

# **State of the Environment Report**

## **Surface Water Quality in Otago**

**May 2007**



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## Chairman's foreword

The high quality of Otago's natural lakes and waterways has come to be expected from our rural and urban communities, and visitors. Maintaining water quality standards is a vital part of ensuring the region's future prosperity.

Parts of Otago are coming under increasing pressure, as seen in many other areas of the country, from intensive agricultural practices, urbanisation and water discharge practices, which all have the potential to negatively affect the quality of water in the region's rivers, streams and lakes. This is even more noticeable where the existing quality is so high.

The Otago Regional Council's Regional Policy Statement and RPW for Otago (RPW) demonstrate the Council's determination to maintain high water quality standards throughout Otago. In addition, the council continues to work closely with farmers, industries and community groups to ensure water quality does not deteriorate.

The council carries out regular and extensive long-term water quality monitoring as part of its State of the Environment programme. This assists regional planning and helps everyone understand the need to protect water quality.

This report summarises the water quality monitoring data recorded throughout the region over several years. It looks at the major lakes and headwaters of our rivers, down to the lowland reaches and urban rivers. The analysis also tracks changes over past years to demonstrate whether patterns are emerging which can be attributed to changes in farming and other land use practices.

Good water quality is paramount for our wellbeing. This report provides a valuable resource on the state of Otago's water quality. Many organisations and people, including farmers, anglers, recreationists, scientists, researchers and others who value good water quality, will find much of interest in it.



Stephen Cairns  
**Chairman**

## Executive summary

The Otago Regional Council carries out a State of Environment monitoring programme for water quality, which covers sites throughout the Otago region. A range of physico-chemical and microbiological water quality parameters have been measured at most sites on a bi-monthly basis since 1995, as well as periphyton and macroinvertebrate monitoring which has been carried out annually since 2001.

This report summarises spatial and temporal trends in the results. Spatial analysis focuses on the Water Quality Index (WQI), Principal Components Analysis and the River Environment Classification System (REC). Trends over time have been calculated using the Seasonal Kendall test. Each of the analytes is also compared against national guideline values.

Results are discussed in relation to policies in the RPW for Otago, to ascertain whether policy objectives are being met. In addition, focus is also given to intensive farming and the impact on water quality.

### Water quality: spatial results

The WQI assessed median results for each site against national water quality guidelines and the sites were classified into one of four categories (see Figure E. 1).

Of the 77 sites:

- 36 sites were classified as very good (blue dots in Figure E. 1)
- 19 sites were classified as good (green dots in Figure E. 1)
- 17 sites were classified as fair (yellow dots in Figure E. 1)
- 5 sites were classified as poor (red dots in Figure E. 1).

Figure E. 2 provides a further breakdown of the fair and poor WQI data, showing sites which failed in high bacteria levels (*E. coli* >126 cfu/ml) or had high nutrient concentrations (a combination of the dissolved reactive phosphorus (DRP) (>0.01 mg/l) and nitrite/nitrate-N (NNN) (>0.444 mg/l) values). Low dissolved oxygen values were only found at three sites, the Minzion Burn, Main Drain and Waiareka Creek. These are pastoral sites, with very slow moving water which reduces natural aeration. Ammoniacal Nitrogen (ammoniacal-N) results were within guideline values at all sites.

The sites with the very good water quality were generally in the upper catchments of large rivers and the outlets from the large lakes. The poorest water quality categories (poor and fair) were predominantly located in South and South West Otago. These sites generally showed elevated bacteria and/or nutrient levels. Good water quality sites have five of the six WQI variables passing guideline values. At 12 of the 19 good category locations the failing variable was bacteria, with eight of these sites in South Otago.

The WQI spatial analysis clearly shows that the main area of concern is South West Otago and around Dunedin where small streams drain developed land (agriculture and urban), while the rivers draining the higher altitude and lesser developed areas of Otago have excellent water quality. The main issues for water quality at these South and South West Otago sites are either high nutrient levels and/or high bacteria levels.

The River Environment Classification system further classified sites, and a clear pattern developed with regard to source of flow and land cover. Water quality was best at sites with high or mountainous elevation, in areas of low intensity farming. Water quality was poorest in low elevation pastoral sites, particularly in areas that are prone to saturated soils and have a high occurrence of tile and mole drains, such as South and South West Otago and urban streams.

Sites draining low elevation land generally had higher concentrations of nutrients (total nitrogen (TN), total phosphorus (TP), ammoniacal-N, and NNN), bacteria and suspended solids (SS) than sites draining hill or mountainous country. Concentrations of analytes tended to be higher at sites with pastoral cover rather than tussock cover, similarly suspended solids and turbidity were higher with pastoral land cover.

Principal Components Analysis, which tests 12 water quality analytes, provided similar spatial results to that found by the WQI classification. The poorest quality sites were generally small streams or drains in agriculturally intensive or urban catchments. The worst sites were the Washpool, Main Drain, Wairuna Stream, Lindsay's Creek, Heriot Burn, Crookston Burn, Waiareka Creek and the Owhiro Stream.

The findings are consistent with the assumption that the effects of intensive farming (pastoral land cover) and urban areas pose risks to fresh water quality and aquatic ecosystems through nutrient contamination, microbial contamination and sediment impacts (reduced water clarity).

#### **Water quality: trends over time**

The sites with few trends and generally excellent water quality are the outlets of the large lakes in Central Otago (Wakatipu, Dunstan, Wanaka, Hawea) and the upper catchments of the larger rivers (Taieri at Stonehenge, Manuherikia at Blackstone Hill, Pomahaka at Glenken).

Improving water quality over time for most analytes were noticeable at only a small number of the sites, including the Taieri at Allanton (which had improved due to the closure of Mosgiel waste water treatment plant) and the Main Drain in the lower Taieri Plain (which has improved due to the cessation of direct discharge of dairy effluent to the drains).

The sites with a trend of declining water quality tended to be the smaller streams in agriculturally intensive catchments; the tributaries of the Pomahaka River stand out as some of the worst sites (Washpool, Wairuna Stream, Heriot Burn, Crookston Burn), particularly with regard to increasing trends in nutrient concentrations.

#### **Ecosystem health**

Macroinvertebrate communities indicating good ecosystem health were found at many sites draining hill country. However, there were varying land uses ranging from exotic forest (Akatore Stream), tussock (Taieri River at Stonehenge) and pasture (Catlins and Waipori Rivers). The highest score was the Catlins River which has a large catchment of native bush and tussock immediately upstream.

The sites with macroinvertebrate communities indicating poor ecosystem health were located predominantly on low elevation sites, with the land use being either pasture or urban. The exception to this is Horne Creek in Queenstown, which has a low MCI score due to a mobile bed which is often disturbed by heavy rain.

Periphyton communities were also indicative of good ecosystem health at the majority of sites. However, smaller tributaries draining intensively farmed areas often had excessive accumulations of algae that prefer eutrophic waters.

### **Regional Plan: Water**

The Regional Plan: Water (RPW) has an objective to maintain or enhance the quality of water in Otago's lakes and rivers so that it is suitable to support their natural and human use values and people's use of that water. Specific sites are identified in the Regional Plan. The results of the water quality analysis were used to assess whether the policies were being met at these sites.

- **Policy 7.6.1** *To enhance the water quality in ten stated water bodies so that they become suitable to support primary contact recreation.*

Only one of the ten sites (Lake Hayes) meets the target of <260 *E. coli*/100ml on every occasion. Eight of the sites had more than 50% non compliance with this target value; of these sites the Water of Leith, an urban stream in Dunedin, is subject to intermittent pollution from stormwater. The other streams all drain low elevation country where agricultural activities are intensive.

- **Policy 7.6.2** *To enhance water quality at ten stated sites so that the Macroinvertebrate Community Index increased.*

The majority of the sites have poor MCI grades, but at the same time water quality is good or very good at most of the sites monitored. A key component of the MCI index is the availability of suitable habitat. The MCI index is designed specifically for stony riffle substrates in flowing water. MCI values can vary due to the availability of suitable habitat and not necessarily due to water quality.

- **Policy 7.6.3** *To enhance water quality in five stated lakes so that the aquatic ecosystem is enhanced.*

Two of the sites exceeded the ANZECC 2000 trigger value for Total Nitrogen (Lake Johnson and Lake Tuakitoto), and three of the sites exceeded the ANZECC 2000 trigger value for Total Phosphorus (Lake Tuakitoto, Lake Waipori and Lake Waihola).

### **Intensive farming and the impact on water quality**

It is recognised nationally that intensification of land use has an adverse impact on water quality. A section of the report looked at known areas of intensive farming and the water quality of the local waterways. The link between land use change (for example, from low intensive sheep to dairy farming) and water quality trends was examined using three case studies, each representing a broadly similar area of Otago.

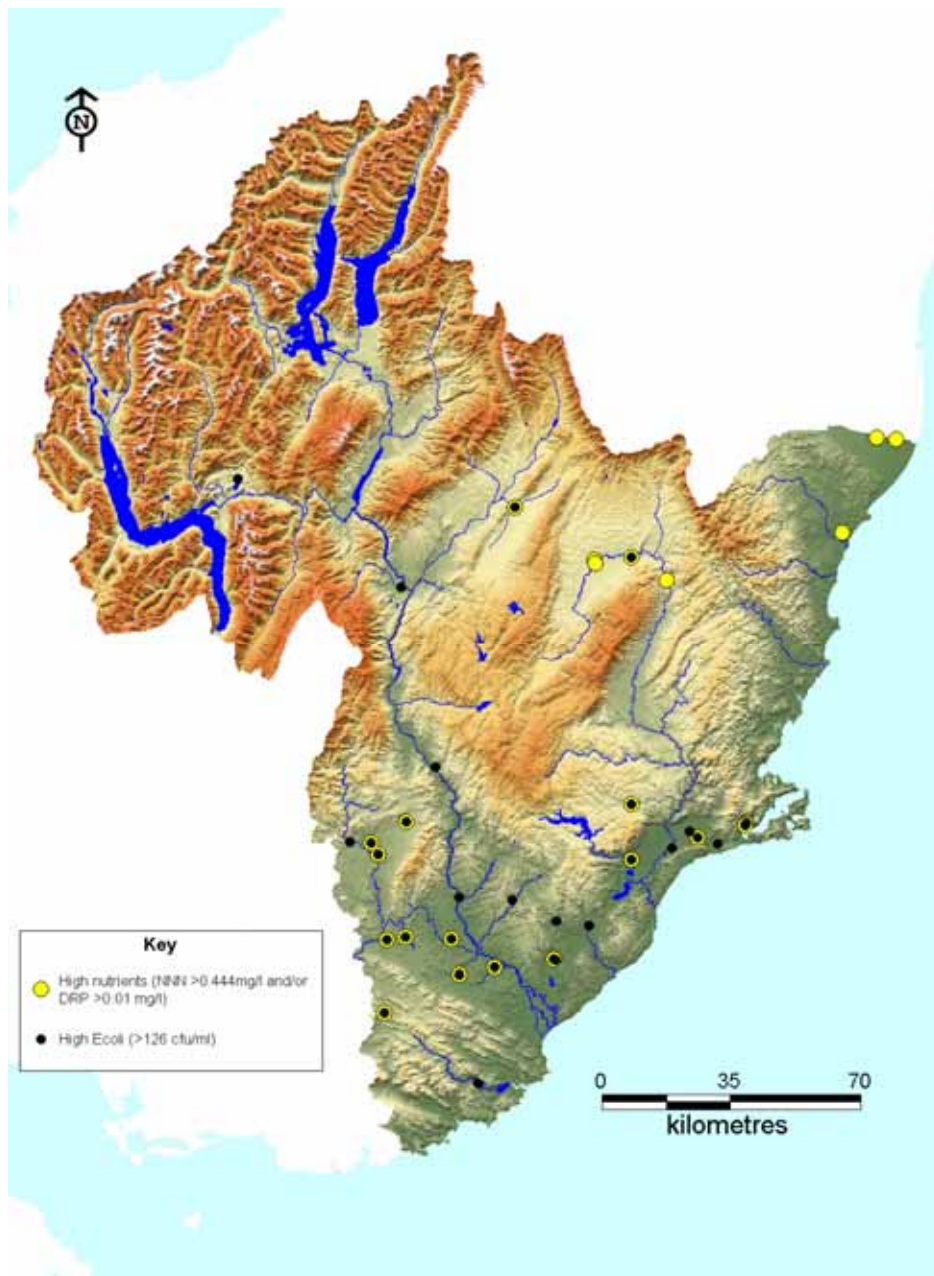
From the WQI, other Spatial Analyses and the Case Studies, it could be seen that the areas at greatest risk of poor water quality are in South and South West Otago, where there is a predominance of intensive dairy farming. A major factor contributing to declining water quality in these areas, particularly increasing nitrogen and bacteria levels, is likely to be the mole and tile drainage network which is a prerequisite for farming in these areas. However, there are still higher risks for poor water quality associated with any form of intensification, wherever it occurs.



**Figure E. 1 Water quality index classification for SOE sites monitored between January 2000 and June 2006**

**Table E. 1 Water Quality Index Classification Variables**

Classification	Definition
Very good	Median values for all six variables comply with guideline values.
Good	Median values for five of the six variables comply with guideline values (DO is one variable which must comply).
Fair	Median values for three or four of the six variables comply with guideline values (DO is one variable which must comply).
Poor	Median values for two or less of the six variables comply with guideline values.
<b>WQI variables</b>	
Turbidity	Caused by suspended matter and interferes with the passage of light through water
DO	Important indicator of the ability of water to support aquatic life
DRP	A growth-limiting nutrient. Affected by e.g. wastewater effluent, fertilisers and animal waste
NH <sub>4</sub>	Can be toxic to fish depending on temperature and pH conditions. Affected by runoff of animal wastes, dairy shed effluent and fertiliser
NNN	Nutrient essential for growth. Affected by e.g. wastewater effluent, agricultural runoff and animal wastes
<i>E. coli</i>	Indicator of faecal contamination. Affected by e.g. wastewater effluent, animal waste, sediment load



**Figure E. 2** Fair and poor sites from the WQI classification showing the sites with high nutrient levels (NNN and DRP) and *E. coli*

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## 1. Introduction

Otago generally enjoys high quality water which provides opportunities for varied use, including recreation, industry, energy, domestic and public water supply and irrigation. It also sustains indigenous flora and fauna, trout and salmon, and contributes to the amenity values and natural character of Otago's lakes and rivers.

The Otago Regional Council (ORC) is responsible for promoting the sustainable management of Otago's lakes, rivers and coastal areas, and undertakes a surface water quality monitoring programme to fulfil its responsibilities under the Resource Management Act (1991), the Regional Policy Statement and the RPW.

The State of the Environment (SOE) monitoring programme involves regular monitoring of physico-chemical and microbiological water quality in selected lakes, rivers and streams. Biological monitoring is also undertaken annually. This monitoring is important because it helps the ORC gauge the state of the region's rivers and streams, it provides feedback on the effectiveness of policies in the RPW, and it enables informed decision making on how water resources are managed.

This report summarises results from the council's SOE surface water quality programme. The primary objectives were to:

1. Assess the state of water quality in the region's rivers spatially, by comparing results to national water quality guidelines, using the Water Quality Index (WQI).
2. Compare water quality at all sites using the River Environment Classification system (REC).
3. Assess the state of water quality by looking at individual analytes and linking results to WQI and REC.
4. Identify any significant trends in water quality, and detect reasons for these trends.
5. Assess the results of macroinvertebrate monitoring (both spatial and temporal).

The reporting period for the first three objectives was between January 2000 and June 2006. The reporting period for the fourth objective was between January 1995 and June 2006.

## **2. Background information**

### **2.1 Otago's rivers**

Otago's distinctive character is derived from its lakes, rivers and wetlands. The character of the region's water bodies is diverse, reflecting the variation in environmental conditions throughout the region.

The Clutha River/Mata-Au drains much of the Otago region; its catchment area totals 21,000 square kilometres and 75% of the total flow of the Clutha River/Mata-Au at Balclutha results from the outflows of Lakes Hawea, Wanaka and Wakatipu. Larger rivers feeding into the Clutha Catchment include the Cardrona, Lindis, Shotover, Nevis, Fraser, Manuherikia, Teviot, Pomahaka, Waitahuna and Waiwera.

The Clutha River/Mata-Au and its principal tributary, the Kawarau River, pass through gorges, two of which are dammed for hydro-electricity generation. One of the larger tributaries of the Clutha River/Mata-Au in its lower reaches is the Pomahaka River, which rises in the mountains above Tapanui.

The second largest catchment in Otago is that of the Taieri River (5060 square kilometres). It rises in the uplands of Central Otago and meanders among the block mountain ranges before passing through an incised gorge and crossing the Taieri Plain. There it joins the waters of the Lake Waipori and Waihola Catchments and becomes tidal before making its way through another gorge to the sea at Taieri Mouth.

Other significant Otago rivers drain the coastal hills in catchments of varying character. In the north, the Kakanui, Waianakarua, Shag and Waikouaiti Rivers rise in high country and pass through predominantly dry downlands. The Tokomairiro River, which flows through Milton to the south of Dunedin, drains rolling country between the Taieri and Clutha Catchments. Rivers to the south of Otago, particularly the Catlins area, emerge from wetter, often forested hills.

The environmental context in which Otago's water bodies exist is characterised by high rainfall in the Southern Alps, and occasional very low rainfall in the semi-arid Central Otago valleys. Despite the generally large water volumes present in the region, some parts of Otago are among the driest areas in New Zealand. Several rivers in Otago are characterised as being water-short, including the Lindis, Manuherikia, Taieri, Shag and Kakanui Rivers and tributaries (RPW 2004).

### **2.2 Water quality guidelines**

Most of the guidelines used in this report are the Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) default trigger values for aquatic ecosystems (referenced as ANZECC 2000).

**Table 2.1 Summary of physico-chemical and microbiological analytes and guideline values**

Analyte	Abbreviation	Guideline Value	Reference
Ammoniacal nitrogen	NH <sub>4</sub>	≤0.9	ANZECC & ARMCANZ (2000)
Nitrite/nitrate nitrogen	NNN	≤0.444	ANZECC & ARMCANZ (2000)
Total nitrogen	TN	≤0.614	ANZECC & ARMCANZ (2000)
Dissolved reactive phosphorus	DRP	≤0.01	ANZECC & ARMCANZ (2000)
Total phosphorus	TP	≤0.033	ANZECC & ARMCANZ (2000)
Water temperature	Deg C	<20	-
Dissolved oxygen	DO	≥80	RMA 1991 Third Schedule
<i>Escherichia coli</i>	<i>E. coli</i>	≤126	Department of Health 1992
<i>Escherichia coli</i>	<i>E. coli</i>	≤260	Acceptable MfE/MoH (2003)
		260-550	Alert MfE/MoH (2003)
		>550	Action MfE/MoH (2003)
pH	pH	6.5-9.0	ANZECC (1992)
Conductivity	Cond	-	-
Turbidity	Turb	≤5.6	ANZECC & ARMCANZ (2000)

These trigger values are intended to be compared with the *median* values over a period of time. They are not statutory standards and exceedences do not necessarily mean an adverse environmental effect would result, but act as an early warning mechanism of potential problem or a change in water quality that may warrant investigation.

The ANZECC (2000) guidelines provide different trigger values for New Zealand upland (>150m altitude) and lowland ecosystems. While Otago's SOE monitoring programme encompasses both upland and lowland sites, only the lowland trigger values were used in the assessment of compliance with water quality guidelines, as generally water quality in upland areas is of high quality and meets the more stringent guidelines.

The best reference conditions or guideline values are set by locally appropriate data. The ANZECC (2000) guidelines therefore recommend deriving site-specific trigger values for different catchments where possible, using a minimum of two years of water quality results from continuous monthly sampling (24 samples) from appropriate reference sites.

Appendix 1 gives details of freshwater ecological parameters and their significance and Appendix 2 gives details of ORC and NIWA monitoring sites.

### 3. Water quality - spatial distribution

The state of water quality at 77 sites was analysed to assess any spatial patterns present. Four methods were used and these are listed below.

- Water quality index (WQI)
- River environment classification system (REC)
- Hierarchical cluster analysis (HCA)
- Principal component analysis (PCA).

The two principal methods were the WQI and REC. The WQI assesses parameters from each site against national water quality guidelines (Table 2. 1), then uses median values of selected variables to derive the water quality index to enable a comparison between sites. The REC is used to explain key spatial patterns in water quality to back up the validity of the WQI, the HCA and PCA that were undertaken. The HCA was used to identify groups of sites with similar characteristics, and the PCA was used to help identify the characteristics that separated each group of sites.

#### 3.1 Water quality index (WQI)

The WQI was used to allow inter-site comparisons about the state of water quality in Otago's rivers and streams.

The WQI for each site was derived from the median values for the following six variables: turbidity, dissolved oxygen (DO) (% saturation), dissolved reactive phosphorus (DRP), ammoniacal nitrogen (NH<sub>4</sub>), nitrite/nitrate nitrogen (NNN) and *E. coli* bacteria. The median values were then assessed against national water quality guidelines (Section 2.2). This approach has been used elsewhere at both a regional level (e.g., Stark and Maxted 2004, Milne and Perrie 2006) and a national level (e.g., Larned et al. 2005).

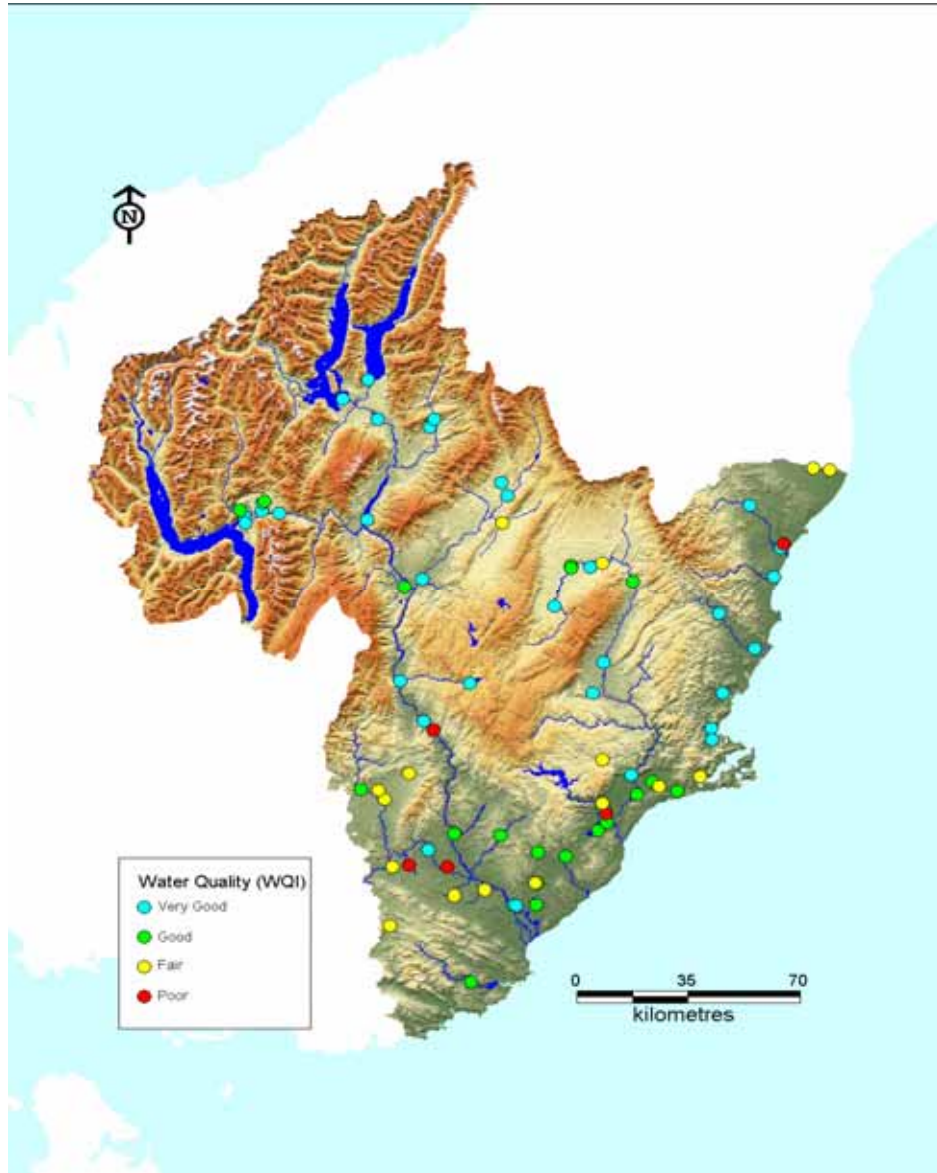
The application of the water quality index enables water quality at each site to be classified into one of four categories (Table 3. 1), to provide a snapshot of water quality in Otago between 2000 and 2006. The categories only indicate how many variables meet guideline standards. Appendix 3 goes into more detail by indicating which guidelines were exceeded, and it also ranks the sites in order of percentage compliance<sup>1</sup> with guideline values. For each parameter, the sites at the top of the list have the highest water quality. Those at the bottom of the list have the poorest water quality.

Of the 77 sites (including eight sites monitored by NIWA):

- 36 sites were classified as very good (blue dots in Figure 3. 1)
- 19 sites were classified as good (green dots in Figure 3. 1)
- 17 sites were classified as fair (yellow dots in Figure 3. 1)
- 5 sites were classified as poor (red dots in Figure 3. 1).

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<sup>1</sup> Percentage compliance is calculated by assessing individual results against guideline values. Then compliance is calculated by assessing the percentage exceedence of the relevant guideline value (for each analyte at each site).



**Figure 3.1** Water quality index classification for SOE sites monitored between January 2000 and June 2006

**Table 3.1 Water quality index classification (Section 2.2 details guideline values)**

Classification	Definition
Very good	Median values for all six variables comply with guideline values.
Good	Median values for five of the six variables comply with guideline values (DO is one variable which must comply).
Fair	Median values for three or four of the six variables comply with guideline values (DO is one variable which must comply).
Poor	Median values for two or less of the six variables comply with guideline values.
<b>WQI variables (a full discussion of each variable is given in Section 4 and Appendix 1)</b>	
Turbidity	Caused by suspended matter and interferes with the passage of light through water
DO	Important indicator of the ability of water to support aquatic life
DRP	A growth-limiting nutrient. Affected by e.g. wastewater effluent, fertilisers and animal waste
NH <sub>4</sub>	Can be toxic to fish depending on temperature and pH conditions. Affected by runoff of animal wastes, dairy shed effluent and fertiliser
NNN	Nutrient essential for growth. Affected by e.g. wastewater effluent, agricultural runoff and animal wastes
<i>E. coli</i>	Indicator of faecal contamination. Affected by e.g. wastewater effluent, animal waste, sediment load

Figure 3. 2 provides a further breakdown of the fair and poor WQI data, showing sites which failed in high bacteria levels (*E. coli* >126 cfu/ml) or had high nutrient concentrations (a combination of the DRP (>0.01 mg/l) and NNN (>0.444 mg/l) values). The other WQI variables were not shown because:

- Low DO values (an automatic poor categorisation) were only found at three sites; the Minzion Burn, Main Drain and Waiareka Creek. These are pastoral sites, with very slow moving water which reduces natural aeration.
- NH<sub>4</sub> results were within guideline values at all sites.
- High turbidity levels are often associated with high nutrients, or specific local conditions such as tidal areas, shallow lakes where resuspension occurs or in high natural erosion areas (e.g. the Shotover River).

The sites with the very good water quality were generally in the upper catchments of large rivers and the outlets from the large lakes. The poorest water quality categories (poor and fair) were predominantly located in South and South West Otago. These sites generally showed elevated bacteria and/or nutrient levels. Good water quality sites have five of the six WQI variables passing guideline values. At 12 of the 19 locations the failing variable was bacteria; eight of these sites were in South Otago.

The WQI spatial analysis clearly shows that the main area of concern is South West Otago and around Dunedin where small streams drain developed land (agriculture and urban), while the rivers draining the higher altitude and lesser developed areas of Otago have excellent water quality. The main issues for water quality at these South and South West Otago sites are either high nutrient levels and/or high bacteria levels.

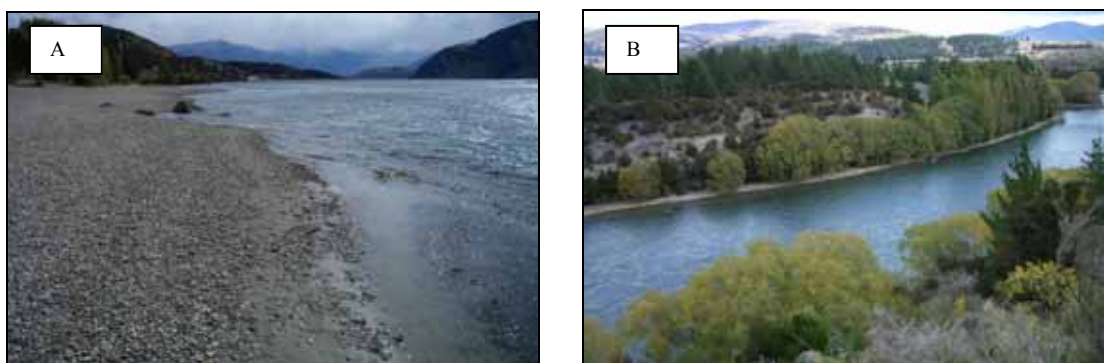
Each WQI classification is discussed more fully below.



**Figure 3.2** Fair and poor sites from the water quality index classification showing the sites with high nutrient (NNN and DRP), *E. coli* and low DO levels

### 3.1.1 Very good water quality

Very good water quality was seen at 36 sites throughout the region; Table 3. 1 defines these sites as complying with all six guideline values (Table 2. 1). Of these, 20 sites are at high or mountainous elevation, six originated from lakes, one is a lake site whose main catchment is exotic forest, tussock and farmland (Lake Waipori), five sites are on the main stem of the Clutha or Taieri Rivers, two others drain a catchment of mainly indigenous forest (Waitati, Careys Creek), and the others (Pig Burn and Shag at the Grange) have a mainly pastoral upstream catchment, but of low intensity farming.



**Figure 3.3 Very good water quality sites. (A) Lake Wanaka at outlet, ranked number 1, (B) Clutha River/Mata-Au at Luggate ranked number 4**

The site with the best water quality was Lake Wanaka, which achieved 100% compliance with the guideline values. Other sites which achieved >99% compliance were Lake Dunstan, Lake Hawea and the Clutha River/Mata-Au at Luggate.

### 3.1.2 Good water quality

Good water quality was seen at 19 sites, meaning that median values for five of the six variables comply with guideline values (including DO). Of these sites, eight were located in low elevation reaches, seven in hill country, two in mountainous regions and two had lake sources.

Median *E. coli* concentrations at 12 sites failed to meet the Department of Health (DoH) guideline of 126 *E. coli*/100ml. When the MfE/MoH green/acceptable mode level is applied (based on a limit of 260 *E. coli*/100ml per single sample), of the 12 sites that exceeded the DoH median guideline, two sites exceeded the MfE limit of 260 *E. coli*/100ml for 50% or more of the time. These sites were the Tokomairiro West Branch (54%) and Kaikorai Stream (65%).

Three sites exceeded the DRP guideline level (Gimmerburn, Taieri at Tiroiti and Taieri at Halls Bridge), and four sites exceeded the turbidity guideline level (Lakes Tuatikoko and Waihola, Shotover and Taieri at Henley Ferry).

Of the 19 sites, the Fraser River had the highest water quality with 92.9% compliance (this river is supplemented with water taken from the Clutha River/Mata-Au) and the Kaikorai Stream at Green Island had the poorest water quality with 68.8% compliance.



**Figure 3.4 Good water quality sites. (A) Fraser River at Marshall Road, ranked number 37, (B) Tokomairiro River at Lisnatunny, ranked number 46**

### 3.1.3 Fair water quality

Fair water quality was seen at 17 sites. Of these 17 sites, 13 were in low elevation and four were in hill country.

Fifteen of the sites had a median *E. coli* concentration that failed to meet the DoH guideline of 126 *E. coli*/100ml. Of these 15 sites, seven exceeded the MfE/MoH green/surveillance (260 *E. coli*/100ml per single sample) on more than 50% of occasions. The streams with the worst bacteria levels were Lindsay's Creek, failing on 94% of all sampling occasions, Crookston Burn at Kelso (75%) and Heriot Burn at Parkhill Kelso Road (71%).

The DRP guideline level was exceeded at 13 sites, 11 sites exceeded the NNN guideline level, and one site exceeded the turbidity guideline level.

Of the 17 sites, Ida Burn had the highest water quality with 78% compliance and Lindsay's Creek had the poorest water quality with 33% compliance.



**Figure 3.5 Fair water quality sites. (A) Lee Stream at SH87 ranked number 58, (B) Lindsay's Creek upstream of Leith, ranked number 72**

### 3.1.4 Poor water quality

Five sites were classified as having poor water quality. Of the five sites, the Minzion Burn, Waiareka Creek and Main Drain failed the DO classification and were automatically put in the poor category. However, all the sites other than the Minzion Burn are low elevation, hard sedimentary pastoral sites. The Wairuna and Washpool sites exceeded guideline levels for nutrients, bacteria and turbidity. The MfE/MoH green/surveillance (260 *E. coli*/100ml per single sample) was exceeded on 70% of occasions in the Washpool and on 83% of occasions in the Wairuna.



**Figure 3.6 Poor water quality sites. (A) Wairuna Stream at Waipahi/Clydesdale Road, ranked number 76, (B) Washpool Stream at Kilhastie Road, ranked number 77**

### 3.2 River Environment Classification System (REC)

The Ministry for the Environment, in conjunction with NIWA developed the New Zealand River Environment Classification (REC) system (Snelder et al., 2004). The REC system characterises river environments at six hierarchical levels, according to: (1) their climate, (2) source of flow, (3) geology, (4) land cover, (5) network position and (6) valley landform, and within each level are a series of categories that are used to describe reaches of rivers throughout New Zealand (Table 3. 2). This system allows sections of rivers that are similar with respect to these factors to be grouped together for management purposes.

Some REC categories are naturally linked; for example pastoral land cover is much more likely to be found in low elevation areas, and tussock is much more likely to be found in hill country. It is the effect of land cover that has the greatest bearing on water quality.

**Table 3. 2 REC classification levels, classes and criteria used to assign river segments to REC classes (from Snelder, 2004). Only the factors highlighted have been analysed in this section**

Factor	Climate	Code	Criteria
1. Climate	Warm extremely wet Warm wet Warm dry Cool extremely wet Cool wet Cool dry	WX WW WD CX CW CD	<i>Mean annual temperature:</i> Warm: $\geq 12^{\circ}\text{C}$ Cool: $\geq 12^{\circ}\text{C}$ <i>Mean annual effective precipitation:</i> Extremely wet: $\geq 1500\text{mm}$ Wet: 500 to 1500 mm, Dry: $\leq 500\text{mm}$
2. Source of Flow	Glacial mountain Mountain Hill Low elevation Lake Spring Regulated Wetland	GM M H L Lk Sp R W	<i>% permanent ice:</i> Glacial Mountain: $>1.5\%$ <i>Rainfall volume in elevation categories:</i> Mountain: $>50\%$ above 1000 m Hill: 50% between 400 to 1000 m Low elevation: 50% below 400 m <i>Lake influence index</i> <i>Others manually assigned</i>
3. Geology	Alluvium Hard sedimentary Soft sedimentary Volcanic basic Volcanic acidic Plutonic Miscellaneous	Al HS SS VB VA Pl M	<i>Spatially dominant geology category, unless:</i> Soft sedimentary $>25\%$ , then classified as sedimentary
4. Land cover	Bare Native forest Pastoral Tussock Scrub Exotic forest Wetland Urban	B IF P T S EF W U	<i>Spatially dominant land cover class, unless:</i> Pasture: $>25\%$ , then classified as pasture Urban: $>15\%$ then classified as urban
5. Network position	Low order Middle order High order	L M H	<i>Stream Order:</i> Low: 1 and 2 Medium: 3 and 4 High: $>5$
6. Valley landform	High gradient Medium gradient Low gradient	H M L	Valley slope: High: $>0.04$ Medium: 0.02 to 0.04 Low: $<0.02$

Sites in Otago were not classified according to climate as nearly all the sites have CD climates - there were only four sites with CW climates (Catlins at Houipapa, Shotover at Bowens, Waipahi at Cairns Peak and Water of Leith at Dundas Street). In this report, the effects of source of flow, land cover and stream order (network position) were analysed to show whether these variables had a significant effect on water quality. The results from stream order analysis are found in full in Appendix 5. Median values for each water quality parameter are calculated, then for each REC class the results are combined in order to show the range of values. Data have been summarised in box plot format (Figure 3. 7, Figure 3. 8 and Appendix 5). The box plot is used as it gives a quick impression of the magnitude of data, the amount of spread and the symmetry. A box encloses the middle 50% of data. The median is drawn as a vertical line inside the

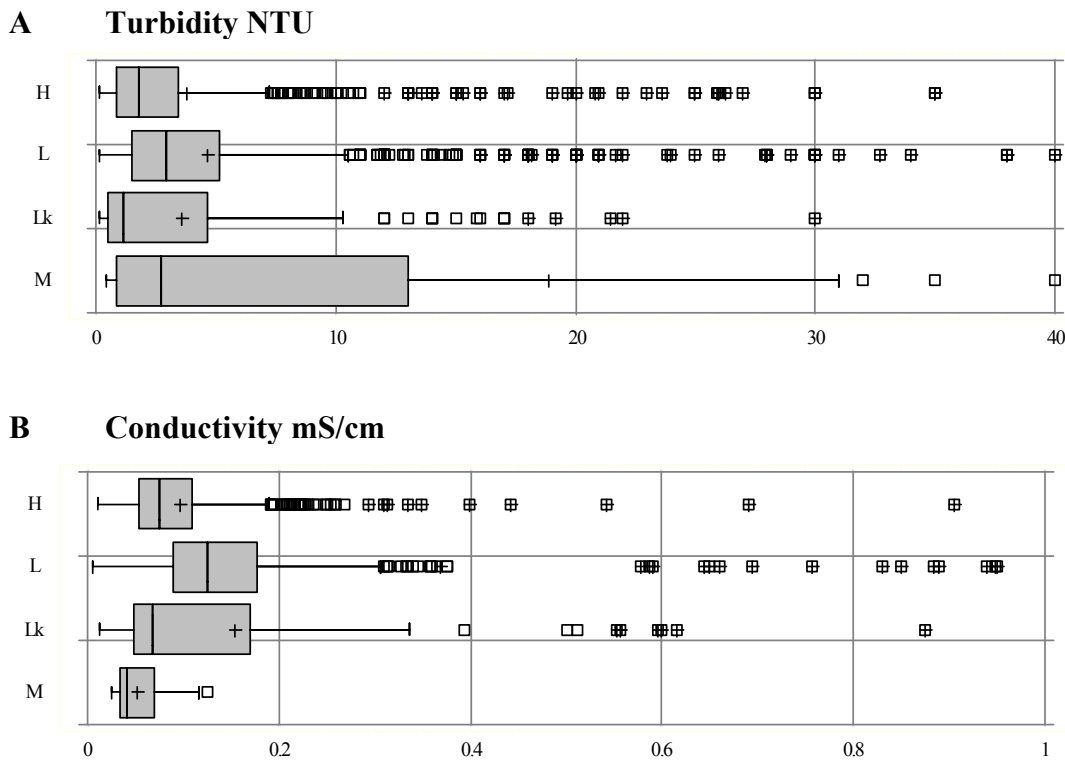
box. The mean is drawn as a cross, which tends to occur inside the box. Horizontal lines known as whiskers, extend from each end of the box. The left (or lower) whisker is drawn from the first quartile to the smallest point within 1.5 interquartile ranges from the lower quartile. The other whisker is drawn from the upper quartile to the largest point within 1.5 interquartile ranges from the upper quartile. Any individual values that fall beyond the whiskers (outliers) are shown as small squares.

**3.2.1 Results: Source of flow**

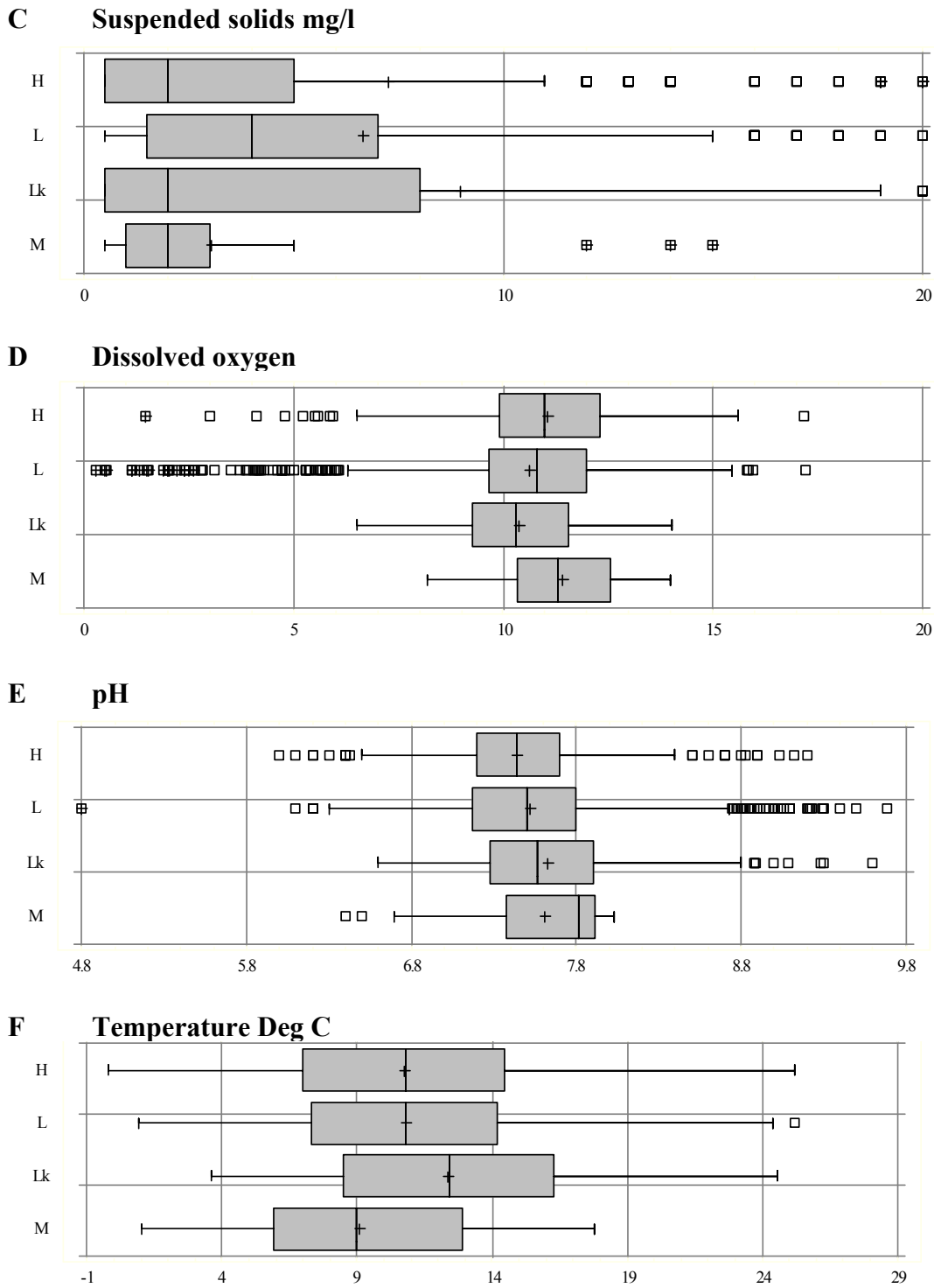
Box plots of analytes and source of flow are shown in Figure 3. 7. Source of flow has been divided into four categories: mountain (M), hill (H), lake (Lk) and low elevation (L). Turbidity was highest in the mountain class, however, this was purely due to the influence of the Shotover River, which is naturally turbid due to a combination of high rainfall and erosion. Otherwise, turbidity was highest and most variable in the low elevation class. Conductivity was highest in the low elevation class and lowest in the mountain class. The lake class has the highest median suspended solids (SS) and the mountain class the lowest.

DO was similar in all four classes, as was pH (median of hill class pH 7.44 and of mountain class pH 7.81).

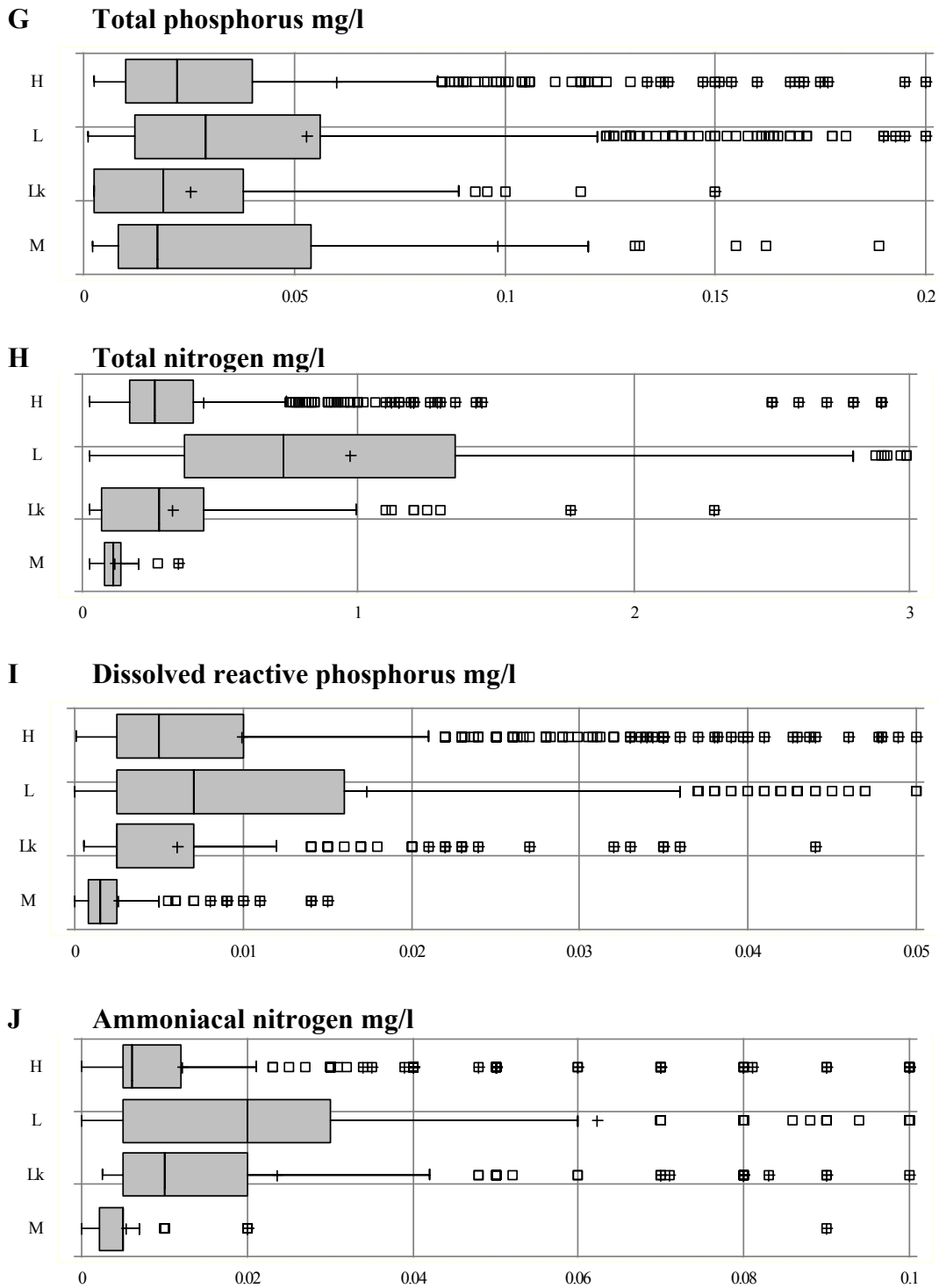
Low elevation country had elevated nutrients compared to the other classes. Total nitrogen (TN), NNN, ammoniacal nitrogen (NH<sub>4</sub>), total phosphorus (TP) and DRP were lowest in the mountain class. This was the same for *E. coli*, which was found in greater numbers in low elevation country than the other three sources, particularly the lake sources which recorded low numbers of the bacteria.



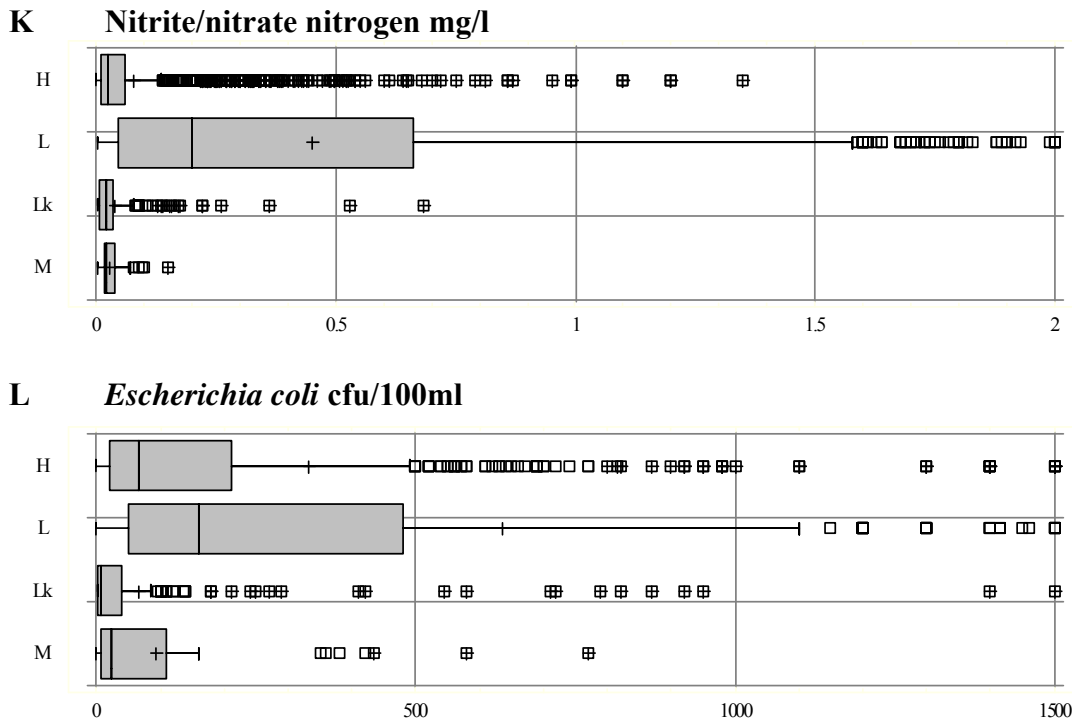
**Figure 3. 7 Comparison of median water quality parameters among REC source of flow classes (H = hill, L = low elevation, Lk = lake, M = mountain)**



**Figure 3. 7 continued Comparison of median water quality parameters among REC source of flow classes (H = hill, L = low elevation, Lk = lake, M = mountain)**



**Figure 3. 7 continued Comparison of median water quality parameters among REC source of flow classes (H = hill, L = low elevation, Lk = lake, M = mountain)**



**Figure 3. 7 continued Comparison of median water quality parameters among REC source of flow classes (H = hill, L = low elevation, Lk = lake, M = mountain)**

### 3.2.2 Results: Land cover

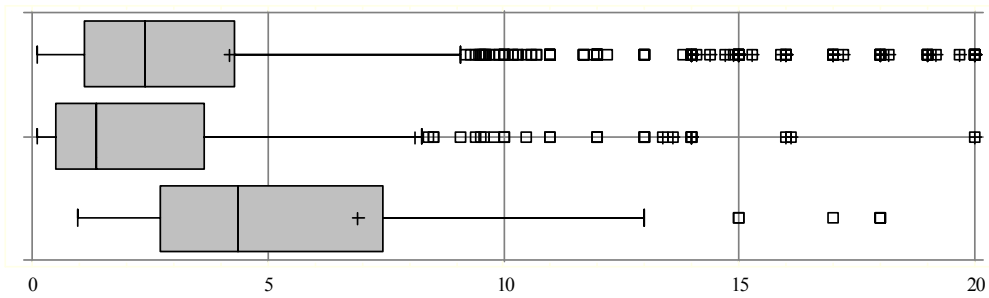
Box plots of analytes and land cover are shown in Figure 3. 8. Land use has been divided into three categories: pasture, tussock and urban.

Turbidity, SS and conductivity are most elevated in the urban catchments. DO and pH are lowest in the pasture catchments and highest in the urban catchments, however, DO has the greatest variability in the pasture catchments, as does temperature.

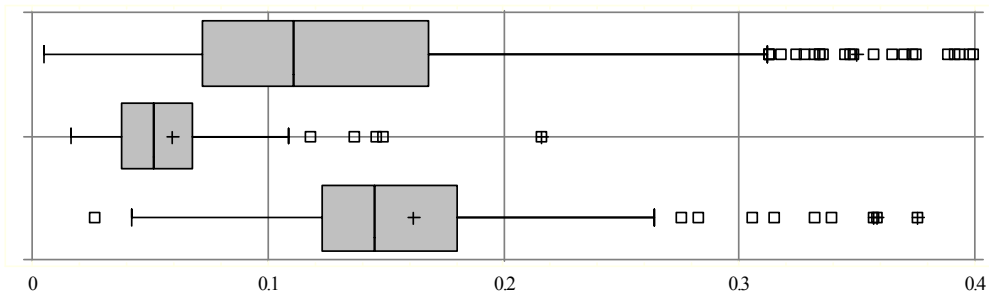
Nutrients are all low in tussock dominated catchments. TP is high in the urban catchments, as is TN.  $\text{NH}_4$  is higher in urban and pastoral catchments, and NNN is extremely elevated in urban catchments. DRP follows the same pattern, being elevated in urban and pastoral catchments.

*E. coli* is elevated in urban catchments with a median count of over 500 *E. coli*/100ml, while low counts are found in tussock. Pastoral land cover generates many outliers, but the median value is 100 *E. coli*/100ml.

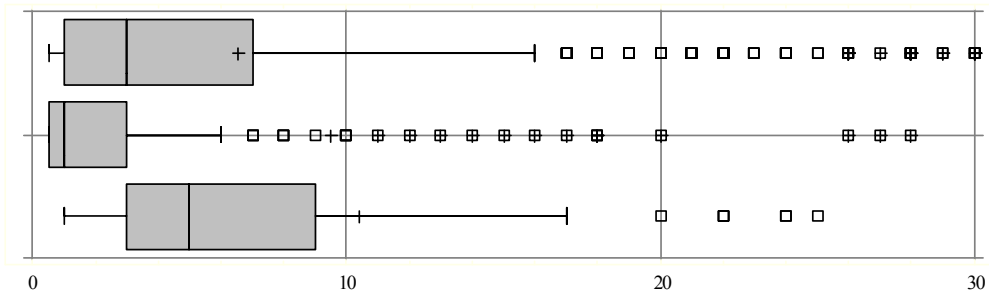
**A Turbidity NTU**



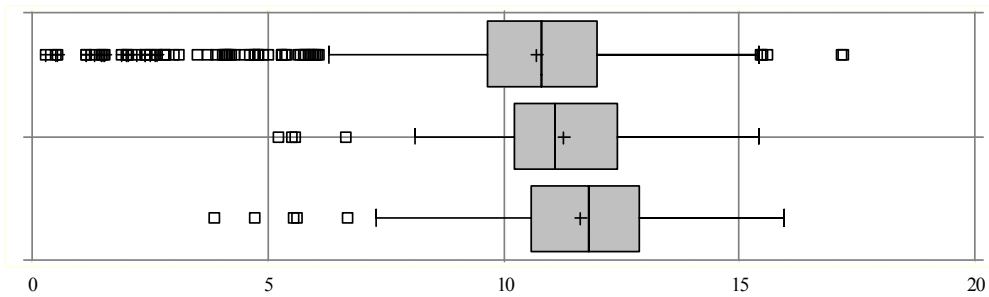
**B Conductivity mS/cm**



**C Suspended solids mg/l**

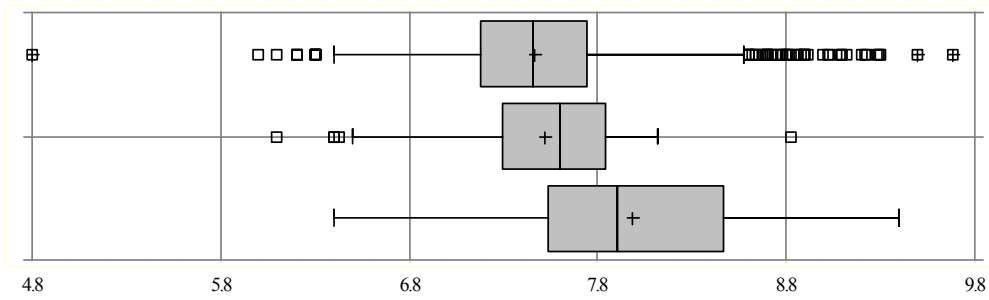


**D Dissolved oxygen mg/l**

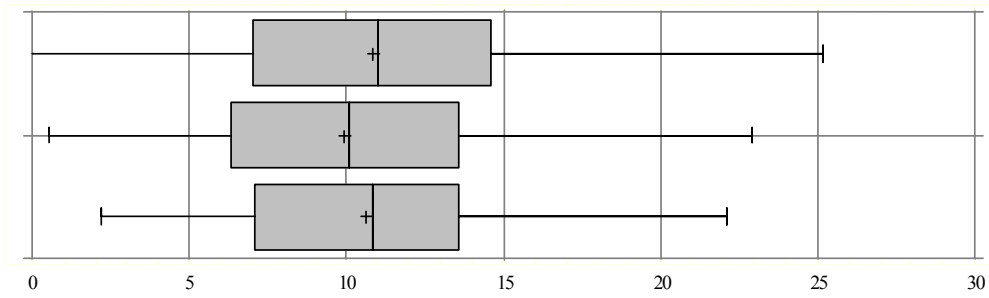


**Figure 3.8 Comparison of median water quality parameters among REC land cover classes (P = pasture, T = tussock, U = urban)**

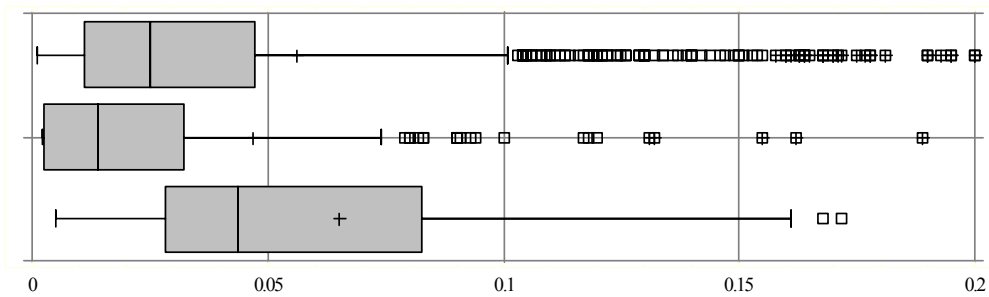
**E pH**



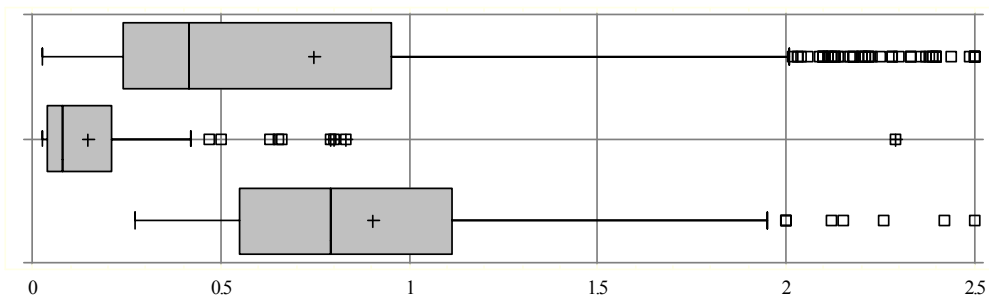
**F Temperature Deg C**



**G Total phosphorus mg/l**

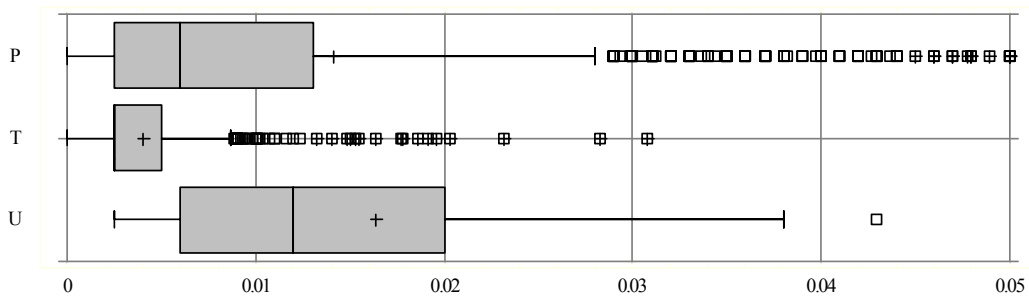


**H Total nitrogen mg/l**

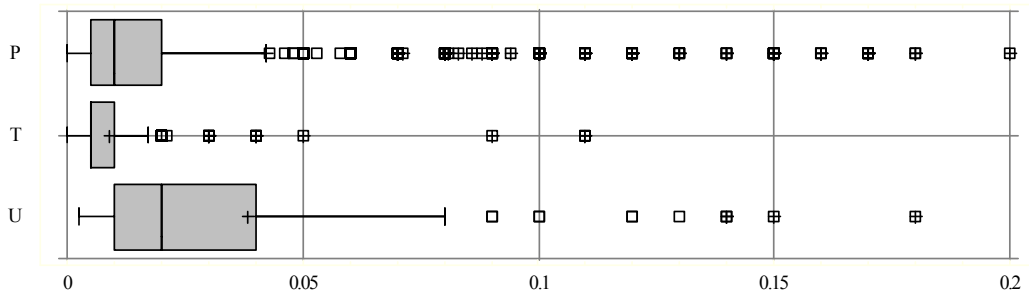


**Figure 3. 8 continued Comparison of median water quality parameters among REC land cover classes (P = pasture, T = tussock, U = urban)**

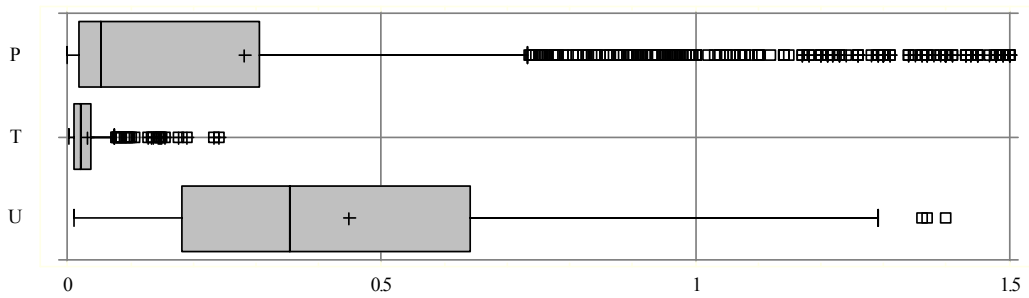
**I Dissolved reactive phosphorus mg/l**



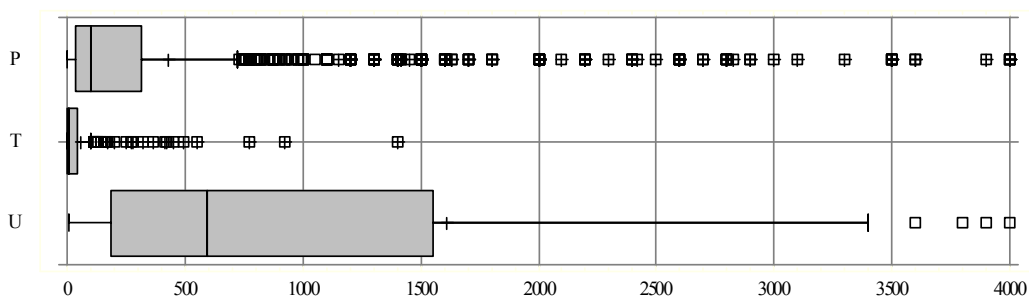
**J Ammoniacal nitrogen mg/l**



**K Nitrite/nitrate nitrogen mg/l**



**L Escherichia coli cfu/100ml**



**Figure 3. 8 continued Comparison of median water quality parameters among REC land cover classes (P = pasture, T = tussock, U = urban)**

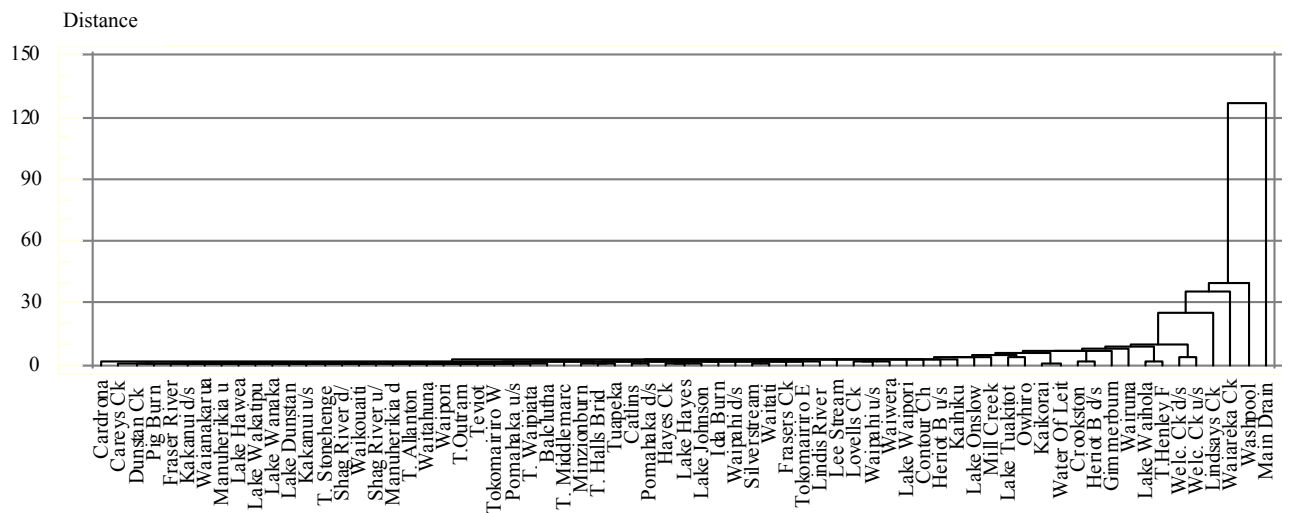
### 3.2.3 Results: Stream order

There are eight categories of stream order, with Stream Order 1 (SO1) representing the smallest waterway, and Stream Order 8 (SO8) representing the largest waterway.

Due to a limited range of sampling sites for SOE monitoring (particularly on SO1 and SO2 streams), a true stream order analysis was difficult. Available results are shown in Appendix 5, but no further comparisons are made.

### 3.3 Hierarchical cluster analysis (HCA)

To identify groups of sites with similar characteristics, an HCA was undertaken using all the water quality data. This technique calculates a distance between sites depending on their similarity in terms of water quality, i.e. the clusters are groups of observations with similar characteristics. All variables were log transformed to improve the normality of the data before analysis. The cluster analysis is shown in Figure 3. 9 and identified that for most sites there was a distance between sites of less than five. However, a small number of sites had a distance of more than thirty, including Lindsay’s Creek, Wairareka Creek, the Washpool and the Main Drain. The effect of the water quality at these sites being so different to other sites in Otago means that the groupings of all the other sites are not easily seen in Figure 3. 9.



**Figure 3.9 Hierarchical cluster analysis of SOE sites; a small number of sites mask the groupings**

### 3.4 Principal component analysis (PCA)

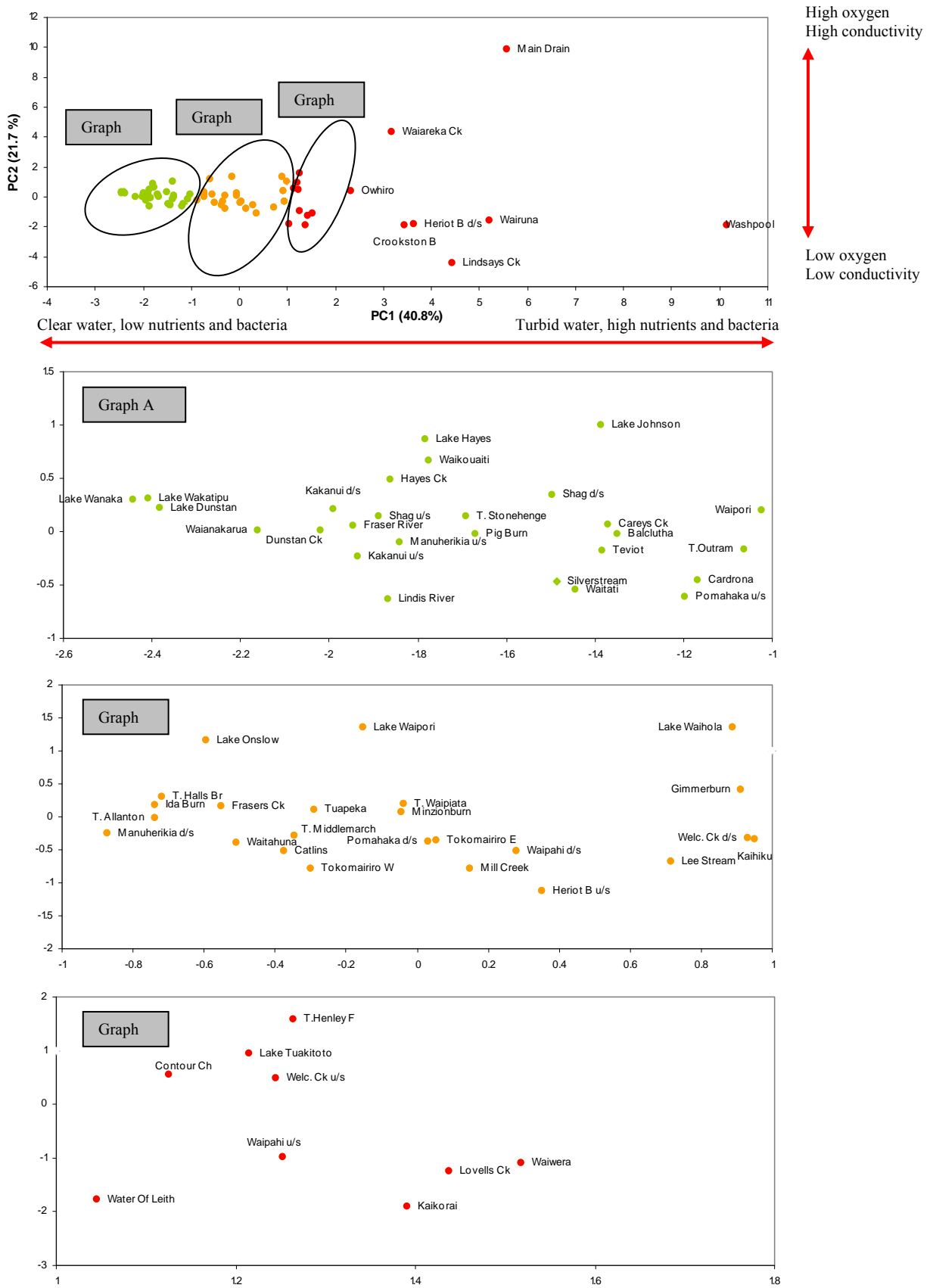
A PCA was then undertaken in order to obtain a small number of combinations of the 12 variables (water quality analytes) which account for most of the variability in data. Full details are given in Appendix 4. Variables that are highly correlated with each other are likely to be combined into one component. Five components were chosen which accounted for 91.2% of the variability in the original data.

The first principal component (PC1) explained 40.8% of the total variance in the data, and was highly correlated with nutrients and turbidity. The second principal component (PC2) explained 21.7% of the variability and was highly correlated with conductivity, DO and NH<sub>4</sub>. The two principal components were plotted and are shown in Figure 3. 10. Sites with similar characteristics are plotted closely together, whilst those with very different characteristics are plotted well apart.

The sites have been split into three groups (Figure 3. 10). The sites with poorer water quality (higher concentrations of nutrients and faecal indicator bacteria) are shown in red. These sites typically exceed water quality guidelines and most of the sites which lie to the extreme right of the graph are small streams draining lowland areas that are intensively drained for urban or agricultural use. These include the Main Drain, which drains the low lying Taieri Plain which is dominated by dairy farming, and the Washpool, a tributary of the Pomahaka which drains an intensive farming catchment in south west Otago. It is surprising that the upper Waipahi is in this grouping, and the lower Waipahi is classified as having better water quality.

The orange sites have water quality somewhere between the poorer red sites and the better green sites. The orange sites incorporate Lakes Waipori, Waiholo and Onslow, as well as large rivers (lower Taieri, Manuherikia, Pomahaka). The sites which sit towards the red end of Figure 3. 10 are smaller streams which drain areas used intensively for agriculture. However, Welcome Creek is spring-fed with naturally high nutrient levels, and the Gimmerburn is affected by irrigation run-off. The Catlins River is in this grouping, which is surprising as the catchment is heavily forested and it was expected to fall into the highest water quality category. The downgrading may be due to elevated bacteria levels influenced by agricultural activity immediately surrounding the sampling site.

The green sites have the highest water quality and include the Clutha main stem, the Central Otago Lakes (Wanaka, Wakatipu, Dunstan, Hawea, Hayes, Johnson), the upper Taieri, Manuherikia and Pomahaka, as well as smaller streams draining less intensively farmed areas.



**Figure 3. 10** Principal components analysis. The red sites depict poorer water quality, orange sites fair water quality and green sites good water quality

#### 4. Water quality (January 2000 to June 2006) – linking analyte results to WQI and REC

Water quality analysis was undertaken on samples taken by the ORC and NIWA between January 2000 and June 2006 (77 sites). Analytes were compared against guideline values (refer to Table 2. 1), and the percentage of samples that exceeded guideline levels were reported for selected sites.

The results are linked to both their REC class (refer to Table 3. 2) and their WQI grade (Appendix 3). Appendix 6 details the full results.

A full description on the physico-chemical and microbiological parameters is given in Appendix 1, however, a brief summary is also given at the start of each of the following sections.

##### 4.1 Water temperature

- Temperature controls the rate of metabolic and reproductive activities, determines which fish species can survive, affects the concentration of dissolved oxygen and can influence the activity of bacteria and toxic chemicals in water.
- Temperature is affected by the amount of riparian vegetation, the flow rate and any discharges (industrial or agricultural).

Water temperature exceeded 20°C at 27 of the 77 sites on at least one occasion during the reporting period (Appendix 6). However, the only sites to exceed 20°C for more than 5% of the time are listed in Table 4. 1.

**Table 4. 1 Sites that exceeded 20°C for more than 5 percent of the time**

Site	Median	% samples above guideline level	REC Category (Refer Table 3. 2)	WQI Grade
Main Drain at Waipori Pump	12.00	5.1	CD/L/AI/P	Poor
Contour Channel	11.26	5.4	CD/L/HS/P	Fair
Taieri at Waipiata	13.90	5.7	CD/H/HS/P	Good
Waianakarua at Browns Pump	11.53	8.8	CD/H/HS/P	Very Good
Lake Waipori at SE Corner	11.40	11.0	CD/L/AI/P	Very Good
Lake Waihola at Jetty	16.19	12.0	CD/Lk/HS/P	Good

The majority of the sites are located in lowland areas near the coast, with the exception of the Taieri at Waipiata which is low gradient, meandering and in an area that records high summer ambient temperatures. All the sites are predominantly pastoral and, as shown earlier in Figure 3. 7, pastoral sites generally have the highest maximum temperatures compared to those sites with scrub, tussock or urban cover. The sites with the most exceedences are lake sites with shallow beaches - the water at these sites heat comparatively quickly compared to a flowing river.

The lowest recorded median was recorded at the Cardrona River in Central Otago (7.3°C). The highest temperature recorded was 25.2°C taken at the Silver Stream at Riccarton Road on the Mosgiel Plain. This site has low flows and is a shallow uniform channel with little riparian cover.

#### 4.2 Dissolved oxygen

- DO is an important indicator of the ability of water to support aquatic life. DO enters the water by absorption directly from the atmosphere or by aquatic plant and algae photosynthesis. DO is removed from the water by respiration and decomposition of organic matter.
- DO is affected by the volume and velocity of water flowing in the water body, climate and season, the altitude, the amount of dissolved nutrients and suspended solids present and the number and type of organisms/plants in the water body.

The Third Schedule of the RMA 1991 states that DO levels should not fall below 6 mg/l, or 80% saturation. There were many gaps in the database for DO, but of the data available, no sites dropped below the 6 mg/l concentrations. However, three sites recorded levels below 80% saturation and these are detailed in Table 4. 2 (Main Drain, Waiareka Creek, Minzion Burn). Both sites drain intensive pastoral catchments - the Main Drain is often static, with excessive algal growth during the summer months and Waiareka Creek is a slow flowing stream, again with plenty of weed growth. Using the WQI, any site that fails to achieve 6 mg/l is automatically classified as poor.

The highest median oxygen levels were found in Lindsay's Creek and the Water of Leith in Dunedin, see Table 4. 2.

**Table 4. 2 Sites with the minimum and maximum dissolved oxygen levels**

Site	DO mg/l	% exceedence below guideline value	REC Category (Refer Table 3. 2)	WQI Grade
Main Drain at Waipori pump	63.20	32.25	CD/L/AI/P	Poor
Waiareka Ck at Teschmakers	68.00	28.57	CD/L/SS/P	Poor
Minzion Burn at Millers Flat	73.90	45.50	CD/H/HS/P	Poor
Water of Leith at Dundas St	106.90	100.00	CD/H/HS/T	Fair
Lindsay's Creek at N Road Br	109.30	100.00	CD/L/VB/U	Fair

Both watercourses are urban streams, but they have steep gradients originating in indigenous forest cover. The steep gradient allows for plenty of mixing. The Main Drain and Waiareka Creek are low gradient watercourses with slow flowing water and little natural mixing. The Minzion Burn is also slow flowing at the point of sampling, as the Clutha River/Mata-Au water backs up.

### 4.3 pH

- Changes in the pH value of water affect the organisms that live there. Most aquatic organisms have adapted to a specific pH and may die if even slight pH changes occur. Serious problems occur when pH drops below 5 or increases above 9.5.
- pH is affected by carbon dioxide, geology and soils of the catchment, mine drainage, algal blooms and air pollution.

The median value of all 77 sites fell between pH 6.5 and pH 9.0. The minimum pH fell below 6.5 at 28 sites, but the maximum pH rose above pH 9.0 at 12 sites. Three sites recorded more than pH 9.5 (Lake Johnson, Kaikorai Stream and Waipahi at Waipahi). Of the 29 sites that recorded pH below 6.5, there was a fairly even split between hill and low elevation sites, although the majority of sites (22) were pastoral.

### 4.4 Turbidity

- Turbidity in water is caused by suspended matter such as clay, silt, and organic matter and by plankton and other microscopic organisms that interfere with the passage of light through the water.
- Turbidity is affected by high flow rates, soil erosion, urban run-off, wastewater effluent, decaying plant and animal matter, bottom feeding fish and algal blooms.

The ANZECC (2000) trigger value for turbidity is 5.6NTU. Of the 77 sites, seven had median values above the trigger value. Two of these are shallow lakes (Waihola and Tuakitoto), two are tidal (Taieri at Henley Ferry and Lake Waihola), one is naturally high in sediment (Shotover), and the other three (Washpool, Wairuna and Owhiro) have low flows and drain low lying intensive pastoral or urban catchments.

**Table 4.3 Sites with a median turbidity greater than 5.6 NTU for more than 50% of results. Shaded cells represent tidal sites**

Site	Median	% samples above guideline level	REC Category (Refer Table 3. 2)	WQI Grade
Lake Waihola	6.03	51.4	CD/Lk/HS/P	Good
Taieri at Henley Ferry	6.10	60.9	CD/Lk/HS/P	Good
Lake Tuakitoto	6.50	50.0	CD/L/HS/P	Good
Owhiro Stream	7.26	71.8	CD/L/AI/U	Fair
Wairuna Stream	9.70	100.0	CD/L/HS/P	Poor
Shotover River	9.80	61.8	CW/M/HS/T	Good
Washpool Stream	14.50	95.0	CD/L/SS/P	Poor

Seventeen sites had very good median turbidity levels of less than 1 NTU. The source of ten of these sites originated from either hill country, lake or mountainous areas, and of these, six sites were the Central Otago lakes (Wakatipu, Wanaka, Hawea, Dunstan, Hayes, Johnson).

#### 4.5 Conductivity

- Conductivity increases with the number of ions in the water. These may be naturally occurring minerals (chlorides, sulphates, carbonates, sodium, magnesium, calcium and potassium), or there could be contaminants that are in the water as a result of human activities.
- Conductivity is affected by geology and soils, land use, urban development, industrial development, flow, run-off, groundwater inflows, temperature, evaporation and dilution.

There is no guideline level for conductivity. Those sites with a median conductivity >0.2mS/cm are shown in Table 4. 4. Three of the sites with the highest conductivity correspond to sites with high median turbidity (Washpool, Taieri at Henley and Lake Waihola). The other sites are all low elevation pastoral sites. Three of the sites are tidally influenced - these are shaded in grey in Table 4. 4.

**Table 4. 4 Sites with a median conductivity greater than 0.2mS/cm**

Shaded cells represent sites with a tidal influence.

Site	Median	REC Category (Refer Table 3.2)	WQI Grade
Washpool Stream	0.221	CD/L/SS/P	Poor
Careys Creek	0.2467	CD/L/SS/P	Very Good
Lake Waihola	0.575	CD/Lk/HS/P	Good
Lake Waipori	0.590	CD/L/Al/P	Very Good
Taieri Henley Ferry	0.633	CD/Lk/HS/P	Good
Waiareka Creek	1.267	CD/L/SS/P	Poor
Main Drain	3.225	CD/L/Al/P	Poor

The sites with low conductivity (<0.05 mS/cm) were all hill country sites (Lake Onslow, Teviot River, Taieri River at Stonehenge, Manuherikia River at Blackstone Hill, Waipori River, Minzion Burn and Sutton Stream). All the sites had hard sedimentary geology, three had tussock land cover and four had pastoral land cover.

#### 4.6 Nitrite/Nitrate Nitrogen

- Nutrients are essential for growth. Additional algae and other plant growth due to the nutrients may be beneficial up to a point, but may easily become a nuisance. NNN is the nitrogen actually available for growth - NNN better reflects bioavailability than TN.
- NNN is affected by wastewater effluent, agricultural run-off, animal waste, fossil fuels and industrial discharges.

Figure 3. 8 showed that even though pastoral land cover does not produce the highest average NNN, it produces many outliers. Figure 3. 8 shows that low elevation sites have elevated NNN levels compared to other sources, and Appendix 5 shows that the lower order streams monitored in Otago generally have higher concentrations of NNN.

The ANZECC (2000) trigger value for NNN is 0.444 mg/l. Fourteen of the sites had median values above this trigger level. The sites with median values above 0.9 mg/l (which is the NH<sub>4</sub> guideline level) are listed in Table 4. 5. All the sites are in intensive pastoral catchments. Of the six sites, four are of low elevation, and Welcome Creek (upstream and downstream sites) is a spring fed stream with naturally high nitrogen levels.

**Table 4. 5 Sites with a median level of NNN greater than 0.9 mg/l**

Site	Median	% samples above guideline level	REC Category (Refer Table 3. 2)	WQI Grade
Waipahi River	0.92	81.5	CD/L/SS/P	Fair
Wairuna Stream	0.97	80.0	CD/L/HS/P	Poor
Heriot Burn at PK Rd	0.99	90.9	CD/L/HS/P	Fair
Welcome Creek d/s	1.28	97.5	CD/Sp/AI/P	Fair
Crookston Burn	1.3	82.1	CD/L/AI/P	Fair
Welcome Creek u/s	1.68	100	CD/Sp/AI/P	Fair

Sites with very low median NNN levels (<0.01 mg/l) are sourced from hill country or lakes, have a hard sedimentary geology, and are equally distributed between tussock and pastoral land cover. The WQI grade indicates that all the streams with high NNN are classified in the fair or poor categories.

#### 4.7 Ammoniacal nitrogen

- Ammonia refers to two chemical species which are in equilibrium in water (NH<sub>3</sub>, un-ionized gas and NH<sub>4</sub><sup>+</sup>, ionized). The toxicity of ammonia is primarily attributable to the un-ionized form as opposed to the ionized. In general, more NH<sub>3</sub> and greater toxicity exists at higher pH and higher temperature.
- Ammonia is affected by runoff of animal wastes and fertilisers from farm land, the discharge of sewage effluents, dairy shed effluents and food-processing wastes such as those from freezing works. Ammonia also comes from the bacterial breakdown in water of organic matter that contains nitrogenous material.

An ammoniacal nitrogen value of 0.9 mg/L (at pH 8, 20 °C) has been suggested as a high reliability (95 %) trigger value for freshwater (ANZECC 2000). No sites exceeded this concentration. The sites with median NH<sub>4</sub> concentrations >0.05mg/l are listed in Table 4. 6.

**Table 4. 6 Sites with a median ammoniacal nitrogen concentrations greater than 0.05 mg/l**

Site	Median	REC Category (Refer Table 3.2)	WQI Grade
Contour Channel	0.05	CD/L/HS/P	Fair
Wairuna Stream	0.05	CD/L/HS/P	Poor
Washpool Stream	0.09	CD/L/SS/P	Poor
Main Drain	0.42	CD/L/AI/P	Poor

Two of these sites are drains on the Taieri Plain (Contour Channel and Main Drain). There is little flow in the watercourses and the area drained is predominantly intensive pastoral, as are the catchments for the Wairuna and Washpool Streams. The WQI classifies all of the sites with high  $\text{NH}_4$  as either fair or poor.

#### 4.8 Total nitrogen

- Nitrogen is required by all organisms for the basic processes of life to make proteins, to grow, and to reproduce. Nitrogen is very common and found in many forms. Inorganic forms include nitrate ( $\text{NO}_3$ ), nitrite ( $\text{NO}_2$ ), ammonia ( $\text{NH}_3$ ), and nitrogen gas ( $\text{N}_2$ ). Organic nitrogen is found in the cells of all living things and is a component of proteins, peptides, and amino acids.
- TN is affected by wastewater effluent, agricultural run-off, animal waste, fossil fuels and industrial discharges.

Figure 3. 7 showed that low elevation sites produce the highest median concentrations of TN, and Figure 3. 8 indicates that pastoral and urban catchments are likely to have higher concentrations of TN than scrub and tussock catchments.

The ANZECC 2000 trigger value for TN is 0.614 mg/l. At 22 sites the median concentrations was above this trigger value. The sites with a median concentrations  $>1.0$  mg/l are listed in Table 4.7.

**Table 4. 7 Sites with median concentrations of TN greater than 1.0 mg/l**

Site	Median	% samples above guideline value	REC Category (Refer Table 3. 2)	WQI Grade
Kaihiku Stream	1.050	65.1	CD/L/SS/P	Fair
Lovells Creek	1.060	85.3	CD/L/HS/P	Fair
Lindsay's Creek	1.105	91.2	CD/L/VB/U	Fair
Waiwera River	1.230	77.4	CD/L/SS/P	Fair
Waipahi River	1.370	72.1	CD/L/SS/P	Fair
Heriot Burn	1.410	97.4	CD/L/HS/P	Fair
Welcome Creek d/s	1.535	97.5	CD/L/AI/P	Fair
Wairuna Stream	1.650	100	CD/L/HS/P	Poor
Welcome Creek u/s	1.790	97.5	CD/L/AI/P	Fair
Crookston Burn	1.850	89.2	CD/L/AI/P	Fair
Main Drain	2.100	100	CD/L/AI/P	Poor
Washpool Stream	2.330	100	CD/L/SS/P	Poor

Most of these sites have been mentioned in the  $\text{NH}_4$  and NNN sections. They are all of low elevation with a pastoral land cover. The only exception is Lindsay's Creek, which is an urban stream in Dunedin.

#### 4.9 Dissolved reactive phosphorus

- DRP is a measure of orthophosphate, the filterable (soluble, inorganic) fraction of phosphorus, which is directly taken up by plant cells. Phosphorus is often found to be the growth-limiting nutrient, because it occurs in the least amount relative to the needs of plants.
- DRP is affected by wastewater effluent, fertilisers, animal waste, urban development and industrial discharges.

The ANZECC (2000) trigger value for DRP is 0.01 mg/l. At 19 sites, the median concentration was above this trigger value, these sites are listed in Table 4. 8.

**Table 4. 8 Sites with median concentrations of DRP greater than 0.01 mg/l**

Site	Median	% samples above guideline value	REC Category (Refer Table 3. 2)	WQI Grade
Taieri Halls Br	0.011	52.1	CD/H/HS/P	Good
Taieri Waipiata	0.011	55.9	CD/H/HS/P	Good
Ida Burn	0.012	68.4	CD/H/HS/P	Good
Water Of Leith	0.013	58.3	CW/L/VB/U	Fair
Lee Stream	0.014	70.0	CD/H/HS/P	Fair
Waiwera River	0.015	68.85	CD/L/SS/P	Fair
NIWA Tiroiti	0.015	76.1	CD/H/HS/P	Good
Heriot Burn PK	0.016	80.5	CD/L/HS/P	Fair
Crookston Burn	0.017	84.6	CD/L/AI/P	Fair
Contour Ch	0.018	75.7	CD/L/HS/P	Fair
Owhiro Stream	0.018	62.5	CD/L/AI/U	Fair
Welcome Creek d/s	0.018	77.5	CD/L/AI/P	Faor
Kaihiku Stream	0.019	79.5	CD/L/SS/P	Fair
Lindsay's Creek	0.019	70.6	CD/L/VB/U	Fair
Wairuna Stream	0.023	91.4	CD/L/HS/P	Poor
Welcome Creek u/s	0.029	92.7	CD/L/AI/P	Fair
Gimmerburn	0.032	92.6	CD/H/AI/P	Good
Washpool Stream	0.056	100	CD/L/SS/P	Poor
Waiareka Creek	0.086	89.4	CD/L/SS/P	Good

The number of exceedences was extremely high at many of these sites, with the Washpool Stream recording a 100% exceedence of the ANZECC (2000) trigger level. All the sites either drain pastoral or urban catchments, and the majority are low elevation with the exception of sites on the Taieri River (Waipiata, Tiroiti, Lee Stream) and Manuherikia (Ida Burn, Gimmer Burn). Of the sites that had no exceedences, the majority were the Central Otago lakes, main stem Clutha and Upper Taieri.

#### 4.10 Total phosphorus

- TP is a measure of all the forms of phosphorus, dissolved or particulate, that are found in a sample. Phosphorus is a natural element found in rocks, soils and organic material, and clings tightly to soil particles.
- TP is affected by wastewater effluent, fertilisers, animal waste, urban development and industrial discharges.

The ANZECC (2000) trigger value for TP is 0.033 mg/l. Twenty four of the sites had median concentrations of TP exceeding this trigger value. Of these sites, 14 also exceeded the ANZECC (2000) trigger value for DRP. Included in the sites that did not exceed the DRP trigger level were Lake Tuakitoto, Lake Waiholo, Lake Waipori, the Main Drain and the Shotover River. These sites have a high sediment load (either naturally or, in the case of lakes, through being shallow and sediment being prone to resuspension by wind or waterfowl), and thus a high TP load which is not reflected in DRP concentrations. It can be seen that all the sites with a high percentage exceedence had a pastoral land cover, most were of low elevation and the majority had a hard sedimentary geology. The Gimmerburn was an exception - this site is affected by an input of nutrients from irrigation run-off (ORC, 2006). Table 4. 9 shows the sites with the highest percentage exceedences of the ANZECC trigger value for TP (>80%).

**Table 4. 9 Sites recording the TP exceedences of >80%**

Site	Median	% samples above guideline value	REC Category (Refer Table 3. 2)	WQI Grade
Contour Channel	0.058	81.1	CD/L/HS/P	Fair
Lake Tukitoto	0.074	82.4	CD/L/HS/P	Good
Gimmer Burn	0.083	25.2	CD/H/AI/P	Good
Heriot Burn PK Rd	0.065	87.2	CD/L/HS/P	Fair
Lee Stream	0.065	85	CD/L/HS/P	Fair
Waiareka Creek	0.135	87.7	CD/L/SS/P	Poor
Wairuna Stream	0.118	100	CD/L/HS/P	Poor
Washpool Stream	0.255	100	CD/L/SS/P	Poor

#### 4.11 *Escherichia coli*

- Faecal bacteria are present in large numbers in the faeces and intestinal tracts of humans and other warm-blooded animals, and can enter water bodies from human and animal waste. If a large number of faecal coliform bacteria (over 260 colonies/100ml) are found in water, it is possible that pathogenic (disease or illness-causing) organisms are also present in the water.
- Faecal coliform by themselves are usually not pathogenic - they are indicator organisms. *E. coli* is an indicator organism which means they may indicate the presence of other pathogenic bacteria. Pathogens are typically present in such small amounts it is impractical to monitor them directly.
- *E. coli* numbers are affected by wastewater effluent, animal waste, sediment load, temperature and nutrient concentrations.

Department of Health (1992) guidelines for contact recreation waters recommend a season median of 126 *E. coli*/100 ml. Of the 69 sites (*E. coli* was not recorded at the eight NIWA sites), 28 had a median concentrations exceeding this value.

**Table 4. 10 Sites with *E. coli* exceedences of >80%**

Site	Median	% samples above guideline value	REC Category (Refer Table 3. 2)	WQI Grade
Waiwera River	300	82.9	CD/L/SS/P	Fair
Water of Leith	445	83.3	CD/L/VB/U	Fair
Washpool Stream	780	83.3	CD/L/SS/P	Poor
Crookston Burn	870	86.5	CD/L/AI/P	Fair
Kaikorai Stream	445	86.8	CD/L/SS/U	Good
Lovells Creek	340	88.2	CD/L/HS/P	Fair
Heriot Burn PK Rd	535	92.9	CD/L/HS/P	Fair
Wairuna Stream	680	93.3	CD/L/HS/P	Poor
Lindsay's Creek	1150	100	CD/L/VB/U	Fair

The highest *E. coli* result came from Lindsay's Creek in Dunedin, and the Water of Leith and Kaikorai Stream also recorded elevated levels of *E. coli*. These two streams also drain urban catchments in Dunedin. Figure 3. 7 shows that urban sites have much higher median concentrations than pastoral or tussock areas. The rest of the sites are low elevation sites in pastoral catchments. Section 3.2.1 (REC source of flow) shows that bacteria levels are lower in sites sourced from mountain, hill and lakes rather than low elevation sites.

The only sites to record median levels of *E. coli* below the DoH guideline level were Lake Hayes, Lake Onslow, Lake Dunstan, Lake Johnson, Lake Hawea, Lake Wanaka and Hayes Creek. Lake Wakatipu recorded one result of 1400 *E. coli*/100ml, which should be treated with suspicion as none of the other analytes recorded on the same day were elevated. This may well be due to a very localised effect such as waterfowl faeces.

## 5. Ecosystem health

### 5.1 Biological parameters

Ecosystem health takes into account a wide range of inter-linked factors, such as water quality, habitat and instream biota. It is generally assessed using two communities that are important to the food chain in rivers and streams: streambed macroinvertebrates (e.g. insects, crustaceans, snails, worms), and periphyton (e.g. algae).

Biological indices used to assess ecosystem health put a large amount of information into a compact form. They are therefore inherently coarse tools that give a broad view of general patterns. However, they are useful as the presence or absence, abundance, and distribution of species can tell us much about the quality and condition of the site in which they live.

### 5.2 Macroinvertebrates

Macroinvertebrates include insect larvae (e.g. caddisflies, mayflies, stoneflies), aquatic worms (oligochaetes), aquatic snails, and crustaceans (e.g., amphipods, isopods and freshwater crayfish). Because different macroinvertebrate species have different tolerances to environmental factors, such as dissolved oxygen, chemical pollutants and fine sediment, the presence or absence of different species can also indicate changes in water quality.

The following biotic indices are widely used as a tool to help interpret the health of a waterway:

*Species richness* is the total number of species (or taxa) collected at a sampling site. In general terms, high species richness may be considered good, though often mildly impacted or polluted rivers with slight nutrient enrichment can have higher species richness than naturally healthy streams and rivers.

*EPT species* is an index which is a sum of the total number of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) species collected. These groups of insects are often the most sensitive to organic and mineral pollution, therefore low numbers of these species might indicate a polluted environment. In some cases, the percentage of EPT species compared to the total number of species found at a site can give an indication of the importance of these species in the overall community.

The *Macroinvertebrate Community Index* (MCI) developed by Stark (1985, 1993, 1998), for assessing organic enrichment of stony or hard-bottomed streams based on sampling macroinvertebrates from riffle habitats, is an index based on adding the pollution tolerance scores of all species found at a site. Species that are very sensitive to pollution score highly, whereas more pollution-tolerant species receive a low score. MCI values are calculated as follows:

$$\text{MCI} = \frac{\sum_{i=1}^{i=S} a_i}{S} \times 20$$

where  $S$  = the total number of taxa in the sample, and  $a_i$  is the score for the  $i$ th taxon.

Taxa are scored between 1 and 10, with low scores indicating high tolerance to organic pollution and high scores indicating taxa that will only be found in pristine rivers (Stark 1985). A site score is obtained by summing the scores of individual taxa and dividing this total by the number of taxa present at the site, then multiplying by 20. Scores can range from 0 (no species present) to 200, with different scores indicating different pollution status.

*Semi-quantitative Macroinvertebrate Community Index* (SQMCI) is a variation of the MCI that accounts for the abundance of pollution sensitive and tolerant species. The SQMCI is calculated from coded count data (individual taxa counts are assigned to one of Rare (R), Common (C), Abundant (A), Very Abundant (VA) or Very Very Abundant (VVA) abundance classes) as follows:

$$QMCI = \sum_{i=1}^{i=S} \frac{(n_i \times a_i)}{N}$$

where  $S$  = the total number of taxa in the sample,  $n_i$  is the coded abundance for the  $i$ th scoring taxon (i.e. R=1, C=5, A=20, VA=100, VVA=500),  $a_i$  is the score for the  $i$ th taxon and  $N$  is the total of the coded abundances for the entire sample. The QMCI and SQMCI indices range from 0 to 10.

**Table 5.1 Criteria for macroinvertebrate health according to different macroinvertebrate indices**

Macroinvertebrate Index	Poor	Fair	Good	Excellent
MCI	<80	80 – 99	100 – 119	>120
SQMCI	<4	4 – 4.99	5 – 5.99	>6
Total species	<10	15 – 20	20 – 30	>30
Total EPT species	<5	6 – 15	15 – 20	>20

MCI and QMCI scores may be affected by a number of factors other than pollution (e.g. bed stability, recent flow conditions and regimes, water temperature, habitat type). Consequently, a useful approach is to compare MCI and QMCI scores upstream and downstream of an impact. In such a situation, the differences between scores for the index are much more important than the actual scores.

A key component of the MCI index is the availability of suitable habitat. The MCI index is designed specifically for stony riffle substrates in flowing water, therefore MCI values can vary due to the availability of suitable habitat and not necessarily due to water quality. As substrate type can vary greatly between riffles it is often more appropriate to compare changes in MCI values at the same site over a period of time rather than between sites throughout the catchment. However, by understanding the limitation of the MCI index, it still can be useful for picking up improvements or deterioration in water quality at individual sites over time.

### 5.3 Periphyton

Periphyton is the slime and algae coating stones, wood, weeds or any other stable surface in streams and rivers. This group of organisms is essential for ecosystem functioning but can proliferate and cause a nuisance. The community is composed predominantly of algae, cyanobacteria (formerly blue-green algae) and diatoms (Biggs 2000). Periphyton occurs in a variety of thicknesses and forms depending on conditions.

Aquatic grazing animals, mainly invertebrates, feed on periphyton, which in turn are fed upon by fish. Without periphyton many waterways would be barren of life. Periphyton also plays a role in the maintenance of water quality through removing Nitrogen, Phosphorus and unwanted organic contaminants (Biggs 2000). During periods of low flows and high nutrient levels, periphyton communities may proliferate to the extent that aesthetics, biodiversity and other in stream parameters are compromised.

Periphyton is assessed by ORC once during summer, the monitoring being loosely based on Quantitative method 1b (QM-1b) (Biggs et.al 2000). The ORC protocol was introduced after consultation with Dr. Barry Biggs and involves random selection of three rocks at each site (taken from one quarter, one half and three quarters stream width), and pooling the scrapings of a 5cm x 5cm area from each into a jar. Where soft substrate is predominant, three 5cm x 5cm area surface scoops of sediment are taken. Samples are then frozen with stream water and sent to a laboratory for identification and assessment of relative dominance using Biggs' semi-quantitative methodology.

#### 5.3.1 Periphyton guidelines

The New Zealand Periphyton Guidelines (MfE 2000) provide a range of thresholds for periphyton biomass and cover designed to protect various instream values, including aesthetics, benthic biodiversity and trout habitat and angling.

**Table 5.2 Common taxon and preferred trophic state**

Taxon	Oligotrophic	Oligotrophic-Mesotrophic	Mesotrophic	Mesotrophic-Eutrophic	Eutrophic
<b>Filamentous green algae</b>					
<i>Microspora</i>			3	2	
<i>Rhizoclonium</i>					2
<i>Spirogyra</i>			2		
<i>Stigeocionium</i>			2		
<i>Ulothrix</i>		2			
<b>Filamentous red algae</b>					
<i>Audouinella</i>	3	2	1		
<b>Diatoms</b>					
<i>Cymbella</i>		2	2		
<i>Frustulia</i>	2				
<i>Gomphoneis</i>		2	1		
<i>Naviculoid diatoms</i>		2			

The Ministry for the Environment (2000) lists the trophic designations of some algal taxa commonly found in New Zealand periphyton communities. These trophic designations are where algal taxa are most likely to dominate communities or be abundant. Table 5. 2 shows the trophic designations of taxon found in Otago in 2006.

One denotes a reasonable indicator value, two denotes a good indicator and three denotes a very good indicator (i.e. these taxa have very specific habitat requirements), (Ministry for the Environment 2000). Oligotrophic is nutrient-poor water, eutrophic is nutrient-rich water and mesotrophic is an intermediate condition between oligotrophic and eutrophic.

#### 5.4 Macroinvertebrate Community Index (MCI)

Of the 78 sites which have been monitored at various times since 2001, three were graded very good, 37 were graded good, 23 were graded fair and 15 were graded poor. These are depicted in Figure 5. 1 and results can be seen in Appendix 7.

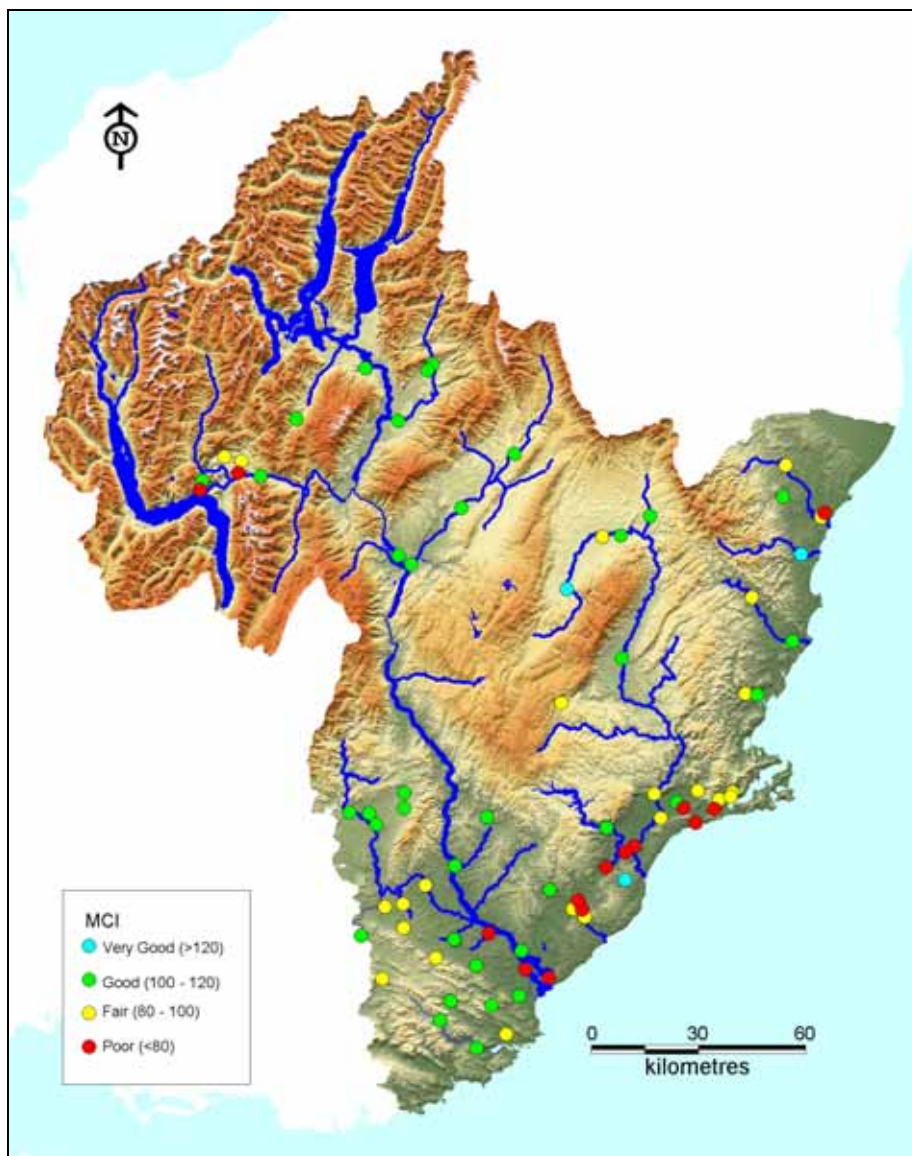


Figure 5. 1 Average MCI scores at each site

At an REC level, four of the sites were graded very good - two of these were located on hill sites and had hard sedimentary geology. There were varying land uses ranging from exotic forest (Akatore Stream), tussock (Taieri at Stonehenge) and pasture (Catlins and Waipori). The highest score was the Catlins, which has a large catchment of native bush immediately upstream.

The sites with the lowest scores were located predominantly at low elevation, with the land use being either pasture or urban. The exception to this is Horne Creek in Queenstown, which has a low MCI score due to a mobile bed which is often disturbed by heavy rain.

### 5.5 Semi-quantitative Macroinvertebrate Community Index (SQMCI)

Of the 78 sites monitored, 23 were graded very good, 15 were graded good, 22 were graded fair and 18 were graded poor. The distribution is shown in Figure 5. 2.

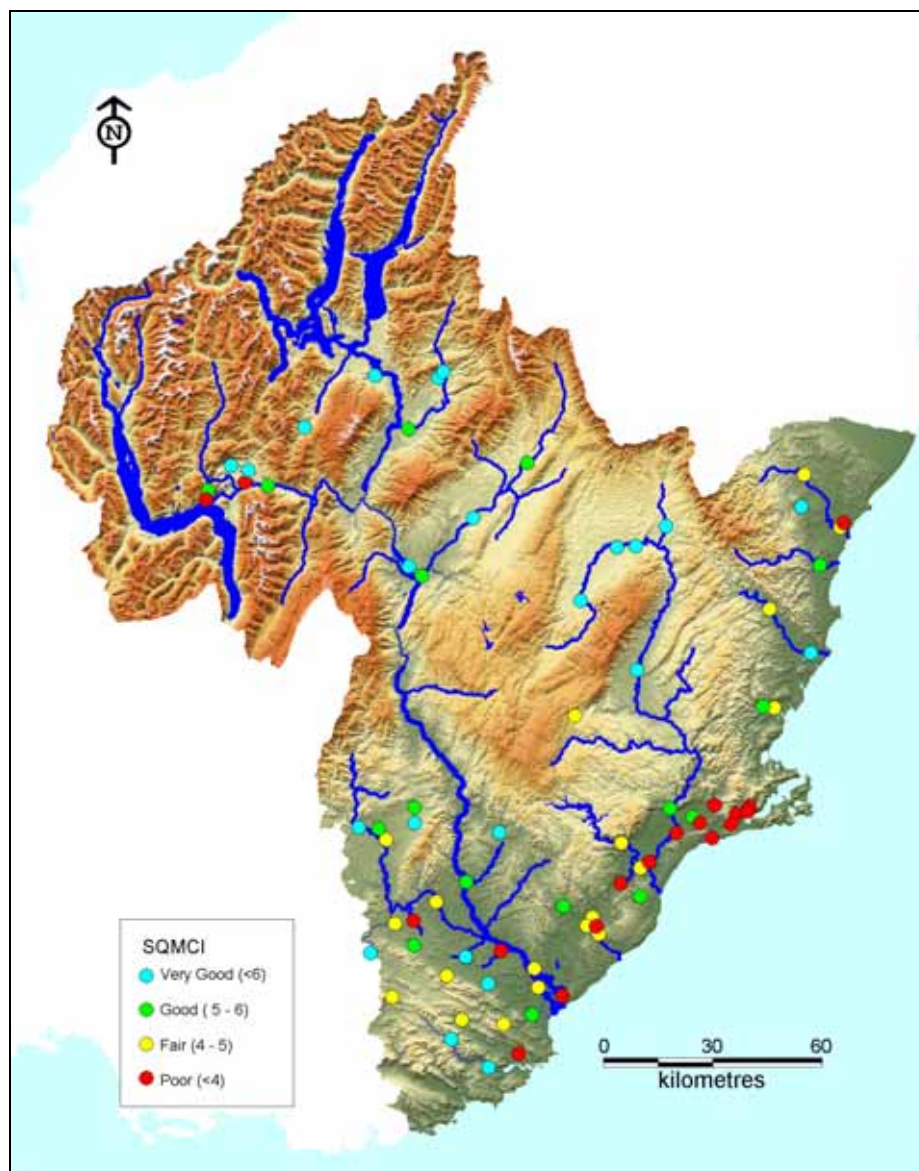


Figure 5. 2 Average SQMCI scores at each site

Of the 24 sites graded very good, 14 are located in hill or mountainous country. Perhaps surprisingly, 15 of the 24 sites were draining pastoral catchments, with the rest draining tussock. The distribution as seen in Figure 5. 2 is quite telling, with seven of the sites graded poor situated in urban areas, draining low elevation catchments. Horne Creek in Queenstown is again an exception, as are three lake sites (which are no longer monitored due to the unsuitability of the sites for macroinvertebrate sampling). The main stem Clutha also scores poorly, but the sites were unsuitable for biological monitoring and have been removed from the sampling programme.

### 5.6 Percentage Ephemeroptera , Plecoptera and Trichoptera (EPT)

Of the 78 sites monitored, five were graded very high, 13 were graded high, 37 were graded moderate, 13 were graded low and ten were graded very low. The location of these sites is depicted in Figure 5. 3.

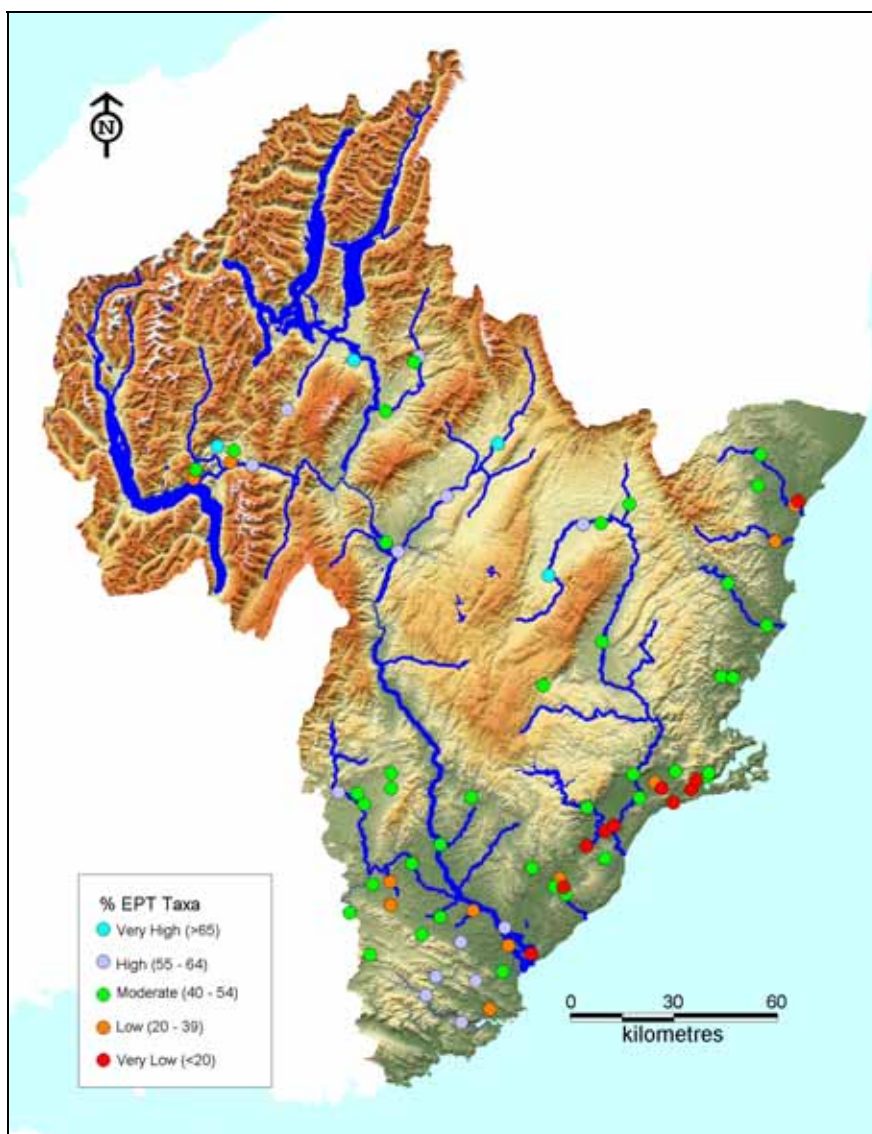
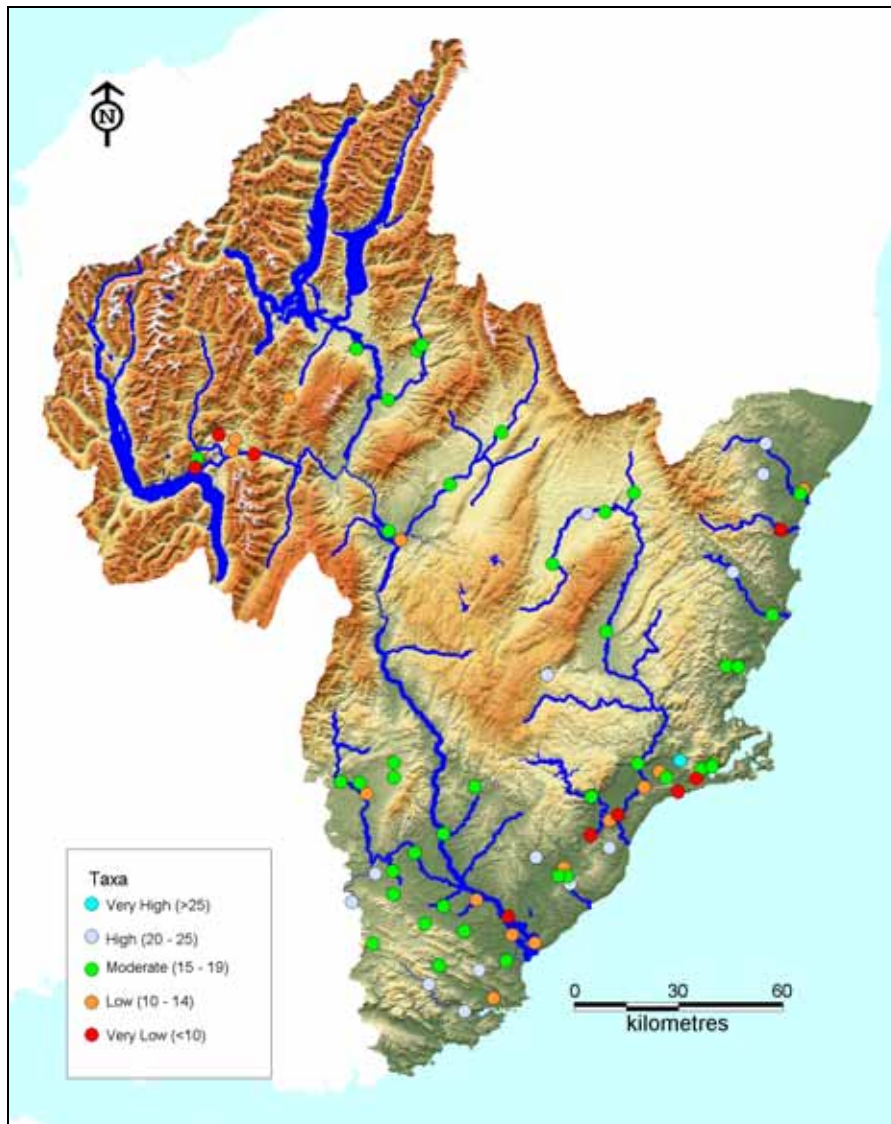


Figure 5. 3 Average % EPT scores at each site

The average %EPT scores follow a similar pattern to the MCI and SQMCI scores. Sites with low scores are in the low elevation, pastoral or urban catchments, and sites scoring highly are in hill or mountainous country, draining mainly tussock catchments.

### 5.7 Taxa richness

Of the 78 sites monitored, one was graded very high, 15 were graded high, 40 were graded moderate, 16 were graded low and seven were graded very low. The site locations are depicted in Figure 5. 4.



**Figure 5. 4 Average taxa richness or number of types of invertebrates found at each site**

At an REC level, the site with the highest taxa richness was the Silver Stream, which is located downstream of indigenous forest. The sites which were graded good were fairly evenly split between hill country and sites draining low elevation reaches. However, of the low elevation reaches, three were classified by REC as being in a wet climate (Catlins and Glenomarau), and one had a catchment of exotic forest. The poorer sites included urban streams (Kaikorai) and large river sites such as the Clutha and Shotover.

## 5.8 REC and macroinvertebrate results

For all five variates of land cover; Exotic Forest (EF), Indigenous Forest (IF), Pastoral (P), Tussock (T) and Urban (U), exploratory data analysis was undertaken using box plots and two way tabulations. In many cases there were no recorded observations, thus any potential two way interactions could not be detected in subsequent analysis.

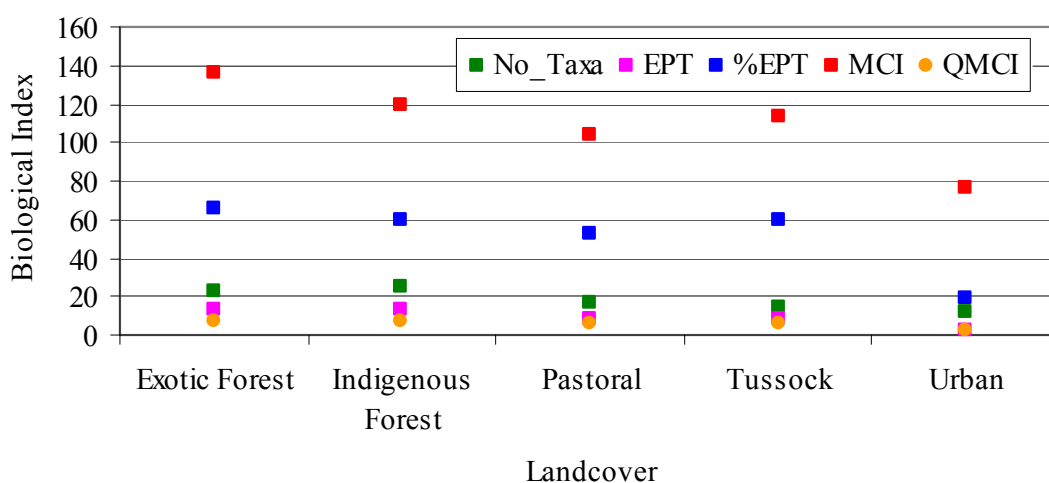
To further investigate the effects of land cover and source of flow on biological indices, a model (Genstat 9.1, Copyright 2006, Lawes Agricultural Trust Rothamsted Experimental Station) was used<sup>2</sup>.

### 5.8.1 Land cover

Table 5. 3 gives the results of the effect of land cover on all the biological indices, and this is displayed graphically in Figure 5. 5.

**Table 5. 3 The effect of land cover on biological indices**

	Exotic Forest (IF)	Indigenous Forest (IF)	Pastoral (P)	Tussock (T)	Urban (U)
No samples	2	3	158	24	19
No taxa	22.13	24.77	17.00	14.79	11.42
Std error	3.89	3.31	1.18	1.51	1.80
EPT	13.39	13.67	8.92	8.91	2.55
Std error	2.96	2.64	0.908	1.15	1.39
%EPT	65.76	59.61	53.02	59.40	18.82
Std error	13.12	11.59	4.01	5.09	6.15
MCI	136.3	119.4	103.5	113.0	75.9
Std error	14.74	13.34	4.53	5.73	6.97
QMCI	7.12	6.69	5.84	6.30	2.87
Std error	1.16	1.00	0.32	0.45	0.54



**Figure 5. 5 Biological indices and land cover**

<sup>2</sup> The biological monitoring sites were treated as random effects in which the year effects were nested with an autoregressive error structure. A Wald statistic was used to identify significant fixed effects.

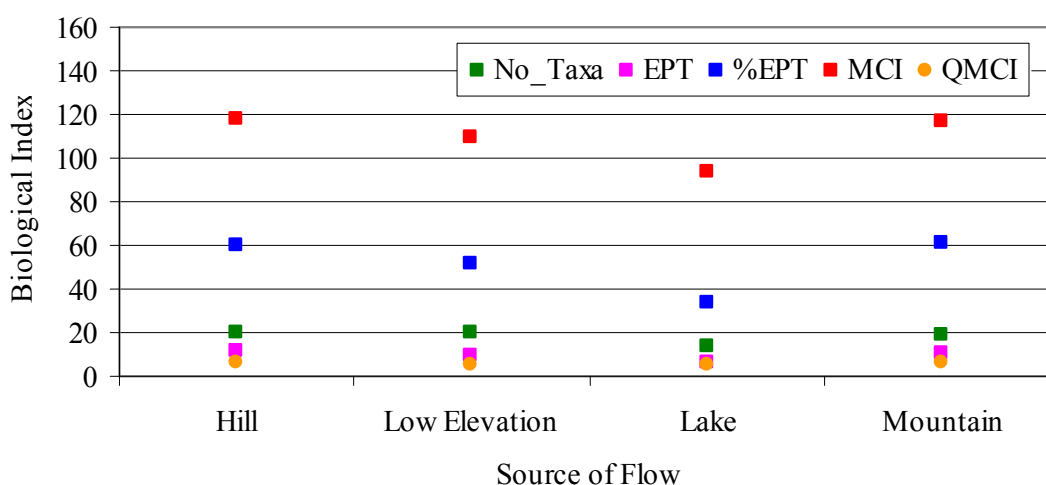
It is clear that land cover has some effect on biological indices, with exotic and indigenous forestry scoring more highly than urban and pastoral land cover.

### 5.8.2 Source of flow

Table 5. 4 gives the results of the effect of source of flow on all the biological indices, and this is displayed graphically in Figure 5. 6.

**Table 5. 4 Biological indices and source of flow**

	Hill (H)	Low Elevation (L)	Lake (Lk)	Mountain (M)
No Samples	84	106	11	5
No_Taxa	19.51	19.59	13.98	19.01
Std Error	1.58	1.20	2.08	2.61
EPT	11.18	9.92	5.94	10.91
Std Error	1.23	0.94	1.58	1.98
%EPT	59.71	51.12	33.31	61.15
Std Error	5.44	4.14	6.99	8.78
MCI	117.7	110.0	94.2	116.6
Std Error	6.18	4.710	7.86	9.88
SQMCI	6.04	5.35	4.87	6.80
Std Error	0.48	0.36	0.62	0.78



**Figure 5. 6 Biological indices and source of flow**

It is clear that source of flow has some effect on biological indices, with lakes scoring more poorly than the other indices. However, lake outlets tend to have specialist macroinvertebrates that have adapted to living in that particular environment.

### 5.8.3 Predictions from analysis (using Genstat)

Table 5. 5 demonstrates that, in many cases, there were no recorded observations between source of flow and land cover. It was therefore impossible to make accurate predications of biological indices according to these two parameters.

**Table 5.5 Source of flow and land cover (numbers in brackets represent the number of samples)**

	Exotic Forest (2)	Indigenous Forest (3)	Pastoral (158)	Tussock (24)	Urban (19)
Hill (84)	0	0	62	22	0
Low Elevation (106)	22	3	82	0	19
Lake (11)	0	0	11	0	0
Mountain (5)	0	0	3	2	0

However, it was possible to predict the biological indices scores according to land use. The results of this are shown in Table 5.6, and it is clear that in Otago, indigenous forestry and exotic forestry score highly (although only two sites had exotic forestry as the dominant land cover), and urban sites score poorly.

**Table 5.6 Predictions of biological indices according to different land cover**

	Exotic Forest (IF)	Indigenous Forest (IF)	Pastoral (P)	Tussock (T)	Urban (U)
No Samples	2	3	158	24	19
No_Taxa	22.13	24.77	17.00	14.79	11.42
Std Error	3.89	3.31	1.18	1.51	1.80
EPT	13.39	13.67	8.92	8.91	2.55
Std Error	2.96	2.637	0.91	1.15	1.39
%EPT	65.76	59.61	53.02	59.40	18.82
Std Error	13.12	11.59	4.01	5.09	6.15
MCI	136.3	119.4	103.5	113.0	75.9
Std Error	14.74	13.34	4.53	5.73	6.97
SQMCI	7.12	6.69	5.84	6.30	2.87
Std Error	1.16	1.00	0.32	0.45	0.54

## 5.9 Periphyton

Table 5.7 lists the algal samples that contained taxa that prefer eutrophic (high nutrient) water, and correlates them with their REC class.

**Table 5.7 Taxon that prefer eutrophic water, and sites in Otago where they have been found**

Taxon	Site	Year	REC Class
<i>Rhizoclonium</i>	Waipahi @ Waipahi	2006	CD/L/SS/P
<i>Gompheonema parvulum</i>	Wairuna @ Clydevale Waipahi Rd	2001	CD/L/HS/P
	Owaka @ SH92	2001	CW/L/SS/P
	Crookston Burn @ SH90	2001	CD/H/HS/P
	Heriot Burn @ SH90	2001	CD/H/HS/P
	Cardrona @ Waiarou Rd Br	2001	CD/H/HS/T
	Catlins @ Chloris	2001	CW/L/SS/P
	Owhiro @ Burns St	2001/2002	CD/L/AI/U

In 2006, the Waipahi River at Conical Hill Road Bridge was dominated by the filamentous green algae *Rhizoclonium* which prefers eutrophic waters. It was, however, ranked quite low at 61 of 77 watercourses monitored. The Waipahi River lies in a low elevation area of intensive agriculture and nutrient enrichment is likely.

In 2001, *Gompheonema parvulum* was found at many sites, three of which were in the Pomahaka Catchment tributaries. These sites are located in catchments with pastoral activity. The Wairuna Stream has a WQI classification of poor, the Crookston Burn and Heriot Burn have a WQI of fair, and nutrient enrichment is not surprising. The two sites in South Otago (Catlins at Chloris and Owaka at SH92) had no WQI classification, but again are located in areas of intense agricultural activity. The odd result was finding *Gompheonema parvulum* in the Cardrona River. This river has a WQI classification of very good water quality and is ranked 23 of 77 watercourses, drains hill country with mainly tussock cover, and there is no evidence of nutrient enrichment in the Cardrona River.

The Owhiro Stream at Burns Street was dominated by the diatom *Gompheonema parvulum* in 2001 and 2002. This taxa prefers eutrophic water, which is certainly the case in the low flowing, nutrient rich Owhiro stream. The WQI classified this stream as fair (with high DRP, turbidity and *E. coli*).

Factors other than nutrient levels also influence the composition of benthic algal communities. These include substrate character, the flow regime of the river, the amount of light reaching the river bed and the water temperature. For example, the Cardrona River in 2006 was dominated by the diatom *Cymbella*, which is known to form blooms during periods of low flow (Moore 2000). The Cardrona River was also dominated by the filamentous green algae *Microspora*, which is often found entangled amongst aquatic plants in gravely streams with moderate current speeds (Moore 2000).

Appendix 8 lists the dominant and abundant periphyton taxon monitored between 2001 and 2004 and in 2006. No monitoring was carried out in 2005 due to high river flows. The taxon are correlated with eutrophic designations.

## 6. Water quality – temporal trends

To determine whether water quality has improved or declined, trend analyses was undertaken on water quality data from each of the 77 monitoring sites. The length of data for each site varies, and is detailed in Appendix 2.

### 6.1 Seasonal Kendall trend test

The trend test calculates the probability of getting a trend slope at least as big as measured, if in fact there was no trend at all. This is the p-value.

If the p-value is small enough there is a statistically significant trend. The p-value is calculated by comparing the total number of increasing monthly slopes with the total number of decreasing slopes. If the net result is close to zero, the p-value will be large, so the slope can be regarded as being due to chance. Conversely, a large difference between the numbers of increasing and decreasing slopes produces a low p-value, meaning the slope is unlikely to be due to chance. p-values of 0.05 or less are conventionally regarded as indicating that a trend is statistically significant (i.e. unlikely to be due to chance). The p-value depends on the number of samples in a water quality record, with weak trends less likely to be identified in records with fewer observations (and vice versa). Appendix 9 gives more details.

Throughout this section, symbols have been used to describe any significant trends in water quality. These are shown in Table 6. 1.

**Table 6. 1 Explanation of symbols used to define trends in water quality**

Trend	Symbol
Significant improvement in water quality at the 95% confidence interval	▲▲▲
Significant improvement in water quality at the 90% confidence interval	▲▲
Significant improvement in water quality at the 80% confidence interval	▲
No significant change	•
Significant decrease in water quality at the 80% confidence interval	▼
Significant decrease in water quality at the 90% confidence interval	▼▼
Significant decrease in water quality at the 95% confidence interval	▼▼▼

### 6.2 Flow adjustment

The flow rate of most of the region's rivers and streams varies with time, and routine samples for each site are collected at different flows. Because some water quality variables vary with flow, this increases the overall variability of the water quality record. This variability can obscure any underlying trend in water quality. However, in many situations water quality varies with flow in an identifiable fashion. As a result, identifying and allowing-for the effect of flow can usefully reduce the overall variability in a water quality record, and thus permit any underlying trend to be more readily observed. Flow-adjustment was performed for eight sites (Shotover, Kawarau, Taieri at Outram and Tiroiti, Sutton Stream, Clutha at Balclutha, Millers Flat and Luggate) using WQSTAT PLUS by identifying a flow corresponding to each sampling occasion.

## 6.3 Clutha River/Mata-Au

### 6.3.1 Clutha River/Mata-Au Lake outlets

Lakes Wakatipu, Wanaka, Hawea, Hayes, Johnson and Dunstan have long-term monitoring records at their outlets. Table 6. 2 shows trends in water quality analytes. Where there is a significant trend, they are mainly all negative, indicating an improvement in water quality. Those analytes that showed deteriorating water quality were TP in Lake Dunstan and both *E. coli* and SS were increasing in Lake Onslow.

**Table 6. 2 Water quality trends in the Clutha Lakes (outlets)**

Statistically significant trends are depicted in blue for improving water quality and red for declining water quality (▲=p <0.2, ▲▲=p <0.1, ▲▲▲=p <0.05, ● = no change).

	Lake Wakatipu	Lake Wanaka	Lake Hawea	Lake Hayes	Lake Johnson	Lake Dunstan	Lake Onslow
<b>WQI</b>	V Good	V Good	V Good	V Good	V Good	V Good	V Good
<b>NH<sub>4</sub></b>	●	●	▲▲▲	●	●	●	▲
<b>Cond</b>	▲▲▲	▲▲	▲▲	▲	●	▲▲▲	●
<b><i>E. coli</i></b>	●	▲▲▲	●	●	●	●	▼
<b>NNN</b>	●	▲▲▲	●	▲▲▲	▲▲	▲▲▲	●
<b>SS</b>	▲▲▲	▲▲	▲▲	▲	●	▲	▼
<b>TN</b>	●	●	●	▲▲▲	●	●	●
<b>TP</b>	●	●	●	●	●	▼	●
<b>Turb</b>	▲▲	▲▲▲	●	▲▲	▲▲▲	▲▲▲	●

### 6.3.2 Clutha River/Mata-Au Main Stem

Three sites on the Clutha River/Mata-Au main stem have been monitored by NIWA (Table 6. 3). Clutha at Luggate is at the top of the catchment, just downstream of Lake Wanaka and Lake Hawea. As this site is near the head of the catchments, with the majority of its water coming from Lake Wanaka and Lake Hawea, it was expected that there would be no increasing trends, however, there is an increasing trend in many of the analytes. Appendix 9 indicates that conductivity increases by +0.000174 mS/cm year, TN (+0.0011 mg/l year) and TP (+0.000054 mg/l year).

**Table 6.3 Water quality trends in the Clutha River**

Statistically significant trends are depicted in blue for improving water quality and red for declining water quality ( $\blacktriangle = p < 0.2$ ,  $\blacktriangle\blacktriangle = p < 0.1$ ,  $\blacktriangle\blacktriangle\blacktriangle = p < 0.05$ ,  $\bullet =$  no change)

	Clutha River/Mata-Au at Luggate (Flow Adjusted)	Clutha River/Mata-Au at Millers Flat (Flow Adjusted)	Clutha River/Mata-Au at Balclutha (Flow Adjusted)
<b>WQI</b>	Very Good	Very Good	Very Good
<b>NH<sub>4</sub></b>	$\blacktriangle\blacktriangle\blacktriangle$	$\blacktriangle\blacktriangle\blacktriangle$	$\blacktriangle\blacktriangle\blacktriangle$
<b>Cond</b>	$\blacktriangledown\blacktriangledown\blacktriangledown$	$\blacktriangle$	$\blacktriangledown$
<b>TN</b>	$\blacktriangledown\blacktriangledown\blacktriangledown$	$\blacktriangledown\blacktriangledown\blacktriangledown$	$\blacktriangledown\blacktriangledown\blacktriangledown$
<b>TP</b>	$\blacktriangledown\blacktriangledown\blacktriangledown$	$\bullet$	$\bullet$
<b>Turb</b>	$\bullet$	$\blacktriangle\blacktriangle\blacktriangle$	$\bullet$

\* NNN was not monitored by NIWA

There is a trend of decreasing NH<sub>4</sub> at all three sites, however, the increasing trend of TN is seen throughout the catchment. Increasing trends of conductivity and TP are only seen at Luggate. Even though the water quality at Luggate shows a long-term downward trend, it is still of extremely good quality, as indicated by the WQI.

### 6.3.3 Clutha River/Mata-Au tributaries

Table 6.4 shows that nutrients increased at some sites, which indicates a deterioration in water quality. At the Kawarau and Shotover sites TN increased; however there was a corresponding decrease in NH<sub>4</sub> in the Shotover. The Teviot, Minzion Burn and Fraser River showed an increase in TP. The only rivers with an obvious improvement in water quality were the Tuapeka River and the Waitahuna River where both SS and turbidity have decreased. The Cardrona river also showed a general improvement in water quality other than a deterioration in NH<sub>4</sub>.

The Kaihiku had an increasing trend in conductivity and TN, while the Waiwera showed a deterioration in TN, TP and SS. The Lindis River did not have a long enough data set to determine any trends.

The SOE site for the Cardrona River is situated at Mt Barker, located approximately 5km upstream of the confluence of the Cardrona River and Clutha River/Mata-Au. There has been a statistically significant improvement in water quality for many analytes: NNN (-0.0039 mg/l year), SS (-0.33 mg/l year) and turbidity (-0.1097 NTU year). However, NH<sub>4</sub> showed a significant increase (Table 6.4).

**Table 6.4 Water quality trends in the Clutha River/Mata-Au tributaries**

Statistically significant trends are depicted in blue for improving water quality and red for declining water quality ( $\blacktriangle$ = $p < 0.2$ ,  $\blacktriangle\blacktriangle$ = $p < 0.1$ ,  $\blacktriangle\blacktriangle\blacktriangle$ = $p < 0.05$ ,  $\bullet$  = no change)

	Niwa Kawarau	Niwa Shotover	Cardrona River	Lindis River	Fraser River	Minziona Burn	Teviot River	Tuapeka River	Waihahuna River	Waiwera at SH1	Kaihiku Stream
<b>WQI</b>	Very Good	Good	Very Good	Very Good	Good	Poor	Very Good	Good	Good	Fair	Fair
<b>NH<sub>4</sub></b>	▼	▲▲▲	▼▼	n/a	●	●	●	●	●	●	●
<b>Cond</b>	●	●	●	n/a	▲	●	●	●	●	▲	▼▼▼
<b><i>E. coli</i></b>	●	●		n/a	●	●	●	●	●	●	●
<b>NNN</b>	●	●	▲▲▲	n/a	●	●	●	●	●	●	●
<b>SS</b>	●	●	▲▲▲	n/a	●	●	▲▲	▲▲	▲	▼▼	●
<b>TN</b>	▼▼▼	▼▼▼	▲▲	n/a	▲▲	●	●	●	●	▼▼▼	▼
<b>TP</b>	●	●	●	n/a	▼▼	▼	▼▼	●	●	▼▼▼	●
<b>Turb</b>	●	●	▲▲	n/a	●	●	●	▲▲	▲	●	●

Shaded cells represent a site with a short term record (Refer to Appendix 2)

### 6.3.4 Manuherikia River

There are two long-term monitoring sites on the main stem Manuherikia; the upper site at Blackstone and the lower site at Galloway (Table 6.5). The upper site showed a significant decrease in NH<sub>4</sub> (-0.00077 mg/l year), conductivity (-0.001069 mS/cm year), SS (-0.2497 mg/l year) and turbidity (-0.021 NTU year). This is in contrast to the lower site which showed an increase in *E. coli* and TP. However, the lower site still showed an improving trend for NH<sub>4</sub> and NNN.

Two tributaries also have enough data for trend analysis; Dunstan Creek and the Ida Burn. Dunstan Creek is generally of good water quality. However, there is an increasing trend for TP. The Ida Burn has deteriorating water quality (*E. coli*, suspended solids, TP and turbidity). The Ida Burn is affected by flood irrigation run-off.

**Table 6.5 Water quality trends in the Manuherikia River**

Statistically significant trends are depicted in blue for improving water quality and red for declining water quality ( $\blacktriangle$ = $p < 0.2$ ,  $\blacktriangle\blacktriangle$ = $p < 0.1$ ,  $\blacktriangle\blacktriangle\blacktriangle$ = $p < 0.05$ ,  $\bullet$  = no change)

	Manuherikia at Blackstone	Manuherikia at Galloway	Dunstan Creek at Beatties Rd	Ida Burn at Auripo Road
<b>WQI</b>	Very Good	Very Good	Very Good	Fair
<b>NH<sub>4</sub></b>	▲▲▲	▲▲	●	●
<b>Cond</b>	▲▲	●	●	●
<b><i>E. coli</i></b>	▼	▼▼	●	▼▼▼
<b>NNN</b>	●	▲▲	●	●
<b>SS</b>	▲▲	●	●	▼
<b>TN</b>	▲▲	●	●	●
<b>TP</b>	●	▼▼	▼▼	▼▼
<b>Turb</b>	▲▲▲	▲▲▲	●	▼

### 6.3.5 Lake Hayes, Mill Creek and Hayes Creek

Mill Creek is Lake Hayes' main source of water, while Hayes Creek drains Lake Hayes. Lake Hayes has been eutrophic for many years - phosphorus has been recognised as the limiting factor in the lake and the main reason for its eutrophication. The high abundance of phosphorus is the result of agricultural use of the catchment in the past, runoff from agricultural land, and erosion during floods (Robertson 1998, ORC and Queenstown Lakes District Council, 1995). ORC implemented a management strategy in 1995 with remedial works for the streams in the catchment area, aiming to reduce phosphorus input to the lake. In the last ten years some change in land use within the Lake Hayes catchment has also occurred, particularly a decrease in agriculture and grazing, and an increase in residential areas and lifestyle blocks. (GNS, 2006).

**Table 6. 6 Water quality trends in the Lake Hayes Catchment**

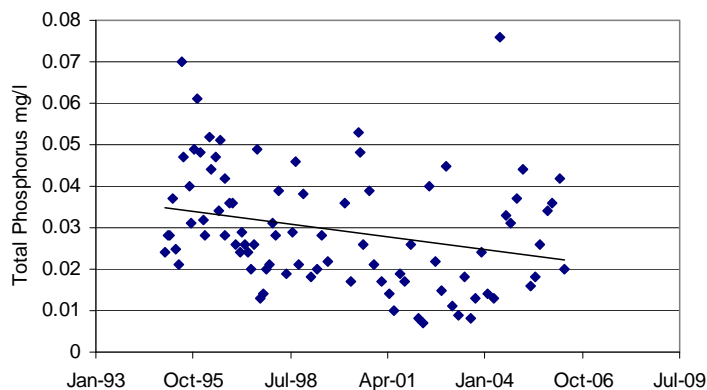
Statistically significant trends are depicted in blue for improving water quality and red for declining water quality (▲=p <0.2, ▲▲=p <0.1, ▲▲▲=p <0.05, ● = no change)

	Mill Creek	Lake Hayes	Hayes Creek
<b>WQI</b>	Good	Very Good	Very Good
<b>NH<sub>4</sub></b>	▲	●	▲▲▲
<b>Cond</b>	▲▲▲	▲	▲▲▲
<b><i>E. coli</i></b>	●	●	●
<b>NNN</b>	▲▲▲	▲▲▲	▲▲▲
<b>SS</b>	▲▲▲	▲	▲▲▲
<b>TN</b>	▲▲▲	▲▲▲	▲▲▲
<b>TP</b>	▲▲▲	●	●
<b>Turb</b>	▲▲▲	▲▲	▲▲▲

Table 6. 6 shows that Mill Creek has a trend of improving NH<sub>4</sub>, conductivity, NNN, SS, TN, TP and turbidity.

In Lake Hayes there has been a improvement in NH<sub>4</sub>, NNN, SS, TN and turbidity, and in Hayes Creek there has been a similar improvement in water quality with a significant decrease in the concentration of NH<sub>4</sub>, conductivity, NNN, SS, TN and turbidity (Table 6. 6). Even though there has been a decrease in the amount of phosphorous entering the lake, there has been no corresponding decrease in Hayes Creek. This is likely to be due to the sediments in Lake Hayes acting as a sink for phosphorus.

Figure 6. 1 shows the declining TP levels recorded in Mill Creek (the main tributary of Lake Hayes).



**Figure 6.1** Total phosphorus concentrations, Mill Creek. The black line shows the trend in the data record

**6.3.5 Pomahaka River and tributaries**

**Table 6.7** Water quality trends in the Pomahaka Catchment.

Statistically significant trends are depicted in blue for improving water quality and red for declining water quality (▲=p <0.2, ▲▲=p <0.1, ▲▲▲=p <0.05, ● = no change)

	Pomahaka at Glenken	Pomahaka at Burkes Ford	Crookston Burn at Kelso	Heriot Burn at PK Road	Heriot Burn at SH90	Waipahi at Waipahi	Waipahi at Cairns Pk	Wairuna at W/C Road	Washpool at Kilhastie Rd
<b>WQI</b>	Good	Very Good	Fair	Fair	Fair	Fair	Fair	Poor	Poor
<b>NH<sub>4</sub></b>	▲▲	▲▲	▲	●	▼	▲	●	▲	●
<b>Cond</b>	▲	●	▼▼	●	●	●	●	●	●
<b>E. coli</b>	●	●	●	●	▲	●	●	●	●
<b>NNN</b>	●	●	▼▼▼	▼	▼▼	▼	▲	●	●
<b>SS</b>	●	●	●	●	●	●	●	●	●
<b>TN</b>	●	●	▼▼▼	▼▼	▼▼▼	●	●	●	●
<b>TP</b>	●	●	●	●	▼▼▼	●	▼▼▼	●	●
<b>Turb</b>	▲▲▲	●	▲▲▲	▲▲	●	●	▼▼	●	●

Shaded cells represent a site with a short term record (Refer to Appendix 2)

The Pomahaka Catchment is in South West Otago and enters the Clutha River/Mata-Au downstream of Clydevale. ORC has long-term water quality data for two sites, at Glenken (upstream) and Burkes Ford (downstream).

These sites as well as its tributaries are shown in Table 6. 7. At Glenken turbidity, NH<sub>4</sub> and conductivity improved, while at Burkes Ford NH<sub>4</sub> improved. Neither of these sites showed any statistically significant downward trends (p<0.05) in water quality (Table 6. 7).

The Crookston Burn, Heriot Burn, Wairuna and Waipahi are all tributaries of the Pomahaka. The Crookston Burn showed a significant increase in NNN (+0.07 mg/l year), TN (+0.09 mg/l year) and a decrease in turbidity (-0.37 NTU year) and NH<sub>4</sub>. The Heriot Burn showed an increase in NNN and TN. Water quality is poor in both the Heriot Burn and Crookston Burn, particularly in the lower reaches.

Water in these streams is characterised by high nutrient and *E. coli* bacteria concentrations. Median concentrations of *E. coli* and faecal coliforms in these rivers are extremely high. Most sites in the Heriot Burn and Crookston Burn recorded median values greater than the MfE/MoH action red mode (>550 *E. coli*/100ml).

The Waipahi, Wairuna and Washpool streams are also in the Pomahaka Catchment. The lower Waipahi showed a deterioration in NNN (but improving NH<sub>4</sub>), however, the upper Waipahi showed a trend of increasing TP and turbidity (but improving NNN). The Washpool has only been monitored since 2003, therefore only limited trend analysis was available,

Water in these streams is also of poor quality. This is indicated by the WQI (Section 3), which rates the Waipahi and Waiwera as fair and the Washpool and Wairuna as poor.

### 6.3.7 Lake Tuakitoto Catchment

Frasers Stream is a tributary of Lovells Creek, which flows into Lake Tuakitoto. The lake outflow enters the Clutha River/Mata-Au just upstream of Kaitangata. Lovells Creek has shown a significant increase in NNN (0.028 mg/l year) and TN (0.03 mg/l year). Frasers Stream does not show any trend in water quality other than SS. Lake Tuakitoto has increasing concentrations of *E. coli* and a decreasing trend in NH<sub>4</sub> (Table 6.8).

**Table 6.8 Water quality trends in the Lake Tuakitoto Catchment**

Statistically significant trends are depicted in blue for improving water quality and red for declining water quality (▲=p <0.2, ▲▲=p <0.1, ▲▲▲=p <0.05, ● = no change)

	Lovells Creek	Frasers Stream	Lake Tuakitoto
WQI	Fair	Good	Good
NH <sub>4</sub>	▲	●	▲▲
Cond	●	●	●
<i>E. coli</i>	●	●	▼
NNN	▼▼▼	●	●
SS	●	▲	●
TN	▼▼	●	●
TP	●	●	●
Turb	●	●	●

## 6.4 Taieri River

### 6.4.1 Taieri River Main Stem

Six sites are monitored by the ORC and two sites by NIWA (Table 6. 9). Of the eight sites monitored, Stonehenge is in the upper catchment, then the sites downstream are Halls Bridge, Waipiata, Tiroiti (NIWA), Middlemarch, Outram (NIWA), Allanton and Henley Ferry (a tidal site).

Table 6. 5 shows the trends in the Taieri River. It can be seen that the long-term water quality trend shows a deterioration between Stonehenge and Tiroiti, and an improvement towards Allanton. The most notable increase is at Tiroiti, where TN is increasing by 0.003mg/l year and TP is increasing by 0.0079 mg/l year. This is reflected further ddownstream at Outram, where TN is increasing by 0.0024 mg/l year and TP is increasing by 0.00033 mg/l year.

The closure of Mosgiel sewage discharge from the Taieri River in July 2000 has resulted in the most significant improvement in water quality, as shown for the Allanton site. Records show significant decreasing trends in NH<sub>4</sub> (-0.0049 mg/l year), NNN (-0.0058 mg/l year), SS (-0.56 mg/l year), TN (-0.020 mg/l year) and TP (-0.0029 mg/l year).

**Table 6. 9 Water quality trends at several sites in the Taieri River**

Statistically significant trends are depicted in blue for improving water quality and red for declining water quality (▲=p <0.2, ▲▲=p <0.1, ▲▲▲=p <0.05, ● = no change)

	Stone-Henge	Halls Bridge	Waipiata	NIWA Tiroiti	Middle-march	NIWA Outram	Allanton	Henley Ferry
<b>WQI</b>	Very Good	Good	Fair	Good	Very Good	Very Good	Good	Good
<b>NH<sub>4</sub></b>	▲	▲▲▲	●	▲▲▲	●	▲▲▲	▲▲▲	▲▲▲
<b>Cond</b>	●	●	●	▼	▲▲▲	●	●	▲▲▲
<b><i>E. coli</i></b>	●	▲▲	▲		▲	N/A	●	●
<b>NNN</b>	▲▲▲	▲▲▲	▲	N/A	▲▲▲	N/A	▲▲▲	●
<b>SS</b>	▲▲▲	▲▲▲	▲▲	●	●	●	▲▲▲	●
<b>TN</b>	●	●	▲	▼▼▼	●	▼▼	▲▲▲	▲▲▲
<b>TP</b>	●	●	▼	▼▼▼	●	▼	▲▲▲	▲▲▲
<b>Turb</b>	●	▲▲▲	●	●	●	▲▲	●	▲▲

Shaded cells represent a site with a short term record (Refer to Appendix 2)

### 6.4.2 Taieri tributaries

Table 6. 10 shows trends in the Taieri tributaries. Three sites were monitored by the ORC and one site by NIWA. The only declining trend was found in the Sutton Stream, which showed an increase in TP, although NH<sub>4</sub> decreased. Trends in the Lee Stream and Gimmer Burn show that NNN is decreasing, whilst in the Pig Burn TN is decreasing.

**Table 6. 10 Water quality trends in the Taieri tributaries**

Statistically significant trends are depicted in blue for improving water quality and red for declining water quality (▲=p <0.2, ▲▲=p <0.1, ▲▲▲=p <0.05, ● = no change)

	Gimmer Burn at Wilsons Road	Pig Burn at O'Neill Road	Lee Stream at SH87	NIWA Sutton Stream
<b>WQI</b>	Good	Very Good	Fair	Very Good
<b>NH<sub>4</sub></b>	●	●	●	▲▲▲
<b>Cond</b>	●	●	●	●
<b><i>E. coli</i></b>	●	▲	●	●
<b>NNN</b>	▲▲	●	▲▲▲	●
<b>SS</b>	●	●	●	●
<b>TN</b>	●	▲▲	●	●
<b>TP</b>	●	●	●	▼▼
<b>Turb</b>	●	▲▲▲	●	●

Shaded cells represent a site with a short term record (Refer to Appendix 2)

### 6.4.3 Taieri lakes and drains

The Taieri River lake and drain sites monitored are shown in Table 6. 11. The Main Drain collects water from the western Taieri Plain, which is then pumped from the Main Drain into Lake Waipori. Records show significant decreasing trends (p<0.05) in NH<sub>4</sub> (0.2418 mg/l year), NNN (-0.055 mg/l year), SS (-0.65 mg/l year), TN (-0.31 mg/l year), TP (-0.0087 mg/l year) and turbidity (-0.52 NTU year). The Contour Channel does not show such a marked improvement, with a trend of increasing *E. coli* and TP, however, NNN is decreasing.

**Table 6. 11 Water quality trend in the Taieri lakes and drains**

Statistically significant trends are depicted in blue for improving water quality and red for declining water quality (▲=p <0.2, ▲▲=p <0.1, ▲▲▲=p <0.05, ● = no change)

	Lake Waipori	Lake Waihola	Waipori River	Silver Stream	Main Drain	Contour Channel	Owhiro Stream
<b>WQI</b>	Very Good	Good	Very Good	Good	Poor	Fair	Fair
<b>NH<sub>4</sub></b>	●	▲▲▲	●	▲▲▲	▲▲▲	●	●
<b>Cond</b>	●	●	●	▼	▼▼▼	●	▲▲▲
<b><i>E. coli</i></b>	●	●	●	●	●	▼▼▼	●
<b>NNN</b>	▲▲▲	▲▲▲	●	▲▲	▲▲▲	▲▲▲	●
<b>SS</b>	●	▲	●	▲▲	▲▲▲	●	●
<b>TN</b>	●	▲▲▲	●	▲▲	▲▲▲	●	▲▲▲
<b>TP</b>	●	▲	▼	●	▲▲▲	▼	●
<b>Turb</b>	●	▲▲▲	▲▲	●	▲▲▲	●	▲

Shaded cells represent a site with a short term record (Refer to Appendix 2)

Lake Waihola is classified as supertrophic and Lake Waipori is classified as eutrophic. They both show improving NNN concentrations, and Lake Waihola shows NH<sub>4</sub>, TN, TP and turbidity are also improving. This is consistent with the findings of a trophic level analysis undertaken by ORC between 2002 and 2004.

The Silverstream and Owhiro Stream are monitored in their lower catchments in Mosgiel. The catchment is varied, with both agricultural and urban pressures affecting the watercourses.

The only deteriorating trend in water quality was found in the Silverstream, where conductivity was increasing. Both streams showed an improvement in TN, and the Silverstream an improvement in NH<sub>4</sub>.

The Waipori River is the main inflow into Lake Waipori. It shows a small deterioration in TP, but an improvement in turbidity.

## 6.5 Northern Coastal Catchments

The northern coastal rivers and streams are shown in Table 6. 12.

**Table 6. 12 Water quality trends in the Northern Coastal Catchments**

Statistically significant trends are depicted in blue for improving water quality and red for declining water quality (▲=p <0.2, ▲▲=p <0.1, ▲▲▲=p <0.05, ● = no change)

	Welcome Creek Upstream	Welcome Creek Downstream	Kakanui at Clifton Falls	Kakanui at Pringles	Waiareka Creek	Waiarakura at Browns Pump	Shag River at Grange	Shag River at Goodwood
<b>WQI</b>	Fair	Fair	Very Good	Very Good	Poor	Very Good	Very Good	Very Good
<b>NH<sub>4</sub></b>	▲▲▲	▲	▼	▲▲▲	●	●	▲▲▲	▲
<b>Cond</b>	●	●	●	●	●	●	●	●
<b><i>E. coli</i></b>	●	●	●	●	●	●	●	●
<b>NNN</b>	▲▲▲	●	●	▼	●	▲▲▲	▲▲	▲▲▲
<b>SS</b>	●	●	●	●	●	▼▼▼	●	▲▲▲
<b>TN</b>	▲	▼▼	●	●	●	▲	●	▲▲
<b>TP</b>	●	▼▼▼	▼▼▼	●	▼▼▼	▼▼	●	●
<b>Turb</b>	▲▲▲	▲	▼	●	▲▲▲	●	▼	●

Welcome Creek is a spring fed stream that is monitored at its source and approximately 2km downstream. The upper site shows a decreasing trend for NH<sub>4</sub>, NNN, TN and turbidity (Table 6. 12). The lower site shows a decreasing trend for NH<sub>4</sub> and turbidity, but an increasing trend in TN and TP.

The Kakanui Catchment has long-term monitoring at two sites; Clifton Falls (upper site) and Pringles (lower site). Clifton Falls, which is upstream of land used intensively, showed a significant increase in NH<sub>4</sub>, TP and turbidity (Table 6. 12). Pringles showed a decreasing trend in ammoniacal nitrogen (-0.00076 mg/l year). The increasing trend in some nutrients at the upper site is surprising, as the upstream catchment has low intensity agriculture.

Waiareka Creek is a tributary of the Kakanui River, its confluence being in the Kakanui estuary. The stream is monitored at Teschmakers at the bottom of the catchment. Table 6.16 shows increasing trends of TP (0.017 mg/l year), and a decrease in turbidity (-0.27 NTU year) and TN (-0.014 mg/l year). The area has naturally low flows coupled with intensive agricultural land use.

The Waianakarua River showed a significant improvement in NNN (-0.016 mg/l year) as well as a smaller improving trend in TN. However, the monitoring site shows an increasing trend in TP and SS (Table 6. 12).

The Shag River has two long-term monitoring sites; The Grange in the mid catchment and at Goodwood drinking water intake in the lower catchment. At the Grange there was a significant decrease in NH<sub>4</sub> and NNN, but an increase in turbidity. At Goodwood there was a statistically significant decrease in NH<sub>4</sub>, NNN, SS and TN.

## 6.6 Southern Coastal Catchments

The southern coastal rivers and streams are shown in Table 6. 13.

**Table 6. 13 Water quality trends in the Southern Coastal Catchments**

Statistically significant trends are depicted in blue for improving water quality and red for declining water quality (▲=p <0.2, ▲▲=p <0.1, ▲▲▲=p <0.05, ● = no change)

	Waikouaiti River	Careys Creek	Waitati River	Tokomairiro East Branch	Tokomairiro West Branch	Catlins at Houipapa
<b>WQI</b>	Very Good	Very Good	Very Good	Good	Good	Good
<b>NH<sub>4</sub></b>	▲▲▲	●	●	●	●	▲▲▲
<b>Cond</b>	▼	●	●	▲▲▲	▲▲▲	●
<b><i>E. coli</i></b>	●	●	▼	●	●	▼
<b>NNN</b>	●	●	▲▲	●	●	▼▼▼
<b>SS</b>	▲▲▲	▲▲	●	▲▲	▲▲	●
<b>TN</b>	▲▲	●	●	●	●	▼▼▼
<b>TP</b>	▲▲	●	▼▼	●	▼	●
<b>Turb</b>	●	▲	●	●	▼▼▼	●

The Waikouaiti River at Orbells Crossing showed a significant decrease in NH<sub>4</sub> (-0.00086 mg/l year) and SS (-0.126 mg/l year), and TN and TP showed smaller decreases (Table 6.13). The only increasing trend was that of conductivity.

The Waitati River and Careys Creek enter the Pacific Ocean at Blueskin Bay. The Waitati River has a declining trend in TP and *E. coli*, but an improvement in NNN and Careys Creek shows an improvement in both turbidity and SS.

The Tokomairiro River shows water quality improvements in the East Branch, but in the West Branch there are decreasing trends for TP and turbidity. Monitoring below the confluence is not undertaken by ORC, due to the influence of Milton Waste Water Treatment Plant.

The Catlins River is monitored at Houipapa, and over the reporting period there has been a decrease in NH<sub>4</sub> (-0.00044 mg/l year), but an increase in NNN (0.012 mg/l year) and TN (0.018 mg/l year).

## 6.7 Urban streams

Three urban streams were monitored (Table 6. 14) - the Water of Leith, Lindsay's Creek, and the Kaikorai Stream - all of which are in Dunedin.

Lindsay's Creek showed a significant improvement in conductivity and NNN. The Water of Leith showed an improvement in NH<sub>4</sub>, NNN, SS, TN, TP and turbidity. The only significant trends in the Kaikorai Stream were an increase in TP and a decrease in *E. coli* and NNN.

The Water of Leith is an urban stream whose main tributary is the Lindsay's Creek. The improvement in water quality in both streams is attributed to a decrease in sewage entering the water courses through foul sewer overflows, or cross connections.

**Table 6. 14 Water quality trends in urban streams**

Statistically significant trends are depicted in blue for improving water quality and red for declining water quality (▲=p <0.2, ▲▲=p <0.1, ▲▲▲=p <0.05, ● = no change)

	Water of Leith at Dundas Street	Lindsay's Creek at North Road Bridge	Kaikorai Stream at Green Island
<b>WQI</b>	Fair	Fair	Good
<b>NH<sub>4</sub></b>	▲▲	▼	●
<b>Cond</b>	●	▲▲▲	●
<b><i>E. coli</i></b>	●	●	▲
<b>NNN</b>	▲	▲	▲
<b>SS</b>	▲	●	●
<b>TN</b>	▲	●	●
<b>TP</b>	▲	●	▼▼▼
<b>Turb</b>	▲▲	●	●

## 6.8 Summary of water quality trend results

The results above detailed all the statistically significant results. The discussion below focuses on trends that are statistically significant at the 95% confidence level. The results of the p>0.05 Seasonal Kendall trend tests for the 77 SOE monitoring sites are summarised in Table 6. 15 and given in full in Appendix 9.

Overall water quality is improving for 94 variables and declining for 29 variables. It is important that the WQI is taken into consideration when a deteriorating trend is encountered. For example, the Clutha River/Mata-Au at Luggate ranks number 4 in the WQI, indicating that it still has extremely good water quality, even though the longer term trend shows some deterioration.

**Table 6. 15 Summary of statistically significant ( $p < 0.05$ ) trends in raw water quality variables at SOE sites**

	Declining Water Quality	Improving Water Quality
Ammoniacal nitrogen ( $\text{NH}_4$ )		23
Conductivity (Cond)	3	10
<i>Escherichia coli</i> ( <i>E. coli</i> )	2	1
Nitrite/nitrate nitrogen (NNN)	3	19
Suspended solids (SS)		12
Total nitrogen (TN)	9	8
Total phosphorus (TP)	9	4
Turbidity (Turb)	2	16

Where water quality is of great concern is when the sites are ranked poorly in the WQI and still have a longer term trend of deteriorating water quality, for example, some of the tributaries of the Pomahaka River (Crookston Burn, Heriot Burn and Waipahi), which are already ranked in the fair category, but are still deteriorating.

There is a significant improvement (decreasing trend) in ammoniacal nitrogen, seen at 23 sites (Table 6. 15).  $\text{NH}_4$  The two sites with the largest decreases were the Main Drain (-0.215 mg/l year), and the Taieri at Allanton (-0.0049 mg/l year). The Main Drain is in the Lower Taieri Catchment and the improvement may be due to the cessation of direct discharges of dairy effluent into the watercourse. The other site is the Taieri at Allanton, and the sharp decrease here can be explained by the closure of Mosgiel sewage discharge from the Taieri River in July 2000.

NNN has decreased at 19 sites. However, three sites have seen an increasing trend; the Catlins at Houipapa (0.012 mg/l year), Lovells Creek (0.028 mg/l year) and the Crookston Burn (0.07 mg/l year). TN has increased at nine sites, the largest increases being in the Heriot Burn (0.1 mg/l year) and Crookston Burn (0.095 mg/l year) in South West Otago. The site with the most significant decrease in TN was the Main Drain (0.31 mg/l year).

TP showed an increasing trend in nine rivers. The largest trends were in the South West Otago rivers (Heriot Burn, Waipahi, Waiwera), Waiareka Creek in North Otago and the Clutha River/Mata-Au at Luggate. The Kakanui River at Clifton Falls also showed an increasing trend in TP. Even if this result is biased by two higher readings (outliers), the long-term trend still shows a deterioration in  $\text{NH}_4$ .

Waiareka Creek is now augmented by the North Otago Irrigation scheme, which opened at the end of October 2006. Water quality is likely to improve due to increased flow sourced from the Waitaki River. On the other hand, agriculture is likely to intensify, which may continue to adversely affect water quality.

There has also been an increase in TN in the Clutha River/Mata-Au main stem at Luggate. There is no direct discharge immediately upstream of Luggate, however, the Wanaka oxidation ponds discharge into the Clutha River/Mata-Au at Albert Town and may be responsible for some of the increases. There is also a trend of increasing pH (Appendix 9), which may be caused by *Didymosphenia geminata* (Didymo). Luggate is

heavily colonised by *Didymo*, and it is known the *Didymo* causes pH to rise in its immediate vicinity.

Other rivers which show an increase in nutrient levels are the Catlins River (NNN and TN), which probably reflects the onset of intensive farming in this area, and Welcome Creek, which shows a deterioration in TP. This is likely to be due to extensive agriculture coupled with irrigation run-off. Irrigation run-off also adversely affects the Ida Burn in the Manuherikia catchment.

An improvement in water quality, particularly nutrients, is seen in the Shag River (NNN,  $\text{NH}_4$  and TN). This improvement probably reflects improved farming practices, but it may also reflect the conversion of large areas of farmland to forestry. The Waikouaiti River also shows improvements in water quality ( $\text{NH}_4$ , SS, TN and TP) and is likely to be because of improved farming practices upstream.

Conductivity has shown a significant decrease at ten of the sites, with small increases at three sites: Clutha at Luggate (0.001813 mS/cm year), Kaihiku Stream (0.003388 mS/cm year, and the Main Drain (0.2512 mS/cm year).

Only Lake Wanaka showed a significant decreasing trend in *E. coli*, while two sites showed an upward trend in *E. coli* levels - the Contour Channel (55 cfu/100ml year) and the Ida Burn (35 cfu/100ml year). The Kaikorai Stream at Green Island also demonstrated a decreasing trend ( $p < 0.2$ ) of over 90 cfu/100ml year.

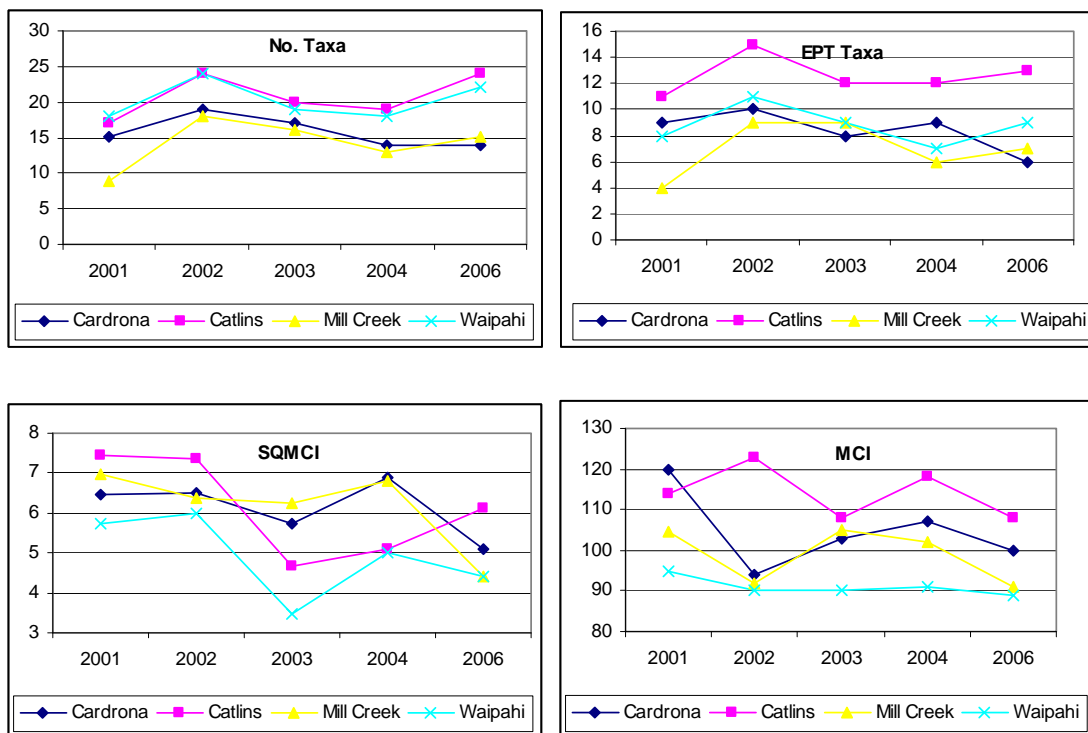
SS decreased at 12 sites and turbidity decreased at 16 sites. There were only two sites with an increasing trend in turbidity; these were the Waiwera in South West Otago and the Tokomairiro West Branch.

Overall, sites with declining water quality tended to be smaller streams draining agriculturally intensive or urban catchments. The tributaries of the Pomahaka River stand out as some of the worst sites (Washpool, Wairuna Stream, Heriot Burn, Crookston Burn). The sites with good water quality and few trends tend to be the large lake outlets in Central Otago (Wakatipu, Dunstan, Wanaka, Hawea) as well as the upper catchments of the large rivers (Taieri at Stonehenge, Manuherikia at Blackstone and Cardrona).

## 7. Temporal trends in macroinvertebrate distribution

There were four sites which had complete records of the five years in which recording was carried out - Cardrona River at the Larches, Catlins River at Houipapa, Mill Creek at Fish Trap and Waipahi River at Waipahi. The plots in Figure 7. 1 show results of each biological index.

There are seven sites where both 2001 and 2006 data are available - Cardrona River at the Larches, Catlins River at Houipapa, Mill Creek at Fish Trap, Waipahi River at Waipahi, Kaikorai Stream at Brighton, Lindsay's Creek upstream of the Water of Leith and the Water of Leith at Dundas Street. There were no significant differences between data from 2001 and 2006 that would indicate a trend for any of the biological indices. However, there are very little data and so the power of the tests are low. If there is a trend present it is unable to be detected.



**Figure 7. 1 Time trend for each biological index at the four sites where biological monitoring has occurred annually**

## 8. Discussion

Policy 7.5.1 of the RPW for Otago is to maintain or enhance the quality of water in Otago's lakes and rivers so that it is suitable to support their natural and human use values and people's use of water.

In addition to this, there are specific policies for the enhancement of water quality so that they become suitable to support primary contact recreation (7.6.1), the enhancement of water quality so that the Macroinvertebrate Community Index score is increased (7.6.2), and the enhancement of water quality so that lake aquatic ecosystems are enhanced (7.6.3).

This section focuses on whether policy objectives are being achieved by assessing the findings of the spatial and temporal trend assessments discussed in Sections 3 and 6.

### 8.1 Policy 7.6.1

Table 8. 1 shows the sites mentioned in section 7.6.1 of the RPW for Otago. The policy is to enhance the water quality in these following water bodies so that they become suitable to support primary contact recreation. The grade and rank of the water body using the water quality index is also given as well as the percentage of samples that exceed the MfE/MoH green surveillance level of 260 *E. coli* per 100ml.

**Table 8. 1 Sites indicated in Policy 7.6.1 of the Regional Plan: Water for Otago, WQI grade and rank and compliance with the MfE/MoH *Escherichia coli* criteria**

Site Name	WQI Grade	WQI Rank	% samples >260 Ec/cfu	REC (Refer to Table 3. 2)
Lake Hayes	Very good	28	0	CD/H/HS/P
Taieri d/s Allanton	Good	43	21	CD/H/HS/P
Silverstream d/s Riccarton Rd	Good	39	28	Cd/L/HS/P
Mill Creek	Good	50	28	CD/H/HS/P
Tokomairiro River (E Branch)	Good	46	40	CD/L/HS/P
Tokomairiro River (W Branch)	Good	44	54	CD/L/HS/P
Lower Waiwera River (below SH1)	Fair	68	57	CD/L/SS/P
Heriot Burn at SH90	Fair	60	59	CD/L/HS/P
Water of Leith	Fair	62	61	CW/L/VB/U
Kaikorai Stream	Good	55	65	CD/L/SS/U
Heriot Burn	Fair	71	71	CD/L/HS/P
Crookston Burn	Fair	70	75	CD/L/AI/P
Lindsay's Creek (Water of Leith)	Fair	72	94	Cd/L/VB/U
Clutha River/Mata-Au - Koau Branch – see text below				

The Clutha River/Mata-Au Koau Branch is not monitored by ORC as part of the SOE monitoring programme. It is, however, monitored by PPCS Finegrind as a condition of its resource consent.

It can be seen that only Lake Hayes meets the target of <260 *E. coli*/100ml on every occasion. Eight of the sites had >50% non compliance with this target value. Of these sites the Water of Leith, Lindsay's Creek and the Kaikorai Stream are urban streams in Dunedin, while the other streams all drain low elevation country whose agricultural activities are intensive and heavily biased towards dairy farming.

Microbiological contamination in low elevation, pastoral and urban catchments is common. At a further four sites to those listed in Policy 7.6.1, more than 50% of *E. coli* results exceeded 260 *E. coli*/100ml (Table 8. 2). Of these sites, only one was in hill country, the rest are low elevation sites, however, all drained either pastoral or urban catchments. The sites with some of the highest percentage non compliance are found in South West Otago, particularly in the area south of the Clutha (Crookston Burn, Heriot Burn, Waipahi, Wairuna, Waiwera and Washpool). This area has high rainfall, often saturated soils and drainage enhanced by tile and mole drains.

**Table 8. 2 Sites which are not listed in Policy 7.6.1 where >50% of results exceed 260 *E. coli*/100ml**

Site	WQI Grade	WQI Rank	% results>260 <i>E. coli</i> /100ml	REC (Refer to Table 3. 2)
Waipahi Cairns Peak	Fair	64	50	CW/L/SS/P
Minzion Burn	Poor	73	65	CD/H/HS/P
Washpool	Poor	77	70	CD/L/SS/P
Wairuna	Poor	76	83	CD/L/HS/P

Tile drainage systems are in place throughout much of South West Otago, in areas prone to saturated soils. Streams drained by catchments with tile drains are likely to have elevated *E. coli* levels as well as elevated nutrient levels, which can be partly attributed to these drains carrying contaminated surface water runoff to the nearest watercourse.

Lindsay's Creek in Dunedin had particularly high non compliance (94%). The other Dunedin urban streams recorded 65% non compliance (Kaikorai Stream) and 61% non compliance (Water of Leith). Although the urban streams are not commonly used for full immersion recreational activities, they are often used as a focus for family activities, i.e. picnics, paddling etc. The high levels of faecal bacteria indicate a higher health risk arising from these activities.

The Dunedin City Council is aware of the high faecal bacteria levels in Dunedin's streams, however, they are not aware of any regular sewage overflow or cross connection that may be the cause of these elevated levels. Historically there have been problems of sewage infiltration into Lindsay's Creek. Extensive investigations have been undertaken by Dunedin City Council and considerable capital committed on past and future improvement works, including a planned major upgrade of the sewer pipeline in the area between Craighleith Street and Gardens Corner.

## 8.2 Policy 7.6.2

Table 8.3 shows the sites mentioned in section 7.6.2 of the RPW for Otago. The policy is to enhance water quality so that the Macroinvertebrate Community Index improves. The water quality index shows the grade and rank of the water body, the macroinvertebrate rank is shown as well as MCI and SQMCI grades.

**Table 8.3 Sites indicated in Policy 7.6.2 of the Regional Plan: Water for Otago, WQI grade and rank, macroinvertebrate rank and MCI and SQMCI grades**

Site Name	WQI Rank	WQI Grade	MCI Grade	SQMCI Grade	Macroinvertebrate Rank
Hayes Creek	18	Very good	Poor	Poor	63
Lower Waipori River	31	Very good	Fair	Fair	66
Lower Tokomairiro River – W Br	44	Good	Fair	Fair	45
Lower Tokomairiro River – E Br	46	Good	Poor	Fair	47
Lower Wairuna Stream	76	Poor	Fair	Poor	49
Taieri River below Allanton	43	Good	Fair	Poor	56
Lower Kaihiku Stream	69	Fair	Poor	Poor	69
Lower Waiareka Creek	74	Poor	Poor	Poor	72
Kaikorai Stream	55	Good	Poor	Poor	78
Lower Owaka River	-n/a	-n/a	Good	Poor	55
Lower Horne Creek	-n/a	n/a-	Poor	Poor	23

As can be seen from the above table, the majority of these sites have poor MCI grades, but at the same time, water quality is good or very good at most of the sites monitored. This is contrary to the thought that these MCI sites were all degraded because of poor water quality.

The condition of aquatic habitat can be measured by the Macroinvertebrate Community Index (MCI), which is an indicator of the condition of benthic (bottom dwelling) invertebrate communities. The MCI is the most widely used and best-known index for New Zealand aquatic invertebrates, and is an appropriate indicator of the life-supporting capacity of rivers.

Ecosystem health takes into account a wide range of inter-linked factors, such as water quality and habitat. Biological indices put a large amount of information into a compact form, therefore, they are inherently coarse tools that give a broad view of general patterns. However, they are useful because the presence or absence, abundance, and distribution of species can tell us much about the quality and condition of the site in which they live.

**Table 8. 4 Sites targeted by Policy 7.6.2 of the Regional Plan: Water for Otago, substrate and habitat type**

Site Name	Substrate	Habitat Type
Hayes Creek	Mud and sand	Run
Lower Horne Creek	Sand and gravel (urban environment)	Run
Kaikorai Stream	Gravel and stone (urban environment)	Riffle
Taieri River below Allanton	Gravel and sand (large river)	Run
Lower Waipori River	Gravel and sand (large river)	Run
Lower Tokomairiro River – W Br	Gravel and sand	Run
Lower Tokomairiro River – E Br	Mud	Run
Lower Owaka River	Gravel and stone	Riffle
Lower Waiareka Creek	Mud	Pool
Lower Kaihiku Stream	Mud	Run
Lower Wairuna Stream	Mud	Pool Run

A key component of the MCI index is the availability of suitable habitat. The MCI index is designed specifically for stony riffle substrates in flowing water, therefore, MCI values can vary due to the availability of suitable habitat and not necessarily due to water quality. For example, Hayes Creek is a deep and very slow flowing habitat, providing only muddy and weedy substrate at the State Highway 6 sampling site.

These conditions are not suitable for most aquatic insect taxa, particularly the sensitive members of the mayflies, stoneflies or caddisflies. Low MCI values can therefore be expected and this is confirmed by the poor grading of Hayes Creek. As can be seen in Table 8.4, the substrate and habitat of many of the sites in Policy 7.6.2 are unsuitable for traditional MCI assessment.

### 8.3 Policy 7.6.3

Table 8. 5 shows the sites mentioned in section 7.6.3 of the RPW for Otago. The policy is to enhance water quality to a standard which supports an enhanced aquatic ecosystem, through management of point and non point source discharges.

**Table 8. 5 Sites targeted by Policy 7.6.3 of the Regional Plan: Water for Otago, median TN mg/l, TP mg/l and WQI grades and ranks (2000-2005)**

Site Name	Median TN mg/l	Median TP mg/l	WQI Grade	WQI Rank
Lake Hayes	0.31	0.018	Very good	28
Lake Johnson	0.67	0.028	Very good	29
Lake Waipori	0.54	0.035	Very good	33
Lake Waihola	0.44	0.041	Good	40
Lake Tuakitoto	0.95	0.74	Good	54

The sites listed in The RPW for Otago and Table 8. 4 above all had either nitrogen and or phosphorus loadings exceeding that recommended (0.5 mg/l and 0.05 mg/l respectively – ANZECC Guidelines) as being suitable for aquatic ecosystems.

The trigger values which are commonly used in New Zealand are for slightly disturbed (modified) lowland river ecosystems. The ANZECC (2000) trigger values are 0.614 mg/l for total nitrogen and 0.033 mg/l for total phosphorus.

The results listed in Table 8. 4 are the median of all results taken between 2000 and 2005. Using the ANZECC (2000) trigger values, it can be seen that only two of the sites exceed the trigger value for total nitrogen (Lake Johnson and Lake Tuakitoto), and three of the sites exceed the trigger value for total phosphorus (Lake Tuakitoto, Lake Waipori and Lake Waihola).

It is interesting that the total phosphorus exceeded the trigger value in the three shallow lakes. Wind-induced turbulence of lake water can re-suspend large amounts of sedimented materials which, as phosphorus binds to soil particles, may explain the elevated levels found, and this situation is unlikely to change. Lake Johnson and Lake Tuakitoto exceed the trigger value for total nitrogen, Lake Tuakitoto by a larger degree than Lake Johnson. In both lakes, poor water quality is predominantly due to non-point source nutrient contamination from water running off land.

## 9. Intensive farming and the impact on water quality

### 9.1 Introduction

Land use change is on-going in Otago. Previous national reports have pointed to the intensification of land use as a cause of the deteriorating water quality in some of New Zealand's streams, rivers and lakes. To assess if this is the case in Otago, the water quality trend analysis and water quality results have been compared to catchment land use change.

The timeframe being examined is constrained by the dates of water quality sampling, which in this case is from 1995-2006, and also the available land use information. Most land use change has been obtained from local knowledge and from historical land use maps. AgriQuality Ltd supplied the ORC with the most recent (2006) and most historical (1999) Agribase™ land use GIS layers. However, there were many gaps in the 1999 dataset, making comparisons between 1999 and 2006 unreliable, therefore only the maps showing current land use in 2006 are shown.

Intensification of land use that has been occurring in Otago includes the:

- Conversion of sheep and beef, and cropping properties to dairy farms;
- Increasing of stocking rates on both sheep and beef properties through irrigation development; and,
- Introduction of winter grazing of dairy stock.

Generally polluted surface water in grazed catchments is characterised by elevated levels of faecal bacteria, ammoniacal-N, nitrate-N, suspended solids and phosphorus. Poor land use practices in intensive farming would see an increase in these parameters, but they can be controlled through good effluent management practices and riparian management. However, reduction in nitrate-N levels in waterways can not be achieved solely by the above practices. This is because nitrate is generated from grazed pasture mainly from animal urine patches. Nitrate-N leaches with percolating water and contaminates ground water and subsequently surface water. If the drainage water is intercepted by tile and mole drains, direct and instant contamination of surface water occurs.

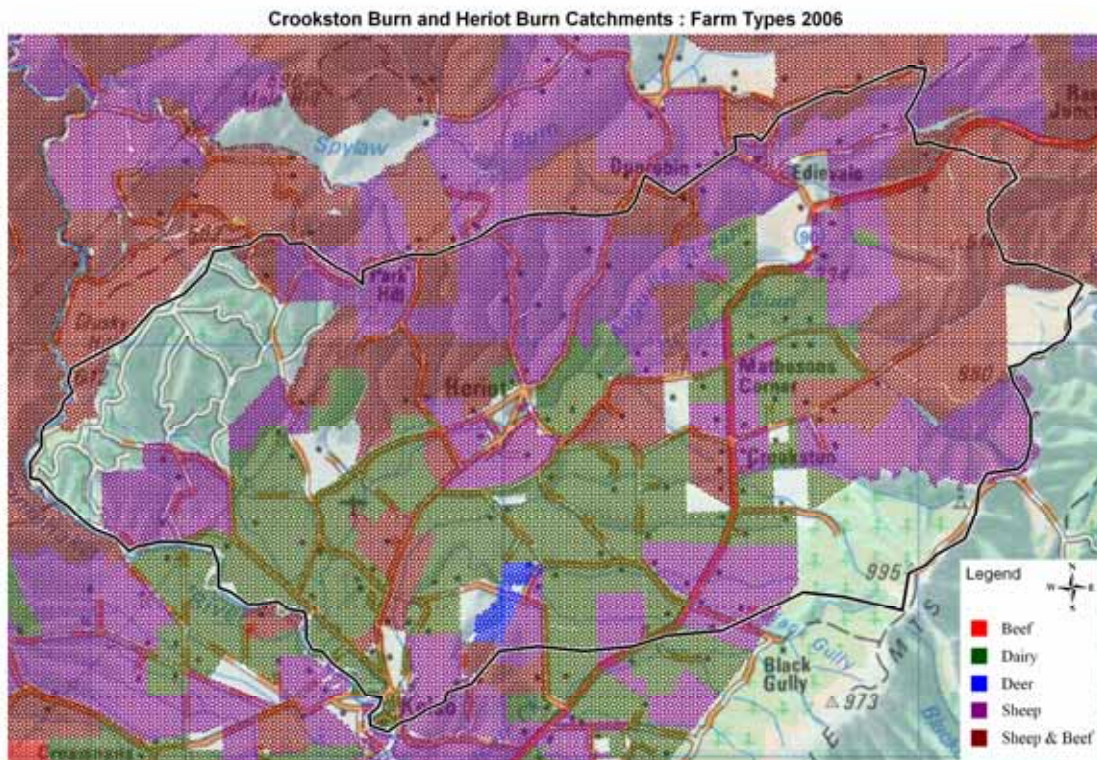
As land use intensifies from sheep to dairying, nitrate leaching increases, with greater levels of nitrate-N being present in surface water. This is due to large urine patches, as dairying leaches three to four fold nitrate-N more than than sheep farming. If surface water nitrate-N levels are already at elevated levels, increasing land use intensity will only accentuate nitrate pollution.

The link between land use change and water quality trends is examined using three case studies, each representing a broadly similar area of Otago. Case Study 1 is of West and South Otago, an area of high rainfall and soils with extensive sub-surface mole and tile drainage. The North Otago area is used for Case Study 2. This is an area of lower rainfall where there is a greater reliance on irrigation. The Upper Taieri is the area discussed in Case Study 3, with farming occurring alongside the distinctive Scroll Plain wetlands. A map showing current land use is included for each of the case study areas where data are available.

## 9.2 Case study 1: West and South Otago

### 9.2.1 Crookston Burn and Heriot Burn Catchment, West Otago

The Crookston Burn and Heriot Burn are tributaries of the Pomahaka River. The land use in the catchment of the two streams is approximately 50% dairy. The dairy farms are located on the flatter land, and sheep beef and forestry on the rolling hill country. Intensification of land use through dairy conversions has occurred over the last 15 years, with most of the conversions occurring from 1998 to 2003. Figure 9. 1 shows the land use of the Crookston and Heriot Burn Catchments in 2006.



**Figure 9. 1 Map of land use in the Crookston Burn and Heriot Burn Catchments 2006**

The water quality of both the Crookston Burn and Heriot Burn was given a WQI of fair, with elevated concentrations of NNN, *E. coli* and DRP. The trend analysis for the Crookston Burn showed a significant increase in TN and NNN concentrations, and a decrease in turbidity and  $\text{NH}_4$ . Significant TN and moderate NNN increases were also reported for the Heriot Burn. Changes in turbidity readings in the Heriot Burn ranged from no change to a moderate decline at the respective sampling sites.  $\text{NH}_4$  concentrations in the Heriot Burn ranged from no change to a slight increase.

Increases in NNN concentrations in the waterways are not unexpected given the nature of the soils in both catchments, particularly in the winter and early spring period, and in the presence of mole and tile drainage. These soil properties will be exacerbating the problem of nitrogen losses to the waterways.

In both catchments, an improvement in water clarity is indicated through the trend turbidity readings. This trend could be an early indicator that the fencing of waterways on dairy farms has been positive in terms of reducing sediment inputs. The trends in NH<sub>4</sub> concentrations differ between the two streams. Improved effluent management or the exclusion of dairy cows from the waterways may explain part of the positive trend in the Crookston Burn, but there remains a negative trend in the Heriot Burn.

### ***9.2.2 Waipahi, Washpool and Wairuna Catchments, South Otago***

The Waipahi, Washpool and Wairuna Creeks also flow into the Pomahaka River. Dairy farming is a significant land use in all of these catchments, particularly in its lower reaches. Most of the conversions to dairying occurred during the late 1990s. Sheep and beef farming is the predominant land use in the upper catchments.

The water quality in the Washpool and Wairuna Catchments has a WQI of poor. The trend analysis indicated that there has been little or no change in water quality in either catchment, despite the increase in dairying in both catchments.

The water quality in the Waipahi is fair and the trend analysis shows that there has been little change except for turbidity and TP levels. Both of these parameters show a deteriorating trend. This could be attributed to an increase in sediment run-off and/or streambank erosion.

### ***9.2.3 Waiwera Catchment, South Otago***

The Waiwera Catchment is located in South Otago but drains directly to the Clutha River/Mata-Au. The land use in the catchment is a combination of sheep, beef, deer and some dairy farming on the flatter lowland country. Land use has changed in the last ten years, with three dairy conversions above the sampling site on the State Highway between Balclutha and Clinton. The Waiwera River is mostly an unmodified stream with natural character.

The water quality in the stream was rated as fair with elevated levels of *E. coli*, NNN and DRP. The trend analysis showed that the water quality has deteriorated in respect to TN and TP.

### ***9.2.4 Discussion***

During the period 1995-2006 there have been significant land use changes in the tributary catchments of South and West Otago. The main trend has been an increase in the number of properties converting to dairy farming. During this same period trends in water quality have been variable. While there is evidence that there has been a downward trend in water quality in some waterways which has corresponded with the period of intensification of land use, the trends are not consistent across all the waterways.

The water quality data suggest that the environmental risks associated with intensive farming in South and West Otago are significant. A major factor contributing to declining water quality, particularly increasing NNN, TN and *E. coli* levels, is likely to be the mole and tile drainage network which is a prerequisite for farming in these areas.

The access of stock to waterways continues to be a problem in some areas, and is thought to be a contributing factor to an increase in turbidity and TP at some locations. The main problem areas are those associated with the wintering of cattle.

Further conversions to dairy farming in South and West Otago are likely. Acknowledgement of the risks to waterways is essential to prevent further downward trends in water quality. It should also be noted that the use of best management practices to minimise the leaching and run-off of contaminants with these soil types in this climatic zone is unlikely to fully protect waterways in all areas.

### 9.3 Case study 2: North Otago

#### 9.3.1 Kakanui Catchment

The land use in the Kakanui catchment (excluding the Waiareka subcatchment which is discussed below) is sheep, beef, deer and dairy. Dairying has increased over the last ten years, with an increase from two to 11 properties either being used for dairy grazing or milking platforms. The dairy farms are confined to the Kakanui Valley flats.

The water quality is measured at two sites in the catchment - Clifton Falls higher in the catchment upstream of the dairying areas, and Pringles lower in the catchment downstream of dairying. Both sites were classified with a WQI of very good water quality. The trend analysis showed deterioration in TP at Clifton Falls. The trend analysis also showed the levels of NH<sub>4</sub> and turbidity to be increasing. This is, however, only a slight trending down in quality ( $p < 0.2$ ), and the levels of both parameters are below guidelines.

The water quality at Pringles downstream of the dairying has shown an improvement in the concentration of NH<sub>4</sub>. Better effluent management and fencing to prevent stock accessing the waterway has occurred on both dairy and beef properties in recent years.

#### 9.3.2 Waiareka Catchment (Kakanui sub-catchment)

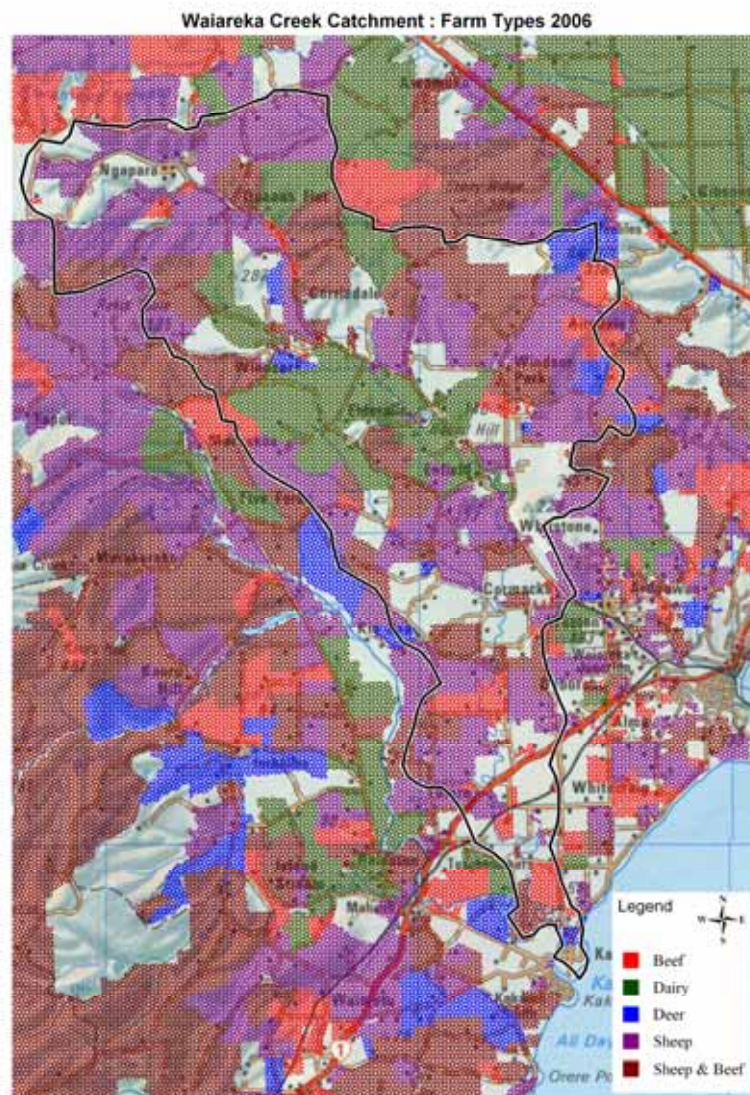
Land use in the Waiareka catchment is changing quite rapidly due to the introduction of the North Otago Irrigation (NOIC) scheme in 2006. Prior to the irrigation scheme, land use in the catchment was a mix of sheep, beef, deer, cropping and some dairy. The land being used for dairying has expanded over the last five years, with both conversions and dairy stock being grazed on run-off blocks during winter. The introduction of irrigation will result in higher stocking rates of all stock types throughout the catchment. Figure 9.2 shows the land use in the Waiareka Creek Catchment in 2006.

The water quality in the Waiareka has a WQI of poor, and the trend analysis showed TP continuing to worsen but turbidity improving. The stream is a slow sluggish waterway with very low flows.

### 9.3.3 Discussion

Although dairying has expanded in the Kakanui Valley, the water quality has improved slightly. From the data available, dairying has not yet had a detrimental effect on water quality in this catchment.

The Waiareka Catchment is a subcatchment of the Kakanui, and the water quality is poor. Flow in this creek is now augmented by the North Otago Irrigation scheme, which opened at the end of October 2006. Water quality is likely to improve due to increased flow sourced from the Waitaki, although on the other hand, the impacts from the intensification of agriculture may adversely affect water quality. The potential environmental risks and benefits were recognised during the planning stages of the scheme. In response, measures have been introduced to minimise negative impacts and, where possible, enhance the waterway. As well as augmentation of stream flow, all North Otago Irrigation Company farms have an approved environmental farm plan, which is a consent requirement and is audited annually.



**Figure 9.2** Map of land use in the Waiareka Creek Catchment in 2006

## 9.4 Case study 3: Upper Taieri

### 9.4.1 Upper Taieri

Land use on the Upper Taieri is sheep, beef and dairy. The dairy farms cover a small portion of the land area on the Upper Taieri. However, they are located alongside the Scroll Plain wetland section of the Taieri River.

The water quality of the Upper Taieri is measured at four sites: Stonehenge, Halls Bridge, Waipiata and Tiroiti. Stonehenge and Halls Bridge are located upstream of the dairy units and Waipiata and Tiroiti downstream. All the sites (excluding Waipiata, which has a short term record) were classified as either good or very good water quality. The trend analysis showed the upstream sites, Stonehenge and Halls Bridge, were improving in water quality while Tiroiti showed deterioration in two parameters, TN and TP. However, the concentration of  $\text{NH}_4$  at Tiroiti is improving.

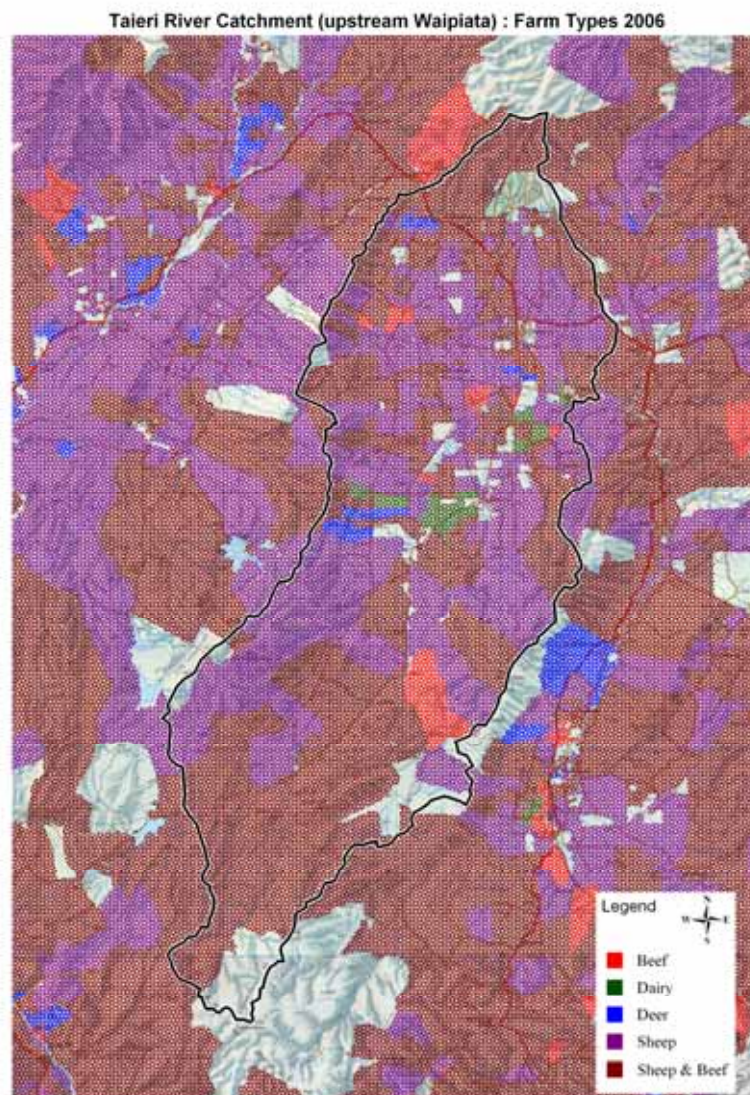


Figure 9.3 Map of land use in the Upper Taieri catchment 2006

### 9.4.2 Discussion

The results from sampling programme in the Upper Taieri are inconclusive regarding the impacts of land use intensification on water quality. Dairying is possibly having an impact on water quality at the Tiroiti site, with increasing trends in TN and TP being recorded. However, there is reasonable distance between the dairy farms and the Tiroiti site. Continued sampling at the Waipiata site, located closer to the dairy properties, will give a more accurate record of the impact of dairying.

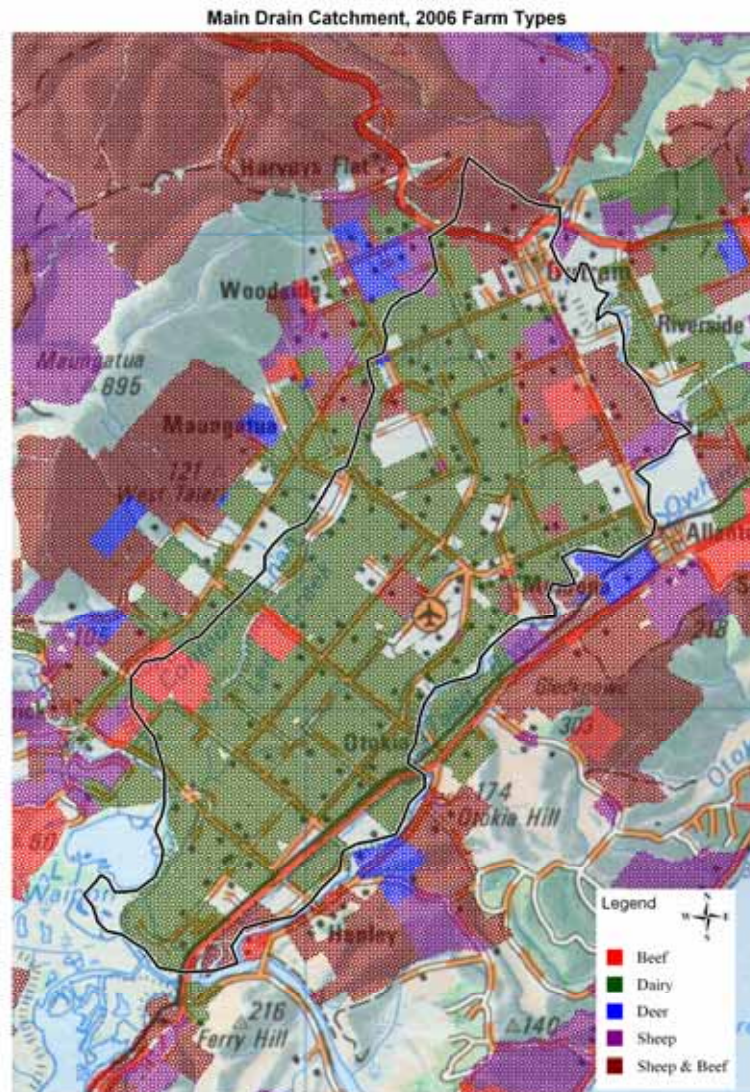
#### **Land use, land practices and water quality**

In all areas, the intensification of land use may have an adverse impact on water quality. The biggest risks are in areas with pallic soils and tile and mole drainage, although the risks associated with intensification in other areas can never be discounted.

Careful management is required to avoid adverse impacts, particularly in high risk areas. Changes in farm practices can go a long way to protecting waterways, however, the introduction of intensive land uses, such as dairying, will increase the nutrient input to the catchment.

The impact of existing land use on water quality can be reduced by improved farming practices. An example of this can be seen in the Main Drain subcatchment of the Lower Taieri Catchment.

The catchment of the Main Drain was a long established dairy farming area (see Figure 9.4). The Main Drain has a current WQI of poor due to low dissolved oxygen levels, however, it also has elevated TN and NH<sub>4</sub> levels. Despite the poor rating, trend analysis indicates an improvement in water quality and a decline in TN, NH<sub>4</sub>, NNN and TP concentrations.



**Figure 9.4** Map of land use in the Main Drain catchment 2006

The land use has not changed in this catchment during the last ten years. However, practices on the dairy farms have been modified. For example, dairy shed effluent is more commonly applied to land rather than being discharged to waterways after being settled in a pond.

The Main Drain water quality could still be improved further, however, change for the better has occurred.

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## Glossary

Term	Explanation
<b>Alkaline</b>	Any of various soluble mineral salts found in natural water and arid soils having a pH greater than 7. In water analysis, it represents the carbonates, bicarbonates, hydroxides, and occasionally the borates, silicates and phosphates in the water.
<b>Ammoniacal-N (mg/L)</b>	High levels of ammoniacal-N indicate some contamination due to wastes or anaerobic waters. Of the wide range of aquatic organisms tested, fish have proven to be most sensitive to unionised ammonia. The toxicity of ammonia is dependent on the pH and temperature of the solution (ANZECC, 1992).
<b>ANZECC</b>	Australian and New Zealand Environment and Conservation Council.
<b>Benthic</b>	Associated with the bed of a water body, e.g., invertebrates found in riverbed habitats.
<b>Biomonitoring</b>	The use of biological indicators to assess water and habitat quality.
<b>Bloom</b>	Conspicuous biological population growth, usually of algae.
<b>Box and whisker plot</b>	Graphical summary of the spread of data, usually showing the interquartile range (middle 50%) as a box, and values outside this range as a bar (or whisker). Median, average and outlier values may also be shown.
<b>Buffering capacity</b>	Ability of riparian vegetation to reduce inputs of sediment, nutrients and other contaminants to a water body.
<b>Contact recreation</b>	Forms of recreational use of water, often divided into “primary contact” e.g. swimming, and “secondary contact” e.g. boating.
<b>Contaminant</b>	Includes any substance (including gases, liquids, solids and micro-organisms) or energy (excluding noise) or heat, that either by itself or in combination with the same, similar, or other substances, energy or heat: <ol style="list-style-type: none"> <li>a) When discharged into water, changes or is likely to change the physical, chemical or biological condition of water; or</li> <li>b) When discharged onto or into land or into air, changes or is likely to change the physical, chemical, or biological condition of the land or air onto or into which it is discharged</li> </ol>
<b>Dissolved oxygen (mg/L)/ Percentage Saturation</b>	Dissolved oxygen is important for fish and other aquatic life to breathe. Water should be greater than 80 percent saturated with dissolved oxygen for aquatic plants and animals to live in it. Low levels of dissolved oxygen often indicate the presence of large numbers of aquatic plants, especially in small streams. The

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## Glossary

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Term	Explanation
	concentrations of dissolved oxygen in a water body may vary enormously in the course of 24 hours, particularly in streams where there is significant nutrient enrichment. The solubility of dissolved oxygen in water is dependent on temperature, atmospheric pressure and salinity (ANZECC, 1992).
<b>Dissolved reactive phosphorus (mg/L)</b>	Dissolved reactive phosphorus is a form of phosphate that is available immediately for plant growth and will assist in interpretation of periphyton growth results (ANZECC, 1992). Dissolved reactive phosphorus levels in water samples are often inversely related to periphyton cover due to uptake of the nutrient by periphyton (Smith et.al, 1993).
<b>Ecosystem</b>	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.
<b>Effluent</b>	A waste liquid discharge from a manufacturing or treatment process, in its natural state or partially or completely treated, that discharges into the environment.
<b>Electrical conductance (conductivity)</b>	A measure of the ease with which a conducting current can be caused to flow through a material under the influence of an applied electric field. It is the reciprocal of resistivity and is measured in milli siemens per metre.
<b>Escherichia coli (cfu/100ml)</b>	<i>E. coli</i> bacteria are used as an indicator of the human health risk from harmful micro-organisms present in water, for example from human or animal faeces. The median number of <i>E. coli</i> bacteria present in water samples should be less than 126 per 100 ml of water if it is to be used for recreation. The maximum number of <i>E. coli</i> bacteria present in any single water sample should be less than 550 per 100 ml of water.
<b>Eutrophic</b>	Waters characterised by sufficiently high nutrient levels to promote high algal productivity, usually in reference to lakes.
<b>Faecal Coliforms (/100mL)</b>	Faecal coliforms are useful for determining the suitability of waters for contact recreation and stock drinking. The most common diseases associated with swimming areas are eye, ear, nose and throat infections, skin diseases and gastrointestinal disorders. A number of pathogens and parasites can be transmitted by contaminated water to livestock which may result in reduced growth, or mortality. Faecal coliforms are <i>indicator organisms</i> . This means their presence in water is indicative of harmful pathogens. Measurement of harmful pathogens themselves is difficult or impossible (ANZECC, 1992).
<b>Macro-</b>	Invertebrates retained by a 0.5mm mesh sieve, i.e. those generally used in biomonitoring.

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## Glossary

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Term	Explanation
<b>invertebrates</b>	
<b>Macroinvertebrate Community Index</b>	Macroinvertebrates include aquatic insects, crustaceans, worms and snails living in the beds of rivers and streams. These macroinvertebrates are usually collected from cobble beds and are used to calculate what is known as the Macroinvertebrate Community Index (Stark, 1985). The Macroinvertebrate Community Index is based in the pollution tolerances of aquatic invertebrates where each taxon is assigned a score from 1 to 10. The more sensitive taxa are allocated higher scores while highly tolerant forms are allocated low scores. A Macroinvertebrate Community Index score is estimated by averaging the taxa scores and multiplying the result by a scaling factor of 20. Macroinvertebrates are susceptible to changes in sedimentation, periphyton abundance, temperatures (Quinn et. al, 1992), pH, dissolved oxygen and toxins. Macroinvertebrates indicate long-term water quality conditions compared with spot chemical samples which only represent water quality at time of sampling.
<b>Median</b>	The middle value when a set of values is ordered from lowest to highest.
<b>Nutrient enrichment</b>	The degree of nutrient inputs to a water body. May refer to inorganic or organic nutrients and point source or diffuse source inputs.
<b>Nitrate/Nitrite-N (mg/L)</b>	Nitrate/Nitrite-N (NNN) is mainly derived from land and subsoil drainage. If most of nitrogen in the water is in the NNN form, the waters may be considered stabilised and indicate previous pollution. Nitrate is an important nutrient for the growth of algae and other plants and may be harmful to stock in sufficient concentrations (ANZECC, 1992).
<b>Organic enrichment</b>	Input of organic matter from wastes such as dairy-shed effluent and sewage discharges to a water body.
<b>Oxidation</b>	The combining of an element with oxygen.
<b>Periphyton</b>	Commonly used term to describe algae and other organisms forming slimes in fresh waters.
<b>pH</b>	pH is a measure of the acidity or alkalinity of water. A very high or very low pH means that water can be toxic for aquatic life. The pH range that is suitable for aquatic plants and animals is 6.5 to 9. Alkaline conditions may also increase the toxicity of other pollutants such as ammonia-N, which in turn may adversely impact upon aquatic fauna (ANZECC, 1992).

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## Glossary

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<b>Term</b>	<b>Explanation</b>
<b>Physico-chemical</b>	Aspects of physical and chemical water quality including temperature, turbidity pH, dissolved oxygen, nutrients and any other contaminants.
<b>Riffle</b>	Aquatic habitat characterised by shallow, stony, fast-flowing (where the surface of the water is broken) conditions, favoured by most aquatic invertebrates.
<b>Sediment</b>	Any of a number of materials deposited at the Earth's surface by physical agents (such as wind, water and ice) chemical agents (precipitation from oceans, lakes and rivers) or biological events (organisms, living or dead).
<b>Taxa</b>	Groups of related organisms usually identified to species, genus or family level. One group is a "taxon".
<b>Taxonomic richness</b>	The number of taxa (different types) of organisms found at a site.
<b>Temperature (°C)</b>	Water temperature has a substantial effect on the functioning of aquatic ecosystems and the physiology of the biota. A change in ambient temperature may affect the species exposed in a variety of ways such as growth and metabolism, timing and success of reproduction, mobility and migration patterns and production. Effects may be direct through changes to the metabolism, or indirect through the influence on the solubility of oxygen in water and changes to the toxicity of ammonia-N (ANZECC, 1992). Between May and September, when trout are spawning, water should be less than 12°C. Between October and April, water should be less than 20°C for general trout health and less than 25°C for most native fish.
<b>Total nitrogen (mg/L)</b>	Nitrogen is a nutrient that can encourage the growth of nuisance aquatic plants. These plants can choke up waterways and out-compete native species. High levels of nitrogen in water can be a result of runoff and leaching from agricultural land. Ideally, Total Nitrogen levels in water should be less than 0.5 grams per cubic metre to prevent excessive growth of nuisance plants.
<b>Total phosphorus (mg/L)</b>	Phosphorus is a nutrient that can encourage the growth of nuisance aquatic plants. These plants can choke up waterways and out-compete native species. High levels of phosphorus in water can be a result of either waste water or, more often, runoff from agricultural land. Ideally, Total phosphorus levels in water should be less than 0.04 grams per cubic metre to prevent excessive growth of nuisance plants.
<b>Trophic status</b>	State of a water body in terms of nutrient levels and algal productivity, usually in reference to lakes.

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## Glossary

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Term	Explanation
<b>Turbidity</b> (NTU)	Turbidity may be defined as the relative tendency of water to scatter light; it is synonymous with <i>cloudiness</i> (lack of visual clarity). Changes in water clarity may be used to interpret the aesthetic value of waterways. Differences in water clarity also affect the ability of sight feeding predators, such as fish and birds, to locate prey and the ability of algae to photosynthesise and hence provide feed for animals further up the food chain. Turbidity should be less than 5 NTU (turbidity measurement scale) for water to support plant growth.
<b>Undesirable Biological Growths</b>	Undesirable biological growths are the plants (usually algae) which grow on objects such as stones, logs and other plants. Undesirable biological growths may block intake screens for water supply, and reduce the aesthetic, recreational and ecosystem values of rivers and streams (MFE, 1992).
<b>Water Clarity</b> (m)	Refers to the transmission of light through water. Poor water clarity may reduce the ability of light to reach aquatic plant life, the ability for predators to see their prey, and reduce the aesthetic value of streams and rivers (MFE, 1994).

## Appendix 1 Water quality parameters

This appendix provides background information on the physico-chemical and microbiological parameters reported and discussed throughout the report.

### Physical and chemical parameters

#### pH

Water (H<sub>2</sub>O) contains both H<sup>+</sup> (hydrogen) ions and OH<sup>-</sup> (hydroxide) ions. The pH measures a quantity that is related to the hydrogen ion concentration. This measurement tells us if a solution is acidic or a basic. pH values usually lie between 1 and 14. Most natural waters fall within the pH range of 6.5 to 8.0 (ANZECC 2000), and in the absence of contaminants, most waters maintain a pH value that varies only a few tenths of a pH unit.

A more appropriate means of setting pH limits involves using the 20th and 80th percentiles, calculated from seasonal medians in a reference site (ANZECC 2000). It is recommended that changes of more than 0.5 units from the natural seasonal maximum and minimum are investigated (ANZECC 1992).

The type of rocks and minerals present in the soil may have a strong influence on the acid levels of the local water. Acid waters with low pH can occur naturally from humic acids or from young sedimentary geologies with a pyrite component. When these come into contact with metals that naturally occur in soils and bedrock the metals can be released into the water. Alkaline waters with higher than average pH can occur where a catchment contains limestone geology. If limestone is present, the alkaline (basic) limestone neutralizes the effect acids might have on lakes and streams.

Changes in the pH value of water affect the organisms that live there. Most aquatic organisms have adapted to a specific pH and may die if even slight pH changes occur. Serious problems occur in waters with a pH below 5 or above 9.5. A higher pH will increase the ratio of toxic un-ionised to ionised ammonium ions.

Immature stages of aquatic insects and young fish are extremely sensitive to low pH values. Heavy metals can collect on fish gills or cause deformities in young fish, making it harder for them to survive.

#### Temperature (Deg C)

Temperature exerts an enormous influence over aquatic organisms. As temperature is increased by 10°C within the tolerance range of a resting animal, its physiological demands will usually double.

If the overall temperature of an aquatic system is altered, a shift in community composition can be expected.

## Appendix 1 continued - Water quality parameters

Introduced sport fish (trout and salmon species) are very susceptible to high temperatures and, as temperatures increase above about 20°C, suffer physiological stress. Preferred temperatures of some New Zealand fish species include: just above 25°C for shortfin eels, just below 25°C for long fins and about 20°C for many bully species, and below 20°C for trout and galaxid species (Richardson et al. 1994).

The size of the temperature change varies greatly from river to river and between rivers, depending on interactions between surface waters and groundwater inflows, as the latter can have a substantial buffering effect on temperature. Many factors affect water temperature including: fluctuations in air temperature, changes in the shape of stream channel and lake margins, reductions in overhanging vegetation, cloudiness, reductions in water flow, and wastes discharged into water.

Water temperature can affect abundance, growth, metabolism, reproduction, and activity levels of aquatic insects. A detailed analysis of 88 New Zealand rivers (Quinn and Hickey 1990) identified water temperature as one of the important variables affecting species distribution. Stoneflies (Plecoptera) were largely confined to rivers between 13 and 19°C, and mayflies (Ephemeroptera) were less common in rivers with maximum temperatures of > 21.5°C (Quinn and Hickey 1990).

Temperature varies widely both spatially and temporally in aquatic systems, and it is recommended that temperatures should not be varied beyond the 20th and 80th percentiles of natural ecosystem temperature distribution (ANZECC 2000).

### Dissolved oxygen (DO)

This is measured either as the concentration of oxygen dissolved in the water (expressed as grams of oxygen per cubic metre of water), or as the proportion of oxygen actually present relative to the theoretical oxygen-holding capacity of the water (expressed as percentage saturation). The latter measure is sometimes preferred because the ability of water to hold oxygen varies with temperature.

DO is a basic requirement for a healthy aquatic ecosystem. Most desirable fish species (such as trout and salmon) suffer if DO concentrations fall below 3 to 4 mg/l. Larvae and juvenile fish are more sensitive, requiring even higher concentrations of DO. Prolonged exposure to low DO conditions can suffocate adult fish or reduce their reproductive survival by suffocating sensitive eggs and larvae. Fish can starve when aquatic insect larvae and other prey die in response to the altered conditions. Low DO concentrations also favour anaerobic (without oxygen) bacterial activity that produces noxious gases or foul odours often associated with polluted water bodies.

Bacteria use oxygen to break apart (or decompose) organic materials. Pollution containing organic wastes provides a continuous supply of food for the bacteria, which accelerates bacterial activity and bacterial population growth. In polluted waters, bacterial consumption of oxygen can rapidly outpace oxygen replenishment from the atmosphere and photosynthesis performed by algae and aquatic plants. The result is a net decline in oxygen concentrations in the water.

## Appendix 1 continued - Water quality parameters

Other factors, such as temperature and salinity, influence the amount of oxygen dissolved in water. Prolonged hot weather will depress oxygen concentrations and may cause fish kills even in clean waters, because warm water cannot hold as much oxygen as cold water. Warm conditions further cause oxygen depletion by stimulating bacterial activity, which consumes oxygen.

Water quality criteria for DO generally state that daytime DO concentrations should not be permitted to fall below 6 mg/L (80% saturation) for water quality classes aquatic ecosystems (AE), fisheries (F), (fish spawning (FS), and gathering or cultivation of shellfish for human consumption (SG), as specified in the Third Schedule of the RMA 1991.

### **Suspended sediment (SS) and turbidity**

Sediment consists of particles of all sizes, including fine clay particles, silt, sand, and gravel. In a water quality context the particles of greatest concern are the fine clays and silts. Sediment in the water column is usually referred to as suspended sediment, and measured as a concentration in mg/l.

Sediment may also carry other pollutants into water bodies. Nutrients and toxic chemicals such as heavy metals may attach to sediment, from where they are carried into surface waters. They can then settle with the sediment, or detach and become soluble in the water column.

Rain washes silt and other soil particles off all surfaces, but particularly those where the vegetative cover has been disturbed. Consequently, soil erosion, and activities such as earthworks, vegetation clearance, and cultivation can result in sediment movement into surface water, particularly after heavy rainfall. Stock trampling in the bed of a stream or trampling the margins and banks can release large amounts of sediment into the water.

A water quality measure that is related to SS is turbidity. This quantifies the degree to which light travelling through water is scattered by the suspended particles present. The greater the amount of suspended material, the greater the light scattering and the higher the turbidity. The light-scattering particles may be both organic (e.g. algae and other plant or animal debris), or inorganic (e.g. fine silts or clays).

Increased water turbidity, caused by suspended sediments, can affect benthic algae and macrophyte growth by reducing light penetration through the water column. As well as reducing algal growth by reducing light penetration, fine sediments can smother algae and plants when they settle out. Reduction of light penetration reduces periphyton production, which may result in a limiting food supply for the invertebrates (as stated above). It can also severely alter aquatic communities by clogging and damaging fish gills, filling in the spaces between gravel where fish lay eggs, impairing the growth in fish that use vision during feeding, and resulting in high egg mortality due to reduced oxygen levels in gravel fouled by silt deposition.

## Appendix 1 continued - Water quality parameters

Discharges of contaminants to water are not supposed to cause conspicuous changes in water colour and clarity (Resource Management Act 1991, section 70). Most people accept that the visual clarity of running water decreases as the flow increases (Davis-Colley 1990). However, increases in turbidity that occur during low or normal flows are generally regarded as unacceptable.

For lowland New Zealand rivers ANZECC (2000) recommends a turbidity trigger levels of 5.6 NTU.

### Conductivity

Conductivity is a measure of how well water can conduct an electrical current, and increases with increasing amount and mobility of ions. These ions, which come from the breakdown of compounds, conduct electricity because they are negatively or positively charged when dissolved in water. Therefore, conductivity is an indirect measure of the presence of dissolved solids such as chloride, nitrate, sulphate, phosphate, sodium, magnesium, calcium, and iron, and can be used as an indicator of water pollution.

Some rock and soil release ions very easily when water flows over them; for example, if acidic water flows over rocks containing calcite ( $\text{CaCO}_3$ ), such as calcareous shales, calcium ( $\text{Ca}^{2+}$ ) and carbonate ( $\text{CO}_3^{2-}$ ), ions will dissolve into the water. Therefore, conductivity will increase. However, some rocks, such as quartz ( $\text{SiO}_2$ ), are very resistant, and don't dissolve easily when water flows over them (and even if  $\text{SiO}_2$  does dissolve, it is not conductive). Conductivity of waters draining areas where the geology only consists of quartz or other resistant rocks will be low (unless other factors are involved).

The concentration of dissolved solids in solution is generally determined by salinity or conductivity measurements. Conductivity is a numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions, their total concentration, mobility, valence, and relative concentrations, and on the temperature during measurement (APHA 1985).

There are no guidelines for conductivity levels in water (ANZECC 2000) but it is suggested that guidelines for southeastern Australian coastal rivers may be applicable where geology is not a significant factor (i.e. 0.125-0.3 mS/cm).

### Nitrogen (N) and phosphorus (P)

The nutrients most often responsible for water quality degradation are N and P. Because these are found in the environment in a number of forms, they are measured in different ways. N present in water may be bound up in plant or animal tissue, in which case it is referred to as organic N. Such N eventually breaks down into inorganic forms; nitrate

## Appendix 1 continued - Water quality parameters

(NO<sub>3</sub>), nitrite (NO<sub>2</sub>) or ammonia (NH<sub>3</sub>). The relative proportions of these different forms provide clues as to the possible sources of nutrient-rich contaminants, or the time since their discharge to the water body.

P can be measured as total P (TP), or dissolved reactive phosphate (DRP), also sometimes called phosphate (PO<sub>4</sub>) or orthophosphate (ortho-P). The last three represent different terms used to describe the fraction of TP that is soluble or available to organisms for growth.

Nutrients, which are essential for the growth of algae and other plants, are considered beneficial up to a point, but may easily become a nuisance. Aquatic plant and algal growths are important in rivers and streams as they provide food for both invertebrate and vertebrate life forms that live in, or are associated with, the water. However, if algal growth becomes excessive, due to an oversupply of nutrients (particularly N and P), the quality of the river or lake ecosystem deteriorates.

One chemical form of an element can be converted into another. The conditions under which the conversion occurs are influenced by many factors, such as pH, temperature, oxygen concentration, and biological activity.

The total concentration of a nutrient (e.g. TP or TN) is not necessarily the most useful measurement. For example, if a sample is analyzed for TP, all forms of the element are measured, including the P locked up in biological tissue and insoluble mineral particles. In some circumstances, it is more useful to consider nitrite/nitrate nitrogen (NNN) and ammoniacal nitrogen (NH<sub>4</sub>) and dissolved reactive phosphorus (DRP), as these are the forms that are readily assimilated by living organisms.

For New Zealand lowland rivers, the trigger value for TN is 0.614 mg/L, and for TP 0.033 mg/L (ANZECC 2000). Trigger values for NNN are 0.444 mg/L, and for DRP 0.010 mg/L (ANZECC 2000).

### **Ammoniacal nitrogen, ammonia, and ammonium**

Ammonia is the least stable form of nitrogen in water. Ammonia is easily transformed to nitrate in waters that contain oxygen and to nitrogen gas in waters that are low in oxygen. Ammonia is found in water in two forms - the ammonium ion (NH<sub>4</sub><sup>+</sup>), and dissolved, unionized (no electrical charge) ammonia gas (NH<sub>3</sub>). Total ammonia is the sum of ammonium and unionized ammonia. The dominant form depends on the pH, temperature and salinity of the water (Table A 1.1).

Concentrations are usually expressed either as total ammonia (or ammoniacal nitrogen, the sum of NH<sub>3</sub> and NH<sub>4</sub><sup>+</sup>), or as concentration of the un-ionised NH<sub>3</sub> only. NH<sub>3</sub> is the main toxic component for aquatic organisms, so when ammoniacal nitrogen is quoted, the pH and temperature are also relevant in determining toxicity.

## Appendix 1 continued - Water quality parameters

**Table A1.1 Un-ionized NH<sub>3</sub> as a percent of ammoniacal nitrogen (by temperature and pH)**

Temp (C)	Percent NH <sub>3</sub> of total ammonia							
	6.5	7	7.5	8	8.5	9	9.5	10
8	0.05	0.15	0.5	1.5	4.8	13.7	33.5	61.4
10	0.06	0.19	0.6	1.8	5.6	15.7	37.1	65
12	0.07	0.21	0.7	2.1	6.4	17.9	40.8	68.5
14	0.08	0.25	0.8	2.5	7.4	20.2	44.5	71.7
16	0.09	0.29	0.9	2.9	8.5	22.8	48.3	74.7
18	0.11	0.34	1.1	3.3	9.8	25.5	52	77.4
20	0.13	0.39	1.2	3.8	11.2	28.4	55.6	79.9

Most of the trigger values for toxicants in the 2000 ANZECC guidelines have been derived using data from single-species toxicity tests on a range of test species, because these formed the bulk of the concentration–response information. High reliability trigger values were calculated from chronic no observable effect concentration (NOEC) data. However, the majority of trigger values were moderate reliability trigger values, derived from short-term acute toxicity data (from tests  $\leq$  96 hour duration) by applying acute-to-chronic conversion factors.

An ammoniacal nitrogen value of 0.9 mg/L (at pH 8, 20°C), has been suggested as a high reliability (95%) trigger value for freshwater (ANZECC 2000). However, this trigger value varies with pH and temperature, and most temperatures and pHs are lower than this, so the trigger value for most streams will be higher (Table A 1.2).

**Table A1.2 2000 ANZECC freshwater trigger values for ammoniacal nitrogen at different pH (temperature not taken into account)**

pH	Freshwater trigger value (mg/l for ammoniacal nitrogen-N)	pH	Freshwater trigger value (mg/l for ammoniacal nitrogen-N)
6.5	2.46	7.8	1.18
6.6	2.43	7.9	1.03
6.7	2.38	8	0.9
6.8	2.33	8.1	0.78
6.9	2.26	8.2	0.66
7	2.18	8.3	0.56
7.1	2.09	8.4	0.48
7.2	1.99	8.5	0.4
7.3	1.88	8.6	0.34
7.4	1.75	8.7	0.29
7.5	1.61	8.8	0.24
7.6	1.47	8.9	0.21
7.7	1.32	9	0.18

## Appendix 1 continued - Water quality parameters

### Faecal microbiological indicators, *Escherichia coli* (*E. coli*) and Enterococci (Ent)

Certain bacteria, viruses and protozoa cause human illnesses that range from gastrointestinal disease to minor respiratory and skin diseases. Examples of water-borne diseases include: salmonella, gastroenteritis, hepatitis, and giardia.

Because it is impractical to test waters for every possible disease-causing organism, it is usual to measure indicator bacteria that are found in high numbers in the stomachs and intestines of warm-blooded animals and people.

The most frequently used organisms for this purpose are faecal coliforms, or a species of these, *E. coli*. For marine waters, a group of bacteria known as Enterococci is now commonly used.

These organisms may enter waters through a number of routes, including inadequately treated sewage, stormwater drains, septic tanks, runoff from pastoral farm land, animal processing plants, and from wildlife living in and around water bodies.

The presence of such bacteria indicates the possible presence of faecal material and, with it, the possibility that other disease-causing organisms may be present. Indicator bacteria concentrations are used to determine if water quality is adequate for contact recreation, or as a source of drinking water. Indicator bacteria are measured as a concentration, usually expressed as an estimate of the number of individual organisms per 100 ml of water.

Numerical standards are applied to New Zealand waters to protect them for recreational water use and for the gathering of shellfish for consumption. Water quality safety is assessed and reported according to the Ministry for the Environment and Ministry of Health 'Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas' revised and issued in 2003. The results are compared to these national guidelines and forwarded to the district and city councils, as well as Public Health South, for follow up action when elevated above the guidelines.

The guidelines recommend a three-tier (traffic-light) management framework according to single sample results of *E. coli* (freshwaters) and Ent (marine waters) bacterial counts. These categories are given below:

**Table A1.3 MfE/MoH contact recreation guideline values**

Mode	Freshwater ( <i>E. coli</i> /100ml)	Marine (Ent/100ml)
Surveillance/Green <b>Should be very safe for swimming</b>	No single sample > 260	No single sample > 140
Alert/Amber <b>Should be satisfactory for swimming</b>	One single sample between 261 and 550	One single sample between 141 and 280
Action/Red <b>Could be a health-risk for swimming</b>	One single sample > 550	Two consecutive single samples > 280

## Appendix 1 continued - Water quality parameters

For medians, the Department of Health (1992) guidelines for contact recreation waters recommend a season median of 126 *E. coli*/100 ml, with ANZECC (2000) stipulating a median of 150 faecal coliform cfu/100 ml and 35 Ent/100 ml as a safe limit.

The ANZECC 1992 guidelines specify for stock drinking a faecal coliform limit of 1000 cfu/100 ml. Guidelines for shellfish gathering recommend that the mean faecal coliform content shall not exceed 14 cfu/100 ml, and not more than 10% should exceed 43 cfu/100 ml (MfE 2003).

## Appendix 2 – ORC monitoring sites

**Table A2.1 ORC monitoring sites showing length of dataset**

Site ID	Site	Sample Start Date	Sample End Date	No Samples
OTA7520127	Cardrona River at Mt Barker	8/08/1996	6/04/2006	67
OTA7330004	Careys Creek d/s SH1 Bridge	1/07/1997	20/04/2006	52
OTA7550005	Catlins at Houipapa	22/07/1997	29/03/2006	66
OTA7520194	Clutha River at Balclutha	19/06/1996	8/02/2006	68
OTA7430332	Contour Channel at No. 4 Bridge	1/08/2000	4/04/2006	41
OTA7520371	Crookston Burn at Kelso	17/04/1996	15/05/2006	66
OTA7520655	Dunstan Creek at Beatties Road	25/09/1997	30/03/2006	29
OTA7520040	Fraser River at End Of Marshall Rd	24/09/1997	30/03/2006	31
OTA7520554	Frasers Creek at Station Rd	7/02/1995	10/04/2006	61
OTA7430264	Gimmer Burn at Wilson Road	20/08/1997	22/03/2006	37
OTA7520032	Hayes Creek at SH6 Bridge	17/12/1996	12/04/2006	64
OTA7520372	Heriot Burn at Parkhill/Kelso Rd	5/03/1996	15/05/2006	65
OTA7520512	Heriot Burn at SH90	26/03/1999	15/05/2006	37
OTA7520876	Ida Burn at Auripo Rd	5/08/1999	28/03/2006	25
OTA7520646	Kaihiku Stream at Clifton Road	10/07/1997	15/05/2006	67
OTA7400007	Kaikorai Stream at Green Island Bridge	13/08/1997	3/04/2006	59
OTA7170001	Kakanui River at Clifton Falls	17/01/1995	19/04/2006	73
OTA7170004	Kakanui River at Pringles	31/05/1995	19/04/2006	77
OTA7520643	Lake Dunstan at Dead Mans Pt	23/07/1997	16/08/2006	58
OTA7529115	Lake Hawea at Outlet	1/02/1995	16/08/2006	67
OTA7520001	Lake Hayes at Surface – Mid Lake	8/02/1995	14/08/2006	55
OTA7520158	Lake Johnson at Surface	17/09/1997	14/08/2006	45
OTA7520875	Lake Onslow at Boat Ramp	13/07/1999	3/08/2006	23
OTA7520267	Lake Tuakitoto at At Outlet	7/02/1995	10/08/2006	68
OTA7430021	Lake Waiholo at End Of Jetty	23/04/1996	10/08/2006	81
OTA7430126	Lake Waipori at SE Corner	11/04/1995	10/08/2006	81
OTA7520303	Lake Wakatipu at Outlet	31/01/1995	13/06/2006	74
OTA7520289	Lake Wanaka at Outlet	1/02/1995	15/08/2006	70
OTA7430139	Lee Stream at SH87	26/08/1998	21/03/2006	29
OTA7520130	Lindis River at Lindis Peak	27/08/2003	7/04/2006	20
OTA7350060	Lindsay's Creek 15m u/s Leith Confluence	14/01/1998	3/04/2006	61
OTA7520555	Lovells Creek at Station Rd	7/02/1995	10/04/2006	66
OTA7430128	Main Drain at Waipori Pumping Station	21/02/1995	16/05/2006	108
OTA7520639	Manuherikia at Blackstone Hill	23/07/1997	30/03/2006	46
OTA7520640	Manuherikia at Galloway Bridge	23/07/1997	30/03/2006	73
OTA7520031	Mill Creek at Fish Trap	10/01/1995	12/04/2006	93
OTA7520740	Minzion Burn at Millers Flat Road	12/08/1998	25/05/2005	28
NIWA	NIWA Balclutha	25/01/1989	14/12/2005	208
NIWA	NIWA Kawarau	02/02/1989	14/12/2005	201
NIWA	NIWA Luggate	01/02/1989	14/12/2005	201
NIWA	NIWA Millers Flt	02/02/1989	14/12/2005	200

## Appendix 2 continued – ORC monitoring sites

**Table A2. 1 continued ORC monitoring sites showing length of dataset**

Site ID	Site	Sample Start Date	Sample End Date	No Samples
NIWA	NIWA Outram	24/01/1989	15/12/2005	208
NIWA	NIWA Shotover	01/02/1989	14/12/2005	201
NIWA	NIWA Sutton Stm	24/01/1989	15/12/2005	208
NIWA	NIWA Tiroiti	24/01/1989	15/12/2005	208
OTA7430347	Owhiro Stream at Burns St	16/10/2001	4/04/2006	34
OTA7430369	Pig Burn at O'Neill Rd	26/09/2001	22/02/2006	41
OTA7520115	Pomahaka River at Burkes Ford	10/07/1997	16/05/2006	56
OTA7520628	Pomahaka River at Glenkenich W/S	30/04/1997	15/05/2006	64
OTA7260010	Shag River at Goodwood Water Supply Intake	1/03/2006	20/04/2006	72
OTA7260012	Shag River at The Grange	1/03/1995	20/04/2006	47
OTA7439031	Silver Stream at Riccarton Road	21/02/1995	3/04/2006	43
OTA7430004	Taieri River Allanton	21/02/1995	4/04/2006	55
OTA7430122	Taieri River Halls Bridge	24/01/1996	21/03/2006	76
OTA7430007	Taieri River Henley Ferry Bridge	21/02/1995	4/04/2006	76
OTA7430033	Taieri River Middlemarch	20/08/1997	21/03/2006	55
OTA7430001	Taieri River Outram	21/02/1995	3/04/2006	103
OTA7430023	Taieri River Stonehenge	11/01/1995	21/03/2006	80
OTA7430026	Taieri River Waipiata Bridge	7/11/2001	27/03/2006	53
OTA7520642	Teviot at Roxburgh East	22/07/1997	29/03/2006	35
OTA7480002	Tokomairiro River East Branch at Lisnatunny	11/02/1995	10/04/2006	51
OTA7480012	Tokomairiro River West Branch at SH8 Bridge	11/01/1995	10/04/2006	48
OTA7520645	Tuapeka River at Tuapeka Mouth	10/07/1997	16/05/2006	56
OTA7200007	Waianakarua River at Browns Pump	4/08/1999	19/04/2006	38
OTA7170096	Waiareka Creek at Teschmakers Rd	4/08/1999	19/04/2006	52
OTA7310002	Waikouaiti River at Orbells Crossing	16/01/1995	20/04/2006	79
OTA7520540	Waipahi River ds at Waipahi	15/07/1997	15/05/2006	64
OTA7520998	Waipahi River us at Cairns Peak	21/10/1995	15/05/2006	31
OTA7430124	Waipori River d/s Contour Channel Confluence	11/08/1998	4/04/2006	38
OTA7520541	Wairuna Stream at Waipahi/Clydevale Road	10/07/1997	16/05/2006	52
OTA7520644	Waitahuna at Tweeds Bridge	10/07/1997	16/05/2006	53
OTA7340015	Waitati River at Mt Cargill Road	1/07/1997	20/04/2006	52
OTA7520188	Waiwera River at SH1	21/05/2002	15/05/2006	38
OTA7521000	Washpool Stream at Kilhastie Rd	21/10/2002	23/01/2006	26
OTA7350008	Water Of Leith at Dundas St Bridge	22/02/1995	3/04/2006	71
OTA7110024	Welcome Creek ds at Lower Site	15/04/1997	19/04/2006	58
OTA7110025	Welcome Creek us at Upper Site	15/04/1997	19/04/2006	59

Most of these sites have been sampled bi-monthly. Eight sites in the Otago Region are part of NIWA's National River Water Quality Network (NRWQN) and have been sampled monthly since 1989 using a standardized protocol (Smith & Maasdam, 1994).

### Appendix 3 – Water quality index results

**Table A3.1 Water quality index, guideline compliance (median values) and REC.**  
(Refer to Table 3.2 for REC codes)

Site Name	Rank	Guideline compliance (median values)						REC
		Amm. N	DO	DRP	Ec	NNN	Turb	
		>0.9 mg/l	<80 %	>0.01 mg/l	>126 cfu/ml	>0.444 mg/l	>5.6 NTU	
<b>Very Good Water Quality</b>								
Lake Wanaka at Outlet	1	✓	✓	✓	✓	✓	✓	CD/L/AI/T
Lake Wakatipu at Outlet	2	✓	✓	✓	✓	✓	✓	CX/Lk/HS/T
Lake Dunstan at Dead Mans Pt	3	✓	✓	✓	✓	✓	✓	CD/H/HS/P
NIWA Luggate Br	4	✓	✓	✓	✓	✓	✓	CD/L/AI/P
NIWA Sutton Stream	5	✓	✓	✓	✓	✓	✓	CD/H/HS/P
Lake Hawea at Outlet	6	✓	✓	✓	✓	✓	✓	CX/Lk/HS/T
NIWA Millers Flat	7	✓	✓	✓	✓	✓	✓	CD/L/HS/P
Waianakarua River	8	✓	✓	✓	✓	✓	✓	CD/H/HS/P
NIWA Kawarau at Chards Rd	9	✓	✓	✓	✓	✓	✓	CD/H/AI/P
Kakanui River at Pringles	10	✓	✓	✓	✓	✓	✓	CD/H/HS/P
Taieri Stonehenge	11	✓	✓	✓	✓	✓	✓	CD/H/HS/T
Teviot at Roxburgh East	12	✓	✓	✓	✓	✓	✓	CD/H/HS/P
Waikouaiti River at Orbells	13	✓	✓	✓	✓	✓	✓	CD/H/HS/P
Pig Burn at O'Neill Rd	14	✓	✓	✓	✓	✓	✓	CD/L/AI/P
Dunstan Creek at Beatties Rd	15	✓	✓	✓	✓	✓	✓	CD/M/HS/T
NIWA Balclutha	16	✓	✓	✓	✓	✓	✓	CD/L/HS/P
Lindis River at Lindis Peak	17	✓	✓	✓	✓	✓	✓	CD/H/HS/T
Hayes Creek at SH6 Bridge	18	✓	✓	✓	✓	✓	✓	CD/Lk/HS/P
Lake Onslow at Boat Ramp	19	✓	✓	✓	✓	✓	✓	CD/H/HS/T
Manuherikia at Blackstone Hill	20	✓	✓	✓	✓	✓	✓	CD/H/HS/T
Shag Grange	21	✓	✓	✓	✓	✓	✓	CD/L/AI/P
Clutha River at Balclutha	22	✓	✓	✓	✓	✓	✓	CD/L/HS/P
Cardrona River at Mt Barker	23	✓	✓	✓	✓	✓	✓	CD/H/HS/T
Shag Goodwood Water Supply	24	✓	✓	✓	✓	✓	✓	CD/H/HS/P
Careys Creek d/s Sh1 Bridge	25	✓	✓	✓	✓	✓	✓	CD/L/HS/P
Kakanui River at Clifton Falls	26	✓	✓	✓	✓	✓	✓	CD/H/SS/P
NIWA Outram	27	✓	✓	✓	✓	✓	✓	CD/H/HS/P
Lake Hayes at Surface	28	✓	✓	✓	✓	✓	✓	CD/H/HS/P
Lake Johnson at Surface	29	✓	✓	✓	✓	✓	✓	CD/Lk/HS/S
Waitati River at Mt Cargill	30	✓	✓	✓	✓	✓	✓	CD/L/VB/P
Waipori River d/s Contour Ch	31	✓	✓	✓	✓	✓	✓	CD/Lk/HS/P
Taieri Outram	32	✓	✓	✓	✓	✓	✓	CD/H/HS/P
Lake Waipori at SE Corner	33	✓	✓	✓	✓	✓	✓	CD/L/AI/P
Manuherikia at Galloway Br	34	✓	✓	✓	✓	✓	✓	CD/H/HS/P
Taieri Middlemarch	35	✓	✓	✓	✓	✓	✓	CD/H/HS/P
Pomahaka River at Burkes Fd	36	✓	✓	✓	✓	✓	✓	CD/L/HS/P

## Appendix 3 continued – Water quality index results

**Table A3.1 continued** Water quality index, guideline compliance (median values) and REC. (Refer to Table 3.2 for REC codes)

Site Name	Rank	Guideline compliance (median values)						REC
		Amm. N	DO	DRP	Ec	NNN	Turb	
		>0.9 mg/l	<80 %	>0.01 mg/l	>126 cfu/ml	>0.444 mg/l	>5.6 NTU	
<b>Good Water Quality</b>								
Fraser River at Marshall Rd	37	✓	✓	✓	✗	✓	✓	CD/M/HS/P
NIWA Shotover	38	✓	✓	✓	✓	✓	✗	CW/M/HS/T
Silver Stream at Riccarton Road	39	✓	✓	✓	✗	✓	✓	CD/L/HS/P
Lake Waiholo at End of Jetty	40	✓	✓	✓	✓	✓	✗	CD/Lk/HS/P
Pomahaka River at Glenkenich	41	✓	✓	✓	✗	✓	✓	CD/H/HS/P
Frasers Creek at Station Rd	42	✓	✓	✓	✗	✓	✓	CD/L/SS/P
Taieri Allanton	43	✓	✓	✓	✗	✓	✓	CD/H/HS/P
Tokomairiro River West Br	44	✓	✓	✓	✗	✓	✓	CD/L/HS/P
Taieri Henley Ferry	45	✓	✓	✓	✓	✓	✗	CD/Lk/HS/P
Tokomairiro River East Br	46	✓	✓	✓	✗	✓	✓	CD/L/HS/P
NIWA Tiroiti	47	✓	✓	✗	✓	✓	✓	CD/H/HS/P
Waitahuna at Tweeds Bridge	48	✓	✓	✓	✗	✓	✓	CD/L/HS/P
Taieri Halls Bridge	49	✓	✓	✗	✓	✓	✓	CD/H/HS/P
Mill Creek at Fish Trap	50	✓	✓	✓	✗	✓	✓	CD/H/HS/P
Catlins at Houipapa	51	✓	✓	✓	✗	✓	✓	CW/L/SS/P
Tuapeka River at Mouth	52	✓	✓	✓	✗	✓	✓	CD/L/HS/P
Gimmerburn at Wilson Road	53	✓	✓	✗	✓	✓	✓	CD/H/AI/P
Lake Tuakitoto at Outlet	54	✓	✓	✓	✓	✓	✗	CD/L/HS/P
Kaikorai Stream	55	✓	✓	✓	✗	✓	✓	CD/L/SS/U
<b>Fair Water Quality</b>								
Ida Burn at Auripo Rd	56	✓	✓	✗	✗	✓	✓	CD/H/HS/P
Taieri Waipiata	57	✓	✓	✗	✗	✓	✓	CD/H/HS/P
Lee Stream at SH87	58	✓	✓	✗	✗	✓	✓	CD/H/HS/P
Owhiro Stream at Burns St	59	✓	✓	✗	✗	✓	✗	CD/L/AI/U
Heriot Burn at SH90	60	✓	✓	✓	✗	✗	✓	CD/H/HS/P
Waipahi River at Waipahi	61	✓	✓	✓	✗	✗	✓	CD/L/SS/P
Water Of Leith at Dundas St	62	✓	✓	✗	✗	✓	✓	CW/L/VB/U
Lovells Creek at Station Rd	63	✓	✓	✓	✗	✗	✓	CD/L/HS/P
Waipahi River at Cairns Peak	64	✓	✓	✓	✗	✗	✓	CW/L/SS/P
Welcome Creek at Lower Site	65	✓	✓	✗	✓	✗	✓	CD/L/AI/P
Contour Channel at No. 4 Br	66	✓	✓	✗	✗	✓	✓	CD/L/HS/P
Welcome Creek at Upper Site	67	✓	✓	✗	✓	✗	✓	CD/L/AI/P
Waiwera River at SH1	68	✓	✓	✗	✗	✗	✓	CD/L/SS/P
Kaihiku Stream at Clifton Rd	69	✓	✓	✗	✗	✗	✓	CD/L/SS/P
Crookston Burn at Kelso	70	✓	✓	✗	✗	✗	✓	CD/L/AI/P
Heriot Burn at Pkhill/Kelso Rd	71	✓	✓	✗	✗	✗	✓	CD/L/HS/P
Lindsay's Creek u/s Leith	72	✓	✓	✗	✗	✗	✓	CD/L/VB/U
<b>Poor Water Quality</b>								
Minzion Burn at Millers Flat Rd	73	✓	✗	✓	✗	✓	✓	CD/H/HS/P
Waiareka Creek - Teschmakers	74	✓	✗	✗	✓	✓	✓	CD/L/SS/P
Main Drain at Pumping Stn	75	✓	✗	✓	✓	✓	✓	CD/L/AI/P
Wairuna Stream at W/C Rd	76	✓	✓	✗	✗	✗	✗	CD/L/HS/P
Washpool Stm at Kilhastie Rd	77	✓	✓	✗	✗	✗	✗	CD/L/SS/P

## Appendix 4 – Principal components analysis

**Table A4.1 Principal components analysis**

	Site	PCA 1	PCA 2	PCA 3	PCA 4	PCA 5
1	Cardrona	-1.16739	-0.450116	-1.37612	-0.163131	-0.68314
2	Careys Ck	-1.37035	0.0618815	-0.118437	0.768744	0.188481
3	Catlins	-0.376295	-0.52544	-0.0699112	-0.577892	0.119233
4	Balclutha	-1.35012	-0.0220097	-0.611948	0.127162	-0.405584
5	Contour Channel	1.12612	0.545969	0.544464	-0.719833	-0.369906
6	Crookston	3.43384	-1.87604	0.268744	-0.0419223	2.27985
7	Dunstan Ck	-2.02009	0.0105795	0.324947	-0.734484	0.138836
8	Fraser River	-1.94488	0.0535684	0.163365	-0.113391	0.0258942
9	Frasers Ck	-0.550023	0.158856	0.344522	-1.02043	0.703484
10	Gimmerburn	0.911275	0.418386	2.35829	-0.00439408	-1.43089
11	Hayes Ck	-1.86143	0.491137	0.0254727	2.1361	-0.320998
12	Heriot Burn d/s	3.62876	-1.80353	0.141698	-0.376482	1.3798
13	Heriot Burn u/s	0.353231	-1.12374	0.471564	-0.126718	1.33056
14	Ida Burn	-0.737007	0.171797	0.6658	0.383362	-0.622722
15	Kaihiku	0.95021	-0.334645	0.590946	0.443875	-0.162285
16	Kaikorai	1.39092	-1.89617	-1.54731	1.62959	-0.187447
17	Kakanui Clifton	-1.93436	-0.230227	0.194393	0.506708	0.2137
18	Kakanui Pringles	-1.98953	0.209217	0.362919	0.244261	0.306826
19	Lake Dunstan	-2.38131	0.224915	0.0429385	1.34232	-0.124966
20	Lake Hawea	-2.44528	0.204348	0.244796	0.383884	0.0780845
21	Lake Hayes	-1.78308	0.870323	0.113071	2.22796	-0.283067
22	Lake Johnson	-1.38556	0.999536	0.324442	2.09367	-0.137141
23	Lake Onslow	-0.595646	1.15972	0.0896962	-1.92968	-0.611727
24	Lake Tuakitot	1.21521	0.941176	-0.671936	-0.303294	-1.09158
25	Lake Waihola	0.889374	1.35948	-2.3646	-1.43489	-1.41722
26	Lake Waipori	-0.152602	1.36132	-0.485872	-0.561573	-0.288846
27	Lake Wakatipu	-2.4069	0.313523	0.290485	0.660032	0.0516516
28	Lake Wanaka	-2.44124	0.302201	0.252705	0.886847	0.0516476
29	Lee Stream	0.715802	-0.68739	-0.316075	-0.937503	-0.841186
30	Lindis River	-1.86572	-0.633811	-0.630188	0.0172823	-0.420892
31	Lindsay's Ck	4.44468	-4.43034	-1.07995	3.04041	1.05537
32	Lovells Ck	1.43786	-1.25584	-0.373864	-0.568806	1.13816
33	Main Drain	5.56889	9.86451	-2.74161	1.47735	2.93864
34	Manuherikia us	-1.84131	-0.0974516	-0.0909475	-0.469241	-0.186206
35	Manuherikia ds	-0.870822	-0.256847	-0.20325	0.00968185	-0.61816
36	Mill Creek	0.149585	-0.782558	-1.6705	0.274045	-0.136296
37	Minzion Burn	-0.0429348	0.0753026	0.34979	-0.381342	-0.435186
38	Owhiro	2.33421	0.432396	-0.271146	-0.894694	-1.27065
39	Pig Burn	-1.66981	-0.0213589	0.221848	-0.517272	0.239552
40	Pomahaka d/s	0.0318191	-0.371968	-0.33935	-0.295551	0.24348
41	Pomahaka u/s	-1.19712	-0.611447	-0.0969546	-0.158575	0.0649537
42	Shag River d/s	-1.49656	0.348996	0.397205	0.362189	0.503363
43	Shag River u/s	-1.88915	0.147313	0.1932	1.05224	0.0975742
44	Silver Stream	-1.486	-0.461388	-0.299513	1.91532	-0.0126651

## Appendix 4 continued – Principal components analysis

**Table A4. 1 continued Principal components analysis**

	Site	PCA 1	PCA 2	PCA 3	PCA 4	PCA 5
45	T. Allanton	-0.739721	-0.0161613	-0.151285	-0.771869	-0.266573
46	T. Middlemarch	-0.344235	-0.280125	-0.752058	-0.694941	-0.910272
47	T. Halls Bridge	-0.717781	0.310067	0.830028	-0.717066	-0.347129
48	T.Henley F	1.26403	1.58839	-2.91306	-1.90471	-1.54195
49	T.Outram	-1.06205	-0.161964	-0.101924	-0.458274	-0.333091
50	T. Stonehenge	-1.69099	0.141024	0.445682	-1.12183	0.241471
51	T. Waipiata	-0.0381574	0.199212	0.0343916	-0.844526	-0.813812
52	Teviot	-1.38313	-0.182861	-0.114554	-1.20936	-0.144653
53	Tokomairiro E	0.055339	-0.353175	-0.678798	-1.6012	-0.227281
54	Tokomairiro W	-0.298859	-0.787002	-0.0890267	-0.378039	0.245994
55	Tuapeka	-0.288959	0.102038	0.562116	-0.406502	-0.193155
56	Waianakarua	-2.16224	0.0158681	0.323014	0.487485	0.404231
57	Waiareka Ck	3.18157	4.33028	4.92716	1.3909	-2.80431
58	Waikouaiti	-1.77375	0.661917	0.411644	0.354768	0.162274
59	Waipahi u/s	1.25282	-0.974083	-0.380507	-1.34947	0.90027
60	Waipahi d/s	0.279608	-0.524975	0.0268991	0.581647	0.797987
61	Waipori	-1.0237	0.195154	-0.0611941	-1.10678	-0.170986
62	Wairuna	5.21053	-1.59101	-0.301928	-0.534015	-0.0407608
63	Waitahuna	-0.508034	-0.395271	-0.339258	-0.620861	-0.200841
64	Waitati	-1.44334	-0.548983	-0.640296	1.60239	-0.225226
65	Waiwera	1.51729	-1.09598	0.131004	0.104325	0.861907
66	Washpool	10.1624	-1.85795	0.997187	0.460319	-2.77389
67	Water Of Leith	1.04503	-1.78285	-0.777381	1.89824	-0.00729508
68	Welc. Ck d/s	0.932471	-0.322512	1.83358	-1.2268	2.75694
69	Welc. Ck u/s	1.24453	0.476828	3.16076	-1.58576	3.53978

All these sites were monitored as part of the SOE water quality monitoring programme. The sites sampled by NIWA were not included in PCA analysis.

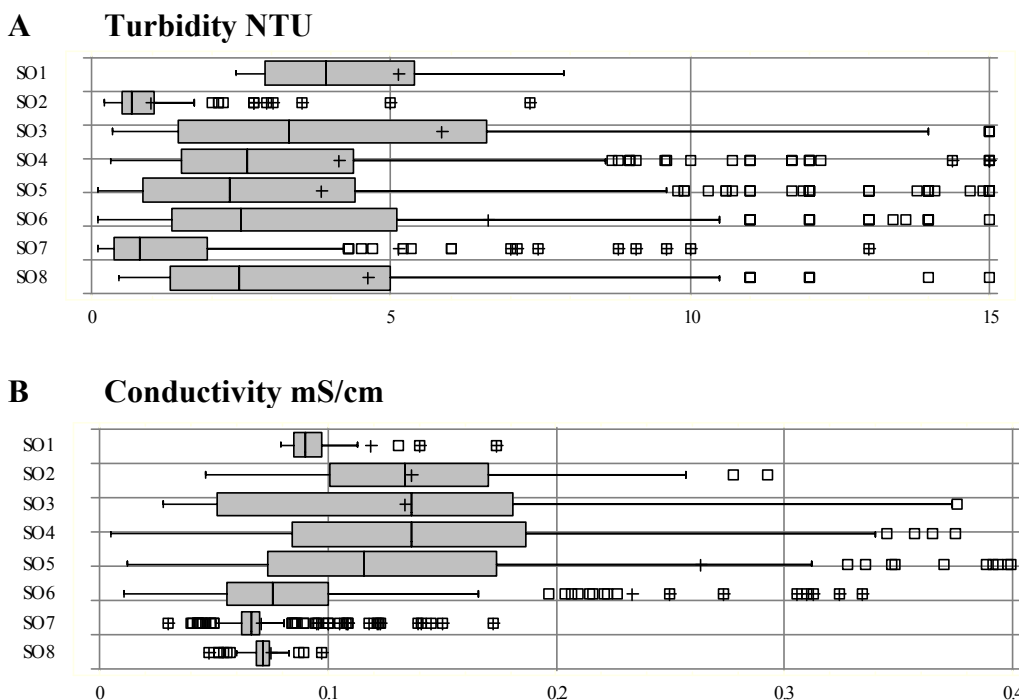
### Appendix 5 – REC stream order

There are eight categories of stream order, with Stream Order 1 (SO1) being the smallest, and the Clutha River/Mata-Au being the only Stream Order 8 (SO8) in Otago. Only a small number of targeted SO1 and SO2 streams were incorporated in the analysis (sampling has been undertaken due to the presence of suspected pollution i.e. from irrigation or tile drains) so this has skewed the results, as the majority of SO1/SO2 streams are of extremely good water quality.

The figure shows that turbidity and SS were low in SO2, but this category incorporated only three sites; Lake Johnson and two sites on Welcome Creek. Categories SO1 and SO3 had the highest turbidity which in general decreases with size of watercourse. Conductivity is highest in categories SO3 and SO4, the smaller order tributaries, but again conductivity then decreases with the size of the watercourse. DO is relatively constant in all the size classes.

Median TP concentrations are relatively constant across all categories, but there are a large number of outliers in categories SO4, SO5 and SO6. TN concentrations are highest in SO2 (Lake Johnson and Welcome Creek), but generally decrease with size of watercourse. DRP has many outliers in categories SO3 to SO6; NH<sub>4</sub> is highest in SO3 and SO4 and NNN again decreases with size of waterbody (with SO2 having the highest median).

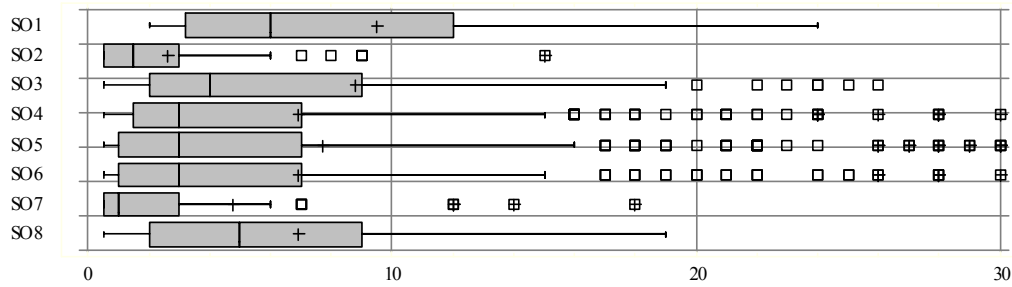
Ec has the highest median count in SO3, but again counts decrease with size of waterbody. However, there are many elevated outliers in categories SO4 to SO6.



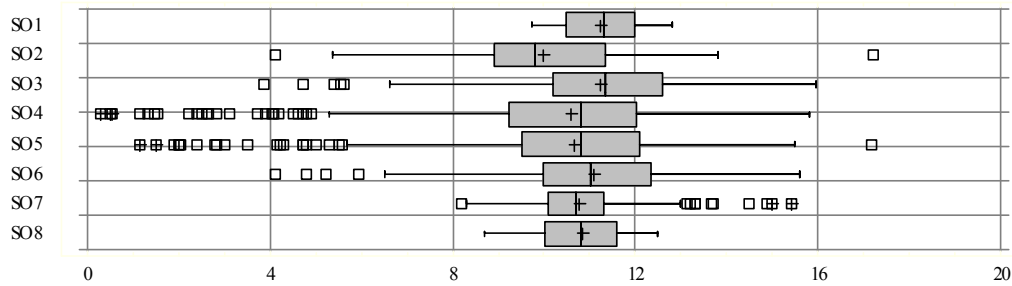
**Figure A5.1 Comparison of median water quality parameters among REC stream order classes (SO = stream order)**

Appendix 5 continued – REC stream order

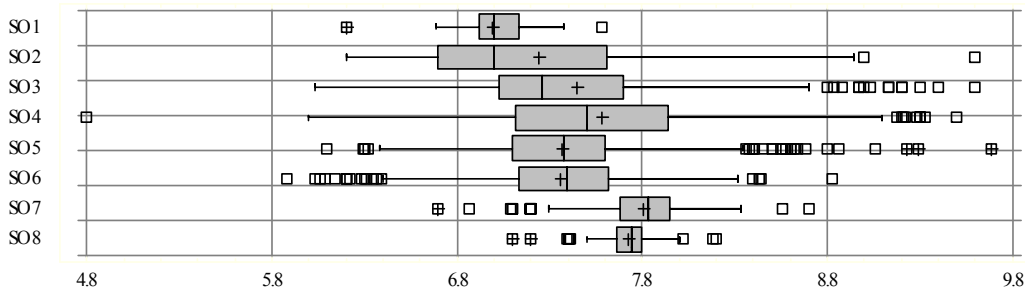
C Suspended solids mg/l



D Dissolved oxygen mg/l



E pH



F Temperature Deg C

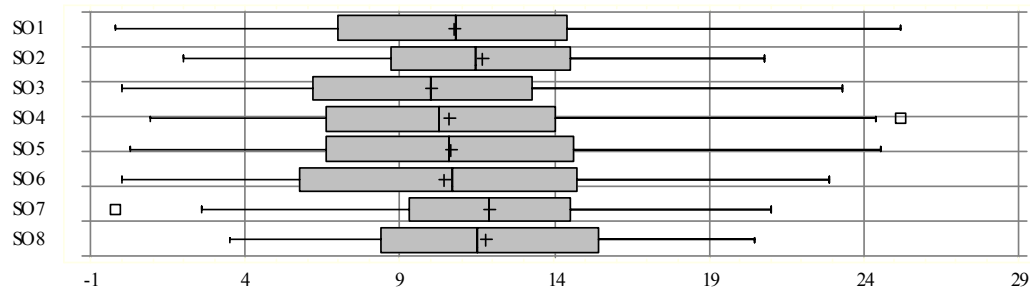
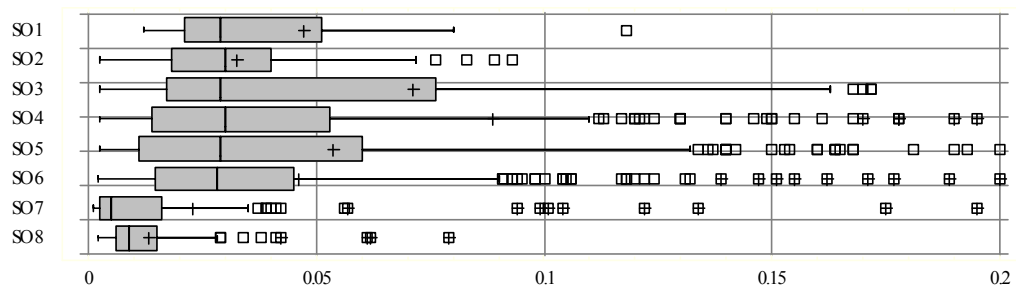


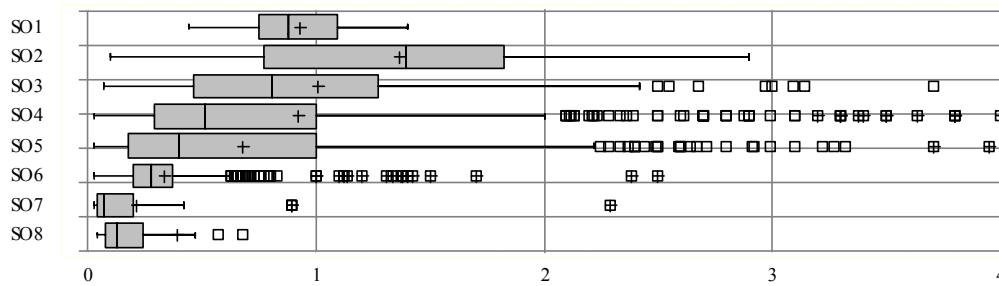
Figure A5. 1 continued Comparison of median water quality parameters among REC stream order classes (SO = stream order)

Appendix 5 continued – REC stream order

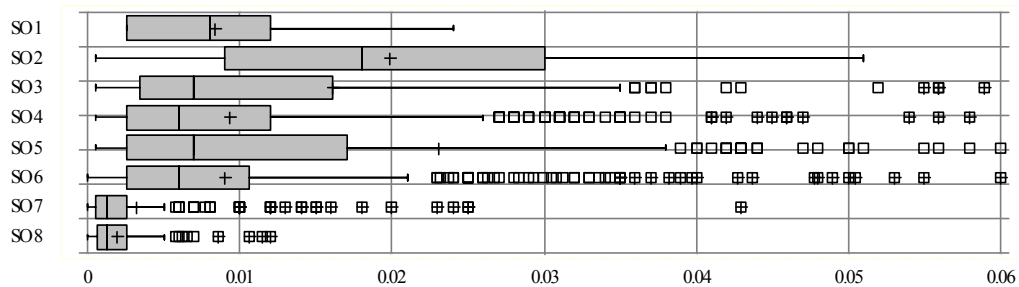
G Total phosphorus mg/l



H Total nitrogen mg/l



I Dissolved reactive phosphorus mg/l



J Ammoniacal nitrogen mg/l

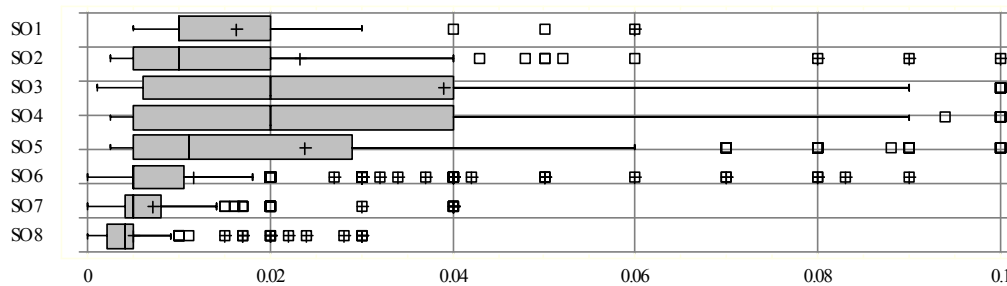
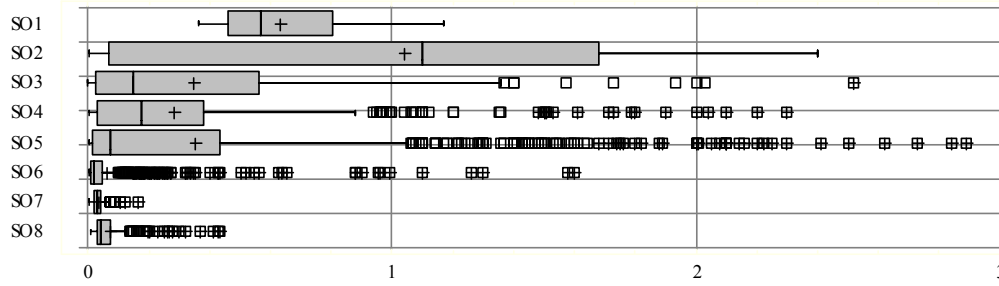


Figure A5. 1 continued Comparison of median water quality parameters among REC stream order classes (SO = stream order)

### Appendix 5 continued – REC stream order

#### K Nitrite/nitrate nitrogen mg/l



#### L *Escherichia coli* cfu/100ml

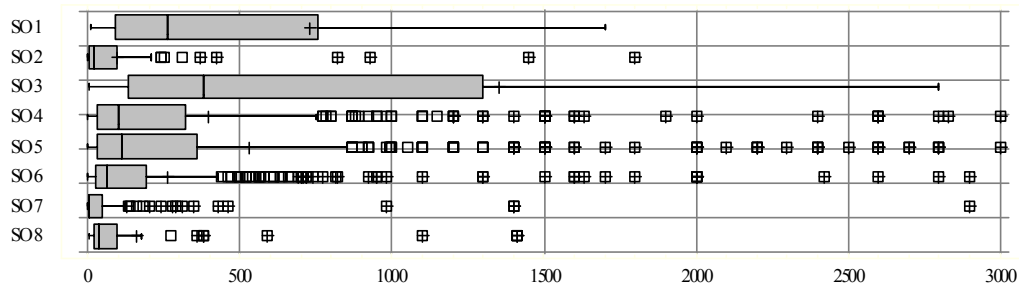


Figure A5.1 continued Comparison of median water quality parameters among REC stream order classes (SO = stream order)

## Appendix 6 – Summary of water quality results

Table A6.1 Summary of water quality results including median values and the percent of samples exceeding guideline values (%)

Parameter		NH <sub>4</sub>	Cond	DO	DRP	<i>E. coli</i>	NNN	pH	Temp	TN	TP	Turb
		mg/l	mS/cm	mg/l	mg/l	cfu/100ml	mg/l	pH	C	mg/l	mg/l	NTU
<b>Guideline Values</b>		<b>&gt;0.09</b>	<b>n/a</b>	<b>&lt;6.5</b>	<b>&gt;0.01</b>	<b>&gt;126</b>	<b>&gt;0.444</b>	<b>&gt;9 or</b>	<b>&gt;20</b>	<b>&gt;0.614</b>	<b>&gt;0.033</b>	<b>&gt;5.6</b>
<b>Cardrona River</b>	<b>%&gt;</b>	0.000	n/a	0.00	0.000	24	0.000	0.00	0.00	2.7027	16.216	27.03
<b>Cardrona River</b>	<b>average</b>	0.011	0.092	11.93	0.003	129	0.066	7.60	7.66	0.162	0.039	8.33
<b>Cardrona River</b>	<b>count</b>	37.000	37.000	37.00	37.000	37	37.000	38.00	37.00	37.000	37.000	37.00
<b>Cardrona River</b>	<b>maximum</b>	0.050	0.149	15.43	0.009	920	0.240	8.10	17.66	0.790	0.380	48.00
<b>Cardrona River</b>	<b>median</b>	0.005	0.090	12.04	0.003	68	0.045	7.65	7.30	0.110	0.008	2.20
<b>Cardrona River</b>	<b>minimum</b>	0.003	0.062	8.89	0.001	5	0.003	7.00	0.50	0.040	0.003	0.15
<b>Careys Creek</b>	<b>%&gt;</b>	0.000	n/a	0.00	0.000	40	8.333	0.00	0.00	13.8889	2.778	5.56
<b>Careys Creek</b>	<b>average</b>	0.013	0.285	11.07	0.004	186	0.197	7.64	8.61	0.3725	0.012	2.60
<b>Careys Creek</b>	<b>count</b>	36.000	36.000	35.00	36.000	35	36.000	36.00	36.00	36.0000	36.000	36.00
<b>Careys Creek</b>	<b>maximum</b>	0.060	1.482	14.00	0.010	1100	2.100	8.20	14.89	2.0000	0.050	11.00
<b>Careys Creek</b>	<b>median</b>	0.010	0.247	11.00	0.003	100	0.068	7.67	8.80	0.265	0.008	2.10
<b>Careys Creek</b>	<b>minimum</b>	0.003	0.141	7.62	0.001	6	0.008	7.10	2.20	0.0900	0.003	0.80
<b>Catlins</b>	<b>%&gt;</b>	0.000	n/a	0.00	40.426	50	12.766	0.00	0.00	17.021	25.532	13.04
<b>Catlins</b>	<b>average</b>	0.012	0.098	11.72	0.012	168	0.315	7.27	9.10	0.513	0.037	4.28
<b>Catlins</b>	<b>count</b>	47.000	45.000	43.00	47.000	46	47.000	45.00	47.00	47.000	47.000	46.00
<b>Catlins</b>	<b>maximum</b>	0.046	0.130	14.90	0.045	1500	0.544	7.81	16.30	1.280	0.504	43.80
<b>Catlins</b>	<b>median</b>	0.010	0.103	11.64	0.009	130	0.310	7.34	8.80	0.490	0.024	2.90
<b>Catlins</b>	<b>minimum</b>	0.005	0.005	7.40	0.002	14	0.048	6.60	3.80	0.250	0.006	1.60
<b>Clutha Balclutha</b>	<b>%&gt;</b>	0.000	n/a	0.00	2.857	26	0.000	0.00	2.78	2.8571	8.571	20.00
<b>Clutha Balclutha</b>	<b>average</b>	0.010	0.085	10.80	0.003	133	0.098	7.61	11.51	0.1740	0.014	4.22
<b>Clutha Balclutha</b>	<b>count</b>	34.000	35.000	35.00	35.000	35	35.000	36.00	36.00	35.0000	35.000	35.00
<b>Clutha Balclutha</b>	<b>maximum</b>	0.030	0.650	12.50	0.012	1100	0.435	8.18	20.20	0.6800	0.079	21.70
<b>Clutha Balclutha</b>	<b>median</b>	0.005	0.069	10.80	0.003	55	0.053	7.56	12.09	0.13	0.010	2.46
<b>Clutha Balclutha</b>	<b>minimum</b>	0.005	0.048	8.70	0.001	10	0.015	7.10	3.50	0.0400	0.003	0.80
<b>Contour Ch</b>	<b>%&gt;</b>	24.324	n/a	2.78	75.676	62	21.622	2.70	5.41	45.946	81.081	21.62
<b>Contour Ch</b>	<b>average</b>	0.101	0.126	9.89	0.021	1129	0.292	7.07	10.62	0.825	0.101	7.35
<b>Contour Ch</b>	<b>count</b>	37.000	37.000	36.00	37.000	37	37.000	37.00	37.00	37.000	37.000	37.00
<b>Contour Ch</b>	<b>maximum</b>	0.530	0.830	13.12	0.058	17000	1.530	8.70	21.20	3.380	0.766	75.00

## Appendix 6 continued - Summary of water quality results

Table A6. 1 continued Summary of water quality results including median values and the percent of samples exceeding guideline values (%)

Parameter		NH <sub>4</sub> mg/l	Cond mS/cm	DO mg/l	DRP mg/l	<i>E. coli</i> cfu/100ml	NNN mg/l	pH pH	Temp C	TN mg/l	TP mg/l	Turb NTU
Contour Ch	median	0.050	0.097	9.98	0.018	250	0.181	6.97	11.26	0.530	0.058	3.40
Contour Ch	minimum	0.005	0.012	4.70	0.003	2	0.009	4.80	2.48	0.200	0.015	1.51
Crookston Burn	%>	12.500	n/a	0.00	84.615	86	82.051	3.03	0.00	89.189	70.270	23.08
Crookston Burn	average	0.047	0.152	11.23	0.019	1287	1.415	7.31	9.79	1.863	0.049	4.78
Crookston Burn	count	40.000	33.000	35.00	39.000	37	39.000	33.00	37.00	37.000	37.000	39.00
Crookston Burn	maximum	0.200	0.940	14.00	0.039	9700	3.090	8.68	18.20	3.950	0.129	18.20
Crookston Burn	median	0.040	0.124	11.50	0.017	870	1.300	7.32	9.80	1.850	0.041	3.50
Crookston Burn	minimum	0.005	0.063	8.60	0.003	49	0.181	6.40	3.00	0.400	0.018	1.60
Dunstan Creek	%>	0.000	n/a	0.00	12.500	17	0.000	4.00	0.00	0.0000	4.167	0.00
Dunstan Creek	average	0.011	0.034	11.24	0.005	79	0.028	7.08	8.98	0.1077	0.012	1.03
Dunstan Creek	count	24.000	24.000	22.00	24.000	24	24.000	25.00	24.00	24.0000	24.000	25.00
Dunstan Creek	maximum	0.090	0.042	13.83	0.015	770	0.094	7.50	15.84	0.3500	0.057	3.60
Dunstan Creek	median	0.005	0.034	11.09	0.003	31	0.020	7.15	8.90	0.085	0.010	0.70
Dunstan Creek	minimum	0.005	0.025	9.30	0.001	2	0.003	6.45	1.00	0.0250	0.003	0.40
Fraser River	%>	0.000	n/a	0.00	3.846	35	0.000	0.00	0.00	0.000	3.846	3.85
Fraser River	average	0.007	0.069	11.06	0.004	131	0.047	7.35	10.48	0.121	0.011	1.77
Fraser River	count	26.000	26.000	26.00	26.000	26	26.000	26.00	26.00	26.000	26.000	26.00
Fraser River	maximum	0.020	0.125	13.68	0.014	580	0.150	7.68	17.40	0.270	0.059	20.00
Fraser River	median	0.005	0.069	11.28	0.003	30	0.040	7.40	10.05	0.115	0.010	0.81
Fraser River	minimum	0.005	0.029	8.20	0.003	1	0.003	6.77	4.80	0.040	0.003	0.45
Frasers Ck	%>	0.000	n/a	0.00	3.030	67	12.121	0.00	0.00	42.424	15.152	3.03
Frasers Ck	average	0.023	0.155	10.28	0.004	379	0.232	6.85	9.72	0.580	0.019	2.80
Frasers Ck	count	33.000	31.000	32.00	33.000	33	33.000	33.00	32.00	33.000	33.000	33.00
Frasers Ck	maximum	0.086	0.218	13.00	0.011	4000	0.865	7.37	17.80	1.800	0.051	7.50
Frasers Ck	median	0.020	0.152	10.30	0.003	220	0.143	6.83	9.85	0.470	0.017	2.53
Frasers Ck	minimum	0.005	0.100	6.60	0.001	27	0.009	6.50	2.70	0.070	0.003	0.65
Gimmerburn	%>	0.000	n/a	7.69	92.593	48	3.704	0.00	0.00	29.630	85.185	7.41
Gimmerburn	average	0.018	0.203	10.33	0.076	1104	0.024	7.17	10.96	0.611	0.148	2.87
Gimmerburn	count	27.000	27.000	26.00	27.000	27	27.000	27.00	27.00	27.000	27.000	27.00

## Appendix 6 continued - Summary of water quality results

Table A6. 1 continued Summary of water quality results including median values and the percent of samples exceeding guideline values (%)

Parameter		NH <sub>4</sub>	Cond	DO	DRP	<i>E. coli</i>	NNN	pH	Temp	TN	TP	Turb
		mg/l	mS/cm	mg/l	mg/l	cfu/100ml	mg/l	pH	C	mg/l	mg/l	NTU
Gimmerburn	maximum	0.080	0.905	14.40	0.532	15000	0.486	7.85	19.76	1.430	0.833	12.00
Gimmerburn	median	0.010	0.161	10.60	0.032	110	0.005	7.20	11.60	0.480	0.083	2.11
Gimmerburn	minimum	0.005	0.050	3.00	0.003	9	0.001	6.55	0.40	0.270	0.016	0.65
Hayes Creek	%>	2.778	n/a	0.00	33.333	0	0.000	0.00	2.78	5.5556	38.889	0.00
Hayes Creek	average	0.030	0.156	10.23	0.010	9	0.022	8.21	12.57	0.338	0.029	0.79
Hayes Creek	count	36.000	37.000	6.00	36.000	35	36.000	27.00	36.00	36.000	36.000	36.00
Hayes Creek	maximum	0.110	0.250	12.70	0.035	86	0.090	9.30	21.40	1.770	0.150	2.90
Hayes Creek	median	0.020	0.150	9.58	0.004	9	0.009	8.11	12.34	0.290	0.020	0.58
Hayes Creek	minimum	0.005	0.125	8.70	0.001	1	0.002	7.30	5.40	0.200	0.003	0.30
Heriot B SH90	median	0.020	0.076	11.30	0.010	325	0.516	7.18	9.00	0.835	0.028	1.65
Heriot B SH90	average	0.016	0.077	11.34	0.011	700	0.624	7.19	8.93	0.831	0.027	1.84
Heriot B SH90	minimum	0.005	0.054	6.50	0.002	19	0.123	6.60	3.50	0.260	0.003	0.70
Heriot B SH90	maximum	0.070	0.144	14.80	0.026	2600	1.350	8.10	15.00	1.450	0.051	3.80
Heriot B SH90	count	30.000	23.000	24.00	27.000	27	30.000	25.00	27.00	24.000	24.000	30.00
Heriot B SH90	%>	0.000	n/a	0.00	48.148	78	60.000	0.00	0.00	66.667	33.333	0.00
Heriot Burn PKR	%>	6.818	n/a	0.00	80.488	93	90.909	2.50	0.00	97.436	87.179	34.88
Heriot Burn PKR	average	0.046	0.115	11.10	0.028	1410	1.031	7.17	9.52	1.537	0.075	5.64
Heriot Burn PKR	count	44.000	37.000	39.00	41.000	42	44.000	40.00	41.00	39.000	39.000	43.00
Heriot Burn PKR	maximum	0.380	0.226	13.80	0.340	11200	2.250	8.05	17.00	2.590	0.200	22.00
Heriot Burn PKR	median	0.030	0.110	11.30	0.016	535	0.991	7.20	9.40	1.410	0.065	4.60
Heriot Burn PKR	minimum	0.003	0.061	8.10	0.002	68	0.145	6.40	2.00	0.460	0.012	0.61
Ida Burn	%>	0.000	n/a	0.00	68.421	53	0.000	0.00	0.00	5.2632	47.368	10.53
Ida Burn	average	0.012	0.103	10.49	0.028	570	0.033	7.51	10.54	0.3226	0.048	2.81
Ida Burn	count	19.000	18.000	18.00	19.000	19	19.000	17.00	18.00	19.0000	19.000	19.00
Ida Burn	maximum	0.020	0.227	14.24	0.120	4400	0.120	7.98	17.65	0.6500	0.151	11.00
Ida Burn	median	0.010	0.079	10.30	0.012	140	0.017	7.47	10.90	0.27	0.033	1.60
Ida Burn	minimum	0.005	0.044	7.10	0.003	2	0.003	6.92	2.00	0.1200	0.003	0.60
Kaihiku Stream	%>	4.545	n/a	2.27	79.545	71	54.545	2.22	0.00	65.116	69.767	31.82
Kaihiku Stream	average	0.027	0.169	10.76	0.023	1047	0.621	7.47	10.67	1.085	0.059	4.77

## Appendix 6 continued - Summary of water quality results

Table A6. 1 continued Summary of water quality results including median values and the percent of samples exceeding guideline values (%)

Parameter		NH <sub>4</sub> mg/l	Cond mS/cm	DO mg/l	DRP mg/l	<i>E. coli</i> cfu/100ml	NNN mg/l	pH pH	Temp C	TN mg/l	TP mg/l	Turb NTU
Kaihiku Stream	count	44.000	45.000	44.00	44.000	45	44.000	45.00	45.00	43.000	43.000	44.00
Kaihiku Stream	maximum	0.150	0.347	14.70	0.063	13200	2.000	8.80	18.60	3.320	0.142	19.00
Kaihiku Stream	median	0.020	0.170	10.65	0.019	250	0.590	7.40	10.69	1.050	0.056	3.45
Kaihiku Stream	minimum	0.005	0.030	5.70	0.003	20	0.003	6.38	2.60	0.270	0.011	1.10
Kaikorai Stream	%>	7.895	n/a	0.00	36.842	87	23.684	0.00	0.00	52.632	42.105	31.58
Kaikorai Stream	average	0.034	0.137	11.95	0.009	1135	0.367	8.06	10.58	0.772	0.045	6.86
Kaikorai Stream	count	38.000	39.000	38.00	38.000	38	38.000	39.00	38.00	38.000	38.000	38.00
Kaikorai Stream	maximum	0.180	0.332	15.98	0.055	8000	1.400	9.60	19.51	2.000	0.250	38.00
Kaikorai Stream	median	0.020	0.117	11.83	0.006	445	0.317	8.10	10.75	0.620	0.031	3.95
Kaikorai Stream	minimum	0.005	0.042	7.82	0.003	30	0.024	6.60	3.10	0.270	0.005	1.20
Kakanui CF	%>	0.000	n/a	0.00	0.000	48	0.000	5.71	2.70	6.452	9.677	2.94
Kakanui CF	average	0.011	0.078	11.29	0.004	1028	0.015	7.48	11.31	0.185	0.011	1.32
Kakanui CF	count	36.000	37.000	37.00	36.000	33	36.000	35.00	37.00	31.000	31.000	34.00
Kakanui CF	maximum	0.040	0.151	17.19	0.010	24200	0.123	8.23	20.74	1.060	0.084	27.00
Kakanui CF	median	0.005	0.078	11.15	0.003	120	0.013	7.50	11.50	0.130	0.003	0.40
Kakanui CF	minimum	0.005	0.036	7.60	0.001	6	0.002	6.40	1.40	0.060	0.003	0.10
Kakanui Prin	%>	0.000	n/a	2.44	0.000	15	0.000	0.00	2.38	0.000	4.878	2.33
Kakanui Prin	average	0.009	0.107	10.87	0.003	92	0.115	7.45	12.02	0.231	0.009	1.09
Kakanui Prin	count	44.000	42.000	41.00	44.000	41	44.000	43.00	42.00	41.000	41.000	43.00
Kakanui Prin	maximum	0.030	0.210	14.40	0.008	980	0.400	8.32	21.28	0.540	0.049	5.81
Kakanui Prin	median	0.005	0.098	11.10	0.003	34	0.086	7.43	12.00	0.210	0.006	0.63
Kakanui Prin	minimum	0.003	0.010	5.95	0.001	1	0.003	6.90	3.60	0.040	0.003	0.20
Lake Dunstan	%>	0.000	n/a	0.00	0.000	0	0.000	0.00	3.03	0.000	0.000	0.00
Lake Dunstan	average	0.009	0.067	10.76	0.002	2	0.031	7.97	13.39	0.080	0.005	1.00
Lake Dunstan	count	36.000	35.000	33.00	36.000	37	36.000	36.00	33.00	36.000	36.000	36.00
Lake Dunstan	maximum	0.050	0.109	13.22	0.008	11	0.062	8.70	20.07	0.200	0.032	5.40
Lake Dunstan	median	0.005	0.066	11.08	0.003	1	0.030	7.96	12.93	0.085	0.003	0.52
Lake Dunstan	minimum	0.003	0.051	7.29	0.001	1	0.003	7.40	6.50	0.025	0.003	0.30
Lake Hawea	%>	5.714	n/a	0.00	0.000	0	0.000	0.00	0.00	0.000	0.000	2.94

## Appendix 6 continued - Summary of water quality results

Table A6. 1 continued Summary of water quality results including median values and the percent of samples exceeding guideline values (%)

Parameter		NH <sub>4</sub>	Cond	DO	DRP	<i>E. coli</i>	NNN	pH	Temp	TN	TP	Turb
		mg/l	mS/cm	mg/l	mg/l	cfu/100ml	mg/l	pH	C	mg/l	mg/l	NTU
Lake Hawea	average	0.013	0.076	10.95	0.002	2	0.016	7.53	12.19	0.046	0.005	0.79
Lake Hawea	count	35.000	35.000	34.00	35.000	35	35.000	35.00	34.00	35.000	35.000	34.00
Lake Hawea	maximum	0.110	0.511	13.41	0.004	40	0.073	7.95	16.80	0.190	0.031	14.00
Lake Hawea	median	0.005	0.050	10.88	0.003	1	0.013	7.55	11.96	0.040	0.003	0.27
Lake Hawea	minimum	0.003	0.038	8.20	0.001	1	0.002	7.00	8.00	0.025	0.003	0.10
Lake Hayes	%>	16.667	n/a	0.00	37.500	0	0.000	0.00	4.00	0.000	33.333	0.00
Lake Hayes	average	0.054	0.306	10.11	0.011	2	0.028	8.30	13.46	0.300	0.031	0.64
Lake Hayes	count	24.000	25.000	24.00	24.000	24	24.000	24.00	25.00	24.000	24.000	24.00
Lake Hayes	maximum	0.290	1.560	13.05	0.041	6	0.100	9.20	21.10	0.430	0.120	1.39
Lake Hayes	median	0.032	0.155	9.37	0.004	1	0.013	8.11	14.30	0.310	0.018	0.53
Lake Hayes	minimum	0.005	0.019	8.12	0.001	1	0.002	7.30	6.00	0.190	0.003	0.30
Lake Johnson	%>	20.000	n/a	0.00	36.667	0	3.333	0.00	3.33	63.333	46.667	3.33
Lake Johnson	average	0.048	0.181	9.80	0.012	4	0.042	8.25	12.55	0.678	0.036	0.95
Lake Johnson	count	30.000	30.000	30.00	30.000	28	30.000	30.00	30.00	30.000	30.000	30.00
Lake Johnson	maximum	0.190	0.293	13.50	0.063	29	0.682	9.60	20.80	1.200	0.093	7.33
Lake Johnson	median	0.020	0.180	9.50	0.004	2	0.008	8.37	12.68	0.670	0.028	0.70
Lake Johnson	minimum	0.005	0.047	7.06	0.001	1	0.002	7.47	4.70	0.120	0.003	0.35
Lake Onslow	%>	0.000	n/a	13.33	0.000	0	0.000	13.33	0.00	0.000	46.667	26.67
Lake Onslow	average	0.017	0.027	9.00	0.003	3	0.029	6.85	10.03	0.324	0.040	4.71
Lake Onslow	count	15.000	14.000	15.00	15.000	14	15.000	15.00	14.00	15.000	15.000	15.00
Lake Onslow	maximum	0.030	0.043	12.01	0.007	10	0.155	7.40	20.00	0.500	0.073	13.00
Lake Onslow	median	0.020	0.026	8.99	0.003	2	0.008	6.86	11.30	0.300	0.033	3.00
Lake Onslow	minimum	0.005	0.016	5.50	0.001	1	0.003	6.10	1.50	0.130	0.022	2.00
Lake Tuakitoto	%>	17.647	n/a	3.03	38.235	41	23.529	0.00	2.94	85.294	82.353	50.00
Lake Tuakitoto	average	0.057	0.161	9.31	0.012	169	0.247	7.61	11.36	1.064	0.078	9.85
Lake Tuakitoto	count	34.000	33.000	33.00	34.000	34	34.000	34.00	34.00	34.000	34.000	34.00
Lake Tuakitoto	maximum	0.360	0.221	12.30	0.047	800	1.360	9.50	22.20	2.210	0.204	50.00
Lake Tuakitoto	median	0.030	0.164	9.40	0.009	80	0.045	7.40	11.86	0.950	0.074	6.52
Lake Tuakitoto	minimum	0.005	0.081	2.40	0.001	20	0.005	6.70	3.50	0.110	0.003	1.15

## Appendix 6 continued - Summary of water quality results

Table A6. 1 continued Summary of water quality results including median values and the percent of samples exceeding guideline values (%)

Parameter		NH <sub>4</sub> mg/l	Cond mS/cm	DO mg/l	DRP mg/l	<i>E. coli</i> cfu/100ml	NNN mg/l	pH pH	Temp C	TN mg/l	TP mg/l	Turb NTU
Lake Waiholo	%>	2.857	n/a	0.00	0.000	10	0.000	6.25	12.00	11.765	55.882	51.43
Lake Waiholo	average	0.020	1.331	10.10	0.004	77	0.021	7.32	14.53	0.476	0.046	10.04
Lake Waiholo	count	35.000	50.000	48.00	35.000	49	31.000	48.00	50.00	34.000	34.000	35.00
Lake Waiholo	maximum	0.150	12.930	13.42	0.009	870	0.134	8.55	24.55	1.300	0.260	63.00
Lake Waiholo	median	0.010	0.575	10.00	0.003	20	0.006	7.30	16.20	0.435	0.041	6.03
Lake Waiholo	minimum	0.005	0.012	7.40	0.001	1	0.003	6.29	4.60	0.160	0.003	2.10
Lake Waipori	%>	22.857	n/a	0.00	14.286	14	3.226	5.71	11.43	37.143	51.429	17.14
Lake Waipori	average	0.144	0.826	9.86	0.007	108	0.077	7.29	12.06	0.786	0.056	4.62
Lake Waipori	count	35.000	35.000	32.00	35.000	35	31.000	35.00	35.00	35.000	35.000	35.00
Lake Waipori	maximum	2.130	3.660	13.09	0.046	1100	0.523	8.90	24.00	4.380	0.313	24.00
Lake Waipori	median	0.036	0.590	9.53	0.005	40	0.043	7.20	11.40	0.540	0.035	3.90
Lake Waipori	minimum	0.005	0.026	6.50	0.002	1	0.003	6.30	3.73	0.160	0.003	0.70
Lake Wakatipu	%>	0.000	n/a	0.00	0.000	3	0.000	0.00	0.00	2.703	0.000	0.00
Lake Wakatipu	average	0.009	0.053	10.60	0.002	45	0.025	7.65	11.68	0.116	0.004	0.43
Lake Wakatipu	count	37.000	37.000	36.00	37.000	37	37.000	37.00	37.00	37.000	37.000	37.00
Lake Wakatipu	maximum	0.040	0.086	12.96	0.006	1400	0.054	8.10	16.10	2.290	0.020	1.80
Lake Wakatipu	median	0.005	0.054	10.67	0.003	2	0.024	7.70	12.06	0.050	0.003	0.35
Lake Wakatipu	minimum	0.005	0.030	8.30	0.001	1	0.005	7.20	7.60	0.025	0.003	0.10
Lake Wanaka	%>	0.000	n/a	0.00	0.000	0	0.000	0.00	0.00	0.000	0.000	0.00
Lake Wanaka	average	0.008	0.069	10.62	0.002	4	0.036	7.74	12.16	0.057	0.003	0.34
Lake Wanaka	count	36.000	36.000	35.00	36.000	36	36.000	36.00	36.00	36.000	36.000	36.00
Lake Wanaka	maximum	0.040	0.109	12.66	0.003	49	0.059	8.16	19.90	0.120	0.010	1.18
Lake Wanaka	median	0.005	0.067	10.60	0.003	1	0.036	7.73	12.07	0.050	0.003	0.28
Lake Wanaka	minimum	0.003	0.055	8.90	0.001	1	0.017	7.20	8.44	0.025	0.003	0.10
Lee Stream	%>	0.000	n/a	0.00	70.000	60	0.000	0.00	0.00	30.000	95.000	25.00
Lee Stream	average	0.021	0.071	11.67	0.013	1286	0.130	7.11	9.42	0.584	0.074	5.48
Lee Stream	count	20.000	20.000	20.00	20.000	20	20.000	20.00	20.00	20.000	20.000	20.00
Lee Stream	maximum	0.040	0.108	14.80	0.023	9800	0.280	7.56	18.50	1.200	0.150	19.00
Lee Stream	median	0.020	0.067	11.70	0.014	155	0.137	7.18	9.24	0.520	0.065	3.65

## Appendix 6 continued - Summary of water quality results

Table A6. 1 continued Summary of water quality results including median values and the percent of samples exceeding guideline values (%)

Parameter		NH <sub>4</sub> mg/l	Cond mS/cm	DO mg/l	DRP mg/l	<i>E. coli</i> cfu/100ml	NNN mg/l	pH pH	Temp C	TN mg/l	TP mg/l	Turb NTU
Lee Stream	minimum	0.005	0.042	9.00	0.003	12	0.003	6.55	1.40	0.025	0.024	2.50
Lindis River	%>	0.000	n/a	0.00	6.250	13	0.000	0.00	0.00	0.0000	18.750	18.75
Lindis River	average	0.007	0.056	12.63	0.006	56	0.020	7.54	6.30	0.1119	0.021	2.53
Lindis River	count	16.000	16.000	15.00	16.000	15	16.000	16.00	15.00	16.0000	16.000	16.00
Lindis River	maximum	0.020	0.080	14.41	0.011	320	0.085	8.00	13.00	0.4700	0.066	10.00
Lindis River	median	0.005	0.053	12.97	0.006	16	0.012	7.62	5.90	0.07	0.013	1.20
Lindis River	minimum	0.005	0.033	10.10	0.003	2	0.005	6.60	0.90	0.0250	0.003	0.40
Lindsay's Creek	%>	5.882	n/a	0.00	70.588	100	88.235	2.78	2.78	91.176	70.588	37.50
Lindsay's Creek	average	0.040	0.165	12.29	0.024	3307	0.716	8.02	11.12	1.167	0.068	6.17
Lindsay's Creek	count	34.000	36.000	33.00	34.000	34	34.000	36.00	36.00	34.000	34.000	48.00
Lindsay's Creek	maximum	0.420	0.208	15.85	0.194	60000	2.000	9.20	21.30	2.500	0.441	30.00
Lindsay's Creek	median	0.020	0.170	12.36	0.019	1150	0.640	7.83	11.30	1.105	0.045	3.92
Lindsay's Creek	minimum	0.005	0.101	9.16	0.003	140	0.140	6.40	3.40	0.440	0.008	1.50
Lovells Creek	%>	0.000	n/a	0.00	23.520	88	61.765	0.00	0.00	85.290	58.824	29.41
Lovells Creek	average	0.026	0.131	11.47	0.007	642	0.754	7.13	9.76	1.181	0.038	5.68
Lovells Creek	count	34.000	37.000	36.00	34.000	34	34.000	34.00	36.00	34.000	34.000	34.00
Lovells Creek	maximum	0.070	0.170	14.00	0.022	3300	2.300	7.59	17.20	2.390	0.096	31.00
Lovells Creek	median	0.020	0.133	11.30	0.006	340	0.645	7.14	10.03	1.060	0.036	4.55
Lovells Creek	minimum	0.005	0.081	8.90	0.001	64	0.072	6.60	2.70	0.350	0.003	1.80
Main Drain	%>	83.051	n/a	54.39	20.330	34	35.593	0.00	5.08	100.000	74.576	40.68
Main Drain	average	0.788	3.232	5.99	0.010	235	0.523	7.33	12.00	2.514	0.096	6.70
Main Drain	count	59.000	58.000	57.00	59.000	59	59.000	59.00	59.00	59.000	59.000	59.00
Main Drain	maximum	3.210	6.106	13.00	0.146	4800	2.200	8.34	24.40	7.900	0.476	28.00
Main Drain	median	0.420	3.225	6.08	0.003	56	0.300	7.31	12.00	2.100	0.056	5.10
Main Drain	minimum	0.020	0.019	0.28	0.001	2	0.008	6.55	2.70	0.720	0.003	0.80
Manuherikia BS	%>	0.000	n/a	0.00	13.790	14	0.000	3.57	0.00	0.000	3.448	13.79
Manuherikia BS	average	0.009	0.032	11.42	0.006	61	0.018	7.28	9.12	0.104	0.011	2.70
Manuherikia BS	count	29.000	29.000	29.00	29.000	28	29.000	28.00	29.00	29.000	29.000	29.00
Manuherikia BS	maximum	0.040	0.060	13.99	0.020	310	0.084	7.60	18.50	0.350	0.038	14.00

## Appendix 6 continued - Summary of water quality results

Table A6. 1 continued Summary of water quality results including median values and the percent of samples exceeding guideline values (%)

Parameter		NH <sub>4</sub>	Cond	DO	DRP	<i>E. coli</i>	NNN	pH	Temp	TN	TP	Turb
		mg/l	mS/cm	mg/l	mg/l	cfu/100ml	mg/l	pH	C	mg/l	mg/l	NTU
Manuherikia BS	median	0.005	0.032	10.93	0.003	31	0.007	7.31	10.10	0.090	0.009	1.60
Manuherikia BS	minimum	0.005	0.022	9.08	0.002	1	0.003	6.49	0.25	0.025	0.003	0.70
Manuherikia G	%>	0.000	n/a	0.00	48.571	36	0.000	0.00	2.63	5.710	40.000	13.89
Manuherikia G	average	0.010	0.103	11.44	0.014	338	0.046	7.49	10.88	0.281	0.039	5.05
Manuherikia G	count	35.000	36.000	36.00	35.000	44	35.000	34.00	38.00	35.000	35.000	36.00
Manuherikia G	maximum	0.040	0.441	15.43	0.067	4800	0.166	8.70	21.00	0.890	0.311	50.00
Manuherikia G	median	0.005	0.085	11.21	0.010	94	0.040	7.50	11.95	0.230	0.026	1.92
Manuherikia G	minimum	0.003	0.056	8.20	0.003	8	0.005	6.70	-0.20	0.090	0.003	0.80
Mill Creek	%>	0.000	n/a	0.00	2.703	54	50.000	0.00	0.00	61.100	29.730	5.41
Mill Creek	average	0.015	0.159	11.84	0.004	356	0.461	7.86	8.18	0.663	0.025	3.08
Mill Creek	count	36.000	####	36.00	37.000	35	36.000	37.00	36.00	36.000	37.000	37.00
Mill Creek	maximum	0.050	1.186	13.96	0.016	4800	0.870	8.90	14.29	1.000	0.076	7.00
Mill Creek	median	0.008	0.130	11.62	0.003	140	0.452	7.81	8.25	0.650	0.021	2.50
Mill Creek	minimum	0.005	0.020	8.80	0.001	12	0.003	7.20	1.50	0.190	0.007	1.10
Minzion Burn	%>	0.000	n/a	5.00	35.000	75	0.000	5.00	0.00	10.000	50.000	5.00
Minzion Burn	average	0.016	0.043	10.05	0.010	827	0.045	7.16	10.30	0.343	0.046	3.83
Minzion Burn	count	20.000	####	20.00	20.000	20	20.000	20.00	18.00	20.000	20.000	20.00
Minzion Burn	maximum	0.050	0.055	14.20	0.029	8600	0.202	7.72	17.20	1.100	0.170	26.30
Minzion Burn	median	0.013	0.043	10.30	0.009	350	0.029	7.16	10.35	0.275	0.034	2.20
Minzion Burn	minimum	0.005	0.030	1.44	0.003	22	0.005	6.00	3.70	0.080	0.019	1.30
NIWA Balclu	%>	1.471	n/a	0.00	2.985		0.000	0.00	1.47	1.493	5.970	25.00
NIWA Balclu	average	0.012	73.112	10.85	0.002		0.097	7.78	11.98	0.195	0.014	4.67
NIWA Balclu	count	0.068	68.000	68.00	67.000		67.000	68.00	68.00	67.000	67.000	68.00
NIWA Balclu	maximum	0.021	89.400	12.51	0.011		0.428	8.20	20.50	0.766	0.062	29.00
NIWA Balclu	median	0.012	0.073	10.85	0.002		0.061	7.78	12.00	0.144	0.010	2.85
NIWA Balclu	minimum	0.006	54.300	9.07	0.000		0.011	7.54	5.80	0.074	0.004	0.68
NIWA Kawarau	%>	0.000	n/a	0.00	0.000		0.000	0.00	0.00	0.000	13.433	19.12
NIWA Kawarau	average	0.012	65.769	10.64	0.001		0.025	7.83	11.64	0.088	0.048	12.54
NIWA Kawarau	count	0.068	68.000	68.00	68.000		68.000	68.00	68.00	67.000	67.000	68.00

## Appendix 6 continued - Summary of water quality results

Table A6. 1 continued Summary of water quality results including median values and the percent of samples exceeding guideline values (%)

Parameter		NH <sub>4</sub>	Cond	DO	DRP	<i>E. coli</i>	NNN	pH	Temp	TN	TP	Turb
		mg/l	mS/cm	mg/l	mg/l	cfu/100ml	mg/l	pH	C	mg/l	mg/l	NTU
NIWA Kawarau	maximum	0.017	72.000	12.30	0.006		0.046	8.00	16.70	0.406	1.369	379.00
NIWA Kawarau	median	0.012	0.066	10.71	0.001		0.025	7.84	11.75	0.078	0.013	2.60
NIWA Kawarau	minimum	0.006	59.500	9.55	0.000		0.014	7.69	6.10	0.051	0.004	0.45
NIWA Luggate	%>	0.000	n/a	0.00	0.000		0.000	0.00	0.00	0.000	3.030	4.41
NIWA Luggate	average	0.005	67.847	10.77	0.001		0.038	8.05	12.65	0.086	0.009	2.80
NIWA Luggate	count	0.067	68.000	68.00	68.000		68.000	68.00	68.00	68.000	66.000	68.00
NIWA Luggate	maximum	0.028	74.700	12.01	7.669		0.066	8.56	17.20	0.347	0.248	114.00
NIWA Luggate	median	0.004	0.068	10.78	0.000		0.039	8.06	12.20	0.079	0.003	0.55
NIWA Luggate	minimum	0.000	61.000	9.77	0.000		0.020	7.68	9.10	0.048	0.001	0.23
NIWA Millers Flat	%>	0.000	n/a	0.00	0.000		0.000	0.00	0.00	0.000	1.493	14.71
NIWA Millers Flat	average	0.012	71.137	10.85	0.001		0.039	7.74	11.79	0.102	0.012	4.73
NIWA Millers Flat	count	0.068	68.000	68.00	68.000		68.000	68.00	68.00	66.000	67.000	68.00
NIWA Millers Flat	maximum	0.017	78.600	12.37	0.005		0.075	7.87	17.20	0.224	0.213	120.00
NIWA Millers Flat	median	0.012	0.071	10.87	0.001		0.037	7.74	11.50	0.095	0.007	1.70
NIWA Millers Flat	minimum	0.007	64.800	9.35	0.000		0.022	7.56	6.60	0.054	0.002	0.44
NIWA Outram	%>	2.941	n/a	0.00	34.328		0.000	0.00	2.94	5.970	44.776	17.65
NIWA Outram	average	0.011	76.319	11.68	0.010		0.042	7.55	10.50	0.333	0.042	4.99
NIWA Outram	count	0.068	68.000	68.00	67.000		67.000	68.00	68.00	67.000	67.000	68.00
NIWA Outram	maximum	0.023	101.500	14.84	0.031		0.232	8.83	22.90	0.904	0.302	68.00
NIWA Outram	median	0.011	0.076	11.72	0.008		0.029	7.54	10.65	0.293	0.031	2.45
NIWA Outram	minimum	0.001	48.500	9.01	0.003		0.001	6.87	1.30	0.124	0.009	0.78
NIWA Shotover	%>	0.000	n/a	0.00	0.000		0.000	0.00	0.00	1.471	57.353	61.76
NIWA Shotover	average	0.009	99.709	11.61	0.001		0.022	7.89	8.63	0.089	0.162	31.96
NIWA Shotover	count	0.068	67.000	68.00	68.000		68.000	68.00	68.00	68.000	68.000	68.00
NIWA Shotover	maximum	0.018	#####	14.00	0.005		0.059	8.03	17.80	0.874	3.260	904.00
NIWA Shotover	median	0.009	0.102	11.44	0.001		0.017	7.90	8.85	0.062	0.045	9.75
NIWA Shotover	minimum	0.001	60.800	9.33	0.000		0.004	7.64	1.30	0.021	0.002	0.46
NIWA Sutton St	%>	1.471	n/a	0.00	2.985		0.000	0.00	1.47	1.493	10.448	1.47
NIWA Sutton St	average	0.009	43.895	11.31	0.005		0.022	7.16	8.78	0.268	0.023	1.64

## Appendix 6 continued - Summary of water quality results

Table A6. 1 continued Summary of water quality results including median values and the percent of samples exceeding guideline values (%)

Parameter		NH <sub>4</sub> mg/l	Cond mS/cm	DO mg/l	DRP mg/l	<i>E. coli</i> cfu/100ml	NNN mg/l	pH pH	Temp C	TN mg/l	TP mg/l	Turb NTU
NIWA Sutton St	count	0.068	68.000	68.00	67.000		67.000	68.00	68.00	67.000	67.000	68.00
NIWA Sutton St	maximum	0.022	59.900	14.30	0.016		0.175	7.43	21.80	0.838	0.221	17.00
NIWA Sutton St	median	0.008	0.043	11.50	0.004		0.013	7.16	7.85	0.245	0.018	1.00
NIWA Sutton St	minimum	0.000	27.800	7.42	0.001		0.000	6.86	0.00	0.120	0.008	0.35
NIWA Tiroiti	%>	1.493	n/a	0.00	76.119		0.000	0.00	1.47	1.4925	79.104	26.47
NIWA Tiroiti	average	0.009	87.563	10.90	0.020		0.021	7.49	9.29	0.3	0.054	5.05
NIWA Tiroiti	count	0.067	68.000	68.00	67.000		67.000	68.00	68.00	67	67.000	68.00
NIWA Tiroiti	maximum	0.021	#####	14.20	0.083		0.085	7.98	21.20	0.6	0.147	23.00
NIWA Tiroiti	median	0.009	0.087	10.77	0.015		0.017	7.49	9.00	0.3	0.047	3.55
NIWA Tiroiti	minimum	0.000	48.800	7.67	0.002		0.002	6.97	0.00	0.2	0.019	1.40
Owhiro	%>	15.625	n/a	86.21	62.500	19	28.125	90.63	3.13	87.5000	#####	71.88
Owhiro	average	0.051	0.206	10.17	0.019	237	0.337	7.29	10.80	1.021	0.106	11.22
Owhiro	count	32.000	#####	29.00	32.000	32	32.000	32.00	32.00	32.000	32.000	32.00
Owhiro	maximum	0.150	0.376	14.86	0.056	1269	1.360	9.14	22.13	2.420	0.225	40.00
Owhiro	median	0.040	0.193	10.51	0.018	0	0.136	7.28	11.17	0.855	0.096	7.26
Owhiro	minimum	0.005	0.090	3.87	0.003	0	0.009	6.03	2.20	0.290	0.040	0.95
Pig Burn	%>	0.000	n/a	0.00	0.006	29	0.000	0.00	0.00	0.0000	14.286	0.00
Pig Burn	average	0.013	0.109	11.53	0.006	89	0.108	7.18	9.63	0.264	0.015	1.67
Pig Burn	count	7.000	6.000	7.00	7.000	7	7.000	7.00	7.00	7.000	7.000	7.00
Pig Burn	maximum	0.020	0.200	14.57	0.012	340	0.328	7.52	14.90	0.450	0.035	4.00
Pig Burn	median	0.010	0.092	11.60	0.007	52	0.072	7.24	9.11	0.230	0.012	1.50
Pig Burn	minimum	0.005	0.056	8.72	0.003	2	0.022	6.56	4.98	0.140	0.003	0.75
Pomahaka BF	%>	0.000	n/a	0.00	27.778	40	47.222	0.00	0.00	60.000	34.286	26.47
Pomahaka BF	average	0.019	0.125	11.26	0.008	591	0.548	7.43	11.06	0.895	0.032	4.40
Pomahaka BF	count	36.000	#####	34.00	36.000	35	36.000	37.00	35.00	35.000	35.000	34.00
Pomahaka BF	maximum	0.070	0.950	14.30	0.024	9700	1.600	8.43	17.80	2.500	0.073	16.00
Pomahaka BF	median	0.020	0.090	11.07	0.008	110	0.432	7.50	11.70	0.730	0.029	3.50
Pomahaka BF	minimum	0.005	0.057	8.70	0.001	1	0.003	6.60	3.00	0.090	0.006	0.90
Pomahaka GK	%>	0.000	n/a	0.00	12.500	62	2.500	2.63	0.00	5.260	13.158	7.50

## Appendix 6 continued - Summary of water quality results

Table A6. 1 continued Summary of water quality results including median values and the percent of samples exceeding guideline values (%)

Parameter		NH <sub>4</sub> mg/l	Cond mS/cm	DO mg/l	DRP mg/l	<i>E. coli</i> cfu/100ml	NNN mg/l	pH pH	Temp C	TN mg/l	TP mg/l	Turb NTU
Pomahaka GK	average	0.013	0.065	11.59	0.006	561	0.084	7.25	8.81	0.271	0.020	2.36
Pomahaka GK	count	40.000	#####	34.00	40.000	39	40.000	38.00	37.00	38.000	38.000	40.00
Pomahaka GK	maximum	0.040	0.334	15.20	0.021	4800	0.560	7.85	16.40	1.000	0.067	19.70
Pomahaka GK	median	0.010	0.050	11.60	0.003	170	0.034	7.30	9.30	0.210	0.017	1.45
Pomahaka GK	minimum	0.005	0.030	9.00	0.001	18	0.002	6.20	0.20	0.025	0.003	0.45
Shag Grange	%>	0.000	n/a	0.00	10.714	33	0.000	0.00	3.45	7.1400	0.000	0.00
Shag Grange	average	0.011	0.167	10.88	0.005	162	0.034	7.73	10.59	0.2546	0.011	0.62
Shag Grange	count	28.000	29.000	28.00	28.000	27	28.000	29.00	29.00	28.0000	28.000	28.00
Shag Grange	maximum	0.080	0.293	13.54	0.012	1100	0.250	9.06	20.50	1.3000	0.030	2.60
Shag Grange	median	0.005	0.158	11.32	0.003	80	0.010	7.71	9.10	0.16	0.009	0.48
Shag Grange	minimum	0.005	0.089	7.14	0.001	13	0.003	6.80	0.59	0.0700	0.003	0.10
Shag Goodwood	%>	2.778	n/a	2.94	2.777	36	5.556	0.00	0.00	5.710	2.778	2.78
Shag Goodwood	average	0.014	0.187	10.37	0.004	218	0.191	7.44	11.57	0.378	0.012	1.38
Shag Goodwood	count	36.000	#####	34.00	36.000	36	36.000	37.00	37.00	35.000	36.000	36.00
Shag Goodwood	maximum	0.110	0.328	13.80	0.018	2000	1.600	8.56	19.14	1.700	0.051	20.00
Shag Goodwood	median	0.010	0.182	10.10	0.003	89	0.128	7.38	12.80	0.310	0.012	0.62
Shag Goodwood	minimum	0.003	0.084	6.40	0.001	4	0.018	6.70	2.80	0.130	0.003	0.20
Silver Stream	%>	0.000	n/a	0.00	9.523	52	4.762	0.00	4.35	9.500	4.762	0.00
Silver Stream	average	0.009	0.155	11.76	0.006	238	0.193	8.17	12.04	0.358	0.015	1.49
Silver Stream	count	21.000	23.000	22.00	21.000	21	21.000	23.00	23.00	21.000	21.000	21.00
Silver Stream	maximum	0.020	0.196	15.47	0.025	1300	0.516	9.30	25.20	0.960	0.039	3.90
Silver Stream	median	0.005	0.162	11.93	0.005	160	0.169	8.17	11.70	0.320	0.015	1.20
Silver Stream	minimum	0.005	0.095	8.14	0.003	5	0.007	7.01	3.50	0.140	0.003	0.40
T Allanton	%>	0.000	n/a	0.00	221.875	50	0.000	8.82	0.00	6.200	37.500	18.75
T Allanton	average	0.018	0.077	10.83	0.007	217	0.063	7.14	10.49	0.333	0.031	3.29
T Allanton	count	32.000	34.000	33.00	32.000	32	32.000	34.00	34.00	32.000	32.000	32.00
T Allanton	maximum	0.090	0.103	15.40	0.025	1700	0.318	8.02	20.00	0.770	0.106	9.64
T Allanton	median	0.010	0.078	10.34	0.006	130	0.040	7.21	11.07	0.305	0.031	2.40
T Allanton	minimum	0.005	0.050	7.80	0.001	15	0.002	6.03	2.55	0.160	0.003	0.75

## Appendix 6 continued - Summary of water quality results

Table A6. 1 continued Summary of water quality results including median values and the percent of samples exceeding guideline values (%)

Parameter		NH <sub>4</sub> mg/l	Cond mS/cm	DO mg/l	DRP mg/l	<i>E. coli</i> cfu/100ml	NNN mg/l	pH pH	Temp C	TN mg/l	TP mg/l	Turb NTU
T Halls Br	%>	2.083	n/a	2.22	52.083	46	0.000	10.42	0.00	8.300	62.500	8.33
T Halls Br	average	0.016	0.076	10.22	0.018	410	0.015	7.05	10.81	0.352	0.048	2.55
T Halls Br	count	48.000	48.000	45.00	48.000	48	48.000	48.00	48.00	48.000	48.000	48.00
T Halls Br	maximum	0.310	0.313	15.50	0.100	8100	0.272	8.04	19.80	0.760	0.210	7.38
T Halls Br	median	0.005	0.065	10.10	0.011	110	0.007	7.06	11.39	0.330	0.038	2.06
T Halls Br	minimum	0.003	0.031	4.79	0.002	5	0.002	6.28	0.80	0.160	0.003	1.20
T Henley	%>	0.000	n/a	0.00	17.073	20	0.000	9.30	4.76	4.870	43.902	60.98
T Henley	average	0.025	2.632	9.92	0.006	127	0.050	7.17	11.65	0.361	0.034	7.21
T Henley	count	40.000	42.000	42.00	41.000	41	41.000	43.00	42.00	41.000	41.000	41.00
T Henley	maximum	0.083	23.500	13.29	0.023	950	0.260	7.91	22.00	1.200	0.087	19.20
T Henley	median	0.020	0.633	10.04	0.006	52	0.024	7.20	12.07	0.310	0.029	6.10
T Henley	minimum	0.005	0.046	6.50	0.001	6	0.005	5.88	3.60	0.150	0.003	2.50
T Middlemarch	%>	0.000	n/a	0.00	34.285	43	0.000	0.00	2.86	2.860	51.429	25.71
T Middlemarch	average	0.011	0.096	11.24	0.009	296	0.021	7.32	10.99	0.293	0.041	9.54
T Middlemarch	count	35.000	36.000	34.00	35.000	35	35.000	36.00	35.00	35.000	35.000	35.00
T Middlemarch	maximum	0.060	0.542	14.50	0.018	2800	0.083	8.08	20.90	0.680	0.200	150.00
T Middlemarch	median	0.005	0.081	11.30	0.008	120	0.016	7.30	11.29	0.300	0.034	3.70
T Middlemarch	minimum	0.003	0.052	8.40	0.003	11	0.003	6.78	1.60	0.025	0.003	0.75
T Outram	%>	0.000	n/a	0.00	17.073	43	0.000	5.88	1.82	2.430	29.268	19.51
T Outram	average	0.011	0.081	11.31	0.007	210	0.043	7.28	12.15	0.290	0.031	4.41
T Outram	count	40.000	55.000	54.00	41.000	56	41.000	51.00	55.00	41.000	41.000	41.00
T Outram	maximum	0.034	0.690	15.28	0.018	1630	0.187	8.45	20.81	0.660	0.093	26.00
T Outram	median	0.008	0.070	11.17	0.007	96	0.032	7.33	13.38	0.280	0.028	2.78
T Outram	minimum	0.005	0.043	8.60	0.003	7	0.002	6.14	2.81	0.160	0.007	0.85
T Stonehenge	%>	2.222	n/a	2.38	0.000	16	0.000	11.11	0.00	11.110	11.111	2.22
T Stonehenge	average	0.014	0.039	11.01	0.003	83	0.011	6.91	9.67	0.289	0.020	1.69
T Stonehenge	count	45.000	46.000	42.00	45.000	45	45.000	45.00	46.00	45.000	45.000	45.00
T Stonehenge	maximum	0.220	0.216	15.40	0.010	490	0.049	7.62	18.00	0.830	0.118	13.60
T Stonehenge	median	0.005	0.031	10.67	0.003	52	0.009	6.93	10.50	0.250	0.014	1.34

## Appendix 6 continued - Summary of water quality results

Table A6. 1 continued Summary of water quality results including median values and the percent of samples exceeding guideline values (%)

Parameter		NH <sub>4</sub>	Cond	DO	DRP	<i>E. coli</i>	NNN	pH	Temp	TN	TP	Turb
		mg/l	mS/cm	mg/l	mg/l	cfu/100ml	mg/l	pH	C	mg/l	mg/l	NTU
T Stonehenge	minimum	0.003	0.020	5.22	0.001	5	0.002	6.06	0.80	0.100	0.003	0.65
T Waipiata	%>	0.000	n/a	3.13	55.882	64	0.000	5.88	5.71	5.880	64.706	8.82
T Waipiata	average	0.015	0.089	10.34	0.016	494	0.018	7.14	11.75	0.363	0.051	3.82
T Waipiata	count	34.000	33.000	32.00	34.000	39	34.000	34.00	35.00	34.000	34.000	34.00
T Waipiata	maximum	0.040	0.165	15.60	0.060	10100	0.071	7.90	20.50	0.710	0.177	17.20
T Waipiata	median	0.010	0.091	10.45	0.011	230	0.012	7.19	13.90	0.355	0.043	3.02
T Waipiata	minimum	0.005	0.044	4.10	0.003	11	0.002	6.40	0.70	0.200	0.011	2.20
Teviot	%>	0.000	n/a	0.00	3.846	12	0.000	3.85	0.00	0.000	15.385	8.00
Teviot	average	0.012	0.036	11.69	0.004	61	0.032	7.00	8.88	0.270	0.023	2.97
Teviot	count	26.000	26.000	26.00	26.000	25	26.000	26.00	26.00	26.000	26.000	25.00
Teviot	maximum	0.050	0.215	14.44	0.011	410	0.231	7.60	17.50	0.460	0.052	6.70
Teviot	median	0.008	0.030	11.55	0.003	28	0.016	7.04	8.52	0.265	0.020	2.80
Teviot	minimum	0.005	0.019	8.21	0.003	7	0.003	6.20	1.90	0.100	0.008	1.60
Tokomairiro E Br	%>	0.000	n/a	0.00	7.692	74	11.538	3.85	0.00	15.380	46.154	11.54
Tokomairiro E Br	average	0.016	0.071	10.87	0.005	385	0.183	6.87	9.92	0.435	0.035	3.87
Tokomairiro E Br	count	27.000	27.000	27.00	26.000	27	26.000	26.00	27.00	26.000	26.000	26.00
Tokomairiro E Br	maximum	0.040	0.101	13.32	0.016	3600	0.677	7.29	17.40	0.900	0.082	9.10
Tokomairiro E Br	median	0.020	0.070	10.60	0.003	190	0.103	6.86	10.00	0.410	0.032	3.32
Tokomairiro E Br	minimum	0.005	0.045	8.00	0.001	32	0.011	6.40	2.50	0.170	0.009	0.91
Tokomairiro W Br	%>	0.000	n/a	0.00	13.636	64	18.182	3.85	0.00	18.180	36.364	4.55
Tokomairiro W Br	average	0.015	0.066	11.43	0.006	774	0.238	7.14	9.37	0.513	0.035	3.29
Tokomairiro W Br	count	22.000	22.000	22.00	22.000	22	22.000	22.00	22.00	22.000	22.000	22.00
Tokomairiro W Br	maximum	0.030	0.097	13.80	0.012	7800	0.966	7.71	17.60	1.100	0.121	18.00
Tokomairiro W Br	median	0.010	0.067	11.05	0.006	300	0.134	7.12	8.66	0.410	0.033	2.45
Tokomairiro W Br	minimum	0.005	0.042	9.10	0.003	24	0.010	6.60	2.10	0.250	0.003	1.40
Tuapeka River	%>	2.857	n/a	0.00	45.714	54	8.571	0.00	0.00	20.580	76.471	5.71
Tuapeka River	average	0.018	0.103	10.18	0.012	652	0.157	7.15	9.93	0.446	0.049	2.89
Tuapeka River	count	35.000	34.000	33.00	35.000	35	35.000	36.00	34.00	34.000	34.000	35.00
Tuapeka River	maximum	0.130	0.171	13.50	0.034	11000	0.643	7.83	16.00	1.000	0.107	7.10

## Appendix 6 continued - Summary of water quality results

Table A6. 1 continued Summary of water quality results including median values and the percent of samples exceeding guideline values (%)

Parameter		NH <sub>4</sub> mg/l	Cond mS/cm	DO mg/l	DRP mg/l	<i>E. coli</i> cfu/100ml	NNN mg/l	pH pH	Temp C	TN mg/l	TP mg/l	Turb NTU
Tuapeka River	median	0.010	0.099	9.70	0.009	160	0.106	7.20	10.84	0.390	0.044	2.60
Tuapeka River	minimum	0.005	0.067	7.00	0.002	34	0.011	6.60	2.80	0.070	0.015	1.10
Waianakarua River	%>	0.000	n/a	0.00	0.000	9	0.000	0.00	8.82	2.850	0.000	0.00
Waianakarua River	average	0.011	0.107	11.37	0.004	38	0.138	7.55	11.73	0.272	0.007	0.39
Waianakarua River	count	35.000	34.000	32.00	35.000	35	35.000	34.00	34.00	35.000	35.000	34.00
Waianakarua River	maximum	0.030	0.910	15.50	0.010	190	0.380	8.41	22.10	0.970	0.028	1.90
Waianakarua River	median	0.010	0.076	11.45	0.003	20	0.130	7.51	11.53	0.250	0.003	0.30
Waianakarua River	minimum	0.003	0.046	8.42	0.001	1	0.003	7.00	3.20	0.080	0.003	0.10
Waiareka Creek	%>	12.766	n/a	50.00	89.361	27	0.000	0.00	0.00	86.360	97.727	4.35
Waiareka Creek	average	0.051	1.219	6.69	0.174	151	0.077	7.53	11.71	0.866	0.243	1.67
Waiareka Creek	count	47.000	45.000	44.00	47.000	44	47.000	46.00	45.00	44.000	44.000	46.00
Waiareka Creek	maximum	0.240	2.200	14.58	1.680	1200	0.390	8.36	19.34	1.790	1.800	12.00
Waiareka Creek	median	0.037	1.267	6.50	0.086	43	0.031	7.53	12.50	0.800	0.135	1.10
Waiareka Creek	minimum	0.005	0.035	1.12	0.005	2	0.003	6.91	2.40	0.420	0.031	0.25
Waikouaiti River	%>	2.703	n/a	0.00	2.702	16	0.000	0.00	0.00	0.000	2.703	2.70
Waikouaiti River	average	0.012	0.155	9.89	0.003	265	0.056	7.48	11.33	0.212	0.012	1.38
Waikouaiti River	count	37.000	38.000	37.00	37.000	37	37.000	38.00	38.00	37.000	37.000	37.00
Waikouaiti River	maximum	0.100	0.239	13.25	0.011	4900	0.360	8.10	18.75	0.460	0.034	15.00
Waikouaiti River	median	0.009	0.149	9.80	0.003	56	0.033	7.50	12.10	0.180	0.009	0.85
Waikouaiti River	minimum	0.003	0.088	6.50	0.001	5	0.010	6.90	1.53	0.090	0.003	0.39
Waipahi CP	%>	0.000	n/a	0.00	37.037	68	81.481	3.70	0.00	96.200	40.741	22.22
Waipahi CP	average	0.016	0.118	11.24	0.008	727	0.633	6.99	8.69	0.929	0.047	5.11
Waipahi CP	count	27.000	26.000	25.00	27.000	28	27.000	27.00	26.00	27.000	27.000	27.00
Waipahi CP	maximum	0.060	0.660	12.80	0.024	4900	1.170	7.58	15.00	1.400	0.326	20.00
Waipahi CP	median	0.010	0.090	11.30	0.008	260	0.569	7.00	8.87	0.870	0.029	3.90
Waipahi CP	minimum	0.005	0.079	9.73	0.003	10	0.361	6.20	2.40	0.440	0.012	2.40
Waipahi Waipahi	%>	0.000	n/a	0.00	39.534	65	69.767	0.00	0.00	72.090	41.860	20.93
Waipahi Waipahi	average	0.019	0.172	11.25	0.009	675	0.917	7.68	10.99	1.259	0.035	3.74
Waipahi Waipahi	count	43.000	43.000	40.00	43.000	43	43.000	44.00	43.00	43.000	43.000	43.00

## Appendix 6 continued - Summary of water quality results

Table A6. 1 continued Summary of water quality results including median values and the percent of samples exceeding guideline values (%)

Parameter		NH <sub>4</sub>	Cond	DO	DRP	<i>E. coli</i>	NNN	pH	Temp	TN	TP	Turb
		mg/l	mS/cm	mg/l	mg/l	cfu/100ml	mg/l	pH	C	mg/l	mg/l	NTU
Waipahi Waipahi	maximum	0.070	1.250	13.80	0.028	10800	2.220	9.69	19.30	2.800	0.104	15.00
Waipahi Waipahi	median	0.020	0.123	11.34	0.007	150	0.920	7.49	10.60	1.370	0.031	2.90
Waipahi Waipahi	minimum	0.005	0.079	7.40	0.003	19	0.002	6.50	3.70	0.170	0.003	0.19
Waipori River	%>	3.226	n/a	0.00	18.750	31	3.125	5.88	0.00	9.370	18.750	15.63
Waipori River	average	0.024	0.059	10.78	0.006	187	0.087	7.06	10.59	0.345	0.027	3.65
Waipori River	count	31.000	34.000	33.00	32.000	32	32.000	34.00	34.00	32.000	32.000	32.00
Waipori River	maximum	0.180	0.197	13.39	0.027	1500	0.530	8.20	19.98	1.250	0.118	17.00
Waipori River	median	0.020	0.043	11.08	0.003	45	0.063	6.96	10.53	0.260	0.019	2.90
Waipori River	minimum	0.005	0.025	8.31	0.003	1	0.003	6.32	3.60	0.180	0.003	1.30
Wairuna Stream	%>	28.571	n/a	0.00	91.428	93	80.000	2.86	0.00	100.000	#####	100.00
Wairuna Stream	average	0.067	0.171	11.19	0.032	859	0.991	7.31	10.77	1.649	0.121	10.32
Wairuna Stream	count	35.000	29.000	27.00	35.000	30	35.000	35.00	33.00	29.000	29.000	32.00
Wairuna Stream	maximum	0.170	0.240	14.94	0.137	3000	2.840	9.23	18.90	3.710	0.270	15.00
Wairuna Stream	median	0.050	0.168	11.36	0.023	680	0.972	7.30	11.50	1.650	0.118	9.69
Wairuna Stream	minimum	0.005	0.110	8.62	0.007	66	0.029	6.30	2.90	0.860	0.050	6.20
Waitahuna	%>	0.000	n/a	0.00	17.647	65	11.765	0.00	0.00	24.240	24.242	11.76
Waitahuna	average	0.015	0.098	11.16	0.006	340	0.163	7.18	10.52	0.417	0.030	3.38
Waitahuna	count	34.000	32.000	32.00	34.000	34	34.000	34.00	33.00	33.000	33.000	34.00
Waitahuna	maximum	0.060	0.850	14.10	0.025	4000	0.920	7.85	18.50	1.460	0.071	7.61
Waitahuna	median	0.011	0.071	11.07	0.005	210	0.077	7.20	10.60	0.320	0.028	3.05
Waitahuna	minimum	0.005	0.053	7.00	0.001	22	0.006	6.60	1.60	0.060	0.003	1.20
Waitati River	%>	2.778	n/a	0.00	8.333	44	5.556	2.78	0.00	8.3300	8.333	8.33
Waitati River	average	0.022	0.204	13.71	0.005	383	0.100	8.06	9.34	0.3086	0.018	4.80
Waitati River	count	36.000	35.000	35.00	36.000	36	36.000	36.00	36.00	36.0000	36.000	36.00
Waitati River	maximum	0.350	0.760	94.10	0.016	6400	0.590	9.22	16.00	0.9700	0.149	71.00
Waitati River	median	0.008	0.179	11.10	0.003	115	0.032	8.00	9.15	0.225	0.013	1.90
Waitati River	minimum	0.005	0.113	9.00	0.001	2	0.003	6.40	0.89	0.1200	0.003	0.70
Waiwera River	%>	2.941	n/a	0.00	68.750	83	73.529	0.00	0.00	77.410	69.697	15.15
Waiwera River	average	0.025	0.130	11.37	0.018	747	0.791	7.45	9.22	1.148	0.049	4.59

## Appendix 6 continued - Summary of water quality results

Table A6. 1 continued Summary of water quality results including median values and the percent of samples exceeding guideline values (%)

Parameter		NH <sub>4</sub> mg/l	Cond mS/cm	DO mg/l	DRP mg/l	<i>E. coli</i> cfu/100ml	NNN mg/l	pH pH	Temp C	TN mg/l	TP mg/l	Turb NTU
Waiwera River	count	34.000	33.000	32.00	32.000	35	34.000	33.00	34.00	31.000	33.000	33.00
Waiwera River	maximum	0.150	0.239	13.80	0.083	7000	1.680	8.60	18.10	1.860	0.160	20.00
Waiwera River	median	0.020	0.124	11.20	0.015	300	0.764	7.44	9.30	1.230	0.042	3.70
Waiwera River	minimum	0.005	0.093	8.50	0.003	28	0.065	6.70	2.70	0.470	0.013	1.20
Washpool Stream	%>	50.000	n/a	4.35	#####	83	75.000	0.00	4.35	100.000	#####	95.00
Washpool Stream	average	0.150	0.230	10.94	0.083	1696	0.935	7.50	10.83	2.400	0.313	15.38
Washpool Stream	count	24.000	22.000	23.00	17.000	24	24.000	19.00	23.00	15.000	22.000	20.00
Washpool Stream	maximum	0.960	0.374	14.80	0.269	8400	2.520	8.54	23.30	4.030	0.645	38.00
Washpool Stream	median	0.090	0.221	10.90	0.056	780	0.734	7.40	9.30	2.330	0.255	14.50
Washpool Stream	minimum	0.020	0.138	5.40	0.011	48	0.077	6.88	2.20	0.790	0.114	2.60
Water Of Leith	%>	5.556	n/a	0.00	58.333	83	27.778	0.00	0.00	52.777	50.000	22.22
Water Of Leith	average	0.029	0.146	11.86	0.015	1181	0.375	8.05	10.08	0.691	0.047	4.17
Water Of Leith	count	36.000	37.000	36.00	36.000	36	36.000	38.00	38.00	36.000	36.000	36.00
Water Of Leith	maximum	0.320	0.644	15.81	0.066	10500	1.000	8.92	17.90	1.500	0.240	21.00
Water Of Leith	median	0.020	0.140	11.78	0.013	445	0.299	8.00	10.03	0.635	0.033	2.90
Water Of Leith	minimum	0.003	0.026	8.84	0.003	82	0.063	7.17	3.30	0.280	0.007	1.10
Welcome Lower	%>	0.000	n/a	0.00	77.500	35	97.500	2.63	0.00	97.500	35.000	0.00
Welcome Lower	average	0.014	0.118	10.70	0.020	203	1.256	6.93	11.13	1.459	0.030	1.38
Welcome Lower	count	40.000	37.000	36.00	40.000	40	40.000	38.00	37.00	40.000	40.000	39.00
Welcome Lower	maximum	0.040	0.278	13.81	0.071	1800	2.310	7.60	15.64	2.590	0.083	5.00
Welcome Lower	median	0.010	0.112	10.57	0.018	87	1.275	6.95	10.50	1.535	0.028	1.03
Welcome Lower	minimum	0.003	0.056	7.20	0.003	4	0.174	6.30	7.00	0.210	0.003	0.35
Welcome Upper	%>	0.000	n/a	13.16	92.682	12	100.000	17.50	0.00	97.500	46.341	0.00
Welcome Upper	average	0.013	0.120	9.41	0.025	57	1.559	6.78	11.71	1.755	0.032	0.62
Welcome Upper	count	41.000	40.000	38.00	41.000	41	41.000	40.00	40.00	41.000	41.000	40.00
Welcome Upper	maximum	0.060	0.257	17.20	0.043	820	2.400	7.91	16.20	2.900	0.062	2.10
Welcome Upper	median	0.010	0.110	9.45	0.029	13	1.680	6.70	11.19	1.790	0.033	0.55
Welcome Upper	minimum	0.003	0.056	4.10	0.007	1	0.604	6.20	7.20	0.100	0.009	0.20

## Appendix 7 – Biological indices scores

**Table A7.1 Average scores for biological indices at SoE sampling sites**

Site	REC	EPT		EPT%		No Taxa		MCI		SQMCI		Rank
Catlins @ Chloris	CW/L/SS/P	14.00	G	60.80	G	23.00	G	115.50	G	7.36	VG	1
Akatore Stream	CD/L/HS/EF	11.50	G	54.21	M	22.00	G	125.9	VG	5.95	G	2
T. @ Stonehenge	CD/H/HS/T	10.50	G	65.00	VG	16.41	M	120.9	VG	6.34	VG	3
Waianakarua	CD/L/SS/P	9.00	M	59.82	G	15.00	M	126.50	VG	5.50	G	4
Catlins @ Houipapa	CW/L/SS/P	12.60	G	60.91	G	20.80	G	114.27	G	6.12	VG	5
Lindis River u/s	CD/L/AI/P	10.00	G	61.98	G	16.33	M	119.00	G	6.32	VG	6
Luggate Creek	CW/M/HS/T	12.00	G	66.67	VG	18.00	M	106.67	G	6.17	VG	7
Manu. @ Blkst	CD/H/HS/T	9.50	M	65.28	VG	15.00	M	110.00	G	5.99	G	8
Pomahaka @ GK	CD/L/HS/P	10.10	G	56.08	G	18.00	M	113.00	G	6.00	VG	9
Silverstm @ 3MH	CD/L/HS/IF	12.67	G	49.06	M	25.33	VG	109.33	G	5.40	G	10
Kaihiku @ Hillfoot	CD/L/SS/P	9.25	M	56.81	G	16.25	M	112.00	G	6.69	VG	11
Sutton Stm	CD/H/HS/P	11.00	G	49.00	M	22.50	G	113.00	G	5.45	G	12
Manuh @ Omakau	CD/H/HS/P	9.00	M	56.25	G	16.00	M	113.00	G	6.66	VG	13
Fraser River	CD/M/HS/P	10.67	G	54.33	M	19.67	G	109.31	G	6.13	VG	14
Cardrona @ Waiorau	CD/H/HS/T	7.00	M	63.64	G	11.00	P	112.00	G	6.22	VG	15
Waiwera @ T Rd	CD/L/HS/P	9.00	M	56.25	G	16.00	M	111.00	G	6.86	VG	16
Waipahi @ Kaiwera	CD/H/HS/P	11.50	G	53.40	M	21.50	G	102.00	G	6.19	VG	17
Tuapeka @ SH8	CD/L/HS/P	10.00	G	52.63	M	19.00	M	106.00	G	6.80	VG	18
T. @ Outram	CD/H/HS/P	9.33	M	65.00	VG	14.80	M	97.50	F	5.12	G	19
Toko. @ Mt Stuart	CD/L/HS/P	11.25	G	51.00	M	22.12	G	102.03	G	5.34	G	20
Waipori @ Reserve	CD/Lk/HS/P	10.00	G	52.63	M	19.00	M	104.00	G	4.62	F	21
Kauru River	CD/H/HS/P	12.00	G	40.00	M	20.00	G	112.00	G	6.18	VG	22
Cardrona @ Larches	CD/H/HS/T	8.40	M	53.37	M	15.80	M	104.80	G	6.15	VG	23
Heriotb @ PHK Rd	CD/H/HS/P	9.25	M	54.22	M	17.75	M	101.00	G	5.70	G	24
Owaka @ Hunt Rd	CW/L/SS/P	9.00	M	56.25	G	16.00	M	102.00	G	4.25	F	25
Horne Ck @	CD/H/HS/T	8.50	M	45.52	M	19.00	M	109.00	G	5.38	G	26
Waiwera @ SH1	CD/L/SS/P	8.50	M	50.00	M	17.00	M	107.00	G	4.78	F	27
T. @ Middlemarch	CD/H/HS/P	7.75	M	53.05	M	15.75	M	102.50	G	6.09	VG	28
T. us Outram	CD/H/HS/P	9.00	M	53.00	M	17.00	M	100.33	G	4.83	F	29
Kyeburn @ SH85	CD/H/HS/P	9.00	M	45.63	M	19.50	G	103.00	G	6.33	VG	30
Tuapeka @ Mouth	CD/L/HS/P	8.67	M	48.44	M	17.67	M	102.67	G	5.07	G	31
Clutha @ F Hogan	CD/L/HS/P	5.00	M	62.50	G	8.00	VP	102.50	G	4.33	F	32
Heriotb. @ SH90	CD/L/HS/P	8.25	M	50.37	M	16.50	M	100.25	G	5.57	G	33
Kakanui @ Clifton	CD/H/SS/P	10.50	G	47.12	M	22.25	G	96.00	F	4.99	F	34
Manu. @ Shaky Br	CD/H/HS/P	6.25	M	55.38	G	11.25	P	101.50	G	5.89	G	35
T. @ Waipiata	CD/H/HS/P	7.67	M	50.32	M	15.33	M	100.33	G	6.05	VG	36
Waik. @ McGrath	CD/L/SS/P	8.00	M	50.00	M	16.00	M	101.00	G	4.00	F	37
Shag @ Grange	CD/H/HS/P	9.25	M	44.79	M	21.25	G	98.25	F	4.46	F	38
Waipahi @ C Pk	CD/H/HS/P	8.00	M	46.94	M	17.00	M	99.78	F	4.52	F	39
Crookstb. @ SH90	CD/L/AI/P	6.00	M	40.00	M	15.00	M	108.00	G	7.21	VG	40
Mill Ck @ Fish Trap	CD/H/HS/P	7.00	M	48.70	M	14.20	P	98.81	F	6.17	VG	41
Mill Ck @ Hunter	CD/H/HS/P	4.00	P	66.67	VG	6.00	VP	90.00	F	7.80	VG	42
Crookstb @ Kelso	CD/L/AI/P	6.00	M	45.83	M	13.33	P	102.00	G	4.87	F	43
Lindis @ Ardgour	CD/H/HS/T	6.00	M	40.00	M	15.00	M	104.00	G	5.61	G	44
Owaka @ SH92	CW/L/SS/P	5.00	M	35.71	P	14.00	P	112.00	G	3.77	P	45
Toko. @ Blackbridge	CD/L/HS/P	8.00	M	47.00	M	17.00	M	94.00	F	4.24	F	46
Waipahi @ Waipahi	CD/Lk/HS/P	8.80	M	43.49	M	20.20	G	91.02	F	4.92	F	47

## Appendix 7 continued – Biological indices scores

**Table A7.2 Average scores for biological indices at SoE sampling sites**

Site	REC	EPT		EPT%		No Taxa		MCI		SQMCI		Rank
Shag @ Palmerston	CD/L/AI/P	7.75	M	44.93	M	17.25	M	92.75	F	4.85	F	48
Waikou @ Bucklands	CW/L/SS/P	7.00	M	46.67	M	15.00	M	92.00	F	5.94	G	49
Waiwera @ Gg Rd	CD/L/SS/P	7.50	M	44.17	M	16.50	M	92.50	F	4.53	F	50
Water of Leith	CW/L/VB/U	7.75	M	42.08	M	18.25	M	92.75	F	3.36	P	51
Pomahaka @ BF	CD/H/HS/P	8.00	M	41.04	M	19.50	G	91.00	F	4.08	F	52
Toko @ Coal Gully	CD/L/HS/P	8.67	M	43.00	M	20.00	G	87.00	F	4.29	F	53
Shotover @ SH6	CW/M/HS/T	5.00	M	62.50	G	8.00	VP	77.00	P	7.70	VG	54
Lindsays Ck	CD/L/VB/U	6.00	M	42.86	M	14.00	P	88.57	F	3.23	P	55
T. @ Allanton	CD/H/HS/P	6.25	M	41.96	M	14.75	M	86.58	F	3.70	P	56
Wairuna @ Siding	CD/L/HS/P	6.00	M	31.58	P	19.00	M	91.00	F	5.39	G	57
Kakanui @ Pringles	CD/H/HS/P	7.25	M	37.50	P	17.75	M	84.65	F	4.74	F	58
Wairuna @ W-C Rd	CW/L/SS/P	6.25	M	36.42	P	17.75	M	86.75	F	3.71	P	59
Waikoua @ Orbells	CD/H/HS/P	5.00	M	35.09	P	14.00	P	87.00	F	4.31	F	60
Lindsays Ck u/s WoL	CD/L/VB/U	5.50	M	33.81	P	15.25	M	81.92	F	2.95	P	61
Toko. ds Milton	CD/L/HS/P	2.00	P	13.33	VP	15.00	M	102.66	G	3.96	P	62
Silverstm @ Ric. Rd	CD/L/HS/P	4.67	P	30.00	P	14.00	P	84.67	F	3.45	P	63
Clutha @ Finegand	CD/L/HS/P	5.00	M	38.46	P	13.00	P	72.30	P	4.30	F	64
Hayes Ck @ SH6	CD/Lk/HS/P	4.50	P	32.05	P	14.00	P	72.00	P	3.42	P	65
T @ Creamery Rd	CD/Lk/HS/P	11.00	G	18.00	VP	20.00	G	67.00	P	6.40	VG	66
Waipori @ Sh1	CD/H/HS/P	2.00	P	22.22	P	9.00	VP	84.00	F	4.92	F	67
Kaihiku @ Clifton	CD/L/SS/P	3.25	P	23.32	P	14.00	P	74.50	P	3.92	P	68
Toko. @ Table Hill	CD/L/HS/P	3.00	P	21.00	P	13.00	P	77.50	P	4.20	F	69
T. @ Ferry Br	CD/Lk/HS/P	1.50	P	12.70	VP	11.50	P	75.50	P	4.81	F	70
Clutha @ Kaitangata	CD/L/HS/P	2.00	P	14.29	VP	14.00	P	70.00	P	3.52	P	71
Waiareka @ Tesch.	CD/L/SS/P	1.50	P	10.82	VP	14.50	M	70.50	P	3.91	P	72
Horne Ck u/s Lake	CD/H/HS/T	2.00	P	23.81	P	8.00	VP	64.50	P	2.57	P	73
T. @ Henley	CD/H/HS/P	1.50	P	18.00	VP	9.00	VP	67.00	P	3.94	P	74
Kaikorai @ Brighton	CD/L/SS/U	3.00	P	18.75	VP	16.00	M	59.43	P	1.45	P	75
Owhiro @ Burns St	CD/L/AI/U	0.50	P	2.50	VP	15.00	M	67.00	P	3.13	P	76
Kaikorai @ Townleys	CD/L/VB/U	1.00	P	8.33	VP	9.67	P	63.33	P	2.20	P	77
Kaikorai @ Brckv	CD/L/SS/U	0.50	P	5.56	VP	7.75	VP	59.43	P	1.80	P	78

Abbreviations: VG =Very Good, G = Good, M = Moderate, P = Poor, VP =Very Poor

## Appendix 8 – Periphyton communities

**Table A8.1 Trophic designations of some taxa (dominant or abundant) found in Otago’s periphyton communities**

Taxon	Trophic Designations	2001	2002	2003	2004	2006
<b>Filamentous Green Algae</b>						
<i>Rhizoclonium</i>	<i>Eutrophic</i>					Waipahi @ Conical Hill
<i>Microspora</i>	<i>Mesotrophic (3)</i>			Waipahi @ Cairns Peak	Mill Creek @ Fishtrap	Cardrona @ Larches
	<i>Mesotrophic-Eutrophic (2)</i>					
<i>Nitzschia spp.</i>	<i>Mesotrophic-Eutrophic (1)</i>				Kakanui @ Pringles	
<i>Spirogyra</i>	<i>Mesotrophic (2)</i>	Waikouaiti @ Bucklands	Kakanui @ Pringles	Horne Creek @ Mill Rd		Kauru River
		Horne Creek @ Gorge Road		Kye Burn @ SH85		
		Cardrona @ Mt Barker		Lindis @ Lindis Peak		
				Mill Creek @ Fishtrap		
				Waikouaiti @ McGrath Rd		
<i>Stigeoclonium</i>	<i>Mesotrophic (2)</i>		Heriot Burn @ SH90	Catlins @ Houipapa	Kakanui @ Pringles	Lindis @ Ardgour
					Manuherikia @ Shaky Bridge	
					Silver Stream @ Riccarton Rd	
<i>Cladophera</i>	<i>Mesotrophic (3)</i>	Manuherikia @ Shaky Br			Owhiro @ Burns St	
		Shag @ Goodwood			Shag @ Grange	
Mougeotia sp.	<i>Mesotrophic (3)</i>			Manuherikia @ Blackstone Hill	Silverstream @ 3MH Rd	
					Kakanui @ Clifton	
					Shag @ Goodwood	
<b>Filamentous Green Algae</b>						

## Appendix 8 continued – Periphyton communities

Table A8. 1 continued Trophic designations of some taxa (dominant or abundant) found in Otago’s periphyton communities

Taxon	Trophic Designations	2001	2002	2003	2004	2006
Stigeoclonium	<i>Mesotrophic</i> (2)		Heriot Burn @ SH90	Catlins @ Houipapa	Manuherikia @ Shaky Bridge	
					Silverstream @ Riccarton	
					Taieri @ Outram	
					Kakanui @ Pringles	
Oedogonium spp.	<i>Mesotrophic</i> (3)		Tuapeka @ Tuapeka Mouth	Waipahi @ Cairns Peak	Silverstream @ 3MH Rd	
	<i>Oligotrophic-Mesotrophic</i> (2)			Wairuna @ Waipahi-Clyde Rd	Taieri @ Allanton	
				Pomahaka @ Burkes Ford	Owhiro @ Burns St	
				Owhiro @ Burns St	Waipori @ Reserve	
				Taieri @ Henley Ferry	Manuherikia @ Blackstone	
<i>Ulothrix</i>	<i>Oligotrophic-Mesotrophic</i> (2)		Crookston Burn @ Kelso		Taieri @ Middlemarch	
<i>Bulbochaetae</i> sp.	<i>Oligotrophic</i> (2)				Kakanui @ Clifton	
	<i>Oligotrophic-Mesotrophic</i> (2)					
<b>Filamentous Red Algae</b>						
<i>Audouinella</i>	<i>Oligotrophic</i> (3)		Heriot Burn @ Parkhill K Rd	Fraser River @ Marshall Rd	Fraser River @ Marshall Rd	
	<i>Oligotrophic-Mesotrophic</i> (2)		Tokomairiro @ Blackbridge	Heriot Burn @ Parkhill K Rd	Lindis @ Lindis Peak	
	<i>Mesotrophic</i> (1)		Tokomairiro @ Coal Gully Rd	Pomahaka @ Glenken	Manuherikia @ Shaky Bridge	
			Wairuna @ Wairuna Siding Rd	Tokomairiro @ Mt Stuart	Waiakarua @ SH1	
			Waiwera @ SH1	Tuapeka @ Mouth	Waipori @ Falls Reserve	

## Appendix 8 continued – Periphyton communities

Table A8. 1 continued Trophic designations of some taxa (dominant or abundant) found in Otago's periphyton communities

Taxon	Trophic Designations	2001	2002	2003	2004	2006
				Waiwera @ SH1		
<b>Diatoms</b>						
<i>Gomphonema parvulum</i>	<i>Eutrophic (3)</i>	Wairuna @ Clydevale-Waipahi Rd	Catlins @ Chloris	Owhiro @ Burns St	Owhiro @ Burns St	
		Owaka @ SH92				
		Crookston Burn @ Sh90				
		Heriot Burn @ SH90				
		Cardrona @ Waiarou Rd Br				
<i>Melosira varians</i>	<i>Mesotrophic-Eutrophic (2)</i>	Water of Leith	Taieri @ Allanton	Tokomairiro @ Coal Gully	Fraser River @ Marshall Rd	
		Lindsay's Creek	Taieri @ Outram	Fraser River @ Marshall Rd	Tokomairiro @ Coal Gully	
		Kaikorai @ Brighton Rd	Crookston Burn @ Kelso	Horne Creek @ Gorge		
		Pomahaka @ Burkes Ford	Pomahaka @ Burkes Ford	Lindis @ Lindis Peak		
		Tuapeka @ Mouth	Tokomairiro E @ Table Hill	Wairuna @ Wairuna Clyde Rd		
		Glenomarau @ Romahapa		Pomahaka @ Burkes Ford		
		Owaka @ Purikireka				
		Waiwera @ Conical Hill				
		Horne Creek @ Gardens				
<i>Cymbella</i>	<i>Oligotrophic-Mesotrophic (2)</i>	Hayes Creek @ SH6	Kakanui @ Pringles	Waipahi @ Clement Rd	Kakanui @ Pringles	
	<i>Mesotrophic (2)</i>	Waikouaiti @ McGrath Rd	Shag @ Grange			
		Silver Stream @ Riccarton Rd	Shag @ Goodwood			
<i>Frustulia</i>	<i>Oligotrophic (2)</i>	Waipori d/s Contour Channel				

## Appendix 8 continued – Periphyton communities

Table A8. 1 continued Trophic designations of some taxa (dominant or abundant) found in Otago's periphyton communities

Taxon	Trophic Designations	2001	2002	2003	2004	2006
		Shag @ Grange				
		Waiwera @ Conical Hill				
<b>Diatoms</b>						
<i>Gomphoneis</i>	<i>Oligotrophic-Mesotrophic (2)</i>	Horne Creek @ Botanical Gdns	Cardrona @ Larches	Catlins @ Houipapa	Shag @ Goodwood	Fraser River @ Marshall Rd
	<i>Mesotrophic (1)</i>	Water of Leith @ Dundas St	Kakanui @ Clifton	Kye Burn @ SH85	Shag @ Grange	Kaikorai @ Townleys Rd
		Lindsay's Creek u/s Leith	Kakanui @ Pringles	Lindis @ Lindis Peak	Taieri @ Middlemarch	
		Shag @ Goodwood	Manuherikia @ Shaky Bridge	Pomahaka @ Burkes Ford	Taieri @ Outram	
		Waipahi @ Waipahi	Mill Creek @ Fishtrap	Waipahi @ Clement Rd		
		Pomahaka @ Glenken	Pomahaka @ Burkes Ford	Waiwera @ Conical Hill		
		Pomahaka @ Burkes Ford	Shag @ Goodwood			
		Waikouaiti @ McGrath Rd	Shag @ Grange			
		Kakanui @ Pringles	Taieri @ Creamery Rd			
		Tuapeka @ Mouth	Taieri @ Middlemarch			
		Glenomaru @ Romahapa	Taieri @ Outram			
		Glenomaru @ Valley Rd	Taieri d/s Outram			
		Owaka @ Purikeka	Waipahi @ Conical Hill			
		Owaka @ SH92				
		Catlins @ Chloris				
		Catlins @ Houipapa				
		Heriot Burn @ Parkhill K Rd				

## Appendix 8 continued – Periphyton communities

Table A8. 1 continued      Trophic designations of some taxa (dominant or abundant) found in Otago's periphyton communities

Taxon	Trophic Designations	2001	2002	2003	2004	2006
		Manuherikia @ Dan O'Connell				
		Manuherikia @ Shaky Bridge				
<b>Diatoms</b>						
Naviculoid diatom	<i>Oligotrophic-Mesotrophic (2)</i>	Water of Leith @ Dundas St	Catlins @ Houipapa	Mill Creek @ Fishtrap		Catlins @ Houipapa
		Lindsay's Creek u/s Leith	Heriot Burn @ Parkhill K Rd			
		Kaikorai @ Brockville	Tokomairiro @ Blackbridge			
		Kaikorai @ Townleys Rd	Wairuna @ Wairuna Siding Rd			
		Waipori d/s Contour Channel	Waiwera @ SH1			
		Wairuna @ Siding Rd				
		Glenomaru @ Valley Rd				
		Waiwera @ Conical Hill				
<b>Cyanobacteria</b>						
Phormidium sp.	<i>Mesotrophic (2)</i>	Catlins @ Chloris	Kakanui @ Clifton	Waipori @ Falls Reserve		
			Taieri @ Allanton	Tokomairiro @ Mt Stuart		
			Heriot Burn @ SH90	Akatore Creek @ Taieri Rd		
				Kakanui @ Pringles		

## Appendix 9 – Statistical methods for temporal trend analysis

### Seasonal Kendall trend test

Trend analysis over time using ordinary linear regression is not usually appropriate for water quality data because the required assumption of normally distributed residuals is often violated (Smith and Maasdam, 1994). Also, it fails to account for seasonal components of variability, so that statistical power to detect trends can be greatly diminished. The Seasonal Kendall test (Hirsch and others, 1982) is a non-parametric test for trend in water quality. The test, which is a generalisation of the Mann-Kendall test (Mann, 1945; Kendall, 1975), reduces the adverse effect that seasonal differences in concentration may have on trend detection by only making comparisons of data from similar seasons.

Consequently, the non-parametric Seasonal Kendall was used to determine trend slopes. The magnitude of the trend is determined by the Seasonal Kendall slope estimator (SKSE), the greater the slope (either positive or negative), the greater the trend.

### Flow adjustment

Flow adjustment removes the effect of river or stream flow on water quality constituents prior to statistical analysis. Flow adjustment was performed for 8 sites (Shotover, Kawarau, Taieri at Outram and Tiroiti, Sutton Stream, Clutha at Balclutha, Millers Flat and Luggate) using WQSTAT PLUS. The following log-log relationship between water quality and flow is assumed:

$$\text{Log Concentration} = b(\log \text{ flow}) + a$$

WQSTAT plus uses linear regression to estimate the slope and intercept of the line above, then with each water quality observation (log concentration), the corresponding prediction based on flow,  $b(\log \text{ flow}) + a$  is subtracted, producing a series of residuals with a mean of zero. To each residual, the mean of the original log concentrations series is added, producing series of residuals with a mean of zero. To each residual the mean of the original log concentration series is added, producing a flow adjusted series of log concentrations which has the same mean as the original. Next, the antilogs of the log concentrations are found, and a final correction is made so that the resulting series in original concentration units will have the same mean as the original series of observations (Milne et al, 2006).

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9.1 Trend analysis - starting date from January 1995, end point June 2006**

Site	Variable	Slope	z	n	p	
Cardona River	Ammoniacal Nitrogen	0	1.811	63	<0.1	
at Mt Barker	Conductivity	-0.0004561	0.5293	62	NS	
	Dissolved Oxygen	0.02157	0.3522	64	NS	
	Dissolved Reactive Phosphorus	0.0002829	4.112	63	<0.05	
	Escherichia coli	0	0.1306	30	NS	
	Nitrite/Nitrate Nitrogen	-0.003997	-2.8	62	<0.05	
	pH	-0.005843	-0.7648	49	NS	
	Suspended Solids	-0.3331	-2.191	63	<0.05	
	Temperature	0.005381	0.1243	64	NS	
	Total Nitrogen	-0.006315	1.875	56	<0.1	
	Total Phosphorus	0	0.2666	63	NS	
	Turbidity	-0.1097	-1.865	62	<0.1	
	Site	Variable	Slope	z	n	p
Careys Creek	Ammoniacal Nitrogen	0	1.166	51	NS	
at SH1	Conductivity	0.003467	1.041	50	NS	
	Dissolved Oxygen	-0.1461	1.867	51	<0.1	
	Dissolved Reactive Phosphorus	0.0004946	3.677	51	<0.05	
	Escherichia coli	0	0	25	NS	
	Nitrite/Nitrate Nitrogen	0.001065	0.5644	51	NS	
	pH	-0.01786	-1.726	44	<0.1	
	Suspended Solids	0	-1.832	50	<0.1	
	Temperature	0.0319	0.184	52	NS	
	Total Nitrogen	0.009844	1.281	50	NS	
	Total Phosphorus	0	0.09641	51	NS	
	Turbidity	-0.1191	-1.631	50	<0.2	
	Site	Variable	Slope	z	n	p
Catlins	Ammoniacal Nitrogen	-0.0004387	2.116	66	<0.05	
at Houipapa	Conductivity	-0.0009658	0.9328	60	NS	
	Dissolved Oxygen	-0.08859	0	62	NS	
	Dissolved Reactive Phosphorus	0.0012	2.806	66	<0.05	
	Escherichia coli	2	1.558	34	<0.2	
	Nitrite/Nitrate Nitrogen	0.012	2.732	66	<0.05	
	pH	-0.005577	-0.761	52	NS	
	Suspended Solids	0	-0.4901	63	NS	
	Temperature	-0.1649	-1.618	65	<0.2	
	Total Nitrogen	0.01371	2.397	63	<0.05	
	Total Phosphorus	0.0008326	0.8771	66	NS	
	Turbidity	-0.0238	-0.2159	64	NS	

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued Trend analysis - starting date from January 1995, end point June 2006**

Site	Variable	Slope	z	n	p
Clutha	Ammoniacal nitrogen	-0.0002482	2.036	62	<0.05
at Balclutha	Conductivity	0.0003322	-1.55	58	<0.2
	Dissolved oxygen	0.2154	0	64	NS
	Dissolved reactive phosphorus	0.0000511	2.028	63	<0.05
	Escherichia coli	2.152	1.048	27	NS
	Nitrite/nitrate nitrogen	0.0008611	0.6872	64	NS
	pH	0	0.3375	62	NS
	Suspended solids	-0.16666	-1.293	64	<0.2
	Temperature	-0.07369	-0.9398	65	NS
	Total nitrogen	0.001998	0.5113	55	NS
	Total phosphorus	-0.0002227	-0.7553	63	NS
	Turbidity	-0.01444	-0.2173	63	NS
Site	Variable	Slope	z	n	p
Contour Channel	Ammoniacal nitrogen	0.003323	0.5252	41	NS
	Conductivity	-0.001038	-0.6005	41	NS
	Dissolved oxygen	-0.002661	0	40	NS
	Dissolved reactive phosphorus	0.001084	0.8881	41	NS
	Escherichia coli	54.75	2.003	41	<0.05
	Nitrite/nitrate nitrogen	-0.04192	-2.279	39	<0.05
	pH	0.003324	0.2949	31	NS
	Suspended solids	0.4771	1.131	35	NS
	Temperature	-0.2483	-0.7211	41	NS
	Total nitrogen	-0.01806	-0.5226	41	NS
	Total phosphorus	0.006145	1.563	41	<0.2
	Turbidity	0.2127	1.042	41	NS
Site	Variable	Slope	z	n	p
Crookston Burn	Ammoniacal nitrogen	-0.001676151	1.514	58	<0.2
at Kelso	Conductivity	0.002277	1.78	55	<0.1
	Dissolved oxygen	-0.03137	0.7332	57	NS
	Dissolved reactive phosphorus	0.0003937	0.9983	57	NS
	Escherichia coli	0.3155	0.2277	21	NS
	Nitrite/nitrate nitrogen	0.07035	1.963	57	<0.05
	pH	-0.015479	0.5831	52	NS
	Suspended solids	-0.1665	-0.4735	50	NS
	Temperature	-0.07663	-0.4255	59	NS
	Total nitrogen	0.09464	2.168	53	<0.05
	Total phosphorus	0	0.105	57	NS
	Turbidity	-0.3712	-2.85	55	<0.05

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued Trend analysis - starting date from January 1995, end point June 2006**

Site	Variable	Slope	z	n	p
Dunstan Creek	Ammoniacal nitrogen	0	-0.1705	28	NS
at Beatties Rd	Conductivity	0.00003103	0	26	NS
	Dissolved oxygen	-0.01702	-0.1709	25	NS
	Dissolved reactive phosphorus	0.001489	3.055	28	<0.05
	Escherichia coli	3.044	0.4693	26	NS
	Nitrite/nitrate nitrogen	0	0	24	NS
	pH	-0.03473	-0.7764	27	NS
	Suspended solids	0	0.07063	29	NS
	Temperature	0.3142	0.693	27	NS
	Total nitrogen	0	0.07809	27	NS
	Total phosphorus	0.00211	1.812	28	<0.1
	Turbidity	-0.04389	-0.969729	29	NS
Site	Variable	Slope	z	n	p
Fraser River	Ammoniacal nitrogen	0	0.2665	30	NS
at Marshall Road	Conductivity	-0.007843	1.582	30	<0.2
	Dissolved oxygen	0.1418	1.241	30	NS
	Dissolved reactive phosphorus	0.0003997	2.941	30	<0.05
	Escherichia coli	Insufficient seasonal data for analysis			
	Nitrite/nitrate nitrogen	-0.007011	1.175	30	NS
	pH	-0.02165	1.084	27	NS
	Suspended solids	0	0	30	NS
	Temperature	0.1439	0.2064	30	NS
	Total Nitrogen	-0.005001	-1.767	29	<0.1
	Total Phosphorus	0.0005001	1.343	30	<0.1
	Turbidity	-0.02996	-0.7664	30	NS
Site	Variable	Slope	z	n	p
Frasers Creek	Ammoniacal Nitrogen	-0.0002227	0.991	61	NS
	Conductivity	0.0005512	1.107	53	NS
	Dissolved Oxygen	-0.1199	1.931	60	<0.1
	Dissolved Reactive Phosphorus	0.0002482	2.832	61	<0.05
	Escherichia coli	Insufficient data for analysis			
	Nitrite/Nitrate Nitrogen	0	-0.02284	61	NS
	pH	0	-0.07971	55	NS
	Suspended Solids	-0.08216	-1.398	61	<0.2
	Temperature	-0.2209	-1.506	60	<0.2
	Total Nitrogen	0.007745	0.9884	53	NS
	Total Phosphorus	-0.000157	-0.3203	61	NS
	Turbidity	0.05106	1.111	60	NS

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued Trend analysis - starting date from January 1995, end point June 2006**

Site	Variable	Slope	z	n	p	
Gimmer Burn	Ammoniacal Nitrogen	0	0	34	NS	
at Wilson Road	Conductivity	0.0008833	0.3636	32	NS	
	Dissolved Oxygen	-0.1524	1.044	33	NS	
	Dissolved Reactive Phosphorus	0.0003322	0.2274	34	NS	
	Escherichia coli	-5.439	0.4137	28	NS	
	Nitrite/Nitrate Nitrogen	-0.0002519	1.821	34	<0.1	
	pH	-0.03738	0.9948	23	NS	
	Suspended Solids	-0.141	-1.044	34	NS	
	Temperature	0.1022	0.4522	34	NS	
	Total Nitrogen	-0.007417	-0.6393	33	NS	
	Total Phosphorus	0	-0.057	34	NS	
Turbidity	-0.04993	-0.7498	34	NS		
Site	Variable	Slope	z	n	p	
Hayes Creek	Ammoniacal Nitrogen	-0.0002527	2.037	54	<0.05	
	Conductivity	-0.001509	2.077	54	<0.05	
	Dissolved Oxygen	-0.02612	0.4101	55	NS	
	Dissolved Reactive Phosphorus	0.0001424	2.067	54	<0.05	
	Escherichia coli	0	0.194	23	NS	
	Nitrite/Nitrate Nitrogen	-0.001124	-3.466	56	<0.05	
	pH					
	Suspended Solids	0	-2.043	51	<0.05	
	Temperature	-0.1531	-0.165	56	NS	
	Total Nitrogen	-0.01634	-3.311	46	<0.05	
Total Phosphorus	-0.0003431	-0.4924	55	NS		
Turbidity	-0.04792	-3.248	53	<0.05		
Site	Variable	Slope	z	n	p	
Heriot Burn	Ammoniacal Nitrogen	0	0.4938	58	NS	
P-Kelso Rd	Conductivity	0.0007809	1.009	52	NS	
	Dissolved Oxygen	-0.07052	1.232	57	NS	
	Dissolved Reactive Phosphorus	0	0.07928	57	NS	
	Escherichia coli	6.537	0.7212	23	NS	
	Nitrite/Nitrate Nitrogen	0.03285	1.52	58	<0.2	
	pH	-0.009994	0.9372	52	NS	
	Suspended Solids	-0.1832	-0.616	53	NS	
	Temperature	-0.1694	-1.298	60	<0.2	
	Total Nitrogen	0.04614	1.804	51	<0.1	
	Total Phosphorus	-0.0005216	-0.3687	57	NS	
Turbidity	-0.1589	-1.672	57	<0.1		

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9.1 continued Trend analysis - starting date from January 1995, end point June 2006**

Site	Variable	Slope	z	n	p
Heriot Burn	Ammoniacal Nitrogen	0	1.643	33	<0.2
at SH90	Conductivity	-0.001203	-0.9696	28	NS
	Dissolved Oxygen	-0.06048	-0.3875	30	NS
	Dissolved Reactive Phosphorus	0.003067	3.212	30	<0.05
	Escherichia coli	-103	-1.323	30	<0.2
	Nitrite/Nitrate Nitrogen	0.09472	1.857	30	<0.1
	pH	-0.1026	-1.785	26	<0.1
	Suspended Solids	0.4325	0.6613	21	NS
	Temperature	-0.6201	-1.931	33	<0.1
	Total Nitrogen	0.1005	2.762	27	<0.05
	Total Phosphorus	0.003093	2.748	27	<0.05
	Turbidity	0.1093	0.7693	33	NS
Site	Variable	Slope	z	n	p
Ida Burn	Ammoniacal Nitrogen	0	0.6423	25	NS
at Auripo Road	Conductivity	-0.002027	-0.5544	22	NS
	Dissolved Oxygen	-0.2124	-1.832	23	<0.1
	Dissolved Reactive Phosphorus	0.007271	2.984	25	<0.05
	Escherichia coli	34.58	-2.362	25	<0.05
	Nitrite/Nitrate Nitrogen	Insufficient seasonal data for analysis			
	pH	-0.1052	-2.244	20	<0.05
	Suspended Solids	0.6008	1.423	25	<0.2
	Temperature	0.3707	0.9122	23	NS
	Total Nitrogen	-0.002325	0	25	NS
	Total Phosphorus	0.01147	1.843	25	<0.1
	Turbidity	0.6307	1.58	25	<0.2
Site	Variable	Slope	z	n	p
Kaihiku	Ammoniacal Nitrogen	0	1.147	61	NS
	Conductivity	0.003388	2.099	55	<0.05
	Dissolved Oxygen	0.1399	1.579	60	<0.2
	Dissolved Reactive Phosphorus	0.001468	2.249	61	<0.05
	Escherichia coli	0.8328	0.06435	29	NS
	Nitrite/Nitrate Nitrogen	0.004061	0.5421	60	NS
	pH	-0.04066	-1.519	52	<0.2
	Suspended Solids	0	0.3392	59	NS
	Temperature	-0.333	-1.718	61	<0.1
	Total Nitrogen	0.02873	1.488	57	<0.2
	Total Phosphorus	0.001944	1.179	60	NS
	Turbidity	0.125	1.031	61	NS

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued Trend analysis - starting date from January 1995, end point June 2006**

Site	Variable	Slope	z	n	p
Kaikorai Stream	Ammoniacal Nitrogen	0	0.05363	54	NS
at Green Island	Conductivity	-0.0007402	0.5784	53	NS
	Dissolved Oxygen	0.02623	0.2504	55	NS
	Dissolved Reactive Phosphorus	0.00049	1.413	54	<0.2
	Escherichia coli	-92.16	-1.357	29	<0.2
	Nitrite/Nitrate Nitrogen	-0.01355	-1.35	54	<0.2
	pH	0.02237	0.4349	45	NS
	Suspended Solids	0	0.05509	51	NS
	Temperature	-0.08753	-0.3739	55	NS
	Total Nitrogen	-0.01309	-0.732952	54	NS
	Total Phosphorus	0.0006541	2.719	47	<0.05
	Turbidity	-0.09994	-0.8856	54	NS
Site	Variable	Slope	z	n	p
Kakanui	Ammoniacal Nitrogen	0	1.603	52	<0.2
at Clifton Falls	Conductivity	0.0002701	0.315	54	NS
	Dissolved Oxygen	-0.02401	0.4816	54	NS
	Dissolved Reactive Phosphorus	0.0001898	4.614	52	<0.05
	Escherichia coli	Insufficient seasonal data for analysis			
	Nitrite/Nitrate Nitrogen	0	-0.11	52	NS
	pH	0.02596	1.313	43	<0.2
	Suspended Solids	0	0.07955	44	NS
	Temperature	-0.09266	-0.3555	56	NS
	Total Nitrogen	0.006391	1.106	36	NS
	Total Phosphorus	0.0005218	2.641	48	<0.05
	Turbidity	0.01345	1.327	50	<0.2
Site	Variable	Slope	z	n	p
Kakanui	Ammoniacal Nitrogen	-0.0007354	3.537	73	<0.05
at Pringles	Conductivity	-0.0002026	-0.1096	69	NS
	Dissolved Oxygen	-0.006423	0.1267	70	NS
	Dissolved Reactive Phosphorus	0.00006205	1.512	73	<0.2
	Escherichia coli	0.1034	0.3567	37	NS
	Nitrite/Nitrate Nitrogen	0.002855	1.439	73	<0.2
	pH	0.02666	2.019	66	<0.05
	Suspended Solids	0	0.9592	67	NS
	Temperature	0.01643	0.167	73	NS
	Total Nitrogen	0.002498	0.4458	59	NS
	Total Phosphorus	-0.01249	-0.178	71	NS
	Turbidity				

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued** Trend analysis - starting date from January 1995, end point June 2006

Site	Variable	Slope	z	n	p
Lake Dunstan	Ammoniacal Nitrogen	0	0	53	NS
	Conductivity	-0.001273	2.628	52	<0.05
	Dissolved Oxygen	0.08567	1.704	50	<0.1
	Dissolved Reactive Phosphorus	0.00008395	4.449	52	<0.05
	Escherichia coli	0	0.1356	48	NS
	Nitrite/Nitrate Nitrogen	-0.001499	-2.05	51	<0.05
	pH	-0.02516	-1.399	51	<0.2
	Suspended Solids	0	-1.358	51	<0.2
	Temperature	-0.09497	-0.5299	50	NS
	Total Nitrogen	0	0.6172	50	NS
	Total Phosphorus	0	1.615	52	<0.2
	Turbidity	-0.04	-2.745	51	<0.05
Site	Variable	Slope	z	n	p
Lake Hawea	Ammoniacal Nitrogen	-0.00009125	-2.224	65	<0.05
	Conductivity	-0.0003869	-1.868	65	<0.1
	Dissolved Oxygen	0.1125	3.357	63	<0.05
	Dissolved Reactive Phosphorus	0.000073	4.381	65	<0.05
	Escherichia coli	0	0.7468	46	NS
	Nitrite/Nitrate Nitrogen	0	-0.2635	63	NS
	pH	0.003348	1.088	64	NS
	Suspended Solids	0	-0.818	65	<0.1
	Temperature	-0.05997	1.419	63	<0.2
	Total Nitrogen	0	-2.302	55	NS
	Total Phosphorus	0	1.047	64	NS
	Turbidity	-0.01263	-1.218	64	NS
Site	Variable	Slope	z	n	p
Lake Hayes	Ammoniacal Nitrogen	-0.0001935	-0.8552	44	NS
	Conductivity	-0.001333	-1.453	48	<0.2
	Dissolved Oxygen	-0.02398	-0.5813	49	NS
	Dissolved Reactive Phosphorus	0	1.114	45	NS
	Escherichia coli	0	0.442	34	NS
	Nitrite/Nitrate Nitrogen	-0.001278	-30395	38	<0.05
	pH	-0.01994	-1.196	47	NS
	Suspended Solids	0	-1.487	41	<0.2
	Temperature	-0.059997	-0.6394	50	NS
	Total Nitrogen	-0.009992	-2.85	43	<0.05
	Total Phosphorus	-0.0001697	0.1938	47	NS
	Turbidity	-0.05502	-1.833	43	<0.1

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued Trend analysis - starting date from January 1995, end point June 2006**

Site	Variable	Slope	z	n	p
Lake Johnson	Ammoniacal Nitrogen	-0.0007205	-1.093	48	NS
	Conductivity	-0.0005583	-0.9592	47	NS
	Dissolved Oxygen	0.002066	0.1992	47	NS
	Dissolved Reactive Phosphorus	0.00007847	1.674	43	<0.1
	Escherichia coli	0	0.6478	38	NS
	Nitrite/Nitrate Nitrogen	-0.000638	-1.743	40	<0.1
	pH	0.004993	0.4907	45	NS
	Suspended Solids	0	-0.1073	45	NS
	Temperature	0	0	47	NS
	Total Nitrogen	-0.02166	-2.558	47	NS
	Total Phosphorus	-0.0002884	0.665147	NS	NS
	Turbidity	-0.06993	-3.14	46	<0.05
Site	Variable	Slope	z	n	p
Lake Onslow	Ammoniacal Nitrogen	-0.00008395	-1.529	22	<0.2
	Conductivity	Insufficient seasonal data for analysis			
	Dissolved Oxygen	Insufficient seasonal data for analysis			
	Dissolved Reactive Phosphorus	0.00009673	2.094	22	<0.05
	Escherichia coli	0.1688	1.643	21	<0.2
	Nitrite/Nitrate Nitrogen	Insufficient seasonal data for analysis			
	pH	0.01839	0.4266	22	NS
	Suspended Solids	-0.5101	-1.368	22	<0.2
	Temperature	Insufficient seasonal data for analysis			
	Total Nitrogen	Insufficient seasonal data for analysis			
	Total Phosphorus	Insufficient seasonal data for analysis			
	Turbidity	Insufficient seasonal data for analysis			
Site	Variable	Slope	z	n	p
Lake Tuakitoto	Ammoniacal Nitrogen	-0.002429	-1.761	65	<0.1
	Conductivity	0.0008271	0.6147	64	NS
	Dissolved Oxygen	0.1124	1.591	63	<0.2
	Dissolved Reactive Phosphorus	0	0.2729	65	NS
	Escherichia coli	4.46	1.523	48	<0.2
	Nitrite/Nitrate Nitrogen	-0.0004541	-0.6354	63	NS
	pH	0.005369	0.8498	64	NS
	Suspended Solids	-0.205	-1.041	64	NS
	Temperature	-0.2532	1.459	62	<0.2
	Total Nitrogen	-0.00307	-0.1604	55	NS
	Total Phosphorus	-0.002013	-0.9303	62	NS
	Turbidity	-0.1935	-0.9528	62	NS

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9.1 continued** Trend analysis - starting date from January 1995, end point June 2006

Site	Variable	Slope	z	n	p
Lake Waiholā	Ammoniacal Nitrogen	-0.0008755	-2.035	61	<0.05
	Conductivity	0.03038	0.018	67	NS
	Dissolved Oxygen	-0.1574	-2.884	66	<0.05
	Dissolved Reactive Phosphorus	0	0	56	NS
	Escherichia coli	1.859	1.103	52	NS
	Nitrite/Nitrate Nitrogen	-0.001709	-2.626	52	<0.05
	pH	-0.01855	-0.7611	65	NS
	Suspended Solids	-0.8382	-1.472	60	<0.02
	Temperature	-0.01841	-0.1992	67	NS
	Total Nitrogen	-0.02688	-20606	56	<0.05
	Total Phosphorus	-0.002339	-1.389	60	<0.2
	Turbidity	-0.3947	-2.162	60	<0.05
Site	Variable	Slope	z	n	p
Lake Waipori	Ammoniacal Nitrogen	-0.002498	-1.2	66	NS
	Conductivity	0.01499	0.8026	67	NS
	Dissolved Oxygen	0.0987	0.9236	63	NS
	Dissolved Reactive Phosphorus	0	0.4783	60	NS
	Escherichia coli	-1.1	-0.2282	46	NS
	Nitrite/Nitrate Nitrogen	-0.009121	-2.611	55	<0.05
	pH	0.01609	1.105	65	NS
	Suspended Solids	-0.2074	-1.114	65	NS
	Temperature	0.06161	0.5788	67	NS
	Total Nitrogen	0.0008568	0.04561	58	NS
	Total Phosphorus	-0.00179	-0.9873	65	NS
	Turbidity	-0.1247	-0.9694	65	NS
Site	Variable	Slope	z	n	p
Lake Wakatipu	Ammoniacal Nitrogen	0	-1.201	68	NS
	Conductivity	-0.0004931	-2.153	66	<0.05
	Dissolved Oxygen	0.0411	1.425	65	
	Dissolved Reactive Phosphorus	0.0001022	5.116	68	<0.05
	Escherichia coli	0	-0.2106	47	NS
	Nitrite/Nitrate Nitrogen	-0.0002482	-1.002	67	NS
	pH	0.005066	1.052	66	NS
	Suspended Solids	-0.08271	-3.47	65	<0.05
	Temperature	-0.0571	-1.041	65	NS
	Total Nitrogen	0	-0.7334	57	NS
	Total Phosphorus	0	-0.9766	68	NS
	Turbidity	-0.01802	-1.658	67	<0.1

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued Trend analysis - starting date from January 1995, end point June 2006**

Site	Variable	Slope	z	n	p
Lake Wanaka	Ammoniacal Nitrogen	0	-0.972	66	NS
	Conductivity	-0.0002683	-1.312	65	<0.1
	Dissolved Oxygen	0.05194	1.509	65	<0.2
	Dissolved Reactive Phosphorus	0.0000584	4.702	65	<0.05
	Escherichia coli	-0.09764	-3.307	46	<0.05
	Nitrite/Nitrate Nitrogen	-0.001173	-3.671	65	<0.05
	pH	0.02116	2.08	65	<0.05
	Suspended Solids	0	-1.958	67	<0.1
	Temperature	-0.04997	-1.251	67	NS
	Total Nitrogen	0	0.1317	55	NS
	Total Phosphorus	0	1.122	65	NS
	Turbidity	-0.02642	-2.627	66	<0.05
Site	Variable	Slope	z	n	p
Lee Stream	Ammoniacal Nitrogen	0	-0.07941	28	NS
	Conductivity	-0.01034	-0.9816	28	NS
	Dissolved Oxygen	0.06555	1.363	28	<0.2
	Dissolved Reactive Phosphorus	0.0008141	1.759	28	<0.1
	Escherichia coli	Insufficient seasonal data for analysis			
	Nitrite/Nitrate Nitrogen	-0.009826	-2.427	29	<0.05
	pH	-0.009829	-0.2453	20	NS
	Suspended Solids	0	-0.7472	29	NS
	Temperature	0.09528	0.4079	30	NS
	Total Nitrogen	0	0	29	NS
	Total Phosphorus	0.001179	0.5008	29	NS
	Turbidity	-0.007059	-0.1427	29	NS
Site	Variable	Slope	z	n	p
Lindsay's Creek	Ammoniacal Nitrogen	0.001302	1.327	42	<0.2
	Conductivity	-0.00306	1.75	40	<0.05
	Dissolved Oxygen	-0.2083	-1.398	38	<0.2
	Dissolved Reactive Phosphorus	0.002	3	42	<0.05
	Escherichia coli	21.19	0.5129	41	NS
	Nitrite/Nitrate Nitrogen	-0.02598	-1.581	42	<0.2
	pH	-0.009621	-0.04547	36	NS
	Suspended Solids	0	0.2234	41	NS
	Temperature	-0.005993	-0.03471	42	NS
	Total Nitrogen	-0.02248	-0.4794	41	NS
	Total Phosphorus	0.002998	1.125	42	NS
	Turbidity	-0.0316	-0.1054	42	NS

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued** Trend analysis - starting date from January 1995, end point June 2006

Site	Variable	Slope	z	n	p	
Lindis River	Ammoniacal Nitrogen	Insufficient seasonal data for analysis				
at Lindis Peak	Conductivity	Insufficient seasonal data for analysis				
	Dissolved Oxygen	Insufficient seasonal data for analysis				
	Dissolved Reactive Phosphorus	Insufficient seasonal data for analysis				
	Escherichia coli	Insufficient seasonal data for analysis				
	Nitrite/Nitrate Nitrogen	Insufficient seasonal data for analysis				
	pH	Insufficient seasonal data for analysis				
	Suspended Solids	Insufficient seasonal data for analysis				
	Temperature	Insufficient seasonal data for analysis				
	Total Nitrogen	Insufficient seasonal data for analysis				
	Total Phosphorus	Insufficient seasonal data for analysis				
	Turbidity	Insufficient seasonal data for analysis				
	Site	Variable	Slope	z	n	p
Lovells Creek	Ammoniacal Nitrogen	-0.0005997	-1.451	62	<0.2	
	Conductivity	0.0006513	0.7403	57	NS	
	Dissolved Oxygen	0.04448	0.7116	63	NS	
	Dissolved Reactive Phosphorus	0.0002008	1.432	62	<0.2	
	Escherichia coli	-6.49	-1.165	29	NS	
	Nitrite/Nitrate Nitrogen	0.02798	1.971	62	<0.05	
	pH	0.03331	2.641	55	<0.05	
	Suspended Solids	0	0.5998	61	NS	
	Temperature	0.2627	2.028	62	<0.05	
	Total Nitrogen	0.03198	1.936	54	<0.1	
	Total Phosphorus	0.0001643	0.244	62	NS	
	Turbidity	0.04134	0.6521	61	NS	
Site	Variable	Slope	z	n	p	
Main Drain	Ammoniacal Nitrogen	-0.2148	-6.31	104	<0.05	
	Conductivity	0.2512	3.955	98	<0.05	
	Dissolved Oxygen	0.02399	0.2021	102	NS	
	Dissolved Reactive Phosphorus	0	0.5219	104	NS	
	Escherichia coli	-0.1538	-0.3007	89	NS	
	Nitrite/Nitrate Nitrogen	-0.05581	-4.635	104	<0.05	
	pH	0.02088	1.537	93	<0.2	
	Suspended Solids	-0.6599	-3.06	103	<0.05	
	Temperature	-0.093957	-0.08596	105	NS	
	Total Nitrogen	-0.3147	-5.034	91	<0.05	
	Total Phosphorus	-0.008731	-3.565	104	<0.05	
	Turbidity	-0.5216	-3.697	103	<0.05	

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9.1 continued Trend analysis - starting date from January 1995, end point June 2006**

Site	Variable	Slope	z	n	p
Manuherikia	Ammoniacal Nitrogen	-0.0003608	-1.934	52	<0.1
at Galloway	Conductivity	-0.0004615	-0.2012	49	NS
	Dissolved Oxygen	-0.03997	-0.583	52	NS
	Dissolved Reactive Phosphorus	0.0009791	3.269	52	<0.05
	Escherichia coli	9.837	1.875	25	<0.1
	Nitrite/Nitrate Nitrogen	-0.003148	-1.903	52	<0.1
	pH	-0.00461	-1.149	47	NS
	Suspended Solids	0	-0.956	50	NS
	Temperature	0.2777	1.473	54	<0.1
	Total Nitrogen	-0.001533	-0.4003	52	NS
	Total Phosphorus	0.0009875	1.703	52	<0.1
	Turbidity	-0.1351	-2.534	49	<0.05
Site	Variable	Slope	z	n	p
Manuherikia	Ammoniacal Nitrogen	-0.0007745	-2.423	46	<0.05
at Blackstone	Conductivity	-0.001069	-1.906	43	<0.1
	Dissolved Oxygen	-0.06537	-1.178	45	NS
	Dissolved Reactive Phosphorus	0.0004999	30777	46	<0.05
	Escherichia coli	4.397	1.332	19	<0.2
	Nitrite/Nitrate Nitrogen	-0.0001798	-0.6298	46	NS
	pH	-0.02498	-1.972	41	<0.05
	Suspended Solids	-0.2497	-1.648	43	<0.1
	Temperature	0.2727	1.807	46	<0.1
	Total Nitrogen	-0.005105	-1.748	46	<0.1
	Total Phosphorus	0.00006205	0.7125	46	NS
	Turbidity	-0.2082	-2.549	42	<0.05
Site	Variable	Slope	z	n	p
Mill Creek	Ammoniacal Nitrogen	-0.0002044	-1.44	83	<0.2
	Conductivity	-0.001057	-2.222	84	<0.05
	Dissolved Oxygen	0.1281	3.902	83	<0.05
	Dissolved Reactive Phosphorus	0	-0.4043	84	NS
	Escherichia coli	-2.475	0.2346	44	NS
	Nitrite/Nitrate Nitrogen	-0.03248	-5.357	83	<0.05
	pH	0.01998	2.074	84	<0.05
	Suspended Solids	-1.249	-5.357	80	<0.05
	Temperature	-1.355	-1.242	85	NS
	Total Nitrogen	-0.03829	-5.163	59	<0.05
	Total Phosphorus	-0.001749	-3.332	84	<0.05
	Turbidity	-0.2303	-4.206	83	<0.05

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued** Trend analysis - starting date from January 1995, end point June 2006

Site	Variable	Slope	z	n	p
Minzion Burn	Ammoniacal Nitrogen	-0.0006139	-0.8539	28	0
at Millers Flat	Conductivity	-0.0002774	-0.3486	25	NS
	Dissolved Oxygen	-0.1868	-1.647	28	<0.1
	Dissolved Reactive Phosphorus	0.0005187	1.138	28	NS
	Escherichia coli	-16.28	-0.6971	27	NS
	Nitrite/Nitrate Nitrogen	Insufficient seasonal data for analysis			
	pH	-0.04902	-1.558	26	<0.2
	Suspended Solids	0	0.1586	27	NS
	Temperature	-0.1788	-0.8962	26	NS
	Total Nitrogen	-0.02039	-0.8303	28	NS
	Total Phosphorus	0.002521	1.434	28	<0.2
	Turbidity	-0.06088	-0.3089	27	NS
Site	Variable	Slope	z	n	p
NIWA Balclutha	Ammoniacal Nitrogen	-0.0002552	-6.029	191	<0.05
	Conductivity	0.00001252	0.2483	204	NS
	Dissolved Oxygen	-0.05524	-1.748	203	<0.1
	Dissolved Reactive Phosphorus	0.00001394	1.923	203	<0.1
	pH	0	-0.06615	202	NS
	Temperature	0.03211	1.083	204	NS
	Total Nitrogen	0.002748	3.677	191	<0.05
	Total Phosphorus	0	-0.1316	203	NS
	Turbidity	0	-0.1629	204	NS
Site	Variable	Slope	z	n	p
NIWA Kawarau	Ammoniacal Nitrogen	0	1.793	189	<0.2
	Conductivity	-0.00002148	-0.5567	200	NS
	Dissolved Oxygen	0	-0.1011	199	NS
	Dissolved Reactive Phosphorus	0.00001428	2.196	200	<0.05
	pH	-0.004008	-3.407	198	<0.05
	Temperature	0.02846	1.131	200	NS
	Total Nitrogen	0.001922	6.315	186	<0.05
	Total Phosphorus	0	-0.507	199	NS
	Turbidity	0.008844	0.4353	200	NS

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued Trend analysis - starting date from January 1995, end point June 2006**

Site	Variable	Slope	z	n	p
NIWA Luggate	Ammoniacal Nitrogen	-0.0002221	-6.549	189	<0.05
	Conductivity	0.0001813	3.729	201	<0.05
	Dissolved Oxygen	0.17	5.313	200	<0.05
	Dissolved Reactive Phosphorus	0.00001237	2.454	200	<0.05
	pH	0.00596	2.653	199	<0.05
	Temperature	0.03056	1.6	200	<0.2
	Total Nitrogen	0.001007	3.913	189	<0.05
	Total Phosphorus	0	2.585	199	<0.05
	Turbidity	0.00461	1.136	201	NS
Site	Variable	Slope	z	n	p
NIWA Millers Flat	Ammoniacal Nitrogen	-0.0003285	-8.524	188	<0.05
	Conductivity	-0.00006661	-1.29	200	<0.2
	Dissolved Oxygen	0	0.2658	199	NS
	Dissolved Reactive Phosphorus	0	-0.04251	199	NS
	pH	-0.001999	-1.884	198	<0.1
	Temperature	0.02525	0.9176	200	NS
	Total Nitrogen	0.0009994	2.836	186	<0.05
	Total Phosphorus	0	0.157	199	NS
	Turbidity	-0.04354	-2.376	200	<0.05
Site	Variable	Slope	z	n	p
NIWA Outram	Ammoniacal Nitrogen	-0.0001928	-4.156	190	<0.05
	Conductivity	0.0001256	0.83	202	NS
	Dissolved Oxygen	-0.01884	-0.4785	201	NS
	Dissolved Reactive Phosphorus	0.00006633	1.545	201	<0.2
	pH	-0.001665	-0.7191	202	NS
	Temperature	0.03569	0.9171	202	NS
	Total Nitrogen	0.002395	1.923	190	<0.1
	Total Phosphorus	0.0003278	1.561	201	<0.2
	Turbidity	-0.05106	-1.843	202	<0.1

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9.1 continued Trend analysis - starting date from January 1995, end point June 2006**

Site	Variable	Slope	z	n	p
NIWA Shotover	Ammoniacal Nitrogen	-0.0001666	-6.674	189	<0.05
	Conductivity	0.00001933	0.1496	201	NS
	Dissolved Oxygen	0.02018	1.064	199	NS
	Dissolved Reactive Phosphorus	0	0.436	201	NS
	pH	-0.004927	-4.042	199	<0.05
	Temperature	0.03331	0.9523	201	NS
	Total Nitrogen	0.0009165	2.594	189	<0.05
	Total Phosphorus	0	0.09149	201	NS
	Turbidity	0	0.1289	201	NS
Site	Variable	Slope	z	n	p
NIWA Sutton Stm	Ammoniacal Nitrogen	-0.0003241	-6.429	190	<0.05
	Conductivity	-0.0001139	-1.177	202	NS
	Dissolved Oxygen	0.01665	0.4876	202	NS
	Dissolved Reactive Phosphorus	0	0.1375	201	NS
	pH	-0.0007408	-0.4712	202	NS
	Temperature	0.07342	1.76	202	<0.1
	Total Nitrogen	0.001024	0.9458	190	NS
	Total Phosphorus	0.0001428	1.677	201	<0.1
	Turbidity	-0.009829	-1.008	202	NS
Site	Variable	Slope	z	n	p
NIWA Tirioiti	Ammoniacal Nitrogen	-0.0002211	-4.758	189	<0.05
	Conductivity	0.0004106	1.491	202	<0.2
	Dissolved Oxygen	-0.02129	-0.7852	202	NS
	Dissolved Reactive Phosphorus	0.0003749	4.461	201	<0.05
	pH	-0.002725	-1.037	202	NS
	Temperature	0.07065	1.752	202	<0.1
	Total Nitrogen	0.003084	2.629	190	<0.05
	Total Phosphorus	0.0007818	3.319	201	<0.05
	Turbidity	-0.02552	-1.05	202	NS
Site	Variable	Slope	z	n	p
Owhiro Stream at Burns Street	Ammoniacal Nitrogen	-0.003568	-1.208	34	NS
	Conductivity	-0.01756	-2.263	33	<0.05
	Dissolved Oxygen	0.29	0.2454	31	NS
	Dissolved Reactive Phosphorus	0.004238	3.304	34	<0.05
	Escherichia coli	-45.22	-0.9184	34	NS
	Nitrite/Nitrate Nitrogen	-0.006628	-0.3039	32	NS
	pH	0.08917	0.7487	25	NS
	Suspended Solids	Insufficient seasonal data for analysis			
	Temperature	0.2798	1.082	34	NS
	Total Nitrogen	-0.07816	-2.055	34	<0.05
	Total Phosphorus	-0.001827	-0.4327	34	NS
Turbidity	-1.009	-1.459	34	<0.2	

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued** Trend analysis - starting date from January 1995, end point June 2006

Site	Variable	Slope	z	n	p
Pig Burn	Ammoniacal Nitrogen	0	-0.5828	40	NS
at O'Neill Rd	Conductivity	-0.003453	-1.179	38	NS
	Dissolved Oxygen	Insufficient seasonal data for analysis			
	Dissolved Reactive Phosphorus	0.0002357	1.448	40	<0.2
	Escherichia coli	-26.04	-1.577	40	<0.2
	Nitrite/Nitrate Nitrogen	Insufficient seasonal data for analysis			
	pH	0.1164	1.087	26	NS
	Suspended Solids	0	-0.0415	39	NS
	Temperature	-0.1816	0.9603	40	NS
	Total Nitrogen	-0.03828	-1.884	40	<0.1
	Total Phosphorus	0	0.1547	40	NS
	Turbidity	-0.349	-1.999	40	<0.05
Site	Variable	Slope	z	n	p
Pomahaka	Ammoniacal Nitrogen	-0.0009992	-1.818	54	<0.1
Burkes Ford	Conductivity	0.0008505	0.7783	53	NS
	Dissolved Oxygen	0	0	52	NS
	Dissolved Reactive Phosphorus	0.0004232	1.126	54	NS
	Escherichia coli	0.5822	0.4988	46	NS
	Nitrite/Nitrate Nitrogen	-0.0005827	0	54	NS
	pH	-0.03569	-1.576	54	<0.2
	Suspended Solids	0	0.3785	53	NS
	Temperature	-0.2497	-1.344	53	<0.2
	Total Nitrogen	-0.009994	-0.2305	50	NS
	Total Phosphorus	6201	0.2951	53	NS
	Turbidity	0.01043	0.1172	50	NS
Site	Variable	Slope	z	n	p
Pomahaka	Ammoniacal Nitrogen	-0.0003322	-1.91256	56	<0.1
Glenken	Conductivity	-0.001308	-1.481	55	<0.2
	Dissolved Oxygen	-0.01338	-0.3909	53	NS
	Dissolved Reactive Phosphorus	0.0002719	1.527	56	<0.2
	Escherichia coli	-6.672	-1.11	52	NS
	Nitrite/Nitrate Nitrogen	-0.001565	-1.152	56	NS
	pH	-0.03424	-1.764	56	<0.1
	Suspended Solids	0	-0.4954	54	NS
	Temperature	0.0333	0.2841	57	NS
	Total Nitrogen	0.00371	0.8542	55	NS
	Total Phosphorus	-0.0002081	-0.3782	56	NS
	Turbidity	-0.1749	-2.103	56	<0.05

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued** Trend analysis - starting date from January 1995, end point June 2006

Site	Variable	Slope	z	n	p	
Shag	Ammoniacal Nitrogen	-0.0002811	-1.355	64	<0.2	
Goodwood	Conductivity	0.001394	1.057	67	NS	
	Dissolved Oxygen	-0.1785	-2.742	62	<0.05	
	Dissolved Reactive Phosphorus	0	0.5188	64	NS	
	Escherichia coli	2.664	0.5797	44	NS	
	Nitrite/Nitrate Nitrogen	-0.00851	-2.549	66	<0.05	
	pH	-0.03723	-2.025	66	<0.05	
	Suspended Solids	0	-2.264	64	<0.05	
	Temperature	-0.06493	-0.5595	69	NS	
	Total Nitrogen	-1.91533	-1.904	54	<0.1	
	Total Phosphorus	-0.0002008	-0.8232	64	NS	
	Turbidity	-0.0009998	-0.3862	65	NS	
	Site	Variable	Slope	z	n	p
Shag	Ammoniacal Nitrogen	-0.0002738	-2.362	45	<0.05	
Grange	Conductivity	0.0006069	0.1633	47	NS	
	Dissolved Oxygen	-0.1485	-2.236	44	<0.05	
	Dissolved Reactive Phosphorus	0.0001132	1.278	45	NS	
	Escherichia coli	Insufficient seasonal data for analysis				
	Nitrite/Nitrate Nitrogen	-0.0007307	-1.671	45	<0.1	
	pH	-0.05125	-2.486	47	<0.05	
	Suspended Solids	0	-0.686445	45	NS	
	Temperature	-0.09572	-0.6536	47	NS	
	Total Nitrogen	-0.003964	-0.7253	37	NS	
	Total Phosphorus	0	0.2855	45	NS	
	Turbidity	0.00999	1.5	45	<0.2	
	Site	Variable	Slope	z	n	p
Silver Stream	Ammoniacal Nitrogen	-0.0005037	-2.102	39	<0.05	
	Conductivity	0.00222	1.63	42	<0.2	
	Dissolved Oxygen	-0.07388	-0.604	41	NS	
	Dissolved Reactive Phosphorus	0.000303	2.378	39	<0.05	
	Escherichia coli	Insufficient seasonal data for analysis				
	Nitrite/Nitrate Nitrogen	-0.0121	-1.95339	39	<0.1	
	pH	0.1024	3.024	41	<0.05	
	Suspended Solids	-0.203	-1.707	39	<0.1	
	Temperature	0.1583	1.224	42	NS	
	Total Nitrogen	-0.01871	-1.829	28	<0.1	
	Total Phosphorus	0.0001989	0.5836	39	NS	
	Turbidity	-0.07139	-1.261	38	NS	

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued Trend analysis - starting date from January 1995, end point June 2006**

Site	Variable	Slope	z	n	p
Taieri	Ammoniacal Nitrogen	-0.0049	-4.873	52	<0.05
Allanton	Conductivity	0.0002154	-0.1615	53	NS
	Dissolved Oxygen	-0.01208	-0.2023	51	NS
	Dissolved Reactive Phosphorus	-0.00121	-3.145	52	<0.05
	Escherichia coli	4.986	0.3037	35	NS
	Nitrite/Nitrate Nitrogen	-0.005804	-2.98952	52	<0.05
	pH	0.01734	0.734	53	NS
	Suspended Solids	-0.5658	-2.665	40	<0.05
	Temperature	-0.002874	-0.02689	53	NS
	Total Nitrogen	-0.01999	-1.888	41	<0.5
	Total Phosphorus	-0.002901	-3.125	52	<0.05
	Turbidity	-0.07118	-0.9412	50	NS
Site	Variable	Slope	z	n	p
Taieri	Ammoniacal Nitrogen	-0.0005024	-2.044	67	<0.05
Halls Br	Conductivity	-0.0005303	-0.7048	69	NS
	Dissolved Oxygen	0	-0.08584	66	NS
	Dissolved Reactive Phosphorus	0.0001953	0.5735	67	NS
	Escherichia coli	-12.51	-1.695	53	<0.1
	Nitrite/Nitrate Nitrogen	-0.0006864	-2.468	67	<0.05
	pH	-0.0009912	-0.2388	66	NS
	Suspended Solids	-0.4893	-3.627	67	<0.05
	Temperature	0.0287	0.2256	68	NS
	Total Nitrogen	-0.006285	-1.013	61	NS
	Total Phosphorus	-0.0007718	-0.931	67	NS
	Turbidity	-0.1581	-3.408	67	<0.05
Site	Variable	Slope	z	n	p
Taieri River at Henley Ferry	Ammoniacal Nitrogen	-0.002398	-3.555	71	<0.05
	Conductivity	-0.06982	2.402	72	<0.05
	Dissolved Oxygen	-0.08296	-1.802	75	<0.1
	Dissolved Reactive Phosphorus	-0.0002081	-1.679	72	<0.1
	Escherichia coli	-1.527	-0.3327	50	NS
	Nitrite/Nitrate Nitrogen	-0.0005818	-0.1238	41	NS
	pH	0.01346	1.233	61	NS
	Suspended Solids	0	0.05699	66	NS
	Temperature	-0.0009866	-0.04816	75	NS
	Total Nitrogen	-0.02298	-3.30261	61	<0.05
	Total Phosphorus	-0.001705	-2.024	72	<0.05
	Turbidity	-0.2735	-1.675	71	<0.1

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued** Trend analysis - starting date from January 1995, end point June 2006

Site	Variable	Slope	z	n	p
Taieri	Ammoniacal Nitrogen	0	-0.8355	52	NS
Middlemarch	Conductivity	-0.003208	-2.753	56	<0.05
	Dissolved Oxygen	0	0	53	NS
	Dissolved Reactive Phosphorus	0.0005106	2.067	52	<0.05
	Escherichia coli	-6.76	-1.455	47	<0.2
	Nitrite/Nitrate Nitrogen	-0.002047	-2.424	52	<0.05
	pH	-0.05473	-3.329	54	<0.05
	Suspended Solids	0	-0.3697	52	NS
	Temperature	0.1806	0.8466	55	NS
	Total Nitrogen	-0.003712	-0.5051	51	NS
	Total Phosphorus	0.0001971	0.3375	52	NS
	Turbidity	-0.0999	-0.7352	52	NS
Site	Variable	Slope	z	n	p
Taieri	Ammoniacal Nitrogen	-0.0007493	-2.93969	69	<0.05
Outram	Conductivity	-0.0003532	-0.6186	71	NS
	Dissolved Oxygen	-0.06749	-1.412	69	<0.2
	Dissolved Reactive Phosphorus	0	0.4288	70	NS
	Escherichia coli	-1.149	-0.2755	50	NS
	Nitrite/Nitrate Nitrogen	-0.004497	-3.456	70	<0.05
	pH	0	0.09171	69	NS
	Suspended Solids	-0.4362	-2.628	65	<0.05
	Temperature	0.02553	0.212	71	NS
	Total Nitrogen	-0.01376	-2.389	60	<0.05
	Total Phosphorus	-0.00102	-1.42	70	<0.2
	Turbidity	-0.1199	-1.596	70	<0.2
Site	Variable	Slope	z	n	p
Taieri	Ammoniacal Nitrogen	-0.000146	-1.555	72	<0.2
Stonehenge	Conductivity	-0.0002774	-0.7833	75	NS
	Dissolved Oxygen	0.003711	0.09792	70	NS
	Dissolved Reactive Phosphorus	0	0.5633	72	NS
	Escherichia coli	-0.734	-0.3032	52	NS
	Nitrite/Nitrate Nitrogen	-0.001332	-5.226	72	<0.05
	pH	-0.00333	-0.4493	73	NS
	Suspended Solids	-0.1249	-2.732	72	<0.05
	Temperature	-0.02552	-0.1575	76	NS
	Total Nitrogen	-0.00289	-0.8147	61	NS
	Total Phosphorus	-0.000423	-1.254	72	NS
	Turbidity	-0.01645	-1.647	72	NS

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued Trend analysis - starting date from January 1995, end point June 2006**

Site	Variable	Slope	z	n	p
Taieri River	Ammoniacal Nitrogen	0	-0.9814	38	NS
at Waipiata	Conductivity	0.001543	0.4371	33	NS
	Dissolved Oxygen	0.3931	1.873	34	<0.1
	Dissolved Reactive Phosphorus	0.0003657	3.291	36	<0.05
	Escherichia coli	-24.17	-1.334	51	<0.2
	Nitrite/Nitrate Nitrogen	-0.00144	-1.387	34	<0.2
	pH	0.1675	1.099	25	NS
	Suspended Solids	-0.9556	-1.671	36	<0.1
	Temperature	-0.1404	-0.1713	37	NS
	Total Nitrogen	-0.01846	-1.522	36	<0.2
	Total Phosphorus	0.004037	1.289	36	<0.2
	Turbidity	0.05022	0.3217	36	NS
Site	Variable	Slope	z	n	p
Teviot	Ammoniacal Nitrogen	0	-1.108	35	NS
	Conductivity	-0.0007136	-0.653	35	NS
	Dissolved Oxygen	-0.03997	-0.1088	35	NS
	Dissolved Reactive Phosphorus	0.0001314	3.777	35	<0.05
	Escherichia coli	-1.713	-0.3029	28	NS
	Nitrite/Nitrate Nitrogen	0.000999	1.151	35	NS
	pH	0.004924	0.05729	34	NS
	Suspended Solids	-0.176	-1.947	33	<0.1
	Temperature	0.2399	1.959	35	<0.1
	Total Nitrogen	-0.001132	-0.3847	35	NS
	Total Phosphorus	0.001374	1.913	35	<0.1
	Turbidity	-0.06745	-0.8835	33	NS
Site	Variable	Slope	z	n	p
Tokomairiro	Ammoniacal Nitrogen	-0.0002008	-1.13547	48	NS
East Br	Conductivity	-0.0008649	-2.396	48	<0.05
	Dissolved Oxygen	0	0	49	NS
	Dissolved Reactive Phosphorus	0	0.06667	48	NS
	Escherichia coli	Insufficient seasonal data for analysis			
	Nitrite/Nitrate Nitrogen	-0.000475	0.5564	48	NS
	pH	0.004216	0.3125	49	NS
	Suspended Solids	-0.4754	-1.876	44	<0.1
	Temperature	-0.2237	-2.245	49	<0.05
	Total Nitrogen	Insufficient seasonal data for analysis			
	Total Phosphorus	0.0004438	0.6874	49	NS
	Turbidity	0.02995	0.3118	49	NS

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued** Trend analysis - starting date from January 1995, end point June 2006

Site	Variable	Slope	z	n	p	
Tokomairiro	Ammoniacal Nitrogen	0	-0.5125	42	NS	
West Br	Conductivity	-0.00134	-2.568	43	<0.05	
	Dissolved Oxygen	0.0357	0.9314	44	NS	
	Dissolved Reactive Phosphorus	0.0002482	1.1517	43	<0.2	
	Escherichia coli	Insufficient seasonal data for analysis				
	Nitrite/Nitrate Nitrogen	0.002271	0.6455	43	NS	
	pH	0.006183	0.3881	44	NS	
	Suspended Solids	-0.1499	-1.769	44	<0.1	
	Temperature	-0.1008	-0.8907	44	NS	
	Total Nitrogen	Insufficient seasonal data for analysis				
	Total Phosphorus	0.0007862	1.592	44	<0.2	
	Turbidity	0.0742	2.03	44	<0.05	
	Site	Variable	Slope	z	n	p
Tuapeka	Ammoniacal Nitrogen	0	-0.8893	53	NS	
	Conductivity	-0.0004413	-0.395	51	NS	
	Dissolved Oxygen	-0.0212	-0.2137	51	NS	
	Dissolved Reactive Phosphorus	0.0009464	2.224	53	<0.05	
	Escherichia coli	-10	-0.9445	46	NS	
	Nitrite/Nitrate Nitrogen	-0.005013	-0.6029	53	NS	
	pH	-0.02821	-1.8	52	<0.1	
	Suspended Solids	-0.3158	-1.813	52	<0.1	
	Temperature	-0.1665	-1.241	51	NS	
	Total Nitrogen	-0.004997	-0.4332	50	NS	
	Total Phosphorus	0	-0.2716	52	NS	
	Turbidity	-0.1836	-1.682	52	<0.1	
Site	Variable	Slope	z	n	p	
Waianakarua	Ammoniacal Nitrogen	0	-1.112	37	NS	
	Conductivity	-0.0009994	-0.305237	35	NS	
	Dissolved Oxygen	-0.06796	-0.6796	35	NS	
	Dissolved Reactive Phosphorus	0.0009986	4.269	37	<0.05	
	Escherichia coli	-2.882	0.9624	37	NS	
	Nitrite/Nitrate Nitrogen	-0.01567	-2.007	37	<0.05	
	pH	0.01333	0.613	37	NS	
	Suspended Solids	0	2.602	37	<0.05	
	Temperature	0.1249	0.5236	37	NS	
	Total Nitrogen	-0.0176	-1.529	37	<0.2	
	Total Phosphorus	0	1.646	37	<0.1	
	Turbidity	-0.03749	-1.093	37	NS	

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued Trend analysis - starting date from January 1995, end point June 2006**

Site	Variable	Slope	z	n	p
Waiareka	Ammoniacal Nitrogen	-0.0005331	-0.8614	50	NS
	Conductivity	0.01412	0.3259	44	NS
	Dissolved Oxygen	0.1965	0.8426	48	NS
	Dissolved Reactive Phosphorus	0.01754	5.271	50	<0.05
	Escherichia coli	Insufficient seasonal data for analysis			
	Nitrite/Nitrate Nitrogen	0.4993	0.09944	46	NS
	pH	0.07997	2.487	39	<0.05
	Suspended Solids	0	0.3027	46	NS
	Temperature	0.08001	0.4541	49	NS
	Total Nitrogen	-0.01427	-1.35	48	<0.2
	Total Phosphorus	0.01757	3.675	48	<0.05
	Turbidity	-0.2715	-4.75	50	<0.05
Site	Variable	Slope	z	n	p
Waikouaiti at Orbell's	Ammoniacal Nitrogen	-0.0008565	-3.437	75	<0.05
	Conductivity	0.002008	1.444	73	<0.2
	Dissolved Oxygen	-0.107	-1.955	75	<0.1
	Dissolved Reactive Phosphorus	0	0.5848	76	NS
	Escherichia coli	0	0.3163	32	NS
	Nitrite/Nitrate Nitrogen	-0.3094	-0.1762	75	NS
	pH	0.01997	1.526	69	<0.2
	Suspended Solids	-0.1262	-3.984	75	<0.05
	Temperature	0.1294	1.545	77	<0.2
	Total Nitrogen	-0.007205	-1.701	59	<0.1
	Total Phosphorus	-0.0004685	-1.704	76	<0.1
	Turbidity	-0.00408	-0.3886	75	NS
Site	Variable	Slope	z	n	p
Waipahi at Waipahi	Ammoniacal Nitrogen	-0.0003389	-1.379	60	<0.2
	Conductivity	-0.0001971	-0.2326	56	NS
	Dissolved Oxygen	0.03997	0.6649	57	NS
	Dissolved Reactive Phosphorus	0.0006864	1.726	60	<0.1
	Escherichia coli	0.8162	0.07155	28	NS
	Nitrite/Nitrate Nitrogen	10.56	1.431	52	<0.2
	pH	-0.02846	-1.091	53	NS
	Suspended Solids	0	-0.3564	58	NS
	Temperature	-0.05001	-0.3539	60	NS
	Total Nitrogen	-0.029999	-0.704	58	NS
	Total Phosphorus	0	-0.09487	60	NS
	Turbidity	-0.06665	-0.5127	59	NS

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued** Trend analysis - starting date from January 1995, end point June 2006

Site	Variable	Slope	z	n	p	
Waipahi River	Ammoniacal Nitrogen	0	0.6265	30	NS	
at Cairns Peak	Conductivity	0.002466	0.7155	29	NS	
	Dissolved Oxygen	0.1015	0.6611	28	NS	
	Dissolved Reactive Phosphorus	0.004546	3.186	30	<0.05	
	Escherichia coli	-18.69	-0.2562	30	NS	
	Nitrite/Nitrate Nitrogen	-0.05172	-1.573	27	<0.2	
	pH	-0.09446	-1.496	24	<0.2	
	Suspended Solids	0.853	0.8729	29	NS	
	Temperature	0	0	29	NS	
	Total Nitrogen	0.02354	0.3316	30	NS	
	Total Phosphorus	0.01027	2.729	30	<0.05	
	Turbidity	0.6701	1.791	30	<0.1	
	Site	Variable	Slope	z	n	p
Waipori	Ammoniacal Nitrogen	0	0.5422	35	NS	
	Conductivity	0	0	35	NS	
	Dissolved Oxygen	0.04	0.3245	35	NS	
	Dissolved Reactive Phosphorus	0	0.9332	35	NS	
	Escherichia coli	0.6322	0.9974	34	NS	
	Nitrite/Nitrate Nitrogen	-1.199	-0.3302	34	NS	
	pH	0	0	29	NS	
	Suspended Solids	-0.1714	-0.4351	33	NS	
	Temperature	-0.25	-0.6126	36	NS	
	Total Nitrogen	0.007493	0.669	35	NS	
	Total Phosphorus	0.001799	1.477	35	<0.2	
	Turbidity	-0.1844	-1.844	34	<0.1	
Site	Variable	Slope	z	n	p	
Wairuna	Ammoniacal Nitrogen	-0.003749	-1.502	50	<0.2	
	Conductivity	0.0004163	0.313	41	NS	
	Dissolved Oxygen	-0.04895	-0.4513	42	NS	
	Dissolved Reactive Phosphorus	0.0009994	1.047	50	NS	
	Escherichia coli	Insufficient seasonal data for analysis				
	Nitrite/Nitrate Nitrogen	34.94	0.882	41	NS	
	pH	-0.02256	-1.289	44	<0.2	
	Suspended Solids	-0.1428	-0.8057	43	NS	
	Temperature	-0.2248	-1.032	49	NS	
	Total Nitrogen	-0.02552	-0.5003	42	NS	
	Total Phosphorus	-0.0009972	-0.3628	44	NS	
	Turbidity	-0.1747	-1.107	46	NS	

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued Trend analysis - starting date from January 1995, end point June 2006**

Site	Variable	Slope	z	n	p
Waitahuna	Ammoniacal Nitrogen	-0.0001643	-1.071	53	NS
	Conductivity	0.0001862	0.3025	45	NS
	Dissolved Oxygen	0.07493	1.24	51	NS
	Dissolved Reactive Phosphorus	0.0006389	2.782	53	<0.05
	Escherichia coli	4.851	0.8807	27	NS
	Nitrite/Nitrate Nitrogen	-4.179	-0.3963	51	NS
	pH	-0.03022	-1.389	45	<0.2
	Suspended Solids	-0.333	-1.411	52	<0.2
	Temperature	-0.1731	-0.7887	52	NS
	Total Nitrogen	0.002498	0.3286	50	NS
	Total Phosphorus	-0.0001679	-0.2237	52	NS
	Turbidity	-0.1197	-1.368	52	<0.2
Site	Variable	Slope	z	n	p
Waitati	Ammoniacal Nitrogen	0	0.9466	51	NS
	Conductivity	0.002713	0.4875	50	NS
	Dissolved Oxygen	-0.1893	-1.991	51	<0.05
	Dissolved Reactive Phosphorus	0.0006247	3.346	51	<0.05
	Escherichia coli	3.5	1.336	24	<0.2
	Nitrite/Nitrate Nitrogen	-15.42	-1.943	48	<0.1
	pH	0.007344	0.6282	44	NS
	Suspended Solids	0	-0.7792	49	NS
	Temperature	0.01444	0.03065	52	NS
	Total Nitrogen	-0.004911	-0.3481	50	NS
	Total Phosphorus	0.0009209	1.78	51	<0.1
	Turbidity	-0.05099	-1.089	49	NS
Site	Variable	Slope	z	n	p
Water of Leith	Ammoniacal Nitrogen	-0.0003997	-1.582	64	<0.1
	Conductivity	0.001049	0.9596	62	NS
	Dissolved Oxygen	-0.09888	-1.528	63	>0.2
	Dissolved Reactive Phosphorus	-0.0004281	-1.097	64	NS
	Escherichia coli	5.614	0.3682	54	NS
	Nitrite/Nitrate Nitrogen	-30.79	-1.514	65	<0.2
	pH	0.04997	1.966	58	<0.05
	Suspended Solids	-1.5929	-1.393	63	<0.2
	Temperature	-0.01751	-0.1647	66	<0.2
	Total Nitrogen	-0.01999	-1.381	54	<0.2
	Total Phosphorus	-0.001441	-1.428	64	<0.2
	Turbidity	-0.1624	-1.77	64	<0.1

## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued Trend analysis - starting date from January 1995, end point June 2006**

Site	Variable	Slope	z	n	p
Waiwera River	Ammoniacal Nitrogen	0	0	37	NS
at SH1	Conductivity	-0.004256	-1.343	34	<0.2
	Dissolved Oxygen	-0.066466	-0.4196	35	NS
	Dissolved Reactive Phosphorus	0.005909	3.701	35	<0.1
	Escherichia coli	35.94	0.7723	38	NS
	Nitrite/Nitrate Nitrogen	0	0	34	NS
	pH	-0.01734	-0.2693	29	NS
	Suspended Solids	1.058	1.912	33	<0.1
	Temperature	0.4205	0.5551	37	NS
	Total Nitrogen	0.02512	0.676	34	NS
	Total Phosphorus	0.01297	3.547	36	<0.05
	Turbidity	0.8866	2.284	36	<0.05
Site	Variable	Slope	z	n	p
Washpool Stream	Ammoniacal Nitrogen	-0.01245	-0.373	25	NS
at Kilhastie Rd	Conductivity	Insufficient seasonal data for analysis			
	Dissolved Oxygen	0.6311	1.822	24	<0.1
	Dissolved Reactive Phosphorus	Insufficient seasonal data for analysis			
	Escherichia coli	-480	-0.4047	25	NS
	Nitrite/Nitrate Nitrogen	-0.1486	-0.8778	24	NS
	pH	Insufficient seasonal data for analysis			
	Suspended Solids	Insufficient seasonal data for analysis			
	Temperature	Insufficient seasonal data for analysis			
	Total Nitrogen	-0.1214	-0.4884	23	NS
	Total Phosphorus	Insufficient seasonal data for analysis			
	Turbidity	-0.7669	0	21	NS
Site	Variable	Slope	z	n	p
Welcome Creek	Ammoniacal Nitrogen	-0.0006847	-1.433	56	<0.2
Lower Site	Conductivity	0.00152	1.114	52	NS
	Dissolved Oxygen	0.1999	2.884	54	<0.05
	Dissolved Reactive Phosphorus	0.001448	2.528	56	<0.05
	Escherichia coli	4.146	1.103	29	NS
	Nitrite/Nitrate Nitrogen	-4.829	-1.257	55	NS
	pH	0	-0.8395	56	NS
	Suspended Solids	0	-0.8395	56	NS
	Temperature	0.07745	1.068	55	NS
	Total Nitrogen	0.03997	1.86	55	<0.1
	Total Phosphorus	0.001599	2.405	56	<0.05
	Turbidity	-0.09464	-1.458	55	<0.2

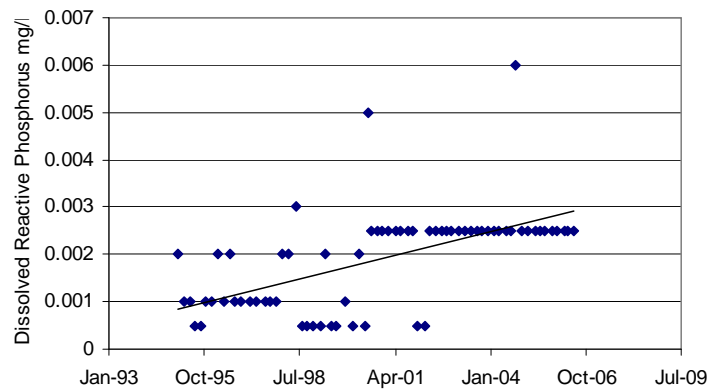
## Appendix 9 continued - Statistical methods for temporal trend analysis

**Table A9. 1 continued** Trend analysis - starting date from January 1995, end point June 2006

Site	Variable	Slope	z	n	p
Welcome Creek	Ammoniacal Nitrogen	-0.0009756	-2.764	57	<0.05
Upper Site	Conductivity	0.000146	0.3079	55	NS
	Dissolved Oxygen	0.003331	0.04962	56	NS
	Dissolved Reactive Phosphorus	0.002446	2.741	57	<0.05
	Escherichia coli	0.999	0.9002	30	NS
	Nitrite/Nitrate Nitrogen	-3.495	-2.957	56	<0.05
	pH	0.06661	3.498	46	<0.05
	Suspended Solids	0	-0.3506	56	NS
	Temperature	-0.06972	-0.8589	58	NS
	Total Nitrogen	-0.0413	-1.633	56	<0.2
	Total Phosphorus	0.0009669	0.768	57	NS
	Turbidity	-0.04329	-2.497	56	<0.05

### Appendix 9A – DRP trend analysis

Trend analysis for many sites (including Lakes Wakatipu, Wanaka, Hawea and Dunstan) showed an increasing trend in DRP. This is solely due to an upward change in detection limit of DRP, (ie a higher detection limit with a change in laboratory). This is demonstrated in the Figure A9 below which shows DRP for Lake Wakatipu. The 0.0025 concentrations seen since 2001 is in fact one half of the detection limit of 0.005 mg/l, while prior to this the detection limit was 0.001 mg/l, hence on the graph the concentrations is seen as 0.0005 mg/l. The upward trend is therefore misleading.



**Figure A9A.1 Dissolved reactive phosphorus concentrations, Lake Wakatipu**

The black line shows the misleading trend in the data record, due to changes in detection limits.