

# State of the Environment Monitoring: River Water Quality Annual Report 2012

July 2013      Technical Report 2013/032





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Technical Report 2013/032

Auckland Council  
Technical Report 2013/032  
ISSN 2230-4525 (Print)  
ISSN 2230-4533 (Online)

ISBN 978-1-927266-02-1 (Print)  
ISBN 978-1-927266-03-8 (PDF)

This report has been peer reviewed by the Peer Review Panel using the Panel's terms of reference

Submitted for review on 24 May 2013  
Review completed on 22 July 2013  
Reviewed by one reviewer

Approved for Auckland Council publication by:



Name: Grant Barnes

Position: Manager, Research, Investigations and Monitoring Unit

Date: 22 July 2013

Recommended citation:

Lockie, S and Neale, M W (2013). State of the environment monitoring: river water quality annual report 2012. Auckland Council technical report, TR2013/032

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# State of the Environment Monitoring: River Water Quality Annual Report 2012

Stacey E Lockie  
Martin W Neale

Research, Investigations and Monitoring Unit  
Auckland Council

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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 2012 calendar year.

Water quality is assessed monthly at 34 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 2012 the best river water quality was in the Cascade Stream and Opanuku Stream, followed by Wairoa Tributary and West Hoe Stream, all of which were classified as having excellent water quality. Low water quality was observed in streams in and around the urban area, as well as a selection of rural sites. Pakuranga Creek (Greenmount Drive) had the lowest ranked water quality in 2012.

## 2 Introduction

### 2.1 Auckland's rivers

The Auckland region has an estimated 16500 km of permanently flowing rivers, which increases to 28240 km when intermittent and ephemeral rivers are included (Storey and Wadhwa, 2009). As no mainland location in the region is greater than 20 km from the coast, the catchment areas of each river are relatively small. This means that most of the rivers reach the sea before they merge with others to form large rivers. Consequently, most rivers are first and second order (Table 1), meaning they are relatively small, with most less than a few metres wide.

The relatively low elevation 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.

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. These pressures extend to rural areas due to their close proximity to the city.

**Table 2**

Catchment land cover for rivers in Auckland and New Zealand.

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

## 2.3 Auckland Council monitoring programme

The overall aim 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 the effects of environmental stressors and the effectiveness of management approaches to be assessed and evaluated. To meet this aim, 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. 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 river quality monitoring programmes, of which the Water Quality Programme is one. The Water Quality Programme monitors the physical, chemical and microbiological properties of rivers at 34 sites. This monitoring provides information on the temperature, amounts of nutrients, oxygen, sediment and other pollutants in the sampled rivers. The results enable us to assess the life-supporting capacity of the river (how suitable it is for supporting plant and animal life) and its suitability for human use.

The River Water Quality Programme initially commenced with eight 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. Between 2009 and 2011, 31 sites were monitored. Three new sites were added to the network at the beginning of 2012, bringing the current total to 34 sites. Each of the 34 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 us to extrapolate the results to infer the likely water quality of rivers that we do not sample.

## 2.4 Programme objectives

The information generated by the River Water Quality Programme, in conjunction with the Council's other monitoring programmes, is used to meet the following objectives;

- Satisfy the obligations for state of the environment monitoring as required by section 35 of the Resource Management Act 1991.
- Contribute to community outcome monitoring required by the Local Government Act (2002).
- Help inform the efficiency and efficacy of policy initiatives and strategies.
- Assist with the identification of large scale or cumulative impacts of contaminants and disturbance associated with varying land uses.
- Provide baseline, regionally representative data to support preparation of environmental effects assessments required through the resource consent process.
- Address queries from the public and promote awareness of freshwater issues.

A key issue is to manage the effects of development on our natural environment. This includes balancing the needs for sustainable environmental management with the community's social, economic and cultural well being.

Specific objectives include managing and minimising the adverse effects of present and future urban and rural development, growth and intensification across the region. Water quality provides information on the condition of the region's streams and feedback on management actions. Such information is necessary to confirm that Council's management strategies are effective in sustaining stream functions and uses.

## 2.5 Report scope

This report provides a tabular and graphical summary of the data collected from the 34 sites in the River Water Quality Programme during the 2012 calendar year. Furthermore,

the 2012 water quality data is 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 23<sup>rd</sup> annual report since the inception of the monitoring programme, and the eighth 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](http://www.aucklandcouncil.govt.nz/publications)).

## **3 Methods**

### **3.1 Sample sites**

The current River Water Quality Programme operates with a network of 34 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 January 2012. The location of the 34 sites is displayed on page 13 (Figure 1).

### **3.2 Monitoring network design**

The sampling network began with eight sites in 1977-78 with the objective of providing long-term data on water quality in the Auckland region (ARC, 1982). The current network was designed to provide broad geographical coverage and to cover the four major land cover classes (native forest, exotic forest, rural and urban) that exist in the Auckland region (ARC, 2008).

### **3.3 Programme changes**

The programme was last reviewed in 2008 and subsequent changes were described in the 2009 Annual Report (Neale, 2010).

In June 2011, it was discovered that the *in situ* water quality measurements were producing some inaccurate pH values. From July 2011 pH was measured both *in situ* with a handheld probe, and at Watercare laboratories. The pH data in this report is laboratory tested data.

Three new sites were added in January 2012; Avondale Stream, Nukumea Stream and Papakura Stream (Alfriston Road). Avondale Stream and Papakura Stream (Alfriston Rd) were added to evaluate the effectiveness of restoration projects. Nukumea was added as a reference site to supplement the three existing sites (Cascades Stream, Wairoa Tributary and West Hoe Stream). There were no further site changes during 2012.

### **3.4 Sampling methodology**

For the 32 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). Six parameters are determined in the field; the remainder are determined by laboratory tests.

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). Metals 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).

**Table 3**

Sites sampled in 2012 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	1735628	5916378	Native forest	1978
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	2012
Oakley Creek	1751963	5917636	Urban	1994
Okura Creek	1751405	5938716	Rural	2003
Omaru Creek	1766268	5916749	Urban	1985
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 34 sampling sites used in the Auckland Council River Water Quality Programme.



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>.

### 3.5 Data processing and analysis

All field and laboratory data generated by 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 2012 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 using the default percentile functions. The boxes represent the inter-quartile range (25<sup>th</sup> to 75<sup>th</sup> percentile) and the whiskers represent the 5<sup>th</sup> and 95<sup>th</sup> percentiles. The median is shown as a line in each box.
- Summary tables which provide a statistical summary of each parameter at each site. These were produced using the summary statistics function in Excel.
- Water Quality Indices were produced using the data for seven water quality parameters to allow a water quality class to be assigned to each site. These were produced using an Excel workbook produced by the Canadian Council of Ministers of the Environment (2001). The application of this method to the Council's water quality data is described in Appendix 1.

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

**Table 4**

Parameters tested in 2012 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 <sup>-1</sup>	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 <sup>-1</sup>	APHA (2005) 2540 D
Turbidity	Turb	NTU	APHA (2005) 2130 B
Ammoniacal nitrogen	Ammonia	mg N l <sup>-1</sup>	APHA (2005) 4500-NH3 G
Total oxidised nitrogen	TON	mg N l <sup>-1</sup>	APHA (2005) 4500-NO3 F
Kjedahl nitrogen	KN	mg N l <sup>-1</sup>	By calculation
Total nitrogen	TN	mg N l <sup>-1</sup>	APHA (2005) 4500-N C
Soluble reactive phosphorus	SRP	mg P l <sup>-1</sup>	APHA (2005) 4500-P F
Total phosphorus	TP	mg P l <sup>-1</sup>	APHA (2005) 4500-P B, F
Soluble copper	Cu sol	µg l <sup>-1</sup>	USEPA 200.8
Total copper	Cu tot	µg l <sup>-1</sup>	USEPA 200.8
Soluble zinc	Zn sol	µg l <sup>-1</sup>	USEPA 200.8
Total zinc	Zn tot	µg l <sup>-1</sup>	USEPA 200.8
Soluble lead	Pb sol	µg l <sup>-1</sup>	USEPA 200.8
Total Lead	Pb tot	µg l <sup>-1</sup>	USEPA 200.8
Eschericia coli	E. coli	cfu/100ml	APHA (2005) 9213 F

## **4 Results**

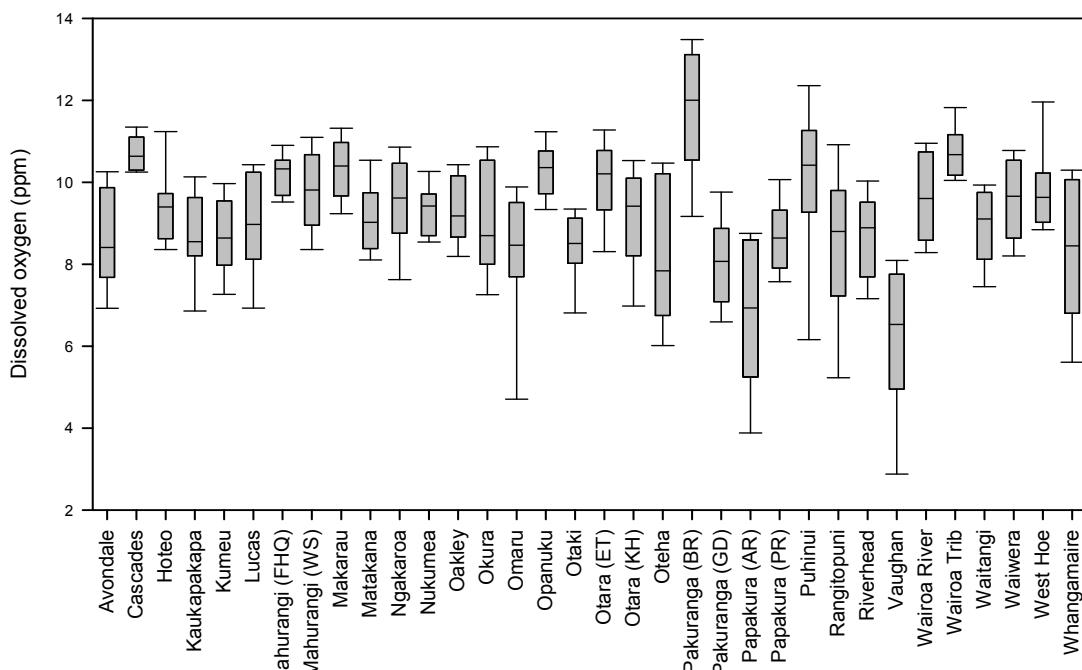
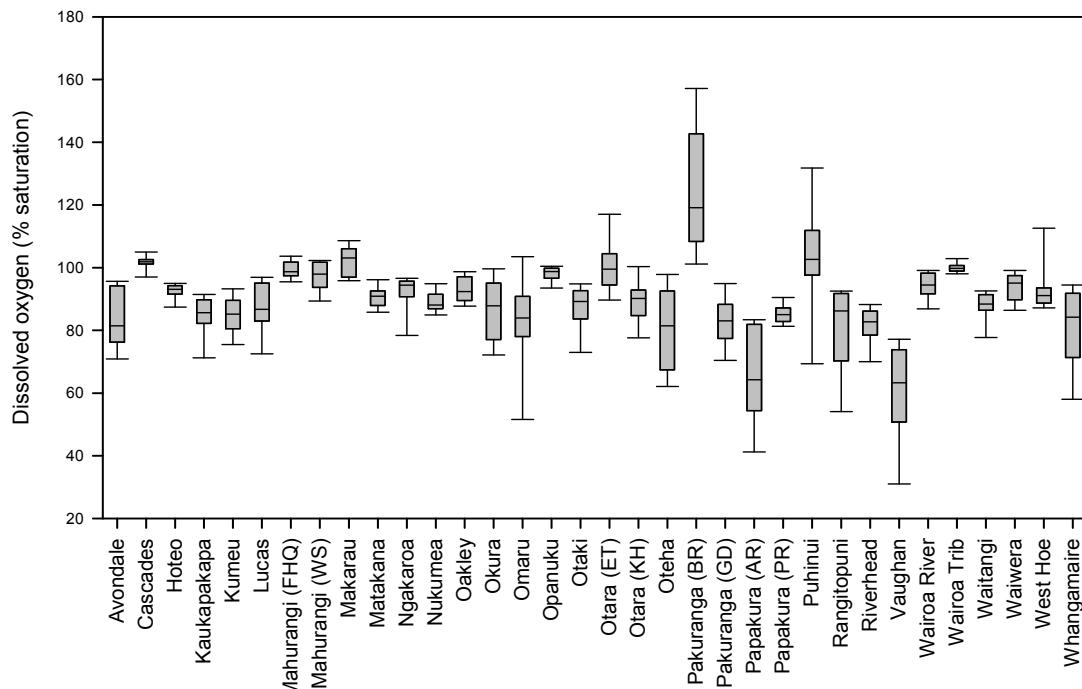
The data from the 2012 calendar year are presented as;

- box plots which display the variation in the measured parameters at each of the sites (Section 4.1).
- tables which provide a statistical summary of each parameter at each site (Section 4.2)
- water quality indices produced using the data for seven water quality parameters allowing a water quality class to be assigned to each site (Section 4.3)

## 4.1 Box plots

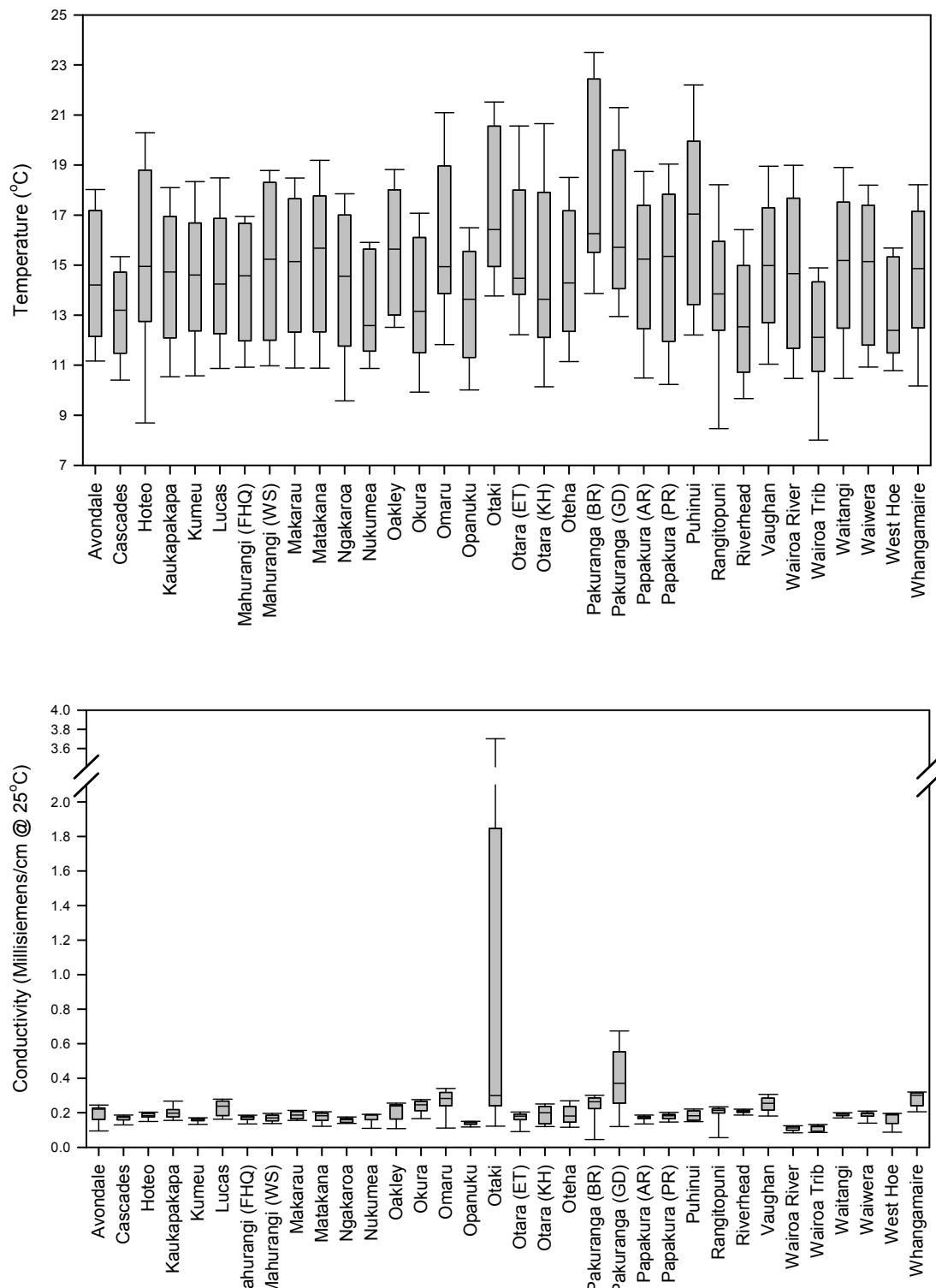
**Figure 3**

Box plots showing the variation in dissolved oxygen % saturation (upper plot) and ppm (lower plot) at the 34 sites using data collected during the 2012 calendar year.



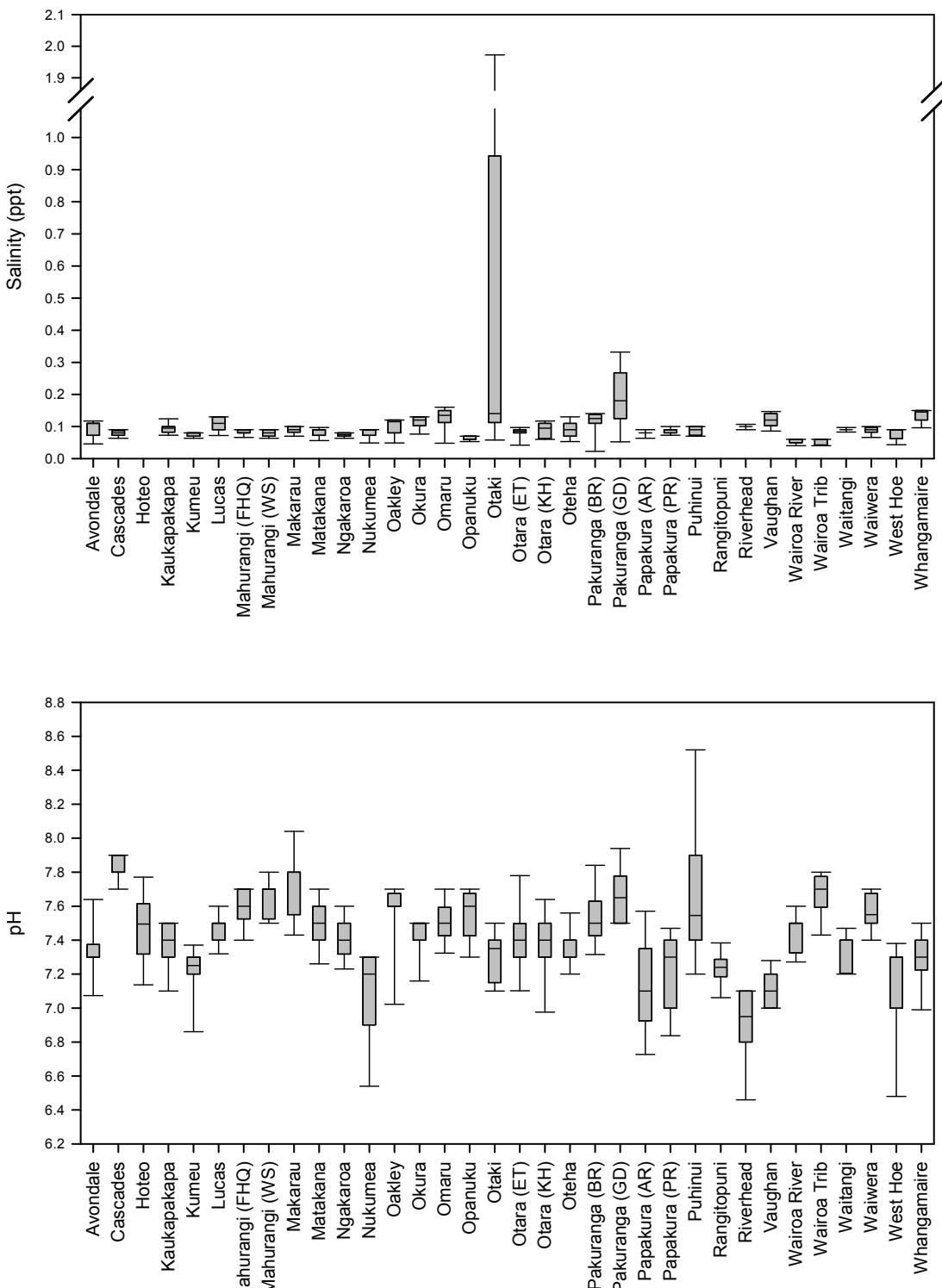
**Figure 4**

Box plots showing the variation in temperature (upper plot) and conductivity (lower plot) at the 34 sites using data collected during the 2012 calendar year. Note the axis break and scale change on the y-axis of the conductivity plot.



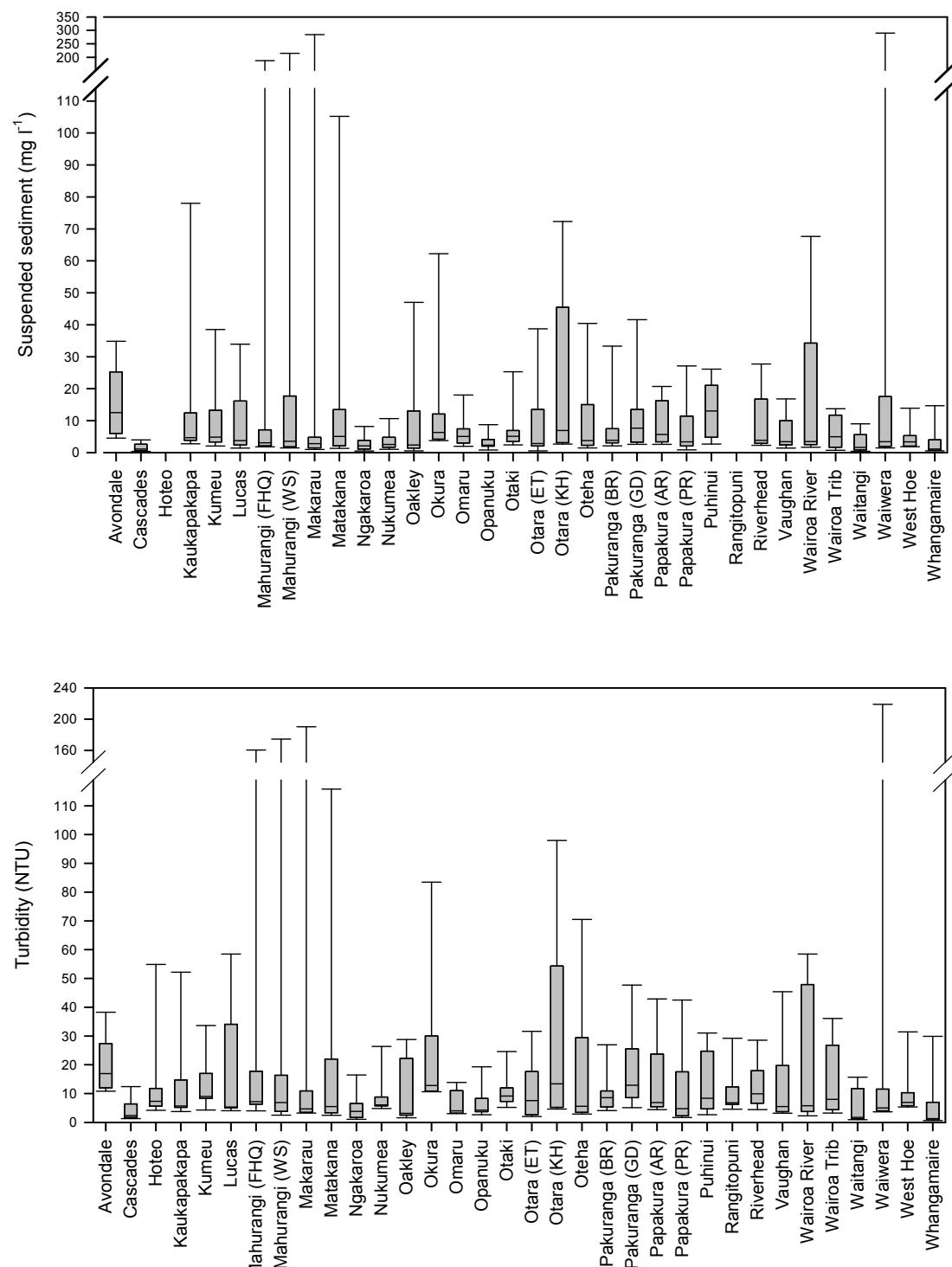
**Figure 5**

Box plots showing the variation in salinity (upper plot) and pH (lower plot) at the 34 sites using data collected during the 2012 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.



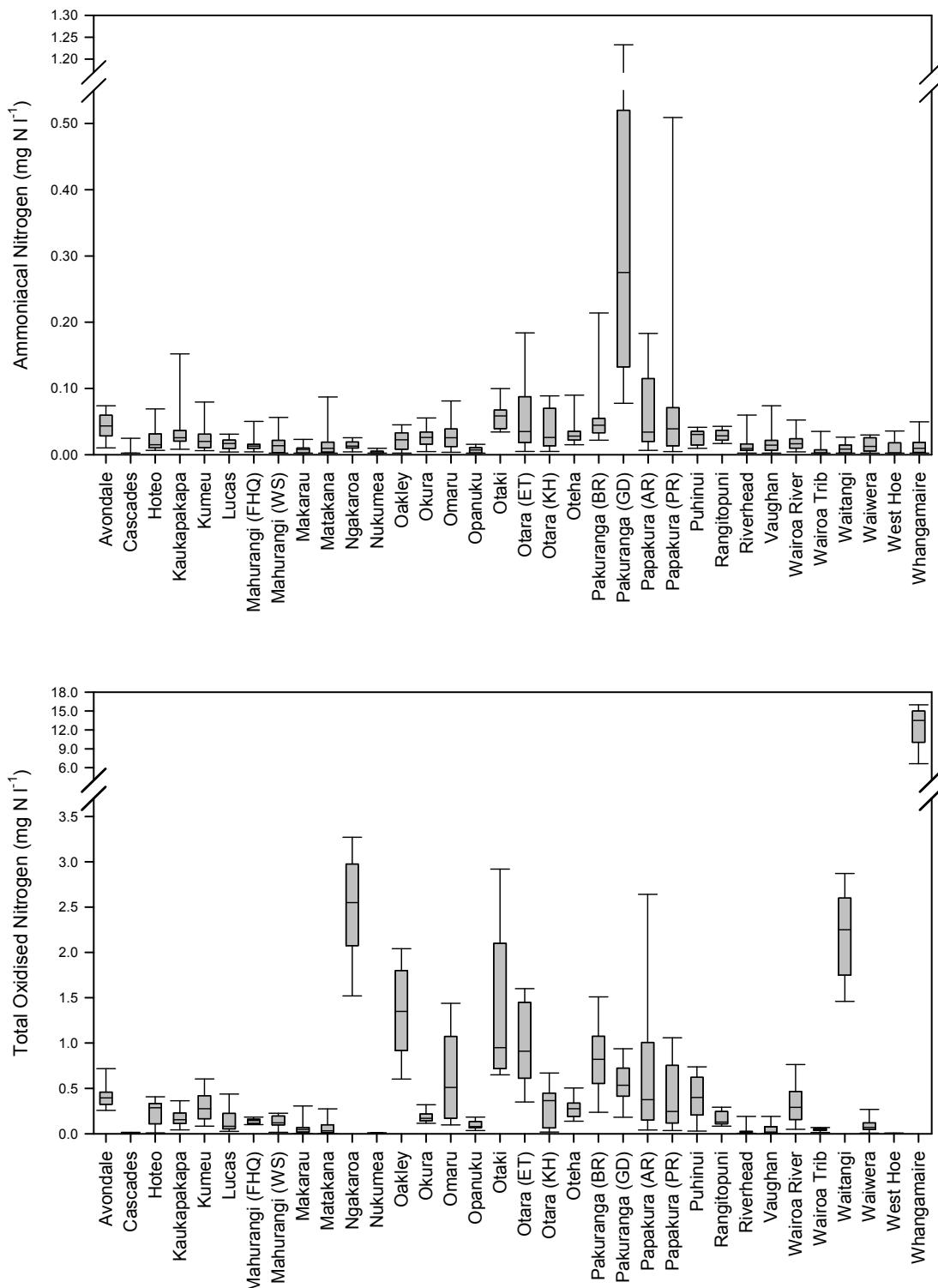
**Figure 6**

Box plots showing the variation in suspended sediment (upper plot) and turbidity (lower plot) at the 34 sites using data collected during the 2012 calendar year. Note the axis break and scale change on the y-axis of both plots. Also note that no suspended sediment data is collected for Hoteo River and Rangitopuni River.



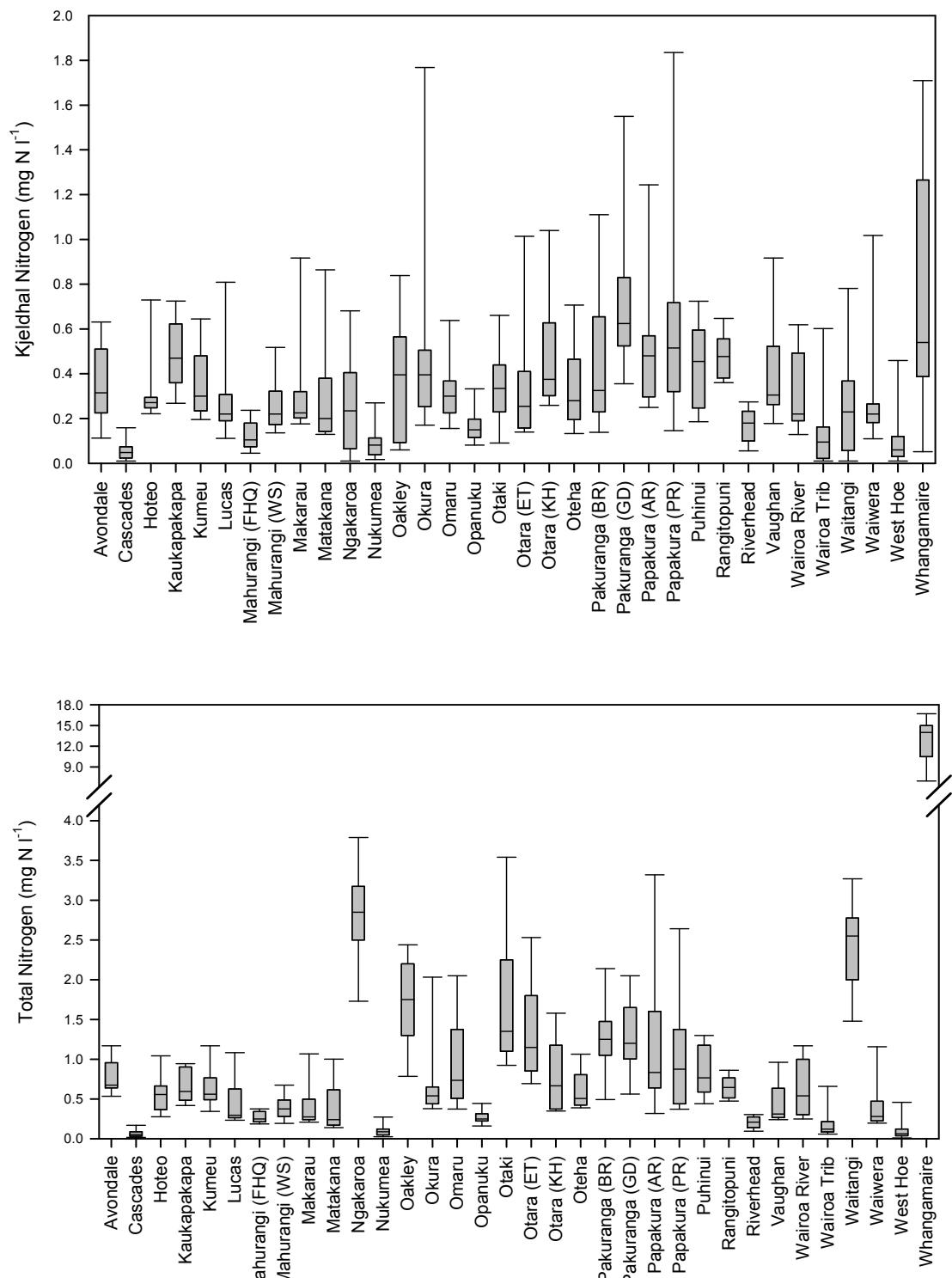
**Figure 7**

Box plots showing the variation in ammoniacal nitrogen (upper plot) and total oxidised nitrogen (lower plot) at the 34 sites using data collected during the 2012 calendar year. Note the axis break and scale change on the y-axis of both plots.



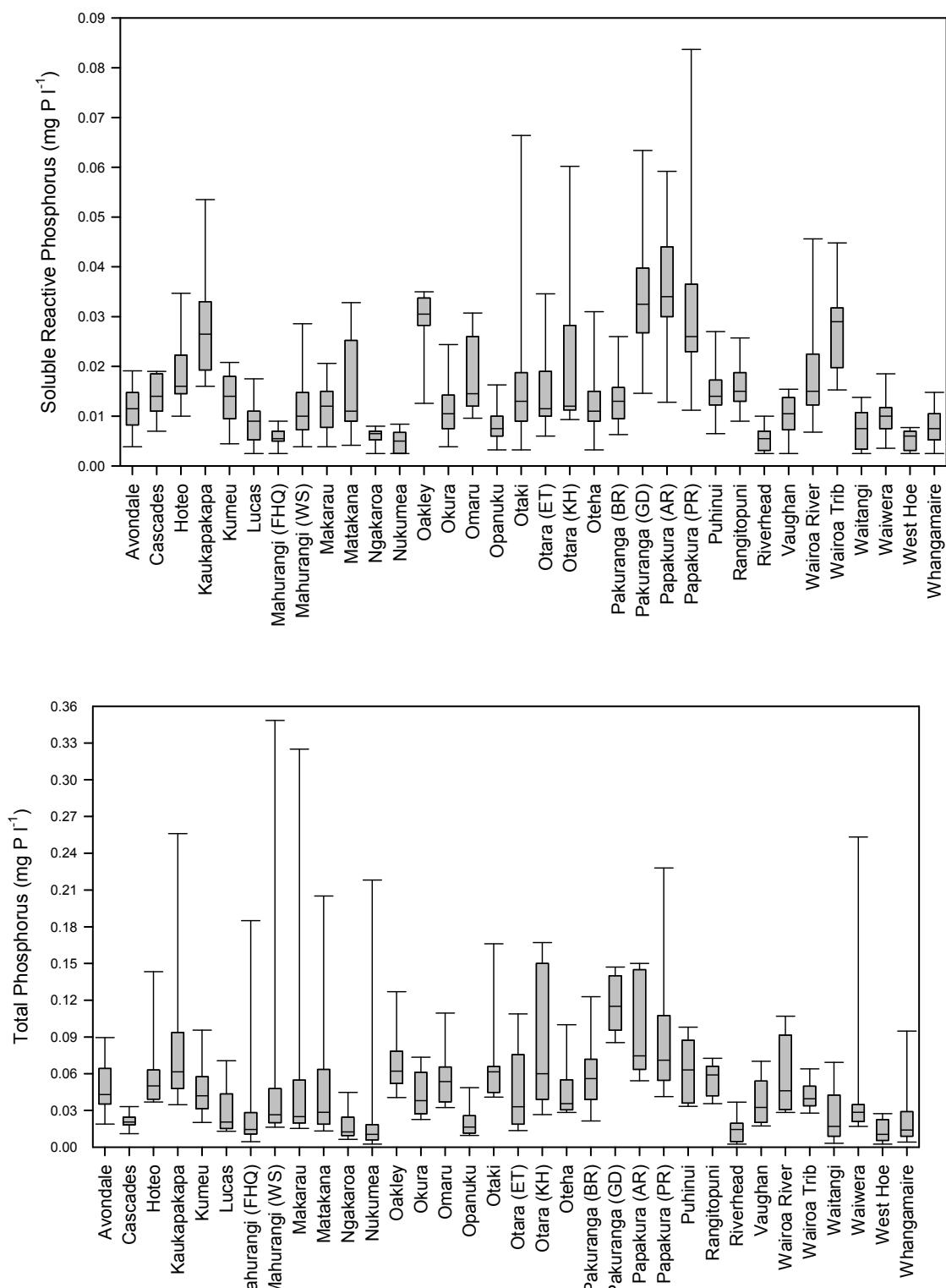
**Figure 8**

Box plots showing the variation in Kjeldhal nitrogen (upper plot) and total nitrogen (lower plot) at the 34 sites using data collected during the 2012 calendar year. Note the axis break and scale change on the y-axis of the total nitrogen plot.



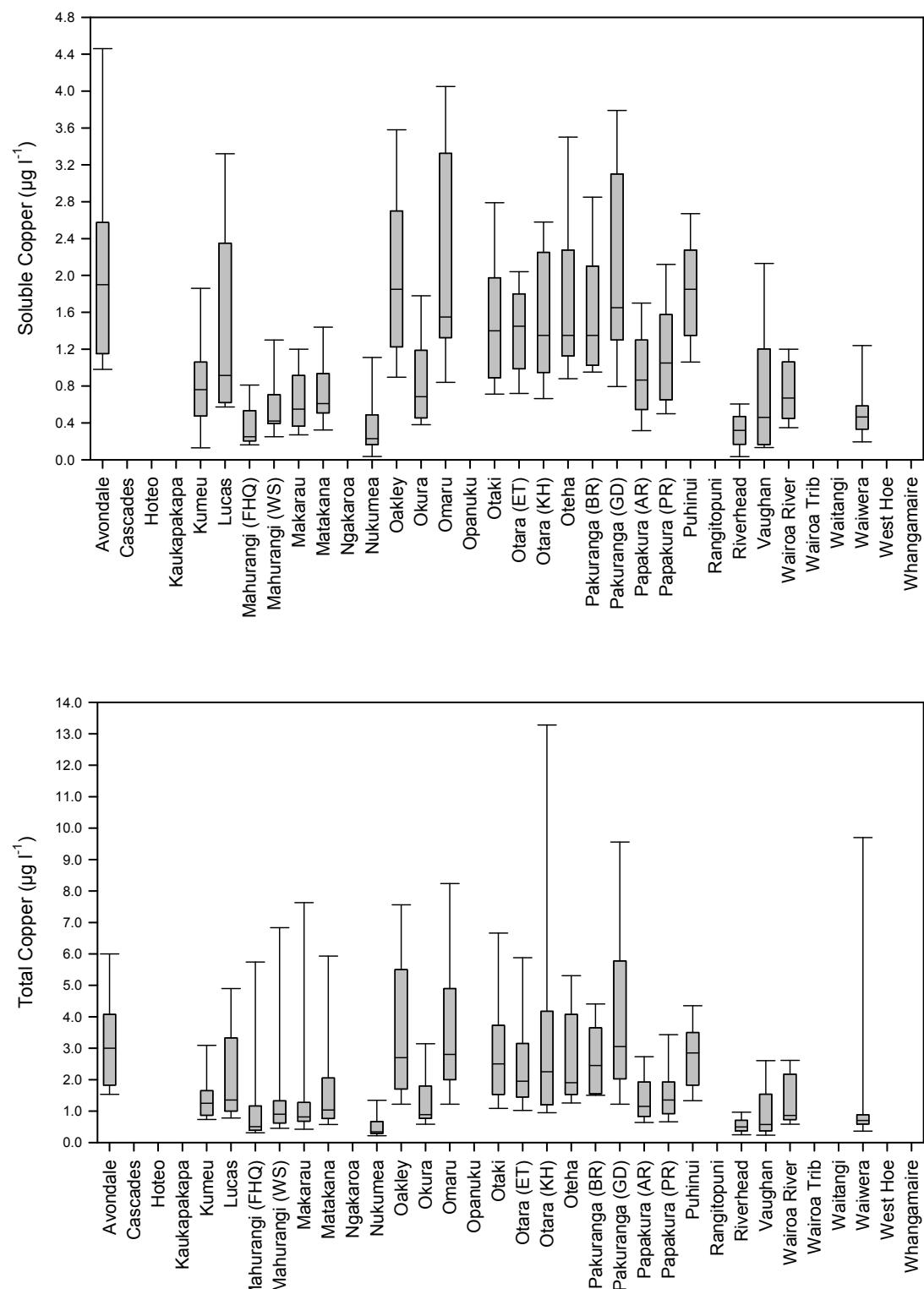
**Figure 9**

Box plots showing the variation in soluble reactive phosphorus (upper plot) and total phosphorus (lower plot) at the 34 sites using data collected during the 2012 calendar year.



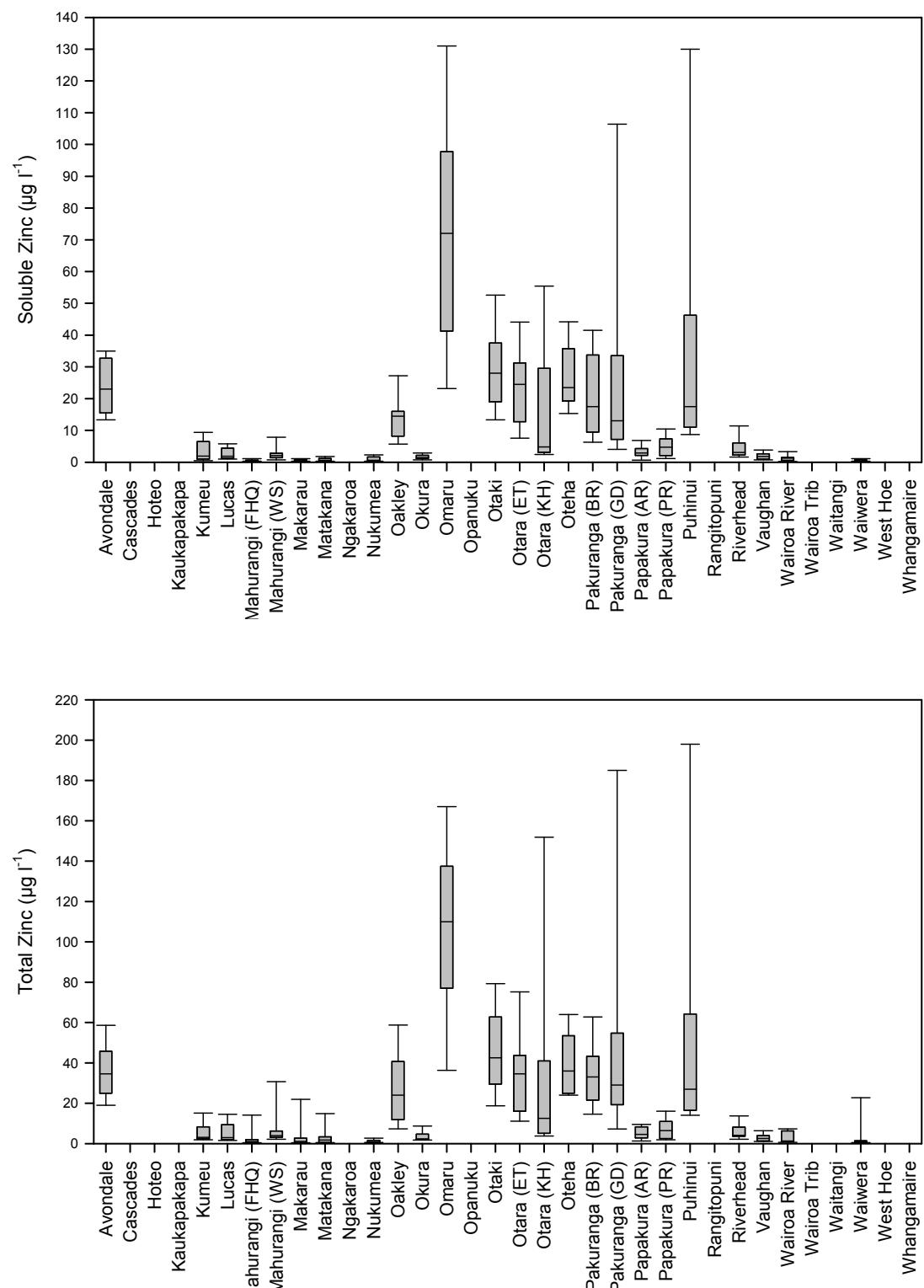
**Figure 10**

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 2012 calendar year.



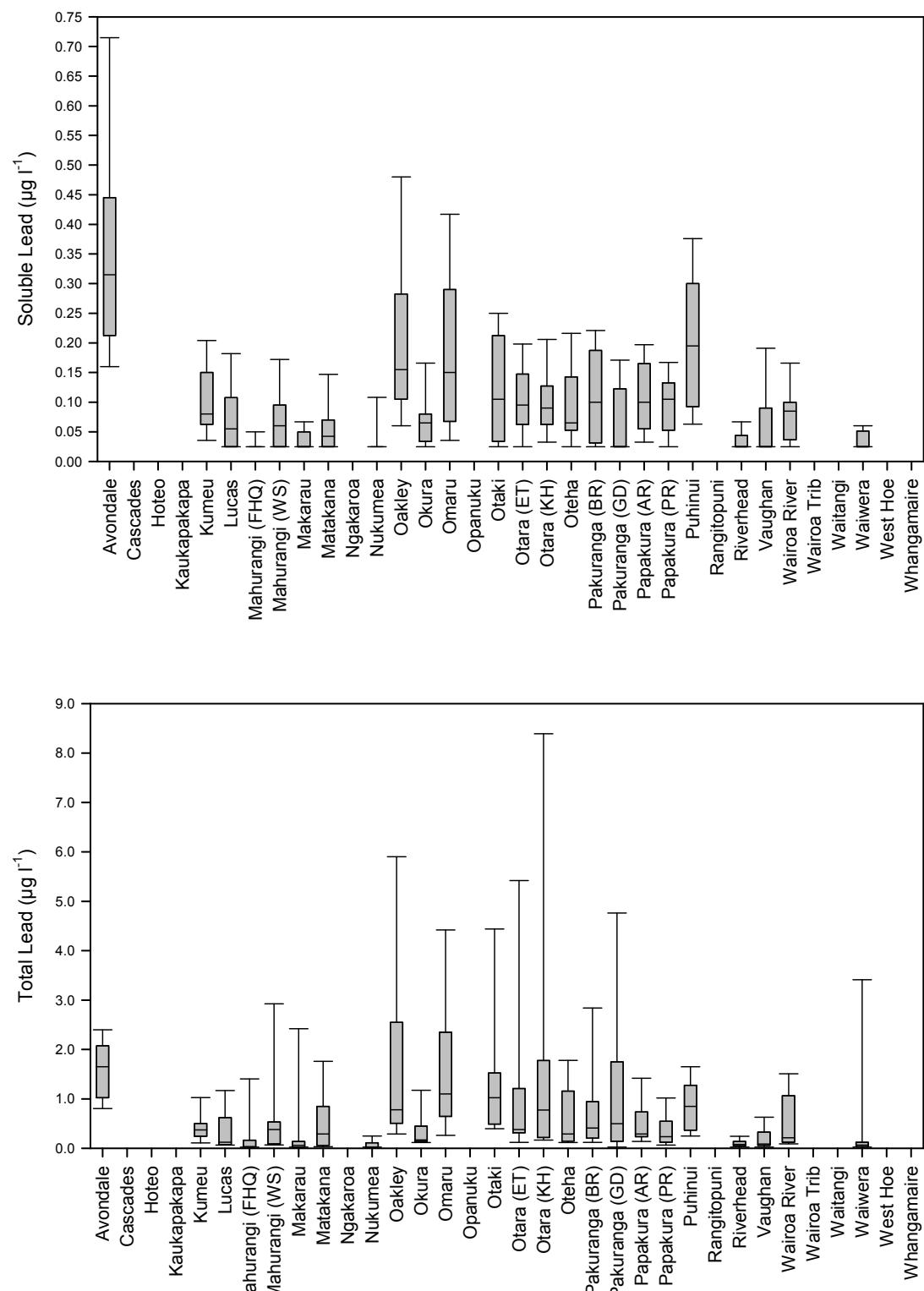
**Figure 11**

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 2012 calendar year.



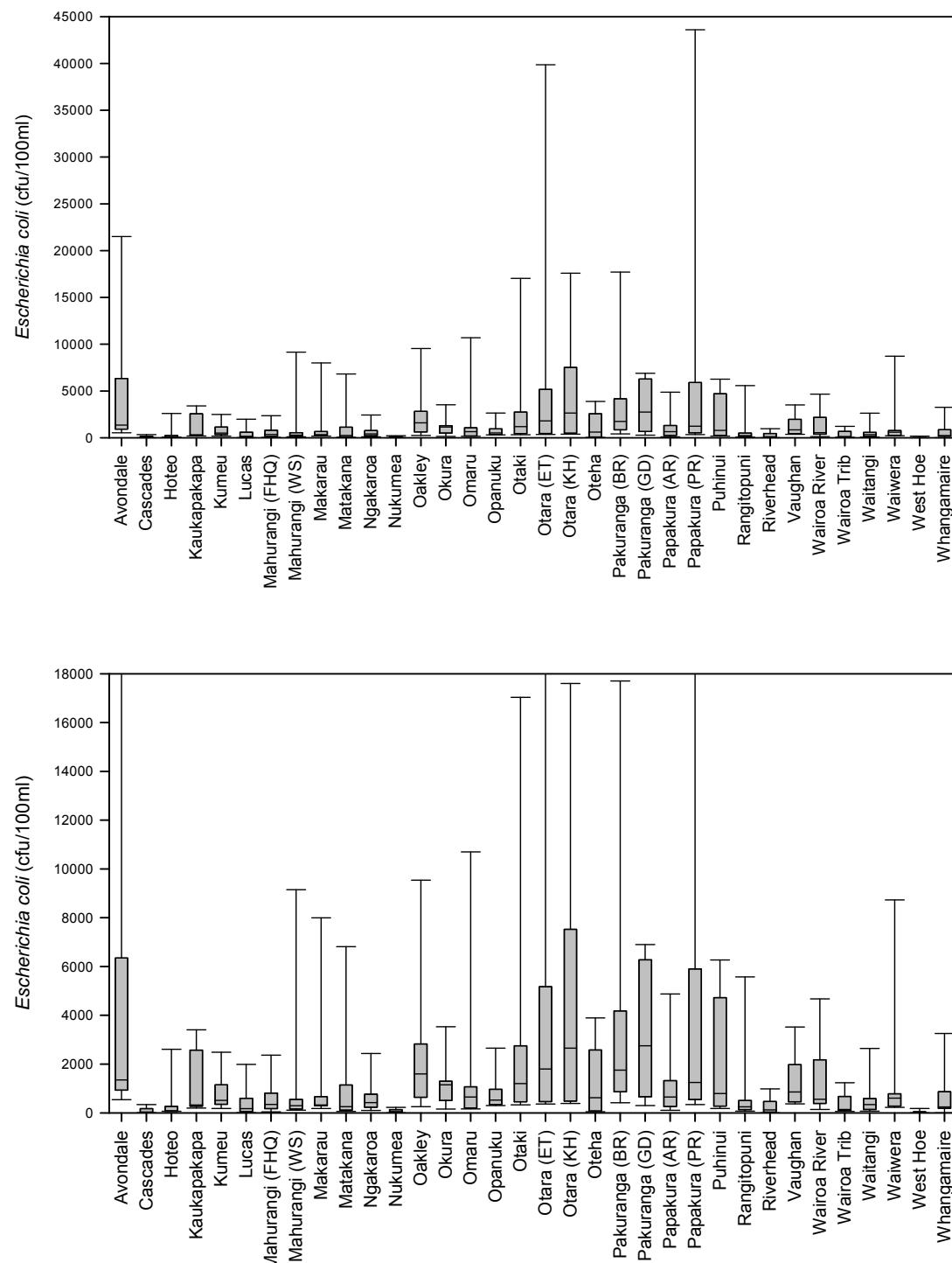
**Figure 12**

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 2012 calendar year.



**Figure 13**

Box plot showing the variation in *Escherichia coli* at the 34 sites using data collected during the 2012 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 18000 to provide greater resolution for sites with lower *Escherichia coli* levels.



## 4.2 Summary tables

**Table 6**  
Dissolved oxygen (% saturation)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	69.5	95.7	81.5	83.8	2.66
Cascade Stream	12	95.3	105.0	101.9	101.8	0.70
Hoteo River (NIWA operated)	12	87.3	95.0	93.1	92.4	0.74
Kaukapakapa River	12	68.8	91.6	85.6	84.7	1.87
Kumeu River	12	75.0	94.3	85.2	84.8	1.69
Lucas Creek	12	70.9	97.4	86.7	87.2	2.37
Mahurangi River (Forestry HQ)	12	95.0	104.2	98.7	99.3	0.77
Mahurangi River (Water Supply)	12	88.6	102.3	97.9	97.2	1.33
Makarau River	12	95.7	109.3	103.1	102.0	1.37
Matakana River	12	85.1	96.6	90.9	90.8	0.95
Ngakaroa Stream	12	74.1	96.9	94.4	92.1	1.79
Nukumea Stream	12	84.5	95.4	88.1	89.0	0.93
Oakley Creek	12	87.6	99.0	92.4	93.1	1.14
Okura Creek	12	71.4	100.1	87.9	86.7	2.82
Omaru Creek	12	41.2	105.2	84.0	82.8	4.55
Opanuku Stream	12	93.2	100.5	98.8	98.1	0.69
Otaki Creek	12	71.4	95.2	89.2	87.4	2.07
Otara Creek (East Tamaki)	12	88.9	117.4	99.6	100.8	2.52
Otara Creek (Kennel Hill)	12	77.5	100.9	90.2	89.0	2.09
Oteha Stream	12	60.4	98.8	81.5	79.7	3.67
Pakuranga Creek (Botany Rd)	12	98.7	157.6	119.1	125.1	5.69
Pakuranga Creek (Greenmount Drive)	12	69.9	95.6	83.0	82.7	2.28
Papakura Stream (Alfriston-Ardmore Rd)	12	37.6	83.8	64.3	66.1	4.39
Papakura Stream (Porchester Rd)	12	81.3	91.7	85.0	85.1	0.87
Puhinui Stream	12	61.2	136.5	102.7	102.9	5.22
Rangitopuni River (NIWA operated)	12	48.5	92.6	86.2	80.4	3.95
Riverhead Forest Stream	12	68.9	88.8	82.7	81.3	1.74
Vaughan Stream	12	22.9	77.7	63.3	60.3	4.59
Wairoa Tributary	12	97.9	103.2	99.8	100.0	0.44
Wairoa River	12	85.0	99.4	94.5	94.3	1.20
Waitangi River	12	77.1	92.8	88.4	87.5	1.41
Waiwera River	12	85.6	99.1	95.1	94.1	1.28
West Hoe Stream	12	86.6	119.7	91.1	93.3	2.53
Whangamaire Stream	12	56.0	95.0	84.2	80.7	3.67

**Table 7**  
Dissolved oxygen (ppm)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	6.9	10.3	8.4	8.6	0.35
Cascade Stream	12	10.3	11.4	10.6	10.7	0.12
Hoteo River (NIWA operated)	12	8.3	11.6	9.4	9.4	0.26
Kaukapakapa River	12	6.7	10.2	8.6	8.7	0.30
Kumeu River	12	7.2	10.1	8.6	8.7	0.27
Lucas Creek	12	6.9	10.5	9.0	8.9	0.36
Mahurangi River (Forestry HQ)	12	9.5	10.9	10.3	10.2	0.14
Mahurangi River (Water Supply)	12	8.3	11.1	9.8	9.8	0.28
Makarau River	12	9.2	11.4	10.4	10.3	0.21
Matakana River	12	8.1	10.8	9.0	9.1	0.24
Ngakaroa Stream	12	7.3	11.0	9.6	9.5	0.31
Nukumea Stream	12	8.5	10.3	9.4	9.3	0.17
Oakley Creek	12	8.1	10.5	9.2	9.3	0.23
Okura Creek	12	7.1	10.9	8.7	9.1	0.39
Omaru Creek	12	3.9	10.0	8.5	8.2	0.48
Opanuku Stream	12	9.3	11.2	10.4	10.3	0.19
Otaki Creek	12	6.8	9.4	8.5	8.4	0.25
Otara Creek (East Tamaki)	12	8.1	11.3	10.2	10.0	0.28
Otara Creek (Kennel Hill)	12	6.9	10.5	9.4	9.1	0.36
Oteha Stream	11	5.9	10.5	7.8	8.2	0.51
Pakuranga Creek (Botany Rd)	12	8.6	13.6	12.0	11.8	0.44
Pakuranga Creek (Greenmount Drive)	12	6.5	9.9	8.1	8.1	0.30
Papakura Stream (Alfriston-Ardmore Rd)	12	3.5	8.8	6.9	6.8	0.52
Papakura Stream (Porchester Rd)	12	7.5	10.3	8.6	8.6	0.24
Puhinui Stream	12	5.3	12.8	10.4	10.0	0.55
Rangitopuni River (NIWA operated)	12	4.6	11.4	8.8	8.4	0.53
Riverhead Forest Stream	12	7.1	10.1	8.9	8.6	0.29
Vaughan Stream	12	2.1	8.2	6.5	6.2	0.52
Wairoa Tributary	12	10.0	11.9	10.7	10.8	0.18
Wairoa River	12	8.2	11.0	9.6	9.6	0.30
Waitangi River	12	7.4	10.0	9.1	8.9	0.26
Waiwera River	12	8.1	10.8	9.7	9.6	0.27
West Hoe Stream	12	8.8	12.6	9.6	9.8	0.30
Whangamaire Stream	12	5.5	10.4	8.5	8.3	0.49

**Table 8**  
Temperature (°C)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	10.9	18.2	14.2	14.5	0.74
Cascade Stream	12	10.3	15.5	13.2	13.0	0.50
Hoteo River (NIWA operated)	12	7.4	20.5	15.0	15.1	1.09
Kaukapakapa River	12	10.5	18.2	14.7	14.5	0.80
Kumeu River	12	10.4	18.7	14.6	14.5	0.76
Lucas Creek	12	10.8	18.7	14.2	14.5	0.81
Mahurangi River (Forestry HQ)	12	10.8	17.0	14.6	14.2	0.69
Mahurangi River (Water Supply)	12	10.8	18.8	15.2	15.2	0.88
Makarau River	12	10.8	18.6	15.1	15.0	0.82
Matakana River	12	10.5	19.3	15.7	15.4	0.87
Ngakaroa Stream	12	9.2	17.9	14.6	14.2	0.87
Nukumea Stream	12	10.8	15.9	12.6	13.3	0.58
Oakley Creek	12	12.4	18.8	15.6	15.5	0.72
Okura Creek	12	9.8	17.2	13.2	13.6	0.77
Omaru Creek	12	11.3	21.8	14.9	15.9	0.89
Opanuku Stream	12	9.9	16.7	13.6	13.4	0.67
Otaki Creek	12	13.4	21.6	16.4	17.3	0.84
Otara Creek (East Tamaki)	12	11.6	21.4	14.5	15.7	0.80
Otara Creek (Kennel Hill)	12	9.9	21.5	13.6	14.7	1.02
Oteha Stream	12	11.1	18.7	14.3	14.7	0.78
Pakuranga Creek (Botany Rd)	12	13.2	23.8	16.3	18.3	1.08
Pakuranga Creek (Greenmount Drive)	12	12.6	21.8	15.7	16.7	0.87
Papakura Stream (Alfriston-Ardmore Rd)	12	10.4	18.8	15.2	14.9	0.88
Papakura Stream (Porchester Rd)	12	10.2	19.1	15.4	14.9	0.95
Puhinui Stream	12	11.9	22.4	17.0	16.9	1.05
Rangitopuni River (NIWA operated)	12	7.0	18.3	13.9	14.0	0.88
Riverhead Forest Stream	12	9.6	17.0	12.5	12.8	0.68
Vaughan Stream	12	11.0	19.2	15.0	14.9	0.83
Wairoa Tributary	12	7.7	15.1	12.1	12.1	0.69
Wairoa River	12	10.2	19.1	14.7	14.7	0.92
Waitangi River	12	10.2	18.9	15.2	14.9	0.87
Waiwera River	12	10.8	18.2	15.1	14.9	0.82
West Hoe Stream	12	10.7	15.7	12.4	13.1	0.56
Whangamaire Stream	12	9.8	18.3	14.9	14.6	0.82

**Table 9**

Conductivity (Millisiemens/cm @ 25°C)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	0.08	0.25	0.22	0.20	0.015
Cascade Stream	12	0.12	0.19	0.17	0.17	0.005
Hoteo River (NIWA operated)	11	0.14	0.20	0.18	0.18	0.005
Kaukapakapa River	12	0.15	0.28	0.20	0.20	0.010
Kumeu River	12	0.13	0.17	0.16	0.16	0.004
Lucas Creek	11	0.16	0.28	0.24	0.23	0.013
Mahurangi River (Forestry HQ)	12	0.13	0.19	0.17	0.17	0.005
Mahurangi River (Water Supply)	12	0.14	0.20	0.17	0.17	0.006
Makarau River	12	0.16	0.22	0.19	0.19	0.006
Matakana River	12	0.11	0.21	0.18	0.17	0.008
Ngakaroa Stream	12	0.14	0.18	0.16	0.16	0.004
Nukumea Stream	12	0.10	0.19	0.19	0.17	0.008
Oakley Creek	12	0.09	0.26	0.24	0.21	0.015
Okura Creek	12	0.15	0.28	0.25	0.24	0.011
Omaru Creek	12	0.08	0.34	0.28	0.27	0.021
Opanuku Stream	12	0.11	0.15	0.14	0.14	0.003
Otaki Creek	12	0.08	4.43	0.30	0.99	0.375
Otara Creek (East Tamaki)	12	0.06	0.21	0.18	0.17	0.011
Otara Creek (Kennel Hill)	12	0.12	0.26	0.20	0.19	0.014
Oteha Stream	12	0.11	0.27	0.18	0.19	0.016
Pakuranga Creek (Botany Rd)	12	0.04	0.30	0.26	0.23	0.025
Pakuranga Creek (Greenmount Drive)	12	0.10	0.71	0.37	0.39	0.053
Papakura Stream (Alfriston-Ardmore Rd)	12	0.13	0.19	0.18	0.17	0.005
Papakura Stream (Porchester Rd)	12	0.14	0.20	0.18	0.18	0.005
Puhinui Stream	12	0.15	0.22	0.18	0.18	0.008
Rangitopuni River (NIWA operated)	11	0.19	0.24	0.22	0.21	0.004
Riverhead Forest Stream	12	0.18	0.22	0.21	0.21	0.003
Vaughan Stream	12	0.17	0.31	0.26	0.25	0.012
Wairoa Tributary	12	0.09	0.13	0.12	0.11	0.005
Wairoa River	12	0.08	0.13	0.11	0.11	0.004
Waitangi River	12	0.16	0.20	0.19	0.19	0.003
Waiwera River	12	0.13	0.21	0.19	0.19	0.006
West Hoe Stream	12	0.08	0.20	0.19	0.17	0.011
Whangamaire Stream	12	0.19	0.32	0.30	0.28	0.012

**Table 10**  
Salinity (ppt)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	0.04	0.12	0.11	0.09	0.007
Cascade Stream	12	0.06	0.09	0.08	0.08	0.003
Hoteo River (NIWA operated)	Not measured at this site					
Kaukapakapa River	12	0.07	0.13	0.10	0.10	0.005
Kumeu River	12	0.06	0.08	0.08	0.08	0.002
Lucas Creek	11	0.07	0.13	0.11	0.11	0.007
Mahurangi River (Forestry HQ)	12	0.06	0.09	0.08	0.08	0.002
Mahurangi River (Water Supply)	12	0.06	0.09	0.08	0.08	0.003
Makarau River	12	0.07	0.10	0.09	0.09	0.003
Matakana River	12	0.05	0.10	0.09	0.08	0.004
Ngakaroa Stream	12	0.06	0.08	0.08	0.07	0.002
Nukumea Stream	12	0.04	0.09	0.09	0.08	0.004
Oakley Creek	12	0.04	0.12	0.12	0.10	0.008
Okura Creek	12	0.07	0.13	0.12	0.11	0.005
Omaru Creek	12	0.03	0.16	0.14	0.13	0.011
Opanuku Stream	12	0.05	0.07	0.07	0.07	0.002
Otaki Creek	12	0.04	2.38	0.14	0.51	0.201
Otara Creek (East Tamaki)	12	0.03	0.10	0.09	0.08	0.005
Otara Creek (Kennel Hill)	12	0.06	0.12	0.10	0.09	0.007
Oteha Stream	12	0.05	0.13	0.09	0.09	0.008
Pakuranga Creek (Botany Rd)	12	0.02	0.14	0.13	0.11	0.012
Pakuranga Creek (Greenmount Drive)	12	0.04	0.35	0.18	0.19	0.027
Papakura Stream (Alfriston-Ardmore Rd)	12	0.06	0.09	0.08	0.08	0.002
Papakura Stream (Porchester Rd)	12	0.07	0.10	0.09	0.09	0.003
Puhinui Stream	12	0.07	0.10	0.09	0.09	0.004
Rangitopuni River (NIWA operated)	Not measured at this site					
Riverhead Forest Stream	12	0.09	0.11	0.10	0.10	0.001
Vaughan Stream	12	0.08	0.15	0.12	0.12	0.006
Wairoa Tributary	12	0.04	0.06	0.06	0.05	0.003
Wairoa River	12	0.04	0.06	0.05	0.05	0.002
Waitangi River	12	0.08	0.10	0.09	0.09	0.001
Waiwera River	12	0.06	0.10	0.09	0.09	0.003
West Hoe Stream	12	0.04	0.09	0.09	0.08	0.005
Whangamaire Stream	12	0.09	0.15	0.15	0.14	0.006

**Table 11**  
pH (pH units)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	7.0	7.7	7.3	7.3	0.05
Cascade Stream	12	7.7	7.9	7.8	7.8	0.02
Hoteo River (NIWA operated)	12	7.1	7.8	7.5	7.5	0.06
Kaukapakapa River	12	7.1	7.5	7.4	7.4	0.04
Kumeu River	12	6.8	7.4	7.3	7.2	0.05
Lucas Creek	11	7.3	7.6	7.5	7.5	0.03
Mahurangi River (Forestry HQ)	12	7.4	7.7	7.6	7.6	0.03
Mahurangi River (Water Supply)	12	7.5	7.8	7.7	7.7	0.03
Makarau River	12	7.4	8.1	7.8	7.7	0.06
Matakana River	12	7.2	7.7	7.5	7.5	0.04
Ngakaroa Stream	12	7.2	7.6	7.4	7.4	0.04
Nukumea Stream	11	6.5	7.3	7.2	7.1	0.08
Oakley Creek	12	6.8	7.7	7.6	7.6	0.07
Okura Creek	11	7.1	7.5	7.5	7.4	0.04
Omaru Creek	12	7.3	7.7	7.5	7.5	0.03
Opanuku Stream	12	7.3	7.7	7.6	7.5	0.04
Otaki Creek	12	7.1	7.5	7.4	7.3	0.04
Otara Creek (East Tamaki)	12	7.1	7.9	7.4	7.4	0.06
Otara Creek (Kennel Hill)	12	6.9	7.7	7.4	7.4	0.06
Oteha Stream	11	7.2	7.6	7.4	7.4	0.03
Pakuranga Creek (Botany Rd)	12	7.3	7.9	7.5	7.5	0.05
Pakuranga Creek (Greenmount Drive)	12	7.5	8.0	7.7	7.7	0.05
Papakura Stream (Alfriston-Ardmore Rd)	12	6.7	7.6	7.1	7.1	0.08
Papakura Stream (Porchester Rd)	12	6.8	7.5	7.3	7.2	0.07
Puhinui Stream	12	7.2	8.7	7.5	7.6	0.12
Rangitopuni River (NIWA operated)	12	7.0	7.4	7.2	7.2	0.03
Riverhead Forest Stream	12	6.4	7.1	7.0	6.9	0.07
Vaughan Stream	11	7.0	7.3	7.1	7.1	0.03
Wairoa Tributary	12	7.4	7.8	7.7	7.7	0.04
Wairoa River	12	7.3	7.6	7.5	7.4	0.03
Waitangi River	12	7.2	7.5	7.4	7.3	0.03
Waiwera River	12	7.4	7.7	7.6	7.6	0.03
West Hoe Stream	11	6.4	7.4	7.3	7.1	0.09
Whangamaire Stream	12	6.9	7.5	7.3	7.3	0.05

**Table 12**  
Suspended sediment ( $\text{mg l}^{-1}$ )

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	4.4	36.0	12.5	15.8	3.19
Cascade Stream	12	0.3	4.1	1.1	1.5	0.38
Hoteo River (NIWA operated)	Not measured at this site					
Kaukapakapa River	12	2.4	99.0	4.7	15.2	7.91
Kumeu River	12	1.8	43.0	4.8	10.7	3.62
Lucas Creek	12	1.3	39.0	3.7	9.2	3.35
Mahurangi River (Forestry HQ)	12	1.7	260.0	3.1	25.8	21.33
Mahurangi River (Water Supply)	12	1.4	280.0	3.6	32.4	23.05
Makarau River	12	0.9	400.0	2.8	36.7	33.05
Matakana River	12	1.2	140.0	5.1	18.0	11.26
Ngakaroa Stream	12	0.4	8.2	2.1	2.9	0.77
Nukumea Stream	12	0.8	13.0	2.6	3.6	0.94
Oakley Creek	12	0.3	56.0	2.4	10.0	4.71
Okura Creek	12	3.7	82.0	6.3	13.4	6.33
Omaru Creek	12	1.6	22.0	5.1	6.3	1.56
Opanuku Stream	12	0.3	10.0	2.3	3.3	0.73
Otaki Creek	12	2.0	33.0	5.1	7.2	2.40
Otara Creek (East Tamaki)	12	0.3	48.0	2.8	9.7	3.87
Otara Creek (Kennel Hill)	12	2.6	78.0	6.9	23.2	7.60
Oteha Stream	12	1.4	41.0	3.7	10.9	4.13
Pakuranga Creek (Botany Rd)	12	2.0	39.0	3.8	8.3	3.13
Pakuranga Creek (Greenmount Drive)	12	2.6	44.0	7.7	12.5	3.90
Papakura Stream (Alfriston-Ardmore Rd)	12	2.5	21.0	5.7	8.6	2.04
Papakura Stream (Porchester Rd)	12	0.8	31.0	3.4	7.5	2.62
Puhinui Stream	12	2.6	27.0	13.0	13.5	2.42
Rangitopuni River (NIWA operated)	Not measured at this site					
Riverhead Forest Stream	12	2.2	31.0	3.8	8.8	2.74
Vaughan Stream	12	1.0	18.0	3.4	6.2	1.56
Wairoa Tributary	12	0.4	14.0	5.0	6.4	1.51
Wairoa River	12	1.6	73.0	3.5	18.2	7.08
Waitangi River	12	0.3	10.0	1.7	3.1	0.88
Waiwera River	12	1.4	400.0	3.4	40.2	32.83
West Hoe Stream	12	1.8	17.0	3.4	4.6	1.22
Whangamaire Stream	12	0.5	19.0	1.1	3.2	1.49

**Table 13**  
Turbidity (NTU)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	10.8	39.0	17.0	20.0	2.85
Cascade Stream	12	1.2	14.0	2.4	4.2	1.12
Hoteo River (NIWA operated)	12	3.9	72.0	7.3	13.3	5.42
Kaukapakapa River	12	3.6	60.0	5.7	13.4	4.91
Kumeu River	12	3.6	40.0	9.0	13.0	2.80
Lucas Creek	12	3.9	60.0	5.4	18.1	6.06
Mahurangi River (Forestry HQ)	12	3.1	220.0	7.2	27.2	17.60
Mahurangi River (Water Supply)	12	2.3	230.0	6.9	28.9	18.59
Makarau River	12	3.2	260.0	4.7	28.6	21.13
Matakana River	12	2.3	150.0	5.5	22.7	11.97
Ngakaroa Stream	12	0.9	18.0	3.8	5.4	1.50
Nukumea Stream	12	4.7	30.0	6.1	9.2	2.16
Oakley Creek	12	1.4	29.0	3.1	10.6	3.18
Okura Creek	12	10.6	100.0	12.9	24.3	7.56
Omaru Creek	12	3.0	14.0	4.0	6.6	1.25
Opanuku Stream	12	2.6	22.0	4.3	6.7	1.63
Otaki Creek	12	4.6	29.7	9.2	10.8	1.86
Otara Creek (East Tamaki)	12	2.0	35.0	7.6	11.4	3.00
Otara Creek (Kennel Hill)	12	4.6	110.0	13.4	29.4	9.77
Oteha Stream	12	2.8	75.0	5.6	18.3	7.17
Pakuranga Creek (Botany Rd)	12	3.8	31.2	8.6	10.1	2.19
Pakuranga Creek (Greenmount Drive)	12	5.0	55.0	12.9	18.0	4.13
Papakura Stream (Alfriston-Ardmore Rd)	12	4.2	45.0	6.9	14.8	4.12
Papakura Stream (Porchester Rd)	12	1.6	50.0	4.8	11.8	4.11
Puhinui Stream	12	2.4	32.0	8.4	13.3	3.04
Rangitopuni River (NIWA operated)	12	4.6	29.5	6.8	10.9	2.53
Riverhead Forest Stream	12	4.0	31.3	10.0	12.6	2.30
Vaughan Stream	12	3.1	55.0	5.5	12.6	4.35
Wairoa Tributary	12	3.1	37.4	8.0	14.2	3.62
Wairoa River	12	2.2	60.0	5.8	20.4	6.88
Waitangi River	12	0.8	16.9	1.7	5.4	1.72
Waiwera River	12	3.5	300.0	5.0	32.2	24.44
West Hoe Stream	12	5.2	38.0	7.0	10.3	2.67
Whangamaire Stream	12	0.6	38.4	1.3	5.9	3.10

**Table 14**  
Ammoniacal Nitrogen (mg N l<sup>-1</sup>)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	0.003	0.076	0.044	0.044	0.0060
Cascade Stream	12	0.003	0.027	0.003	0.006	0.0024
Hoteo River (NIWA operated)	12	0.005	0.085	0.015	0.024	0.0062
Kaukapakapa River	12	0.007	0.180	0.026	0.042	0.0138
Kumeu River	12	0.005	0.098	0.020	0.026	0.0072
Lucas Creek	12	0.003	0.032	0.017	0.017	0.0025
Mahurangi River (Forestry HQ)	12	0.003	0.058	0.013	0.017	0.0042
Mahurangi River (Water Supply)	12	0.003	0.070	0.014	0.017	0.0054
Makarau River	12	0.003	0.028	0.008	0.008	0.0021
Matakana River	12	0.003	0.100	0.010	0.021	0.0084
Ngakaroa Stream	12	0.003	0.027	0.013	0.014	0.0019
Nukumea Stream	12	0.003	0.011	0.003	0.004	0.0008
Oakley Creek	12	0.003	0.049	0.023	0.022	0.0042
Okura Creek	12	0.003	0.062	0.026	0.027	0.0045
Omaru Creek	12	0.003	0.084	0.026	0.031	0.0072
Opanuku Stream	12	0.003	0.017	0.007	0.007	0.0013
Otaki Creek	12	0.034	0.100	0.059	0.060	0.0064
Otara Creek (East Tamaki)	12	0.003	0.220	0.035	0.055	0.0175
Otara Creek (Kennel Hill)	12	0.003	0.091	0.026	0.038	0.0089
Oteha Stream	12	0.013	0.100	0.028	0.036	0.0070
Pakuranga Creek (Botany Rd)	12	0.018	0.280	0.045	0.062	0.0201
Pakuranga Creek (Greenmount Drive)	12	0.068	1.500	0.275	0.388	0.1131
Papakura Stream (Alfriston-Ardmore Rd)	12	0.003	0.210	0.034	0.063	0.0178
Papakura Stream (Porchester Rd)	12	0.003	0.690	0.039	0.093	0.0549
Puhinui Stream	12	0.009	0.043	0.031	0.026	0.0034
Rangitopuni River (NIWA operated)	12	0.016	0.044	0.029	0.029	0.0025
Riverhead Forest Stream	12	0.003	0.070	0.009	0.016	0.0056
Vaughan Stream	12	0.003	0.089	0.015	0.020	0.0069
Wairoa Tributary	12	0.003	0.040	0.003	0.008	0.0034
Wairoa River	12	0.003	0.058	0.017	0.020	0.0044
Waitangi River	12	0.003	0.031	0.009	0.010	0.0024
Waiwera River	12	0.003	0.030	0.013	0.014	0.0029
West Hoe Stream	12	0.003	0.041	0.003	0.010	0.0036
Whangamaire Stream	12	0.003	0.057	0.010	0.015	0.0046

**Table 15**  
Total oxidised Nitrogen (mg N l<sup>-1</sup>)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	0.250	0.790	0.395	0.422	0.0413
Cascade Stream	12	0.001	0.018	0.008	0.008	0.0014
Hoteo River (NIWA operated)	12	0.001	0.421	0.287	0.232	0.0396
Kaukapakapa River	12	0.032	0.390	0.155	0.175	0.0288
Kumeu River	12	0.052	0.670	0.275	0.294	0.0480
Lucas Creek	12	0.025	0.510	0.083	0.140	0.0408
Mahurangi River (Forestry HQ)	12	0.097	0.190	0.145	0.141	0.0082
Mahurangi River (Water Supply)	12	0.001	0.230	0.120	0.132	0.0198
Makarau River	12	0.001	0.320	0.046	0.079	0.0300
Matakana River	12	0.001	0.340	0.032	0.068	0.0273
Ngakaroa Stream	12	1.400	3.300	2.550	2.517	0.1691
Nukumea Stream	12	0.001	0.012	0.008	0.007	0.0011
Oakley Creek	12	0.600	2.100	1.350	1.338	0.1517
Okura Creek	12	0.110	0.350	0.170	0.184	0.0189
Omaru Creek	12	0.096	1.500	0.510	0.634	0.1397
Opanuku Stream	12	0.027	0.190	0.080	0.096	0.0141
Otaki Creek	12	0.640	3.100	0.950	1.403	0.2454
Otara Creek (East Tamaki)	12	0.250	1.600	0.910	0.978	0.1309
Otara Creek (Kennel Hill)	12	0.007	0.700	0.365	0.303	0.0676
Oteha Stream	12	0.120	0.570	0.275	0.280	0.0338
Pakuranga Creek (Botany Rd)	12	0.110	1.600	0.820	0.830	0.1147
Pakuranga Creek (Greenmount Drive)	12	0.110	0.970	0.535	0.548	0.0672
Papakura Stream (Alfriston-Ardmore Rd)	12	0.017	3.300	0.375	0.703	0.2591
Papakura Stream (Porchester Rd)	12	0.029	1.100	0.245	0.405	0.1086
Puhinui Stream	12	0.001	0.740	0.400	0.406	0.0688
Rangitopuni River (NIWA operated)	12	0.080	0.301	0.130	0.166	0.0223
Riverhead Forest Stream	12	0.001	0.260	0.022	0.040	0.0202
Vaughan Stream	12	0.001	0.230	0.018	0.047	0.0193
Wairoa Tributary	12	0.005	0.073	0.047	0.046	0.0049
Wairoa River	12	0.045	0.800	0.290	0.337	0.0670
Waitangi River	12	1.400	2.900	2.250	2.208	0.1417
Waiwera River	12	0.001	0.280	0.071	0.095	0.0244
West Hoe Stream	12	0.001	0.008	0.004	0.004	0.0007
Whangamaire Stream	12	5.300	16.000	13.500	12.558	0.9200

**Table 16**Kjeldhal Nitrogen by calculation (mg N l<sup>-1</sup>)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	0.08	0.67	0.32	0.35	0.049
Cascade Stream	12	0.01	0.19	0.05	0.06	0.014
Hoteo River (NIWA operated)	12	0.22	0.84	0.27	0.33	0.050
Kaukapakapa River	12	0.25	0.74	0.47	0.48	0.044
Kumeu River	12	0.19	0.69	0.30	0.36	0.044
Lucas Creek	12	0.08	0.92	0.22	0.30	0.065
Mahurangi River (Forestry HQ)	12	0.04	0.24	0.11	0.13	0.019
Mahurangi River (Water Supply)	12	0.13	0.56	0.22	0.26	0.036
Makarau River	12	0.17	1.10	0.23	0.32	0.075
Matakana River	12	0.13	0.93	0.20	0.30	0.075
Ngakaroa Stream	12	0.01	0.72	0.24	0.26	0.065
Nukumea Stream	12	0.01	0.33	0.08	0.09	0.024
Oakley Creek	12	0.06	0.95	0.40	0.37	0.079
Okura Creek	12	0.15	2.20	0.40	0.53	0.159
Omaru Creek	12	0.15	0.74	0.30	0.32	0.045
Opanuku Stream	12	0.08	0.36	0.15	0.17	0.023
Otaki Creek	12	0.06	0.73	0.34	0.35	0.050
Otara Creek (East Tamaki)	12	0.14	1.20	0.26	0.36	0.086
Otara Creek (Kennel Hill)	12	0.25	1.10	0.38	0.49	0.078
Oteha Stream	12	0.13	0.71	0.28	0.34	0.058
Pakuranga Creek (Botany Rd)	12	0.13	1.20	0.33	0.46	0.095
Pakuranga Creek (Greenmount Drive)	12	0.29	1.70	0.63	0.75	0.108
Papakura Stream (Alfriston-Ardmore Rd)	12	0.25	1.40	0.48	0.54	0.093
Papakura Stream (Porchester Rd)	12	0.09	2.30	0.52	0.63	0.163
Puhinui Stream	12	0.18	0.73	0.46	0.43	0.058
Rangitopuni River (NIWA operated)	12	0.36	0.65	0.48	0.48	0.029
Riverhead Forest Stream	12	0.06	0.28	0.18	0.17	0.022
Vaughan Stream	12	0.16	0.92	0.31	0.43	0.073
Wairoa Tributary	12	0.01	0.74	0.10	0.15	0.058
Wairoa River	12	0.12	0.64	0.22	0.31	0.052
Waitangi River	12	0.01	0.88	0.23	0.28	0.073
Waiwera River	12	0.09	1.30	0.22	0.30	0.092
West Hoe Stream	12	0.01	0.48	0.06	0.12	0.045
Whangamaire Stream	12	0.01	1.80	0.54	0.73	0.162

**Table 17**  
Total Nitrogen (mg N l<sup>-1</sup>)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	0.52	1.20	0.68	0.77	0.062
Cascade Stream	12	0.01	0.20	0.06	0.07	0.014
Hoteo River (NIWA operated)	12	0.26	1.16	0.56	0.56	0.070
Kaukapakapa River	12	0.41	0.95	0.60	0.66	0.060
Kumeu River	12	0.33	1.20	0.56	0.65	0.077
Lucas Creek	12	0.23	1.20	0.30	0.44	0.087
Mahurangi River (Forestry HQ)	12	0.18	0.38	0.25	0.27	0.020
Mahurangi River (Water Supply)	12	0.18	0.74	0.38	0.39	0.044
Makarau River	12	0.21	1.20	0.28	0.40	0.086
Matakana River	12	0.14	1.10	0.24	0.38	0.090
Ngakaroa Stream	12	1.70	4.00	2.85	2.78	0.182
Nukumea Stream	12	0.02	0.33	0.09	0.10	0.023
Oakley Creek	12	0.65	2.50	1.75	1.70	0.160
Okura Creek	12	0.37	2.50	0.54	0.71	0.169
Omaru Creek	12	0.33	2.20	0.74	0.96	0.166
Opanuku Stream	12	0.14	0.49	0.25	0.27	0.025
Otaki Creek	12	0.90	3.90	1.35	1.75	0.259
Otara Creek (East Tamaki)	12	0.67	2.80	1.15	1.34	0.181
Otara Creek (Kennel Hill)	12	0.34	1.70	0.67	0.81	0.132
Oteha Stream	12	0.38	1.10	0.51	0.62	0.069
Pakuranga Creek (Botany Rd)	12	0.37	2.20	1.25	1.30	0.141
Pakuranga Creek (Greenmount Drive)	12	0.40	2.20	1.20	1.28	0.133
Papakura Stream (Alfriston-Ardmore Rd)	12	0.27	3.80	0.84	1.25	0.286
Papakura Stream (Porchester Rd)	12	0.35	3.00	0.88	1.03	0.221
Puhinui Stream	12	0.43	1.30	0.77	0.84	0.095
Rangitopuni River (NIWA operated)	12	0.46	0.89	0.64	0.65	0.039
Riverhead Forest Stream	12	0.08	0.31	0.21	0.20	0.021
Vaughan Stream	12	0.24	0.98	0.31	0.47	0.077
Wairoa Tributary	12	0.06	0.80	0.12	0.20	0.059
Wairoa River	12	0.24	1.20	0.54	0.64	0.101
Waitangi River	12	1.30	3.30	2.55	2.46	0.162
Waiwera River	12	0.19	1.40	0.28	0.40	0.097
West Hoe Stream	12	0.01	0.48	0.06	0.12	0.045
Whangamaire Stream	12	5.70	17.00	14.00	13.05	0.929

**Table 18**Soluble Reactive Phosphorus ( $\text{mg P l}^{-1}$ )

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	0.003	0.020	0.012	0.012	0.0014
Cascade Stream	12	0.007	0.019	0.014	0.014	0.0013
Hoteo River (NIWA operated)	12	0.010	0.038	0.016	0.019	0.0022
Kaukapakapa River	12	0.016	0.061	0.027	0.028	0.0035
Kumeu River	12	0.003	0.022	0.014	0.014	0.0015
Lucas Creek	12	0.003	0.019	0.009	0.009	0.0014
Mahurangi River (Forestry HQ)	12	0.003	0.009	0.006	0.006	0.0006
Mahurangi River (Water Supply)	12	0.003	0.034	0.010	0.012	0.0023
Makarau River	12	0.003	0.023	0.012	0.012	0.0015
Matakana River	12	0.003	0.034	0.011	0.015	0.0029
Ngakaroa Stream	12	0.003	0.008	0.007	0.006	0.0005
Nukumea Stream	12	0.003	0.009	0.005	0.005	0.0006
Oakley Creek	12	0.009	0.035	0.031	0.029	0.0021
Okura Creek	12	0.003	0.028	0.011	0.012	0.0018
Omaru Creek	12	0.009	0.031	0.015	0.018	0.0022
Opanuku Stream	12	0.003	0.019	0.008	0.008	0.0012
Otaki Creek	12	0.003	0.067	0.013	0.020	0.0063
Otara Creek (East Tamaki)	12	0.006	0.040	0.012	0.014	0.0027
Otara Creek (Kennel Hill)	12	0.009	0.071	0.012	0.021	0.0052
Oteha Stream	12	0.003	0.034	0.011	0.013	0.0025
Pakuranga Creek (Botany Rd)	12	0.006	0.026	0.013	0.014	0.0019
Pakuranga Creek (Greenmount Drive)	12	0.011	0.064	0.033	0.035	0.0043
Papakura Stream (Alfriston-Ardmore Rd)	12	0.008	0.061	0.034	0.036	0.0040
Papakura Stream (Porchester Rd)	12	0.007	0.096	0.026	0.033	0.0066
Puhinui Stream	12	0.005	0.030	0.014	0.015	0.0017
Rangitopuni River (NIWA operated)	12	0.009	0.026	0.015	0.016	0.0016
Riverhead Forest Stream	12	0.003	0.010	0.006	0.006	0.0007
Vaughan Stream	12	0.003	0.016	0.011	0.010	0.0013
Wairoa Tributary	12	0.015	0.049	0.029	0.028	0.0027
Wairoa River	12	0.005	0.054	0.015	0.019	0.0036
Waitangi River	12	0.003	0.015	0.008	0.007	0.0011
Waiwera River	12	0.003	0.020	0.010	0.010	0.0013
West Hoe Stream	12	0.003	0.008	0.006	0.005	0.0006
Whangamaire Stream	12	0.003	0.016	0.008	0.008	0.0011

**Table 19**  
Total Phosphorus (mg P l<sup>-1</sup>)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	0.018	0.090	0.043	0.049	0.0066
Cascade Stream	12	0.011	0.034	0.021	0.021	0.0020
Hoteo River (NIWA operated)	12	0.036	0.176	0.050	0.059	0.0110
Kaukapakapa River	12	0.031	0.310	0.062	0.086	0.0218
Kumeu River	12	0.019	0.110	0.042	0.047	0.0069
Lucas Creek	12	0.012	0.075	0.021	0.030	0.0059
Mahurangi River (Forestry HQ)	12	0.003	0.250	0.015	0.036	0.0196
Mahurangi River (Water Supply)	12	0.016	0.460	0.027	0.069	0.0360
Makarau River	12	0.015	0.430	0.025	0.066	0.0336
Matakana River	12	0.012	0.260	0.029	0.053	0.0198
Ngakaroa Stream	12	0.006	0.046	0.013	0.018	0.0038
Nukumea Stream	12	0.003	0.300	0.011	0.035	0.0242
Oakley Creek	12	0.039	0.130	0.062	0.070	0.0083
Okura Creek	12	0.022	0.077	0.038	0.043	0.0053
Omaru Creek	12	0.032	0.120	0.054	0.057	0.0072
Opanuku Stream	12	0.009	0.054	0.017	0.021	0.0037
Otaki Creek	12	0.040	0.200	0.062	0.069	0.0125
Otara Creek (East Tamaki)	12	0.013	0.120	0.033	0.046	0.0097
Otara Creek (Kennel Hill)	12	0.026	0.170	0.060	0.084	0.0160
Oteha Stream	12	0.028	0.100	0.036	0.047	0.0075
Pakuranga Creek (Botany Rd)	12	0.018	0.140	0.056	0.060	0.0090
Pakuranga Creek (Greenmount Drive)	12	0.083	0.150	0.115	0.115	0.0066
Papakura Stream (Alfriston-Ardmore Rd)	12	0.054	0.150	0.075	0.094	0.0113
Papakura Stream (Porchester Rd)	12	0.041	0.270	0.071	0.091	0.0181
Puhinui Stream	12	0.033	0.100	0.063	0.063	0.0074
Rangitopuni River (NIWA operated)	12	0.034	0.074	0.059	0.055	0.0037
Riverhead Forest Stream	12	0.003	0.040	0.015	0.015	0.0032
Vaughan Stream	12	0.017	0.075	0.033	0.038	0.0055
Wairoa Tributary	12	0.027	0.066	0.040	0.042	0.0033
Wairoa River	12	0.028	0.110	0.046	0.058	0.0089
Waitangi River	12	0.003	0.075	0.017	0.025	0.0066
Waiwera River	12	0.016	0.340	0.029	0.054	0.0261
West Hoe Stream	12	0.003	0.028	0.011	0.013	0.0027
Whangamaire Stream	12	0.003	0.120	0.014	0.025	0.0091

**Table 20**  
Soluble Copper ( $\mu\text{g l}^{-1}$ )

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	0.93	4.70	1.90	2.14	0.338
Cascade Stream			Not measured at this site			
Hoteo River (NIWA operated)			Not measured at this site			
Kaukapakapa River			Not measured at this site			
Kumeu River	12	0.01	2.10	0.76	0.82	0.153
Lucas Creek	12	0.57	3.50	0.92	1.39	0.298
Mahurangi River (Forestry HQ)	12	0.16	0.91	0.25	0.36	0.066
Mahurangi River (Water Supply)	12	0.24	1.30	0.42	0.59	0.104
Makarau River	12	0.25	1.20	0.55	0.63	0.096
Matakana River	12	0.29	1.50	0.61	0.73	0.105
Ngakaroa Stream			Not measured at this site			
Nukumea Stream	12	0.01	1.20	0.23	0.36	0.102
Oakley Creek	12	0.85	3.70	1.85	2.01	0.262
Okura Creek	12	0.37	1.90	0.69	0.83	0.140
Oamaru Creek	12	0.82	4.20	1.55	2.11	0.333
Opanuku Stream			Not measured at this site			
Otaki Creek	12	0.64	3.00	1.40	1.50	0.208
Otara Creek (East Tamaki)	12	0.64	2.10	1.45	1.43	0.131
Otara Creek (Kennel Hill)	12	0.63	2.70	1.35	1.48	0.200
Oteha Stream	12	0.83	3.80	1.35	1.69	0.256
Pakuranga Creek (Botany Rd)	12	0.94	3.00	1.35	1.61	0.195
Pakuranga Creek (Greenmount Drive)	12	0.72	4.00	1.65	2.02	0.304
Papakura Stream (Alfriston-Ardmore Rd)	12	0.26	1.70	0.87	0.95	0.138
Papakura Stream (Porchester Rd)	12	0.50	2.30	1.05	1.14	0.160
Puhinui Stream	12	1.00	2.70	1.85	1.85	0.159
Rangitopuni River (NIWA operated)			Not measured at this site			
Riverhead Forest Stream	12	0.01	0.62	0.32	0.33	0.054
Vaughan Stream	12	0.12	2.40	0.46	0.69	0.205
Wairoa Tributary			Not measured at this site			
Wairoa River	12	0.33	1.20	0.67	0.75	0.090
Waitangi River			Not measured at this site			
Waiwera River	12	0.17	1.30	0.47	0.55	0.096
West Hoe Stream			Not measured at this site			
Whangamaire Stream			Not measured at this site			

**Table 21**  
Total Copper ( $\mu\text{g l}^{-1}$ )

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	1.50	6.30	3.00	3.22	0.440
Cascade Stream		Not measured at this site				
Hoteo River (NIWA operated)		Not measured at this site				
Kaukapakapa River		Not measured at this site				
Kumeu River	12	0.72	3.60	1.25	1.42	0.225
Lucas Creek	12	0.78	4.90	1.35	2.06	0.450
Mahurangi River (Forestry HQ)	12	0.29	7.60	0.51	1.21	0.590
Mahurangi River (Water Supply)	12	0.39	8.60	0.90	1.64	0.656
Makarau River	12	0.39	10.00	0.82	1.67	0.768
Matakana River	12	0.52	7.40	1.04	1.77	0.545
Ngakaroa Stream		Not measured at this site				
Nukumea Stream	12	0.20	1.40	0.34	0.52	0.114
Oakley Creek	12	1.10	8.10	2.70	3.53	0.636
Okura Creek	12	0.57	3.50	0.89	1.28	0.254
Omaru Creek	12	1.10	8.90	2.80	3.62	0.663
Opanuku Stream		Not measured at this site				
Otaki Creek	12	0.95	7.80	2.50	2.82	0.533
Otara Creek (East Tamaki)	12	0.90	6.90	1.95	2.50	0.465
Otara Creek (Kennel Hill)	12	0.88	17.00	2.25	3.58	1.276
Oteha Stream	12	1.20	5.40	1.90	2.60	0.438
Pakuranga Creek (Botany Rd)	12	1.50	4.50	2.45	2.66	0.322
Pakuranga Creek (Greenmount Drive)	12	0.93	11.00	3.05	3.96	0.805
Papakura Stream (Alfriston-Ardmore Rd)	12	0.61	3.00	1.15	1.38	0.205
Papakura Stream (Porchester Rd)	12	0.60	4.00	1.35	1.54	0.261
Puhinui Stream	12	1.30	4.50	2.85	2.74	0.295
Rangitopuni River (NIWA operated)		Not measured at this site				
Riverhead Forest Stream	12	0.20	1.00	0.50	0.54	0.068
Vaughan Stream	12	0.23	2.90	0.57	0.91	0.242
Wairoa Tributary		Not measured at this site				
Wairoa River	12	0.53	2.70	0.86	1.30	0.224
Waitangi River		Not measured at this site				
Waiwera River	12	0.34	13.00	0.71	1.79	1.026
West Hoe Stream		Not measured at this site				
Whangamaire Stream		Not measured at this site				

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

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	13.00	35.00	23.00	23.83	2.364
Cascade Stream					Not measured at this site	
Hoteo River (NIWA operated)					Not measured at this site	
Kaukapakapa River					Not measured at this site	
Kumeu River	12	0.30	10.00	1.90	3.40	0.937
Lucas Creek	12	0.88	6.00	1.85	2.66	0.508
Mahurangi River (Forestry HQ)	12	0.30	1.20	0.31	0.48	0.086
Mahurangi River (Water Supply)	12	0.49	10.00	2.05	2.57	0.705
Makarau River	12	0.30	1.10	0.39	0.53	0.088
Matakana River	12	0.30	1.80	0.63	0.84	0.153
Ngakaroa Stream					Not measured at this site	
Nukumea Stream	12	0.30	2.50	0.59	0.98	0.209
Oakley Creek	12	5.60	29.00	14.50	13.98	1.987
Okura Creek	12	0.64	3.00	1.45	1.63	0.208
Omaru Creek	12	22.00	140.00	72.00	73.33	10.250
Opanuku Stream					Not measured at this site	
Otaki Creek	12	13.00	55.00	28.00	29.83	3.709
Otara Creek (East Tamaki)	12	7.40	48.00	24.50	23.53	3.426
Otara Creek (Kennel Hill)	12	2.20	56.00	4.80	15.55	5.950
Oteha Stream	12	15.00	46.00	23.50	26.50	2.893
Pakuranga Creek (Botany Rd)	12	5.90	43.00	17.50	21.54	3.703
Pakuranga Creek (Greenmount Drive)	12	3.20	110.00	13.00	29.10	10.471
Papakura Stream (Alfriston-Ardmore Rd)	12	0.39	7.40	2.90	3.25	0.549
Papakura Stream (Porchester Rd)	12	0.92	11.00	4.70	5.09	0.933
Puhinui Stream	12	8.20	130.00	17.50	37.83	12.886
Rangitopuni River (NIWA operated)					Not measured at this site	
Riverhead Forest Stream	12	1.50	12.00	3.05	4.53	0.969
Vaughan Stream	12	0.72	4.20	1.80	1.86	0.305
Wairoa Tributary					Not measured at this site	
Wairoa River	12	0.15	4.10	1.30	1.24	0.295
Waitangi River					Not measured at this site	
Waiwera River	12	0.30	1.20	0.52	0.57	0.077
West Hoe Stream					Not measured at this site	
Whangamaire Stream					Not measured at this site	

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

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	19.00	61.00	34.50	36.33	3.797
Cascade Stream	Not measured at this site					
Hoteo River (NIWA operated)	Not measured at this site					
Kaukapakapa River	Not measured at this site					
Kumeu River	12	1.80	16.00	3.10	5.86	1.378
Lucas Creek	12	1.60	16.00	2.95	5.16	1.377
Mahurangi River (Forestry HQ)	12	0.35	19.00	1.03	2.60	1.507
Mahurangi River (Water Supply)	12	2.00	37.00	3.95	7.63	2.877
Makarau River	12	0.42	28.00	1.10	3.84	2.277
Matakana River	12	0.47	18.00	1.70	3.43	1.451
Ngakaroa Stream	Not measured at this site					
Nukumea Stream	12	0.57	2.80	0.82	1.19	0.214
Oakley Creek	12	7.10	63.00	24.00	27.23	4.972
Okura Creek	12	1.70	10.00	2.35	3.40	0.705
Omaru Creek	12	36.00	170.00	110.00	105.50	12.381
Opanuku Stream	Not measured at this site					
Otaki Creek	12	16.00	82.00	42.50	45.50	5.816
Otara Creek (East Tamaki)	12	9.50	77.00	34.50	35.54	6.148
Otara Creek (Kennel Hill)	12	3.60	190.00	12.50	32.53	15.285
Oteha Stream	12	24.00	64.00	36.00	38.75	4.454
Pakuranga Creek (Botany Rd)	12	14.00	70.00	33.00	33.75	4.503
Pakuranga Creek (Greenmount Drive)	12	5.60	200.00	29.00	52.13	17.346
Papakura Stream (Alfriston-Ardmore Rd)	12	1.10	9.70	4.55	5.22	0.846
Papakura Stream (Porchester Rd)	12	1.70	16.00	6.45	7.37	1.498
Puhinui Stream	12	14.00	210.00	27.00	55.58	18.846
Rangitopuni River (NIWA operated)	Not measured at this site					
Riverhead Forest Stream	12	2.10	14.00	4.10	6.04	1.142
Vaughan Stream	12	1.10	7.30	2.55	2.83	0.518
Wairoa Tributary	Not measured at this site					
Wairoa River	12	0.68	7.70	1.25	3.27	0.810
Waitangi River	Not measured at this site					
Waiwera River	12	0.50	31.00	0.81	3.53	2.508
West Hoe Stream	Not measured at this site					
Whangamaire Stream	Not measured at this site					

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

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	0.16	0.82	0.32	0.35	0.053
Cascade Stream	Not measured at this site					
Hoteo River (NIWA operated)	Not measured at this site					
Kaukapakapa River	Not measured at this site					
Kumeu River	12	0.03	0.21	0.08	0.10	0.016
Lucas Creek	12	0.03	0.20	0.06	0.07	0.016
Mahurangi River (Forestry HQ)	12	0.03	0.05	0.03	0.03	0.003
Mahurangi River (Water Supply)	12	0.03	0.19	0.06	0.07	0.014
Makarau River	12	0.03	0.07	0.03	0.04	0.005
Matakana River	12	0.03	0.15	0.04	0.06	0.013
Ngakaroa Stream	Not measured at this site					
Nukumea Stream	12	0.03	0.12	0.03	0.04	0.009
Oakley Creek	12	0.06	0.54	0.16	0.20	0.040
Okura Creek	12	0.03	0.19	0.07	0.07	0.013
Omaru Creek	12	0.03	0.45	0.15	0.18	0.037
Opanuku Stream	Not measured at this site					
Otaki Creek	12	0.03	0.25	0.11	0.12	0.025
Otara Creek (East Tamaki)	12	0.03	0.21	0.10	0.10	0.017
Otara Creek (Kennel Hill)	12	0.03	0.23	0.09	0.10	0.016
Oteha Stream	12	0.03	0.24	0.07	0.09	0.018
Pakuranga Creek (Botany Rd)	12	0.03	0.23	0.10	0.11	0.022
Pakuranga Creek (Greenmount Drive)	12	0.03	0.18	0.03	0.06	0.017
Papakura Stream (Alfriston-Ardmore Rd)	12	0.03	0.20	0.10	0.11	0.017
Papakura Stream (Porchester Rd)	12	0.03	0.17	0.11	0.10	0.014
Puhinui Stream	12	0.06	0.40	0.20	0.20	0.032
Rangitopuni River (NIWA operated)	Not measured at this site					
Riverhead Forest Stream	12	0.03	0.07	0.03	0.03	0.005
Vaughan Stream	12	0.03	0.23	0.03	0.06	0.018
Wairoa Tributary	Not measured at this site					
Wairoa River	12	0.03	0.19	0.09	0.08	0.013
Waitangi River	Not measured at this site					
Waiwera River	12	0.03	0.06	0.03	0.03	0.005
West Hoe Stream	Not measured at this site					
Whangamaire Stream	Not measured at this site					

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

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	0.78	2.40	1.65	1.60	0.167
Cascade Stream			Not measured at this site			
Hoteo River (NIWA operated)			Not measured at this site			
Kaukapakapa River			Not measured at this site			
Kumeu River	12	0.09	1.10	0.37	0.43	0.084
Lucas Creek	12	0.06	1.20	0.13	0.34	0.123
Mahurangi River (Forestry HQ)	12	0.03	1.90	0.04	0.23	0.154
Mahurangi River (Water Supply)	12	0.06	3.90	0.38	0.61	0.305
Makarau River	12	0.03	3.30	0.06	0.35	0.269
Matakana River	12	0.03	2.00	0.29	0.49	0.175
Ngakaroa Stream			Not measured at this site			
Nukumea Stream	12	0.03	0.26	0.03	0.07	0.024
Oakley Creek	12	0.23	6.50	0.78	1.74	0.563
Okura Creek	12	0.11	1.40	0.17	0.33	0.109
Omaru Creek	12	0.25	5.20	1.10	1.61	0.401
Opanuku Stream			Not measured at this site			
Otaki Creek	12	0.39	5.40	1.03	1.35	0.400
Otara Creek (East Tamaki)	12	0.09	7.10	0.38	1.15	0.557
Otara Creek (Kennel Hill)	12	0.16	11.00	0.78	1.73	0.869
Oteha Stream	12	0.11	1.90	0.29	0.61	0.179
Pakuranga Creek (Botany Rd)	12	0.10	3.20	0.41	0.78	0.267
Pakuranga Creek (Greenmount Drive)	12	0.03	5.00	0.50	1.28	0.482
Papakura Stream (Alfriston-Ardmore Rd)	12	0.13	1.60	0.29	0.49	0.126
Papakura Stream (Porchester Rd)	12	0.06	1.20	0.24	0.36	0.093
Puhinui Stream	12	0.24	1.80	0.85	0.87	0.141
Rangitopuni River (NIWA operated)			Not measured at this site			
Riverhead Forest Stream	12	0.03	0.25	0.08	0.10	0.021
Vaughan Stream	12	0.03	0.73	0.09	0.19	0.061
Wairoa Tributary			Not measured at this site			
Wairoa River	12	0.08	1.60	0.22	0.52	0.159
Waitangi River			Not measured at this site			
Waiwera River	12	0.03	4.70	0.07	0.48	0.385
West Hoe Stream			Not measured at this site			
Whangamaire Stream			Not measured at this site			

**Table 26**  
*Escherichia coli* (cfu/100ml)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Avondale Stream	12	510	26000	1350	4699	2148
Cascade Stream	12	7	380	26	86	35
Hoteo River (NIWA operated)	12	63	3448	86	436	278
Kaukapakapa River	12	190	3400	325	1091	392
Kumeu River	12	160	2700	510	833	227
Lucas Creek	12	2	2200	170	475	198
Mahurangi River (Forestry HQ)	12	9	2900	350	614	227
Mahurangi River (Water Supply)	12	100	12000	290	1443	978
Makarau River	12	170	11000	320	1290	885
Matakana River	12	54	7200	255	1354	713
Ngakaroa Stream	12	81	2700	420	686	226
Nukumea Stream	12	0	230	54	77	23
Oakley Creek	12	240	9900	1600	2716	926
Okura Creek	12	130	4100	1150	1216	311
Omaru Creek	12	150	14000	650	1851	1128
Opanuku Stream	12	290	2800	525	868	238
Otaki Creek	12	300	23000	1200	3193	1823
Otara Creek (East Tamaki)	12	350	53000	1800	6801	4272
Otara Creek (Kennel Hill)	12	360	20000	2650	5008	1732
Oteha Stream	12	38	4100	625	1262	418
Pakuranga Creek (Botany Rd)	12	410	21000	1750	4103	1717
Pakuranga Creek (Greenmount Drive)	12	270	6900	2750	3268	782
Papakura Stream (Alfriston-Ardmore Rd)	12	54	5500	645	1229	467
Papakura Stream (Porchester Rd)	12	290	58000	1250	7220	4697
Puhinui Stream	12	180	6300	790	2123	708
Rangitopuni River (NIWA operated)	12	64	7701	249	904	620
Riverhead Forest Stream	12	2	1100	125	258	99
Vaughan Stream	12	360	4000	855	1227	320
Wairoa Tributary	12	60	1400	140	359	124
Wairoa River	12	81	5300	560	1328	453
Waitangi River	12	72	2700	340	686	263
Waiwera River	12	220	12000	605	1504	958
West Hoe Stream	12	0	210	30	45	17
Whangamaire Stream	12	0	4100	240	707	328

## 4.3 Water Quality Indices and classes

Using the methodology described in Appendix 1, water quality indices and classes were generated for each of the 34 sites (Table 27).

The Cascade and Opanuku Streams exhibited the best water quality in 2012, each with perfect scores of 100. The only other Auckland streams classified as having excellent water quality for 2012 were West Hoe Stream and Wairoa Tributary. Cascade Stream, West Hoe Stream and Wairoa Tributary are all situated in native forest catchments and are reference sites for the Auckland Region. Opanuku Stream is classed as rural, but still has a significant amount of native forest in its catchment. Cascade Stream and West Hoe Stream were also classed as having excellent water quality in 2011, whereas Opanuku Stream and Wairoa Tributary were classed as having fair water quality.

Pakuranga Creek (at Greenmount Drive) had the worst water quality of the monitoring sites in 2012, with exceedances of the target levels common and often of high magnitudes. Pakuranga Creek (Greenmount Drive) exceeded target levels of Ammoniacal Nitrogen on every sampling occasion during 2012.

There are 13 sites that had the same water quality class in 2012 as in 2011 (Lockie and Neale, 2012), with 18 sites showing a change in class. Of these 18 sites, ten recorded an improvement in class, whereas eight recorded a decline in class. However, of these 18 sites, only two sites changed by more than one class. Waitangi River moved from poor water quality in 2011 to good in 2012; and Waiwera Stream moved from excellent to fair. Such large changes in water quality class are unusual and these sites should be monitored closely to determine the reasoning of these water quality changes.

The WQI has now been used since 2007 for reporting the results of the water quality programme. The mean WQI from 2009, 2010 and 2011 was used as a reference point to assess the 2012 results. This comparison identified how the WQI for a particular site in 2012 deviated from the three-year average for that site (final column in Table 27).

Whilst most sites were within +/- 10 units of the three-year average for that site, there were 10 sites that 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 2012 was observed at the Waitangi River site, where the 2012 WQI (76.8) was 23.5 points higher than the three year mean (53.3).

Table 27 indicates that, in general, urban sites were typically ranked lower in 2012. 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 28). The native forest sites had the best water quality indices in 2012 (excellent), followed by the exotic forest sites (good), with the urban sites having the worst water quality indices (fair), but the same quality class as rural sites (fair). The sites with rural and exotic forest catchments typically had water quality indices intermediate between native forest and urban sites.

**Table 27**

Site based water quality indices and classes based on 2012 data. Deviation is based on the difference between 2012 WQI and the mean 2009, 2010 and 2011 WQI (comparisons are not possible for the sites added in 2012 (new sites)).

	Site	Scope	Frequency	Magnitude	2012 WQI	2012 class	Deviation
1	Cascade Stream	0.0	0.0	0.0	100.0	Excellent	8.4
2	Opanuku Stream	0.0	0.0	0.0	100.0	Excellent	8.3
3	Wairoa Tributary	14.3	1.2	0.2	91.7	Excellent	2.8
4	West Hoe Stream	14.3	1.2	0.2	91.7	Excellent	-2.8
5	Riverhead Stream	28.6	3.6	0.3	83.4	Good	3.0
6	Nukumea Stream	28.6	2.4	2.7	83.4	Good	New site
7	Mahurangi River (Forestry HQ)	28.6	2.4	8.1	82.8	Good	-0.6
8	Ngakaroa Stream	14.3	14.3	26.2	80.9	Good	14.3
9	Waitangi River	28.6	16.7	22.9	76.8	Good	23.5
10	Rangitopuni River (NIWA)	42.9	7.1	1.0	74.9	Good	3.4
11	Oakley Creek	42.9	19.0	14.8	71.6	Good	4.4
12	Lucas Creek	57.1	9.5	2.6	66.5	Fair	-3.0
13	Okura Creek	57.1	9.5	5.4	66.4	Fair	11.2
14	Makarau River	57.1	6.0	11.8	66.1	Fair	-6.0
15	Waiwera Stream	57.1	6.0	12.2	66.1	Fair	-17.2
16	Mahurangi River (Water Supply)	57.1	9.5	11.3	65.9	Fair	-9.1
17	Wairoa River	57.1	15.5	4.7	65.7	Fair	3.7
18	Kumeu River	71.4	7.1	2.3	58.5	Fair	-2.4
19	Hoteo River	71.4	8.3	3.8	58.4	Fair	-22.1
20	Matakana River	71.4	8.3	7.4	58.3	Fair	-16.8
21	Avondale Stream	71.4	11.9	2.3	58.2	Fair	New site
22	Omaru Creek	71.4	15.5	7.2	57.6	Fair	11.2
23	Vaughan Stream	71.4	19.0	6.8	57.1	Fair	-0.4
24	Puhinui Stream	71.4	21.4	4.3	56.9	Fair	2.9
25	Otara Creek (Kennel Hill)	71.4	21.4	12.1	56.4	Fair	-1.6
26	Otara Creek (East Tamaki)	71.4	21.4	13.4	56.3	Fair	-1.2
27	Papakura Stream (Porchester Rd)	71.4	21.4	19.4	55.5	Fair	-3.9
28	Pakuranga Creek (Botany Rd)	71.4	27.4	14.7	55.0	Fair	11.4
29	Otaki Creek	71.4	29.8	17.5	54.2	Fair	15.4
30	Kaukapakapa River	85.7	15.5	7.7	49.5	Poor	-5.5
31	Oteha Stream	85.7	19.0	4.9	49.2	Poor	-14.4
32	Papakura Stream (Alfriston Rd)	85.7	29.8	18.7	46.5	Poor	New Site
33	Whangamaire Stream	71.4	22.6	68.8	41.3	Poor	-2.0
34	Pakuranga Creek (Greenmount Dr)	85.7	50.0	48.2	36.3	Poor	-8.4

**Table 28**

Mean 2012 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	1.2	0.8	91.7	Excellent
Exotic forest (2)	28.6	3.0	4.2	83.1	Good
Rural (17)	57.1	12.7	13.5	64.0	Fair
Urban (11)	70.1	22.4	12.9	56.2	Fair

## **5 Acknowledgements**

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

During 2012, Peter Williams, Simon Tredgett, Peter Hancock, Jade Khin, Francesca Mitchell, Matt Hope, Ed Clayton, Nick Reid, Nicholas Holwerda, and Clive Coleman 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.

## 6 Appendix

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 29). 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 (2007 to 2011). 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 29**

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 2007 and 2011.

Dissolved oxygen (% saturation)	Between 74 and 120%
pH	Between 6.4 and 8.1
Turbidity	Less than 33 NTU
Ammoniacal nitrogen	Less than 0.06 mg N l <sup>-1</sup>
Temperature	Less than 18 °C
Total phosphorus	Less than 0.09 mg P l <sup>-1</sup>
Total nitrogen	Less than 0.8 mg N l <sup>-1</sup>

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