




State of the Environment Monitoring
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State of the Environment Monitoring: River Water Quality Annual Report 2007

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1 Executive Summary

The Auckland Regional 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 provides a summary of the data collected during the 2007 calendar year.

Water quality is assessed monthly at 27 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.

For the first time, the 2007 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 2007 the best river water quality was in the Cascades Stream in the Waitakere Ranges, closely followed by West Hoe Stream in Rodney. The worst water quality was observed in streams in and around the metropolitan urban area, of which Otaki Creek was the lowest ranked in 2007.

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 ARC monitoring programme

The overall aim of the ARC'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 ARC's 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 ARC 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 27 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 27 site network has been operating since 2003. Each of the 27 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 ARC's other monitoring programmes, is used to meet the following objectives;

- Satisfy the ARC's 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 ARC's 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 from which impacts of individual activities can be measured through compliance monitoring.
- 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 for the region 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 ARC's management strategies are effective in sustaining stream functions and uses. By achieving this outcome we are working towards achieving the ARC mission of "working in partnership with our regional community to achieve social, economic, cultural and environmental well being".

2.5 Report scope

This report provides a tabular and graphical summary of the data collected from the 27 sites in the River Water Quality Programme during the 2007 calendar year. Furthermore, the 2007 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 18th annual report since the inception of the monitoring programme, although only the third time since 2000 that the river water quality data has been reported separately from the marine and lake data. Furthermore, a comprehensive state and trends analysis of the water quality data was carried out during 2007 (see Scarsbrook, 2007).

All reports can be obtained from the publications area of the ARC website (www.arc.govt.nz).

3 Methods

3.1 Sample sites

The current ARC River Water Quality Programme operates with a network of 27 sites (Table 3). The number of sites sampled each year has varied due to logistical considerations and programme objectives, but has been consistent since 2003. The location of the 27 sites is displayed on page 8 (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 2005 and subsequent changes were described in the 2005 data report (ARC, 2007).

Analytical changes in 2007 have involved the expansion of faecal coliform testing to all sites in July 2007 and the addition of heavy metal testing (lead, copper and zinc) to the sites which drain into the Tamaki estuary. There were no site changes in 2007.

3.4 Sampling methodology

All sample collection is carried out by ARC 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 Regional 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 to the ARC 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 2007 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	1735254	5972546	Rural	1986
Kumeu River	1739252	5928781	Rural	1993
Lucas Creek	1751468	5934510	Urban	1993
Mahurangi River (Forestry HQ)	1747750	5965035	Exotic forest	1993
Mahurangi River (Town Bridge)	1748748	5970343	Rural	1986
Mahurangi River (Water Supply)	1748864	5970457	Rural	1993
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 Dr)	1769473	5910813	Urban	1985
Pakuranga Creek (Guy's Rd)	1769999	5910998	Urban	1985
Papakura Stream	1771240	5900290	Rural	1993
Puhinui Stream	1766440	5904295	Urban	1994
Rangitopuni River	1744450	5932301	Rural	1986
Vaughan Stream	1755414	5938729	Rural	2001
Wairoa River	1782682	5901720	Rural	1978
Waiwera River	1748628	5953665	Rural	1986
West Hoe Stream	1748314	5950610	Native forest	2002

Figure 1

The distribution of the 27 sampling sites used in the ARC River Water Quality Programme.



Table 4

Parameters tested in 2007 in the River Water Quality Programme.

Parameter	Code	Units	Method
Dissolved oxygen	DO (sat)	% sat	Portable YSI meter
Dissolved oxygen	DO (ppm)	ppm	Portable YSI meter
Temperature	Temp	°C	Portable YSI meter
Conductivity	Cond	mS cm ⁻¹	Portable YSI meter
Salinity	Salinity	ppt	Portable YSI meter
pH	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 oxidisable nitrogen	TON	mg N l ⁻¹	APHA (2005) 4500-NO3 F
Kjedahl nitrogen	KN	mg N l ⁻¹	APHA (2005) 4500-Norg, 4500-NH3 C
Total nitrogen	TN	mg N l ⁻¹	By calculation
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
Faecal coliforms	Faecal	mpn/100ml	APHA (2005) 9221 E
<i>Eschericia coli</i>	E. coli	cfu/100ml	APHA (2005) 9213 F

3.5 Data processing and analysis

All field and laboratory data are stored in the ARC's water quality archiving database (HYDSTRA). The 2007 data was extracted 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 ARC 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.

4 Results

The data from the 2007 calendar year are presented as;

- box plots which display the variation in the measured parameters at each of the sites (Section 3.1).
- tables which provide a statistical summary of each parameter at each site (Section 3.2)
- water quality indices produced using the data for seven water quality parameters allowing a water quality class to be assigned to each site (Section 3.3)

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

- Salinity
 - The precision and sensitivity of the meter resulted in the majority of salinity results being recorded as 0.1 ppt. This resulted in many sites having a minimum, maximum, median and mean of 0.1 ppt with a standard error of zero. This analysis is of limited value; the only real finding at these sites is that salinity is always below 0.1 ppt. The use of an alternative meter, with better resolution at low levels of salinity, is currently being investigated.
- Heavy metals at Tamaki Estuary sites
 - Heavy metal analysis was added to the testing profile at these sites in September and therefore there were only four samples from these sites tested for heavy metals in 2007. The results are presented in the summary tables, but have been omitted from the box plots because the calculation of meaningful percentiles is not possible with only four data points.
- Soluble lead
 - Soluble lead levels were typically very low in 2007 and hence the majority of tests returned results below the limit of detection. This resulted in many sites having a minimum, maximum, median and mean of $0.025 \mu\text{g l}^{-1}$ with a standard error of zero. This analysis is of limited value; the only real finding at these sites is that soluble lead is always below $0.05 \mu\text{g l}^{-1}$.

4.1 Box plots

Figure 2

Box plot showing the variation in dissolved oxygen % saturation (upper plot) and ppm (lower plot) at the 27 sites using data collected during the 2007 calendar year.

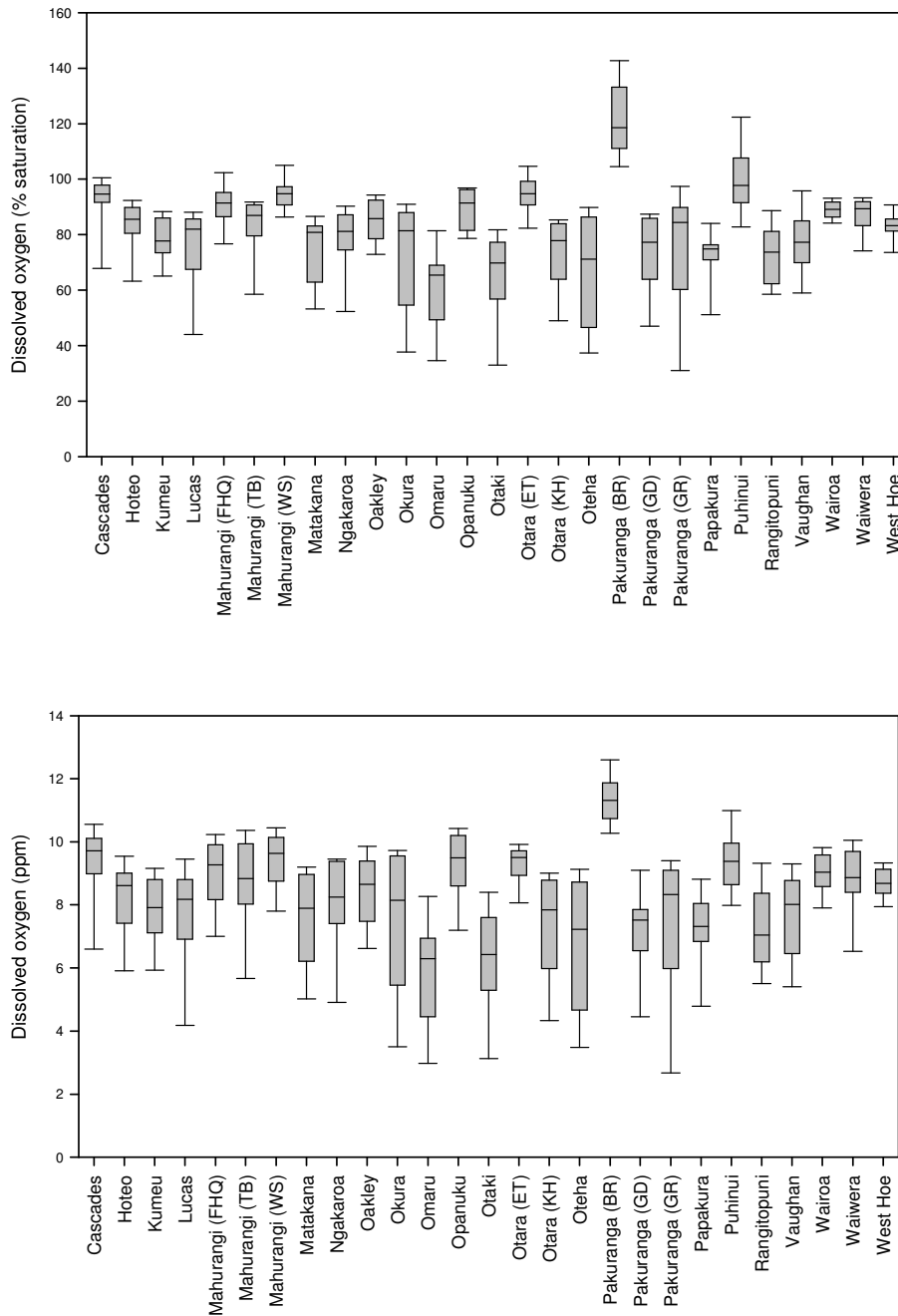


Figure 3

Box plot showing the variation in temperature (upper plot) and conductivity (lower plot) at the 27 sites using data collected during the 2007 calendar year. Note the axis break and scale change on the y-axis of the conductivity plot.

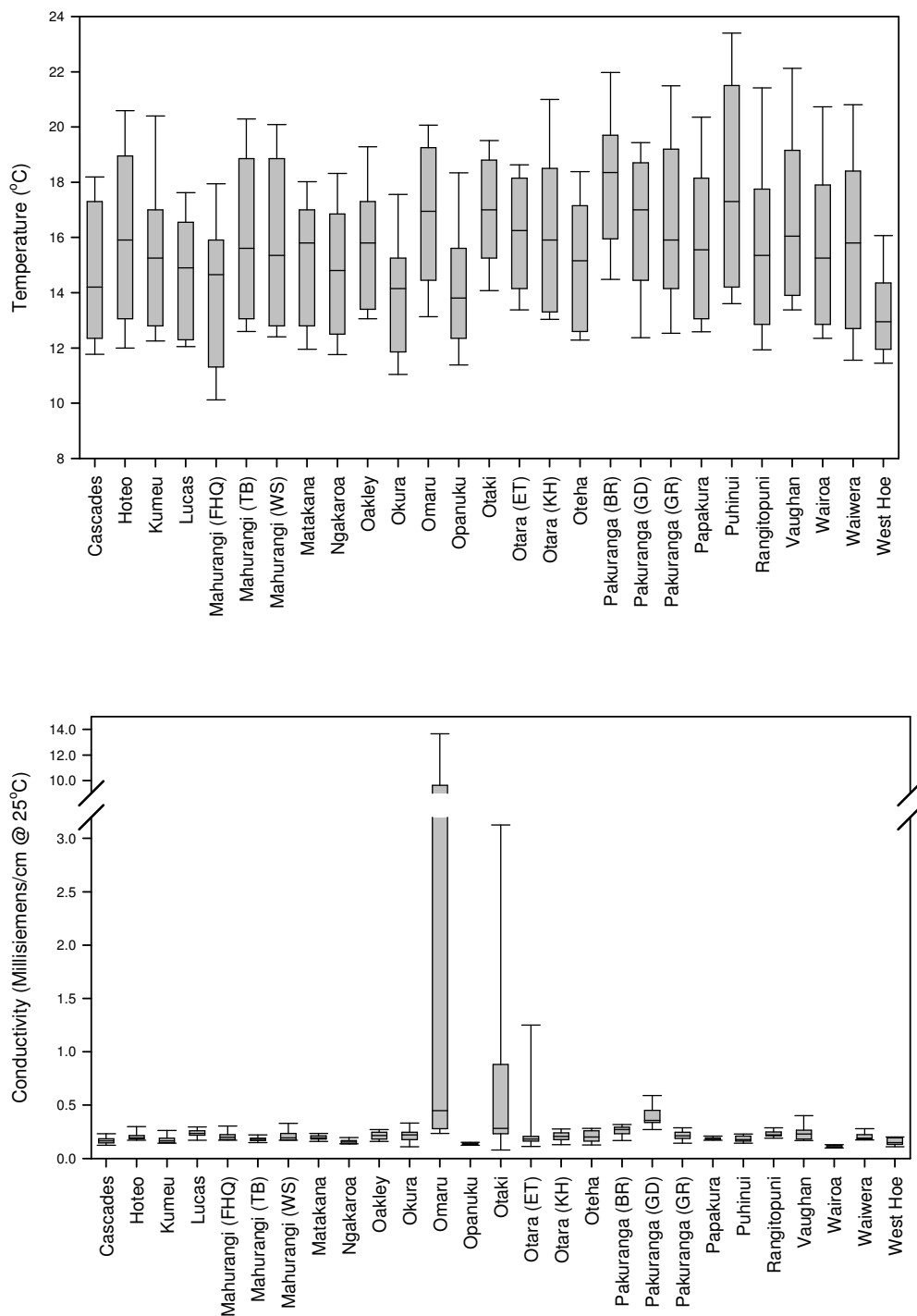


Figure 4

Box plot showing the variation in salinity (upper plot) and pH (lower plot) at the 27 sites using data collected during the 2007 calendar year. Note the axis break and scale change on the y-axis of the salinity plot.

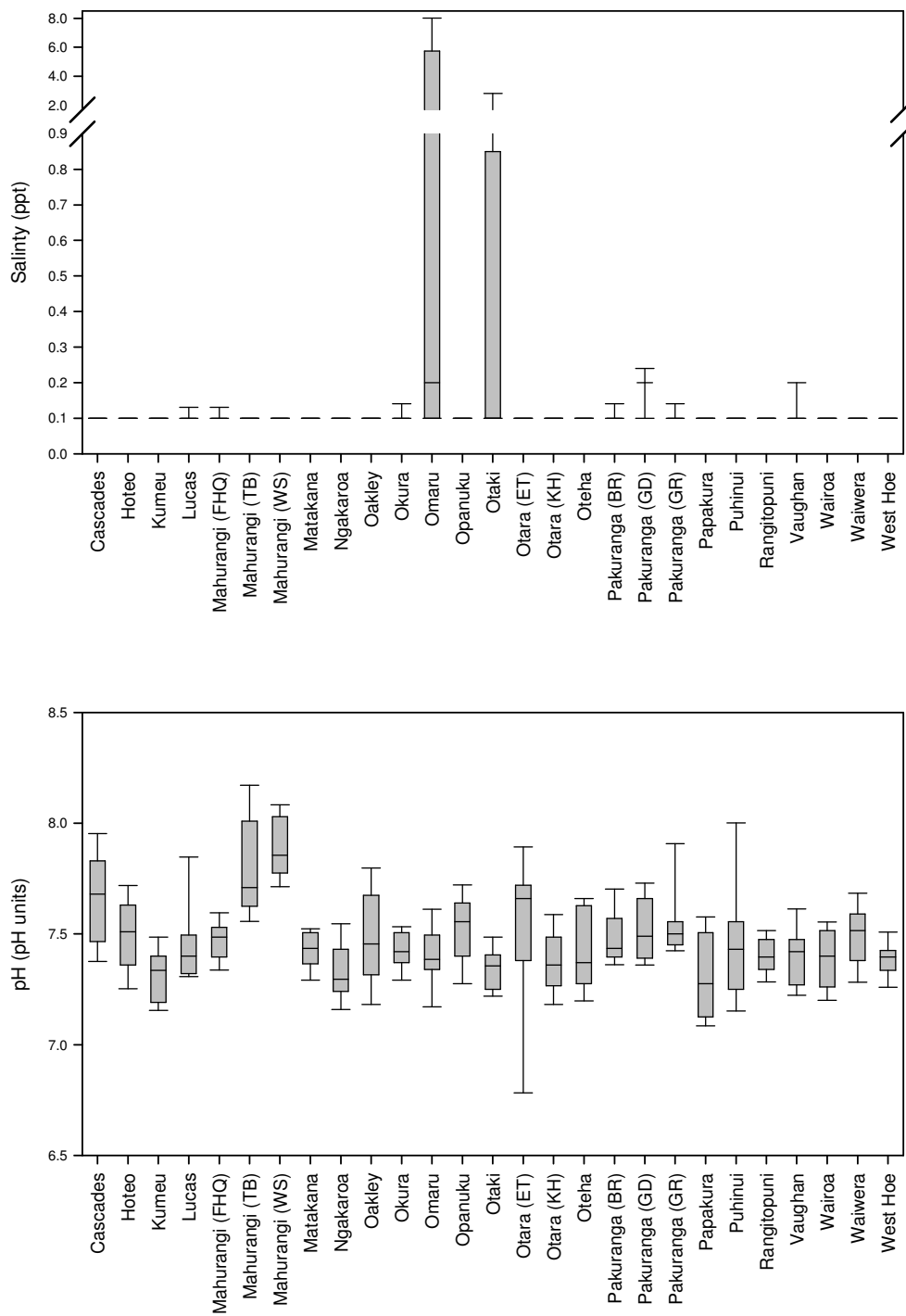


Figure 5

Box plot showing the variation in suspended sediment (upper plot) and turbidity (lower plot) at the 27 sites using data collected during the 2007 calendar year.

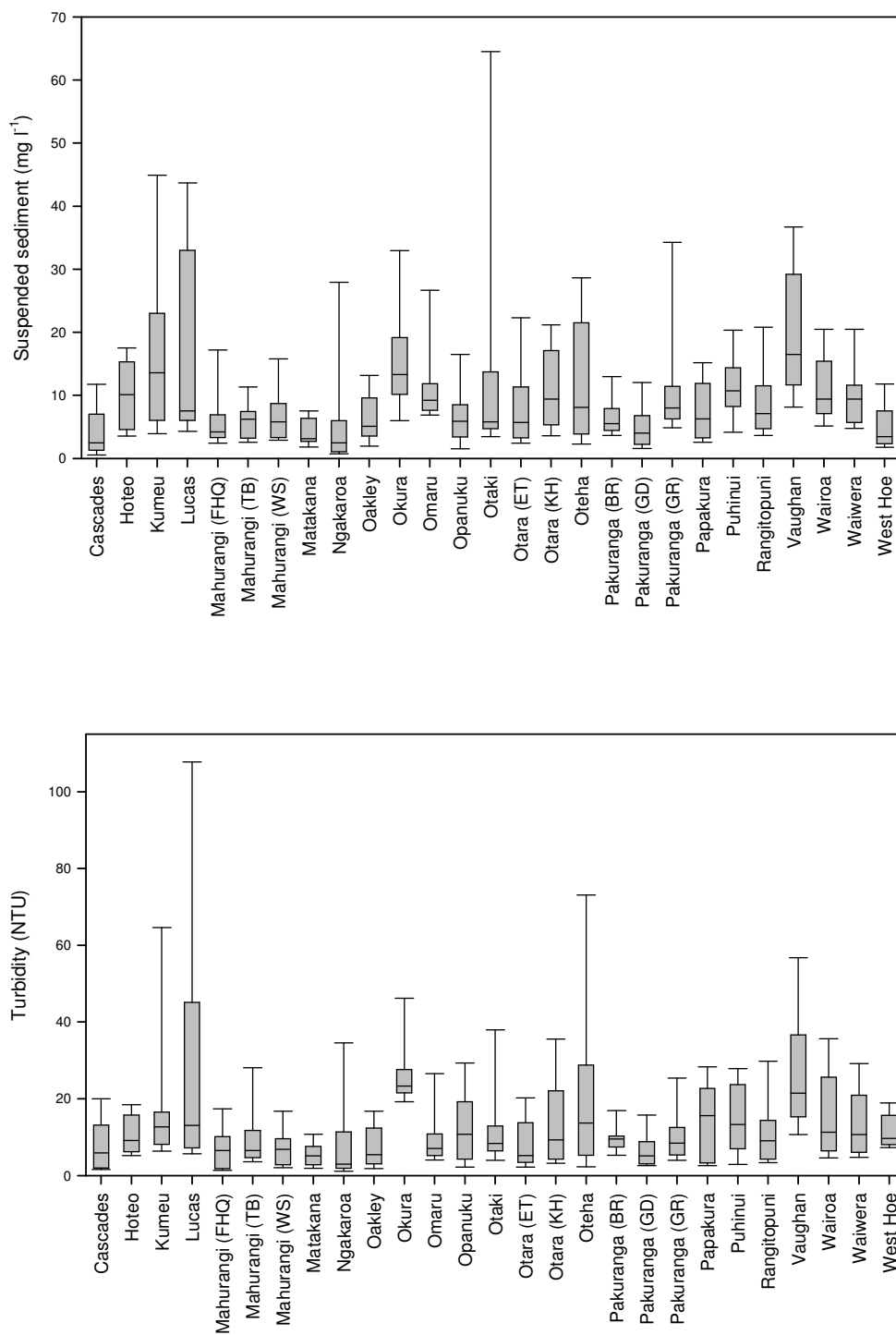


Figure 6

Box plot showing the variation in Ammoniacal nitrogen (upper plot) and total oxidised nitrogen (lower plot) at the 27 sites using data collected during the 2007 calendar year. Note the axis break and scale change on the y-axis of the ammoniacal nitrogen plot.

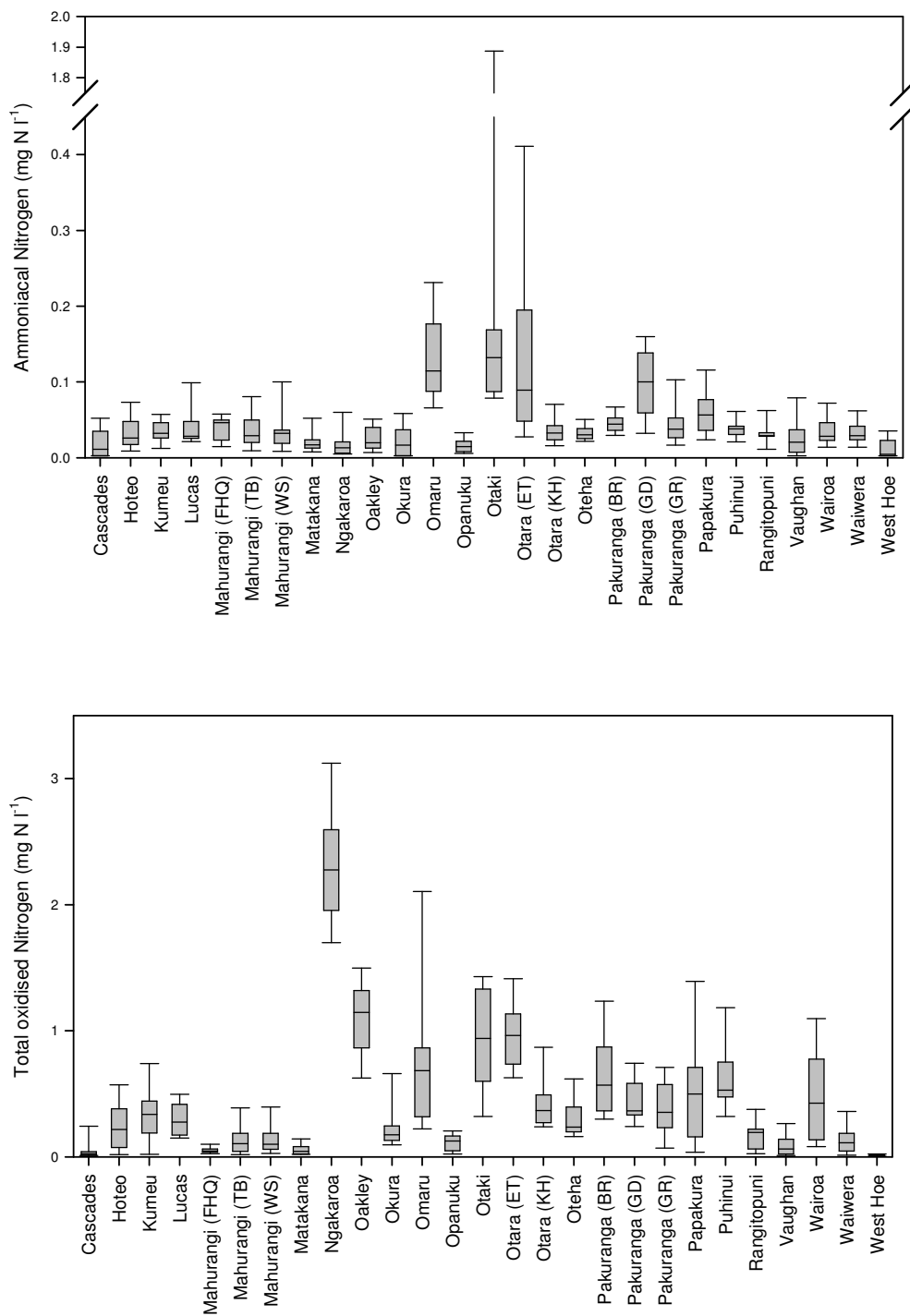


Figure 7

Box plot showing the variation in Kjeldhal nitrogen (upper plot) and total nitrogen (lower plot) at the 27 sites using data collected during the 2007 calendar year.

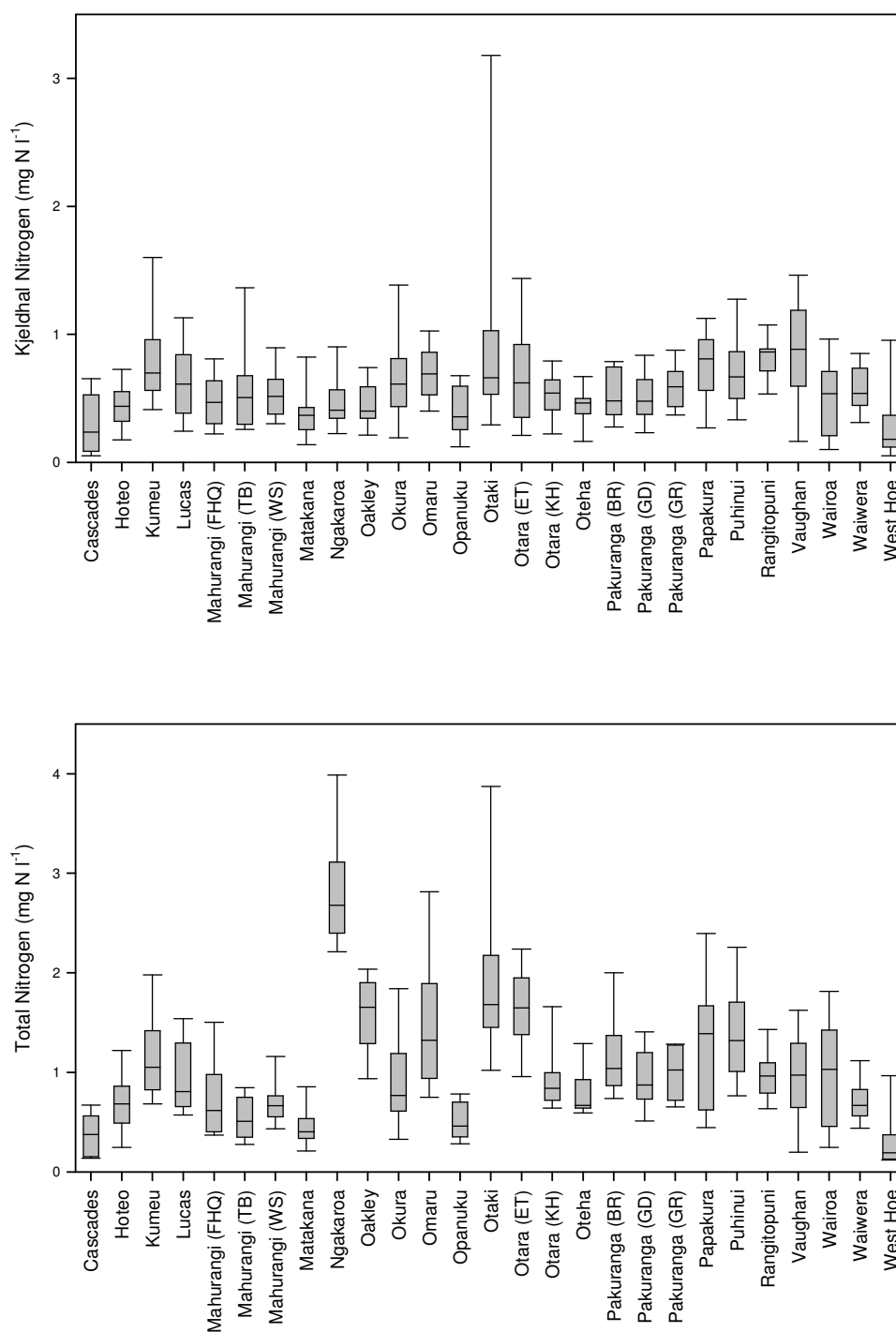


Figure 8

Box plot showing the variation in soluble reactive phosphorus (upper plot) and total phosphorus (lower plot) at the 27 sites using data collected during the 2007 calendar year. Note the axis break and scale change on the y-axis of the total phosphorus plot.

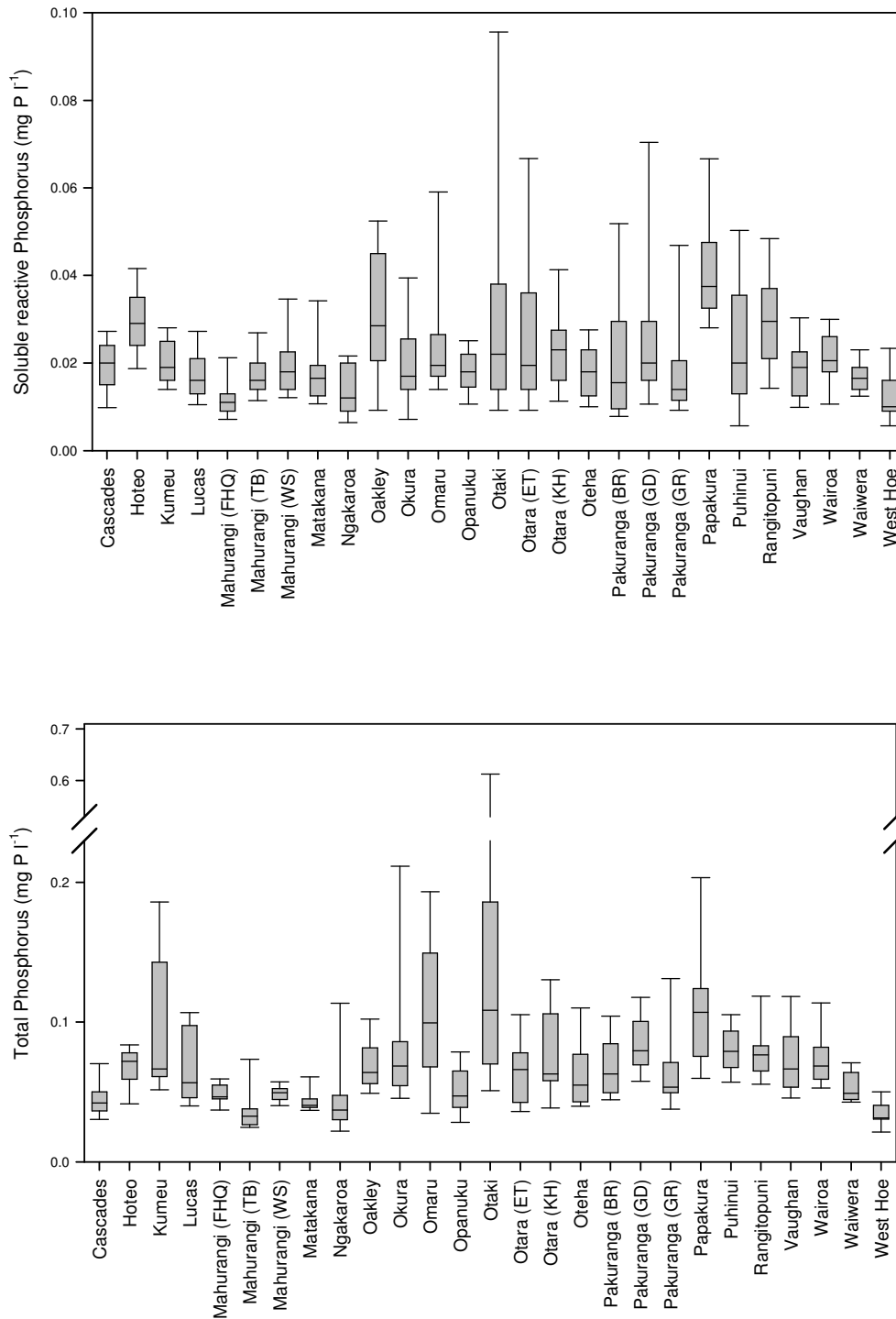


Figure 9

Box plot showing the variation in soluble copper (upper plot) and total copper (lower plot) at the 12 sites where it is monitored, using data collected during the 2007 calendar year.

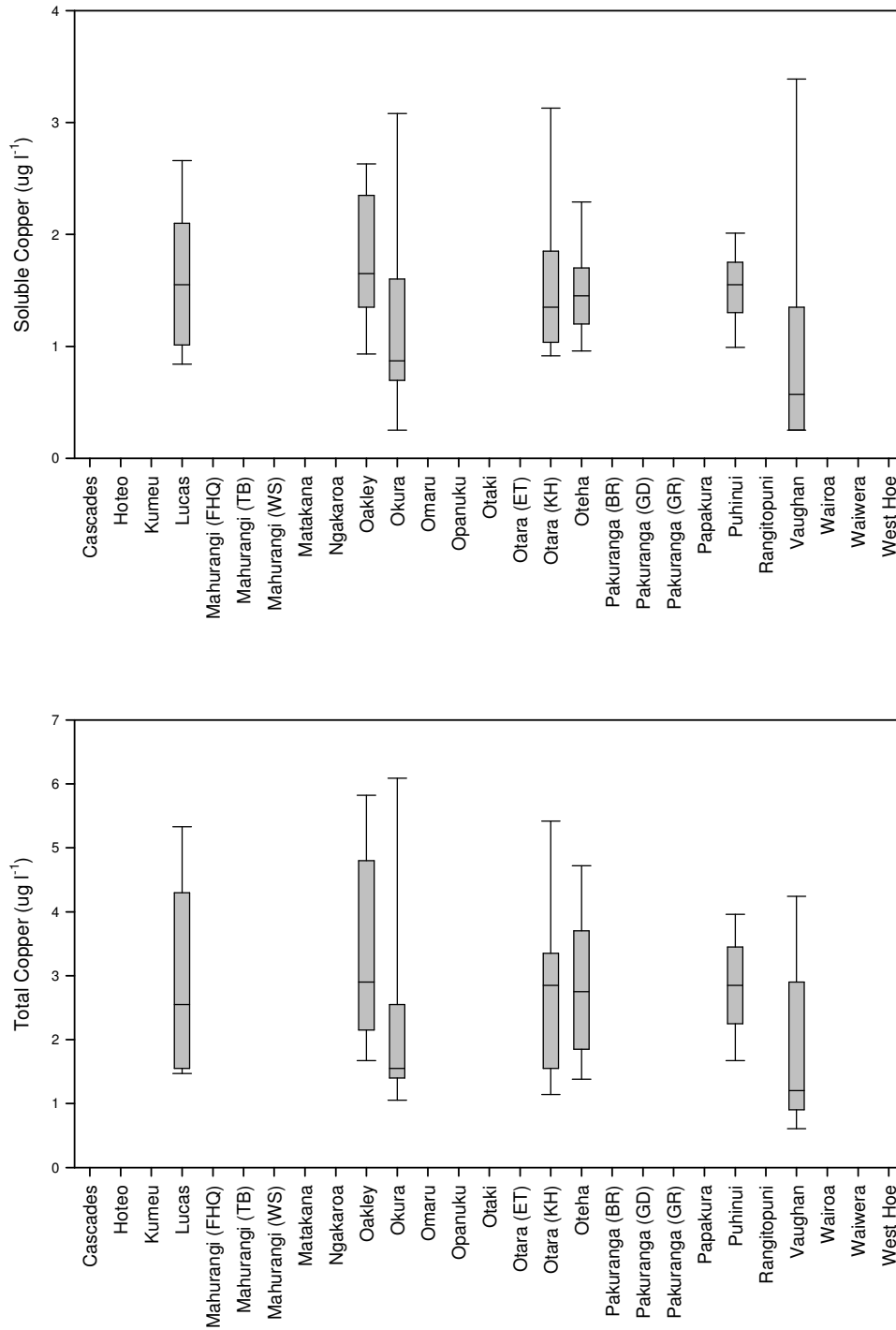


Figure 10

Box plot showing the variation in soluble zinc (upper plot) and total zinc (lower plot) at the 12 sites where it is monitored, using data collected during the 2007 calendar year.

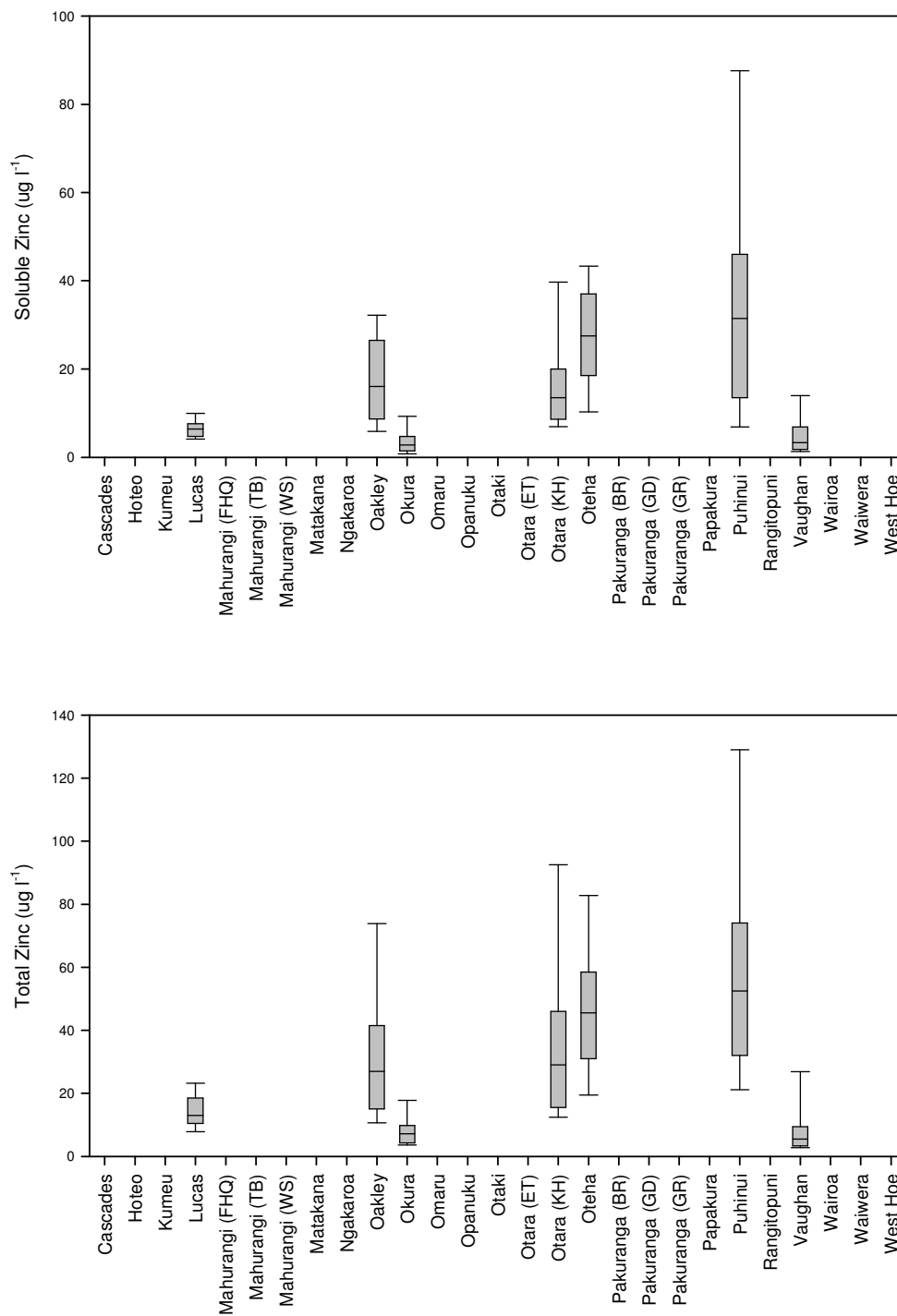


Figure 11

Box plot showing the variation in soluble lead (upper plot) and total lead (lower plot) at the 12 sites where it is monitored, using data collected during the 2007 calendar year.

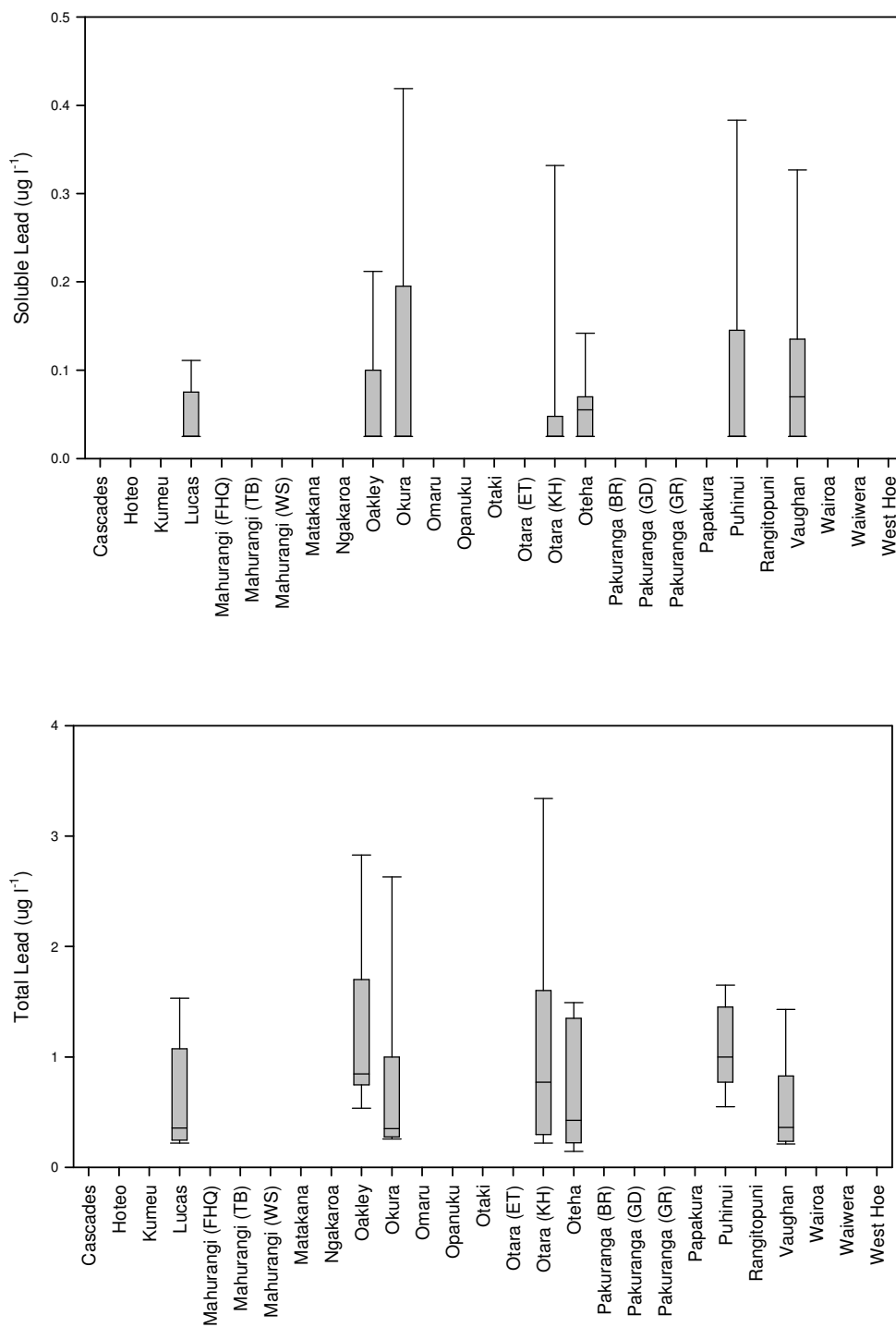


Figure 12

Box plot showing the variation in faecal coliforms at the 27 sites using data collected during the 2007 calendar year. The upper plot has y-axis which covers the full range of the data; the lower plot y-axis is limited to 10000 to provide greater resolution for sites with lower faecal coliform levels. Note the axis break and scale change on the y-axis of the upper plot.

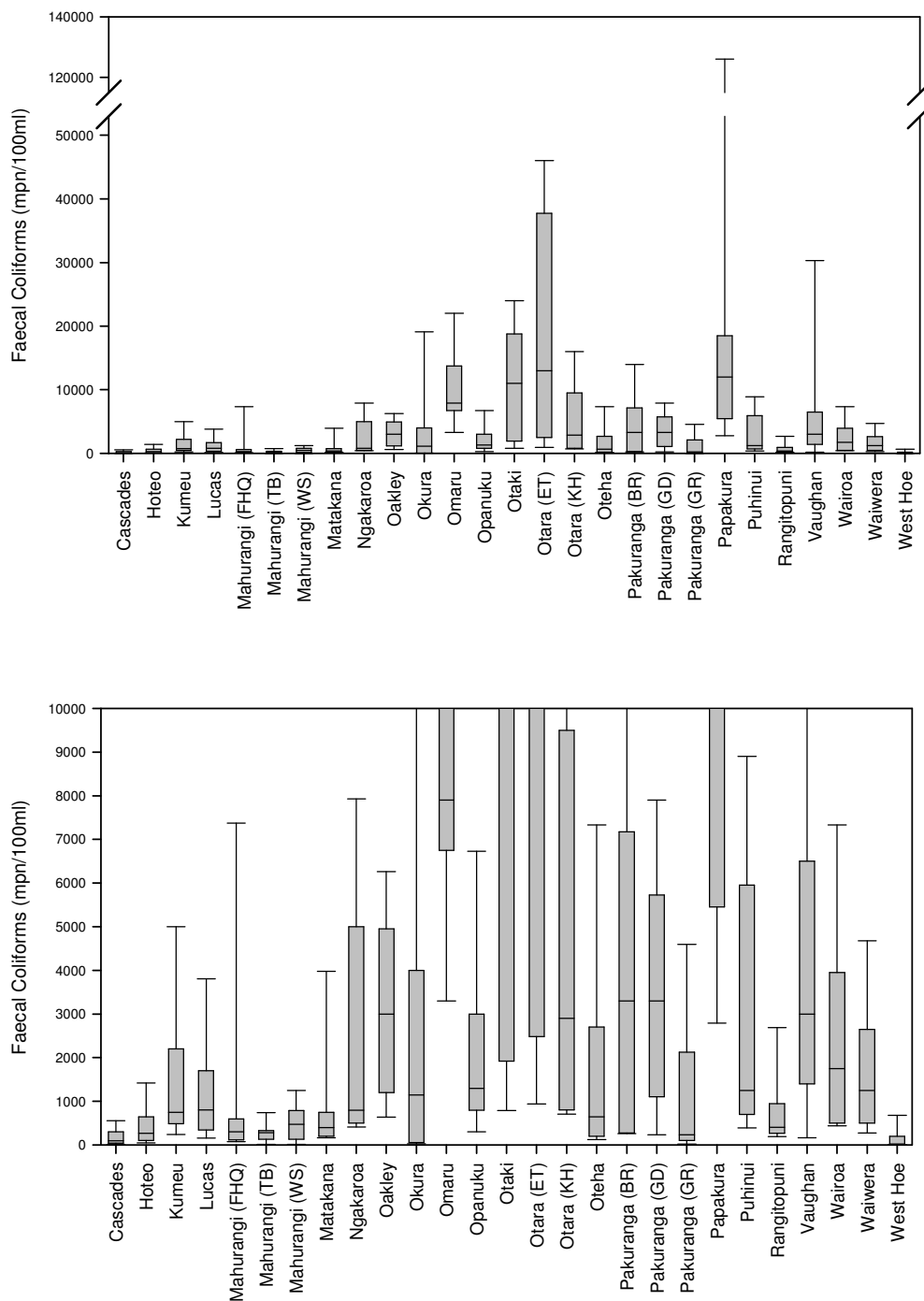
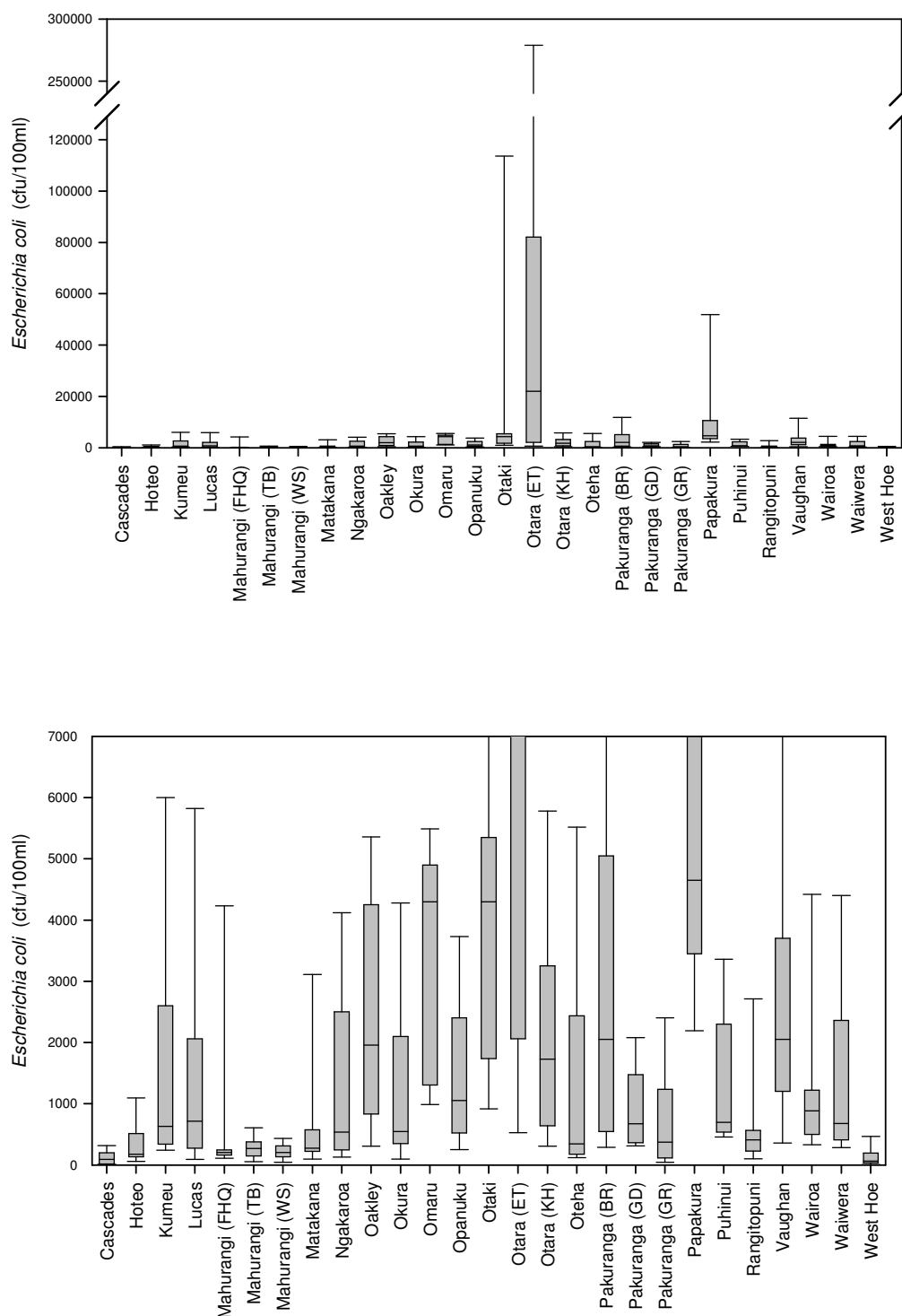


Figure 13

Box plot showing the variation in *Escherichia coli* at the 27 sites using data collected during the 2007 calendar year. The upper plot has y-axis which covers the full range of the data; the lower plot y-axis is limited to 7000 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 5

Dissolved oxygen (% saturation)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	11	67.6	103.4	95.2	91.2	3.6
Hoteo River	12	62.4	92.7	85.6	82.7	2.9
Kumeu River	11	62.5	93.6	79.2	79.3	2.9
Lucas Creek	12	37.6	88.6	81.9	73.6	4.8
Mahurangi River (Forestry HQ)	12	43.8	92.9	87.0	81.8	4.1
Mahurangi River (Town Bridge)	12	74.9	109.6	91.5	90.9	2.7
Mahurangi River (Water Supply)	12	81.9	111.6	94.7	94.9	2.1
Matakana River	12	43.1	88.0	80.9	74.1	4.1
Ngakaroa Stream	12	46.9	94.5	81.2	77.8	4.1
Oakley Creek	12	68.9	94.9	85.8	84.8	2.4
Okura Creek	12	9.9	91.5	81.4	70.2	7.1
Omaru Creek	12	24.4	83.6	65.5	60.1	5.0
Opanuku Stream	12	73.0	97.1	91.4	89.1	2.3
Otaki Creek	12	25.2	89.8	69.8	65.0	5.5
Otara Creek (East Tamaki)	12	73.5	104.9	94.8	94.0	2.5
Otara Creek (Kennell Hill)	12	48.7	87.0	77.8	73.0	3.9
Oteha Stream	12	36.6	89.9	71.2	66.5	6.0
Pakuranga Creek (Botany Rd)	12	99.3	146.0	118.6	121.4	4.2
Pakuranga Creek (Greenmount Dr)	12	45.3	87.3	77.3	72.9	4.3
Pakuranga Creek (Guy's Rd)	12	4.3	111.7	84.4	74.0	8.3
Papakura Stream	12	41.3	86.1	74.9	71.6	3.5
Puhinui Stream	12	77.7	125.8	97.7	99.5	4.2
Rangitopuni River	12	55.0	89.3	73.7	72.2	3.4
Vaughan Stream	12	38.2	114.0	77.3	77.2	5.1
Wairoa River	12	80.2	94.7	89.2	88.8	1.1
Waiwera River	12	70.0	94.2	89.4	86.7	2.1
West Hoe Stream	12	69.4	92.5	83.2	82.8	1.8

Table 6

Dissolved oxygen (ppm)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	12	5.9	10.7	9.7	9.2	0.4
Hoteo River	12	5.6	10.1	8.6	8.2	0.4
Kumeu River	10	5.3	9.2	7.9	7.8	0.4
Lucas Creek	12	3.5	9.5	8.2	7.5	0.5
Mahurangi River (Forestry HQ)	12	4.3	10.5	8.8	8.5	0.5
Mahurangi River (Town Bridge)	12	7.0	10.6	9.3	9.0	0.3
Mahurangi River (Water Supply)	12	7.4	10.9	9.6	9.4	0.3
Matakana River	12	3.8	9.2	7.9	7.5	0.5
Ngakaroa Stream	12	4.4	9.5	8.2	8.0	0.5
Oakley Creek	12	5.6	10.1	8.7	8.4	0.4
Okura Creek	12	1.0	9.9	8.2	7.3	0.8
Omaru Creek	12	2.2	9.0	6.3	5.8	0.6
Opanuku Stream	12	6.1	10.5	9.5	9.2	0.4
Otaki Creek	12	2.5	9.7	6.4	6.3	0.6
Otara Creek (East Tamaki)	12	7.2	10.0	9.5	9.2	0.2
Otara Creek (Kennell Hill)	12	4.2	9.1	7.8	7.3	0.5
Oteha Stream	12	3.5	9.6	7.2	6.7	0.7
Pakuranga Creek (Botany Rd)	12	9.7	13.4	11.3	11.4	0.3
Pakuranga Creek (Greenmount Dr)	12	4.1	9.5	7.5	7.1	0.5
Pakuranga Creek (Guy's Rd)	12	0.4	9.9	8.3	7.2	0.8
Papakura Stream	12	4.3	9.1	7.3	7.2	0.4
Puhinui Stream	12	6.7	11.5	9.4	9.4	0.4
Rangitopuni River	12	4.9	9.6	7.0	7.2	0.4
Vaughan Stream	12	3.4	9.8	8.0	7.5	0.5
Wairoa River	12	7.7	10.1	9.0	9.0	0.2
Waiwera River	12	5.9	10.2	8.9	8.7	0.4
West Hoe Stream	12	7.5	9.6	8.7	8.7	0.2

Table 7

Temperature (°C)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	12	11.7	18.4	13.1	14.4	0.76
Hoteo River	12	11.5	20.8	15.9	16.1	0.96
Kumeu River	10	12.2	23.0	15.4	15.8	0.96
Lucas Creek	12	11.9	18.6	14.9	14.8	0.66
Mahurangi River (Forestry HQ)	12	9.2	19.9	14.7	14.0	0.90
Mahurangi River (Town Bridge)	12	12.6	20.5	15.6	16.1	0.86
Mahurangi River (Water Supply)	12	12.4	20.3	15.4	15.9	0.87
Matakana River	12	11.6	19.7	15.8	15.2	0.72
Ngakaroa Stream	12	11.4	18.6	14.8	14.7	0.74
Oakley Creek	12	12.7	20.4	15.8	15.7	0.73
Okura Creek	12	10.9	18.4	14.2	13.9	0.69
Omaru Creek	12	11.8	20.7	17.0	16.8	0.81
Opanuku Stream	12	11.1	19.6	13.8	14.3	0.76
Otaki Creek	12	11.9	20.0	17.0	16.9	0.66
Otara Creek (East Tamaki)	12	13.3	18.7	16.3	16.2	0.59
Otara Creek (Kennell Hill)	12	12.4	21.0	15.9	16.2	0.90
Oteha Stream	12	12.0	18.8	15.2	15.2	0.69
Pakuranga Creek (Botany Rd)	12	12.8	22.4	18.4	18.1	0.81
Pakuranga Creek (Greenmount Dr)	12	11.6	19.5	17.0	16.4	0.76
Pakuranga Creek (Guy's Rd)	12	11.2	21.7	15.9	16.6	0.95
Papakura Stream	12	12.3	20.5	15.6	15.9	0.87
Puhinui Stream	12	13.6	24.1	17.3	17.9	1.15
Rangitopuni River	12	11.3	21.7	15.4	15.8	1.00
Vaughan Stream	12	12.6	22.2	16.1	16.8	0.98
Wairoa River	12	12.2	20.8	15.3	15.7	0.91
Waiwera River	12	10.5	21.3	15.8	15.8	1.01
West Hoe Stream	12	10.6	16.7	13.0	13.3	0.52

Table 8

Conductivity (Millisiemens/cm @ 25°C)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	11	0.08	0.27	0.16	0.17	0.01
Hoteo River	12	0.15	0.35	0.19	0.21	0.02
Kumeu River	11	0.14	0.30	0.17	0.18	0.01
Lucas Creek	12	0.15	0.32	0.24	0.24	0.01
Mahurangi River (Forestry HQ)	12	0.12	0.24	0.18	0.18	0.01
Mahurangi River (Town Bridge)	12	0.17	0.46	0.20	0.22	0.02
Mahurangi River (Water Supply)	12	0.17	0.43	0.19	0.22	0.02
Matakana River	12	0.14	0.27	0.19	0.20	0.01
Ngakaroa Stream	12	0.14	0.22	0.15	0.16	0.01
Oakley Creek	12	0.14	0.27	0.21	0.21	0.01
Okura Creek	11	0.03	0.39	0.22	0.22	0.03
Omaru Creek	12	0.23	14.50	0.45	4.15	1.67
Opanuku Stream	12	0.12	0.16	0.14	0.14	0.00
Otaki Creek	12	0.05	6.50	0.28	0.98	0.52
Otara Creek (East Tamaki)	12	0.07	3.60	0.18	0.46	0.29
Otara Creek (Kennell Hill)	12	0.03	0.28	0.21	0.20	0.02
Oteha Stream	12	0.12	0.30	0.20	0.20	0.02
Pakuranga Creek (Botany Rd)	12	0.10	0.32	0.27	0.26	0.02
Pakuranga Creek (Greenmount Dr)	12	0.22	0.60	0.36	0.39	0.03
Pakuranga Creek (Guy's Rd)	12	0.12	0.33	0.21	0.22	0.02
Papakura Stream	12	0.16	0.22	0.19	0.19	0.00
Puhinui Stream	12	0.14	0.24	0.18	0.18	0.01
Rangitopuni River	12	0.17	0.29	0.22	0.23	0.01
Vaughan Stream	11	0.17	0.42	0.23	0.25	0.03
Wairoa River	12	0.09	0.14	0.11	0.11	0.00
Waiwera River	12	0.15	0.34	0.19	0.21	0.01
West Hoe Stream	11	0.08	0.20	0.15	0.16	0.01

Table 9
Salinity (ppt)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	11	0.1	0.1	0.1	0.10	0
Hoteo River	12	0.1	0.1	0.1	0.10	0
Kumeu River	11	0.1	0.1	0.1	0.10	0
Lucas Creek	12	0.1	0.2	0.1	0.11	0.008
Mahurangi River (Forestry HQ)	12	0.1	0.1	0.1	0.10	0
Mahurangi River (Town Bridge)	12	0.1	0.2	0.1	0.11	0.008
Mahurangi River (Water Supply)	12	0.1	0.1	0.1	0.10	0
Matakana River	12	0.1	0.1	0.1	0.10	0
Ngakaroa Stream	12	0.1	0.1	0.1	0.10	0
Oakley Creek	12	0.1	0.1	0.1	0.10	0
Okura Creek	11	0.1	0.2	0.1	0.11	0.009
Omaru Creek	11	0.1	8.5	0.2	2.55	1.041
Opanuku Stream	12	0.1	0.1	0.1	0.10	0
Otaki Creek	11	0.1	3.6	0.1	0.75	0.350
Otara Creek (East Tamaki)	11	0.1	0.1	0.1	0.08	0
Otara Creek (Kennell Hill)	12	0.1	0.1	0.1	0.10	0
Oteha Stream	12	0.1	0.1	0.1	0.10	0
Pakuranga Creek (Botany Rd)	11	0.1	0.2	0.1	0.11	0.009
Pakuranga Creek (Greenmount Dr)	11	0.1	0.3	0.2	0.19	0.016
Pakuranga Creek (Guy's Rd)	11	0.1	0.2	0.1	0.11	0.009
Papakura Stream	12	0.1	0.1	0.1	0.10	0
Puhinui Stream	12	0.1	0.1	0.1	0.10	0
Rangitopuni River	12	0.1	0.1	0.1	0.10	0
Vaughan Stream	11	0.1	0.2	0.1	0.12	0.012
Wairoa River	12	0.1	0.1	0.1	0.10	0
Waiwera River	12	0.1	0.1	0.1	0.10	0
West Hoe Stream	11	0.1	0.1	0.1	0.10	0

Table 10
pH (pH units)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	12	7.3	8.1	7.8	7.7	0.07
Hoteo River	12	7.2	7.8	7.5	7.5	0.05
Kumeu River	10	7.2	7.6	7.3	7.3	0.04
Lucas Creek	12	7.3	8.3	7.4	7.5	0.08
Mahurangi River (Forestry HQ)	12	7.3	7.6	7.5	7.5	0.03
Mahurangi River (Town Bridge)	12	7.5	8.2	7.7	7.8	0.07
Mahurangi River (Water Supply)	12	7.7	8.1	7.9	7.9	0.04
Matakana River	12	7.3	7.5	7.4	7.4	0.03
Ngakaroa Stream	12	7.1	7.6	7.3	7.3	0.04
Oakley Creek	12	6.9	7.8	7.5	7.5	0.07
Okura Creek	12	7.3	7.5	7.4	7.4	0.03
Omaru Creek	12	7.2	7.7	7.4	7.4	0.04
Opanuku Stream	12	7.2	7.8	7.6	7.5	0.05
Otaki Creek	12	7.2	7.5	7.4	7.3	0.03
Otara Creek (East Tamaki)	12	6.8	8.1	7.7	7.5	0.12
Otara Creek (Kennell Hill)	12	7.1	7.7	7.4	7.4	0.05
Oteha Stream	11	7.1	7.7	7.4	7.4	0.06
Pakuranga Creek (Botany Rd)	12	7.3	7.9	7.4	7.5	0.04
Pakuranga Creek (Greenmount Dr)	12	7.3	7.8	7.5	7.5	0.04
Pakuranga Creek (Guy's Rd)	12	7.4	8.5	7.5	7.6	0.08
Papakura Stream	12	7.1	7.6	7.3	7.3	0.06
Puhinui Stream	12	7.1	8.1	7.4	7.5	0.09
Rangitopuni River	12	7.2	7.6	7.4	7.4	0.03
Vaughan Stream	12	7.2	7.7	7.4	7.4	0.04
Wairoa River	12	7.2	7.6	7.4	7.4	0.04
Waiwera River	12	7.2	7.8	7.5	7.5	0.05
West Hoe Stream	12	7.2	7.5	7.4	7.4	0.03

Table 11Suspended sediment (mg l⁻¹)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	12	0.4	13.5	2.4	3.8	1.3
Hoteo River	12	2.4	18.8	10.1	9.9	1.7
Kumeu River	10	3.6	58.0	12.2	16.9	4.8
Lucas Creek	12	4.0	57.0	7.5	18.3	5.1
Mahurangi River (Forestry HQ)	12	2.0	41.0	4.2	7.5	3.1
Mahurangi River (Town Bridge)	12	2.4	18.2	6.2	6.5	1.2
Mahurangi River (Water Supply)	12	2.6	29.2	5.8	7.6	2.1
Matakana River	12	1.8	8.0	3.1	4.3	0.6
Ngakaroa Stream	12	0.6	65.6	2.5	8.5	5.3
Oakley Creek	12	0.4	13.4	5.1	6.4	1.2
Okura Creek	12	3.5	42.0	13.3	16.1	3.0
Omaru Creek	12	6.0	55.0	9.2	13.2	3.9
Opanuku Stream	12	0.4	20.0	5.9	7.0	1.6
Otaki Creek	12	3.3	103.0	5.8	18.2	8.5
Otara Creek (East Tamaki)	12	2.0	23.0	5.7	8.5	2.1
Otara Creek (Kennell Hill)	12	2.4	21.6	9.4	11.4	2.0
Oteha Stream	11	2.0	29.5	8.1	12.3	3.2
Pakuranga Creek (Botany Rd)	12	2.8	18.8	5.5	6.9	1.3
Pakuranga Creek (Greenmount Dr)	12	1.4	13.0	4.0	5.1	1.1
Pakuranga Creek (Guy's Rd)	12	4.4	78.7	8.0	14.3	5.9
Papakura Stream	12	2.0	16.0	6.3	7.7	1.5
Puhinui Stream	12	2.2	21.0	10.7	11.5	1.6
Rangitopuni River	12	2.8	39.0	7.1	10.0	2.8
Vaughan Stream	12	7.0	50.0	16.5	20.3	3.6
Wairoa River	12	5.0	22.0	9.4	11.4	1.6
Waiwera River	12	4.2	22.0	9.4	10.3	1.6
West Hoe Stream	12	1.2	12.0	3.5	5.0	1.1

Table 12
Turbidity (NTU)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	11	1.6	27.8	5.1	8.4	2.5
Hoteo River	12	4.9	19.0	9.2	10.9	1.5
Kumeu River	11	6.4	87.3	13.2	20.9	7.3
Lucas Creek	12	4.9	119.0	13.1	33.8	11.3
Mahurangi River (Forestry HQ)	12	3.4	62.1	6.5	11.8	4.7
Mahurangi River (Town Bridge)	12	0.6	18.5	6.5	7.2	1.7
Mahurangi River (Water Supply)	12	1.7	18.8	6.8	7.5	1.6
Matakana River	12	1.2	16.3	5.1	5.8	1.2
Ngakaroa Stream	12	1.0	75.6	2.9	11.1	6.0
Oakley Creek	12	1.3	22.6	5.4	7.7	1.9
Okura Creek	12	15.7	57.6	23.3	27.4	3.3
Omaru Creek	12	2.2	38.4	7.0	10.5	2.9
Opanuku Stream	12	1.9	30.6	10.8	12.6	2.9
Otaki Creek	12	3.8	60.1	8.3	14.2	4.6
Otara Creek (East Tamaki)	12	1.6	25.6	5.2	8.6	2.2
Otara Creek (Kennell Hill)	12	1.6	36.2	9.3	13.7	3.7
Oteha Stream	11	2.2	91.8	13.7	24.5	8.5
Pakuranga Creek (Botany Rd)	12	3.1	29.5	9.5	10.2	1.9
Pakuranga Creek (Greenmount Dr)	12	1.9	18.3	5.2	6.9	1.5
Pakuranga Creek (Guy's Rd)	12	2.8	49.8	8.5	11.9	3.6
Papakura Stream	12	1.3	33.8	15.6	14.6	3.2
Puhinui Stream	12	1.6	29.4	13.3	14.5	2.8
Rangitopuni River	12	3.1	56.1	9.0	12.9	4.2
Vaughan Stream	12	9.8	60.3	21.4	27.6	4.9
Wairoa River	12	2.9	39.8	11.3	16.4	3.5
Waiwera River	12	4.1	37.3	10.7	14.4	3.0
West Hoe Stream	12	7.0	19.3	9.7	11.6	1.3

Table 13Ammoniacal Nitrogen (mg N l⁻¹)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	11	0.003	0.066	0.011	0.019	0.006
Hoteo River	11	0.003	0.079	0.026	0.034	0.007
Kumeu River	10	0.003	0.061	0.032	0.035	0.005
Lucas Creek	11	0.020	0.144	0.028	0.044	0.011
Mahurangi River (Forestry HQ)	11	0.014	0.061	0.046	0.037	0.005
Mahurangi River (Town Bridge)	12	0.009	0.103	0.029	0.037	0.008
Mahurangi River (Water Supply)	12	0.003	0.103	0.032	0.037	0.009
Matakana River	11	0.003	0.052	0.017	0.022	0.005
Ngakaroa Stream	12	0.003	0.090	0.013	0.021	0.007
Oakley Creek	12	0.006	0.057	0.020	0.026	0.005
Okura Creek	12	0.003	0.076	0.017	0.024	0.007
Omaru Creek	12	0.060	0.299	0.115	0.134	0.020
Opanuku Stream	12	0.005	0.035	0.015	0.016	0.003
Otaki Creek	12	0.078	5.400	0.132	0.580	0.439
Otara Creek (East Tamaki)	12	0.026	0.706	0.089	0.163	0.055
Otara Creek (Kennell Hill)	12	0.010	0.104	0.033	0.037	0.007
Oteha Stream	11	0.021	0.057	0.030	0.033	0.003
Pakuranga Creek (Botany Rd)	12	0.028	0.076	0.044	0.046	0.004
Pakuranga Creek (Greenmount Dr)	12	0.009	0.161	0.100	0.098	0.014
Pakuranga Creek (Guy's Rd)	12	0.009	0.110	0.038	0.045	0.009
Papakura Stream	12	0.013	0.152	0.057	0.063	0.011
Puhinui Stream	12	0.007	0.080	0.038	0.039	0.005
Rangitopuni River	11	0.003	0.067	0.029	0.032	0.005
Vaughan Stream	12	0.003	0.174	0.021	0.032	0.013
Wairoa River	12	0.009	0.114	0.028	0.037	0.008
Waiwera River	11	0.003	0.070	0.029	0.034	0.005
West Hoe Stream	12	0.003	0.038	0.005	0.012	0.004

Table 14Total oxidised Nitrogen (mg N l⁻¹)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	11	0.010	0.389	0.022	0.056	0.034
Hoteo River	12	0.011	0.701	0.216	0.256	0.061
Kumeu River	11	0.017	0.746	0.319	0.333	0.073
Lucas Creek	12	0.136	0.562	0.276	0.301	0.041
Mahurangi River (Forestry HQ)	12	0.017	0.161	0.045	0.055	0.011
Mahurangi River (Town Bridge)	12	0.012	0.404	0.104	0.143	0.038
Mahurangi River (Water Supply)	12	0.022	0.410	0.099	0.147	0.038
Matakana River	12	0.019	0.146	0.043	0.059	0.013
Ngakaroa Stream	12	1.560	3.710	2.275	2.358	0.164
Oakley Creek	12	0.554	1.680	1.145	1.107	0.094
Okura Creek	12	0.037	0.796	0.175	0.250	0.064
Omaru Creek	12	0.098	4.050	0.684	0.887	0.303
Opanuku Stream	12	0.020	0.235	0.125	0.117	0.021
Otaki Creek	12	0.217	1.470	0.939	0.913	0.122
Otara Creek (East Tamaki)	12	0.540	1.470	0.962	0.972	0.083
Otara Creek (Kennell Hill)	12	0.193	1.040	0.366	0.439	0.072
Oteha Stream	11	0.141	0.815	0.235	0.323	0.059
Pakuranga Creek (Botany Rd)	12	0.281	1.310	0.569	0.653	0.100
Pakuranga Creek (Greenmount Dr)	12	0.098	0.800	0.365	0.437	0.059
Pakuranga Creek (Guy's Rd)	12	0.013	0.776	0.354	0.389	0.069
Papakura Stream	12	0.026	1.860	0.497	0.557	0.155
Puhinui Stream	12	0.263	1.350	0.529	0.638	0.093
Rangitopuni River	12	0.015	0.499	0.194	0.179	0.040
Vaughan Stream	12	0.006	0.469	0.062	0.105	0.037
Wairoa River	12	0.039	1.300	0.425	0.496	0.117
Waiwera River	12	0.009	0.406	0.110	0.142	0.036
West Hoe Stream	12	0.004	0.024	0.011	0.011	0.002

Table 15Kjeldhal Nitrogen (mg N l⁻¹)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	11	0.05	0.66	0.22	0.29	0.07
Hoteo River	12	0.05	0.78	0.44	0.44	0.06
Kumeu River	11	0.35	1.83	0.67	0.79	0.14
Lucas Creek	12	0.22	1.22	0.61	0.64	0.09
Mahurangi River (Forestry HQ)	12	0.10	0.94	0.47	0.49	0.07
Mahurangi River (Town Bridge)	12	0.20	1.70	0.50	0.60	0.13
Mahurangi River (Water Supply)	12	0.22	1.35	0.52	0.56	0.08
Matakana River	12	0.05	0.83	0.37	0.39	0.07
Ngakaroa Stream	12	0.14	1.42	0.41	0.50	0.09
Oakley Creek	12	0.05	0.91	0.40	0.45	0.06
Okura Creek	12	0.05	2.05	0.61	0.71	0.15
Omaru Creek	12	0.35	1.03	0.69	0.70	0.06
Opanuku Stream	12	0.05	0.70	0.36	0.40	0.06
Otaki Creek	12	0.29	7.16	0.66	1.25	0.55
Otara Creek (East Tamaki)	12	0.21	1.45	0.62	0.69	0.12
Otara Creek (Kennell Hill)	12	0.05	1.03	0.54	0.53	0.07
Oteha Stream	12	0.05	0.81	0.46	0.44	0.05
Pakuranga Creek (Botany Rd)	12	0.26	0.82	0.48	0.52	0.06
Pakuranga Creek (Greenmount Dr)	12	0.17	1.01	0.48	0.51	0.07
Pakuranga Creek (Guy's Rd)	12	0.37	1.01	0.59	0.60	0.06
Papakura Stream	12	0.05	1.42	0.81	0.74	0.10
Puhinui Stream	12	0.29	1.87	0.67	0.75	0.12
Rangitopuni River	12	0.33	1.48	0.86	0.82	0.08
Vaughan Stream	12	0.05	1.49	0.88	0.85	0.13
Wairoa River	12	0.05	1.18	0.54	0.52	0.10
Waiwera River	12	0.24	1.01	0.54	0.58	0.06
West Hoe Stream	12	0.05	1.36	0.18	0.33	0.11

Table 16Total Nitrogen by calculation (mg N l⁻¹)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	11	0.13	0.69	0.26	0.36	0.07
Hoteo River	12	0.14	1.48	0.68	0.70	0.10
Kumeu River	11	0.53	2.10	1.05	1.13	0.15
Lucas Creek	12	0.44	1.55	0.81	0.94	0.11
Mahurangi River (Forestry HQ)	12	0.12	0.98	0.51	0.54	0.07
Mahurangi River (Town Bridge)	12	0.34	1.71	0.62	0.75	0.13
Mahurangi River (Water Supply)	12	0.29	1.37	0.66	0.71	0.08
Matakana River	12	0.12	0.89	0.40	0.45	0.06
Ngakaroa Stream	12	2.14	4.02	2.68	2.85	0.18
Oakley Creek	12	0.65	2.06	1.66	1.56	0.12
Okura Creek	12	0.23	2.85	0.77	0.96	0.20
Omaru Creek	12	0.74	4.40	1.32	1.58	0.29
Opanuku Stream	12	0.21	0.93	0.46	0.52	0.06
Otaki Creek	12	0.96	7.52	1.68	2.16	0.50
Otara Creek (East Tamaki)	12	0.91	2.82	1.65	1.66	0.15
Otara Creek (Kennell Hill)	12	0.62	2.07	0.84	0.97	0.12
Oteha Stream	11	0.56	1.30	0.67	0.80	0.08
Pakuranga Creek (Botany Rd)	12	0.57	2.07	1.04	1.18	0.13
Pakuranga Creek (Greenmount Dr)	12	0.46	1.48	0.87	0.95	0.09
Pakuranga Creek (Guy's Rd)	12	0.64	1.29	1.02	0.99	0.08
Papakura Stream	12	0.14	3.28	1.39	1.31	0.24
Puhinui Stream	12	0.55	2.33	1.32	1.38	0.16
Rangitopuni River	12	0.54	1.98	0.96	1.00	0.10
Vaughan Stream	12	0.11	1.96	0.97	0.96	0.15
Wairoa River	12	0.20	2.48	1.03	1.02	0.19
Waiwera River	12	0.43	1.18	0.67	0.72	0.07
West Hoe Stream	12	0.11	1.37	0.19	0.35	0.11

Table 17Soluble reactive Phosphorus (mg P l⁻¹)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	11	0.007	0.026	0.018	0.018	0.002
Hoteo River	12	0.018	0.043	0.029	0.029	0.002
Kumeu River	11	0.014	0.031	0.020	0.021	0.002
Lucas Creek	12	0.007	0.030	0.016	0.017	0.002
Mahurangi River (Forestry HQ)	12	0.005	0.024	0.011	0.012	0.002
Mahurangi River (Town Bridge)	12	0.010	0.036	0.016	0.018	0.002
Mahurangi River (Water Supply)	12	0.010	0.050	0.018	0.021	0.003
Matakana River	12	0.010	0.044	0.017	0.019	0.003
Ngakaroa Stream	12	0.005	0.023	0.012	0.013	0.002
Oakley Creek	12	0.005	0.058	0.029	0.031	0.005
Okura Creek	12	0.005	0.045	0.017	0.020	0.003
Omaru Creek	12	0.014	0.064	0.020	0.026	0.005
Opanuku Stream	12	0.005	0.030	0.018	0.018	0.002
Otaki Creek	12	0.005	0.125	0.022	0.035	0.010
Otara Creek (East Tamaki)	12	0.005	0.108	0.020	0.029	0.008
Otara Creek (Kennell Hill)	12	0.005	0.042	0.023	0.023	0.003
Oteha Stream	11	0.007	0.030	0.018	0.018	0.002
Pakuranga Creek (Botany Rd)	12	0.005	0.056	0.016	0.022	0.005
Pakuranga Creek (Greenmount Dr)	12	0.005	0.090	0.020	0.029	0.007
Pakuranga Creek (Guy's Rd)	12	0.005	0.049	0.014	0.019	0.004
Papakura Stream	12	0.028	0.068	0.038	0.042	0.004
Puhinui Stream	12	0.005	0.051	0.020	0.024	0.005
Rangitopuni River	12	0.010	0.054	0.030	0.030	0.004
Vaughan Stream	12	0.005	0.031	0.019	0.019	0.002
Wairoa River	12	0.005	0.030	0.021	0.021	0.002
Waiwera River	12	0.011	0.030	0.017	0.017	0.001
West Hoe Stream	12	0.005	0.024	0.010	0.013	0.002

Table 18Total Phosphorus (mg P l⁻¹)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	11	0.03	0.08	0.04	0.04	0.004
Hoteo River	12	0.04	0.09	0.07	0.07	0.005
Kumeu River	11	0.05	0.23	0.07	0.09	0.017
Lucas Creek	12	0.04	0.11	0.06	0.07	0.008
Mahurangi River (Forestry HQ)	12	0.02	0.13	0.03	0.04	0.008
Mahurangi River (Town Bridge)	12	0.04	0.06	0.05	0.05	0.002
Mahurangi River (Water Supply)	12	0.03	0.06	0.05	0.05	0.002
Matakana River	12	0.03	0.06	0.04	0.04	0.003
Ngakaroa Stream	12	0.01	0.22	0.04	0.05	0.016
Oakley Creek	12	0.04	0.11	0.06	0.07	0.006
Okura Creek	12	0.03	0.42	0.07	0.10	0.030
Omaru Creek	12	0.02	0.20	0.10	0.11	0.017
Opanuku Stream	12	0.01	0.10	0.05	0.05	0.006
Otaki Creek	12	0.03	1.10	0.11	0.21	0.086
Otara Creek (East Tamaki)	12	0.04	0.15	0.07	0.07	0.009
Otara Creek (Kennell Hill)	12	0.04	0.17	0.06	0.08	0.011
Oteha Stream	12	0.04	0.12	0.06	0.06	0.008
Pakuranga Creek (Botany Rd)	12	0.04	0.12	0.06	0.07	0.007
Pakuranga Creek (Greenmount Dr)	12	0.06	0.15	0.08	0.09	0.007
Pakuranga Creek (Guy's Rd)	12	0.04	0.16	0.05	0.07	0.010
Papakura Stream	12	0.05	0.21	0.11	0.11	0.015
Puhinui Stream	12	0.05	0.11	0.08	0.08	0.005
Rangitopuni River	12	0.05	0.19	0.08	0.08	0.010
Vaughan Stream	12	0.04	0.16	0.07	0.07	0.009
Wairoa River	12	0.05	0.12	0.07	0.07	0.006
Waiwera River	12	0.04	0.07	0.05	0.05	0.003
West Hoe Stream	12	0.01	0.06	0.03	0.03	0.003

Table 19Soluble Copper ($\mu\text{g l}^{-1}$)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	Not measured at this site					
Hoteo River	Not measured at this site					
Kumeu River	Not measured at this site					
Lucas Creek	12	0.25	4.90	0.87	1.32	0.37
Mahurangi River (Forestry HQ)	Not measured at this site					
Mahurangi River (Town Bridge)	Not measured at this site					
Mahurangi River (Water Supply)	Not measured at this site					
Matakana River	Not measured at this site					
Ngakaroa Stream	Not measured at this site					
Oakley Creek	12	0.25	6.40	0.57	1.21	0.50
Okura Creek	12	0.93	2.50	1.45	1.52	0.14
Omaru Creek	4	0.75	2.80	1.50	1.60	0.20
Opanuku Stream	Not measured at this site					
Otaki Creek	4	0.73	2.50	1.55	1.54	0.13
Otara Creek (East Tamaki)	4	0.77	2.70	1.65	1.81	0.18
Otara Creek (Kennell Hill)	12	0.88	3.20	1.35	1.62	0.23
Oteha Stream	12	1.00	3.50	2.25	2.25	0.72
Pakuranga Creek (Botany Rd)	4	1.30	2.00	1.85	1.75	0.16
Pakuranga Creek (Greenmount Dr)	4	0.93	3.80	1.45	1.91	0.66
Pakuranga Creek (Guy's Rd)	4	0.93	1.90	1.50	1.46	0.20
Papakura Stream	Not measured at this site					
Puhinui Stream	12	1.50	2.70	1.70	1.90	0.27
Rangitopuni River	Not measured at this site					
Vaughan Stream	12	0.63	1.90	1.07	1.17	0.27
Wairoa River	Not measured at this site					
Waiwera River	Not measured at this site					
West Hoe Stream	Not measured at this site					

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

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	Not measured at this site					
Hoteo River	Not measured at this site					
Kumeu River	Not measured at this site					
Lucas Creek	12	1.4	6.8	2.6	3.1	0.5
Mahurangi River (Forestry HQ)	Not measured at this site					
Mahurangi River (Town Bridge)	Not measured at this site					
Mahurangi River (Water Supply)	Not measured at this site					
Matakana River	Not measured at this site					
Ngakaroa Stream	Not measured at this site					
Oakley Creek	12	1.6	6.8	2.9	3.4	0.5
Okura Creek	12	0.7	7.0	1.6	2.4	0.6
Omaru Creek	4	3.2	5.8	3.7	4.1	0.6
Opanuku Stream	Not measured at this site					
Otaki Creek	4	1.3	3.2	2.1	2.2	0.5
Otara Creek (East Tamaki)	4	2.2	17.0	5.7	7.7	3.2
Otara Creek (Kennell Hill)	12	1.0	5.7	2.9	2.8	0.4
Oteha Stream	12	1.1	5.7	2.8	2.9	0.4
Pakuranga Creek (Botany Rd)	4	1.8	3.1	3.0	2.7	0.3
Pakuranga Creek (Greenmount Dr)	4	2.9	3.9	3.5	3.5	0.2
Pakuranga Creek (Guy's Rd)	4	2.2	4.4	2.8	3.0	0.5
Papakura Stream	Not measured at this site					
Puhinui Stream	12	1.6	4.1	2.9	2.9	0.2
Rangitopuni River	Not measured at this site					
Vaughan Stream	12	0.6	6.2	1.2	1.9	0.5
Wairoa River	Not measured at this site					
Waiwera River	Not measured at this site					
West Hoe Stream	Not measured at this site					

Table 21Soluble Zinc ($\mu\text{g l}^{-1}$)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	Not measured at this site					
Hoteo River	Not measured at this site					
Kumeu River	Not measured at this site					
Lucas Creek	12	0.3	18.0	2.8	4.0	1.4
Mahurangi River (Forestry HQ)	Not measured at this site					
Mahurangi River (Town Bridge)	Not measured at this site					
Mahurangi River (Water Supply)	Not measured at this site					
Matakana River	Not measured at this site					
Ngakaroa Stream	Not measured at this site					
Oakley Creek	12	0.6	29.0	2.4	5.4	2.3
Okura Creek	12	6.3	51.0	27.5	28.4	3.6
Omaru Creek	4	3.3	14.0	6.4	6.6	0.8
Opanuku Stream	Not measured at this site					
Otaki Creek	4	5.1	110.0	31.5	37.2	8.9
Otara Creek (East Tamaki)	4	4.7	42.0	16.0	18.2	3.2
Otara Creek (Kennell Hill)	12	4.8	120.0	15.0	26.3	9.2
Oteha Stream	12	15.0	46.0	30.0	30.3	6.9
Pakuranga Creek (Botany Rd)	4	0.9	16.0	8.5	8.5	3.2
Pakuranga Creek (Greenmount Dr)	4	1.4	47.0	22.5	23.4	10.6
Pakuranga Creek (Guy's Rd)	4	9.0	39.0	16.5	20.3	6.6
Papakura Stream	Not measured at this site					
Puhinui Stream	12	8.2	81.0	46.0	45.3	16.4
Rangitopuni River	Not measured at this site					
Vaughan Stream	12	22.0	32.0	26.5	26.8	2.8
Wairoa River	Not measured at this site					
Waiwera River	Not measured at this site					
West Hoe Stream	Not measured at this site					

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

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	Not measured at this site					
Hoteo River	Not measured at this site					
Kumeu River	Not measured at this site					
Lucas Creek	12	4.6	26.0	13.0	14.7	1.8
Mahurangi River (Forestry HQ)	Not measured at this site					
Mahurangi River (Town Bridge)	Not measured at this site					
Mahurangi River (Water Supply)	Not measured at this site					
Matakana River	Not measured at this site					
Ngakaroa Stream	Not measured at this site					
Oakley Creek	12	9.7	120.0	27.0	34.9	8.7
Okura Creek	12	3.6	29.0	7.2	8.6	2.0
Omaru Creek	4	16.0	92.0	68.5	61.3	17.1
Opanuku Stream	Not measured at this site					
Otaki Creek	4	29.0	51.0	40.0	40.0	5.8
Otara Creek (East Tamaki)	4	26.0	60.0	44.5	43.8	7.8
Otara Creek (Kennell Hill)	12	11.0	180.0	29.0	41.8	13.3
Oteha Stream	12	9.0	87.0	45.5	46.4	6.6
Pakuranga Creek (Botany Rd)	4	22.0	55.0	29.0	33.8	7.7
Pakuranga Creek (Greenmount Dr)	4	3.0	24.0	20.5	17.0	4.9
Pakuranga Creek (Guy's Rd)	4	4.1	44.0	15.5	19.8	8.5
Papakura Stream	Not measured at this site					
Puhinui Stream	12	19.0	150.0	52.5	60.5	11.5
Rangitopuni River	Not measured at this site					
Vaughan Stream	12	2.3	29.0	5.5	9.0	2.6
Wairoa River	Not measured at this site					
Waiwera River	Not measured at this site					
West Hoe Stream	Not measured at this site					

Table 23Soluble Lead ($\mu\text{g l}^{-1}$)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	Not measured at this site					
Hoteo River	Not measured at this site					
Kumeu River	Not measured at this site					
Lucas Creek	12	0.025	0.160	0.025	0.054	0.012
Mahurangi River (Forestry HQ)	Not measured at this site					
Mahurangi River (Town Bridge)	Not measured at this site					
Mahurangi River (Water Supply)	Not measured at this site					
Matakana River	Not measured at this site					
Ngakaroa Stream	Not measured at this site					
Oakley Creek	12	0.025	0.380	0.025	0.079	0.030
Okura Creek	12	0.025	0.790	0.025	0.140	0.064
Omaru Creek	4	0.025	0.025	0.025	0.025	0.000
Opanuku Stream	Not measured at this site					
Otaki Creek	4	0.025	0.025	0.025	0.025	0.000
Otara Creek (East Tamaki)	4	0.025	0.025	0.025	0.025	0.000
Otara Creek (Kennell Hill)	12	0.025	0.360	0.025	0.081	0.035
Oteha Stream	12	0.025	0.310	0.055	0.068	0.023
Pakuranga Creek (Botany Rd)	4	0.025	0.025	0.025	0.025	0.000
Pakuranga Creek (Greenmount Dr)	4	0.025	0.025	0.025	0.025	0.000
Pakuranga Creek (Guy's Rd)	4	0.025	0.025	0.025	0.025	0.000
Papakura Stream	Not measured at this site					
Puhinui Stream	12	0.025	0.530	0.025	0.115	0.047
Rangitopuni River	Not measured at this site					
Vaughan Stream	12	0.025	0.530	0.07	0.115	0.043
Wairoa River	Not measured at this site					
Waiwera River	Not measured at this site					
West Hoe Stream	Not measured at this site					

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

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	Not measured at this site					
Hoteo River	Not measured at this site					
Kumeu River	Not measured at this site					
Lucas Creek	12	0.19	1.60	0.36	0.67	0.15
Mahurangi River (Forestry HQ)	Not measured at this site					
Mahurangi River (Town Bridge)	Not measured at this site					
Mahurangi River (Water Supply)	Not measured at this site					
Matakana River	Not measured at this site					
Ngakaroa Stream	Not measured at this site					
Oakley Creek	12	0.50	2.80	0.85	1.25	0.24
Okura Creek	12	0.25	4.10	0.35	0.89	0.33
Omaru Creek	4	0.45	1.80	1.05	1.09	0.29
Opanuku Stream	Not measured at this site					
Otaki Creek	4	0.55	1.40	0.90	0.94	0.19
Otara Creek (East Tamaki)	4	0.60	0.81	0.71	0.71	0.04
Otara Creek (Kennell Hill)	12	0.19	4.60	0.77	1.27	0.38
Oteha Stream	12	0.10	1.70	0.43	0.69	0.17
Pakuranga Creek (Botany Rd)	4	0.23	0.79	0.39	0.45	0.12
Pakuranga Creek (Greenmount Dr)	4	0.07	0.24	0.23	0.19	0.04
Pakuranga Creek (Guy's Rd)	4	0.20	0.49	0.34	0.34	0.06
Papakura Stream	Not measured at this site					
Puhinui Stream	12	0.47	2.00	1.00	1.08	0.13
Rangitopuni River	Not measured at this site					
Vaughan Stream	12	0.19	1.50	0.36	0.58	0.13
Wairoa River	Not measured at this site					
Waiwera River	Not measured at this site					
West Hoe Stream	Not measured at this site					

Table 25

Faecal Coliforms (mpn/100ml)

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	11	1	790	80	192	73
Hoteo River	12	50	1700	265	480	154
Kumeu River	11	130	5000	700	1505	547
Lucas Creek	12	30	5000	800	1333	427
Mahurangi River (Forestry HQ)	12	70	22000	300	2152	1806
Mahurangi River (Town Bridge)	6	1	790	280	302	110
Mahurangi River (Water Supply)	6	1	1300	475	529	192
Matakana River	12	170	7900	400	1170	635
Ngakaroa Stream	12	230	8000	795	2750	859
Oakley Creek	12	500	9200	3000	3467	723
Okura Creek	12	17	24000	1150	4438	2248
Omaru Creek	5	3300	22000	7900	10420	3145
Opanuku Stream	12	300	11000	1300	2491	868
Otaki Creek	5	790	24000	11000	11018	4387
Otara Creek (East Tamaki)	5	940	46000	13000	19588	8948
Otara Creek (Kennell Hill)	12	490	23000	2900	5908	1970
Oteha Stream	12	110	13000	645	2238	1069
Pakuranga Creek (Botany Rd)	5	260	14000	3300	4548	2526
Pakuranga Creek (Greenmount Dr)	5	230	7900	3300	3566	1355
Pakuranga Creek (Guy's Rd)	5	22	4600	230	1256	867
Papakura Stream	12	2300	350000	12000	39850	28295
Puhinui Stream	12	230	11000	1250	3258	1044
Rangitopuni River	12	130	5000	405	923	393
Vaughan Stream	12	70	79000	3000	9815	6346
Wairoa River	12	300	13000	1750	2842	1038
Waiwera River	12	220	7900	1250	1960	624
West Hoe Stream	12	2	1100	23	180	95

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

Site	Count	Minimum	Maximum	Median	Mean	Standard error
Cascades Stream	11	10	510	36	123	46
Hoteo River	12	50	1600	175	384	131
Kumeu River	11	200	6600	510	1665	683
Lucas Creek	12	50	7500	715	1674	682
Mahurangi River (Forestry HQ)	12	27	12900	205	1269	1058
Mahurangi River (Town Bridge)	12	5	920	270	299	68
Mahurangi River (Water Supply)	12	5	470	205	225	40
Matakana River	12	90	5000	275	848	415
Ngakaroa Stream	12	36	6500	535	1467	552
Oakley Creek	12	280	7600	1955	2614	630
Okura Creek	12	5	8900	545	1644	707
Omaru Creek	12	700	6400	4300	3585	556
Opanuku Stream	12	50	3800	1050	1543	371
Otaki Creek	12	650	360000	4300	33322	29705
Otara Creek (East Tamaki)	12	500	510000	22000	78597	42258
Otara Creek (Kennell Hill)	12	14	8300	1730	2424	671
Oteha Stream	12	50	9300	345	1722	785
Pakuranga Creek (Botany Rd)	12	164	13100	2050	3633	1261
Pakuranga Creek (Greenmount Dr)	12	220	2500	670	950	215
Pakuranga Creek (Guy's Rd)	12	27	2400	370	756	252
Papakura Stream	12	1010	105000	4650	15359	8442
Puhinui Stream	12	450	3500	695	1355	349
Rangitopuni River	12	40	5900	410	886	466
Vaughan Stream	12	240	21000	2050	3946	1647
Wairoa River	12	260	6100	885	1458	496
Waiwera River	12	240	5800	675	1540	522
West Hoe Stream	12	5	900	62	159	73

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 27 sites (Table 27).

The Cascades Stream had the best water quality in 2007, with the Cascades Stream and West Hoe Stream the only sites classified as having excellent water quality.

Table 27

Site based water quality indices and classes based on 2007 data.

Rank	Site	Scope	Frequency	Magnitude	Water quality index	Water quality class
1	Cascades Stream	0.0	0.0	0.0	100.0	Excellent
2	West Hoe Stream	14.3	1.2	0.8	91.7	Excellent
3	Matakana River	28.6	6.0	0.8	83.1	Good
4	Opanuku Stream	42.9	3.6	0.5	75.2	Good
5	Mahurangi River (Water Supply)	42.9	4.8	1.3	75.1	Good
6	Waiwera River	42.9	8.4	1.5	74.8	Good
7	Mahurangi River (Town Bridge)	42.9	8.3	2.8	74.7	Good
8	Hoteo River	42.9	9.6	1.9	74.6	Good
9	Mahurangi River (Forestry HQ)	57.1	4.8	2.7	66.9	Fair
10	Oteha Stream	57.1	15.0	8.3	65.6	Fair
11	Kumeu River	57.1	18.4	12.7	64.6	Fair
12	Oakley Creek	57.1	19.0	12.8	64.4	Fair
13	Okura Creek	57.1	19.0	16.1	64.0	Fair
14	Pakuranga Creek (Botany Rd)	57.1	25.0	8.3	63.7	Fair
15	Pakuranga Creek (Greenmount Dr)	57.1	25.0	8.7	63.6	Fair
16	Puhinui Stream	57.1	26.2	11.3	63.1	Fair
17	Otara Creek (East Tamaki)	57.1	26.2	22.6	61.4	Fair
18	Ngakaroa Stream	57.1	19.0	29.1	61.4	Fair
19	Wairoa River	71.4	17.9	8.0	57.2	Fair
20	Rangitopuni River	71.4	20.5	6.9	56.9	Fair
21	Lucas Creek	71.4	22.9	13.0	56.0	Fair
22	Otara Creek (Kennel Hill)	85.7	22.6	7.1	48.7	Poor
23	Vaughan Stream	85.7	22.6	10.4	48.5	Poor
24	Pakuranga Creek (Guy's Rd)	85.7	20.2	18.8	48.0	Poor
25	Papakura Stream	85.7	26.2	15.7	47.5	Poor
26	Omaru Creek	85.7	36.9	23.3	44.5	Poor
27	Otaki Creek	71.4	36.9	55.1	43.7	Poor

The Otaki Creek had the worst water quality of the monitoring sites in 2007, with exceedances of the target levels common and often of high magnitudes.

Table 27 indicates that urban sites were typically ranked lower in 2007. 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 clearly had the best water quality indices in 2007, with urban sites the worst. Whilst sites with rural and exotic forest catchments typically had water quality indices intermediate between native forest and urban sites, they were also classified as having fair water quality.

Table 28

Mean 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 (2)	7.1	0.6	0.4	95.9	Excellent
Exotic forest (1)	57.1	4.8	2.7	66.9	Fair
Rural (13)	56.0	14.2	8.3	66.0	Fair
Urban (11)	67.5	25.1	17.2	56.6	Fair

5 Acknowledgements

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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 ARC 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;

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

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 ARC 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 ARC water quality data are tested (Table 29) are derived from the ranges observed at the two ARC reference sites (Cascades Stream and West Hoe Stream) over a five year period (2002 to 2006). 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 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.

Parameter	Objective
Dissolved oxygen (% saturation)	Between 60 and 120%
pH	Between 7 and 8.5
Turbidity	Less than 30 NTU
Ammoniacal nitrogen	Less than 0.1 g N m ⁻³
Temperature	Less than 20 °C
Total phosphorus	Less than 0.08 g P m ⁻³
Total nitrogen	Less than 0.8 g N m ⁻³

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