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State of the Environment Monitoring: River Water Quality Annual Report 2013

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1 Executive summary

The Auckland Council operates a long-term river water quality monitoring programme throughout the region. The objectives of this monitoring include State of the Environment reporting, identification of major environmental issues and the assessment of the efficacy of council policy initiatives and strategies. This report documents any changes to the monitoring programme and provides a summary of the data collected during the 2013 calendar year.

Water quality is assessed monthly at 36 sites around the region using a combination of field based and laboratory tested parameters. The results are presented as box plots, which display the variation in the measured parameters at each of the sites, and in tables, which provide a statistical summary of each parameter at each of the sites.

The data was used to produce water quality indices, which allowed sites to be ranked and assigned a water quality class. This analysis allows the complex water quality data to be communicated in a simple form. The water quality indices indicated that during 2013 the best river water quality was in the Opanuku Stream, followed by Wairoa Tributary, Cascades Stream (Whakanewha) and West Hoe Stream, all of which were classified as having excellent water quality. Five other sites were also classed as having excellent water quality. Low water quality was observed in streams in and around the urban area, with Otara Creek (East Tamaki) having the lowest ranked water quality in 2013.

2 Introduction

2.1 Auckland's rivers

The Auckland region has an estimated 16,500km of permanently flowing rivers, which increases to 28,240km when intermittent and ephemeral rivers are included (Storey and Wadhwa, 2009). As no mainland location in the region is greater than 20km from the coast, the catchment areas of each river are relatively small, with most reaching the sea before they merge with others to form larger rivers. Consequently, most rivers are first and second order (Table 1), meaning they are small, with most less than a few metres wide.

The relatively gentle topography of the Auckland region and the underlying geology also have a profound influence on the nature of the rivers, usually resulting in slow flowing, low gradient rivers with soft substrate beds. Fast flowing, high gradient rivers with hard stony substrates are mostly restricted to catchments that drain the Waitakere or Hunua Ranges.

Table 1

Permanent rivers of the Auckland region stratified by stream order (Storey and Wadhwa, 2009).

Stream order	Length (km)	% in order	Cumulative %
1	8753	52.7	52.7
2	4262	25.6	78.3
3	2121	12.7	91.0
4	1003	6.0	97.0
5	372	2.2	99.2
6	122	0.7	99.9
7	16	0.1	100

2.2 Water quality

The water quality (its physical and chemical characteristics) of a river partly determines how suitable it is for supporting animal and plant life and for use by humans.

At a given point in a river, water quality is a function of the temperature, amount of nutrients, oxygen, sediment and other pollutants in the water, and is dependent upon many factors of its catchment. In the absence of human influences, these factors include climate, topography, geology and soil type. Where there are human influences, the type of land cover and activities in the river's catchment can also strongly affect water quality (Mason, 1998)

The River Environment Classification (REC) (Snelder *et al.*, 2004) classified each river in New Zealand by the land cover in its catchment, as this is known to affect the quality and quantity of water, the types of ecological habitats and flow patterns in the river. The classification used is based on the following land cover classes;

- Native forest (including natural alpine environments)
- Exotic forest
- Rural (includes all non-forested rural land)
- Urban

The majority (63%) of rivers within the Auckland region drain non-forested rural catchments (pastoral farming, horticulture and rural residential), followed by native forest catchments (21%), with exotic forest and urban catchments accounting for 8% each (Table 2).

The catchment land cover of rivers within the Auckland region is quite different from New Zealand as a whole (Table 2). Auckland's high population density means that a greater percentage of the region's rivers are classed as 'urban' compared to New Zealand overall, and are subsequently impacted by the associated environmental pressures.

Table 2

Catchment land cover for rivers in Auckland and New Zealand.

Land cover	% of rivers	
	Auckland	New Zealand
Rural	63	43
Native forest (includes alpine)	21	51
Exotic forest	8	5
Urban	8	1

2.3 Auckland Council's freshwater monitoring programmes

The objective of the Auckland Council's freshwater State of the Environment monitoring programmes is to describe the quantity and quality of the region's freshwater resources. This allows for the assessment and evaluation of the effects of environmental stressors and the efficacy of the council's policy initiatives and management approaches. To meet this objective, the council's freshwater monitoring is carried out under two concurrent work streams. The **quantity** work stream measures the volume of the region's freshwater resources and the **quality** work stream measures the condition of the region's freshwater resource using a combination of physical, chemical and biological measures. The Auckland Council operates two monitoring programmes within the quality work stream, of which the Water Quality Programme is one and the focus of this report. The River Ecology programme is the other and is reported elsewhere.

2.3.1 River water quality programme

The Water Quality Programme monitors the physical, chemical and microbiological properties of 31 rivers at 36 sites. This monitoring provides information on the temperature, amounts of nutrients, oxygen, sediment and other variables in the sampled

rivers. The results enable Auckland Council to assess the life-supporting capacity of the river and its suitability for human use.

2.3.1.1 Programme design

The River Water Quality Programme initially commenced with 8 sites in 1977-78 and ran until 1981; it was re-started with 17 sites in 1986 and has been running continuously ever since. The programme has evolved throughout its duration, with sites added or moved according to requirements. The programme was last reviewed in 2008 and subsequent changes were described in the 2009 Annual Report (Neale, 2010).

Between 2009 and 2011 31 sites were monitored. Three new sites were added to the network at the beginning of 2012, and a further two in February of 2013, bringing the current total to 36 sites. Each of the 36 sites is sampled monthly. It should be noted that two of the sites are monitored by the National Institute for Water and Atmospheric Research (NIWA) as part of the National River Water Quality Network (NRWQN).

The monitoring programme is regionally representative. This means that it monitors all sizes and types of rivers, and also covers the range of different catchment land cover classes found across the region. This allows the extrapolation of the results to infer the likely water quality of rivers that are not sampled.

The two new sites added in February 2013 are located on Waiheke Island (Cascades Stream (Whakanewha) and Onetangi Stream) and were added to the programme to provide information for the freshwater report cards (see <http://stateofauckland.aucklandcouncil.govt.nz/>). These sites are classed as rural for land use, but each has a significant proportion of native vegetation in the catchment and hence they are considered to be low-impact rural sites. It should be noted that there are now two sites called 'Cascades Stream'; the new site on Waiheke Island located in Whakanewha Regional Park, and the long-established site located in Waitakere Ranges Regional Park. These sites will be identified based on their location throughout this report.

There were no further site changes during 2013.

2.4 Report scope

This report provides a tabular and graphical summary of the data collected from the 36 sites in the River Water Quality Programme during the 2013 calendar year. This data is also used to produce an index for each site, which allows the complex water quality data to be communicated in a simple form.

This is the 24th annual report since the inception of the monitoring programme, and the ninth time since 2000 that the river water quality data has been reported separately from the marine and lake data. In addition, a comprehensive state and trends analysis of the water quality data was carried out in 2007 (see Scarsbrook, 2007).

All reports can be obtained from the publications area of the Auckland Council website (www.aucklandcouncil.govt.nz/publications).

3 Methods

3.1 Sample sites

The current River Water Quality Programme operates with a network of 36 sites (Table 3). The number of sites sampled each year has varied due to logistical considerations and programme objectives, and the current network has only been operating since February 2013. The location of the 36 sites is displayed in Figure 1.

3.2 Sampling methodology

For the 34 sites monitored by Auckland Council, all sample collection is carried out by council staff. Up to 22 water quality parameters are routinely monitored in the programme (Table 4). Table 4 shows that six parameters are determined in the field using a portable YSI meter, whilst the remainder are determined by laboratory tests.

A number of sites have no significant sources of heavy metals within their catchments and previous monitoring showed heavy metals to be below detection limits. These sites are therefore not routinely monitored for heavy metals, but are tested on an intermittent basis. This testing was most recently carried out in 2009 and the results reported in Neale (2010). These sites are identified in Tables 22 to 27 as not having metals measured.

Quality control measures are undertaken in accordance with Auckland Council's internal standards which meet ISO 9001:2008. This covers procedures for the collection, transport and storage of samples, methods for data verification and quality assurance to ensure consistency and accuracy across the monitoring programmes.

Laboratory samples are analysed under contract by Watercare Laboratory Services Ltd, an IANZ accredited laboratory. Analytical methods (for all analytes except metals) follow the *Standard Methods for the Examination of Water and Wastewater* 22nd edition (APHA, 2012). Metal analytes are tested according to US EPA Method 200.8 for the *Determination of Trace Metals in Waters and Wastes by Inductively Coupled Plasma – Mass Spectrometry* Revision 5.4 (US EPA, 1994).

For the two National River Water Quality Network (NRWQN) sites, sample collection is carried out by NIWA field teams. The NRWQN sites are monitored for the same parameters listed in Table 4, with the exception of salinity, suspended solids and heavy metals. Temperature and dissolved oxygen are determined in the field; the remainder are determined by laboratory tests at NIWA's water quality laboratory in Hamilton. Further information can be obtained from <https://secure.niwa.co.nz/wqis/index.do>.

Table 3

Sites sampled in 2013 in the River Water Quality Programme, together with their location details, catchment land cover and record start date.

Site name	NZTM X	NZTM Y	Land cover	Start date
Avondale Stream	1750600	5912264	Urban	2012
Cascades Stream (Waitakere)	1735628	5916378	Native forest	1978
Cascades Stream (Whakanewha)	1785942	5923254	Rural	2013
Hoteo River (NIWA operated)	1735254	5972546	Rural	1986
Kaukapakapa River	1735833	5944978	Rural	2009
Kumeu River	1739252	5928781	Rural	1993
Lucas Creek	1751468	5934510	Urban	1993
Mahurangi River (Forestry HQ)	1747750	5965035	Exotic forest	1993
Mahurangi River (Water Supply)	1748864	5970457	Rural	1993
Makarau River	1736150	5953126	Rural	2009
Matakana River	1753500	5976481	Rural	1986
Ngakaroa Stream	1775164	5881624	Rural	1993
Nukumea Stream	1749411	5951400	Native forest	2012
Oakley Creek	1751963	5917636	Urban	1994
Okura Creek	1751405	5938716	Rural	2003
Oamaru Creek	1766268	5916749	Urban	1985
Onetangi Stream	1786243	5926204	Rural	2013
Opanuku Stream	1742086	5915581	Rural	1978
Otaki Creek	1764306	5907216	Urban	1985
Otara Creek (East Tamaki)	1767422	5907535	Urban	1986
Otara Creek (Kennell Hill)	1768335	5908376	Urban	1992
Oteha Stream	1751325	5933519	Urban	1986
Pakuranga Creek (Botany Rd)	1770686	5913036	Urban	1985
Pakuranga Creek (Greenmount Drive)	1769473	5910813	Urban	1985
Papakura Stream (Alfriston Rd)	1774247	5902648	Rural	2012
Papakura Stream (Porchester Rd)	1771240	5900290	Rural	1993
Puhinui Stream	1766440	5904295	Urban	1994
Rangitopuni River (NIWA operated)	1744450	5932301	Rural	1986
Riverhead Forest Stream	1737125	5933216	Exotic forest	2009
Vaughan Stream	1755414	5938729	Rural	2001
Wairoa River	1782682	5901720	Rural	1978
Wairoa Tributary	1786700	5892817	Native forest	2009
Waitangi River	1754343	5878534	Rural	2009
Waiwera River	1748628	5953665	Rural	1986
West Hoe Stream	1748314	5950610	Native forest	2002
Whangamaire Stream	1763578	5884625	Rural	2009

Figure 1

The distribution of the 36 sampling sites used in the Auckland Council River Water Quality Programme for 2013.



Table 4

Parameters tested in 2013 in the River Water Quality Programme (laboratory test methods refer to those tests carried out by Watercare Services Ltd under contract).

Parameter	Code	Units	Method
Dissolved oxygen	DO (sat)	% sat	Portable YSI 556 meter
Dissolved oxygen	DO (ppm)	ppm	Portable YSI 556 meter
Temperature	Temp	°C	Portable YSI 556 meter
Conductivity	Cond	mS cm ⁻¹	Portable YSI 556 meter
Salinity	Salinity	ppt	Portable YSI 556 meter
pH (field)	pH	pH units	Portable YSI 556 meter
pH (lab)	pH	pH units	APHA (2005) 4500-H B
Suspended solids	TSS	mg l ⁻¹	APHA (2005) 2540 D
Turbidity	Turb	NTU	APHA (2005) 2130 B
Ammoniacal nitrogen	Ammonia	mg N l ⁻¹	APHA (2005) 4500-NH3 G
Total oxidised nitrogen	TON	mg N l ⁻¹	APHA (2005) 4500-NO3 F
Kjedahl nitrogen	KN	mg N l ⁻¹	By calculation
Total nitrogen	TN	mg N l ⁻¹	APHA (2005) 4500-N C
Soluble reactive phosphorus	SRP	mg P l ⁻¹	APHA (2005) 4500-P F
Total phosphorus	TP	mg P l ⁻¹	APHA (2005) 4500-P B, F
Soluble copper	Cu sol	µg l ⁻¹	USEPA 200.8
Total copper	Cu tot	µg l ⁻¹	USEPA 200.8
Soluble zinc	Zn sol	µg l ⁻¹	USEPA 200.8
Total zinc	Zn tot	µg l ⁻¹	USEPA 200.8
Soluble lead	Pb sol	µg l ⁻¹	USEPA 200.8
Total Lead	Pb tot	µg l ⁻¹	USEPA 200.8
<i>Escherichia coli</i>	E. coli	cfu/100ml	APHA (2005) 9213 F

3.3 Data processing and analysis

All field and laboratory data generated by Auckland Council are stored in the council's water quality archiving database (HYDSTRA). The data from the two sites operated by NIWA was extracted from the NIWA's web-based Water Quality Information System. The 2013 data was collated and used to produce:

- Box plots which display the variation in the measured parameters at each of the sites. These were produced in the software package SigmaPlot 12.0 using the default percentile functions.
- Summary tables which provide a statistical summary of each parameter at each site.
- Water Quality Indices were calculated using the data for seven water quality parameters allowing a water quality class to be assigned to each site. These were produced using a workbook produced by the Canadian Council of Ministers of the Environment (2001). The application of this method to the Auckland Council's water quality data is described in Appendix 1.

For the purposes of the analysis in this report, results that were reported as below the limit of detection were replaced by a value of half the limit of detection value as recommended by Chapman (1996). For example, a value reported as less than a 1 mg l^{-1} limit of detection would be included in the data analysis as 0.5 mg l^{-1} .

4 Results

The water quality data from the 2013 calendar year are presented as;

- box plots which display the variation in the measured parameters at each of the sites (Section 4.1).
- water quality indices produced using the data for seven water quality parameters allowing a water quality class to be assigned to each site (Section 4.2)
- tables which provide a statistical summary of each parameter at each site (Appendix 2)

4.1 Box plots

The following box plots show the variation within the 2013 data for each parameter tested at each of the 36 sites. The boxes represent the inter-quartile range (25th to 75th percentile) and the whiskers represent the 5th and 95th percentiles. The median is the centre line in each box.

Figure 2

Box plots showing the variation in dissolved oxygen % saturation (upper plot) and ppm (lower plot) at the 36 sites using data collected during the 2013 calendar year.

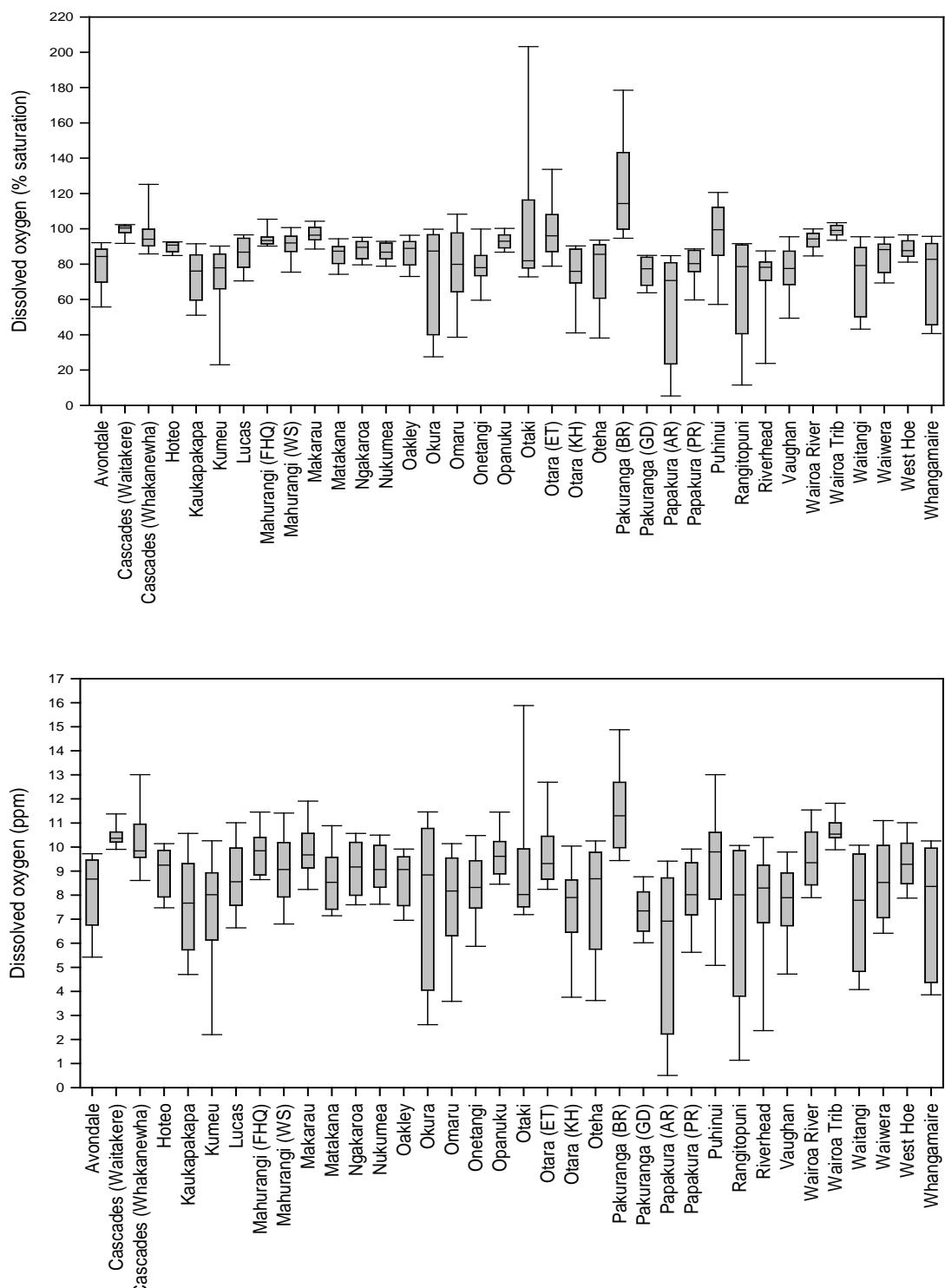


Figure 3

Box plots showing the variation in temperature (upper plot) and conductivity (lower plot) at the 36 sites using data collected during the 2013 calendar year. Note the axis break and scale change on the y-axis of the conductivity plot.

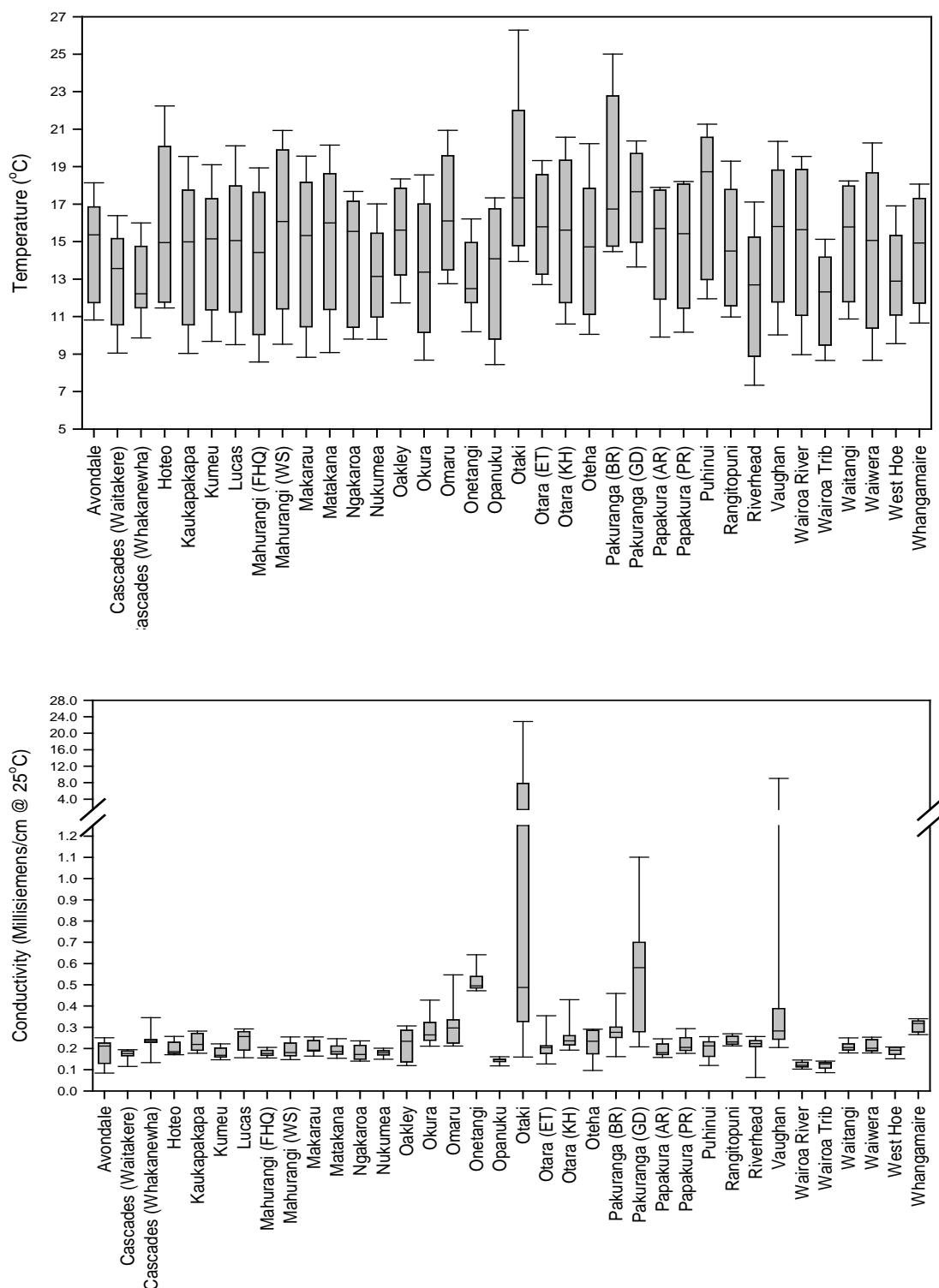


Figure 4

Box plots showing the variation in salinity (upper plot) and pH (lower plot) at the 36 sites using data collected during the 2013 calendar year. Note the axis break and scale change on the y-axis of the salinity plot. Also note that no salinity data is collected for Hoteo River and Rangitopuni River.

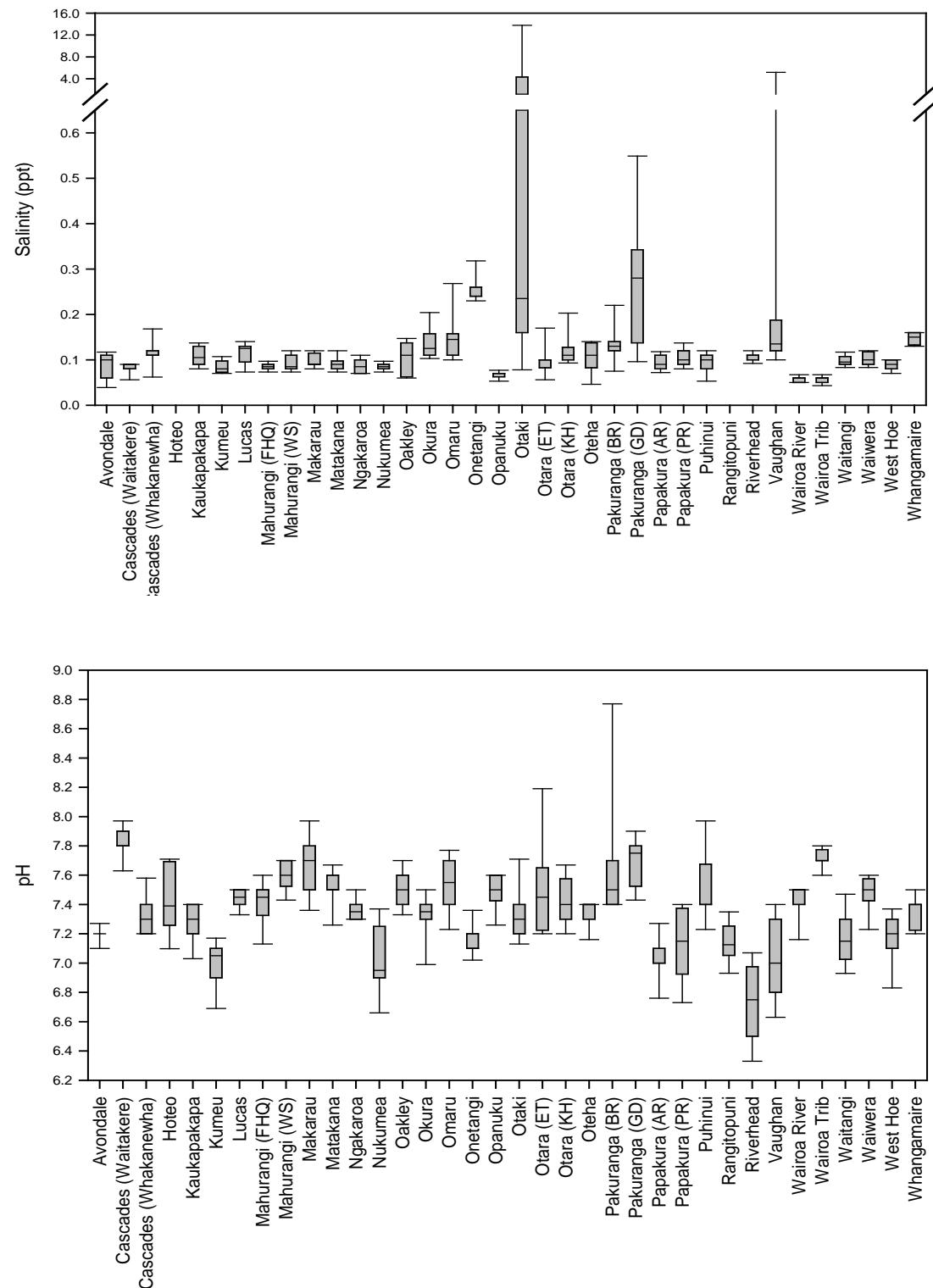


Figure 5

Box plots showing the variation in suspended sediment (upper plot) and turbidity (lower plot) at the 36 sites using data collected during the 2013 calendar year. Note that no suspended sediment data is collected for Hoteo River and Rangitopuni River.

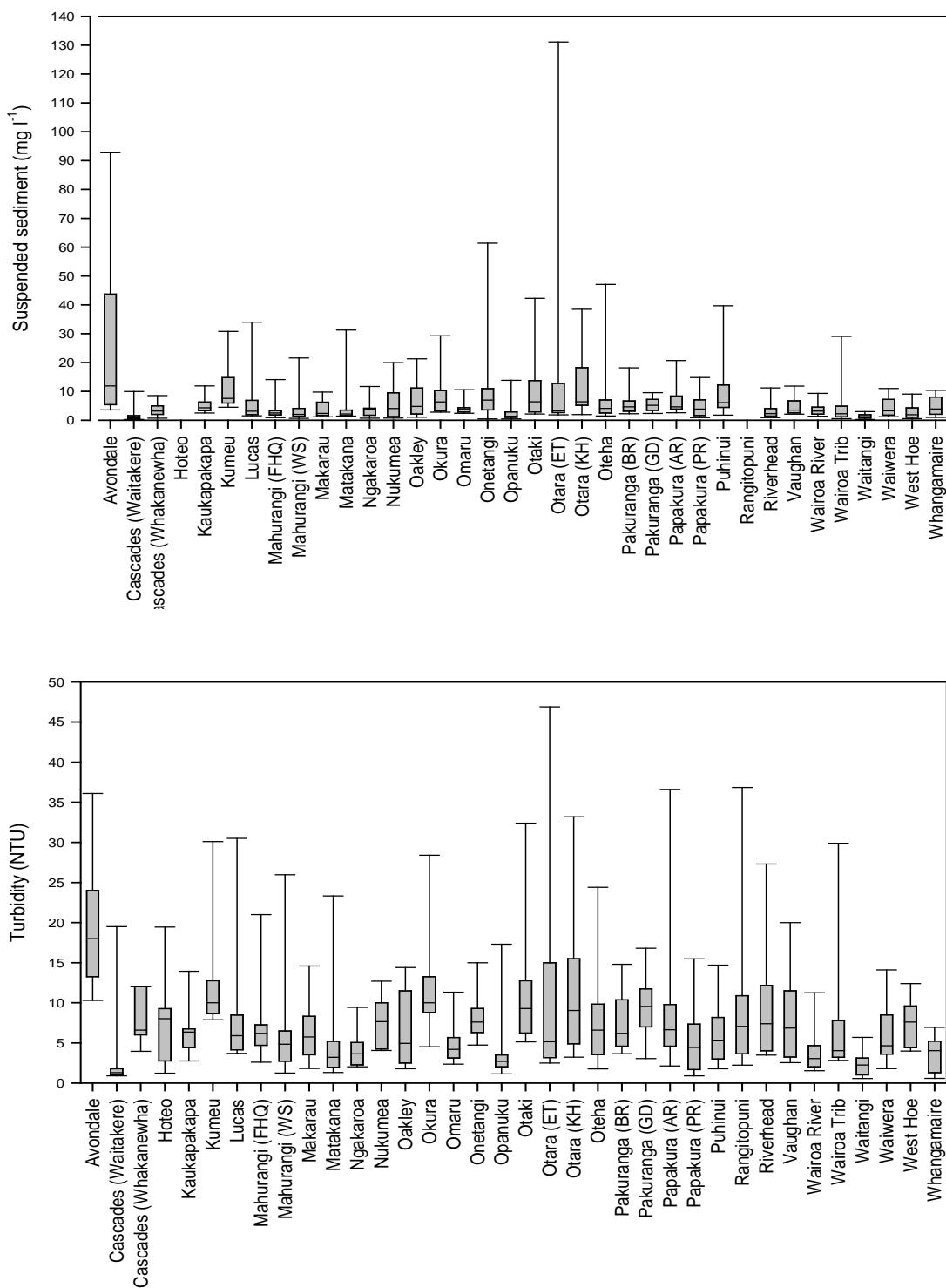


Figure 6

Box plots showing the variation in ammoniacal nitrogen (upper plot) and total oxidised nitrogen (lower plot) at the 36 sites using data collected during the 2013 calendar year. Note the axis break and scale change on the y-axis of both plots.

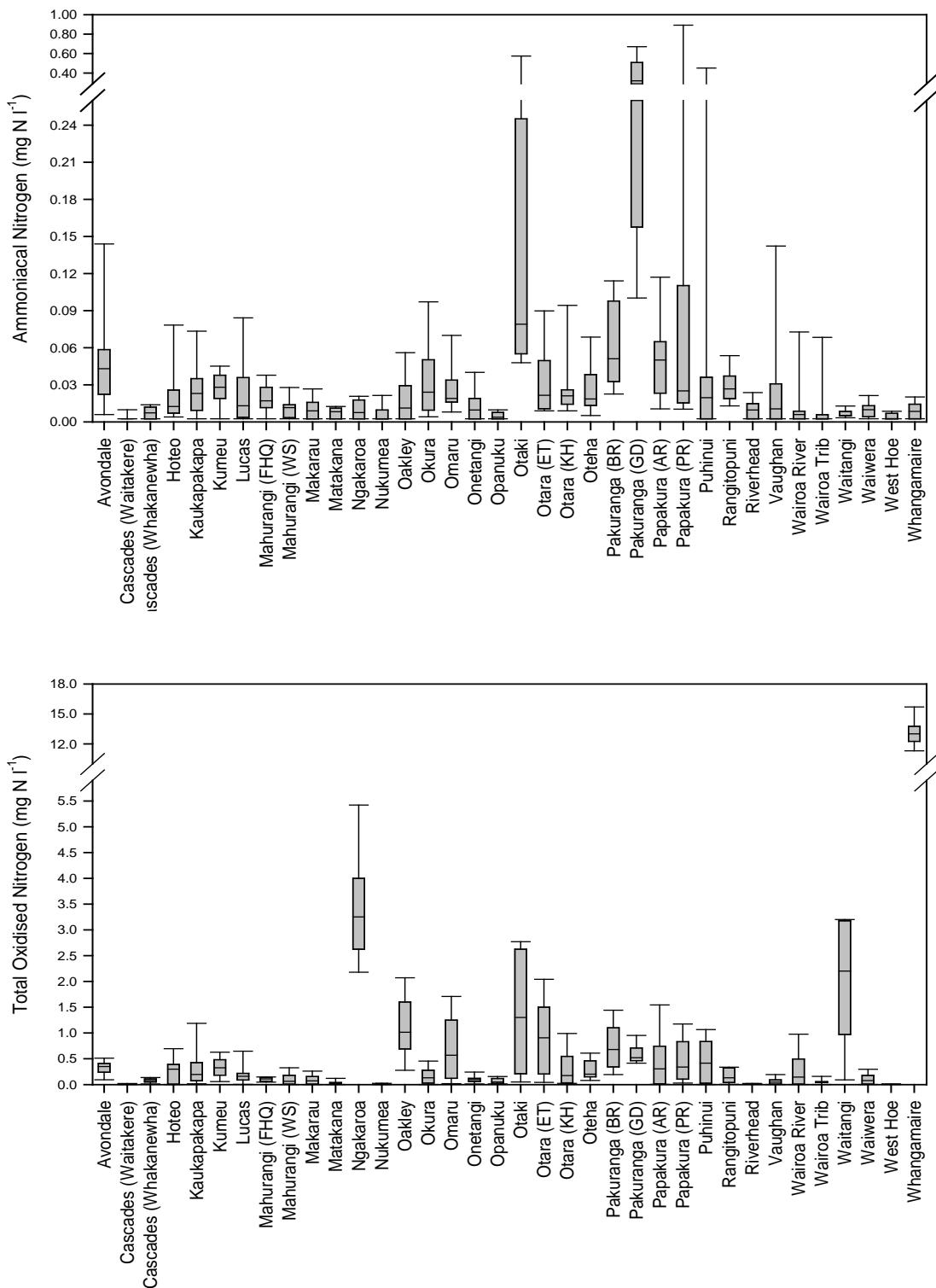


Figure 7

Box plots showing the variation in Kjeldhal nitrogen (upper plot) and total nitrogen (lower plot) at the 36 sites using data collected during the 2013 calendar year. Note the axis break and scale change on the y-axis of the total nitrogen plot.

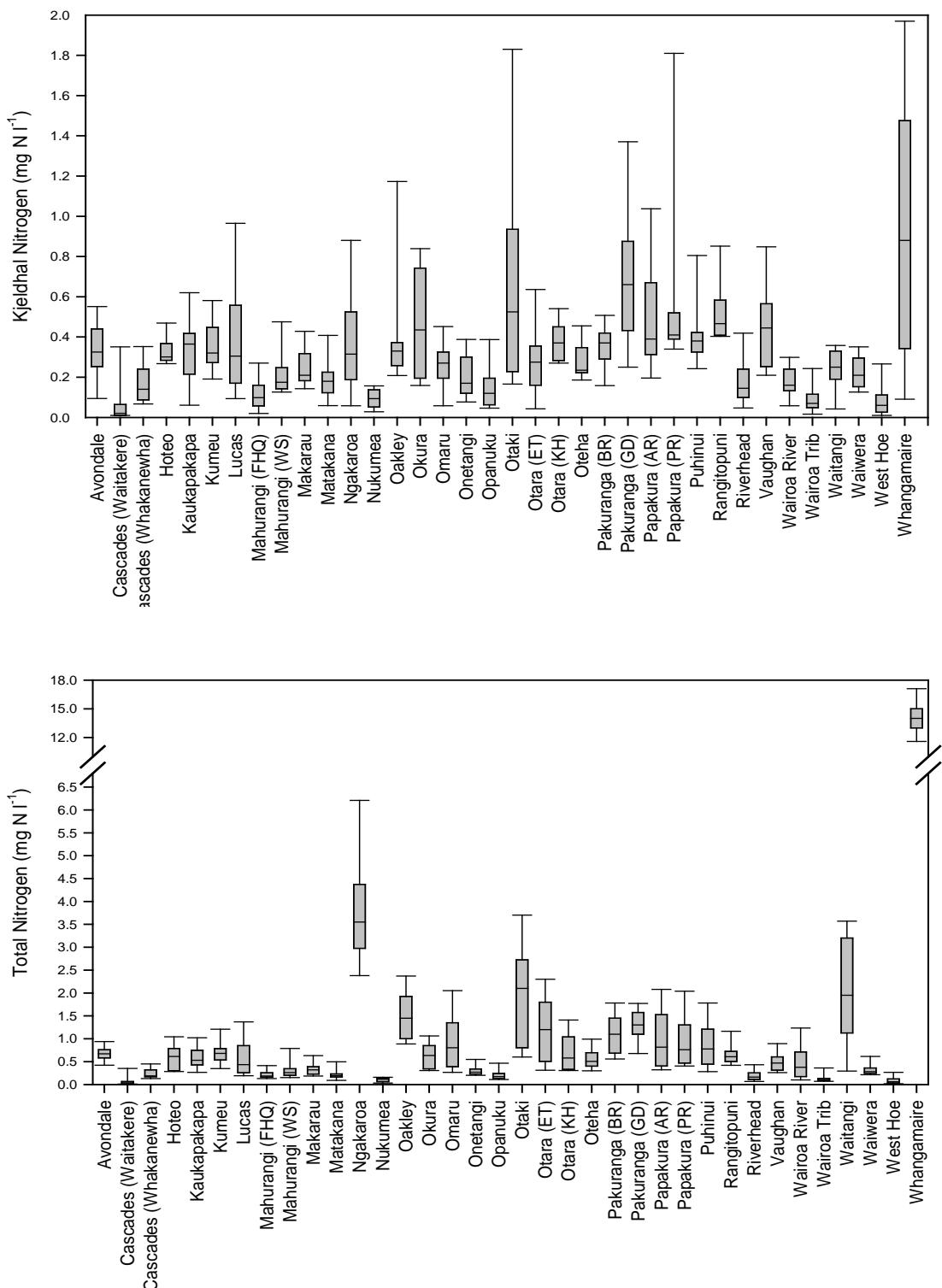


Figure 8

Box plots showing the variation in soluble reactive phosphorus (upper plot) and total phosphorus (lower plot) at the 36 sites using data collected during the 2013 calendar year. Note the axis break and scale change on the y-axis of the soluble reactive phosphorous plot.

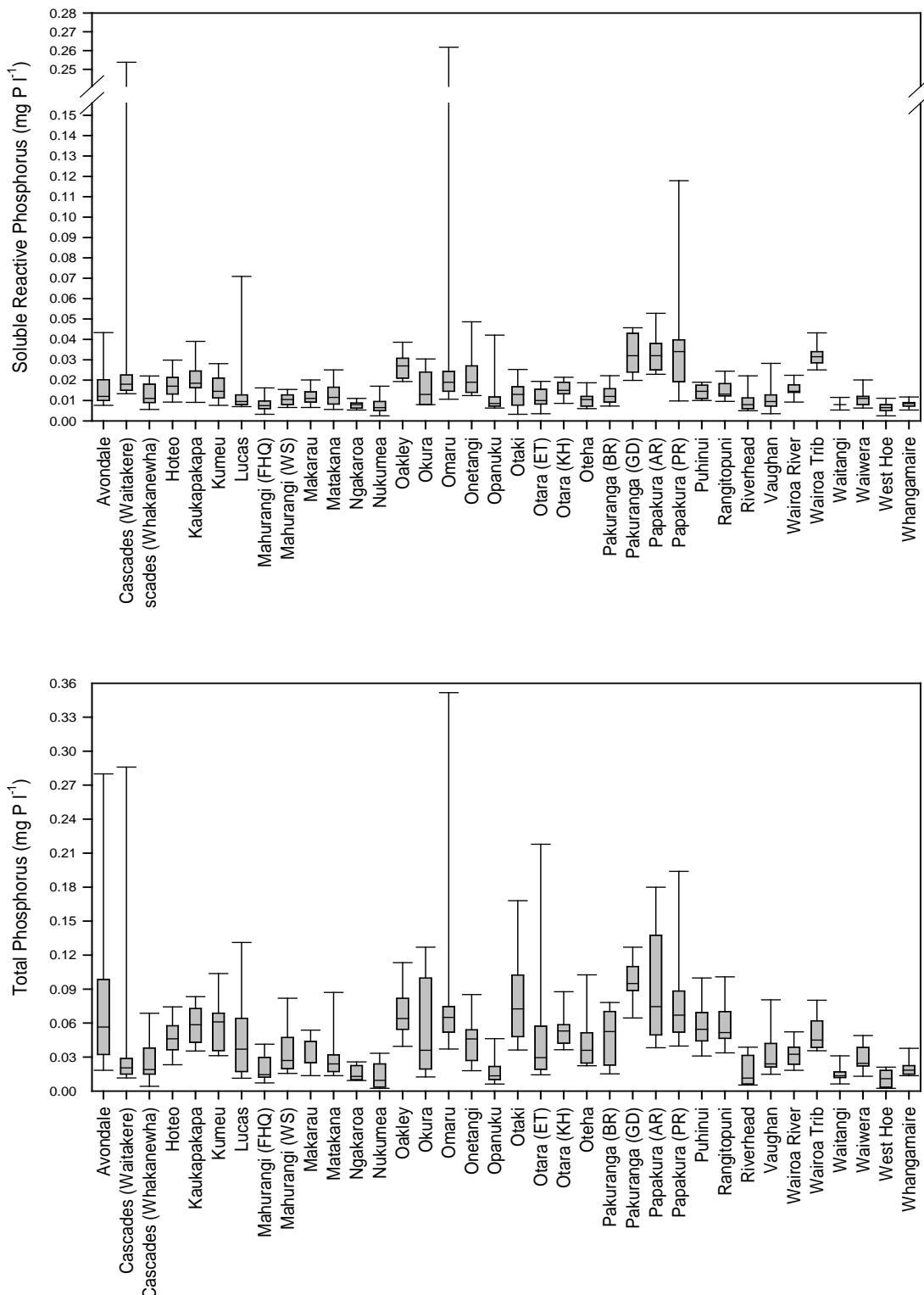


Figure 9

Box plots showing the variation in soluble copper (upper plot) and total copper (lower plot) at the 24 sites where it is monitored, using data collected during the 2013 calendar year.

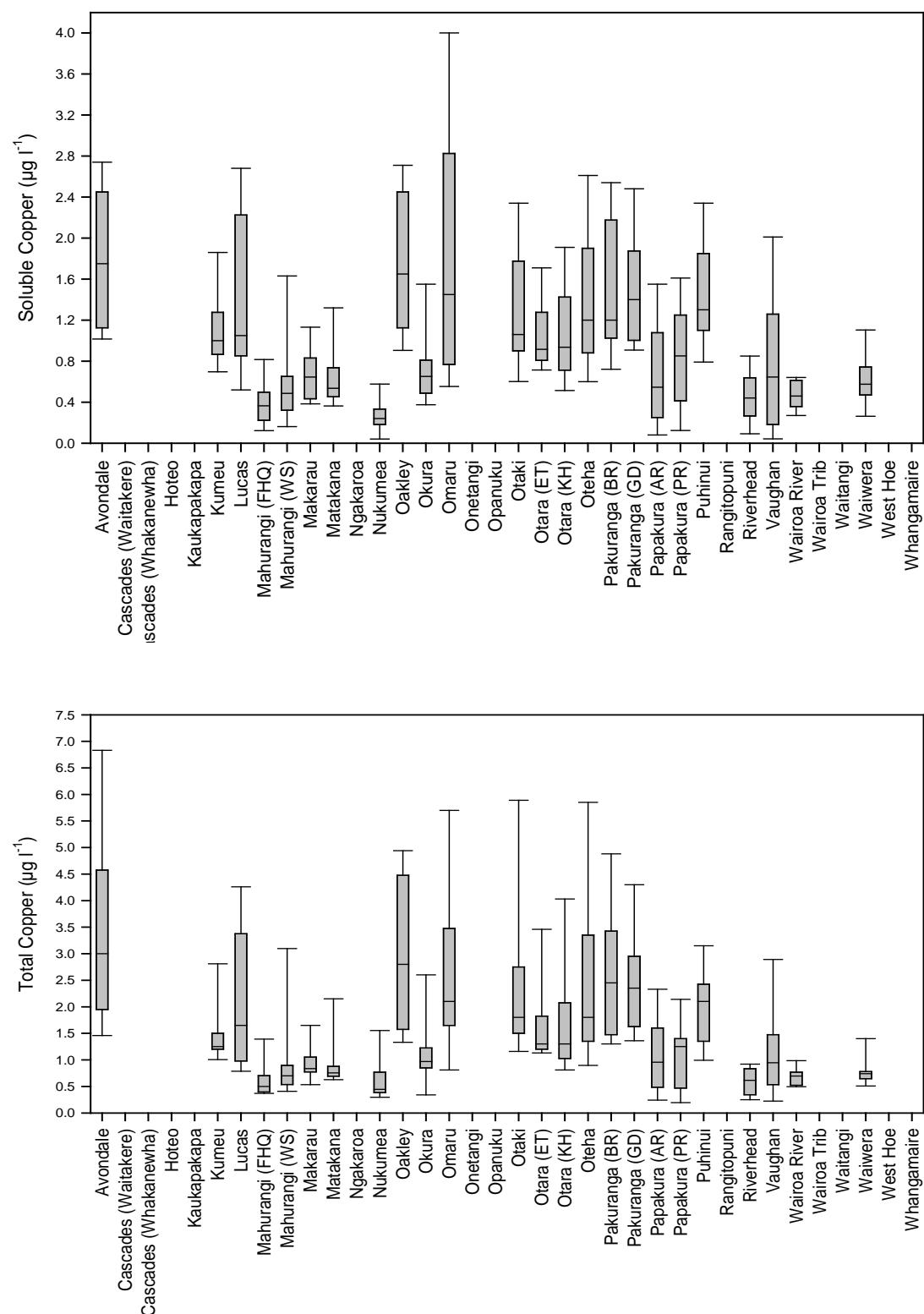


Figure 10

Box plots showing the variation in soluble zinc (upper plot) and total zinc (lower plot) at the 24 sites where it is monitored, using data collected during the 2013 calendar year.

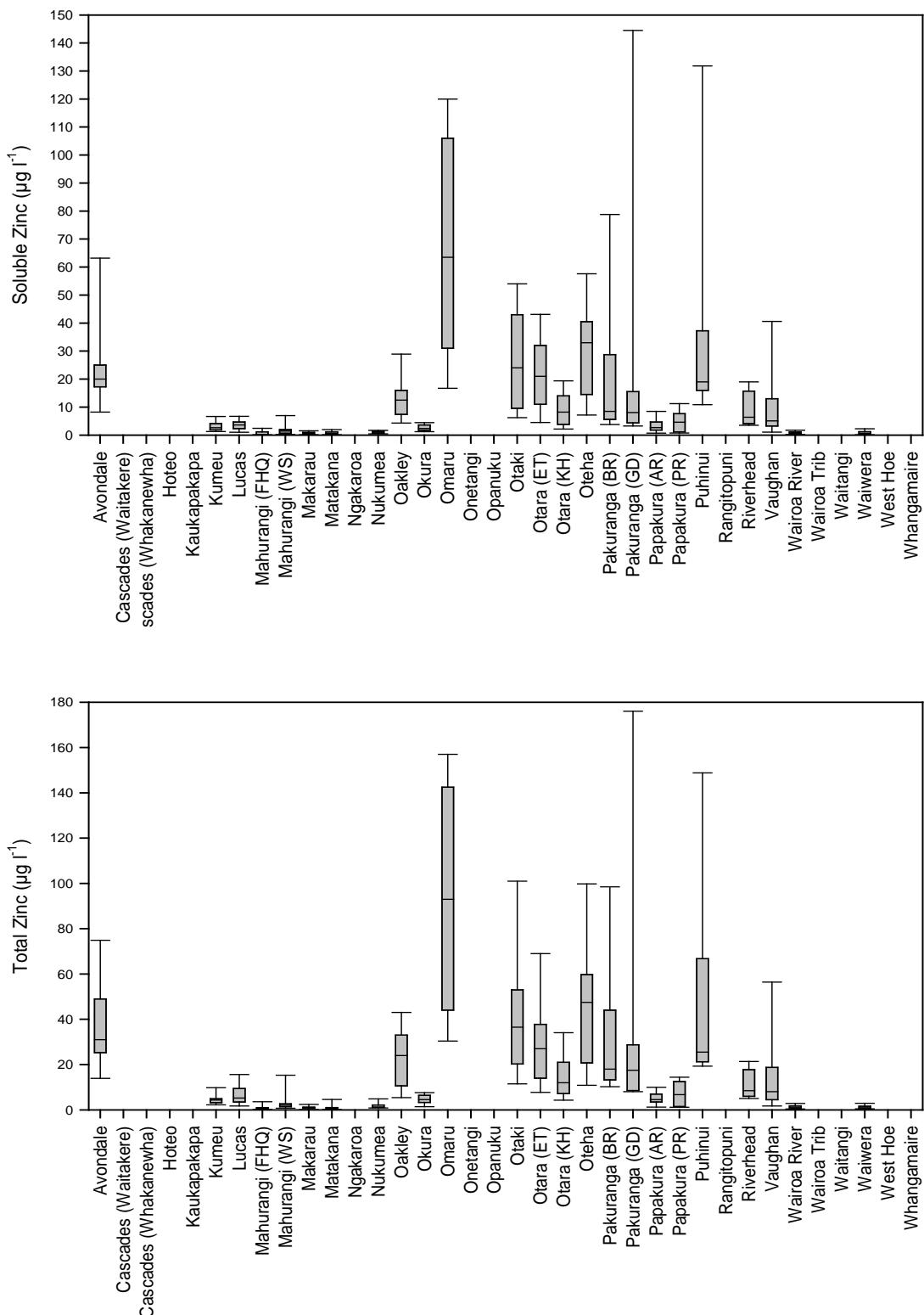


Figure 11

Box plots showing the variation in soluble lead (upper plot) and total lead (lower plot) at the 24 sites where it is monitored, using data collected during the 2013 calendar year.

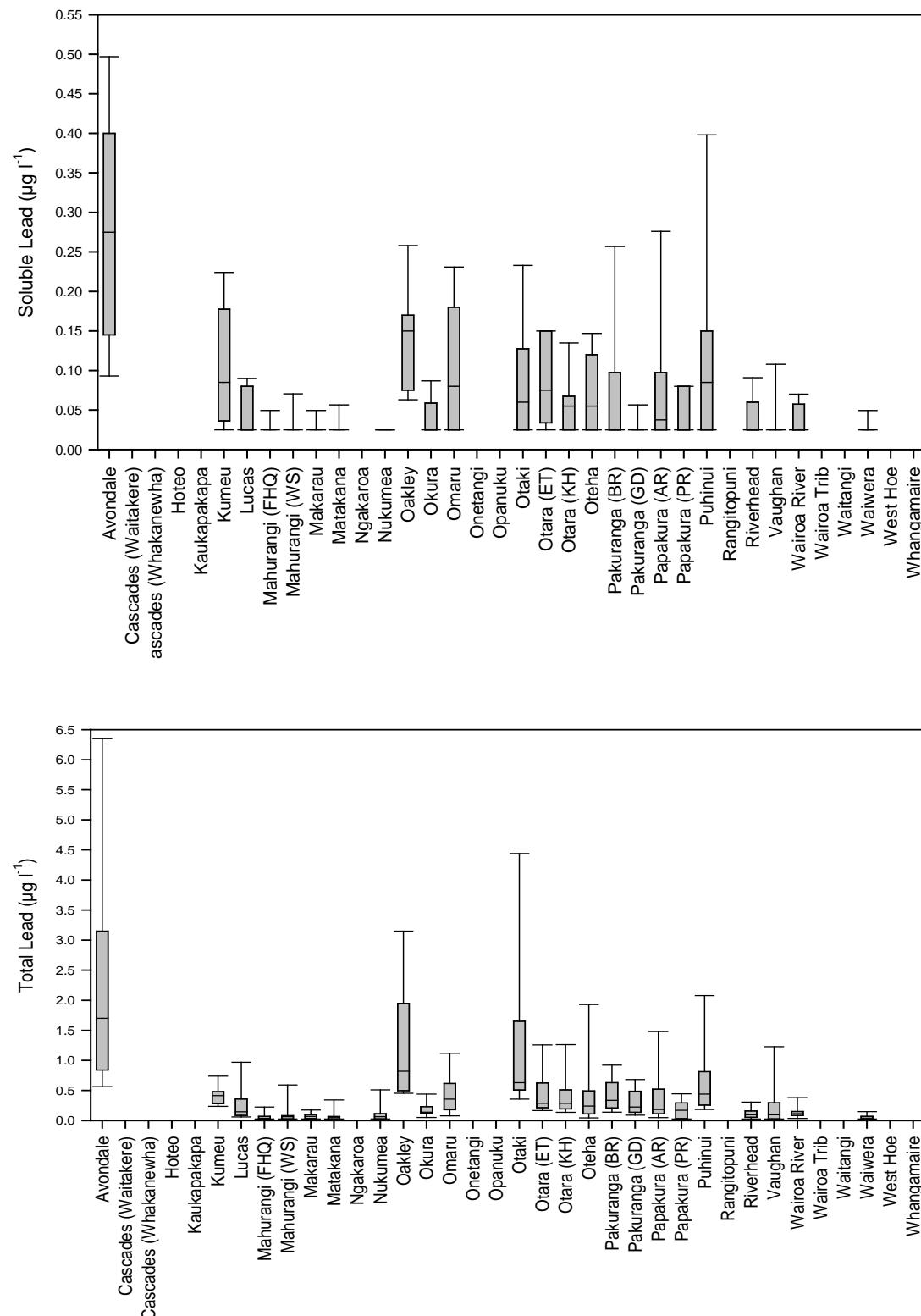
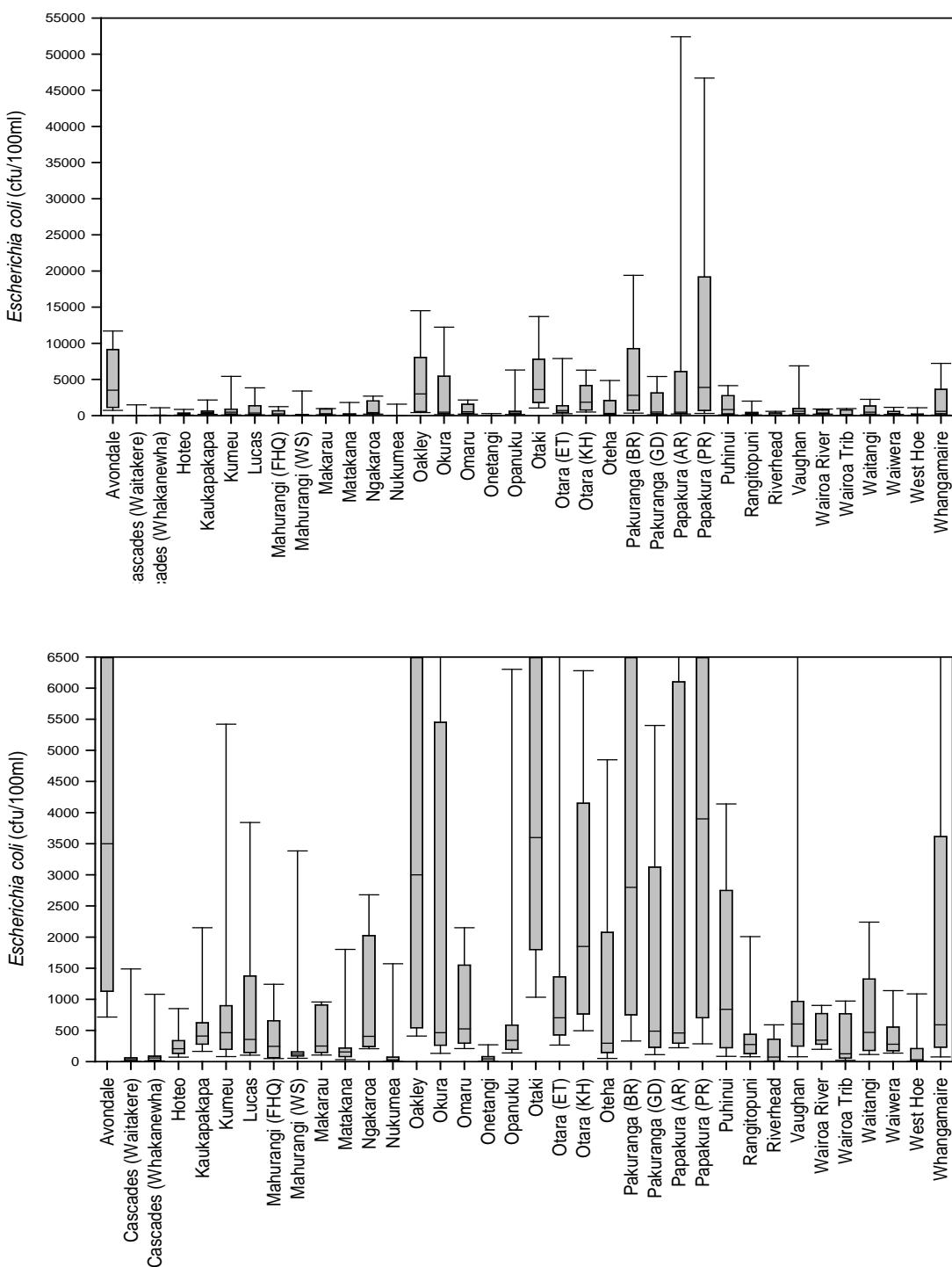


Figure 12

Box plot showing the variation in *Escherichia coli* at the 36 sites using data collected during the 2013 calendar year. The upper plot has a y-axis which covers the full range of the data; the lower plot y-axis is limited to 6500 to provide greater resolution for sites with lower *Escherichia coli* levels.



4.2 Water Quality Indices and classes

Using the methodology described in Appendix 1, water quality indices and classes were generated for each of the 36 sites (Table 5).

Opanuku Stream exhibited the best water quality in 2013 with a Water Quality Index (WQI) score of 100. Eight other Auckland streams were classified as having excellent water quality in 2013 (Table 5). All of the sites with native forest land cover were assessed as having excellent water quality. In addition, five sites with rural land cover also had excellent water quality in 2013, (Opanuku Stream, Cascades Stream (Whakandewha), Mahurangi River (FHQ), Makarau River and Onetangi Stream).

Most of the sites classed as excellent water quality have remained in this category from 2012 (or are new sites in 2013). No sites that were classed as ‘excellent’ in 2012 have decreased in rating class; however three sites have increased to the ‘excellent’ rating. Two of these sites (Mahurangi River at Forestry HQ and Nukumea Stream) were rated as ‘good water quality’, and one (Makarau River) was rated as ‘fair’ water quality in 2012.

Otara Creek (East Tamaki) had the worst water quality of the monitoring sites in 2013, with all parameters exceeding objective thresholds at some stage during the year. Three other sites also rated as poor water quality; Avondale Stream, Pakuranga Creek (Greenmount Drive) and Otaki Creek. All the sites in the poor water quality category are dominated by urban land cover.

Overall, 16 of the 36 sites had the same water quality class in 2013 as in 2012 (Lockie and Neale, 2012), 18 showed a change in class, and two were new sites. Only one site, Makarau River, exhibited a change of more than one water quality classification level (fair to excellent).

The WQI has been used since 2007 for reporting the results of the water quality programme and longer term averages can be used to provide context for the 2013 results. As a result, the preceding three years WQI (mean WQI from 2010, 2011 and 2012) was used to assess the 2013 results. This comparison identified how the WQI in 2013 deviated from the three-year average for a particular site (final column in Table 5). Whilst most sites were within 10 units of the three-year average, six sites showed a deviation of greater than 10 units. This likely represents the variable nature of water quality data. The largest deviation from the 3-year site average in 2013 was observed at the Makarau River site, where the 2013 WQI (91.3) was 24.9 points higher than the three year mean (66.4).

Table 5 and Figure 13 indicate that urban sites were typically ranked lower in 2013, with all urban sites classed as either ‘fair’ or ‘poor’. To allow the relationship between catchment land cover and water quality to be described in more detail, the mean indices were calculated for all sites within each of the four land use classes used in the monitoring programme (Table 6). The native forest sites had the best water quality indices in 2013 (excellent), followed by the exotic forest sites (good) and the rural sites (good). The urban sites had the worst water quality indices (fair). The sites with rural and exotic forest catchments typically had water quality indices intermediate between native forest and urban sites.

Table 5

Site based water quality indices and classes based on 2013 data. Deviation is based on the difference between 2013 WQI and the mean 2010, 2011 and 2012 WQI (comparisons are not possible for the sites added in 2013 (new sites)).

Site	Scope	Frequency	Magnitude	2013 WQI	2013 class	Deviation
Opanuku Stream	0.0	0.0	0.0	100.0	excellent	8.3
West Hoe Stream	14.3	1.2	0.0	91.7	excellent	-2.8
Cascades Stream (Whakanewha)	14.3	1.3	0.1	91.7	excellent	new site
Wairoa Tributary	14.3	1.2	0.7	91.7	excellent	2.8
Mahurangi River (Forestry HQ)	14.3	2.4	0.1	91.6	excellent	5.7
Nukumea Stream	14.3	2.4	0.1	91.6	excellent	8.3
Cascades Stream (Waitakere)	14.3	1.2	3.8	91.4	excellent	-3.0
Makarau River	14.3	4.8	0.2	91.3	excellent	24.9
Onetangi Stream	14.3	9.1	1.3	90.2	excellent	new site
Waiwera River	28.6	10.7	1.0	82.4	good	4.8
Riverhead Forest Stream	28.6	13.1	7.7	81.3	good	0.9
Matakana River	42.9	9.5	0.7	74.6	good	5.2
Mahurangi River (Water Supply)	42.9	9.5	1.0	74.6	good	0.0
Wairoa River	42.9	9.5	2.0	74.6	good	5.5
Hoteo River (NIWA operated)	42.9	9.6	1.9	74.6	good	2.4
Ngakaroa Stream	28.6	15.5	34.6	72.6	good	-0.1
Waitangi River	42.9	22.6	21.1	69.5	fair	12.3
Kaukapakapa River	57.1	15.5	3.7	65.8	fair	13.6
Kumeu River	57.1	14.3	11.0	65.4	fair	10.0
Oteha Stream	71.4	11.9	4.5	58.1	fair	-2.6
Lucas Creek	71.4	14.3	3.9	57.9	fair	-8.8
Vaughan Stream	71.4	16.7	5.0	57.6	fair	-2.5
Okura Creek	71.4	17.9	9.5	57.1	fair	-3.8
Otara Creek (Kennel Hill)	71.4	20.2	6.6	57.0	fair	5.2
Rangitopuni River (NIWA operated)	71.4	14.3	16.2	56.9	fair	-11.9
Omaru Creek	71.4	22.6	12.9	56.1	fair	9.8
Oakley Creek	71.4	23.8	11.7	56.0	fair	-16.3
Puhinui Stream	71.4	22.6	15.3	55.8	fair	-3.6
Pakuranga Creek (Botany Road)	71.4	27.4	11.7	55.3	fair	9.5
Papakura Stream (Porchester Rd)	71.4	23.8	25.7	54.1	fair	-5.3
Whangamaire Stream	42.9	22.6	70.8	50.4	fair	8.3
Papakura Stream (Alfriston Rd)	71.4	32.1	36.6	50.1	fair	3.6
Avondale Stream	85.7	17.9	7.8	49.2	poor	-8.9
Pakuranga Creek (Greenmount Drive)	71.4	52.4	44.7	42.7	poor	5.3
Otaki Creek	85.7	40.5	35.0	41.7	poor	1.1
Otara Creek (East Tamaki)	100.0	22.6	12.3	40.4	poor	-8.1

Figure 13

The sampling sites used in the Auckland Council River Water Quality Programme for 2013 with labels coded by the Water Quality Class.

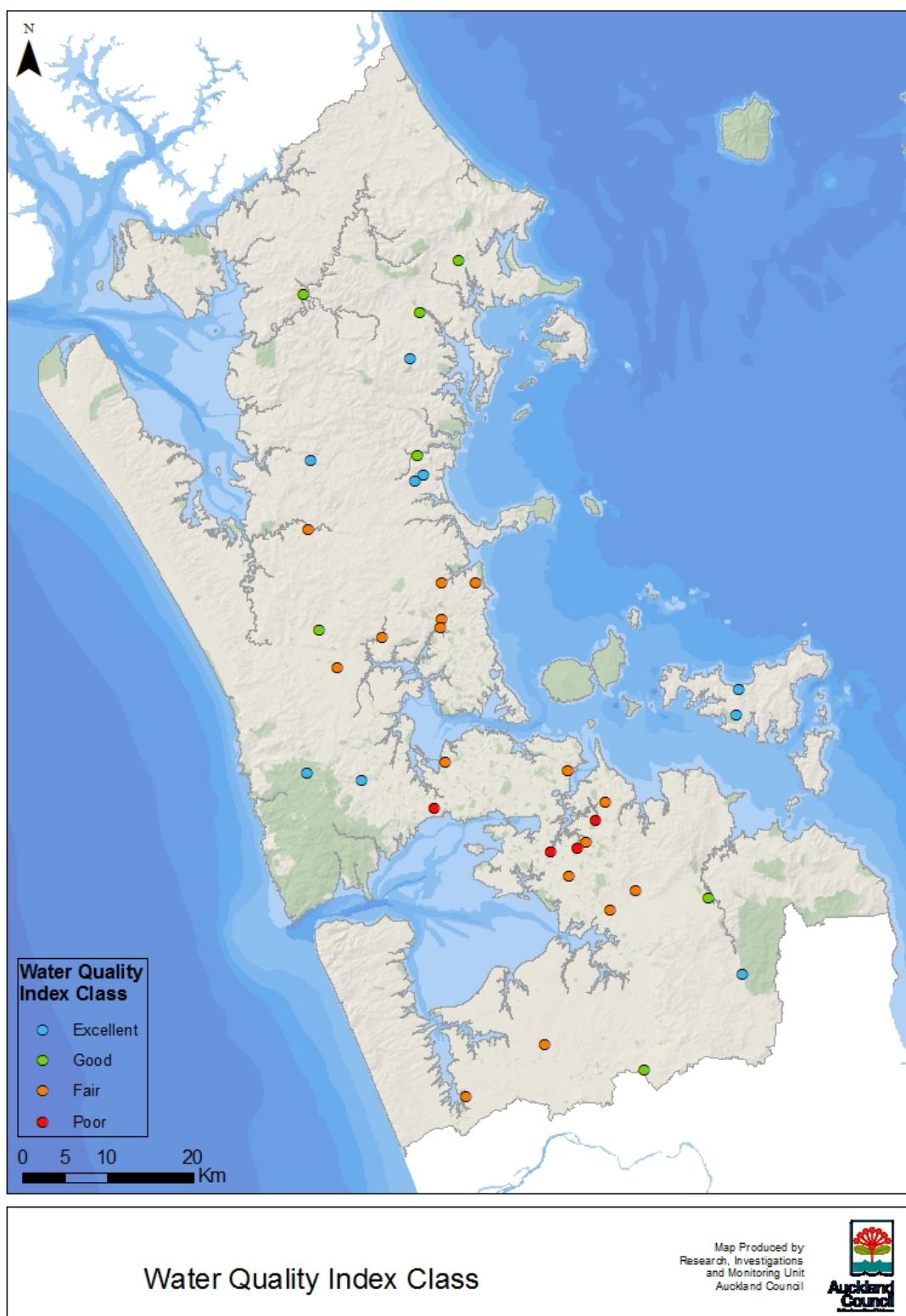


Table 6

Mean 2013 water quality index scores and water quality class for all sites within a catchment land cover class

Land Cover (number of sites)	Scope	Frequency	Magnitude	Water quality index	Water quality class
Native forest (4)	14.3	1.5	1.2	91.6	Excellent
Exotic forest (2)	21.4	7.7	3.9	86.5	Good
Rural (19)	42.9	13.6	12.9	71.6	Good
Urban (11)	75.0	24.2	14.8	53.0	Fair

5 Summary

The results from the Auckland Council's long-term river water quality monitoring programme for the 2013 year have been summarised in this report. Water quality was assessed monthly at 36 sites around the region using a combination of field based and laboratory tested parameters. The results were presented as box plots to show the intra- and inter-site variation for each of the parameters and a statistical summary of each parameter at each of the sites was presented in Appendix 2.

The data was used to produce water quality indices, which summarised the complex multivariate dataset to facilitate communication, allowed sites to be ranked and assigned a water quality class. The water quality indices indicated that during 2013 the best river water quality was in the Opanuku Stream, followed by Wairoa Tributary, Cascades Stream (Whakanewha) and West Hoe Stream. Nine sites were classified as having excellent water quality in 2013. Poor water quality was observed in streams in and around the urban area, with Otara Creek (East Tamaki) having the lowest ranked water quality in 2013.

6 Acknowledgements

The Auckland Council river water quality monitoring has benefitted from the efforts of numerous people since its inception in 1977.

During 2013 Nick Reid, Clive Coleman, Frances Mitchell, Peter Williams, Nicholas Holwerda, Ed Clayton, Jade Khin, Blair Sowman, Peter Hancock, Kent Steel and a number of RIMU's Environmental Monitoring team students contributed to sample collection and data management. Laboratory analyses were carried out by Watercare Laboratory Services Ltd.

The data from the Rangitopuni River and Hoteo River sites are used under licence from NIWA.

7 Appendix 1

The communication of water quality data is often hampered by the volume of results and the complexity of the information. In this report, a water quality index developed by the Canadian Council of Ministers for the Environment (CCME) (2001) was applied to the river water quality data collected by the Auckland Council to enable improved understanding and communication of the work.

The CCME approach uses water quality results to produce four water quality indices, and these indices can be used to assign a water quality class to each monitoring site. The four indices are;

- Scope – This represents the percentage of parameters that failed to meet the objective at least once during the time period under consideration (the lower this index, the better).
- Frequency – This represents the percentage of all individual tests that failed to meet the objective during the time period under consideration (the lower this index, the better).
- Magnitude – This represents the amount by which failed tests exceeded the objective (the lower this index, the better). This is based on the collective amount by which individual tests are out of compliance with the objectives and is scaled to be between 1 and 100. This is the most complex part of the index derivation and the reader is referred to CCME (2001) for full details.
- WQI – This represents an overall water quality index based on a combination of the three indices described above. It is calculated thus;

$$\text{WQI} = 100 - [\sqrt{(\text{Scope}^2 + \text{Frequency}^2 + \text{Magnitude}^2)} \div 1.732]$$

The divisor 1.732 normalises the resultant values to a range between 0 and 100, where 0 represents the “worst” water quality and 100 represents the “best” water quality.

The WQI index is used by Auckland Council to assign a water quality class to each site using the following ranges;

- Greater than 90 = excellent water quality
- Between 70 and 90 = good water quality
- Between 50 and 70 = fair water quality
- Lower than 50 = poor water quality

The above indices are calculated for each site based on seven water quality parameters (Table 7). The objectives against which the Auckland Council water quality data are tested are derived from the range observed at the three Auckland Council reference sites (Cascades Stream, Wairoa Tributary and West Hoe Stream) over the five years preceding this report (2008 to 2012). This represents a change from the 2007 and 2008 reports. It was considered thresholds based on the fixed period (2002 to 2006) used in

the 2007 and 2008 reports, whilst providing consistency, would not capture natural variation in water quality, nor account for improvements in the measurement of parameters (for example, improved meter performance or improvements in detection limits).

The ranges at these reference sites were used as this represents the best achievable water quality in Auckland. Therefore, the index represents the deviation from “natural” conditions in the Auckland Region, rather than indicating whether the water quality is suitable for a particular purpose.

Table 7

The seven water quality parameters, and their objectives, used to produce the water quality indices in this report. The objectives are based on the 98th percentile of the data from reference sites in the programme collected between 2008 and 2012.

Dissolved oxygen (% saturation)	Between 82 and 120%
pH	Between 6.4 and 8.0
Turbidity	Less than 38 NTU
Ammoniacal nitrogen	Less than 0.06 mg N l ⁻¹
Temperature	Less than 18 °C
Total phosphorus	Less than 0.09 mg P l ⁻¹
Total nitrogen	Less than 0.8 mg N l ⁻¹

8 Appendix 2 - Summary tables

Table 8

Dissolved oxygen (% saturation)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	51.7	92.8	84.3	79.9	3.58
Cascade Stream (Waitakere)	12	90.2	102.7	100.5	99.3	1.02
Cascades Stream (Whakanewha)	11	85.5	128.3	94.1	98.0	3.76
Hoteo River (NIWA operated)	12	84.8	92.6	90.8	89.8	0.86
Kaukapakapa River	12	50.5	93.3	76.1	72.9	4.13
Kumeu River	12	9.1	91.5	77.9	71.8	6.42
Lucas Creek	12	67.7	97.0	86.8	85.8	2.68
Mahurangi River (Forestry HQ)	12	90.0	108.1	93.4	94.6	1.42
Mahurangi River (Water Supply)	12	73.6	102.1	92.0	90.3	2.25
Makarau River	12	86.8	104.4	96.4	96.9	1.44
Matakana River	12	72.5	96.1	87.3	85.6	1.85
Ngakaroa Stream	12	78.6	95.7	89.6	88.1	1.61
Nukumea Stream	12	78.8	93.0	86.8	86.7	1.44
Oakley Creek	12	71.9	97.3	88.9	86.8	2.28
Okura Creek	12	25.2	99.9	87.4	71.6	8.53
Omaru Creek	12	32.3	110.1	79.9	79.0	6.50
Onetangi Stream	11	58.1	103.0	78.0	78.6	3.55
Opanuku Stream	12	86.3	101.0	93.0	92.9	1.27
Otaki Creek	12	71.8	204.8	81.9	105.9	13.65
Otara Creek (East Tamaki)	12	76.8	143.6	96.1	99.3	5.00
Otara Creek (Kennel Hill)	12	40.1	90.4	76.0	73.8	4.87
Oteha Stream	12	32.7	94.1	85.6	76.6	5.69
Pakuranga Creek (Botany Rd)	12	94.6	189.9	114.3	123.7	8.32
Pakuranga Creek (Greenmount Rd)	12	63.4	85.0	77.4	76.4	2.32
Papakura Stream (Alfriston Rd)	12	3.1	84.9	70.8	54.3	9.18
Papakura Stream (Porchester Rd)	12	57.4	88.7	80.3	79.0	2.81
Puhinui Stream	12	51.8	122.2	99.5	96.1	5.92
Rangitopuni River (NIWA operated)	12	7.8	91.7	78.6	65.7	8.81
Riverhead Stream	12	11.9	89.0	78.3	71.1	6.03
Vaughan Stream	12	49.0	98.4	77.5	75.7	4.26
Wairoa Tributary	12	92.8	103.7	99.1	98.9	0.96
Wairoa River	12	84.3	100.0	94.3	93.4	1.46
Waitangi River	12	40.9	97.4	79.2	72.5	5.84
Waiwera River	12	67.4	95.9	88.2	84.1	2.65
West Hoe Stream	12	80.1	97.0	87.7	88.5	1.51
Whangamaire Stream	12	40.6	96.9	82.7	73.4	6.44

Table 9

Dissolved oxygen (ppm)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	5.00	9.74	8.67	8.16	0.435
Cascade Stream (Waitakere)	12	9.89	11.45	10.37	10.46	0.134
Cascades Stream (Whakanewha)	11	8.44	13.41	9.84	10.34	0.397
Hoteo River (NIWA operated)	12	7.41	10.25	9.25	9.02	0.287
Kaukapakapa River	12	4.57	10.78	7.67	7.56	0.592
Kumeu River	12	0.87	10.40	8.02	7.40	0.733
Lucas Creek	12	6.48	11.06	8.56	8.77	0.438
Mahurangi River (Forestry HQ)	12	8.59	11.66	9.85	9.78	0.276
Mahurangi River (Water Supply)	12	6.67	11.74	9.07	9.06	0.431
Makarau River	12	7.88	11.94	9.68	9.90	0.336
Matakana River	12	7.13	11.23	8.53	8.66	0.368
Ngakaroa Stream	12	7.51	10.58	9.17	9.07	0.329
Nukumea Stream	12	7.51	10.54	9.07	9.12	0.290
Oakley Creek	12	6.90	9.96	9.07	8.70	0.311
Okura Creek	12	2.34	11.61	8.84	7.62	1.011
Omaru Creek	12	2.95	10.18	8.17	7.75	0.629
Onetangi Stream	11	5.74	10.71	8.32	8.28	0.425
Opanuku Stream	12	8.34	11.68	9.62	9.73	0.276
Otaki Creek	12	7.14	16.23	8.03	9.42	0.880
Otara Creek (East Tamaki)	12	8.17	13.38	9.31	9.79	0.419
Otara Creek (Kennel Hill)	12	3.59	10.09	7.90	7.44	0.575
Oteha Stream	12	3.10	10.32	8.68	7.85	0.670
Pakuranga Creek (Botany Rd)	12	9.34	15.64	11.30	11.43	0.520
Pakuranga Creek (Greenmount Rd)	12	5.96	8.78	7.35	7.35	0.273
Papakura Stream (Alfriston Rd)	12	0.29	9.60	6.92	5.66	1.008
Papakura Stream (Porchester Rd)	12	5.41	9.93	8.02	8.06	0.424
Puhinui Stream	12	4.58	13.23	9.80	9.36	0.704
Rangitopuni River (NIWA operated)	12	0.79	10.08	8.01	6.87	0.996
Riverhead Stream	12	1.19	10.50	8.30	7.71	0.729
Vaughan Stream	12	4.69	9.84	7.90	7.58	0.480
Wairoa Tributary	12	9.70	12.04	10.54	10.68	0.169
Wairoa River	12	7.87	11.59	9.35	9.50	0.370
Waitangi River	12	3.87	10.11	7.79	7.41	0.699
Waiwera River	12	6.27	11.20	8.53	8.62	0.479
West Hoe Stream	12	7.65	11.11	9.29	9.34	0.309
Whangamaire Stream	12	3.82	10.38	8.36	7.57	0.755

Table 10

Temperature (°C)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	10.80	18.18	15.37	14.71	0.778
Cascade Stream (Waitakere)	12	8.99	16.71	13.57	13.06	0.754
Cascades Stream (Whakanewha)	11	9.85	16.00	12.22	12.93	0.658
Hoteo River (NIWA operated)	12	11.40	22.90	14.95	15.78	1.183
Kaukapakapa River	12	9.00	20.19	14.99	14.58	1.093
Kumeu River	12	9.65	19.79	15.15	14.69	0.951
Lucas Creek	12	9.48	20.61	15.05	14.82	1.099
Mahurangi River (Forestry HQ)	12	8.30	19.25	14.42	14.13	1.100
Mahurangi River (Water Supply)	12	9.21	21.12	16.08	15.81	1.233
Makarau River	12	8.65	20.04	15.33	14.71	1.136
Matakana River	12	8.53	20.44	16.00	15.31	1.133
Ngakaroa Stream	12	9.66	17.72	15.55	14.35	0.939
Nukumea Stream	12	9.65	17.65	13.14	13.34	0.743
Oakley Creek	12	11.67	18.41	15.62	15.49	0.716
Okura Creek	12	8.57	18.91	13.37	13.72	1.031
Omaru Creek	12	12.71	21.41	16.10	16.45	0.888
Onetangi Stream	11	10.12	16.27	12.49	13.17	0.627
Opanuku Stream	12	8.30	17.47	14.09	13.54	0.989
Otaki Creek	12	13.72	27.09	17.34	18.74	1.251
Otara Creek (East Tamaki)	12	12.58	19.34	15.79	15.94	0.746
Otara Creek (Kennel Hill)	12	10.36	20.74	15.61	15.58	1.079
Oteha Stream	12	9.91	20.95	14.72	14.92	1.049
Pakuranga Creek (Botany Rd)	12	14.43	25.15	16.74	18.70	1.229
Pakuranga Creek (Greenmount Rd)	12	13.56	20.49	17.66	17.32	0.726
Papakura Stream (Alfriston Rd)	12	9.73	17.93	15.70	14.93	0.901
Papakura Stream (Porchester Rd)	12	10.11	18.21	15.42	14.91	0.940
Puhinui Stream	12	11.77	21.39	18.73	17.28	1.053
Rangitopuni River (NIWA operated)	12	10.80	19.80	14.50	14.67	0.895
Riverhead Stream	12	7.05	17.77	12.70	12.42	0.984
Vaughan Stream	12	9.77	20.52	15.80	15.42	1.068
Wairoa Tributary	12	8.60	15.34	12.32	12.00	0.690
Wairoa River	12	8.76	19.79	15.64	15.04	1.162
Waitangi River	12	10.76	18.28	15.78	15.12	0.861
Waiwera River	12	8.56	20.60	15.06	14.88	1.227
West Hoe Stream	12	9.34	17.57	12.89	13.17	0.741
Whangamaire Stream	12	10.48	18.19	14.93	14.70	0.820

Table 11

Conductivity (Millisiemens/cm @ 25°C)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.069	0.260	0.212	0.185	0.0167
Cascade Stream (Waitakere)	12	0.106	0.196	0.176	0.170	0.0072
Cascades Stream (Whakanewha)	11	0.110	0.371	0.234	0.236	0.0177
Hoteo River (NIWA operated)	12	0.169	0.258	0.185	0.203	0.0092
Kaukapakapa River	12	0.177	0.283	0.219	0.227	0.0114
Kumeu River	12	0.144	0.224	0.168	0.179	0.0075
Lucas Creek	12	0.152	0.294	0.256	0.241	0.0142
Mahurangi River (Forestry HQ)	12	0.151	0.207	0.177	0.179	0.0047
Mahurangi River (Water Supply)	12	0.142	0.256	0.181	0.194	0.0107
Makarau River	12	0.158	0.255	0.192	0.206	0.0089
Matakana River	12	0.147	0.246	0.186	0.193	0.0086
Ngakaroa Stream	12	0.139	0.241	0.172	0.180	0.0100
Nukumea Stream	12	0.144	0.204	0.180	0.179	0.0047
Oakley Creek	12	0.118	0.310	0.234	0.218	0.0206
Okura Creek	12	0.200	0.438	0.264	0.287	0.0208
Omaru Creek	12	0.211	0.627	0.297	0.309	0.0323
Onetangi Stream	11	0.471	0.665	0.495	0.517	0.0165
Opanuku Stream	12	0.114	0.163	0.148	0.144	0.0038
Otaki Creek	12	0.122	23.242	0.487	5.316	2.4448
Otara Creek (East Tamaki)	12	0.114	0.415	0.204	0.208	0.0206
Otara Creek (Kennel Hill)	12	0.187	0.487	0.236	0.255	0.0226
Oteha Stream	12	0.082	0.292	0.234	0.221	0.0199
Pakuranga Creek (Botany Rd)	12	0.134	0.524	0.276	0.283	0.0256
Pakuranga Creek (Greenmount Rd)	12	0.194	1.255	0.581	0.563	0.0844
Papakura Stream (Alfriston Rd)	11	0.156	0.248	0.180	0.192	0.0089
Papakura Stream (Porchester Rd)	12	0.176	0.298	0.205	0.222	0.0117
Puhinui Stream	12	0.115	0.259	0.212	0.199	0.0131
Rangitopuni River (NIWA operated)	12	0.210	0.270	0.231	0.236	0.0059
Riverhead Stream	12	0.005	0.257	0.223	0.208	0.0191
Vaughan Stream	12	0.201	12.594	0.282	1.350	1.0231
Wairoa Tributary	12	0.080	0.142	0.127	0.121	0.0052
Wairoa River	12	0.102	0.149	0.121	0.123	0.0040
Waitangi River	12	0.177	0.260	0.205	0.208	0.0066
Waiwera River	12	0.175	0.255	0.201	0.212	0.0079
West Hoe Stream	12	0.148	0.207	0.192	0.186	0.0059
Whangamaire Stream	12	0.263	0.340	0.318	0.307	0.0080

Table 12
Salinity (ppt)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.03	0.12	0.10	0.09	0.008
Cascade Stream (Waitakere)	12	0.05	0.09	0.08	0.08	0.003
Cascades Stream (Whakanewha)	11	0.05	0.18	0.11	0.11	0.009
Hoteo River (NIWA operated)	Not measured at this site					
Kaukapakapa River	12	0.08	0.14	0.11	0.11	0.006
Kumeu River	12	0.07	0.11	0.08	0.09	0.004
Lucas Creek	12	0.07	0.14	0.13	0.12	0.007
Mahurangi River (Forestry HQ)	12	0.07	0.10	0.09	0.09	0.002
Mahurangi River (Water Supply)	12	0.07	0.12	0.09	0.09	0.005
Makarau River	12	0.08	0.12	0.09	0.10	0.004
Matakana River	12	0.07	0.12	0.09	0.09	0.005
Ngakaroa Stream	12	0.07	0.11	0.09	0.09	0.004
Nukumea Stream	12	0.07	0.10	0.09	0.09	0.002
Oakley Creek	12	0.06	0.15	0.11	0.10	0.010
Okura Creek	12	0.10	0.21	0.13	0.14	0.010
Omaru Creek	12	0.10	0.31	0.15	0.15	0.016
Onetangi Stream	11	0.23	0.33	0.24	0.25	0.009
Opanuku Stream	12	0.05	0.08	0.07	0.07	0.002
Otaki Creek	12	0.06	14.01	0.24	3.10	1.476
Otara Creek (East Tamaki)	12	0.05	0.20	0.10	0.10	0.010
Otara Creek (Kennel Hill)	12	0.09	0.23	0.11	0.12	0.011
Oteha Stream	12	0.04	0.14	0.11	0.11	0.010
Pakuranga Creek (Botany Rd)	12	0.06	0.25	0.13	0.14	0.012
Pakuranga Creek (Greenmount Rd)	12	0.09	0.63	0.28	0.27	0.043
Papakura Stream (Alfriston Rd)	11	0.07	0.12	0.09	0.09	0.005
Papakura Stream (Porchester Rd)	12	0.08	0.14	0.10	0.10	0.006
Puhinui Stream	12	0.05	0.12	0.10	0.09	0.007
Rangitopuni River (NIWA operated)	Not measured at this site					
Riverhead Stream	11	0.09	0.12	0.11	0.11	0.003
Vaughan Stream	12	0.10	7.25	0.14	0.75	0.591
Wairoa Tributary	12	0.04	0.07	0.06	0.06	0.002
Wairoa River	12	0.05	0.07	0.06	0.06	0.002
Waitangi River	12	0.08	0.12	0.10	0.10	0.003
Waiwera River	12	0.08	0.12	0.10	0.10	0.004
West Hoe Stream	12	0.07	0.10	0.09	0.09	0.003
Whangamaire Stream	12	0.13	0.16	0.15	0.15	0.004

Table 13
pH (pH units)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	7.1	7.3	7.2	7.2	0.01
Cascade Stream (Waitakere)	12	7.6	8.0	7.8	7.8	0.03
Cascades Stream (Whakanewha)	11	7.2	7.6	7.3	7.3	0.04
Hoteo River (NIWA operated)	12	7.1	7.7	7.4	7.4	0.06
Kaukapakapa River	12	7.0	7.4	7.3	7.3	0.04
Kumeu River	12	6.6	7.2	7.1	7.0	0.05
Lucas Creek	12	7.3	7.5	7.5	7.4	0.02
Mahurangi River (Forestry HQ)	12	7.1	7.6	7.5	7.4	0.04
Mahurangi River (Water Supply)	12	7.4	7.7	7.6	7.6	0.03
Makarau River	12	7.3	8.0	7.7	7.7	0.06
Matakana River	12	7.2	7.7	7.5	7.5	0.04
Ngakaroa Stream	12	7.3	7.5	7.4	7.4	0.02
Nukumea Stream	12	6.6	7.4	7.0	7.0	0.07
Oakley Creek	12	7.3	7.7	7.5	7.5	0.04
Okura Creek	12	6.9	7.5	7.4	7.3	0.05
Omaru Creek	12	7.2	7.8	7.6	7.5	0.05
Onetangi Stream	11	7.0	7.4	7.1	7.1	0.03
Opanuku Stream	12	7.2	7.6	7.5	7.5	0.03
Otaki Creek	12	7.1	7.8	7.3	7.3	0.05
Otara Creek (East Tamaki)	12	7.2	8.4	7.5	7.5	0.10
Otara Creek (Kennel Hill)	12	7.2	7.7	7.4	7.4	0.05
Oteha Stream	12	7.1	7.4	7.4	7.4	0.03
Pakuranga Creek (Botany Rd)	12	7.4	9.1	7.5	7.7	0.14
Pakuranga Creek (Greenmount Rd)	12	7.4	7.9	7.8	7.7	0.05
Papakura Stream (Alfriston Rd)	12	6.7	7.3	7.0	7.0	0.04
Papakura Stream (Porchester Rd)	12	6.7	7.4	7.2	7.1	0.07
Puhinui Stream	12	7.2	8.0	7.4	7.5	0.07
Rangitopuni River (NIWA operated)	12	6.9	7.4	7.1	7.1	0.04
Riverhead Stream	12	6.3	7.1	6.8	6.7	0.07
Vaughan Stream	12	6.6	7.4	7.0	7.0	0.08
Wairoa Tributary	12	7.6	7.8	7.7	7.7	0.02
Wairoa River	12	7.1	7.5	7.5	7.4	0.04
Waitangi River	12	6.9	7.5	7.2	7.2	0.05
Waiwera River	12	7.2	7.6	7.5	7.5	0.04
West Hoe Stream	12	6.8	7.4	7.2	7.2	0.05
Whangamaire Stream	12	7.2	7.5	7.4	7.4	0.03

Table 14
Suspended sediment (mg l^{-1})

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	3.4	110.0	11.9	25.3	9.15
Cascade Stream (Waitakere)	12	0.2	13.0	0.8	2.0	1.02
Cascades Stream (Whakanewha)	11	0.4	8.7	3.2	3.8	0.76
Hoteo River (NIWA operated)	Not measured at this site					
Kaukapakapa River	12	2.2	14.0	4.3	5.2	0.90
Kumeu River	12	4.4	32.0	7.6	11.6	2.66
Lucas Creek	12	1.4	43.0	3.2	7.3	3.38
Mahurangi River (Forestry HQ)	12	0.8	16.0	2.5	4.0	1.27
Mahurangi River (Water Supply)	12	0.4	24.0	2.0	5.0	2.11
Makarau River	12	1.2	11.0	2.4	3.9	0.88
Matakana River	12	1.4	43.0	2.2	5.8	3.39
Ngakaroa Stream	12	0.4	14.0	3.9	4.1	1.01
Nukumea Stream	12	0.8	23.0	4.1	6.2	1.91
Oakley Creek	12	0.8	24.0	4.8	7.2	1.99
Okura Creek	12	2.8	35.0	6.4	8.9	2.63
Omaru Creek	12	2.4	13.0	3.8	4.3	0.82
Onetangi Stream	11	0.2	69.0	7.0	13.7	6.06
Opanuku Stream	12	0.4	16.0	1.4	3.3	1.33
Otaki Creek	12	2.0	54.0	6.4	11.2	4.13
Otara Creek (East Tamaki)	12	1.8	180.0	3.3	20.2	14.60
Otara Creek (Kennel Hill)	12	1.8	46.0	6.4	12.1	3.57
Oteha Stream	12	1.2	63.0	4.1	9.3	4.93
Pakuranga Creek (Botany Rd)	12	2.2	20.0	4.7	6.4	1.54
Pakuranga Creek (Greenmount Rd)	12	2.3	10.0	5.2	5.4	0.69
Papakura Stream (Alfriston Rd)	12	2.2	24.0	4.7	7.3	1.75
Papakura Stream (Porchester Rd)	12	0.8	17.0	3.9	5.0	1.33
Puhinui Stream	12	0.8	49.0	6.1	10.5	3.75
Rangitopuni River (NIWA operated)	Not measured at this site					
Riverhead Stream	12	0.8	14.0	2.3	3.5	1.03
Vaughan Stream	12	2.1	14.0	3.6	4.9	0.98
Wairoa Tributary	12	0.4	36.0	2.3	5.8	2.92
Wairoa River	12	1.4	10.0	3.2	3.8	0.75
Waitangi River	12	0.2	3.4	1.3	1.4	0.25
Waiwera River	12	1.2	12.0	3.3	4.3	1.00
West Hoe Stream	12	0.4	9.4	1.9	3.2	0.85
Whangamaire Stream	12	0.9	11.0	3.9	4.9	0.99

Table 15
Turbidity (NTU)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	10.0	40.0	18.0	19.3	2.41
Cascade Stream (Waitakere)	12	0.9	24.0	1.3	3.8	1.95
Cascades Stream (Whakanewha)	11	3.9	12.0	6.6	7.6	0.92
Hoteo River (NIWA operated)	12	1.2	22.9	8.0	7.7	1.69
Kaukapakapa River	12	2.4	17.0	6.4	6.5	1.04
Kumeu River	12	7.8	37.0	10.0	12.6	2.29
Lucas Creek	12	3.6	32.0	5.9	9.6	2.74
Mahurangi River (Forestry HQ)	12	2.0	24.0	6.2	7.7	1.69
Mahurangi River (Water Supply)	12	0.8	34.0	4.9	6.8	2.54
Makarau River	12	1.6	17.0	5.8	6.4	1.18
Matakana River	12	1.2	31.0	3.2	5.5	2.36
Ngakaroa Stream	12	2.0	11.0	3.7	4.1	0.73
Nukumea Stream	12	4.0	13.0	7.7	7.5	0.94
Oakley Creek	12	1.7	15.0	5.0	6.8	1.41
Okura Creek	12	4.5	32.0	10.0	12.1	2.16
Omara Creek	12	2.3	13.0	4.2	4.9	0.85
Onetangi Stream	11	4.5	16.0	7.6	8.2	0.94
Opanuku Stream	12	0.9	20.0	2.7	4.6	1.58
Otaki Creek	12	5.1	39.0	9.3	11.8	2.67
Otara Creek (East Tamaki)	12	2.4	55.0	5.2	12.1	4.46
Otara Creek (Kennel Hill)	12	3.1	38.0	9.1	11.7	2.89
Oteha Stream	12	1.5	25.0	6.6	8.7	2.22
Pakuranga Creek (Botany Rd)	12	3.3	16.0	6.2	7.5	1.09
Pakuranga Creek (Greenmount Rd)	12	2.6	18.0	9.6	9.6	1.21
Papakura Stream (Alfriston Rd)	12	1.8	45.0	6.7	10.3	3.35
Papakura Stream (Porchester Rd)	12	0.9	18.0	4.5	5.4	1.40
Puhinui Stream	12	1.4	15.0	5.4	6.4	1.24
Rangitopuni River (NIWA operated)	12	1.9	45.6	7.1	10.1	3.43
Riverhead Stream	12	3.4	30.0	7.4	9.8	2.36
Vaughan Stream	12	2.3	23.0	6.9	8.2	1.71
Wairoa Tributary	12	2.7	32.0	4.1	8.4	2.78
Wairoa River	12	1.5	13.0	3.1	4.2	0.93
Waitangi River	12	0.6	6.6	2.3	2.3	0.49
Waiwera River	12	1.2	15.0	4.7	6.2	1.15
West Hoe Stream	12	3.9	13.0	7.6	7.3	0.87
Whangamaire Stream	12	0.5	7.3	4.1	3.5	0.66

Table 16
Ammoniacal Nitrogen (mg N l⁻¹)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.003	0.170	0.043	0.050	0.0127
Cascade Stream (Waitakere)	12	0.003	0.013	0.003	0.003	0.0009
Cascades Stream (Whakanewha)	11	0.003	0.014	0.007	0.007	0.0014
Hoteo River (NIWA operated)	11	0.003	0.088	0.012	0.021	0.0073
Kaukapakapa River	12	0.003	0.083	0.023	0.027	0.0066
Kumeu River	12	0.003	0.046	0.028	0.026	0.0041
Lucas Creek	12	0.003	0.100	0.013	0.023	0.0081
Mahurangi River (Forestry HQ)	12	0.003	0.038	0.017	0.019	0.0034
Mahurangi River (Water Supply)	12	0.003	0.032	0.012	0.011	0.0024
Makarau River	12	0.003	0.029	0.009	0.011	0.0024
Matakana River	12	0.003	0.013	0.008	0.007	0.0012
Ngakaroa Stream	12	0.003	0.021	0.007	0.010	0.0022
Nukumea Stream	12	0.003	0.025	0.003	0.006	0.0020
Oakley Creek	12	0.003	0.061	0.011	0.018	0.0055
Okura Creek	12	0.003	0.110	0.024	0.033	0.0090
Omaru Creek	12	0.006	0.084	0.019	0.026	0.0059
Onetangi Stream	11	0.003	0.044	0.010	0.014	0.0038
Opanuku Stream	12	0.003	0.010	0.004	0.005	0.0008
Otaki Creek	12	0.046	0.640	0.079	0.168	0.0539
Otara Creek (East Tamaki)	12	0.009	0.093	0.022	0.033	0.0083
Otara Creek (Kennel Hill)	12	0.009	0.120	0.021	0.028	0.0086
Oteha Stream	12	0.003	0.077	0.019	0.026	0.0060
Pakuranga Creek (Botany Rd)	12	0.021	0.120	0.051	0.061	0.0097
Pakuranga Creek (Greenmount Rd)	12	0.096	0.700	0.320	0.346	0.0581
Papakura Stream (Alfriston Rd)	12	0.009	0.120	0.050	0.053	0.0100
Papakura Stream (Porchester Rd)	12	0.010	1.200	0.025	0.143	0.0972
Puhinui Stream	12	0.003	0.580	0.020	0.074	0.0475
Rangitopuni River (NIWA operated)	12	0.012	0.055	0.027	0.029	0.0039
Riverhead Stream	12	0.003	0.027	0.010	0.010	0.0021
Vaughan Stream	12	0.003	0.180	0.011	0.028	0.0145
Wairoa Tributary	12	0.003	0.095	0.003	0.011	0.0076
Wairoa River	12	0.003	0.100	0.006	0.013	0.0079
Waitangi River	12	0.003	0.014	0.005	0.006	0.0009
Waiwera River	12	0.003	0.024	0.010	0.010	0.0018
West Hoe Stream	12	0.003	0.009	0.003	0.004	0.0007
Whangamaire Stream	12	0.003	0.021	0.008	0.009	0.0019

Table 17Total oxidised Nitrogen (mg N l⁻¹)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.048	0.550	0.350	0.331	0.0370
Cascade Stream (Waitakere)	12	0.001	0.022	0.006	0.008	0.0019
Cascades Stream (Whakanewha)	11	0.004	0.140	0.077	0.077	0.0120
Hoteo River (NIWA operated)	11	0.000	0.744	0.297	0.281	0.0690
Kaukapakapa River	12	0.007	1.500	0.195	0.313	0.1169
Kumeu River	12	0.041	0.650	0.325	0.335	0.0542
Lucas Creek	12	0.001	0.770	0.160	0.198	0.0589
Mahurangi River (Forestry HQ)	12	0.048	0.150	0.110	0.101	0.0108
Mahurangi River (Water Supply)	12	0.001	0.370	0.065	0.104	0.0334
Makarau River	12	0.001	0.280	0.072	0.089	0.0272
Matakana River	12	0.001	0.130	0.019	0.033	0.0118
Ngakaroa Stream	12	2.000	5.900	3.250	3.392	0.2989
Nukumea Stream	12	0.001	0.024	0.005	0.009	0.0027
Oakley Creek	12	0.200	2.100	1.015	1.084	0.1723
Okura Creek	12	0.001	0.470	0.130	0.168	0.0452
Omaru Creek	12	0.001	1.800	0.570	0.681	0.1750
Onetangi Stream	11	0.004	0.270	0.096	0.099	0.0204
Opanuku Stream	12	0.010	0.160	0.049	0.065	0.0149
Otaki Creek	12	0.032	2.800	1.300	1.329	0.3260
Otara Creek (East Tamaki)	12	0.001	2.100	0.905	0.918	0.2073
Otara Creek (Kennel Hill)	12	0.021	1.100	0.175	0.311	0.1000
Oteha Stream	12	0.057	0.650	0.200	0.283	0.0541
Pakuranga Creek (Botany Rd)	12	0.170	1.500	0.680	0.738	0.1244
Pakuranga Creek (Greenmount Rd)	12	0.400	1.000	0.520	0.591	0.0524
Papakura Stream (Alfriston Rd)	12	0.003	1.800	0.305	0.473	0.1556
Papakura Stream (Porchester Rd)	12	0.027	1.300	0.340	0.457	0.1163
Puhinui Stream	12	0.001	1.100	0.415	0.443	0.1149
Rangitopuni River (NIWA operated)	11	0.002	0.339	0.132	0.171	0.0381
Riverhead Stream	12	0.005	0.022	0.014	0.013	0.0013
Vaughan Stream	12	0.001	0.210	0.046	0.059	0.0191
Wairoa Tributary	12	0.001	0.200	0.045	0.053	0.0145
Wairoa River	12	0.001	1.100	0.145	0.289	0.0989
Waitangi River	12	0.090	3.200	2.200	1.937	0.3397
Waiwera River	12	0.001	0.330	0.078	0.101	0.0307
West Hoe Stream	12	0.001	0.013	0.003	0.004	0.0010
Whangamaire Stream	12	11.000	16.000	13.000	13.167	0.3860

Table 18Kjeldhal Nitrogen by calculation (mg N l⁻¹)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.066	0.590	0.325	0.335	0.0409
Cascade Stream (Waitakere)	12	0.010	0.450	0.021	0.068	0.0361
Cascades Stream (Whakanewha)	11	0.066	0.370	0.140	0.164	0.0297
Hoteo River (NIWA operated)	11	0.263	0.491	0.301	0.331	0.0200
Kaukapakapa River	12	0.010	0.680	0.365	0.346	0.0485
Kumeu River	12	0.170	0.620	0.320	0.354	0.0361
Lucas Creek	12	0.082	1.100	0.305	0.377	0.0835
Mahurangi River (Forestry HQ)	12	0.010	0.270	0.099	0.119	0.0238
Mahurangi River (Water Supply)	12	0.120	0.520	0.175	0.217	0.0339
Makarau River	12	0.140	0.440	0.210	0.250	0.0281
Matakana River	12	0.046	0.480	0.180	0.188	0.0316
Ngakaroa Stream	12	0.010	1.000	0.315	0.376	0.0746
Nukumea Stream	12	0.024	0.160	0.094	0.094	0.0134
Oakley Creek	12	0.190	1.500	0.330	0.409	0.1007
Okura Creek	12	0.150	0.860	0.435	0.457	0.0764
Omaru Creek	12	0.010	0.470	0.270	0.267	0.0339
Onetangi Stream	11	0.071	0.400	0.170	0.203	0.0317
Opanuku Stream	12	0.045	0.450	0.120	0.148	0.0331
Otaki Creek	12	0.160	2.100	0.525	0.649	0.1634
Otara Creek (East Tamaki)	12	0.010	0.750	0.275	0.281	0.0527
Otara Creek (Kennel Hill)	12	0.270	0.550	0.370	0.377	0.0280
Oteha Stream	12	0.180	0.500	0.235	0.278	0.0263
Pakuranga Creek (Botany Rd)	12	0.140	0.540	0.370	0.351	0.0308
Pakuranga Creek (Greenmount Rd)	12	0.190	1.400	0.660	0.711	0.1031
Papakura Stream (Alfriston Rd)	12	0.150	1.100	0.390	0.501	0.0794
Papakura Stream (Porchester Rd)	11	0.340	2.100	0.410	0.587	0.1537
Puhinui Stream	12	0.218	0.940	0.380	0.412	0.0519
Rangitopuni River (NIWA operated)	11	0.402	0.902	0.466	0.519	0.0450
Riverhead Stream	12	0.029	0.440	0.145	0.182	0.0346
Vaughan Stream	12	0.210	0.950	0.445	0.446	0.0622
Wairoa Tributary	12	0.010	0.270	0.070	0.092	0.0206
Wairoa River	12	0.047	0.320	0.160	0.174	0.0221
Waitangi River	11	0.010	0.360	0.250	0.245	0.0308
Waiwera River	12	0.120	0.360	0.210	0.225	0.0230
West Hoe Stream	12	0.010	0.320	0.060	0.084	0.0245
Whangamaire Stream	12	0.010	2.000	0.880	0.923	0.1856

Table 19
Total Nitrogen (mg N l⁻¹)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.410	1.000	0.670	0.666	0.0452
Cascade Stream (Waitakere)	12	0.010	0.450	0.040	0.074	0.0353
Cascades Stream (Whakanewha)	11	0.130	0.470	0.190	0.241	0.0319
Hoteo River (NIWA operated)	12	0.283	1.112	0.613	0.587	0.0769
Kaukapakapa River	12	0.210	1.100	0.530	0.576	0.0681
Kumeu River	12	0.340	1.300	0.680	0.692	0.0759
Lucas Creek	12	0.180	1.400	0.435	0.578	0.1200
Mahurangi River (Forestry HQ)	12	0.130	0.420	0.185	0.219	0.0280
Mahurangi River (Water Supply)	12	0.140	0.890	0.260	0.321	0.0602
Makarau River	12	0.180	0.720	0.320	0.338	0.0411
Matakana River	12	0.060	0.600	0.195	0.220	0.0373
Ngakaroa Stream	12	2.200	6.900	3.550	3.758	0.3472
Nukumea Stream	12	0.024	0.160	0.115	0.103	0.0126
Oakley Creek	12	0.870	2.400	1.450	1.492	0.1510
Okura Creek	12	0.300	1.100	0.635	0.623	0.0813
Omaru Creek	12	0.240	2.200	0.805	0.939	0.1746
Onetangi Stream	11	0.200	0.570	0.270	0.303	0.0346
Opanuku Stream	12	0.110	0.500	0.175	0.211	0.0341
Otaki Creek	12	0.580	4.000	2.100	1.967	0.3117
Otara Creek (East Tamaki)	12	0.270	2.300	1.200	1.210	0.2015
Otara Creek (Kennel Hill)	12	0.300	1.500	0.580	0.688	0.1163
Oteha Stream	12	0.290	1.100	0.505	0.555	0.0639
Pakuranga Creek (Botany Rd)	12	0.550	1.900	1.100	1.100	0.1224
Pakuranga Creek (Greenmount Rd)	12	0.590	1.800	1.300	1.289	0.1000
Papakura Stream (Alfriston Rd)	12	0.320	2.200	0.815	0.972	0.1795
Papakura Stream (Porchester Rd)	12	0.400	2.100	0.760	0.959	0.1652
Puhinui Stream	12	0.220	1.900	0.775	0.853	0.1434
Rangitopuni River (NIWA operated)	12	0.407	1.241	0.606	0.666	0.0683
Riverhead Stream	12	0.051	0.450	0.160	0.197	0.0345
Vaughan Stream	12	0.250	0.950	0.470	0.503	0.0599
Wairoa Tributary	12	0.061	0.380	0.105	0.143	0.0287
Wairoa River	12	0.089	1.400	0.375	0.467	0.1097
Waitangi River	12	0.290	3.600	1.950	1.991	0.3353
Waiwera River	12	0.210	0.660	0.280	0.326	0.0379
West Hoe Stream	12	0.010	0.320	0.060	0.088	0.0240
Whangamaire Stream	12	11.000	18.000	14.000	14.167	0.4898

Table 20Soluble Reactive Phosphorus (mg P l⁻¹)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.007	0.052	0.012	0.017	0.0035
Cascade Stream (Waitakere)	12	0.013	0.330	0.018	0.048	0.0261
Cascades Stream (Whakanewha)	11	0.005	0.023	0.011	0.013	0.0017
Hoteo River (NIWA operated)	12	0.009	0.032	0.017	0.018	0.0019
Kaukapakapa River	12	0.007	0.039	0.019	0.021	0.0027
Kumeu River	12	0.007	0.029	0.015	0.016	0.0020
Lucas Creek	12	0.007	0.076	0.010	0.019	0.0067
Mahurangi River (Forestry HQ)	12	0.003	0.018	0.008	0.008	0.0011
Mahurangi River (Water Supply)	12	0.006	0.016	0.011	0.011	0.0008
Makarau River	12	0.006	0.021	0.011	0.012	0.0012
Matakana River	12	0.005	0.028	0.012	0.013	0.0018
Ngakaroa Stream	12	0.005	0.011	0.008	0.008	0.0005
Nukumea Stream	12	0.003	0.020	0.007	0.007	0.0013
Oakley Creek	12	0.019	0.041	0.027	0.027	0.0019
Okura Creek	12	0.008	0.031	0.013	0.016	0.0025
Omaru Creek	12	0.010	0.350	0.019	0.048	0.0276
Onetangi Stream	11	0.012	0.053	0.019	0.023	0.0035
Opanuku Stream	12	0.006	0.055	0.009	0.013	0.0039
Otaki Creek	12	0.003	0.027	0.013	0.013	0.0020
Otara Creek (East Tamaki)	12	0.003	0.020	0.010	0.011	0.0015
Otara Creek (Kennel Hill)	12	0.008	0.022	0.015	0.016	0.0012
Oteha Stream	12	0.006	0.019	0.011	0.011	0.0012
Pakuranga Creek (Botany Rd)	12	0.007	0.024	0.012	0.013	0.0014
Pakuranga Creek (Greenmount Rd)	12	0.019	0.046	0.032	0.032	0.0028
Papakura Stream (Alfriston Rd)	12	0.022	0.054	0.032	0.033	0.0029
Papakura Stream (Porchester Rd)	12	0.008	0.150	0.034	0.038	0.0106
Puhinui Stream	12	0.010	0.019	0.015	0.014	0.0010
Rangitopuni River (NIWA operated)	12	0.009	0.026	0.013	0.015	0.0014
Riverhead Stream	12	0.005	0.023	0.008	0.010	0.0017
Vaughan Stream	12	0.003	0.030	0.010	0.012	0.0022
Wairoa Tributary	12	0.025	0.045	0.032	0.032	0.0016
Wairoa River	12	0.008	0.023	0.015	0.016	0.0011
Waitangi River	12	0.005	0.013	0.008	0.008	0.0005
Waiwera River	12	0.006	0.021	0.011	0.011	0.0013
West Hoe Stream	12	0.003	0.012	0.007	0.007	0.0008
Whangamaire Stream	12	0.005	0.012	0.009	0.008	0.0006

Table 21
Total Phosphorus (mg P l^{-1})

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.018	0.340	0.057	0.085	0.0254
Cascade Stream (Waitakere)	12	0.011	0.390	0.021	0.053	0.0308
Cascades Stream (Whakanewha)	11	0.003	0.076	0.019	0.026	0.0060
Hoteo River (NIWA operated)	12	0.023	0.080	0.046	0.047	0.0046
Kaukapakapa River	12	0.035	0.086	0.059	0.059	0.0049
Kumeu River	12	0.030	0.110	0.061	0.059	0.0069
Lucas Creek	12	0.011	0.150	0.037	0.046	0.0115
Mahurangi River (Forestry HQ)	12	0.006	0.045	0.015	0.019	0.0034
Mahurangi River (Water Supply)	12	0.015	0.084	0.027	0.037	0.0066
Makarau River	12	0.013	0.054	0.025	0.031	0.0039
Matakana River	12	0.013	0.099	0.024	0.032	0.0070
Ngakaroa Stream	12	0.009	0.026	0.013	0.015	0.0018
Nukumea Stream	12	0.003	0.034	0.010	0.014	0.0033
Oakley Creek	12	0.035	0.120	0.064	0.070	0.0066
Okura Creek	12	0.011	0.130	0.036	0.056	0.0128
Omaru Creek	12	0.035	0.460	0.065	0.096	0.0335
Onetangi Stream	11	0.017	0.087	0.046	0.046	0.0067
Opanuku Stream	12	0.005	0.054	0.014	0.018	0.0038
Otaki Creek	12	0.036	0.180	0.073	0.080	0.0125
Otara Creek (East Tamaki)	12	0.014	0.280	0.030	0.055	0.0212
Otara Creek (Kennel Hill)	12	0.035	0.100	0.053	0.054	0.0048
Oteha Stream	12	0.022	0.120	0.036	0.044	0.0078
Pakuranga Creek (Botany Rd)	12	0.014	0.080	0.053	0.047	0.0068
Pakuranga Creek (Greenmount Rd)	12	0.057	0.130	0.095	0.097	0.0055
Papakura Stream (Alfriston Rd)	12	0.037	0.180	0.075	0.093	0.0150
Papakura Stream (Porchester Rd)	12	0.037	0.230	0.067	0.081	0.0147
Puhinui Stream	12	0.028	0.110	0.055	0.058	0.0061
Rangitopuni River (NIWA operated)	12	0.032	0.109	0.052	0.059	0.0061
Riverhead Stream	12	0.005	0.039	0.012	0.018	0.0039
Vaughan Stream	12	0.013	0.094	0.024	0.032	0.0064
Wairoa Tributary	12	0.035	0.085	0.045	0.051	0.0044
Wairoa River	12	0.018	0.054	0.033	0.033	0.0032
Waitangi River	12	0.006	0.035	0.014	0.015	0.0022
Waiwera River	12	0.011	0.052	0.025	0.029	0.0033
West Hoe Stream	12	0.003	0.022	0.011	0.011	0.0020
Whangamaire Stream	12	0.013	0.038	0.019	0.021	0.0024

Table 22
Soluble Copper ($\mu\text{g l}^{-1}$)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.98	2.80	1.75	1.79	0.192
Cascade Stream (Waitakere)	ND					
Cascades Stream (Whakanewha)	ND					
Hoteo River (NIWA operated)	ND					
Kaukapakapa River	ND					
Kumeu River	12	0.63	2.10	1.00	1.09	0.108
Lucas Creek	12	0.51	2.80	1.05	1.43	0.227
Mahurangi River (Forestry HQ)	12	0.11	0.93	0.37	0.39	0.064
Mahurangi River (Water Supply)	12	0.11	2.00	0.49	0.59	0.138
Makarau River	12	0.38	1.20	0.65	0.66	0.073
Matakana River	12	0.33	1.50	0.54	0.64	0.090
Ngakaroa Stream	ND					
Nukumea Stream	12	0.01	0.66	0.24	0.26	0.046
Oakley Creek	12	0.82	2.80	1.65	1.74	0.195
Okura Creek	12	0.35	1.70	0.65	0.74	0.108
Omaru Creek	12	0.55	4.30	1.45	1.77	0.346
Onetangi Stream	ND					
Opanuku Stream	ND					
Otaki Creek	12	0.58	2.40	1.06	1.30	0.174
Otara Creek (East Tamaki)	12	0.68	1.80	0.92	1.07	0.098
Otara Creek (Kennel Hill)	12	0.51	2.00	0.94	1.06	0.133
Oteha Stream	12	0.54	2.70	1.20	1.44	0.195
Pakuranga Creek (Botany Rd)	12	0.66	2.60	1.20	1.49	0.188
Pakuranga Creek (Greenmount Rd)	12	0.89	2.60	1.40	1.50	0.156
Papakura Stream (Alfriston Rd)	12	0.08	1.70	0.55	0.65	0.143
Papakura Stream (Porchester Rd)	12	0.10	1.70	0.85	0.83	0.143
Puhinui Stream	12	0.71	2.40	1.30	1.46	0.146
Rangitopuni River (NIWA operated)	ND					
Riverhead Stream	12	0.08	0.90	0.44	0.45	0.070
Vaughan Stream	12	0.03	2.10	0.65	0.76	0.197
Wairoa Tributary	ND					
Wairoa River	12	0.26	0.64	0.46	0.47	0.039
Waitangi River	ND			#VALUE!		
Waiwera River	12	0.25	1.20	0.58	0.61	0.074
West Hoe Stream	ND					
Whangamaire Stream	ND					

Table 23Total Copper ($\mu\text{g l}^{-1}$)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	1.40	7.40	3.00	3.48	0.529
Cascade Stream (Waitakere)				Not measured at this site		
Cascades Stream (Whakanewha)				Not measured at this site		
Hoteo River (NIWA operated)				Not measured at this site		
Kaukapakapa River				Not measured at this site		
Kumeu River	12	0.92	3.20	1.25	1.47	0.172
Lucas Creek	12	0.73	4.50	1.65	2.11	0.373
Mahurangi River (Forestry HQ)	12	0.37	1.60	0.50	0.63	0.100
Mahurangi River (Water Supply)	12	0.37	4.00	0.70	0.96	0.282
Makarau River	12	0.45	1.80	0.84	0.93	0.099
Matakana River	12	0.62	2.60	0.76	0.92	0.157
Ngakaroa Stream				Not measured at this site		
Nukumea Stream	12	0.29	1.80	0.45	0.62	0.123
Oakley Creek	12	1.30	5.00	2.80	3.02	0.414
Okura Creek	12	0.22	2.90	0.97	1.12	0.198
Omaru Creek	12	0.75	6.30	2.10	2.59	0.450
Onetangi Stream				Not measured at this site		
Opanuku Stream				Not measured at this site		
Otaki Creek	12	1.10	6.70	1.80	2.39	0.454
Otara Creek (East Tamaki)	12	1.10	4.00	1.30	1.65	0.233
Otara Creek (Kennel Hill)	12	0.75	4.30	1.30	1.72	0.313
Oteha Stream	12	0.81	6.60	1.80	2.40	0.475
Pakuranga Creek (Botany Rd)	12	1.30	5.30	2.45	2.55	0.354
Pakuranga Creek (Greenmount Rd)	12	1.30	4.60	2.35	2.45	0.279
Papakura Stream (Alfriston Rd)	12	0.23	2.60	0.96	1.07	0.197
Papakura Stream (Porchester Rd)	12	0.13	2.20	1.25	1.12	0.185
Puhinui Stream	12	0.86	3.30	2.10	2.01	0.198
Rangitopuni River (NIWA operated)				Not measured at this site		
Riverhead Stream	12	0.22	0.93	0.62	0.59	0.072
Vaughan Stream	12	0.19	3.10	0.95	1.14	0.247
Wairoa Tributary				Not measured at this site		
Wairoa River	12	0.49	1.00	0.70	0.69	0.048
Waitangi River				Not measured at this site		
Waiwera River	12	0.49	1.40	0.74	0.80	0.084
West Hoe Stream				Not measured at this site		
Whangamaire Stream				Not measured at this site		

Table 24Soluble Zinc ($\mu\text{g l}^{-1}$)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	7.5000	77.0000	20.0000	24.2000	5.1298
Cascade Stream (Waitakere)						
Cascades Stream (Whakanewha)						
Hoteo River (NIWA operated)						
Kaukapakapa River						
Kumeu River	12	1.3000	7.6000	2.6500	3.0833	0.5039
Lucas Creek	12	0.5500	7.2000	3.6500	3.7292	0.5054
Mahurangi River (Forestry HQ)	12	0.1500	2.7000	0.2500	0.6883	0.2366
Mahurangi River (Water Supply)	12	0.1500	7.9000	1.4500	2.0483	0.6296
Makarau River	12	0.1500	1.7000	0.5850	0.6733	0.1344
Matakana River	12	0.1500	2.2000	0.6750	0.7533	0.1743
Ngakaroa Stream						
Nukumea Stream	12	0.3400	1.8000	1.0500	1.0508	0.1162
Oakley Creek	12	4.2000	34.0000	12.5000	13.1000	2.2711
Okura Creek	12	1.2000	4.5000	2.3500	2.6500	0.3297
Omaru Creek	12	14.0000	120.0000	63.5000	67.4167	10.9907
Onetangi Stream						
Opanuku Stream						
Otaki Creek	12	5.1000	57.0000	24.0000	26.7750	4.9977
Otara Creek (East Tamaki)	12	2.6000	44.0000	21.0000	21.8000	3.7405
Otara Creek (Kennel Hill)	12	1.8000	20.0000	8.2000	9.4667	1.7545
Oteha Stream	12	4.7000	63.0000	33.0000	30.3083	4.6791
Pakuranga Creek (Botany Rd)	12	3.4000	80.0000	8.5000	22.6833	7.8798
Pakuranga Creek (Greenmount Rd)	12	3.1000	170.0000	8.0500	27.8000	14.4731
Papakura Stream (Alfriston Rd)	12	0.5800	9.6000	2.7000	3.3400	0.7173
Papakura Stream (Porchester Rd)	12	0.7300	12.0000	4.6000	5.0508	1.0675
Puhinui Stream	12	9.5000	160.0000	19.0000	35.3750	12.1694
Rangitopuni River (NIWA operated)						
Riverhead Stream	12	3.5000	19.0000	6.4000	9.3833	1.8053
Vaughan Stream	12	1.0000	52.0000	5.1000	10.1917	4.0054
Wairoa Tributary						
Wairoa River	12	0.1500	1.8000	0.8800	0.9233	0.1400
Waitangi River					ND	
Waiwera River	12	0.1500	2.6000	0.6450	0.8500	0.1991
West Hoe Stream						
Whangamaire Stream						

Table 25Total Zinc ($\mu\text{g l}^{-1}$)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	13.00	86.00	31.00	37.67	5.683
Cascade Stream (Waitakere)				Not measured at this site		
Cascades Stream (Whakanewha)				Not measured at this site		
Hoteo River (NIWA operated)				Not measured at this site		
Kaukapakapa River				Not measured at this site		
Kumeu River	12	2.10	11.00	4.35	4.71	0.681
Lucas Creek	12	1.40	18.00	5.25	6.67	1.306
Mahurangi River (Forestry HQ)	12	0.15	3.90	0.59	1.03	0.338
Mahurangi River (Water Supply)	12	0.57	19.00	2.05	3.64	1.465
Makarau River	12	0.15	2.80	1.10	1.08	0.197
Matakana River	12	0.15	6.10	0.72	1.04	0.472
Ngakaroa Stream				Not measured at this site		
Nukumea Stream	12	0.81	5.90	1.25	1.83	0.398
Oakley Creek	12	5.40	46.00	24.00	22.56	3.718
Okura Creek	12	1.20	7.90	4.55	4.59	0.582
Omaru Creek	12	28.00	160.00	93.00	92.17	13.590
Onetangi Stream				Not measured at this site		
Opanuku Stream				Not measured at this site		
Otaki Creek	12	10.00	110.00	36.50	43.17	8.369
Otara Creek (East Tamaki)	12	5.50	78.00	27.00	29.63	5.671
Otara Creek (Kennel Hill)	12	3.70	38.00	12.00	14.51	2.853
Oteha Stream	12	9.10	110.00	47.50	46.68	8.106
Pakuranga Creek (Botany Rd)	12	9.90	100.00	18.00	33.24	9.208
Pakuranga Creek (Greenmount Rd)	12	7.90	200.00	17.50	39.48	17.104
Papakura Stream (Alfriston Rd)	12	1.00	11.00	4.55	4.95	0.785
Papakura Stream (Porchester Rd)	12	1.10	15.00	6.70	7.07	1.469
Puhinui Stream	12	19.00	180.00	25.50	47.75	13.389
Rangitopuni River (NIWA operated)				Not measured at this site		
Riverhead Stream	12	4.80	22.00	8.45	11.41	1.807
Vaughan Stream	12	1.00	72.00	8.05	14.89	5.527
Wairoa Tributary				Not measured at this site		
Wairoa River	12	0.39	2.90	1.20	1.33	0.231
Waitangi River				Not measured at this site		
Waiwera River	12	0.41	3.00	0.92	1.27	0.235
West Hoe Stream				Not measured at this site		
Whangamaire Stream				Not measured at this site		

Table 26Soluble Lead ($\mu\text{g l}^{-1}$)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.09	0.50	0.28	0.28	0.041
Cascade Stream (Waitakere)	ND			Not measured at this site		
Cascades Stream (Whakanewha)	ND			Not measured at this site		
Hoteo River (NIWA operated)	ND			Not measured at this site		
Kaukapakapa River	ND			Not measured at this site		
Kumeu River	12	0.03	0.23	0.09	0.11	0.021
Lucas Creek	12	0.03	0.09	0.03	0.05	0.009
Mahurangi River (Forestry HQ)	12	0.03	0.06	0.03	0.03	0.003
Mahurangi River (Water Supply)	12	0.03	0.09	0.03	0.03	0.005
Makarau River	12	0.03	0.06	0.03	0.03	0.003
Matakana River	12	0.03	0.07	0.03	0.03	0.004
Ngakaroa Stream	ND			Not measured at this site		
Nukumea Stream	12	0.03	0.03	0.03	0.03	0.000
Oakley Creek	12	0.06	0.27	0.15	0.14	0.019
Okura Creek	12	0.03	0.09	0.03	0.04	0.007
Omaru Creek	12	0.03	0.24	0.08	0.10	0.023
Onetangi Stream	ND			Not measured at this site		
Opanuku Stream	ND			Not measured at this site		
Otaki Creek	12	0.03	0.26	0.06	0.09	0.021
Otara Creek (East Tamaki)	12	0.03	0.15	0.08	0.09	0.015
Otara Creek (Kennel Hill)	12	0.03	0.15	0.06	0.06	0.011
Oteha Stream	12	0.03	0.15	0.06	0.07	0.014
Pakuranga Creek (Botany Rd)	12	0.03	0.32	0.03	0.07	0.025
Pakuranga Creek (Greenmount Rd)	12	0.03	0.07	0.03	0.03	0.004
Papakura Stream (Alfriston Rd)	12	0.03	0.33	0.04	0.08	0.026
Papakura Stream (Porchester Rd)	12	0.03	0.08	0.03	0.05	0.008
Puhinui Stream	12	0.03	0.47	0.09	0.12	0.037
Rangitopuni River (NIWA operated)	ND			Not measured at this site		
Riverhead Stream	12	0.03	0.10	0.03	0.04	0.007
Vaughan Stream	12	0.03	0.12	0.03	0.04	0.009
Wairoa Tributary	ND			Not measured at this site		
Wairoa River	12	0.03	0.07	0.03	0.04	0.006
Waitangi River	ND			Not measured at this site		
Waiwera River	12	0.03	0.06	0.03	0.03	0.003
West Hoe Stream	ND			Not measured at this site		
Whangamaire Stream	ND			Not measured at this site		

Table 27Total Lead ($\mu\text{g l}^{-1}$)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	0.56	6.80	1.70	2.30	0.567
Cascade Stream (Waitakere)				Not measured at this site		
Cascades Stream (Whakanewha)				Not measured at this site		
Hoteo River (NIWA operated)				Not measured at this site		
Kaukapakapa River				Not measured at this site		
Kumeu River	12	0.23	0.75	0.42	0.42	0.048
Lucas Creek	12	0.06	1.20	0.15	0.26	0.093
Mahurangi River (Forestry HQ)	12	0.03	0.29	0.04	0.06	0.021
Mahurangi River (Water Supply)	12	0.03	0.80	0.07	0.12	0.062
Makarau River	12	0.03	0.19	0.07	0.08	0.014
Matakana River	12	0.03	0.45	0.06	0.08	0.034
Ngakaroa Stream				Not measured at this site		
Nukumea Stream	12	0.03	0.66	0.07	0.12	0.051
Oakley Creek	12	0.45	3.30	0.82	1.30	0.282
Okura Creek	12	0.03	0.49	0.14	0.18	0.035
Omaru Creek	12	0.06	1.30	0.36	0.43	0.099
Onetangi Stream				Not measured at this site		
Opanuku Stream				Not measured at this site		
Otaki Creek	12	0.30	5.40	0.63	1.25	0.413
Otara Creek (East Tamaki)	12	0.16	1.50	0.29	0.45	0.110
Otara Creek (Kennel Hill)	12	0.13	1.50	0.29	0.42	0.110
Oteha Stream	12	0.03	2.50	0.24	0.44	0.194
Pakuranga Creek (Botany Rd)	12	0.12	0.98	0.34	0.43	0.077
Pakuranga Creek (Greenmount Rd)	12	0.08	0.73	0.23	0.32	0.061
Papakura Stream (Alfriston Rd)	12	0.03	1.60	0.19	0.41	0.142
Papakura Stream (Porchester Rd)	12	0.03	0.50	0.17	0.18	0.043
Puhinui Stream	12	0.17	2.60	0.44	0.64	0.191
Rangitopuni River (NIWA operated)				Not measured at this site		
Riverhead Stream	12	0.03	0.31	0.10	0.12	0.028
Vaughan Stream	12	0.03	1.60	0.10	0.25	0.127
Wairoa Tributary				Not measured at this site		
Wairoa River	12	0.03	0.39	0.12	0.15	0.033
Waitangi River				Not measured at this site		
Waiwera River	12	0.03	0.16	0.07	0.07	0.011
West Hoe Stream				Not measured at this site		
Whangamaire Stream				Not measured at this site		

Table 28
Escherichia coli (cfu/100ml)

Site	Count	Minimum	Maximum	Median	Mean	Standard Error
Avondale Stream	12	680	12000	3500	5118	1201
Cascade Stream (Waitakere)	12	2	2100	30	203	173
Cascades Stream (Whakanewha)	11	10	1200	58	201	112
Hoteo River (NIWA operated)	12	55	980	207	284	74
Kaukapakapa River	12	140	2600	410	616	194
Kumeu River	12	54	6500	465	1126	536
Lucas Creek	12	90	4500	355	1004	376
Mahurangi River (Forestry HQ)	12	45	1400	245	414	120
Mahurangi River (Water Supply)	12	36	4600	120	520	373
Makarau River	12	90	960	250	468	106
Matakana River	12	18	2400	155	339	190
Ngakaroa Stream	12	200	2800	405	974	286
Nukumea Stream	12	1	2100	28	226	172
Oakley Creek	12	390	17000	3000	4715	1453
Okura Creek	12	98	14000	465	2744	1295
Omaru Creek	12	200	2300	525	872	211
Onetangi Stream	11	3	300	44	67	27
Opanuku Stream	12	140	8700	340	1045	698
Otaki Creek	12	790	14000	3600	5358	1294
Otara Creek (East Tamaki)	12	230	9800	705	1648	781
Otara Creek (Kennel Hill)	12	430	6400	1850	2462	611
Oteha Stream	12	36	5900	295	1165	497
Pakuranga Creek (Botany Rd)	12	260	23000	2800	5186	1940
Pakuranga Creek (Greenmount Rd)	12	99	6300	490	1546	564
Papakura Stream (Alfriston Rd)	12	210	65000	460	8426	5479
Papakura Stream (Porchester Rd)	12	260	53000	3900	11178	4776
Puhinui Stream	12	81	4500	840	1352	431
Rangitopuni River (NIWA operated)	12	69	2419	276	479	192
Riverhead Stream	12	3	600	74	174	65
Vaughan Stream	12	72	8500	605	1374	689
Wairoa Tributary	12	9	1000	125	335	109
Wairoa River	12	170	910	345	466	77
Waitangi River	12	99	2600	470	747	216
Waiwera River	12	130	1200	280	428	100
West Hoe Stream	12	2	1400	32	190	115
Whangamaire Stream	12	68	8000	590	1795	766

9 References

- APHA. 2012. *Standard methods for the examination of water and wastewater (22nd Edition)*. American Public Health Association.
- ARC. 1982. *Baseline data on water quality in the Auckland water region obtained from 1977-1982*. Auckland Regional Water Board Technical Publication 22.
- ARC. 1992. *Tamaki catchment and estuary: review of water quality*. Auckland Regional Council Technical Publication 20.
- ARC. 2007. *State of the environment monitoring: rivers and streams water quality data report 2005*. Auckland Regional Council Technical Publication 327.
- ARC. 2008. *State of the environment monitoring: rivers and streams water quality data report 2006*. Auckland Regional Council Technical Publication 342.
- Canadian Council of Ministers of the Environment. 2001. Canadian water quality guidelines for the protection of aquatic life: CCME water quality index 1.0, user's manual. In. *Canadian environmental quality guidelines*, 1999, Canadian Council of Ministers of the Environment, Winnipeg.
- Chapman, D. (Ed). 1996. *Water quality assessments; a guide to the use of biota, sediments and water in environmental monitoring (2nd Edition)*. E and FN Spon, London.
- Lockie, S and Neale, M.W. 2012. *State of the Environment Monitoring: River Water Quality Annual Report 2011*. Auckland Council Technical Report 2012/013.
- Mason, C.F. 1998. Biology of Freshwater Pollution. Longman, U.K.
- Neale, M.W. 2010. *State of the environment monitoring: river water quality annual report 2009*. Auckland Regional Council Technical Report 2010/030.
- Scarsbrook, M. 2007. *River water quality; state and trends in the Auckland region*. Auckland Regional Council Technical Publication 336.
- Snelder, T., Biggs, B. and Weatherhead, M. 2004 *New Zealand river environment classification user guide*. Ministry for the Environment, Wellington.
- Snelder, T., Scarsbrook, M. and Larned, S. 2006. Assessment of the national pool of river water quality monitoring sites using the river environment classification. Ministry for the Environment, Wellington.
- Storey, R and Wadhwa, S. 2009. *An assessment of the lengths of permanent, intermittent and ephemeral streams in the Auckland region*. Auckland Regional Council Technical Report 2009/028.
- U.S. EPA. 1994. *Method 200.8: Determination of Trace Elements in Waters and Wastes by ICP-MS (Revision 5.4)*. U.S. Environmental Protection Agency, Ohio.