Interim Global Stormwater Consent

Wet Weather Monitoring Report for the period May 2013 – April 2014

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Wet Weather Surface Water Quality Monitoring Report for the period May 2013 – April 2014

1 Introduction

In accordance with the Interim Global Stormwater Consent (IGSC; CRC090292), this report summarises the results of the Christchurch City Council (CCC) wet weather surface water quality and stormwater outfall monitoring for the period May 2013 to April 2014.

Section 3 of the IGSC monitoring plan details that stormwater outfall samples will be taken every year from eight sites with varying catchment influences of residential, commercial and industrial (Table 1; Figure 1). One storm event per site will be sampled, over three time periods for each event. Given difficulties in undertaking this sampling both logistically and in terms of having sufficient rain events, only five of eight stormwater outfall sites were analysed this monitoring year, consistent with that achieved last monitoring year.

Under section 4.1 of the monitoring plan, surface water samples within different river catchments each monitoring year are also required to be taken during two wet weather events. This report presents the second consecutive and final year for the Avon River catchment; surface water samples were collected from seven[1] sites within this catchment (Table 2; Figure 2).

2 Methods

2.1 Sites and Sample Collection

Both surface water and stormwater outfall samples were collected by the Christchurch City Council laboratory, according to the protocol in the monitoring plan. The stormwater outfall sites were collected during a number of different wet weather events, as outlined in Table 1. The surface water samples were collected during two wet weather events on the 25th March and 14th May 2014. Stormwater outfall samples were collected using autosamplers that took samples over three time periods of the wet weather event (each two hours apart from each other). Surface water samples were collected using grab samples by laboratory staff.

For the surface water sampling, the classification of each waterway sampled with respect to the Environment Canterbury (ECan) Proposed Land and Water Regional Plan (pLWRP) is shown in Table 2. These classifications determine the relevant guideline levels under this plan for each of the measured parameters. All the waterways in this report are classified as 'spring-fed – plains – urban'. Results in this report are compared against these guidelines, as well as the annual monitoring results for the same sites (which are presented as another appendix in the main IGSC monitoring report). For the stormwater outfalls, the ultimate receiving environment for each outfall is also detailed in Table 1.

[1] Only six sites are required to be sampled under the monitoring program, but Riccarton Main Drain was also sampled to better understand the poor water quality of this catchment

Table 1. Interim Global Stormwater Consent stormwater outfall monitoring site descriptions, GPS coordinates, receiving environments and sampling dates for the 2013-2014 monitoring period

Site Description	Sampling Date	Easting	Northing	Receiving Environment
Waltham (manhole at Ontrack – Wilsons Road)	14th May 2014	2482072	5740124	Heathcote River
South Central City (outfall at "Tiffanys" Oxford Terrace)	Not Sampled	2480299	5741424	Avon River
Bromley (Charlesworth Drain in manhole at 250 Dyers Road)	8th April 2014	2486033	5740911	Charlesworth Street Stream ↓ Estuary
Curletts Road Branch Drain (adjacent to 65 Treffers Road)	Not Sampled	2475645	5740038	Haytons Stream ↓ Heathcote River
St Albans (Lower Frees Creek at Manchester Street outfall)	9th June 2014	2480911	5742110	Avon River
Northwood top basin inlet	9th June 2014	2478627	5749485	Styx River
Westmorland (24 Penruddock Rise silt trap)	26th March 2014	2477952	5736573	Cashmere Stream ↓ Heathcote River
Avonhead (Norton Street)	Not Sampled	2474275	5742736	Austins Stream ↓ Avon River

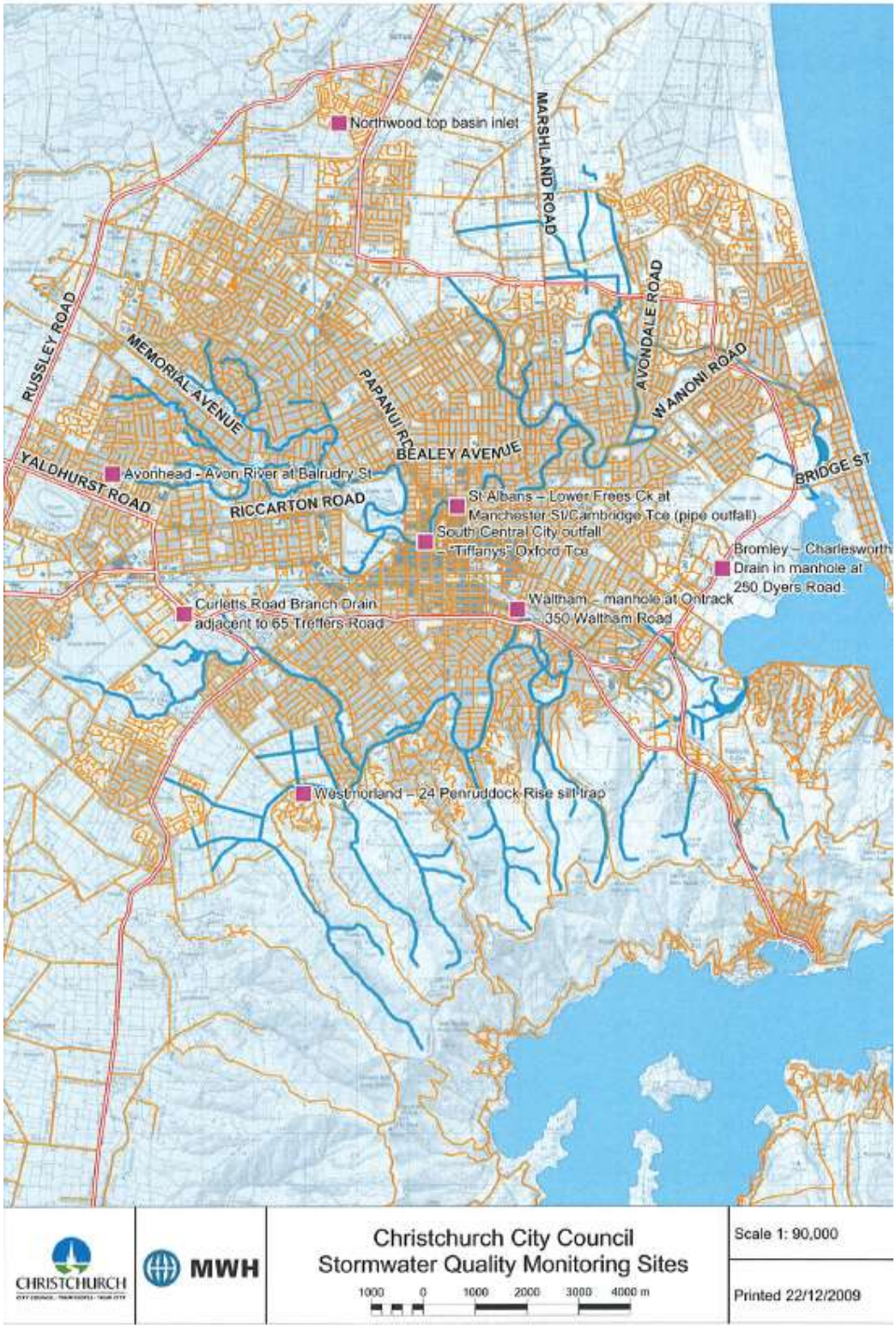

Figure 1. Location of Christchurch City Council Interim Global Stormwater Consent Stormwater Outfall monitoring sites

Table 2. Christchurch City Council wet weather surface water quality monitoring sites required under the Interim Global Stormwater Consent (pLWRP = proposed Land & Water Regional Plan)

Site Description	Easting	Northing	Environment Canterbury pLWRP Waterway Classification
Avon River at Mona Vale	2478334	5742658	Spring-fed – plains – urban
Avon River at Carlton Mill corner	2479737	5742871	Spring-fed – plains – urban
Riccarton Main Drain	2479019	5741648	Spring-fed – plains – urban
Addington Brook	2479427	5741438	Spring-fed – plains – urban
Avon River at Manchester Street	2480890	5742093	Spring-fed – plains – urban
Dudley Creek	2482575	5743763	Spring-fed – plains – urban
Avon River at Avondale Road	2484754	5745170	Spring-fed – plains – urban

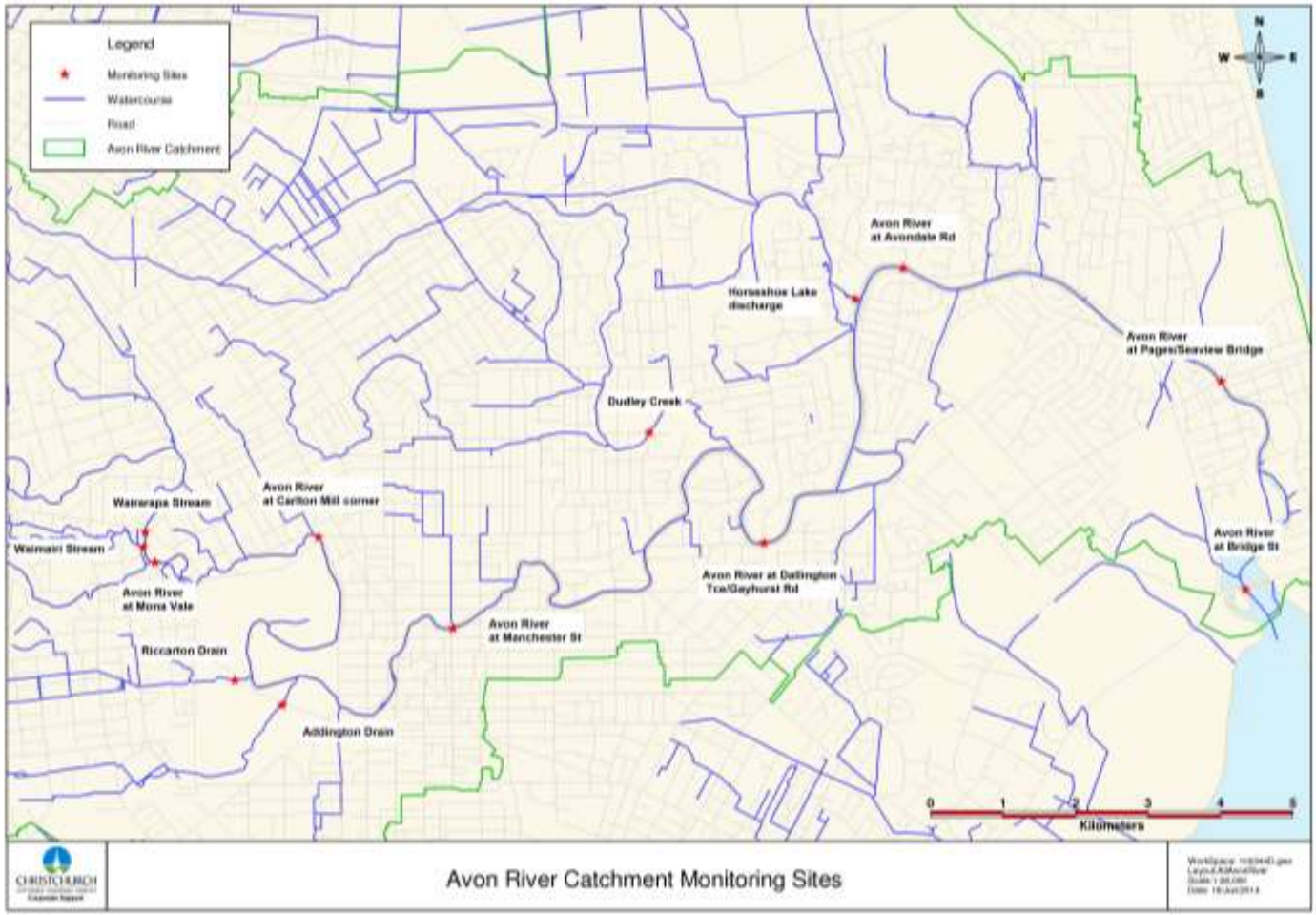

Figure 2. Location of Christchurch City Council Avon River catchment surface water quality monitoring sites, including the seven wet weather sampling sites of this report

2.2 Water Quality Parameters Tested

Both stormwater outfall and surface water samples were tested at the laboratory for a range of different water quality parameters, as outlined in Table 3. A brief discussion of each parameter, their importance and relevant guideline levels are included in the following paragraphs.

Metals, in particular, *arsenic, cadmium, 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 'spring-fed – plains – urban' 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 ECan do not consider this guideline value is useful, due to natural variations in levels (Abigail Bartram, ECan, personal communication). They instead consider that analysis of trends is more useful.

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). A guideline level for TSS is not provided in the pLWRP. 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). A guideline level for this parameter is not provided in the pLWRP. ANZECC (2000) provides a guideline of 5.6 Nephelometric Turbidity Units (NTU) for 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 – plains – urban' waterways is 70%.

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

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

Total ammonia (ammoniacal nitrogen) is typically a minor component of the nitrogen available for plant growth, but at high levels can have toxic effects on aquatic ecosystems. The toxicity of ammonia varies with pH (ANZECC, 2000). Therefore, the pLWRP water quality standards also vary depending on pH, ranging from 2.57 mg/L at pH 6 to 0.18 mg/L at pH 9 (Environment Canterbury, 2012). For this report, the water quality standard was adjusted based on the median pH levels for all river sites during the annual monitoring being 8.0, resulting in an ammonia standard of 0.9 mg/L.

Nitrate can also be toxic to stream biota and guidelines for this parameter have recently been developed to protect freshwater species (Hickey, 2013). Guidelines are available for 99%, 95% and 90% species protection. As the pLWRP uses a 90% level of species protection for 'spring-fed – plains – urban' waterways, this equivalent level of protection for the Hickey (2013) nitrate level was used for the sites in this report. It is also noted that these guidelines define this level of protection as being appropriate for highly disturbed systems, which the urban sites of this IGSC monitoring program represent. Within this 90% level of species protection there are two guideline values: the 'grading' guideline (3.8 mg/L) that provides for ecosystem protection for average long-term exposure (measured against medians) and the 'surveillance' guideline (5.6 mg/L) that assesses seasonal maximum concentrations (measured against annual 95% percentiles). Both guideline levels have been assessed in this report to investigate both long-term and short-term effects.

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

Dissolved Inorganic Nitrogen (DIN), which is the sum of ammonia, nitrite and nitrate, 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). This value for 'spring-fed – plains – urban' waterways is 1.5 mg/L.

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 – plains – urban' waterways is 0.016 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 for 'spring-fed – plains – urban' waterways.

Table 3. Parameters analysed in wet weather surface water samples taken in accordance with the Interim Global Stormwater Consent

Parameter	Units of measurement
Total arsenic	mg/L
Total & dissolved cadmium	mg/L
Total & dissolved copper	mg/L
Total & dissolved lead	mg/L
Total & dissolved zinc	mg/L
pH	
Electrical conductivity	µS/cm
Total Suspended Solids (TSS)	mg/L
Turbidity	NTU
Dissolved Oxygen (DO)	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
Nitrate-Nitrite-Nitrogen (NNN)	mg/L
Dissolved Inorganic Nitrogen (DIN)	mg/L
Total nitrogen	mg/L
Dissolved Reactive Phosphorus (DRP)	mg/L
Total phosphorus	mg/L
Faecal coliforms	CFU/100 mL
Escherichia coli	CFU/100 mL
Dissolved Organic Carbon (DOC)	mg/L
Total petroleum hydrocarbons	mg/L

2.3 Surface Water Data Analysis

Concentrations of parameters from the two surface water wet weather sampling events are compared in this report to the summary statistics of the annual water quality data for the same monitoring period; the detailed annual monitoring summaries are presented in a stand-alone document in Appendix 2 of the main monitoring report.

These annual summary statistics 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. Annual data was then 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 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, 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 did 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. The concentrations from the two wet weather events are presented in the graphs alongside the annual monitoring data. The sites are ordered from upstream to downstream in the graphs.

3 Surface Water Results

Appendix B of this report presents the raw wet weather data for each surface water site and parameter for the monitoring period. The rainfall and flow within the waterways at the time of sampling, and the results of the monitoring in relation to the receiving water quality guidelines and the annual monitoring (for parameters of particular importance to instream values), are detailed below.

3.1 Rainfall and Flow Rates

Rainfall[2] for both the 24- and 48-hours preceding the first wet weather event on the 25th March 2014 was 8 millimetres. Rainfall for the 24- and 48-hour periods preceding the second wet weather event on the 14th May 2014 was 21 and 22 millimetres, respectively. Flow rates in the Avon River at the time of sampling are indicated in Figure 3 and Figure 4.

[2] Recorded at the Botanic Gardens

Figure 3. Flow rate in the Avon River at Gloucester Street on the 25th March 2014. Wet weather samples were collected between 3.50 – 5.15pm on this day, as indicated on the graph.

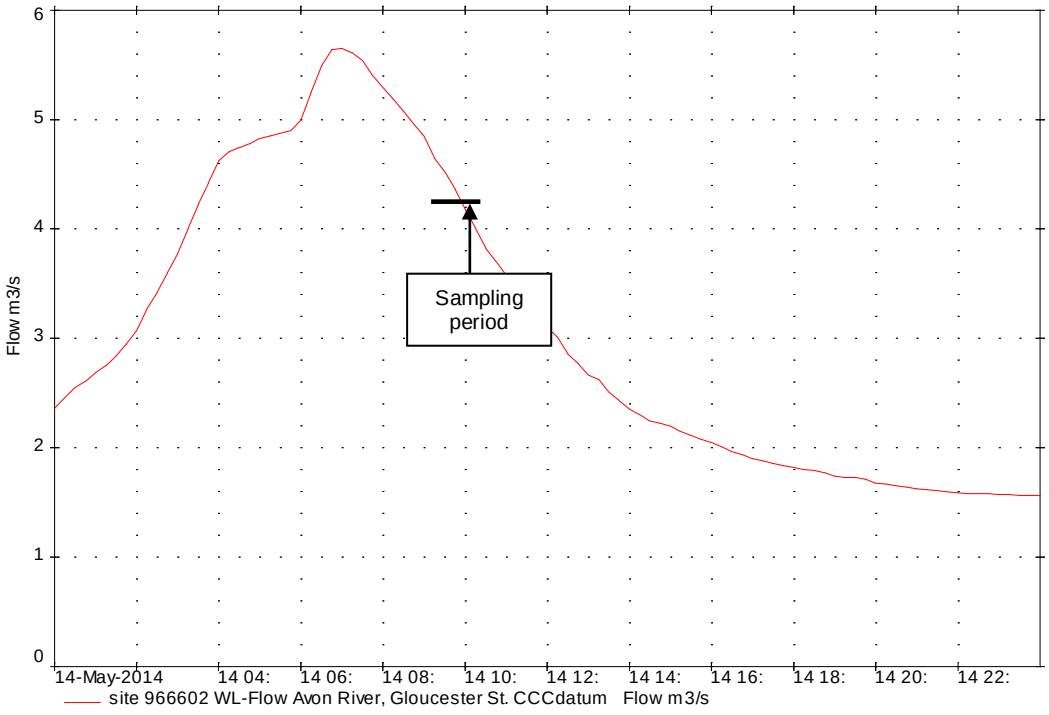

Figure 4. Flow rate in the Avon River at Gloucester Street on the 14th May 2014. Wet weather samples were collected between 9.05 – 10.20am on this day, as indicated on the graph.

3.2 Dissolved Copper

Wet weather dissolved copper concentrations were generally much higher than that recorded during the annual monitoring (Figure 5). The first wet weather event recorded higher concentrations across all sites than the second wet weather event. Wet weather concentrations were generally well above the guideline level of 0.00356 mg/L. In contrast, no sites recorded medians above this guideline value during the annual monitoring. The highest level during the wet weather monitoring was recorded at the Carlton Mill Corner site during the first event (0.035 mg/L); this may be due to cumulative inputs from the Riccarton Main Drain and Addington Brook, as these sites also had high levels.

3.3 Dissolved Lead

The concentrations of dissolved lead during the first wet weather event were well above that recorded during the annual monitoring (Figure 6). In contrast, values recorded during the second event were consistent with the median levels recorded during the annual monitoring. The Avon River at Carlton Mill corner recorded substantially higher concentrations than the other sites (0.048 mg/L), well above the guideline level. The only other wet weather event where the guideline level was exceeded was in the Dudley Creek during the first wet weather event. In comparison, all sites during the annual monitoring recorded values below this guideline level.

3.4 Dissolved Zinc

Wet weather dissolved zinc concentrations were greater for the first event compared to the second for all sites, with the exception of the Mona Vale and Avondale Road bridge sites (Figure 7). Concentrations for both events were generally higher at all sites than the highest values recorded during the annual monitoring. As with the other metals, the Carlton Mill corner site recorded the highest value, during the first wet weather event (0.19 mg/L). This level may again be due to cumulative inputs from Riccarton Main Drain and Addington Brook, which also recorded high levels. All wet weather samples, with the exception of the Avon River at Avondale Road bridge site, had zinc concentrations above the guideline value of 0.0297 mg/L. No sites recorded medians above this guideline during the annual monitoring.

3.5 pH

pH levels were generally similar between wet weather events and levels were generally within that recorded for the annual monitoring at all sites (Figure 8). As was the case with the annual monitoring, all values were within the guideline level of 6.5 – 8.5. Wet weather concentrations were generally similar between sites.

3.6 Conductivity

Wet weather conductivity levels for all sites were generally lower than that recorded during the annual monitoring (Figure 9). The exception to this was the Avondale Road bridge site during the first wet weather event, where a value of 777 µS/cm was

recorded; this value is four times greater than the median value recorded for this site during the annual monitoring period (177 µS/cm). The time of sampling at this site coincided with mid-tide, therefore this high conductivity is likely due to tidal influence. This is further supported by this site recording comparably low levels of other parameters during this monitoring that could indicate contaminated input, such as metals. Across all sites, neither of the two storm events appeared to consistently record higher values compared to the other.

3.7 Total Suspended Solids

The concentrations of TSS for all sites and both wet weather events were well above the large proportion of annual monitoring results (Figure 10). Levels were generally greater during the first event than the second. The highest values were recorded in Addington Brook and Dudley Creek, during the first wet weather event (140 and 130 mg/L, respectively). The majority of wet weather concentrations were above the guideline level of 25 mg/L. In comparison, for the annual monitoring no site median exceeded this guideline.

3.8 Turbidity

Turbidity levels were mostly higher during the first wet weather event (Figure 11). As with TSS, turbidity levels for all sites and both wet weather events were well above the large proportion of annual monitoring results, and Addington Brook and Dudley Creek recorded the highest values during the first wet weather event (50 and 81 NTU, respectively). All wet weather levels were above the guideline value of 5.6 NTU, which contrasts the annual monitoring, where all sites recorded medians below this guideline.

3.9 Dissolved Oxygen

Dissolved oxygen levels in water samples from the wet weather events were consistent with that recorded during the annual monitoring at all sites, and generally similar between sites and wet weather events (Figure 12). All wet weather values were above the minimum guideline value of 70% saturation, consistent with that recorded during the annual monitoring.

3.10 Water Temperature

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

3.11 Biochemical Oxygen Demand

BOD levels were generally substantially greater for the first wet weather event than the second (Figure 14). Levels from both wet weather events were much higher than that recorded during the annual monitoring. The highest wet weather concentration was recorded in Addington Brook during the first event (8.5 mg/L). All sites recorded

concentrations above the guideline value of 2 mg/L during at least one of the storm events, with the exception of the Avon River site at the Avondale Road bridge. This contrasts that recorded for the annual monitoring, where all sites recorded medians below this guideline.

3.12 Total Ammonia (Ammoniacal Nitrogen)

There was no clear pattern in concentrations between wet weather sampling events (Figure 15). Some of the sites recorded wet weather concentrations within the range of the annual monitoring values: Addington Brook, Avon River at Manchester Street, Dudley Creek and the Avon River at the Avondale Road bridge. However, some sites recorded values higher than that recorded during the annual monitoring: Avon River at Mona Vale, Riccarton Main Drain, Avon River at Carlton Mill corner. The highest concentration recorded during the wet monitoring was at the Riccarton Main Drain site during the second event (0.230 mg/L). However, all values were well below the receiving water quality guideline of 0.9 mg/L, consistent with that recorded for the annual monitoring.

3.13 Nitrate

There was no obvious trend in nitrate levels between wet weather events (Figure 16). Levels were generally similar or lower than the annual monitoring results. The Avon River at Manchester Street site recorded the highest value of 1.7 mg/L during the first wet weather event, but this value was below the annual monitoring median for this site. All wet weather concentrations were below the guideline levels of 3.8 and 5.6 mg/L, as was the case with the annual monitoring.

3.14 Nitrate Nitrite Nitrogen

Consistent with nitrate levels, there was no clear pattern in concentrations between wet weather events, and levels were similar or lower than the annual monitoring results (Figure 17). This is not surprising given that NNN concentrations are typically driven by nitrate levels. For example, the Avon River at Manchester Street site again recorded the highest value (1.7 mg/L) during the first wet weather event, with nitrite contributing only a very small proportion to the levels (0.010 mg/L). Most sites recorded wet weather concentrations above the guideline level of 0.444 mg/L on at least one of the sampling events; the exceptions to this was the Avon River at Carlton Mill corner and Dudley Creek sites. However, in contrast, all sites exceeded this guideline value during the annual monitoring, except Dudley Creek.

3.15 Dissolved Inorganic Nitrogen

As with nitrate and NNN, there was no apparent pattern in concentrations between wet weather events, and the levels recorded were similar or lower than that recorded during the annual monitoring (Figure 18). Again, this is not unexpected given that DIN is the sum of NNN and ammonia. The highest values were recorded at the Avon River at Mona Vale and Manchester Street sites during the first event (1.8 and 1.7 mg/L, respectively). The majority of wet weather concentrations were below the guideline level of 1.5 mg/L, with the exception of these two sites. With respect to the annual monitoring, more sites exceeded this guideline value for the annual monitoring.

3.16 Dissolved Reactive Phosphorus

DRP levels were generally lower during the first wet weather event compared to the second (Figure 19); this is the only parameter in this monitoring to show this trend. Concentrations at all sites were generally substantially higher during the wet weather events than the annual monitoring. The highest value recorded was 0.160 mg/L during the second wet weather event at the Addington Brook site. All wet weather samples were above the guideline concentration of 0.016 mg/L. In contrast, some of the sites in the annual monitoring had median values below this guideline (Avon River at Mona Vale, Carlton Mill corner and Manchester Street).

3.17 Escherichia coli

There was no clear pattern in *E. coli* concentrations between wet weather events (Figure 20). Levels were much higher than that recorded during the annual monitoring. The guideline level of 550 CFU/100ml was exceeded by all wet weather samples, with the exception of the first event at the Avon River Avondale Road bridge site. Riccarton Main Drain and the Avon River at Carlton Mill corner recorded the highest value of 24,000 CFU/100ml, on the second and first wet weather events, respectively. This concentration is 44 time greater than the guideline value.

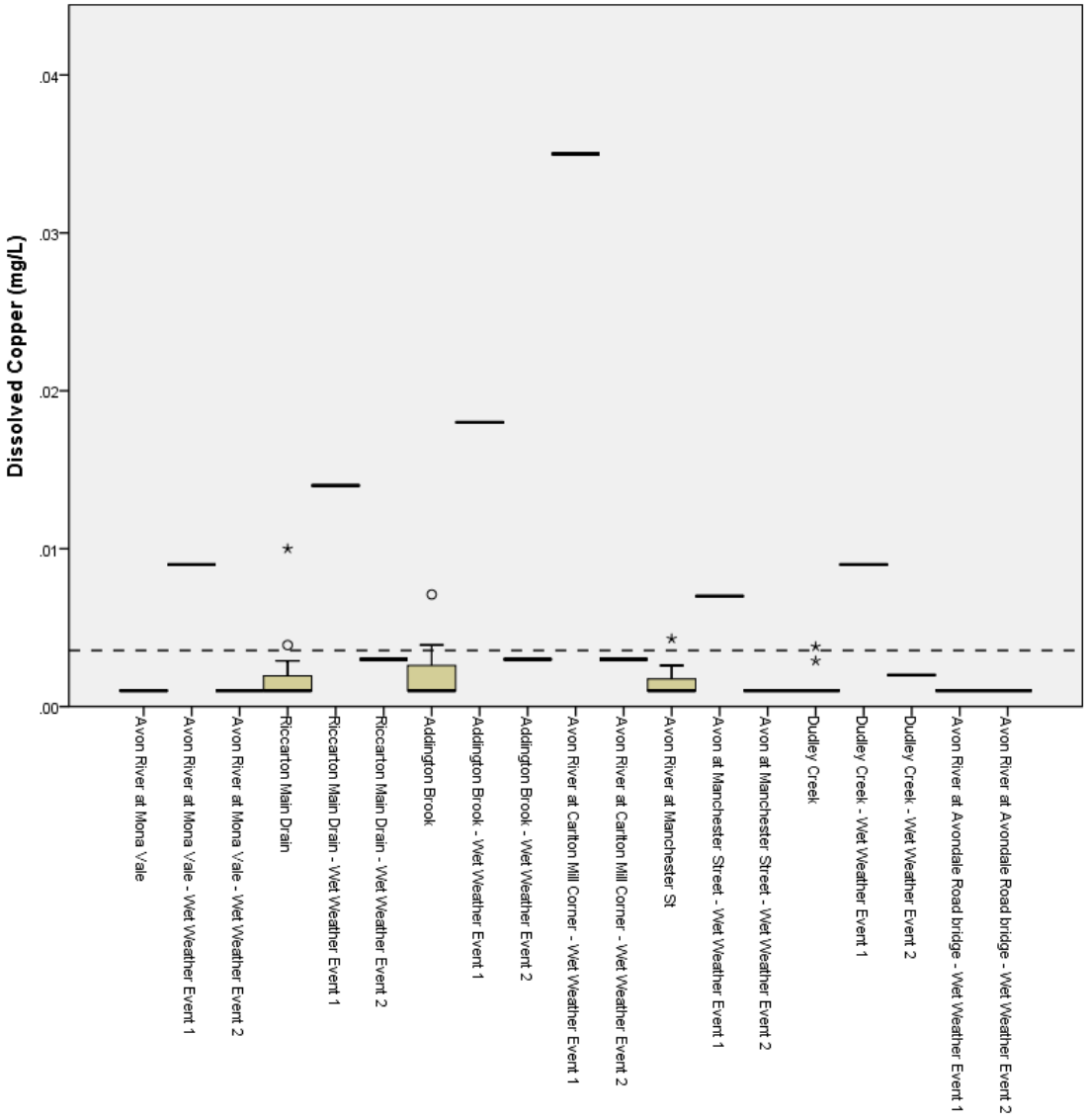

Figure 5. Dissolved copper levels in water samples from two wet weather events on the 25th March and 14th May 2014, compared to results from the annual monitoring (May 2013 to April 2014) for the same sites. Note that the Carlton Mill Corner and Avondale bridge sites were not monitored for this parameter during the annual monitoring. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Proposed Canterbury Land and Water Regional Plan trigger value (Environment Canterbury, 2012), which has been modified to account for water hardness (0.00356 mg/L), 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.

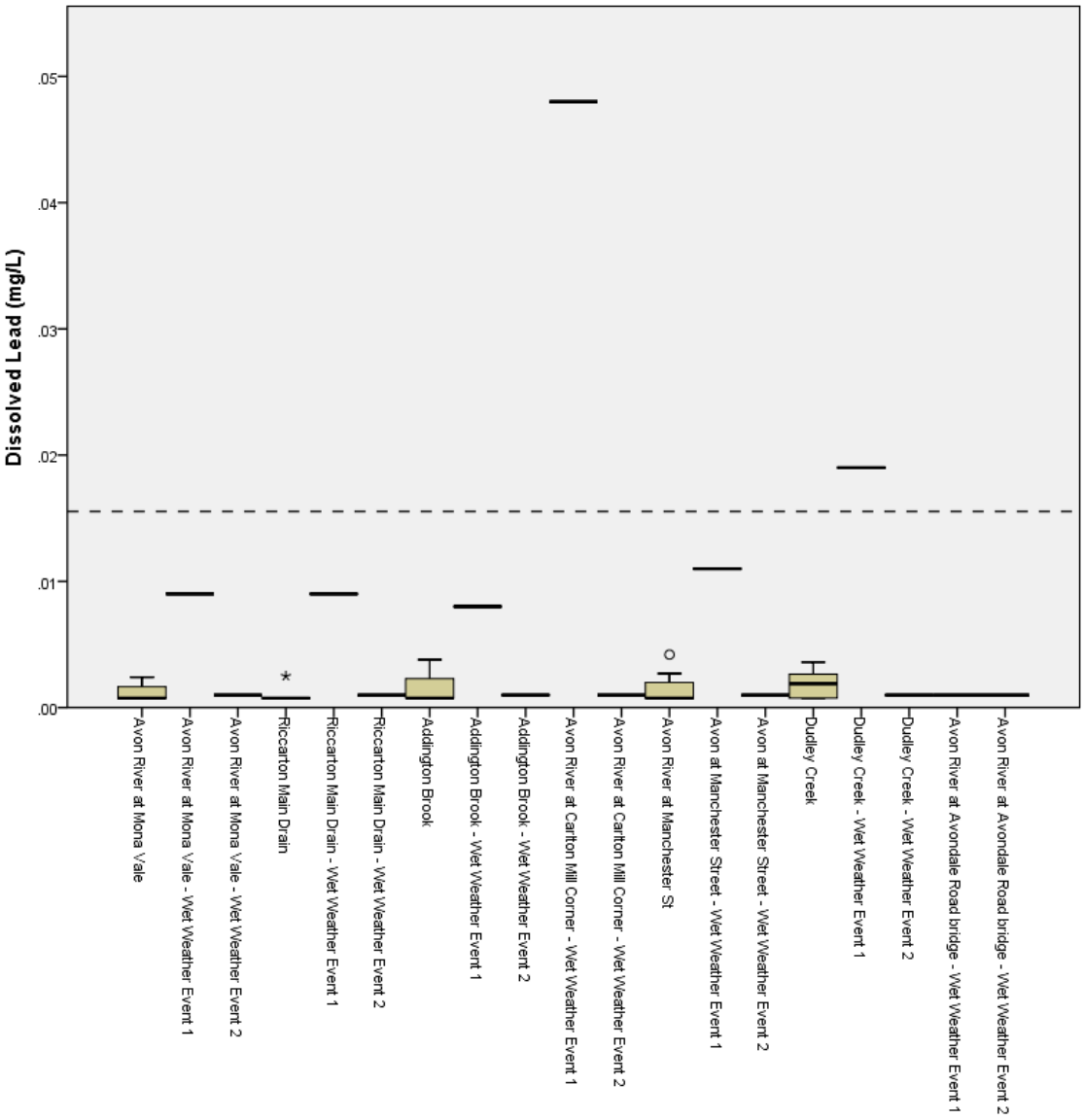

Figure 6. Dissolved lead levels in water samples from two wet weather events on the 25th March and 14th May 2014, compared to results from the annual monitoring (May 2013 to April 2014) for the same sites. Note that the Carlton Mill Corner and Avondale bridge sites were not monitored for this parameter during the annual monitoring. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Proposed Canterbury Land and Water Regional Plan trigger value (Environment Canterbury, 2012), which has been modified to account for water hardness (0.01554 mg/L), as per the ANZECC (2000) guidelines methodology. 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.

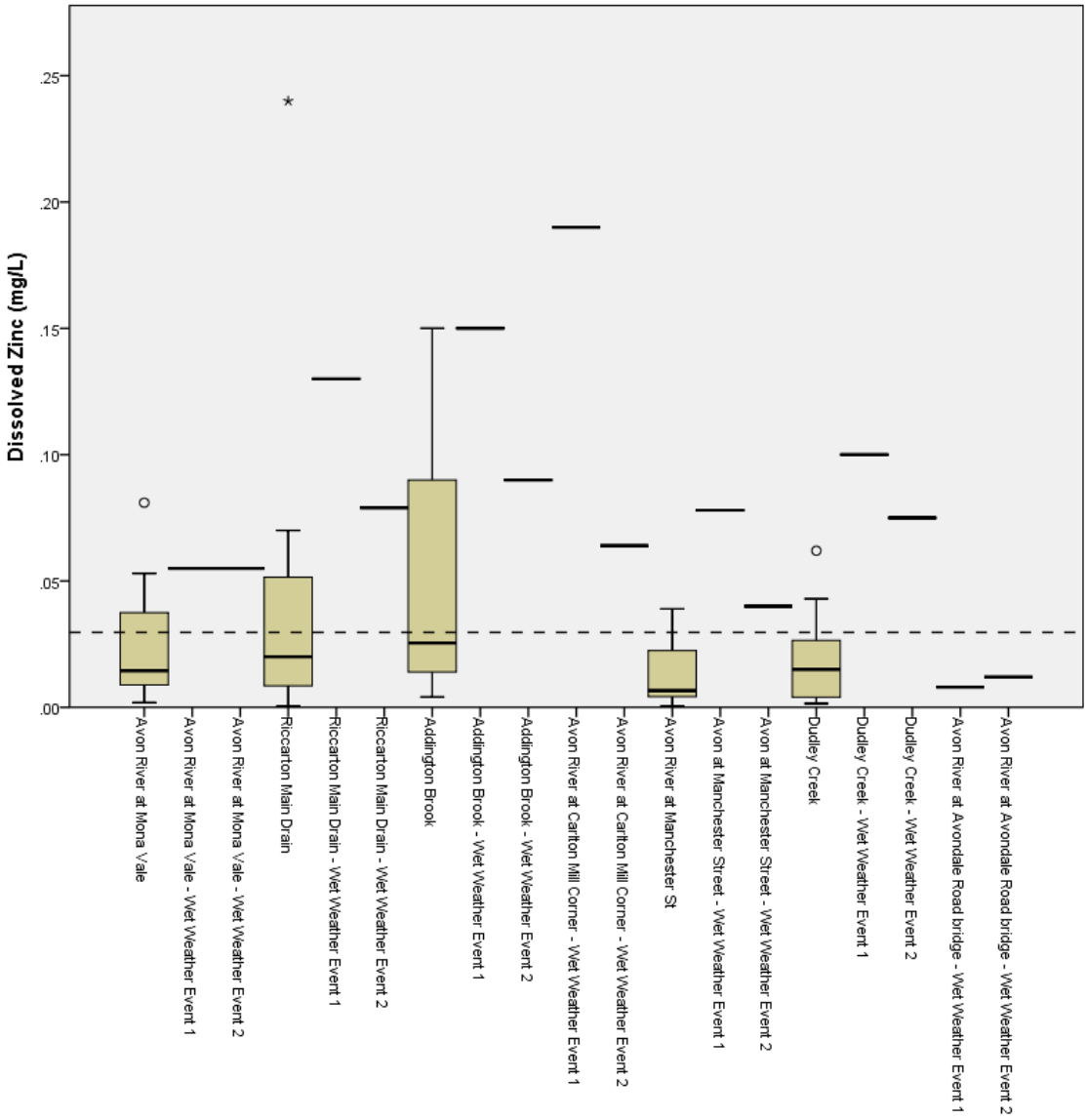

Figure 7. Dissolved zinc levels in water samples from two wet weather events on the 25th March and 14th May 2014, compared to results from the annual monitoring (May 2013 to April 2014) for the same sites. Note that the Carlton Mill Corner and Avondale bridge sites were not monitored for this parameter during the annual monitoring. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Proposed Canterbury Land and Water Regional Plan trigger value (Environment Canterbury, 2012), which has been modified to account for water hardness (0.02970 mg/L), as per the ANZECC (2000) guidelines methodology. The Laboratory Limit of Detection was 0.0010 mg/L – analysed as half this value (0.0005 mg/L) to allow statistics to be undertaken.

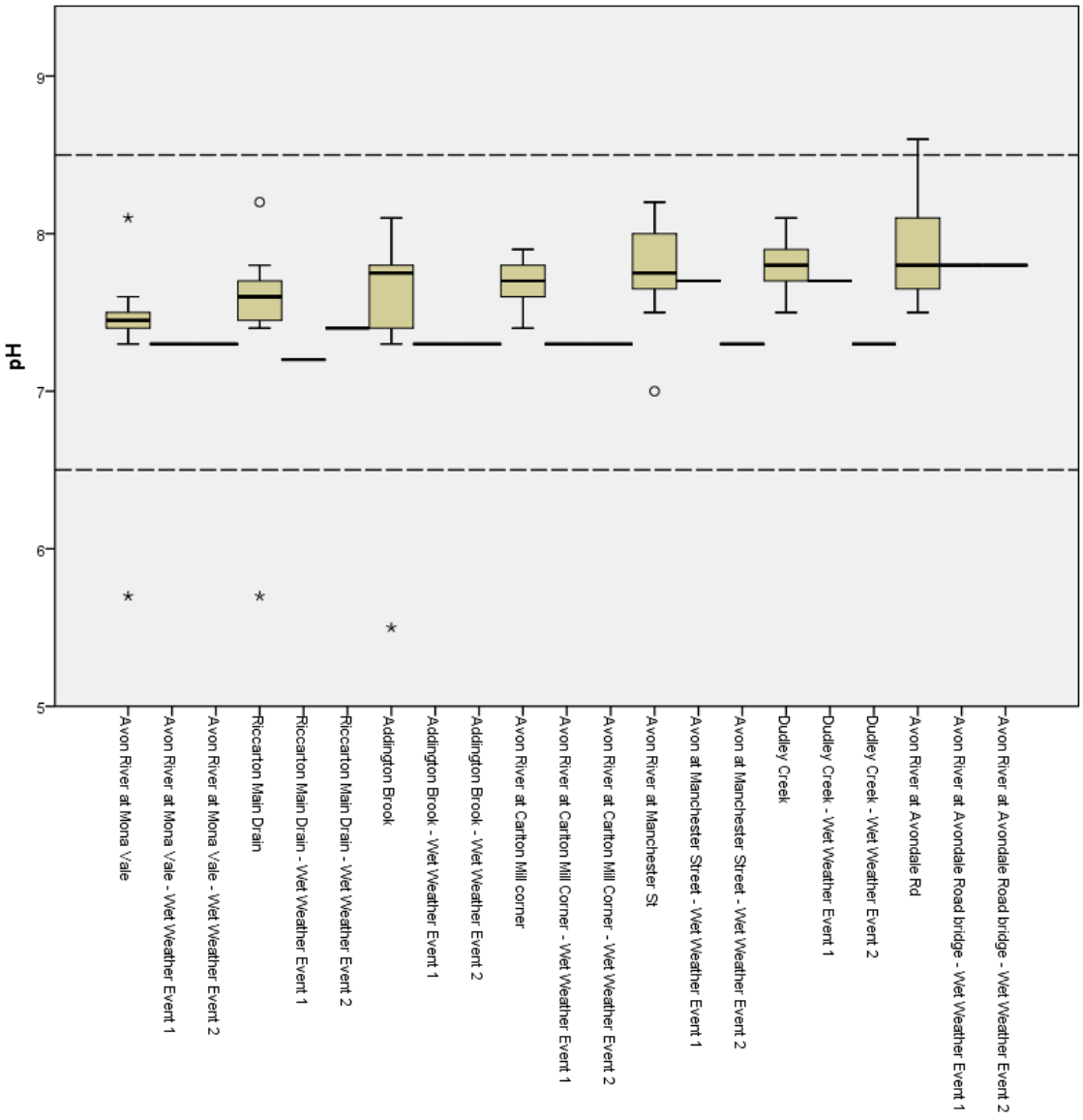

Figure 8. pH levels in water samples from two wet weather events on the 25th March and 14th May 2014, compared to results from the annual monitoring (May 2013 to April 2014) for the same sites. Sites are ordered from upstream to downstream (left to right). The dotted lines represent the Proposed Canterbury Land and Water Regional Plan lower (6.5) and upper (8.5) limits (Environment Canterbury, 2012).

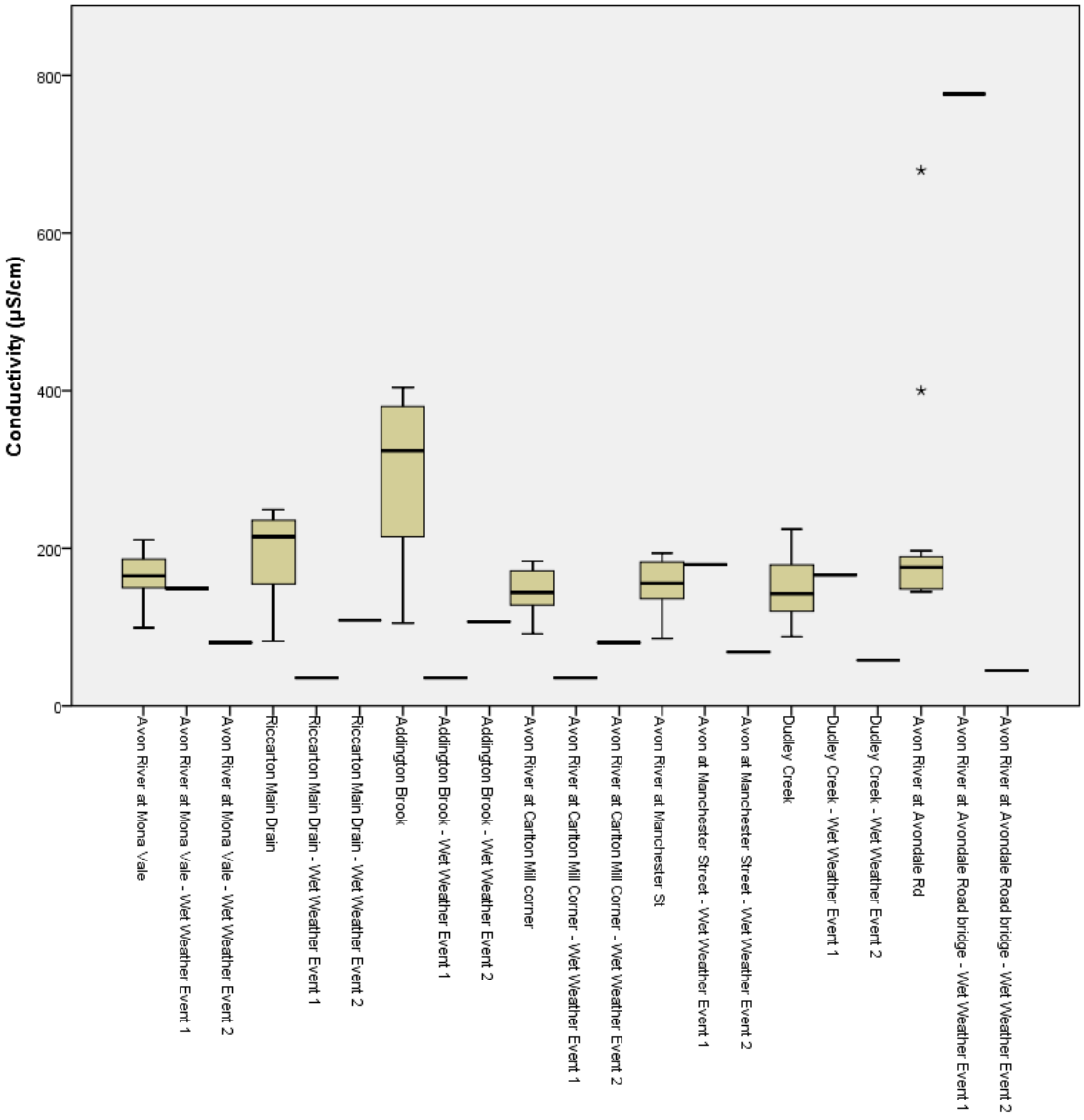

Figure 9. Conductivity levels in water samples from two wet weather events on the 25th March and 14th May 2014, compared to results from the annual monitoring (May 2013 to April 2014) for the same sites. Sites are ordered from upstream to downstream (left to right). There are no relevant guideline levels for this parameter.

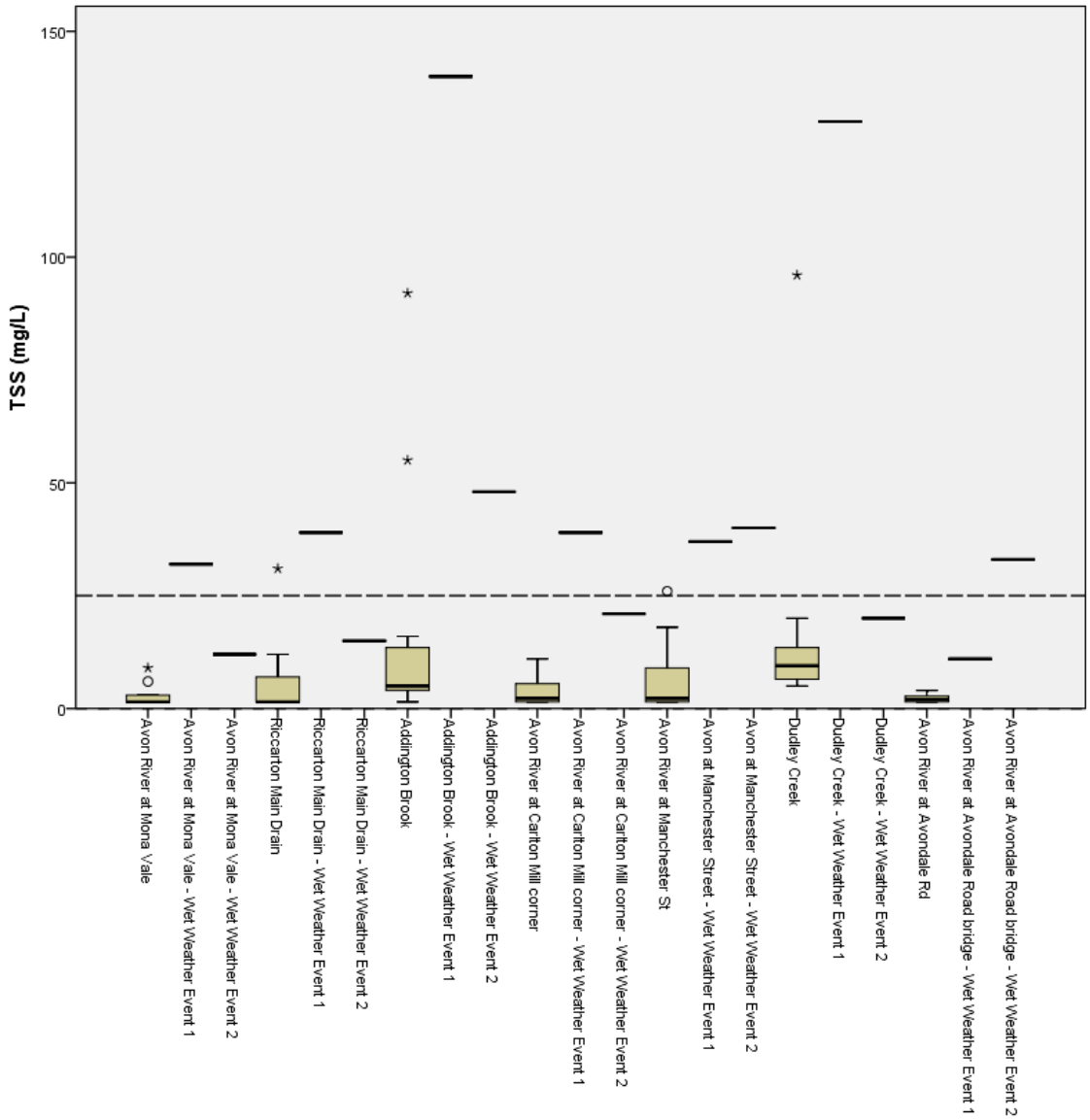

Figure 10. Total Suspended Solids (TSS) levels in water samples from two wet weather events on the 25th March and 14th May 2014, compared to results from the annual monitoring (May 2013 to April 2014) for the same sites. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Ryan (1991) guideline value of 25 mg/L. The Laboratory Limit of Detection was 5.0 mg/L – analysed as half this value (2.5 mg/L) to allow statistics to be undertaken.

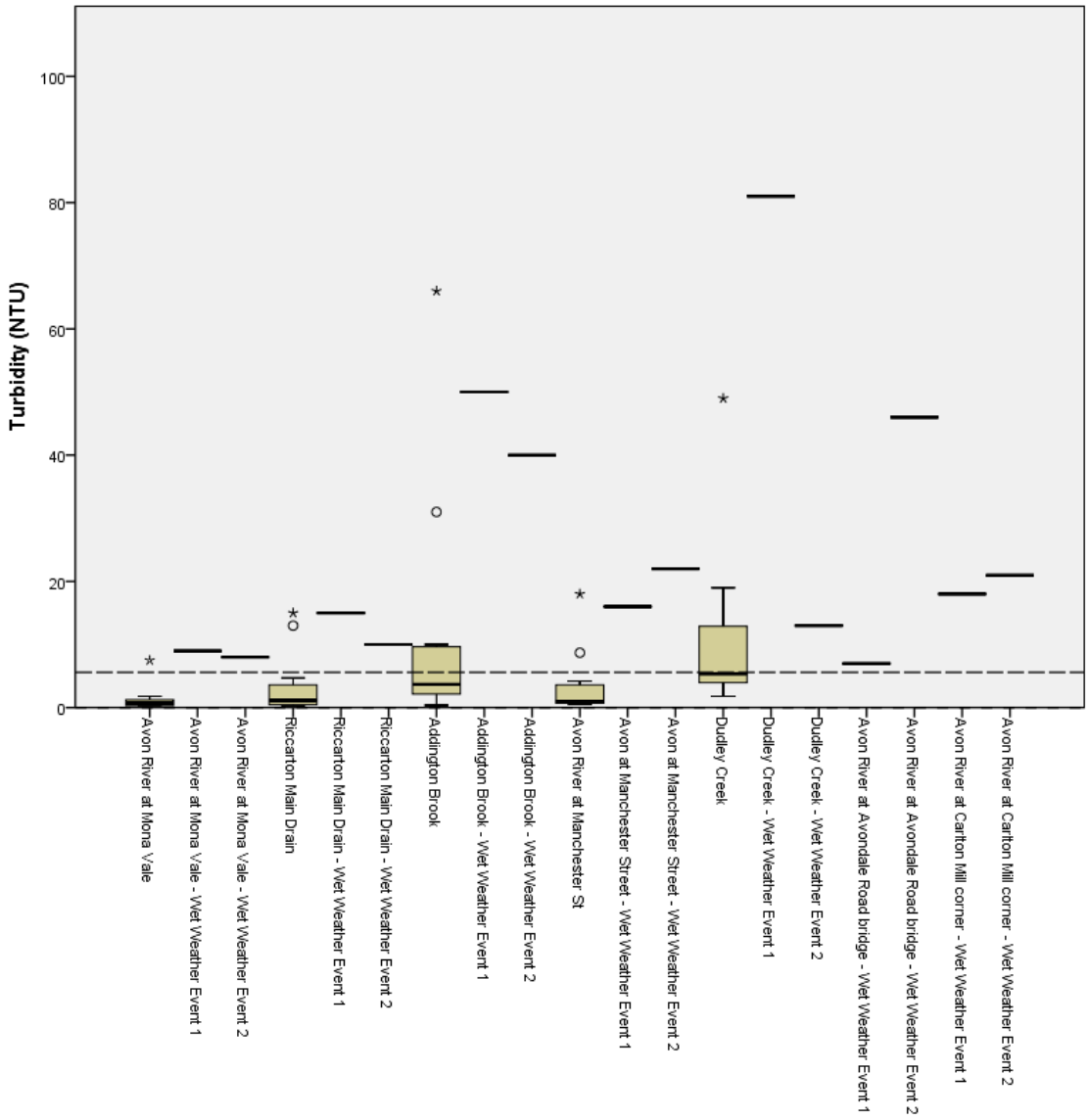

Figure 11. Turbidity levels in water samples from two wet weather events on the 25th March and 14th May 2014, compared to results from the annual monitoring (May 2013 to April 2014) for the same sites. Note that the Carlton Mill Corner and Avondale bridge sites were not monitored for this parameter during the annual monitoring. 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).

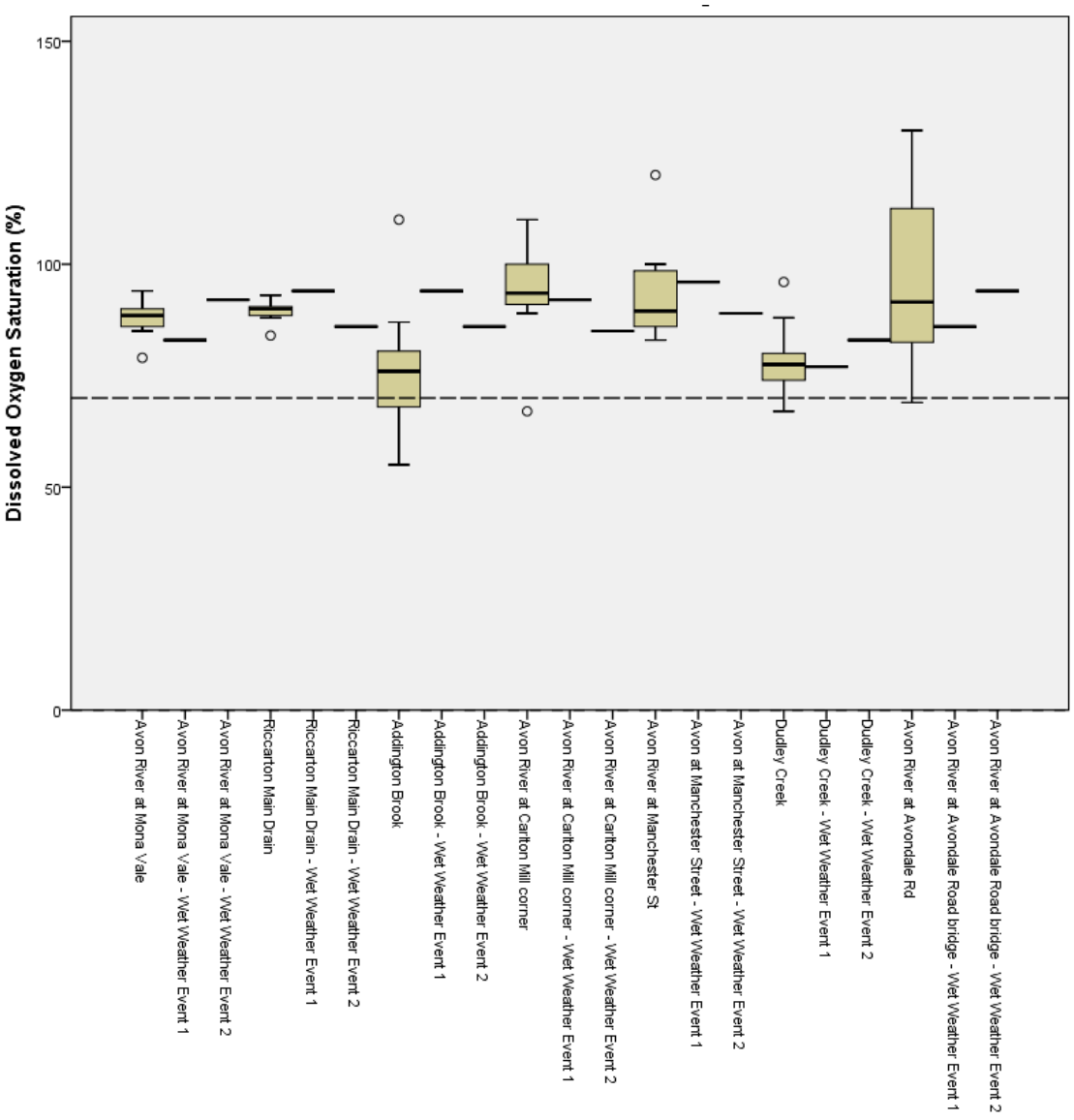

Figure 12. Dissolved oxygen levels in water samples from two wet weather events on the 25th March and 14th May 2014, compared to results from the annual monitoring (May 2013 to April 2014) for the same sites. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Proposed Canterbury Land and Water Regional Plan minimum guideline value (70%, Environment Canterbury, 2012).

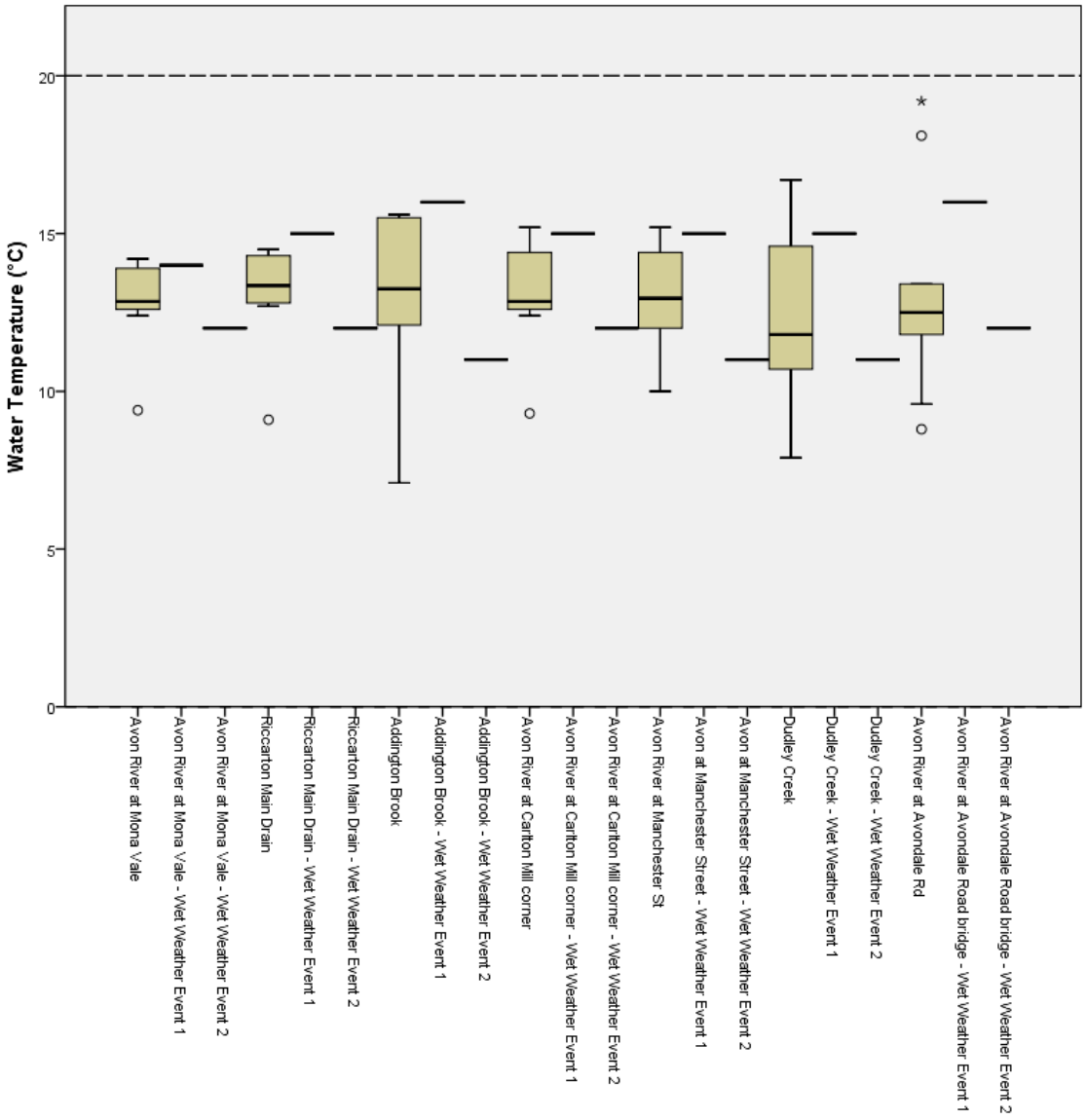

Figure 13. Temperature of water samples at the time of sampling during two wet weather events on the 25th March and 14th May 2014, compared to results from the annual monitoring (May 2013 to April 2014) for the same sites. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Proposed Canterbury Land and Water Regional Plan maximum guideline value (20ºC, Environment Canterbury, 2012).

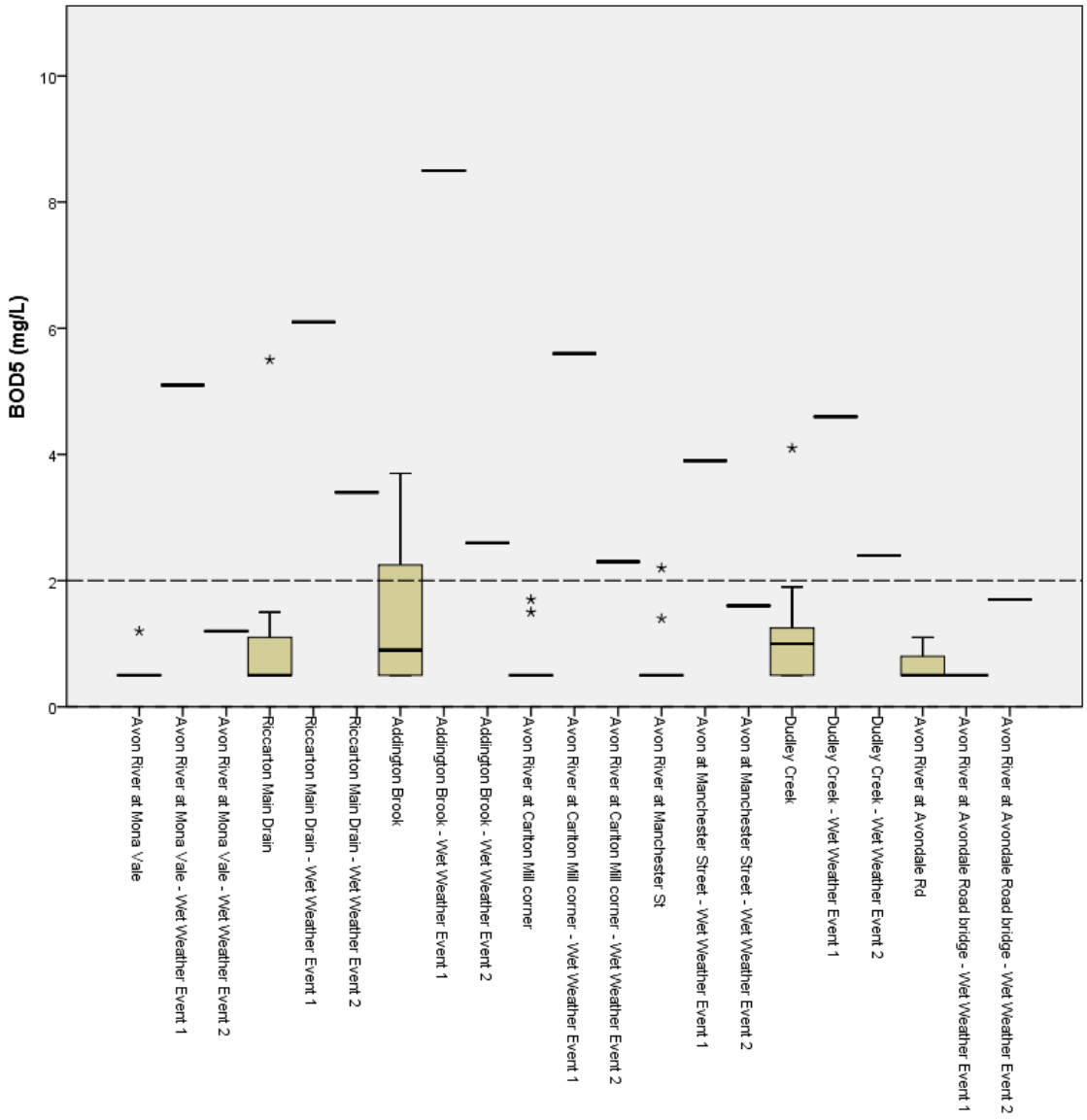

Figure 14. Biochemical Oxygen Demand (BOD_5) levels in water samples from two wet weather events on the 25th March and 14th May 2014, compared to results from the annual monitoring (May 2013 to April 2014) for the same sites. Sites are ordered from upstream to downstream (left to right). The dotted line 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, analysed as half this value (0.5 mg/L) to allow statistics to be undertaken.

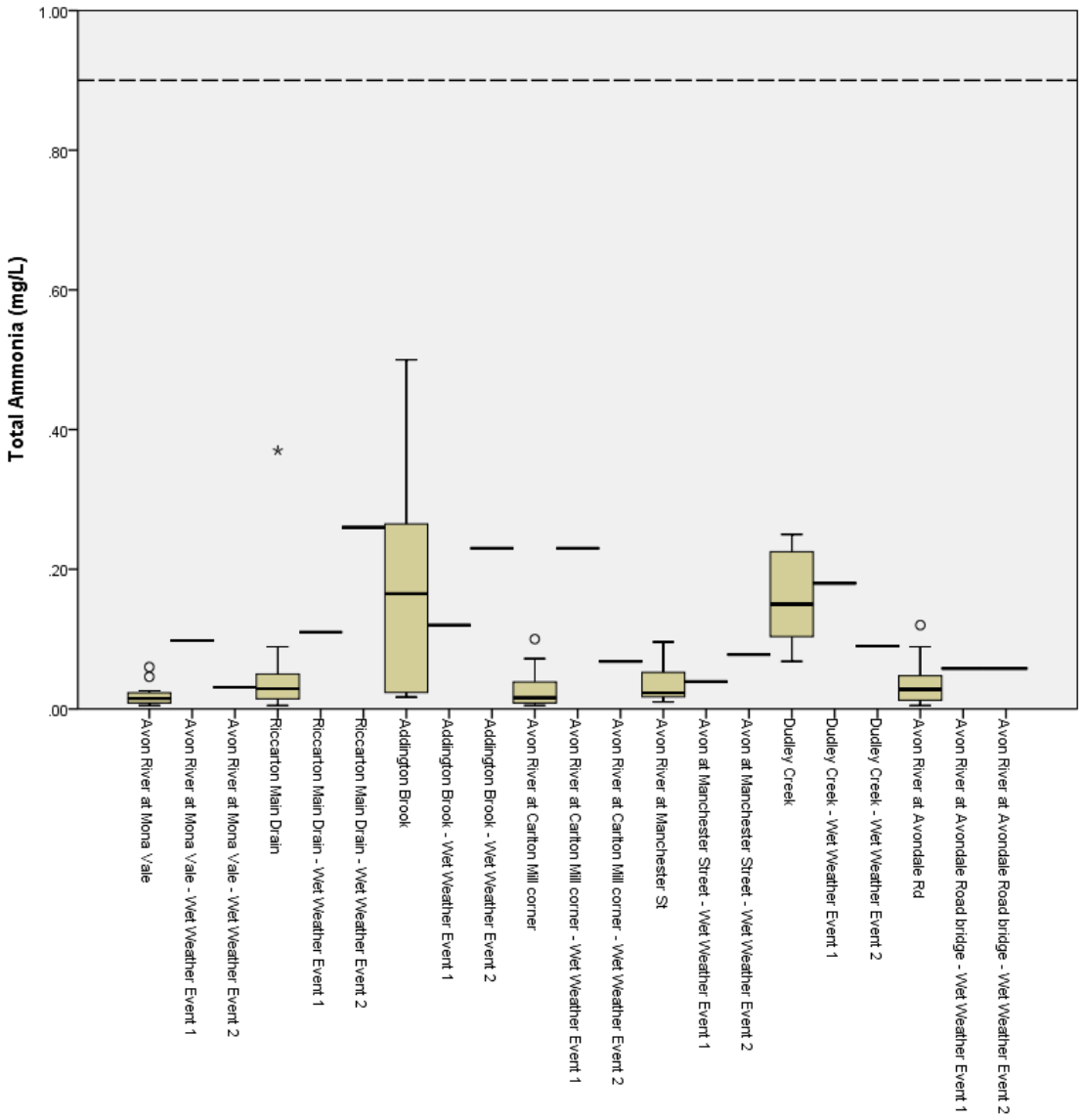

Figure 15. Total ammonia levels in water samples from two wet weather events on the 25th March and 14th May 2014, compared to results from the annual monitoring (May 2013 to April 2014) for the same sites. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Proposed Canterbury Land and Water Regional Plan trigger value (0.9 mg/L; Environment Canterbury, 2012), calculated based on median pH levels (8.0) for the annual monitoring period.

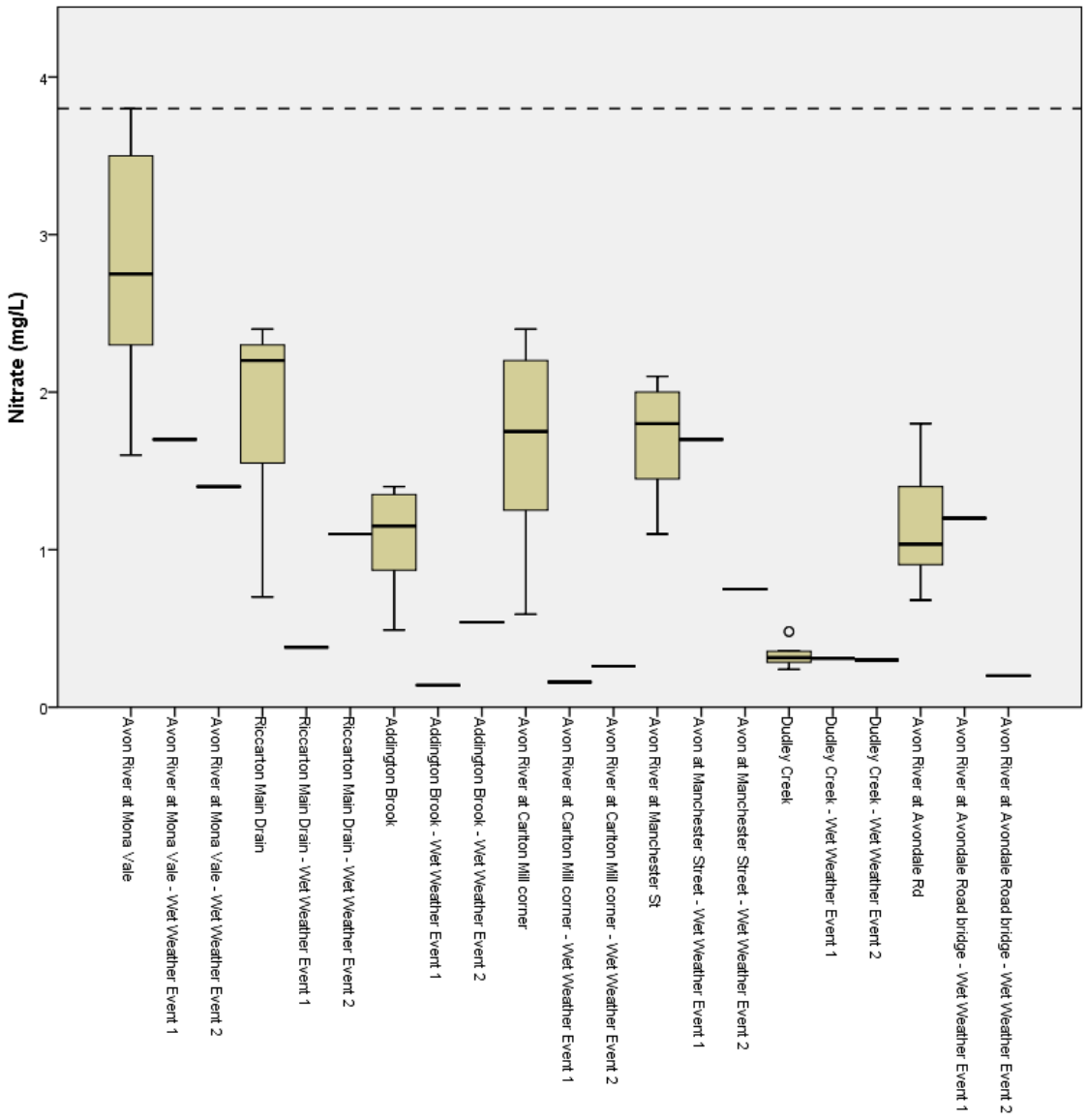

Figure 16. Nitrate levels in water samples from two wet weather events on the 25th March and 14th May 2014, compared to results from the annual monitoring (May 2013 to April 2014) for the same sites. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Hickey (2013) grading guideline level of 3.8 mg/L. The surveillance guideline level (5.6 mg/L) is not shown on the graph, as the y-axis scale does not extend this far.

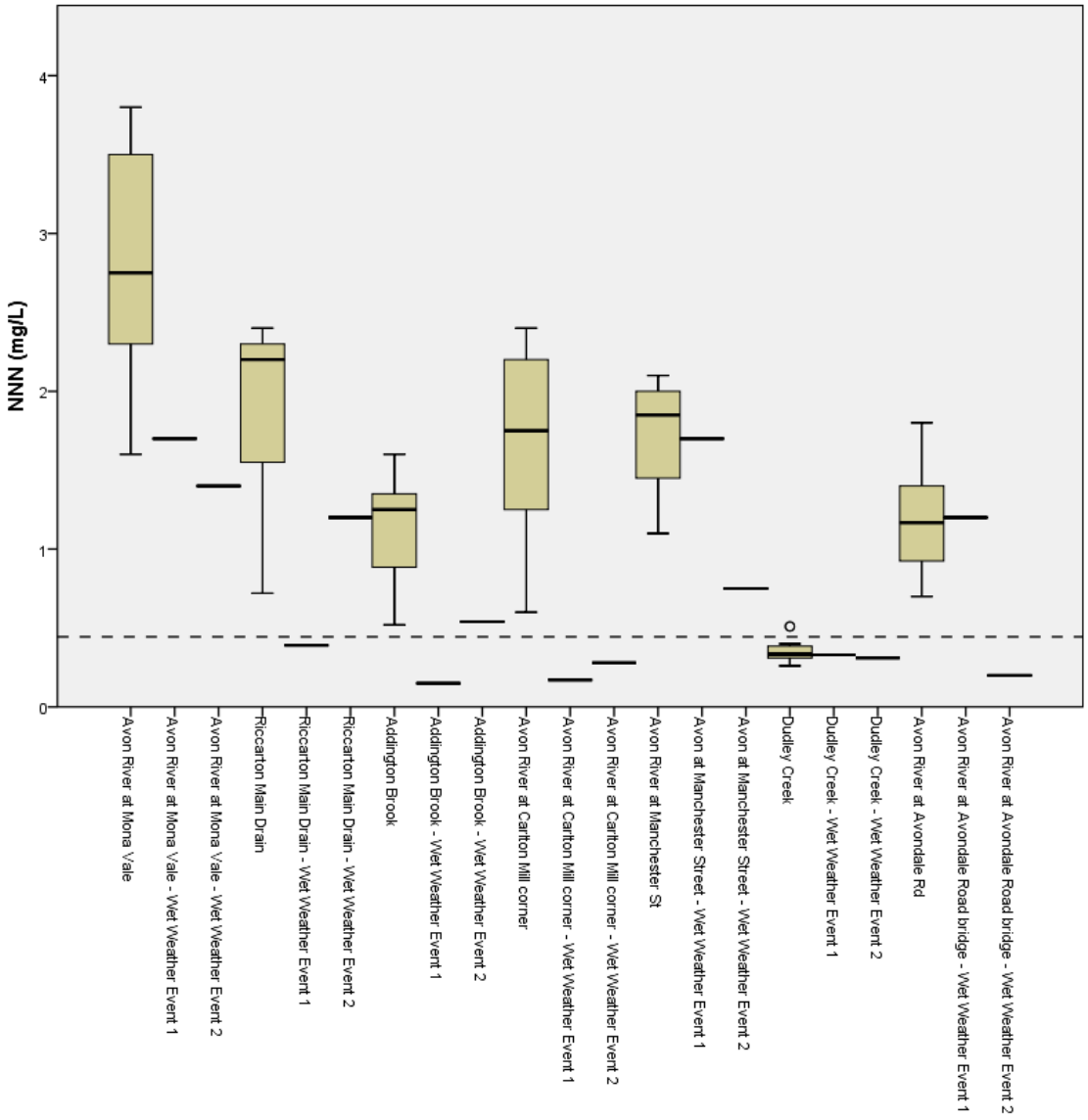

Figure 17. Nitrate Nitrite Nitrogen (NNN) levels in water samples from two wet weather events on the 25th March and 14th May 2014, compared to results from the annual monitoring (May 2013 to April 2014) for the same sites. Sites are ordered from upstream to downstream (left to right). The dotted line represents the ANZECC water quality guideline (0.444 mg/L; ANZECC, 2000).

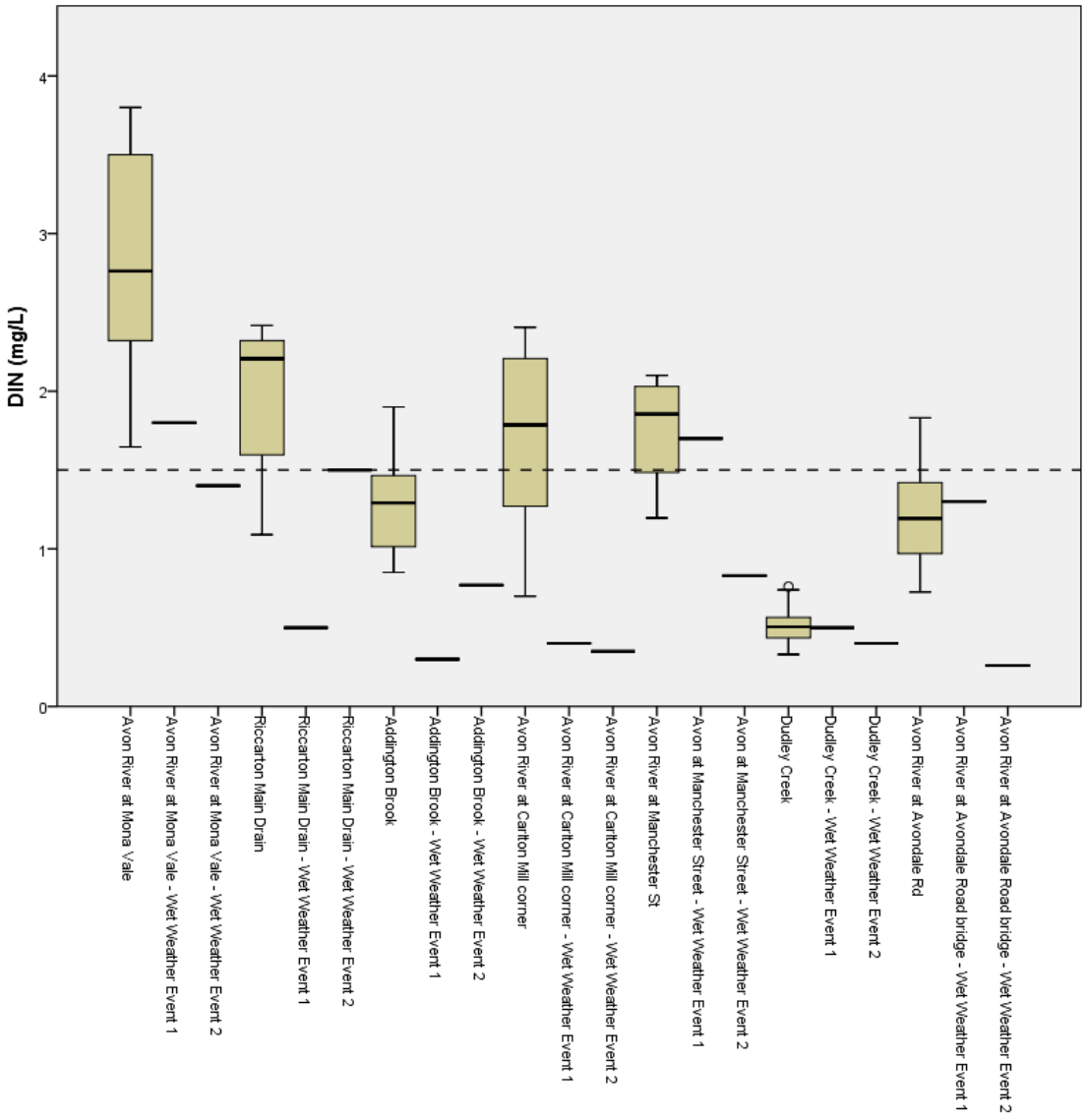

Figure 18. Dissolved Inorganic Nitrogen (DIN) levels in water samples from two wet weather events on the 25th March and 14th May 2014, compared to results from the annual monitoring (May 2013 to April 2014) for the same sites. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Proposed Canterbury Land and Water Regional Plan trigger value of 1.5 mg/L (Environment Canterbury, 2012).

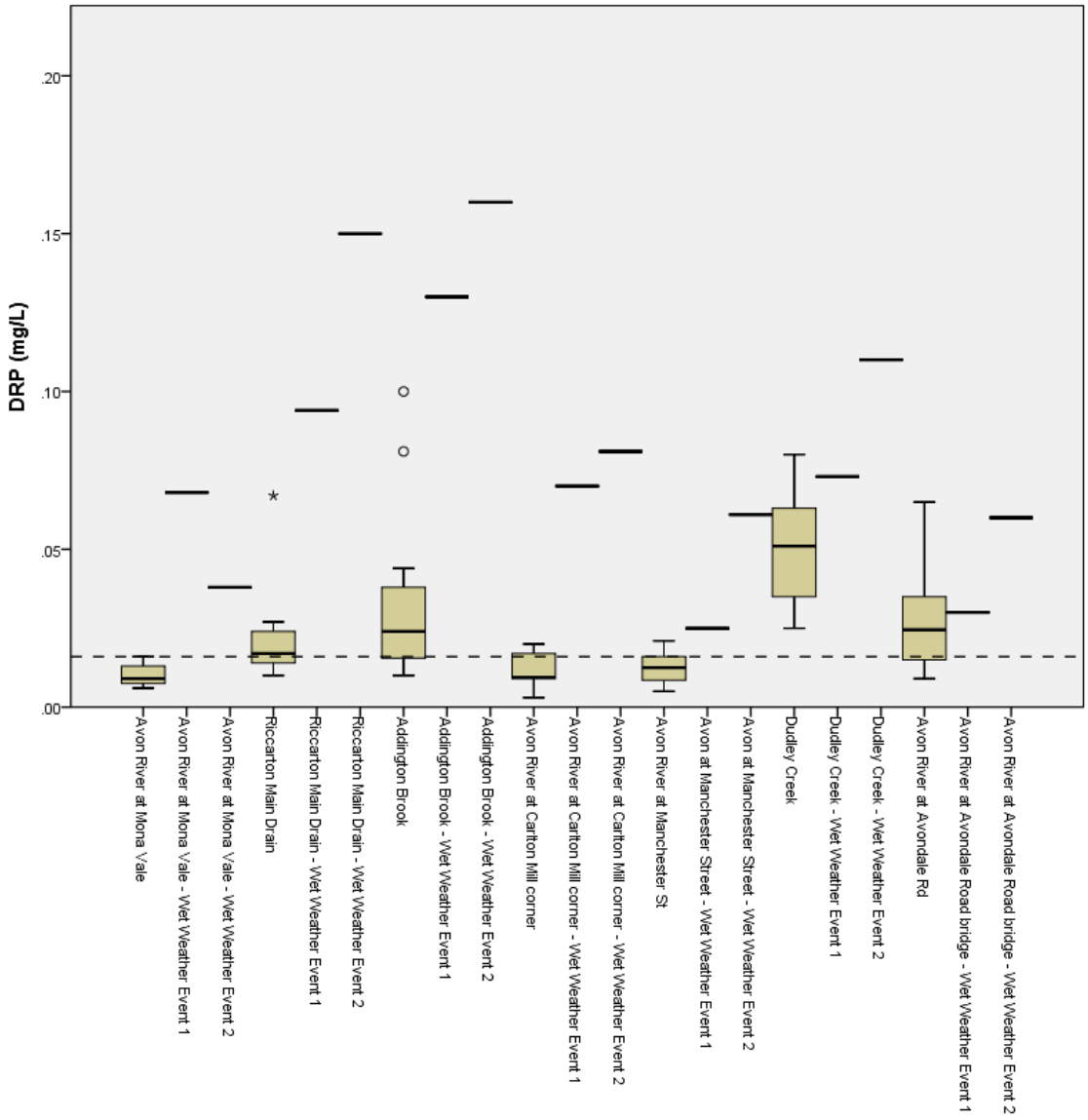

Figure 19. Dissolved Reactive Phosphorous (DRP) levels in water samples from two wet weather events on the 25th March and 14th May 2014, compared to results from the annual monitoring (May 2013 to April 2014) for the same sites. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Proposed Canterbury Land and Water Regional Plan trigger value of 0.016 mg/L (Environment Canterbury, 2012). The Laboratory Limit of Detection was 0.01 mg/L, analysed as half this value (0.005 mg/L) to allow statistics to be undertaken.

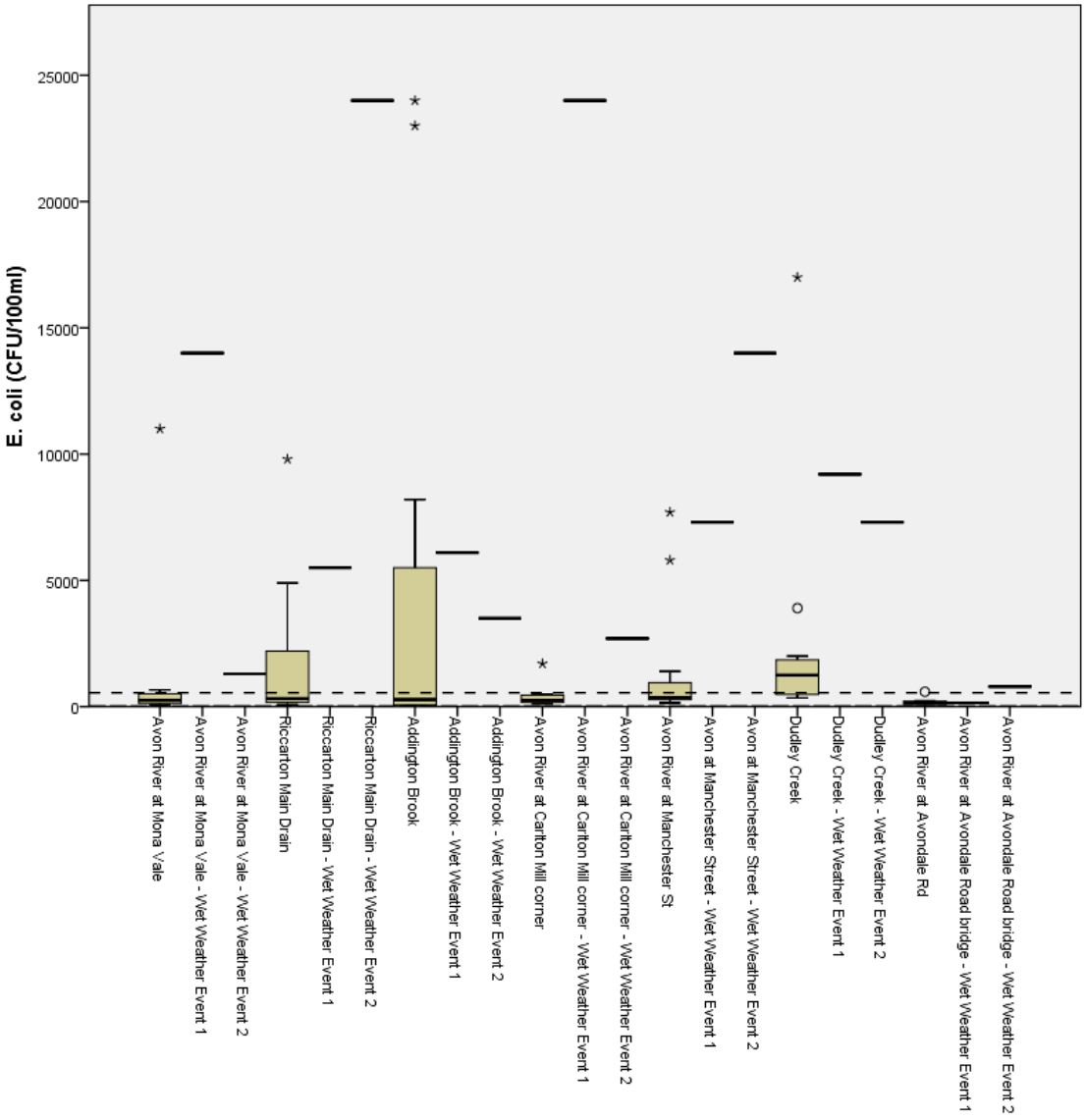

Figure 20. *Escherichia coli* levels in water samples from two wet weather events on the 25th March and 14th May 2014, compared to results from the annual monitoring (May 2013 to April 2014) for the same sites. Sites are ordered from upstream to downstream (left to right). The dotted line represents the Proposed Canterbury Land and Water Regional Plan trigger value of 550 CFU/100ml for 95% of samples (Environment Canterbury, 2012).

4 Stormwater Outfall Results

Appendix B of this report presents the raw wet weather stormwater outfall results over the three time periods per event, along with the rainfall prior to each sampling event. Parameters of importance to instream values are discussed in the following sections, with graphs presented that compare concentrations to receiving water guidelines. However, it is noted that stormwater will be diluted after discharge to waterways and therefore this comparison is a very conservative assessment of potential adverse effects.

4.1 Rainfall

The amount of rainfall 24-hours prior to sampling was similar across sites for all three time periods (Figure 21). The exception to this was the Westmorland outfall, which recorded relatively low rainfall during the sampling event compared to the other sites. This suggests that each outfall was sampled during similar conditions (a minimum dry period of one week was also ensured before sampling, so that contaminants could accumulate on surfaces). Overall, rainfall increased across the three time periods of each event, as to be expected.

4.2 Dissolved Copper

Dissolved copper levels in the outfalls were below the receiving water quality guideline of 0.00356 mg/L for the Bromley, St Albans and Northwood samples, but in contrast were well above the guideline for all three time periods for Waltham and Westmorland (Figure 22). Levels were similar between the three different time periods for all sites except Westmorland, which recorded substantially higher levels during the first time period.

4.3 Dissolved Lead

All sites recorded dissolved lead levels below the receiving water quality guideline of 0.01554 mg/L for all samples (Figure 23). Northwood recorded levels below the LOD for all samples, as did St Albans for two of the three samples. Westmorland recorded higher levels than the other sites for the first time period. There was no clear pattern between time periods.

4.4 Dissolved Zinc

The only outfalls that did not exceed the receiving water quality guideline during at least one time period were the Bromley and Northwood sites (Figure 24). The Waltham site recorded substantially higher values than the other sites. There were no apparent trends in concentrations between time periods.

4.5 pH

All pH levels were within the receiving water quality guidelines of 6.5 to 8.5 (Figure 25). However, the second time period for the St Albans outfall was only just above the lower

pH limit of 6.5 (recording a pH of 6.6). Levels were similar across sites and time periods.

4.6 Conductivity

Conductivity levels varied between time periods, but there was no obvious trend in concentrations (Figure 26). Levels were similar between the Waltham, Northwood and Westmorland sites; these sites recorded higher levels than the Bromley and St Albans outfalls.

4.7 TSS

All sites recorded TSS concentrations above the receiving water quality guideline of 25 mg/L on at least one time period, with the exception of the Northwood site (Figure 27). Concentrations were generally similar between time periods, although levels increased progressively during sampling for Westmorland. This site recorded much higher levels than the other outfalls.

4.8 Turbidity

Turbidity levels showed similar trends to TSS, although all sites recorded levels above the guideline of 5 NTU (Figure 28). Westmorland again recorded substantially higher concentrations than the other sites.

4.9 BOD_5

The Waltham and Westmorland sites recorded considerably higher levels than the receiving water quality guideline of 2 mg/L (Figure 29). The other sites recorded levels below this guideline. There was no obvious trend between time periods.

4.10 Total Ammonia

All samples for all sites were substantially below the receiving water quality guideline of 0.9 mg/L (Figure 30). Concentrations were generally similar between time periods. The Waltham outfall recorded much higher levels compared to the other sites.

4.11 Nitrate

Nitrate levels in all samples were well below the grading and surveillance guideline levels for receiving waters of 3.8 and 5.6 mg/L, respectively (Figure 31). Concentrations showed no apparent trend across time periods. Levels were generally similar between sites.

4.12 NNN

All samples recorded NNN levels well below the receiving water quality guideline of 0.444 mg/L (Figure 32). Levels varied between time periods between sites. Concentrations were generally similar between outfalls.

4.13 DIN

As with nitrate and NNN, DIN concentrations for all time periods and sites were considerably below the receiving water quality guideline of 1.5 mg/L (Figure 33). There was no obvious pattern between time periods. Waltham recorded higher levels compared to the other outfalls.

4.14 DRP

DRP levels were all substantially higher than the receiving water quality guideline of 0.016 mg/L for samples (Figure 34). Levels between sites varied between the different time periods. The Bromley and St Albans outfalls recorded higher levels than the other sites.

4.15 E. coli

Waltham, Bromley and Westmorland outfalls recorded *E. coli* levels above the guideline of 550 CFU/100ml on at least one time period; the St Albans and Northwood sites recorded levels well below this guideline (Figure 35). Again, there was no apparent trend in concentrations between time periods. Westmorland recorded considerably higher levels than the other sites.

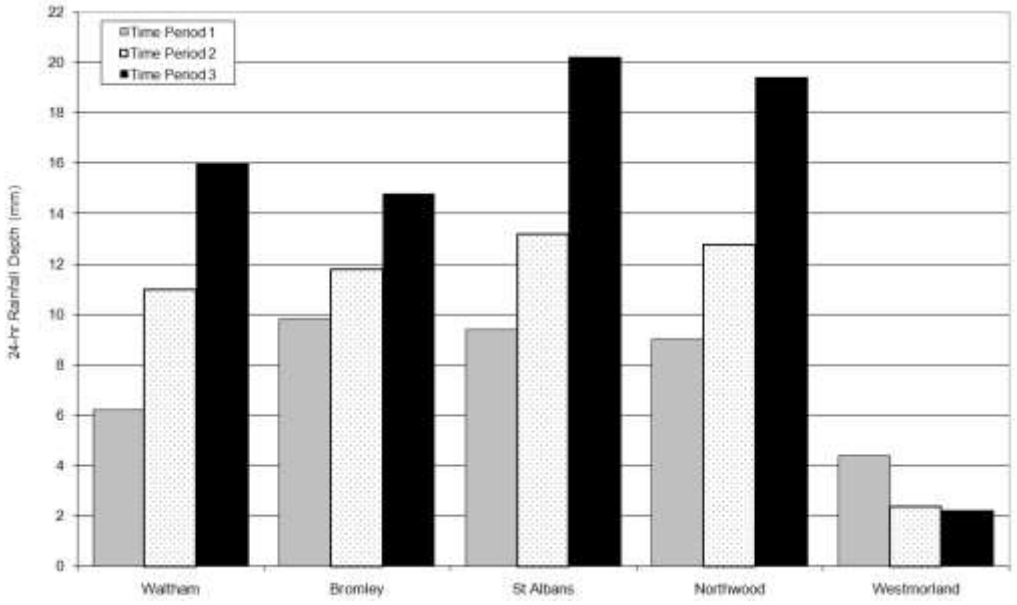

Figure 21. 24-hour rainfall prior to water quality sampling at each of the stormwater outfall sites of the Interim Global Stormwater Consent

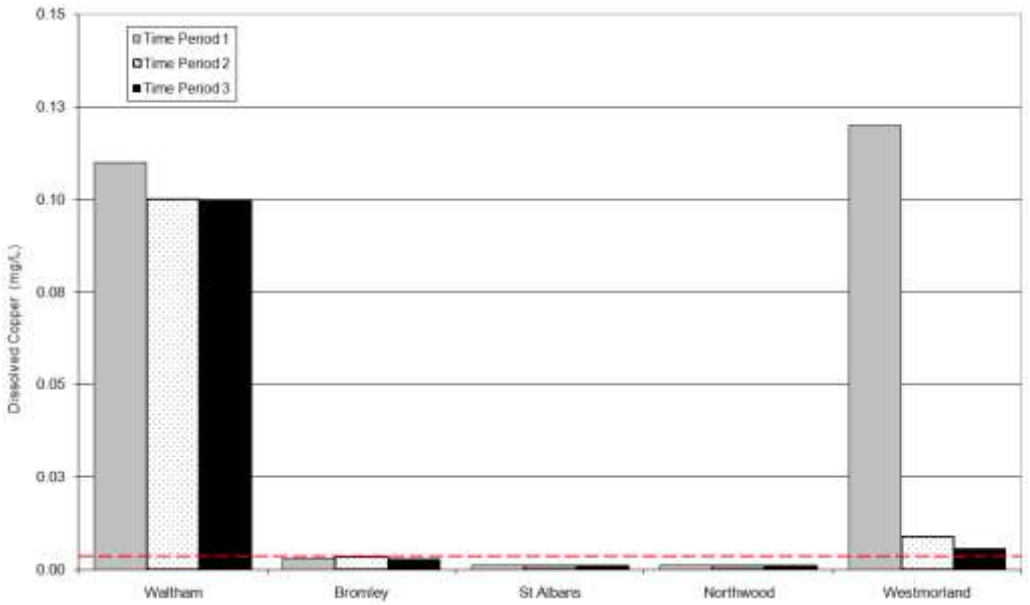

Figure 22. Dissolved copper levels in water samples from stormwater outfalls, during three time periods of a wet weather event (collected using autosamplers). The dotted line represents the Proposed Canterbury Land and Water Regional Plan trigger value for receiving waters (Environment Canterbury, 2012), which has been modified to account for water hardness (0.00356 mg/L), as per the ANZECC (2000) guidelines methodology. Values below the Laboratory Limit of Detection of 0.002 mg/L were converted to half this limit (0.001 mg/L) for statistical presentation.

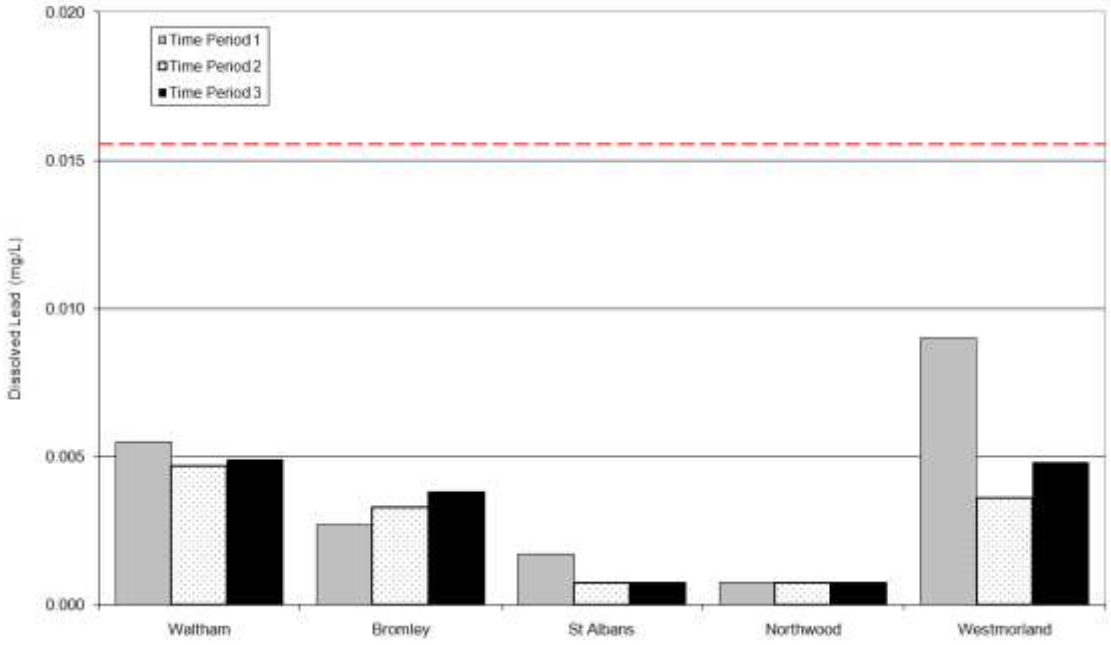

Figure 23. Dissolved lead levels in water samples from stormwater outfalls, during three time periods of a wet weather event (collected using autosamplers). The dotted line represents the Proposed Canterbury Land and Water Regional Plan trigger value for receiving waters (Environment Canterbury, 2012), which has been modified to account for water hardness (0.01554 mg/L), as per the ANZECC (2000) guidelines methodology. Values below the Laboratory Limit of Detection of 0.0015 mg/L were converted to half this limit (0.00075 mg/L) for statistical presentation.

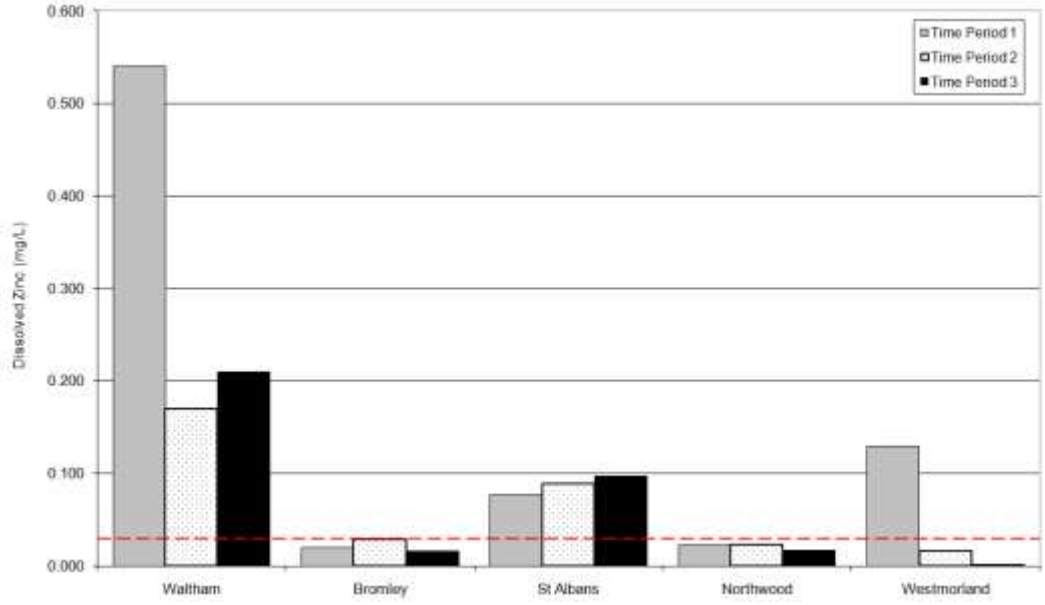

Figure 24. Dissolved zinc levels in water samples from stormwater outfalls, during three time periods of a wet weather event (collected using autosamplers). The dotted line represents the Proposed Canterbury Land and Water Regional Plan trigger value for receiving waters (Environment Canterbury, 2012), which has been modified to account for water hardness

(0.02970 mg/L), as per the ANZECC (2000) guidelines methodology. No values were below the Laboratory Limit of Detection of 0.0010 mg/L.

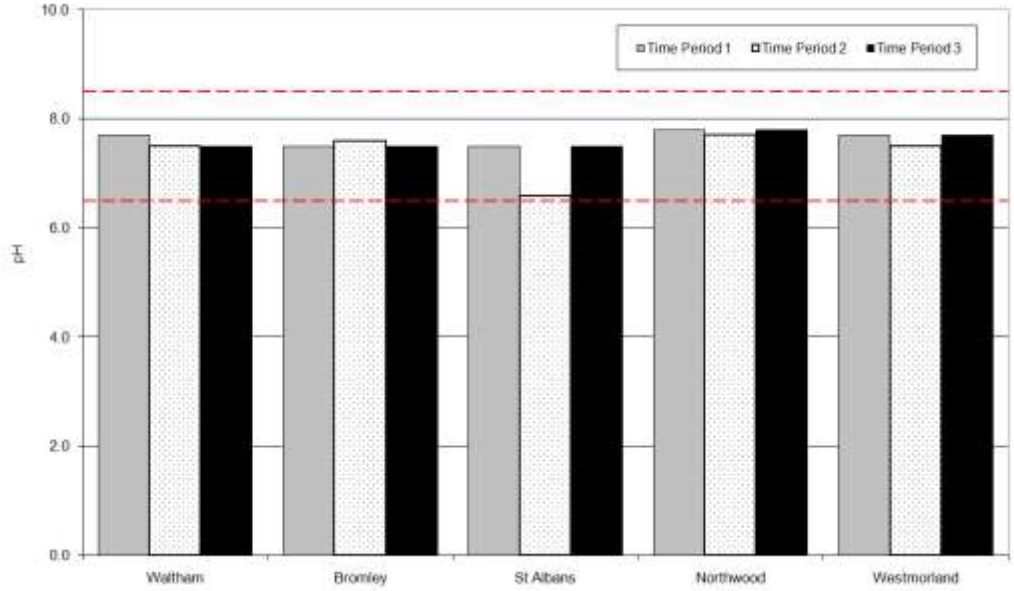

Figure 25. pH levels in water samples from stormwater outfalls, during three time periods of a wet weather event (collected using autosamplers). The dotted lines represent the Proposed Canterbury Land and Water Regional Plan receiving waters lower (6.5) and upper (8.5) limits (Environment Canterbury, 2012).

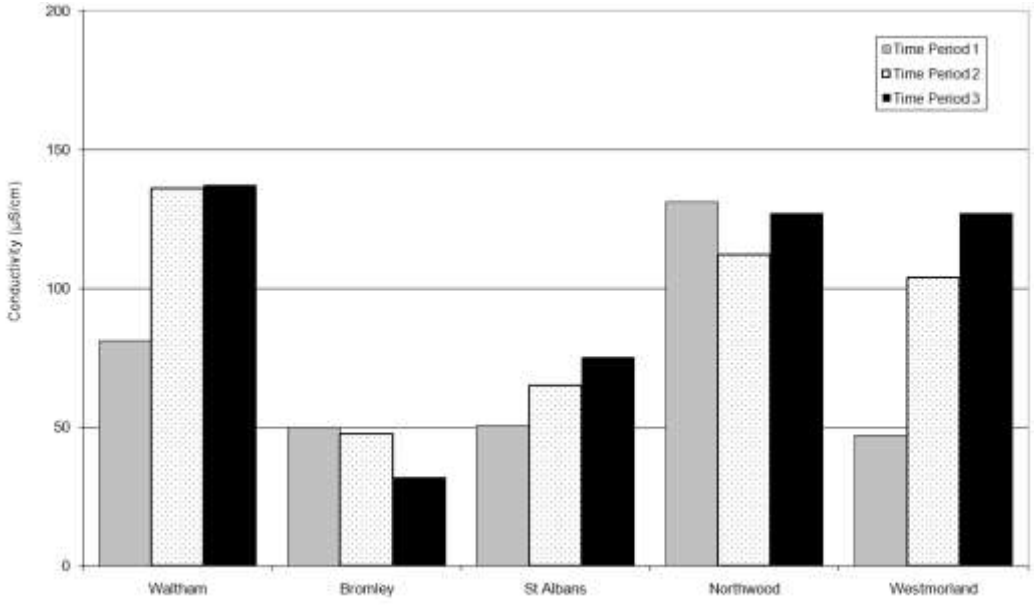

Figure 26. Conductivity levels in water samples from stormwater outfalls, during three time periods of a wet weather event (collected using autosamplers). There are no relevant guideline levels for this parameter.

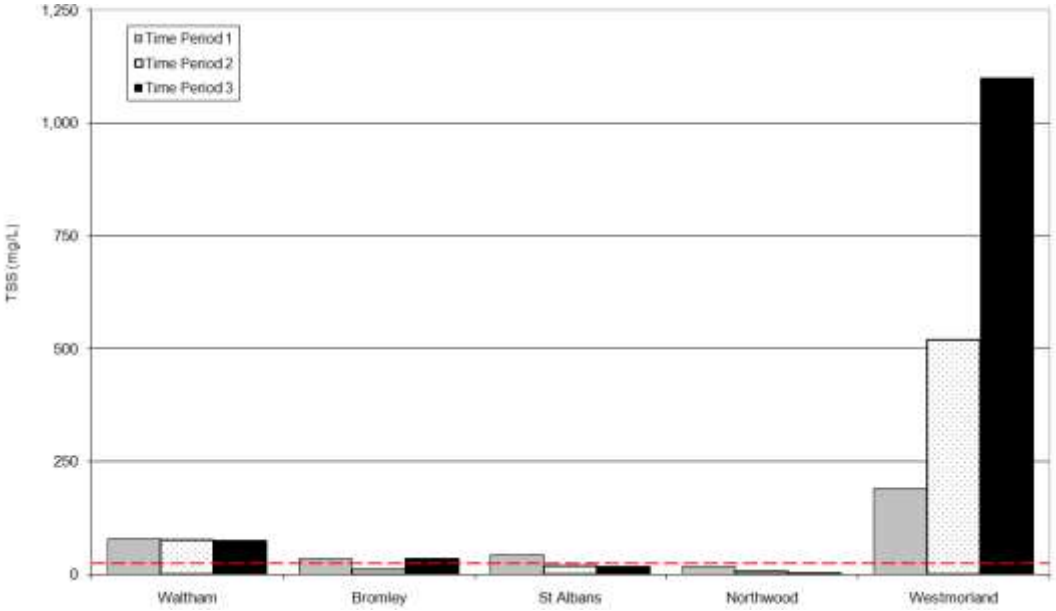

Figure 27. Total Suspended Solid (TSS) levels in water samples from stormwater outfalls, during three time periods of a wet weather event (collected using autosamplers). The dotted line represents the Ryan (1991) guideline value for receiving waters of 25 mg/L. No concentrations were below the Laboratory Limit of Detection of 5.0 mg/L.

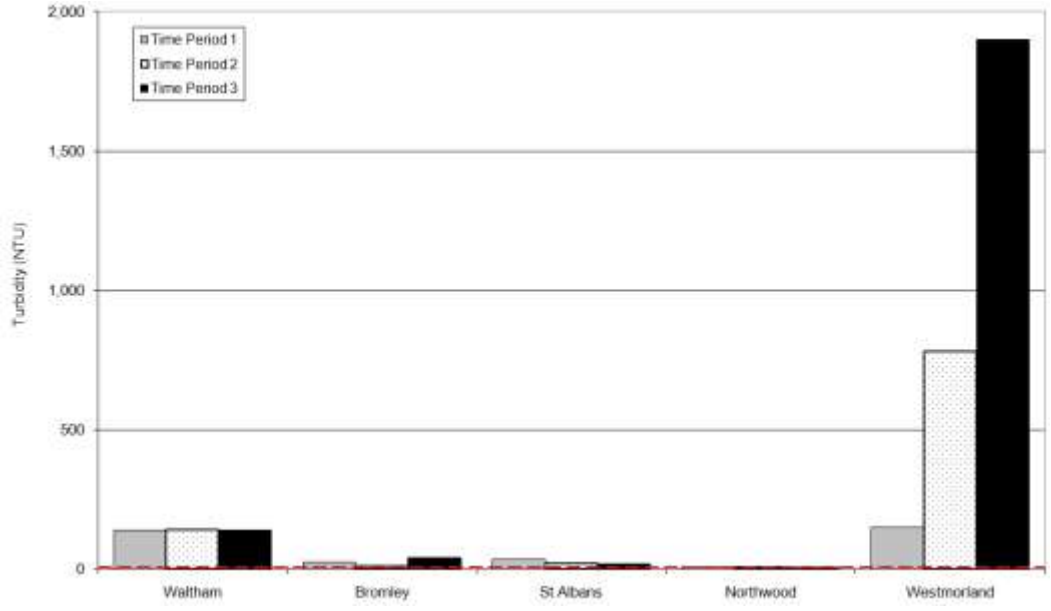

Figure 28. Turbidity levels in water samples from stormwater outfalls, during three time periods of a wet weather event (collected using autosamplers). The dotted line represents the ANZECC (2000) receiving water guideline value of 5.6 Nephelometric Turbidity Units (NTU).

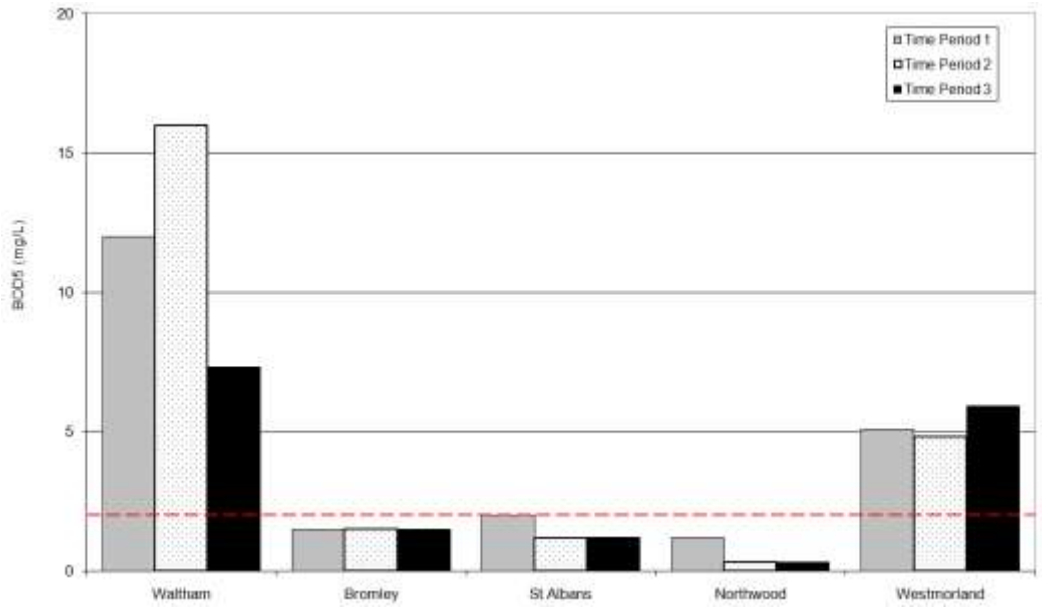

Figure 29. Biochemical Oxygen Demand (BOD_5) levels in water samples from stormwater outfalls, during three time periods of a wet weather event (collected using autosamplers). The dotted line represents the Ministry for the Environment guideline value for receiving waters (2 mg/L; Ministry for the Environment, 1992). 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.

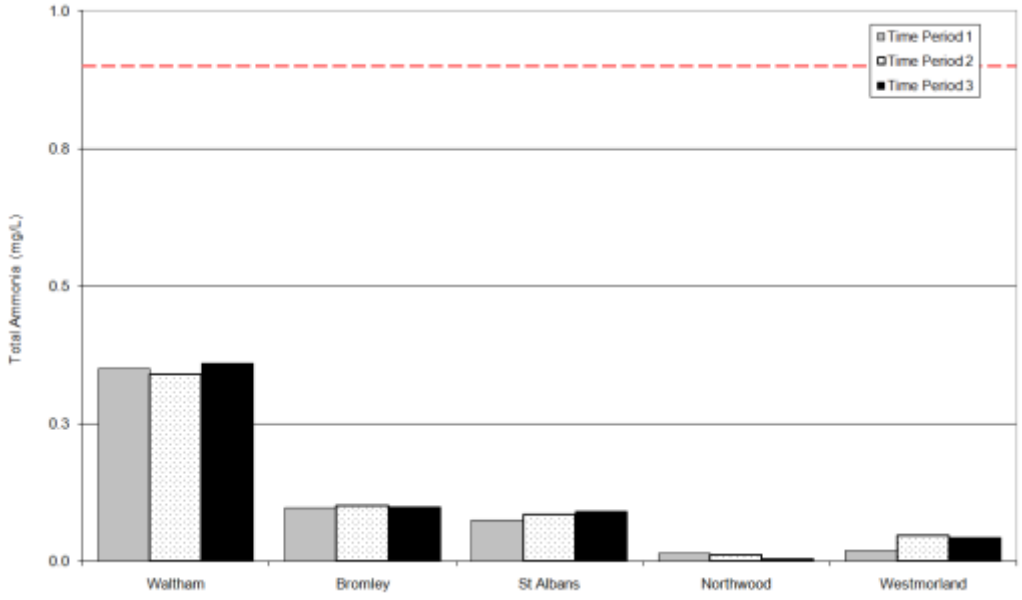

Figure 30. Total ammonia levels in water samples from stormwater outfalls, during three time periods of a wet weather event (collected using autosamplers). The dotted line represents the Proposed Canterbury Land and Water Regional Plan receiving waters trigger value (0.9 mg/L; Environment Canterbury, 2012), calculated based on median pH levels (8.0) for the annual monitoring period.

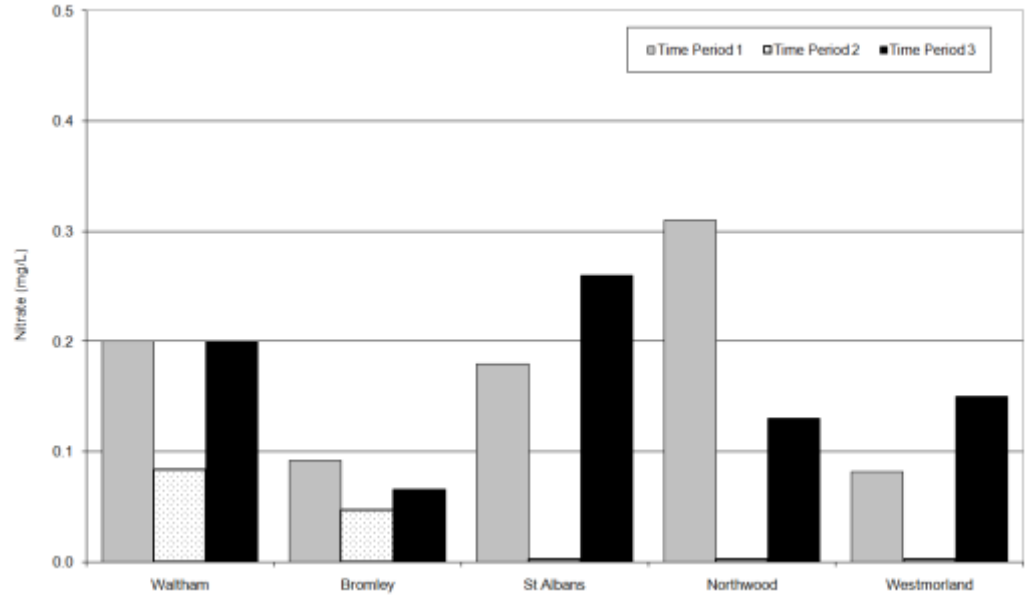

Figure 31. Nitrate levels in water samples from stormwater outfalls, during three time periods of a wet weather event (collected using autosamplers). The Hickey (2013) grading and surveillance guideline levels for receiving waters (3.8 mg/L and 5.6 mg/L, respectively) are not shown on the graph, as the y-axis scale does not extend this far.

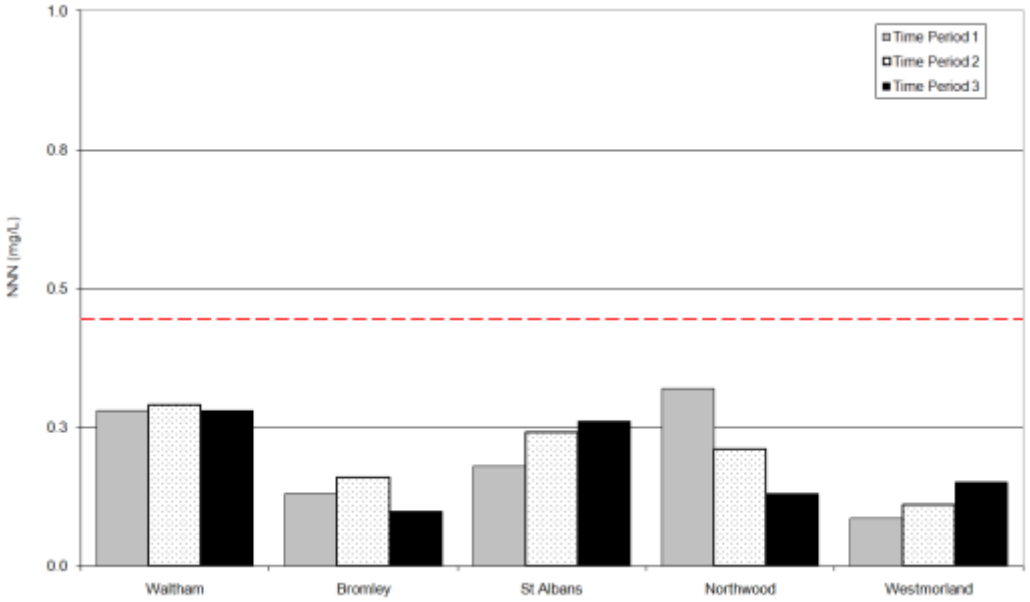

Figure 32. Nitrate Nitrite Nitrogen (NNN) levels in water samples from stormwater outfalls, during three time periods of a wet weather event (collected using autosamplers). The dotted line represents the ANZECC receiving water guideline (0.444 mg/L; ANZECC, 2000).

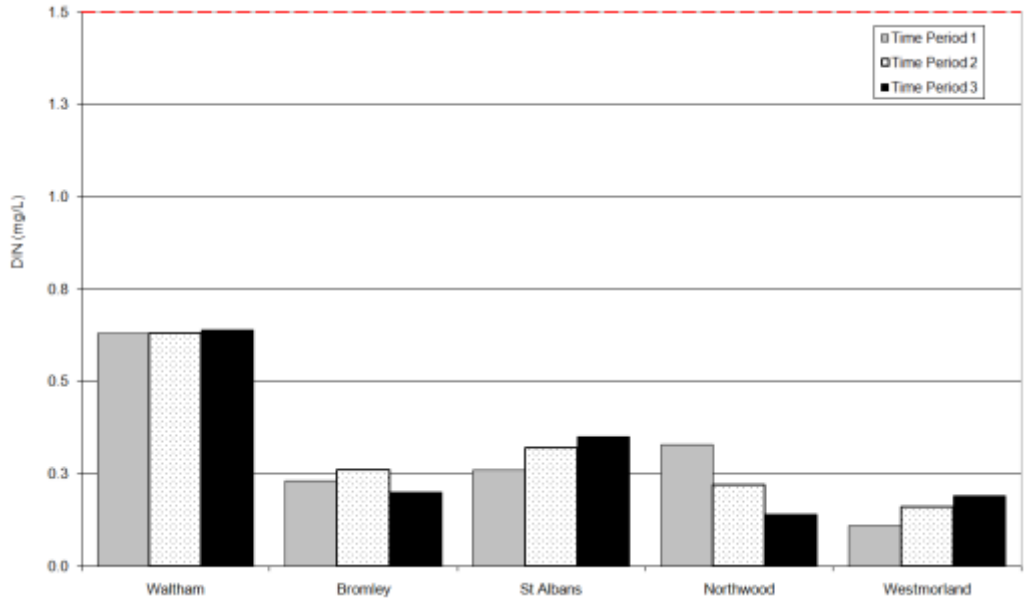

Figure 33. Dissolved Inorganic Nitrogen (DIN) levels in water samples from stormwater outfalls, during three time periods of a wet weather event (collected using autosamplers). The dotted line represents the Proposed Canterbury Land and Water Regional Plan receiving water trigger value of 1.5 mg/L (Environment Canterbury, 2012).

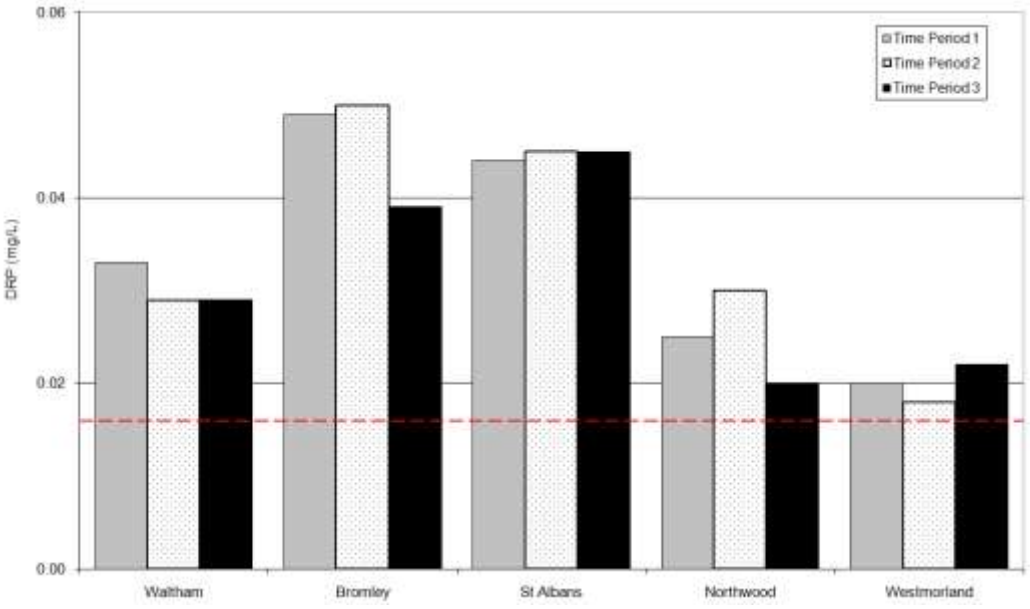

Figure 34. Dissolved Reactive Phosphorous (DRP) levels in water samples from stormwater outfalls, during three time periods of a wet weather event (collected using autosamplers). The dotted line represents the Proposed Canterbury Land and Water Regional Plan receiving water trigger value of 0.016 mg/L (Environment Canterbury, 2012). No concentrations were below the Laboratory Limit of Detection of 0.01 mg/L.

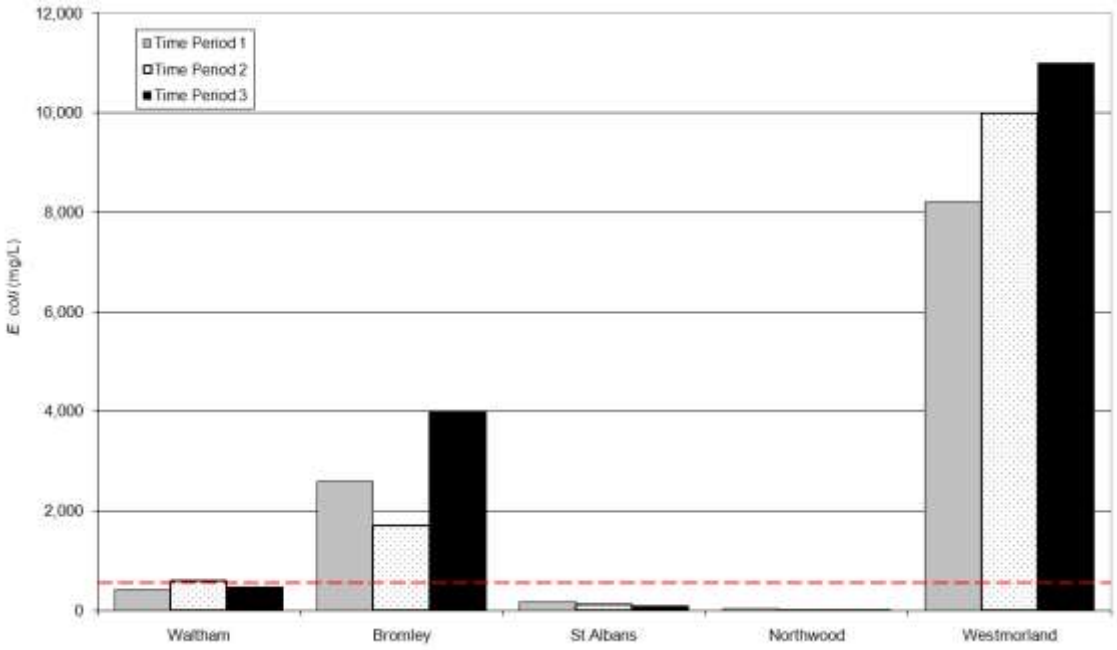

Figure 35. *Escherichia coli* levels in water samples from stormwater outfalls, during three time periods of a wet weather event (collected using autosamplers). The dotted line represents the Proposed Canterbury Land and Water Regional Plan receiving water trigger value of 550 CFU/100ml for 95% of samples (Environment Canterbury, 2012).

5 Discussion

5.1 Surface Water

There were a number of parameters for the wet weather surface water monitoring that consistently met the guideline values and therefore do not appear to be having adverse effects on the waterways. These were pH, dissolved oxygen, temperature, total ammonia and nitrate. However, there were a number of parameters that recorded values well above the guidelines across most sites: dissolved copper, dissolved zinc, TSS, turbidity, BOD_5, NNN, DRP and *E. coli*. Dissolved lead levels were also above guideline levels at the Avon River Carlton Mill corner and Dudley Creek sites, as was DIN at the Avon River Mona Vale and Manchester Street sites (the other sites recorded values below these respective guideline levels). All these parameters may therefore be having adverse effects on biota (i.e. copper, zinc, TSS, turbidity, BOD_5, lead and 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*).

Compared to the annual monitoring, which is undertaken during any weather condition (i.e. wet or dry), there were some parameters that recorded much higher levels during these wet weather events. These included copper, lead, zinc, TSS, turbidity, BOD_5, DRP and *E. coli*. For all but the last two of these parameters, guideline levels were not exceeded during the annual monitoring, but were for the wet weather monitoring. For DRP and *E. coli*, guideline levels were exceeded in both the annual and wet weather monitoring. These additional guideline exceedances during wet weather indicates that these contaminants may pass through the system or settle out following wet weather events, resulting in water quality outside of storm events being much better. This might mean that these contaminants are only having short-term (although potentially still detrimental) effects on biota in the river and on contact recreation. In contrast, the nitrogen parameters (nitrate, NNN and DIN) all recorded lower levels during the wet weather sampling compared to the annual monitoring. It is commonly thought that nitrogen levels in the waterways are due to contaminated input from springs. Therefore, lower levels during wet weather events compared to the annual monitoring may be due to the dilution of spring baseflow by flood waters/stormwater. The Council currently has a project underway to investigate this potential input of nitrogen into waterways from springs. There appeared to be little difference in wet weather and annual monitoring concentrations for pH, conductivity, dissolved oxygen, temperature and ammonia.

The results of this wet weather monitoring suggests that stormwater (and potentially wastewater overflows) contributes a large proportion of contaminants to waterways, as expected. Spring input may also be contributing nitrogen, as discussed above. This wet weather monitoring also highlights potential differences in results depending on when events are sampled. The first event consistently recorded higher levels than the second. This may be due to sampling for the first event occurring during the peak of the storm when contaminants are likely present in the river, as opposed to sampling of the second event occurring during the tail end of the storm, when contaminants may have already been washed downstream (Figure 3 & Figure 4). This highlights the importance of undertaking wet weather sampling at the right time; however, this is difficult to achieve in practice with grab sampling. One notable exception to this was DRP, which showed higher concentrations in the second storm event. The reason for this is unknown, but may be due to phosphorous inputs (e.g. from animal faeces, soil and fertilisers) from grassed areas taking longer to reach the waterways, compared to

hardstand areas that are quickly directed to the reticulation system. This is supported by a Wisconsin study that recorded lawns contributing more total and dissolved phosphorus in stormwater than streets (Waschbusch et al. 1999).

The sites that recorded the highest surface water wet weather concentrations were Addington Brook (for TSS, turbidity, BOD_5 and DRP) and the Avon River at Carlton Mill corner (for copper, zinc, lead and *E. coli*). Addington Brook was also highlighted as one of the sites with the worst water quality in the annual monitoring report, likely due to the industrial and commercial nature of this catchment. The Carlton Mill corner site is not monitored for metals in the annual monitoring, so it is unclear whether this site has comparably high levels usually. Given the results of this wet weather monitoring, testing of metals has now been instigated for the annual monitoring, to see if this site regularly has high levels. The location of this site is immediately downstream of at least four stormwater outfalls from the adjacent busy roads and this is likely the reason for these high values during this wet weather monitoring.

Monitoring of the same sites was also undertaken for last years wet weather monitoring (2012 – 2013) during two events. In comparison to this year, last years monitoring recorded (based on visual comparisons only, not statistical analyses):

1. less exceedances of the guideline values for dissolved copper, dissolved lead, TSS and BOD_5
2. more exceedances in the guideline level for NNN
3. lower concentrations of DRP, ammonia and *E. coli*, and generally higher levels of dissolved zinc

These differences may be attributable to the 2012 – 2013 wet weather events both being sampled during the tail of the storm when there are likely less stormwater contaminants, but more flow for dilution of nitrogen, or during a time when contaminants had not yet reached the waterways.

5.2 Stormwater Outfalls

Parameters in the stormwater outfall samples that were well above the receiving water quality guidelines, and therefore may cause adverse effects if dilution in the receiving water is not sufficient enough, were dissolved copper, dissolved zinc, TSS, turbidity, BOD_5, DRP and *E. coli*. These results are consistent with the contaminants recorded to be high in the wet weather surface water monitoring. These constituents may cause adverse effects on biota (copper, zinc, TSS, turbidity and BOD_5), cause proliferation of algae and plants (DRP) and result in human health risks for contact recreation (*E. coli*). The remainder of the parameters did not exceed the receiving water quality guidelines, so may not be having adverse effects on these waterways. In particular, nitrate and NNN levels were low in the stormwater samples, indicating that these contaminants are entering waterways from other sources, such as springs, as mentioned previously in this report.

The stormwater outfalls recording the highest levels of contaminants were typically Waltham (for copper, zinc, BOD_5, ammonia, DIN) and Westmorland (for copper, BOD_5 and *E. coli*). These outfalls discharge to the Heathcote River and Cashmere Stream, respectively. This may be due to the first outfall being located primarily in a commercial and industrial catchment, and the latter site in a primarily residential and surrounding

rural catchment. The site with the lowest levels of parameters overall was Northwood (which discharges to the Styx River), likely due to the primarily modern residential nature of this catchment.

For all parameters there were no apparent trends in concentrations across the three time periods. As rainfall prior to sampling was largely consistent, this may be due to differences in the time of concentration (i.e. the time taken for stormwater to reach the outfalls) for each of the catchments (due to different catchment sizes and characteristics).

Sampling was also undertaken of the Bromley, Waltham and Westmorland outfalls during last years 2012 – 2013 wet weather monitoring (Whyte, 2013). When these two monitoring periods were visually compared (i.e. statistical comparisons were not carried out) the following observations were made regarding last years monitoring period[3]:

1. Rainfall depth before sampling was generally lower
2. There was also no clear pattern between time periods
3. TSS levels across the three sites were lower
4. BOD_5 levels were exceeded at the Bromley outfall (levels were below this guideline during this monitoring year), and Waltham and Westmorland levels were lower (levels were exceeded at these sites during both years)
5. Ammonia levels were higher, with Westmorland exceeding the guideline during one of the time periods (no samples exceeded the guideline level during this years monitoring)
6. NNN levels were much higher, breaching the guideline level at all three of these sites (no sites exceeded the guideline during this monitoring year)
7. DRP levels were also much higher (although the guideline level was exceeded for all sites for both last and this years monitoring)
8. *E. coli* levels were substantially higher

These differences may be due to sampling last year being undertaken during a smaller storm event, with potentially less mobilisation of contaminants (i.e. for TSS) and dilution of nitrogen-rich baseflow (i.e. for NNN), or at a time when contaminants had not yet reached the outfalls. However, this does not explain the higher levels recorded last year for ammonia, DRP and *E. coli*. Equally, these differences could be the result of the idiosyncratic nature of stormwater, with different sampling events showing different results depending on the relative influence of inputs at the time.

6 Conclusion

In summary, the water quality of the Avon River catchment is affected by the discharge of contaminants during wet weather events. Monitoring of the stormwater outfalls indicated high levels of dissolved copper, dissolved zinc, TSS, turbidity, BOD_5, DRP and *E. coli* in stormwater. The surface water wet weather monitoring showed exceedances of guideline levels for these same parameters. These guidelines were not exceeded during the annual monitoring (with the exception of DRP and *E. coli*). All these parameters may therefore be causing adverse effects on biota, proliferation of aquatic plants and algae, and contact recreation human health risks. These parameters should therefore continue to be the focus of treatment throughout the catchment.

[3] Although it is noted that more parameters were analysed for this monitoring report than last years

Stormwater outfalls sites recording particularly high levels of contaminants were Waltham (which discharges to the Heathcote River) and Westmorland (which discharges to Cashmere Stream). In contrast, the Northwood site (which discharges to the Styx River) recorded the lowest levels of parameters. Locations recording particularly high levels of parameters during the surface water wet weather monitoring were the Addington Brook and the Avon River at Carlton Mill corner sites. Water quality throughout these catchments should improve over time with the instigation of the Christchurch City Council's stormwater management plans (e.g. the Avon Stormwater Management Plan) and ECan catchment pollution projects (e.g. for Addington Brook and Riccarton Main Drain).

7 References

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8 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).

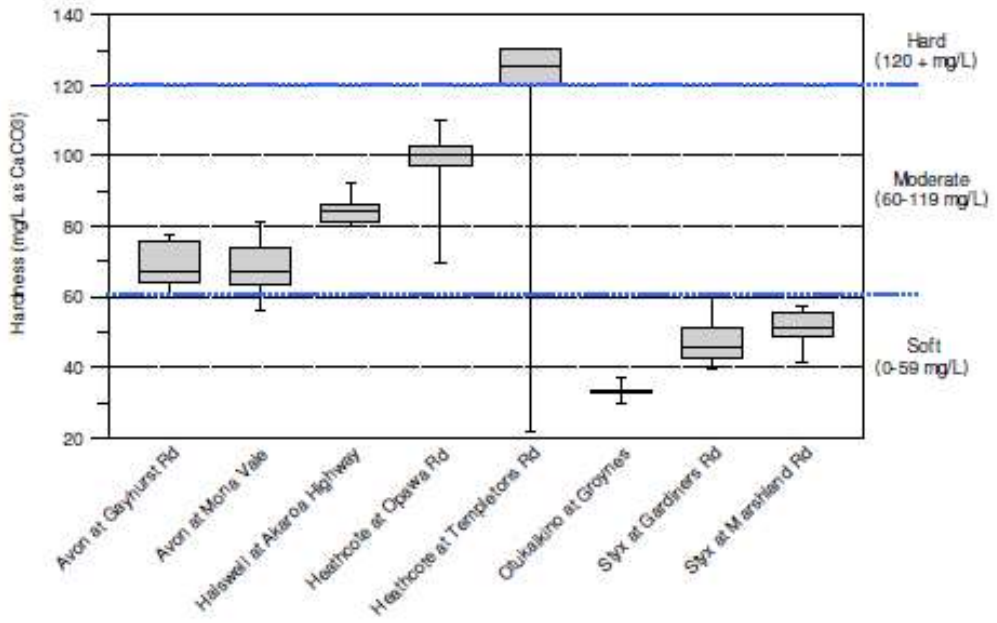

Figure 1 Box plots displaying median (and upper, lower quartiles, max and min) water hardness values for monitoring sites on the Avon, Heathcote, Halswell, Styx and Otukaikino rivers between December 2010 and March 2012.

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.

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9 Appendix B: Raw Data

9.1 Surface Water Wet Weather Monitoring

Parameter	Avon River at Manchester St (Avon04)		Avon River at Mona Vale (Avon07)		Riccarton Main Drain (Avon08)		Addington Brook (Avon09)		Dudley Creek (Avon10)		Avon River at Carlton Mill Corner (Avon12)		Avon River at Avondale (Avon13)	
Date	25-Mar-14	14-May-14	25-Mar-14	14-May-14	25-Mar-14	14-May-14	25-Mar-14	14-May-14	25-Mar-14	14-May-14	25-Mar-14	14-May-14	25-Mar-14	14-May-14
Time	1715	0935	1635	0950	1650	1020	1700	1010	1610	0920	1625	0920	1550	0905
24-hour rainfall (mm)*	8	21	8	21	8	21	8	21	8	21	8	21	8	21
48-hour rainfall (mm)*	8	24	8	24	8	24	8	24	8	24	8	24	8	24
Arsenic - Total (mg/L)	<0.002	0.002	0.002	<0.0018	0.004	0.004	0.010	0.004	0.006	0.004	0.004	0.004	0.014	0.002
BOD5 (mg/L)	3.9	1.6	5.1	1.2	6.1	3.4	8.5	2.6	4.6	2.4	5.6	2.3	<1	1.7
Cadmium - Dissolved (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Cadmium - Total (mg/L)	<0.0001	<0.00010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Conductivity (µS/cm)	180	69.4	149	80.9	36	109	36	107	167	58.4	36	80.9	777	45
Copper - Dissolved (mg/L)	0.007	<0.0020	0.009	<0.0020	0.014	0.003	0.018	0.003	0.009	0.002	0.035	0.003	<0.0020	<0.0020
Copper - Total (mg/L)	0.007	0.005	0.020	0.003	0.012	0.006	0.034	0.008	0.010	0.005	0.017	0.008	<0.0015	0.003
Dissolved Oxygen Saturation (%)	96	89	83	92	94	86	94	86	77	83	92	85	86	94
Dissolved Oxygen (mg/L)	9.7	9.7	8.4	10	9.5	9.4	9.3	9.5	7.8	9.2	9.2	9.2	8.5	10.3
Dissolved Organic Carbon (mg/L)	2.8	2.0	4.3	1.7	5.5	4.5	7.6	6.1	5.4	3.7	4.2	3.3	2.4	2.2
E. coli (CFU/100mL)	7300	14000	14000	1300	5500	>24000	6100	3500	9200	7300	>24000	2700	150	790
Faecal Coliforms (CFU/100mL)	6800	4900	12000	2100	2700	24000	6100	3100	11000	4500	16000	3500	300	800
Lead - Dissolved (mg/L)	0.011	<0.0015	0.009	<0.0015	0.009	<0.0015	0.008	<0.0015	0.019	<0.0015	0.048	<0.0015	<0.0015	<0.0015
Lead - Total (mg/L)	0.010	0.007	0.007	0.002	0.008	0.003	0.051	0.006	0.021	0.006	0.011	0.005	<0.0017	0.004
Nitrogen - Ammonia (mg/L)	0.039	0.078	0.098	0.031	0.110	0.260	0.120	0.230	0.180	0.090	0.230	0.068	0.058	0.058
Nitrogen - Dissolved Inorganic (mg/L)	1.7	0.83	1.8	1.4	0.5	1.5	0.3	0.77	0.5	0.4	0.4	0.35	1.3	0.26
Nitrogen - Nitrate (mg/L)	1.7	0.75	1.7	1.4	0.38	1.1	0.14	0.54	0.31	0.3	0.16	0.26	1.2	0.2
Nitrogen - Nitrite (mg/L)	0.010	0.008	0.006	<0.0050	0.010	0.016	0.008	0.020	0.026	0.010	0.009	0.012	0.016	0.008
Nitrogen - Nitrate-Nitrite-Nitrogen (mg/L)	1.7	0.75	1.7	1.4	0.39	1.2	0.15	0.54	0.33	0.31	0.17	0.28	1.2	0.2
Nitrogen - Total (mg/L)	2.1	1.2	2.5	1.5	1.0	2.2	1.6	1.5	1.5	0.78	1.3	0.71	1.5	0.5
pH	7.7	7.3	7.3	7.3	7.2	7.4	7.3	7.3	7.7	7.3	7.3	7.3	7.8	7.8
Phosphorus - Dissolved Reactive (mg/L)	0.025	0.061	0.068	0.038	0.094	0.150	0.130	0.160	0.073	0.110	0.070	0.081	0.030	0.060
Phosphorous - Total (mg/L)	0.120	0.140	0.190	0.069	0.180	0.220	0.560	0.280	0.310	0.180	0.200	0.140	0.089	0.100
Total Petroleum Hydrocarbons (mg/L)	<0.30	<0.3	0.88	<0.3	<0.30	<0.3	<0.30	<0.3	<0.30	<0.3	<0.30	<0.3	<0.3	<0.3
Total Suspended Solids (mg/L)	37	40	32	12	39	15	140	48	130	20	39	21	11	33
Turbidity (NTU)	16	22	9	8	15	10	50	40	81	13	18	21	7	46
Water Temperature (°C)	15	11	14	12	15	12	16	11	15	11	15	12	16	12
Zinc - Dissolved (mg/L)	0.078	0.040	0.055	0.055	0.130	0.079	0.150	0.090	0.100	0.075	0.190	0.064	0.008	0.012
Zinc - Total (mg/L)	0.078	0.064	0.055	0.060	0.140	0.087	0.210	0.130	0.110	0.097	0.150	0.071	0.010	0.087

* rainfall recorded at Botanic Gardens

9.2 Stormwater Outfall Wet Weather Monitoring

	Waltham - Ontrack			Bromley - Charlesworth			St Albans - Lower Frees Ck		
Parameter	**Time 1**	**Time 2**	**Time 3**	**Time 1**	**Time 2**	**Time 3**	**Time 1**	**Time 2**	**Time 3**
Date	14/05/2014	14/05/2014	14/05/2014	08/04/2014	08/04/2014	08/04/2014	09/06/2014	09/06/2014	09/06/2014
24-hour rainfall (mm)*	6	11	16	10	12	15	9	13	20
48-hour rainfall (mm)*	6	11	16	10	12	15	10	14	21
Time	0030	0230	0430	0245	0445	0645	1830	2030	2230
Arsenic - Total (mg/L)	0.008	0.008	0.008	<0.0015	<0.0015	<0.0015	0.005	0.004	0.003
Arsenic - Dissolved (mg/L)	<0.0015	<0.0015	<0.0015	Not measured	Not measured	Not measured	<0.0015	<0.0015	<0.0015
BOD5 (mg/L)	12	16	7	<3.0	<3.0	<3.0	2	1.2	1.2
Cadmium - Total (mg/L)	0.0018	0.0017	0.0017	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Cadmium - Dissolved (mg/L)	0.0006	0.0003	0.0003	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Conductivity (µS/cm)	81	136	137	50	47	32	50.4	65	75
Copper - Total (mg/L)	0.840	0.850	0.860	0.012	0.008	0.013	0.0079	0.005	0.006
Copper - Dissolved (mg/L)	0.110	0.100	0.100	0.003	0.003	0.003	<0.0020	<0.0020	<0.0020
Dissolved Oxygen (mg/L)	Not measured	Not measured	Not measured	Not measured	Not measured	Not measured	Not measured	Not measured	Not measured
Dissolved Oxygen Saturation (%)	Not measured	Not measured	Not measured	Not measured	Not measured	Not measured	Not measured	Not measured	Not measured
Dissolved Organic Carbon (mg/L)	12	12	12	3	3	2	1.7	1.7	1.9
E. coli (CFU/100mL)	410	600	480	2600	1700	4000	170	120	86
Faecal Coliforms (CFU/100mL)	100	100	200	6100	2700	3700	2200	3400	1400
Lead - Total (mg/L)	0.790	0.820	0.820	0.024	0.007	0.026	0.018	0.007	0.0059
Lead - Dissolved (mg/L)	0.006	0.005	0.005	0.003	0.003	0.004	0.0017	<0.0015	<0.0015
Nitrogen - Ammonia (mg/L)	0.35	0.34	0.36	0.10	0.10	0.10	0.075	0.084	0.09
Nitrogen - Dissolved Inorganic (mg/L)	0.63	0.63	0.64	0.23	0.26	0.2	0.26	0.32	0.35
Nitrogen - Nitrate (mg/L)	0.20	0.21	0.20	0.09	0.11	0.07	0.18	0.23	0.26
Nitrogen - Nitrite (mg/L)	0.08	0.08	0.08	0.04	0.05	0.03	0.005	<0.0050	<0.0050
Nitrogen - Nitrate-Nitrite-Nitrogen (mg/L)	0.28	0.29	0.28	0.13	0.16	0.10	0.18	0.24	0.26
Nitrogen - Total (mg/L)	1.80	1.90	1.90	0.61	0.52	0.51	0.57	0.51	0.52
pH	7.7	7.5	7.5	7.5	7.6	7.5	7.5	6.6	7.5
Phosphorus - Dissolved Reactive (mg/L)	0.03	0.03	0.03	0.05	0.05	0.04	0.044	0.045	0.045
Phosphorous - Total (mg/L)	0.31	0.33	0.33	0.14	0.09	0.12	0.16	0.11	0.095
Total Petroleum Hydrocarbons (mg/L)	<0.3	<0.3	<0.3	<0.35	<0.3	<0.3	<0.3	<0.3	<0.3
TPH (S) Band C15-C36 (mg/L)	<0.2	<0.2	<0.2	<0.35	<0.21	<0.22	<0.2	<0.2	<0.2
TPH (S) Band C10-C14 (mg/L)	<0.2	<0.2	<0.2	<0.35	<0.21	<0.22	<0.2	<0.2	<0.2
TPH (S) Band C7-C9 (mg/L)	<0.2	<0.2	<0.2	<0.35	<0.21	<0.22	<0.2	<0.2	<0.2
Total Suspended Solids (mg/L)	80	77	76	36	10	35	43	19	18
Turbidity (NTU)	140	140	140	26	10	39	33	20	18
Water Temperature (°C)	13.8	13.3	13.1	17.4	16.6	16.6	12.1	11.9	11.9
Zinc - Total (mg/L)	2.000	1.600	2.000	0.020	0.029	0.020	0.15	0.13	0.14
Zinc - Dissolved (mg/L)	0.540	0.170	0.210	0.020	0.029	0.016	0.077	0.089	0.097

* rainfall recorded at Botanic Gardens

	Northwood Top Basin			Westmorland		
Parameter	**Time 1**	**Time 2**	**Time 3**	**Time 1**	**Time 2**	**Time 3**
Date	09/06/2014	09/06/2014	09/06/2014	26/03/2014	26/03/2014	26/03/2014
24-hour rainfall (mm)*	9	13	19	4	2	2
48-hour rainfall (mm)*	9	13	20	11	11	11
Time	1815	2015	2215	1445	1745	2045
Arsenic - Total (mg/L)	0.002	<0.0015	0.002	0.009	0.015	0.024
Arsenic - Dissolved (mg/L)	<0.0015	<0.0015	<0.0015	Not measured	Not measured	Not measured
BOD5 (mg/L)	1.2	<0.67	<0.60	5.1	4.8	5.9
Cadmium - Total (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Cadmium - Dissolved (mg/L)	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Conductivity (µS/cm)	131	112	127	47	104	127
Copper - Total (mg/L)	0.021	0.0025	0.14	0.041	0.009	0.023
Copper - Dissolved (mg/L)	<0.0020	<0.0020	<0.0020	0.120	0.009	0.006
Dissolved Oxygen (mg/L)	Not measured	Not measured	Not measured	Not measured	Not measured	Not measured
Dissolved Oxygen Saturation (%)	Not measured	Not measured	Not measured	Not measured	Not measured	Not measured
Dissolved Organic Carbon (mg/L)	0.22	0.14	3.7	7	7	10
E. coli (CFU/100mL)	31	20	10	8200	10000	11000
Faecal Coliforms (CFU/100mL)	300	160	80	8400	8900	8800
Lead - Total (mg/L)	<0.0015	<0.0015	<0.0015	0.011	0.029	0.055
Lead - Dissolved (mg/L)	<0.0015	<0.0015	<0.0015	0.009	0.004	0.005
Nitrogen - Ammonia (mg/L)	0.014	0.012	<0.010	0.02	0.05	0.04
Nitrogen - Dissolved Inorganic (mg/L)	0.33	0.22	0.14	0.11	0.16	0.19
Nitrogen - Nitrate (mg/L)	0.31	0.21	0.13	0.08	0.11	0.15
Nitrogen - Nitrite (mg/L)	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Nitrogen - Nitrate-Nitrite-Nitrogen (mg/L)	0.32	0.21	0.13	0.09	0.11	0.15
Nitrogen - Total (mg/L)	0.7	0.33	0.31	1.40	2.00	3.40
pH	7.8	7.7	7.8	7.7	7.5	7.7
Phosphorus - Dissolved Reactive (mg/L)	0.025	0.03	0.02	0.02	0.02	0.02
Phosphorous - Total (mg/L)	0.1	0.057	0.054	0.39	0.48	0.67
Total Petroleum Hydrocarbons (mg/L)	<0.3	<0.3	<0.3	<0.4	<0.4	<1.0
TPH (S) Band C15-C36 (mg/L)	<0.2	<0.2	<0.2	<0.4	<0.4	<1.0
TPH (S) Band C10-C14 (mg/L)	<0.2	<0.2	<0.2	<0.4	<0.4	<1.0
TPH (S) Band C7-C9 (mg/L)	<0.2	<0.2	<0.2	<0.4	<0.4	<1.0
Total Suspended Solids (mg/L)	18	6	3	190	520	1100
Turbidity (NTU)	8.8	5.8	4.3	150	780	1900
Water Temperature (°C)	13.2	13	11.7	17.4	17.3	17.7
Zinc - Total (mg/L)	0.036	0.021	0.021	0.170	0.024	0.005
Zinc - Dissolved (mg/L)	0.023	0.023	0.017	0.130	0.016	0.002

* rainfall recorded at Botanic Gardens