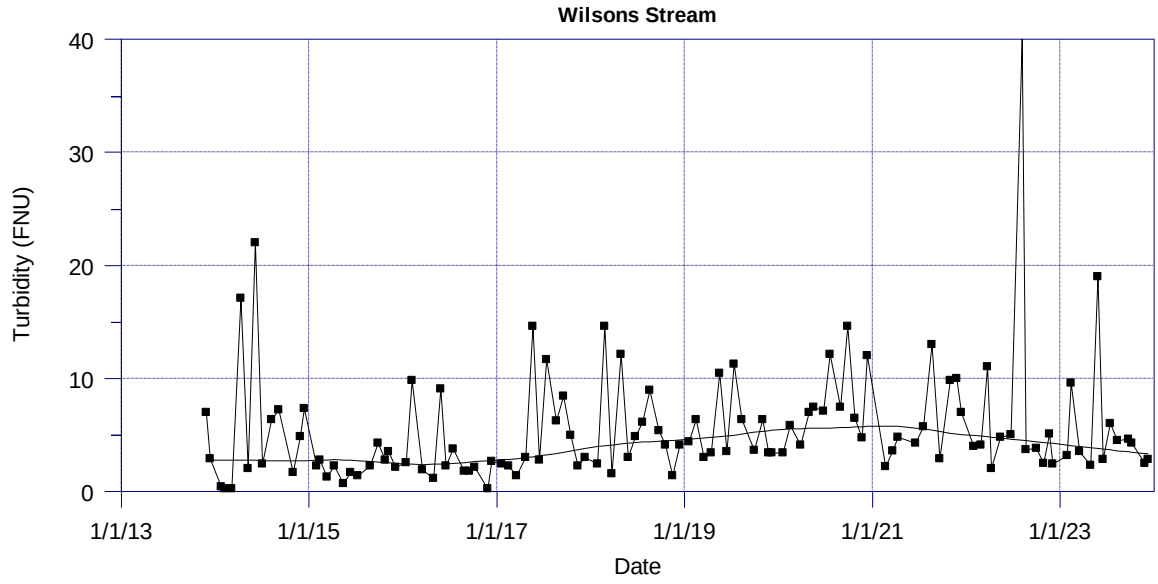

Figure 5. Turbidity at Wilson Stream for the monitoring period November 2013 to December 2023. Squares indicate individual sampling events. An increasing trend of 8% was recorded over the sampling period.

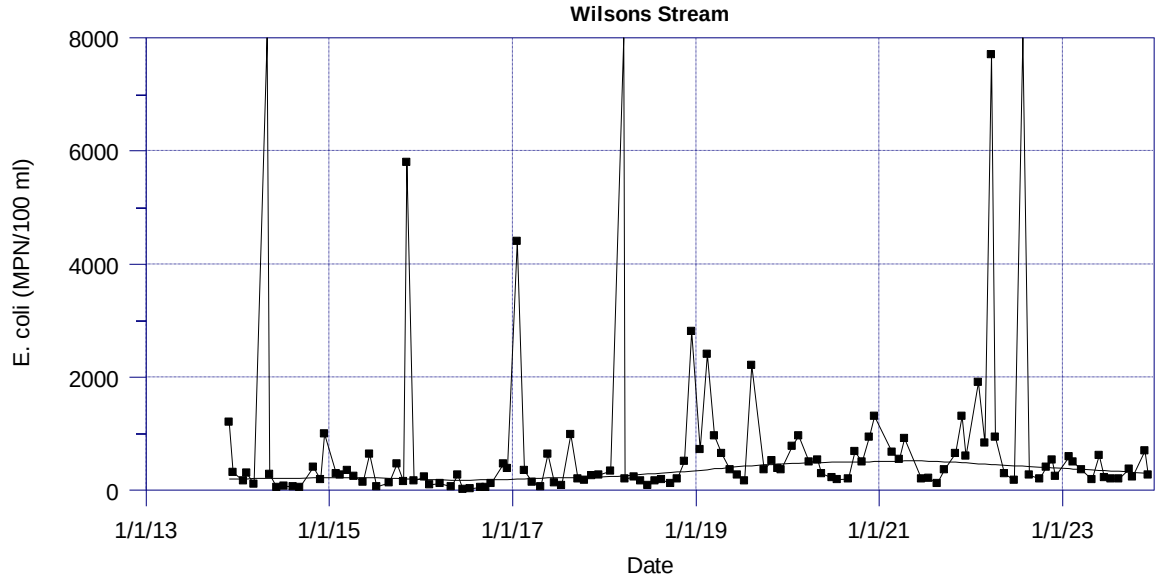

Figure 6. *E.coli* concentrations at Wilson Stream for the monitoring period November 2013 to December 2023. Squares indicate individual sampling events. An increasing trend of 9% was recorded over the sampling period.

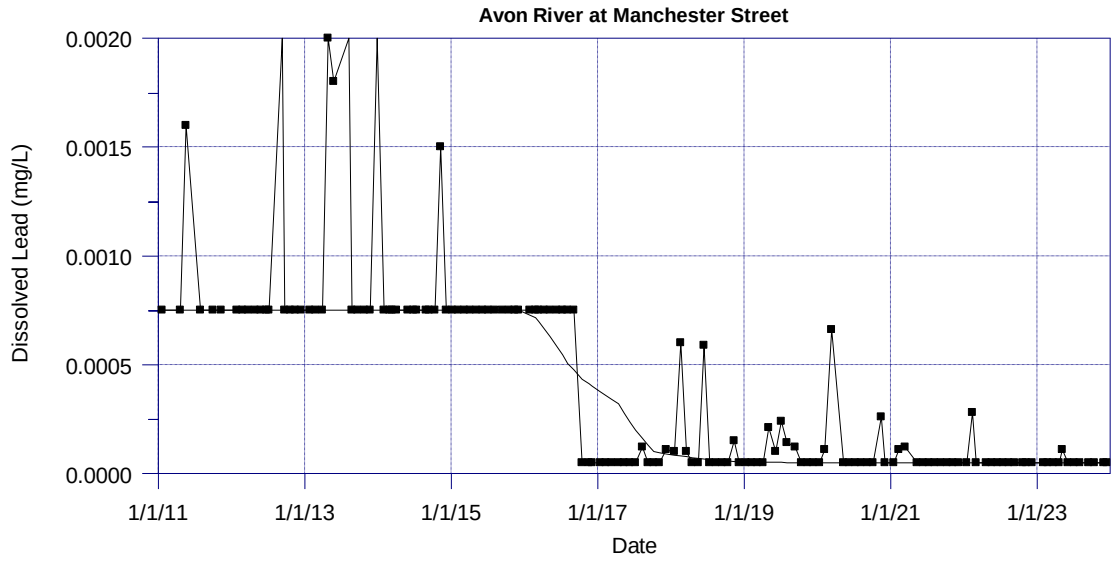

Figure 7. Dissolved lead concentrations at Avon River at Manchester St for the monitoring period January 2011 to December 2023. Squares indicate individual sampling events. A decreasing trend of 63% was recorded over the sampling period. The sharp drop indicates a change in the Laboratory Limit of Detection.

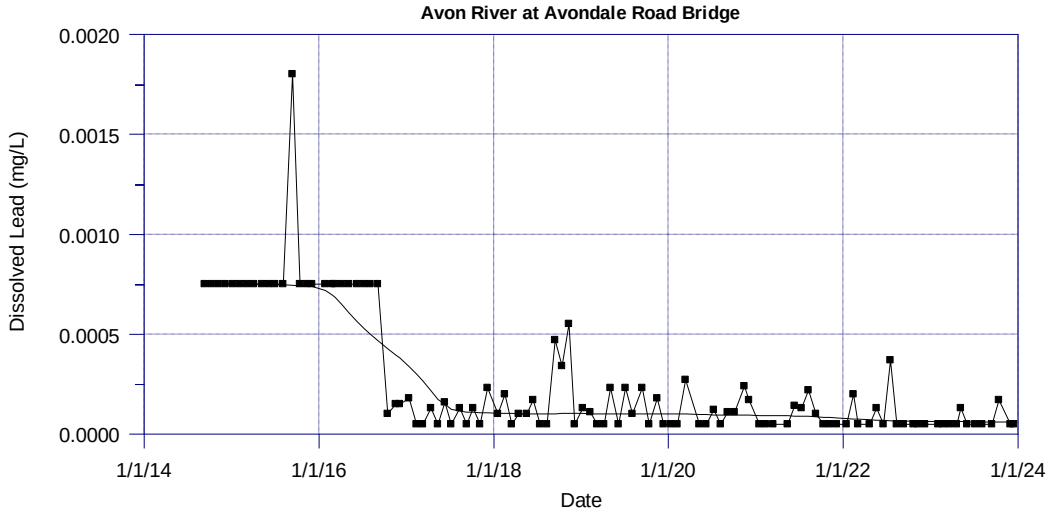

Figure 8. Dissolved lead concentrations at Avon River at Avondale Rd for the monitoring period September 2014 to December 2023. Squares indicate individual sampling events. A decreasing trend of 43% was recorded over the sampling period. The sharp drop indicates a change in the Laboratory Limit of Detection.

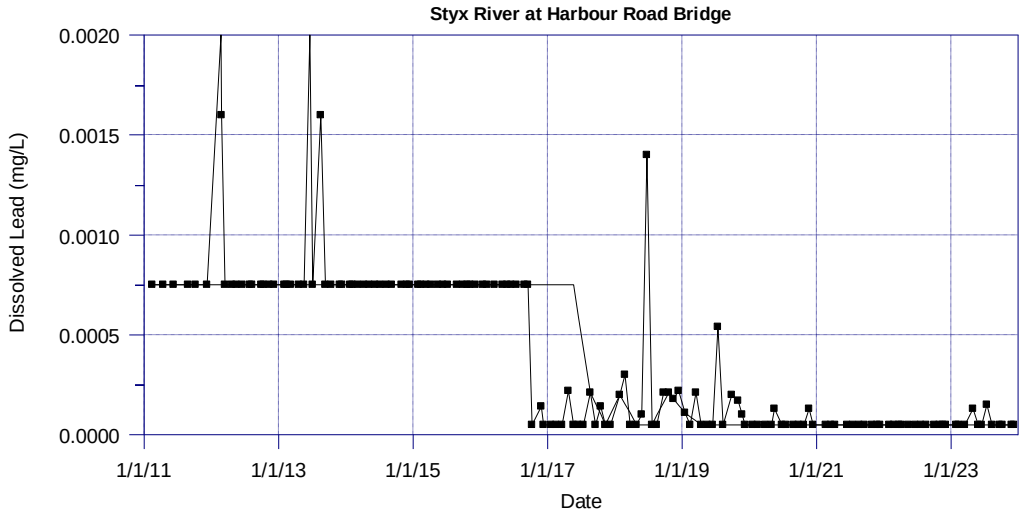

Figure 9. Dissolved lead concentrations at Styx River at Harbour Rd for the monitoring period February 2011 to December 2023. Squares indicate individual sampling events. A decreasing trend of 41% was recorded over the sampling period. The sharp drop indicates a change in the Laboratory Limit of Detection.

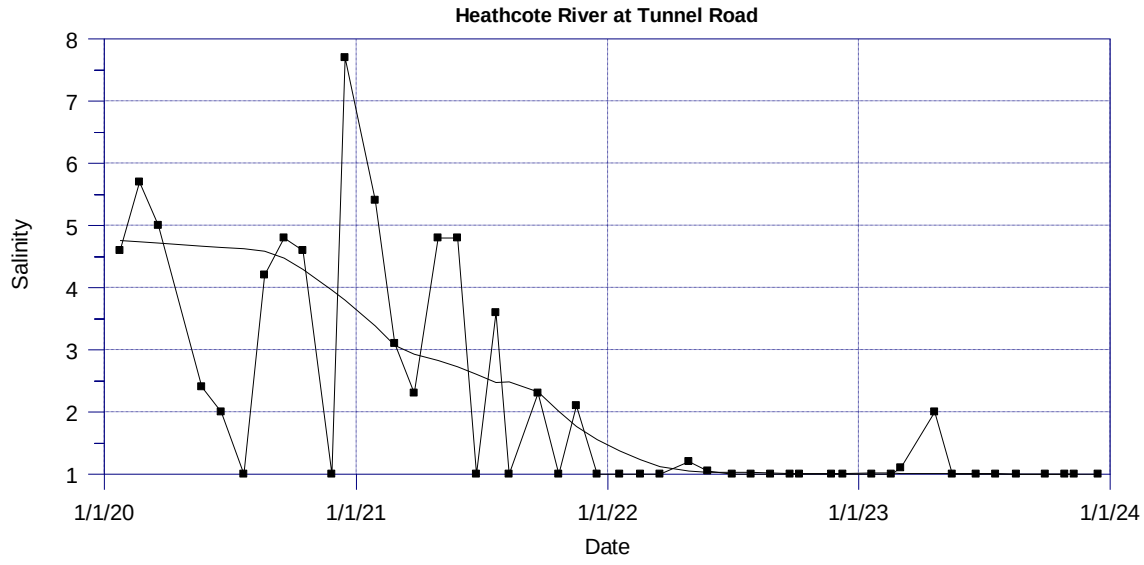

Figure 10. Salinity concentrations at Heathcote River at Tunnel Road for the monitoring period January 2020 to December 2023. Squares indicate individual sampling events. A decreasing trend of 67% was recorded over the sampling period.

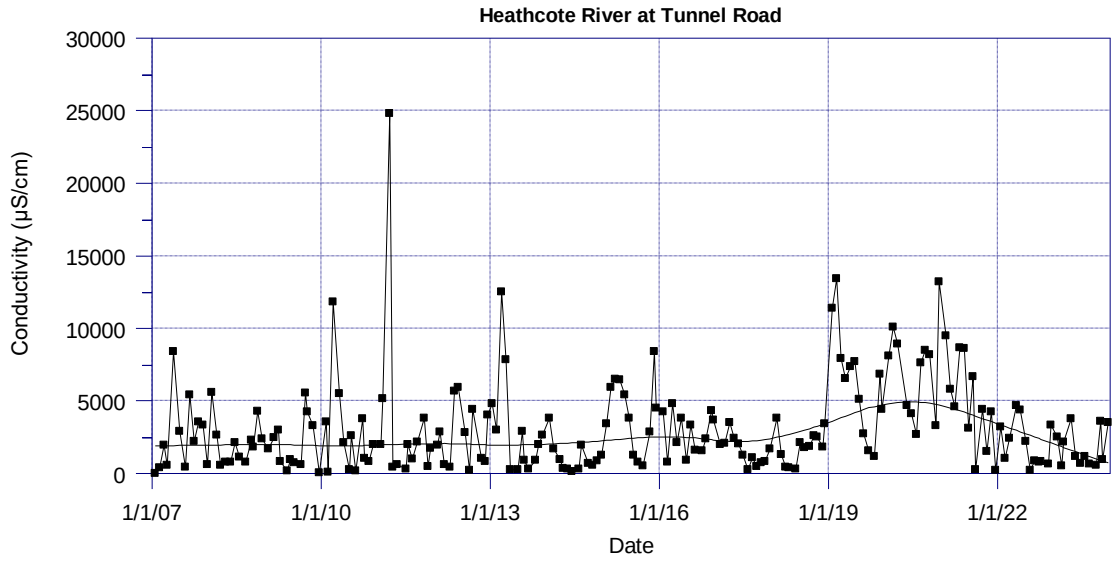

Figure 11. Conductivity at Heathcote River at Tunnel Road for the monitoring period January 2007 to December 2023. Squares indicate individual sampling events. No significant change was recorded; however, these results show the salinity results are likely an artefact of a short dataset.

3.2.2. Dissolved Copper

- Over half of the 13 sites in the Ōtākaro-Avon River catchment met their respective guidelines for dissolved copper (based on 95th percentile concentrations; Appendix E, Figure i (a) – (b)). In the Ōpāwaho-Heathcote River catchment, Heathcote River at Warren Crescent, Haytons Stream and Steamwharf Stream were the only sites out of 15 to meet the guideline. All sites in the Pūharakekenui-Styx and Ōtūkaikino River catchments met the guideline. In the Halswell-Huritini catchment, only two out of the four sites sampled met the guidelines. Linwood Canal, the three Banks Peninsula waterway sites, and all coastal sites except Cass Bay exceeded their respective guidelines.
- Copper concentrations were generally higher in the Ōpāwaho-Heathcote River and the Ōtākaro-Avon River compared to the other catchments.
- The two Curlett Stream sites recorded much higher concentrations than the other sites. Heathcote River at Rose Street, Heathcote River at Tunnel Road, Stream Reserve Drain, and Lyttelton Port recorded generally higher concentrations than the other sites. Aylmers Stream and the Ihutai/Avon-Heathcote Estuary site also recorded high values on occasion. The three highest concentrations recorded were 0.12 mg/L at the Aylmers Stream site (August 2023 – associated with rain), 0.05 mg/L at the Ihutai/Avon-Heathcote Estuary (May 2022 – not

associated with rain) and 0.023 mg/L at Curlett Stream at Motorway Rd (February 2023 – associated with rain).

- Concentrations have not generally changed since monitoring began (Appendix F, Tables i–iv). The notable exceptions to this were large reductions at three sites: Steamwharf Stream (36%), Heathcote River at Warren Cres (34%), and Avon River at Carlton Mill (25%). However, both Steamwharf Stream and Heathcote River at Warren Cres are short datasets (3.5 years). Notably, in the Ōtākaro-Avon River catchment no changes in concentrations were recorded last year but four sites decreased this year, likely due to a reduction in peak concentrations. Additionally, notable site changes were recorded at Curlett Stream U/S of Heathcote, which last year had a decrease of 9% but no significant change this year, concentrations have been steadily increasing over the last two years. No site recorded a statistically significant increase in dissolved copper.

3.2.3. Dissolved Lead

- The 95th percentile of dissolved lead concentrations at all sites complied with the respective guidelines, except for Aylmers Stream (Appendix E, Figure ii (a) – (b)).
- Concentrations were generally similar between catchments, and between waterway and coastal sites.
- Addington Brook typically had higher concentrations compared to all other waterway sites. The three highest concentrations were from Ihutai/Avon-Heathcote Estuary (0.025 mg/L in May 2022– not associated with rain), Aylmers Stream site (0.0073 mg/L in August 2023 – associated with rain) and Wairarapa Stream (0.0057 mg/L – not associated with rain).
- Twelve sites recorded a decrease in concentrations. The largest decreases were at Avon River at Manchester St (63%), Avon River at Avondale Rd (43%), Styx at Harbour Rd (41%), Avon River at Dallington Tce (27%), Heathcote River at Bowenvale Ave (26%), Linwood Canal (26%) and Lyttelton Port (20%) (Appendix F, Tables i–iv). Haytons Stream showed a sustained and improving decrease in dissolved lead concentration, changing from a decrease of 11% last year to a decrease of 18% this year. No site recorded an increase.

3.2.4. Dissolved Zinc

- The 95th percentile of dissolved zinc concentrations at 9 out of the 13 sites in the Ōtākaro-Avon River catchment and 7 of the 15 sites in the

Ōpāwaho-Heathcote River catchment met the guidelines (Appendix E, Figure iii (a) – (b)). Five of the eight sites in the Pūharakekenui-Styx River catchment, two of the three sites in the Ōtūkaikino River catchment, and three of the four sites in the Huritini-Halswell river catchment met the guidelines. Linwood Canal and all three Banks Peninsula sites did not meet the guidelines. Only one of the four coastal sites (Cass Bay) met the guideline.

- Dissolved zinc concentrations were generally higher at the sites in the Ōpāwaho-Heathcote River and the Ōtākaro-Avon River catchments compared to the other catchments. Banks Peninsula waterways and the coastal sites were similar to the Pūharakekenui-Styx and Ōtūkaikino River catchments.
- Addington Brook, Dudley Creek, Haytons Stream, Curlett Stream, Heathcote River at Rose Street, and Nottingham Drain at Candys Rd typically had higher concentrations than the rest of the sites. Riccarton Main Drain, Heathcote River at MacKenzie Ave, Linwood Canal, Aylmers Stream and Ihutai/Avon-Heathcote Estuary also recorded high values on occasion. The three highest concentrations were all from Curletts Stream at Motorway (0.79 mg/L in February 2023 – associated with rain, 0.6 mg/L June 2022 – not associated with rain, 0.52 mg/L in June 2023 – not associated with rain).
- Nine sites recorded a decrease in concentrations, and three sites an increase (Appendix F, Tables i–iv). The three greatest decreases were at Ōtūkaikino at Groynes, Smacks Creek at Gardiners Rd, and Horseshoe Lake (12%, 9%, and 9%, respectively). The site that recorded the biggest increase was Heathcote River at Ferrymead Bridge (6%).

3.2.5. pH

- Median pH values at all Council and SLLT sites complied with the guideline levels, except for Lyttelton Port and Smacks at Willowbank (Appendix E, Figure iv (a) – (c)).
- Waterway sites were generally similar to each other, and coastal sites recorded generally higher pH than waterway sites.
- The three highest values were 8.5 (Avon River at Avondale in November 2023), 8.4 (Avon River at Pages Road and Wilsons Stream in November 2023, and Heathcote River at Tunnel Road in January 2021) and 8.3 (Curletts Stream at Motorway in February 2021, Heathcote River at Ferrymead Bridge in March 2023, Cass Bay and Ihutai/Avon-Heathcote Estuary in January 2022, and Wilsons Stream in February 2022). Only

the Heathcote River at Tunnel Road value was recorded in association with rain.

- The lowest recorded pH at Council sites was 5.3 at Curletts Stream at Motorway (February 2023 – associated with rain), followed by 6.4 at Curletts Stream U/S of Heathcote River (March 2023 – not associated with rain) and 6.5 at Hayton Stream (October 2021, December 2021, February 2022, July 2022, and March 2023; December 2021 and July 2022 were associated with rain while the others were not), Curletts Stream U/S of Heathcote River (December 2021 and February 2023 – both associated with rain) and Heathcote River at Warren Crescent (July 2022 – associated with rain).
- No substantial changes in pH levels were recorded since monitoring began (Appendix F, Tables i–v).

3.2.6. Conductivity

- None of the CCC and SLLT sites met the guideline, except the two CCC Ōtūkaikino Creek sites (Appendix E, Figure v (a) – (c)). Coastal and tidal waterway sites had much higher values and variability compared to non-tidal waterway sites, due to saline influence (Appendix E, Figure v (a) – (c)). Excluding tidally influenced conductivity readings, levels were typically higher at the Riccarton Main Drain, Addington Brook, Heathcote River at Warren Cres and Curletts Stream at Motorway sites.
- As mentioned above, caution should be taken when interpreting these results, as the guideline levels may be subject to inaccuracies.
- The majority of the sites in the Ōpāwaho-Heathcote River Catchment, and many of the sites in the Ōtākaro-Avon River catchment, showed more variability and higher levels compared to other catchments.
- The three highest values were from Cass Bay (52500 µS/cm in March 2021), Akaroa Harbour (51900 µS/cm in October 2022) and Lyttelton Port (51800 µS/cm in March 2021). None of these values were recorded in associated with rain.
- Conductivity generally did not change over time at the sites by any large degree, except in Linwood Canal which had a 7% increase (Appendix F, Tables i–v).

3.2.7. Salinity

- No relevant guidelines currently exist for salinity.
- The coastal sites recorded much higher salinity than the strongly tidal waterway sites (Appendix E, Figure vi).

- The highest values were recorded at Akaroa Harbour (35 during February 2021 and May 2022) and Ihutai/Avon-Heathcote Estuary (35 during June 2022), with only the May 2022 sample associated with rain.
- Two sites recorded a decrease over time: Heathcote River at Tunnel Rd (67%) and Heathcote River at Ferrymead Bridge (26%) (Appendix F, Tables i–v). Last year Avon River at Bridge St recorded a 26% decrease but no significant change this year. Salinity has only been monitored at these sites for four years, but conductivity data has been collected since 2007. Examination of the conductivity data shows a co-varying decrease in conductivity and the change in salinity is likely a return to baseline conditions as data from 2019-2021 was atypically high. This highlights potential issues with short datasets.

3.2.8. Total Suspended Solids

- Median concentrations at all sites complied with the guideline level for total suspended solids (Appendix E, Figure vii (a) – (b)).
- Concentrations were particularly high at Ōpāwaho-Heathcote catchment sites compared to the other catchments. The coastal sites generally recorded concentrations similar to the waterway sites with higher TSS. In the Ōtākaro-Avon and Ōpāwaho-Heathcote River catchments, tidal sites typically had higher TSS concentrations than non-tidal sites. This is likely due to resuspension of the naturally finer substrate at these locations during tide changes and due to being at the bottom of the catchments. The Banks Peninsula waterway sites were similar to the remaining waterway sites.
- Curletts Stream U/S of Heathcote, Cashmere Stream at Worsleys and Halswell River at Tai Tapu Rd recorded high values compared to the other sites. High levels were recorded on occasion at a number of sites in the Ōtākaro-Avon, Ōpāwaho-Heathcote, Pūharakekenui-Styx, and Huritini-Halswell River catchments. The three highest TSS concentrations were recorded at Avon River at Avondale Rd (350 mg/L in June 2022 – not associated rain), Styx River at Marshland Rd (200 mg/L in August 2022 - associated with rain) and Heathcote River at Bowenvale Ave (170 mg/L in December 2021 – associated with rain).
- TSS concentrations generally did not change over time (Appendix F, Tables i–iv). The largest increases were from Akaroa Harbour (46%) and Steamwharf Stream (27%). The biggest decreases were from Lyttelton Port (51%), and Halswell River at Wroots Rd (36%). All four of these sites are short datasets (3.5 years) and the longer-term monitoring sites generally did not change over time by any large degree.

3.2.9. Turbidity

- The 80th percentiles were above the guidelines for all but four sites: Cashmere Stream at Sutherlands Rd, both Ōtūkaikino River sites and Styx River at Gardiners Rd (Appendix E, Figure viii (a) – (b)).
- As mentioned above, caution should be taken when interpreting these results, as the guideline levels may be subject to inaccuracies.
- The Ōpāwaho-Heathcote River catchment recorded higher turbidity concentrations compared to the other sites. The lower tidal waterway and coastal sites typically had higher turbidity than non-tidal sites, likely due to resuspension of the naturally softer substrate at these locations during tide changes. Additionally, three tributaries in the Ōtākaro-Avon River catchment had notably higher turbidity than the other non-tidal sites in the catchment. The Banks Peninsula waterway sites were similar to the other waterway catchments.
- Curletts StreamDrain U/S of Heathcote River, Heathcote River at Tunnel Rd and Heathcote River at Ferrymead Bridge recorded higher values than the other sites. High levels were recorded on occasion from almost half of all sites. The three highest turbidity readings were recorded from Heathcote River at Bowenvale Ave (150 FNU in December 2021), Heathcote River at Ferniehurst St (130 FNU in June 2022), and Cashmere River at Worsleys Rd (120 FNU in December 2021 and July 2022). All of these recordings were associated with rain.
- The majority of sites did not record a change in turbidity over time (Appendix F, Tables i–iv). The most substantial decreases over time were at Halswell River at Wroots Rd (18%), Avon River at Avondale Rd (16%). The most substantial increases were from Lyttelton Port (56%) and Akaroa Harbour (27%). Only the Avon River at Avondale Rd site was not a short dataset (3.5 years). The most substantial increase from the longer-term monitoring sites was from Cashmere River at Sutherland Rd which increased by 12%.

3.2.10. Water Clarity (SLLT sites only)

- Water clarity was similar across sites, and between the mainstem and tributary sites.
- The highest possible value of 100 cm was recorded at Kā Pūtahi at Blakes Rd (October 2022), Styx River at Conservation Reserve (February and April 2023), Styx Drain at Redbrook Rd (September 2022, and January and February 2023), Smacks at Willowbank (April 2023) and Smacks at Wilkinsons Rd (September 2022, and February and April 2023). The three poorest values were recorded at Styx River at Radcliffe

Road (16 cm in October 2022) and Horners Drain at Hawkins Rd (36 cm in September 2021 and 37 cm in September 2023).

- No substantial changes were recorded over time (Appendix F, Table v).

3.2.11. Dissolved Oxygen

- Median dissolved oxygen concentrations at over half of the sites met the minimum guideline levels, but there were some sites that did not meet the guideline within each catchment, with the exception of the Ōtūkaikino River, Huritini-Halswell River and coastal sites (Appendix E, Figure x (a) – (b)). None of the three Banks Peninsula waterway sites met the guideline.
- Dissolved oxygen concentrations were typically lower in the Ōpāwaho-Heathcote River catchment, particularly at the upstream tributary sites. DO concentrations were generally higher at the coastal sites than the waterway sites.
- The two Curlett Stream sites, Cashmere River at Sutherlands Rd, Hayton Stream, Heathcote River at Warren Cres and Linwood Canal typically recorded lower concentrations than the other sites. The three lowest readings were from Curlett Stream U/S of Heathcote (4.7% in January 2022, 9.2% in April 2022, and 9.4% in March 2022), and Curlett Stream at Motorway (9.2% in November 2022). Only the Curlett Stream at Motorway sample was recorded in association with rain.
- No substantial changes in oxygen were recorded at the sites over time (Appendix F, Tables i–iv).

3.2.12. Water Temperature

- Median water temperatures at all the Council and the SLLT sites complied with their respective guidelines, and temperature overall was similar across all waterway and coastal sites (Appendix E, Figure xi (a) – (c)).
- Temperature was typically more stable in the upper reaches of the Ōtākaro-Avon River and Ōpāwaho-Heathcote River catchments compared to the more downstream sites. The three highest readings were from Linwood Canal (24.5°C in January 2021, 24.2°C in February 2023), and Avon River at Bridge Street (22.8 °C in February 2023). None of these records were associated with rain.
- Temperature generally did not change over time (Appendix F, Tables i–v).

3.2.13. Biological Oxygen Demand

- Medians at all sites complied with the guideline (Appendix E, Figure xii (a) – (b)).
- Concentrations were typically higher in the tributary sites compared to the mainstem river sites, and highest overall in the Ōpāwaho-Heathcote River catchment.
- Hayton Drain and Curlett Stream recorded higher concentrations than the other sites. High levels were recorded on occasion from Heathcote River at Warren Cres. The highest concentrations recorded were from Hayton Stream (12 mg/L in January 2022), Heathcote River at Warren Cres (11 mg/L in March 2021), followed by 7.6 mg/L at Heathcote River at Ferniehurst St in February 2021. None of these events were associated with rain.
- Most sites did not record significant changes over time (Appendix F, Tables i–iv). The largest decrease was 5% from Linwood Canal.

3.2.14. Total Ammonia

- The 95th percentiles at all sites complied with their respective guidelines, except for Stream Reserve Drain where the guideline of 0.32 mg/L was exceeded with a 95th percentile of 0.3202 (Appendix E, Figure xiii (a) – (b)).
- Total ammonia was generally higher and more variable in the tributaries compared to mainstem river sites.
- Addington Brook, the two Curlett Stream sites, and Linwood Canal recorded high levels compared to the other sites. High levels were also recorded on occasion from Stream Reserve Drain. The three highest concentrations were all from the Curlett Stream at Motorway site (0.97 mg/L in April 2023, 0.96mg/L in February 2023 and 0.88 mg/L in March 2022). Only the February sample was associated with rain.
- Many sites recorded a decrease in ammonia over time, with the largest reductions at Halswell River at Wroots Rd and Balguerie Stream (14%). Both these are newer sites with short datasets (3.5 years). For the longer-term monitoring sites the greatest reduction was at Ōtūkaikino at Scout Camp (13%) (Appendix F, Tables i–iv). No sites recorded an increase.

3.2.15. Nitrate and Dissolved Inorganic Nitrogen

- The majority of all the sites complied with the nitrate guidelines (Appendix D, Figure xiv (a) – (b)). The exceptions to this being Heathcote River at Warren Cres, the two Cashmere Stream sites, Knights at Sabys Rd, Halswell River at Wroots Rd, and Halswell River at Tai Tapu Rd.
- The medians at over half the sites complied with their respective DIN guideline (Appendix E, Figure xv (a) – (b)). The exceptions being Waimairi Stream, Avon at Mona Vale, Riccarton Main Drain, Wilsons Stream, three of the four Huritini-Halswell River sites (Knights at Sabys Rd, and Halswell River at Wroots and Tai Tapu Roads), almost half of the 15 sites in the Ōpāwaho-Heathcote River Catchment and all Banks Peninsula sites.
- Both parameters typically decreased downstream in the mainstems and were typically higher in the Huritini-Halswell River catchment, followed by the Ōpāwaho-Heathcote and Ōtākaro-Avon River catchments.
- The sites typically recording the highest concentrations were Heathcote River at Warren Cres, Knights at Sabys Rd, and Halswell River at Wroots and Tai Tapu Roads. High concentrations were also recorded on occasion from Riccarton Main Drain. The three highest concentrations of DIN were from Heathcote River at Warren Cres (5.3 mg/L in December 2023), Riccarton Main Drain (5 mg/L in November 2022), and Knights at Sabys (4.8 mg/L in June 2023). None of these records were in association with rain.
- The majority of sites recorded minor decreases in DIN concentrations over time (Appendix F, Tables i–iv). A large decrease was recorded at Curletts Stream at Motorway site (26%). Six sites recorded increases in concentrations, the most notable being Balguerie Stream (32%) and Aylmers Stream (30%).

3.2.16. Dissolved Reactive Phosphorus

- The median concentrations of DRP at over half the sites did not comply with their respective guidelines, and the Ōtūkaikino River catchment was the only one where the guideline was met at all sites (Appendix E, Figure xvi (a) – (b)).
- Sites in the Ōpāwaho-Heathcote and Huritini-Halswell catchments typically recorded higher levels than those in the other catchments, although there were also occasional high values in most catchments. Levels at the mainstem sites typically increased downstream in the Ōtākaro-Avon, Ōpāwaho-Heathcote and Pūharakekenui-Styx

catchments. The Banks Peninsula sites recorded levels on the higher end of the waterway sites.

- The sites recording the highest values consistently were Dudley Creek, Horseshoe Lake, Hayton Stream, both Curlett Stream sites and Linwood Canal. Most sites recorded high levels on occasion. The three highest concentrations were from Curletts Stream at Motorway (1.3 mg/L in May 2022 and 0.45 in March 2021), and Curletts Stream U/S of Heathcote (0.25 mg/L in February 2023). Only the Curletts Stream U/S of Heathcote sample was associated with rain.
- The majority of sites recorded a decrease in DRP concentrations (Appendix F, Tables i–iv). The largest decreases were at the Hayton Stream site (15%) and Otukaikino River at the Groynes and Omaka Scout Camp (10%). No site recorded an increase.

3.2.17. *E. coli*, Enterococci, and Faecal Coliforms

- None of the sites complied with the 95th percentile *E. coli* guideline level, except for Cashmere Stream at Sutherlands Rd and Ihutai/Avon-Heathcote Estuary (Appendix E, Figure xvii (a) – (b)).
- The single sample guideline value for enterococci was exceeded at all sites except Akaroa Harbour (Appendix E, Figure xviii).
- The Akaroa Harbour site is the only site monitored for faecal coliforms. The site complied with the median guideline, but not the 90th percentile guideline (Appendix E, Figure xviii). The highest faecal coliform concentration (141 MPN/100 ml) was recorded in November 2022 and was not associated with rain or wastewater overflows.
- Addington Brook, Dudley Creek, Curletts Stream at Motorway, Heathcote River at Rose Street, Kā Pūtahi at Belfast Rd, and Nottingham Stream at Candys Rd recorded higher concentrations of *E. coli* compared to the other sites. Occasionally high concentrations were recorded from most sites. The highest *E. coli* concentration (>24,000 MPN/100ml) was recorded at Riccarton Main Drain (January 2023), Nottingham Stream at Candys Rd (December 2021) and Curletts Stream at Motorway (December 2021, October 2022 and February 2023). Only the Riccarton Main Drain sample was not associated with rain. The second highest concentration of 20,000 MPN/100 ml was from Heathcote River at Ferrymead Bridge (December 2021) and Halswell River at Tai Tapu Rd (December 2021) and both were associated with rain. The third highest concentration of 17,000 MPN/100 ml was recorded from Steamwharf Stream in December 2021 and was

associated with rain. No wastewater overflows were recorded during these events.

- Linwood Canal, Lyttelton Port and both of the tidal Ōpāwaho/Heathcote River sites recorded generally higher concentrations of enterococci compared to the other sites. The highest enterococci concentration (24,000 MPN/100ml) was recorded in December 2021 from both Ōpāwaho/Heathcote River sites. Both of these results were associated with rain, but not wastewater overflows.
- *E. coli* levels generally did not change at the sites over time (Appendix F, Tables i–iv). Aylmers Stream recorded a 51% decrease last year but no significant change this year. This is likely due to some peak concentrations in 2023 and the short dataset, with this round of analysis being the first where seasonal (i.e., monthly) data was able to be analysed for every month (3.5 years). Of note, approximately a third of the sites in the Ōpāwaho-Heathcote River catchment recorded a decrease in concentrations. The largest increase was recorded at Wilsons Stream (9%) and largest decrease at Halswell River at Wroots Rd (27%).
- Changes over time in enterococci was recorded at three of the eight sites: Avon River at Bridge St (8% reduction), Heathcote River at Ferrymead Bridge (5% reduction), and Linwood canal (8% reduction).
- Faecal coliform concentrations did not change over time at the Akaroa Harbour site.

3.3. Water Quality Index

- The most common WQI categories were ‘good’ (33% - 14 sites), ‘fair’ (33% - 14 sites), and ‘poor’ (21% - 9 sites) as presented in Table 3. The category ‘very good’ was represented by 5 sites (12%) and ‘very poor’ by a single site equating to 2% of sites.
- Based on the median WQI for each catchment, the Ōtākaro-Avon River, Pūharakekenui-Styx and Ōtūkaikino River recorded ‘good’ water. Both the Ōpāwaho-Heathcote River and Huritini-Halswell River recorded ‘fair’ water quality while Banks Peninsula waterways recorded ‘poor’ water quality (Figure 13).
- The Ōtūkaikino River recorded the best water quality out of all the catchments and Banks Peninsula recorded the worst water quality (Table 4).

- The best sites for water quality were jointly Wairarapa Stream, Waimairi Stream and Avon River at Mona Vale, followed by Ōtūkaikino at Scout Camp and Avon River at Manchester Street (Table 4).
- The worst site for water quality was Curletts Stream at Motorway, followed by Curletts Stream U/S of Heathcote, and Aylmers Stream (Table 4).
- At the catchment scale, Time Trends analysis showed no significant change in WQI over the analysed period (2016–2023) (Figure 13). Compared to last year, median catchment categories improved in three catchments (Ōtākaro-Avon River 'fair' to 'good', Ōpāwaho-Heathcote River 'poor' to 'fair' and Pūharakekenui-Styx 'poor' to 'good'). As reflected by the lack of statistical change over time, catchment medians were within the ranges previously recorded.
- Significant changes over time in WQI were recorded for Dudley Creek (3% reduction) and Hayton Stream (8% increase).

Table 3. Water Quality Index (WQI) scores and categories for 2023, and direction of significant temporal trends (2016–2023) at each Christchurch City Council surface water quality monitoring site.

Catchment	Site	WQI Score	WQI Category	WQI Temporal Trends
Ōpāwaho-Heathcote	Curletts Stream at Motorway	39.0	Very Poor	
Ōpāwaho-Heathcote	Curletts Stream U/S of Heathcote	46.0	Poor	
Banks Peninsula	Aylmers Stream	55.3	Poor	
Ōtākaro-Avon	Dudley Creek	57.0	Poor	↓3%
Banks Peninsula	Stream Reserve Drain	58.4	Poor	
Ōpāwaho-Heathcote	Cashmere Stream at Worsleys Rd	61.6	Poor	
Ōpāwaho-Heathcote	Heathcote River at Opawa Rd	66.7	Poor	
Ōpāwaho-Heathcote	Heathcote River at Ferniehurst St	67.0	Poor	
Ōpāwaho-Heathcote	Hayton Stream	68.7	Poor	↑8%
Huritini-Halswell	Nottingham Drain at Candys Rd	68.9	Poor	
Ōpāwaho-Heathcote	Heathcote River at Rose St	70.3	Fair	
Ōpāwaho-Heathcote	Heathcote River at Catherine St	71.0	Fair	
Ōpāwaho-Heathcote	Heathcote River at Bowenvale Ave	71.4	Fair	
Ōtākaro-Avon	Addington Brook	71.9	Fair	
Huritini-Halswell	Halswell River at Wroots Rd	72.1	Fair	
Ōtākaro-Avon	Avon River at Pages Rd	72.4	Fair	
Huritini-Halswell	Halswell River at Tai Tapu Rd	72.5	Fair	
Ōtūkaikino	Wilsons Stm	73.4	Fair	
Ōtākaro-Avon	Horseshoe Lake	74.1	Fair	
Banks Peninsula	Balguerie Stream	74.5	Fair	
Ōpāwaho-Heathcote	Steamwharf Stream	75.7	Fair	
Ōpāwaho-Heathcote	Heathcote River at MacKenzie Ave	76.3	Fair	
Ōtākaro-Avon	Riccarton Main Drain	77.5	Fair	
Pūharakekenui-Styx	Kā Pūtahi at Belfast Rd	78.8	Fair	
Ōpāwaho-Heathcote	Heathcote River at Warren Cres	80.8	Good	
Pūharakekenui-Styx	Styx River at Richards Bridge	82.2	Good	
Pūharakekenui-Styx	Kā Pūtahi at Blakes Rd	82.2	Good	
Huritini-Halswell	Knights Stream at Sabys Rd	82.6	Good	
Pūharakekenui-Styx	Styx River at Marshland Rd	82.8	Good	
Pūharakekenui-Styx	Styx River at Main North Rd	83.8	Good	
Ōpāwaho-Heathcote	Cashmere Stream at Sutherlands Rd	84.3	Good	
Pūharakekenui-Styx	Styx River at Harbour Rd	86.3	Good	
Pūharakekenui-Styx	Styx River at Gardiners Rd	86.4	Good	
Ōtākaro-Avon	Avon River at Avondale Rd	87.9	Good	
Pūharakekenui-Styx	Smacks at Gardiners Rd	88.0	Good	
Ōtākaro-Avon	Avon River at Dallington Tce	88.6	Good	
Ōtūkaikino	Ōtūkaikino Creek at Groynes	89.2	Good	
Ōtākaro-Avon	Avon River at Carlton Mill	89.5	Good	

Ōtākaro-Avon	Avon River at Manchester St	93.3	Very Good	
Ōtūkaikino	Ōtūkaikino Creek at Scout Camp	94.3	Very Good	
Ōtākaro-Avon	Avon River at Mona Vale	94.7	Very Good	
Ōtākaro-Avon	Waimairi Stream	94.7	Very Good	
Ōtākaro-Avon	Wairarapa Stream	94.7	Very Good	

Table 4. Best and worst catchments and sites for the monitoring period January to December 2022, based on the Water Quality Index (WQI).

Placing	Best Sites		Worst Sites	
	Catchment Scale	Site Scale	Catchment Scale	Site Scale
	Ōtūkaikino River (median WQI = 89)	Wairarapa Stream, Waimairi Stream and Avon at Mona Vale (WQI = 95)	Bank Peninsula (median WQI = 58)	Curletts Stream at Motorway (WQI = 39)
	Ōtākaro-Avon River (median WQI = 88)	Ōtūkaikino at Scout Camp (WQI = 94)	Ōpāwaho-Heathcote River (median WQI = 70)	Curletts Stream U/S of Heathcote (WQI = 46)
	Pūharakekenui-Styx (median WQI = 83)	Avon at Manchester St (WQI = 93)	Huritini-Halswell (median WQI = 72)	Aylmers Stream (WQI = 55)

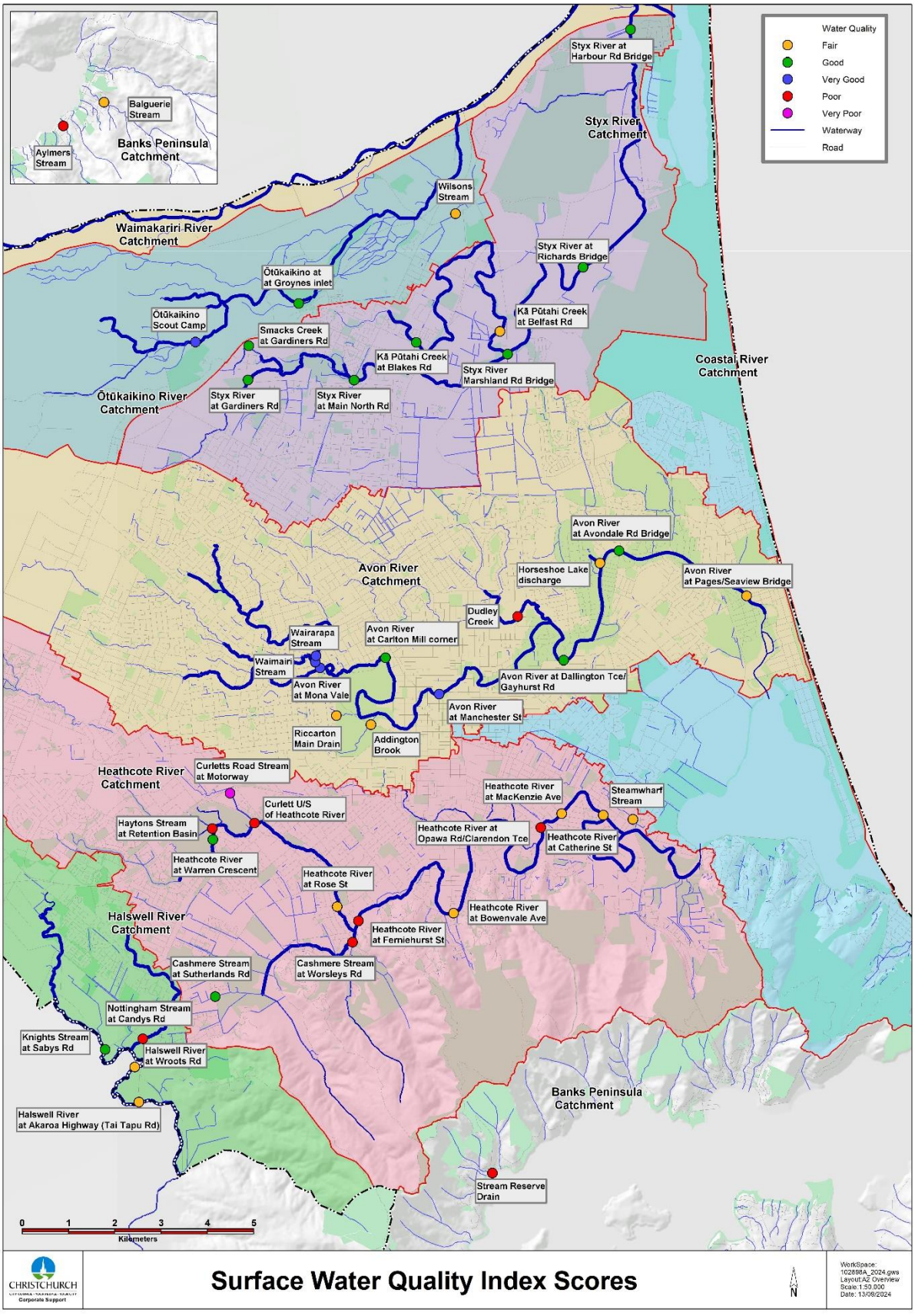

Figure 12. Water Quality Index (WQI) categories for 2023 at the Christchurch City Council surface water quality monitoring sites.

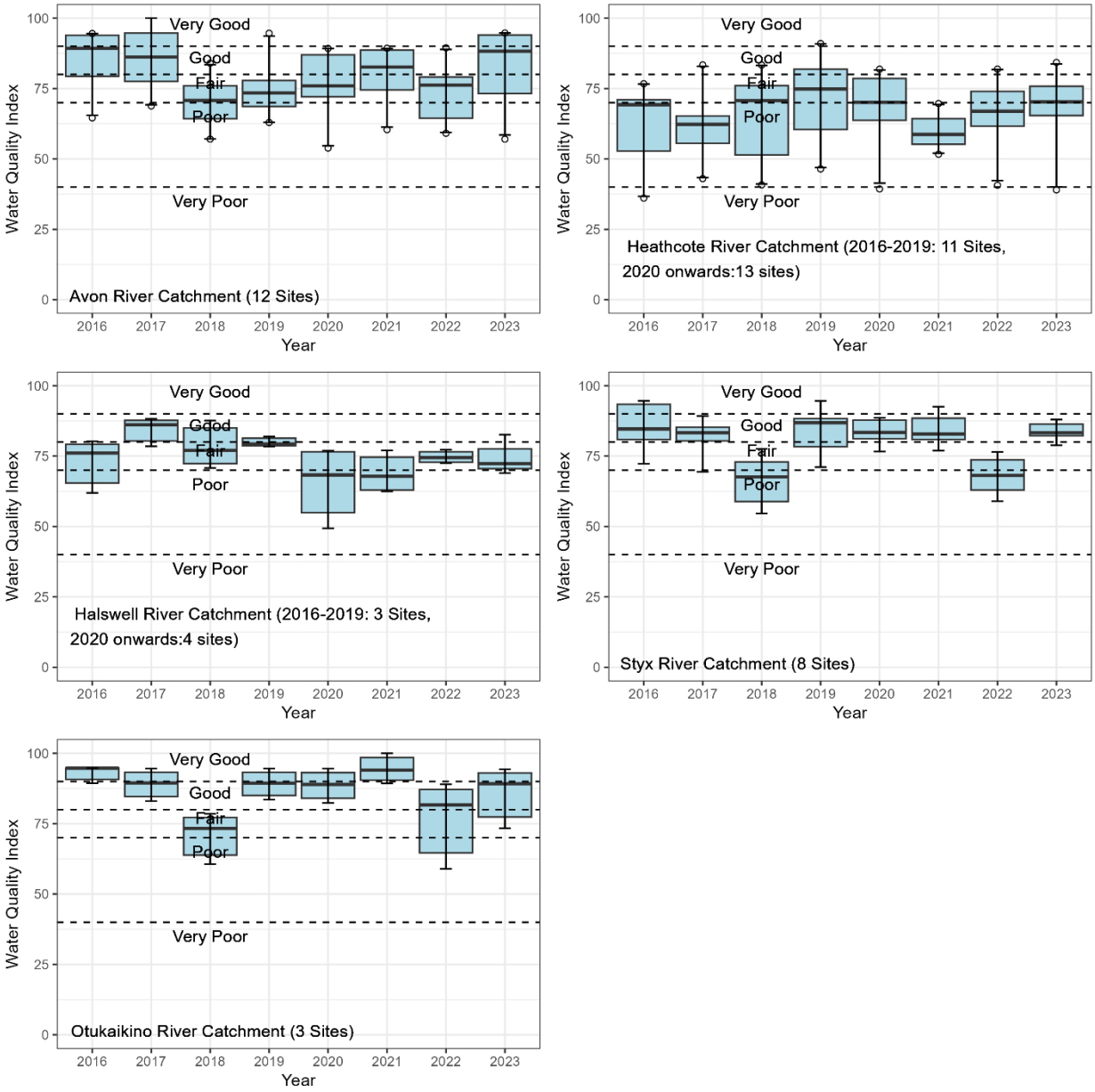

Figure 13. Boxplots of Water Quality Index for each catchment for the 2016 to 2023 monitoring years

3.4. Assessment against Attribute Target Levels

- A requirement for this report under the CSNDC EMP is to assess the Council monthly data against the consent Objectives and Attribute Target Levels (ATLs) for TSS, dissolved copper, lead, and zinc, as specified in Schedules 7 (Waterways) and 8 (Coastal Waters) of the consent conditions. If these ATLs are not met, water quality investigations are triggered to determine whether the water quality is due to stormwater inputs.
- These ATLs require that (a) the guidelines used in this report are met, and (b) no increasing trends in concentrations are recorded. This assessment is for results from the monitoring year, not the three-year dataset as used elsewhere in this report.
- 25 of the 50 sites (Lyttelton Port is not included, as it is excluded from meeting ATLs under Schedule 8 of the CSNDC) monitored in 2023 did not meet the CSNDC ATLs for at least one of the parameters (Table 5; Appendix G).
- The sites that are prioritised for investigation are those where a guideline was not met, and an increasing trend was recorded. These sites this monitoring year are Nottingham Stream at Candys Road, Heathcote River at Ferrymead Bridge and Heathcote River at Tunnel Road.
- Nottingham Stream at Candys Road has been prioritised every year since 2021, due to dissolved zinc. Heathcote at Ferrymead Bridge was prioritised in 2021 and 2022, however not in 2023.These two sites have been further discussed under the Condition 59 investigations) since the consent was granted.
- It was the first time Heathcote River at Tunnel Rd has been prioritised for further investigation (due to dissolved zinc). Further details on this site are included in next years Condition 59 report.
- For the two previous years Addington Brook has also been prioritised (due to copper and zinc); however, this year ATLs were only triggered for the dissolved zinc guideline and no significant increases were recorded. Stormwater treatment options in the catchment are currently being designed and continued monitoring will determine if this improvement is continuing.

Table 5. Assessment of Christchurch City Council surface water quality monitoring sites against the Comprehensive Stormwater Network Discharge Consent (CSNDC) Attribute Target Levels (ATLs) for Total Suspended Solids (TSS), dissolved copper, dissolved lead and dissolved zinc, for the monitoring year January – December 2023. G = guideline level not met; I = statistically significant increase recorded; N/A = parameter not measured; blank cell = investigation not triggered (i.e., ATLs are met). Sites not in the table are those that met all the ATL. Lyttelton Port is not included, as it is excluded from meeting ATLs under Schedule 8 of the CSNDC. There is no TSS guideline ATL for the strongly tidal waterway sites; however, this will likely be implemented in next year's report.

Site	Dissolved Copper (95^{th} percentiles)	Dissolved Lead (95^{th} percentiles)	Dissolved Zinc (95^{th} percentiles)	TSS (median)	Investigation Prioritised?	Comments
Nottingham at Candys Rd			G,I		Yes	2021 & 2022 Condition 59 investigation site; Targeted Wet Weather Monitoring Project site
Heathcote River at Ferrymead Bridge	G		G, I		Yes	2021 Condition 59 investigation site
Heathcote River at Tunnel Rd	G		G, I		Yes	
Curletts Stream at Motorway	G		G	I		2021 & 2022 Condition 59 investigation site; Targeted Wet Weather Monitoring Project site
Curletts Stream U/S of Heathcote	G		G	I		Targeted Wet Weather Monitoring Project site
Akaroa Harbour	G		G	I		
Aylmers Stream	G	G	G			
Cashmere Stream at Worsleys Rd	G		G			

Site	Dissolved Copper (95th percentiles)	Dissolved Lead (95th percentiles)	Dissolved Zinc (95th percentiles)	TSS (median)	Investigation Prioritised?	Comments
Heathcote River at Rose St	G		G			
Stream Reserve Drain	G		G			
Dudley Creek	G		G			
Halswell River at Tai Tapu Rd				I		
Steamwharf Stream				I		
Wilsons Stream				I		
Heathcote River at Ferniehurst St	G					
Heathcote River at Bowenvale Ave	G					
Heathcote River at Opawa Rd	G					
Waimairi Stream	G					
Heathcote River at MacKenzie Ave	G					
Avon River at Bridge St			G			
Hayton Stream			G			
Riccarton Main Drain			G			
Addington Brook			G			2021 & 2022 Condition 59 investigation site; Targeted

Site	Dissolved Copper (95th percentiles)	Dissolved Lead (95th percentiles)	Dissolved Zinc (95th percentiles)	TSS (median)	Investigation Prioritised?	Comments
						Wet Weather Monitoring Project site
Linwood Canal			G			
Balguerie Stream			G			

3.5. Catchment Summary

A collation of the WQI results and contaminants of concern for each catchment are provided in Table 6. Of particular note:

- Dissolved copper and zinc, turbidity, DRP, and *E. coli* are of concern in most waterway catchments.
- Dissolved copper, dissolved zinc, turbidity and enterococci are the contaminants of concern in coastal areas.
- Water quality in the monitored Banks Peninsula settlement waterways is no better than waterways in the City and is particularly poor at Stream Reserve Drain in Governors Bay and Aylmers Stream in Akaroa.

Table 6. Catchment summary of surface water quality and contaminants of concern, based on data presented in this 2023 monitoring report. WQI = Water Quality Index; N/A = Not Applicable (due to the WQI not being calculated, or only one site being monitored so a catchment summary is not relevant); * = catchment level assessment; DIN = Dissolved Inorganic Nitrogen, DRP = Dissolved Reactive Phosphorus; TSS = Total Suspended Solids; BOD_5 = Biochemical Oxygen Demand, DO = Dissolved Oxygen.

Catchment	WQI Category	Best sites (Highest WQI Score)	Worst sites (Lowest WQI Score)	WQI Time Trend (2016-2022)	Contaminants of Concern	
					Catchment Level	Site Level (based on guidelines not being met)
Ōtākaro-Avon River	Fair (Median WQI = 88)*	Wairarapa Stream (94.7) Waimairi Stream (94.7) Avon River at Mona Vale (94.7)	Dudley Creek (57) Addington Brook (71.9) Avon River at Pages (72.4)	No significant trend*	*E. coli* Conductivity, turbidity, DRP	Wairarapa Stream (*E. coli*, turbidity) Waimairi Stream (*E. coli,* turbidity, DIN) Avon River at Mona Vale (*E. coli,* turbidity, DIN) Avon River at Carlton Mill (*E. coli*, turbidity) Riccarton Main Drain (Zinc, *E. coli,* turbidity, DIN) Addington Brook (Copper, zinc, E. *coli,* turbidity, DO, DRP) Avon River at Manchester St (*E. coli,* turbidity) Dudley Creek (Zinc, *E. coli,* turbidity, copper, DRP) Avon River at Dallington Tce (*E. coli,* turbidity, DRP) Horseshoe Lake (*E. coli,* turbidity, DO, DRP) Avon River at Avondale Rd (*E. coli,* turbidity, DRP) Avon River at Pages Rd (*E. coli,* turbidity, DRP) Avon River at Bridge Street (Copper, zinc, *E. coli,* turbidity, DRP, enterococci)

Catchment	WQI Category	Best sites (Highest WQI Score)	Worst sites (Lowest WQI Score)	WQI Time Trend (2016-2022)	Contaminants of Concern	
					Catchment Level	Site Level (based on guidelines not being met)
Ōpāwaho-Heathcote River	Fair (Median WQI = 70)*	Cashmere Stream at Sutherlands Rd (84.3) Heathcote River at Warren Cres (80.8) Heathcote River at MacKenzie Ave (76.3)	Curletts Stream at Motorway (39.0) Curletts Stream U/S of Heathcote (46.0) Cashmere Stream at Worsleys Road (61.6)	No significant trend*	*E. coli*, Copper, zinc, turbidity, Conductivity, DO, DRP	Heathcote River at Warren Cres (*E. coli,* turbidity, DO, DIN, nitrate) Hayton Stream (Zinc, *E. coli,* turbidity, DO, DRP) Curletts Stream at Motorway (Copper, zinc, *E. coli,* turbidity, DRP, DO) Curletts Stream U/S of Heathcote (Copper, zinc, *E. coli,* turbidity, DO, DRP) Heathcote River at Rose St (Copper, zinc, *E. coli,* turbidity, DIN, DRP,) Cashmere Stream at Sutherlands Rd (Copper, DO, DIN, nitrate) Cashmere Stream at Worsleys Rd (Copper, zinc, *E. coli,* turbidity, DO, DIN, nitrate) Heathcote River at Ferniehurst St (Copper, *E. coli,* turbidity, DIN, DRP) Heathcote River at Bowenvale Ave (Copper, *E. coli,* turbidity, DRP, DIN) Heathcote River at Opawa Rd (Copper, *E. coli,* turbidity, DIN, DO, DRP) Heathcote River at MacKenzie Ave (Copper, zinc, *E. coli,* turbidity, DO, DRP)

Catchment	WQI Category	Best sites (Highest WQI Score)	Worst sites (Lowest WQI Score)	WQI Time Trend (2016-2022)	Contaminants of Concern	
					Catchment Level	Site Level (based on guidelines not being met)
						Heathcote River at Catherine St (*E. coli,* turbidity, copper, DRP) Heathcote River at Tunnel Rd (Copper, zinc, *E. coli*, turbidity, DO, DRP, enterococci) Steamwharf Stream (*E. coli,* turbidity, DRP) Heathcote at Ferrymead Bridge (Copper, zinc, *E. coli,* turbidity, DRP, enterococci)
Pūharakekenui-Styx River	Good (Median WQI = 83)*	Smacks at Gardiners Rd (88.0) Styx River at Gardiners Rd (86.4) Styx River at Harbour Rd (86.3)	Kā Pūtahi at Belfast Rd (78.8) Kā Pūtahi at Blakes Rd (82.2) Styx River at Richards Bridge (82.2)	No significant trend*	Conductivity, turbidity, DRP, *E. coli*	Styx River at Gardiners Rd (*E. coli,* DO) Smacks at Gardiners Rd (Zinc, *E. coli,* turbidity, DO) Styx River at Main North Rd (Zinc, *E. coli,* turbidity) Kā Pūtahi at Blakes Rd (Zinc, *E. coli,* turbidity, DRP, DO) Kā Pūtahi at Belfast Rd (*E. coli,* turbidity, DRP) Styx River at Marshland Rd (*E. coli,* turbidity, DRP) Styx River at Richards Bridge (*E. coli,* turbidity, DRP) Styx River at Harbour Rd (*E. coli,* turbidity, DRP, DO)
Ōtūkaikino River	Good (Median WQI = 89)*	Ōtūkaikino at Scout Camp (94.3) Ōtūkaikino at Groynes (89.2)	Wilsons Stream (73.4)	No significant trend*	*E. coli*	Ōtūkaikino at Scout Camp (*E. coli*) Ōtūkaikino at Groynes (*E. coli*) Wilsons Stream (Zinc, *E. coli,* turbidity, DIN, DRP)

Catchment	WQI Category	Best sites (Highest WQI Score)	Worst sites (Lowest WQI Score)	WQI Time Trend (2016-2022)	Contaminants of Concern	
					Catchment Level	Site Level (based on guidelines not being met)
Huritini-Halswell River	Fair (Median WQI = 72)*	Knights at Sabys Rd (82.6) Halswell River at Tai Tapu Rd (72.5)	Nottingham at Candys Rd (68.9) Halswell River at Wroots Rd (72.1)	No significant trend*	Copper, turbidity, nitrate, DIN, DRP, *E. coli*	Knights at Sabys Rd (*E. coli,* turbidity, DIN, nitrate) Nottingham at Candys Rd (Zinc, *E. coli,* turbidity, DRP) Halswell River at Wroots Rd (Copper, *E. coli,* turbidity, DRP, DIN, nitrate) Halswell River at Tai Tapu Rd (Copper, *E. coli*, turbidity, DIN, nitrate)
Bank Peninsula	Poor (WQI = 58)*	Balguerie Stream (74.5)	Aylmers Stream (55.3) Stream Reserve Drain (58.4)	No significant trend*	Copper, zinc, turbidity, DO, DIN, DRP, *E. coli*	Stream Reserve Drain (Copper, zinc, *E. coli,* turbidity, DO, DIN, DRP, total ammonia) Balguerie Stream (Copper, zinc, *E. coli,* turbidity, DO, DIN, DRP) Aylmers Stream (Copper, lead, zinc, DO, DIN, DRP,)
Coastal	N/A	N/A	N/A	N/A	Copper, zinc, turbidity, enterococci	Ihutai – Avon-Heathcote Estuary (Copper, zinc, *E. coli,* turbidity, enterococci) Lyttelton Port (Copper, zinc, turbidity, pH, enterococci) Cass Bay (turbidity, enterococci (limited dataset)) Akaroa Harbour (Copper, zinc, turbidity, faecal coliforms) Linwood Canal (Copper, zinc, *E. coli*, turbidity, DO, DRP, enterococci)

3.6. Wet Weather Monitoring

3.6.1. Rainfall

- The total amount of rainfall within the Pūharakekenui-Styx River catchment for the first and second wet weather events was 34.4 mm and 15.8 mm, respectively (Figure 14). Based on times provided by NIWA 2023, Nalgene samplers filled during the first 6.6-22.4 mm of rainfall for the first event and 4-15.8 mm during the second event.
- Consequently, it is unknown whether the First Flush of stormwater (15-25 mm) was met for any or all of the sampling events.
- All events met the criteria of a minimum of three antecedent dry days prior to sampling.
- Given the criteria for wet weather sampling was not fully met, it is likely that the results of the monitoring do not accurately represent stormwater contaminant levels.

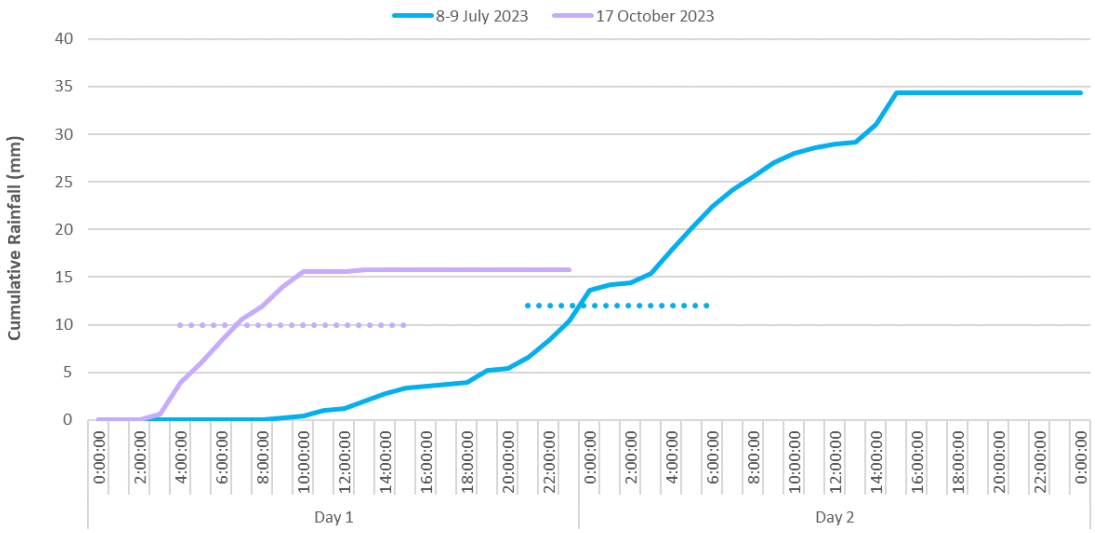

Figure 14. Rainfall during the wet weather events of 8-9 July 2023 (blue line) and 17 October 2023 (purple line) within the Pūharakekenui/Styx River catchment, with approximate Nalgene sampling times indicated by dotted lines.

3.6.1. Water Quality Parameters

- Concentrations were higher in the first event for most parameters (dissolved copper, dissolved lead, dissolved zinc, TSS, turbidity, water temperature, BOD5 (Figure 15 - Figure 18)). In contrast E. coli was higher in the second event. The remaining parameters varied between events depending on site. At the site scale, Kā Pūtahi Stream at Blakes Road had notably higher concentrations for all dissolved metals (despite having the lowest recorded conductivity for both events), TSS and turbidity. An insufficient number of sites were sampled to determine any reliable

upstream/downstream patterns, or comparison of tributary and mainstem sites.

- For the first event, the guidelines were not met at any site for: dissolved copper, dissolved zinc, DRP and E. coli. Turbidity did not meet the guideline for a single sample in either event. All sites for both events met the pH, DO, temperature, total ammonia, nitrate and DIN guidelines. Other contaminants did not meet the guidelines on occasion: dissolved copper (second event only – two occasions), dissolved lead (one occasion), dissolved zinc (second event only - two occasions), conductivity (seven occasions), TSS (two occasions), BOD5 (five occasions), DRP (second event only – four occasions), and E. coli (second event only – four occasions).
- There were several high values recorded during the wet weather monitoring. The Kā Pūtahi Stream at Blakes Road site recorded 0.12 mg/L for zinc, 98 mg/L for TSS and 94 FNU for turbidity during the first event. A DRP value of 0.11 mg/L was recorded at Kā Pūtahi Stream at Belfast Road during the first event.
- Compared to the monthly monitoring, dissolved copper, dissolved lead, dissolved zinc and BOD5 were higher (sometimes markedly so) during the wet weather monitoring. The previously mentioned individual high values were substantially higher than any results recorded during the monthly monitoring.

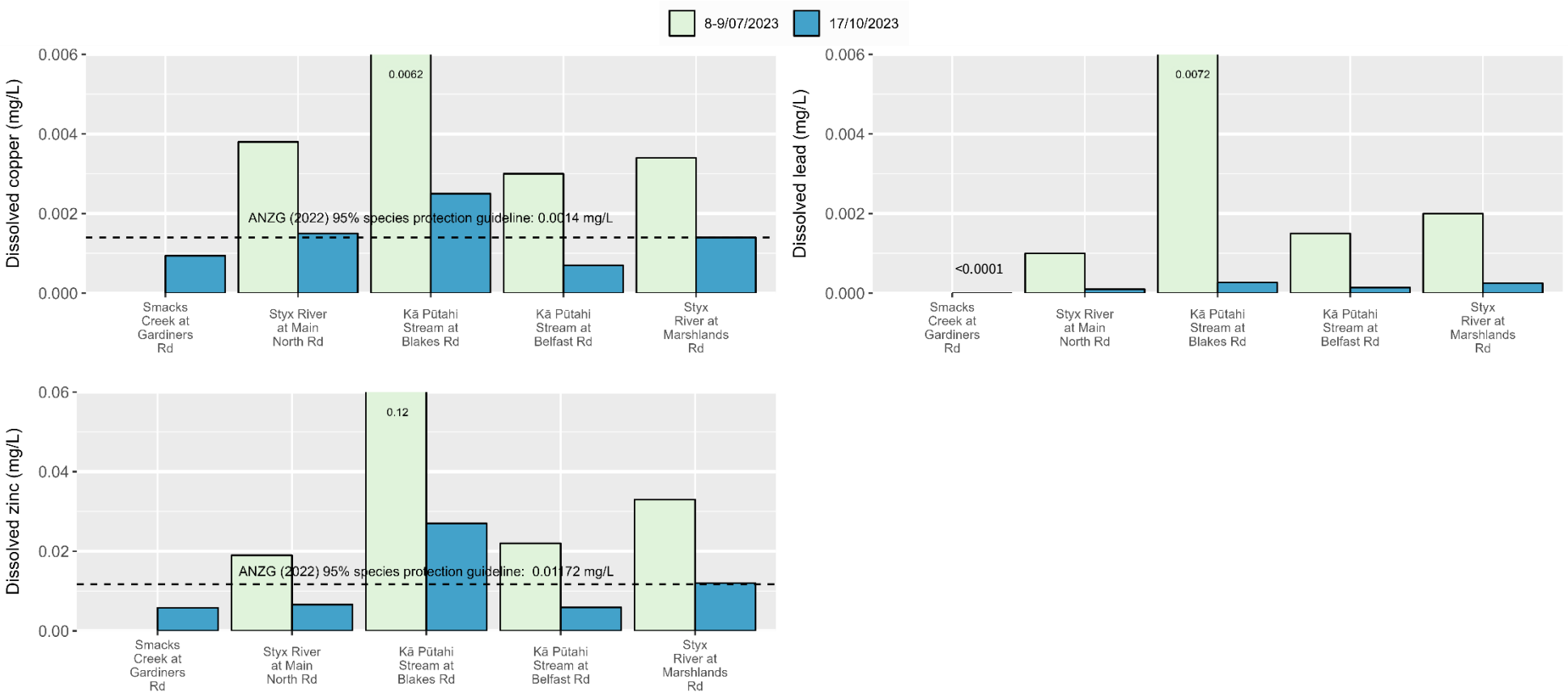

Figure 15. Dissolved copper (top left), dissolved lead (top right), and dissolved zinc (bottom left) concentrations in water samples taken from the Pūharakekenui-Styx River catchment during two wet weather events in 2023. Sites are ordered from upstream to downstream (left to right). The dashed lines represent either the 95% default (copper) or hardness modified (lead, zinc) guideline values (HMGV) as per ANZG (2022). The dissolved lead guideline (0.00601 mg/L) is not visible as it is greater than the axis limit. No sample was collected from Smacks Creek in July 2023.

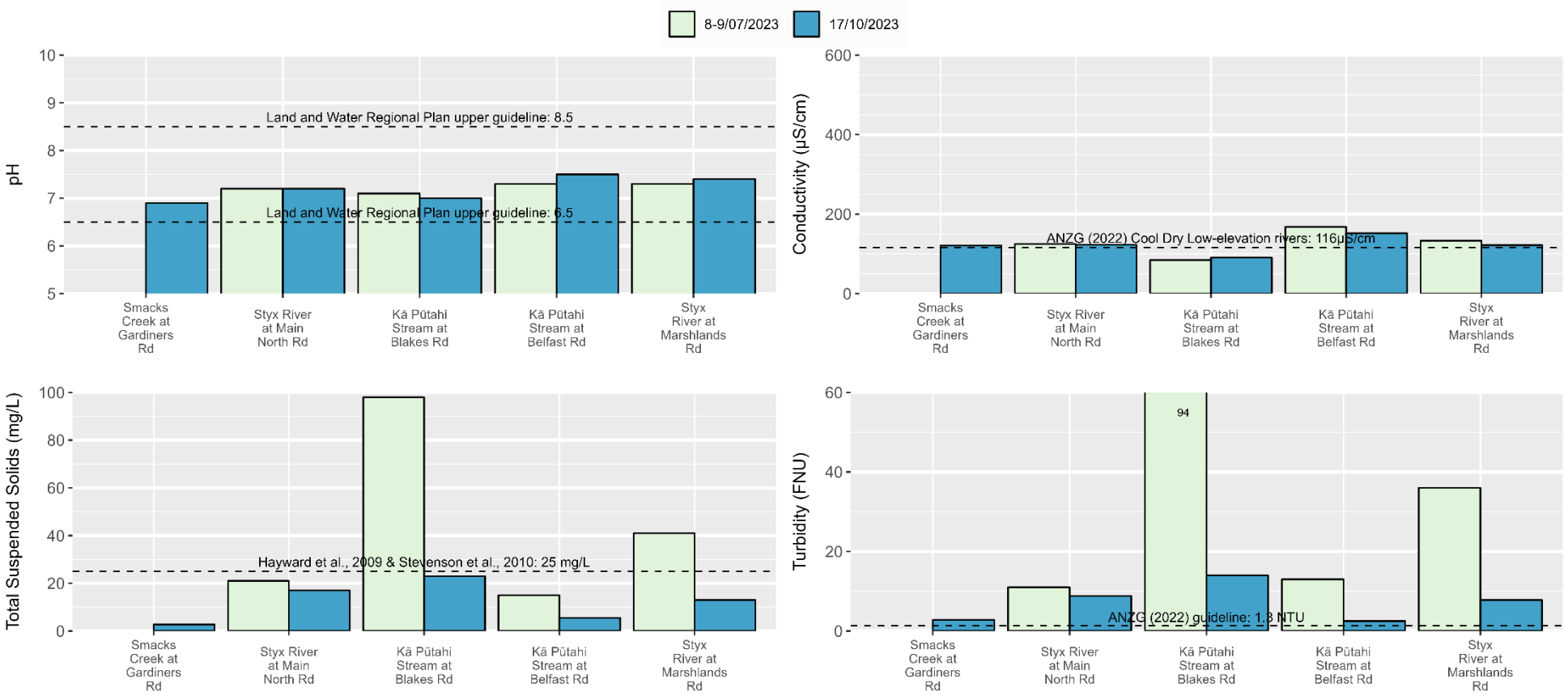

Figure 16. Conductivity (top left), pH (top right), Total Suspended Solids (TSS; bottom left) and turbidity (bottom right) concentrations in water samples taken from the Pūharakekenui-Styx River catchment during two wet weather events in 2023. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the respective guidelines (pH: Land and Water Regional Plan guidelines); TSS: Hayward et al. (2009) & Stevenson et al. (2010); Turbidity and Conductivity: ANZG (2022)). No sample was collected from Smacks Creek in July 2023.

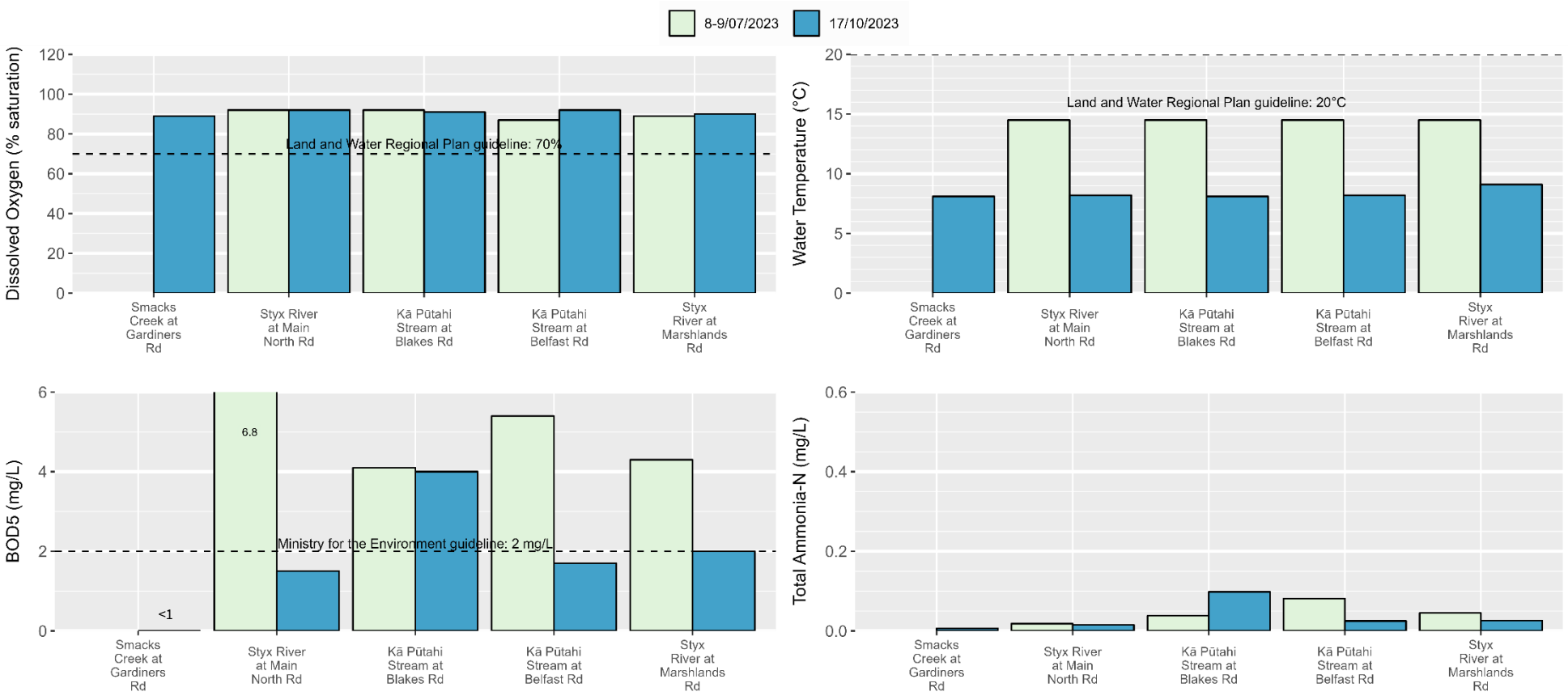

Figure 17. Dissolved oxygen (DO; top left), water temperature (top right), BOD_5 (bottom left) and total ammonia (bottom right) concentrations in water samples taken from the Pūharakekenui-Styx River catchment during two wet weather events in 2023. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the respective guidelines (DO and water temperature: Environment Canterbury, 2019; BOD_5: Ministry for the Environment, 1992;). The total ammonia (1.8 mg/L), adjusted in accordance with sample pH of 7 (Environment Canterbury, 2019) is not visible as it is greater than the axis limit. No sample was collected from Smacks Creek in July 2023.

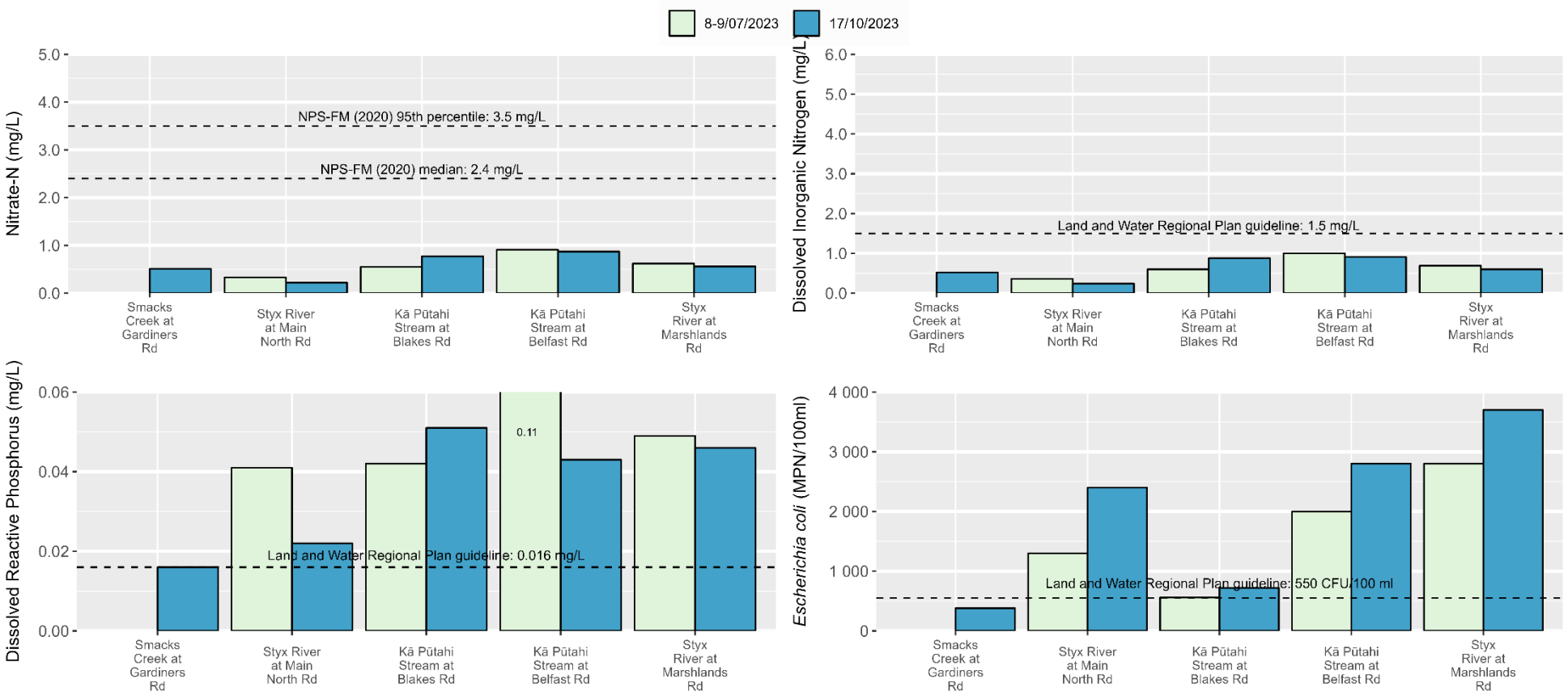

Figure 18. Nitrate (top left), Dissolved Inorganic Nitrogen (DIN; top right), Dissolved Reactive Phosphorus (DRP; bottom left), and *E. coli* (bottom right) concentrations in water samples taken from the Pūharakekenui-Styx River catchment during two wet weather events in 2023. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the respective guidelines (Nitrate-N: Ministry for the Environment, 2023; DIN, DRP, and *E. coli*: Environment Canterbury, 2019). No sample was collected from Smacks Creek in July 2023.

4. Discussion

4.1. Priority Contaminants for Stormwater Management

There were several parameters that were recorded at concentrations unlikely to cause adverse effects, including dissolved lead, water temperature, BOD_5, TSS, pH, and total ammonia. Parameters exceeded at the most sites were turbidity (47 sites), *E. coli* (46 sites), conductivity (41 sites), DRP (30 sites), dissolved zinc (24 sites) and dissolved copper (23 sites). The concentrations of parameters at the sites have mostly remained steady over time (62% of parameter-site combinations), but some improvements in water quality were recorded this year (24% of parameter-site combinations) and some declines (10% of parameter-site combinations). For some parameters (e.g., pH, conductivity and salinity), a significant change could indicate either an improvement or decline in water quality, which represented 4% of the parameter-site combinations this year. These results are supported by generally no change in WQI over time at the catchment or the site-level. Decreasing trends were recorded across many sites for total ammonia, DIN, and DRP.

Based on these results, the priority parameters to address for improved stormwater management across all catchments include bacteria (as indicated by *E. coli*), sediment, dissolved copper, phosphorus, and dissolved zinc. Bacteria is present in waterways predominantly due to direct input of waterfowl faeces during both dry and wet weather (Moriarty & Gilpin, 2015), and wastewater discharges on occasion during wet weather (Moriarty & Gilpin, 2015), but can also be entrained in stormwater due to bird and dog faeces being present on surfaces, and stock inputs in rural areas. Sediment can enter waterways through erosion and the discharge of sediment laden water from construction areas. Larger particles generally settle out in areas such as stormwater basins or in low velocity sections of waterways (e.g., slow runs) and the lighter particles can stay suspended in the water column. This is evidenced by turbidity being elevated at a range of sites but not TSS. Dissolved copper and dissolved zinc are likely to be present in the waterways mostly due to stormwater, through such sources as roofing, tyres, and industrial practices. Some metals may also be present due to illicit dry weather industrial discharges. Phosphorus can enter streams through direct sediment inputs, but is also present in stormwater discharges (e.g., due to fertilisers and sediment runoff).

4.2. Priority Catchments and Sites for Stormwater Management

Based on the WQI, Banks Peninsula recorded 'poor' water quality, the Ōpāwaho-Heathcote River and Huritini-Halswell River catchments recorded 'fair' water quality, and the Ōtākaro-Avon River, Pūharakekenui-Styx River, and Ōtūkaikino

River catchments recorded 'good' water quality. The Ōtūkaikino River recorded the best overall water quality out of all the catchments. The best site for water quality was jointly Wairarapa Stream, Waimairi Stream and Avon River at Mona Vale, followed by Ōtūkaikino at Scout Camp, and Avon River at Manchester St. The catchment or area recording the worst water quality was the Banks Peninsula settlement waterways. The worst site for water quality was Curletts Stream at Motorway, followed by Curletts Stream U/S of Heathcote River, and Aylmers Stream. All these results are generally similar to those recorded in previous years. There were several contaminants of concern at these three worst sites (Curletts Stream at Motorway and Curletts Stream U/S of Heathcote River: dissolved copper, dissolved zinc, conductivity, turbidity, DO, DRP and *E. coli*; Aylmers Stream: dissolved copper, dissolved lead, dissolved zinc, conductivity, turbidity, DO, DIN, DRP and *E. coli*).

The only significant trends in WQI at a site scale was a 3% reduction at Dudley Creek and an 8% increase at Haytons Stream. The decline in water quality at Dudley Creek was driven by increases in the percentage of parameters not meeting the relevant guidelines, specifically for BOD_5 and TSS. The improvement at Haytons Stream was driven by a decrease in the percentage of parameters not meeting the relevant guidelines and a reduction in magnitude, specifically for pH and dissolved copper. Council have recently undertaken works to expand the Wigram stormwater basin, however more monitoring is required to see any direct improvements from these measures.

The seven waterway sites and four coastal sites located in proximity to main stormwater outfalls generally did not appear to record differing results compared to the other waterway sites. For example, Curletts Stream and Haytons Stream were the only waterway sites to be in the top ten worst sites for water quality based on the WQI. This could be due to (a) many of the other sites being located in waterways saturated with stormwater outfalls/discharges, (b) the monthly monitoring not often being carried out during the early stages of a wet weather event (when the 'first flush' of contaminants typically occurs), and/or (c) stormwater not having any noticeable effects in these locations.

Banks Peninsula sites in general recorded 'poor' water quality, particularly Aylmers Stream. It is important to note the guideline values for Banks Peninsula waterways are more strict compared to the city waterway guidelines, due to the sensitive ecological values. This was the first year there was sufficient data to run trends analysis and no significant trends were recorded, however, some contaminant concentrations were elevated and exceeded guidelines. This was largely due to several peaks associated with rainfall events and that there being little stormwater treatment in these catchments. This will be further discussed

in the Banks Peninsula Stormwater Management Plan which is currently being developed by Council.

There were several high values recorded during the wet weather monitoring in the Pūharakekenui-Styx River catchment, particularly in the Kā Pūtahi Stream at Blakes and Belfast Road sites. Compared to the monthly monitoring, dissolved copper, dissolved lead, dissolved zinc and BOD_5 were higher (sometimes markedly so) during the wet weather monitoring. This highlights the importance of incorporating wet weather monitoring into routine monitoring programmes to focus on specific stormwater discharges.

Twenty-five of the 50 sites triggered further investigations under the CSNDC, due to not meeting the ATLs for TSS, dissolved copper, dissolved lead, and dissolved zinc. Three sites have been prioritised for further investigation due to not only exceeding guidelines but recording a statistically significant increase. These three sites are Nottingham at Candys Rd in the Huritini-Halswell River catchment and Heathcote River at Ferrymead Bridge and Heathcote at Tunnel Rd in Ōpāwaho-Heathcote River catchment. Nottingham at Candys Road has been prioritised for investigation for the last three years and Condition 59 investigations are underway. Heathcote River at Ferrymead Bridge was prioritised in 2021 and 2022 but not in 2023 however, has been triggered again this year. As this site has previously been triggered, investigations are underway as part of Condition 59. This is the first time Heathcote River at Tunnel Rd has been triggered for further investigation. Curletts Stream at Motorway and Addington Brook were both triggered in 2023 but were not triggered this monitoring year. This is due to not recording a statistically significant increase in zinc at both sites nevertheless, both sites still exceed the zinc guideline. A statistically significant increase in TSS continues to be recorded at Curletts Stream but it is below the guideline levels. Further monitoring will be able to pick up any potential improving trends at these sites.

5. Recommendations

- The following three sites are a high priority for water quality investigations to determine contaminant sources, due to not meeting CSNDC ATLs: Nottingham at Candys Rd, Heathcote River at Tunnel Rd and Heathcote River at Ferrymead Bridge. These investigations have been discussed in further detail in the Condition 59 responses to monitoring report.
- Nottingham Stream, Curletts Stream, Aylmers Stream, Addington Brook and the Lower Heathcote River should be a high priority for contaminant source control and stormwater treatment, via the following actions:
    - Council and Environment Canterbury (ECan) should continue working with landowners to reduce contaminants entering stormwater systems or waterways directly. Industrial site audits are proving a good avenue for targeting key contaminant sources and increasing education around stormwater.
    - Stormwater treatment by the large Council facilities proposed for Nottingham Stream should be prioritised.
    - Dry weather discharge investigations should be carried out to identify if there are contaminants entering the stormwater systems outside of stormwater events and to pinpoint industries for pollution prevention.
    - Addington Brook stormwater treatment facility continue to be designed and restoration works continue to be constructed.
- Construction of the Council stormwater wetlands in Belfast (Ōtūkaikino River catchment) is also a high priority, due to the increases recorded for TSS, ammonia, nitrogen, and *E. coli* in Wilsons Stream.
- Although phosphorus levels appear to be decreasing across most sites, an investigation should be carried out to determine sources (e.g., fertilisers and faecal input) and how concentrations can be reduced, due to this contaminant being one of the parameters of concern in the waterways.
- Additional monitoring to investigate contaminant sources within Banks Peninsula.
- Council and Environment Canterbury should continue to work together to investigate the increasing levels of *E. coli* and turbidity in the Ōtūkaikino River and ways to mitigate this.

- Erosion and sediment control measures continue to be implemented as a high priority. In particular, further investigations are carried out to determine how to mitigate discharges of loess sediment into the Ōpāwaho-Heathcote River (principally Cashmere Stream). This work should incorporate Council's Port Hills sediment and erosion control project.
- Council continue to implement the Erosion Sediment Control – Remediation Action Plan (ESC – RAP) to reduce discharge of sediment from building sites.
- Investigations are carried out to identify how best to reduce faecal contamination within the waterways, particularly with the public interest in swimmable rivers and that waterfowl control within the city may be unpopular with some people.
- A whole-of-community approach to addressing stormwater contaminants is promoted through the Community Waterway Partnership[8].
- Council and ECan continue to work together with the community, landowners and industry within the City and Banks Peninsula to improve catchment management practices through such measures as:
    - Source control. For example, Council currently work with ECan to audit businesses in key catchments, helping reduce the amount of contaminants entering the stormwater system.
    - Installation of more effective stormwater treatment devices. For example, Council are constructing a number of stormwater basins for the purpose of flood mitigation and stormwater treatment and investigating options for Banks Peninsula.
    - Community education. For example, ECan's Stormwater Superhero programme and other stormwater initiatives, and the Community Waterways Partnership.
    - Implementation of new regional and national policies for improving water quality.
- The Council's Healthy Waterbodies Action Plan should be finalised and implemented. This plan contains objectives, goals, and tasks, and considers what we want to achieve for our waterways (this may vary between different people) and what is required to achieve this. For

[8] https://ccc.govt.nz/environment/water/waterways/community-waterways-partnership

example, an improvement in stormwater quality may not result in an increase in biodiversity, due to other habitat limitations.

6. Conclusions

The results of this year's monitoring are largely consistent with those recorded in previous years[9]. This indicates that many waterways of Christchurch and Banks Peninsula are historically and currently subjected to contamination from stormwater, wastewater and other inputs (e.g., agriculture, waterfowl faeces and industrial discharges). These parameters may be having short-term and long-term adverse effects on biota (i.e., nitrogen, dissolved copper, dissolved zinc, sediment, BOD_5 and lack of dissolved oxygen), may encourage the proliferation of aquatic plants and/or algae (i.e., nitrogen and phosphorus), may indicate human health risks from contact recreation (i.e., faecal indicator bacteria), and may affect water clarity/aesthetics (sediment). Overall, water quality at the monitoring sites is not improving or declining over time.

The results of this report support the Urban Stream Syndrome (Walsh *et al*., 2005). Lower water quality is recorded internationally in urban (particularly industrial) areas (i.e., Ōtākaro-Avon and Ōpāwaho-Heathcote River catchments) and generally better water quality is recorded in rural areas (i.e., Pūharakekenui-Styx River and Ōtūkaikino River catchments). While there was a notable improvement in WQI in the Ōtākaro-Avon catchment this year, this was not reflected in a significant improving catchment-wide trend.

The priority contaminants to address for improved stormwater management across all catchments include faecal indicator bacteria, sediment, dissolved copper, phosphorus, and dissolved zinc. The waterways requiring particular water quality management are Nottingham Stream, Lower Heathcote, Curletts Road Stream, Aylmers Stream and Addington Brook.

The results of this monitoring trigger further investigations under the CSNDC. It is recommended that the following three sites are prioritised for water quality investigations: Nottingham Stream at Candys Rd; Heathcote River at Tunnel Rd and Heathcote River at Ferrymead Bridge.

If the recommendations in this report are implemented (at a bare minimum), surface water quality improvements are anticipated across the city. However, this would require significant financial investment which is not currently being allocated to these tasks. In addition, these changes may only occur over long time scales, due to the size of the issues and the lag time in observing reductions in contaminants within the environment.

[9] Monitoring reports since 2012 can be viewed online at https://www.ccc.govt.nz/environment/water/waterways/waterway-monitoring

7. Acknowledgements

Council laboratory staff collected the monthly monitoring samples and NIWA collected the wet weather samples. Ian Jowett (Jowett Consulting) and David Wood (NIWA) provided invaluable advice on analyses. Salina Poudyal Dhakal provided essential support through her thorough review and verification of the data. Melanie Burns and Michele Stevenson of ECan provided helpful comments on the draft report.

8. References

ANZECC (Australian and New Zealand Environment and Conservation Council, ANZECC, and Agriculture and Resource Management Council of Australia and New Zealand, ARMCANZ), 2000. Australian and New Zealand guidelines for fresh and marine water quality. Volume 1: The guidelines. ANZECC & ARMCANZ, Artarmon, New South Wales.

ANZG, 2022. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra, ACT, Australia. https://www.waterquality.gov.au/anz-guidelines.

Canadian Council of Ministers of the Environment, 2001. Canadian water quality guidelines for the protection of aquatic life: CCME Water Quality Index 1.0, Technical Report. In: Canadian environmental quality guidelines, 1999. Winnipeg: Canadian Council of Ministers of the Environment.

Crowe, A. & Hay, J., 2004. Effects of fine sediment on river biota. Report No. 951, prepared for Motueka Integrated Catchment Management Programme. Cawthron Institute, Nelson.

Dudley, B., Plew, D., Whitehead, A., & Zeldis, J., 2019. Canterbury coastal and harbour water quality investigation. Report prepared for Environment Canterbury.

Environment Canterbury, 2009. Review of proposed NRRP water quality objectives and standards for rivers and lakes in the Canterbury region. Report No. R09/16. Environment Canterbury, Christchurch.

Environment Canterbury, 2019. Canterbury Land and Water Regional Plan. September 2017. Environment Canterbury, Christchurch. Accessed from: https://eplan.ecan.govt.nz/eplan/#Rules/0/55/1/25081.

Harding, J.S., 2005. Impacts of metals and mining on stream communities, in Metal Contaminants in New Zealand, T.A. Moore, A. Black, J.A. Centeno, J.S. Harding & D.A. Trumm (Editors), p. 343-357. Resolutionz press, Christchurch.

Hayward, S., Meredith, A., & Stevenson, M., 2009. Review of proposed NRRP water quality objectives and standards for rivers and lakes in the Canterbury region. Environment Canterbury Repot R09/16, March 2009.

Ministry for the Environment, 1992. Water Quality Guidelines No. 1: Guidelines for the control of undesirable biological growths in water. Ministry for the Environment, Wellington.

Ministry for the Environment, 2003. Microbiological water quality guidelines for marine and freshwater recreational areas. Ministry for the Environment, Wellington.

Ministry for the Environment, 2023. National Policy Statement for freshwater management 2020. Amended February 2023. Ministry for the Environment, Wellington. Retrieved from https://environment.govt.nz/publications/national-policy-statement-for-freshwater-management-2020-amended-february-2023/.

Moriarty, E. & Gilpin, B., 2015. Faecal Sources in the Avon River/Ōtākaro, Heathcote River/Ōpāwaho and the Estuary of the Heathcote & Avon Rivers/Ihutai. Report No. CSC15022. Report prepared for Environment Canterbury, Community and Public Health. Institute of Environmental Science and Research Limited, Christchurch. https://www.ccc.govt.nz/assets/Uploads/Faecal-source-tracking-of-Avon-and-Heathcote-Rivers-and-Avon-Heathcote-Estuary-2015-PDF-2.39-MB.pdf

Munro, B. 2015. CCC instream spring water quality project – Waimairi and Wairarapa Stream. Report prepared by Pattle Delamore Partners Limited for Christchurch City Council, Christchurch, New Zealand

NEMS (2019). Water quality. Part 2 of 4: sampling, measuring, processing and archiving of discrete river water quality data. National Environmental Monitoring Standards. https://bucketeer-54c224c2-e505-4a32-a387-75720cbeb257.s3.amazonaws.com/public/Documents/NEMS-Water-Quality-Part-2-Sampling-Measuring-Processing-and-Archiving-of-Discrete-River-Water-Quality-Data-v1.0.0.pdf.

NIWA, 2022. Trend and equivalence analysis. Software Version 9. NIWA. http://www.jowettconsulting.co.nz/home/time-1

Environment Canterbury (2012). Regional Coastal Environment Plan for the Canterbury Region – Volume 1 (amended 20 September 2012). Environment Canterbury.

Ryan, P.A., 1991. Environmental effects of sediment on New Zealand streams: a review. New Zealand Journal of Marine and Freshwater Research 25: 207-221.

Stevenson, M., Wilks, T. & Hayward, S. 2010. An overview of the state and trends in water quality of Canterbury's rivers and streams. Environment Canterbury Report R10/117, Christchurch.

Walsh C.J., Roy A.H., Feminella J.W., Cottingham P.D., Groffman P.M. & Morgan R.P., 2005. The urban stream syndrome: current knowledge and the search for a cure. Journal of the North American Benthological Society 24: 706-723.

Warne M.St.J., Batley G.E., van Dam R.A., Chapman J.C., Fox D.R., Hickey C.W. and Stauber J.L. 2018. Revised Method for Deriving Australian and New Zealand Water Quality Guideline Values for Toxicants – update of 2015 version. Prepared for the revision of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra, 48 pp.

Appendix A

Table i. Summary of the date of first monthly sampling at the 51 water quality monitoring sites. Dissolved metals were monitored from 2011, unless otherwise specified.

Catchment	Site Description	Monitoring Instigated
Ōtākaro-Avon	Wairarapa Stream	January 2007[10]
	Waimairi Stream	January 2007[10]
	Avon River at Mona Vale	January 2007[10]
	Avon River at Carlton Mill Corner	October 2008[11, 12]
	Riccarton Main Drain	October 2008
	Addington Brook	October 2008
	Avon River at Manchester Street	July 2008[13]
	Dudley Creek	October 2008
	Avon River at Dallington Terrace/Gayhurst Road[8]	January 2007
	Horseshoe Lake Discharge	October 2008
	Avon River at Avondale Road	October 2008[11,12]
	Avon River at Pages/Seaview Bridge	January 2007
	Avon River at Bridge Street	January 2007[10]
Ōpāwaho-Heathcote	Heathcote River at Warren Crescent	January 2020
	Haytons Stream at Retention Basin	April 2007[14, 15]
	Curlett Road Stream Upstream of Heathcote River	October 2008
	Curlett Road Stream at Motorway	October 2008[11,12]
	Heathcote River at Rose Street	June 2008[16]
	Cashmere Stream at Sutherlands Road	December 2010
	Cashmere Stream at Worsleys Road	January 2007
	Heathcote River at Ferniehurst Street	July 2008[15, 17]
	Heathcote River at Bowenvale Avenue	January 2007
	Heathcote River at Opawa Road/Clarendon Terrace	January 2007
	Heathcote River at Mackenzie Avenue	October 2008[11,12]
	Heathcote River at Catherine Street	October 2008[11,12]
	Heathcote River at Tunnel Road	January 2007[18]
	Steamwharf Stream	January 2020[19]
	Heathcote River at Ferrymead Bridge	January 2007

[10] Dissolved oxygen monitored from June 2007
[11] Dissolved metals monitored from September 2014
[12] Turbidity monitored since January 2020
[13] Dissolved oxygen monitored from October 2008
[14] Location changed slightly in May 2020 due to upgrades to the basin
[15] Dissolved oxygen, total ammonia, conductivity, *E. coli*, nitrogen parameters, pH, DRP and water temperature monitored from October 2008
[16] Dissolved oxygen, BOD_5, conductivity, nitrate, pH, TSS and water temperature monitored from August 2008. Total ammonia, *E. coli*, nitrogen parameters (excluding nitrate) and DRP monitored from October 2008.
[17] BOD_5 and TSS monitored from October 2008
[18] Enterococci monitored from January 2020
[19] Salinity monitored from July 2020

Catchment	Site Description	Monitoring Instigated
Pūharakekenui-Styx	Smacks Creek at Gardiners Road	January 2007[20]
	Styx River at Gardiners Road	January 2007[20]
	Styx River at Main North Road	January 2007[20]
	Kā Pūtahi at Blakes Road	January 2007[20]
	Kā Pūtahi at Belfast Road	January 2007[20]
	Styx River at Marshland Road Bridge	January 2007[20]
	Styx River at Richards Bridge	October 2008
	Styx River at Harbour Road Bridge	January 2008
Huritini-Halswell	Knights Stream at Sabys Road	May 2012
	Nottingham Stream at Candys Road	October 2008
	Halswell River at Wroots Road	January 2020
	Halswell River at Akaroa Highway	October 2008
Ōtūkaikino	Ōtūkaikino Creek at Omaka Scout Camp	October 2014
	Ōtūkaikino River at Groynes Inlet	October 2008
	Wilsons Drain at Main North Road	November 2013
Linwood	Linwood Canal	January 2007[10]
Stream Reserve Drain/Zephyr Stream	Stream Reserve Drain Above Outfall to Governors Bay	May 2020
Balguerie Stream	Balguerie Stream Downstream of Settlers Hill (road)	May 2020
Aylmers Stream	Aylmers Stream Downstream of Rue Jolie, Next to Bruce Terrace	May 2020
Ihutai/ Avon-Heathcote Estuary	Estuary of the Heathcote and Avon Rivers/Ihutai at the Eastern Tip by Beachville Road	May 2020
The Operational Area of the Port of Lyttelton	Lyttelton Port at the Small Wharf Opposite Voelas Road	May 2020
Cass Bay	Eastern Side of Cass Bay off the Cass Bay Walkway (high tide sample)	June 2023
Akaroa Harbour	Akaroa Harbour at the Termination of Rue Balguerie	May 2020

[20] Dissolved oxygen monitored from March 2007

Appendix B

Table i. Parameters analysed in surface water samples and the corresponding guideline levels. Guidelines are compared to median levels, unless otherwise indicated. Relevant waterway classifications for comparison to guideline levels are presented in **Table 1** of Section 2.1 (Monitoring Sites). ANZG = Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2022); HMGV = Hardness Modified Guideline Value; LWRP = Land and Water Regional Plan (Environment Canterbury, 2015); NPS-FM = National Policy Statement for Freshwater Management (Ministry for the Environment, 2023); RCEP = Regional Coastal Environment Plan (RCEP, 2012).

Parameter	Environmental Concern	Non-tidal Waterway Guideline Level	Coastal and Tidal Waterway Guideline Level
Dissolved copper	Negatively affect fecundity, maturation, respiration, physical structure, and behaviour of aquatic species (Harding, 2005)	ANZG (2022) (95th percentile, not medians): • Ōtākaro-Avon and Ōpāwaho-Heathcote River catchments (90% species protection: ≤0.0018 mg/L • Huritini-Halswell, Pūharakekenui-Styx and Ōtūkaikino River catchments (95% species protection): ≤0.0014 mg/L • Cashmere Stream and Banks Peninsula waterways (99% species protection): ≤0.001 mg/L	ANZG (2022) (95th percentile, not medians): • ≤0.0013 mg/L
Dissolved lead		ANZG (2022) HMGV (95th percentile, not medians): • Ōtākaro-Avon River catchment (90% species protection): ≤0.01539 mg/L • Ōpāwaho-Heathcote River catchment (90% species protection): ≤0.02388 mg/L • Cashmere Stream (99% species protection): ≤0.00427 mg/L • Huritini-Halswell River catchment (95% species protection): ≤0.01089 mg/L	ANZG (2022) (95th percentile, not medians): • ≤0.0044 mg/L

		• Pūharakekenui-Styx River catchment (95% species protection): ≤0.00601 mg/L • Ōtūkaikino River catchment (95% species protection): ≤0.00414 mg/L • Stream Reserve Drain & Aylmers Stream (Banks Peninsula): ≤0.00135 mg/L • Balguerie Stream (Banks Peninsula): ≤0.00109mg/L	
Dissolved zinc		ANZG HMGV (95th percentile, not medians): • Ōtākaro-Avon River catchment (90% species protection): ≤0.02951 mg/L • Ōpāwaho-Heathcote River catchment (90% species protection): ≤0.0396 mg/L • Cashmere Stream (99% species protection: ≤0.00634 mg/L • Huritini-Halswell River catchment (95% species protection): ≤0.01743 mg/L • Pūharakekenui-Styx River catchment (95% species protection): ≤0.01172 mg/L • Ōtūkaikino River catchment (95% species protection): ≤0.00912 mg/L • Stream Reserve Drain & Aylmers Stream (Banks Peninsula): ≤0.00293 mg/L • Balguerie Stream (Banks Peninsula): ≤0.00254 mg/L	ANZG (2022) (95th percentile, not medians): • ≤0.008 mg/L
Total water hardness and Dissolved	These parameters are mostly relevant to determine the toxicity of other parameters, such as metals	No guidelines exist	Not sampled

Organic Carbon (DOC)			
pH	Appropriate pH levels are essential for the physiological functions of biota, such as respiration and excretion (Environment Canterbury, 2009)	LWRP: • All waterways: 6.5 - 8.5	ANZECC (2000)[21]: • Ihutai and tidal waterway sites: 7.0-8.5 • Lyttelton Port, Akaroa Harbour and Cass Bay: 8.0-8.4
Conductivity	May indicate presence of such parameters as nutrients, metals and salinity	ANZG (2022) (Cool Dry Low-elevation rivers: 80th percentile, not medians): • 116 µS/cm	No guidelines exist
Salinity	The amount of salt dissolved in a body of water – relevant to tidal, estuarine and coastal sites	Not relevant to waterway sites	No New Zealand guidelines currently exist, should they become available these will be used
Total Suspended Solids (TSS)	Elevated levels in the water column decrease the clarity of the water and can adversely affect aquatic plants, invertebrates and fish (Crowe & Hay, 2004; Ryan, 1991)	Hayward et al., 2009; Stevenson et al., 2010: • All waterways: ≤25 mg/L	CCC data: • Ihutai: 17.7 mg/L (all available data: May 2020-Dec 2023) • Lyttelton Port: 29.7 mg/L (all available data: May 2020-Dec 2023) • Akaroa Harbour: 13 mg/L (all available data: May 2020-Dec 2023) • Cass Bay: 30.1 mg/L interim guideline until more data is available. All available data: June 2023-Dec 2023)

[21] These values are from the ANZECC (2000) guidelines for estuaries of South-East Australia; the guidelines recommend these values are used for New Zealand while no other guidelines are available, but they should be used with caution due to the differing ecosystems between countries and replaced with national guidelines should they become available

			Tidal Waterway sites: To be calculated in next year's report. Compared to freshwater guidelines in this report.
Turbidity	Turbidity decreases the clarity of the water and can negatively affect stream biota (Ryan, 1991)	ANZG (2022) (80th percentile, not medians): • All waterways: ≤1.3 NTU (Cool Dry Low-elevation)	80th percentiles, not medians: • Ihutai: ≤9.8 FNU (all available CCC data: May 2020-Dec 2023) • Lyttelton: ≤22.3 FNU (all available CCC data: May 2020-Dec 2023) • Akaroa Harbour: ≤5.5 FNU (all available CCC data: May 2020-Dec 2023) • Cass Bay: ≤23.4 FNU interim guideline until more data is available. All available CCC data: June 2023-Dec 2023 Tidal Waterway sites: To be calculated in next year's report. Compared to freshwater guidelines in this report.
Water clarity	Low clarity of the water can affect aesthetics and negatively affect stream biota	NPS-FM: • ≥1.55 m[22] Only tested at Styx Living Laboratory Trust sites and using a clarity tube which is only 1m in length, so it is not possible to assess against this guideline value using this method.	Not sampled

[22] Suspended fine sediment attribute – Band B, Sediment Class 1

Dissolved Oxygen (DO)	Adequate DO levels are essential for aquatic animals, such as fish and invertebrates	LWRP: • 'Spring-fed – plains – urban' and 'spring-fed – plains waterways:' ≥70 % • Banks Peninsula waterways: ≥90	RCEP: • ≥ 80 %
Water temperature	Water temperature that is too low or high can adversely impact aquatic animals, such as fish and invertebrates	LWRP: • All waterways: ≤20°C	RCEP: • ≤25°C
Biochemical Oxygen Demand (BOD_5)	High BOD_5 values indicate the potential for bacteria to deplete oxygen levels in the water	Ministry for the Environment (1992): • All waterways: ≤2 mg/L	RCEP, excluding The Operational Area of the Port of Lyttelton (Environment Canterbury, 2012): • ≤2 mg/L

Total ammonia (ammoniacal nitrogen)	High levels can have toxic effects on aquatic ecosystems	LWRP (95th percentiles, not medians):
		• Banks Peninsula waterways: ≤0.32 mg/L
		• All other waterways determined by median catchment pH:
		  ○ Ōtākaro-Avon River catchment: ≤1.88 mg/L
		  ○ Ōpāwaho-Heathcote River catchment:
		  ○ Main catchment (excluding Cashmere and Haytons Streams): ≤1.88 mg/L
		  ○ Haytons Stream: ≤ 2.38 mg/L
		  ○ Linwood Canal catchment: ≤1.75 mg/L
		  ○ Huritini-Halswell River catchment: ≤1.75 mg/L
		  ○ Pūharakekenui-Styx River catchment: ≤1.99 mg/L
		  ○ Ōtūkaikino River catchment: ≤2.09 mg/L
			Not sampled

Nitrate nitrogen	Can be toxic to stream biota at high concentrations (Hickey, 2013)	LWRP: • Banks Peninsula waterways: Median: ≤1.0 mg/L; 95th percentile: ≤1.5 mg/L NPS-FM (Ministry for the Environment, 2023): • Median: ≤2.4 mg/L; 95th percentile: ≤3.5 mg/L[23]	Not sampled
Dissolved Inorganic Nitrogen (DIN)	High levels can contribute to eutrophication (enrichment of water by nutrient salts that causes prolific growth of algae and aquatic plants)	LWRP: • 'Spring-fed – plains – urban' and 'spring-fed – plains' waterways: ≤1.5 mg/L • Banks Peninsula waterways: ≤0.09 mg/L	Not sampled
Nitrite nitrogen		No guidelines exist	Not sampled
Dissolved Reactive Phosphorus (DRP)	High levels can contribute to eutrophication (enrichment of water by nutrient salts that causes prolific growth of algae and aquatic plants)	LWRP: • 'Spring-fed – plains – urban' and 'spring-fed – plains' waterways: ≤0.016 mg/L • Banks Peninsula waterways: ≤0.025 mg/L	Not sampled
Escherichia coli	An indicator of faecal contamination in freshwater and therefore health risk from contact recreation (Ministry for the Environment, 2003)	LWRP: • All waterways: ≤550 CFU/100ml (95th percentile, not medians)	No guidelines exist; only tested at Ihutai/Avon-Heathcote Estuary, as enterococci more relevant at the other coastal sites
Enterococci	An indicator of faecal contamination in freshwater and therefore health risk from contact recreation	Not sampled	Ministry for the Environment (2003) (Single sample, not medians): • All coastal and strongly tidal sites: : < 140 CFU/100ml (alert level)
Faecal coliforms	An indicator of faecal contamination in freshwater and therefore health risk from contact recreation	Not relevant and not sampled	Ministry for the Environment (2013): • Akaroa Harbour: 14 CFU /100 mL (median) and 43 CFU /100 mL (not

[23] National bottom line – to be used for all waterway sites, except those in Banks Peninsula

			exceeded in more than 10% of samples – i.e., 90th percentile) Not sampled at the remaining coastal or tidal waterway sites

Appendix C

Table i. Laboratory methods used over time to calculate parameter concentrations. N/A = Not Applicable. Due to high salinity concentrations, samples collected from coastal sites were diluted to allow dissolved metals analysis.

Group	Parameter	Limit of Detection	Date	Analysis Method
Metals	Total copper	<0.001 mg/L	1 July 2018 - current day	APHA 3125 B modified, (Varian7900 ICP- MS). Digestion APHA 3030 E
		Varies between <0.001-<0.005 mg/L	5 May 2016 - 30 June 2018	APHA 3125 B modified, (Varian7900 ICP- MS) using nylon 0.45um filters. Digestion APHA 3030 E
		Varies between <0.001-<0.005 mg/L	Sampling instigation – 4 May 2016	
	Dissolved copper	<0.0001 mg/L	October 2016 - current day	APHA 3125 B modified, (Varian7900 ICP- MS) using nylon 0.45um filters
		<0.002 mg/L	December 2008 – September 2016	APHA 3125 B modified, (Varian7900 ICP- MS) using nylon 0.45um filters
		<0.004 mg/L	2007 - November 2008)	Graphite furnace (GFAA - graphite furnace atomic absorption, Varian) using acid washed GF/F filters
	Total lead	<0.001 mg/L	1 July 2018 - current day	APHA 3125 B modified (Varian7900 ICP- MS). Digestion APHA 3030 E
		Varies between <0.004 - <0.0015 mg/L	Sampling instigation - 30 June 2018	APHA 3125 B modified (Varian7900 ICP- MS). Digestion APHA 3030 E
	Dissolved lead	<0.0001 mg/L	October 2016 - current day	APHA 3125 B modified, (Varian7900 ICP- MS) using nylon 0.45um filters
		<0.0015 mg/L	December 2008 - September 2016	APHA 3125 B modified (Varian7900 ICP- MS), using nylon 0.45um filters. Digestion APHA 3030 E
		<0.006 mg/L	2007 - November 2008	APHA 3125 B modified (Varian7900 ICP- MS), using nylon 0.45um filters. Digestion APHA 3030 E
	Total zinc	<0.005 mg/L	1 July 2018 - current day	APHA 3125 B modified, (Varian7900 ICP- MS). Digestion APHA 3030 E
		<0.001 mg/L	5 May 2016 – 30 June 2018	APHA 3125 B modified, (Varian7900 ICP- MS) using nylon 0.45um filters
		<0.001 mg/L	March 2009 – 4 May 2016	ICPOES (Inductively coupled optical emission spectrometer, Perkin Elmer) using acid washed GF/F filters

Group	Parameter	Limit of Detection	Date	Analysis Method
		<0.006 mg/L	Sampling instigation - February 2009	ICPOES (Inductively coupled optical emission spectrometer, Perkin Elmer) using acid washed GF/F filters
	Dissolved zinc	<0.0001 mg/L	October 2016 - current day	APHA 3125 B modified, (Varian7900 ICP- MS) using nylon 0.45um filters
		<0.001 mg/L	5 May 2016 – September 2016	APHA 3125 B modified, (Varian7900 ICP- MS) using nylon 0.45um filters
		<0.001 mg/L	March 2009 – 4 May 2016	ICPOES (Inductively coupled optical emission spectrometer, Perkin Elmer) using acid washed GF/F filters
		<0.006 mg/L	Sampling instigation - February 2009	ICPOES (Inductively coupled optical emission spectrometer, Perkin Elmer) using acid washed GF/F filters
Nutrients	Total nitrogen	<0.010mg/L	1 July 2018 - current day	APHA 4500-N C (persulphate digestion and continuous flow analyser)
		<0.01 mg/L	10 July 2014 - 30 June 2018	APHA 4500-N C 22nd Ed. 2012 (persulphate digestion and continuous flow analyser)
		<0.05 mg/L	4 March 2009 - 9 July 2014	
		<1.0 mg/L	Sampling instigation - 3 March 2009	
	Nitrate nitrogen	0.002 mg/L	1 July 2018 - current day	4500-NO3 F, Automated Cadmium Reduction Method
		<0.003 mg/L	9 September 2014 - 30 June 2018	APHA 4500-NO3 F (Continuous Flow Autoanalyser)
		<0.05 mg/L	Sampling instigation - 8 September 2014	APHA 4500-NO3 H (Hydrazine Reduction Discrete Analyser)
	Nitrite nitrogen	<0.001 mg/L	1 July 2018 - current day	APHA 4500-NO3 F (continuous flow analyser)
		<0.001 mg/L	9 September 2014 - 30 June 2018	APHA 4500-NO3 F 22nd Ed. 2012 (cadmium reduction and continuous flow analyser)
		<0.005 mg/L	Sampling instigation - 8 September 2014	APHA 4500-NO2 B (Discrete Analyser)
	Nitrate Nitrite Nitrogen (NNN)	<0.002mg/L	1 July 2018 - current day	APHA 4500-NO3 E (Continuous Flow Autoanalyser)
		<0.01 mg/L	27 July 2011 - 30 June 2018	APHA 4500-NO3 E (Continuous Flow Autoanalyser)
		<0.05 mg/L	3 April 2009 - 26 July 2011	APHA 4500-NO3 E (Continuous Flow Autoanalyser)
		<0.05 mg/L	Sampling instigation – 2 April 2009	Nitrate + Nitrite
		<0.007 mg/L	1 July 2018 - current day	Total ammonia + Nitrite-Nitrate-Nitrogen

Group	Parameter	Limit of Detection	Date	Analysis Method
	Dissolved Inorganic Nitrogen (DIN)	<0.02 mg/L	Sampling instigation - 30 June 2018	Total ammonia + Nitrite-Nitrate-Nitrogen
	Total ammonia (ammoniacal nitrogen)	<0.005 mg/L	4 September 2014 - current day	APHA 4500-NH3 G (Continuous Flow Autoanalyser)
		<0.01 mg/L	sampling instigation - 3 September 2014	4500-NH3 F (Discrete Analyser)
	Total phosphorus	<0.001 mg/L	1 July 2018 - current day	APHA 4500-P J (persulphate digestion and continuous flow analyser)
		<0.003 mg/L	10 July 2014 - 30 June 2018	APHA 4500-P J 22nd Ed. 2012 (persulphate digestion and continuous flow analyser)
		<0.02 mg/L	17 November 2009 - 09 July 2014	APHA 4500-P J (Discrete Analyser)
		<0.06 mg/L	Sampling instigation - 16 November 2009	APHA 4500-P J (Discrete Analyser)
	Dissolved Reactive Phosphorus (DRP)	<0.001 mg/L	1 July 2018 - current day	APHA 4500-P F (Continuous Flow Autoanalyser)
		<0.003 mg/L	22 December 2010 - 30 June 2018	APHA 4500-P F (Continuous Flow Autoanalyser)
		<0.02 mg/L	1 December 2010 - 21 December 2010	4500-P E (Discrete Analyser)
		<0.003 mg/L	17 November 2009 - 30 November 2010	4500-P E (Discrete Analyser)
		<0.01 mg/L	Sampling instigation - 16 November 2009	4500-P E (Discrete Analyser)
Bacteria	*Escherichia coli*	<1 and >24,000 MPN/100ml	1 July 2018 - current day	Colilert APHA 4500 9223 B
		Varies depending on required dilution	Sampling instigation - 30 June 2018	Colilert APHA 4500 9223 B
	Enterococci	<10 and >24,000 MPN/100ml	sampling instigation - current day	Enterolert APHA 9230 D
	Faecal coliforms	<1 MPN/100ml	sampling instigation - current day	APHA 9222D
Clarity	Total Suspended Solids (TSS)	<1 mg/L	1 July 2018 - current day	APHA 2540 D
		<3 mg/L	September 2010 - 30 June 2018	APHA 2540 D
		<5 mg/L	Sampling instigation - August 2010	APHA 2540 D

Group	Parameter	Limit of Detection	Date	Analysis Method
	Turbidity	<0.1 FNU	1 December - current day	ISO7027
		<0.1 NTU	28 August 2018 - 30 November 2020	TL230 ISO 7027 (concurrent testing)
		<0.1 NTU	Sampling instigation - current day	APHA 2130 B, (turbidity meter Hach 2100AN) (concurrent testing)
Other	Dissolved Oxygen (DO)	N/A	1 July 2018 - current day	APHA 4500-O G, YSI Pro ODO meter
		N/A	Sampling instigation - 30 June 2018	APHA 4500-O G
	Biochemical Oxygen Demand (BOD_5)	<1.0 mg/L	Sampling instigation- current day	APHA 5210 B
	Total water hardness	N/A	Sampling instigation- current day	APHA 2340 B calculation from calcium and magnesium measured by APHA 3125 B modified (Varian7900 ICP- MS,) using nylon 0.45um filters
	Conductivity	N/A	Sampling instigation- current day	APHA 2510 B
	Salinity	<2	May 2020 – current day	APHA 2520 B
	pH	N/A	Sampling instigation- current day	APHA 4500-H+ B
	Water temperature	N/A	Sampling instigation- current day	APHA 2550 B.YSI Pro ODO meter
	TPH[24]	<0.3 mg/L	Sampling instigation- current day	Extraction DCM (GC-FID)

[24] Analysed by Watercare Laboratory (IANZ accredited)

Appendix D

Hardness Modified Guideline Values for Metals in Christchurch City and Bank Peninsula Waterways

Introduction

The Australian and New Zealand guidelines for fresh and marine water quality provide a set of default guideline values for dissolved metals (ANZG, 2022). If measured concentrations of toxicants are below the default guideline values, then there is a low risk of adverse environmental effects.

The guidelines also provide a process of modifying the default guideline values for local environmental conditions, namely hardness, which can affect the toxicity of metals (excluding copper) and therefore increase the risk of adverse biological effects (Warne et al., 2018). The default guideline values for metals assume that water is soft (hardness 0–59 mg/L as $CaCO_3$). However, as water hardness increases, the toxicity of some metals decreases and therefore the guideline value may increase, without increasing the risk of adverse biological effects.

Hardness Modified Guideline Values (HMGV), formerly known as Hardness Modified Trigger Values, have been previously calculated by Christchurch City Council (Dewson, 2012; Margetts & Marshall, 2015). It is considered that hardness values are unlikely to change over the years, so these values can be reassessed approximately every five years.

A 2020 memorandum by Marshall & Margetts (2020) included the first five-yearly update of these values for Christchurch City waterways under the Comprehensive Stormwater Network Discharge Consent (CRC190445) and reflected the recommendation that copper is no longer modified by hardness (Warne *et al*., 2018). This current memorandum is an update to the 2020 memorandum to include Banks Peninsula waterway values. To have the assessments all in one place, this memorandum includes the 2020 City waterways values, as well as the Banks Peninsula values. The next review will be undertaken in 2025 – this will include Banks Peninsula values, even though this will be less than five years, to bring them into the same scheduling.

Methods

For waterway sites within Christchurch City, water samples were collected monthly in 2019 from 36 non-tidal sites across the five main river catchments within the City (Avon, Heathcote, Styx, Ōtūkaikino and Halswell Rivers), as well as a tidal site within Linwood Canal, giving a total of 12 samples for each of the 37 sites (Appendix A, Tables i and ii). Tidal sites within the wider monitoring programme[25] were excluded from the analyses, as tidal sites typically have high hardness levels, which would skew the results for each catchment, resulting in inappropriately higher guideline levels. As there was only one site for Linwood Canal, it did not matter that this site was tidal. However, it has since been established that coastal guideline values are more appropriate for Linwood Canal and therefore hardness modification is not required.

For Banks Peninsula waterway sites, water samples were collected in 2021 from three sites (Zephyr Stream, Balguerie Stream, and Aylmers Stream). Five samples were collected at Stream Reserve Drain and Balguerie Stream, and four samples were collected at Aylmers Stream.

[25] Avon River at Pages/Seaview Bridge, Avon River at Bridge Street, Heathcote River at Catherine Street, Heathcote River at Tunnel Road and Heathcote River at Ferrymead Bridge.

Boxplots of the water hardness data were created in RStudio (version 1.2.5033), to show the median and interquartile range. The dark line in the boxplots represents the median, and the bottom and top lines of the box represent the 25th and 75th percentiles (the interquartile range), respectively. The T-bars that extend from the box approximate the location of the 5th and 95th percentiles (using HAZEN methodology).

To calculate the HMGV, the following species protection levels were chosen, as per ECan (2018).

- Avon River, Heathcote River, and Linwood Canal catchments: 90% (Spring-fed – plains – urban)
- Styx, Ōtūkaikino, and Halswell River catchments: 95% (Spring-fed – plains)
- Cashmere Stream and Banks Peninsula catchments: 99% (Banks Peninsula)

These default guideline values were then modified by the median catchment hardness, as per the below formula (Warne *et al.*, 2018).

$$\boldsymbol{Lead\ HMGV = Default\ Guideline\ Value\ x} \left(\frac{\boldsymbol{hardness}}{\boldsymbol{30}}\right)^{\boldsymbol{1.27}}$$

$$\boldsymbol{Zinc\ HMGV = Default\ Guideline\ Value\ x} \left(\frac{\boldsymbol{hardness}}{\boldsymbol{30}}\right)^{\boldsymbol{0.85}}$$

Results and Conclusions

Median water hardness in the five main river catchments in Christchurch City (Avon, Heathcote, Styx, Ōtūkaikino and Halswell Rivers) ranged from 'soft' to 'moderate'; however, Linwood Canal fell between the 'very hard' and 'extremely hard' categories (Table 1; Figures 1–2). Median water hardness at the three Bank Peninsula sites (Zephyr Stream, Balguerie Stream, and Aylmers Stream) was soft (Table 1; Figure 3). The HMGV are all greater than the default guideline values in each of the waterways, as the default values assume water is 'soft' to conservatively protect aquatic ecosystems (Table 1).

Table 1. Default and Hardness Modified Guideline Values (HMGV; ANZG, 2022) for dissolved zinc and lead in Christchurch City and Banks Peninsula waterways.

Catchment	Median hardness (mg/L)	Species protection level (ECan, 2018)	Zinc guideline		Lead guideline	
			Default (mg/L)	HMGV (mg/L)	Default (mg/L)	HMGV (mg/L)
Heathcote River – Cashmere Stream	94.0	99%	0.0024	0.00634	0.0010	0.00427
Halswell River	75.0	95%	0.0080	0.01743	0.0034	0.01089
Styx River	47.0	95%	0.0080	0.01172	0.0034	0.00601
Ōtūkaikino River	35.0	95%	0.0080	0.00912	0.0034	0.00414
Avon River	66.5	90%	0.0150	0.02951	0.0056	0.01539
Heathcote River – remainder	94.0	90%	0.0150	0.03960	0.0056	0.02388
Linwood Canal	370.0	90%	0.0150	0.12691	0.0056	0.13610
Stream Reserve Drain	38.0	99%	0.0024	0.00293	0.0010	0.00135
Balguerie Stream	32.0	99%	0.0024	0.00254	0.0010	0.00109
Aylmers Stream	38.0	99%	0.0024	0.00293	0.0010	0.00135

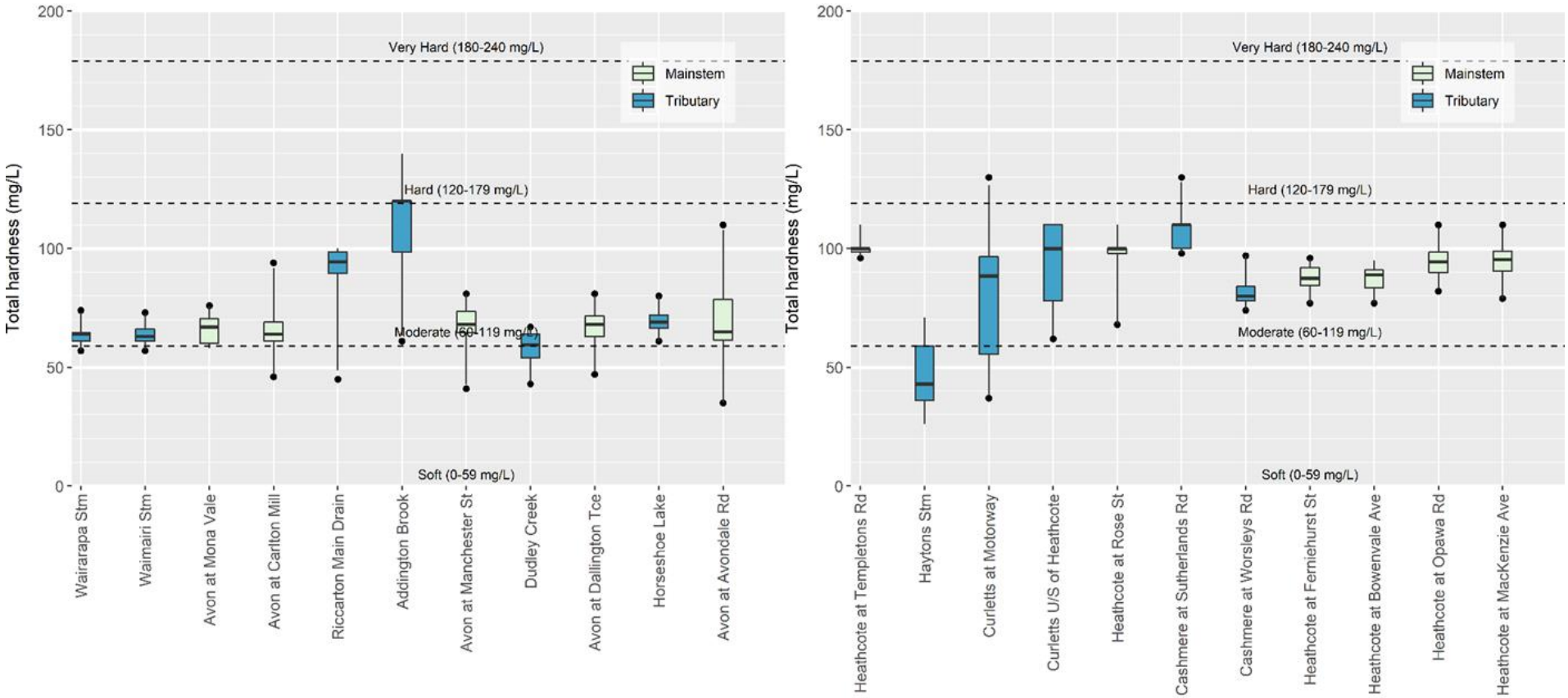

Figure 1. Total hardness (as $CaCO_3$) levels in water samples taken monthly from non-tidal sites within the Ōtākaro/Avon (left graph) and Ōpāwaho/Heathcote (right graph) River sites, for the monitoring period January to December 2019. No monitoring was undertaken at the Haytons Stream site in March and June, as the site was dry. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the ANZECC (2000) delineations between water hardness categories.

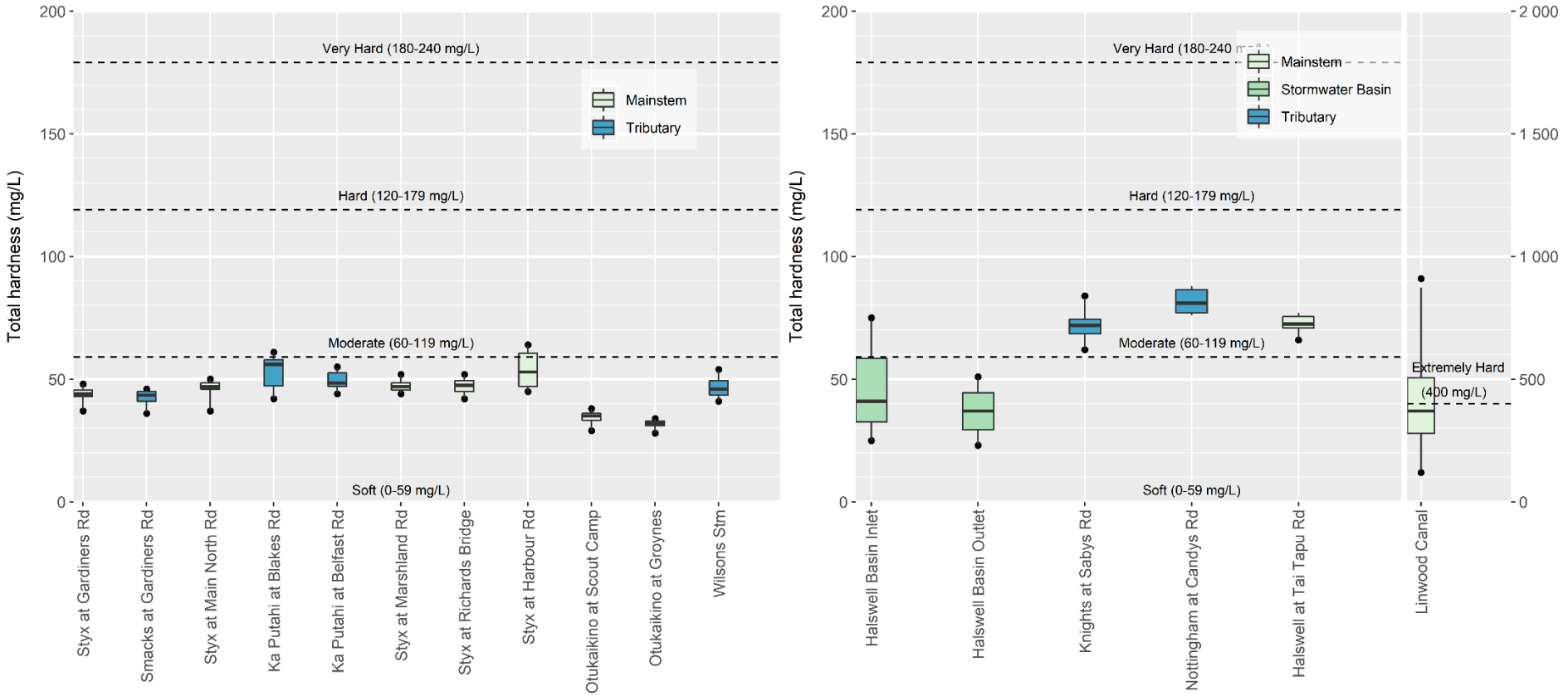

Figure 2. Total hardness (as $CaCO_3$) levels in water samples taken monthly from non-tidal sites within the Pūharakekenui/Styx and Ōtūkaikino Rivers (left graph), and the Huritini/Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2019. No monitoring was undertaken at the Kā Pūtahi Creek at Blakes Road site in August and the Ōtūkaikino Creek at Omaka Scout Camp site in February, as these sites could not be accessed. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the ANZG (2000) delineations between water hardness categories.

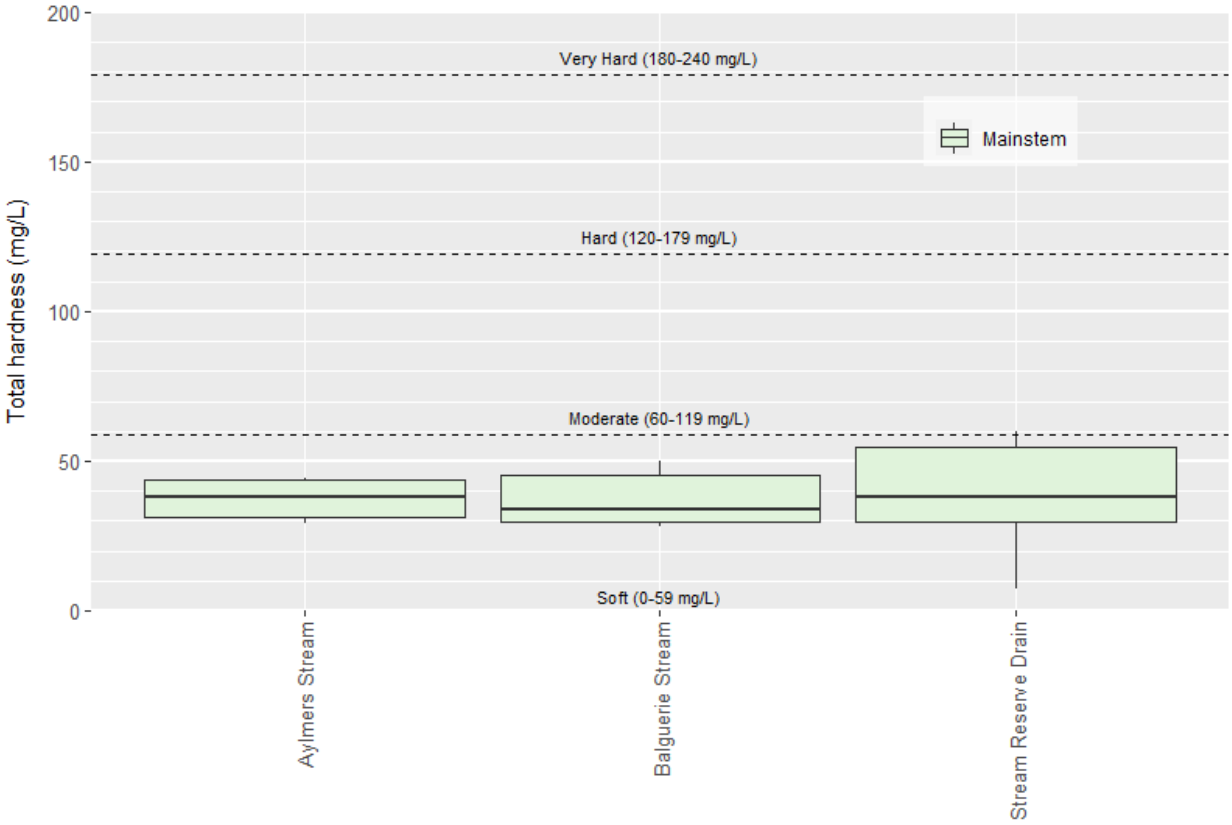

Figure 3. Total hardness (as $CaCO_3$) levels in water samples taken from three waterway sites in Bank Peninsula (Zephyr Stream, Balguerie Stream, and Aylmers Stream) for the monitoring period January to December 2021. The dashed lines represent the ANZG (2000) delineations between water hardness categories.

References

ANZG 2022. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra, ACT, Australia. https://www.waterquality.gov.au/anz-guidelines. Accessed May 2022.

ANZECC (Australian and New Zealand Environment and Conservation Council, ANZECC, and Agriculture and Resource Management Council of Australia and New Zealand, ARMCANZ), 2000. Australian and New Zealand guidelines for fresh and marine water quality. Volume 1: The guidelines. ANZECC & ARMCANZ, Artarmon, New South Wales.

Dewson, Z. (2012). Hardness modified trigger values for river water quality. Christchurch City Council, Christchurch. TRIM No. 13/333219.

Environment Canterbury, 2018. Canterbury Land and Water Regional Plan - Volume 1. May 2018. Environment Canterbury, Christchurch.

Warne, M., Batley, G., Van Dam, R., Chapman, J., Fox, D., Hickey, C. and Stauber, J. (2018) Revised method for deriving Australian and New Zealand water quality guideline values for toxicants – update of 2015 version. Prepared for the revision of the Australian and New Zealand guidelines for fresh and marine water quality. Canberra, Australia: Australian and New Zealand Governments and Australian state and territory governments.

Margetts, B. & Marshall, W. (2015). Linwood Canal hardness modified trigger values for metals. Christchurch City Council, Christchurch.

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29th June 2022

Appendix A: Site locations

Table i. Water quality monitoring sites for the water hardness investigations in the Avon and Heathcote River catchments.

Catchment	Site	Easting (NZTM)	Northing (NZTM)
Ōtākaro/ Avon	Avon River at Dallington Terrace/Gayhurst Road	1573560	5181210
	Avon River at Manchester Street	1570890	5180481
	Wairarapa Stream	1568250	5181303
	Waimairi Stream	1568233	5181172
	Avon River at Mona Vale	1568334	5181046
	Riccarton Main Drain	1568683	5180019
	Addington Brook	1569427	5179826
	Dudley Creek	1572574	5182150
	Horseshoe Lake Discharge	1574342	5183294
	Avon River at Carlton Mill Corner	1569737	5181259
	Avon River at Avondale Road	1574752	5183557
Ōpāwaho/ Heathcote	Heathcote River at Opawa Road/Clarendon Terrace[4]	1573071	5177615
	Heathcote River at Bowenvale Avenue	1571198	5175780
	Cashmere Stream at Worsleys Road	1569030	5175155
	Heathcote River at Rose Street	1568701	5175918
	Heathcote River at Ferniehurst Street	1569157	5175612
	Heathcote River at Templetons Road	1565915	5176897
	Haytons Stream at Retention Basin	1566020	5177596
	Curletts Road Stream Upstream of Heathcote River Confluence	1566928	5177711
	Heathcote River at Mackenzie Avenue Footbridge	1573520	5177917
	Curletts Road Stream at Southern Motorway	1566405	5178358
	Cashmere Stream at Sutherlands Road	1566086	5173988

Table ii. Water quality monitoring sites for the water hardness investigations in the Styx River, Halswell River, Ōtūkaikino River and Linwood Canal catchments.

Catchment	Site	Easting (NZTM)	Northing (NZTM)
Pūharakekenui/ Styx	Smacks Creek at Gardiners Road near Styx Mill Road	1566804	5187956
	Styx River at Gardiners Road	1566790	5187226
	Styx River at Main North Road	1569066	5187219
	Kā Pūtahi Creek at Blakes Road	1570401	5188030
	Kā Pūtahi Creek at Belfast Road	1572194	5188267
	Styx River at Marshland Road Bridge	1572358	5187778
	Styx River at Richards Bridge	1573975	5189640
	Styx River at Harbour Road Bridge	1574998	5194749
Huritini/ Halswell	Halswell Retention Basin Inlet	1561701	5177022
	Halswell Retention Basin Outlet	1561796	5176914
	Nottingham Stream at Candys Road	1564532	5173080
	Halswell River at Akaroa Highway (Tai Tapu Road)	1564446	5171721
	Knights Stream at Sabys Road	1563723	5172852
Ōtūkaikino	Ōtūkaikino River at Groynes Inlet	1567878	5188869
	Wilsons Drain at Main North Road	1571241	5190793
	Ōtūkaikino Creek at Omaka Scout Camp	1565664	5188038
Linwood	Linwood Canal/City Outfall Drain	1575952	5178026

Table iii. Water quality monitoring sites for the water hardness investigations within Banks Peninsula waterways (Zephyr Stream, Balguerie Stream, and Aylmers Stream).

Catchment	Site	Easting (NZTM)	Northing (NZTM)
Zephyr Stream	Stream Reserve Drain Above Outfall to Governors Bay	2482036	5731805
Balguerie Stream	Balguerie Stream Downstream of Settlers Hill (road)	2507759	5711175
Aylmers Stream	Aylmers Stream Downstream of Rue Jolie, Next to Bruce Terrace	2506930	5710693

Appendix E

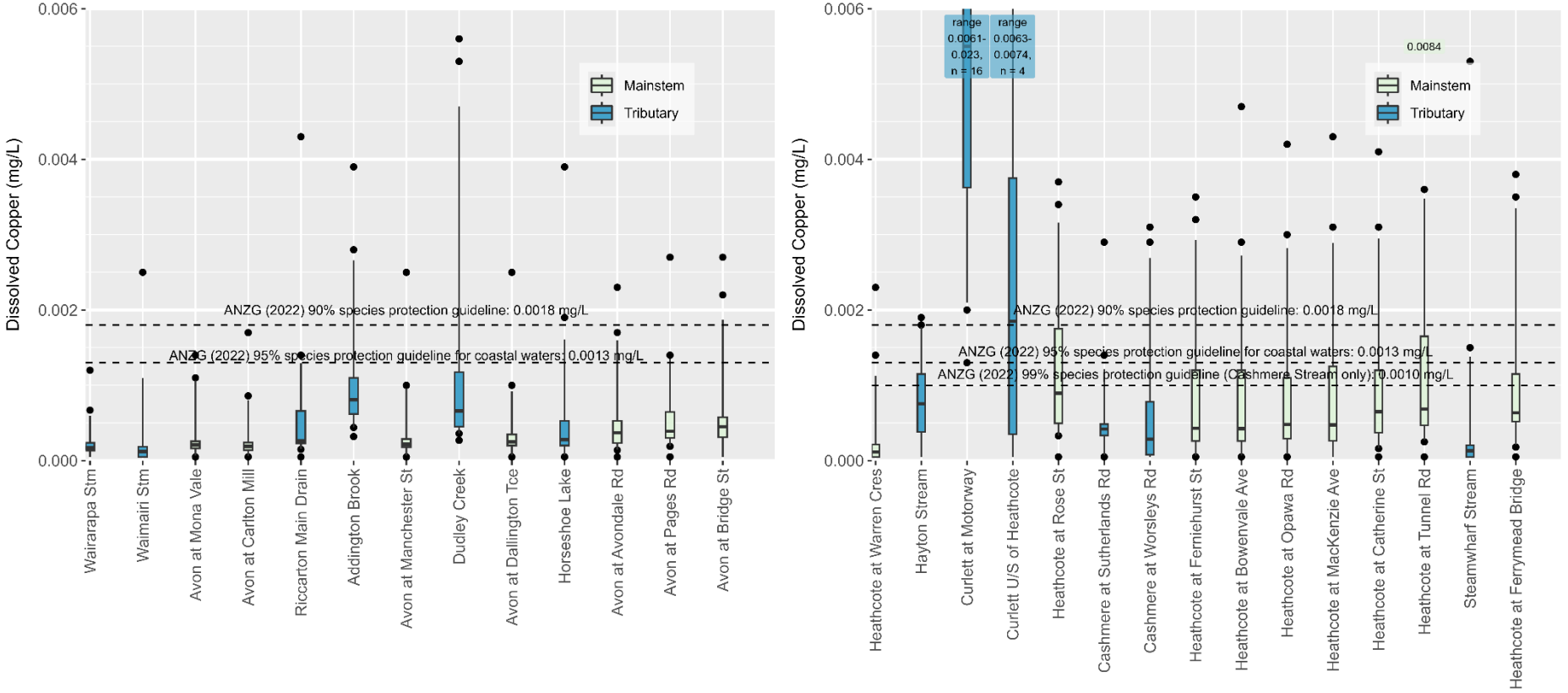

Figure i (a). Dissolved copper concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2021 to December 2023. The dashed lines represent the ANZG (2022) guideline values. Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) should be compared to the coastal water guidelines. The Laboratory Limit of Detection was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis, with 'n' being the number of these data points.

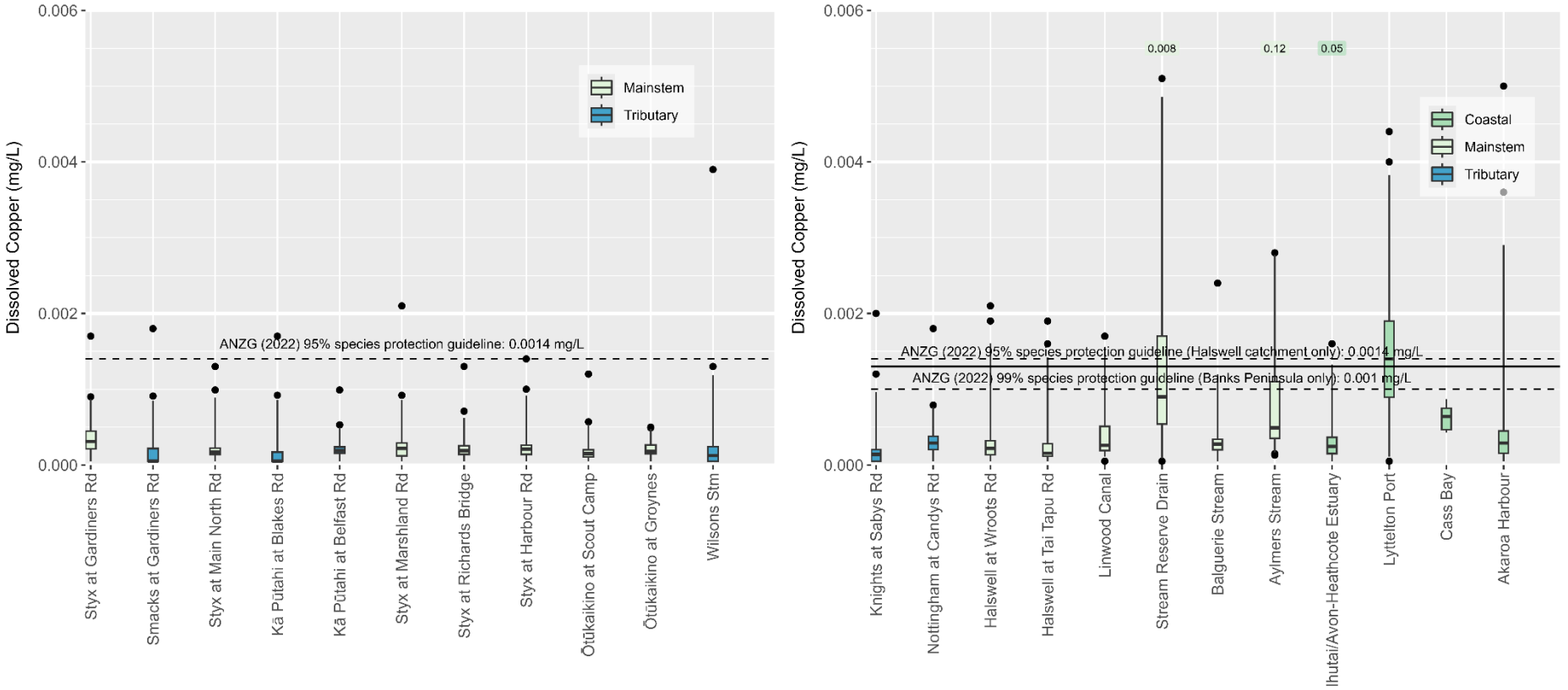

Figure i (b). Dissolved copper concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula, and coastal sites (right graph), for the monitoring period January 2021 to December 2023. The dashed lines represent the ANZG (2022) waterway guideline values. The solid line represents the ANZG (2022) coastal guideline. The strongly tidal Linwood Canal site should be compared to the coastal water guideline. The Laboratory Limit of Detection was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

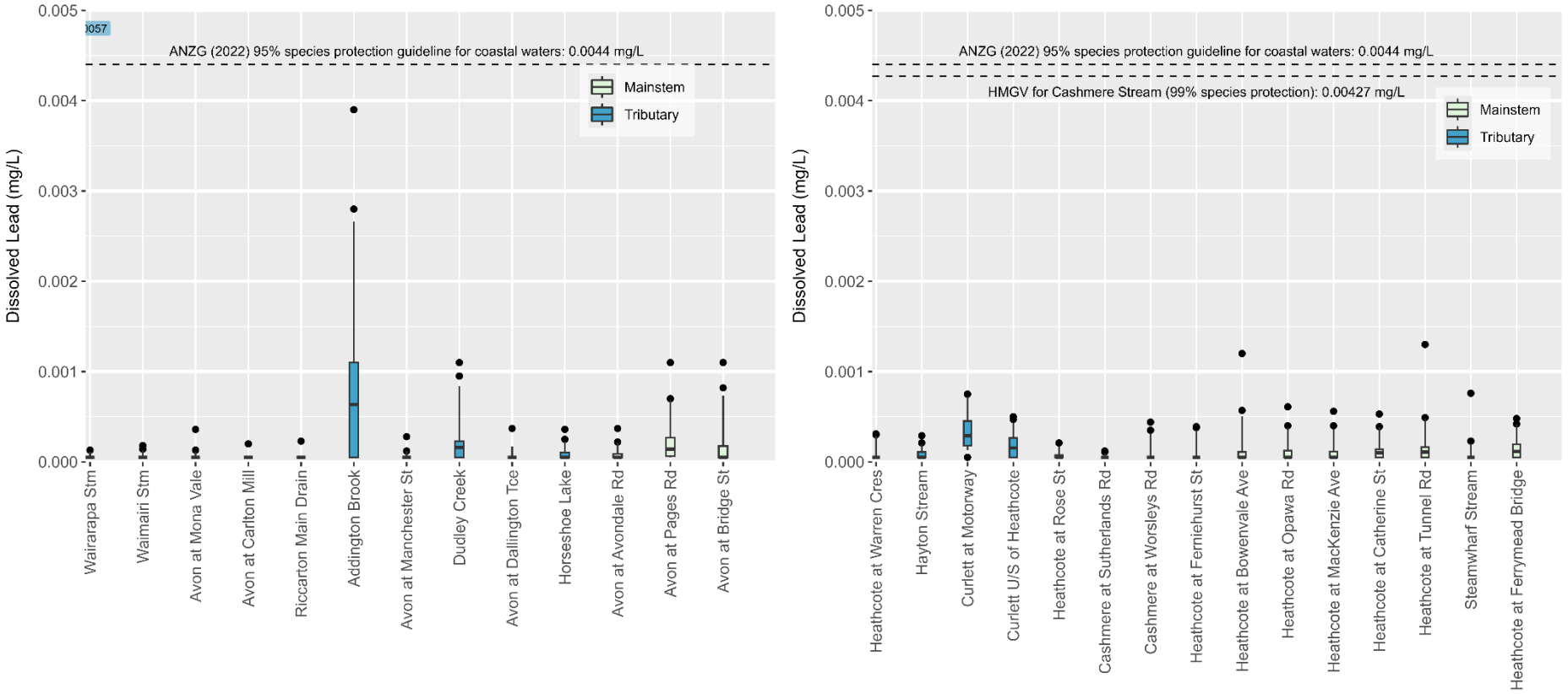

Figure ii (a). Dissolved lead concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2021 to December 2023. The 90% protection HMGV for the Ōtākaro-Avon River (0.01539 mg/L) and the Ōpāwaho-Heathcote River (0.02388 mg/L) are not shown as they are off the scale. Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) are compared to the coastal water guidelines. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

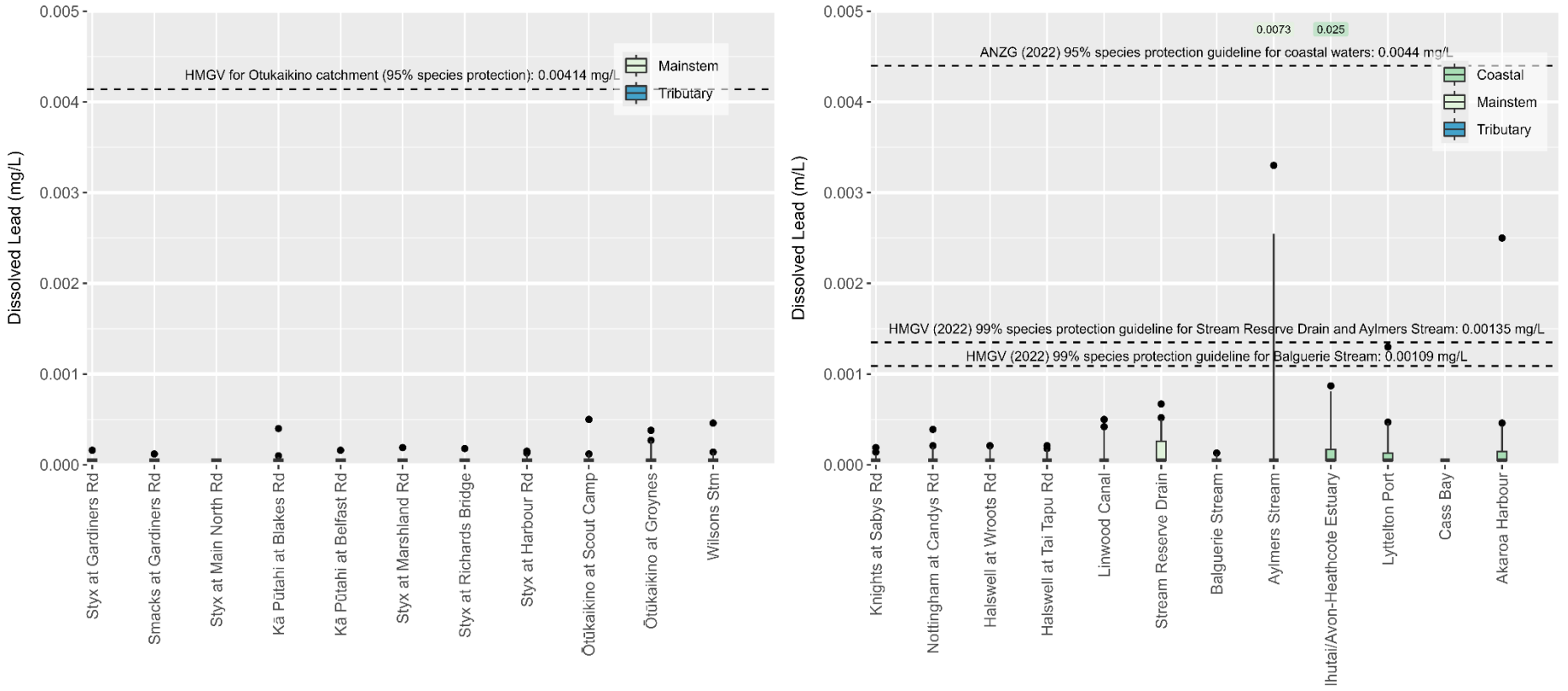

Figure ii (b). Dissolved lead concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2021 to December 2023. The dashed lines represent the ANZG (2022) guideline values, which have been modified to account for water hardness (Hardness Modified Guideline Value = HMGV), as per the Warne et al. (2018) guidelines methodology. The 95% protection HMGV for the Pūharakekenui-Styx River (0.00601 mg/L) and the Huritini-Halswell River (0.01089 mg/L) are not shown as they are off the scale. The strongly tidal Linwood Canal site is compared to the coastal water guideline. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

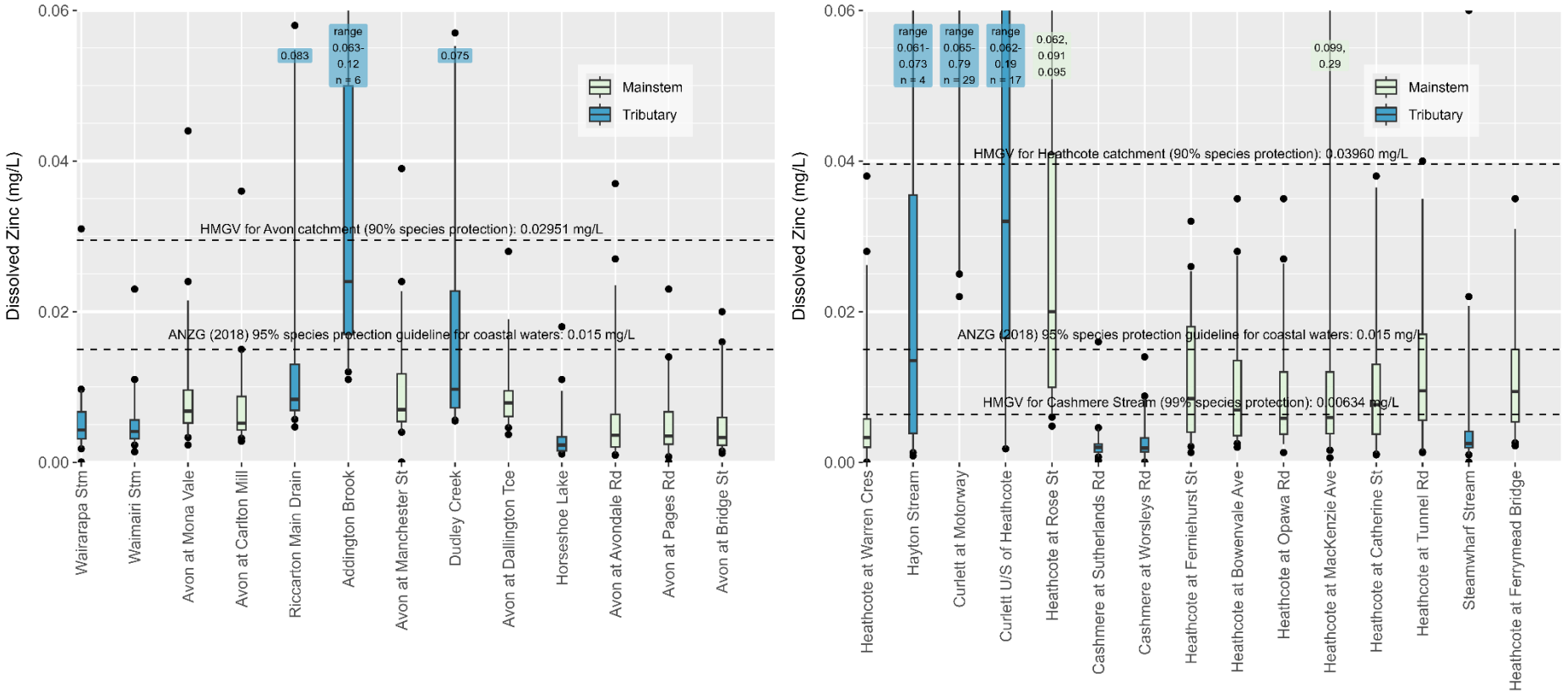

Figure iii (a). Dissolved zinc concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2021 to December 2023. The dashed lines represent the ANZG (2022) guideline values, which have been modified to account for water hardness (Hardness Modified Guideline Value = HMGV), as per the Warne et al. (2018) guidelines methodology. Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) are compared to the coastal water guidelines. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

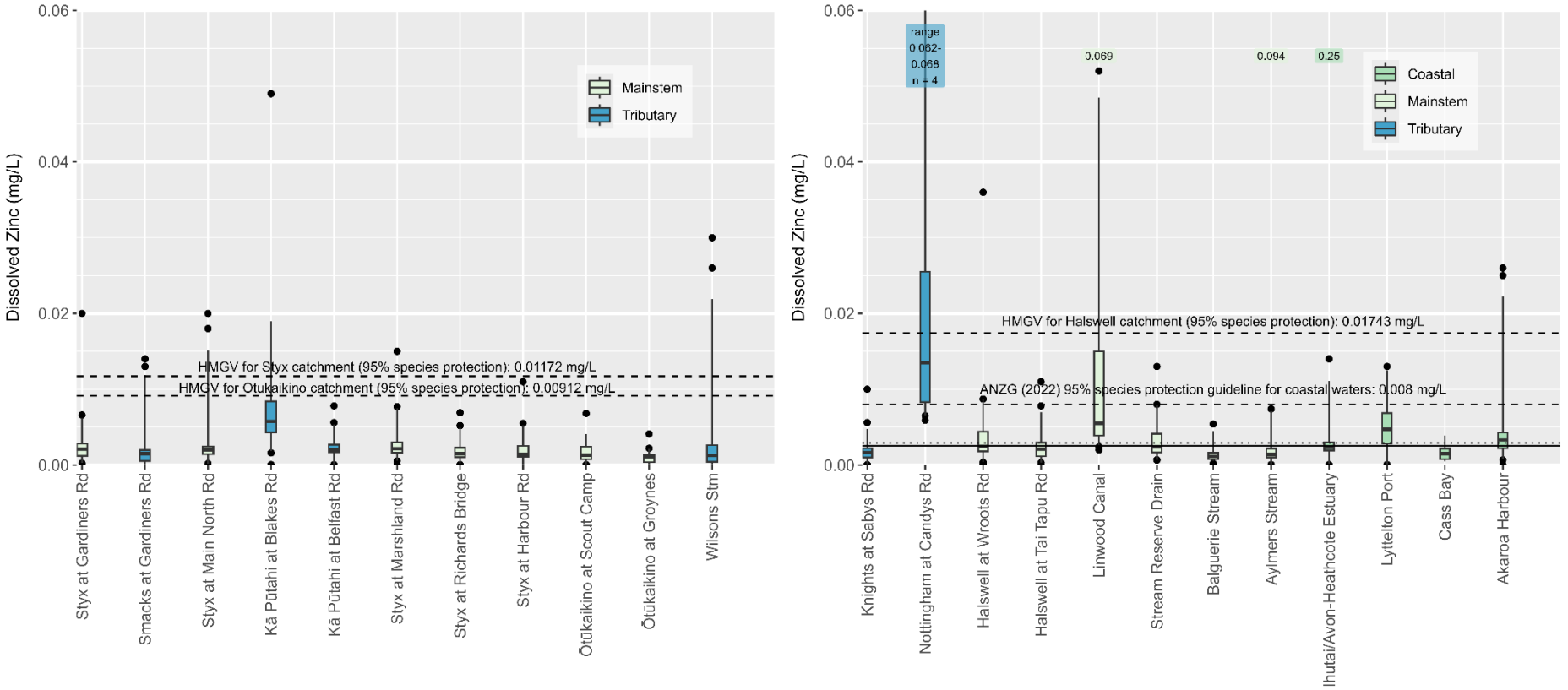

Figure iii (b). Dissolved zinc concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2021 to December 2023. The lines represent the ANZG (2022) guideline values, with the dotted line representing Stream Reserve Drain and Aylmers Stream (0.00293 mg/L) and solid line Balguerie Stream (0.00254 mg/L). The strongly tidal Linwood Canal site is compared to the coastal water guideline. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

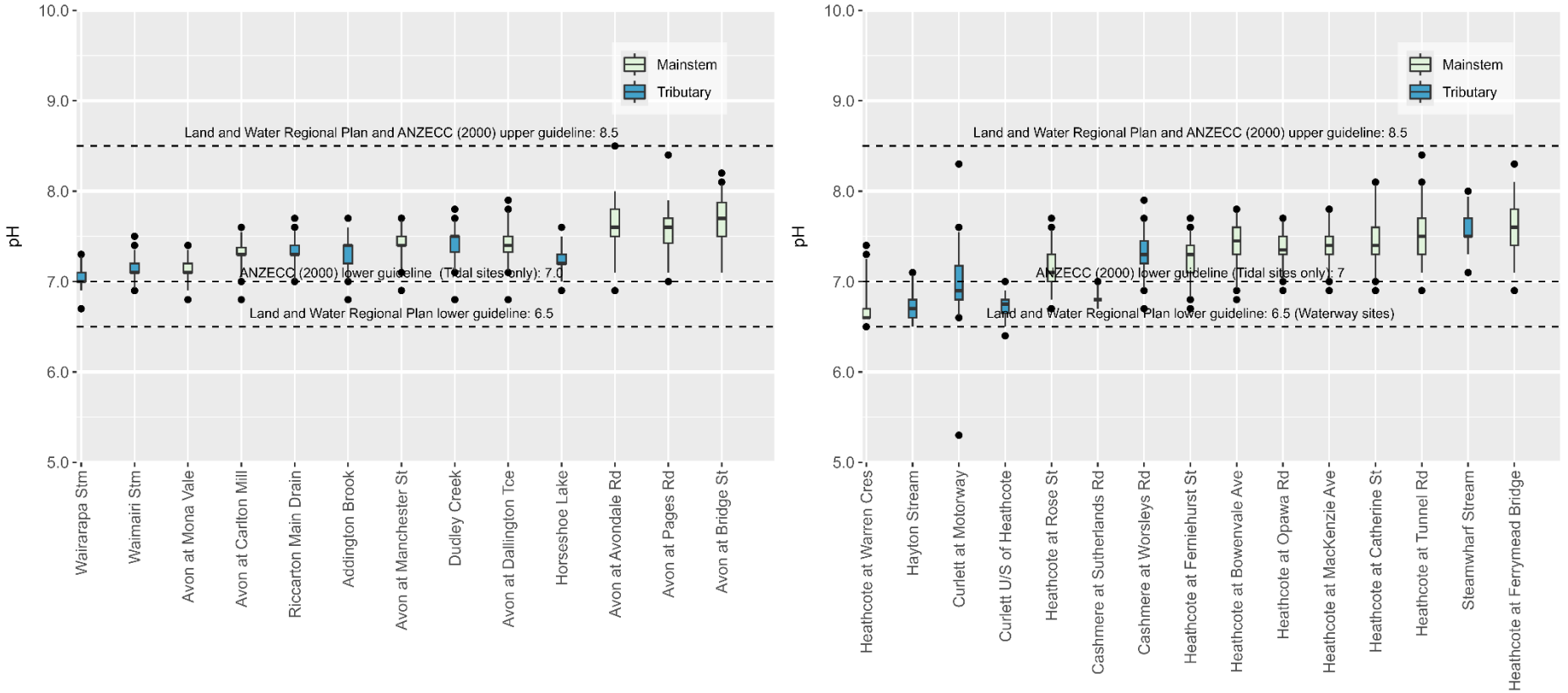

Figure iv (a). pH levels in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2021 to December 2023. The dashed lines represent limits for waterway sites (lower = 6.5, upper = 8.5) (Environment Canterbury, 2019), and the limits for estuarine (and strongly tidal) sites (lower = 7.0, upper = 8.5) (ANZECC, 2000).

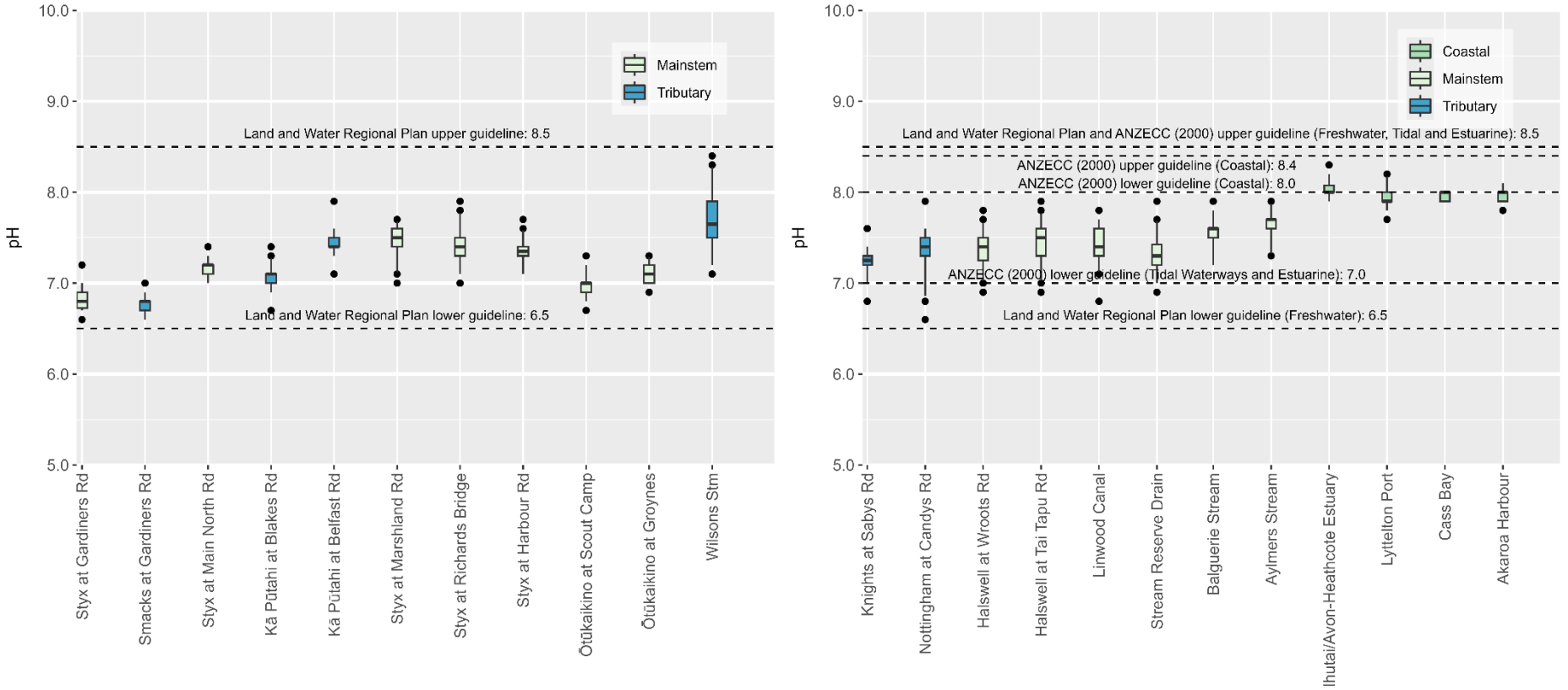

Figure iv (b). pH levels in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2021 to December 2023. The dashed lines represent limits for waterway sites (lower = 6.5, upper = 8.5) (Environment Canterbury, 2019), limits for estuarine (and strongly tidal) sites (lower = 7.0, upper = 8.5) (ANZECC, 2000), and limits for coastal sites (lower = 8.0, upper = 8.4) (ANZECC, 2000).

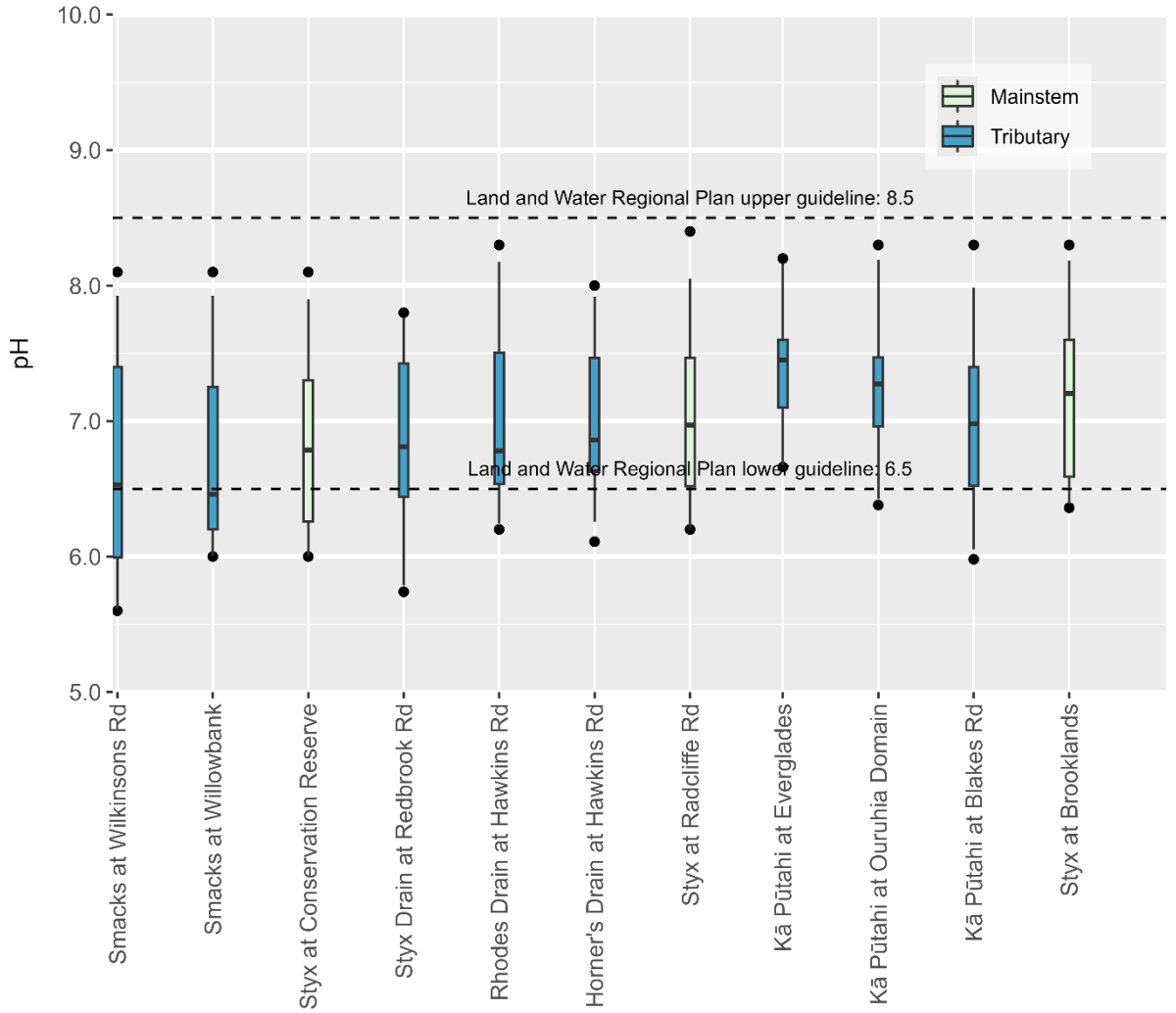

Figure iv (c). pH levels in water samples taken from the Pūharakekenui-Styx River catchment by the Styx Living Laboratory Trust volunteers for the monitoring period January 2021 to December 2023. The dashed lines represent the Land and Water Regional Plan lower (6.5) and upper (8.5) limits (Environment Canterbury, 2019).

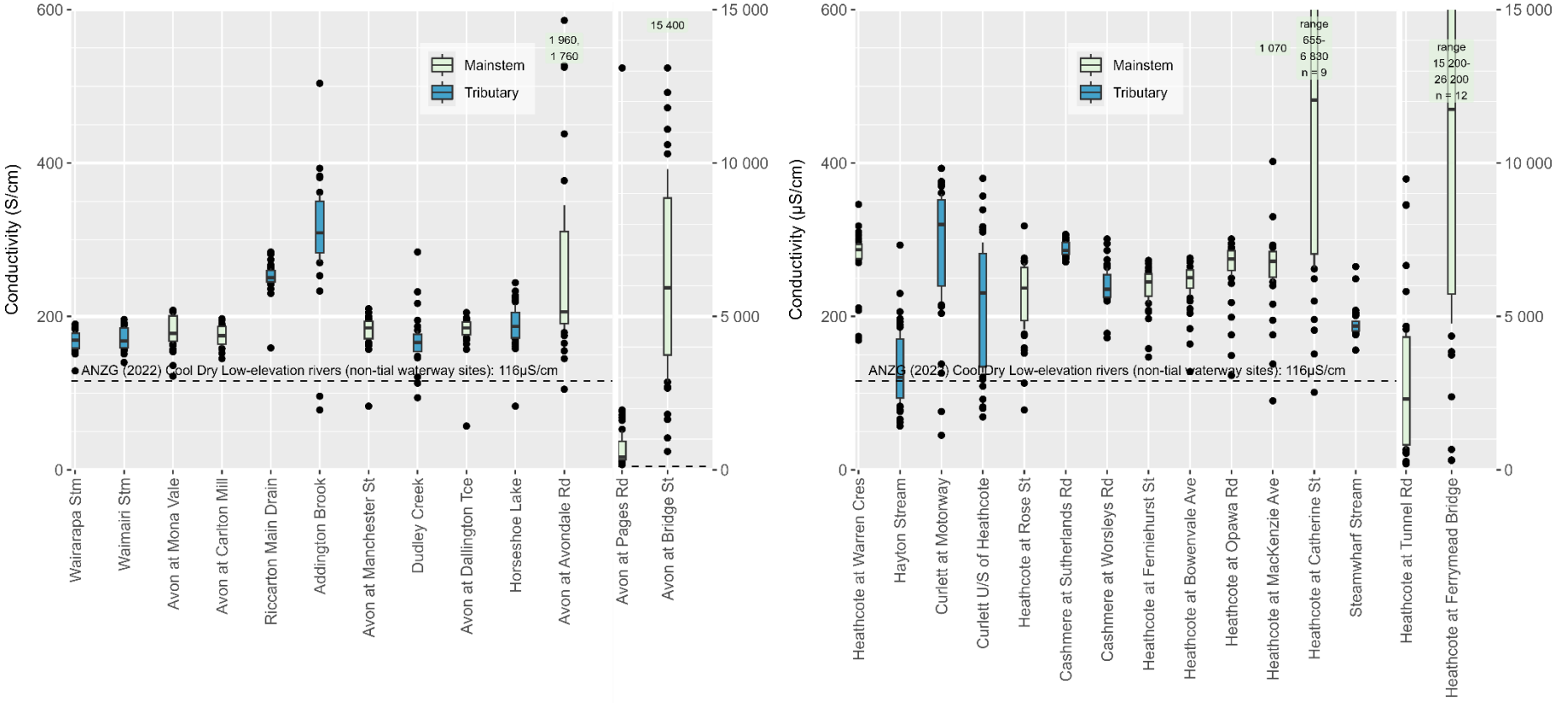

Figure v (a). Conductivity levels in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2021 to December 2023. The ANZG (2022) guideline for waterway sites (116 µS/cm) is shown by the dashed line. As no coastal guideline exists, and the waterway guideline is not appropriate, the strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) were not compared to any guidelines. Given the large differences in concentrations within catchments, some sites are presented with an alternate scale on the secondary (right) axis following the vertical, thick, white line. The numbers in shaded boxes indicate samples that exceeded the y-axis, with 'n' being the number of these data points.

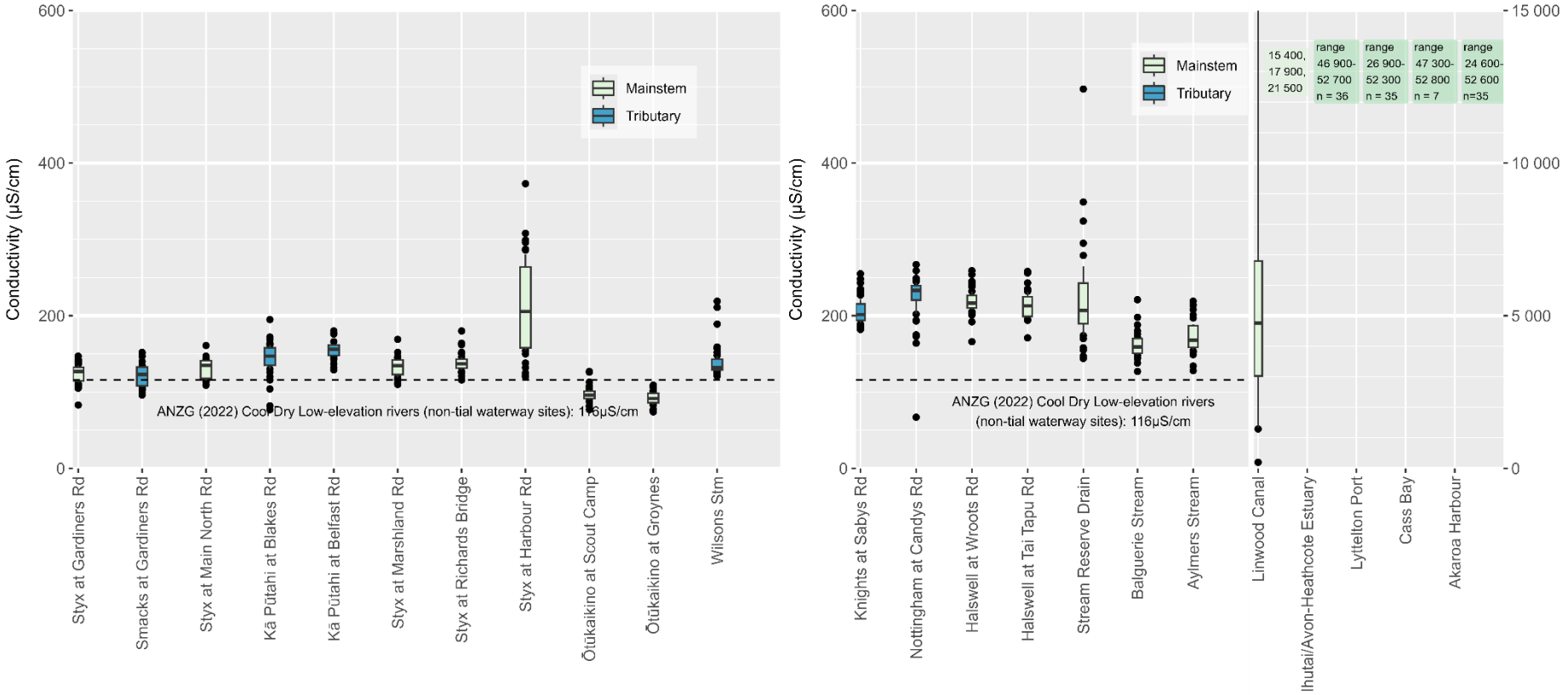

Figure v (b). Conductivity levels in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2021 to December 2023. The ANZG (2022) guideline for waterway sites (116 µS/cm) is shown by the dashed line. As no coastal guideline exists, strongly tidal sites (Linwood Canal) shall be compared to the waterway guideline. All conductivity graphs have the same scale presented on the primary (left) axis. Given the large differences in concentrations within catchments, some sites are presented with an alternate scale on the secondary (right) axis following the vertical, thick, white line. The numbers in shaded boxes indicate samples that exceeded the y-axis, with 'n' being the number of these data points.

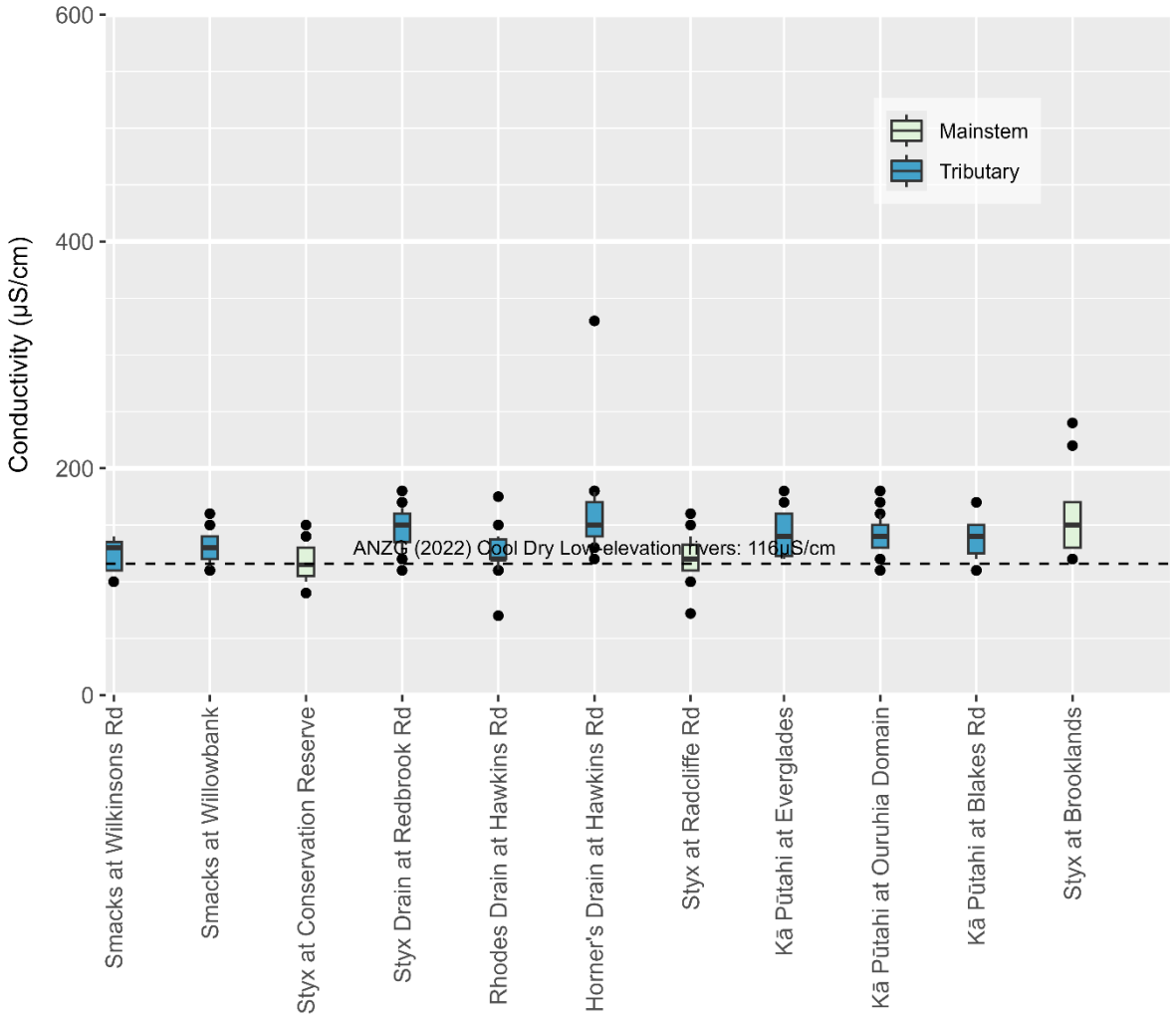

Figure v (c). Conductivity concentrations in water samples taken from the Pūharakekenui-Styx River catchment by the Styx Living Laboratory Trust volunteers for the monitoring period January 2021 to December 2023. The ANZG (2022) guideline for waterway sites (116 µS/cm) is shown by the dashed line.

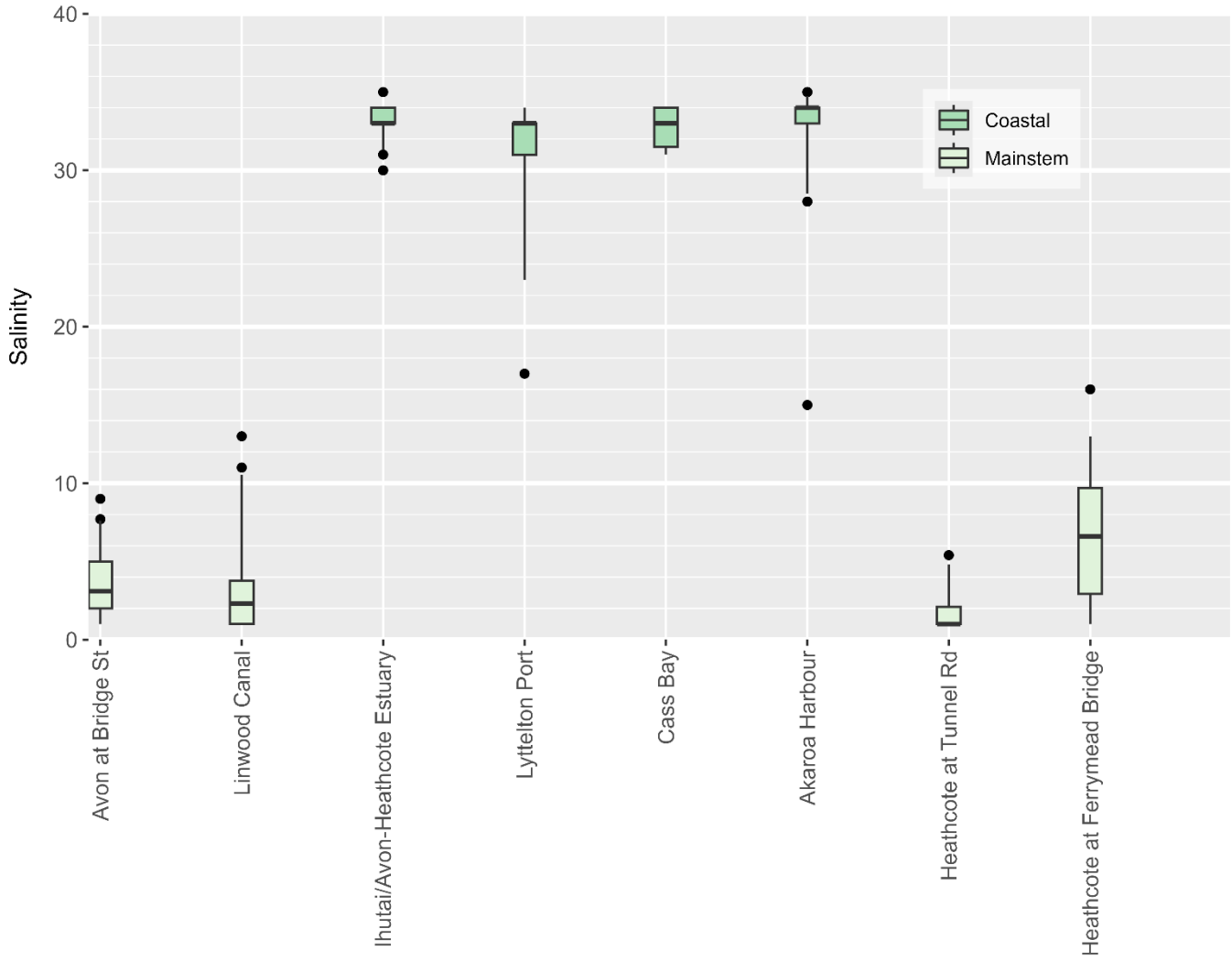

Figure vi. Salinity concentrations in water samples taken from strongly tidal waterway and coastal sites, for the monitoring period January 2021 to December 2023. The Laboratory Limit of Detection was <2.0 – graphed as half this value (1.0).

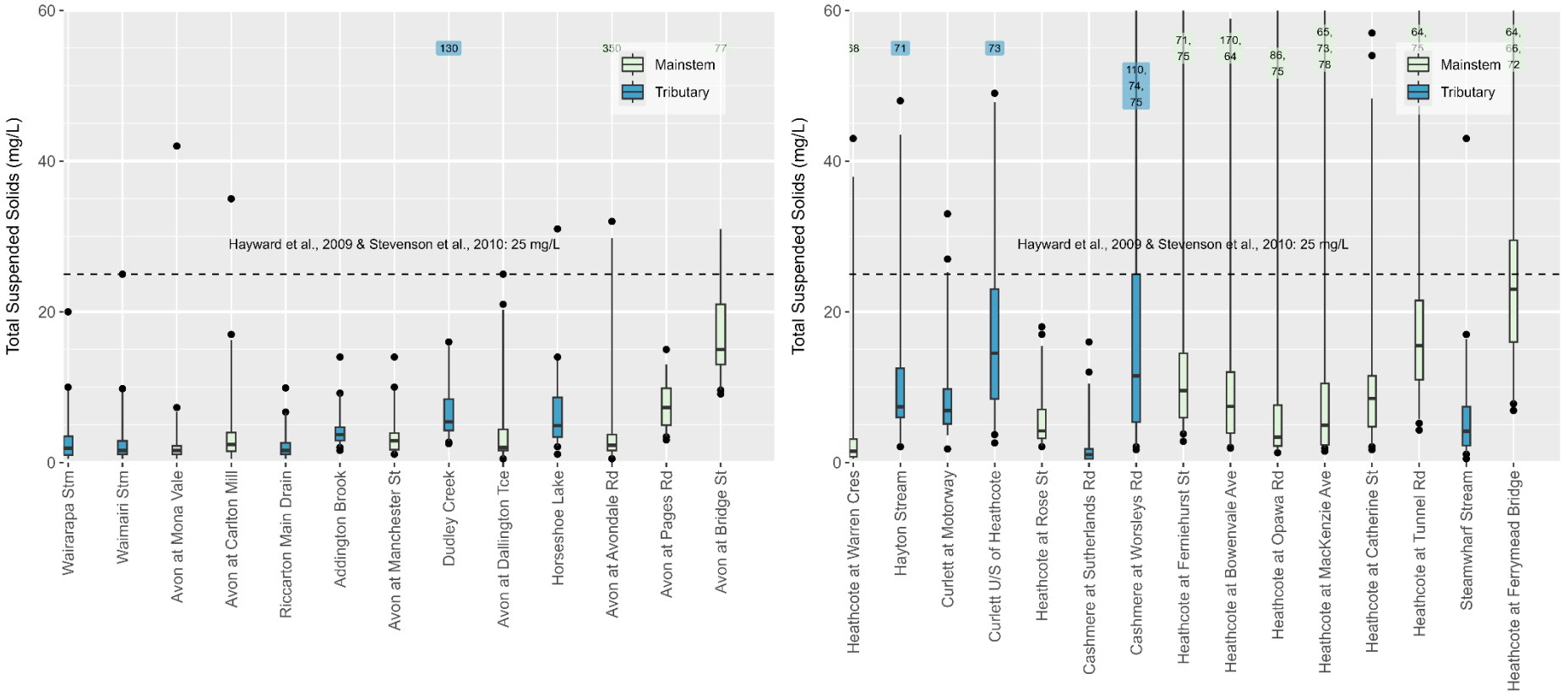

Figure vii (a). Total Suspended Solid (TSS) concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2021 to December 2023. The dashed lines represent the guideline value of 25 mg/L (Hayward et al., 2009; Stevenson et al., 2010). No guidelines currently exist for the strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge), as such they should be compared to waterway guidelines. The Laboratory Limit of Detection was 1.0 mg/L – graphed as half this value (0.5 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

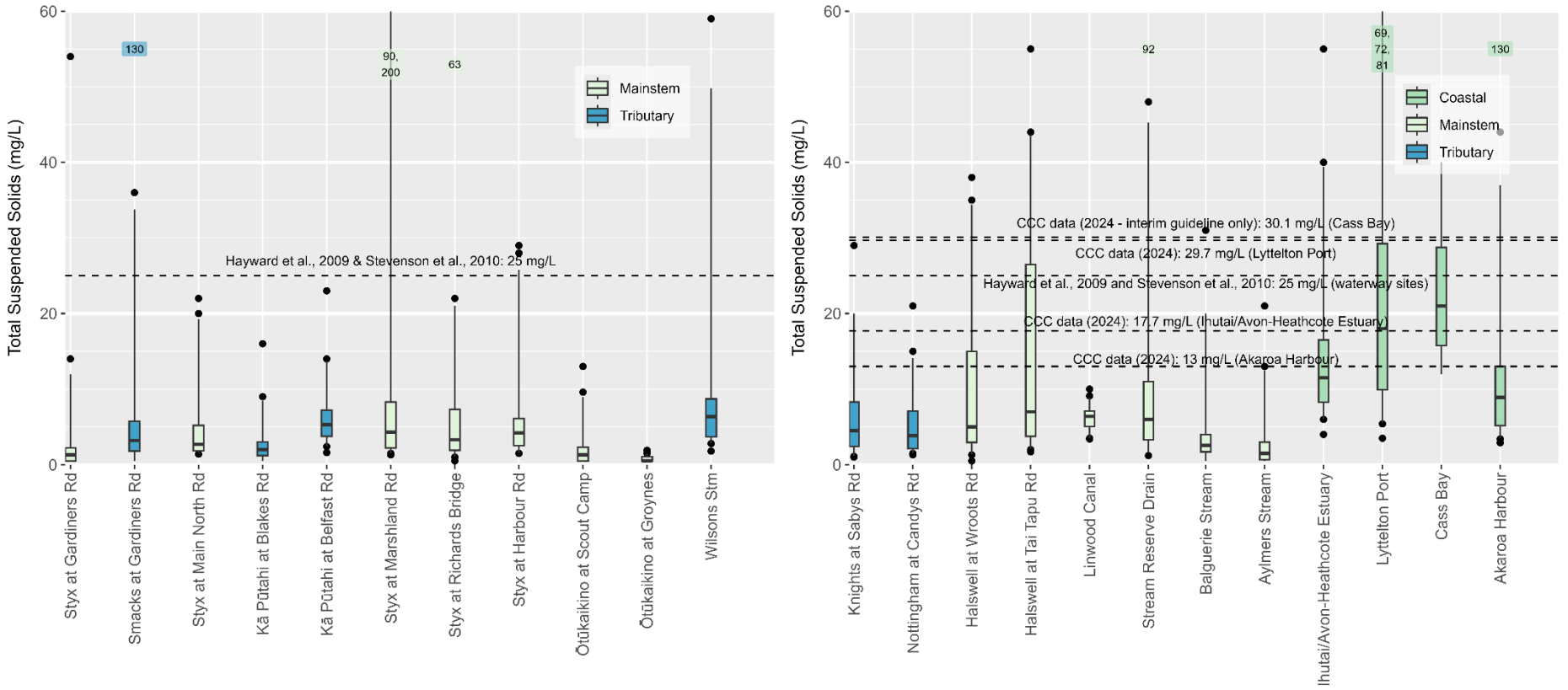

Figure vii (b). Total Suspended Solid (TSS) concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2021 to December 2023. The dashed lines represent either the waterway guideline value of 25 mg/L (Hayward et al., 2009; Stevenson et al., 2010), or for coastal sites, the site-specific coastal guideline (all available CCC data). Cass Bay guideline is interim as more data is required (June – December 2023 only). No guidelines currently exist for the strongly tidal Linwood Canal site, as such they should be compared to waterway guidelines. The Laboratory Limit of Detection was 1.0 mg/L – graphed as half this value (0.5 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

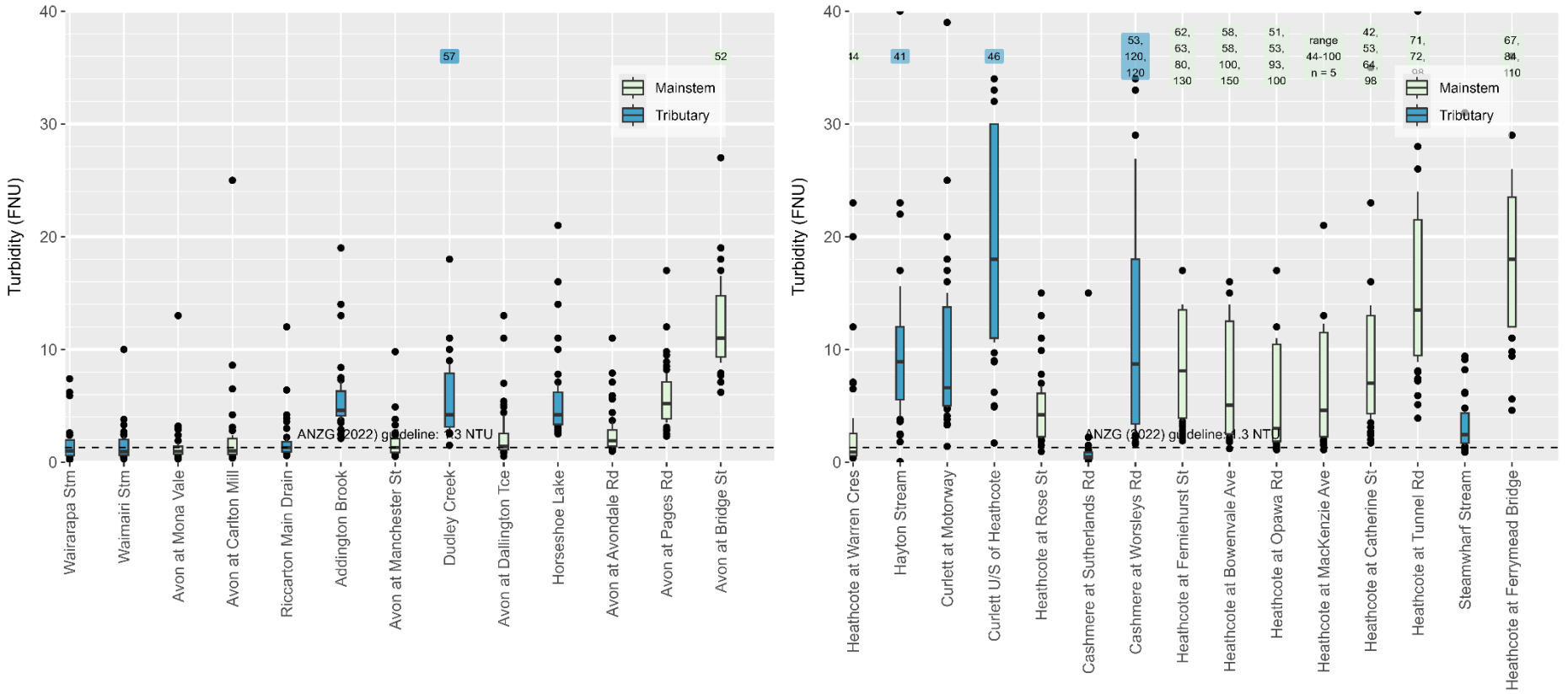

Figure viii (a). Turbidity concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2021 to December 2023. The dashed lines represent the ANZECC (2000) guideline values of 1.3 Nephelometric Turbidity Units (NTU: comparable to Formazin Nephelometric Units (FNU)) for waterway sites. No guidelines currently exist for the strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge), as such they should be compared to waterway guidelines. The Laboratory Limit of Detection was 0.1 FNU – graphed as half this value (0.05 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

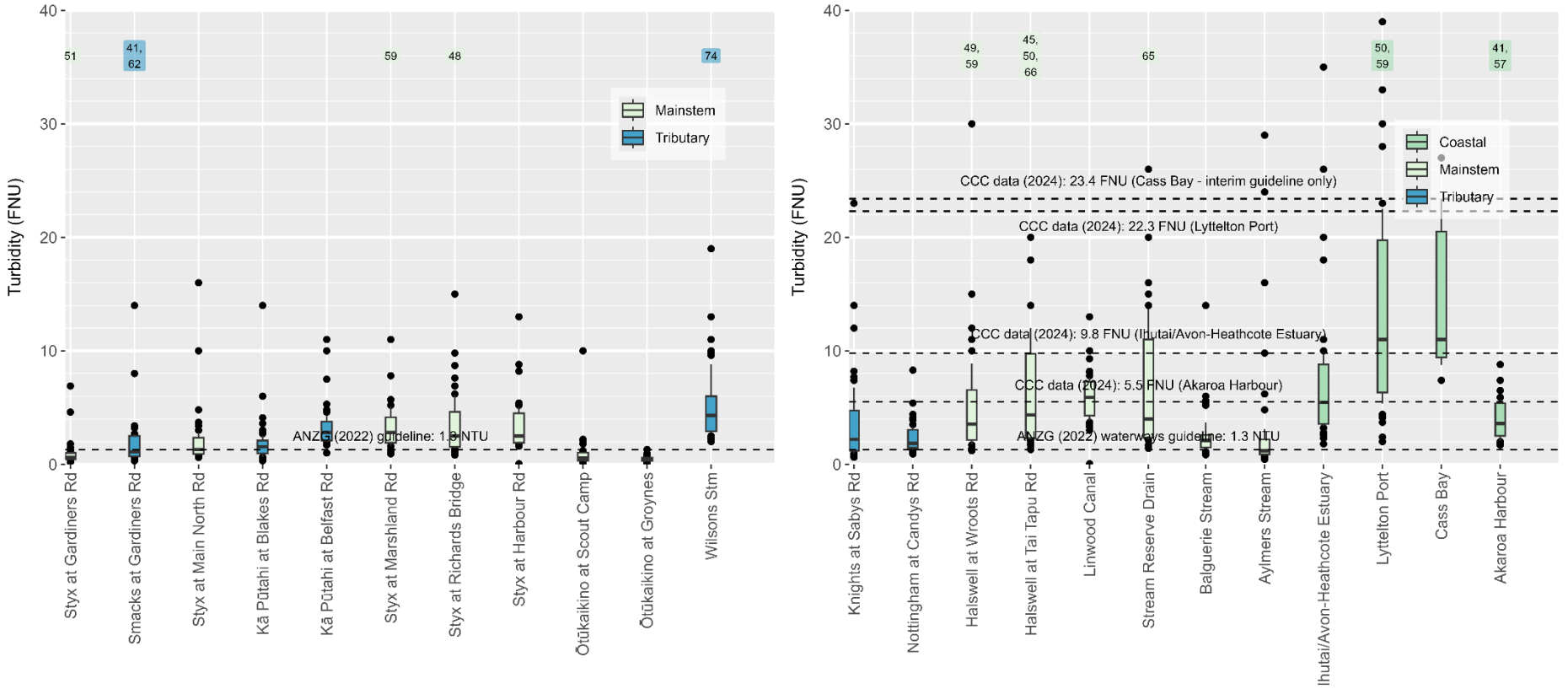

Figure viii (b). Turbidity concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2021 to December 2023. The dashed lines represent the ANZECC (2000) guideline values of 1.3 Nephelometric Turbidity Units (NTU; comparable to Formazin Nephelometric Units (FNU)) for waterway sites, or for coastal sites, the site-specific coastal guideline (all available CCC data). Cass Bay guideline is interim as more data is required (June – December 2023 only). No guidelines currently exist for the strongly tidal sites (Linwood Canal), as such they should be compared to waterway guidelines. The Laboratory Limit of Detection was 0.1 FNU – graphed as half this value (0.05 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

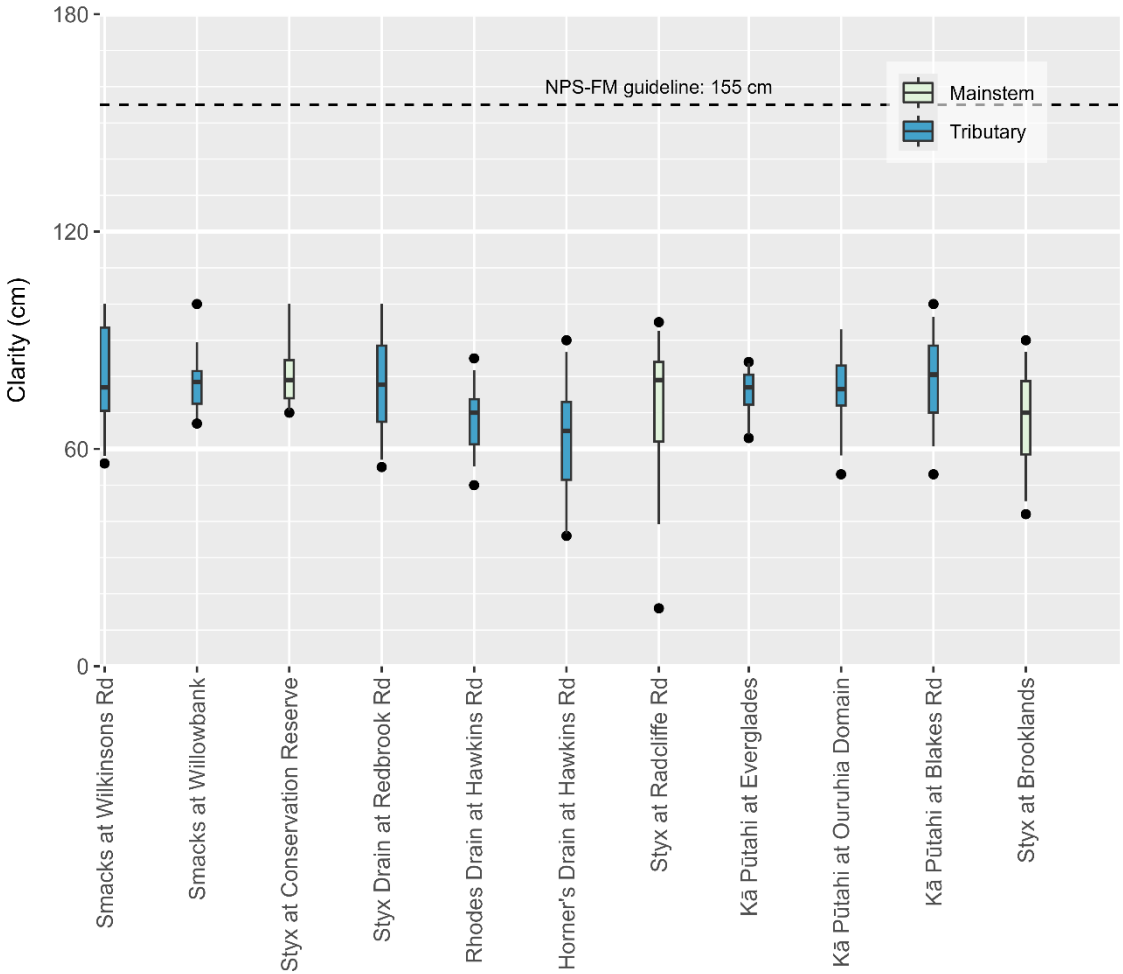

Figure ix. Water clarity levels in water samples taken from the Pūharakekenui-Styx River catchment by the Styx Living Laboratory Trust volunteers for the monitoring period January 2021 to December 2023. The dashed line represents the NPS-FM (Ministry for the Environment, 2023) guideline value of 155 cm for attribute band B.

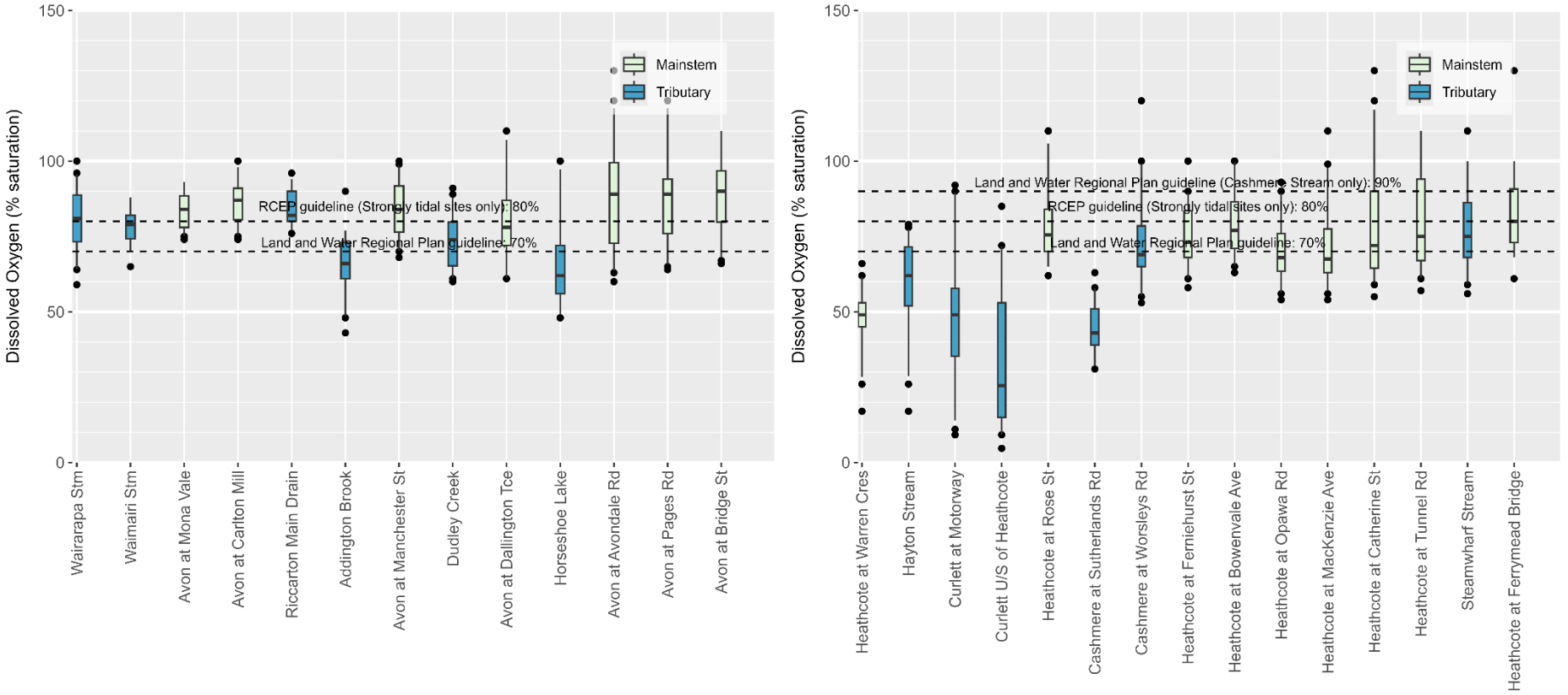

Figure x (a). Dissolved oxygen concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2021 to December 2023. The dashed lines represent the Land and Water Regional Plan minimum guideline value for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (70%; Environment Canterbury, 2019), Banks Peninsula waterways (90%; Cashmere Stream only; Environment Canterbury, 2019), and coastal sites (80%; Environment Canterbury, 2012). Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) should be compared to the coastal water guidelines.

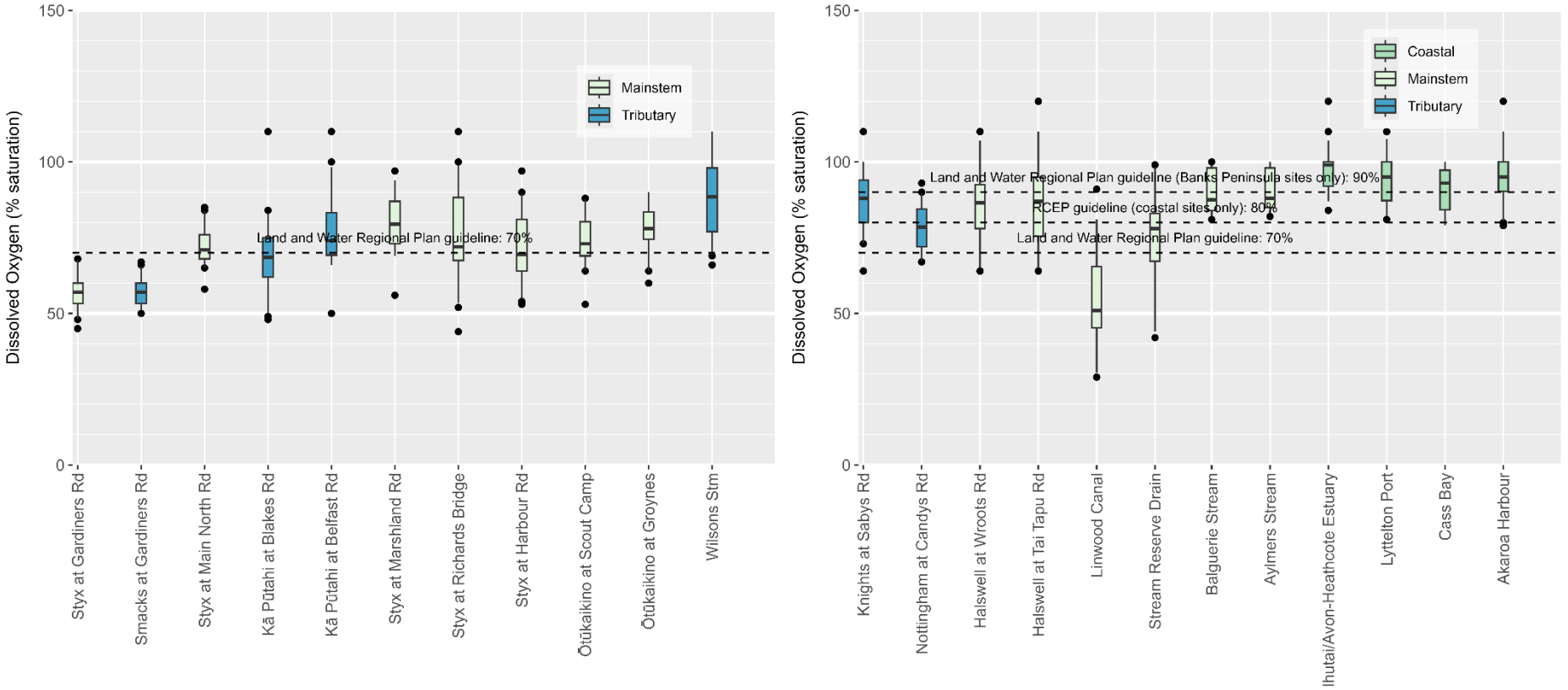

Figure x (b). Dissolved oxygen concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2021 to December 2023. The dashed lines represent the Land and Water Regional Plan minimum guideline value for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (70%; Environment Canterbury, 2019), Banks Peninsula waterways (90%; Environment Canterbury, 2019), and coastal sites (80%; Environment Canterbury, 2012). The strongly tidal Linwood Canal site should be compared to the coastal water guideline.

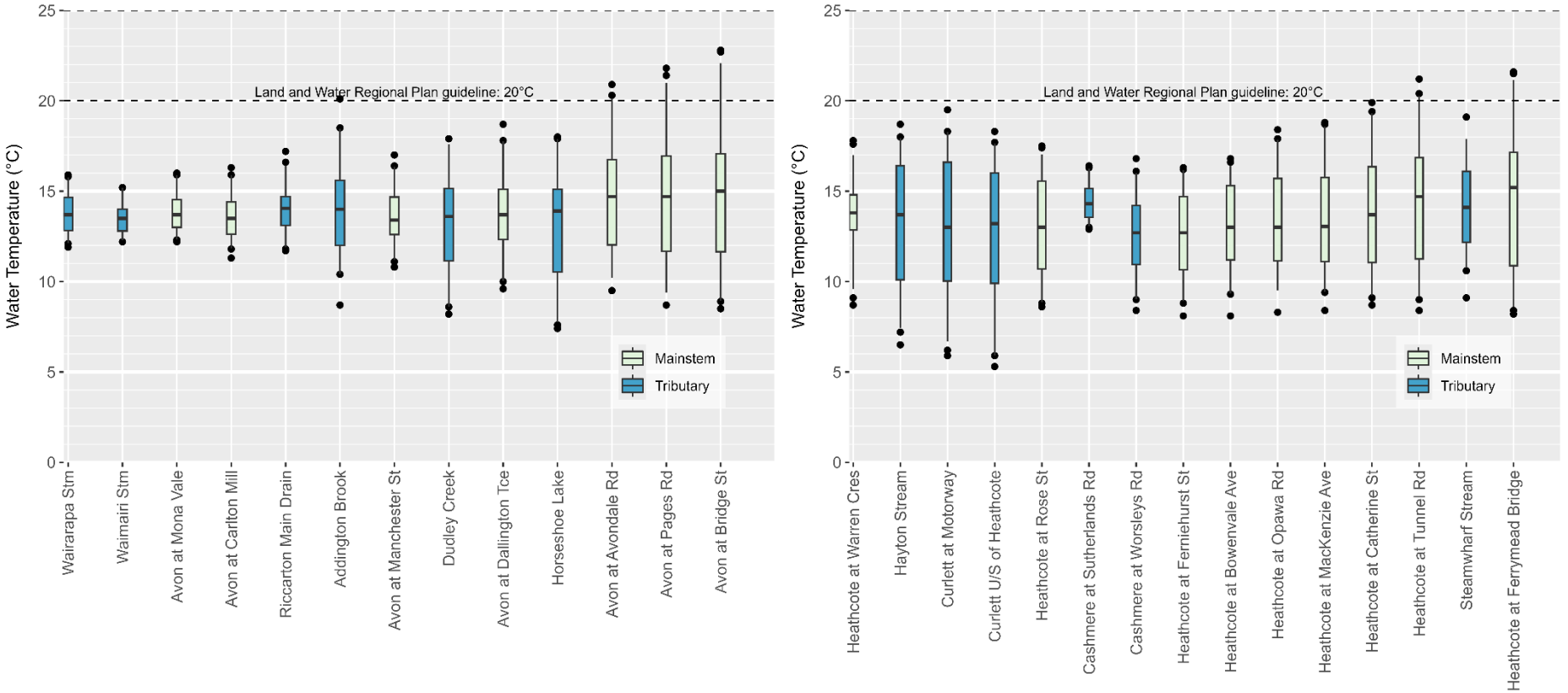

Figure xi (a). Water temperature at the time of sampling at the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2021 to December 2023. The dashed lines represent the coastal (top) and waterway (bottom) guidelines of 25°C (Environment Canterbury, 2012) and 20°C (Environment Canterbury, 2019), respectively. Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) should be compared to the coastal water guidelines.

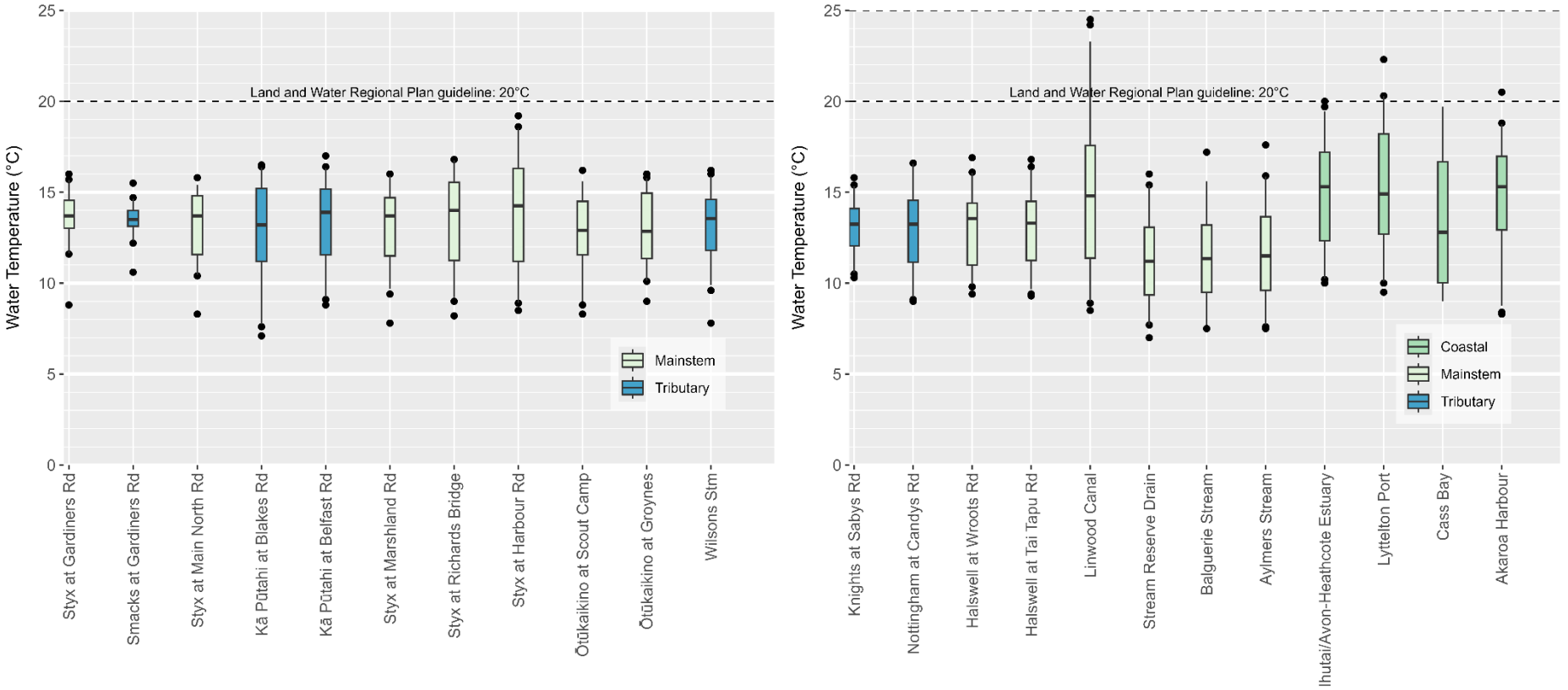

Figure xi (b). Water temperature of the water at the time of sampling at the water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2021 to December 2023. The dashed lines the coastal (top – right graph only) and waterway (bottom) guidelines of 25°C (Environment Canterbury, 2012) and 20°C (Environment Canterbury, 2019), respectively. The strongly tidal Linwood Canal site should be compared to the coastal water guideline.

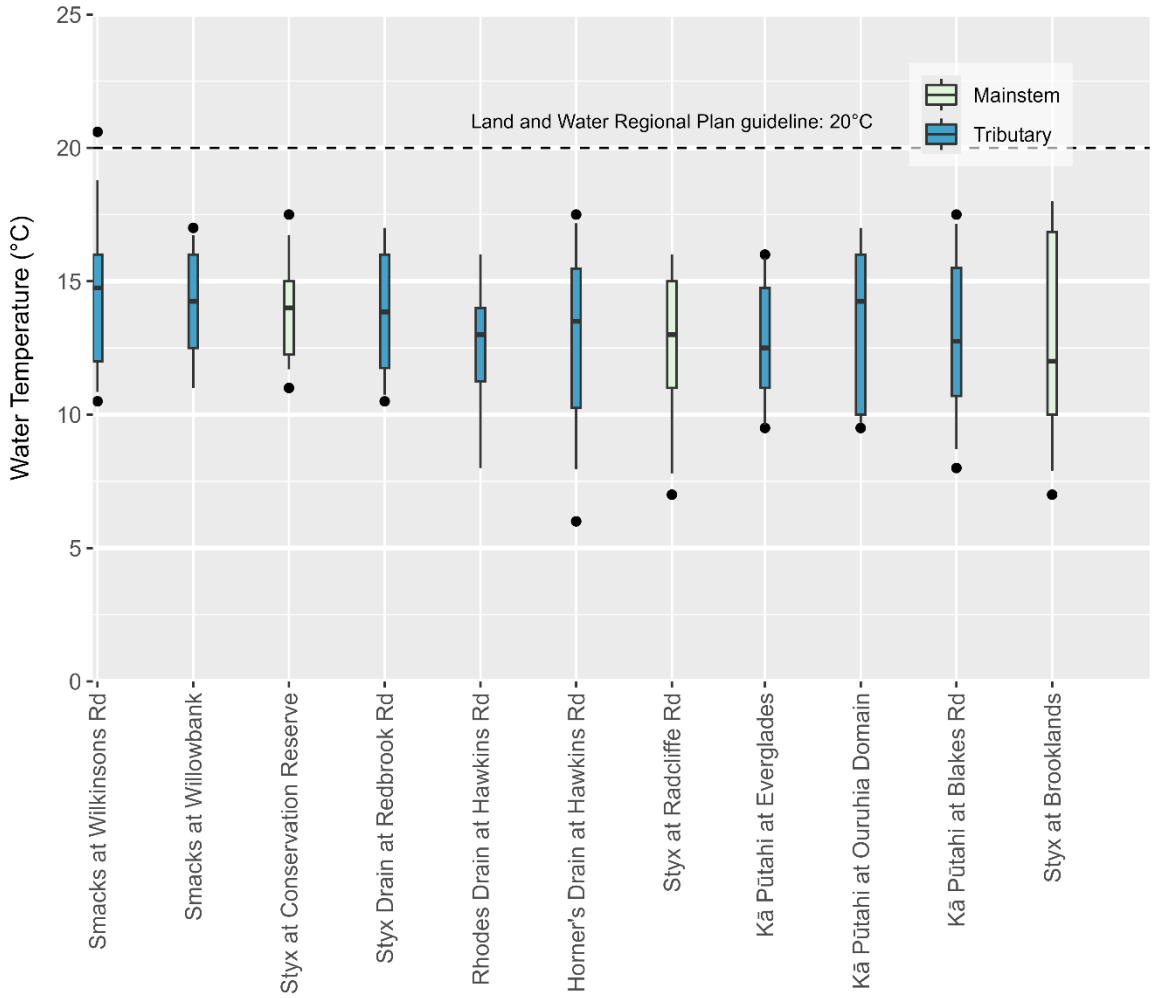

Figure xi (c). Water temperature of the water at the time of sampling by the Styx Living Laboratory Trust volunteers for the monitoring period January 2021 to December 2023. The dashed lines represent the Land and Water Regional Plan maximum guideline value (20 °C, Environment Canterbury, 2019).

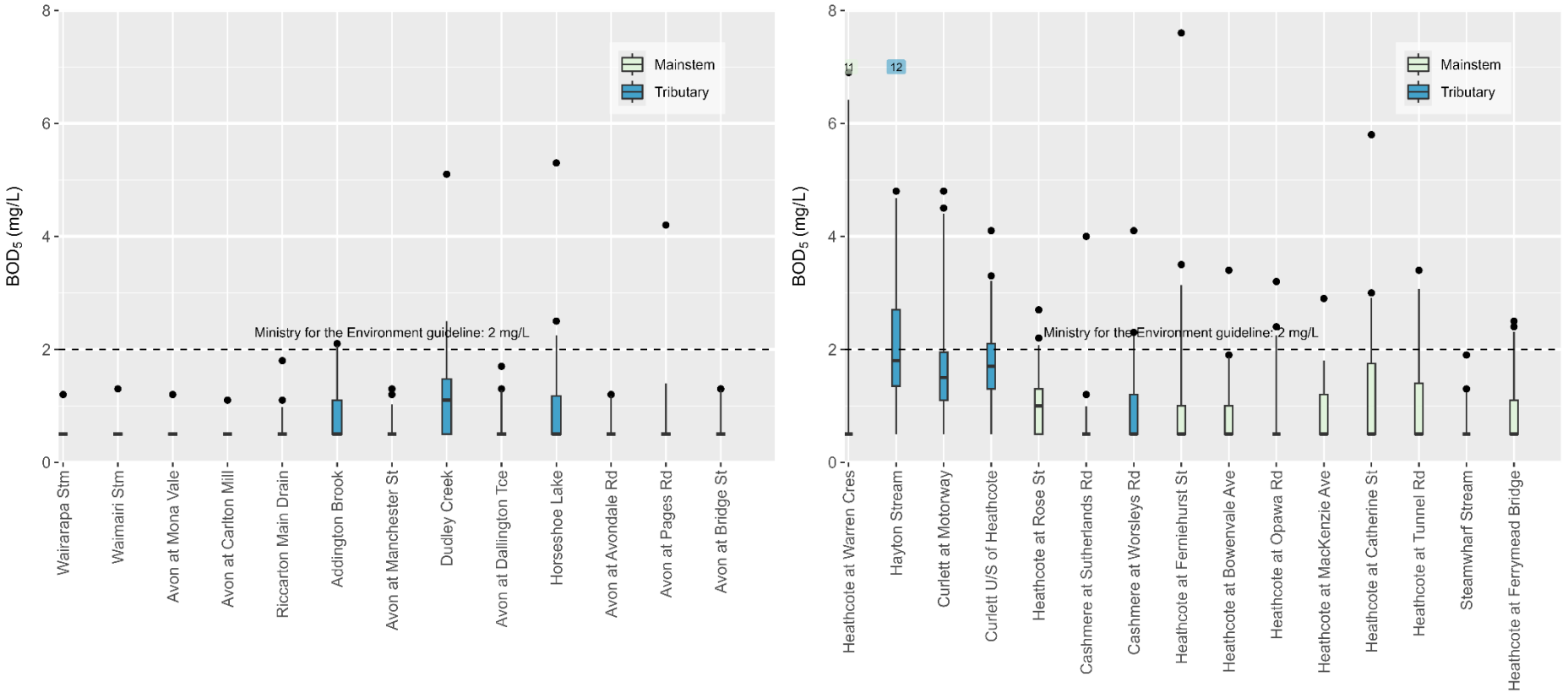

Figure xii (a). Biochemical Oxygen Demand (BOD_5) concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2021 to December 2023. The dashed lines represent the Ministry for the Environment waterway guideline value (Ministry for the Environment, 1992) and the coastal guideline value (Environment Canterbury, 2012). The Laboratory Limit of Detection was 1.0 mg/L, graphed as half this value (0.5 mg/L).

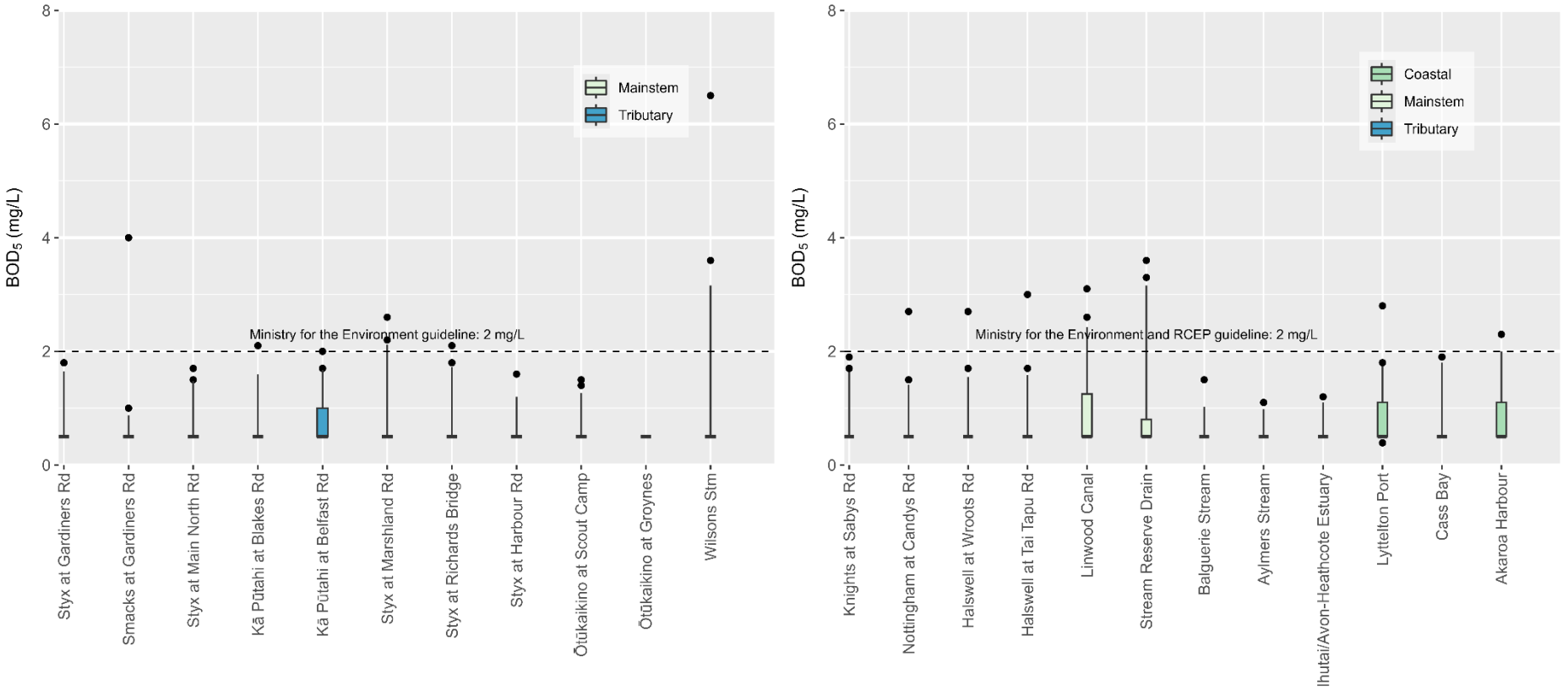

Figure xii (b). Biochemical Oxygen Demand (BOD_5) concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2021 to December 2023. The dashed lines represent the Ministry for the Environment waterway guideline value (Ministry for the Environment, 1992) and the coastal guideline value (Environment Canterbury, 2012). No guideline exists for Lyttelton Port. The Laboratory Limit of Detection was 1.0 mg/L, graphed as half this value (0.5 mg/L).

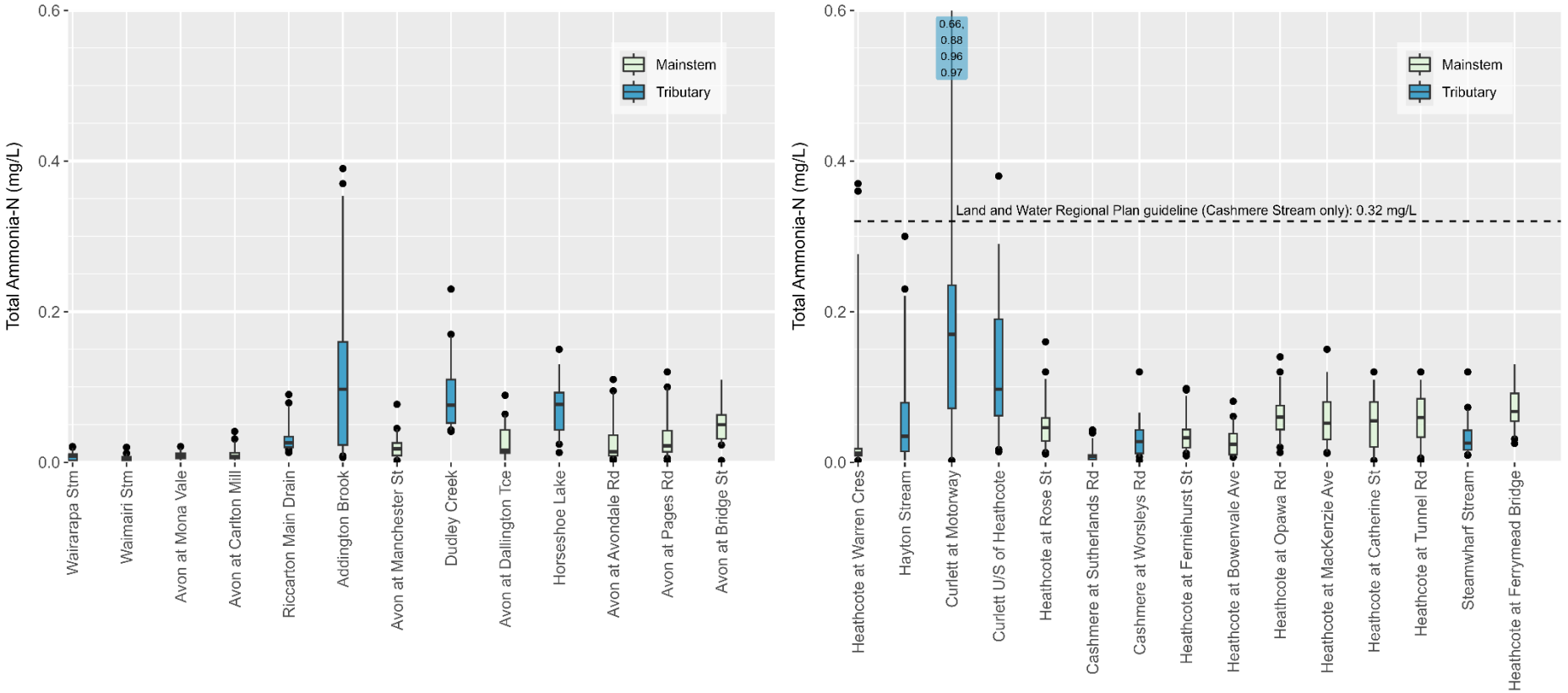

Figure xiii (a). Total ammonia concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2021 to December 2023. The Land and Water Regional Plan guideline value (Ōtākaro-Avon catchment: 1.88 mg/L, Ōpāwaho-Heathcote (excluding Haytons Stream): 1.88 mg/L, Haytons Stream: 2.38 mg/L, Environment Canterbury, 2019), which has been adjusted in accordance with median pH levels for the monitoring period (Ōtākaro-Avon catchment: 7.3, Ōpāwaho-Heathcote catchment (excluding Haytons and Cashmere Streams): 7.3, Haytons Stream: 6.7), are not presented on the graph as they are off the scale. The dashed line represents the Land and Water Regional Plan maximum guideline value for Banks Peninsula waterways (0.32 mg/L, Cashmere Stream only; Environment Canterbury, 2019). As no coastal guideline exists, strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) shall be compared to the waterway guideline. The Laboratory Limit of Detection was 0.005 mg/L – graphed as half this value (0.0025 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

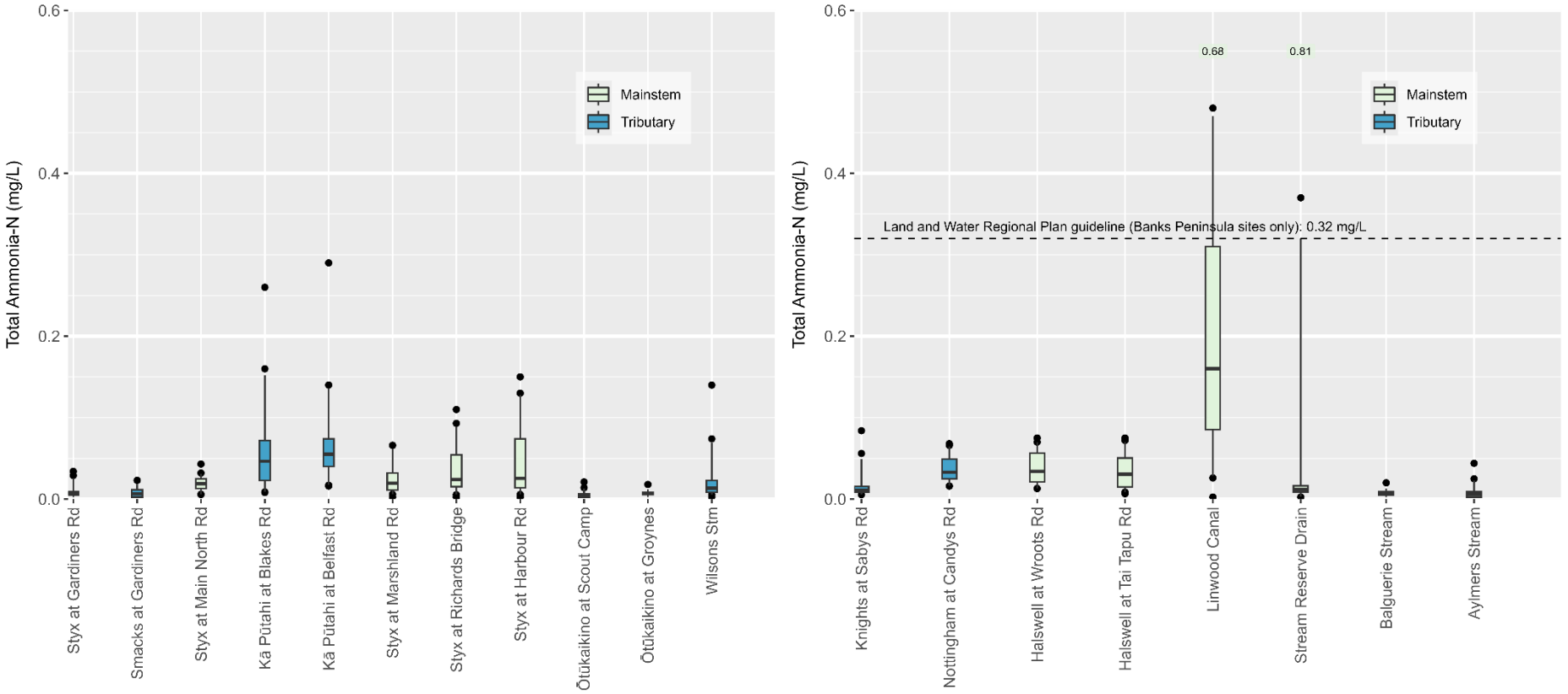

Figure xiii (b). Total ammonia concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, and Banks Peninsula sites (right graph), for the monitoring period January 2021 to December 2023. The Land and Water Regional Plan guideline values (Pūharakekenui-Styx catchment: 1.99 mg/L, Ōtūkaikino catchment: 2.09 mg/L, Huritini-Halswell catchment: 1.75 mg/L, Linwood Canal: 1.75 mg/L; Environment Canterbury, 2019), adjusted in accordance with median pH levels for the monitoring period (Pūharakekenui-Styx catchment: 7.2, Ōtūkaikino catchment: 7.1, Huritini-Halswell catchment: 7.4, Linwood Canal: 7.4), are not presented on the graph as they are off the scale. The dashed line represents the Land and Water Regional Plan maximum guideline value for Banks Peninsula waterways (0.32 mg/L; Environment Canterbury, 2019). The Laboratory Limit of Detection was 0.005 mg/L – graphed as half this value (0.0025 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

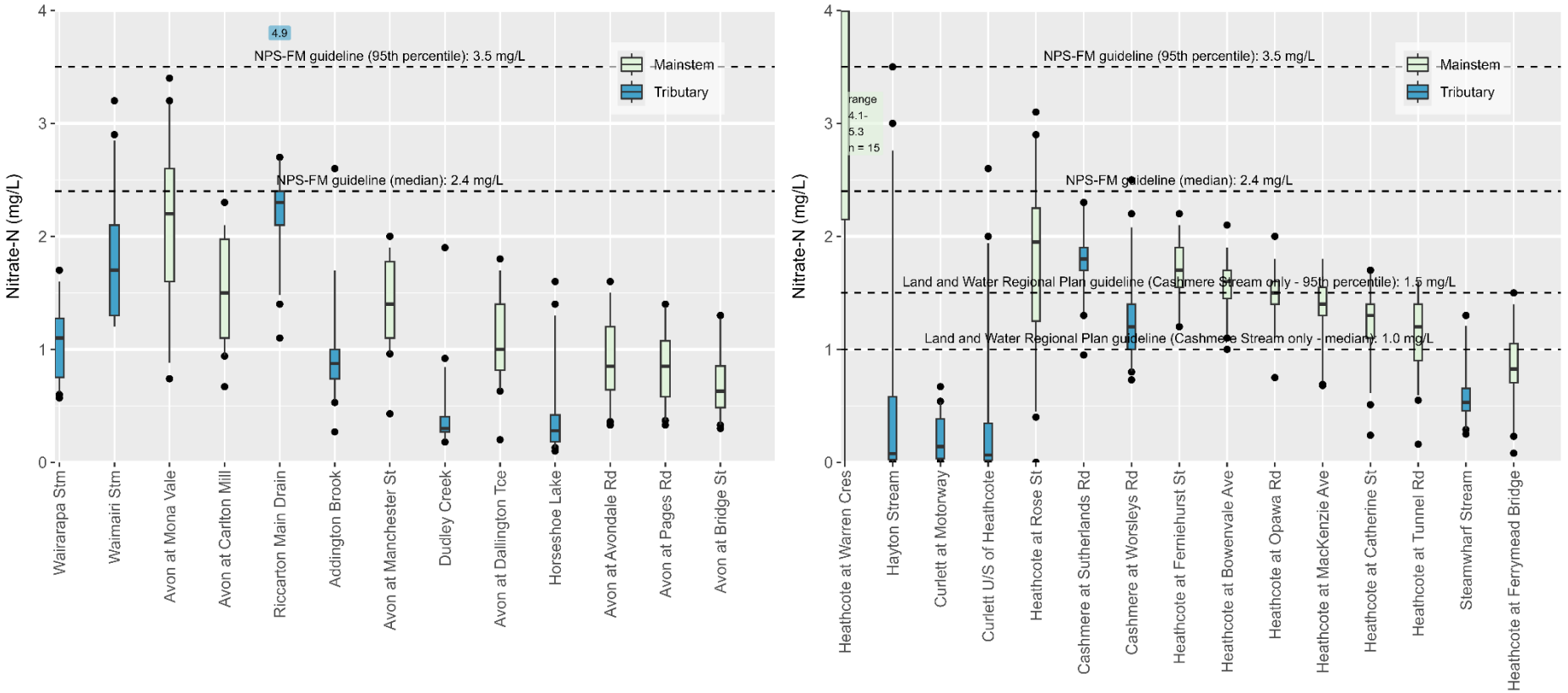

Figure xiv (a). Nitrate-nitrogen concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2021 to December 2023. The dashed lines represent the NPS-FM median (2.4 mg/L) and 95th percentile (3.5 mg/L) guideline levels (Ministry for the Environment, 2023), or the Land and Water Regional Plan median (1.0 mg/L) and 95th percentile (1.5 mg/L) guideline for Cashmere Stream (Environment Canterbury, 2019). As no coastal guideline exists, strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) shall be compared to the waterway guideline. The Laboratory Limit of Detection was 0.002 mg/L – graphed as half this value (0.001 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

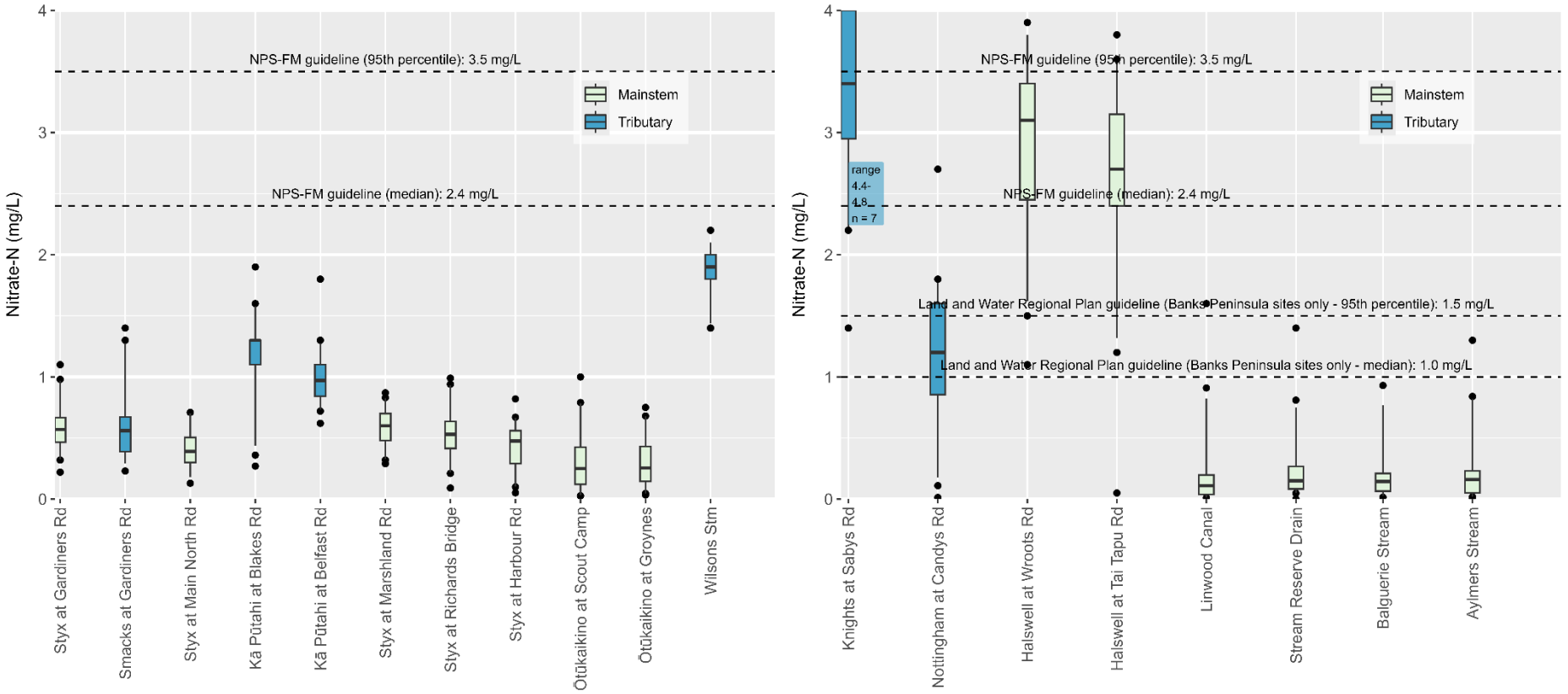

Figure xiv (b). Nitrate concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, and Banks Peninsula sites (right graph), for the monitoring period January 2021 to December 2023. The dashed lines represent the NPS-FM median (2.4 mg/L) and 95th percentile (3.5 mg/L) guideline levels (Ministry for the Environment, 2023), or the Land and Water Regional Plan median (1.0 mg/L) and 95th percentile (1.5 mg/L) guideline for Banks Peninsula sites (Environment Canterbury, 2019). As no coastal guideline exists, strongly tidal sites (Linwood Canal) shall be compared to the waterway guideline. The Laboratory Limit of Detection was 0.002 mg/L – graphed as half this value (0.001 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis. Nutrients are not sampled at coastal sites.

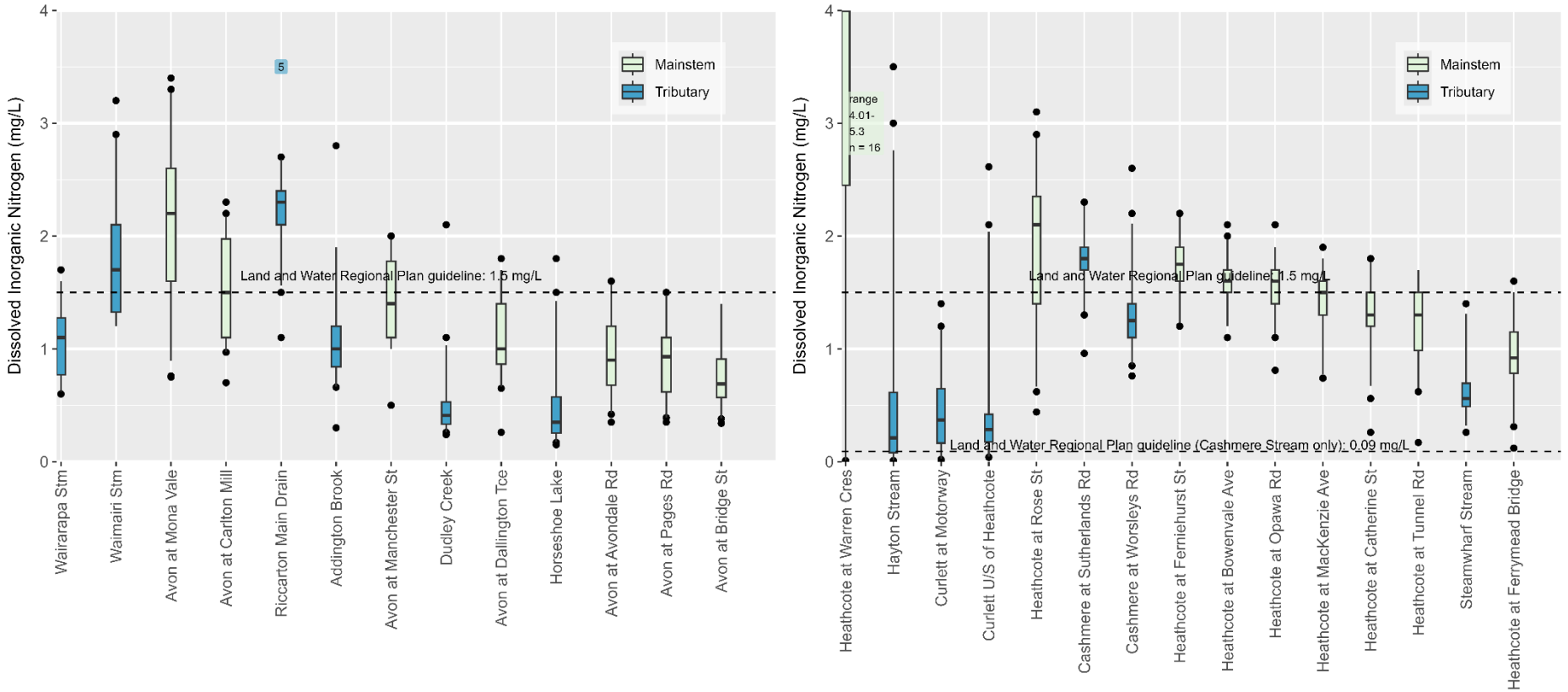

Figure xv (a). Dissolved Inorganic Nitrogen (DIN) concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2021 to December 2023. The dashed lines represent the Land and Water Regional Plan guideline value of 1.5 mg/L for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways, and 0.09 mg/L for Banks Peninsula waterways (Cashmere Stream only), respectively (Environment Canterbury, 2019). As no coastal guideline exists, strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) shall be compared to the waterway guideline. The Laboratory Limit of Detection was 0.002 mg/L – graphed as half this value (0.001 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

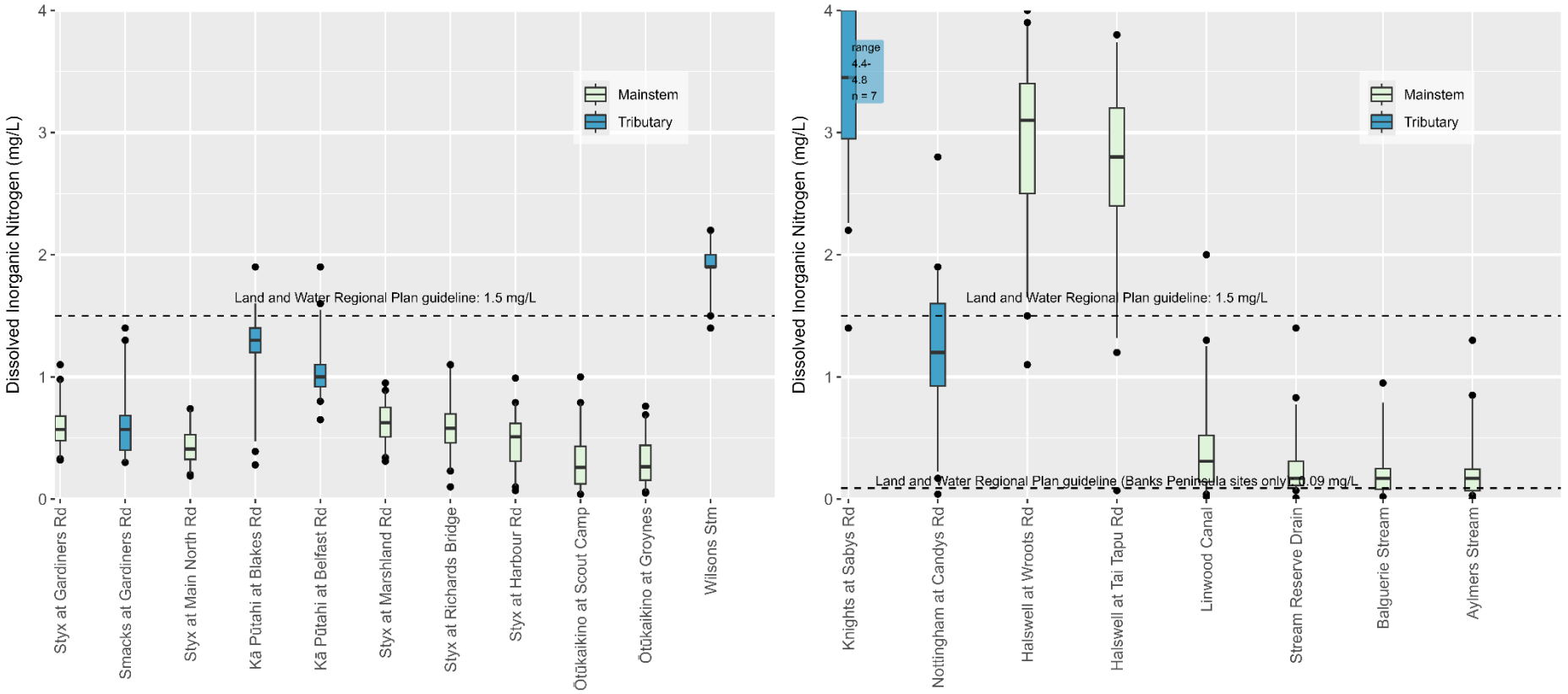

Figure xv (b). Dissolved Inorganic Nitrogen (DIN) concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, and Banks Peninsula sites (right graph), for the monitoring period January 2021 to December 2023. The dashed lines represent the Land and Water Regional Plan guideline value of 1.5 mg/L for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways, and 0.09 mg/L for Banks Peninsula waterways, respectively (Environment Canterbury, 2019). As no coastal guideline exists, strongly tidal sites (Linwood Canal) shall be compared to the waterway guideline. The Laboratory Limit of Detection was 0.002 mg/L – graphed as half this value (0.001 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis. Nutrients are not sampled at coastal sites.

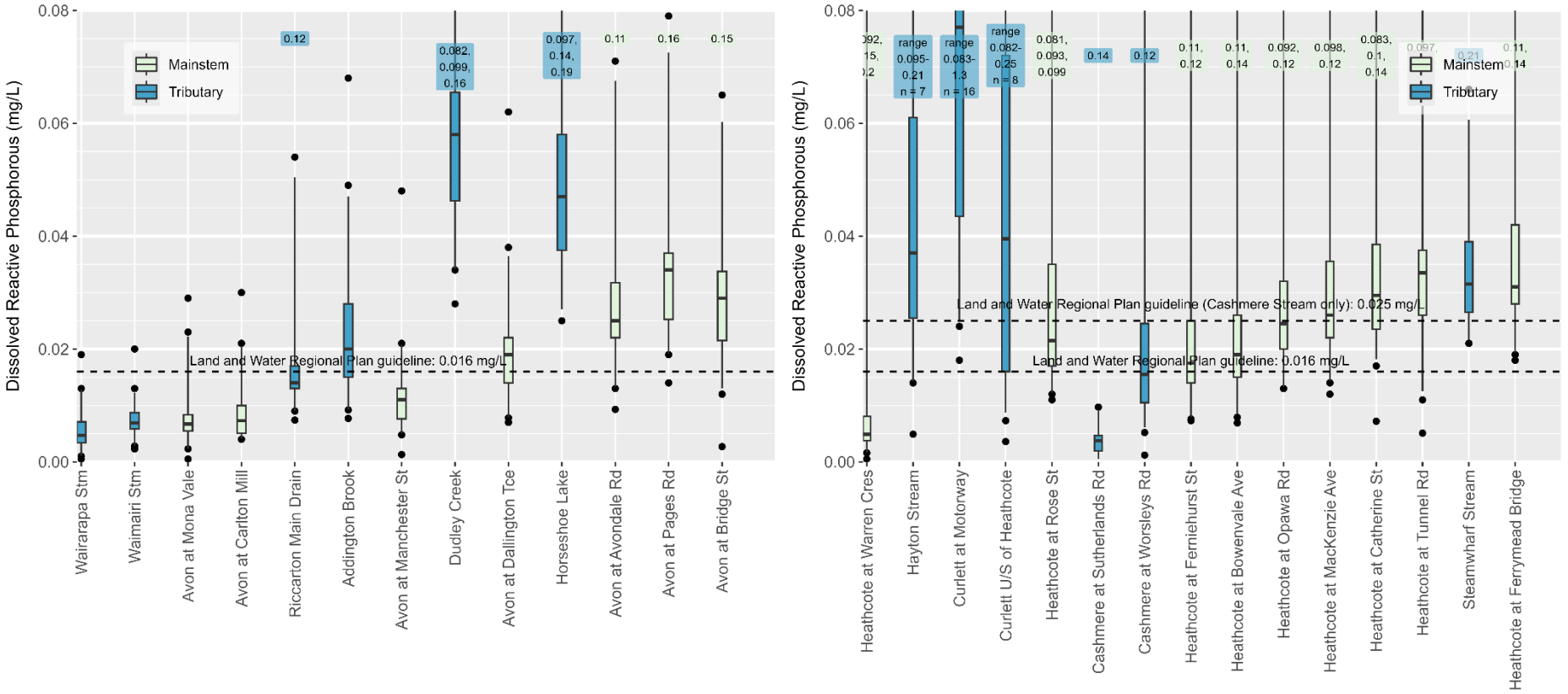

Figure xvi (a). Dissolved Reactive Phosphorus (DRP) concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2021 to December 2023. The dashed lines represent either the Land and Water Regional Plan guideline value of 0.016 mg/L for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways, or the Land and Water Regional Plan guideline value of 0.025 mg/L for Banks Peninsula waterways (Cashmere Stream only), (Environment Canterbury, 2019). As no coastal guideline exists, strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) shall be compared to the waterway guideline. The Laboratory Limit of Detection was 0.001 mg/L, graphed as half this value (0.0005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

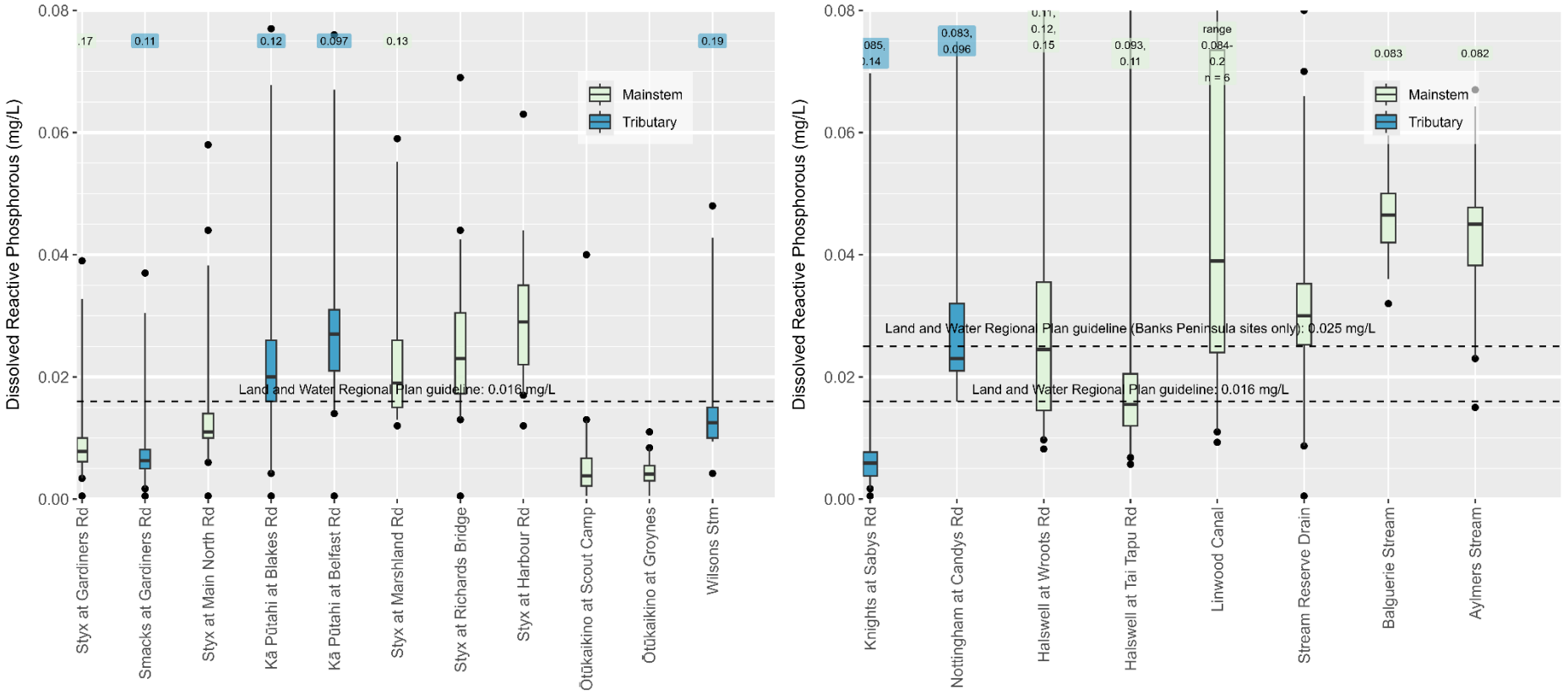

Figure xvi (b). Dissolved Reactive Phosphorus (DRP) concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, and Banks Peninsula sites (right graph), for the monitoring period January 2021 to December 2023. The dashed lines represent either the Land and Water Regional Plan guideline value of 0.016 mg/L for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways, or the Land and Water Regional Plan guideline value of 0.025 mg/L for Banks Peninsula waterways, (Environment Canterbury, 2019). As no coastal guideline exists, strongly tidal sites (Linwood Canal) shall be compared to the waterway guideline. The Laboratory Limit of Detection was 0.001 mg/L, graphed as half this value (0.0005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis. Nutrients are not sampled at coastal sites.

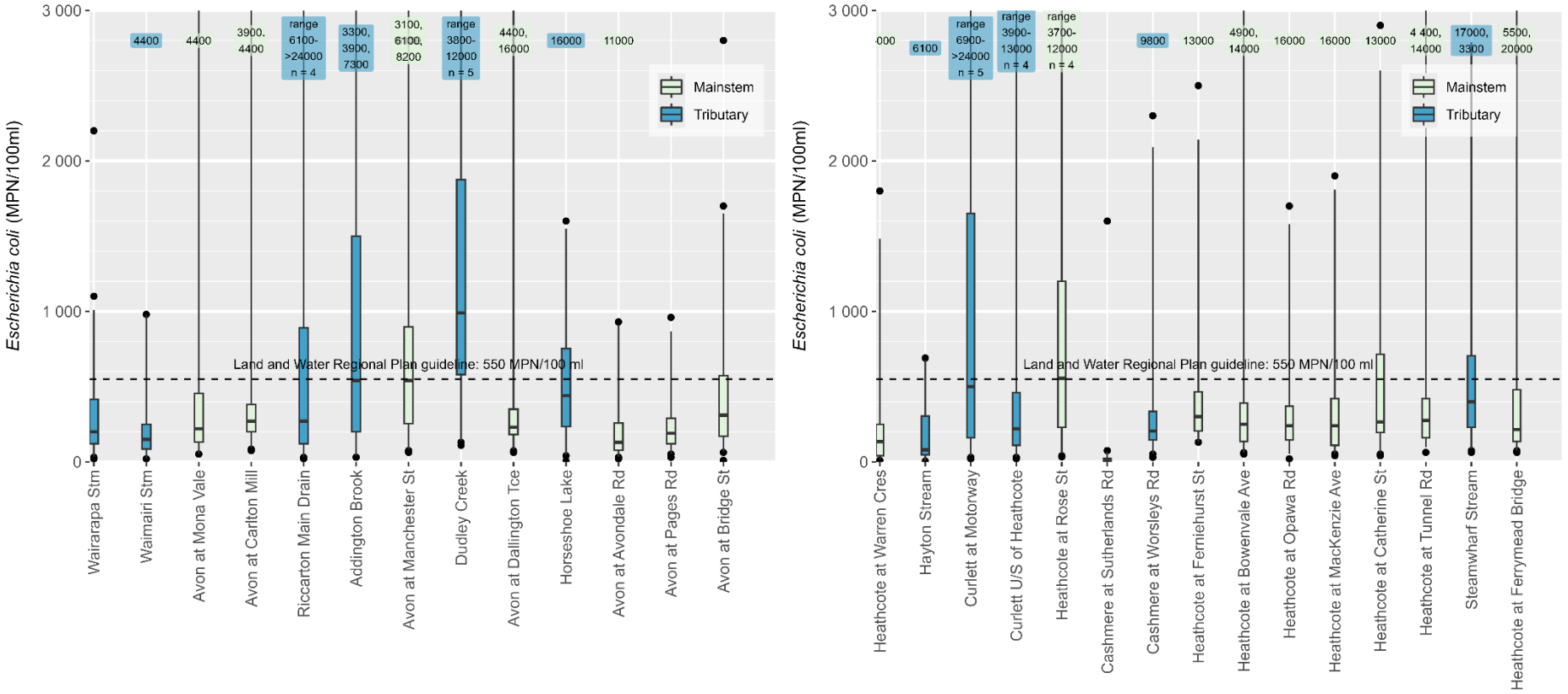

Figure xvii (a). *Escherichia coli* concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2021 to December 2023. The dashed lines represent the Land and Water Regional Plan guideline value of 550 MPN/100ml for 95% of samples for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (Environment Canterbury, 2019). As no coastal guideline exists, strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) shall be compared to the waterway guideline. The Laboratory Limit of Detection varied depending on the necessary dilution of the sample, but all were graphed as half this value. Values reaching the maximum laboratory limit for counting (24,000 MPN/100ml) were graphed as 24,000. The numbers in shaded boxes indicate samples that exceeded the y-axis.

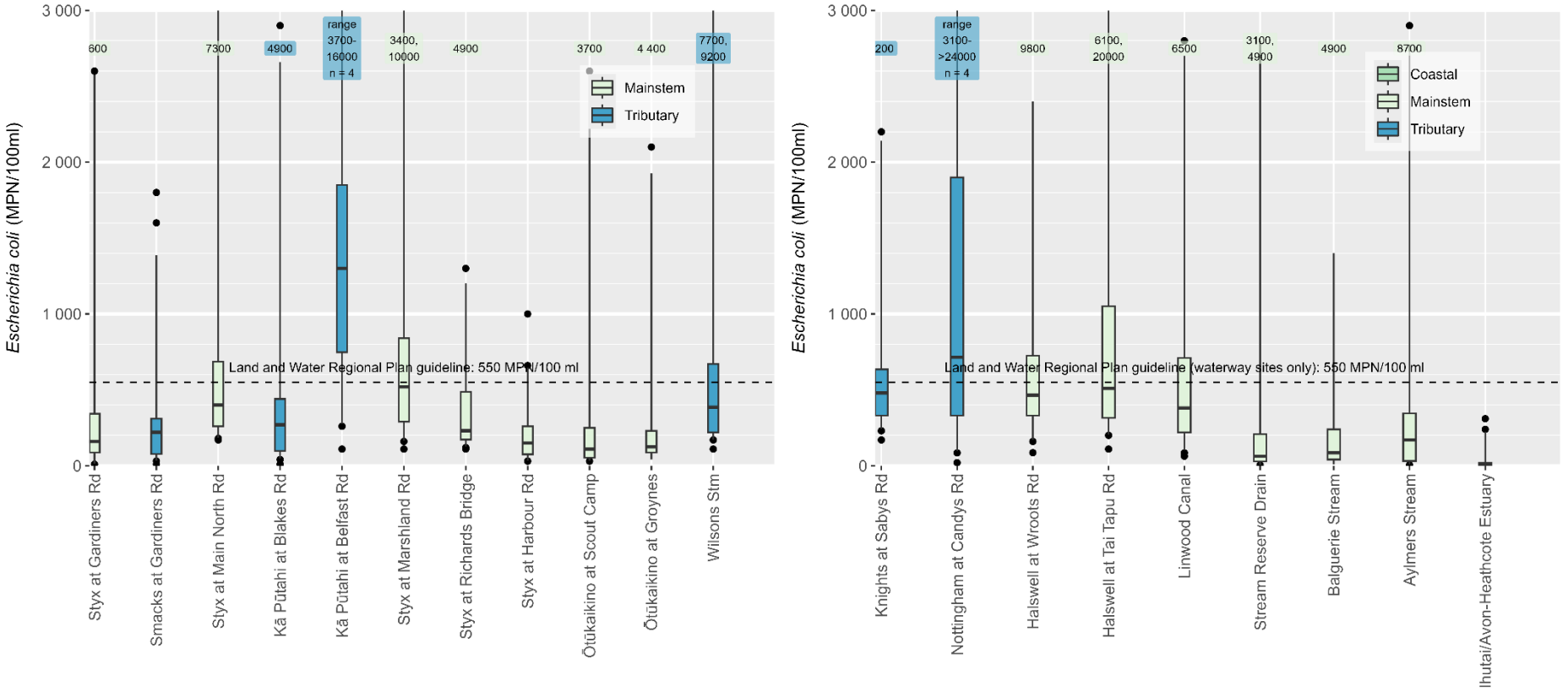

Figure xvii (b). *Escherichia coli* concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, and Banks Peninsula sites (right graph), for the monitoring period January 2021 to December 2023. Only one coastal site is monitored for this parameter. The dashed lines represent the Land and Water Regional Plan guideline value of 550 MPN/100ml for 95% of samples for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (Environment Canterbury, 2019). No guideline for coastal areas exists, as such, strongly tidal sites (Linwood Canal) shall be compared to the waterway guideline. The Laboratory Limit of Detection varied depending on the necessary dilution of the sample, but all were graphed as half this value. Values reaching the maximum laboratory limit for counting (24,000 MPN/100ml) were graphed as 24,000. The numbers in shaded boxes indicate samples that exceeded the y-axis.

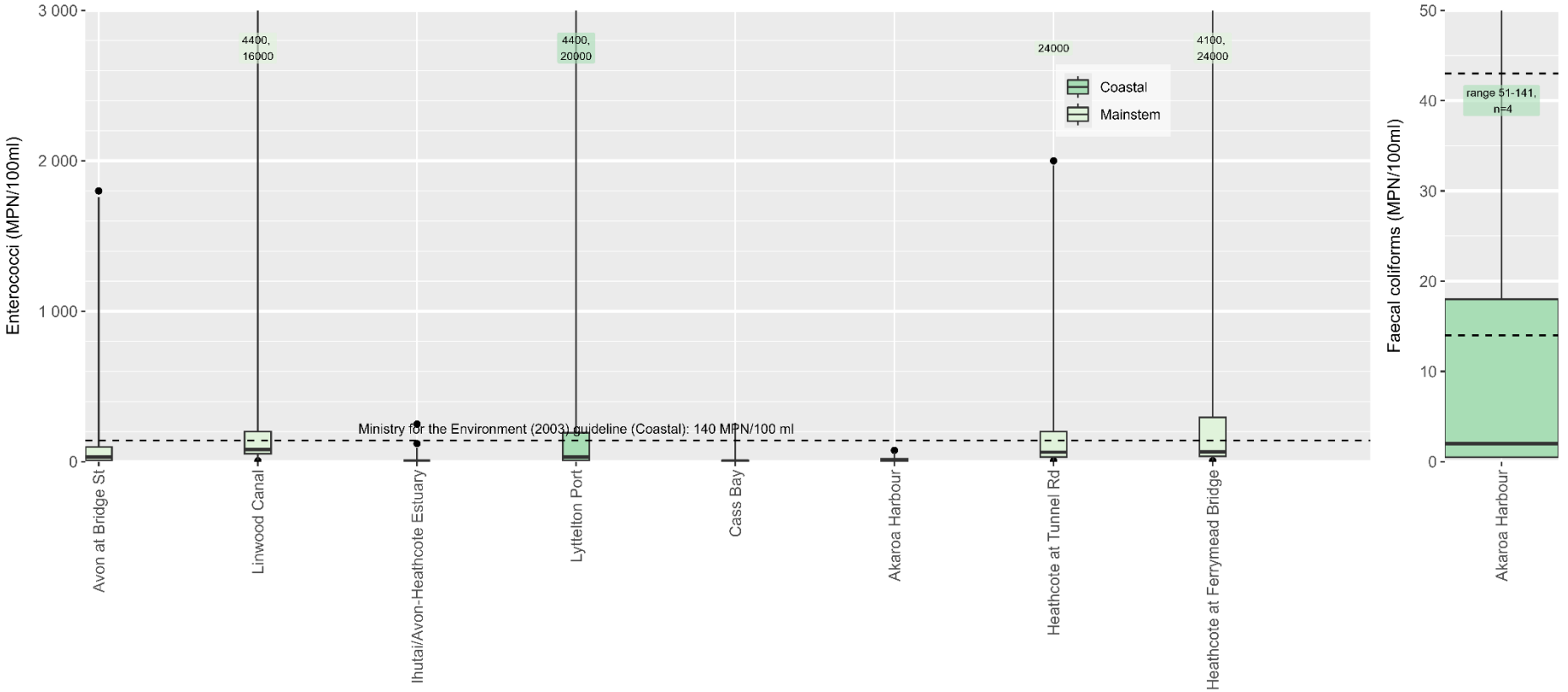

Figure xviii. Enterococci (left graph) and faecal coliforms (right graph) concentrations in water samples taken from the relevant strongly tidal and coastal sites for the monitoring period January 2021 to December 2023. On the left graph the dashed line represents the Ministry for the Environment single sample guideline value of 140 MPN/100ml for coastal sites (Ministry for the Environment, 2013). Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, Heathcote at Ferrymead Bridge and Linwood Canal) shall be compared to the waterway guideline. On the right graph, the top dashed line represents the 90th percentile guideline (43 MPN/100ml) and the bottom dashed line represents the Ministry for the Environment median guideline (14 MPN/100ml) for Akaroa Harbour (Ministry for the Environment, 2013). Laboratory Limit of Detections for enterococci and faecal coliforms was 10 MPN/100ml and 1 MPN/100ml, respectively, graphed as half this value (5 MPN/100ml and 0.5 MPN, respectively). Values reaching the maximum laboratory limit for counting (24,000 MPN/100ml) were graphed as 24,000. The numbers in shaded boxes indicate samples that exceeded the y-axis.

Appendix F

Table i. Direction of significant temporal trends for parameters monitored monthly at each of the sites in the Ōtākaro-Avon River catchment. N/A = Not Applicable due to not having enough long-term monitoring data, or not being tested for that parameter.

Site	Copper	Lead	Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Total Ammonia	DIN	*E. coli*	Entero	Salinity
Wairarapa Stm			↓6%	↓ 7%						↑1%		↓ 4%			N/A	N/A
Waimairi Stm				↓ 6%								↓ 4%	↓ 2%		N/A	N/A
Avon at Mona Vale				↓ 5%								↓ 3%	↓ 1%		N/A	N/A
Avon at Carlton Mill	↓ 25%			↓ 6%					↓ 1%			↓ 3%	↓ 2%		N/A	N/A
Riccarton Main Drain				↓ 4%		↑ 2%							↑ 1%		N/A	N/A
Addington Brook				↓ 2%		↓1%		↓ 2%	↓ 1%	↑ 1%		↓ 3%	↓ 1%	↑ 4%	N/A	N/A
Avon at Manchester St	↓10%	↓63 %		↓4%						↑ 1%		↓4%	↓ 2%		N/A	N/A
Dudley Creek		↓13 %						↓ 3%	↓ 1%	↑ 1%		↓ 4%	↓3%		N/A	N/A
Avon at Dallington Tce	↓8%	↓27 %		↓2%				↓ 3%		↑ 1%		↓ 5%	↓ 1%		N/A	N/A
Horseshoe Lake			↓ 9%				↓ 1%	↓ 3%	↓1%	↑ 1%		↓ 3%	↓ 2%		N/A	N/A
Avon at Avondale Rd		↓43 %		↓ 3%				↓ 16%				↓ 7%	↓ 3%		N/A	N/A
Avon at Pages Rd		↓13 %	↓ 6%	↓1%				↓ 2%		↑ 1%		↓ 4%	↓ 2%	↑ 2%	N/A	N/A
Avon at Bridge St	↓ 7%	↓13 %		↓ 5%		↑ 3%			↑ 1%	↑ 1%		↓ 7%	↓ 2%	↑3%	↓ 8%	

Notes: copper, lead and zinc are dissolved portions, EC = Electrical Conductivity, TSS = Total Suspended Solids, DO = Dissolved Oxygen, Temp = Temperature; BOD_5 = Biochemical Oxygen Demand, DIN = Dissolved Inorganic Nitrogen, and Entero = enterococci. Blank cells indicate no significant upwards or downwards trends.

Table ii. Direction of significant temporal trends analyses for parameters monitored monthly at each of the sites in the Ōpāwaho-Heathcote River catchment. N/A = Not Applicable due to not having enough long-term monitoring data, or not being tested for that parameter.

Site	Copper	Lead	Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Amm.	DIN	*E. coli*	Entero	Salinity
Heathcote at Warren Cres	↓34%				↓1%	↓2%						↓13%			N/A	N/A
Hayton Stream	↓4%	↓18%	↓7%	↓15%	↓1%			↑ 3%	↓ 2%		↓4%	↓12%	↓10%		N/A	N/A
Curletts Stream at Motorway						↑ 1%	↑ 4%		↓ 3%				↓26%		N/A	N/A
Curletts Stream U/S of Heathcote						↓ 1%	↑ 3%	↑ 5%	↓ 4%				↓8%	↓ 7%	N/A	N/A
Heathcote at Rose St			↓4%	↓ 7%					↓ 1%			↓ 5%	↓ 2%		N/A	N/A
Cashmere at Sutherlands Rd			↓ 5%	↓ 8%		↓ 1%		↑ 12%	↓ 1%			↓ 5%	↓ 3%		N/A	N/A
Cashmere at Worsleys Rd				↓ 4%					↓ 1%				↓ 2%	↓ 4%	N/A	N/A
Heathcote at Ferniehurst St			↓3%	↓ 5%		↓1%		↑ 5%	↓ 1%			↓ 3%	↓ 1%	↓ 3%	N/A	N/A
Heathcote at Bowenvale Ave		↓26%		↓ 5%								↓ 3%	↓ 1%	↓ 3%	N/A	N/A
Heathcote at Opawa Road				↓ 5%			↓2%		↓ 1%			↓ 2%	↓ 1%		N/A	N/A
Heathcote at Mackenzie Ave				↓ 5%					↓ 1%	↑1%		↓ 2%	↓1%	↓ 4%	N/A	N/A
Heathcote at Catherine St				↓ 5%		↑ 4%	↓ 2%			↑1%		↓ 5%	↓ 2%		N/A	N/A
Heathcote at Tunnel Rd			↑ 3%	↓ 8%		↑ 2%	↓ 4%	↓ 4%				↓ 8%				↓ 67%
Steamwharf Stream	↓ 36%						↑ 27%						↑ 9%		N/A	N/A
Heathcote at Ferrymead Bridge		↓17%	↑ 6%	↓ 10%			↓ 3%	↓ 2%		↑ 1%		↓ 11%	↓ 3%		↓5%	↓26%

Notes: copper, lead and zinc are dissolved portions, EC = Electrical Conductivity, TSS = Total Suspended Solids, DO = Dissolved Oxygen, Temp = Temperature; BOD_5 = Biochemical Oxygen Demand, Amm. = total ammonia, DIN = Dissolved Inorganic Nitrogen, and Entero = enterococci. Blank cells indicate no significant upwards or downwards trends.

Table iii. Direction of significant trends for parameters monitored monthly at each of the sites in the Huritini-Halswell River catchment and Linwood Canal. N/A = Not Applicable due to not having enough long-term monitoring data, or not being tested for that parameter.

Site	Copper	Lead	Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Amm.	DIN	*E. coli*	Entero	Faecal Coliforms	Salinity
Knights at Sabys Rd				↓ 6%		↓ 1%						↓ 8%	↓ 4%		N/A	N/A	N/A
Nottingham at Candys Rd	↓ 13%		↑ 5%	↓ 1%		↓ 1%		↓ 3%		↑ 1%		↓ 3%	↓ 3%	↑ 3%	N/A	N/A	N/A
Halswell at Wroots Rd					↓ 1%		↓ 36%	↓ 18%				↓ 14%		↓ 27%	N/A	N/A	N/A
Halswell River at Tai Tapu Rd				↓ 2%		↓ 1%	↑ 4%	↑ 2%		↑ 1%			↓ 3%	↑ 7%	N/A	N/A	N/A
Linwood Canal		↓ 26%		↓ 4%		↑ 7%	↓ 2%	↓ 4%	↓ 1%	↑ 1%	↓ 5%	↓ 2%	↓ 3%		↓ 8%	N/A	
Stream Reserve Drain															N/A	N/A	N/A
Balguerie Stream												↓ 14%	↑ 32%		N/A	N/A	N/A
Aylmers Stream						↓ 3%							↑ 30%		N/A	N/A	N/A
Ihutai – Avon-Heathcote Estuary				N/A		↑ 1%						N/A	N/A			N/A	
Lyttelton Port		↓ 20%		N/A			↑ 51%	↑ 56%		↑ 3%		N/A	N/A	N/A		N/A	
Cass Bay				N/A								N/A	N/A	N/A		N/A	
Akaroa Harbour				N/A		↑ 1%	↑ 46%	↑ 27%				N/A	N/A	N/A			

Notes: copper, lead and zinc are dissolved portions, EC = Electrical Conductivity, TSS = Total Suspended Solids, DO = Dissolved Oxygen, Temp = Temperature; BOD_5 = Biochemical Oxygen Demand, Amm. = total ammonia, DIN = Dissolved Inorganic Nitrogen, and Entero = enterococci. Blank cells indicate no significant upwards or downwards trends.

Table iv. Direction of significant trends for parameters monitored monthly at each of the sites in the Pūharakekenui-Styx and Ōtūkaikino River catchments. N/A = Not Applicable due to not having enough long-term monitoring data.

Site	Copper	Lead	Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Total Ammonia	DIN	*E. coli*
Styx at Gardiners Rd				↓ 4%						↑ 1%			↓ 4%	↑ 5%
Smacks at Gardiners Rd	↓ 18%		↓ 9%	↓ 5%		↓ 1%			↓ 1%			↓ 3%	↓ 2%	↑ 4%
Styx at Main North Rd				↓ 2%					↓ 1%			↓ 3%	↓ 4%	↑ 2%
Kā Pūtahi at Blakes Rd						↑ 1%				↓ 1%		↓ 3%		↓ 2%
Kā Pūtahi at Belfast Rd				↓ 4%				↓ 3%	↑ 1%	↑ 1%	↓ 2%	↓ 6%		
Styx at Marshland Rd				↓ 3%						↑ 1%		↓ 4%	↓ 1%	
Styx at Richards Bridge				↓ 4%						↑ 1%		↓ 2%	↓ 1%	
Styx at Harbour Rd		↓ 41%		↓ 3%		↑ 1%				↑ 1%			↓ 2%	
Ōtūkaikino at Groynes			↓ 12%	↓ 10%		↑ 1%		↓ 8%	↓ 1%	↑ 1%		↓ 6%	↓ 3%	
Ōtūkaikino at Scout Camp				↓ 10%	↓ 1%	↑ 2%			↓ 2%			↓ 13%	↑ 6%	↑ 6%
Wilsons Stm						↑ 1%	↑ 5%	↑ 8%					↑ 3%	↑ 9%

Notes: copper, lead and zinc are dissolved portions, EC = Electrical Conductivity, TSS = Total Suspended Solids, DO = Dissolved Oxygen, Temp = Temperature; BOD5 = Biochemical Oxygen Demand, and DIN = Dissolved Inorganic Nitrogen. Blank cells indicate no significant upwards or downwards trends.

Table v. Direction of significant trends for parameters monitored by the Styx Living Laboratory Trust.

Site	Clarity	pH	EC	Temp
Smacks at Wilkinsons Rd			↑ 2%	
Smacks at Willowbank	↓ 1%	↑ 1%		↑ 1%
Styx at Conservation Reserve		↑ 1%	↑ 1%	↑ 1%
Styx Drain				
Styx at Radcliffe Rd		↑ 1%		↑ 1%
Kā Pūtahi at Blakes Rd				
Kā Pūtahi at Ouruhia Domain		↑ 1%		
Kā Pūtahi at Everglades		↑ 1%		
Styx at Brooklands	↓ 1%	↑ 1%		
Horner's Drain at Hawkins Rd				
Rhodes Drain at Hawkins Rd				

Notes: EC = Electrical Conductivity. Blank cells indicate no significant upwards or downwards trends.

Appendix G

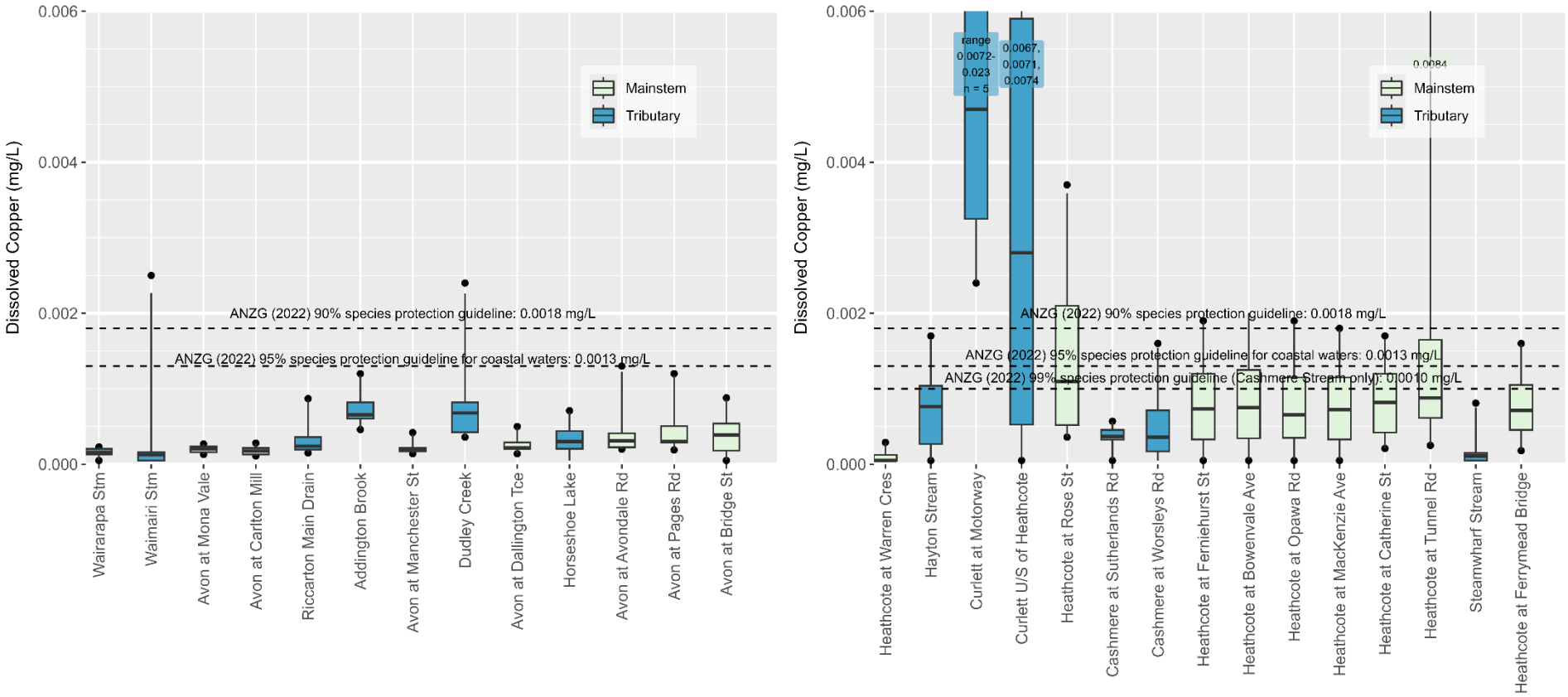

Figure i (a). Dissolved copper concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January to December 2023. The dashed lines represent the ANZG (2022) guideline values. Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) should be compared to the coastal water guidelines. The Laboratory Limit of Detection was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

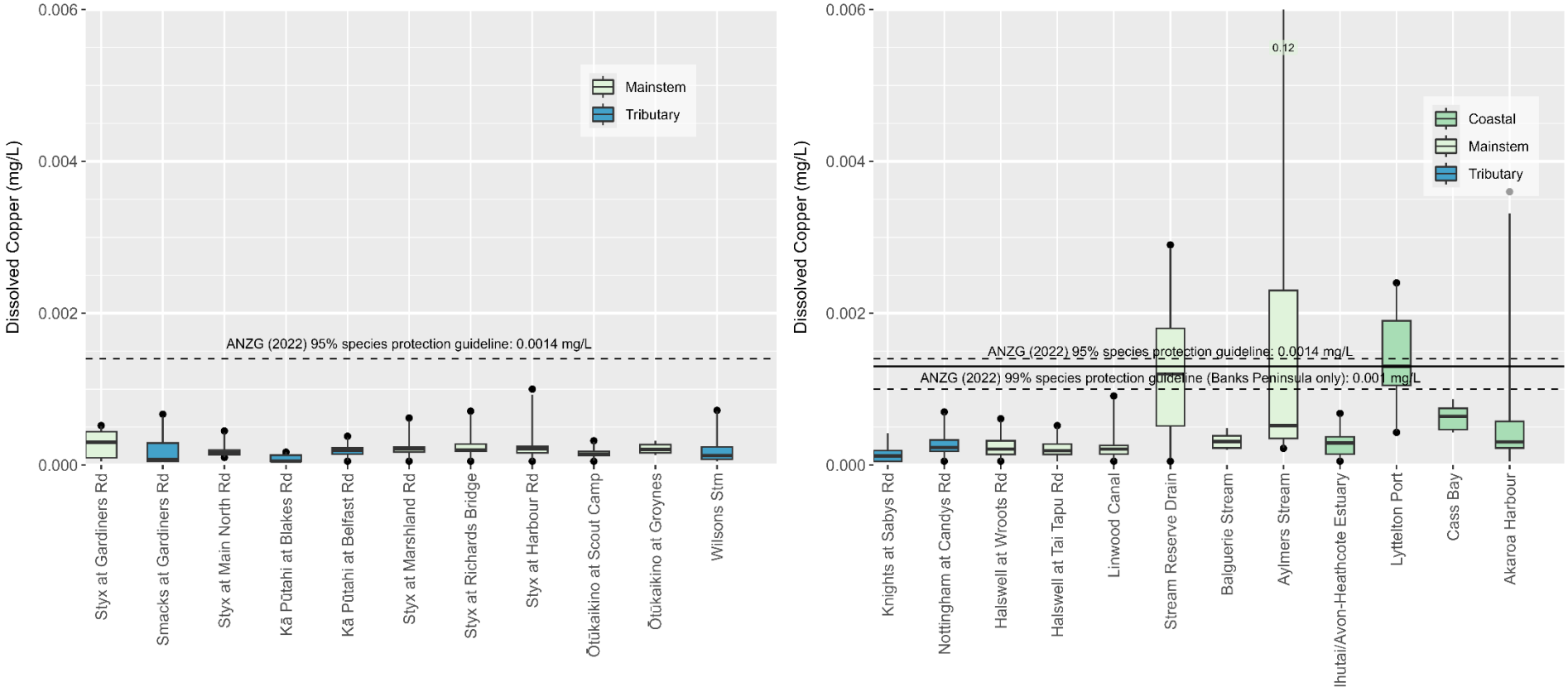

Figure i (b). Dissolved copper concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula, and coastal sites (right graph), for the monitoring period January to December 2023. The dashed lines represent the ANZG (2022) waterway guideline values. The solid line represents the ANZG (2022) coastal guideline. The strongly tidal Linwood Canal site should be compared to the coastal water guideline. The Laboratory Limit of Detection was 0.0001 mg/L – graphed as half this value (0.00005 mg/L).

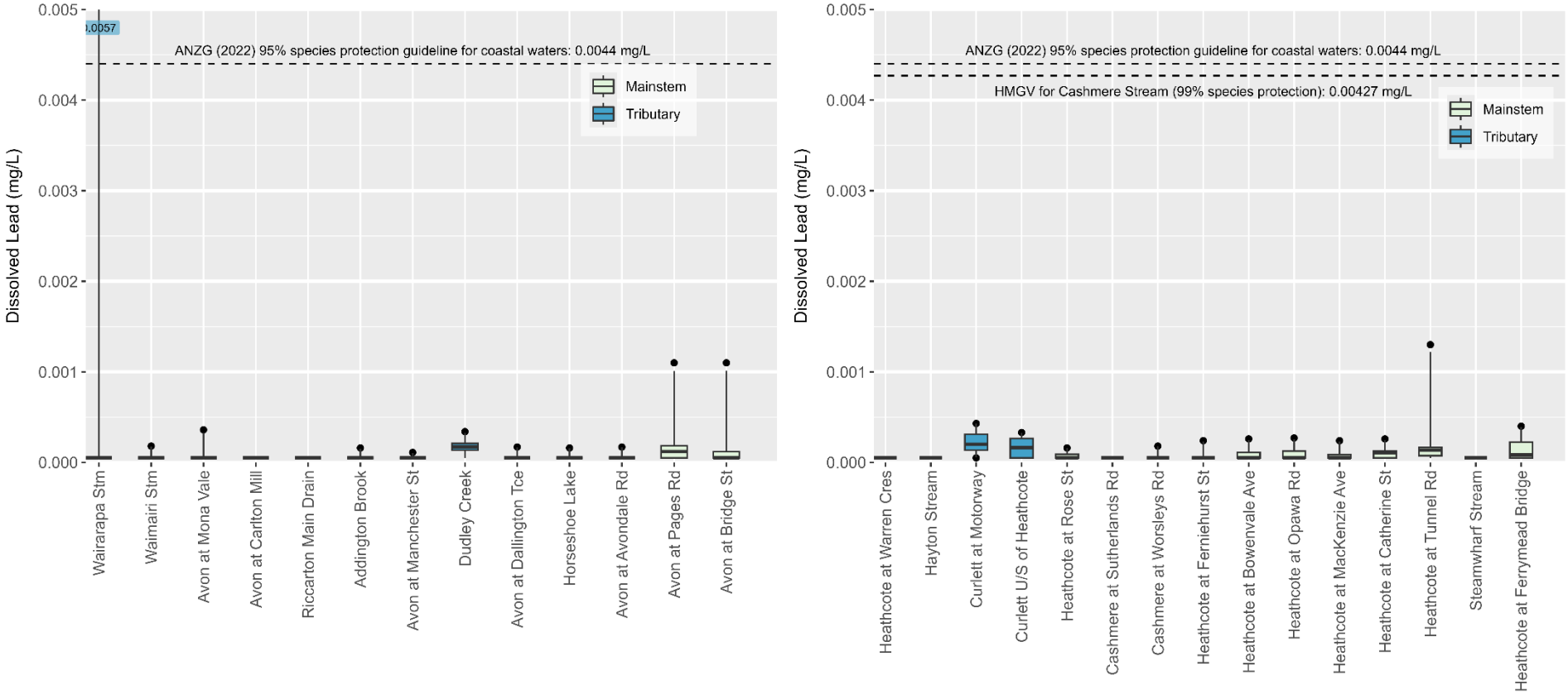

Figure ii (a). Dissolved lead concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January to December 2023. The dashed lines represent the ANZG (2022) Hardness Modified Guideline Values (HMGV). The 90% protection HMGV for the Ōtākaro-Avon River (0.01539 mg/L) and the Ōpāwaho-Heathcote River (0.02388 mg/L) are not shown as they are off the scale. Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) are compared to the coastal water guidelines. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – graphed as half this value (0.00005 mg/L).

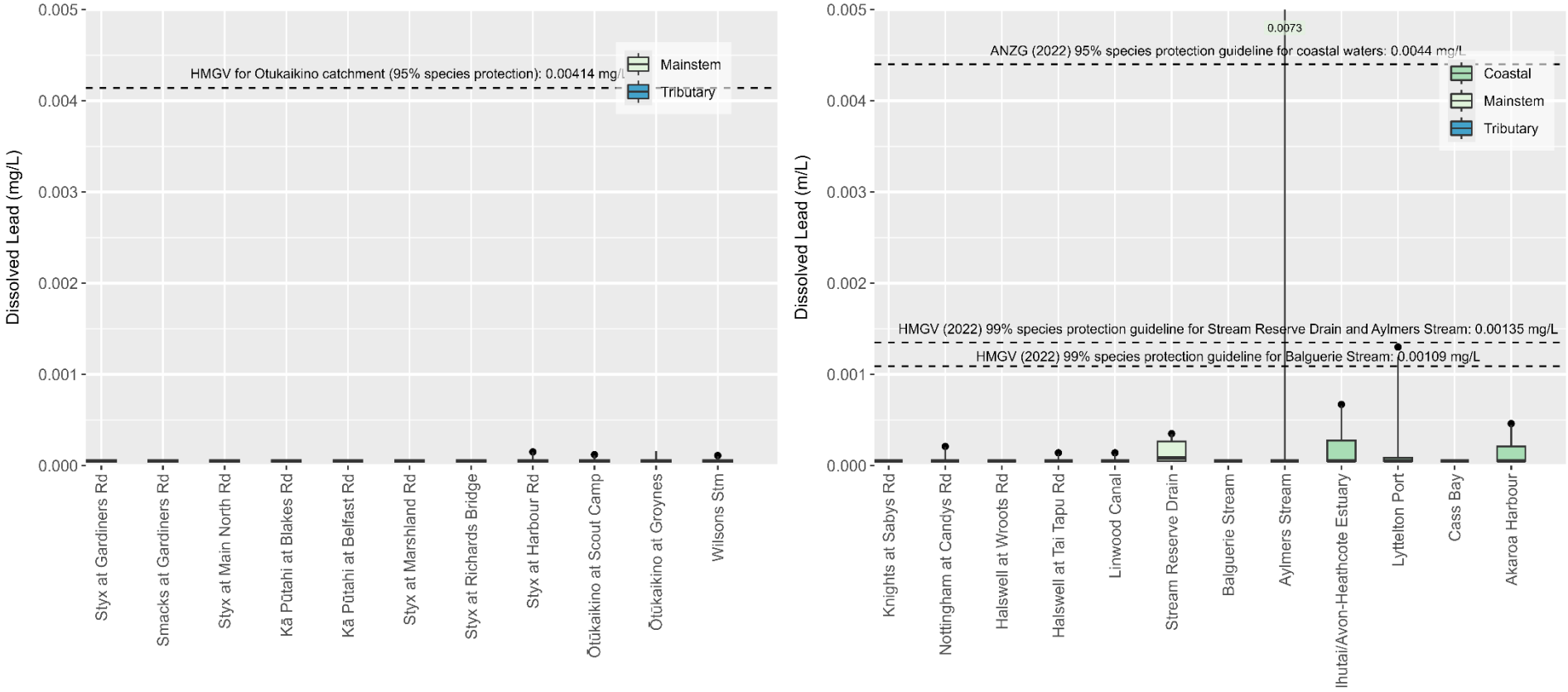

Figure ii (b). Dissolved lead concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January to December 2023. The dashed lines represent the ANZG (2022) guideline values, which have been modified to account for water hardness (Hardness Modified Guideline Value = HMGV), as per the Warne et al. (2018) guidelines methodology. The 95% protection HMGV for the Pūharakekenui-Styx River (0.00601 mg/L) and the Huritini-Halswell River (0.01089 mg/L) are not shown as they are off the scale. The strongly tidal Linwood Canal site is compared to the coastal water guideline. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – graphed as half this value (0.00005 mg/L).

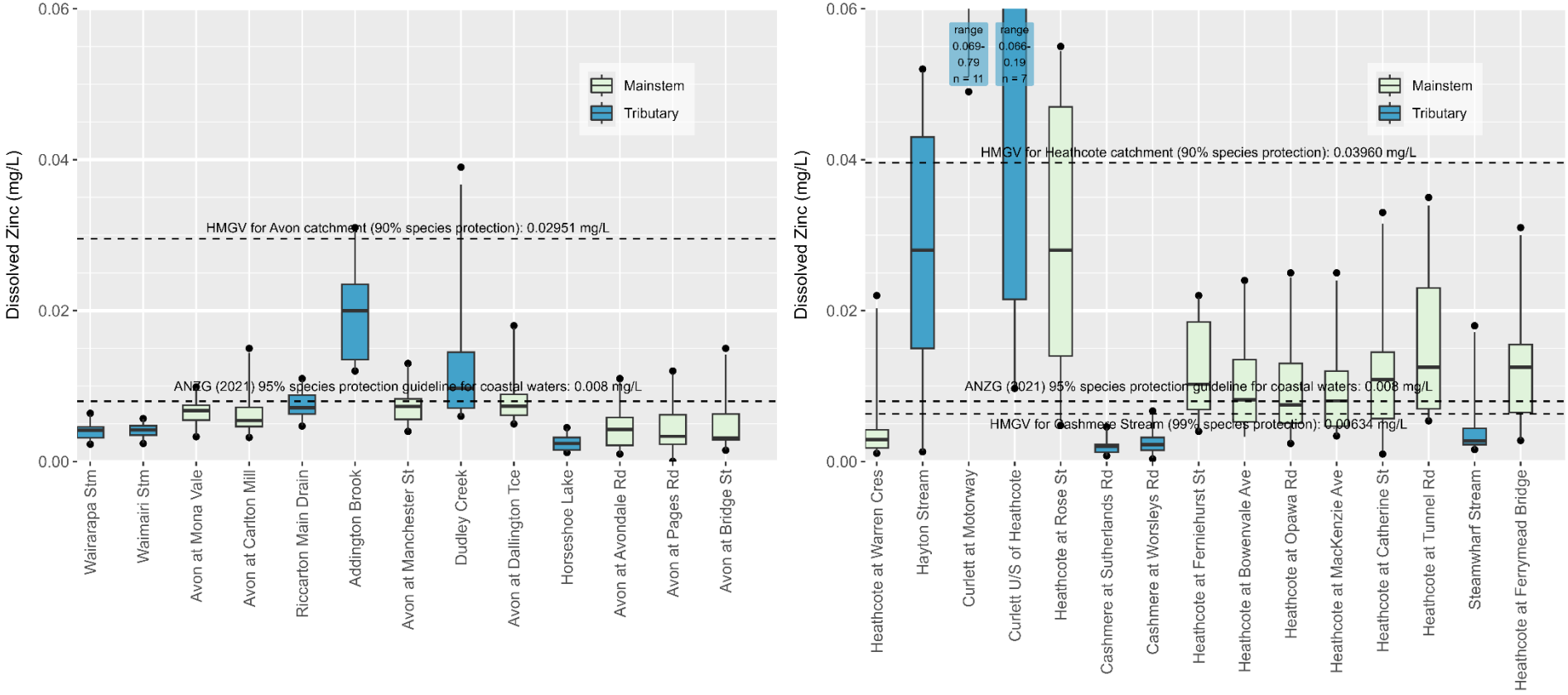

Figure iii (a). Dissolved zinc concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January to December 2023. The lines represent the ANZG (2022) guideline values, which have been modified to account for water hardness (Hardness Modified Guideline Value = HMGV), as per the Warne et al. (2018) guidelines methodology. Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) are compared to the coastal water guidelines. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

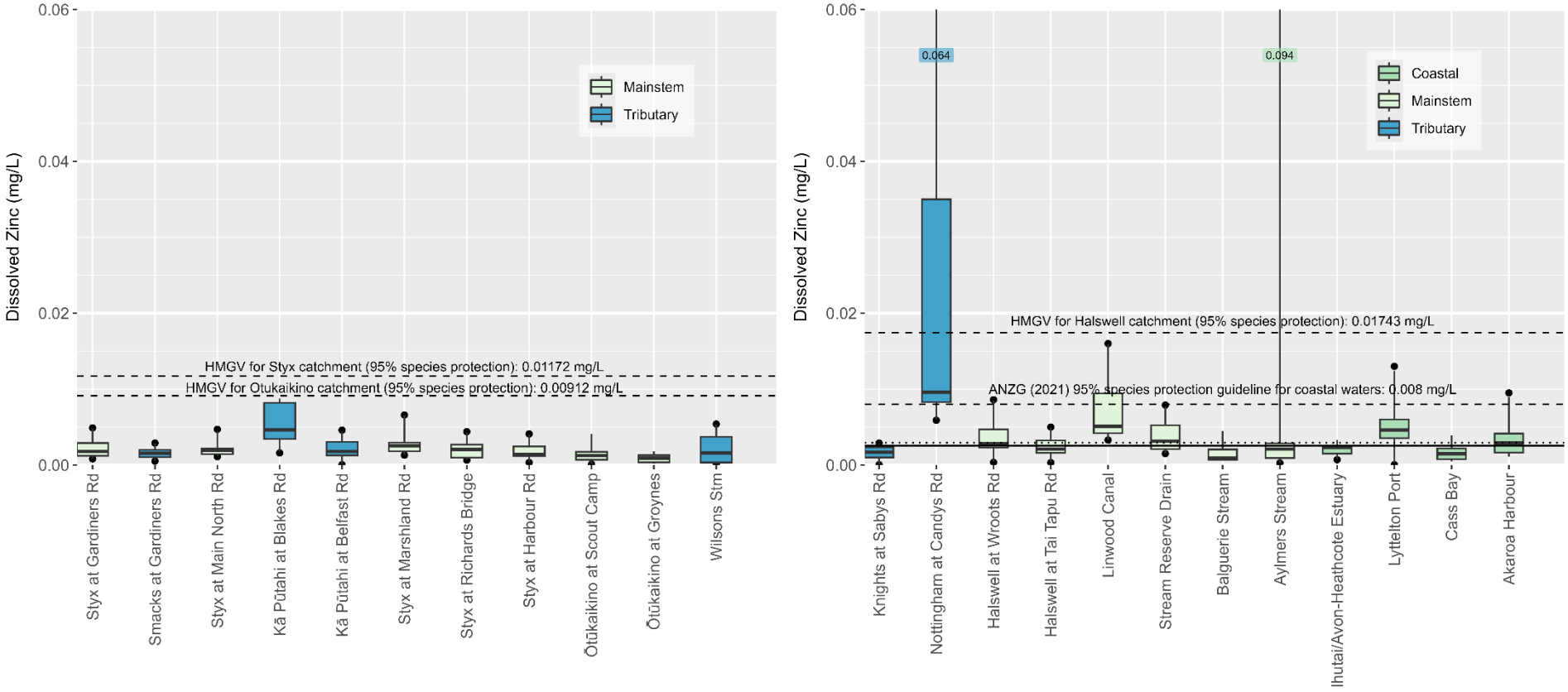

Figure iii (b). Dissolved zinc concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January to December 2023. The lines represent the ANZG (2022) guideline values, which have been modified to account for water hardness (Hardness Modified Guideline Value = HMGV), as per the Warne et al. (2018) guidelines methodology. The unlabelled lines represent the ANZG (2022) guideline values, with the dotted line representing Stream Reserve Drain and Aylmers Stream (0.00293 mg/L) and solid line Balguerie Stream (0.00254 mg/L). The strongly tidal Linwood Canal site is compared to the coastal water guideline. The Laboratory Limit of Detection was 0.0001 mg/L – graphed as half this value (0.00005 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

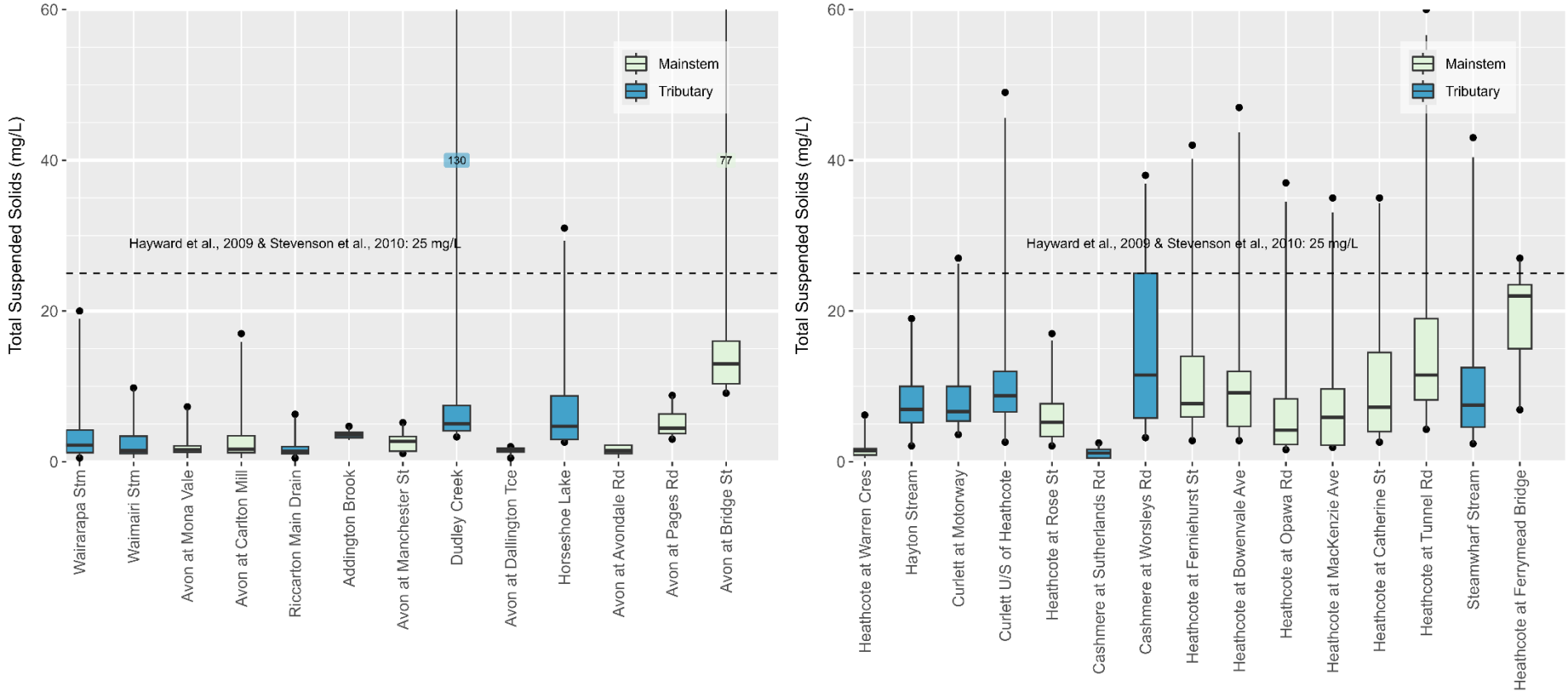

Figure vi (a). Total Suspended Solid (TSS) concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January to December 2023. The dashed lines represent the guideline value of 25 mg/L (Hayward et al., 2009; Stevenson et al., 2010). No guidelines currently exist for the strongly tidal sites, as such they should be compared to waterway guidelines. The Laboratory Limit of Detection was 1.0 mg/L – graphed as half this value (0.5 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.

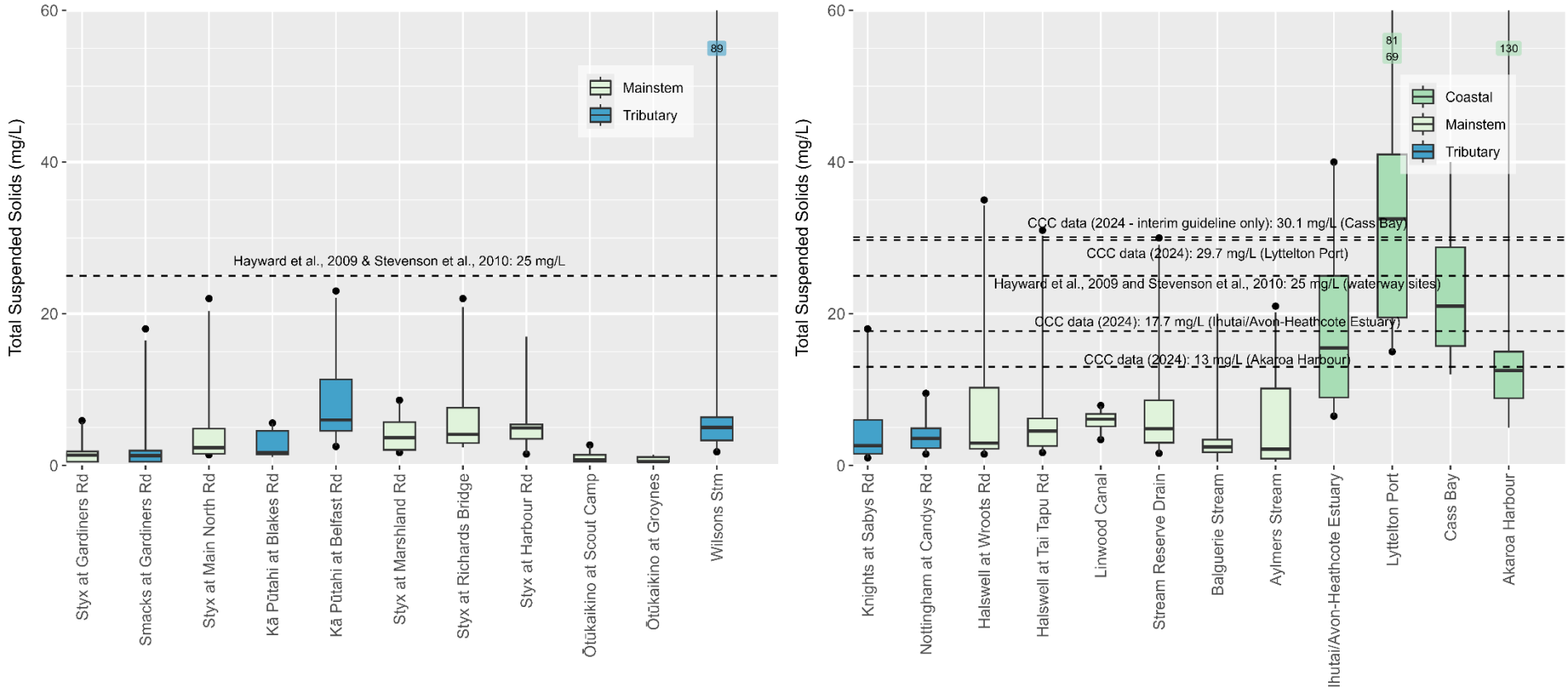

Figure vi (b). Total Suspended Solid (TSS) concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January to December 2023. No guidelines currently exist for the strongly tidal sites, as such they should be compared to waterway guidelines. The dashed lines represent the relevant waterbody guideline value. No guidelines currently exist for the strongly tidal sites, as such they should be compared to waterway guidelines. The Laboratory Limit of Detection was 1.0 mg/L – graphed as half this value (0.5 mg/L). The numbers in shaded boxes indicate samples that exceeded the y-axis.