



State of the Environment Monitoring

River Water Quality Annual Report 2011

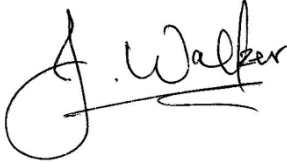
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State of the Environment Monitoring: River Water Quality Annual Report 2011

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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 2011 calendar year.

Water quality is assessed monthly at 31 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 2011 the best river water quality was in the Mahurangi River, followed by West Hoe Stream, Waiwera Stream and Cascades Stream, all of which were classified as having excellent water quality. Low water quality was observed in streams in and around the metropolitan urban area, however a rural site, namely the Whangamaire Stream, had the lowest ranked water quality in 2011.

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 & 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 & 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 types;

- 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). These differences reflect the high population density in Auckland and the environmental pressures associated with this high population.

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, and to assess the effects of environmental stressors upon them. 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 31 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 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 during its duration and the current 31 site network has been operating since January 2009. Each of the 31 sites is sampled monthly.

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 types 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 31 sites in the River Water Quality Programme during the 2011 calendar year. Furthermore, the 2011 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 22nd annual report since the inception of the monitoring programme, and the seventh 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 31 sites (Table 3). The number of sites sampled each year has varied due to logistical considerations and programme objectives, and the current network has been operating since January 2009. The location of the 31 sites is displayed on page 13 (Figure 1).

3.2 Monitoring network design

The sampling network began with 8 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 a combination of field measures (January to June) and laboratory tests (July to December), with erroneous field data removed.

There were no site changes in 2011.

3.4 Sampling methodology

For the 29 sites monitored by Auckland Council, all sample collection is carried out by Council staff. Up to 21 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 9001:2000. This covers procedures for the collection, transport and storage of samples, methods for data verification and quality assurance to ensure consistency across the monitoring programmes.

Laboratory samples are analysed under contract by Watercare Laboratory Services Ltd, an IANZ accredited laboratory. Analytical methods follow the "Standard Methods for the Examination of Water and Wastewater" 21st Edition (APHA, 2005).

Table 3

Sites sampled in 2011 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
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
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)	1769973	5913013	Urban	1985
Pakuranga Creek (Greenmount Drive)	1769473	5910813	Urban	1985
Papakura Stream	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	1784426	5898982	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 31 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 2011 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 (25th to 75th percentile) and the whiskers represent the 5th and 95th 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 which 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⁻¹ limit of detection would be included in the data analysis as 0.5 mg l⁻¹.

Table 4

Parameters tested in 2011 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
Eschericia coli	E. coli	cfu/100ml	APHA (2005) 9213 F

4 Results

The data from the 2011 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)

The results listed below should be used with discretion for the following reasons;

- pH
 - The Council experienced performance issues with one of its field meters during 2011. The issues were restricted to the pH sensor on the probe, which returned numerous erroneous results. To eliminate the effects of this performance issue, any pH data derived from this meter was removed prior to analysis. Hence, for many sites there is not a full complement of pH data for 2011.

4.1 Box plots

Figure 3

Box plots showing the variation in dissolved oxygen % saturation (upper plot) and ppm (lower plot) at the 31 sites using data collected during the 2011 calendar year.

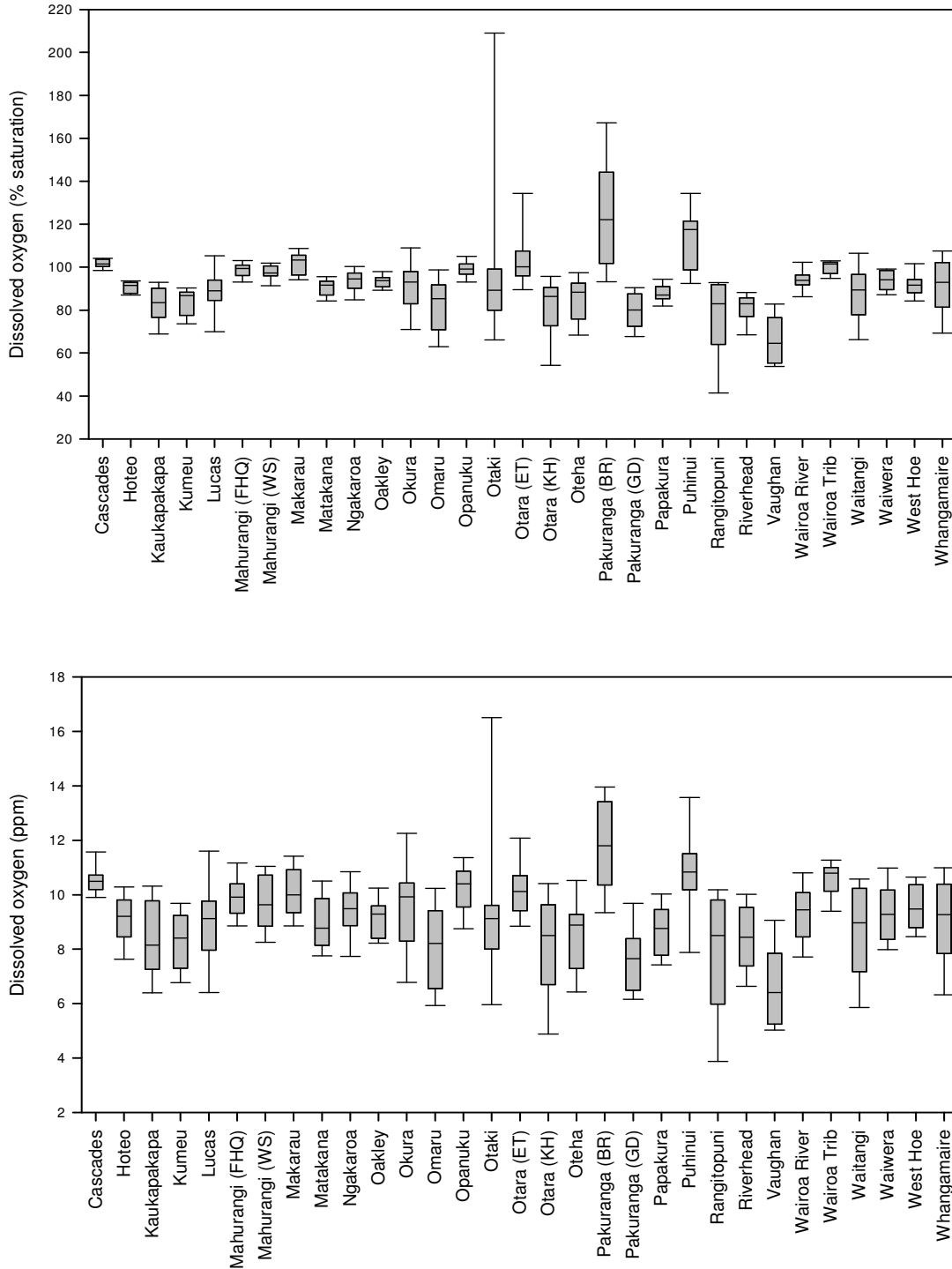


Figure 4

Box plots showing the variation in temperature (upper plot) and conductivity (lower plot) at the 31 sites using data collected during the 2011 calendar year. Note the axis break and scale change on the y-axis of the conductivity plot.

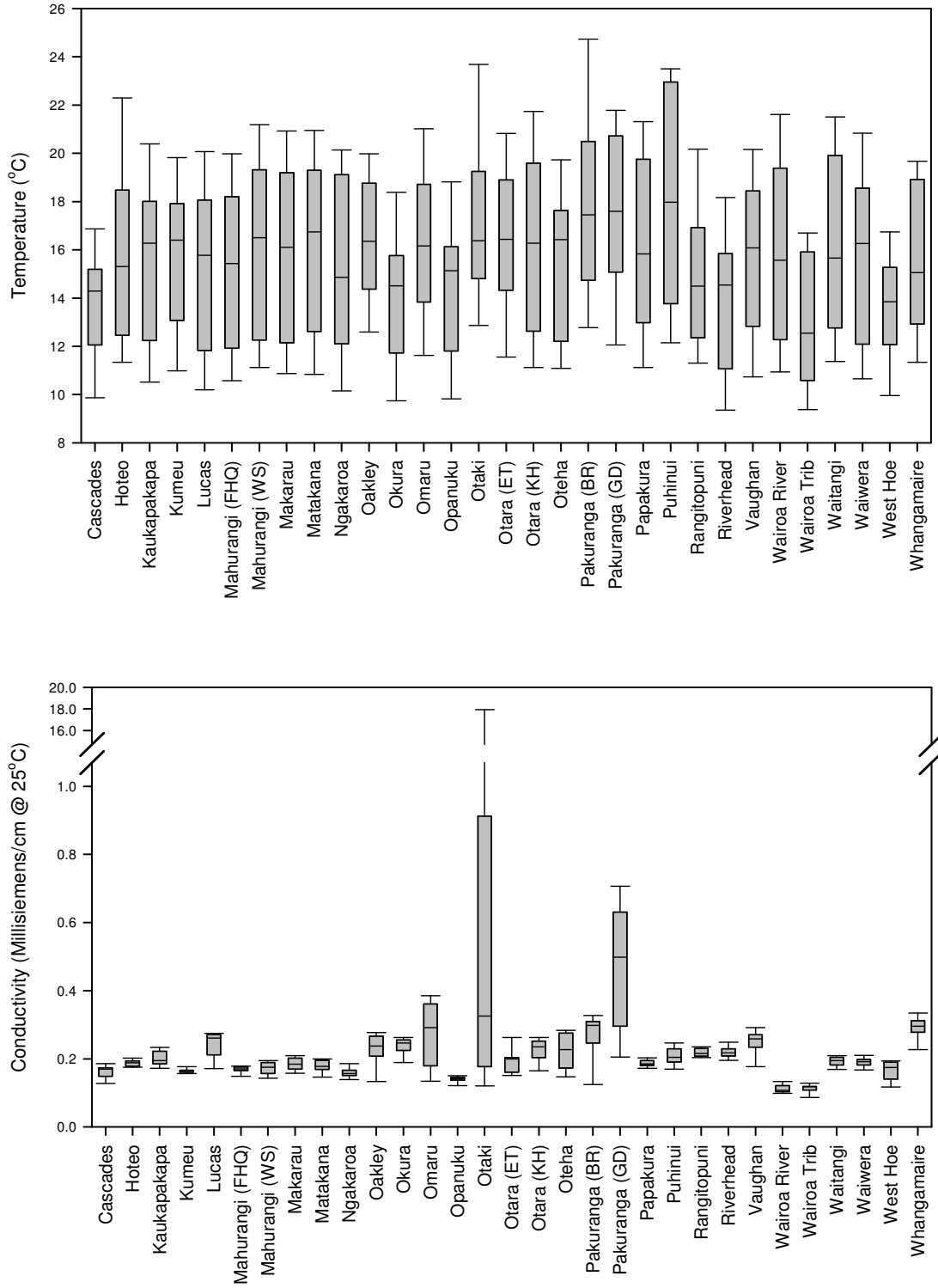


Figure 5

Box plots showing the variation in salinity (upper plot) and pH (lower plot) at the 31 sites using data collected during the 2011 calendar year. Note the axis break and scale change on the y-axis of the salinity plot.

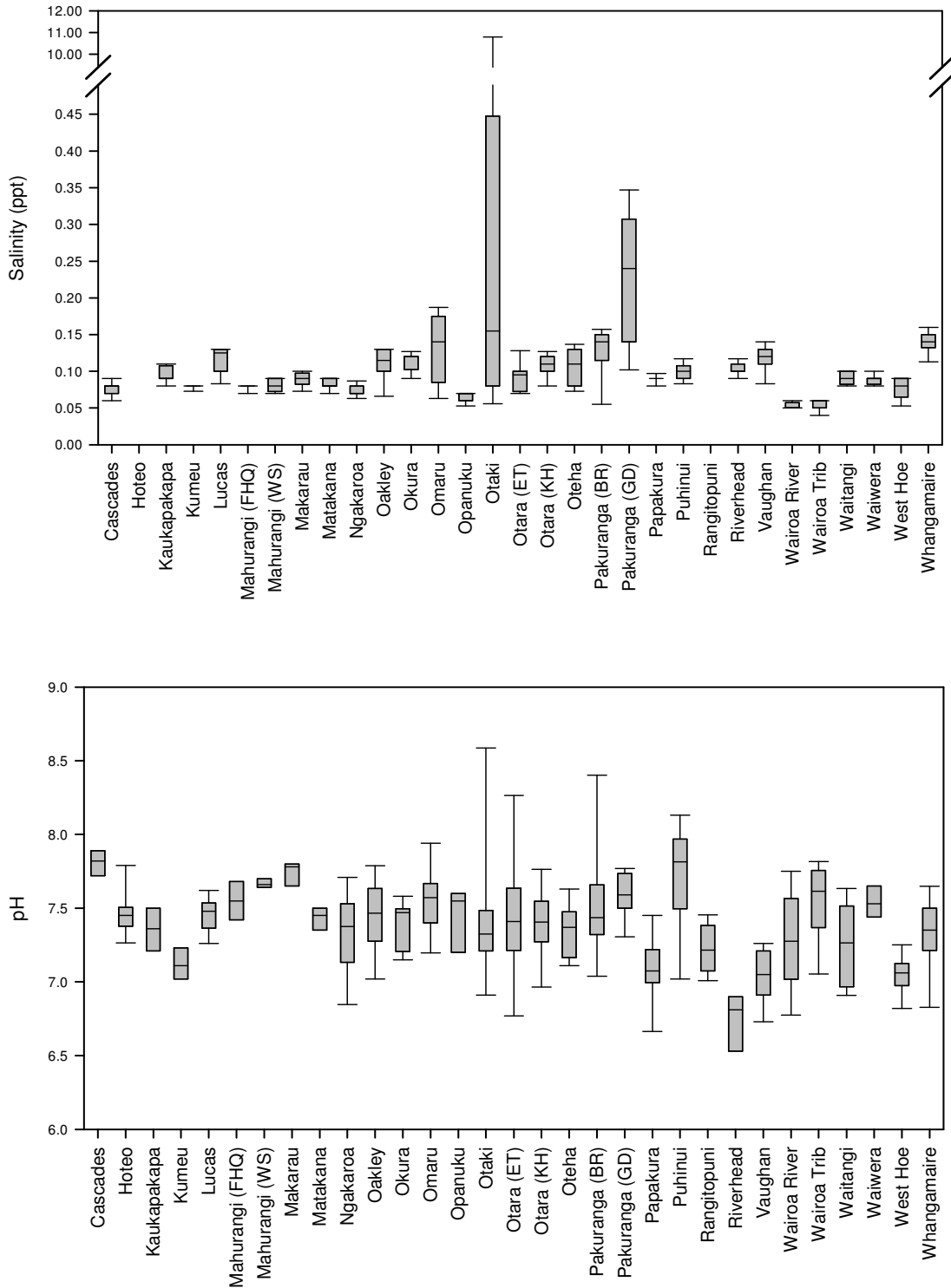


Figure 6

Box plots showing the variation in suspended sediment (upper plot) and turbidity (lower plot) at the 31 sites using data collected during the 2011 calendar year. Note the axis break and scale change on the y-axis of both plots.

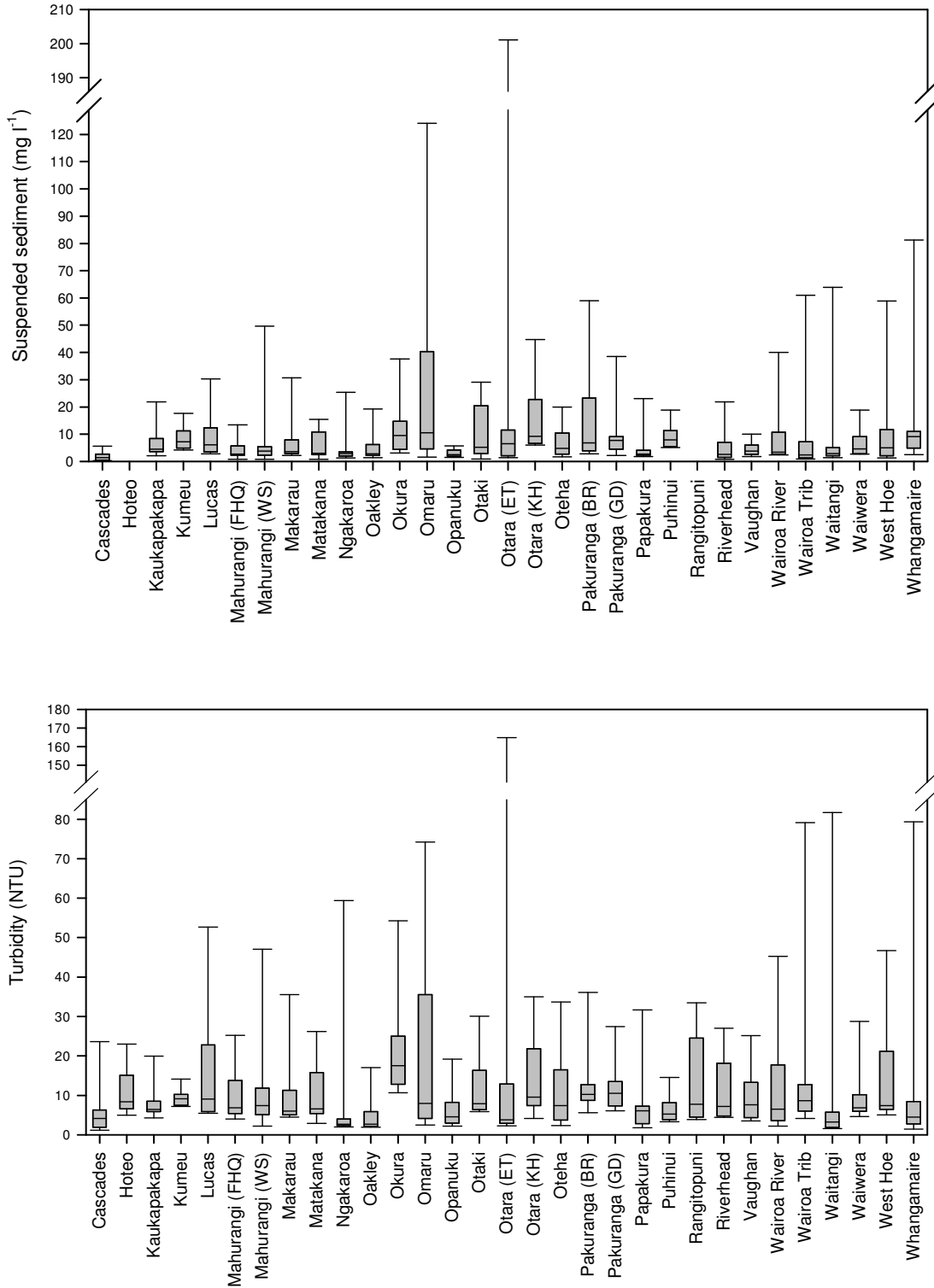


Figure 7

Box plots showing the variation in ammoniacal nitrogen (upper plot) and total oxidised nitrogen (lower plot) at the 31 sites using data collected during the 2011 calendar year. Note the axis break and scale change on the y-axis of the total oxidised nitrogen plot.

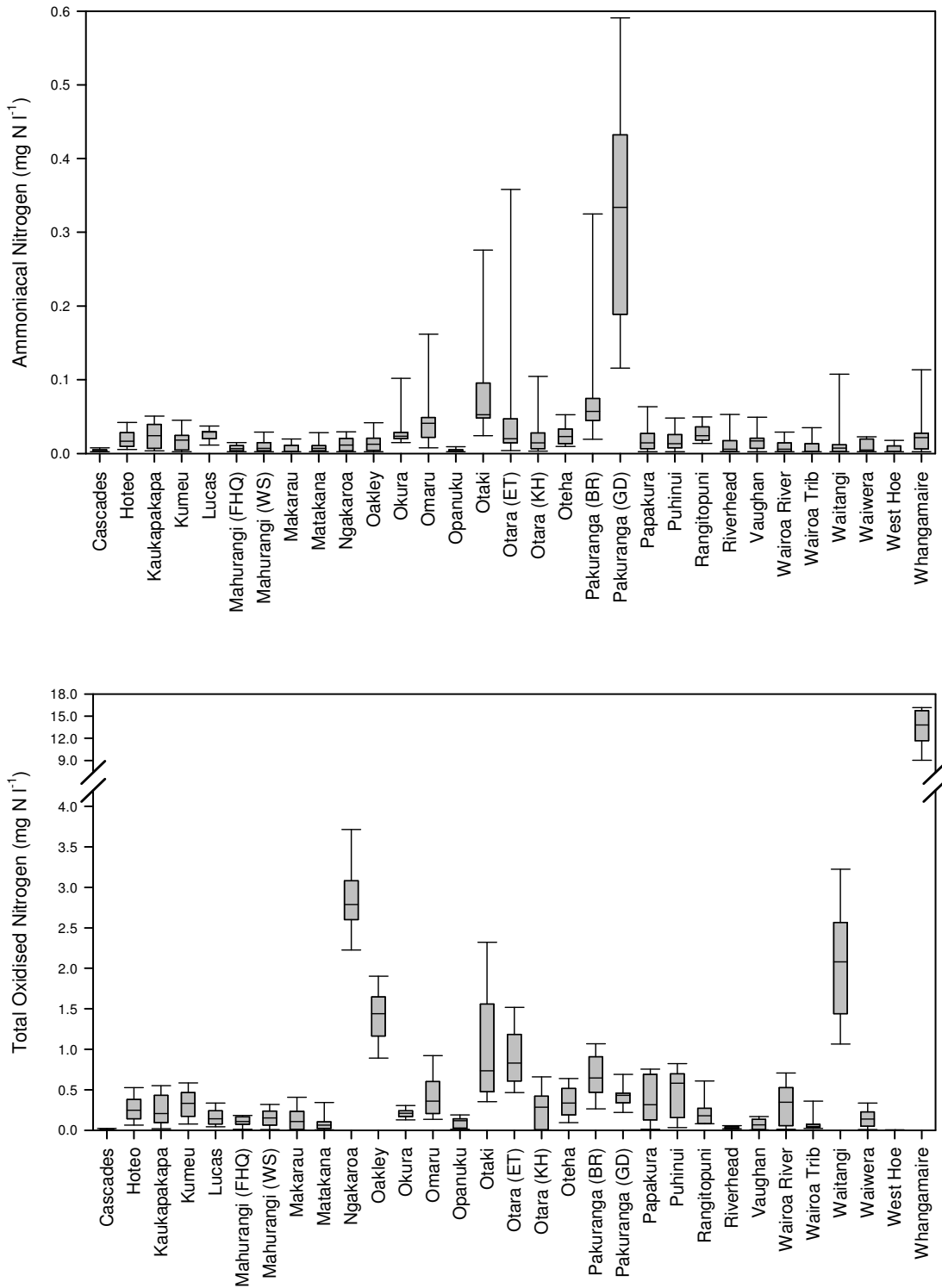


Figure 8

Box plots showing the variation in Kjeldhal nitrogen (upper plot) and total nitrogen (lower plot) at the 31 sites using data collected during the 2011 calendar year. Note the axis break and scale change on the y-axis of both plots.

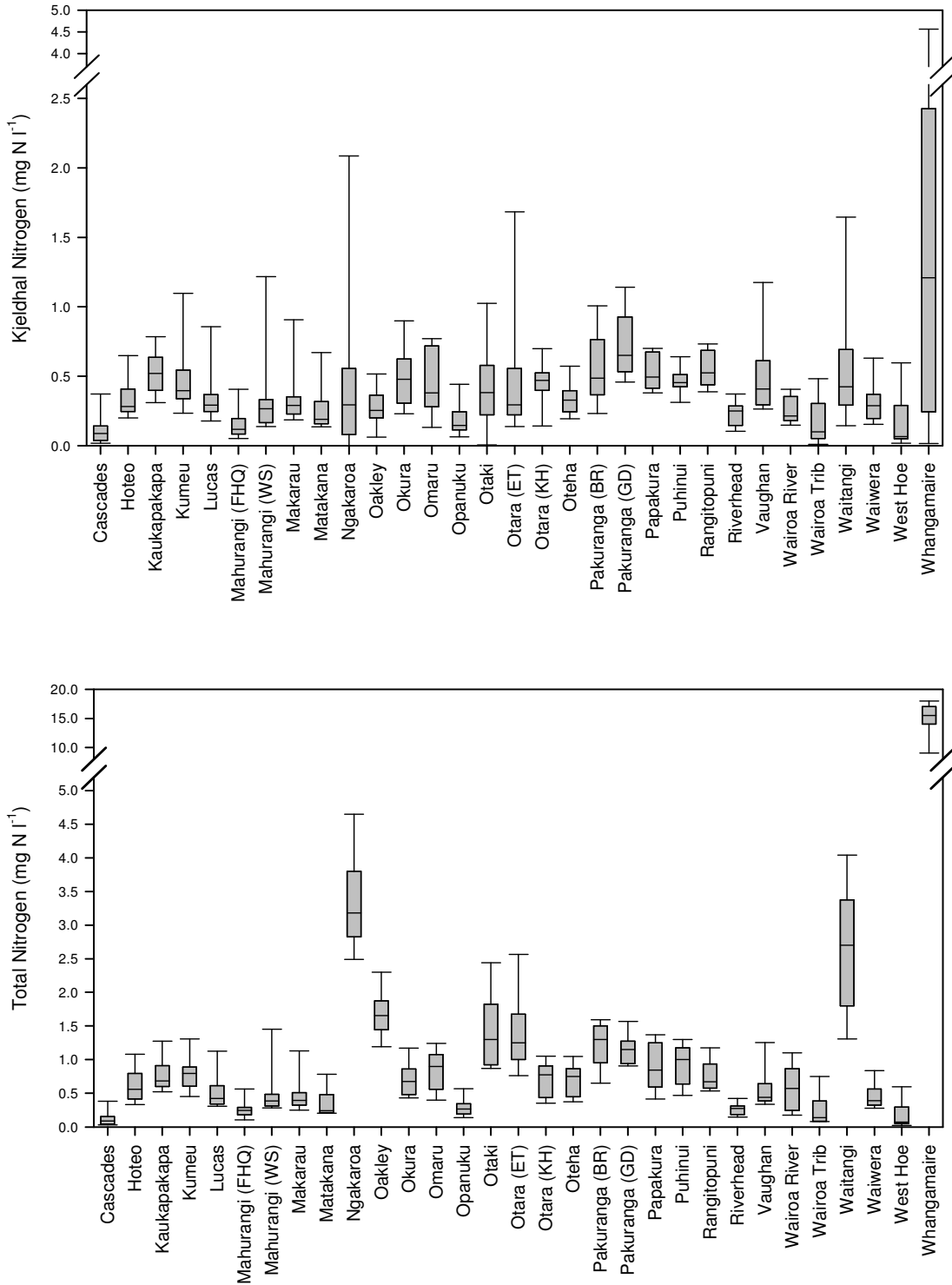


Figure 9

Box plots showing the variation in soluble reactive phosphorus (upper plot) and total phosphorus (lower plot) at the 31 sites using data collected during the 2011 calendar year. Note the axis break and scale change on the y-axis of the soluble reactive phosphorous plot.

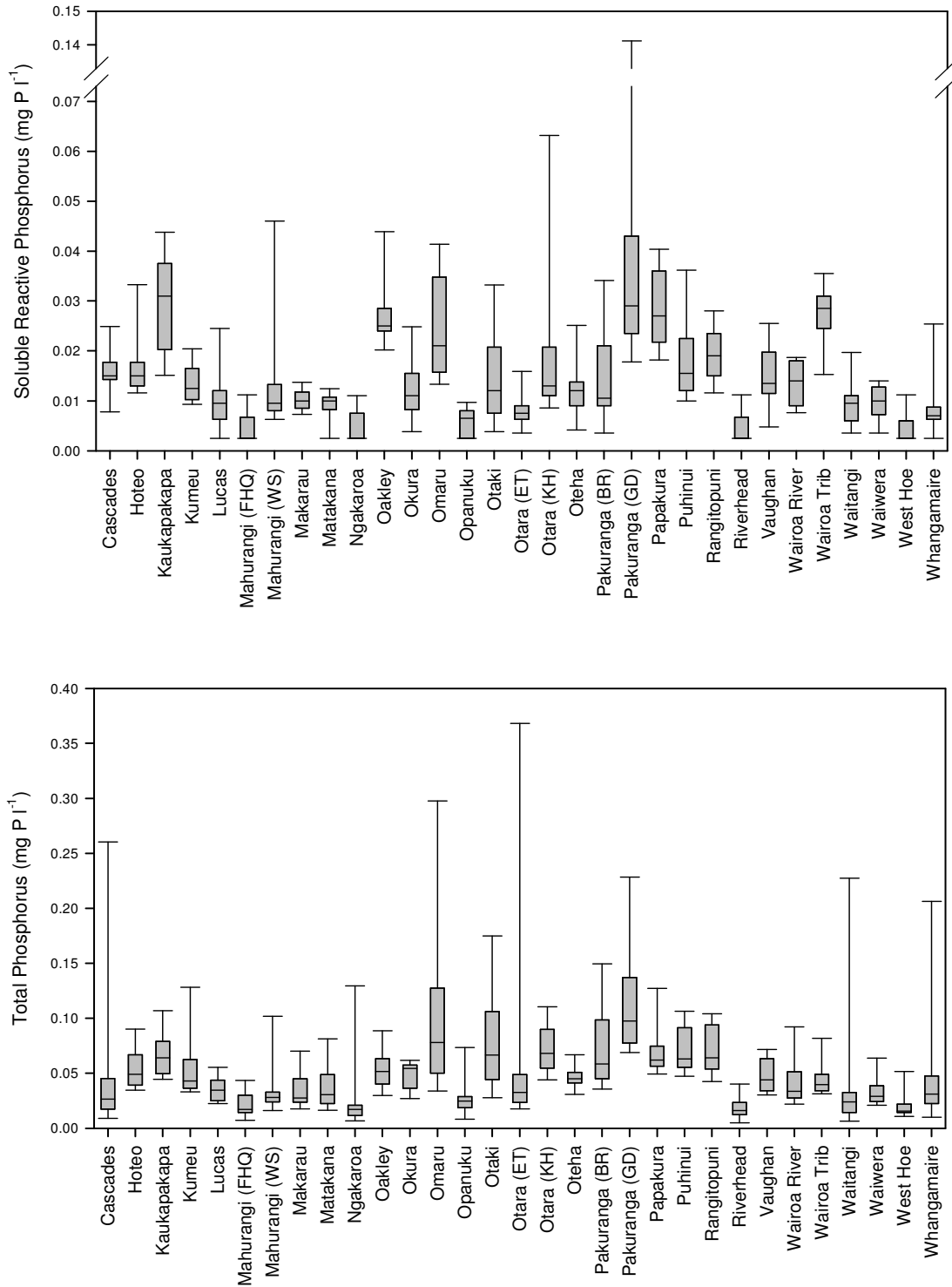


Figure 10

Box plots showing the variation in soluble copper (upper plot) and total copper (lower plot) at the 21 sites where it is monitored, using data collected during the 2011 calendar year. Note the axis break and scale change on the y-axis of both plots.

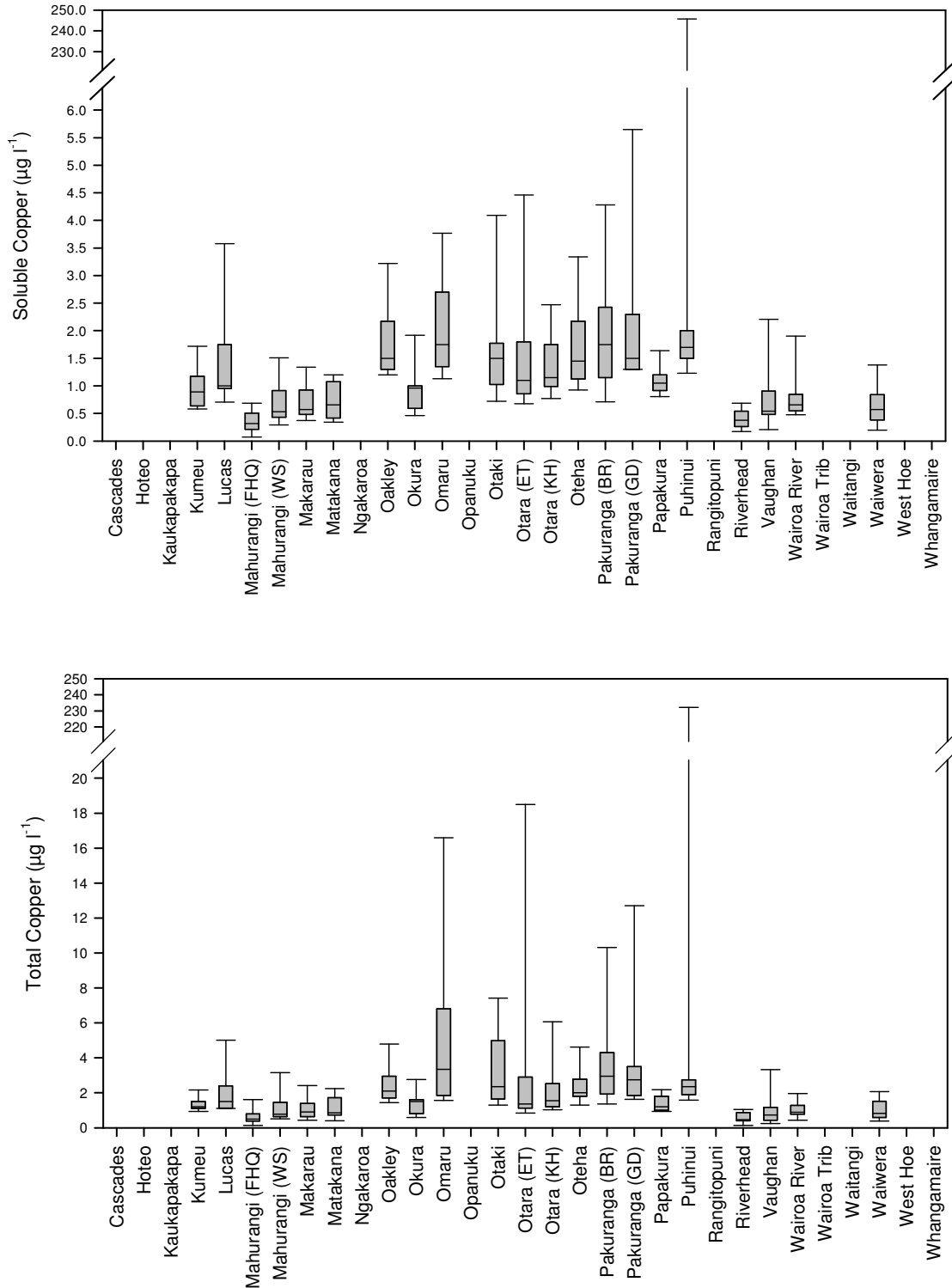


Figure 11

Box plots showing the variation in soluble zinc (upper plot) and total zinc (lower plot) at the 21 sites where it is monitored, using data collected during the 2011 calendar year. Note the axis break and scale change on the y-axis of the soluble zinc plot.

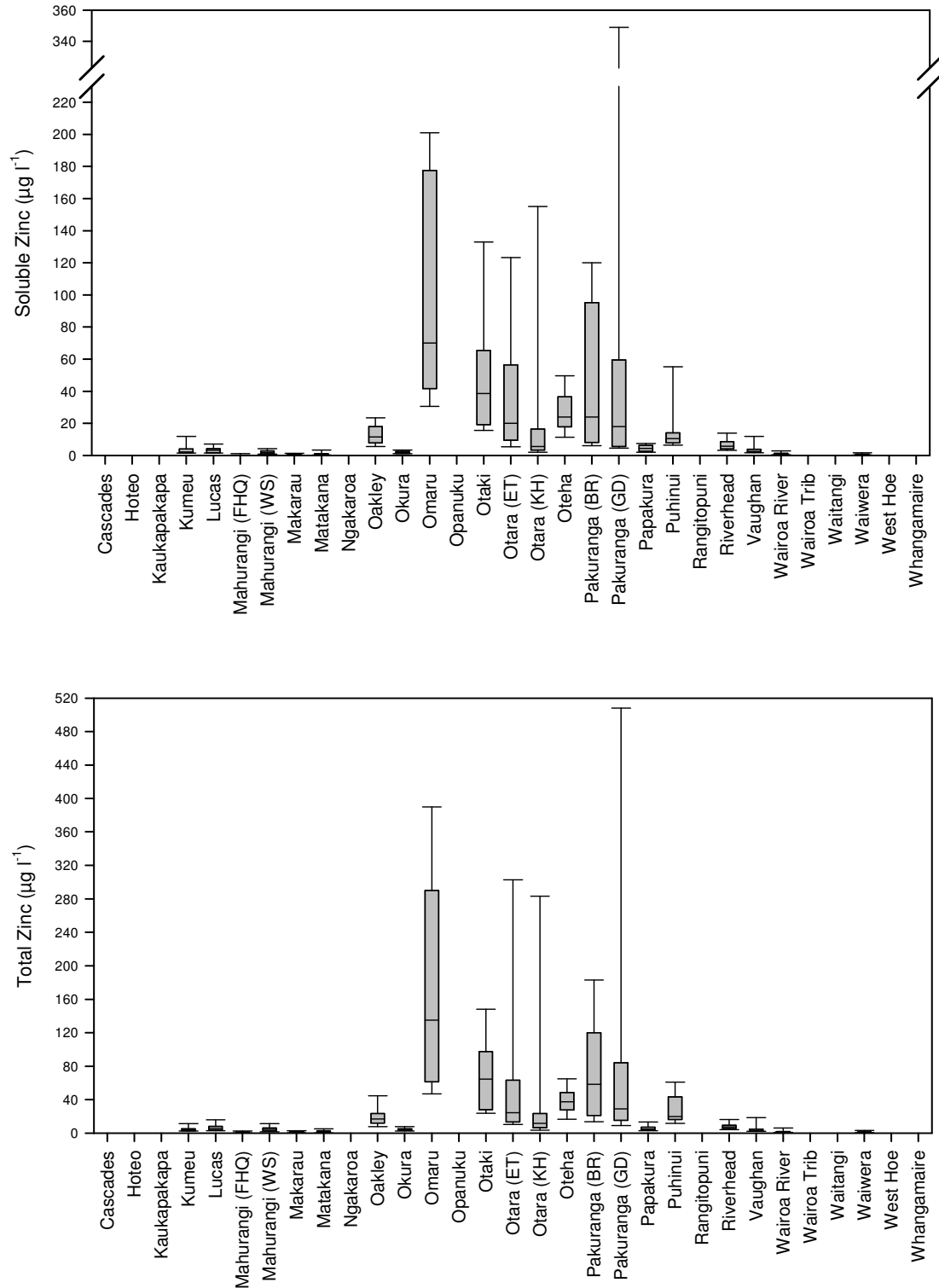


Figure 12

Box plots showing the variation in soluble lead (upper plot) and total lead (lower plot) at the 21 sites where it is monitored, using data collected during the 2011 calendar year. Note the axis break and scale change on the y-axis of both plots.

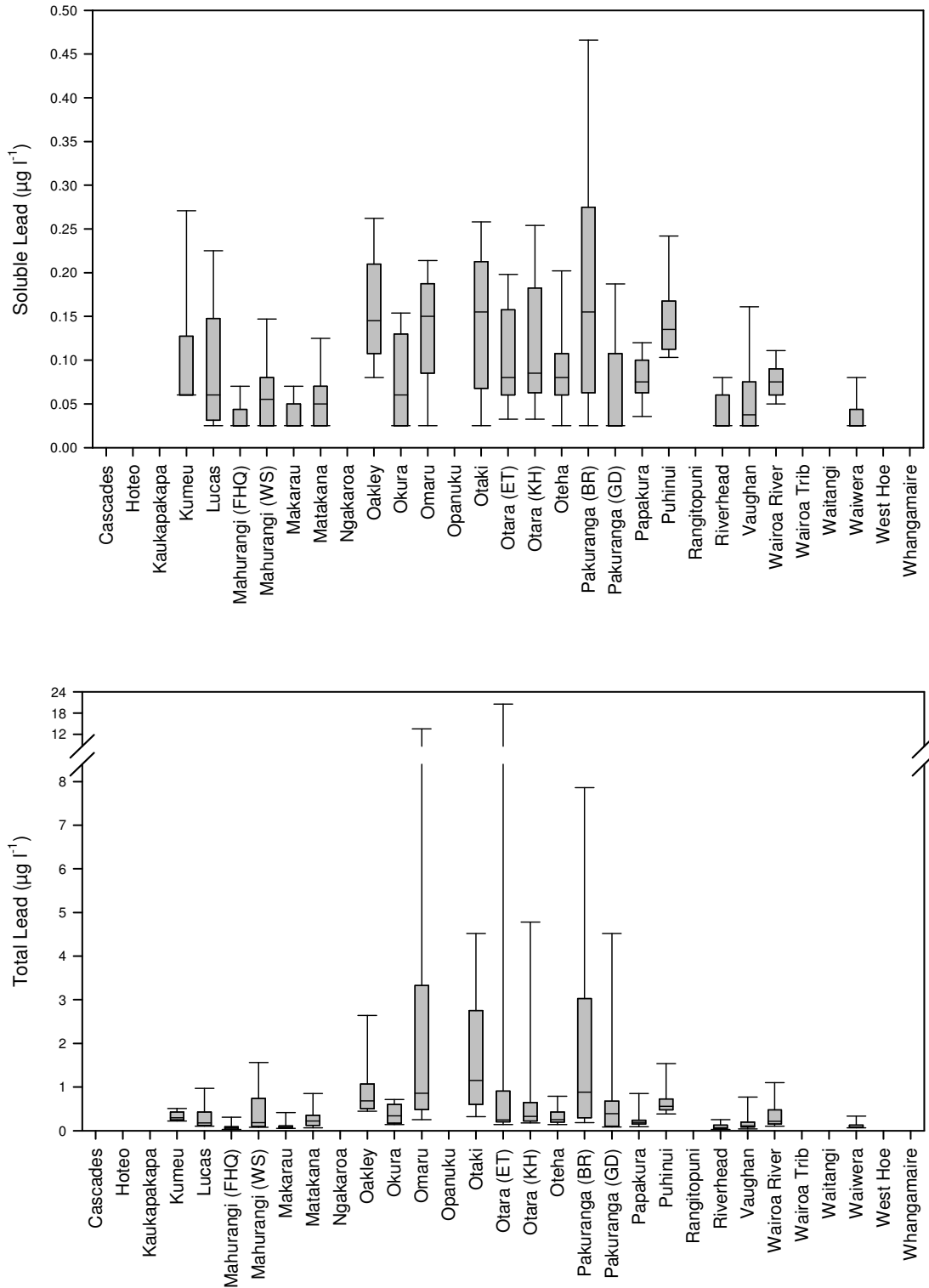
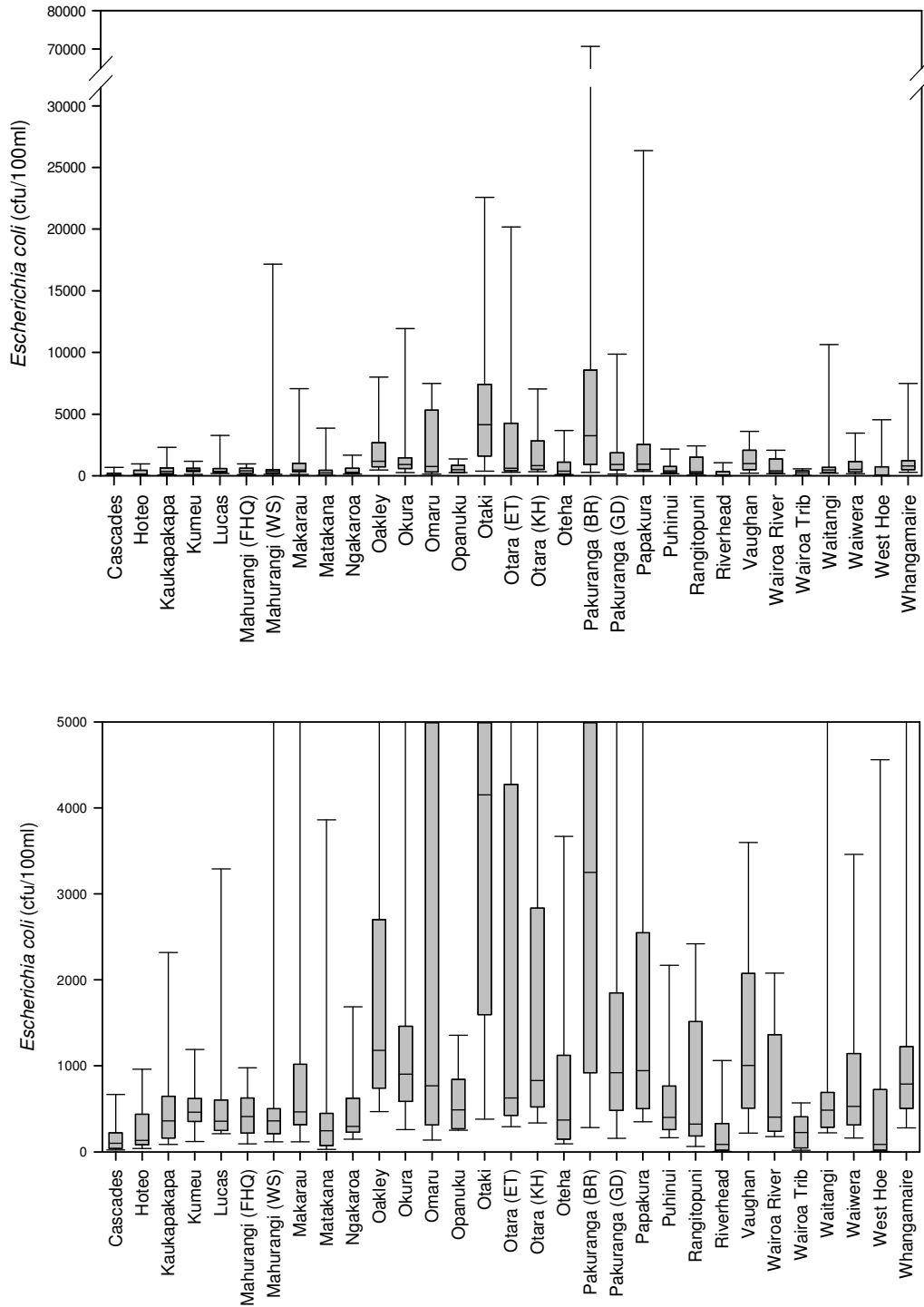


Figure 13

Box plot showing the variation in *Escherichia coli* at the 31 sites using data collected during the 2011 calendar year. The upper plot has y-axis which covers the full range of the data; the lower plot y-axis is limited to 5000 to provide greater resolution for sites with lower *Escherichia coli* levels. Note the axis break and scale change on the y-axis of the upper plot.



4.2 Summary tables

Table 6
Dissolved oxygen (% saturation)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	12	98.3	104.1	101.5	101.7	0.58
Hoteo River (NIWA operated)	12	86.9	93.8	91.6	90.7	0.74
Kaukapakapa River	12	67.6	93.5	83.5	83.0	2.42
Kumeu River	12	72.8	90.9	86.8	83.3	1.83
Lucas Creek	12	67.8	109.4	89.1	88.4	2.99
Mahurangi River (Forestry HQ)	12	92.2	103.7	99.4	98.8	0.92
Mahurangi River (Water Supply)	12	91.1	102.0	97.2	97.5	1.02
Makarau River	12	93.4	109.4	103.4	101.8	1.47
Matakana River	12	83.9	95.8	91.7	90.5	1.14
Ngakaroa Stream	12	82.6	100.6	94.5	93.8	1.44
Oakley Creek	12	89.0	98.2	93.8	93.3	0.83
Okura Creek	12	67.5	113.5	93.2	91.2	3.34
Omaru Creek	12	62.5	100.7	85.3	81.6	3.59
Opanuku Stream	12	92.4	105.5	99.1	99.2	1.07
Otaki Creek	12	64.9	254.2	89.3	100.6	14.36
Otara Creek (East Tamaki)	12	89.0	142.2	100.2	104.1	4.11
Otara Creek (Kennell Hill)	12	53.3	96.0	86.4	80.8	4.02
Oteha Stream	12	67.5	98.4	88.4	85.2	2.85
Pakuranga Creek (Botany Rd)	12	90.5	174.4	122.2	125.0	7.52
Pakuranga Creek (Greenmount Drive)	12	67.1	90.8	80.1	79.7	2.33
Papakura Stream	12	81.8	94.4	87.1	87.9	1.19
Puhinui Stream	12	90.9	137.9	117.6	113.2	4.01
Rangitopuni River (NIWA operated)	12	38.9	93.0	83.0	76.6	5.39
Riverhead Forest Stream	12	67.8	88.6	82.9	80.8	1.91
Vaughan Stream	12	53.7	83.1	64.5	65.5	3.12
Wairoa River	12	84.5	102.9	93.8	94.2	1.39
Wairoa Tributary	12	94.2	103.1	101.5	99.9	0.86
Waitangi River	12	64.7	106.8	89.4	87.8	3.76
Waiwera River	12	86.4	99.2	94.1	93.8	1.26
West Hoe Stream	12	83.0	103.3	91.7	91.7	1.52
Whangamaire Stream	12	66.5	108.9	93.0	90.8	3.63

Table 7

Dissolved oxygen (ppm)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	12	9.9	11.7	10.5	10.5	0.15
Hoteo River (NIWA operated)	12	7.6	10.4	9.2	9.1	0.26
Kaukapakapa River	12	6.4	10.5	8.2	8.4	0.40
Kumeu River	12	6.6	9.7	8.4	8.3	0.31
Lucas Creek	12	6.1	12.3	9.1	9.0	0.45
Mahurangi River (Forestry HQ)	12	8.8	11.2	9.9	10.0	0.22
Mahurangi River (Water Supply)	12	8.1	11.1	9.6	9.7	0.29
Makarau River	12	8.8	11.4	10.0	10.1	0.25
Matakana River	12	7.7	10.6	8.8	9.0	0.28
Ngakaroa Stream	12	7.6	10.9	9.5	9.5	0.28
Oakley Creek	12	8.2	10.4	9.3	9.2	0.20
Okura Creek	12	6.3	12.9	9.9	9.5	0.49
Omaru Creek	12	5.9	10.4	8.2	8.1	0.44
Opanuku Stream	12	8.5	11.5	10.4	10.2	0.25
Otaki Creek	12	5.8	19.3	9.1	9.4	0.98
Otara Creek (East Tamaki)	12	8.7	12.6	10.1	10.2	0.30
Otara Creek (Kennell Hill)	12	4.8	10.5	8.5	8.1	0.55
Oteha Stream	12	6.4	10.9	8.9	8.5	0.38
Pakuranga Creek (Botany Rd)	12	9.2	14.1	11.8	11.8	0.49
Pakuranga Creek (Greenmount Drive)	12	6.1	9.7	7.7	7.7	0.35
Papakura Stream	12	7.4	10.1	8.8	8.7	0.27
Puhinui Stream	12	7.7	13.9	10.8	10.7	0.49
Rangitopuni River (NIWA operated)	12	3.6	10.3	8.5	7.9	0.65
Riverhead Forest Stream	12	6.6	10.2	8.4	8.4	0.34
Vaughan Stream	12	5.0	9.1	6.4	6.6	0.42
Wairoa River	12	7.5	10.9	9.4	9.4	0.29
Wairoa Tributary	12	9.2	11.3	10.8	10.6	0.18
Waitangi River	12	5.7	10.6	9.0	8.7	0.49
Waiwera River	12	7.8	11.1	9.3	9.4	0.30
West Hoe Stream	12	8.4	10.7	9.5	9.6	0.23
Whangamaire Stream	12	6.1	11.0	9.3	9.1	0.45

Table 8
Temperature (°C)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	12	9.2	17.1	14.3	13.8	0.64
Hoteo River (NIWA operated)	12	11.3	22.6	15.3	15.9	1.08
Kaukapakapa River	12	10.4	20.9	16.3	15.5	0.98
Kumeu River	12	10.9	20.0	16.4	15.7	0.87
Lucas Creek	12	10.1	20.8	15.8	15.2	1.00
Mahurangi River (Forestry HQ)	12	10.3	20.6	15.4	15.1	0.93
Mahurangi River (Water Supply)	12	11.0	21.3	16.5	16.1	1.05
Makarau River	12	10.7	21.4	16.1	15.9	1.03
Matakana River	12	10.5	21.5	16.7	16.1	1.01
Ngakaroa Stream	12	10.1	20.3	14.9	15.3	1.04
Oakley Creek	12	12.4	20.1	16.4	16.3	0.74
Okura Creek	12	9.7	18.5	14.5	14.0	0.84
Omaru Creek	12	11.0	21.3	16.2	16.3	0.88
Opanuku Stream	12	9.4	19.4	15.1	14.3	0.84
Otaki Creek	12	12.6	25.0	16.4	17.1	0.99
Otara Creek (East Tamaki)	12	10.9	21.4	16.4	16.4	0.85
Otara Creek (Kennell Hill)	12	10.6	22.1	16.3	16.1	1.10
Oteha Stream	12	10.7	20.0	16.4	15.6	0.88
Pakuranga Creek (Botany Rd)	12	12.2	26.2	17.5	17.8	1.10
Pakuranga Creek (Greenmount Drive)	12	11.8	21.9	17.6	17.4	0.95
Papakura Stream	12	10.9	21.6	15.8	16.1	1.04
Puhinui Stream	12	12.1	23.7	18.0	18.2	1.25
Rangitopuni River (NIWA operated)	12	11.1	20.2	14.5	15.0	0.86
Riverhead Forest Stream	12	9.1	18.2	14.5	13.8	0.88
Vaughan Stream	12	10.6	20.8	16.1	15.7	0.94
Wairoa River	12	10.7	21.9	15.6	16.0	1.09
Wairoa Tributary	12	9.2	16.7	12.6	12.9	0.76
Waitangi River	12	11.4	21.8	15.7	16.1	1.06
Waiwera River	12	10.4	21.4	16.3	15.8	1.02
West Hoe Stream	12	9.9	16.9	13.8	13.6	0.65
Whangamaire Stream	12	11.2	19.7	15.1	15.6	0.89

Table 9

Conductivity (Millisiemens/cm @ 25°C)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	12	0.12	0.19	0.17	0.16	0.005
Hoteo River (NIWA operated)	12	0.18	0.21	0.19	0.19	0.003
Kaukapakapa River	12	0.17	0.24	0.19	0.20	0.006
Kumeu River	12	0.16	0.18	0.16	0.16	0.002
Lucas Creek	12	0.17	0.28	0.26	0.24	0.011
Mahurangi River (Forestry HQ)	12	0.15	0.18	0.17	0.17	0.003
Mahurangi River (Water Supply)	12	0.14	0.20	0.18	0.17	0.005
Makarau River	12	0.16	0.21	0.18	0.19	0.005
Matakana River	12	0.14	0.20	0.18	0.18	0.005
Ngakaroa Stream	12	0.14	0.19	0.16	0.16	0.004
Oakley Creek	12	0.12	0.28	0.24	0.23	0.014
Okura Creek	12	0.19	0.27	0.25	0.24	0.007
Omaru Creek	12	0.13	0.39	0.29	0.27	0.027
Opanuku Stream	12	0.12	0.15	0.14	0.14	0.003
Otaki Creek	12	0.11	24.12	0.33	2.62	1.973
Otara Creek (East Tamaki)	12	0.15	0.29	0.20	0.19	0.010
Otara Creek (Kennell Hill)	12	0.16	0.27	0.24	0.22	0.010
Oteha Stream	12	0.14	0.29	0.23	0.22	0.016
Pakuranga Creek (Botany Rd)	12	0.10	0.33	0.30	0.27	0.019
Pakuranga Creek (Greenmount Drive)	12	0.18	0.71	0.50	0.47	0.052
Papakura Stream	12	0.17	0.21	0.19	0.19	0.003
Puhinui Stream	12	0.16	0.25	0.20	0.21	0.007
Rangitopuni River (NIWA operated)	12	0.20	0.24	0.22	0.22	0.003
Riverhead Forest Stream	12	0.20	0.25	0.22	0.22	0.005
Vaughan Stream	12	0.17	0.29	0.26	0.25	0.011
Wairoa River	12	0.10	0.14	0.11	0.11	0.003
Wairoa Tributary	12	0.08	0.13	0.12	0.11	0.004
Waitangi River	12	0.16	0.21	0.20	0.19	0.004
Waiwera River	12	0.16	0.21	0.19	0.19	0.004
West Hoe Stream	12	0.12	0.20	0.17	0.17	0.008
Whangamaire Stream	12	0.22	0.34	0.30	0.29	0.010

Table 10
Salinity (ppt)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	12	0.06	0.09	0.08	0.08	0.003
Hoteo River (NIWA operated)	Not measured at this site					
Kaukapakapa River	12	0.08	0.11	0.09	0.10	0.003
Kumeu River	12	0.07	0.08	0.08	0.08	0.001
Lucas Creek	12	0.08	0.13	0.13	0.12	0.005
Mahurangi River (Forestry HQ)	12	0.07	0.08	0.08	0.08	0.001
Mahurangi River (Water Supply)	12	0.07	0.09	0.08	0.08	0.002
Makarau River	12	0.07	0.10	0.09	0.09	0.003
Matakana River	12	0.07	0.09	0.08	0.08	0.002
Ngakaroa Stream	12	0.06	0.09	0.07	0.07	0.002
Oakley Creek	12	0.06	0.13	0.12	0.11	0.006
Okura Creek	12	0.09	0.13	0.12	0.11	0.004
Omaru Creek	12	0.06	0.19	0.14	0.13	0.013
Opanuku Stream	12	0.05	0.07	0.07	0.07	0.002
Otaki Creek	12	0.05	14.62	0.16	1.52	1.199
Otara Creek (East Tamaki)	12	0.07	0.14	0.10	0.09	0.006
Otara Creek (Kennell Hill)	12	0.08	0.13	0.11	0.11	0.005
Oteha Stream	12	0.07	0.14	0.11	0.11	0.008
Pakuranga Creek (Botany Rd)	12	0.04	0.16	0.14	0.13	0.010
Pakuranga Creek (Greenmount Drive)	12	0.09	0.35	0.24	0.23	0.025
Papakura Stream	12	0.08	0.10	0.09	0.09	0.001
Puhinui Stream	12	0.08	0.12	0.10	0.10	0.003
Rangitopuni River (NIWA operated)	Not measured at this site					
Riverhead Forest Stream	12	0.09	0.12	0.10	0.10	0.003
Vaughan Stream	12	0.08	0.14	0.12	0.12	0.005
Wairoa River	12	0.05	0.06	0.05	0.05	0.001
Wairoa Tributary	12	0.04	0.06	0.06	0.05	0.002
Waitangi River	12	0.08	0.10	0.09	0.09	0.002
Waiwera River	12	0.08	0.10	0.09	0.09	0.002
West Hoe Stream	12	0.05	0.09	0.08	0.08	0.004
Whangamaire Stream	12	0.11	0.16	0.14	0.14	0.004

Table 11
pH (pH units)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	7	7.1	7.9	7.8	7.7	0.11
Hoteo River (NIWA operated)	12	7.3	7.8	7.5	7.5	0.05
Kaukapakapa River	7	7.1	7.5	7.4	7.3	0.06
Kumeu River	7	6.9	7.3	7.1	7.1	0.05
Lucas Creek	9	7.3	7.6	7.5	7.5	0.04
Mahurangi River (Forestry HQ)	7	7.4	7.7	7.6	7.5	0.04
Mahurangi River (Water Supply)	7	7.5	7.8	7.7	7.7	0.04
Makarau River	7	7.4	7.9	7.8	7.7	0.06
Matakana River	7	7.3	7.7	7.5	7.5	0.04
Ngakaroa Stream	12	6.8	7.8	7.4	7.3	0.08
Oakley Creek	12	7.0	7.8	7.5	7.4	0.07
Okura Creek	9	7.2	7.6	7.5	7.4	0.05
Omaru Creek	12	7.1	8.0	7.6	7.6	0.07
Opanuku Stream	7	6.8	7.6	7.6	7.4	0.11
Otaki Creek	12	6.9	8.8	7.3	7.5	0.15
Otara Creek (East Tamaki)	12	6.8	8.4	7.4	7.4	0.13
Otara Creek (Kennell Hill)	12	6.9	7.8	7.4	7.4	0.07
Oteha Stream	9	7.1	7.6	7.4	7.3	0.06
Pakuranga Creek (Botany Rd)	12	7.0	8.7	7.4	7.5	0.12
Pakuranga Creek (Greenmount Drive)	12	7.3	7.8	7.6	7.6	0.05
Papakura Stream	12	6.6	7.5	7.1	7.1	0.07
Puhinui Stream	12	6.8	8.2	7.8	7.7	0.10
Rangitopuni River (NIWA operated)	12	7.0	7.5	7.2	7.2	0.05
Riverhead Forest Stream	7	6.5	7.0	6.8	6.8	0.07
Vaughan Stream	9	6.7	7.3	7.1	7.0	0.06
Wairoa River	12	6.7	7.8	7.3	7.3	0.09
Wairoa Tributary	12	7.0	7.8	7.6	7.6	0.07
Waitangi River	12	6.9	7.7	7.3	7.3	0.08
Waiwera River	7	7.4	7.7	7.5	7.5	0.04
West Hoe Stream	9	6.8	7.3	7.1	7.0	0.04
Whangamaire Stream	12	6.7	7.7	7.4	7.3	0.07

Table 12Suspended sediment (mg l^{-1})

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	12	0.2	6.4	1.4	1.9	0.53
Hoteo River (NIWA operated)	Not measured at this site					
Kaukapakapa River	12	1.6	27.0	4.5	7.0	1.95
Kumeu River	12	4.0	20.0	7.2	8.4	1.30
Lucas Creek	12	2.7	36.0	6.1	9.2	2.75
Mahurangi River (Forestry HQ)	12	0.4	14.0	2.7	4.5	1.22
Mahurangi River (Water Supply)	12	0.4	64.0	3.8	9.4	5.09
Makarau River	12	1.9	37.0	3.6	7.6	2.90
Matakana River	12	0.8	16.0	3.1	5.5	1.57
Ngakaroa Stream	12	1.2	34.0	2.9	5.3	2.62
Oakley Creek	12	1.3	24.0	2.8	5.2	1.81
Okura Creek	12	2.9	43.0	9.5	12.4	3.31
Omaru Creek	12	1.2	140.0	10.5	28.8	12.42
Opanuku Stream	12	1.4	6.0	2.5	3.0	0.42
Otaki Creek	12	0.8	30.0	5.2	10.7	3.01
Otara Creek (East Tamaki)	12	1.2	280.0	6.5	29.1	22.85
Otara Creek (Kennell Hill)	12	6.0	48.0	9.3	16.7	3.98
Oteha Stream	12	1.4	23.0	4.8	6.8	1.81
Pakuranga Creek (Botany Rd)	12	2.6	68.0	6.9	15.7	5.68
Pakuranga Creek (Greenmount Drive)	12	2.0	49.0	7.7	10.4	3.64
Papakura Stream	12	1.7	31.0	2.8	5.3	2.35
Puhinui Stream	12	5.0	20.0	7.9	9.2	1.35
Rangitopuni River (NIWA operated)	Not measured at this site					
Riverhead Forest Stream	12	0.8	26.0	2.6	5.5	2.09
Vaughan Stream	12	1.6	11.0	3.9	4.6	0.77
Wairoa River	12	2.3	49.0	3.4	9.2	3.90
Wairoa Tributary	12	0.8	82.0	2.4	10.2	6.60
Waitangi River	12	1.4	89.0	2.9	10.2	7.18
Waiwera River	12	2.7	20.0	4.6	6.9	1.63
West Hoe Stream	12	1.2	78.0	5.0	12.1	6.12
Whangamaire Stream	12	1.6	110.0	9.1	16.4	8.57

Table 13
Turbidity (NTU)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	12	1.1	30.3	4.2	5.9	2.30
Hoteo River (NIWA operated)	12	5.0	25.2	8.4	10.8	1.77
Kaukapakapa River	12	4.2	23.2	6.5	8.3	1.49
Kumeu River	12	7.1	14.3	9.2	9.5	0.70
Lucas Creek	12	5.4	62.7	9.1	16.1	4.81
Mahurangi River (Forestry HQ)	12	3.8	26.2	6.9	10.1	2.13
Mahurangi River (Water Supply)	12	2.1	52.6	7.5	12.7	4.37
Makarau River	12	4.3	42.8	6.1	10.5	3.16
Matakana River	12	2.9	27.6	6.6	10.0	2.37
Ngakaroa Stream	12	2.0	82.8	2.7	9.6	6.66
Oakley Creek	12	1.9	20.5	2.7	5.0	1.55
Okura Creek	12	10.3	59.0	17.6	22.3	4.20
Omaru Creek	12	2.4	87.1	8.0	19.5	7.45
Opanuku Stream	12	2.0	23.1	4.6	6.5	1.66
Otaki Creek	12	5.9	34.8	7.9	12.2	2.46
Otara Creek (East Tamaki)	12	2.0	227.0	3.8	25.5	18.40
Otara Creek (Kennell Hill)	12	3.1	35.3	9.6	15.3	3.14
Oteha Stream	12	2.3	39.4	7.4	11.3	3.05
Pakuranga Creek (Botany Rd)	12	5.0	42.1	10.3	13.3	2.89
Pakuranga Creek (Greenmount Drive)	12	5.9	33.2	10.6	12.1	2.10
Papakura Stream	12	1.6	41.4	6.1	8.2	3.09
Puhinui Stream	12	3.3	16.3	5.3	6.6	1.08
Rangitopuni River (NIWA operated)	12	3.7	35.0	7.7	12.9	3.30
Riverhead Forest Stream	12	4.5	29.6	7.2	10.9	2.40
Vaughan Stream	12	3.4	26.4	7.6	10.0	2.15
Wairoa River	12	2.1	53.6	6.5	12.9	4.26
Wairoa Tributary	12	3.5	107.0	8.7	16.8	8.25
Waitangi River	12	1.6	113.0	3.3	12.6	9.15
Waiwera River	12	4.4	30.5	6.9	10.4	2.40
West Hoe Stream	12	4.8	54.0	7.5	14.6	4.24
Whangamaire Stream	12	1.4	107.0	4.5	13.6	8.56

Table 14
Ammoniacal Nitrogen (mg N l^{-1})

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	12	0.003	0.008	0.003	0.004	0.0006
Hoteo River (NIWA operated)	12	0.005	0.045	0.017	0.019	0.0036
Kaukapakapa River	12	0.003	0.053	0.024	0.024	0.0049
Kumeu River	12	0.003	0.051	0.018	0.018	0.0041
Lucas Creek	12	0.008	0.039	0.029	0.026	0.0024
Mahurangi River (Forestry HQ)	12	0.003	0.015	0.007	0.008	0.0012
Mahurangi River (Water Supply)	12	0.003	0.032	0.007	0.011	0.0026
Makarau River	12	0.003	0.021	0.003	0.007	0.0019
Matakana River	12	0.003	0.036	0.007	0.009	0.0026
Ngakaroa Stream	12	0.003	0.030	0.012	0.013	0.0028
Oakley Creek	12	0.003	0.046	0.013	0.015	0.0037
Okura Creek	12	0.014	0.133	0.024	0.032	0.0093
Omaru Creek	12	0.007	0.170	0.041	0.052	0.0148
Opanuku Stream	12	0.003	0.010	0.003	0.004	0.0007
Otaki Creek	12	0.021	0.323	0.053	0.088	0.0240
Otara Creek (East Tamaki)	12	0.003	0.483	0.020	0.064	0.0385
Otara Creek (Kennell Hill)	12	0.003	0.137	0.015	0.025	0.0105
Oteha Stream	12	0.009	0.059	0.023	0.025	0.0041
Pakuranga Creek (Botany Rd)	12	0.016	0.391	0.057	0.089	0.0296
Pakuranga Creek (Greenmount Drive)	12	0.097	0.596	0.334	0.332	0.0463
Papakura Stream	12	0.003	0.068	0.015	0.021	0.0059
Puhinui Stream	12	0.003	0.051	0.014	0.018	0.0043
Rangitopuni River (NIWA operated)	12	0.013	0.054	0.024	0.028	0.0034
Riverhead Forest Stream	12	0.003	0.066	0.006	0.013	0.0052
Vaughan Stream	12	0.003	0.056	0.017	0.018	0.0044
Wairoa River	12	0.003	0.034	0.006	0.009	0.0027
Wairoa Tributary	12	0.003	0.043	0.003	0.009	0.0034
Waitangi River	12	0.003	0.137	0.008	0.020	0.0111
Waiwera River	12	0.003	0.023	0.005	0.010	0.0025
West Hoe Stream	12	0.003	0.020	0.003	0.006	0.0017
Whangamaire Stream	12	0.003	0.125	0.022	0.031	0.0107

Table 15Total oxidised Nitrogen (mg N l⁻¹)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	12	0.001	0.025	0.004	0.007	0.0021
Hoteo River (NIWA operated)	12	0.037	0.552	0.248	0.272	0.0438
Kaukapakapa River	12	0.017	0.580	0.208	0.249	0.0532
Kumeu River	12	0.055	0.605	0.333	0.318	0.0486
Lucas Creek	12	0.042	0.345	0.142	0.168	0.0292
Mahurangi River (Forestry HQ)	12	0.010	0.186	0.107	0.107	0.0171
Mahurangi River (Water Supply)	12	0.004	0.335	0.154	0.156	0.0304
Makarau River	12	0.002	0.456	0.107	0.140	0.0407
Matakana River	12	0.001	0.428	0.066	0.092	0.0329
Ngakaroa Stream	12	2.150	3.950	2.790	2.853	0.1293
Oakley Creek	12	0.867	1.920	1.440	1.419	0.0969
Okura Creek	12	0.125	0.329	0.209	0.206	0.0161
Omaru Creek	12	0.114	1.020	0.360	0.415	0.0765
Opanuku Stream	12	0.011	0.205	0.117	0.098	0.0182
Otaki Creek	12	0.350	2.550	0.737	1.012	0.2000
Otara Creek (East Tamaki)	12	0.414	1.580	0.830	0.921	0.1010
Otara Creek (Kennell Hill)	12	0.001	0.746	0.286	0.258	0.0691
Oteha Stream	12	0.092	0.641	0.335	0.358	0.0555
Pakuranga Creek (Botany Rd)	12	0.262	1.090	0.645	0.659	0.0783
Pakuranga Creek (Greenmount Drive)	12	0.210	0.753	0.431	0.416	0.0410
Papakura Stream	12	0.004	0.777	0.315	0.373	0.0819
Puhinui Stream	12	0.007	0.858	0.581	0.470	0.0822
Rangitopuni River (NIWA operated)	12	0.079	0.638	0.181	0.227	0.0526
Riverhead Forest Stream	12	0.016	0.064	0.029	0.032	0.0038
Vaughan Stream	12	0.004	0.179	0.066	0.073	0.0183
Wairoa River	12	0.014	0.716	0.346	0.340	0.0728
Wairoa Tributary	12	0.020	0.478	0.048	0.086	0.0360
Waitangi River	12	0.957	3.360	2.080	2.093	0.2010
Waiwera River	12	0.004	0.362	0.140	0.146	0.0317
West Hoe Stream	12	0.001	0.006	0.004	0.003	0.0005
Whangamaire Stream	12	8.770	16.200	13.800	13.334	0.7094

Table 16Kjeldhal Nitrogen by calculation (mg N l^{-1})

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	12	0.02	0.39	0.09	0.12	0.034
Hoteo River (NIWA operated)	12	0.19	0.68	0.28	0.34	0.043
Kaukapakapa River	12	0.30	0.82	0.52	0.52	0.044
Kumeu River	12	0.23	1.29	0.40	0.48	0.082
Lucas Creek	12	0.18	0.96	0.29	0.36	0.064
Mahurangi River (Forestry HQ)	12	0.04	0.48	0.12	0.15	0.034
Mahurangi River (Water Supply)	12	0.13	1.51	0.27	0.36	0.109
Makarau River	12	0.18	1.08	0.29	0.36	0.070
Matakana River	12	0.13	0.79	0.19	0.27	0.053
Ngakaroa Stream	12	0.00	2.65	0.30	0.51	0.207
Oakley Creek	12	0.02	0.55	0.26	0.28	0.040
Okura Creek	12	0.23	0.91	0.48	0.50	0.064
Omaru Creek	12	0.10	0.77	0.38	0.44	0.067
Opanuku Stream	12	0.05	0.45	0.15	0.20	0.036
Otaki Creek	12	0.00	1.14	0.38	0.42	0.091
Otara Creek (East Tamaki)	12	0.12	2.11	0.29	0.47	0.157
Otara Creek (Kennell Hill)	12	0.06	0.71	0.47	0.45	0.047
Oteha Stream	12	0.18	0.57	0.33	0.34	0.037
Pakuranga Creek (Botany Rd)	12	0.20	1.03	0.49	0.57	0.075
Pakuranga Creek (Greenmount Drive)	12	0.46	1.21	0.65	0.73	0.067
Papakura Stream	12	0.37	0.70	0.50	0.53	0.036
Puhinui Stream	12	0.29	0.69	0.45	0.46	0.028
Rangitopuni River (NIWA operated)	12	0.38	0.74	0.52	0.54	0.036
Riverhead Forest Stream	12	0.10	0.41	0.25	0.23	0.026
Vaughan Stream	12	0.26	1.36	0.41	0.50	0.089
Wairoa River	12	0.14	0.42	0.21	0.25	0.027
Wairoa Tributary	12	0.00	0.54	0.10	0.17	0.047
Waitangi River	12	0.11	2.04	0.43	0.57	0.145
Waiwera River	12	0.14	0.74	0.29	0.31	0.045
West Hoe Stream	12	0.02	0.65	0.07	0.18	0.059
Whangamaire Stream	12	0.01	5.40	1.21	1.54	0.437

Table 17Total Nitrogen (mg N l⁻¹)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	12	0.03	0.40	0.09	0.13	0.034
Hoteo River (NIWA operated)	12	0.30	1.14	0.56	0.61	0.072
Kaukapakapa River	12	0.50	1.40	0.69	0.77	0.072
Kumeu River	12	0.40	1.44	0.80	0.80	0.076
Lucas Creek	12	0.30	1.20	0.43	0.53	0.081
Mahurangi River (Forestry HQ)	12	0.09	0.67	0.25	0.26	0.042
Mahurangi River (Water Supply)	12	0.28	1.70	0.39	0.52	0.117
Makarau River	12	0.23	1.20	0.40	0.50	0.084
Matakana River	12	0.20	0.87	0.24	0.36	0.060
Ngakaroa Stream	12	2.40	4.80	3.18	3.33	0.204
Oakley Creek	12	1.10	2.30	1.66	1.70	0.103
Okura Creek	12	0.43	1.20	0.68	0.71	0.072
Omaru Creek	12	0.37	1.30	0.90	0.84	0.083
Opanuku Stream	12	0.13	0.58	0.27	0.29	0.040
Otaki Creek	12	0.87	2.50	1.30	1.43	0.162
Otara Creek (East Tamaki)	12	0.75	2.90	1.25	1.39	0.168
Otara Creek (Kennell Hill)	12	0.33	1.10	0.78	0.71	0.072
Oteha Stream	12	0.35	1.10	0.75	0.70	0.067
Pakuranga Creek (Botany Rd)	12	0.62	1.60	1.30	1.23	0.095
Pakuranga Creek (Greenmount Drive)	12	0.90	1.64	1.15	1.15	0.065
Papakura Stream	12	0.40	1.40	0.85	0.90	0.098
Puhinui Stream	12	0.43	1.30	1.00	0.93	0.085
Rangitopuni River (NIWA operated)	12	0.52	1.26	0.67	0.77	0.065
Riverhead Forest Stream	12	0.14	0.47	0.28	0.26	0.026
Vaughan Stream	12	0.33	1.40	0.44	0.57	0.089
Wairoa River	12	0.17	1.10	0.57	0.59	0.097
Wairoa Tributary	12	0.08	0.81	0.14	0.25	0.069
Waitangi River	12	1.18	4.10	2.70	2.66	0.265
Waiwera River	12	0.27	0.88	0.39	0.46	0.055
West Hoe Stream	12	0.02	0.65	0.07	0.18	0.059
Whangamaire Stream	12	8.80	18.00	15.50	14.88	0.855

Table 18Soluble reactive Phosphorus (mg P l⁻¹)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	12	0.006	0.027	0.015	0.016	0.0014
Hoteo River (NIWA operated)	12	0.011	0.039	0.015	0.017	0.0021
Kaukapakapa River	12	0.013	0.045	0.031	0.029	0.0029
Kumeu River	12	0.009	0.021	0.013	0.014	0.0011
Lucas Creek	12	0.003	0.029	0.010	0.010	0.0020
Mahurangi River (Forestry HQ)	12	0.003	0.013	0.003	0.004	0.0009
Mahurangi River (Water Supply)	12	0.006	0.058	0.010	0.014	0.0041
Makarau River	12	0.007	0.014	0.010	0.010	0.0006
Matakana River	12	0.003	0.013	0.010	0.009	0.0009
Ngakaroa Stream	12	0.003	0.011	0.003	0.005	0.0010
Oakley Creek	12	0.019	0.049	0.025	0.027	0.0022
Okura Creek	12	0.003	0.026	0.011	0.013	0.0019
Omaru Creek	12	0.013	0.042	0.021	0.025	0.0030
Opanuku Stream	12	0.003	0.010	0.007	0.006	0.0008
Otaki Creek	12	0.003	0.035	0.012	0.015	0.0028
Otara Creek (East Tamaki)	12	0.003	0.018	0.008	0.008	0.0011
Otara Creek (Kennell Hill)	12	0.008	0.080	0.013	0.020	0.0057
Oteha Stream	12	0.003	0.029	0.012	0.012	0.0018
Pakuranga Creek (Botany Rd)	12	0.003	0.035	0.011	0.014	0.0030
Pakuranga Creek (Greenmount Drive)	12	0.016	0.182	0.029	0.043	0.0129
Papakura Stream	12	0.017	0.041	0.027	0.029	0.0022
Puhinui Stream	12	0.010	0.038	0.016	0.018	0.0026
Rangitopuni River (NIWA operated)	12	0.011	0.028	0.019	0.019	0.0016
Riverhead Forest Stream	12	0.003	0.013	0.003	0.004	0.0009
Vaughan Stream	12	0.003	0.027	0.014	0.015	0.0018
Wairoa River	12	0.007	0.019	0.014	0.014	0.0013
Wairoa Tributary	12	0.015	0.037	0.029	0.027	0.0018
Waitangi River	12	0.003	0.023	0.010	0.010	0.0015
Waiwera River	12	0.003	0.014	0.010	0.010	0.0010
West Hoe Stream	12	0.003	0.013	0.006	0.006	0.0009
Whangamaire Stream	12	0.003	0.029	0.007	0.009	0.0021

Table 19Total Phosphorus (mg P l⁻¹)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	12	0.006	0.340	0.027	0.055	0.0264
Hoteo River (NIWA operated)	12	0.034	0.100	0.049	0.054	0.0054
Kaukapakapa River	12	0.044	0.112	0.064	0.066	0.0060
Kumeu River	12	0.033	0.150	0.043	0.055	0.0095
Lucas Creek	12	0.022	0.059	0.035	0.035	0.0032
Mahurangi River (Forestry HQ)	12	0.006	0.044	0.017	0.021	0.0035
Mahurangi River (Water Supply)	12	0.015	0.117	0.028	0.037	0.0082
Makarau River	12	0.017	0.077	0.028	0.035	0.0050
Matakana River	12	0.016	0.084	0.031	0.038	0.0063
Ngakaroa Stream	12	0.005	0.174	0.017	0.029	0.0133
Oakley Creek	12	0.028	0.098	0.052	0.053	0.0053
Okura Creek	12	0.025	0.063	0.055	0.048	0.0035
Omaru Creek	12	0.032	0.324	0.078	0.110	0.0251
Opanuku Stream	12	0.008	0.088	0.025	0.028	0.0060
Otaki Creek	12	0.024	0.200	0.067	0.079	0.0139
Otara Creek (East Tamaki)	12	0.016	0.487	0.033	0.075	0.0380
Otara Creek (Kennell Hill)	12	0.043	0.113	0.068	0.073	0.0065
Oteha Stream	12	0.029	0.067	0.045	0.047	0.0032
Pakuranga Creek (Botany Rd)	12	0.034	0.159	0.059	0.073	0.0112
Pakuranga Creek (Greenmount Drive)	12	0.068	0.252	0.098	0.115	0.0153
Papakura Stream	12	0.049	0.136	0.062	0.070	0.0074
Puhinui Stream	12	0.045	0.110	0.063	0.071	0.0059
Rangitopuni River (NIWA operated)	12	0.039	0.107	0.064	0.071	0.0062
Riverhead Forest Stream	12	0.003	0.046	0.016	0.018	0.0031
Vaughan Stream	12	0.029	0.074	0.044	0.047	0.0044
Wairoa River	12	0.020	0.103	0.034	0.042	0.0067
Wairoa Tributary	12	0.031	0.094	0.040	0.044	0.0050
Waitangi River	12	0.005	0.310	0.024	0.045	0.0242
Waiwera River	12	0.020	0.069	0.029	0.034	0.0041
West Hoe Stream	12	0.010	0.064	0.016	0.021	0.0041
Whangamaire Stream	12	0.006	0.256	0.031	0.052	0.0195

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

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades 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	0.57	1.90	0.89	0.96	0.110
Lucas Creek	12	0.69	3.70	1.00	1.49	0.287
Mahurangi River (Forestry HQ)	12	0.05	0.76	0.32	0.35	0.057
Mahurangi River (Water Supply)	12	0.27	1.60	0.53	0.68	0.117
Makarau River	12	0.35	1.40	0.58	0.70	0.094
Matakana River	12	0.34	1.20	0.66	0.73	0.095
Ngakaroa Stream	Not measured at this site					
Oakley Creek	12	1.20	3.40	1.50	1.82	0.204
Okura Creek	11	0.40	2.00	0.96	0.96	0.142
Omaru Creek	12	1.10	3.80	1.75	2.10	0.267
Opanuku Stream	Not measured at this site					
Otaki Creek	12	0.61	4.60	1.50	1.72	0.311
Otara Creek (East Tamaki)	12	0.64	5.30	1.10	1.58	0.372
Otara Creek (Kennell Hill)	12	0.70	2.50	1.15	1.39	0.167
Oteha Stream	12	0.92	3.70	1.45	1.71	0.233
Pakuranga Creek (Botany Rd)	12	0.65	4.70	1.75	1.97	0.328
Pakuranga Creek (Greenmount Drive)	12	1.30	6.70	1.50	2.15	0.447
Papakura Stream	12	0.80	1.70	1.05	1.11	0.077
Puhinui Stream	12	1.20	350.00	1.70	30.73	29.025
Rangitopuni River (NIWA operated)	Not measured at this site					
Riverhead Forest Stream	12	0.15	0.72	0.38	0.40	0.049
Vaughan Stream	12	0.12	2.30	0.55	0.82	0.189
Wairoa River	12	0.48	2.30	0.66	0.81	0.142
Wairoa Tributary	Not measured at this site					
Waitangi River	Not measured at this site					
Waiwera River	12	0.15	1.50	0.58	0.66	0.107
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
Cascades 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	0.93	2.40	1.20	1.32	0.116
Lucas Creek	12	1.10	5.10	1.50	2.11	0.406
Mahurangi River (Forestry HQ)	12	0.05	1.70	0.49	0.64	0.135
Mahurangi River (Water Supply)	12	0.48	3.40	0.77	1.20	0.262
Makarau River	12	0.36	2.60	0.91	1.10	0.189
Matakana River	12	0.30	2.40	0.85	1.14	0.180
Ngakaroa Stream	Not measured at this site					
Oakley Creek	12	1.40	5.00	2.10	2.48	0.326
Okura Creek	11	0.54	2.80	1.50	1.49	0.213
Omaru Creek	12	1.50	19.00	3.35	5.26	1.482
Opanuku Stream	Not measured at this site					
Otaki Creek	12	1.20	8.10	2.35	3.17	0.625
Otara Creek (East Tamaki)	12	0.73	25.00	1.35	3.66	1.954
Otara Creek (Kennell Hill)	12	1.00	7.30	1.55	2.18	0.505
Oteha Stream	12	1.30	5.10	2.00	2.38	0.307
Pakuranga Creek (Botany Rd)	12	1.20	11.00	2.95	3.88	0.861
Pakuranga Creek (Greenmount Drive)	12	1.60	16.00	2.75	3.83	1.140
Papakura Stream	12	0.91	2.30	1.20	1.38	0.129
Puhinui Stream	12	1.50	330.00	2.35	29.63	27.307
Rangitopuni River (NIWA operated)	Not measured at this site					
Riverhead Forest Stream	12	0.05	1.10	0.46	0.58	0.087
Vaughan Stream	12	0.21	3.60	0.73	1.07	0.298
Wairoa River	12	0.31	2.20	0.89	1.03	0.135
Wairoa Tributary	Not measured at this site					
Waitangi River	Not measured at this site					
Waiwera River	12	0.32	2.10	0.82	1.02	0.172
West Hoe Stream	Not measured at this site					
Whangamaire Stream	Not measured at this site					

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

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades 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	1.50	15.00	2.25	3.55	1.087
Lucas Creek	12	1.50	8.30	3.20	3.35	0.550
Mahurangi River (Forestry HQ)	12	0.15	1.30	0.15	0.36	0.101
Mahurangi River (Water Supply)	12	0.79	4.60	1.80	2.06	0.338
Makarau River	12	0.15	1.40	0.41	0.56	0.117
Matakana River	12	0.15	4.00	0.64	0.99	0.300
Ngakaroa Stream	Not measured at this site					
Oakley Creek	12	4.90	24.00	11.50	13.26	1.824
Okura Creek	11	1.20	3.60	1.90	2.00	0.225
Omaru Creek	12	30.00	210.00	70.00	97.33	19.716
Opanuku Stream	Not measured at this site					
Otaki Creek	12	15.00	150.00	38.50	49.58	11.483
Otara Creek (East Tamaki)	12	4.00	140.00	20.00	37.26	11.646
Otara Creek (Kennell Hill)	12	2.00	210.00	5.60	25.50	16.912
Oteha Stream	12	11.00	53.00	24.00	27.33	3.644
Pakuranga Creek (Botany Rd)	12	5.90	120.00	24.00	45.20	13.338
Pakuranga Creek (Greenmount Drive)	12	4.30	370.00	18.00	71.64	36.138
Papakura Stream	12	1.90	7.80	4.40	4.48	0.553
Puhinui Stream	12	6.00	64.00	10.50	16.70	4.826
Rangitopuni River (NIWA operated)	Not measured at this site					
Riverhead Forest Stream	12	3.10	15.00	5.85	6.76	1.017
Vaughan Stream	12	1.70	15.00	2.60	3.73	1.055
Wairoa River	12	0.36	3.30	0.81	1.08	0.240
Wairoa Tributary	Not measured at this site					
Waitangi River	Not measured at this site					
Waiwera River	12	0.15	1.90	0.56	0.67	0.144
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
Cascades 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	2.50	14.00	4.00	4.68	0.898
Lucas Creek	12	2.60	18.00	5.75	6.79	1.244
Mahurangi River (Forestry HQ)	12	0.30	3.10	0.84	1.05	0.217
Mahurangi River (Water Supply)	12	1.70	13.00	4.45	4.78	0.917
Makarau River	12	0.30	3.10	1.20	1.41	0.258
Matakana River	12	0.30	5.40	1.50	2.10	0.426
Ngakaroa Stream	Not measured at this site					
Oakley Creek	12	7.60	53.00	17.00	19.40	3.524
Okura Creek	11	2.60	8.00	4.00	4.38	0.511
Omaru Creek	12	46.00	390.00	135.00	172.42	37.555
Opanuku Stream	Not measured at this site					
Otaki Creek	12	23.00	160.00	64.50	68.92	12.994
Otara Creek (East Tamaki)	12	9.90	360.00	24.50	68.08	29.476
Otara Creek (Kennell Hill)	12	3.20	390.00	11.65	44.83	31.493
Oteha Stream	12	15.00	71.00	37.50	38.33	4.372
Pakuranga Creek (Botany Rd)	12	12.00	210.00	58.50	73.08	17.668
Pakuranga Creek (Greenmount Drive)	12	8.80	550.00	29.00	106.73	51.501
Papakura Stream	12	2.60	16.00	4.90	6.03	1.035
Puhinui Stream	12	11.00	64.00	20.00	27.58	5.097
Rangitopuni River (NIWA operated)	Not measured at this site					
Riverhead Forest Stream	12	4.00	17.00	7.45	8.38	1.103
Vaughan Stream	12	2.20	24.00	3.30	5.13	1.749
Wairoa River	12	0.67	7.60	1.65	2.12	0.528
Wairoa Tributary	Not measured at this site					
Waitangi River	Not measured at this site					
Waiwera River	12	0.57	3.50	1.30	1.45	0.230
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
Cascades 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	0.06	0.28	0.06	0.11	0.022
Lucas Creek	12	0.03	0.24	0.06	0.09	0.021
Mahurangi River (Forestry HQ)	12	0.03	0.07	0.03	0.03	0.005
Mahurangi River (Water Supply)	12	0.03	0.15	0.06	0.07	0.012
Makarau River	12	0.03	0.07	0.03	0.04	0.005
Matakana River	12	0.03	0.14	0.05	0.05	0.010
Ngakaroa Stream	Not measured at this site					
Oakley Creek	12	0.08	0.28	0.15	0.16	0.018
Okura Creek	11	0.03	0.16	0.06	0.08	0.013
Omaru Creek	12	0.03	0.22	0.15	0.13	0.019
Opanuku Stream	Not measured at this site					
Otaki Creek	12	0.03	0.27	0.16	0.14	0.023
Otara Creek (East Tamaki)	12	0.03	0.21	0.08	0.10	0.017
Otara Creek (Kennell Hill)	12	0.03	0.26	0.09	0.11	0.022
Oteha Stream	12	0.03	0.22	0.08	0.09	0.016
Pakuranga Creek (Botany Rd)	12	0.03	0.52	0.16	0.18	0.043
Pakuranga Creek (Greenmount Drive)	12	0.03	0.19	0.03	0.07	0.018
Papakura Stream	12	0.03	0.12	0.08	0.08	0.008
Puhinui Stream	12	0.10	0.26	0.14	0.15	0.013
Rangitopuni River (NIWA operated)	Not measured at this site					
Riverhead Forest Stream	12	0.03	0.08	0.03	0.04	0.007
Vaughan Stream	12	0.03	0.17	0.04	0.06	0.014
Wairoa River	12	0.05	0.12	0.08	0.08	0.006
Wairoa Tributary	Not measured at this site					
Waitangi River	Not measured at this site					
Waiwera River	12	0.03	0.08	0.03	0.04	0.006
West Hoe Stream	Not measured at this site					
Whangamaire Stream	Not measured at this site					

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

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades 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	0.21	0.52	0.30	0.33	0.030
Lucas Creek	12	0.10	1.00	0.18	0.33	0.090
Mahurangi River (Forestry HQ)	12	0.03	0.33	0.06	0.09	0.028
Mahurangi River (Water Supply)	12	0.07	1.80	0.19	0.44	0.152
Makarau River	12	0.05	0.49	0.08	0.12	0.036
Matakana River	12	0.05	1.00	0.22	0.29	0.075
Ngakaroa Stream	Not measured at this site					
Oakley Creek	12	0.43	3.30	0.69	0.93	0.226
Okura Creek	11	0.14	0.74	0.34	0.36	0.062
Omaru Creek	12	0.19	17.00	0.86	2.79	1.370
Opanuku Stream	Not measured at this site					
Otaki Creek	12	0.26	4.70	1.15	1.73	0.423
Otara Creek (East Tamaki)	12	0.14	28.00	0.25	2.89	2.295
Otara Creek (Kennell Hill)	12	0.17	6.50	0.33	0.91	0.512
Oteha Stream	12	0.14	0.90	0.25	0.33	0.062
Pakuranga Creek (Botany Rd)	12	0.17	8.70	0.88	2.06	0.774
Pakuranga Creek (Greenmount Drive)	12	0.08	5.60	0.39	0.90	0.455
Papakura Stream	12	0.08	1.10	0.19	0.26	0.078
Puhinui Stream	12	0.36	1.80	0.56	0.68	0.111
Rangitopuni River (NIWA operated)	Not measured at this site					
Riverhead Forest Stream	12	0.03	0.27	0.07	0.10	0.022
Vaughan Stream	12	0.03	0.94	0.11	0.19	0.072
Wairoa River	12	0.10	1.30	0.22	0.35	0.098
Wairoa Tributary	Not measured at this site					
Waitangi River	Not measured at this site					
Waiwera River	12	0.06	0.34	0.08	0.13	0.028
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
Cascades Stream	12	18	780	99	180	63
Hoteo River (NIWA operated)	12	31	980	133	290	95
Kaukapakapa River	12	81	2900	360	591	223
Kumeu River	12	81	1200	460	531	98
Lucas Creek	12	200	3500	355	821	319
Mahurangi River (Forestry HQ)	12	81	1060	410	447	84
Mahurangi River (Water Supply)	12	108	24000	360	2357	1969
Makarau River	12	108	8500	465	1394	704
Matakana River	12	18	5300	245	665	424
Ngakaroa Stream	12	144	2100	295	493	156
Oakley Creek	12	370	10100	1180	2132	768
Okura Creek	12	210	15600	905	2244	1238
Omaru Creek	12	99	7700	770	2369	834
Opanuku Stream	12	250	1510	490	595	110
Otaki Creek	12	144	28000	4150	6111	2154
Otara Creek (East Tamaki)	12	240	25000	625	4063	2047
Otara Creek (Kennell Hill)	12	310	7300	830	1997	696
Oteha Stream	12	81	4300	370	895	357
Pakuranga Creek (Botany Rd)	12	108	95000	3250	11755	7663
Pakuranga Creek (Greenmount Drive)	12	126	12600	920	2033	997
Papakura Stream	12	340	35000	945	4311	2831
Puhinui Stream	12	150	2200	400	677	206
Rangitopuni River (NIWA operated)	12	18	2419	322	750	263
Riverhead Forest Stream	12	5	1280	86	227	108
Vaughan Stream	12	171	3900	1005	1341	331
Wairoa River	12	162	2200	405	742	203
Wairoa Tributary	12	18	580	224	240	57
Waitangi River	12	220	11500	485	2037	1102
Waiwera River	12	144	4300	530	914	330
West Hoe Stream	12	5	5400	86	821	468
Whangamaire Stream	12	210	8300	790	1768	723

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 31 sites (Table 27).

The Mahurangi River at Forestry Headquarters (FHQ) had the best water quality in 2011. The Mahurangi River (FHQ), West Hoe Stream, Waiwera Stream and Cascades Stream were the only sites classified as having excellent water quality. West Hoe Stream and Waiwera Stream were also classed as having excellent water quality in 2010, whereas Mahurangi River (FHQ) and Waiwera Stream were classed as having fair water quality .

The Whangamaire Stream had the worst water quality of the monitoring sites in 2011, with exceedances of the target levels common and often of high magnitudes. Whangamaire Stream exceeded target levels of Total Nitrogen on every sampling occasion during 2011.

There are 17 sites that had the same water quality class in 2011 as in 2010 (Neale, 2012), with 14 sites showing a change in class. Of the 14 sites, eight sites recorded an improvement in class whereas six sites recorded a decline in class. However, of these 14 sites, only two sites changed by more than one class. Mahurangi River (Water Supply) moved from excellent in 2010 to fair in 2011; and Vaughan Stream moved from poor to good. Such large changes in water quality class are unusual and these sites should be monitored closely to determine the nature of these water quality changes. It should be noted however that both sites returned in 2011 to the same class as they were recorded under in 2009 (Neale, 2010).

The WQI has now been used since 2007 for reporting the results of the water quality programme. The mean WQI from 2008, 2009 and 2010 were used as a reference point to assess the 2011 results. This comparison identified how the WQI for a particular site in 2011 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 11 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 2011 was observed at the Waiwera Stream site, where the 2011 WQI (91.6) was 19.5 points higher than the three year mean (72.1).

Table 27 indicates that, in general, urban sites were typically ranked lower in 2011. 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 types used in the monitoring programme (Table 28). The native forest sites had the best water quality indices in 2011 (good), followed closely 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 2011 data. Deviation is based on the difference between 2011 WQI and the mean 2008, 2009 and 2010 WQI (comparisons are not possible for the sites added in 2009 (new sites)).

Site	Scope	Frequency	Magnitude	2010 WQI	2010 class	Deviation	
1	Mahurangi River FHQ	14.3	1.2	0.1	91.7	Excellent	13.9
2	West Hoe Stream	14.3	1.2	0.9	91.7	Excellent	-5.5
3	Waiwera Stream	14.3	2.4	0.2	91.6	Excellent	19.5
4	Cascades Stream	14.3	1.2	3.7	91.4	Excellent	2.5
5	Opanuku Stream	28.6	2.4	0.1	83.4	Good	-13.8
6	Wairoa @ Caitchons	28.6	2.4	3.0	83.4	Good	New site
7	Matakana River	28.6	4.8	0.3	83.3	Good	13.9
8	Riverhead Stream	28.6	6.0	0.3	83.1	Good	New site
9	Hoteo at Gubbs	42.9	4.8	0.8	75.1	Good	3.3
10	Makarau @ Railway	42.9	6.0	0.9	75.0	Good	4.3
11	Vaughn Stream	42.9	13.3	3.3	74.0	Good	16.1
12	Oakley Creek	42.9	19.0	9.4	72.4	Good	10.8
13	Lucas Creek	57.1	4.8	1.7	66.9	Fair	0.5
14	Kumeu River	57.1	6.0	1.7	66.8	Fair	12.3
15	Okura Creek	57.1	7.2	3.0	66.7	Fair	14.5
16	Oteha Stream	57.1	8.4	0.8	66.6	Fair	9.6
17	Wairoa River	57.1	9.5	1.8	66.5	Fair	0.3
18	Kaukapakapa @Taylors	57.1	9.6	1.5	66.5	Fair	New site
19	Mahurangi River WS	57.1	9.5	2.6	66.5	Fair	-8.3
20	Papakura Stream	57.1	13.1	3.3	66.1	Fair	7.7
21	Puhinui Stream	57.1	20.2	3.4	64.9	Fair	14.1
22	Ngakaroa Stream	57.1	20.2	26.9	61.7	Fair	-9.3
23	Rangitopuni at Walkers	71.4	14.3	3.6	57.9	Fair	-13.2
24	Otara Ck Kennel Hill	85.7	16.7	3.8	49.5	Poor	-8.1
25	Omaru at Maybury	85.7	25.0	13.2	47.9	Poor	3.6
26	Waitangi Falls Br.	85.7	23.8	24.3	46.8	Poor	New site
27	Pakuranga Ck Greenmt	85.7	42.9	38.8	40.3	Poor	-2.7
28	Otara Ck East Tamaki	100.0	20.2	21.5	39.8	Poor	-17.4
29	Otaki Creek	100.0	31.0	15.9	38.9	Poor	-2.1
30	Pakuranga Ck Botany	100.0	33.3	14.3	38.6	Poor	-3.8
31	Whangamaire Woodhous	85.7	25.0	67.3	35.5	Poor	New site

Table 28

Mean 2011 water quality index scores and water quality class for all sites within a catchment land cover type

Land Cover (number of sites)	Scope	Frequency	Magnitude	Water quality index	Water quality class
Native forest (3)	19	1.6	2.5	88.8	Good
Exotic forest (2)	21.4	3.6	0.2	87.4	Good
Rural (16)	52.7	10.7	8.9	67.7	Fair
Urban (10)	77.1	22.2	12.3	52.6	Fair

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

6 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;

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

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 (2006 to 2010). 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 the Auckland region. Therefore, the index represents the deviation from “natural” conditions in the Auckland, 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 2005 and 2009.

Parameter	Objective (acceptable if)
Dissolved oxygen (% saturation)	Between 75 and 120%
pH	Between 6.4 and 8.2
Turbidity	Less than 31 NTU
Ammoniacal nitrogen	Less than 0.07 mg N l ⁻¹
Temperature	Less than 19 °C
Total phosphorus	Less than 0.08 mg P l ⁻¹
Total nitrogen	Less than 1 mg N l ⁻¹

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