Surface Water Quality Monitoring Report for Christchurch City Waterways: January – December 2016

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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 2016.
- During the period January to December 2016, monthly water samples were collected from 42 sites within the five major river catchments of Christchurch City (the Ōtākaro/Avon, Ōpāwaho/Heathcote, Huritini/Halswell, Pūharakekenui/Styx and Ōtūkaikino Rivers) and Linwood Canal, as well as two sites within Halswell Retention Basin. Wet weather monitoring was also conducted during two rain events at three sites within the Halswell 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 (BOD_5), ammonia, nitrogen, phosphorus and *Escherichia coli* (as an indicator of pathogens).
- As was recorded for the last two monitoring years, 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 Haytons Stream at Retention Basin, which particularly suffered with elevated levels of copper, zinc, suspended sediment, turbidity, water temperature, BOD_5, ammonia and phosphorus. The sites that recorded the best water quality were both of the Ōtūkaikino River sites. Haytons Stream has one of the most heavily developed, industrial catchments of those monitored, whereas the Ōtūkaikino catchment is the least urbanised.
- 7,335 samples were collected monthly during the monitoring year from the 42 waterway sites. Of these, 82% of samples met 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 guidelines were nitrate plus nitrite-nitrogen (NNN, 73%), dissolved reactive phosphorus (DRP, 59%), dissolved inorganic nitrogen (DIN, 32%), *E. coli* (32%) and dissolved oxygen (23%). For sites overall, 98% of sites (40 of 42 sites) did not meet the guidelines for at least one parameter on at least one occasion.
- As was the case for the previous monitoring year, the time trends analysis showed that the majority of parameter concentrations for all sites have remained steady over time (52% of parameter-site combinations). The most notable parameter-site changes per annum were decreases in: dissolved zinc at Curletts Road Stream Upstream of Heathcote River (46% per annum), Knights Stream (37%) and Dudley Creek (23%); DRP at Cashmere Stream at Sutherlands Road (25%) and Ōtūkaikino at Groynes Inlet (21%); and turbidity at Ōtūkaikino at Groynes Inlet (21%). Increasing trends were less notable; the greatest annual increase was a 16% increase in conductivity at the two most-downstream Avon River sites, associated with earthquake impacts on bed levels and inland migration of saline water.
- The Halswell Retention Basin inlet and outlet sites recorded much higher and more variable contaminant levels than the majority of river sites for a number of parameters, including copper, BOD_5, ammonia and DRP. This is to be expected, given the predominantly stormwater input into the basins and

because rivers are further subjected to dilution from baseflow. Further stormwater treatment facilities are proposed in the catchment in the next 5 years, which should see an overall improvement to the quality of water discharged to the receiving environment over time.

- Contaminant levels at the Halswell Retention Basin Outlet site were better than at the inlet for approximately half of the parameters measured and similar for the remainder.
- Wet weather monitoring in the Halswell River catchment revealed poor water quality in Nottingham Stream, with copper, lead, zinc, total suspended solids, turbidity and BOD_5 all exceeding guidelines at least once.
- Issues of particular concern highlighted in this report are: high ammonia in Haytons Stream, high zinc concentrations in Haytons and Curletts Road Streams, high levels of faecal contamination in Kā Pūtahi Creek, and multiple contaminants of concern in Nottingham Stream. Both Kā Pūtahi Creek and Nottingham Stream require further investigation and additional water quality testing to identify and address contaminant sources. Haytons Stream and Curletts Road Stream are discussed below.
- This report highlights the need for better source control and treatment of stormwater in Christchurch. Haytons Stream and Curletts Road Stream catchments have consistently been amongst the worst contributors of stormwater contaminants of all sites monitored. New or upgraded stormwater treatment facilities are proposed for both of these catchments within the next five years, which should help reduce stormwater contaminant loads, provided it occurs in combination with ongoing improvements at contaminant sources.
- Water quality in most of these catchments should improve over time, provided sufficient funding is allocated to support Christchurch City Council Stormwater Management Plans, as well as joint Christchurch-West Melton Zone Committee, Environment Canterbury and Christchurch City Council catchment pollution projects. However, legislative change is most likely required to meet environmental guidelines for parameters such as zinc and copper.

1 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 2016.

During the period January to December 2016, monthly water samples were collected from 41 sites within the five major river catchments of Christchurch City (the Ōtākaro/Avon, Ōpāwaho/Heathcote, Huritini/Halswell, Pūharakekenui/Styx and Ōtūkaikino Rivers), and one site on Linwood Canal, as well as two sites within the Halswell Retention Basin (inlet and outlet) (Table 1, Figure 1). In total, results from 44 monitoring sites are presented in this report.

The Halswell River catchment was also monitored during two wet weather occasions at all three of the monthly sites (Table 1, Figure 1).

2 Methods

2.1 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 WRRP sites covered by this plan are within the Ōtūkaikino catchment; 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.

2.2 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 2016 monitoring year, the Heathcote River at Templetons Road site was unable to be sampled monthly in January and from March – December, as the site was dry. The two wet weather sampling events within the Halswell River catchment were on the 4th April 2016 and 26th August 2016.

Table 1. Christchurch City Council water quality monitoring sites required under the four Environment Canterbury (ECan) stormwater consents.

Catchment	Site ID	Site	Easting	Northing	ECan Consent	LWRP or WRRP Classification
Avon	AVON01	Avon River at Pages/Seaview Bridge[1]	2487487	5744202	IGSC	Spring-fed – plains – urban (LWRP)
	AVON02	Avon River at Bridge Street[1]	2487694	5742425	IGSC	Spring-fed – plains – urban (LWRP)
	AVON03	Avon River at Dallington Terrace/Gayhurst Road[1]	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[1]	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[1]	2484754	5745170	IGSC	Spring-fed – plains – urban (LWRP)

Notes: IGSC = Interim Global Stormwater Consent; SMP = Stormwater Management Plan; LWRP = Land & Water Regional Plan; WRRP = Waimakariri River Regional Plan. Eastings and Northings are in NZMG map projection.

[1] Tidally influenced site
[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[1]	2486494	5738760	IGSC	Spring-fed – plains – urban (LWRP)
	HEATH02	Heathcote River at Tunnel Road[1]	2485076	5739154	IGSC	Spring-fed – plains – urban (LWRP)
	HEATH03	Heathcote River at Opawa Road/Clarendon Terrace[1]	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

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	Kā Pūtahi[5] Creek at Blakes Road	2480401	5749645	Styx SMP	Unclassified[4]
	STYX05	Kā Pūtahi[5] 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[1]	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)
	OTUKAI03	Ōtūkaikino Creek at Omaka Scout Camp	2475663	5749653	IGSC	OTU/GROYNES (WRRP)
Linwood	OUT01	Linwood Canal/City Outfall Drain[1]	2485954	5739637	IGSC	Unclassified[6]

[4] These waterways were originally classified as WAIM-TRIB in the WRRP, but an amendment was made for this catchment to be covered by the NRRP (where the waterways were classified 'spring-fed - plains'). The LWRP may 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] While officially shown on maps as Kaputone Creek, CCC has recently endorsed the use of the original Māori name for the area, Kā Pūtahi.

[6] 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

* These sites were also monitored during the two additional wet weather events

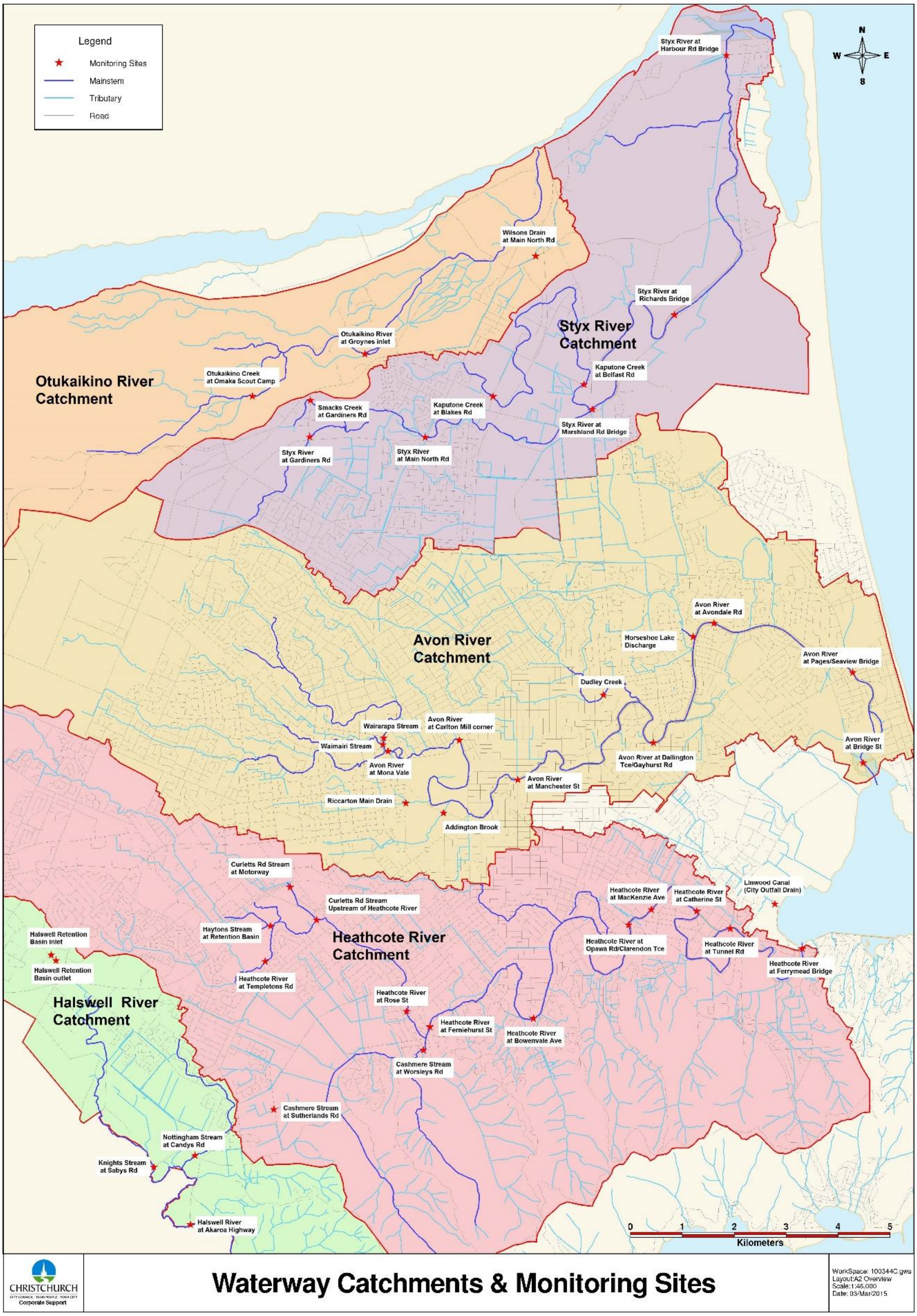


Figure 1. Location of Christchurch City Council surface water quality monitoring sites.

2.3 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 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 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. 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 at high concentrations 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 N/L) that provides for ecosystem protection for average long-term exposure (measured against medians) and the ‘surveillance’ guideline (5.6 mg N/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 N/L (measured against annual median).

Elevated concentrations of *Nitrate and Nitrite Nitrogen* (NNN) can lead to proliferation of algae and aquatic plants (i.e., eutrophication), because nitrate and nitrite are oxidised forms of nitrogen that are readily available to plants. Eutrophication occurs at much lower nitrate concentrations than toxicity. 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. Note that this guideline is based on the 80th percentile of measurements from three lowland reference sites, so it is not “effects-based”. Rather, compliance with the guideline indicates the risk of eutrophication is relatively low. Compliance with NNN guidelines will also protect against nitrate toxicity.

Dissolved Inorganic Nitrogen (DIN), which is the sum of ammonia, nitrite and nitrate, provides a similar measure of eutrophication risk to NNN. The LWRP details a DIN 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. Note that the DIN guideline of 1.5 mg/L in the LWRP is based on a value between the 50th and 80th percentiles of Canterbury Spring-fed plains streams, whereas the 0.09 mg/L LWRP guideline is derived from the New Zealand Periphyton Guideline (Biggs 2000). There is no DIN guideline value 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 eutrophication 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.

Arsenic can be released into the environment naturally by weathering of arsenic-containing rocks, but it is more commonly associated with human-derived sources in the urban environment, such as copper-chrome-arsenic timber treatment. Arsenic is toxic to aquatic life and the ANZECC (2000) trigger value for arsenic (III) is 0.024 mg/L.

Total petroleum hydrocarbon (TPH) is the term used to describe a wide variety of chemical compounds that are found in oil and petroleum-based products. Some of the hydrocarbons found in petroleum products are toxic to aquatic life. In addition, elevated hydrocarbon concentrations can increase microbial activity, resulting in reduced oxygen levels, which can also be harmful to sensitive fish and invertebrate species. There are no guidelines for TPH in New Zealand freshwaters.

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

2.4 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.

2.5 Data Analysis

2.5.1 Summary Statistics and Graphs

Statistical methods followed similar procedures to the previous year's monitoring report. Summary statistics and graphs of the monthly 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 that 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 was one case of this in the 2016 monitoring year, as there were cases 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 parameters important to waterway health and potentially impacted by urban stormwater (copper, zinc, and *E. coli*), the monthly data were also assessed for the frequency of exceedances of their respective guideline levels during the monitoring year, compared to all previous years. Only sites with 12 monthly samples were used for the 2016 data summary, while all data was included for the "all years" comparison. Unlike last year's report, we did not separate dry versus wet-weather samples, for the sake of simplicity and because the majority of samples are taken during dry weather.
In last year's report, a weak positive correlation was found between monthly TSS and DRP data, with the relationship associated with phosphorus-enriched sediment runoff (Margetts & Marshall, 2016). Correlation was not undertaken again this year, as the relationship was considered unlikely to change.

Dissolved arsenic and total petroleum hydrocarbons were sampled in the wet weather monitoring, but not the monthly monitoring.

2.5.2 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 only sampled in

February 2016, 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 metal concentrations, not total metals.

Trends analysis was conducted using the Time Trends software developed by NIWA (NIWA, 2014). Trends analysis cannot be performed on parameters that have a high proportion of data below the LOD or very small values. This software also requires three years of data for temporal trends analysis (NIWA, 2014), therefore results for the Ōtūkaikino at Omaka Scout Camp site should be treated with caution as only the October- December data was analysed, as these were the only months with the required three years of sampling for statistical analysis (Table 3). Dissolved metal results for Avon River at Carlton Mill Corner, Avon River at Avondale Road Bridge, Curletts Road Stream at Motorway, Heathcote River at Mackenzie Avenue, Heathcote River at Catherine Street and both of the Halswell Retention Basin sites should be regarded with caution as only the September - December data was analysed, as these were the only months with the required three years of results for statistical analysis. The Seasonal Kendall trend test was used to test the significance, magnitude and direction of the trends, providing an average annual percentage change.

Version 5 of Time Trends was used for the 2015 temporal trends analysis, while version 6.2 was used this year. These two versions have a different way of treating values below the LOD. In version 5, the LOD is halved and then the analysis is run. In version 6.2 values below the LOD are not considered, because the software author considered that a slope cannot be calculated from a censored value (pers. comm. Ian Jowett). Initial comparison of the two Time Trends versions yielded different results for some parameters and sites (see Appendix F). Therefore, to effectively compare trends and to be consistent with methods used in previous reports, all data below the LOD was converted to half this value before being imported into Time Trends 6.2 (i.e., the same method was used as in last year's report). Because of the removal of the '<' symbol from the data, this method did not allow any warning regarding excessive values below the LOD. To ensure data were correctly analysed, the analysis was also run on the unedited data, which does give a warning. In addition, any site with more than 70% of the data below the LOD was not considered reliable for trend analysis.

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 recorder was directly present (Heathcote River at Ferniehurst Street). It is considered that extrapolation of this flow data to other locations, as well as the use of other flow gauges in Christchurch not directly at the monitoring sites, may bias the results through differences in 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 period of monitoring, it is considered that variations in flow rates between sampling events will not strongly influence the trends analysis, as most events will have been conducted during baseflow conditions.

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 60% and 78% of the variation, respectively. There was no difference in the significance of trend results between the flow adjusted and unadjusted data, therefore the results for unadjusted data are presented.

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

Catchment	Site Description	Monitoring Instigated*
Avon	Wairarapa Stream	January 2007[8]
	Waimairi Stream	January 2007[8]
	Avon River at Mona Vale	January 2007[8]
	Avon River at Carlton Mill Corner	October 2008
	Riccarton Main Drain	October 2008
	Addington Brook	October 2008
	Avon River at Manchester Street	July 2008[9]
	Dudley Creek	October 2008
	Avon River at Dallington Terrace/Gayhurst Road[8]	January 2007
	Horseshoe Lake Discharge	October 2008
	Avon River at Avondale Road	October 2008
	Avon River at Pages/Seaview Bridge	January 2007
	Avon River at Bridge Street	January 2007[8]
Heathcote	Heathcote River at Templetons Road	January 2007[10]
	Haytons Stream at Retention Basin	April 2007[11]
	Curletts Road Stream Upstream of Heathcote River	October 2008
	Curletts Road Stream at Motorway	October 2008
	Heathcote River at Rose Street	June 2008[12]
	Cashmere Stream at Sutherlands Road	December 2010
	Cashmere Stream at Worsleys Road	January 2007
	Heathcote River at Ferniehurst Street	July 2008[11, 13]
	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[10]
	Styx River at Gardiners Road	January 2007[10]
	Styx River at Main North Road	January 2007[10]
	Kā Pūtahi at Blakes Road	January 2007[10]
	Kā Pūtahi at Belfast Road	January 2007[10]
	Styx River at Marshland Road Bridge	January 2007[10]
	Styx River at Richards Bridge	October 2008
	Styx River at Harbour Road Bridge	January 2008
Halswell	Halswell Retention Basin Inlet	April 2007[11]
	Halswell Retention Basin Outlet	April 2007[11, 14]
	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[8]

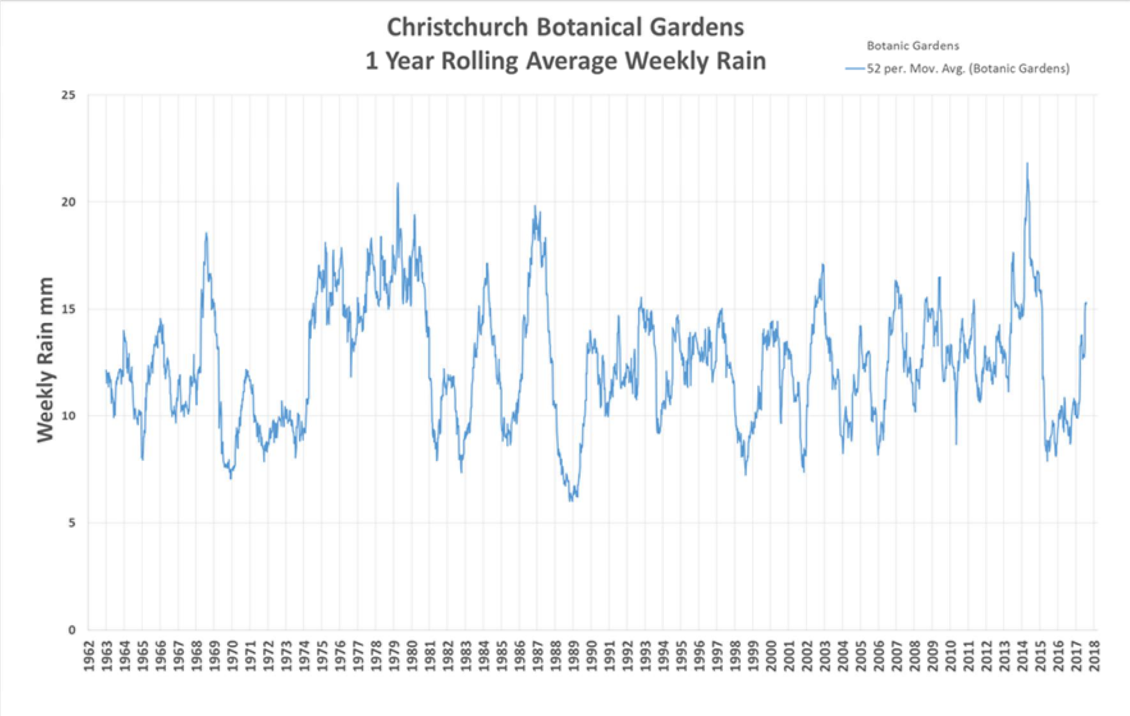
Notes: *Monitoring of dissolved metals began in 2011, with the exception of Avon River at Carlton Mill Corner, Avon River at Avondale Road, Curletts Road Stream at Motorway, Heathcote River at Mackenzie Avenue, Heathcote River at Catherine Street, Halswell Retention Basin Inlet and Halswell Retention Basin Outlet which began in September 2014 and Ōtūkaikino River at Omaka Scout Camp which began in October 2014.

[8] Dissolved oxygen monitored from June 2007
[9] Dissolved oxygen monitored from October 2008
[10] Dissolved oxygen monitored from March 2007
[11] Dissolved oxygen, total ammonia, conductivity, *E. coli*, nitrogen parameters, pH, DRP and water temperature monitored from October 2008
[12] Dissolved oxygen, BOD_5, conductivity, nitrate, pH, TSS and water temperature monitored from August 2008. Total ammonia, *E. coli*, nitrogen parameters (excluding nitrate) and DRP monitored from October 2008
[13] BOD_5 and TSS monitored from October 2008
[14] BOD_5 monitored from April 2008

3 Results

3.1 Historic Rainfall

Daily rainfall is collected by the CCC at the Botanical Gardens in Hagley Park. This data has been collected since the early 1960's and the long-term data set shows that both 2015 and 2016 were dry years (rolling weekly average of the previous 52 weeks). For the 2016 monitoring year, Linwood Canal was the catchment that recorded the most number of sampling days affected by rain (50%), followed by the Avon catchment (32%), Heathcote and Halswell catchments (25% each) and then the Styx and the Ōtūkaikino catchments (17%) each.



3.2 Monthly Monitoring: Summary Statistics and Comparison to Guidelines

Appendix A (Tables i - iv) presents the summary statistics for the monthly data for the 2016 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 relatively 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.

3.2.1 Dissolved Copper

The concentrations of dissolved copper for a large proportion of samples across all catchments during the monitoring period were below the LOD of 0.002 mg/L (Appendix D, Figures i (a) - (d)). Therefore, most interquartile ranges are not visible in the summary boxplots. The exceptions to this were Haytons Stream at Retention Basin, Curletts Road Stream at Motorway, Curletts Road Stream Upstream of Heathcote River, Heathcote River at Rose Street, Heathcote River at Ferniehurst Street and the two Retention Basin sites. 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, with the exception of the Curletts Road Stream at Motorway site and concentrations were similar between the basin inlet and the outlet, although there was more variability at the outlet. Copper concentrations were similar to 2015, except last year's concentrations were higher at the Curletts Road Stream Upstream of Heathcote River site. In addition, four sites (Haytons Stream at Retention Basin, Curletts Road Stream at Motorway, Heathcote River at Rose Street and Heathcote River at Ferniehurst Street) recorded much higher concentrations this year (Margetts & Marshall, 2016).

The highest dissolved copper concentrations recorded across the sites were at the Curletts Road Stream at Motorway site in February (0.016 mg/L) and September (0.01 mg/L). Both these events were recorded in association with rain and are therefore likely due to stormwater inputs. Of the ten highest copper concentrations recorded across all sites, seven were from this site and of these seven, only three were associated with a rain event. With high copper concentrations occurring under baseflow conditions, it is highly likely that copper-contaminated sediment deposits are a significant source of dissolved copper in Curletts Road Stream. It is also possible that there is an, as yet unknown, industrial source that is discharging outside of rainfall events.

The Curletts Road Stream at Motorway site was the only waterway site to record the 95th percentile above the respective guideline level. This site also recorded its median above the guideline level. Additionally, the respective guideline levels were exceeded on one sampling occasion each at the Curletts Road Stream Upstream of Heathcote River, Heathcote River at Rose Street, Kā Pūtahi Creek at Blakes Road and Linwood Canal sites.

Where there were exceedances of the guideline in previous years but not in 2016, the percentage of samples exceeding the guideline did not exceed 10%. The percentage of guideline exceedances was lower in 2016 at all sites except Curletts Road Stream at Motorway, Heathcote River at Rose Street, Kā Pūtahi Creek at Blakes Road and Halswell Retention Basin Inlet. Both the Halswell Retention Basin sites were the only sites to record more than 30% of samples exceeding guidelines in both time categories.

3.2.2 Dissolved Lead

All river sites across all catchments recorded very low dissolved lead concentrations, with most sites consistently below the LOD of 0.0015 mg/L, so boxplots therefore do not show an interquartile range (Appendix D, Figures ii (a) - (b)). Given the low lead levels recorded, there were no trends in concentrations downstream for any of the catchments. Both the Retention Basin Inlet and Outlet recorded similarly low levels to the river sites. Lead concentrations were similar to that recorded in 2015, however there were notable differences in the number of outliers observed in each of the catchments. In 2015 a single outlier was recorded at eight sites in the Avon catchment, three sites in the Heathcote catchment, one site in the Styx catchment, three sites in the Ōtūkaikino catchment and one site in Linwood Canal. This year river outliers were only recorded at one site in the Heathcote catchment. In addition to this, both Dudley Creek and Retention Basin Outlet have improved substantially. In 2015, both sites recorded enough concentrations above the LOD to exhibit an upper interquartile range. This year Dudley Creek recorded all values below the LOD and the Retention Basin Outlet recorded a single value above it.

The only sample that recorded above the dissolved lead LOD from all river sites was at the Heathcote River at Rose Street site (0.0021 mg/L in June) and it was not associated with rain. No concentrations were recorded above the respective receiving water guidelines on any occasion during the monitoring period.

3.2.3 Dissolved Zinc

Generally 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. Zinc concentrations were only slightly lower and less variable at the outlet than the inlet.

Generally, the Heathcote, Halswell and Linwood Canal catchment's dissolved zinc concentrations in 2016 were similar to those measured in 2015. This was also true for the Avon, Styx and Ōtūkaikino catchments, however there was an obvious decrease in the number of exceedances recorded at these sites this year. In 2015, nine (Avon), seven (Styx) and three (Ōtūkaikino) sites exceeded the guideline at least once, compared to one (Avon), two (Styx) and one (Ōtūkaikino) in 2016. At the site level, obvious changes since 2015 include an increase in zinc concentration at Addington Brook, Curletts Road Drain at Motorway, Heathcote River at Rose Street, Heathcote River at Ferniehurst Street, Kā Pūtahi at Blakes Road and Nottingham Stream. Clear decreases were noted in the Heathcote catchment (Curletts Road Stream Upstream of Heathcote River, Cashmere Stream at Sutherlands Road), Styx catchment (Smacks Creek at Gardiners Road, Styx River at Main North Road, Kā Pūtahi at Belfast Road, Styx River at Marshland Road and Styx River at Richards Bridge) and Ōtūkaikino catchment (all sites). The two Halswell Retention Basin sites were comparable to 2015.

Of all the river sites, Curletts Road Stream at Motorway recorded the highest dissolved zinc concentrations, with the 25th percentile well above the guideline level. Haytons Stream at Retention Basin, Curletts Road Stream Upstream of Heathcote River and Heathcote River at Rose Street recorded much higher and variable concentrations compared to all other river sites. The Curletts Road Stream at Motorway site recorded both of the highest concentrations across all sites during the monitoring period (0.57 mg/L in May and 0.54 mg/L in September). While the lower value was recorded in association with rain, the higher was not. Of the ten highest concentrations recorded across all sites, six were from this site and of these six, only three were associated with a rain event. Thus, as for copper (discussed above), with high dissolved zinc concentrations occurring under baseflow conditions, it is highly likely that either zinc-contaminated sediment deposits are a significant source of dissolved zinc in Curletts Road Stream, or there is an industrial source discharging outside of rainfall 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 except the Styx and Ōtūkaikino.

Where there were exceedances of the guideline in previous years but not in 2016, the percentage of samples exceeding the guideline did not exceed 25%, with the exception of Ōtūkaikino River at Omaka Scout Camp (33%). The percentage of guideline exceedances was lower in 2016 at all sites except Haytons Stream at Retention Basin, Curletts Road Stream at Motorway, Heathcote River at Rose Street, Styx River at Marshland Road Bridge, Ōtūkaikino River at Groynes Inlet (by 0.5%), Halswell Retention Basin Inlet and Nottingham Stream. Haytons Stream, Curletts Road Stream at Motorway and both the Halswell Retention Basin sites were the only ones to record more than 40% of samples exceeding guidelines in both time categories.

3.2.4 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 sites were similar to the river sites.

In comparison to 2015, pH levels are similar. However in 2015 (Avon catchment) there were many outliers near the lower guideline but most of these outliers were absent this year. Of the river sites, Linwood Canal has improved the most, in 2015 the 95th percentile exceeded the guideline, while this year all records were below it. The Halswell Retention Basin Inlet site has improved substantially since last year, where the 75th percentile exceeded the guideline. This year all records were below the guideline.

Median pH levels for all river sites were well within the lower and upper guideline levels. However, the 95th percentile for Wilsons Stream exceeded the guideline; the only other site to do so was the Halswell Retention Basin Outlet. It was not raining on any occasion when Wilsons Stream exceeded the guideline. The lower of the two exceedances at Halswell Retention Basin Outlet were recorded in association with rain. The three lowest records at the Nottingham Stream at Candys Road site coincided with the three rain events that were sampled (pH 6.8, 7.1, 7.4).

3.2.5 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 slightly higher levels compared to the other catchments. The Styx and Ōtūkaikino River catchments recorded lower conductivity compared to the other catchments (no value exceeded 200 µS/cm). With the exception of the tidally influenced sites, conductivity levels did not appear to increase or decrease downstream in any of the catchments.

The two Halswell Retention Basin sites generally recorded similar conductivity levels to each other and the river sites. Conductivity appeared to be similar in 2016 compared to 2015, with the exception of the Linwood Canal site which had a higher quartile range this year, but a lower maximum.

The highest conductivity recorded was 22,000 µS/cm at the Heathcote River at Ferrymead Bridge site in March, with no recent rainfall recorded. The highest value recorded for the sites not influenced by salinity was Curletts Road Stream Upstream of Heathcote River (381 µS/cm in July) and this was not associated with a rainfall event. This record was associated with higher water hardness, but it could not be attributed to any of the following parameters: dissolved copper, lead, zinc, reactive phosphorous or inorganic nitrogen.

3.2.6 Total Suspended Solids

TSS concentrations were generally similar between catchments, although the Styx and Ōtūkaikino catchments recorded slightly lower levels than the other catchments (Appendix D, Figures vi (a) - (b)). There appeared to be higher levels at the tidal sites in both the Avon and Heathcote Rivers, likely due to re-suspension of sediment from tidal movement, as these areas have naturally soft-bottomed channels. There was no observable trend in any of the other catchments. TSS concentrations at the Halswell Retention Basin sites were comparable to those recorded for river sites. The outlet had slightly lower TSS concentrations than the inlet. Overall, TSS concentrations were generally similar to that recorded in 2015 across all the catchments. The tidal Heathcote River at Tunnel Road site was slightly lower than last year and the Halswell Retention Basin Inlet site was also had slightly lower concentrations this year than in 2015.

Riccarton Main Drain recorded the highest TSS concentration of all river sites (260 mg/L in October), followed by Heathcote River at Ferrymead Bridge (62 mg/L in May). While the Riccarton Main Drain record was associated with rain, the Heathcote record was not, but was likely due to tidal influence.

The Heathcote River at Ferrymead Bridge site was the only location where median values exceeded the guideline value. The Heathcote River at Tunnel Road site 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 non-tidally influenced sites (see Table 1) in the Avon (three sites), Heathcote (three sites) and Halswell (one site) 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.

3.2.7 Turbidity

The Heathcote River catchment, followed closely by the Avon River catchment, generally recorded higher turbidity levels compared to the other catchments (Appendix D, Figures vii (a) - (b)). Turbidity was generally higher in the Avon and Heathcote River mainstems at the downstream tidal sites. As with TSS, this is likely 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 mainstem sites, with the obvious exception of the tidal sites.

Consistent with TSS, these results appear to be generally similar to that recorded in 2015. Sites that had lower turbidity levels this monitoring year included Addington Brook, Dudley Creek and Curletts Road Drain Upstream of Heathcote River. Turbidity at Styx River at Richards Bridge increased this year.

The Heathcote River at Ferrymead Bridge site recorded relatively large variations in concentration throughout the monitoring period compared to the other sites. Riccarton Main Drain recorded the highest turbidity of all river sites (190 NTU in October), followed by Horseshoe Lake Discharge (41 NTU in August). While the Riccarton Main Drain record was associated with rain, the Horseshoe Lake Discharge record was not. Both of these high turbidity values coincided with elevated TSS concentrations.

Median turbidity concentrations for all sites were below the guideline level, with the exception of Dudley Creek (this site median was only just above the guideline), Avon River at Bridge Street, 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 four sites in the Avon River catchment, two sites in the Heathcote River catchment and seven sites within the Styx/Ōtūkaikino catchments. The tidal sites Avon River at Bridge Street and Heathcote River at Tunnel Road never met the guideline and Heathcote River at Ferrymead Bridge, only met the guideline on one sampling occasion.

3.2.8 Dissolved Oxygen

Dissolved oxygen levels were generally similar within and between catchments, although they were lower in the Heathcote catchment (Appendix D, Figures viii (a) - (b)). There were some sites that recorded higher variability compared to the others, including Haytons Stream at Retention Basin, Curletts Road Stream at Motorway, Curletts Road Stream Upstream of Heathcote River and Wilsons Stream. No trends in concentrations were recorded downstream, although mainstem sites typically had higher DO than tributaries. The Halswell Retention Basin inlet generally recorded a greater range in values compared to the river sites, with the lowest reading at the inlet 34% saturation in October. The outlet recorded higher levels than the inlet and levels similar to the river sites.

Levels of dissolved oxygen saturation across the catchments were generally similar or higher than those recorded during the 2015 monitoring year, with the exception of the Heathcote and Linwood Canal catchments. Of particular note, at the following sites all measurements were at or above the guideline this year, while they were not in 2015: Wairarapa Stream, Avon River at Dallington Terrace/Gayhurst Road, Heathcote River at Ferrymead Bridge and Ōtūkaikino River at Groynes Inlet. Additional sites that showed some improvement since 2015 included Addington Brook, Dudley Creek, Horseshoe Lake Discharge, Cashmere Stream at Sutherlands Road, Styx River at Gardiners Road and Wilsons Stream. Some sites had lower DO this monitoring round, particularly in the Heathcote catchment. Sites that got worse included Heathcote River at Templetons Road (but this site was only monitored once, due to being dry), Haytons Stream at Retention Basin, Curletts Road Stream at Motorway, Heathcote River at

Rose Street, Nottingham Stream at Candys Road and Linwood Canal. Both the Halswell Retention Basin Inlet and Outlet showed some improvement from last year.

The highest dissolved oxygen reading within the river sites was 140% saturation at Wilsons Stream in January, followed by 120% at Curletts Road Stream at Motorway (in November) and Heathcote River at Tunnel Road (in November). The two lowest dissolved oxygen levels were recorded at Curletts Road Stream Upstream of Heathcote River (13% in March) and Heathcote River at Templetons Road (24% in February); the latter event was associated with rainfall in the previous 24 hours and was the only reading from that site all year due to dry conditions. The extremely low oxygen level for Curletts Road Stream could not be explained by the other parameters collected concurrently.

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 site did not meet the guideline level at any time during the monitoring period, which was also the case in 2015. There were also a number of additional sites throughout all catchments that did not meet the respective guideline level on at least one occasion.

3.2.9 Water temperature

Water temperature during the 2016 monitoring period was generally similar between sites and catchments (Appendix D, Figures ix (a) - (b)). The only exceptions being that temperature was typically more stable in the upper reaches and tributaries of the Avon River compared to the lower sites and that the Heathcote River sites downstream of Cashmere Stream increased in variability. 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 temperature recorded from the river sites was 22°C, at Linwood Canal in February, followed by Avon River at Bridge Street and Avon River at Pages/Seaview Bridge in February (21°C).

Median water temperatures were all below the respective guideline levels. There were only four sites that recorded sampling events above the guideline, down from seven last year. The Haytons Stream at Retention Basin site was the only one of these sites that was not tidal.

Overall, temperatures were similar to the 2015 monitoring year across all catchments, however there was a slight reduction in the number of exceedance events. In addition, in 2015 temperature in the Heathcote catchment was typically slightly lower than in the other catchments, however this was not the case this year. Although the Avon River at Pages/Seaview Bridge, Avon River at Bridge Street and Linwood Canal sites still exceeded the guideline in 2016, temperatures were slightly lower.

3.2.10 Biochemical Oxygen Demand

BOD_5 levels were typically higher in the Heathcote catchment, with a number of sites recording samples above the LOD. Most sites consistently recorded values below the LOD (37 out of 42 sites: Appendix D, Figures x (a) - (b)). There were no obvious trends downstream for any of the catchments, although the tributaries of the Avon and Styx catchments typically recorded higher levels than the mainstem. The two Halswell Retention Basin sites recorded higher concentrations and variability than the river sites, with the exception of Haytons Stream at Retention Basin. BOD_5 levels were much lower at the retention basin outlet.

Quite substantial changes have occurred compared to the 2015 monitoring year. All catchments showed improvement, as did all sites with the exception of Haytons Stream at Retention Basin and Heathcote River at Rose Street. BOD_5 at the Haytons Stream at Retention Basin site was extremely high compared to last year; in 2015 the 75%ile just exceeded the guideline whereas this year the 25%ile was equal to it. In 2015 the following catchments and sites had enough samples above the LOD to calculate an interquartile range: Avon (six sites), Heathcote (12 sites), Styx (two sites), Halswell (two sites) and Linwood Canal (one site). In 2016 these figures reduced to: Avon (one site), Heathcote (six sites), Styx (one site) and Halswell (one site). Linwood Canal remained stable with one.

In 2015 the guideline was exceeded at least once in the Avon (five sites), Heathcote (seven sites), Styx (three sites) and Halswell (two sites) catchments. In 2016 these figures reduced to: Avon (one site), Styx (zero sites) and Halswell (zero sites). The Heathcote catchment was the only one to increase, with nine sites recording exceedances in 2016.

The highest BOD_5 levels recorded at the river sites in 2016 were 6.9 mg/L and 5.7 mg/L recorded at Haytons Stream at Retention Basin in August and May respectively; this site also recorded the highest levels in 2015. Median BOD_5 levels for all river sites were below the guideline level of 2 mg/L, with the exception of Haytons Stream at Retention Basin. The five most downstream sites in the Heathcote catchment all recorded their peak BOD_5 concentration in February in association with rain in the previous 24 hours.

3.2.11 Total Ammonia (Ammoniacal Nitrogen)

Ammonia concentrations were generally similar across the catchments, with the exception of Linwood Canal (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 Halswell Retention Basin Inlet site recorded substantially higher levels and variation than most of the river sites. More varied concentrations were recorded at the inlet than the outlet. A maximum concentration of 3.4 mg/L was recorded at the Inlet (August) and 0.69 mg/L at the Outlet (February).

Haytons Stream at Retention Basin, Curletts Road Stream Upstream of Heathcote River and Linwood Canal recorded higher levels and more variation in ammonia concentrations compared to all other river sites. Haytons Stream at Retention Basin was particularly high. The three highest river values recorded were from this site: 3.5 mg/L (October, no rain), 2.5 mg/L (September, rain) and 1.7 mg/L (August, no rain).

Ammonia levels were well below the respective receiving water quality guidelines for all samples at all river sites throughout the monitoring period, with the exception of Haytons Stream at Retention Basin, which recorded three values above this.

Generally the 2016 ammonia data was similar to 2015, although typically fewer outliers were recorded. Sites that recorded lower levels this year included: Riccarton Main Drain, Avon River at Manchester Street and Nottingham Stream at Candys Road. Some sites recorded much higher ammonia concentrations this year, such as Heathcote River at Templetons Road (only one sample taken), Haytons Stream at Retention Basin and Curletts Road Stream Upstream of Heathcote River. Both the Retention Basin Inlet and Outlet recorded much lower concentrations this year.

3.2.12 Nitrate, Nitrate-Nitrite Nitrogen and Dissolved Inorganic Nitrogen

Nitrogen concentrations in the Avon, Heathcote and Halswell River catchments were generally higher than those recorded in the Styx, Ōtūkaikino and Linwood Canal catchments (Appendix D, Figures xii (a) - (b), xiii (a) - (b) and xiv (a) - (b)). Nitrate-nitrogen, DIN, and NNN concentrations all decreased downstream in the Avon and Heathcote River mainstems. It is not surprising that these three parameters followed similar patterns, because NNN is the sum of nitrate-nitrogen and nitrite-nitrogen, and DIN is the sum of NNN and ammonia.

The two Halswell Retention Basin sites generally recorded nitrogen levels comparable to the river sites. The median concentrations at the basin outlet was very similar to the inlet for nitrate and NNN, but much lower for DIN. Compared to 2015, nitrogen concentrations have decreased, particularly at the outlet.

Nitrogen concentrations across all catchments were generally similar to those recorded last year, with 15 sites improving in one or more of the parameters (Wairarapa Stream, Waimairi Stream, Avon River at Mona Vale, Avon River at Carlton Mill Corner, Riccarton Main Drain, both Curletts Road Stream sites, Heathcote River at Rose Street, Styx River at Gardiners Road, Styx River at Main North Road, Kā Pūtahi Creek at Blakes Road, Ōtūkaikino Creek at Omaka Scout Camp, Ōtūkaikino Creek at Groynes Inlet, Knights Stream at Sabys Road and Halswell River at Akaroa Highway (Tai Tapu Road)). Particular improvement was recorded at Waimairi Stream (Nitrate, NNN, DIN), Avon River at Mona Vale (nitrate, NNN), both Curletts Road Stream sites (nitrate, NNN, DIN), Kā Pūtahi Creek at Blakes Road (DIN), Knights Stream at Sabys Road (nitrate, NNN) and Halswell River at Akaroa Highway (Tai Tapu Road) (nitrate, NNN)). Haytons Stream at Retention Basin recorded slightly higher concentrations this year for nitrate and NNN, but much higher for DIN. Only one sample was taken for Heathcote River at Templetons Road site, therefore it has not been assessed for changes.

The Knights Stream at Sabys Road and Halswell River at Akaroa Highway sites recorded much higher concentrations of all three nitrogen parameters than the other sites. Knights Stream at Sabys Road recorded the three highest concentrations of both nitrate and NNN. These were 5 mg/L in January and May, and 4.9 mg/L in March. Haytons Stream at Retention Basin had the highest DIN at 5.5 mg/L in October, followed by Knights Stream at Sabys Road (5.1 mg/L in January and May). None of these events were associated with any rainfall.

All but one site (Knights Stream at Sabys Road) recorded a median nitrate concentration below the grading guideline value of 3.8 mg/L. Halswell River at Akaroa Highway (Tai Tapu Road) was the only other site to record values above the grading guideline, and the surveillance guideline value of 5.6 mg/L was never exceeded, whereas it was in 2015.

The majority of sites recorded median NNN concentrations substantially higher than the guideline value of 0.444 mg/L, with the exception of ten sites, although five of these ten sites did record at least one event above the guideline during the monitoring period.

This year median DIN levels exceeded the guideline at two sites in the Avon River catchment, eight sites in the Heathcote River catchment, one site in the Ōtūkaikino (Wilsons Stream) River catchment, and two sites in the Halswell River catchment.

3.2.13 Dissolved Reactive Phosphorus

Phosphorus concentrations 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 than the mainstem sites. Concentrations generally increased downstream in the Avon, Heathcote and Styx catchments, potentially due to input from the tributaries as well as stormwater runoff. Samples from the Halswell Retention Basin sites were much higher and more variable than the majority of the river sites, with the notable exceptions of Haytons Stream at Retention Basin, both the Curletts Road Stream sites, Heathcote River at Rose Street, Nottingham Stream at Candys Road and Linwood Canal. The Halswell Retention Basin Outlet site recorded levels lower, but no less variable than the inlet.

The Haytons Stream at Retention Basin site recorded substantially higher and more variable phosphorus concentrations than the other river sites, with the highest value of 0.84 mg/L recorded in March (not associated with rain). This concentration was nearly double that of any value recorded from any other river site over the 2016 monitoring period. The eight highest concentrations all came from this site, with only three associated with rainfall. Curletts Road Stream Upstream of Heathcote River was the river site recording the next highest concentration of 0.45 mg/L in February and was associated with rain.

Over half of river sites recorded median concentrations above the guideline levels. Ten sites never exceeded their respective guideline values during the monitoring period and 14 sites always met or exceeded their guideline levels.

Phosphorus concentrations across all catchments were similar to those recorded in 2015 (Margetts & Marshall, 2016). Riccarton Main Drain, Dudley Creek and Linwood Canal recorded markedly lower phosphorus levels than in 2015. The following sites recorded substantially higher phosphorus levels this year: Haytons Stream at Retention Basin, Curletts Road Stream Upstream of Heathcote River, Heathcote River at Rose Street, Heathcote River at Ferniehurst Street and Nottingham Stream at Candys Road. Both the Halswell Retention Basin sites recorded much lower concentrations this year.

3.2.14 Escherichia coli

E. coli counts were generally similar amongst catchments, 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). In the Avon catchment the mid- lower tributaries typically had higher *E. coli* counts than the mainstem, whereas in the Heathcote catchment the mainstem counts were generally higher.

The LWRP 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 42 waterway sites. In addition, *E. coli* counts were greater than 550 CFU/100ml on at least one sampling occasion during the monitoring period at 33 of the 42 river sites. The exceptions to this were: Avon River at Avondale Road Bridge, Cashmere Stream at Sutherlands Road, Styx River at Gardiners Road, Smacks Creek at Gardiners Road, Styx River at Harbour Road Bridge and all three sites in the Ōtūkaikino Creek catchment. Kā Pūtahi 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 790 CFU/100ml in August. The highest river value recorded was >24,000 CFU/100ml at Heathcote River at Ferniehurst Street in January and 24,000 CFU/100ml at Nottingham Stream at Candys Road in February. The latter was associated with a rain event. No exceedances of guideline levels coincided with wastewater overflow events.

E. coli counts in 2016 were generally similar to those recorded during the 2015 monitoring year, although there were far more outliers this year. In addition, the Heathcote catchment has worsened to varying degrees at all but one site (Cashmere Stream at Sutherlands Road). Of note, *E.coli* levels were noticeably higher at Avon River at Manchester Street, Heathcote River at Rose Street, Heathcote River at Bowenvale Avenue and Nottingham Stream. Sites that complied in 2015 but did not in 2016 included Wairarapa Stream, Avon River at Pages/Seaview Road, Heathcote River at Templetons Road (only one sample in 2016), Heathcote River at Opawa Road/Clarendon Terrace and Linwood Canal. Sites that did comply in 2016, but not 2015 included Waimairi Stream, Riccarton Main Drain, Cashmere Stream at Worsleys Road, Styx River at Gardiners Road and Wilsons Stream.

Of the 19 outliers recorded in the Heathcote catchment, 18 exceeded the guideline level of 550 CFU/100ml. Of these 19 outliers, 16 were recorded in association with rain. In contrast, the Avon catchment recorded only five outliers above the guideline in association with rain, despite having rainfall recorded during five sampling rounds compared to the Heathcote's three.

Both the Halswell Retention Basin sites recorded similar values to the Styx catchment, with both sites recording their 95%ile below the guideline and having outliers that exceeded it. While the outlet concentrations were similar to 2015, the basin inlet has improved remarkably. This year there was one record above the guideline (6,500 CFU/100ml in February 2016) whereas in 2015 the median was above the guideline and there was a maximum value of 24,000 CFU/100ml in January.

Where there were exceedances of the *E. coli* guideline in previous years but not in 2016 (Appendix D, Figure xvi (c)), the percentage of samples exceeding the guideline in previous years did not exceed 20%, with the exception of Avon River at Dallington Terrace/Gayhurst Road (36%). The percentage of guideline exceedances was lower in 2016 at 28 sites. At 14 sites the percentage was higher in 2016 than in previous years, with some notable increases being Addington Brook, Horseshoe Lake Discharge, Heathcote at Rose Street, Kā Pūtahi at Belfast Road, Knights Stream at Sabys Road and Halswell River at Akaroa Highway. Sites in the Avon (Dudley Creek and Horseshoe Lake Discharge), Heathcote (Heathcote River at Rose Street, Ferniehurst Street, Bowenvale Avenue and Tunnel Road), Styx (Kā Pūtahi Creek and Styx River at Marshland Road Bridge) and Halswell (Knights Stream and Nottingham Stream) catchments recorded 40% or more of samples exceeding guidelines in both time categories.

Table 4. Waterway sites across all catchments with high ('Best Sites') and low ('Worst Sites') water quality for each parameter during monitoring from January to December 2016.

Contaminant	Best Sites	Worst Sites
Dissolved copper	There were many sites across all catchments that only recorded levels below the LOD	Haytons Stream at Retention Basin Curletts Road Stream at Motorway Curletts Road Stream Upstream of Heathcote River Heathcote River at Rose Street Heathcote River at Ferniehurst Street (Interquartile range)
Dissolved lead	There were many sites across all catchments that only recorded levels below the LOD	None
Dissolved zinc	Horseshoe Lake Discharge Smacks Creek at Gardiners Road Styx River at Main North Road Styx River at Richards Bridge Ōtūkaikino Creek at Omaka Scout Camp Wilsons Stream Knights Stream at Sabys Road Halswell River at Akaroa Highway (all values below Ōtūkaikino River guideline of 0.00868 mg/L)	Addington Brook Haytons Stream at Retention Basin Curletts Road Stream at Motorway Curletts Road Stream Upstream of Heathcote River Heathcote River at Rose Street Nottingham Stream at Candys Road (95%ile above Heathcote River guideline of 0.04526 mg/L)
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	Waimairi Stream Avon River at Dallington Terrace/Gayhurst Road Cashmere Stream at Sutherlands Road Smacks Creek 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 Horseshoe Lake Discharge Avon River at Bridge Street Haytons Stream at Retention Basin Heathcote River at Tunnel Road Heathcote River at Ferrymead Bridge Linwood Canal (95%ile above TSS guideline of 25 mg/L or 75%ile above turbidity guideline of 5.6 NTU)
Dissolved oxygen	Avon River at Carlton Mill Corner Riccarton Main Drain Avon River at Manchester Street Avon River at Bridge Street Ōtūkaikino River at Groynes Inlet Wilsons Stream Knights Stream at Sabys Road Halswell River at Akaroa Highway (all values greater than Ōtūkaikino River guideline of 80%)	Curletts Road Stream at Motorway Curletts Road Stream Upstream of Heathcote River Cashmere Stream at Sutherlands Road Styx River at Gardiners Road Smacks Creek at Gardiners Road Linwood Canal (Median below the LWRP guideline for 'spring-fed – plains' and 'spring-fed – plains – urban' of 70%)
Water temperature	None	Avon River at Pages/Seaview Bridge Avon River at Bridge Street Haytons Stream at Retention Basin Linwood Canal (95%ile above the LWRP guideline of 20 °C)
Biochemical Oxygen Demand	Wairarapa Stream Waimairi Stream Avon River at Mona Vale Avon River at Carlton Mill Corner Riccarton Main Drain Avon River at Manchester Street Avon River at Avondale Road Bridge Avon River at Pages/Seaview Bridge Cashmere Stream at Sutherlands Road Styx River at Gardiners Road Styx River at Main North Road Styx River at Marshland Road Bridge Styx River at Richards Bridge Ōtūkaikino River at Groynes Inlet Knights Stream at Sabys Road Halswell River at Akaroa Highway (all values below the LOD)	Heathcote River at Templetons Road[14] Haytons Stream at Retention Basin Curletts Road Stream at Motorway Heathcote River at Rose Street (95%ile above the MfE and WRRP guideline of 2 mg/L)
Total ammonia	Wairarapa Stream Waimairi Stream Avon River at Carlton Mill Corner Styx River at Gardiners Road Smacks Creek at Gardiners Road Ōtūkaikino Creek at Omaka Scout Camp Wilsons Stream (all values below 0.03 mg/L)	Haytons Stream at Retention Basin (Median above the LWRP guideline for Banks Peninsula waterways of 0.32 mg/L)
Nitrate-N Nitrate Nitrite Nitrogen Dissolved Inorganic Nitrogen	Dudley Creek Styx River at Main North Road 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 (95%ile for nitrate-N above 4 mg/L)
Dissolved Reactive Phosphorus	Wairarapa Stream Waimairi Stream Avon River at Mona Vale Avon River at Carlton Mill Corner Cashmere Stream at Sutherlands Road Styx River at Gardiners Road Smacks Creek at Gardiners Road Ōtūkaikino Creek at Groynes Inlet Ōtūkaikino Creek at Omaka Scout Camp Knights Stream at Sabys Road (all values below predominant guideline of 0.016 mg/L)	Many sites, particularly: Haytons Stream at Retention Basin (95%ile above 0.2 mg/L)
Escherichia coli	Avon River at Avondale Road Bridge Cashmere Stream at Sutherlands Road Styx River at Gardiners Road Styx River at Harbour Road Bridge Ōtūkaikino River at Groynes Inlet Ōtūkaikino Creek at Omaka Scout Camp Wilsons Stream (all values below guideline of 550 CFU/100ml)	Many sites, particularly: Addington Brook Dudley Creek Horseshoe Lake Discharge Heathcote River at Rose Street Heathcote River at Ferniehurst Street Kā Pūtahi Creek at Belfast Road Styx River at Marshland Road Bridge Knights Stream at Sabys Road Nottingham Stream at Candys Road (Median above the LWRP guideline for 'spring-fed – plains', 'spring-fed – plains – urban' and Banks Peninsula waterways of 550 CFU/100ml)

Notes: Best Sites had much lower levels than other sites, except for DO, where higher saturation is generally better. Worst Sites had much higher levels than other sites, except for DO, where lower saturation is generally worse. Criteria for Best and Worst Sites are shown in brackets. All three nitrogen parameters (nitrate, NNN and DIN) 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.

[14] The Heathcote River at Templetons Road site was only monitored for one month due to the site being dry on other dates, so these results should be viewed with caution (refer to the methods section for more information).

Table 5. Summary of the best and worst catchments and sites for 2016, based on how often a catchment or site occurred in Table 4.

Placing	Best Sites		Worst Sites	
	Catchment Scale	Site Scale	Catchment Scale	Site Scale
	Ōtūkaikino River (67%, 24 occurrences)	Ōtūkaikino River at Groynes Inlet Ōtūkaikino Creek at Omaka Scout Camp (7 occurrences)	Heathcote River (17%, 24 occurrences)	Haytons Stream at Retention Basin (7 occurrences)
	Halswell River (26%, 7 occurrences)	Waimairi Stream Avon River at Carlton Mill Corner Cashmere Stream at Sutherlands Road Styx River at Gardiners Road Smacks Creek at Gardiners Road Styx River at Main North Road Wilsons Stream Knights Stream at Sabys Road (4 occurrences)	Halswell River (16%, 5 occurrences)	Curletts Road Stream at Motorway Heathcote River at Rose Street (4 occurrences)
	Styx River (22%, 16 occurrences)	Wairarapa Stream Halswell River at Akaroa Highway (3 occurrences)	Avon River (7%, 9 occurrences)	Curletts Road Stream Upstream of Heathcote River Linwood Canal (3 occurrences)

Notes: 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. To take into account the different number of monitoring sites for each catchment, the catchment scale ranking was calculated as the number of occurrences divided by the total number contaminant-site combinations possible in Table 4. For example, the Avon River had 24 "Best Site" occurrences in Table 4; this was then divided by 13 sites multiplied by 9 contaminants with "Best Site" rankings (i.e., 117 site-contaminant combinations), giving a total of 21% "Best Sites" at the catchment scale.

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 2016. Contaminants of concern are in parentheses.

Catchment	Sites
Avon River	Addington Brook (copper, zinc, *E.coli*) Dudley Creek (turbidity, BOD_5, *E.coli*) Riccarton Main Drain (TSS/turbidity, NNN/DIN) Avon River at Mona Vale (DIN) Horseshoe Lake Discharge (TSS/turbidity) Avon River at Bridge Street (turbidity)
Heathcote River	Haytons Stream at Retention Basin (zinc, turbidity, BOD_5, ammonia, DRP) Curletts Road Stream Upstream of Heathcote River (zinc, DO, BOD_5, DRP) Heathcote River at Rose Street (lead, zinc, DIN, DRP) Heathcote River at Templetons Road (BOD_5, ammonia, DIN) Cashmere Stream at Worsleys Road (zinc, DO, DIN) Curletts Road Stream at Motorway (copper, zinc) Cashmere Stream at Sutherlands Road (DO, DIN) Heathcote River at Ferniehurst Street (DIN, *E.coli*) Heathcote River at Bowenvale Avenue (TSS, DIN) Heathcote River at Ferrymead Bridge (TSS/turbidity) Heathcote River at Opawa Road/Clarendon Terrace (DIN) Heathcote River at Mackenzie Avenue (DIN) Heathcote River at Tunnel Road (turbidity)
Styx River	Kā Pūtahi Creek at Blakes Road (copper, zinc, BOD_5, NNN/DIN) Kā Pūtahi Creek at Belfast Road (BOD_5, NNN/DIN, DRP, *E.coli*) Smacks Creek at Gardiners Road (DO, BOD_5, NNN) Styx River at Marshland Road Bridge (NNN, DRP) Styx River at Richards Bridge (NNN, DRP) Styx River at Gardiners Road (DO) Styx River at Harbour Road Bridge (DRP)
Ōtūkaikino River	Wilsons Stream (pH, nitrate/NNN/DIN)
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/DIN)
Linwood Canal	Linwood Canal (copper, DO, temperature, ammonia, DRP)

Notes: 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. The Templetons Road site was only monitored in February, so these results should be viewed with caution (refer to the methods section for more information).

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 2016.

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	42	493	10 (2.0%) *Ranked 11th*	1 (Curletts Road Stream at Motorway)
Dissolved lead	Varies depending on catchment, from <0.00384 mg/L to <0.167 mg/L	42	493	0 (0%)	0
Dissolved zinc	Varies depending on catchment, from <0.00868 mg/L to <0.146 mg/L	42	493	42 (8.5%) *Ranked 7th*	7
pH	6.5 to 8.5	42	493	2 (0.4%) *Ranked 14th*	0
Total Suspended Solids	<25 mg/L	42	493	24 (4.9%) *Ranked 8th*	1 (Heathcote River at Ferrymead Bridge)
Turbidity	<5.6 NTU	37	433	89 (20.6%) *Ranked 6th*	5
Dissolved oxygen	Varies depending on catchment, from >70% to >90%	42	493	112 (22.7%) *Ranked 5th*	8
Water temperature	Varies depending on catchment, from <20°C to <25°C	42	493	5 (1.0%) *Ranked 12th*	0
Biochemical Oxygen Demand	<2 mg/L	42	493	21 (4.3%) *Ranked 9th*	2 (Heathcote River at Templetons Road, Haytons Stream at Retentions Basin)
Total ammonia	Varies depending on catchment, from <0.32 mg/L to <1.75 mg/L	42	493	3 (0.6%) *Ranked 13th*	1 (Haytons Stream at Retentions Basin)
Nitrate	<3.8 mg/L	42	493	16 (3.2%) *Ranked 10th*	1 (Knights Stream at Sabys Road)
Nitrate Nitrite Nitrogen	<0.444 mg/L	42	493	358 (72.6%) *Ranked 1st*	34
Dissolved Inorganic Nitrogen	Varies depending on catchment, from <0.09 mg/L to <1.5 mg/L	42	493	158 (32.0%) *Ranked 3rd*	13
Dissolved Reactive Phosphorus	Varies depending on catchment, from <0.016 mg/L to <0.025 mg/L	42	493	292 (59.2%) *Ranked 2nd*	23
Escherichia coli	<550/100ml	42	493	156 (31.6%) *Ranked 4th*	30
Total	-	42	7,335	1,288 (17.6%)	40 (95.2%) (for at least one parameter)

Notes: The Heathcote River at Templetons Road site was only monitored once. Each parameter is ranked based on the highest percentage of samples not meeting guideline levels (except lead, which recorded no exceedances).

3.3 Monthly Monitoring: Temporal Trends

For the monitoring sites and parameters with sufficient data to undertake time trends analysis, 52% (281 parameter-site combinations) had no significant upwards or downwards trend, 20% (110 instances) had a significant upward trend, and 28% (149 instances) had a significant downward trend (Tables 8a to 8d). Note that these figures do not include sites where data was unable to be analysed due to having too many records below the LOD (N/A in Tables 8a- d). This pattern is similar to that recorded in 2015 (no trend = 300 incidences, upward trend = 99 incidences and downtrend trend = 110 incidences; Margetts & Marshall, 2016), although the number of sites with decreasing trends has increased noticeably. Note that the number of parameters with no trend differs from what was reported in Margetts & Marshall (2016), as a number of records were inadvertently recorded as having no trend, when in fact there were too many data points below the LOD to determine trends. Most downward trends indicated an improvement in water quality, with the exception of dissolved oxygen, where higher values represent better water quality. Changes in conductivity can also be tidally related at some sites, rather than water quality related. Upwards and downward trends for pH can indicate either a decrease or increase in water quality, as there are upper and lower guideline limits. However, all changes in pH levels during this assessment were small (no greater than 1%). Parameter-site combinations of particular note are examined below.

The majority of sites in the Avon and Heathcote River catchments recorded a decrease in DRP concentrations since monitoring began and turbidity within the Styx River decreased across most sites. These trends are consistent with that recorded during the 2015 monitoring year (Margetts & Marshall, 2016). Turbidity within the Avon and Heathcote catchments decreased at 50% or more of their respective monitoring sites, this is an increase in the number of sites compared to 2015. Temperature increased across all Avon River catchment sites, most of the Styx River catchment and nearly half of the Heathcote River catchment sites, although only by 1-2% (i.e., less than 0.5 °C). This is a new trend for the Heathcote catchment, and an increase in the number of Styx sites. NNN and DIN decreased at over half of the Avon and Styx River catchment sites. While this trend is consistent with the 2015 results for the Styx catchment, it is a new trend for the Avon River catchment. *E. coli* levels within the Styx and Halswell River catchments showed an increasing trend across most sites. This was a new trend only for Knights Stream. BOD_5 decreased at half (seven) of the Heathcote catchment sites, whereas in 2015 it decreased at four sites.

The largest increase at a given site was a 16% increase in conductivity at the Avon River at Pages/Seaview Bridge site (Figure 2) and Avon River at Bridge Street site (Figure 3). The result for the Avon River at Pages/Seaview Bridge site is consistent with last year's monitoring (16%), but the percentage increase in conductivity has lowered slightly at the Bridge Street site where in 2015 it increased by 24% (Margetts & Marshall, 2016).

Several sites showed large (≥20%) decreases in some parameters over time. The largest decrease was for dissolved zinc at the Curletts Road Stream Upstream of Heathcote River site, which decreased by 46% (Figure 4). Last year a decrease of 57% was recorded and a decrease of 146% the year before (Margetts & Marshall, 2015). However, despite the overall decrease since monitoring began, concentrations have generally increased since 2014. Knights Stream (37%, Figure 5) and Dudley Creek (23%, Figure 6) have also seen decreases in dissolved zinc. At the Knights Stream site, peak concentrations of dissolved zinc have been decreasing since 2014. At Dudley Creek, dissolved zinc has been decreasing since 2015. Despite both these latter two sites having large percentage decreases, neither site was found to have a significant change in 2015 (Margetts & Marshall, 2016). Overall, trends in dissolved zinc concentrations should be treated with caution, because the short period of record (two to six years, depending on the site) means that relatively small variations between years can have a disproportionate influence on trends (i.e., statistically significant trends do not necessarily mean a long term trend is present).

Cashmere Stream at Sutherlands Road recorded a decrease in DRP of 25% over the period of record (Figure 7). A decline both in peak and bottom line concentrations has occurred since mid-2013. Both DRP and turbidity decreased by 21% at the Ōtūkaikino at Groynes Inlet site (Figures 8 and 9, respectively). Both these sites had decreased by 20% in Margetts & Marshall (2016). The decrease in DRP has been more marked, particularly over the 2009-2010 period. The decrease in turbidity has been more subtle, however a decrease in both peaks and baseline concentrations is evident, particularly from 2012 onwards.

Five sites recorded no significant trend last year but this year were found to have a trend of 10 to 19% change per annum. These sites are: Halswell Retention Basin Outlet (total ammonia, 18% decrease), Knights Stream (DRP, 16% decrease; *E. coli*, 15% increase), Smacks Creek (dissolved zinc, 16% decrease), Wairarapa Stream (dissolved zinc, 14% decrease) and Avon River at Avondale Road Bridge (total ammonia, 12% decrease). In 2012, concentrations began to decrease at the Halswell Retention Basin Outlet, Knights Stream, Smacks Creek and Avon River at Avondale Road Bridge sites, while Wairarapa Stream did not begin to decrease until 2015 (Figures 10- 11). *E.coli* has been steadily increasing at Knights Stream since 2013 (Figure 10).

Five sites recorded a significant trend of more than 10% change per annum last year, but no significant trend this year (Figures 12- 14). These sites are: Cashmere Stream at Sutherlands Road (dissolved zinc, 29% increase in 2015; total ammonia, 18% decrease in 2015), Addington Brook (dissolved zinc, 17% decrease in 2015), Knights Stream (NNN and DIN, 15% increase in 2015), Curletts Road Stream Upstream of Heathcote River (total ammonia, 14% decrease in 2015) and Halswell Retention Basin Inlet (*E. coli*, 13% increase in 2015).

The result for dissolved zinc at Cashmere Stream is slightly misleading as the data collected in 2015 was affected by poor laboratory analysis, which resulted in three[15] samples being excluded from the data set. As these values were all below 0.01 mg/L, it appears that a false increase was detected, see Margetts & Marshall (2016) for more detail. NNN and DIN increased steadily at the Knights Stream site from sampling instigation until 2015, where it began to decrease and lose much of its variability. *E.coli* at the Halswell Retention Basin Inlet site increased until 2011 where it remained steady until 2014 and then began to decline from 2015. Concentrations are now comparable to initial levels.

Total ammonia at Cashmere Stream at Sutherlands Road generally decreased since monitoring began, however it appears that a slight increase in non-peak concentrations over the last year or two has nullified the trend. Dissolved zinc at the Addington Brook site steadily decreased from 2011- 2015, however peak concentrations were comparable. The LOWESS trendline for dissolved zinc at Addington Brook indicates that a sharp rise has occurred over the 2016 monitoring period. Total ammonia at Curletts Road Stream Upstream of Heathcote River decreased between 2012 and 2013, however a steady increase since 2014 has negated this trend.

No other sites showed a change of ≥10%, however some sites showed new trends of particular interest. Avon River at Manchester Street showed new decreases of 4- 5% for turbidity, NNN and DIN. While the decreasing trend in turbidity was more subtle, the

[15] This was incorrectly reported as five in Margetts & Marshall (2016)

last two years of NNN and DIN data show a strong downwards trend with comparatively little variation around the trendline. A similar trend in NNN/DIN was seen at the Avon River at Carlton Mill site.

Avon River at Pages/Seaview Bridge showed new decreases of 4- 5% for total ammonia, NNN and DIN. Heathcote River at Rose Street had a new 3- 6 % reduction in turbidity, NNN and DIN. Unlike the Avon River at Manchester Street site, there was much variation about the trendline for nitrogen at both these sites over the last two monitoring rounds. Cashmere Stream at Sutherlands Road recorded a new increase of 15% for *E. coli*, however this appears to be a gradual increase since monitoring began rather than significant degradation over 2016. The new reduction of 3- 8% for TSS, total ammonia and DIN seen at the Heathcote River at Catherine Street site was subtle in the graphs, however there was a noticeable reduction in TSS peaks.

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).

Site	Dissolved copper	Dissolved Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Total Ammonia	NNN	DIN	*E. coli*
Wairarapa Stream	N/A	â 14%	â 10%	á 0%			â 4%	á 1%	á 1%	N/A				
Waimairi Stream	N/A		â 6%	á 0%		N/A	â 6%		á 1%	N/A		â 1%	â 2%	
Avon River at Mona Vale	N/A		â 6%	á 0%		N/A	â 7%		á 1%	N/A				á 4%
Avon River at Carlton Mill Corner	N/A	N/A	â 12%	á 1%			Not Sampled		á 1%	N/A		â 4%	â 4%	
Riccarton Main Drain	N/A		â 10%	á 0%	á 4%	N/A			á 1%	N/A		á 9%	á 9%	
Addington Brook	N/A			á 1%	â 2%				á 1%	â 12%				
Avon River at Manchester Street	N/A		â 10%	á 1%			â 5%		á 1%	N/A		â 4%	â 4%	
Dudley Creek	N/A	â 23%		á 1%	â 4%	á 11%	á 7%		á 2%	â 12%		â 11%	â 8%	
Avon River at Dallington Terrace/Gayhurst Road	N/A			á 1%		â 6%	â 10%	á 1%	á 1%	N/A				
Horseshoe Lake Discharge	N/A			á 1%			â 5%		á 1%	â 9%		â 5%	â 5%	á 11%
Avon River at Avondale Road	N/A	N/A	â 5%	á 1%	á 5%		Not Sampled		á 1%	N/A	â 12%	â 6%	â 6%	
Avon River at Pages/Seaview Bridge	N/A	â 15%	â 3%	á 1%	á 16%		â 6%	á 2%	á 1%		â 5%	â 4%	â 4%	á 6%
Avon River at Bridge Street	N/A		â 6%	á 1%	á 16%			á 2%	á 1%		â 7%	â 4%	â 4%	á 11%

Notes: 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. Trends for dissolved metals for Avon River at Carlton Mill Corner and Avon River at Avondale Road should be treated with caution as trends analysis was only able to be undertaken on the September - December data, as these were the only months with the required three years of sampling for statistical analysis. N/A = unable to be analysed, due to many levels being below the laboratory limit of detection.

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).

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 10%							â 6%		â 11%	â 11%	
Curletts Road Stream at Motorway			â 9%	á 1%	á 2%		Not Sampled			â 4%		â 13%	â 13%	
Curletts Road Stream Upstream of Heathcote River		â 46%		á 1%		â 11%	â 17%			â 8%				
Heathcote River at Rose Street	N/A		â 9%	á 1%			â 6%		á 1%	â 8%		â 3%	â 3%	
Cashmere Stream at Sutherlands Road	N/A		â 25%	á 1%	á 1%	N/A				N/A		â 7%	â 7%	á 9%
Cashmere Stream at Worsleys Road	N/A		â 8%	á 1%	â 1%	â 4%	â 8%							
Heathcote River at Ferniehurst Street	N/A		â 9%	á 1%					á 1%			â 1%	â 2%	
Heathcote River at Bowenvale Ave	N/A		â 8%	á 1%			â 6%							
Heathcote River at Opawa Road/Clarendon Terrace	N/A		â 8%	á 0%		â 10%	â 12%				â 3%			
Heathcote River at Mackenzie Avenue	N/A		â 12%	á 1%		â 10%	Not Sampled		á 1%			â 2%	â 2%	
Heathcote River at Catherine Street	N/A		â 10%	á 1%		â 6%	Not Sampled		á 1%	â 9%	â 8%		â 3%	
Heathcote River at Tunnel Road	N/A		â 10%	á 1%		â 4%	â 8%		á 1%	â 5%	â 10%			
Heathcote River at Ferrymead Bridge	N/A		â 16%	á 0%			â 4%	á 1%	á 1%	â 6%	â 14%			

Notes: 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. Trends for dissolved metals for Curletts Road Stream at Motorway, Heathcote River at Mackenzie Avenue and Heathcote River at Catherine Street should be treated with caution as trends analysis was only able to be undertaken on the October- December data, as these were the only months with the required three years of sampling for statistical analysis. 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 2015, November 2015 – January 2016 and March – December 2016, as the site was dry. N/A = unable to be analysed, due to many levels being below the laboratory limit of detection.

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).

Site	Dissolved copper	Dissolved Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Total Ammonia.	NNN	DIN	*E. coli*
Halswell Retention Basin Inlet		N/A				â 6%	Not Sampled			â 14%		á 12%		
Halswell Retention Basin Outlet		N/A				â 14%	Not Sampled			â 16%	â 18%	á 11%		
Knights Stream at Sabys Road	N/A	â 37%	â 16%							N/A				á 15%
Nottingham Stream at Candy's Road	N/A			á 0%	â 5%							â 15%	â 14%	
Halswell River at Akaroa Highway	N/A		â 6%	á 1%	â 1%			á 1%	á 1%	N/A				á 15%
Linwood Canal	N/A			á 1%	á 13%	á 4%			á 2%	â 10%		â 17%	â 7%	

Notes: 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. Trends for both Halswell Retention Basin sites should be treated with caution as trends analysis was only able to be undertaken on the October- December data, as these were the only months with the required three years of sampling for statistical analysis. N/A = unable to be analysed, due to many levels being below the laboratory limit of detection.

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).

Site	Dissolved copper	Dissolved Zinc	DRP	pH	EC	TSS	Turbidity	DO	Temp	BOD_5	Total Ammonia	NNN	DIN	*E. coli*
Styx River at Gardiners Road	N/A		â 5%	á 0%	â 2%	N/A	â 5%		á 1%	N/A		â 7%	â 8%	á 14%
Smacks Creek at Gardiners Road	N/A	â 16%	â 6%	á 1%	â 3%	N/A	â 10%		á 1%	N/A		â 5%	â 5%	
Styx River at Main North Road	N/A		â 4%	á 0%	â 1%	â 6%	â 10%	â 1%	á 1%	N/A		â 7%	â 7%	á 6%
Kā Pūtahi Creek at Blakes Road	N/A			á 0%	á 1%		á 4%					á 4%	á 3%	
Kā Pūtahi Creek at Belfast Road	N/A			á 1%	â 1%		â 5%	á 1%	á 1%			á 3%	á 3%	á 6%
Styx River at Marshland Road Bridge	N/A			á 1%	â 1%	â 4%	â 5%	á 1%	á 1%					á 5%
Styx River at Richards Bridge	N/A		â 3%	á 1%	â 1%				á 1%	N/A		â 3%	â 3%	á 11%
Styx River at Harbour Road Bridge	N/A			á 1%	â 3%		â 6%		á 2%	N/A		â 4%	â 4%	
Ōtūkaikino River at Groynes Inlet	N/A		â 21%		â 1%	N/A	â 21%	â 1%	á 1%	N/A		â 10%	â 11%	â 7%
Ōtūkaikino River at Omaka Scout Camp	N/A					N/A				N/A				
Wilson's Stream	N/A	N/A						á 5%		N/A		á 6%	á 5%	

Notes: EC = Electrical Conductivity, TSS = Total Suspended Solids, DO = Dissolved Oxygen, Temp = Temperature; BOD5 = 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. Trends for Ōtūkaikino Creek at Omaka Scout Camp Stream should be treated with caution as trends analysis was only able to be undertaken on the October- December data, as these were the only months with the required three years of sampling for statistical analysis. N/A = unable to be analysed, due to many levels being below the laboratory limit of detection.

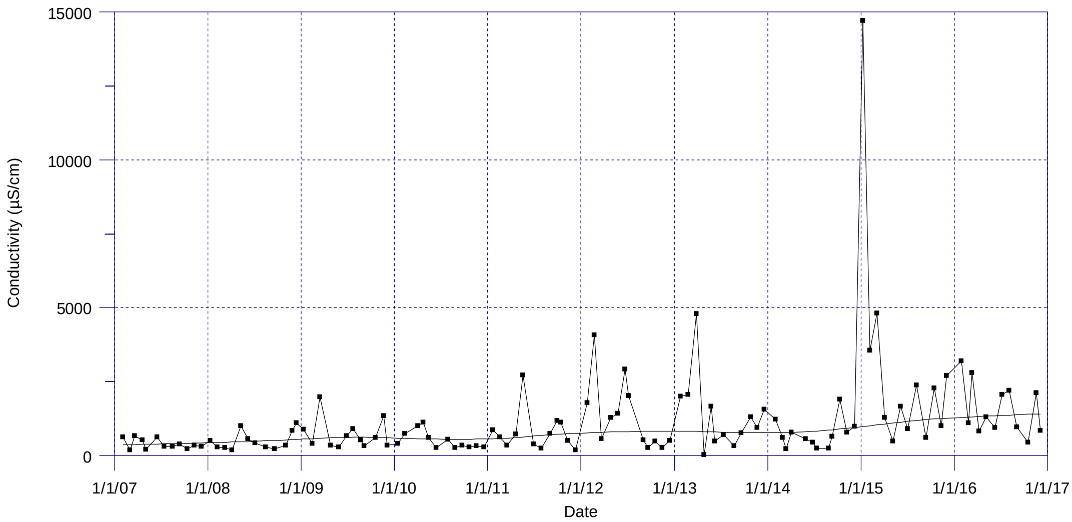


Figure 2. Conductivity levels at the Avon River at Pages/Seaview Bridge site for the monitoring period January 2007 to December 2016. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A positive (i.e. increasing) trend of 16% was recorded over the sampling period.

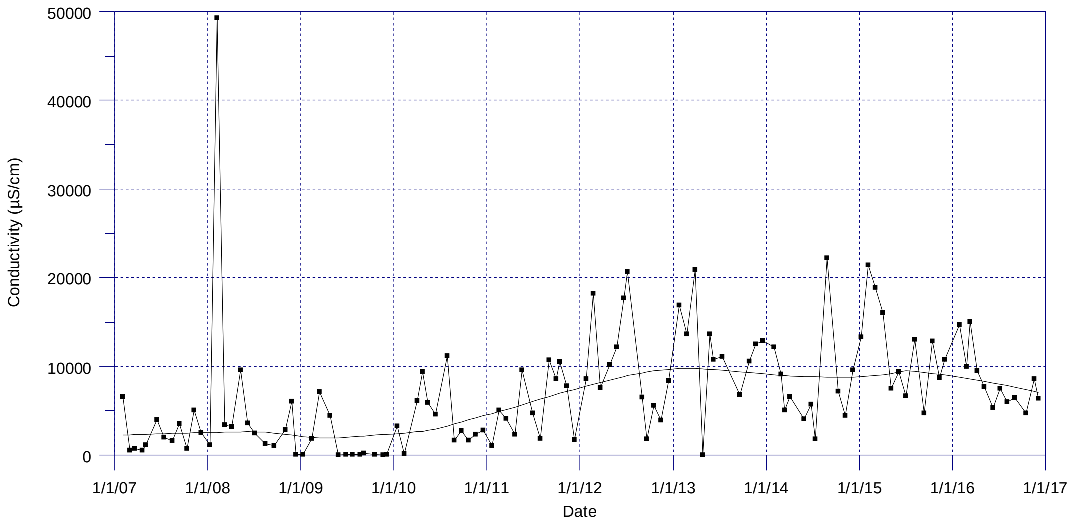


Figure 3. Conductivity levels at the Avon River at Bridge Street site for the monitoring period January 2007 to December 2016. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A positive (i.e. increasing) trend of 16% was recorded over the sampling period.

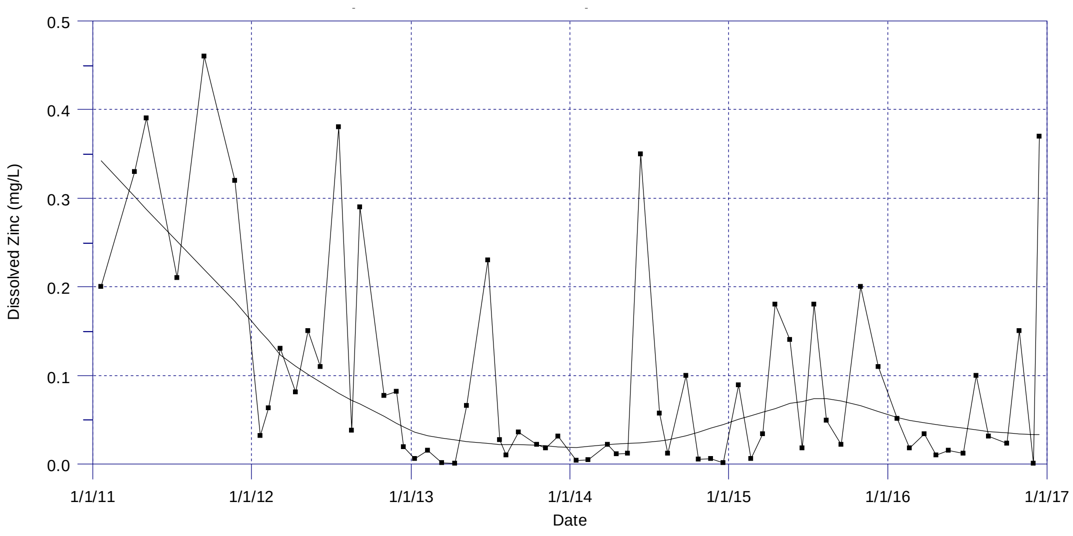


Figure 4. Dissolved zinc levels at the Curletts Road Stream Upstream of Heathcote River site for the monitoring period January 2011 to December 2016. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A negative (i.e. decreasing) trend of 46% was recorded over the sampling period.

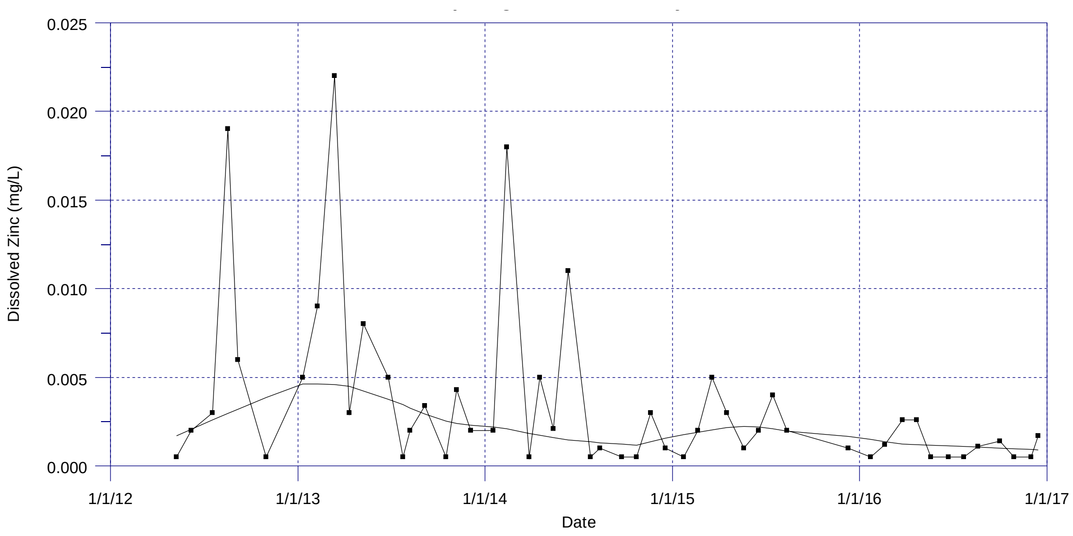


Figure 5. Dissolved zinc levels at the Knights Stream at Sabys Road site for the monitoring period May 2012 to December 2016. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A negative (i.e. decreasing) trend of 37% was recorded over the sampling period.

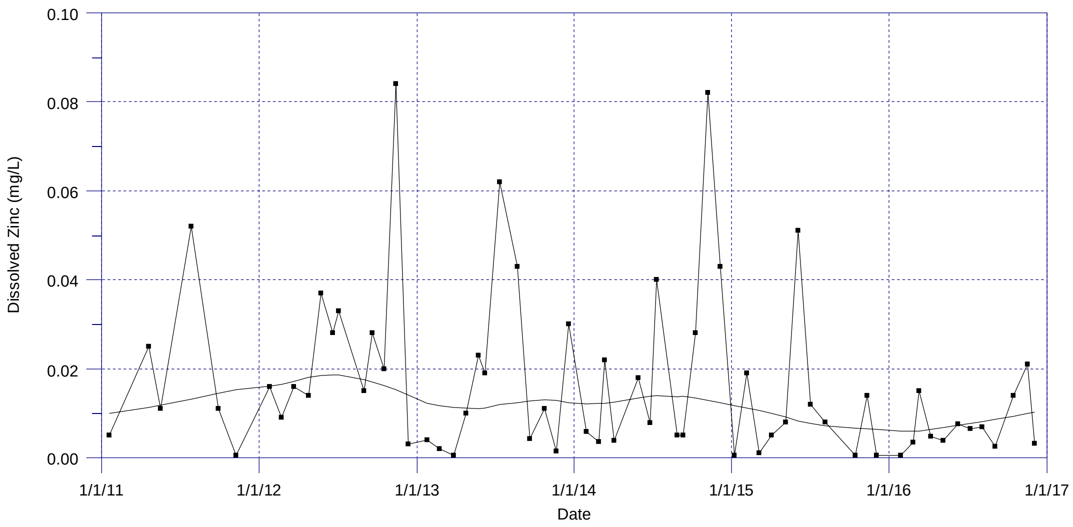


Figure 6. Dissolved zinc levels at the Dudley Creek site for the monitoring period January 2011 to December 2016. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A negative (i.e. decreasing) trend of 23% was recorded over the sampling period.

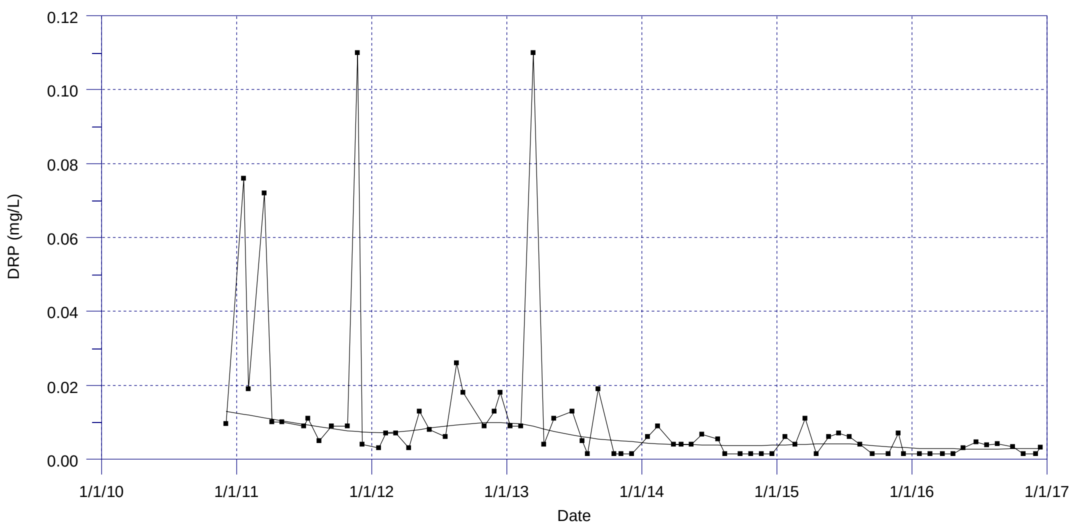


Figure 7. Dissolved Reactive Phosphorous (DRP) levels at the Cashmere Stream at Sutherlands Road site for the monitoring period December 2010 to December 2016. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A negative (i.e. decreasing) trend of 25% was recorded over the sampling period.

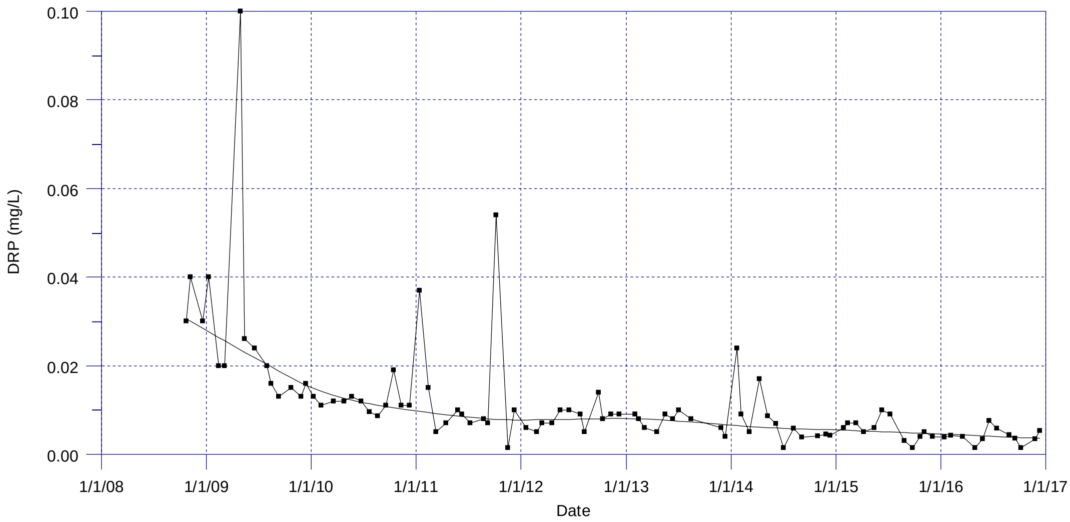


Figure 8. DRP levels at the Ōtūkaikino River at Groynes Inlet site for the monitoring period February 2009 to December 2016. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A negative (i.e. decreasing) trend of 21% was recorded over the sampling period.

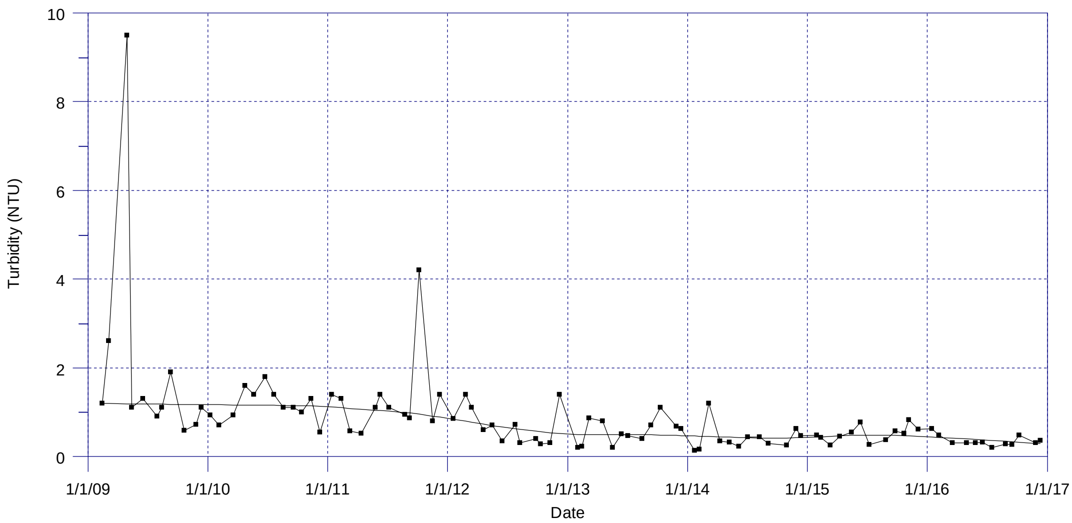
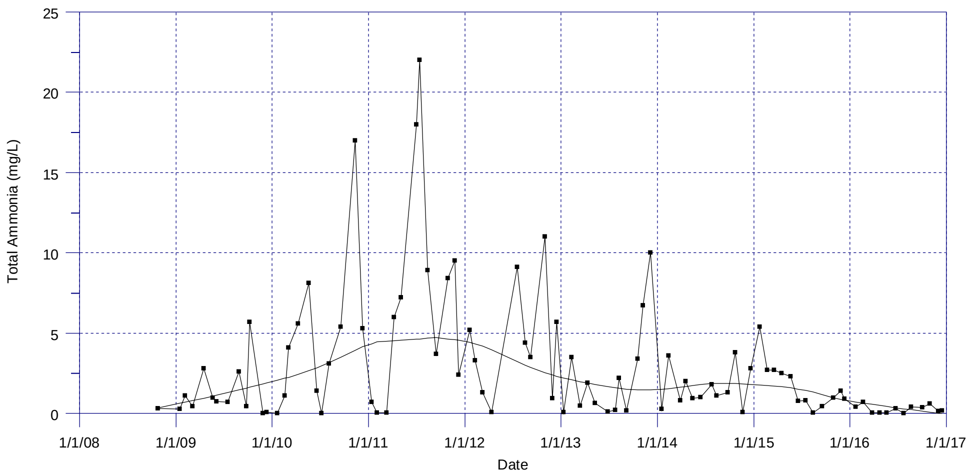
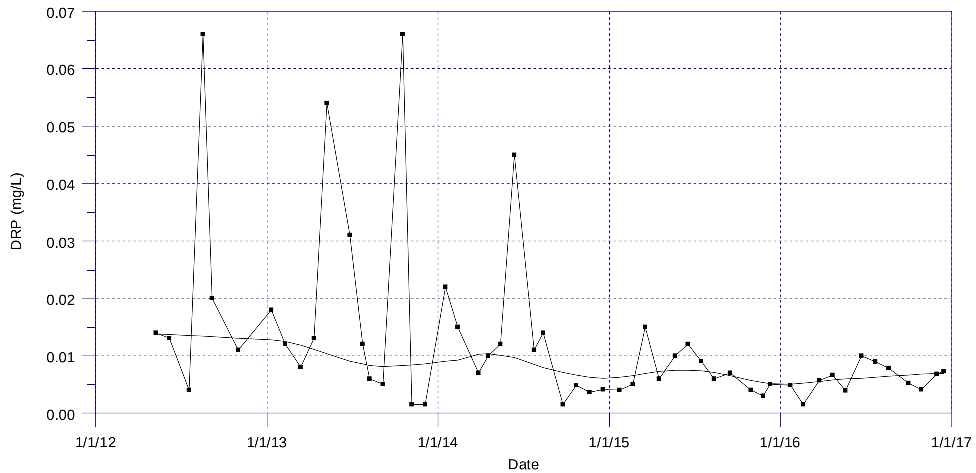


Figure 9. Turbidity levels at the Ōtūkaikino River at Groynes Inlet site for the monitoring period February 2009 to December 2016. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software. A negative (i.e. decreasing) trend of 21% was recorded over the sampling period.





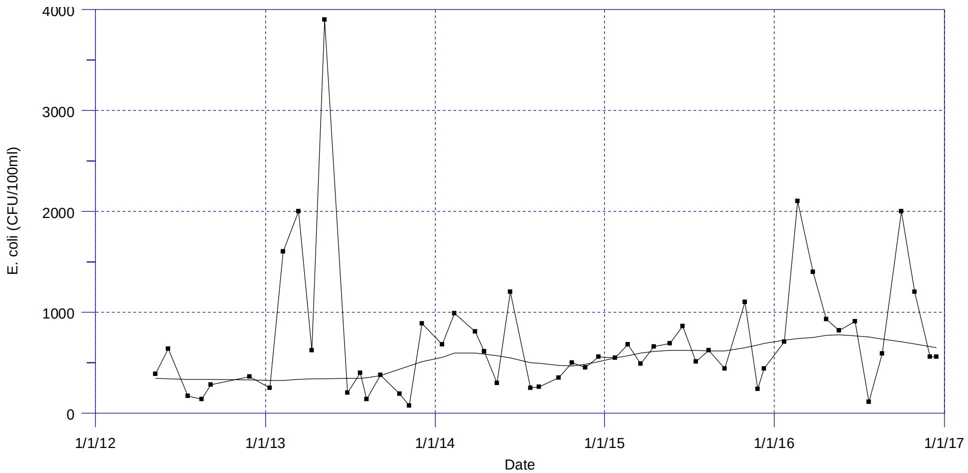
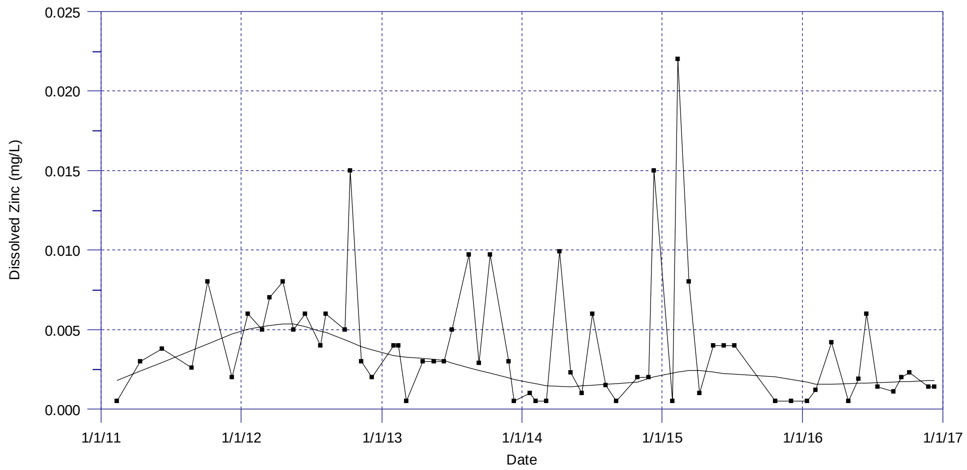
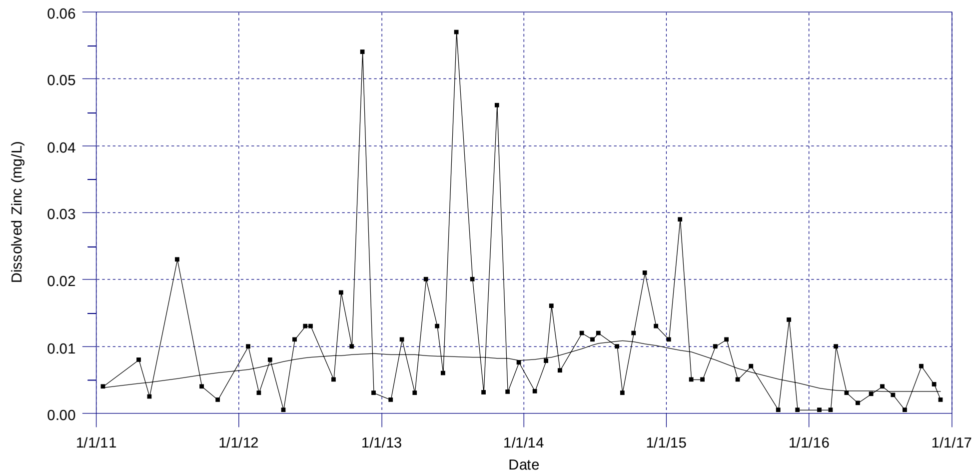


Figure 10. Above left: total ammonia at the Halswell Retention Basin Outlet site for the monitoring period October 2008 to December 2016 (negative (i.e. decreasing) trend: 18%). Above: DRP at the Knights Stream site for the monitoring period May 2012 to December 2016 (negative ((i.e. decreasing) trend: 16%). Left: *E. coli* at the Knights Stream site for the monitoring period May 2012 to December 2016 (positive (i.e. increasing) trend: 16%). Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software.





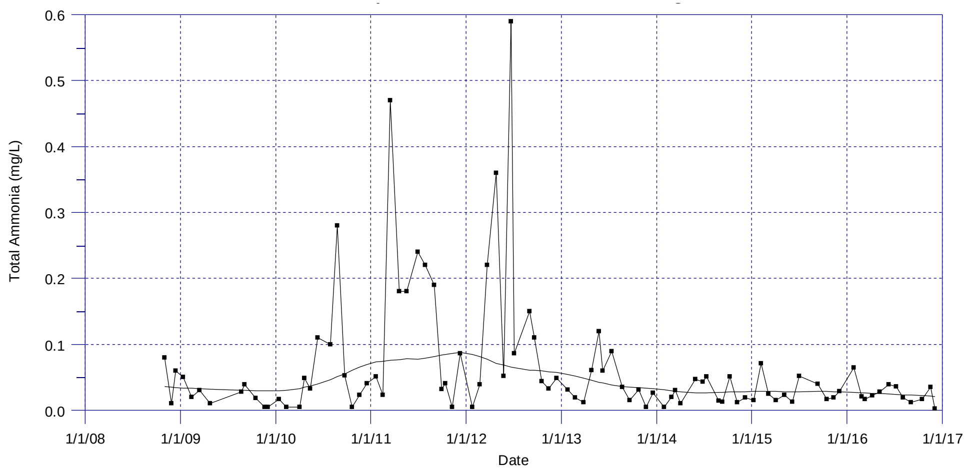
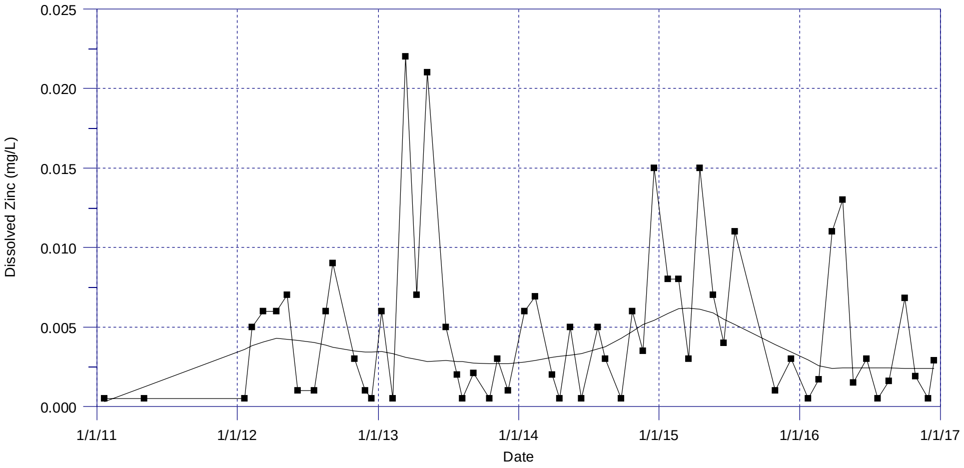


Figure 11. Above left: dissolved zinc at the Smacks Creek site for the monitoring period October 2008 to December 2016 (negative (i.e. decreasing) trend: 16%). Above: dissolved zinc at the Wairarapa Stream site for the monitoring period 2011 to December 2016 (negative (i.e. decreasing) trend: 14%). Left: total ammonia at the Avon River at Avondale Road Bridge site for the monitoring period October 2008 to December 2016 (negative (i.e. decreasing) trend: 12%). Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software.



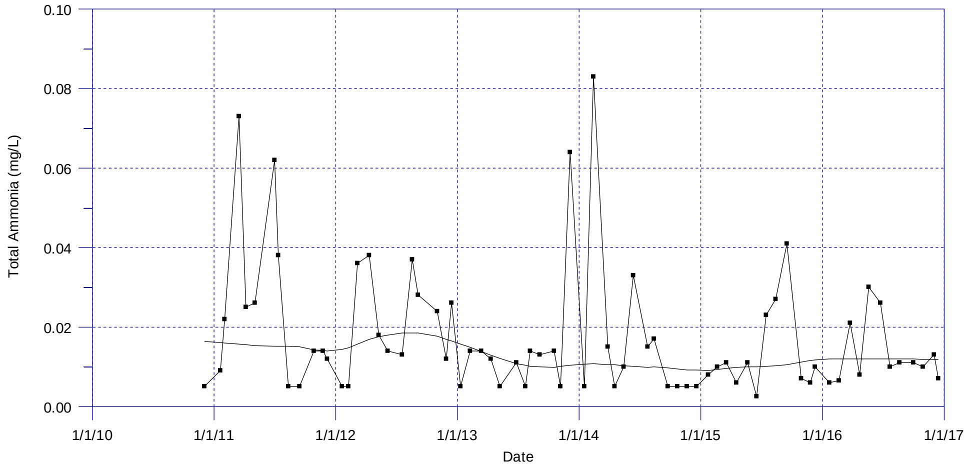
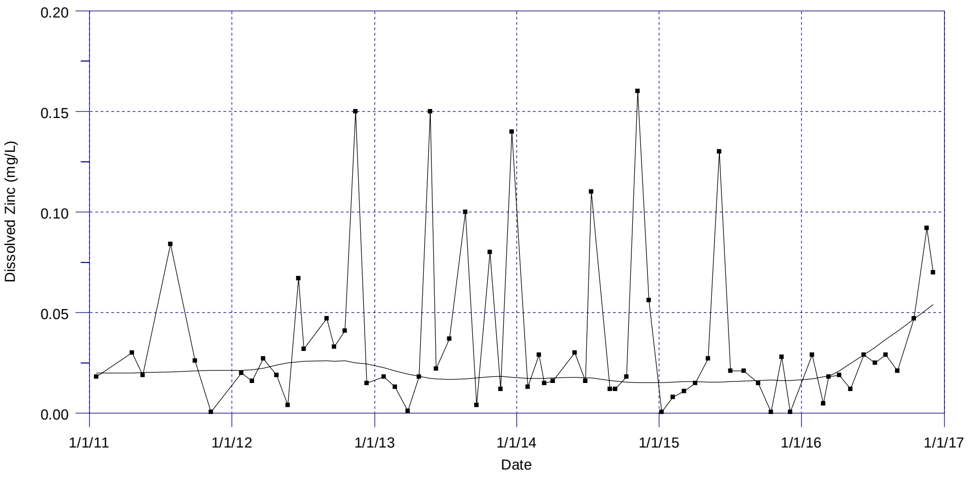
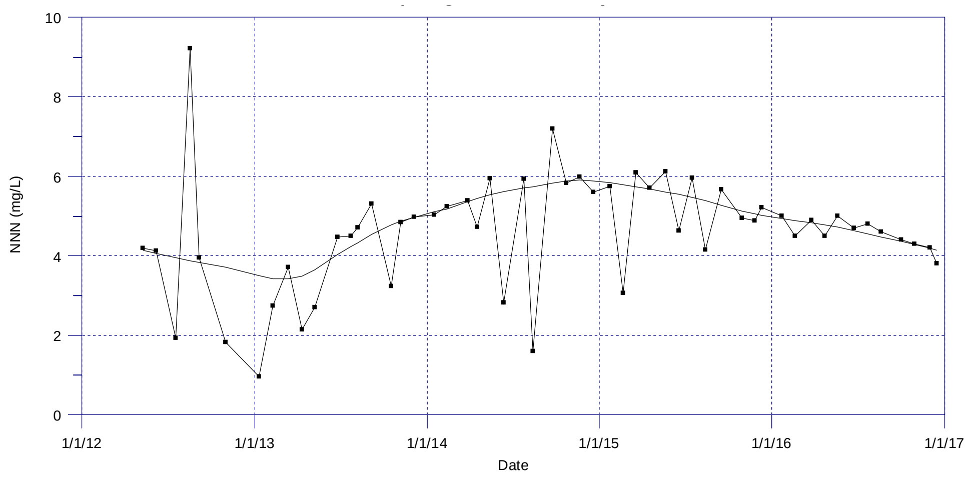


Figure 12. Cashmere Stream at Sutherlands Road. Above left: dissolved zinc for the monitoring period October 2008 to December 2016, no significant trend. Above right: total ammonia for the monitoring period December 2010 to December 2016, no significant trend. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software.





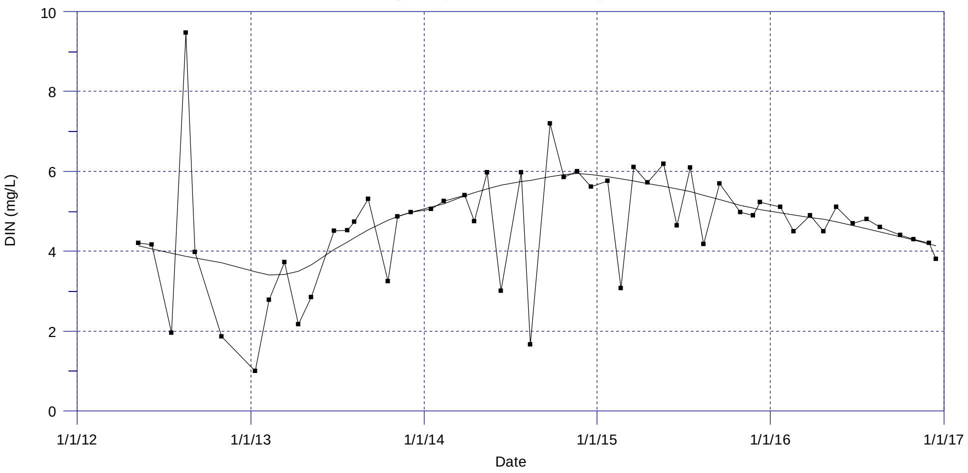
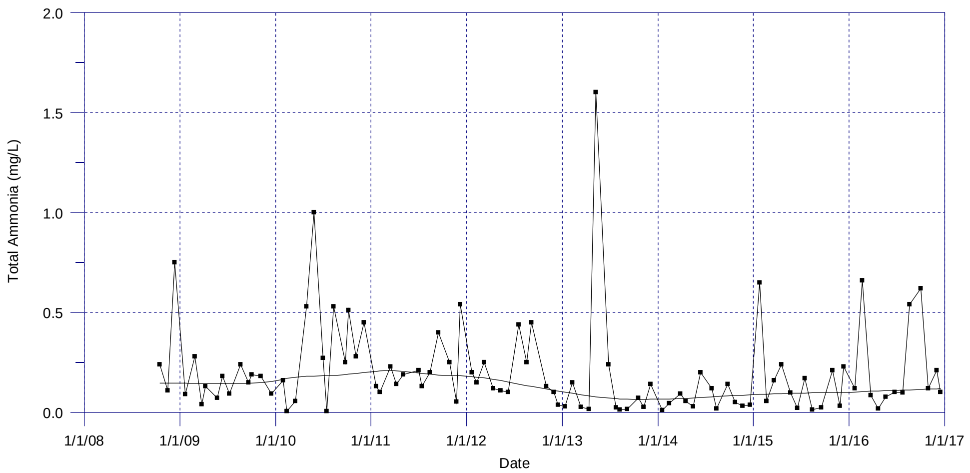


Figure 13. Above left: dissolved zinc at the Addington Brook site for the monitoring period 2011 to December 2016 (no significant trend). NNN (above) and DIN (left) at the Knights Stream site for the monitoring period May 2012 to December 2016 (no significant trend). Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software.



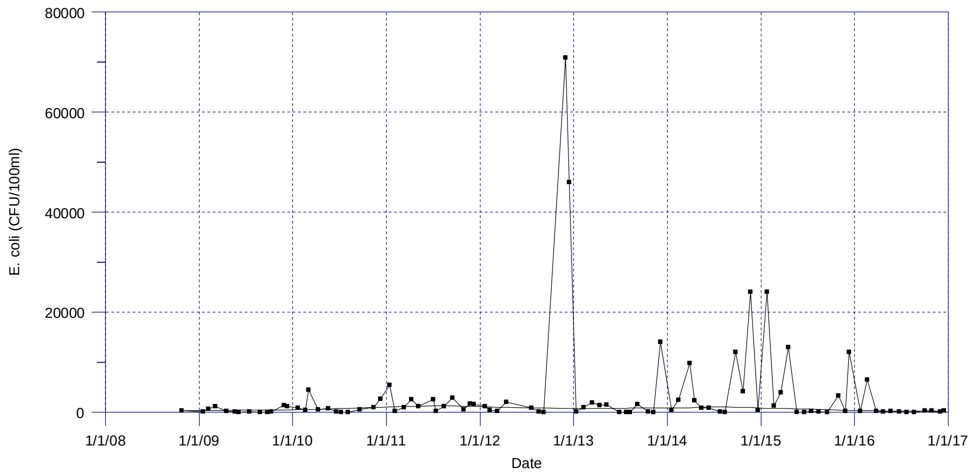


Figure 14. Above left: total ammonia at the Curletts Road Stream Upstream of Heathcote River for the monitoring period October 2008 to December 2016, no significant trend. Above right: *E. coli* at the Halswell Retention Basin Inlet site for the monitoring period October 2008 to December 2016, no significant trend. Squares indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software.

3.4 Wet Weather Monitoring

3.4.1 Rainfall

Wet weather monitoring was undertaken at three sites in the Halswell River catchment: Nottingham Stream at Candys Road, Knights Stream at Sabys Road, and Halswell River at Akaroa Highway. The amount of rainfall preceding sampling for the first wet weather sampling event on 4th of April 2016 was 3.2 mm and rainfall ceased shortly after sampling (Figure 15). Rainfall preceding the second sampling event on 26th of August 2016 was much higher at 9 mm (Figure 15). Both sampling events are considered to have occurred during the first flush (considered to be up to the first 15-25mm; Christchurch City Council, 2003), when stormwater contaminant concentrations are highest. However, higher concentrations of stormwater contaminants might be expected for the August event, due to higher rainfall prior to sampling. Antecedent conditions were otherwise similar for the two sampling rounds, with the April and August rainfall events occurring after 11 and 13 day dry periods, respectively (where daily rainfall totals were less than 1 mm).

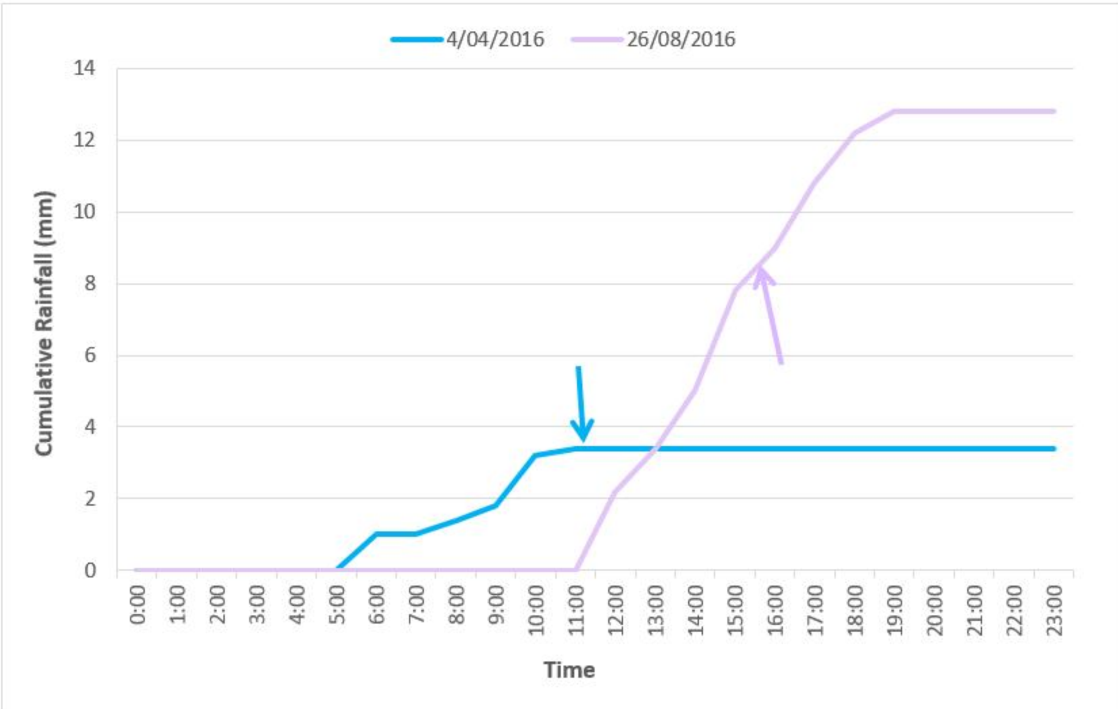


Figure 15. Rainfall during the wet weather events of 04/04/2016 (blue line) and 26/08/2016 (purple line), with approximate times of sampling arrowed.

3.4.2 Copper

Dissolved copper was only recorded above the LOD during the wet weather monitoring at the Nottingham Stream site (0.0024 mg/L in April and 0.011 mg/L in August; Figure 16). While the first event did not exceed the guideline of 0.00336 mg/L, the second event well exceeded it. Both of these concentrations were higher than any recorded at the river sites in this catchment during the monthly monitoring (Appendix D, Figure i (b)).

3.4.3 Dissolved Lead

The Nottingham Stream at Candys Road site was the only site to record dissolved lead concentrations above the LOD and only during the second wet weather event (0.013 mg/L; Figure 16). This lead concentration was just above the guideline level of 0.01257 mg/L. During the monthly monitoring, no river site in this catchment recorded a dissolved lead concentration above the LOD. This value was higher than that recorded at any site during the monthly monitoring (Appendix D, Figure ii (b)).

3.4.4 Dissolved Zinc

In contrast to copper and lead, dissolved zinc was recorded above the LOD at most of the sites during both wet weather events (Figure 16). These concentrations were below the guideline levels, with the exception of the Nottingham Stream site, where 0.054 mg/L and 0.087 mg/L of zinc were recorded in April and August, respectively. Concentrations were greater for the second event compared to the first, which is likely due to the greater rainfall prior to the second sampling event. The zinc concentration recorded during the second wet weather event at Nottingham Stream was higher than the maximum recorded during the monthly monitoring within this catchment (Appendix D, Figure iii (b)). Wet weather zinc concentrations for the Knights Stream and Halswell River sites fell within the range recorded during monthly monitoring.

3.4.5 pH

pH levels were generally similar between wet weather events (Figure 17) and to that recorded for the monthly monitoring (Appendix D, Figure iv (b)). 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.

3.4.6 Conductivity

Wet weather conductivity levels were similar across sites and between rain events (Figure 17). Concentrations were also similar to that recorded during the monthly monitoring (Appendix D, Figure v (b)).

3.4.7 Total Suspended Solids

Total suspended solids concentrations were similar between sites for the first rain event (Figure 18). For the second however they were highly variable. The TSS guideline was exceeded during the second event at the Nottingham Stream (130 mg/L) and Halswell River (41 mg/L) sites. While the concentrations from the first event were similar to that recorded during the monthly monitoring, the Nottingham Stream and Halswell River records from the second event were much higher, particularly for Nottingham Stream (Appendix D, Figure vi (b)).

3.4.8 Turbidity

As for TSS, turbidity levels were similar between sites for the first event but much higher at Nottingham Stream (42 NTU) and Halswell River (18 NTU) for the second (Figure 18). Both these recordings were above the guideline level of 5.6 NTU. All records were comparable to the monthly monitoring, with the exception of Nottingham Stream which recorded higher levels in the second wet weather event than that recorded during the monthly monitoring (Appendix D, Figure vii (b)).

3.4.9 Dissolved Oxygen

Dissolved oxygen levels in water samples were generally similar between events and sites (Figure 19). All samples were above (i.e., complied with) the guideline value. Levels were within the range of that recorded during the monthly monitoring at all sites (Appendix D, Figure viii (b)).

3.4.10 Water Temperature

Water temperatures recorded at the time of sampling were slightly lower during the second wet weather event compared to the first and were generally similar between sites (Figure 19). All samples were within the range of that recorded during the monthly monitoring (Appendix D, Figure ix (b)). As was the case with the monthly monitoring, the wet weather samples were below the guideline level of 20 °C.

3.4.11 Biochemical Oxygen Demand

BOD_5 levels varied between the two rain events and between sites (Figure 20). During the first wet weather event, both Knights Stream and Halswell River samples recorded levels below the LOD, but the Nottingham Stream reading of 2.6 mg/L just exceeded the guideline of 2 mg/L. BOD_5 concentrations from the second wet weather event were much higher than the first and the Knights Stream site was the only one that did not exceed the guideline. Nottingham Stream recorded relatively high concentrations during this event (4.8 mg/L). Wet weather BOD_5 concentrations were generally higher than those recorded during the monthly monitoring (Appendix D, Figure x (b)). BOD_5 levels at these sites during the monthly monitoring never exceeded the guideline value, although Nottingham Stream at Candys Road did meet it on one occasion.

3.4.12 Total Ammonia (Ammoniacal Nitrogen)

Ammonia levels were slightly lower during the first event and Nottingham Stream at Candys Road recorded higher values than the other two sites (Figure 20). All values were well below the guideline value and concentrations were within the range of that recorded during the monthly monitoring (Appendix D, Figure xi (b)). The only exception was Nottingham Stream, which recorded higher levels during the wet weather monitoring (0.17 mg/L and 0.2 mg/L for the first and second event respectively).

3.4.13 Nitrate, Nitrate Nitrite Nitrogen and Dissolved Inorganic Nitrogen

Nitrogen concentrations were similar between events, but much lower at Nottingham Stream than at the other two sites (Figure 21). Compared to the monthly monitoring (Appendix D, Figures xii (b), xiii (b) and xiv (b)), levels were within the same range, but generally towards the lower end. Nitrate levels at Nottingham Stream were well below the grading guideline (3.8 mg/L) on both sampling occasions, while the Halswell River site was only just below the guideline during the second rain event. The first rain event at this site just exceeded the grading guideline and this guideline was exceeded on both occasions at Knights Stream. The surveillance guideline (5.6 mg/L) was never exceeded. Results for NNN and DIN were similar, where both Knights Stream and Halswell River well exceeded the guideline and Nottingham Stream never exceeded it.

3.4.14 Dissolved Reactive Phosphorus

DRP concentrations were generally similar between the two events (Figure 22). Both Knights Stream records were below the guideline and it was the only site not to exceed the guideline. While the Halswell River site just exceeded the guideline during the first rain event, the second well exceeded it, as did both samples from Nottingham Stream. DRP levels were similar to that recorded during the monthly monitoring (Appendix D, Figure xv (b)).

3.4.15 *Escherichia coli*

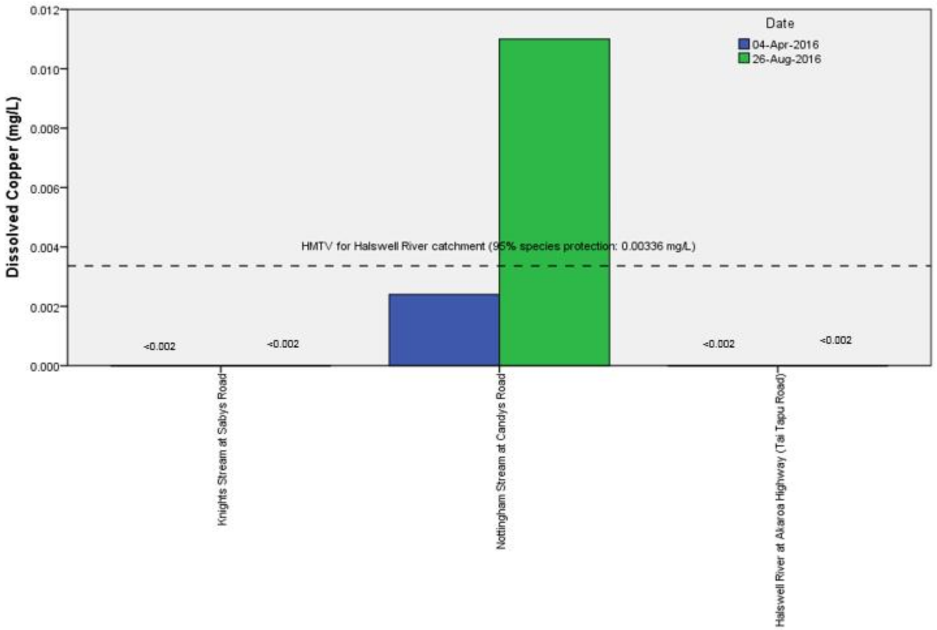
There was some variation in *E. coli* levels across sites, but each site recorded higher levels during the first rain event (Figure 22). The guideline level of 550 CFU/100ml was exceeded on all occasions, but to varying degrees, with Nottingham Stream recording the highest values for each storm event (8,200 CFU/100ml and 2,300 CFU/100ml). Levels were within the range of that recorded during the monthly monitoring (Appendix D, Figure xvi (b)).

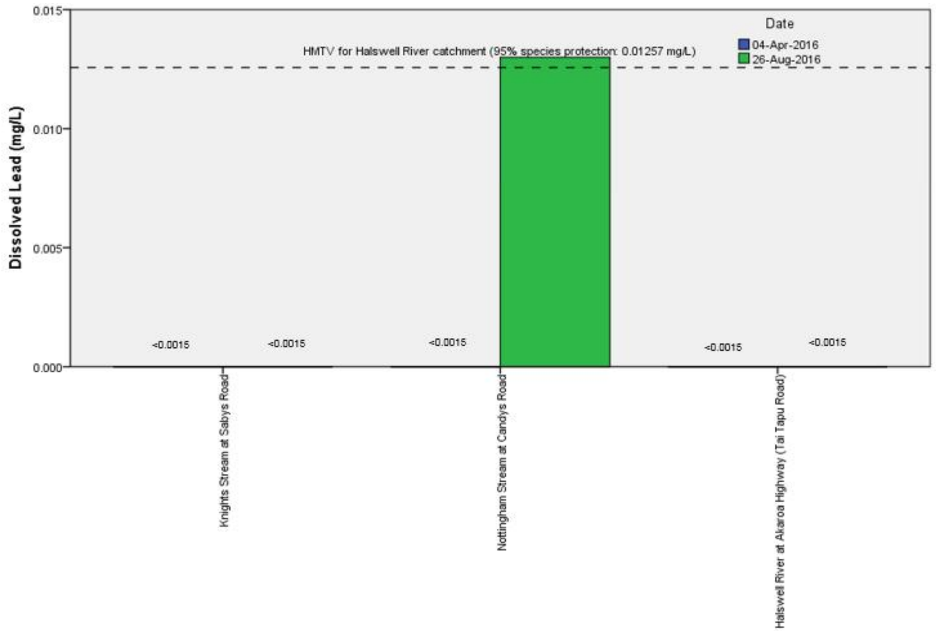
3.4.16 Dissolved Arsenic

Dissolved arsenic was below the LOD on all but two occasions (Figure 23). Values of 0.0057 mg/L (August) and 0.0013 mg/L (April) were recorded at the Nottingham Stream site, which were both below the guideline level for As(V) (0.013 mg/L). Dissolved arsenic is not tested for during the monthly monitoring.

3.4.17 Total Petroleum Hydrocarbons

Total petroleum hydrocarbons (TPH) were below the LOD on all but one occasion (Figure 23). During the second rain event, a value of 0.4 mg/L was recorded at the Nottingham Stream site. TPH is not tested for during the monthly monitoring.





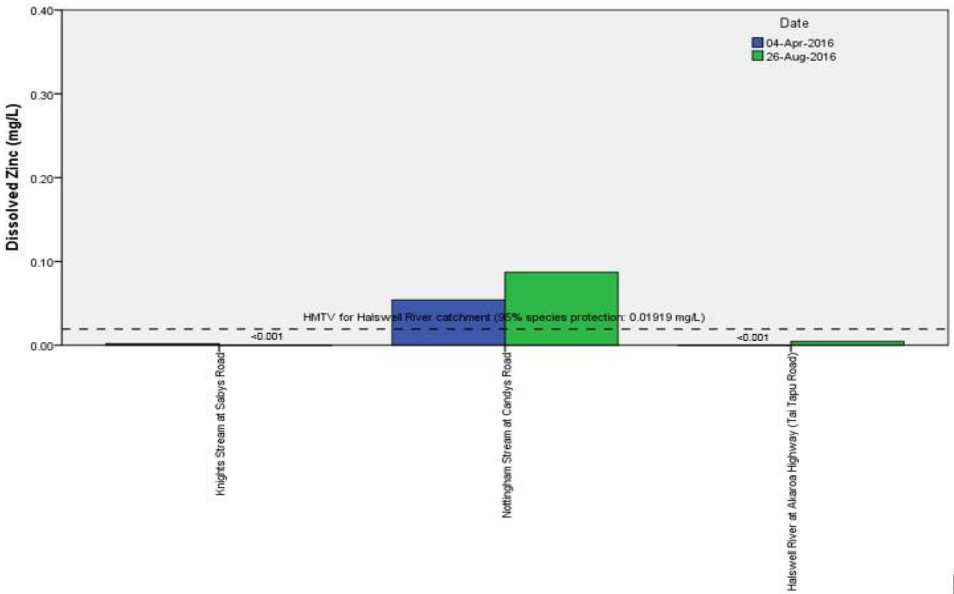


Figure 16. Dissolved copper (top left), lead (top right) and zinc (bottom left) levels in water samples taken from the Halswell River catchment during two rain events. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger values (Environment Canterbury, 2015), which have been modified to account for water hardness (Hardness Modified Trigger Value = HMTV), as per the ANZECC (2000) guidelines methodology.

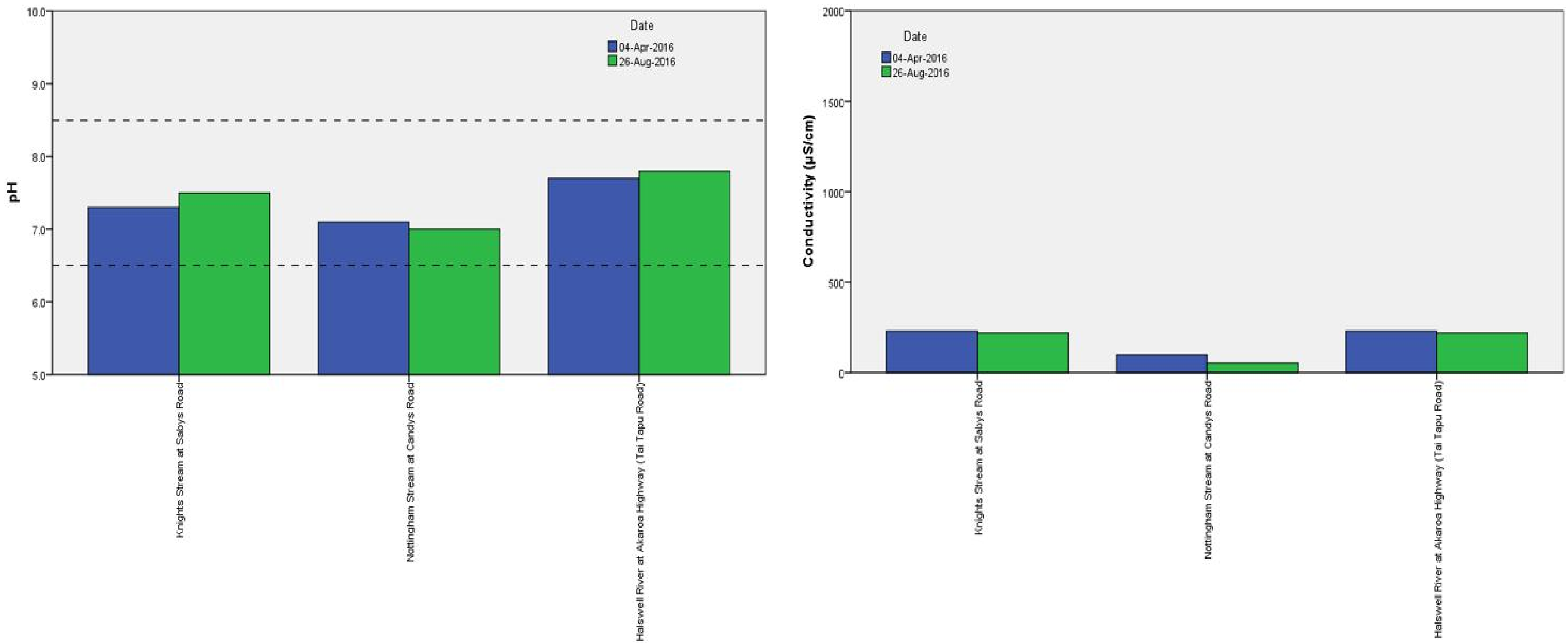
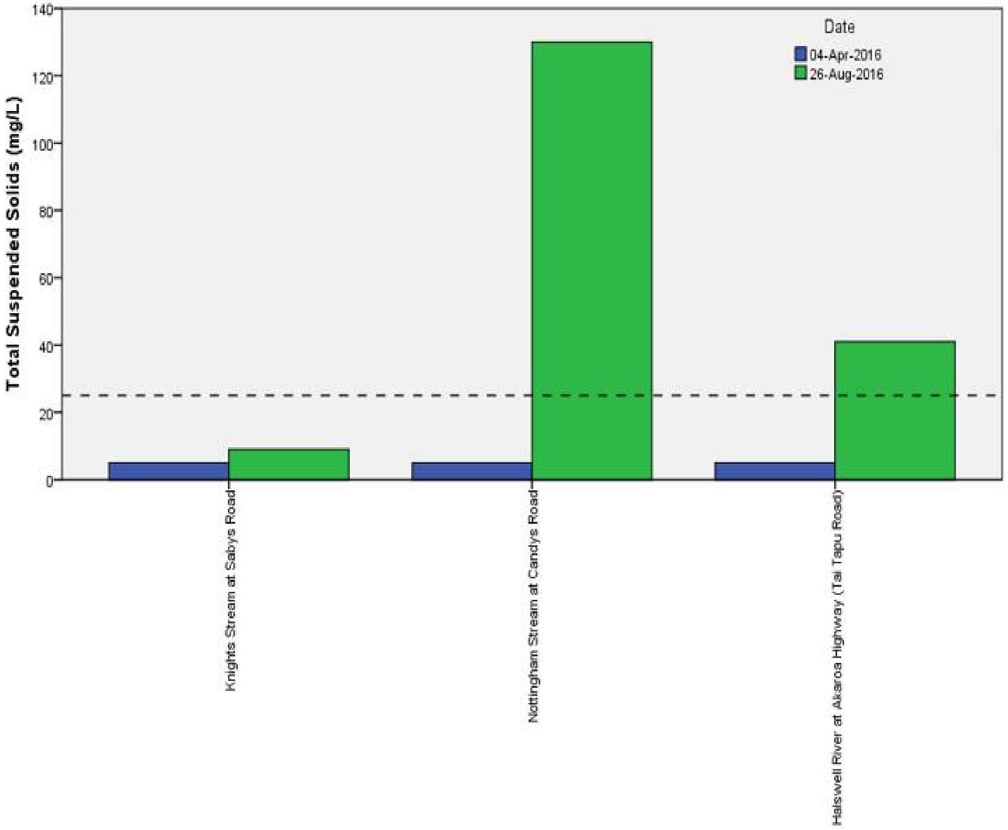


Figure 17. pH (left) and conductivity (right) levels in water samples taken from the Halswell River catchment during two rain events. Sites are ordered from upstream to downstream (left to right). The dashed lines on the pH graph represent the Land and Water Regional Plan lower (6.5) and upper (8.5) limits (Environment Canterbury, 2015).



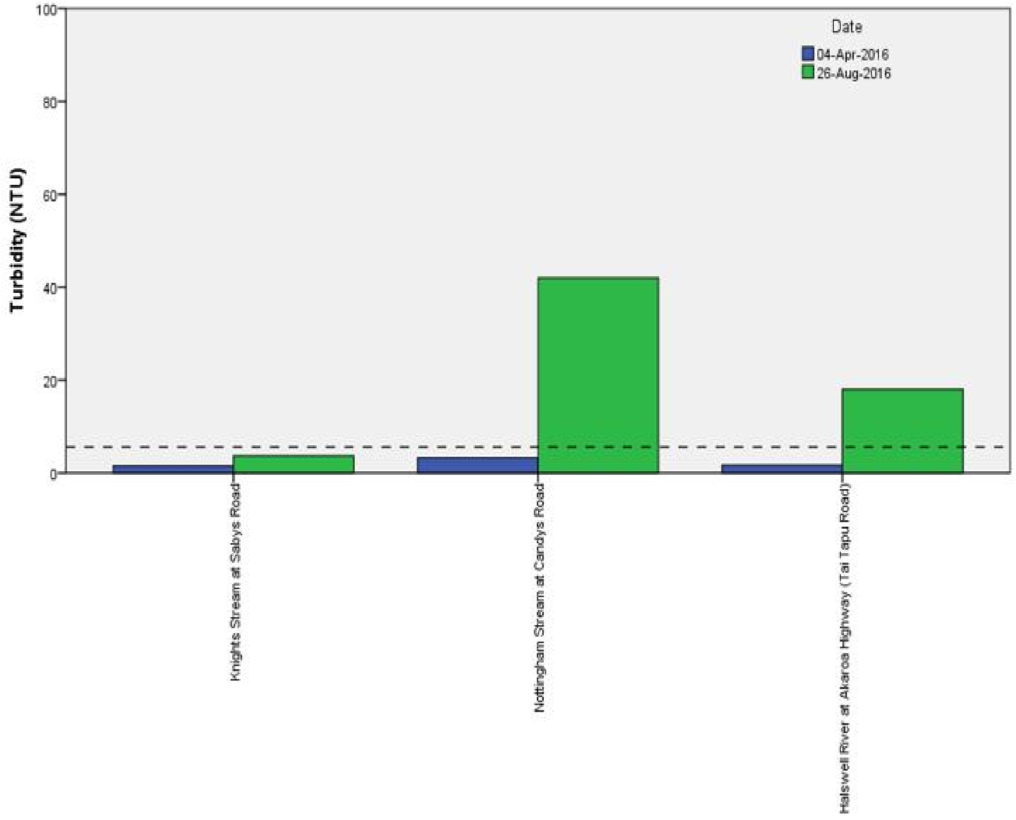
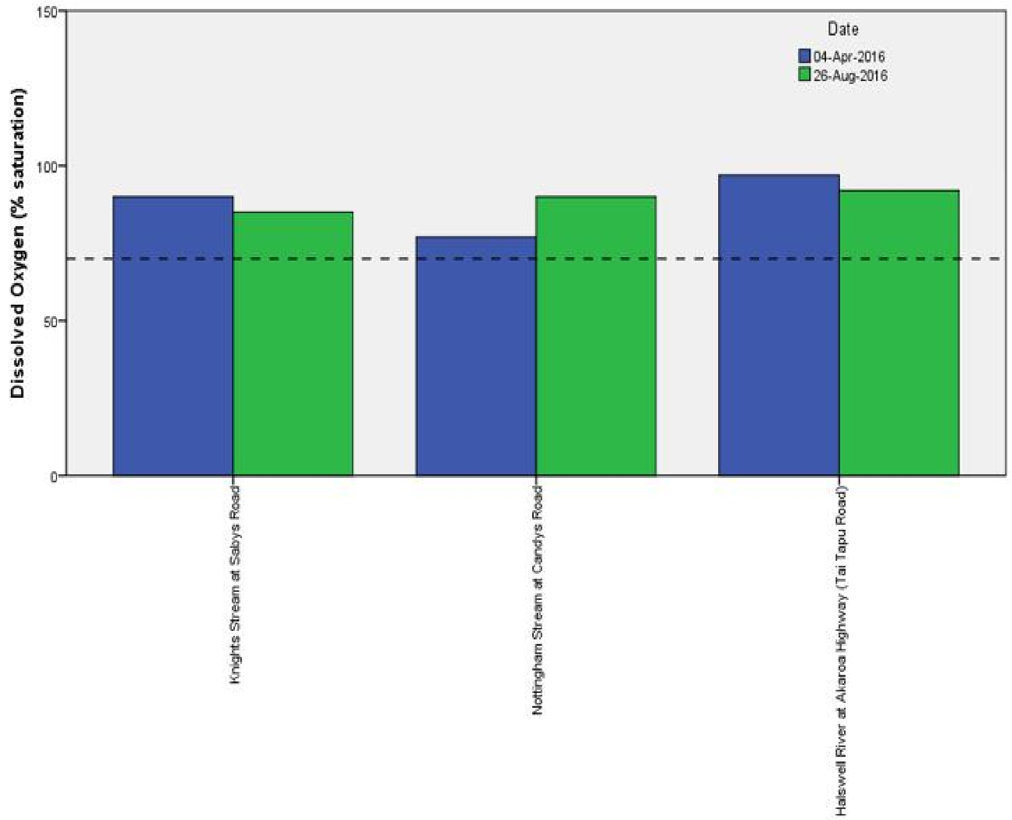


Figure 18. Total Suspended Solid (TSS; left) and turbidity (right) levels in water samples taken from the Halswell River catchment during two rain events. Sites are ordered from upstream to downstream (left to right). On the TSS graph, the dashed line represents the Ryan (1991) guideline value of 25 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 and 0.1 NTU for turbidity.



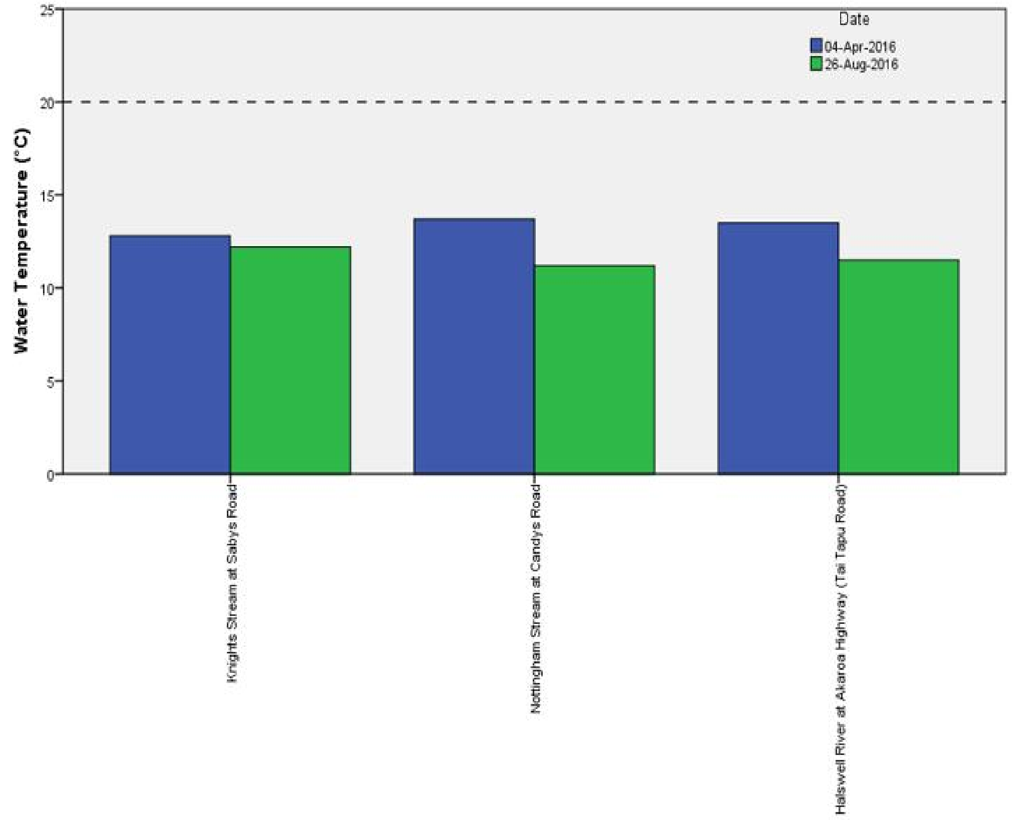


Figure 19. Dissolved oxygen (left) and water temperature (right) levels in water samples taken from the Halswell River catchment during two rain events. Sites are ordered from upstream to downstream (left to right). On the dissolved oxygen graph, the dashed line represents the Land and Water Regional Plan minimum guideline value for 'spring-fed – plains' waterways (70%) (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).

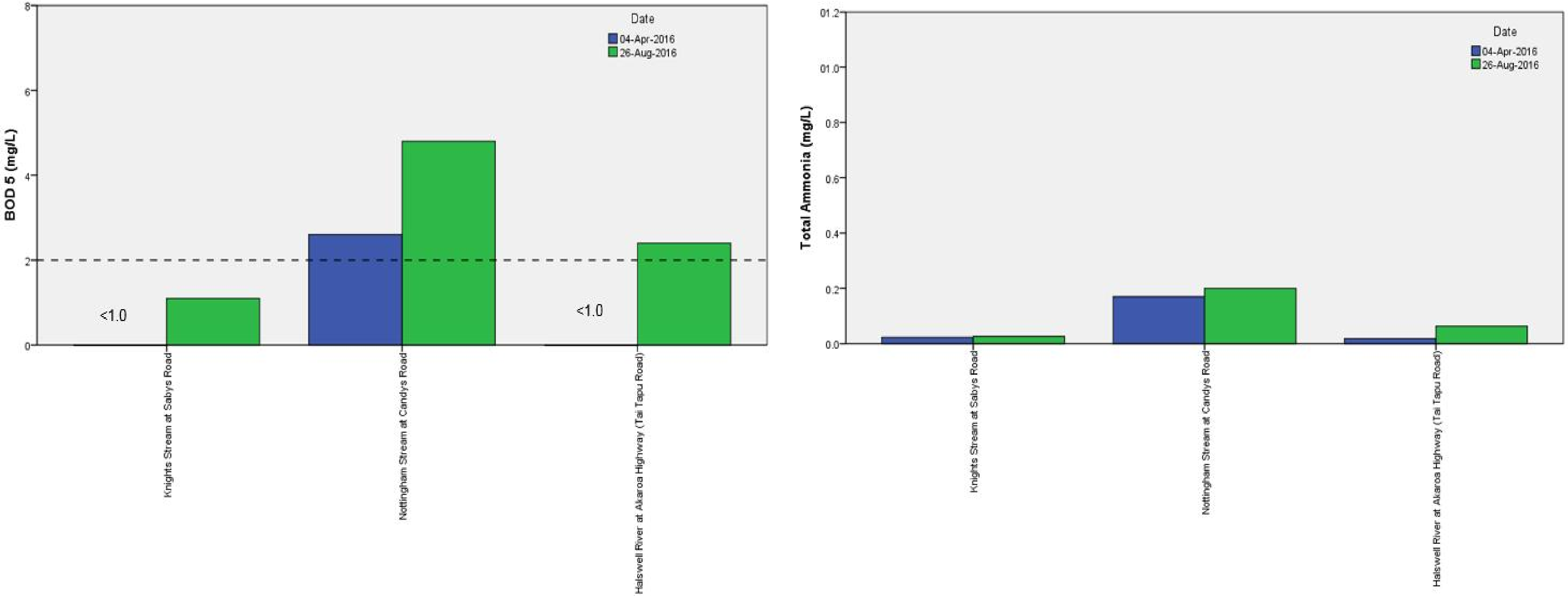
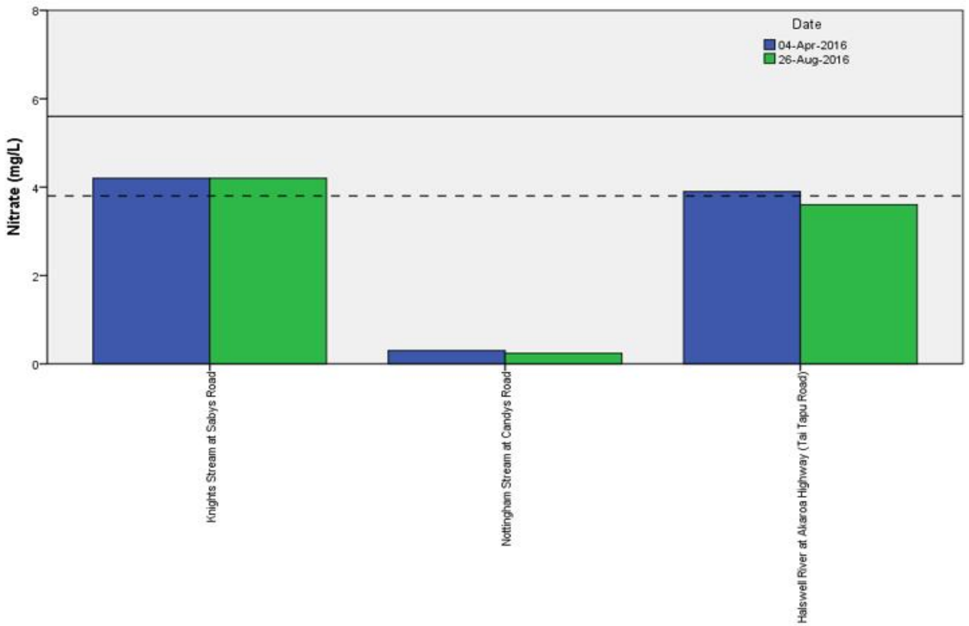
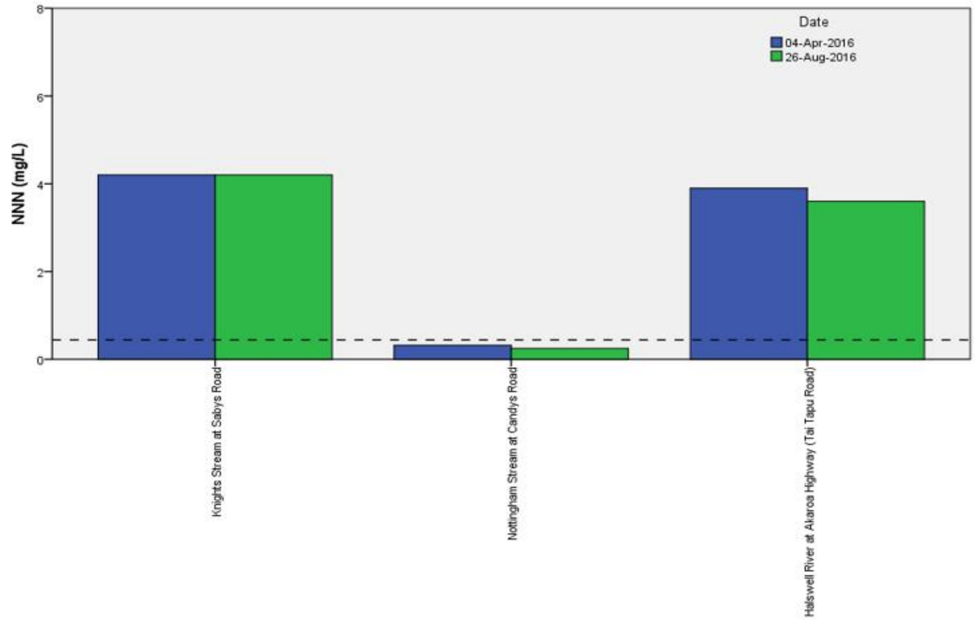


Figure 20. Biochemical Oxygen Demand (BOD_5; left) and total ammonia (right) levels in water samples taken from the Halswell River catchment during two rain events Sites are ordered from upstream to downstream (left to right). On the BOD_5 graph, the dashed line represents the Ministry for the Environment guideline value (2 mg/L; Ministry for the Environment, 1992). 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 Laboratory Limit of Detection for ammonia was 0.005 mg/L.





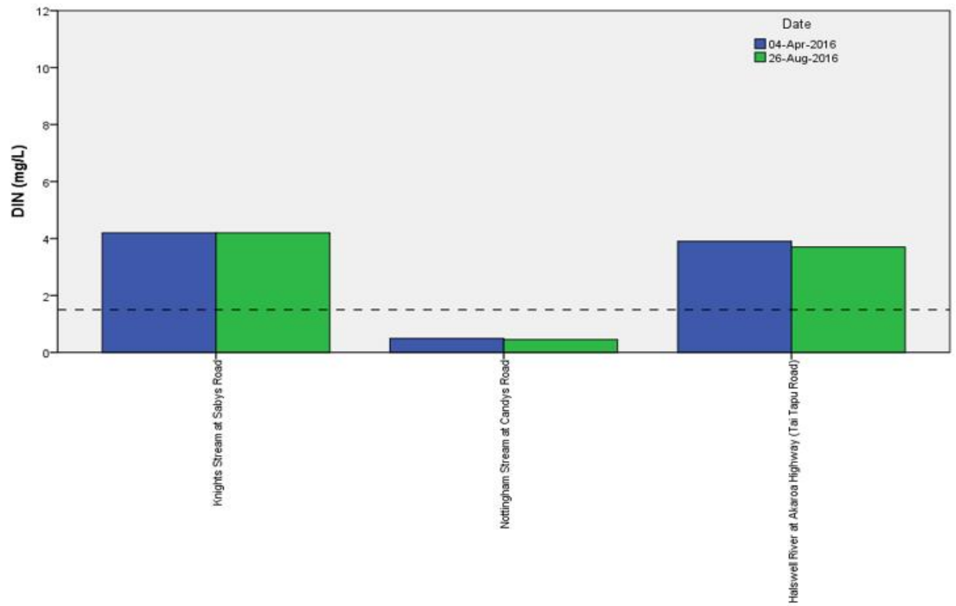


Figure 21. Nitrate (top left), Nitrate Nitrite Nitrogen (NNN; top right) and Dissolved Inorganic Nitrogen (DIN; bottom left) levels in water samples taken from the Halswell River catchment during two rain events. Sites are ordered from upstream to downstream (left to right). On the nitrate graph, the 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 dashed line represents the Land and Water Regional Plan trigger value of 1.5 mg/L for 'spring-fed – plains' waterways (Environment Canterbury, 2015). The Laboratory Limit of Detection for nitrate was 0.05 mg/L, NNN was 0.005 mg/L and DIN 0.02 mg/L.

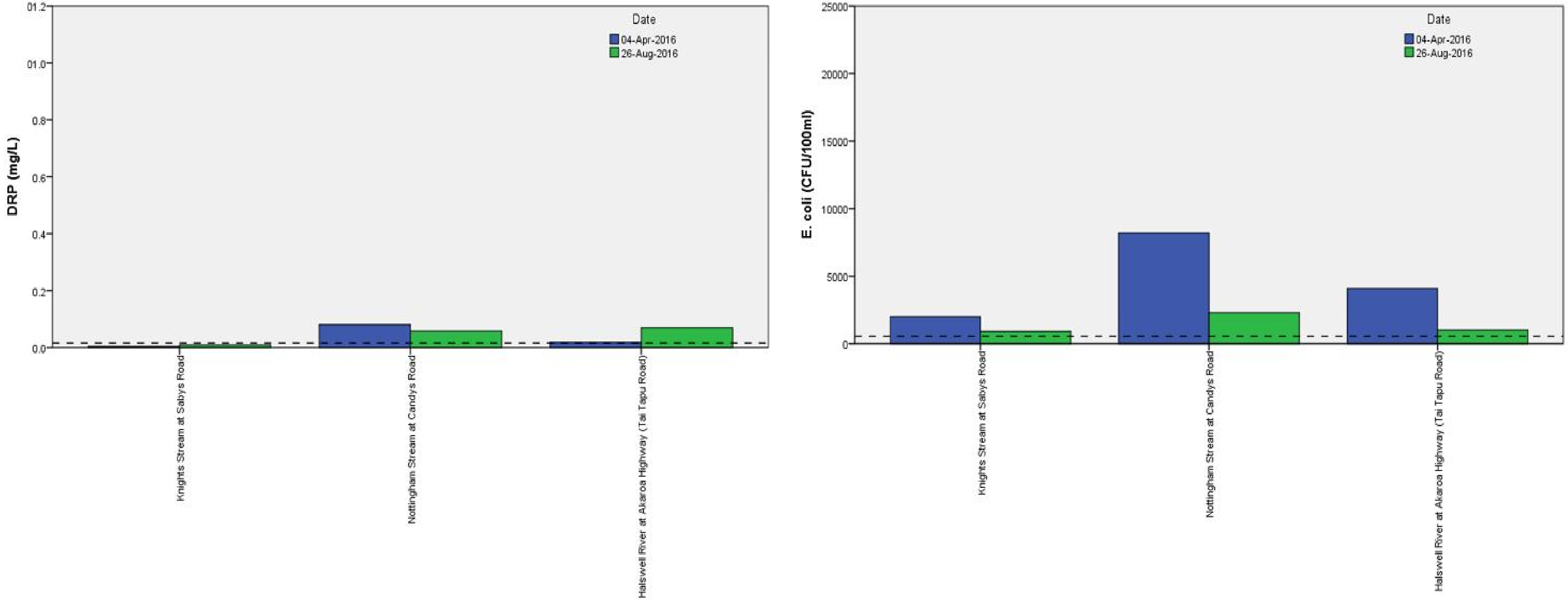


Figure 22. Dissolved Reactive Phosphorus (DRP; left) and *Escherichia coli* (right) levels in water samples taken from the Halswell River catchment during two rain events. Sites are ordered from upstream to downstream (left to right). On the DRP graph the dashed line represents the Land and Water Regional Plan trigger value of 0.016 mg/L for ‘spring-fed – plains’ waterways (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’ 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.

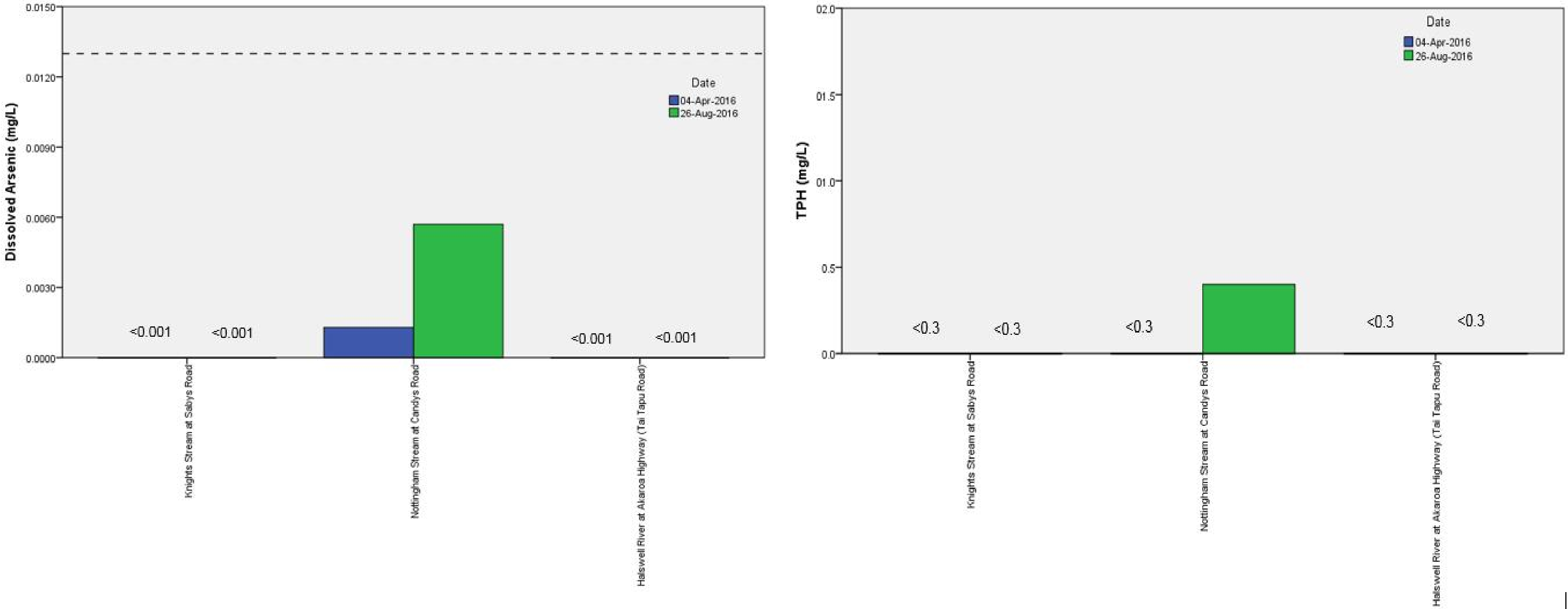


Figure 23. Dissolved arsenic (left) and Total Petroleum Hydrocarbons (TPH; right) levels in water samples taken from the Halswell River catchment during two rain events. Sites are ordered from upstream to downstream (left to right). On the dissolved arsenic graph the dashed line represents the Land and Water Regional Plan trigger value of 0.013 mg/L for 'spring-fed – plains' waterways for As(V), the more conservative of the two figures listed (Environment Canterbury, 2017). The Laboratory Limit of Detection for TPH was 0.3 mg.

4 Discussion

4.1 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 Halswell and Avon River catchments (Table 5). The Ōtūkaikino River catchment recorded the best water quality of all catchments, followed by the Halswell and Styx River catchments. These results are similar to those recorded previously, with the Ōtūkaikino River catchment ranked the best overall and the Heathcote River catchment the worst based on both the 2014 and 2015 data (Margetts & Marshall, 2016). The second and third rankings were slightly different from last year, due to a combination of slightly different ranking methods and differences in the number of occurrences in Table 4. 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. the Heathcote River catchment) and generally better water quality is recorded in rural areas (e.g. the Ōtūkaikino River catchment).

These results also highlight that while waterways may be quite degraded at the catchment scale, they may include sites with relatively good water quality at the site scale. The Heathcote River catchment is a particular case in point, as it includes a number of poor quality sites, such as Haytons Stream and Curletts Road Stream, but also includes Cashmere Stream, which generally has good water quality.

Some of the sites themselves also recorded very low concentrations of 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. The high nitrogen concentrations at this site are typical of rural streams throughout Canterbury, where intensive farming is associated with elevated nitrate concentrations in drainage to groundwater and downgradient spring-fed streams.

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, 2016). In contrast to last year however, the Avon catchment recorded far fewer exceedances.
2. Conductivity: consistent with last year's monitoring (Margetts & Marshall, 2016), 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.
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 comparable to the other catchments. This is in contrast to the findings of the last two reports, which found concentrations to be slightly

higher in the Heathcote catchment (Margetts & Marshall, 2015; Margetts & Marshall, 2016).

4. Dissolved oxygen: levels were generally lower in the Heathcote catchment, particularly in the upstream tributaries. This is consistent with the findings for BOD_5 that also show higher levels in the Heathcote catchment and its upstream tributaries. It is possible that this is a reflection of lower baseflow in the catchment following two dry years. From monitoring instigation in 2007 until 2014, the number of annual monthly samples taken at the Heathcote River at Templetons Road site has varied between ten and twelve. However, in 2015 this site was dry on seven occasions and in 2016, on eleven occasions. Lower baseflow generally decreases water velocity, which typically increases water temperature and encourages the growth of primary producers (e.g. plants and algae). These factors all impact on oxygen concentration. Decreased velocity reduces physical aeration processes, increased water temperature reduces the capacity of water to hold dissolved oxygen and plants produce CO_2 at night during respiration.
5. Water temperature: unlike the two previous monitoring rounds, the Heathcote River catchment did not record lower temperatures compared to the other catchments (Margetts & Marshall, 2015; Margetts & Marshall, 2016). Overall, temperatures were comparable to the 2015 monitoring year across all catchments, but there was a slight reduction in the number of exceedance events. No waterway sampling events exceeded the guideline level for any site in 2014, except Linwood Canal, but in 2015 eight sites did. The number of exceedances reported over the last two years may be a reflection of the lower water levels in 2015 and 2016.
6. BOD_5: the Heathcote River catchment recorded higher levels than the other catchments, consistent with both the 2014 and 2015 monitoring year (Margetts & Marshall, 2015; Margetts & Marshall, 2016). This is likely related to the poorer water quality in this catchment and/or higher levels of plant matter.
7. Total ammonia: levels were higher in the lower reaches across most catchments, possibly due to the tributaries generally recording higher levels than the mainstem sites and therefore contributing to concentrations downstream in the rivers. This contaminant is likely related to pollutants in discharges and faecal input from animals, such as humans and waterfowl. This trend was also recorded over the previous two monitoring rounds (Margetts & Marshall, 2015; Margetts & Marshall, 2016). Concentrations were generally comparable between catchments, with the exception of Linwood Canal which was much higher. Linwood Canal is an almost exclusively urban waterway that for much of its length has concrete banks and a riparian zone that consists of either concrete or short grass. The form of the banks encourages waterfowl to roost and the lack of diverse riparian vegetation does little to inhibit faecal inputs into the system. Generally there were fewer outliers recorded in 2016 than 2015.
8. 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 Avon, Heathcote and Halswell River catchments were higher than the Styx River, Ōtūkaikino River and Linwood Canal catchments. 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.

9. DRP: Similar to last year (Margetts & Marshall, 2016), concentrations generally increased downstream in the Avon, Heathcote and Styx River catchments. Phosphorus inputs can come from fertilisers and faecal matter (animal and human). Tributaries may be contributing phosphorus to the mainstem sites, as they generally recorded higher values than the mainstem.
10. *E. coli*: levels were similar to that recorded during the 2015 monitoring year (Margetts & Marshall, 2016), although there were more outliers this year. The mid-lower tributaries of the Avon River typically had higher levels than the mainstem sites. The reason for this is unknown, but it is possible that a contributing factor may be the number of waterfowl present relative to the volume of water which may be concentrating faecal matter in these waterways.

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

4.2.1 Across all Catchments

The site recording the poorest water quality across all catchments compared to other sites was Haytons Stream at Retention Basin (for copper, zinc, TSS/turbidity, water temperature, BOD_5, total ammonia and DRP) (Tables 4 and 5). The sites tied for second worst (each with four parameters of concern) were Curletts Road Stream at Motorway and Heathcote River at Rose Street. The two sites tied for third worst site were Curletts Road Stream Upstream of Heathcote River and Linwood Canal with three parameters of concern each.

These worst sites differed a little to that recorded last monitoring year (Margetts & Marshall, 2016), where Haytons Stream at Retention Basin and Curletts Road Stream Upstream of Heathcote River were tied for first, Dudley Creek, Curletts Road Stream at Motorway, Cashmere Stream at Sutherlands Road and Kā Pūtahi Creek at Blakes Road were tied for second, and there were 22 other sites tied for third. One notable difference was that Kā Pūtahi at Blakes Road was tied as the second worst site last year, recording poor water quality compared to other sites for dissolved zinc and *E. coli*. This site did not record particularly poor levels compared to other sites this year. These slight differences between years are not surprising given likely environmental and sampling variations, but overall the same key sites were identified between 2015 and 2016 (i.e. Curletts Road Stream, Haytons Stream and Linwood Canal).

The sites that recorded the best water quality across all sites for the 2016 monitoring year were the Ōtūkaikino River at Groynes Inlet and Ōtūkaikino Creek at Omaka Scout Camp sites (seven occurrences), followed by Waimairi Stream, Avon River at Carlton Mill Corner, Cashmere Stream at Sutherlands Road, Styx River at Gardiners and Main North Road, Smacks Creek, Wilsons Stream and Knights Stream (four occurrences) (Tables 4 and 5). Third was tied between Wairarapa Stream and Halswell River at Akaroa Highway (three occurrences each).

The 2016 ranking of best water quality sites is a slightly different result to that recorded last monitoring year (Margetts & Marshall, 2016). Last year, Ōtūkaikino Creek at Omaka Scout Camp was second with six occurrences. Styx River at Gardiners Road and Styx River at Main North Road were tied third, with three occurrences. This year seven new sites were added to the "Best Sites" ranking, with these new sites being ranked either second or third equal. Again, these slight differences between years are not surprising given likely environmental and sampling variations, but overall the same key sites were identified between 2015 and 2016 (i.e. Ōtūkaikino River at Groynes Inlet, Ōtūkaikino Creek at Omaka Scout Camp, Styx River at Gardiners Road and Styx River at Main North Road). The addition of seven new sites is encouraging, with these seven new sites improving in between two and three new parameters compared to last year.

Parameters showing particular improvement compared to last year included dissolved zinc, with eight sites meeting the requirement for "Best Sites" in 2016 compared to two in 2015 and BOD_5 with seven in 2015 and 16 in 2016. Generally, there were also far fewer outliers at each site for dissolved lead. Out of the 42 waterway sites, 16 sites recorded an outlier for lead in 2015, compared to one in 2016. This one outlier was the only waterway concentration above the LOD. In addition to this, consistent improvement was recorded in Dudley Creek, which in 2015 was the only waterway site to exhibit an interquartile range for lead but this year recorded all values below the LOD.

One potential cause for differences in zinc, BOD_5, and lead concentrations between years is how wet the year was, and hence how often sampling coincided with stormwater runoff occurring. The amount of rainfall that fell within Christchurch City was low for the 2015 and 2016 monitoring years. For example, rainfall at the Botanic Gardens in the 2014 calendar year totalled 691mm (above average) and 585mm in 2015 and 553mm in 2016 (below average). The difference in rainfall between 2015 and 2016 is small, and unlikely to be driving the improvement in the three above-mentioned parameters. Furthermore, there was little difference in the total number of samples taken in association with rain (141 in 2015 and 133 in 2016). Therefore, the reason for improved zinc, BOD_5, and lead levels in 2016 does not appear to be due to less rainfall occurring and the actual cause remains uncertain.

4.2.2 Within Catchments

Within each catchment, there were several sites that consistently recorded parameters well outside the guideline levels and/or recorded substantially different one-off events compared to other sites (Table 6). Unfortunately, due to an oversight in the database providing water quality data, no alerts were sent to CCC staff when pre-determined concentrations for each parameter were exceeded. This meant that cause and source of unusually high parameter concentrations were unable to be investigated shortly after sampling and instead were not noted until the preparation of this report. This issue should now have been rectified.

4.2.2.1 Avon River catchment

In the Avon River catchment, sites that recorded parameters outside guideline levels on a number of occasions were Addington Brook and Dudley Creek (three parameters each), followed by Riccarton Main Drain (two parameters) and then Avon River at Mona Vale, Horseshoe Lake Discharge and Avon River at Bridge Street (one parameter). These sites recorded issues with copper, zinc, sediment, oxygen, nitrogen and *E. coli*. 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 impact 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 (also known as Riccarton Stream) and Addington Brook catchments, working in conjunction with ECan and the CCC, with the aim of reducing contaminant levels in these waterways.

For the 2015 monitoring year, Dudley Creek was also identified as having amongst the poorest water quality in the catchment, along with Riccarton Main Drain (four parameters each) (Margetts & Marshall, 2016). This was followed by Avon River at Bridge Street (three parameters). Sites that were identified in Table 6 over both the 2015 and 2016 monitoring years included Addington Brook, Dudley Creek, Riccarton Main Drain, Avon River at Mona Vale, Horseshoe Lake Discharge and Avon River at Bridge Street.

4.2.2.2 Heathcote River catchment

In the Heathcote River catchment, Haytons Stream had the poorest water quality (five parameters), followed by Curletts Road Stream Upstream of Heathcote River and Heathcote River at Rose Street (four parameters each). Heathcote River at Templetons Road and Cashmere Stream at Worsleys Road both had three parameters. The Templetons Road site was only monitored once during 2016 as the site was usually dry, so any data from this site should be regarded with caution. Lead, zinc, sediment, oxygen, ammonia, nitrogen and phosphorus were the parameters of concern at these sites. Heathcote River at Catherine Street was the only site not to record an occurrence. The Cashmere Stream at Sutherlands Road site did not meet the dissolved oxygen guideline level at any time during the monitoring period, which was also the case in 2015. This is unsurprising given that this site is located in close proximity to a spring. Springs commonly have low dissolved oxygen levels due to the recent emergence of low oxygen groundwater.

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 are the higher levels of ammonia within these two waterways compared to other catchments, 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. Despite this, Haytons Stream recorded phenomenally high ammonia this year (independent of rain), with this year's median greater than the maximum concentration recorded last year. In addition to ammonia and the other four parameters of concern listed in Table 6 (zinc, turbidity, BOD_5 and DRP), Haytons Stream also recorded either particularly high levels or marked degradation compared to last year for dissolved copper, dissolved oxygen and DIN. A recent study by Silveira (2017) investigated nitrogen in Haytons Drain, and the data indicate a likely industrial point-source influx of ammonia that is largely responsible for causing the high levels of ammonia. The study did not investigate phosphorus, however it is very likely that the excess DRP in the stream has the same source as ammonia. CCC is currently investigating the ammonia source to Haytons Stream and potential legacy issues of contaminated sediments in the stream, plus this year it has commenced work on upgrading the Wigram Retention Pond stormwater treatment facility.

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. This is necessary as both dissolved copper and zinc concentrations were high even at baseflow. High levels of these contaminants at baseflow were also reflected by high conductivity at this headwater tributary, as both copper and zinc form positively charged ions when dissolved in water. This waterway also had issues with dissolved oxygen, BOD_5 and DRP. A new stormwater facility is currently being designed for Curletts Road Stream, along with investigations into the potential extent and scale of sediment contamination.

The Heathcote River at Templetons Road site is a headwater site, which in the previous report, was given as the most likely reason for the low oxygen levels and high nitrogen concentrations (due to input from contaminated groundwater within springs) recorded at this site. This year, only one sample was taken (February) as the site was dry at the other sampling times. The Heathcote River at Rose Street site is located in the river's upper reaches, downstream of the tributary inputs from Haytons Stream and Curletts Road Stream. This site is 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. In addition to the parameters of particular concern listed in Table 6, Rose Street was also identified as having issues with dissolved copper and *E.coli*. Sediment sampling is proposed for this site, along with sites further upstream in the Heathcote River, Curletts Road Stream and Haytons Stream, to evaluate potential legacy impacts of contaminated sediment on baseflow water quality.

Last monitoring year, Curletts Road Stream Upstream of Heathcote River had the poorest water quality (seven occurrences), followed by Haytons Stream at Retention Basin (six occurrences) (Margetts & Marshall, 2016). Sites that were identified as having the poorest water quality over both the 2015 and 2016 monitoring years included Haytons Stream at Retention Basin, the two Curletts Road Stream sites, Heathcote River at Templetons Road, Heathcote River at Rose Street, the two Cashmere Stream sites, Heathcote River at Mackenzie Avenue, Heathcote River at Bowenvale Avenue, Heathcote River at Ferrymead Bridge, and Heathcote River at Tunnel Road.

4.2.2.3 Styx River catchment

For the Styx River catchment, the sites with the poorest water quality were Kā Pūtahi Creek at Blakes Road and Kā Pūtahi Creek at Belfast Road (four occurrences each) and Smacks Creek at Gardiners Road (three occurrences). The parameters of concern at these sites were copper, zinc, oxygen, 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 two of these events associated with rain. For the last three years, every single *E. coli* sample has exceeded the 550 cfu/100 mL guideline for the Belfast Road site. The Styx River sites are located in primarily rural catchments, with some industry, and the Kā Pūtahi Stream in particular is known to have industrial and agricultural inputs. The Belfast Road site was previously affected by a piggery and Muscovy ducks upstream, but these sources of faecal contamination have been removed, so the current contamination source remains uncertain. A more detailed investigation is recommended (see Recommendations section below).

Both Kā Pūtahi Creek sites have recorded the poorest water quality for the last three years (Margetts & Marshall, 2015; Margetts & Marshall, 2016). Styx River at Main North Road was the only site not to consistently record poor results across both the 2015 and 2016 monitoring years.

4.2.2.4 Ōtūkaikino River catchment

In the Ōtūkaikino River catchment, Wilsons Stream had issues with pH and nitrogen compared to other sites in the catchment. This site is located in an agricultural and residential catchment, so runoff from these areas is likely the source of these contaminants. Wilsons Stream was the only site identified in this catchment as having poor water quality in 2015 and 2016. In 2015 issues with zinc, pH, nitrogen and *E. coli* were recorded (Margetts & Marshall, 2016). There are long-term CCC plans for adding a stormwater treatment facility in the Wilsons Stream catchment. At the time of writing it remains uncertain when the facility will be built, as it depends on funding in the Long Term Plan, which is not yet finalised.

4.2.2.5 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. These results are the same as last year (Margetts & Marshall, 2016).

4.2.2.6 Linwood Canal

This year Linwood Canal recorded poor levels of copper, dissolved oxygen, temperature, ammonia and DRP. This site recorded the same issues last year, with the exception of copper and pH. The issues with temperature and oxygen are reflective of a waterway with low flow.

4.3 Monthly Monitoring: Comparisons to Receiving Environment Guidelines

Of the samples collected from the 42 waterways sites during the monitoring year, 18% (1,288 of 7,335 samples) exceeded the guideline levels (Table 7). 95% of sites (40 of 42 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 (73% of samples), DRP (59% of samples), DIN (32% of samples), *E. coli* (32% of samples) and dissolved oxygen (23% of samples). The four worst parameters are the same as those identified last year and occur in the same order, however in the 2015 monitoring year the fifth worst parameter was turbidity (21% of samples).

High levels of NNN, DRP and DIN reflect the impact of both urban and rural landuse on these nutrients. None of the *E. coli* exceedances coincided with wastewater overflow events. This suggests that the primary causes are due to other issues with the wastewater network (e.g., leaky pipes and cross-connections), dogs or waterfowl.

Faecal source tracking indicates that faecal contamination comes from a mixture of human, ruminant, and avian sources, with avian sources dominant during baseflow conditions (Moriarty & Gilpin 2015). *E. coli* counts were particularly high in Kā Pūtahi at Belfast Road, although the source is not yet certain. The likely cause of low dissolved oxygen varies between sites. For example, some sites are fed by groundwater low in oxygen, others have very high macrophyte cover (or algal density) which will drive oxygen down at night during respiration, and sluggish flows also reduce dissolved oxygen.

The two related parameters turbidity and TSS were ranked 6th and 8th, however several of the monitoring sites are tidal and so high levels of these parameters are not reflective of polluted sites. In addition, some of the Heathcote catchment sites are impacted by sediment-laden runoff from the Port Hills. However, for sites such as Riccarton Main Drain and Haytons Stream, it is more clearly a stormwater issue, due to the absence of either hill or tidal influence. Impacts on water clarity as a result of the Port Hills fires (February 2017) should become apparent in the next annual monitoring report. However, mitigation work (both proposed and underway) includes revegetating erosion-prone slopes and gullies, and purpose-built sediment detention and treatment basins in Hoon Hay Valley and Cashmere Valley.

There were a number of parameters that consistently met the relevant receiving water guidelines for the 2016 monitoring period across most sites and are therefore unlikely to be having adverse effects on the waterways. These were dissolved lead, pH, water temperature, total ammonia and nitrate. There were also some parameters that generally recorded levels within the guidelines, but on a number of occasions, or regularly at a small number of sites, recorded concentrations outside these values: dissolved copper, dissolved zinc, TSS, turbidity, dissolved oxygen and BOD_5. These results are consistent with that recorded during the 2015 monitoring year, except water temperature did not consistently met the guideline level last year although it did in 2014 (Margetts & Marshall, 2015; Margetts & Marshall, 2016).

The low levels of lead recorded reflect the impact of banning leaded petrol in 1996. Since 2011 (when regular monitoring of metals began in the city), dissolved lead concentrations have exceeded guidelines on only six occasions, and no exceedances have occurred for the last three years. The legislation restricting the use of lead in petrol highlights the potential value of imposing regulations for other contaminants, such as copper-free brake pads, and other controls around zinc roofing.

Generally, the percentage of sites exceeding their respective copper guideline was low, with exceedances being recorded for more than 10% of samples at only two waterway sites prior to 2016 (both Curletts Road Drain sites) and one site in 2016 (Curletts Road Drain at Motorway). Generally far more exceedances were recorded for dissolved zinc than copper, however the majority of sites still recorded exceedances for less than 10% of samples for both years. Sites with a particularly high number of samples exceeding zinc guidelines in 2016 included Haytons Stream (50% of samples), Curletts Road Stream at Motorway (92%), and Heathcote River at Rose Street (50%). Only four sites have never recorded a zinc concentration above the guideline, compared to 22 for copper. All sites but one (Ōtūkaikino River at Omaka Scout Camp) have recorded *E. coli* concentrations above the guideline level of 550 CFU/100ml on at least one occasion and only nine sites did not exceed the guideline at all in 2016. Unlike dissolved copper and zinc, very few sites recorded fewer than 10% of samples exceeding the *E. coli* guideline for either time period. Sites with particularly high percentage exceedances in 2016 included Dudley Creek (75%), Horseshoe Lake

Discharge (75%), Heathcote River at Rose Street (83%), Kā Pūtahi Creek at Belfast Road (100%) and Knights Stream (92%).

4.4 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 and TSS/turbidity within the Heathcote and Styx River catchments. New catchment-scale improvements noted this year include a reduction in turbidity, NNN and DIN in the Avon catchment and BOD_5 in the Heathcote. This may mean better land management practices are being undertaken since monitoring began, or it may reflect the impact of two dry years on water quality. *E. coli* levels within the Styx River catchment showed an increasing trend across most sites in both this year and last year's report. This year the majority of Halswell sites (two) also showed an increase in *E. coli*, up from one last year. This might be due to agricultural inputs in this more rural catchment, but also animal-related industries such as within the Kā Pūtahi Creek. Further investigations into E. coli sources are recommended for this catchment..

Both the Avon River at Bridge Street and Avon River at Pages/Seaview Bridge sites recorded the largest increase of any parameter at a given site, with a 16% increase in conductivity, comparable to that recorded over the last two years (Margetts & Marshall, 2015; Margetts & Marshall, 2016). As discussed in the previous annual report (Margetts & Marshall, 2015), this increase is probably related to changes in tidal inundation at this location, caused by the earthquakes.

The largest decrease in contaminant concentrations was a 46% reduction in dissolved zinc at the Curletts Road Stream Upstream of Heathcote River site. Last year a decrease of 57% was recorded and 146% the year before that (Margetts & Marshall, 2015; Margetts & Marshall, 2016). 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. However, zinc concentrations still very frequently exceed guidelines in Curletts Road Stream, particularly at the upstream Motorway site, so further investigation into source control and treatment options is warranted.

Both Dudley Creek and Knights Stream recorded substantial decreases in dissolved zinc (23% and 37% respectively), where no significant trend was recorded last year (Margetts & Marshall, 2016). Because these sites have a relatively short time record (five- six years), trends in dissolved metals should be treated with caution. This downward trend has occurred over the last two- three years (2014- 2016). Both 2015 and 2016 were dry years and it is possible that this is creating a false trend. However, this year (2017) has been comparatively wet and so the available 2017 data was analysed to determine if the trend continued (January- August for Dudley Creek and

January- July for Knights Stream). Both trends were still present with this additional analysis. It appears that a reduction in peak concentration levels (i.e. spikes) is driving the change, but it is uncertain what the cause is.

The 25% decrease in DRP observed this year at the Cashmere Stream at Sutherlands Road site is comparable to that recorded over the previous two years, ranging from a 19% decrease in 2015 to 24% in 2014. Given the rural locality of this site, it is possible this trend is a result of improving catchment management practices. Such practices could involve fencing stock from the waterway, planting the riparian margins, responsible application of fertilisers and retiring land from agriculture.

The 21% decrease in DRP and turbidity at the Ōtūkaikino River at Groynes Inlet site was similar to that recorded last year (20% reduction for each; Margetts & Marshall, 2016). As mentioned in Margetts & Marshall (2015), 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. In Addington Brook a 12% decrease in BOD_5 was recorded, an improvement from 6% last year (Margetts & Marshall, 2016). Last year a general (not significant) decreasing trend in ammonia and phosphorus as well as an increasing trend in *E. coli* was noted. It was thought that if the trends continued it would be likely that significant changes would be recorded. Although the general trend has continued, there was still no statistically significant trend. Last year a 17% reduction in dissolved zinc was recorded at this site, however this year the trend was not significant. This appears largely attributable to high readings from October- December 2016, however the medians for 2014 and 2015 were comparable (around 0.016 mg/L) compared to 0.027 mg/L this year. 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, although the per annum decrease was less this year for these four parameters. Curletts Road Stream recorded significant decreases in zinc, phosphorus, TSS, turbidity, BOD_5 and nitrogen. Last year's decrease in ammonia was no longer significant.

Trend analysis can be very sensitive to levels below the LOD which can create issues for trends analysis. There are alternative statistical methods that may be able to be employed next year that specifically look at trends in guideline compliance over time. A variety of non-linear statistical methods are available for this.

4.5 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, BOD_5, ammonia and DRP. This is to be expected given the predominantly stormwater input into the basins and that the rivers are subjected to dilution from baseflow. In both 2014 and 2015 *E. coli* levels at the inlet were high, however this year they were low and complied with the LWRP trigger value for waterways. The surrounding landuse is predominantly industrial, although it may also take some rural flow. The pattern of high ammonia and DRP but low *E. coli* observed this year indicates that the source of the first two parameters may be industrial in nature (at least in part), rather than from waterfowl as previously suggested. More variability in concentration was also generally recorded at these sites compared to the river sites (e.g. dissolved copper, dissolved zinc, temperature, BOD_5, ammonia, DIN and DRP), possibly due to variable levels of parameters in stormwater and/or the treatment ability of the basin. These results are similar to that recorded over the last two monitoring years, with the obvious exception of *E. coli*, as described above (Margetts & Marshall, 2015; Margetts & Marshall, 2016). Over the last three monitoring rounds (2014- 2016), dissolved lead has been steadily decreasing at both the inlet and the outlet.

Unlike the last two years, the retention basin outlet recorded lower median concentrations than the inlet the majority of the time, compared to approximately half of the time last year (Margetts & Marshall, 2015; Margetts & Marshall, 2016). This indicates that there is 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. The CCC will be upgrading stormwater treatment in the area over the next few years, which should improve overall discharge quality.

Both the inlet and outlet recorded a decreasing trend for BOD_5 (14% and 16% respectively) and TSS (6% and 14% respectively) since monitoring began in April 2007. The outlet also recorded an 18% decrease in ammonia 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 12% and 11%, 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. The decrease in TSS at the inlet and decrease in ammonia at the outlet are new trends this year and unlike last year, there was no significant increase in *E. coli* levels at the inlet.

Overall, the quality of water discharging from the Halswell Retention Basin is poor, and improved water quality treatment is needed. Additional stormwater detention and treatment is proposed within the next five years, which should help improve the removal of stormwater contaminants prior to discharging into waterways downstream.

4.6 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, total ammonia, dissolved arsenic and TPH. 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 insufficient sampling sites to determine downstream trends.

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 BOD_5 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 second event (e.g. TSS, turbidity, BOD_5 and ammonia), some lower during the second event (e.g. temperature and *E. coli*) and some similar between events (e.g. nitrogen). Neither dissolved arsenic nor TPH are measured during monthly monitoring.

The site that generally recorded the poorest water quality during the wet weather monitoring was Nottingham Stream (e.g. for copper, lead, zinc, TSS, turbidity, BOD_5, dissolved arsenic and TPH). Of these parameters, copper, lead, zinc, TSS, turbidity and BOD_5 all exceeded the guideline value at least once. This site was also identified from the monthly monitoring as having an issue with zinc. While none of the wet weather sites from the Heathcote catchment presented in Margetts & Marshall (2016) recorded either dissolved arsenic or TPH above the LOD, this study found both these parameters to be above detection on at least one occasion. Earlier (2010) stormwater samples from the Heathcote catchment measured total arsenic and found concentrations that ranged from the LOD to 0.0081 mg/L.

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; Margetts & Marshall 2016). 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 of contaminants (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 land use).

A key issue highlighted by this year's wet weather monitoring results is a lack of dedicated stormwater sampling. For many of the measured parameters, particularly in Nottingham Stream, there are clearly water quality issues associated with wet weather events. Currently, insufficient sampling events, sampled at an insufficient number of sites, makes it is difficult to locate and prioritise areas for improved stormwater treatment. However, with the current level of sampling, it is possible to identify sites that have particularly significant issues with stormwater-related contaminants; such sites include Curletts Road Stream and Haytons Stream.

5 Recommendations

- Haytons Stream and Curletts Road Stream should be priority areas for improved contaminant source control and stormwater treatment.
    - o CCC and ECan are currently working with landowners to reduce contaminants entering stormwater systems or waterways directly. However, more could still be done in this area, and industrial site audits are proving a good avenue for targeting key contaminant sources.
    - o CCC has committed to new or upgraded stormwater treatment facilities in both of these catchments, with construction currently underway in Haytons Stream catchment, and design work underway in the Curletts Road Stream catchment. Dedicated wet-weather stormwater sampling is recommended to assess the effectiveness of these new and upgraded facilities.
- Investigations into poor water quality in Nottingham Stream should be instigated. Parameters of concern during the monthly sampling include: dissolved zinc, BOD_5, DRP and *E. coli*. During wet weather they include dissolved copper, lead, zinc and arsenic, TSS, BOD_5, DRP and *E. coli*.
- 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. This recommendation was also made in last year's annual report.
    - o One option to encourage good catchment management practices could be via the creation of a catchment management plan that involves input from CCC, ECan, rūnanga, landowners and other stakeholders. A catchment management plan would help address wider catchment issues than just stormwater, but could also incorporate a Stormwater Management Plan. The Christchurch-West Melton Zone Committee could be an avenue to progress such a plan.
- Investigations should be carried out to determine the reason for the high *E. coli* levels within the Styx River catchment. This was also a recommendation last year.
    - o This could be progressed by undertaking more sampling at additional sites, during wet and dry weather conditions, to determine the *E. coli* sources.
- Investigations should be carried out to identify how to reduce faecal contamination of waterways across the city. This was also a recommendation last year.
    - o Faecal source tracking has indicated that waterfowl are a major source of faecal contamination during dry weather, but waterfowl control within the city has previously proven to be unpopular for some residents. With the increase in public interest in making rivers swimmable (i.e., *E. coli* levels below guidelines), this is an area of potential conflict that needs to be carefully worked through. The Christchurch-West Melton Zone Committee could be a good avenue for such discussions.
- Dedicated stormwater quality sampling is recommended, to complement the existing monitoring programme.
    - o The current monitoring programme has enabled CCC to describe the state of the environment and identify areas of very poor water quality. However, the majority of monthly samples are not taken following rain

events, so do not specifically measure stormwater impacts. A programme of dedicated stormwater sampling (i.e., sampling when stormwater runoff is occurring) would allow CCC to both better identify stormwater issues and also monitor the effectiveness of stormwater treatment devices.

- CCC should investigate using devices such as Nalgene Storm Water Sampler bottles installed in stormwater outlets or streams to undertake first-flush stormwater sampling. Such an approach avoids the need to “chase storms” for wet weather sampling (and its associated logistical issues), and there are standard methods used overseas that could be followed. An Envirolink project being undertaken by NIWA is investigating the use of these bottles, as well as other novel methods, to provide a suite of tools to reduce the logistical and financial challenges involved with effective stormwater sampling.

- Next monitoring report to include a discussion on the impact of sampling in close proximity to stormwater pipe discharges for the six affected sites.

6 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 Haytons Stream at Retention Basin (particularly for copper, zinc, TSS, turbidity, temperature, BOD_5, ammonia and DRP). The sites that recorded the best water quality were tied between Ōtūkaikino River at Groynes Inlet and Ōtūkaikino River at Omaka Scout Camp.

Of the samples collected from the 42 waterways sites during the monitoring year, 18% (1,288 of 7,335 samples) did not meet the guideline levels. 95% of sites (40 of 42 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, water temperature, total ammonia and nitrate. However, there were a number of parameters that recorded values well outside the guidelines across most sites, including NNN, DIN, DRP and *E. coli*. 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 guidelines, including: dissolved copper, dissolved zinc, TSS, turbidity, dissolved oxygen 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 many of Christchurch’s waterways are both historically and currently subjected to contamination, potentially from stormwater, wastewater and other inputs (e.g. waterfowl faeces and industrial discharges). 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; Margetts & Marshall, 2016). 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 for promoting improved catchment management practices in Christchurch. Such practices could include better treatment of stormwater and redirection of trade waste (e.g. vehicle wash-down water) 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 by CCC and 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, and new stormwater treatment facilities are built.

7 Acknowledgements

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8 References

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

Biggs, B.J.F., 1988. Algal proliferations in New Zealand's shallow stony foothills-fed rivers: towards a predictive model. *Verhandlungen der Internationalen Vereinigung fűr Theoretische und Angewandte Limnologie 23:* 1405-1411.

Biggs, B.J.F., 2000. The New Zealand periphyton guideline: detecting, monitoring and managing enrichment of streams. Ministry for the Environment, Wellington.

Christchurch City Council, 2003. Waterways, wetlands and drainage guide. Part B: design. Christchurch City Council, Christchurch.

Collier, K.J, Ball, O.J., Graesser, A. K., Main, M.R. & Winterbourn, M.J. 1990. Do organic and anthropogenic acidity have similar effects on aquatic fauna? *Oikos 59:* 33-38.

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

Dewson, Z, 2012. Christchurch Rivers water quality monitoring: annual results summary, May 2011 – April 2012. Christchurch City Council, Christchurch. TRIM # = 13/472519.
http://ccc.govt.nz/assets/Documents/Environment/Water/Monitoring-Reports/City-Wide-Surface-Water-Quality-2012-PDF-3.36-MB.PDF

Dewson, Z, 2013. South-West Stormwater Management Plan: Surface water quality monitoring, annual results summary, January – December 2012. Christchurch City Council, Christchurch.
http://ccc.govt.nz/assets/Documents/Environment/Water/Monitoring-Reports/South-West-SMP-Surface-Water-Quality-2013-PDF-0.58-MB.pdf

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

Environment Canterbury, 2011. Waimakariri River Regional Plan – Incorporating Change 1 to the Waimakariri Regional Plan. Environment Canterbury, Christchurch.

Environment Canterbury, 2015. Canterbury Land and Water Regional Plan - Volume 1. February 2017. Environment Canterbury, Christchurch.

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

Hickey, C.W., 2013. Updating nitrate toxicity effects on freshwater aquatic species. Report prepared for Ministry of Business, Innovation and Employment, Report No. HAM2013-009. NIWA, Hamilton.

Margetts, B.I., 2014a. Interim Global Stormwater Consent: Surface water quality monitoring report for the period May 2013 – April 2014. Christchurch City Council, Christchurch. TRIM # = 14/810303.
http://ccc.govt.nz/assets/Documents/Environment/Water/Monitoring-Reports/City-Wide-Surface-Water-Quality-2014-excluding-South-West-and-Styx-SMP-PDF-1.44-MB.pdf

Margetts, B., 2014b. Interim Global Stormwater Consent: wet weather monitoring report for the period May 2013 – April 2014. Christchurch City Council, Christchurch. TRIM # = 14/810311.
http://ccc.govt.nz/assets/Documents/Environment/Water/Monitoring-Reports/Interim-Global-Stormwater-Consent-Wet-Weather-Surface-Water-Quality-2014-PDF-1.45-MB.pdf

Margetts, B. & Marshall, W., 2015. Surface water quality monitoring report for Christchurch City waterways: January - December 2014. Christchurch City Council, Christchurch. TRIM # = 15/458527.
http://ccc.govt.nz/assets/Documents/Environment/Water/Monitoring-Reports/City-Wide-Surface-Water-Quality-2015-PDF-5.17-MB.PDF

Margetts, B. & Marshall, W., 2016. Surface water quality monitoring report for Christchurch City waterways: January - December 2015. Christchurch City Council, Christchurch. TRIM # = 16/935196.
https://www.ccc.govt.nz/assets/Documents/Environment/Water/Monitoring-Reports/City-Wide-Surface-Water-Quality-2016-PDF-6.03-MB.PDF

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

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

Moriarty, E & Gilpin, B. 2015. Faecal sources in the Avon River/Ōtakaro, Heathcote River/Ōpāwaho and the Estuary of the Heathcote & Avon Rivers/Ihutai. Report by the Institute of Environmental Science and Research Limited for Environment Canterbury, Community and Public Health, Christchurch City Council and the Ministry of Health. TRIM # = 15/1538419.
https://cccgovtnz.cwp.govt.nz/assets/Uploads/Faecal-source-tracking-of-Avon-and-Heathcote-Rivers-and-Avon-Heathcote-Estuary-2015-PDF-2.39-MB.pdf

Munro, B, 2015. CCC instream spring water quality project – Waimairi and Wairarapa Stream. Report by Pattle Delamore Partners Limited for Christchurch City Council, Christchurch. TRIM # = 16/15493.
https://cccgovtnz.cwp.govt.nz/assets/Uploads/Water-quality-of-instream-springs-in-Waimairi-and-Wairarapa-Streams-2015-PDF-10.6-MB.pdf

NIWA, 2014. Trend and equivalence analysis. Software Version 5.0. NIWA. http://www.jowettconsulting.co.nz/home/time-1/Timetrends_setup.zip?attredirects=0.

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

Silveira, F. C., 2017. Sources and transformation of nitrogen compounds in Haytons Stream, a low lying urban drainage stream in Christchurch, New Zealand. *MSc thesis*, Canterbury University, Christchurch. https://ir.canterbury.ac.nz/bitstream/handle/10092/13681/Silveira%2C%20Fabio%20Final%20Masters%20thesis.pdf?sequence=1

Wahl, C.M., Neils, A. & Hooper, D., 2013. Impacts of land use at the catchment scale constrain the habitat benefits of stream riparian buffers. *Freshwater Biology 58(11):* 2310-2324.

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

Whyte (now Margetts), B., 2013a. Christchurch Rivers water quality monitoring: annual results summary May 2012 – April 2013. Christchurch City Council, Christchurch. TRIM # = 13/776628. http://ccc.govt.nz/assets/Documents/Environment/Water/Monitoring-Reports/City-Wide-Surface-Water-Quality-2013-PDF-3.40-MB.pdf

Whyte (now Margetts), B., 2013b. Interim Global Stormwater Consent wet weather monitoring: annual results summary May 2012 – April 2013. Christchurch City Council, Christchurch. TRIM # = 13/726841. http://ccc.govt.nz/assets/Documents/Environment/Water/Monitoring-Reports/Interim-Global-Stormwater-Consent-Wet-Weather-Surface-Water-Quality-2013-PDF-0.42-MB.pdf

Whyte (now Margetts), B.I., 2014a. Styx Stormwater Management Plan: Surface water quality monitoring January – December 2013. Christchurch City Council, Christchurch. TRIM # = 14/394400. http://ccc.govt.nz/assets/Documents/Environment/Water/Monitoring-Reports/Styx-River-SMP-Surface-Water-Quality-2014-PDF-0.91-MB.pdf

Whyte (now Margetts), B.I., 2014b. South-West Stormwater Management Plan: Surface water quality monitoring January – December 2013. Christchurch City Council, Christchurch. TRIM # = 14/396577. https://cccgovtnz.cwp.govt.nz/assets/Uploads/City-Wide-Surface-Water-Quality-2014-South-West-SMP-PDF-2.084-MB.pdf

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 (mg/L)	Dissolved Lead (mg/L)	Dissolved Zinc (mg/L)	pH	Conductivity (µS/cm)	Total Suspended Solids (mg/L)	Turbidity (NTU)	Dissolved Oxygen Saturation (%)
Avon Catchment	Addington Brook	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.027000	7.700	298.00	3.000	4.2000	74.00
		Mean	.001267	.000750	.032975	7.625	286.00	5.958	4.9250	74.92
		Std. Error of Mean	.0001944	.0000000	.0072639	.083	9.868	2.4775	.51861	2.709
		Minimum	.0010	.0008	.0047	6.900	194	1.5	3.30	62
		Maximum	.0032	.0008	.0920	7.900	325	33.0	9.40	97
	Avon River at Avondale Road Bridge	N	12	12	12	12.000	12	12		12
		Median	.001000	.000750	.002400	7.850	315.00	1.500		90.50
		Mean	.001000	.000750	.004358	7.825	445.00	2.167		91.50
		Std. Error of Mean	.0000000	.0000000	.0012950	.045	106.358	.3218		2.709
		Minimum	.0010	.0008	.0005	7.500	180	1.5		80
		Maximum	.0010	.0008	.0150	8.000	1530	5.0		110
	Avon River at Bridge Street	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.004650	7.850	7610.00	20.000	11.0000	89.50
		Mean	.001000	.000750	.004258	7.875	8483.33	21.083	11.8917	92.17
		Std. Error of Mean	.0000000	.0000000	.0007743	.043	974.673	2.1407	1.02310	2.106
		Minimum	.0010	.0008	.0005	7.700	4700	14.0	7.90	85
		Maximum	.0010	.0008	.0090	8.100	15000	36.0	19.00	110
	Avon River at Carlton Mill Corner	N	12	12	12	12.000	12	12		12
		Median	.001000	.000750	.003450	7.600	169.50	1.500		97.50
		Mean	.001000	.000750	.004142	7.608	165.17	2.917		97.83
		Std. Error of Mean	.0000000	.0000000	.0009025	.058	1.988	.6566		1.988
		Minimum	.0010	.0008	.0005	7.200	149	1.5		89
		Maximum	.0010	.0008	.0110	8.000	170	8.0		110
	Avon River at Dallington Terrace/Gayhurst Road	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.004350	7.700	180.00	1.500	1.3000	82.50
		Mean	.001000	.000750	.005217	7.700	177.67	2.083	1.4300	85.58
		Std. Error of Mean	.0000000	.0000000	.0012196	.052	2.583	.2599	.16585	3.239
		Minimum	.0010	.0008	.0005	7.300	160	1.5	.86	70
		Maximum	.0010	.0008	.0160	7.900	192	4.0	3.00	110
	Avon River at Manchester Street	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.005050	7.700	180.00	1.500	1.1000	90.50
		Mean	.001000	.000750	.006783	7.650	176.67	3.667	1.7342	93.00
		Std. Error of Mean	.0000000	.0000000	.0018289	.065	1.963	1.6065	.68227	2.823

Catchment	Site		Dissolved Copper (mg/L)	Dissolved Lead (mg/L)	Dissolved Zinc (mg/L)	pH	Conductivity (µS/cm)	Total Suspended Solids (mg/L)	Turbidity (NTU)	Dissolved Oxygen Saturation (%)
		Minimum	.0010	.0008	.0005	7.200	159	1.5	.61	81
		Maximum	.0010	.0008	.0190	8.000	181	21.0	9.20	110
	Avon River at Mona Vale	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.005500	7.350	180.00	1.500	.5750	84.50
		Mean	.001000	.000750	.006450	7.308	180.00	1.958	.8658	84.00
		Std. Error of Mean	.0000000	.0000000	.0017382	.058	3.662	.4583	.28959	.953
		Minimum	.0010	.0008	.0005	6.900	146	1.5	.34	77
		Maximum	.0010	.0008	.0200	7.600	197	7.0	4.00	89
	Avon River at Pages/Seaview Bridge	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.003650	7.800	1200.00	7.000	4.5000	88.00
		Mean	.001000	.000750	.005417	7.833	1560.83	7.917	4.6833	92.00
		Std. Error of Mean	.0000000	.0000000	.0017914	.066	254.709	.6566	.37393	2.863
		Minimum	.0010	.0008	.0005	7.500	440	6.0	2.30	80
		Maximum	.0010	.0008	.0180	8.300	3200	14.0	7.10	110
	Dudley Creek	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.005650	7.700	152.00	9.500	5.8500	81.00
		Mean	.001000	.000750	.007450	7.700	154.67	10.417	7.3833	81.58
		Std. Error of Mean	.0000000	.0000000	.0017642	.052	3.294	1.3842	1.54977	.933
		Minimum	.0010	.0008	.0005	7.400	130	5.0	3.20	77
		Maximum	.0010	.0008	.0210	8.000	170	20.0	23.00	89
	Horseshoe Lake Discharge	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.002150	7.500	184.50	5.000	4.7000	74.00
		Mean	.001000	.000750	.002775	7.508	193.67	9.667	7.4667	73.67
		Std. Error of Mean	.0000000	.0000000	.0006338	.047	6.675	4.7758	3.08027	1.948
		Minimum	.0010	.0008	.0005	7.300	170	3.0	1.50	60
		Maximum	.0010	.0008	.0080	7.800	240	62.0	41.00	83
	Riccarton Main Drain	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.009450	7.550	260.00	1.500	.9450	90.50
		Mean	.001000	.000750	.010925	7.533	256.50	23.875	16.9817	90.25
		Std. Error of Mean	.0000000	.0000000	.0021811	.054	6.057	21.4739	15.73183	.509
		Minimum	.0010	.0008	.0021	7.200	200	1.5	.40	88
		Maximum	.0010	.0008	.0250	7.800	280	260.0	190.00	94
	Waimairi Stream	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.002050	7.400	160.00	1.500	.5100	78.50
		Mean	.001000	.000750	.003125	7.325	162.17	1.833	.5683	79.08
		Std. Error of Mean	.0000000	.0000000	.0011712	.064	1.862	.2330	.05803	.793
		Minimum	.0010	.0008	.0005	6.900	148	1.5	.27	74

Catchment	Site		Dissolved Copper (mg/L)	Dissolved Lead (mg/L)	Dissolved Zinc (mg/L)	pH	Conductivity (µS/cm)	Total Suspended Solids (mg/L)	Turbidity (NTU)	Dissolved Oxygen Saturation (%)
		Maximum	.0010	.0008	.0150	7.600	170	4.0	.89	83
	Wairarapa Stream	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.002800	7.300	160.00	1.500	.5550	81.00
		Mean	.001000	.000750	.003242	7.258	157.33	5.250	1.3950	84.08
		Std. Error of Mean	.0000000	.0000000	.0008215	.071	1.529	2.5970	.56998	3.467
		Minimum	.0010	.0008	.0005	6.900	145	1.5	.20	72
		Maximum	.0010	.0008	.0100	7.600	162	33.0	6.90	110
Halswell Catchment	Halswell Retention Basin Inlet	N	12	12	12	12.000	12	12		12
		Median	.003750	.000750	.070000	7.500	145.50	13.000		66.50
		Mean	.003708	.000750	.084750	7.558	147.34	14.583		62.33
		Std. Error of Mean	.0002644	.0000000	.0164433	.110	11.441	1.7815		5.256
		Minimum	.0022	.0008	.0120	7.100	94	7.0		34
		Maximum	.0060	.0008	.1800	8.300	214	27.0		97
	Halswell Retention Basin Outlet	N	12	12	12	12.000	12	12		12
		Median	.004300	.000750	.036000	7.550	117.50	8.500		88.50
		Mean	.004458	.000846	.037525	7.833	118.94	9.667		93.58
		Std. Error of Mean	.0003463	.0000958	.0065371	.213	6.196	1.4372		6.655
		Minimum	.0031	.0008	.0073	7.300	87	4.0		71
		Maximum	.0069	.0019	.0790	9.800	160	17.0		160
	Halswell River at Akaroa Highway (Tai Tapu Road)	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.001900	7.800	222.00	5.000	2.4500	98.00
		Mean	.001000	.000750	.002100	7.767	220.17	7.583	3.9417	97.50
		Std. Error of Mean	.0000000	.0000000	.0004870	.031	3.672	2.2155	.99327	3.039
		Minimum	.0010	.0008	.0005	7.600	190	1.5	1.30	85
		Maximum	.0010	.0008	.0057	7.900	233	28.0	13.00	110
	Knights Stream at Sabys Road	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.000800	7.500	230.00	2.750	1.1500	96.50
		Mean	.001092	.000750	.001133	7.475	227.42	5.333	2.9083	95.92
		Std. Error of Mean	.0000917	.0000000	.0002320	.039	3.218	1.5982	.97731	3.024
		Minimum	.0010	.0008	.0005	7.300	204	1.5	.57	83
		Maximum	.0021	.0008	.0026	7.700	240	19.0	11.00	110
	Nottingham Stream at Candys Road	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.011500	7.600	218.00	4.000	1.4500	77.50
		Mean	.001108	.000750	.022050	7.533	199.83	5.833	2.4075	77.42
		Std. Error of Mean	.0001083	.0000000	.0052734	.089	13.897	1.8436	.51270	2.560
		Minimum	.0010	.0008	.0069	6.800	64	1.5	.80	64
		Maximum	.0023	.0008	.0580	7.900	232	24.0	6.50	92

Catchment	Site		Dissolved Copper (mg/L)	Dissolved Lead (mg/L)	Dissolved Zinc (mg/L)	pH	Conductivity (µS/cm)	Total Suspended Solids (mg/L)	Turbidity (NTU)	Dissolved Oxygen Saturation (%)
Heathcote Catchment	Cashmere Stream at Sutherlands Road	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.001800	7.100	340.00	1.500	.2900	49.00
		Mean	.001167	.000750	.003742	7.075	336.25	1.500	.3250	55.67
		Std. Error of Mean	.0001667	.0000000	.0012238	.039	1.702	.0000	.02864	4.663
		Minimum	.0010	.0008	.0005	6.800	327	1.5	.20	36
		Maximum	.0030	.0008	.0130	7.300	344	1.5	.51	79
	Cashmere Stream at Worsleys Road	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.002300	7.700	251.00	4.000	3.2000	85.00
		Mean	.001000	.000750	.003383	7.617	244.17	5.250	3.4833	86.67
		Std. Error of Mean	.0000000	.0000000	.0008193	.058	6.130	.9760	.54507	3.465
		Minimum	.0010	.0008	.0005	7.200	190	1.5	.90	70
		Maximum	.0010	.0008	.0087	7.900	263	12.0	8.00	110
	Curletts Road Stream at Motorway	N	12	12	12	12.000	12	12		12
		Median	.005700	.000750	.190000	7.400	303.00	4.500		59.00
		Mean	.006408	.000750	.233875	7.317	271.25	7.500		60.92
		Std. Error of Mean	.0011508	.0000000	.0526883	.081	25.097	2.3781		7.138
		Minimum	.0010	.0008	.0005	6.800	110	1.5		30
		Maximum	.0160	.0008	.5700	7.700	361	31.0		120
	Curletts Road Stream Upstream of Heathcote River	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.027000	7.250	287.50	4.000	3.3500	59.00
		Mean	.001825	.000750	.067875	7.208	264.58	8.708	4.3417	59.83
		Std. Error of Mean	.0004257	.0000000	.0301707	.091	22.842	2.9197	1.09548	7.739
		Minimum	.0010	.0008	.0005	6.600	110	1.5	1.60	13
		Maximum	.0057	.0008	.3700	7.700	381	33.0	15.00	110
	Haytons Stream at Retention Basin	N	12	12	12	12.000	12	12	12	12
		Median	.001650	.000750	.045000	7.300	104.90	8.000	6.0000	81.50
		Mean	.002058	.000750	.065642	7.233	117.03	8.083	6.1750	81.92
		Std. Error of Mean	.0003667	.0000000	.0158255	.111	10.470	1.3496	.72667	5.376
		Minimum	.0010	.0008	.0087	6.600	80	1.5	2.20	42
		Maximum	.0047	.0008	.1800	7.800	200	16.0	10.00	110
	Heathcote River at Bowenvale Avenue	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.006650	7.750	264.50	4.000	2.9000	85.00
		Mean	.001242	.000750	.012175	7.675	248.25	7.958	4.0583	84.58
		Std. Error of Mean	.0002417	.0000000	.0036508	.077	13.363	3.6037	1.20589	3.480
		Minimum	.0010	.0008	.0005	7.100	120	1.5	1.20	65
		Maximum	.0039	.0008	.0390	8.000	280	47.0	17.00	110
	Heathcote River at Catherine Street	N	12	12	12	12.000	12	12		12

Catchment	Site		Dissolved Copper (mg/L)	Dissolved Lead (mg/L)	Dissolved Zinc (mg/L)	pH	Conductivity (µS/cm)	Total Suspended Solids (mg/L)	Turbidity (NTU)	Dissolved Oxygen Saturation (%)
		Median	.001000	.000750	.006400	7.700	320.00	5.000		70.00
		Mean	.001142	.000750	.009542	7.642	377.67	6.333		71.00
		Std. Error of Mean	.0001417	.0000000	.0021430	.078	55.694	.9949		4.705
		Minimum	.0010	.0008	.0005	7.100	170	4.0		46
		Maximum	.0027	.0008	.0250	8.000	780	15.0		110
	Heathcote River at Ferniehurst Street	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.008950	7.700	258.50	5.000	3.1500	83.00
		Mean	.001317	.000750	.017325	7.575	245.67	5.750	4.2000	82.25
		Std. Error of Mean	.0001683	.0000000	.0051320	.073	10.260	1.0363	.70999	3.010
		Minimum	.0010	.0008	.0038	7.100	160	1.5	1.20	64
		Maximum	.0025	.0008	.0570	7.900	272	13.0	10.00	100
	Heathcote River at Ferrymead Bridge	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.009900	7.750	14100.00	32.000	18.5000	86.50
		Mean	.001083	.000750	.013217	7.733	12359.42	34.750	19.1417	85.42
		Std. Error of Mean	.0000833	.0000000	.0023499	.053	1943.575	3.8791	2.70164	1.798
		Minimum	.0010	.0008	.0050	7.400	963	20.0	2.70	76
		Maximum	.0020	.0008	.0300	8.100	22000	62.0	36.00	100
	Heathcote River at MacKenzie Avenue	N	12	12	12	12.000	12	12		12
		Median	.001000	.000750	.008900	7.700	290.00	3.000		72.50
		Mean	.001242	.000750	.009667	7.625	269.58	3.542		72.25
		Std. Error of Mean	.0002417	.0000000	.0017307	.076	15.431	.9282		3.782
		Minimum	.0010	.0008	.0032	7.000	120	1.5		52
		Maximum	.0039	.0008	.0210	7.900	304	13.0		100
	Heathcote River at Opawa Road/Clarendon Terrace	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.005350	7.700	290.00	3.000	1.8500	73.00
		Mean	.001183	.000750	.007475	7.617	268.08	3.375	2.4667	75.17
		Std. Error of Mean	.0001833	.0000000	.0019757	.076	15.798	.7259	.40775	4.097
		Minimum	.0010	.0008	.0005	7.000	110	1.5	1.10	57
		Maximum	.0032	.0008	.0210	7.900	300	10.0	5.90	110
	Heathcote River at Rose Street	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.048000	7.550	277.50	2.250	1.7500	84.50
		Mean	.002150	.000862	.058500	7.400	245.67	3.417	2.6750	81.17
		Std. Error of Mean	.0006248	.0001125	.0108275	.089	18.995	.7854	.46680	3.651
		Minimum	.0010	.0008	.0200	6.800	110	1.5	1.30	60
		Maximum	.0072	.0021	.1300	7.700	309	10.0	5.90	97
	Heathcote River at Templetons Road	N	1	1	1	1.000	1	1	1	1
		Median	.001000	.000750	.016000	6.900	270.00	9.000	3.9000	24.00

Catchment	Site		Dissolved Copper (mg/L)	Dissolved Lead (mg/L)	Dissolved Zinc (mg/L)	pH	Conductivity (µS/cm)	Total Suspended Solids (mg/L)	Turbidity (NTU)	Dissolved Oxygen Saturation (%)
		Mean	.001000	.000750	.016000	6.900	270.00	9.000	3.9000	24.00
		Std. Error of Mean	.	.	.		.	.	.	.
		Minimum	.0010	.0008	.0160	6.900	270	9.0	3.90	24
		Maximum	.0010	.0008	.0160	6.900	270	9.0	3.90	24
	Heathcote River at Tunnel Road	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.007800	7.800	2865.00	21.000	11.5000	78.50
		Mean	.001192	.000750	.011800	7.725	2796.92	23.000	13.7333	79.33
		Std. Error of Mean	.0001917	.0000000	.0028571	.071	406.756	2.6285	1.78352	4.410
		Minimum	.0010	.0008	.0005	7.300	800	13.0	5.90	56
		Maximum	.0033	.0008	.0290	8.200	4800	37.0	25.00	120
Linwood Canal	Linwood Canal/City Outfall Drain	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.007400	7.700	4800.00	7.000	4.4500	60.50
		Mean	.001292	.000750	.009358	7.750	5565.83	7.583	4.6667	62.33
		Std. Error of Mean	.0002917	.0000000	.0022598	.047	925.517	1.1312	.53546	4.527
		Minimum	.0010	.0008	.0012	7.600	2090	4.0	2.70	40
		Maximum	.0045	.0008	.0230	8.000	13100	16.0	8.60	89
Ōtūkaikino Catchment	Ōtūkaikino Creek at Omaka Scout Camp	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.001200	7.350	80.00	1.500	.3000	85.50
		Mean	.001000	.000750	.001150	7.258	80.89	1.833	.3333	87.92
		Std. Error of Mean	.0000000	.0000000	.0001921	.057	.535	.2330	.01880	2.072
		Minimum	.0010	.0008	.0005	6.900	79	1.5	.25	77
		Maximum	.0010	.0008	.0023	7.500	84	4.0	.45	100
	Ōtūkaikino River at Groynes Inlet	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.001400	7.400	75.65	1.500	.3050	86.50
		Mean	.001000	.000750	.002383	7.292	75.78	1.500	.3517	88.58
		Std. Error of Mean	.0000000	.0000000	.0010205	.056	.319	.0000	.03457	1.794
		Minimum	.0010	.0008	.0005	7.000	74	1.5	.20	81
		Maximum	.0010	.0008	.0130	7.500	78	1.5	.63	100
	Wilsons Stream	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.000500	7.800	130.00	3.000	1.9500	100.00
		Mean	.001000	.000750	.001033	8.025	128.33	4.458	2.7950	101.25
		Std. Error of Mean	.0000000	.0000000	.0003206	.136	1.924	1.0196	.70405	4.528
		Minimum	.0010	.0008	.0005	7.500	120	1.5	.34	81
		Maximum	.0010	.0008	.0043	9.200	140	12.0	8.10	140
Styx Catchment	Kā Pūtahi Creek at Belfast Road	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.001900	7.600	148.50	7.500	3.5500	79.00
		Mean	.001000	.000750	.002342	7.617	145.25	8.833	3.9333	79.92

Catchment	Site		Dissolved Copper (mg/L)	Dissolved Lead (mg/L)	Dissolved Zinc (mg/L)	pH	Conductivity (µS/cm)	Total Suspended Solids (mg/L)	Turbidity (NTU)	Dissolved Oxygen Saturation (%)
		Std. Error of Mean	.0000000	.0000000	.0007340	.042	1.577	.9834	.36893	1.901
		Minimum	.0010	.0008	.0005	7.300	137	4.0	2.40	72
		Maximum	.0010	.0008	.0100	7.800	150	15.0	6.20	95
	Kā Pūtahi Creek at Blakes Road	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.003950	7.350	160.00	3.500	1.3000	76.00
		Mean	.001392	.000750	.005875	7.325	161.67	4.417	3.0000	74.17
		Std. Error of Mean	.0003917	.0000000	.0015104	.048	5.357	1.0147	1.55559	2.907
		Minimum	.0010	.0008	.0005	7.000	132	1.5	.80	53
		Maximum	.0057	.0008	.0200	7.600	200	13.0	20.00	89
	Smacks Creek at Gardiners Road	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.001400	7.250	110.00	1.500	.3250	68.00
		Mean	.001000	.000750	.001992	7.158	109.58	2.000	.4017	68.67
		Std. Error of Mean	.0000000	.0000000	.0004603	.061	.398	.3844	.07457	1.990
		Minimum	.0010	.0008	.0005	6.800	107	1.5	.15	58
		Maximum	.0010	.0008	.0060	7.400	112	6.0	1.10	79
	Styx River at Gardiners Road	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.000850	7.100	105.50	1.500	.6600	62.50
		Mean	.001000	.000750	.002217	7.025	105.58	2.792	1.1808	63.50
		Std. Error of Mean	.0000000	.0000000	.0008803	.064	1.151	.8199	.37099	1.177
		Minimum	.0010	.0008	.0005	6.700	100	1.5	.51	60
		Maximum	.0010	.0008	.0110	7.300	110	11.0	5.10	73
	Styx River at Harbour Road Bridge	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.001450	7.600	143.50	2.250	2.3000	82.00
		Mean	.001000	.000750	.001992	7.600	149.67	3.250	2.3417	79.75
		Std. Error of Mean	.0000000	.0000000	.0004434	.041	6.835	.6440	.30037	3.591
		Minimum	.0010	.0008	.0005	7.300	120	1.5	.70	50
		Maximum	.0010	.0008	.0049	7.800	198	8.0	4.20	92
	Styx River at Main North Road	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.001950	7.500	118.50	1.500	.9350	85.50
		Mean	.001000	.000750	.002042	7.425	116.42	2.042	1.0292	86.08
		Std. Error of Mean	.0000000	.0000000	.0003665	.049	1.221	.2917	.11081	1.401
		Minimum	.0010	.0008	.0005	7.100	110	1.5	.66	80
		Maximum	.0010	.0008	.0054	7.600	120	4.0	1.80	94
	Styx River at Marshland Road Bridge	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.001450	7.700	120.00	2.250	1.9500	90.50
		Mean	.001000	.000750	.002725	7.742	122.92	3.583	2.1000	88.83
		Std. Error of Mean	.0000000	.0000000	.0011447	.038	1.209	.8044	.30101	2.269

Catchment	Site		Dissolved Copper (mg/L)	Dissolved Lead (mg/L)	Dissolved Zinc (mg/L)	pH	Conductivity (µS/cm)	Total Suspended Solids (mg/L)	Turbidity (NTU)	Dissolved Oxygen Saturation (%)
		Minimum	.0010	.0008	.0005	7.500	119	1.5	.80	75
		Maximum	.0010	.0008	.0140	8.000	130	10.0	4.20	98
	Styx River at Richards Bridge	N	12	12	12	12.000	12	12	12	12
		Median	.001000	.000750	.001300	7.600	130.00	6.500	3.2000	84.50
		Mean	.001000	.000750	.001525	7.625	128.00	7.583	3.7417	82.67
		Std. Error of Mean	.0000000	.0000000	.0003276	.041	1.692	1.6752	.76192	2.840
		Minimum	.0010	.0008	.0005	7.400	120	1.5	.90	63
		Maximum	.0010	.0008	.0046	7.900	138	22.0	9.40	96

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

Catchment	Address		Temperature (°C)	BOD5 (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Nitrate+Nitrite Nitrogen (mg/L)	Dissolved Inorganic Nitrogen (mg/L)	Dissolved Reactive Phosphorus (mg/L)	E. coli (CFU/100ml)
Avon Catchment	Addington Brook	N	12	12	12	12	12	12	12	12
		Median	13.700	.5000	.10450	.95000	.96500	1.05000	.024000	560.00
		Mean	13.374	.8167	.08667	.93417	.95250	1.03000	.023400	1379.17
		Std. Error of Mean	.9788	.14865	.013635	.077728	.077695	.084154	.0023669	616.932
		Minimum	7.6	.50	.018	.420	.440	.550	.0068	110
		Maximum	19.6	1.80	.150	1.400	1.400	1.500	.0360	7300
	Avon River at Avondale Road Bridge	N	12	12	12	12	12	12	12	12
		Median	14.600	.5000	.02150	.68000	.69000	.71000	.027500	109.00
		Mean	14.400	.5000	.02613	.62492	.63250	.66000	.028833	140.92
		Std. Error of Mean	.9861	.00000	.004667	.059594	.060266	.059122	.0023863	28.630
		Minimum	8.8	.50	.003	.200	.200	.270	.0160	31
		Maximum	19.0	.50	.065	.840	.850	.890	.0480	360
	Avon River at Bridge Street	N	12	12	12	12	12	12	12	12
		Median	14.450	.5000	.07150	.54450	.54950	.62500	.032500	340.00
		Mean	14.650	.6583	.07067	.51067	.51733	.58833	.034667	372.75
		Std. Error of Mean	1.1854	.12026	.006814	.048495	.049003	.049982	.0030658	81.725
		Minimum	8.5	.50	.024	.270	.270	.340	.0170	63
		Maximum	21.0	1.90	.099	.730	.740	.830	.0600	910
	Avon River at Carlton Mill Corner	N	12	12	12	12	12	12	12	12
		Median	13.250	.5000	.01650	1.20000	1.20000	1.20000	.007500	345.00
		Mean	13.525	.5000	.01692	1.20833	1.20833	1.20833	.008058	461.75
		Std. Error of Mean	.4660	.00000	.001848	.033616	.033616	.033616	.0008400	131.082
		Minimum	11.3	.50	.008	1.000	1.000	1.000	.0035	31
		Maximum	17.1	.50	.027	1.400	1.400	1.400	.0140	1700
	Avon River at Dallington Terrace/Gayhurst Road	N	12	12	12	12	12	12	12	12
		Median	13.700	.5000	.02650	.92000	.90000	.93000	.022500	170.00
		Mean	13.607	.5583	.03425	1.00000	.79925	.83417	.020617	218.50
		Std. Error of Mean	.7280	.05833	.007527	.140292	.077154	.074024	.0018970	49.878
		Minimum	9.7	.50	.011	.660	.031	.130	.0084	10
		Maximum	18.0	1.20	.102	2.500	1.000	1.100	.0300	550
	Avon River at Manchester Street	N	12	12	12	12	12	12	12	12
		Median	13.150	.5000	.01950	1.10000	1.10000	1.10000	.011500	435.00
		Mean	13.242	.5000	.02225	1.05167	1.05250	1.05833	.011775	422.50
		Std. Error of Mean	.5005	.00000	.002441	.054172	.053980	.051945	.0012442	80.294
		Minimum	10.4	.50	.013	.590	.590	.610	.0038	130

Catchment	Address		Temperature (°C)	BOD5 (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Nitrate+Nitrite Nitrogen (mg/L)	Dissolved Inorganic Nitrogen (mg/L)	Dissolved Reactive Phosphorus (mg/L)	E. coli (CFU/100ml)
		Maximum	16.3	.50	.042	1.300	1.300	1.300	.0190	1000
	Avon River at Mona Vale	N	12	12	12	12	12	12	12	12
		Median	13.300	.5000	.01200	2.00000	2.00000	2.00000	.007550	290.00
		Mean	13.492	.5000	.01458	1.92500	1.92500	1.92500	.007867	535.00
		Std. Error of Mean	.2838	.00000	.002330	.059193	.059193	.059193	.0009787	151.795
		Minimum	11.9	.50	.005	1.500	1.500	1.500	.0015	150
		Maximum	15.5	.50	.036	2.200	2.200	2.200	.0140	1800
	Avon River at Pages/Seaview Bridge	N	12	12	12	12	12	12	12	12
		Median	14.450	.5000	.03100	.61000	.62000	.65000	.031000	125.00
		Mean	14.575	.5000	.03517	.58742	.59483	.63167	.031250	259.17
		Std. Error of Mean	1.1546	.00000	.005027	.047276	.048411	.049326	.0017457	72.677
		Minimum	8.3	.50	.012	.289	.289	.330	.0220	52
		Maximum	21.0	.50	.067	.770	.790	.860	.0400	860
	Dudley Creek	N	12	12	12	12	12	12	12	12
		Median	13.100	.5000	.09000	.24000	.25500	.35000	.044500	1150.00
		Mean	13.066	.8667	.09958	.25833	.27167	.37167	.044083	1549.17
		Std. Error of Mean	.8044	.29448	.015966	.015167	.015803	.029072	.0023788	521.040
		Minimum	8.2	.50	.032	.200	.210	.260	.0310	190
		Maximum	17.0	4.00	.220	.340	.360	.530	.0630	6900
	Horseshoe Lake Discharge	N	12	12	12	12	12	12	12	12
		Median	12.950	.5000	.08700	.21500	.22000	.30500	.042500	800.00
		Mean	12.775	.6833	.09250	.24992	.25917	.35083	.041167	1035.00
		Std. Error of Mean	.8990	.12603	.009739	.030541	.030587	.037869	.0031571	271.825
		Minimum	7.3	.50	.050	.160	.170	.240	.0180	190
		Maximum	17.0	1.80	.150	.490	.500	.650	.0540	3700
	Riccarton Main Drain	N	12	12	12	12	12	12	12	12
		Median	14.150	.5000	.01850	2.85000	2.85000	2.85000	.013000	220.00
		Mean	13.842	.5000	.02100	2.62492	2.62492	2.62417	.012483	450.92
		Std. Error of Mean	.3406	.00000	.001267	.208587	.208587	.208695	.0014037	260.903
		Minimum	12.0	.50	.017	1.300	1.300	1.300	.0015	31
		Maximum	15.8	.50	.030	3.500	3.500	3.500	.0220	3300
	Waimairi Stream	N	12	12	12	12	12	12	12	12
		Median	13.200	.5000	.01250	1.45000	1.45000	1.45000	.008050	240.00
		Mean	13.383	.5000	.01275	1.39167	1.40000	1.40000	.007775	459.08
		Std. Error of Mean	.2377	.00000	.001175	.052884	.050752	.050752	.0007271	173.520
		Minimum	12.2	.50	.005	1.000	1.000	1.000	.0015	52
		Maximum	15.4	.50	.020	1.600	1.600	1.600	.0110	2000

Catchment	Address		Temperature (°C)	BOD5 (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Nitrate+Nitrite Nitrogen (mg/L)	Dissolved Inorganic Nitrogen (mg/L)	Dissolved Reactive Phosphorus (mg/L)	E. coli (CFU/100ml)
	Wairarapa Stream	N	12	12	12	12	12	12	12	12
		Median	13.500	.5000	.01700	.72500	.73000	.75000	.006450	180.00
		Mean	13.483	.5000	.01525	.71325	.71658	.73333	.006283	279.00
		Std. Error of Mean	.3931	.00000	.001814	.026874	.026791	.026977	.0008103	62.217
		Minimum	11.4	.50	.006	.579	.579	.600	.0015	52
		Maximum	16.3	.50	.024	.840	.840	.860	.0110	640
Halswell Catchment	Halswell Retention Basin Inlet	N	12	12	12	12	12	12	12	12
		Median	15.500	3.2000	.80500	1.10000	1.20000	2.55000	.071000	195.00
		Mean	15.525	3.2167	1.10967	1.30500	1.41417	2.52833	.083708	705.50
		Std. Error of Mean	1.3809	.27131	.281558	.210153	.223507	.343709	.0154477	527.648
		Minimum	8.1	1.80	.096	.780	.840	.940	.0085	10
		Maximum	22.3	4.60	3.400	3.500	3.700	4.400	.2200	6500
	Halswell Retention Basin Outlet	N	12	12	12	12	12	12	12	12
		Median	15.100	2.2500	.24000	1.10000	1.15000	1.30000	.025500	58.00
		Mean	15.083	2.3833	.26433	1.07750	1.13417	1.39667	.032050	697.92
		Std. Error of Mean	1.4680	.38076	.066922	.112856	.112832	.153165	.0072934	535.008
		Minimum	7.1	.50	.012	.320	.450	.480	.0044	5
		Maximum	22.2	5.10	.690	1.900	2.000	2.600	.0850	6500
	Halswell River at Akaroa Highway (Tai Tapu Road)	N	12	12	12	12	12	12	12	12
		Median	13.050	.5000	.02450	3.70000	3.70000	3.70000	.016500	540.00
		Mean	13.375	.5000	.03900	3.65000	3.65833	3.69167	.016833	1267.50
		Std. Error of Mean	.7231	.00000	.010103	.129977	.131113	.137873	.0010063	572.339
		Minimum	8.8	.50	.012	2.900	2.900	2.900	.0120	330
		Maximum	17.6	.50	.142	4.500	4.500	4.500	.0240	7300
	Knights Stream at Sabys Road	N	12	12	12	12	12	12	12	12
		Median	12.950	.5000	.02550	4.55000	4.55000	4.55000	.006150	865.00
		Mean	13.192	.5000	.02717	4.53333	4.55833	4.57500	.006050	990.83
		Std. Error of Mean	.4765	.00000	.003745	.109637	.102586	.109493	.0006784	171.577
		Minimum	10.1	.50	.014	3.700	3.800	3.800	.0015	110
		Maximum	15.9	.50	.059	5.000	5.000	5.100	.0100	2100
	Nottingham Stream at Candys Road	N	12	12	12	12	12	12	12	12
		Median	12.700	.5000	.05650	.43500	.44500	.51000	.042000	1040.00
		Mean	12.817	.8583	.05250	.41200	.42100	.47500	.053250	3359.25
		Std. Error of Mean	.9704	.14379	.003274	.061743	.062944	.063323	.0082583	1932.478
		Minimum	6.9	.50	.027	.044	.042	.070	.0240	41
		Maximum	18.7	2.00	.067	.660	.670	.720	.1100	24000
Heathcote Catchment	Cashmere Stream at Sutherlands	N	12	12	12	11	12	12	12	12

Catchment	Address		Temperature (°C)	BOD5 (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Nitrate+Nitrite Nitrogen (mg/L)	Dissolved Inorganic Nitrogen (mg/L)	Dissolved Reactive Phosphorus (mg/L)	E. coli (CFU/100ml)
	Road	Median	14.350	.5000	.01050	1.90000	1.90000	1.90000	.002300	36.00
		Mean	14.417	.5000	.01329	1.90909	1.91667	1.91667	.002625	50.92
		Std. Error of Mean	.3561	.00000	.002302	.077991	.071598	.071598	.0003606	13.212
		Minimum	12.6	.50	.006	1.600	1.600	1.600	.0015	5
		Maximum	16.6	.50	.030	2.300	2.300	2.300	.0047	150
	Cashmere Stream at Worsleys Road	N	12	12	12	12	12	12	12	12
		Median	13.200	.5000	.01800	1.70000	1.70000	1.70000	.011500	350.00
		Mean	13.192	.5500	.02379	1.70000	1.70000	1.70833	.011975	776.67
		Std. Error of Mean	.5188	.05000	.005518	.079772	.079772	.082992	.0012284	430.624
		Minimum	9.9	.50	.003	1.100	1.100	1.100	.0057	120
		Maximum	15.9	1.10	.074	2.100	2.100	2.100	.0220	5500
	Curletts Road Stream at Motorway	N	12	12	12	12	12	12	12	12
		Median	12.800	.8000	.11000	.51000	.53500	.71000	.035000	265.00
		Mean	13.158	1.0167	.13317	.64667	.65917	.80500	.043083	1230.58
		Std. Error of Mean	1.1981	.18000	.023659	.126774	.126026	.126506	.0060771	805.248
		Minimum	5.7	.50	.035	.180	.190	.300	.0180	31
		Maximum	18.5	2.40	.270	1.400	1.400	1.500	.0870	9800
	Curletts Road Stream Upstream of Heathcote River	N	12	12	12	12	12	12	12	12
		Median	13.050	.5000	.11000	.91000	.91500	1.10000	.052000	235.00
		Mean	13.658	1.1917	.22892	1.05392	1.07958	1.30667	.106475	1093.08
		Std. Error of Mean	1.0051	.43125	.067340	.236460	.242642	.277323	.0379730	794.897
		Minimum	7.7	.50	.018	.007	.005	.090	.0057	10
		Maximum	19.1	5.30	.660	2.400	2.500	3.100	.4500	9800
	Haytons Stream at Retention Basin	N	12	12	12	12	12	12	12	12
		Median	14.250	3.0000	.68000	.42000	.45000	1.17000	.540000	124.00
		Mean	14.233	3.3250	1.01183	.57533	.62983	1.63917	.532500	1759.08
		Std. Error of Mean	1.3140	.54719	.317389	.146885	.162773	.473778	.0655296	1407.874
		Minimum	6.8	.50	.015	.054	.060	.130	.1100	5
		Maximum	20.2	6.90	3.500	1.800	2.000	5.500	.8400	17000
	Heathcote River at Bowenvale Avenue	N	11	12	12	12	12	12	12	12
		Median	13.500	.5000	.03450	1.65000	1.70000	1.70000	.022500	515.00
		Mean	13.518	.7667	.03825	1.60417	1.62167	1.63500	.033917	1841.50
		Std. Error of Mean	.7281	.14477	.007278	.103070	.100678	.094936	.0100517	1206.239
		Minimum	9.7	.50	.015	.650	.660	.720	.0140	63
		Maximum	17.5	1.80	.110	2.000	2.000	2.000	.1400	15000
	Heathcote River at Catherine Street	N	12	12	12	12	12	12	12	12
		Median	13.500	.5000	.07600	1.25000	1.25000	1.35000	.030500	300.00

Catchment	Address		Temperature (°C)	BOD5 (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Nitrate+Nitrite Nitrogen (mg/L)	Dissolved Inorganic Nitrogen (mg/L)	Dissolved Reactive Phosphorus (mg/L)	E. coli (CFU/100ml)
		Mean	14.150	.6667	.06892	1.27000	1.28250	1.35583	.035417	1328.33
		Std. Error of Mean	.8349	.16667	.009187	.081891	.083159	.082732	.0058974	792.592
		Minimum	9.9	.50	.017	.660	.680	.770	.0130	120
		Maximum	18.6	2.50	.120	1.600	1.700	1.800	.0920	9800
	Heathcote River at Ferniehurst Street	N	12	12	12	12	12	12	12	12
		Median	13.000	.5000	.03800	1.90000	1.90000	1.90000	.022500	590.00
		Mean	13.192	.5750	.04758	1.81083	1.81167	1.84833	.035167	3035.83
		Std. Error of Mean	.6209	.07500	.010396	.099829	.099162	.095520	.0109148	1988.633
		Minimum	9.6	.50	.027	.930	.940	.980	.0140	190
		Maximum	16.6	1.40	.160	2.100	2.100	2.200	.1500	24000
	Heathcote River at Ferrymead Bridge	N	12	12	12	12	12	12	12	12
		Median	14.100	.5000	.10500	.79000	.80500	.90500	.035500	305.00
		Mean	14.808	.6500	.11208	.82583	.85167	.96917	.039667	810.00
		Std. Error of Mean	1.1192	.10408	.008577	.073562	.077897	.079720	.0024965	335.801
		Minimum	9.7	.50	.076	.470	.490	.610	.0310	52
		Maximum	19.8	1.60	.180	1.200	1.300	1.500	.0550	3900
	Heathcote River at MacKenzie Avenue	N	12	12	12	12	12	12	12	12
		Median	13.350	.5000	.07350	1.50000	1.50000	1.55000	.027500	355.00
		Mean	13.967	.6333	.07475	1.44583	1.46417	1.54083	.034750	1156.08
		Std. Error of Mean	.7701	.13333	.011617	.105790	.102967	.099472	.0070616	805.894
		Minimum	10.0	.50	.017	.550	.570	.690	.0120	63
		Maximum	18.1	2.10	.120	2.000	2.000	2.000	.0860	10000
	Heathcote River at Opawa Road/Clarendon Terrace	N	12	12	12	12	12	12	12	12
		Median	13.600	.5000	.07000	1.60000	1.60000	1.65000	.026000	255.00
		Mean	13.983	.6417	.06575	1.46667	1.48417	1.55833	.032583	695.50
		Std. Error of Mean	.7441	.14167	.008126	.106126	.106426	.106215	.0066850	411.674
		Minimum	10.2	.50	.019	.400	.410	.500	.0120	86
		Maximum	18.2	2.20	.110	1.800	1.800	1.900	.0890	5200
	Heathcote River at Rose Street	N	12	12	12	12	12	12	12	12
		Median	12.900	1.1500	.10000	1.55000	1.55000	1.70000	.060500	800.00
		Mean	13.567	1.0250	.12758	1.62833	1.64833	1.77167	.092333	3398.33
		Std. Error of Mean	.9388	.15182	.015741	.190179	.191017	.193414	.0243171	1581.352
		Minimum	8.6	.50	.075	.470	.480	.560	.0230	160
		Maximum	18.5	2.10	.220	2.600	2.700	2.900	.3300	17000
	Heathcote River at Templetons Road	N	1	1	1	1	1	1	1	1
		Median	17.900	2.9000	1.10000	.42000	.52000	1.60000	.048000	14000.00
		Mean	17.900	2.9000	1.10000	.42000	.52000	1.60000	.048000	14000.00

Catchment	Address		Temperature (°C)	BOD5 (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Nitrate+Nitrite Nitrogen (mg/L)	Dissolved Inorganic Nitrogen (mg/L)	Dissolved Reactive Phosphorus (mg/L)	E. coli (CFU/100ml)
		Std. Error of Mean	.	.	.	.	.	.	.	.
		Minimum	17.9	2.90	1.100	.420	.520	1.600	.0480	14000
		Maximum	17.9	2.90	1.100	.420	.520	1.600	.0480	14000
	Heathcote River at Tunnel Road	N	12	12	12	12	12	12	12	12
		Median	14.300	.5000	.09400	1.10000	1.10000	1.20000	.034000	400.00
		Mean	14.792	.7750	.08250	1.09250	1.10583	1.18583	.038167	1254.42
		Std. Error of Mean	1.0094	.15913	.012867	.088482	.089548	.084580	.0047607	616.569
		Minimum	9.8	.50	.010	.500	.520	.630	.0190	86
		Maximum	19.8	2.10	.140	1.500	1.500	1.600	.0760	7700
Linwood Canal	Linwood Canal/City Outfall Drain	N	12	12	12	12	12	12	12	12
		Median	13.500	.5000	.26000	.06500	.07200	.40000	.050500	200.00
		Mean	14.608	.6833	.33083	.06733	.07883	.40833	.059083	332.25
		Std. Error of Mean	1.2732	.10360	.077511	.013673	.013889	.078198	.0057240	83.549
		Minimum	8.0	.50	.025	.014	.017	.060	.0280	97
		Maximum	22.0	1.60	1.000	.160	.160	1.000	.0900	1100
Ōtūkaikino Catchment	Ōtūkaikino Creek at Omaka Scout Camp	N	12	12	12	12	12	12	12	12
		Median	12.900	.5000	.00950	.07450	.07700	.08500	.004550	86.00
		Mean	13.150	.5417	.01071	.10025	.10150	.11417	.006292	107.33
		Std. Error of Mean	.6581	.04167	.001159	.016386	.016144	.015592	.0013530	23.416
		Minimum	9.9	.50	.006	.056	.059	.070	.0015	5
		Maximum	16.6	1.00	.018	.220	.220	.230	.0150	240
	Ōtūkaikino River at Groynes Inlet	N	12	12	12	12	12	12	12	12
		Median	12.500	.5000	.00900	.11000	.11000	.12000	.003950	68.50
		Mean	13.017	.5000	.01217	.11375	.11542	.13167	.004075	86.17
		Std. Error of Mean	.6137	.00000	.002306	.008250	.008459	.007769	.0004865	13.864
		Minimum	10.1	.50	.005	.082	.085	.100	.0015	31
		Maximum	16.2	.50	.030	.160	.170	.180	.0076	200
	Wilsons Stream	N	12	12	12	12	12	12	12	12
		Median	13.600	.5000	.01350	1.60000	1.60000	1.60000	.012000	103.00
		Mean	13.533	.5417	.01475	1.60833	1.60833	1.61667	.012817	152.50
		Std. Error of Mean	.5680	.04167	.001955	.025990	.025990	.027061	.0014009	43.083
		Minimum	11.0	.50	.007	1.400	1.400	1.400	.0073	10
		Maximum	17.3	1.00	.027	1.700	1.700	1.700	.0250	460
Styx Catchment	Kā Pūtahi Creek at Belfast Road	N	12	12	12	12	12	12	12	12
		Median	13.900	.8000	.09950	.99500	1.00000	1.10000	.030500	2050.00
		Mean	13.908	.9417	.10808	1.00667	1.03167	1.14583	.030583	2042.50
		Std. Error of Mean	.6555	.14794	.010006	.023301	.029202	.033404	.0020055	330.846

Catchment	Address		Temperature (°C)	BOD5 (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Nitrate+Nitrite Nitrogen (mg/L)	Dissolved Inorganic Nitrogen (mg/L)	Dissolved Reactive Phosphorus (mg/L)	E. coli (CFU/100ml)
		Minimum	10.9	.50	.059	.840	.850	.950	.0160	790
		Maximum	17.8	2.00	.190	1.100	1.200	1.400	.0450	4400
	Kā Pūtahi Creek at Blakes Road	N	12	12	12	12	12	12	12	12
		Median	14.200	.5000	.06550	1.10000	1.15000	1.20000	.015000	485.00
		Mean	13.825	.6667	.07167	1.01417	1.04333	1.11000	.014842	798.33
		Std. Error of Mean	.8793	.11828	.011558	.106845	.108839	.113217	.0013094	302.634
		Minimum	9.8	.50	.027	.140	.150	.210	.0081	20
		Maximum	18.6	1.80	.138	1.400	1.500	1.600	.0230	3900
	Smacks Creek at Gardiners Road	N	12	12	12	12	12	12	12	12
		Median	13.750	.5000	.01000	.48000	.48500	.49000	.007900	91.50
		Mean	14.092	.6000	.00996	.42367	.46667	.47667	.007983	139.25
		Std. Error of Mean	.3588	.10000	.001768	.037901	.017291	.016392	.0006566	47.644
		Minimum	12.0	.50	.003	.044	.380	.400	.0051	5
		Maximum	16.2	1.70	.020	.530	.540	.550	.0120	550
	Styx River at Gardiners Road	N	12	12	12	12	12	12	12	12
		Median	13.300	.5000	.01050	.32500	.32500	.34500	.007050	230.00
		Mean	13.292	.5000	.01113	.33833	.33917	.35083	.007258	236.25
		Std. Error of Mean	.1252	.00000	.001420	.015067	.014947	.015149	.0002885	33.795
		Minimum	12.5	.50	.003	.300	.300	.300	.0060	85
		Maximum	14.1	.50	.021	.490	.490	.500	.0091	480
	Styx River at Harbour Road Bridge	N	12	12	12	12	12	12	12	12
		Median	14.000	.5000	.03200	.42500	.43000	.45000	.027500	165.00
		Mean	13.783	.5500	.04692	.41250	.42083	.46833	.034083	203.33
		Std. Error of Mean	.9904	.05000	.010262	.032007	.032484	.040468	.0051367	35.062
		Minimum	9.5	.50	.010	.210	.210	.230	.0190	52
		Maximum	18.8	1.10	.110	.530	.540	.640	.0850	410
	Styx River at Main North Road	N	12	12	12	12	12	12	12	12
		Median	13.100	.5000	.01800	.26500	.27500	.29500	.011000	480.00
		Mean	13.467	.5000	.01917	.26500	.26917	.28917	.011192	461.67
		Std. Error of Mean	.4920	.00000	.001419	.008919	.009650	.010478	.0006378	37.716
		Minimum	11.3	.50	.012	.210	.210	.220	.0076	240
		Maximum	16.0	.50	.032	.310	.310	.340	.0160	660
	Styx River at Marshland Road Bridge	N	12	12	12	12	12	12	12	12
		Median	13.300	.5000	.02500	.50500	.51000	.52500	.020500	590.00
		Mean	13.317	.5000	.03508	.49917	.50500	.53917	.021250	566.67
		Std. Error of Mean	.5627	.00000	.008310	.020131	.021267	.025627	.0013092	71.014
		Minimum	11.0	.50	.012	.390	.390	.410	.0140	160

Catchment	Address		Temperature (°C)	BOD5 (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Nitrate+Nitrite Nitrogen (mg/L)	Dissolved Inorganic Nitrogen (mg/L)	Dissolved Reactive Phosphorus (mg/L)	E. coli (CFU/100ml)
		Maximum	16.5	.50	.121	.590	.600	.720	.0310	880
	Styx River at Richards Bridge	N	12	12	12	12	12	12	12	12
		Median	13.200	.5000	.04850	.47000	.47000	.51000	.026500	425.00
		Mean	13.425	.5000	.04567	.48333	.48833	.53500	.027833	510.83
		Std. Error of Mean	.6847	.00000	.008682	.021927	.021945	.028985	.0021456	99.525
		Minimum	10.4	.50	.012	.380	.380	.400	.0140	170
		Maximum	16.9	.50	.098	.580	.590	.670	.0460	1400

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 (mg/L)	Dissolved Lead (mg/L)	Dissolved Zinc (mg/L)	pH	Conductivity (µS/cm)	Total Suspended Solids (mg/L)	Turbidity (NTU)	Dissolved Oxygen Saturation (%)
Avon Catchment	N	156	156	156	156	156	156	132	156
	Median	.001000	.000750	.004300	7.600	180.00	3.000	2.3500	85.00
	Mean	.001021	.000750	.007471	7.596	953.77	7.599	5.3932	86.13
	Std. Error of Mean	.0000155	.0000000	.0008946	.0222	192.216	1.7554	1.47933	.837
	Minimum	.0010	.0008	.0005	6.9	130	1.5	.20	60
	Maximum	.0032	.0008	.0920	8.3	15000	260.0	190.00	110
Halswell Catchment	N	60	60	60	60	60	60	36	60
	Median	.001000	.000750	.010000	7.600	210.00	7.000	2.0000	85.50
	Mean	.002273	.000769	.029512	7.633	182.74	8.600	3.0858	85.35
	Std. Error of Mean	.0002141	.0000192	.0053619	.0536	6.705	.8895	.49256	2.594
	Minimum	.0010	.0008	.0005	6.8	64	1.5	.57	34
	Maximum	.0069	.0019	.1800	9.8	240	28.0	13.00	160
Heathcote Catchment	N	157	157	157	157	157	157	121	157
	Median	.001000	.000750	.011000	7.600	285.00	4.000	3.3000	77.00
	Mean	.001765	.000759	.039405	7.492	1380.92	9.166	6.0421	74.76
	Std. Error of Mean	.0001571	.0000086	.0067539	.0267	296.862	.9016	.62195	1.511
	Minimum	.0010	.0008	.0005	6.6	80	1.5	.20	13
	Maximum	.0160	.0021	.5700	8.2	22000	62.0	36.00	120
Linwood Canal	N	12	12	12	12	12	12	12	12
	Median	.001000	.000750	.007400	7.700	4800.00	7.000	4.4500	60.50
	Mean	.001292	.000750	.009358	7.750	5565.83	7.583	4.6667	62.33
	Std. Error of Mean	.0002917	.0000000	.0022598	.0469	925.517	1.1312	.53546	4.527
	Minimum	.0010	.0008	.0012	7.6	2090	4.0	2.70	40
	Maximum	.0045	.0008	.0230	8.0	13100	16.0	8.60	89
Ōtūkaikino Catchment	N	36	36	36	36	36	36	36	36
	Median	.001000	.000750	.000800	7.400	80.00	1.500	.3600	88.00
	Mean	.001000	.000750	.001522	7.525	95.00	2.597	1.1600	92.58
	Std. Error of Mean	.0000000	.0000000	.0003666	.0786	4.053	.4057	.30047	2.003
	Minimum	.0010	.0008	.0005	6.9	74	1.5	.20	77
	Maximum	.0010	.0008	.0130	9.2	140	12.0	8.10	140
Styx Catchment	N	96	96	96	96	96	96	96	96
	Median	.001000	.000750	.001650	7.500	122.50	3.000	1.6000	80.00
	Mean	.001049	.000750	.002589	7.440	129.89	4.313	2.2160	77.95
	Std. Error of Mean	.0000490	.0000000	.0003126	.0294	2.239	.3975	.25622	1.161
	Minimum	.0010	.0008	.0005	6.7	100	1.5	.15	50
	Maximum	.0057	.0008	.0200	8.0	200	22.0	20.00	98

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		Temperature (°C)	BOD5 (mg/L)	Ammonia Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Nitrate+Nitrite Nitrogen (mg/L)	Dissolved Inorganic Nitrogen (mg/L)	Dissolved Reactive Phosphorus (mg/L)	E. coli (CFU/100ml)
Avon Catchment	N	156	156	156	156	156	156	156	156
	Median	13.600	.5000	.02400	.82500	.82500	.85500	.017000	285.00
	Mean	13.647	.5833	.04213	1.00617	.99651	1.03199	.021404	581.76
	Std. Error of Mean	.2075	.02968	.003197	.056491	.055788	.053999	.0011636	77.832
	Minimum	7.3	.50	.003	.160	.031	.130	.0015	10
	Maximum	21.0	4.00	.220	3.500	3.500	3.500	.0630	7300
Halswell Catchment	N	60	60	60	60	60	60	60	60
	Median	13.500	.5000	.05250	1.30000	1.40000	2.75000	.024000	470.00
	Mean	13.998	1.4917	.29853	2.19557	2.23720	2.53333	.038378	1404.20
	Std. Error of Mean	.4844	.17243	.077751	.216213	.215012	.209774	.0051426	436.536
	Minimum	6.9	.50	.012	.044	.042	.070	.0015	5
	Maximum	22.3	5.10	3.400	5.000	5.000	5.100	.2200	24000
Heathcote Catchment	N	157	157	157	157	157	157	157	157
	Median	13.600	.5000	.07700	1.40000	1.40000	1.60000	.031000	310.00
	Mean	13.911	.9599	.16204	1.30485	1.32218	1.48083	.079694	1497.86
	Std. Error of Mean	.2423	.08384	.031930	.047693	.047540	.054506	.0122375	288.301
	Minimum	5.7	.50	.003	.007	.005	.090	.0015	5
	Maximum	20.2	6.90	3.500	2.600	2.700	5.500	.8400	24000
Linwood Canal	N	12	12	12	12	12	12	12	12
	Median	13.500	.5000	.26000	.06500	.07200	.40000	.050500	200.00
	Mean	14.608	.6833	.33083	.06733	.07883	.40833	.059083	332.25
	Std. Error of Mean	1.2732	.10360	.077511	.013673	.013889	.078198	.0057240	83.549
	Minimum	8.0	.50	.025	.014	.017	.060	.0280	97
	Maximum	22.0	1.60	1.000	.160	.160	1.000	.0900	1100
Ōtūkaikino Catchment	N	36	36	36	36	36	36	36	36
	Median	13.000	.5000	.01050	.13000	.13000	.14500	.005700	85.50
	Mean	13.233	.5278	.01254	.60744	.60842	.62083	.007728	115.33
	Std. Error of Mean	.3464	.01936	.001085	.120075	.119958	.119486	.0009031	17.143
	Minimum	9.9	.50	.005	.056	.059	.070	.0015	5
	Maximum	17.3	1.00	.030	1.700	1.700	1.700	.0250	460
Styx Catchment	N	96	96	96	96	96	96	96	96
	Median	13.600	.5000	.02400	.47500	.48000	.50000	.018000	370.00
	Mean	13.639	.5948	.04346	.55535	.57052	.61438	.019378	619.85
	Std. Error of Mean	.2223	.03025	.004170	.031694	.032305	.035355	.0012639	81.836
	Minimum	9.5	.50	.003	.044	.150	.210	.0051	5
	Maximum	18.8	2.00	.190	1.400	1.500	1.600	.0850	4400

Table v. Raw data for wet weather samples taken in the Halswell Catchment for all parameters presented in this report, sorted from upstream to downstream. All metals presented are in dissolved form.

Site	Date	Time	Copper (mg/L)	Lead (mg/L)	Zinc (mg/L)	pH	Conductivity (µS/cm)	TSS (mg/L)	Turbidity (NTU)	DO (%)	Water Temperature (°C)	BOD5 (mg/L)	Total Ammonia (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	NNN (mg/L)	DIN (mg/L)	DRP (mg/L)	E. coli (CFU/100ml)	TPH (mg/L)
Nottingham Stream at Candys Road	4/04/16	11:05	0.0024	<0.0015	0.054	7.1	100	5.0	3.3	77	13.7	2.6	0.17	0.30	0.014	0.32	0.49	0.081	8200	
	26/08/2016	15:00	0.011	0.013	0.087	7	53	130	42	90	11.2	4.8	0.2	0.24	0.009	0.25	0.45	0.058	2300	0.4
Halswell River at Akaroa Highway (Tai Tapu Road)	4/04/16	10:55	<0.002	<0.0015	<0.001	7.7	230	5.0	1.7	97	13.5	<1.0	0.019	3.9	0.021	3.9	3.9	0.018	4100	
	26/08/2016	15:25	<0.002	<0.0015	0.0044	7.8	220	41	18	92	11.5	2.4	0.063	3.6	0.012	3.6	3.7	0.07	1000	<0.3
Knights Stream at Sabys Road	4/04/16	11:15	<0.002	<0.0015	0.0019	7.3	230	5.0	1.5	90	12.8	<1.0	0.023	4.2	0.0070	4.2	4.2	0.0053	2000	
	26/08/2016	15:10	<0.002	<0.0015	<0.001	7.5	220	9	3.7	85	12.2	1.1	0.026	4.2	0.005	4.2	4.2	0.01	910	<0.3

Appendix B: Metal Hardness Modified Trigger Values

8.1 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).

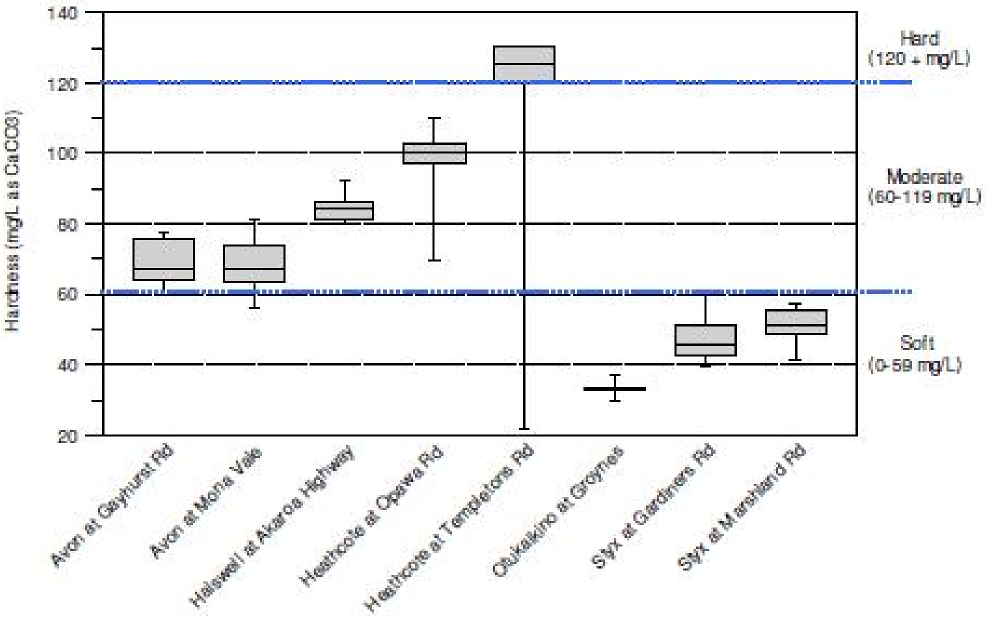

Figure 1 Box plots displaying median (and upper, lower quartiles, max and min) water hardness values for monitoring sites on the Avon, Heathcote, Halswell, Styx and Otukaikino rivers between December 2010 and March 2012.

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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8.2 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

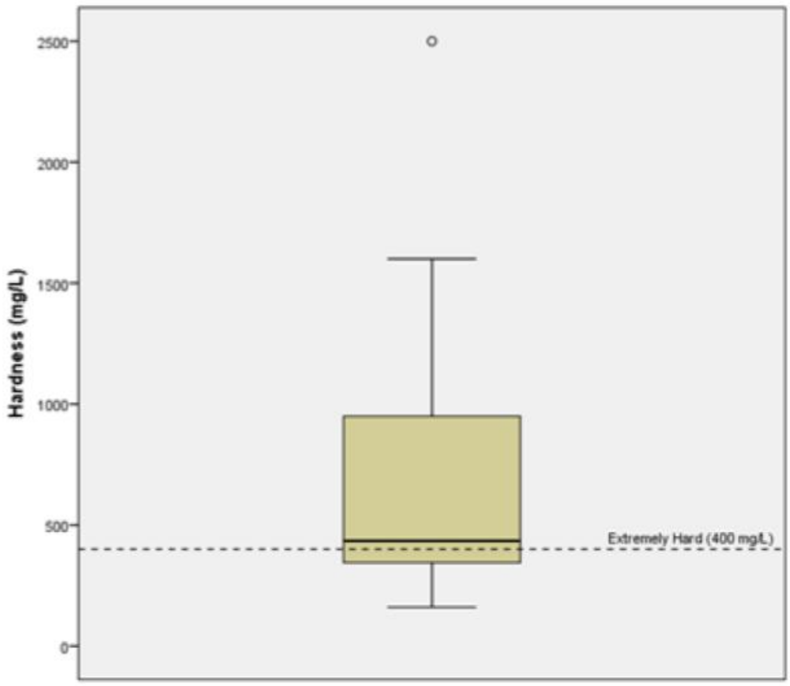

Figure 1. Box plot of water hardness for Linwood Canal for the monitoring period September 2014 - August 2015

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

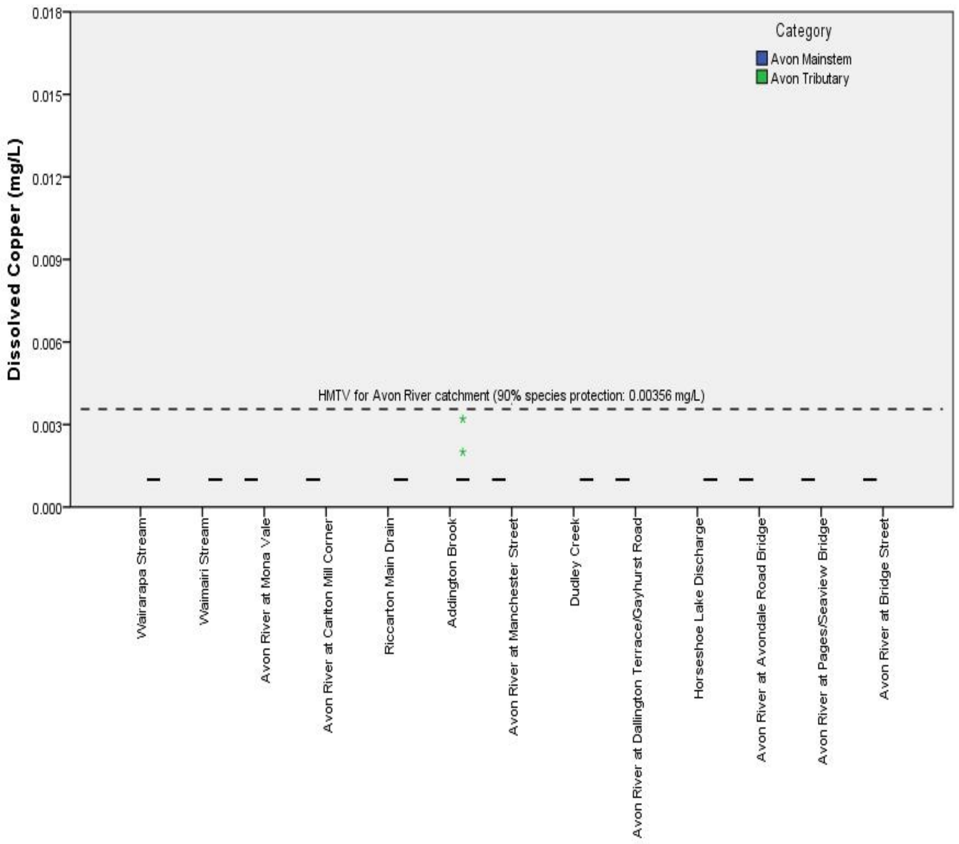
Table i. Laboratory methods used over time to calculate parameter concentrations. N/A = Not Applicable.

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 mg/L (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) <0.005 mg/L (sampling instigation– 8 September 2014)	1 August 2014 - current day	APHA 4500-NO3 F 22nd Ed. 2012 (cadmium reduction and continuous flow analyser)
		Sampling instigation - 31 July 2014	APHA 4500-NO2 B (Discrete Analyser)

Parameter	Limit of Detection (date)	Analysis method dates	Analysis method
Nitrate Nitrite Nitrogen (NNN)	<0.01 mg/L (27 July 2011- current day) <0.05 mg/L (sampling instigation- 26 July 2011)	3 April 2009 - current day	APHA 4500-NO3 E (Continuous Flow Autoanalyser)
		Sampling instigation - 2 April 2009	Nitrate + Nitrite
Dissolved Inorganic Nitrogen (DIN)	<0.02 mg/L	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) <0.02 mg/L (1 December 2010- 21 December 2010) <0.003 mg/L (17 November 2009- 30 November 2010) <0.01 mg/L (sampling instigation – 16 November 2009)	1 August 2014 - current day	APHA 4500-P F (Continuous Flow Autoanalyser)
		Sampling instigation - 31 July 2014	4500-P E (Discrete Analyser)
Total phosphorus	<0.003 mg/L (10 July 2014- current day) <0.02 mg/L (17 November 2009 - 09 July 2014) <0.06 mg/L (sampling instigation - 16 November 2009)	1 August 2014 - current day	APHA 4500-P J 22nd Ed. 2012 (persulphate digestion and continuous flow analyser)
		Sampling instigation - 31 July 2014	APHA 4500-P J (Discrete Analyser)
Total Suspended Solids (TSS)	<3 mg/L (September 2010- current day) <5 mg/L (sampling instigation- August 2010)	Sampling instigation - current day	APHA 2540 D
Water temperature	N/A	Sampling instigation - current day	YSI Pro ODO meter
Total nitrogen	<0.01 mg/L (10 July 2014 - current day) <0.05 mg/L (4 March 2009 - 9 July 2014) <1.0 mg/L (sampling instigation - 3 March 2009)	1 August 2014- current day	APHA 4500-N C 22nd Ed. 2012 (persulphate digestion and continuous flow analyser)
		Sampling instigation - 31 July 2014	APHA 4500-N C (Discrete Analyser)
Turbidity	<0.1 NTU (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) <0.006 mg/L (sampling instigation- February 2009)	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	ICPOES (Inductively coupled optical emission spectrometer, Perkin Elmer) using acid washed GF/F filters
Dissolved arsenic	<0.001 mg/L (October 2015- current day) <0.002 mg/L (sampling instigation – September 2015)	October 2015 – current day	ICPMS APHA 3125B
		Sampling instigation - October 2015	GFAA APHA 3120B
TPH[16]	<0.3 mg/L	Sampling instigation - current day	Extraction DCM (GC-FID)

[16] Analysed by Watercare Laboratory (IANZ accredited)

Appendix D: Monthly Monitoring Graphs



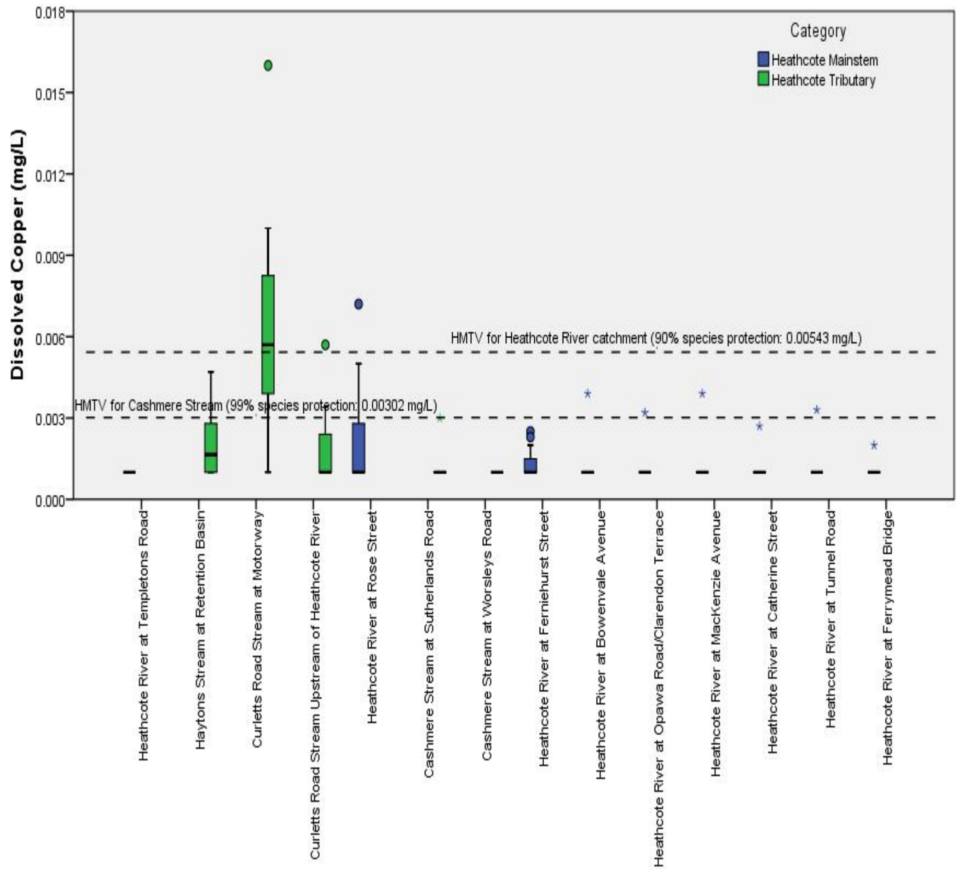


Figure i (a). Dissolved copper levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. No monitoring was undertaken at the Heathcote River at Templeton's Road site in January and from March – December, as the site was dry. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger values (Environment Canterbury, 2017), 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.

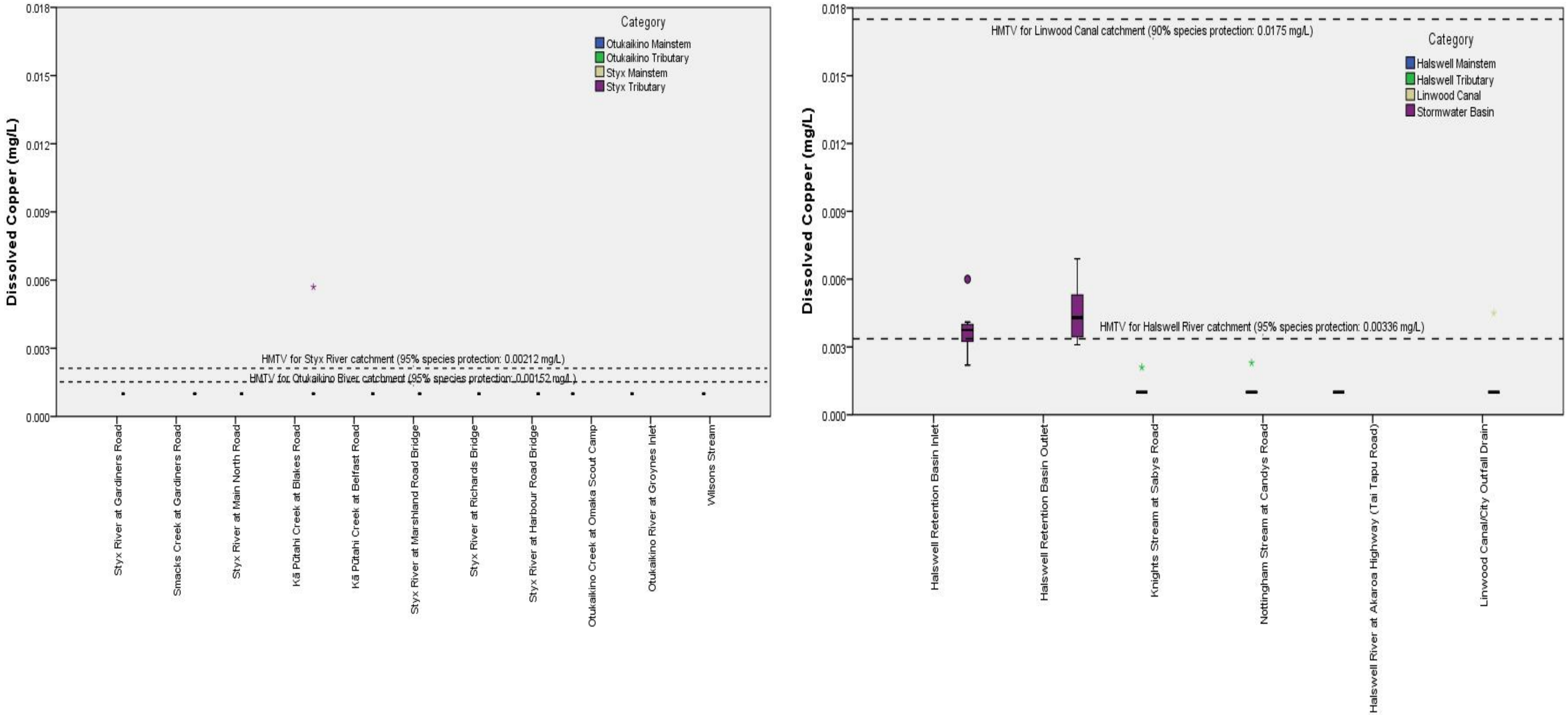


Figure i (b). Dissolved copper levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger values (Environment Canterbury, 2017), 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.

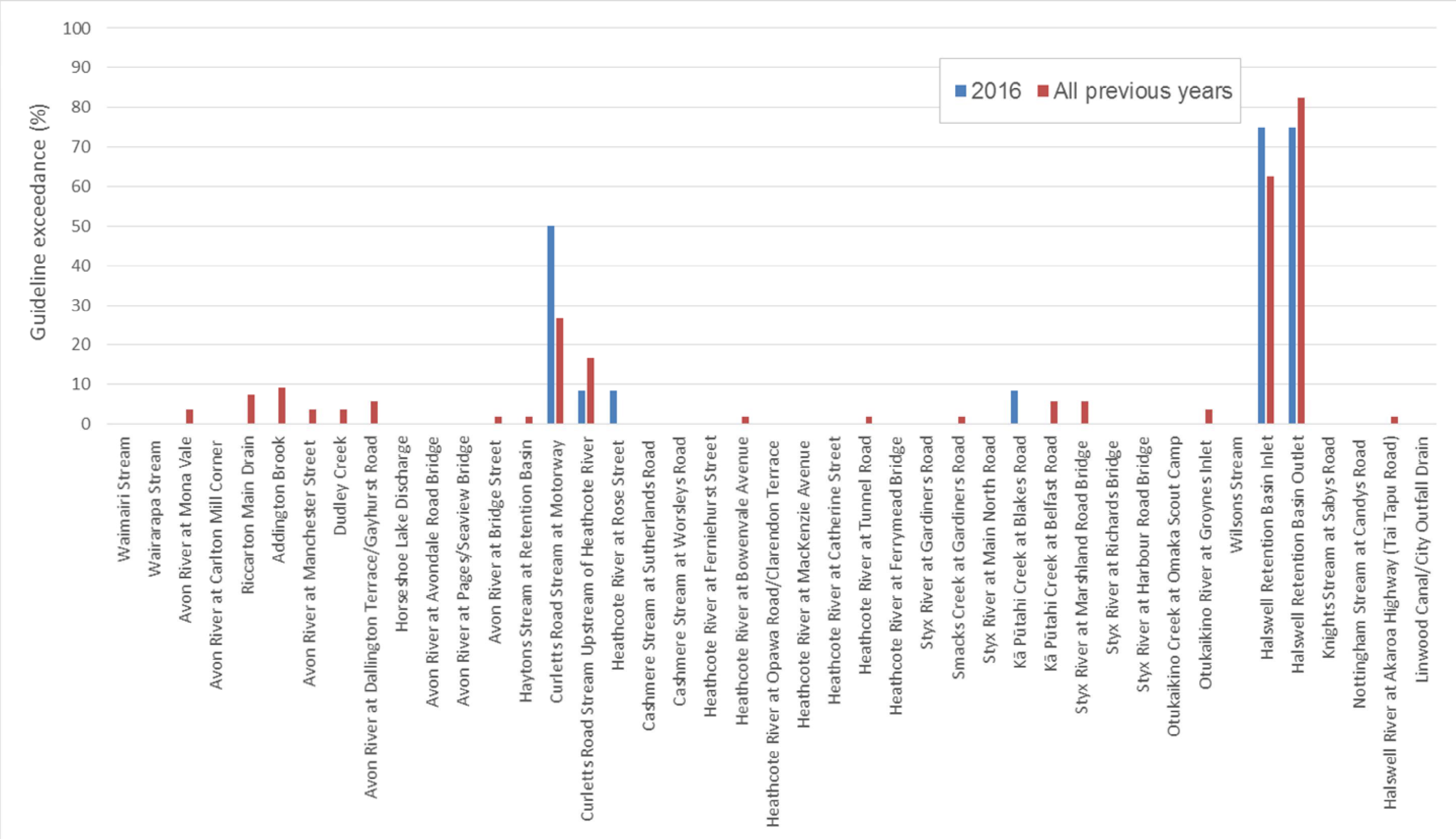
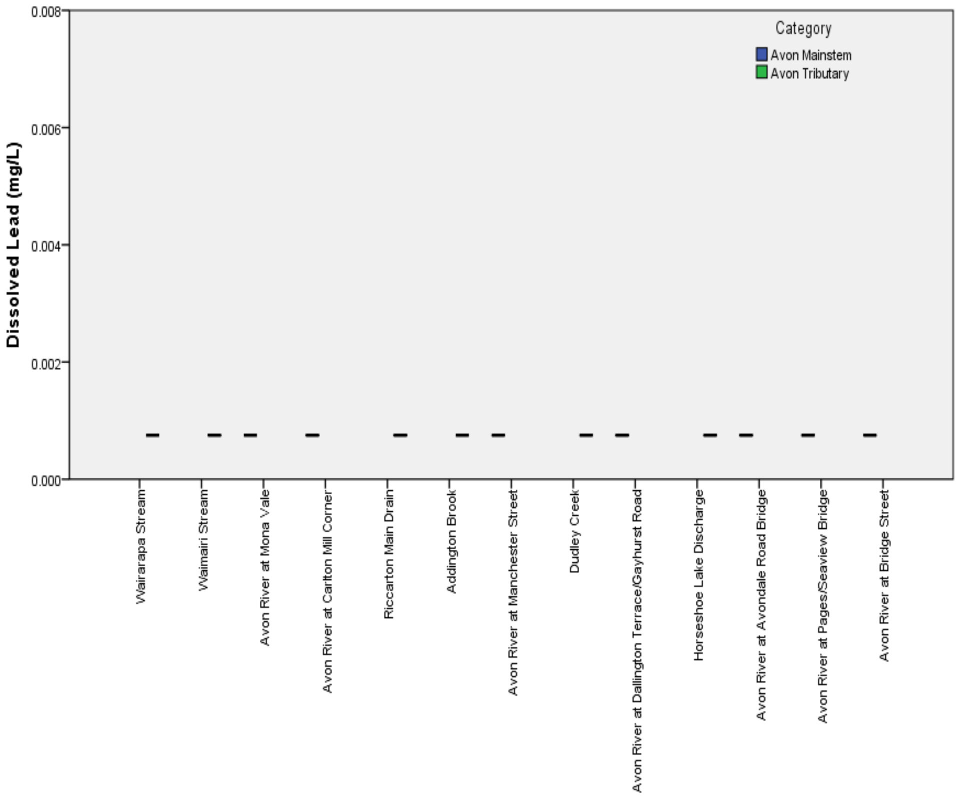


Figure i (c). Percentage of dissolved copper guideline exceedances at each site in 2016 compared to all previous years. Heathcote River at Templetons Road is not presented as it was only sampled once in 2016.



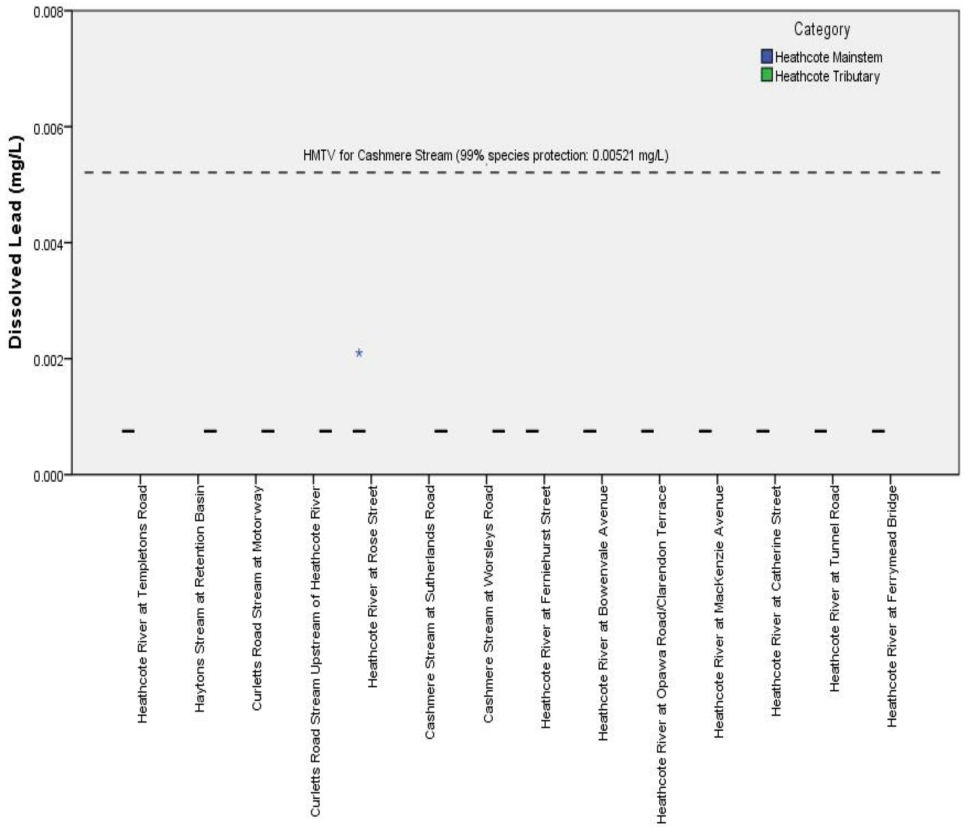
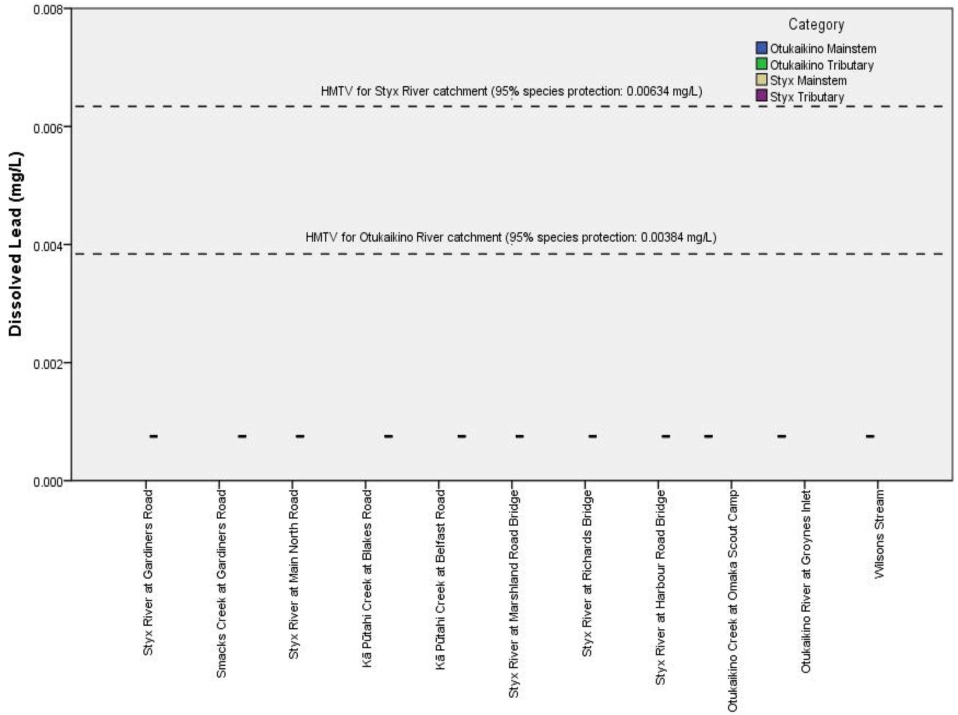


Figure ii (a). Dissolved lead levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. No monitoring was undertaken at the Heathcote River at Templeton's Road site in January and from March– December, as the site was dry. Sites are ordered from upstream to downstream (left to right). The dashed line represents the Land and Water Regional Plan trigger value (Environment Canterbury, 2017), 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.



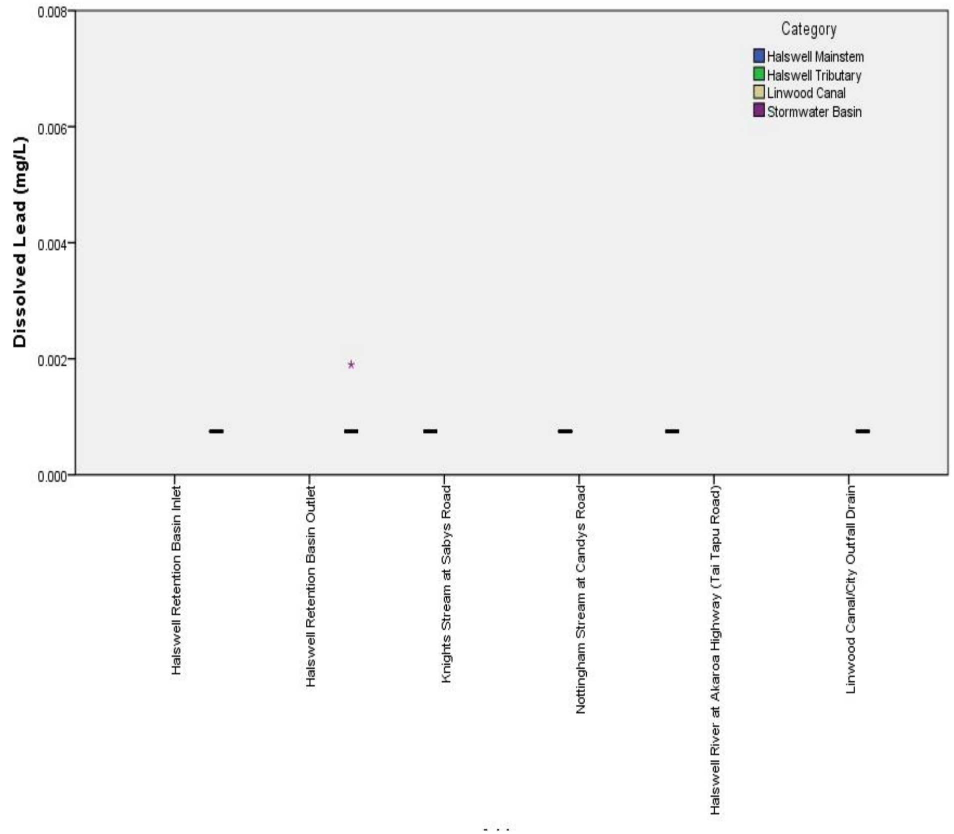


Figure ii (b. Dissolved lead levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger value (Environment Canterbury, 2017), 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.

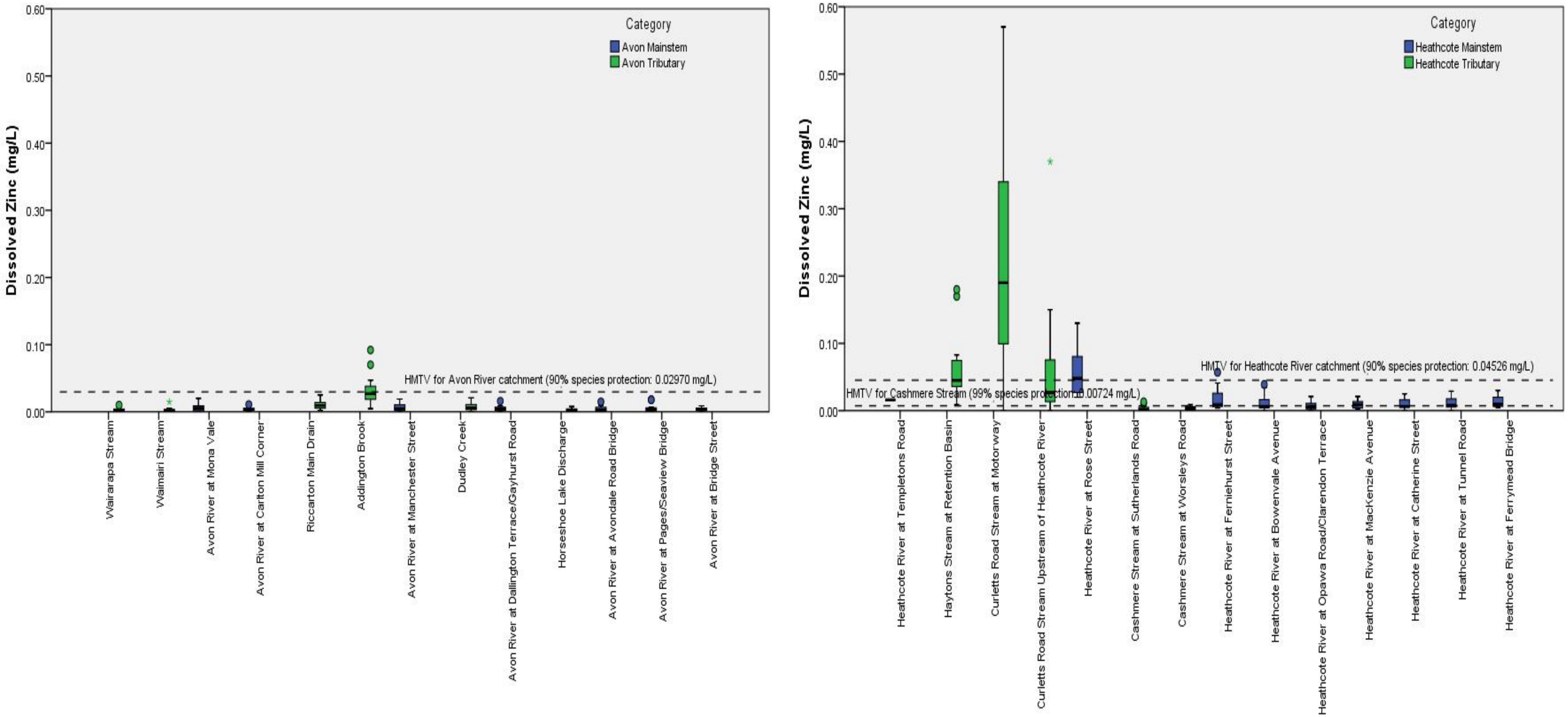


Figure iii (a). Dissolved zinc levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. No monitoring was undertaken at the Heathcote River at Templeton's Road site in January and from March – December, as the site was dry. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger values (Environment Canterbury, 2017), 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.

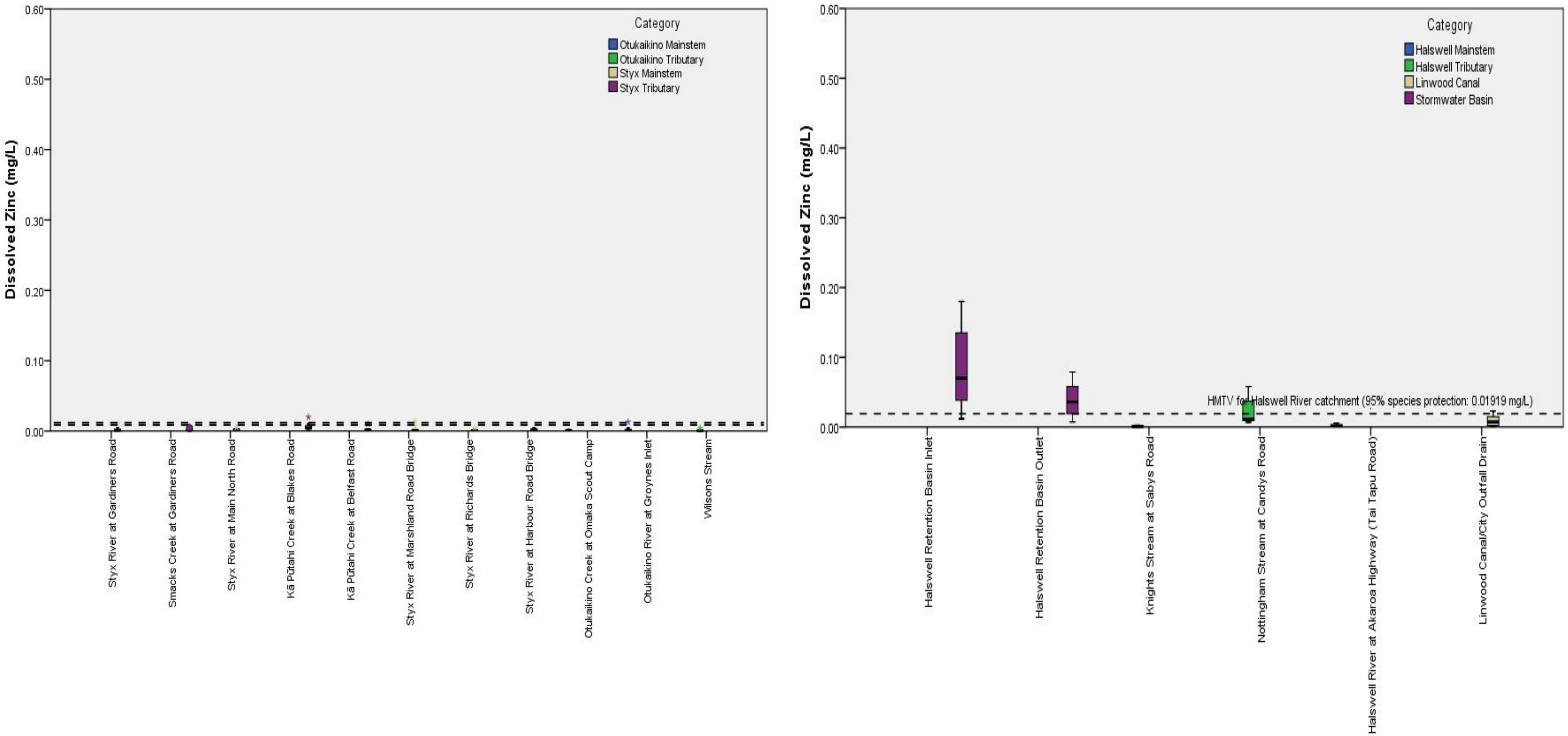


Figure iii (b). Dissolved zinc levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger values (Environment Canterbury, 2017), 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.

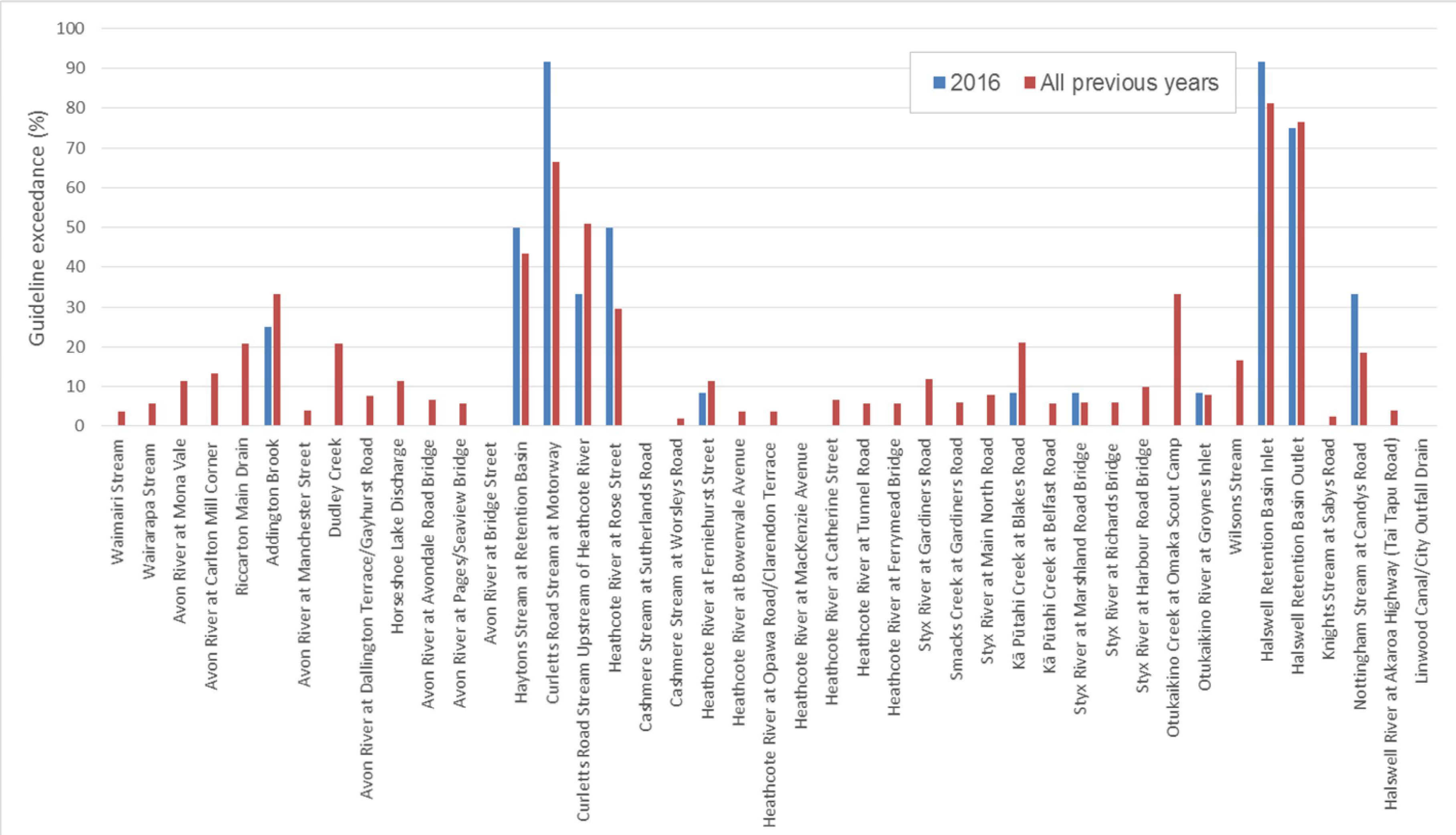


Figure iii (c). Percentage of dissolved zinc guideline exceedances at each site in 2016 compared to all previous years. Heathcote River at Templetons Road is not presented as it was only sampled once in 2016.

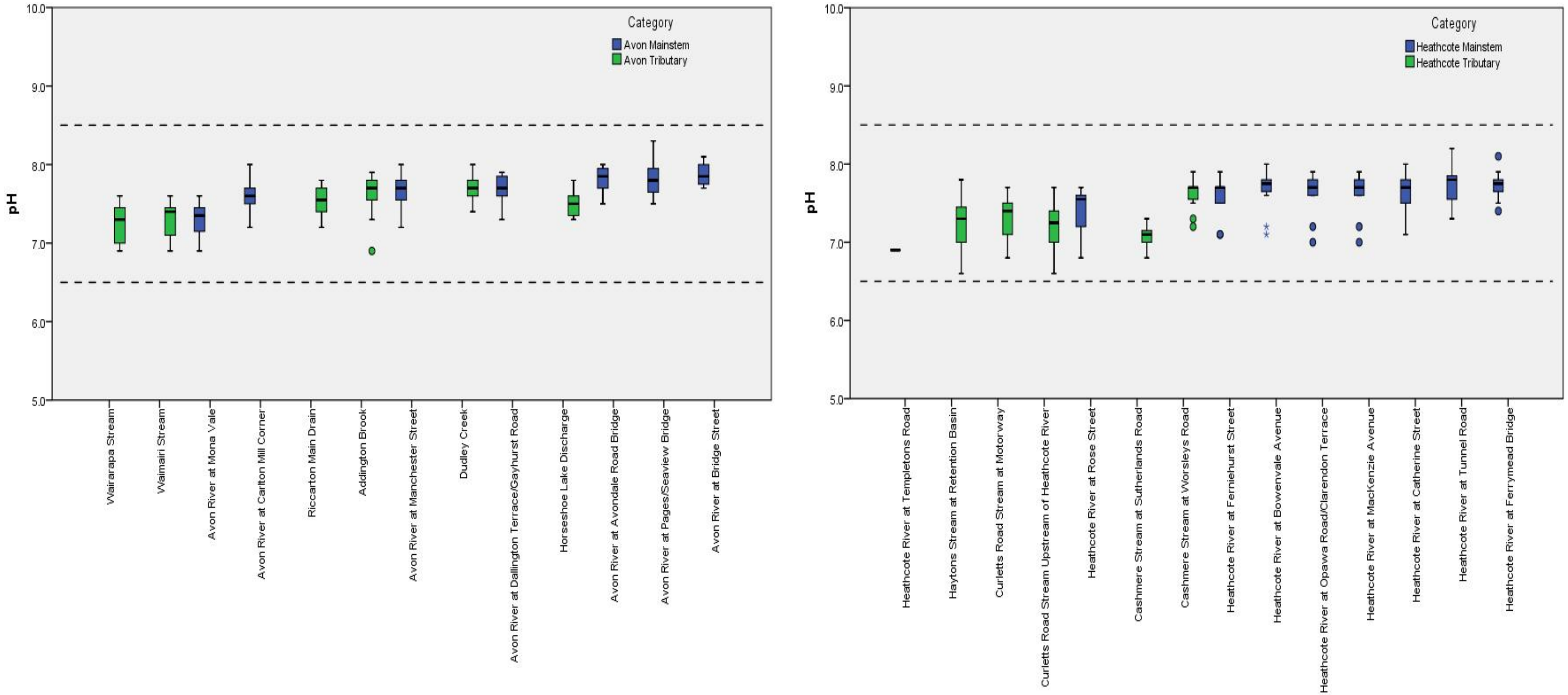


Figure iv (a). pH levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. No monitoring was undertaken at the Heathcote River at Templeton's Road site in January and from March – December, as the site was dry. 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, 2017).

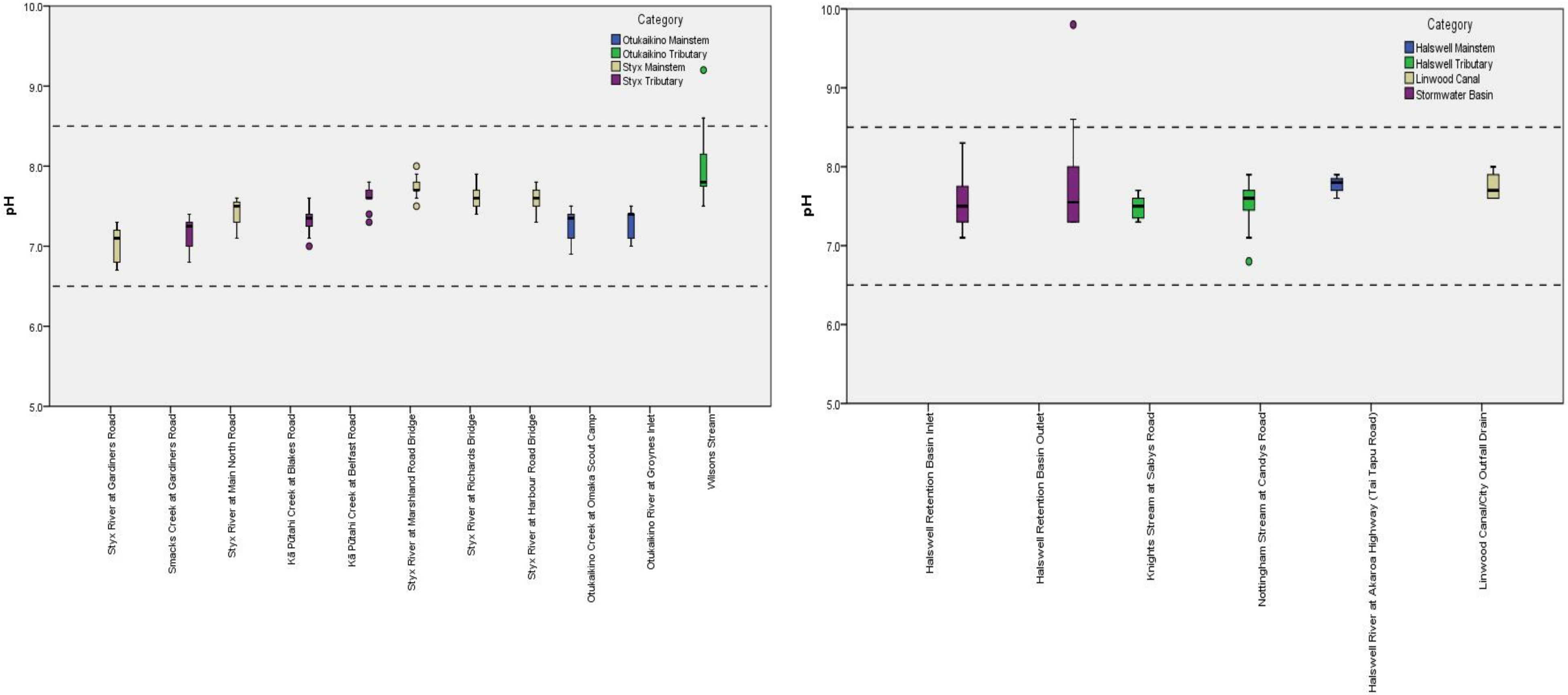
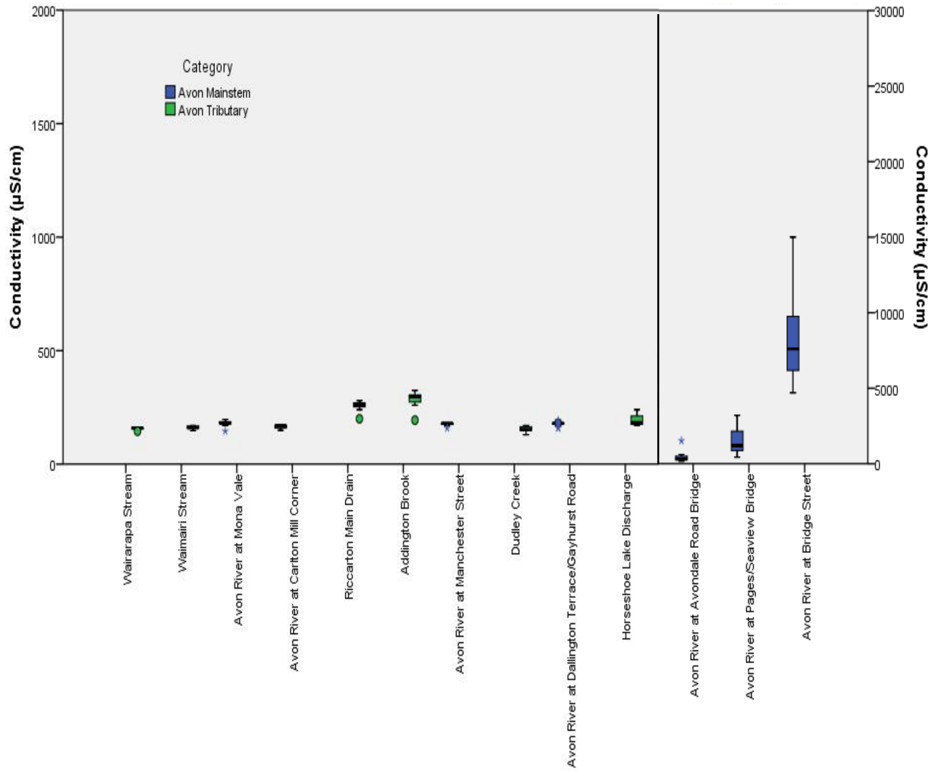


Figure iv (b). pH levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan lower (6.5) and upper (8.5) limits (Environment Canterbury, 2017).



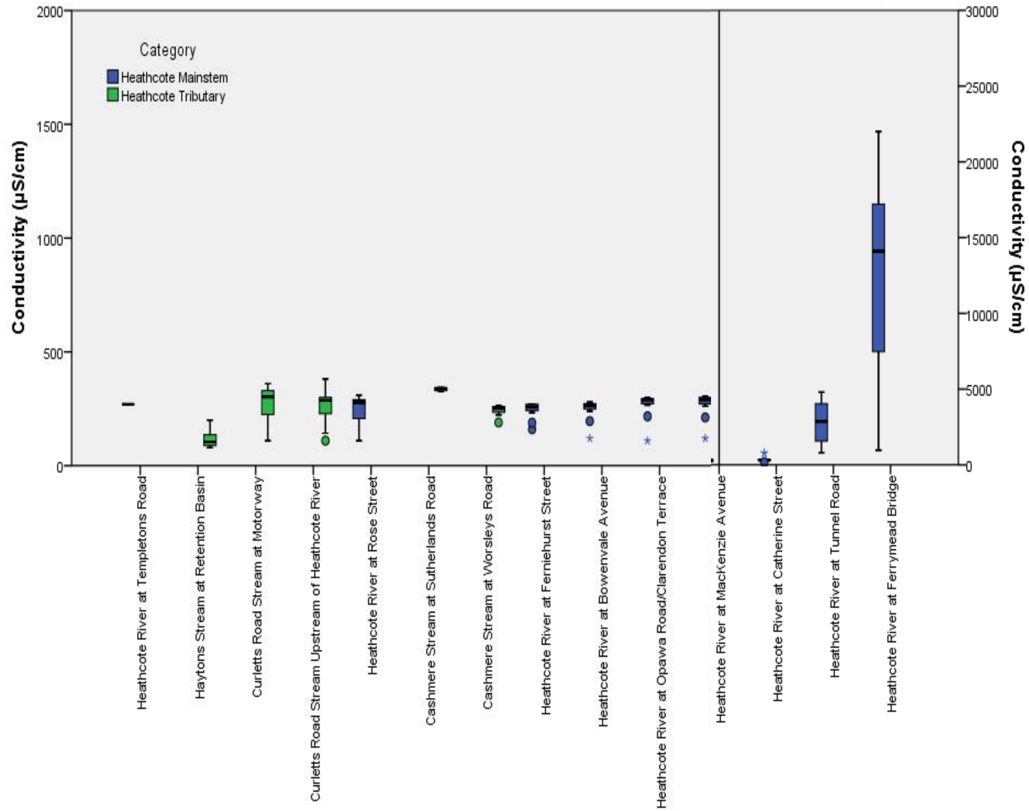


Figure v (a). Conductivity levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. No monitoring was undertaken at the Heathcote River at Templeton's Road site from February – June and November – December, as 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.

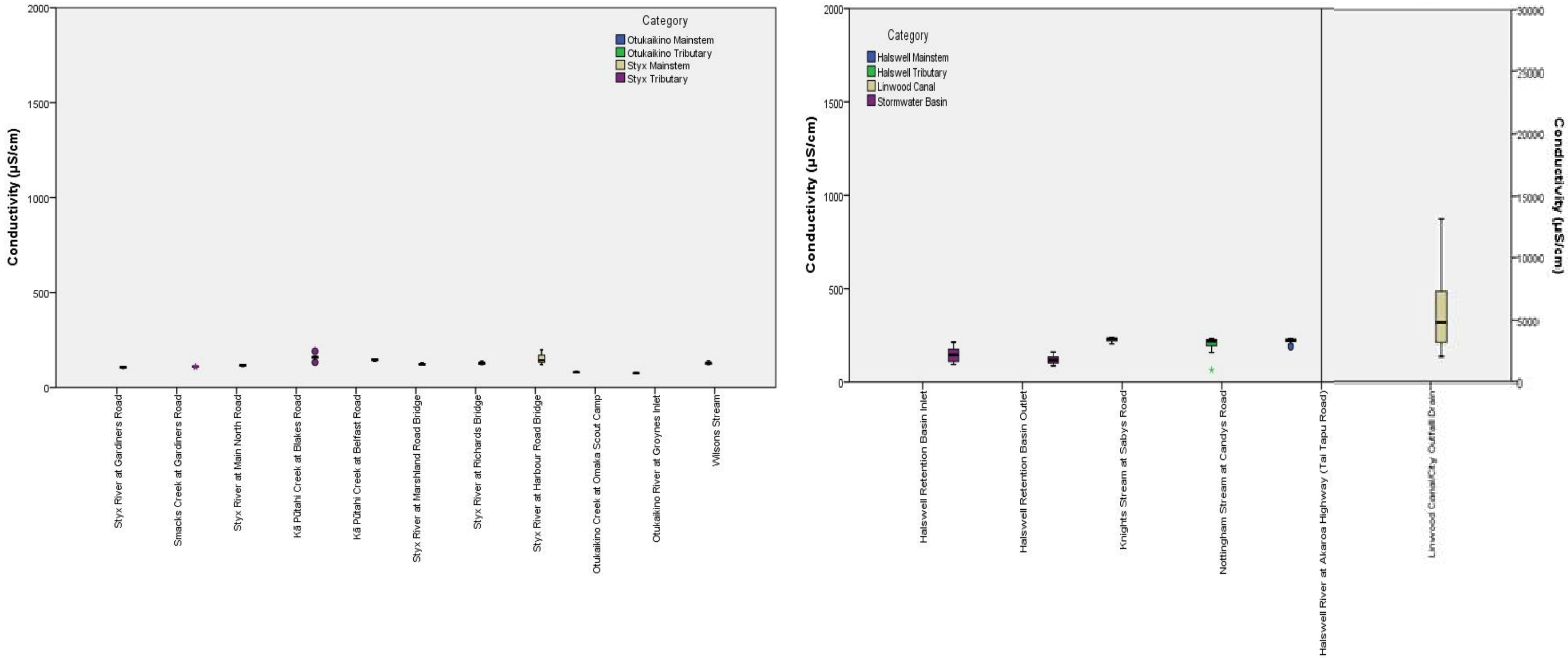


Figure v (b). Conductivity levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (left to right). All conductivity graphs 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.

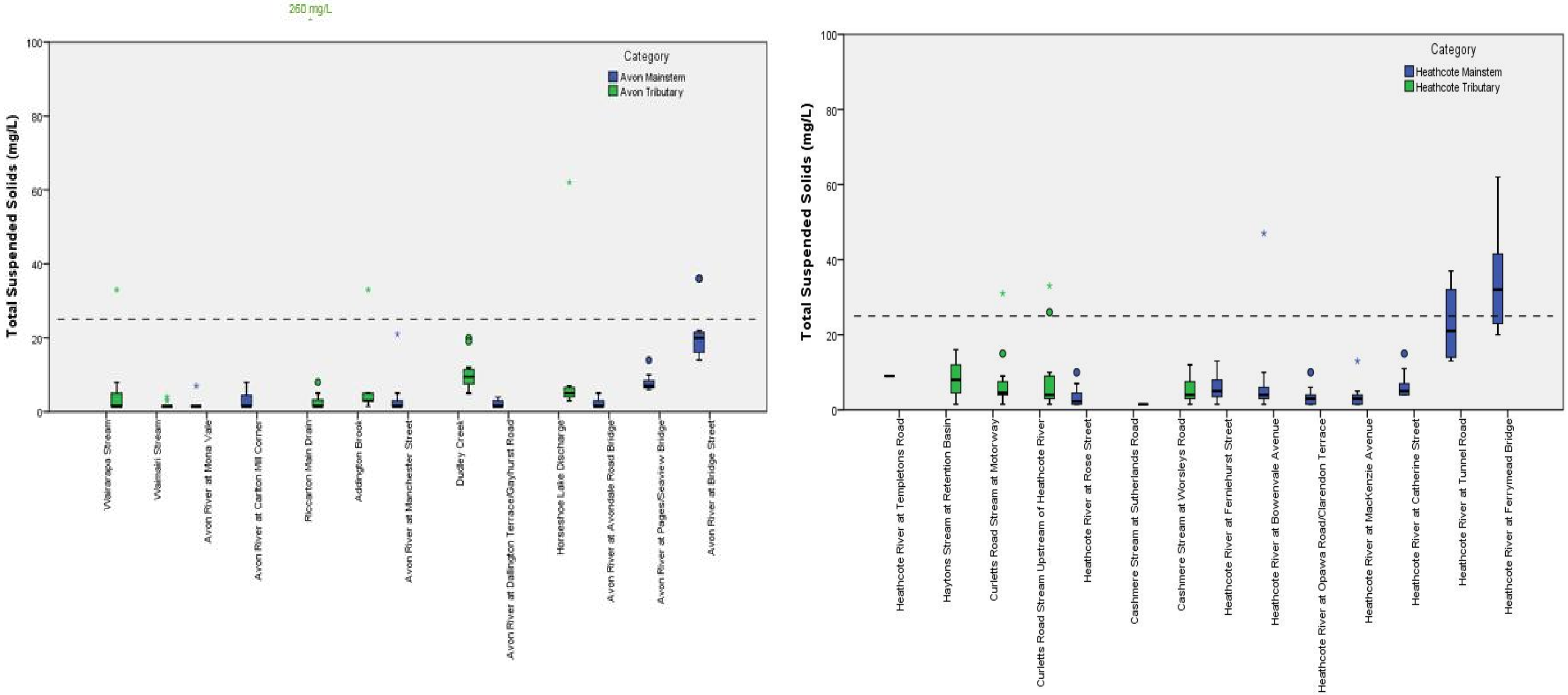
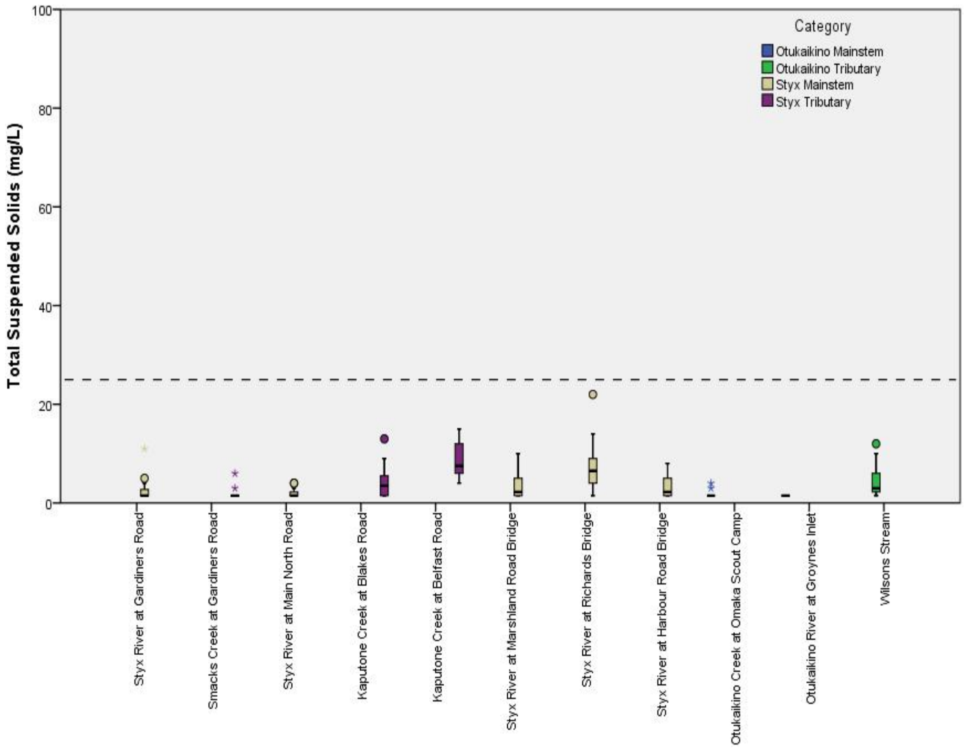


Figure vi (a). Total Suspended Solid (TSS) levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. No monitoring was undertaken at the Heathcote River at Templeton's Road site in January and from March – December, as the site was dry. 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.



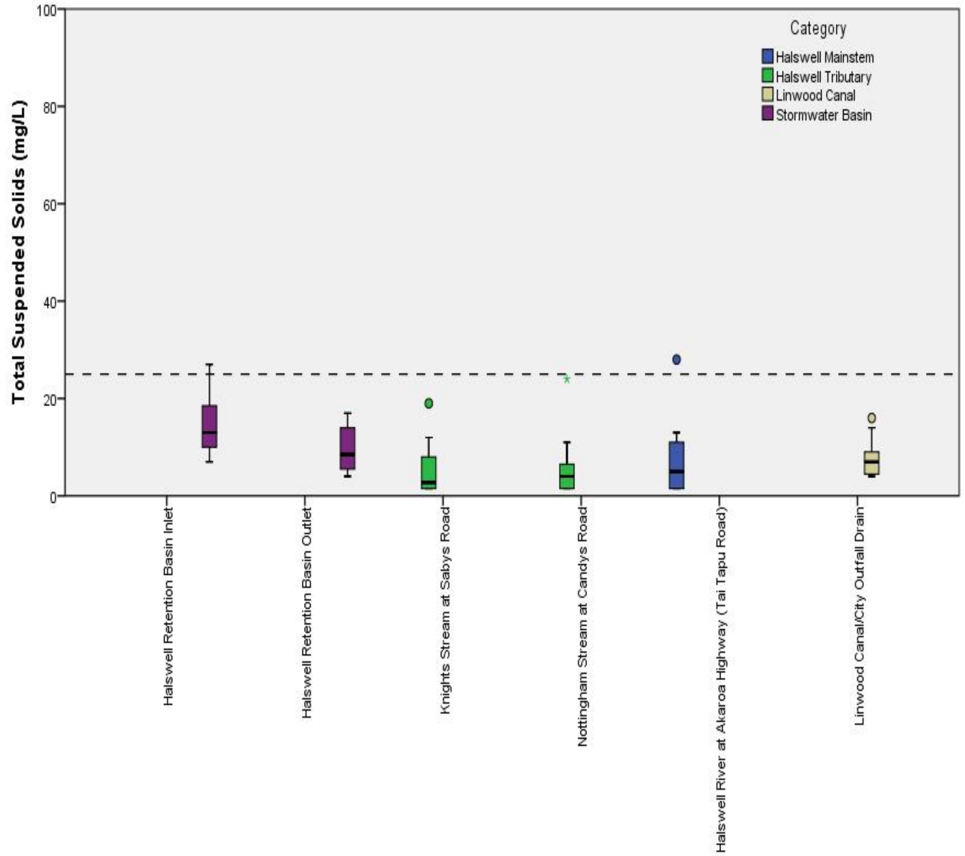


Figure vi (b). Total Suspended Solid (TSS) levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (left to right). The 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.

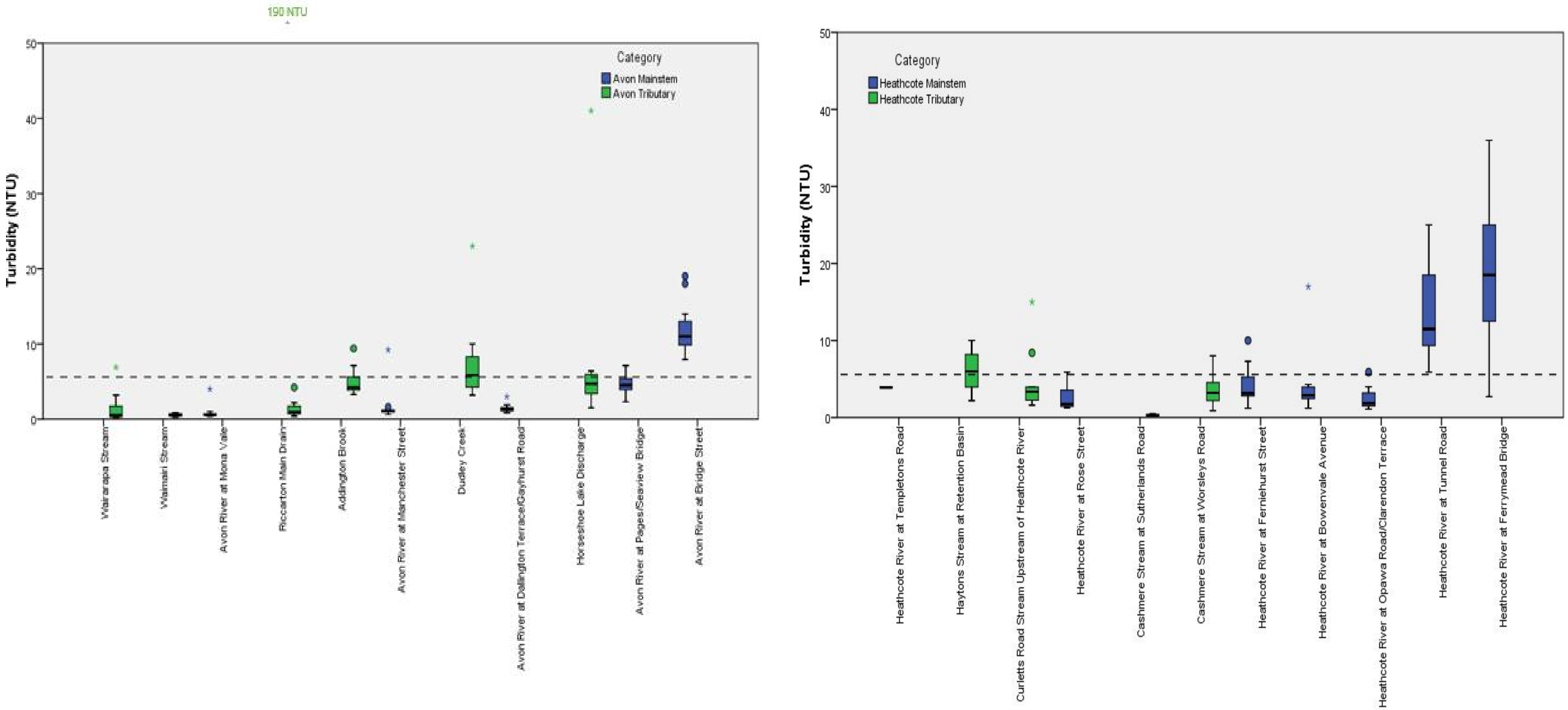
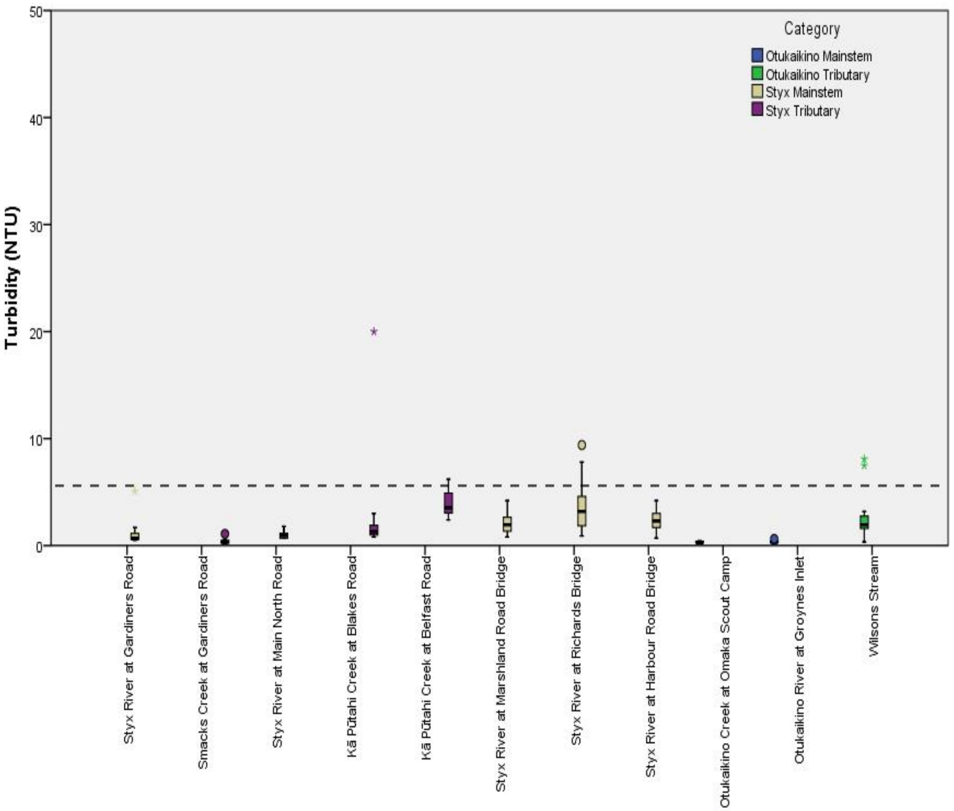


Figure vii (a). Turbidity levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. The following sites were not measured for this parameter: Avon River at Carlton Mill Corner, Avon River at Avondale Road Bridge, 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 in January and from March – December, as the site was dry. 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).



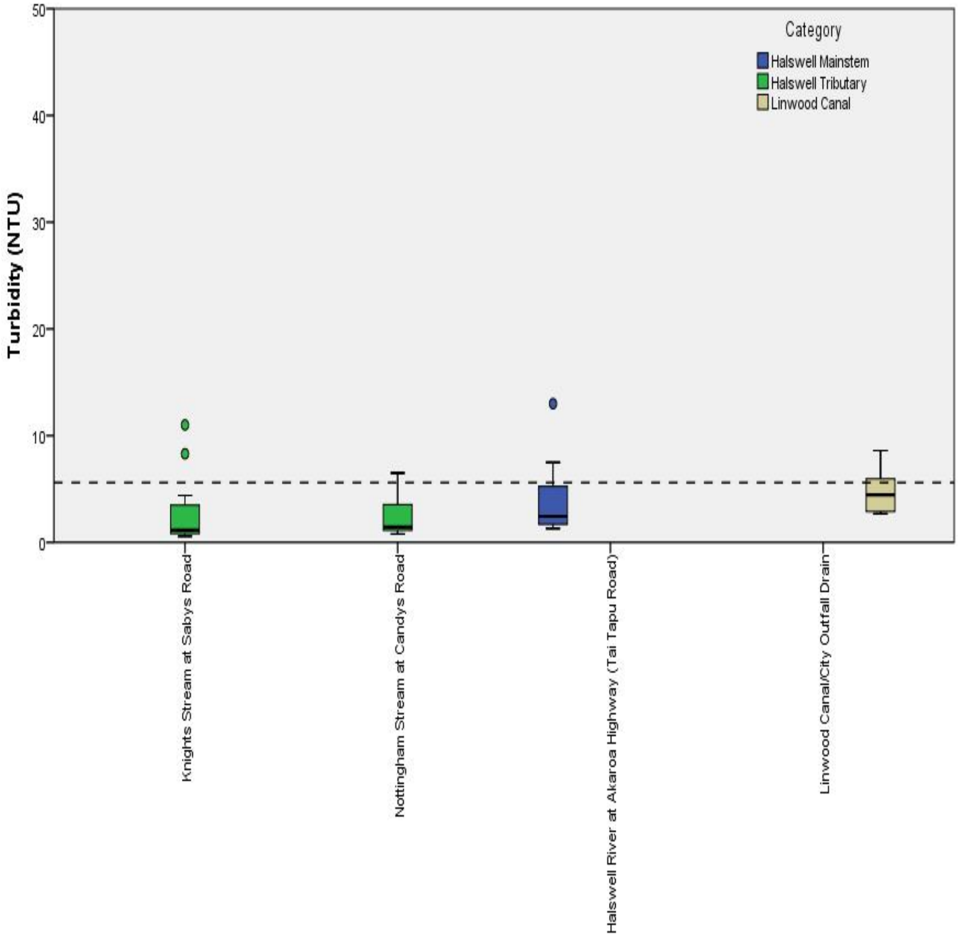


Figure vii (b). Turbidity levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. The following sites were not measured for this parameter: Halswell Retention Basin 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).

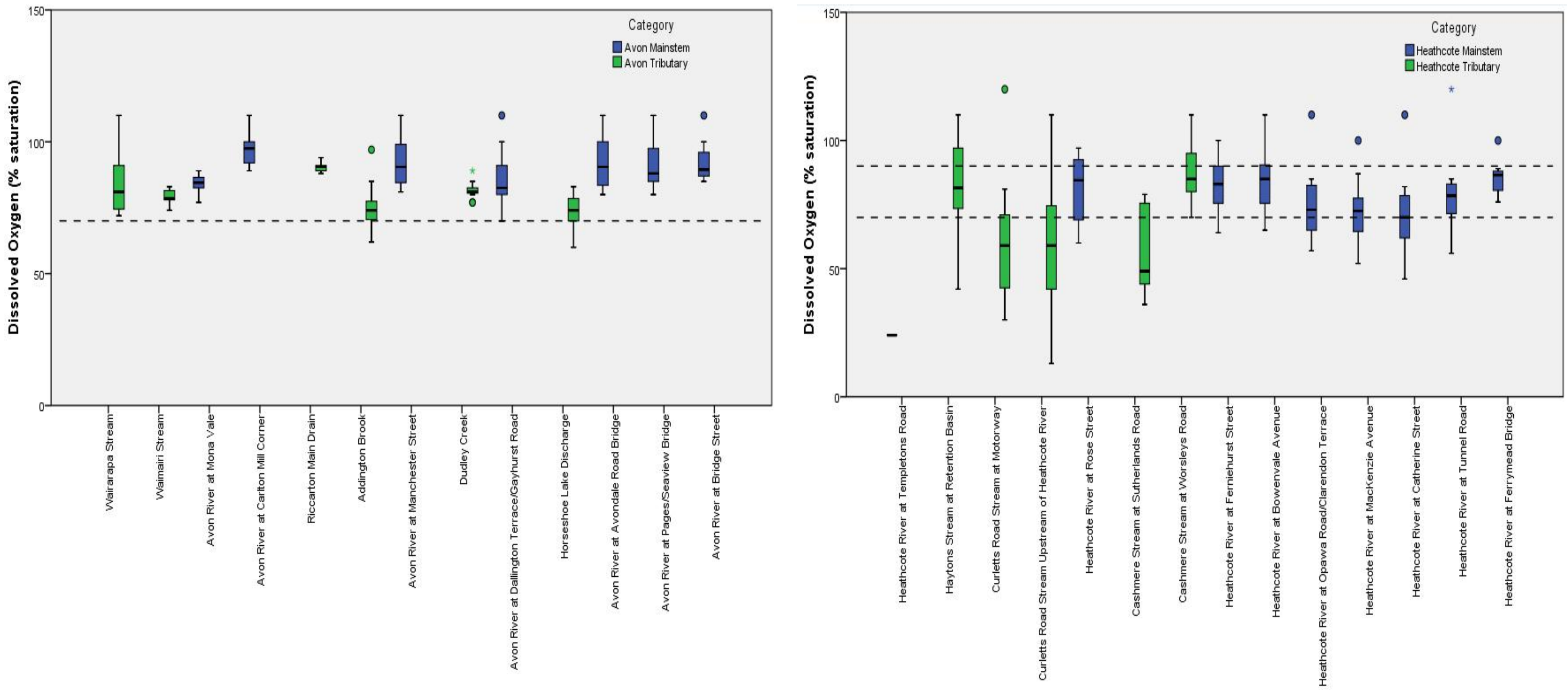


Figure viii (a). Dissolved oxygen levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. No monitoring was undertaken at the Heathcote River at Templeton's Road site in January and from March – December, as 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, 2017).

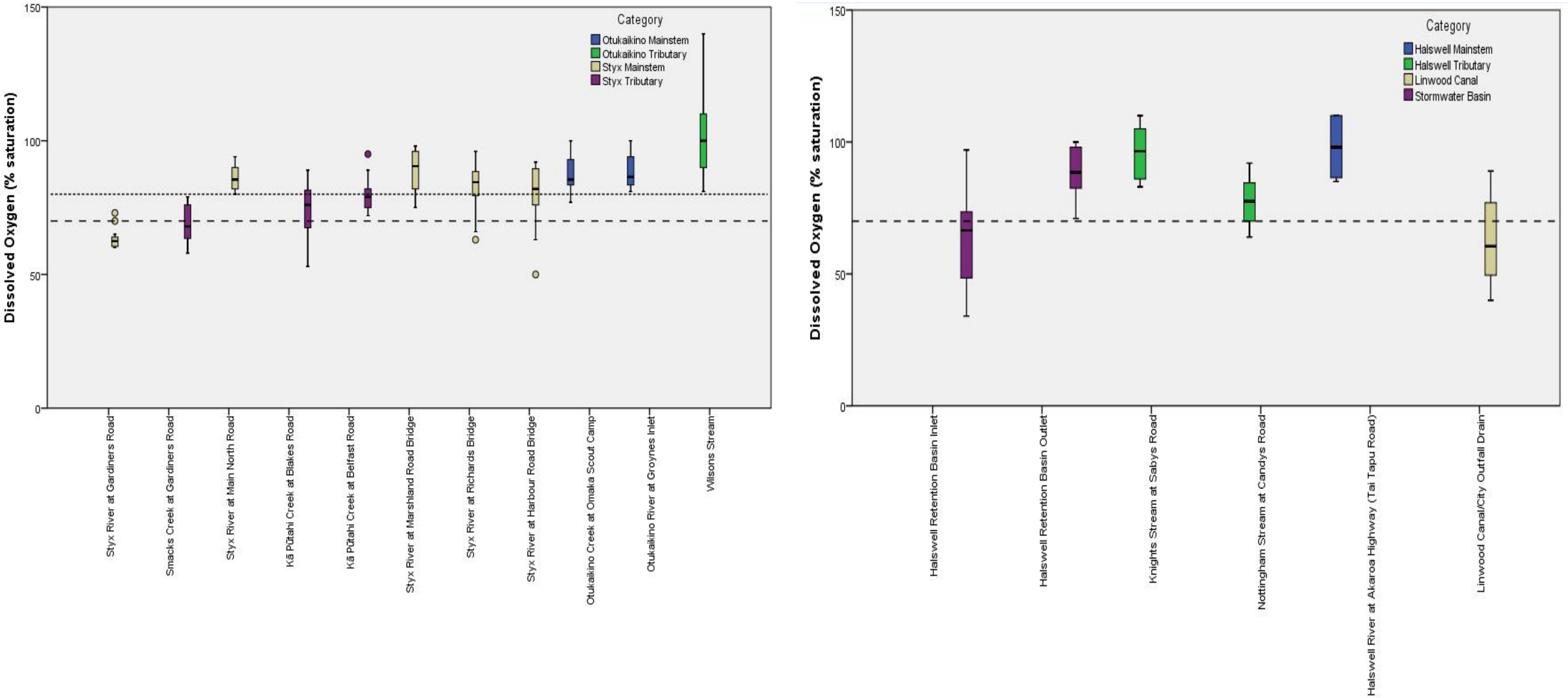


Figure viii (b). Dissolved oxygen levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (left to right). The lower dashed line represents the Land and Water Regional Plan minimum guideline value for 'spring-fed – plains – urban' and 'spring-fed – plains' waterways (70%, Environment Canterbury, 2017). The upper dotted line represents the Waimakariri River Regional Plan minimum guideline value for all Ōtūkaikino sites (80%, Environment Canterbury, 2011).

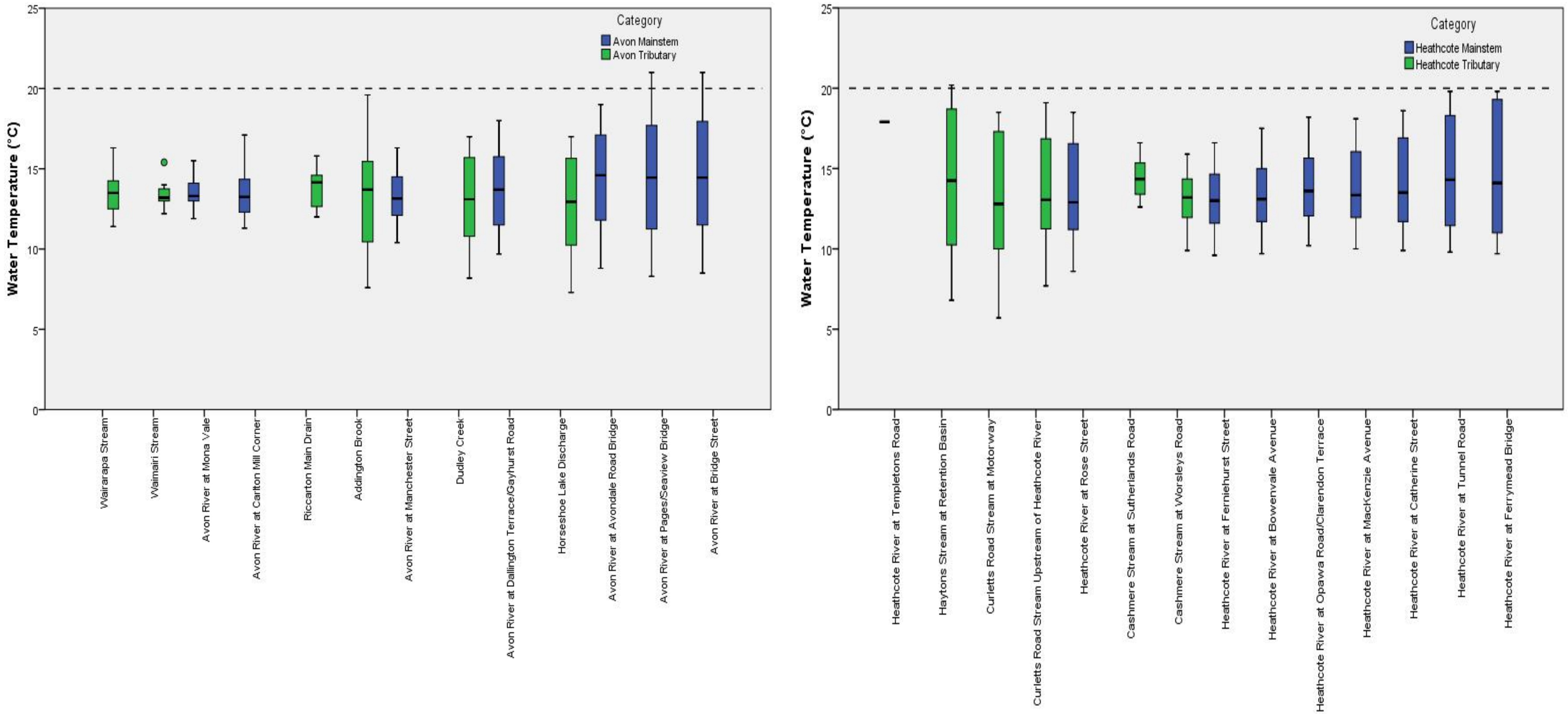


Figure ix (a). Temperature of the water at the time of sampling at the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. No monitoring was undertaken at the Heathcote River at Templeton's Road site in January and from March – December, as the 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, 2017).

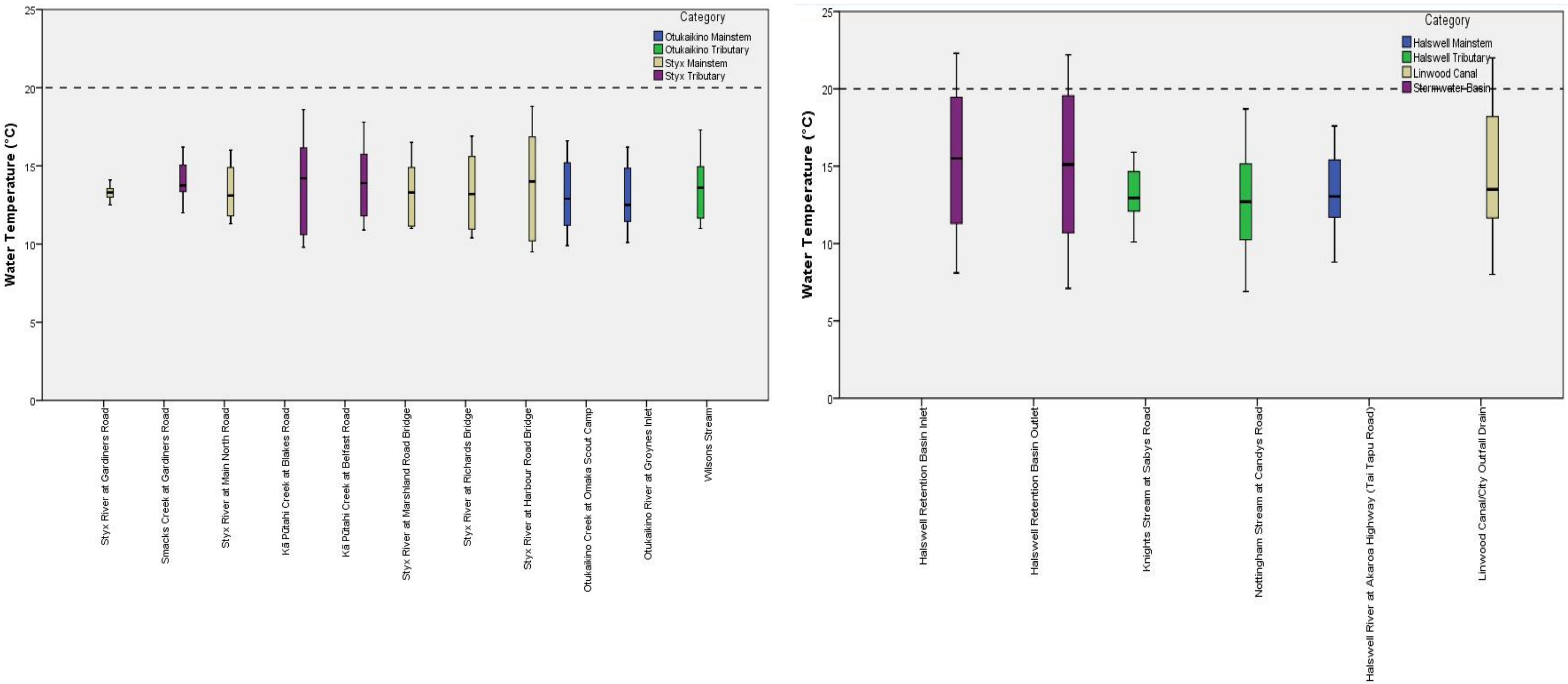


Figure ix (b). Temperature of the water at the time of sampling at the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan maximum guideline value (20 ºC, Environment Canterbury, 2017). 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.

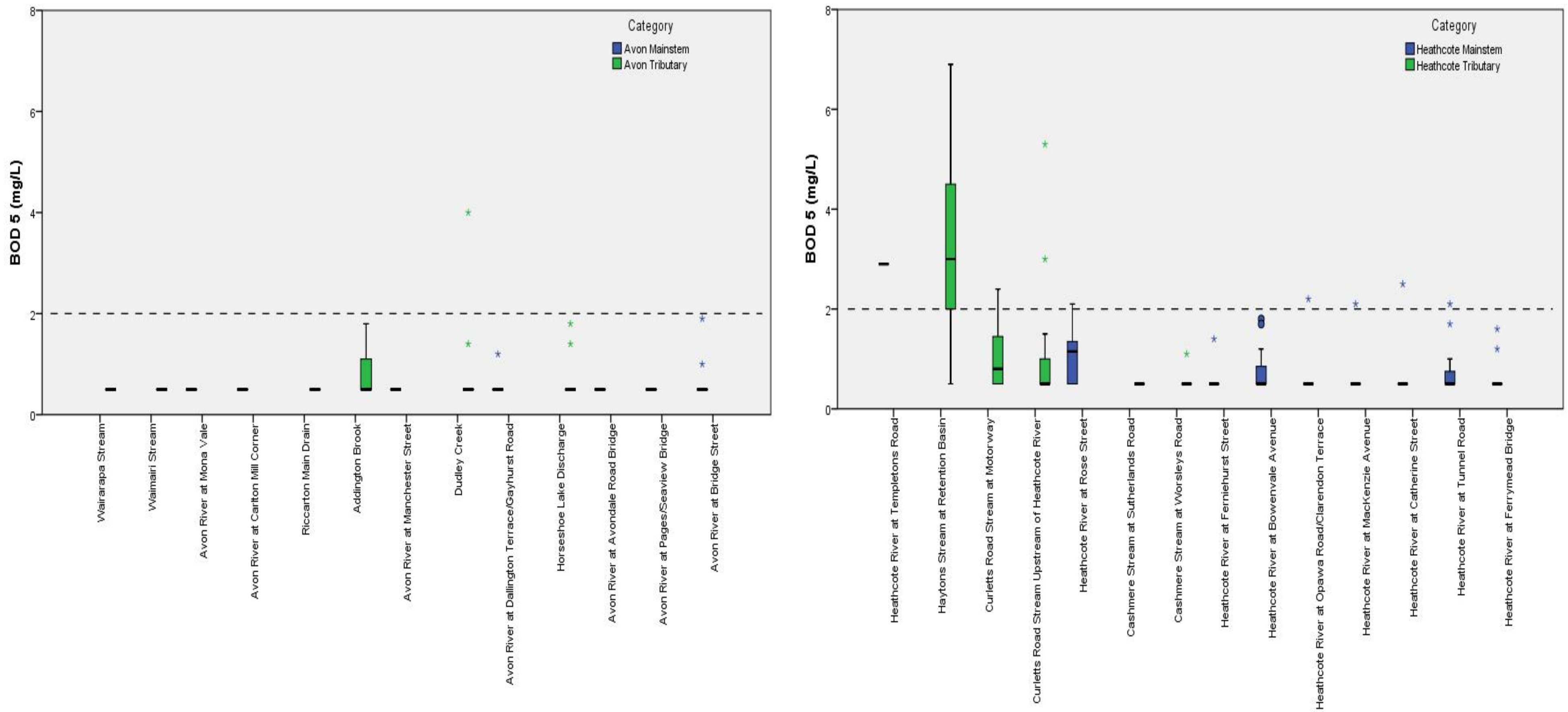


Figure x (a). Biochemical Oxygen Demand (BOD_5) levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. No monitoring was undertaken at the Heathcote River at Templeton's Road site in January and from March – December, as the site was dry. 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.

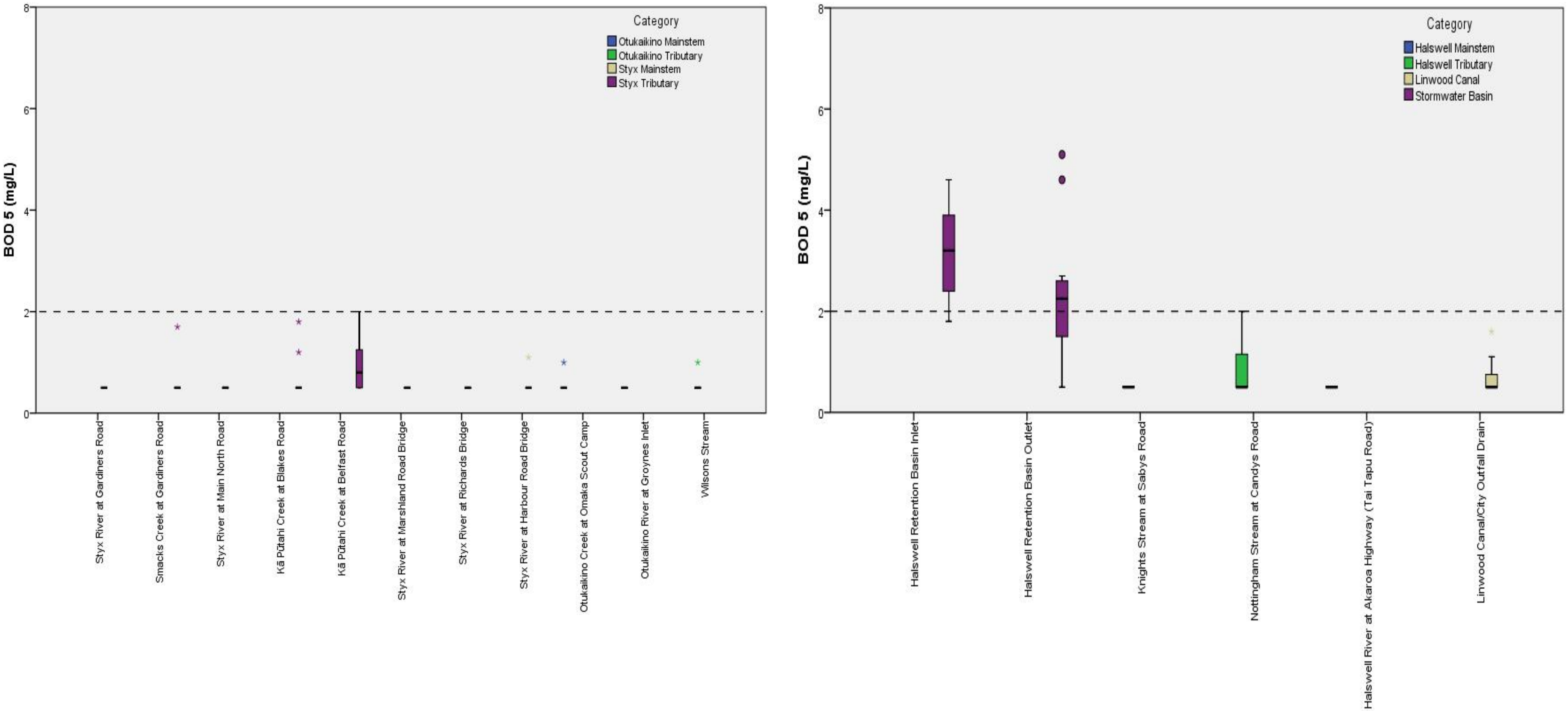


Figure x (b). Biochemical Oxygen Demand (BOD_5) levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (left to right). 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.

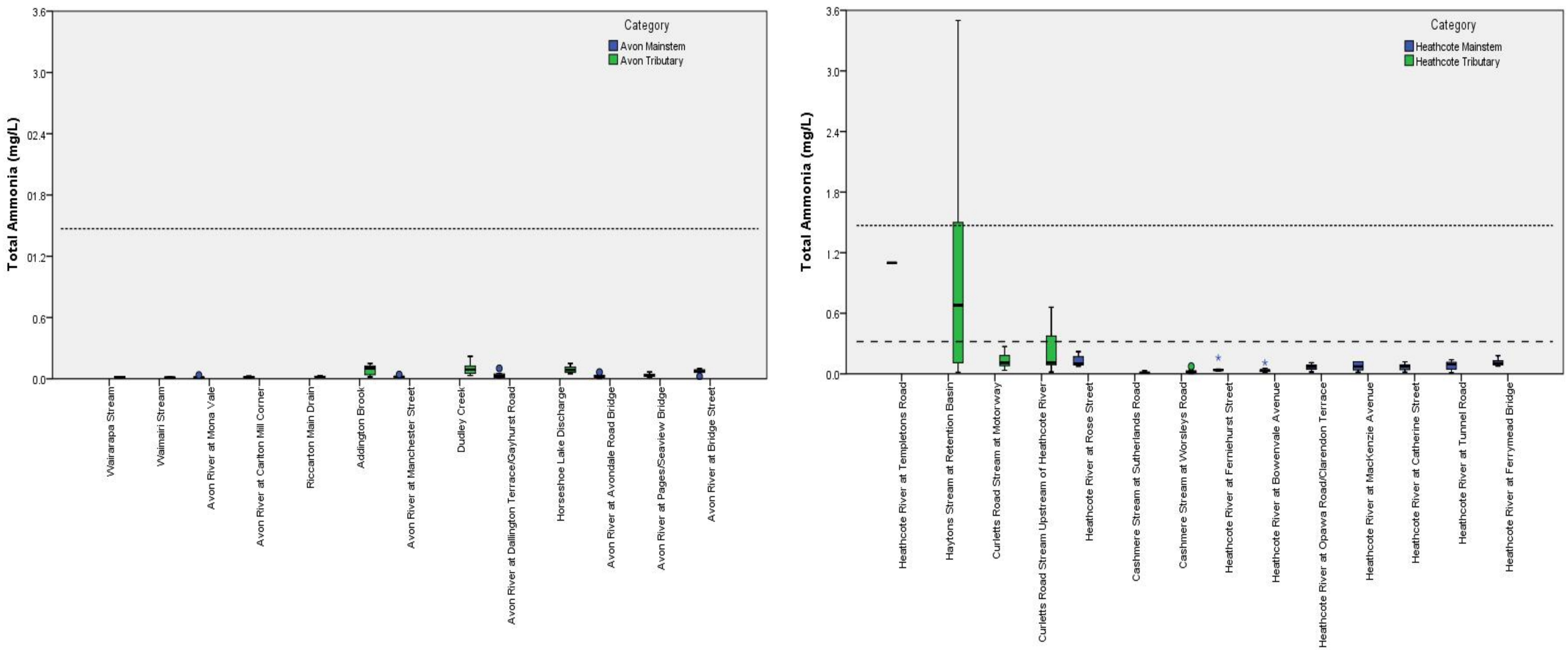
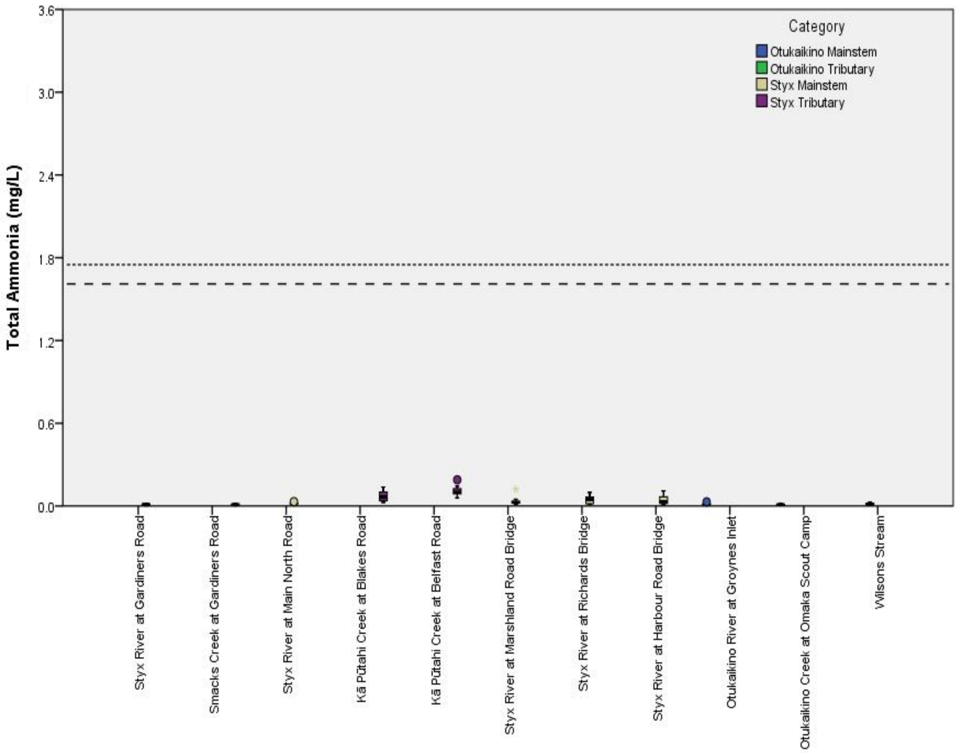


Figure xi (a). Total ammonia levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. No monitoring was undertaken at the Heathcote River at Templeton's Road site in January and from March – December, as the site was dry. 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: 7.6; Heathcote catchment: 7.6; Environment Canterbury, 2017) are presented on the graph. Avon and Heathcote catchment: 1.47 mg/L (dotted line). 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. These graphs are presented on a smaller scale in Appendix E, Figure iii (a).



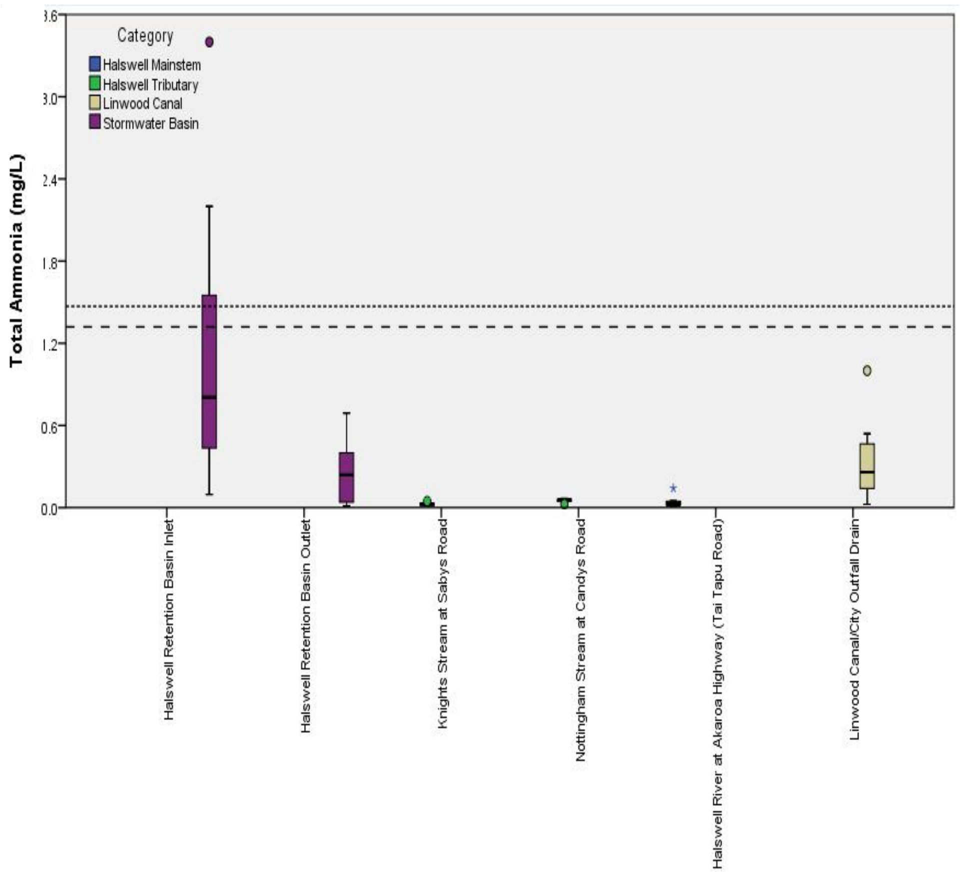


Figure xi (b). Total ammonia levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (left to right), with the exception of Halswell Retention Basin Inlet and Outlet. 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: 7.4; Halswell catchment: 7.6; Linwood Canal: 7.7; Environment Canterbury, 2017), are presented on the graph. Styx catchment: 1.61 mg/L (dashed line, left graph); Ōtūkaikino catchment: 1.75 mg/L (dotted line, left graph); Halswell catchment: 1.47 mg/L (dotted line, right graph); Linwood Canal: 1.32 mg/L (dashed line, right graph). 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. These graphs are presented on a smaller scale in Appendix E, Figure iii (b).

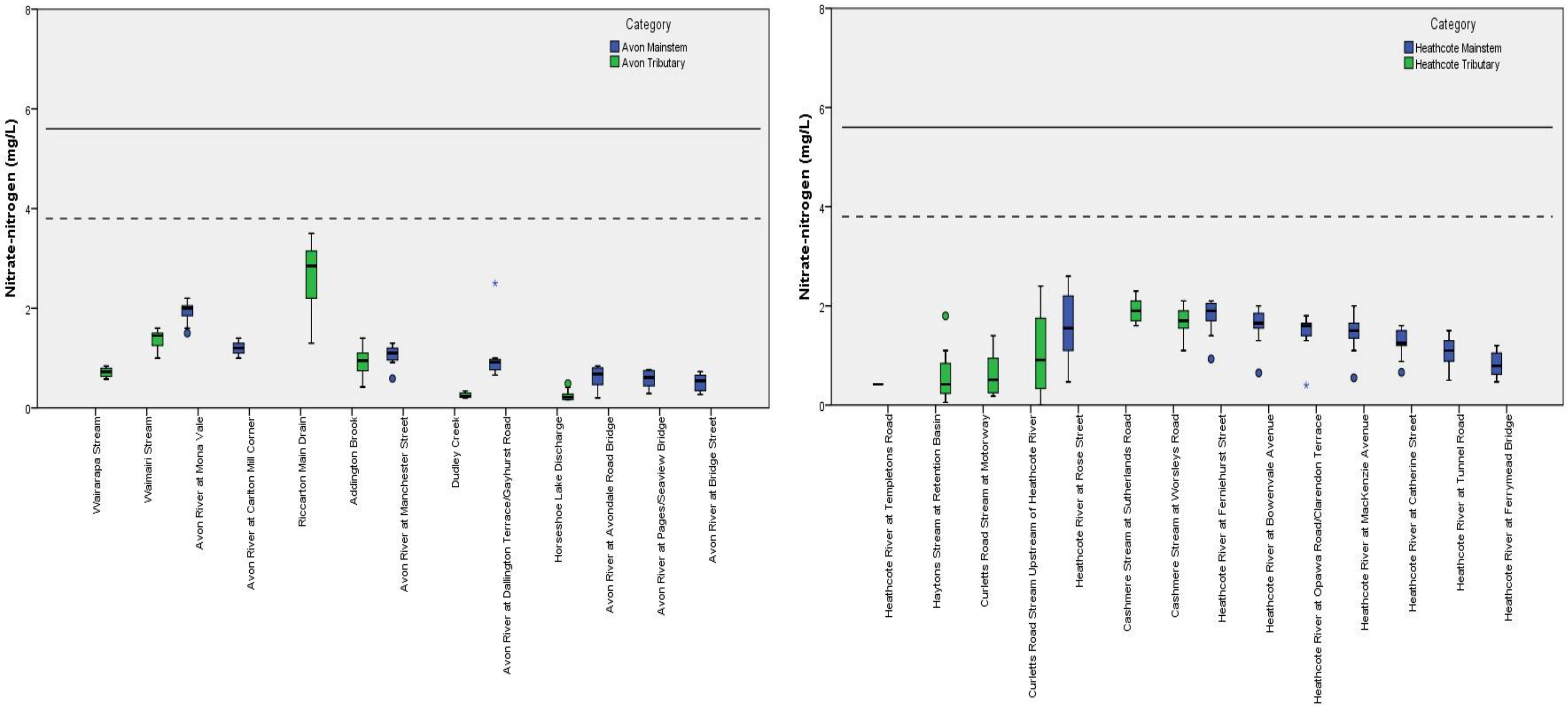


Figure xii (a). Nitrate-nitrogen levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. No monitoring was undertaken at the Heathcote River at Templeton's Road site in January and from March – December, as the site was dry. 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.

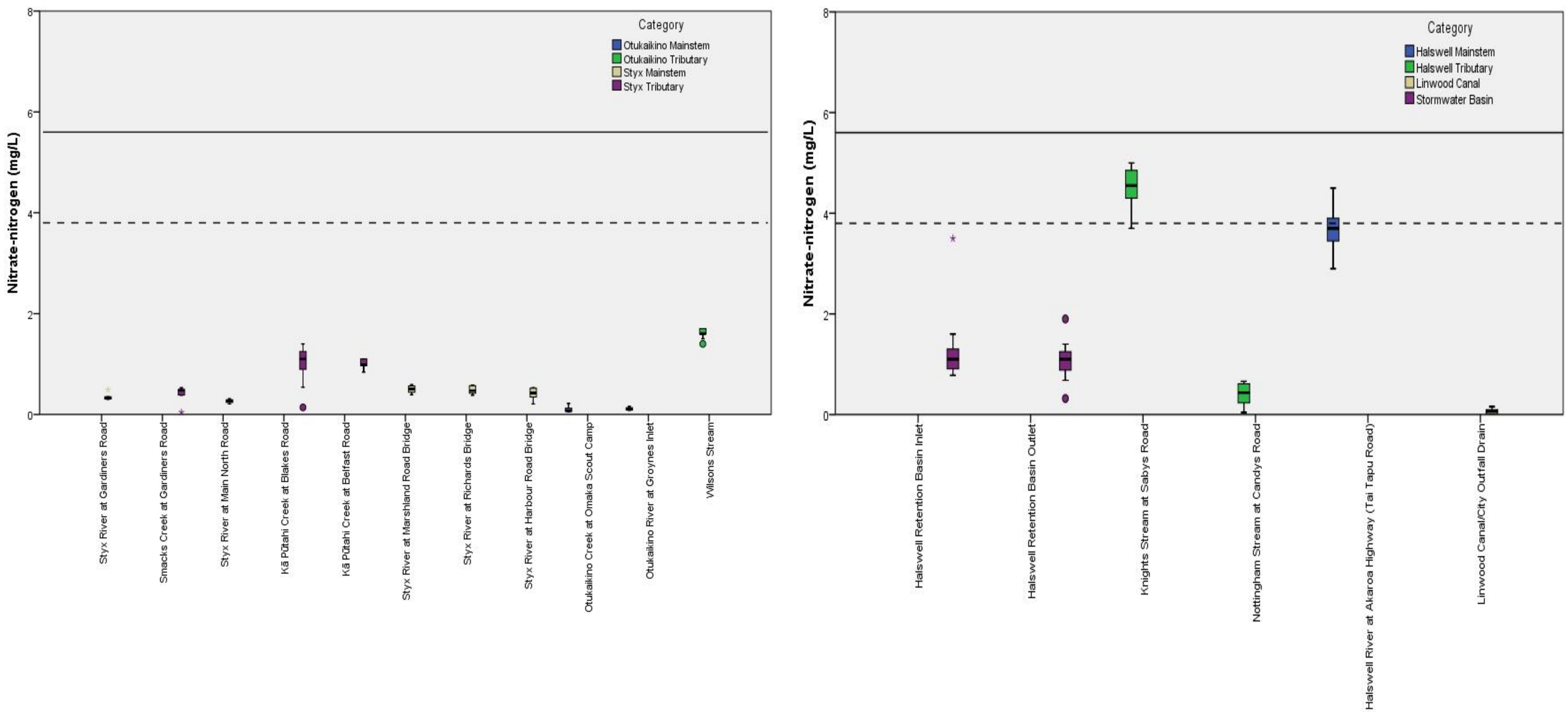
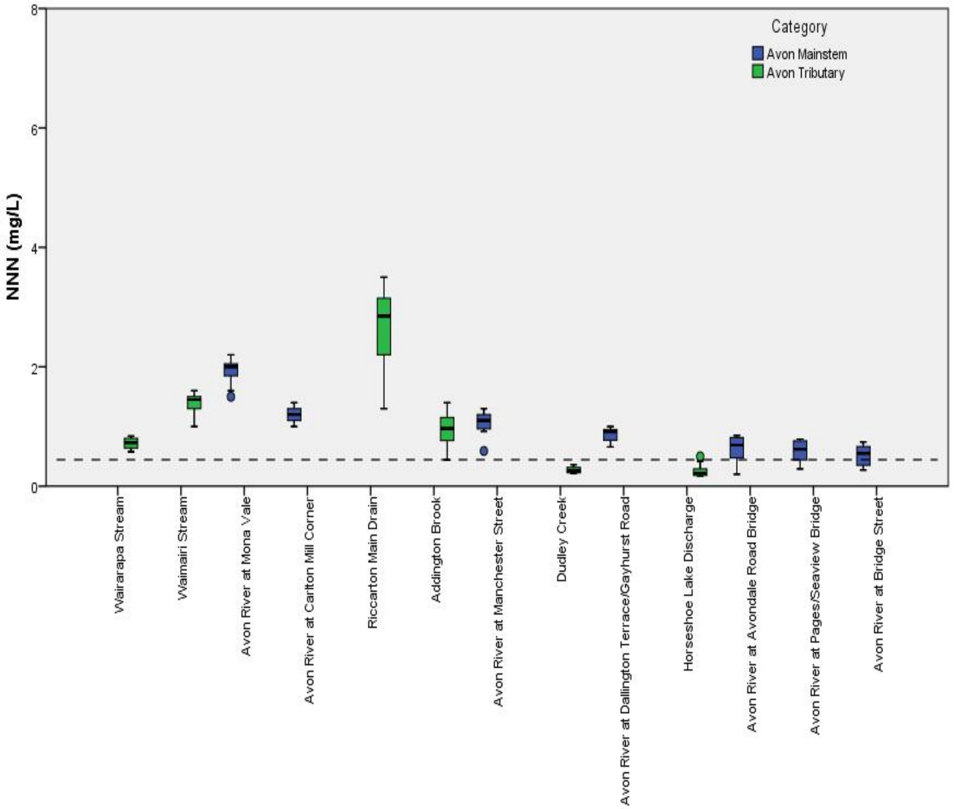


Figure xii (b). Nitrate levels in water samples taken from the Styx and Ōtūkaikino Rivers (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (left to right). The dashed and solid 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.



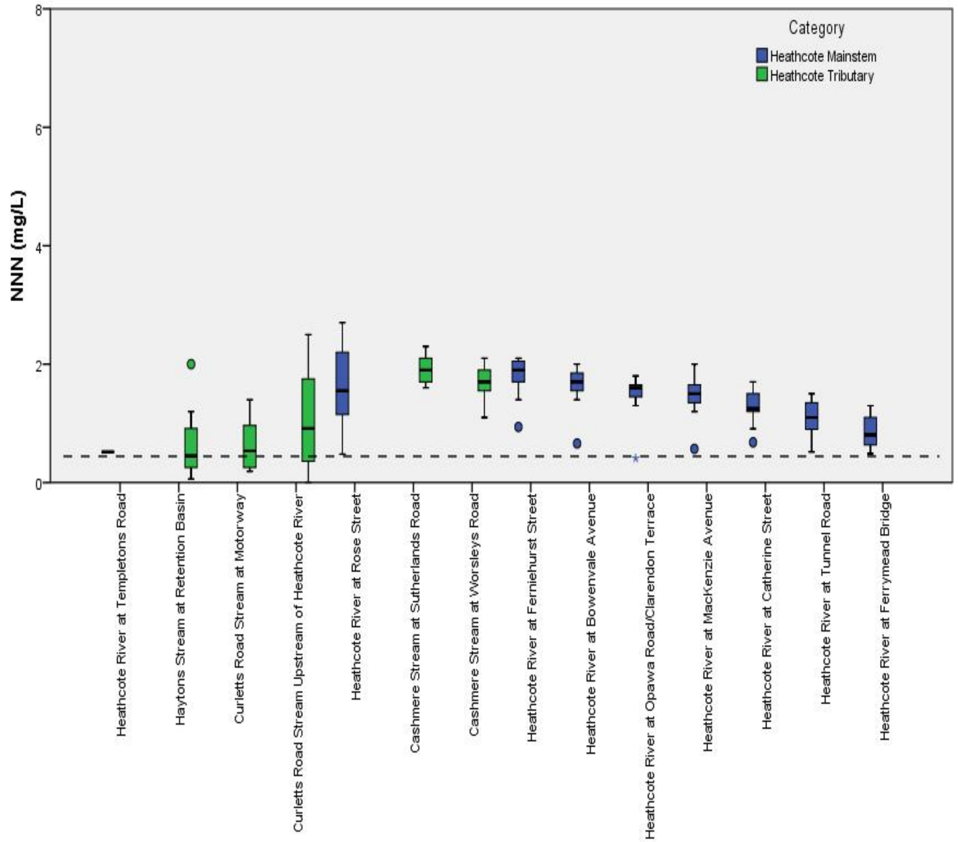
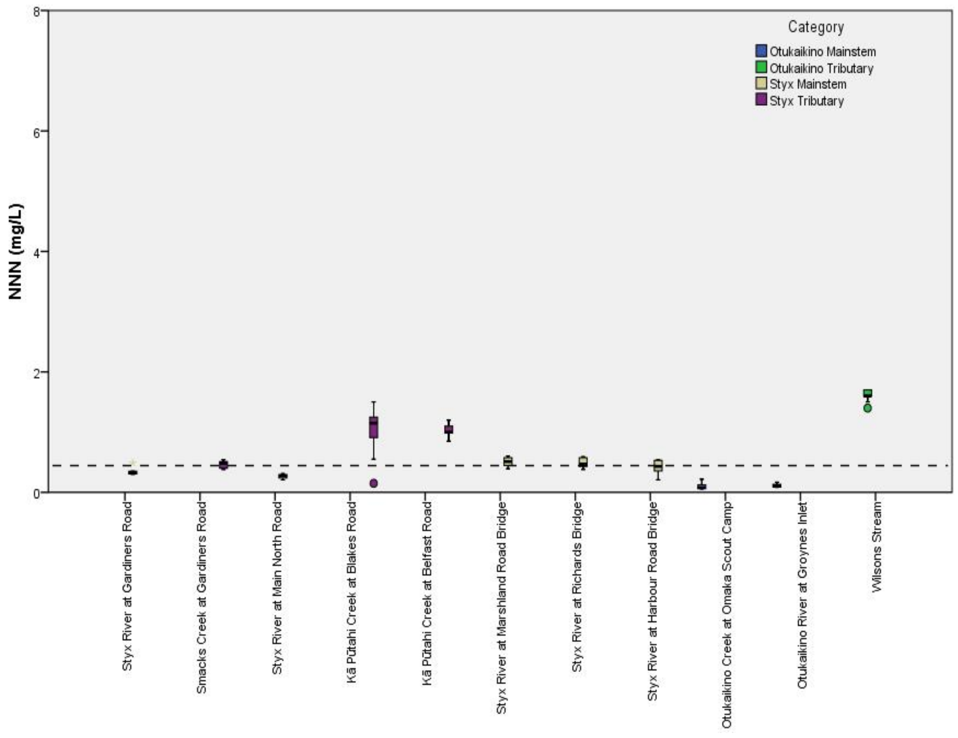


Figure xiii (a). Nitrate Nitrite Nitrogen (NNN) in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. No monitoring was undertaken at the Heathcote River at Templeton's Road site in January and from March – December, as the site was dry. 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).



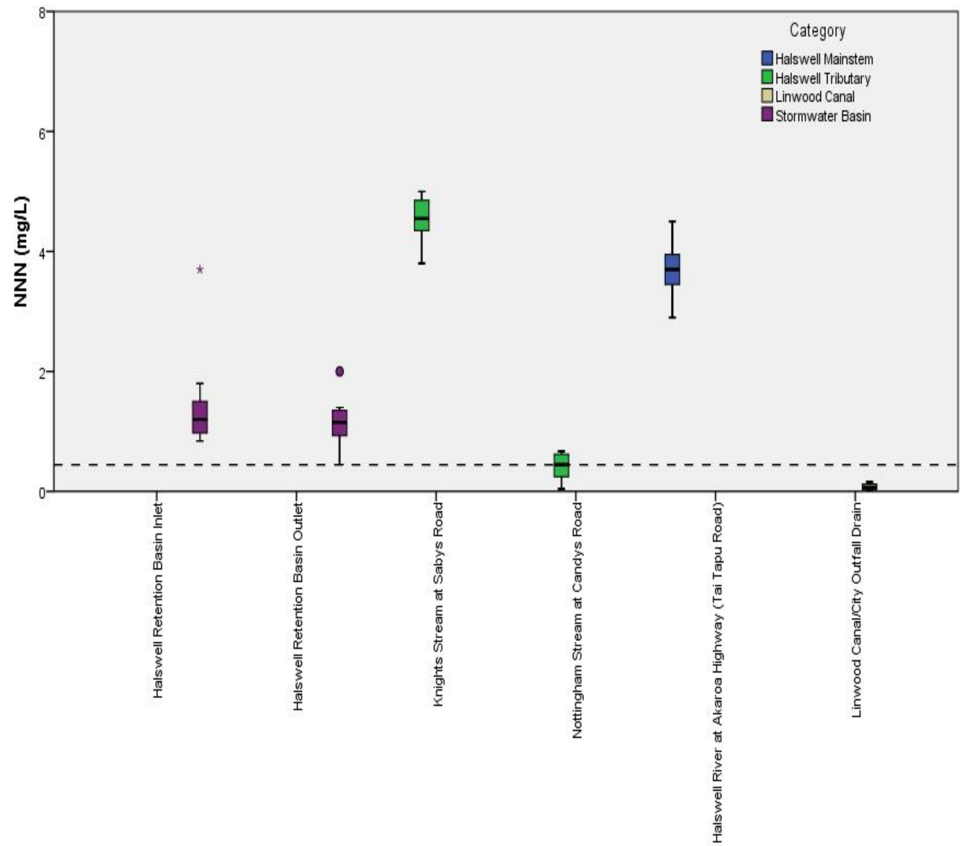


Figure xiii (b). Nitrate Nitrite Nitrogen (NNN) levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (left to right). 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.

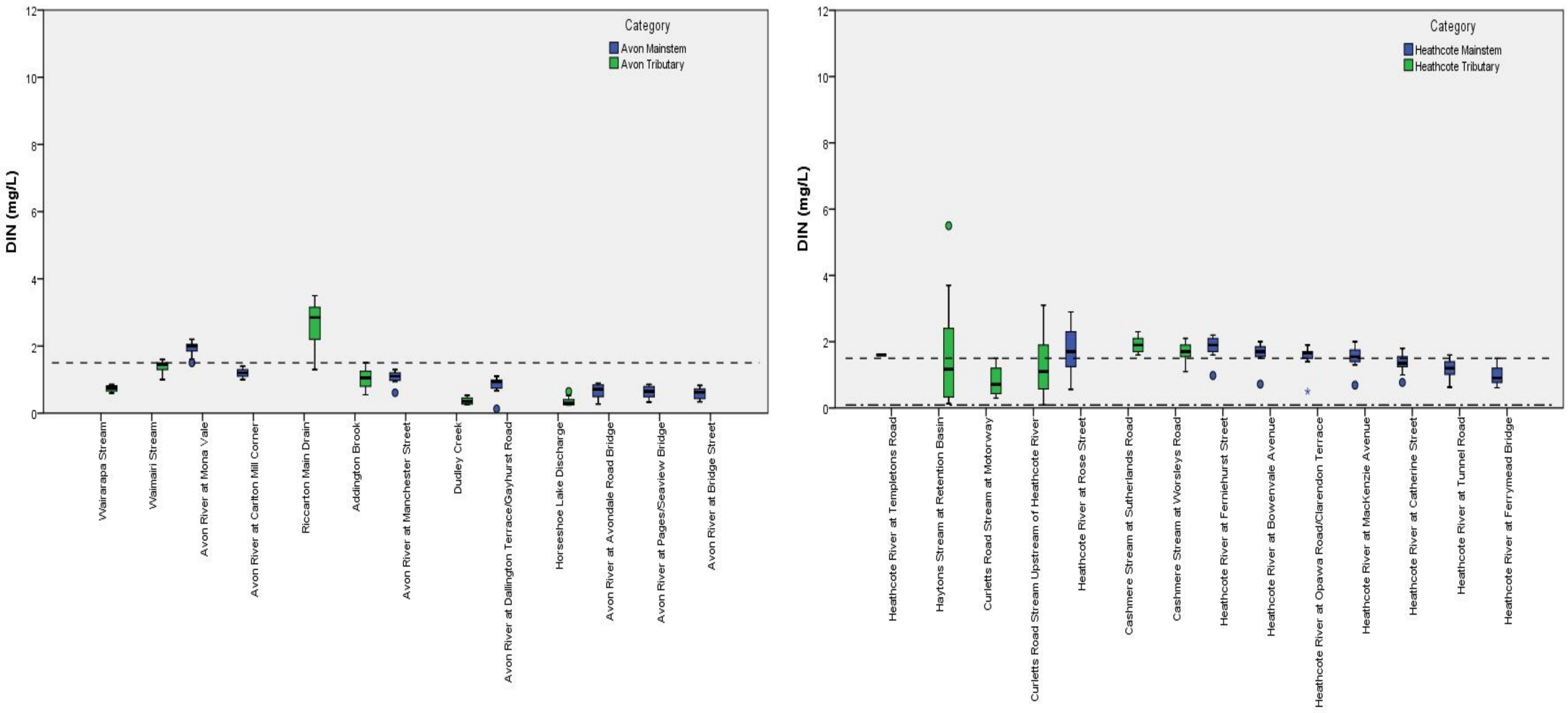
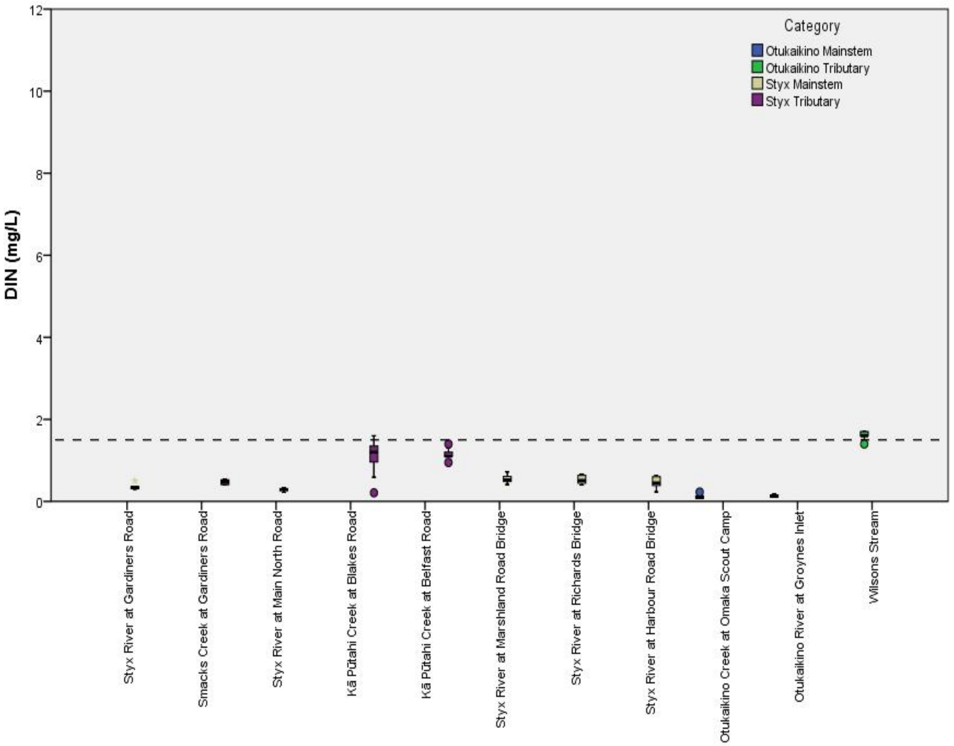


Figure xiv (a). Dissolved Inorganic Nitrogen (DIN) levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. No monitoring was undertaken at the Heathcote River at Templeton's Road site in January and from March – 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 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, 2017).



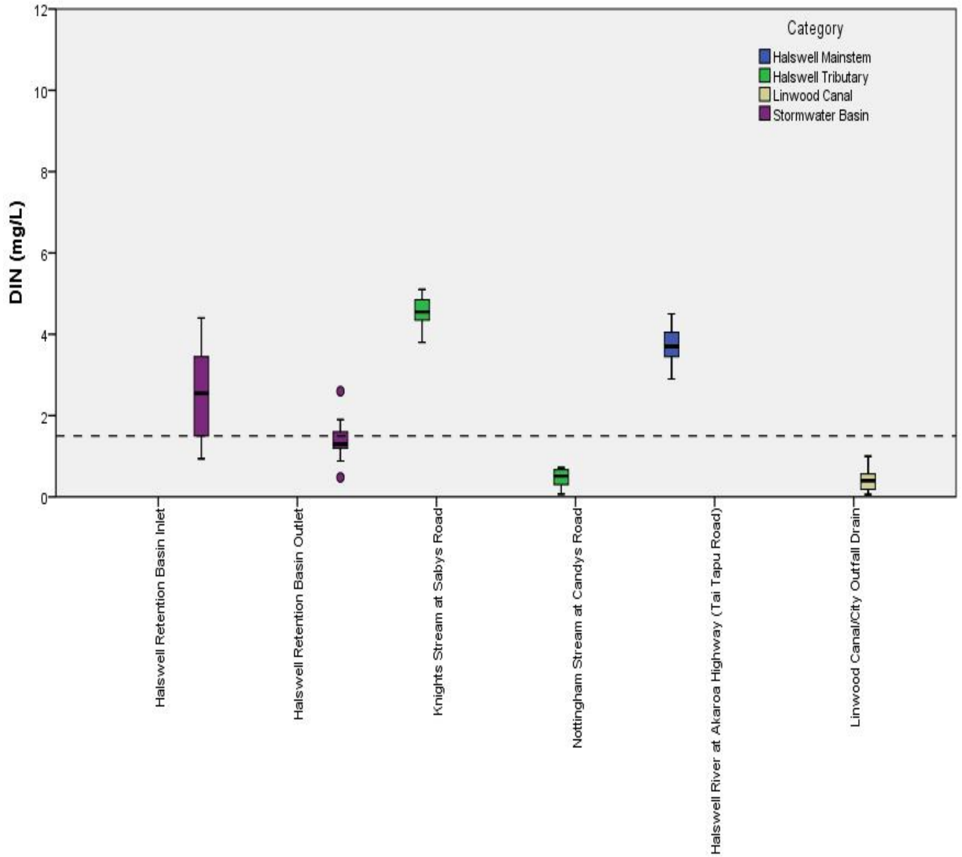


Figure xiv (b). Dissolved Inorganic Nitrogen (DIN) levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (left to right). 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, 2017). 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.

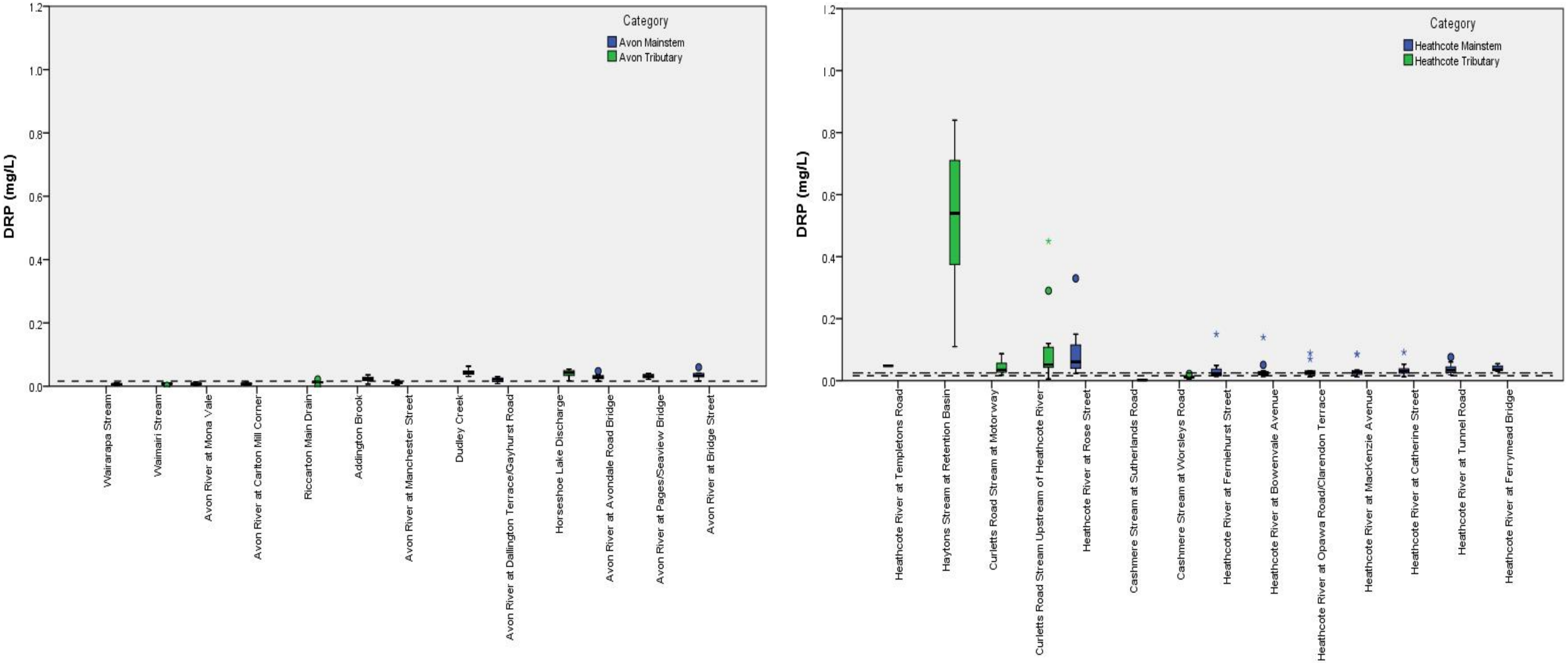


Figure xv (a). Dissolved Reactive Phosphorus (DRP) levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. No monitoring was undertaken at the Heathcote River at Templeton's Road site in January and from March – December, as the site was dry. 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, 2017). 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 iv (a).

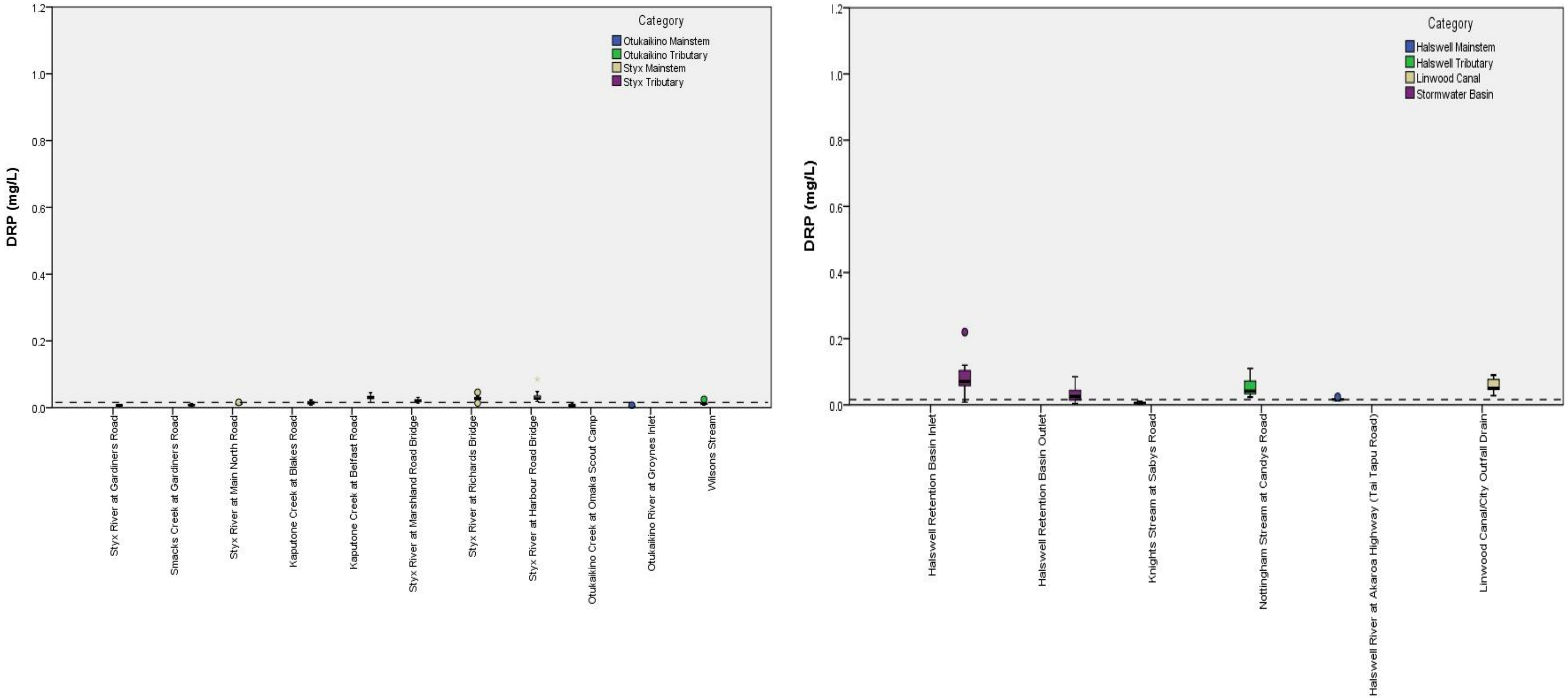


Figure xv (b). Dissolved Reactive Phosphorus (DRP) levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (left to right). 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, 2017). 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 iv (b).

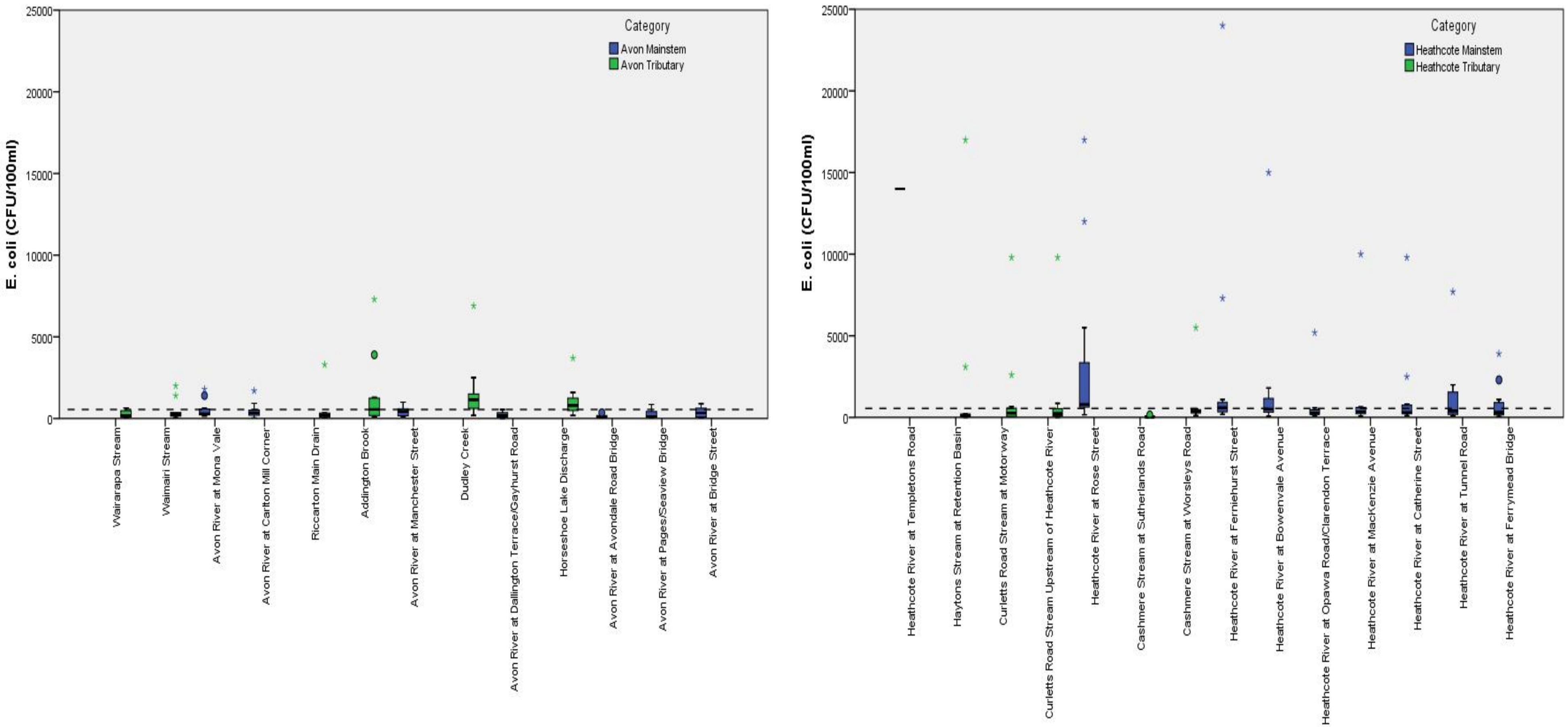
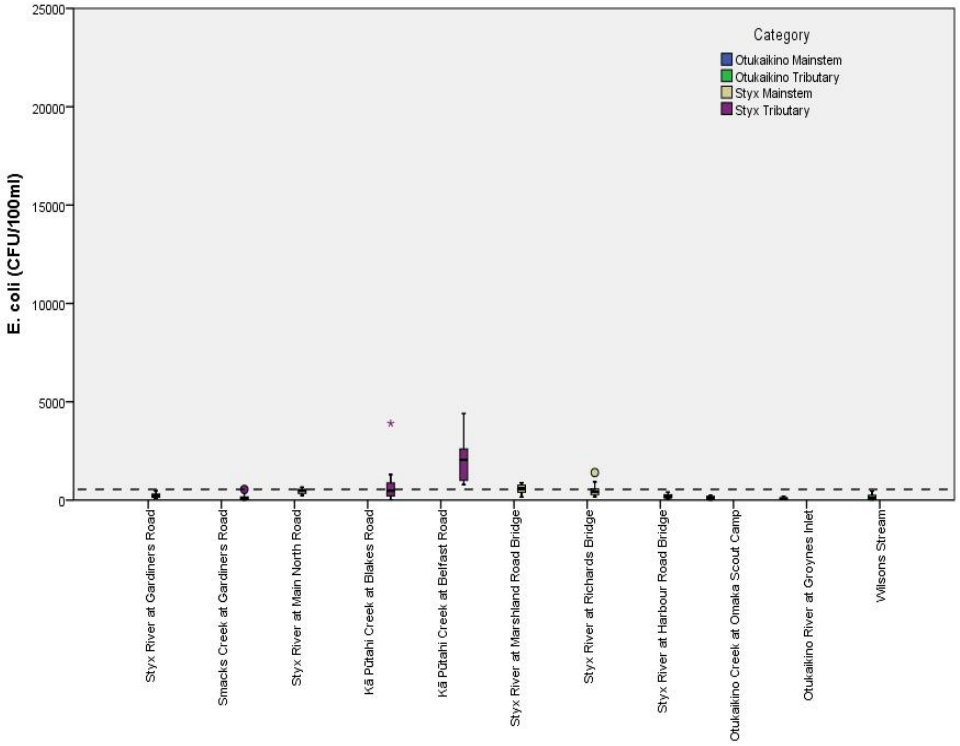


Figure xvi (a). *Escherichia coli* levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. No monitoring was undertaken at the Heathcote River at Templeton's Road site in January and from March – December, as the site was dry. 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, 2017). 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.



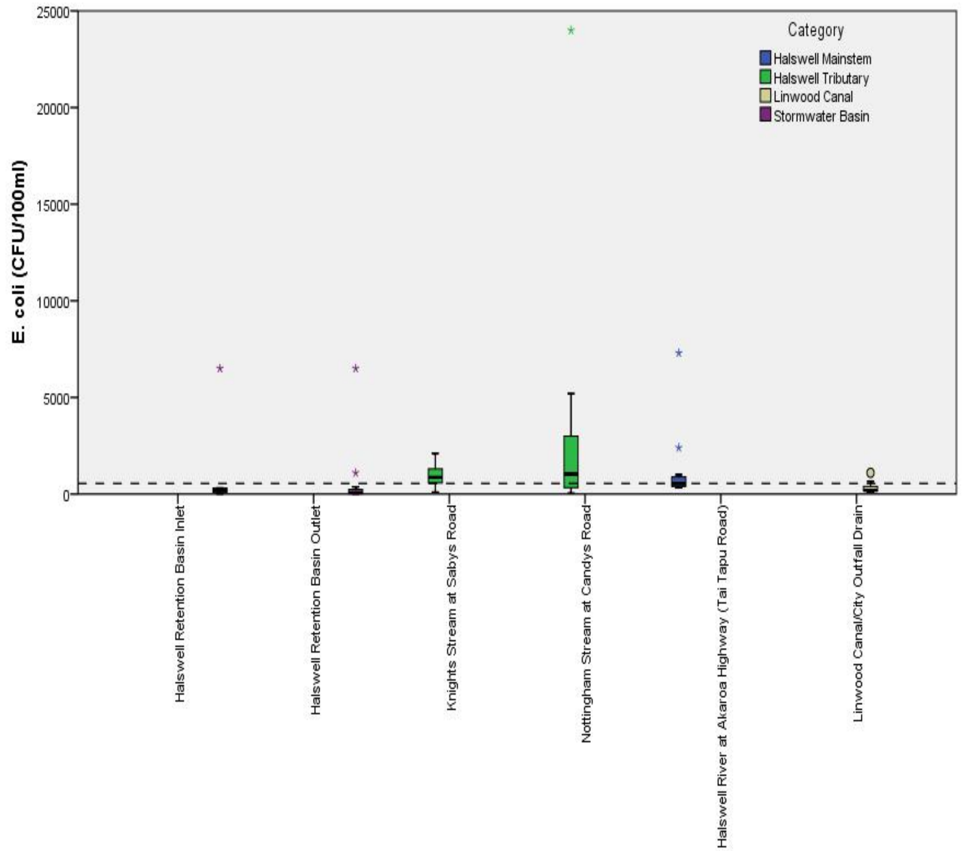


Figure xvi (b). *Escherichia coli* levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (left to right). The dashed 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, 2017). 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 v.

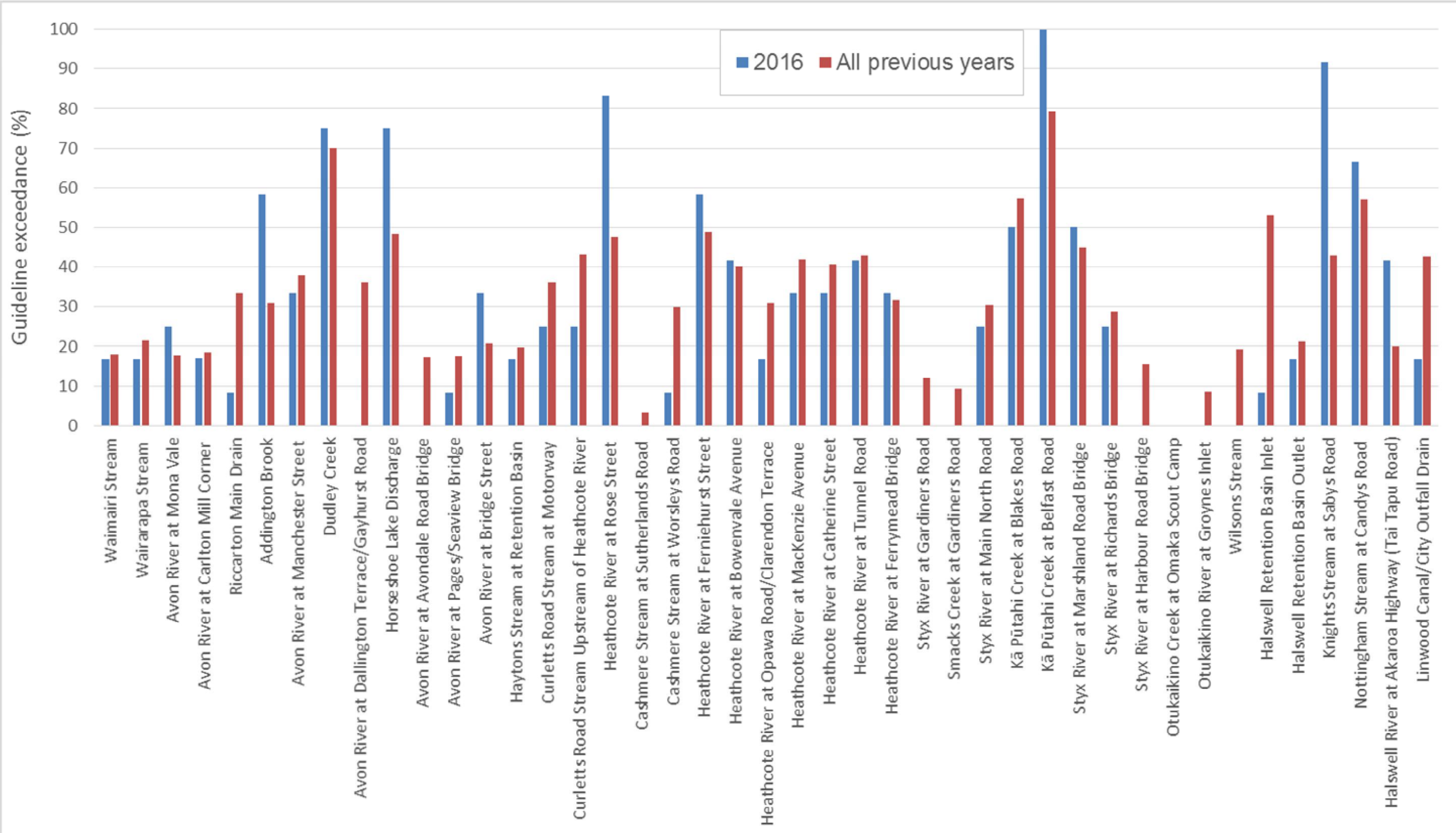


Figure xvi (c). Percentage of samples at each site that exceeded the *Escherichia coli* guideline in 2016 compared to all previous years. Heathcote River at Templetons Road is not presented as it was only sampled once in 2016.

Appendix E: Supplementary Graphs

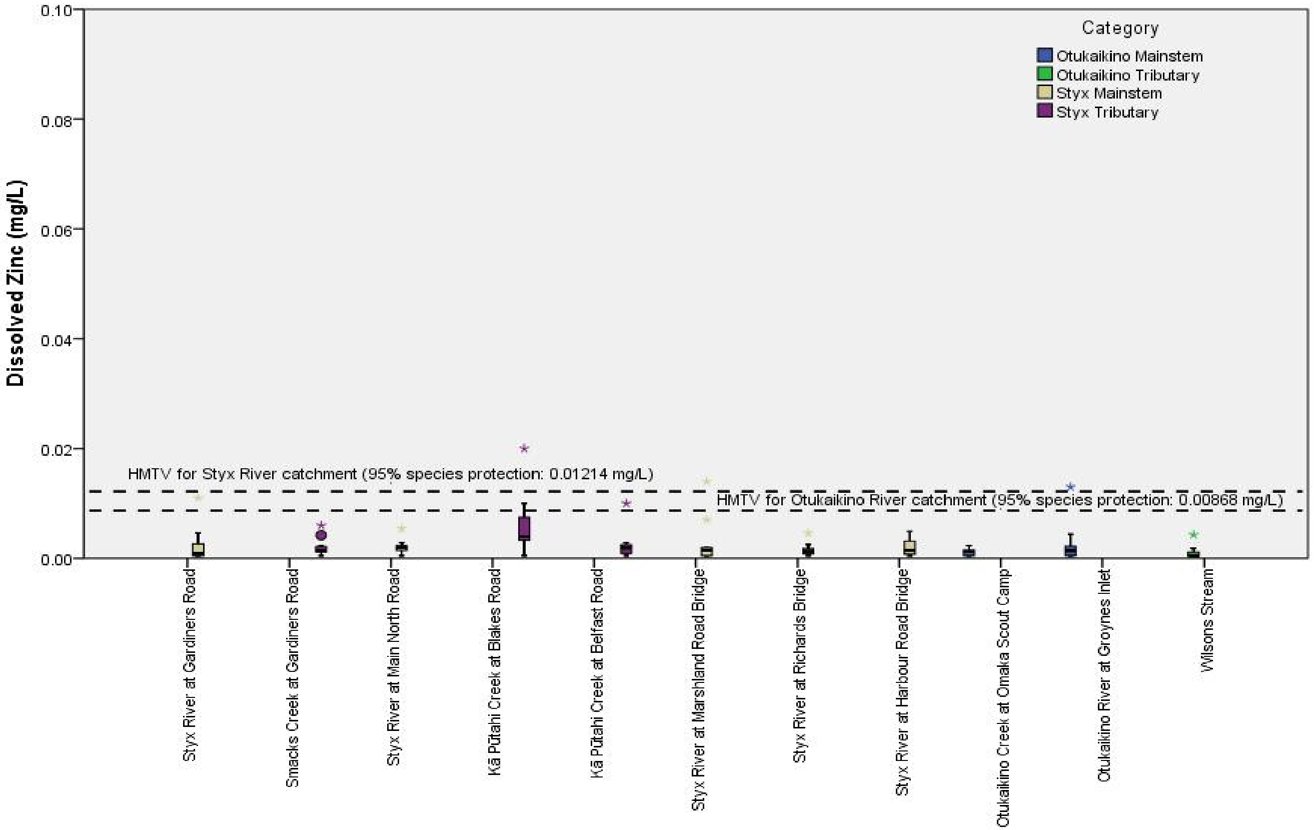


Figure i. This zinc graph is a close up of the graph in Appendix D, Figure iii (b) (left graph). Dissolved zinc levels in water samples taken from the Styx and Ōtūkaikino River for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (left to right). The dashed lines represent the Land and Water Regional Plan trigger values (Environment Canterbury, 2017), 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.

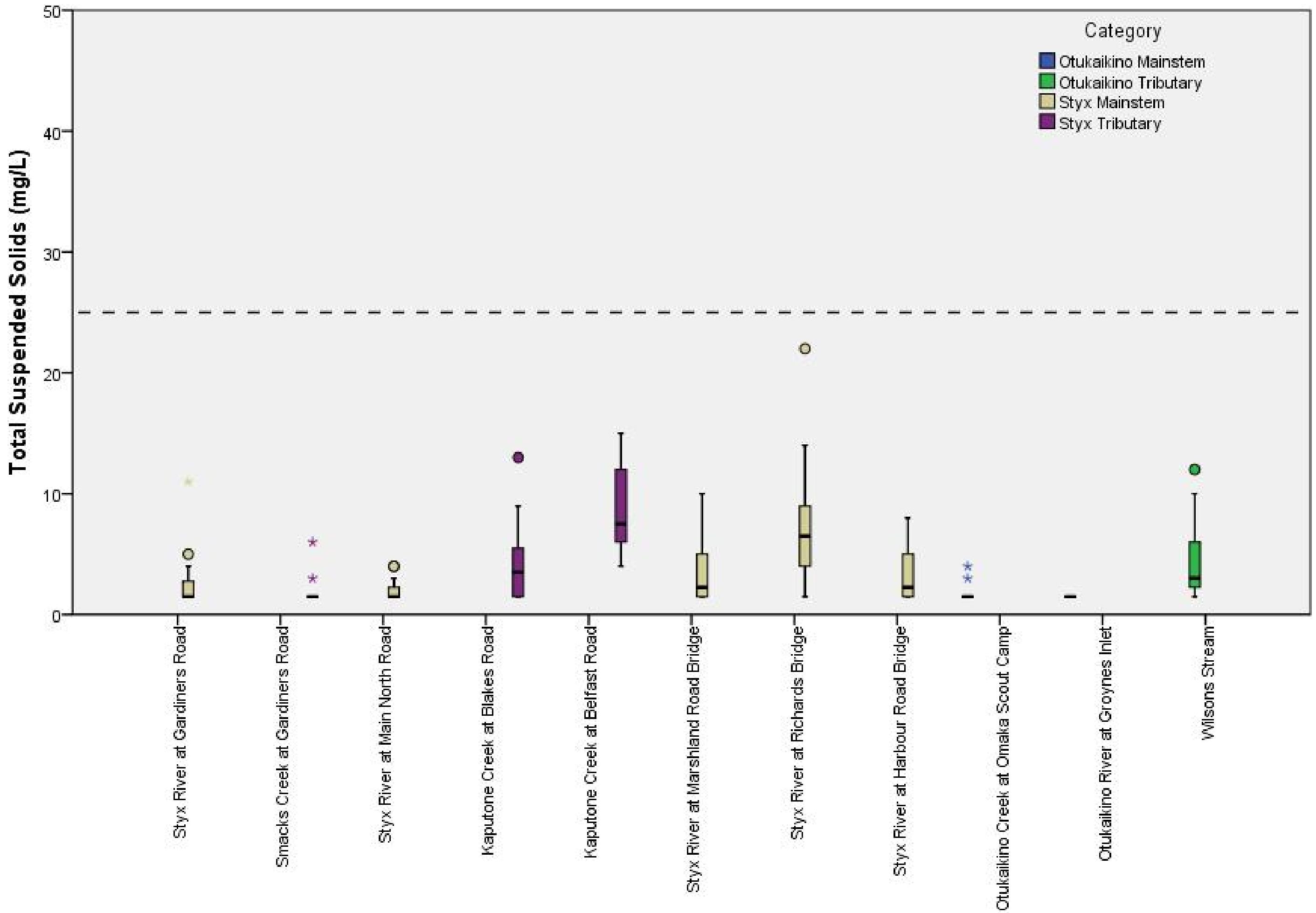
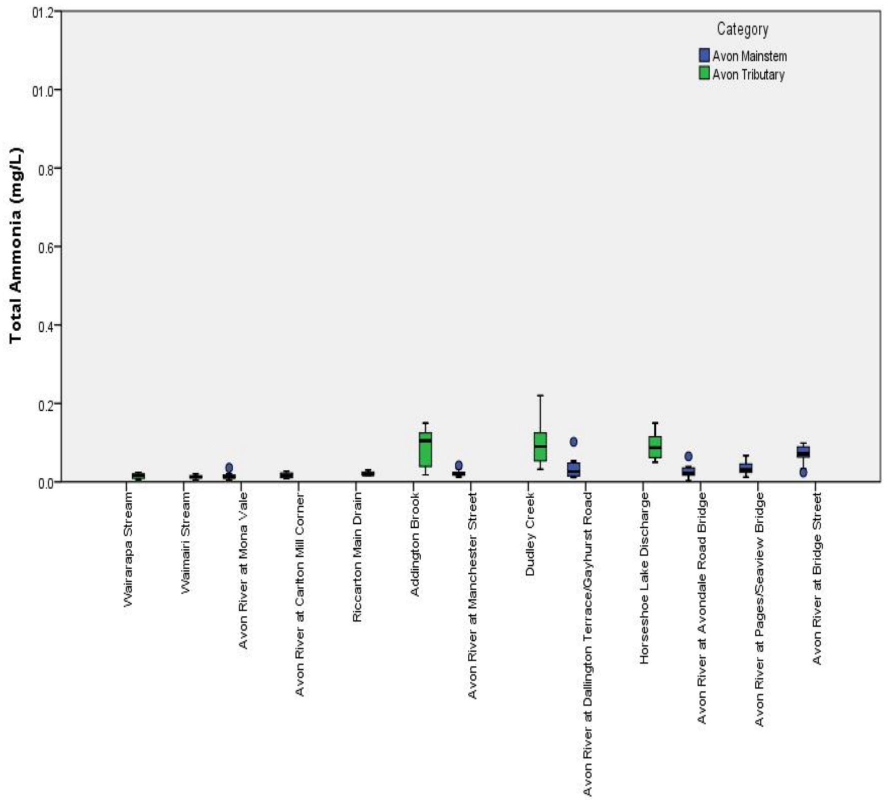


Figure ii. TSS levels in water samples taken from the Styx and Ōtūkaikino Rivers for the monitoring period January to December 2016 (this graph is the same as that presented in Appendix D, Figure vi (b) (left graph), but on a smaller scale). Sites are ordered from upstream to downstream (left to right).



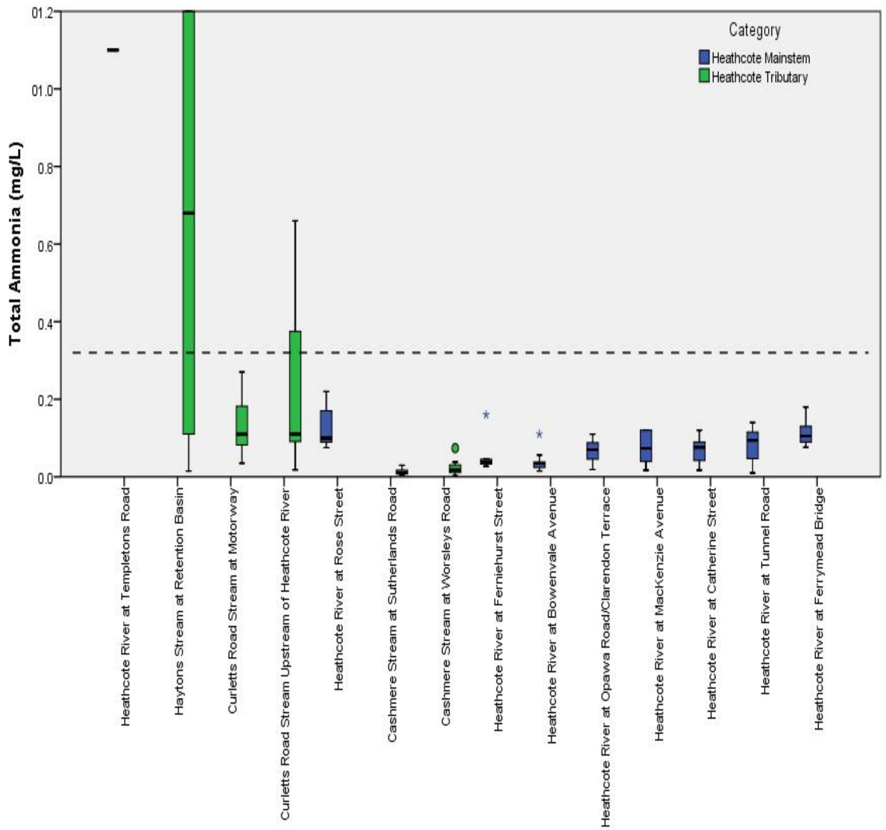


Figure iii (a). These total ammonia graphs are the same as those presented in Appendix D, Figure xi (a), but on a smaller scale. Total ammonia levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. No monitoring was undertaken at the Heathcote River at Templeton's Road site in January and from March – December, as the site was dry. 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: 7.6; Heathcote catchment: 7.6; Environment Canterbury, 2017) are not presented on the graph as they are off the scale. The dashed line represents the Land and Water Regional Plan maximum guideline value for Banks Peninsula waterways (0.32 mg/L, Cashmere Stream only; Environment Canterbury, 2017). 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.

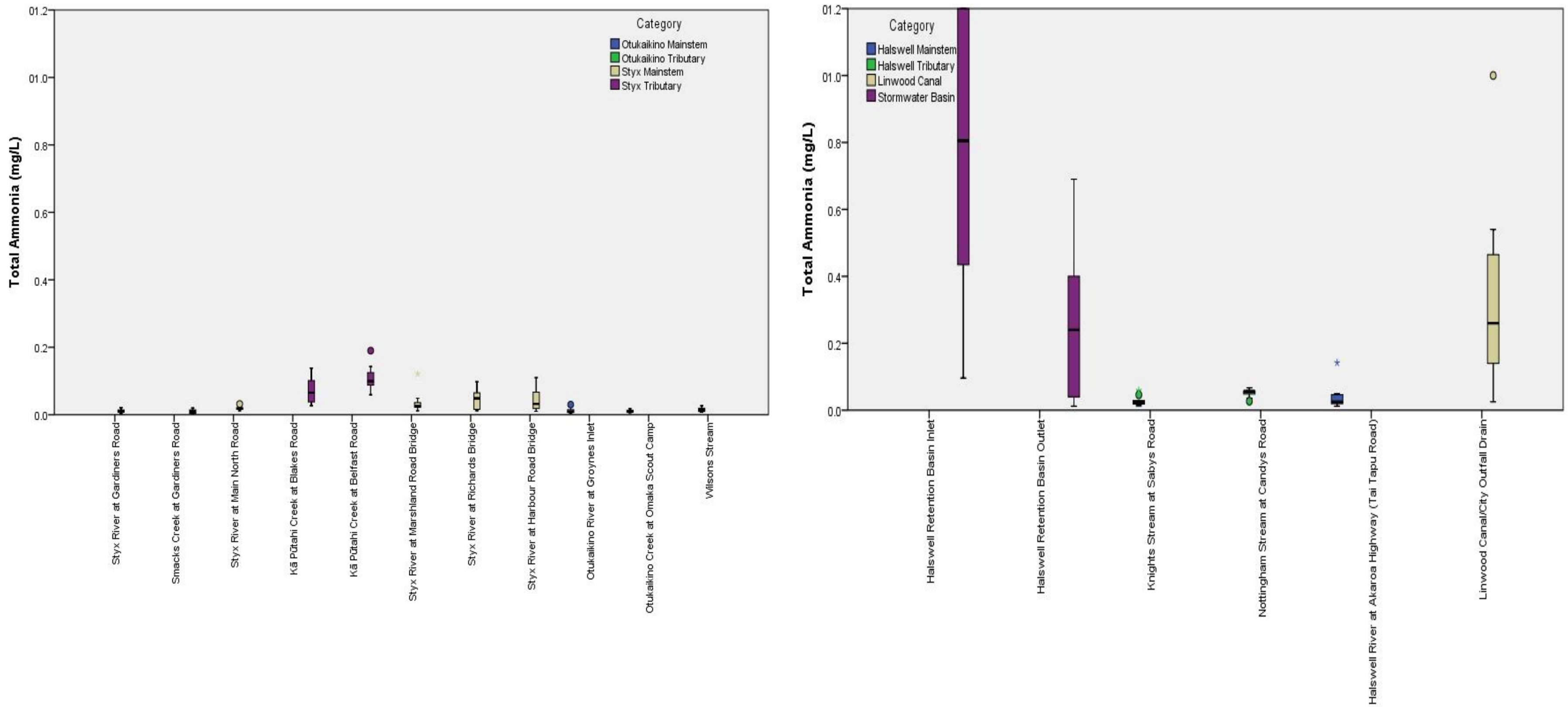


Figure iii (b). These total ammonia graphs are the same as those presented in Appendix D, Figure xi (b), but on a smaller scale. Total ammonia levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (left to right), with the exception of Halswell Retention Basin Inlet and Outlet. 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: 7.4; Halswell catchment: 7.6; Linwood Canal: 7.7; Environment Canterbury, 2017), are not presented on the graph as they are off the scale. The Laboratory Limit of Detection was 0.005 mg/L – analysed as half this value (0.0025 mg/L) to allow statistics to be undertaken.

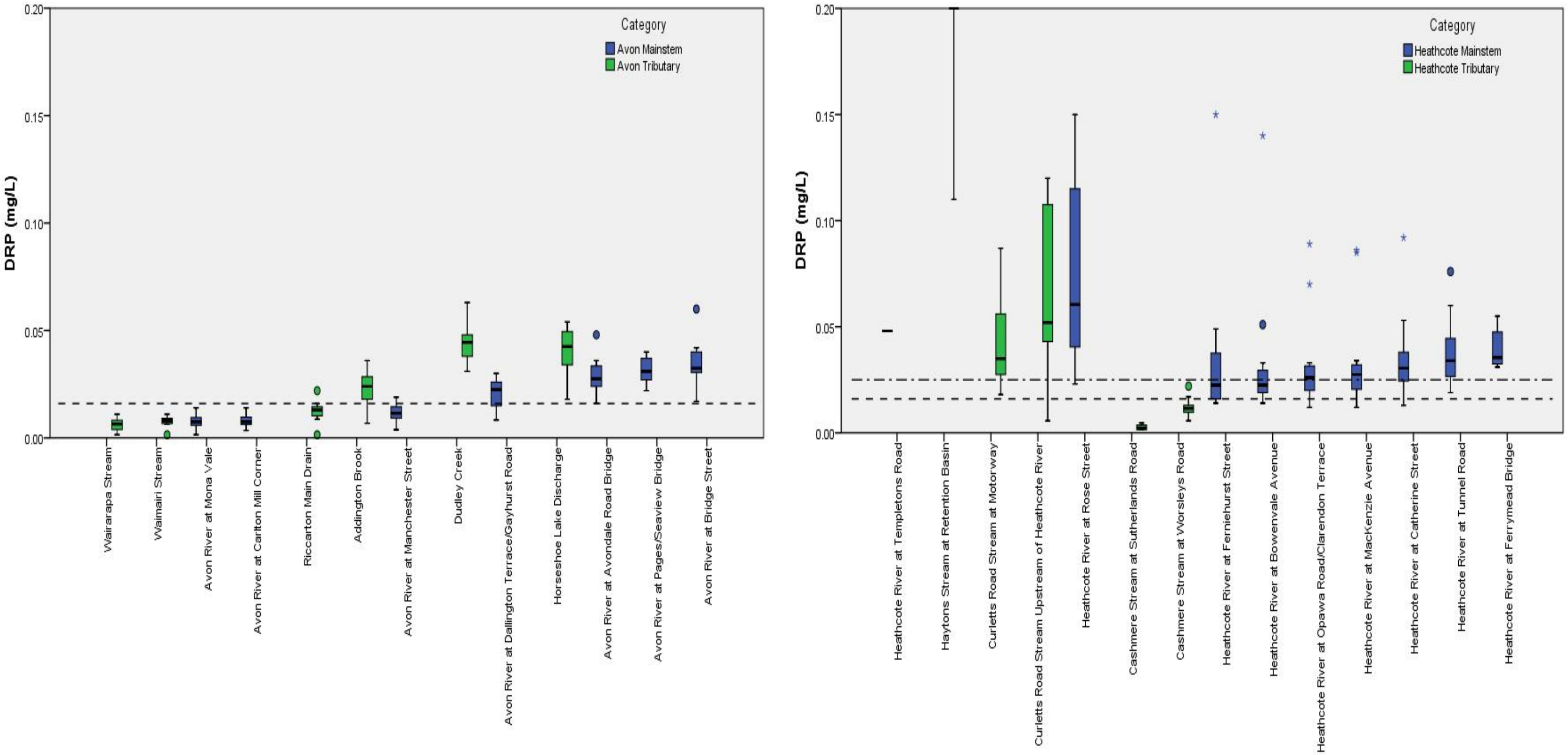


Figure iv (a). These Dissolved Reactive Phosphorus (DRP) graphs are the same as those presented in Appendix D, Figure xv (a), but on a smaller scale. DRP levels in water samples taken from the Avon (left graph) and Heathcote (right graph) River sites, for the monitoring period January to December 2016. No monitoring was undertaken at the Heathcote River at Templeton's Road site in January and from March – December, as the site was dry. 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, 2017). 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.

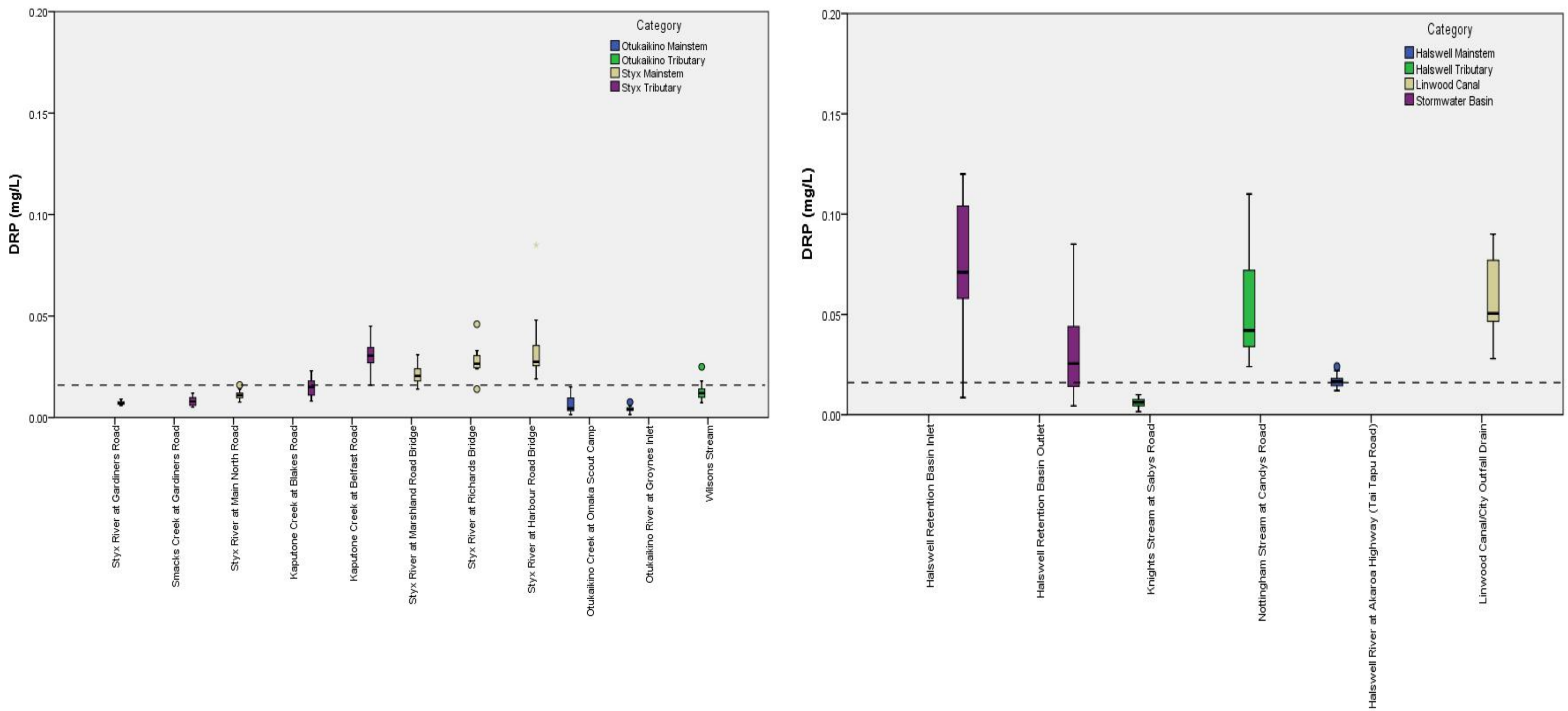


Figure iv (b). These Dissolved Reactive Phosphorus (DRP) graphs are the same as those presented in Appendix D, Figure xv (b), but on a smaller scale. DRP levels in water samples taken from the Styx and Ōtūkaikino River (left graph), and the Halswell River and Linwood Canal sites (right graph) for the monitoring period January to December 2016. 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, 2017). 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.

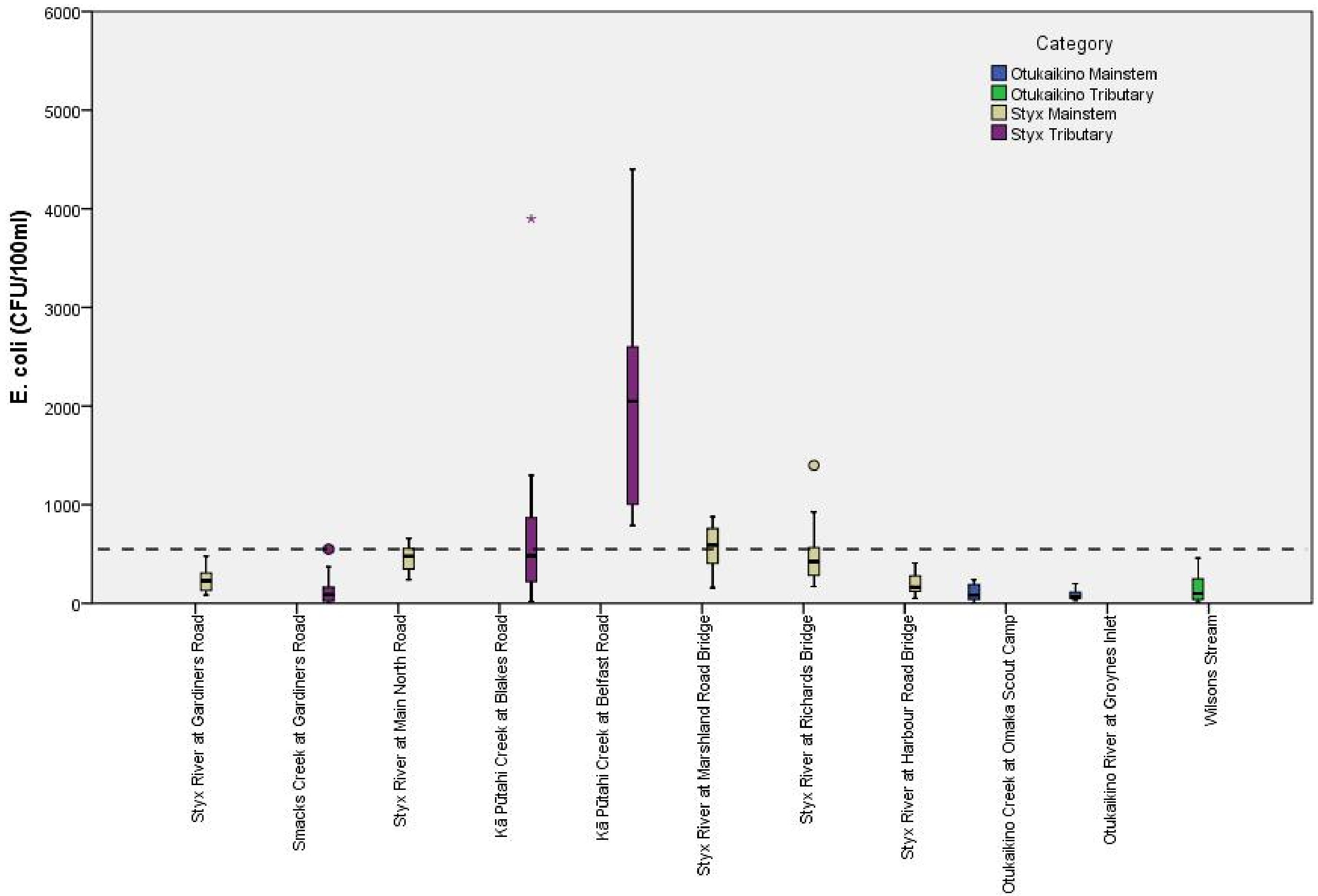


Figure v. This *Escherichia coli* (*E. coli*) graph is the same as that presented in Appendix D, Figure xvi (b), but on a smaller scale. *E. coli* levels in water samples taken from the Styx and Ōtūkaikino Rivers for the monitoring period January to December 2016. Sites are ordered from upstream to downstream (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, 2017). 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.

Appendix F: Comparison of results from Time Trends version 5 and 6.2

Comparison of trend analysis results for selected parameters and sites using Time Trends version 5 (old method) and version 6.2 (new method). To maintain consistency with prior reports, the old method was used for this report. Data are up to December 2015.

Site	Dissolved zinc		DRP		TSS		DIN	
	Old method	New method	Old method	New method	Old method	New method	Old method	New method
Wairarapa Stream	No significant change	No significant change			No significant change	á 93%		
Avon River at Carlton Mill Corner					No significant change	â 20%	No significant change	No significant change
Addington Brook	â 17%	No significant change						
Avon River at Manchester Street	No significant change	No significant change					No significant change	No significant change
Dudley Creek	No significant change	â 28%			á 10%	No significant change		
Avon River at Dallington Terrace/Gayhurst Road	No significant change	No significant change						
Avon River at Pages/Seaview Bridge	â 14%	â 22%						
Cashmere Stream at Sutherlands Road	á 29%	á 30%						
Knights Stream at Sabys Road			No significant change	â 15%			á 15%	á 16%
Nottingham Stream at Candys Road							â 8%	â 8%
Smacks Creek at Gardiners Road	No significant change	No significant change						