Surface Water Quality Monitoring Report for Christchurch City Waterways: January – December 2014

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1 Executive Summary

- In accordance with the requirements of the Interim Global Stormwater Consent, the Styx Stormwater Management Plan (SMP) Consent and the South-West SMP Consent, this report summarises the results of the Christchurch City Council surface water quality monitoring for 2014.
- Monthly water samples were collected from 44 sites within the five major river catchments of Christchurch City (the Avon, Heathcote, Halswell, Styx and Otukaikino), Linwood Canal and Halswell Retention Basin, during the period January to December 2014. A range of different parameters were analysed, but those specifically assessed in this report include: metals (copper, lead and zinc), pH, conductivity, total suspended solids, turbidity, dissolved oxygen, temperature, biochemical oxygen demand, ammonia, nitrogen, phosphorus and *Escherichia coli* (as an indicator of pathogens).
- The levels of parameters recorded were compared spatially within and across catchments, and compared to relevant guideline levels. Parameter concentrations at each site were also compared to historic data to determine whether water quality is staying the same, increasing or decreasing over time.
- The Heathcote River catchment recorded the poorest water quality of all the catchments and the Otukaikino River catchment recorded the best water quality. However, the latter result was largely driven by a new site that has not yet been monitored during autumn and winter (Otukaikino Creek at Omaka Scout Camp).
- Other notable trends included higher concentrations of zinc in the Avon and Heathcote catchments; higher suspended solids, biochemical oxygen demand and ammonia in the Heathcote catchment; higher levels of nitrogen in the Heathcote and Halswell catchments; and lower levels of phosphorus in the Otukaikino catchment.
- The sites recording the poorest water quality across all catchments were Linwood Canal (particularly for suspended solids/turbidity, dissolved oxygen and phosphorus) and Haytons Stream at Retention Basin (particularly for suspended solids/turbidity, biochemical oxygen demand and phosphorus). However, there were many other sites that were also singled out as the worst site for each individual parameter. The site that recorded the best water quality across all sites was the Otukaikino Creek at Omaka Scout Camp.
- Within each catchment, there were a number of sites that consistently recorded parameters well outside the guideline levels and/or recorded substantially different one-off events compared to other sites. These were Dudley Creek, Addington Brook and Horseshoe Lake Discharge in the Avon; Haytons Stream at Retention Basin and Curletts Road Stream Upstream of Heathcote River in the Heathcote; Kaputone Creek at Blakes Road and Kaputone Creek at Belfast Road in the Styx; Wilsons Stream in the Otukaikino; and Knights Stream at Sabys Road in the Halswell.
- When compared to guideline levels, there were a number of parameters that were recorded at levels unlikely to cause adverse effects, including dissolved lead, pH, temperature, total ammonia and nitrate. However, there were a number of parameters that recorded values well outside the guidelines across most sites, including nitrogen, phosphorus and *E. coli*. There were also some parameters that generally recorded levels within the guidelines, but on a number of occasions, or regularly at a small number of sites, recorded

concentrations outside these values: dissolved copper, dissolved zinc, suspended solids, turbidity, dissolved oxygen and biochemical oxygen demand.

- The results of the temporal trends analysis showed that the majority of parameter concentrations for all the sites have remained steady over time. However, parameters at some sites recorded an increasing or decreasing trend in concentrations. Most notable changes were: a 30% increase in nitrogen at Knights Stream at Sabys Road; a 25% increase in conductivity at the Avon River at Bridge Street site; a 146%, 28% and 26% decrease in zinc, copper and turbidity, respectively, at the Curletts Road Stream Upstream of Heathcote River site; and a 25% decrease in turbidity at the Otukaikino River at Groynes Inlet site.
- The Halswell Retention Basin inlet and outlet sites recorded much higher levels than the majority of river sites for a number of parameters, including copper, lead, biochemical oxygen demand, ammonia, phosphorus and *E. coli*. This is to be expected given the predominantly stormwater input into the basins and that the rivers are subjected to dilution from baseflow. These wet basins are also likely impacted by more faecal input from waterfowl, contributing to the high levels of ammonia, phosphorus and *E. coli*. More variability in concentrations was also generally recorded at these sites compared to the river sites, possibly due to variable levels of parameters in stormwater and/or the treatment ability of the basin. The outlet recorded lower median concentrations that the inlet about half of the time, indicating that overall there was some improvement in water quality due to the basin. However, the outlet equally recorded similar levels to the inlet, or higher levels. However, it is difficult to deduce treatment ability given that the inlet and outlet samples are taken at almost exactly the same time, and the actual change in concentration of parameters was not tracked.
- This surface water monitoring indicates that these waterways are subjected to contamination, potentially from stormwater, wastewater and other inputs (i.e. waterfowl faeces). These parameters may be having short-term and long-term adverse effects on biota (i.e. nitrogen, copper, zinc, suspended solids/turbidity, dissolved oxygen and biochemical oxygen demand), 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. *E. coli*) and may affect water clarity/aesthetics (suspended solids/turbidity). These parameters are usually the ones of concern across urban waterways within New Zealand and internationally, and have been the same ones identified in past monitoring reports for these sites. These results also support the Urban Stream Syndrome (Walsh et al., 2005), whereby lower water quality is recorded internationally in urban (particularly industrial) areas (e.g. Avon and Heathcote catchments) and generally better water quality is recorded in rural areas (e.g. Otukaikino catchment).
- The sites and parameters identified to be of concern in this report should be the focus of catchment management practices in Christchurch. Such practices could include better treatment of stormwater and redirection of trade waste (e.g. vehicle wash down) to the sewer, instead of the stormwater system. Water quality in most of these catchments should improve over time with the instigation of Christchurch City Council SMPs, as well as Environment Canterbury catchment pollution projects and other targeted programmes through the Canterbury Water Management Strategy. Improvements should also occur with the progression of rebuild activities, as wastewater network improvements are completed and the level of earthworks and dewatering activity decreases.

2 Introduction

In accordance with the requirements of the Interim Global Stormwater Consent (IGSC; CRC090292), the Styx Stormwater Management Plan (SMP; CRC131249) and the South-West SMP (CRC120223), this report summarises the results of the Christchurch City Council (CCC) surface water quality monitoring for 2014. Monthly water samples were collected from 44 sites within the five major river catchments of Christchurch City (the Avon, Heathcote, Halswell, Styx and Otukaikino), Linwood Canal and Halswell Retention Basin, during the period January to December 2014 (Table 1, Figure 1).

3 Methods

3.1 Sites and Sample Collection

Water samples were collected monthly by the CCC laboratory, which is an International Accreditation New Zealand (IANZ) laboratory, according to the protocol outlined in the monitoring plans of the consents. The classification of each waterway with respect to the Environment Canterbury (ECan) Proposed Land and Water Regional Plan (pLWRP; Environment Canterbury, 2012) and the Waimakariri River Regional Plan (WRRP; Environment Canterbury, 2011) are shown in Table 1. These classifications determine the relevant guideline levels for each of the measured parameters for the various waterways. Results are compared against these guidelines in this report.

The two stormwater basin sites (Halswell Retention Basin Inlet and Outlet) are not classified as waterways and therefore are not compared to receiving water guidelines in this report. The WRRP also does not have guideline levels for a number of the parameters analysed in this report, so pLWRP guidelines were used as a surrogate in these cases. The Otukaikino River sites were the only locations covered by the WRRP; guideline levels for 'spring-fed – plains' in the pLWRP were used where relevant, as this was considered the most appropriate waterway classification for guideline comparison. The occurrence of rainfall during or within the 24 hours prior to sampling was recorded.

Table 1. Christchurch City Council water quality monitoring sites required under the three Environment Canterbury (ECan) stormwater consents. IGSC = Interim Global Stormwater Consent; SMP = Stormwater Management Plan; pLWRP = proposed Land & Water Regional Plan; WRRP = Waimakariri River Regional Plan.

Catchment	Site ID	Site	Easting	Northing	ECan Consent	pLWRP or WRRP Classification
Avon	AVON01	Avon River at Pages/Seaview Bridge	2487487	5744202	IGSC	Spring-fed – plains – urban (pLWRP)
	AVON02	Avon River at Bridge Street	2487694	5742425	IGSC	Spring-fed – plains – urban (pLWRP)
	AVON03	Avon River at Dallington Terrace/Gayhurst Road	2483562	5742822	IGSC	Spring-fed – plains – urban (pLWRP)
	AVON04	Avon River at Manchester Street	2480890	5742093	IGSC	Spring-fed – plains – urban (pLWRP)
	AVON05	Wairarapa Stream	2478250	5742915	IGSC	Spring-fed – plains – urban (pLWRP)
	AVON06	Waimairi Stream	2478232	5742784	IGSC	Spring-fed – plains – urban (pLWRP)
	AVON07	Avon River at Mona Vale	2478334	5742658	IGSC	Spring-fed – plains – urban (pLWRP)
	AVON08	Riccarton Main Drain[1]	2478683	5741631	IGSC	Spring-fed – plains – urban (pLWRP)
	AVON09	Addington Brook	2479427	5741438	IGSC	Spring-fed – plains – urban (pLWRP)
	AVON10	Dudley Creek	2482575	5743763	IGSC	Spring-fed – plains – urban (pLWRP)
	AVON11	Horseshoe Lake Discharge	2484344	5744907	IGSC	Spring-fed – plains – urban (pLWRP)
	AVON12	Avon River at Carlton Mill Corner	2479737	5742871	IGSC	Spring-fed – plains – urban (pLWRP)
	AVON13	Avon River at Avondale Road	2484754	5745170	IGSC	Spring-fed – plains – urban (pLWRP)

[1] This site has been incorrectly presented in past reports as being upstream of Riccarton Avenue, when it is actually upstream of Deans Avenue

Catchment	Site ID	Site	Easting	Northing	ECan Consent	pLWRP or WRRP Classification
Heathcote	HEATH01	Heathcote River at Ferrymead Bridge	2486494	5738760	IGSC	Spring-fed – plains – urban (pLWRP)
	HEATH02	Heathcote River at Tunnel Road	2485076	5739154	IGSC	Spring-fed – plains – urban (pLWRP)
	HEATH03	Heathcote River at Opawa Road/Clarendon Terrace	2483072	5739226	IGSC	Spring-fed – plains – urban (pLWRP)
	HEATH04	Heathcote River at Bowenvale Avenue	2481198	5737390	IGSC	Spring-fed – plains – urban (pLWRP)
	HEATH05	Cashmere Stream at Worsleys Road	2479030	5736765	South-West SMP	Banks Peninsula (pLWRP)
	HEATH06	Heathcote River at Rose Street	2478700	5737528	South-West SMP	Spring-fed – plains – urban (pLWRP)
	HEATH07	Heathcote River at Ferniehurst Street	2479157	5737222	South-West SMP	Spring-fed – plains – urban (pLWRP)
	HEATH08	Heathcote River at Templetons Road	2475913	5738508	South-West SMP	Spring-fed – plains – urban (pLWRP)
	HEATH09	Haytons Stream at Retention Basin	2476019	5739207	South-West SMP	Spring-fed – plains – urban (pLWRP)
	HEATH10	Curletts Road Stream Upstream of Heathcote River Confluence	2476927	5739322	IGSC	Spring-fed – plains – urban (pLWRP)
	HEATH11	Heathcote River at Catherine Street	2484415	5739494	IGSC	Spring-fed – plains – urban (pLWRP)
	HEATH12	Heathcote River at MacKenzie Avenue Footbridge	2483521	5739528	IGSC	Spring-fed – plains – urban (pLWRP)
	HEATH14	Curletts Road Stream at Southern Motorway	2476404	5739969	IGSC	Spring-fed – plains – urban (pLWRP)
	HEATH16	Cashmere Stream at Sutherlands Road	2476084	5735598	South-West SMP	Not classified[2]

[2] But considered in this report a Banks Peninsula waterway, as per the lower reaches

Catchment	Site ID	Site	Easting	Northing	ECan Consent	pLWRP or WRRP Classification
Styx	STYX01	Smacks Creek at Gardiners Road near Styx Mill Road	2476803	5749571	Styx SMP	Unclassified[3]
	STYX02	Styx River at Gardiners Road	2476789	5748841	Styx SMP	Unclassified[3]
	STYX03	Styx River at Main North Road	2479066	5748834	Styx SMP	Unclassified[3]
	STYX04	Kaputone Creek at Blakes Road	2480401	5749645	Styx SMP	Unclassified[3]
	STYX05	Kaputone Creek at Belfast Road	2482195	5749882	Styx SMP	Unclassified[3]
	STYX06	Styx River at Marshland Road Bridge	2482359	5749393	Styx SMP	Unclassified[3]
	STYX07	Styx River at Richards Bridge	2483977	5751255	Styx SMP	Unclassified[3]
	STYX08	Styx River at Harbour Road Bridge	2485000	5756366	Styx SMP	Unclassified[3]
Halswell	HALS01	Halswell Retention Basin Inlet	2471698	5738633	IGSC	Not relevant
	HALS02	Halswell Retention Basin Outlet	2471793	5738525	IGSC	Not relevant
	HALS03	Nottingham Stream at Candys Road	2474530	5734689	South-West SMP	Spring-fed – plains (pLWRP)
	HALS04	Halswell River at Akaroa Highway	2474444	5733330	South-West SMP	Spring-fed – plains (pLWRP)
	HALS05	Knights Stream at Sabys Road	2473720	5734461	South-West SMP	Spring-fed – plains (pLWRP)
Otukaikino	OTUKAI01	Otukaikino River at Groynes Inlet	2477878	5750484	IGSC	OTU/GROYNES (WRRP)
	OTUKAI02	Wilsons Drain at Main North Road	2481242	5752409	Styx SMP	WAIM-TRIB (WRRP)
	OTUKAI03	Otukaikino Creek at Omaka Scout Camp	2475663	5749653	-	OTU/GROYNES (WRRP)
Linwood	OUT01	Linwood Canal/City Outfall Drain	2485954	5739637	IGSC	Unclassified

[3] Under the NRRP these waterways are classified 'spring-fed - plains' and it is likely the pLWRP will be amended to be in line with the NRRP (Michele Stevenson, Environment Canterbury, personal communication); therefore, these locations are considered as 'spring-fed - plains' in this report

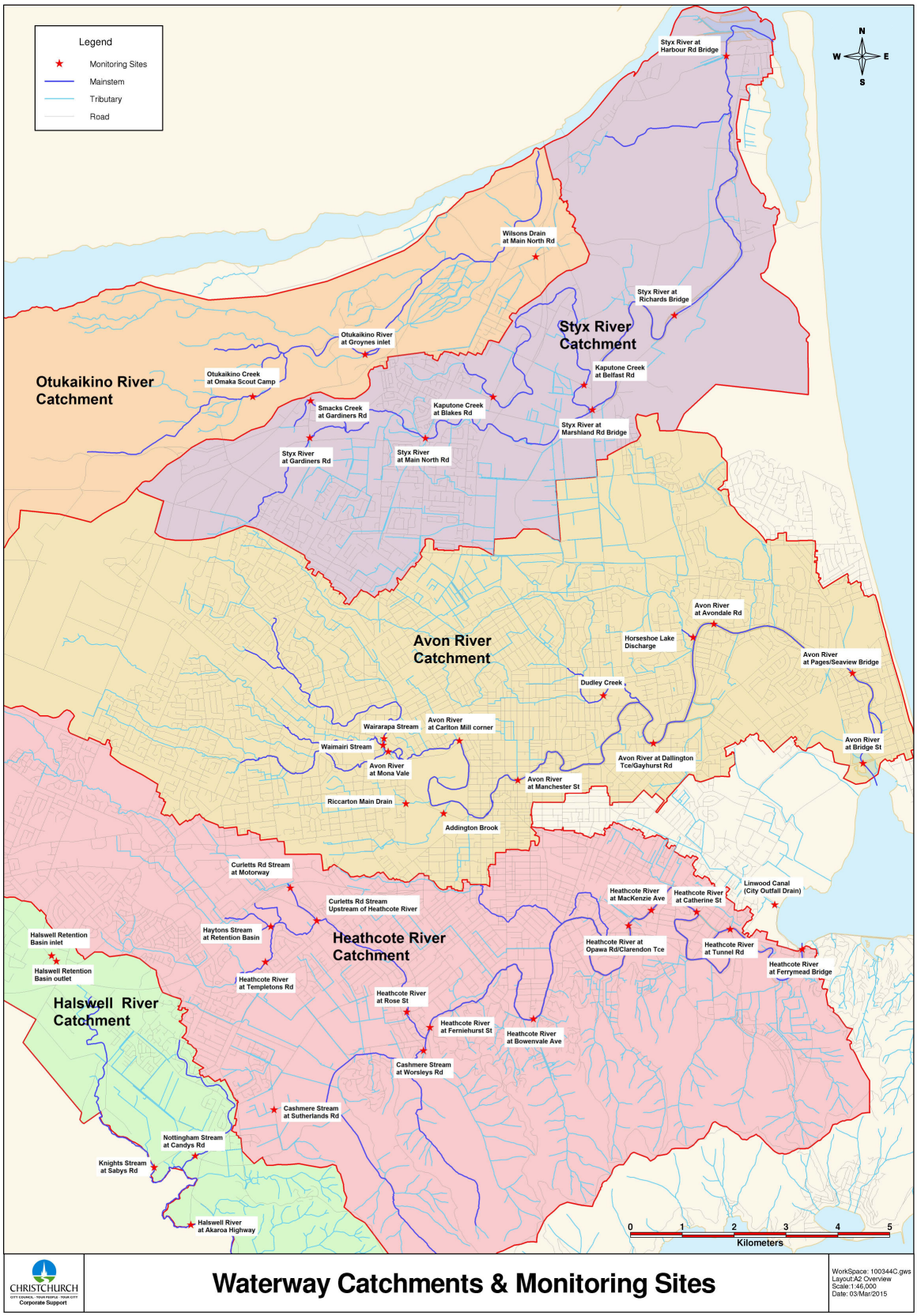

Figure 1. Location of Christchurch City Council surface water quality monitoring sites

3.2 Water Quality Parameters Tested

The samples were tested at the laboratory for a range of different water quality parameters, as outlined in Table 2. Not all parameters are tested at all sites, and only the most pertinent parameters are analysed and discussed in this report. Summary statistics for all parameters at all sites are provided in Appendix A. A brief discussion of each parameter, their importance and relevant guideline levels are included in the following paragraphs.

Metals, in particular, *copper*, *lead* and *zinc*, can be toxic to aquatic organisms, negatively affecting such things as fecundity, maturation, respiration, physical structure and behaviour (Harding, 2005). The toxicity of metals in freshwater, and therefore the risk of adverse biological effects, alters depending on the hardness, pH and alkalinity of the water (ANZECC 2000). Therefore, trigger levels should be calculated with consideration of water hardness (ANZECC 2000). For this monitoring report, this is relevant for dissolved copper, lead and zinc. The CCC has previously calculated Hardness Modified Trigger Values (HMTV) for metals in Christchurch Rivers in accordance with ANZECC (2000) methodology (see Appendix B) and these values are therefore used in this monitoring report.

pH is a measure of acidity or alkalinity, on a scale from 0 to 14; a pH value of seven is neutral, less than seven is acidic and greater than seven is alkaline. Appropriate pH levels are essential for the physiological functions of biota, such as respiration and excretion (Environment Canterbury, 2009). Aquatic species typically have tolerances for certain pH levels and alteration of pH can result in changes in the composition of fish and invertebrate communities, with generally a positive relationship between pH and the number of species present (Collier et al. 1990). The guidelines in the pLWRP for all waterways are a lower limit of 6.5 and an upper limit of 8.5. The WRRP, which covers the Otukaikino River catchment sites in this report, does not detail a guideline level.

Conductivity is a measure of how well water conducts an electrical current. Pure water has very low conductivity, but dissolved ions in the water (e.g. contaminants such as metals and nutrients) increase conductivity. Traditionally, conductivity has been compared to the guideline value of <175 µS/cm recommended by Biggs (1988) to avoid excessive periphyton growth. However, this guideline may be less relevant in urban waterways, where other contaminants that will not encourage periphyton growth may be contributing to high conductivity, such as metals. It is also noted that ECan do not consider this guideline value is useful, due to natural variations in levels (Abigail Bartram, ECan, personal communication 2013). They instead consider that analysis of trends is more useful, which is the approach adopted in this report.

Elevated levels of suspended sediment (*Total Suspended Solids*, TSS) in the water column decrease the clarity of the water and can adversely affect aquatic plants, invertebrates and fish (Crowe & Hay, 2004; Ryan, 1991). For example, sediment can affect photosynthesis of plants and therefore primary productivity within streams, interfere with feeding through the smothering of food supply, and can clog suitable habitat for species (Crowe & Hay, 2004; Ryan, 1991). The pLWRP (decisions version) details in Rule 5.95 standards for TSS in stormwater prior to discharge, but does not detail specifically a guideline value within waterways. The WRRP also does not detail a guideline level. Ryan (1991) recommends a guideline value of 25 mg/L to ensure

protection of aesthetic and ecological values, and therefore this guideline is used in this monitoring report.

Turbidity is a measure of the transmission of light through water. Suspended matter in the water column causes light to be scattered or absorbed as is travels through the water. As for TSS, turbidity decreases the clarity of the water and can negatively affect stream biota (Ryan, 1991). A guideline level for this parameter is not provided in the pLWRP or the WRRP. ANZECC (2000) provides a guideline of 5.6 Nephelometric Turbidity Units (NTU) for lowland rivers, which is used in this report.

Dissolved Oxygen (DO) is the concentration of oxygen dissolved or freely available in water and is commonly expressed as percent saturation. Adequate DO levels are essential for aquatic animals, such as fish and invertebrates, and can be influenced by many factors, including temperature, velocity, decomposition of organic material, and the photosynthesis and respiration of aquatic plants. The pLWRP details a minimum DO level of 70% for 'spring-fed – plains' and 'spring-fed – plains – urban' waterways, and 90% for Banks Peninsula waterways (i.e. Cashmere Stream in this monitoring report). The WRRP details a minimum of 80% for the waterways relevant to this monitoring report (i.e. Otukaikino River catchment).

High *water temperature* can affect aquatic biota, with some studies showing that the presence of sensitive macroinvertebrates decreases with increasing temperature (Wahl et al., 2013). The pLWRP water quality standard for temperature is a maximum of 20°C; the WRRP details a maximum of 25°C for the waterways relevant to this monitoring report (i.e. Otukaikino River catchment).

Biochemical Oxygen Demand (BOD_5) is an indicator of the amount of biodegradable organic material in the water and the amount of oxygen required by bacteria to break down this material. High BOD_5 values are due to plant matter, nitrogen and phosphorus, and indicate the potential for bacteria to deplete oxygen levels in the water. The pLWRP does not have a guideline level for this parameter. The WRRP and the Ministry for the Environment (1992) guideline level is 2 mg/L.

Total ammonia (ammoniacal nitrogen) is typically a minor component of the nitrogen available for plant growth, but at high levels can have toxic effects on aquatic ecosystems. The toxicity of ammonia varies with pH (ANZECC, 2000). Therefore, the pLWRP water quality standards also vary depending on pH, ranging from 2.57 mg/L at pH 6 to 0.18 mg/L at pH 9 (Environment Canterbury, 2012). For this report, the water quality standard was adjusted based on the median pH levels for the relevant catchments. The exception to this is for Banks Peninsula waterways (i.e. Cashmere Stream in this monitoring report), that have a set guideline value regardless of pH (0.32 mg/L). The WRRP does not have a guideline level.

Nitrate can also be toxic to stream biota and specific guidelines for this parameter have recently been developed to protect freshwater species (Hickey, 2013). Guidelines are available for different species protection levels: 99% (pristine environment with high biodiversity and conservation values), 95% (environments which are subject to a range of disturbances from human activities, but with minor effects), 90% (environments which have naturally seasonally elevated concentrations for significant periods of the year (1-3 months)), 80% (environments which are measurably degraded and which have seasonally elevated concentrations for significant periods of the year (1-3 months)), and acute (environments which are significantly degraded; probable chronic effects on multiple species). Based on these descriptions and the predominantly urban

nature of the waterways monitored, most of the waterways in this report would fall under the 80% to acute species description (i.e. Avon, Heathcote and Halswell River catchments). However, the Styx and Otukaikino River catchments (and Cashmere Stream) likely fall under the 90% species protection; these catchments have much better water quality, but exceed some of the receiving water quality guidelines throughout the year. To be conservative, the 90% species protection was chosen as the guideline level for all waterways in this report. Within this 90% level of species protection there are two guideline values: the 'grading' guideline (3.8 mg/L) that provides for ecosystem protection for average long-term exposure (measured against medians) and the 'surveillance' guideline (5.6 mg/L) that assesses seasonal maximum concentrations (measured against annual 95% percentiles). Both guideline levels have been assessed in this report to investigate both long-term and short-term effects.

Elevated concentrations of *Nitrate Nitrite Nitrogen* (NNN) can lead to the proliferation of aquatic plants and algae, because nitrate and nitrite are oxidised forms of nitrogen that are readily available to plants. The pLWRP or the WRRP does not have a guideline value for this parameter, but the ANZECC (2000) water quality guidelines provide a trigger value of 0.444 mg/L for lowland rivers to avoid excessive plant growth.

Dissolved Inorganic Nitrogen (DIN), which is the sum of ammonia, nitrite and nitrate, provides a measure of the risk of eutrophication and toxicity (Environment Canterbury, 2012). The pLWRP details a value of 1.5 mg/L for 'spring-fed – plains' and 'spring-fed – plains – urban' waterways, and 0.09 mg/L for Banks Peninsula waterways. There is no guideline value for this parameter in the WRRP.

Dissolved Reactive Phosphorus (DRP) is a soluble form of phosphorus that is readily available for use by plants. Phosphorus is an essential nutrient for plant growth and can limit primary production at low levels, but can cause proliferation of algae and aquatic plants at high levels. The guideline levels in the pLWRP for 'spring-fed - plains' and 'spring-fed – plains – urban' waterways are 0.016 mg/L, and 0.025 mg/L for Banks Peninsula waterways. There is no guideline value for this parameter in the WRRP.

Escherichia coli is a bacterium that is commonly used as an indicator of faecal contamination in freshwater and therefore health risk from contact recreation (Ministry for the Environment, 2003). The guideline level in the pLWRP for 'spring-fed – plains', 'spring-fed – plains – urban' and Banks Peninsula waterways is 550 *E. coli* per 100ml (for 95% of samples). The WRRP does not have a guideline value for this parameter.

Table 2. Parameters analysed in water samples taken in accordance with consenting requirements

Parameter	Units of Measurement
Total ammonia (ammoniacal nitrogen)	mg/L
Biochemical Oxygen Demand (BOD_5)	mg/L
Conductivity	µS/cm
Total and dissolved copper	mg/L
Dissolved Oxygen (DO)	mg/L and % saturation
Enterococci	MPN/100ml
Escherichia coli	CFU/100ml
Total water hardness	g/m^3 as calcium carbonate
Total and dissolved lead	mg/L
Nitrate nitrogen	mg/L
Nitrite nitrogen	mg/L
Nitrate-Nitrite-Nitrogen (NNN)	mg/L
Dissolved Inorganic Nitrogen (DIN)	mg/L
pH	
Dissolved Reactive Phosphorus (DRP)	mg/L
Total phosphorus	mg/L
Total Suspended Solids (TSS)	mg/L
Water temperature	℃
Total nitrogen	mg/L
Turbidity	NTU
Total and dissolved zinc	

3.3 Data Analysis

3.3.1 Summary Statistics

Summary statistics of monthly water quality data at the sites were analysed using IBM® SPSS® Statistics 20. To allow analysis, water quality values that were less than the laboratory Limit of Detection (LOD) were converted to half the detection limit. *E.coli* levels which exceeded the maximum laboratory limit for counting (24,000 CFU/100ml) where analysed as 24,000; it should be noted that levels may have been much higher than this. Data was graphed using boxplots, to show medians and interquartile ranges. Statistical outliers were not removed from these summary statistics, as values were assumed to be 'real', providing useful information on variations in the concentrations recorded. The sites are ordered from upstream to downstream in the graphs, with mainstem and tributary sites colour-coded.

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 95% of the data. Circles represent statistical outliers and stars represent extreme 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.

3.3.2 Temporal Trends Analysis

Temporal trends analysis was carried out on the data from each of the sites, to determine whether water quality is decreasing, increasing or staying the same over time. Some of the sites have been monitored for longer periods than others, as detailed in Table 3. The Curletts Road Stream at Motorway site was not sampled from February 2012 – May 2014 due to the construction of the motorway, as such, caution should be taken when inferring temporal trends. Dissolved metals have also only been analysed since 2011, with total metals sampled prior to this. Dissolved metals are now considered to be more relevant because they constitute the bio-available proportion of metals that can have adverse effects on biota (ANZECC, 2000). The guidelines also pertain to dissolved metals, not total metals.

Trends analysis was conducted using the Time Trends software developed by NIWA (NIWA, 2014). Trends analysis cannot be performed on parameters that have a high proportion of data below the LOD or very small values, therefore analyses were unable to be undertaken for dissolved copper (except at Curletts Road Stream Upstream of Heathcote River) and dissolved lead. This software also requires three years of data for temporal trends analysis (NIWA, 2014), therefore analysis was unable to be undertaken on two of the Otukaikino River catchment sites (Otukaikino at Omaka Scout Camp and Wilsons Stream; Table 3). The Seasonal Kendall trend test was used to test the significance, magnitude and direction of the trends, providing an average annual percentage change. Where water quality results were less than the LOD, the Time Trends software converted these values to 10% below the LOD.

The 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. Flow adjustment was only undertaken at the one site where a flow gauge was directly present (Heathcote River at Ferniehurst Street). It is considered that extrapolation of this flow gauge 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 habitat and additional stormwater inputs. This may lead to inaccurate trend conclusions. For the sites where flow at the time of sampling is unknown, given the long interval of monitoring, it is considered that variations in flow rates between sampling events will not strongly influence the trends analysis, given most events will have been conducted during baseflow conditions. Data for the Heathcote River at Ferniehurst Street site were adjusted in Time Trends by the flow (m^3/s) for the period 24-hours prior to sampling, using the Locally Weighted Scatterplot Smoothing (LOWESS) method. However, flow did not account for the majority of the variation for most parameters (all contributions were below 50%). The exception to this was for TSS and turbidity (not unexpected, given these parameters are related), where flow accounted for 66% and 79% of the variation, respectively. Therefore, flow adjusted data was presented in this report for these two parameters.

Table 3. Summary of the date of first sampling at the 44 water quality monitoring sites

Catchment	Site Description	Monitoring Instigated
Avon	Wairarapa Stream	January 2007
	Waimairi Stream	January 2007
	Avon River at Mona Vale	January 2007
	Avon River at Carlton Mill Corner	October 2008
	Riccarton Main Drain	October 2008
	Addington Brook	October 2008
	Avon River at Manchester Street	July 2008
	Dudley Creek	October 2008
	Avon River at Dallington Terrace/Gayhurst Road	January 2007
	Horseshoe Lake Discharge	October 2008
	Avon River at Avondale Road	October 2008
	Avon River at Pages/Seaview Bridge	January 2007
	Avon River at Bridge Street	January 2007
Heathcote	Heathcote River at Templetons Road	January 2007
	Haytons Stream at Retention Basin	April 2007
	Curletts Road Stream Upstream of Heathcote River	October 2008
	Curletts Road Stream at Motorway	October 2008
	Heathcote River at Rose Street	June 2008
	Cashmere Stream at Sutherlands Road	December 2010
	Cashmere Stream at Worsleys Road	January 2007
	Heathcote River at Ferniehurst Street	July 2008
	Heathcote River at Bowenvale Avenue	January 2007
	Heathcote River at Opawa Road/Clarendon Terrace	January 2007
	Heathcote River at Mackenzie Avenue	October 2008
	Heathcote River at Catherine Street	October 2008
	Heathcote River at Tunnel Road	January 2007
	Heathcote River at Ferrymead Bridge	January 2007
Styx	Smacks Creek at Gardiners Road	January 2007
	Styx River at Gardiners Road	January 2007
	Styx River at Main North Road	January 2007
	Kaputone at Blakes Road	January 2007
	Kaputone at Belfast Road	January 2007
	Styx River at Marshland Road Bridge	January 2007
	Styx River at Richards Bridge	October 2008
	Styx River at Harbour Road Bridge	January 2008
Halswell	Halswell Retention Basin Inlet	April 2007
	Halswell Retention Basin Outlet	April 2007
	Knights Stream at Sabys Road	May 2012
	Nottingham Stream at Candys Road	October 2008
	Halswell River at Akaroa Highway	October 2008
Otukaikino	Otukaikino Creek at Omaka Scout Camp	October 2014
	Otukaikino River at Groynes Inlet	October 2008
	Wilsons Drain at Main North Road	November 2013
Linwood	Linwood Canal	January 2007

4 Results

4.1 Summary Statistics and Comparison to Guidelines

Appendix A presents the summary statistics for the monitoring period for each parameter at each site. The results of the monitoring in relation to the receiving water quality guidelines are detailed in the sections below. A summary and ranking of the river sites exhibiting high ('Best Sites') and poor ('Worst Sites) water quality for each contaminant is then presented in Tables 4 to 5. Sites within each catchment that recorded parameters well outside the guideline levels, and/or recorded substantially different one-off events compared to other sites, are also summarised in Table 6.

4.1.1 Dissolved Copper

The concentrations of dissolved copper for a significant proportion of samples across all catchments were below the LOD of 0.002 mg/L (analysed as half this value, 0.001 mg/L (Figures 2a and 2b). This lack of variability resulted in the medians being equivalent to the LOD and no interquartile ranges. The exception to this was Haytons Stream, Curletts Road Stream at Motorway and three sites in the lower Heathcote River (all in the Heathcote River catchment), which recorded some variability through the monitoring period. As most sites recorded low levels, there appeared to be no consistent trend in concentrations downstream for any of the catchments. Both of the retention basin sites recorded high levels compared to most of the waterways, and concentrations were similar between the inlet and the outlet.

The largest concentrations recorded across the sites were at the Curletts Road Stream Upstream of Heathcote River site in June (0.011 mg/L) and at the Heathcote River at Tunnel Road site in March (0.008 mg/L). While the former reading was recorded in association with rain and is therefore likely due to stormwater run-off, the latter was not. The Curletts Road Stream at Motorway site also consistently recorded high values compared to all other sites.

The Curletts Road Stream at Motorway site was the only site to record a median concentration above the respective guideline level. Additionally, the respective guideline levels were exceeded on at least one sampling occasion at sites in the Avon River catchment (Riccarton Main Drain, Addington Brook and Dudley Creek) and the Heathcote River catchment (Curletts Road Stream Upstream of Heathcote River and Heathcote River at Tunnel Road). All exceedances, with the exception of the Heathcote River at Tunnel Road site, were associated with rainfall.

4.1.2 Dissolved Lead

The majority of river sites across all catchments recorded dissolved lead concentrations consistently below the LOD of 0.0015 mg/L (analysed as half this value, 0.00075 mg/L, to allow statistics to be undertaken). This was shown by the medians being the same as the LOD and only two river sites exhibiting an interquartile range (Dudley Creek and Heathcote River at Ferrymead Bridge; Figures 3a and 3b). Given the low levels recorded, there were no trends in concentrations downstream for any of

the catchments. Both of the retention basin sites recorded high levels compared to the waterways, and concentrations appeared greater at the outlet compared to the inlet.

Dudley Creek and the Heathcote River at Ferrymead Bridge recorded consistently higher levels than the other sites. The highest levels recorded at all sites were from Addington Brook (0.0037 mg/L in November) and Heathcote River at Ferrymead Bridge (0.0047 mg/L in January). While the former reading was recorded in association with rain, the latter was not. No concentrations above the respective receiving water guidelines were recorded on any occasion during the monitoring period.

4.1.3 Dissolved Zinc

Zinc levels in the Avon and Heathcote River catchments were considerably higher than that recorded in the other catchments (Figures 4a and 4b). The two Halswell Retention Basin sites recorded levels similar to the sites with high values in the Heathcote and Avon River catchments. Levels appeared to be lower at the outlet than the inlet. There were no apparent upstream or downstream trends in concentrations in any of the catchments.

Curletts Road Stream Upstream of Heathcote River recorded the highest concentration across all sites during the monitoring period (0.35 mg/L in June). Although it was not raining at the time of sampling, it had been in the previous 24 hours.

The median levels of dissolved zinc for all river sites were below the respective water quality receiving guidelines. The exception to this was the Curletts Road Stream at Motorway site in the Heathcote River catchment, which recorded highly variable results over the monitoring period (shown by the long interquartile range). There were a few sites that exceeded the guideline on a number of individual sampling events however, as shown by the interquartile range exceeding this value. These sites were the Avon River at Carlton Mill Corner, Addington Brook and Dudley Creek in the Avon catchment; Haytons Stream at Retention Basin, Curletts Road Stream at Motorway and Heathcote River at Catherine Street in the Heathcote catchment; and the Linwood Canal. There were also other one-off events (as shown by the outliers) that exceeded guideline levels in all catchments during the monitoring period.

4.1.4 pH

The levels of pH were similar across all sites and catchments during the monitoring period (Figures 5a and 5b). There were no apparent trends downstream in any of the catchments. pH levels at the Halswell Retention Basin sites were similar to each other and the other river sites.

Median pH levels for all river sites were well within the lower and upper guideline levels. However, pH levels were at or below the lower guideline level on one sampling event at each of the following sites in the Avon and Styx River catchments: Wairarapa Stream, Waimairi Stream, Avon River at Mona Vale, Avon River at Seaview Bridge, Avon River at Bridge Street, Styx River at Gardiners Road, Styx River at Main North Road, Kaputone Creek at Blakes Road and Kaputone Creek at Belfast Road. These values were all relatively low (i.e. acidic), the lowest being pH 5.5, recorded at both the Kaputone Creek sites in May. It was not raining during this sampling event, nor had it been within the previous 24-hours. In addition, Wilsons Stream (Otukaikino River

catchment) recorded a single outlier on the upper guideline value (8.5) in February, the sole river site to equal or exceed the upper limit. It was not raining during the sampling period, nor had it rained in the 24 hours prior. No other river sites recorded pH values above the guideline.

4.1.5 Conductivity

Conductivity levels varied substantially within the Avon and Heathcote River catchments, with the tidal sites generally showing the most variation and the highest values (e.g. the Avon River at Bridge Street, and the Heathcote River at Ferrymead Bridge; Figures 6a and 6b). Saltwater intrusion is known to extend well upstream in the Avon and Heathcote River catchments; as far upstream as the Avon River at Avondale Bridge and Heathcote River at Opawa Road/Clarendon Terrace sites. In addition, the Linwood Canal exhibited high conductivity, being tidal also. These high values are predominantly due to salinity influences, rather than the presence of contaminants. One-off events of higher than normal conductivity (as shown by the outliers) were only observed at the tidal sites, so again this is likely related to salinity changes. The Styx and Otukaikino River catchments recorded lower conductivity compared to the other catchments (no value exceeded 252 µS/cm). Levels in the Heathcote River catchment appeared to be greater than the Avon and Halswell River catchments. Levels did not appear to increase or decrease downstream in any of the catchments. The two Halswell Retention Basin sites generally recorded similar conductivity levels to each other and the river sites.

The highest value recorded (22200 µS/cm) was shared by the Avon River at Bridge Street in August and the Heathcote River at Ferrymead Bridge in January, with no recent rainfall recorded on either date. The highest value recorded for the sites not influenced by salinity was Addington Brook (506 µS/cm in June) and this was not associated with a rainfall event. This site appeared to have consistently higher readings than the other Avon River catchment sites.

4.1.6 Total Suspended Solids

The Heathcote River catchment generally recorded higher TSS levels (with greater variability in concentrations) than the other catchments (Figures 7a and 7b). The other catchments recorded similar levels to each other. There appeared to be a general increase in TSS downstream in both the Avon and Heathcote River mainstems. There was no observable trend in either the Styx or Otukaikino River mainstems. However, these downstream trends in the Avon and Heathcote appear to be driven by the lower tidal sites showing high levels, potentially due to re-suspension of sediment from tidal movement. The other catchments do not have monitoring sites as close to the river mouth for comparison. In the Heathcote River catchment, Cashmere Stream had much higher TSS levels in the most downstream monitoring site compared to the upstream site. Levels at the Halswell Retention Basin sites were similar to the highest levels recorded in the river sites (in the lower reaches of the Heathcote River). The outlet appeared to recorded lower levels than the inlet.

Kaputone Creek at Blakes Road recorded the highest concentration of all river sites of 120 mg/L in September, followed by Dudley Creek in June (91 mg/L), with neither value associated with rainfall. The Halswell Retention Basin Inlet also recorded the same value as Kaputone Creek (120 mg/L) in July.

The Heathcote River at Ferrymead Bridge site was the only location where median values exceeded exceed the guideline value. The Heathcote River at Tunnel Road site exceeded the guideline value on a number of occasions throughout the monitoring period, as shown by the interquartile range extending above this value. There were also a number of sites in the Avon (five sites) and Heathcote River (eight sites) catchments that exceeded the guidelines on one-off sampling events, as shown by the outliers and T-bars extending past this value. Kaputone Creek at Blakes Road, Wilsons Stream and Nottingham Stream also exceeded the guideline during one of the sampling months.

4.1.7 Turbidity

The Heathcote River catchment generally recorded higher levels than the Avon River (Figures 8a and 8b). Styx, Otukaikino and Halswell River catchments recorded similar levels to each other, but lower than the Avon River catchment. Levels generally increased downstream in the Avon and Heathcote River mainstems. However, as discussed for TSS this may be due to these catchments having lower tidal sites that experience re-suspension of sediment due to tidal movement. The most downstream Cashmere Stream site again recorded higher turbidity levels than the upstream site. Turbidity was not recorded at the Halswell Retention Basin sites.

The Heathcote River at Ferrymead Bridge site recorded relatively large variations in concentrations throughout the monitoring period compared to the other sites and recorded the highest value across all sites (97 NTU in July). Although it was not raining at the time of sampling, it had been in the 24-hour period previous. Turbidity at the Dudley Creek site was in general much higher and more variable than the other Avon sites.

Median turbidity concentrations for all sites were below the guideline level, with the exception of Dudley Creek, Avon River at Bridge Street, Haytons Stream at Retention Basin, Heathcote River at Tunnel Road, Heathcote River at Ferrymead Bridge and Linwood Canal. The majority of sites exceeded the guideline level on at least one occasion during the monitoring period, the exceptions being Avon River at Manchester Street, Cashmere Stream at Sutherlands Road and five sites within the Styx/Otukaikino catchment.

4.1.8 Dissolved Oxygen

Dissolved oxygen levels were generally similar within and between catchments (Figures 9a and 9b). Of particular note was that the Haytons Stream site and the two Curletts Road Stream sites recorded more variability compared to the other sites. No trends in concentrations were recorded downstream. The Halswell Retention Basin recorded similar levels to the river sites, but there was more variation at these basin sites. The lowest reading at the inlet was 5% in December, which is much lower compared to that recorded at any of the river sites. The outlet also appeared to generally record higher levels than the inlet.

The highest DO reading within the river sites of 140% was recorded at the Curletts Road Stream at Motorway site in September, where it has rained in the 24-hours

previous to sampling. The lowest recorded river DO level was 15% at the Haytons Stream at Retention Basin site in March and was not associated with rainfall.

The majority of river sites recorded medians above their respective minimum guideline values. However, seven sites recorded median levels below this value: Horseshoe Lake Discharge, Heathcote River at Templetons Road, both Cashmere Stream sites, Styx River at Gardiners Road, Smacks Creek at Gardiners Road and Linwood Canal. There were also a number of additional sites throughout all catchments that did not meet the respective guideline level on at least one occasion.

4.1.9 Water temperature

Water temperature during the monitoring period was generally similar between sites and catchments (Figures 10a and 10b). Temperature was typically more stable in the upper reaches of the Avon River, compared to the lower reaches, which recorded higher and lower temperatures. Lower temperatures in the Heathcote River catchment were also recorded compared to the other catchments, as evident by the T-bars of the boxplot extending below 10 ºC at many sites in the catchment. The two Halswell Retention Basin sites recorded more variation in temperature, with generally higher and lower values recorded. Temperature was similar between the inlet and the outlet.

The water temperature at all river sites throughout the monitoring period was below the respective guideline values. The exception to this was Linwood Canal, which recorded a temperature above this value (20.4 ºC) on one occasion in January; this was not associated with a rainfall event. Cashmere Stream at Sutherlands Road, Otukaikino Creek at Omaka Scout Camp and Styx River at Gardiners Road showed substantially less variation in temperature than other sites. Although for the Otukaikino Creek site, this is likely due to winter samples not yet being taken for this new site.

4.1.10 Biochemical Oxygen Demand

BOD_5 levels were generally similar between sites and catchments (Figures 11a and 11 b). In each catchment, there were both sites where levels were predominantly below the laboratory LOD and others where much higher BOD_5 levels were recorded. However, the Heathcote River catchment did record higher levels across more sites than the other catchments. Quite a few sites in the Avon River also recorded high levels on one-off sampling events, as indicated by the outliers. There were no obvious trends downstream for any of the catchments. The two Halswell Retention Basin sites recorded substantially higher concentrations than the river sites, and median levels were slightly lower at the outlet than the inlet (2.45 mg/L compared to 3.7 mg/L, respectively).

The highest level recorded in the river sites was 5.7 mg/L at Dudley Creek in November and was associated with rain. Sites within each catchment that had notably higher variation included: Dudley Creek and Avon River at Pages/Seaview Bridge (Avon), Haytons Stream at Retention Basin (Heathcote), Kaputone Creek at Belfast Road (Styx) and Wilsons Stream (Otukaikino).

Median BOD_5 levels for all river sites were below the guideline level of 2 mg/L, with the exception of Haytons Stream at Retention Basin. Most of the median values were

equal to the laboratory LOD (35 out of 42 river sites). The guideline level was exceeded in every catchment at least once, as shown by the outliers and T-bars of the boxplots, with the Heathcote catchment recording the most frequent exceedances (nine out of 14 sites). Exceedances were predominantly recorded when it was raining at the time of sampling or had been within the previous 24 hours.

4.1.11 Total Ammonia (Ammoniacal Nitrogen)

Levels of ammonia were generally higher in the Heathcote River catchment than the other catchments (Figures 12a and 12b). Levels appeared to higher in the lower reaches across most catchments. This is possibly due to the tributaries generally recording higher levels than the mainstems and therefore contributing to concentrations downstream in the mainstem. The two Halswell Retention Basin sites recorded substantially higher levels than the river sites. More variation in concentration was recorded at the inlet than the outlet. A maximum value of 8.7 mg/L was recorded at the inlet.

Within the Avon catchment, Dudley Creek, Horseshoe Lake Discharge and (particularly) Addington Brook recorded higher levels and more variation in concentrations compared to the other sites. The same was the case for Haytons Stream at Retention Basin in the Heathcote River catchment and the two Kaputone Creek sites in the Styx River catchment. Linwood Canal also recorded high levels and variation compared to the other sites. The highest river value recorded overall was at Haytons Stream at Retention Basin (0.95 mg/L) in October, when no rainfall was recorded. A high value was also recorded during one individual sampling event at the Kaputone Creek at Belfast Road site (0.83 mg/L in January) during a rainfall event. Ammonia levels were well below the respective receiving water quality guidelines for all samples at all sites throughout the monitoring period.

4.1.12 Nitrate

Levels in the Heathcote and Halswell River catchments were mostly higher than that recorded in the Avon River, and all three of these catchments recorded much higher concentrations than the Styx and Otukaikino (Figures 13a and 13b). Concentrations decreased downstream in the Avon and Heathcote River mainstems. The two Halswell Retention Basin sites generally recorded nitrate levels below that recorded in the Avon and Heathcote catchments, and the Halswell River mainstem site, but similar to the Styx and Otukaikino catchments. The median concentration at the outlet was slightly higher than the inlet.

The Knights Stream at Sabys Road site recorded four of the top five highest nitrate concentrations during the monitoring period, recording the maximum value of 7.2 mg/L in September, with rain recorded in the 24 hours previous. The Heathcote River at Templetons Road site recorded higher levels than the other sites in the Heathcote catchment. Curletts Road Stream Upstream of Heathcote River also showed marked variability compared to the other Heathcote River sites. Wilsons Stream recorded much higher nitrate concentrations than the other two Otukaikino sites.

Most sites recorded median nitrate concentrations below the grading guideline value of 3.8 mg/L. The exception to this was the Knights Stream at Sabys Road and Halswell

River at Akaroa Highway sites, which recorded medians well above the guideline. Other sites within most catchments also recorded at least one sampling occasion (and some many more than this) above this guideline during the monitoring period (Avon River at Carlton Mill Corner, Heathcote River at Templetons Road, Curletts Road Stream Upstream of Heathcote River, Heathcote River at Rose Street and Cashmere Stream at Worsleys Road).

No medians were recorded above the surveillance guideline value of 5.6 mg/L. However, the Heathcote River at Templetons Road and Knights Stream at Sabys Road recorded a number of sampling events above this guideline. One off exceedances were also recorded in the Avon River at Carlton Mill Corner site in November and Cashmere Stream at Worsleys Road site in August. These events were much higher than that recorded at these sites during the rest of the monitoring period (5.7 mg/L). Whilst it was raining at the time of sampling at the Avon River at Carlton Mill Corner site (and had been for the 24 hours previous), there was no record of rain at the Cashmere Stream at Worsleys Road site.

4.1.13 Nitrate Nitrite Nitrogen

The levels of NNN in each catchment were similar to that recorded for nitrate, which is unsurprising given that nitrate makes up a large proportion of NNN. Levels in the Heathcote and Halswell River catchments were mostly higher than that recorded in the Avon River, and the Styx and Otukaikino River catchments recorded much lower levels compared to these (Figures 14a and 14b). Concentrations decreased downstream in the Avon and Heathcote River mainstems. The two Halswell Retention Basin sites generally recorded nitrate levels below that recorded in the Avon and Heathcote catchments, and the Halswell River mainstem site, but similar to the Styx and Otukaikino catchments. The median concentration at the outlet was slightly higher than the inlet.

As for nitrate, Knights Stream at Sabys Road site recorded four of the top five highest NNN concentrations during the monitoring period, recording a peak value of 7.2 mg/L in September, with rain recorded in the 24 hours prior. The Heathcote River at Templetons Road site consistently recorded the next highest values compared to all other sites. The highest value recorded at this site was 6.4 mg/L in September and was related to recent rainfall. Curletts Road Stream Upstream of Heathcote River also showed marked variability compared to the other Heathcote River sites. Wilsons Stream recorded much higher nitrate concentrations than the other two Otukaikino sites.

The vast majority of sites recorded median NNN concentrations substantially higher than the guideline value of 0.444 mg/L. The exceptions to this were Dudley Creek, Horseshoe Lake Discharge, Haytons Stream at Retention Basin, Otukaikino River at Omaka Scout Camp (but a full years monitoring has not been undertaken for this site), Otukaikino River at Groynes Inlet and Linwood Canal. However, the Horseshoe Lake, Haytons Stream at Retention Basin and Otukaikino River at Groynes Inlet sites did record several events above the guideline during the monitoring period. As was the case with nitrate, the Avon River at Carlton Mill Corner and Cashmere Stream at Worsleys Road sites recorded one-off events much higher than that recorded at any other time at these sites during the monitoring period. This concentration (of 5.7 mg/L) was recorded in November at the Avon River at Carlton Mill Corner site and in August

at the Cashmere Stream at Worsleys Road site. It was raining at the time of sampling (and had been for the 24 hours previous) at the former site, but there was no recent rainfall at the latter site.

4.1.14 Dissolved Inorganic Nitrogen

DIN is the sum of NNN and ammonia, so trends were again similar to that shown for nitrate and NNN, especially as ammonia was generally only recorded at low levels at the river sites. DIN in the Heathcote and Halswell River catchments were mostly higher than that recorded in the Avon River, and all three of these catchments recorded much higher concentrations than the Styx and Otukaikino River catchments (Figures 15a and 15b). Concentrations decreased downstream in the Avon and Heathcote River mainstems. However, for the two Halswell Retention Basin sites, as high ammonia levels but low NNN levels were recorded at these sites, a different trend to nitrate and NNN occurred. These sites recorded DIN levels similar to the highest levels recorded at the river sites. The median concentrations were similar between the inlet and outlet, although more variation was shown at the inlet.

As for nitrate and NNN, the highest levels of DIN were recorded at Knights Stream at Sabys Road (7.2 mg/L) and Heathcote River at Templetons Road (6.4 mg/L), both occurring in September 2014, with rain having fallen in the 24 hours previous at both sites. Curletts Road Stream Upstream of Heathcote River also showed marked variability compared to the other Heathcote River sites. Wilsons Stream recorded much higher nitrate concentrations than the other two Otukaikino sites.

Median levels of DIN reached or exceeded the guideline level at all of the Halswell River catchment sites and all but one of the Heathcote River catchment sites (Haytons Stream at Retention Basin). Nearly half of the Avon River catchment sites also exceeded the guideline level for the median value, but only one did so from the Styx River catchment (Kaputone Creek at Blakes Road, 1.6 mg/L) and none from the Otukaikino catchment. Linwood Canal DIN levels were all well below the guideline level throughout the monitoring period.

4.1.15 Dissolved Reactive Phosphorus

Levels were generally similar between all catchments except the Otukaikino, which typically recorded lower values (Figures 16a and 16b). Many of the tributaries recorded higher concentrations that the mainstems. Concentrations generally increased downstream in all catchments, potentially due to this input from tributaries. Samples from the Halswell Retention Basin Inlet were much higher than the majority of those from the river sites, with the notable exception of the Haytons Stream at Retention Basin site. The Halswell Retention Basin Outlet recorded levels much lower and less variable than the inlet.

The Haytons Stream at Retention Basin site recorded substantially higher and more variable concentrations than the other river sites, with the highest value of 1.1 mg/L recorded in February. This concentration is nearly three times higher than any other value recorded over the 2014 monitoring period. It was not raining at the time of sampling. Linwood Canal was the river site recording the next highest and variable concentrations. The Kaputone Creek at Belfast Road site also recorded a couple of

one-off high concentrations during the monitoring event (as indicated by the outliers). These were 0.37 mg/L in January and 0.33 mg/L in April, and it was raining at the time for both these sampling events.

The majority of river sites recorded median concentrations at or above the guideline levels. The exceptions to this were the upper four sites in the Avon River catchment, Avon River at Manchester Street, Heathcote River at Templetons Road, Curletts Road Stream at Motorway, both Cashmere Stream sites, the upper three sites in the Styx River catchment, the three Otukaikino River catchment sites and Knights Stream at Sabys Road. Only three sites did not exceed their respective guideline values at any point: Heathcote River at Templetons Road, Cashmere Stream at Sutherlands Road and Otukaikino Creek at Omaka Scout Camp (although a full year of monitoring was not undertaken for this latter site).

4.1.16 *Escherichia coli*

E. coli levels between catchments were generally similar, although there were some sites in most catchments that recorded higher levels compared to the other sites (Figures 17a and 17b). There appeared to be no trends downstream in the mainstems. The Halswell Retention Basin Inlet recorded substantially higher values than the river sites. In contrast, the outlet recorded similar levels to the river sites.

Of note, *E.coli* levels were higher at the Horseshoe Lake Discharge site and much higher at the Dudley Creek site compared to other sites in the Avon River catchment. *E.coli* at the Cashmere Stream at Sutherlands Road site also recorded particularly low levels compared to all sites across all catchments. Kaputone Creek at Belfast Road was unique among all sites in all catchments, in that it did not record a single event below the guideline level, with the lowest level being 770 CFU/100ml in July. This site also displayed the greatest variability across all river sites. Several river sites recorded values at or above the upper detection limit of 24000 CFU/100ml during the monitoring period. These sites were: Cashmere Stream at Worsleys Road (in February), Kaputone Creek at Blakes Road (in April) and at Belfast Road (in January and April), Styx River at Marshland Road Bridge (in April) and Wilsons Stream (in April). All of these exceedances were related to rainfall events, except the Cashmere Stream site. Other sites also recorded high values during the monitoring period: Avon River at Pages/Seaview Bridge (14,000 CFU/100ml in March) and at Bridge Street (22,000 CFU/100ml in March), Styx River at Main North Road (11,000 CFU/100ml in April) and Heathcote River at Ferniehurst Street (11,000 CFU/100ml in February). All but the last of these events were associated with rainfall.

The ECan guideline states that 95% of *E. coli samples* should be below 550 CFU/100ml (Environment Canterbury, 2012). Therefore comparison against the T-bars of the box-plot graph is more appropriate than comparing against medians, as the T-bars show the approximate location of 95% of the data. *E. coli* concentrations failed to comply with this guideline level at all but 11 sites. In addition, concentrations were greater than 550 CFU/100ml on at least one sampling occasion during the monitoring period at 39 of the 42 river sites. The exceptions to this were Heathcote River at Templetons Road, Cashmere Stream at Sutherlands Road and Otukaikino Creek at Omaka Scout Camp (although this latter site has not yet been monitored during winter).

Table 4. Sites across all catchments exhibiting high ('Best Sites') and low ('Worst Sites') water quality for each of the parameters during the monitoring period of January to December 2014. Best Sites were those with much better levels than other sites. Worst Sites were those that recorded median values (or 95% percentile value for *Escherichia coli*) outside the guideline levels. All three nitrogen parameters (nitrate, Nitrate Nitrite Nitrogen and dissolved inorganic nitrogen) are combined, as are Total Suspended Solids and turbidity, due to these parameters being related to each other. N/A = Not Applicable, as no guideline levels are relevant. LOD = laboratory Limit of Detection. Red font = Avon River catchment, orange font = Heathcote River catchment, blue font = Styx River catchment, green font = Otukaikino River catchment and purple font = Halswell River catchment. Note that for the 'Best Sites', Otukaikino Creek at Omaka Scout Camp has not been monitored for a full year and only during times of lower flow (i.e. spring and summer), so these results might be misleading.

Contaminant	Best Sites	Worst Sites
Dissolved copper	There were many sites across all catchments that only recorded levels below the LOD	Curletts Road Stream Upstream of Heathcote River
Dissolved lead	There were many sites across all catchments that only recorded levels below the LOD	None
Dissolved zinc	Smacks Creek at Gardiners Road Styx River at Main North Road Styx River at Harbour Road Bridge	Curletts Road Stream at Motorway
pH	Otukaikino Creek at Omaka Scout Camp (due to less variability)	None
Conductivity	Otukaikino Creek at Omaka Scout Camp Otukaikino River at Groynes Inlet	N/A
Total Suspended Solids Turbidity	Otukaikino Creek at Omaka Scout Camp Otukaikino River at Groynes Inlet	Dudley Creek Avon River at Bridge Street Haytons Stream at Retention Basin Heathcote River at Tunnel Road Heathcote River at Ferrymead Bridge Linwood Canal
Dissolved oxygen	Avon River at Carlton Mill Corner	Horseshoe Lake Discharge Heathcote River at Templetons Road Cashmere Stream at Sutherlands Road Cashmere Stream at Worsleys Road Styx River at Gardiners Road Smacks Creek at Gardiners Road Linwood Canal
Water temperature	Styx River at Gardiners Road Otukaikino Creek at Omaka Scout Camp (due to less variability)	None
Biochemical Oxygen Demand	Wairarapa Stream Heathcote River at Templetons Road Cashmere Stream at Sutherlands Road Styx River at Gardiners Road Smacks Creek at Gardiners Road	Haytons Stream at Retention Basin
Total ammonia	Styx River at Gardiners Road Smacks Creek at Gardiners Road Otukaikino River at Groynes Inlet	None
Nitrate Nitrate Nitrite Nitrogen Dissolved Inorganic Nitrogen	Dudley Creek Horseshoe Lake Otukaikino Creek at Omaka Scout Camp Linwood Canal	Most sites, particularly: Heathcote River at Templetons Road Curletts Road Stream Upstream of Heathcote River Knights Stream at Sabys Road Halswell River at Akaroa Highway
Dissolved Reactive Phosphorus	Cashmere Stream at Sutherlands Road Otukaikino Creek at Omaka Scout Camp	23 of the 42 sites, particularly: Haytons Stream at Retention Basin Linwood Canal
Escherichia coli	Heathcote River at Templetons Road Cashmere Stream at Sutherlands Road Otukaikino Creek at Omaka Scout Camp	31 of 42 sites, particularly: Dudley Creek Kaputone Creek at Blakes Road Kaputone Creek at Belfast Road

Table 5. Summary of the best and worst sites during the monitoring period of January to December 2014, at a catchment and site scale, based on the number of times a catchment/site occurred in Table 4. Note that for the 'Best Sites', Outukaikino Creek at Omaka Scout Camp has not been monitored for a full year and only during times of lower flow (i.e. spring and summer), so these results might be misleading. Red font = Avon River catchment, orange font = Heathcote River catchment, blue font = Styx River catchment, green font = Otukaikino River catchment and purple font = Halswell River catchment.

Placing	Best Sites		Worst Sites	
	Catchment Scale	Site Scale	Catchment Scale	Site Scale
	Otukaikino River (10 occurrences)	Otukaikino Creek at Omaka Scout Camp (7 occurrences)	Heathcote River (12 occurrences)	Linwood Canal Haytons Stream at Retention Basin (3 occurrences)
	Styx River (8 occurrences)	Otukaikino River at Groynes Inlet Smacks Creek at Gardiners Road Styx River at Gardiners Road Cashmere Stream at Sutherlands Road (3 occurrences)	Styx River (4 occurrences)	Curletts Road Stream Upstream of Heathcote River Heathcote River at Templetons Road (2 occurrences)
	Heathcote River (5 occurrences)	Heathcote River at Templetons Road (2 occurrences)	Avon River (3 occurrences)	Curletts Road Stream at Motorway Avon River at Bridge Street Heathcote River at Tunnel Road Heathcote River at Ferrymead Bridge Horseshoe Lake Discharge Cashmere Stream at Sutherlands Road Cashmere Stream at Worsleys Road Styx River at Gardiners Road Smacks Creek at Gardiners Road Knights Stream at Sabys Road Heathcote River at Akaroa Highway Kaputone Creek at Blakes Road Kaputone Creek at Belfast Road (1 occurrence)

Table 6. Sites within each catchment that recorded parameters well outside the guideline levels and/or recorded substantially different one-off events compared to other sites. Contaminants of concern are in parentheses. Sites are ranked sequentially based on decreasing number of parameters of concern. TSS = Total Suspended Solids, DO = Dissolved Oxygen, BOD_5 = Biochemical Oxygen Demand, NNN = Nitrate Nitrite Nitrogen and DIN = Dissolved Inorganic Nitrogen. Parameters that co-vary, such as nitrogen compounds (nitrate, NNN and DIN) and sediment (TSS/turbidity) have been combined where relevant, as indicated by a forward slash.

Catchment	Sites
Avon River	Dudley Creek (lead, zinc, turbidity, BOD_5, ammonia, *E.coli*) Addington Brook (lead, zinc, ammonia) Horseshoe Lake Discharge (DO, ammonia, *E.coli*) Avon River at Carlton Mill corner (zinc, nitrate/NNN) Avon River at Pages/Seaview Bridge (BOD_5, *E.coli*) Avon River at Bridge Street (turbidity, *E.coli*) Riccarton Main Drain (BOD_5)
Heathcote River	Haytons Stream at Retention Basin (zinc, turbidity, DO, BOD_5, ammonia, DRP) Curletts Road Stream Upstream of Heathcote River (copper, zinc, nitrate/NNN/DIN) Heathcote River at Templetons Road (DO, nitrate/NNN/DIN) Curletts Road Stream at Motorway (copper, zinc) Cashmere Stream at Worsleys Road (DO, *E.coli*) Heathcote River at Tunnel Road (copper, TSS/turbidity) Heathcote River at Ferrymead Bridge (lead, TSS/turbidity) Cashmere Stream at Sutherlands Road (DO) Heathcote River at Ferniehurst Street (*E.coli*) Heathcote River at Catherine Street (zinc)
Styx River	Kaputone Creek at Blakes Road (TSS, ammonia, DIN, *E.coli*) Kaputone Creek at Belfast Road (BOD_5, ammonia, DRP, *E.coli*) Styx River at Gardiners Road (DO) Styx River at Main North Road (*E.coli*) Styx River at Marshland Road Bridge (*E.coli*)
Otukaikino River	Wilsons Stream (pH, BOD_5, nitrate/NNN, *E.coli*)
Halswell River	Knights Stream at Sabys Road (nitrate/NNN/DIN) Halswell River at Akaroa Highway (nitrate)

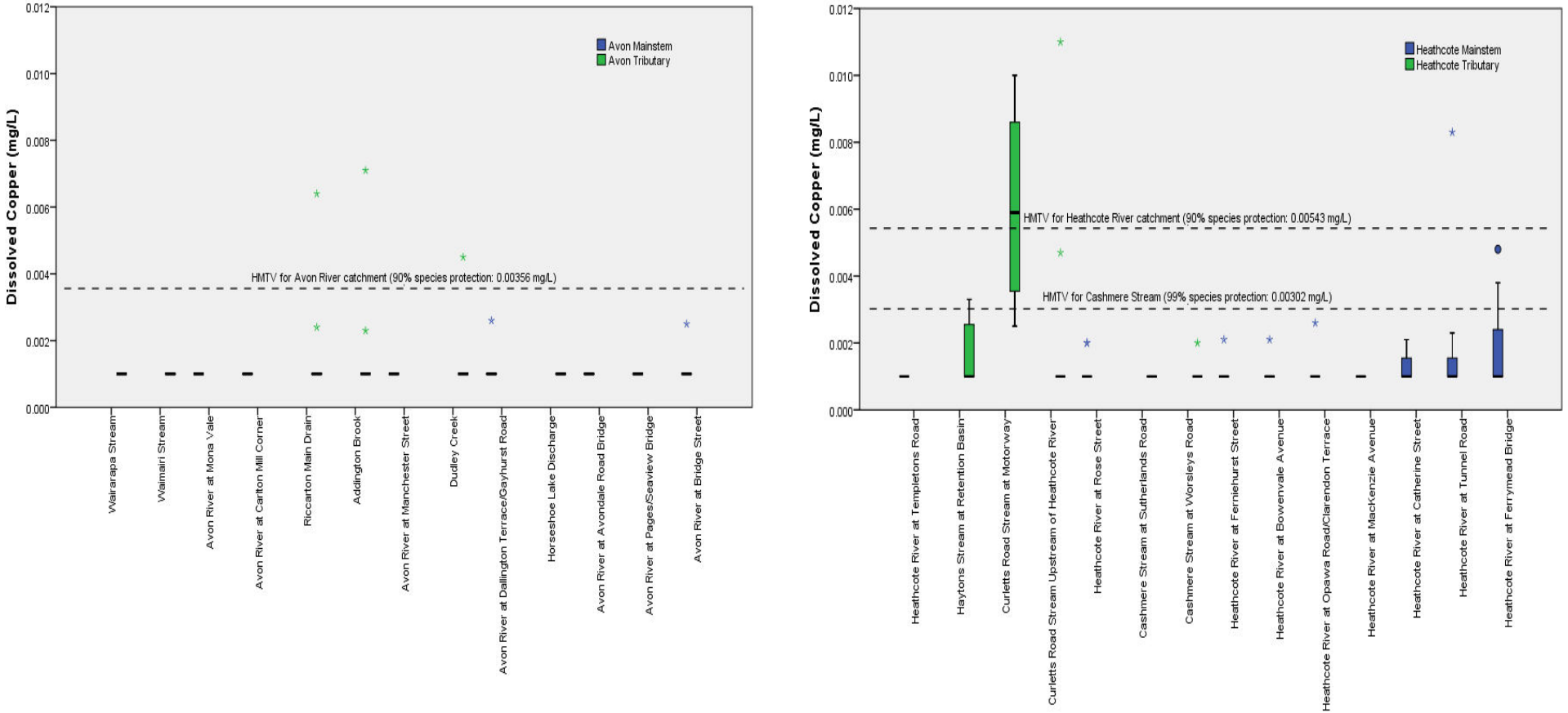

Figure 2a. Dissolved copper levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2014. Not all sites were monitored for the full year (Avon River at Carlton Mill Corner; Avon River at Avondale Road Bridge; Curletts Road Stream at Motorway; Heathcote River at Catherine Street and Heathcote River at Mackenzie Avenue), as sampling for this parameter was only instigated at these sites in September 2014. No monitoring was undertaken at the Avon River at Bridge Street site in September 2014 due to construction. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Proposed Canterbury Land and Water Regional Plan trigger values (Environment Canterbury, 2012), which have been modified to account for water hardness (Hardness Modified Trigger Value = HMTV), as per the ANZECC (2000) guidelines methodology. 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.

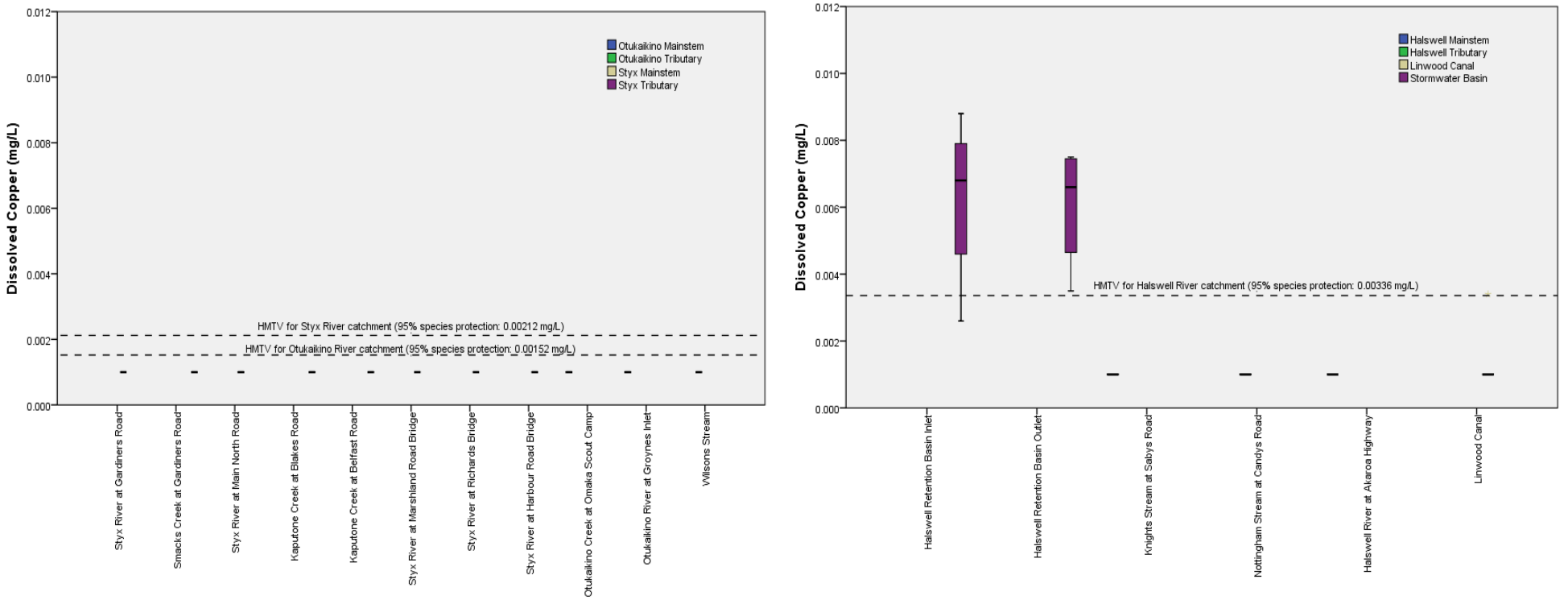

Figure 2b. Dissolved copper levels in water samples taken from the Styx and Otukaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2014. Not all sites were monitored for the full year (Otukaikino Creek at Omaka Scout Camp; Halswell Retention Basin Inlet and Halswell Retention Basin Outlet), as sampling for this parameter was only instigated at these sites in October (Otukaikino) and September (Halswell Retention Basin) 2014. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Proposed Canterbury Land and Water Regional Plan trigger values (Environment Canterbury, 2012), which have been modified to account for water hardness (Hardness Modified Trigger Value = HMTV), as per the ANZECC (2000) guidelines methodology. 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.

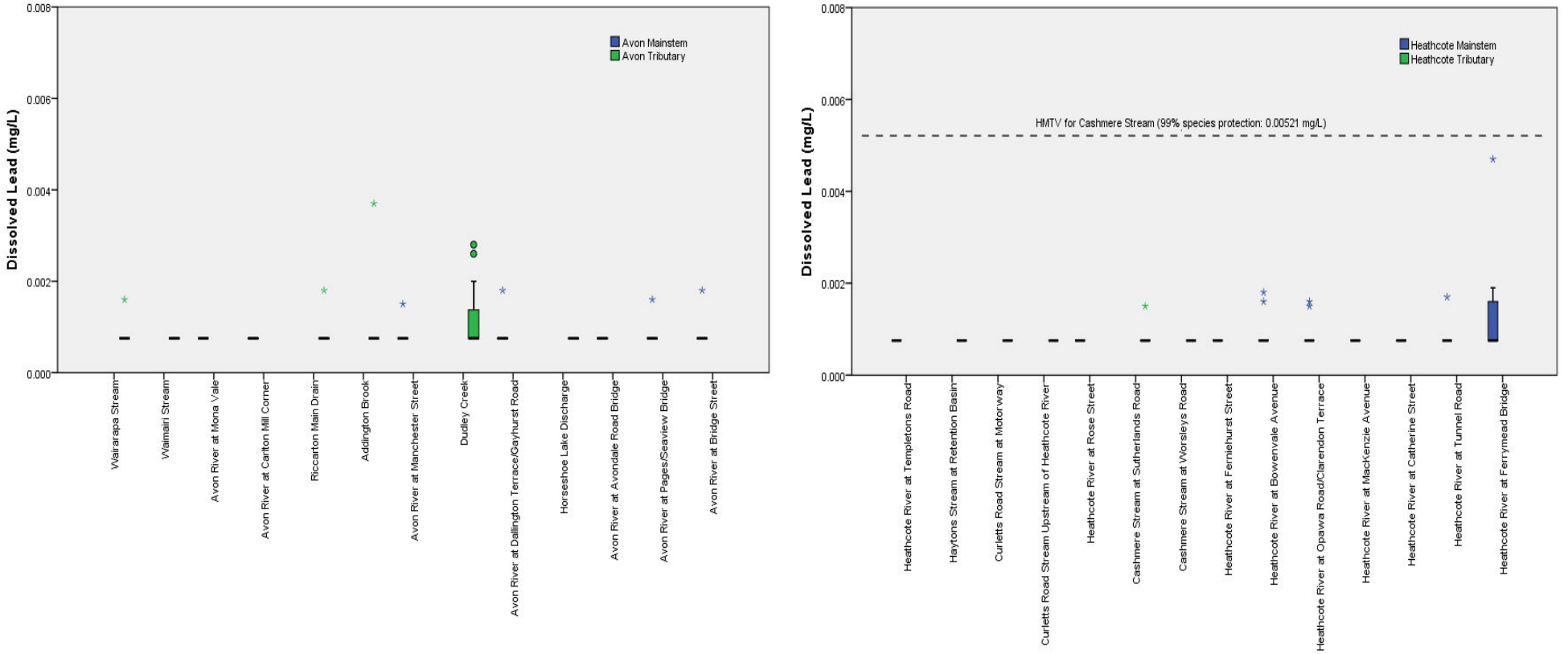

Figure 3a. Dissolved lead levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2014. Not all sites were monitored for the full year (Avon River at Carlton Mill Corner; Avon River at Avondale Road Bridge; Curletts Road Stream at Motorway; Heathcote River at Catherine Street and Heathcote River at Mackenzie Avenue), as sampling for this parameter was only instigated at these sites in September 2014. No monitoring was undertaken at the Avon River at Bridge Street site in September 2014 due to construction. Sites are ordered from upstream to downstream (left to right). The dashed line represents the Proposed Canterbury Land and Water Regional Plan trigger value (Environment Canterbury, 2012), which has been modified to account for water hardness (Hardness Modified Trigger Value = HMTV), as per the ANZECC (2000) guidelines methodology. The 90% protection HMTV for the Avon River (0.01554 mg/L) and the Heathcote River (0.02916 mg/L) are not shown as they are off the scale. The Laboratory Limit of Detection was 0.0015 mg/L – analysed as half this value (0.00075 mg/L) to allow statistics to be undertaken.

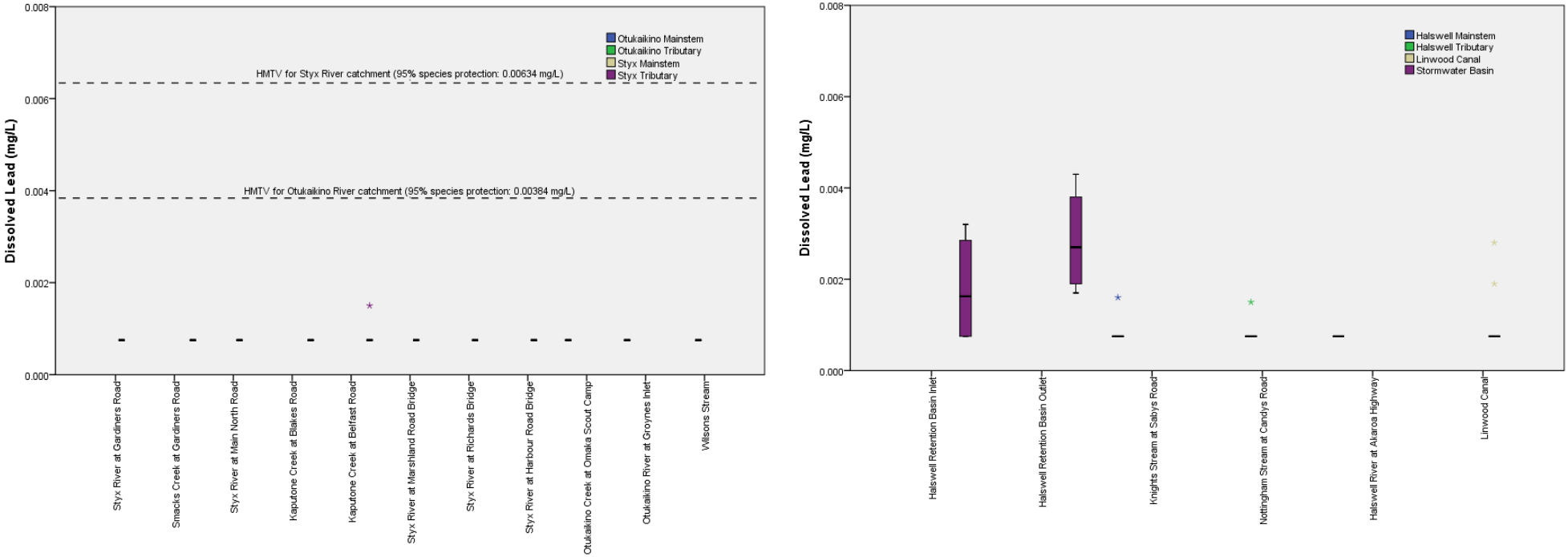

Figure 3b. Dissolved lead levels in water samples taken from the Styx and Otukaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2014. Not all sites were monitored for the full year (Otukaikino Creek at Omaka Scout Camp; Halswell Retention Basin Inlet and Halswell Retention Basin Outlet), as sampling for this parameter was only instigated at these sites in October (Otukaikino) and September (Halswell Retention Basin) 2014. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Proposed Canterbury Land and Water Regional Plan trigger value (Environment Canterbury, 2012), which has been modified to account for water hardness (Hardness Modified Trigger Value = HMTV), as per the ANZECC (2000) guidelines methodology. The 95% protection HMTV for Halswell River (0.01257 mg/) is not visible because it is off the scale. The Laboratory Limit of Detection was 0.0015 mg/L – analysed as half this value (0.00075 mg/L) to allow statistics to be undertaken.

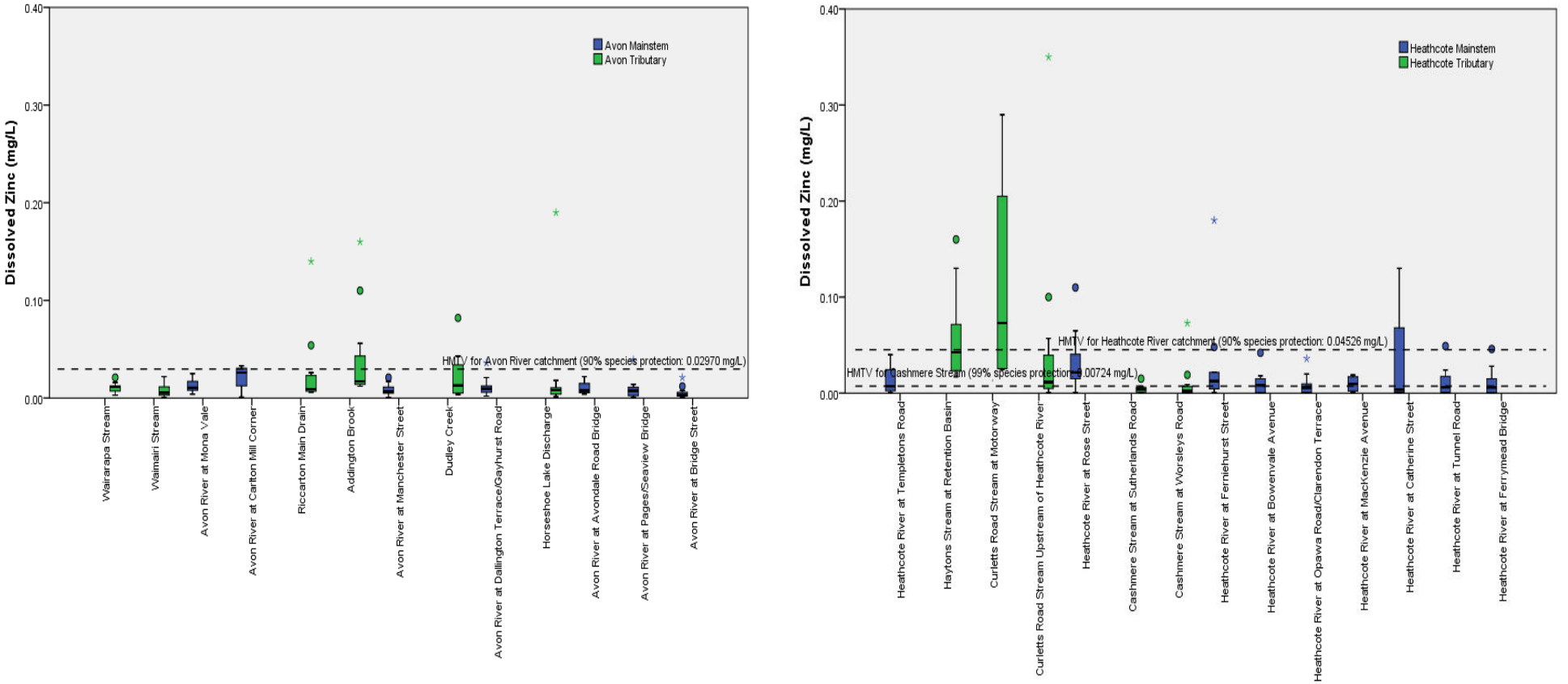

Figure 4a. Dissolved zinc levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2014. Not all sites were monitored for the full year (Avon River at Carlton Mill Corner; Avon River at Avondale Road Bridge; Curletts Road Stream at Motorway; Heathcote River at Catherine Street and Heathcote River at Mackenzie Avenue), as sampling for this parameter was only instigated at these sites in September 2014. No monitoring was undertaken at the Avon River at Bridge Street site in September 2014 due to construction. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Proposed Canterbury Land and Water Regional Plan trigger values (Environment Canterbury, 2012), which have been modified to account for water hardness (Hardness Modified Trigger Value = HMTV), as per the ANZECC (2000) guidelines methodology. 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.

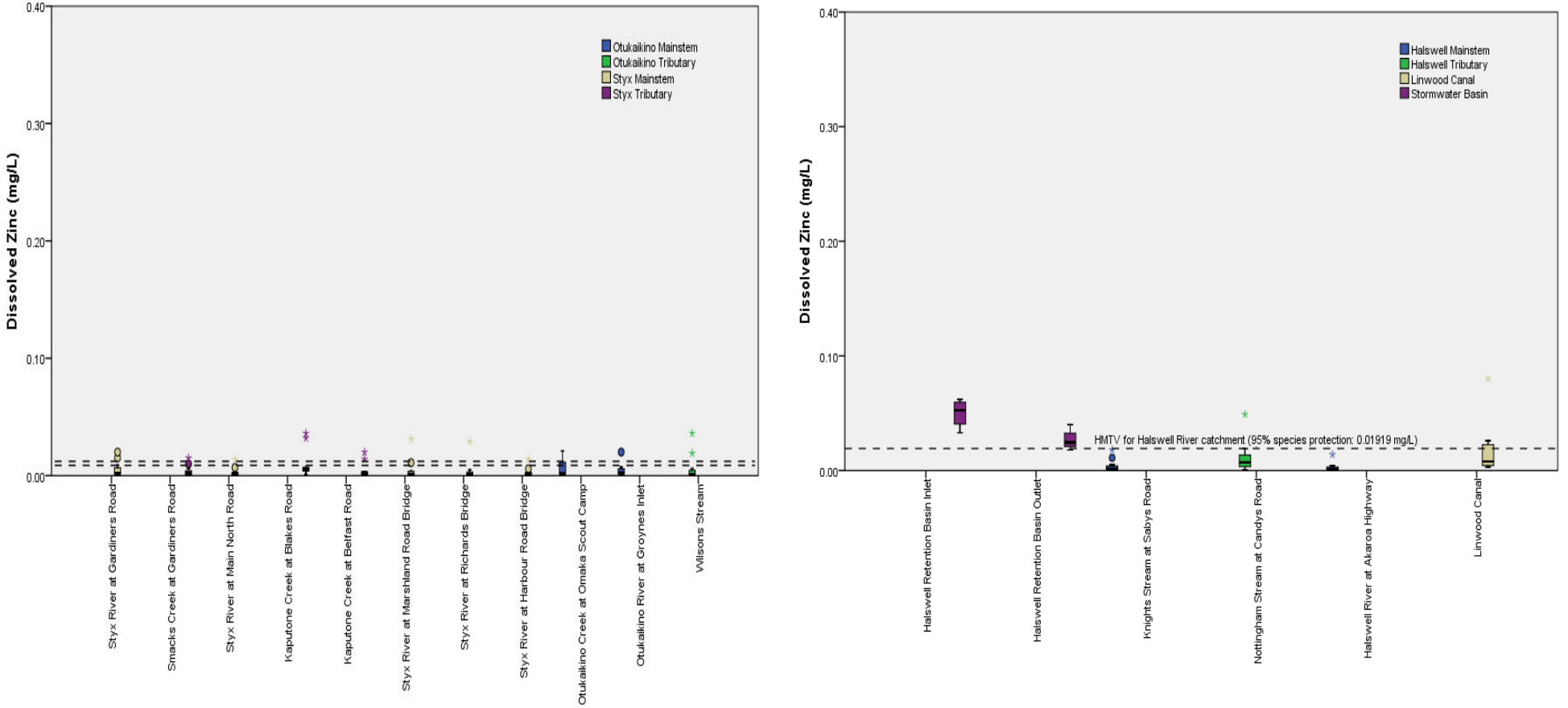

Figure 4b. Dissolved zinc levels in water samples taken from the Styx and Otukaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2014. Not all sites were monitored for the full year (Otukaikino Creek at Omaka Scout Camp; Halswell Retention Basin Inlet and Halswell Retention Basin Outlet), as sampling for this parameter was only instigated at these sites in October (Otukaikino) and September (Halswell Retention Basin) 2014. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Proposed Canterbury Land and Water Regional Plan trigger values (Environment Canterbury, 2012), which have been modified to account for water hardness (Hardness Modified Trigger Value = HMTV), as per the ANZECC (2000) guidelines methodology. On the left graph, Tthe upper dashed line represents the 95% species protection for Styx River catchment (0.01214 mg/L), while the lower represents the 95% species protection for Otukaikino River catchment (0.00868 mg/L). 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. A close up of the left graph is presented in Appendix C, Figure i.

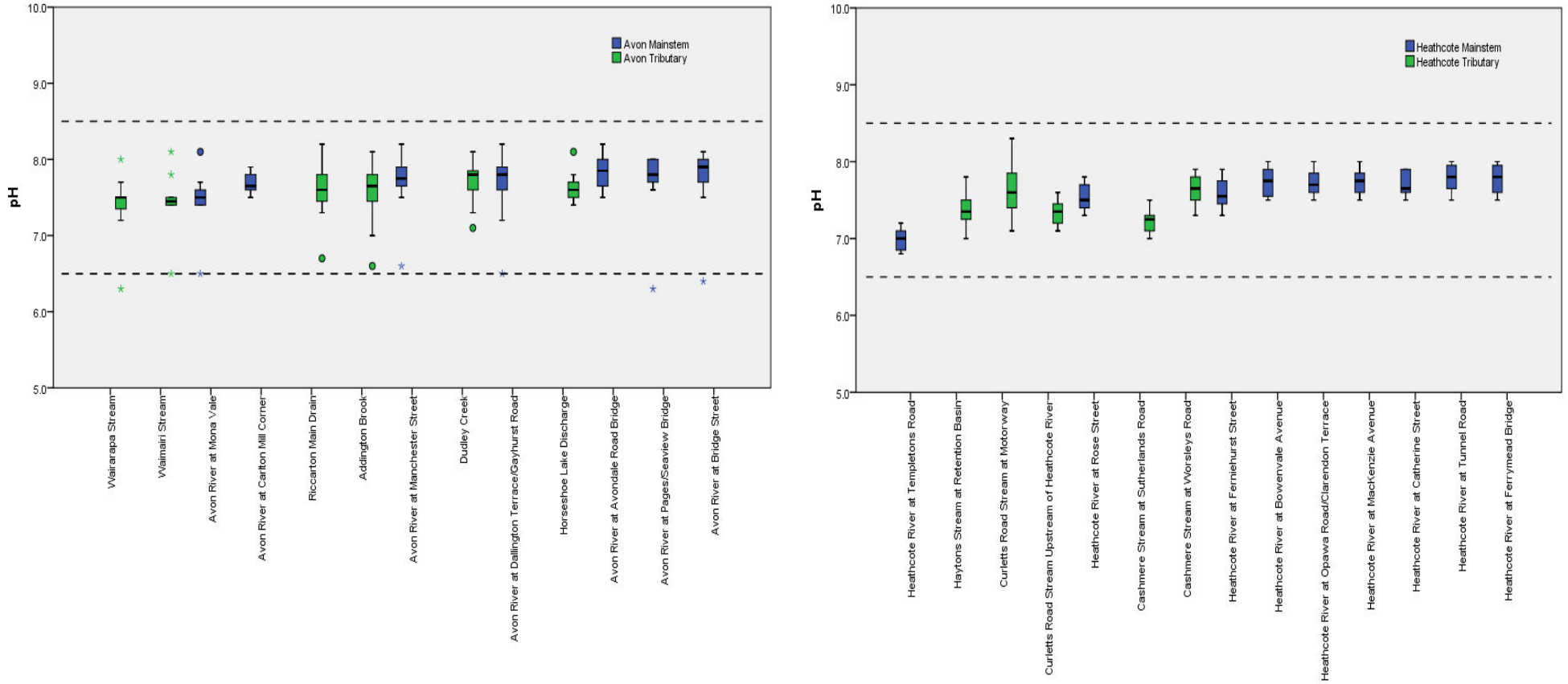

Figure 5a. pH levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2014. No monitoring was undertaken at the Avon River at Bridge Street site in September and the Curletts Road Stream at Motorway site January – May, due to construction. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Proposed Canterbury Land and Water Regional Plan lower (6.5) and upper (8.5) limits (Environment Canterbury, 2012).

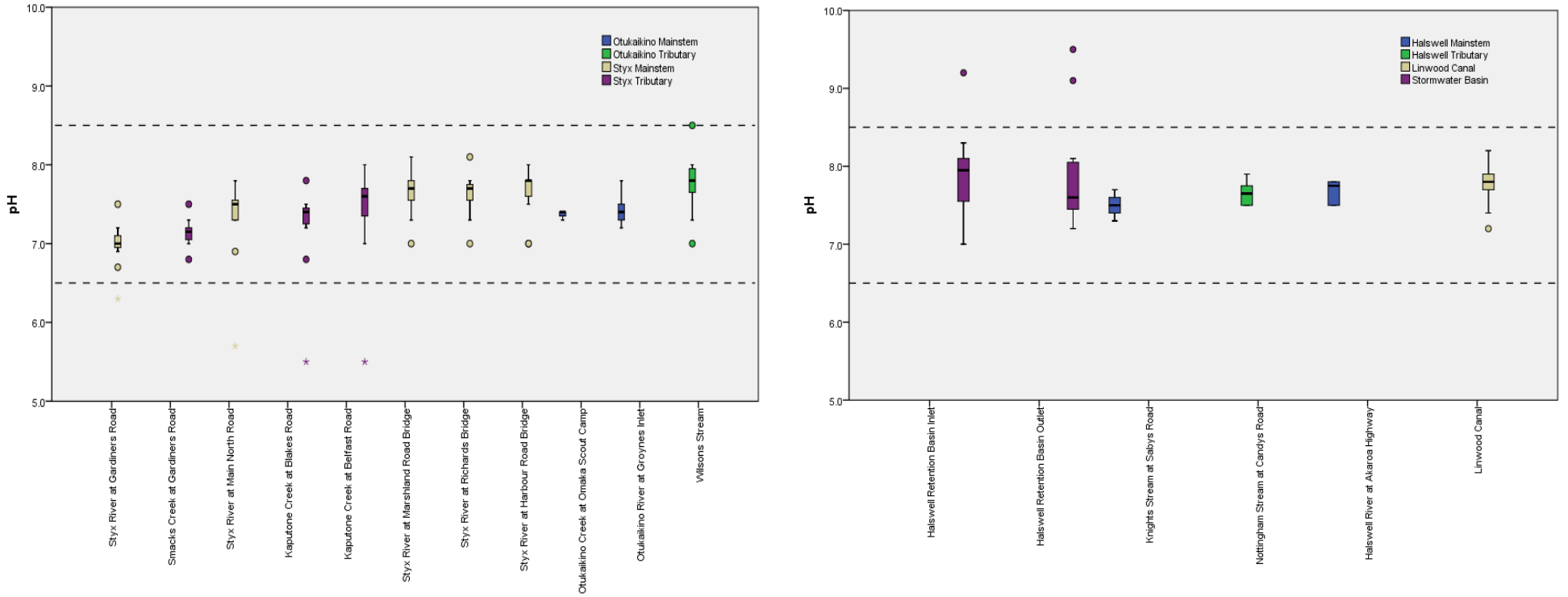

Figure 5b. pH levels in water samples taken from the Styx and Otukaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2014. Sampling at the Otukaikino Creek at Omaka Scout Camp was only instigated in October. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Proposed Canterbury Land and Water Regional Plan lower (6.5) and upper (8.5) limits (Environment Canterbury, 2012).

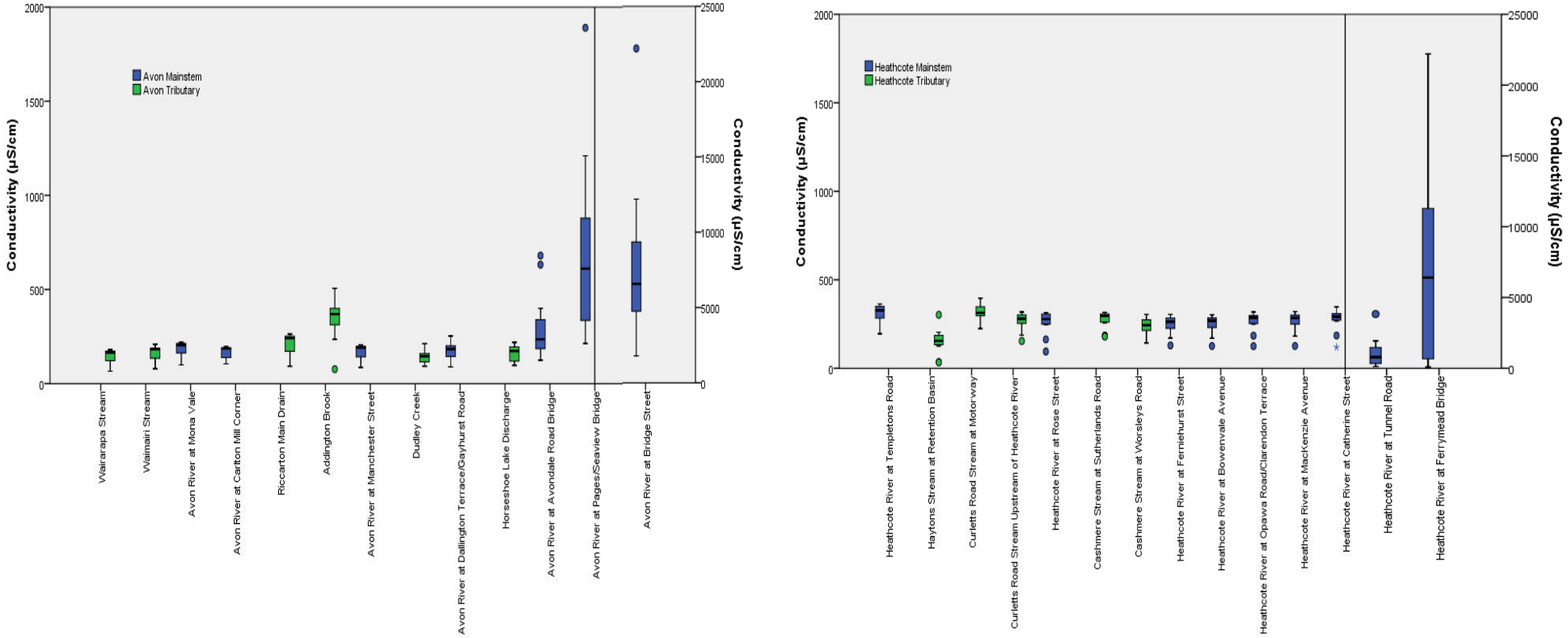

Figure 6a. Conductivity levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2014. No monitoring was undertaken at the Avon River at Bridge Street site in September and the Curletts Road Stream at Motorway site January – May, due to construction. Sites are ordered from upstream to downstream (left to right). All conductivity graphs have the same scale presented on the primary (left) axis. Given the large differences in values within the catchments, some sites are presented with an alternate scale on the secondary (right) axis. Scale change is marked with a solid vertical line.

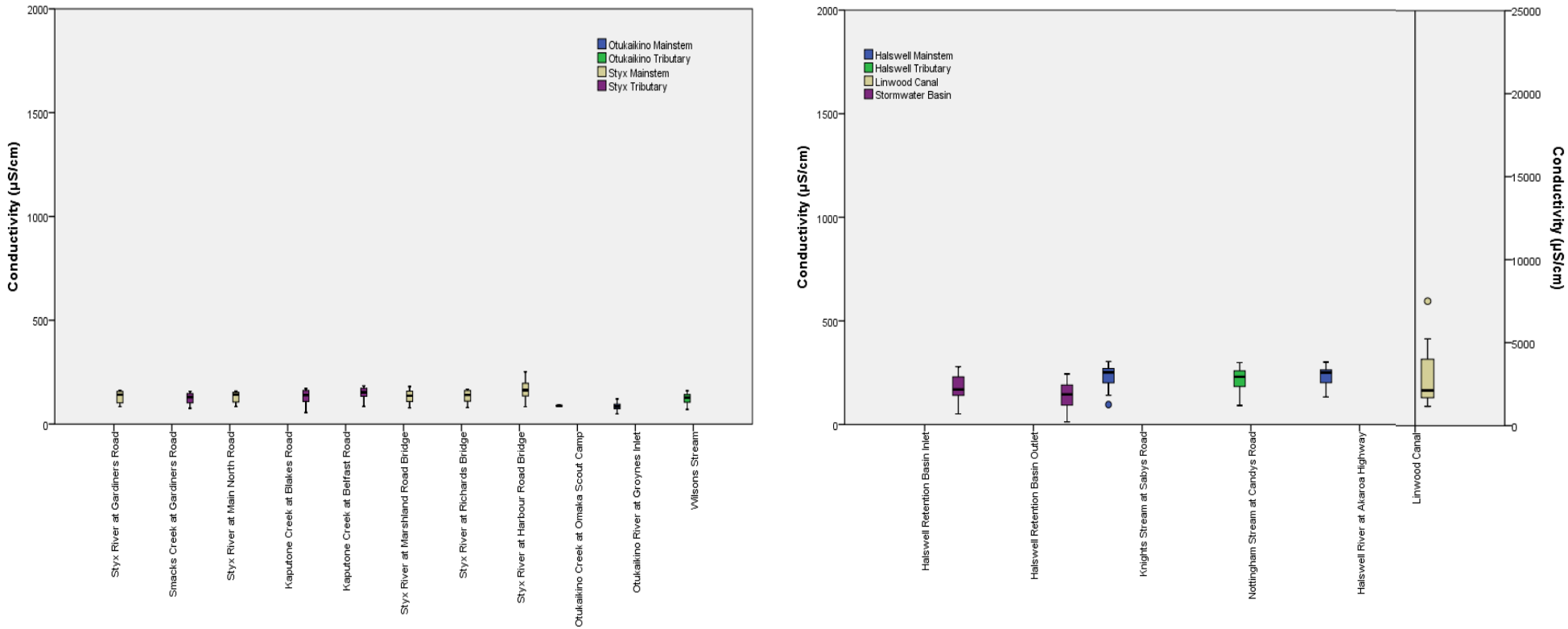

Figure 6b. Conductivity levels in water samples taken from the Styx and Otukaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2014. Sampling at the Otukaikino Creek at Omaka Scout Camp was only instigated in October. Sites are ordered from upstream to downstream (left to right). All conductivity graphs have the same scale presented on the primary (left) axis. Given the large differences in values within the catchments, some sites are presented with an alternate scale on the secondary (right) axis. Scale change is marked with a solid vertical line. A close up of the left graph is presented in Appendix C, Figure ii.

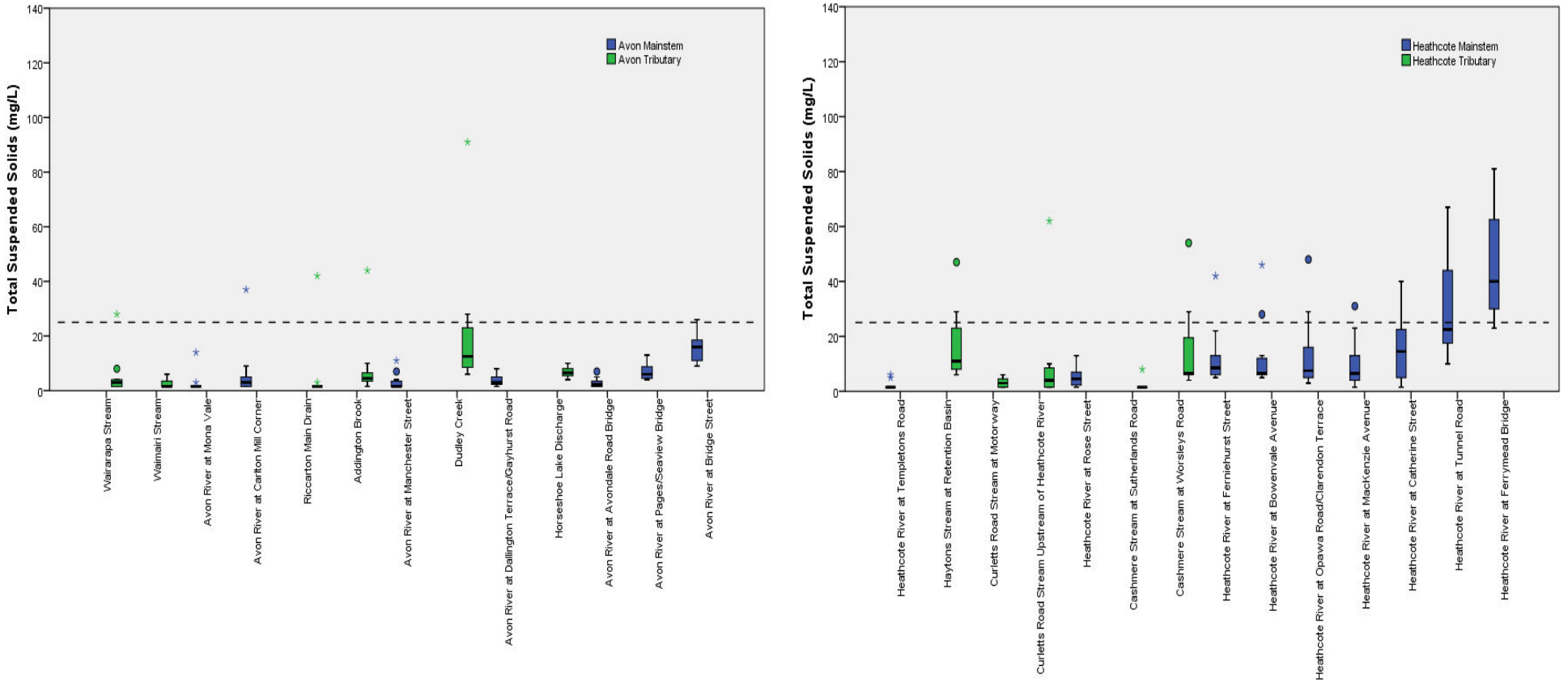

Figure 7a. Total Suspended Solid (TSS) levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2014. No monitoring was undertaken at the Avon River at Bridge Street site in September and the Curletts Road Stream at Motorway site January – May, due to construction. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Ryan (1991) guideline value of 25 mg/L. The Laboratory Limit of Detection was 3.0 mg/L – analysed as half this value (1.5 mg/L) to allow statistics to be undertaken.

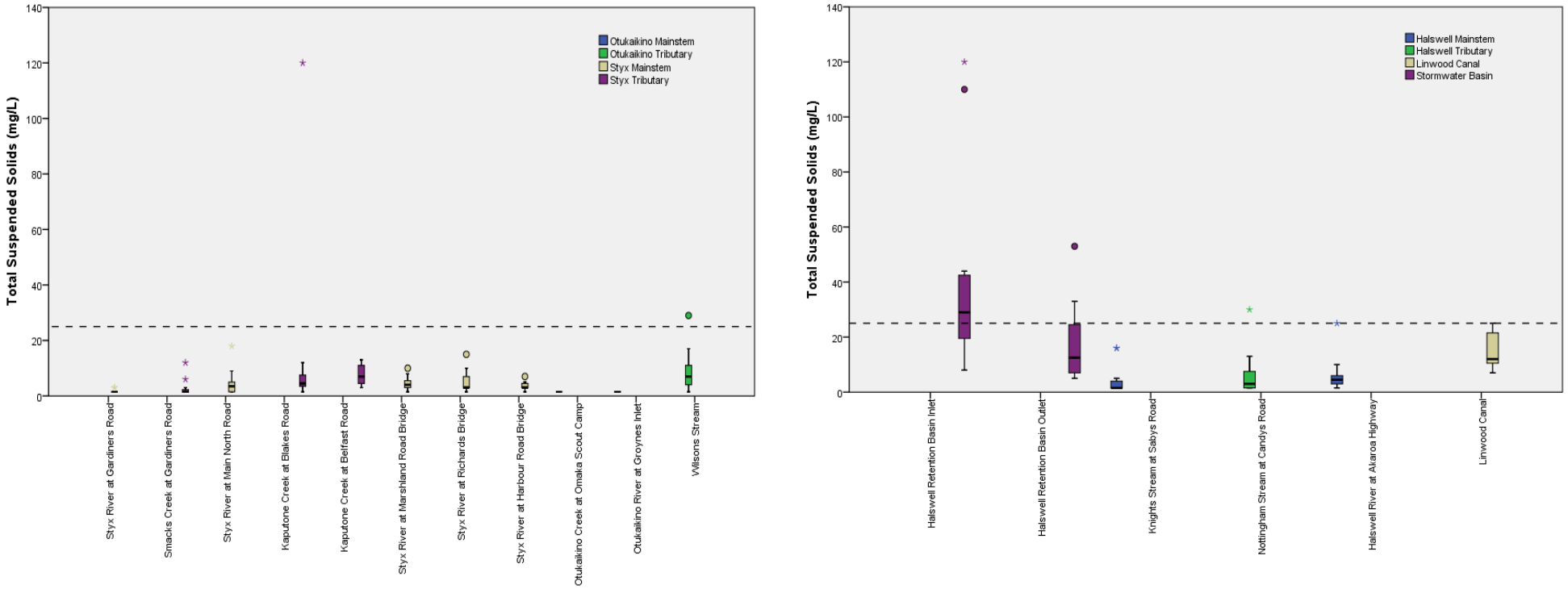

Figure 7b. Total Suspended Solid (TSS) levels in water samples taken from the Styx and Otukaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2014. Sampling at the Otukaikino Creek at Omaka Scout Camp was only instigated in October. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Ryan (1991) guideline value of 25 mg/L. The Laboratory Limit of Detection was 3.0 mg/L – analysed as half this value (1.5 mg/L) to allow statistics to be undertaken.

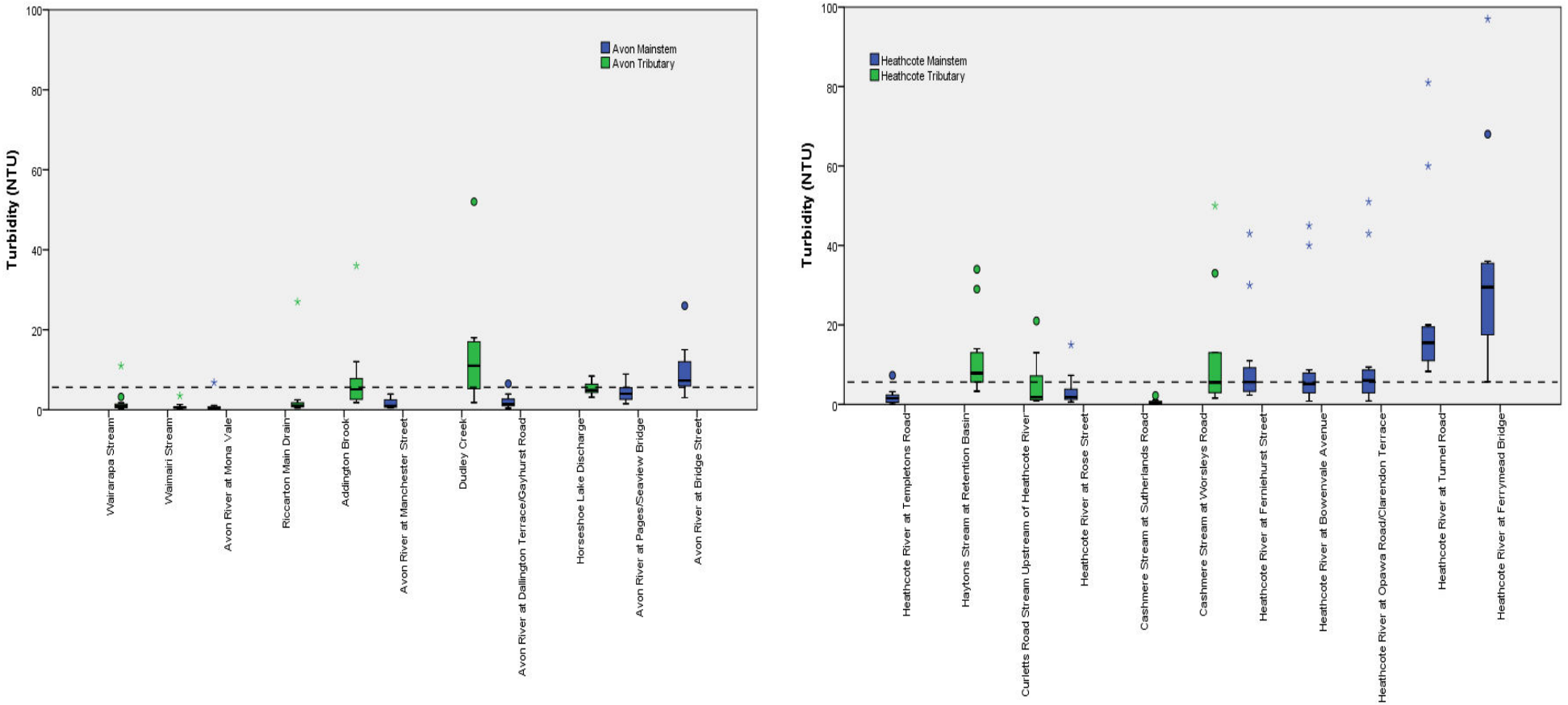

Figure 8a. Turbidity levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2014. The following sites were not measured for this parameter: Avon River at Carlton Mill Corner, Avon River at Avondale Road Bridge, Curletts Road Stream at Motorway, Heathcote River at Catherine Street and Heathcote River at Mackenzie Avenue. No monitoring was undertaken at the Avon River at Bridge Street site in September due to construction. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the ANZECC (2000) guideline value of 5.6 Nephelometric Turbidity Units (NTU). The Laboratory Limit of Detection was 0.1 NTU – analysed as half this value (0.05 NTU) to allow statistics to be undertaken.

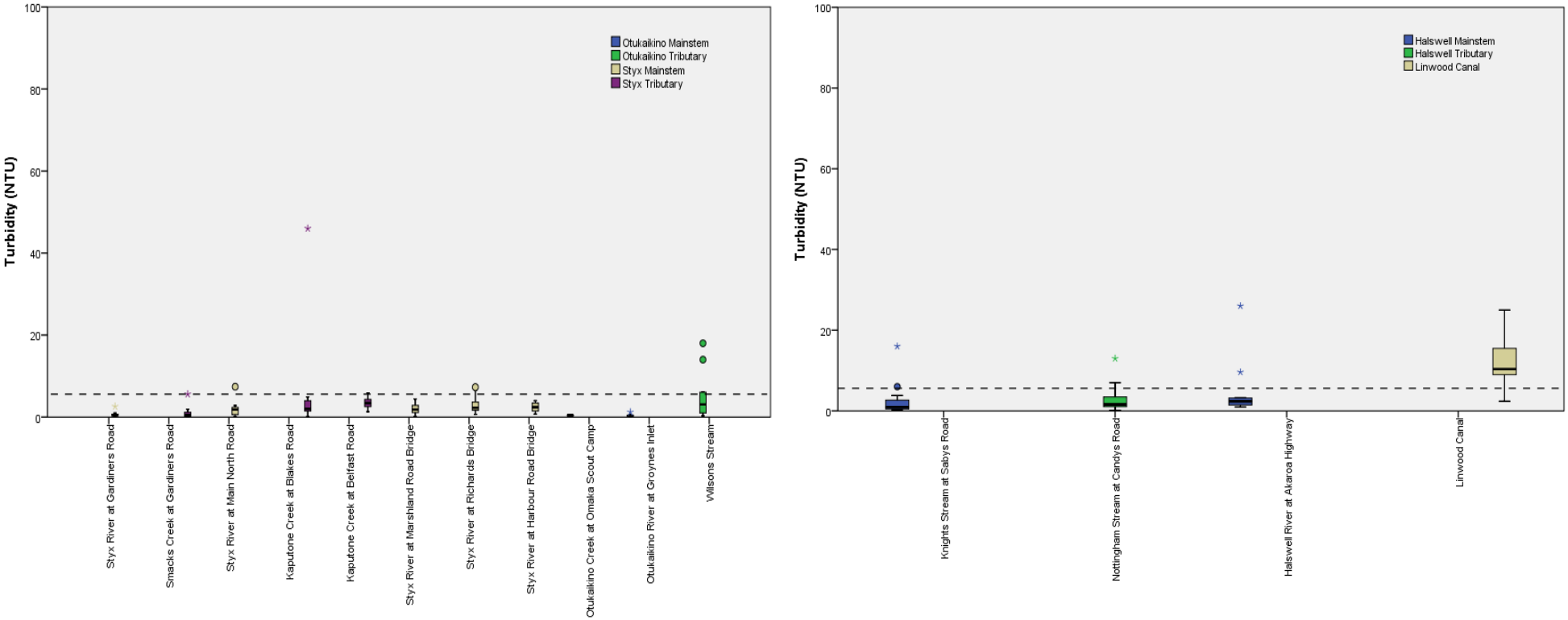

Figure 8b. Turbidity levels in water samples taken from the Styx and Otukaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2014. Sampling at the Otukaikino Creek at Omaka Scout Camp was only instigated in October. The following sites were not measured for this parameter: Halswell Retention Basin Inlet and Halswell Retention Basin Outlet. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the ANZECC (2000) guideline value of 5.6 Nephelometric Turbidity Units (NTU). The Laboratory Limit of Detection was 0.1 NTU – analysed as half this value (0.05 NTU) to allow statistics to be undertaken.

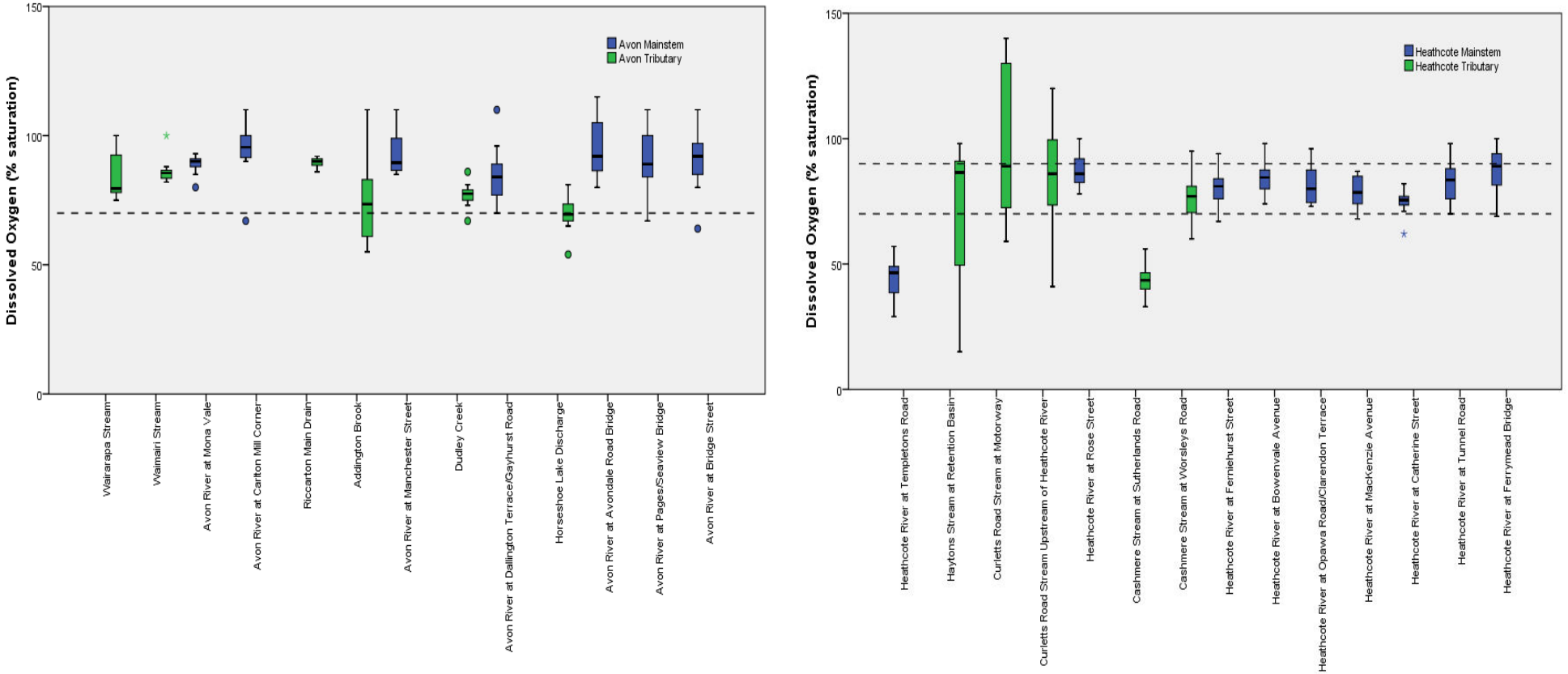

Figure 9a. Dissolved oxygen levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2014. No monitoring was undertaken at the Avon River at Bridge Street site in September and the Curletts Road Stream at Motorway site January – May, due to construction. Sites are ordered from upstream to downstream (left to right). The lower and upper dashed lines represent the Proposed Canterbury 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, 2012).

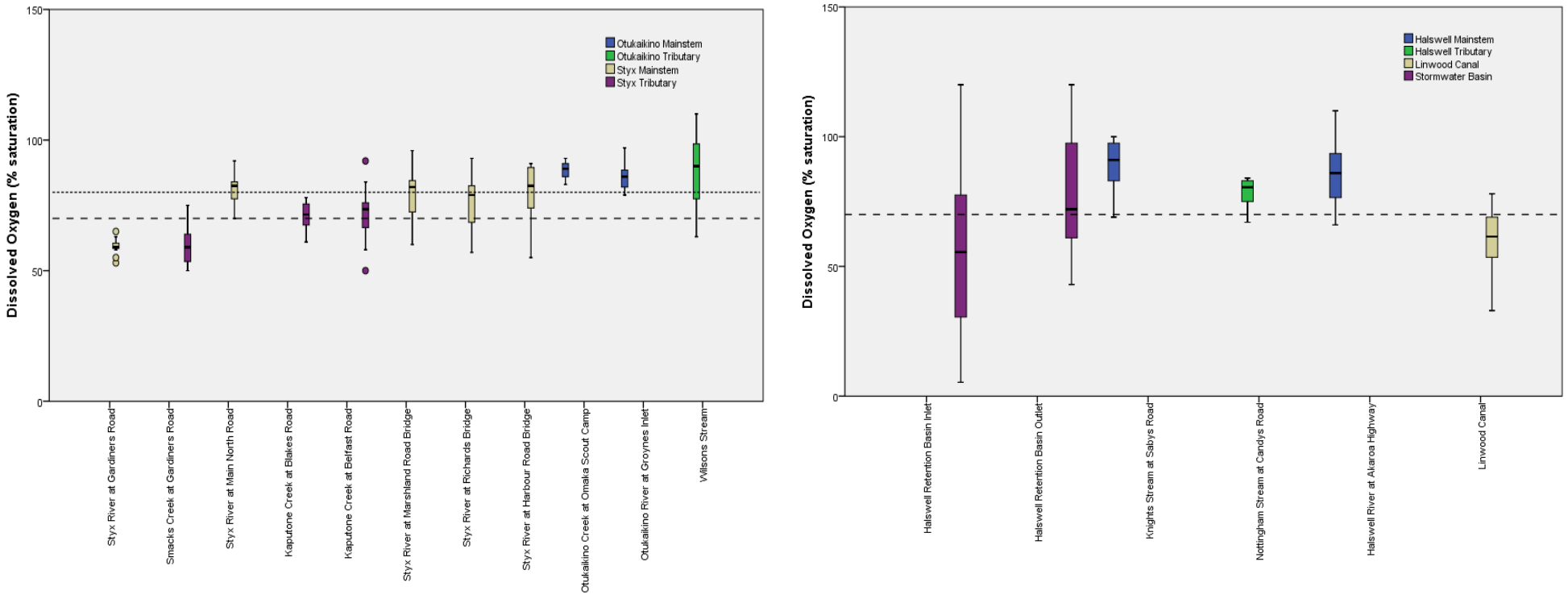

Figure 9b. Dissolved oxygen levels in water samples taken from the Styx and Otukaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2014. Sampling at the Otukaikino Creek at Omaka Scout Camp was only instigated in October. Sites are ordered from upstream to downstream (left to right). The lower dashed line represents the Proposed Canterbury Land and Water Regional Plan minimum guideline value for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (70%, Environment Canterbury, 2012). The upper dotted line represents the Waimakariri River Regional Plan minimum guideline value for all Otukaikino sites (80%, Environment Canterbury, 2011).

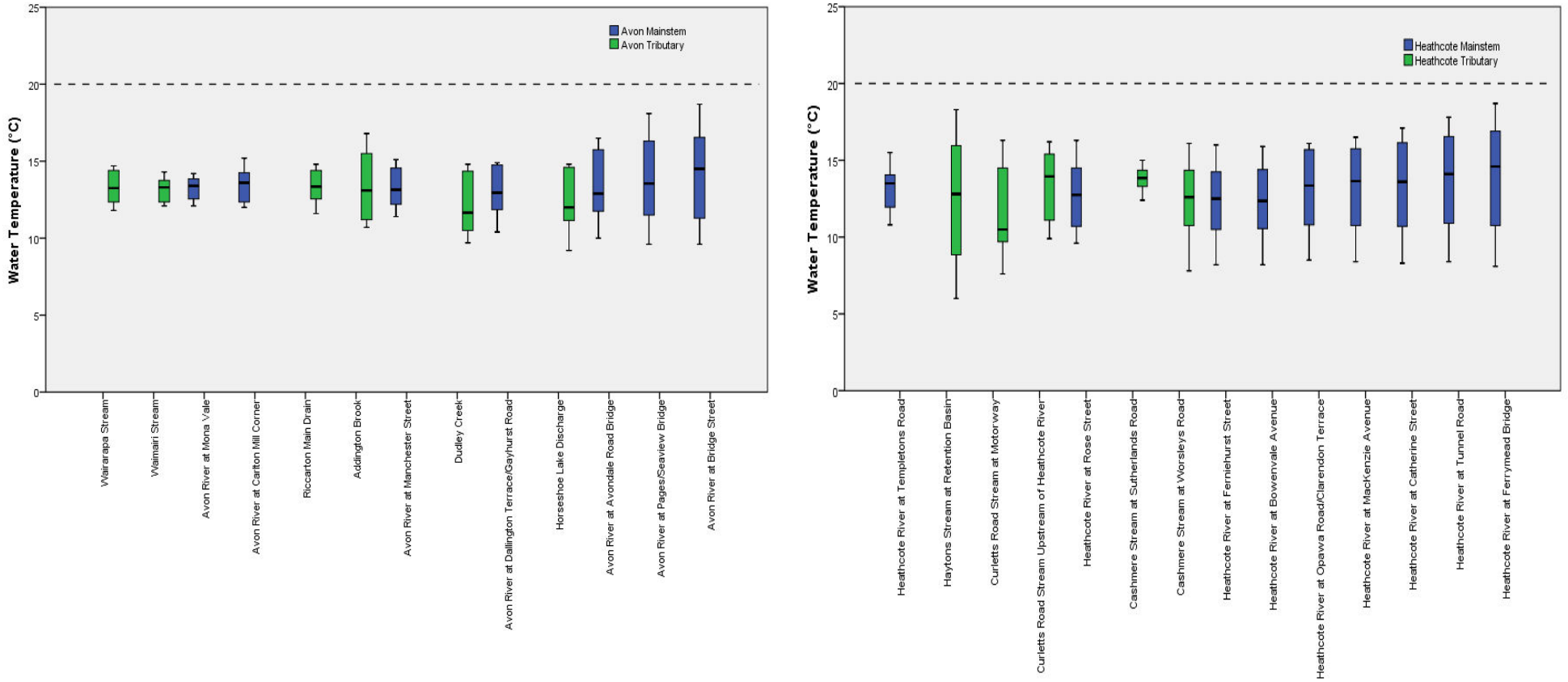

Figure 10a. Temperature of the water at the time of sampling at the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2014. No monitoring was undertaken at the Avon River at Bridge Street site in September and the Curletts Road Stream at Motorway site January – May, due to construction. Sites are ordered from upstream to downstream (left to right). The dashed line represents the Proposed Canterbury Land and Water Regional Plan maximum guideline value (20ºC, Environment Canterbury, 2012).

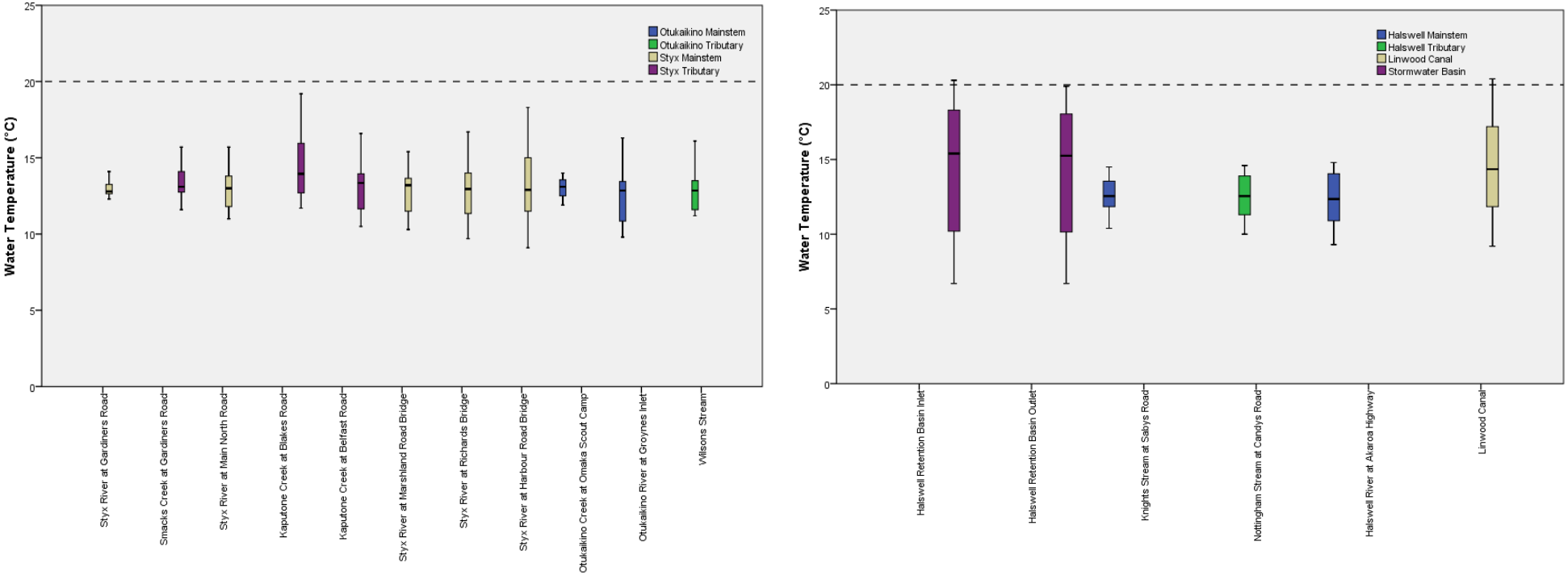

Figure 10b. Temperature of the water at the time of sampling at the Styx and Otukaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2014. Sampling at the Otukaikino Creek at Omaka Scout Camp was only instigated in October. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Proposed Canterbury Land and Water Regional Plan maximum guideline value (20 ºC, Environment Canterbury, 2012). The Waimakariri River Regional Plan maximum guideline value for all Otukaikino sites is 25 ºC (Environment Canterbury, 2011), which is not shown as this is equal to the top of the graph.

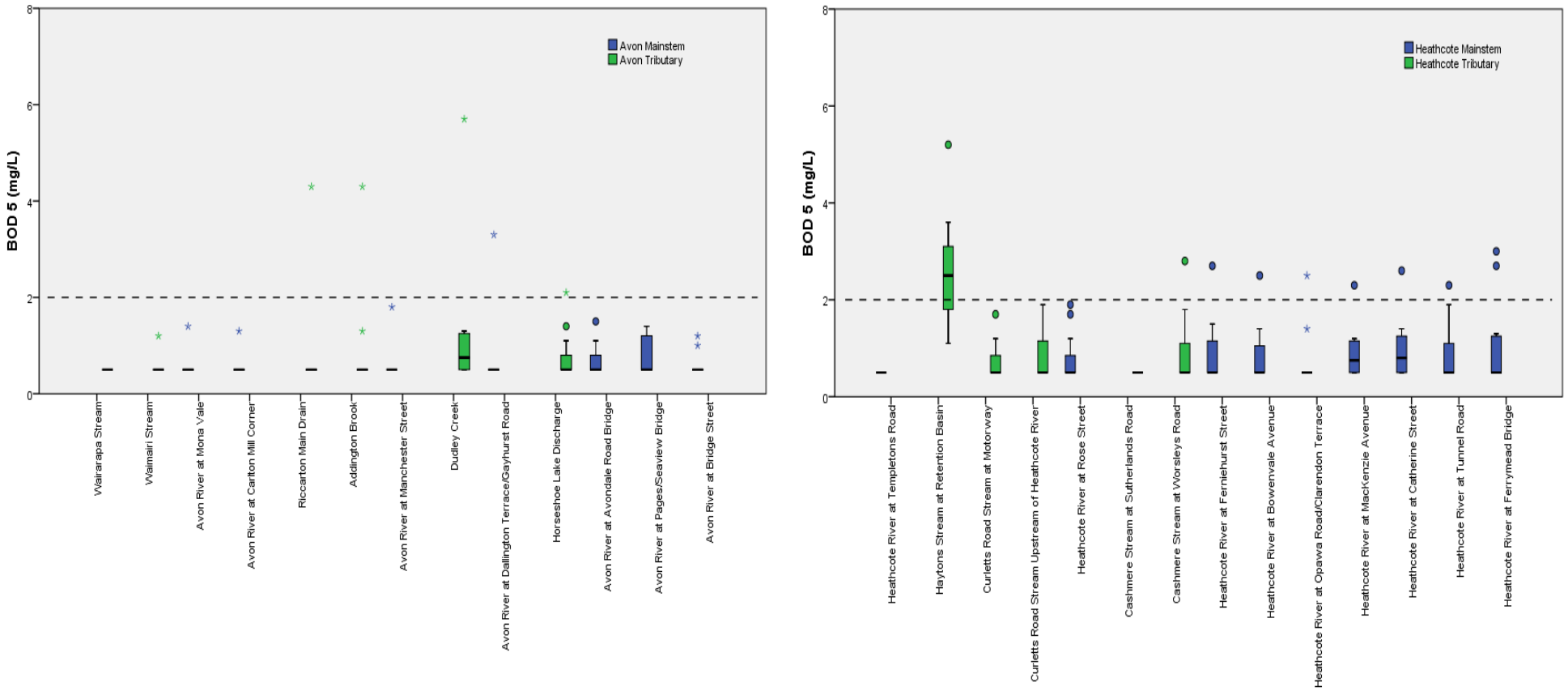

Figure 11a. Biochemical Oxygen Demand (BOD_5) levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2014. No monitoring was undertaken at the Avon River at Bridge Street site in September and the Curletts Road Stream at Motorway site January – May, due to construction. Sites are ordered from upstream to downstream (left to right). The dashed lines represent both the Ministry for the Environment and Waimakariri River Regional Plan guideline value (2 mg/L; Ministry for the Environment, 1992; Environment Canterbury, 2011). 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.

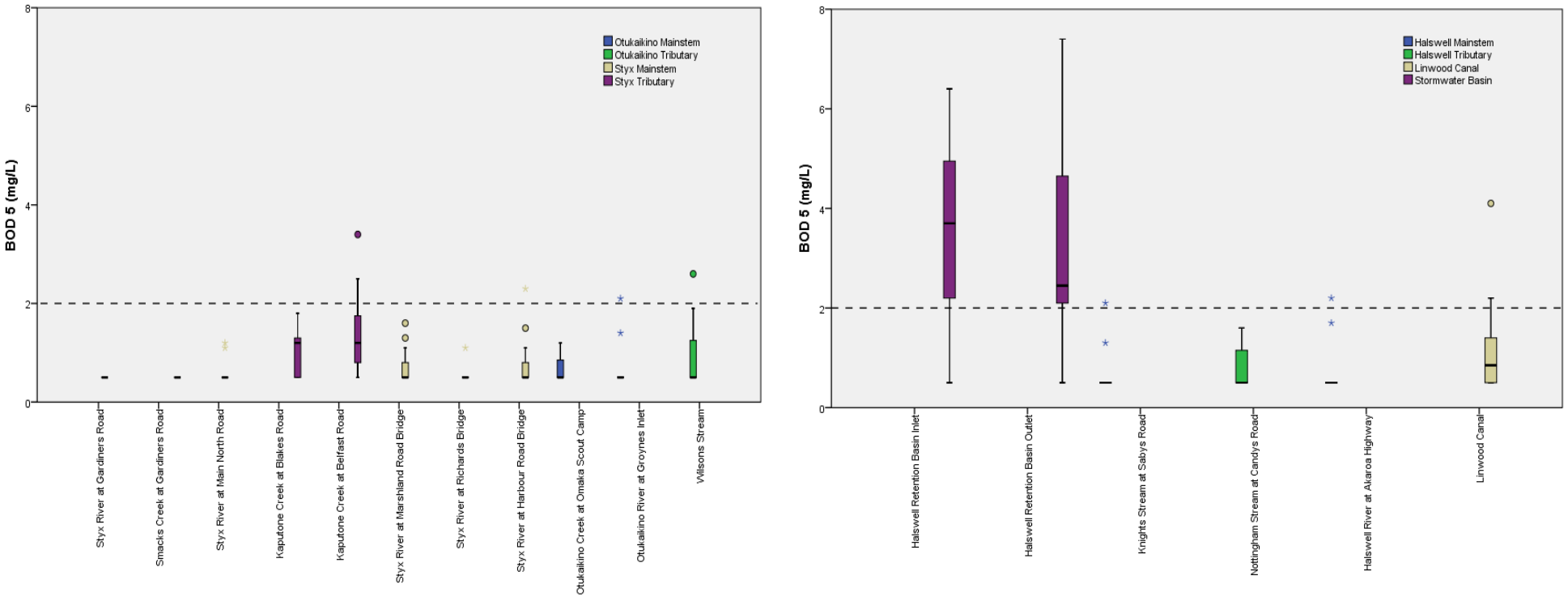

Figure 11b. Biochemical Oxygen Demand (BOD_5) levels in water samples taken from the Styx and Otukaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2014. Sampling at the Otukaikino Creek at Omaka Scout Camp was only instigated in October. Sites are ordered from upstream to downstream (left to right). The dashed lines represent both the Waimakariri River Regional Plan and Ministry for the Environment guideline value (2 mg/L; Ministry for the Environment, 1992; Environment Canterbury, 2011). 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.

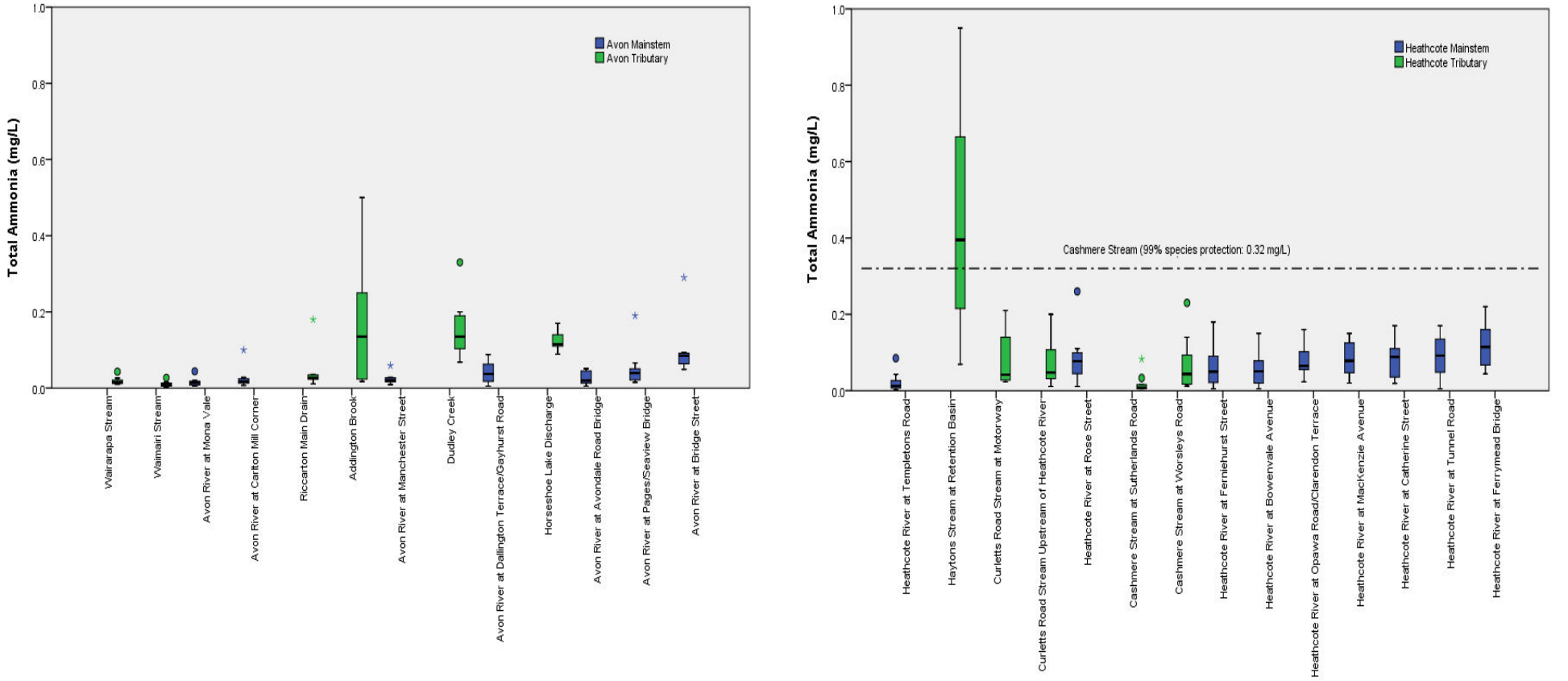

Figure 12a. Total ammonia levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2014. No monitoring was undertaken at the Avon River at Bridge Street site in September and at the Curletts Road Stream at Motorway site January – May, due to construction. Sites are ordered from upstream to downstream (left to right). The Proposed Canterbury Land and Water Regional Plan guideline values, adjusted in accordance with median pH levels for the monitoring period (Avon catchment: 7.7; Heathcote catchment: 7.6; Environment Canterbury, 2012) are not visible as they are off the scale (Avon catchment: 1.32 mg/L; Heathcote catchment: 1.47 mg/L). The dashed line represents the Proposed Canterbury Land and Water Regional Plan maximum guideline value for Banks Peninsula waterways (0.32 mg/L, Cashmere Stream only; Environment Canterbury, 2012). The Laboratory Limit of Detection was 0.01 mg/L – analysed as half this value (0.005 mg/L) to allow statistics to be undertaken.

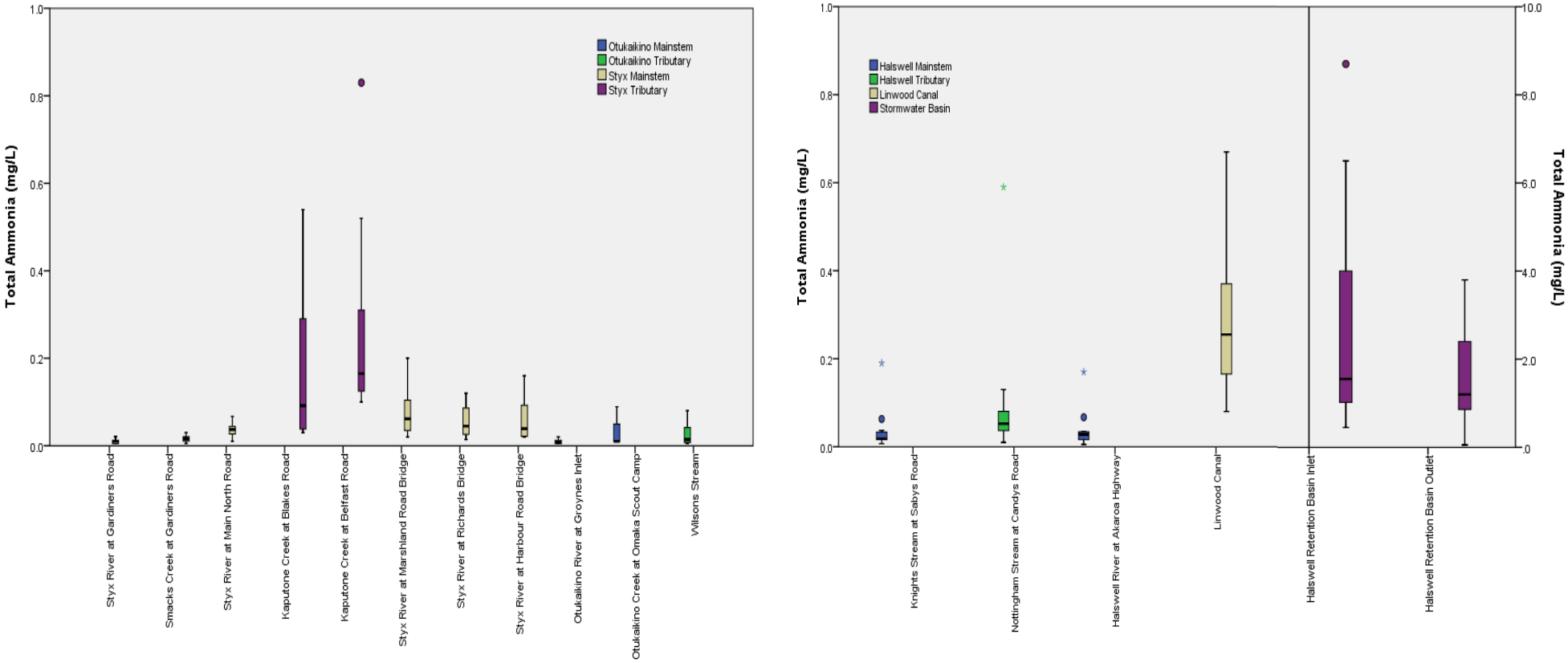

Figure 12b. Total ammonia levels in water samples taken from the Styx and Otukaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2014. Sampling at the Otukaikino Creek at Omaka Scout Camp was only instigated in October. Sites are ordered from upstream to downstream (left to right). All graphs have the same scale presented on the primary (left) axis. Given the large differences in values at the Halswell Retention Basin sites, these are presented with an alternate scale on the secondary (right) axis. Scale change is marked with a solid vertical line. The Proposed Canterbury Land and Water Regional Plan guideline values, adjusted in accordance with median pH levels for the monitoring period (Styx catchment: 7.5; Otukaikino catchment: 7.5; Halswell catchment: 7.6; Linwood Canal: 7.8; Environment Canterbury, 2012), are not visible as they are off the scale (Styx catchment: 1.61 mg/L; Otukaikino catchment: 1.61 mg/L; Halswell catchment: 1.47 mg/L; Linwood Canal: 1.18 mg/L). The Laboratory Limit of Detection was 0.01 mg/L – analysed as half this value (0.005 mg/L) to allow statistics to be undertaken.

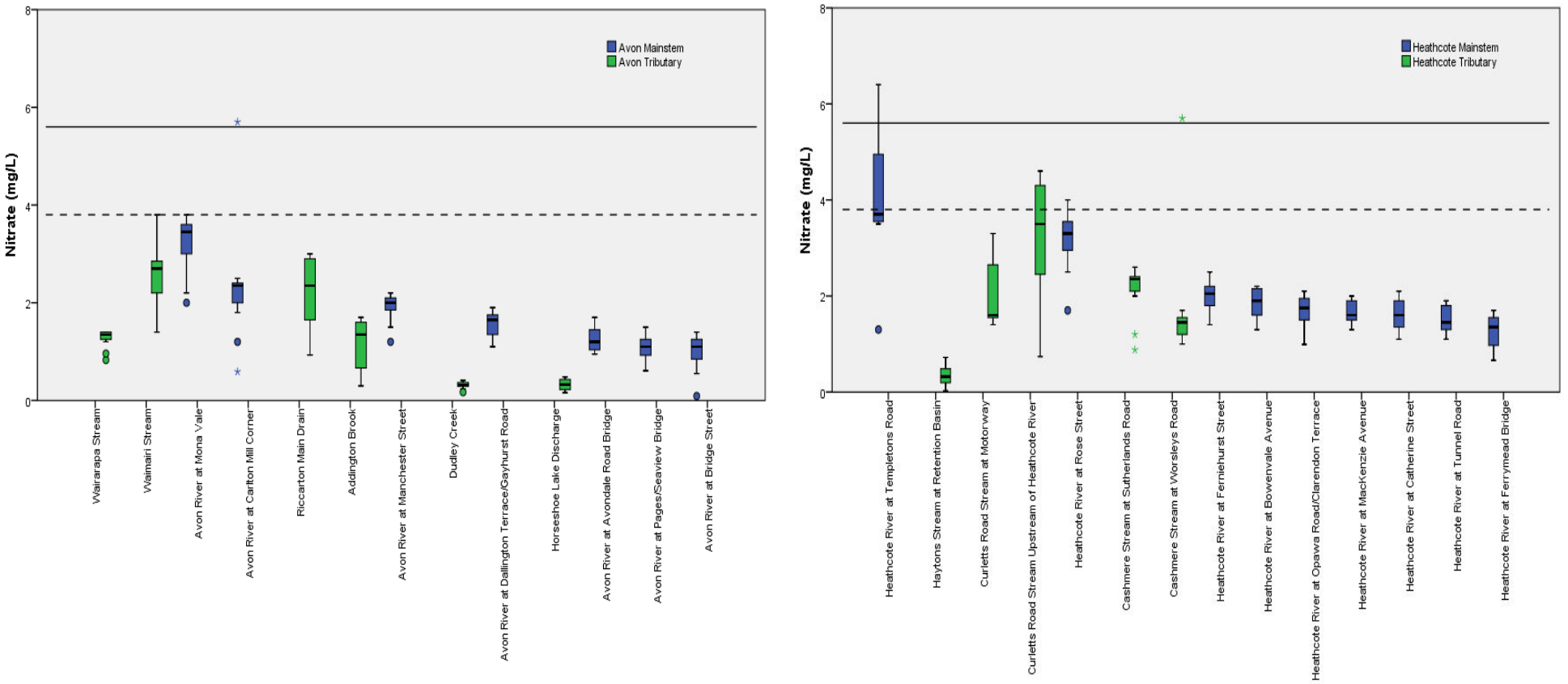

Figure 13a. Nitrate levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2014. No monitoring was undertaken at the Avon River at Bridge Street site in September and at the Curletts Road Stream at Motorway site January – May, due to construction. Sites are ordered from upstream to downstream (left to right). The dashed and solid lines represent the Hickey (2013) grading (3.8 mg/L) and surveillance (5.6 mg/L) guideline levels, respectively. The Laboratory Limit of Detection was 0.05 mg/L – analysed as half this value (0.025 mg/L) to allow statistics to be undertaken.

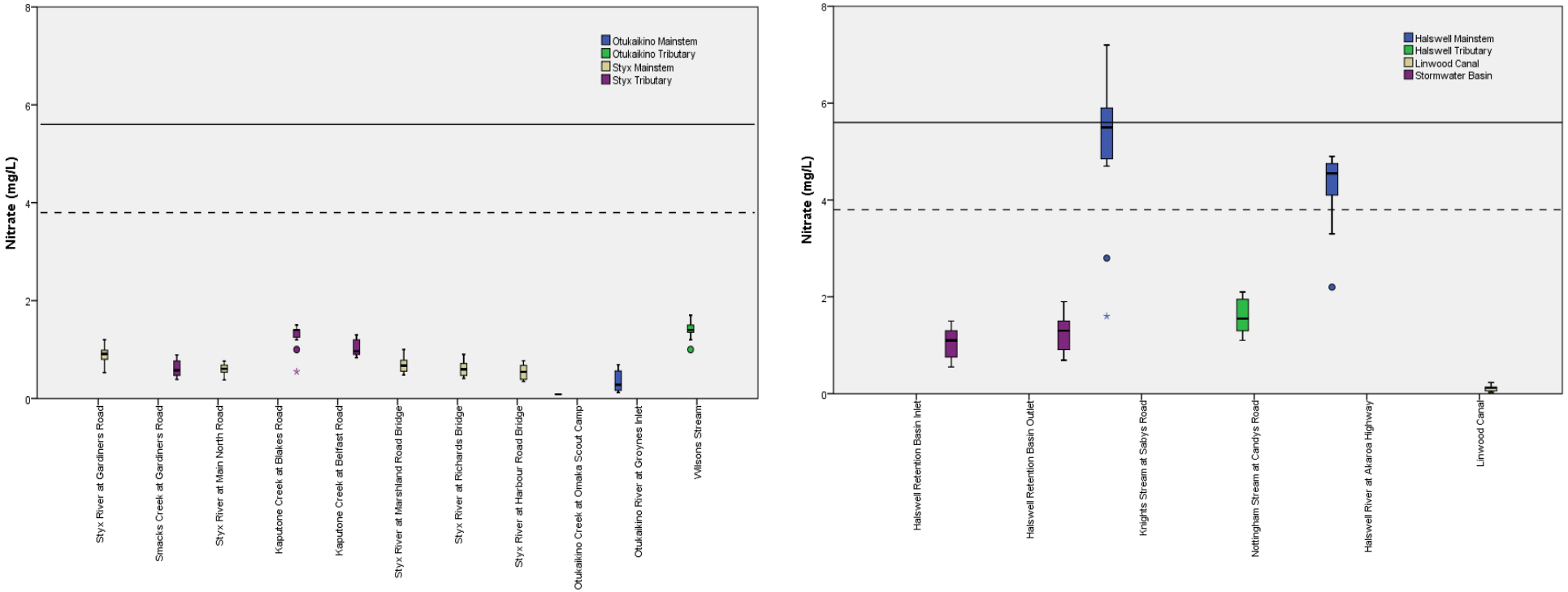

Figure 13b. Nitrate levels in water samples taken from the Styx and Otukaikino Rivers (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2014. Sampling at the Otukaikino Creek at Omaka Scout Camp was only instigated in October. Sites are ordered from upstream to downstream (left to right). The dashed and solid lines represent the Hickey (2013) grading (3.8 mg/L) and surveillance (5.6 mg/L) guideline levels, respectively. The Laboratory Limit of Detection was 0.05 mg/L – analysed as half this value (0.025 mg/L) to allow statistics to be undertaken.

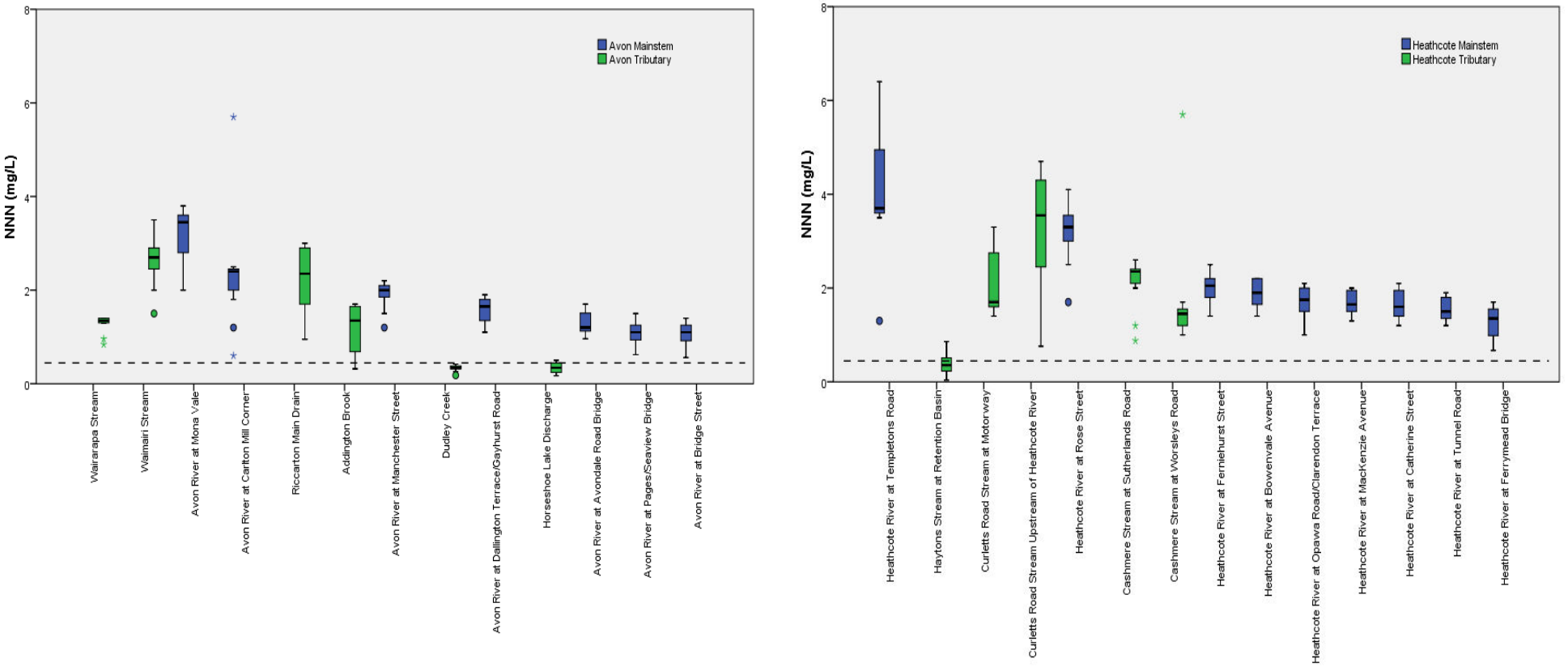

Figure 14a. Nitrate Nitrite Nitrogen (NNN) in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2014. No monitoring was undertaken at the Avon River at Bridge Street site in September and at the Curletts Road Stream at Motorway site January – May, due to construction. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the ANZECC water quality guideline (0.444 mg/L; ANZECC, 2000).

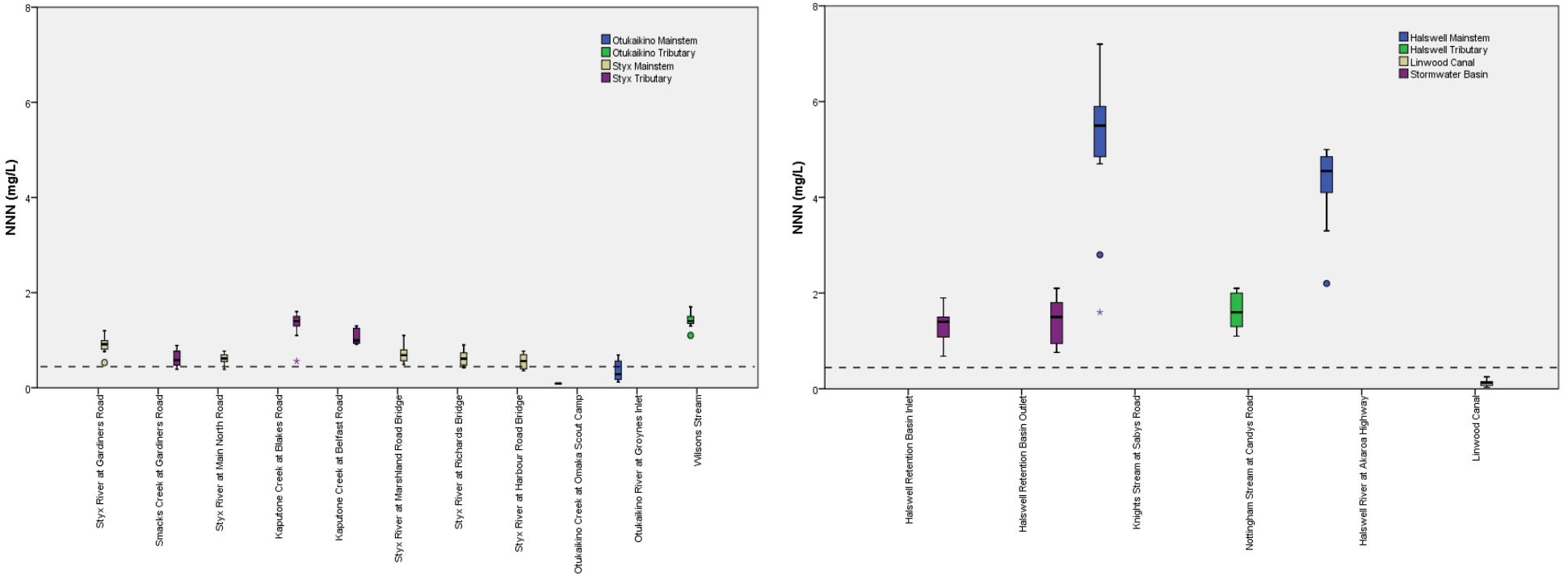

Figure 14b. Nitrate Nitrite Nitrogen (NNN) levels in water samples taken from the Styx and Otukaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2014. Sampling at the Otukaikino Creek at Omaka Scout Camp was only instigated in October. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the ANZECC water quality guideline (0.444 mg/L; ANZECC, 2000).

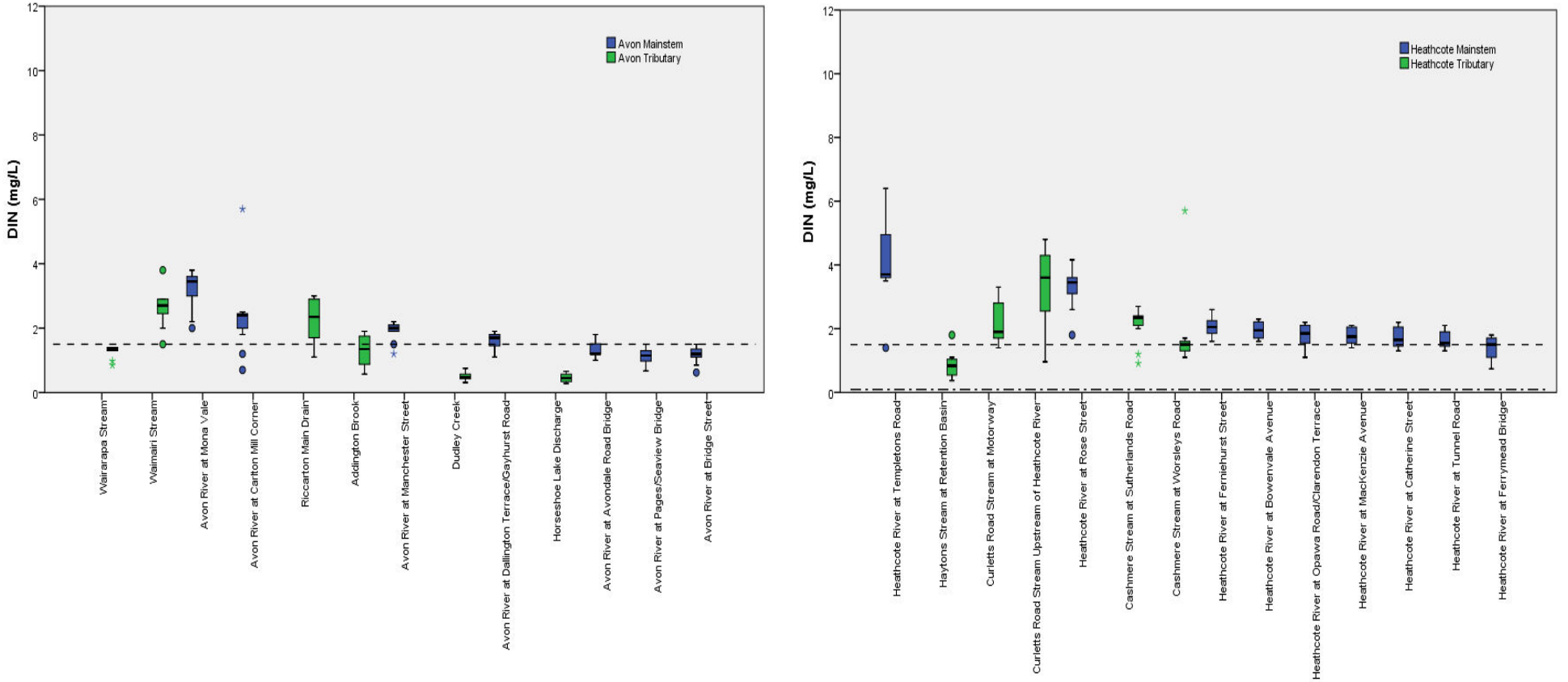

Figure 15a. Dissolved Inorganic Nitrogen (DIN) levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2014. No monitoring was undertaken at the Avon River at Bridge Street site in September and at the Curletts Road Stream at Motorway site January – May, due to construction. Sites are ordered from upstream to downstream (left to right). The lower and upper dashed lines represent the Proposed Canterbury Land and Water Regional Plan trigger 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, 2012).

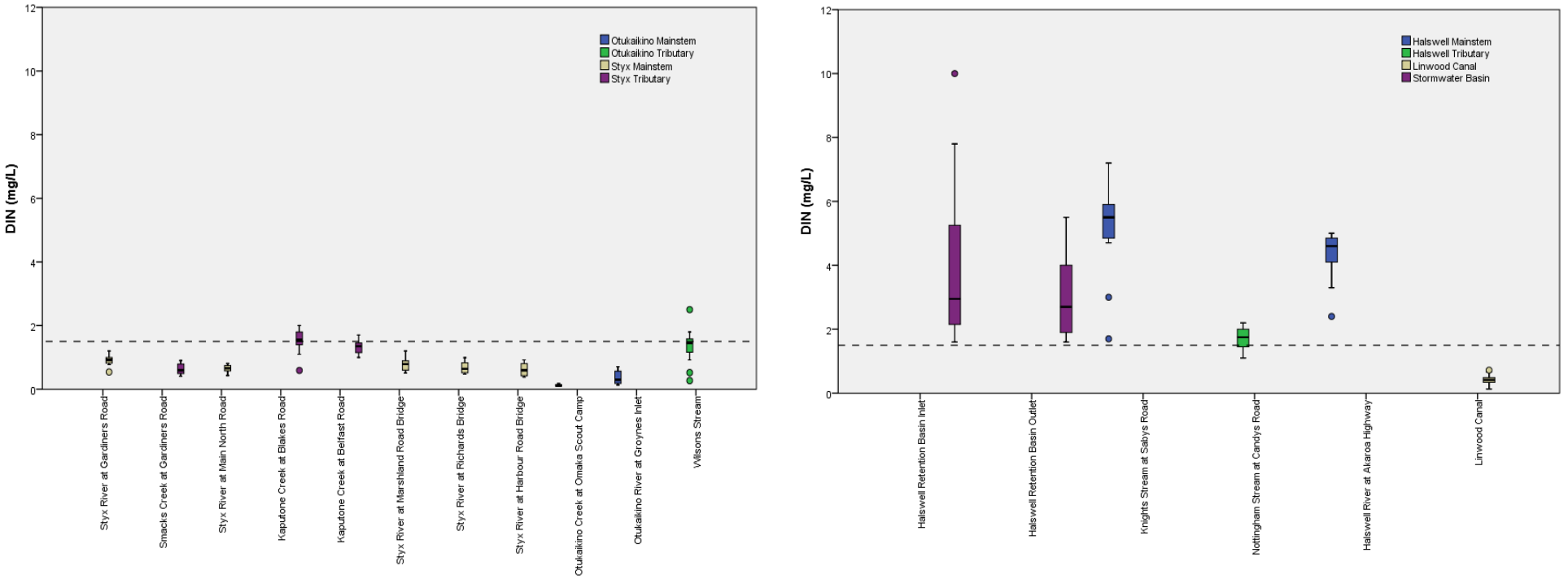

Figure 15b. Dissolved Inorganic Nitrogen (DIN) levels in water samples taken from the Styx and Otukaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2014. Sampling at the Otukaikino Creek at Omaka Scout Camp was only instigated in October. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Proposed Canterbury Land and Water Regional Plan trigger value for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways of 1.5 mg/L (Environment Canterbury, 2012).

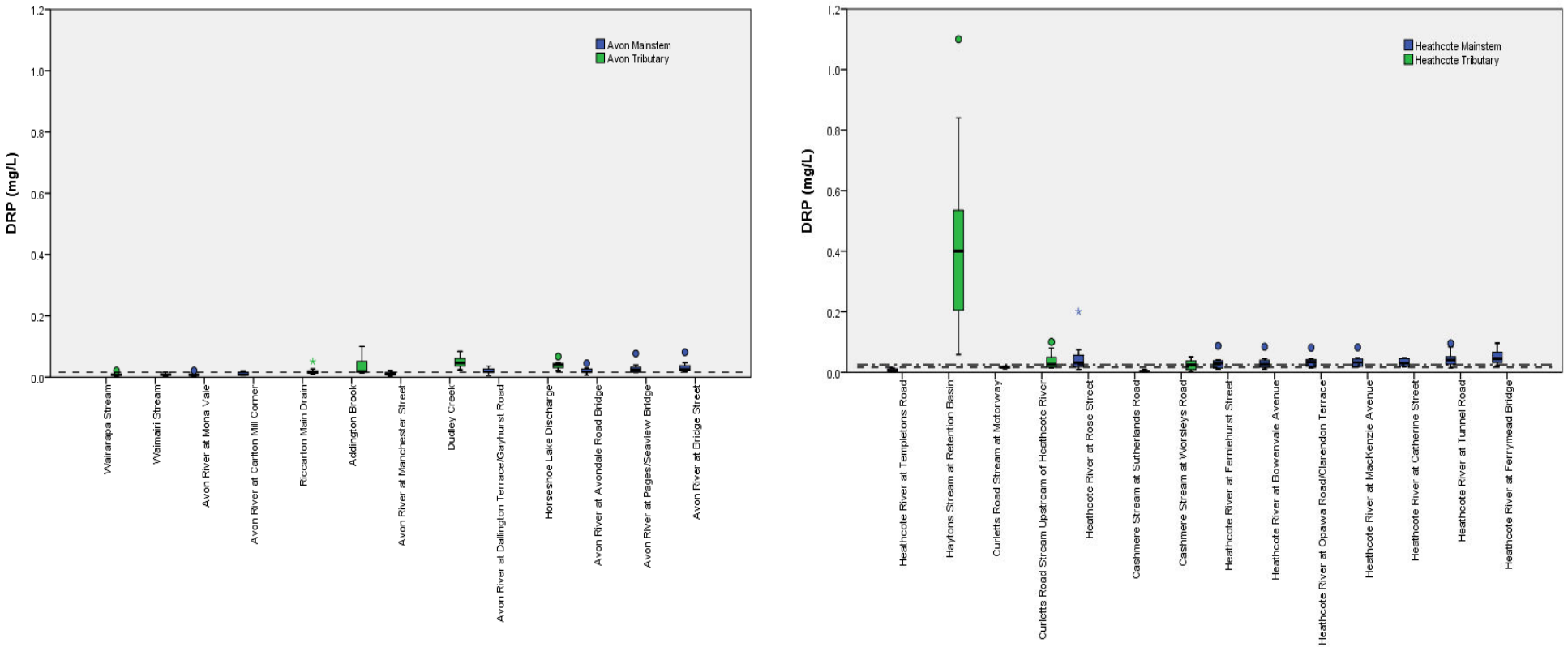

Figure 16a. Dissolved Reactive Phosphorus (DRP) levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2014. No monitoring was undertaken at the Avon River at Bridge Street site in September and at the Curletts Road Stream at Motorway site January – May, due to construction. Sites are ordered from upstream to downstream (left to right). The lower and upper dashed lines represent the Proposed Canterbury Land and Water Regional Plan trigger value of 0.016 mg/L for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways, and 0.025 mg/L for Banks Peninsula waterways (Cashmere Stream only), respectively (Environment Canterbury, 2012). The Laboratory Limit of Detection was 0.003 mg/L, analysed as half this value (0.0015 mg/L) to allow statistics to be undertaken. A close up of the graph is presented in Appendix C, Figure iii(a).

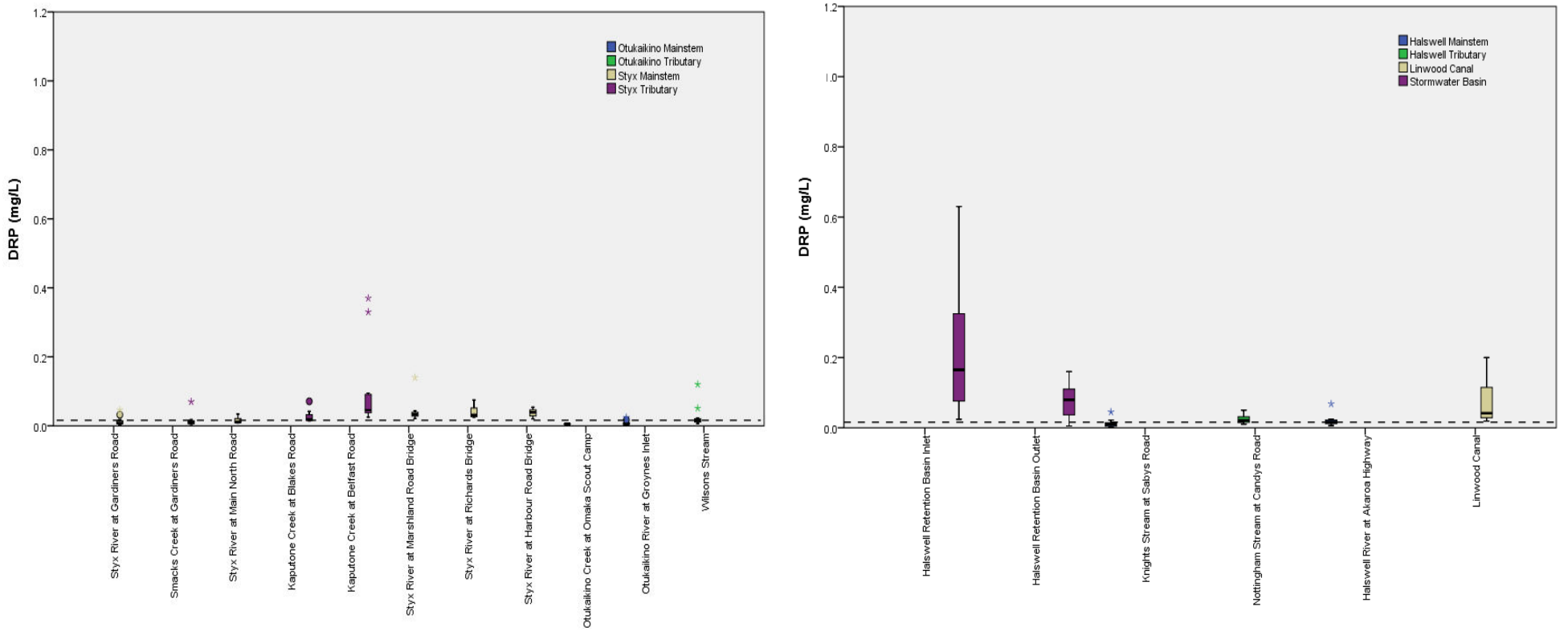

Figure 16b. Dissolved Reactive Phosphorus (DRP) levels in water samples taken from the Styx and Otukaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2014. Sampling at the Otukaikino Creek at Omaka Scout Camp was only instigated in October. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Proposed Canterbury Land and Water Regional Plan trigger value of 0.016 mg/L for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (Environment Canterbury, 2012). The Laboratory Limit of Detection was 0.003 mg/L, analysed as half this value (0.0015 mg/L) to allow statistics to be undertaken. A close up of this graph is presented in Appendix C, Figure iii(b).

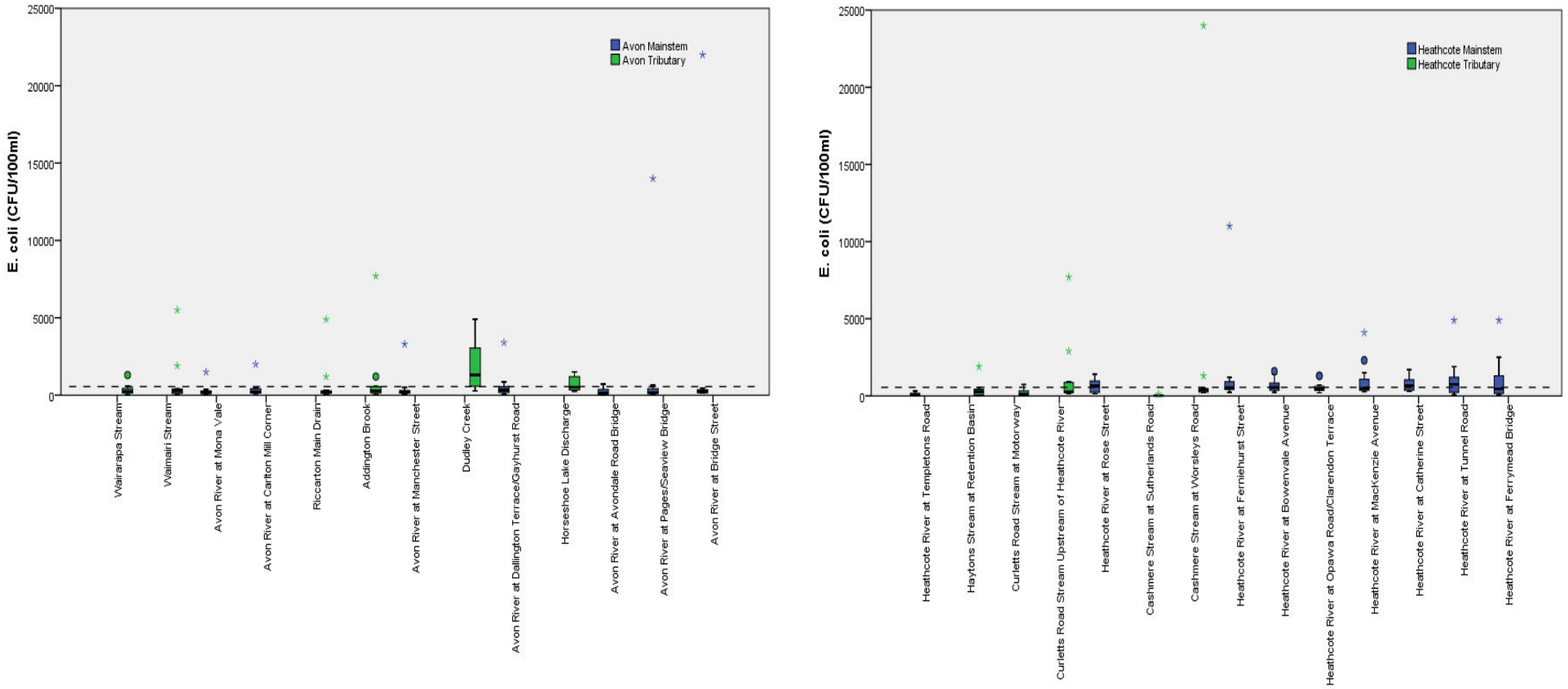

Figure 17a. *Escherichia coli* levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2014. No monitoring was undertaken at the Avon River at Bridge Street site in September and at the Curletts Road Stream at Motorway site January – May, due to construction. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Proposed Canterbury Land and Water Regional Plan trigger value of 550 CFU/100ml for 95% of samples for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (Environment Canterbury, 2012). 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 maximum limit of detection was 24,000 CFU/100ml, which was analysed as 24,000 CFU/100ml to allow statistics to be undertaken.

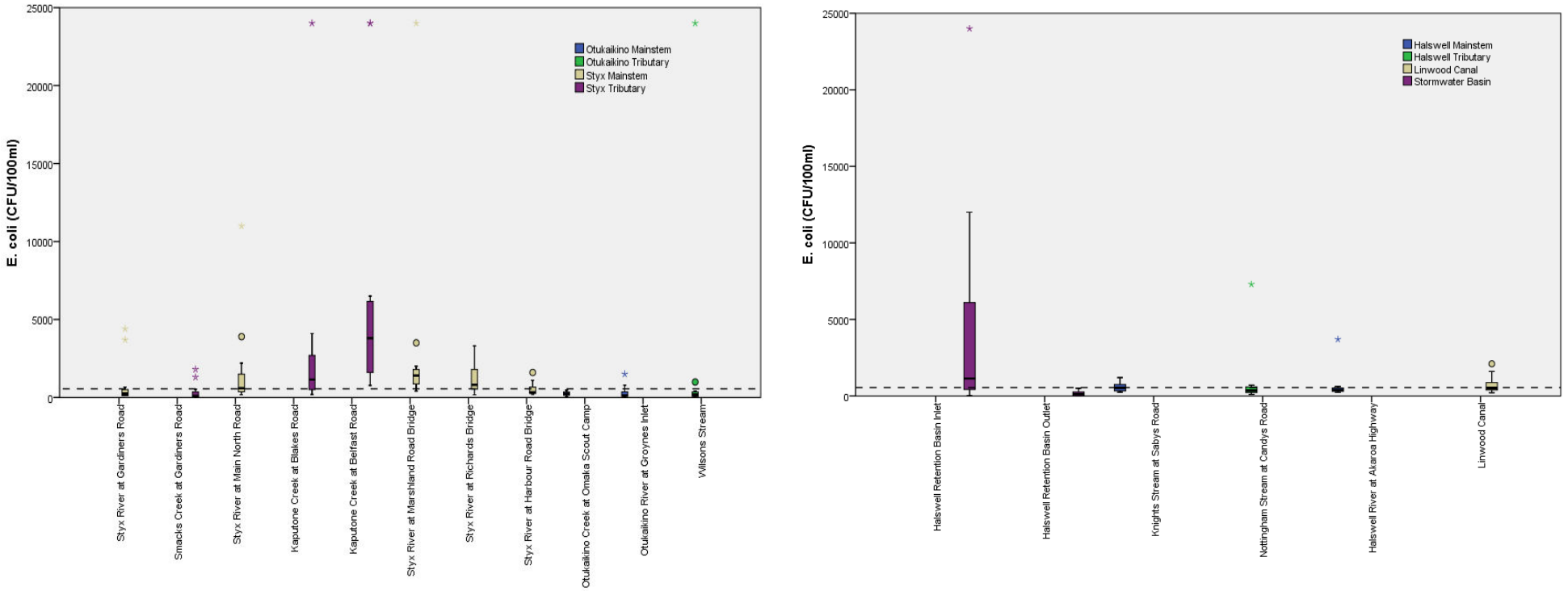

Figure 17b. *Escherichia coli* levels in water samples taken from the Styx and Otukaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2014. Sampling at the Otukaikino Creek at Omaka Scout Camp was only instigated in October. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Proposed Canterbury Land and Water Regional Plan trigger value of 550 CFU/100ml for 95% of samples for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (Environment Canterbury, 2012). 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 maximum limit of detection was 24,000 CFU/100ml, which was analysed as 24,000 CFU/100ml to allow statistics to be undertaken.

4.2 Temporal Trends

The majority of parameters across all sites had no significant upwards or downwards trends in concentrations, meaning that parameter levels have remained static between years (335 incidences; Tables 7a to 7d). However, a number of sites recorded statistically significant upward (104 incidences) and downward (108 incidences) trends in concentrations. Most downward trends indicated an improvement in water quality, with the exception of dissolved oxygen, where higher values represent better water quality. Changes in conductivity can also be tidally related at some sites, rather than water quality related. Upwards and downward trends for pH can indicate either a decrease or increase in water quality, as there are upper and lower guideline limits.

The largest increase recorded was a 30% change in DIN at the Knights Stream at Sabys Road site (
Figure 18). This site has shown a fairly steady increase in DIN concentration since January 2013, although there have been some large changes during this time (e.g., decreases in August and October 2014, and an increase in August 2012). Another notable parameter increase was conductivity at the Avon River at Bridge Street site (25%), with the increase probably related to salinity variations at this tidal site (Figure 19).

The largest decrease was for dissolved zinc at the Curletts Road Stream Upstream of Heathcote River site, which decreased by 146% (Figure 20). Despite the rapid decrease in concentration, spikes well in excess of the guideline continue to be recorded every year. This site also recorded a 38% drop in dissolved copper levels over the same monitoring period (Figure 21), with many of the spikes mirroring the other. Turbidity also recorded a decreasing trend at this site (26%; Figure 22), following high levels recorded during the earthquakes. Another notable downwards trend was a 25% decrease in turbidity at the Otukaikino River at Groynes Inlet site, which has recorded a gradual decline in this parameter since 2009 (Figure 23).

Table 7a. Direction of significant trends (p≤0.05) for parameters at each of the sites in the Avon River catchment, calculated from monthly sampling conducted during January 2007 to April 2013. EC = Electrical Conductivity, TSS = Total Suspended Solids, DO = Dissolved Oxygen, Temp = Temperature; BOD_5 = Biochemical Oxygen Demand, NNN = Nitrate Nitrite Nitrogen and DIN = Dissolved Inorganic Nitrogen. Blank cells indicate no significant upwards or downwards trends.

Site	Dissolved Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Total Ammonia	NNN	DIN	*E. coli*
Wairarapa Stream		↓ 8%	↑ 1%		↓ 6%		↑ 1%						
Waimairi Stream		↓ 4%	↑ 1%		↓ 6%	↓ 6%	↑ 1%						
Avon River at Mona Vale		↓ 4%	↑ 1%		↓ 8%	↓ 11%							
Avon River at Carlton Mill Corner		↓ 10%	↑ 1%										
Riccarton Main Drain		↓ 10%	↑ 1%	↑ 3%	↓ 6%			↑ 1%			↑ 9%	↑ 8%	
Addington Brook			↑ 1%						↓ 8%				
Avon River at Manchester Street		↓ 9%	↑ 1%		↓ 2%			↑ 1%					
Dudley Creek			↑ 1%	↓ 6%	↑ 18%	↑ 13%			↓ 6%	↑ 9%	↓ 10%	↓ 5%	
Avon River at Dallington Terrace/Gayhurst Road			↑ 1%		↓ 8%	↓ 11%	↑ 2%	↑ 1%					
Horseshoe Lake Discharge			↑ 1%	↓ 4%					↓ 5%				↑ 13%
Avon River at Avondale Road		↓ 8%	↑ 1%		↓ 7%				↓ 3%				
Avon River at Pages/Seaview Bridge			↑ 1%	↑ 11%		↓ 6%	↑ 2%	↑ 1%					↑ 11%
Avon River at Bridge Street		↓ 5%	↑ 1%	↑ 25%	↓ 5%		↑ 2%	↑ 1%	↓ 1%	↓ 5%			↑ 13%

Table 7b. Direction of significant trends (p≤0.05) for parameters at each of the sites in the Heathcote River catchment, calculated from monthly sampling conducted during January 2007 to April 2013. EC = Electrical Conductivity, TSS = Total Suspended Solids, DO = Dissolved Oxygen, Temp = Temperature; BOD_5 = Biochemical Oxygen Demand, NNN = Nitrate Nitrite Nitrogen and DIN = Dissolved Inorganic Nitrogen. Blank cells indicate no significant upwards or downwards trends. N/A = unable to be analysed, due to many levels being below the laboratory limit of detection. No monitoring was undertaken at the Curletts Road Stream at Motorway site January – May, due to construction. Trends recording 0% are due to rounding down percent changes of less than one to the nearest whole number.

Site	Dissolved Copper	Dissolved Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Total Ammonia	NNN	DIN	*E. coli*
Heathcote River at Templetons Road	N/A		↓ 13%	↑ 0%	↑ 2%	↓ 7%			↑ 1%			↑ 5%	↑ 4%	
Haytons Stream at Retention Basin	N/A		↓ 19%							↓ 8%		↓ 23%	↓ 22%	
Curletts Road Stream at Motorway	N/A		↓ 22%	↑ 1%	↑ 2%							↓ 8%	↓ 9%	
Curletts Road Stream Upstream of Heathcote River	↓ 38%	↓ 146%		↑ 1%		↓ 12%	↓ 26%		↑ 2%	↓ 10%	↓ 15%			
Heathcote River at Rose Street	N/A		↓ 13%	↑ 1%					↑ 1%	↓ 10%				
Cashmere Stream at Sutherlands Road	N/A		↓ 24%	↑ 1%	↓ 2%			↓ 6%				↓ 4%		
Cashmere Stream at Worsleys Road	N/A			↑ 0%				↓ 2%				↓ 1%		
Heathcote River at Ferniehurst Street	N/A		↓6	↑ 1%					↑ 1%			↓ 1%	↓ 4%	
Heathcote River at Bowenvale Ave	N/A			↑ 1%										
Heathcote River at Opawa Road/Clarendon Terrace	N/A		↓ 6%	↑ 1%		↓ 7%	↓ 9%			↓ 2%				
Heathcote River at Mackenzie Avenue	N/A		↓ 11%	↑ 1%		↓ 10%				↓ 2%				
Heathcote River at Catherine Street	N/A		↓ 11%	↑ 1%				↑ 1%		↓ 4%				
Heathcote River at Tunnel Road	N/A		↓ 9%	↑ 1%		↓ 5%	↓ 8%				↓ 10%			
Heathcote River at Ferrymead Bridge	N/A		↓ 14%	↑ 0%				↑ 2%	↑ 1%	↓ 4%	↓ 20%			↑ 9%

Table 7c. Direction of significant trends (p≤0.05) for parameters at each of the sites in the Halswell River catchment and Linwood Canal, calculated from monthly sampling conducted during January 2007 to April 2013. EC = Electrical Conductivity, TSS = Total Suspended Solids, DO = Dissolved Oxygen, Temp = Temperature; BOD_5 = Biochemical Oxygen Demand, NNN = Nitrate Nitrite Nitrogen and DIN = Dissolved Inorganic Nitrogen. Blank cells indicate no significant upwards or downwards trends.

Site	Dissolved Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Total Ammonia	NNN	DIN	*E. coli*
Halswell Retention Basin Inlet			↑ 2%						↓ 13%		↑ 19%	↑ 8%	↑ 18%
Halswell Retention Basin Outlet									↓ 15%		↑ 13%		
Knights Stream at Sabys Road											↑ 30%	↑ 30%	
Nottingham Stream at Candy's Road		↓ 4%	↑ 1%	↓ 6%				↑ 1%					
Halswell River at Akaroa Highway		↓ 8%	↑ 1%					↑ 1%					↑ 11%
Linwood Canal			↑ 1%	↑ 19%	↑ 10%	↑ 6%		↑ 1%	↓ 8%		↓ 16%	↓ 7%	↑ 10%

Table 7d. Direction of significant trends (p≤0.05) for parameters at each of the sites in the Styx and Otukaikino River catchments, calculated from monthly sampling conducted during January 2007 to April 2013. EC = Electrical Conductivity, TSS = Total Suspended Solids, DO = Dissolved Oxygen, Temp = Temperature; BOD_5 = Biochemical Oxygen Demand, NNN = Nitrate Nitrite Nitrogen and DIN = Dissolved Inorganic Nitrogen. Blank cells indicate no significant upwards or downwards trends. Trends recording 0% are due to rounding down percent changes of less than one to the nearest whole number.

Site	Dissolved Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Total Ammonia	NNN	DIN	*E. coli*
Styx River at Gardiners Road		↓ 4%	↑ 0%[3]	↓ 3%	↓ 11%	↓ 13%						↓ 6%	↑ 17%
Smacks Creek at Gardiners Road			↑ 0%	↓ 4%	↓ 7%	↓ 13%					↓ 4%	↓ 4%	
Styx River at Main North Road			↑ 1%	↓ 2%	↓ 8%	↓ 15%	↓ 1%						↑ 10%
Kaputone Creek at Blakes Road		↑ 5%	↑ 0%							↑ 13%	↑ 7%	↑ 7%	↑ 12%
Kaputone Creek at Belfast Road		↑ 5%	↑ 1%		↓ 6%	↓ 9%		↑ 1%			↑ 4%	↑ 4%	
Styx River at Marshland Road Bridge		↑ 5%	↑ 1%		↓ 8%	↓ 10%				↑ 9%		↑ 2%	↑ 11%
Styx River at Richards Bridge			↑ 1%	↓ 2%	↓ 6%		↓ 1%			↑ 9%			↑ 20%
Styx River at Harbour Road Bridge			↑ 1%	↓ 4%	↓ 9%	↓ 7%		↑ 2%					↑ 16%
Otukaikino River at Groynes Inlet		↓ 22%			↓ 11%	↓ 25%	↓ 1%						

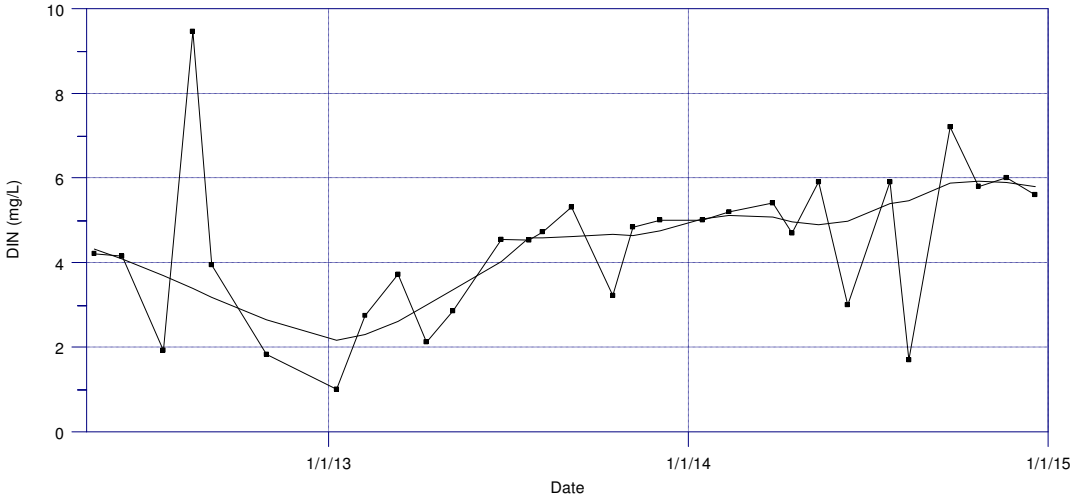

Figure 18. Dissolved Inorganic Nitrogen (DIN) levels at the Knights Stream at Sabys Road site for the monitoring period May 2012 to December 2014. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A positive trend of 30% was recorded over the sampling period.

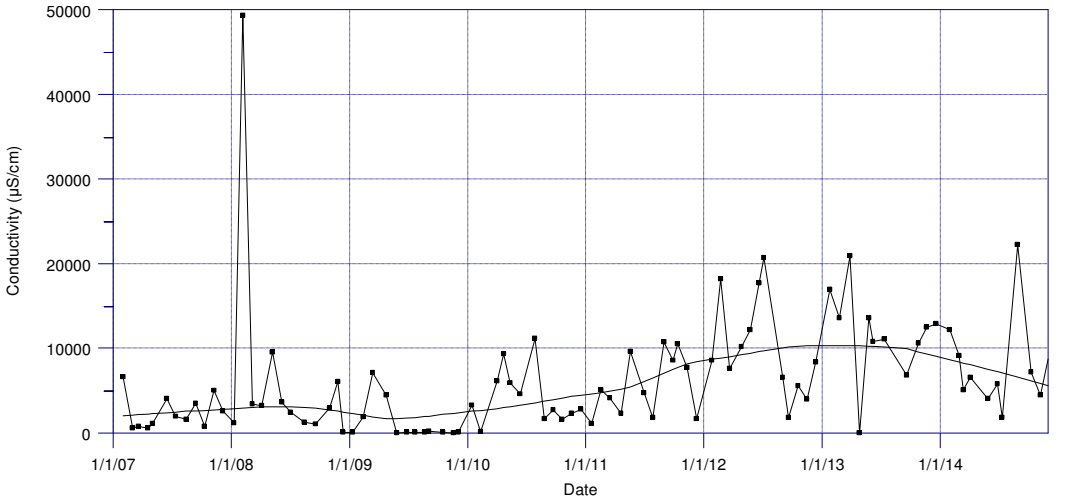

Figure 19. Conductivity levels at the Avon River at Bridge Street site for the monitoring period January 2007 to December 2014. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A positive trend of 25% was recorded over the sampling period.

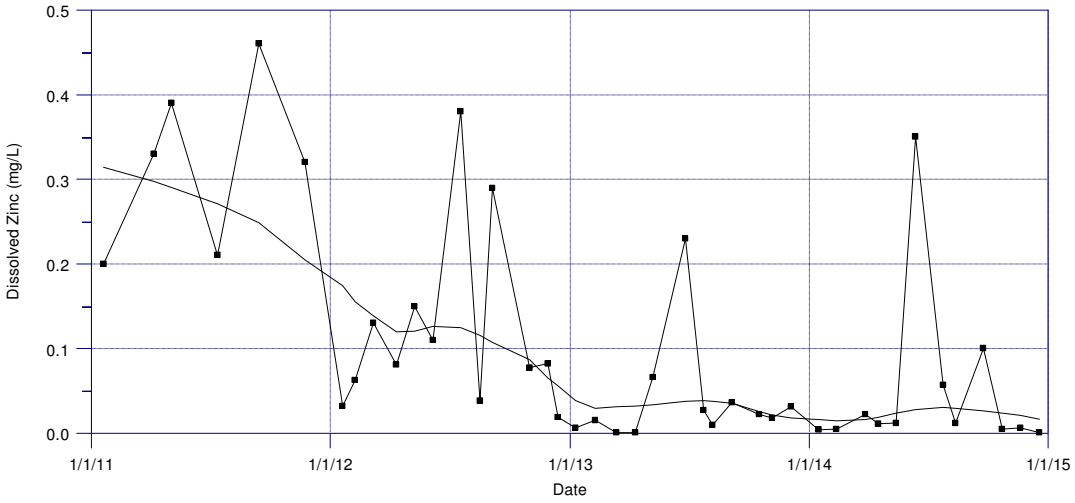

Figure 20. Dissolved zinc levels at the Curletts Road Stream Upstream of Heathcote River site for the monitoring period January 2011 to December 2014. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A negative trend of 146% was recorded over the sampling period.

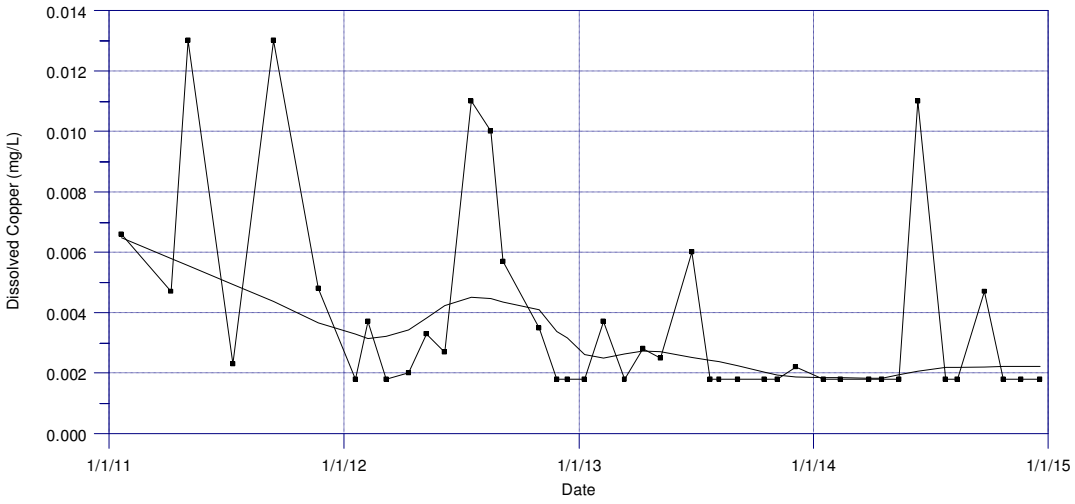

Figure 21. Dissolved copper levels at the Curletts Road Stream Upstream of Heathcote River site for the monitoring period January 2011 to December 2014. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A negative trend of 38% was recorded over the sampling period.

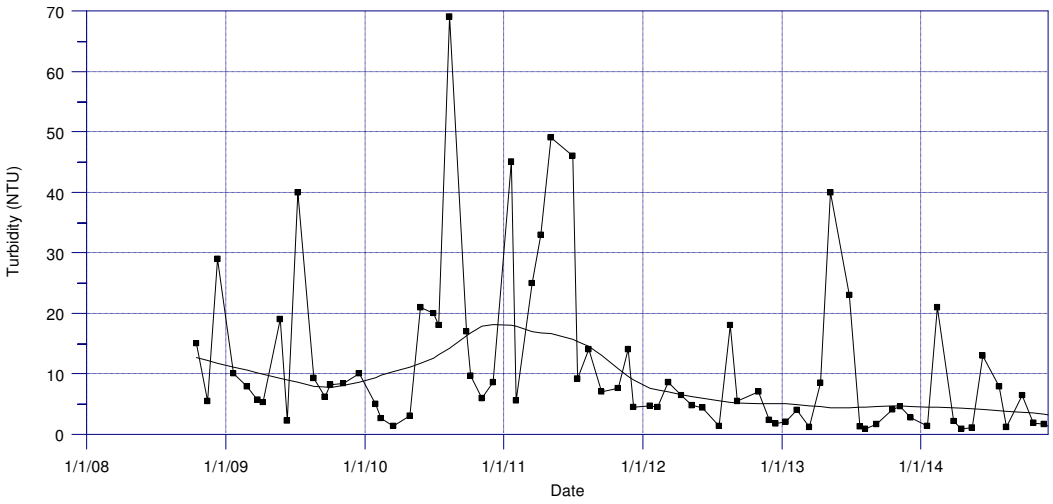

Figure 22. Turbidity levels at the Curletts Road Stream Upstream of Heathcote River site for the monitoring period October 2008 to December 2014. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A negative trend of 26% was recorded over the sampling period.

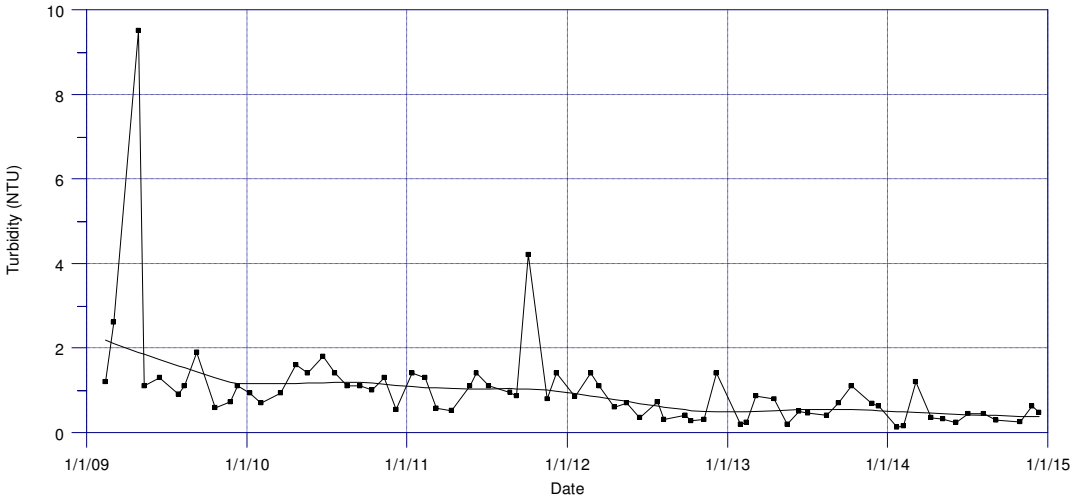

Figure 23. Turbidity levels at the Otukaikino River at Groynes Inlet site for the monitoring period February 2009 to December 2014. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A negative trend of 25% was recorded over the sampling period.

5 Discussion

5.1 Differences in Water Quality between Catchments

Overall, the Heathcote River catchment recorded the poorest water quality of all the catchments, followed by the Styx River and Avon River catchments (Tables 4 and 5). The Otukaikino River catchment recorded the best water quality of all catchments. Interestingly, the Styx River and Heathcote River also recorded the second and third best water quality of the catchments. This highlights that these two catchments have sites with water quality on both spectrums of the scale. For instance, the Styx River catchment includes sites with poor water quality such as Kaputone Creek, but sites of relatively good water quality in the mainstem. The Heathcote River catchment also includes the poor sites of Haytons Stream and Curletts Road Stream, but also Cashmere Stream, which generally has good water quality. Some of these sites themselves also recorded very low levels for some contaminants, but high levels for others. For example, the Heathcote River at Templetons Road site was one of the best sites for BOD_5 and *E. coli,* but one of the worst sites for dissolved oxygen and nitrogen (the latter two possibly due to the site being in the upper headwaters with lower water levels).

These results all support the Urban Stream Syndrome (Walsh et al., 2005), whereby lower water quality is recorded internationally in urban (particularly industrial) areas (e.g. Avon and Heathcote catchments) and generally better water quality is recorded in rural areas (e.g. Otukaikino catchment). However, it should also be noted that the Otukaikino River results were largely driven by one site where monitoring has only been undertaken since October 2014 (Otukaikino Creek at Omaka Scout Camp). Therefore, this site has not been monitored during times of high flow and rain events in autumn and winter, when contaminated inputs are likely to be higher. Next years monitoring report should give us a better indicator of how the water quality of this site, and therefore the catchment, compares to the other sites. It is feasible though that this site will have good water quality, as it is located in a catchment typically recording better water quality.

Other notable spatial trends between catchments during the monitoring period were:

1. Zinc: concentrations in the Avon and Heathcote River catchment were considerably higher than the other catchments. This is likely related to a greater level of contaminated stormwater inputs.
2. Conductivity: the Styx and Otukaikino River catchments recorded lower conductivity compared to the other catchments. Levels in the Heathcote River catchment appeared to be greater than the Avon and Halswell River catchments. This is also likely related to contaminated discharges, as conductivity is influenced by pollutants, such as metals and nutrients.
3. TSS and turbidity: levels increased downstream in both the Avon and Heathcote River mainstems, but there was no trend downstream in the Styx and Otukaikino River mainstems. These trends could due to increasing sediment levels as the rivers flow downstream and receive more stormwater and tributary input. Or, this could be due to having monitoring sites in the lower reaches in these catchments, which are potentially affected by re-suspension from tidal activity. Concentrations in the Heathcote River catchment were higher

than the other catchments. This is likely due to this catchment incorporating the unstable Port Hills, which discharge fine loess sediment.

4. Water temperature: the Heathcote River catchment recorded lower temperatures compared to the other catchments. This might be related to cooler water coming from the more vegetated and shaded Port Hills, or more riparian planting along the mainstem that provides more shading. However, this is only supposition and the cause for this trend is not certain.
5. BOD_5: the Heathcote River catchment recorded higher levels across more sites than the other catchments. This is likely related to the poorer water quality in this catchment and/or higher levels of plant matter.
6. Total ammonia: concentrations were generally higher in the Heathcote River catchment than the other catchments. Levels also appeared to higher in the lower reaches across most catchments, possibly due to the tributaries generally recording higher levels than the mainstems and therefore contributing to concentrations downstream in the mainstems. This contaminant is likely related to pollutants in discharges and faecal input from animals, such as waterfowl.
7. Nitrogen (nitrate, NNN and DIN): concentrations decreased downstream in the Avon and Heathcote River mainstems, but there was no trend observed for the other catchments. Levels in the Heathcote and Halswell River catchments were higher than the Avon River catchment, and the Styx and Otukaikino River catchments recorded much lower levels than the other catchments. The trend of increasing nitrogen downstream has been observed for many years across Christchurch's rivers and has often been attributed to nitrogen-rich spring input in the upper catchment (due to rural land use practices), with levels diluted as the waterways flow downstream. Consequently, the Council has recently instigated an investigation into nitrogen input into waterways from instream springs, starting with the Avon River catchment. The results of this study are not yet available. Differences in levels between catchments are likely due to differing groundwater influences and inputs; more information is required to assess this.
8. DRP: the Otukaikino River catchment typically recorded lower values than the other catchments. This is potentially due to less influence from land use practices (i.e. runoff from agriculture and unstable soils) and animal faeces (i.e. waterfowl). Particularly as CCC rangers have been increasingly fencing and planting riparian margins in this area. Concentrations generally increased downstream in all catchments, potentially due to the input from tributaries, which recorded higher values than the mainstem.

5.2 Sites with the Best and Worst Water Quality

5.2.1 Across all Catchments

The sites recording the poorest water quality across all catchments were Linwood Canal (particularly for TSS/turbidity, dissolved oxygen and DRP) and Haytons Stream at Retention Basin (particularly for TSS/turbidity, BOD_5 and DRP), followed by Curletts Road Stream Upstream of Heathcote River (particularly for copper and nitrogen) and Heathcote River at Templetons Road (particularly for dissolved oxygen and nitrogen) (Tables 4 and 5). However, there were many other sites that were also singled out as the worst site for each individual parameter, with seventeen sites making the list for the top three worst sites (there were two sites joint for first, two sites joint for second and thirteen sites joint for third).

The site that recorded the best water quality across all sites was the Otukaikino Creek at Omaka Scout Camp (Tables 4 and 5). This site was the best site for seven of the thirteen collated parameters assessed. However, as discussed above, this site has only been monitored since October 2014 and therefore has not been monitored during times of high flow when contaminated inputs are likely to be higher. Four sites were tied second for the best site (with three occurrences on the best site list): Otukaikino River at Groynes Inlet, Smacks Creek at Gardiners Road, Styx River at Gardiners Road and Cashmere Stream at Sutherlands Road. The Heathcote River at Templetons Road was third, with two occurrences.

5.2.2 Within Catchments

Within each catchment, there were a number of sites that consistently recorded parameters well outside the guideline levels and/or recorded substantially different one-off events compared to other sites (Table 6). In the Avon River catchment, these sites were Dudley Creek, followed by Addington Brook and Horseshoe Lake Discharge. The first two sites are all associated with urban areas (residential, commercial and industrial) and therefore not surprisingly the contaminants of concern included metals, sediment and ammonia. ECan is working with industries to identify and reduce the levels of contaminants in Addington Brook. The latter site is likely due to this lake system having high inputs from waterfowl faeces, combined with limited flushing, with the parameters of concern specifically low oxygen levels, ammonia and *E. coli*. Dudley Creek also had high levels of *E. coli*. Significant amounts of untreated wastewater were discharged into this waterway during the earthquakes and subsequently a lot of instream works have been undertaken, primarily for flood remediation, including sediment removal. It could be that these works have mobilised *E. coli* living in the sediment, resulting in the high levels. It is also possible that damaged sewers, both public and private, could be leaking into the ground and finding its way into Dudley Creek, which may continue to do so for quite some time; this is supported by the change in long term average flows measured through the wastewater treatment plant (Mike Bourke, Christchurch City Council, 16th April 2015, personal communication).

In the Heathcote River catchment, Haytons Stream at Retention Basin had the poorest water quality, followed by Curletts Road Stream Upstream of Heathcote River. Again, these sites are located in largely industrial catchments, which were reflected by the parameters of concern being metals, sediment, low oxygen levels, ammonia (Haytons Stream only), phosphorus (Haytons Stream only) and nitrogen (Curletts Road Stream only). The ammonia and phosphorus in Haytons Stream might be related to the Ravensdown fertiliser operation in the catchment; this company is actively working with ECan to address this issue. Alternatively, this might be due to the pond nature of the sampling site, with likely high waterfowl faecal input.

For the Styx River catchment, the sites with the poorest water quality were Kaputone Creek at Blakes Road and Kaputone Creek at Belfast Road. The parameters of concern at both sites were ammonia and *E. coli*, plus sediment and nitrogen at Blakes Road, and BOD_5 and phosphorus at Belfast Road. Of particular concern was that the Belfast Road site recorded high *E. coli* values at every sampling event during the monitoring period and only half of these events were associated with rain. These events were also not related to wastewater overflows. Further analysis of the data indicates that the concentration of ammonia, *E. coli* and phosphorus at the Belfast Road site are correlated, indicating a common source of pollution. The Kaputone Stream is well known to have industrial and agricultural inputs. The CCC (and others)

has already planted the riparian margins of parts of this catchment and is proposing to plant the majority of the remainder, which should help filter these contaminants if they are discharged via sheet flow. However, the Belfast Road site is potentially affected by discharges from a piggery further upstream. In addition, a landowner adjacent to the site is also farming muscovy ducks, which reside directly in the waterway. Site visits show that these ducks appear to be introducing faecal matter into the waterway and affecting the stream banks.

Wilsons Stream in the Otukaikino catchment had issues with high pH, BOD_5, nitrogen and *E. coli* compared to other sites in the catchment. This site is located in an agricultural catchment, so runoff from these areas is likely the source of these contaminants. Particularly as riparian planting in this catchment appears to be limited.

In the Halswell catchment, Knights Stream at Sabys Road showed high levels of nitrogen compared to the other sites. This occurred both when it had and had not been raining. This may be due to nitrogen-rich input from groundwater in this catchment, associated with higher levels of agricultural land use. The CCC Christchurch River Environment Assessment System (CREAS) database records a small instream spring just upstream of this site and elsewhere in the catchment. Alternatively, earthworks in the Knights Stream headwaters (where lots of subdivision activity has been occurring recently) may also have released nitrogen from the soil (Michele Stevenson, Environment Canterbury, 14th April 2015, personal communication). These high levels do not appear to be affecting the lower reaches of the downstream receiving environment of the Halswell River, as positive trends were not recorded at the Akaroa Highway site, suggesting levels are diluted as the water flows downstream.

5.3 Comparisons to Receiving Environment Guidelines

There were a number of parameters that consistently met the relevant receiving water guidelines for the 2014 monitoring period across most sites and are therefore unlikely to be having adverse effects on the waterways. These were dissolved lead, pH, temperature, total ammonia and nitrate. However, there were a number of parameters that recorded values well outside the guidelines across most sites: NNN, DIN, DRP and *E. coli*. There were also some parameters that generally recorded levels within the guidelines, but on a number of occasions, or regularly at a small number of sites, recorded concentrations outside these values: dissolved copper, dissolved zinc, TSS, turbidity, dissolved oxygen and BOD_5.

This indicates that these waterways are subjected to contamination, potentially from stormwater, wastewater and other inputs (i.e. waterfowl faeces). These parameters may be having short-term and long-term adverse effects on biota (i.e. DIN, copper, zinc, TSS/turbidity, dissolved oxygen and BOD_5), may encourage the proliferation of aquatic plants and/or algae (i.e. NNN and DRP), may indicate human health risks from contact recreation (i.e. *E. coli*) and may affect water clarity/aesthetics (TSS/turbidity). These parameters are usually the ones of concern across urban waterways within New Zealand and internationally, and have been the same ones identified in past monitoring reports for these sites (Margetts, 2014a; Margetts, 2014b; Whyte, 2014a; Whyte, 2014b).

5.4 Changes in Water Quality over Time

The results of the temporal trends analysis showed that the majority of parameter concentrations for all the sites have remained steady over time. This indicates that water quality is neither improving nor declining. However, parameters at some sites recorded an increasing or decreasing trend in concentrations.

The largest increase was a 30% change in NNN and DIN at Knights Stream at Sabys Road. As with the comments previously on nitrogen at this site, this may be due to the increasing influence of nitrogen-rich springs in the waterway due to agricultural land use, or earthworks in the headwaters releasing nitrogen from the soil.

Conductivity at Avon River at Bridge Street also recorded an increasing trend of 25%. The CCC undertakes monitoring of the ecology of this area annually and these surveys have shown that the tide level appears to be higher than previous years; changes in the bank vegetation also suggest a change in the inundation of the area, specifically the salt marsh plants have been replaced by macro algae (Nick Hempston, EOS Ecology Limited, March 2014, personal communication). This change could potentially be related to alterations in estuary bathymetry or tidal extent due to the earthquakes, as the change in conductivity appears to occur around the time of seismic activity and now looks to have stabilised. In support of this, research by NIWA has also shown that the estuary and lower river reaches have changed in bathymetry due to the earthquakes, with some areas uplifting and other areas dropping (Measures & Bind, 2013). Alternately (or cumulatively), it is suspected that some of the obstructions in the river due to the Bridge Street bridge construction have affected the tidal regime (Nick Hempston, EOS Ecology Limited, personal communication, March 2014,). The works are estimated to be completed by April 2015 (Anita Collie, SCIRT, March 2015) and it is hoped conductivity will then return to normal levels, but may not if the changes are earthquake derived.

The largest decrease in concentrations by far was dissolved zinc at Curletts Road Stream Upstream of Heathcote River (146% decrease). This site also recorded a 38% and 26% drop in dissolved copper and turbidity levels, respectively. These contaminants have largely been decreasing in concentration since monitoring began in 2008 for turbidity and 2011 for the dissolved metals. However, spikes in these contaminants above guideline levels still occurred during the 2014 monitoring period. These peaks in zinc and copper appeared to be correlated with each other, indicating they come from the same source (e.g. stormwater). It is unclear why these reductions have occurred at this site, but could be related to better catchment management practices resulting in less contaminants discharged to the waterway (likely primarily during rain events). Such practices could include treatment of previously untreated stormwater or redirection of trade waste (e.g. vehicle wash down) to the sewer, instead of the stormwater system. Or, these changes could be related to the realigning of upstream portions of this waterway as part of the motorway construction in approximately 2011. The waterway was realigned along the motorway and away from the industrial areas with potentially more contaminated discharges. The bed was also recreated and therefore the water potentially no longer influenced by historically contaminated sediment. It could also be that contaminants were released during the time of re-alignment, contributing to high levels observed at the beginning of the monitoring period. There is an upstream water quality monitoring site in this waterway at the motorway itself that has been presented throughout this report (Curletts Road Stream at Motorway), but this site was not monitored between February 2012 and May 2014 due to construction of the motorway, so the sites cannot be compared to determine trends.

Another notable downwards trend was a 25% decrease in turbidity at the Otukaikino River at Groynes Inlet site, which has recorded a gradual decline in this parameter since 2009. This is likely due to improved land use practices in the catchment that have been instigated by CCC rangers, such as fencing to keep out stock and riparian planting. This river has recently won the Most Improved River Award at the 2014 New Zealand River Awards, due to a decrease in DRP levels, likely also because the instigation of these catchment management practices.

5.5 Halswell Retention Basin Sites

With respect to the Halswell Retention Basin inlet and outlet, these sites recorded much higher levels than the majority of river sites for a number of parameters, including copper, lead, BOD_5, ammonia, DRP and *E. coli*. This is to be expected given the predominantly stormwater input into the basins and that the rivers are subjected to dilution from baseflow. These wet basins are also likely impacted by more faecal input from waterfowl, contributing to the high levels of ammonia, DRP and *E. coli*. More variability in concentrations was also generally recorded at these sites compared to the river sites (e.g. for dissolved oxygen, temperature, BOD_5, ammonia, DIN, DRP and *E. coli*), possibly due to variable levels of parameters in stormwater and/or the treatment ability of the basin.

The outlet recorded lower median concentrations that the inlet about half of the time, indicating that overall there was some improvement in water quality due to the basin. However, the outlet equally recorded similar levels to the inlet, or higher levels. These results should be taken with caution though, as it is difficult to deduce treatment ability given that the inlet and outlet samples are taken at almost exactly the same time, and the actual change in concentration of parameters was not tracked. Higher concentrations may be recorded at the outlet than the inlet, but these outlet levels may still be lower than the original influent concentration.

Both the inlet and outlet recorded a decreasing trend (13% and 15%, respectively) in BOD_5 levels since monitoring began in April 2007, indicating an improvement in the quality of stormwater entering the basin over time for this parameter. However, nitrogen levels at both the inlet and outlet recorded an increasing trend of similar magnitude (19% and 13%., respectively), suggesting increasingly higher levels of this contaminant within stormwater. *E. coli* levels at the inlet recorded an increasing trend of 18% and the outlet recorded neither an upwards or downwards trend, suggesting that this parameter is increasing in concentration in stormwater, but that the basin is not discharging any greater concentration over time.

5.6 Conclusions

In summary, the Heathcote River catchment recorded the poorest water quality of all the catchments and the Otukaikino River catchment recorded the best water quality. The sites recording the poorest water quality across all catchments were Linwood Canal (particularly for TSS/turbidity, dissolved oxygen and DRP) and Haytons Stream at Retention Basin (particularly for TSS/turbidity, BOD_5 and DRP). The site that recorded the best water quality across all sites was the Otukaikino Creek at Omaka Scout Camp. However, this site is a new site and has not yet been monitored over winter when contaminated inputs are likely higher.

There were a number of parameters that were recorded at levels unlikely to cause adverse effects, including dissolved lead, pH, temperature, total ammonia and nitrate. However, there were a number of parameters that recorded values well outside the guidelines across most sites, including NNN, DIN, DRP and *E. coli*. The results of the temporal trends analysis showed that the majority of parameter concentrations for all the sites have remained steady over time. This indicates that water quality is neither improving nor declining. However, parameters at some sites recorded an increasing or decreasing trend in concentrations.

This monitoring report indicates that these waterways are both historically and currently subjected to contamination, potentially from stormwater, wastewater and other inputs (i.e. waterfowl faeces). These parameters may be having short-term and long-term adverse effects on biota (i.e. DIN, copper, zinc, TSS/turbidity, dissolved oxygen and BOD_5), may encourage the proliferation of aquatic plants and/or algae (i.e. NNN and DRP), may indicate human health risks from contact recreation (i.e. *E. coli*) and may affect water clarity/aesthetics (TSS/turbidity). These parameters are usually the ones of concern across urban waterways within New Zealand and internationally, and have been the same ones identified in past monitoring reports for these sites. These results support the Urban Stream Syndrome (Walsh et al., 2005), whereby lower water quality is recorded internationally in urban (particularly industrial) areas (e.g. Avon and Heathcote catchments) and generally better water quality is recorded in rural areas (e.g. Otukaikino catchment).

The sites and parameters identified to be of concern in this report should be the focus of catchment management practices in Christchurch. Such practices could include better treatment of stormwater and redirection of trade waste (e.g. vehicle wash down) to the sewer, instead of the stormwater system. Water quality in most of these catchments should improve over time with the instigation of CCC SMPs, as well as ECan catchment pollution projects and other targeted programmes through the Canterbury Water Management Strategy. Improvements should also occur with the progression of rebuild activities, as wastewater network improvements are completed and the level of earthworks and dewatering activity decreases.

6 Acknowledgements

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8 Appendix A: Summary Data

Table i. Summary statistics for all sites for the first eight parameters presented in this report (dissolved copper to dissolved oxygen saturation), sorted alphabetically by catchment.

Catchment	Site		Dissolved Copper	Dissolved Lead	Dissolved Zinc	pH	Conductivity	Total Suspended Solids	Turbidity	Dissolved Oxygen Saturation
Avon catchment	Addington Brook	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.017000	7.65	369.500	4.50	5.100	73.50
		Mean	.00162	.0009958	.040583	7.57	344.633	8.13	7.733	73.67
		Std. Error of Mean	.000510	.00024583	.0135766	.119	31.3954	3.324	2.7211	4.478
		Minimum	.001	.00075	.0120	7	76.6	2	1.8	55
		Maximum	.007	.00370	.1600	8	506.0	44	36.0	110
	Avon River at Avondale Road Bridge	N	4	4	4	12	12	12		12
		Median	.00100	.0007500	.007500	7.85	235.500	2.25		92.00
		Mean	.00100	.0007500	.010250	7.85	297.000	2.83		95.23
		Std. Error of Mean	.000000	0E-8	.0040078	.063	52.7220	.509		3.353
		Minimum	.001	.00075	.0040	8	124.0	2		80
		Maximum	.001	.00075	.0220	8	680.0	7		115
	Avon River at Bridge Street	N	11	11	11	11	11	11	11	11
		Median	.00100	.0007500	.003000	7.90	6570.000	16.00	7.300	92.00
		Mean	.00114	.0008455	.005518	7.73	7996.364	15.73	9.864	90.55
		Std. Error of Mean	.000136	.00009545	.0018320	.143	1668.1881	1.711	1.9393	3.681
		Minimum	.001	.00075	.0005	6	1790.0	9	3.0	64
		Maximum	.003	.00180	.0210	8	22200.0	26	26.0	110
	Avon River at Carlton Mill Corner	N	4	4	4	12	12	12		12
		Median	.00100	.0007500	.026000	7.65	186.000	3.00		95.50
		Mean	.00100	.0007500	.021500	7.68	167.000	6.04		95.25
		Std. Error of Mean	.000000	0E-8	.0070770	.039	9.5727	2.890		3.203
		Minimum	.001	.00075	.0010	8	105.0	2		67
		Maximum	.001	.00075	.0330	8	196.0	37		110
	Avon River at Dallington Terrace/Gayhurst Road	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.009550	7.80	183.500	3.00	1.400	84.00
		Mean	.00113	.0008375	.011350	7.67	173.500	3.71	2.002	84.83
		Std. Error of Mean	.000133	.00008750	.0026870	.129	12.7252	.589	.5240	3.067
		Minimum	.001	.00075	.0020	7	89.0	2	.3	70
		Maximum	.003	.00180	.0360	8	253.0	8	6.5	110
	Avon River at Manchester Street	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.006450	7.75	190.500	1.50	.960	89.50

Catchment	Site		Dissolved Copper	Dissolved Lead	Dissolved Zinc	pH	Conductivity	Total Suspended Solids	Turbidity	Dissolved Oxygen Saturation
		Mean	.00100	.0008125	.008058	7.72	169.325	3.21	1.539	93.83
		Std. Error of Mean	.000000	.00006250	.0018103	.117	11.1496	.854	.3486	2.648
		Minimum	.001	.00075	.0005	7	85.9	2	.5	85
		Maximum	.001	.00150	.0210	8	206.0	11	3.9	110
	Avon River at Mona Vale	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.010500	7.50	205.500	1.50	.390	90.00
		Mean	.00100	.0007500	.012300	7.48	184.017	2.67	1.032	89.08
		Std. Error of Mean	.000000	0E-8	.0018538	.105	11.3171	1.038	.5288	1.055
		Minimum	.001	.00075	.0040	7	99.2	2	.3	80
		Maximum	.001	.00075	.0250	8	219.0	14	6.8	93
	Avon River at Pages/Seaview Bridge	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.007400	7.80	611.000	6.00	4.000	89.00
		Mean	.00100	.0008208	.009283	7.73	709.583	6.88	4.375	90.75
		Std. Error of Mean	.000000	.00007083	.0029693	.137	138.8017	.784	.6482	3.691
		Minimum	.001	.00075	.0005	6	213.0	4	1.5	67
		Maximum	.001	.00160	.0390	8	1890.0	13	8.9	110
	Dudley Creek	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.012900	7.80	145.500	12.50	11.000	77.50
		Mean	.00129	.0011792	.022000	7.71	143.175	20.58	13.633	77.00
		Std. Error of Mean	.000292	.00022991	.0068140	.081	10.2078	6.751	3.8946	1.343
		Minimum	.001	.00075	.0036	7	92.3	6	1.8	67
		Maximum	.005	.00280	.0820	8	212.0	91	52.0	86
	Horseshoe Lake Discharge	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.008100	7.60	173.000	6.50	4.900	69.50
		Mean	.00100	.0007500	.022867	7.64	162.517	6.75	5.367	69.75
		Std. Error of Mean	.000000	0E-8	.0152483	.053	11.5722	.579	.4513	1.935
		Minimum	.001	.00075	.0013	7	97.2	4	3.1	54
		Maximum	.001	.00075	.1900	8	219.0	10	8.4	81
	Riccarton Main Drain	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.009200	7.60	241.000	1.50	.980	90.00
		Mean	.00157	.0008375	.026083	7.60	208.367	5.00	3.275	89.67
		Std. Error of Mean	.000454	.00008750	.0110914	.109	16.6196	3.366	2.1643	.541
		Minimum	.001	.00075	.0060	7	92.4	2	.4	86
		Maximum	.006	.00180	.1400	8	263.0	42	27.0	92

Catchment	Site		Dissolved Copper	Dissolved Lead	Dissolved Zinc	pH	Conductivity	Total Suspended Solids	Turbidity	Dissolved Oxygen Saturation
	Waimairi Stream	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.005500	7.45	183.500	1.50	.650	85.50
		Mean	.00100	.0007500	.007892	7.45	164.475	2.54	.854	86.17
		Std. Error of Mean	.000000	0E-8	.0020489	.106	11.1309	.428	.2532	1.359
		Minimum	.001	.00075	.0005	7	78.7	2	.3	82
		Maximum	.001	.00075	.0220	8	209.0	6	3.5	100
	Wairarapa Stream	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.011500	7.50	166.500	3.00	.860	79.50
		Mean	.00100	.0008208	.010625	7.40	147.367	5.13	1.864	84.08
		Std. Error of Mean	.000000	.00007083	.0014720	.115	10.3188	2.150	.8599	2.506
		Minimum	.001	.00075	.0030	6	65.4	2	.3	75
		Maximum	.001	.00160	.0210	8	180.0	28	11.0	100
	Total	N	139	139	139	155	155	155	131	155
		Median	.00100	.0007500	.008700	7.70	190.000	4.00	2.000	86.00
		Mean	.00115	.0008486	.016117	7.63	789.752	6.80	4.646	86.11
		Std. Error of Mean	.000066	.00003375	.0022393	.030	197.1355	.809	.6094	.971
		Minimum	.001	.00075	.0005	6	65.4	2	.3	54
		Maximum	.007	.00370	.1900	8	22200.0	91	52.0	115
Halswell catchment	Halswell Retention Basin Inlet	N	4	4	4	12	12	12		12
		Median	.00680	.0016250	.052500	7.95	169.000	29.00		55.50
		Mean	.00625	.0018000	.050000	7.92	175.233	40.58		56.36
		Std. Error of Mean	.001307	.00062283	.0063640	.158	19.8245	10.515		9.645
		Minimum	.003	.00075	.0330	7	51.2	8		5
		Maximum	.009	.00320	.0620	9	279.0	120		120
	Halswell Retention Basin Outlet	N	4	4	4	12	12	12		12
		Median	.00660	.0027000	.024500	7.60	145.000	12.50		72.00
		Mean	.00605	.0028500	.026750	7.88	135.592	17.50		78.33
		Std. Error of Mean	.000935	.00059090	.0046793	.207	19.4888	4.182		6.782
		Minimum	.004	.00170	.0180	7	12.4	5		43
		Maximum	.008	.00430	.0400	10	244.0	53		120
	Halswell River at Akaroa Highway	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.001150	7.75	250.500	4.50	2.350	86.00
		Mean	.00100	.0007500	.002642	7.68	231.500	6.17	4.663	85.67
		Std. Error of Mean	.000000	0E-8	.0010970	.041	15.2983	1.836	2.0513	3.432

Catchment	Site		Dissolved Copper	Dissolved Lead	Dissolved Zinc	pH	Conductivity	Total Suspended Solids	Turbidity	Dissolved Oxygen Saturation
		Minimum	.001	.00075	.0005	8	133.0	2	1.0	66
		Maximum	.001	.00075	.0140	8	301.0	25	26.0	110
	Knights Stream at Sabys Road	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.001500	7.50	252.000	1.50	.920	91.00
		Mean	.00100	.0008208	.003717	7.52	229.675	4.33	2.738	89.33
		Std. Error of Mean	.000000	.00007083	.0015664	.037	17.4378	1.602	1.3019	2.808
		Minimum	.001	.00075	.0005	7	96.1	2	.3	69
		Maximum	.001	.00160	.0180	8	304.0	16	16.0	100
	Nottingham Stream at Candys Road	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.007000	7.65	230.500	3.00	1.600	80.50
		Mean	.00100	.0008125	.011100	7.65	217.125	6.42	3.029	78.42
		Std. Error of Mean	.000000	.00006250	.0038136	.040	17.4706	2.368	1.0648	1.559
		Minimum	.001	.00075	.0005	8	91.5	2	.1	67
		Maximum	.001	.00150	.0490	8	299.0	30	13.0	84
	Total	N	44	44	44	60	60	60	36	60
		Median	.00100	.0007500	.003500	7.60	207.000	6.00	1.500	80.50
		Mean	.00194	.0010727	.011739	7.73	197.825	15.00	3.477	77.62
		Std. Error of Mean	.000329	.00012077	.0024845	.056	9.1470	2.889	.8704	2.869
		Minimum	.001	.00075	.0005	7	12.4	2	.1	5
		Maximum	.009	.00430	.0620	10	304.0	120	26.0	120
Heathcote catchment	Cashmere Stream at Sutherlands Road	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.004250	7.25	296.500	1.50	.305	43.50
		Mean	.00100	.0008125	.004492	7.23	276.167	2.04	.551	43.75
		Std. Error of Mean	.000000	.00006250	.0011629	.045	13.6053	.542	.1696	1.985
		Minimum	.001	.00075	.0005	7	179.0	2	.1	33
		Maximum	.001	.00150	.0150	8	316.0	8	2.2	56
	Cashmere Stream at Worsleys Road	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.002500	7.65	243.000	6.50	5.550	77.00
		Mean	.00108	.0007500	.009800	7.62	237.000	14.83	12.125	77.00
		Std. Error of Mean	.000083	0E-8	.0059466	.054	14.0324	4.257	4.2710	2.850
		Minimum	.001	.00075	.0005	7	143.0	4	1.6	60
		Maximum	.002	.00075	.0730	8	304.0	54	50.0	95
	Curletts Road Stream at Motorway	N	4	4	4	7	7	7		7
		Median	.00590	.0007500	.073000	7.60	313.000	3.00		89.00

Catchment	Site		Dissolved Copper	Dissolved Lead	Dissolved Zinc	pH	Conductivity	Total Suspended Solids	Turbidity	Dissolved Oxygen Saturation
		Mean	.00608	.0007500	.115250	7.64	317.286	3.21		99.00
		Std. Error of Mean	.001623	0E-8	.0623637	.153	21.0280	.697		12.675
		Minimum	.003	.00075	.0250	7	224.0	2		59
		Maximum	.010	.00075	.2900	8	396.0	6		140
	Curletts Road Stream Upstream of Heathcote River	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.011500	7.35	280.000	4.00	1.800	86.00
		Mean	.00214	.0007500	.048692	7.33	266.750	9.08	4.961	84.50
		Std. Error of Mean	.000862	0E-8	.0286425	.045	14.6003	4.898	1.8159	6.078
		Minimum	.001	.00075	.0005	7	154.0	2	.8	41
		Maximum	.011	.00075	.3500	8	318.0	62	21.0	120
	Haytons Stream at Retention Basin	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.042500	7.35	154.500	11.00	7.850	86.50
		Mean	.00173	.0007500	.057500	7.39	152.650	16.33	11.825	70.25
		Std. Error of Mean	.000273	0E-8	.0133101	.071	20.6987	3.526	2.8163	8.930
		Minimum	.001	.00075	.0170	7	33.0	6	3.3	15
		Maximum	.003	.00075	.1600	8	302.0	47	34.0	98
	Heathcote River at Bowenvale Avenue	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.008250	7.75	268.500	6.50	5.150	84.50
		Mean	.00109	.0009083	.010583	7.73	249.083	12.33	10.801	84.55
		Std. Error of Mean	.000092	.00010746	.0034305	.052	15.3062	3.577	4.3306	1.859
		Minimum	.001	.00075	.0005	8	126.0	5	.8	74
		Maximum	.002	.00180	.0420	8	302.0	46	45.0	98
	Heathcote River at Catherine Street	N	4	4	4	12	12	12		12
		Median	.00100	.0007500	.003500	7.65	292.000	14.50		75.50
		Mean	.00128	.0007500	.034375	7.72	276.000	16.04		74.83
		Std. Error of Mean	.000275	0E-8	.0318992	.044	18.2549	3.526		1.450
		Minimum	.001	.00075	.0005	8	119.0	2		62
		Maximum	.002	.00075	.1300	8	347.0	40		82
	Heathcote River at Ferniehurst Street	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.012500	7.55	263.500	8.50	5.600	81.00
		Mean	.00109	.0007500	.027417	7.59	247.667	12.25	10.358	80.58
		Std. Error of Mean	.000092	0E-8	.0143697	.054	15.2252	3.040	3.6877	2.036
		Minimum	.001	.00075	.0005	7	129.0	5	2.3	67
		Maximum	.002	.00075	.1800	8	304.0	42	43.0	94

Catchment	Site		Dissolved Copper	Dissolved Lead	Dissolved Zinc	pH	Conductivity	Total Suspended Solids	Turbidity	Dissolved Oxygen Saturation
	Heathcote River at Ferrymead Bridge	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.005900	7.80	6405.000	40.00	29.500	89.00
		Mean	.00188	.0013167	.010775	7.78	6932.958	45.92	33.308	87.25
		Std. Error of Mean	.000373	.00033185	.0040110	.057	1998.2051	5.736	7.4107	2.588
		Minimum	.001	.00075	.0005	8	80.5	23	5.7	69
		Maximum	.005	.00470	.0460	8	22200.0	81	97.0	100
	Heathcote River at MacKenzie Avenue	N	4	4	4	12	12	12		12
		Median	.00100	.0007500	.009500	7.75	284.500	6.50		78.50
		Mean	.00100	.0007500	.009625	7.73	264.583	9.96		78.83
		Std. Error of Mean	.000000	0E-8	.0043940	.045	16.5906	2.585		1.705
		Minimum	.001	.00075	.0005	8	126.0	2		68
		Maximum	.001	.00075	.0190	8	320.0	31		87
	Heathcote River at Opawa Road/Clarendon Terrace	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.005700	7.70	286.000	7.50	6.000	80.00
		Mean	.00113	.0008833	.008250	7.73	264.500	13.00	11.928	81.83
		Std. Error of Mean	.000133	.00009010	.0030037	.046	16.2628	3.867	4.8088	2.156
		Minimum	.001	.00075	.0005	8	125.0	3	.8	73
		Maximum	.003	.00160	.0360	8	318.0	48	51.0	96
	Heathcote River at Rose Street	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.021500	7.50	277.500	4.50	1.850	86.00
		Mean	.00117	.0007500	.031775	7.53	259.050	5.04	3.493	87.33
		Std. Error of Mean	.000112	0E-8	.0087652	.047	19.2862	.991	1.1779	1.940
		Minimum	.001	.00075	.0005	7	94.6	2	.6	78
		Maximum	.002	.00075	.1100	8	314.0	13	15.0	100
	Heathcote River at Templetons Road	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.007150	7.00	327.500	1.50	1.550	46.50
		Mean	.00100	.0007500	.013575	6.98	308.083	2.17	1.903	44.25
		Std. Error of Mean	.000000	0E-8	.0040817	.041	16.4853	.454	.5643	2.416
		Minimum	.001	.00075	.0005	7	195.0	2	.1	29
		Maximum	.001	.00075	.0400	7	363.0	6	7.3	57
	Heathcote River at Tunnel Road	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.006000	7.80	782.500	22.50	15.500	83.50
		Mean	.00181	.0008292	.011500	7.78	1070.333	30.50	23.475	83.08
		Std. Error of Mean	.000605	.00007917	.0041201	.053	299.2981	5.540	6.5664	2.575

Catchment	Site		Dissolved Copper	Dissolved Lead	Dissolved Zinc	pH	Conductivity	Total Suspended Solids	Turbidity	Dissolved Oxygen Saturation
		Minimum	.001	.00075	.0005	8	119.0	10	8.3	70
		Maximum	.008	.00170	.0490	8	3830.0	67	81.0	98
	Total	N	144	144	144	163	163	163	132	163
		Median	.00100	.0007500	.008150	7.60	287.000	7.00	5.500	79.00
		Mean	.00149	.0008333	.023953	7.55	809.073	14.09	11.339	75.80
		Std. Error of Mean	.000125	.00003266	.0039171	.023	197.7470	1.299	1.4361	1.609
		Minimum	.001	.00075	.0005	7	33.0	2	.1	9
		Maximum	.011	.00470	.3500	8	22200.0	81	97.0	140
Linwood Canal	Linwood Canal	N	12	12	12	12	11	12	12	12
		Median	.00100	.0007500	.007850	7.80	2120.000	12.00	10.350	61.50
		Mean	.00120	.0010167	.016442	7.77	3036.364	15.13	12.392	60.75
		Std. Error of Mean	.000200	.00018813	.0062661	.076	600.3503	1.842	1.8311	3.724
		Minimum	.001	.00075	.0030	7	1160.0	7	2.4	33
		Maximum	.003	.00280	.0800	8	7500.0	25	25.0	78
	Total	N	12	12	12	12	11	12	12	12
		Median	.00100	.0007500	.007850	7.80	2120.000	12.00	10.350	61.50
		Mean	.00120	.0010167	.016442	7.77	3036.364	15.13	12.392	60.75
		Std. Error of Mean	.000200	.00018813	.0062661	.076	600.3503	1.842	1.8311	3.724
		Minimum	.001	.00075	.0030	7	1160.0	7	2.4	33
		Maximum	.003	.00280	.0800	8	7500.0	25	25.0	78
Otukaikino catchment	Otukaikino River at Groynes Inlet	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.002500	7.40	84.000	1.50	.335	86.00
		Mean	.00100	.0007500	.004333	7.43	84.625	1.50	.408	85.83
		Std. Error of Mean	.000000	0E-8	.0015774	.045	5.3719	.000	.0825	1.502
		Minimum	.001	.00075	.0005	7	49.6	2	.1	79
		Maximum	.001	.00075	.0200	8	121.0	2	1.2	97
	Otukaikino Creek at Omaka Scout Camp	N	3	3	3	3	3	3	3	3
		Median	.00100	.0007500	.001600	7.40	87.200	1.50	.440	89.00
		Mean	.00100	.0007500	.007867	7.37	88.667	1.50	.387	88.33
		Std. Error of Mean	.000000	0E-8	.0065690	.033	1.7227	.000	.0636	2.906
		Minimum	.001	.00075	.0010	7	86.7	2	.3	83
		Maximum	.001	.00075	.0210	7	92.1	2	.5	93
	Wilsons Stream	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.000750	7.80	127.000	7.00	3.100	90.00

Catchment	Site		Dissolved Copper	Dissolved Lead	Dissolved Zinc	pH	Conductivity	Total Suspended Solids	Turbidity	Dissolved Oxygen Saturation
		Mean	.00100	.0007500	.005875	7.77	122.683	8.96	5.008	88.33
		Std. Error of Mean	.000000	0E-8	.0031339	.108	7.5435	2.218	1.6228	3.976
		Minimum	.001	.00075	.0005	7	70.4	2	.3	63
		Maximum	.001	.00075	.0360	9	160.0	29	18.0	110
	Total	N	27	27	27	27	27	27	27	27
		Median	.00100	.0007500	.001600	7.50	93.800	1.50	.460	87.00
		Mean	.00100	.0007500	.005411	7.57	101.989	4.81	2.450	87.22
		Std. Error of Mean	.000000	0E-8	.0016531	.061	5.4208	1.205	.8353	1.878
		Minimum	.001	.00075	.0005	7	49.6	2	.1	63
		Maximum	.001	.00075	.0360	9	160.0	29	18.0	110
Styx catchment	Kaputone Creek at Belfast Road	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.002000	7.60	152.500	7.00	3.400	73.50
		Mean	.00100	.0008125	.004275	7.40	148.000	7.58	3.467	72.00
		Std. Error of Mean	.000000	.00006250	.0017832	.188	8.4737	1.011	.4188	3.231
		Minimum	.001	.00075	.0005	6	85.0	3	1.3	50
		Maximum	.001	.00150	.0200	8	184.0	13	5.9	92
	Kaputone Creek at Blakes Road	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.005150	7.40	139.500	4.50	2.000	71.50
		Mean	.00100	.0007500	.009567	7.22	131.467	14.71	5.936	71.17
		Std. Error of Mean	.000000	0E-8	.0033408	.170	10.8270	9.606	3.6648	1.492
		Minimum	.001	.00075	.0010	6	55.3	2	.1	61
		Maximum	.001	.00075	.0360	8	171.0	120	46.0	78
	Smacks Creek at Gardiners Road	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.001750	7.15	130.000	1.50	.455	59.00
		Mean	.00100	.0007500	.003517	7.14	124.758	2.88	1.020	59.42
		Std. Error of Mean	.000000	0E-8	.0013168	.050	7.6579	.913	.4449	2.234
		Minimum	.001	.00075	.0005	7	76.3	2	.1	50
		Maximum	.001	.00075	.0150	8	158.0	12	5.6	75
	Styx River at Gardiners Road	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.002000	7.00	141.500	1.50	.505	59.00
		Mean	.00100	.0007500	.004883	6.98	131.025	1.75	.664	59.17
		Std. Error of Mean	.000000	0E-8	.0018520	.082	8.6961	.169	.1892	.911
		Minimum	.001	.00075	.0005	6	84.2	2	.2	53
		Maximum	.001	.00075	.0200	8	162.0	3	2.6	65

Catchment	Site		Dissolved Copper	Dissolved Lead	Dissolved Zinc	pH	Conductivity	Total Suspended Solids	Turbidity	Dissolved Oxygen Saturation
	Styx River at Harbour Road Bridge	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.001000	7.80	163.500	3.00	2.400	82.50
		Mean	.00100	.0007500	.002567	7.65	165.150	3.58	2.378	79.92
		Std. Error of Mean	.000000	0E-8	.0011301	.094	14.4930	.447	.3140	3.225
		Minimum	.001	.00075	.0005	7	83.8	2	.8	55
		Maximum	.001	.00075	.0140	8	252.0	7	4.0	91
	Styx River at Main North Road	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.001500	7.50	142.000	3.50	1.800	82.50
		Mean	.00100	.0007500	.002825	7.30	131.475	4.75	1.940	80.83
		Std. Error of Mean	.000000	0E-8	.0011457	.159	7.6685	1.357	.5588	1.757
		Minimum	.001	.00075	.0005	6	84.0	2	.1	70
		Maximum	.001	.00075	.0140	8	159.0	18	7.4	92
	Styx River at Marshland Road Bridge	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.001450	7.70	136.500	4.00	1.850	82.00
		Mean	.00100	.0007500	.004758	7.65	133.192	4.54	2.029	79.42
		Std. Error of Mean	.000000	0E-8	.0025327	.083	8.9271	.695	.3819	3.014
		Minimum	.001	.00075	.0005	7	77.7	2	.2	60
		Maximum	.001	.00075	.0310	8	181.0	10	4.4	96
	Styx River at Richards Bridge	N	12	12	12	12	12	12	12	12
		Median	.00100	.0007500	.001000	7.70	140.500	3.00	2.250	79.00
		Mean	.00100	.0007500	.003917	7.63	134.367	5.17	2.946	76.00
		Std. Error of Mean	.000000	0E-8	.0023158	.081	8.6140	1.159	.5964	3.196
		Minimum	.001	.00075	.0005	7	79.4	2	.7	57
		Maximum	.001	.00075	.0290	8	168.0	15	7.3	93
	Total	N	96	96	96	96	96	96	96	96
		Median	.00100	.0007500	.002000	7.45	141.000	3.00	1.800	74.00
		Mean	.00100	.0007578	.004539	7.37	137.429	5.62	2.547	72.24
		Std. Error of Mean	.000000	.00000781	.0007312	.048	3.5144	1.253	.4884	1.202
		Minimum	.001	.00075	.0005	6	55.3	2	.1	50
		Maximum	.001	.00150	.0360	8	252.0	120	46.0	96

Table ii. Summary statistics for all sites for the second eight parameters presented in this report (water temperature to *E. coli*), sorted alphabetically by catchment.

Catchment	Site		Water Temperature	BOD5	Total Ammonia	Nitrate NO3	Nitrate - Nitrite	Dissolved Inorganic Nitrogen	Dissolved Reactive Phosphorus	*E. coli*
Avon catchment	Addington Brook	N	12	12	12	12	12	12	12	12
		Median	13.100	.500	.135000	1.35000	1.3500	1.35000	.018500	275.00
		Mean	13.425	.883	.160167	1.15583	1.1792	1.31667	.034833	966.08
		Std. Error of Mean	.6633	.3176	.0412955	.147912	.14780	.143824	.0088599	618.818
		Minimum	10.7	.5	.0170	.300	.32	.570	.0140	61
		Maximum	16.8	4.3	.5000	1.700	1.70	1.900	.1000	7700
	Avon River at Avondale Road Bridge	N	12	12	12	12	12	12	12	12
		Median	12.900	.500	.019500	1.20000	1.2000	1.20100	.017500	120.00
		Mean	13.550	.683	.026250	1.24917	1.2832	1.30900	.020867	228.42
		Std. Error of Mean	.6565	.0999	.0049896	.072931	.06959	.070820	.0029490	73.283
		Minimum	10.0	.5	.0050	.950	.96	1.000	.0064	10
		Maximum	16.5	1.5	.0510	1.700	1.70	1.800	.0450	720
	Avon River at Bridge Street	N	11	11	11	11	11	11	11	11
		Median	14.500	.500	.085000	1.10000	1.1000	1.20000	.025000	260.00
		Mean	14.209	.609	.094455	.99364	1.0782	1.18818	.033727	2219.09
		Std. Error of Mean	.9296	.0744	.0202028	.119706	.08026	.081874	.0054441	1978.381
		Minimum	9.6	.5	.0490	.090	.56	.620	.0190	130
		Maximum	18.7	1.2	.2900	1.400	1.40	1.500	.0810	22000
	Avon River at Carlton Mill Corner	N	12	12	12	12	12	12	12	12
		Median	13.600	.500	.017000	2.35000	2.4000	2.40000	.008150	210.00
		Mean	13.458	.567	.024000	2.34083	2.3667	2.37500	.010733	389.75
		Std. Error of Mean	.3338	.0667	.0071425	.348417	.34801	.344244	.0015633	151.091
		Minimum	12.0	.5	.0070	.590	.60	.700	.0056	97
		Maximum	15.2	1.3	.1000	5.700	5.70	5.700	.0200	2000
	Avon River at Dallington Terrace/Gayhurst Road	N	12	12	12	12	12	12	12	12
		Median	12.950	.500	.037000	1.65000	1.6500	1.70000	.017500	330.00
		Mean	13.092	.733	.040833	1.56667	1.5750	1.61667	.020175	596.92
		Std. Error of Mean	.4717	.2333	.0077585	.074196	.07600	.070532	.0026751	263.222
		Minimum	10.4	.5	.0050	1.100	1.10	1.100	.0051	73
		Maximum	14.9	3.3	.0880	1.900	1.90	1.900	.0360	3400
	Avon River at Manchester Street	N	12	12	12	12	12	12	12	12
		Median	13.150	.500	.020500	2.00000	2.0000	2.00000	.010750	240.00
		Mean	13.283	.608	.022750	1.90833	1.9083	1.91667	.011508	473.08
		Std. Error of Mean	.3729	.1083	.0037460	.082992	.08299	.082419	.0015530	259.353

Catchment	Site		Water Temperature	BOD5	Total Ammonia	Nitrate NO3	Nitrate - Nitrite	Dissolved Inorganic Nitrogen	Dissolved Reactive Phosphorus	*E. coli*
		Minimum	11.4	.5	.0090	1.200	1.20	1.200	.0043	63
		Maximum	15.1	1.8	.0590	2.200	2.20	2.200	.0210	3300
	Avon River at Mona Vale	N	12	12	12	12	12	12	12	12
		Median	13.400	.500	.014000	3.45000	3.4500	3.45000	.006750	195.00
		Mean	13.208	.575	.015083	3.21667	3.1833	3.21667	.008233	287.00
		Std. Error of Mean	.2116	.0750	.0030413	.168700	.17915	.168700	.0016378	114.429
		Minimum	12.1	.5	.0050	2.000	2.00	2.000	.0015	20
		Maximum	14.2	1.4	.0440	3.800	3.80	3.800	.0210	1500
	Avon River at Pages/Seaview Bridge	N	12	12	12	12	12	12	12	12
		Median	13.550	.500	.039500	1.10000	1.1000	1.15000	.023000	165.00
		Mean	13.942	.758	.048000	1.07500	1.0783	1.11583	.027750	1370.83
		Std. Error of Mean	.7817	.1118	.0137091	.072483	.07134	.070887	.0050799	1149.333
		Minimum	9.6	.5	.0150	.610	.62	.670	.0150	63
		Maximum	18.1	1.4	.1900	1.500	1.50	1.500	.0770	14000
	Dudley Creek	N	12	12	12	12	12	12	12	12
		Median	11.650	.750	.135000	.32000	.3350	.48000	.046500	1300.00
		Mean	12.300	1.208	.151833	.31583	.3358	.50250	.050000	1933.33
		Std. Error of Mean	.5623	.4200	.0205938	.019206	.01928	.039488	.0056287	476.137
		Minimum	9.7	.5	.0680	.170	.18	.310	.0240	270
		Maximum	14.8	5.7	.3300	.410	.42	.750	.0840	4900
	Horseshoe Lake Discharge	N	12	12	12	12	12	12	12	12
		Median	12.000	.500	.115000	.32500	.3400	.45000	.040500	515.00
		Mean	12.542	.758	.124083	.32167	.3375	.46167	.039083	731.67
		Std. Error of Mean	.5743	.1490	.0070501	.031929	.03257	.035544	.0035215	133.711
		Minimum	9.2	.5	.0890	.160	.17	.280	.0210	250
		Maximum	14.8	2.1	.1700	.480	.50	.660	.0670	1500
	Riccarton Main Drain	N	12	12	12	12	12	12	12	12
		Median	13.350	.500	.026500	2.35000	2.3500	2.35000	.016000	205.00
		Mean	13.450	.817	.039167	2.25250	2.2625	2.27500	.019200	652.33
		Std. Error of Mean	.3071	.3167	.0129561	.192075	.18901	.181377	.0032071	396.088
		Minimum	11.6	.5	.0110	.930	.95	1.100	.0094	52
		Maximum	14.8	4.3	.1800	3.000	3.00	3.000	.0510	4900
	Waimairi Stream	N	12	12	12	12	12	12	12	12
		Median	13.300	.500	.008000	2.70000	2.7000	2.70000	.007550	270.00

Catchment	Site		Water Temperature	BOD5	Total Ammonia	Nitrate NO3	Nitrate - Nitrite	Dissolved Inorganic Nitrogen	Dissolved Reactive Phosphorus	*E. coli*
		Mean	13.125	.558	.010042	2.53333	2.6167	2.64208	.008392	784.00
		Std. Error of Mean	.2206	.0583	.0020042	.189230	.14451	.159824	.0011367	452.907
		Minimum	12.1	.5	.0025	1.400	1.50	1.500	.0034	20
		Maximum	14.3	1.2	.0270	3.800	3.50	3.800	.0170	5500
	Wairarapa Stream	N	12	12	12	12	12	12	12	12
		Median	13.250	.500	.015500	1.35000	1.3500	1.35000	.007250	250.00
		Mean	13.300	.500	.018167	1.27417	1.2833	1.28583	.008458	350.17
		Std. Error of Mean	.3287	.0000	.0026424	.054944	.05393	.052404	.0015858	98.924
		Minimum	11.8	.5	.0100	.830	.84	.850	.0015	20
		Maximum	14.7	.5	.0430	1.400	1.40	1.400	.0210	1300
	Total	N	155	155	155	155	155	155	155	155
		Median	13.400	.500	.027000	1.40000	1.4000	1.40000	.017000	260.00
		Mean	13.293	.713	.059377	1.55774	1.5792	1.63531	.022463	835.95
		Std. Error of Mean	.1466	.0549	.0058549	.077593	.07654	.073833	.0015075	184.838
		Minimum	9.2	.5	.0025	.090	.17	.280	.0015	10
		Maximum	18.7	5.7	.5000	5.700	5.70	5.700	.1000	22000
Halswell catchment	Halswell Retention Basin Inlet	N	12	12	12	12	12	12	12	12
		Median	15.400	3.700	1.550000	1.10000	1.4000	2.95000	.165000	1140.00
		Mean	14.350	3.542	2.832500	1.06333	1.3225	4.14167	.220417	4547.08
		Std. Error of Mean	1.3414	.5163	.7444411	.096878	.09656	.754929	.0545004	2101.204
		Minimum	6.7	.5	.4500	.550	.68	1.600	.0240	10
		Maximum	20.3	6.4	8.7000	1.500	1.90	10.000	.6300	24000
	Halswell Retention Basin Outlet	N	12	12	12	12	12	12	12	12
		Median	15.250	2.450	1.200000	1.30000	1.5000	2.70000	.079500	126.50
		Mean	14.042	3.217	1.619417	1.26417	1.4192	3.05000	.075825	155.33
		Std. Error of Mean	1.3109	.6029	.3531963	.113894	.13274	.416970	.0136446	45.514
		Minimum	6.7	.5	.0530	.690	.76	1.600	.0050	5
		Maximum	19.9	7.4	3.8000	1.900	2.10	5.500	.1600	500
	Halswell River at Akaroa Highway	N	12	12	12	12	12	12	12	12
		Median	12.350	.500	.028000	4.55000	4.5500	4.60000	.016000	390.00
		Mean	12.467	.742	.038500	4.25000	4.2833	4.30833	.020008	669.17
		Std. Error of Mean	.5116	.1658	.0128042	.227470	.23350	.221037	.0046768	277.637
		Minimum	9.3	.5	.0050	2.200	2.20	2.400	.0061	240
		Maximum	14.8	2.2	.1700	4.900	5.00	5.000	.0680	3700

Catchment	Site		Water Temperature	BOD5	Total Ammonia	Nitrate NO3	Nitrate - Nitrite	Dissolved Inorganic Nitrogen	Dissolved Reactive Phosphorus	*E. coli*
	Knights Stream at Sabys Road	N	12	12	12	12	12	12	12	12
		Median	12.550	.500	.018000	5.50000	5.5000	5.50000	.010500	530.00
		Mean	12.575	.700	.037750	5.09167	5.0917	5.11667	.012500	580.00
		Std. Error of Mean	.3652	.1435	.0144862	.435622	.43562	.421727	.0033979	86.278
		Minimum	10.4	.5	.0070	1.600	1.60	1.700	.0015	250
		Maximum	14.5	2.1	.1900	7.200	7.20	7.200	.0450	1200
	Nottingham Stream at Candys Road	N	12	12	12	12	12	12	12	12
		Median	12.550	.500	.052500	1.55000	1.6000	1.75000	.021500	350.00
		Mean	12.525	.808	.100917	1.60000	1.6167	1.72500	.025000	940.42
		Std. Error of Mean	.4164	.1171	.0454022	.101504	.10360	.098569	.0037009	581.088
		Minimum	10.0	.5	.0100	1.100	1.10	1.100	.0100	97
		Maximum	14.6	1.6	.5900	2.100	2.10	2.200	.0500	7300
	Total	N	60	60	60	60	60	60	60	60
		Median	12.700	1.050	.068500	1.70000	1.9000	3.15000	.024000	410.00
		Mean	13.192	1.802	.925817	2.65383	2.7467	3.66833	.070750	1425.07
		Std. Error of Mean	.4049	.2326	.2168191	.240607	.23310	.244759	.0149265	475.693
		Minimum	6.7	.5	.0050	.550	.68	1.100	.0015	5
		Maximum	20.3	7.4	8.7000	7.200	7.20	10.000	.6300	24000
Heathcote catchment	Cashmere Stream at Sutherlands Road	N	12	12	12	12	12	12	12	12
		Median	13.850	.500	.007500	2.35000	2.3500	2.35000	.004000	10.00
		Mean	13.800	.500	.016917	2.13167	2.1317	2.14250	.003883	23.92
		Std. Error of Mean	.2306	.0000	.0064743	.156097	.15610	.156777	.0007248	8.705
		Minimum	12.4	.5	.0050	.880	.88	.910	.0015	5
		Maximum	15.0	.5	.0830	2.600	2.60	2.700	.0090	110
	Cashmere Stream at Worsleys Road	N	12	12	12	12	12	12	12	12
		Median	12.600	.500	.043500	1.45000	1.4500	1.50000	.024000	370.00
		Mean	12.467	.900	.066833	1.72500	1.7333	1.79167	.023542	2386.67
		Std. Error of Mean	.6947	.2096	.0189940	.366624	.36584	.359178	.0046584	1966.676
		Minimum	7.8	.5	.0120	1.000	1.00	1.100	.0032	210
		Maximum	16.1	2.8	.2300	5.700	5.70	5.700	.0500	24000
	Curletts Road Stream at Motorway	N	7	7	7	7	7	7	7	7
		Median	10.500	.500	.042000	1.60000	1.7000	1.90000	.015000	110.00
		Mean	11.829	.771	.087143	2.10000	2.1571	2.22857	.016000	224.71
		Std. Error of Mean	1.2486	.1835	.0287687	.300793	.30226	.287613	.0012536	98.294

Catchment	Site		Water Temperature	BOD5	Total Ammonia	Nitrate NO3	Nitrate - Nitrite	Dissolved Inorganic Nitrogen	Dissolved Reactive Phosphorus	*E. coli*
		Minimum	7.6	.5	.0230	1.400	1.40	1.400	.0120	10
		Maximum	16.3	1.7	.2100	3.300	3.30	3.300	.0200	730
	Curletts Road Stream Upstream of Heathcote River	N	12	12	12	12	12	12	12	12
		Median	13.950	.500	.047500	3.50000	3.5500	3.60000	.026500	260.00
		Mean	13.292	.875	.069417	3.29500	3.3217	3.38000	.036833	1185.83
		Std. Error of Mean	.6710	.1488	.0165925	.343151	.34296	.331306	.0083028	632.590
		Minimum	9.9	.5	.0110	.740	.76	.960	.0140	150
		Maximum	16.2	1.9	.2000	4.600	4.70	4.800	.1000	7700
	Haytons Stream at Retention Basin	N	12	12	12	12	12	12	12	12
		Median	12.800	2.500	.395000	.32000	.3550	.83500	.400000	270.00
		Mean	12.408	2.592	.446583	.35792	.3938	.83833	.427333	382.92
		Std. Error of Mean	1.2483	.3253	.0906885	.063417	.06983	.114481	.0876416	146.994
		Minimum	6.0	1.1	.0690	.025	.04	.370	.0580	5
		Maximum	18.3	5.2	.9500	.720	.86	1.800	1.1000	1900
	Heathcote River at Bowenvale Avenue	N	12	12	12	12	12	12	12	12
		Median	12.350	.500	.050500	1.90000	1.9000	1.95000	.026500	555.00
		Mean	12.408	.833	.054000	1.85000	1.8833	1.95200	.031167	671.67
		Std. Error of Mean	.6625	.1760	.0122078	.090034	.08602	.078938	.0057798	127.629
		Minimum	8.2	.5	.0050	1.300	1.40	1.600	.0110	230
		Maximum	15.9	2.5	.1500	2.200	2.20	2.300	.0840	1600
	Heathcote River at Catherine Street	N	12	12	12	12	12	12	12	12
		Median	13.600	.800	.088500	1.60000	1.6000	1.65000	.029500	670.00
		Mean	13.308	.983	.083250	1.60000	1.6417	1.72500	.032000	777.50
		Std. Error of Mean	.8309	.1825	.0140212	.090453	.09167	.092216	.0036763	136.282
		Minimum	8.3	.5	.0190	1.100	1.20	1.300	.0180	280
		Maximum	17.1	2.6	.1700	2.100	2.10	2.200	.0480	1700
	Heathcote River at Ferniehurst Street	N	12	12	12	12	12	12	12	12
		Median	12.500	.500	.050000	2.05000	2.0500	2.05000	.028500	540.00
		Mean	12.408	.917	.061167	2.00833	2.0000	2.06883	.030667	1472.50
		Std. Error of Mean	.6606	.1918	.0144657	.090836	.08704	.079745	.0061179	870.416
		Minimum	8.2	.5	.0050	1.400	1.40	1.600	.0100	230
		Maximum	16.0	2.7	.1800	2.500	2.50	2.600	.0870	11000
	Heathcote River at Ferrymead Bridge	N	12	12	12	12	12	12	12	12
		Median	14.600	.500	.114500	1.35000	1.3500	1.50000	.045000	450.00

Catchment	Site		Water Temperature	BOD5	Total Ammonia	Nitrate NO3	Nitrate - Nitrite	Dissolved Inorganic Nitrogen	Dissolved Reactive Phosphorus	*E. coli*
		Mean	13.892	1.058	.116333	1.25833	1.2708	1.40167	.049250	1062.00
		Std. Error of Mean	.9994	.2572	.0159504	.095678	.09565	.102320	.0067556	405.592
		Minimum	8.1	.5	.0440	.660	.67	.740	.0210	74
		Maximum	18.7	3.0	.2200	1.700	1.70	1.800	.0960	4900
	Heathcote River at MacKenzie Avenue	N	12	12	12	12	12	12	12	12
		Median	13.650	.750	.078000	1.60000	1.6500	1.75000	.032000	480.00
		Mean	13.217	.908	.084750	1.65833	1.6833	1.77500	.034750	985.83
		Std. Error of Mean	.7776	.1554	.0130315	.073297	.07470	.072952	.0053684	332.001
		Minimum	8.4	.5	.0200	1.300	1.30	1.400	.0190	270
		Maximum	16.5	2.3	.1500	2.000	2.00	2.100	.0820	4100
	Heathcote River at Opawa Road/Clarendon Terrace	N	12	12	12	12	12	12	12	12
		Median	13.350	.500	.065000	1.75000	1.7500	1.85000	.034000	425.00
		Mean	13.108	.742	.078583	1.69917	1.7083	1.80000	.033667	554.17
		Std. Error of Mean	.7424	.1764	.0119560	.095111	.09650	.095346	.0053063	107.149
		Minimum	8.5	.5	.0230	.990	1.00	1.100	.0140	200
		Maximum	16.1	2.5	.1600	2.100	2.10	2.200	.0810	1300
	Heathcote River at Rose Street	N	12	12	12	12	12	12	12	12
		Median	12.750	.500	.077000	3.30000	3.3000	3.45000	.031500	645.00
		Mean	12.875	.775	.082917	3.19167	3.2083	3.29675	.048842	647.50
		Std. Error of Mean	.6419	.1503	.0183375	.181933	.18483	.179038	.0149077	132.277
		Minimum	9.6	.5	.0110	1.700	1.70	1.800	.0091	130
		Maximum	16.3	1.9	.2600	4.000	4.10	4.161	.2000	1400
	Heathcote River at Templetons Road	N	12	12	12	12	12	12	12	12
		Median	13.500	.500	.012500	3.70000	3.7000	3.70000	.005500	92.00
		Mean	13.208	.500	.021208	4.05000	4.0583	4.06667	.006492	117.33
		Std. Error of Mean	.4140	.0000	.0067131	.368967	.36793	.362302	.0013973	26.715
		Minimum	10.8	.5	.0025	1.300	1.30	1.400	.0015	5
		Maximum	15.5	.5	.0850	6.400	6.40	6.400	.0140	310
	Heathcote River at Tunnel Road	N	12	12	12	12	12	12	12	12
		Median	14.100	.500	.091500	1.45000	1.5000	1.55000	.040500	745.00
		Mean	13.742	.908	.089750	1.50833	1.5500	1.65000	.043250	1079.50
		Std. Error of Mean	.9143	.1777	.0151613	.083900	.07538	.081184	.0070390	381.876
		Minimum	8.4	.5	.0050	1.100	1.20	1.300	.0140	74
		Maximum	17.8	2.3	.1700	1.900	1.90	2.100	.0950	4900

Catchment	Site		Water Temperature	BOD5	Total Ammonia	Nitrate NO3	Nitrate - Nitrite	Dissolved Inorganic Nitrogen	Dissolved Reactive Phosphorus	*E. coli*
	Total	N	163	163	163	163	163	163	163	163
		Median	13.300	.500	.061000	1.80000	1.8000	1.90000	.027000	370.00
		Mean	13.033	.953	.097365	2.02887	2.0498	2.14884	.059706	845.04
		Std. Error of Mean	.2071	.0614	.0108786	.088246	.08792	.083545	.0104181	172.790
		Minimum	6.0	.5	.0025	.025	.04	.370	.0015	5
		Maximum	18.7	5.2	.9500	6.400	6.40	6.400	1.1000	24000
Linwood Canal	Linwood Canal	N	12	12	12	12	12	12	12	12
		Median	14.350	.850	.255000	.12000	.1300	.41500	.041500	525.00
		Mean	14.500	1.208	.291667	.11217	.1249	.41675	.072917	742.50
		Std. Error of Mean	.9809	.3069	.0484429	.017429	.01870	.049522	.0166890	165.480
		Minimum	9.2	.5	.0800	.026	.03	.130	.0190	210
		Maximum	20.4	4.1	.6700	.230	.25	.719	.2000	2100
	Total	N	12	12	12	12	12	12	12	12
		Median	14.350	.850	.255000	.12000	.1300	.41500	.041500	525.00
		Mean	14.500	1.208	.291667	.11217	.1249	.41675	.072917	742.50
		Std. Error of Mean	.9809	.3069	.0484429	.017429	.01870	.049522	.0166890	165.480
		Minimum	9.2	.5	.0800	.026	.03	.130	.0190	210
		Maximum	20.4	4.1	.6700	.230	.25	.719	.2000	2100
Otukaikino catchment	Otukaikino River at Groynes Inlet	N	12	12	12	12	12	12	12	12
		Median	12.850	.500	.007500	.28000	.2850	.29500	.005450	125.00
		Mean	12.492	.708	.009333	.34500	.3492	.36058	.007900	307.75
		Std. Error of Mean	.5753	.1469	.0015242	.063586	.06341	.064091	.0018529	126.446
		Minimum	9.8	.5	.0050	.120	.12	.130	.0015	20
		Maximum	16.3	2.1	.0200	.690	.69	.707	.0240	1500
	Otukaikino Creek at Omaka Scout Camp	N	3	3	3	3	3	3	3	3
		Median	13.100	.500	.010000	.08600	.0890	.11000	.005200	230.00
		Mean	13.000	.733	.036333	.08533	.0887	.12667	.005033	247.33
		Std. Error of Mean	.6083	.2333	.0263333	.003480	.00376	.027285	.0002186	118.098
		Minimum	11.9	.5	.0100	.079	.08	.090	.0046	52
		Maximum	14.0	1.2	.0890	.091	.10	.180	.0053	460
	Wilsons Stream	N	12	12	12	12	12	12	12	12
		Median	12.850	.500	.014500	1.40000	1.4000	1.45000	.015500	175.00
		Mean	12.800	.917	.026833	1.40833	1.4250	1.36450	.025975	2219.00
		Std. Error of Mean	.3977	.2026	.0073204	.052884	.04459	.168241	.0091631	1981.552

Catchment	Site		Water Temperature	BOD5	Total Ammonia	Nitrate NO3	Nitrate - Nitrite	Dissolved Inorganic Nitrogen	Dissolved Reactive Phosphorus	*E. coli*
		Minimum	11.2	.5	.0050	1.000	1.10	.270	.0068	41
		Maximum	16.1	2.6	.0800	1.700	1.70	2.500	.1200	24000
	Total	N	27	27	27	27	27	27	27	27
		Median	12.900	.500	.010000	.67000	.6800	.52000	.008900	160.00
		Mean	12.685	.804	.020111	.78874	.7984	.78078	.015615	1150.48
		Std. Error of Mean	.3105	.1124	.0045081	.115451	.11595	.129507	.0044457	881.245
		Minimum	9.8	.5	.0050	.079	.08	.090	.0015	20
		Maximum	16.3	2.6	.0890	1.700	1.70	2.500	.1200	24000
Styx catchment	Kaputone Creek at Belfast Road	N	12	12	12	12	12	12	12	12
		Median	13.350	1.200	.165000	.96500	.9950	1.35000	.045500	3800.00
		Mean	13.033	1.400	.259167	1.03750	1.0700	1.32667	.100750	6647.50
		Std. Error of Mean	.5092	.2492	.0626009	.049987	.04671	.062393	.0343017	2398.677
		Minimum	10.5	.5	.1000	.830	.91	1.000	.0250	770
		Maximum	16.6	3.4	.8300	1.300	1.30	1.700	.3700	24000
	Kaputone Creek at Blakes Road	N	12	12	12	12	12	12	12	12
		Median	13.950	1.200	.091500	1.40000	1.4000	1.55000	.019000	1150.00
		Mean	14.425	1.050	.177000	1.27917	1.3300	1.51833	.026167	3282.50
		Std. Error of Mean	.6556	.1311	.0486470	.077229	.07914	.109854	.0048208	1918.236
		Minimum	11.7	.5	.0300	.550	.56	.590	.0140	190
		Maximum	19.2	1.8	.5400	1.500	1.60	2.000	.0710	24000
	Smacks Creek at Gardiners Road	N	12	12	12	12	12	12	12	12
		Median	13.100	.500	.017000	.57500	.5800	.59500	.009650	91.50
		Mean	13.392	.500	.016500	.61917	.6217	.63833	.014883	363.17
		Std. Error of Mean	.3168	.0000	.0021760	.049028	.04897	.048925	.0051678	167.520
		Minimum	11.6	.5	.0050	.390	.39	.410	.0042	20
		Maximum	15.7	.5	.0300	.890	.89	.900	.0700	1800
	Styx River at Gardiners Road	N	12	12	12	12	12	12	12	12
		Median	12.800	.500	.010000	.91000	.9150	.92000	.008100	235.00
		Mean	12.950	.500	.010167	.90667	.9100	.91708	.013617	875.83
		Std. Error of Mean	.1390	.0000	.0014026	.054123	.05391	.052859	.0036712	432.669
		Minimum	12.3	.5	.0050	.530	.53	.540	.0032	110
		Maximum	14.1	.5	.0210	1.200	1.20	1.200	.0460	4400
	Styx River at Harbour Road Bridge	N	12	12	12	12	12	12	12	12
		Median	12.900	.500	.039000	.54500	.5600	.59500	.039000	340.00

Catchment	Site		Water Temperature	BOD5	Total Ammonia	Nitrate NO3	Nitrate - Nitrite	Dissolved Inorganic Nitrogen	Dissolved Reactive Phosphorus	*E. coli*
		Mean	13.208	.783	.062333	.54833	.5617	.62417	.038083	534.17
		Std. Error of Mean	.7704	.1660	.0145755	.042690	.04301	.055013	.0031967	122.465
		Minimum	9.1	.5	.0200	.350	.36	.380	.0200	210
		Maximum	18.3	2.3	.1600	.770	.77	.920	.0540	1600
	Styx River at Main North Road	N	12	12	12	12	12	12	12	12
		Median	13.000	.500	.037000	.60500	.6150	.66000	.011000	595.00
		Mean	12.933	.608	.036500	.60167	.6108	.64817	.015175	1787.50
		Std. Error of Mean	.4014	.0733	.0049306	.030272	.03054	.032329	.0024806	892.786
		Minimum	11.0	.5	.0100	.380	.39	.430	.0081	170
		Maximum	15.7	1.2	.0670	.760	.77	.810	.0340	11000
	Styx River at Marshland Road Bridge	N	12	12	12	12	12	12	12	12
		Median	13.200	.500	.061500	.67000	.6850	.79000	.032500	1400.00
		Mean	12.792	.708	.074000	.69000	.7117	.78417	.041167	3275.83
		Std. Error of Mean	.4341	.1131	.0150136	.046645	.05171	.058807	.0091824	1898.761
		Minimum	10.3	.5	.0200	.480	.49	.510	.0210	410
		Maximum	15.4	1.6	.2000	1.000	1.10	1.200	.1400	24000
	Styx River at Richards Bridge	N	12	12	12	12	12	12	12	12
		Median	12.950	.500	.045000	.59500	.6100	.64000	.031500	810.00
		Mean	12.825	.550	.056250	.60833	.6217	.67833	.039167	1208.33
		Std. Error of Mean	.5592	.0500	.0103390	.043272	.04257	.050735	.0048505	305.237
		Minimum	9.7	.5	.0140	.410	.42	.470	.0250	170
		Maximum	16.7	1.1	.1200	.900	.90	.990	.0750	3300
	Total	N	96	96	96	96	96	96	96	96
		Median	13.150	.500	.039000	.73500	.7400	.81000	.026500	695.00
		Mean	13.195	.763	.086490	.78635	.8047	.89191	.036126	2246.85
		Std. Error of Mean	.1803	.0526	.0129959	.030490	.03164	.039378	.0052211	495.901
		Minimum	9.1	.5	.0050	.350	.36	.380	.0032	20
		Maximum	19.2	3.4	.8300	1.500	1.60	2.000	.3700	24000

Table iii. Summary statistics for all catchments for the first eight parameters presented in this report (dissolved copper to dissolved oxygen saturation), sorted alphabetically by catchment..

Catchment		Dissolved Copper	Dissolved Lead	Dissolved Zinc	pH	Conductivity	Total Suspended Solids	Turbidity	Dissolved Oxygen Saturation
Avon catchment	N	139	139	139	155	155	155	131	155
	Median	.00100	.0007500	.008700	7.70	190.000	4.00	2.000	86.00
	Mean	.00115	.0008486	.016117	7.63	789.752	6.80	4.646	86.11
	Std. Error of Mean	.000066	.00003375	.0022393	.030	197.1355	.809	.6094	.971
	Minimum	.001	.00075	.0005	6	65.4	2	.3	54
	Maximum	.007	.00370	.1900	8	22200.0	91	52.0	115
Halswell catchment	N	44	44	44	60	60	60	36	60
	Median	.00100	.0007500	.003500	7.60	207.000	6.00	1.500	80.50
	Mean	.00194	.0010727	.011739	7.73	197.825	15.00	3.477	77.62
	Std. Error of Mean	.000329	.00012077	.0024845	.056	9.1470	2.889	.8704	2.869
	Minimum	.001	.00075	.0005	7	12.4	2	.1	5
	Maximum	.009	.00430	.0620	10	304.0	120	26.0	120
Heathcote catchment	N	144	144	144	163	163	163	132	163
	Median	.00100	.0007500	.008150	7.60	287.000	7.00	5.500	79.00
	Mean	.00149	.0008333	.023953	7.55	809.073	14.09	11.339	76.26
	Std. Error of Mean	.000125	.00003266	.0039171	.023	197.7470	1.299	1.4361	1.556
	Minimum	.001	.00075	.0005	7	33.0	2	.1	15
	Maximum	.011	.00470	.3500	8	22200.0	81	97.0	140
Linwood Canal	N	12	12	12	12	11	12	12	12
	Median	.00100	.0007500	.007850	7.80	2120.000	12.00	10.350	61.50
	Mean	.00120	.0010167	.016442	7.77	3036.364	15.13	12.392	60.75
	Std. Error of Mean	.000200	.00018813	.0062661	.076	600.3503	1.842	1.8311	3.724
	Minimum	.001	.00075	.0030	7	1160.0	7	2.4	33
	Maximum	.003	.00280	.0800	8	7500.0	25	25.0	78
Otukaikino catchment	N	27	27	27	27	27	27	27	27
	Median	.00100	.0007500	.001600	7.50	93.800	1.50	.460	87.00
	Mean	.00100	.0007500	.005411	7.57	101.989	4.81	2.450	87.22
	Std. Error of Mean	.000000	0E-8	.0016531	.061	5.4208	1.205	.8353	1.878
	Minimum	.001	.00075	.0005	7	49.6	2	.1	63
	Maximum	.001	.00075	.0360	9	160.0	29	18.0	110
Styx catchment	N	96	96	96	96	96	96	96	96
	Median	.00100	.0007500	.002000	7.45	141.000	3.00	1.800	74.00
	Mean	.00100	.0007578	.004539	7.37	137.429	5.62	2.547	72.24
	Std. Error of Mean	.000000	.00000781	.0007312	.048	3.5144	1.253	.4884	1.202

Catchment		Dissolved Copper	Dissolved Lead	Dissolved Zinc	pH	Conductivity	Total Suspended Solids	Turbidity	Dissolved Oxygen Saturation
	Minimum	.001	.00075	.0005	6	55.3	2	.1	50
	Maximum	.001	.00150	.0360	8	252.0	120	46.0	96
Total	N	462	462	462	513	512	513	434	513
	Median	.00100	.0007500	.006000	7.60	194.000	5.00	2.350	81.00
	Mean	.00129	.0008449	.015119	7.57	616.224	9.95	6.198	78.71
	Std. Error of Mean	.000055	.00001941	.0014712	.017	89.9126	.659	.5272	.774
	Minimum	.001	.00075	.0005	6	12.4	2	.1	5
	Maximum	.011	.00470	.3500	10	22200.0	120	97.0	140

Table iv. Summary statistics for all catchments for the second eight parameters presented in this report (water temperature to *E. coli*), sorted alphabetically by catchment.

Catchment		Water Temperature	BOD5	Total Ammonia	Nitrate NO3	Nitrate - Nitrite	Dissolved Inorganic Nitrogen	Dissolved Reactive Phosphorus	*E. coli*
Avon catchment	N	155	155	155	155	155	155	155	155
	Median	13.400	.500	.027000	1.40000	1.4000	1.40000	.017000	260.00
	Mean	13.293	.713	.059377	1.55774	1.5792	1.63531	.022463	835.95
	Std. Error of Mean	.1466	.0549	.0058549	.077593	.07654	.073833	.0015075	184.838
	Minimum	9.2	.5	.0025	.090	.17	.280	.0015	10
	Maximum	18.7	5.7	.5000	5.700	5.70	5.700	.1000	22000
Halswell catchment	N	60	60	60	60	60	60	60	60
	Median	12.700	1.050	.068500	1.70000	1.9000	3.15000	.024000	410.00
	Mean	13.192	1.802	.925817	2.65383	2.7467	3.66833	.070750	1378.40
	Std. Error of Mean	.4049	.2326	.2168191	.240607	.23310	.244759	.0149265	473.362
	Minimum	6.7	.5	.0050	.550	.68	1.100	.0015	5
	Maximum	20.3	7.4	8.7000	7.200	7.20	10.000	.6300	24000
Heathcote catchment	N	163	163	163	163	163	163	163	163
	Median	13.300	.500	.061000	1.80000	1.8000	1.90000	.027000	370.00
	Mean	13.033	.953	.097365	2.02887	2.0498	2.14884	.059706	845.04
	Std. Error of Mean	.2071	.0614	.0108786	.088246	.08792	.083545	.0104181	172.790
	Minimum	6.0	.5	.0025	.025	.04	.370	.0015	5
	Maximum	18.7	5.2	.9500	6.400	6.40	6.400	1.1000	24000
Linwood Canal	N	12	12	12	12	12	12	12	12
	Median	14.350	.850	.255000	.12000	.1300	.41500	.041500	525.00
	Mean	14.500	1.208	.291667	.11217	.1249	.41675	.072917	742.50
	Std. Error of Mean	.9809	.3069	.0484429	.017429	.01870	.049522	.0166890	165.480
	Minimum	9.2	.5	.0800	.026	.03	.130	.0190	210
	Maximum	20.4	4.1	.6700	.230	.25	.719	.2000	2100
Otukaikino catchment	N	27	27	27	27	27	27	27	27
	Median	12.900	.500	.010000	.67000	.6800	.52000	.008900	160.00
	Mean	12.685	.804	.020111	.78874	.7984	.78078	.015615	1150.48
	Std. Error of Mean	.3105	.1124	.0045081	.115451	.11595	.129507	.0044457	881.245
	Minimum	9.8	.5	.0050	.079	.08	.090	.0015	20
	Maximum	16.3	2.6	.0890	1.700	1.70	2.500	.1200	24000
Styx catchment	N	96	96	96	96	96	96	96	96
	Median	13.150	.500	.039000	.73500	.7400	.81000	.026500	695.00
	Mean	13.195	.763	.086490	.78635	.8047	.89191	.036126	2246.85
	Std. Error of Mean	.1803	.0526	.0129959	.030490	.03164	.039378	.0052211	495.901

Catchment		Water Temperature	BOD5	Total Ammonia	Nitrate NO3	Nitrate - Nitrite	Dissolved Inorganic Nitrogen	Dissolved Reactive Phosphorus	*E. coli*
	Minimum	9.1	.5	.0050	.350	.36	.380	.0032	20
	Maximum	19.2	3.4	.8300	1.500	1.60	2.000	.3700	24000
Total	N	513	513	513	513	513	513	513	513
	Median	13.200	.500	.044000	1.40000	1.4000	1.50000	.021000	350.00
	Mean	13.176	.942	.181226	1.61699	1.6452	1.82366	.043321	1186.14
	Std. Error of Mean	.1023	.0421	.0283193	.054382	.05414	.059058	.0039992	142.697
	Minimum	6.0	.5	.0025	.025	.03	.090	.0015	5
	Maximum	20.4	7.4	8.7000	7.200	7.20	10.000	1.1000	24000

9 Appendix B: Metal Hardness Modified Trigger Values

1. Introduction

The Australian and New Zealand guidelines for fresh and marine water quality (ANZECC, 2000) provides a set of default guideline trigger values for metals, with which to compare measured contaminant concentrations. These trigger values represent concentrations below which there is considered to be a low risk of adverse biological effects (ANZECC, 2000). The guidelines also provide a process for modifying the given trigger values for local environmental conditions. If measured concentrations of toxicants are below default trigger values, then there is a low risk of adverse effects. However, if measured concentrations exceed these guidelines, then it is possible to consider site specific factors that may modify the trigger values, to gain a better understanding of whether a real risk exists. If measured concentrations also exceed modified trigger values, then the next step would be to directly assess biological effects.

Christchurch City Council has measured concentrations of metals (total cadmium, total copper, total lead, total zinc) in water samples from 33 river monitoring sites across the city since 2008. Measured concentrations vary widely across the monitoring sites, and there are several sites where values often exceed guideline trigger values. In fresh waters, the hardness, pH and alkalinity of the water can alter the toxicity of metals and hence the risk of adverse biological effects (ANZECC, 2000). The default guideline trigger values for metals assume that water is soft (with a hardness value of between 0 and 59 mg/L as CaCO3), but as water hardness increases, the toxicity of some metals decreases and therefore the trigger value may increase, without increasing the risk of adverse biological effects.

To make an informed assessment of the real risks associated with exceeding the default trigger values, additional monitoring for water hardness has been included at sites within each catchment for the purpose of calculating appropriate hardness modified trigger values (HMTV) for Christchurch rivers using the water hardness dependent algorithms provided in the ANZECC (2000) guidelines.

2. Sites and sampling regime

Water samples are collected monthly at sites across the five main catchments within Christchurch City (Avon, Heathcote, Styx, Halswell, Otukaikino). These samples are analysed at the Christchurch City Council laboratory for a range of physical and chemical characteristics, including temperature, nutrients, microbiological indicators and metals. Since December 2010, samples from the eight sites listed in Table 1 have also been analysed for water hardness measured in mg/L as $CaCO_3$. Routine water quality monitoring was disrupted on several occasions during 2011, by the significant earthquakes experienced in the city. Despite this, each of the sites had between 9 and 12 water hardness measures recorded by March 2012 and the results were relatively consistent over time for each site.

Table 1. Sampling sites for water hardness investigation (December 2010 to March 2012)

Site Description	Easting	Northing	Number of water hardness samples
Otukaikino at Groynes Inlet	2477878	5750484	11
Styx River at Gardiners Road	2476786	5748821	12
Styx River at Marshland Road bridge	2482356	5749417	12
Avon River at Mona Vale	2478279	5742653	9
Avon River at Gayhurst Road	2483549	5742827	9
Heathcote River at Templetons Road	2475913	5738516	12
Heathcote at Opawa Road/Clarendon Terrace	2483072	5739226	12
Halswell River at Akaroa Highway	2474427	5733346	9

3. Results

3.1. Water Hardness by catchment

Sites on the Styx and Otukaikino rivers had median hardness values within the 'soft' water category, the Avon and Halswell river sites were within the 'moderate' hardness category and the Heathcote sites had 'moderate' to 'hard' water (Figure 1). For the Heathcote River, the Templetons Road site had a number of low hardness outlier values, but median water hardness was higher at the upstream site (Templetons Road) than the downstream site (Opawa Road).

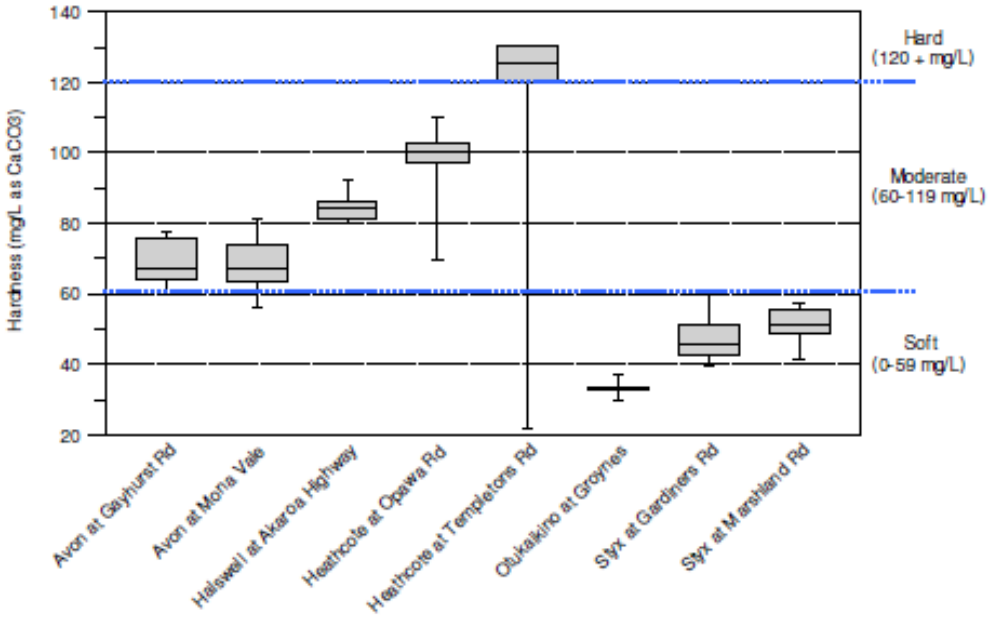

Figure 1 Box plots displaying median (and upper, lower quartiles, max and min) water hardness values for monitoring sites on the Avon, Heathcote, Halswell, Styx and Otukaikino rivers between December 2010 and March 2012.

3.2. Hardness Modified Trigger Values (HMTV)

Hardness modified trigger values (HMTV) are greater than default trigger values in each of the rivers in Christchurch (Table 1). This is because the default values assume that water is in the 'soft' category and this provides trigger values to conservatively protect aquatic ecosystems values in the absence of further information to refine these values.

Table 2 Default and HMTV for metals in the Avon, Heathcote, Halswell, Styx and Otukaikino rivers, based on 99, 95 and 90% levels of species protection as described by ANZECC (2000).

		Default trigger values (µg/L) (ANZECC, 2000)			Hardness modified trigger values (µg/L)		
Level of species protection		**99%**	**95%**	**90%**	**99%**	**95%**	**90%**
Avon	Cadmium	0.06	0.20	0.40	0.12	0.41	0.82
	Copper	1.00	1.40	1.80	1.98	2.77	3.56
	Lead	1.00	3.40	5.60	2.77	9.43	15.54
	Zinc	2.40	8.00	15.00	4.75	15.84	29.70
Heathcote	Cadmium	0.06	0.20	0.40	0.19	0.64	1.27
	Copper	1.00	1.40	1.80	3.02	4.22	5.43
	Lead	1.00	3.40	5.60	5.21	17.71	29.16
	Zinc	2.40	8.00	15.00	7.24	24.14	45.26
Halswell	Cadmium	0.06	0.20	0.40	0.15	0.50	1.00
	Copper	1.00	1.40	1.80	2.40	3.36	4.32
	Lead	1.00	3.40	5.60	3.70	12.57	20.71
	Zinc	2.40	8.00	15.00	5.76	19.19	35.99
Styx	Cadmium	0.06	0.20	0.40	0.09	0.31	0.62
	Copper	1.00	1.40	1.80	1.52	2.12	2.73
	Lead	1.00	3.40	5.60	1.86	6.34	10.44
	Zinc	2.40	8.00	15.00	3.64	12.14	22.76
Otukaikino	Cadmium	0.06	0.20	0.40	0.07	0.22	0.44
	Copper	1.00	1.40	1.80	1.08	1.52	1.95
	Lead	1.00	3.40	5.60	1.13	3.84	6.32
	Zinc	2.40	8.00	15.00	2.60	8.68	16.27

4. References

ANZECC (Australian and New Zealand Environment and Conservation Council), 2000. Australian and New Zealand guidelines for fresh and marine water quality.

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10 Appendix C: Supplementary Graphs

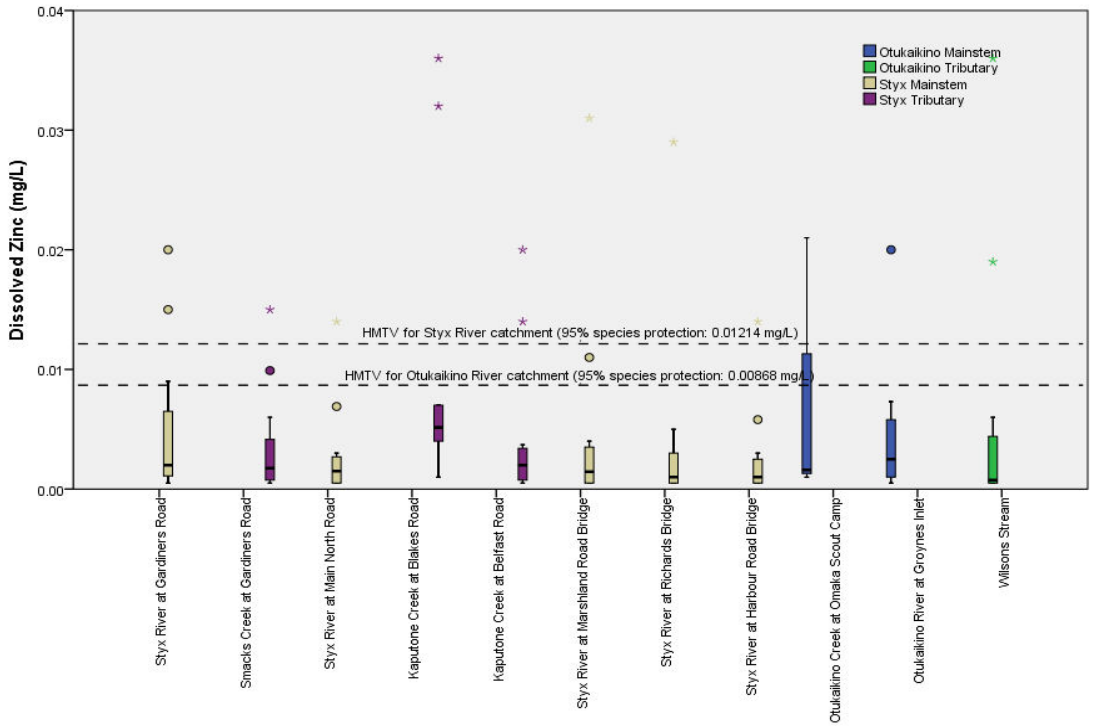

Figure i. This zinc graph is a close up of Figure 4b (left graph). Dissolved zinc levels in water samples taken from the Styx and Otukaikino River for the monitoring period January to December 2014. Not all sites were monitored for the full year (Otukaikino Creek at Omaka Scout Camp; Halswell Retention Basin Inlet and Halswell Retention Basin Outlet), as sampling for this parameter was only instigated at these sites in October (Otukaikino) and September (Halswell Retention Basin) 2014. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Proposed Canterbury Land and Water Regional Plan trigger values (Environment Canterbury, 2012), which have been modified to account for water hardness (Hardness Modified Trigger Value = HMTV), as per the ANZECC (2000) guidelines methodology. On the left graph, Tthe upper dashed line represents the 95% species protection for Styx River catchment (0.01214 mg/L), while the lower represents the 95% species protection for Otukaikino River catchment (0.00868 mg/L). 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.

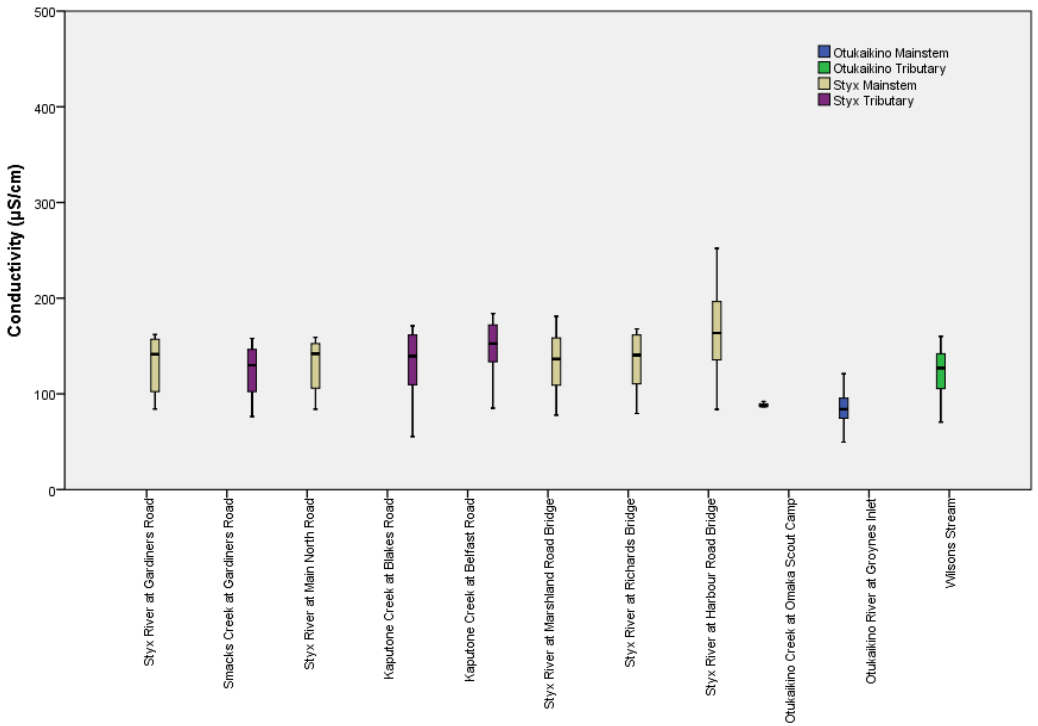

Figure ii. This conductivity graph is a close up of Figure 6b (left graph). Conductivity levels in water samples taken from the Styx and Otukaikino River for the monitoring period January to December 2014. Sampling at the Otukaikino Creek at Omaka Scout Camp was only instigated in October. Sites are ordered from upstream to downstream (left to right).

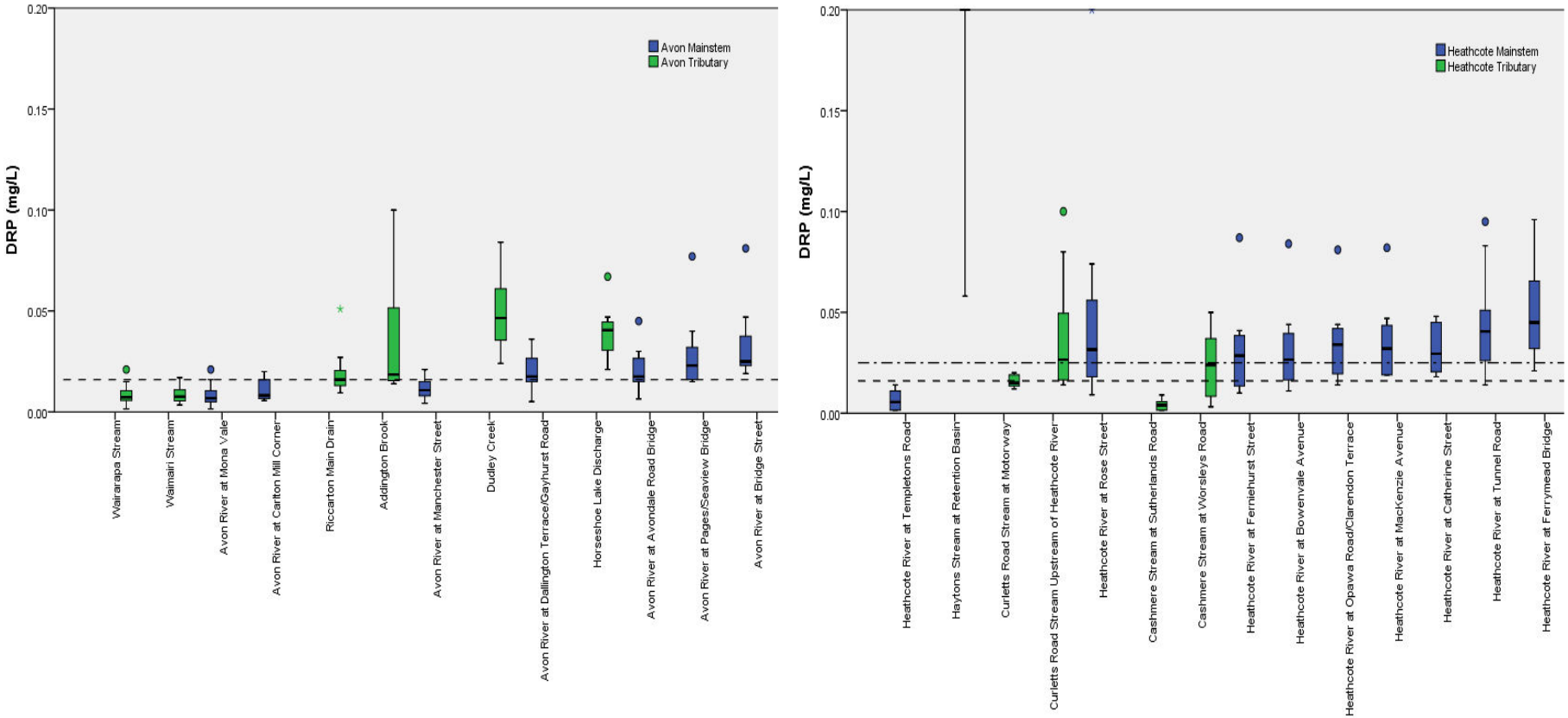

Figure iii(a). This Dissolved Reactive Phosphorus (DRP) graph is a close up of Figure 16a. DRP levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2014. No monitoring was undertaken at the Avon River at Bridge Street site in September and at the Curletts Road Stream at Motorway site January – May, due to construction. Sites are ordered from upstream to downstream (left to right). The lower and upper dashed lines represent the Proposed Canterbury Land and Water Regional Plan trigger value of 0.016 mg/L for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways, and 0.025 mg/L for Banks Peninsula waterways (Cashmere Stream only), respectively (Environment Canterbury, 2012). The Laboratory Limit of Detection was 0.003 mg/L, analysed as half this value (0.0015 mg/L) to allow statistics to be undertaken.

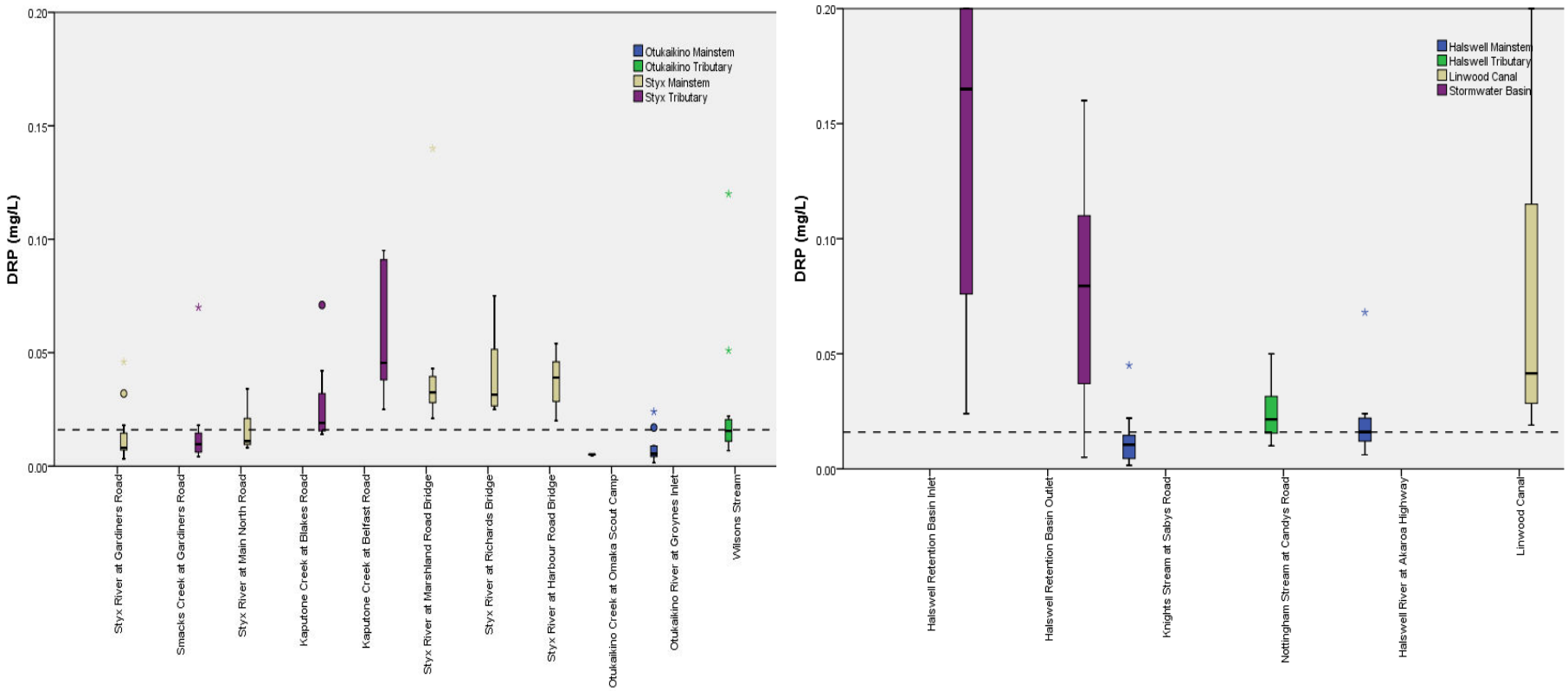

Figure iii(b). This Dissolved Reactive Phosphorus (DRP) graph is a close up of Figure 16b. DRP levels in water samples taken from the Styx and Otukaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2014. Sampling at the Otukaikino Creek at Omaka Scout Camp was only instigated in October. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Proposed Canterbury Land and Water Regional Plan trigger value of 0.016 mg/L for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (Environment Canterbury, 2012). The Laboratory Limit of Detection was 0.003 mg/L, analysed as half this value (0.0015 mg/L) to allow statistics to be undertaken.