Report on the Surface Water Quality of the Upper Taieri River Catchment, November 2001 to December 2002

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Front cover: Children swimming in the Taieri River at Creamery Road

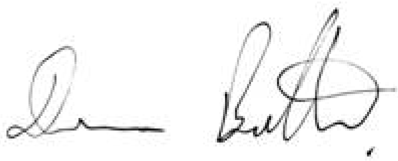
Chairperson's Foreword

The Taieri River originates in the rolling tussock tops of the Lammermoor and Lammerlaw Ranges in Central Otago. It then flows on through the Styx and Maniototo Basins, west of the Rock and Pillar Range. The large scroll plains on the Maniototo and associated wetlands and oxbows are important features of the upper Taieri River catchment.

Water quality in the upper Taieri River catchment has been monitored for the last nine years as part of the Otago Regional Council's state of the environment monitoring programme. Signs of deterioration were observed and so between November 2001 and December 2002 more intensive monitoring was carried out. This report summarises the results of that monitoring.

The monitoring confirmed some degradation of water quality compared to what is normally expected for a river draining an agricultural catchment. A number of issues including stock in water, bank erosion and irrigation and effluent run-off have been identified as contributing to the deteriorating water quality.

The Council intends working with the local community through the Upper Taieri Catchment Programme to develop ways of improving the situation. This report forms a scientific basis to start from as we head towards improving the water quality in this valuable river.



Duncan Butcher
Chairperson

Executive Summary

Water quality monitoring of the upper Taieri River catchment began in 1994 as part of the Council's state of environment monitoring programme. In November 2001 a more intensive 14-month surface water quality monitoring programme commenced as part of the Upper Taieri Catchment Programme. The programme was launched in response to growing concerns from Council staff, interest groups and the local community that upper Taieri River water quality may be deteriorating. Much of this concern centred on the potential impacts of the introduction of high density dairy farming into the area.

The water quality monitoring programme focused on six sites in the upper Taieri River and also included sites in the lower reaches of two tributaries, the Pig Burn and the Ewe Burn. Spot water sampling was conducted at fortnightly-monthly intervals over November 2001 to December 2002 inclusive with water samples tested for a range of physico-chemical and microbiological parameters. These included dissolved oxygen, temperature, conductivity, pH, horizontal black disc (clarity), suspended solids, turbidity, five-day biochemical oxygen demand (BOD), faecal coliforms, *Escherichia coli (E. coli*), ammoniacal nitrogen, nitrite-nitrate nitrogen, total nitrogen, dissolved reactive phosphorus and total phosphorus. Periphyton and macroinvertebrate sampling was also conducted at three sites in early autumn 2002.

The monitoring results indicate that there is a significant decline in water quality in the upper Taieri River between Stonehenge and Waipiata. Median suspended sediment, turbidity, faecal bacteria, and nutrient concentrations all increase with distance downstream while water clarity and dissolved oxygen concentrations decrease. Indicator bacteria and most nutrient concentrations exceed recommended guidelines at many monitoring sites. Macroinvertebrate values also decline with distance downstream although this is likely to be due primarily to differences in physical habitat rather than the deterioration in water quality.

Although a decrease in water quality with distance downstream is typical for a river draining an agricultural catchment, the deterioration in the upper Taieri River is quite marked, with median concentrations of most physico-chemical and microbiological water quality parameters higher at Waipiata than in the middle and lower reaches of the Taieri River.

Increased sedimentation and turbidity (and therefore reduced clarity) with distance downstream, along with faecal bacteria contamination are key water quality concerns. Although median dissolved phosphorus concentrations exceed the Australia and New Zealand Environment and Conservation Council (ANZECC) 2000 default trigger values for upland river ecosystems at many sites, nutrient enrichment may be of less importance at present because median dissolved inorganic nitrogen concentrations are well below the ANZECC default trigger values. This suggests that a lack of available nitrogen may limit aquatic plant growth, helping to prevent nuisance algal blooms and weeds in the upper Taieri River.

Poor water quality at most monitoring sites is attributed to factors such as stock access to water and riparian margins, effluent and irrigation runoff, and bank erosion. Stock, including sheep, beef cattle and dairy cows, had direct access to the water and river banks at almost all monitoring sites and were regularly seen in the Taieri River or its tributaries. Dairy cows in

the lower reaches of the Pig Burn were the primary reason for the exceptionally high bacteria concentrations recorded at this site during much of the monitoring programme.

Effluent and irrigation runoff is a problem in many low lying dairying areas, with runoff identified on several occasions immediately above Puketoi. Run-off may also have accounted for poor water quality in the Ewe Burn on one occasion. Most problems appear to be due to inappropriate siting of irrigators and excessive irrigation. It is likely that runoff from border-dyke irrigation systems is also impacting on water quality but this requires further investigation.

The banks of the upper Taieri River are comprised of exposed soil in many places which is likely to be easily shifted downstream during significant rain or flow events. This is particularly the case near Creamery Bridge and Waipiata where the highest turbidity and suspended sediment concentrations were recorded. It is unclear whether the erosion is solely a function of the meandering river flow pattern in the upper Taieri but fluctuations in river level due to hydroelectric power generation and grazing of river banks by cattle may be contributing to erosion in some areas.

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1 Introduction

In November 2001 the Otago Regional Council began an intensive 14-month surface water quality monitoring programme in the upper Taieri River catchment. The programme forms part of the Upper Taieri Catchment Programme and was launched in response to growing concerns from Council staff, interest groups and the local community that upper Taieri River water quality may be deteriorating. Much of this concern centred on the potential impacts of the introduction of high density dairy farming into the area.

The monitoring programme involved fortnightly to monthly physico-chemical and microbiological water quality sampling at six sites on the upper Taieri River between Stonehenge (Hores Bridge) and Waipiata along with one site on the Pig Burn, a tributary of the upper Taieri River. Another tributary, the Ewe Burn, was also sampled over July to December 2002.

This report presents the results and findings of the 14-month monitoring programme. Information is also drawn from the Otago Regional Council's long-term state of the environment monitoring sites, principally those located at Stonehenge (Hores Bridge) and Halls Bridge.

Figure 1.1 The Taieri River below Waipiata

1.1 Aims and Objectives

The principal aim of this report was to assess water quality in the upper Taieri River catchment. Specific objectives included:

- To determine the state (health) of water quality in the upper Taieri River catchment through comparison of water quality data against the Australia and New Zealand Conservation Council Water Quality Guidelines (2000).
- To examine spatial and temporal trends in water quality in the upper Taieri River catchment.
- To identify sites that are of poor water quality and attempt to identify the causes of water quality problems.

2 Background Information

2.1 Catchment Description

The Taieri River originates in the rolling tussock tops of the Lammermoor and Lammerlaw Ranges in Central Otago at an altitude of almost 1,200 m. The river then flows through the semi-arid Styx and Maniototo Basins, west of the Rock and Pillar Range. At the southern end of this range is the man-made Logan Burn reservoir, which forms part of the Combined Maniototo Irrigation and Hydroelectric Scheme. A secondary reservoir for this scheme is located near Paerau.

The Taieri River meanders extensively through large “scroll plains” in the Maniototo. These and associated oxbows and wetlands are dominant, unique and scientifically important features of the upper Taieri River catchment. Several small tributaries feed into the upper Taieri River including the Sow Burn, Pig Burn, Wether Burn (or Gimmer Burn) and the Ewe Burn. Downstream of these reaches, the Taieri River is met by further tributaries carrying discharges of treated wastewater from the townships of Naseby and Ranfurly. Beyond the northern end of the Rock and Pillar Range and below Waipiata, the Kye Burn flows into the Taieri River. This tributary often contributes high levels of fine sediment to the river which may be in part due to historic gold mining activities in the Kye Burn catchment (Otago Regional Council 1999).

Sheep and beef farming are the predominant land uses in the upper reaches of the Taieri River although high intensity dairy farming has recently been introduced. The predominant dairying areas are located adjacent to the Taieri River at Puketoi and Helenslea and in the lower reaches of the Pig Burn and Ewe Burn.

The upper Taieri River is popular for fishing and several reaches, including Stonehenge, provide high quality habitats for both native and salmonid fisheries (Otago Regional Council 2000). Several irrigation scheme reservoirs in the Maniototo area are also stocked with trout and have produced locally important fisheries.

Despite being a dry area, there is some potential for the river to flood in the upper catchment. As a result, willow clearing and channel modifications were undertaken in the 1980s between Stonehenge and Waipiata as part of the “Upper Taieri Channel Improvement Scheme” (Otago Regional Council 1999).

2.2 Physico-chemical and Microbiological Water Quality Monitoring

The Otago Regional Council has monitored physico-chemical and microbiological water quality in the upper Taieri River catchment since the mid 1990s. Water samples are typically collected at two-monthly intervals and tested for a variety of parameters, including dissolved oxygen, temperature, pH, conductivity, visual clarity, turbidity, suspended solids, nutrients and faecal bacteria. Current routine state of the environment (SOE) monitoring sites include the Taieri River at Stonehenge (Hores Bridge) and Halls Bridge and the Pig Burn at O’Neill Road. The Taieri River at Waipiata was also recently added to the list of SOE monitoring sites. In addition, a number of tributaries have been monitored intermittently including Totara Creek (Puketoi Runs Rd), Eden Creek (Lower Gimmerburn Road), the Wether Burn (Wilson Road) and the Sow Burn (Patearoa/Styx Road).

2.3 Biological Monitoring

Biological monitoring in the upper Taieri River catchment began in 1996 at Stonehenge and Halls Bridge. Monitoring incorporates analysis of the riverbed periphyton and macroinvertebrate communities and is now undertaken annually at Stonehenge and Waipiata during the summer low flow period. During 2001-2002, one-off sampling was also conducted at Creamery Road.

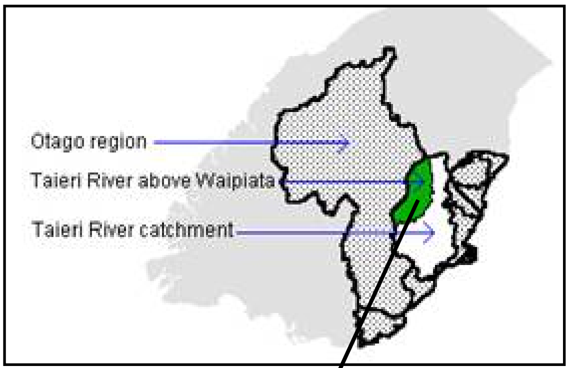
3 Study Area and Methods

3.1 Monitoring Sites

Physico-chemical and microbiological water quality monitoring was conducted at six sites on the upper Taieri River and on two tributaries, the Pig Burn and the Ewe Burn over November 2001 to December 2002 inclusive (Figure 3.1):

- Taieri River at Stonehenge (Hores Bridge)*
- Taieri River at Puketoi (Cogans Bridge)
- Taieri River at Helenslea
- Taieri River at Halls Bridge
- Taieri River at Creamery Bridge*
- Pig Burn below O'Neill Road
- Ewe Burn at Gimmerburn-Waipiata Road
- Taieri River at Waipiata (Green Bridge)*

* Also sampled for periphyton and macroinvertebrates



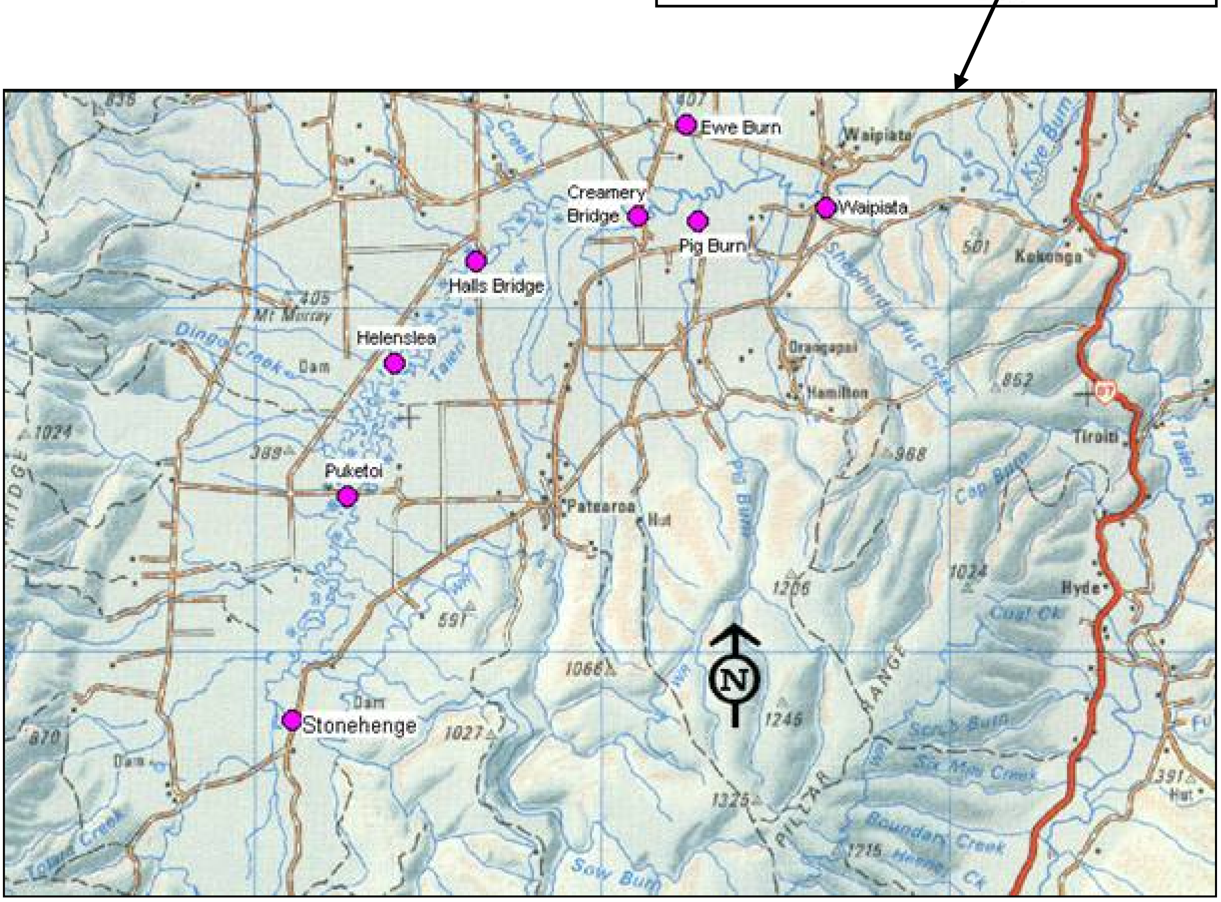


Figure 1.1 The location of physico-chemical and microbiological water quality monitoring sites sampled during November 2001 to December 2002. Periphyton and macroinvertebrate sampling was conducted at Stonehenge, Creamery Road and Waipiata.

3.1.1 Stonehenge (Hores Bridge)

Stonehenge, or Hores Bridge, is the uppermost site of the monitoring programme located immediately downstream of the Patearoa Power Station. Agricultural activity is relatively sparse above Stonehenge, making it an ideal water quality reference site. The site at Stonehenge forms part of the Otago Regional Council's state of the environment (SOE) monitoring programme for physico-chemical and microbiological water quality, and also biological monitoring. The site is characterised by its dark tannin stained waters flowing over a clean cobble bed (Figure 3.2). It is known to support a high quality macroinvertebrate fauna as well as a good population of adult brown trout.

Figure 3.2 Stonehenge sampling site, looking downstream

3.1.2 Puketoi (Cogans Bridge)

This site is located at Cogans Bridge on Puketoi-Patearoa Road below the largest dairy farm on the Maniototo (approximately 6,000 dairy cows) (Figure 3.3). The wetland boundary in this area is unfenced and pasture can be grazed right down to the river.

Figure 3.3 Puketoi sampling site, looking upstream

3.1.3 Helenslea

The sampling site at Helenslea is located approximately 600 m southeast of Wilson Road above the confluence the Taieri River with the Stot Burn (Figure 3.4). Neighbouring land is used for dairy farming. The sampling site is unfenced.

Figure 3.4 Helenslea sampling site, looking downstream

3.1.4 Halls Bridge

Halls Bridge is located approximately 200 metres below the confluence of the Taieri River with the Wether Burn and is one of the Otago Regional Council's long-term SOE physico-chemical and microbiological water quality monitoring sites. The river is quite sluggish in this reach and supports a large number of submerged macrophytes overlaying a bed of pebbles and gravel (Figure 3.5). The adjacent land is used predominantly for sheep grazing. Stock have free access to the river both upstream and downstream.

Figure 3.5 Halls Bridge sampling site, looking downstream

3.1.5 Creamery Bridge

This site is located on the Ranfurly-Patearoa Road 100 m south of the Creamery Road intersection (Figure 3.6). There is a swimming hole upstream of the bridge that is very popular with locals in the summer (refer cover photo). As with Halls Bridge, the adjacent farmland is predominantly used for sheep grazing and stock have access to the river both upstream and downstream.

Figure 3.6 Creamery Bridge sampling site, looking upstream

3.1.6 Waipiata (Green Bridge)

Waipiata is the sixth and last Taieri River sampling site and is located immediately downstream of the Green Bridge on Patearoa-Waipiata Road (Figure 3.7). This site has also been recently added to the Otago Regional Council's SOE monitoring programme for physico-chemical and microbiological water quality monitoring, and biological monitoring. It is a very popular swimming site in summer, bordered by willows on its true left bank and a large gravel bar on its true right bank. Neither bank is fenced off from stock.

Figure 3.7 Waipiata sampling site, looking downstream

3.1.7 Pig Burn

The Pig Burn was sampled approximately 900 m downstream of the Otago Regional Council's long-term SOE water quality sampling site at O'Neill Road, close to its confluence with the Taieri River. The land immediately upstream and adjacent to the sampling site is used for dairy farming. Further upstream land is grazed by sheep and beef cattle. In spring 2002 riparian fencing was erected below O'Neill Road (Figure 3.8). Prior to this time, cattle had direct access to the stream. There is no riparian fencing upstream of O'Neill Road.

The Pig Burn is subjected to large water abstractions and often runs dry or disappears underground in its upper reaches during the summer. Stream flow reappears further downstream following subsurface recharge.

The Pig Burn and other tributaries of the upper Taieri River have historically provided important spawning gravels for sports fish, notably brown trout.

Figure 3.8 The Pig Burn at O'Neill Road, looking downstream

3.1.8 Ewe Burn

The Ewe Burn was sampled at Gimmerburn-Waipiata Road close to its confluence with the Taieri River (Figure 3.9). Adjacent land has traditionally been used for sheep grazing but dairy farming is now being established in the lower reaches. Like the Pig Burn and many other tributaries, stream flows are dramatically reduced in the summer months and it is not uncommon for the Ewe Burn to run dry. Stock have access to the water above the sampling site.

Figure 3.9 The Ewe Burn sampling site, looking upstream

3.2 Sampling Frequency

Monitoring sites were initially sampled at fortnightly intervals (November 2001 to February 2002 inclusive) to obtain baseline information on water quality at each location. Sampling was then reduced to monthly intervals. The Ewe Burn was only included in the monitoring programme from July 2002.

Periphyton and macroinvertebrate samples were collected on one occasion from the Taieri River at Stonehenge, Creamery Road (above Creamery bridge) and Waipiata in March 2002.

3.3 Sampling Methods

Grab (spot) sampling was conducted at all sites. Water samples were stored on ice upon collection and transported to the Otago Regional Council's contracted laboratories for analysis within 24 hours of collection. Field measurements (dissolved oxygen, temperature and conductivity) were taken using approved water quality meters.

Periphyton sampling was conducted by pooling the scrapings from three randomly selected cobbles of approximately 5 cm^2 in area. Samples were identified and the relative abundance of each different taxa assessed using methodology developed by Biggs and Kilroy (2000). Macroinvertebrate samples were collected and processed in accordance with Protocols C1 and P1 of the Ministry for the Environment's Protocol for Sampling Macroinvertebrates in Wadeable Streams (Stark *et al*. 2001). This involved sampling 0.6 – 1.0 m^2 of substrate by kick-net at each monitoring site. One sample was collected from riffle habitats at each site.

3.4 Monitoring Analytes

Water samples were tested for a range of physico-chemical and microbiological parameters.

These included dissolved oxygen, temperature, conductivity, pH, horizontal black disc (clarity), suspended solids, turbidity, faecal coliforms, *Escherichia coli (E. coli*), ammoniacal nitrogen, nitrite-nitrate nitrogen, total nitrogen, dissolved reactive phosphorus and total phosphorus. 5-day biochemical oxygen demand (BOD) was also tested during the first seven months of sampling. Following a review of the results in June 2002, BOD testing was then only retained for samples collected from the Taieri River at Puketoi, the Pig Burn and the Ewe Burn. Due to sampling time constraints, black disc clarity measurements ceased in the Pig Burn in July 2002 and no measurements were taken in the Ewe Burn.

3.5 Data Analysis

Summary statistics were tabulated for all water quality data with non-detect values taken as being half the detection limit (e.g., a result reported as <0.1 g/m^3 is taken as 0.05 g/m^3). Median results were graphed by site for all water quality analytes. Time series plots were used to illustrate the results over the course of the 14-month monitoring programme. The raw results are presented in Appendix 1.

Statistical analyses were also performed to compare the results between Taieri River monitoring sites. As the data did not conform to the statistical assumptions of the Analysis of Variance (ANOVA), one-sided Kruskal-Wallis and Mann Whitney (Wilcoxin) tests were used to determine whether differences in median results between monitoring sites were significant, using a significance level (p) of 0.05. The output of these tests is presented in Appendix 2 and the conclusions are presented in Section 4.

4 Results

A summary of physico-chemical and microbiological water quality results for the upper Taieri River catchment programme is presented in both tabular and graphical form in this section. Periphyton and macroinvertebrate sampling results are also presented.

Table 4.1 summarises the minimum, median (middle) and maximum results for each monitoring site. The *median* results of key water quality analytes are compared against the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000). The guidelines set default trigger values for slightly disturbed (modified) upland[1] river ecosystems in New Zealand. Exceedances of the trigger values are an ‘early warning’ mechanism to alert attention to resource managers of a potential problem or emerging change that should be followed up. Therefore exceedances do not necessarily mean an adverse environmental effect would result, but that the exceedance should “trigger” further investigation (ANZECC 2000).

The ANZECC 2000 Guidelines emphasise that the best reference conditions are set by locally appropriate data. The guidelines therefore recommend deriving *site-specific* trigger values for different catchments where possible using water quality data from an appropriate reference site. The guidelines recommend that a minimum of two years of water quality results from continuous monthly sampling (24 samples) be used to develop site specific guidelines. A trigger for further action is deemed to have occurred when the *median* concentration of *n* independent samples taken at a test site exceeds the 80th percentile of the same indicator at a suitably chosen reference site (ANZECC 2000).

The Taieri River at Stonehenge provides a suitable reference site for the upper Taieri River catchment and there are more than eight years of monitoring data available from which to assess water quality. As Stonehenge has only been sampled at two-monthly intervals under the SOE monitoring programme, it was necessary to draw on data gathered over a greater time period than two years so as to obtain a sufficient number of samples on which to derive trigger values; 16 December 1997 to November 2001 (26 samples). Note that data collected during the catchment monitoring programme over the last 14 months was excluded to avoid bias as a result of the increased sampling frequency over this period.

The ANZECC 2000 default and site-specific trigger values are presented in Table 4.1 and discussed by analyte below. For simplicity and to enable the Stonehenge data to be assessed against water quality guidelines, only exceedances of the *default* trigger values are highlighted in Table 4.1. The exception is pH where all Taieri River data need to be compared against the site-specific trigger value (refer Section 4.2).

[1] Where upland rivers are defined as those at >150 m altitude.

Table 4.1 Summary water quality data for the upper Taieri River catchment monitoring sites, November 2001 to December 2002 inclusive – exceedances of ANZECC 2000 default trigger values shown in bold type

	Temperature (^{o}C)			Dissolved Oxygen (g/m^3)			pH			Suspended Solids (g/m^3)			Turbidity (NTU)			Clarity (m)			Conductivity (mS/cm)			Faecal Coliforms (cfu/100 ml)			*E. coli* (MPN/100 ml)		
ANZECC 2000 Default Trigger Value†	***No guideline***			***No guideline***			***7.3-8.0***			***No guideline***			***<4.1***			***>0.6***			***No guideline***			***<100 cfu/100 ml for stockwater***			***<126 E.coli/100 ml for bathing‡***		
ANZECC 2000 Site-Specific Trigger Value††	***N/A (seasonally dependant)***			***9.7-12.4***			***6.6-7.2***			***<3***			***<2.1***			***>1.25***			***-***								
	Median	**Range**	***n***	**Median**	**Range**	***n***	**Median**	**Range**	***n***	**Median**	**Range**	***n***	**Median**	**Range**	***n***	**Median**	**Range**	***n***	**Median**	**Range**	***n***	**Median**	**Range**	***n***	**Median**	**Range**	***n***
Taieri River																											
Stonehenge	12.0	2.0-18.0	18	10.3	5.2-13.7	18	6.8	6.4-7.6	17	2	0.5-26	17	1.4	1.1-13.6	18	1.55	0.36-2.1	17	0.030	0.023-0.061	18	82	16-520	18	61	10-490	18
Puketoi	13.9	3.0-18.5	16	9.1	4.9-12.2	16	6.7	6.3-7.5	16	4	0.5-23	16	2.3	1.5-9.7	16	1.02	0.42-1.6	12	0.049	0.029-0.078	16	**135**	8-700	16	90	6-700	16
Helenslea	13.6	2.0-18.9	15	8.9	5.0-12.8	15	6.8	6.2-7.6	15	4	0.5-15	15	2.2	1.2-7.5	15	1.18	0.64-2.3	14	0.056	0.031-0.090	15	**140**	24-780	15	120	12-730	15
Halls Bridge	13.2	2.0-19.6	18	9.7	4.8-12.4	18	6.9	6.3-7.9	18	1	0.5-9	18	2.2	1.3-7.4	18	1.25	0.53-2.6	17	0.059	0.034-0.094	18	**255**	29-10,800	16	**195**	20-10,800	16
Creamery Bridge	14.5	2.0-18.1	16	9.7	4.4-12.5	16	6.9	6.2-7.3	16	9	0.5-39	16	3.2	1.6-19.9	16	0.82	0.44-2.1	15	0.063	0.035-0.092	16	**210**	26-8,100	18	**150**	26-8,100	18
Waipiata	14.7	2.0-17.8	15	8.8	4.1-12.8	15	6.9	6.4-7.4	16	11.5	0.5-31	16	3.7	2.2-17.2	16	0.88	0.35-1.8	14	0.083	0.044-0.110	15	**355**	12-10,100	16	**305**	11-10,100	16
Pig Burn																											
900 m below O'Neill Rd	12.5	1.5-18.1	16	10.2	5.1-13.4	16	7.2	6.7-7.7	16	8	0.5-43	15	3.1	1.3-13.0	16	1.40	0.24-2.3	9	0.095	0.061-0.177	16	**560**	8-13,300	16	**355**	6-13,300	16
Ewe Burn																											
Gimmerburn-Waipiata Rd*	10.4	5-13.5	6	12.4	11.4-14.0	6	7.6	7.0-8.8	6	5.5	1-13	6	2.9	1.0-14.0	6	-	-	-	0.114	0.050-0.197	6	**205**	5-3,300	6	**130**	130-2,000	6

† Default trigger values for physical and chemical stressors in "slightly disturbed" upland ecosystems in New Zealand, Tables 3.3.10-3.3.11
†† Site–specific trigger values (ANZECC 2000), using 80th percentile water quality data for Stonehenge over Dec 1997-Nov 2001
‡ Interim Acceptable/Green Mode for freshwater recreational areas, Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (Ministry of Environment/Ministry of Health 2002) – applies to the summer bathing season
* Only added to the monitoring programme in July 2002

	BOD (g/m^3)			Nitrite-Nitrate Nitrogen (g/m^3)			Ammoniacal Nitrogen (g/m^3)			Total Nitrogen (g/m^3)			Dissolved Reactive Phosphorus (g/m^3)			Total Phosphorus (g/m^3)		
ANZECC 2000 Default Trigger Value†	***No guideline***			***<0.167***			***<0.010***			***<0.295***			***<0.009***			***<0.026***		
ANZECC 2000 Site-Specific Trigger Value††	***<1.0***			***<0.020***			***<0.020***			***<0.340***			***<0.004***			***<0.027***		
	Median	**Range**	***n***	**Median**	**Range**	***n***	**Median**	**Range**	***n***	**Median**	**Range**	***n***	**Median**	**Range**	***n***	**Median**	**Range**	***n***
Taieri River																		
Stonehenge	0.5	0.5-1.5	12	0.010	0.002-0.022	18	0.005	0.005-0.030	18	0.280	0.210-0.800	18	0.003	0.003-0.010	18	0.013	0.005-0.118	18
Puketoi	0.5	0.5-2.0	16	0.009	0.002-0.035	16	0.008	0.005-0.004	16	**0.335**	0.260-1.310	16	0.006	0.003-0.026	16	0.026	0.005-0.098	16
Helenslea	0.5	0.5-1.0	9	0.004	0.002-0.036	15	0.005	0.005-0.030	15	**0.360**	0.270-0.520	15	0.008	0.003-0.022	15	**0.032**	0.003-0.094	15
Halls Bridge	0.5	0.5-1.0	12	0.004	0.002-0.039	18	0.005	0.005-0.003	18	**0.355**	0.250-0.630	18	**0.010**	0.003-0.053	18	**0.035**	0.006-0.171	18
Creamery Bridge	0.5	0.5-1.0	10	0.011	0.005-0.054	16	0.005	0.005-0.040	16	**0.345**	0.250-0.720	16	**0.011**	0.003-0.069	16	**0.048**	0.003-0.201	16
Waipiata	0.5	0.5-1.0	10	0.012	0.002-0.071	16	**0.010**	0.005-0.040	16	**0.365**	0.270-0.710	16	**0.010**	0.003-0.060	16	**0.043**	0.011-0.177	16
Pig Burn																		
Below O'Neill Rd	0.5	0.5-2.0	16	0.054	0.017-0.261	16	**0.010**	0.005-0.110	16	**0.370**	0.080-1.270	16	0.003	0.003-0.019	16	0.017	0.003-0.120	16
Ewe Burn																		
Gimmerburn-Waipiata Rd*	0.8	0.5-1.0	6	0.031	0.018-0.086	6	**0.010**	0.005-0.360	6	**0.355**	0.260-0.430	6	**0.010**	0.003-0.023	5	**0.048**	0.003-0.073	6

† Default trigger values for physical and chemical stressors in "slightly disturbed" upland ecosystems in New Zealand, Tables 3.3.10-3.3.11
†† Site–specific trigger values (ANZECC 2000), using 80th percentile water quality data for Stonehenge over Dec 1997-Nov 2001

* Only added to the monitoring programme in July 2002

4.1 Water Temperature and Dissolved Oxygen

4.1.1 Definition and Significance

Water temperature has a substantial effect on the functioning of aquatic ecosystems and the physiology of biota, including cell function, enzyme activity, bacteriological reproduction rates, and plant growth rates. Temperature also influences dissolved oxygen concentrations (the higher the temperature, the lower the oxygen concentration) and can affect the toxicity of certain chemicals such as ammonia.

Dissolved oxygen refers to the amount of oxygen dissolved in the water and is essential for aquatic life. Dissolved oxygen concentrations are reduced by organic matter in the water (e.g., sewage), as bacteria require oxygen to break organic matter down (refer Section 4.5).

Both temperature and dissolved oxygen exhibit large diurnal fluctuations, with the lowest temperatures and oxygen concentrations generally recorded at night and early morning (respectively). Dissolved oxygen concentrations also vary with season, in response to changes in aquatic plant growth.

4.1.2 Guidelines

There are no guidelines for temperature other than a requirement in the Third Schedule of the Resource Management Act (RMA) 1991 that discharges into water bodies should not change the water temperature by more than $3^{o}C$. Similarly there are no standards for dissolved oxygen although it is generally accepted that absolute concentrations should remain above 6.5 g/m^3 to maintain a healthy aquatic ecosystem. Concentrations less than 5 g/m^3 adversely affect trout and levels of 2-3 g/m^3 may result in fish kills. The ANZECC 2000 Guidelines stipulate that dissolved oxygen concentrations, expressed as percentage saturation, should be within the range 99-103% in upland waters. The “bottom-line” in the Third Schedule of the RMA is that the concentration of dissolved oxygen should not fall below 80% saturation and this is the critical trigger value used in this report.

4.1.3 Results

Median water temperature values in the Taieri River increased with distance downstream between Stonehenge and Waipiata while median dissolved oxygen concentrations decreased (Table 4.1). These “trends” could be partially a product of the sampling programme given that the uppermost monitoring sites at Stonehenge and Puketoi were sampled earlier in the day (i.e., cooler conditions) than those located further downstream (e.g., Waipiata). Dissolved oxygen concentrations at all monitoring sites remained above 6.5 g/m^3.

Absolute concentrations were converted to percentage saturation data to remove the influence of temperature on the results and thereby allow an assessment to be made of differences in dissolved oxygen concentrations between sites. The results indicate that there definitely is a decrease in median Taieri River dissolved oxygen concentrations (expressed as percentage saturation) with distance downstream from Stonehenge (Table 4.2). Statistical analysis indicated that the median values at Puketoi, Helenslea and Waipiata were significantly lower than the median value recorded at Stonehenge. Despite this, the median values were well above 80% saturation at all monitoring sites (Figure 4.1).

Table 4.2 Summary dissolved oxygen data for the upper Taieri River catchment monitoring sites, November 2001-December 2002

	Dissolved Oxygen (% saturation)		
Critical Value (Third Schedule, RMA 1991)	***80***		
	Median	**Range**	***n***
Taieri River			
Stonehenge	98	80.5-112	18
Puketoi	90	77-106	16
Helenslea	88	75-108	15
Halls Bridge	89	77-114	18
Creamery Bridge	92	80.5-127	16
Waipiata	91	72-102.5	14
Pig Burn			
900 m below O'Neill Rd	98	79-108	15
Ewe Burn			
Gimmerburn-Waipiata Rd*	113	101-125	6

* Only added to the monitoring programme in July 2002

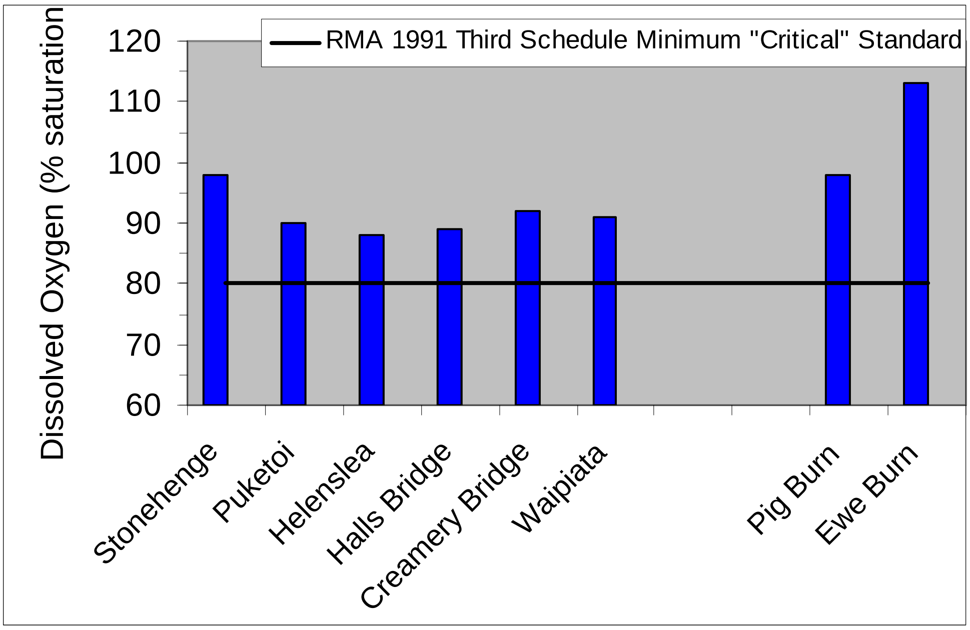


Figure 4.1 Median dissolved oxygen levels (expressed as percentage saturation), recorded at each monitoring site over November 2001 to December 2002 inclusive

Dissolved oxygen concentrations were highest in the tributaries, especially the Ewe Burn which recorded a median concentration of 113%. The reason for such a high median result is unclear but caution should be exercised given that this value was derived from just six sample results. A saturation greater than 100% can indicate the effect of aquatic plants photosynthesising in daylight.

4.2 pH

4.2.1 Definition and Significance

The measurement of pH is related to the hydrogen ion concentration in a water body. All aquatic organisms have pH optima for cell functioning. pH also influences many chemical reactions and can affect the toxicity of contaminants such as ammonia and heavy metals. pH is measured on a logarithmic scale ranging from 1 (strongly acidic) to 14 (strongly alkaline). New Zealand streams are generally slightly alkaline with most streams having a pH between 7.5 and 8.5 (Close and Davies-Colley 1990).

4.2.2 Guidelines

It is generally accepted that the pH of fresh waters should not vary beyond the range 6.5 to 9.0 (ANZECC 1992) although the ANZECC 2000 guidelines suggest a more restricted range of 7.3 to 8.0 for upland rivers. The latter range is not considered appropriate for the upper Taieri River catchment which drains numerous bogs and wetlands rich in natural organic acids (e.g., tannic, humic, and uronic acids). The effects of these acidic substances on pH are buffered to some extent from the local calcite and schist geology, resulting in only weakly acidic water in the upper Taieri River.

4.2.3 Results

All pH values recorded during the study period were within the expected range of 6.5 to 9. All Taieri River median values were below pH 7 and there were no significant differences in median values between Taieri River monitoring sites. Both the Pig Burn and Ewe Burn recorded higher pH values that were closer to those recorded in most New Zealand streams (Figure 4.2).

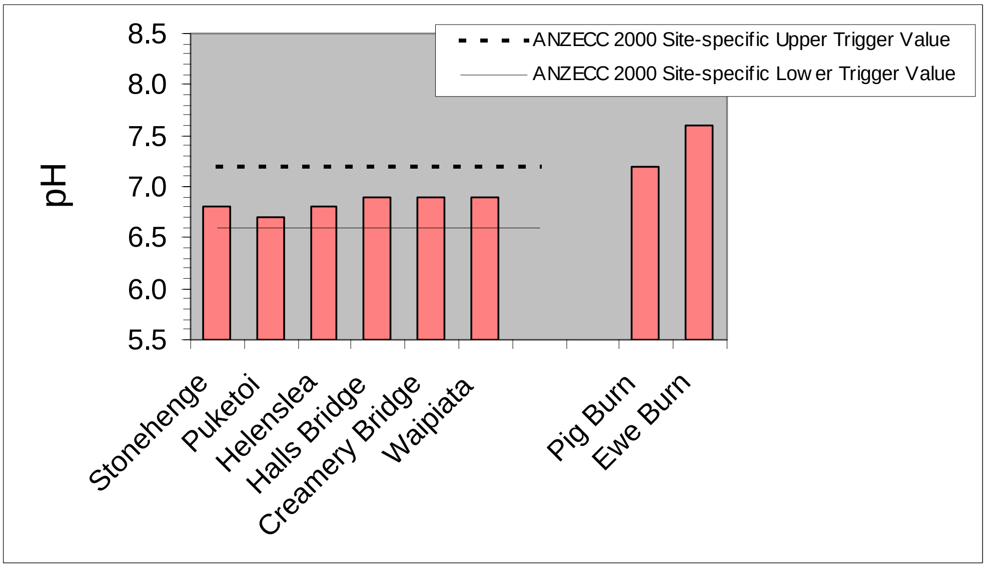


Figure 4.2 Median pH measurements recorded at each monitoring site over November 2001 to December 2002 inclusive, along with ANZECC 2000 site-specific (Taieri River at Stonehenge) trigger values for slightly disturbed upland aquatic ecosystems

Otago Regional Council

4.3 Suspended Sediment, Turbidity and Clarity

4.3.1 Definition and Significance

Suspended sediment, turbidity and clarity are all interrelated. Suspended sediment (referred to here as suspended solids) is a measure of soil and other solid material suspended in the water column. As such it indicates the potential for sedimentation from the water column which may have a range of adverse effects on aquatic flora and fauna. Such effects include the smothering of habitat, abrasion (e.g., clogging of fish gills) and reduction of light penetration and food quality.

Turbidity is an optical property of water where suspended and dissolved materials cause light to be scattered and absorbed. Informally turbidity is synonymous with “cloudiness” and indicates aesthetics and the ability of light to reach the streambed.

Clarity is a measure of the transmission of light through water. It is similar to turbidity but gives a horizontal distance able to be seen through the water. Clarity is measured using a “Black Disc” and is affected by both suspended solids and dissolved coloured substances.

For most rivers, the concentration of suspended solids is positively correlated with turbidity, with both suspended sediment concentration and turbidity inversely correlated with visual clarity. Therefore, as suspended solid concentrations and turbidity increase in a river, the clarity of the water decreases.

4.3.2 Guidelines

There are no guidelines for suspended sediment concentrations in water. Concentrations in clean freshwaters typically range from <1 to 5 g/m^3 although higher values can occur, particularly in glacial fed waters. The ANZECC 2000 guidelines specify the following default trigger values for turbidity and visual clarity in upland freshwater rivers and streams:

- Turbidity: 4.1 NTU
- Visual Clarity: >0.6 m

The Ministry for the Environment (MfE) has also published guidelines for visual clarity (MfE 1994). These guidelines state that visual clarity affects bather preferences and stipulate that the horizontal sighting range of a black disc should exceed 1.6 m.

4.3.3 Results

There is a clear trend of increasing suspended solids and turbidity with distance downstream from Stonehenge (Figure 4.3). A statistical comparison of median values between Taieri River sites found that both Creamery Bridge and Waipiata had significantly higher suspended solid concentrations than Stonehenge, Helenslea and Halls Bridge. Waipiata also had a significantly higher median concentration than Puketoi.

All median turbidity values were below the ANZECC 2000 default trigger value of 4.1 NTU. However, median turbidity values at all Taieri River sites between Puketoi and Waipiata were significantly higher than the median level recorded at Stonehenge, reflecting the increase in suspended solids with distance downstream. Turbidity at Waipiata was also significantly

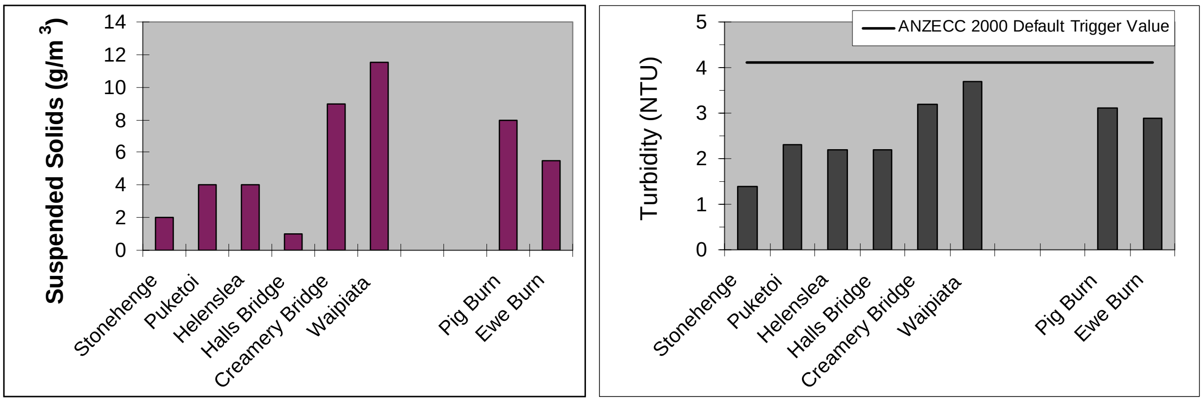


Figure 4.3 Median suspended solids and turbidity concentrations recorded at each monitoring site over November 2001 to December 2002 inclusive

higher than the median levels recorded at Puketoi, Helenslea and Halls Bridge, indicating that the water was much dirtier at this site in comparison with the other sites. High turbidity levels were also recorded at Creamery Bridge and the median value was significantly higher than that recorded one site upstream at Halls Bridge.

Clarity generally decreased with distance downstream from Stonehenge (Figure 4.4) although Puketoi recorded a lower median value than sites downstream at Helenslea and Halls Bridge. With the exception of Halls Bridge, median clarity values at all Taieri River sites were significantly lower than the median value recorded at Stonehenge. In addition, clarity was significantly lower at Creamery Bridge and Waipiata than Halls Bridge. No median clarity values were below the ANZECC 2000 minimum default trigger value of 0.6 m but there were no sites with a median result that met the MfE bathing guideline of 1.6 m.

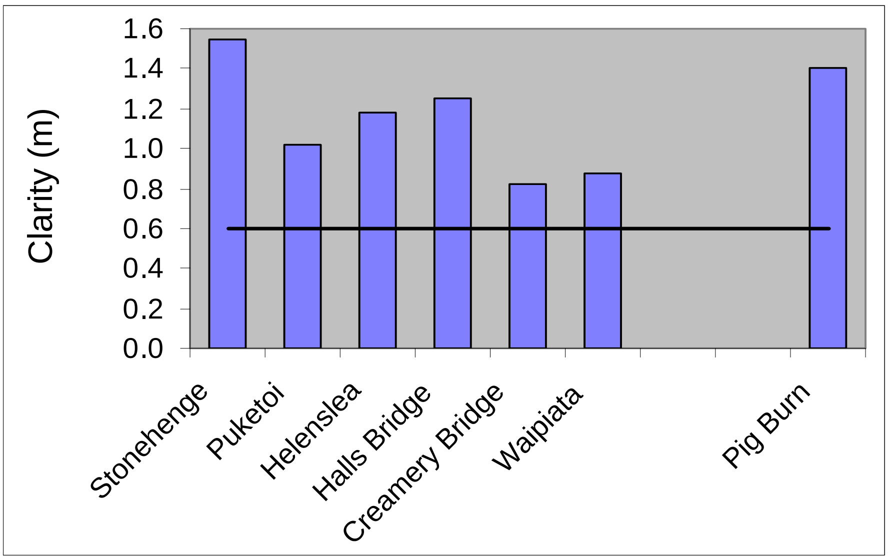


Figure 4.4 Median clarity measurements recorded at each monitoring site over November 2001 to December 2002 inclusive, along with the ANZECC 2000 default trigger value for slightly disturbed upland aquatic ecosystems
(Note: no clarity measurements were taken in the Ewe Burn)

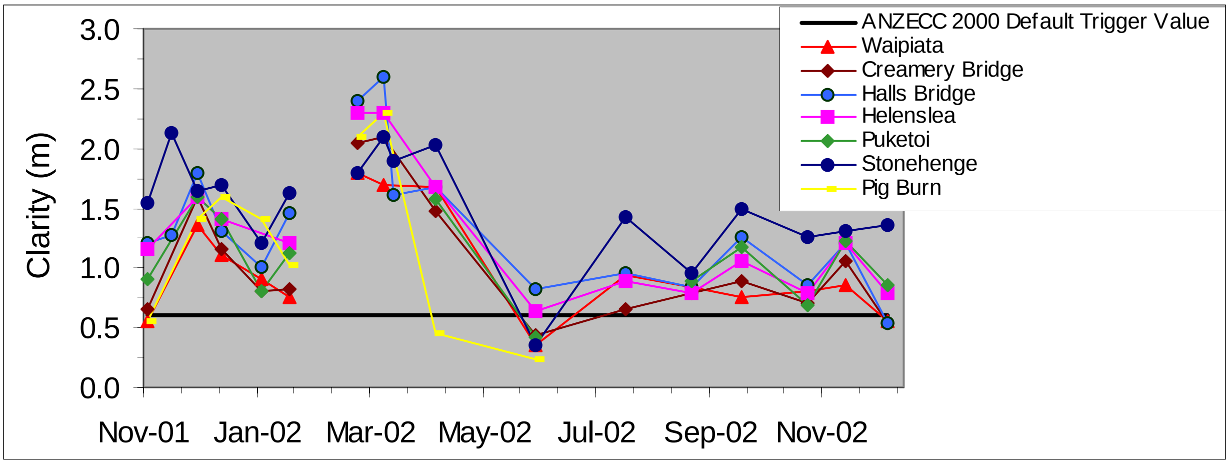


Figure 4.5 Clarity measurements recorded at each monitoring site over November 2001 to December 2002 inclusive, along with the ANZECC 2000 default trigger value for slightly disturbed upland aquatic ecosystems (Note: no clarity measurements taken in the Ewe Burn)

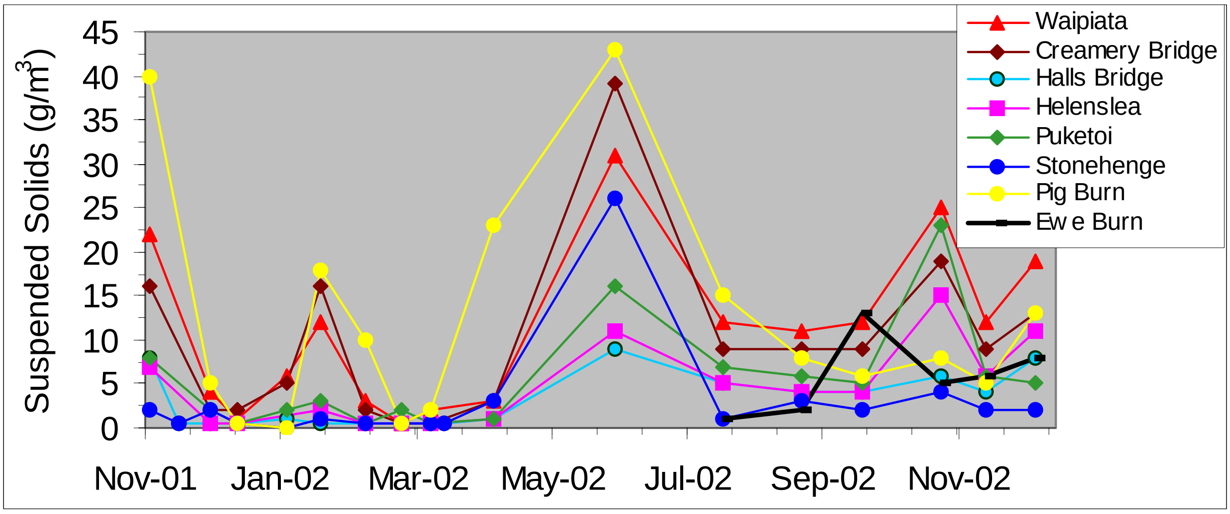


Figure 4.6 Suspended solid concentrations recorded at each monitoring site over November 2001 to December 2002 inclusive

The lowest clarity values were recorded during sampling on 5 June 2002 (Figure 4.5). This corresponded with elevated suspended solid concentrations (Figure 4.6) and turbidity values (Figure 4.7). Although no rainfall was recorded in the Otago Regional Council rain gauge at Pat-Paerau in the week prior to sampling (Appendix 3), river flows were starting to climb in response to snowmelt (Figure 4.8).

Very high turbidity measurements were recorded in the Pig Burn on 7 November 2001, 12 February 2002 and 11 April 2002 when measurements at all other monitoring sites were low (Figure 4.7). Dairy cows were observed in the creek and/or a tributary on these three sampling occasions. The highest turbidity value recorded in the Ewe Burn was 14 NTU on 24 September 2002. The creek had a slightly milky discolouration at the time of sampling.

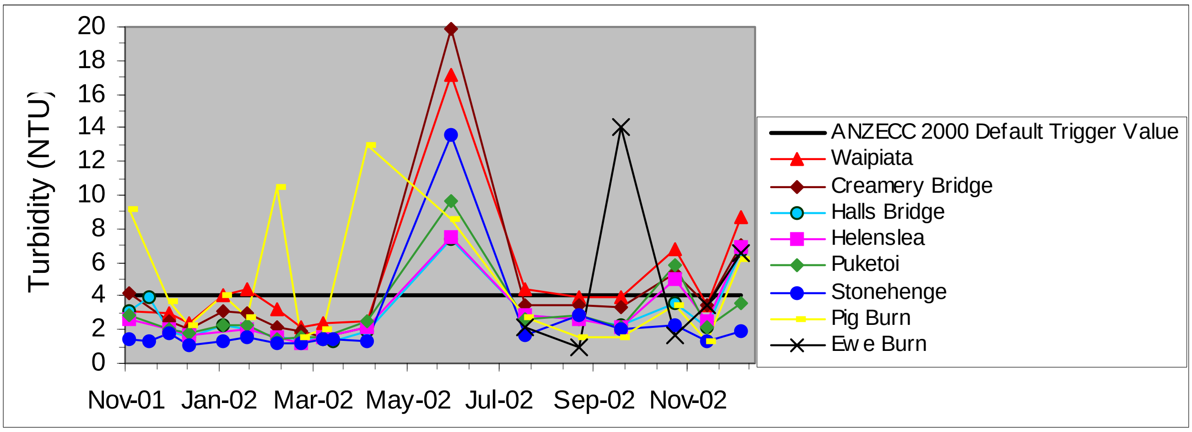


Figure 4.7 Turbidity measurements recorded at each monitoring site over November 2001 to December 2002 inclusive, along with the ANZECC 2000 default trigger value for slightly disturbed upland aquatic ecosystems

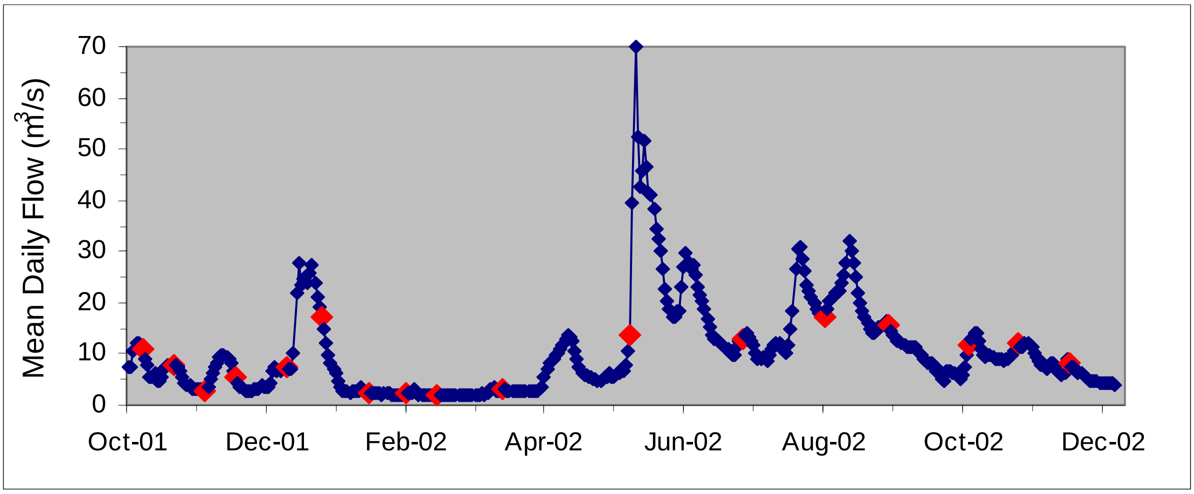


Figure 4.8 Mean daily flows recorded in the Taieri River at Waipiata over November 2001 to December 2002 inclusive, with the flows on sampling days denoted by a red diamond

4.4 Conductivity

4.4.1 Definition and Significance

Conductivity refers to the ability of water to conduct electricity. This gives an indication of the mineral content of the water. The lower the value, the purer the water is. Wastewater and effluents therefore have higher concentrations of minerals than natural water and a large increase in the conductivity in a water body can often be traced back to waste discharges.

4.4.2 Guidelines

There are no guidelines for conductivity concentrations in water. Concentrations in freshwaters typically range from 0.02 to 0.15 mS/cm although higher values can occur, particularly where there is a significant groundwater or wastewater input.

4.4.3 Results

Median Taieri River conductivity concentrations increased with distance downstream of Stonehenge (Figure 4.9). All median concentrations between Puketoi and Waipiata were significantly higher than the median concentration of 0.030 mS/cm recorded at Stonehenge and median concentrations at all sites below Helenslea were also significantly higher than the median value recorded at Puketoi. The median value at Waipiata (0.083 mS/cm) was significantly higher than that recorded at all five upstream sites, indicating that the increase with distance downstream is quite marked.

The highest conductivity concentrations were recorded in the Pig Burn and Ewe Burn (Figure 4.10). Peaks at these sites only partially correlated with peaks in the Taieri River monitoring sites.

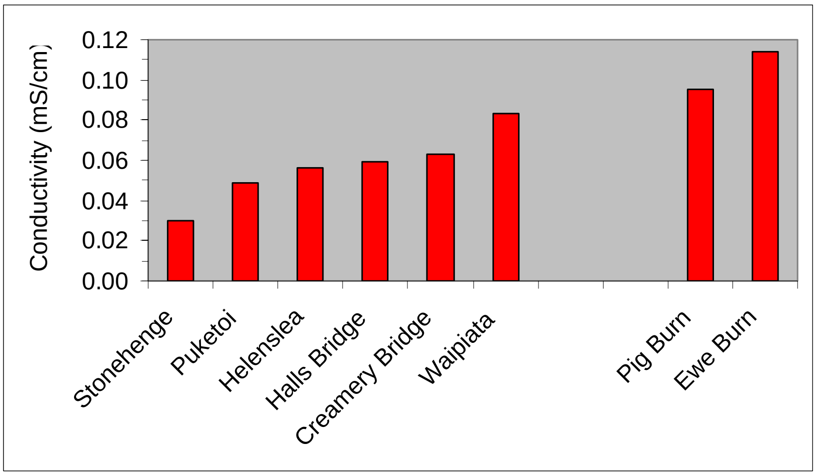


Figure 4.9 Median conductivity concentrations recorded at each monitoring site over November 2001 to December 2002 inclusive

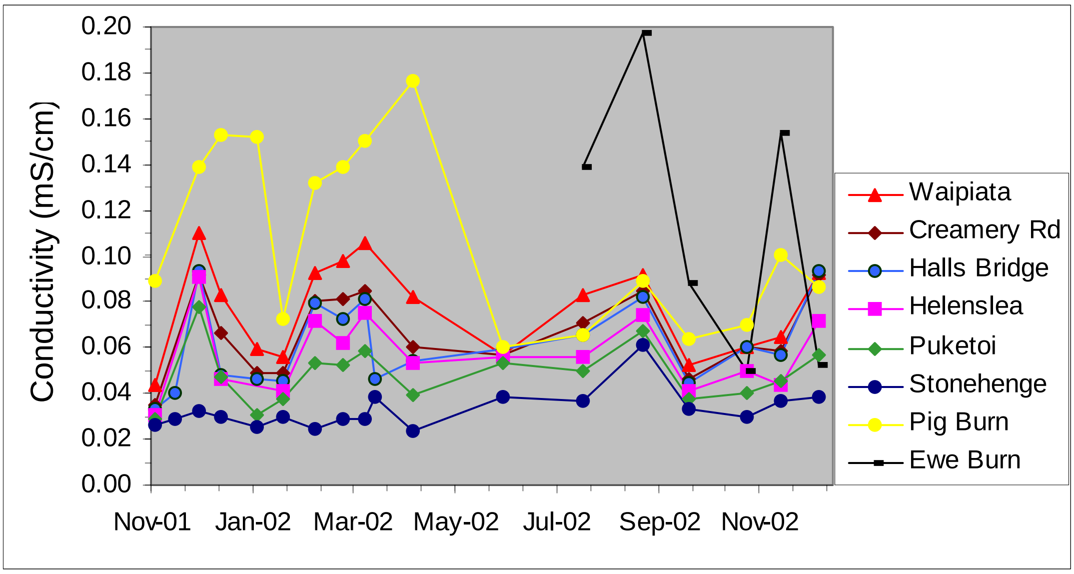


Figure 4.10 Conductivity concentrations recorded at each monitoring site over November 2001 to December 2002 inclusive

4.5 Biochemical Oxygen Demand (BOD)

4.5.1 Definition and Significance

BOD provides a measure of the oxygen required by bacteria, under standard conditions, to oxidise carbonaceous organic material into a stable inorganic form. It therefore indicates the amount of biodegradable organic matter present in the water, and the potential for bacteria to deplete oxygen concentrations. Waste matter rich in organic matter such as dairy shed and piggery effluent has very high BOD values and so can rapidly deplete oxygen levels when discharged into water.

4.5.2 Guidelines

There is no guideline for BOD in the ANZECC 2000 water quality guidelines. A guideline of 2 g/m^3 has been specified to avoid undesirable biological growths in water (MfE 1992). Concentrations in unpolluted waters are always less than this.

4.5.3 Results

Median BOD concentrations were below detection at all sampling sites and on the majority of sampling occasions BOD was not detected. On all other occasions, concentrations were at the detection limit (1 g/m^3), the exception being the Taieri River at Puketoi and the Pig Burn on two occasions where concentrations of 2 g/m^3 were recorded (Figure 4.11). For this reason, BOD testing ceased at most sites after the June 2002 sampling round.

4.6 Nitrogen and Phosphorus

4.6.1 Definition and Significance

Nitrogen and phosphorus are vital elements for aquatic plant and algal growth which in turn provide food for the invertebrate and vertebrates that live in or are associated with the water. These elements may be limiting factors in plant growth when in short supply but in sufficient quantities they may also promote unsightly algal blooms and nuisance macrophyte growth. Excessive proliferations of both algae and aquatic plants can choke waterways, reducing their drainage capacity, and amenity and fishery values (Robertson Ryder & Associates 1995).

Both nitrogen and phosphorus are found in a number of different chemical forms, however the principal forms available to plants are those that are soluble. For this reason dissolved inorganic nutrient concentrations are most relevant for predicting the potential for nuisance periphyton and macrophyte growths. These forms include ammoniacal nitrogen and nitrite-nitrate nitrogen (collectively referred to as dissolved inorganic nitrogen) and dissolved reactive phosphorus. Total nutrient concentrations are also relevant in surface waters, because particulate matter can settle out in quiescent areas and become biologically available to plants via mineralisation (Ministry for the Environment 1992).

Ammoniacal nitrogen is comprised of ammonium (NH_{4+}) and unionzied ammonia (NH_3). Ammonia is rarely found in any significant amounts in natural waters and its presence most commonly indicates the presence of domestic, agricultural or industrial effluent. Ammonia is very soluble in water and can be toxic to aquatic life, especially fish. Toxicity is a function of both temperature and pH, with toxicity increasing with increasing water temperature and alkalinity (ANZECC 2000).

4.6.2 Guidelines

The ANZECC 2000 water quality guidelines specify the following default trigger values for dissolved and total nutrients in upland freshwater rivers and streams:

- Ammonical nitrogen: 0.010 g/m^3
- Nitrite-nitrate nitrogen: 0.167 g/m^3
- Total nitrogen: 0.295 g/m^3
- Dissolved reactive phosphorus: 0.009 g/m^3
- Total phosphorus: 0.026 g/m^3

It is important to note that it can be difficult to link periphyton biomass to stream nutrient concentrations. Many plants may take up extra nutrients when concentrations are high and use them for growth later when nitrogen or phosphorus becomes limiting.

The ANZECC 2000 guidelines also specify specific toxicity trigger values for ammonia correlated with the level of protection that is assigned to a particular ecosystem. For slightly disturbed ecosystems such as the upper Taieri River, a 95% protection level can be applied. This correlates to a default trigger value of 0.9 g/m^3 as ammoniacal nitrogen at pH 8.0.

4.6.3 Results

All median ammoniacal nitrogen concentrations were below the ANZECC 2000 default trigger value of 0.010 g/m^3, except the Taieri River at Waipiata and the two tributaries (Pig Burn and Eweburn) where the median concentrations were equal to the default trigger value (Figure 4.11). The median concentration at Waipiata was significantly higher than the median concentrations recorded at Stonehenge, Helenslea and Halls Bridge.

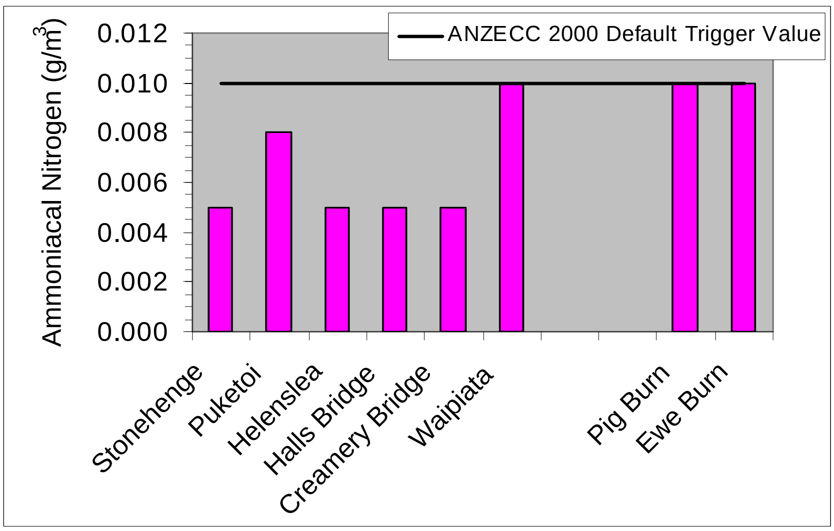


Figure 4.11 Median ammoniacal nitrogen concentrations recorded at each monitoring site over November 2001 to December 2002 inclusive, along with the ANZECC 2000 default trigger value for slightly disturbed upland aquatic ecosystems

Several ammoniacal nitrogen "spikes" were recorded during the monitoring programme (Figure 4.12). The highest of these were recorded in the Ewe Burn on 24 September 2002 (0.36 g/m^3) and in the Pig Burn on 11 April 2002 (0.11 g/m^3). Based on the pH measurement recorded at the time of sample collection, the result of 0.36 g/m^3 in the Ewe Burn exceeded the ANZECC 2000 toxicity trigger value of 0.24 g/m^3 at pH 8.8.[2]

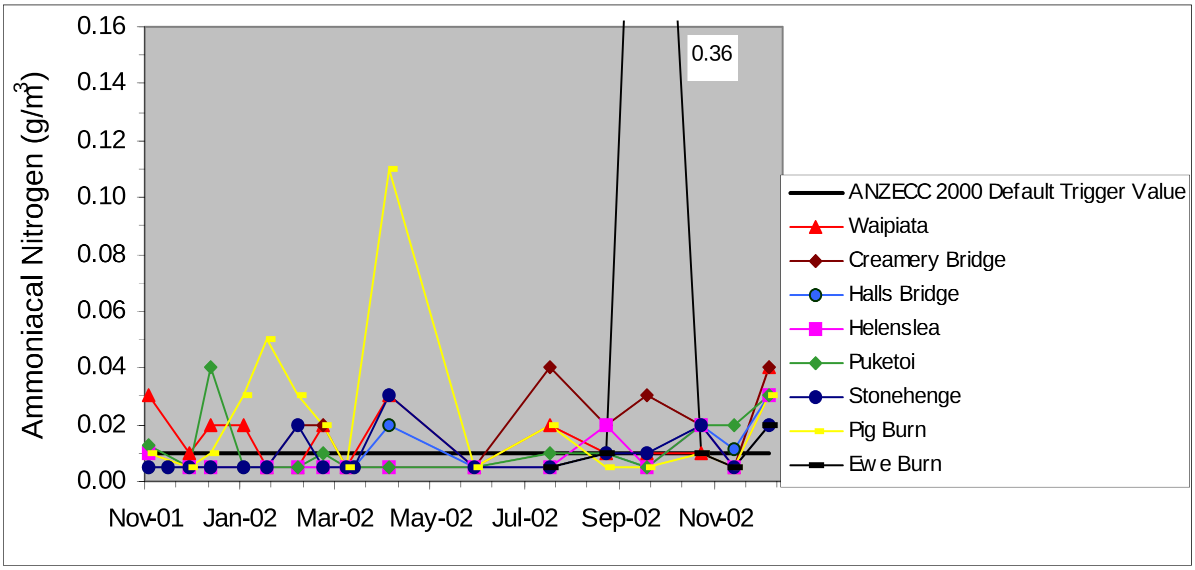


Figure 4.12 Ammoniacal nitrogen concentrations recorded at each monitoring site over November 2001 to December 2002 inclusive, along with the ANZECC 2000 default trigger value for slightly disturbed aquatic ecosystems

Median nitrite-nitrate nitrogen concentrations were below the ANZECC 2000 default trigger value of 0.167 g/m^3 at all monitoring sites. The highest median concentrations were recorded in the Pig Burn and the Ewe Burn (Figure 4.13). The lowest concentrations were recorded in

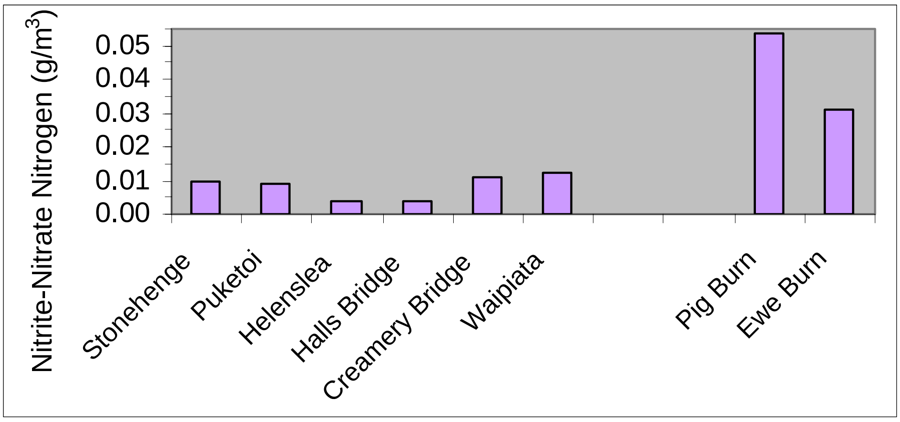


Figure 4.13 Median nitrite-nitrate nitrogen concentrations recorded at each monitoring site over November 2001 to December 2002 inclusive. The ANZECC 2000 default trigger value for slightly disturbed upland aquatic ecosystems is 0.167 g/m^3

[2] The temperature and pH measurements were 11.5°C and 8.77. The pH of 8.77 corresponds to a toxicity trigger value of 0.24 g/m^3 as per Table 8.3.7 of the ANZECC 2000 guidelines.

the Taieri River at Helenslea and Halls Bridge. The median concentrations at these two sites were significantly lower than those recorded both upstream at Stonehenge and Puketoi and downstream at Creamery Road and Waipiata.

Taieri River nitrite-nitrate nitrogen concentrations varied with season, tending to be lowest in summer and highest in winter, the exception being on 11 December 2002 when several sites recorded their highest concentrations of the monitoring programme (Figure 4.14). Concentrations in the Pig Burn were more erratic with the highest concentrations recorded during the first half of the monitoring programme.

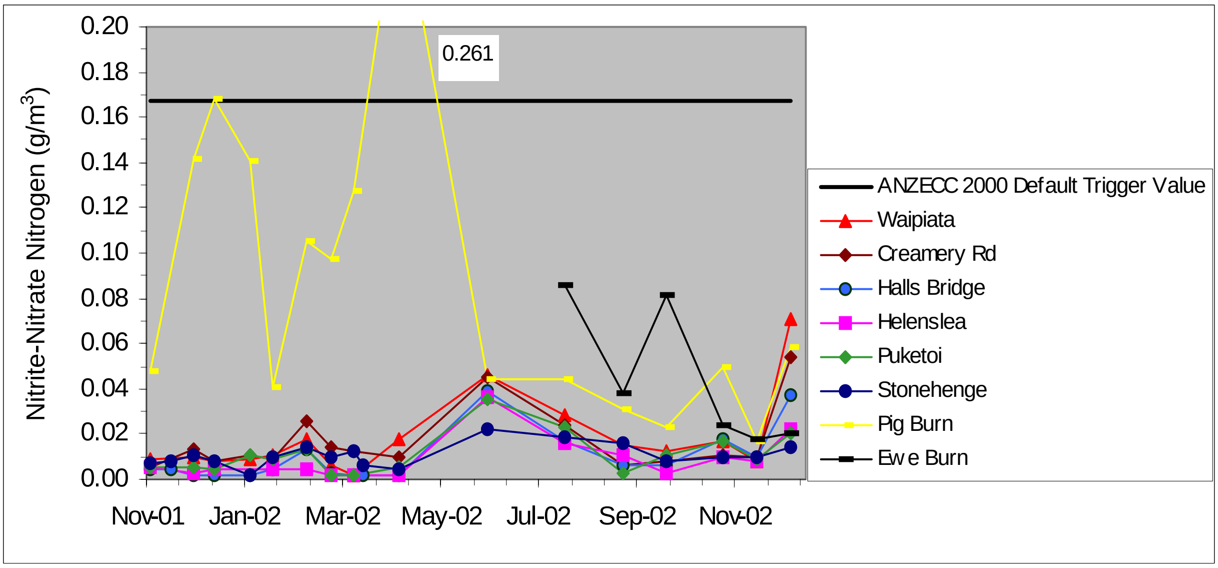


Figure 4.14 Nitrite-nitrate nitrogen concentrations recorded at each monitoring site over November 2001 to December 2002 inclusive, along with the ANZECC 2000 default trigger value for slightly disturbed upland aquatic ecosystems

Total nitrogen concentrations increased with distance downstream (Figure 4.15). Median concentrations at all five Taieri River sites between Puketoi and Waipiata were significantly higher than the median concentration recorded at Stonehenge (0.280 g/m^3), and all sites except Stonehenge exceeded the ANZECC 2000 default trigger value of 0.295 g/m^3 and the site-specific trigger value of 0.340 g/m^3.

The highest total nitrogen concentrations were recorded at most sites on 23 January 2002, 5 June 2002, 29 October 2002 and 11 December 2002 and generally coincided with rainfall events or elevated river flows (Figure 4.16). The exceptions were the Pig Burn and the Taieri River at Puketoi. These sites recorded maximum concentrations of 1.27 g/m^3 and 1.31 g/m^3 on 11 April 2002 and 24 September 2002 respectively.

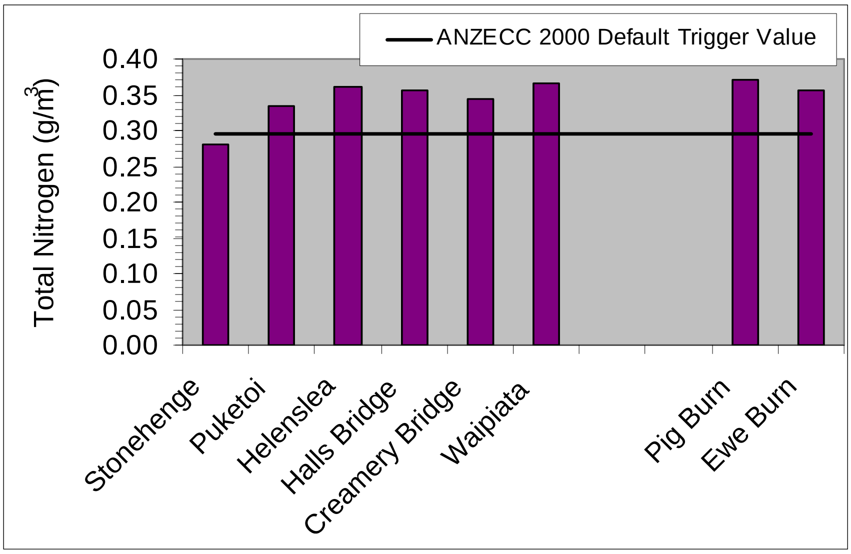


Figure 4.15 Median total nitrogen concentrations recorded at each monitoring site over November 2001 to December 2002 inclusive, along with the ANZECC 2000 default trigger value for slightly disturbed upland aquatic ecosystems

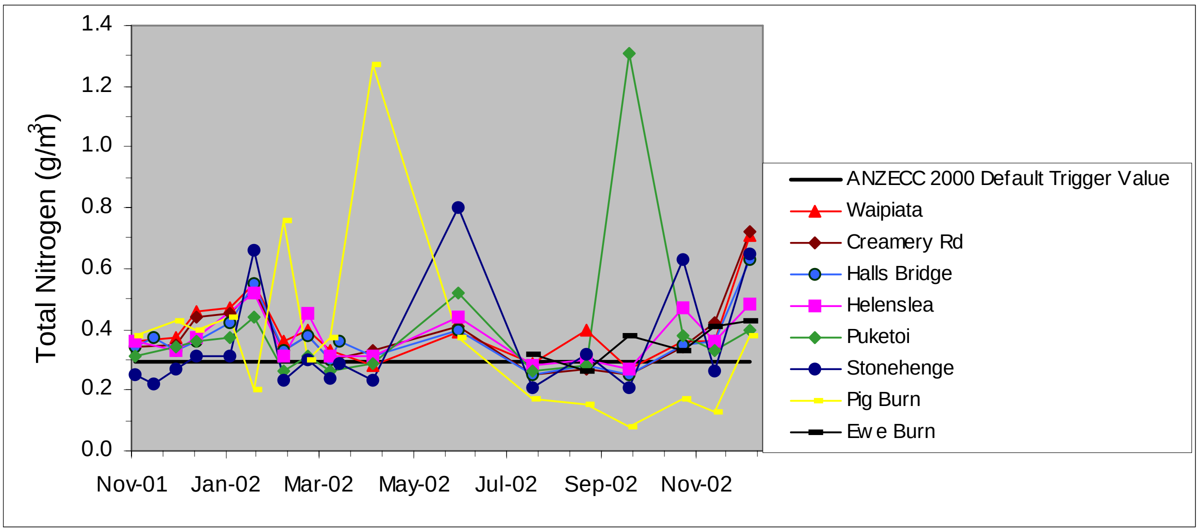


Figure 4.16 Total nitrogen concentrations recorded at each monitoring site over November 2001 to December 2002 inclusive, along with the ANZECC 2000 default trigger value for slightly disturbed upland aquatic ecosystems

Median dissolved reactive phosphorus concentrations also increased with distance downstream of Stonehenge but the increases are more marked than those for total nitrogen (Figure 4.17). All median concentrations in the Taieri River between Puketoi and Waipiata were significantly higher than the median concentration of 0.003 mS/cm recorded at Stonehenge and sites between Halls Bridge and Waipiata exceeded the ANZECC 2000 default trigger value of 0.009 g/m^3. The median concentration in the Pig Burn was only 0.003 g/m^3 while the Ewe Burn had a median concentration of 0.010 g/m^3.

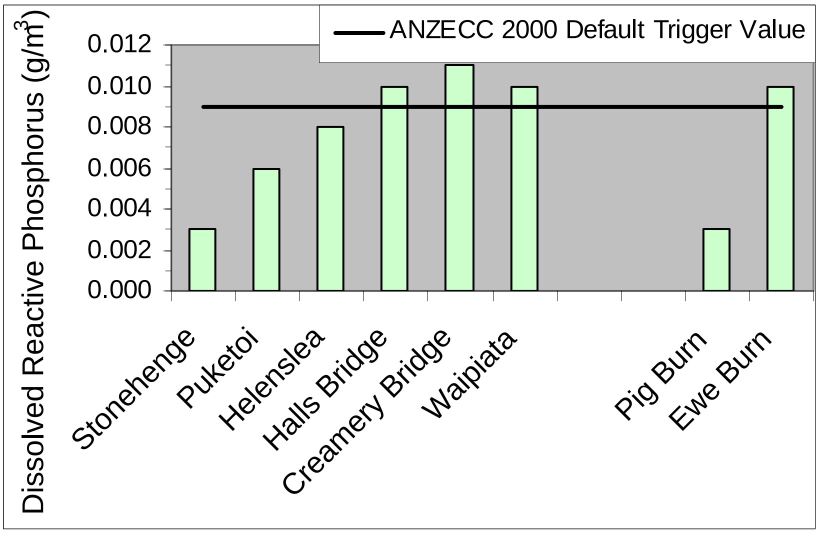


Figure 4.17 Median dissolved reactive phosphorus concentrations recorded at each monitoring site over November 2001 to December 2002 inclusive, along with the ANZECC 2000 default trigger value for slightly disturbed upland aquatic ecosystems

Like nitrite-nitrate nitrogen, dissolved reactive phosphorus concentrations varied significantly with season. However, the seasonal pattern is reversed, with the highest concentrations recorded in summer and the lowest concentrations recorded in winter (Figure 4.18).

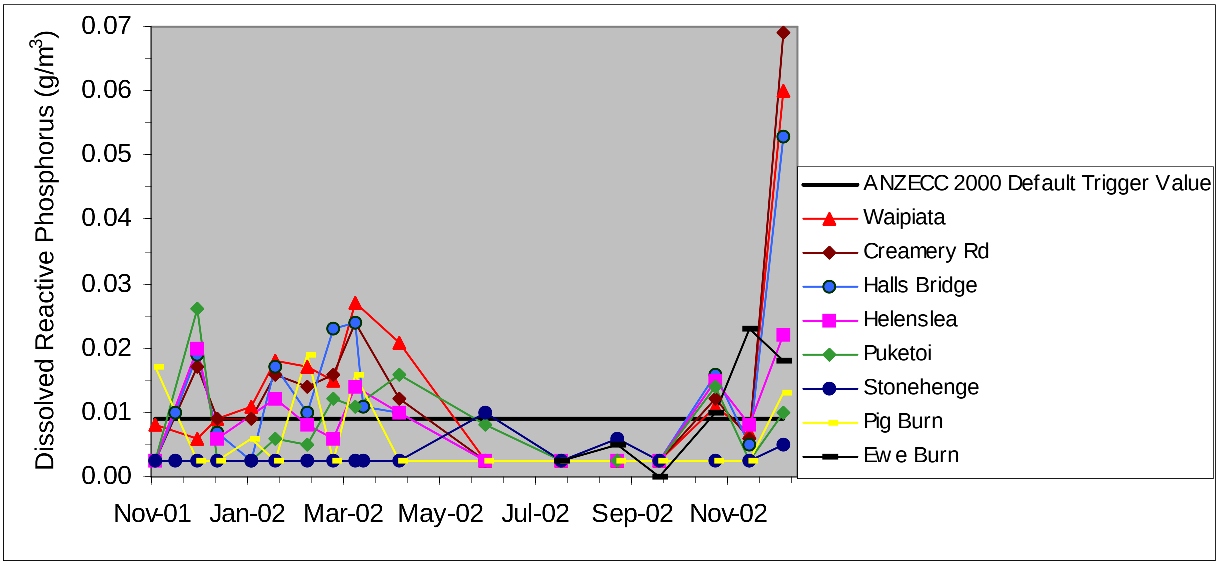


Figure 4.18 Dissolved reactive phosphorus concentrations recorded at each monitoring site over November 2001 to December 2002 inclusive, along with the ANZECC 2000 default trigger value for slightly disturbed upland aquatic ecosystems

Median total phosphorus concentrations followed the same pattern as median dissolved reactive phosphorus concentrations and increased with distance downstream (Figure 4.19). All median concentrations in the Taieri River between Puketoi and Waipiata were significantly higher than the median concentration of 0.013 mS/cm recorded at Stonehenge

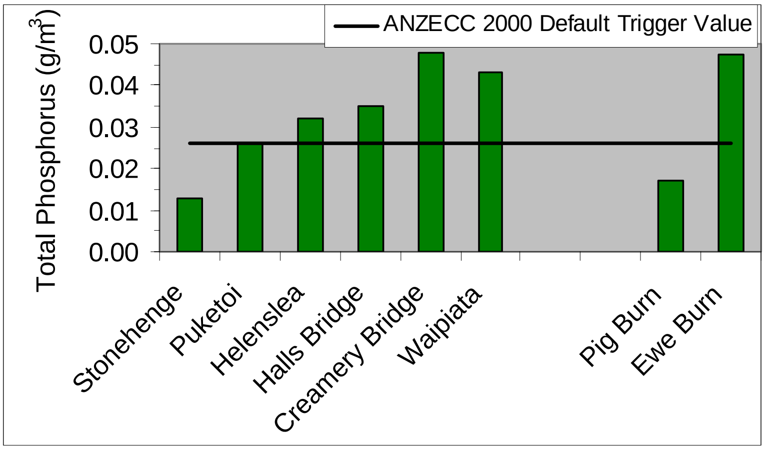


Figure 4.19 Median total phosphorus concentrations recorded at each monitoring site over November 2001 to December 2002 inclusive, along with the ANZECC 2000 default trigger value for slightly disturbed upland aquatic ecosystems

and sites between Helenslea and Waipiata exceeded the ANZECC 2000 default trigger value of 0.026 g/m^3. The median concentration in the Pig Burn was only marginally higher than that recorded at Stonehenge while the Ewe Burn had a median concentration of 0.035 g/m^3.

The highest total phosphorus concentrations were recorded during summer sampling runs, especially those following rainfall events (Figure 4.20).

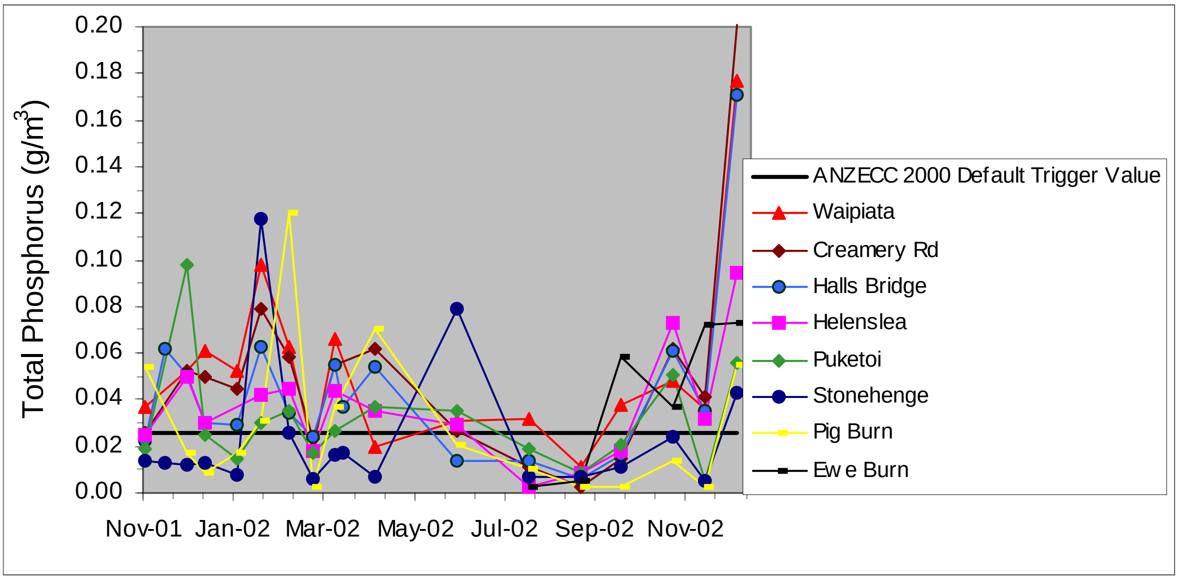


Figure 4.20 Total phosphorus concentrations recorded at each monitoring site over November 2001 to December 2002 inclusive, along with the ANZECC 2000 default trigger value for slightly disturbed upland aquatic ecosystems

4.7 Pathogens: Faecal Coliforms and *E. coli*

4.7.1 Definition and Significance

Faecal coliforms and *E. coli* are indicator bacteria associated with the gut of warm-blooded animals. Their presence in water may indicate the presence of harmful pathogens that can cause eye, ear, nose and throat infections, skin diseases, and gastrointestinal disorders. A number of parasites and pathogens can also be transmitted to stock and affect their health.

E. coli is the most specific indicator of faecal contamination and is nearly always found in high numbers in the gut of humans and warm blooded animals. *E. coli* is the preferred microbiological indicator for faecal contamination and health effects in freshwater (Ministry for the Environment/Ministry of Health 2002).

4.7.2 Guidelines

Guidelines for faecal coliform and *E. coli* in fresh waters differ depending on the use of water. The New Zealand Drinking Water Standards (Ministry of Health 1995) specify that faecal coliform concentrations in water used for human consumption should be less than 1 cfu/100 ml. However water in the upper Taieri River catchment is generally only used for irrigation, stock drinking water or contact recreation. The ANZECC 2000 guidelines specify that the concentration of faecal coliforms in irrigation waters used for pasture and fodder for grazing animals should contain less than 1,000 cfu/100 ml (ANZECC 2000). The trigger value is reduced to 100 cfu/100ml for dairy animals without a 5-day withholding period). These guidelines also state that drinking water for livestock should contain less than 100 faecal coliforms per 100 ml as a *median* value based on a number of readings over time from a regular monitoring programme. Further investigation is warranted where 20% of the results exceed four times the median trigger value.

Recreational water quality guidelines for freshwaters are still being finalised by the Ministry for the Environment. The interim guideline in the New Zealand Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (Ministry of the Environment/Ministry of Health 2002) specifies a running median of 126 *E. coli*/100 ml as the Acceptable/Green Mode for contact recreation. This is based on weekly sampling over one month during the bathing season. Additional sampling is recommended when the median exceeds 126 *E. coli*/100 ml (Alert/Amber Mode I), with daily sampling required when any single result exceeds *273 E. coli* /100 ml (Alert/Amber Mode II). Public notification and erection of warning signs are recommended where any sample result at a designated bathing area exceeds 410 *E. coli*/100 ml (Action/Red Mode).

4.7.3 Results

Both median faecal coliform and median *E. coli* bacteria concentrations increased in the Taieri River with distance downstream from Stonehenge (61 MPN/100 ml) to Waipiata (305 MPN/100 ml) (Figure 4.21 and Figure 4.22). Median concentrations at and below Halls Bridge were significantly higher than those recorded at Stonehenge and the median *E. coli* concentration at Waipiata was also significantly higher than that recorded at Puketoi and Helenslea.

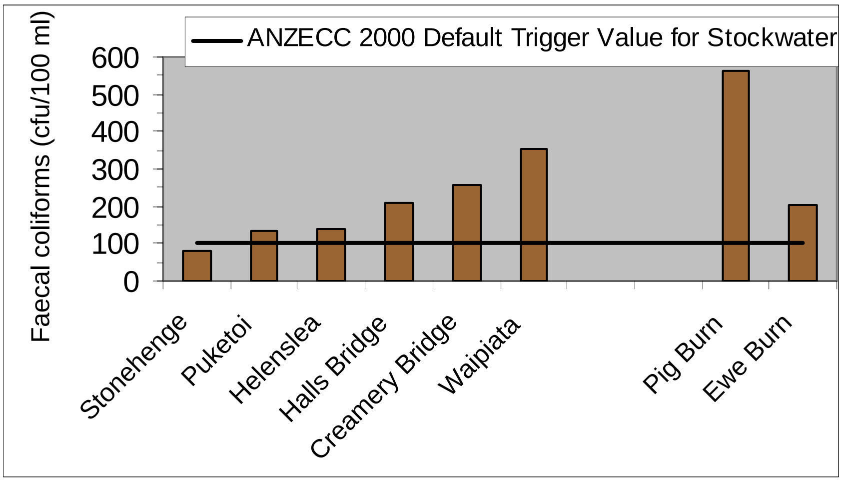


Figure 4.21 Median faecal coliform concentrations recorded at each monitoring site over November 2001 to December 2002 inclusive, along with the ANZECC 2000 default trigger value for stock drinking water

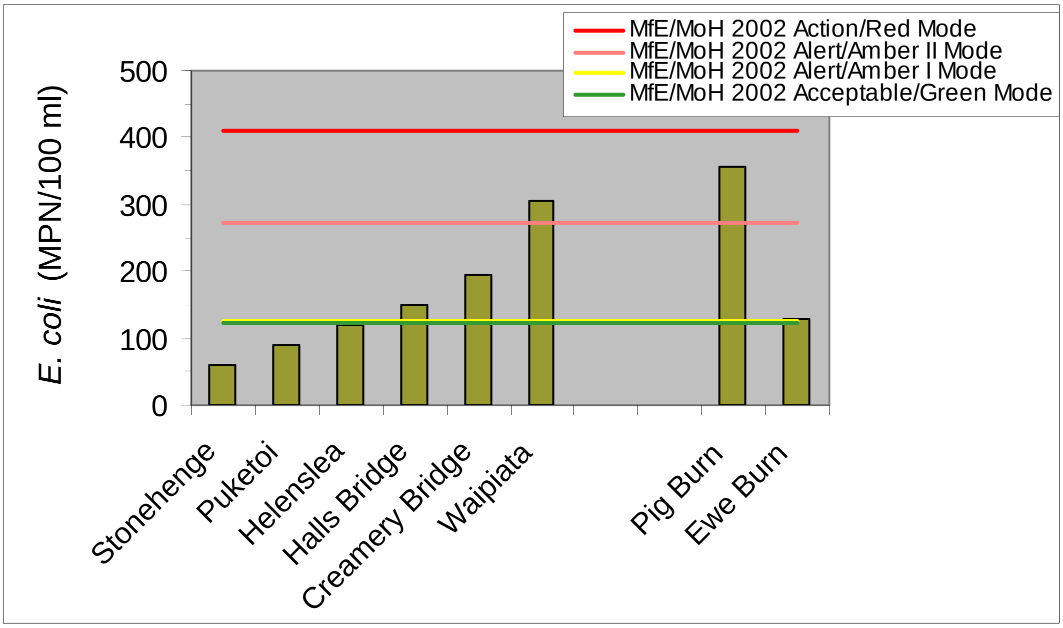


Figure 4.22 Median *E. coli* concentrations recorded at each monitoring site over November 2001 to December 2002 inclusive, along with the interim MfE/MoH 2002 microbiological guidelines for freshwater recreational areas – these guidelines are indicative only as the green mode should only be applied to the summer bathing season (i.e., 1 November to 31 March)

Based on the 16 or so sample results collected at each site over the monitoring period, the median faecal coliform result exceeds the ANZECC 2000 stockwater trigger value of 100 cfu/100ml all sites except Stonehenge. Four sites also recorded concentrations more than four times the trigger value on more than 20% of the sampling occasions. These sites and the percentage of results above 400 cfu/100 ml were the Pig Burn (50%) and the Taieri River at Halls Bridge (33%), Creamery Bridge (25%) and Waipiata (44%).

The sampling frequency was not sufficient to assess whether the swimming sites at Creamery Bridge and Waipiata complied with the recommended contact recreation guidelines outlined above but based on both the median and the individual results available for each site over the monitoring period, it is unlikely (Figure 4.22 and Figure 4.23).

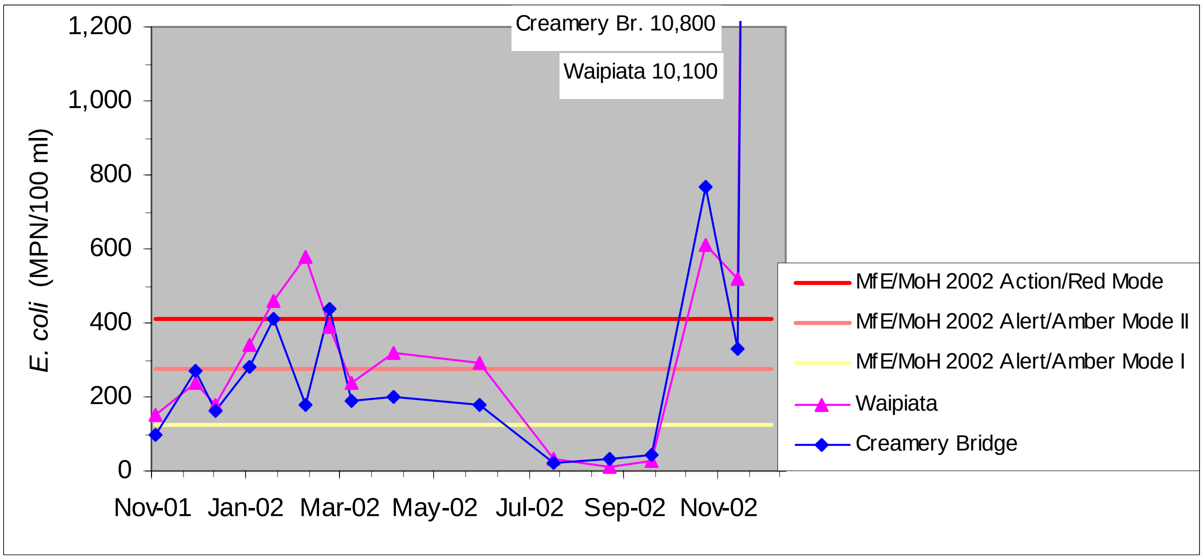


Figure 4.23 *E. coli* concentrations recorded in the Taieri River at Creamery Bridge and Waipiata over November 2001 to December 2002 inclusive, along with the interim amber/alert and action/red modes specified in the MfE/MoH 2002 microbiological guidelines for freshwater recreational areas

The Pig Burn recorded the highest faecal bacteria concentrations of all monitoring sites (Figure 4.21), including a result of 13,300 MPN/100 ml on 12 February 2002. With the exception of another high result following a thunderstorm on 11 December 2002, concentrations were much lower at this site during the latter half of the monitoring programme (Figure 4.24).

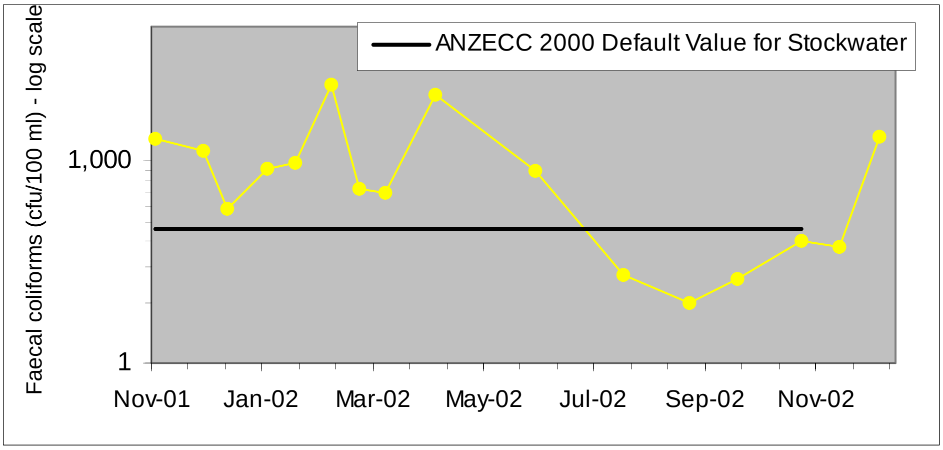


Figure 4.24 Faecal coliform concentrations (log scale) recorded in the Pig Burn below O'Neill Road over November 2001 to December 2002 inclusive, along with the ANZECC 2000 default trigger value for stockwater

In general indicator bacteria concentrations were elevated at most sites when sampling followed rainfall events or increases in river flow. This was the case on 29 October 2002. The highest *E. coli* bacteria concentrations recorded in the Taieri River were 10,800 MPN/100 ml, 10,100 MPN/100 ml and 8,100 MPN/100 ml at Creamery Road, Waipiata, and Halls Bridge respectively (Figure 4.25). All three results were recorded on 11 December 2002 following a thunderstorm that appeared to only affect some of the monitoring sites. The highest *E. coli* concentration in the Ewe Burn was also recorded at this time (2,000 MPN/100 ml).

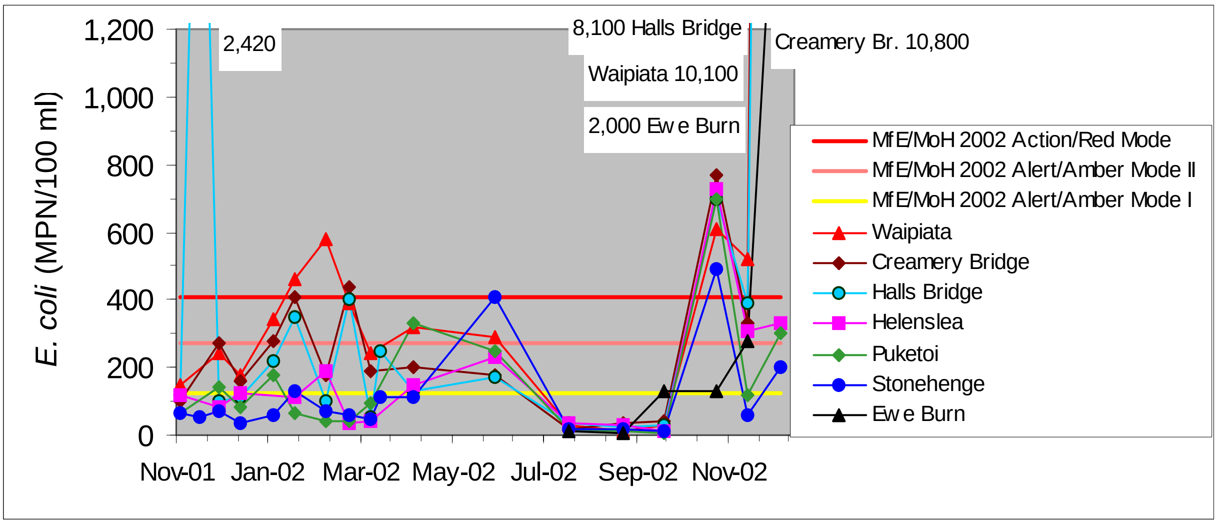


Figure 4.25 *E. coli* concentrations recorded at monitoring sites in the Taieri River and in the Ewe Burn over November 2001 to December 2002 inclusive, along with the interim amber/alert and action/red modes specified in the MfE/MoH 2002 microbiological guidelines for freshwater recreational areas

4.8 Periphyton and Macroinvertebrates

4.8.1 Definition and Significance

Periphyton is the slimy material attached to the surfaces of rocks and other bottom substrate in rivers and streams. It is comprised of algae, diatoms, bacteria and fungi and plays a key role in aquatic food webs because it is the main source of food for benthic invertebrates, which in turn are an important food source for fish. Excessive periphyton growths are unsightly, reducing the aesthetic and recreational values of a river. Excessive growths can also negatively affect fish and invertebrate communities.

Macroinvertebrates are organisms that lack a backbone and are larger than 250 microns in size. Four major groups of macroinvertebrates exist; *insects* such as mayflies, caddisflies and dragonflies, *molluscs* such as snails and mussels, *crustaceans* such as freshwater shrimps and amphipods, and *oligochaetes*, aquatic worm species that live in muddy streambeds.

Periphyton and macroinvertebrates can serve as good indicators of ecological change in freshwater environments. For example, changes in abundance (density) of macroinvertebrates can indicate changes in periphyton productivity, which may be indicative of increased nutrient inputs. Different macroinvertebrate species also have different tolerances to environmental factors such as dissolved oxygen, nutrients and fine sediment, such that the presence or absence of different species in an environment may indicate changes in water quality.

4.8.2 Guidelines

The New Zealand Periphyton Guidelines (Ministry for the Environment 2000) outline a range of guidelines for periphyton biomass and cover designed to protect various instream values including aesthetics, benthic biodiversity and trout habitat and angling. These guidelines are not considered in this report as Otago Regional Council SOE periphyton monitoring focuses only on species richness and relative abundance.

Macroinvertebrate guidelines exist in the form of biotic indices that have been developed over the last 10 to 20 years. These indices are based on the number, type and abundance of macroinvertebrate taxa present at a monitoring site with different taxa assigned different "pollution sensitivity" scores ranging from 1 (pollution tolerant) to 10 (pollution sensitive) (e.g., Stark, 1985, Stark 1998). Indices used by the Otago Regional Council include:

- Species richness: the number of taxa present
- Macroinvertebrate community index (MCI): a sensitivity score based solely on the number of different taxa present
- Semi-quantitative macroinvertebrate community index (SQMCI): a sensitivity score based on the number of different taxa present and the relative abundance of each taxon
- % EPT Richness: the percentage of pollution-sensitive Empheroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) groups present

4.8.3 Results

The results of periphyton and macroinvertebrate sampling undertaken at Stonehenge, Creamery Road and Waipiata in the upper Taieri River on 12 March 2002 are summarised in Tables 4.3 and 4.4 respectively and the full results are presented as Appendix 4. The periphyton community was dominated by predominantly oligotrophic to mesotrophic (low to moderate nutrient) taxa at all sites with only sparse periphyton growth at Stonehenge.

The macroinvertebrate results indicate that a relatively healthy instream community was present at all three monitoring sites. However the quality of the macroinvertebrate community was clearly higher at Stonehenge than Creamery Road and Waipiata. The quality of the habitat was also superior at this site, with the dominant substrate at Creamery Road and Waipiata comprised of smaller pebbles and gravels.

Table 4.3 Species richness and dominant taxa for single replicate periphyton samples collected from riffle habitats in the upper Taieri River in March 2002

	Stonehenge (Hores Bridge)	Creamery Road	Waipiata (Green Bridge)
Species Richness:	4	9	8
Dominant taxa†	None	*Gomphoneis* spp.	*cf. Lyngbya, Audouinella*

† Abundance classes 7 and 8 of Biggs & Kilroy's (2000) scale of relative abundance

Table 4.4 Species richness, MCI, SQMCI and & EPT scores for single replicate macroinvertebrate samples collected from riffle habitats in the upper Taieri River in March 2002

Biological Index	Stonehenge (Hores Bridge)	Creamery Road	Waipiata (Green Bridge)
Species Richness:	14	20	12
MCI:	121.4	97.0	98.3
SQMCI:	7.32	6.40	6.71
% EPT Richness:	64.3	55.0	41.7
Dominant taxa & sensitivity score (1-10):	*Pycnocentria evecta* (caddisfly - 7), *Deleatidium* spp. (mayfly - 8), *Beraeoptera roria* (caddisfly - 8)	*Hydora nitida* (beetle - 6), *Deleatidium* spp. (mayfly –8), *Potamopyrgus antipodarum* (snail - 4)	*Deleatidium* spp. (mayfly - 8), *Hydora nitida* (beetle - 6), *Potamopyrgus antipodarum* (snail - 4)
Dominant Substrate:	Cobbles	Pebbles	Pebbles

Interpretation of Scores:

- MCI >120 or SQMCI >6 = clean water (and good habitat, e.g., fast-flowing water over clean cobbles)
- MCI 100-120 or SQMCI 5-6 = doubtful quality or possible mild pollution
- MCI 80-100 or SQMCI 4-5 = probable moderate pollution
- MCI <80 or SQMCI<4 = probable severe pollution

5 Discussion

Two key findings emerge from the water quality monitoring results presented in Section 4. Firstly there is a clear decline in water quality in the Taieri River between Stonehenge and Waipiata. Secondly, there were a number of localised impacts on water quality that appear to be directly related to landuse practices adjacent to specific monitoring sites. These are discussed below along with the key water quality problems and the likely causes of these problems. Suggestions for further investigation are also outlined.

5.1 Water Quality in the Taieri River

The results of the 14-month monitoring programme indicate that there is a significant deterioration in water quality in the Taieri River with distance downstream from Stonehenge (Hores Bridge) to Waipiata. Suspended sediment (solids), turbidity, faecal bacteria, conductivity and nutrient concentrations all increase with distance downstream while water clarity and dissolved oxygen concentrations decrease. Although this trend of decreasing water quality is typical for a river draining an agricultural catchment, the deterioration is quite marked. This is illustrated in Table 5.1 which compares the percentage changes in median water quality data at Puketoi, Helenslea, Halls Bridge, Creamery Bridge and Waipiata against the median values recorded at the Stonehenge reference site during the monitoring period.

From Table 5.1 it can be seen that between Stonehenge and Waipiata:

- Turbidity and suspended sediment increase by 164% and 475% respectively
- Visual clarity decreases by 43%
- Median conductivity concentrations increase by 177%
- Median dissolved reactive phosphorus and total phosphorus concentrations increase by 233% and 231% respectively
- Median ammoniacal nitrogen and total nitrogen concentrations increase by 100% and 30% respectively
- Median faecal coliform and *E. coli* concentrations increase by one order of magnitude

Table 5.2 compares December 2000-December 2002 water quality data from the three Otago Regional Council upper Taieri River SOE monitoring sites with water quality data from SOE monitoring sites located in the mid reaches (Cottesbrook Bridge, Middlemarch) and lower reaches (Outram Glen and Allanton) of the Taieri River. Median concentrations of most chemical and microbiological water quality parameters are actually higher at Waipiata than further downstream, indicating that most aspects of water quality are better in the middle and lower reaches of the Taieri River than at Waipiata.

The macroinvertebrate sampling results also indicate a decline in the quality of the macroinvertebrate community in the upper Taieri River between Stonehenge and Waipiata. However caution is required when interpreting whether the decline is due to a decline in physico-chemical water quality or changes in substrate. Table 5.3 summarises the results of single-kick net samples collected at all Otago Regional Council SOE biomonitoring sites in the Taieri River during summer/autumn 2002. The results clearly indicate that the high scoring sites (Stonehenge and Middlemarch) have a predominantly cobble river bed. This type of substrate tends to support a greater range of pollution-sensitive stoneflies, mayflies

Table 5.1 Median physico-chemical and microbiological water quality data for the upper Taieri River catchment monitoring sites over November 2001 to December 2002 inclusive with % increase (+) or % decrease (-) compared with the median value for Stonehenge

	Dissolved Oxygen (% Saturation)		Suspended Solids (g/m^3)		Turbidity (NTU)		Clarity (m)		Conductivity (mS/cm)		Faecal Coliforms (cfu/100 ml)		*E. coli* (MPN/100 ml)		Nitrite-Nitrate Nitrogen (g/m^3)		Ammoniacal Nitrogen (g/m^3)		Total Nitrogen (g/m^3)		Dissolved Reactive Phosphorus (g/m^3)		Total Phosphorus (g/m^3)	
	Median	**% change**	**Median**	**% change**	**Median**	**% change**	**Median**	**% change**	**Median**	**% change**	**Median**	**% change**	**Median**	**% change**	**Median**	**% change**	**Median**	**% change**	**Median**	**% change**	**Median**	**% change**	**Median**	**% change**
Stonehenge	98		2		1.4		1.55		0.030		82		61		0.010		0.005		0.280		0.003		0.013	
Puketoi	90	-8	4	+100	2.3	+64	1.02	-34	0.049	+63	135	+65	90	+48	0.009	-10	0.008	+60	0.335	+20	0.006	+100	0.026	+100
Helenslea	88	-10	4	+100	2.2	+57	1.18	-24	0.056	+87	140	+71	120	+97	0.004	-60	0.005	0	0.360	+29	0.008	+167	0.032	+146
Halls Bridge	89	-9	1	-50	2.2	+57	1.25	-19	0.059	+97	210	+156	150	+146	0.004	-60	0.005	0	0.355	+27	0.010	+233	0.035	+169
Creamery Bridge	92	-6	9	+350	3.2	+129	0.82	-47	0.063	+110	255	+211	195	+220	0.011	+10	0.005	0	0.345	+23	0.011	+267	0.048	+269
Waipiata	91	-7	12	+475	3.7	+164	0.88	-43	0.083	+177	355	+333	305	+400	0.012	+20	0.010	+100	0.365	+30	0.010	+233	0.043	+231

Table 5.2 Selected physico-chemical and microbiological water quality data for Otago Regional Council Taieri River SOE monitoring sites, December 2000-December 2002*

	Suspended Solids (g/m^3)		Turbidity (NTU)		Clarity (m)		Conductivity (mS/cm)		Faecal Coliforms (cfu/100 ml)		*E. coli* (MPN/100 ml)		Nitrite-Nitrate Nitrogen (g/m^3)		Ammoniacal Nitrogen (g/m^3)		Total Nitrogen (g/m^3)		Dissolved Reactive Phosphorus (g/m^3)		Total Phosphorus (g/m^3)	
	Median	***n***	**Median**	***n***	**Median**	***n***	**Median**	***n***	**Median**	***n***	**Median**	***n***	**Median**	***n***	**Median**	***n***	**Median**	***n***	**Median**	***n***	**Median**	***n***
Upper Taieri																						
Stonehenge	2.0	21	1.4	22	1.63	21	0.030	22	78	22	58	22	0.010	22	0.005	22	0.265	22	0.003	22	0.013	22
Halls Bridge	1.0	22	2.2	22	1.28	21	0.060	22	200	22	156	22	0.006	22	0.005	22	0.355	22	0.010	22	0.036	22
Waipiata	11.5	16	3.7	16	0.85	15	0.082	16	355	16	305	16	0.012	16	0.010	16	0.365	16	0.010	16	0.043	16
Mid Taieri																						
Cottesbrook Bridge	12.0	11	4.9	11	0.80	11	0.069	11	180	11	130	11	0.021	11	0.005	11	0.300	11	0.005	11	0.031	11
Lower Taieri																						
Outram Glen	2.5	14	2.8	19	1.05	13	0.065	33	106	18	100	31	0.029	19	0.005	19	0.270	19	0.004	19	0.026	19
Allanton	7.5	4	2.7	14	1.00	2	0.073	14	145	8	145	14	0.040	14	0.020	14	0.305	14	0.003	14	0.027	14

* Note that due to differences in sampling frequency between standard SOE sites and SOE sites included in intensive catchment monitoring programmes, the number of samples from which the median values are determined varies from site to site.

Table 5.3 Species richness, macroinvertebrate community index (MCI) and semi-quantitative macroinvertebrate community index (SQMCI) values for single macroinvertebrate samples collected from riffle flow habitats in the Taieri River in March 2002

Biological Index	**Upper Taieri**			**Mid Taieri**	**Lower Taieri**	
	Stonehenge (Hores Bridge)	**Creamery Rd**	**Waipiata (Green Bridge)**	**Cottesbrook Bridge**	**Outram Glen**	**Allanton***
Species Richness: number of taxa present	14	20	12	14	19	12
MCI: a sensitivity score based solely on the number of different taxa present	121.4	97.0	98.3	111.4	92.6	91.7
SQMCI: a sensitivity score based on the number of different taxa present and the relative abundance of each taxon	7.32	6.40	6.71	6.68	6.57	4.83
% EPT Richness: the percentage of pollution-sensitive Empheroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) groups present	64.3	55.0	41.7	64.3	63.2	41.7
Dominant Substrate: A key habitat feature that influences which macroinvertebrates inhabit the site. Examples include boulders, cobbles, pebbles, gravel, sand and mud.	Cobbles	Pebbles	Pebbles	Cobbles	Cobbles	Pebbles & Gravel

Interpretation of Scores:
- MCI >120 or SQMCI >6 = clean water (and good habitat, e.g., fast-flowing water over clean stones)
- MCI 100-120 or SQMCI 5-6 = doubtful quality or possible mild pollution
- MCI 80-100 or SQMCI 4-5 = probable moderate pollution
- MCI <80 or SQMCI<4 = probable severe pollution

* This site was regarded as a "run" and therefore will naturally not support the same diversity of taxa as a riffle habitat

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and caddisflies than the pebble-dominated substrates that exist at Creamery Road and Waipiata. Nonetheless an increase in sediment concentrations at Creamery Road and Waipiata will reduce the quality of the macroinvertebrate communities at these sites.

5.1.1 Water Quality Over Time

It is difficult to determine whether physico-chemical and microbiological water quality in the upper Taieri River is any different from 10 or 20 years ago due to a lack of long-term monitoring data. The Otago Regional Council Taieri River SOE sites have only been routinely monitored since 1994 (Stonehenge) and 1996 (Halls Bridge) and one of these sites is a reference site located above the recent changes in land use practices. Similarly the Pig Burn has only been monitored since 1998 and the SOE site is located at O'Neill Road, above some intensive land use.

Table 5.4 summarises the results of a time series analysis for selected water quality analytes recorded at Halls Bridge over 1996-2002. As most water quality analytes exhibit seasonal variation throughout the year (e.g., temperature, nutrients), it was necessary to remove this seasonal effect in order to display the true underlying trend. This was performed using the Seasonal Kendall test. A *p*-value of less than 0.05 was deemed a significant result (refer Appendix 5 for the full results).

Table 5.4 Seasonal Kendall test results for selected water quality analytes monitored in the Taieri River at Halls Bridge over January 1996 to December 2002 inclusive

	n	Z Statistic	Slope	*p*-value	Significant Trend
Turbidity (NTU)	45	-2.396	-0.2439	<0.05	Yes – decrease
Suspended Solids (g/m^3)	45	-3.02	-0.5066	<0.05	Yes – decrease
Faecal Coliforms (cfu/100 ml)	45	1.124	6.245	>0.2	No
Ammoniacal Nitrogen (g/m^3)	45	-2.169	-0.0014	<0.05	Yes - decrease
Total Nitrogen (g/m^3)	39	-0.2671	-0.0017	>0.2	No
Total Phosphorus (g/m^3)	45	-1.801	-0.0033	$0.05 < p < 0.10$	No

Table 5.4 indicates that there has not been any significant change in total nitrogen, total phosphorus or faecal coliform concentrations at Halls Bridge over 1996-2002. However, both turbidity (Figure 5.1) and suspended solid (Figure 5.2) concentrations show significant downward trends (0.25 NTU/year and 0.51 g/m^3/year respectively), suggesting that there has been some improvement in these aspects of water quality at Halls Bridge over the last six years. The reason for the improvement is unclear. Analysis of river flows for the days of sampling revealed only a weak correlation between suspended solid concentrations and river flow.

Ammoniacal nitrogen also shows a significant downward trend. However as concentrations recorded to date have often been at or near the detection limit, the corresponding slope of the trend line is less than 0.001 g/m^3/year. Thus, the Seasonal Kendall test is not valid in this instance.

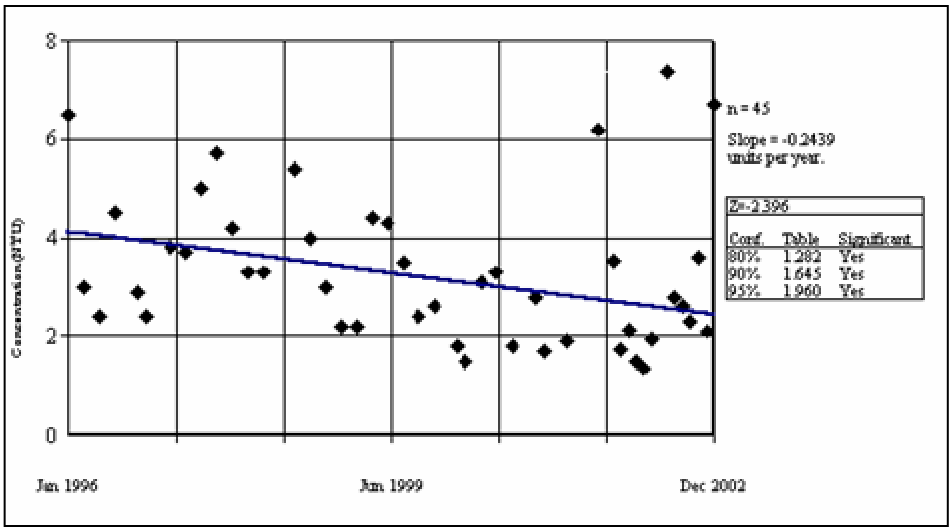

Figure 5.1 Turbidity measurements recorded in the Taieri River at Halls Bridge since state of the environment monitoring commenced at this site in January 1996, along with the Seasonal Kendall slope estimator (trend line)

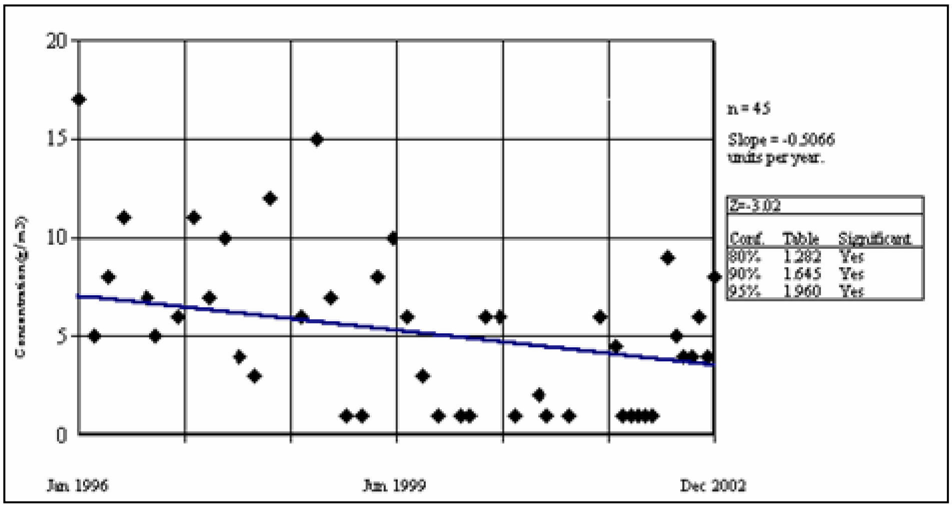

Figure 5.2 Suspended solid concentrations recorded in the Taieri River at Halls Bridge since state of the environment monitoring commenced at this site in January 1996, along with the Seasonal Kendall slope estimator (trend line)

5.2 Localised Impacts

As a well as a trend of a decrease in water quality in the Taieri River between Stonehenge and Waipiata, there were a number of "spikes" in the water quality data at specific monitoring sites on occasions during the monitoring programme. These "spikes" are indicative of localised water quality issues and are a product of the landuse adjacent to, or upstream of specific monitoring sites. The sites where localised impacts were identified are outlined briefly below and the causes are discussed in Section 5.4.

5.2.1 Pig Burn below O'Neill Road

The Pig Burn below O'Neill Road at times was very turbid (refer Figure 4.7) and recorded some very high indicator bacteria concentrations, especially during the first half of the monitoring programme (refer Figure 4.24). Along with the Taieri River at Puketoi, this was also the only monitoring site to record BOD concentrations greater than the detection limit of 1 g/m^3. One of these occasions (11 April 2002) coincided with very high concentrations of indicator bacteria (10,000 cfu/100 ml and 9,700 MPN/100 ml faecal coliforms and *E. coli* respectively), suspended sediment (23 g/m^3), ammoniacal nitrogen (0.11 g/m^3) and total nitrogen (1.29 g/m^3).

5.2.2 Ewe Burn at Gimmerburn-Waipiata Road

On 24 September 2002 the Ewe Burn was slightly milky in colour. Water samples collected on this date were turbid (Figure 4.7) and returned high suspended solid and ammoniacal nitrogen concentrations. The pH was also high and this resulted in an ammoniacal nitrogen concentration that was potentially toxic to aquatic life.

5.2.3 Taieri River at Puketoi

BOD was detected in the Taieri River at Puketoi on two occasions while concentrations were always at or below the detection limit at all other Taieri River monitoring sites. The detection of BOD indicates that some form of organic matter may have entered the river.

A quite clear localised impact at Puketoi is reduced visual clarity. Between Stonehenge and Puketoi there was a 34% decrease in visual clarity, with the median value lower at Puketoi than at sites downstream at Helenslea and Halls Bridge (refer Figure 4.4).

5.2.4 Taieri River at Creamery Bridge and Waipiata

At both Creamery Bridge and Waipiata, median suspended solid concentrations were found to be significantly higher than at all four Taieri River sites further upstream (refer Figure 4.3). As a result, turbidity levels were also high and visual clarity was greatly reduced (refer Figure 4.4). The median clarity values for Creamery Bridge and Waipiata (0.82 m and 0.88 m respectively) were more than 40% lower than the median value for Stonehenge (1.55 m).

5.3 Key Water Quality Issues

Based on the results over the 14-month monitoring period, the key water quality issues in the upper Taieri River catchment appear to be:

- Increased sedimentation and turbidity and a subsequent decrease in water clarity with distance downstream; and
- Increased faecal contamination with distance downstream.

Although the increases in most nutrients with distance downstream are statistically significant, it is difficult to determine whether the increases are *ecologically* significant. The median dissolved reactive phosphorus, total phosphorus and total nitrogen concentrations exceed the default trigger values of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000) at most sites below Stonehenge, but median dissolved inorganic nitrogen concentrations do not. This suggests that a lack of available nitrogen may limit aquatic plant growth, helping to prevent nuisance algal blooms in the upper Taieri River. However, it is possible that plants have taken up and are storing these nutrients for later use.

5.3.1 Sedimentation, Turbidity and Water Clarity

Although no monitoring sites exceeded the ANZECC 2000 default trigger values for turbidity and clarity, the increase in suspended sediment and turbidity with distance downstream from Stonehenge is very marked. Creamery Bridge, Waipiata and Puketoi were the most affected Taieri River sites and the Pig Burn was also affected, particularly during the first half of the monitoring programme.

The primary effects of increased sediment loads and a reduction in clarity would appear to be a reduction in ecological habitat, and aesthetic and recreational values. Fine sediments fill the interstitial spaces in river cobbles, smothering natural habitat of many sensitive macroinvertebrates and fish. This in turn reduces the value of the river for recreational activities such as fishing and swimming. Water clarity at both Creamery Road and Waipiata is only half that considered acceptable to bathers (Ministry for the Environment 1992).

The increase in sediment and turbidity and associated decrease in water clarity are attributed to several factors including bank erosion, irrigation bywash runoff and stock access to the water and its margins. This is discussed further in Section 5.4.

5.3.2 Faecal Contamination

The upper Taieri River is used for contact recreation activities during the summer and there are popular swimming holes in the river at Waipiata and Creamery Road. However, on the basis of the *E. coli* obtained to date (refer Figure 4.24), at times it may be unsafe to swim at these sites.

Two points of caution should be exercised when interpreting the *E. coli* results and assessing compliance with the Acceptable/Green Mode of the MfE/MoH 2002 Microbiological Guidelines for Freshwater Bathing:

- The guidelines recommend that the median result of weekly samples taken over the bathing season (1 November to 31 March) be compared against the Acceptable/Green Mode of 126 *E. coli*/100 ml – such intensive sampling was not undertaken in the 14-month programme.
- The freshwater bathing guidelines are still being finalised; it is expected that the final guidelines will be available in June 2003. The latest draft (and therefore unofficial) guidelines have set higher tolerable *E. coli* concentrations than those set in the current interim guidelines (Table 5.5).

Table 5.5 Current interim and proposed freshwater bathing guidelines

Current guideline values		*Proposed guideline values*	
Acceptable/Green Mode	Running median is less than 126 *E. coli*/100 ml	Surveillance/Green Mode	No single sample >260 *E. coli*/100 ml
Alert/Amber Mode I	Running median between 126 and 273 *E. coli*/100 ml	Alert/Amber Mode	Single sample >260 *E. coli*/100 ml
Alert/Amber II Mode	Single sample *>273 E. coli*/100 ml		
Action/Red Mode	Single sample *>410 E. coli*/100 ml	Action/Red Mode	Single sample >550 *E. coli*/100 ml

Faecal contamination is not only of concern for contact recreation but also for farmers utilising river or stream water for stockwater. The ANZECC 2000 guidelines set a default trigger value for stock drinking water at just 100 faecal coliforms per 100 ml. While this guideline is considered to be quite conservative and faecal coliforms are only an indicator of *potential* contamination by pathogens, the median concentrations recorded at most monitoring sites significantly exceeded this trigger value (refer Figure 4.21). The Pig Burn and the Taieri River at Halls Bridge, Creamery Bridge and Waipiata all recorded concentrations more than four times the trigger value on more than 20% of the sampling occasions, suggesting further investigation of faecal bacteria contamination may be warranted at these sites.

The increase in faecal bacteria contamination with distance downstream is attributed largely to stock access to the water and its margins. Runoff from irrigation may also play a role. These issues are discussed further in Section 5.4.

5.4 Causes of Water Quality Problems

The upper Taieri River catchment is an agricultural catchment and farming practices can be expected to impact to a certain extent on water quality in both the Taieri River proper and its tributaries. However the results obtained during monitoring to date suggest that some practices are having more than a minor effect on water quality.

The principal issues that appear to be impacting on water quality include stock, irrigation runoff and bank erosion. These issues are discussed separately below.

5.4.1 Direct Stock Access to Watercourses and Riparian Areas

Stock had free access to the water and banks at all sampling sites. This can reduce water quality in several ways:

- Removal of riparian vegetation and therefore the ability of vegetation to buffer the water from sediment, nutrients and faecal bacteria;
- Disturbance and erosion of banks, contributing to high instream sediment loads and reduced water clarity; and
- Direct defecation of waterways.

The problems above were evident at most sampling sites, in particular the lower Pig Burn where dairy cows roamed free throughout the creek and in an upstream tributary during much of the monitoring programme. This resulted in a series of very high faecal bacteria concentrations, the highest being 13,300 cfu/100 ml in February 2002. Following the removal of dairy cows from the paddocks during the winter and the erection of riparian fencing during spring 2002, there was a dramatic decrease in instream faecal bacteria concentrations (Table 5.6, see also Figure 4.24).

Table 5.6 Faecal coliform and *E. coli* concentrations recorded in the Pig Burn below O'Neill Road before and after removal of dairy cows and the erection of riparian fencing

	Faecal Coliforms (cfu/100 ml) ***ANZECC 2000 Stockwater default trigger value: Median result should not exceed 100 faecal coliforms/100 ml***			***E. coli*** **(MPN/100 ml)** ***MfE/MoH 2002 Acceptable Green Mode: Median result should not exceed 126 E. coli/100 ml***		
	Median	**Range**	***n***	**Median**	**Range**	***n***
Nov 2001-Jun 2002	855	199-13,300	10	655	199-13,300	10
Jul 2002-Dec 2002	36	8-2,300	6	22	6-1,300	6

High faecal bacteria concentrations at other monitoring sites are also attributed to stock having access to either the river or its margins. Halls Bridge has recorded some very high faecal coliform concentrations both historically and during the monitoring programme (Figure 5.3). This site is located just below the confluence with the Wether Burn (Gimmer Burn) and beef cattle and sheep have been regularly observed in this stream (Figure 5.4). It is likely that a considerable amount of faecal contamination also occurs at Halls Bridge itself. The riverbanks at this site are low-lying and often prone to flooding, meaning that faecal matter deposited by stock on the banks is easily washed into the river during rainfall and high river flows (Figure 5.5). Similarly at Puketoi dairy cattle have frequently been observed grazing on low-lying river banks which are inundated with water during high river flows (Figure 5.6).

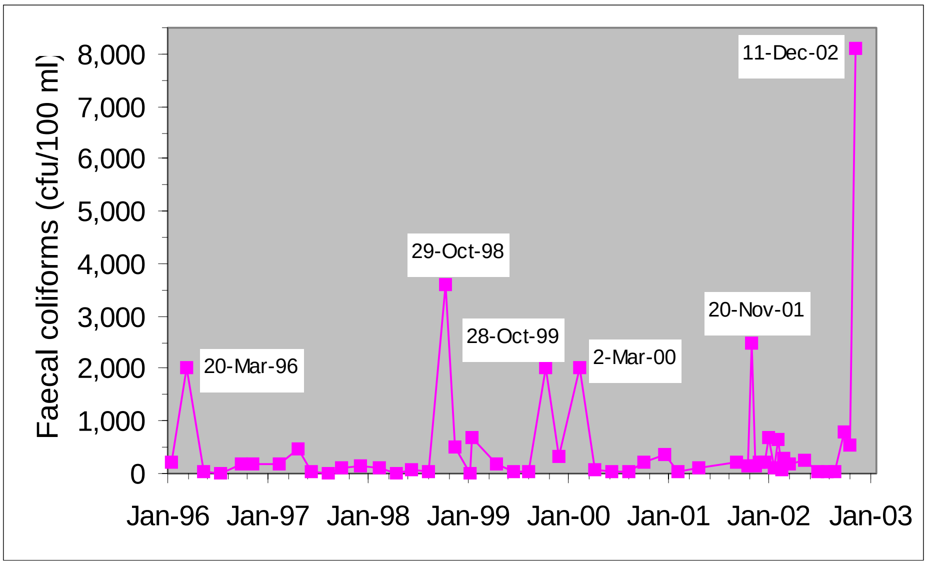

Figure 5.3 Faecal coliform concentrations recorded in the Taieri River at Halls Bridge since state of the environment monitoring commenced at this site in January 1996

Figure 5.4 Beef cattle observed in the Gimmer Burn at Wilson Road, 23 January 2003

Figure 5.5 Sheep grazing the true right river bank of the Taieri River upstream of Halls Bridge, 23 January 2003

Figure 5.6 Low lying riparian margins of the Taieri River above Cogans Bridge at Puketoi – faecal matter deposited by dairy cows grazing these margins will wash into the river during high rainfall and river flows events

Stock having direct access to waterways can also contribute to significant areas of localised sedimentation, resulting in a loss of gravel habitat for sensitive macroinvertebrates and fish spawning. This was noticeable in the Pig Burn below O'Neill Road where dairy cows had been regularly crossing through the stream during late 2002 and early 2003 (Figure 5.7).

Figure 5.7 Stock crossing in the lower Pig Burn – note the faecal deposits on the stream banks and the fine sediments smothering the streambed immediately downstream, 6 February 2003

5.4.2 Irrigation Run-off

There have been several reports of irrigation water and dairy effluent run-off into the Taieri River at Puketoi. In most instances it appears that irrigation has been excessive or poorly managed, resulting in runoff into an on-farm watercourse and then into the wetland areas adjacent to the oxbows of the Taieri River (Figure 5.8). On several occasions, foul-smelling, silt-laden water was also seen exiting the wetland on Puketoi Road and entering the Taieri River via a roadside culvert (Figure 5.9).

The problem of agricultural runoff has been exacerbated due to grazing of wetland and riparian vegetation by dairy cattle in these areas (Figure 5.10). Loss of riparian wetlands reduces their capacity to buffering the river from excess nutrients, sediment and bacteria.

The impacts of irrigation run-off, particularly from border-dyke irrigation systems, have not been easy to quantify in this monitoring programme but may be quite significant. For example, irrigation bywash periodically enters the Ewe Burn resulting in significant silt levels in this creek. It is likely that other tributaries such as Eden Creek and the Gimmer Burn (Wether Burn) are also affected by irrigation bywash at times.
On several occasions dirty water was seen flowing toward the true right bank of the Taieri River from an on-farm watercourse above Ranfurly-Patearoa Road. This may have contributed to some of the elevated turbidity and suspended solid concentrations recorded at the Creamery Bridge monitoring site.

(Photo courtesy of Fish & Game Otago)

Figure 5.8 Ponded irrigation water at the base of the Patearoa side of Puketoi-Patearoa Road, upstream of Cogans Bridge, 12 February 2003 – dairy cows had been grazing in this wetland area a few days prior to this photograph being taken (refer Figure 5.10)

(Photo courtesy of Fish & Game Otago)

Figure 5.9 Run-off from Figure 5.6 exiting a culvert on the downstream side of Puketoi-Patearoa Road, 12 February 2003 and prior to entry into an oxbow of the Taieri River below Cogans Bridge

(Photo courtesy of Fish & Game Otago)

Figure 5.10 Dairy cows grazing in the wetland and oxbow areas adjacent to the Taieri River at Puketoi-Patearoa Road, 5 February 2003

5.4.3 Bank Erosion

A number of stretches of the upper Taieri River banks are comprised of exposed soil which is likely to be easily shifted downstream during significant rain or flow events (Figure 5.11). This is particularly the case near Creamery Bridge and Waipiata where the highest turbidity and suspended solid concentrations were recorded (Figure 5.12). It is unclear whether this erosion is solely a function of the meandering river flow pattern in the upper Taieri but it is likely that fluctuations in river level due to hydroelectric power generation and grazing of river banks by cattle are contributing to erosion in some areas.

Figure 5.11 Erosion on the true left bank of the Taieri River at the Helenslea monitoring site, November 2001

***(Photo courtesy of Fish & Game** Otago)*

Figure 5.12 Exposed banks of the Taieri River below Creamery Bridge, winter 2002

5.5 Further Investigation

There are several areas that may warrant further investigation. Firstly there is little information on the effects of border-dyke irrigation bywash on water quality in the Taieri River. Bywash water periodically enters tributaries such as the Ewe Burn, Gimmer Burn, Wether Burn and Eden Creek and this is likely to have some effect on water quality, particularly through increased turbidity and suspended sediment concentrations, but also possibly increased nutrients and faecal bacteria.

Secondly it may be worth investigating the effects of temporary or partial exclusion of stock, particularly cattle, from riparian wetland margins on water quality in selected areas of the Taieri River and its tributaries. The oxbow and wetland area adjacent to Puketoi-Patearoa Road may be one area to focus on given that impacts on water quality have been identified at the Puketoi monitoring site.

Thirdly, the status of water quality in the Taieri River downstream of Waipiata is unknown. It is likely that water quality improves quite quickly as the river exits the Maniototo Plain there appears to be little information available to confirm this is the case. The Otago Regional Council undertook some limited physico-chemical and microbiological water quality monitoring approximately 5 kilometres downstream at Kokonga (SH87 bridge) during 1999 and it may be worth picking up some monitoring at this site again for a limited period.

6 Conclusions

The results of an intensive 14-month surface water quality monitoring programme in the upper Taieri River catchment indicate that there is a significant decline in water quality in the upper Taieri River between Stonehenge and Waipiata. Median suspended sediment, turbidity, faecal bacteria, and nutrient concentrations all increase with distance downstream while water clarity and dissolved oxygen concentrations decrease. Indicator bacteria and most nutrient concentrations exceed recommended guidelines at many monitoring sites. Macroinvertebrate values also decline with distance downstream although this is likely to be due primarily to differences in physical habitat rather than the deterioration in water quality.

Although a decrease in water quality with distance downstream is typical for a river draining an agricultural catchment, the deterioration in the upper Taieri River is quite marked, with median concentrations of most physico-chemical and microbiological water quality parameters higher at Waipiata than in the middle and lower reaches of the Taieri River.

Increased sedimentation and turbidity (and therefore reduced clarity) with distance downstream, along with faecal bacteria contamination are key water quality concerns. Although median dissolved phosphorus concentrations exceed the Australia and New Zealand Environment and Conservation Council (ANZECC) 2000 default trigger values for upland river ecosystems at many sites, nutrient enrichment may be of less importance at present because median dissolved inorganic nitrogen concentrations are well below the ANZECC default trigger values. This suggests that a lack of available nitrogen may limit aquatic plant growth, helping to prevent nuisance algal blooms and weeds in the upper Taieri River.

Poor water quality at most monitoring sites is attributed to factors such as stock access to water and riparian margins, effluent and irrigation runoff, and bank erosion. Stock, including sheep, beef cattle and dairy cows, had direct access to the water and river banks at almost all monitoring sites and were regularly seen in the Taieri River or its tributaries. Dairy cows in the lower reaches of the Pig Burn were the primary reason for the exceptionally high bacteria concentrations recorded at this site during much of the monitoring programme.

Effluent and irrigation runoff is a problem in many low lying dairying areas, with runoff identified on several occasions immediately above Puketoi. Run-off may also have accounted for poor water quality in the Ewe Burn on one occasion. Most problems appear to be due to inappropriate siting of irrigators and excessive irrigation. It is likely that runoff from border-dyke irrigation systems is also impacting on water quality but this requires further investigation.

The banks of the upper Taieri River banks are comprised of exposed soil in many places which is likely to be easily shifted downstream during significant rain or flow events. This is particularly the case near Creamery Bridge and Waipiata where the highest turbidity and suspended sediment concentrations were recorded. It is unclear whether the erosion is solely a function of the meandering river flow pattern in the upper Taieri but fluctuations in river level due to hydroelectric power generation and grazing of river banks by cattle may be contributing to erosion in some areas.

7 References

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Appendix 1 – Raw Water Quality Results

UPPER TAIERI WATER QUALITY DATA - RESULTS (NOV 2001-DEC 2002 PLUS SOME HISTORICAL DATA AT STONEHENGE & HALLS BRIDGE)

SITE NAME	Date Sampled	Time Collected (24 hr NZST)	Clarity (m)		BOD5 (g/m3)	Conductivity (mS/cm)	Diss Ox. (g/m3)		Diss. Reactive P (g/m3)	*E. coli* (MPN/100 ml)	F. coliforms cfu/100 ml)		Ammon. N (g/m3)		Nitrite-Nitrate N (g/m3)	pH		Susp. Solids (g/m3)	Temp. (oC)		Total N (g/m3)	To tal P	(g/m3)	Turbidity (NTU)
Taieri River @ Stonehenge	9-Aug-94	11:00			1	0.04	12.6		0.006		**20**		0.008		0.029	6.8		3	2.4		0.48		0.03	1.5
Taieri River @ Stonehenge	4-Oct-94	09:40		<	1	0.0444	11.1		0.003		**4**		0.004		0.02	6.35		2	5.9				0.012	0.8
Taieri River @ Stonehenge	28-Nov-94	11:10			3	0.0281	10.6	<	0.001		**54**	<	0.003		0.014	6.94		10	14.1				0.027	1.3
Taieri River @ Stonehenge	11-Jan-95	10:00			1	0.0545	10.2		0.003		**160**		0.007		0.015	7		2	13.6		0.19		0.021	1.3
Taieri River @ Stonehenge	8-Mar-95	11:30		<	1	0.038	10.4		0.002		**37**	<	0.003		0.022	6.95		3	15				0.02	1
Taieri River @ Stonehenge	30-May-95	12:10			1	0.0519	12.6		0.007		**27**		0.009		0.033	6.22		4	4				0.012	0.85
Taieri River @ Stonehenge	31-Jul-95	11:15		<	1		14.15		0.003		**8**	<	0.003		0.037	6.72		2	0.3				0.019	1.1
Taieri River @ Stonehenge	26-Sep-95	11:05			2	0.0194			0.006		**16**		0.012		0.023	6.79		4	5.9				0.023	1.4
Taieri River @ Stonehenge	8-Nov-95	0000		<	1	0.0248	10.2		0.003		**23**		0.02		0.01	6.98		4	13				0.027	1.4
Taieri River @ Stonehenge	24-Jan-96	08:15		<	1	0.0335	9.6		0.008		**260**		0.03		0.036	6.45		3	14.1		0.28		0.032	1.2
Taieri River @ Stonehenge	20-Mar-96	13:45			1	0.0315	10.8		0.003		**78**		0.006		0.02	6.5		5	11.8				0.015	1
Taieri River @ Stonehenge	22-May-96	13:50		<	1	0.0383	12.3		0.002		**46**		0.01		0.012	6.61		4	3.9				0.011	9.4
Taieri River @ Stonehenge	24-Jul-96	14:15		<	1	0.0396	13		0.003		**16**		0.025		0.024	6.68		2	2.9		0.22		0.025	2.9
Taieri River @ Stonehenge	8-Oct-96	13:05			2	0.037	10.8		0.006		**18**		0.013		0.02	7.2		2	9.1				0.025	1.4
Taieri River @ Stonehenge	19-Nov-96	12:45		<	1	0.0356	9.8		0.003		**39**		0.01		0.014			1	11.6				0.015	0.8
Taieri River @ Stonehenge	20-Feb-97	11:00			1	0.0304	9.5		0.004		**140**		0.014		0.028	7.3	<	3	19		0.33		0.031	1.4
Taieri River @ Stonehenge	30-Apr-97	13:30			1	0.0262	11.2		0.007		320		0.017		0.01	6.9		2	8.1		0.31		0.031	1.3
Taieri River @ Stonehenge	19-Jun-97	11:30		<	1	0.036	12.4		0.004		19		0.008		0.013	7.2	<	3	3.4				0.013	2
Taieri River @ Stonehenge	20-Aug-97	09:00	1.60	<	1	0.0261	12.1		0.004		27		0.016		0.01	6.9		2	4.8		0.23		0.019	2.3
Taieri River @ Stonehenge	9-Oct-97	09:00	2.70	<	1	0.0326	11.3		0.005		50		0.015		0.01	7.1		2	7.5		0.18		0.019	1.4
Taieri River @ Stonehenge	16-Dec-97	09:10	2.10	<	1	0.0314	8.8		0.002		52		0.012		0.015	7.1		1	15.9		0.22		0.021	1.2
Taieri River @ Stonehenge	25-Feb-98	08:00	0.90		2	0.0297	10		0.003		450		0.023		0.015	7		4	12.9		0.38		0.03	2.9
Taieri River @ Stonehenge	29-Apr-98	11:10	1.80			0.0378	11.35												8.9					
Taieri River @ Stonehenge	24-Jun-98	11:55	2.95	<	1	0.0378	14.1		0.003		11	<	0.005		0.02	7.2	<	3	0.3				0.011	1.1
Taieri River @ Stonehenge	26-Aug-98	10:00			1	0.0398	12.4		0.002	15	15		0.02	<	0.003	7.3		2	3.3		0.23	<	0.005	2.2
Taieri River @ Stonehenge	29-Oct-98	09:00	1.80	<	1	0.0307	11.2		0.002	29	40		0.006	<	0.003	7.1	<	3	11		0.16		0.02	1.4
Taieri River @ Stonehenge	2-Dec-98	08:30	1.55		2	0.0364	10.6		0.001	40	40		0.037		0.016	7.2		2	13.5		0.2		0.009	2
Taieri River @ Stonehenge	22-Jan-99	12:55				0.0381	9.2												16.5					
Taieri River @ Stonehenge	3-Feb-99	08:20	1.30		1	0.0359	18.9	<	0.001	110	110		0.038		0.02	7.1		3	16		0.49		0.009	3.4
Taieri River @ Stonehenge	29-Apr-99	09:30	1.20		1	0.0384	10.5	<	0.001	52	52		0.023		0.019	7		1	6		0.27		0.006	1.7
Taieri River @ Stonehenge	30-Jun-99	09:00	3.00		1	0.0321	14.2	<	0.001	8	8		0.009		0.012	7	<	3	0.9		0.16		0.007	1
Taieri River @ Stonehenge	25-Aug-99	09:45	2.00	<	1	0.0346	12.3	<	0.001	22	22		0.008		0.006	7.1		3	5.2		0.17		0.01	1.4
Taieri River @ Stonehenge	3-Sep-99	13:20				0.0235										7.05			7.9					
Taieri River @ Stonehenge	28-Oct-99	09:40	0.80		1	0.04	10.3		0.001	42	42		0.013		0.01	7.4		2	12.9		0.14		0.017	1.7
Taieri River @ Stonehenge	14-Dec-99	07:30	0.59		2	0.03	14.4		0.002	550	550		0.029		0.012	7.1		9	10.3		0.55		0.061	4.8
Taieri River @ Stonehenge	25-Feb-00	11:44				0.03										**7.1**			16.4					
Taieri River @ Stonehenge	2-Mar-00	08:30	2.00	<	1	0.04	9.8		0.002	70	70		0.012		0.01	7.2	<	3	14		0.31		0.024	1.9
Taieri River @ Stonehenge	27-Apr-00	9.40	1.20	<	1	0.04	12.4		0.004	38	38	<	0.005		0.049	7.2		2	7		0.83		0.018	1.4
Taieri River @ Stonehenge	29-Jun-00	9.45	?		1	0.0216	13.8		0.003	23	23		0.009		0.007	6.8		3	1.2		0.25		0.043	2.7
Taieri River @ Stonehenge	31-Aug-00	10.15	1.30		1	0.0238	11.6	<	0.005	8	**11**	<	0.01	<	0.005	**6.6**		4	5.1		0.18		0.02	2.6
Taieri River @ Stonehenge	26-Oct-00	08:45	2.30	<	1	0.03	11.6	<	0.005	20	38		0.02		0.014	**6.4**	<	1	9.5		0.21		0.017	0.91
Taieri River @ Stonehenge	10-Jan-01	09:45	1.50	<	1	0.042	9.2		0.006	57	120		0.02		0.01	7.2		3	15.5		0.34		0.04	1.7

Taieri River @ Stonehenge	28-Feb-01	09:30	1.70	<	1	0.029	9.1	<	0.005	115	58	<	0.01		0.021	7.2	<	1	13.5		0.26	<	0.005	1.5
Taieri River @ Stonehenge	9-May-01	09:00	2.90	<	1	0.036	11.7	<	0.005	33	32	<	0.01		0.047	7.3		3	10.3		0.14		0.013	1.34
Taieri River @ Stonehenge	26-Sep-01	10:37	2.52	<	1	0.0268		<	0.005	24	24	<	0.01		0.008	6.8	<	1	7.9		0.14		0.013	1.05
Taieri River @ Stonehenge	7-Nov-01	11:00	1.55	<	1	0.026	9.15	<	0.005	63	86	<	0.01		0.007	**6.47**		2	12.7		0.25		0.014	1.47
Taieri River @ Stonehenge	20-Nov-01	10:15	2.12	<	1	0.0291	10.6	<	0.005	56	56	<	0.01		0.008	6.8	<	1	11.5		0.22		0.013	1.34
Taieri River @ Stonehenge	4-Dec-01	11:30	1.65	<	1	0.0319	9.5	<	0.005	69	80	<	0.01		0.011	7.1		2	16.8		0.27		0.012	1.78
Taieri River @ Stonehenge	17-Dec-01	10:40	1.70	<	1	0.03	9.85	<	0.005	33	33	<	0.01		0.008	7.1	<	1	16.1		0.31		0.013	1.1
Taieri River @ Stonehenge	8-Jan-02	12:10	1.20	<	1	0.0251	10.61	<	0.005	58	64	<	0.01	<	0.003	7.2			14.5		0.31		0.008	1.29
Taieri River @ Stonehenge	23-Jan-02	13:10	1.63		1	0.0294	10.4	<	0.005	130	210	<	0.01		0.01	6.6		1	18		0.66		0.118	1.6
Taieri River @ Stonehenge	12-Feb-02	12:00		<	1	0.0241	10.14	<<	0.005	72	72		0.02		0.014		<	1	15.4		0.23		0.026	1.23
Taieri River @ Stonehenge	28-Feb-02	13:20	1.80	<	1	0.0292	9.03	<	0.005	58	84	<	0.01		0.01	6.8	<	1	13.5		0.3		0.006	1.23
Taieri River @ Stonehenge	14-Mar-02	12:05	2.10	<	1	0.029	8.26	<	0.005	48	76	<	0.01		0.012	**6.6**	<	1	13.1		0.24		0.016	1.37
Taieri River @ Stonehenge	20-Mar-02	11:37	1.89	<	1	0.0387	9.2	<	0.005	110	110	<	0.01		0.006	6.5	<	1	11		0.29		0.017	1.39
Taieri River @ Stonehenge	11-Apr-02	12:25	2.02	<	1	0.0233	5.22	<	0.005	110	96		0.03		0.004	**7.62**		3	8.62		0.23		0.007	1.31
Taieri River @ Stonehenge	5-Jun-02	10:40	0.36	<	3	0.0381	12.2		0.01	410	510	<	0.01		0.022	6.4		26	3.5		0.8		0.079	13.6
Taieri River @ Stonehenge	23-Jul-02	11:25	1.42			0.037	12.9	<	0.005	17	24	<	0.01		0.019	6.84		1	2		0.21		0.007	1.7
Taieri River @ Stonehenge	28-Aug-02	11:25	0.95			0.0612	13.7		0.006	16	32		0.01		0.016	6.93		3	3		0.32		0.007	2.8
Taieri River @ Stonehenge	24-Sep-02	11:30	1.49			0.0328	11.5	<	0.005	10	16		0.01		0.008	6.55		2	6.2		0.21		0.011	2
Taieri River @ Stonehenge	29-Oct-02	11:00	1.26			0.03	11.5	<	0.005	490	520		0.02		0.01	6.81		4	8		0.63		0.024	2.3
Taieri River @ Stonehenge	19-Nov-02	08:30	1.31			0.0366	12.1	<	0.005	58	100	<	0.01		0.01	6.86		2	7		0.26		0.005	1.3
Taieri River @ Stonehenge	11-Dec-02	08:35	1.35			0.038	10.23		0.005	200	290		0.02		0.014	6.95		2	12.4		0.65		0.043	1.9
Taieri River @ Creamery Bridge	7-Nov-01	11:45	0.65	<	1	0.0347	8.3	<	0.005	99	140	<	0.01		0.005	**6.6**		16	15.4		0.34		0.026	4.11
Taieri River @ Creamery Bridge	4-Dec-01	10:40	1.60	<	1	0.092	9.2		0.017	270	320	<	0.01		0.013	7.3		2	18		0.35		0.052	2.46
Taieri River @ Creamery Bridge	17-Dec-01	10:00	1.15	<	1	0.0661	9.7		0.009	160	270	<	0.01		0.008	7.2		2	18.1		0.44		0.05	2
Taieri River @ Creamery Bridge	8-Jan-02	09:50	0.80	<	1	0.049	9.05		0.009	280	340	<	0.01		0.011	7		5	16.3		0.45		0.045	3.06
Taieri River @ Creamery Bridge	23-Jan-02	09:55	0.82		1	0.0492	8.2		0.016	410	450	<	0.01		0.009	6.2		16	17		0.53		0.079	2.97
Taieri River @ Creamery Bridge	12-Feb-02	09:30		<	1	0.0806	8.55		0.014	180	200		0.02		0.026	**6.76**		2	17.5		0.33		0.058	2.1
Taieri River @ Creamery Bridge	28-Feb-02	10:55	2.05	<	1	0.0813	12.4		0.016	440	330		0.02		0.014	7.1	<	1	15.2		0.38		0.023	1.85
Taieri River @ Creamery Bridge	14-Mar-02	09:30	2.10		1	0.0849	7.9		0.024	190	220	<	0.01		0.012	**6.8**	<	1	14.9		0.3		0.055	1.57
Taieri River @ Creamery Bridge	11-Apr-02	10:36	1.47	<	1	0.06	4.4		0.012	200	210	<	0.01		0.01	**7.26**		3	10.22		0.33		0.062	2.17
Taieri River @ Creamery Bridge	5-Jun-02	12:30	0.44	<	1	0.0564	11.7	<	0.005	180	240	<	0.01		0.045	6.8		39	3.8		0.41		0.027	19.9
Taieri River @ Creamery Bridge	23-Jul-02	10:20	0.66			0.0711	12.3	<	0.005	20	29		0.04		0.024	7.1		9	2		0.25		0.011	3.4
Taieri River @ Creamery Bridge	28-Aug-02	10:30	0.79			0.0846	12.5	<	0.005	33	34		0.02		0.006	6.92		9	2.5		0.27	<	0.005	3.4
Taieri River @ Creamery Bridge	24-Sep-02	10:20	0.90			0.0465	10.7	<	0.005	44	79		0.03		0.008	6.61		9	7		0.25		0.015	3.3
Taieri River @ Creamery Bridge	29-Oct-02	09:00	0.70			0.06	10		0.012	770	770		0.02		0.011	6.95		19	9.2		0.34		0.062	5.3
Taieri River @ Creamery Bridge	19-Nov-02	10:25	1.05			0.0586	10.4		0.006	330	700	<	0.01		0.01	6.8		9	9		0.42		0.041	3.4
Taieri River @ Creamery Bridge	11-Dec-02	10:45	0.54			0.0919	9.63		0.069	10,800	10,800		0.04		0.054	6.94		13	14		0.72		0.201	7
Taieri River @ Waipiata bridge	7-Nov-01	13:00	0.55	<	1	0.0439	8		0.008	150	160		0.03		0.009	**6.74**		22	16.4		0.36		0.037	3.04
Taieri River @ Waipiata bridge	4-Dec-01	09:05	1.35	<	1	0.1103	8.8		0.006	240	320		0.01		0.01	7.4		4	17.8		0.37		0.052	2.95
Taieri River @ Waipiata bridge	17-Dec-01	09:30	1.10	<	1	0.083	9.6		0.009	180	280		0.02		0.008	6.9		1	17.1		0.46		0.061	2.36
Taieri River @ Waipiata bridge	8-Jan-02	09:30	0.90	<	1	0.059	9.61		0.011	340	550		0.02		0.009	7.1		6	16.4		0.47		0.052	4.06
Taieri River @ Waipiata bridge	23-Jan-02	08:45	0.75		1	0.0558	8.5		0.018	460	460	<	0.01		0.011	6.4		12	17		0.55		0.098	4.39

Taieri River @ Waipiata bridge	12-Feb-02	08:20		<	1	0.0922	8.2		0.017	580	610	<	0.01		0.018	**6.95**		3	17.3		0.36		0.063	3.24
Taieri River @ Waipiata bridge	28-Feb-02	09:30	1.80	<	1	0.0978	8.05		0.015	390	390		0.02		0.006	6.9	<	1	14.7		0.4		0.018	2.2
Taieri River @ Waipiata bridge	14-Mar-02	08:05	1.70	<	1	0.1055	7.1		0.027	240	280	<	0.01	<	0.003	**6.42**		2	14.8		0.33		0.066	2.35
Taieri River @ Waipiata bridge	11-Apr-02	09:45	1.68	<	1	0.0818	4.1		0.021	320	520		0.03		0.018	**7.21**		3	10.48		0.28		0.02	2.48
Taieri River @ Waipiata bridge	5-Jun-02	13:07	0.35	<	1	0.0568	11	<	0.005	290	260	<	0.01		0.046	6.8		31	6		0.39		0.031	17.2
Taieri River @ Waipiata bridge	23-Jul-02	09:35	0.94			0.0826	12.8	<	0.005	31	31		0.02		0.028	7.34		12	2		0.29		0.032	4.4
Taieri River @ Waipiata bridge	28-Aug-02	09:30	0.83			0.0914	12.2	<	0.005	11	12		0.01		0.015	7.03		11	3.2		0.4		0.011	3.9
Taieri River @ Waipiata bridge	24-Sep-02	09:29						<	0.005	28	48		0.01		0.012	6.86		12			0.27		0.038	3.9
Taieri River @ Waipiata bridge	29-Oct-02	12:30	0.80			0.06	10.5		0.011	610	720		0.01		0.017	7.16		25	11.5		0.36		0.048	6.8
Taieri River @ Waipiata bridge	19-Nov-02	11:30	0.85			0.0646	10.6		0.007	520	790	<	0.01		0.008	6.79		12	9.2		0.36		0.036	3.5
Taieri River @ Waipiata bridge	11-Dec-02	11:55	0.56			0.093	8.15		0.06	10,100	10,100		0.04		0.071	7.06		19	13.9		0.71		0.177	8.7
Taieri River @ Halls Bridge	24-Jan-96	09:00		<	1	0.0607	8.9		0.015		**210**		0.04		0.027	7.02		17	15.8		0.49		0.076	6.5
Taieri River @ Halls Bridge	20-Mar-96	13:00			1	0.099	10.8		0.045		**2,000**		0.011		0.076	7.05		5	14				0.098	3
Taieri River @ Halls Bridge	22-May-96	13:00		<	1	0.0715	12.8		0.003		**52**	<	0.006		0.023	6.52		8	3.3				0.027	2.4
Taieri River @ Halls Bridge	24-Jul-96	13:40		<	1	0.0674	12.6		0.003		**8**		0.029		0.025	6.49		11	2.6		0.31		0.029	4.5
Taieri River @ Halls Bridge	8-Oct-96	12:35			2	0.0608	10.55		0.006		**180**		0.008		0.017	7.05		7	10.9				0.039	2.9
Taieri River @ Halls Bridge	19-Nov-96	13:15		<	1	0.0534	10.1		0.007		**170**		0.008		0.013			5	13				0.037	2.4
Taieri River @ Halls Bridge	20-Feb-97	10:30			1	0.066	8.1		0.017		**168**		0.014		0.02	7.3		6	21		0.45		0.074	3.8
Taieri River @ Halls Bridge	30-Apr-97	13:00			1	0.045	9.9		0.015		480		0.021		0.01	6.8		11	8		0.39		0.054	3.7
Taieri River @ Halls Bridge	19-Jun-97	11:10		<	1	0.052	11.8		0.006		24		0.016		0.022	7.1		7	3.1				0.031	5
Taieri River @ Halls Bridge	20-Aug-97	09:30	?	<	1	0.046	11		0.025		16		0.025		0.009	6.9		10	5.5		0.32		0.033	5.7
Taieri River @ Halls Bridge	9-Oct-97	09:30	1.50	<	1	0.1176	10		0.076		94		0.03		0.011	7.3		4	9.9		0.23		0.038	4.2
Taieri River @ Halls Bridge	16-Dec-97	09:45	1.20	<	1	0.1038	8.4		0.035		150		0.013		0.012	7.4		3	17.2		0.41		0.079	3.3
Taieri River @ Halls Bridge	25-Feb-98	08:50			2	0.0719	9		0.017		120		0.023		0.008	7.1		12	13.8		0.52		0.075	3.3
Taieri River @ Halls Bridge	29-Apr-98	10:15	1.45			0.1253	10.25												9.1					
Taieri River @ Halls Bridge	24-Jun-98	10:55	1.15	<	1	0.0601	13.05		0.008		57		0.009		0.024	7.2		6	1.2				0.027	5.4
Taieri River @ Halls Bridge	26-Aug-98	09:15		<	1	0.0449	11.9		0.003	37	37		0.038	<	0.003	7.2		15	4.1	<	0.08		0.031	4
Taieri River @ Halls Bridge	29-Oct-98	08:05	1.20	<	1	0.043	10.2		0.019	3,600	3,600		0.016	<	0.003	7		7	12		0.19		0.051	3
Taieri River @ Halls Bridge	2-Dec-98	09:30	1.95		2	0.0818	8.5		0.031	380	510		0.023		0.006	7.5	<	3	15.7		0.36		0.055	2.2
Taieri River @ Halls Bridge	22-Jan-99	13:45				0.0479	8.6												16.8					
Taieri River @ Halls Bridge	3-Feb-99	08:45	1.70		1	0.068	7.9		0.05	680	680		0.11		0.009	7.1	<	3	17.1		0.59		0.065	2.2
Taieri River @ Halls Bridge	29-Apr-99	10:00	0.70		2	0.0582	8		0.02	190	190		0.018		0.018	6.8		8	7		0.42		0.065	4.4
Taieri River @ Halls Bridge	30-Jun-99	10:40	0.90		2	0.0523	13.7		0.003	32	37		0.012		0.011	7.1		10	1.1		0.2		0.024	4.3
Taieri River @ Halls Bridge	25-Aug-99	10:10	0.90	<	1	0.0503	12	<	0.001	29	29		0.005		0.006	7.2		6			0.2		0.017	3.5
Taieri River @ Halls Bridge	28-Oct-99	10:10	0.90		2	0.09	9.2		0.11	2,000	2,000		0.008		0.006	7.4		3	15.8		0.32		0.15	2.4
Taieri River @ Halls Bridge	14-Dec-99	09:00	1.18		1	0.09	14.6		0.034	340	340		0.053		0.003	7.6	<	3	13.6		0.51		0.092	2.6
Taieri River @ Halls Bridge	2-Mar-00	09:10	?	<	1	0.09	8.5		0.025	1,600	2,000		0.011	<	0.003	7.4	<	3	16.4		0.34		0.085	1.8
Taieri River @ Halls Bridge	27-Apr-00	10.10	1.50	<	1	0.07	11		0.009	60	60	<	0.005		0.027	7.4		1	8.9		0.22		0.025	1.5
Taieri River @ Halls Bridge	29-Jun-00	10.20	1.10		1	0.0313	11		0.006	49	49		0.011		0.004	6.6		6	2.1		0.68		0.051	3.1
Taieri River @ Halls Bridge	31-Aug-00	09:45	1.05		1	0.0541	9.85		0.007	40	53	<	0.01	<	0.005	6.6		6	5.5		0.23		0.028	3.3
Taieri River @ Halls Bridge	26-Oct-00	10:10	1.80		1	0.0641	10		0.011	190	200		0.02		0.007	**6.6**		1	11.8		0.42		0.041	1.8
Taieri River @ Halls Bridge	10-Jan-01	10:15	1.60		1	0.092	8		0.1	360	370	<	0.01		0.007	6.9		2	18		0.62		0.21	2.8
Taieri River @ Halls Bridge	28-Feb-01	09:50	2.10	<	1	0.088	8.1		0.025	24	28	<	0.01		0.017	7.3	<	1	15.7		0.4	<	0.005	1.7
Taieri River @ Halls Bridge	9-May-01	10:15	3.10	<	1	0.13	10.1		0.009	142	116	<	0.01		0.009	7.1	<	1	11		0.26		0.037	1.9

Taieri River @ Halls Bridge	26-Sep-01	10:00	0.82	<	1	0.0469			0.021	170	200		0.02		0.016	6.4		6	9		0.19		0.049	6.19
Taieri River @ Halls Bridge	7-Nov-01	08:45	1.20	<	1	0.0336	8.3	<	0.005	120	140	<	0.01		0.004	**6.45**		8	13.8		0.34		0.022	3.15
Taieri River @ Halls Bridge	20-Nov-01	11:00	1.28		1	0.0402	10.9		0.01	2,420	2,500	<	0.01		0.004	6.9	<	1	12		0.37		0.062	3.88
Taieri River @ Halls Bridge	4-Dec-01	13:15	1.80	<	1	0.0932	9.9		0.019	100	150	<	0.01	<	0.003	7.9	<	1	19.6		0.33		0.051	1.88
Taieri River @ Halls Bridge	17-Dec-01	12:40	1.30	<	1	0.0484	10.2		0.007	110	200	<	0.01	<	0.003	7.3	<	1	19.5		0.36		0.03	1.6
Taieri River @ Halls Bridge	8-Jan-02	10:45	1.00	<	1	0.0465	9.57	<	0.005	220	220	<	0.01	<	0.003	7.3		1	16.6		0.42		0.029	2.23
Taieri River @ Halls Bridge	23-Jan-02	10:20	1.47		1	0.0457	7.1		0.017	350	670	<	0.01		0.004	6.3	<	1	17.8		0.55		0.063	2.01
Taieri River @ Halls Bridge	12-Feb-02	10:00		<	1	0.0792	9.1		0.01	100	100	<	0.01		0.013	**6.84**	<	1	18.1		0.33		0.034	1.54
Taieri River @ Halls Bridge	28-Feb-02	11:30	2.40	<	1	0.0727	8.2		0.023	400	640	<	0.01		0.003	7.1	<	1	15.6		0.38		0.024	1.4
Taieri River @ Halls Bridge	14-Mar-02	10:05	2.60	<	1	0.0813	7.6		0.024	54	68	<	0.01	<	0.003	**6.8**	<	1	15.5		0.3		0.055	1.38
Taieri River @ Halls Bridge	20-Mar-02	10:37	1.61	<	1	0.0461	9.2		0.011	250	290	<	0.01	<	0.003	7.1	<	1	12.5		0.36		0.037	1.34
Taieri River @ Halls Bridge	11-Apr-02	11:00	1.67	<	1	0.0545	4.79		0.01	130	170		0.02	<	0.003	**7.44**		1	10.2		0.31		0.054	1.94
Taieri River @ Halls Bridge	5-Jun-02	12:05	0.82		1	0.0598	11.7	<	0.005	170	250	<	0.01		0.039	6.5		9	3.5		0.4		0.014	7.38
Taieri River @ Halls Bridge	23-Jul-02	10:50	0.96			0.0659	12.4	<	0.005	38	38	<	0.01		0.017	6.94		5	2		0.25		0.014	2.8
Taieri River @ Halls Bridge	28-Aug-02	10:55	0.84			0.0821	12	<	0.005	26	26		0.01		0.006	6.83		4	3.5		0.28		0.006	2.6
Taieri River @ Halls Bridge	24-Sep-02	10:50	1.25			0.0447	10.2	<	0.005	30	41	<	0.01		0.006	6.52		4	7.5		0.25		0.016	2.3
Taieri River @ Halls Bridge	29-Oct-02	09:30	0.86			0.06	9.9		0.016	700	790		0.02		0.018	6.84		6	9.5		0.35		0.061	3.6
Taieri River @ Halls Bridge	19-Nov-02	10:00	1.21			0.0572	9.8		0.005	390	530		0.011		0.01	6.8		4	8		0.36		0.035	2.1
Taieri River @ Halls Bridge	11-Dec-02	10:20	0.53			0.0938	9.6		0.053	8,100	8,100		0.03		0.037	6.95		8	14.3		0.63		0.171	6.7
Taieri River @ Helenslea	7-Nov-01	09:40	1.15	<	1	0.0309	8.3	<	0.005	120	38		0.01		0.005	**6.39**		7	13.6		0.36		0.025	2.61
Taieri River @ Helenslea	4-Dec-01	12:50	1.60	<	1	0.0904	8.8		0.02	85	120	<	0.01		0.003	7.6	<	1	18.8		0.33		0.05	2.02
Taieri River @ Helenslea	17-Dec-01	12:10	1.40	<	1	0.0461	10		0.006	122	160	<	0.01		0.004	6.9	<	1	18.2		0.37		0.03	1.72
Taieri River @ Helenslea	23-Jan-02	12:15	1.21		1	0.0413	8.9		0.012	110	210	<	0.01		0.004	6.2		2	18.9		0.52		0.042	1.99
Taieri River @ Helenslea	12-Feb-02	10:30		<	1	0.0717	8.9		0.008	190	210	<	0.01		0.004	**6.73**	<	1	18.2		0.31		0.045	1.5
Taieri River @ Helenslea	28-Feb-02	12:00	2.30	<	1	0.0623	8.04		0.006	34	72	<	0.01	<	0.003	7	<	1	15.4		0.45		0.018	1.22
Taieri River @ Helenslea	14-Mar-02	10:45	2.30	<	1	0.0754	7.45		0.014	39	52	<	0.01	<	0.003	**6.68**	<	1	15.4		0.31		0.044	1.58
Taieri River @ Helenslea	11-Apr-02	11:30	1.68	<	1	0.0535	5.0		0.01	150	140	<	0.01	<	0.003	**7.37**		1	10.02		0.31		0.035	2.17
Taieri River @ Helenslea	5-Jun-02	11:40	0.64		1	0.0563	10.2	<	0.005	230	360	<	0.01		0.036	6.4		11	3.5		0.44		0.029	7.48
Taieri River @ Helenslea	23-Jul-02	12:30	0.89			0.0561	12.2	<	0.005	34	48	<	0.01		0.016	6.87		5	2		0.28	<	0.005	2.80
Taieri River @ Helenslea	28-Aug-02	12:10	0.79			0.0739	12.8	<	0.005	27	41		0.02		0.011	6.8		4	3.2		0.3		0.009	2.60
Taieri River @ Helenslea	24-Sep-02	13:05	1.05			0.0411	11.0	<	0.005	12	24	<	0.01	<	0.005	6.78		4	8.2		0.27		0.018	2.10
Taieri River @ Helenslea	29-Oct-02	10:00	0.78			0.05	10.0		0.015	730	780		0.02		0.01	6.86		15	9.4		0.47		0.073	5.00
Taieri River @ Helenslea	19-Nov-02	09:45	1.21			0.0433	10.6		0.008	310	540	<	0.01		0.008	6.85		6	7.4		0.36		0.032	2.50
Taieri River @ Helenslea	11-Dec-02	10:00	0.79			0.0714	7.43		0.022	330	640		0.03		0.022	6.8		11	14.7		0.48		0.094	6.90
Taieri River @ Puketoi	7-Nov-01	10:15	0.90	<	1	0.0287	8.75	<	0.005	65	130		0.01		0.005	**6.48**		8	13.7		0.31		0.019	2.82
Taieri River @ Puketoi	4-Dec-01	12:15	1.60	<	1	0.0781	8.6		0.026	140	150	<	0.01		0.005	7.2		2	18		0.34		0.098	2.08
Taieri River @ Puketoi	17-Dec-01	11:30	1.40	<	1	0.047	9.8	<	0.005	82	96		0.04		0.004	6.9	<	1	17.5		0.36		0.025	1.77
Taieri River @ Puketoi	8-Jan-02	11:20	0.80	<	1	0.031	8.85	<	0.005	180	270	<	0.01		0.011	6.6		2	15.7		0.37		0.015	2.22
Taieri River @ Puketoi	23-Jan-02	11:00	1.13		2	0.0373	8.6		0.006	64	140	<	0.01		0.009	6.3		3	18.5		0.44		0.03	2.3
Taieri River @ Puketoi	12-Feb-02	11:20		<	1	0.0537	9.4		0.005	40	48	<	0.01		0.013	6.63	<	1	18		0.26		0.035	1.47
Taieri River @ Puketoi	28-Feb-02	12:30		<	1	0.052	7.62		0.012	43	68		0.01	<	0.003	6.8		2	14.3		0.31		0.017	1.5
Taieri River @ Puketoi	14-Mar-02	11:30		<	1	0.0583	7.7		0.011	97	110	<	0.01	<	0.003	6.7	<	1	15		0.26		0.027	1.54

Taieri River @ Puketoi	11-Apr-02	12:00	1.58	<	1	0.039	4.87		0.016	330	260	<	0.01		0.005	7.51		1	9.3		0.29		0.037	2.51
Taieri River @ Puketoi	5-Jun-02	11:10	0.42		2	0.0536	10.4		0.008	250	260	<	0.01		0.035	6.4		16	3.5		0.52		0.035	9.69
Taieri River @ Puketoi	23-Jul-02	11:55	NR?	<	1	0.0502	12.2	<	0.005	15	24		0.01		0.023	6.76		7	3		0.26		0.019	2.6
Taieri River @ Puketoi	28-Aug-02	11:50	0.90	<	1	0.0675	12.2	<	0.005	12	16		0.01	<	0.005	6.66		6	3.2		0.28		0.009	2.8
Taieri River @ Puketoi	24-Sep-02	12:40	1.17	<	1	0.0378	10.7	<	0.005	6	8	<	0.01		0.011	6.72		5	7.2		1.31		0.021	2.2
Taieri River @ Puketoi	29-Oct-02	10:30	0.69	<	1	0.04	10.4		0.014	700	700		0.02		0.017	6.73		23	9		0.38		0.051	5.8
Taieri River @ Puketoi	19-Nov-02	09:00	1.23		1	0.045	10.5	<	0.005	120	300		0.02		0.009	6.8		6	7.7		0.33		0.005	2.2
Taieri River @ Puketoi	11-Dec-02	09:10	0.86		1	0.0568	7.94		0.01	300	360		0.03		0.02	6.76		5	14		0.4		0.056	3.6
Pig Burn 900m d/s O'Neill Rd	7-Nov-01	12:30	0.55		1	0.0895	8		0.017	2,100	2,100		0.01		0.048	**7.03**		40	18.1		0.38		0.054	9.12
Pig Burn 900m d/s O'Neill Rd	4-Dec-01	10:00	1.40	<	1	0.1389	9.9	<	0.005	1,400	1,460	<	0.01		0.142	7.7		5	15		0.43		0.017	3.7
Pig Burn 900m d/s O'Neill Rd	17-Dec-01	09:30	1.60	<	1	0.153	10.54	<	0.005	199	199		0.01		0.168	7.4	<	1	15.3		0.4		0.009	2.3
Pig Burn 900m d/s O'Neill Rd	8-Jan-02	10:10	1.40	<	1	0.152	9.85		0.006	770	770		0.03		0.141	7.3			15.7		0.44		0.017	4.06
Pig Burn 900m d/s O'Neill Rd	23-Jan-02	09:25	1.03	<	1	0.0726	10.4	<	0.005	290	940		0.05		0.041	6.7		18	14.9		0.2		0.031	2.68
Pig Burn 900m d/s O'Neill Rd	12-Feb-02	09:00			2	0.1316	9.2		0.019	13,300	13,300		0.03		0.105	**6.85**		10	15		0.76		0.12	10.5
Pig Burn 900m d/s O'Neill Rd	28-Feb-02	10:00	2.10	<	1	0.139	8.8	<	0.005	380	380		0.02		0.097	7.6		<1	13.8		0.3	<	0.005	1.55
Pig Burn 900m d/s O'Neill Rd	14-Mar-02	08:45	2.30	<	1	0.1506	8.3		0.016	330	340	<	0.01		0.127	**6.72**		2	12.2		0.37		0.037	1.98
Pig Burn 900m d/s O'Neill Rd	11-Apr-02	10:10	0.46		2	0.1767	5.13	<	0.005	9,700	10,000		0.11		0.261	**7.19**		23	10.63		1.27		0.07	13
Pig Burn 900m d/s O'Neill Rd	5-Jun-02	12:45	0.24	<	1	0.0605	11.4	<	0.005	540	740	<	0.01		0.044	7.1		43	6.7		0.37		0.021	8.54
Pig Burn 900m d/s O'Neill Rd	23-Jul-02	10:00		<	1	0.0654	12.9	<	0.005	6	20		0.02		0.044	7.01		15	1.5		0.17		0.01	2.7
Pig Burn 900m d/s O'Neill Rd	28-Aug-02	10:00		<	1	0.089	13.4	<	0.005	8	8	<	0.01		0.031	7.16		8	2.5		0.15	<	0.005	1.6
Pig Burn 900m d/s O'Neill Rd	24-Sep-02	09:53		<	1	0.0638	12.2	<	0.004	12	18	<	0.01		0.023	7		6	6		0.08	<	0.005	1.6
Pig Burn 900m d/s O'Neill Rd	29-Oct-02	11:45		<	1	0.07	11	<	0.005	65	65		0.01		0.05	7.32		8	11.5		0.17		0.014	3.5
Pig Burn 900m d/s O'Neill Rd	19-Nov-02	11:00		<	1	0.1002	11.4	<	0.005	31	52	<	0.01		0.017	7.26		5	8.7		0.13	<	0.005	1.3
Pig Burn 900m d/s O'Neill Rd	11-Dec-02	11:25			1	0.0864	8.93		0.013	1,300	2,300		0.03		0.058	7.18		13	12.8		0.38		0.055	6.2
Eweburn @ Gimmerburn-Waipiata Rd	23-Jul-02	13:05		<	1	0.1393	13	<	0.005	13	16	<	0.01		0.086	7.66		1	5		0.32	<	0.005	2.2
Eweburn @ Gimmerburn-Waipiata Rd	28-Aug-02	12:50		<	1	0.197	14		0.005	5	5		0.01		0.038	8.53		2	7.2		0.26		0.005	0.95
Eweburn @ Gimmerburn-Waipiata Rd	24-Sep-02	13:30			1	0.0885	13.3		0.404*	130	230		0.36		0.081	8.77		13	11.5		0.38		0.058	14
Eweburn @ Gimmerburn-Waipiata Rd	29-Oct-02	12:10		<	1	0.05	11.4		0.01	130	180		0.01		0.024	7.41		5	13.5		0.33		0.037	1.7
Eweburn @ Gimmerburn-Waipiata Rd	19-Nov-02	10:45			1	0.1535	11.4		0.023	280	390	<	0.01		0.018	7.54		6	9.2		0.41		0.072	3.5
Eweburn @ Gimmerburn-Waipiata Rd	11-Dec-02	11:05			1	0.0526	11.8		0.018	2000	3300		0.02		0.02	6.99		8	13.5		0.43		0.073	6.6
NOTE:																								
An asterisk * denotes a suspect result																								
pH results in bold type denote measurements taken in the FIELD																								

Appendix 2 – Statistical Analyses

Analyses performed on upper Taieri River water quality data (7 Nov 2001-11 Dec 2002 inclusive) using Statgraphics® Plus (©1994-1997). Significant results indicated in bold type. Refer Appendix 1 for the water quality data.

Analyte 1: Dissolved Oxygen (DO % saturation)

1)Kruskal-Wallis test for a significant difference amongst medians:

Test Statistic	*p*-value
7.6640	0.1758

2)Mann Whitney (Wilcoxin) W tests (one-sided) to compare medians between sites:

- testing whether Median 1 < Median 2 where Median 1 is always the *downstream* site (i.e., assumption: median DO will decrease with distance downstream)
- a *p*-value < 0.05 indicates a significant difference between the 2 medians at the 95% confidence level

		MEDIAN 2									
	SITE	**Stonehenge**		**Puketoi**		**Helenslea**		**Halls Bridge**		**Creamery Br.**	
		W	***p***	**W**	***p***	**W**	***p***	**W**	***p***	**W**	***p***
MEDIAN 1	**Puketoi**	188.5	**0.0111**								
	Helenslea	172.5	**0.0174**	105.5	0.5000						
	Halls Bridge	192.0	0.0524	123.0	0.5601	103.0	0.7317				
	Creamery Br.	167.0	0.0702	91.0	0.8086	84.5	0.8090	107.5	0.7695		
	Waipiata	171.5	**0.0194**	96.5	0.6366	94.5	0.5549	123.5	0.4368	117.5	0.3001

Analyte 2: pH

1) Kruskal-Wallis test for a significant difference amongst medians:

Test Statistic	*p*-value
8.100	0.1508

Analyte 3: Suspended Solids (SS)

1) Kruskal-Wallis test for a significant difference amongst medians:

Test Statistic	*p*-value
19.450	**0.0016**

2) Mann Whitney (Wilcoxin) W tests (one-sided) to compare medians between sites:

- testing whether Median 1 > Median 2 where Median 1 is always the *downstream* site (i.e., assumption: median SS will increase with distance downstream)
- a *p*-value < 0.05 indicates a significant difference between the 2 medians at the 95% confidence level

		MEDIAN 2									
	SITE	**Stonehenge**		**Puketoi**		**Helenslea**		**Halls Bridge**		**Creamery Br.**	
		W	***p***	**W**	***p***	**W**	***p***	**W**	***p***	**W**	***p***
MEDIAN 1	**Puketoi**	82.5	**0.0259**								
	Helenslea	95.5	0.1113	133.0	0.6913						
	Halls Bridge	141.5	0.3533	184.0	0.9176	159.0	0.8103				
	Creamery Br.	59.5	**0.0027**	90.0	0.0774	77.0	**0.0452**	66.5	**0.0035**		
	Waipiata	47.0	**0.0006**	79.5	0.0347	64.0	**0.0137**	57.0	**0.0013**	111.0	0.2663

Analyte 4: Turbidity (TURB)

2) Kruskal-Wallis test for a significant difference amongst medians:

Test Statistic	***p*-value**
30.114	**<0.0001**

2) Mann Whitney (Wilcoxin) W tests (one-sided) to compare medians between sites:
- testing whether Median 1 > Median 2 where Median 1 is always the *downstream* site (i.e., assumption: median TURB will increase with distance downstream)
- a *p*-value < 0.05 indicates a significant difference between the 2 medians at the 95% confidence level

		MEDIAN 2									
	SITE	**Stonehenge**		**Puketoi**		**Helenslea**		**Halls Bridge**		**Creamery Br.**	
		W	***p***	**W**	***p***	**W**	***p***	**W**	***p***	**W**	***p***
MEDIAN 1	**Puketoi**	54.5	**0.0011**								
	Helenslea	62.5	**0.0046**	128.5	0.6241						
	Halls Bridge	75.0	**0.0031**	156.5	0.6607	142.5	0.5999				
	Creamery Br.	33.5	**<0.0001**	89.0	0.0733	81.0	0.0639	94.5	**0.0454**		
	Waipiata	20.0	**<0.0001**	55.0	**0.0031**	57.0	**0.0067**	59.0	**0.0018**	96.0	0.1175

Analyte 5: Visual Clarity (VC)

3) Kruskal-Wallis test for a significant difference amongst medians:

Test Statistic	***p*-value**
14.187	**0.0145**

2) Mann Whitney (Wilcoxin) W tests (one-sided) to compare medians between sites:
- testing whether Median 1 < Median 2 where Median 1 is always the *downstream* site (i.e., assumption: median VC will decrease with distance downstream)
- a *p*-value < 0.05 indicates a significant difference between the 2 medians at the 95% confidence level

		MEDIAN 2									
	SITE	**Stonehenge**		**Puketoi**		**Helenslea**		**Halls Bridge**		**Creamery Br.**	
		W	***p***	**W**	***p***	**W**	***p***	**W**	***p***	**W**	***p***
MEDIAN 1	**Puketoi**	167.0	**0.0021**								
	Helenslea	163.0	**0.0421**	71.0	0.7401						
	Halls Bridge	191.0	0.0565	68.5	0.9281	102.0	0.7439				
	Creamery Br.	195.5	**0.0054**	103.0	0.2708	134.5	0.1026	178.0	**0.0295**		
	Waipiata	187.5	**0.0035**	93.5	0.3216	122.5	0.1349	161.5	**0.0477**	101.0	0.5607

Analyte 6: Conductivity (COND)

4) Kruskal-Wallis test for a significant difference amongst medians:

Test Statistic	*p*-value
48.019	**<0.0001**

2) Mann Whitney (Wilcoxin) W tests (one-sided) to compare medians between sites:
- testing whether Median 1 > Median 2 where Median 1 is always the *downstream* site (i.e., assumption: median COND will increase with distance downstream)
- a *p*-value < 0.05 indicates a significant difference between the 2 medians at the 95% confidence level

		MEDIAN 2									
	SITE	**Stonehenge**		**Puketoi**		**Helenslea**		**Halls Bridge**		**Creamery Br.**	
		W	***p***	**W**	***p***	**W**	***p***	**W**	***p***	**W**	***p***
MEDIAN 1	**Puketoi**	40.0	**0.0002**								
	Helenslea	16.0	**<0.0001**	82.0	0.0691						
	Halls Bridge	16.0	**<0.0001**	83.0	**0.0184**	117.5	0.2694				
	Creamery Br.	13.0	**<0.0001**	52.0	**0.0022**	82.0	0.0691	113.0	0.1462		
	Waipiata	5.0	**<0.0001**	23.5	**0.0001**	45.0	**0.0027**	72.5	**0.0125**	79.0	0.0546

Analyte 7: Faecal Coliforms (FC)

5) Kruskal-Wallis test for a significant difference amongst medians:

Test Statistic	*p*-value
13.754	**0.0173**

2) Mann Whitney (Wilcoxin) W tests (one-sided) to compare medians between sites:
- testing whether Median 1 > Median 2 where Median 1 is always the *downstream* site (i.e., assumption: median FC will increase with distance downstream)
- a *p*-value < 0.05 indicates a significant difference between the 2 medians at the 95% confidence level

		MEDIAN 2									
	SITE	**Stonehenge**		**Puketoi**		**Helenslea**		**Halls Bridge**		**Creamery Br.**	
		W	***p***	**W**	***p***	**W**	***p***	**W**	***p***	**W**	***p***
MEDIAN 1	**Puketoi**	114.0	0.1543								
	Helenslea	105.0	0.1430	113.0	0.3986						
	Halls Bridge	86.0	**0.0085**	104.5	0.0891	103.0	0.1273				
	Creamery Br.	68.5	**0.0048**	79.5	**0.0352**	84.5	0.0832	132.5	0.3521		
	Waipiata	67.5	**0.0044**	64.5	**0.0088**	77.0	**0.0464**	121.5	0.2239	105.5	0.2035

Analyte 8: *E. coli* (EC)

6) Kruskal-Wallis test for a significant difference amongst medians:

Test Statistic	*p*-value
13.767	**0.0172**

2) Mann Whitney (Wilcoxin) W tests (one-sided) to compare medians between sites:
- testing whether Median 1 > Median 2 where Median 1 is always the *downstream* site (i.e., assumption: median EC will increase with distance downstream)
- a *p*-value < 0.05 indicates a significant difference between the 2 medians at the 95% confidence level

		MEDIAN 2									
	SITE	**Stonehenge**		**Puketoi**		**Helenslea**		**Halls Bridge**		**Creamery Br.**	
		W	***p***	**W**	***p***	**W**	***p***	**W**	***p***	**W**	***p***
MEDIAN 1	**Puketoi**	124.0	0.2505								
	Helenslea	105.0	0.1429	110.5	0.3610						
	Halls Bridge	94.5	**0.0170**	99.5	0.0644	104.0	0.1350				
	Creamery Br.	72.5	**0.0071**	85.0	0.0545	79.0	0.0546	130.0	0.3207		
	Waipiata	66.0	**0.0037**	69.5	**0.0144**	68.5	**0.0219**	116.5	0.1757	109.0	0.7573

Analyte 9: Biochemical Oxygen Demand (BOD)

7) Kruskal-Wallis test for a significant difference amongst medians:

Test Statistic	***p*-value**
1.253	**0.9397**

Analyte 10: Ammoniacal Nitrogen (AN)

8) Kruskal-Wallis test for a significant difference amongst medians:

Test Statistic	***p*-value**
8.027	0.1548

2) Mann Whitney (Wilcoxin) W tests (one-sided) to compare medians between sites:
- testing whether Median 1 > Median 2 where Median 1 is always the *downstream* site (i.e., assumption: median AN will increase with distance downstream)
- a *p*-value < 0.05 indicates a significant difference between the 2 medians at the 95% confidence level

		MEDIAN 2									
	SITE	**Stonehenge**		**Puketoi**		**Helenslea**		**Halls Bridge**		**Creamery Br.**	
		W	***p***	**W**	***p***	**W**	***p***	**W**	***p***	**W**	***p***
MEDIAN 1	**Puketoi**	121.5	0.1963								
	Helenslea	142.5	0.6225	145.5	0.8709						
	Halls Bridge	170.5	0.6221	173.5	0.8745	134.5	0.5000				
	Creamery Br.	118.5	0.1605	122.5	0.4186	94.0	0.1181	112.0	0.1007		
	Waipiata	91.0	**0.0254**	99.5	0.1344	70.5	**0.0179**	84.5	**0.0133**	111.5	0.2623

Analyte 11: Nitrite-Nitrate Nitrogen (NNN)

9) Kruskal-Wallis test for a significant difference amongst medians:

Test Statistic	***p*-value**
13.439	**0.0196**

2) Mann Whitney (Wilcoxin) W tests (one-sided) to compare medians between sites:
- testing whether Median 1 > Median 2 where Median 1 is always the *downstream* site (i.e., assumption: median NNN will increase with distance downstream)
- a *p*-value < 0.05 indicates a significant difference between the 2 medians at the 95% confidence level

		MEDIAN 2									
	SITE	**Stonehenge**		**Puketoi**		**Helenslea**		**Halls Bridge**		**Creamery Br.**	
		W	***p***	**W**	***p***	**W**	***p***	**W**	***p***	**W**	***p***
MEDIAN 1	**Puketoi**	159.5	**0.6980**								
	Helenslea	183.0	0.9578	147.5	0.8582						
	Halls Bridge	220.5	0.9676	176.5	0.8671	140.5	0.5727				
	Creamery Br.	113.0	0.1451	87.0	0.0630	55.5	**0.0056**	71.5	**0.0063**		
	Waipiata	110.0	0.1230	90.5	0.0811	61.5	**0.0108**	76.0	**0.0096**	123.0	0.4325

Analyte 12: Total Nitrogen (TN)

10) Kruskal-Wallis test for a significant difference amongst medians:

Test Statistic	*p*-value
8.920	0.1123

2) Mann Whitney (Wilcoxin) W tests (one-sided) to compare medians between sites:
- testing whether Median 1 > Median 2 where Median 1 is always the *downstream* site (i.e., assumption: median TN will increase with distance downstream)
- a *p*-value < 0.05 indicates a significant difference between the 2 medians at the 95% confidence level

		MEDIAN 2									
	SITE	**Stonehenge**		**Puketoi**		**Helenslea**		**Halls Bridge**		**Creamery Br.**	
		W	***p***	**W**	***p***	**W**	***p***	**W**	***p***	**W**	***p***
MEDIAN 1	**Puketoi**	93.0	**0.0405**								
	Helenslea	80.0	**0.0242**	103.5	0.2629						
	Halls Bridge	97.0	**0.0205**	135.0	0.3844	141.0	0.5791				
	Creamery Br.	85.0	**0.0217**	112.0	0.2793	121.0	0.5079	135.0	0.3844		
	Waipiata	76.0	**0.0099**	94.0	0.1027	103.5	0.2626	110.5	0.1262	109.5	0.2484

Analyte 13: Dissolved Reactive Phosphorus (DRP)

11) Kruskal-Wallis test for a significant difference amongst medians:

Test Statistic	*p*-value
18.281	**0.0026**

2) Mann Whitney (Wilcoxin) W tests (one-sided) to compare medians between sites:
- testing whether Median 1 > Median 2 where Median 1 is always the *downstream* site (i.e., assumption: median DRP will increase with distance downstream)
- a *p*-value < 0.05 indicates a significant difference between the 2 medians at the 95% confidence level

		MEDIAN 2									
	SITE	**Stonehenge**		**Puketoi**		**Helenslea**		**Halls Bridge**		**Creamery Br.**	
		W	***p***	**W**	***p***	**W**	***p***	**W**	***p***	**W**	***p***
MEDIAN 1	**Puketoi**	79.0	**0.0046**								
	Helenslea	58.0	**0.0009**	106.0	0.2910						
	Halls Bridge	68.0	**0.0005**	117.0	0.1731	120.5	0.3028				
	Creamery Br.	56.0	**0.0004**	96.5	0.1148	102.0	0.2406	141.0	0.4650		
	Waipiata	46.5	**0.0001**	91.0	0.0800	97.5	0.1891	133.0	0.3567	123.0	0.4319

Analyte 14: Total Phosphorus (TP)

12) Kruskal-Wallis test for a significant difference amongst medians:

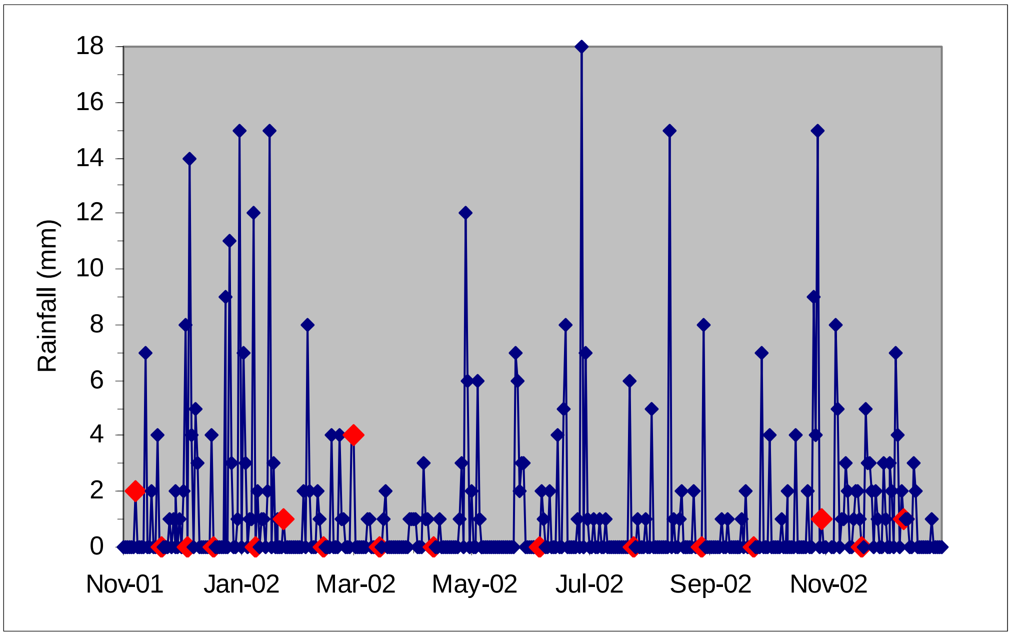
Test Statistic	*p*-value
17.087	**0.0004**

2) Mann Whitney (Wilcoxin) W tests (one-sided) to compare medians between sites:
- testing whether Median 1 > Median 2 where Median 1 is always the *downstream* site (i.e., assumption: median TP will increase with distance downstream)
- a *p*-value < 0.05 indicates a significant difference between the 2 medians at the 95% confidence level

		MEDIAN 2									
	SITE	**Stonehenge**		**Puketoi**		**Helenslea**		**Halls Bridge**		**Creamery Br.**	
		W	***p***	**W**	***p***	**W**	***p***	**W**	***p***	**W**	***p***
MEDIAN 1	**Puketoi**	81.0	**0.0155**								
	Helenslea	68.0	**0.0081**	101.5	0.2382						
	Halls Bridge	74.5	**0.0029**	111.5	0.1346	124.5	0.3588				
	Creamery Br.	66.5	**0.0039**	85.0	0.0545	94.5	0.1614	128.5	0.3023		
	Waipiata	49.5	**0.0006**	69.0	**0.0137**	82.5	0.0717	113.5	0.1502	121.5	0.4105

Appendix 3 – Rainfall Data – Pat-Paerau

Daily rainfall (mm) recorded at Pat-Paerua over 1 Nov 2001-15 Dec 2002 inclusive – rainfall recorded in the 24 hours prior to sampling is denoted with a red diamond.



Appendix 4 – Periphyton & Macroinvertebrate Results

Results of periphyton and macroinvertebrate sampling undertaken on 12 March 2002 in the Taieri River at Stonehenge (Hores Bridge), Creamery Road and Waipiata (Green Bridge).

1. Periphyton

		Stonehenge	Creamery Rd	Waipata
Green filamentous	*Stigeoclonium*		5	
Red filaments	*Audouinella*		6	7
Green, non-filamentous	*Closterium*		1	
Diatoms	*Achnanthidium*	2	4	
Diatoms	*Cocconeis placentula*	2	3	6
Diatoms	*Gomphoneis* spp.		8	5
Diatoms	*Gomphonema cf. parvulum*		6	5
	Nitzschia spp. (small)		4	
	Pinnularia spp.	2		
	cf. Sellaphora			1
	cf. *Stauroneis*			1
	Synedra ulna	2		
Cyanobacteria	*Phormidium*		3	5
Cyanobacteria	*cf. Lyngbya*			8
Relative abundance scores:	8 dominant			
	7 abundant			
	6 common - abundant			
	5 common			
	4 occasional - common			
	3 occasional			
	2 rare - occasional			
	1 rare			

2. Macroinvertebrates

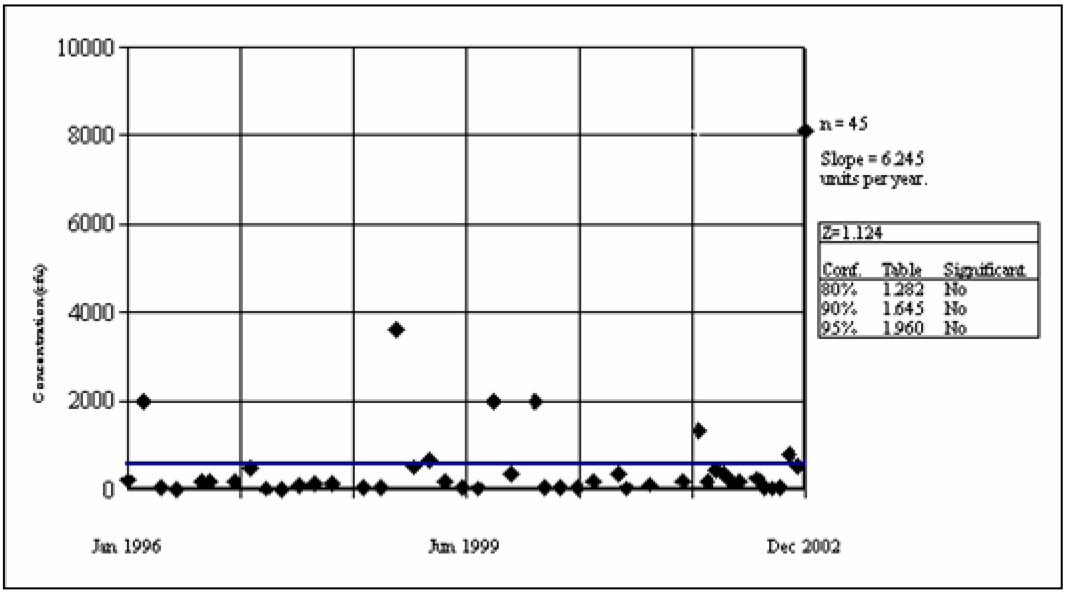
Taxa	**MCI sensitivity score**	Stonehenge	Creamery Rd	Waipiata
ORDER COLEOPTERA				
Hydora nitida	6	C	VVA	VA
ORDER TRICHOPTERA				
Aoteapsyche colonica	4		A	A
Beraeoptera roria	8	VA		
Costachorema other spp.	7		R	
Hudsonema amabile	6		C	
Hydrobiosis clavigera	5			C
Hydrobiosis copis	5	R		
Hydrobiosis early instar	5	A	C	
Hydrobiosis frater	5		R	
Hydrobiosis harpidiosa	5		C	
Oxyethira albiceps	2		A	
Philorheithrus agilis	8		C	C
Psilochorema species	8	R	C	
Pycnocentria evecta	7	VVA	C	A
Pycnocentrodes species	5	A	A	A
Orthocladiinae	2		A	
Maoridiamesa species	3		C	
Austrosimulium australense	3		A	A
ORDER EPHEMEROPTERA				
Coloburiscus humeralis	9	A		
Deleatidium species	8	VVA	VVA	VVA
Nesameletus ornatus	9	R		
ORDER MEGALOPTERA				
Archichauliodes diversus	7	C		
ORDER MOLLUSCA				
Physa species	3		C	
Potamopyrgus antipodarum	4	A	VA	VA
OLIGOCHAETA	1	C	R	A
CRUSTACEA				
Ostracoda	3	A		C
Paracalliope fluviatilis	5		C	C
Total Richness		14	20	12
EPT Richness		9	11	5
% EPT Richness		64.29	55.00	41.67
MCI Score		121.43	97.00	98.33
SQMCI Score		7.32	6.40	6.71

Abundance classes: R – rare
C – common
A – abundant
VA – very abundant
VVA – very very abundant

Appendix 5 – Seasonal Kendall Test Results for the Taieri River at Halls Bridge

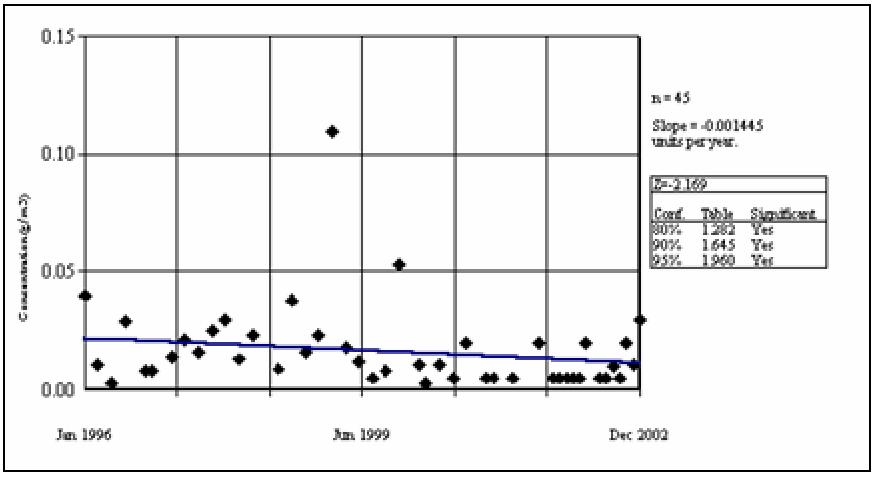
Seasonal Kendall tests were performed on the following Taieri River (Halls Bridge) physico-chemical and microbiological water data (January 1996 to December 2002 inclusive): turbidity, suspended solids, faeal coliforms, ammoniacal nitrogen, total nitrogen and total phosphorus. The raw data used in the tests are presented in Appendix 1 and the results of the tests not shown in the text of the report are presented graphically below. Note that due to differences in laboratory detection limits for suspended solid tests performed between 1996-2000 and 2000-2002, a mean-weighted detection limit was applied to all non-detect values in the data set[3]. This was necessary to ensure that differences in detection limits did not bias assessment of any trend in suspended solid concentrations over time.

Faecal Coliforms

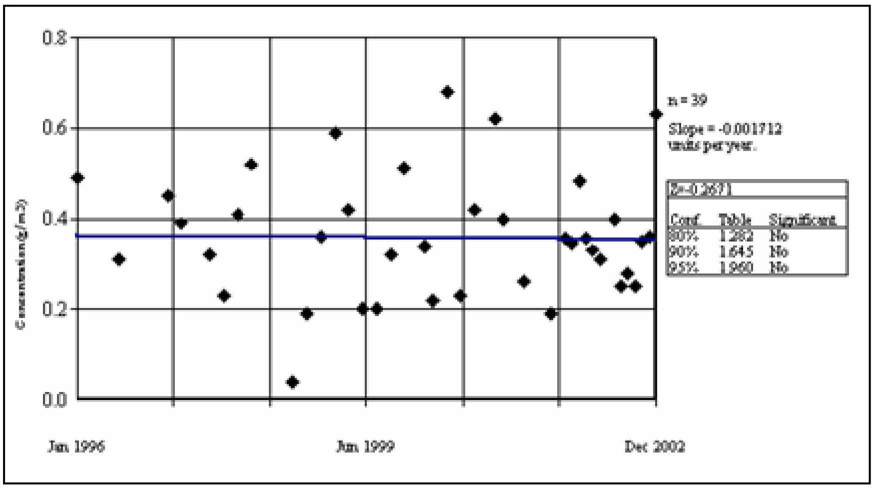


[3] Between 1996-July 2000 the detection limit was 3 g/m^3. This limit was reduced to 1 g/m^3 from July 2000. As non-detect values are typically reported at half the detection limit (i.e., 1.5 and 0.5 g/m^3 for the 1996-2000 and 2000-2002 data respectively), the average of the two detection limits was applied to all non detect data for the 1996-2002 Seasonal Kendall test (i.e., all non-detect values were taken as being 1 g/m^3).

Ammoniacal Nitrogen



Total Nitrogen



Total Phosphorus