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**Regional** Council
TE RAUHĪTANGA TAIAO

State of the Environment Monitoring

# River Water Quality Annual Report 2008

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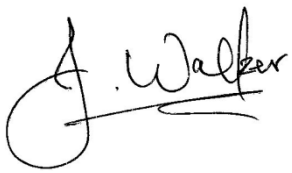

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# State of the Environment Monitoring: River Water Quality Annual Report 2008

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# Contents

# 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 and provides a summary of the data collected during the 2008 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.

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 2008 the best river water quality was in the West Hoe Stream in Rodney, closely followed by the Opanuku Stream in Waitakere. The worst water quality was observed in streams in and around the metropolitan urban area, of which sites on the Pakuranga Creek (at Greenmount Drive and Botany Road) were the lowest ranked in 2008.

# 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 2008 calendar year. Furthermore, the 2008 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 19th annual report since the inception of the monitoring programme, and the fourth 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 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).

There were no analytical or site changes in 2008.

## 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 2008 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 2008 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 | $^{o}C$ | 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 |
| Kjedhahl 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 |
| *Eschericia coli* | 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 2008 data was extracted and used to produce;

- Box plots which display the variation in the measured parameters at each of the sites. These were produce in the software package Sigmaplot using the default percentile functions. The boxes represent the inter-quartile range ($25^{th}$ to $75^{th}$ percentile) and the whiskers represent the $5^{th}$ and $95^{th}$ 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 a 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 2008 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 0.1ppt 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.
- Soluble lead
    - Soluble lead levels were typically very low in 2008 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 $\mu g\ l^{-1}$ 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 $\mu g\ l^{-1}$.

## 4.1 Box plots

**Figure 2**

Box plots showing the variation in dissolved oxygen % saturation (upper plot) and ppm (lower plot)) at the 27 sites using data collected during the 2008 calendar year.

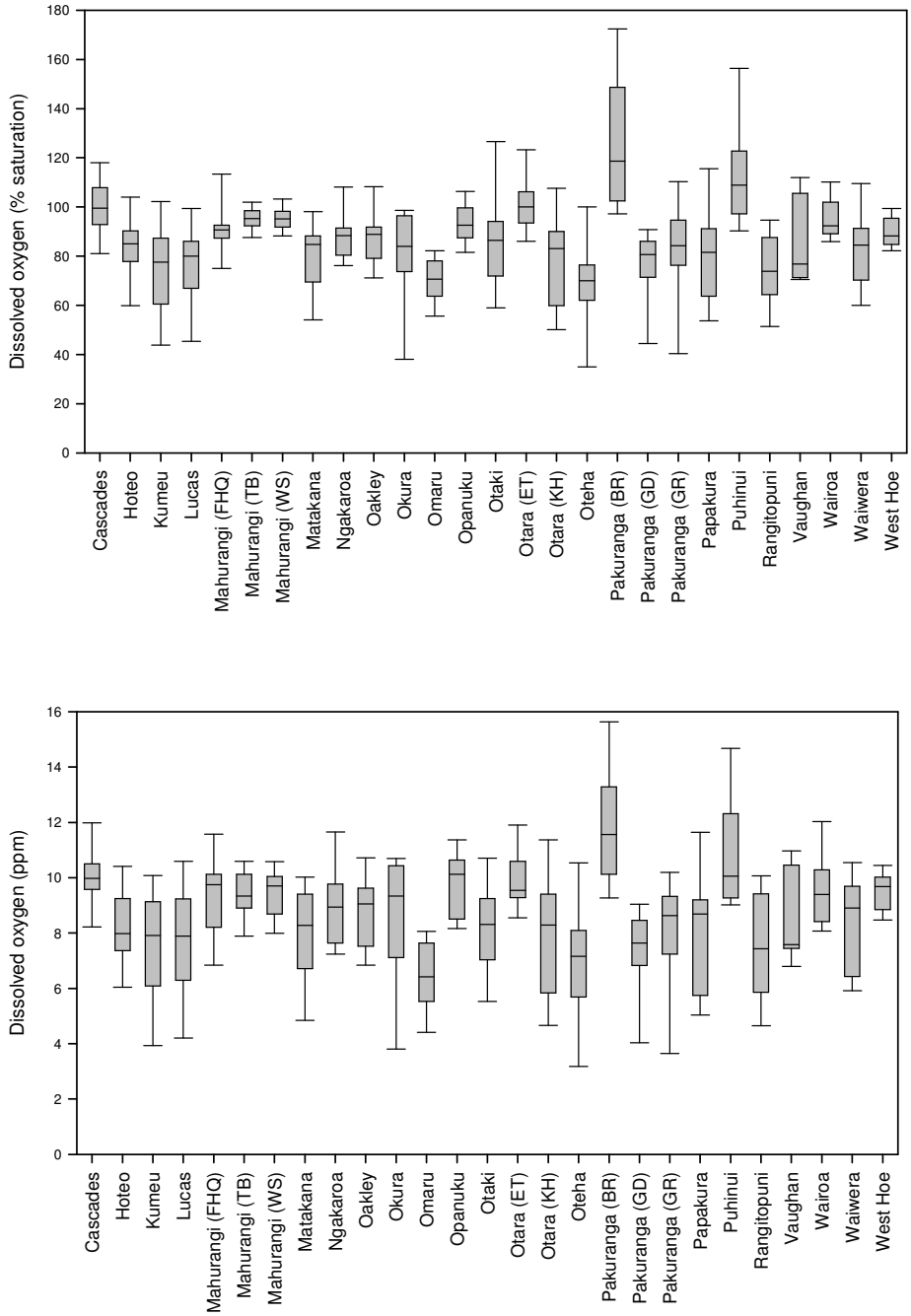


**Figure 3**

Box plots showing the variation in temperature (upper plot) and conductivity (lower plot) at the 27 sites using data collected during the 2008 calendar year. Note the axis break and scale change on the y-axis of the conductivity plot.

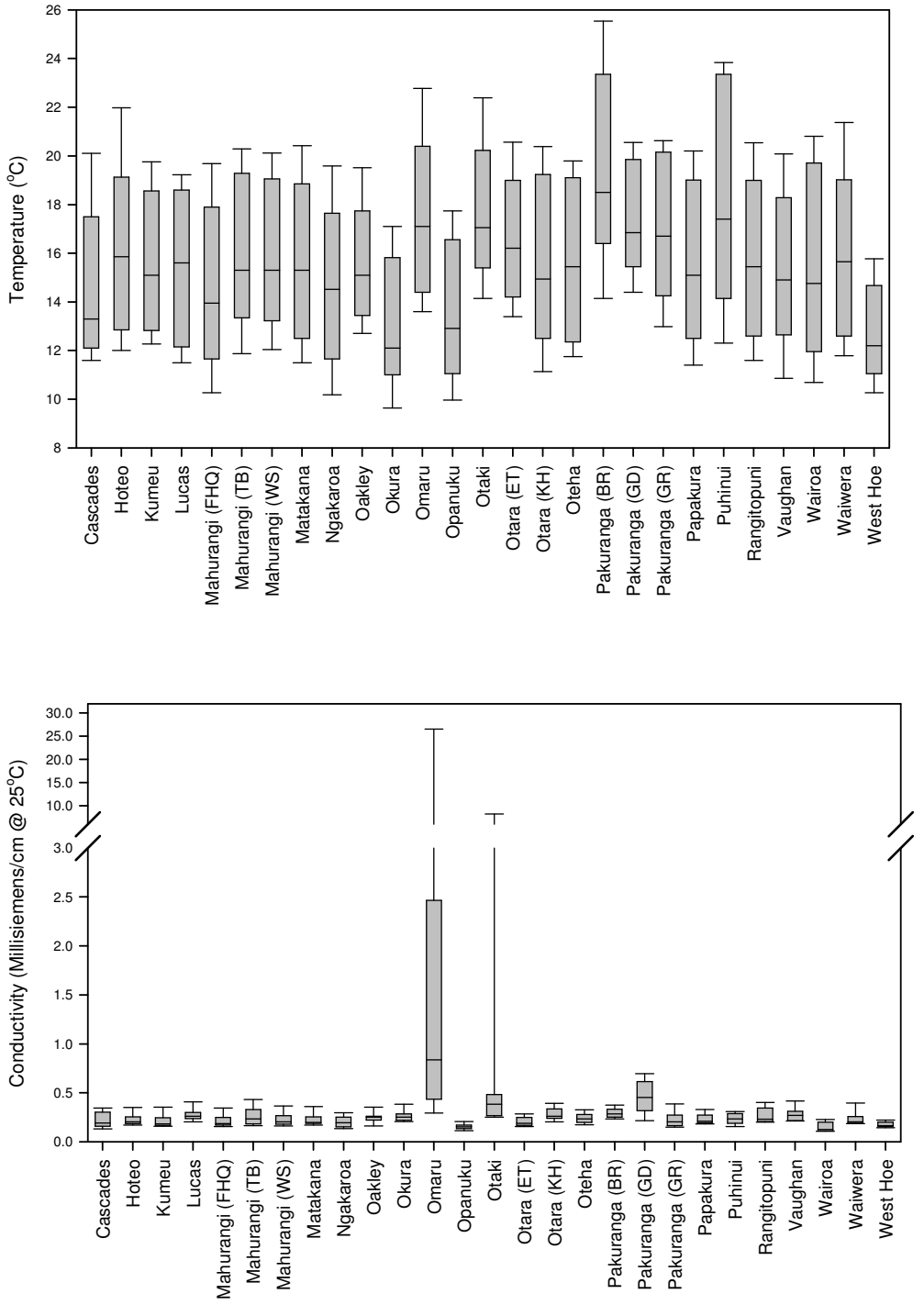


**Figure 4**

Box plots showing the variation in salinity (upper plot) and pH (lower plot) at the 27 sites using data collected during the 2008 calendar year. Note the axis break and scale change on the y-axis of the salinity plot.

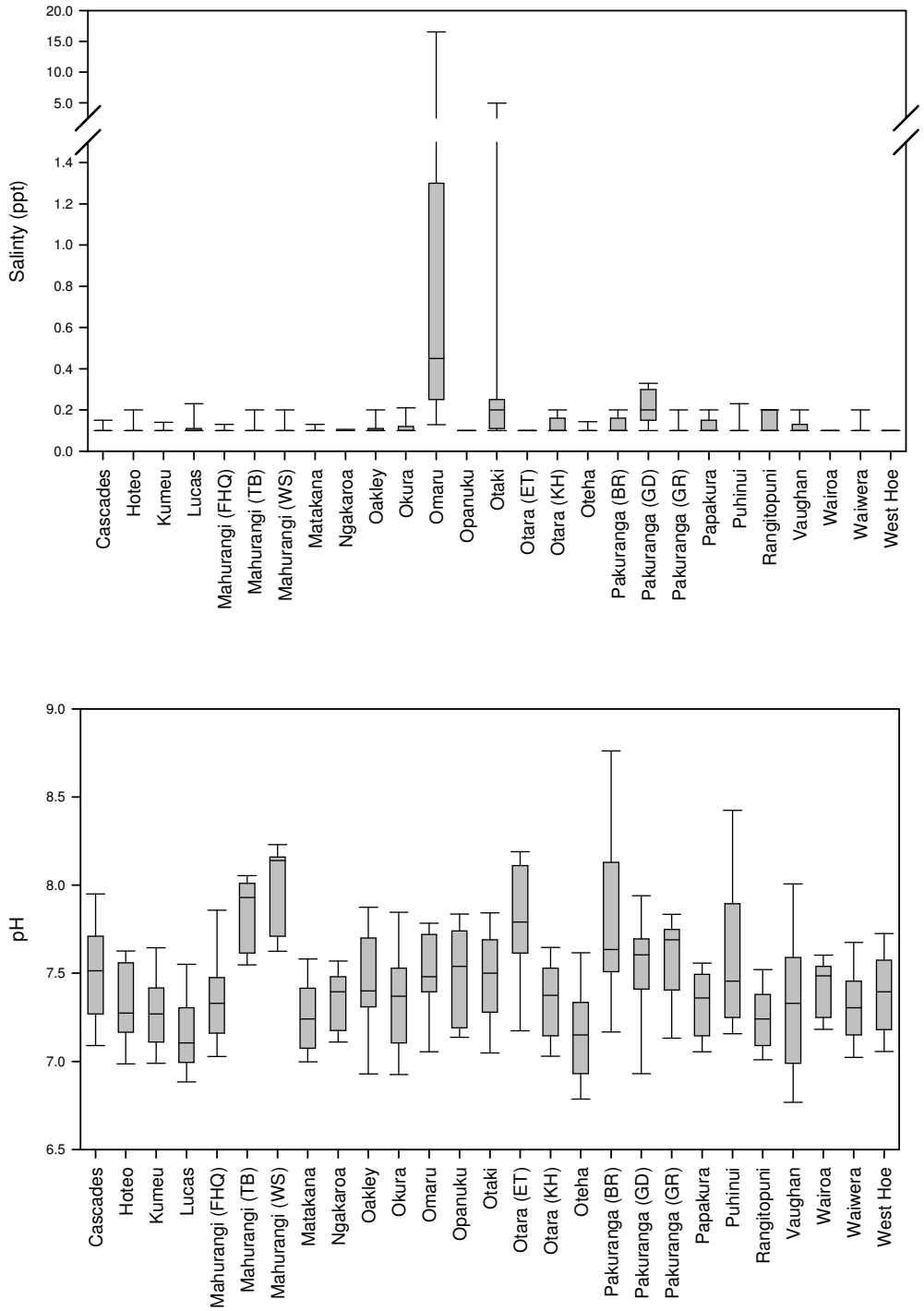


**Figure 5**

Box plots showing the variation in suspended sediment (upper plot) and turbidity (lower plot) at the 27 sites using data collected during the 2008 calendar year. Note the axis break and scale change on the y-axis of both plots.

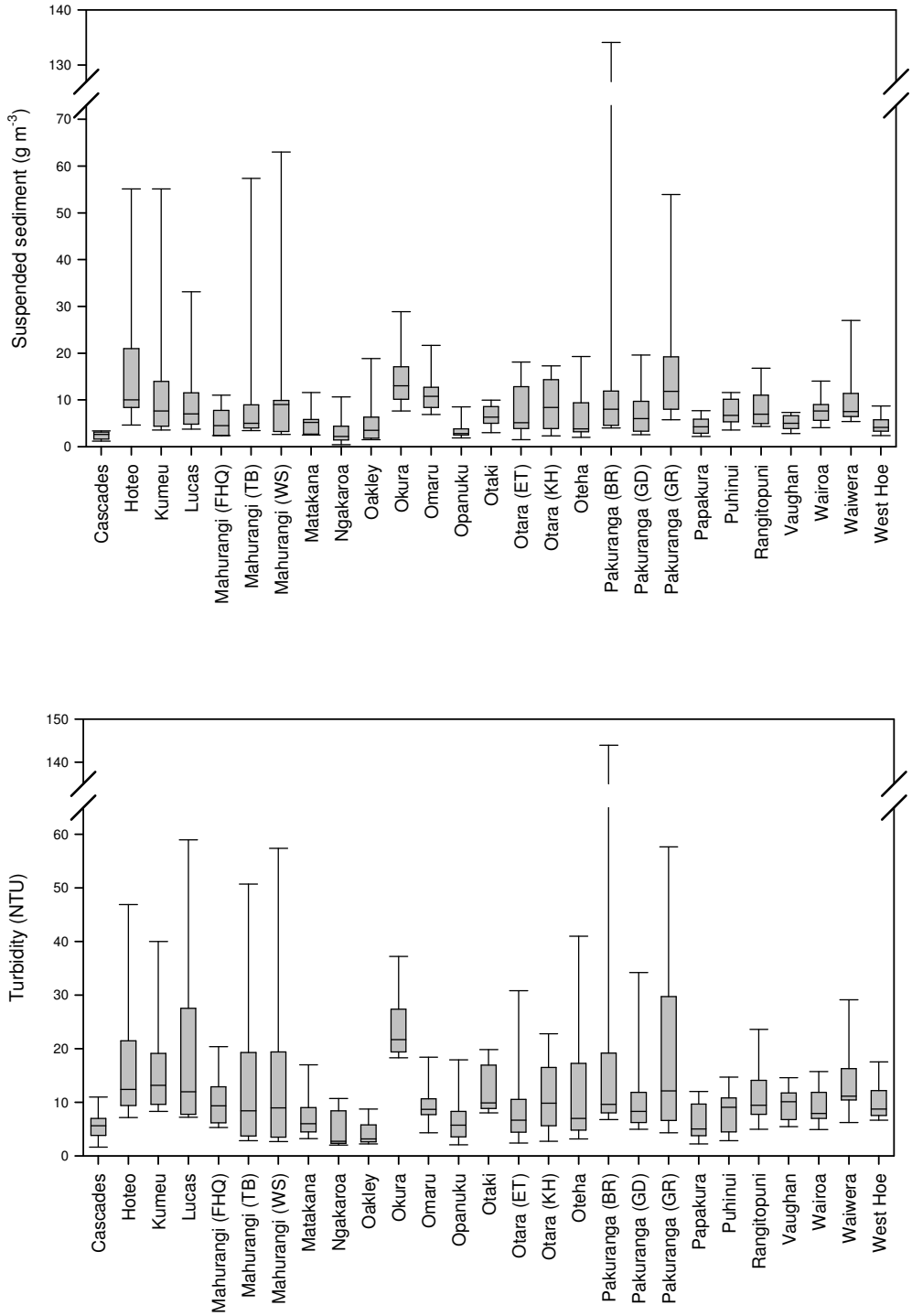


**Figure 6**

Box plots showing the variation in Ammoniacal nitrogen (upper plot) and total oxidised nitrogen (lower plot) at the 27 sites using data collected during the 2008 calendar year. Note the axis break and scale change on the y-axis of the ammoniacal nitrogen plot.

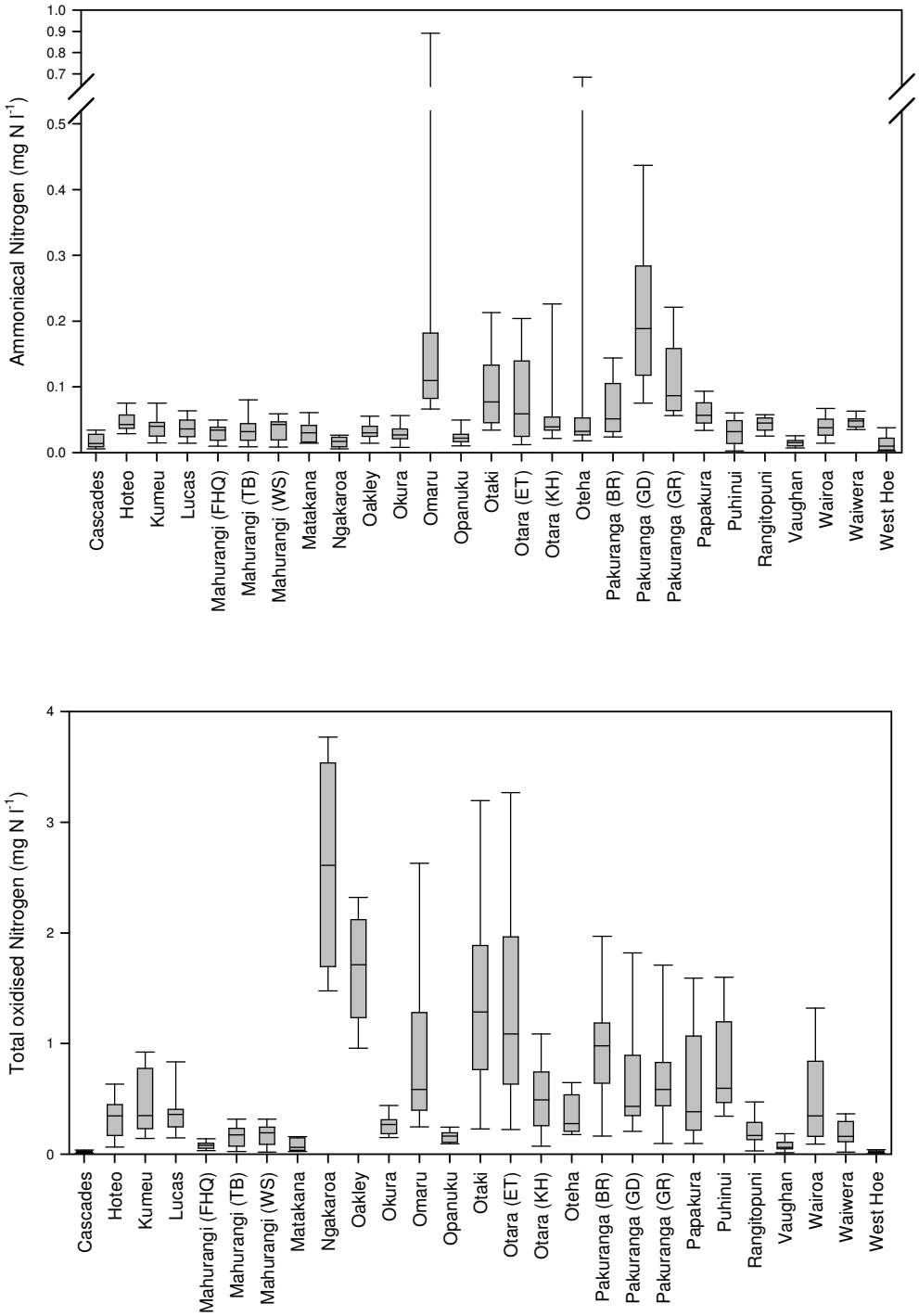


**Figure 7**

Box plots showing the variation in Kjeldhal nitrogen (upper plot) and total nitrogen (lower plot) at the 27 sites using data collected during the 2008 calendar year.

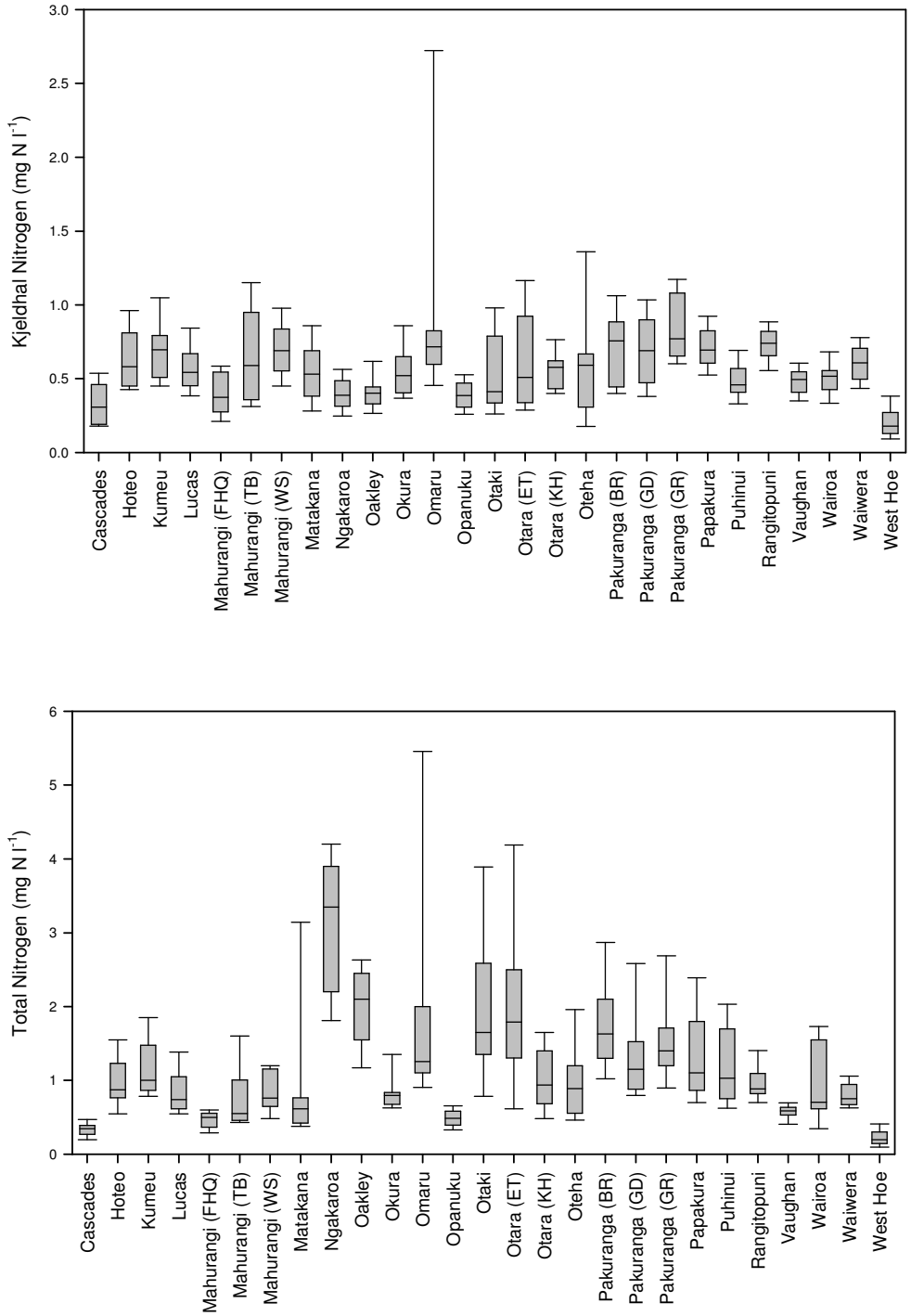


**Figure 8**

Box plots showing the variation in soluble reactive phosphorus (upper plot) and total phosphorus (lower plot) at the 27 sites using data collected during the 2008 calendar year. Note the axis break and scale change on the y-axis of the soluble reactive phosphorus plot.

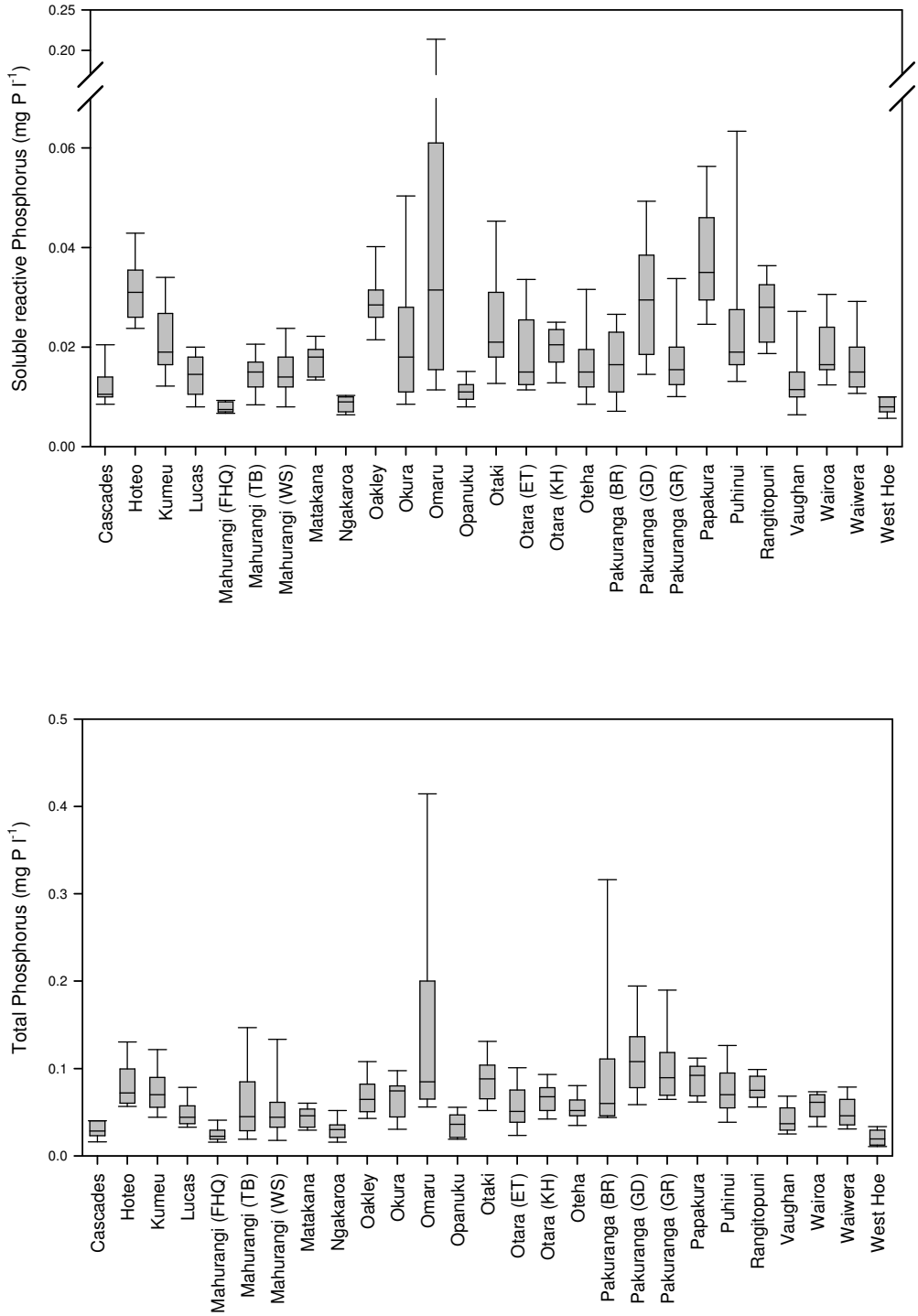


**Figure 9**

Box plots showing the variation in soluble copper (upper plot) and total copper (lower plot) at the 13 sites where it is monitored, using data collected during the 2008 calendar year.

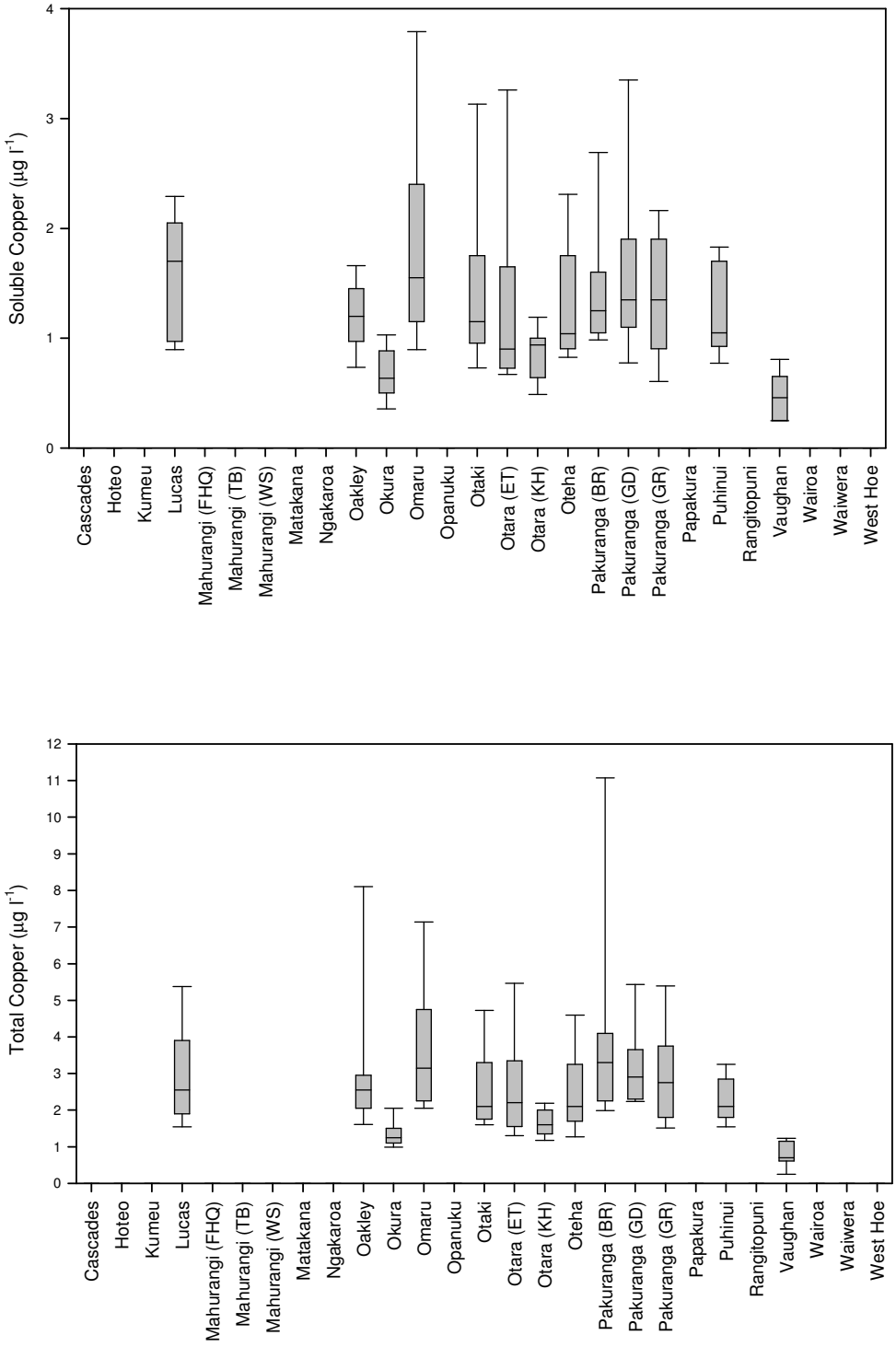


**Figure 10**

Box plots showing the variation in soluble zinc (upper plot) and total zinc (lower plot) at the 13 sites where it is monitored, using data collected during the 2008 calendar year.

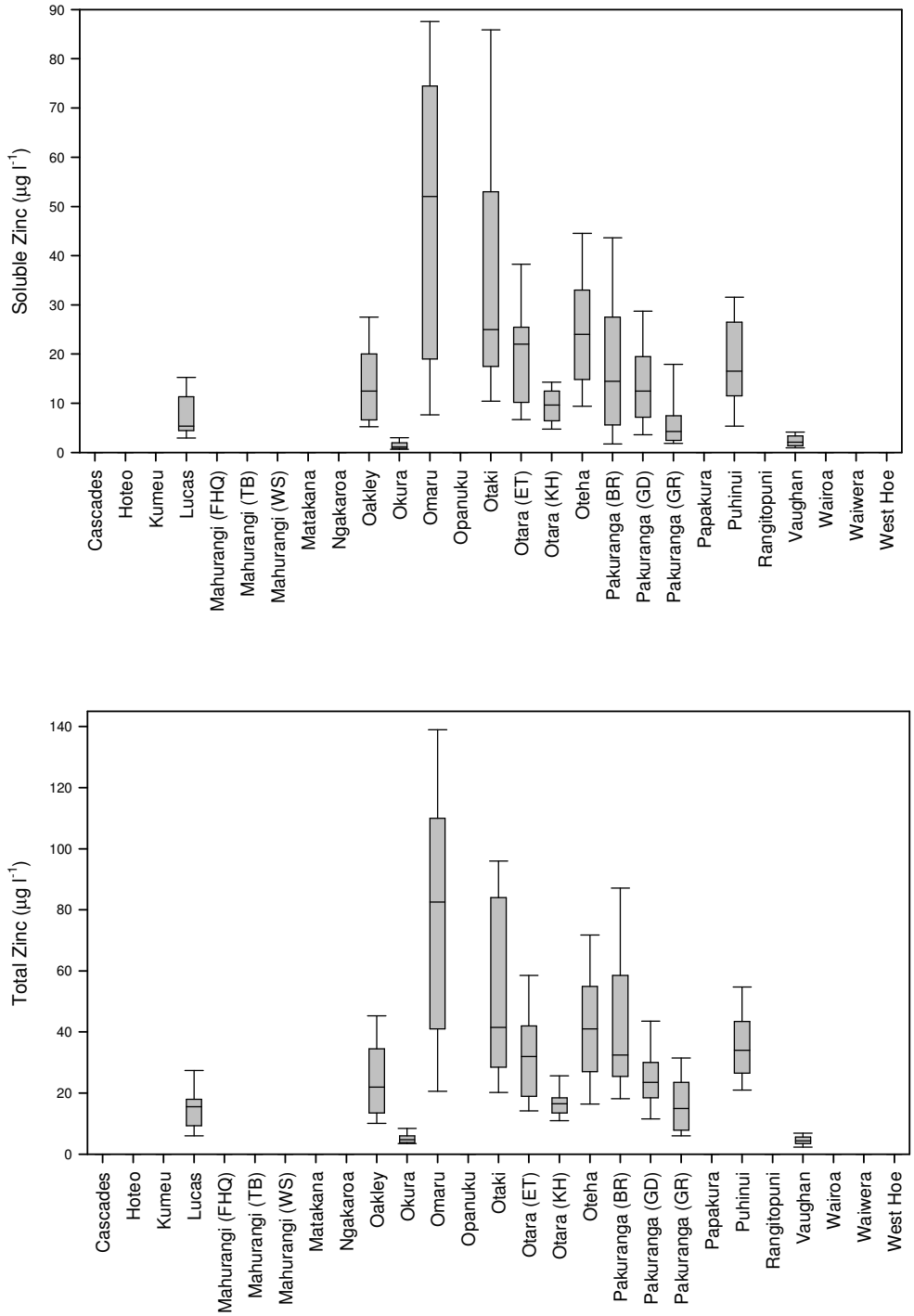


**Figure 11**

Box plots showing the variation in soluble lead (upper plot) and total lead (lower plot) at the 13 sites where it is monitored, using data collected during the 2008 calendar year.

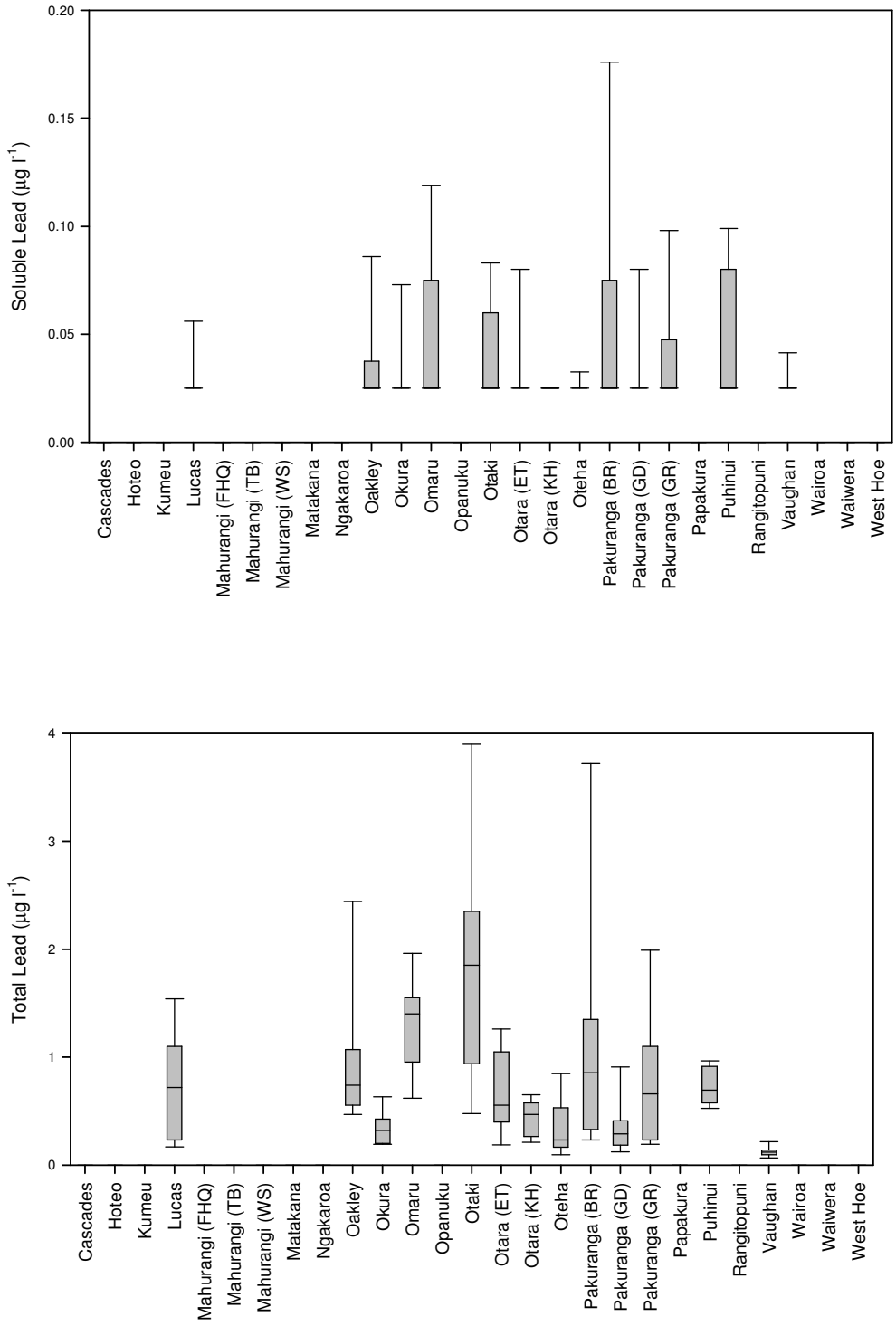


**Figure 12**

Box plots showing the variation in faecal coliforms at the 27 sites using data collected during the 2008 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.

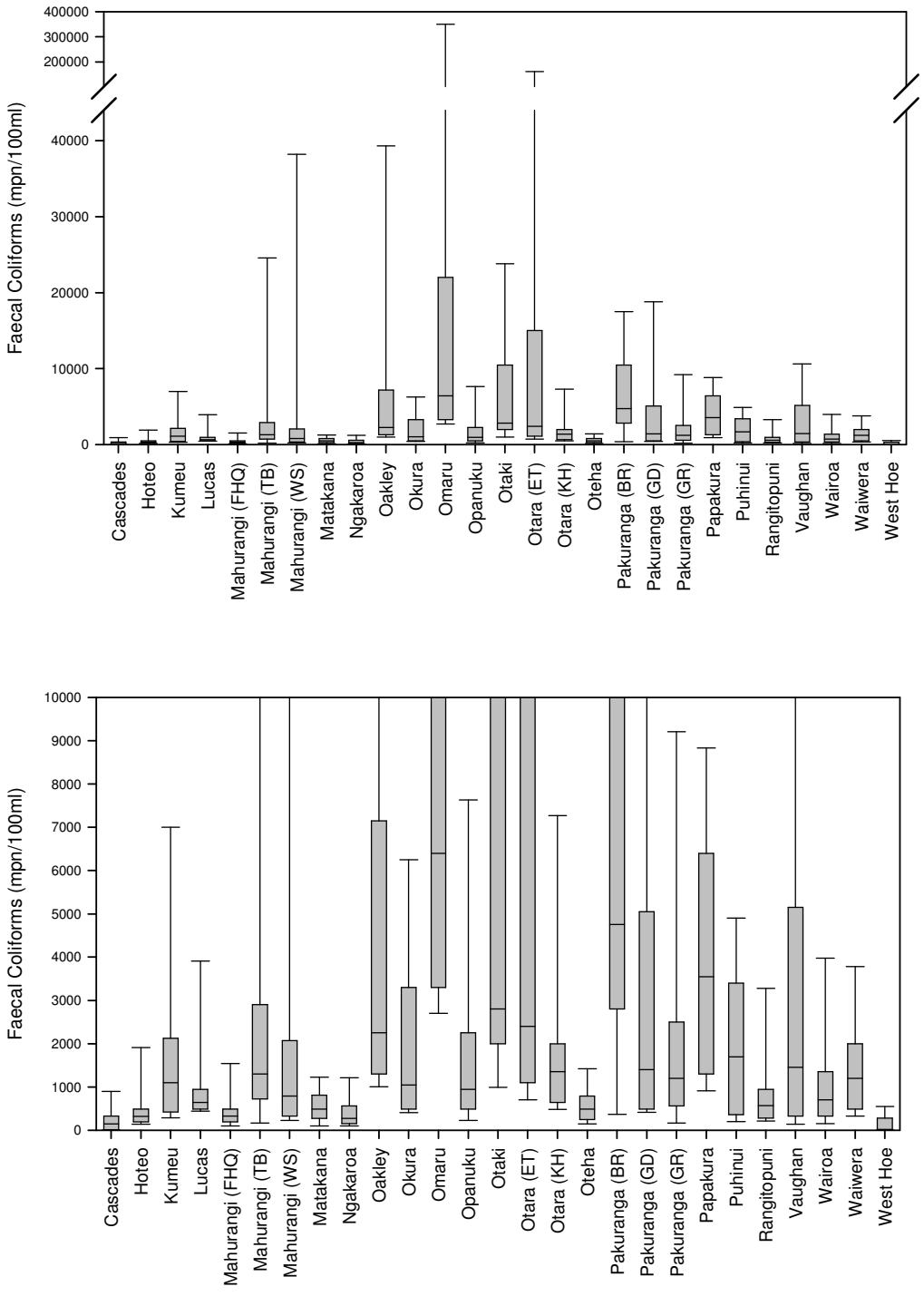
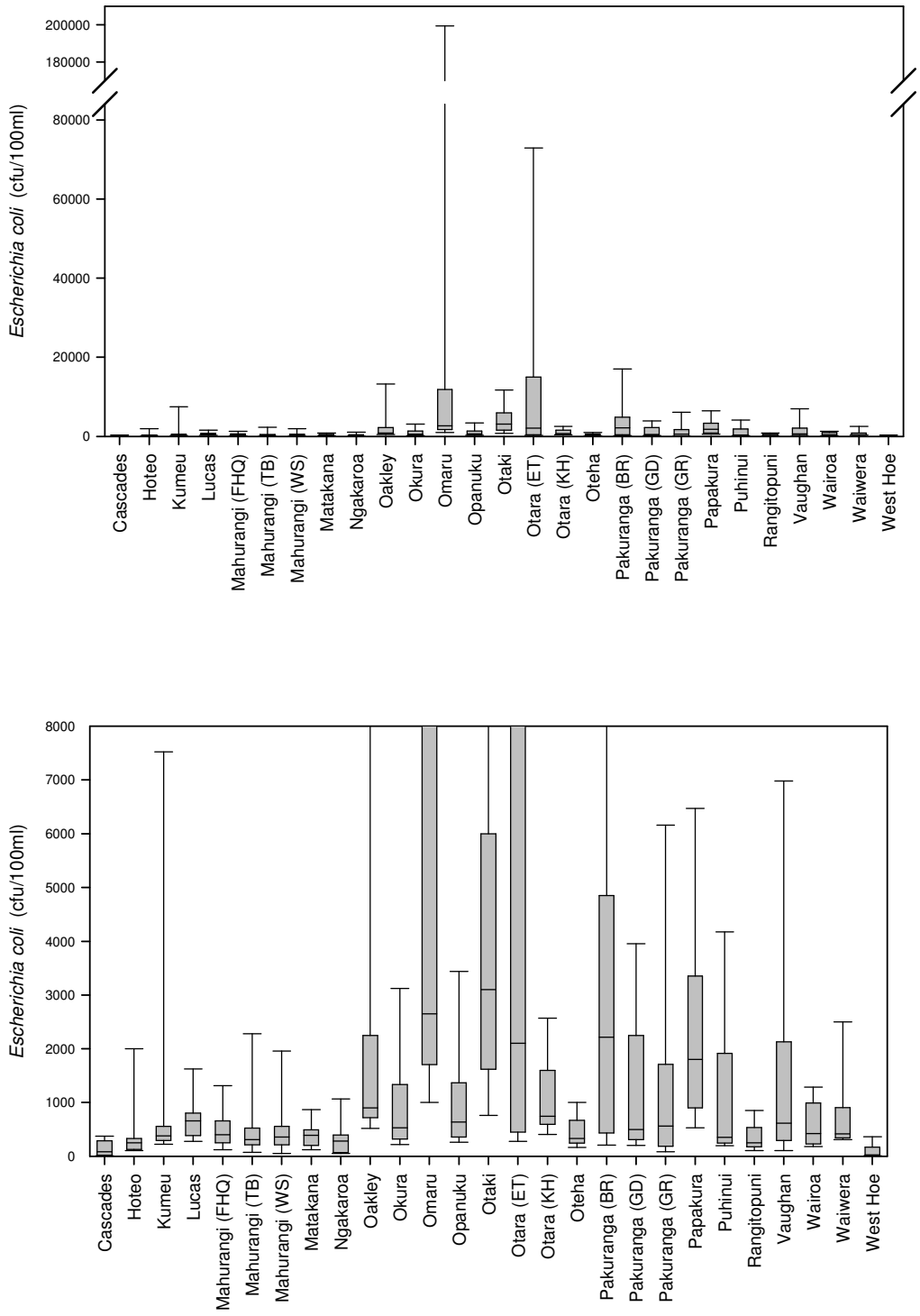


**Figure 13**

Box plots showing the variation in *Escherichia coli* at the 27 sites using data collected during the 2008 calendar year. The upper plot has y-axis which covers the full range of the data; the lower plot y-axis is limited to 8000 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 | 10 | 74.2 | 126.0 | 99.5 | 99.5 | 4.4 |
| Hoteo River | 12 | 58.3 | 113.9 | 85.0 | 84.0 | 4.4 |
| Kumeu River | 11 | 24.9 | 109.1 | 77.6 | 74.2 | 6.9 |
| Lucas Creek | 12 | 25.6 | 124.0 | 80.1 | 76.0 | 6.8 |
| Mahurangi River (Forestry HQ) | 12 | 64.8 | 136.0 | 90.8 | 92.1 | 4.8 |
| Mahurangi River (Town Bridge) | 10 | 83.4 | 104.9 | 95.3 | 95.2 | 1.8 |
| Mahurangi River (Water Supply) | 10 | 85.5 | 105.3 | 95.2 | 95.5 | 1.8 |
| Matakana River | 12 | 48.8 | 109.5 | 84.8 | 79.9 | 4.9 |
| Ngakaroa Stream | 12 | 76.0 | 143.2 | 88.4 | 90.1 | 5.1 |
| Oakley Creek | 12 | 68.2 | 126.4 | 88.9 | 88.4 | 4.3 |
| Okura Creek | 11 | 30.5 | 98.9 | 84.0 | 79.4 | 6.9 |
| Omaru Creek | 12 | 41.1 | 83.1 | 70.6 | 69.4 | 3.3 |
| Opanuku Stream | 12 | 80.1 | 108.4 | 92.6 | 93.5 | 2.6 |
| Otaki Creek | 12 | 38.0 | 149.0 | 86.4 | 87.3 | 7.9 |
| Otara Creek (East Tamaki) | 12 | 81.1 | 136.2 | 100.1 | 102.0 | 4.2 |
| Otara Creek (Kennell Hill) | 12 | 35.5 | 143.3 | 83.2 | 78.9 | 7.8 |
| Oteha Stream | 12 | 18.1 | 143.3 | 70.1 | 69.8 | 8.4 |
| Pakuranga Creek (Botany Rd) | 12 | 93.5 | 188.6 | 118.7 | 127.0 | 8.6 |
| Pakuranga Creek (Greenmount Dr) | 12 | 25.2 | 96.3 | 80.7 | 74.8 | 5.5 |
| Pakuranga Creek (Guy's Rd) | 12 | 32.6 | 112.1 | 84.3 | 81.4 | 6.8 |
| Papakura Stream | 12 | 47.0 | 156.1 | 81.5 | 82.9 | 8.1 |
| Puhinui Stream | 12 | 90.2 | 179.9 | 108.9 | 115.8 | 7.5 |
| Rangitopuni River | 12 | 34.4 | 109.7 | 73.8 | 74.6 | 5.5 |
| Vaughan Stream | 11 | 70.1 | 112.0 | 76.8 | 85.7 | 5.3 |
| Wairoa River | 12 | 80.8 | 127.2 | 92.3 | 96.2 | 3.4 |
| Waiwera River | 12 | 58.8 | 120.2 | 84.5 | 83.4 | 5.2 |
| West Hoe Stream | 11 | 81.1 | 99.8 | 88.3 | 89.6 | 2.0 |

**Table 6**

Dissolved oxygen (ppm)

| Site | Count | Minimum | Maximum | Median | Mean | Standard error |
|---|---|---|---|---|---|---|
| Cascades Stream | 10 | 6.9 | 13.2 | 10.0 | 10.0 | 0.5 |
| Hoteo River | 12 | 5.6 | 11.7 | 8.0 | 8.3 | 0.5 |
| Kumeu River | 11 | 2.2 | 11.1 | 7.9 | 7.4 | 0.7 |
| Lucas Creek | 12 | 2.4 | 12.9 | 7.9 | 7.7 | 0.8 |
| Mahurangi River (Forestry HQ) | 12 | 5.8 | 14.4 | 9.8 | 9.4 | 0.6 |
| Mahurangi River (Town Bridge) | 10 | 7.4 | 10.7 | 9.3 | 9.4 | 0.3 |
| Mahurangi River (Water Supply) | 10 | 7.7 | 10.6 | 9.7 | 9.4 | 0.3 |
| Matakana River | 12 | 4.3 | 11.1 | 8.3 | 7.9 | 0.6 |
| Ngakaroa Stream | 12 | 6.9 | 14.8 | 8.9 | 9.2 | 0.6 |
| Oakley Creek | 12 | 6.7 | 13.0 | 9.1 | 8.8 | 0.5 |
| Okura Creek | 11 | 3.1 | 10.8 | 9.3 | 8.4 | 0.8 |
| Omaru Creek | 12 | 3.6 | 8.3 | 6.4 | 6.4 | 0.4 |
| Opanuku Stream | 12 | 7.8 | 11.7 | 10.1 | 9.8 | 0.4 |
| Otaki Creek | 12 | 3.3 | 12.0 | 8.3 | 8.2 | 0.6 |
| Otara Creek (East Tamaki) | 12 | 7.2 | 13.8 | 9.5 | 9.9 | 0.5 |
| Otara Creek (Kennell Hill) | 12 | 3.3 | 15.1 | 8.3 | 8.0 | 0.9 |
| Oteha Stream | 12 | 1.7 | 14.9 | 7.2 | 7.1 | 0.9 |
| Pakuranga Creek (Botany Rd) | 12 | 8.8 | 15.8 | 11.6 | 11.8 | 0.7 |
| Pakuranga Creek (Greenmount Dr) | 12 | 2.3 | 9.2 | 7.6 | 7.2 | 0.6 |
| Pakuranga Creek (Guy's Rd) | 12 | 2.9 | 10.7 | 8.6 | 7.9 | 0.7 |
| Papakura Stream | 12 | 4.5 | 16.4 | 8.7 | 8.4 | 0.9 |
| Puhinui Stream | 12 | 9.0 | 15.4 | 10.1 | 10.9 | 0.6 |
| Rangitopuni River | 12 | 3.1 | 11.4 | 7.4 | 7.5 | 0.7 |
| Vaughan Stream | 11 | 6.6 | 11.1 | 7.6 | 8.6 | 0.5 |
| Wairoa River | 12 | 8.0 | 13.4 | 9.4 | 9.7 | 0.5 |
| Waiwera River | 12 | 5.2 | 12.2 | 8.9 | 8.3 | 0.6 |
| West Hoe Stream | 11 | 8.1 | 11.0 | 9.7 | 9.5 | 0.2 |

**Table 7**

Temperature (°C)

| Site | Count | Minimum | Maximum | Median | Mean | Standard error |
|---|---|---|---|---|---|---|
| Cascades Stream | 10 | 11.4 | 21.2 | 13.3 | 14.9 | 1.10 |
| Hoteo River | 12 | 11.3 | 22.4 | 15.9 | 16.3 | 1.11 |
| Kumeu River | 11 | 12.1 | 20.6 | 15.1 | 15.7 | 0.93 |
| Lucas Creek | 12 | 10.8 | 19.3 | 15.6 | 15.4 | 0.93 |
| Mahurangi River (Forestry HQ) | 12 | 10.2 | 20.1 | 14.0 | 14.7 | 1.04 |
| Mahurangi River (Town Bridge) | 11 | 11.4 | 21.3 | 15.3 | 16.2 | 1.01 |
| Mahurangi River (Water Supply) | 11 | 11.5 | 20.6 | 15.3 | 16.0 | 0.96 |
| Matakana River | 12 | 10.8 | 20.7 | 15.3 | 15.8 | 1.02 |
| Ngakaroa Stream | 12 | 9.2 | 19.8 | 14.5 | 14.8 | 1.05 |
| Oakley Creek | 12 | 12.5 | 20.5 | 15.1 | 15.7 | 0.78 |
| Okura Creek | 11 | 8.5 | 18.3 | 12.1 | 13.3 | 0.91 |
| Omaru Creek | 12 | 12.9 | 23.9 | 17.1 | 17.7 | 1.06 |
| Opanuku Stream | 12 | 8.7 | 19.0 | 12.9 | 13.6 | 0.96 |
| Otaki Creek | 12 | 13.3 | 22.6 | 17.1 | 17.7 | 0.89 |
| Otara Creek (East Tamaki) | 12 | 12.7 | 21.2 | 16.2 | 16.7 | 0.82 |
| Otara Creek (Kennell Hill) | 12 | 9.8 | 21.3 | 14.9 | 15.6 | 1.13 |
| Oteha Stream | 12 | 11.4 | 20.0 | 15.5 | 15.6 | 0.96 |
| Pakuranga Creek (Botany Rd) | 12 | 14.0 | 26.8 | 18.5 | 19.7 | 1.24 |
| Pakuranga Creek (Greenmount Dr) | 12 | 13.7 | 20.9 | 16.9 | 17.4 | 0.71 |
| Pakuranga Creek (Guy's Rd) | 12 | 12.7 | 20.9 | 16.7 | 17.1 | 0.89 |
| Papakura Stream | 12 | 10.0 | 20.9 | 15.1 | 15.6 | 1.06 |
| Puhinui Stream | 12 | 11.6 | 24.0 | 17.4 | 18.2 | 1.38 |
| Rangitopuni River | 12 | 11.6 | 22.5 | 15.5 | 15.9 | 1.06 |
| Vaughan Stream | 11 | 9.0 | 21.7 | 14.9 | 15.5 | 1.11 |
| Wairoa River | 12 | 10.2 | 21.3 | 14.8 | 15.6 | 1.19 |
| Waiwera River | 12 | 11.3 | 23.4 | 15.7 | 16.2 | 1.12 |
| West Hoe Stream | 11 | 9.3 | 17.2 | 12.2 | 12.8 | 0.70 |

**Table 8**

Conductivity (Millisiemens/cm @ 25°C)

| Site | Count | Minimum | Maximum | Median | Mean | Standard error |
|---|---|---|---|---|---|---|
| Cascades Stream | 10 | 0.12 | 0.38 | 0.19 | 0.22 | 0.03 |
| Hoteo River | 12 | 0.16 | 0.44 | 0.20 | 0.23 | 0.02 |
| Kumeu River | 11 | 0.15 | 0.38 | 0.18 | 0.22 | 0.02 |
| Lucas Creek | 12 | 0.19 | 0.61 | 0.26 | 0.29 | 0.03 |
| Mahurangi River (Forestry HQ) | 12 | 0.14 | 0.46 | 0.18 | 0.22 | 0.03 |
| Mahurangi River (Town Bridge) | 11 | 0.16 | 0.46 | 0.23 | 0.27 | 0.03 |
| Mahurangi River (Water Supply) | 11 | 0.16 | 0.43 | 0.20 | 0.24 | 0.02 |
| Matakana River | 12 | 0.16 | 0.48 | 0.20 | 0.24 | 0.03 |
| Ngakaroa Stream | 12 | 0.12 | 0.30 | 0.19 | 0.20 | 0.02 |
| Oakley Creek | 12 | 0.16 | 0.37 | 0.25 | 0.25 | 0.02 |
| Okura Creek | 11 | 0.20 | 0.52 | 0.25 | 0.27 | 0.03 |
| Omaru Creek | 12 | 0.29 | 37.97 | 0.84 | 5.78 | 3.40 |
| Opanuku Stream | 12 | 0.10 | 0.22 | 0.15 | 0.16 | 0.01 |
| Otaki Creek | 12 | 0.23 | 25.05 | 0.38 | 2.45 | 2.06 |
| Otara Creek (East Tamaki) | 12 | 0.15 | 0.29 | 0.19 | 0.21 | 0.01 |
| Otara Creek (Kennell Hill) | 12 | 0.18 | 0.44 | 0.26 | 0.28 | 0.02 |
| Oteha Stream | 12 | 0.16 | 0.34 | 0.23 | 0.24 | 0.02 |
| Pakuranga Creek (Botany Rd) | 12 | 0.21 | 0.39 | 0.28 | 0.29 | 0.02 |
| Pakuranga Creek (Greenmount Dr) | 12 | 0.21 | 0.73 | 0.45 | 0.46 | 0.05 |
| Pakuranga Creek (Guy's Rd) | 12 | 0.14 | 0.44 | 0.20 | 0.23 | 0.03 |
| Papakura Stream | 12 | 0.18 | 0.33 | 0.21 | 0.23 | 0.02 |
| Puhinui Stream | 12 | 0.15 | 0.33 | 0.23 | 0.24 | 0.02 |
| Rangitopuni River | 12 | 0.20 | 0.42 | 0.23 | 0.27 | 0.02 |
| Vaughan Stream | 11 | 0.21 | 0.50 | 0.27 | 0.28 | 0.03 |
| Wairoa River | 12 | 0.10 | 0.25 | 0.13 | 0.15 | 0.01 |
| Waiwera River | 12 | 0.18 | 0.43 | 0.20 | 0.24 | 0.02 |
| West Hoe Stream | 10 | 0.13 | 0.22 | 0.16 | 0.18 | 0.01 |

**Table 9**

Salinty (ppt)

| Site | Count | Minimum | Maximum | Median | Mean | Standard error |
|---|---|---|---|---|---|---|
| Cascades Stream | 10 | 0.1 | 0.2 | 0.1 | 0.1 | 0.01 |
| Hoteo River | 12 | 0.1 | 0.2 | 0.1 | 0.1 | 0.01 |
| Kumeu River | 11 | 0.1 | 0.2 | 0.1 | 0.1 | 0.01 |
| Lucas Creek | 12 | 0.1 | 0.3 | 0.1 | 0.1 | 0.02 |
| Mahurangi River (Forestry HQ) | 12 | 0.1 | 0.2 | 0.1 | 0.1 | 0.01 |
| Mahurangi River (Town Bridge) | 11 | 0.1 | 0.2 | 0.1 | 0.1 | 0.01 |
| Mahurangi River (Water Supply) | 11 | 0.1 | 0.2 | 0.1 | 0.1 | 0.01 |
| Matakana River | 12 | 0.1 | 0.2 | 0.1 | 0.1 | 0.01 |
| Ngakaroa Stream | 12 | 0.1 | 0.1 | 0.1 | 0.1 | 0.00 |
| Oakley Creek | 12 | 0.1 | 0.2 | 0.1 | 0.1 | 0.01 |
| Okura Creek | 10 | 0.1 | 0.3 | 0.1 | 0.1 | 0.02 |
| Omaru Creek | 12 | 0.1 | 24.8 | 0.5 | 3.6 | 2.20 |
| Opanuku Stream | 12 | 0.1 | 0.1 | 0.1 | 0.1 | 0.00 |
| Otaki Creek | 12 | 0.1 | 15.3 | 0.2 | 1.5 | 1.26 |
| Otara Creek (East Tamaki) | 12 | 0.1 | 0.1 | 0.1 | 0.1 | 0.00 |
| Otara Creek (Kennell Hill) | 12 | 0.1 | 0.2 | 0.1 | 0.1 | 0.01 |
| Oteha Stream | 12 | 0.1 | 0.2 | 0.1 | 0.1 | 0.01 |
| Pakuranga Creek (Botany Rd) | 12 | 0.1 | 0.2 | 0.1 | 0.1 | 0.01 |
| Pakuranga Creek (Greenmount Dr) | 12 | 0.1 | 0.4 | 0.2 | 0.2 | 0.03 |
| Pakuranga Creek (Guy's Rd) | 12 | 0.1 | 0.2 | 0.1 | 0.1 | 0.01 |
| Papakura Stream | 12 | 0.1 | 0.2 | 0.1 | 0.1 | 0.01 |
| Puhinui Stream | 12 | 0.1 | 0.3 | 0.1 | 0.1 | 0.02 |
| Rangitopuni River | 12 | 0.1 | 0.2 | 0.1 | 0.1 | 0.01 |
| Vaughan Stream | 10 | 0.1 | 0.2 | 0.1 | 0.1 | 0.01 |
| Wairoa River | 12 | 0.1 | 0.1 | 0.1 | 0.1 | 0.01 |
| Waiwera River | 12 | 0.1 | 0.2 | 0.1 | 0.1 | 0.01 |
| West Hoe Stream | 10 | 0.1 | 0.1 | 0.1 | 0.1 | 0.00 |

**Table 10**

pH (pH units)

| Site | Count | Minimum | Maximum | Median | Mean | Standard error |
|---|---|---|---|---|---|---|
| Cascades Stream | 10 | 7.1 | 8.1 | 7.5 | 7.5 | 0.10 |
| Hoteo River | 12 | 6.9 | 7.7 | 7.3 | 7.3 | 0.07 |
| Kumeu River | 11 | 7.0 | 7.7 | 7.3 | 7.3 | 0.07 |
| Lucas Creek | 12 | 6.9 | 7.9 | 7.1 | 7.2 | 0.08 |
| Mahurangi River (Forestry HQ) | 12 | 6.9 | 7.9 | 7.3 | 7.4 | 0.08 |
| Mahurangi River (Town Bridge) | 11 | 7.5 | 8.1 | 7.9 | 7.8 | 0.06 |
| Mahurangi River (Water Supply) | 11 | 7.6 | 8.3 | 8.1 | 8.0 | 0.08 |
| Matakana River | 12 | 6.9 | 7.8 | 7.2 | 7.3 | 0.07 |
| Ngakaroa Stream | 12 | 7.1 | 7.6 | 7.4 | 7.4 | 0.05 |
| Oakley Creek | 12 | 6.9 | 8.0 | 7.4 | 7.5 | 0.10 |
| Okura Creek | 12 | 6.8 | 7.9 | 7.4 | 7.4 | 0.09 |
| Omaru Creek | 12 | 6.8 | 7.8 | 7.5 | 7.5 | 0.08 |
| Opanuku Stream | 12 | 7.1 | 7.9 | 7.5 | 7.5 | 0.08 |
| Otaki Creek | 12 | 6.9 | 8.1 | 7.5 | 7.5 | 0.09 |
| Otara Creek (East Tamaki) | 12 | 6.4 | 8.2 | 7.8 | 7.7 | 0.14 |
| Otara Creek (Kennell Hill) | 12 | 7.0 | 7.7 | 7.4 | 7.3 | 0.07 |
| Oteha Stream | 12 | 6.7 | 8.0 | 7.2 | 7.2 | 0.10 |
| Pakuranga Creek (Botany Rd) | 12 | 6.8 | 9.3 | 7.6 | 7.8 | 0.19 |
| Pakuranga Creek (Greenmount Dr) | 12 | 6.6 | 8.2 | 7.6 | 7.5 | 0.11 |
| Pakuranga Creek (Guy's Rd) | 12 | 6.7 | 7.9 | 7.7 | 7.6 | 0.09 |
| Papakura Stream | 12 | 7.0 | 7.6 | 7.4 | 7.3 | 0.06 |
| Puhinui Stream | 12 | 7.1 | 9.0 | 7.5 | 7.6 | 0.16 |
| Rangitopuni River | 12 | 7.0 | 7.6 | 7.2 | 7.3 | 0.06 |
| Vaughan Stream | 12 | 6.7 | 8.1 | 7.3 | 7.3 | 0.13 |
| Wairoa River | 12 | 7.1 | 7.6 | 7.5 | 7.4 | 0.05 |
| Waiwera River | 12 | 7.0 | 7.7 | 7.3 | 7.3 | 0.07 |
| West Hoe Stream | 12 | 7.0 | 7.8 | 7.4 | 7.4 | 0.07 |

**Table 11**

Suspended sediment (mg $l^{-1}$)

| Site | Count | Minimum | Maximum | Median | Mean | Standard error |
|---|---|---|---|---|---|---|
| Cascades Stream | 10 | 0.9 | 3.6 | 2.7 | 2.4 | 0.3 |
| Hoteo River | 12 | 3.6 | 60.0 | 10.0 | 18.8 | 5.4 |
| Kumeu River | 11 | 3.2 | 89.8 | 7.6 | 16.9 | 7.7 |
| Lucas Creek | 12 | 3.2 | 38.0 | 7.0 | 11.4 | 3.2 |
| Mahurangi River (Forestry HQ) | 12 | 2.2 | 14.0 | 4.5 | 5.6 | 1.1 |
| Mahurangi River (Town Bridge) | 11 | 3.0 | 94.0 | 5.0 | 16.0 | 8.2 |
| Mahurangi River (Water Supply) | 11 | 2.3 | 66.0 | 9.0 | 16.5 | 7.1 |
| Matakana River | 12 | 2.2 | 13.0 | 5.2 | 5.4 | 1.0 |
| Ngakaroa Stream | 12 | 0.4 | 17.8 | 2.2 | 3.9 | 1.4 |
| Oakley Creek | 12 | 1.2 | 35.8 | 3.5 | 6.7 | 2.8 |
| Okura Creek | 12 | 7.2 | 30.8 | 13.0 | 15.1 | 2.2 |
| Omaru Creek | 12 | 5.6 | 23.2 | 10.8 | 11.8 | 1.5 |
| Opanuku Stream | 12 | 1.0 | 18.0 | 2.8 | 4.1 | 1.3 |
| Otaki Creek | 12 | 2.8 | 11.2 | 6.4 | 6.6 | 0.7 |
| Otara Creek (East Tamaki) | 12 | 1.2 | 23.0 | 5.2 | 8.1 | 1.9 |
| Otara Creek (Kennell Hill) | 12 | 2.0 | 18.0 | 8.4 | 8.8 | 1.7 |
| Oteha Stream | 12 | 0.8 | 27.0 | 3.8 | 7.3 | 2.2 |
| Pakuranga Creek (Botany Rd) | 12 | 3.0 | 362.0 | 8.0 | 39.1 | 29.5 |
| Pakuranga Creek (Greenmount Dr) | 12 | 2.0 | 21.0 | 6.0 | 7.8 | 1.8 |
| Pakuranga Creek (Guy's Rd) | 12 | 2.8 | 117.0 | 11.8 | 21.5 | 8.9 |
| Papakura Stream | 12 | 1.6 | 8.0 | 4.3 | 4.5 | 0.6 |
| Puhinui Stream | 12 | 1.8 | 13.0 | 6.7 | 7.4 | 0.9 |
| Rangitopuni River | 12 | 3.6 | 21.0 | 7.0 | 8.7 | 1.5 |
| Vaughan Stream | 12 | 2.8 | 7.6 | 5.0 | 5.1 | 0.5 |
| Wairoa River | 12 | 3.8 | 18.8 | 7.7 | 8.2 | 1.2 |
| Waiwera River | 12 | 4.8 | 55.0 | 7.5 | 12.3 | 4.0 |
| West Hoe Stream | 12 | 1.6 | 13.2 | 4.2 | 4.9 | 0.9 |

**Table 12**

Turbidity (NTU)

| Site | Count | Minimum | Maximum | Median | Mean | Standard error |
|---|---|---|---|---|---|---|
| Cascades Stream | 10 | 1.4 | 13.1 | 5.6 | 5.9 | 1.1 |
| Hoteo River | 12 | 7.0 | 64.1 | 12.4 | 19.2 | 4.9 |
| Kumeu River | 11 | 7.4 | 49.3 | 13.2 | 17.6 | 3.9 |
| Lucas Creek | 12 | 6.6 | 63.7 | 12.0 | 21.3 | 5.7 |
| Mahurangi River (Forestry HQ) | 12 | 4.5 | 21.7 | 9.4 | 10.5 | 1.6 |
| Mahurangi River (Town Bridge) | 11 | 2.7 | 95.2 | 8.4 | 17.8 | 8.0 |
| Mahurangi River (Water Supply) | 11 | 2.2 | 75.1 | 9.0 | 18.4 | 6.8 |
| Matakana River | 12 | 3.0 | 23.1 | 6.0 | 8.0 | 1.7 |
| Ngakaroa Stream | 12 | 1.3 | 13.4 | 2.7 | 5.0 | 1.1 |
| Oakley Creek | 12 | 2.2 | 10.3 | 3.2 | 4.5 | 0.7 |
| Okura Creek | 12 | 17.0 | 38.2 | 21.7 | 24.5 | 2.0 |
| Omaru Creek | 12 | 3.2 | 24.3 | 8.7 | 10.0 | 1.6 |
| Opanuku Stream | 12 | 1.7 | 23.9 | 5.7 | 7.5 | 1.8 |
| Otaki Creek | 12 | 7.8 | 20.0 | 9.9 | 12.5 | 1.3 |
| Otara Creek (East Tamaki) | 12 | 1.5 | 39.1 | 6.7 | 10.6 | 3.2 |
| Otara Creek (Kennell Hill) | 12 | 2.0 | 27.0 | 9.8 | 11.2 | 2.3 |
| Oteha Stream | 12 | 3.2 | 60.1 | 7.0 | 14.2 | 4.9 |
| Pakuranga Creek (Botany Rd) | 12 | 5.6 | 404.0 | 9.6 | 45.6 | 32.7 |
| Pakuranga Creek (Greenmount Dr) | 12 | 3.8 | 41.4 | 8.3 | 12.5 | 3.3 |
| Pakuranga Creek (Guy's Rd) | 12 | 1.9 | 87.7 | 12.2 | 21.8 | 7.0 |
| Papakura Stream | 12 | 1.7 | 13.2 | 5.0 | 6.4 | 1.1 |
| Puhinui Stream | 12 | 2.5 | 16.4 | 9.1 | 8.6 | 1.3 |
| Rangitopuni River | 12 | 4.8 | 27.9 | 9.4 | 11.7 | 2.0 |
| Vaughan Stream | 12 | 4.1 | 15.0 | 10.1 | 9.6 | 1.0 |
| Wairoa River | 12 | 2.2 | 16.2 | 7.9 | 9.2 | 1.2 |
| Waiwera River | 12 | 6.0 | 49.1 | 11.2 | 15.1 | 3.4 |
| West Hoe Stream | 12 | 6.5 | 18.1 | 8.7 | 10.4 | 1.1 |

**Table 13**

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

| Site | Count | Minimum | Maximum | Median | Mean | Standard error |
|---|---|---|---|---|---|---|
| Cascades Stream | 10 | 0.003 | 0.040 | 0.014 | 0.018 | 0.004 |
| Hoteo River | 12 | 0.021 | 0.092 | 0.043 | 0.049 | 0.005 |
| Kumeu River | 11 | 0.003 | 0.085 | 0.040 | 0.041 | 0.007 |
| Lucas Creek | 12 | 0.003 | 0.072 | 0.036 | 0.037 | 0.006 |
| Mahurangi River (Forestry HQ) | 12 | 0.009 | 0.060 | 0.034 | 0.031 | 0.004 |
| Mahurangi River (Town Bridge) | 11 | 0.003 | 0.088 | 0.032 | 0.035 | 0.008 |
| Mahurangi River (Water Supply) | 11 | 0.003 | 0.060 | 0.043 | 0.035 | 0.006 |
| Matakana River | 12 | 0.013 | 0.070 | 0.030 | 0.032 | 0.005 |
| Ngakaroa Stream | 12 | 0.005 | 0.030 | 0.017 | 0.017 | 0.002 |
| Oakley Creek | 12 | 0.003 | 0.057 | 0.030 | 0.033 | 0.004 |
| Okura Creek | 12 | 0.003 | 0.071 | 0.027 | 0.030 | 0.005 |
| Omaru Creek | 12 | 0.034 | 1.090 | 0.110 | 0.248 | 0.097 |
| Opanuku Stream | 12 | 0.008 | 0.058 | 0.022 | 0.025 | 0.004 |
| Otaki Creek | 12 | 0.025 | 0.218 | 0.077 | 0.097 | 0.019 |
| Otara Creek (East Tamaki) | 12 | 0.003 | 0.270 | 0.059 | 0.086 | 0.023 |
| Otara Creek (Kennell Hill) | 12 | 0.003 | 0.606 | 0.040 | 0.086 | 0.047 |
| Oteha Stream | 12 | 0.008 | 2.100 | 0.033 | 0.209 | 0.172 |
| Pakuranga Creek (Botany Rd) | 12 | 0.019 | 0.165 | 0.052 | 0.068 | 0.014 |
| Pakuranga Creek (Greenmount Dr) | 12 | 0.072 | 0.499 | 0.189 | 0.218 | 0.039 |
| Pakuranga Creek (Guy's Rd) | 12 | 0.046 | 0.271 | 0.087 | 0.116 | 0.020 |
| Papakura Stream | 12 | 0.009 | 0.096 | 0.057 | 0.059 | 0.007 |
| Puhinui Stream | 12 | 0.003 | 0.071 | 0.032 | 0.031 | 0.006 |
| Rangitopuni River | 12 | 0.022 | 0.060 | 0.045 | 0.043 | 0.004 |
| Vaughan Stream | 12 | 0.003 | 0.027 | 0.015 | 0.015 | 0.002 |
| Wairoa River | 12 | 0.008 | 0.070 | 0.038 | 0.039 | 0.005 |
| Waiwera River | 12 | 0.030 | 0.085 | 0.048 | 0.048 | 0.004 |
| West Hoe Stream | 12 | 0.003 | 0.066 | 0.010 | 0.016 | 0.005 |

**Table 14**

Total oxidised Nitrogen (mg N $l^{-1}$)

| Site | Count | Minimum | Maximum | Median | Mean | Standard error |
|---|---|---|---|---|---|---|
| Cascades Stream | 10 | 0.010 | 0.040 | 0.025 | 0.024 | 0.003 |
| Hoteo River | 12 | 0.021 | 0.650 | 0.346 | 0.331 | 0.058 |
| Kumeu River | 11 | 0.133 | 0.970 | 0.349 | 0.463 | 0.093 |
| Lucas Creek | 12 | 0.111 | 0.899 | 0.359 | 0.391 | 0.068 |
| Mahurangi River (Forestry HQ) | 12 | 0.028 | 0.155 | 0.082 | 0.081 | 0.011 |
| Mahurangi River (Town Bridge) | 11 | 0.016 | 0.391 | 0.175 | 0.170 | 0.034 |
| Mahurangi River (Water Supply) | 11 | 0.005 | 0.388 | 0.194 | 0.177 | 0.034 |
| Matakana River | 12 | 0.022 | 0.170 | 0.063 | 0.083 | 0.016 |
| Ngakaroa Stream | 12 | 1.300 | 3.860 | 2.610 | 2.607 | 0.281 |
| Oakley Creek | 12 | 0.672 | 2.410 | 1.710 | 1.661 | 0.157 |
| Okura Creek | 12 | 0.127 | 0.499 | 0.269 | 0.270 | 0.031 |
| Omaru Creek | 12 | 0.013 | 3.960 | 0.586 | 1.015 | 0.313 |
| Opanuku Stream | 12 | 0.080 | 0.253 | 0.162 | 0.158 | 0.017 |
| Otaki Creek | 12 | 0.041 | 5.030 | 1.285 | 1.541 | 0.375 |
| Otara Creek (East Tamaki) | 12 | 0.026 | 4.080 | 1.085 | 1.418 | 0.336 |
| Otara Creek (Kennell Hill) | 12 | 0.062 | 1.310 | 0.492 | 0.544 | 0.108 |
| Oteha Stream | 12 | 0.166 | 0.736 | 0.276 | 0.361 | 0.056 |
| Pakuranga Creek (Botany Rd) | 12 | 0.028 | 3.230 | 0.978 | 1.028 | 0.232 |
| Pakuranga Creek (Greenmount Dr) | 12 | 0.013 | 2.120 | 0.433 | 0.695 | 0.180 |
| Pakuranga Creek (Guy's Rd) | 12 | 0.008 | 1.770 | 0.584 | 0.701 | 0.155 |
| Papakura Stream | 12 | 0.070 | 1.710 | 0.383 | 0.647 | 0.164 |
| Puhinui Stream | 12 | 0.157 | 1.620 | 0.596 | 0.793 | 0.141 |
| Rangitopuni River | 12 | 0.009 | 0.491 | 0.169 | 0.208 | 0.043 |
| Vaughan Stream | 12 | 0.008 | 0.191 | 0.063 | 0.080 | 0.017 |
| Wairoa River | 12 | 0.077 | 1.480 | 0.346 | 0.519 | 0.139 |
| Waiwera River | 12 | 0.014 | 0.423 | 0.161 | 0.194 | 0.037 |
| West Hoe Stream | 12 | 0.006 | 0.059 | 0.017 | 0.022 | 0.004 |

**Table 15**

Kjeldhal Nitrogen (mg N $l^{-1}$)

| Site | Count | Minimum | Maximum | Median | Mean | Standard error |
|---|---|---|---|---|---|---|
| Cascades Stream | 10 | 0.17 | 0.57 | 0.31 | 0.33 | 0.05 |
| Hoteo River | 12 | 0.42 | 1.20 | 0.58 | 0.64 | 0.07 |
| Kumeu River | 11 | 0.38 | 1.11 | 0.70 | 0.70 | 0.07 |
| Lucas Creek | 12 | 0.33 | 0.85 | 0.54 | 0.57 | 0.05 |
| Mahurangi River (Forestry HQ) | 12 | 0.12 | 0.64 | 0.37 | 0.39 | 0.05 |
| Mahurangi River (Town Bridge) | 11 | 0.28 | 1.23 | 0.59 | 0.65 | 0.10 |
| Mahurangi River (Water Supply) | 11 | 0.40 | 1.15 | 0.69 | 0.70 | 0.06 |
| Matakana River | 12 | 0.26 | 1.00 | 0.53 | 0.55 | 0.06 |
| Ngakaroa Stream | 12 | 0.18 | 0.61 | 0.39 | 0.40 | 0.04 |
| Oakley Creek | 12 | 0.18 | 0.80 | 0.40 | 0.42 | 0.04 |
| Okura Creek | 12 | 0.37 | 1.11 | 0.52 | 0.57 | 0.06 |
| Omaru Creek | 12 | 0.44 | 3.18 | 0.72 | 1.03 | 0.25 |
| Opanuku Stream | 12 | 0.20 | 0.58 | 0.39 | 0.39 | 0.03 |
| Otaki Creek | 12 | 0.22 | 1.07 | 0.41 | 0.55 | 0.08 |
| Otara Creek (East Tamaki) | 12 | 0.28 | 1.48 | 0.51 | 0.65 | 0.11 |
| Otara Creek (Kennell Hill) | 12 | 0.38 | 0.96 | 0.58 | 0.56 | 0.05 |
| Oteha Stream | 12 | 0.17 | 2.88 | 0.59 | 0.67 | 0.21 |
| Pakuranga Creek (Botany Rd) | 12 | 0.39 | 1.35 | 0.76 | 0.73 | 0.08 |
| Pakuranga Creek (Greenmount Dr) | 12 | 0.37 | 1.16 | 0.69 | 0.70 | 0.07 |
| Pakuranga Creek (Guy's Rd) | 12 | 0.56 | 1.32 | 0.77 | 0.85 | 0.07 |
| Papakura Stream | 12 | 0.51 | 0.93 | 0.69 | 0.71 | 0.04 |
| Puhinui Stream | 12 | 0.26 | 0.82 | 0.46 | 0.49 | 0.04 |
| Rangitopuni River | 12 | 0.40 | 0.94 | 0.74 | 0.73 | 0.04 |
| Vaughan Stream | 12 | 0.30 | 0.64 | 0.49 | 0.48 | 0.03 |
| Wairoa River | 12 | 0.33 | 0.82 | 0.52 | 0.51 | 0.04 |
| Waiwera River | 12 | 0.42 | 0.86 | 0.61 | 0.61 | 0.04 |
| West Hoe Stream | 12 | 0.05 | 0.44 | 0.18 | 0.21 | 0.03 |

**Table 16**

Total Nitrogen by calculation (mg N $l^{-1}$)

| Site | Count | Minimum | Maximum | Median | Mean | Standard error |
|---|---|---|---|---|---|---|
| Cascades Stream | 10 | 0.19 | 0.48 | 0.35 | 0.34 | 0.03 |
| Hoteo River | 12 | 0.49 | 1.90 | 0.87 | 0.99 | 0.11 |
| Kumeu River | 11 | 0.70 | 2.20 | 1.00 | 1.17 | 0.14 |
| Lucas Creek | 12 | 0.52 | 1.70 | 0.74 | 0.86 | 0.10 |
| Mahurangi River (Forestry HQ) | 12 | 0.20 | 0.66 | 0.50 | 0.46 | 0.04 |
| Mahurangi River (Town Bridge) | 11 | 0.41 | 1.60 | 0.55 | 0.78 | 0.14 |
| Mahurangi River (Water Supply) | 11 | 0.36 | 1.20 | 0.76 | 0.84 | 0.09 |
| Matakana River | 12 | 0.33 | 8.30 | 0.62 | 1.23 | 0.64 |
| Ngakaroa Stream | 12 | 1.60 | 4.20 | 3.35 | 3.07 | 0.28 |
| Oakley Creek | 12 | 1.10 | 2.70 | 2.10 | 2.01 | 0.16 |
| Okura Creek | 12 | 0.63 | 1.80 | 0.80 | 0.87 | 0.09 |
| Omaru Creek | 12 | 0.90 | 7.50 | 1.26 | 2.10 | 0.57 |
| Opanuku Stream | 12 | 0.30 | 0.76 | 0.49 | 0.49 | 0.04 |
| Otaki Creek | 12 | 0.75 | 6.20 | 1.65 | 2.13 | 0.42 |
| Otara Creek (East Tamaki) | 12 | 0.40 | 5.10 | 1.79 | 2.08 | 0.38 |
| Otara Creek (Kennell Hill) | 12 | 0.42 | 2.00 | 0.94 | 1.06 | 0.14 |
| Oteha Stream | 12 | 0.38 | 3.50 | 0.89 | 1.06 | 0.24 |
| Pakuranga Creek (Botany Rd) | 12 | 0.91 | 4.10 | 1.63 | 1.80 | 0.24 |
| Pakuranga Creek (Greenmount Dr) | 12 | 0.76 | 3.20 | 1.15 | 1.38 | 0.21 |
| Pakuranga Creek (Guy's Rd) | 12 | 0.75 | 3.00 | 1.40 | 1.55 | 0.19 |
| Papakura Stream | 12 | 0.65 | 2.60 | 1.10 | 1.34 | 0.19 |
| Puhinui Stream | 12 | 0.49 | 2.10 | 1.03 | 1.20 | 0.16 |
| Rangitopuni River | 12 | 0.65 | 1.60 | 0.89 | 0.97 | 0.08 |
| Vaughan Stream | 12 | 0.38 | 0.73 | 0.59 | 0.57 | 0.03 |
| Wairoa River | 12 | 0.06 | 1.80 | 0.71 | 0.95 | 0.16 |
| Waiwera River | 12 | 0.58 | 1.10 | 0.75 | 0.81 | 0.05 |
| West Hoe Stream | 12 | 0.07 | 0.50 | 0.20 | 0.23 | 0.04 |

**Table 17**

Soluble reactive Phosphorus (mg P $l^{-1}$)

| Site | Count | Minimum | Maximum | Median | Mean | Standard error |
|---|---|---|---|---|---|---|
| Cascades Stream | 10 | 0.008 | 0.025 | 0.011 | 0.012 | 0.002 |
| Hoteo River | 12 | 0.021 | 0.045 | 0.031 | 0.032 | 0.002 |
| Kumeu River | 11 | 0.011 | 0.043 | 0.019 | 0.022 | 0.003 |
| Lucas Creek | 12 | 0.008 | 0.020 | 0.015 | 0.014 | 0.001 |
| Mahurangi River (Forestry HQ) | 12 | 0.006 | 0.010 | 0.008 | 0.008 | 0.000 |
| Mahurangi River (Town Bridge) | 11 | 0.006 | 0.023 | 0.015 | 0.015 | 0.001 |
| Mahurangi River (Water Supply) | 11 | 0.005 | 0.025 | 0.014 | 0.015 | 0.002 |
| Matakana River | 12 | 0.012 | 0.025 | 0.018 | 0.017 | 0.001 |
| Ngakaroa Stream | 12 | 0.005 | 0.011 | 0.009 | 0.009 | 0.001 |
| Oakley Creek | 12 | 0.018 | 0.050 | 0.029 | 0.030 | 0.002 |
| Okura Creek | 12 | 0.005 | 0.056 | 0.018 | 0.022 | 0.005 |
| Omaru Creek | 12 | 0.010 | 0.236 | 0.032 | 0.062 | 0.022 |
| Opanuku Stream | 12 | 0.008 | 0.020 | 0.011 | 0.011 | 0.001 |
| Otaki Creek | 12 | 0.005 | 0.053 | 0.021 | 0.025 | 0.004 |
| Otara Creek (East Tamaki) | 12 | 0.010 | 0.042 | 0.015 | 0.019 | 0.003 |
| Otara Creek (Kennell Hill) | 12 | 0.010 | 0.025 | 0.021 | 0.020 | 0.001 |
| Oteha Stream | 12 | 0.005 | 0.040 | 0.015 | 0.017 | 0.003 |
| Pakuranga Creek (Botany Rd) | 12 | 0.005 | 0.028 | 0.017 | 0.017 | 0.002 |
| Pakuranga Creek (Greenmount Dr) | 12 | 0.011 | 0.057 | 0.030 | 0.030 | 0.004 |
| Pakuranga Creek (Guy's Rd) | 12 | 0.008 | 0.038 | 0.016 | 0.018 | 0.003 |
| Papakura Stream | 12 | 0.019 | 0.064 | 0.035 | 0.038 | 0.004 |
| Puhinui Stream | 12 | 0.011 | 0.111 | 0.019 | 0.029 | 0.008 |
| Rangitopuni River | 12 | 0.018 | 0.042 | 0.028 | 0.028 | 0.002 |
| Vaughan Stream | 12 | 0.005 | 0.037 | 0.012 | 0.014 | 0.002 |
| Wairoa River | 12 | 0.011 | 0.032 | 0.017 | 0.019 | 0.002 |
| Waiwera River | 12 | 0.010 | 0.032 | 0.015 | 0.017 | 0.002 |
| West Hoe Stream | 12 | 0.005 | 0.010 | 0.008 | 0.008 | 0.000 |

**Table 18**

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

| Site | Count | Minimum | Maximum | Median | Mean | Standard error |
|---|---|---|---|---|---|---|
| Cascades Stream | 10 | 0.014 | 0.040 | 0.029 | 0.029 | 0.003 |
| Hoteo River | 12 | 0.049 | 0.159 | 0.072 | 0.083 | 0.009 |
| Kumeu River | 11 | 0.035 | 0.157 | 0.070 | 0.075 | 0.010 |
| Lucas Creek | 12 | 0.033 | 0.096 | 0.044 | 0.050 | 0.005 |
| Mahurangi River (Forestry HQ) | 12 | 0.010 | 0.043 | 0.023 | 0.025 | 0.003 |
| Mahurangi River (Town Bridge) | 11 | 0.010 | 0.187 | 0.045 | 0.064 | 0.016 |
| Mahurangi River (Water Supply) | 11 | 0.014 | 0.138 | 0.044 | 0.058 | 0.012 |
| Matakana River | 12 | 0.028 | 0.061 | 0.046 | 0.044 | 0.003 |
| Ngakaroa Stream | 12 | 0.012 | 0.059 | 0.030 | 0.030 | 0.004 |
| Oakley Creek | 12 | 0.038 | 0.150 | 0.065 | 0.071 | 0.009 |
| Okura Creek | 12 | 0.024 | 0.134 | 0.075 | 0.068 | 0.008 |
| Omaru Creek | 12 | 0.054 | 0.493 | 0.085 | 0.155 | 0.041 |
| Opanuku Stream | 12 | 0.017 | 0.060 | 0.036 | 0.035 | 0.004 |
| Otaki Creek | 12 | 0.033 | 0.138 | 0.088 | 0.087 | 0.009 |
| Otara Creek (East Tamaki) | 12 | 0.020 | 0.103 | 0.051 | 0.056 | 0.008 |
| Otara Creek (Kennell Hill) | 12 | 0.040 | 0.101 | 0.068 | 0.067 | 0.005 |
| Oteha Stream | 12 | 0.030 | 0.110 | 0.052 | 0.056 | 0.006 |
| Pakuranga Creek (Botany Rd) | 12 | 0.041 | 0.539 | 0.060 | 0.116 | 0.041 |
| Pakuranga Creek (Greenmount Dr) | 12 | 0.058 | 0.263 | 0.108 | 0.117 | 0.016 |
| Pakuranga Creek (Guy's Rd) | 12 | 0.061 | 0.215 | 0.090 | 0.104 | 0.014 |
| Papakura Stream | 12 | 0.061 | 0.128 | 0.092 | 0.089 | 0.006 |
| Puhinui Stream | 12 | 0.028 | 0.165 | 0.070 | 0.077 | 0.011 |
| Rangitopuni River | 12 | 0.047 | 0.110 | 0.075 | 0.077 | 0.005 |
| Vaughan Stream | 12 | 0.025 | 0.088 | 0.037 | 0.043 | 0.005 |
| Wairoa River | 12 | 0.028 | 0.081 | 0.062 | 0.057 | 0.005 |
| Waiwera River | 12 | 0.030 | 0.080 | 0.046 | 0.050 | 0.005 |
| West Hoe Stream | 12 | 0.010 | 0.040 | 0.020 | 0.021 | 0.003 |

**Table 19**

Soluble Copper (μg $l^{-1}$)

| 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 | 0.9 | 2.5 | 1.7 | 1.6 | 0.2 |
| 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 | 0.3 | 1.8 | 1.2 | 1.2 | 0.1 |
| Okura Creek | 12 | 0.3 | 1.1 | 0.6 | 0.7 | 0.1 |
| Omaru Creek | 12 | 0.7 | 5.4 | 1.6 | 2.0 | 0.4 |
| Opanuku Stream | Not measured at this site | | | | | |
| Otaki Creek | 12 | 0.7 | 3.2 | 1.2 | 1.5 | 0.2 |
| Otara Creek (East Tamaki) | 12 | 0.7 | 3.4 | 0.9 | 1.4 | 0.3 |
| Otara Creek (Kennell Hill) | 12 | 0.3 | 1.4 | 0.9 | 0.9 | 0.1 |
| Oteha Stream | 12 | 0.8 | 2.8 | 1.0 | 1.3 | 0.2 |
| Pakuranga Creek (Botany Rd) | 12 | 1.0 | 2.9 | 1.3 | 1.5 | 0.2 |
| Pakuranga Creek (Greenmount Dr) | 12 | 0.3 | 4.4 | 1.4 | 1.6 | 0.3 |
| Pakuranga Creek (Guy's Rd) | 12 | 0.3 | 2.3 | 1.4 | 1.4 | 0.2 |
| Papakura Stream | Not measured at this site | | | | | |
| Puhinui Stream | 12 | 0.6 | 1.9 | 1.1 | 1.2 | 0.1 |
| Rangitopuni River | Not measured at this site | | | | | |
| Vaughan Stream | 12 | 0.3 | 0.9 | 0.5 | 0.5 | 0.1 |
| Wairoa River | Not measured at this site | | | | | |
| Waiwera River | Not measured at this site | | | | | |
| West Hoe Stream | Not measured at this site | | | | | |

**Table 20**

Total Copper (µg $l^{-1}$)

| 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 | 6.0 | 2.6 | 3.0 | 0.4 |
| 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 | 1.4 | 13.0 | 2.6 | 3.5 | 0.9 |
| Okura Creek | 12 | 1.0 | 2.4 | 1.3 | 1.4 | 0.1 |
| Omaru Creek | 12 | 1.7 | 9.8 | 3.2 | 3.9 | 0.7 |
| Opanuku Stream | Not measured at this site | | | | | |
| Otaki Creek | 12 | 1.6 | 5.7 | 2.1 | 2.6 | 0.4 |
| Otara Creek (East Tamaki) | 12 | 1.3 | 5.6 | 2.2 | 2.7 | 0.4 |
| Otara Creek (Kennell Hill) | 12 | 1.1 | 2.4 | 1.6 | 1.7 | 0.1 |
| Oteha Stream | 12 | 1.2 | 5.5 | 2.1 | 2.5 | 0.4 |
| Pakuranga Creek (Botany Rd) | 12 | 1.5 | 25.0 | 3.3 | 5.0 | 1.8 |
| Pakuranga Creek (Greenmount Dr) | 12 | 2.1 | 7.6 | 2.9 | 3.3 | 0.4 |
| Pakuranga Creek (Guy's Rd) | 12 | 1.3 | 7.7 | 2.8 | 3.1 | 0.5 |
| Papakura Stream | Not measured at this site | | | | | |
| Puhinui Stream | 12 | 1.4 | 3.6 | 2.1 | 2.3 | 0.2 |
| Rangitopuni River | Not measured at this site | | | | | |
| Vaughan Stream | 12 | 0.3 | 1.3 | 0.7 | 0.8 | 0.1 |
| Wairoa River | Not measured at this site | | | | | |
| Waiwera River | Not measured at this site | | | | | |
| West Hoe Stream | Not measured at this site | | | | | |

**Table 21**

Soluble Zinc (µg $l^{-1}$)

| 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 | 1.8 | 16.0 | 5.4 | 7.5 | 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 | 5.2 | 31.0 | 12.5 | 14.2 | 2.5 |
| Okura Creek | 12 | 0.6 | 3.1 | 1.1 | 1.5 | 0.3 |
| Omaru Creek | 12 | 3.7 | 110.0 | 52.0 | 50.3 | 9.6 |
| Opanuku Stream | Not measured at this site | | | | | |
| Otaki Creek | 12 | 4.5 | 130.0 | 25.0 | 38.0 | 10.0 |
| Otara Creek (East Tamaki) | 12 | 4.1 | 53.0 | 22.0 | 21.2 | 3.8 |
| Otara Creek (Kennell Hill) | 12 | 4.0 | 15.0 | 9.7 | 9.6 | 1.1 |
| Oteha Stream | 12 | 8.9 | 48.0 | 24.0 | 25.1 | 3.7 |
| Pakuranga Creek (Botany Rd) | 12 | 1.4 | 45.0 | 14.5 | 18.2 | 4.3 |
| Pakuranga Creek (Greenmount Dr) | 12 | 1.9 | 42.0 | 12.5 | 14.6 | 3.1 |
| Pakuranga Creek (Guy's Rd) | 12 | 1.1 | 20.0 | 4.3 | 6.5 | 1.7 |
| Papakura Stream | Not measured at this site | | | | | |
| Puhinui Stream | 12 | 3.2 | 33.0 | 16.5 | 18.0 | 2.8 |
| Rangitopuni River | Not measured at this site | | | | | |
| Vaughan Stream | 12 | 0.5 | 4.7 | 2.1 | 2.4 | 0.4 |
| Wairoa River | Not measured at this site | | | | | |
| Waiwera River | Not measured at this site | | | | | |
| West Hoe Stream | Not measured at this site | | | | | |

**Table 22**

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

| 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 | 5.2 | 33.0 | 15.5 | 15.6 | 2.3 |
| 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 | 7.8 | 53.0 | 22.0 | 25.3 | 4.0 |
| Okura Creek | 12 | 3.1 | 9.1 | 4.7 | 5.2 | 0.5 |
| Omaru Creek | 12 | 15.0 | 160.0 | 82.5 | 78.6 | 13.0 |
| Opanuku Stream | Not measured at this site | | | | | |
| Otaki Creek | 12 | 16.0 | 110.0 | 41.5 | 52.3 | 9.0 |
| Otara Creek (East Tamaki) | 12 | 7.7 | 69.0 | 32.0 | 33.2 | 5.0 |
| Otara Creek (Kennell Hill) | 12 | 11.0 | 32.0 | 16.5 | 17.2 | 1.7 |
| Oteha Stream | 12 | 15.0 | 78.0 | 41.0 | 42.3 | 5.8 |
| Pakuranga Creek (Botany Rd) | 12 | 14.0 | 120.0 | 32.5 | 44.3 | 8.7 |
| Pakuranga Creek (Greenmount Dr) | 12 | 8.1 | 59.0 | 23.5 | 25.8 | 3.8 |
| Pakuranga Creek (Guy's Rd) | 12 | 5.9 | 42.0 | 15.0 | 16.8 | 3.1 |
| Papakura Stream | Not measured at this site | | | | | |
| Puhinui Stream | 12 | 14.0 | 59.0 | 34.0 | 36.0 | 3.7 |
| Rangitopuni River | Not measured at this site | | | | | |
| Vaughan Stream | 12 | 2.2 | 7.5 | 4.4 | 4.6 | 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 23**

Soluble Lead (µg $l^{-1}$)

| 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 | 0.07 | 0.03 | 0.03 | 0.00 |
| 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 | 0.17 | 0.03 | 0.04 | 0.01 |
| Okura Creek | 12 | 0.025 | 0.08 | 0.03 | 0.03 | 0.01 |
| Omaru Creek | 12 | 0.025 | 0.14 | 0.03 | 0.05 | 0.01 |
| Opanuku Stream | Not measured at this site | | | | | |
| Otaki Creek | 12 | 0.025 | 0.09 | 0.03 | 0.04 | 0.01 |
| Otara Creek (East Tamaki) | 12 | 0.025 | 0.08 | 0.03 | 0.03 | 0.01 |
| Otara Creek (Kennell Hill) | 12 | 0.025 | 0.03 | 0.03 | 0.03 | 0.00 |
| Oteha Stream | 12 | 0.025 | 0.05 | 0.03 | 0.03 | 0.00 |
| Pakuranga Creek (Botany Rd) | 12 | 0.025 | 0.19 | 0.03 | 0.06 | 0.02 |
| Pakuranga Creek (Greenmount Dr) | 12 | 0.025 | 0.08 | 0.03 | 0.03 | 0.01 |
| Pakuranga Creek (Guy's Rd) | 12 | 0.025 | 0.14 | 0.03 | 0.04 | 0.01 |
| Papakura Stream | Not measured at this site | | | | | |
| Puhinui Stream | 12 | 0.025 | 0.12 | 0.03 | 0.05 | 0.01 |
| Rangitopuni River | Not measured at this site | | | | | |
| Vaughan Stream | 12 | 0.025 | 0.08 | 0.03 | 0.03 | 0.00 |
| Wairoa River | Not measured at this site | | | | | |
| Waiwera River | Not measured at this site | | | | | |
| West Hoe Stream | Not measured at this site | | | | | |

**Table 24**

Total Lead (µg $l^{-1}$)

| 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 | 0.16 | 2.10 | 0.72 | 0.77 | 0.17 |
| 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 | 0.44 | 5.10 | 0.74 | 1.13 | 0.37 |
| Okura Creek | 12 | 0.18 | 0.94 | 0.32 | 0.36 | 0.06 |
| Omaru Creek | 12 | 0.57 | 2.10 | 1.40 | 1.31 | 0.13 |
| Opanuku Stream | Not measured at this site | | | | | |
| Otaki Creek | 12 | 0.47 | 6.00 | 1.85 | 1.98 | 0.43 |
| Otara Creek (East Tamaki) | 12 | 0.11 | 1.40 | 0.56 | 0.68 | 0.12 |
| Otara Creek (Kennell Hill) | 12 | 0.17 | 0.79 | 0.47 | 0.45 | 0.05 |
| Oteha Stream | 12 | 0.09 | 1.10 | 0.24 | 0.37 | 0.09 |
| Pakuranga Creek (Botany Rd) | 12 | 0.15 | 8.20 | 0.86 | 1.42 | 0.63 |
| Pakuranga Creek (Greenmount Dr) | 12 | 0.06 | 1.00 | 0.29 | 0.37 | 0.08 |
| Pakuranga Creek (Guy's Rd) | 12 | 0.18 | 2.20 | 0.66 | 0.81 | 0.19 |
| Papakura Stream | Not measured at this site | | | | | |
| Puhinui Stream | 12 | 0.47 | 1.00 | 0.70 | 0.74 | 0.05 |
| Rangitopuni River | Not measured at this site | | | | | |
| Vaughan Stream | 12 | 0.06 | 0.35 | 0.12 | 0.13 | 0.02 |
| 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 | 10 | 5 | 1300 | 150 | 273 | 125 |
| Hoteo River | 12 | 63 | 4900 | 320 | 694 | 385 |
| Kumeu River | 11 | 220 | 7000 | 1100 | 2053 | 760 |
| Lucas Creek | 12 | 330 | 7900 | 640 | 1363 | 612 |
| Mahurangi River (Forestry HQ) | 12 | 78 | 3300 | 330 | 586 | 254 |
| Mahurangi River (Town Bridge) | 11 | 79 | 54000 | 1300 | 6281 | 4791 |
| Mahurangi River (Water Supply) | 11 | 220 | 92000 | 790 | 9290 | 8274 |
| Matakana River | 12 | 79 | 1300 | 490 | 572 | 116 |
| Ngakaroa Stream | 12 | 68 | 2200 | 275 | 473 | 172 |
| Oakley Creek | 12 | 790 | 54000 | 2250 | 9649 | 4807 |
| Okura Creek | 12 | 220 | 9400 | 1045 | 2314 | 773 |
| Omaru Creek | 12 | 1300 | 350000 | 6400 | 65067 | 38496 |
| Opanuku Stream | 12 | 220 | 14000 | 945 | 2476 | 1116 |
| Otaki Creek | 12 | 270 | 49000 | 2800 | 8614 | 3884 |
| Otara Creek (East Tamaki) | 12 | 490 | 280000 | 2400 | 36182 | 23882 |
| Otara Creek (Kennell Hill) | 12 | 460 | 7900 | 1350 | 2219 | 726 |
| Oteha Stream | 12 | 79 | 1700 | 490 | 619 | 141 |
| Pakuranga Creek (Botany Rd) | 12 | 92 | 28000 | 4750 | 7415 | 2238 |
| Pakuranga Creek (Greenmount Dr) | 12 | 230 | 23000 | 1400 | 4791 | 2167 |
| Pakuranga Creek (Guy's Rd) | 12 | 20 | 23000 | 1200 | 3130 | 1833 |
| Papakura Stream | 12 | 460 | 11000 | 3550 | 4130 | 976 |
| Puhinui Stream | 12 | 130 | 4900 | 1700 | 1990 | 513 |
| Rangitopuni River | 12 | 170 | 7900 | 570 | 1185 | 619 |
| Vaughan Stream | 12 | 78 | 17000 | 1450 | 3567 | 1444 |
| Wairoa River | 12 | 110 | 7900 | 700 | 1377 | 620 |
| Waiwera River | 12 | 310 | 4900 | 1200 | 1559 | 399 |
| West Hoe Stream | 12 | 5 | 680 | 19 | 153 | 67 |

**Table 26**

*Escherichia coli* (cfu/100ml)

| Site | Count | Minimum | Maximum | Median | Mean | Standard error |
|---|---|---|---|---|---|---|
| Cascades Stream | 10 | 9 | 420 | 85 | 147 | 48 |
| Hoteo River | 12 | 70 | 5600 | 250 | 675 | 449 |
| Kumeu River | 11 | 220 | 11000 | 380 | 1770 | 1022 |
| Lucas Creek | 12 | 210 | 3100 | 660 | 799 | 220 |
| Mahurangi River (Forestry HQ) | 12 | 40 | 2700 | 400 | 596 | 202 |
| Mahurangi River (Town Bridge) | 11 | 10 | 3000 | 310 | 660 | 275 |
| Mahurangi River (Water Supply) | 11 | 30 | 2200 | 360 | 615 | 214 |
| Matakana River | 12 | 118 | 1190 | 390 | 426 | 86 |
| Ngakaroa Stream | 12 | 40 | 2400 | 285 | 415 | 186 |
| Oakley Creek | 12 | 340 | 29000 | 900 | 3846 | 2339 |
| Okura Creek | 12 | 173 | 5500 | 530 | 1125 | 435 |
| Omaru Creek | 12 | 970 | 324000 | 2650 | 42617 | 28191 |
| Opanuku Stream | 12 | 250 | 6100 | 635 | 1247 | 476 |
| Otaki Creek | 12 | 440 | 16000 | 3100 | 4598 | 1293 |
| Otara Creek (East Tamaki) | 12 | 280 | 96000 | 2105 | 16661 | 8862 |
| Otara Creek (Kennell Hill) | 12 | 390 | 3900 | 745 | 1198 | 291 |
| Oteha Stream | 12 | 64 | 1210 | 330 | 466 | 98 |
| Pakuranga Creek (Botany Rd) | 12 | 70 | 31000 | 2215 | 5184 | 2518 |
| Pakuranga Creek (Greenmount Dr) | 12 | 160 | 4300 | 500 | 1300 | 446 |
| Pakuranga Creek (Guy's Rd) | 12 | 50 | 14000 | 560 | 1918 | 1129 |
| Papakura Stream | 12 | 320 | 9909 | 1800 | 2609 | 786 |
| Puhinui Stream | 12 | 170 | 6200 | 355 | 1303 | 543 |
| Rangitopuni River | 12 | 30 | 1150 | 252 | 374 | 91 |
| Vaughan Stream | 12 | 60 | 8100 | 615 | 1866 | 768 |
| Wairoa River | 12 | 145 | 1500 | 425 | 622 | 136 |
| Waiwera River | 12 | 290 | 3200 | 420 | 859 | 263 |
| West Hoe Stream | 12 | 5 | 390 | 23.5 | 102 | 40 |

## 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).

**Table 27**

Site based water quality indices and classes based on 2008 data (2007 water quality class is provided for comparison (Neale, 2009))

| Rank | Site | Scope | Frequency | Magnitude | Water quality index | 2008 water quality class | 2007 water quality class |
|---|---|---|---|---|---|---|---|
| 1 | West Hoe Stream | 0.0 | 0.0 | 0.0 | 100.0 | Excellent | Excellent |
| 2 | Opanuku Stream | 0.0 | 0.0 | 0.0 | 100.0 | Excellent | Good |
| 3 | Cascades Stream | 28.6 | 2.9 | 0.2 | 83.4 | Good | Excellent |
| 4 | Mahurangi River (Forestry HQ) | 42.9 | 3.6 | 0.2 | 75.2 | Good | Fair |
| 5 | Vaughan Stream | 42.9 | 6.1 | 0.3 | 75.0 | Good | Poor |
| 6 | Ngakaroa Stream | 28.6 | 15.5 | 28.9 | 74.9 | Good | Fair |
| 7 | Wairoa River | 57.1 | 10.7 | 5.2 | 66.3 | Fair | Fair |
| 8 | Mahurangi River (Town Bridge) | 57.1 | 10.5 | 8.0 | 66.1 | Fair | Good |
| 9 | Matakana River | 57.1 | 8.3 | 10.5 | 66.1 | Fair | Good |
| 10 | Mahurangi River (Water Supply) | 57.1 | 13.2 | 6.5 | 65.9 | Fair | Good |
| 11 | Papakura Stream | 57.1 | 26.2 | 11.7 | 63.1 | Fair | Poor |
| 12 | Waiwera Stream | 71.4 | 13.1 | 2.3 | 58.1 | Fair | Good |
| 13 | Okura Creek | 71.4 | 15.9 | 5.1 | 57.7 | Fair | Fair |
| 14 | Lucas Creek | 71.4 | 17.9 | 6.9 | 57.3 | Fair | Fair |
| 15 | Rangitopuni River | 71.4 | 22.6 | 5.2 | 56.6 | Fair | Fair |
| 16 | Puhinui Stream | 71.4 | 26.2 | 10.7 | 55.6 | Fair | Fair |
| 17 | Oakley Creek | 71.4 | 22.6 | 18.7 | 55.4 | Fair | Fair |
| 18 | Hoteo River | 85.7 | 20.2 | 8.0 | 48.9 | Poor | Good |
| 19 | Otara Creek (Kennel Hill) | 85.7 | 21.4 | 12.0 | 48.5 | Poor | Poor |
| 20 | Kumeu River | 85.7 | 28.6 | 10.3 | 47.5 | Poor | Fair |
| 21 | Oteha Stream | 85.7 | 20.2 | 26.3 | 46.9 | Poor | Fair |
| 22 | Otaki Creek | 85.7 | 32.1 | 23.9 | 45.4 | Poor | Poor |
| 23 | Omaru Creek | 85.7 | 38.1 | 38.1 | 41.5 | Poor | Poor |
| 24 | Otara Creek (East Tamaki) | 100.0 | 26.2 | 22.4 | 38.9 | Poor | Fair |
| 25 | Pakuranga Creek (Guy's Rd) | 100.0 | 39.3 | 21.9 | 36.7 | Poor | Poor |
| 26 | Pakuranga Creek (Botany Rd) | 100.0 | 40.5 | 32.1 | 35.0 | Poor | Fair |
| 27 | Pakuranga Creek (Greenmount Dr) | 100.0 | 44.0 | 27.3 | 35.0 | Poor | Fair |

The West Hoe Stream had the best water quality in 2008, with West Hoe Stream and Opanuku Stream the only sites classified as having excellent water quality. West Hoe Stream retained its excellent quality class from 2007, whereas the Cascades Stream dropped from excellent in 2007 to good in 2008.

The Pakuranga Creek, particularly at the Greenmount Drive and Botany Road sites, had the worst water quality of the monitoring sites in 2008, with exceedances of the target levels common and often of high magnitudes.

There are 16 sites that changed quality class from 2007 to 2008, which reflects the variable nature of water quality data. However, of these 16, two sites changed by two classes; Vaughan Stream from poor to good, and Hoteo River from good to poor. Such large changes in water quality class are unexpected and these sites should be monitored closely to determine the nature of these water quality changes.

Table 27 indicates that urban sites were typically ranked lower in 2008. 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. The sites with rural and exotic forest catchments typically had water quality indices intermediate between native forest and urban sites, with the exotic forest site classified as having good water quality and rural sites 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) | 14.3 | 1.4 | 0.1 | 95.9 | Excellent |
| Exotic forest (1) | 42.9 | 3.6 | 0.2 | 75.2 | Good |
| Rural (13) | 57.1 | 14.7 | 7.9 | 65.1 | Fair |
| Urban (11) | 87 | 29.9 | 21.8 | 45.1 | Poor |

# 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 $^{o}C$ |
| Total phosphorus | Less than 0.08 g P $m^{-3}$ |
| Total nitrogen | Less than 0.8 g N $m^{-3}$ |

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