Styx Stormwater Management Plan Surface Water Quality Monitoring January – December 2013

Dr Belinda Whyte
Asset and Network Planning Unit

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1 Introduction

The resource consent for the Styx Stormwater Management Plan (Styx SMP; CRC131249) commenced on the 24 October 2013 and includes conditions relating to the monitoring of surface water quality. This report summarises the results of this monitoring for the year 2013 (January to December). The monitoring program involves monthly collection and analysis of water quality samples from nine sites in the Styx River catchment.

2 Methods

2.1 Sites and Sample Collection

One site is located in Smacks Creek, five sites are located on the Styx River mainstem and two sites are located in Kaputone Creek (Table 1, Figure 1). An additional site is located in Wilsons Drain, but this is only a new site and therefore no water quality data was available for this monitoring report (this site will be up and running for the next report). Water samples were collected from these sites monthly by the Christchurch City Council laboratory, according to the protocol outlined in the monitoring plan. All three waterways are classified with respect to Environment Canterbury's Proposed Land and Water Regional Plan (pLWRP) as 'spring-fed – lower basin'. These classifications determine the relevant guideline levels under this plan for each of the measured parameters, which are compared against the results of this monitoring in this report.

Table 1. Surface water quality monitoring sites of the Styx Stormwater Management Plan

Site	Easting	Northing
Smacks Creek at Gardiners Road	2476819	5749565
Styx River at Gardiners Road	2476786	5748840
Styx River at Main North Road	2479066	5748833
Kaputone Creek at Blakes Road	2480401	5749645
Kaputone Creek at Belfast Road	2482195	5749882
Styx River at Marshland Road bridge	2482359	5749393
Styx River at Richards bridge	2483980	5751255
Styx River at Harbour Road bridge	2485000	5756366
Wilsons Drain at Main North Road	2481242	5752409

Christchurch City Council

Figure 1. Surface water quality monitoring sites in the Styx Stormwater Management Plan area

2.2 Water Quality Parameters Tested

The samples were tested at the laboratory for a range of different water quality parameters, as outlined in Table 2. A brief discussion of each parameter, their importance and relevant guideline values are included in the following paragraphs.

Metals, in particular, *copper*, *lead* and *zinc*, can be toxic to aquatic organisms, negatively affecting such things as fecundity, maturation, respiration, physical structure and behaviour (Harding, 2005). The toxicity of metals in freshwater, and therefore the risk of adverse biological effects, alters depending on the hardness, pH and alkalinity of the water, with a positive relationship between toxicity and water hardness (ANZECC 2000). Therefore, trigger levels should be calculated with consideration of water hardness (ANZECC 2000). For this monitoring report, this is relevant for dissolved copper, lead and zinc. The Council has previously calculated Hardness Modified Trigger Values (HMTV) for metals in Christchurch Rivers in accordance with ANZECC (2000) methodology (see Appendix A) 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. The water quality standards in the pLWRP for Styx SMP waterways are a lower and upper pH limit of 6.5 and 8.5, respectively. 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).

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 Environment Canterbury do not consider this guideline value is useful, due to natural variations in levels (Abigail Bartram, Environment Canterbury, personal communication). 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). Ryan (1991) recommends a guideline value of 25 mg/L to ensure protection of aesthetic and ecological values.

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). ANZECC (2000) provides a guideline of 5.6 Nephelometric Turbidity Units (NTU) for turbidity in lowland rivers.

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 DO minimum water quality standard in the pLWRP for 'spring-fed – lower basin' waterways is 90%.

High *water temperature* can affect aquatic biota, with some studies showing that the presence of sensitive macroinvertebrates decreases with increasing temperature (Wahl et al., 2013). The pLWRP water quality standard for temperature is a minimum of 20°C.

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 values of BOD_5 indicate the potential for bacteria to deplete oxygen levels in the water. The Ministry for the Environment (1992) guideline level for BOD_5 for waterways is 2 mg/L.

Total ammonia (ammoniacal nitrogen) is typically a minor component of the nitrogen available for plant growth, but at high levels can have toxic effects on aquatic ecosystems. The toxicity of ammonia varies with pH (ANZECC, 2000). Therefore, the pLWRP water quality standards also vary depending on pH, ranging from 2.57 mg/L at pH 6 to 0.18 mg/L at pH 9 (Environment Canterbury, 2012). The water quality standard for the sites was therefore adjusted based on the median pH levels for all sites being 7.5 for the monitoring period, resulting in an ammonia standard of 1.61 mg/L.

The water samples were analysed for nitrate and nitrite, but guidelines only exist for the sum of these parameters, *Nitrate Nitrite Nitrogen* (NNN); therefore, this parameter only is presented in this monitoring report. Elevated concentrations of NNN can lead to the proliferation of aquatic plants and algae, because nitrate and nitrite are oxidised forms of nitrogen that are readily available to plants. ANZECC (2000) water quality guidelines provide a trigger value of 0.444 mg/L for lowland rivers to avoid excessive plant growth. *Dissolved Inorganic Nitrogen* (DIN), which is the sum of ammonia, nitrite and nitrate, is also discussed in this report, as this parameter has a water quality standard in the pLWRP, providing a measure of the risk of eutrophication and toxicity (Environment Canterbury, 2012).

Dissolved Reactive Phosphorus (DRP) is a soluble form of phosphorus that is readily available for use by plants. Phosphorus is an essential nutrient for plant growth and can limit primary production at low levels, but can cause proliferation of algae and aquatic plants at high levels. The pLWRP standard for 'spring-fed – lower basin' waterways is 0.01 mg/L.

Escherichia coli is a bacterium that is commonly used as an indicator of freshwater faecal contamination and therefore health risk from contact recreation (Ministry for the Environment, 2003). The pLWRP water quality standards state that 95% of samples should be below 550 *E. coli*/100 mL.

Table 2. Water quality parameters analysed for sites within the Styx Stormwater Management Plan area

Parameter	Units of measurement
Total and dissolved copper	µg/L
Total and dissolved lead	µg/L
Total and dissolved zinc	µg/L
pH	
Electrical conductivity	µS/cm
Total Suspended Solids (TSS)	mg/L
Turbidity	NTU
Dissolved oxygen	mg/L and % saturation
Water temperature	°C
Biochemical Oxygen Demand (BOD_5)	mg/L
Total ammonia (ammoniacal nitrogen)	mg/L
Nitrate nitrogen	mg/L
Nitrite nitrogen	mg/L
Dissolved Reactive Phosphorus (DRP)	mg/L
Escherichia coli	CFU/100 mL
Water hardness	g/m^3 as calcium carbonate

2.3 Data Analysis

2.3.1 Summary Statistics

Summary statistics of monthly water quality data at the sites from January to December 2013 were analysed using IBM® SPSS® Statistics 20. To allow analysis, water quality values that were less than the laboratory Limit of Detection (LOD) were converted to half the detection limit. Data was graphed using boxplots, to show medians and interquartile ranges. Statistical outliers were not removed from these summary statistics, as values were assumed to be 'real', providing useful information on variations in the concentrations recorded. The sites are ordered from upstream to downstream in the graphs, with mainstem and tributary sites colour-coded.

The dark lines in the boxes of the boxplots represent the medians, and the top and bottom lines of the boxes represent the 25th and 75th percentiles, respectively. The T-bars that extend from the boxes approximate the location of 95% of the data. Circles represent statistical outliers and stars represent extreme outliers. In some cases, boxplots do not show all components, such as the percentiles, due to a lack of variation in the data, with some showing only the medians. This usually occurred where a large proportion of the data were below the LOD.

2.3.2 Temporal Trend Analysis

Temporal trend analysis was carried out on data collected monthly from all the sites between January 2007 and December 2013. The exception to this was dissolved metals, which have only been analysed since 2011. Total metals have been measured since 2007 and continue to be sampled, but these are not presented in this report, as dissolved metals are considered to be more relevant because they constitute the bio-available proportion of metals that can have adverse effects on biota (ANSECC, 2000). The guidelines also pertain to dissolved metals, not total metals.

Trend analysis was conducted using the Time Trends software developed by NIWA (NIWA, 2011). Trend analysis cannot be performed on parameters that have a high proportion of data reported below the LOD; therefore analyses were unable to be undertaken for dissolved copper and lead. The Seasonal Kendall trend test was used to test the significance of trends. The non-parametric Seasonal Kendall Sen Slope Estimator was then used to measure the magnitude and direction of the trend, normalised by dividing by the site median, to provide a measure of the slope as a percent change per year (NIWA 2011). Where water quality results were less than the LOD, the Time Trends software converted these values to 10% below the LOD.

The concentrations of parameters can vary depending on the flow rates at the time of sampling, due to variations in the level of dilution. Therefore, flow-adjusted data can be used in the Time Trends software to account for this potentially confounding factor. However, no flow gauges are present within this catchment and therefore this adjustment was unable to be carried out. Given the large interval of monitoring (since 2007), it is hoped that variations in flow rates between sampling events will not strongly influence concentrations, given most events will have been conducted during baseflow conditions.

3 Results

3.1 Summary Statistics and Comparison to Guidelines

3.1.1 Dissolved Copper

The concentrations of dissolved copper for the majority of samples were below the LOD of 0.002 mg/L (recorded as half this value, 0.001 mg/L, to allow analyses to be undertaken), as shown by the medians for every site being equivalent to this value and no interquartile ranges being recorded due to a lack of variation in the data (Figure 2). Individual samples were also predominantly below the hardness modified trigger value of 0.00212 mg/L (ANZECC, 2000; Environment Canterbury, 2012) throughout the monitoring period. The exception to this was a number of extreme outlier events at the Smacks Creek, Kaputone Creek at Belfast Road and Styx River at Marshland Road Bridge sites. The largest value recorded was at Kaputone Creek at Belfast Road (0.022 mg/L in June). There were no apparent upstream to downstream trends in concentrations in the Styx River mainstem.

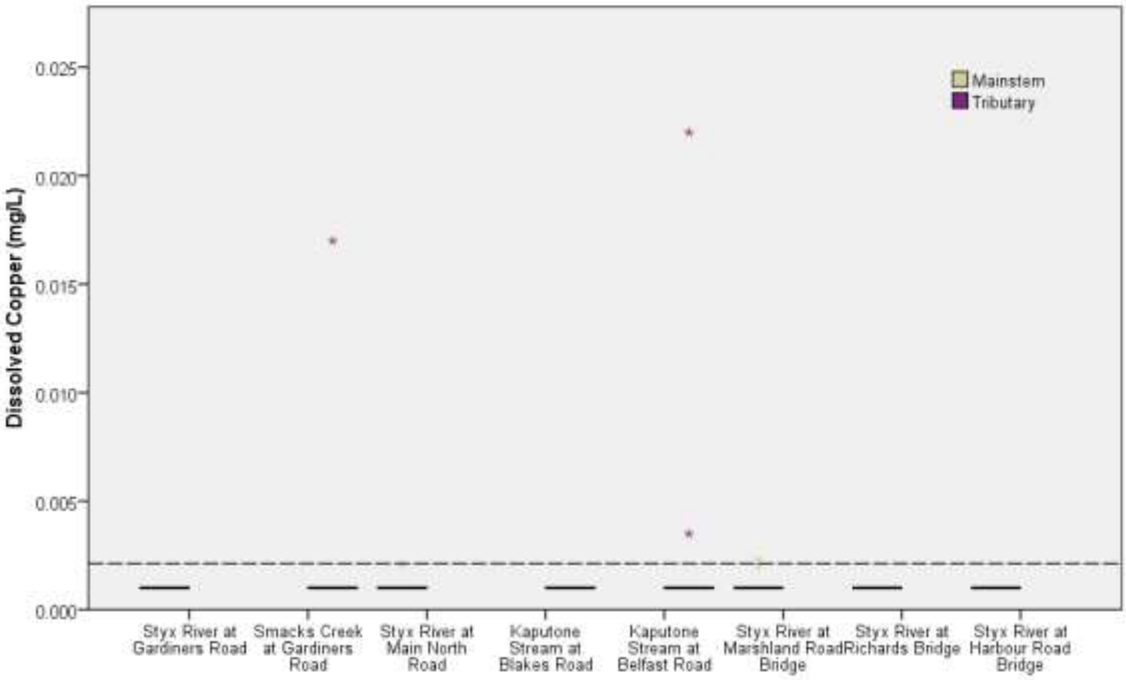

Figure 2. Dissolved copper levels in water samples at the eight sites within the Styx Stormwater Management Plan area for the monitoring period January to December 2013. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Proposed Canterbury Land and Water Regional Plan trigger value of 0.00212 mg/L (Environment Canterbury, 2012), which has been modified to account for water hardness as per the ANZECC (2000) guidelines methodology. The Laboratory Limit of Detection was 0.002 mg/L – recorded as half this value (0.001 mg/L) to allow analyses to be undertaken.

3.1.2 Dissolved Lead

A large proportion of samples recorded dissolved lead concentrations below the LOD of 0.0015 mg/L (recorded as half this value, 0.00075 mg/L, to allow analyses to be undertaken), as shown by the medians all being the same as the LOD and very few interquartile ranges being recorded due to a lack of variation in the data (Figure 3). Levels above the LOD were recorded on a number of sampling occasions at various sites, but these concentrations were still well below the receiving water guideline of 0.00634 mg/L. The exception to this was one sample at Kaputone Creek at Belfast Road, which recorded a concentration of 0.0072 mg/L in June (coinciding with the high dissolved copper level). There were no downstream to upstream trends in concentrations in the Styx River mainstem.

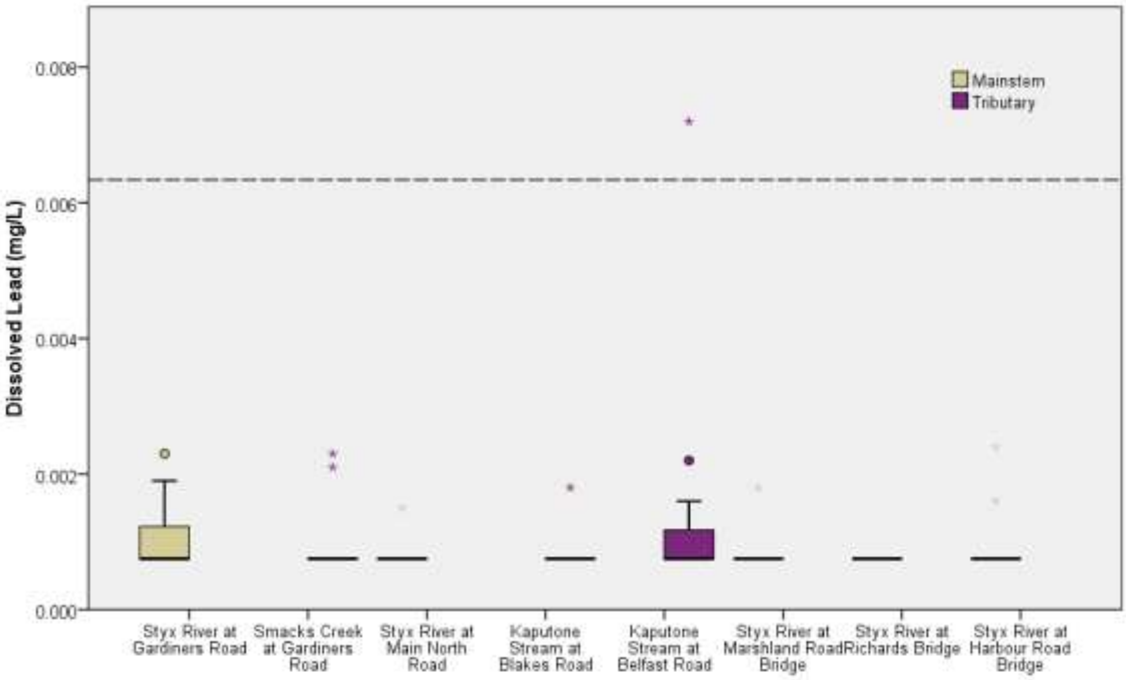

Figure 3. Dissolved lead levels in water samples at the eight sites within the Styx Stormwater Management Plan area for the monitoring period January to December 2013. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Proposed Canterbury Land and Water Regional Plan trigger value of 0.00634 mg/L (Environment Canterbury, 2012), which has been modified to account for water hardness as per the ANZECC (2000) guidelines methodology. The Laboratory Limit of Detection was 0.0015 mg/L – recorded as half this value (0.00075 mg/L) to allow analyses to be undertaken.

3.1.3 Dissolved Zinc

The majority of samples for the monitoring period recorded dissolved zinc levels below the guideline level of 0.01214 mg/L (Figure 4). A number of individual samples at the Styx River at Gardiners Road, Kaputone Creek at Blakes Road and Styx River at Richards Bridge sites did exceed this guideline on occasion, however. The Styx River at Gardiners Road site recorded the highest concentration across all sites during the monitoring period (0.075 mg/L in June). There was no apparent downstream trend in concentrations in the Styx River mainstem.

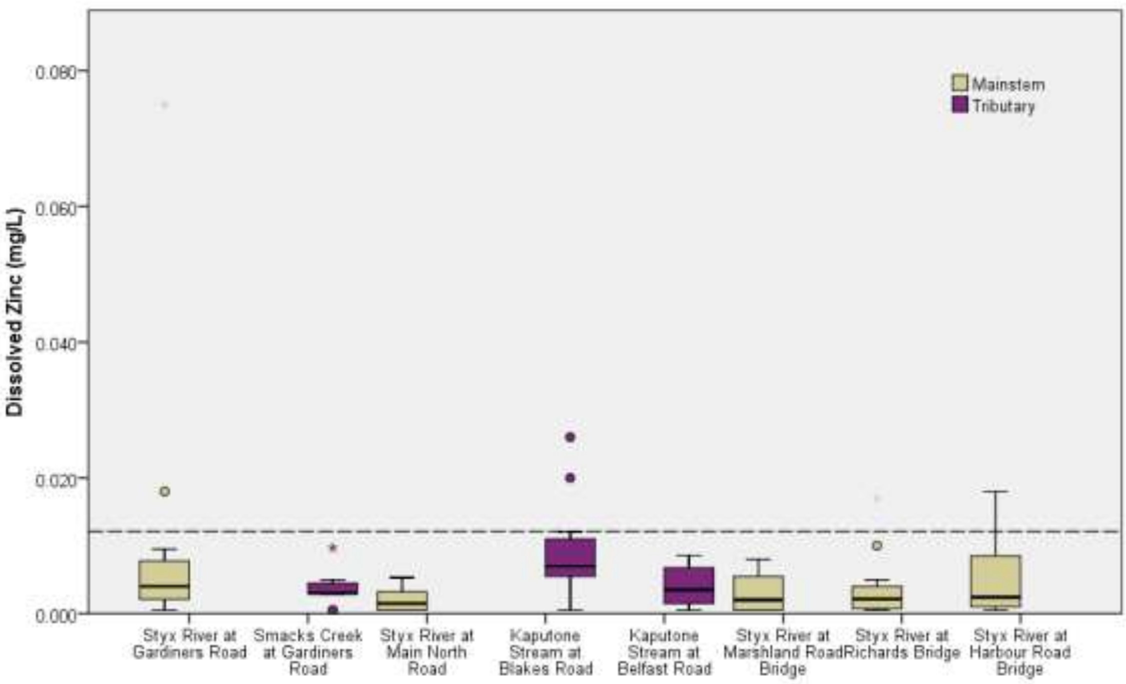

Figure 4. Dissolved zinc levels in water samples at the eight sites within the Styx Stormwater Management Plan area for the monitoring period January to December 2013. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Proposed Canterbury Land and Water Regional Plan trigger value of 0.01214 mg/L (Environment Canterbury, 2012), which has been modified to account for water hardness as per the ANZECC (2000) guidelines methodology. The Laboratory Limit of Detection was 0.0010 mg/L – recorded as half this value (0.0005 mg/L) to allow analyses to be undertaken.

3.1.4 pH

None of the sites recorded median pH levels during the monitoring period below the lower guideline limit of 6.5 or above the upper limit of 8.5 (Figure 5). However, a number of individual sampling events in the three lower reach sites of the Styx River mainstem did record values outside these guidelines. The highest pH level during sampling was recorded at the Styx River Richards Bridge site (pH of 9.1 in April). The lowest value was recorded at the Styx River Marshland Road bridge site (pH of 5.8 in March). There was no strong upstream to downstream trends in concentrations in the mainstem. The most upstream site of Styx River at Gardiners Road had lower pH levels compared to the other sites.

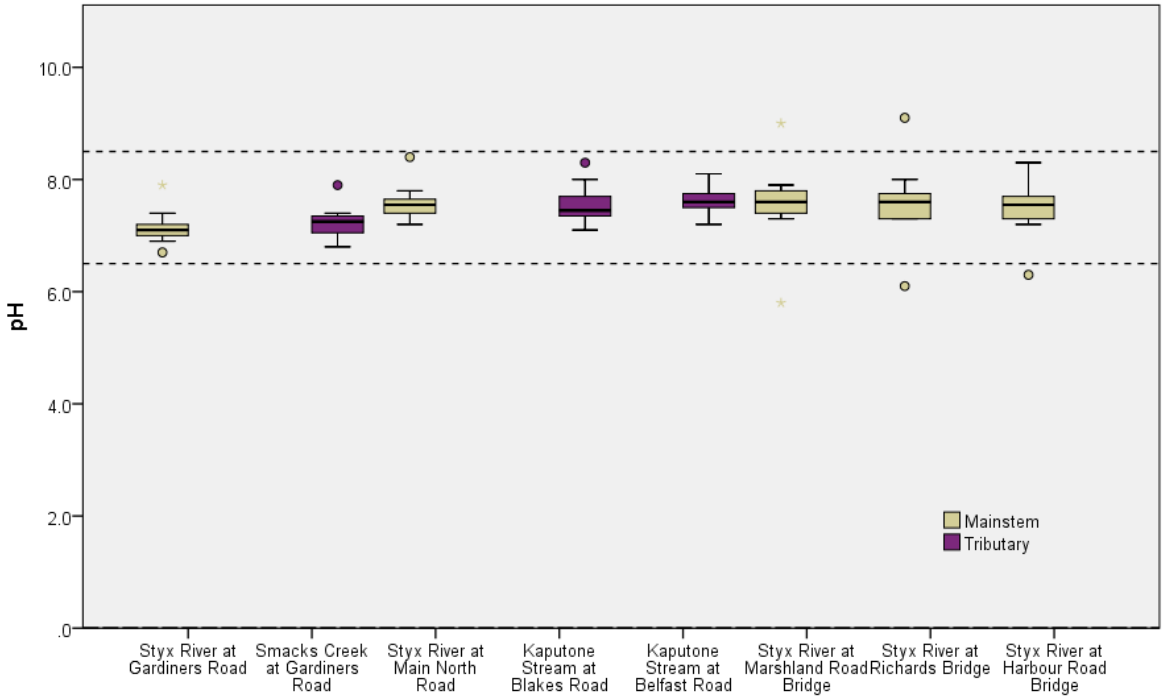

Figure 5. pH levels in water samples at the eight sites within the Styx Stormwater Management Plan area for the monitoring period January to December 2013. Sites are ordered from upstream to downstream (left to right). The dotted lines represent the Proposed Canterbury Land and Water Regional Plan lower (6.5) and upper (8.5) limits (Environment Canterbury, 2012).

3.1.5 Conductivity

Conductivity levels were fairly similar across sites, with no apparent downstream or upstream trends in concentrations (Figure 6). A number of individual sampling events at the majority of sites recorded outlier events, with the highest value overall being recorded at the most upstream site of Styx River at Gardiners Road (331 µS/cm).

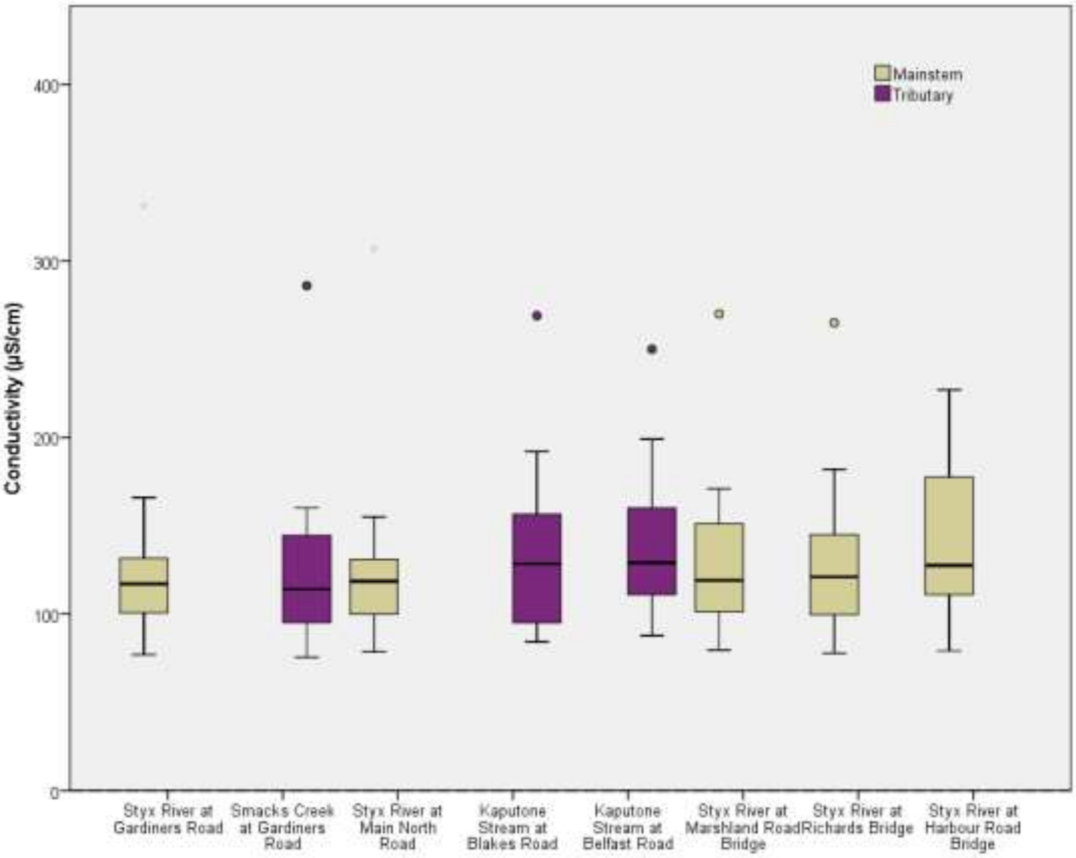

Figure 6. Conductivity levels in water samples at the eight sites within the Styx Stormwater Management Plan area for the monitoring period January to December 2013. Sites are ordered from upstream to downstream (left to right).

3.1.6 Total Suspended Solids

All sites recorded values below the guideline level of 25 mg/L for all sampling events (Figure 6). The exception to this was the Kaputone Creek at Belfast Road site, which recorded many values above the guideline level, represented by the long T-bar extending past this value, although the median for this site was below the guideline. The upper reach sites recorded substantially lower TSS levels compared to the other sites. The Kaputone Creek recorded considerably higher concentrations than the other sites, perhaps due to input from the agricultural catchment of this waterway. It would appear that the discharge from Kaputone Creek into the Styx River (upstream of the Styx River Marshland Road Bridge site) is increasing the levels of TSS in the mainstem. Levels then decrease downstream in the lower reach sites. The largest concentration recorded was at the Kaputone Creek at Belfast Road site (38 mg/L in April).

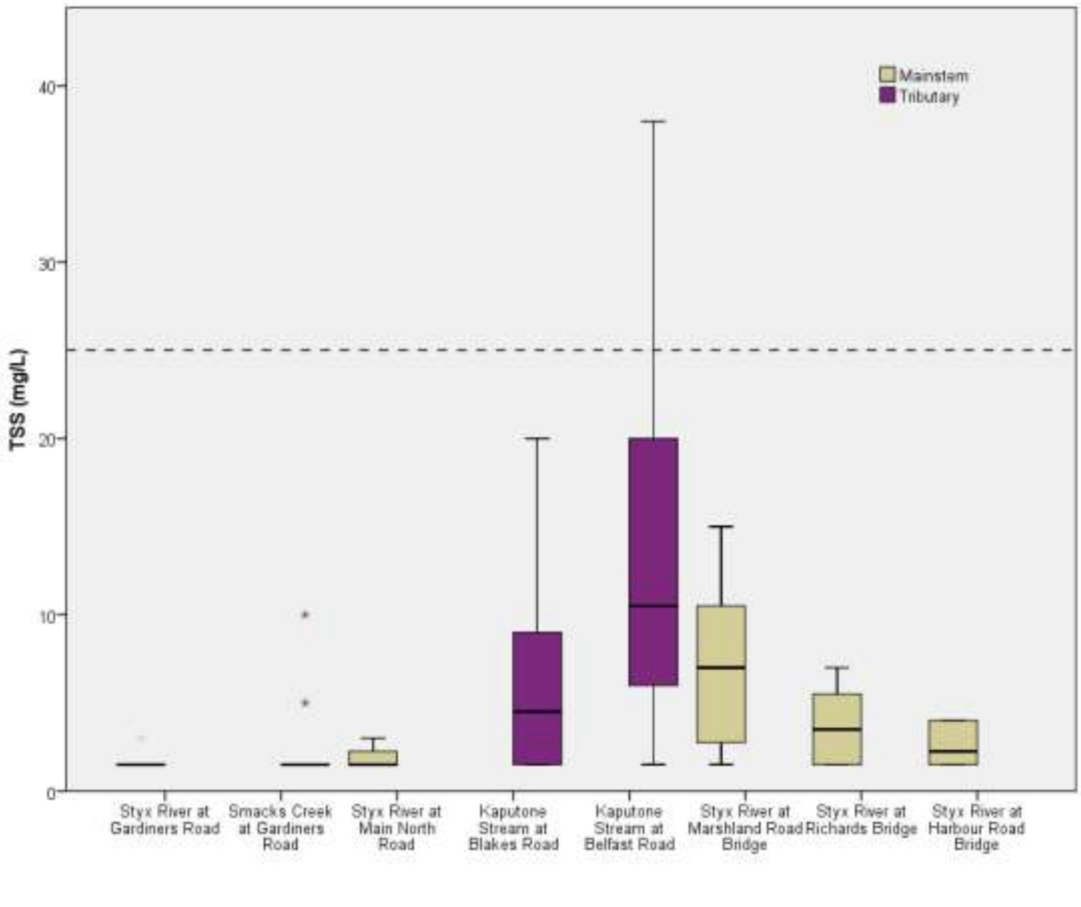

Figure 7. Total Suspended Solid (TSS) levels in water samples at the eight sites within the Styx Stormwater Management Plan area for the monitoring period January to December 2013. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Ryan (1991) guideline value of 25 mg/L. The Laboratory Limit of Detection was 5.0 mg/L – recorded as half this value (2.5 mg/L) to allow analyses to be undertaken.

3.1.7 Turbidity

The majority of samples were above the LOD of 0.7 NTU. Median turbidity concentrations for all sites were below the guideline level of 5.6 NTU, with the exception of the Kaputone Creek at Belfast Road site, which recorded many values above the guideline (Figure 8). Three other sites also recorded values above the guideline on occasion: Kaputone Creek at Blakes Road, and the Styx River at the Marshland and Richards Bridges. Not surprisingly, the pattern recorded is similar to that observed for TSS. As with TSS levels, the highest turbidity value was recorded at the Kaputone Creek Belfast Road site in April (17 NTU). Again, the high levels at the three lower Styx River mainstem sites are likely influenced by the higher level of sediment discharged into the mainstem from the Kaputone Creek.

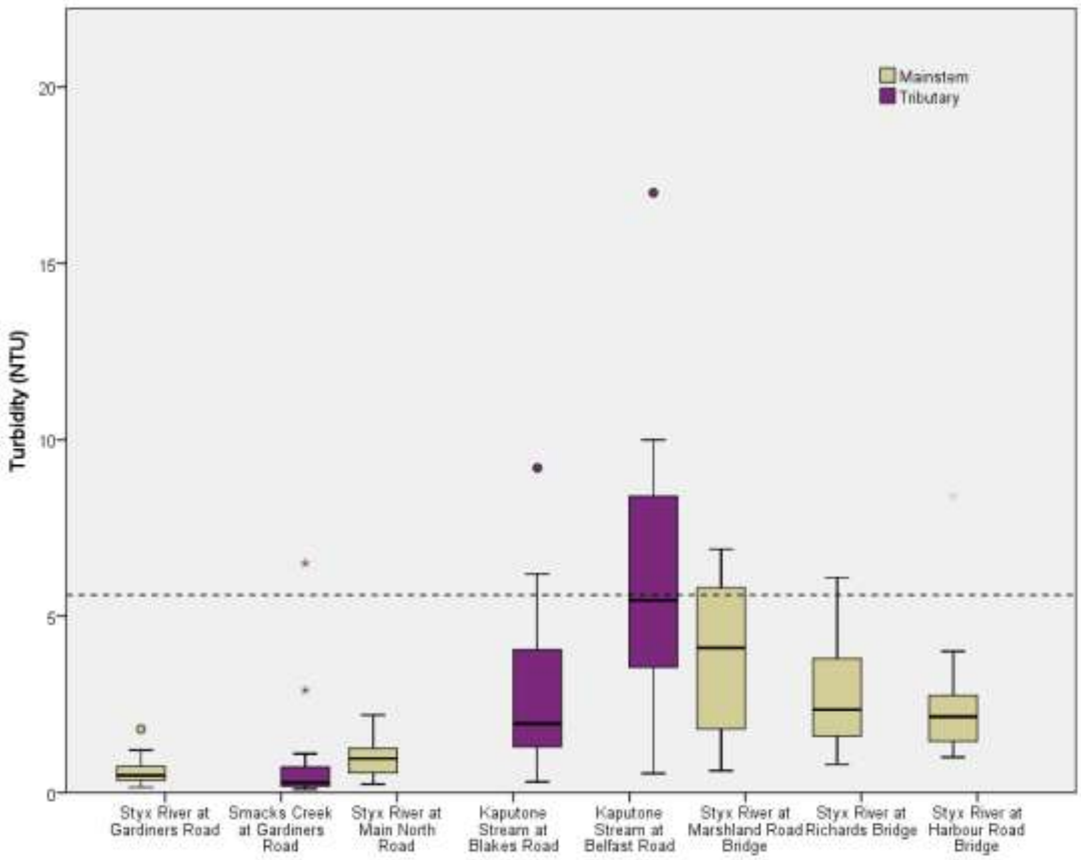

Figure 8. Turbidity levels in water samples at the eight sites within the Styx Stormwater Management Plan area for the monitoring period January to December 2013. Sites are ordered from upstream to downstream (left to right). The dotted line represents the ANZECC (2000) guideline value of 5.6 Nephelometric Turbidity Units (NTU).

3.1.8 Dissolved Oxygen

Half of the sites recorded medians above the minimum guideline value of 70% saturation: Styx River at Main North Road, Kaputone Creek at Blakes Road, Styx River at Marshland Road Bridge and Styx River at Richards Bridge (Figure 9). The other four sites recorded medians below this value. The two upstream sites, Styx River at Gardiners Road and Smacks Creek at Gardiners Road, recorded lower levels relative to the other sites. The Styx River at Main North Road site recorded the highest DO levels. There was no apparent downstream trend in DO levels in the Styx River mainstem.

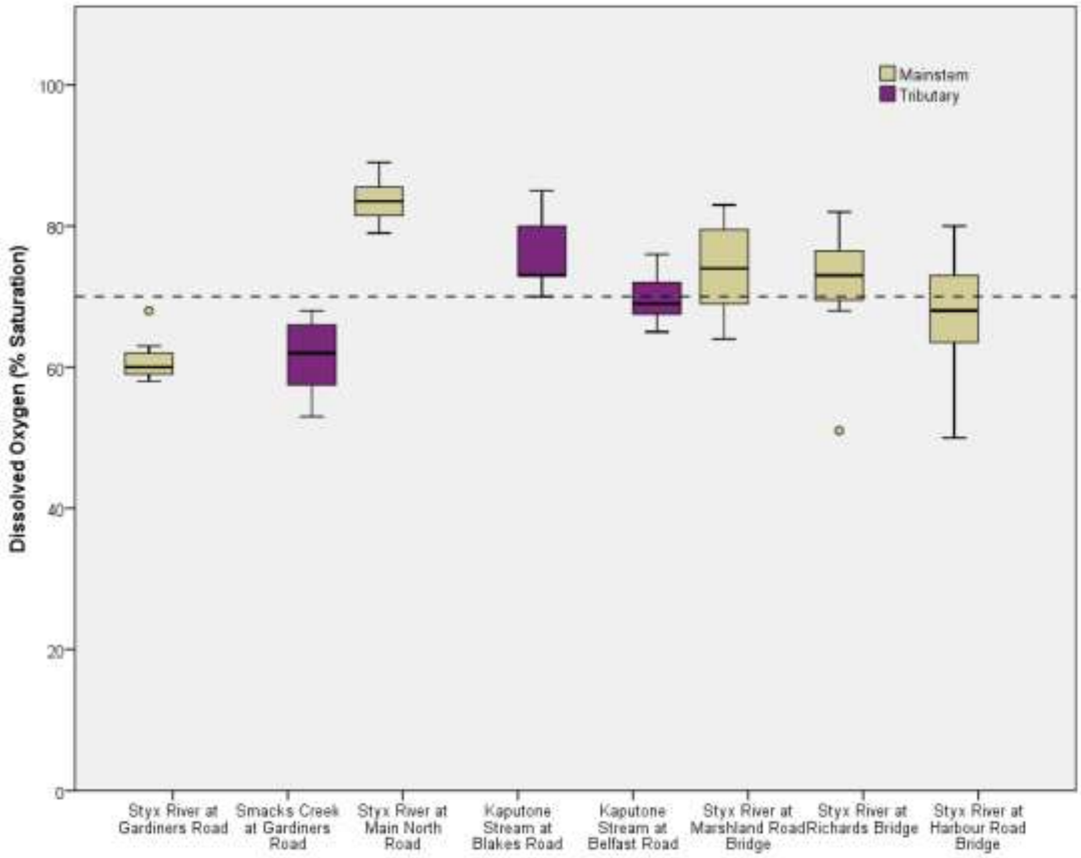

Figure 9. Dissolved oxygen levels in water samples at the eight sites within the Styx Stormwater Management Plan area for the monitoring period January to December 2013. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Proposed Canterbury Land and Water Regional Plan minimum guideline value (70%, Environment Canterbury, 2012).

3.1.9 Water temperature

The temperature of water samples were all below the guideline value of 20ºC, with no samples at any of the sites during the monitoring period recording temperatures above this value (Figure 10). Temperatures were generally similar across sites, although the most upstream site of Styx River at Gardiners Road recorded considerably less variation in temperature than the other sites.

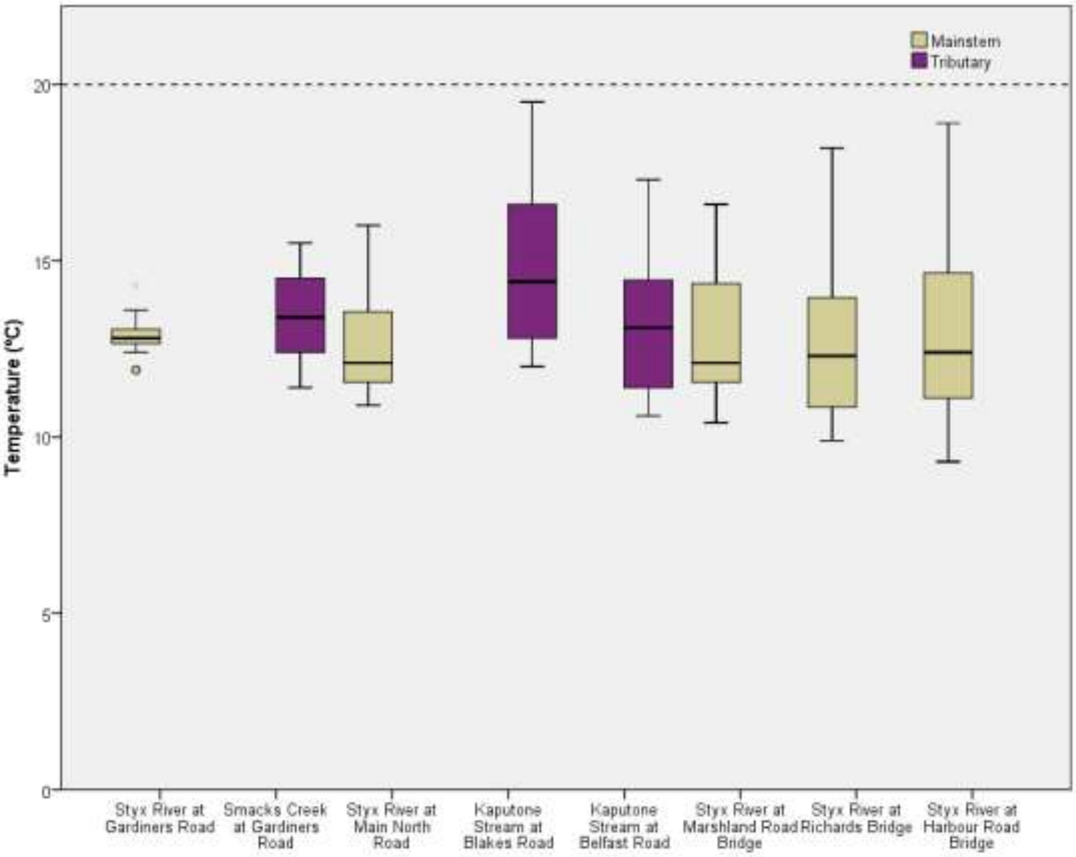

Figure 10. Water temperature of samples at the eight sites within the Styx Stormwater Management Plan area for the monitoring period January to December 2013. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Proposed Canterbury Land and Water Regional Plan maximum guideline value (20ºC, Environment Canterbury, 2012).

3.1.10 Biochemical Oxygen Demand

Many of the levels of BOD_5 recorded in the samples during the monitoring period were below the LOD; most notably for the three upper sites, which recorded medians equivalent to the LOD and no interquartile ranges (Figure 11). All samples at all sites generally recorded concentrations below the guideline level of 2 mg/L. However, a number of samples at some of the sites exceeded this guideline during the monitoring period, with the highest value recorded in Kaputone Creek at Blakes Road (7 mg/L in January). Levels were generally much lower in the more upstream sites compared to the downstream sites.

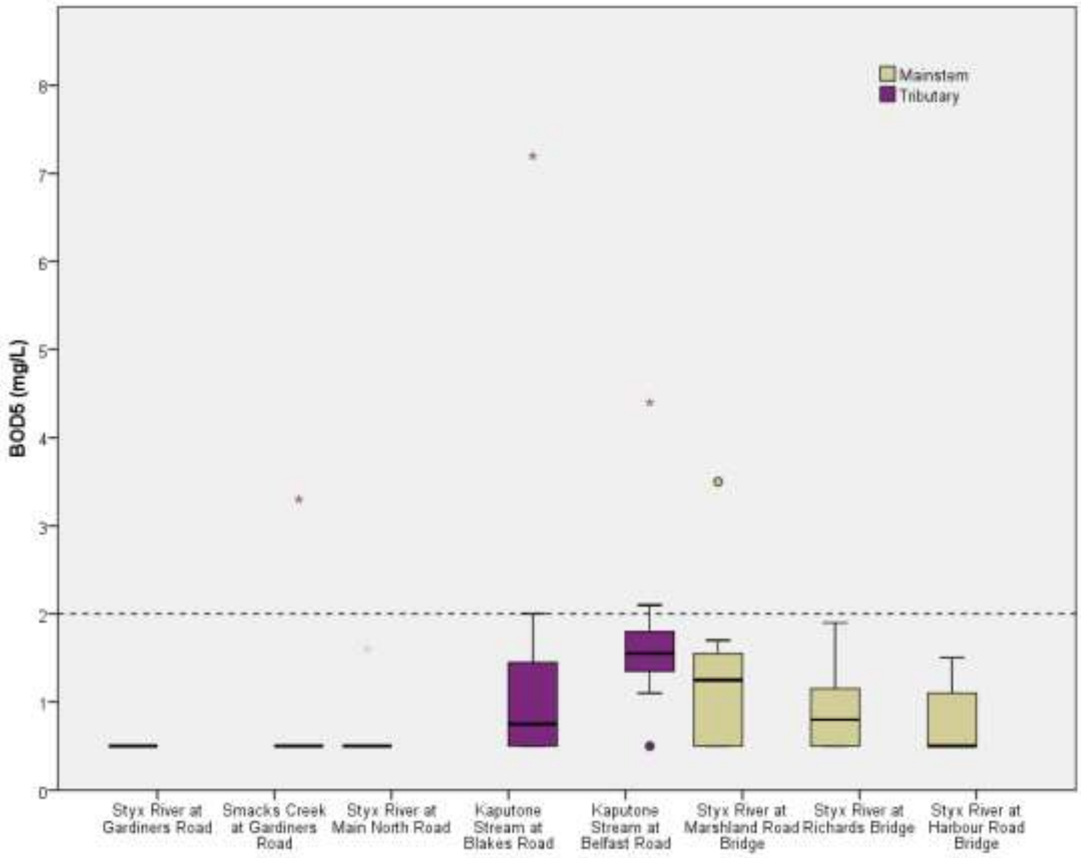

Figure 11. Biochemical Oxygen Demand (BOD_5) levels of water samples at the eight sites within the Styx Stormwater Management Plan area for the monitoring period January to December 2013. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Ministry for the Environment guideline value (2 mg/L; Ministry for the Environment, 1992). The Laboratory Limit of Detection was 1.0 mg/L, recorded as half this value (0.5 mg/L) to allow analyses to be undertaken.

3.1.11 Total Ammonia (Ammoniacal Nitrogen)

Kaputone Creek recorded substantially higher levels of total ammonia and greater variation in concentrations, compared to all other sites (Figure 12). As shown with TSS and turbidity, the Kaputone Creek appeared to elevate concentrations in the Styx River sites downstream of the confluence with this tributary. However, ammonia levels at all sites were well below the receiving water quality trigger value of 1.61 mg/L, with no sample at any of the sites ever recording a concentration above this value.

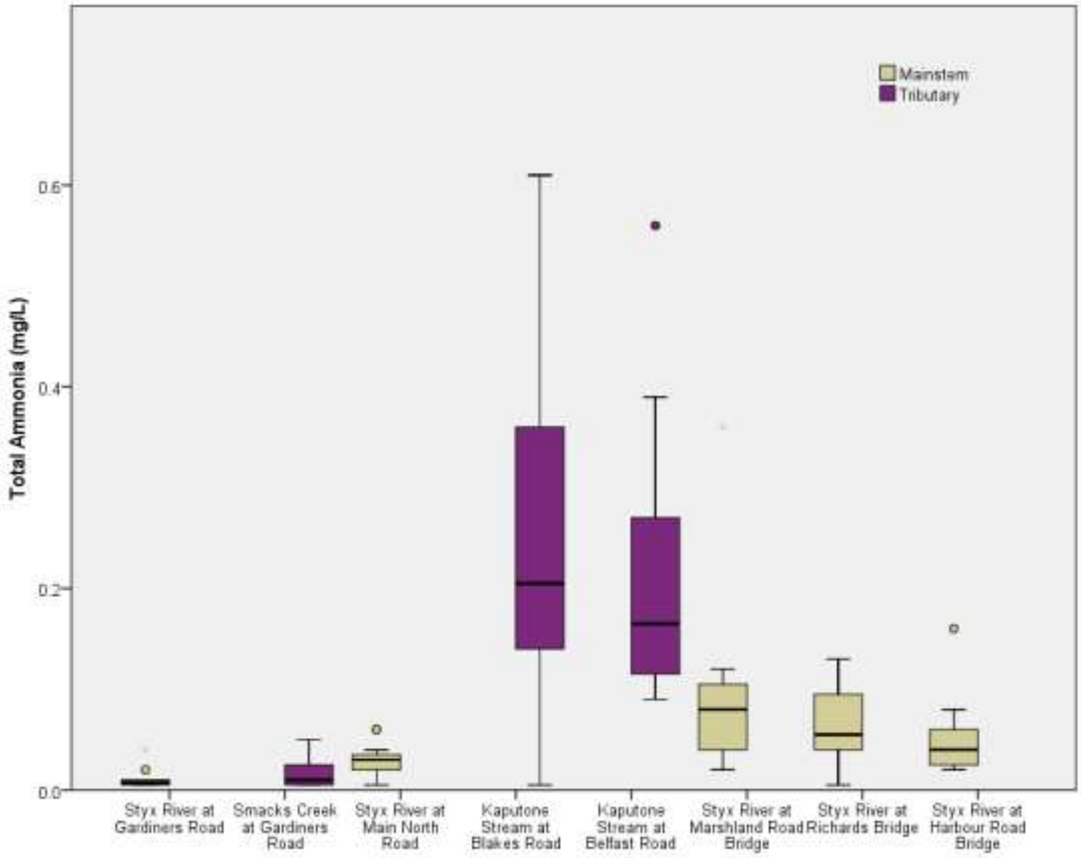

Figure 12. Total ammonia levels of water samples at the eight sites within the Styx Stormwater Management Plan area for the monitoring period January to December 2013. Sites are ordered from upstream to downstream (left to right). The Proposed Canterbury Land and Water Regional Plan trigger value of 1.61 mg/L (adjusted in accordance with median pH levels of 7.5 for the monitoring period; Environment Canterbury, 2012) is not included on the graph as the scale does not extend this far.

3.1.12 Nitrate Nitrite Nitrogen

All sites recorded NNN concentrations substantially higher than the guideline value of 0.444 mg/L consistently throughout the monitoring period (Figure 13). The highest concentrations overall were recorded at the Kaputone Creek at Belfast Road site, with this site recording its highest concentration of 1.6 mg/L in January and June. Again, levels in the downstream sites appear to be elevated due to high levels in the Kaputone Creek discharge.

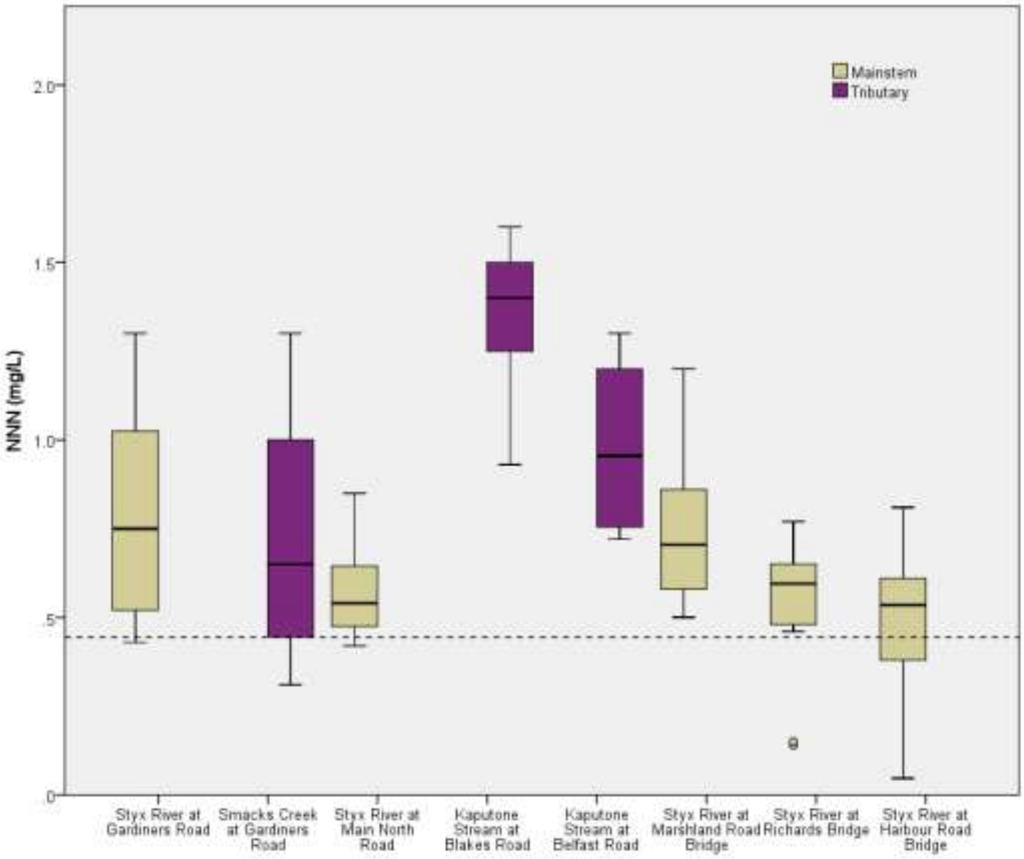

Figure 13. Nitrate Nitrite Nitrogen (NNN) levels of water samples at the eight sites within the Styx Stormwater Management Plan area for the monitoring period January to December 2013. Sites are ordered from upstream to downstream (left to right). The dotted line represents the ANZECC water quality guideline (0.444 mg/L; ANZECC, 2000).

3.1.13 Dissolved Inorganic Nitrogen

All sites recorded DIN concentrations well above the trigger value of 0.47 mg/L throughout the monitoring period (Figure 14). Kaputone Creek recorded the highest levels compared to the other sites. The highest value recorded at this site was 2.11 mg/L in August. Kaputone Creek again appeared to elevate DIN levels in the Styx River mainstem.

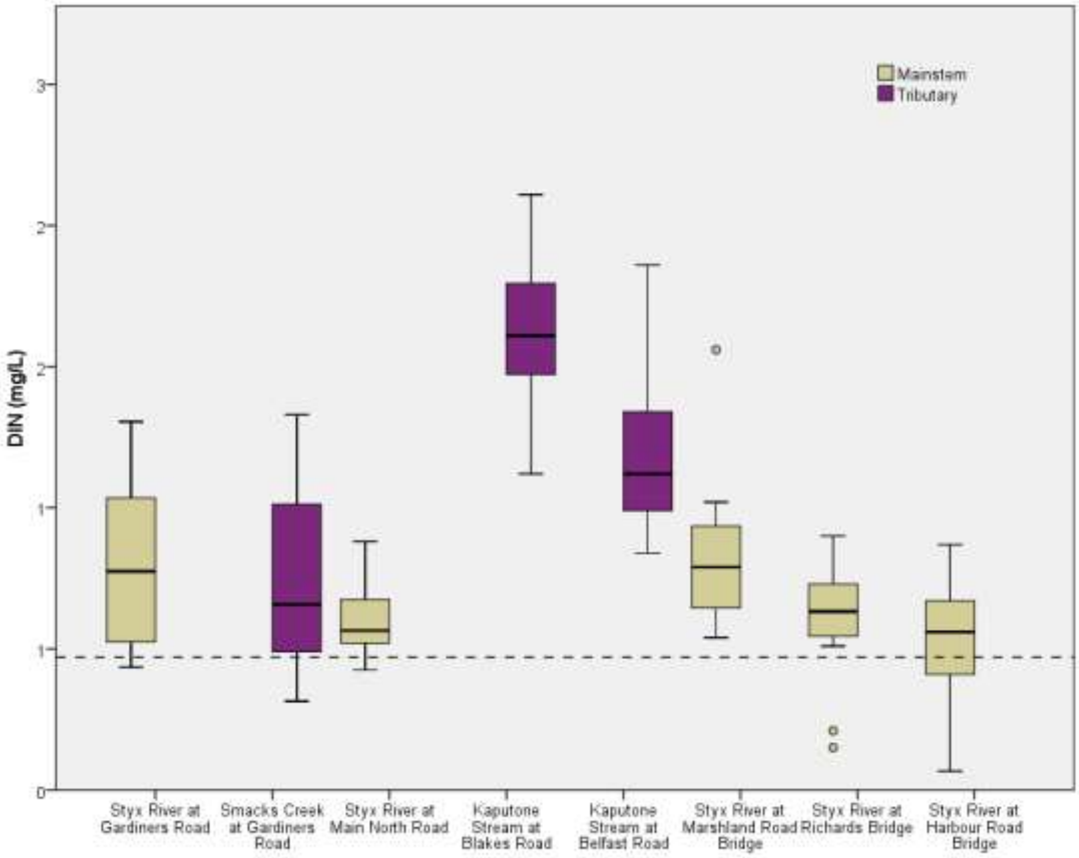

Figure 14. Dissolved Inorganic Nitrogen (DIN) levels of water samples at the eight sites within the Styx Stormwater Management Plan area for the monitoring period January to December 2013. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Proposed Canterbury Land and Water Regional Plan trigger value of 0.47 mg/L (Environment Canterbury, 2012).

3.1.14 Dissolved Reactive Phosphorus

The majority of sites recorded DRP concentrations in all samples from the monitoring period above the trigger value of 0.01 mg/L (Figure 15). The upstream sites of Styx River at Gardiners Road and Smacks Creek recorded lower DRP concentrations compared to the other sites. It is likely that Kaputone Creek is again elevating levels in the Styx River mainstem downstream of the confluence with this tributary. The Kaputone Creek Belfast Road site recorded the highest concentrations across all sites for the monitoring period (0.160 mg/L in February).

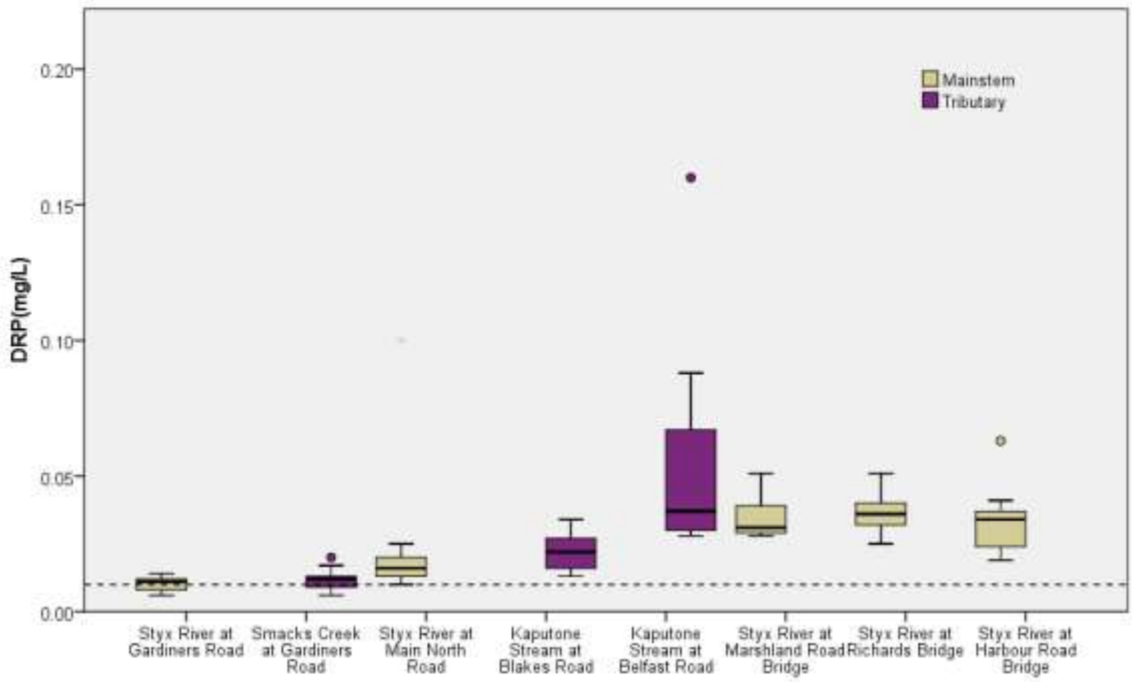

Figure 15. Dissolved Reactive Phosphorous (DRP) levels of water samples at the eight sites within the Styx Stormwater Management Plan area for the monitoring period January to December 2013. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Proposed Canterbury Land and Water Regional Plan trigger value of 0.01 mg/L (Environment Canterbury, 2012), which is also the Laboratory Limit of Detection (recorded as half this value, 0.005 mg/L, to allow analyses to be undertaken).

3.1.15 *Escherichia coli*

The Environment Canterbury guideline states that 95% of *E. coli samples* should be below 550 CFU/100ml (Environment Canterbury, 2012). Therefore comparison against the T-bars of the box-plot graph is more appropriate than comparing against the medians. *E. coli* concentrations were above the guideline level at all sites for the monitoring period (Figure 16). Smacks Creek recorded the lowest *E. coli* levels during the monitoring period and Kaputone Creek at Belfast Road recorded the highest levels. The highest level recorded overall was 7300 CFU/100mL in January at the Kaputone Creek Belfast Road site. There were no apparent trends downstream.

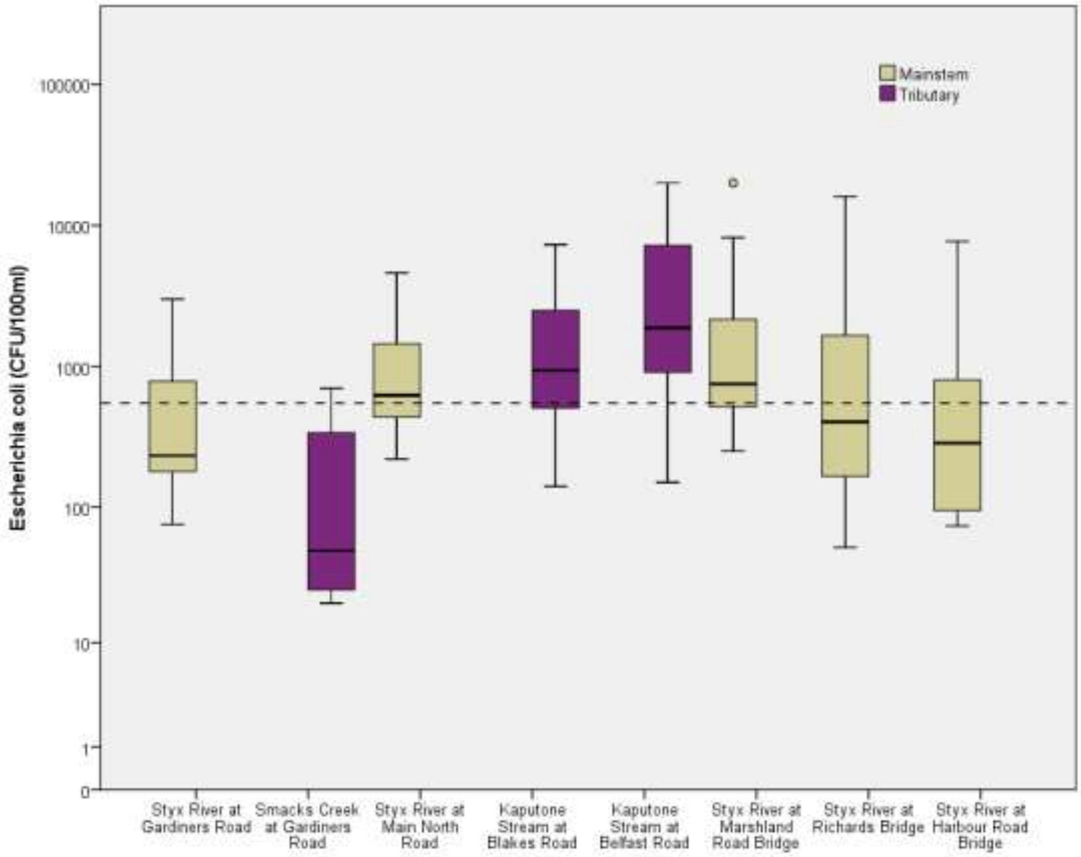

Figure 16. *Escherichia coli* levels of water samples at the eight sites within the Styx Stormwater Management Plan area for the monitoring period January to December 2013. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Proposed Canterbury Land and Water Regional Plan trigger value of 550 CFU/100ml, for 95% of samples (Environment Canterbury, 2012). Note: the y-axis is on a log_{10} scale.

3.2 Temporal Trends

A large proportion of parameters across all sites had no significant upwards or downwards trends in concentrations over time, meaning that parameter levels remained static between years (Table 3). Four parameters in particular recorded no trends across any of the sites: pH, temperature, BOD_5 and DRP. The largest trend was a 25% increase in total ammonia at Kaputone Creek at Blakes Road (Figure 17). There were also small to moderate increases in the concentrations of NNN, DIN and *E. coli* at some sites, and very small increases across some sites for pH and dissolved oxygen (only 1% increases). Many of the sites also recorded small to moderate decreases in conductivity, TSS, turbidity, NNN and DIN.

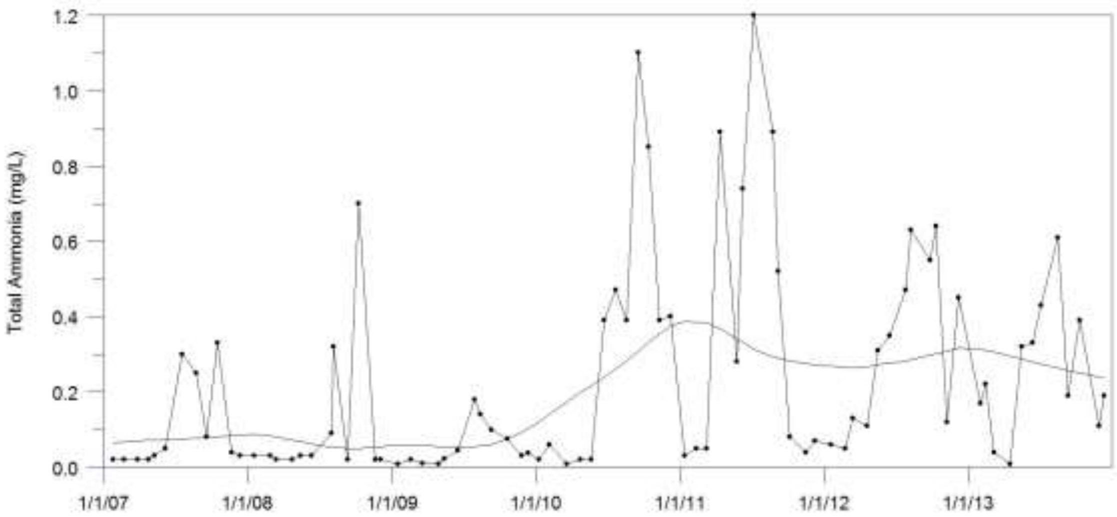

Figure 17. Total ammonia levels recorded at the Kaputone Creek Blakes Road site during the monitoring period January to December 2013. Circles indicate individual sampling events. The trendline was fitted using the Locally Weighted Scatterplot Smoothing (LOWESS) method in the Time Trends software.

Table 3. Direction of significant trends ($p<0.05$) for a range of parameters at the Styx Stormwater Management Plan surface water quality monitoring sites, calculated from monthly sampling conducted between January 2007 to December 2013. EC = Electrical Conductivity, TSS = Total Suspended Solids, DO = Dissolved Oxygen saturation and NNN = Nitrate Nitrite Nitrogen. pH, temperature, Biochemical Oxygen Demand and Dissolved Reactive Phosphorus are not presented in the table as no upward or downward trends were recorded at any of the sites.

Site	pH	EC	TSS	Turbidity	DO	Total Ammonia	NNN	DIN	*E. coli*
Smacks Creek at Gardiners Road		↓ 4%	↓ 8%	↓ 15%			↓ 5%	↓ 5%	
Styx River at Gardiners Road		↓ 4%	↓ 8%	↓ 16%	↑ 1%		↓ 9%	↓ 10%	↑ 16%
Styx River at Main North Road	↑ 1%	↓ 3%	↓ 10%	↓ 20%			↓ 7%	↓ 7%	
Kaputone Creek at Blakes Road						↑ 25%	↑ 9%	↑ 10%	↑ 12%
Kaputone Creek at Belfast Road	↑ 1%		↓ 9%	↓ 13%			↑ 3%	↑ 4%	
Styx River at Marshland Road bridge	↑ 1%	↓ 2%	↓ 10%	↓ 8%					
Styx River at Richards bridge		↓ 4%	↓ 8%		↓ 3%		↓ 6%	↓ 5%	
Styx River at Harbour Road bridge	↑ 1%	↓ 6%	↓ 10%	↓ 8%	↓ 2%		↓ 8%	↓ 9%	

4 Discussion

There were a number of parameters that consistently met the relevant receiving water guidelines for the 2013 monitoring period and are therefore unlikely to be having adverse effects on the waterways. These were dissolved lead, temperature and total ammonia. However, there were a number of parameters that constantly recorded values at some sites well outside the guidelines (DO, NNN, DIN, DRP and *E. coli*). This indicates that the waterways are subjected to contaminated input, potentially from stormwater, wastewater and other discharges. These parameters may be having adverse effects on biota (i.e. DIN), may encourage the proliferation of aquatic plants or algae (i.e. NNN, DIN and DRP) and may indicate human health risks from contact recreation (i.e. *E. coli*). There were also some parameters that generally recorded levels within the guidelines, but on occasion had concentrations at some sites well outside the guidelines: dissolved copper, dissolved zinc, pH, TSS, turbidity and BOD_5.

The sites that generally recorded lower levels of contaminants compared to the other sites were the three most upstream sites: Styx River at Gardiners Road, Smacks Creek at Gardiners Road and Styx River at Main North Road. In contrast, both sites within Kaputone Creek (at Blakes and Belfast Roads) consistently recorded levels of parameters well above the guideline levels and much higher that that recorded at other sites (e.g. TSS, turbidity, ammonia, NNN, DIN and DRP). This waterway flows through a predominantly agricultural catchment and has been subject historically to adjacent hazardous land use, including freezing work and wool scour activities. A piggery is also located upstream of the Belfast Road site. These activities could explain the presence of these contaminants in the waterway. Furthermore, concentrations of contaminants in the Styx River mainstem at the site immediately downstream of the confluence with the Kaputone Creek are high compared to the other mainstem sites. These concentrations then decrease as the sites move down the mainstem. Due to this and the fact that the contaminants of concern are similar between this Styx River site and the Kaputone Creek (e.g. TSS, turbidity, ammonia, NNN, DIN and DRP), it is likely that this tributary is elevating the levels of these contaminants in the mainstem. Over time, the SMP should address the influence of these activities, by intercepting and treating stormwater discharges, and re-developing the catchment, resulting in decreases in contaminants within Kaputone Creek and therefore the Styx River. However, potential discharges as a result of the current piggery may also need to be investigated by Environment Canterbury.

The results of the trends analysis was mixed, with some good reductions in contaminants since 2007 across a number of sites and parameters (including conductivity, TSS, turbidity and nitrogen) and some sites where concentrations have at least remained steady. However, there were other sites where parameter concentrations appear to be increasing, notably total ammonia, NNN, DIN (all these three parameters are related) and *E.coli* in Kaputone Creek, and *E. coli* in the Styx River at Main North Road.

In summary, it appears that the water quality at these Styx SMP sites has not degraded further in the last monitoring year and has even increased across a number of parameters in part. The exception to this is Kaputone Creek, which is showing elevated levels of ammonia and nitrogen. There are still high levels of some contaminants across the catchment that could be causing adverse effects on biota, proliferation of aquatic plants and algae, and contact recreation human health risks. It is predicted that contaminant levels in these waterways will reduce over time, once the SMP has been implemented fully. It would be prudent to focus treatment on Kaputone Creek, to get the best 'bang for buck'. This should be in conjunction with Environment Canterbury, due to the potential that some of the contaminants are of non-stormwater origin.

5 References

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6 Appendix A: Metal Hardness Modified Trigger Values

1. Introduction

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

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

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

2. Sites and sampling regime

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

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

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

3. Results

3.1. Water Hardness by catchment

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

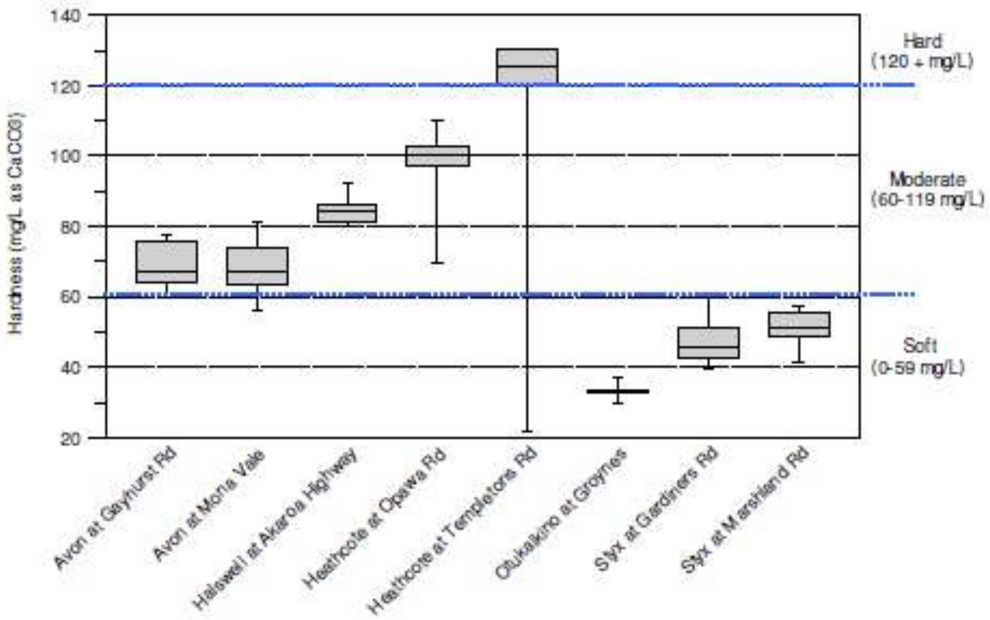

Figure 1 Box plots displaying median (and upper, lower quartiles, max and min) water hardness values for monitoring sites on the Avon, Heathcote, Halswell, Styx and Otukaikino rivers between December 2010 and March 2012.

3.2. *Hardness Modified Trigger Values (HMTV)*

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

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

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

4. References

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

Zoë Dewson
WATERWAYS PLANNER ECOLOGIST, CHRISTCHURCH CITY COUNCIL
Ph. 941-8464
zoe.dewson@ccc.govt.nz