# Christchurch City Surface Water Quality Annual Report 2020

Prepared to meet the Requirements of CRC214226

Christchurch City Council

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Christchurch City Council

# Internal Document Review

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# Executive Summary


- The Christchurch City Council (CCC) monitors the water quality of representative waterbodies within Christchurch and Banks Peninsula, as part of the Comprehensive Stormwater Network Discharge Consent (CSNDC; CRC214226).
- 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 of these sites were introduced in 2020; in particular, the Banks Peninsula and coastal sites. Eleven sites in the Pūharakekenui-Styx River catchment were monitored by the Styx Living Laboratory Trust. Two wet weather monitoring events were also monitored in the Ōpāwaho-Heathcote River catchment.
- Over 32,000 tests were conducted and there were several parameters at concentrations unlikely to cause adverse effects. However, 17% of samples (3,490 of 21,182 samples) did not meet the guideline.
- The priority parameters to address include phosphorus (Dissolved Reactive Phosphorus), nitrogen (Dissolved Inorganic Nitrogen), sediment (turbidity), bacteria (as indicated by *E. coli*), dissolved copper, and dissolved zinc. The coastal sites generally only had issues with copper contamination.
- Based on the Water Quality Index, the Ōtūkaikino and Pūharakekenui-Styx River catchments generally had 'good' water quality; however, all other catchments generally had 'fair' or 'poor' water quality. The Ōtūkaikino River recorded the best overall water quality out of all the catchments. The best site was Ōtūkaikino River at Groynes, followed jointly by Smacks Creek at Gardiners Road, Waimairi Stream, Avon River at Carlton Mill and Wilsons Stream, and then Styx River at Gardiners Road. The catchment recording the worst water quality was the Huritini-Halswell River, followed by Ōpāwaho-Heathcote River. The worst sites were Curlett Stream at Motorway, then Nottingham Stream at Candys Road, Haytons Stream, and Addington Brook.
- Water quality at the sites has mostly remained steady over time.
- Wet weather monitoring concentrations were generally similar to that recorded for the monthly monitoring; however, there were some notable exceptions to this for most parameters.
- Thirty-two of the 51 sites triggered further investigations under the CSNDC, due to not meeting the Attribute Target Levels for Total Suspended Solids, copper, lead, and zinc. These sites are prioritised to four: Curlett Stream at Motorway and Heathcote River at Ferrymead Bridge (Ōpāwaho-Heathcote River catchment), Addington Brook (Ōtākaro-Avon River catchment), and Nottingham Stream at Candys Rd (Huritini-Halswell River catchment).
- A number of recommendations are provided in the report. In particular:
    - Curlett Stream, Nottingham Stream, and Addington Brook are prioritised for contaminant source control and stormwater treatment.
    - Erosion and sediment control measures continue to be implemented as a priority, and further investigations in particular are carried out to determine how to mitigate discharges of loess sediment into the Ōpāwaho-Heathcote River (principally Cashmere Stream).
    - A whole-of-community approach to addressing stormwater contaminants is cemented through the Community Waterway Partnership.
    - CCC and Environment Canterbury continue to work together with the community, landowners and industry to improve catchment management practices.
    - Investigations are carried out to identify how best to reduce faecal contamination within the waterways, particularly from waterfowl.
    - An Action Plan for the CCC Community Outcome for Healthy Water Bodies is developed that considers what we want to achieve for our waterways and what is required to achieve this.
- If the report recommendations are implemented (at a bare minimum), surface water quality improvements are anticipated. However, 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 (CCC) 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; CRC214226). In accordance with the CSNDC Environmental Monitoring Programme (EMP), monitoring was undertaken monthly at waterway and coastal sites. This report summarises the results for the monthly monitoring for the 2020 calendar year and analyses trends over time since monitoring has been undertaken. The report also analyses wet weather monitoring at ten sites in the Ōpāwaho-Heathcote River in 2020/2021. The results of community monitoring in the Pūharakekenui-Styx River catchment in 2020 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 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

CCC 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 oxygen using a hand-held meter (YSI Pro ODO meter). There were eight sites that were in strongly tidal areas[2] (defined by having median 2020 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 exception to this was the Ihutai – Avon-Heathcote Estuary site, which was sampled at high tide.

In 2019, no monitoring was undertaken at the Kā Pūtahi at Blakes Rd during August and the Ōtūkaikino at Scout Camp during February, as these sites could not be accessed due to construction works (Kā Pūtahi) and locked gates (Ōtūkaikino). For the other long-term monitoring sites, due to the COVID-19 lockdown, some sites were unable to be sampled in March (both Ōtūkaikino River sites) and April 2020 (Ōtākaro-Avon River and Linwood Canal catchments, Heathcote at Ferrymead Bridge, Heathcote at Tunnel Rd, and Ōtūkaikino at Groynes). Two unreliable nitrate and Dissolved Inorganic Nitrogen (DIN) records (February and March) were removed from the Curlett U/S of Heathcote site.

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

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

The following sites were introduced to the monitoring program in 2020: Heathcote at Warren Cres, Steamwharf Stream, Halswell at Wroots Rd, Aylmers Stream, Balguerie Stream, Stream Reserve Drain, Ihutai – Avon-Heathcote Estuary, Cass Bay, Akaroa Harbour, and Lyttelton Harbour. The sampling site at Haytons Stream was moved to the new retention basin outlet in June 2020, as the old outlet was retired. Data from the old and new location for this site have been combined; this is not expected to bias the analyses given the new site has the same upstream catchment within only the addition of the wetlands following the original basin. This will also allow an assessment of the change following installation of the wetlands. The Purau Bay Drain Number 1 site was due to be implemented in 2020, but was dry on all occasions during the monitoring year and therefore no samples could be collected. Turbidity monitoring at the following long-term sites was also implemented in 2020: Avon at Carlton Mill, Avon at Avondale, Curlett at Motorway, Heathcote at Mackenzie Ave, and Heathcote at Catherine St. $BOD_5$ was not implemented at coastal sites until 2021.

Wet weather samples from ten sites in the Ōpāwaho-Heathcote River catchment were collected on the 1st of September 2020 and 12th of May 2021. Wet weather samples were anticipated to all be collected via Nalgene bottles, except at the tidal site of Heathcote at Catherine St, where Nalgene set-up was not possible. However, grab sampling had to be carried out at the following non-tidal sites, due to the Nalgene bottles failing: Cashmere Stream at Sutherlands Rd (both events), Haytons Stream at Retention Basin (both events), Heathcote River at Warren Cres (both events), Curletts Rd Stream Upstream of Heathcote River confluence (Event 1), Cashmere Stream at Worsleys Rd (Event 2), Heathcote River at Ferniehurst St (Event 2), and Heathcote River at Bowenvale Ave (Event 2).

Temperature and oxygen were tested in the field using a hand-held meter (YSI Pro ODO or DSS meter). Sampling 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 (this means that tide cycles needed to be taken into consideration for tidal sites).

Monthly and wet weather samples were analysed at the CCC International Accreditation New Zealand (IANZ) laboratory for the parameters outlined in Table i in Appendix B. The exception to this was field measurements of temperature and oxygen 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 oxygen readings should be viewed with caution, as they are taken outside of the wet weather event when the Nalgene bottles are 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. 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 ranged from 6 – 11. Of note:

- There was no data available for 2016;
- 2015 and 2017 had a small number of recordings; 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.

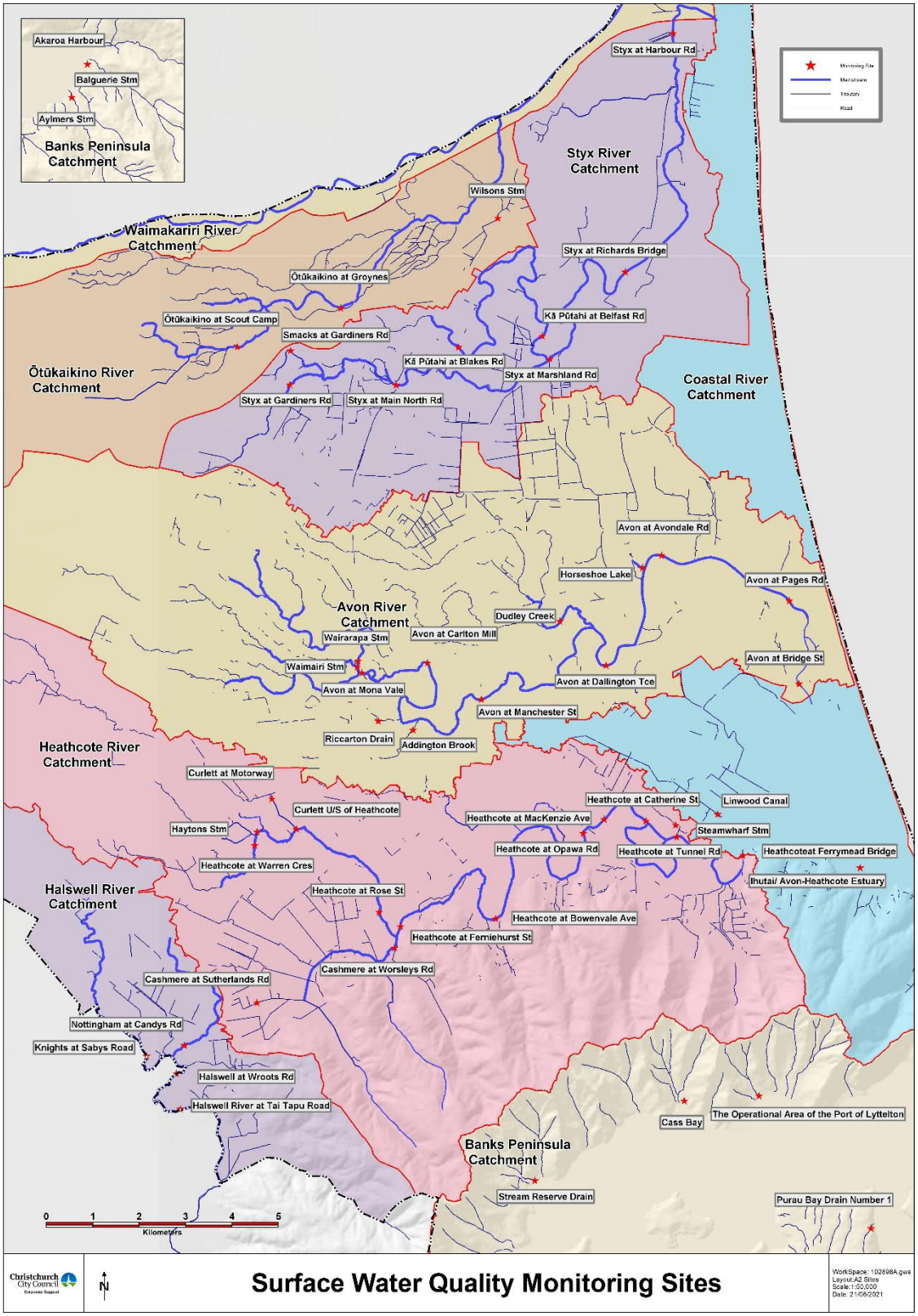


Figure 1. Location of Christchurch City Council surface water quality monitoring sites

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 |
|---|---|---|---|---|---|
| **Ō**t**ā**karo-Avon | AVON01 | Avon River at Pages/Seaview Bridge[3] | 1577484 | 5182589 | Spring-fed – plains – urban |
| | AVON02 | Avon River at Bridge Street[3] | 1577691 | 5180813 | Spring-fed – plains – urban |
| | AVON03 | Avon River at Dallington Terrace/Gayhurst Road[3] | 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[3] | 1574342 | 5183294 | Spring-fed – plains – urban |
| | AVON12 | Avon River at Carlton Mill Corner[4] | 1569737 | 5181259 | Spring-fed – plains – urban |
| | AVON13 | Avon River at Avondale Road[3,4] | 1574752 | 5183557 | Spring-fed – plains – urban |
| **Ō**p**ā**waho-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[3] | 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 |

[3] Tidally influenced site
[4] These sites are specifically located in proximity to stormwater outfalls

| Catchment | Site ID | Site | Easting (NZTM) | Northing (NZTM) | Waterway Classification |
|---|---|---|---|---|---|
| | HEATH09 | Haytons Stream at Retention Basin[5] | 2476087 | 5739262 | 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[3,4] | 1574413 | 5177883 | Spring-fed – plains – urban |
| | HEATH12 | Heathcote River at Mackenzie Avenue Footbridge[3,4] | 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[3] | 2485052 | 5739405 | Spring-fed – plains – urban |
| | HEATH31 | Heathcote River at Warren Crescent | 2476033 | 5738970 | 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[3] | 1574998 | 5194749 | 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 | 2474357 | 5734086 | Spring-fed - plains |
| Ōtūkaikino | OTUKAI01 | Ōtūkaikino River at Groynes Inlet | 1567878 | 5188869 | Spring-fed – plains |

[5] This monitoring site was moved from the old outlet location to the new outlet location in May 2020.
[6] While officially shown on maps as Kaputone Creek, CCC has recently endorsed the use of the original Māori name for the area, Kā Pūtahi Creek.

| Catchment | Site ID | Site | Easting (NZTM) | Northing (NZTM) | Waterway Classification |
|---|---|---|---|---|---|
| | 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 | OUT01 | Linwood Canal/City Outfall Drain[3] | 1575952 | 5178026 | Spring-fed – plains – urban |
| Stream Reserve Drain/Zephyr Stream | BP01 | Stream Reserve Drain Above Outfall to Governors Bay | 2482036 | 5731805 | Banks Peninsula |
| Purau Bay Drain Number 1 | BP02 | Purau Bay Drain Number 1 Above Purau Avenue | 2489237 | 5730787 | Banks Peninsula |
| Balguerie Stream | BP03 | Balguerie Stream Downstream of Settlers Hill (road) | 2507759 | 5711175 | Banks Peninsula |
| Aylmers Stream | BP04 | Aylmers Stream Downstream of Rue Jolie, next to Bruce Terrace | 2506930 | 5710693 | Banks Peninsula |
| Ihutai - Avon-Heathcote Estuary | CW01 | Estuary of the Heathcote and Avon Rivers – Ihutai at the Eastern Tip by Beachville Road[4] | 2489005 | 5738492 | Coastal Contact Recreation Water |
| The Operational Area of the Port of Lyttelton | CW02 | Lyttelton Port at the Small Wharf Opposite Voelas Road[7] | 2486837 | 5733612 | Coastal Aquatic Ecology Water |
| Cass Bay | CW03 | Eastern Side of Cass Bay off the Cass Bay Walkway[4] | 2485238 | 5733505 | Coastal Contact Recreation Water |
| Akaroa Harbour | CW04 | Akaroa Harbour at the Termination of Rue Balguerie[4] | 2507268 | 5711403 | 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 1.2.5033) for the most pertinent parameters (typically those with guideline levels). To allow statistical analyses of monthly samples, concentrations less than the LOD were converted to half the detection limit. In some years, monthly *E. coli* concentrations exceeded the maximum laboratory limit for counting (24,000 MPN/100ml) and were analysed as 24,000, although concentrations may have been much higher than this. There were three such *E. coli* cases for this report: two during 2019 and three during 2018.

The dark lines in the boxes of the boxplots represent the medians, and the bottom and top lines of the boxes represent the 25$^{th}$ and 75$^{th}$ percentiles (the interquartile range), respectively. The T-bars that extend from the boxes approximate the location of 90% of the data (i.e., the 5$^{th}$ and 95$^{th}$ 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 10$^{th}$ and 90$^{th}$ percentiles). This adjustment was necessary as faecal coliform guidelines refer to the 90$^{th}$ 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 monitoring data. Additional graphs with data from the monitoring year 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 (Condition 59).

Turbidity has historically been analysed at the laboratory using NTU, but since December 2020 has been analysed using Formazin Nephelometric Units (FNU), in accordance with the requirements of the National Environmental Monitoring Standards (NEMS, 2019). Turbidity NTU values prior to December 2020 have been converted to FNU at the catchment scale, using a conversion factor calculated from 12 months of concurrent testing of both methods (NEMS, 2019).

### 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 (95$^{th}$ or 90$^{th}$) versus medians, as required by the individual guidelines. Background on the environmental concern surrounding each parameter is also provided in this table.

Dissolved lead and zinc guidelines for waterway sites were modified to account for water hardness (Warne et al., 2018). Metals, TSS, and turbidity for strongly tidal waterway sites (Avon at Bridge St, Heathcote at Ferrymead Bridge, Heathcote at Tunnel Rd, and Linwood Canal) were compared to the coastal water guidelines, rather than waterway guidelines, as this was considered more appropriate. Although turbidity is now measured using FNU and not NTU, the NTU waterway and coastal guideline values are still used for direct comparison against this FNU data (Michele Stevenson, ECan, personal communication, May 2021).

### 2.3.2. Water Quality Index

A Water Quality Index (WQI) was developed in excel for the CCC 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 CCC WQI were copper, zinc, pH, TSS, DO, temperature, $BOD_5$, total ammonia, nitrate, DRP and E. coli. The WQI was amended this year to include nitrate instead of Nitrate-Nitrite-Nitrogen (NNN), as nitrate and its associated guideline was considered more appropriate than NNN. DIN could not be used in the WQI, as ammonia forms part of this parameter, and ammonia is already included in the index, so this may have potentially biased the results. Due to the inclusion of nitrate, WQI scores presented in this report cannot be compared to CCC WQI scores published prior to 2021.

WQI scores could not be calculated at the coastal sites as total ammonia, nitrate, and DRP are not collected. No TSS guideline exists for coastal sites, therefore WQI scores could also not be generated for the strongly tidal waterway sites (Avon at Bridge St, Heathcote at Tunnel Rd, Heathcote at Ferrymead Rd and Linwood Canal).

WQI scores were used to categorise the CCC 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 2016-2020. Temporal trends could not be undertaken for sites where monitoring began in 2020 (Section 2.2, and Appendix A, Table i).

Trends analysis was conducted using Time Trends Version 7.0, build 1 (NIWA, 2014). 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 site data were dependent of each other (i.e., the concentrations at one site were not influenced by the concentrations at another site). A change was considered meaningful when there was a statistically significant positive or negative result of greater than 1% (NIWA, 2020).

Time Trends accommodates for variable LODs and the option for using censored concentrations (records below the LOD) in Sen slope calculation was selected. For some of the parameters, a large proportion of data was below the LOD (e.g., dissolved copper, lead, and $BOD_5$), or missing (e.g., SLLT data in some years), affecting the accuracy of the Time Trends analyses. Due to this, the direction of

change for $BOD_5$ could be calculated at most sites, but not the magnitude (i.e., %). Future reports will investigate a more robust method of analysing data with a larger proportion of values below the LOD.

This software requires three years of data and therefore the following sites were unable to be analysed: 11 CCC sites where monitoring was instigated in 2020 (Appendix A, Table i); five CCC sites where turbidity was recently instigated (Appendix A, Table i), seven CCC sites where salinity was instigated in 2020, one site where enterococci was instigated in 2020, and two SLLT monitoring sites (Rhodes Drain at Hawkins Rd, and Horner's Drain at Hawkins Rd), which were instigated in 2019. Trend lines on graphs were fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method.

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 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 baseflow conditions. To ensure accurate comparisons between sites, the flow data for Heathcote River at Ferniehurst St was not used even for this site.

# 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 CCC since the early 1960's.
- Over the last six years Christchurch City rainfall has been variable, including dry years (2015, 2016, 2020), wet years (2017 and 2018), and intermediate years (2019) (Figure 2a).
- The Banks Peninsula surface water quality monitoring sites were instigated in 2020 – this year began with intermediate rainfall volume, but ended as a very dry year (Figure 2b).
- For the CCC monthly data within the City, the Linwood Canal catchment recorded the greatest number of sampling days affected by rain (45%), followed by the Ōtākaro-Avon River catchment (39%), Huritini-Halswell River catchment (25%), Ōtūkaikino catchment (24%), Ōpāwaho-Heathcote River catchment (23%), and Pūharakekenui-Styx River catchment (18%). This was 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 cautiously. None of the samples from the Ihutai – Avon-Heathcote Estuary site were collected in association with rain.
- For the CCC monthly data on Banks Peninsula, the Aylmers and Balguerie Stream sites recorded the greatest number of sampling days affected by rain (57%), followed by Akaroa Harbour (50%), Stream Reserve Drain (43%), and jointly Cass Bay and Lyttelton Port (13%).

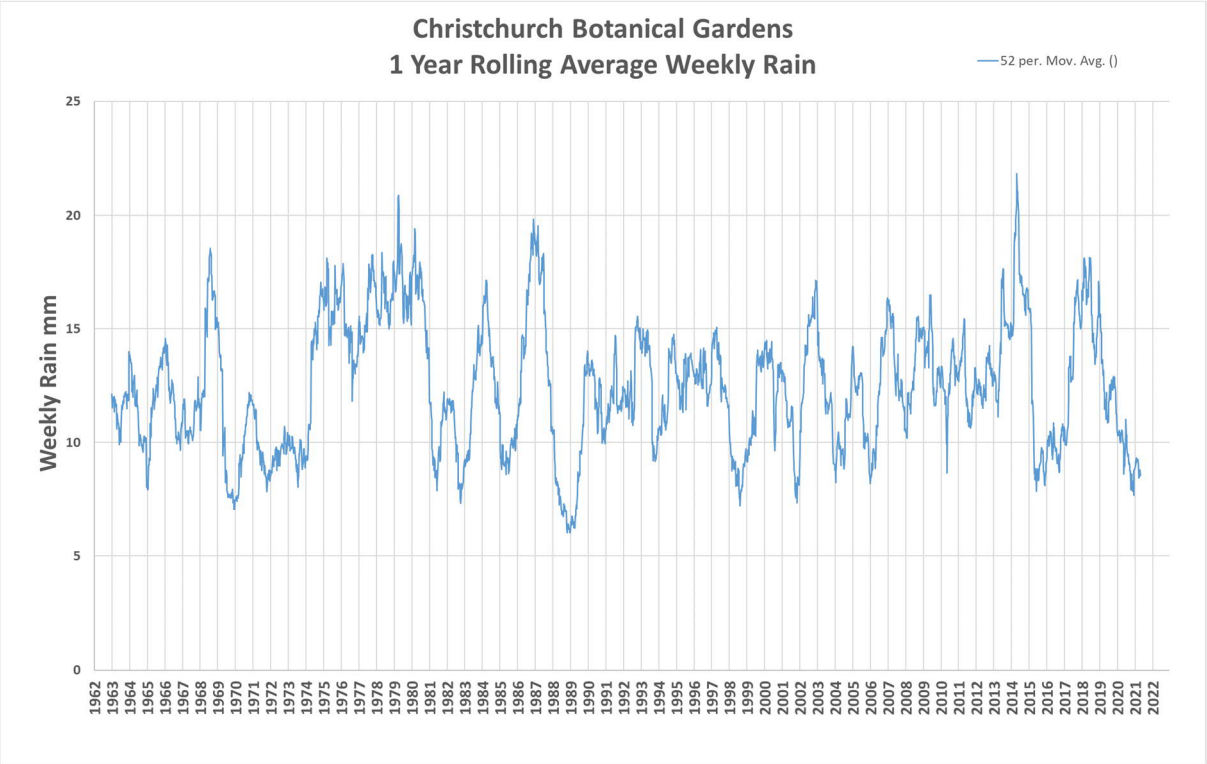


Figure 2(a). Average weekly rainfall at the Botanic Gardens in Hagley Park, Christchurch.

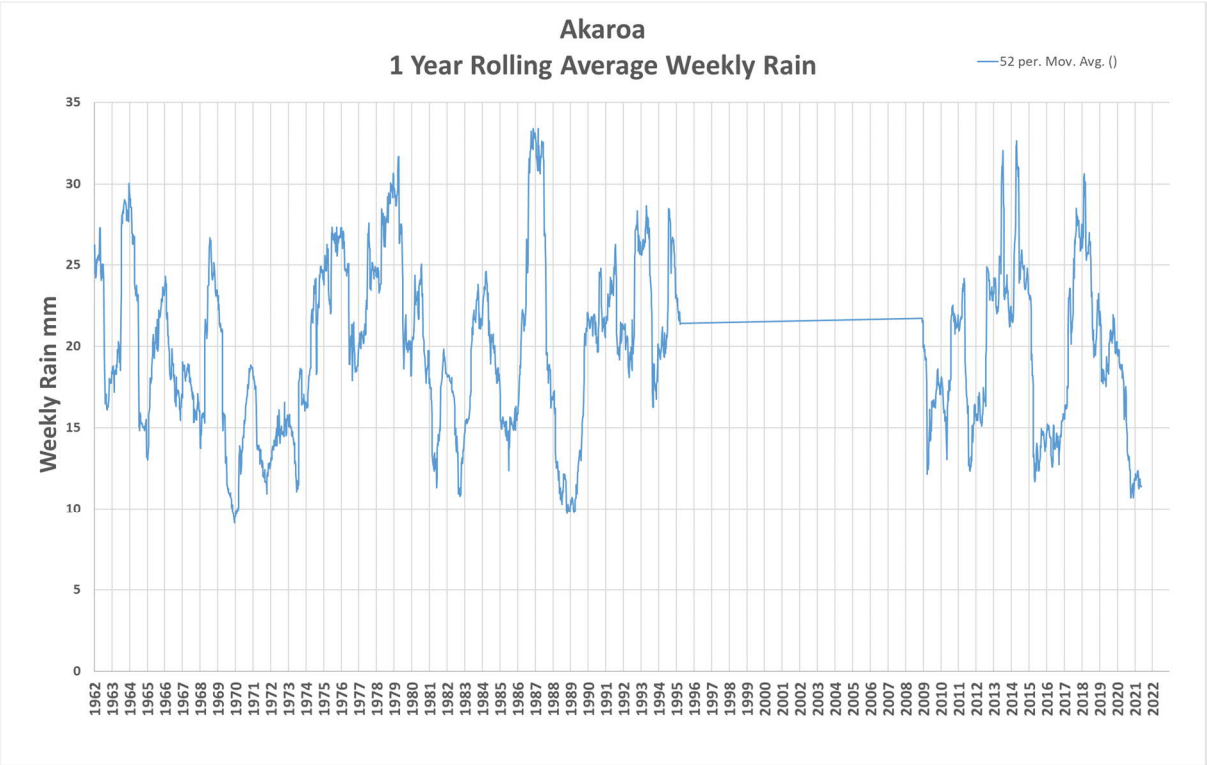


Figure 2(b). Average weekly rainfall in Akaroa. From approximately 1992 to 2008 no data was collected.

## 3.2. Water Quality Parameters

### 3.2.1. Summary

- Over 32,000 tests were conducted during 2018-2020 for the CCC monthly monitoring, with 21,182 of these allowing the assessment of each waterway site against relevant guideline levels (Table 2).
- Seventeen percent of these samples did not meet the guideline level, with 51 sites (100%) not meeting the guideline for at least one parameter.
- Parameters that exceeded guidelines at the most sites were *E. coli* (45 sites), dissolved copper (33 sites), DRP (29 sites), and dissolved zinc (28 sites). The DRP guideline was exceeded most frequently (56% of samples), followed by DIN (38% of samples) and jointly *E. coli* and turbidity (29% of samples).
- Most parameters did not show a statistical change in concentration since monitoring began, with 356 (62%) parameter-site combinations recording no significant upwards or downwards trends in concentrations (Appendix E, Tables i–iv). However, 159 (28%) parameter-site combinations recorded a significant improvement in water quality, 56 (10%) recorded a significant decline in water quality, and 1 (0.2%) recorded a significant change that could represent either a decline or improvement in water quality (pH).
- The majority of sites across all catchments recorded small decreases in $BOD_5$, DRP, and DIN.
- The largest increases in parameter concentrations at individual sites were:
    - 25% for *E. coli* at the Ōtūkaikino at Scout Camp site, due to a steady increase over the last two years (Figure 3). This is likely due to direct contamination from waterfowl in the area, and/or runoff from adjacent stock grazing.
    - 16% increase in turbidity at Wilsons Stm, due to a steady increase since 2017 (Figure 4). The reason for this is unclear.

- The largest decreases in parameter concentrations at individual sites were:
    - 24% for DIN at the Curlett at Motorway site, due to lower concentrations since 2016 (Figure 5). This is likely due to a decrease in nitrogen sources from industrial sites within the catchment.
    - 16% for turbidity at the Otukaikino at Groynes site, due to lower concentrations since 2013 (Figure 6). This may be a reflection of the planting undertaken over the years within the catchment filtering sediment loads, as well as less stock accessing the waterways due to fencing.
    - 16% in DRP at the Cashmere at Sutherlands site, due to lower concentrations since 2013 (Figure 7). This is likely due to the gradual urbanisation for this traditionally agricultural catchment (i.e., reducing runoff and erosion).
    - 15% for DRP at the Heathcote at Ferrymead site, due to a steady decline since monitoring began (Figure 8). Most of the other catchment sites also recorded a decrease in DRP concentrations, along with DIN. This suggests less inputs across the catchment from related sources such as fertilisers and faecal input, but this would need further investigation to confirm.
- Whilst not classified as one of the largest changes over time, the following results are of interest:
    - 13% and 11% reduction in copper and zinc, respectively, at Curlett U/S of Heathcote, due to steady decreases over time in copper, and a sharp reduction in zinc from 2011–2013 and a general reduction in large peaks. This site is downstream of the Curlett at Motorway site, followed by the Curlett Wetland which has recently been constructed within Curlett Road Stream. These decreases in contaminants may be due to reductions in roading sources (brake pads for copper and tyres for zinc), due to the building of the motorway with related stormwater treatment in approximately 2011. However, peaks in concentrations were still recorded many years following 2011,

which could reflect resuspension from historical contamination of sediment and/or other non-roading sources within the catchment (e.g., roofs and industrial activities).
  - 7% increase in zinc in Addington Brook, due to steady increases since 2016. This is a new trend this monitoring year. This suggests an increase in loads from roofs, tyres and/or industrial practices.

### 3.2.2. Dissolved Copper

- 95th percentiles for most sites in each catchment exceeded their respective guideline levels, except for the Pūharakekenui-Styx River catchment (Appendix D, Figure i (a) – (b)).
- Copper concentrations were generally higher in the Ōtākaro-Avon, Ōpāwaho-Heathcote and coastal catchments compared to the other catchments.
- Addington Brook, Haytons Stream, Curlett at Motorway, and Aylmers Stream recorded higher concentrations than the other waterway sites.
- The three highest concentrations recorded were all from 2020. The highest (0.036 mg/L – Nottingham at Candys Rd) and third highest (0.027 mg/L – Curlett at Motorway) records were associated with rain, while the second highest record (0.035 mg/L – Styx at Richards Bridge) was not. Oil was visible at the Candys Rd site during this sampling occasion.
- The Coastal sites recorded concentrations generally higher than the waterway sites, except for the Curlett at Motorway site. Copper concentrations in Lyttelton Port were particularly high.
- Concentrations did not significantly change since monitoring began, except for the Curlett U/S of Heathcote (decrease of 13%), Curlett at Motorway (increase of 10%), and Heathcote at Rose St (decrease of 3%) sites (Appendix E, Tables i–iv).

### 3.2.3. Dissolved Lead

- All 95th percentiles for each site complied with the respective guidelines (Appendix D, Figure ii (a) – (b)).
- The three highest concentrations were from Dudley creek (0.021 mg/L), Heathcote at MacKenzie Ave (0.0096 mg/L), and jointly Heathcote at Catherine St and Nottingham at Candys Rd (0.0059 mg/L). Avon at Bridge St also recorded a high concentration (0.0052 mg/L). Only the Heathcote at Catherine St sample was not associated with rain; however, this sample was collected during August 2019 when upstream dredging by CCC was occurring.
- Addington Brook typically had higher concentrations than all other waterway sites.
- Concentrations at the coastal sites were generally comparable to most waterway sites, except for the Ihutai – Avon-Heathcote Estuary site, which had typically higher concentrations.
- Concentrations did not significantly change over time, except at the Dudley Creek and Curlett U/S of Heathcote sites, which each recorded a 13% reduction in concentrations (Appendix E, Tables i–iv).

### 3.2.4. Dissolved Zinc

- 95th percentiles for most sites in the Ōtākaro-Avon and Ōpāwaho-Heathcote River catchments, as well as the Kā Pūtahi at Blakes Rd, Wilsons Stm, Nottingham at Candys Rd, Linwood Canal and Ihutai – Avon-Heathcote Estuary sites, all exceeded their respective guideline levels (Appendix D, Figure iii (a) – (b)).
- Zinc concentrations were generally higher in the Ōtākaro-Avon and Ōpāwaho-Heathcote catchments compared to the other catchments.

- The three highest concentrations (0.77 mg/L, 0.64 mg/L and 0.6 mg/L) were from the Curlett at Motorway site and only the highest record was not associated with rain. Additionally, the Ihutai – Avon-Heathcote Estuary site recorded 0.64 mg/L and this sample was not associated with rain.
- Concentrations at the coastal sites were generally comparable to waterway sites.
- Sites within areas with high industrial and commercial land use, such as Addington Brook, Haytons Stream and Curlett Road Stream, typically had higher concentrations than the rest of their respective catchments.
- Concentrations generally remained stable since sampling was instigated (Appendix E, Tables i–iv). A few sites recorded large decreases in zinc: Wairarapa Stm (11%), Curlett U/S of Heathcote (11%), Cashmere at Sutherlands Rd (10%), Halswell River at Tai Tapu Rd (10%), Styx at Gardiners Rd (10%), Smacks at Gardiners Rd (12%), and Ōtūkaikino at Groynes (13%). A large increase was recorded at Heathcote at Ferrymead Bridge (10%).

### 3.2.5. pH

- Medians of all CCC and SLLT waterway sites complied with the guideline levels (Appendix D, Figure iv (a) – (c)).
- The three highest values were from the Haytons Stream (9.6, 9.5 and 9.5) and Curlett at Motorway (9.1) sites, with none of these values recorded in association with rain. The lowest recorded pH of 6.0 was at the Styx at Gardiners Rd and Smacks at Gardiners Rd sites, and these were not associated with rain.
- Coastal sites recorded generally higher pH than waterway sites.
- No substantial changes in pH levels over time were recorded (Appendix E, Tables i–v).

### 3.2.6. Conductivity

- Coastal and tidal waterway sites had much higher levels compared to non-tidal waterway sites, due to saline influence (Appendix D, Figure v (a) – (c)).
- Addington Brook and both Curlett Road Stream sites had more variability and higher concentrations compared to other non-tidal waterway sites, indicating the presence of contaminants, such as metals.
- Concentrations generally did not change over time by any large degree (Appendix E, Tables i–v).

### 3.2.7. Salinity

- Avon at Pages Rd, Steamwharf Stream, and Styx at Harbour Rd all recorded samples below the LOD of 2.0‰ (Appendix D, Figure vi).
- Heathcote at Ferrymead Bridge generally recorded the highest salinity of the waterway sites.

### 3.2.8. TSS

- Medians of all waterway sites complied with the guideline level (Appendix D, Figure vi (a) – (b)).
- The two highest TSS concentrations were recorded from the Ōpāwaho-Heathcote River catchment in association with the CCC dredging project: Heathcote at Mackenzie Ave (2700 mg/L in December 2018) and Heathcote at Opawa Rd (310 mg/L in November 2019). The third highest record was at the Halswell at Wroots Rd site (300 mg/L in May 2020) and this sample was associated with rain.
- The coastal sites generally recorded concentrations similar to the waterway sites. The Cass Bay site had notably higher TSS than the other coastal and waterway sites.

- Typically, higher TSS was recorded in the lower, tidal sites of the Ōtākaro-Avon and Ōpāwaho-Heathcote River catchments. This is to be expected due to resuspension of the naturally softer substrate at these locations during tide changes. However, this monitoring also indicates that the CCC dredging project resulted in much higher TSS in the lower Ōpāwaho-Heathcote River than what would occur naturally. Concentrations were very high at the Halswell at Wroots Rd site compared to all other waterway sites. Concentrations were also high at the Curlett at Motorway and Cashmere at Worsleys Rd sites compared to the other non-tidal waterway sites.
- Wilsons Stm was the only site to record a substantial change in concentrations over time, with a 13% increase recorded (Figure 6; Appendix E, Tables i–iv).

### 3.2.9. Turbidity

- The medians of over half of the Ōpāwaho-Heathcote catchment sites exceeded the relevant guideline, in addition to the following exceedances in other catchments: Addington Brook, Horseshoe Lake, Avon at Pages Rd, Avon at Bridge St, Halswell at Wroots Rd and Linwood Canal (Appendix D, Figure vii (a) – (b)). None of the coastal sites exceeded the coastal guideline.
- The three highest turbidity readings were recorded from the Ōpāwaho-Heathcote catchment: Heathcote at Opawa Rd (124 FNU in December 2019, 97 FNU in November 2019) and Heathcote at Catherine St (69 FNU in May 2020). None of these recordings were associated with rain; however, they were all recorded in association with the CCC dredging project.
- The Ōpāwaho-Heathcote River catchment, followed by the Ōtākaro-Avon River and Huritini-Halswell River catchments, generally recorded higher turbidity concentrations compared to the other catchments. The lower three Ōpāwaho-Heathcote River tidal sites typically recorded higher turbidity than the other sites in this catchment, due to resuspension of the naturally softer substrate at these locations during tide changes. Concentrations were particularly high at the Cashmere at Worsleys Rd site compared to the upstream site (Cashmere at Sutherlands Rd).
- The most substantial decrease over time (16%) was at the Ōtūkaikino at Groynes site and the most substantial increase (16%) was at the Wilsons Stm site (Appendix E, Tables i–iv).

### 3.2.10. Water Clarity (SLLT sites only)

- No site complied with the guideline (Appendix D, Figure viii).
- The three poorest values were from the Horner's Drain at Hawkins Rd (35 cm, 40 cm), and Rhodes Drain at Hawkins Rd (42 cm) sites.
- Except for Horner's Drain at Hawkins Rd and Rhodes Drain at Hawkins Rd, water clarity was similar across sites, and between the mainstem and tributaries.
- No substantial changes in were recorded over time (Appendix E, Table v).

### 3.2.11. DO

- Medians of the following sites did not meet the guideline: Horseshoe Lake, Heathcote at Warren Cres, both Curlett Road Stream sites, both Cashmere Stream sites, Styx at Gardiners Rd, Smacks at Gardiners Rd, Linwood Canal and Stream Reserve Drain (Appendix D, Figure ix (a) – (b)).
- The three lowest readings were from the Haytons Stream (8.1%) and the Curlett U/S of Heathcote (8.4% and 9.4%) sites. The third lowest record was associated with rain.
- DO concentrations were generally higher at the coastal sites than the waterway sites.
- Dissolved oxygen concentrations were lower in the Ōpāwaho-Heathcote catchment, particularly at the upstream sites.

- Oxygen saturation levels did not change over time by any large degree at any of the sites (Appendix E, Tables i–iv).

### 3.2.12. Water Temperature

- Medians of all CCC and SLLT sites complied with their respective guidelines, and temperature overall was similar across all waterway and coastal sites (Appendix D, Figure x (a) – (c)).
- The three highest readings from the waterway sites were from Linwood Canal (23.2°C, 22.8 °C, 22.4 °C), Haytons Stream (22.4°C) and Heathcote at Tunnel Rd (22.4 °C). Only the 22.4 °C record from Linwood Canal was associated with rain.
- The SLLT sites recorded generally similar temperatures to the CCC sites.
- Concentrations did not change over time by any large degree (Appendix E, Tables i–v).

### 3.2.13. $BOD_5$

- Medians of all waterway sites complied with the guideline (Appendix D, Figure xi (a) – (b)).
- The highest concentrations recorded at the waterway sites were from Heathcote at MacKenzie Ave (>6.5 mg/L), Haytons Stream (8 mg/L), and jointly Curlett at Motorway and Riccarton Main Drain (6.8 mg/L) . The Haytons Stream concentration was recorded in association with rain.
- Concentrations were typically higher in the Ōtākaro-Avon River and Ōpāwaho-Heathcote River catchments, particularly at the tributary sites Addington Brook, Dudley Creek, Horseshoe Lake, Haytons Stream, and both Curlett Road Stream sites.
- No large changes in concentrations of $BOD_5$ were recorded over time (Appendix E, Tables i–iv).

### 3.2.14. Total Ammonia

- 95$^{th}$ percentiles of all sites complied with their respective guidelines (Appendix D, Figure xii (a) – (b)).
- The three highest concentrations were from the Kā Pūtahi at Blakes Rd (1.5 mg/L on two occasions), jointly Curlett at Motorway and Heathcote at Catherine St (1.1 mg/L), and Haytons Stm (0.78 mg/L) sites, with only one of the Kā Pūtahi at Blakes Rd samples associated with rain.
- Ammonia was generally higher in the tributaries compared to mainstems.
- Over half of sites remained stable over time, with the remaining sites recording small decreases in concentrations, although Heathcote at Ferrymead Bridge recorded a relatively large decrease (13%) (Appendix E, Tables i–iv). The exception to these decreases was Wilsons Stm, which recorded an increase of 6%. This site recorded a 12% increase in total ammonia in the 2019 monitoring year. The reduced per annum increase reported this year is likely due to lower contaminant concentrations in 2020 compared to the 2017–2019 monitoring years. Lower contaminant concentrations may have been due to less contaminant inputs or a result of less stormwater inputs during the comparatively drier year.

### 3.2.15. Nitrate and DIN

- The majority of waterway sites complied with the nitrate guidelines (Appendix D, Figure xiii (a) – (b)). However, there were exceptions to this (medians - Riccarton Main Drain, Heathcote at Warren Cres, Heathcote at Rose St, the two Cashmere Stream sites, Knights at Sabys Rd, and the two Halswell River sites; 95$^{th}$ percentiles - Heathcote at Warren Cres, Curlett U/S of Heathcote, the two Cashmere Stream sites, Knights at Sabys Rd, and the two Halswell River sites).

- The medians of over half of the sites complied with their respective DIN guideline, but the majority of sites in the Ōpāwaho-Heathcote did not (Appendix D, Figure xiv (a) – (b)).
- Heathcote at Warren Cres and Knights at Sabys Rd recorded much higher concentrations of nitrogen than the other sites, with the three highest exceedances of nitrate and DIN all from the Heathcote at Warren Cres site (Nitrate and DIN: 5.6 mg/L, 5.4 mg/L, and 5.3 mg/L). Only one record was associated with rain (5.4 mg/L).
- All three parameters typically decreased downstream in the mainstems, and were higher in the Ōtākaro-Avon, Ōpāwaho-Heathcote, and Huritini-Halswell River catchments.
- DIN concentrations generally remained stable or decreased over time, with 75% of sites recording a small decrease (Appendix E, Tables i–iv). The exception to this was a comparatively large decrease at Curlett at Motorway (DIN = 24%; Figure 5). An increase in DIN (10%) was recorded at Ōtūkaikino at Scout Camp, due to some high peaks in concentrations during 2017–2019.

### 3.2.16. DRP

- The medians of over half of the sites did not comply with their respective guidelines, with most sites in the Ōpāwaho-Heathcote and Pūharakekenui-Styx catchments exceeding this concentration (Appendix D, Figure xv (a) – (b)).
- The three highest concentrations were all from Haytons Stream (0.73 mg/L, 0.65 mg/L and 0.49 mg/L). None of the samples were associated with rain.
- DRP generally increased downstream in the catchments.
- Most sites recorded a decrease in DRP concentrations since monitoring began (Appendix E, Tables i–iv). The largest decreases were from Cashmere at Sutherlands Rd (16%), Heathcote at Ferrymead Bridge (15%), Ōtūkaikino at Groynes (14%), Ōtūkaikino at Scout Camp (13%), Haytons Stream (12%) and Heathcote at Tunnel Rd (11%). No site increased in concentration.

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

- For *E. coli*, the 95$^{th}$ percentiles for Cashmere at Sutherlands Rd, and Ōtūkaikino at Groynes complied with the guideline level (Appendix D, Figure xvi (a) – (b)). Concentrations exceeded the guideline at all other waterway sites.
- Of the eight sites where enterococci was collected in 2020, the 95$^{th}$ percentiles for Ihutai – Avon-Heathcote Estuary and both Heathcote River sites complied with the guideline level (Appendix D, Figure xvii). Concentrations exceeded the guideline at all other sites.
- The Akaroa Harbour site is the only site monitored for faecal coliforms, and it complied with both the median and 90$^{th}$ percentile guideline (Appendix D, Figure xvii).
- The highest *E. coli* concentration (>24,000 MPN/100ml) was recorded on one occasion each at the Dudley Creek, Riccarton Main Drain, Linwood Canal, and Nottingham at Candys Rd sites. The next highest record of 24,000 MPN/100ml was recorded at the Addington Brook, Kā Pūtahi at Belfast Rd, Riccarton Main Drain (two occasions), and Wilsons Stm sites. The third highest concentration of 20,000 MPN was recorded at three sites (Addington Brook, Avon at Manchester St, and Nottingham at Candys Rd). Some of these records were associated with rain, but not all. Only the Riccarton Main Drain >24,000 MPN/100ml sample was associated with a wastewater overflow event during the 2018 monitoring year.
- The highest enterococci concentrations were recorded from Cass Bay (>24 000 MPN/100m), and Linwood Canal (3,500 MPN/100 ml and 3,700 MPN/100 ml). Both Linwood Canal samples were associated with rain. None of these records were associated with a wastewater overflow event.
- The highest faecal coliform record was 34 MPN/100ml, and this was not associated with rain or a wastewater overflow event.

- The Ihutai – Avon-Heathcote Estuary site had much lower concentrations than other sites for both *E. coli* and enterococci. *E. coli* is not tested for at the remaining coastal sites.
- Concentrations of *E. coli* generally remained stable over time (Appendix E, Tables i–iv). The largest changes were recorded at Ōtūkaikino at Scout Camp (25% increase), Wilsons Stm (14% increase), Curlett U/S of Heathcote (12% decrease), and Halswell River at Tai Tapu Rd (10% increase).
- Of the three sites where sufficient data was available to calculate enterococci trends (Avon at Bridge St, Heathcote at Ferrymead Bridge, and Linwood Canal), all recorded decreases of 9–13%.
- Insufficient data was available to measure trends in faecal coliforms.

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/95$^{th}$ percentiles, depending on the parameter) not meeting the guideline levels, during the monitoring period of January 2018 to December 2020.

| Parameter | Guideline | Number of Sites Monitored | Number of Samples Analysed | Number of Samples Not Meeting Guideline | Number of Sites Not Meeting Guideline |
|---|---|---|---|---|---|
| *Escherichia coli* | 95%$^{th}$ percentile ≤550/100ml | 47 | 1,513 | 445 (29.4%) | 45 |
| Dissolved copper | Varies depending on catchment, from 95$^{th}$ percentile ≤0.001 mg/L to ≤0.0018 mg/L | 51 | 1,545 | 170 (11.0%) | 33 |
| Dissolved Reactive Phosphorus | Varies depending on catchment, from median ≤0.016 mg/L to ≤0.025 mg/L | 47 | 1,513 | 844 (55.8%) | 29 |
| Dissolved zinc | Varies depending on catchment, from 95$^{th}$ percentile ≤0.00634 mg/L to ≤0.0396 mg/L | 51 | 1,545 | 200 (12.9%) | 28 |
| Dissolved Inorganic Nitrogen | Varies depending on catchment, from median ≤0.09 mg/L to ≤1.5 mg/L | 47 | 1,511 | 572 (37.9%) | 18 |
| Turbidity | Varies depending on catchment, from median ≤5.6 NTU to ≤10 NTU | 51 | 1,376 | 404 (29.4%) | 14 |
| Dissolved oxygen | Varies depending on catchment, from median ≥70% to ≥90% | 51 | 1,545 | 380 (24.5%) | 10 |
| 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 | 1,511 | 236 (15.6%) | 9 |
| Enterococci | Varies depending on catchment, from 95$^{th}$ percentile ≤500 MPN/100ml to ≤200 MPN/100ml | 8 | 147 | 15 (10.2%) | 5 |
| Total Suspended Solids | Median ≤25 mg/L for waterway sites only | 43 | 1,373 | 87 (6.3%) | 0 |
| Biochemical Oxygen Demand | Median ≤2 mg/L | 51 | 1,513 | 92 (6.1%) | 0 |
| Water temperature | Varies depending on catchment, from median ≤20°C to ≤25°C | 51 | 1,506 | 30 (2.0%) | 0 |
| pH | Varies depending on catchment, from median 6.5 to 8.5, to 7.0 to 8.5 | 51 | 1,545 | 13 (0.8%) | 0 |
| Dissolved lead | Varies depending on catchment, from 95$^{th}$ percentile ≤0.00427 mg/L to ≤0.02388 mg/L | 51 | 1,545 | 4 (0.3%) | 0 |

| Parameter | Guideline | Number of Sites Monitored | Number of Samples Analysed | Number of Samples Not Meeting Guideline | Number of Sites Not Meeting Guideline |
|---|---|---|---|---|---|
| Faecal coliforms | Median ≤14MPN/100ml and/or 90$^{th}$ percentile ≤43 MPN/100 ml | 1 | 8 | 1 (12.5%) | 0 |
| Total ammonia | Varies depending on catchment, from 95$^{th}$ percentile ≤0.32 mg/L to ≤1.99 mg/L | 47 | 1,513 | 0 (0%) | 0 |
| Total | - | 51 | 21,182 | 3,490 (16.5%) | 51 of 51 (100%) (for at least one parameter) |

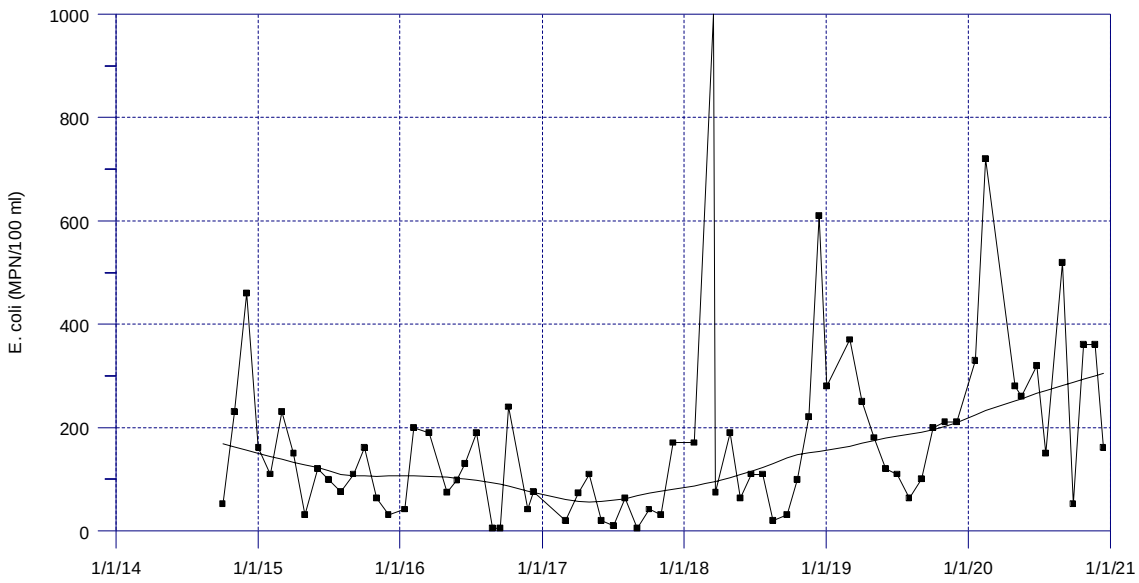


Figure 3. *E. coli* concentrations at the Ōtūkaikino at Scout Camp site for the monitoring period October 2014 to December 2020. Squares indicate individual sampling events. An increasing trend of 25% was recorded over the sampling period.

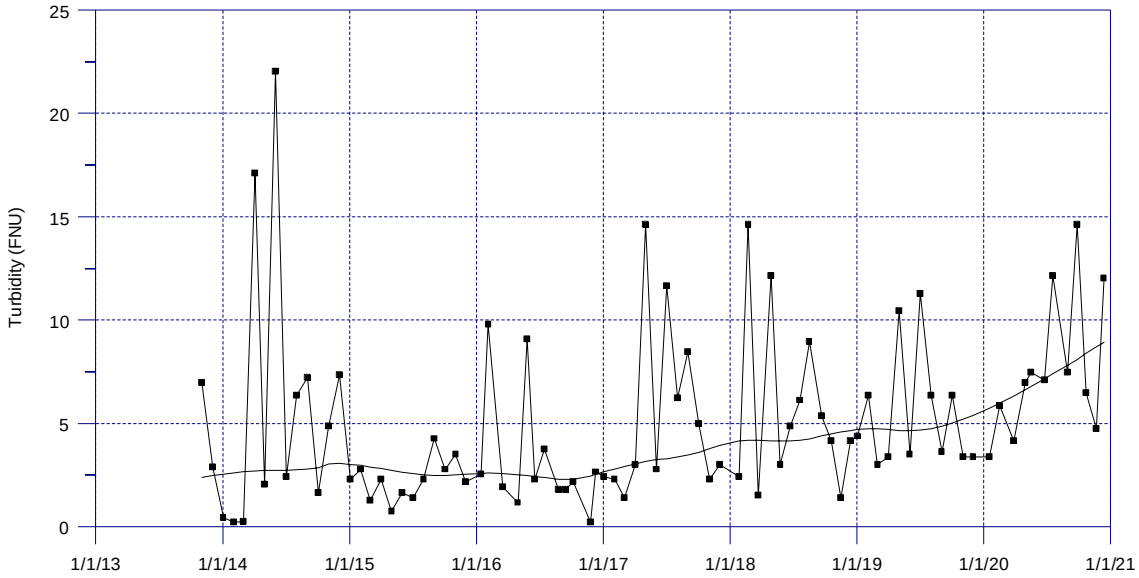


Figure 4. Turbidity concentrations at the Wilsons Stm site for the monitoring period November 2013 to December 2020. Squares indicate individual sampling events. An increasing trend of 16% was recorded over the sampling period.

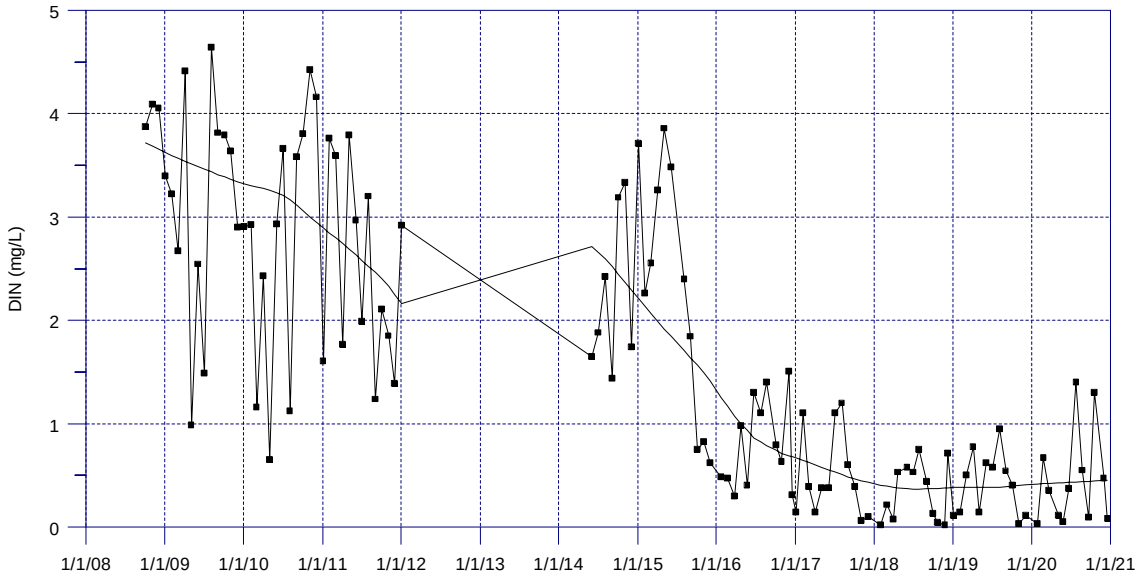


Figure 5. DIN concentrations at the Curlett at Motorway site for the monitoring period October 2008 to December 2020. Squares indicate individual sampling events. A decreasing trend of 24% was recorded over the sampling period. This site was unable to be sampled from February 2012– May 2014, due to motorway construction.

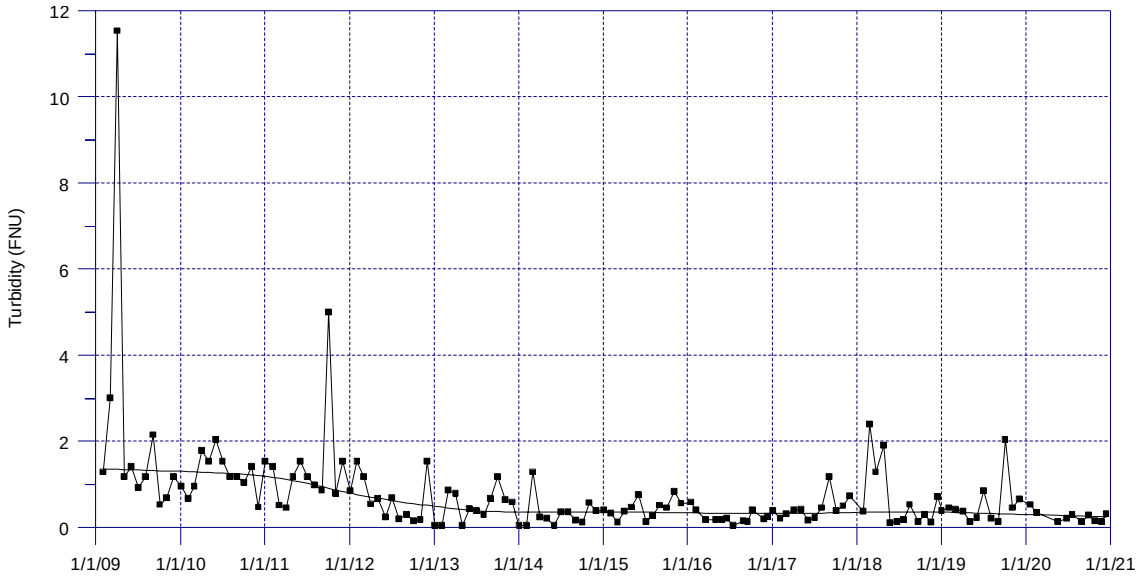


Figure 6. Turbidity at the Otukaikino at Groynes site for the monitoring period October 2008 to December 2020. Squares indicate individual sampling events. A decreasing trend of 16% was recorded over the sampling period.

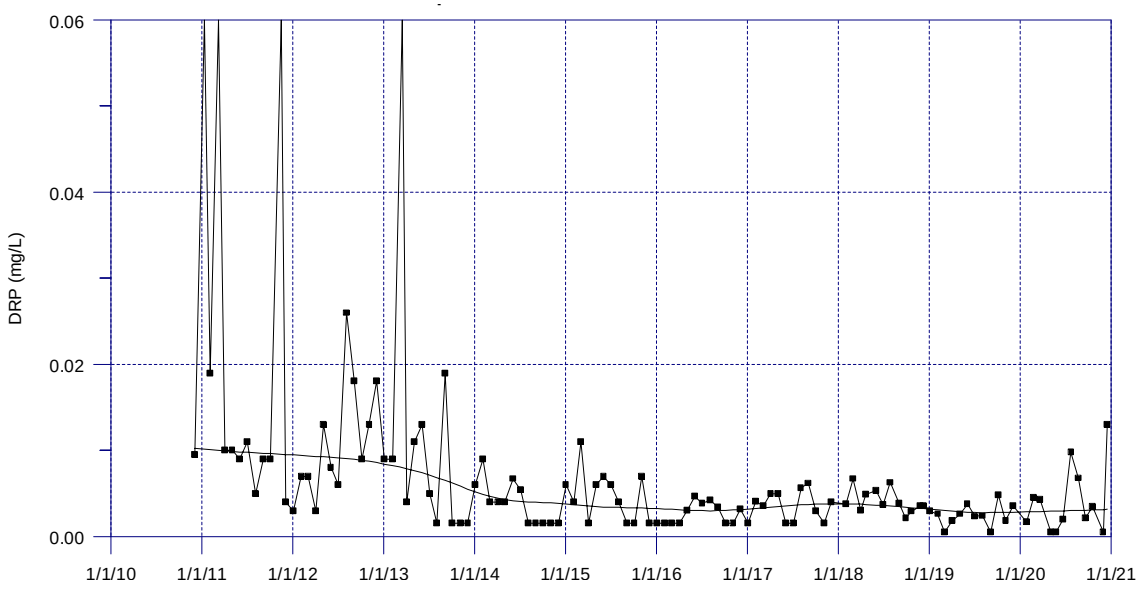


Figure 7. DRP concentrations at the Cashmere at Sutherlands Rd site for the monitoring period December 2010 to December 2020. Squares indicate individual sampling events. A decreasing trend of 16% was recorded over the sampling period.

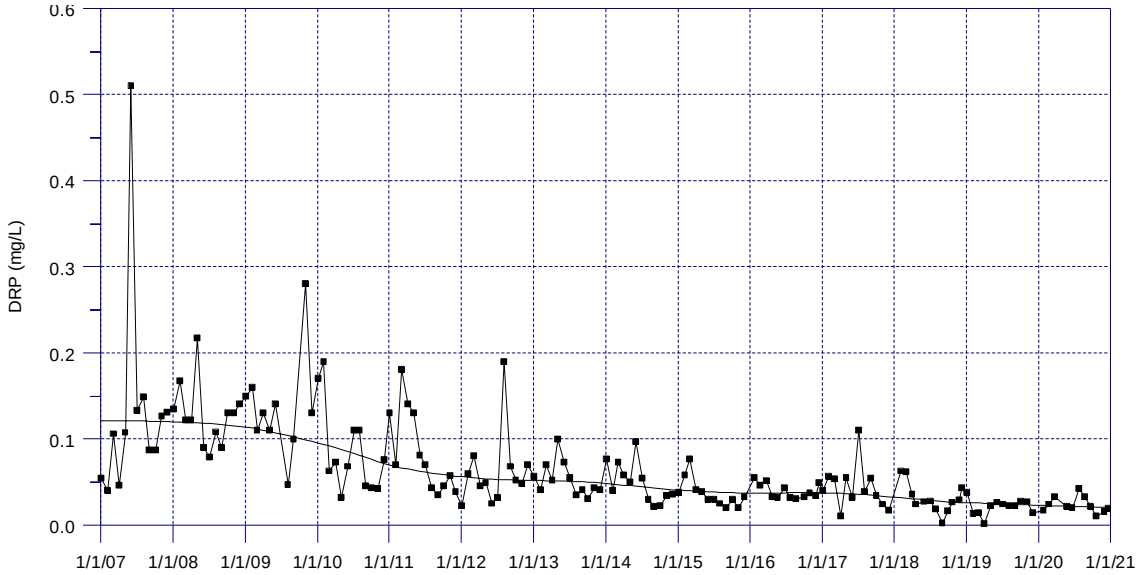


Figure 8. DRP concentrations at the Heathcote at Ferrymead Rd site for the monitoring period January 2007 to December 2020. Squares indicate individual sampling events. A decreasing trend of 15% was recorded over the sampling period.

## 3.3. Water Quality Index

- 2% (1 site), 26% (11 sites), 35% (15 sites), 35% (15 sites), and 2% (1 site) of sites recorded 'very poor', 'poor', 'fair', 'good' and 'very good' WQI categories, respectively (Table 3; Figure 9).
- Based on the median WQI for each catchment, the Huritini-Halswell River recorded 'poor' water quality, the Ōtākaro-Avon and Ōpāwaho-Heathcote recorded 'fair' water quality, and the Pūharakekenui-Styx River and Ōtūkaikino River recorded 'good' water quality (Figure 10). The Banks Peninsula waterway sites recorded 'poor' (2 sites) and 'fair' (1 site) water quality (Figure 9).
- The Ōtūkaikino River recorded the best water quality out of all the catchments and Huritini-Halswell catchment recorded the worst water quality (Table 4).
- The best site for water quality was Ōtūkaikino at Groynes, followed jointly by Smacks at Gardiners Rd, Waimairi Stream, Avon at Carlton Mill and Wilsons Stream, and then Styx at Gardiners Road (Table 4).
- The worst site for water quality was Curlett at Motorway, followed by Nottingham at Candys Rd, and then Haytons Stream (Table 4).
- Time Trends analysis showed no catchment significantly improved or declined in WQI over the analysed period (2016–2020), except for the Ōtākaro-Avon River catchment where the WQI decreased by 4% (Figure 10). The medians of most catchments varied from 'poor' through to 'good' depending on the year; however, the Ōtūkaikino River catchment median was 'very good' in 2016.
- Time Trends analysis showed that two sites recorded a significant decline in WQI over time (Avon at Dallington Tce and Avon at Mona Vale), and one site showed a significant increase (Haytons Stream) (Table 3).

Table 3. Water Quality Index (WQI) scores, categories, and direction of significant temporal trends (2016–2020) at each Christchurch City Council surface water quality monitoring site in 2020.

| Catchment | Site | WQI Score | WQI Category | WQI Temporal Trends |
|---|---|---|---|---|
| Ōpāwaho-Heathcote | Curlett at Motorway | 39.3 | Very Poor | |
| Huritini-Halswell | Nottingham at Candys Rd | 49.3 | Poor | |
| Ōpāwaho-Heathcote | Haytons Stm | 53.0 | Poor | ↑10% |
| Ōtākaro-Avon | Addington Brook | 53.9 | Poor | |
| Ōpāwaho-Heathcote | Curlett U/S of Heathcote | 55.4 | Poor | |
| Stream Reserve Drain/Zephyr Stream | Stream Reserve Drain | 59.7 | Poor | |
| Huritini-Halswell | Halswell at Wroots Rd | 60.4 | Poor | |
| Ōtākaro-Avon | Dudley Creek | 61.8 | Poor | |
| Ōpāwaho-Heathcote | Heathcote at MacKenzie Ave | 66.5 | Poor | |
| Ōpāwaho-Heathcote | Cashmere at Worsleys Rd | 67.1 | Poor | |
| Ōpāwaho-Heathcote | Heathcote at Bowenvale Ave | 67.4 | Poor | |
| Aylmers Stream | Aylmers Stream | 69.6 | Poor | |
| Ōpāwaho-Heathcote | Heathcote at Rose St | 70.1 | Fair | |
| Ōtākaro-Avon | Riccarton Main Drain | 71.7 | Fair | |
| Ōtākaro-Avon | Avon at Dallington Tce | 72.4 | Fair | ↓ 7% |
| Ōpāwaho-Heathcote | Heathcote at Catherine St | 72.7 | Fair | |
| Ōtākaro-Avon | Avon at Mona Vale | 72.9 | Fair | ↓ 7% |
| Ōtākaro-Avon | Horseshoe Lake | 74.1 | Fair | |
| Huritini-Halswell | Halswell River at Tai Tapu Rd | 76.2 | Fair | |
| | | | | |
| Balguerie Stream | Balguerie Stream | 76.3 | Fair | |
| Ōpāwaho-Heathcote | Heathcote at Opawa Rd | 76.6 | Fair | |
| Pūharakekenui-Styx | Kā Pūtahi at Belfast Rd | 76.6 | Fair | |
| Huritini-Halswell | Knights at Sabys Rd | 76.9 | Fair | |
| Ōtākaro-Avon | Avon at Manchester St | 77.8 | Fair | |
| Ōpāwaho-Heathcote | Heathcote at Ferniehurst St | 78.1 | Fair | |
| Pūharakekenui-Styx | Styx at Richards Bridge | 79.8 | Fair | |
| Ōpāwaho-Heathcote | Heathcote at Warren Cres | 80.0 | Fair | |
| Ōpāwaho-Heathcote | Cashmere at Sutherlands Rd | 80.1 | Good | |
| Ōpāwaho-Heathcote | Steamwharf Stream | 81.9 | Good | |
| Ōtūkaikino | Otukaikino at Scout Camp | 82.4 | Good | |
| Pūharakekenui-Styx | Styx at Marshland Rd | 82.6 | Good | |
| Pūharakekenui-Styx | Kā Pūtahi at Blakes Rd | 82.6 | Good | |

| Catchment | Site | WQI Score | WQI Category | WQI Temporal Trends |
|---|---|---|---|---|
| Ōtākaro-Avon | Wairarapa Stm | 83.6 | Good | |
| Pūharakekenui-Styx | Styx at Main North Rd | 84.2 | Good | |
| Ōtākaro-Avon | Avon at Pages Rd | 86.9 | Good | |
| Ōtākaro-Avon | Avon at Avondale Rd | 86.9 | Good | |
| Pūharakekenui-Styx | Styx at Harbour Rd | 87.5 | Good | |
| Pūharakekenui-Styx | Styx at Gardiners Rd | 88.0 | Good | |
| Pūharakekenui-Styx | Smacks at Gardiners Rd | 88.6 | Good | |
| Ōtākaro-Avon | Waimairi Stm | 88.8 | Good | |
| Ōtūkaikino | Wilsons Stm | 88.9 | Good | |
| Ōtākaro-Avon | Avon at Carlton Mill | 89.2 | Good | |
| Ōtūkaikino | Otukaikino at Groynes | 94.5 | Very Good | |

Table 4. Best and worst catchments and sites for the monitoring period January to December 2019, based on the Water Quality Index (WQI). Red = Ōtākaro-Avon River catchment, orange = Ōpāwaho-Heathcote River catchment, blue = Pūharakekenui-Styx River catchment, green = Ōtūkaikino River catchment, and purple = Huritini-Halswell River catchment. Stream Reserve Drain (WQI = 60), Aylmers Stream (WQI = 74), and Balguerie Stream (WQI = 76) are not included as a catchment, as only one site is monitored.

| Placing | Best Sites | | Worst Sites | |
|---|---|---|---|---|
| | Catchment Scale | Site Scale | Catchment Scale | Site Scale |
|  | Ōtūkaikino River (median WQI = 89) | Ōtūkaikino at Groynes (WQI = 95) | Huritini-Halswell River (median WQI = 68) | Curlett at Motorway (WQI = 39) |
|  | Pūharakekenui-Styx River (median WQI = 83) | Smacks at Gardiners Rd<br>Waimairi Stream<br>Avon at Carlton Mill<br>Wilsons Stream<br>(WQI = 89) | Ōpāwaho-Heathcote River (median WQI = 70) | Nottingham at Candys Rd (WQI = 49) |
|  | Ōtākaro-Avon River (median WQI = 76) | Styx at Gardiners Rd (WQI = 88) | Ōtākaro-Avon River (median WQI = 76) | Haytons Stream (WQI = 53) |

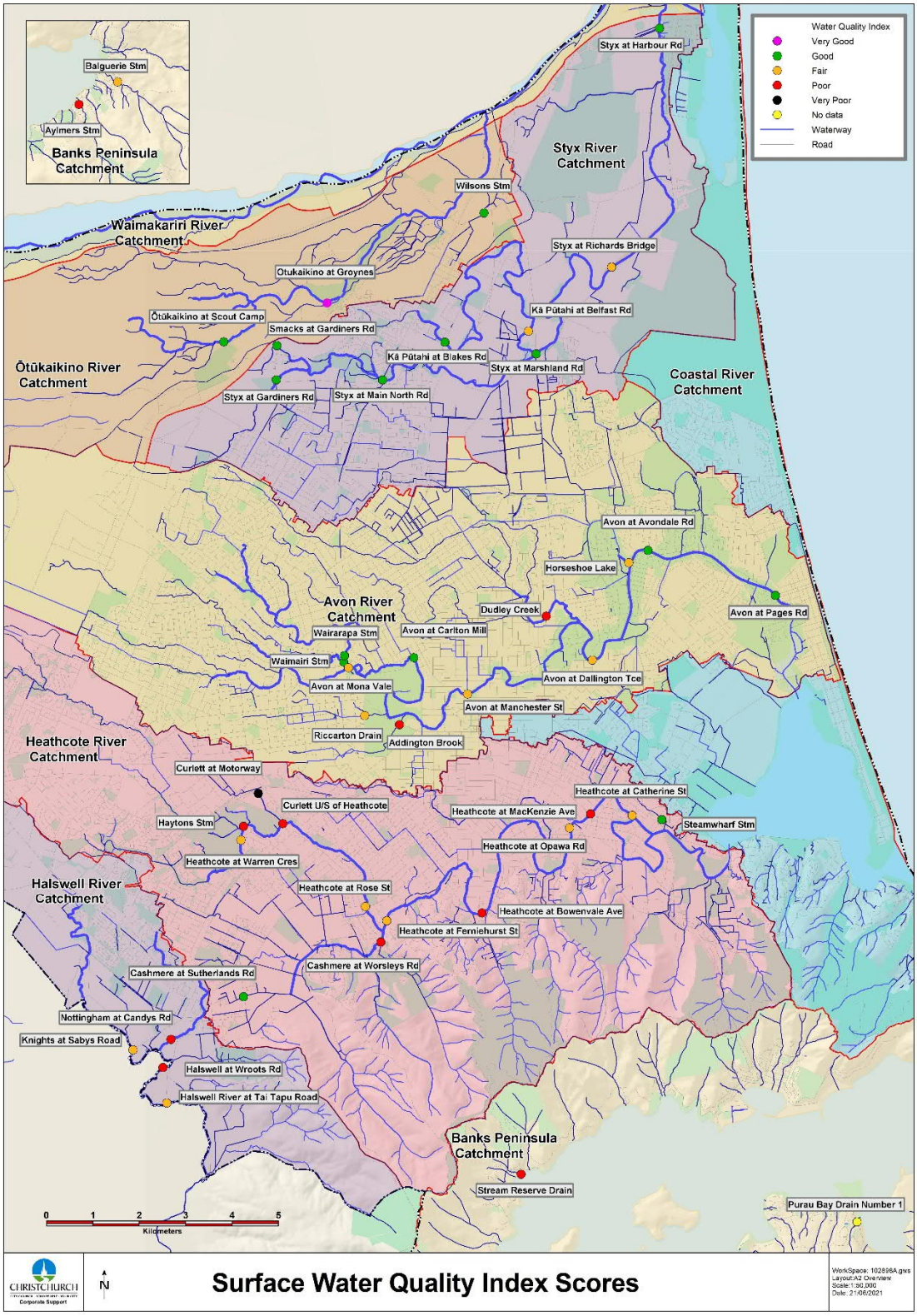


Figure 9. Water Quality Index (WQI) categories for 2020 at the Christchurch City Council water quality monitoring sites.

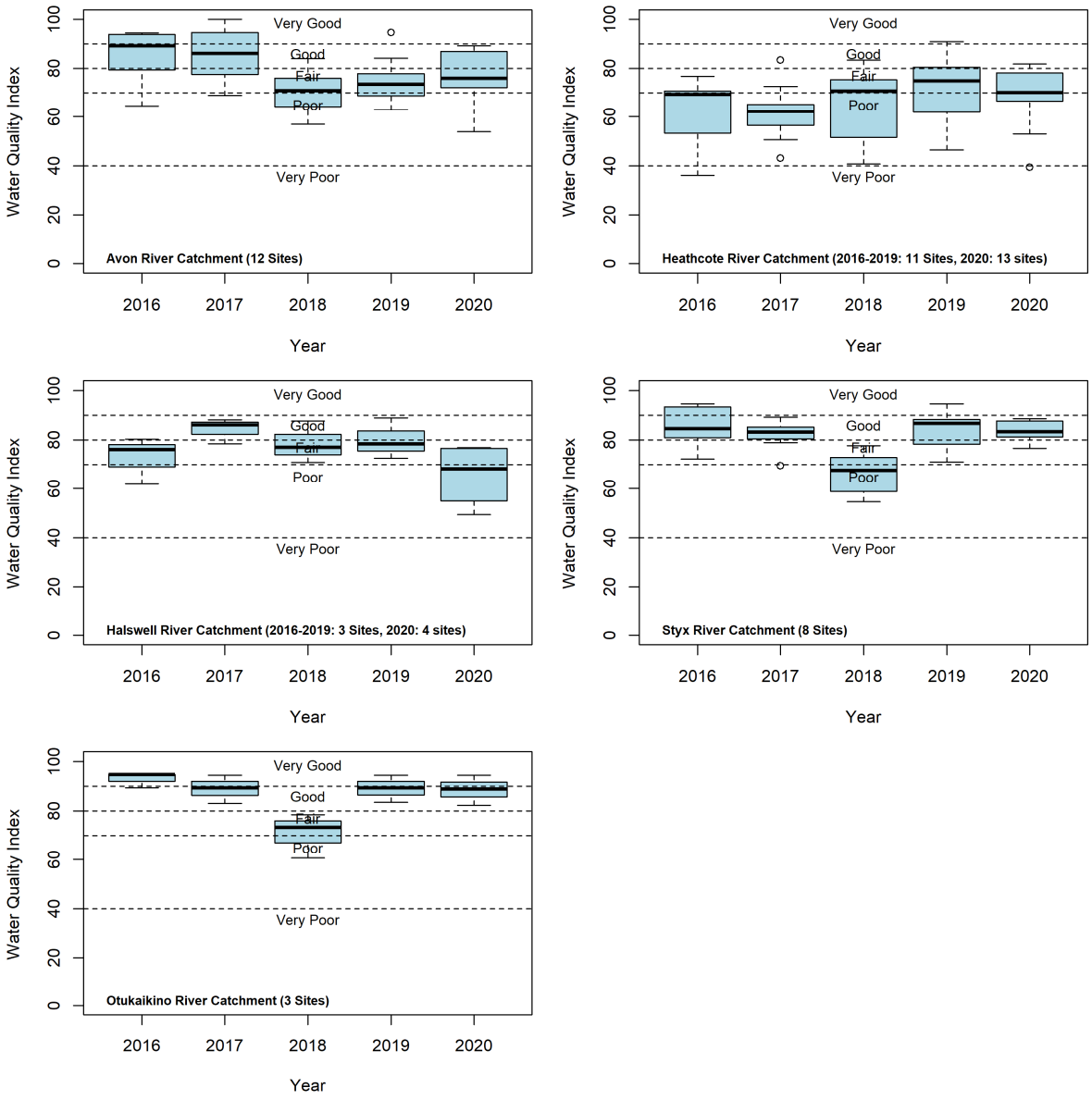


Figure 10. Boxplots of Water Quality Index for each catchment for the 2016 to 2020 monitoring years

## 3.4. Assessment against Attribute Target Levels

- A requirement for this report under the CSNDC EMP is to assess the CCC monthly data against the consent Objectives and Attribute Target Levels (ATLs) for TSS, 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.
- 32 of the 51 sites did not meet the CSNDC ATLs (Table 5; Appendix F).
- As this is a large number of sites triggering further investigation, sites were prioritised into five categories:
    1. A guideline was not met and an increasing trend was recorded (4 sites)
    2. A guideline was not met, no trend was recorded, and the site is within a priority catchment (7 sites)
    3. A guideline was not met, no trend was recorded, and the site is not within a priority catchment (19 sites)
    4. A guideline was met, but an increasing trend was recorded (2 sites)
    5. A guideline was not met, but a decreasing trend was recorded (1 sites)
- Priority catchments were those that were considered to have comparatively high ecological value (e.g., the presence of inanga spawning sites or high biodiversity) relative to other catchments in the surface water quality monitoring programme. These were:
    - Horseshoe Lake
    - Steamwharf Stream
    - Cashmere Stream
    - Ōtūkaikino River
    - Stream Reserve Drain
    - Balguerie Stream
    - Aylmers Stream
    - Ihutai – Avon-Heathcote Estuary
- The four sites in Priority Category 1 are recommended for further investigation, as this is a manageable amount to work on in detail for the coming year, rather than doing more projects in less detail. These sites include: Curlett at Motorway and Heathcote at Ferrymead Bridge (Ōpāwaho-Heathcote River catchment), Addington Brook (Ōtākaro-Avon River catchment), and Nottingham at Candys Rd (Huritini-Halswell River catchment). These sites cover the top three worst catchments recorded this monitoring year.

Table 5. Assessment of Christchurch City Council surface water quality monitoring sites against the Comprehensive Stormwater Network Discharge Consent (CSNDC) Attribute Target Levels for Total Suspended Solids, dissolved copper, dissolved lead, and dissolved zinc, for the monitoring year January – December 2020. A tick represents a trigger under the CSNDC for further investigations into parameter concentrations, due to levels either not meeting the guidelines or levels statistically increasing over time. The Lyttelton Port site is not included in this table as it is excluded from meeting Target Attribute Levels under Schedule 8 of the CSNDC. G = guideline level not met; C = statistically significant change recorded; N/A = parameter not measured; blank cell = investigation not triggered (i.e., Attribute Target Levels are met).

| Site- Annual | Dissolved copper | Dissolved lead | Dissolved zinc | TSS (median) | Priority | Comments |
|---|---|---|---|---|---|---|
| Curlett at Motorway | ✓G,C | | ✓G,C | ✓C | 1 | Review existing work programme |
| Heathcote at Ferrymead Bridge | ✓G | | ✓C | N/A | 1 | Site affected by dredging which may be potentially causing resuspension of sediment-bound copper and zinc |
| Addington Brook | ✓G | | ✓G,C | | 1 | Review existing work programme |
| Nottingham at Candys Rd | ✓G | | ✓G,C | | 1 | |
| Ihutai – Avon-Heathcote Estuary | ✓G | | ✓G | N/A | 2 | Priority catchment |
| Cashmere at Sutherlands Rd | ✓G | | | | 2 | Priority catchment |
| Cashmere at Worsleys Rd | ✓G | | ✓G | | 2 | Priority catchment |
| Ōtūkaikino at Scout Camp | ✓G | | | | 2 | Priority catchment |
| Aylmers Stream | ✓G | | ✓G | | 2 | Priority catchment |
| Balguerie Stream | | | ✓G | | 2 | Priority catchment |
| Stream Reserve Drain | ✓G | | ✓G | | 2 | Priority catchment |
| Avon at Mona Vale | ✓G | | ✓G | | 3 | |
| Avon at Carlton Mill | ✓G | | | | 3 | |
| Riccarton Main Drain | ✓G | | ✓G | | 3 | |

| Site- Annual | Dissolved copper | Dissolved lead | Dissolved zinc | TSS (median) | Priority | Comments |
|---|---|---|---|---|---|---|
| Avon at Manchester St | ✓G | | | | 3 | |
| Dudley Creek | ✓G | | ✓G | | 3 | |
| Avon at Dallington Tce | ✓G | | | | 3 | |
| Linwood Canal | ✓G | | | N/A | 3 | |
| Haytons Stream | ✓G | | ✓G | ✓C | 3 | |
| Heathcote at Rose St | | | ✓G | | 3 | |
| Heathcote at Ferniehurst St | ✓G | | | | 3 | |
| Heathcote at Bowenvale Ave | ✓G | | ✓G | | 3 | |
| Heathcote at MacKenzie Ave | | | ✓G | | 3 | |
| Smacks Creek | ✓G | | | | 3 | |
| Styx at Marshland Rd | ✓G | | | | 3 | |
| Styx at Richards Bridge | ✓G | | | | 3 | |
| Halswell at Wroots Rd | ✓G | | | | 3 | |
| Cass Bay | ✓G | | | N/A | 3 | |
| Akaroa Harbour | ✓G | | | N/A | 3 | |
| Wilsons Stream | | | | ✓C | 4 | |
| Halswell at Tai Tapu Rd | | | | ✓C | 4 | |
| Curlett U/S of Heathcote | ✓G | | ✓G | | 5 | |

## 3.5. Catchment Summary

A collation of the WQI results and contaminants of concern for each catchment are provided in Table 6. Issues of particular note that have not previously been discussed in the results section include:

- Dissolved metals are a concern in all catchments, except the Pūharakekenui-Styx River.
- Copper is the contaminant of concern in coastal areas.
- Water quality at the Banks Peninsula waterways is no better than waterways in the City and is particularly poor at Stream Reserve Drain in Governors Bay.
- Turbidity is of particular concern in the Ōpāwaho-Heathcote River. Exceedances in the lower mainstem sites may have been exacerbated by the CCC dredging project during 2018-2020. However, this does not explain the high turbidity recorded further up the catchment, which is likely due to sediment discharges from the Port Hills via Cashmere Stream and other tributaries.

Table 6. Catchment summary of surface water quality and contaminants of concern, based on data presented in this 2020 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.

| Catchment | WQI Category | Best sites (Highest WQI Score) | Worst sites (Lowest WQI Score) | WQI Time Trend (2016-2020) | Contaminants of Concern | |
|---|---|---|---|---|---|---|
| | | | | | Catchment Level | Site Level |
| **Ō**t**ā**karo-Avon River | Fair (Median WQI = 76)* | Avon at Carlton Mill<br>Waimairi Stm<br>Avon at Avondale Rd<br>Avon at Pages Rd | Addington Brook<br>Dudley Creek<br>Riccarton Main Drain | Declining trend* | Copper, zinc, DRP, *E. coli* | Riccarton Main Drain (copper, zinc, nitrate, DIN, *E. coli*)<br>Horseshoe Lake (copper, turbidity, DO, DRP, *E. coli*)<br>Avon at Pages Rd (copper, zinc, turbidity, DRP, *E. coli*)<br>Avon at Bridge Street (copper, zinc, turbidity, DRP, *E. coli*)<br>Dudley Creek (copper, zinc, DRP, *E. coli*)<br>Addington Brook (copper, zinc – with a 7% increase, turbidity, *E. coli*)<br>Avon at Mona Vale (copper, zinc, DIN, *E. coli*)<br>Avon at Dallington Tce (copper, zinc, DRP, *E. coli*)<br>Avon at Avondale Rd (copper, zinc, DRP, *E. coli*)<br>Avon at Carlton Mill (copper, zinc, *E. coli*)<br>Avon at Manchester St (copper, zinc, *E. coli*)<br>Waimairi Stm (zinc, DIN, *E. coli*)<br>Wairarapa Stm (zinc, *E. coli*) |
| **Ō**p**ā**waho-Heathcote River | Fair (Median WQI = 73)* | Heathcote at Warren Cres<br>Cashmere at Sutherlands Rd<br>Steamwharf Stream | Curlett at Motorway<br>Curlett U/S of Heathcote<br>Heathcote at MacKenzie Ave | No significant trend* | Copper, zinc, turbidity, DIN, DRP, *E. coli* | Cashmere at Worsleys Rd (copper, zinc, turbidity, DO, nitrate, DIN, *E. coli*)<br>Curlett U/S of Heathcote (copper, zinc, turbidity, DO, nitrate, DRP, *E. coli*)<br>Curlett at Motorway (copper, zinc, turbidity, DO, DRP, *E. coli*)<br>Heathcote at Ferrymead Bridge (copper, zinc, TSS, turbidity, DRP *E. coli*)<br>Heathcote at Rose St (copper, zinc, nitrate, DIN, DRP, *E. coli*) |

| Catchment | WQI Category | Best sites (Highest WQI Score) | Worst sites (Lowest WQI Score) | WQI Time Trend (2016-2020) | Contaminants of Concern | |
|---|---|---|---|---|---|---|
| | | | | | Catchment Level | Site Level |
| | | | | | | Heathcote at Tunnel Rd (copper, zinc, turbidity, DRP, *E. coli*)<br>Heathcote at Ferniehurst St (copper, zinc, turbidity, DIN, DRP, *E. coli*)<br>Haytons Stream (copper, zinc, turbidity, DRP, *E. coli*)<br>Heathcote at MacKenzie Ave (copper, zinc, DIN, DRP, *E. coli*)<br>Heathcote at Bowenvale Ave (copper, DIN, DRP, *E. coli*)<br>Heathcote at Opawa Rd (turbidity, DIN, DRP, *E. coli*)<br>Cashmere at Sutherlands Rd (DO, nitrate, DIN)<br>Heathcote at Warren Cres (DO, nitrate, *E. coli*)<br>Heathcote at Catherine St (turbidity, DRP, *E. coli*)<br>Steamwharf Stream (DRP, *E. coli*) |
| Huritini-Halswell River | Poor (Median WQI = 68)* | Knights at Sabys Rd<br>Halswell at Tai Tapu Rd | Nottingham at Candys Rd<br>Halswell at Wroots Rd | No significant trend* | Copper, nitrate, DIN, DRP, *E. coli* | Halswell at Wroots Rd (copper, turbidity, nitrate, DIN, DRP, *E. coli*)<br>Nottingham at Candys Rd (copper, zinc, DRP, *E. coli*)<br>Halswell at Tai Tapu Rd (copper, nitrate, DIN, *E. coli*)<br>Knights at Sabys Rd (nitrate, DIN, *E. coli*) |
| **Pū**harakekenui-Styx River | Good (Median WQI = 83)* | Styx at Harbour Rd<br>Styx at Gardiners Rd<br>Smacks at Gardiners Rd | Kā Pūtahi at Belfast Rd<br>Styx at Richards Bridge<br>Styx at Marshland Rd<br>Kā Pūtahi at Blakes Rd | No significant trend* | DRP, *E. coli* | Styx at Marshland Rd (copper, DRP, *E. coli*)<br>Kā Pūtahi at Blakes Rd (zinc, DRP, *E. coli*)<br>Smacks at Gardiners Rd (DO, *E. coli*)<br>Styx at Richards Bridge (DRP, *E. coli*)<br>Styx at Gardiners Rd (DO, *E. coli*)<br>Styx at Harbour Rd (DRP, *E. coli*)<br>Kā Pūtahi at Belfast Rd (DRP, *E. coli*)<br>Styx at Main North Rd (*E. coli*) |
| **Ō**t**ū**kaikino River | Good (Median WQI = 89)* | Otukaikino at Groynes<br>Wilsons Stream | Otukaikino at Scout Camp | No significant trend* | Copper, *E. coli* | Wilsons Stream (zinc, DIN, *E. coli*; and a 16% increase in turbidity) |

| Catchment | WQI Category | Best sites (Highest WQI Score) | Worst sites (Lowest WQI Score) | WQI Time Trend (2016-2020) | Contaminants of Concern | |
|---|---|---|---|---|---|---|
| | | | | | Catchment Level | Site Level |
| | | | | | | Ōtūkaikino at Scout Camp (copper, *E. coli* – with a 25% increase)<br>Ōtūkaikino at Groynes (copper) |
| Linwood Canal | N/A | N/A | N/A | No significant trend | N/A | Copper, zinc, turbidity, DO, DRP, *E. coli* |
| Aylmers Stream | Fair (WQI = 74) | N/A | N/A | N/A | N/A | Copper, zinc, DIN, DRP, *E. coli* |
| Balguerie Stream | Fair (WQI = 76) | N/A | N/A | N/A | N/A | Zinc, DIN, DRP, *E. coli* |
| Stream Reserve Drain | Poor (WQI = 60) | N/A | N/A | N/A | N/A | Copper, zinc, DO, DIN, DRP, *E.coli* |
| Coastal | N/A | N/A | N/A | N/A | Copper | Ihutai – Avon-Heathcote Estuary (copper, zinc)<br>Lyttelton Port (copper)<br>Cass Bay (copper)<br>Akaroa Harbour (copper) |

## 3.6. Wet Weather Monitoring

### 3.6.1. Rainfall

- The total amount of rainfall for the first and second wet weather event was 9 mm and 29 mm, respectively (Error! Reference source not found.).
- Sampling for the first event occurred at 6-9 mm total rainfall depth, which was during the First Flush (15-25 mm). Sampling for the second event occurred at 25-29 mm total rainfall depth, which was after the First Flush. Both sampling events met the criteria of three dry days and a minimum of 5 mm total rainfall depth prior to sampling.
- The concentrations of parameters for the second event may therefore be lower than what typically occurs in waterways during the First Flush.

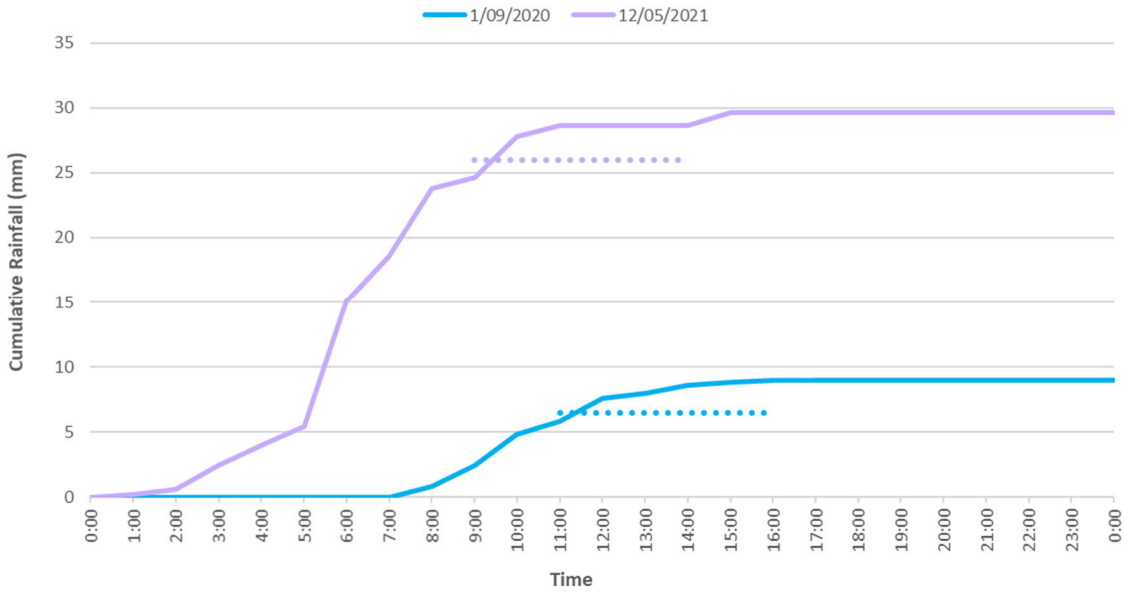


Figure 11. Rainfall during the wet weather events of 1/09/2020 (blue line) and 12/05/2021 (purple line), with approximate sampling times indicated by dotted lines.

### 3.6.1. Water Quality Parameters

- Parameter concentrations were generally higher during the second event for dissolved copper and lead, ammonia, TSS/turbidity, temperature, DRP, and *E. coli*, variable between events for zinc, pH, and $BOD_5$, and typically higher in the first event for conductivity, dissolved oxygen, and nitrate/DIN (Figures 12– 15).
- The parameters with higher concentrations in the second event are mostly stormwater derived. The higher nitrate concentrations in the first event are likely due to groundwater inputs, which were assumed to be diluted in the second event due to stormwater inputs. Both these results highlight that the second event was a good indication of the First Flush of contaminants, but that the first event may not have caught the peak of stormwater contaminants and may therefore underestimate concentrations.
- The guidelines were not met for:

  - Dissolved copper at Curlett at Motorway (both events), Curlett U/S of Heathcote (first event), and Heathcote at Catherine St (second event).
  - Dissolved zinc at Curlett at Motorway (both events), Cashmere at Sutherlands (first event), Cashmere at Worsleys Rd (both events), Heathcote at Ferniehurst St (first event), and Heathcote at Catherine St (second event).
  - TSS at most sites for one or both events, except Heathcote at Warren Cres and Haytons Stream. Particularly high concentrations were recorded at the Curlett at Motorway (first event: 190 mg/L), Heathcote at Rose St (second event: 360 mg/L), and Heathcote at Bowenvale Ave (first event: 120 mg/L) sites.
  - Turbidity at all sites during the second event and most sites during the first event; concentrations were particularly high at the Heathcote at Rose St (second event: 190 FNU) and Heathcote at Bowenvale Ave (first event: 150 FNU) sites.
  - Dissolved oxygen at the following sites: Heathcote at Warren Cres (both events), Curlett U/S of Heathcote (both events), and both Cashmere Stream sites (both events).
  - $BOD_5$ at all sites for one or both events, except for the Cashmere at Worsleys Rd site.
  - Nitrate median at Heathcote at Rose St (first event), Cashmere at Sutherlands (first event), and Cashmere Stream at Worsleys Rd (both events), and the 95$^{th}$ percentile at the Heathcote at Warren Cres site (first event).
  - DIN median at Heathcote at Rose St (second event), Cashmere at Sutherlands (first event), Cashmere Stream at Worsleys Rd (both events), and Heathcote at Ferniehurst St (second event), and the 95$^{th}$ percentile during the first event at the Heathcote at Warren Cres, Heathcote at Rose St, and lower three Heathcote sites.
  - DRP at most sites during the second event, and during the first event at both Curlett Road Stream sites and at Heathcote at Catherine St. Concentrations were particularly high at the Heathcote at Warren Cres site during the second event.
  - *E. coli* at the lower six sites during the second event, and during the first event at Curlett at Motorway, and the lower three sites. No *E. coli* samples were associated with a recorded wastewater overflow event.

- Concentrations were generally comparable to the monthly monitoring (which also included rain events), with the following notable exceptions:
  - Dissolved zinc at the Heathcote at Ferniehurst St site was notably higher during the first event.
  - Conductivity was lower during the second event at the Heathcote at Warren Cres, Cashmere at Sutherlands Rd, and Heathcote at Catherine St sites.
  - TSS concentrations at the Curlett at Motorway (first event), Heathcote at Rose St (second event), and Cashmere at Sutherlands (second event) sites were much higher.
  - Turbidity at the Heathcote at Rose St (second event), Cashmere at Sutherlands (second event), and Heathcote at Bowenvale Ave (first event) sites were much higher.
  - DO concentrations were higher at the Cashmere Stream at Sutherlands Rd site during both events.
  - Water temperature was generally lower at all sites during wet weather monitoring.
  - $BOD_5$ was generally higher at most sites during both events.

- Nitrate and DIN were substantially lower at the Heathcote at Warren Cres site during the second event.
- DRP at the Heathcote at Warren Cres, Cashmere at Worsleys Rd, and Heathcote at Catherine St sites were much higher during the second event.
- *E. coli* was much higher at both Cashmere Stream sites during the second event and Heathcote at Bowenvale Ave during both events.

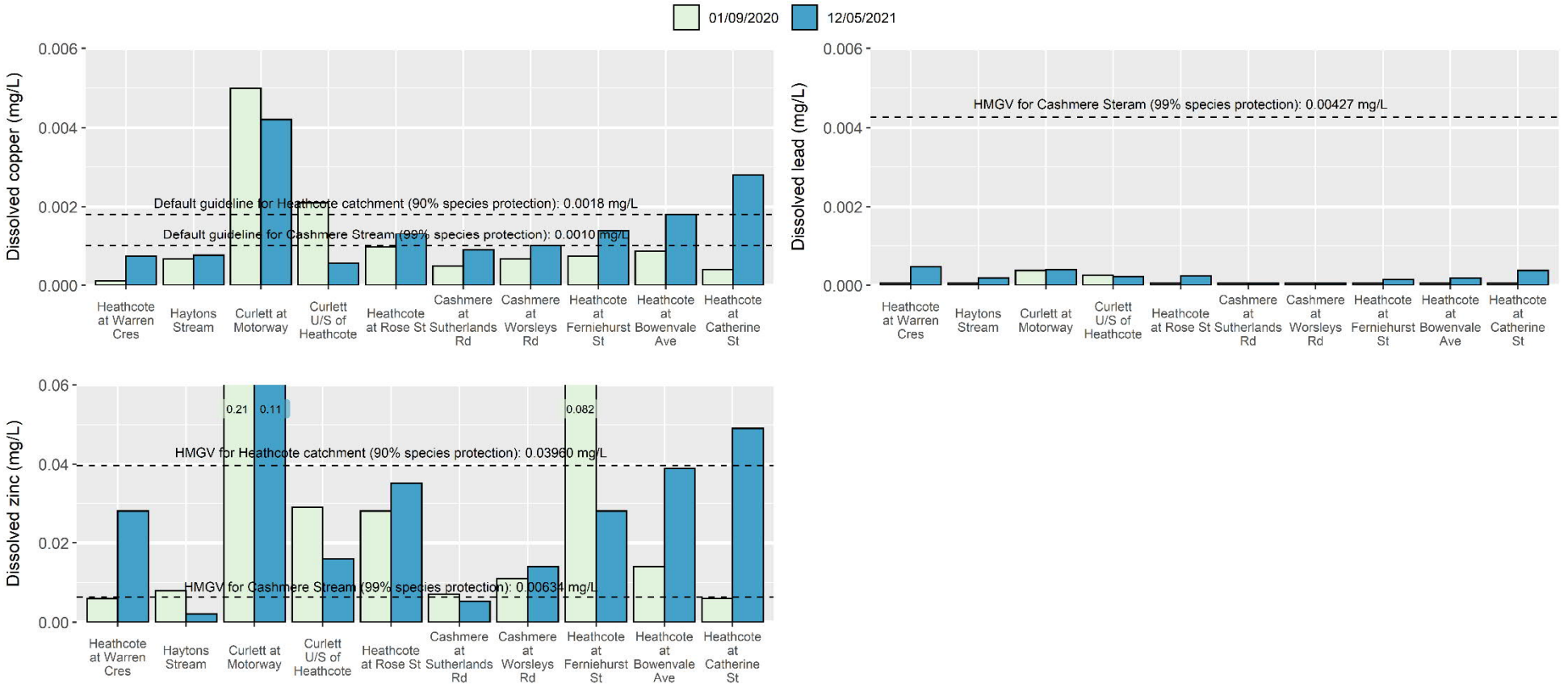


Figure 12. Dissolved copper (top left), lead (top right), and zinc (bottom left) concentrations in water samples taken from the Ōpāwaho-Heathcote River catchment during two wet weather events in 2020/2021. Sites are ordered from upstream to downstream (left to right). The dashed lines represent either the 95% default (copper) or hardness modified (lead, zinc) guideline values as per ANZG (2018).

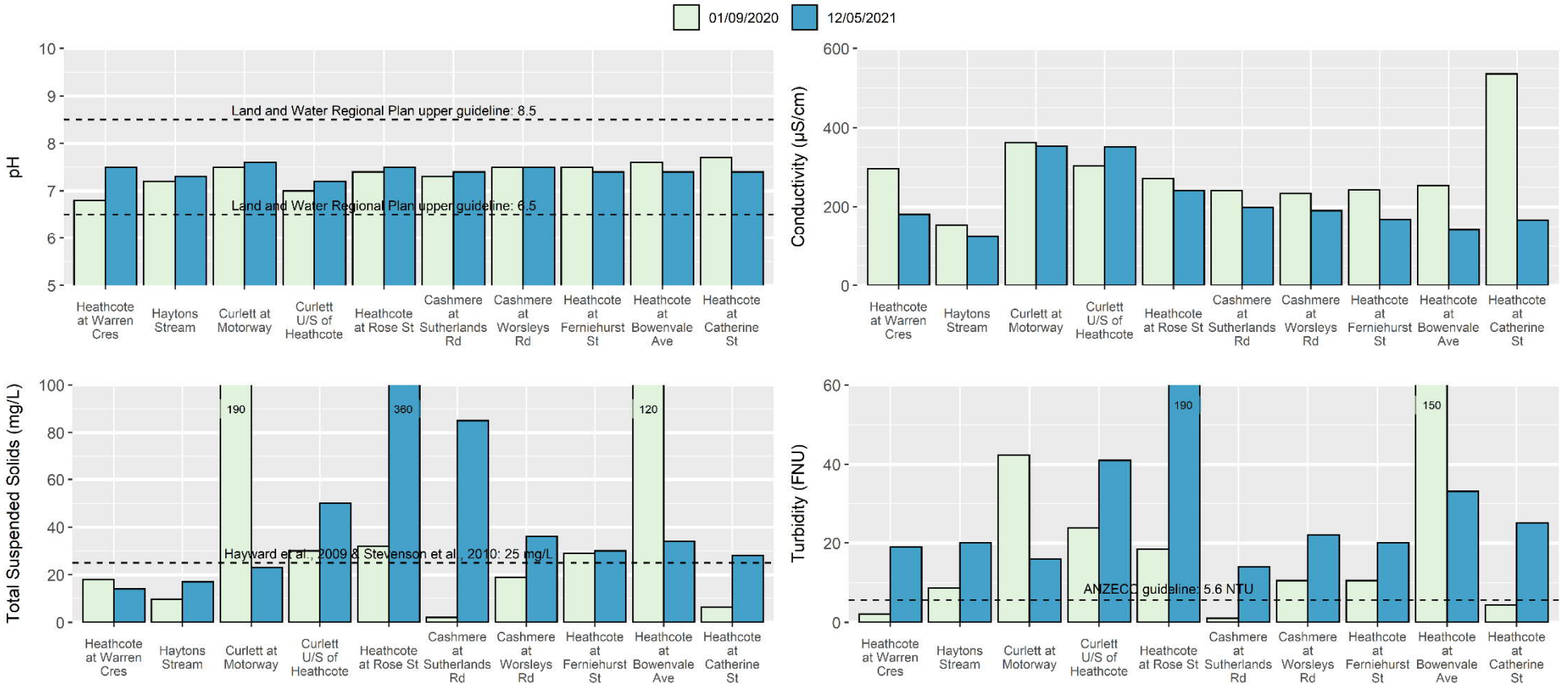


Figure 13. pH (top left), conductivity (top right), Total Suspended Solids (TSS; bottom left) and turbidity (bottom right) concentrations in water samples taken from the Ōpāwaho-Heathcote River catchment during two wet weather events in 2020/2021. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the respective guidelines (pH: Environment Canterbury (2019); TSS: Hayward et al. (2009) & Stevenson et al. (2010); Turbidity: ANZECC (2000)).

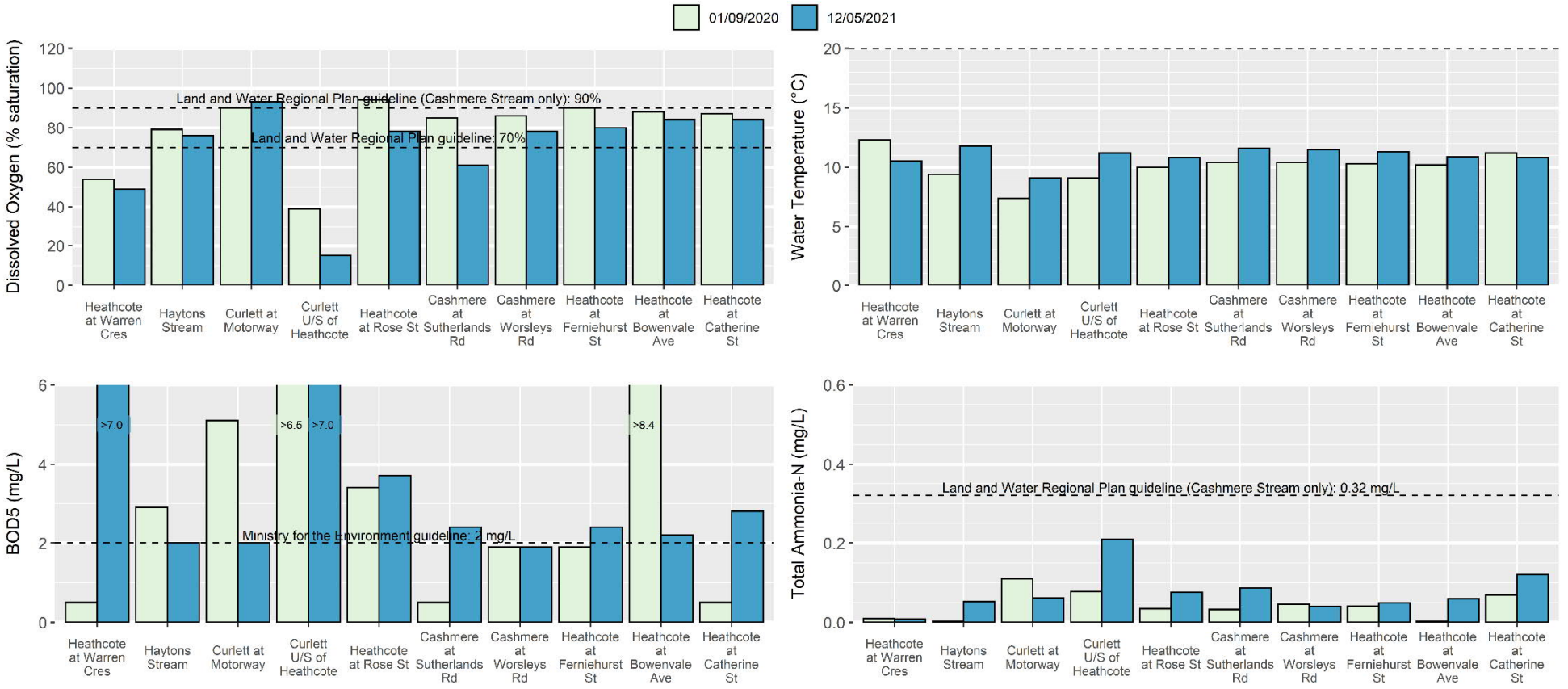


Figure 14. Dissolved oxygen (DO; top left), water temperature (top right), $BOD_5$ (bottom left) and total ammonia-N (bottom right) concentrations in water samples taken from the Ōpāwaho-Heathcote River catchment during two wet weather events in 2020/2021. Sites are ordered from upstream to downstream (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 guideline value for total ammonia-N, adjusted in accordance with median 2020 pH (7.5; Environment Canterbury, 2019), is not visible as it is off the scale (1.61 mg/L).

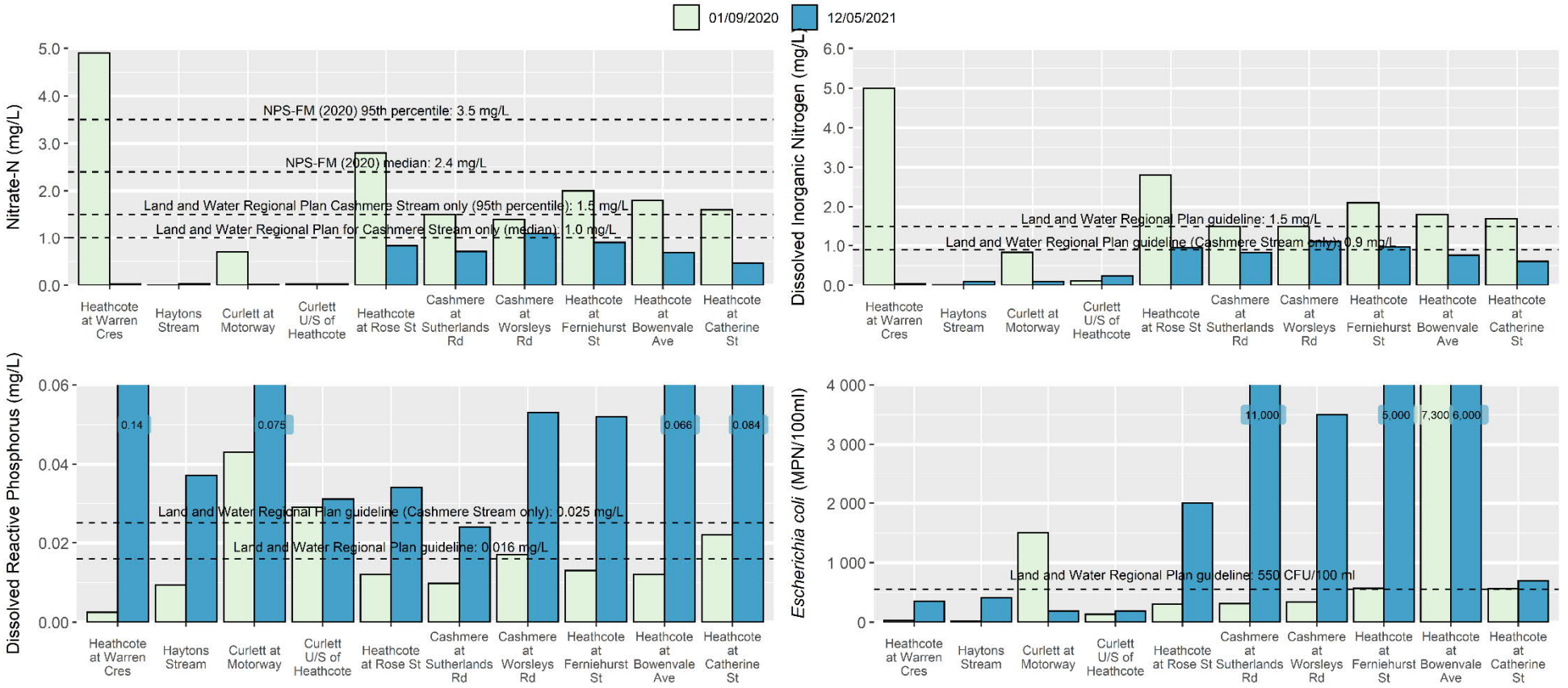


Figure 15. Nitrate-N (top left), Dissolved Inorganic Nitrogen (DIN; top right), Dissolved Reactive Phosphorus (DRP; bottom left), and *E. coli* (bottom right) concentrations in water samples taken from the Ōpāwaho-Heathcote River catchment during two wet weather events in 2020/2021. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the respective guidelines (Nitrate-N: Cashmere Stream (Environment Canterbury, 2019), remaining sites (NPS-FM); DIN, DRP, and *E. coli*: Environment Canterbury, 2019).

# 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, pH, water temperature, $BOD_5$, and total ammonia. However, 17% of samples (3,490 of 21,182 samples) did not meet the guideline levels. The parameters that were exceeded in the most samples were DRP (56%), DIN (38%), *E. coli* (29%) and turbidity (29%). Parameters exceeded at the most sites were *E. coli* (45 sites), dissolved copper (33 sites), DRP (29 sites), and dissolved zinc (28 sites). The concentrations of parameters at the sites have mostly remained steady over time (62%), but some improvements in water quality were recorded this year (28%) and some declines (10%).

Based on these results, the priority parameters to address for improved stormwater management across all catchments include phosphorus (as indicated by DRP), nitrogen (as indicated by DIN), sediment (turbidity), bacteria (as indicated by *E. coli*), dissolved copper, and dissolved zinc. Phosphorus can enter streams through direct sediment inputs, but is also present in stormwater discharges (e.g., due to fertilisers and sediment runoff). Nitrogen, however, is likely not present in waterways due to stormwater discharges, but from spring input of contaminated groundwater due to agricultural practices, and faeces from waterfowl directly using these water bodies. Sediment, whilst natural, has been exacerbated by land use and enters waterways through stormwater discharges. 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. Dissolved copper and 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.

## 4.2. Priority Catchments and Sites for Stormwater Management

Based on the WQI, the Ōtūkaikino and Pūharakekenui-Styx River catchments generally had 'good' water quality; however, all other catchments generally had 'fair' or 'poor' water quality. The Ōtūkaikino River recorded the best overall water quality out of all the catchments. The best site was Ōtūkaikino at Groynes, followed jointly by Smacks at Gardiners Rd, Waimairi Stream, Avon at Carlton Mill and Wilsons Stream, and then Styx at Gardiners Rd.

The catchment recording the worst water quality was the Huritini-Halswell River, followed by Ōpāwaho-Heathcote River. This is the first year since reporting began in this manner for the 2014 monitoring year that the Ōpāwaho-Heathcote River is not the worst catchment. Last year the Huritini-Halswell River was third worst and this catchment has on occasion over the years been in the top three, but never first. This change appears to be due to a combination of (a) the WQI this year including nitrate, rather than the lower NNN guideline, reducing the number of guideline exceedances in the Ōpāwaho-Heathcote River and other catchments, (b) the addition of the Wroots Rd site into the Huritini-Halswell River catchment this year, which recorded the sixth lowest WQI score, pulling down the catchment median score, (c) the Huritini-Halswell River catchment recording higher levels of contaminants compared to previous years (particularly at Nottingham Stream, due to dissolved zinc, DO, TSS, and *E. coli* exceedances), (d) the Ōpāwaho-Heathcote River recording lower levels of contaminants compared to previous years (Figure 9), and (e) the removal of strongly tidal sites from the WQI calculation due to coastal guidelines being more appropriate (WQI is not calculated for coastal sites).

The worst sites were Curlett at Motorway, then Nottingham at Candys Rd and Haytons Stream. There were several contaminants of concern at these sites (Curlett at Motorway: copper, zinc, turbidity, DO, DRP, and *E. coli*; Nottingham at Candys Rd: copper, zinc, DRP, and *E. coli*; Haytons Stream: copper, zinc, turbidity, DRP and *E. coli*). The Nottingham stream site is not typically reported as one of the worst sites (2014–2019 data). The worst sites have typically all been in the Ōpāwaho-Heathcote River catchment, within Curlett Stream, Haytons Stream, and the lower tidal sites of the river. This change is likely due to a combination of (a) the WQI this year including nitrate, rather than the lower NNN guideline, reducing the number of guideline exceedances in the Ōpāwaho-Heathcote River catchment, (b) Nottingham at Candys Rd recording higher levels of contaminants compared to previous years, (c) the Ōpāwaho-Heathcote River recording lower levels of contaminants compared to previous years (Figure 9), and d) the removal of strongly tidal sites from the WQI calculation.

Significant declines in WQI scores over time were recorded at the Avon at Dallington Rd and Avon at Mona Vale sites (both by 7%). This change was predominately due to an increase in the percentage of parameters not meeting the relevant guideline. Parameters of concern causing this change at the Avon at Dallington Rd site were $BOD_5$, dissolved copper, dissolved zinc, DO, *E. coli*, and TSS, while at the Avon at Mona Vale site they were $BOD_5$, dissolved copper, dissolved zinc, DRP, and TSS. A significant improvement in WQI scores was recorded at the Haytons Stream site (10%). The improvement in WQI was due to a decrease in the percentage of parameters and samples not meeting the relevant guideline. The main parameters driving the improvement were dissolved copper, dissolved zinc, ammonia, $BOD_5$ and *E. coli*.

The six waterway sites located in proximity to main stormwater outfalls generally did not appear to record differing results compared to the other waterway sites. This could be due to (a) many of the other sites being located in waterways saturated with stormwater 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. The exception to this was Curlett at Motorway, which generally recorded worse levels of contaminants than other waterway sites (for copper, zinc, pH, dissolved oxygen, $BOD_5$ and DRP). Haytons Stm also recorded worse concentrations of DO and $BOD_5$ compared to the other waterway sites, as did Avon at Mona Vale, Heathcote at Catherine St, and Heathcote at MacKenzie Ave occasionally for TSS.

Thirty-two of the 51 sites triggered further investigations under the CSNDC, due to not meeting the ATLs for TSS, copper, lead, and zinc. As per Section 3.4, these sites are prioritised to four: Curlett at Motorway and Heathcote at Ferrymead Bridge (Ōpāwaho-Heathcote River catchment), Addington Brook (Ōtākaro-Avon River catchment), and Nottingham at Candys Rd (Huritini-Halswell River catchment).

# 5. Recommendations

- The following four sites are prioritised for water quality investigations to determine contaminant sources, due to not meeting CSNDC ATLs: Curlett at Motorway and Heathcote at Ferrymead Bridge (Ōpāwaho-Heathcote River catchment), Addington Brook (Ōtākaro-Avon River catchment), and Nottingham at Candys Rd (Huritini-Halswell River catchment).
- Curlett Stream, Nottingham Stream, Haytons Stream, and Addington Brook are prioritised for contaminant source control and stormwater treatment:
    - CCC and 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.
    - The CSNDC targeted wet weather monitoring project should continue to focus on Curlett Stream and Haytons Stream. In time as resources allow, the project should

extend to Addington Brook. ECan have wet weather monitoring data in this catchment that should be assessed as a starting point.
    - The recommendations within the ECan catchment management plan for Addington Brook and the Haytons Stream Action Plan should be undertaken.
    - Stormwater treatment by the large CCC facilities proposed for Addington Brook and Riccarton Main Drain should be prioritised.
    - CCC should prioritise providing stormwater treatment in the Nottingham Stream catchment, as none currently exists. Very preliminary planning is currently being undertaken.
- A dry weather discharge investigation is carried out jointly by CCC and ECan, to identify if there are contaminants entering the stormwater system outside of stormwater events and to pinpoint industries for pollution prevention. The Curlett Road Stream and Haytons Stream catchments would be ideal locations for initial investigations. These waterways are already the focus of the CSNDC Targeted Wet Weather Monitoring Project and typically record poor water quality. The Curlett at Motorway site is also recommended for further investigation due to not meeting ATLs.
- An investigation by the Ōtūkaikino River Healthy Waterways and Catchment Plan joint working group is implemented to examine the increasing levels of *E. coli* in the Ōtūkaikino River and ways to mitigate this.
- Construction of the CCC stormwater wetlands in Belfast (Ōtūkaikino River catchment) is prioritised, due to the gradual increase in turbidity recorded in Wilsons Stream.
- Phosphorus sources (e.g., fertilisers or faecal input) in stormwater and how concentrations can be reduced is investigated, due to this contaminant being one of the parameters of concern in the waterways.
- Erosion and sediment control measures continue to be implemented as a priority and further investigations in particular are carried out to determine how to mitigate discharges of loess sediment into the Ōpāwaho-Heathcote River (principally Cashmere Stream).
- 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 cemented through the Community Waterway Partnership[8].
- CCC 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 (e.g., redirection of stormwater to trade waste). For example, CCC currently work with ECan to audit business in key catchments, helping reduce the amount of contaminants entering the stormwater system.
    - Installation of more effective stormwater treatment devices. For example, CCC are constructing a number of stormwater basins for the purpose of flood mitigation and stormwater treatment.
    - Community education. For example, ECan's Stormwater Superhero programme and other stormwater initiatives, and the CCC Community Waterways Partnership.
    - Implementation of new regional and national policies for improving water quality.
- An Action Plan for the CCC Community Outcome for Healthy Water Bodies is developed that considers what we want to achieve for our waterways (this may vary between different people) and what is required to get achieve this. For example, an improvement in stormwater quality may not result in an increase in biodiversity, due to other habitat limitations.

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

# 6. Conclusions

The results of this year's monitoring are largely consistent with those recorded in previous years[9]. This indicates that many of Christchurch's and Banks Peninsula waterways are both 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, copper, zinc, sediment, dissolved oxygen (lack of), and $BOD_5$), 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., bacteria), and may affect water clarity/aesthetics (sediment). Overall, water quality at the monitoring sites is not improving or declining over time.

These results 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).

The priority contaminants to address for improved stormwater management across all catchments include phosphorus, sediment, bacteria, dissolved copper, and dissolved zinc. The catchments for priority focus are the Huritini-Halswell River and the Ōpāwaho-Heathcote River. The waterways requiring particular water quality management are Curlett Road Stream, Nottingham Stream, Haytons Stream, and Addington Brook.

The results of this monitoring trigger further investigations under the CSNDC – it is recommended that all Priority 1 sites are scheduled for investigation. These four sites include: Curlett at Motorway and Heathcote at Ferrymead Bridge (Ōpāwaho-Heathcote River catchment), Addington Brook (Ōtākaro-Avon River catchment), and Nottingham at Candys Rd (Huritini-Halswell River catchment). These sites cover the top three worst catchments recorded this monitoring year and most of the sites recording the poorest water quality.

If the recommendations in this report are implemented (at a bare minimum), surface water quality improvements are anticipated across the City. However, 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.

# 7. Acknowledgements

CCC laboratory staff collected the monthly monitoring samples and Instream Consulting Limited collected the wet weather samples. Dr James Ross (Lincoln University), Ian Jowett (Jowett Consulting), Dr Amy Whitehead (NIWA), and Dr Jennifer Gadd (NIWA) provided invaluable advice on statistical analyses. Dr Lesley Bolton-Ritchie and Michele Stevenson of ECan provided helpful comments on the draft report.

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

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# 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 | May 2020 |
| | 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[14] |
| | Cashmere Stream at Sutherlands Road | December 2010 |
| | Cashmere Stream at Worsleys Road | January 2007 |
| | Heathcote River at Ferniehurst Street | July 2008[15,16] |
| | 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[17] |
| | Steamwharf Stream | January 2020[18] |
| | Heathcote River at Ferrymead Bridge | January 2007 |
| Pūharakekenui-Styx | Smacks Creek at Gardiners Road | January 2007[19] |
| | 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 |

[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] 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
[15] $BOD_5$ and TSS monitored from October 2008
[16] Dissolved oxygen, total ammonia, conductivity, E. coli, nitrogen parameters, pH, DRP and water temperature monitored from October 2008
[17] Enterococci monitored from January 2020
[18] Salinity monitored from July 2020
[19] Dissolved oxygen monitored from March 2007

| Catchment | Site Description | Monitoring Instigated |
|---|---|---|
| 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 | May 2020 |
| Akaroa Harbour | Akaroa Harbour at the Termination of Rue Balguerie | May 2020 |

# 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 ,2018); HMTV = Hardness Modified Trigger Value; LWRP = Land and Water Regional Plan (Environment Canterbury, 2015); NPS-FM = National Policy Statement for Freshwater Management (New Zealand Government, 2020); RCEP = Regional Coastal Environment Plan (Environment Canterbury, 2012).

| Parameter | Environmental Concern | Waterway Guideline Level | Coastal Guideline Level |
|---|---|---|---|
| Dissolved copper | Negatively affect fecundity, maturation, respiration, physical structure, and behaviour of aquatic species (Harding, 2005) | ANZG (95$^{th}$ percentile, not medians):<br>• Ōtākaro-Avon and Ōpāwaho-Heathcote River catchments (90% species protection: ≤0.0018 mg/L<br>• Huritini-Halswell, Pūharakekenui-Styx and Ōtūkaikino River catchments (95% species protection): ≤0.0014 mg/L<br>• Cashmere Stream and Banks Peninsula waterways (99% species protection): ≤0.001 mg/L | ANZG (95$^{th}$ percentile, not medians):<br>• ≤0.0013 mg/L |
| Dissolved lead | | ANZG HMGV (95$^{th}$ percentile, not medians):<br>• Ōtākaro-Avon River catchment (90% species protection): ≤0.01539 mg/L<br>• Ōpāwaho-Heathcote River catchment (90% species protection): ≤0.02388 mg/L<br>• Cashmere Stream (99% species protection): ≤0.00427 mg/L<br>• Huritini-Halswell River catchment (95% species protection): ≤0.01089 mg/L<br>• Pūharakekenui-Styx River catchment (95% species protection): ≤0.00601 mg/L<br>• Ōtūkaikino River catchment (95% species protection): ≤0.00414 mg/L | ANZG (95$^{th}$ percentile, not medians):<br>• ≤0.0044 mg/L |

| | | | |
|---|---|---|---|
| | | ANZG default (95th percentile, not medians)[20]:<br>• Banks Peninsula: ≤0.001 mg/L | |
| Dissolved zinc | | ANZG HMGV (95th percentile, not medians):<br>• Ōtākaro-Avon River catchment (90% species protection): ≤0.02951 mg/L<br>• Ōpāwaho-Heathcote River catchment (90% species protection): ≤0.0396 mg/L<br>• Cashmere Stream (99% species protection: ≤0.00634 mg/L<br>• Huritini-Halswell River catchment (95% species protection): ≤0.01743 mg/L<br>• Pūharakekenui-Styx River catchment (95% species protection): ≤0.01172 mg/L<br>• Ōtūkaikino River catchment (95% species protection): ≤0.00912 mg/L<br>ANZG default (95th percentile, not medians)[21]:<br>• Banks Peninsula: ≤0.0024 mg/L | ANZG (95th percentile, not medians):<br>• ≤0.015 mg/L |
| Total water hardness and Dissolved Organic Carbon (DOC) | These parameters are mostly relevant to determine the toxicity of other parameters, such as metals | No guidelines exist | Not sampled |
| pH | Appropriate pH levels are essential for the physiological functions of biota, such as respiration and excretion (Environment Canterbury, 2009) | LWRP:<br>• All waterways: 6.5 - 8.5 | ANZECC[22]:<br>• 7.0 - 8.5 |
| Conductivity | May indicate presence of such parameters as nutrients, metals and salinity | No guidelines exist | No guidelines exist |

[20] These are default ANZG (2018) values, as insufficient hardness data was collected this monitoring year to calculate hardness modified values, due to the sites only recently being instigated

[21] These are default ANZG (2018) values, as insufficient hardness data was collected this monitoring year to calculate hardness modified values, due to the sites only recently being instigated

[22] 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

| | | | |
|---|---|---|---|
| Salinity | The amount of salt dissolved in a body of water – relevant to tidal, estuarine and coastal sites | No guidelines exist<br>(only tested at the salinity affected sites: Avon River at Pages Road, Avon River at Bridge Street Bridge, Heathcote River at Tunnel Road, Heathcote River at Ferrymead Bridge, Steamwharf Stream upstream of Dyers Road, Styx River at Harbour Bridge and Linwood Canal) | No guidelines exist |
| 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:<br>• All waterways: ≤25 mg/L | No guidelines exist |
| Turbidity | Turbidity decreases the clarity of the water and can negatively affect stream biota (Ryan, 1991) | ANZECC:<br>• All waterways: ≤5.6 NTU | ANZECC[23]:<br>• ≤10 NTU |
| Water clarity | Low clarity of the water can affect aesthetics and negatively affect stream biota | NPS-FM:<br>• ≥1.55 m[24]<br>(only tested at Styx Living Laboratory Trust sites) | Not sampled |
| Dissolved Oxygen (DO) | Adequate DO levels are essential for aquatic animals, such as fish and invertebrates | LWRP:<br>• 'Spring-fed – plains – urban' and 'spring-fed – plains waterways:' ≥70 %<br>• Banks Peninsula waterways: ≥90 | RCEP:<br>• ≥ 80 % |
| Water temperature | Water temperature that is too low or high can adversely impact aquatic animals, such as fish and invertebrates | LWRP:<br>• All waterways: ≤20ºC | RCEP:<br>• ≤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):<br>• All waterways: ≤2 mg/L | RCEP, excluding The Operational Area of the Port of Lyttelton:<br>• ≤2 mg/L |

[23] 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

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

| | | | |
|---|---|---|---|
| Total ammonia (ammoniacal nitrogen) | High levels can have toxic effects on aquatic ecosystems | LWRP:<br>• Banks Peninsula waterways: ≤0.32 mg/L<br>• All other waterways determined by median catchment pH:<br>o Ōtākaro-Avon River catchment: ≤1.75 mg/L<br>o Opāwaho-Heathcote River catchment: ≤1.61 mg/L<br>o Linwood Canal catchment: ≤1.661 mg/L<br>o Huritini-Halswell River catchment: ≤1.61 mg/L<br>o Pūharakekenui-Styx River catchment: ≤1.88 mg/L<br>o Ōtūkaikino River catchment: ≤1.99 mg/L | Not sampled |
| Nitrate nitrogen | Can be toxic to stream biota at high concentrations (Hickey, 2013) | LWRP:<br>• Banks Peninsula waterways: Median: ≤1.0 mg/L; 95th percentile: ≤1.5 mg/L<br>NPS-FM (2020):<br>• Median: ≤2.4 mg/L; 95th percentile: ≤3.5 mg/L[25] | 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:<br>• 'Spring-fed – plains – urban' and 'spring-fed – plains' waterways: ≤1.5 mg/L<br>• 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:<br>• 'Spring-fed – plains – urban' and 'spring-fed – plains' waterways: ≤0.016 mg/L<br>• 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:<br>• 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 | Ministry for the Environment (2013):<br>• At all measured sites: ≤500 CFU/100 ml (95th percentile, not medians) | Ministry for the Environment (2013)[26]: |

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

[26] These values are more stringent for coastal areas where swimming is likely to occur

| | | | |
|---|---|---|---|
| | | (only tested at the salinity affected sites: Avon River at Pages Road, Avon River at Bridge Street Bridge, Heathcote River at Tunnel Road, Heathcote River at Ferrymead Bridge, Steamwharf Stream upstream of Dyers Road, Styx River at Harbour Bridge and Linwood Canal) | • Ihutai - Avon-Heathcote Estuary, Cass Bay and Akaroa Harbour: ≤200 CFU/100 ml (95$^{th}$ percentile, not medians)<br>• Lyttelton Harbour: ≤500 CFU/100 ml (95$^{th}$ percentile, not medians) |
| 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):<br>• Akaroa Harbour: 14 CFU /100 mL (median) and 43 CFU /100 mL (not exceeded in more than 10% of samples)<br><br>Not sampled at the remaining coastal 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) |

| Group | Parameter | Limit of Detection | Date | Analysis Method |
|---|---|---|---|---|
| | | <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 |
| | Dissolved Inorganic Nitrogen (DIN) | <0.007 mg/L | 1 July 2018 - current day | Total ammonia + Nitrite-Nitrate-Nitrogen |
| | | <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 | | <1 mg/L | 1 July 2018 - current day | APHA 2540 D |

| Group | Parameter | Limit of Detection | Date | Analysis Method |
|---|---|---|---|---|
| | Total Suspended Solids (TSS) | <3 mg/L | September 2010 - 30 June 2018 | APHA 2540 D |
| | | <5 mg/L | Sampling instigation - August 2010 | APHA 2540 D |
| | 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[27] | <0.3 mg/L | Sampling instigation- current day | Extraction DCM (GC-FID) |

[27] Analysed by Watercare Laboratory (IANZ accredited)

# Appendix D

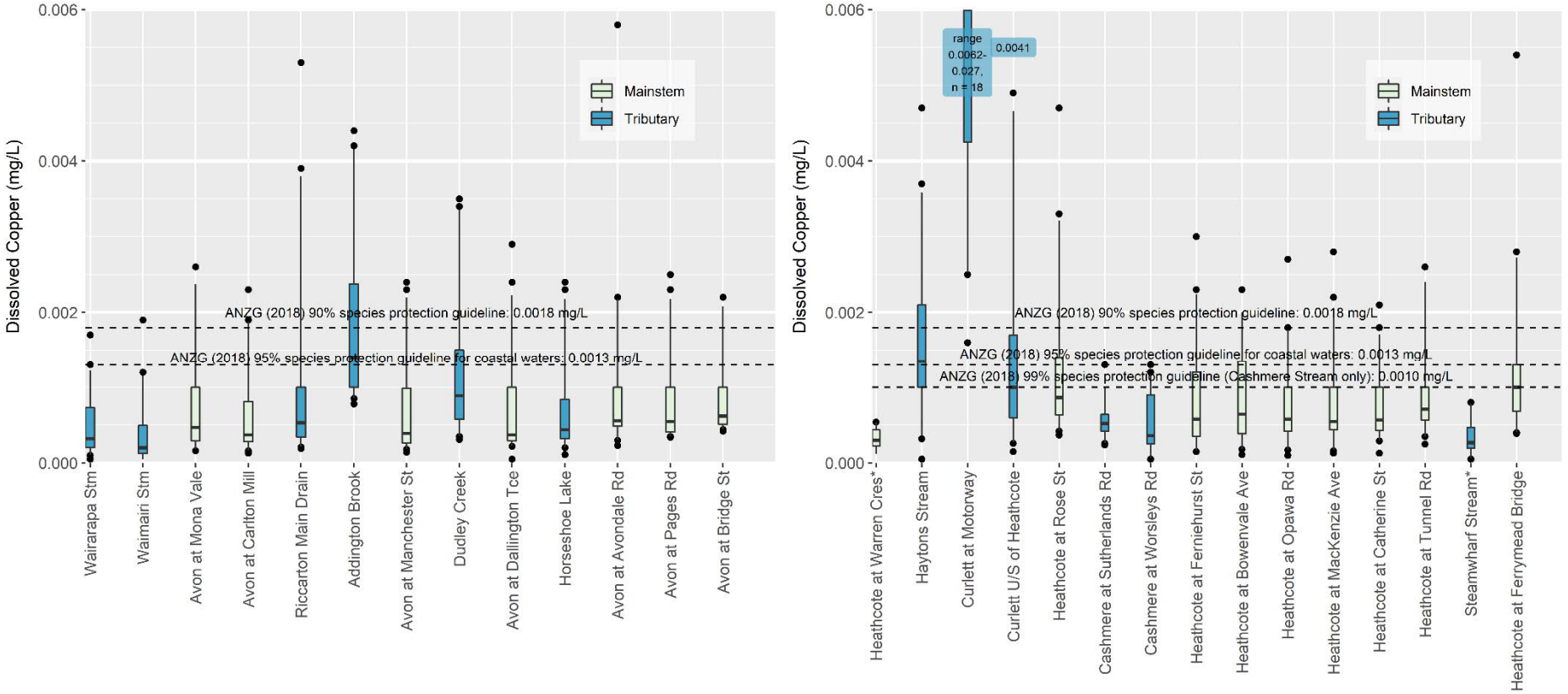


Figure i (c). Dissolved copper concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the ANZG (2018) guideline values. Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) should be compared to the more conservative coastal water guidelines. The Laboratory Limit of Detection was 0.0001 mg/L – analysed as half this value (0.00005 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

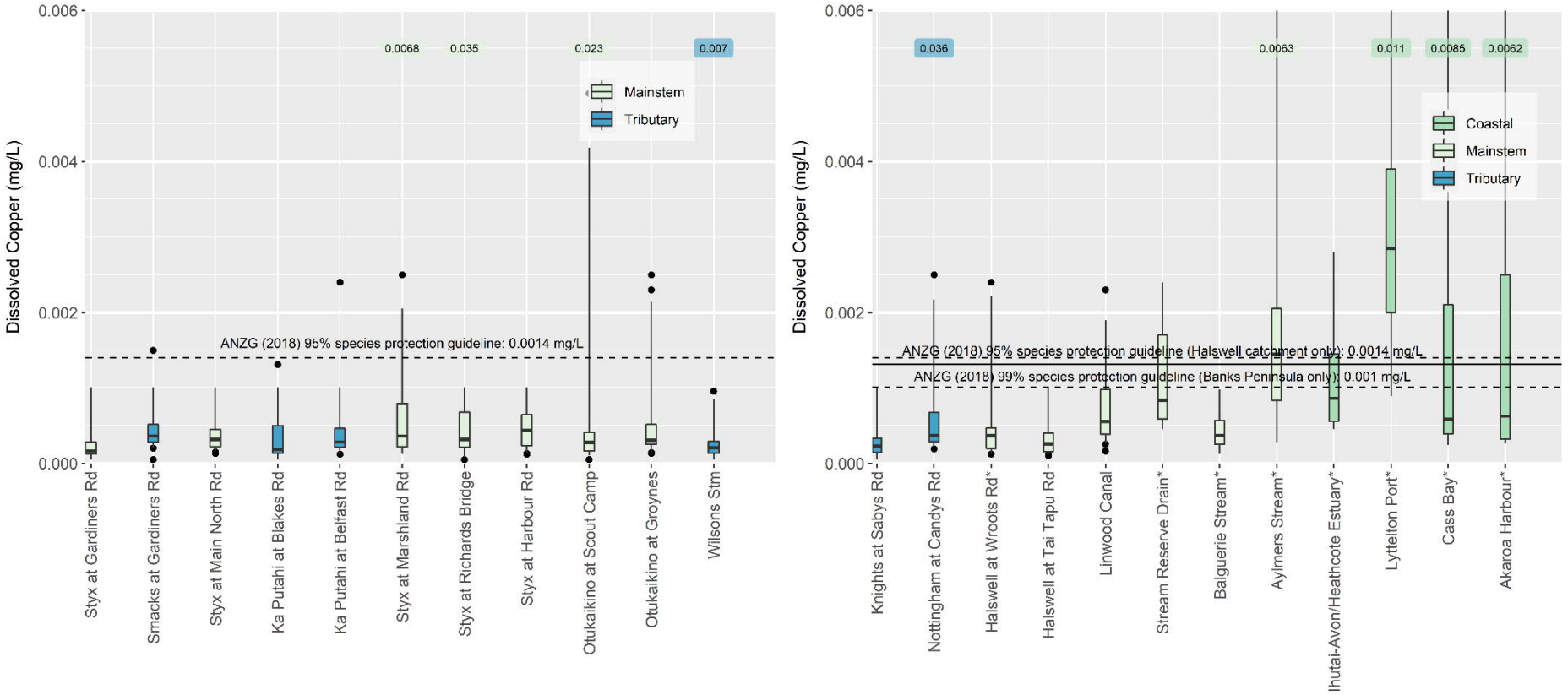


Figure i (d). Dissolved copper concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula, and coastal sites (right graph), for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the ANZG (2018) waterway guideline values. The solid line represents the ANZG (2018) coastal guideline. The strongly tidal Linwood Canal site should be compared to the more conservative coastal water guideline. The Laboratory Limit of Detection was 0.0001 mg/L – analysed as half this value (0.00005 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

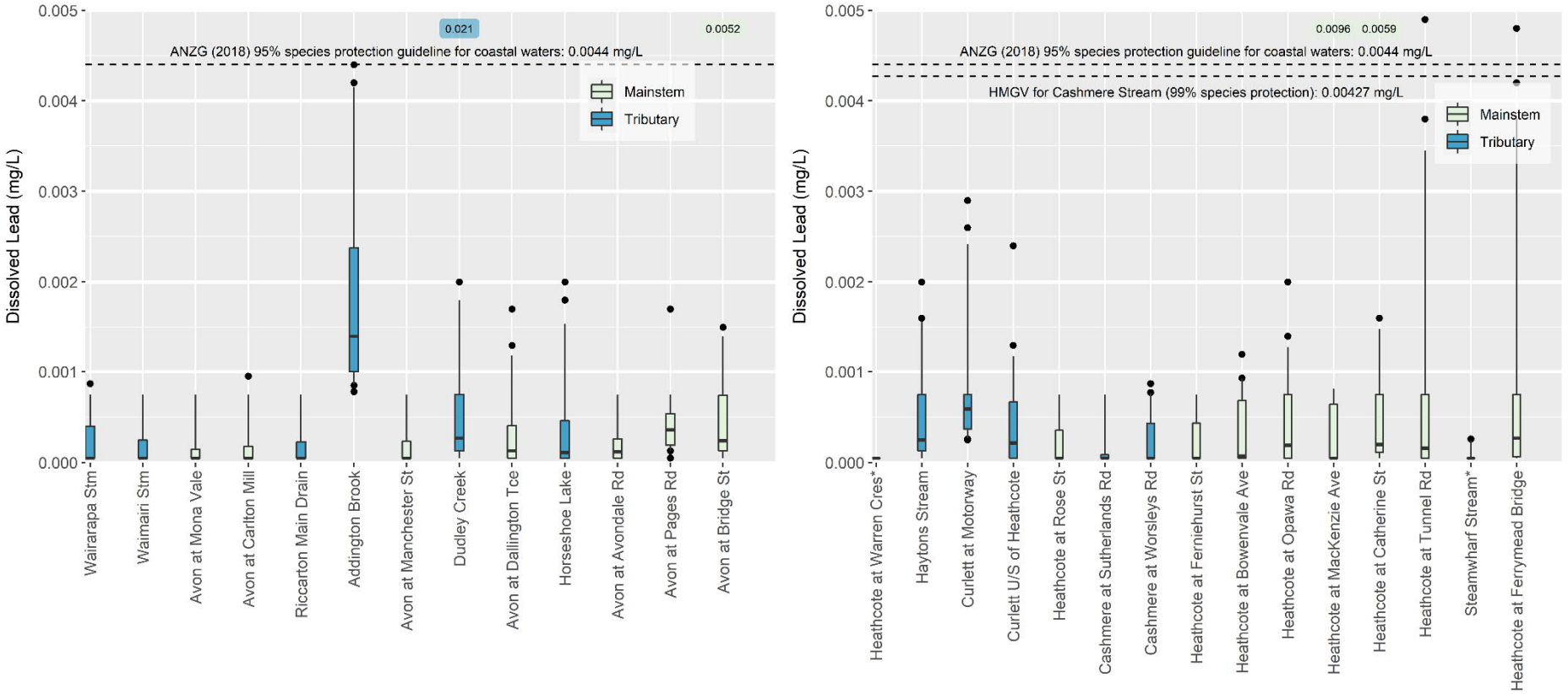


Figure ii (a). Dissolved lead concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the ANZG (2018) 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 more conservative coastal water guidelines. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – analysed as half this value (0.00005 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

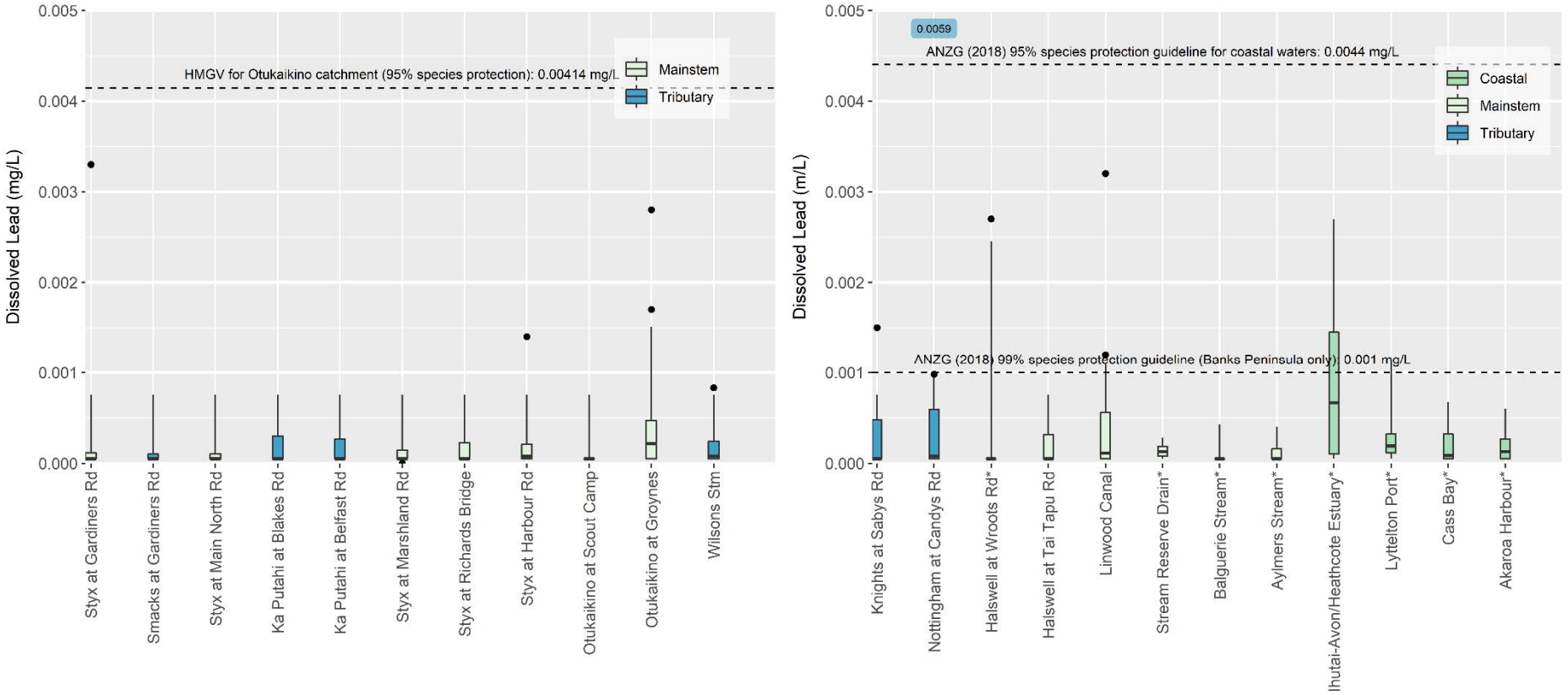


Figure ii (b). Dissolved lead concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the ANZG (2018) 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 more conservative coastal water guideline. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – analysed as half this value (0.00005 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

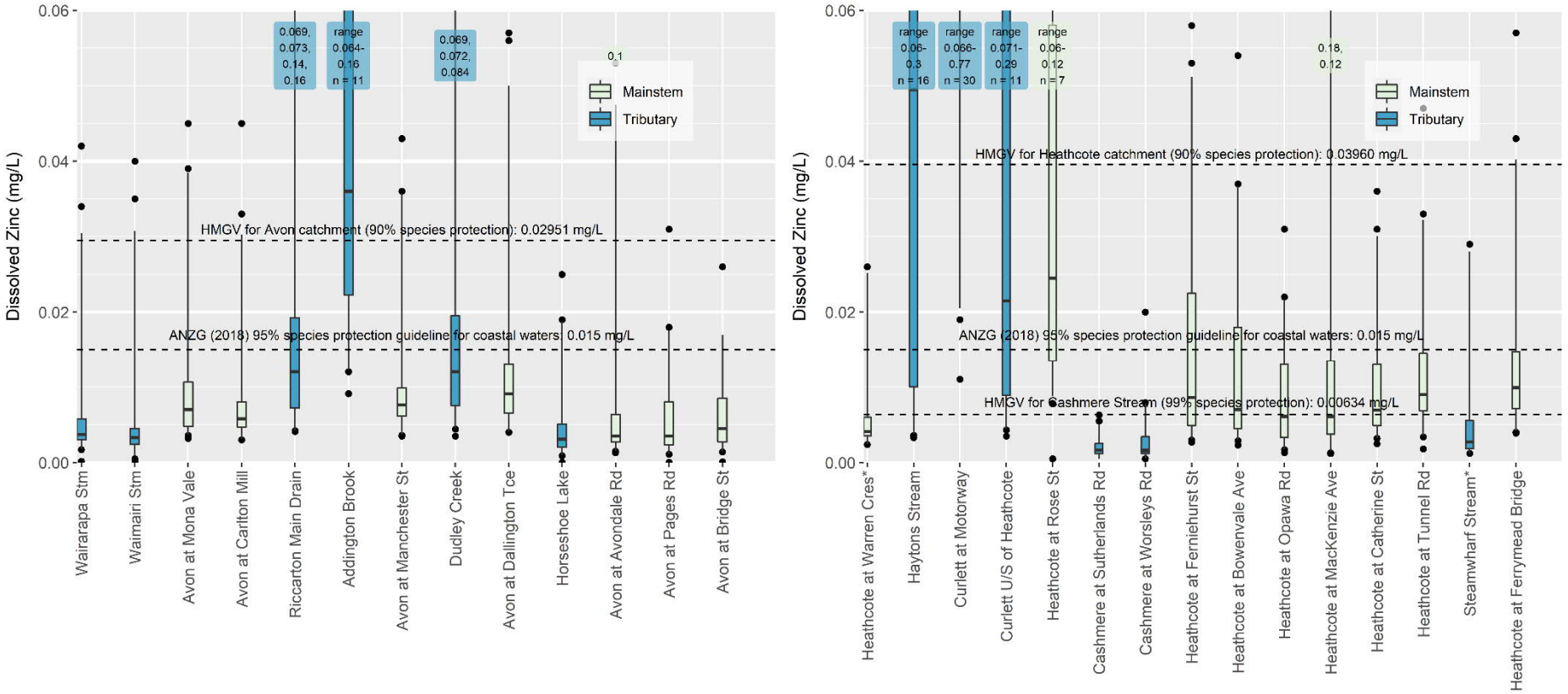


Figure iii (a). Dissolved zinc concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the ANZG (2018) 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 more conservative coastal water guidelines. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – analysed as half this value (0.00005 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

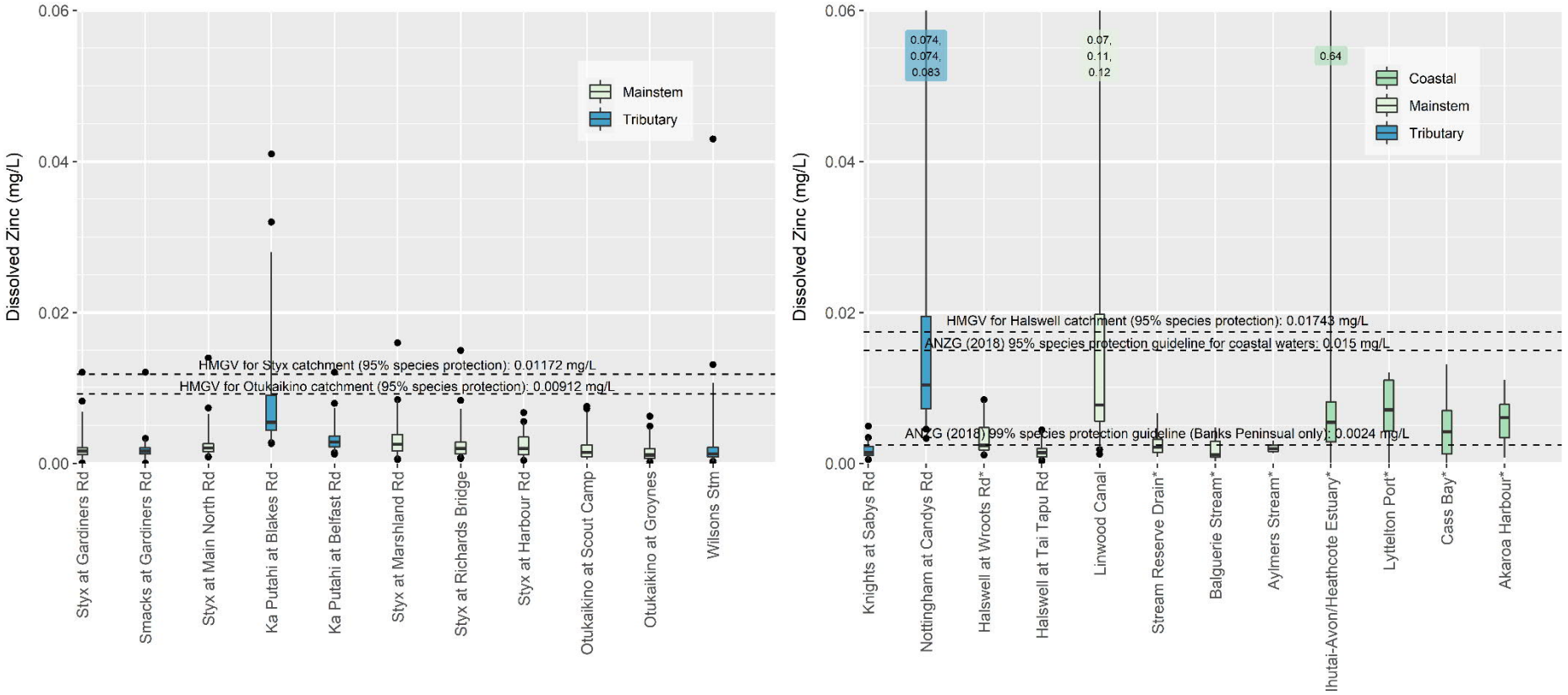


Figure iii (b). Dissolved zinc concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the ANZG (2018) guideline values. The strongly tidal Linwood Canal site is compared to the more conservative coastal water guideline. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – analysed as half this value (0.00005 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

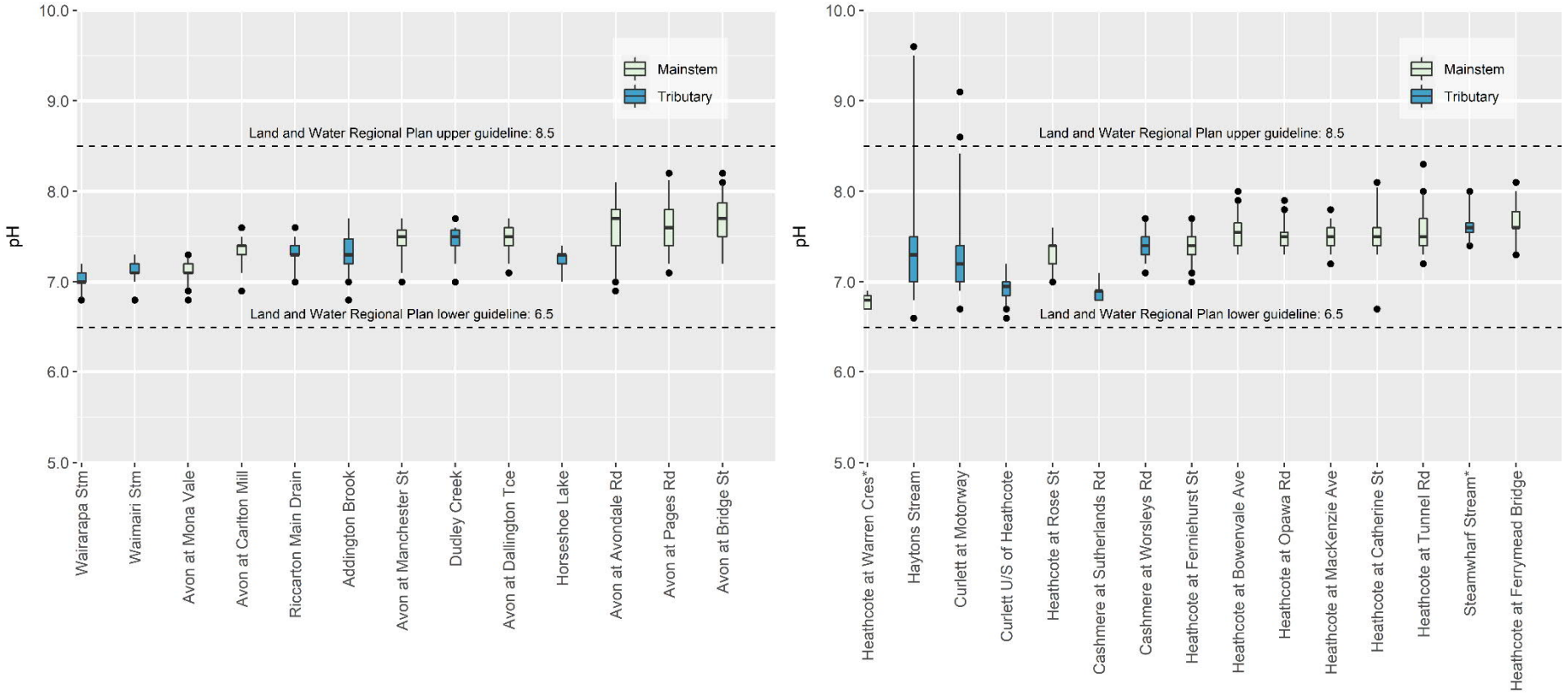


Figure iv (a). pH levels in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the Land and Water Regional Plan lower (6.5) and upper (8.5) limits (Environment Canterbury, 2019) for waterway sites. The numbers in shaded boxes indicate samples that exceeded the y-axis.

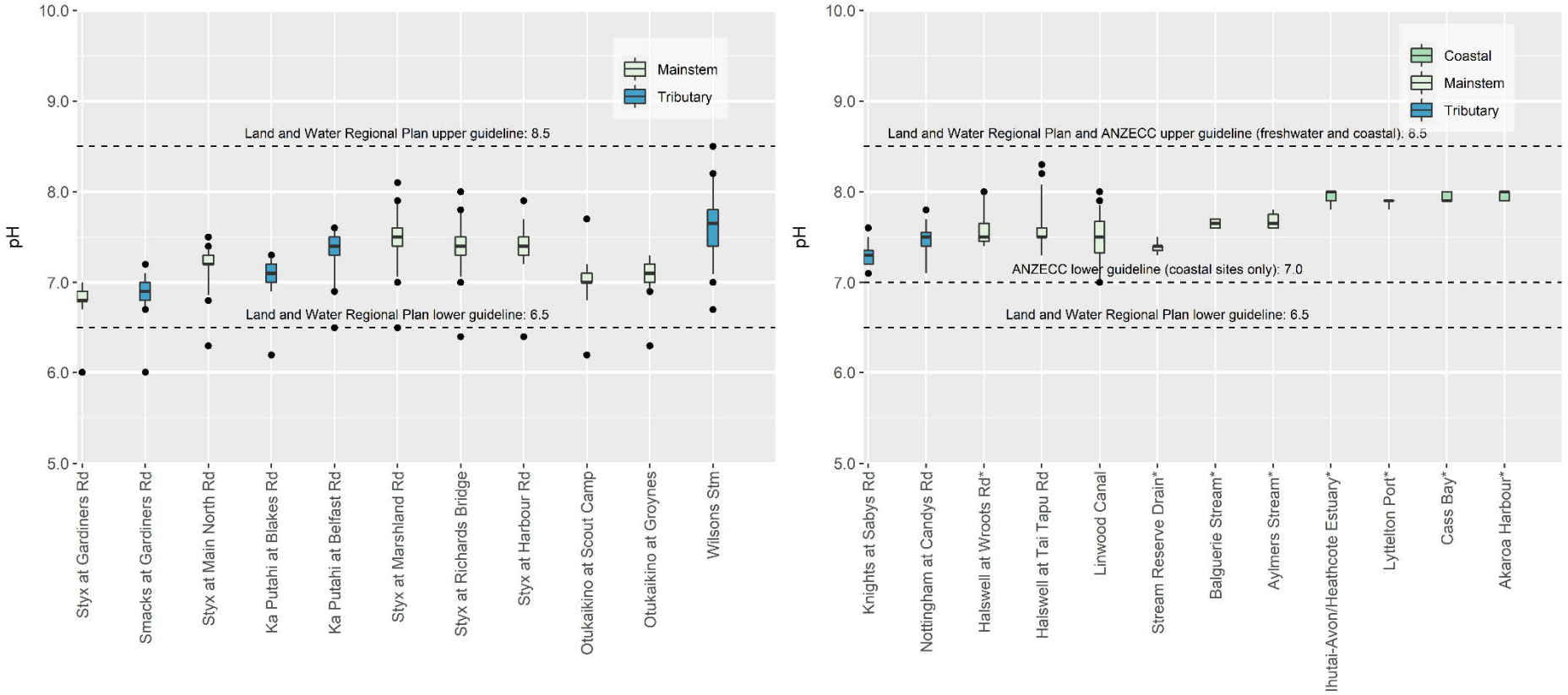


Figure iv (b). pH levels in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the Land and Water Regional Plan lower (6.5) and upper (8.5) limits (Environment Canterbury, 2019) for waterway sites, and the ANZECC (2000) lower (7.0) and upper (8.5) limits for coastal sites. The numbers in shaded boxes indicate samples that exceeded the y-axis.

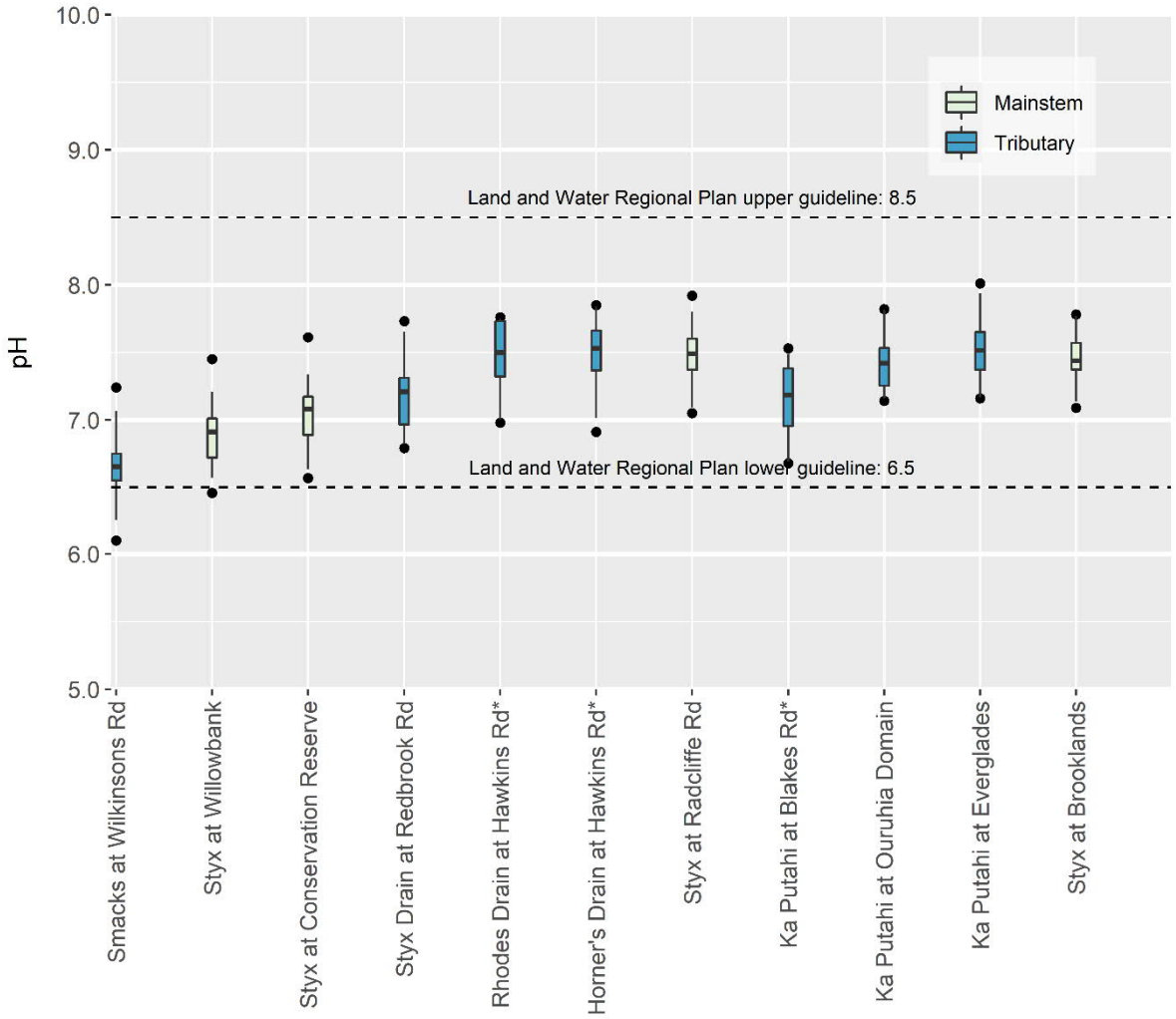


Figure iv (c). pH levels in water samples taken from the Pūharakekenui-Styx River catchment by the Styx Living Laboratory Trust volunteers for the monitoring period January 2018 to December 2020 (n = 19–30 samples per site). Sites with an asterisk indicate where sampling began in 2019. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan lower (6.5) and upper (8.5) limits (Environment Canterbury, 2019).

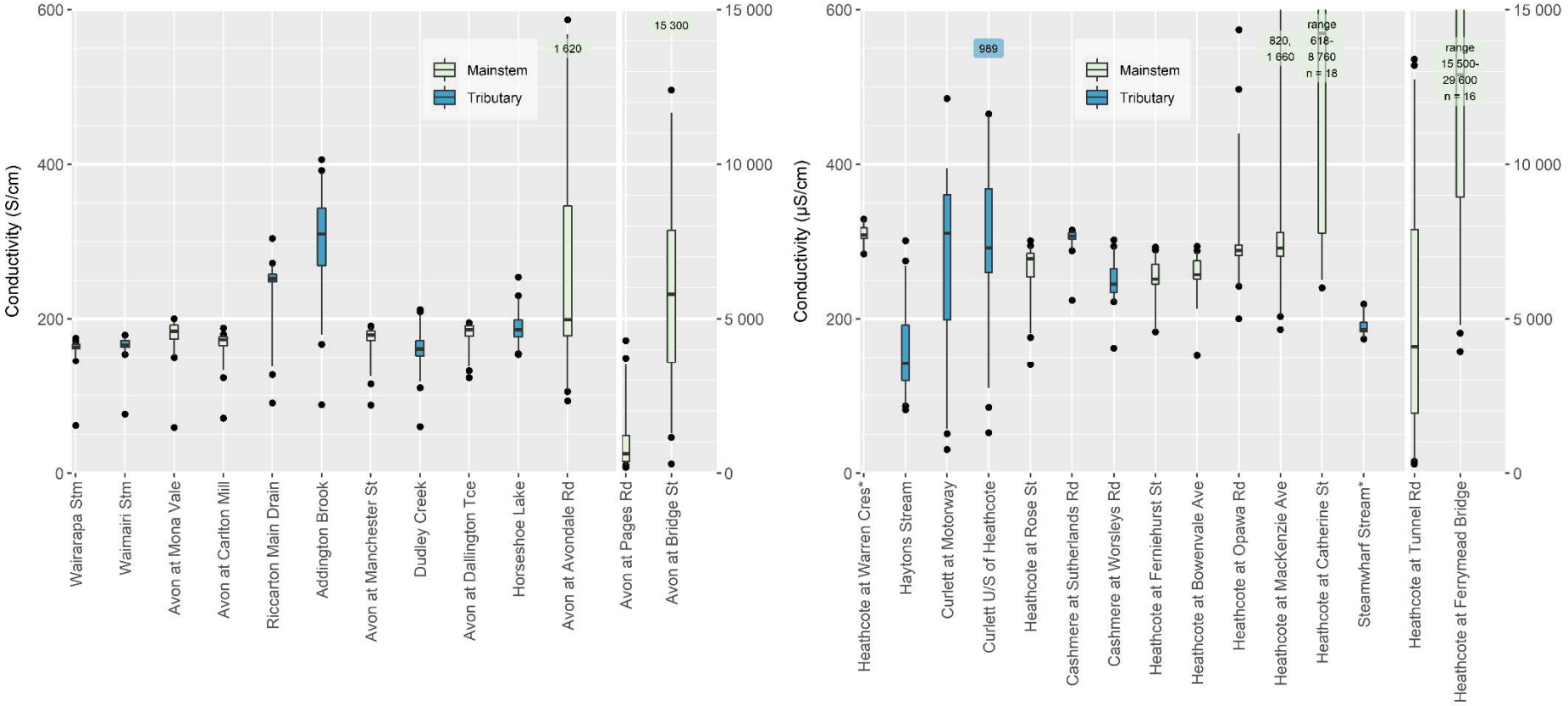


Figure v (a). Conductivity levels in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. Given the large differences in concentrations 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.

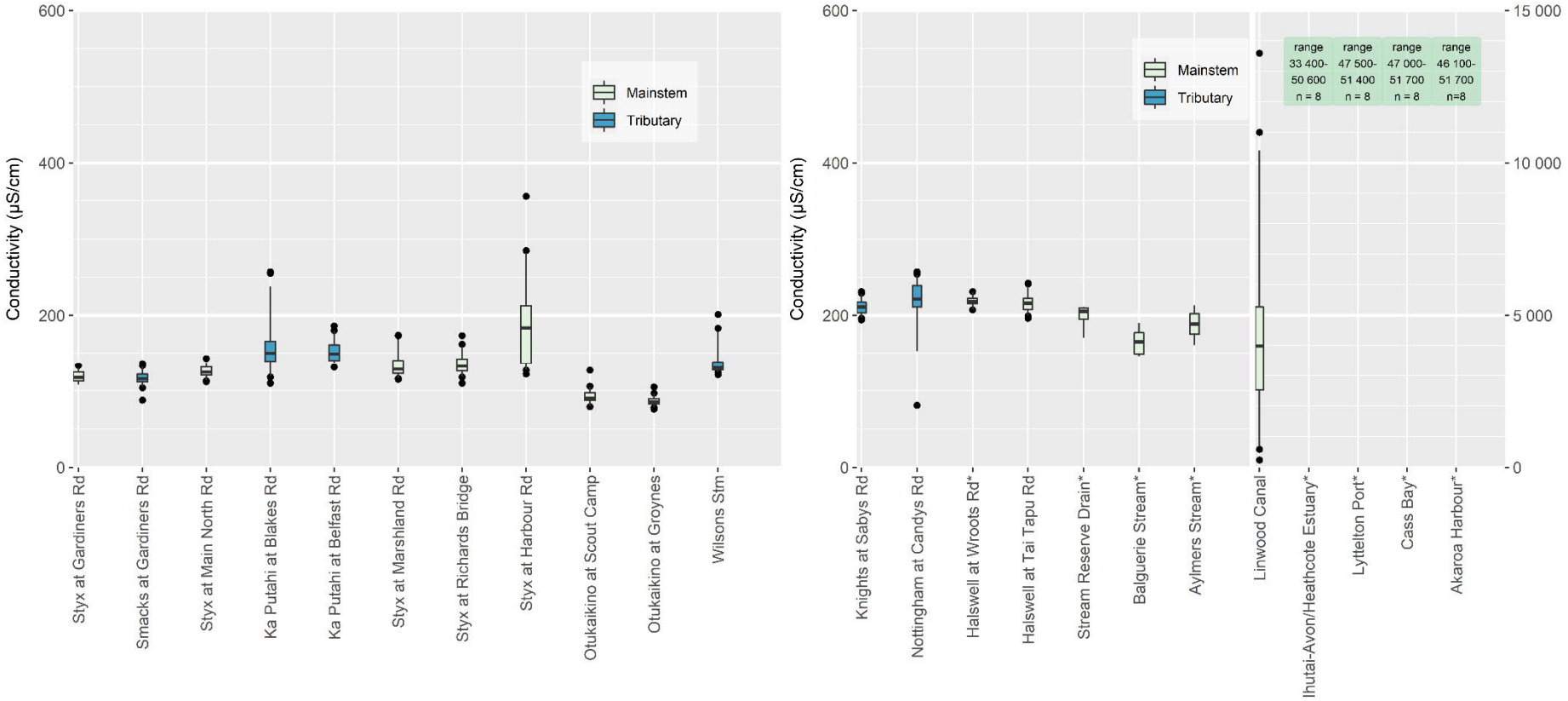


Figure v (b). Conductivity levels in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. 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.

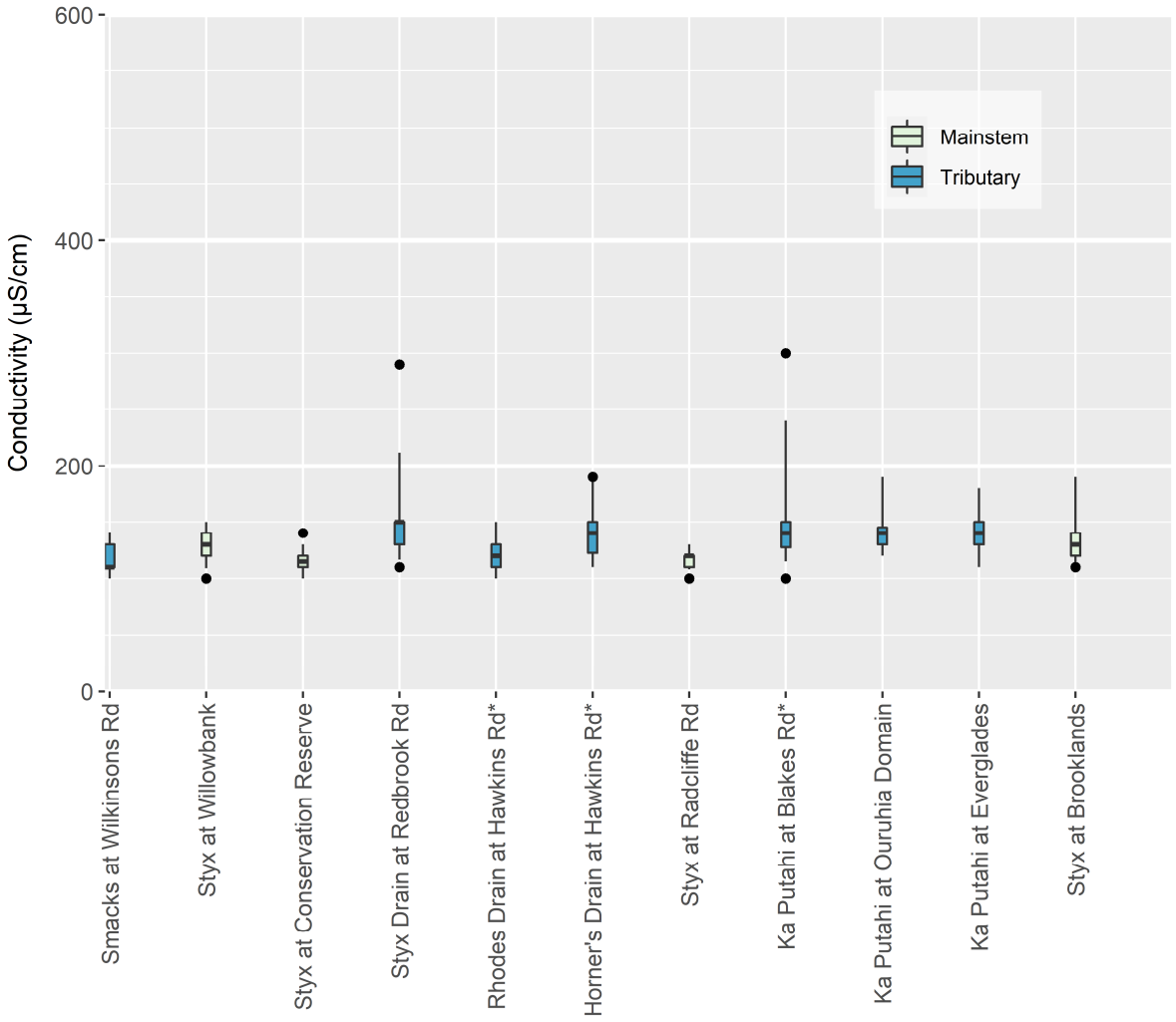


Figure v(c). Conductivity concentrations in water samples taken from the Pūharakekenui-Styx River catchment by the Styx Living Laboratory Trust volunteers for the monitoring period January 2018 to December 2020 (n = 19–30 samples per site). Sites with an asterisk indicate where sampling began in 2019.). Sites are ordered from upstream to downstream (left to right).

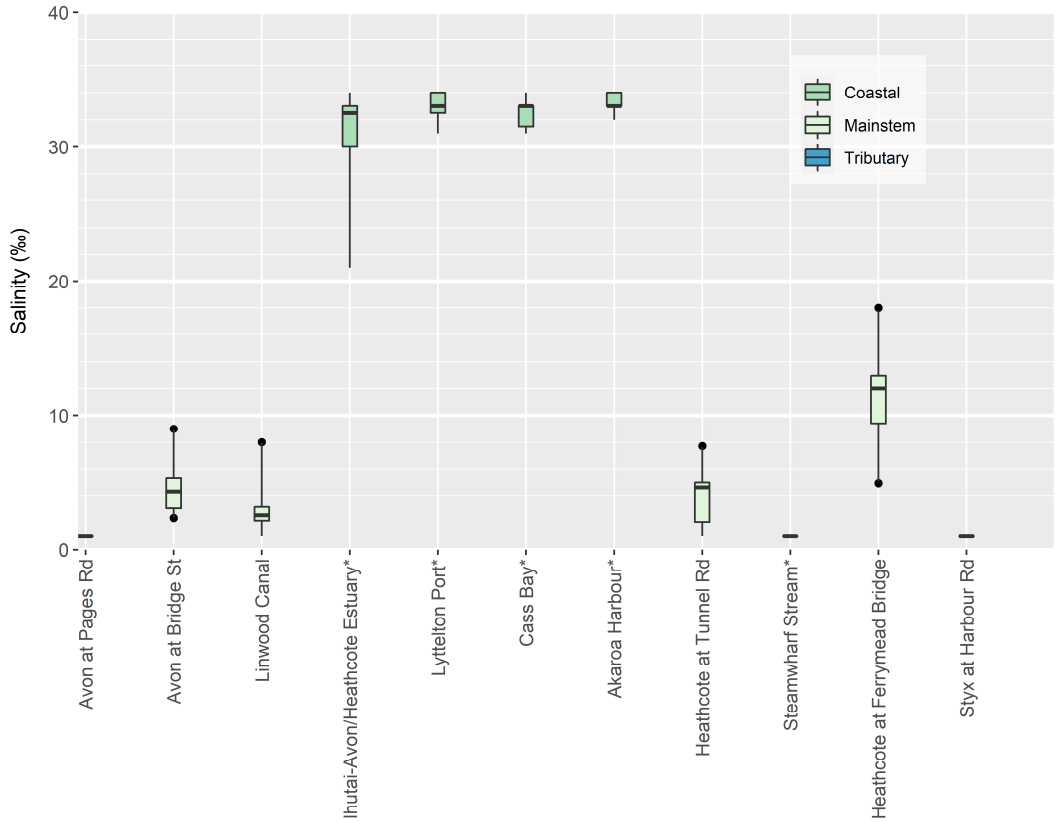


Figure vi. Salinity concentrations in water samples taken from lower tidal waterway and coastal sites, for the monitoring period January to December 2020. Salinity monitoring at these sites was implemented in January 2020, except for Steamwharf Stream (July 2020) and coastal sites (May 2020). The Laboratory Limit of Detection was 2.0‰ – analysed as half this value (1.0‰) to allow statistics to be undertaken.

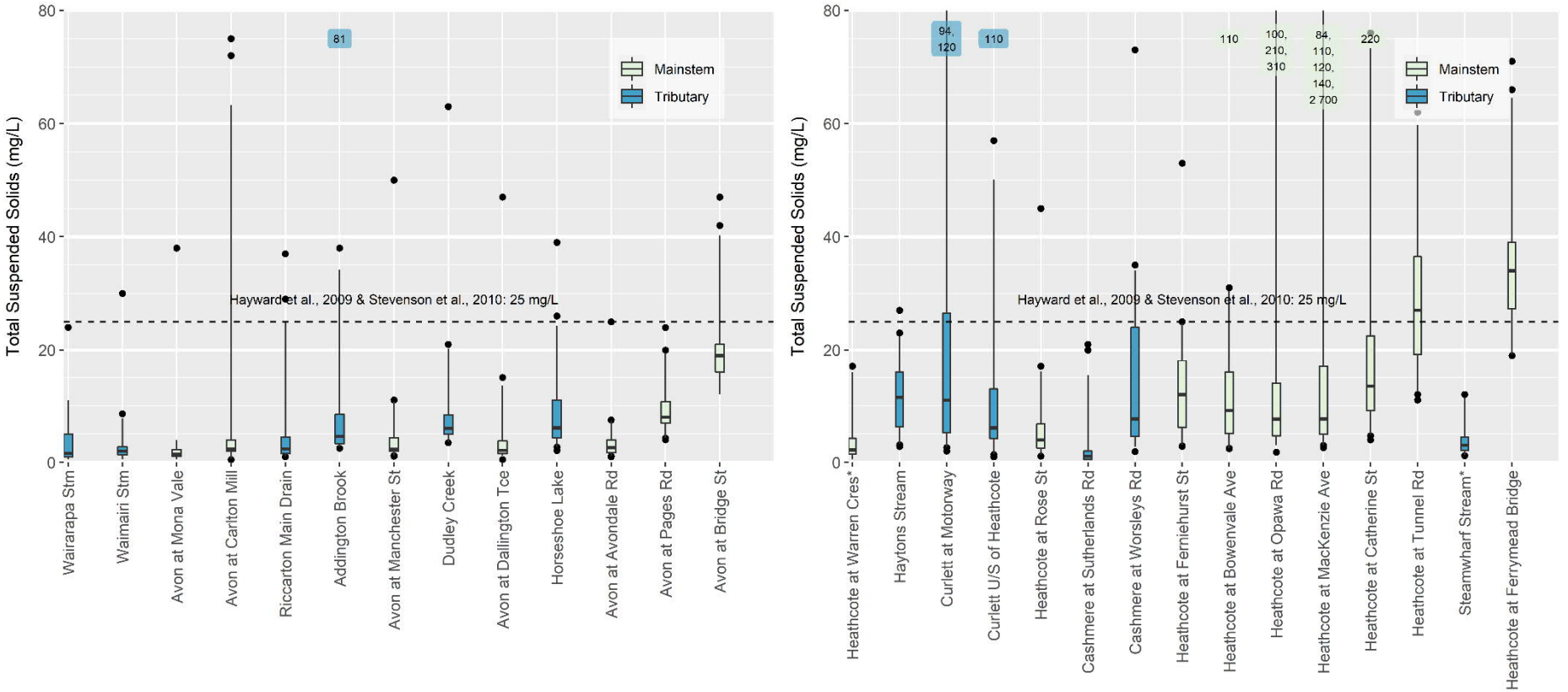


Figure vii (a). Total Suspended Solid (TSS) concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the guideline value of 25 mg/L (Hayward et al., 2009; Stevenson et al., 2010). There is no guideline for coastal sites. The Laboratory Limit of Detection was 1.0 mg/L – analysed as half this value (0.5 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

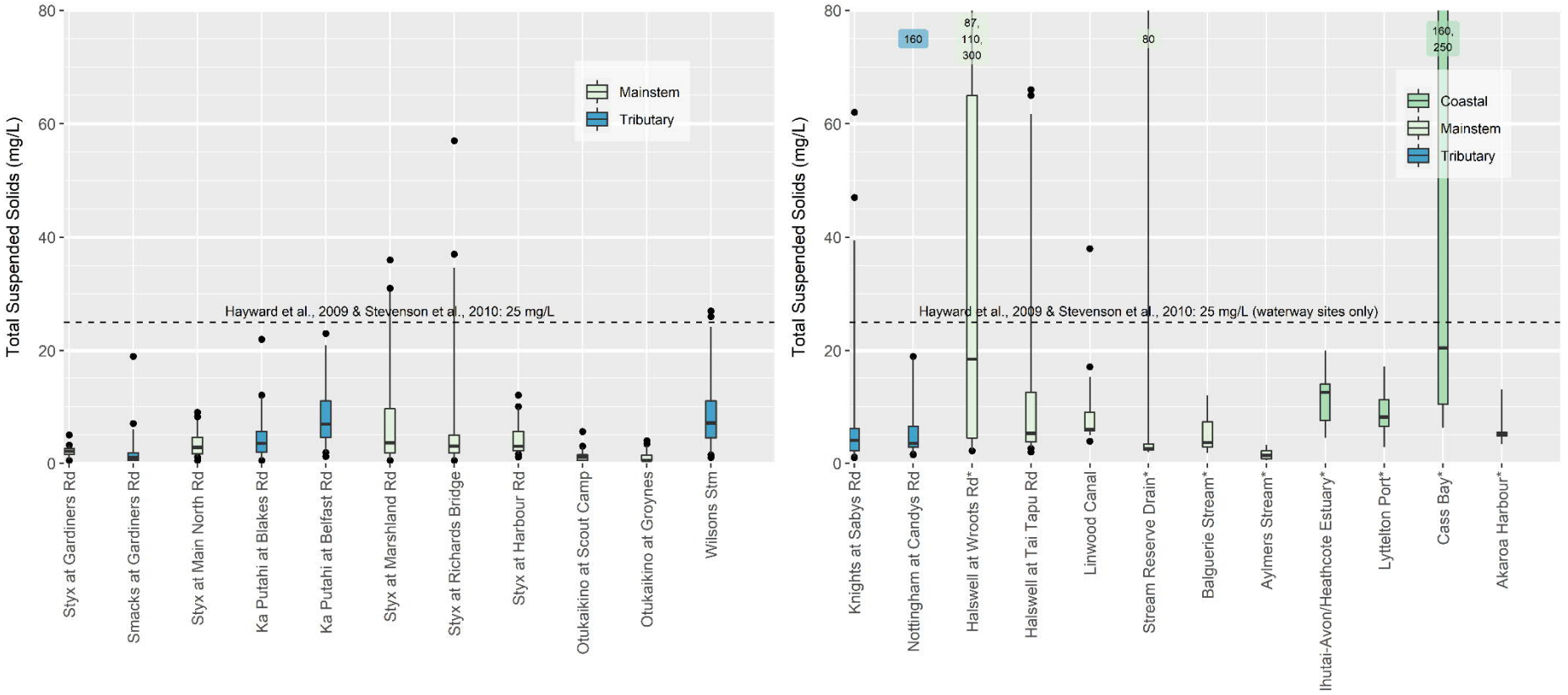


Figure vii (b). Total Suspended Solid (TSS) concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the waterway guideline value of 25 mg/L (Hayward et al., 2009; Stevenson et al., 2010). There is no guideline for coastal sites. The Laboratory Limit of Detection was 1.0 mg/L – analysed as half this value (0.5 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

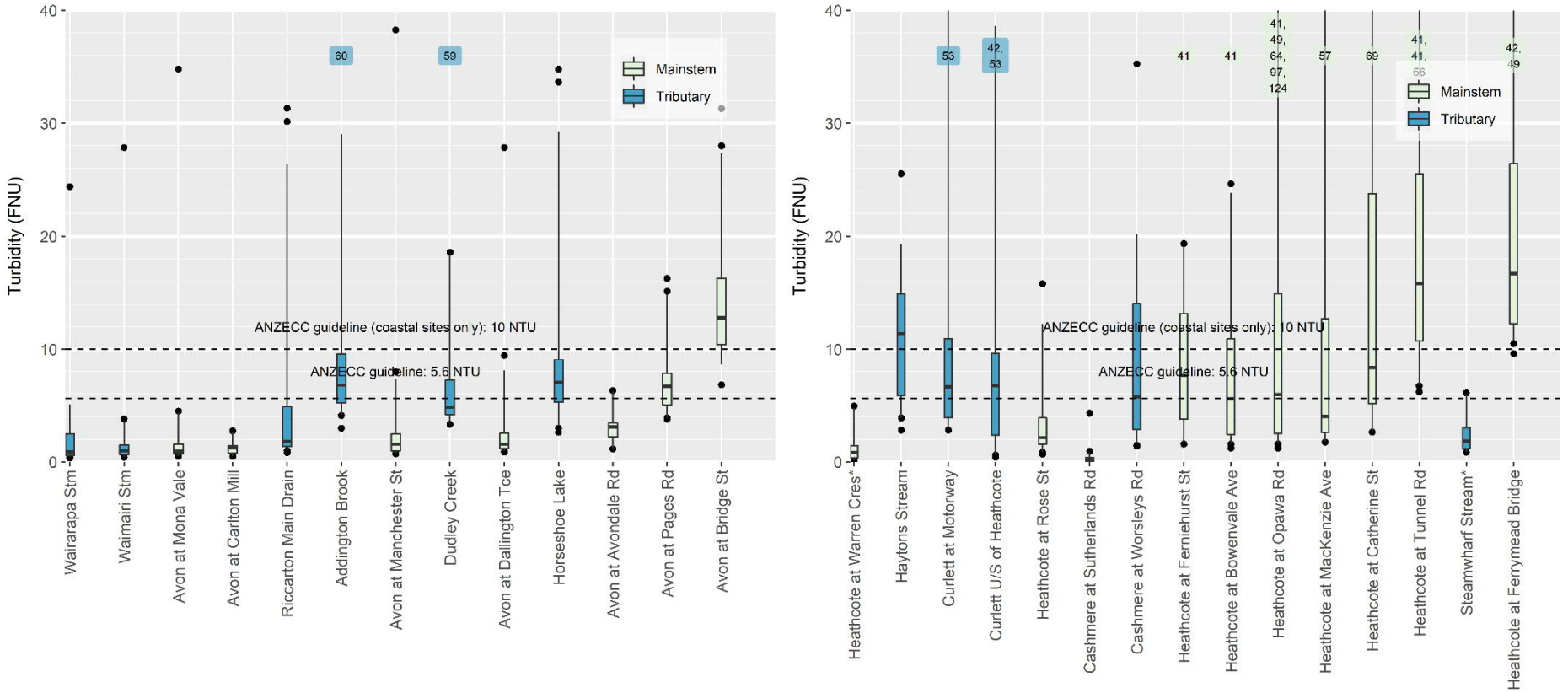


Figure viii (a). Turbidity concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the ANZECC (2000) guideline values of 5.6 Nephelometric Turbidity Units (NTU) for waterway sites, or 10 NTU for coastal sites. Strongly tidal sites ( Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) should be compared to the coastal water guideline. The Laboratory Limit of Detection was 0.1 FNU – analysed as half this value (0.05 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

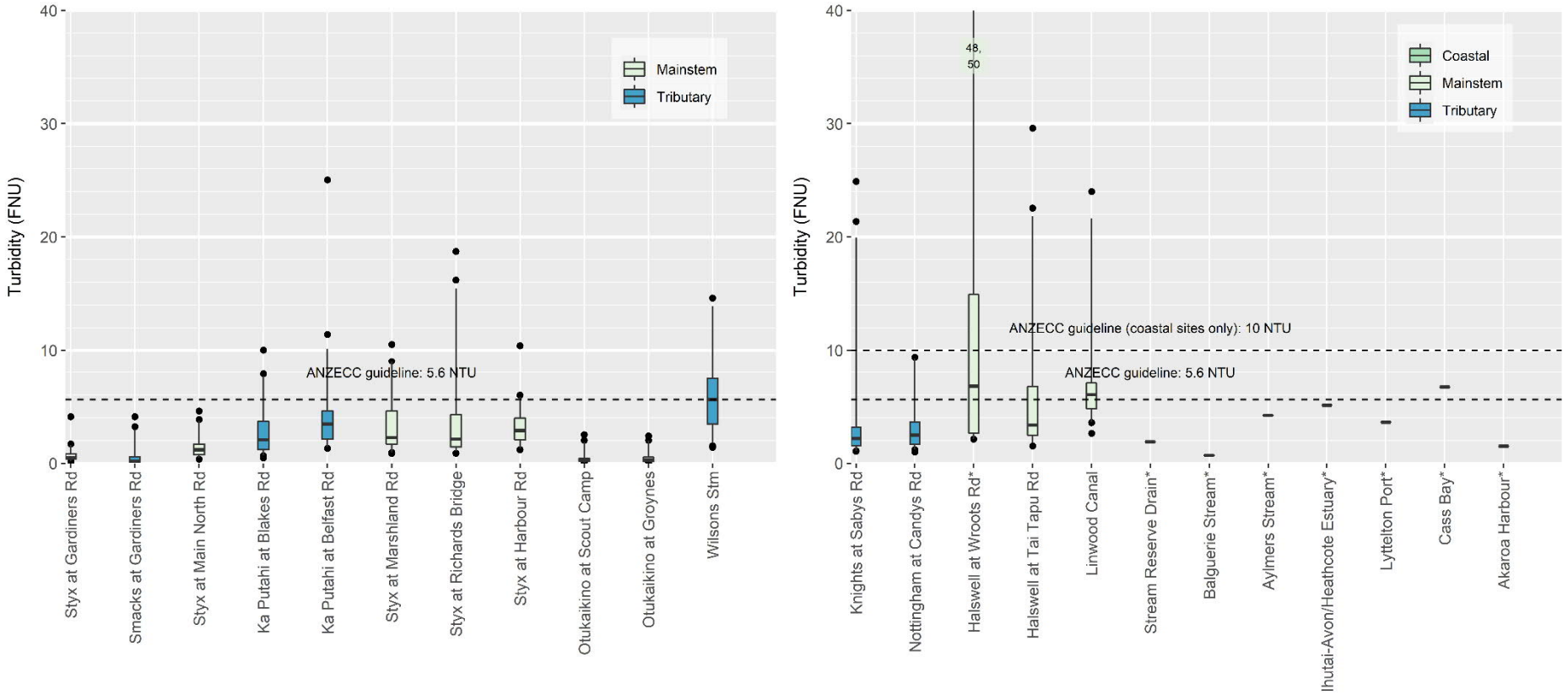


Figure viii (b). Turbidity concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling for turbidity began in December 2020. The dashed lines represent the ANZECC (2000) guideline values of 5.6 Nephelometric Turbidity Units (NTU) for waterway sites, or 10 NTU for coastal sites. The strongly tidal Linwood Canal site should be compared to the coastal water guideline. The Laboratory Limit of Detection was 0.1 FNU – analysed as half this value (0.05 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

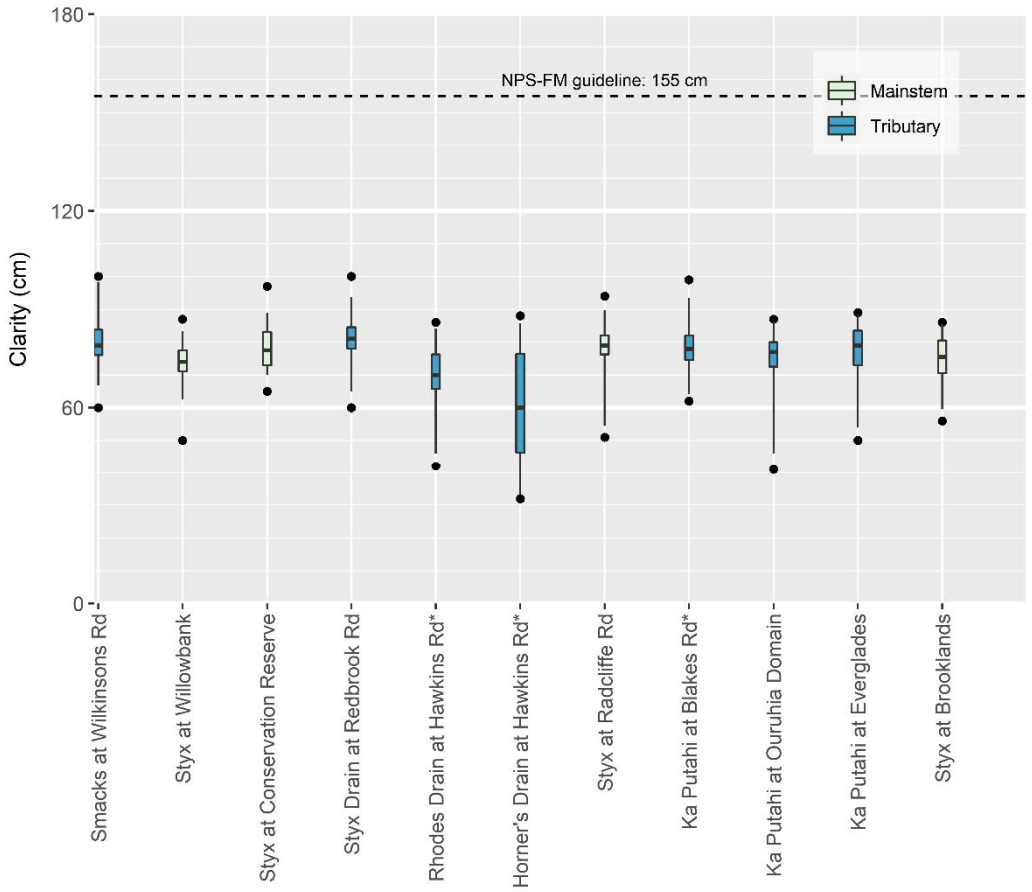


Figure ix. Water clarity levels in water samples taken from the Pūharakekenui-Styx River catchment by the Styx Living Laboratory Trust volunteers for the monitoring period January 2018 to December 2019 (n = 19–30 samples per site). Sites with an asterisk indicate where sampling began in 2019.Sites are ordered from upstream to downstream (left to right). The dashed line represents the NPS-FM (2020) guideline value of 155 cm for attribute band B.

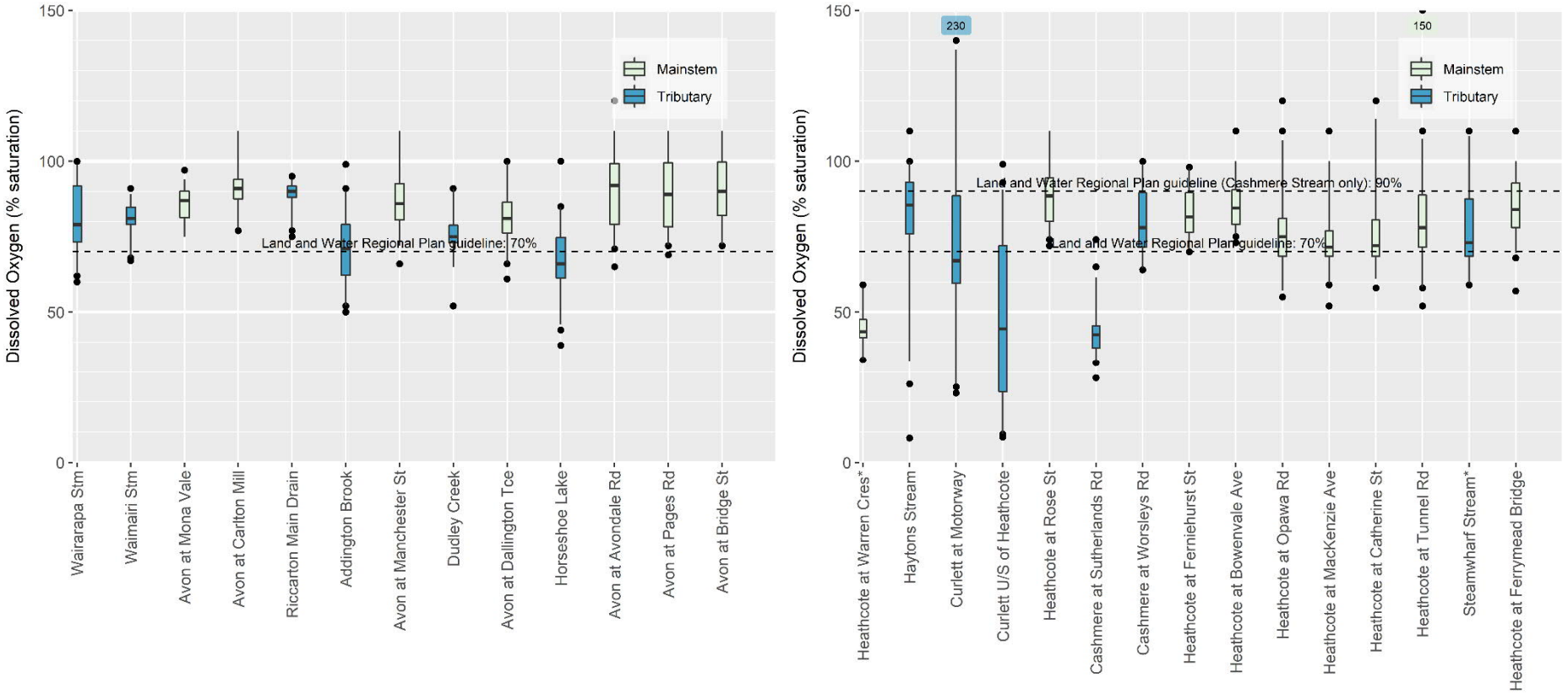


Figure x (a). Dissolved oxygen concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The lower and upper dashed lines represent the Land and Water Regional Plan minimum guideline value for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (70%), and Banks Peninsula waterways (90%; Cashmere Stream only), respectively (Environment Canterbury, 2019). The numbers in shaded boxes indicate samples that exceeded the y-axis.

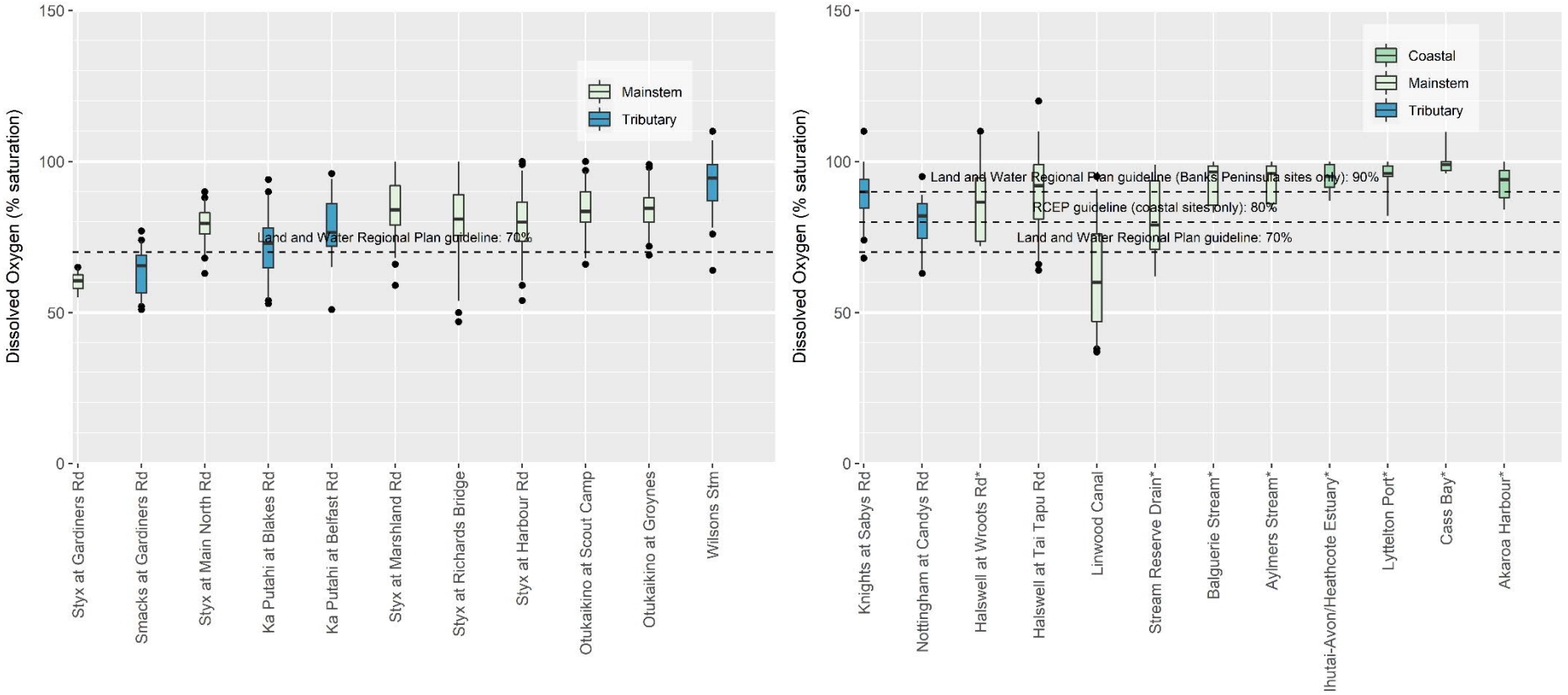


Figure x (b). Dissolved oxygen concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the Land and Water Regional Plan minimum guideline value for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (70%), Banks Peninsula waterways (90%), and coastal sites (80%), respectively (Environment Canterbury, 2019; RCEP, 2012). The numbers in shaded boxes indicate samples that exceeded the y-axis.

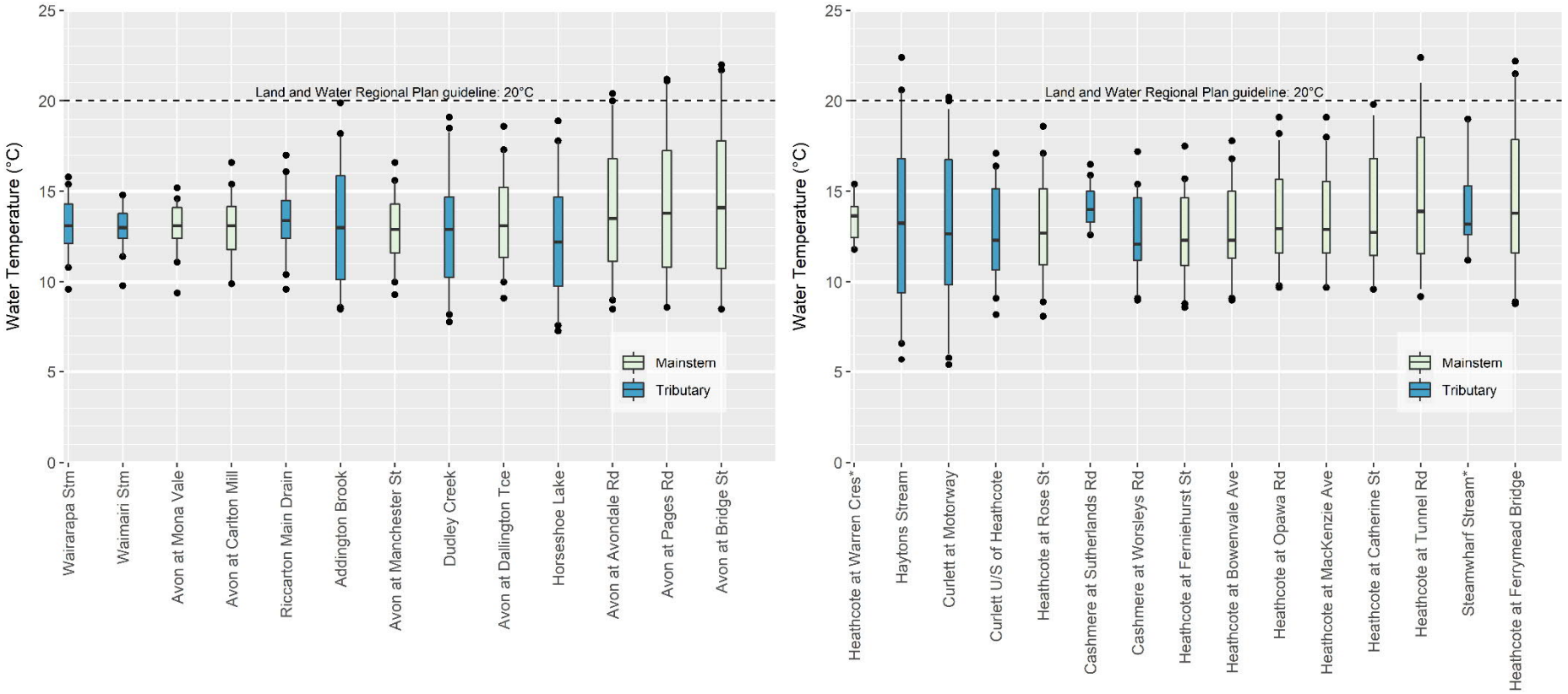


Figure xi (a). Temperature at the time of sampling at the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed line represents the Land and Water Regional Plan maximum guideline value (20ºC, Environment Canterbury, 2019). The numbers in shaded boxes indicate samples that exceeded the y-axis.

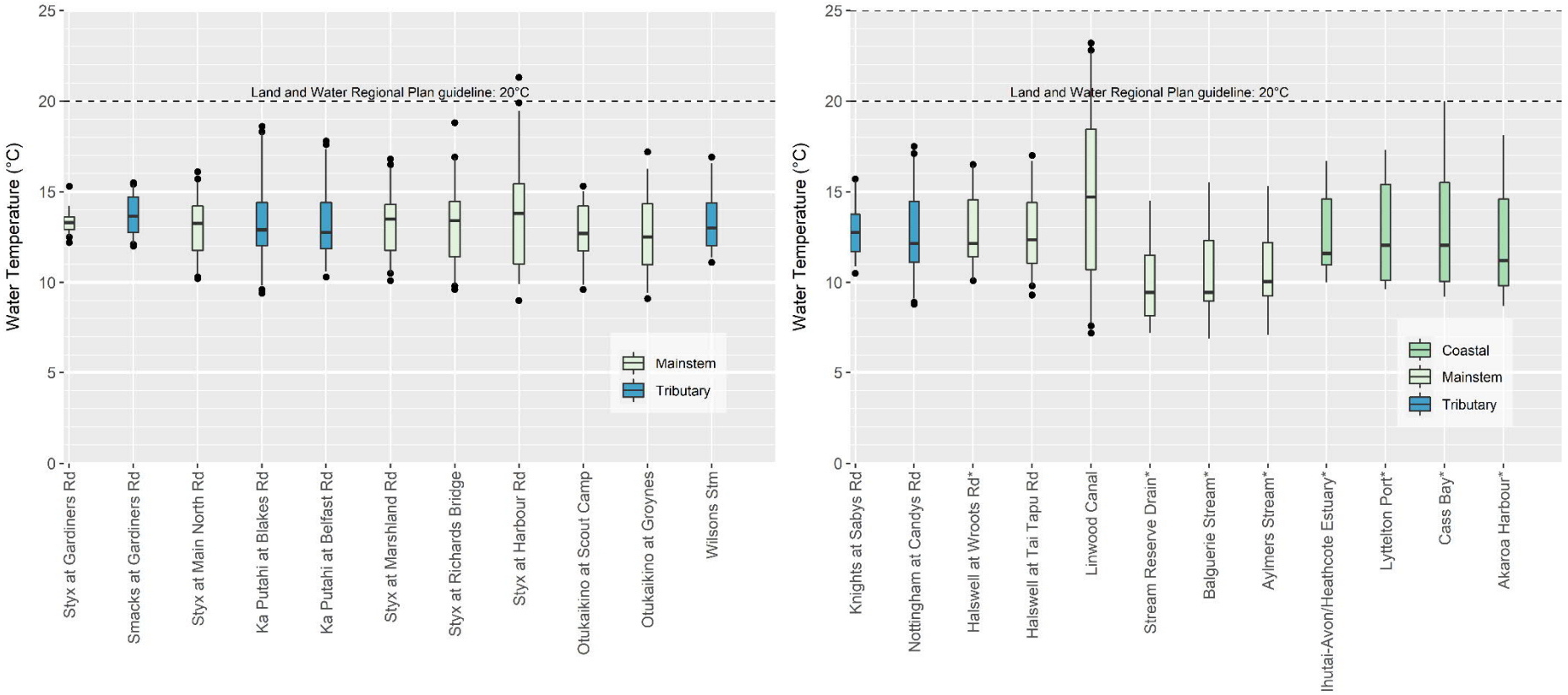


Figure xi (b). Temperature of the water at the time of sampling at the water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the Land and Water Regional Plan maximum guideline value for waterway sites (20°C), and coastal sites (25°C), respectively (Environment Canterbury, 2019; RCEP, 2012). The numbers in shaded boxes indicate samples that exceeded the y-axis.

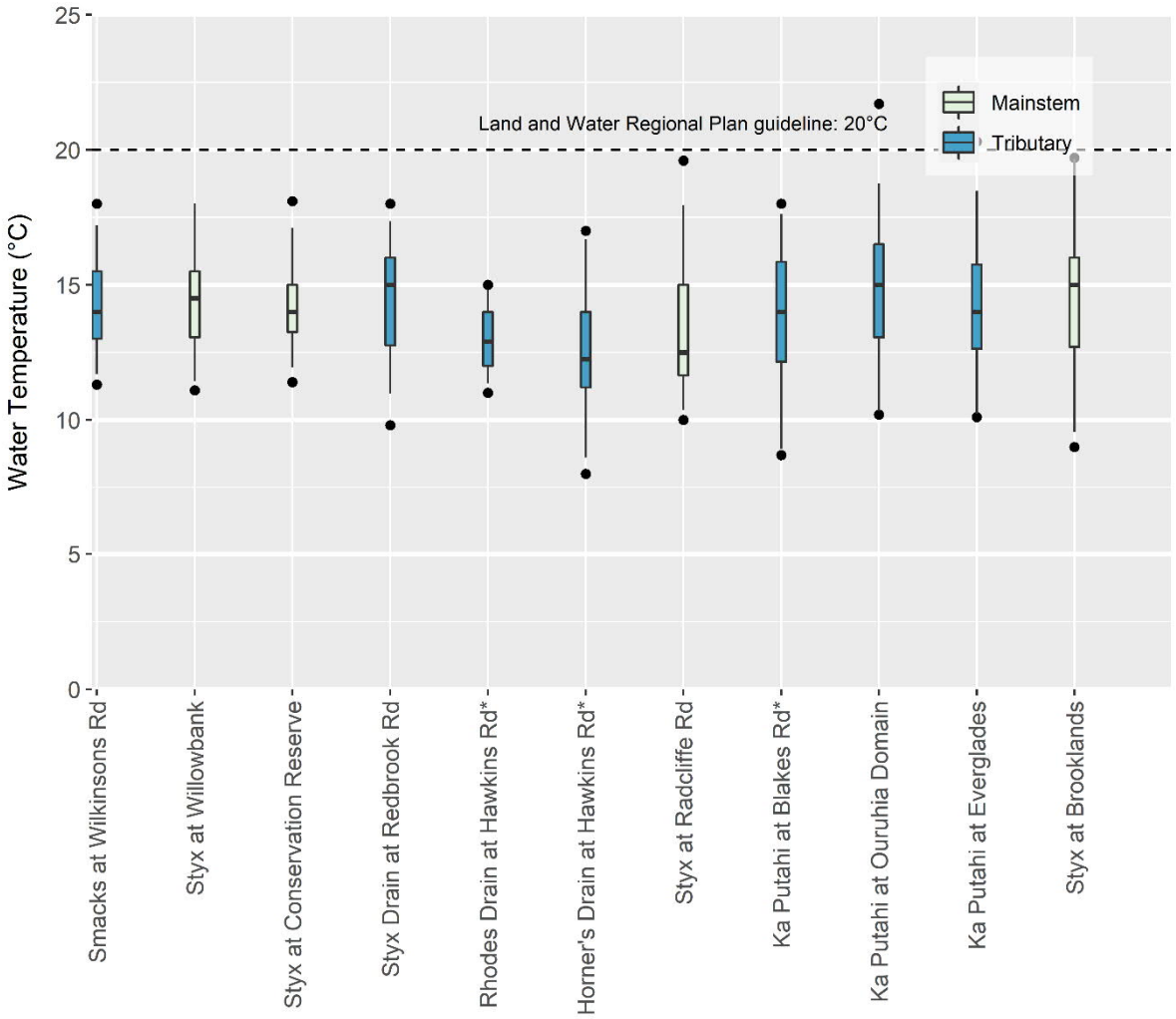


Figure xi (c). Temperature of the water at the time of sampling by the Styx Living Laboratory Trust volunteers for the monitoring period January 2018 to December 2019 (n = 19–30 samples per site). Sites with an asterisk indicate where sampling began in 2019.Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan maximum guideline value (20 ºC, Environment Canterbury, 2019).

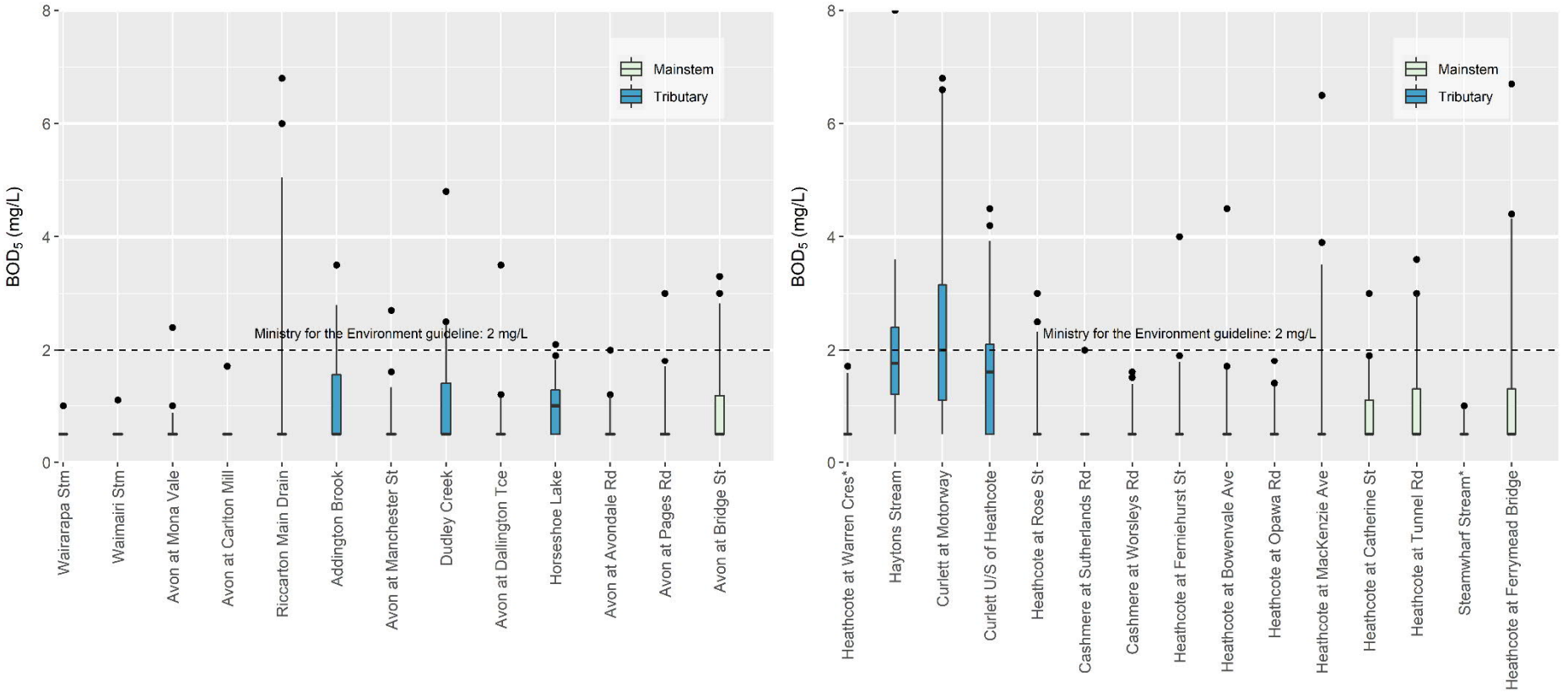


Figure xii (a). Biochemical Oxygen Demand ($BOD_5$) concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the Ministry for the Environment guideline value (Ministry for the Environment, 1992). The Laboratory Limit of Detection was 1.0 mg/L, analysed as half this value (0.5 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

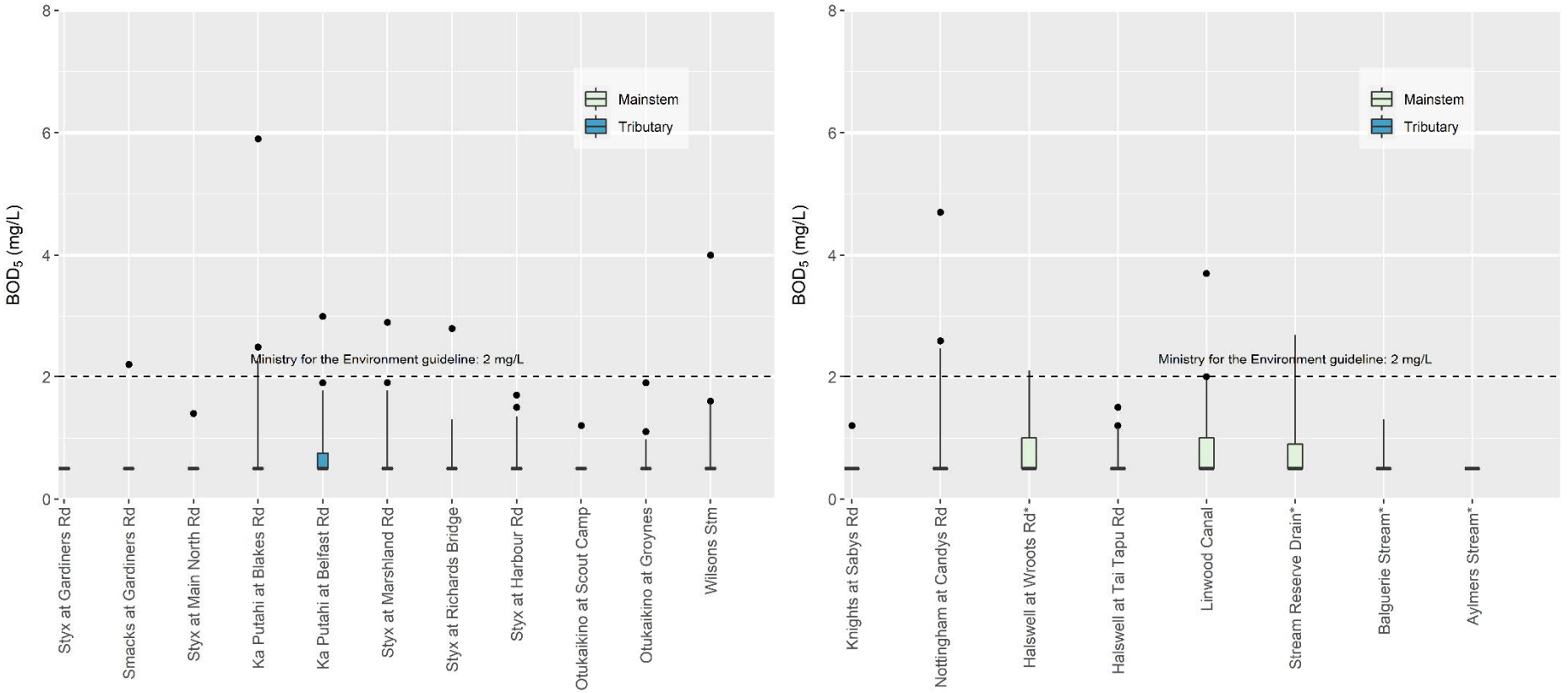


Figure xii (b). Biochemical Oxygen Demand ($BOD_5$) concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the Ministry for the Environment guideline value (2 mg/L; Ministry for the Environment, 1992). The Laboratory Limit of Detection was 1.0 mg/L, analysed as half this value (0.5 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

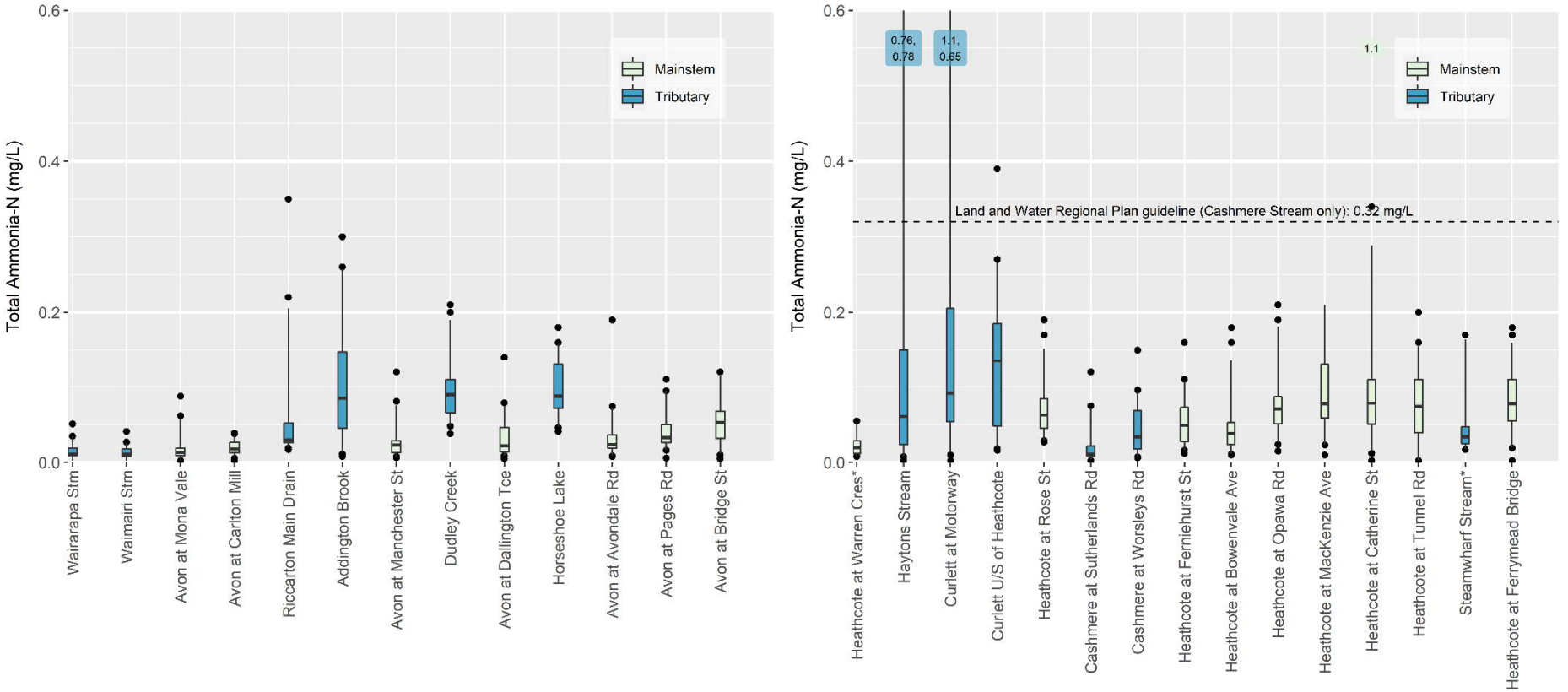


Figure xiii (a). Total ammonia concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The Land and Water Regional Plan guideline value (Ōtākaro-Avon catchment: 1.75 mg/L, Ōpāwaho-Heathcote: 1.61 mg/L,; Environment Canterbury, 2019), which has been adjusted in accordance with median pH levels for the monitoring period (Ōtākaro-Avon catchment: 7.4, Ōpāwaho-Heathcote catchment: 7.5), 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). The Laboratory Limit of Detection was 0.005 mg/L – analysed as half this value (0.0025 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

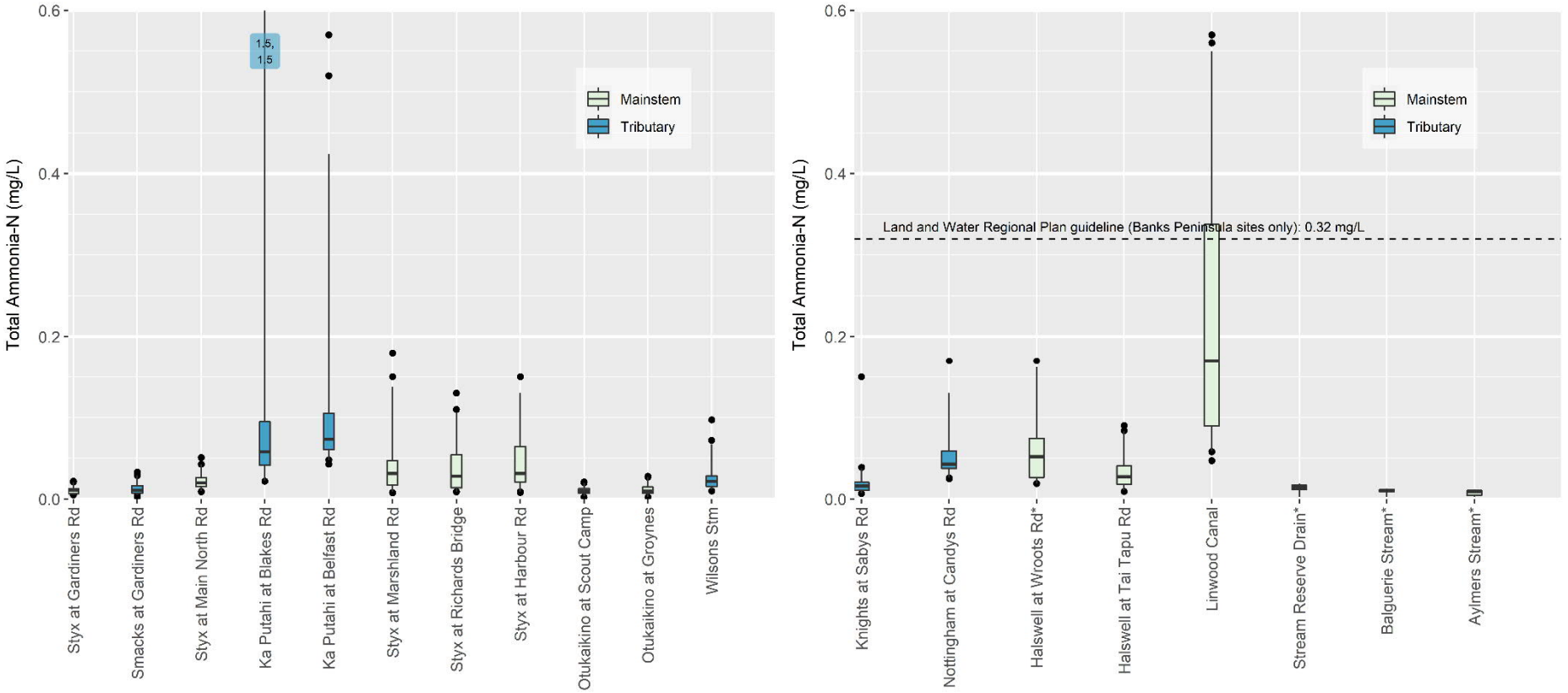


Figure xiii (b). Total ammonia concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, and Banks Peninsula sites (right graph), for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The Land and Water Regional Plan guideline values (Pūharakekenui-Styx catchment: 1.88 mg/L, Ōtūkaikino catchment: 1.99 mg/L, Huritini-Halswell catchment: 1.61 mg/L, Linwood Canal: 1.61 mg/L; Environment Canterbury, 2019), adjusted in accordance with median pH levels for the monitoring period (Pūharakekenui-Styx catchment: 7.3, Ōtūkaikino catchment: 7.2, Huritini-Halswell catchment: 7.5, Linwood Canal: 7.5), are not presented on the graph as they are off the scale. The Laboratory Limit of Detection was 0.005 mg/L – analysed as half this value (0.0025 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

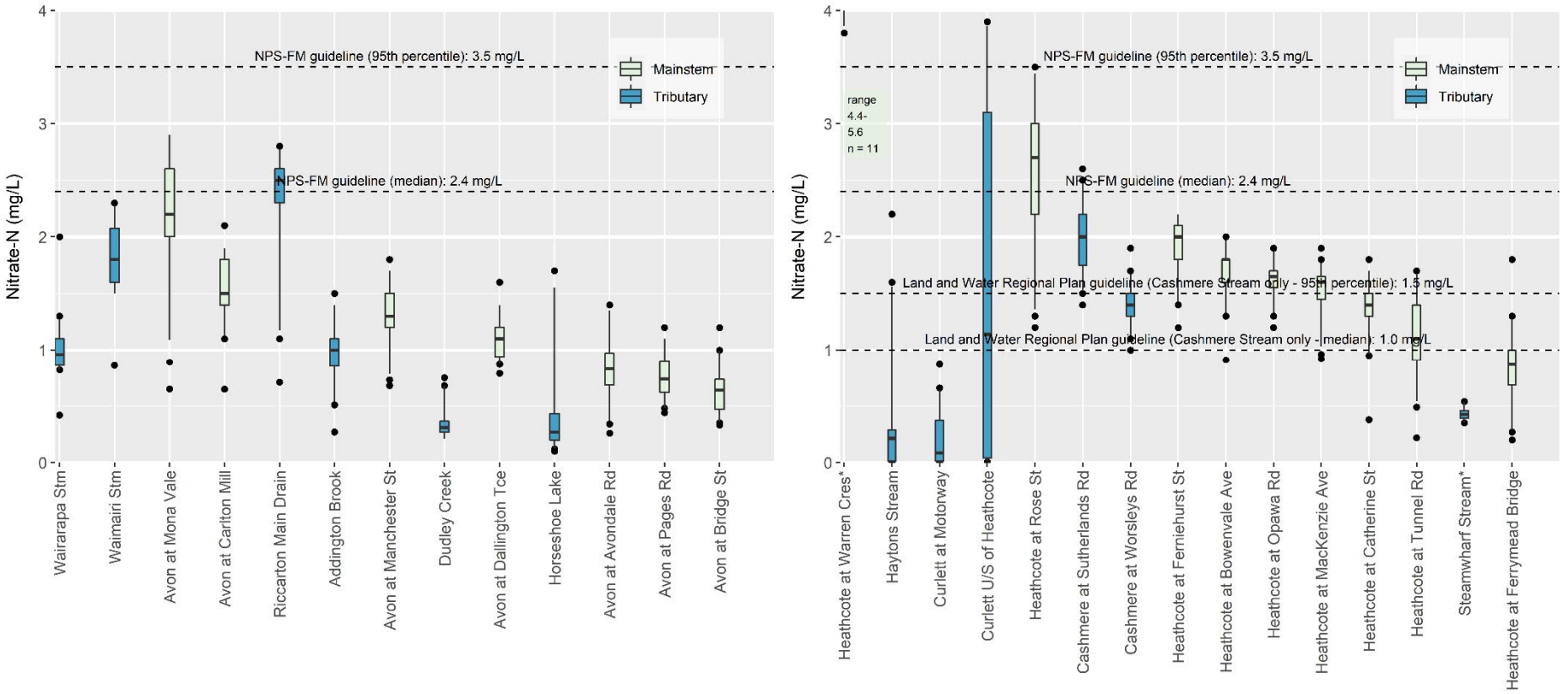


Figure xiv (a). Nitrate-nitrogen concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the NPS-FM median (2.4 mg/L) and 95th percentile (3.5 mg/L) guideline levels, or the Land and Water Regional Plan median (1.0 mg/L) and 95th percentile (1.5 mg/L) guideline for Cashmere Stream. The Laboratory Limit of Detection was 0.002 mg/L – analysed as half this value (0.001 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

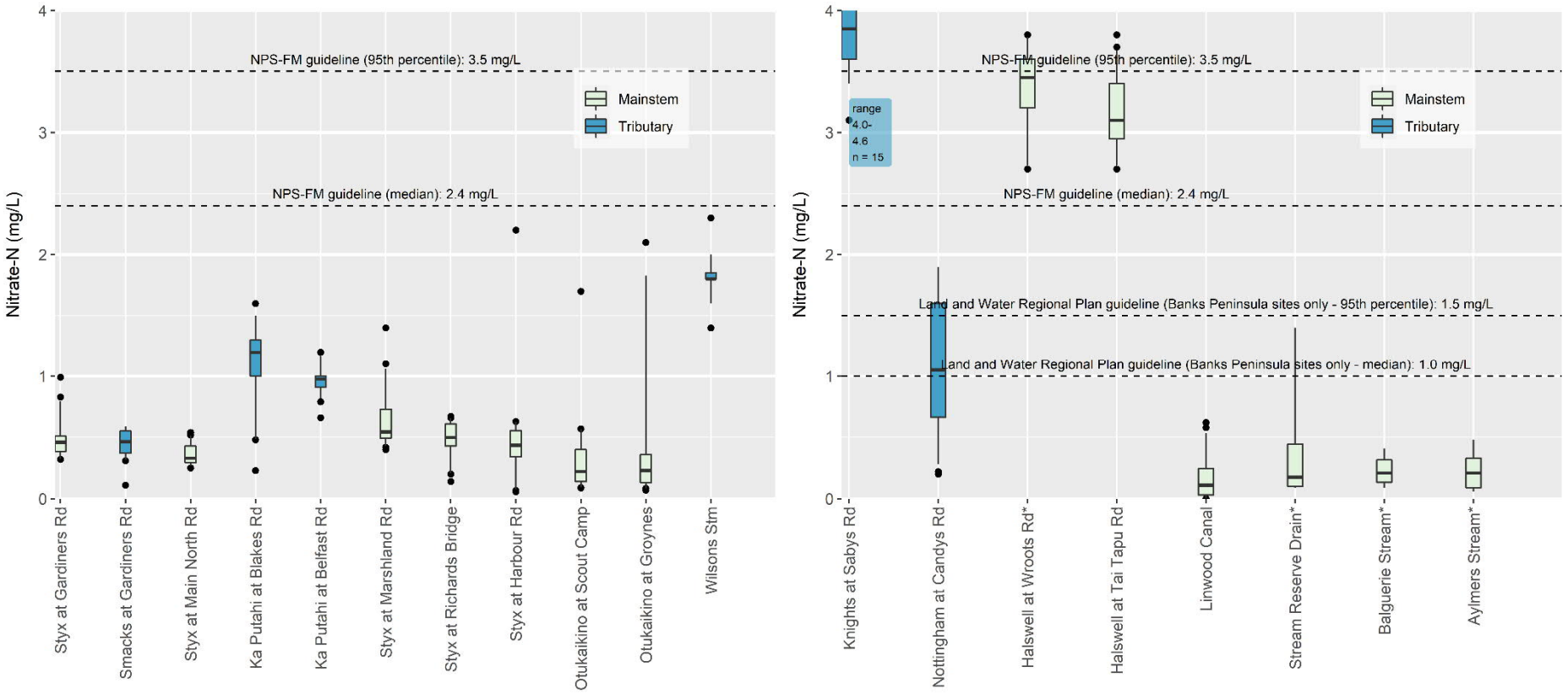


Figure xiv (b). Nitrate concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, and Banks Peninsula sites (right graph), for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the NPS-FM median (2.4 mg/L) and 95$^{th}$ percentile (3.5 mg/L) guideline levels, or the Land and Water Regional Plan median (1.0 mg/L) and 95$^{th}$ percentile (1.5 mg/L) guideline for Banks Peninsula sites. The Laboratory Limit of Detection was 0.002 mg/L – analysed as half this value (0.001 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

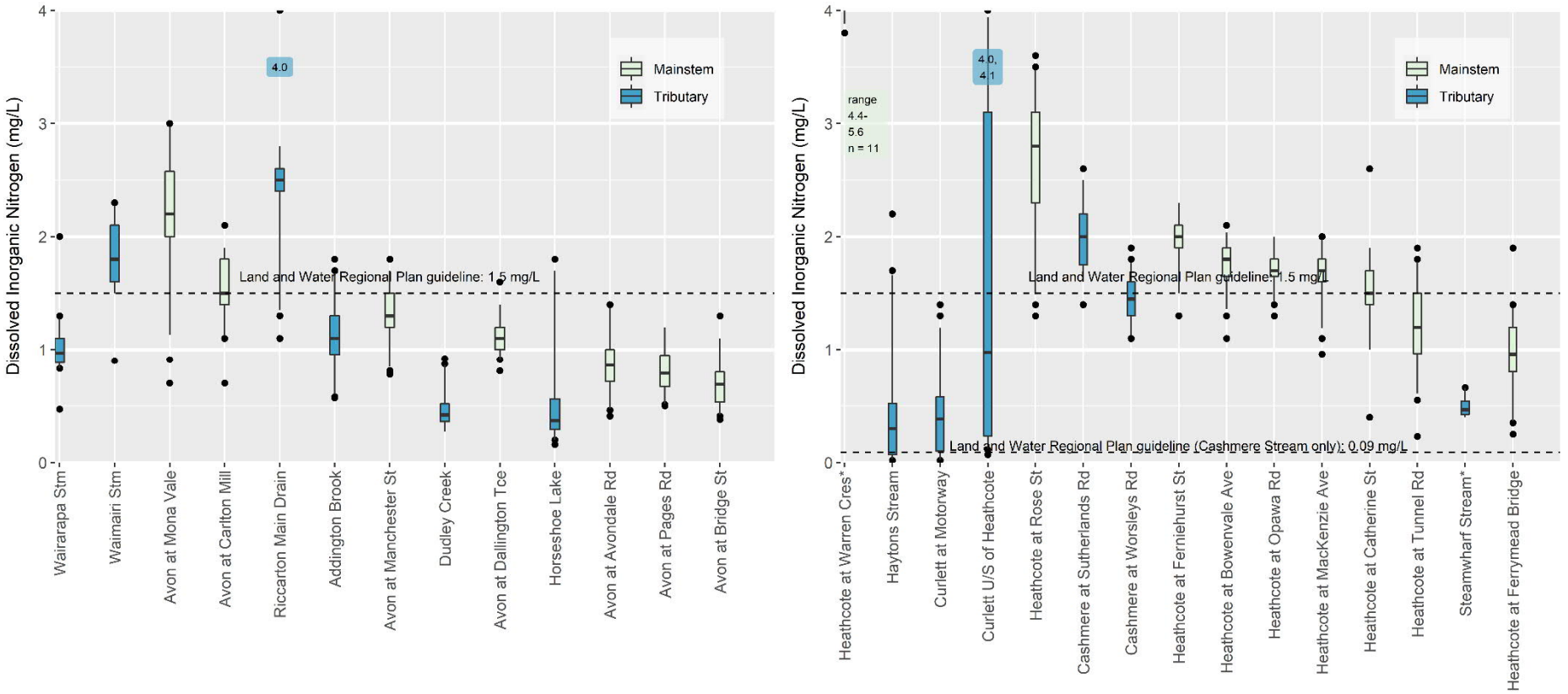


Figure xv (a). Dissolved Inorganic Nitrogen (DIN) concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed 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). The Laboratory Limit of Detection was 0.002 mg/L – analysed as half this value (0.001 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

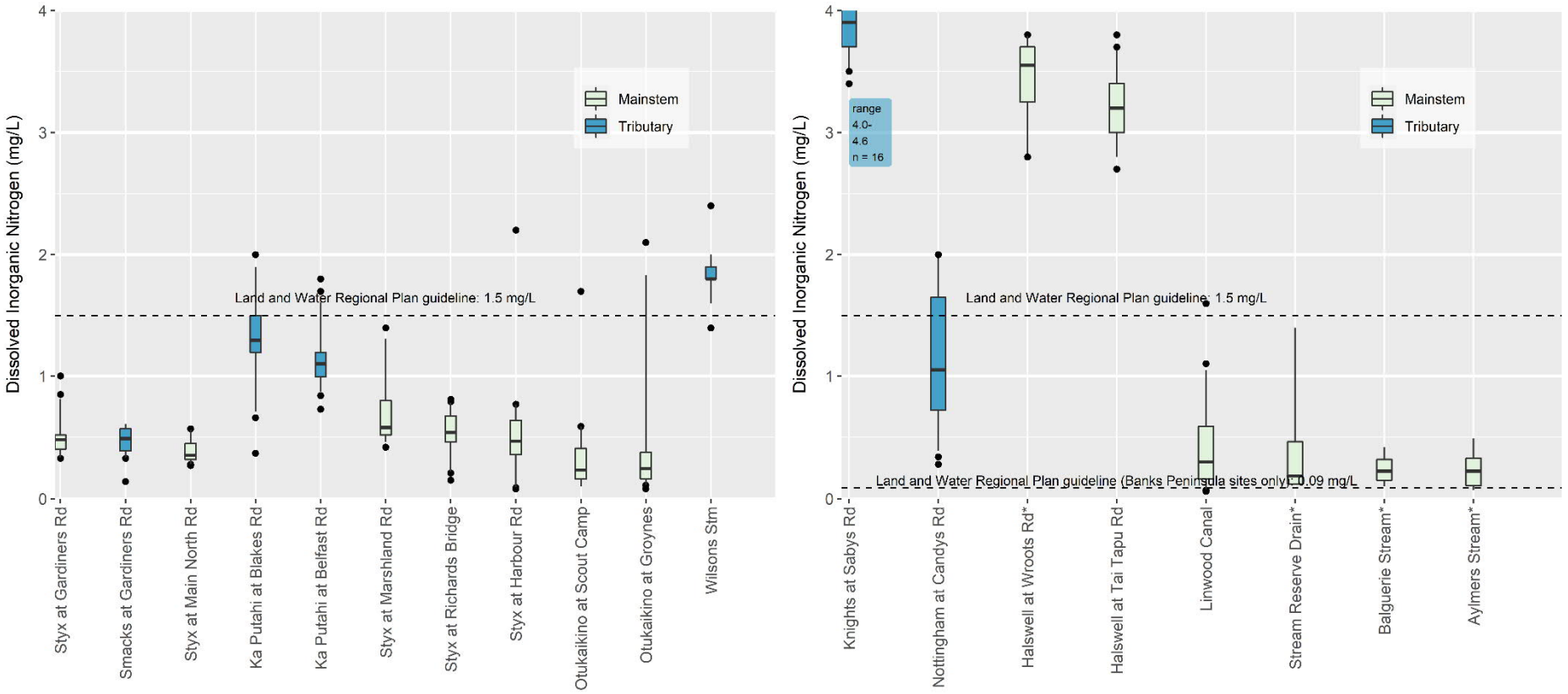


Figure xv (b). Dissolved Inorganic Nitrogen (DIN) concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, and Banks Peninsula sites (right graph), for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. 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). The Laboratory Limit of Detection was 0.002 mg/L – analysed as half this value (0.001 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

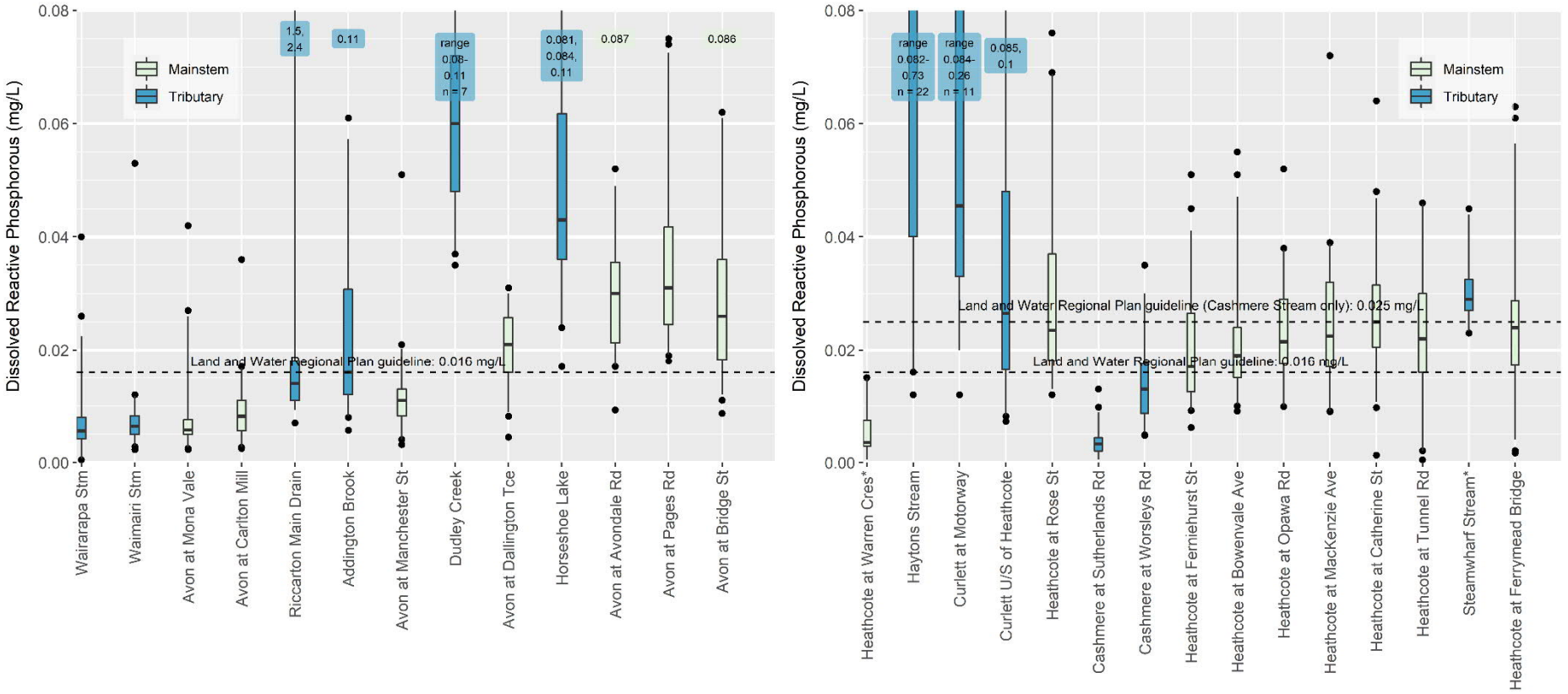


Figure xvi (a). Dissolved Reactive Phosphorus (DRP) concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed 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). The Laboratory Limit of Detection was 0.001 mg/L, analysed as half this value (0.0005 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

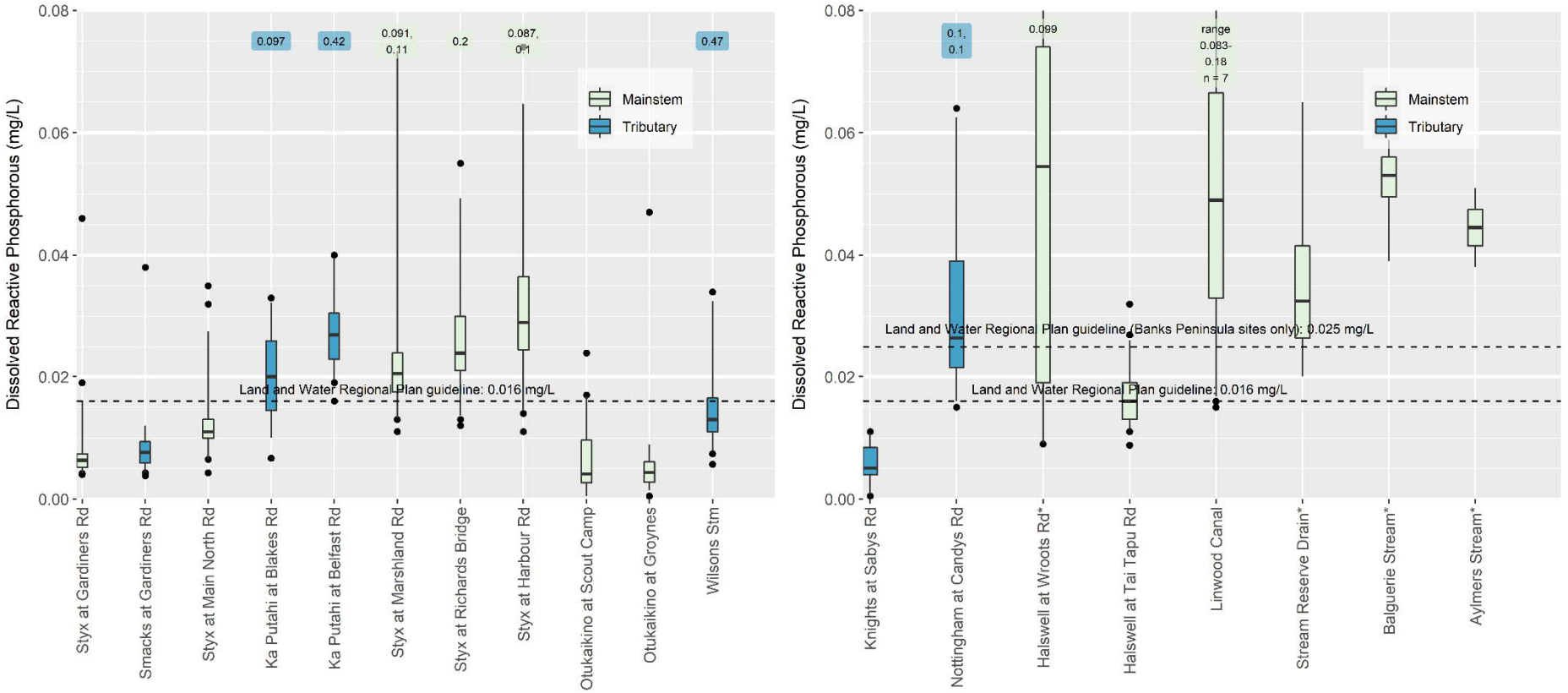


Figure xvi (b). Dissolved Reactive Phosphorus (DRP) concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, and Banks Peninsula sites (right graph), for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. 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). The Laboratory Limit of Detection was 0.001 mg/L, analysed as half this value (0.0005 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

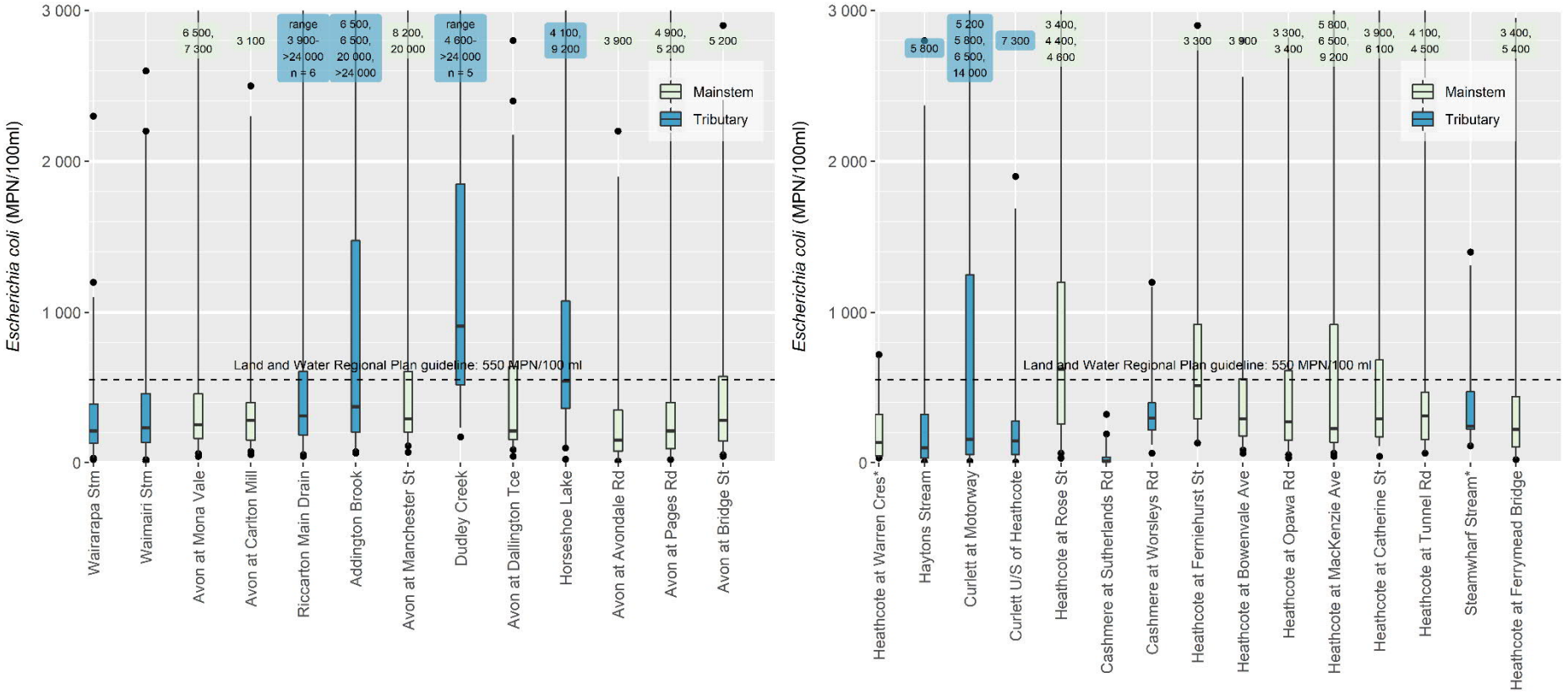


Figure xvii (a). *Escherichia coli* concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent 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). The Laboratory Limit of Detection varied depending on the necessary dilution of the sample, but all were analysed as half this value to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

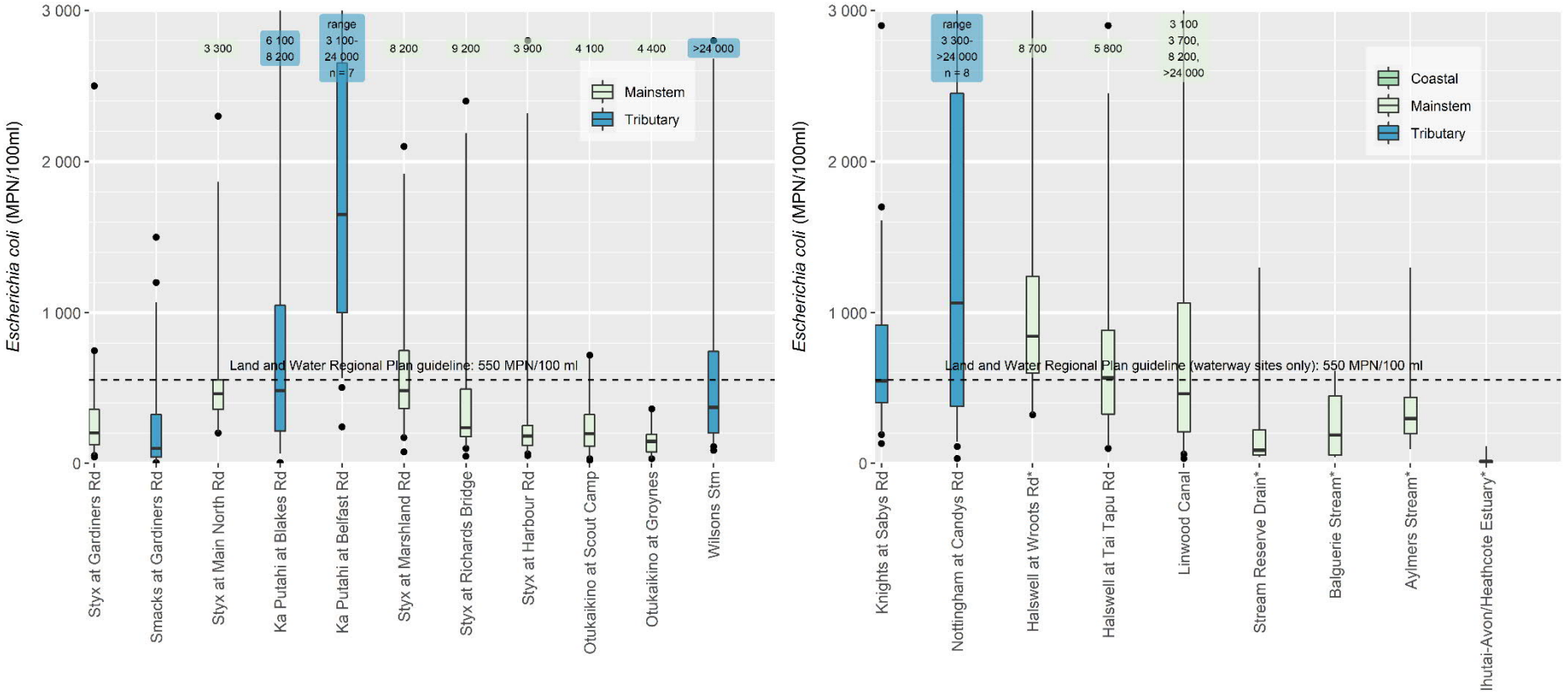


Figure xvii (b). *Escherichia coli* concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, and Banks Peninsula sites (right graph), for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. 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. The Laboratory Limit of Detection varied depending on the necessary dilution of the sample, but all were analysed as half this value to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

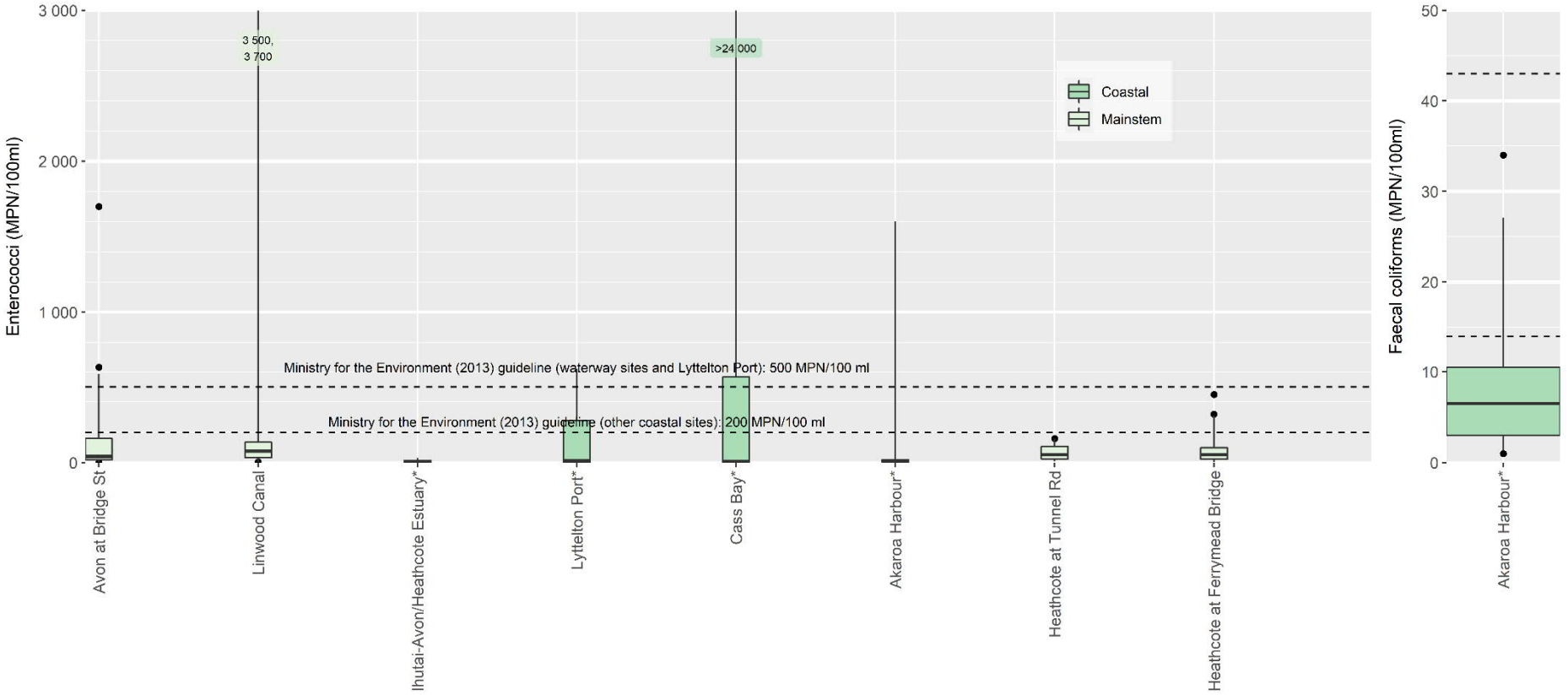


Figure xviii. Enterococci (left graph) and faecal coliforms (right graph) concentrations in water samples taken from the relevant strongly tidal and coastal sites for the monitoring period January 2018 to December 2020. Sites with an asterisk indicate where sampling began in 2020. Only one site is monitored for faucal coliforms. On the left graph the dashed lines either represent the Ministry for the Environment guideline value of 500 MPN/100ml for waterway and Lyttelton Port sites, or the Ministry for the Environment guideline value of 200 MPN/100ml for coastal sites (Ministry for the Environment, 2013). On the right graph, the dashed lines represent the Ministry for the Environment guideline median (14 MPN/100ml) and 90$^{th}$ percentile (43 MPN/100ml) for Akaroa harbour (Ministry for the Environment, 2013). Laboratory Limit of Detection (enterococci) was <10 MPN100ml, analysed as half this value (5 MPN/100ml) to allow statistics to be undertaken. Laboratory Limit of Detection (faecal coliforms) was <1 MPN100ml, analysed as half this value (0.5 MPN/100ml) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

# Appendix E

Table i. Direction of significant temporal trends for parameters monitored monthly at each of the sites in the Ōtākaro-Avon River catchment. Parameter changes represented by an arrow with no number are where a statistically significant change was recorded, but due to a high proportion of censored data, only the direction of change could be calculated. 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* | Enterococci |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wairarapa Stm | | | ↓ 11% | ↓ 9% | | | | | | | ↓ | | ↓ 1% | | N/A |
| Waimairi Stm | | | | ↓ 7% | | | | | | | | | ↓ 2% | | N/A |
| Avon at Mona Vale | | | | | | | | | | | | | ↓ 2% | | N/A |
| Avon at Carlton Mill | | | | ↓ 8% | | | | N/A | ↓ 1% | | ↓ | | ↓ 3% | | N/A |
| Riccarton Main Drain | | | | ↓ 6% | | ↑ 2% | | | | | | | ↑ 3% | | N/A |
| Addington Brook | | | ↑ 7% | ↓ 3% | | ↓ 1% | | | | | ↓ | | ↓ 1% | | N/A |
| Avon at Manchester St | | | | ↓ 6% | | | | | | | ↓ | ↓ 4% | ↓ 3% | | N/A |
| Dudley Creek | | ↓ 13% | | | | ↓ 1% | | | | ↑ 1% | ↓ 5% | ↓ 4% | ↓ 4% | | N/A |
| Avon at Dallington Tce | | | | | | | ↓ 2% | ↓ 4% | ↑ 1% | ↑ 1% | ↓ | ↓ 5% | ↓ 2% | | N/A |
| Horseshoe Lake | | | ↓ 8% | | | | | | | | ↓ | ↓ 2% | ↓ 2% | | N/A |
| Avon at Avondale Rd | | | | ↓ 3% | | | | N/A | | | ↓ | ↓ 4% | ↓ 5% | | N/A |
| Avon at Pages Rd | | | ↓ 8% | ↓ 2% | | ↑ 5% | | ↓ 2% | ↑ 1% | ↑ 1% | ↓ | ↓ 3% | ↓ 3% | ↑ 4% | N/A |
| Avon at Bridge St | | | | ↓ 5% | | ↑ 5% | | | ↑ 1% | ↑ 1% | ↓ | ↓ 7% | ↓ 3% | ↑ 4% | ↓ 6% |

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, and DIN = Dissolved Inorganic Nitrogen. 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. Parameter changes represented by an arrow with no number are where a statistically significant change was recorded, but due to a high proportion of censored data, only the direction of change could be calculated. 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* | Enterococci |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Haytons Stream | | | | ↓12% | | | ↑ 3% | ↑ 4% | ↓1% | | ↓5% | ↓7% | ↓13% | | |
| Curlett at Motorway | ↑ 10% | | ↑ 16% | | | | ↑ 8% | N/A | | | | | ↓24% | | N/A |
| Curlett U/S of Heathcote | ↓13% | ↓13% | ↓11% | | | | | | | | | | ↓3% | ↓ 12% | N/A |
| Heathcote at Rose St | ↓3% | | | ↓ 8% | | | | | | | ↓ 7% | | ↓ 1% | | N/A |
| Cashmere at Sutherlands Rd | | | ↓ 10% | ↓ 16% | | | | | ↓ 2% | | ↓ | | ↓ 3% | | N/A |
| Cashmere at Worsleys Rd | | | | ↓ 6% | | | | | | | ↓ | | ↓ 1% | ↓ 3% | N/A |
| Heathcote at Ferniehurst St | | | | ↓ 7% | | | | | | | ↓ | | ↓ 1% | | N/A |
| Heathcote at Bowenvale Ave | | | | ↓ 6% | | | | | | | ↓ | | | | N/A |
| Heathcote at Opawa Road | | | | ↓ 6% | | | | | ↓ 1% | | ↓ | | | | N/A |
| Heathcote at Mackenzie Ave | | | | ↓ 8% | | | | N/A | | ↑ 1% | ↓ | | | | N/A |
| Heathcote at Catherine St | | | | ↓ 8% | | ↑ 5% | | N/A | | ↑ 1% | ↓ | ↓ 3% | ↓ 1% | | N/A |
| Heathcote at Tunnel Rd | | | | ↓ 11% | | ↑ 7% | ↓ 3% | ↓ 5% | | ↑ 1% | ↓ | ↓ 8% | | | N/A |
| Heathcote at Ferrymead Bridge | | | ↑ 10% | ↓ 15% | | | | ↓ 2% | ↑ 1% | ↑ 1% | ↓ 3% | ↓ 13% | ↓ 3% | | ↓ 11% |

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, and DIN = Dissolved Inorganic Nitrogen. 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. Parameter changes represented by an arrow with no number are where a statistically significant change was recorded, but due to a high proportion of censored data, only the direction of change could be calculated. 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* | Enterococci |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Knights at Sabys Rd | | | ↓ 8% | ↓ 9% | | ↓ 2% | | | | | ↓ | ↓ 7% | ↓ 4% | | N/A |
| Nottingham at Candy's Rd | | | ↑ 6% | | | ↓ 3% | | | | ↑ 1% | ↓ | | ↓ 6% | ↑ 5% | N/A |
| Halswell River at Tai Tapu Rd | | | ↓ 10% | ↓ 2% | | ↓ 1% | ↑ 5% | | ↑ 1% | ↑ 1% | ↓ | | ↓ 3% | ↑ 10% | N/A |
| Linwood Canal | | | | ↓ 4% | | ↑ 8% | | ↓ 4% | | ↑ 1% | ↓ 8% | | ↓ 5% | | ↓ 13% |

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, and DIN = Dissolved Inorganic Nitrogen. 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. Parameter changes represented by an arrow with no number are where a statistically significant change was recorded, but due to a high proportion of censored data, only the direction of change could be calculated. 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 | | | ↓ 10% | ↓ 6% | | ↓ 1% | | | | | ↓ | | ↓ 7% | ↑ 7% |
| Smacks at Gardiners Rd | | | ↓ 12% | ↓ 5% | | ↓ 1% | | ↓ 8% | | ↑ 1% | ↓ | | ↓ 3% | |
| Styx at Main North Rd | | | | ↓ 3% | | ↓ 1% | | ↓ 4% | ↓ 1% | | ↓ | ↓ 2% | ↓ 5% | ↑ 2% |
| Kā Pūtahi at Blakes Rd | | | | | | ↑ 1% | | ↑ 3% | | ↓ 1% | ↓ | | | |
| Kā Pūtahi at Belfast Rd | | | | ↓ 4% | | | | ↓ 3% | ↑ 1% | ↑ 1% | ↓ 4% | ↓ 4% | ↑ 1% | |
| Styx at Marshland Rd | | | | ↓ 2% | | | | | ↑ 1% | ↑ 1% | ↓ | | | |
| Styx at Richards Bridge | | | | ↓ 4% | | ↓ 1% | | | ↑ 1% | ↑ 1% | ↓ | | ↓ 1% | |
| Styx at Harbour Rd | | | | ↓ 2% | | | | | | ↑ 1% | ↓ | | ↓ 3% | |
| Ōtūkaikino at Groynes | | | ↓ 13% | ↓ 14% | | | | ↓ 16% | ↓ 1% | ↑ 1% | ↓ | ↓ 3% | ↓ 5% | |
| Ōtūkaikino at Scout Camp | | | | ↓ 13% | ↓ 1% | | | | ↓ 1% | | | | ↑ 10% | ↑ 25% |
| Wilsons Stm | | | | | | ↑ 1% | ↑ 13% | ↑ 16% | | | | ↑ 6% | ↑ 4% | ↑ 14% |

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 (p≤0.05) for parameters monitored by the Styx Living Laboratory Trust, with sufficient data to run Time Trends analysis.

| Site | Clarity | pH | EC | Temp |
|---|---|---|---|---|
| Smacks at Wilkinsons Rd | | ↓ 2% | | |
| Styx at Willowbank | ↓ 2% | ↑ 1% | | ↑ 1% |
| Styx at Conservation Reserve | | ↑ 1% | ↑ 1% | ↑ 1% |
| Styx Drain | | | | |
| Styx at Radcliffe Rd | | ↑ 2% | | ↑ 1% |
| Kā Pūtahi at Blakes Rd | | | ↓ 7% | ↓ 6% |
| Kā Pūtahi at Ouruhia Domain | | ↑ 1% | ↑ 1% | ↑ 1% |
| Kā Pūtahi at Everglades | | ↑ 1% | ↑ 1% | |
| Styx at Brooklands | ↓ 1% | ↑ 1% | | ↑ 1% |

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

# Appendix F

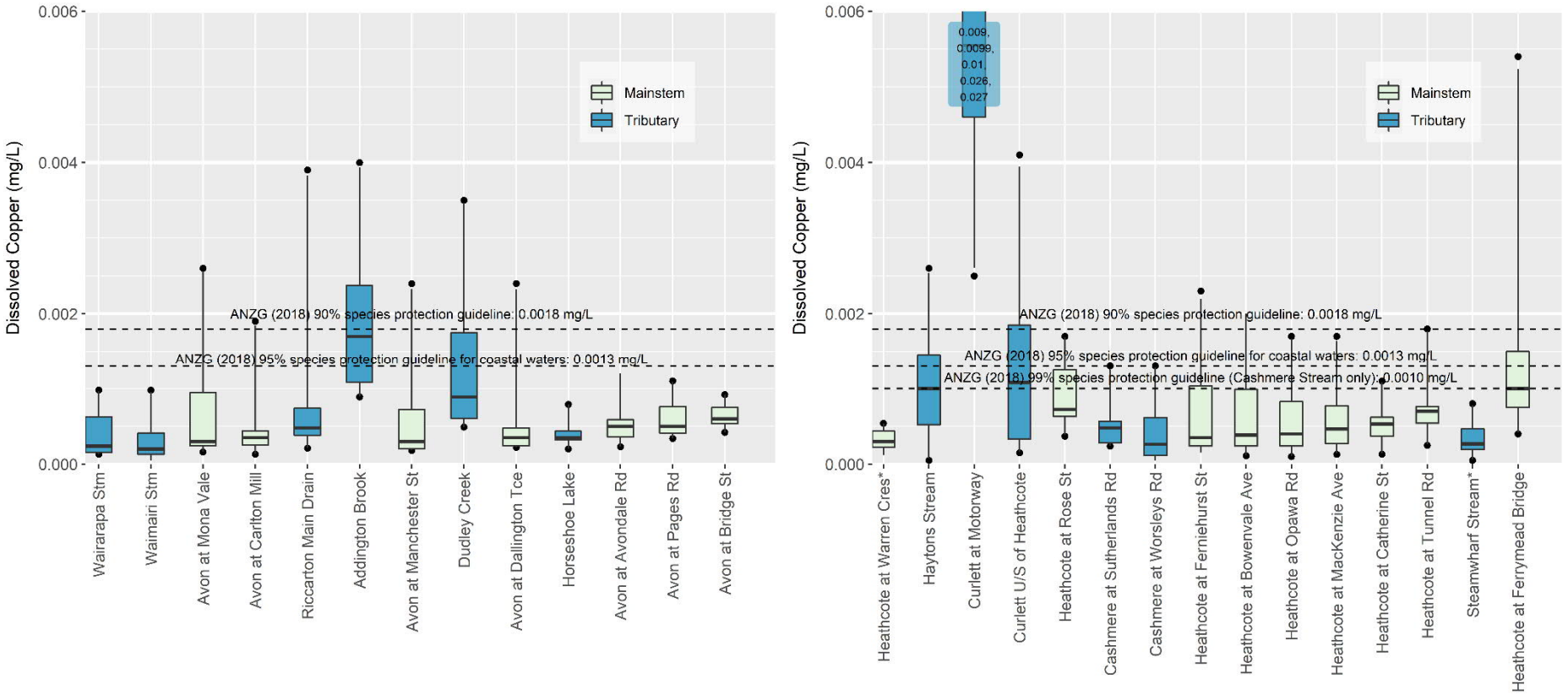


Figure i (c). Dissolved copper concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the ANZG (2018) guideline values. Strongly tidal sites (Avon at Bridge St, Heathcote at Tunnel Rd, and Heathcote at Ferrymead Bridge) should be compared to the more conservative coastal water guidelines. The Laboratory Limit of Detection was 0.0001 mg/L – analysed as half this value (0.00005 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

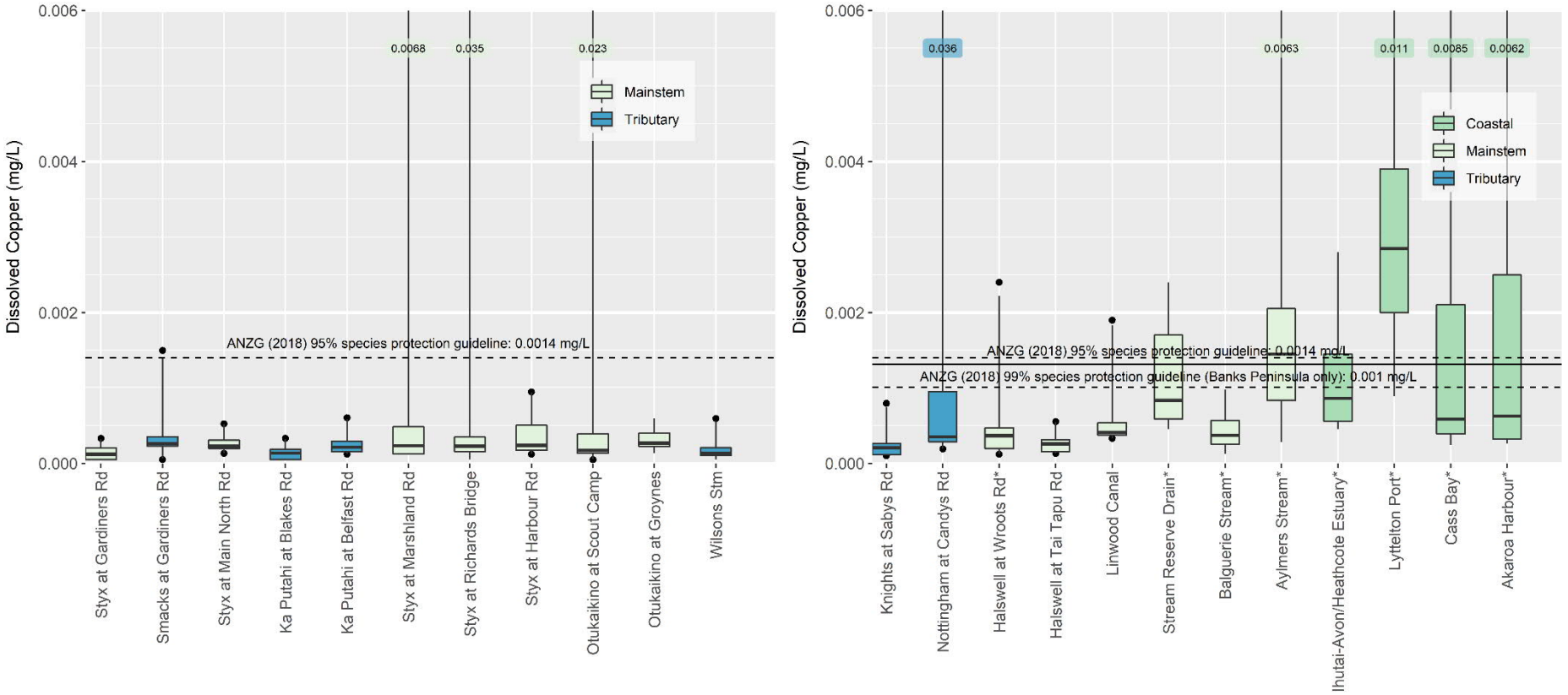


Figure i (d). Dissolved copper concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula, and coastal sites (right graph), for the monitoring period January to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the ANZG (2018) waterway guideline values. The solid line represents the ANZG (2018) coastal guideline. The strongly tidal Linwood Canal site should be compared to the more conservative coastal water guideline. The Laboratory Limit of Detection was 0.0001 mg/L – analysed as half this value (0.00005 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

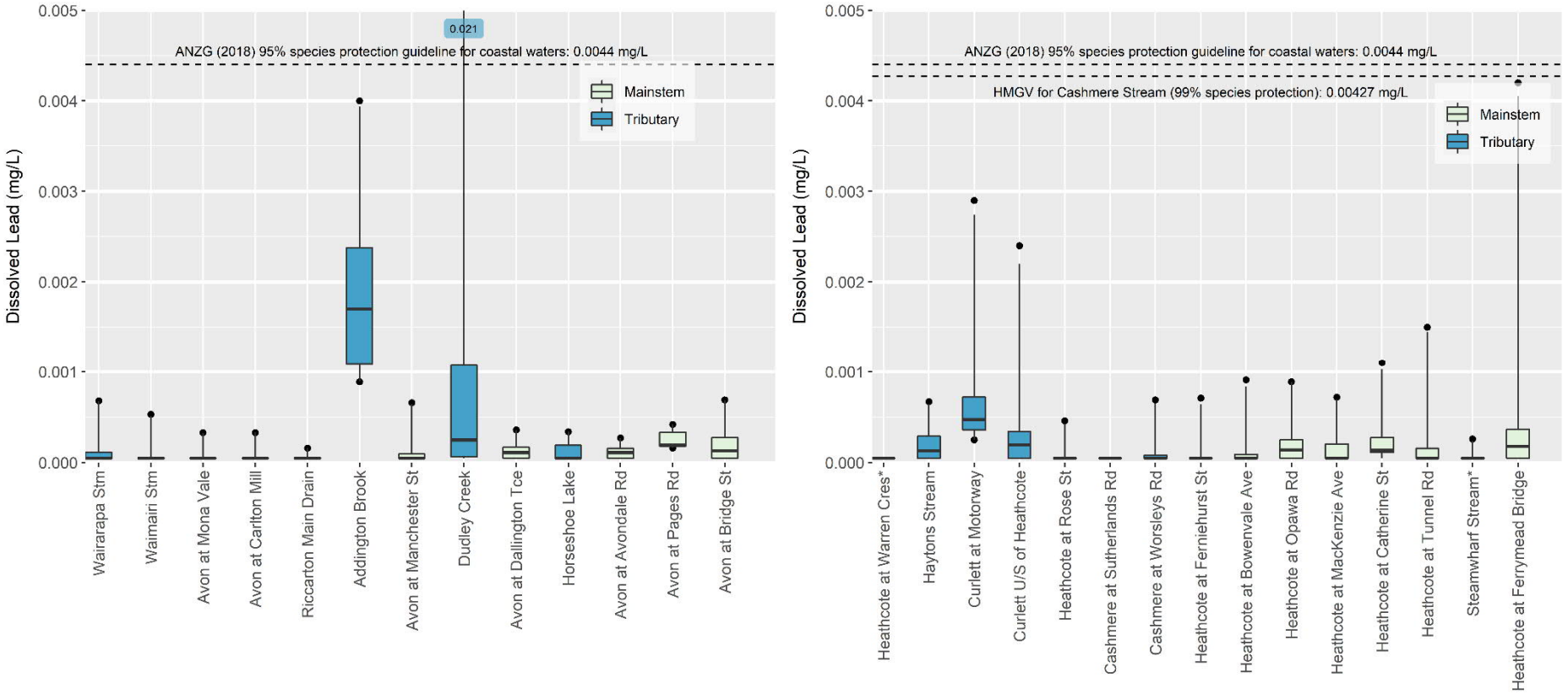


Figure ii (a). Dissolved lead concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the ANZG (2018) 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 more conservative coastal water guidelines. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – analysed as half this value (0.00005 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

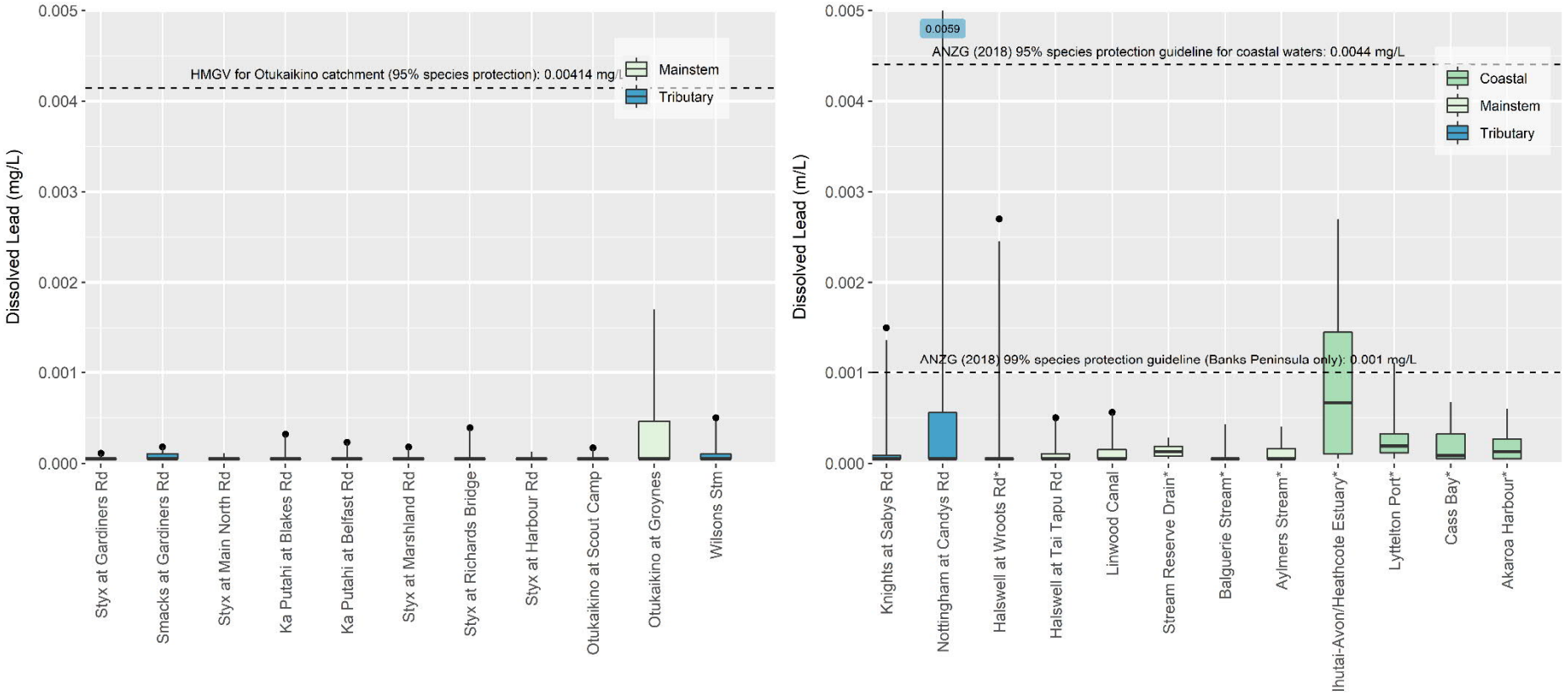


Figure ii (b). Dissolved lead concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the ANZG (2018) 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 more conservative coastal water guideline. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – analysed as half this value (0.00005 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

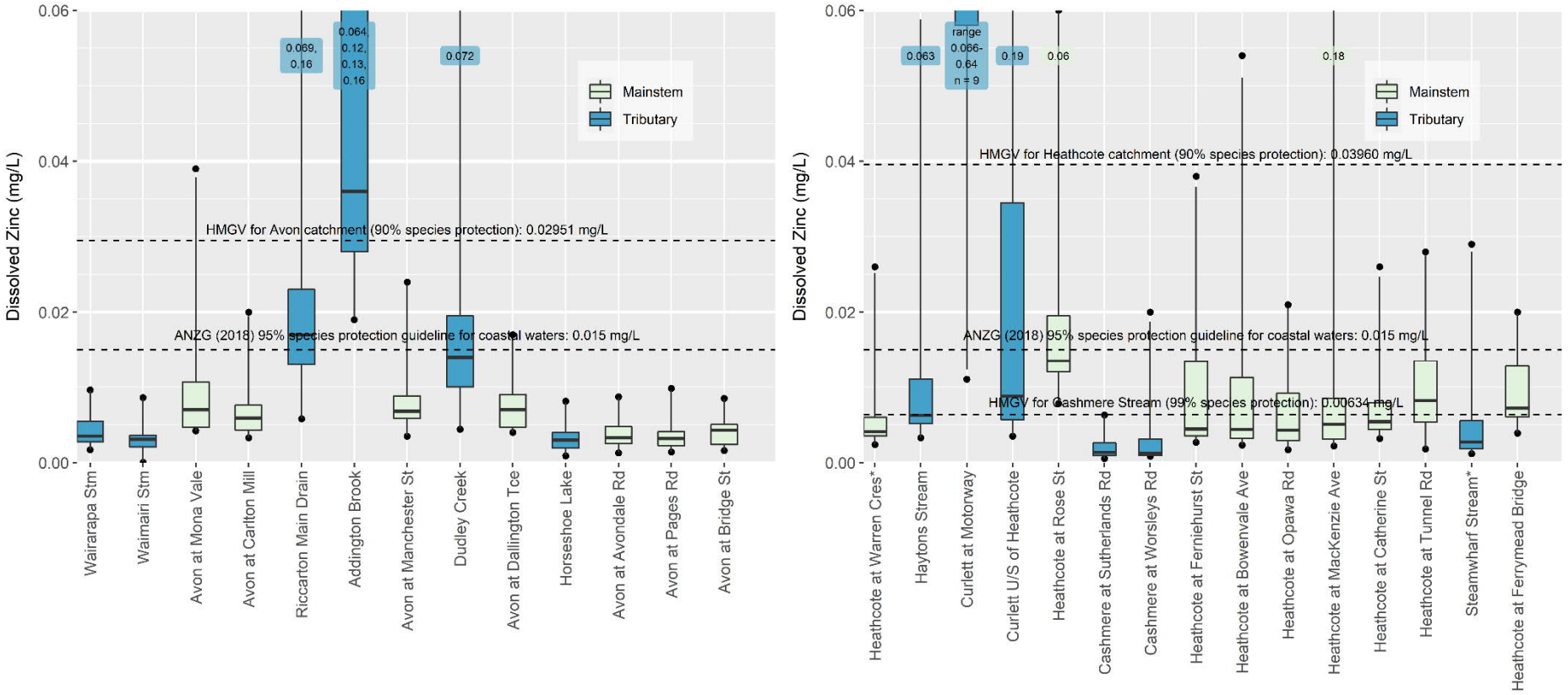


Figure iii (a). Dissolved zinc concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the ANZG (2018) 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 more conservative coastal water guidelines. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – analysed as half this value (0.00005 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

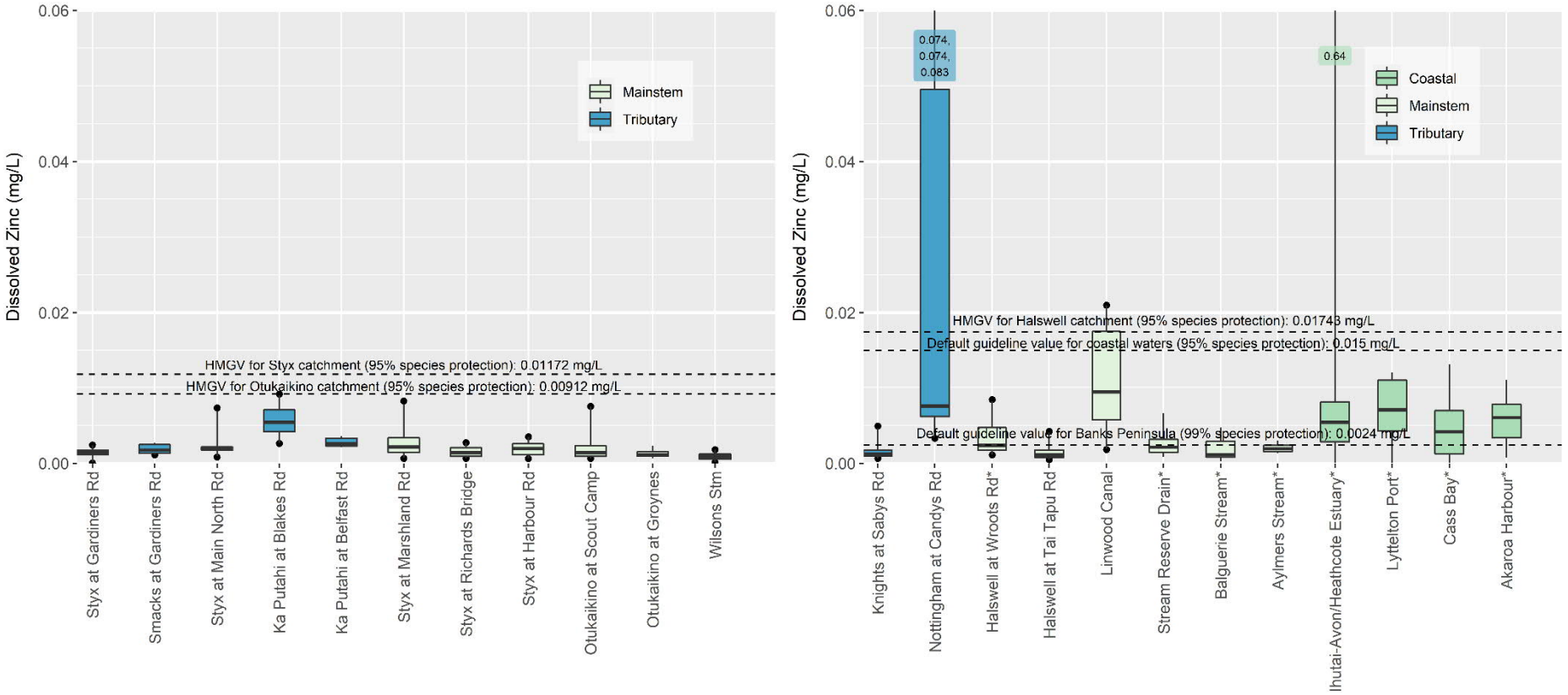


Figure iii (b). Dissolved zinc concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the ANZG (2018) guideline values. The strongly tidal Linwood Canal site is compared to the more conservative coastal water guideline. The Laboratory Limit of Detection for these two catchments was 0.0001 mg/L – analysed as half this value (0.00005 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

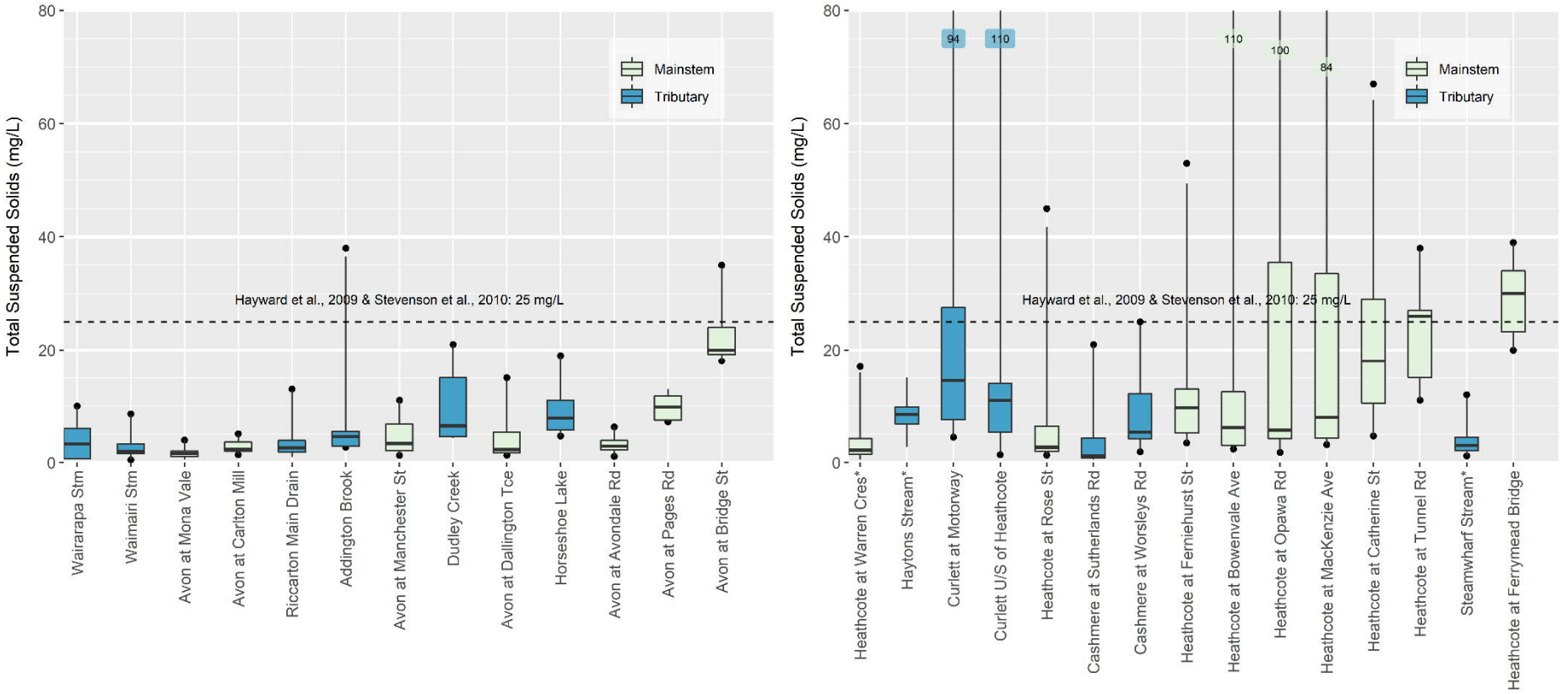


Figure vi (a). Total Suspended Solid (TSS) concentrations in water samples taken from the Ōtākaro-Avon (left graph) and Ōpāwaho-Heathcote (right graph) River sites, for the monitoring period January to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the guideline value of 25 mg/L (Hayward et al., 2009; Stevenson et al., 2010). There is no guideline for coastal sites. The Laboratory Limit of Detection was 1.0 mg/L – analysed as half this value (0.5 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.

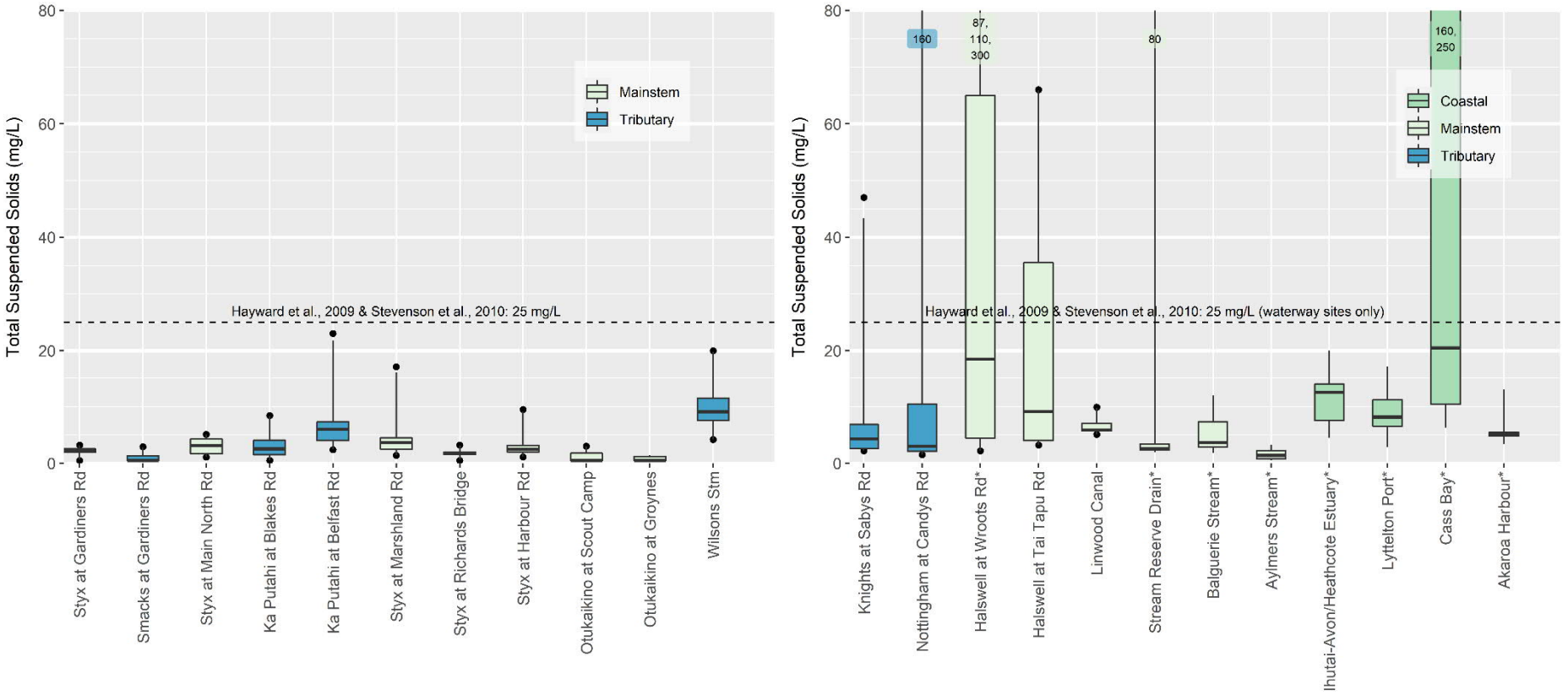


Figure vi (b). Total Suspended Solid (TSS) concentrations in water samples taken from the Pūharakekenui-Styx and Ōtūkaikino River (left graph), and the Huritini-Halswell River, Linwood Canal, Banks Peninsula and coastal sites (right graph), for the monitoring period January to December 2020. Sites with an asterisk indicate where sampling began in 2020. The dashed lines represent the waterway guideline value of 25 mg/L (Hayward et al., 2009; Stevenson et al., 2010). There is no guideline for coastal sites. The Laboratory Limit of Detection was 1.0 mg/L – analysed as half this value (0.5 mg/L) to allow statistics to be undertaken. The numbers in shaded boxes indicate samples that exceeded the y-axis.