Surface Water Quality Monitoring Report for Christchurch City Waterways: January – December 2015

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1 Executive Summary

- In accordance with the requirements of the Interim Global Stormwater Consent, the Styx Stormwater Management Plan Consent and the South-West Stormwater Management Plan Consent, this report summarises the results of the Christchurch City Council surface water quality monitoring for 2015.
- During the period January to December 2015, monthly water samples were collected from 42 sites within the five major river catchments of Christchurch City (the Avon, Heathcote, Halswell, Styx and Ōtūkaikino Rivers) and Linwood Canal, as well as two sites within Halswell Retention Basin. Wet weather monitoring was also conducted during two events at six sites within the Heathcote River catchment. 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 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, declining or improving over time.
- As was recorded last monitoring year, the Heathcote River catchment recorded the poorest water quality of all the catchments and the Ōtūkaikino River catchment recorded the best water quality.
- Other notable trends between catchments included higher concentrations of zinc in the Avon and Heathcote River catchments; higher suspended solids, turbidity and biochemical oxygen demand in the Heathcote River catchment; lower water temperature in the Heathcote River catchment; higher levels of nitrogen in the Heathcote and Halswell River catchments; and a decrease in nitrogen and an increase in phosphorus with increasing distance downstream. Most of these trends are consistent with that recorded last monitoring year.
- The sites recording the poorest water quality across all catchments were Haytons Stream at Retention Basin (particularly for zinc, suspended sediment, turbidity and phosphorus) and Curletts Road Stream Upstream of the Heathcote River (particularly for copper, zinc and dissolved oxygen). The site that recorded the best water quality was the Ōtūkaikino River at Groynes Inlet. However, there were many other sites that were also singled out as the worst and best sites for each individual parameter. These sites differ slightly to that recorded last monitoring year.
- 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 Riccarton Main Drain, Dudley Creek, Avon River at Bridge Street and Addington Brook in the Avon River catchment; Curletts Road Stream Upstream of Heathcote River, Haytons Stream at Retention Basin, Curletts Road Stream at Motorway and Heathcote River at Templetons Road in the Heathcote River catchment; Kaputone Creek at Blakes Road, Kaputone Creek at Belfast Road and Styx River at Richards Bridge in the Styx River catchment; Wilsons Stream in the Ōtūkaikino River catchment; Nottingham Stream at Candys Road in the Halswell River catchment; and Linwood Canal.

- 7,353 samples were collected during the monitoring year from the 43 monthly[1] waterway sites. Of these, 38% did not meet the relevant guideline levels for the parameters assessed in this report. The top five parameters with the highest percentage of samples that did not meet guideline levels were NNN (77% of samples), DRP (56% of samples), DIN (41% of samples), *E. coli* (30% of samples) and turbidity (21% of samples).
- For sites overall, 98% of sites (42 of 43 sites) did not meet the guidelines for at least one parameter (assessed against site medians or 95th percentiles, depending on the parameter).
- There were a number of parameters that were recorded at levels unlikely to cause adverse effects, including dissolved lead, pH, 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, water temperature and biochemical oxygen demand. This is consistent with that recorded last monitoring year.
- The number of guideline exceedances for dry versus wet weather was also assessed for the monthly data for lead, copper, zinc, sediment, phosphorus and *E. coli*. Lead did not record any exceedances during wet or dry weather. Both dry and wet weather exceedances occurred for all other parameters. Dry exceedances were generally greater than that recorded in 2014 and wet weather exceedances were generally lower. The maximum number of exceedances per site for the monitoring year for wet and dry events combined was two for copper (Curletts Road Stream at Motorway site), eight for zinc (at the Curletts Road Stream at Motorway site), eleven for TSS (at the Heathcote River at Ferrymead Bridge site), twelve for DRP (seven sites) and twelve for *E. coli* (at the Kaputone Creek at Belfast Road site).
- As was the case last monitoring year, the results of the temporal trends analysis showed that the majority of parameter concentrations for all sites have remained steady over time. However, parameters at some sites recorded an increasing or decreasing trend in concentrations. The most notable changes were: a decrease in phosphorus within the Avon and Heathcote River catchments; a decrease in turbidity and nitrogen, and an increase in *E. coli*, within the Styx River catchment; a 29% increase in zinc at the Cashmere Stream at Sutherlands Road site, a 24% increase in conductivity at the Avon River at Bridge Street site; a 57% and 20% decrease in zinc and turbidity, respectively, at the Curletts Road Stream Upstream of Heathcote River site; and a 20% decrease in turbidity and phosphorus at the Ōtūkaikino River at Groynes Inlet site. The majority of these trends are consistent with that recorded last monitoring year.
- 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, likely contributing to the high levels of ammonia, phosphorus and *E. coli*. More variability in

[1] With the exception of Snellings Drain, which was sampled quarterly

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 there was some improvement in water quality due to the basin. 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. These results are very similar to the 2014 monitoring year.

- There were a number of parameters for the Heathcote River catchment wet weather monitoring that generally met the guideline values and therefore are not likely to have caused adverse effects on the waterways during the two monitored storm events. These were copper, lead, zinc, pH, suspended sediment, turbidity, dissolved oxygen, temperature, biochemical oxygen demand, total ammonia and nitrate. However, there were a number of parameters that recorded values above the guidelines across most sites: nitrate nitrite nitrogen, dissolved inorganic nitrogen, phosphorus and *E. coli*.
- Levels were generally similar between the wet weather monitoring and the monthly monitoring. The notable exceptions being that zinc levels were generally higher during the wet weather monitoring and nitrogen levels were generally lower. The sites that recorded the poorest water quality were the Heathcote River at Rose Street, Heathcote River at Bowenvale Avenue and Heathcote River at Catherine Street sites.
- 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, whereby lower water quality is recorded internationally in urban (particularly industrial) areas (e.g. Avon and Heathcote River catchments) and generally better water quality is recorded in rural areas (e.g. Ōtūkaikino River 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 Stormwater Management Plans, as well as current joint Christchurch-West Melton Zone Committee, Environment Canterbury and Christchurch City Council catchment pollution projects. Improvements should also occur with the progression of rebuild activities (e.g. a reduction in the level of earthworks and dewatering activities will result in less sediment-laden discharges).

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 2015.

During the period January to December 2015, monthly water samples were collected from 42 sites within the five major river catchments of Christchurch City (the Avon, Heathcote, Halswell, Styx and Ōtūkaikino Rivers) and Linwood Canal, as well as two sites within the Halswell Retention Basin (inlet and outlet) (Table 1, Figure 1). Quarterly samples were also taken from a site in Snellings Drain, a tributary of the Avon River, as a requirement of a stormwater consent for the area (CRC101249). However, this consent was surrendered in September 2015; therefore, this report only presents three sampling events (March, June and September). In total, 45 monitoring sites are presented in this report.

The Heathcote River catchment was also monitored during two wet weather occasions at six of the fourteen monthly sites (Table 1, Figure 1).

3 Methods

3.1 Stream Classifications for Guideline Levels

The classification of each waterway with respect to the Environment Canterbury (ECan) Land and Water Regional Plan (LWRP; Environment Canterbury, 2015) 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. The only sites covered by this plan are within the Ōtūkaikino River; guideline levels for 'spring-fed – plains' in the LWRP were used where none are available in the WRRP, as this was considered the most appropriate classification for these sites.

3.2 Sample Collection and Testing

Water samples were collected 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. For the monthly sampling, the occurrence of rainfall during or within the 24 hours prior to sampling was also recorded. During the 2015 monitoring year, the Heathcote River at Templetons Road site was unable to be sampled monthly from February – June and November – December, as the site was dry. The two wet weather sampling events within the Heathcote River catchment were on the 12th November 2015 and the 4th April 2016.

For the month of May 2015 and on the 3rd June 2015, equipment failure at the CCC laboratory resulted in monthly copper and lead testing being undertaken by Watercare (an IANZ accredited laboratory) instead. However, the Limit of Detection (LOD) at Watercare for these parameters was lower than the CCC laboratory LOD. Therefore, these concentrations were increased to the CCC LOD to match the long-term dataset, to prevent data analyses showing a false reduction in concentrations due to the differing LOD. This affected 54 samples.

In addition, monthly zinc samples were sent to Watercare to be analysed from July to December 2015, again due to CCC laboratory instrument failure. However, the samples were processed by Watercare in a different manner to that done by the CCC laboratory, with samples diluted by a factor of 10 prior to testing, resulting in the Watercare LOD being 0.01, compared to the CCC LOD of 0.001. These results were therefore unable to be used, as data analyses of the long-term dataset would potentially show a false increase in concentrations due to the differing LOD. As a consequence, 68 results from the 2015 monthly monitoring were not included in the dataset. These data were from all catchments, with only six sites not affected on any occasion (Addington Brook, Heathcote River at Rose Street, Curletts Road Stream at Motorway, Halswell Retention Basin Inlet, Halswell Retention Basin Outlet and Nottingham Stream at Candys Road). The month of September was the most affected with 33 results, followed by November and August (19 and 12 incidences, respectively). The most affected site was Cashmere Stream at Sutherlands Road, where five results were unable to be used, followed by Cashmere Stream at Worsleys Road, Knights Stream at Sabys Road and Halswell River at Akaroa Highway, where four samples were unable to be used.

This higher LOD for the zinc samples analysed at Watercare also affected two results from the wet weather monitoring. These were for the two Cashmere Stream sites (Sutherlands Road and Worsleys Road) during the first storm event. However, these results are still presented within this report, as they are one-off samples that did not require statistical analyses in conjunction with other monitoring results. Due to this differing LOD, these zinc levels should be treated with caution when comparing across sites and to wet weather monitoring conducted during previous years.

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

Catchment	Site ID	Site	Easting	Northing	ECan Consent	LWRP or WRRP Classification
Avon	AVON01	Avon River at Pages/Seaview Bridge	2487487	5744202	IGSC	Spring-fed – plains – urban (LWRP)
	AVON02	Avon River at Bridge Street	2487694	5742425	IGSC	Spring-fed – plains – urban (LWRP)
	AVON03	Avon River at Dallington Terrace/Gayhurst Road	2483562	5742822	IGSC	Spring-fed – plains – urban (LWRP)
	AVON04	Avon River at Manchester Street	2480890	5742093	IGSC	Spring-fed – plains – urban (LWRP)
	AVON05	Wairarapa Stream	2478250	5742915	IGSC	Spring-fed – plains – urban (LWRP)
	AVON06	Waimairi Stream	2478232	5742784	IGSC	Spring-fed – plains – urban (LWRP)
	AVON07	Avon River at Mona Vale	2478334	5742658	IGSC	Spring-fed – plains – urban (LWRP)
	AVON08	Riccarton Main Drain[2]	2478683	5741631	IGSC	Spring-fed – plains – urban (LWRP)
	AVON09	Addington Brook	2479427	5741438	IGSC	Spring-fed – plains – urban (LWRP)
	AVON10	Dudley Creek	2482575	5743763	IGSC	Spring-fed – plains – urban (LWRP)
	AVON11	Horseshoe Lake Discharge	2484344	5744907	IGSC	Spring-fed – plains – urban (LWRP)
	AVON12	Avon River at Carlton Mill Corner	2479737	5742871	IGSC	Spring-fed – plains – urban (LWRP)
	AVON13	Avon River at Avondale Road	2484754	5745170	IGSC	Spring-fed – plains – urban (LWRP)
	AVON27	Snellings Drain	2483899	5745774	CRC101249	Spring-fed – plains – urban (LWRP)

[2] 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	LWRP or WRRP Classification
Heathcote	HEATH01	Heathcote River at Ferrymead Bridge	2486494	5738760	IGSC	Spring-fed – plains – urban (LWRP)
	HEATH02	Heathcote River at Tunnel Road	2485076	5739154	IGSC	Spring-fed – plains – urban (LWRP)
	HEATH03	Heathcote River at Opawa Road/Clarendon Terrace	2483072	5739226	IGSC	Spring-fed – plains – urban (LWRP)
	HEATH04	Heathcote River at Bowenvale Avenue*	2481198	5737390	IGSC	Spring-fed – plains – urban (LWRP)
	HEATH05	Cashmere Stream at Worsleys Road*	2479030	5736765	South-West SMP	Banks Peninsula (LWRP)
	HEATH06	Heathcote River at Rose Street*	2478700	5737528	South-West SMP	Spring-fed – plains – urban (LWRP)
	HEATH07	Heathcote River at Ferniehurst Street*	2479157	5737222	South-West SMP	Spring-fed – plains – urban (LWRP)
	HEATH08	Heathcote River at Templetons Road	2475913	5738508	South-West SMP	Spring-fed – plains – urban (LWRP)
	HEATH09	Haytons Stream at Retention Basin	2476019	5739207	South-West SMP	Spring-fed – plains – urban (LWRP)
	HEATH10	Curletts Road Stream Upstream of Heathcote River Confluence	2476927	5739322	IGSC	Spring-fed – plains – urban (LWRP)
	HEATH11	Heathcote River at Catherine Street*	2484415	5739494	IGSC	Spring-fed – plains – urban (LWRP)
	HEATH12	Heathcote River at Mackenzie Avenue Footbridge	2483521	5739528	IGSC	Spring-fed – plains – urban (LWRP)
	HEATH14	Curletts Road Stream at Southern Motorway	2476404	5739969	IGSC	Spring-fed – plains – urban (LWRP)
	HEATH16	Cashmere Stream at Sutherlands Road*	2476084	5735598	South-West SMP	Not classified[3]

[3] But considered in this report a Banks Peninsula waterway, as per the lower reaches
* These sites were also monitored during the two additional wet weather events

Catchment	Site ID	Site	Easting	Northing	ECan Consent	LWRP or WRRP Classification
Styx	STYX01	Smacks Creek at Gardiners Road near Styx Mill Road	2476803	5749571	Styx SMP	Unclassified[4]
	STYX02	Styx River at Gardiners Road	2476789	5748841	Styx SMP	Unclassified[4]
	STYX03	Styx River at Main North Road	2479066	5748834	Styx SMP	Unclassified[4]
	STYX04	Kaputone Creek at Blakes Road	2480401	5749645	Styx SMP	Unclassified[4]
	STYX05	Kaputone Creek at Belfast Road	2482195	5749882	Styx SMP	Unclassified[4]
	STYX06	Styx River at Marshland Road Bridge	2482359	5749393	Styx SMP	Unclassified[4]
	STYX07	Styx River at Richards Bridge	2483977	5751255	Styx SMP	Unclassified[4]
	STYX08	Styx River at Harbour Road Bridge	2485000	5756366	Styx SMP	Unclassified[4]
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 (LWRP)
	HALS04	Halswell River at Akaroa Highway	2474444	5733330	South-West SMP	Spring-fed – plains (LWRP)
	HALS05	Knights Stream at Sabys Road	2473720	5734461	South-West SMP	Spring-fed – plains (LWRP)
Ōtūkaikino	OTUKAI01	Ōtūkaikino River at Groynes Inlet	2477878	5750484	IGSC	OTU/GROYNES (WRRP)
	OTUKAI02	Wilsons Drain at Main North Road	2481242	5752409	Styx SMP	WAIM-TRIB (WRRP)
Linwood	OUT01	Linwood Canal/City Outfall Drain	2485954	5739637	IGSC	Unclassified[5]

[4] Although these waterways were originally classified as WAIM-TRIB in the WRRP, an amendment was made for this catchment to be covered by the NRRP (where the waterways were classified 'spring-fed - plains'). It is likely the LWRP will be amended in the future to be in line with the now inoperative NRRP (Michele Stevenson, Environment Canterbury, personal communication). Therefore, these locations are considered as 'spring-fed - plains' in this report. This is a conservative approach, as the standards for 'spring-fed - plains' in the LWRP are more stringent than the standards for WAIM-TRIB in the WRRP.

[5] It is considered that 'spring-fed – plains – urban' is the most appropriate classification for this waterway under the LWRP, in line with the Styx River catchment

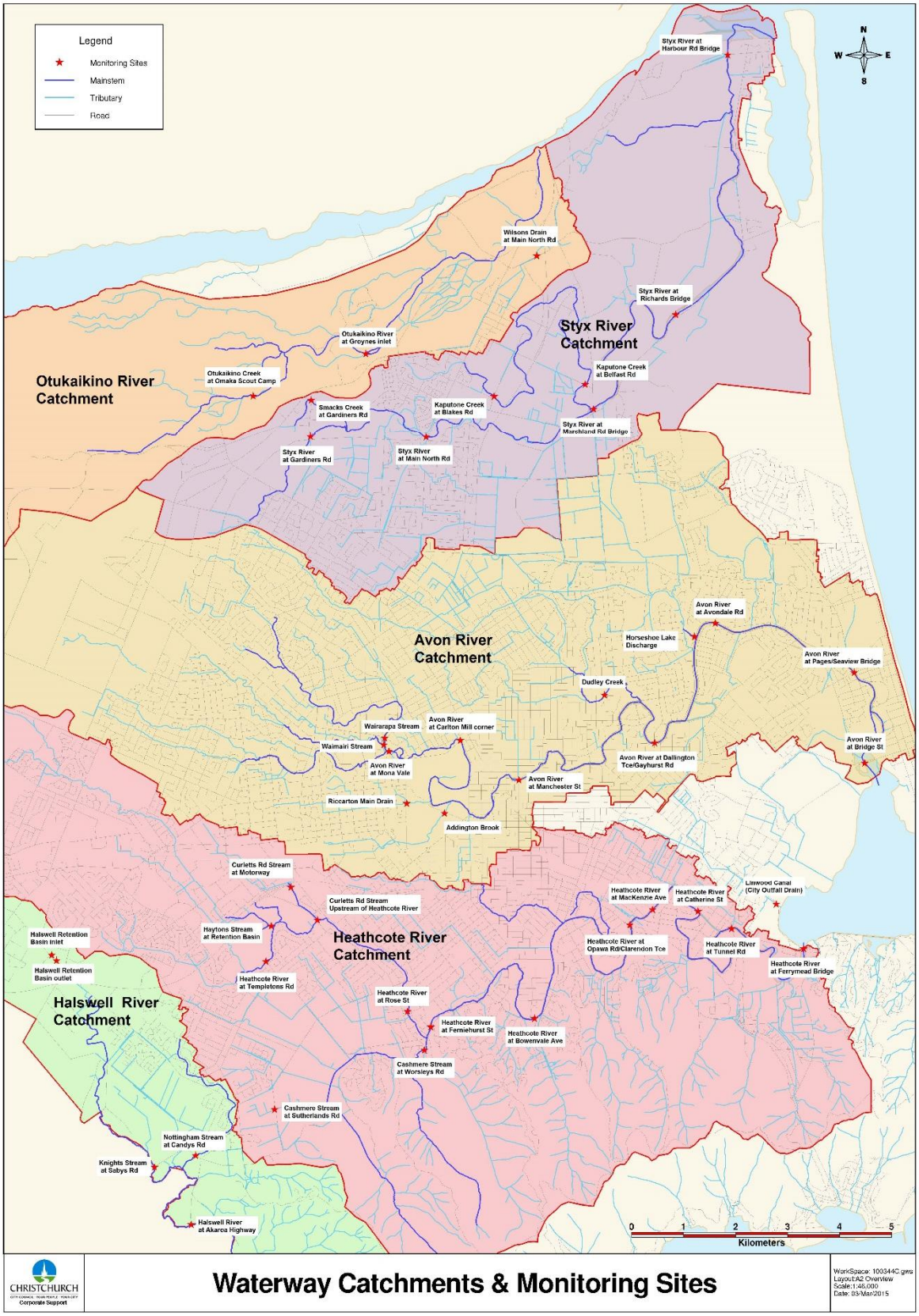


Figure 1. Location of Christchurch City Council surface water quality monitoring sites. Note that the Snellings Drain site is not presented.

3.3 Water Quality Parameters and Guideline Levels

The monthly and wet weather samples were tested at the laboratory for a range of different water quality parameters, as outlined in Table 2. Not all parameters were 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 for the monthly monitoring and the Snellings Drain quarterly monitoring, and the raw data for wet weather monitoring, 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 LWRP for all waterways are a lower limit of 6.5 and an upper limit of 8.5. The WRRP, which covers the Ōtūkaikino 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 LWRP (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 LWRP 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 LWRP 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. Ōtūkaikino 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 LWRP water quality standard for temperature is a maximum of 20°C for all waterway classifications; the WRRP details a maximum of 25°C for the waterways relevant to this monitoring report (i.e. Ōtūkaikino 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 LWRP does not have a guideline level for this parameter. The WRRP and the Ministry for the Environment (1992) guideline level is 2 mg/L, which is the value used in this report.

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 LWRP 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, 2015). For this report, the water quality standard (for both monthly and wet weather sampling) was adjusted based on the median pH levels from monthly sampling 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 Ōtūkaikino 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 95th percentiles). Both guideline levels have been assessed in this report to investigate both long-term and short-term effects. It is also noted that Schedule 8 (region-wide water quality limits) of ECan's LWRP gives a nitrate toxicity limit for lowland streams of 3.8 mg/L (measured against annual median).

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 LWRP and the WRRP do 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, 2015). The LWRP 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 LWRP 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 LWRP 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 monthly and wet weather water samples taken in accordance with consenting requirements. * = wet weather samples only.

Parameter	Units of Measurement
Total ammonia (ammoniacal nitrogen)	mg/L
Total and dissolved arsenic*	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 Petroleum Hydrocarbons*	mg/L
Total phosphorus	mg/L
Total Suspended Solids (TSS)	mg/L
Water temperature	°C
Total nitrogen	mg/L
Turbidity	NTU
Total and dissolved zinc	mg/L

3.4 Laboratory Analysis Methods

The methods used to analyse each parameter at the CCC laboratory are presented in Appendix C, Table i. Some of these methods have changed over time, as more advanced equipment has become available.

3.5 Data Analysis

3.5.1 Summary Statistics and Graphs

Summary statistics and graphs of the monthly (which also included the Snellings Drain quarterly sampling) and wet weather data were produced using IBM® SPSS® Statistics 23. To allow statistical analyses of monthly samples, values less than the laboratory Limit of Detection (LOD) were converted to half the detection limit. Monthly *E.coli* levels which exceeded the maximum laboratory limit for counting (24,000 CFU/100ml) were analysed as 24,000; it should be noted that levels may have been much higher than this. There were none of these cases in the 2015 monitoring year, but there have been in previous years, which is relevant to temporal trends analysis detailed below.

Monthly 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. Wet weather monitoring data was graphed using bar graphs. The sites in both monthly and wet weather graphs are ordered from upstream to downstream, 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 25th and 75th percentiles (the interquartile range), respectively. The T-bars that extend from the boxes approximate the location of 95% of the data (i.e. the 95th percentile). 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.

In line with the respective guideline documents and ECan guidance (Dr Lesley Bolton-Ritchie, Environment Canterbury, 6th April 2016, personal communication), the monthly data were compared to guideline levels using median levels. The exceptions being for *E. coli*, toxicants (metals and ammonia) and the 'surveillance' nitrate level, which were compared to the 95th percentiles.

For a select number of important parameters to instream health (copper, lead, zinc, TSS, DRP and *E. coli*), the monthly data were also assessed for the number of exceedances of their respective guideline levels during the monitoring year, compared to the preceding year. These comparisons also included the number of wet versus dry exceedances during these monitoring years. This is the first year that number of exceedances has been presented. Although lead was assessed, no guideline exceedances in the 2014 or 2015 monitoring year were identified, so no comparisons are presented.

Correlations were also run between monthly TSS and DRP data, for all the Avon River catchment sites combined and all the Heathcote River catchment sites combined, to determine if there was a relationship between these two parameters. This is due to phosphorus commonly being present within soil. These tests were undertaken within IBM® SPSS® Statistics 23, using Spearman's rho (as the data was not normally distributed) and scatterplots with linear trendlines.

Dissolved arsenic and total petroleum hydrocarbons were sampled in the wet weather monitoring, but not the monthly monitoring. However, as these parameters were all below the LOD, they are not presented in the results section of this report (raw data is presented in Appendix A).

3.5.2 Temporal Trends Analysis

Temporal trends analysis was carried out on the monthly data from each of the sites, to determine whether water quality is declining, improving or staying the same over time. Some of the sites have been monitored for longer periods than others, as detailed in Table 3. As the Heathcote River at Templetons Road site was not sampled from February – June and November – December 2015, due to the site being dry, 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. During the 2015 monitoring year, not all sites were sampled for zinc each month, as detailed in the methods section, so these results should also be viewed with caution.

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 (with the exception of Curletts Road Stream at Motorway and both Halswell Retention Basin sites) 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 Ōtūkaikino River catchment sites (Ōtūkaikino at Omaka Scout Camp and Wilsons Stream; Table 3). Temporal trends analysis was not able to be undertaken for Snellings Drain, given only a small number of samples were available for analysis. 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 discharge 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, as 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 monthly sampling at the 45 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
	Snellings Drain	~ August 2006
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
Ōtūkaikino	Ōtūkaikino Creek at Omaka Scout Camp	October 2014
	Ōtūkaikino River at Groynes Inlet	October 2008
	Wilsons Drain at Main North Road	November 2013
Linwood	Linwood Canal	January 2007

4 Results

4.1 Monthly Monitoring: Summary Statistics and Comparison to Guidelines

Appendix A (Tables i - iv) presents the summary statistics for the monthly (but also including the Snellings Drain quarterly sampling) data for the 2015 monitoring period. The results of the monitoring in relation to the receiving water quality guidelines are detailed in the sections below, with graphs presented in Appendix D and E.

A summary and ranking of the river sites exhibiting good ('Best Sites') and poor ('Worst Sites) water quality for each contaminant is 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. The number of samples and sites (based on medians or 95th percentiles, depending on the parameter) not meeting guideline levels for the monitoring year for each parameter is presented in Table 7.

4.1.1 Dissolved Copper

The concentrations of dissolved copper for a significant proportion of samples across all catchments during the monitoring period were below the LOD of 0.002 mg/L (Appendix D, Figures i (a) - (b)). Therefore, most interquartile ranges were not visible. The exceptions to this were the Curletts Road Stream at Motorway, Curletts Road Stream Upstream of Heathcote River and the two Retention Basin sites, 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, although there was more variability at the inlet. Compared to the 2014 monitoring year, levels were similar, except last year concentrations were much higher at the Haytons Stream and Curletts Road Stream at Motorway sites, and much lower at Curletts Road Stream Upstream of Heathcote River (Margetts & Marshall, 2015).

The largest concentrations recorded across the sites were in October at the Curletts Road Stream at Motorway site (0.011 mg/L) and at the Retention Basin Inlet site (0.0091 mg/L). Both these events were recorded in association with rain and are therefore likely due to stormwater inputs.

Both of the Curletts Road Stream sites were the only waterway sites to record their 95th percentile above the respective guideline level. Additionally, the respective guideline levels were exceeded on one sampling occasion each at the Avon River at Manchester Street, Heathcote River at Bowenvale Ave and the Ōtūkaikino River at Groynes Inlet sites.

Exceedances in 2015 were only recorded across the Avon (one site), Heathcote (three sites) and Ōtūkaikino River (one site) catchments (Appendix D, Figure i (c)). There were generally less rain events at the time of sampling in 2015 compared to 2014 across all sites. The number of guideline exceedances during wet weather mostly reduced between 2014 and 2015, with the Avon River catchment recording a reduction

at all sites, due to no exceedances occurring during 2015. There were only three sites that recorded dry exceedances in 2015, with the number of dry exceedances either greater or lower than that recorded in 2014, depending on the site. During the 2015 monitoring year, the maximum number of exceedances recorded per site, for both wet and dry sampling, was two. It is unclear why exceedances might occur during dry weather, as copper is usually associated with stormwater. This may be due to atmospheric deposition (Murphy, 2015), re-suspension of copper in sediment or this contaminant staying in suspension for a long period of time.

4.1.2 Dissolved Lead

All river sites across all catchments recorded dissolved lead concentrations consistently below the LOD of 0.0015 mg/L, with sites therefore not showing an interquartile range (Appendix D, Figures ii (a) - (b)). The exception to this was Dudley Creek, which recorded enough values above the LOD to exhibit an interquartile range. Given the low levels recorded, there were no trends in concentrations downstream for any of the catchments. The Retention Basin Inlet recorded similarly low levels to the river sites, but the outlet recorded high levels compared to the waterways and more variable concentrations. Levels were similar to that recorded in 2014, although concentrations at the Heathcote River at Ferrymead Bridge site, and the Halswell Retention basin inlet and outlet, were significantly lower this year.

Dudley Creek recorded consistently higher levels than the other sites. The highest levels recorded from all river sites were at the Curletts Road Stream at Motorway (0.0033 mg/L in September) and Addington Brook (0.0028 mg/L in April) sites. Neither reading was in association with rain. No concentrations were recorded above the respective receiving water guidelines on any occasion during the monitoring period.

4.1.3 Dissolved Zinc

Zinc levels in the Avon and Heathcote River catchments were higher than that recorded in the other catchments (Appendix D, Figures iii (a) - (b)). The two Halswell Retention Basin sites recorded levels similar to the sites with high values in the Heathcote River catchment. Levels appeared to be lower and less variable at the outlet than the inlet. Levels were generally similar compared to the 2014 monitoring year. Although Addington Brook, Dudley Creek and Heathcote River at Catherine Street recorded lower levels this year, and Curletts Road Stream Upstream of Heathcote River and the two Halswell Retention Basin sites recorded much higher levels.

Haytons and Curletts Road Streams recorded much higher and variable concentrations compared to all other river sites. As the first mainstem site downstream of the confluences with these tributaries, Heathcote River at Rose Street also recorded high levels compared to other sites, these tributaries may also be influencing levels in the mainstem. However, the Rose Street site is at least 4 kilometres downstream of the confluences, which is a long way for a contaminant plume to extend. There are, however, a number of stormwater discharges entering the river between these tributaries and the Rose Street site, which may be contributing to the high levels. The Curletts Road Stream at Motorway site recorded both of the highest concentrations across all sites during the monitoring period (0.55 mg/L in October and 0.29 mg/L in March). It was raining at the time of sampling for both events.

The 95th percentile for dissolved zinc at most river sites was below the respective water quality receiving guidelines. However, there were exceptions to this in all of the catchments. There were also other sites across the catchments that recorded values above the guidelines at certain times during the monitoring period.

Exceedances in 2015 were recorded across the five main river catchments, but not for Linwood Canal (Appendix D, Figures iii (c) – (d)[7]. There were generally less rain events at the time of sampling in 2015 compared to 2014 across all sites, although many sites in the Styx and Ōtūkaikino River catchments had a similar number of rain events. The number of guideline exceedances during wet weather mostly reduced or were similar between 2014 and 2015. In contrast, dry exceedances mostly increased across the catchments. During the 2015 monitoring year, the maximum number of exceedances recorded per site during wet weather was two (at both Curletts Road Stream sites, Heathcote River at Rose Street, Kaputone Creek at Blakes Road and Wilsons Stream). The Heathcote catchment recorded much higher dry weather exceedances than any other catchment, with a maximum value of six recorded at a site during 2015 (at the Curletts Road Stream at Motorway site).

4.1.4 pH

The levels of pH were similar across all sites and catchments during the monitoring period (Appendix D, Figures iv (a) - (b)). There were no apparent trends downstream in any of the catchments, except for a slight increase downstream within the Avon River mainstem. pH levels at the Halswell Retention Basin outlet were similar to the other river sites, although a couple of high pH levels were recorded during the monitoring period in August (9.6) and September (9.1). However, the inlet was generally higher and more variable, ranging from 7.2 - 10.2. These results are consistent with that recorded during the 2014 monitoring year.

Median pH levels for all river sites were well within the lower and upper guideline levels. However, pH was recorded at the lower guideline level in Wairarapa Stream in June 2015. It was raining during this sampling event, but it had not been in the 24-hours prior. In addition, Wilsons Stream in the Ōtūkaikino River catchment and Linwood Canal recorded a value of 8.8, above the upper guideline value of 8.5, in November (Linwood Canal) and in December (Wilsons Stream and Linwood Canal). It was not raining during the sampling periods, 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 within the Avon and Heathcote River catchments, with the tidal sites showing the most variation and the highest values, due to the higher salinity at these sites (Appendix D, Figures v (a) - (b)). In addition, the Linwood Canal site exhibited high conductivity, being tidal also. The Heathcote River recorded higher levels compared to the other catchments. The Styx and Ōtūkaikino River catchments recorded lower conductivity compared to the other catchments (no value exceeded 176 µS/cm). With the exception of the tidally influenced sites, levels did not appear to increase or decrease downstream in any of the catchments. The two Halswell

[7] Comparisons between years for the Heathcote River at Templetons Road and Curletts Road Stream at Motorway sites should be treated with caution, as they were not sampled for the whole monitoring period in 2015 and 2014, respectively.

Retention Basin sites generally recorded similar conductivity levels to each other and the river sites, although these sites recorded more variation compared to the river sites. Conductivity levels generally appeared to be lower in 2015 compared to 2014, with the exception of the tidal sites within the Avon and Heathcote Rivers, which generally appeared to have higher concentrations in 2015.

The highest value recorded (25,800 µS/cm) was at the Heathcote River at Ferrymead Bridge site in February, with no recent rainfall recorded. The highest value recorded for the sites not influenced by salinity was Heathcote River at Templetons Road (390 µS/cm in October) and this was associated with a rainfall event. This site generally recorded higher readings than the other river sites.

4.1.6 Total Suspended Solids

TSS levels were generally similar between catchments, although the Heathcote River recorded slightly higher levels than the other catchments when outliers were taken into consideration (Appendix D, Figures vi (a) - (b)). There appeared to be higher levels at the tidal sites in both the Avon and Heathcote Rivers, potentially due to re-suspension of sediment from tidal movement, where these areas naturally have soft-bottomed channels. There was no observable trend in any of the other catchments. Levels at the Halswell Retention Basin sites were in the higher range of that recorded for river sites. The outlet appeared to recorded lower levels than the inlet. These concentrations appear to be generally similar or lower than that recorded in 2014 across all the catchments. In particular, Dudley Creek, Cashmere Stream at Worsleys Road and the tidal sites in the Heathcote River mainstem recorded much lower concentrations this monitoring year.

Heathcote River at Tunnel Road recorded the highest concentration of all river sites (150 mg/L in October), followed by Heathcote River at Templetons Road (100 mg/L in October). Both these values were associated with rainfall. The Halswell Retention Basin Inlet recorded the highest overall value of 360 mg/L, also in October and was associated with rainfall.

The Heathcote River sites at Tunnel Road and Ferrymead Bridge were the only locations where median values exceeded the guideline value. This was due to the former site exceeding the guideline on a number of occasions throughout the year and the latter site exceeding the guideline on all sampling occasions. The Avon River at Bridge Street and Nottingham Stream at Candys Road sites also exceeded the guideline value on a number of occasions during the monitoring period, as shown by the interquartile range extending above the guideline value. There were also a number of sites in the Avon (three sites) and Heathcote River (four sites) catchments that exceeded the guidelines on one-off sampling events, as shown by the outliers. Both the Styx and Ōtūkaikino catchments did not record any values above the guideline during any sampling occasion.

The number of guideline exceedances during wet weather generally reduced between 2014 and 2015 for all catchments, although not by large numbers (Appendix D, Figure vi (c))[8]. Dry exceedances mostly increased slightly, but to a larger degree at the Heathcote River tidal sites. There were less rain events at the time of sampling in 2015

[8] Comparisons between years for the Heathcote River at Templetons Road and Curletts Road Stream at Motorway sites should be treated with caution, as they were not sampled for the whole monitoring period in 2015 and 2014, respectively.

compared to 2014 across all sites. Tidal sites in the Heathcote River generally recorded a greater number of exceedances than the other sites (maximum of 3 wet and 9 dry exceedances for a site in 2015).

There was a significant relationship between TSS and phosphorus within both the Avon and Heathcote River catchments, with phosphorus concentrations increasing as TSS concentrations increase (Avon: p=0.000; n=160; r_s =0.54; Heathcote: p=0.000; n=160; r_s=0.41). The r_s values suggest that these relationships are weak-moderate.

4.1.7 Turbidity

The Heathcote River catchment, followed by the Avon River catchment, generally recorded higher turbidity levels compared to the other catchments (Appendix D, Figures vii (a) - (b)). Levels were generally greater in the Avon and Heathcote River mainstems at the downstream tidal sites. As with TSS, this may be due to re-suspension of sediment from tidal movement and the naturally soft-bottomed channels at these locations. Turbidity was not recorded at the Halswell Retention Basin sites. Tributary sites often recorded higher levels than the mainstems, with the obvious exception of the tidal sites. Consistent with TSS, these results appear to be generally similar or lower to that recorded in 2014. In particular, Dudley Creek and Cashmere Stream at Worsleys Road recorded much lower concentrations this monitoring year.

The Heathcote River at Ferrymead Bridge site recorded relatively large variations in concentrations throughout the monitoring period compared to the other sites. Heathcote River at Tunnel Road recorded the highest value across all sites (69 NTU in October), it was raining at the time of sampling and had also been in the previous 24-hours.

Median turbidity concentrations for all sites were at or below the guideline level, with the exception of Dudley Creek, Avon River at Bridge Street, Heathcote River at Templetons Road, Haytons Stream at Retention Basin (this site median was only just above the guideline), Heathcote River at Tunnel Road and Heathcote River at Ferrymead Bridge. The majority of sites also exceeded the guideline level on at least one occasion during the monitoring period, the exceptions being three sites in the Avon River catchment, two sites in the Heathcote River catchment, six sites within the Styx/Ōtūkaikino catchment and Knights Stream at Sabys Road. The tidal sites of Avon River at Bridge Street, and Heathcote River at Tunnel Road and Ferrymead Bridge, only met the guideline on one sampling occasion.

4.1.8 Dissolved Oxygen

Dissolved oxygen levels were generally similar within and between catchments (Appendix D, Figures viii (a) - (b)). However, there were some sites that recorded higher variability compared to the other sites, including Curletts Road Stream Upstream of Heathcote River, Curletts Road Stream at Motorway, Styx River at Richards Bridge and Linwood Canal. No trends in concentrations were recorded downstream. The Halswell Retention Basin inlet generally recorded a greater range in values compared to the river sites, with the lowest reading at the inlet 16% in January. The outlet recorded higher levels than the inlet and levels similar to the river sites. These levels across the catchments are generally similar or higher to that recorded during the 2014 monitoring year. Of note, the Heathcote River at Templetons Road (but this site was

only monitored for part of the year, due to being dry), Haytons Stream at Retention Basin, Curletts Road Stream Upstream of Heathcote River, Wilsons Stream and Linwood Canal recorded markedly higher and generally less variable oxygen levels in 2015.

The highest dissolved oxygen reading within the river sites was 130% at Linwood Canal in December, followed by 120% at the following sites: Curletts Road Stream at Motorway (in September), Curletts Road Stream Upstream of Heathcote River (in November), Heathcote River at Rose Street (in September) and Wilsons Stream (in December). The three lowest dissolved oxygen levels were recorded at Curletts Road Stream Upstream of Heathcote River (13% in December, 17% in January and 24% in October); the December record was not associated with rainfall, but the other two records were.

The majority of river sites recorded medians above their respective minimum guideline values. However, eight sites recorded median levels below this value. The Cashmere Stream at Sutherlands Road and Styx River at Gardiners Road sites did not meet their guideline level at any time during the monitoring period. 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 2015 monitoring period was generally similar between sites and catchments (Appendix D, Figures ix (a) - (b)). The only exception being that temperature was typically more stable in the upper reaches and tributaries of the Avon River compared to the lower sites, which recorded higher and lower temperatures. Lower temperatures were recorded in the Heathcote River catchment compared to the other catchments. The two Halswell Retention Basin sites generally recorded greater variations in temperature compared to the river sites. Temperature was similar between the inlet and the outlet.

The highest value recorded was 24.6°C at Kaputone Creek at Blakes Road in December, followed by Linwood Canal in January and February (22.8°C and 21.8° C, respectively).

Median water temperatures were all below the respective guideline levels. There were only seven sites that recorded individual sampling events above the guideline. The Curletts Road and Kaputone Creek sites are the only ones of these sites that are not tidal.

Overall, higher temperatures were recorded more frequently during the 2015 monitoring year across all catchments, compared to the 2014 monitoring year. No sampling events exceeded the guidelines level for any site in 2014, except Linwood Canal, but many sites recorded values above the guideline level in 2015. This may be a reflection of lower water levels in 2015.

4.1.10 Biochemical Oxygen Demand

BOD_5 levels were typically lower in the Styx and Ōtūkaikino catchments, with most sites in this catchment consistently recording values below the LOD (Appendix D, Figures x (a) - (b)). The Heathcote River catchment recorded higher levels across more sites than the other catchments. There were no obvious trends downstream for any of the catchments, although the tributaries of the Avon catchment typically recorded higher levels than the mainstem. The two Halswell Retention Basin sites recorded substantially higher concentrations and variability than the river sites. Levels were slightly lower at the outlet. Within the Avon, Heathcote and Halswell River catchments, levels were mostly higher in 2015 compared to the 2014 monitoring year. In contrast, levels were lower in 2015 within the Styx and Ōtūkaikino River catchments.

The highest levels recorded at the river sites were 6.5 mg/L at Haytons Stream in August and 6.3 mg/L at the Heathcote River at Templetons Road site in October. Median BOD_5 levels for all river sites were below the guideline level of 2 mg/L. Most of the median values were equal to the laboratory LOD (32 out of 43 river sites). However, there were many sites that exceeded the guideline value on individual sampling events throughout the year.

4.1.11 Total Ammonia (Ammoniacal Nitrogen)

Levels of ammonia were generally similar across the catchments (Appendix D, Figures xi (a) - (b). Concentrations were generally higher in the lower reaches of the mainstems and the tributaries generally recorded higher levels than the mainstems. The two Halswell Retention Basin sites recorded substantially higher levels and variation than the river sites. Higher and more varied concentrations were recorded at the inlet than the outlet. A maximum value of 5.4 mg/L was recorded at the outlet and 5.2 mg/L at the inlet.

Linwood Canal recorded higher levels and more variation in concentrations compared to all other river sites. The highest river value recorded was in this waterway (1.0 mg/L) in July, when no rainfall was recorded. Ammonia levels were well below the respective receiving water quality guidelines for all samples at all sites throughout the monitoring period, with the exception of Linwood Canal, which recorded one value above this (1.0 mg/L in July).

These trends were variable to that recorded during the 2014 monitoring year, with some sites recording higher levels in 2015 and others lower levels. In particular, levels recorded in Addington Brook, Haytons Stream and the two Kaputone Creek sites were substantially lower in 2015.

4.1.12 Nitrate, Nitrate Nitrite Nitrogen and Dissolved Inorganic Nitrogen

Nitrogen levels in the Heathcote and Halswell River catchments were generally higher than that recorded in the other catchments (Appendix D, Figures xii (a) - (b), xiii (a) - (b) and xiv (a) - (b)). Sites in the Styx and Ōtūkaikino River catchments generally recorded lower concentrations than the other sites. Concentrations decreased downstream in the Avon and Heathcote River mainstems. These consistent trends between these three

parameters are not surprising, considering NNN is the sum of nitrate and nitrite, and DIN is the sum of NNN and ammonia.

The two Halswell Retention Basin sites generally recorded nitrate and NNN levels below that recorded in the Avon, Heathcote and Halswell River catchments, but similar to the Styx and Ōtūkaikino River catchments. The median concentrations at the basin outlet was slightly higher than the inlet for these parameters. For DIN, due to the high ammonia levels, the basin inlet and outlet recorded DIN levels similar to the highest levels recorded at the river sites, and generally recorded more variability. Median DIN concentrations were similar between the inlet and outlet.

Nitrogen concentrations across the sites were generally lower than that recorded last monitoring year, but the trends were similar. The Heathcote River at Templetons Road (although only monitored for part of the year) and Knights Stream at Sabys Road sites recorded much lower concentrations compared to last year. However, this first site was only monitored for part of the monitoring year this year. In contrast, the Halswell River at Akaroa Highway site recorded much higher levels this monitoring year compared to last.

The Knights Stream at Sabys Road and Halswell River at Akaroa Highway sites recorded much higher concentrations of all three nitrogen than the other sites. The latter site recorded the maximum nitrate, NNN and DIN value of 7.0 mg/L in March, with rain in the present within the 24 hours prior to sampling. Knights Stream at Sabys Road also recorded a high DIN value in May (6.2 mg/L). No rain occurred within 24 hours prior to sampling at this site. The Heathcote River at Templetons Road, Curletts Road Stream at Motorway and Curletts Road Stream Upstream of Heathcote River sites also showed marked variability compared to the other 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. Two other sites in the Heathcote catchment also recorded values above the grading guideline on at least one sampling occasion (Heathcote River at Templetons Road and Curletts Road Stream Upstream of Heathcote River). Knights Stream at Sabys Road and Halswell River at Akaroa Highway were also exceeded the surveillance guideline value of 5.6 mg/L.

The vast majority of sites recorded median NNN concentrations substantially higher than the guideline value of 0.444 mg/L, with the exception of eleven sites, although four of these eleven sites did record several events above the guideline during the monitoring period.

Median DIN levels exceeded the guideline at five sites in the Avon River catchment, nine sites in the Heathcote River catchment, one site each in the Styx (Kaputone Creek at Blakes Road) and Ōtūkaikino (Wilsons Stream) River catchments, and two sites in the Halswell River catchment.

4.1.13 Dissolved Reactive Phosphorus

Phosphorus levels were generally similar between catchments (Appendix D, Figures xv (a) - (b), and Appendix E, Figures iv (a) - (b)). Many of the tributaries recorded higher concentrations that the mainstems. Concentrations generally increased downstream in the Avon, Heathcote and Styx catchments, potentially due to this input from the

tributaries. Samples from the Halswell Retention Basin sites were much higher and variable than the majority of the river sites, with the notable exception of the Haytons Stream at Retention Basin site. The Halswell Retention Basin sites Outlet recorded levels lower and less variable than the inlet, and within the upper range of that recorded by the river sites.

The Haytons Stream at Retention Basin site recorded substantially higher and more variable concentrations than the other river sites, with the highest value of 0.6 mg/L recorded in December (not associated with rain). This concentration was at least three times higher than any value recorded from any other river site over the 2015 monitoring period. Linwood Canal was the river site recording the next highest and variable concentrations (0.029 - 0.19 mg/L).

Just over half of river sites recorded median concentrations above the guideline levels. Eight sites never exceeded their respective guideline values during the monitoring period and nine sites always exceeded their guideline levels.

When compared to last year's monitoring, levels across all catchments were similar or lower to that recorded in 2015 (Margetts & Marshall, 2015). Addington Brook, and Kaputone Creek at Belfast and Blakes Roads recorded markedly lower phosphorus levels than in 2014.

Most sites recorded either less or a similar numbers of rain events at the time of sampling in 2015 compared to 2014 (Appendix D, Figures xv (c) - (d))[9]. The number of guideline exceedances during wet weather generally reduced between 2014 and 2015 across all catchments. Dry exceedances mostly increased, with a smaller number of sites remaining stable. The Kaputone Creek, and all sites within the Styx River downstream of this tributary, recorded the highest number of wet weather exceedances during the monitoring year for all catchments (all sites recording 6 - 7 exceedances). The Avon River catchment and Linwood Canal recorded the highest number of dry exceedances in 2015 (maximum of 11 exceedances at a given site), followed by the Heathcote and Halswell River catchments (maximum of 9 exceedances at a given site).

4.1.14 *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 (Appendix D, Figures xvi (a) – (b), Appendix E, Figure v). Levels were similar to that recorded during the 2014 monitoring year, although the Styx River catchment appeared to recorded lower levels in 2015. The Halswell Retention Basin Inlet recorded substantially higher values and variability than the river sites. In contrast, the outlet recorded similar levels to the river sites.

Of note, *E.coli* levels were noticeably higher and more variable at Addington Brook, Dudley Creek, and the two Kaputone Creek sites. 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 660 CFU/100ml in September. The highest river value recorded was 24,000 CFU/100ml at Riccarton Main Drain in July

[9] Comparisons between years for the Heathcote River at Templetons Road and Curletts Road Stream at Motorway sites should be treated with caution, as they were not sampled for the whole monitoring period in 2015 and 2014, respectively.

and Nottingham Stream at Candys Road in September. Neither of these events were associated with rain.

The ECan guideline states that 95% of *E. coli samples* should be below 550 CFU/100ml (Environment Canterbury, 2015). Therefore comparison against the T-bars of the box-plot graphs 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 30 of the 43 waterway sites. In addition, concentrations were greater than 550 CFU/100ml on at least one sampling occasion during the monitoring period at 39 of the 43 sites. These exceptions being Wairarapa Stream, Avon River at Pages/Seaview Bridge, Ōtūkaikino Creek at Omaka Scout Camp and the Ōtūkaikino River at Groynes Inlet.

The number of exceedances during wet weather mostly decreased across the catchments compared to 2014, especially in the Avon River catchment (nine of thirteen sites where exceedances were recorded) and the Styx River catchment (seven of eight sites where exceedances were recorded) (Appendix D, Figures xvi (c) - (d))[10]. The number of guideline exceedances during dry weather were variable compared to 2014, with some sites showing an increase, reduction or similar number of exceedances. The Avon River catchment in particular showed an increase at nine of the ten sites where exceedances were recorded. There were generally similar or less rain events at the time of sampling in 2015 compared to 2014 across all catchments, although many sites in the Styx and Ōtūkaikino River catchments had a similar number of rain events. The highest number of wet weather exceedances in 2015 were recorded within the Styx River Catchment (maximum value of 6 exceedances). The Avon River catchment recorded the highest number of dry weather exceedances, with a maximum of eight. No exceedances of guideline levels coincided with wastewater overflow events.

[10] Comparisons between years for the Heathcote River at Templetons Road and Curletts Road Stream at Motorway sites should be treated with caution, as they were not sampled for the whole monitoring period in 2015 and 2014, respectively.

Table 4. Waterway 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 2015. Best Sites were those with much better levels than other sites. Worst Sites were those that recorded median/95th percentile values 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 = Ōtūkaikino River catchment, purple font = Halswell River catchment and black font = Linwood Canal. Not all sites were analysed for zinc every month, and the Heathcote River at Templetons Road and Snellings Drain sites were not monitored at all during certain months, so these results should be viewed with caution (refer to the methods section for more information).

Contaminant	Best Sites	Worst Sites
Dissolved copper	There were many sites across all catchments that only recorded levels below the LOD	Curletts Road Stream at Motorway 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	Heathcote River at Templetons Road Knights Stream at Sabys Road (all values below Ōtūkaikino River guideline of 0.00868 mg/L)	Avon River at Dallington Terrace/Gayhurst Road Haytons Stream at Retention Basin Curletts Road Stream at Motorway Curletts Road Stream Upstream of Heathcote River Heathcote River at Rose Street Cashmere Stream at Sutherlands Road Styx River at Main North Road Kaputone Creek at Blakes Road Styx River at Richards Bridge Ōtūkaikino Creek at Omaka Scout Camp Wilsons Stream Nottingham Stream at Candys Road
pH	None	None
Conductivity	Ōtūkaikino Creek at Omaka Scout Camp Ōtūkaikino River at Groynes Inlet (all values below 100 µS/cm)	N/A
Total Suspended Solids Turbidity	Cashmere Stream at Sutherlands Road Styx River at Gardiners Road Styx River at Main North Road Ōtūkaikino Creek at Omaka Scout Camp Ōtūkaikino River at Groynes Inlet (all TSS values below 5 mg/L or all turbidity values below 2 NTU)	Dudley Creek Avon River at Bridge Street Heathcote River at Templetons Road Haytons Stream at Retention Basin Heathcote River at Tunnel Road Heathcote River at Ferrymead Bridge
Dissolved oxygen	Avon River at Mona Vale Avon River at Carlton Mill Corner Riccarton Main Drain Avon River at Manchester Street Avon River at Bridge Street Wilsons Stream (all values greater than Ōtūkaikino River guideline of 80%)	Horseshoe Lake Discharge Curletts Road Stream Upstream of Heathcote River Cashmere Stream at Sutherlands Road Cashmere Stream at Worsleys Road Heathcote River at Mackenzie Avenue Heathcote River at Catherine Street Styx River at Gardiners Road Smacks Creek at Gardiners Road
Water temperature	None	None
Biochemical Oxygen Demand	Wairarapa Stream Waimairi Stream Avon River at Avondale Road Bridge Smacks Creek at Gardiners Road Styx River at Main North Road Ōtūkaikino Creek at Omaka Scout Camp Ōtūkaikino River at Groynes Inlet (all values below the LOD)	None
Total ammonia	Styx River at Gardiners Road Ōtūkaikino River at Groynes Inlet Ōtūkaikino Creek at Omaka Scout Camp (all values below 0.03 mg/L)	None
Nitrate Nitrate Nitrite Nitrogen Dissolved Inorganic Nitrogen	Dudley Creek Snellings Drain Horseshoe Lake Ōtūkaikino River at Groynes Inlet Ōtūkaikino Creek at Omaka Scout Camp Linwood Canal (all values below nitrate and NNN guideline of 3.8 mg/L and 0.444 mg/L, respectively)	Most sites, particularly: Knights Stream at Sabys Road Halswell River at Akaroa Highway
Dissolved Reactive Phosphorus	Waimairi Stream Cashmere Stream at Sutherlands Road Styx River at Gardiners Road Smacks Creek at Gardiners Road Styx River at Main North Road Ōtūkaikino Creek at Groynes Inlet Knights Stream at Sabys Road (all values below predominant guideline of 0.016 mg/L)	23 of the 43 sites, particularly: Haytons Stream at Retention Basin Linwood Canal
Escherichia coli	Wairarapa Stream Avon River at Pages/Seaview Bridge Ōtūkaikino River at Groynes Inlet Ōtūkaikino Creek at Omaka Scout Camp (all values below guideline of 550 CFU/100ml)	31 of 43 sites, particularly: Addington Brook Dudley Creek Kaputone Creek at Blakes Road Kaputone Creek at Belfast Road

Table 5. Summary of the best and worst waterway sites during the monitoring period of January to December 2015, at a catchment and site scale, based on the number of times a catchment/site occurred in Table 4. The Heathcote River at Templetons Road site was not monitored for a full year, so these results should be viewed with caution. Red font = Avon River catchment, orange font = Heathcote River catchment, blue font = Styx River catchment, green font = Ōtūkaikino River catchment, purple font = Halswell River catchment and black font = Linwood Canal.

Placing	Best Sites		Worst Sites	
	Catchment Scale	Site Scale	Catchment Scale	Site Scale
	Ōtūkaikino River Avon River (14 occurrences)	Ōtūkaikino River at Groynes Inlet (7 occurrences)	Heathcote River (17 occurrences)	Haytons Stream at Retention Basin Curletts Road Stream Upstream of Heathcote River (3 occurrences)
	Styx River (8 occurrences)	Ōtūkaikino Creek at Omaka Scout Camp (6 occurrences)	Styx River (7 occurrences)	Dudley Creek Curletts Road Stream at Motorway Cashmere Stream at Sutherlands Road Kaputone Creek at Blakes Road (2 occurrences)
	Heathcote River (3 occurrences)	Styx River at Gardiners Road Styx River at Main North Road (3 occurrences)	Avon River (6 occurrences)	Addington Brook Horseshoe Lake Discharge Avon River at Dallington Terrace/Gayhurst Road Avon River at Bridge Street Heathcote River at Templetons Road Heathcote River at Rose Street Cashmere Stream at Worsleys Road Heathcote River at Mackenzie Avenue Heathcote River at Catherine Street Heathcote River at Tunnel Road Heathcote River at Ferrymead Bridge Styx River at Richards Bridge Styx River at Gardiners Road Smacks Creek at Gardiners Road Styx River at Main North Road Kaputone Creek at Belfast Road Ōtūkaikino River at Groynes Inlet Ōtūkaikino Creek at Omaka Scout Camp Knights Stream at Sabys Road Nottingham Stream at Candys Road Halswell River at Akaroa Highway Linwood Canal (1 occurrence)

Table 6. Waterway sites within each catchment that recorded medians/95th percentiles outside the guideline levels and/or recorded substantially different one-off events compared to other sites within the catchment during the monitoring period of January to December 2015. 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, DIN = Dissolved Inorganic Nitrogen and DRP = Dissolved Reactive Phosphorus. Parameters that co-vary, such as nitrogen compounds (nitrate, NNN and DIN) and sediment (TSS/turbidity) have been combined where relevant. As most sites did not meet the NNN, DRP and *E. coli* guidelines, only those sites with the highest levels are recorded. Not all sites were analysed for zinc every month, and the Heathcote River at Templetons Road and Snellings Drain sites were not monitored at all during certain months, so these results should be viewed with caution (refer to the methods section for more information).

Catchment	Sites
Avon River	Riccarton Main Drain (BOD_5, nitrate/NNN/DIN, DRP, *E.coli*) Dudley Creek (lead, turbidity, DRP, *E.coli*) Avon River at Bridge Street (turbidity, temperature, BOD_5) Addington Brook (DO, *E.coli*) Avon River at Mona Vale (nitrate/NNN/DIN) Waimairi Stream (*E.coli*) Avon River at Manchester Street (copper) Avon River at Dallington Terrace/Gayhurst Road (zinc) Horseshoe Lake Discharge (DO) Avon River at Avondale Bridge (temperature) Avon River at Pages/Seaview Bridge (temperature)
Heathcote River	Curletts Road Stream Upstream of Heathcote River (copper, zinc, turbidity, DO, ammonia, nitrate/NNN/DIN, DRP) Haytons Stream at Retention Basin (zinc, turbidity, DO, BOD_5, ammonia, DRP) Curletts Road Stream at Motorway (copper, zinc, lead, temperature, nitrate/NNN, DRP) Heathcote River at Templetons Road (turbidity, BOD_5, nitrate/NNN/DIN) Heathcote River at Rose Street (zinc, nitrate/NNN/DIN, DRP) Cashmere Stream at Sutherlands Road (zinc, DO) Cashmere Stream at Worsleys Road (turbidity, DO) Heathcote River at Mackenzie Ave (DO, *E.coli*) Heathcote River at Catherine Street (DO, ammonia) Heathcote River at Ferrymead Bridge (TSS/turbidity, temperature) Heathcote River at Bowenvale Ave (*E.coli*) Heathcote River at Tunnel Road (TSS/turbidity)
Styx River	Kaputone Creek at Blakes Road (zinc, temperature, BOD_5, ammonia, nitrate/NNN/DIN, *E.coli*) Kaputone Creek at Belfast Road (BOD_5, ammonia, nitrate/NNN, DRP, *E.coli*) Styx River at Richards Bridge (zinc, DO, DRP) Styx River at Harbour Road Bridge (DO, DRP) Styx River at Gardiners Road (DO) Smacks Creek at Gardiners Road (DO) Styx River at Main North Road (zinc) Styx River at Marshland Road Bridge (BOD_5)
Ōtūkaikino River	Wilsons Stream (zinc, pH, nitrate/NNN, *E.coli*) Ōtūkaikino River at Groynes Inlet (copper)
Halswell River	Nottingham Stream at Candys Road (zinc, DRP, *E.coli*) Knights Stream at Sabys Road (nitrate/NNN/DIN) Halswell River at Akaroa Highway (nitrate/NNN)
Linwood Canal	Linwood Canal (pH, DO, temperature, ammonia, DRP)

Table 7. Number of waterway sites monitored for each parameter, the number of samples taken and the number of samples and sites (based on medians/95th percentiles) not meeting the guideline levels, during the monitoring period of January to December 2015. Not all sites were analysed for zinc every month, and the Heathcote River at Templetons Road and Snellings Drain sites were not monitored at all during certain months. Each parameter is ranked based on the highest percentage of samples not meeting guideline levels (except lead, which recorded no exceedances).

Parameter	Guideline	Number of Sites Monitored	Number of Samples Analysed	Number of Samples Not Meeting Guideline	Number of Sites Not Meeting Guidelines
Dissolved copper	Varies depending on catchment, from <0.00152 mg/L to <0.00543 mg/L	43	499	6 (1.2%) *Ranked 12th*	2 (Curletts Road Stream at Motorway, Curletts Road Stream Upstream of Heathcote River)
Dissolved lead	Varies depending on catchment, from <0.00384 mg/L to <0.167 mg/L	43	499	0 (0%)	0
Dissolved zinc	Varies depending on catchment, from <0.00868 mg/L to <0.146 mg/L	43	431	60 (13.9%) *Ranked 7th*	12
pH	6.5 to 8.5	43	499	3 (0.6%) *Ranked 13th*	0
Total Suspended Solids	<25 mg/L	43	499	33 (6.6%) *Ranked 8th*	2 (Heathcote River at Tunnel Road, Heathcote River at Ferrymead Bridge)
Turbidity	<5.6 NTU	38	440	94 (21.4%) *Ranked 5th*	6
Dissolved oxygen	Varies depending on catchment, from >70% to >90%	42	497	104 (20.9%) *Ranked 6th*	8
Water temperature	Varies depending on catchment, from <20°C to <25°C	42	497	14 (2.8%) *Ranked 11th*	0
Biochemical Oxygen Demand	<2 mg/L	43	499	28 (5.6%) *Ranked 9th*	0
Total ammonia	Varies depending on catchment, from <0.32 mg/L to <1.61 mg/L	43	498	1 (0.2%) *Ranked 14th*	0
Nitrate	<3.8 mg/L	43	499	24 (4.8%) *Ranked 10th*	2 (Knights Stream at Sabys Road, Halswell River at Akaroa Highway)
Nitrate Nitrite Nitrogen	<0.444 mg/L	43	499	382 (76.6%) *Ranked 1st*	32
Dissolved Inorganic Nitrogen	Varies depending on catchment, from <0.09 mg/L to <1.5 mg/L	43	499	203 (40.7%) *Ranked 3rd*	18
Dissolved Reactive Phosphorus	Varies depending on catchment, from <0.016 mg/L to <0.025 mg/L	43	499	278 (55.7%) *Ranked 2nd*	25
Escherichia coli	<550/100ml	43	499	149 (29.9%) *Ranked 4th*	30
Total	-	43	7,353	2,765 (37.6%)	42 (97.7%) (for at least one parameter)

4.2 Monthly Monitoring: 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 since monitoring began (332 incidences, 61.4%; Tables 8a to 8d). However, a number of sites recorded statistically significant upward (99 incidences, 18.3%) and downward (110 incidences, 20.3%) trends in concentrations. This is similar to that recorded in 2014 (no trend = 335 incidences, upward trend = 104 incidences and downtrend trend = 108 incidences; Margetts & Marshall, 2015). Most downward trends indicated an improvement in water quality, with the exception of dissolved oxygen (6 incidences), 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. However, all changes in pH levels during this assessment were small (no greater than 1%).

Of note, the majority of sites in the Avon and Heathcote River catchments recorded a decrease in DRP levels since monitoring began. Turbidity within the Styx River decreased across most sites. Temperature also increased across all Avon River catchment sites, although only by 1-2%. NNN decreased at five of the eight Styx River catchment sites. *E. coli* levels within the Styx River catchment showed an increasing trend across most sites. All of these trends are consistent to that recorded during the 2014 monitoring year (Margetts & Marshall, 2015).

The largest increase at a given site was a 29% change in dissolved zinc at the Cashmere Stream at Sutherlands Road site (Figure 2). With the exclusion of a couple of record high spikes in concentrations in early 2013, this site has shown fairly stable zinc levels since monitoring began until late 2015, when additional spikes in concentrations have occurred, causing the significant positive trend. These peaks were not associated with rainfall. No significant increase or decrease in zinc levels was recorded at this site last monitoring year (i.e. levels were stable; Margetts & Marshall, 2015). However, it should be noted that five samples were unable to be analysed from this site during the monitoring year (refer to the methods for more information). This may therefore may have skewed the trend analysis, making the trend more significant. To check this, we re-ran the temporal trends with all the samples we currently have processed from the 2016 monitoring year, which included January to June. With the addition of these six samples, there was no longer a significant change in zinc levels at this site.

Another notable increase was conductivity at the Avon River at Bridge Street site (24%; Figure 3). This result is consistent with last year's monitoring, which recorded a 25% increase (Margetts & Marshall, 2015). This increase has occurred gradually since 2010.

The largest decrease was for dissolved zinc at the Curletts Road Stream Upstream of Heathcote River site, which decreased by 57% (Figure 4; based on eleven samples over the monitoring year). Last year a decrease of 146% was recorded (Margetts & Marshall, 2015). Despite the overall decrease since monitoring began, concentrations increased over the 2015 monitoring year. This site also recorded a 20% decrease in turbidity following high levels in 2010/2011 (Figure 5). A 26% percent reduction in turbidity was recorded last year at this site (Margetts & Marshall, 2015). Copper also recorded a 38% decrease last monitoring year (Margetts & Marshall, 2015), but there were too many samples below the LOD this year to allow the Time Trends analysis to run.

The Ōtūkaikino River at Groynes Inlet site also recorded a 20% decrease in turbidity and DRP, due to gradual declines in both parameters since 2009 (Figures 6 - 7). This is consistent with that recorded last year (22% and 25% reduction in DRP and turbidity, respectively; Margetts & Marshall, 2015).

Table 8a. Direction of significant trends (p≤0.05) for parameters monitored monthly at each of the sites in the Avon River catchment (refer to Table 3 for sample periods). 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 of 0% are due to rounding values of less than one to the nearest whole number. Zinc results should be treated with caution, as not all sites were able to be monitored every month during the 2015 monitoring year (refer to the methods for more information).

Site	Dissolved Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Total Ammonia	NNN	DIN	*E. coli*
Wairarapa Stream		â 8%	á 0%				á 1%	á 1%					
Waimairi Stream		â 6%	á 1%			â 6%	á 1%	á 0%					
Avon River at Mona Vale		â 7%	á 1%			â 7%		á 1%					
Avon River at Carlton Mill Corner		â 12%	á 1%			Not Sampled		á 1%					
Riccarton Main Drain		â 10%	á 0%	á 4%				á 1%			á 10%	á 10%	
Addington Brook	â 17%		á 1%					á 1%	â 6%				
Avon River at Manchester Street		â 13%	á 1%					á 2%					
Dudley Creek			á 1%	â 5%	á 10%	á 11%		á 2%	â 8%		â 11%	â 8%	
Avon River at Dallington Terrace/Gayhurst Road			á 1%		â 12%			á 2%					
Horseshoe Lake Discharge			á 1%	â 3%				á 2%	â 4%		â 4%	â 4%	á 12%
Avon River at Avondale Road		â 7%	á 1%			Not Sampled		á 1%				â 3%	
Avon River at Pages/Seaview Bridge	â 14%	â 4%	á 1%	á 16%		â 6%	á 2%	á 1%					á 9%
Avon River at Bridge Street		â 7%	á 1%	á 24%			á 2%	á 1%		â 6%			á 13%

Table 8b. Direction of significant trends (p≤0.05) for parameters monitored monthly at each of the sites in the Heathcote River catchment (refer to Table 3 for sample periods). 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 of 0% are due to rounding values of less than one to the nearest whole number. No monitoring was undertaken at the Curletts Road Stream at Motorway site January – May 2014, due to construction, and at the Heathcote River at Templeton's Road site from February – June and November – December 2015, as the site was dry. Zinc results should be treated with caution, as not all sites were able to be monitored every month during the 2015 monitoring year (refer to the methods for more information). Insufficient data = site not monitored for this parameter for the required three years to be able to undertake analyses (site only monitored since September 2014). N/A = unable to be analysed, due to many levels being below the laboratory limit of detection.

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		â 12%	á 1%	á 2%									
Haytons Stream at Retention Basin	N/A		â 16%							â 9%		â 17%	â 19%	
Curletts Road Stream at Motorway			â 15%	á 1%	á 2%		Not Sampled					â 7%	â 7%	
Curletts Road Stream Upstream of Heathcote River	N/A	â 57%		á 1%		â 9%	â 20%				â 14%			
Heathcote River at Rose Street	N/A		â 13%	á 1%						â 8%				
Cashmere Stream at Sutherlands Road	N/A	á 29%	â 19%	á 1%				â 2%			â 18%	â 6%	â 6%	
Cashmere Stream at Worsleys Road	N/A		â 7%	á 1%	â 1%	â 3%	â 8%							
Heathcote River at Ferniehurst Street	N/A		â 11%	á 1%										
Heathcote River at Bowenvale Ave	N/A		â 8%	á 1%			â 5%							
Heathcote River at Opawa Road/Clarendon Terrace	N/A		â 8%	á 1%		â 7%	â 11%							
Heathcote River at Mackenzie Avenue	N/A	Insufficient Data	â 12%	á 1%		â 10%	Not Sampled							
Heathcote River at Catherine Street	N/A		â 12%	á 1%			Not Sampled			â 3%				
Heathcote River at Tunnel Road	N/A		â 11%	á 1%		â 4%	â 8%				â 9%			
Heathcote River at Ferrymead Bridge	N/A		â 15%	á 0%			â 4%	á 1%		â 3%	â 16%			

Table 8c. Direction of significant trends (p≤0.05) for parameters monitored monthly at each of the sites in the Halswell River catchment and Linwood Canal (refer to Table 3 for sample periods). 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. Zinc results should be treated with caution, as not all sites were able to be monitored every month during the 2015 monitoring year (refer to the methods for more information). N/A = unable to be analysed, due to many levels being below the laboratory limit of detection.

Site	Dissolved copper	Dissolved Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Total Ammonia	NNN	DIN	*E. coli*
Halswell Retention Basin Inlet				á 1%	á 4%		Not Sampled			â 14%		á 14%		á 13%
Halswell Retention Basin Outlet						â 13%	Not Sampled			â 14%		á 18%		
Knights Stream at Sabys Road	N/A				á 8%				â 2%			á 15%	á 15%	
Nottingham Stream at Candy's Road	N/A			á 1%	â 6%							â 10%	â 8%	
Halswell River at Akaroa Highway	N/A		â 8%	á 1%										á 14%
Linwood Canal	N/A			á 1%	á 14%	á 7%			á 2%	â 6%		â 17%	â 8%	

Table 8d. Direction of significant trends (p≤0.05) for parameters monitored monthly at each of the sites in the Styx and Ōtūkaikino River catchments (refer to Table 3 for sample periods). 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 of 0% are due to rounding values of less than one to the nearest whole number. Ōtūkaikino Creek at Omaka Scout Camp and Wilsons Stream were not assessed, as three years of sampling is required for statistical analysis. Zinc results should be treated with caution, as not all sites were able to be monitored every month during the 2015 monitoring year (refer to the methods for more information).

Site	Dissolved Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Total Ammonia	NNN	DIN	*E. coli*
Styx River at Gardiners Road		â 4%	á 0%	â 2%		â 9%		á 0%			â 6%	â 7%	á 16%
Smacks Creek at Gardiners Road		â 5%	á 1%	â 3%		â 9%		á 1%			â 5%	â 5%	
Styx River at Main North Road			á 1%	â 1%		â 12%	â 1%				â 6%	â 5%	á 8%
Kaputone Creek at Blakes Road			á 0%			á 6%				á 6%	á 6%	á 6%	á 7%
Kaputone Creek at Belfast Road			á 1%	â 1%	â 5%	â 7%	á 1%	á 1%			á 3%	á 3%	á 7%
Styx River at Marshland Road Bridge			á 1%	â 1%	â 6%	â 7%		á 1%					á 7%
Styx River at Richards Bridge			á 1%	â 1%							â 3%		á 12%
Styx River at Harbour Road Bridge			á 1%	â 4%		â 6%		á 2%			â 5%	â 5%	
Ōtūkaikino River at Groynes Inlet		â 20%	á 0%			â 20%	â 2%				â 8%	â 8%	

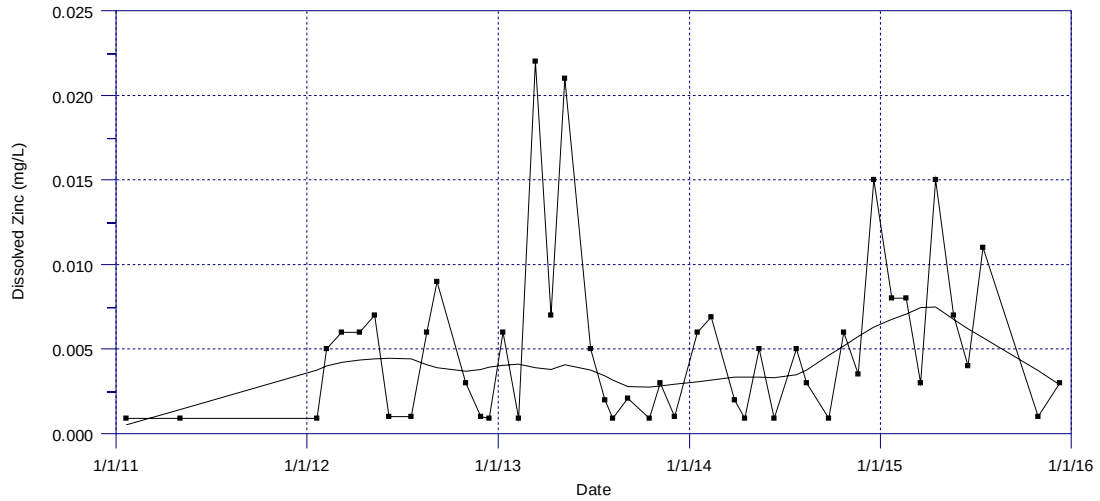


Figure 2. Dissolved zinc levels at the Cashmere Stream at Sutherlands Road site for the monitoring period December 2010 to December 2015. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A positive trend of 29% was recorded over the sampling period. These results should be taken with caution, as only seven samples were able to be taken during the 2015 monitoring year.

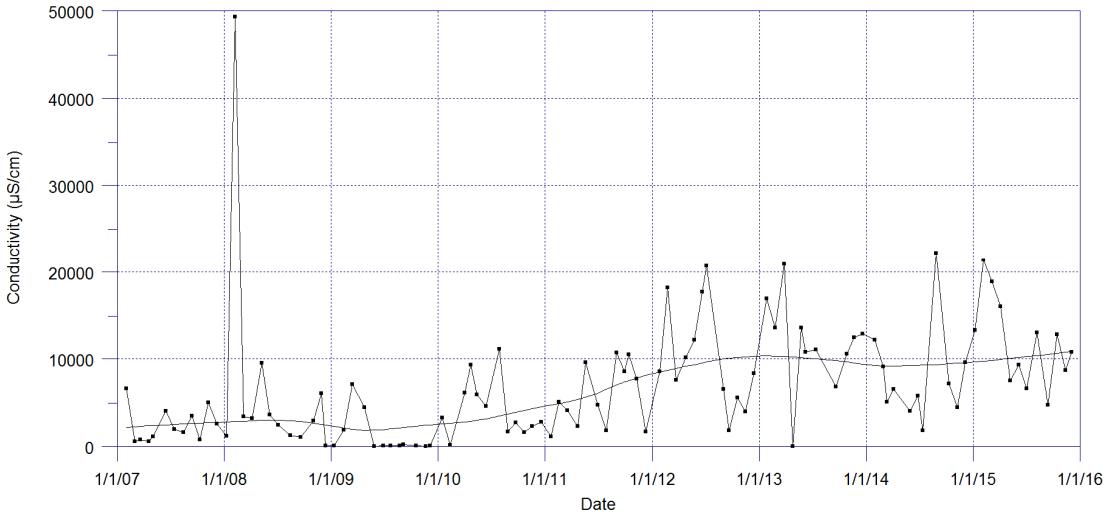


Figure 3. Conductivity levels at the Avon River at Bridge Street site for the monitoring period January 2007 to December 2015. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A positive trend of 24% was recorded over the sampling period.

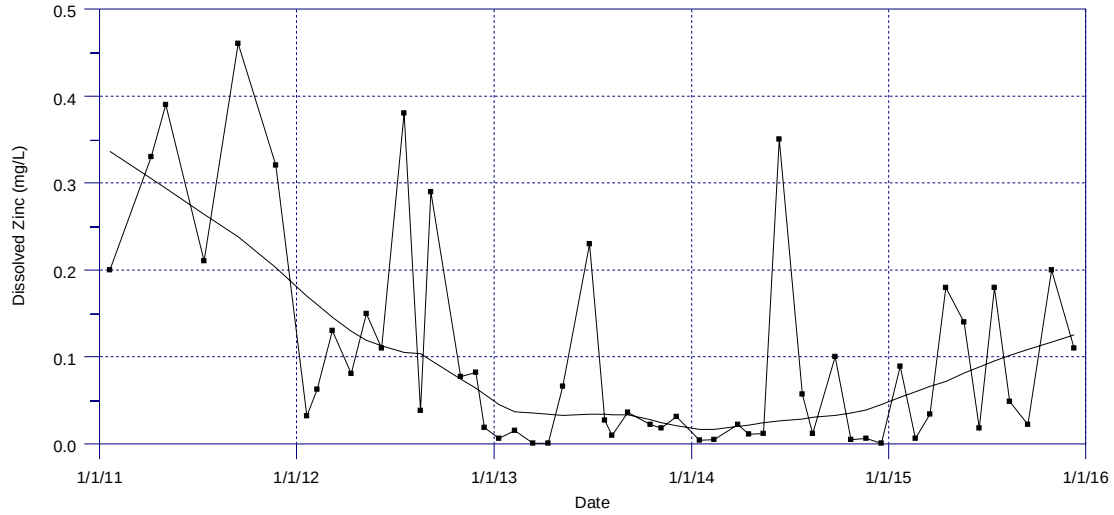


Figure 4. Dissolved zinc levels at the Curletts Road Stream Upstream of Heathcote River site for the monitoring period January 2011 to December 2015. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A negative trend of 57% was recorded over the sampling period. Only eleven samples were taken during the 2015 monitoring year.

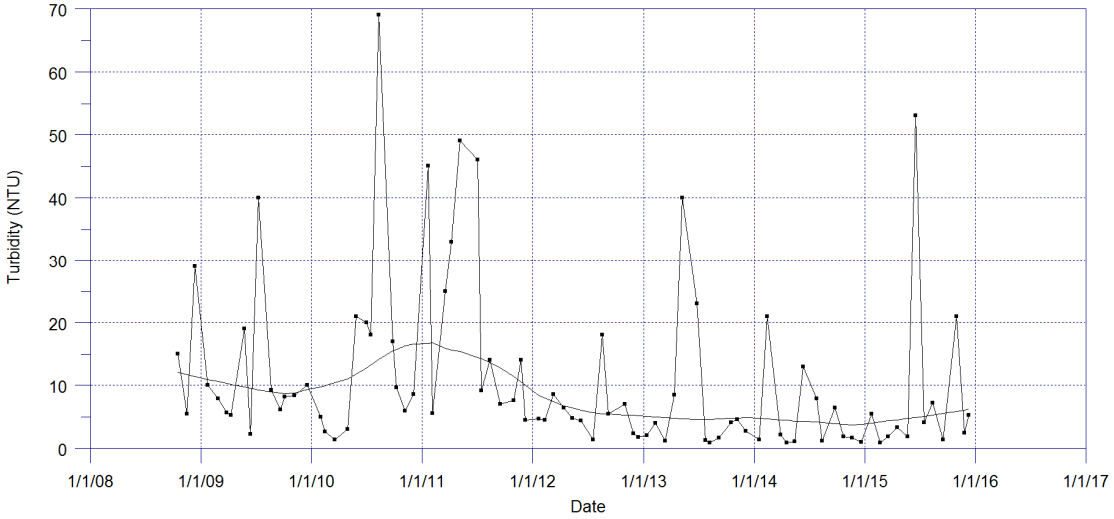


Figure 5. Turbidity levels at the Curletts Road Stream Upstream of Heathcote River site for the monitoring period October 2008 to December 2015. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A negative trend of 20% was recorded over the sampling period.

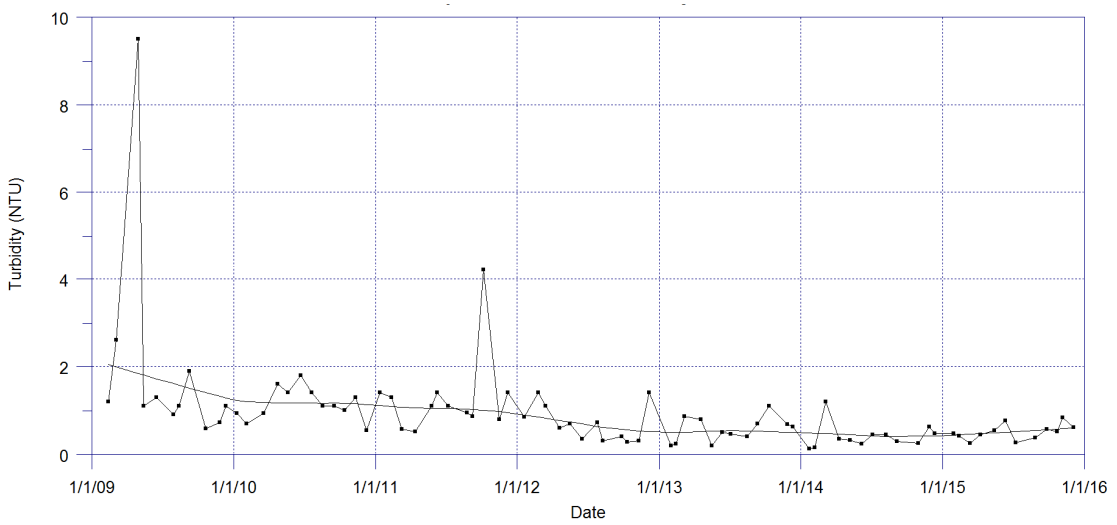


Figure 6. Turbidity levels at the Ōtūkaikino River at Groynes Inlet site for the monitoring period February 2009 to December 2015. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A negative trend of 20% was recorded over the sampling period.

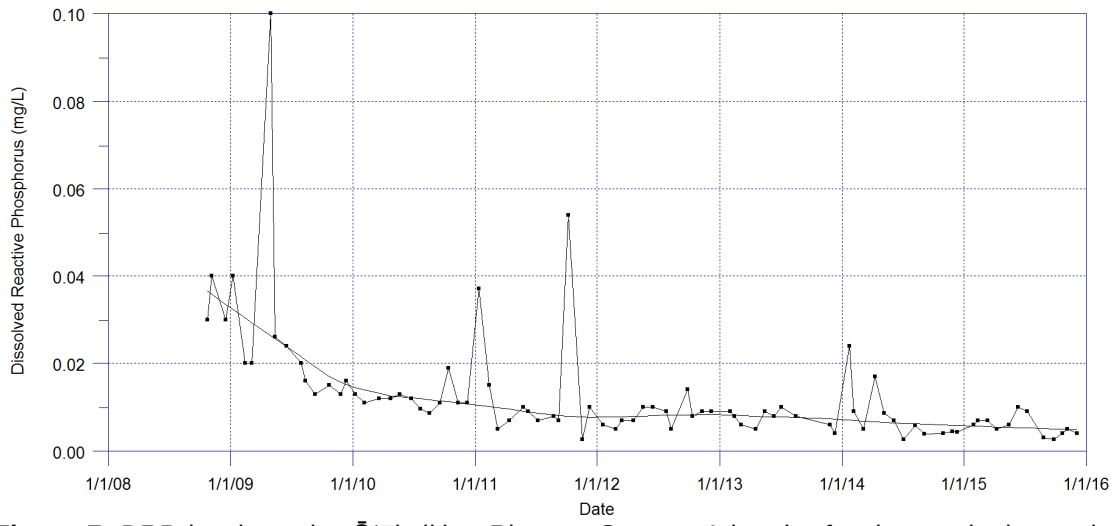


Figure 7. DRP levels at the Ōtūkaikino River at Groynes Inlet site for the monitoring period February 2009 to December 2015. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A negative trend of 20% was recorded over the sampling period.

4.3 Wet Weather Monitoring

4.3.1 Rainfall

The amount of rainfall preceding the sampling for the first event on the 12th November 2015 was 10-12mm, depending on the site location (Figure 8). As such, the samples were taken during the First Flush (considered to be up to the first 15-25mm; Christchurch City Council, 2003), when contaminants are likely to be discharged within stormwater. The storm event appeared to cease shortly after sampling. Based on Christchurch rainfall characteristics, this event was of a good size to represent contaminants discharged within stormwater.

Rainfall preceding the second event on the 4th April 2016 was much lower at 1-2mm, depending on the location (Figure 9). Rainfall ceased approximately at the time of sampling. Whilst sampling still occurred during the First Flush, a high concentration of contaminants would generally not be expected, due to the rainfall event being small in size.

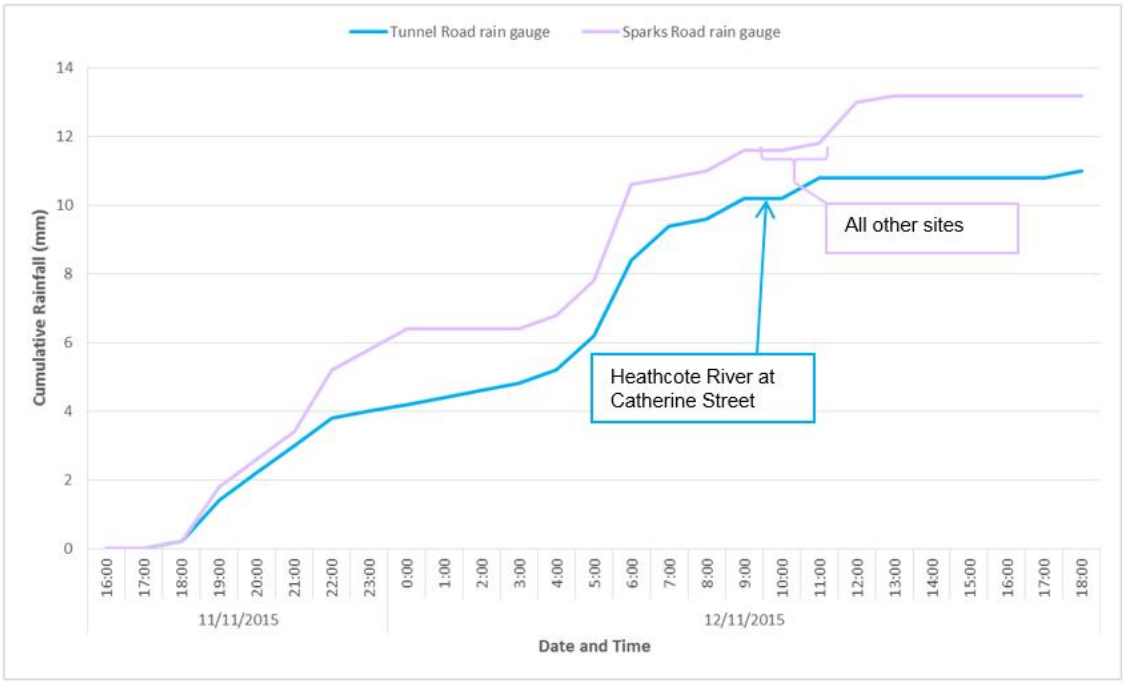


Figure 8. Rainfall during the first wet weather event, with approximate times of sampling arrowed or bracketed.

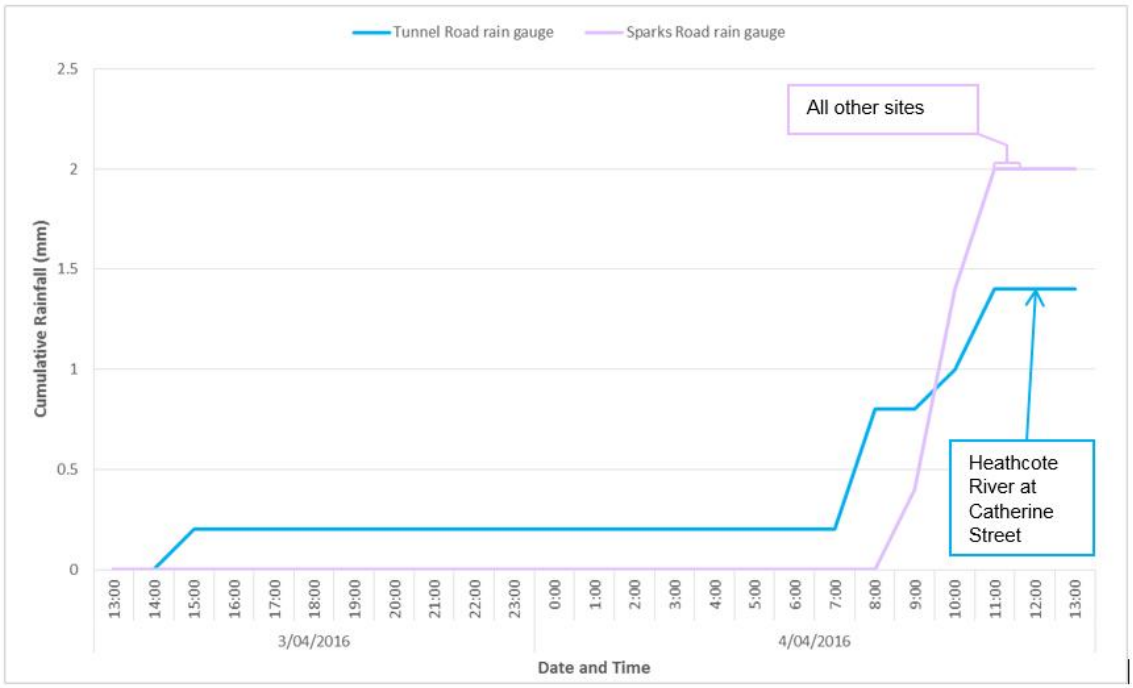


Figure 9. Rainfall during the second wet weather event, with approximate times of sampling arrowed or bracketed.

4.3.2 Copper

Dissolved copper was only recorded above the LOD during the wet weather monitoring at the Heathcote River at Rose Street site during the first rain event (0.0043 mg/L; Figure 10). This level was below the guideline level of 0.00543 mg/L. This concentration was higher than that any recorded at this site during the monthly monitoring (Appendix D, Figure i (a)). However, this value was greater than any of the records for other sites during the monthly monitoring, with the exception of the Curletts Road Stream at Motorway and Upstream of Heathcote River sites.

4.3.3 Dissolved Lead

The Heathcote River at Bowenvale Avenue site was the only site to record dissolved lead above the LOD and only during the second wet weather event (0.0016 mg/L; Figure 10). However, this concentration was well below the guideline level of 0.02916 mg/L. This record was higher than that recorded at the site during the monthly monitoring, but there were other sites in the monthly monitoring that recorded higher values (Appendix D, Figure ii (a)).

4.3.4 Dissolved Zinc

In contrast to copper and lead, dissolved zinc was recorded above the LOD at a number of sites during both wet weather events (Figure 10). These concentrations were below the guideline levels, with the exception of the first event at the Heathcote River at Rose Street and Heathcote River at Catherine Street sites, where 0.09 mg/L and 0.046 mg/L of zinc were recorded, respectively. Concentrations were greater for the first event compared to the second event, which is likely due to the larger rainfall for

the former. Levels were higher during the wet weather monitoring compared to the monthly monitoring within this catchment (Appendix D, Figure iii (a)). The concentration recorded at the Heathcote River at Rose Street site was higher than that recorded for all sites during the monthly monitoring, with the exception of the Haytons Stream and two Curletts Road Stream sites.

4.3.5 pH

pH levels were generally similar between wet weather events (Figure 11) and were slightly lower that that recorded for the monthly monitoring (Appendix D, Figure iv (a)). As was the case with the monthly monitoring, all values were within the guideline level of 6.5 – 8.5. Wet weather concentrations were generally similar between sites.

4.3.6 Conductivity

Wet weather conductivity levels were similar across sites and slightly higher during the second rain event (Figure 11). Concentrations were also similar to that recorded during the monthly monitoring (Appendix D, Figure v (a)).

4.3.7 Total Suspended Solids

The concentrations of TSS were generally similar between sites and rain events (Figure 12). The only notable exception was the high levels at the Heathcote River at Bowenvale Avenue site during the second event (26 mg/L). The latter recording was above the guideline level of 25 mg/L. These concentrations were similar to that recorded during the monthly monitoring (Appendix D, Figure vi (a)). However, the high value at the Bowenvale Avenue site during the second event was higher than the concentrations recorded at this site during the monthly monitoring.

4.3.8 Turbidity

Turbidity levels were mostly higher during the second wet weather event (Figure 12). The Heathcote River at Bowenvale Avenue and Catherine Street sites recorded higher values than the other sites during the second event (11 NTU and 7.3 NTU, respectively). Both these recordings were above the guideline level of 5.6 NTU. These levels were similar or lower than that recorded during the monthly monitoring (Appendix D, Figure vii (a)). The exception being the Heathcote River at Bowenvale Avenue site, which recorded higher levels in the second wet weather event than that recorded during the monthly monitoring.

4.3.9 Dissolved Oxygen

Dissolved oxygen levels in water samples from the second wet weather event were generally slightly higher than the first event (Figure 13). Most samples were above their respective guideline value, with the exception of most samples from the two Cashmere Stream sites and the first event at the Heathcote River at Catherine Street site. Levels

were within the range of that recorded during the monthly monitoring at all sites (Appendix D, Figure viii (a)).

4.3.10 Water Temperature

Water temperatures recorded at the time of sampling were lower during the first wet weather event compared to the second event and were generally similar between sites (Figure 13). All samples were within the range of that recorded during the monthly monitoring (Appendix D, Figure ix (a)). As was the case with the monthly monitoring, the wet weather samples were below the guideline level of 20 °C.

4.3.11 Biochemical Oxygen Demand

BOD_5 levels varied between the two storm events and between sites (Figure 14). Almost half of the samples recorded levels below the LOD. The Heathcote River at Rose Street site recorded particularly high concentrations during the first event (3.6 mg/L). Four samples were above the guideline value of 2 mg/L: the first event at the Heathcote River at Rose Street site, both events at the Heathcote River Bowenvale Avenue site and the first event at the Heathcote River at Catherine Street site. BOD_5 concentrations were similar to that recorded during the monthly monitoring (Appendix D, Figure x (a)), although the Heathcote River at Rose Street and Bowenvale Avenue sites recorded much higher levels during this wet weather sampling. Levels at these sites during the monthly monitoring never exceeded the guideline value.

4.3.12 Total Ammonia (Ammoniacal Nitrogen)

Ammonia levels were generally lower during the second event and varied between sites (Figure 14). All values were well below their respective guideline value. Concentrations were within the range of that recorded during the monthly monitoring (Appendix D, Figure xi (a)), the exception being the Heathcote River at Bowenvale Avenue site, which recorded higher levels during the wet weather monitoring (0.094 mg/L and 0.15 mg/L for the first and second event, respectively).

4.3.13 Nitrate, Nitrate Nitrite Nitrogen and Dissolved Inorganic Nitrogen

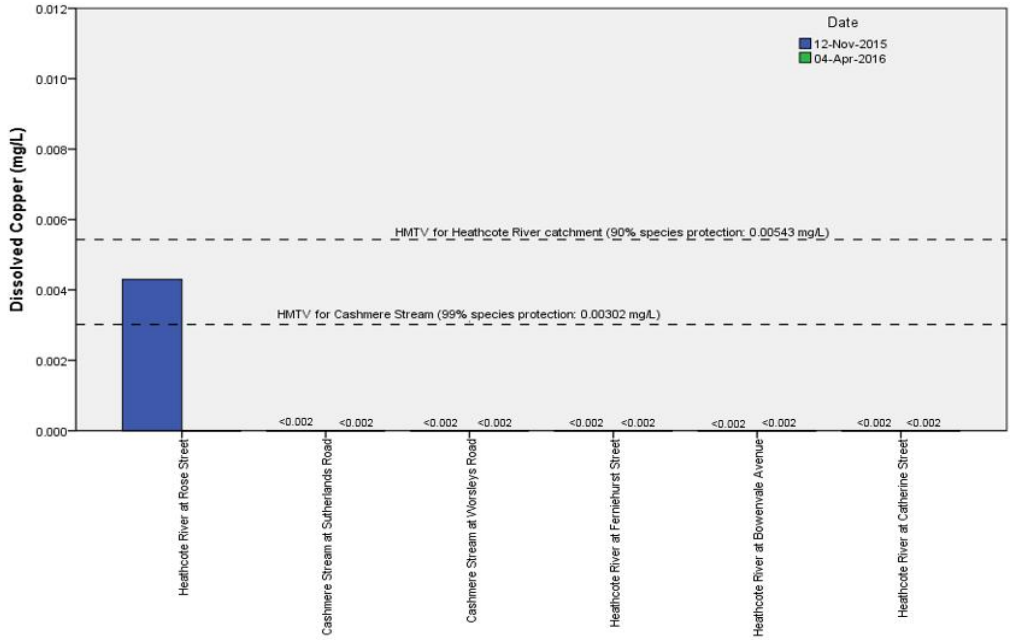
The second wet weather event generally recorded higher nitrogen levels than the first event and concentrations were fairly similar between sites (Figure 15). Compared to the monthly monitoring (Appendix D, Figures xii (a), xiii (a) and xiv (a)), levels were generally lower during the wet weather monitoring. Nitrate levels at all sites were well below the guideline levels of 3.8 and 5.6 mg/L. All sites were above the NNN guideline value of 0.444 mg/L. The majority of sites were also at or above their respective DIN guideline level. When compared to guideline levels, these trends were the same as that recorded for the monthly monitoring.

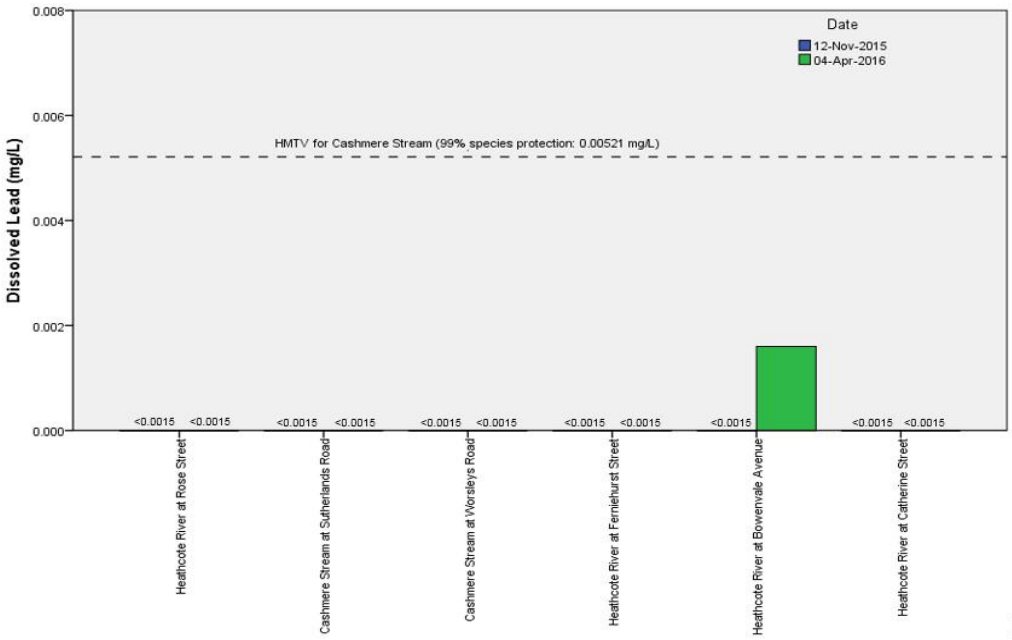
4.3.14 Dissolved Reactive Phosphorus

DRP levels were generally lower during the second wet weather event compared to the first (Figure 16). Concentrations were similar between sites, except for the Cashmere Stream at Sutherlands Road site, which only recorded levels below the LOD. Samples for all sites were generally at or above their respective guideline values. DRP levels were similar or lower than that recorded during the monthly monitoring (Appendix D, Figure xv (a)).

4.3.15 *Escherichia coli*

There was some variation in *E. coli* levels across sites and storm events, with the Cashmere Stream sites recording lower levels during both events (Figure 16). The guideline level of 550 CFU/100ml was well exceeded by the majority of wet weather samples. The highest value was recorded at the Heathcote River at Bowenvale Avenue site during the first event (6,100 CFU/100ml). Levels were generally within the range or much higher than that recorded during the monthly monitoring (Appendix D, Figure xvi (a)).





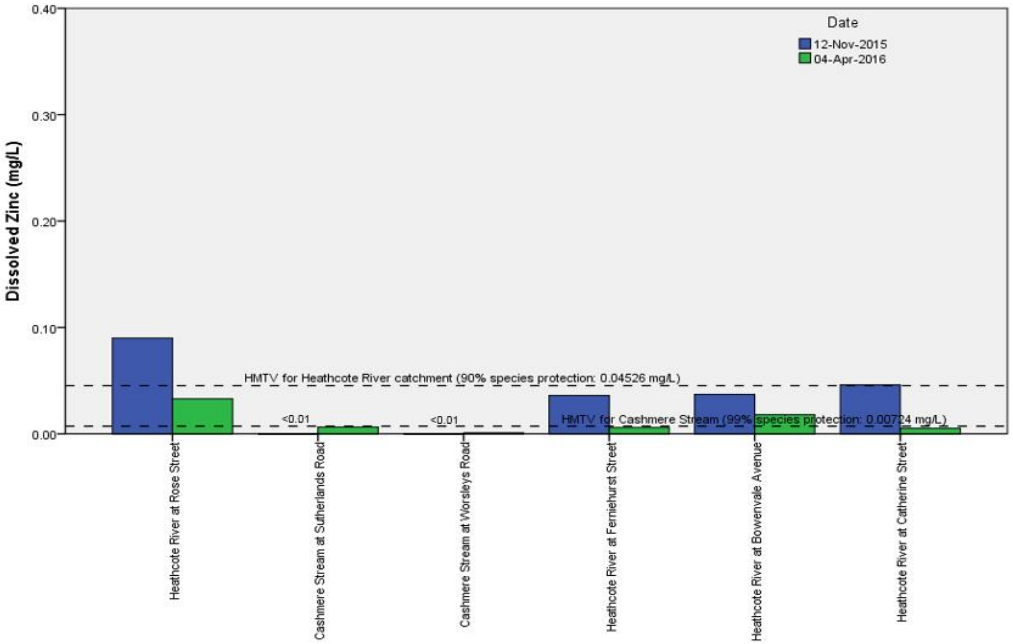


Figure 10. Dissolved copper (top left), lead (top right) and zinc (bottom left) levels in water samples taken from the Heathcote River catchment during two rain events. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger values (Environment Canterbury, 2015), which have been modified to account for water hardness (Hardness Modified Trigger Value = HMTV), as per the ANZECC (2000) guidelines methodology. The 90% protection HMTV for lead for the Heathcote River (0.02916 mg/L) is not shown as it is off the scale. The Laboratory Limit of Detection for zinc was 0.001 mg/L, with the exception of two sites on one sampling occasion where the LOD was <0.01 mg/L - the levels recorded were below this LOD (see zinc graph).

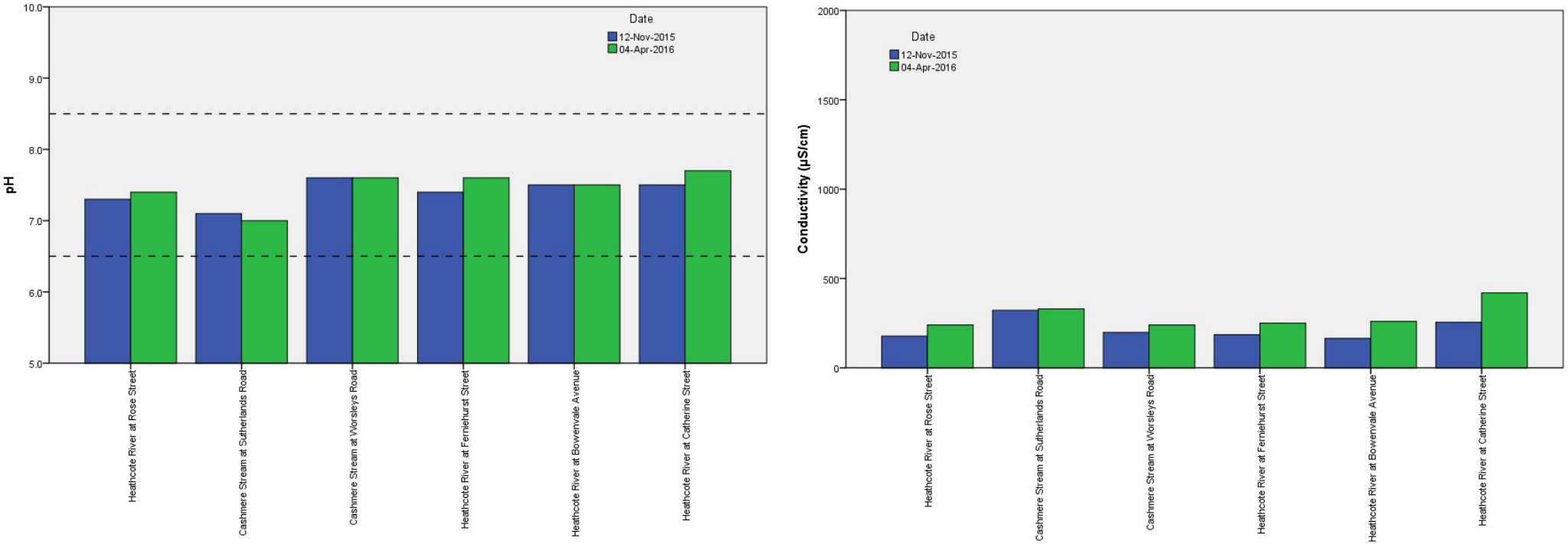


Figure 11. pH (left) and conductivity (right) levels in water samples taken from the Heathcote River catchment during two rain events. Sites are ordered from upstream to downstream (left to right). The dashed lines on the pH graph represent the Land and Water Regional Plan lower (6.5) and upper (8.5) limits (Environment Canterbury, 2015).

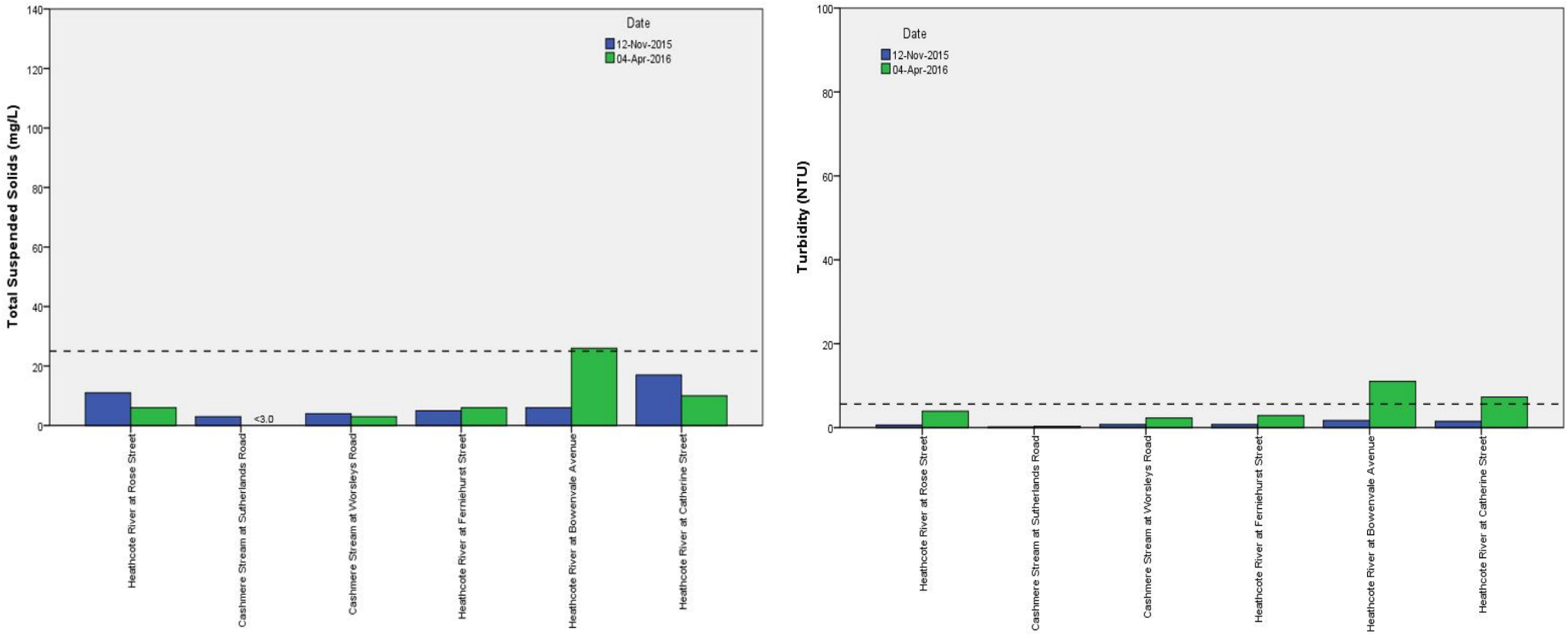


Figure 12. Total Suspended Solid (TSS; left) and turbidity (right) levels in water samples taken from the Heathcote River catchment during two rain events. Sites are ordered from upstream to downstream (left to right). On the TSS graph, the dashed line represents the Ryan (1991) guideline value of 25 mg/L. On the turbidity graph, the dashed line represents the ANZECC (2000) guideline value of 5.6 Nephelometric Turbidity Units (NTU). The Laboratory Limit of Detection for TSS was 3.0 mg/L.

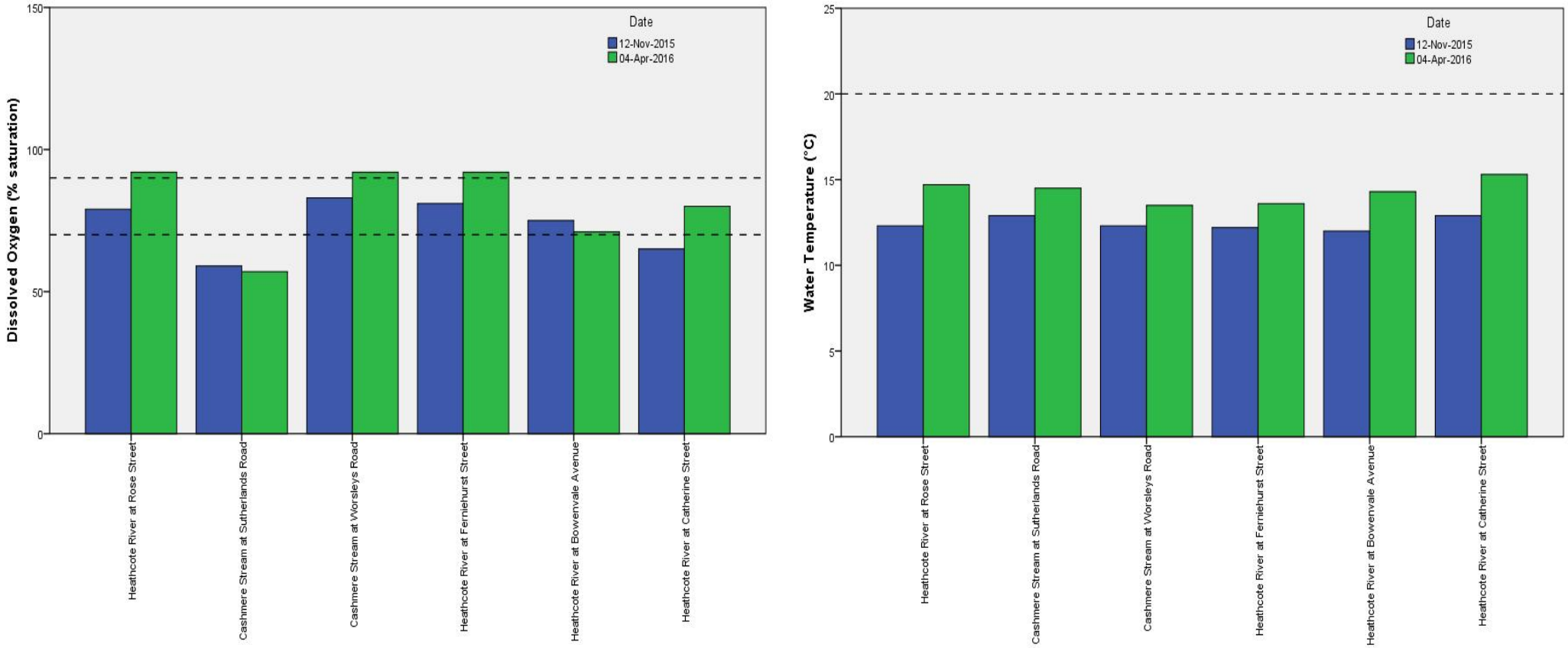


Figure 13. Dissolved oxygen (left) and water temperature (right) levels in water samples taken from the Heathcote River catchment during two rain events. Sites are ordered from upstream to downstream (left to right). On the dissolved oxygen graph, the lower and upper dashed lines represent the Land and Water Regional Plan minimum guideline value for 'spring-fed – plains – urban' waterways (70%) and Banks Peninsula waterways (90%; Cashmere Stream only), respectively (Environment Canterbury, 2015). On the water temperature graph, the dashed line represents the Land and Water Regional Plan maximum guideline value (20ºC, Environment Canterbury, 2015).

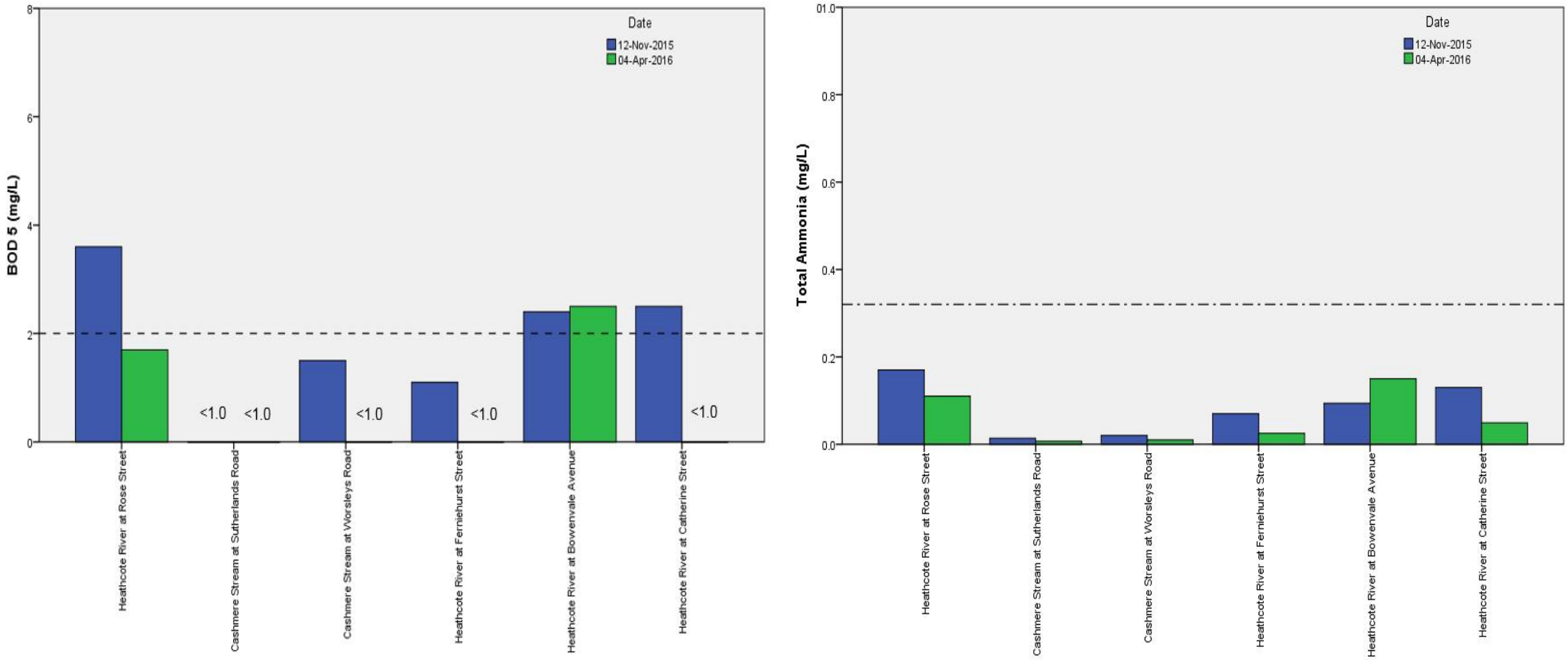
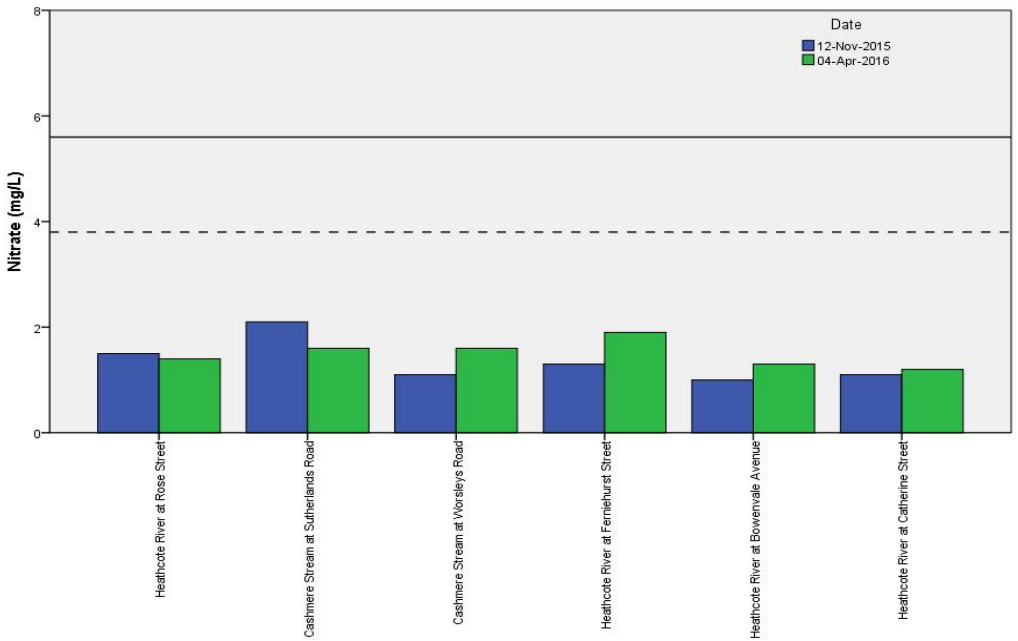
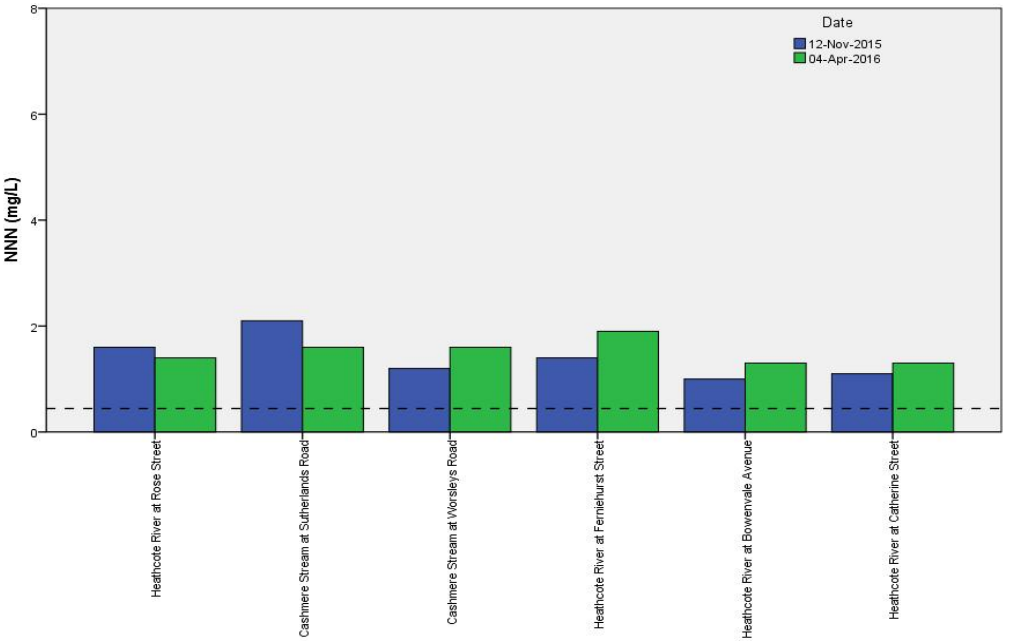


Figure 14. Biochemical Oxygen Demand (BOD_5; left) and total ammonia (right) levels in water samples taken from the Heathcote River catchment during two rain events Sites are ordered from upstream to downstream (left to right). On the BOD_5 graph, the dashed line represents the Ministry for the Environment guideline value (2 mg/L; Ministry for the Environment, 1992). The Laboratory Limit of Detection was 1.0 mg/L. For the ammonia graph, the Land and Water Regional Plan guideline value, adjusted in accordance with median pH level for the monitoring period (7.6; Environment Canterbury, 2015), is not visible as it is off the scale (1.47 mg/L). The dot-dash line represents the Land and Water Regional Plan maximum guideline value for Banks Peninsula waterways (0.32 mg/L, Cashmere Stream only; Environment Canterbury, 2015). The Laboratory Limit of Detection was 0.005 mg/L.





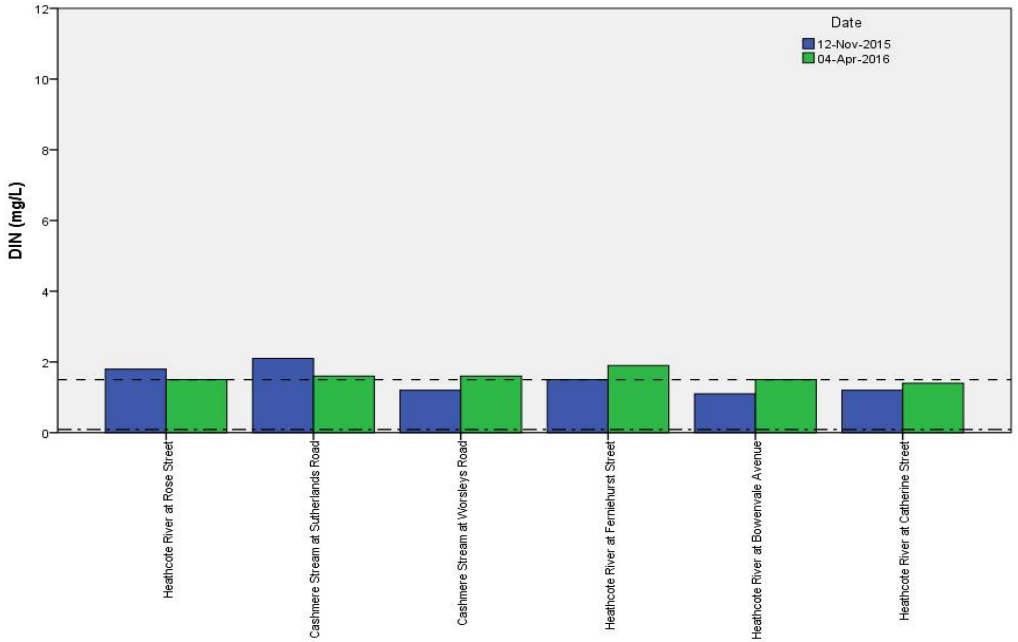


Figure 15. Nitrate (top left), Nitrate Nitrite Nitrogen (NNN; top right) and Dissolved Inorganic Nitrogen (DIN; bottom left) levels in water samples taken from the Heathcote River catchment during two rain events. Sites are ordered from upstream to downstream (left to right). On the nitrate graph, the dashed and solid lines represent the Hickey (2013) grading (3.8 mg/L) and surveillance (5.6 mg/L) guideline levels, respectively. On the NNN graph, the dashed lines represent the ANZECC water quality guideline (0.444 mg/L; ANZECC, 2000). On the DIN graph, the lower and upper dashed lines represent the Land and Water Regional Plan trigger value of 1.5 mg/L for 'spring-fed – plains – urban' waterways and 0.09 mg/L for Banks Peninsula waterways (Cashmere Stream only) (Environment Canterbury, 2015). The Laboratory Limit of Detection for nitrate was 0.05 mg/L.

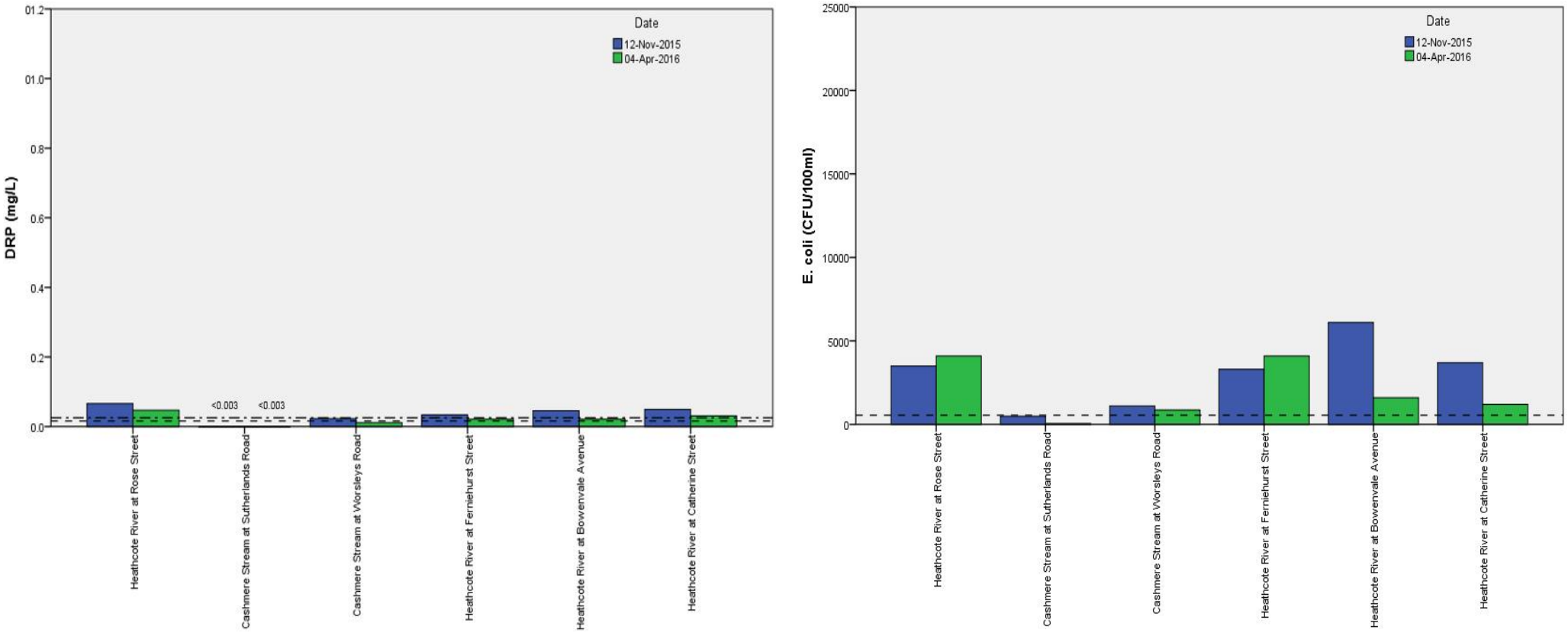


Figure 16. Dissolved Reactive Phosphorus (DRP; left) and *Escherichia coli* (right) levels in water samples taken from the Heathcote River catchment during two rain events. Sites are ordered from upstream to downstream (left to right). On the DRP graph the dashed lines represent the Land and Water Regional Plan trigger value of 0.016 mg/L for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways, and the dot-dash line represents the Land and Water Regional Plan trigger value of 0.025 mg/L for Banks Peninsula waterways (Cashmere Stream only), (Environment Canterbury, 2015). On the *E. coli* graph, the dashed lines represent the 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, 2015). The Laboratory Limit of Detection for DRP was 0.003 mg/L. The Laboratory Limit of Detection for *E. coli* varied depending on the necessary dilution of the sample.

5 Discussion

5.1 Monthly Monitoring: 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. The Ōtūkaikino River catchment recorded the best water quality of all catchments, followed by the Styx River and Heathcote River. These results are the same as that recorded last monitoring year (Margetts & Marshall, 2015). 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. the Avon and Heathcote River catchments) and generally better water quality is recorded in rural areas (e.g. the Ōtūkaikino River catchment).

These results highlight that the Heathcote and Styx River 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 the sites themselves also recorded very low levels for some contaminants, but high levels for others. For example, Knights Stream at Sabys Road was one of the best sites for zinc, but one of the worst sites for nitrogen.

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

1. Zinc: concentrations in the Avon and Heathcote River catchments were higher than the other catchments. This is likely related to a greater level of contaminated stormwater inputs and is consistent with that recorded last year (Margetts & Marshall, 2015).
2. Conductivity: consistent with last year's monitoring (Margetts & Marshall, 2015), the Styx and Ōtūkaikino River catchments recorded lower conductivity compared to the other catchments. This is likely related to less input from contaminated discharges, as conductivity is influenced by pollutants, such as metals and nutrients. Tidal sites also recorded higher conductivity, as expected due to the saline influence at these locations. Levels were lower in 2015 compared to 2014 (Margetts & Marshall, 2015).
3. TSS and turbidity: levels were greater at the tidal downstream sites in both the Avon and Heathcote River mainstems, but there was no trend downstream in the Styx and Ōtūkaikino River mainstems. These higher levels at tidal sites are potentially due to re-suspension of sediment from tidal movement, where these areas naturally have soft-bottomed channels. Concentrations in the Heathcote River catchment were slightly higher than the other catchments. This may be due to this catchment incorporating the unstable Port Hills, which discharge fine loess sediment, as well as the poor water quality of tributaries such as Curletts Road Stream. These results are similar to that recorded during last year's monitoring (Margetts & Marshall, 2015), although levels appeared to be lower across all catchments in 2015.
4. Water temperature: as was recorded during the 2014 monitoring year (Margetts & Marshall, 2015), 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. Overall, higher temperatures were recorded more frequently during the 2015 monitoring year across all catchments, compared to the 2014 monitoring year. No sampling events exceeded the guideline level for any site in 2014, except Linwood Canal, but many sites recorded values above the guideline level in 2015. This may be a reflection of the lower water levels and warmer temperatures in 2015.

5. BOD_5: the Heathcote River catchment recorded higher levels than the other catchments, consistent with the 2014 monitoring year (Margetts & Marshall, 2015). This is likely related to the poorer water quality in this catchment and/or higher levels of plant matter. BOD_5 levels were typically lower in the Styx and Ōtūkaikino River catchments, with most sites in these catchments consistently recording values below the LOD. Within the Avon, Heathcote and Halswell River catchments, levels were mostly higher in 2015 compared to the 2014 monitoring year (Margetts & Marshall, 2015), potentially due to the lower water levels and poorer water quality in these locations. In contrast, levels were lower in 2015 within the Styx and Ōtūkaikino River catchments.
6. Total ammonia: levels 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 humans and waterfowl. This trend was also recorded last year (Margetts & Marshall, 2015).
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 Ōtūkaikino River catchments recorded much lower levels than the other catchments. These results are consistent with that recorded in 2014 (Margetts & Marshall, 2015). The trend of decreasing 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. Recent research by the CCC within the Avon River catchment has confirmed that springs contribute high levels of nitrogen and phosphorus into waterways, accounting for this downstream trend in nitrogen concentrations (Munro, 2015). Differences in levels between catchments are likely due to differing groundwater characteristics, in-stream spring inputs and catchment land use practices.
8. DRP: as was recorded last year (Margetts & Marshall, 2015), concentrations generally increased downstream in all catchments. A positive correlation was recorded between TSS and DRP (albeit only weak-moderate), indicating that this increase may be related in part to cumulative sediment inputs downstream. Phosphorus inputs can also come from fertilisers and faecal matter (animal and human). Tributaries may be contributing phosphorus to the mainstems, as they generally recorded higher values than the mainstem.
9. *E. coli*: levels were similar to that recorded during the 2014 monitoring year (Margetts & Marshall, 2015), although the Styx River catchment appeared to record lower levels in 2015.

5.2 Monthly Monitoring: Sites with the Best and Worst Water Quality

5.2.1 Across all Catchments

The sites recording the poorest water quality across all catchments compared to other sites were Haytons Stream at Retention Basin (for zinc, TSS/turbidity and DRP) and Curletts Road Stream Upstream of Heathcote River (for copper, zinc and dissolved oxygen) (Tables 4 and 5). The sites tied for second worst (each with two occurrences) were Dudley Creek, Curletts Road Stream at Motorway, Cashmere Stream at Sutherlands Road, and Kaputone Creek at Blakes Road. Twenty-two sites were joint for third (each with one occurrence).

These worst sites differed a little to that recorded last monitoring year (Margetts & Marshall, 2015), where Linwood Canal and Haytons Stream at Retention Basin were tied for first, Curletts Road Stream Upstream of Heathcote River and Heathcote River at Templetons Road were tied for second, and there were thirteen other sites tied for third. One notable difference was that Linwood Canal was tied as the worst site last year, recording poor water quality compared to other sites for TSS/turbidity, dissolved oxygen and phosphorus. This site only recorded poor levels compared to other sites for phosphorus this year - TSS/turbidity levels at the site were lower than last year, but dissolved oxygen levels were similar. The Heathcote River at Templetons Road site was not monitored for the full year either, so the results for this site might have been different had this been the case. These slight differences between years are not surprising given likely environmental and sampling variations, but overall the same key sites were identified between 2014 and 2015 (i.e. Curletts Road and Haytons Streams).

The site that recorded the best water quality across all sites for the 2015 monitoring year was the Ōtūkaikino River at Groynes Inlet (seven occurrences), followed by Ōtūkaikino Creek at Omaka Scout Camp (six occurrences) (Tables 4 and 5). Third was tied between the Styx River at Gardiners Road and at Main North Road (three occurrences each).

This is a slightly different result to that recorded last monitoring year (Margetts & Marshall, 2015). Last year, Ōtūkaikino Creek at Omaka Scout Camp was first with seven occurrences, although this site was new and not monitored for the whole year. Ōtūkaikino River at Groynes Inlet, Smacks Creek at Gardiners Road, Styx River at Gardiners Road, and Cashmere Stream at Sutherlands Road were tied second, with three occurrences, and the Heathcote River at Templetons Road was third with two occurrences. As mentioned above, the Heathcote River at Templetons Road site was not monitored for the full year, so the results for this site might have been different had this been the case. Again, these slight differences between years are not surprising given likely environmental and sampling variations, but overall the same key sites were identified between 2014 and 2015 (i.e. Ōtūkaikino River at Groynes Inlet, Ōtūkaikino Creek at Omaka Scout Camp and Styx River at Gardiners Road).

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).

5.2.2.1 Avon River catchment

In the Avon River catchment, these sites were Riccarton Main Drain and Dudley Creek (four occurrences each), followed by the Avon River at Bridge Street (three occurrences), and Addington Brook (two occurrences). These sites recorded issues with oxygen, nitrogen, phosphorus, pathogens, lead, sediment and temperature. These sites are located within a mixture of residential, industrial and commercial catchments, and it is likely that a contribution of a range of different inputs is creating this poor water quality, including stormwater, wastewater, waterfowl and other commercial/industrial discharges. The Christchurch-West Melton Zone Committee currently has working groups for the Riccarton Main Drain and Addington Brook catchments, working in conjunction with ECan and the CCC, which will help reduce contaminants levels in these waterways.

For the 2014 monitoring year, Dudley Creek was also identified as having the poorest water quality in the catchment (six occurrences), followed by Addington Brook and Horseshoe Lake (three occurrences each) (Margetts & Marshall, 2015). Sites that were identified within these tables over both the 2014 and 2015 monitoring years included Riccarton Main Drain, Dudley Creek, Avon River at Bridge Street, Addington Brook, Horseshoe Lake Discharge, and Avon River at Pages/Seaview Bridge.

5.2.2.2 Heathcote River catchment

In the Heathcote River catchment, Curletts Road Stream Upstream of Heathcote River had the poorest water quality (seven occurrences), followed by Haytons Stream at Retention Basin and Curletts Road Stream at Motorway (six occurrences each), then the Heathcote River at Templetons Road (although only monitored for part of the year) and Rose Street (three occurrences each). Copper, zinc, lead, turbidity, oxygen, ammonia, nitrogen and phosphorus were the parameters of concern at these sites. Curletts Road and Haytons Streams are located in largely industrial catchments, which are known to be impacted by stormwater inputs and other discharges from industry. Of note is the higher levels of ammonia within these two waterways compared to other catchments (although levels were below guidelines), which is a phenomenon that has occurred for a number of years and is likely due to industrial discharges. Haytons Stream is also a priority catchment for the Christchurch-West Melton Zone Committee, and ECan and the CCC are working together to address contaminant issues in this waterway. Both ECan and the CCC are also aware of the issues within Curletts Road Stream and are working towards water quality management in this catchment as well. The Heathcote River at Templetons Road site is a headwater site, which is most likely the reason for the low oxygen levels and high nitrogen concentrations (due to input from contaminated groundwater within springs) recorded at this site. Similarly, Rose Street is located in the upper reaches of the Heathcote River, impacted by predominantly residential catchments and potentially upgradient agricultural land use, which is reflected in the high levels of zinc, nitrogen and phosphorus at this site.

Last monitoring year, Haytons Stream at Retention Basin had the poorest water quality (six occurrences), followed by Curletts Road Stream Upstream of Heathcote River (three occurrences) (Margetts & Marshall, 2015). Sites that were identified as having the poorest water quality over both the 2014 and 2015 monitoring years included Haytons Stream at Retention Basin, the two Curletts Road Stream sites, Heathcote River at Templetons Road, the two Cashmere Stream sites, Heathcote River at

Catherine Street, Heathcote River at Ferrymead Bridge, and the Heathcote River at Tunnel Road.

5.2.2.3 Styx River catchment

For the Styx River catchment, the sites with the poorest water quality were Kaputone Creek at Blakes Road (six occurrences), Kaputone Creek at Belfast Road (five occurrences) and Styx River at Richards Bridge (three occurrences). The parameters of concern at these sites were zinc, temperature, oxygen, ammonia, nitrogen, phosphorus and *E. coli*. Of particular concern was that the Belfast Road site recorded *E. coli* values above the guideline during every sampling event during the monitoring period, with only half of these events associated with rain. This is exactly the same as that recorded at this site last monitoring year. These sites are located in primarily rural catchments, with some industry, and the Kaputone Stream in particular is well known to have industrial and agricultural inputs. The CCC and others have already planted the riparian margins of parts of this catchment and are 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, although it would appear that this is now ceasing activities. In addition, a landowner adjacent to the site is also farming Muscovy ducks, which have in the past been kept directly within the waterway, which has introduced faecal matter into the waterway and onto the stream banks. These ducks have subsequently been removed from the water due to the water quality issues. For all these reasons, the CCC hopes to see an improvement in water quality within this catchment over time.

Both Kaputone Creek sites were also the sites that had the poorest water quality last year (four occurrences each) (Margetts & Marshall, 2015). Consistently poor sites across both the 2014 and 2015 monitoring years were the two Kaputone Creek sites, and the Styx River at Gardiners Road, Main North Road and Marshland Road Bridge.

5.2.2.4 Ōtūkaikino River catchment

Wilsons Stream in the Ōtūkaikino River catchment had issues with zinc, pH, 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. The Ōtūkaikino River at Groynes Inlet site also recorded a one-off high level of copper during one of the sampling occasions during the monitoring year. This result is unusual considering there are no direct stormwater discharges in this area. Last monitoring year, Wilsons Stream was the only site identified in this catchment as having poor water quality, recording issues with pH, oxygen, nitrogen and *E. coli* (Margetts & Marshall, 2015).

5.2.2.5 Halswell River catchment

In the Halswell catchment, Nottingham Stream at Candys Road had the poorest water quality, recording high levels of zinc, phosphorus and *E. coli* compared to other sites in the catchment. This is likely due to the site being located within a rural and residential catchment. Knights Stream at Sabys Road and Halswell River at Akaroa Highway also recorded high levels of nitrogen compared to the other sites. This may be due to nitrogen-rich input from groundwater in this catchment, due to adjacent agricultural land use. Last monitoring year, Knights Stream at Sabys Road and Halswell River at Akaroa

Highway were the only sites identified as having poor water quality in this catchment, both because of high nitrogen levels (Margetts & Marshall, 2015).

5.2.2.6 Linwood Canal

Linwood Canal also recorded poor levels of pH, dissolved oxygen, temperature, ammonia and DRP compared to the other sites. This site recorded similar issues last year with TSS/turbidity, dissolved oxygen and phosphorus.

5.3 Monthly Monitoring: Comparisons to Receiving Environment Guidelines

Of the samples collected from the 43 waterways sites during the monitoring year, 38% (2,765 of 7,353 samples) exceeded the guideline levels (Table 7). 98% of sites (42 of 43 sites) did not meet the guidelines for at least one parameter (assessed against site medians or 95th percentiles, depending on the parameter). The top five parameters with the highest percentage of samples that did not meet guideline levels were NNN (77% of samples), DRP (56% of samples), DIN (41% of samples), *E. coli* (30% of samples) and turbidity (21% of samples).

There were a number of parameters that consistently met the relevant receiving water guidelines for the 2015 monitoring period across most sites and are therefore unlikely to be having adverse effects on the waterways. These were dissolved lead, pH, total ammonia and nitrate. However, there were a number of parameters that recorded values well outside the guidelines across many 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, water temperature and BOD_5. These results are consistent with that recorded during the 2014 monitoring year, except water temperature consistently met the guideline level last year (Margetts & Marshall, 2015).

The number of wet weather exceedances in 2015 for copper, zinc, TSS, DRP and *E. coli* were mostly lower than that recorded in 2014. However, there were generally less rain events during 2015, which could explain the lower number of wet weather exceedances, rather than better water quality. Lead did not record any exceedances during wet or dry weather. Dry exceedances occurred for all other parameters and were generally greater than that recorded in 2014. The maximum number of exceedances per site for the monitoring year for wet and dry events combined was two for copper (Curletts Road Stream at Motorway site), eight for zinc (at the Curletts Road Stream at Motorway site), eleven for TSS (at the Heathcote River at Ferrymead Bridge site), twelve for DRP (seven sites) and twelve for *E. coli* (at the Kaputone Creek at Belfast Road site).

The majority of these parameters are typically associated with stormwater, so it is surprising so many dry weather exceedances were recorded. These high levels may be due to atmospheric deposition (Murphy, 2015), re-suspension of contaminated sediment (i.e. copper or zinc), or these parameters staying in suspension for a period of time. It is also possible that groundwater contaminated from urban activities in adjacent catchments could be contributing high levels in these spring-fed streams. With respect to sediment, tidal sites showed a higher number of dry exceedances, which is likely due to re-suspension of sediment from tidal movement in the naturally soft-

bottomed channels. Suspended sediment during dry weather may also be due to erosion of the banks and channel, and construction and dewatering discharges. Dry exceedances of phosphorus may be due to naturally-occurring phosphorus in sediment, or faecal input from waterfowl and wastewater. The former is supported by the positive correlation (albeit only weak-moderate) we recorded between TSS and phosphorus during this monitoring year. Dry weather *E. coli* exceedances are likely due to faecal input from waterfowl, which are present in high numbers within some waterway locations (Moriarty & Gilpin, 2015).

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 (Dewson, 2012; Dewson, 2013; Whyte, 2013a; Whyte, 2014a; Whyte, 2014b; Margetts, 2014a; Margetts & Marshall, 2015).

5.4 Monthly Monitoring: 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, specific parameters at some sites recorded an increasing or decreasing trend in concentrations.

At a catchment-scale, there were some improvements in water quality. There were significant reductions in both this and last year's assessment for: DRP in the Avon and Heathcote River catchments, TSS and turbidity within the Heathcote and Styx River catchments, and BOD_5 in the Heathcote River catchment. This may mean better land management practices are being undertaken since monitoring began. However, *E. coli* levels within the Styx River catchment showed an increasing trend across most sites both this and last year. This might be due to agricultural inputs in this more rural catchment, but also animal-related industries such as within the Kaputone Creek.

The Cashmere Stream at Sutherlands Road site recorded the largest increase of any parameter at a given site, with a 29% change in dissolved zinc. This is a new trend recorded this monitoring year. Levels are generally low at this site compared to other sites and trends analyses are likely more sensitive to high recordings compared to other locations. In addition, only seven samples were able to be taken from this site during this monitoring year, which may mean that these higher results have skewed the data. In support of this, when the temporal trends analysis was re-run with 2016 monitoring data from January – June, there was no longer a significant change recorded. There were also exceedances of the zinc guideline at this site during the monitoring year. Although it is noted that the LWRP classification for this stream is ‘Banks Peninsula’, which has a very conservative guideline value and the stream is more characteristic of a ‘spring-fed – plains – urban’ waterway. With the latter classification, no guideline exceedances would have been recorded during the monitoring year. However, it would be beneficial to keep an eye on this site, to ensure zinc levels do not increase over time. Of particular interest is that although zinc is typically stormwater derived (usually due to roof and road runoff), the two highest

values in 2015 were associated with dry weather, so could not have been stormwater derived. This headwater site is also located within a rural area, upstream of any roads, where no stormwater network discharges into the waterway. It is possible that groundwater contaminated from urban activities in adjacent catchments could be contributing to levels in this spring-fed stream, or discharges from adjacent old roofs into the groundwater or waterway.

The Avon River at Bridge Street site also recorded one of the greatest changes in levels over time, with a 24% increase in conductivity, consistent with that recorded last year (Margetts & Marshall, 2015). As discussed in last year's report, this increase is probably related to changes in tidal inundation at this location, caused by the earthquakes.

The largest decrease in concentrations was a 57% reduction in dissolved zinc at the Curletts Road Stream Upstream of Heathcote River site. Last year a decrease of 146% was recorded (Margetts & Marshall, 2015). The 2014 monitoring report concluded that the reduction was potentially due to improvements in catchment management practices (e.g. re-direction of vehicle wash down water to the sewer instead of the stormwater system), or the realignment of the waterway in 2011 for the motorway (potentially removing or releasing contaminated sediment, improving network connections or realigning away from 'dirty' stormwater catchments). This is likely still the case for this monitoring year.

The 20% decrease in DRP and turbidity at the Ōtūkaikino River at Groynes Inlet site was similar to that recorded last year (22% and 25% reduction, respectively; Margetts & Marshall, 2015). As mentioned in last year's report, this is likely due to improved land use practices and planting within the catchment, reducing the influence of stock and runoff on the waterway.

As discussed previously, Addington Brook, Riccarton Main Drain, Haytons Stream and Curletts Road Stream have been prioritised for water quality management by the Christchurch-West Melton Zone Committee, ECan and the CCC. Compared to last year, Addington Brook showed reductions in ammonia and phosphorus, and an increase in *E. coli*, but these trends were not reflected into significant changes in the Time Trends analysis. If these trends continue, it is likely significant changes will be recorded. However, significant decreases in zinc and BOD_5 were recorded. Within Riccarton Main Drain, a significant decrease was recorded for DRP, and a significant increase for both NNN and DIN. Haytons Stream recorded significant decreases for DRP, BOD_5, NNN and DIN. Copper also appeared to increase compared to last year, and ammonia appeared to decrease, but significant changes were not recorded by Time Trends. Curletts Road Stream recorded significant decreases in zinc, phosphorus, TSS, turbidity, ammonia and nitrogen. There also appeared to be an increase in copper and an increase in oxygen within the waterway compared to last year, but significant trends were not recorded in Time Trends.

The amount of rainfall that fell within Christchurch City was particularly low this monitoring year. For example, rainfall at the Botanic Gardens in the 2014 and 2015 calendar years totalled 691mm (which is above average) and 585mm (which is below average), respectively. As shown by the number of exceedances data, a lower number of rain events were also recorded across most sites during the 2015 monitoring year, compared to the 2014 monitoring year. This lower rainfall in 2015 may mean that less contaminants are mobilised within catchments and discharged into the waterways. Alternatively, the same amount of contaminants could have been discharged, but to

greater concentrations over less storm events, potentially causing greater pulses in contaminant concentrations. However, when comparing between the 2014 and 2015 monitoring year, although there are some differences between the years that may be contributed to the lower rainfall in 2015 (e.g. a lower number of wet weather exceedances for copper, zinc and TSS), overall the general concentrations, trends, and contaminants, sites and catchments of concern, are consistent.

5.5 Monthly Monitoring: Halswell Retention Basin Sites

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 (outlet only), 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 (inlet only), temperature, BOD_5, ammonia, DIN, DRP and *E. coli* (inlet only)), possibly due to variable levels of parameters in stormwater and/or the treatment ability of the basin. These results are very similar to that recorded last monitoring year (Margetts & Marshall, 2015).

Similar to last year (Margetts & Marshall, 2015), the outlet recorded lower median concentrations that the inlet about half of the time, indicating that there was some improvement in water quality due to the basin, but not always. These results should be taken with caution though, as it is difficult to deduce treatment ability given that the inlet and outlet samples were 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 of 14% for BOD_5 since monitoring began in April 2007. The outlet also recorded a 13% decrease in TSS over time. This indicates either an improvement in the quality of stormwater entering the basin over time for these parameters, or improvements in the treatment ability of the basin. However, NNN levels at both the inlet and outlet significantly increased by 14% and 18%, respectively. This is likely due to greater concentrations of this parameter within stormwater discharged to the basin, rather than the interception of groundwater containing greater levels over time, as the basin was originally lined. *E. coli* levels at the inlet increased by 13%, suggesting that this parameter is increasing in concentration within stormwater, but that the basin is still not discharging any greater levels over time. These results are all similar to that recorded last monitoring year (Margetts & Marshall, 2015).

5.6 Wet Weather Monitoring

There were a number of parameters for this year's wet weather monitoring that generally met the guideline values and therefore are not likely to have caused adverse effects on the waterways during these storm events. These were copper, lead, zinc, pH, TSS, turbidity, dissolved oxygen, temperature, BOD_5, total ammonia and nitrate. However, there were a number of parameters that recorded values above the guidelines across most sites: NNN, DIN, DRP and *E. coli*. These parameters may be having adverse effects on biota (i.e. DIN), may encourage the proliferation of aquatic

plants and/or algae (i.e. NNN and DRP), and may indicate human health risks from contact recreation (i.e. *E. coli*). There were no obvious trends downstream for the mainstem for any of the parameters.

Levels were generally similar between the wet weather monitoring and the monthly monitoring, which is undertaken during any weather condition (i.e. wet or dry). The notable exceptions being that zinc levels were generally higher during the wet weather monitoring and nitrogen levels were generally lower. Results varied between the wet weather events, with some parameters greater during the larger first event (e.g. zinc, ammonia and DRP), some lower during the first event (e.g. nitrogen, turbidity) and some similar between events (e.g. TSS).

The sites that recorded the poorest water quality during the wet weather monitoring were the Heathcote River at Rose Street (e.g. for copper, zinc and BOD_5), Heathcote River at Bowenvale Avenue (e.g. for lead, BOD_5, TSS, turbidity and *E. coli*) and Heathcote River at Catherine Street (e.g. for zinc, turbidity, oxygen and BOD_5). The Heathcote River at Rose Street was also identified from the monthly monitoring as having an issue with zinc. High *E. coli* levels were also recorded during the monthly monitoring for the Bowenvale Avenue site. The Catherine Street site was also identified in the monthly monitoring as having issues with oxygen.

Previous CCC wet weather monitoring in other catchments has shown higher levels of copper, zinc, TSS, turbidity, BOD_5, DRP and *E. coli*, and lower levels of nitrogen, compared to monthly monitoring (Whyte, 2013b; Margetts, 2014b). On many of these occasions, guideline levels for these parameters were exceeded. This contrasted with some of the monthly monitoring results, where guidelines were not always exceeded. There appears to be little difference in wet weather and monthly monitoring results across all studies for pH, conductivity, dissolved oxygen and temperature. The differences between wet weather monitoring studies are likely due to variations in the storm events monitored and in catching the first flush (as shown by the variations between monitored events in the same catchment), as well as stormwater discharge characteristics within the catchment (i.e. industrial versus residential).

These additional guideline exceedances during wet weather indicates that these contaminants are directly related to stormwater or are mobilised instream by flood waters (e.g. sediment). Wastewater overflows triggered by stormwater reducing the capacity of the sewer system during wet weather events, may also potentially contribute to *E. coli* levels if it is a large enough event. However, the majority of *E. coli* levels are known to be related to waterfowl input (Moriarty & Gilpin, 2015), which may be exacerbated during wet weather. Lower concentrations following storm events may be due to settlement, dilution, mobilisation downstream or attachment to instream sediment. This might mean that some of these contaminants are only having short-term (although potentially still detrimental) effects on biota in the river and on contact recreation at some of the sites. With respect to nitrogen, lower levels during wet weather are likely due to dilution of contaminated spring baseflow (as discussed earlier in this report) by flood waters/stormwater.

6 Recommendations

- The Heathcote River catchment, in particular Haytons and Curletts Road Streams, should be priority areas for water quality management. This should be achieved through improvement in CCC stormwater treatment facilities, pollution

prevention programmes with landowners to reduce contaminants entering stormwater systems or waterways directly, and investigations into contaminant sources. These initiatives are already being carried out, involving a multi-agency approach (e.g. CCC, ECan, Christchurch-West Melton Zone Committee and University of Canterbury), and these projects should continue to be collaboratively developed.

- Catchment management practices should also focus on the Ōtūkaikino River to ensure the good water quality in this catchment is maintained, particularly if development pressure increases in the future.
- Research should be undertaken into how contaminants predominantly not occurring from stormwater or other point source discharges can be reduced. Namely, *E. coli* (as an indicator of pathogens) that are influenced heavily by waterfowl (Moriarty & Gilpin, 2015) and nitrogen, which appears to be entering waterways due to inputs from springs contaminated from adjacent agricultural land use (Munro, 2015).
- Investigations should be carried out to determine the reason for the increasing *E. coli* levels within the Styx River catchment.
- Zinc levels at the Cashmere Stream at Sutherlands Road site should be monitored closely, so if levels are increasing over time these are detected early and investigations are instigated in a timely manner.
- Research should be conducted into the reasons for dry exceedances of TSS and DRP, as well as the predominantly stormwater derived contaminants copper and zinc.

7 Conclusions

In summary, the Heathcote River catchment recorded the poorest water quality of all the catchments and the Ōtūkaikino River catchment recorded the best water quality. The site recording the poorest water quality across all catchments was a tie between Haytons Stream at Retention Basin (particularly for zinc, TSS, turbidity and DRP) and Curletts Road Stream Upstream of the Heathcote River (particularly for copper, zinc and dissolved oxygen). The site that recorded the best water quality was the Ōtūkaikino River at Groynes Inlet.

Of the samples collected from the 43 waterways sites during the monitoring year, 38% (2,765 of 7,353 samples) exceeded the guideline levels. 98% of sites (42 of 43 sites) did not meet the guidelines for at least one parameter (assessed against site medians or 95th percentiles, depending on the parameter).

There were a number of parameters that were recorded at levels unlikely to cause adverse effects, including dissolved lead, pH, 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*. 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, water temperature and BOD_5. 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 results of this year's monitoring is largely consistent with that recorded in previous years.

This monitoring report indicates that these waterways are both historically and currently subjected to contamination, potentially from stormwater, wastewater and other inputs (e.g. waterfowl faeces and industrial discharge). 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 (Dewson, 2012; Dewson, 2013; Whyte, 2013a; Whyte, 2014a; Whyte, 2014b; Margetts, 2014a; Margetts & Marshall, 2015). 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 River catchments) and generally better water quality is recorded in rural areas (e.g. Ōtūkaikino River 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, particularly as the level of earthworks and dewatering activity decreases.

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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	.001000	.0007500	.015000	7.750	308.50	5.00	5.600	74.50
		Mean	.001083	.0009208	.023125	7.642	292.83	7.63	6.283	76.92
		Std. Error of Mean	.0000833	.00017083	.0101181	.1069	17.348	2.083	1.0096	4.530
		Minimum	.0010	.00075	.0005	6.7	106	2	2.1	52
		Maximum	.0020	.00280	.1300	8.0	336	28	13.0	110
	Avon River at Avondale Road Bridge	N	12	12	11	12	12	12		12
		Median	.001000	.0007500	.002000	7.950	472.50	2.25		94.50
		Mean	.001000	.0008375	.007591	7.833	938.50	3.50		94.00
		Std. Error of Mean	.0000000	.00008750	.0034679	.1089	301.377	.776		2.477
		Minimum	.0010	.00075	.0005	7.0	192	2		76
		Maximum	.0010	.00180	.0390	8.3	3740	9		110
	Avon River at Bridge Street	N	12	12	11	12	12	12	12	12
		Median	.001000	.0007500	.001000	8.000	11800.00	23.00	11.000	97.50
		Mean	.001000	.0007500	.004500	7.900	11928.33	24.25	9.963	95.92
		Std. Error of Mean	.0000000	.00000000	.0018427	.0870	1446.973	1.528	1.3382	2.058
		Minimum	.0010	.00075	.0005	7.3	4720	18	.7	84
		Maximum	.0010	.00075	.0180	8.2	21400	34	16.0	110
	Avon River at Carlton Mill Corner	N	12	12	11	12	12	12		12
		Median	.001000	.0007500	.004000	7.700	178.00	1.50		98.00
		Mean	.001000	.0008542	.012045	7.592	179.25	3.04		98.00
		Std. Error of Mean	.0000000	.00010417	.0071425	.1026	1.805	.978		2.071
		Minimum	.0010	.00075	.0005	6.8	170	2		85
		Maximum	.0010	.00200	.0820	8.0	188	12		110
	Avon River at Dallington Terrace/Gayhurst Road	N	12	12	11	12	12	12	12	12
		Median	.001000	.0007500	.005000	7.700	190.50	1.50	1.150	75.00
		Mean	.001000	.0007500	.013500	7.658	191.67	2.13	1.362	78.50
		Std. Error of Mean	.0000000	.00000000	.0039972	.0811	3.056	.349	.3014	3.156
		Minimum	.0010	.00075	.0005	7.1	180	2	.4	64
		Maximum	.0010	.00075	.0400	8.1	219	5	4.5	100
	Avon River at Manchester Street	N	12	12	10	12	12	12	12	12
		Median	.001000	.0007500	.002500	7.750	191.50	1.50	.825	96.50
		Mean	.001233	.0007500	.005650	7.700	188.92	3.08	1.438	96.58
		Std. Error of Mean	.0002333	.00000000	.0023393	.0961	2.759	1.111	.6578	2.819

	Minimum	.0010	.00075	.0005	6.9	166	2	.3	83
	Maximum	.0038	.00075	.0240	8.1	198	15	8.6	110
Avon River at Mona Vale	N	12	12	11	12	12	12	12	12
	Median	.001000	.0007500	.006000	7.350	197.50	1.50	.875	87.00
	Mean	.001000	.0008375	.012955	7.292	198.42	2.71	1.334	87.00
	Std. Error of Mean	.0000000	.00008750	.0054637	.0892	3.596	.703	.4085	.778
	Minimum	.0010	.00075	.0005	6.6	172	2	.3	83
	Maximum	.0010	.00180	.0590	7.7	215	9	5.2	92
Avon River at Pages/Seaview Bridge	N	12	12	11	12	12	12	12	12
	Median	.001000	.0007500	.004000	8.000	1970.00	9.00	4.800	97.00
	Mean	.001108	.0007500	.010409	7.892	3027.42	9.58	4.913	95.17
	Std. Error of Mean	.0001083	.00000000	.0061036	.0933	1123.896	1.055	.6703	2.299
	Minimum	.0010	.00075	.0005	7.2	484	5	.8	80
	Maximum	.0023	.00075	.0700	8.2	14700	19	9.5	110
Dudley Creek	N	12	12	11	12	12	12	12	12
	Median	.001000	.0007500	.008000	7.700	147.00	9.50	7.350	78.50
	Mean	.001000	.0009958	.010864	7.608	147.58	12.92	9.558	78.92
	Std. Error of Mean	.0000000	.00013434	.0044298	.0988	3.613	2.932	2.7021	1.540
	Minimum	.0010	.00075	.0005	6.8	131	6	3.1	71
	Maximum	.0010	.00210	.0510	8.0	176	43	38.0	88
Horseshoe Lake Discharge	N	12	12	11	12	12	12	12	12
	Median	.001000	.0007500	.007000	7.650	175.50	6.00	5.300	69.50
	Mean	.001000	.0008125	.023864	7.533	176.50	6.63	5.308	75.00
	Std. Error of Mean	.0000000	.00006250	.0151584	.1032	4.085	.757	.4981	3.525
	Minimum	.0010	.00075	.0005	6.8	156	3	1.9	65
	Maximum	.0010	.00150	.1700	8.0	202	11	8.4	110
Riccarton Main Drain	N	12	12	11	12	12	12	12	12
	Median	.001000	.0007500	.014000	7.550	251.00	1.50	1.030	89.50
	Mean	.001000	.0008458	.020227	7.475	238.33	2.33	1.459	89.08
	Std. Error of Mean	.0000000	.00009583	.0076534	.0946	10.962	.414	.4702	1.076
	Minimum	.0010	.00075	.0005	6.8	130	2	.4	81
	Maximum	.0010	.00190	.0880	7.9	263	6	6.4	94
Snellings Drain	N	3	3	3	3	3	3	3	1
	Median	.001000	.0007500	.009000	7.600	175.00	7.00	5.100	68.00
	Mean	.001000	.0007500	.008333	7.467	170.00	7.33	6.267	68.00
	Std. Error of Mean	.0000000	.00000000	.0017638	.2404	14.933	2.603	2.4660	.
	Minimum	.0010	.00075	.0050	7.0	142	3	2.7	68
	Maximum	.0010	.00075	.0110	7.8	193	12	11.0	68
Waimairi Stream	N	12	12	11	12	12	12	12	12

		Median	.001000	.0007500	.005000	7.350	175.50	1.50	.615	81.50
		Mean	.001000	.0008125	.005727	7.317	176.17	4.38	.999	82.25
		Std. Error of Mean	.0000000	.00006250	.0012781	.0878	1.353	1.528	.3351	1.053
		Minimum	.0010	.00075	.0005	6.7	170	2	.1	76
		Maximum	.0010	.00150	.0140	7.7	183	19	4.0	90
	Wairarapa Stream	N	12	12	11	12	12	12	12	12
		Median	.001000	.0007500	.007000	7.300	169.50	1.50	.560	84.00
		Mean	.001000	.0008792	.008909	7.242	168.92	4.92	1.761	83.92
		Std. Error of Mean	.0000000	.00012917	.0023939	.0908	1.422	2.676	1.0331	3.343
		Minimum	.0010	.00075	.0005	6.5	160	2	.2	67
		Maximum	.0010	.00230	.0290	7.6	175	34	13.0	110
	Total	N	159	159	146	159	159	159	135	157
		Median	.001000	.0007500	.005000	7.600	192.00	3.50	2.000	87.00
		Mean	.001032	.0008289	.012298	7.589	1350.59	6.71	4.084	86.90
		Std. Error of Mean	.0000203	.00002438	.0018290	.0302	282.013	.615	.4165	.944
		Minimum	.0010	.00075	.0005	6.5	106	2	.1	52
		Maximum	.0038	.00280	.1700	8.3	21400	43	38.0	110
Halswell Catchment	Halswell Retention Basin Inlet	N	11	11	11	11	11	11		12
		Median	.003600	.0007500	.043000	8.200	215.00	19.00		56.00
		Mean	.003809	.0009091	.077727	8.255	213.91	56.82		57.25
		Std. Error of Mean	.0006292	.00015909	.0240779	.3186	16.837	31.083		7.810
		Minimum	.0010	.00075	.0030	7.0	130	10		16
		Maximum	.0091	.00250	.2500	10.2	310	360		120
	Halswell Retention Basin Outlet	N	12	12	12	12	12	12		12
		Median	.003700	.0007500	.033000	7.500	158.50	9.00		75.50
		Mean	.003817	.0013208	.041083	7.808	172.25	12.08		81.75
		Std. Error of Mean	.0002691	.00022834	.0086991	.2176	12.918	2.254		5.611
		Minimum	.0025	.00075	.0140	7.2	123	3		58
		Maximum	.0059	.00290	.1200	9.6	260	24		120
	Halswell River at Akaroa Highway (Tai Tapu Road)	N	12	12	10	12	12	12	12	12
		Median	.001000	.0007500	.002000	7.700	241.50	3.50	1.900	88.50
		Mean	.001000	.0007500	.002900	7.683	241.08	7.13	3.861	88.58
		Std. Error of Mean	.0000000	.00000000	.0007371	.0366	3.039	2.046	.9707	1.987
		Minimum	.0010	.00075	.0010	7.5	223	2	.8	76
		Maximum	.0010	.00075	.0090	7.9	259	22	9.9	100
	Knights Stream at Sabys Road	N	12	12	9	12	12	12	12	12
		Median	.001000	.0007500	.002000	7.500	250.50	3.00	1.050	86.50
		Mean	.001000	.0007500	.002278	7.458	251.83	4.92	1.654	88.33
		Std. Error of Mean	.0000000	.00000000	.0004938	.0358	2.648	1.547	.4090	1.499

		Minimum	.0010	.00075	.0005	7.3	240	2	.3	78
		Maximum	.0010	.00075	.0050	7.7	267	17	4.7	96
	Nottingham Stream at Candys Road	N	12	12	12	12	12	12	12	12
		Median	.001000	.0007500	.009000	7.650	209.50	5.00	1.700	81.50
		Mean	.001000	.0007500	.010292	7.683	208.33	10.96	4.560	82.25
		Std. Error of Mean	.0000000	.00000000	.0022734	.0441	2.016	3.211	1.4944	1.452
		Minimum	.0010	.00075	.0005	7.5	194	2	.6	70
		Maximum	.0010	.00075	.0260	7.9	218	35	18.0	89
	Total	N	59	59	54	59	59	59	36	60
		Median	.001000	.0007500	.010500	7.600	224.00	8.00	1.700	84.50
		Mean	.002097	.0008958	.028167	7.769	217.54	17.73	3.358	79.63
		Std. Error of Mean	.0002190	.00006068	.0064693	.0801	5.471	6.169	.6277	2.454
		Minimum	.0010	.00075	.0005	7.0	123	2	.3	16
		Maximum	.0091	.00290	.2500	10.2	310	360	18.0	120
Heathcote Catchment	Cashmere Stream at Sutherlands Road	N	12	12	9	12	12	12	12	12
		Median	.001000	.0007500	.007000	7.100	330.00	1.50	.395	48.50
		Mean	.001000	.0007500	.006667	7.150	328.58	2.13	.461	48.08
		Std. Error of Mean	.0000000	.00000000	.0014814	.0452	2.006	.349	.0828	1.681
		Minimum	.0010	.00075	.0010	6.9	312	2	.1	39
		Maximum	.0010	.00075	.0150	7.4	340	5	1.2	58
	Cashmere Stream at Worsleys Road	N	12	12	9	12	12	12	12	12
		Median	.001000	.0007500	.002000	7.600	245.00	4.50	3.200	86.50
		Mean	.001000	.0007500	.003222	7.700	245.67	10.88	6.278	86.50
		Std. Error of Mean	.0000000	.00000000	.0011847	.0492	3.811	6.504	3.4492	2.943
		Minimum	.0010	.00075	.0005	7.5	228	2	.9	74
		Maximum	.0010	.00075	.0110	8.0	265	82	44.0	100
	Curletts Road Stream at Motorway	N	11	11	11	11	11	11		11
		Median	.003300	.0007500	.098000	7.600	297.00	8.00		83.00
		Mean	.004191	.0009818	.147091	7.591	291.73	9.36		79.36
		Std. Error of Mean	.0007688	.00023182	.0473162	.0803	16.955	2.019		6.855
		Minimum	.0021	.00075	.0050	7.1	148	3		50
		Maximum	.0110	.00330	.5500	8.0	364	20		120
	Curletts Road Stream Upstream of Heathcote River	N	12	12	11	12	12	12	12	12
		Median	.001000	.0007500	.089000	7.250	290.50	6.00	3.700	57.50
		Mean	.002142	.0007500	.093455	7.225	296.83	14.79	8.993	59.33
		Std. Error of Mean	.0004502	.00000000	.0218987	.0538	12.596	7.487	4.2933	10.065
		Minimum	.0010	.00075	.0060	6.9	248	2	.9	13
		Maximum	.0055	.00075	.2000	7.6	386	95	53.0	120
	Haytons Stream at Retention Basin	N	12	12	11	12	12	12	12	12

	Median	.001000	.0007500	.040000	7.450	138.50	6.25	5.650	91.00
	Mean	.001258	.0007500	.053364	7.475	149.58	7.71	6.908	85.50
	Std. Error of Mean	.0001794	.00000000	.0144022	.0494	10.893	1.341	1.1663	5.534
	Minimum	.0010	.00075	.0100	7.2	115	3	2.1	35
	Maximum	.0029	.00075	.1600	7.7	232	18	16.0	110
Heathcote River at Bowenvale Avenue	N	12	12	11	12	12	12	12	12
	Median	.001000	.0007500	.010000	7.700	265.00	5.00	2.500	86.50
	Mean	.001508	.0007500	.010409	7.792	264.58	5.63	2.850	86.92
	Std. Error of Mean	.0004048	.00000000	.0028989	.0417	3.454	.987	.3336	2.973
	Minimum	.0010	.00075	.0005	7.6	246	2	1.1	68
	Maximum	.0058	.00075	.0310	8.0	283	15	5.4	110
Heathcote River at Catherine Street	N	12	12	11	12	12	12		12
	Median	.001000	.0007500	.011000	7.700	519.00	8.00		69.00
	Mean	.001175	.0007500	.011909	7.683	679.67	11.08		72.83
	Std. Error of Mean	.0001750	.00000000	.0027351	.0386	149.183	2.314		3.240
	Minimum	.0010	.00075	.0020	7.5	308	5		59
	Maximum	.0031	.00075	.0340	7.9	2130	35		93
Heathcote River at Ferniehurst Street	N	12	12	11	12	12	12	12	12
	Median	.001000	.0007500	.016000	7.600	258.50	5.00	3.400	83.50
	Mean	.001000	.0007500	.012818	7.675	262.17	5.58	3.775	85.75
	Std. Error of Mean	.0000000	.00000000	.0022796	.0479	3.542	.947	.6789	3.280
	Minimum	.0010	.00075	.0020	7.5	246	2	1.0	70
	Maximum	.0010	.00075	.0250	8.0	281	12	9.2	110
Heathcote River at Ferrymead Bridge	N	12	12	10	12	12	12	12	12
	Median	.001000	.0007500	.002000	7.800	20800.00	37.50	18.500	87.00
	Mean	.001000	.0007500	.005400	7.833	17606.67	38.83	18.517	85.00
	Std. Error of Mean	.0000000	.00000000	.0020545	.0396	2108.968	2.452	2.0539	2.453
	Minimum	.0010	.00075	.0005	7.7	5660	28	3.2	62
	Maximum	.0010	.00075	.0170	8.1	25800	54	30.0	95
Heathcote River at Mackenzie Avenue	N	12	12	10	12	12	12		12
	Median	.001000	.0007500	.013000	7.700	295.50	4.00		69.50
	Mean	.001408	.0008208	.012100	7.667	292.83	5.00		70.92
	Std. Error of Mean	.0002770	.00007083	.0022679	.0376	4.183	.788		3.749
	Minimum	.0010	.00075	.0020	7.4	260	3		43
	Maximum	.0037	.00160	.0230	7.9	320	13		91
Heathcote River at Opawa Road/Clarendon Terrace	N	12	12	11	12	12	12	12	12
	Median	.001000	.0007500	.010000	7.600	292.50	4.00	2.500	73.50
	Mean	.001142	.0007500	.010091	7.650	288.08	4.50	2.838	74.00
	Std. Error of Mean	.0001417	.00000000	.0016704	.0435	3.991	.855	.5143	4.017

		Minimum	.0010	.00075	.0020	7.4	257	2	.9	45
		Maximum	.0027	.00075	.0180	7.9	301	12	7.4	100
	Heathcote River at Rose Street	N	12	12	12	12	12	12	12	12
		Median	.001000	.0007500	.020500	7.500	291.50	4.00	2.550	86.50
		Mean	.001133	.0007500	.031500	7.558	292.50	5.42	3.125	91.25
		Std. Error of Mean	.0001333	.00000000	.0069134	.0398	5.594	1.592	.6748	4.385
		Minimum	.0010	.00075	.0020	7.4	251	2	1.2	72
		Maximum	.0026	.00075	.0650	7.9	315	22	9.9	120
	Heathcote River at Templetons Road	N	5	5	3	5	5	5	5	5
		Median	.001000	.0007500	.007000	7.300	357.00	21.00	7.000	88.00
		Mean	.001000	.0009400	.006000	7.500	359.40	31.50	10.372	87.00
		Std. Error of Mean	.0000000	.00019000	.0010000	.1643	8.942	17.577	4.7849	6.686
		Minimum	.0010	.00075	.0040	7.2	336	2	.6	63
		Maximum	.0010	.00170	.0070	8.1	390	100	28.0	100
	Heathcote River at Tunnel Road	N	12	12	11	12	12	12	12	12
		Median	.001000	.0007500	.012000	7.700	4175.00	31.00	18.000	81.00
		Mean	.001183	.0007500	.010727	7.717	4157.08	40.58	21.258	81.00
		Std. Error of Mean	.0001833	.00000000	.0020631	.0423	721.485	10.242	4.6357	2.791
		Minimum	.0010	.00075	.0010	7.5	523	20	3.1	66
		Maximum	.0032	.00075	.0250	7.9	8400	150	69.0	97
	Total	N	160	160	141	160	160	160	125	160
		Median	.001000	.0007500	.013000	7.600	295.50	5.00	3.300	81.50
		Mean	.001441	.0007772	.031975	7.591	1896.11	13.04	7.615	77.71
		Std. Error of Mean	.0000981	.00001774	.0053961	.0202	397.817	1.542	.9344	1.533
		Minimum	.0010	.00075	.0005	6.9	115	2	.1	13
		Maximum	.0110	.00330	.5500	8.1	25800	150	69.0	120
Linwood Canal	Linwood Canal/City Outfall Drain	N	12	12	11	12	12	12	12	12
		Median	.001000	.0007500	.002000	7.950	3275.00	8.50	5.500	81.50
		Mean	.001000	.0008542	.008591	7.958	6071.67	9.17	5.958	81.08
		Std. Error of Mean	.0000000	.00010417	.0036926	.1685	1888.022	.968	.7653	7.628
		Minimum	.0010	.00075	.0005	6.9	2620	5	1.6	42
		Maximum	.0010	.00200	.0420	8.8	24700	16	12.0	130
	Total	N	12	12	11	12	12	12	12	12
		Median	.001000	.0007500	.002000	7.950	3275.00	8.50	5.500	81.50
		Mean	.001000	.0008542	.008591	7.958	6071.67	9.17	5.958	81.08
		Std. Error of Mean	.0000000	.00010417	.0036926	.1685	1888.022	.968	.7653	7.628
		Minimum	.0010	.00075	.0005	6.9	2620	5	1.6	42
		Maximum	.0010	.00200	.0420	8.8	24700	16	12.0	130
Ōtūkaikino Catchment	Ōtūkaikino Creek at Omaka Scout	N	12	12	9	12	12	12	12	12

Camp		Median	.001000	.0007500	.004000	7.400	80.95	1.50	.450	90.00
		Mean	.001000	.0008542	.008389	7.408	81.57	1.63	.838	89.00
		Std. Error of Mean	.0000000	.00010417	.0041523	.0260	.513	.125	.4165	1.710
		Minimum	.0010	.00075	.0005	7.3	79	2	.2	77
		Maximum	.0010	.00200	.0400	7.5	86	3	5.4	100
Ōtūkaikino River at Groynes Inlet		N	12	12	9	12	12	12	12	12
		Median	.001000	.0007500	.004000	7.400	79.15	1.50	.500	85.00
		Mean	.001542	.0008292	.007500	7.400	79.61	1.63	.506	84.83
		Std. Error of Mean	.0005417	.00007917	.0040320	.0275	1.179	.125	.0512	1.313
		Minimum	.0010	.00075	.0005	7.3	75	2	.3	78
		Maximum	.0075	.00170	.0390	7.6	90	3	.8	95
Wilsons Stream		N	12	12	10	12	12	12	12	12
		Median	.001000	.0007500	.001750	7.900	125.00	3.00	2.000	93.00
		Mean	.001000	.0008458	.004550	7.950	128.92	2.71	2.003	93.92
		Std. Error of Mean	.0000000	.00009583	.0017296	.0917	2.732	.351	.2279	2.917
		Minimum	.0010	.00075	.0005	7.5	124	2	.7	84
		Maximum	.0010	.00190	.0150	8.8	158	5	3.6	120
Total		N	36	36	28	36	36	36	36	36
		Median	.001000	.0007500	.004000	7.500	82.00	1.50	.565	88.00
		Mean	.001181	.0008431	.006732	7.586	96.70	1.99	1.116	89.25
		Std. Error of Mean	.0001806	.00005252	.0019103	.0541	3.975	.154	.1889	1.331
		Minimum	.0010	.00075	.0005	7.3	75	2	.2	77
		Maximum	.0075	.00200	.0400	8.8	158	5	5.4	120
Styx Catchment	Kaputone Creek at Belfast Road	N	12	12	10	12	12	12	12	12
		Median	.001000	.0007500	.002500	7.600	145.00	6.00	3.100	76.00
		Mean	.001000	.0008208	.006750	7.625	145.58	5.46	3.240	76.75
		Std. Error of Mean	.0000000	.00007083	.0030968	.0305	1.062	.938	.6027	2.585
		Minimum	.0010	.00075	.0005	7.5	140	2	.7	68
		Maximum	.0010	.00160	.0320	7.8	153	11	6.8	100
	Kaputone Creek at Blakes Road	N	12	12	10	12	12	12	12	12
		Median	.001000	.0007500	.005500	7.400	142.50	4.00	2.600	75.50
		Mean	.001000	.0007500	.009700	7.425	143.17	5.21	3.071	75.92
		Std. Error of Mean	.0000000	.00000000	.0038117	.0392	3.509	1.396	.7796	1.258
		Minimum	.0010	.00075	.0005	7.2	127	2	.9	69
		Maximum	.0010	.00075	.0390	7.7	168	19	11.0	83
	Smacks Creek at Gardiners Road	N	12	12	9	12	12	12	12	12
		Median	.001000	.0007500	.004000	7.200	112.00	1.50	.525	67.50
		Mean	.001000	.0007500	.004944	7.225	114.83	2.29	1.022	65.83
		Std. Error of Mean	.0000000	.00000000	.0022904	.0305	1.660	.545	.3505	1.796

	Minimum	.0010	.00075	.0005	7.1	108	2	.1	55
	Maximum	.0010	.00075	.0220	7.4	126	8	3.9	74
Styx River at Gardiners Road	N	12	12	9	12	12	12	12	12
	Median	.001000	.0007500	.003000	7.050	118.50	1.50	.580	58.00
	Mean	.001000	.0007500	.006056	7.067	122.67	2.00	.692	57.67
	Std. Error of Mean	.0000000	.00000000	.0036699	.0376	3.610	.213	.1023	.414
	Minimum	.0010	.00075	.0005	6.8	111	2	.4	55
	Maximum	.0010	.00075	.0350	7.3	144	3	1.5	60
Styx River at Harbour Road Bridge	N	12	12	9	12	12	12	12	12
	Median	.001000	.0007500	.002000	7.600	141.00	3.00	1.900	78.00
	Mean	.001000	.0007500	.004111	7.608	145.83	4.04	2.450	76.00
	Std. Error of Mean	.0000000	.00000000	.0018926	.0468	4.172	1.268	.4686	3.229
	Minimum	.0010	.00075	.0005	7.4	125	2	1.0	56
	Maximum	.0010	.00075	.0180	7.9	176	17	7.0	90
Styx River at Main North Road	N	12	12	9	12	12	12	12	12
	Median	.001000	.0007500	.002000	7.500	127.50	1.50	.900	84.50
	Mean	.001000	.0007500	.004611	7.525	129.67	1.96	.975	85.50
	Std. Error of Mean	.0000000	.00000000	.0016219	.0305	2.577	.250	.1118	1.621
	Minimum	.0010	.00075	.0005	7.4	119	2	.5	79
	Maximum	.0010	.00075	.0140	7.7	144	4	1.6	100
Styx River at Marshland Road Bridge	N	12	12	9	12	12	12	12	12
	Median	.001000	.0007500	.001000	7.700	128.00	6.00	2.750	82.50
	Mean	.001000	.0007500	.005611	7.725	127.58	5.75	2.767	85.17
	Std. Error of Mean	.0000000	.00000000	.0031145	.0329	1.368	1.363	.5656	2.878
	Minimum	.0010	.00075	.0005	7.6	120	2	.6	74
	Maximum	.0010	.00075	.0280	7.9	136	18	7.2	110
Styx River at Richards Bridge	N	12	12	9	12	12	12	12	12
	Median	.001000	.0007500	.002000	7.650	134.50	2.25	1.700	79.00
	Mean	.001000	.0007500	.003444	7.617	133.83	3.67	2.412	77.75
	Std. Error of Mean	.0000000	.00000000	.0014104	.0458	1.507	.813	.5870	4.715
	Minimum	.0010	.00075	.0005	7.4	123	2	.7	52
	Maximum	.0010	.00075	.0130	7.8	141	9	6.9	110
Total	N	96	96	74	96	96	96	96	96
	Median	.001000	.0007500	.002000	7.500	133.50	3.00	1.450	76.00
	Mean	.001000	.0007589	.005723	7.477	132.90	3.80	2.079	75.07
	Std. Error of Mean	.0000000	.00000885	.0009682	.0251	1.422	.360	.1964	1.266
	Minimum	.0010	.00075	.0005	6.8	108	2	.1	52
	Maximum	.0010	.00160	.0390	7.9	176	19	11.0	110

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 DRP	E. coli
Avon Catchment	Addington Brook	N	12	12	12	12	12	12	12	12
		Median	13.500	.750	.07800	1.28000	1.297500	1.40750	.02250	340.00
		Mean	13.692	.992	.09717	1.20725	1.232083	1.32925	.02400	1950.50
		Std. Error of Mean	.8106	.1836	.020463	.108393	.1090526	.104092	.003102	985.242
		Minimum	9.1	.5	.017	.462	.4850	.705	.010	20
		Maximum	18.2	2.4	.220	1.818	1.8600	1.944	.040	12000
	Avon River at Avondale Road Bridge	N	12	12	11	12	12	12	12	12
		Median	15.200	.500	.02300	.91350	.924500	.94450	.02900	200.00
		Mean	15.175	.500	.02900	.87500	.883667	.91025	.02625	477.67
		Std. Error of Mean	1.1030	.0000	.005525	.063924	.0651329	.064131	.002813	267.951
		Minimum	9.5	.5	.013	.420	.4200	.449	.009	52
		Maximum	21.0	.5	.071	1.140	1.1510	1.203	.037	3400
	Avon River at Bridge Street	N	12	12	12	12	12	12	12	12
		Median	15.600	1.300	.08100	.61250	.624000	.73650	.02450	280.00
		Mean	15.358	1.333	.08454	.61500	.624417	.70875	.02800	598.92
		Std. Error of Mean	1.2194	.2542	.015458	.063611	.0638717	.070047	.004121	167.619
		Minimum	8.7	.5	.003	.263	.2690	.352	.011	97
		Maximum	21.2	3.2	.160	.899	.9050	1.057	.052	2100
	Avon River at Carlton Mill Corner	N	12	12	12	12	12	12	12	12
		Median	13.400	.500	.01850	1.81050	1.819500	1.91350	.00850	320.00
		Mean	13.608	.617	.03458	1.81554	1.820583	1.85517	.00971	446.92
		Std. Error of Mean	.3537	.0796	.012498	.062636	.0626678	.063361	.001883	125.473
		Minimum	11.6	.5	.009	1.505	1.5090	1.521	.002	63
		Maximum	15.6	1.3	.160	2.147	2.1520	2.162	.023	1700
	Avon River at Dallington Terrace/Gayhurst Road	N	12	12	12	12	12	12	12	12
		Median	13.950	.500	.04300	1.27100	1.287500	1.34050	.02200	295.00
		Mean	14.283	.550	.04883	1.15625	1.170167	1.21900	.01883	492.75
		Std. Error of Mean	.7309	.0500	.012599	.064219	.0652026	.070915	.002719	153.165
		Minimum	9.8	.5	.012	.737	.7430	.761	.003	30
		Maximum	18.1	1.1	.170	1.366	1.3780	1.489	.030	1900
	Avon River at Manchester Street	N	12	12	12	12	12	12	12	12
		Median	13.450	.500	.02250	1.53550	1.553500	1.60800	.01000	245.00
		Mean	13.758	.633	.05092	1.50375	1.512333	1.56325	.00971	342.75
		Std. Error of Mean	.4528	.0899	.020356	.050534	.0508325	.055577	.001652	85.741

	Minimum	11.1	.5	.010	1.262	1.2690	1.279	.002	73
	Maximum	16.1	1.3	.260	1.784	1.7920	1.832	.020	1200
Avon River at Mona Vale	N	12	12	12	12	12	12	12	12
	Median	13.400	.500	.01900	2.64800	2.655500	2.73600	.00700	320.00
	Mean	13.558	.592	.03575	2.67900	2.689333	2.72508	.00704	475.25
	Std. Error of Mean	.2880	.0917	.011629	.134312	.1342599	.131386	.001425	143.212
	Minimum	12.2	.5	.008	2.042	2.0440	2.056	.002	73
	Maximum	15.4	1.6	.120	3.360	3.3600	3.368	.021	1900
Avon River at Pages/Seaview Bridge	N	12	12	12	12	12	12	12	12
	Median	15.650	.500	.03200	.76550	.774000	.78900	.02800	170.00
	Mean	15.325	.692	.04671	.71408	.748000	.79450	.02800	221.83
	Std. Error of Mean	1.1573	.0830	.013627	.074031	.0832482	.089229	.002871	40.428
	Minimum	9.0	.5	.003	.325	.3280	.336	.012	84
	Maximum	20.9	1.2	.140	1.011	1.1870	1.211	.045	500
Dudley Creek	N	12	12	12	12	12	12	12	12
	Median	13.150	.750	.07800	.25000	.269500	.34250	.04700	1145.00
	Mean	13.192	1.008	.10458	.26558	.280667	.38525	.05483	1754.17
	Std. Error of Mean	.7558	.2372	.018300	.013179	.0137732	.027375	.007508	420.208
	Minimum	8.3	.5	.052	.211	.2230	.282	.029	420
	Maximum	16.8	3.4	.280	.373	.3840	.564	.110	4600
Horseshoe Lake Discharge	N	12	12	12	12	12	12	12	12
	Median	13.000	.500	.07950	.25050	.258500	.31350	.03750	720.00
	Mean	13.408	.875	.08025	.25333	.264667	.34492	.03850	931.67
	Std. Error of Mean	.7920	.2474	.009073	.022891	.0236334	.031140	.002867	187.935
	Minimum	8.3	.5	.026	.117	.1240	.150	.026	220
	Maximum	17.2	3.4	.130	.421	.4310	.561	.057	2500
Riccarton Main Drain	N	12	12	12	12	12	12	12	12
	Median	13.650	.500	.02450	3.13800	3.143000	3.17850	.01500	175.00
	Mean	13.700	1.225	.04863	3.04210	3.046833	3.09525	.02467	2547.83
	Std. Error of Mean	.3205	.4347	.016975	.092487	.0920723	.085768	.009838	1981.527
	Minimum	12.1	.5	.003	2.219	2.2280	2.294	.006	41
	Maximum	15.4	4.5	.220	3.456	3.4600	3.475	.130	24000
Snellings Drain	N	1	3	3	3	3	3	3	3
	Median	11.500	.500	.08400	.24000	.252000	.34600	.03700	510.00
	Mean	11.500	.700	.06467	.19133	.199667	.26433	.03967	536.67
	Std. Error of Mean	.	.2000	.024504	.069631	.0716341	.095485	.005364	116.237
	Minimum	11.5	.5	.016	.054	.0580	.074	.032	350

		Maximum	11.5	1.1	.094	.280	.2890	.373	.050	750
Waimairi Stream		N	12	12	12	12	12	12	12	12
		Median	13.250	.500	.01500	2.10150	2.105000	2.13650	.00800	195.00
		Mean	13.442	.500	.02675	2.14783	2.149417	2.17617	.00867	1157.58
		Std. Error of Mean	.2321	.0000	.009886	.086725	.0864244	.082040	.000752	896.672
		Minimum	12.4	.5	.006	1.668	1.6730	1.801	.006	41
		Maximum	14.8	.5	.130	2.638	2.6430	2.656	.014	11000
Wairarapa Stream		N	12	12	12	12	12	12	12	12
		Median	13.450	.500	.02350	1.12000	1.138000	1.21850	.00600	215.00
		Mean	13.642	.500	.03700	1.12958	1.135333	1.17233	.00683	236.67
		Std. Error of Mean	.3852	.0000	.012842	.041389	.0412814	.044033	.001241	46.904
		Minimum	11.7	.5	.010	.946	.9490	.969	.002	31
		Maximum	15.8	.5	.170	1.322	1.3260	1.368	.017	520
Total		N	157	159	158	159	159	159	159	159
		Median	13.500	.500	.03450	1.19900	1.202000	1.27900	.01700	310.00
		Mean	13.995	.769	.05609	1.31714	1.328862	1.38455	.02226	888.20
		Std. Error of Mean	.2056	.0527	.004314	.070084	.0698872	.068875	.001534	187.510
		Minimum	8.3	.5	.003	.054	.0580	.074	.002	20
		Maximum	21.2	4.5	.280	3.456	3.4600	3.475	.130	24000
Halswell Catchment	Halswell Retention Basin Inlet	N	12	11	11	11	11	11	11	12
		Median	13.050	3.400	2.30000	1.07200	1.195000	3.52200	.11000	760.00
		Mean	14.058	3.909	2.42455	.98797	1.174455	3.59900	.19982	4840.42
		Std. Error of Mean	1.6254	.4237	.485932	.085337	.0736369	.519592	.062594	2194.572
		Minimum	6.6	2.2	.360	.496	.7190	1.079	.052	5
		Maximum	21.8	6.4	5.200	1.419	1.5680	6.612	.750	24000
	Halswell Retention Basin Outlet	N	12	12	12	12	12	12	12	11
		Median	12.750	3.050	1.18000	1.61800	1.739500	3.46450	.07550	120.00
		Mean	13.575	3.242	1.74300	1.74338	1.846250	3.58925	.08692	455.45
		Std. Error of Mean	1.7017	.3039	.426192	.172741	.1749073	.437487	.015466	219.550
		Minimum	6.0	2.0	.026	1.033	1.1230	1.600	.007	5
		Maximum	21.8	5.7	5.400	3.342	3.4250	6.918	.190	2500
	Halswell River at Akaroa Highway (Tai Tapu Road)	N	12	12	12	12	12	12	12	12
		Median	11.600	.500	.03000	4.52400	4.543000	4.56300	.01400	550.00
		Mean	11.950	.892	.03158	4.54379	4.552208	4.58379	.01575	630.83
		Std. Error of Mean	.6331	.2759	.004387	.319492	.3187819	.319053	.001638	90.641
		Minimum	8.4	.5	.011	2.831	2.8350	2.880	.010	290
		Maximum	15.6	3.8	.055	6.995	7.0110	7.032	.028	1300
	Knights Stream at Sabys Road	N	12	12	12	12	12	12	12	12

		Median	11.800	.500	.01600	5.43200	5.438500	5.45600	.00600	585.00
		Mean	12.092	.800	.03125	5.17218	5.179167	5.21042	.00717	606.67
		Std. Error of Mean	.4182	.2579	.010768	.262582	.2629185	.266801	.001050	63.905
		Minimum	9.7	.5	.008	3.054	3.0610	3.077	.003	240
		Maximum	14.6	3.6	.140	6.109	6.1170	6.179	.015	1100
	Nottingham Stream at Candys Road	N	12	12	12	12	12	12	12	12
		Median	11.050	1.000	.07700	.64850	.670500	.70950	.04050	795.00
		Mean	11.283	.883	.08808	.61944	.634333	.72242	.03783	2875.42
		Std. Error of Mean	.7446	.1014	.016623	.040768	.0410305	.045707	.003715	1926.308
		Minimum	6.7	.5	.018	.277	.2850	.313	.017	5
		Maximum	15.6	1.3	.210	.798	.8080	.932	.060	24000
	Total	N	60	59	59	59	59	59	59	59
		Median	11.800	1.200	.07300	1.71300	1.815000	4.08850	.03400	630.00
		Mean	12.592	1.912	.83724	2.64090	2.702754	3.53999	.06729	1905.93
		Std. Error of Mean	.5170	.2144	.179196	.262964	.2580493	.253532	.014788	618.719
		Minimum	6.0	.5	.008	.277	.2850	.313	.003	5
		Maximum	21.8	6.4	5.400	6.995	7.0110	7.032	.750	24000
Heathcote Catchment	Cashmere Stream at Sutherlands Road	N	12	12	12	12	12	12	12	12
		Median	13.900	.500	.01000	2.01800	2.021500	2.03100	.00500	41.00
		Mean	13.800	.542	.01354	1.99339	1.998667	2.01200	.00475	117.25
		Std. Error of Mean	.2823	.0417	.003224	.054647	.0550240	.056372	.000858	68.363
		Minimum	12.3	.5	.003	1.741	1.7450	1.756	.002	5
		Maximum	15.5	1.0	.041	2.235	2.2430	2.253	.011	860
	Cashmere Stream at Worsleys Road	N	12	12	12	12	12	12	12	12
		Median	12.450	.500	.01750	1.52350	1.531000	1.54300	.01200	250.00
		Mean	12.442	.750	.02050	1.50260	1.510750	1.53125	.01233	348.25
		Std. Error of Mean	.5678	.1459	.003149	.046198	.0460502	.046610	.001394	91.863
		Minimum	9.3	.5	.006	1.268	1.2780	1.290	.006	63
		Maximum	15.3	2.1	.041	1.778	1.7850	1.806	.024	1200
	Curletts Road Stream at Motorway	N	11	11	11	11	11	11	11	11
		Median	10.900	1.100	.12000	2.27500	2.303000	2.39700	.03200	240.00
		Mean	12.600	1.364	.12636	2.15945	2.195909	2.32227	.04618	505.91
		Std. Error of Mean	1.4516	.2868	.022804	.375858	.3728263	.361945	.014067	185.178
		Minimum	5.9	.5	.038	.447	.4900	.619	.016	5
		Maximum	20.7	3.5	.260	3.755	3.7840	3.854	.180	2100
	Curletts Road Stream Upstream of Heathcote River	N	12	12	12	12	12	12	12	12
		Median	11.700	1.700	.12950	1.95850	1.987000	2.08350	.02550	285.00
		Mean	11.992	1.550	.15892	1.93892	1.963167	2.12208	.04450	521.00
		Std. Error of Mean	.8351	.2488	.051034	.379077	.3787703	.344768	.012987	170.227

	Minimum	7.8	.5	.014	.021	.0260	.256	.012	52
	Maximum	17.5	2.8	.650	3.981	3.9970	4.021	.170	2100
Haytons Stream at Retention Basin	N	12	12	12	12	12	12	12	12
	Median	11.650	1.600	.08400	.32350	.340000	.44650	.29000	86.00
	Mean	12.083	2.050	.13108	.33358	.349500	.48058	.30667	283.67
	Std. Error of Mean	1.4115	.4470	.034993	.062645	.0652488	.083636	.039968	125.028
	Minimum	5.7	.5	.028	.027	.0300	.071	.130	5
	Maximum	19.0	6.5	.400	.680	.6980	.974	.600	1400
Heathcote River at Bowenvale Avenue	N	12	12	12	12	12	12	12	12
	Median	12.200	.500	.02950	1.61300	1.624000	1.65300	.01850	335.00
	Mean	12.475	.733	.03200	1.67287	1.688250	1.72025	.01967	773.08
	Std. Error of Mean	.6931	.1018	.003840	.064762	.0651946	.066116	.002692	459.036
	Minimum	8.5	.5	.017	1.398	1.4050	1.425	.008	97
	Maximum	16.3	1.4	.054	2.021	2.0320	2.082	.044	5800
Heathcote River at Catherine Street	N	12	12	12	12	12	12	12	12
	Median	12.900	.750	.07800	1.39725	1.411750	1.46975	.03000	495.00
	Mean	13.408	.967	.09600	1.36829	1.387042	1.48304	.02808	837.50
	Std. Error of Mean	.9837	.1667	.028762	.066037	.0653094	.081478	.002911	285.490
	Minimum	8.9	.5	.023	.983	.9990	1.069	.009	170
	Maximum	18.5	2.3	.400	1.677	1.6910	2.091	.044	3300
Heathcote River at Ferniehurst Street	N	12	12	12	12	12	12	12	12
	Median	12.150	.500	.03500	1.96100	1.973000	2.00850	.01600	445.00
	Mean	12.308	.700	.03867	1.92817	1.939250	1.97792	.01767	450.50
	Std. Error of Mean	.6619	.1108	.004501	.085692	.0857098	.086538	.002667	69.565
	Minimum	8.5	.5	.020	1.450	1.4580	1.478	.007	86
	Maximum	15.5	1.6	.069	2.349	2.3590	2.389	.044	990
Heathcote River at Ferrymead Bridge	N	12	12	12	12	12	12	12	12
	Median	12.900	1.100	.15500	.70100	.717000	.88700	.03150	310.00
	Mean	13.500	1.017	.13958	.81287	.834667	.97425	.03675	453.83
	Std. Error of Mean	1.2784	.1199	.016309	.091027	.0930021	.101842	.004724	114.841
	Minimum	8.0	.5	.040	.514	.5250	.565	.020	52
	Maximum	20.2	1.6	.240	1.455	1.4700	1.710	.077	1100
Heathcote River at Mackenzie Avenue	N	12	12	12	12	12	12	12	12
	Median	12.750	.500	.07500	1.40450	1.421000	1.48500	.02700	250.00
	Mean	13.133	.817	.07800	1.43056	1.447583	1.52558	.02600	855.92
	Std. Error of Mean	.8371	.1440	.009929	.074760	.0738410	.075810	.003109	379.384
	Minimum	9.0	.5	.014	1.085	1.1000	1.181	.009	41
	Maximum	17.8	1.9	.130	1.824	1.8370	1.937	.048	4600
Heathcote River at Opawa	N	12	12	12	12	12	12	12	12

	Road/Clarendon Terrace	Median	12.750	.500	.06050	1.55600	1.565000	1.62200	.02500	280.00
		Mean	13.058	.650	.06942	1.51599	1.526275	1.59569	.02450	514.50
		Std. Error of Mean	.7428	.1019	.010169	.066110	.0637000	.064241	.002875	205.670
		Minimum	9.2	.5	.020	1.150	1.1660	1.215	.009	31
		Maximum	17.2	1.5	.160	1.891	1.9040	1.968	.047	2600
	Heathcote River at Rose Street	N	12	12	12	12	12	12	12	12
		Median	12.050	.750	.07100	3.05950	3.087000	3.17050	.02850	555.00
		Mean	12.558	.958	.09033	2.72617	2.749917	2.84025	.03567	916.67
		Std. Error of Mean	.9729	.1525	.011634	.198285	.1975947	.197460	.008269	228.819
		Minimum	7.3	.5	.039	1.361	1.3840	1.438	.013	130
		Maximum	17.9	1.8	.150	3.450	3.4700	3.539	.120	2200
	Heathcote River at Templetons Road	N	5	5	5	5	5	5	5	5
		Median	10.800	1.800	.02400	2.76200	2.774000	2.78700	.00400	10.00
		Mean	10.420	2.240	.02720	2.61580	2.631000	2.65820	.01830	178.00
		Std. Error of Mean	1.5390	1.0666	.007716	.876752	.8801865	.883591	.014936	142.518
		Minimum	6.2	.5	.013	.010	.0160	.040	.002	5
		Maximum	15.2	6.3	.056	4.975	5.0000	5.028	.078	740
	Heathcote River at Tunnel Road	N	12	12	12	12	12	12	12	12
		Median	13.250	.500	.13000	1.09050	1.111000	1.20900	.03050	360.00
		Mean	13.575	1.058	.11592	1.15123	1.169167	1.28508	.03317	693.33
		Std. Error of Mean	1.1049	.2231	.014706	.064864	.0649214	.071479	.003270	209.217
		Minimum	8.5	.5	.013	.869	.8900	1.009	.020	110
		Maximum	19.6	2.5	.180	1.629	1.6460	1.806	.058	2300
	Total	N	160	160	160	160	160	160	160	160
		Median	12.600	.500	.06050	1.55100	1.563000	1.60500	.02500	280.00
		Mean	12.767	1.048	.08333	1.60830	1.625505	1.70882	.04798	547.76
		Std. Error of Mean	.2573	.0699	.006688	.068684	.0687142	.067114	.006774	62.429
		Minimum	5.7	.5	.003	.010	.0160	.040	.002	5
		Maximum	20.7	6.5	.650	4.975	5.0000	5.028	.600	5800
	Linwood Canal	Linwood Canal/City Outfall Drain	N	12	12	12	12	12	12	12	12
			Median	14.900	.500	.10150	.02550	.030500	.13200	.08350	322.50
			Mean	15.825	1.017	.25688	.06517	.074833	.33208	.08533	378.33
			Std. Error of Mean	1.3557	.1878	.089090	.023287	.0265626	.109082	.013575	119.123
			Minimum	7.4	.5	.003	.004	.0050	.010	.029	2
			Maximum	22.8	1.9	1.000	.252	.2730	1.229	.190	1600
		Total	N	12	12	12	12	12	12	12	12
			Median	14.900	.500	.10150	.02550	.030500	.13200	.08350	322.50
			Mean	15.825	1.017	.25688	.06517	.074833	.33208	.08533	378.33
			Std. Error of Mean	1.3557	.1878	.089090	.023287	.0265626	.109082	.013575	119.123

		Minimum	7.4	.5	.003	.004	.0050	.010	.029	2
		Maximum	22.8	1.9	1.000	.252	.2730	1.229	.190	1600
Ōtūkaikino Catchment	Ōtūkaikino Creek at Omaka Scout Camp	N	12	12	12	12	12	12	12	12
		Median	12.100	.500	.00950	.18100	.184000	.19800	.00750	110.00
		Mean	12.975	.500	.01221	.18492	.186917	.19913	.00925	111.50
		Std. Error of Mean	.8484	.0000	.001747	.037103	.0369923	.036667	.001298	16.772
		Minimum	8.9	.5	.006	.052	.0540	.060	.005	31
		Maximum	18.3	.5	.023	.480	.4800	.489	.018	230
	Ōtūkaikino River at Groynes Inlet	N	12	12	12	12	12	12	12	12
		Median	11.950	.500	.01300	.14950	.152000	.16500	.00550	135.00
		Mean	12.850	.500	.01508	.17517	.176833	.19192	.00563	139.00
		Std. Error of Mean	.7787	.0000	.001621	.024982	.0248306	.025530	.000699	24.808
		Minimum	9.0	.5	.009	.074	.0760	.085	.002	5
		Maximum	16.6	.5	.029	.301	.3010	.316	.010	270
	Wilsons Stream	N	12	12	12	12	12	12	12	12
		Median	13.000	.500	.01300	1.56700	1.570500	1.58200	.01400	255.00
		Mean	13.400	.550	.01650	1.58758	1.590833	1.60733	.01367	723.58
		Std. Error of Mean	.6532	.0500	.002592	.025366	.0255120	.026307	.001117	463.773
		Minimum	10.6	.5	.009	1.493	1.4960	1.514	.009	63
		Maximum	18.5	1.1	.038	1.788	1.7940	1.832	.019	5800
	Total	N	36	36	36	36	36	36	36	36
		Median	12.000	.500	.01300	.26650	.268500	.27800	.00900	150.00
		Mean	13.075	.517	.01460	.64922	.651528	.66613	.00951	324.69
		Std. Error of Mean	.4304	.0167	.001179	.113386	.1134938	.113742	.000817	157.808
		Minimum	8.9	.5	.006	.052	.0540	.060	.002	5
		Maximum	18.5	1.1	.038	1.788	1.7940	1.832	.019	5800
Styx Catchment	Kaputone Creek at Belfast Road	N	12	12	12	12	12	12	12	12
		Median	12.950	.500	.11000	.96800	.988000	1.10100	.03400	1600.00
		Mean	13.600	1.042	.11300	.96979	.988167	1.10117	.03667	2230.83
		Std. Error of Mean	.8687	.2457	.011520	.026775	.0270000	.028373	.003824	445.553
		Minimum	9.2	.5	.068	.843	.8580	.934	.017	660
		Maximum	20.1	2.8	.190	1.161	1.1770	1.254	.070	5800
	Kaputone Creek at Blakes Road	N	12	12	12	12	12	12	12	12
		Median	13.750	.500	.05800	1.47450	1.482500	1.55550	.01750	825.00
		Mean	14.692	.717	.10417	1.42693	1.439833	1.54400	.01692	968.33
		Std. Error of Mean	1.3070	.1696	.034309	.043427	.0427078	.026604	.000866	214.246
		Minimum	9.3	.5	.021	1.047	1.0640	1.398	.010	190
		Maximum	24.6	2.5	.350	1.580	1.5950	1.678	.021	2600
	Smacks Creek at Gardiners	N	12	12	12	12	12	12	12	12

Road	Median	14.000	.500	.01000	.41000	.412000	.43000	.00900	63.00
	Mean	13.908	.500	.01429	.41471	.416750	.43083	.00883	171.92
	Std. Error of Mean	.5639	.0000	.002839	.035370	.0353151	.034258	.000661	78.870
	Minimum	11.3	.5	.003	.235	.2380	.273	.004	10
	Maximum	17.5	.5	.035	.603	.6050	.613	.012	960
Styx River at Gardiners Road	N	12	12	12	12	12	12	12	12
	Median	13.050	.500	.00900	.42000	.422500	.43075	.00800	210.00
	Mean	13.075	.592	.01254	.46333	.464917	.47746	.00838	314.50
	Std. Error of Mean	.2161	.0917	.002179	.034455	.0344147	.033978	.000776	74.923
	Minimum	12.1	.5	.006	.343	.3450	.369	.002	10
	Maximum	14.6	1.6	.026	.698	.7000	.707	.012	830
Styx River at Harbour Road Bridge	N	12	12	12	12	12	12	12	12
	Median	13.350	.500	.01800	.41100	.417500	.42800	.03050	205.00
	Mean	13.683	.558	.03967	.36683	.375000	.41467	.03442	229.17
	Std. Error of Mean	1.0096	.0583	.013295	.043555	.0444570	.053022	.003876	44.079
	Minimum	8.3	.5	.007	.088	.0910	.101	.016	63
	Maximum	18.0	1.2	.170	.537	.5490	.693	.060	630
Styx River at Main North Road	N	12	12	12	12	12	12	12	12
	Median	13.000	.500	.02150	.36775	.373950	.39245	.01250	420.00
	Mean	13.325	.500	.02283	.36338	.368658	.39149	.01200	525.00
	Std. Error of Mean	.6533	.0000	.001813	.019618	.0197934	.019909	.000728	72.619
	Minimum	10.0	.5	.016	.247	.2510	.267	.006	230
	Maximum	17.9	.5	.035	.487	.4940	.519	.015	1100
Styx River at Marshland Road Bridge	N	12	12	12	12	12	12	12	12
	Median	12.650	.500	.01550	.48850	.493000	.50700	.02150	515.00
	Mean	13.142	.867	.02867	.51228	.517667	.54633	.02117	513.33
	Std. Error of Mean	.6734	.2664	.008276	.030349	.0310157	.036179	.000944	35.341
	Minimum	9.7	.5	.007	.421	.4240	.432	.017	350
	Maximum	17.8	3.7	.095	.829	.8410	.914	.028	740
Styx River at Richards Bridge	N	12	12	12	12	12	12	12	12
	Median	12.350	.500	.01450	.50050	.510000	.54150	.02900	395.00
	Mean	13.333	.650	.03825	.43786	.445417	.48367	.03300	444.17
	Std. Error of Mean	.8445	.1077	.009626	.042946	.0434339	.050445	.003335	71.472
	Minimum	8.8	.5	.009	.192	.1960	.209	.019	170
	Maximum	18.5	1.7	.100	.593	.6020	.675	.056	1100
Total	N	96	96	96	96	96	96	96	96
	Median	13.300	.500	.02200	.48750	.492500	.50900	.01800	410.00
	Mean	13.595	.678	.04668	.61939	.627051	.67370	.02142	674.66
	Std. Error of Mean	.2851	.0547	.006202	.038489	.0388824	.042250	.001385	90.018

	Minimum	8.3	.5	.003	.088	.0910	.101	.002	10
	Maximum	24.6	3.7	.350	1.580	1.5950	1.678	.070	5800

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	159	159	146	159	159	159	135	157
	Median	.001000	.0007500	.005000	7.600	192.00	3.50	2.000	87.00
	Mean	.001032	.0008289	.012298	7.589	1350.59	6.71	4.084	86.90
	Std. Error of Mean	.0000203	.00002438	.0018290	.0302	282.013	.615	.4165	.944
	Minimum	.0010	.00075	.0005	6.5	106	2	.1	52
	Maximum	.0038	.00280	.1700	8.3	21400	43	38.0	110
Halswell Catchment	N	59	59	54	59	59	59	36	60
	Median	.001000	.0007500	.010500	7.600	224.00	8.00	1.700	84.50
	Mean	.002097	.0008958	.028167	7.769	217.54	17.73	3.358	79.63
	Std. Error of Mean	.0002190	.00006068	.0064693	.0801	5.471	6.169	.6277	2.454
	Minimum	.0010	.00075	.0005	7.0	123	2	.3	16
	Maximum	.0091	.00290	.2500	10.2	310	360	18.0	120
Heathcote Catchment	N	160	160	141	160	160	160	125	160
	Median	.001000	.0007500	.013000	7.600	295.50	5.00	3.300	81.50
	Mean	.001441	.0007772	.031975	7.591	1896.11	13.04	7.615	77.71
	Std. Error of Mean	.0000981	.00001774	.0053961	.0202	397.817	1.542	.9344	1.533
	Minimum	.0010	.00075	.0005	6.9	115	2	.1	13
	Maximum	.0110	.00330	.5500	8.1	25800	150	69.0	120
Linwood Canal	N	12	12	11	12	12	12	12	12
	Median	.001000	.0007500	.002000	7.950	3275.00	8.50	5.500	81.50
	Mean	.001000	.0008542	.008591	7.958	6071.67	9.17	5.958	81.08
	Std. Error of Mean	.0000000	.00010417	.0036926	.1685	1888.022	.968	.7653	7.628
	Minimum	.0010	.00075	.0005	6.9	2620	5	1.6	42
	Maximum	.0010	.00200	.0420	8.8	24700	16	12.0	130
Ōtūkaikino Catchment	N	36	36	28	36	36	36	36	36
	Median	.001000	.0007500	.004000	7.500	82.00	1.50	.565	88.00
	Mean	.001181	.0008431	.006732	7.586	96.70	1.99	1.116	89.25
	Std. Error of Mean	.0001806	.00005252	.0019103	.0541	3.975	.154	.1889	1.331
	Minimum	.0010	.00075	.0005	7.3	75	2	.2	77
	Maximum	.0075	.00200	.0400	8.8	158	5	5.4	120
Styx Catchment	N	96	96	74	96	96	96	96	96
	Median	.001000	.0007500	.002000	7.500	133.50	3.00	1.450	76.00
	Mean	.001000	.0007589	.005723	7.477	132.90	3.80	2.079	75.07
	Std. Error of Mean	.0000000	.00000885	.0009682	.0251	1.422	.360	.1964	1.266
	Minimum	.0010	.00075	.0005	6.8	108	2	.1	52
	Maximum	.0010	.00160	.0390	7.9	176	19	11.0	110

Total	N	522	522	454	522	522	523	440	521
	Median	.001000	.0007500	.006000	7.600	208.50	4.00	2.100	83.00
	Mean	.001281	.0008093	.018792	7.598	1187.85	9.76	4.399	81.09
	Std. Error of Mean	.0000438	.00001245	.0020065	.0164	161.242	1.111	.3211	.720
	Minimum	.0010	.00075	.0005	6.5	75	2	.1	13
	Maximum	.0110	.00330	.5500	10.2	25800	360	69.0	130

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 DRP	E. coli
Avon Catchment	N	157	159	158	159	159	159	159	159
	Median	13.500	.500	.03450	1.19900	1.202000	1.27900	.01700	310.00
	Mean	13.995	.769	.05609	1.31714	1.328862	1.38455	.02226	888.20
	Std. Error of Mean	.2056	.0527	.004314	.070084	.0698872	.068875	.001534	187.510
	Minimum	8.3	.5	.003	.054	.0580	.074	.002	20
	Maximum	21.2	4.5	.280	3.456	3.4600	3.475	.130	24000
Halswell Catchment	N	60	59	59	59	59	59	59	59
	Median	11.800	1.200	.07300	1.71300	1.815000	4.08850	.03400	630.00
	Mean	12.592	1.912	.83724	2.64090	2.702754	3.53999	.06729	1905.93
	Std. Error of Mean	.5170	.2144	.179196	.262964	.2580493	.253532	.014788	618.719
	Minimum	6.0	.5	.008	.277	.2850	.313	.003	5
	Maximum	21.8	6.4	5.400	6.995	7.0110	7.032	.750	24000
Heathcote Catchment	N	160	160	160	160	160	160	160	160
	Median	12.600	.500	.06050	1.55100	1.563000	1.60500	.02500	280.00
	Mean	12.767	1.048	.08333	1.60830	1.625505	1.70882	.04798	547.76
	Std. Error of Mean	.2573	.0699	.006688	.068684	.0687142	.067114	.006774	62.429
	Minimum	5.7	.5	.003	.010	.0160	.040	.002	5
	Maximum	20.7	6.5	.650	4.975	5.0000	5.028	.600	5800
Linwood Canal	N	12	12	12	12	12	12	12	12
	Median	14.900	.500	.10150	.02550	.030500	.13200	.08350	322.50
	Mean	15.825	1.017	.25688	.06517	.074833	.33208	.08533	378.33
	Std. Error of Mean	1.3557	.1878	.089090	.023287	.0265626	.109082	.013575	119.123
	Minimum	7.4	.5	.003	.004	.0050	.010	.029	2
	Maximum	22.8	1.9	1.000	.252	.2730	1.229	.190	1600
Ōtūkaikino Catchment	N	36	36	36	36	36	36	36	36
	Median	12.000	.500	.01300	.26650	.268500	.27800	.00900	150.00
	Mean	13.075	.517	.01460	.64922	.651528	.66613	.00951	324.69
	Std. Error of Mean	.4304	.0167	.001179	.113386	.1134938	.113742	.000817	157.808
	Minimum	8.9	.5	.006	.052	.0540	.060	.002	5
	Maximum	18.5	1.1	.038	1.788	1.7940	1.832	.019	5800
Styx Catchment	N	96	96	96	96	96	96	96	96
	Median	13.300	.500	.02200	.48750	.492500	.50900	.01800	410.00
	Mean	13.595	.678	.04668	.61939	.627051	.67370	.02142	674.66
	Std. Error of Mean	.2851	.0547	.006202	.038489	.0388824	.042250	.001385	90.018
	Minimum	8.3	.5	.003	.088	.0910	.101	.002	10
	Maximum	24.6	3.7	.350	1.580	1.5950	1.678	.070	5800

Total	N	521	522	521	522	522	522	522	522
	Median	13.000	.500	.03900	1.14850	1.191000	1.30100	.02000	325.00
	Mean	13.361	.955	.15294	1.35284	1.370464	1.52309	.03565	809.02
	Std. Error of Mean	.1375	.0411	.023108	.051012	.0510231	.055878	.002846	95.779
	Minimum	5.7	.5	.003	.004	.0050	.010	.002	2
	Maximum	24.6	6.5	5.400	6.995	7.0110	7.032	.750	24000

Table v. Raw data for wet weather samples taken in the Heathcote Catchment for all parameters presented in this report, sorted from upstream to downstream. All metals presented are in dissolved form. *This LOD is higher than the other samples.

Site	Date	Time	Total Ammonia	Arsenic	BOD_5	Conductivity	Copper	DO	*E. coli*	Lead	Nitrate	Nitrite	NNN	DIN	pH	DRP	TSS	Water Temperature	Turbidity	Zinc	TPH
Heathcote River at Rose Street	12/11/2015	10:10	0.17	<0.0015	3.6	178	0.0043	79	3500	<0.0015	1.5	0.03	1.6	1.8	7.3	0.066	11	12.3	0.6	0.09	<0.36
	4/04/2016	12:20	0.11	<0.0015	1.7	240	<0.0020	92	4100	<0.0015	1.4	0.018	1.4	1.5	7.4	0.047	6.0	14.7	3.9	0.033	
Cashmere Stream at Sutherlands Road	12/11/2015	10:30	0.014	<0.0015	<1	322	<0.0020	59	490	<0.0015	2.1	0.0075	2.1	2.1	7.1	<0.0030	3	12.9	0.18	<0.01*	<0.37
	4/04/2016	12:00	0.0070	<0.0015	<1.0	330	<0.0015	57	52	<0.0015	1.6	0.0040	1.6	1.6	7.0	<0.0030	<3.0	14.5	0.3	0.0065	
Cashmere Stream at Worsleys Road	12/11/2015	11:00	0.02	<0.0010	1.5	198	<0.0020	83	1100	<0.0015	1.1	0.012	1.2	1.2	7.6	0.023	4	12.3	0.74	<0.01*	<0.37
	4/04/2016	11:35	0.010	<0.0015	<1.0	240	<0.0020	92	860	<0.0015	1.6	0.0070	1.6	1.6	7.6	0.011	3.0	13.5	2.3	0.001	
Heathcote River at Ferniehurst Street	12/11/2015	10:50	0.07	<0.0015	1.1	185	<0.0020	81	3300	<0.0015	1.3	0.017	1.4	1.5	7.4	0.034	5	12.2	0.75	0.036	<0.37
	4/04/2016	11:45	0.025	<0.0015	<1.0	250	<0.0020	92	4100	<0.0015	1.9	0.010	1.9	1.9	7.6	0.021	6.0	13.6	2.9	0.0059	
Heathcote River at Bowenvale Avenue	12/11/2015	11:10	0.094	<0.0015	2.4	165	<0.0020	75	6100	<0.0015	1	0.015	1	1.1	7.5	0.046	6	12	1.7	0.037	<0.36
	4/04/2016	11:25	0.15	<0.0015	2.5	260	<0.0020	71	1600	0.0016	1.3	0.012	1.3	1.5	7.5	0.021	26	14.3	11	0.018	
Heathcote River at Catherine Street	12/11/2015	10:40	0.13	<0.0015	2.5	255	<0.0020	65	3700	<0.0015	1.1	0.023	1.1	1.2	7.5	0.049	17	12.9	1.5	0.046	<0.36
	04/04/2016	11:50	0.049	<0.0015	<1.0	420	<0.0020	80	1200	<0.0015	1.2	0.022	1.3	1.4	7.7	0.031	10	15.3	7.3	0.0052	

Appendix B: Metal Hardness Modified Trigger Values

9.1 Avon, Heathcote, Styx, Ōtūkaikino and Halswell River Catchments

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).

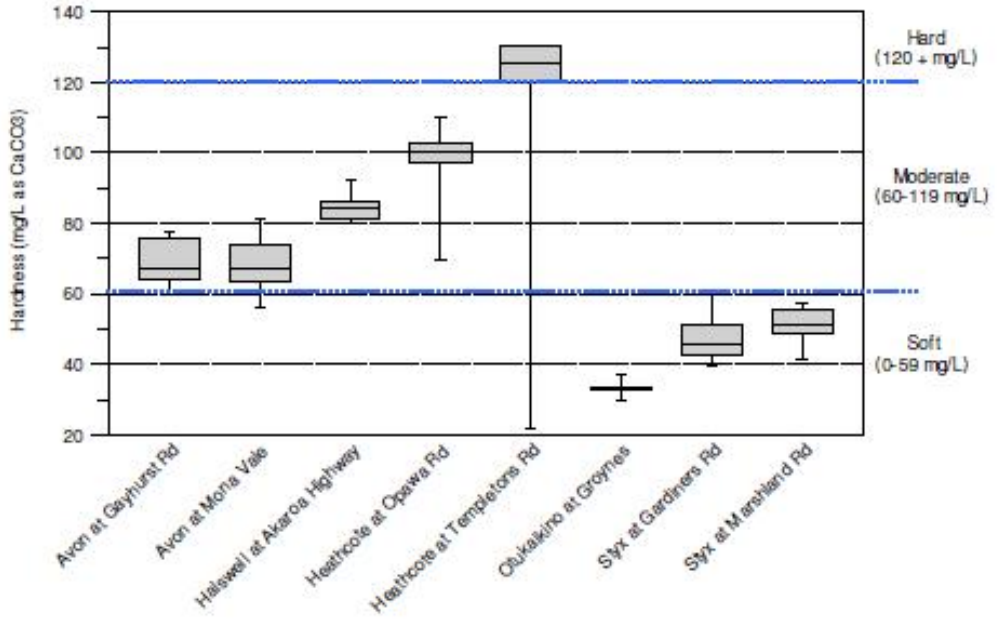

Figure 1 Box plots displaying median (and upper, lower quartiles, max and min) water hardness values for monitoring sites on the Avon, Heathcote, Halswell, Styx and Otukaikino rivers between December 2010 and March 2012.

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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9.2 Linwood Canal

Linwood Canal Hardness Modified Trigger Values for Metals

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 dissolved metals. If measured concentrations of toxicants are below default trigger values, then there is considered to be a low risk of adverse effects. The guidelines also provide a process for modifying the given trigger values for local environmental conditions, namely hardness, which can affect the toxicity of metals and therefore increase 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). However, 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. Hardness Modified Trigger Values (HMTV) for dissolved metals for the Avon, Heathcote, Halswell, Styx and Otukaikino Rivers have previously been calculated by the Christchurch City Council (Dewson, 2012) and these are the guidelines used in reporting. It is considered that hardness values are unlikely to change over the years, so these values should only need to be re-assessed approximately every five years. However, no values have previously been calculated for the Linwood Canal (City Outfall Drain), which is in its own catchment. This memorandum therefore outlines hardness modified values for this waterway, which have also been calculated based on the water hardness algorithms provided in the ANZECC guidelines (ANZECC, 2000).

2. Methods

Linwood Canal at Humphreys Drive (2485954E, 5739637N) has been sampled monthly for a variety of water quality parameters since January 2007. However, water hardness has only been monitored (measured in mg/L as CaCO3) since September 2014. One full year of data has now be collected to enable the calculation of Hardness Modified Trigger Values for metals. Dissolved copper, lead and zinc trigger values were calculated, given these are the primary metals of concern, which are commonly compared against guidelines levels.

Boxplots of the water hardness data were created in IBM® SPSS Statistics 20, to show the median and interquartile range. Statistical outliers were not removed, as values were assumed to be 'real', providing useful information on variations in the concentrations recorded. The dark line in the boxplots represents the median, and the bottom and top lines of the box represent the 25th and 75th percentiles (the interquartile range), respectively. The T-bars that extend from the box approximate the location of 95% of the data. Circles represent statistical outliers and stars represent extreme outliers.

To calculate the HMTV for metals for Linwood Canal, 90% species protection was chosen. This waterway is not classified under the proposed Land and Water Regional Plan (Environment Canterbury, 2012), but is considered to best fit the 'spring-fed – plains – urban' classification, which relates to 90% species protection under this plan. The algorithms in the ANZECC (2000) guidelines were then used to calculate the final trigger values.

3. Results

Median water hardness at Linwood Canal fell within the 'extremely hard' category (greater than 400 mg/L) of the ANZECC (2000) guidelines (Table 1 & Figure 1). Therefore, HMTV for copper, lead and zinc were calcluated to be 0.0175 mg/L, 0.168 mg/L and 0.146 mg/L, respectively (Table 2).

Table 1. Summary of the monitoring data for water hardness (mg/L) in Linwood Canal from September 2014 - August 2015.

Sample Size	Median	Mean	Standard Error of the Mean	Minimum	Maximum
12	435	738	206	160	2500

Table 3. Calculations of Hardness Modified Trigger Values for copper, lead and zinc for Linwood Canal, using 90% species protection and the ANZECC (2000) algorithms. HMTV = Hardness Modified Trigger Value; TV = Trigger Value; H = Hardness.

Copper	Lead	Zinc
$HMTV = TV(H/30)^{0.85}$	$HMTV = TV(H/30)^{1.27}$	$HMTV = TV(H/30)^{0.85}$
$= 1.8 \times (435/30)^{0.85}$	$= 5.6 \times (435/30)^{1.27}$	$= 15 \times (435/30)^{0.85}$
= 17.5 µg/L	= 167 µg/L	= 146 µg/L
= 0.0175 mg/L	= 0.167 mg/L	= 0.146 mg/L

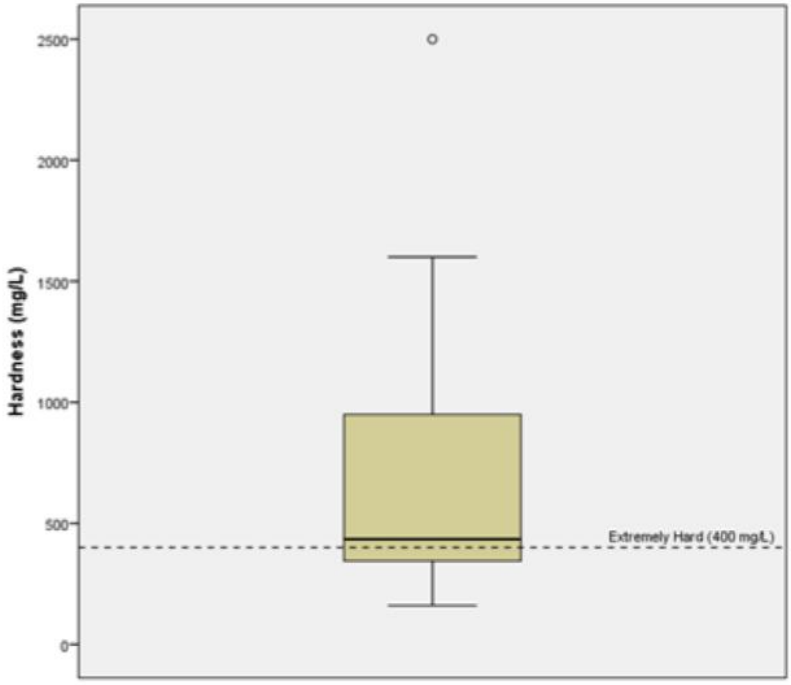

Figure 1. Box plot of water hardness for Linwood Canal for the monitoring period September 2014 - August 2015

3. References

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

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

Environment Canterbury (2012). Proposed Canterbury Land and Water Regional Plan - Volume 1. Environment Canterbury, Christchurch.

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11th September 2015

Appendix C: Laboratory Methods and Limits of Detection

Table i. Laboratory methods used over time to calculate parameter concentrations. N/A = Not Applicable.

Parameter	Limit of Detection (date)	Analysis method dates	Analysis method
Total ammonia (ammoniacal nitrogen)	<0.005 mg/L (4 September 2014 - current day) <0.01 mg/L(sampling instigation - 3 September 2014)	1 August 2014 - current day	APHA 4500-NH3 G (Continuous Flow Autoanalyser)
		Sampling instigation – 31 July 2014	4500-NH3 F (Discrete Analyser)
Biochemical Oxygen Demand (BOD_5)	<1.0 (sampling instigation- current day)	Sampling instigation - current day	APHA 5210 B
Conductivity		Sampling instigation - current day	APHA 2510 B
Total and dissolved copper	Total Copper: Varies between 0.001mg/L-0.005 mg/L (sampling instigation- current day) Dissolved Copper: <0.002 mg/L (December 2008- current day) <0.004 mg/L (2007-November 2008)	5 May 2016 - current day	APHA 3125 B modified, (Varian7900 ICP- MS) using nylon 0.45um filters. Digestion APHA 3030 E.
		Sampling instigation - 04 May 2016	Graphite furnace (GFAA - graphite furnace atomic absorption, Varian) using acid washed GF/F filters.
Dissolved Oxygen (DO)	N/A	Sampling instigation - current day	APHA 4500-O G
Enterococci	<10 MPN/100mL (sampling instigation - current day)	Sampling instigation - current day	Enterolert APHA 9230 D
Escherichia coli	Varies depending on required dilution (Sampling instigation - current day)	Sampling instigation - current day	Colilert APHA 4500 9223 B
Total water hardness	N/A	Sampling instigation - current day	APHA 2340 B calculation from calcium and magnesium measured by APHA 3125 B modified (Varian7900 ICP- MS,) using nylon 0.45um filters
Total and dissolved lead	Total Lead: Varies between 0.004 mg/L-0.0015 mg/L (sampling instigation - current day) Dissolved lead: <0.0015 mg/L (December 2008- current day) <0.006 mg/L (2007-November 2008)	Sampling instigation - current day	APHA 3125 B modified (Varian7900 ICP- MS), using nylon 0.45um filters. Digestion APHA 3030 E.
Nitrate nitrogen	<0.003 mg/L (9 September 2014- current day) <0.05 mg/L (sampling instigation- 8 September 2014)	1 August 2014 - current day	APHA 4500-NO3 F (Continuous flow autoanalyser)
		Sampling instigation - 31 July 2014	APHA 4500-NO3 H (Hydrazine Reduction Discrete Analyser)
Nitrite nitrogen	<0.001 mg/L (9 September 2014- current day)	1 August 2014 - current day	APHA 4500-NO3 F 22nd Ed. 2012 (cadmium reduction and continuous flow analyser)

Parameter	Limit of Detection (date)	Analysis method dates	Analysis method
	<0.005 mg/L (sampling instigation– 8 September 2014)	Sampling instigation - 31 July 2014	APHA 4500-NO2 B (Discrete Analyser)
Nitrate Nitrite Nitrogen (NNN)	0.01 mg/L (27 July 2011- current day)	3 April 2009 - current day	APHA 4500-NO3 E (Continuous Flow Autoanalyser)
	0.05 mg/L (sampling instigation- 26 July 2011)	Sampling instigation - 2 April 2009	Nitrate + Nitrite
Dissolved Inorganic Nitrogen (DIN)	<0.02	Sampling instigation - current day	Total ammonia + Nitrite-Nitrate-Nitrogen
pH	N/A	Sampling instigation - current day	APHA 4500-H+ B 22nd Ed. 2012 (pH meter)
Dissolved Reactive Phosphorus (DRP)	<0.003 mg/L (22 December 2010- current day)	1 August 2014 - current day	APHA 4500-P F (Continuous Flow Autoanalyser)
	<0.02 mg/L (1 December 2010- 21 December 2010)	Sampling instigation - 31 July 2014	4500-P E (Discrete Analyser)
	<0.003 mg/L (17 November 2009- 30 November 2010)		
	<0.01 mg/L (sampling instigation – 16 November 2009)		
Total phosphorus	0.003 mg/L (10 July 2014- current day)	1 August 2014 - current day	APHA 4500-P J 22nd Ed. 2012 (persulphate digestion and continuous flow analyser)
	0.02 mg/L (17 November 2009 - 09 July 2014)	Sampling instigation - 31 July 2014	APHA 4500-P J (Discrete Analyser)
	0.06 mg/L (sampling instigation - 16 November 2009)		
Total Suspended Solids (TSS)	3 mg/L (September 2010- current day)	Sampling instigation - current day	APHA 2540 D
	<5 mg/L (sampling instigation- August 2010)		
Water temperature	N/A	Sampling instigation - current day	YSI Pro ODO meter
Total nitrogen	0.01 mg/L (10 July 2014 - current day)	1 August 2014- current day	APHA 4500-N C 22nd Ed. 2012 (persulphate digestion and continuous flow analyser)
	0.05 mg/L (4 March 2009 - 9 July 2014)	Sampling instigation - 31 July 2014	APHA 4500-N C (Discrete Analyser)
	1.0 mg/L (sampling instigation - 3 March 2009)		
Turbidity	<0.1 (sampling instigation- current day)	Sampling instigation - current day	APHA 2130 B 22nd Ed 2012 (turbidity meter Hach 2100AN)
Total and dissolved zinc	Total and dissolved zinc: <0.001 mg/L (March 2009- current day)	5 May 2016 - current day	APHA 3125 B modified, (Varian7900 ICP- MS) using nylon 0.45um filters. Digestion APHA 3030 E.
	<0.006 (sampling instigation- February 2009)	Sampling instigation - 04 May 2016	ICPOES (Inductively coupled optical emission spectrometer, Perkin Elmer) using acid washed GF/F filters

Appendix D: Monthly Monitoring Graphs

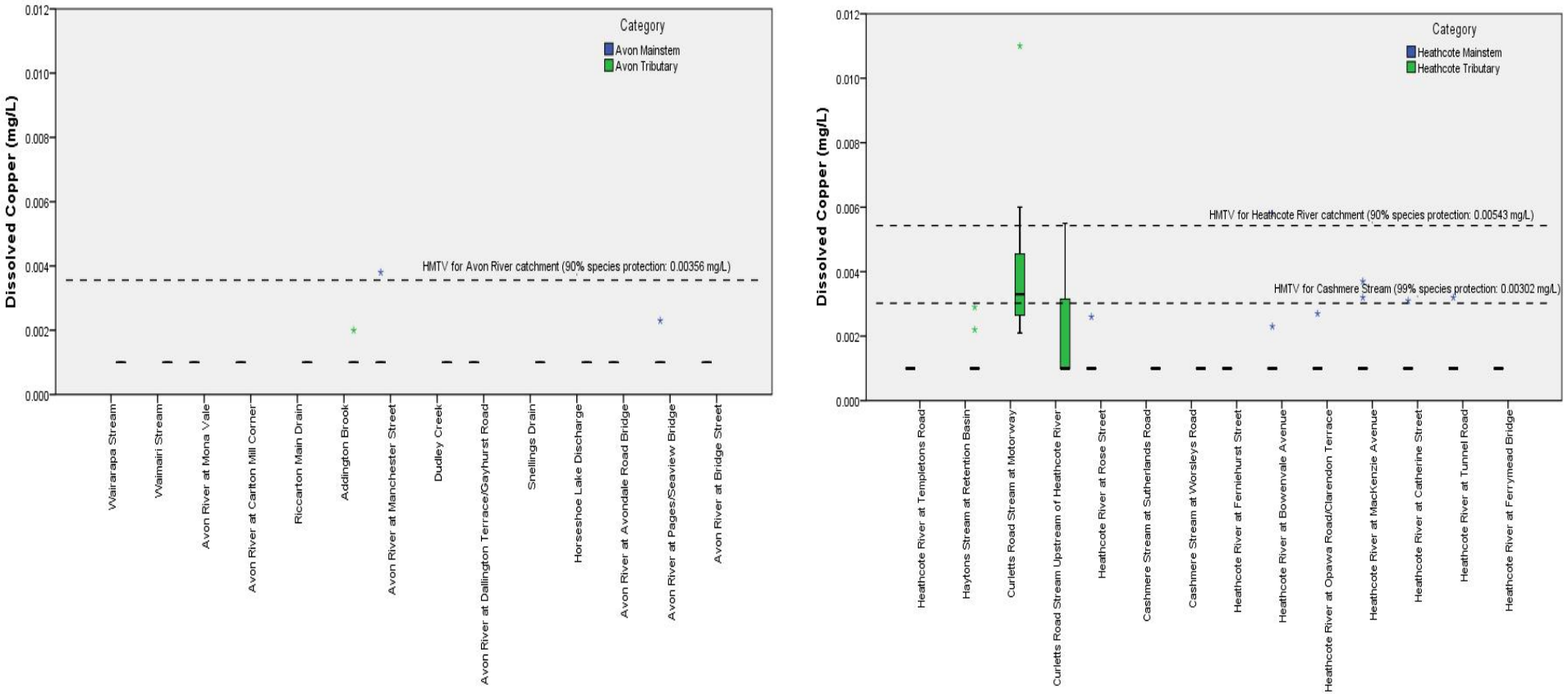

Figure i (a). Dissolved copper levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2015. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as the site was dry. Snellings Drain was sampled in March, June and September. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger values (Environment Canterbury, 2015), 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.

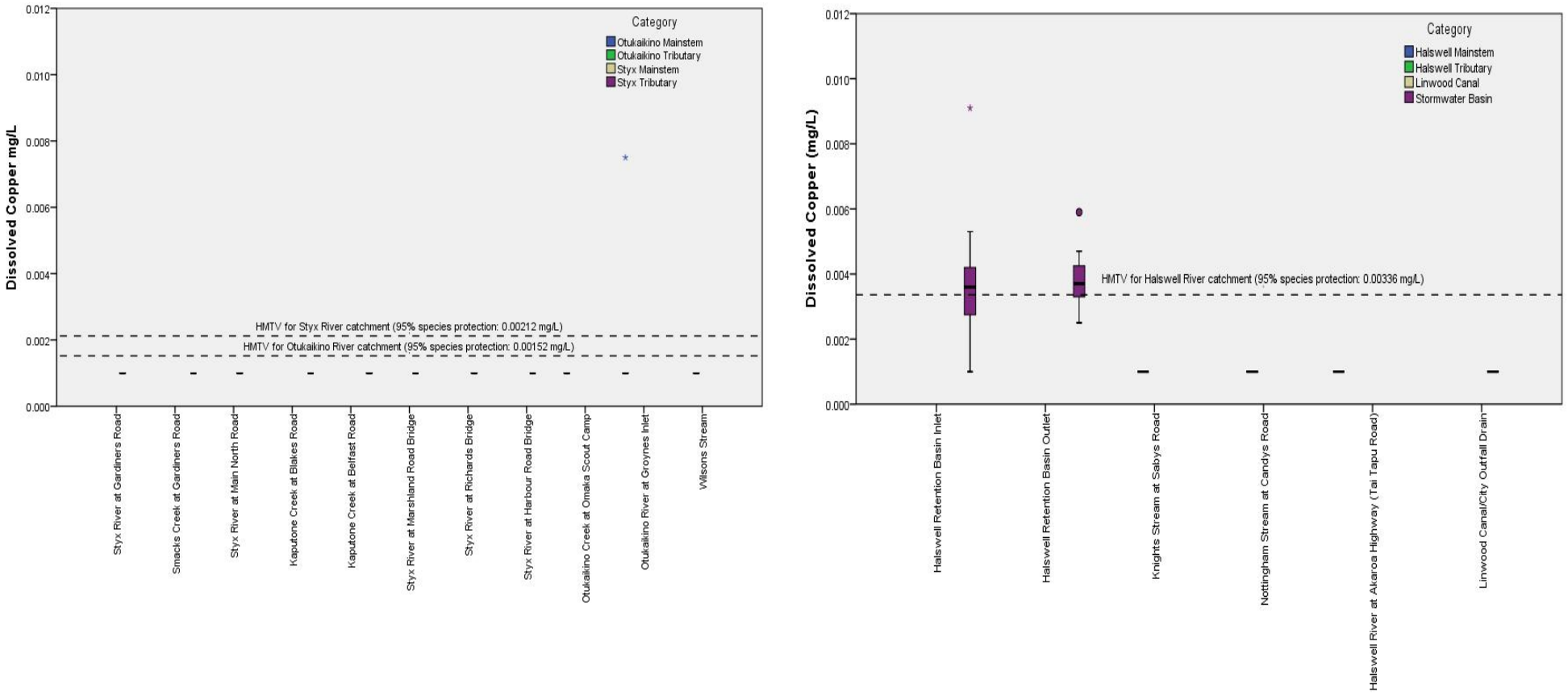

Figure i (b). Dissolved copper levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger values (Environment Canterbury, 2015), which have been modified to account for water hardness (Hardness Modified Trigger Value = HMTV), as per the ANZECC (2000) guidelines methodology. The 90% protection HMTV for Linwood Canal (0.0175 mg/L) is not shown as it is off the scale. 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.

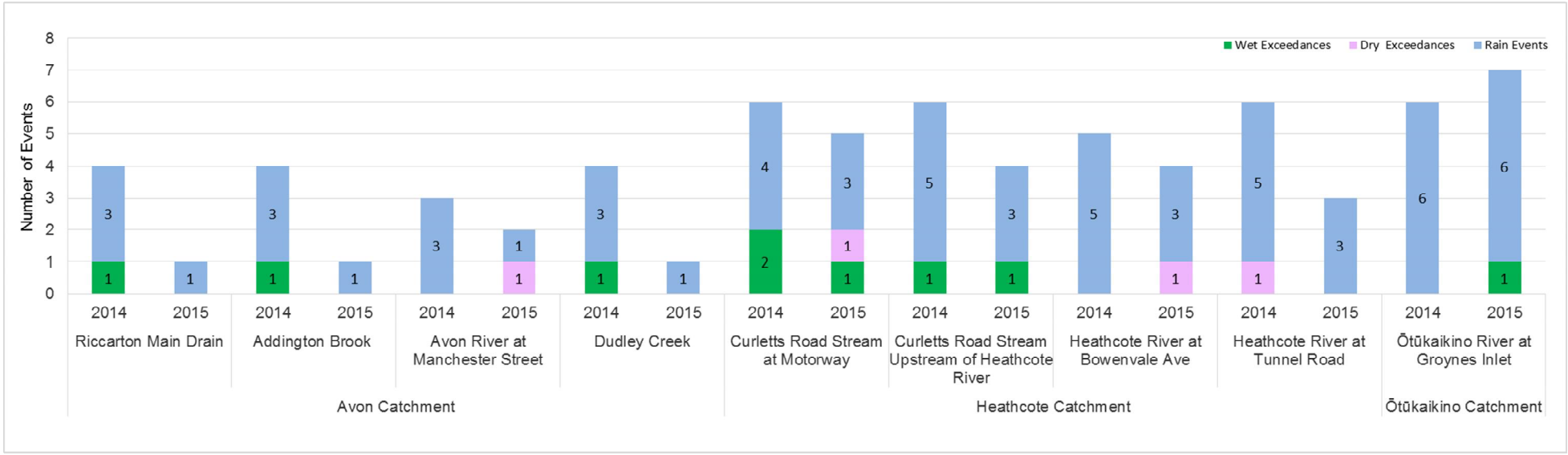

Figure i (c). Number of dissolved copper values that exceeded the catchment-specific guidelines in January - December 2014 and January - December 2015. Sites that did not record any exceedances have been omitted from the graph. Wet and dry exceedances are exceedances where rain was recorded or not recorded, respectively, at the time of sampling or within the previous 24-hours; number of rain events is the number of sampling occasions for the monitoring year where rain was recorded at the time of sampling or within the 24-hours previous, regardless of whether an exceedance was recorded or not. Only seven samples were taken at the Curletts Road Stream at Motorway site during the 2014 monitoring year, due to construction activities.

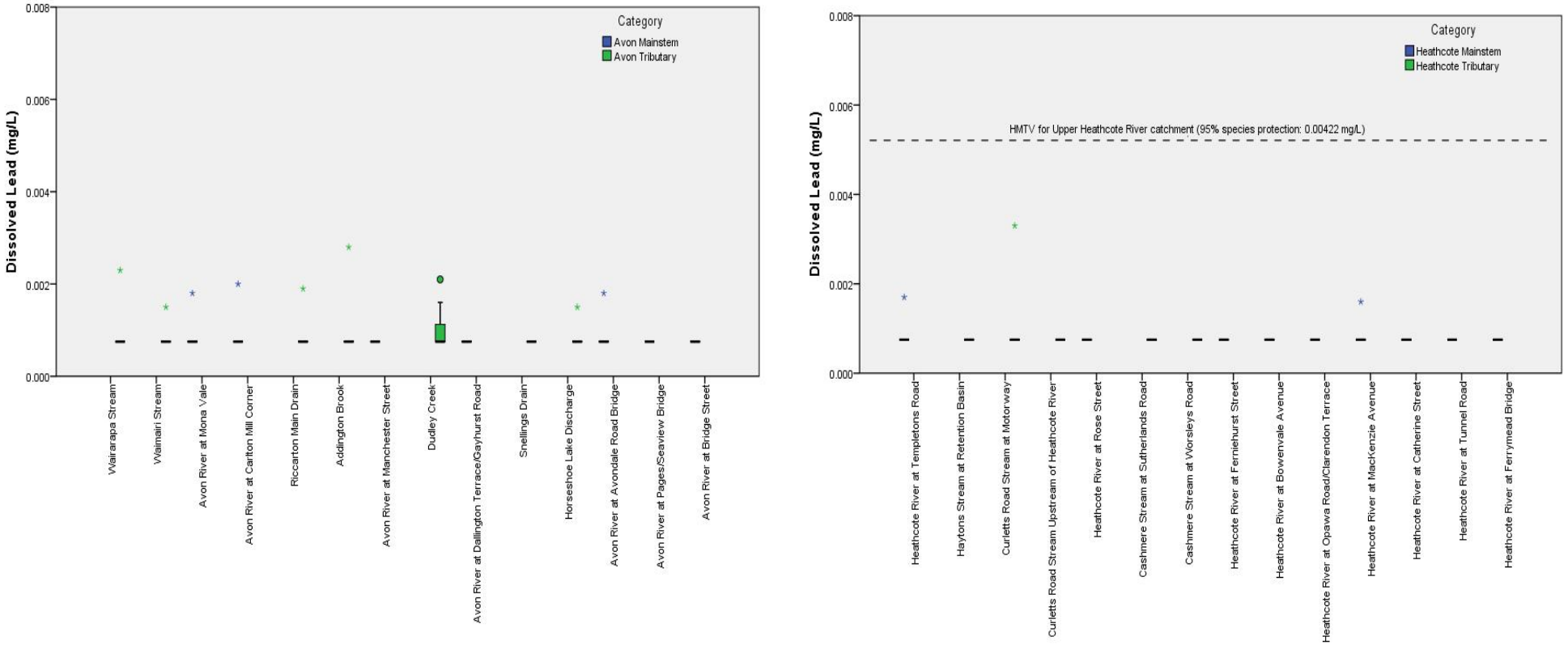

Figure ii (a). Dissolved lead levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2015. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as the site was dry. Snellings Drain was sampled in March, June and September. Sites are ordered from upstream to downstream (left to right). The dashed line represents the Land and Water Regional Plan trigger value (Environment Canterbury, 2015), 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.

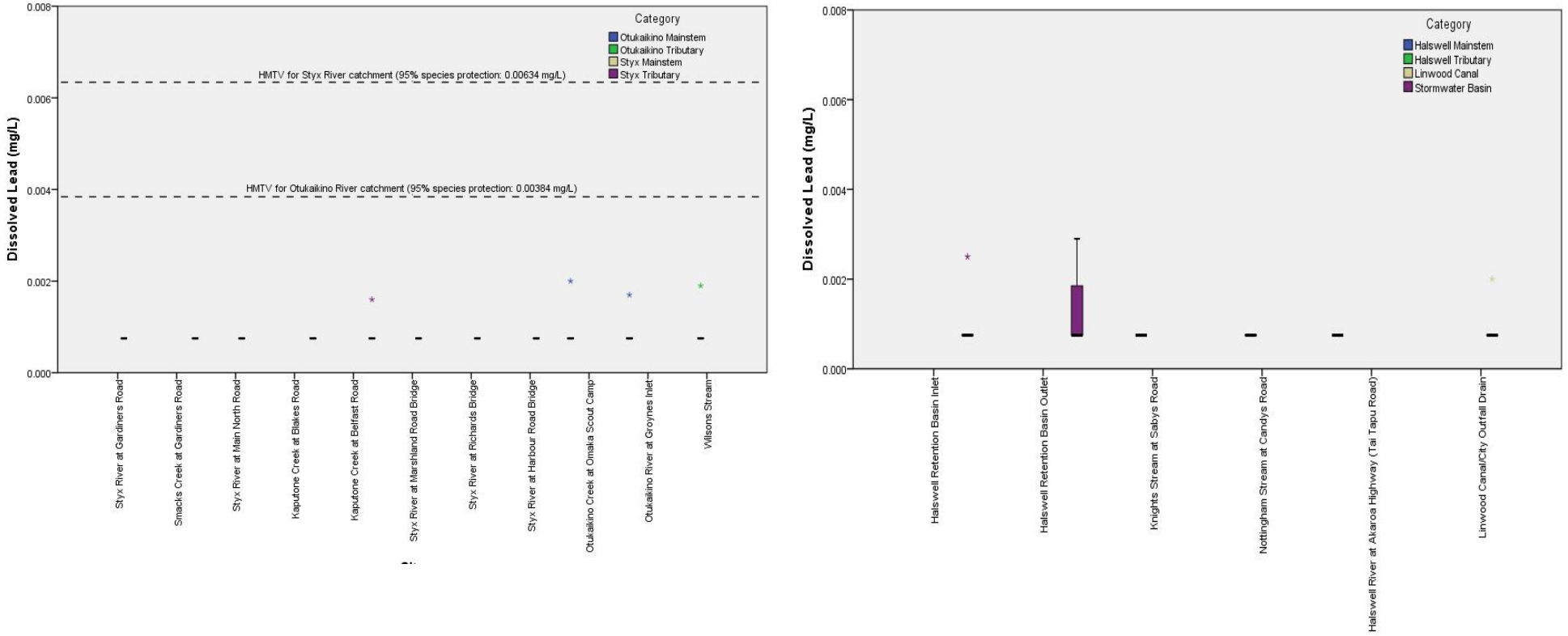

Figure ii (b. Dissolved lead levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger value (Environment Canterbury, 2015), 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/L) and 90% protection HMTV for Linwood Canal (0.167 mg/L) are not visible because 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.

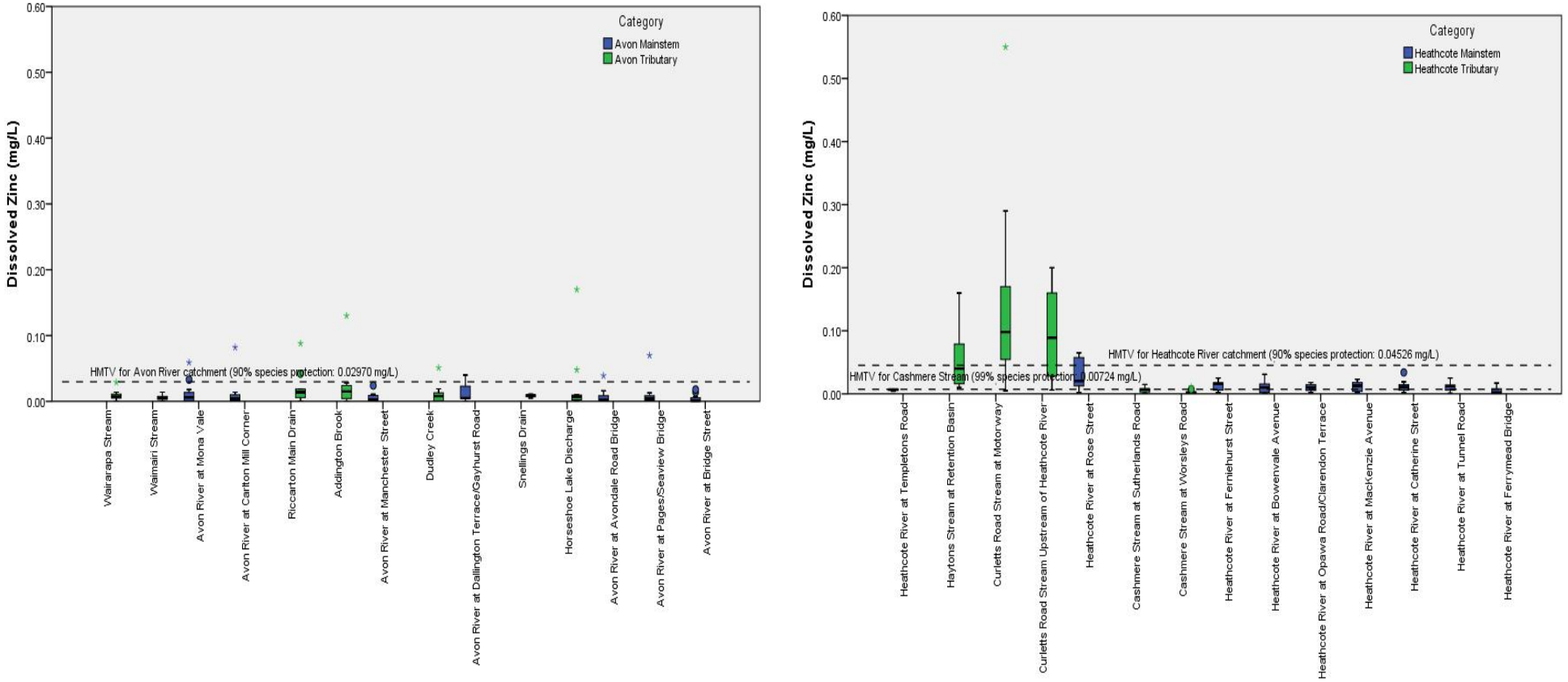

Figure iii (a). Dissolved zinc levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2015. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as the site was dry. Snellings Drain was sampled in March, June and September. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger values (Environment Canterbury, 2015), 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.

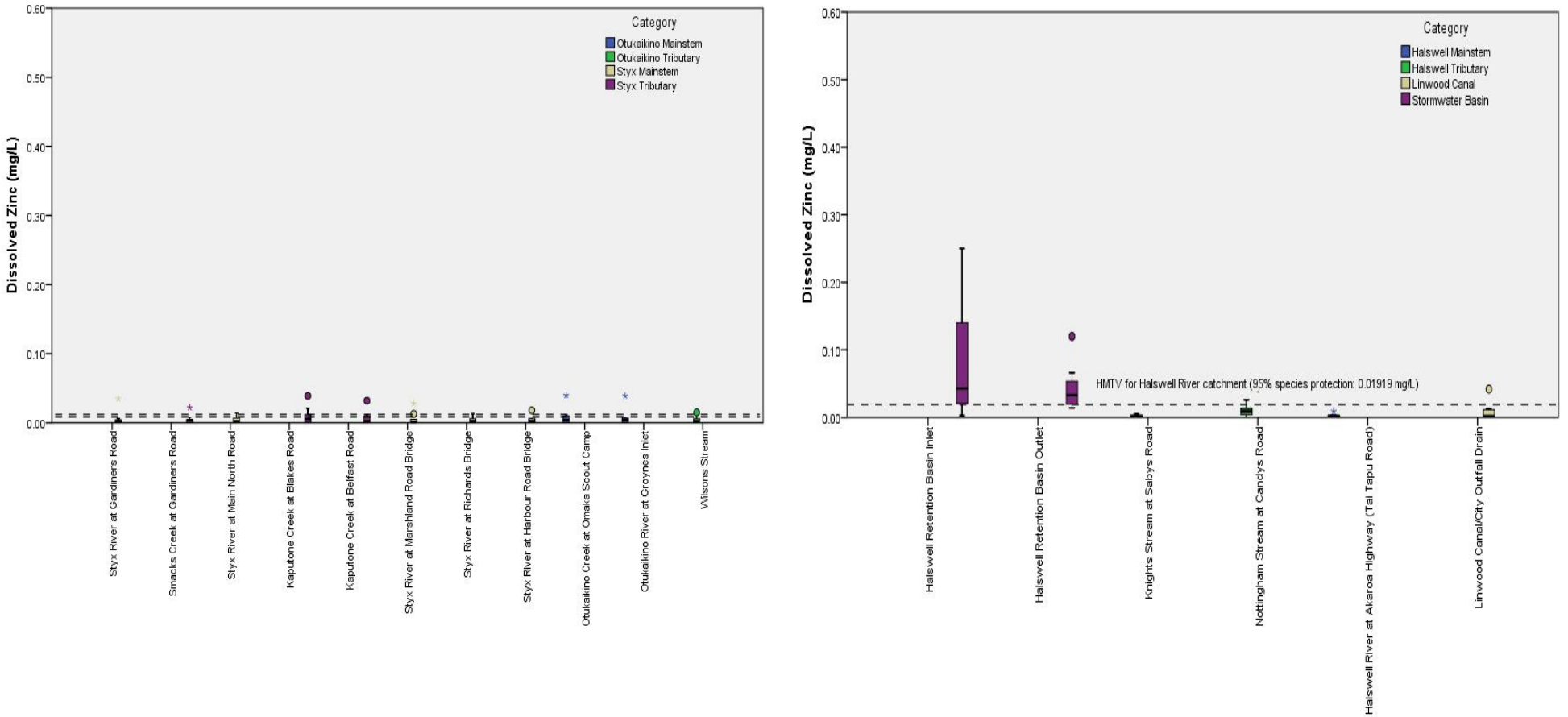

Figure iii (b). Dissolved zinc levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger values (Environment Canterbury, 2015), 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, the 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 Ōtūkaikino River catchment (0.00868 mg/L). The 90% protection HMTV for Linwood Canal (0.146 mg/L) is not visible because it is off the scale. The Laboratory Limit of Detection was 0.001 mg/L – analysed as half this value (0.0005 mg/L) to allow statistics to be undertaken. The left graph is presented on a smaller scale in Appendix E, Figure i.

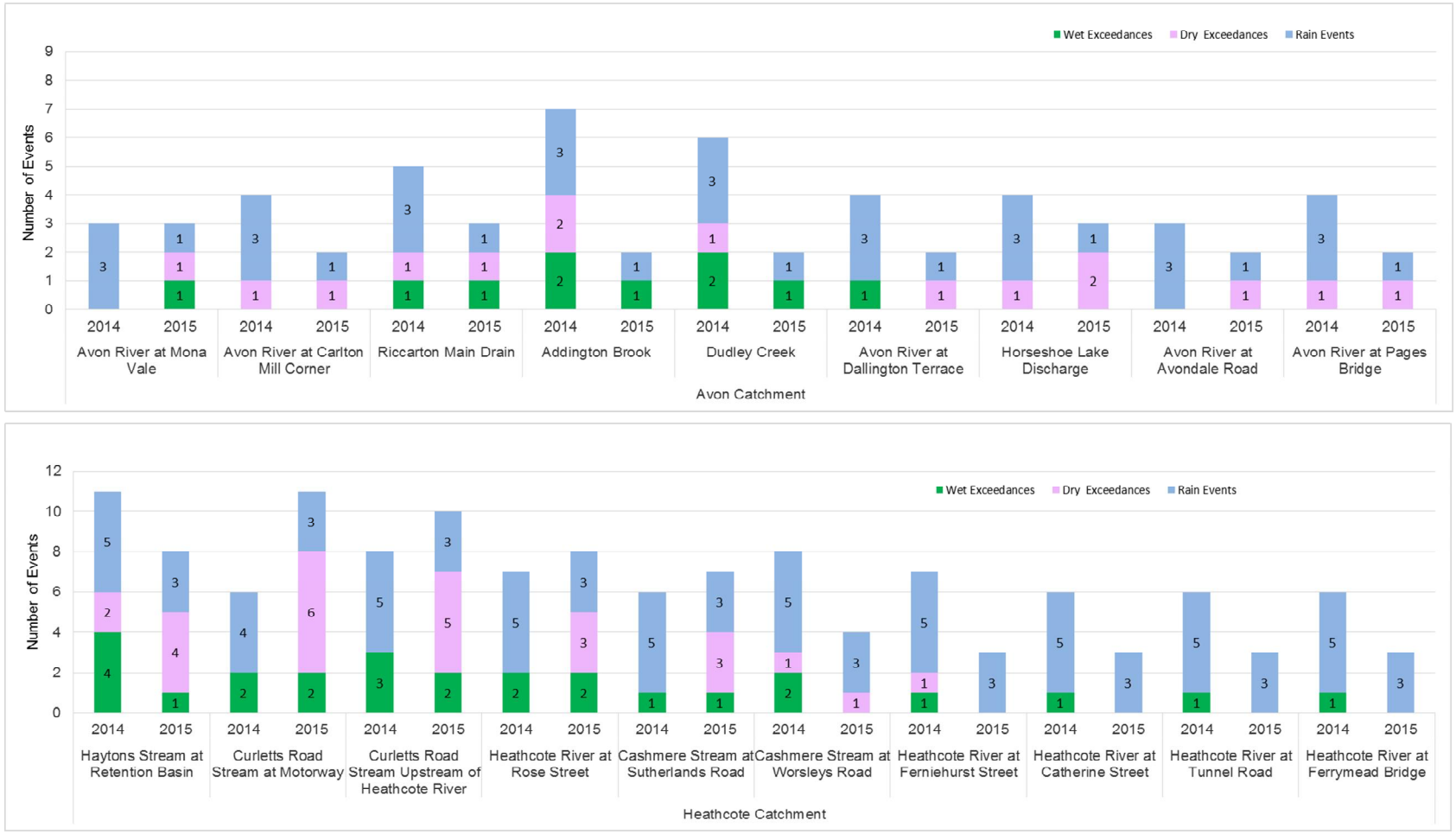

Figure iii (c). Number of dissolved zinc values that exceeded the catchment-specific guidelines in January - December 2014 and January - December 2015 for the Avon River (top) and the Heathcote River (bottom) catchments. Sites that did not record any exceedances have been omitted from the graph. Wet and dry exceedances are exceedances where rain was recorded or not recorded, respectively, at the time of sampling or within the previous 24-hours; number of rain events is the number of sampling occasions for the monitoring year where rain was recorded at the time of sampling or within the 24-hours previous, regardless of whether an exceedance was recorded or not. Only seven samples were taken at the Curletts Road Stream at Motorway site during the 2014 monitoring year, due to construction.

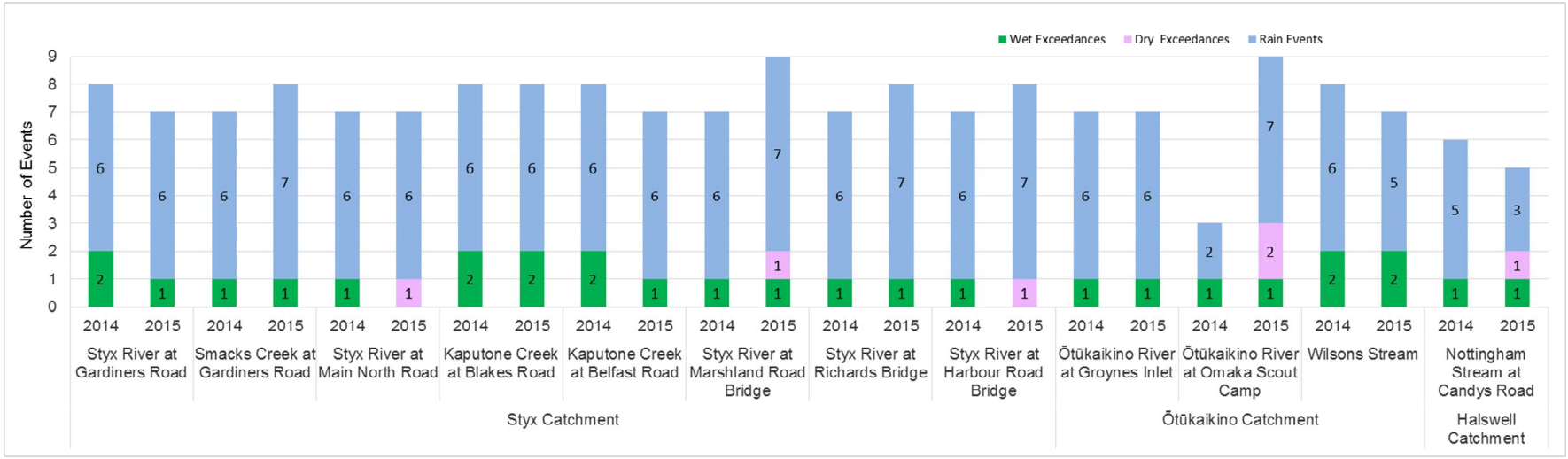

Figure iii (d). Number of dissolved zinc values that exceeded the catchment-specific guideline in January - December 2014 and January - December 2015 for the Styx, Ōtūkaikino and Halswell River catchments. Sites that did not record any exceedances have been omitted from the graph. Wet and dry exceedances are exceedances where rain was recorded or not recorded, respectively, at the time of sampling or within the previous 24-hours; number of rain events is the number of sampling occasions for the monitoring year where rain was recorded at the time of sampling or within the 24-hours previous, regardless of whether an exceedance was recorded or not.

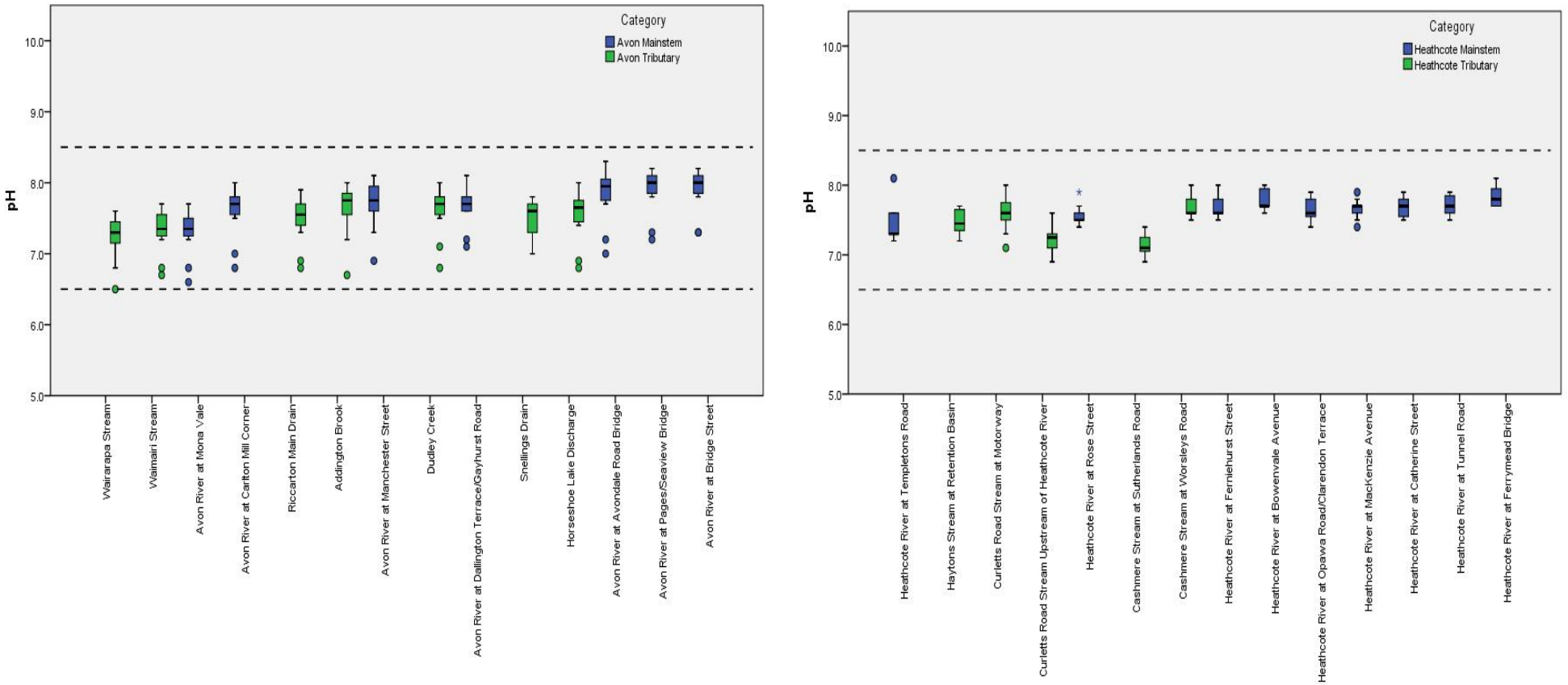

Figure iv (a). pH levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2015. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as the site was dry. Snellings Drain was sampled in March, June and September. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan lower (6.5) and upper (8.5) limits (Environment Canterbury, 2015).

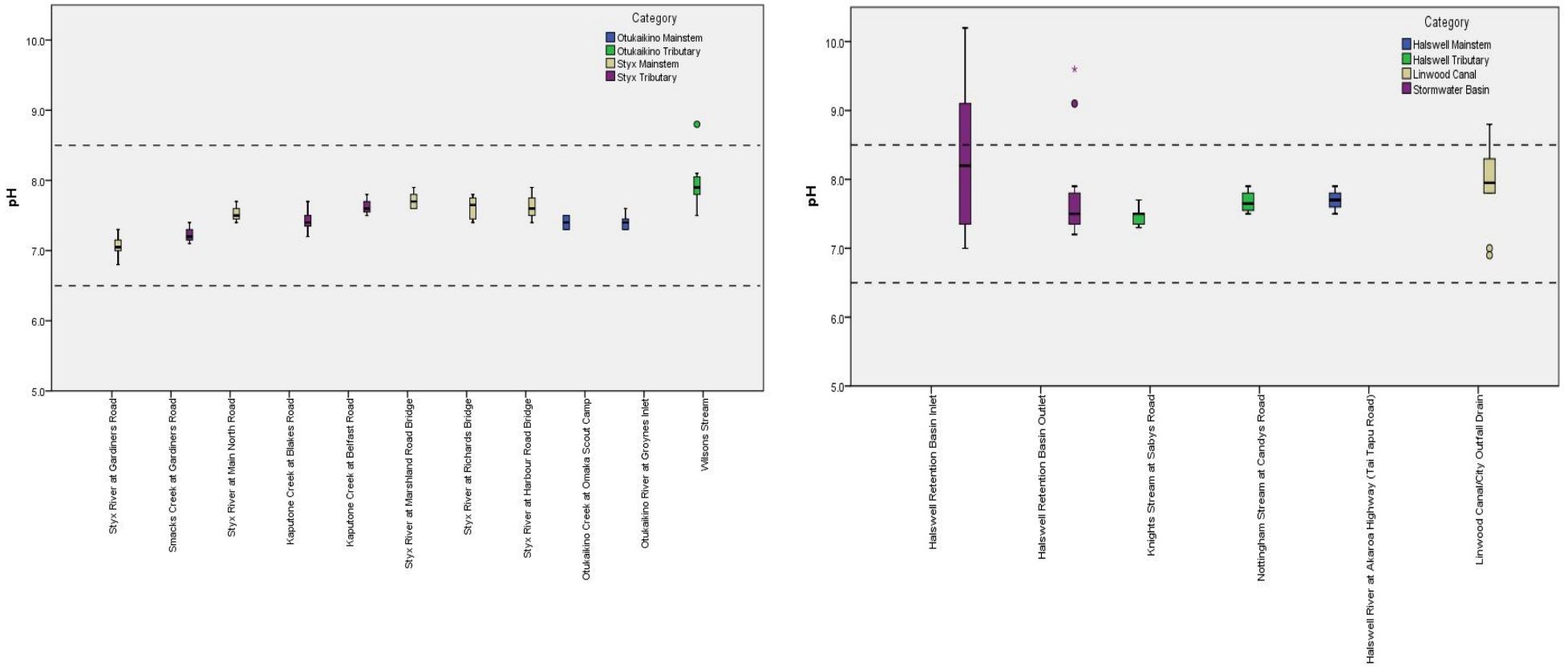

Figure iv (b). pH levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan lower (6.5) and upper (8.5) limits (Environment Canterbury, 2015).

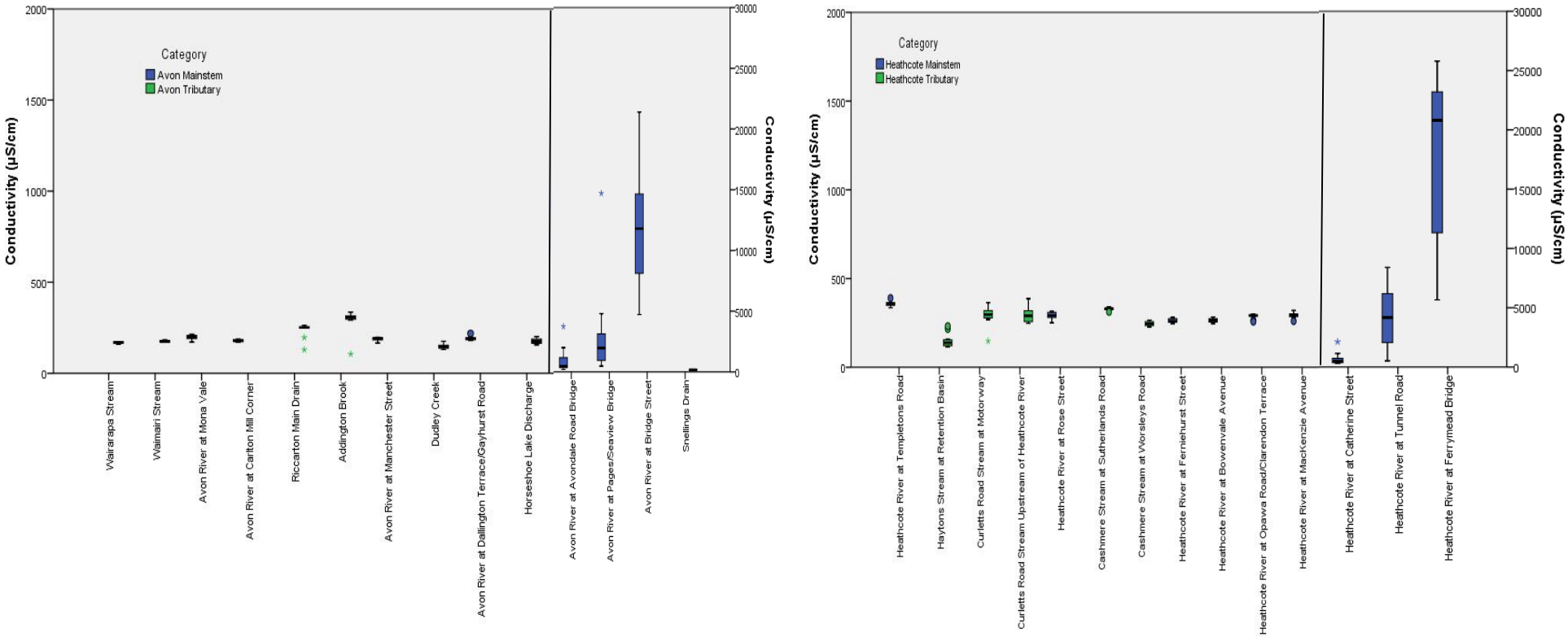

Figure v (a). Conductivity levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2015. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as the site was dry. Snellings Drain was sampled in March, June and September. 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.

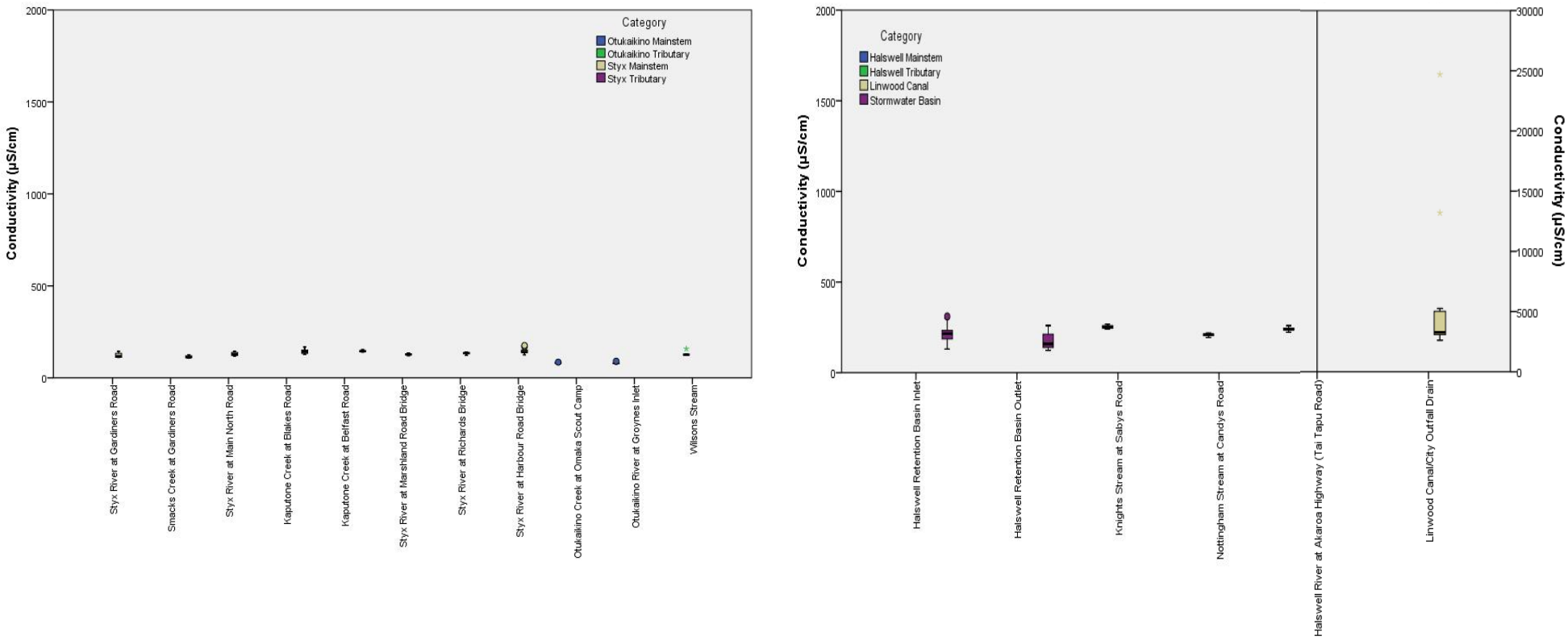

Figure v (b). Conductivity levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right). All conductivity graphs 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.

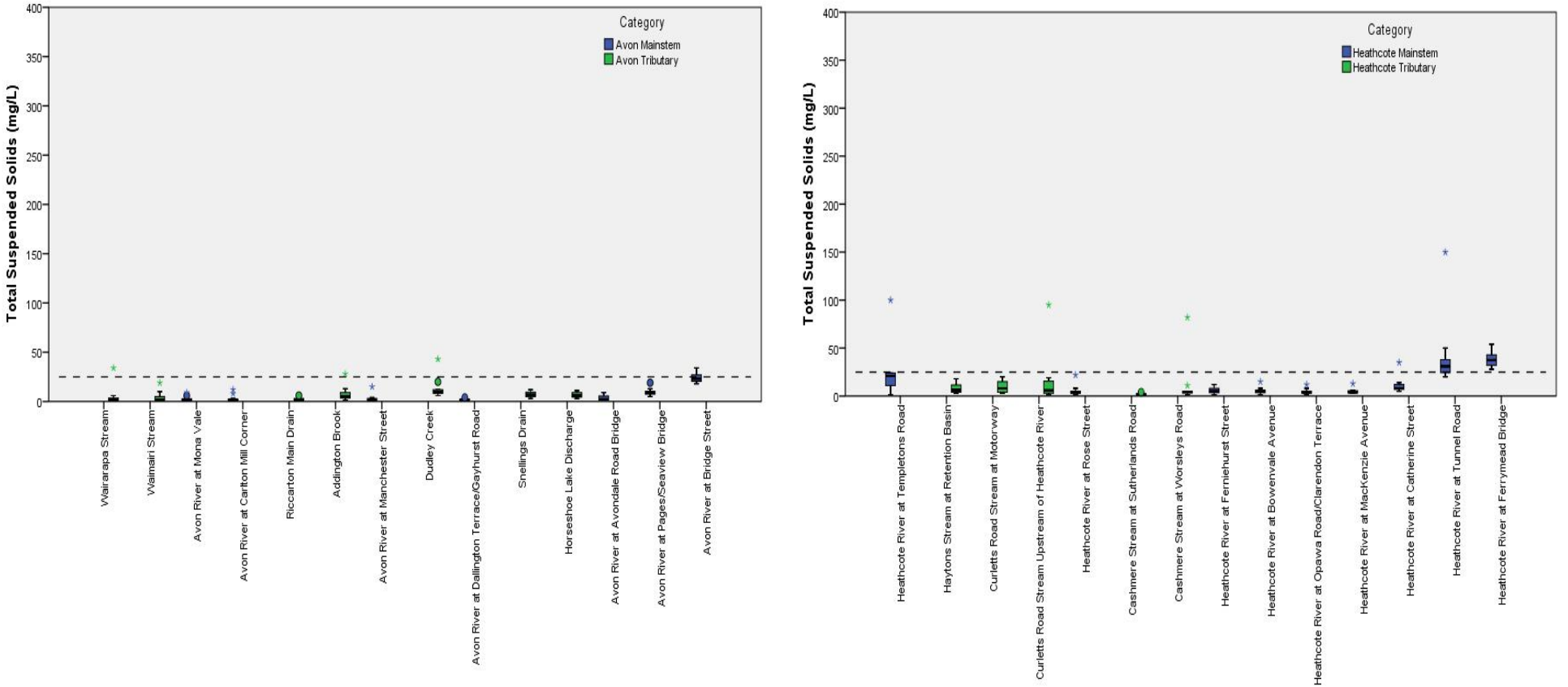

Figure vi (a). Total Suspended Solid (TSS) levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2015. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as the site was dry. Snellings Drain was sampled in March, June and September. 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.

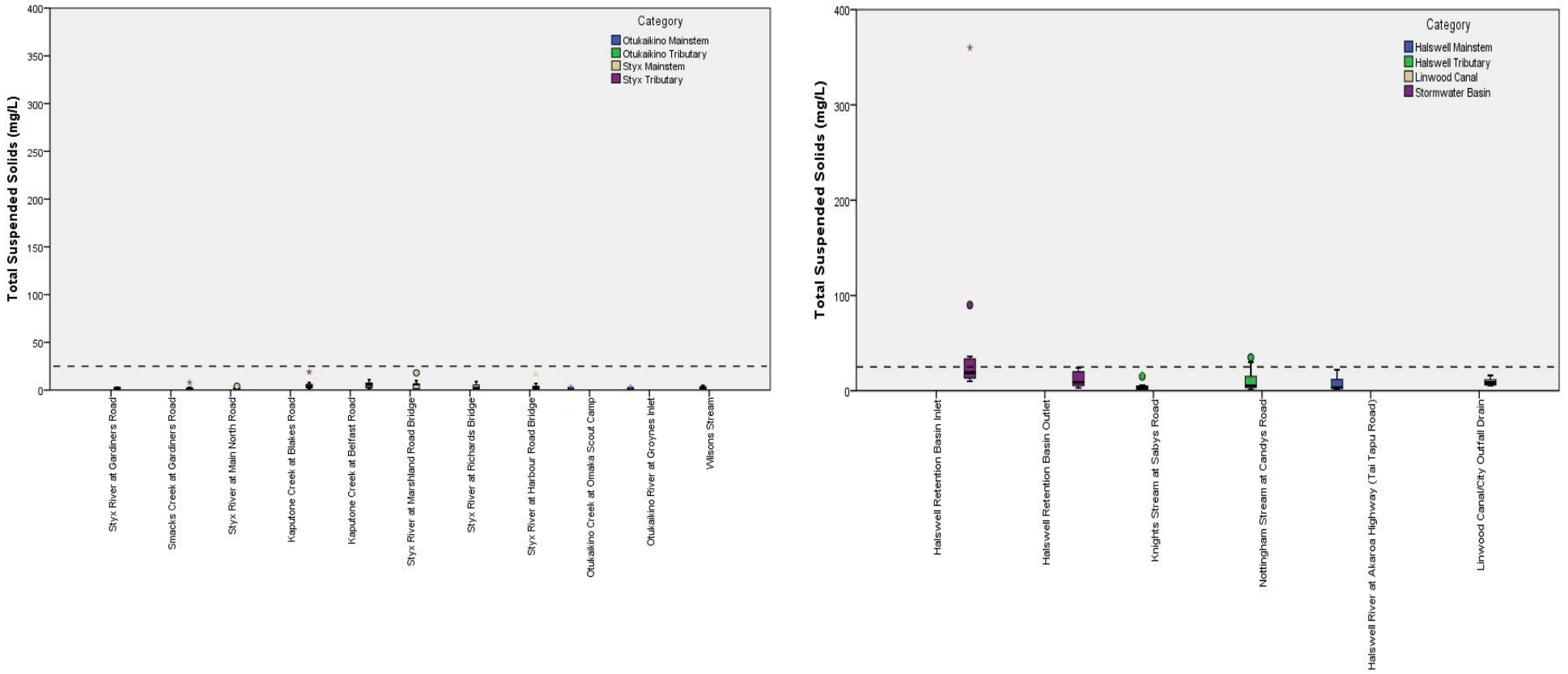

Figure vi (b). Total Suspended Solid (TSS) levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right). The 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. This graph is presented on a smaller scale in Appendix E, Figure ii.

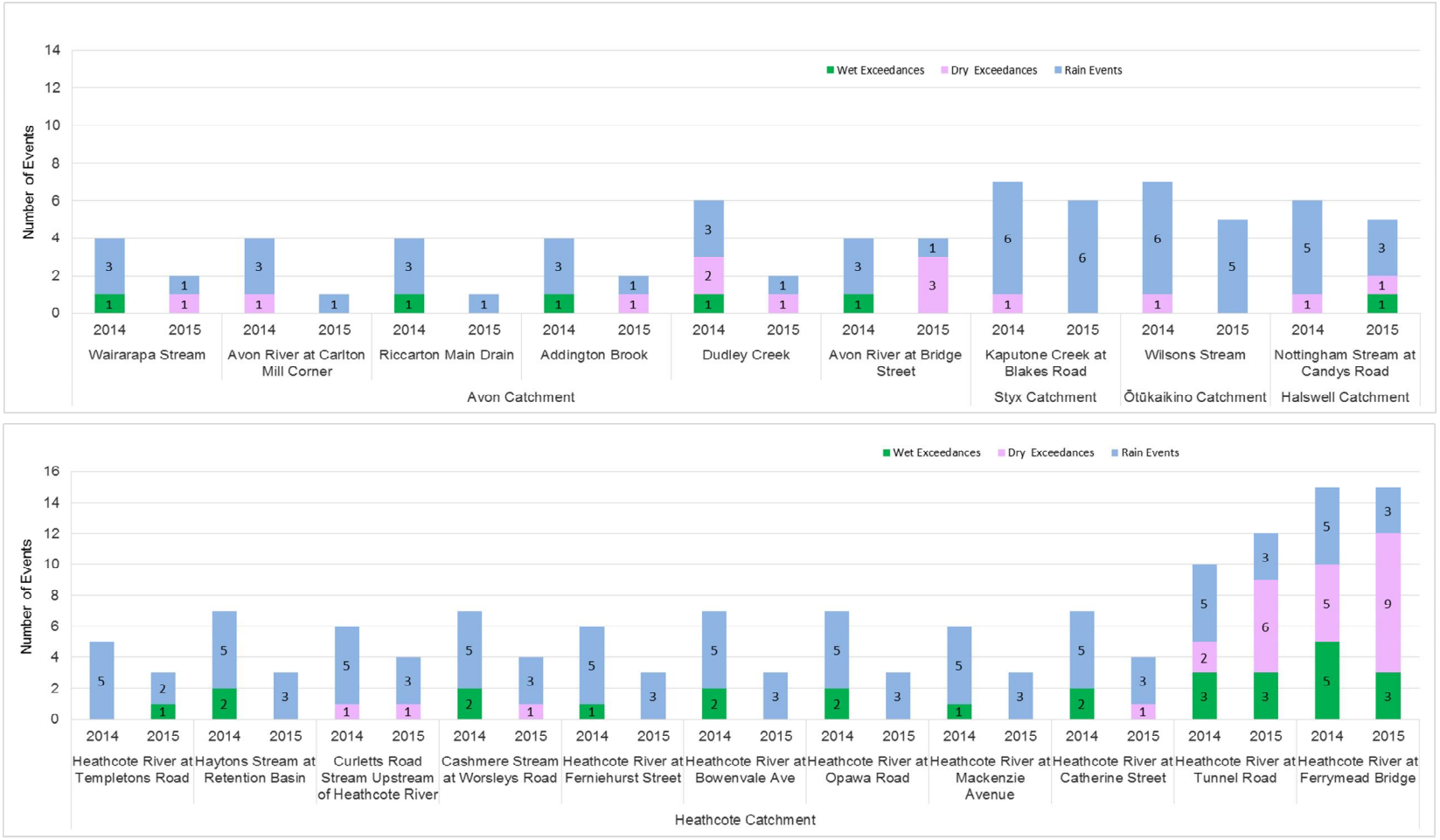

Figure vi (c). Number of Total Suspended Solids values that exceeded the catchment-specific guidelines in January - December 2014 and January - December 2015 for the Avon, Styx, Ōtūkaikino and Halswell River catchments (top), and the Heathcote River catchment (bottom). Sites that did not record any exceedances have been omitted from the graph. Wet and dry exceedances are exceedances where rain was recorded or not recorded, respectively, at the time of sampling or within the previous 24-hours; number of rain events is the number of sampling occasions for the monitoring year where rain was recorded at the time of sampling or within the 24-hours previous, regardless of whether an exceedances was recorded or not. Only five samples were taken at the Heathcote River Templetons Road site during the 2015 monitoring year, due to the site being dry.

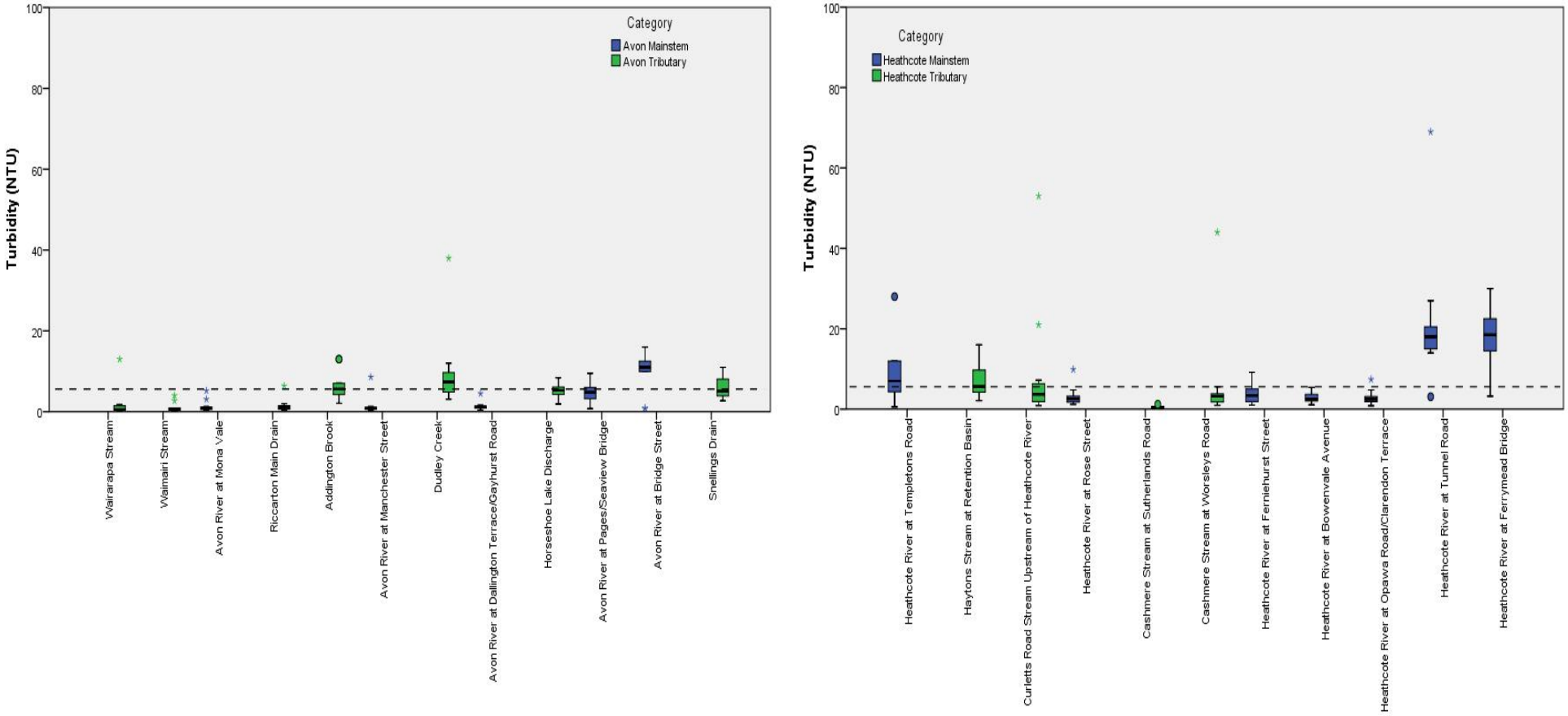

Figure vii (a). Turbidity levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2015. The following sites were not measured for this parameter: Avon River at Carlton Mill Corner, Avon River at Avondale Road Bridge, Curletts Road Stream at Motorway, Heathcote River at Catherine Street and Heathcote River at Mackenzie Avenue. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as the site was dry. Snellings Drain was sampled in March, June and September. 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).

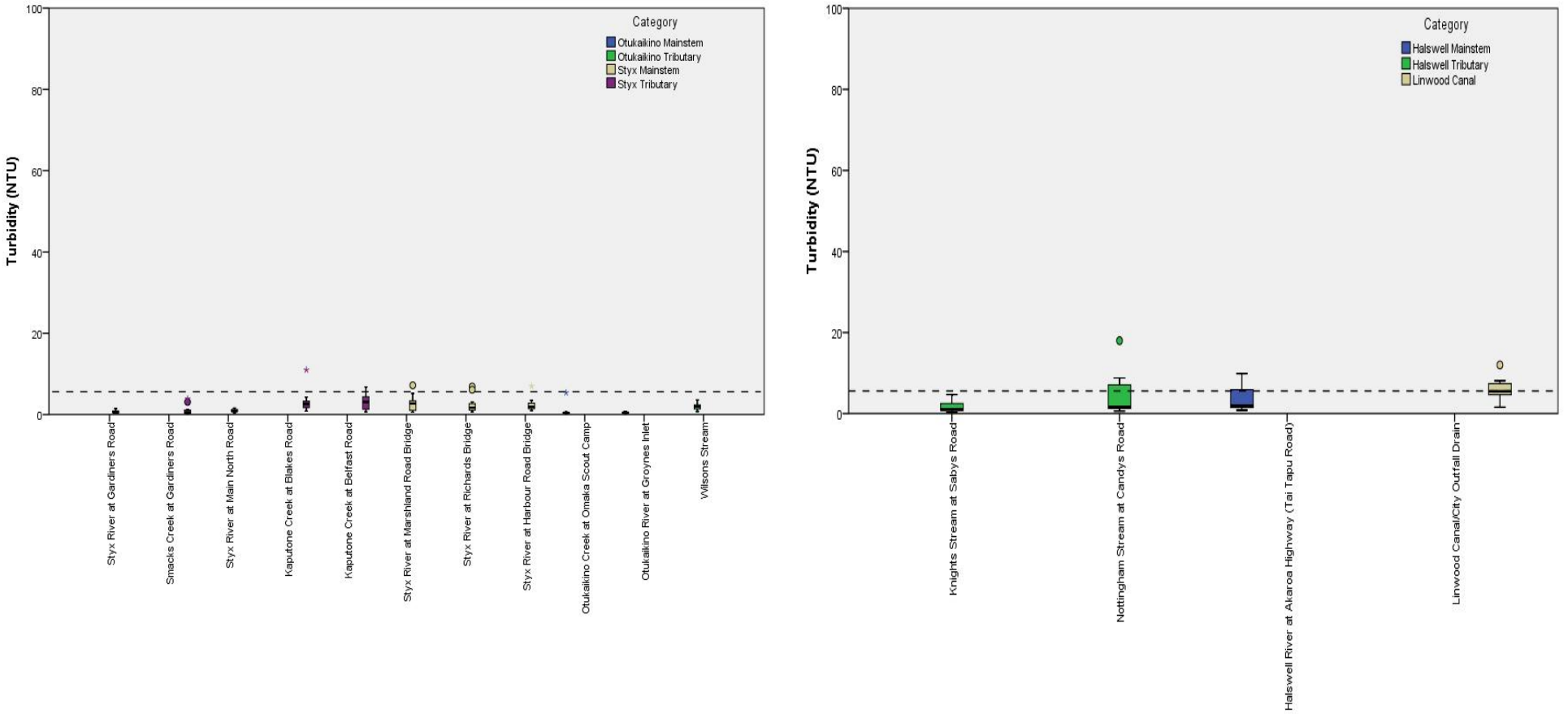

Figure vii (b). Turbidity levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2015. The following sites were not measured for this parameter: Halswell Retention Basin 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).

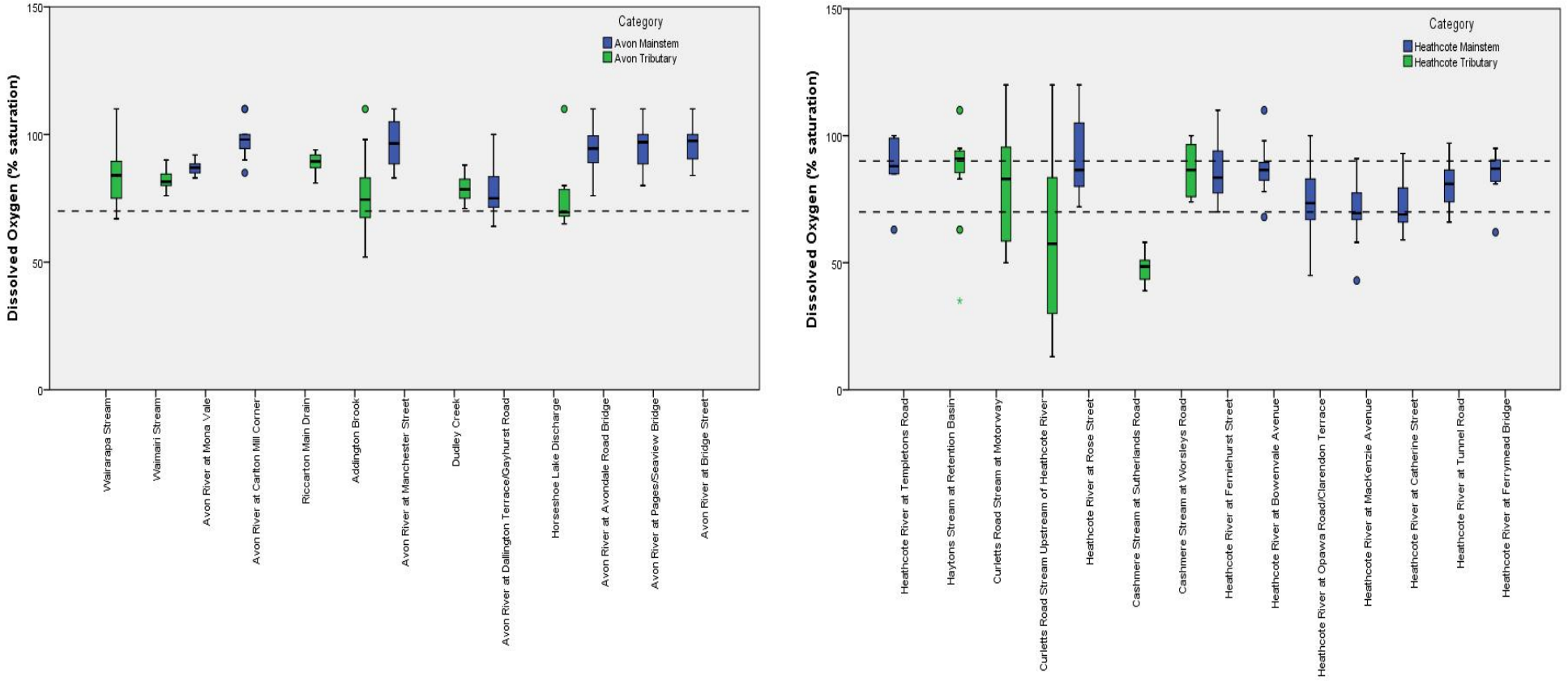

Figure viii (a). Dissolved oxygen levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2015. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as the site was dry. Sites are ordered from upstream to downstream (left to right). The lower and upper dashed lines represent the Land and Water Regional Plan minimum guideline value for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (70%), and Banks Peninsula waterways (90%; Cashmere Stream only), respectively (Environment Canterbury, 2015).

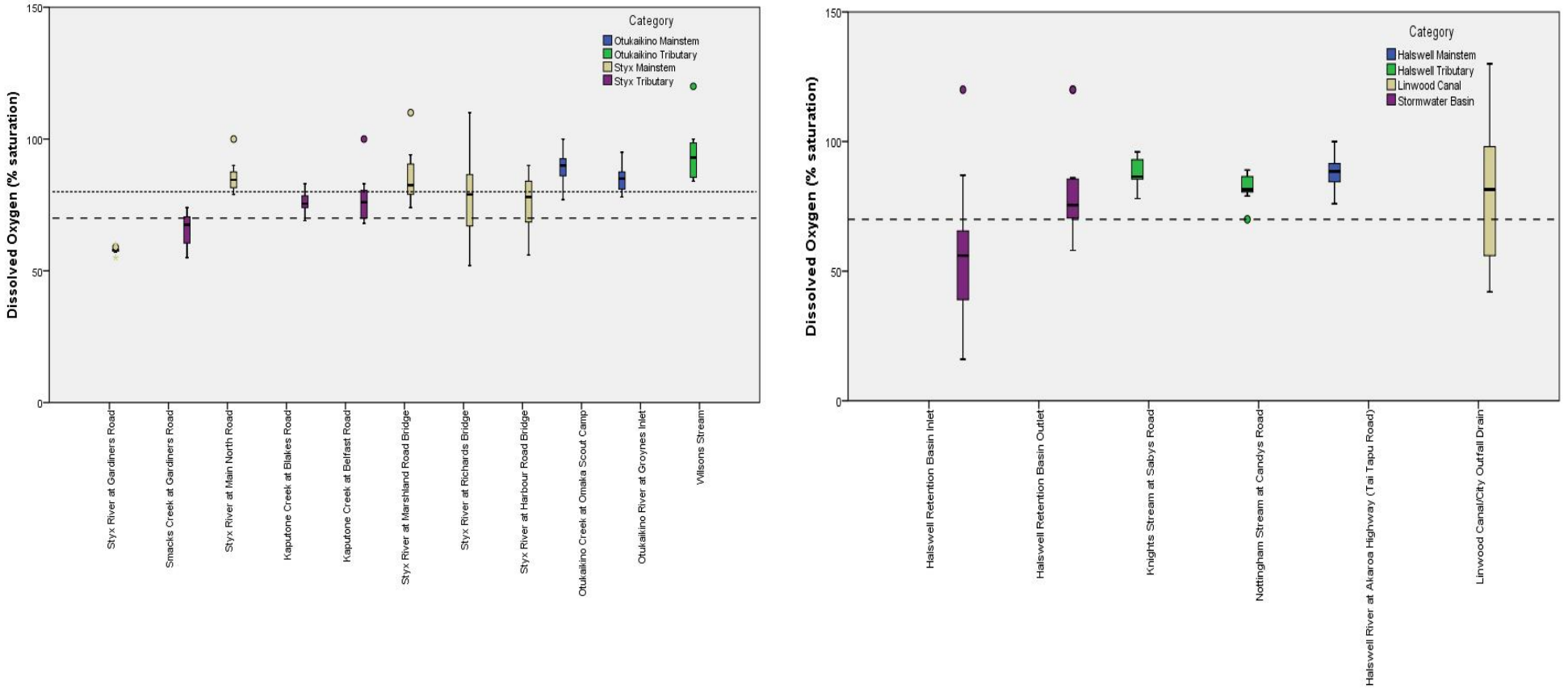

Figure viii (b). Dissolved oxygen levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right). The lower dashed line represents the Land and Water Regional Plan minimum guideline value for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (70%, Environment Canterbury, 2015). The upper dotted line represents the Waimakariri River Regional Plan minimum guideline value for all Ōtūkaikino sites (80%, Environment Canterbury, 2011).

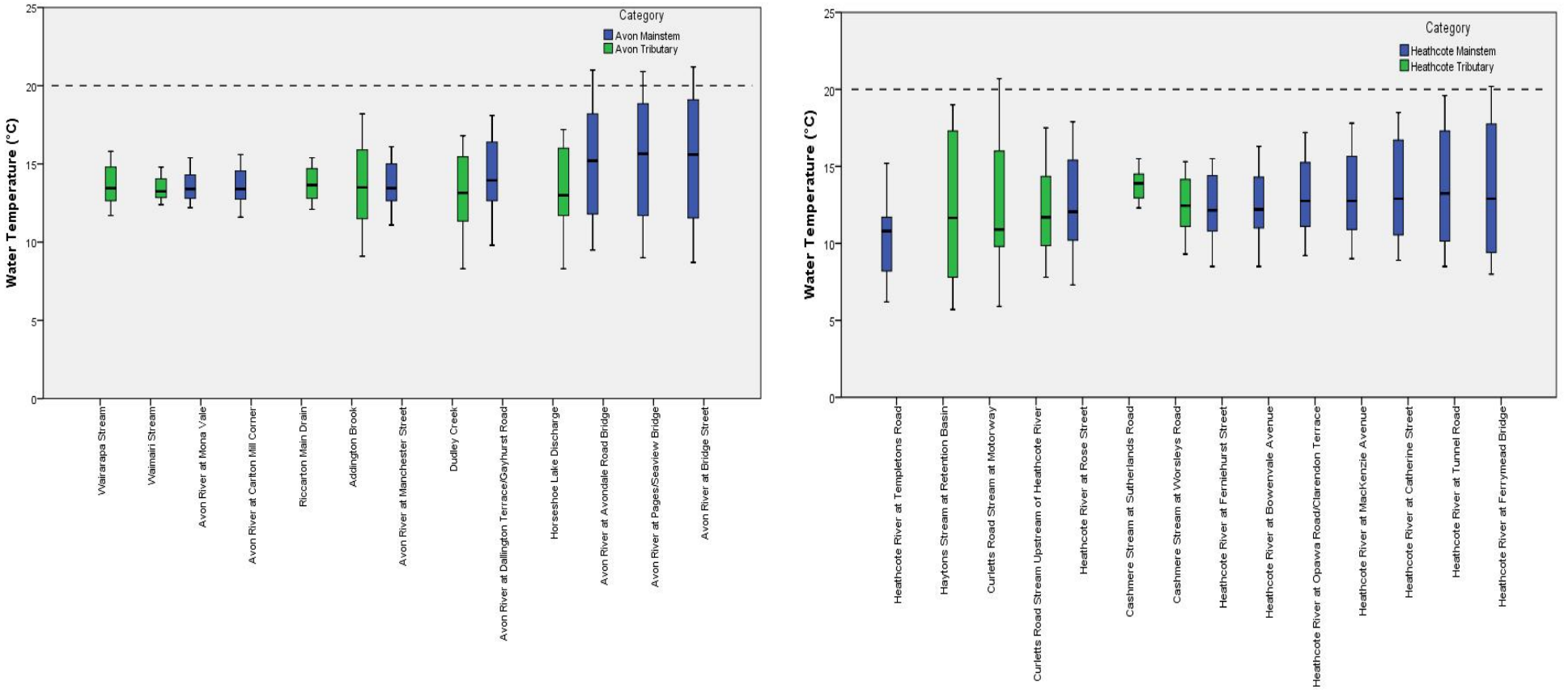

Figure ix (a). Temperature of the water at the time of sampling at the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2015. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as the site was dry. Sites are ordered from upstream to downstream (left to right). The dashed line represents the Land and Water Regional Plan maximum guideline value (20ºC, Environment Canterbury, 2015).

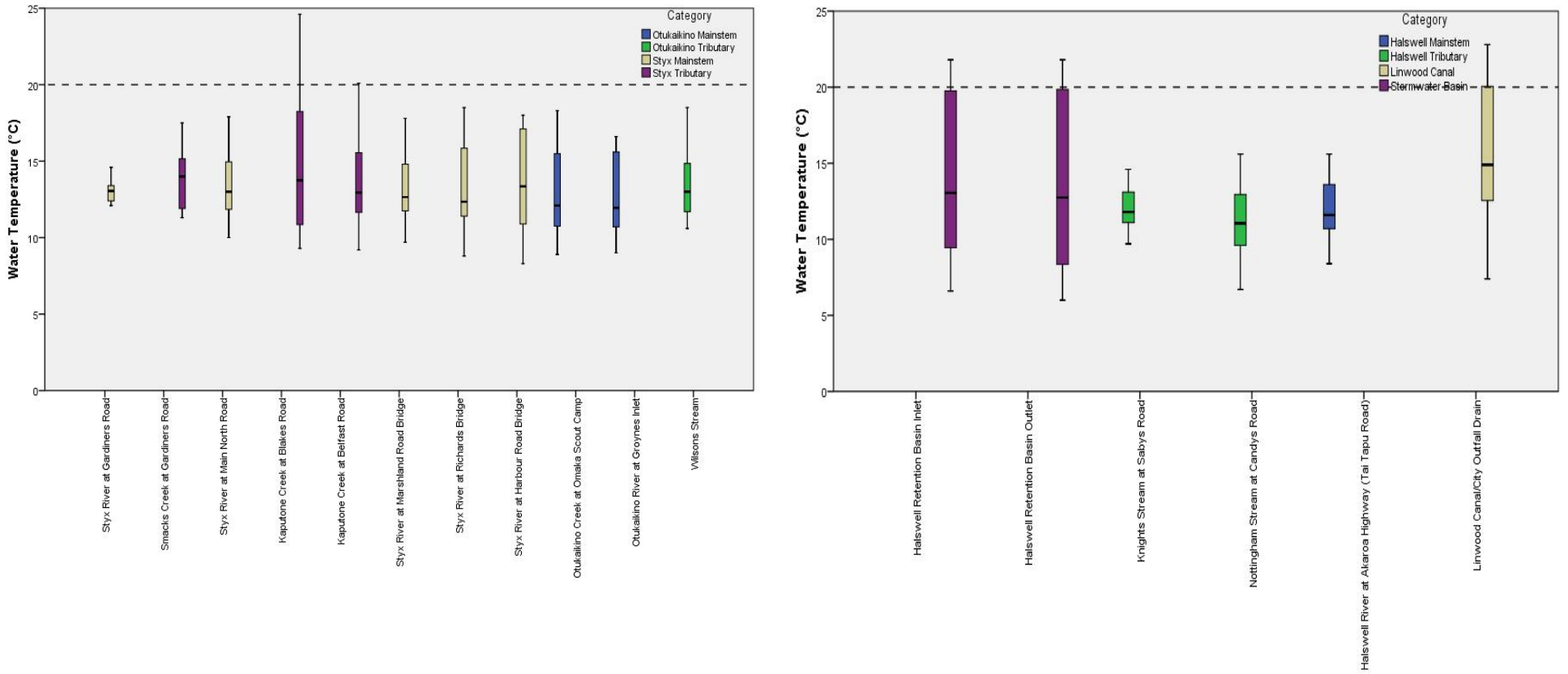

Figure ix (b). Temperature of the water at the time of sampling at the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan maximum guideline value (20 ºC, Environment Canterbury, 2015). The Waimakariri River Regional Plan maximum guideline value for all Ōtūkaikino sites is 25 ºC (Environment Canterbury, 2011), which is not shown as this is equal to the top of the graph.

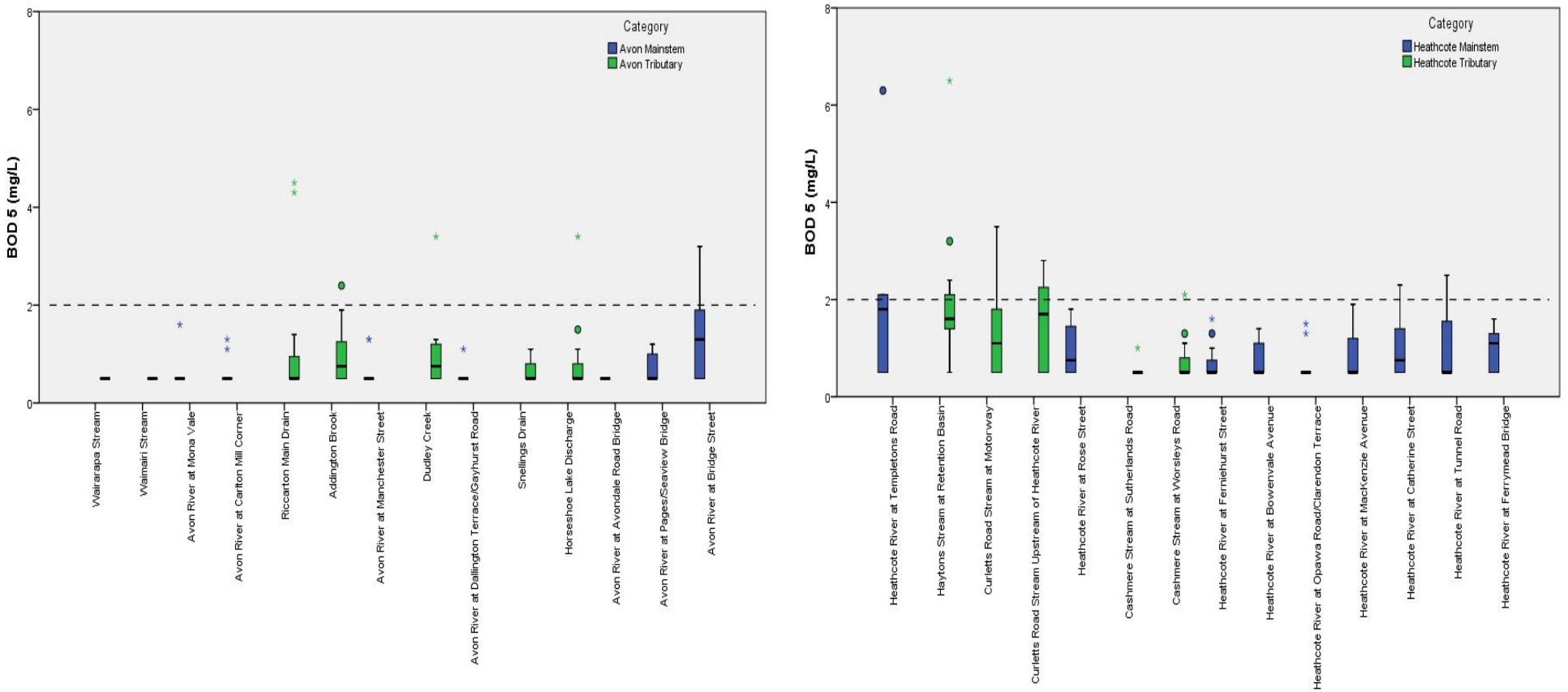

Figure x (a). Biochemical Oxygen Demand (BOD_5) levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2015. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as the site was dry. Snellings Drain was sampled in March, June and September. 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.

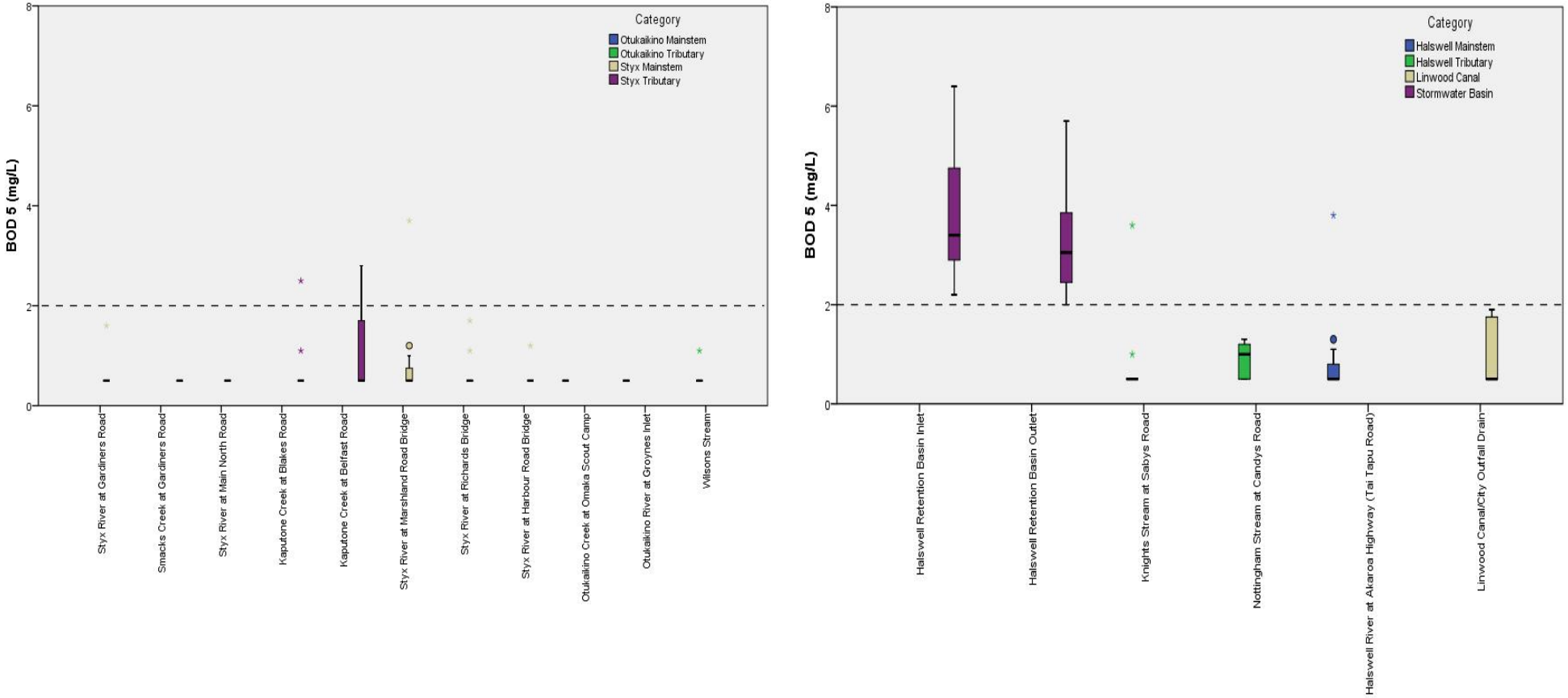

Figure x (b). Biochemical Oxygen Demand (BOD_5) levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right). 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.

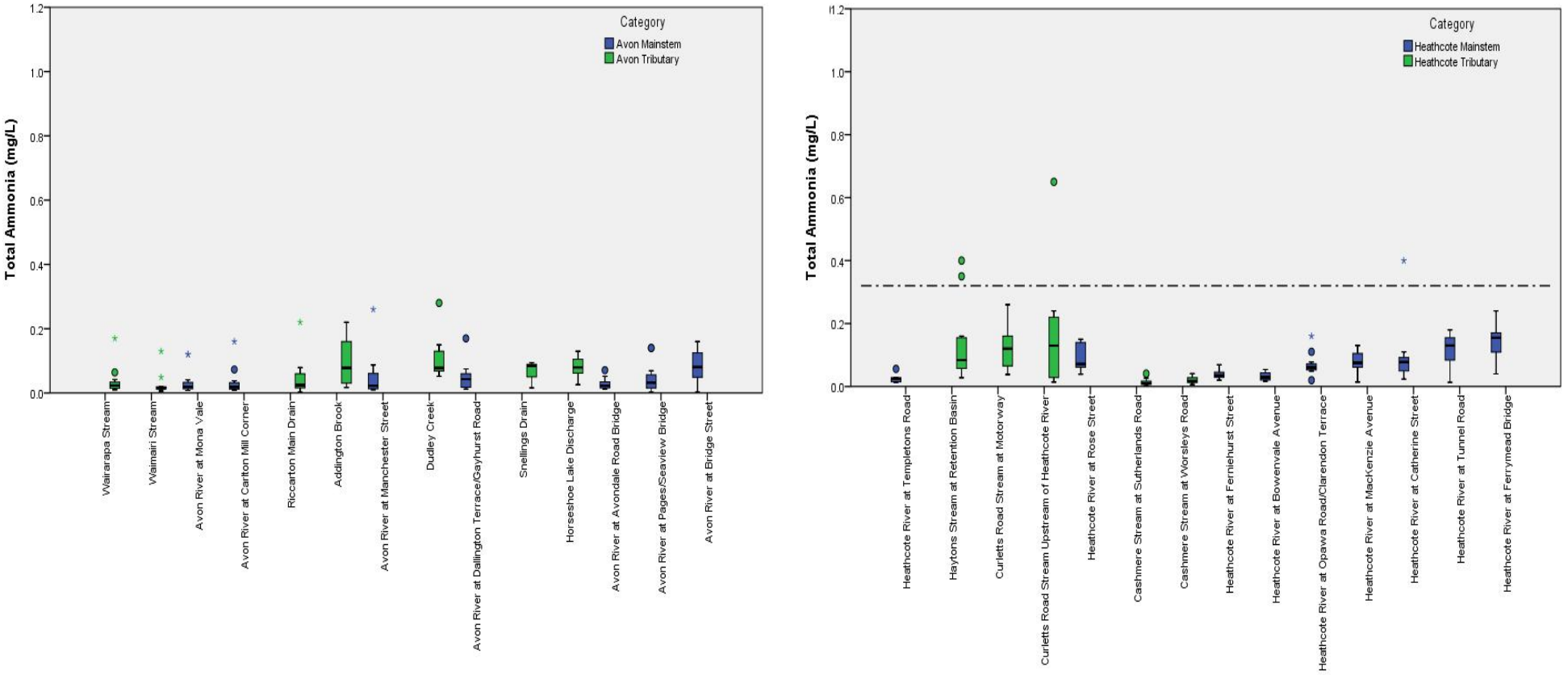

Figure xi (a). Total ammonia levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2015. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as the site was dry. Snellings Drain was sampled in March, June and September. Sites are ordered from upstream to downstream (left to right). The 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, 2015) 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 Land and Water Regional Plan maximum guideline value for Banks Peninsula waterways (0.32 mg/L, Cashmere Stream only; Environment Canterbury, 2015). The Laboratory Limit of Detection was 0.005 mg/L – analysed as half this value (0.0025 mg/L) to allow statistics to be undertaken.

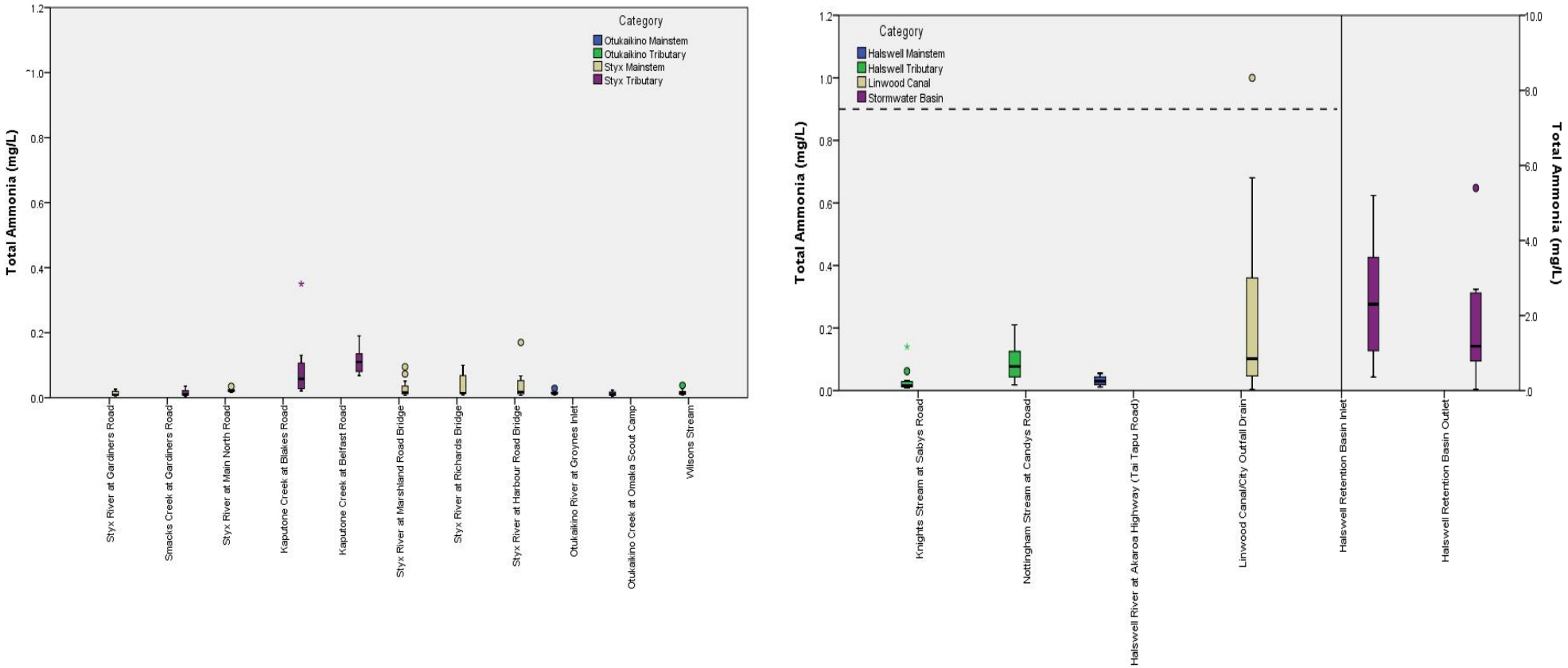

Figure xi (b). Total ammonia levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right), with the exception of Halswell Retention Basin Inlet and Outlet. 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 Land and Water Regional Plan guideline values, adjusted in accordance with median pH levels for the monitoring period (Styx catchment: 7.5; Ōtūkaikino catchment: 7.5; Halswell catchment: 7.6; Linwood Canal: 8.0; Environment Canterbury, 2015), are not visible as they are off the scale with the exception of Linwood Canal (Styx catchment: 1.61 mg/L; Ōtūkaikino catchment: 1.61 mg/L; Halswell catchment: 1.47 mg/L; Linwood Canal: 0.9 mg/L). The Laboratory Limit of Detection was 0.005 mg/L – analysed as half this value (0.0025 mg/L) to allow statistics to be undertaken.

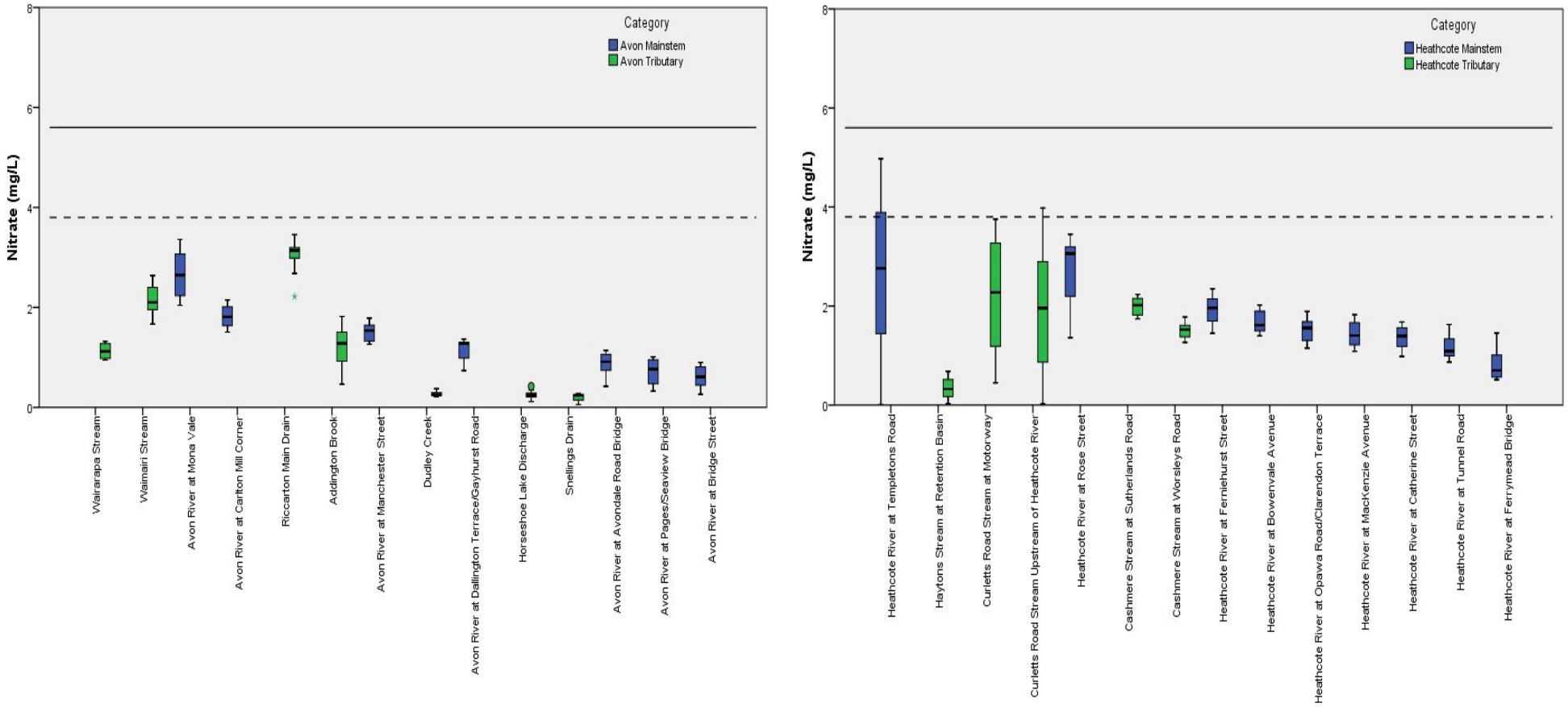

Figure xii (a). Nitrate levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2015. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as the site was dry. Snellings Drain was sampled in March, June and September. 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.

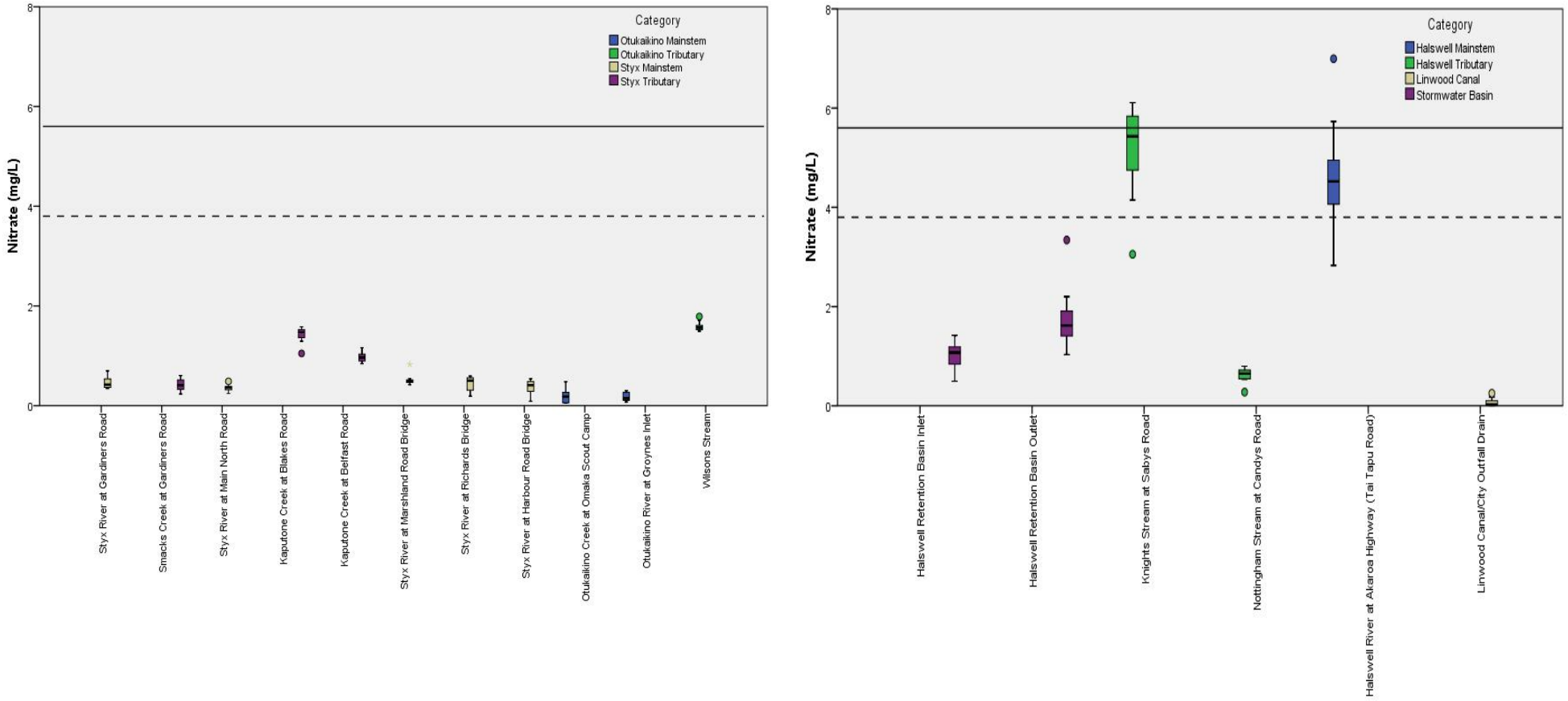

Figure xii (b). Nitrate levels in water samples taken from the Styx and Ōtūkaikino Rivers (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right). The dashed and solid 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.

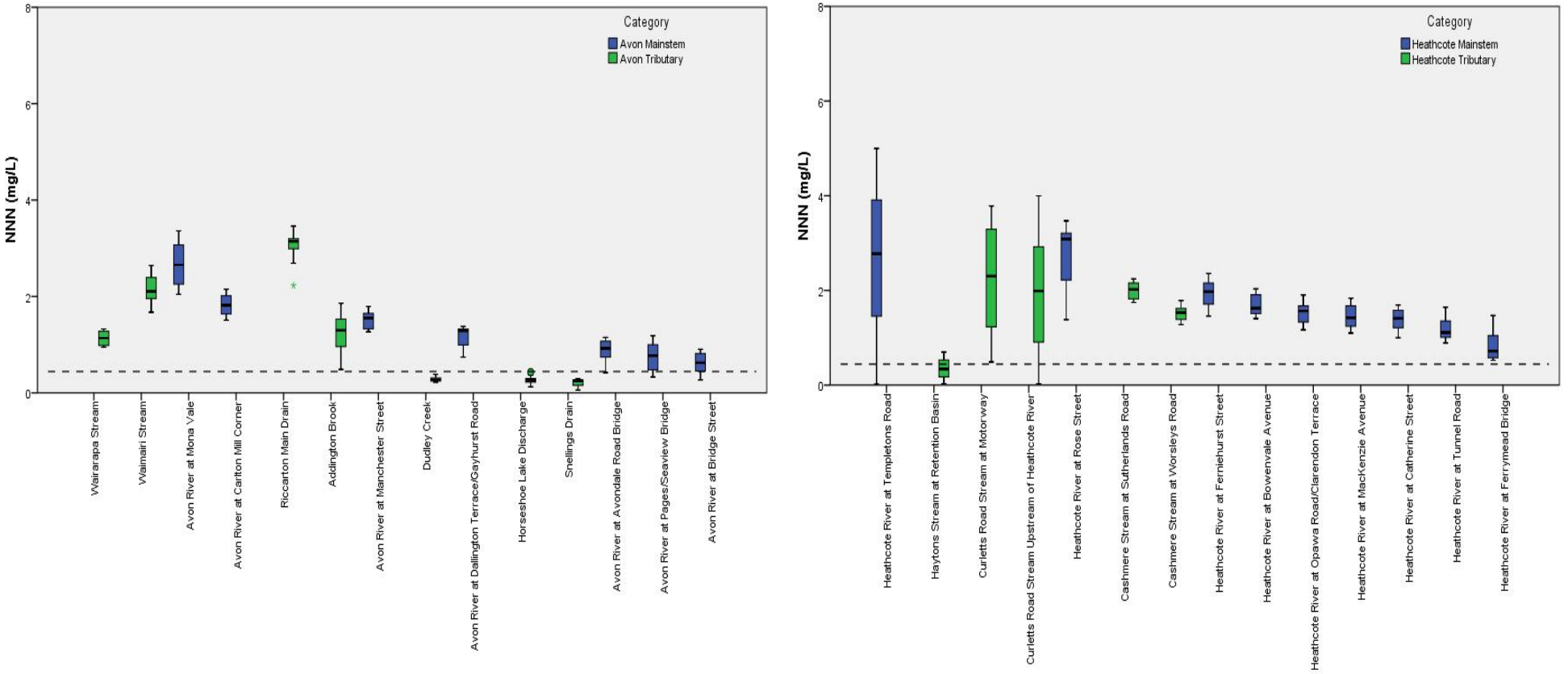

Figure xiii (a). Nitrate Nitrite Nitrogen (NNN) in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2015. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as the site was dry. Snellings Drain was sampled in March, June and September. 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).

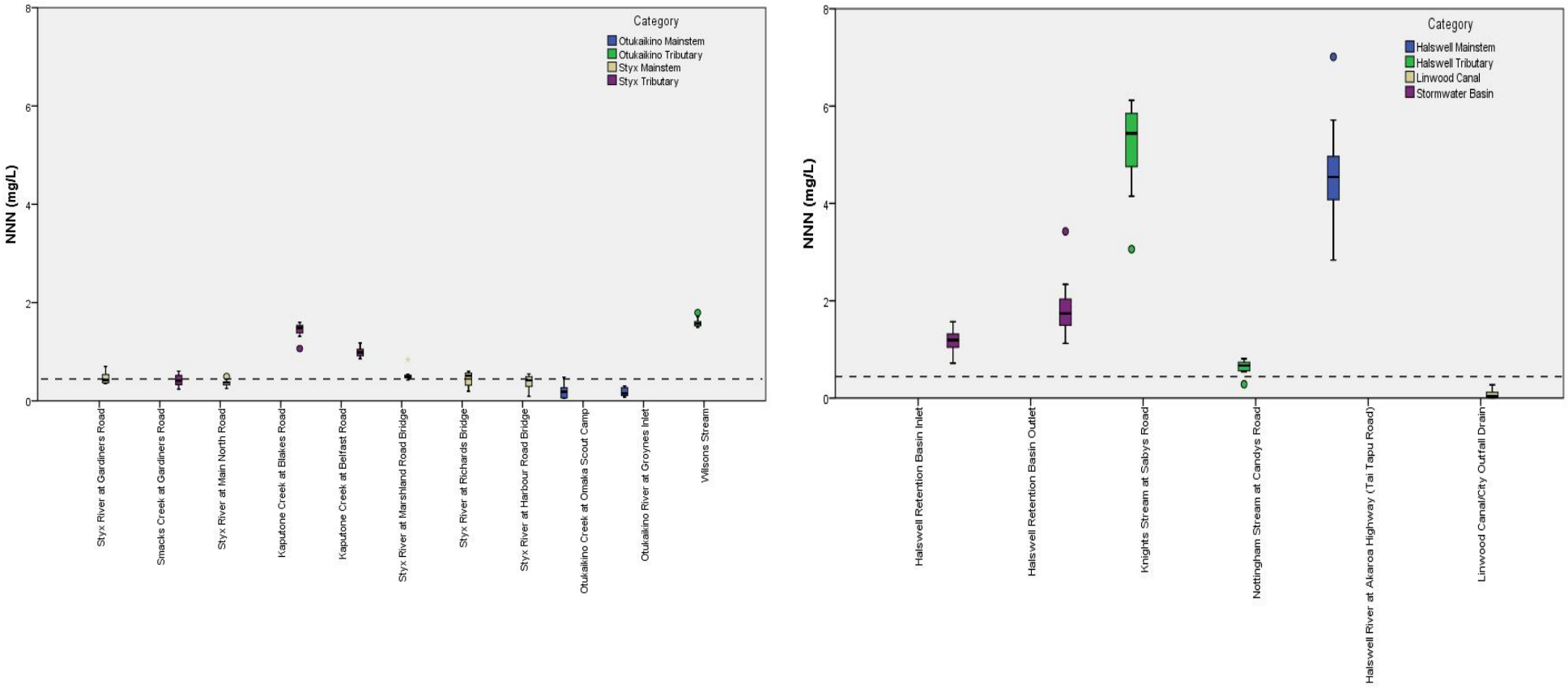

Figure xiii (b). Nitrate Nitrite Nitrogen (NNN) levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the ANZECC water quality guideline (0.444 mg/L; ANZECC, 2000). The Laboratory Limit of Detection was 0.005 mg/L – analysed as half this value (0.0025 mg/L) to allow statistics to be undertaken.

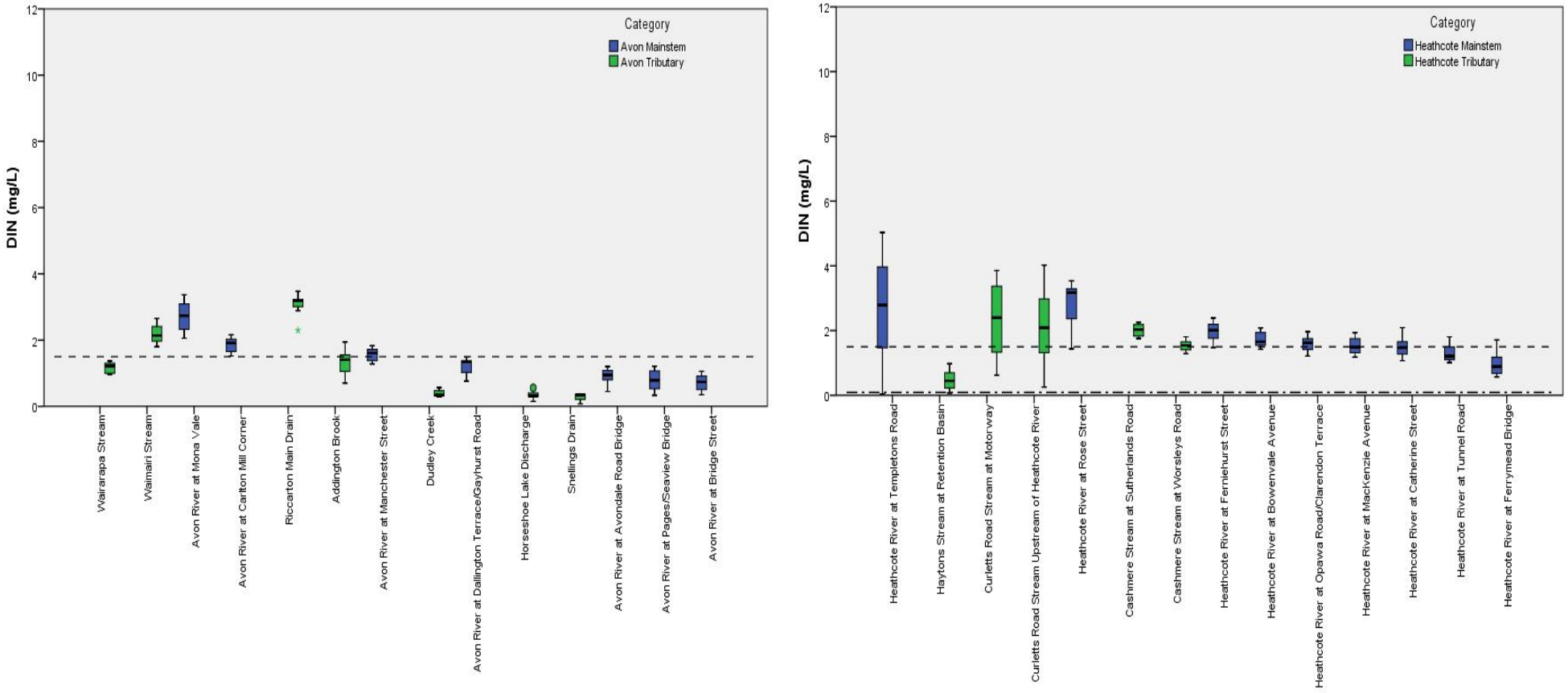

Figure xiv (a). Dissolved Inorganic Nitrogen (DIN) levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2015. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as the site was dry. Snellings Drain was sampled in March, June and September. Sites are ordered from upstream to downstream (left to right). The lower and upper dashed lines represent the 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, 2015).

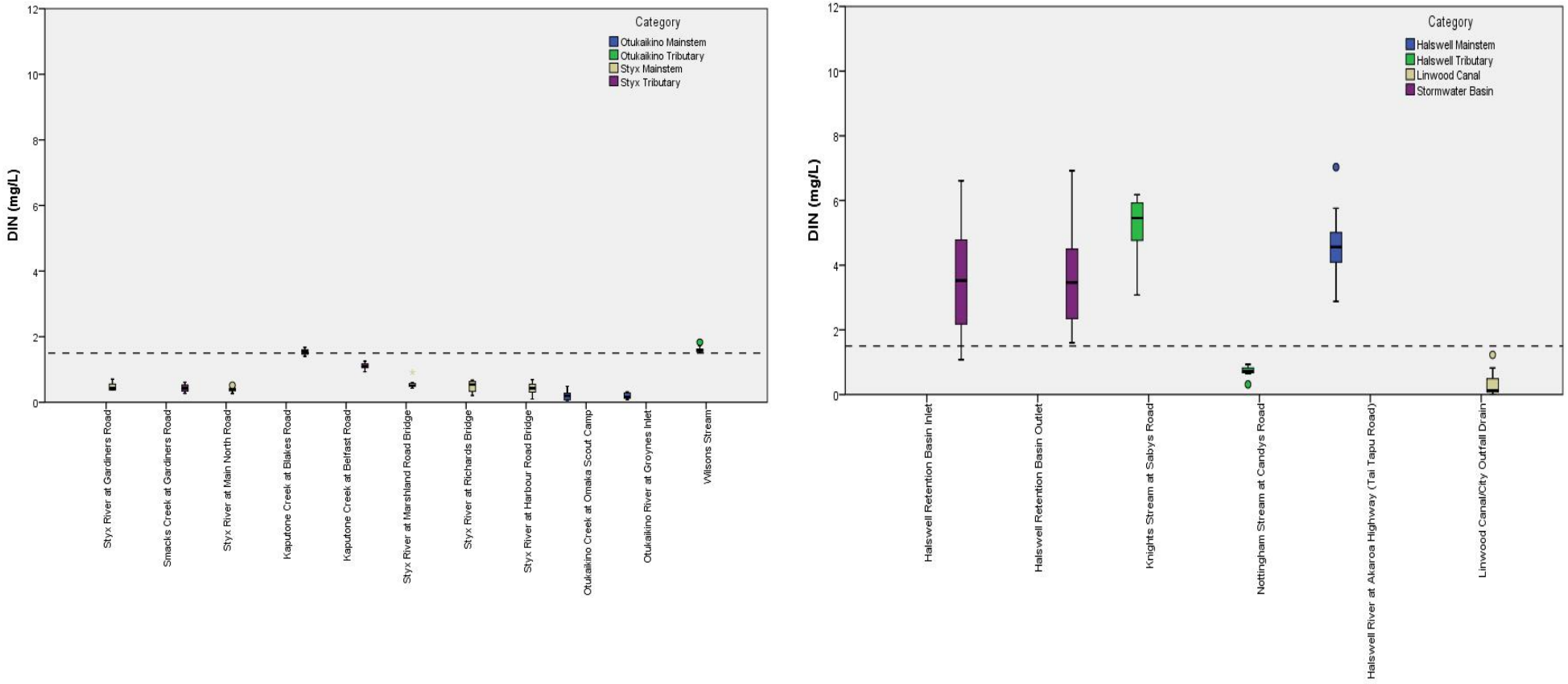

Figure xiv (b). Dissolved Inorganic Nitrogen (DIN) levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger value for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways of 1.5 mg/L (Environment Canterbury, 2015). The Laboratory Limit of Detection was 0.02 mg/L – analysed as half this value (0.01 mg/L) to allow statistics to be undertaken.

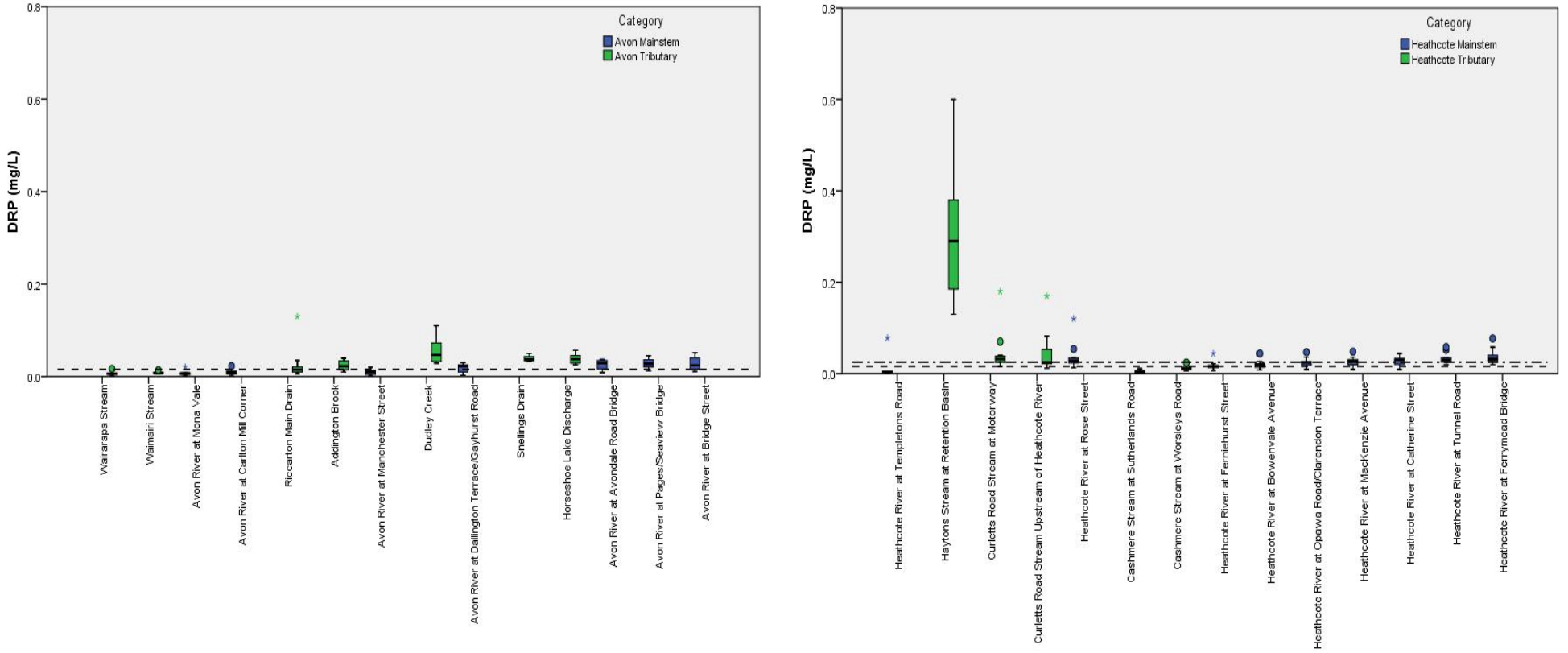

Figure xv (a). Dissolved Reactive Phosphorus (DRP) levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2015. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as the site was dry. Snellings Drain was sampled in March, June and September. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger value of 0.016 mg/L for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways, and the dash-dot line (right graph only), represents the Land and Water Regional Plan trigger value of 0.025 mg/L for Banks Peninsula waterways (Cashmere Stream only), (Environment Canterbury, 2015). 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. These graphs are presented on a smaller scale in Appendix E, Figure iii (a).

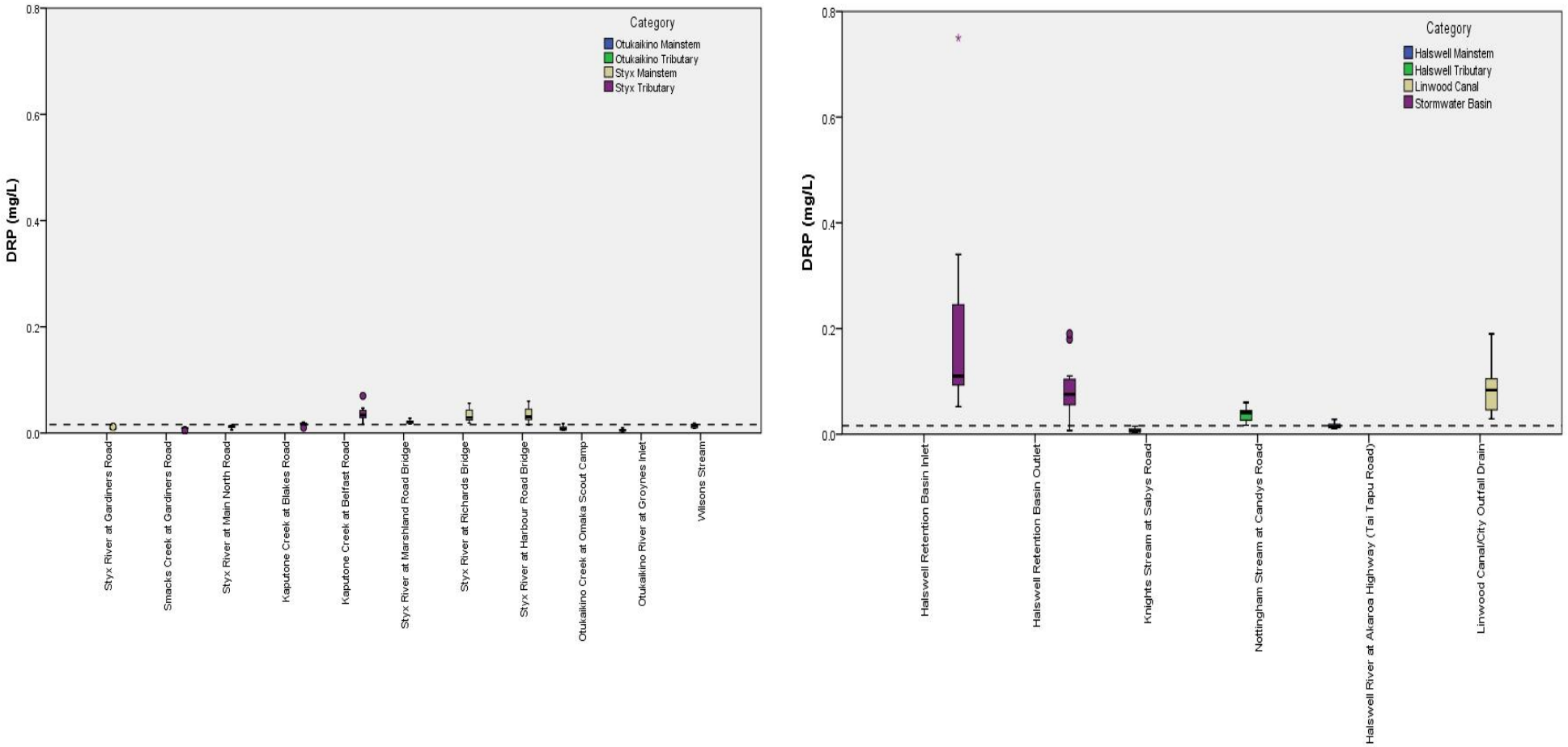

Figure xv (b). Dissolved Reactive Phosphorus (DRP) levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger value of 0.016 mg/L for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (Environment Canterbury, 2015). 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. These graphs are presented on a smaller scale in Appendix E, Figure iii (b).

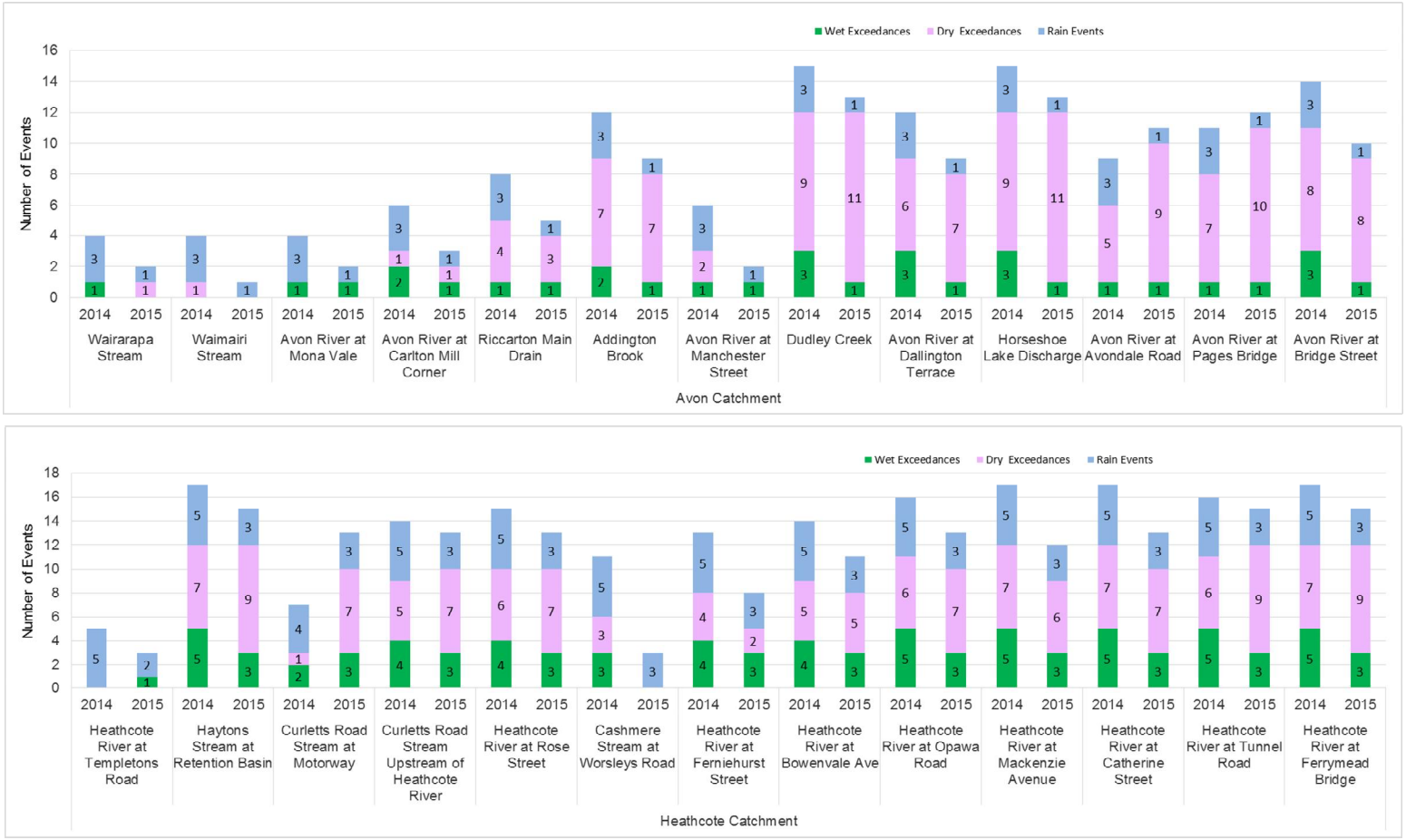

Figure xv (c). Number of Dissolved Reactive Phosphorus values that exceeded the catchment-specific guidelines in January - December 2014 and January - December 2015 for the Avon River catchment (top), and Heathcote River catchment (bottom). Sites that did not record any exceedances have been omitted from the graph. Wet and dry exceedances are exceedances where rain was recorded or not recorded, respectively, at the time of sampling or within the previous 24-hours; number of rain events is the number of sampling occasions for the monitoring year where rain was recorded at the time of sampling or within the 24-hours previous, regardless of whether an exceedances was recorded or not. Only seven samples were taken at the Curletts Road Stream at Motorway site during the 2014 monitoring year, due to construction activities. Only five samples were taken at the Heathcote River Templetons Road site during the 2015 monitoring year, due to the site being dry.

Figure xv (d). Number of Dissolved Reactive Phosphorus values that exceeded the catchment-specific guidelines in January - December 2014 and January - December 2015 for the Styx and Ōtūkaikino River (top), and Halswell River and Linwood Canal catchments (bottom). Sites that did not record any exceedances have been omitted from the graph. Wet and dry exceedances are exceedances where rain was recorded or not recorded, respectively, at the time of sampling or within the previous 24-hours; number of rain events is the number of sampling occasions for the monitoring year where rain was recorded at the time of sampling or within the 24-hours previous, regardless of whether an exceedances was recorded or not.

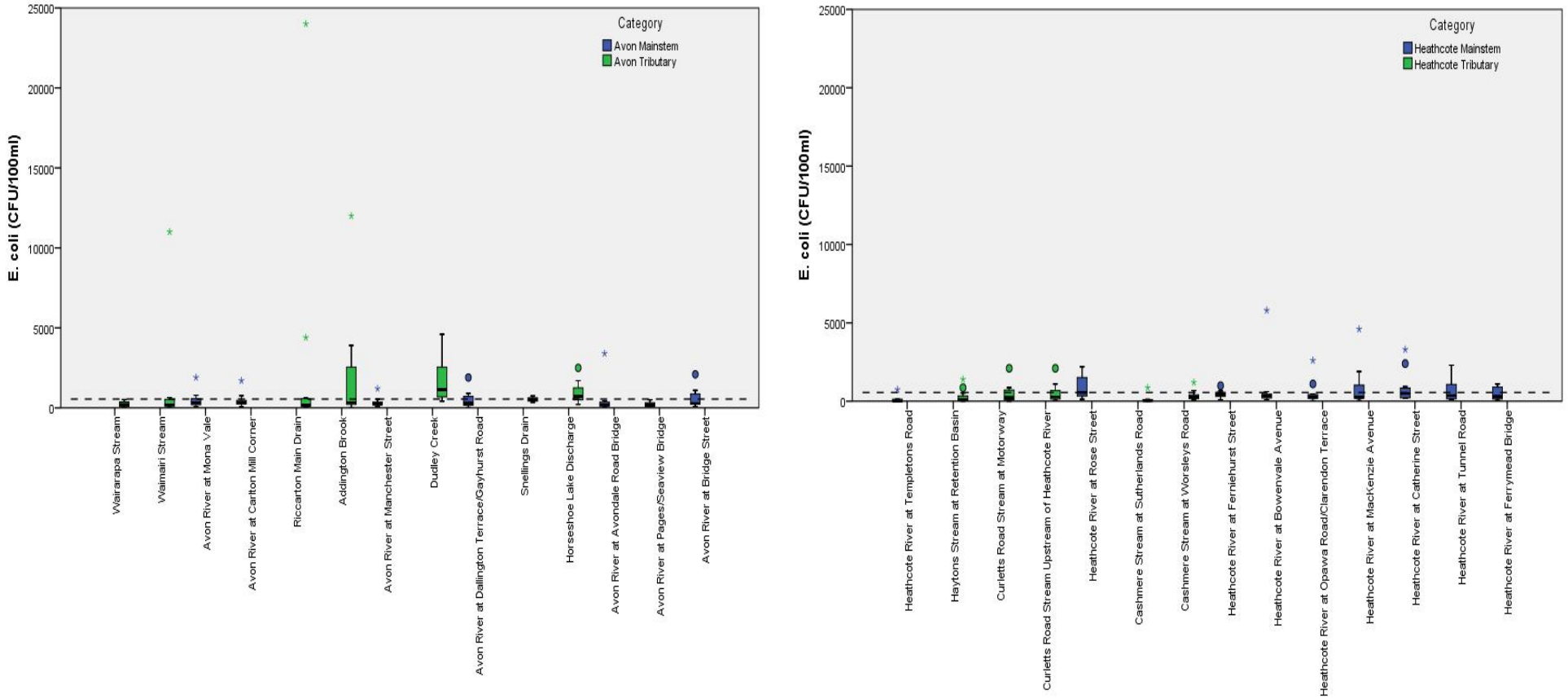

Figure xvi (a). *Escherichia coli* levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2015. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as the site was dry. Snellings Drain was sampled in March, June and September. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the 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, 2015). 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.

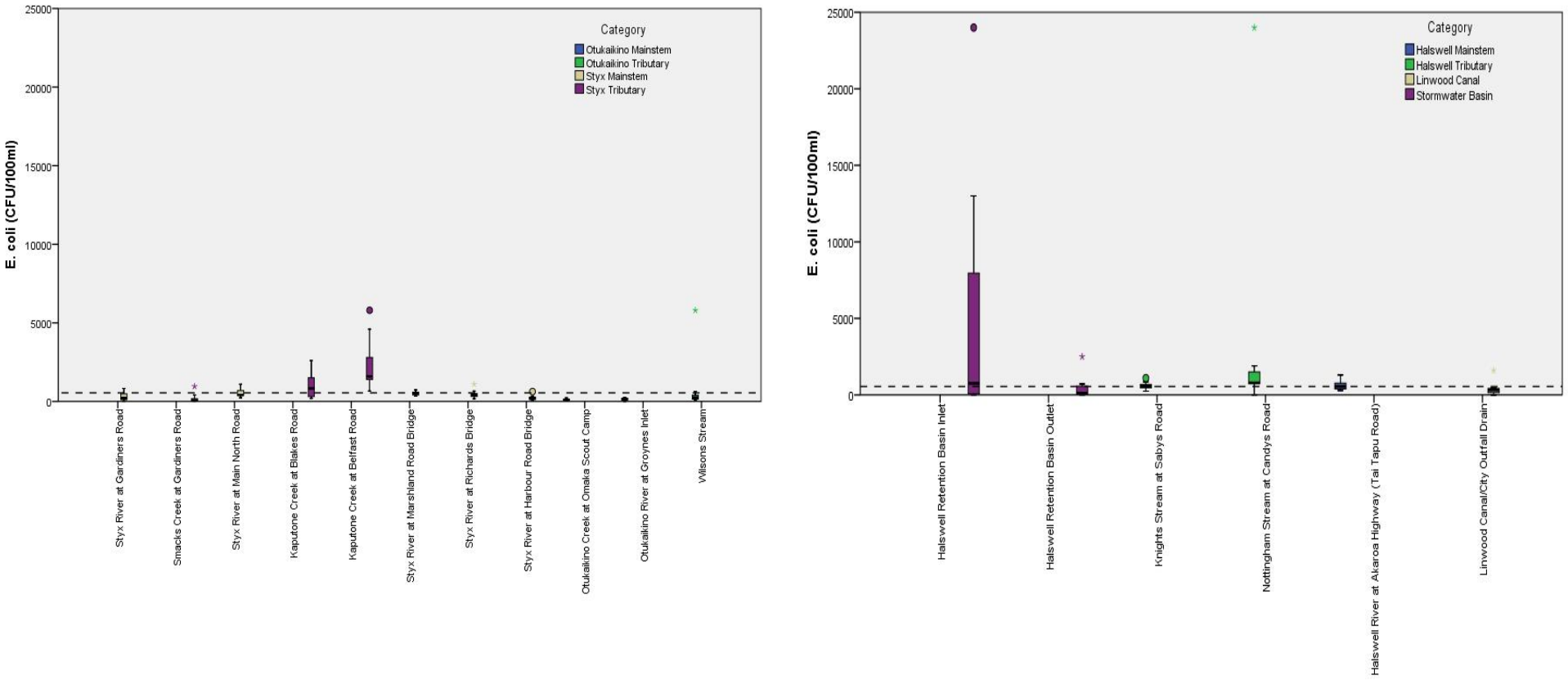

Figure xvi (b). *Escherichia coli* levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the 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, 2015). 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 left graph is presented on a smaller scale in Appendix E, Figure iv.

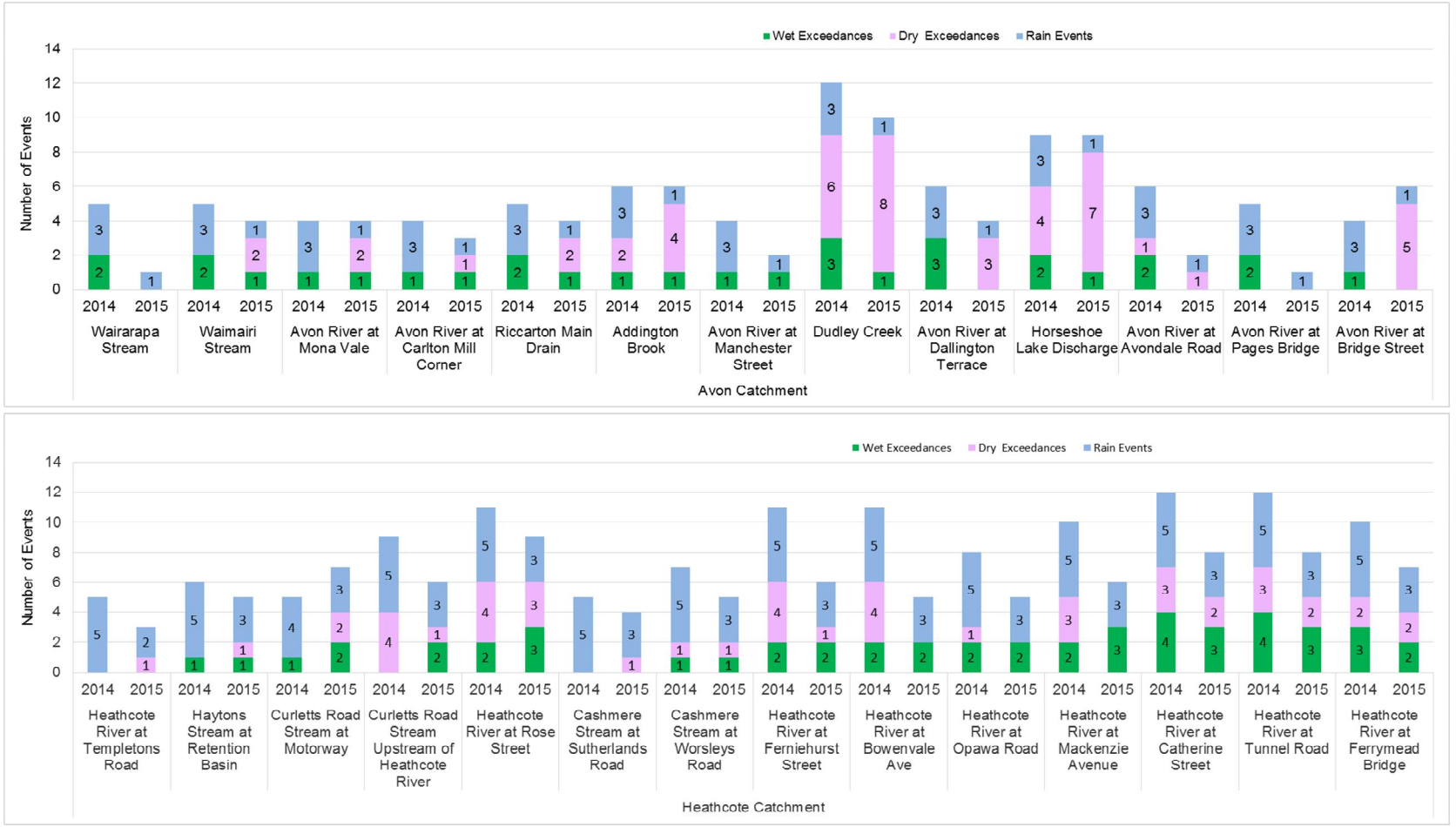

Figure xvi (c). Number of *Escherichia coli* values that exceeded the catchment-specific guidelines in January - December 2014 and January - December 2015 for the Avon River (top) and Heathcote River (bottom) catchments. Sites that did not record any exceedances have been omitted from the graph. Wet and dry exceedances are exceedances where rain was recorded or not recorded, respectively, at the time of sampling or within the previous 24-hours; number of rain events is the number of sampling occasions for the monitoring year where rain was recorded at the time of sampling or within the 24-hours previous, regardless of whether an exceedances was recorded or not. Only seven samples were taken at the Curletts Road Stream at Motorway site during the 2014 monitoring year, due to construction. Only five samples were taken at the Heathcote River Templetons Road site during the 2015 monitoring year, due to the site being dry.

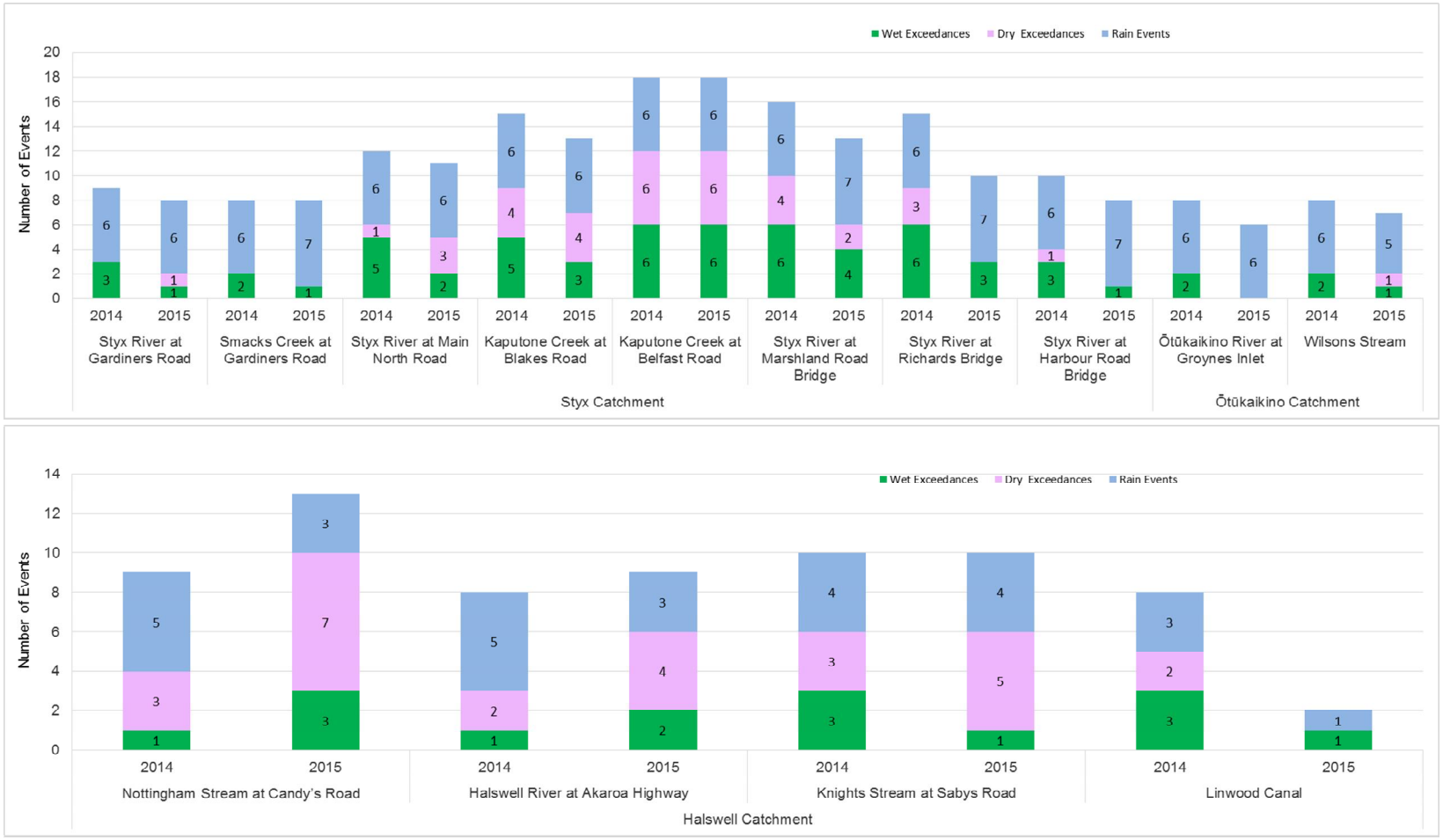

Figure xvi (d). Number of *Escherichia coli* values that exceeded the catchment-specific guidelines in January - December 2014 and January - December 2015 for the Styx and Ōtūkaikino River (top), and Halswell River and Linwood Canal (bottom) catchments. Sites that did not record any exceedances have been omitted from the graph. Wet and dry exceedances are exceedances where rain was recorded or not recorded, respectively, at the time of sampling or within the previous 24-hours; number of rain events is the number of sampling occasions for the monitoring year where rain was recorded at the time of sampling or within the 24-hours previous, regardless of whether an exceedances was recorded or not.

Appendix E: Supplementary Graphs

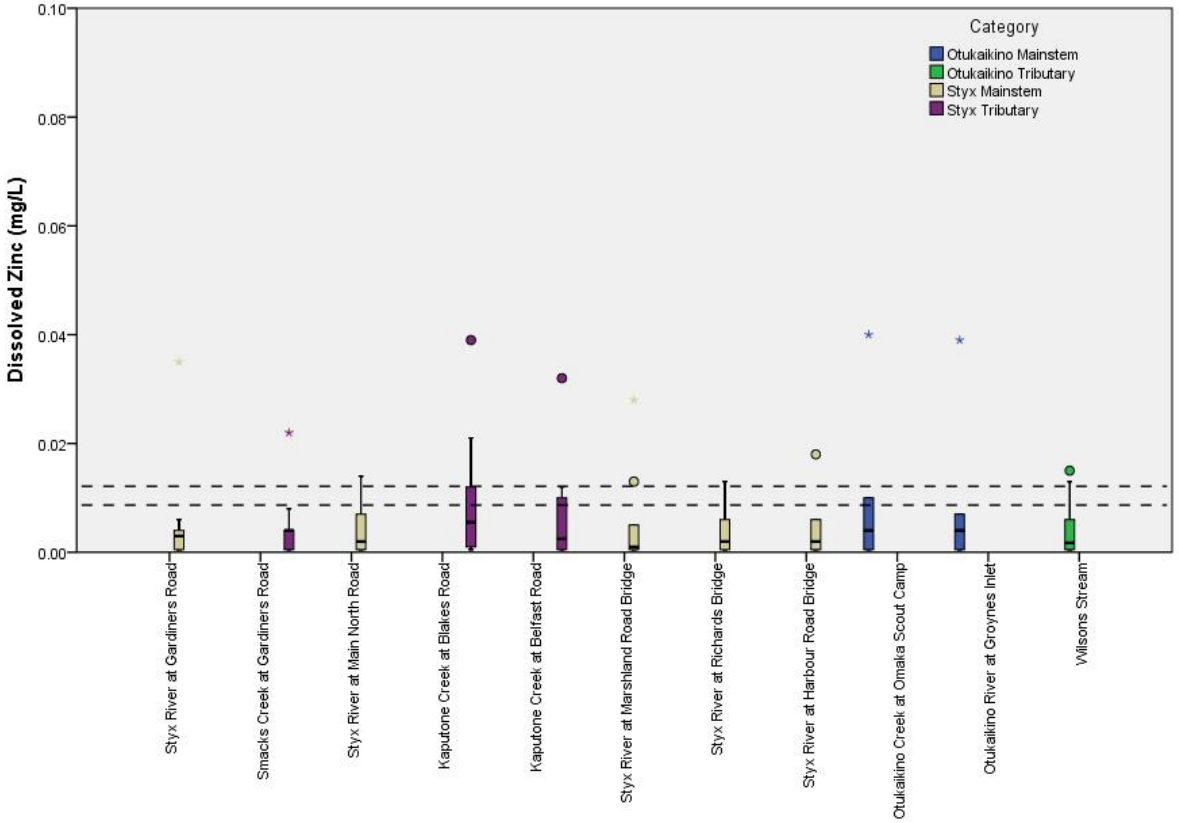

Figure i. This zinc graph is a close up of Figure 4b (left graph). Dissolved zinc levels in water samples taken from the Styx and Ōtūkaikino River for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger values (Environment Canterbury, 2015), which have been modified to account for water hardness (Hardness Modified Trigger Value = HMTV), as per the ANZECC (2000) guidelines methodology. The 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 Ōtūkaikino 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.

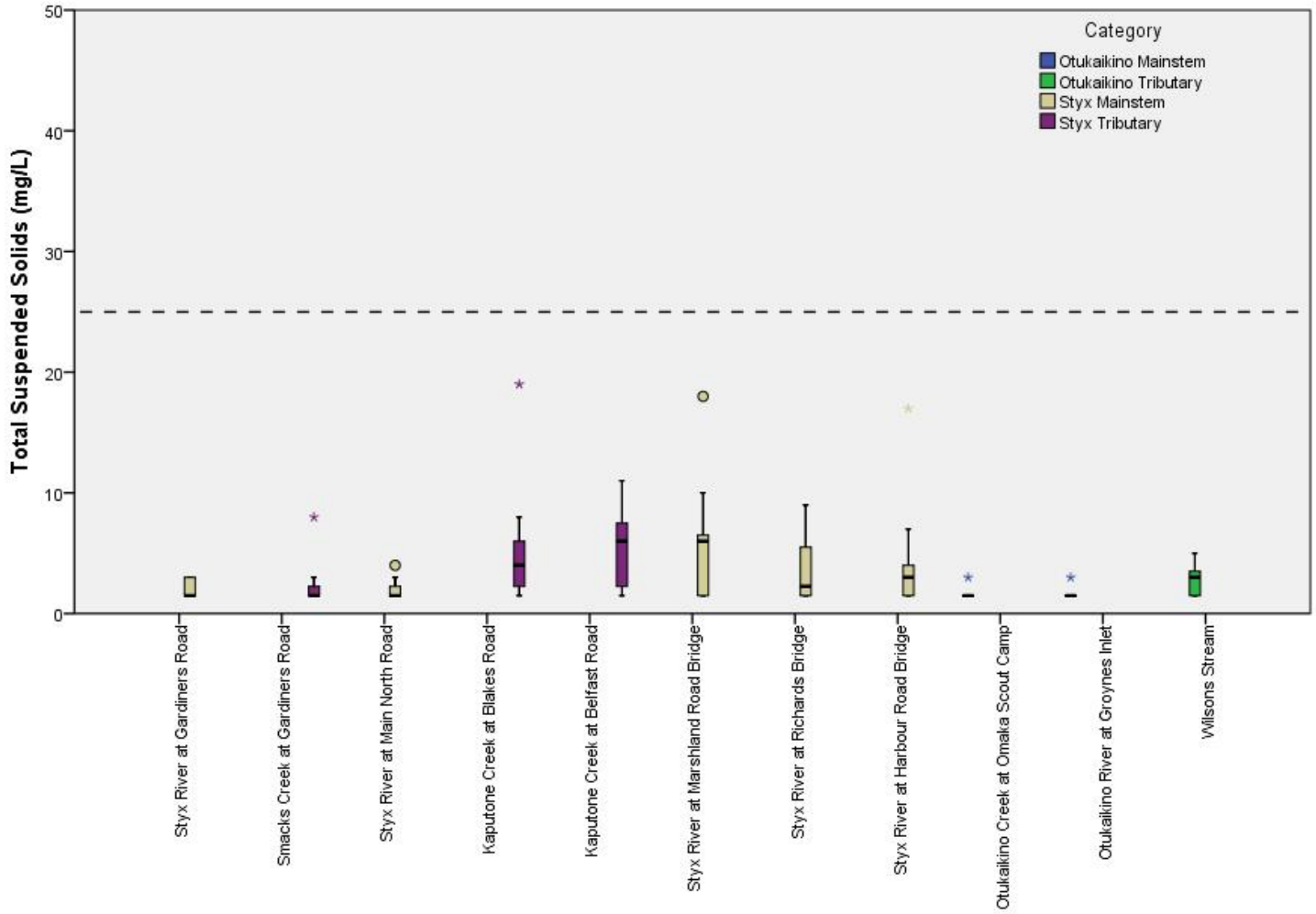

Figure ii. TSS levels in water samples taken from the Styx and Ōtūkaikino Rivers for the monitoring period January to December 2015 (this graph is the same as that presented in Figure 7b (left graph), but on a smaller scale). Sites are ordered from upstream to downstream (left to right).

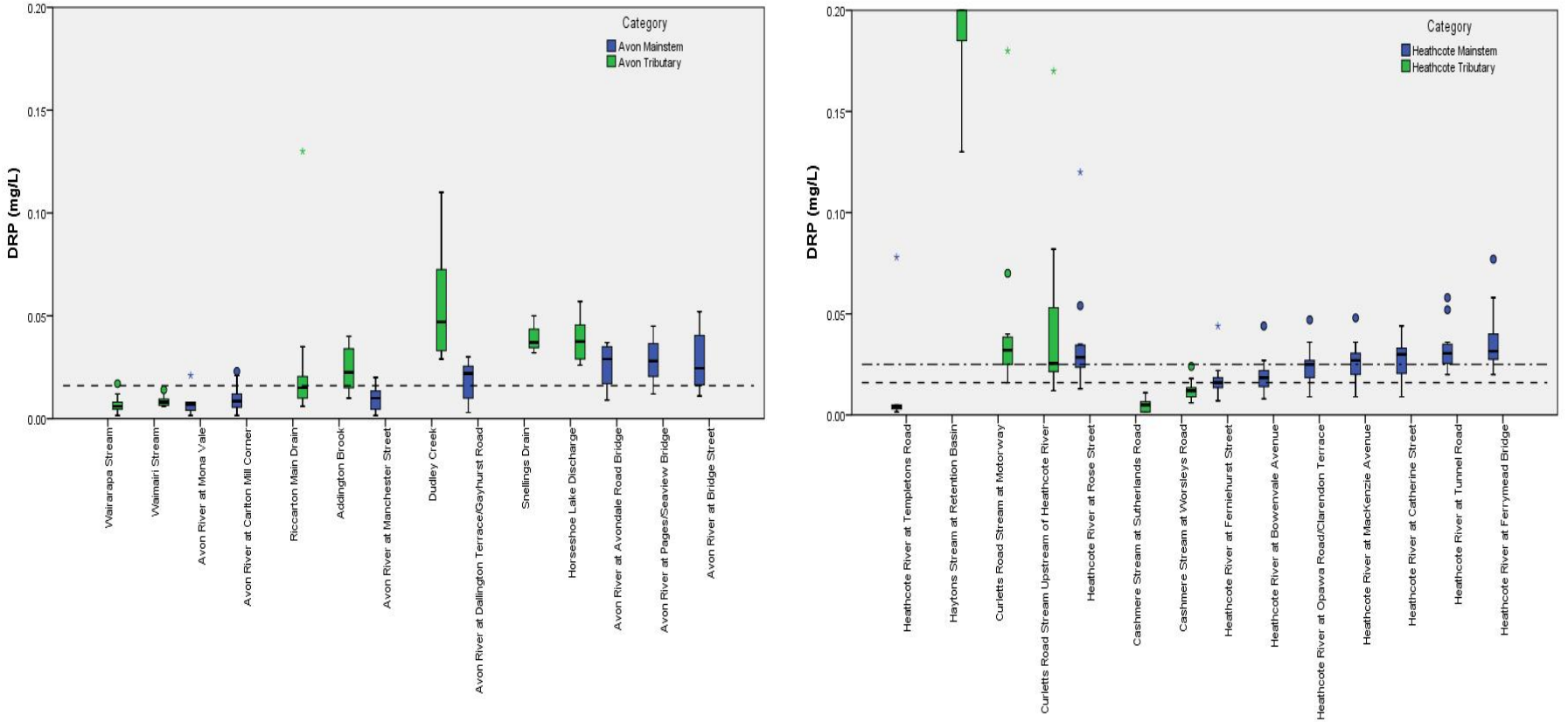

Figure iii (a). These Dissolved Reactive Phosphorus (DRP) graphs are the same as those presented in Figure 16a, but on a smaller scale. DRP levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2015. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as the site was dry. Snellings Drain was sampled in March, June and September. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger value of 0.016 mg/L for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways, and the dash-dot line (right graph only), represents the Land and Water Regional Plan trigger value of 0.025 mg/L for Banks Peninsula waterways (Cashmere Stream only), (Environment Canterbury, 2015). 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.

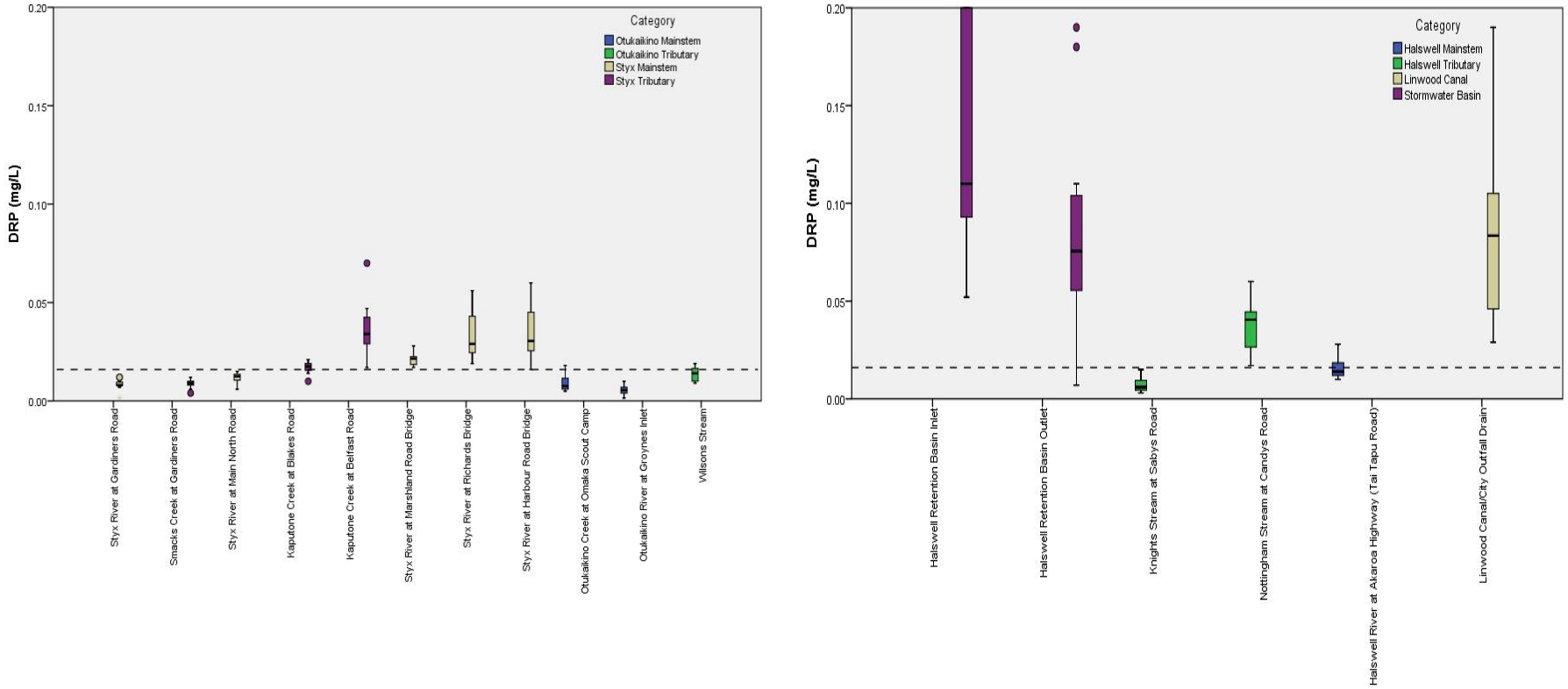

Figure iii (b). These Dissolved Reactive Phosphorus (DRP) graphs are the same as those presented in Figure 16b, but on a smaller scale. DRP levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger value of 0.016 mg/L for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (Environment Canterbury, 2015). 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.

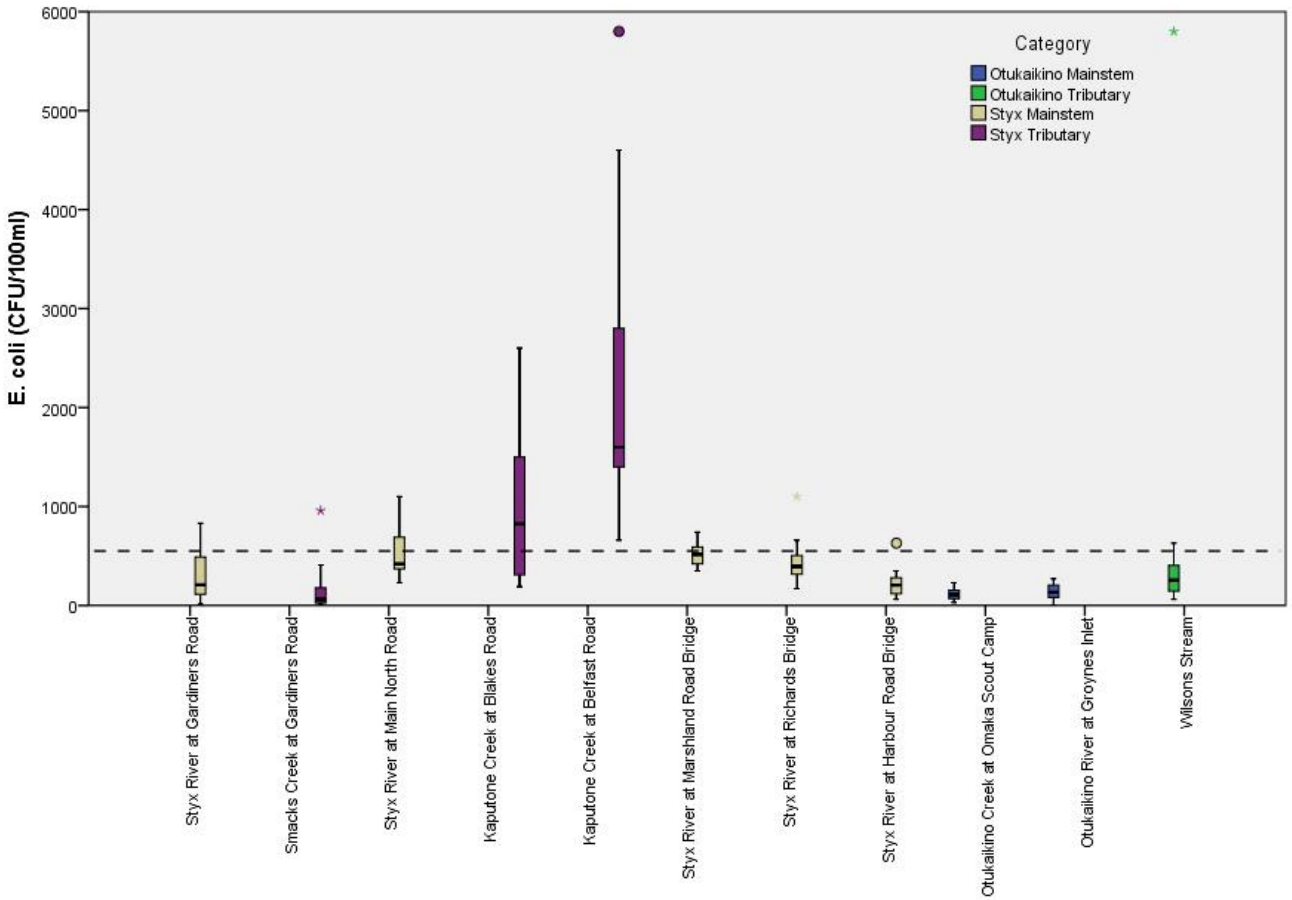

Figure iv. This *Escherichia coli* (*E. coli*) graph is the same as that presented in Figure 17b, but on a smaller scale. *E. coli* levels in water samples taken from the Styx and Ōtūkaikino Rivers for the monitoring period January to December 2015. Sites are ordered from upstream to downstream (left to right). The dashed line represents the 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, 2015). 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.