Effects of land use on water quality in the Pomahaka catchment

Published April 2011

ISBN 978-0-478-37608-1

Foreword

The Otago Regional Council (ORC) carries out regular and extensive long-term water quality monitoring as part of its State of Environment programme, plus additional targeted detailed short-term monitoring programmes. This report provides the results from one of these more detailed investigations carried out in the Pomahaka River catchment. The investigation was implemented to more accurately understand how different land-uses can affect water quality and in-stream ecological values.

The Pomahaka River in South Otago has a long history of agricultural land use, however climate and soil type mean that farming in the Pomahaka catchment relies on artificial drainage predominantly in the form of tile and mole drains. Changes in land-use, especially in the mid and lower catchment where dairy farm conversions are prevalent, combined with inappropriate land management, are putting pressure on the naturally high water quality found in the catchment. The Pomahaka River is recognised as a regionally-significant trout fishery, which is a major asset for the region.

ORC has a broad range of regulatory and non regulatory approaches to ensuring that the water quality in the Pomahaka is maintained, and where possible enhanced. ORC is in the process of implementing a new water quality strategy and is in the process of revising its Water Plan to deal with water quality issues in consultation with the Otago Community.

The results from this report will be used to guide future policy decisions and will be shared with the community and other stakeholders to promote good practice to maintain and enhance water quality in and around the Pomahaka River.

Executive summary

Water quality in the lower Pomahaka catchment has been deteriorating for a number of years, while land use has rapidly intensified. The catchment is characterised by poor draining pallic soils, which has resulted in tile and mole drainage being installed to improve grazing land use. However, one of the main attributable factors to the deterioration in water quality is the management practises employed on this tile and mole drainage network.

The Otago Regional Council initiated a 12-month water quality sampling programme in 2008, with the aim of getting a better understanding of the effects of land use on water quality in the Pomahaka catchment. The main objectives of this project were to determine the spatial and seasonal patterns of water quality within the Pomahaka catchment. In particular to monitor water quality from tile drains, draining both intensive and non-intensive land use units within the catchment, and to determine the ecological effect of declining water quality.

Guideline values were chosen to reflect the nature of the Pomahaka catchment, and, where possible, guidelines that reflected any discernable affects on ecological, angling and contact recreation values.

This study has shown that tiles draining dairy farms are typically well above effects-based water quality guideline values for nutrients and have substantially higher concentrations of contaminants than tiles draining sheep farms. These nutrient-enriched discharges were the result of inappropriate effluent application when the soil was saturated or the application rate of effluent was too high for the soils to absorb.

The following conclusions have been drawn:

- Tiles draining dairy farms had more Dissolved Reactive Phosphorus (DRP), Suspended Sediment (SS), Total Nitrogen (TN) and Nitrite-Nitrate Nitrogen (NNN) than those sheep farms.
- *Escherichia coli (E.coli)* levels were high from both dairy and sheep tile-drained land after rainfall. (The highest two values recorded were from sheep farm drains.) High *E.coli* values were also recorded from dairy farm tile drains during dry weather. However, in five of the 11 samples for sheep farms and six out of 11 samples for dairy farms, *E.coli* concentration was below the 260 cfu/mL guideline.
- In-stream effects-based guidelines and an ecological value classification have been used to understand the effects of water quality degradation and habitat health. These have shown that the main issues of concern to the health of the river system are sediment, *E.coli* and DRP. Each of these are likely linked to poor land management practices.
- NNN concentrations are only an ecological issue during summer low flows, as NNN is rapidly flushed from the system during high flows.
- Results from this study indicate that sediment is an issue all year round, at all flow levels. Sediment control is critical as it can smother habitat, harbour bacteria and bind phosphorus (P). P previously bound to sediment can be released back into the system during the low flow periods, potentially increasing algal growth. *E.coli* that has been harboured in sediment can be released by sediment disturbance at times of low flow when contact recreational activities are most likely to occur.

- The provision of stock drinking water, excluding all stock types of waterways and the use of native riparian vegetation, will result in improvements to physical habitat within the stream and will ultimately improve instream values. Dairy farmers need to continue the improvements the industry has made in managing dairy shed effluent.
- Water quality values from both the stream and tile sites provide the basis for calculating in-stream standards and tile-discharge standards. These could form the basis of community discussion prior to any future policy changes aimed at maintaining or improving ecological values.

Table of Contents

List of Figures

Otago Regional Council

List Tables

1 Introduction

Water quality in the lower Pomahaka catchment has been decreasing for a number of years as land use has rapidly intensified. A ranking of water quality in 77 sites across Otago placed four of the eight sites from the Pomahaka catchment in the worst ten sites in Otago (ORC, 2007).

Farming in the Pomahaka catchment relies on artificial drainage predominantly in the form of tile drains. Unfortunately, subsurface drainage has been identified as a significant source of contaminants from grazed pastures to waterways (Wilcock et al. 1999, Monaghan et al. 2002a, Monaghan et al. 2002b). If inappropriately managed, these tile and mole drains accelerate water and associated contaminant flows of nitrogen (N), phosphorous (P) and bacteria to local watercourses and the tile drains also allow riparian zones to be bypassed (Nguyen et al. 2002).

Concern about degrading water quality resulting from dairy farm conversions has been evident for a number of years. In 2005, regional and central government, as well as the dairy industry, established a voluntary accord known as the Clean Streams Accord Regional Action Plan (RAP). However, the RAP did not deal with the serious issue of dairying on tile and mole-drained land. Therefore, the Otago Regional Council (ORC) and Fonterra drafted a Memorandum of Understanding (MoU) at the same time the RAP was drawn up, in which they agreed to work cooperatively to address the water quality impacts of dairy farming on tile and mole-drained land. The ORC has also been working closely with local farmers (of all land uses) to promote best management practices.

However, continued degrading of the water quality in the Pomahaka catchment clearly shows that the RAP, MOU and existing educative methods are proving insufficient, and further intensification is placing additional pressure on the environment.

ORC has conducted this investigation into the Pomahaka catchment to increase understanding of the issues causing this decline in water quality and its effects on ecosystem values. Specifically, the purpose of this investigation was to:

1. determine the spatial and seasonal patterns of water quality within the Pomahaka catchment
2. monitor the effects tile drains have on water quality in both intensive and non-intensive land use units within the catchment
3. determine the effects that degrading water quality has on ecological values
4. provide information that will aid policy decisions to halt this decline and ultimately improve water quality in the Pomahaka catchment.

This study is based on water quality, habitat condition and ecological values. It does not include views from local iwi, community or other stakeholders; nor has there been an assessment of recreational values or socio-economic benefits. The results will become part of the future debate of acceptable land-use management practices in the catchment.

2 Background information

2.1 The Pomahaka catchment

The Pomahaka catchment is located in south-west Otago and has a catchment area of roughly 2060 km2. It flows from its headwaters in the Umbrella Range in a south-west direction to its junction with the Clutha River/Mata-Au, near Clydevale (Figure 2-1). Much of the upper half of the catchment is located in steep mountainous areas dominated by tussock, while the lower catchment lies primarily in pastoral rolling hill country. A small section of the Pomahaka catchment, primarily the Kaiwera Stream, is not within the Otago Region.

The catchment has relatively high, reliable rainfall, ranging from 700 mm annually in low-lying areas to 1400 in some high-elevation areas of the Blue Mountains, Umbrella Mountains and the upper catchment of the Waipahi (ORC data). Rainfall intensities vary greatly throughout the catchment, due to a combination of factors such as altitude, aspect and topography.

Soil profiles vary primarily by topography and elevation, with the rolling hill-country of the lower catchment being dominated by insoluble organic, pallic and grey soils, and the more mountainous areas of the catchment having primarily semi-arid soils.

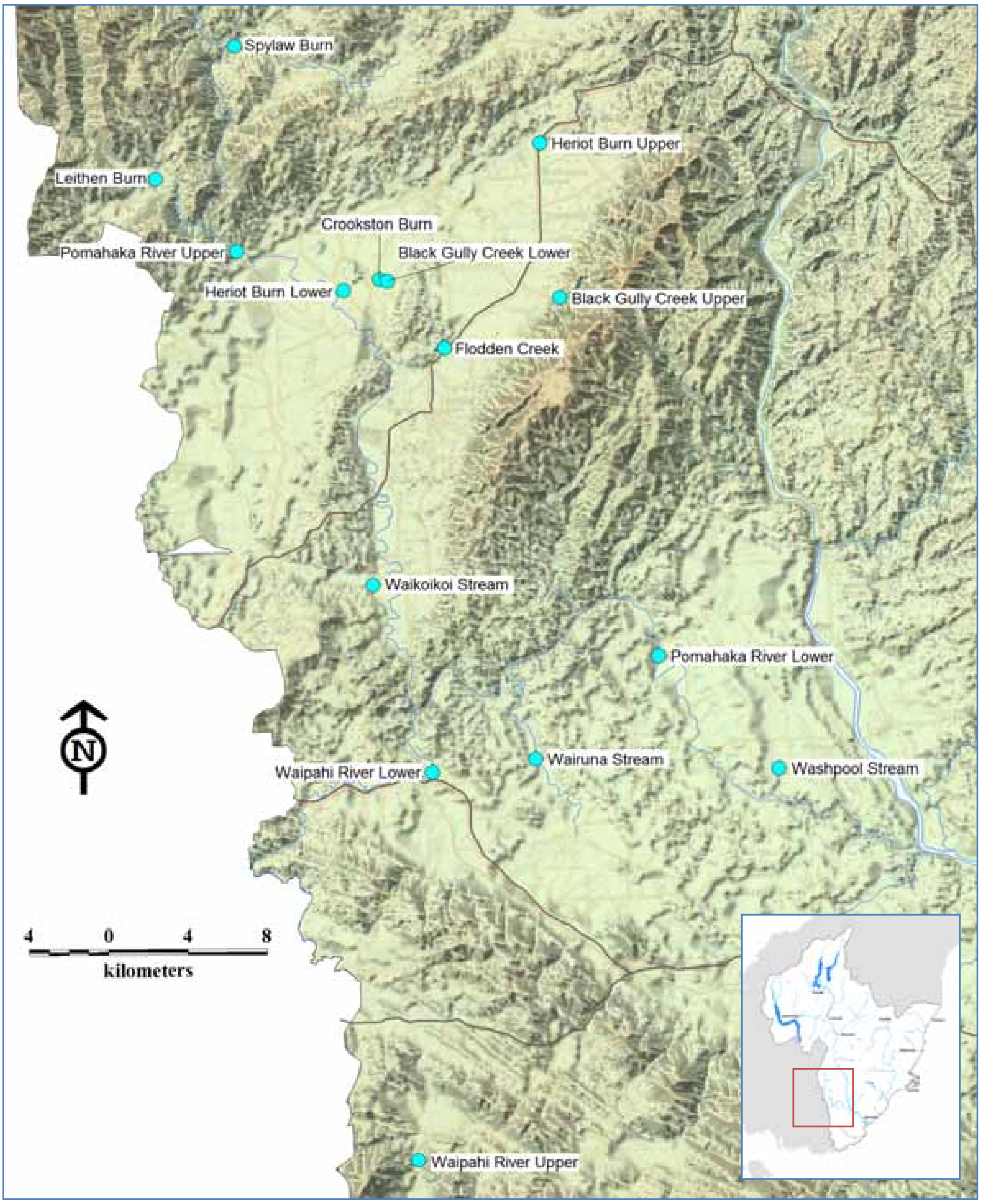


Figure 2-1 The Pomahaka catchment and stream-sampling sites

2.2 Hydrology

The Pomahaka catchment climate is considered mild, with consistent rainfall throughout the year. Annual rainfall for the catchment generally varies from around 700 mm in the low altitude parts of the catchment to 1400 mm in the Blue Mountains and Umbrella Mountains. This rainfall contributes to higher river flows in the Pomahaka, including, in particular, numerous flushing flows. The lowest flow recorded in the Pomahaka River at Glenken (Upper) was 0.83 m^3/s, while the maximum discharge recorded at the same site was 479.4 m^3/s.

The Pomahaka River typically experiences about eight flushing flows each year. These larger flows are important for removing algae, flushing nutrients and moving sediment. Streams with a low frequency of flushing flows are susceptible to algal proliferations, particularly if they contain high nutrient levels. Relative to North or Central Otago streams, the Pomahaka River has a high frequency of flushing flows, which become obvious when the Pomahaka River is compared with the Shag River in North Otago (Figure 2-2).

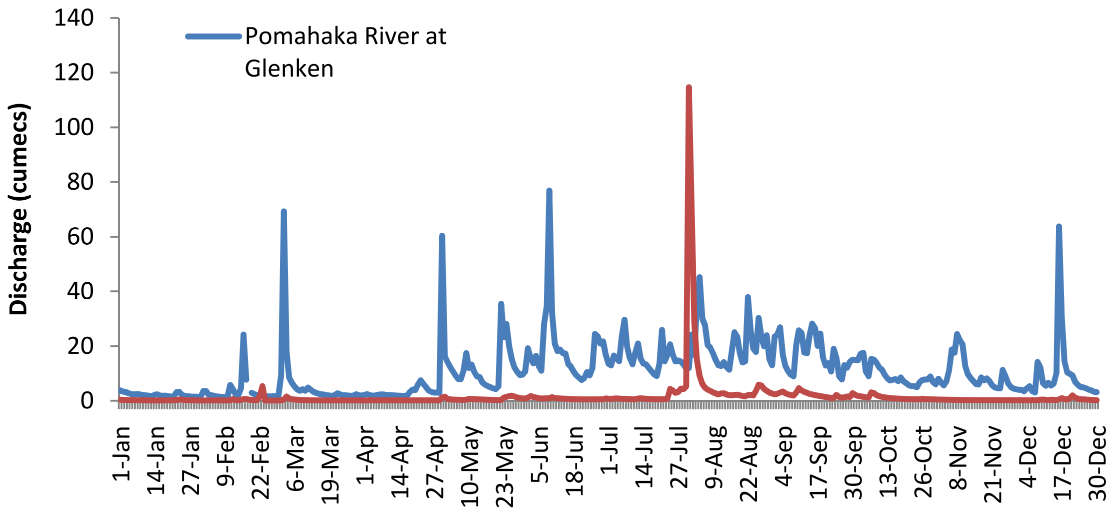


Figure 2-2 River discharge for the Pomahaka River at Glenken (Upper) and the Shag River at the Grange during 2008

2.3 Natural values

The Regional Plan: Water for Otago[1] (2004) lists many natural values for the Pomahaka River, including high fish and macroinvertebrate diversity, rare macroinvertebrates, salmon and trout spawning and rearing habitat, the significant presence of eels, and the significant presence of game birds. The catchment is also listed as having a regionally significant brown trout fishery.

The Pomahaka catchment supports a diverse freshwater fish fauna with nine species of fish and one species of freshwater crayfish (*Paranephrops zealandicus*) (Figure 2-3) listed as being present (NIWA freshwater database, Otago Fish and Game). Brown Trout (*Salmo trutta*) (Figure 2-4) and Rainbow Trout (*Oncorhynchus mykiss*) (Figure 2-5) are the two main sports fish in the catchment, with Brown Trout being the most common of all fish. Information from Otago Fish and Game states that perch (*Perca fluviatilis*) are also found in the lower reaches of the Pomahaka River. Sensitive native species have also been found specifically, Clutha flathead galaxids (*Galaxias* sp D) (Figure 2-6) and Longfin Eel (*Auguilla dieffenbachia*) (Figure 2-7) which are both listed as being in gradual decline. Lamprey (*Geotria australis*) (Figure 2-8) are also present in the Pomahaka River, which are sparse and regionally significant populations. Upland bully (*Gobiomorphus breviceps*) (Figure 2-9) and Common Bully (*Gobiomorphus cotidianus*) (Figure 2-10) are also present through out the catchment, but don't co-occur together.

[1] Schedule 1A of the Regional Plan: Water for Otago (2004), pg 296.

Figure 2-3 Freshwater Crayfish

Figure 2-4 Brown Trout

Figure 2-5 Rainbow Trout

Figure 2-6 Clutha flathead galaxid: Source: Richard Allibone

Figure 2-7 Longfin eel

Figure 2-8 Lamprey. Source: S.C. Moore

Figure 2-9 Upland Bully: Source: S.C. Moore

Figure 2-10 Common Bully

2.4 Recreational values

The most significant recreational pursuits carried out on the Pomahaka River are game bird hunting and angling, with the catchment being notable among Otago rivers for its large fish size (over 3 kg)., In the past 15 years, total fishing effort has fallen by 17,230 days across Otago (Unwin, 2009). Specifically for the Pomahaka catchment, an estimated 4,140 fishing days were undertaken in the Pomahaka during 2007/2008, which was down from 6,780 in 1994/1995 (Unwin, 2009). Fishing days have remained static between 2001/2002 and 2007/2008 but there has been a shift from river fishing to lake fishing.

Land use

Sheep and beef grazing represent about half of the recorded land use in the catchment, with dairy, deer and forestry being less common forms of agriculture. Native forest and tussock lands comprise about 9% of the catchment area and are located primarily in the steeper areas of the Blue and Umbrella Mountains (Figure 2-11).

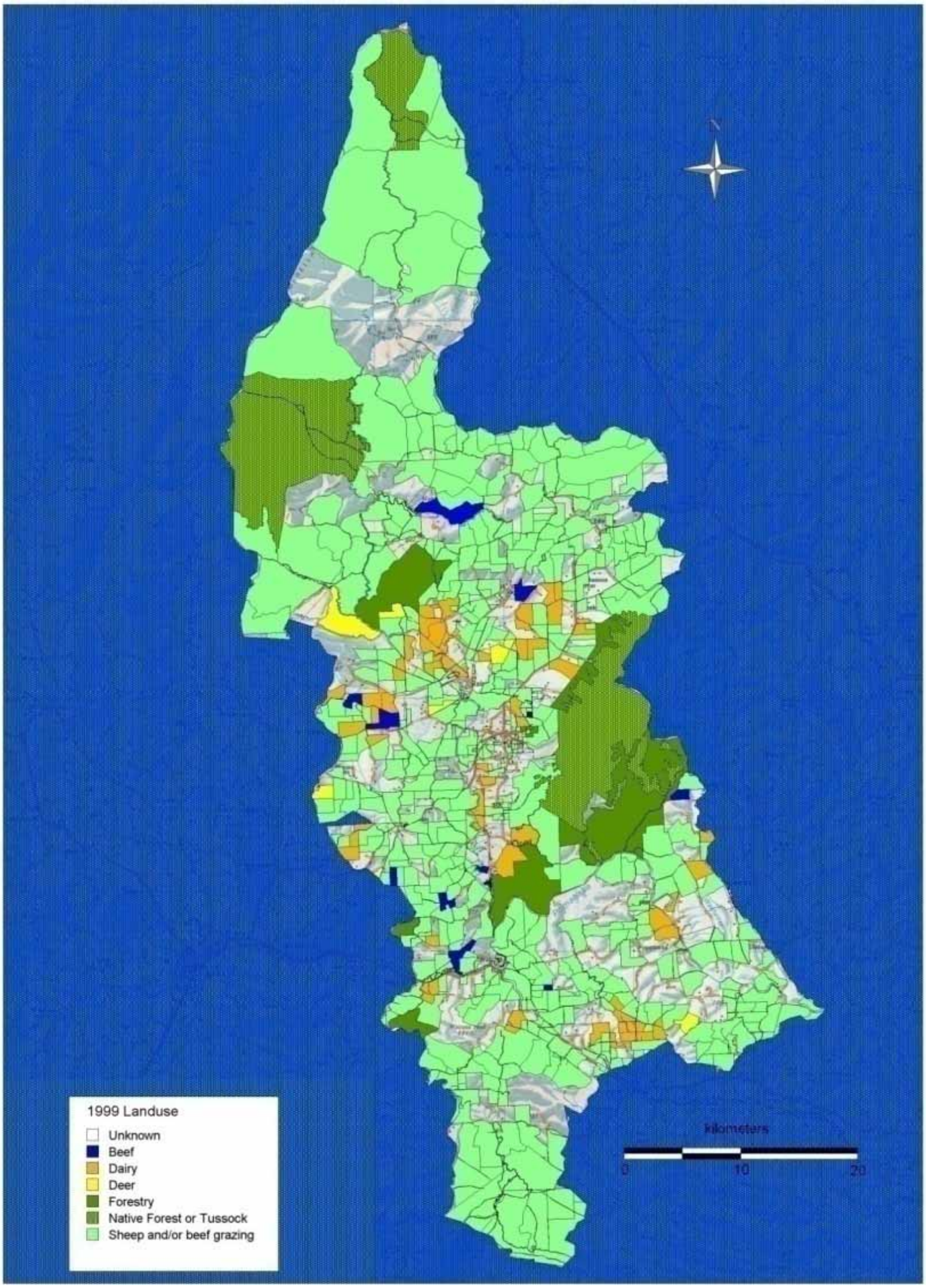


Figure 2-11 The 1999 distribution of various land use types in the Pomahaka catchment.

Between 1999 and 2008, the number of dairy farms increased from 38 to 105; average dairy farm size also increased from 179 to 197 hectares in the same period (Table 2-1). Anecdotal evidence (private conversations with farmers in the area) suggests that intensity has increased in existing dairy farms as well.

Table 2-1 The abundance and total area of dairy farms in the Pomahaka catchment in both 1999 and 2008, as well as the percentage of total catchment area covered by dairy farms for each year. Conversions are ongoing

	Total catchment land area (km^2)	Dairy (km^2)	Number of dairy farms	% of catchment in dairy
1999	2060	68	38	3%
2008		207	105	10%

Dairy farm conversions have occurred in the middle and lower areas of the catchment, in particular in the areas around Tapanui, Heriot and Clydevale. Most of these farms are in relatively low-lying areas (Figure 2-12). At the catchment level, Black Gully Upper is dominated by forestry, while Washpool and Wairuna are dominated by dairy farming followed by Crookston Burn, Black Gully Lower and Flodden Creek (Table 2-2).

Table 2-2 Different land uses for each sub-catchment in the Pomahaka catchment

Site	Catchment area (km^2)	% Catchment dairy	% Catchment sheep and beef	% Catchment forest/native cover
Washpool	35	79	21	0
Wairuna	94	51	49	0
Waipahi Upper	15	0	100	0
Waipahi Lower	299	1	96	3
Leithen Burn	72	0	60	40
Heriot Burn Upper	25	12	64	24
Heriot Burn Lower	142	15	73	12
Waikoikoi	116	20	80	0
Pomahaka Upper	714	0	94	6
Pomahaka Lower	1881	7	80	13
Spylaw Burn	167	1	99	0
Flodden Creek	43	26	30	44
Black Gully Upper	6	0	0	100
Black Gully Lower	25	36	40	24
Crookston Burn	32	44	31	25

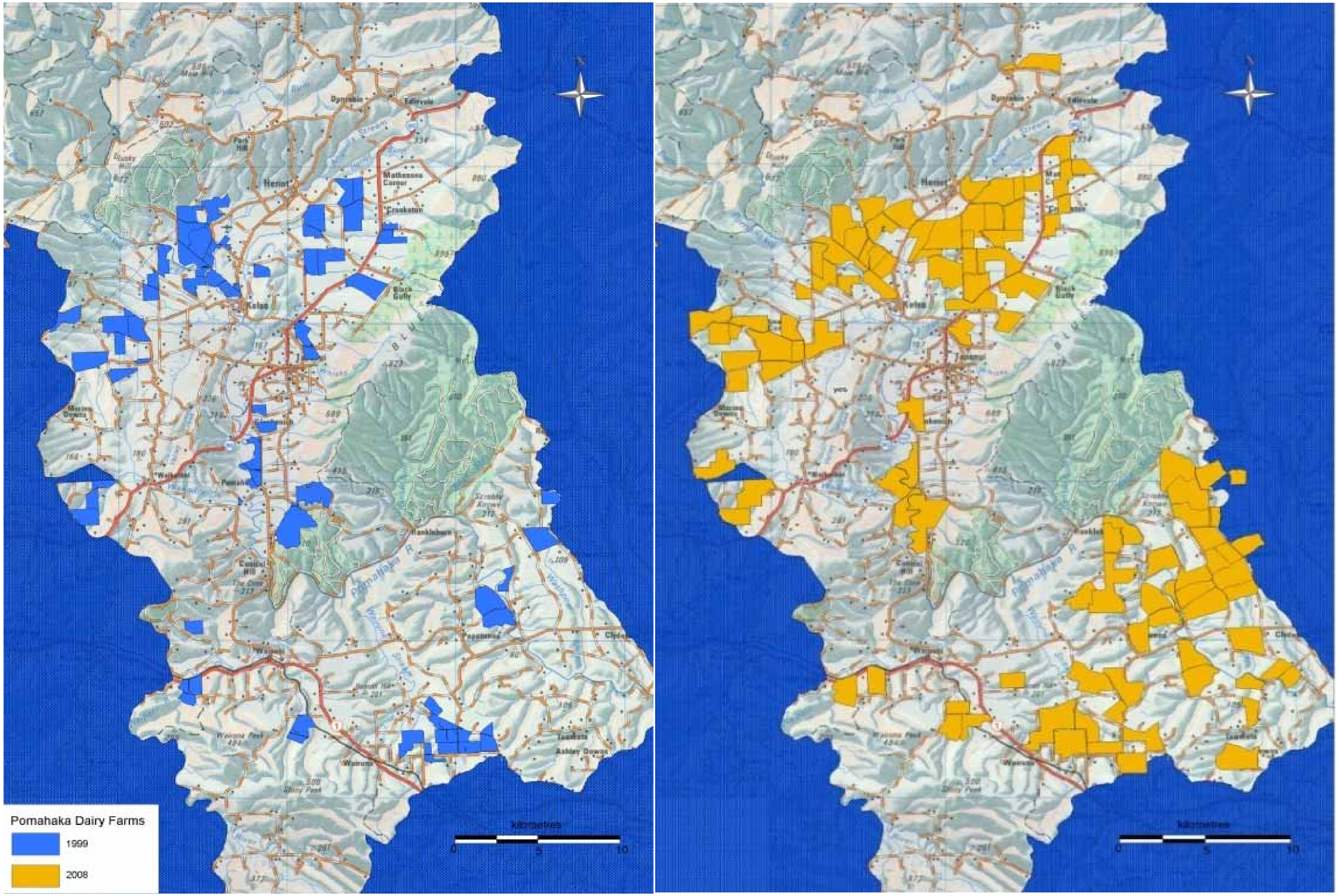


Figure 2-12 The distribution of dairy farms in the Pomahaka catchment in 1999 (blue) and 2008 (orange)

3 Methods

This section outlines the methods that were followed to collect the water chemistry, physical habitat and ecological values in the Pomahaka catchment. The physico-chemistry section outlines the analytes that were sampled, and the sampling frequency and guidelines that were used for the study. The physical assessment involved using key measures from the Physical Habitat Assessment Protocols (Harding *et al.* 2009). The macroinvertebrate and fishery values section outlines the methods for selecting habitat to sample and methods for the collection of data and interpretation of data.

3.1 Physico-chemical assessment

Between November 2008 and November 2009, 15 streams (three headwater sites and 12 lowland sites) were sampled fortnightly on the same day (Figure 2-1). Each of the 15 sites was dominated by different land-use types (Table 2-1). The majority of stream sites were existing sites with at least three years of historical data; there were also three long term State of Environment (SOE) monitoring sites (Pomahaka at Glenken (Upper), Pomahaka at Burkes Ford (Lower) and Waipahi at Waipahi (Lower)). The sites were positioned in both tributary and main-stem locations, and at most sites continuous flow was monitored; where it was not, a virtual flow measurement was able to be substituted.

In addition to stream sampling, 21 tile drains were sampled monthly during receding flow. The carrying capacity of the Pomahaka catchment soils is about 50% saturation. Because samples would not be collected during extreme climate events (e.g. high rainfall or extremely high soil moisture content), they were taken at descending soil moisture content, as this most accurately reflects typical nutrient loadings in tile drains

Soil moisture monitoring was undertaken at two permanent sites (Lone Hill, in the Washpool catchment, and Kelso, in the Heriot Burn catchment). Representative tile drains were selected from paddocks draining dairy (12 tile drains) and sheep paddocks (nine tile drains). At each stream site and tile drain, water samples were collected for analysis of analytes, including: Total Phosphorus (TP); Total Nitrogen (TN); Nitrite-Nitrate Nitrogen (NNN), Ammoniacal Nitrogen (NH4); Dissolved Reactive Phosphorus (DRP); Escherichia coli (*E.coli*); and Suspended Solids (SS).

Water quality guidelines

The guideline values in this report have been chosen to reflect the nature of the Pomahaka catchment; in particular, the recognition that the Pomahaka River is a regionally significant trout fishery (Table 3-1). Where possible, guideline standards reflecting discernable effects on ecological, angling and contact recreation have been used. The ANZECC (2000) guidelines are referenced for NH_4, TN and TP guideline values, while the biologically available nutrients (DRP and NNN) are referenced against the New Zealand Periphyton Guidelines (2000) for angling. Bacteria guidelines are drawn from the MfE/MoH microbiological water quality guidelines (2003) for human health. Suspended solid guidelines are drawn from Cawthron (1999), where 5 NTU was found to be the maximum turbidity value before an effect was had on drift-feeding trout growth potential. A regression between SS and turbidity data (R^2=0.86) on long term SOE data from the Pomahaka River Lower (Burkes Ford) gave a suspended solid value of 7.2 mg/ L (at 5 NTU).

Table 3-1 Physico-chemical and microbiological analytes and guideline values

Analyte	Guideline value	Ecological effect
NH_4	<0.9 mg/L*	High levels of ammonia are toxic to aquatic life, especially fish. The level of total ammonia in water should be less than 0.88 grams per cubic metre to be safe for fish. Ammonia in waterways comes from either waste waters or animal wastes (dung and urine).
TN	<0.614 mg/L*	Encourages the growth of nuisance aquatic plants. These plants can choke up waterways and out-compete native species. High levels can be a result of runoff and leaching from agricultural land.
NNN	<0.295 mg/L**	The biologically available component of TN, an excess of this nutrient may cause nuisance algal growths.
TP	<0.033 mg/L*	Encourages the growth of nuisance aquatic plants, which can choke up waterways and out-compete native species. High levels can be a result of either waste water or, more often, runoff from agricultural land.
DRP	<0.026 mg/L**	The biologically available component of TP, an excess of this nutrient may cause nuisance algal growths.
E.coli	<126 cfu/100 mL*** (^1) <260 cfu/100 mL (^2) 260-550 cfu/ 100 mL (^3) <550 cfu/ 100 mL	*E. coli* bacteria are used as an indicator of the human health risk from harmful micro-organisms present in water, for example from human or animal faeces.
SS	<7.2 mg/L^^	Suspended solids smother larger substrate, reducing available habitat for macroinvertebrates and fish. Nutrients may attach to sediments. High levels may affect clarity and photosynthesis. High levels would also makes it difficult for fish and other animals to see their prey.

*ANZECC & ARMCANZ (2000), **Biggs (2000), ***ANZECC (1992), ^MfE/MoH (2003) - ^1 = acceptable level, ^2 = alert level, ^3 = action level, ^^Cawthron (1999)/ ORC 2010: This value is based on taking the 5 NTU (turbidity) guideline recommended by Cawthron (1999) as the value that compromises trout growth potential and then applying the NTU value to a regression equation that was based on long turbidity and SS data from our sampling site at Pomahaka at Burkes Ford (Lower).

3.2 Physical Habitat assessment

Physical habitat condition was assessed at all 15 sites during baseline summer flows in February 2010, as habitat availability is an important determinant for ecological values (Death, 2000; Quinn, 2000). Four indices were assessed:

- compactness
- particle size (or Wolman index) (quantitative measurements of 100 particles along the longest axis)
- the percentage of fine sediment cover
- shuffle index.

At each site, five transects were established. On each transect, compactness, and the percentage of fine sediment (< 2mm) cover at five random locations along each transect, were estimated. Compactness is a measure of how tightly packed substrate is. Under certain conditions (e.g. frequent flash flows or sedimentation), substrate can become highly compacted. When this happens, bed substrate can become very stable, which adversely effects steam biological health by reducing or eliminating interstitial spaces, the habitat for macroinvertebrates and fish. Compactness was assessed with standard categorical measures from Harding *et al.* (2009). It is measured on a scale of 1-4:

1 = loose, easily moved substrate

2 = mostly loose, little compaction

3 = moderately packed

4 = tightly packed substrate.

The score was given according to the amount of effort in trying to remove the dominant substrate from a transect.

Wolman particle counts were then completed by measuring the longest axis of 20 pieces of streambed sediment.

Finally, a shuffle index was completed. The shuffle index is an index of fine sediment (< 2 mm) built up in the substrate. In a run, a white tile was placed on the stream bed, while an individual stood 3 m upstream and disturbed the substrate vigorously for five seconds. Each site was then given a ranking of 1-5, depending on how long it took for the plume to clear: 1 = no or small plume; 2 = plume briefly reduces visibility at tile; 3 = plume partially obscures tile but quickly clears; 4 = plume partially to fully obscures tile but slowly clears; 5 = plume fully obscures tile and persists even after shuffling ceases (Figure 3-1).

Level 1: No or small plume	**Level 2**: Plume briefly reduces visibility at tile	**Level 3**: Plume partially obscures tile but quickly clears
		
Level 4: Plume partially to fully obscures tile but slowly clears	**Level 5**: Plume fully obscures tile and persists even after shuffling ceases	
		

Figure 3-1 Visual guidelines for shuffle index grades (proposed guidelines for the assessment of fine sediment)

3.3 Biological assessment

Macroinvertebrates

Aquatic macroinvertebrates are organisms that live on or within the bottom substrate (e.g. rocks, gravels, sands, silts, organic matter such as macrophytes or organic debris such as logs and leaves) in rivers and streams. Examples of these include insect larvae (e.g. mayflies, stoneflies, caddisflies and beetles), aquatic oligochaetes (worms), snails and crustaceans (e.g. amphipods and crayfish). These macroinvertebrates are a useful tool to assess the biological health of a river because they are found everywhere and they have different tolerances to temperature, dissolved oxygen, sediment and chemical pollution. Thus, the presence or absence of taxa can provide significant insight into long- term changes in water quality.

Macroinvertebrate communities were sampled in the 15 streams that were part of this study in November 2009. At each site, one extensive kick-net sample was collected, following Protocol C2: hard-bottomed, semi-quantitative sampling of stream macroinvertebrate communities (Stark *et al.* 2001). This requires sampling a range of habitats, including riffles, mosses, wooden debris and leaf packs. Samples were preserved in 90% ethanol in the field and returned to a laboratory to be processed. Following Protocol 1, semi-quantitative coded abundance, macroinvertebrate samples were coded into one of five abundance categories: Rare (1-4), Common (5-19), Abundant (20-99), Very Abundant (100-499) or Very, Very Abundant (500+).

While there are no guideline values currently in place for macroinvertebrate community indices, the commonly accepted categories are summarised in Table 3-2. The indices often used to measure stream health are summarised below:

- ***Species richness***: The total number of species (or taxa) collected at a sampling site. In general terms, high species richness may be considered good; however, mildly impacted or polluted rivers with slight nutrient enrichment can have higher species richness than un-impacted, pristine streams.
- ***Ephemeroptera Plecoptera and Trichoptera (EPT) richness***: An index which is the sum of the total number of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) species collected. These groups of insects are often the most sensitive to organic and mineral pollution; therefore, low numbers of these species might indicate a polluted environment. In some cases, the percentage of EPT species compared to the total number of species found at a site can give an indication of the importance of these species in the overall community.
- ***Macroinvertebrate Community Index* (MCI)**: This index was developed to assess organic enrichment of stony- or hard-bottomed streams, based on sampling macroinvertebrates from the riffle habitats. It is an index based on adding the pollution tolerance scores of all species found at a site. Species that are very sensitive to pollution score highly, whereas more pollution tolerant species receive a low score.
- ***Semi-quantitative Macroinvertebrate Community Index* (SQMCI)**: A variation of the MCI that accounts for the abundance of pollution sensitive and tolerant species. The SQMCI is calculated from coded count data (individual taxa counts are assigned to one of Rare (R), Common (C), Abundant (A), Very Abundant (VA), Very Very Abundant (VVA) abundance classes).

Table 3-2 Criteria for aquatic macroinvertebrate health, according to different macroinvertebrate indices. There is no guideline for macroinvertebrate communities; however, these are accepted criteria (Stark *et al.* 2001)

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

Fish communities

Each of the 15 sites was electro-fished to see how fish species composition and density varied between sites. A 100 m^2 reach was fished at each of the 15 sites; the reach was isolated with top and bottom stop nets extending the width of the reach.

Each site was fished by three-pass downstream electric fishing, using a pulsed DC Kainga EFM300 backpack electro-shocker. A 15-minute rest period between electric fishing passes was used to allow fish to settle between passes. The backpack operator used a sieve dip net, while another team member used a pole net immediately below the electro-shocker, and a third member carried buckets for fish collection. In all, there were three experienced operators at all sites. Fish from each pass were kept separate, counted and released after the third electric fishing pass. At each site, native fish were identified and counted, while trout were counted, weighed in grams and measured in length from the tip of the snout to the caudal fork.

At each site, 50 trout were targeted for an assessment of trout condition. All trout were collected from the netted-off sections and weighed and measured. If 50 trout were not caught in the netted off section, then a further area was electro-fished until 50 trout were caught. If, after one further hour, 50 trout were still not caught, then the aim was to catch 30 trout, and if, after two hours, 30 trout were not caught, then electro-fishing ceased. All trout were weighed and measured so that trout condition could be calculated. Calculating trout condition is important because it is a relationship between a trout’s length and weight and unrelated to age. The formula for trout condition is:

$$K = \frac{10^{N}W}{L^{3}}$$

Where K is the condition factor; W is the weight of the fish in grams (g), L is the length of the fish in millimetres (mm), and N equals 5. This formula then produced the K values (condition values) in Table 2-1, while photographic representation is shown in Figure 3-2.

Table 3-3 K-value of fish condition (Barnham and Baxter 1998).

K value	Comments
1.6	**Excellent** condition, trophy class fish
1.4	**Good**, well-proportioned fish
1.2	**Fair** fish, acceptable to many anglers
1	**Poor** fish, long and thin
0.8	**Extremely poor** fish resembling a Barracuda, big head and narrow, thin body

Extremely poor

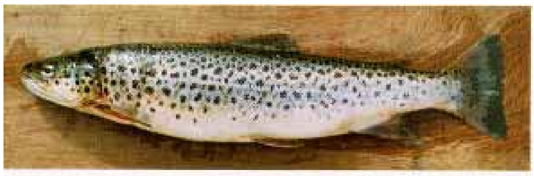
K = 0.78

Poor

K = 0.95

Fair

K = 1.19



Good

K = 1.36

Excellent

K = 1.66

Exceptional

K = 2.02

Figure 3-2 Photo representation of trout with different condition factors (Barnham and Baxter, 1998)

Fish density classes

The following method provides a simple way of comparing the relative fish densities recorded from the tributaries of the Pomahaka River in this study relative to other Clutha catchment streams. NIWA's New Zealand Freshwater Fish Database (NZFFD) was interrogated to obtain fish density data for sites in the Clutha catchment (based on three pass electric fishing over a known area (m^2)); data collected by ORC and Fish and Game Otago were also incorporated. All sites were ranked on fish density per square metre (total fish density, brown trout density and non-migratory galaxiid density) and then broken into quartiles. For the purpose of this report, each quartile was classed as Excellent, Good, Fair or Poor based on their relative density to the entire Clutha data set.

4 Results

The results section has been divided into four parts: Section 5.1 describes the results from tile drains, specifically the comparisons between sheep and dairy tile drains. Sheep and dairy tile drains were identified through discussion with the landowners to determine what stock type was run over the tiles during the study. Data was flow adjusted for every sample and plotted against the effects-based guidelines identified in Table 3-1. Section 5.2 presents the ranges of data that were recorded in the tile drains. Section 5.3 describes the results of stream water quality. Data have been presented against effects based water quality guidelines (Table 3-1) for flows above and below median flow; with median flows representing when recreational activity is most likely to occur. Section 5.4 summarises the findings from the macroinvertebrate sampling and Section 5.5 summarises trout and native fish values for condition and density, particularly in a local context for native fish.

4.1 Tile drains

Flow characteristics

The tile drains showed different flow characteristics (Figure 4-1). Two tile drains that recorded flow on every occasion were excluded from the results as they were obviously draining seeps and would not be a true record of pasture drainage. As expected, the main factor influencing the flow in tile drains was local soil moisture; any increase in soil moisture increased the amount of water discharging out of drains.

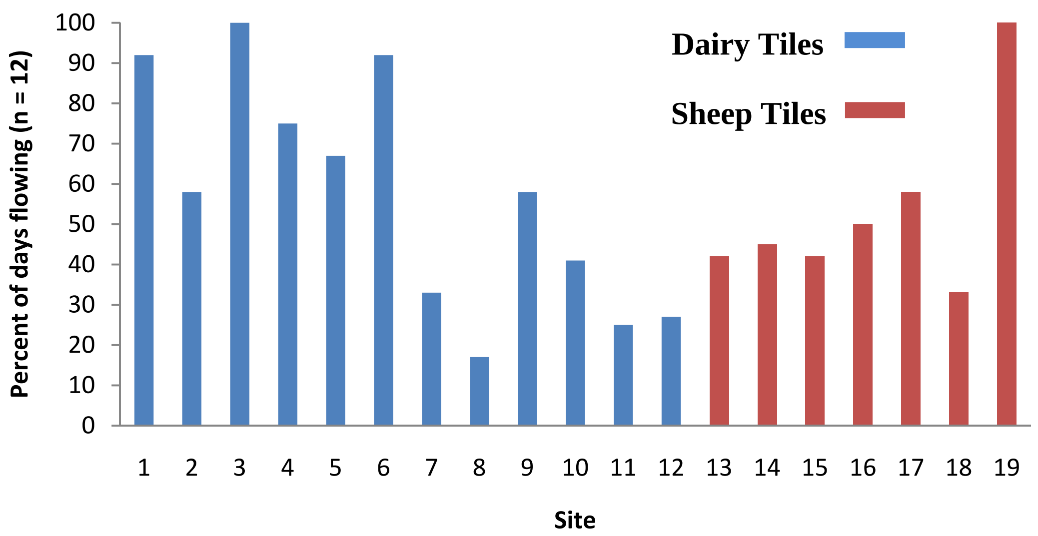


Figure 4-1 The percentage of days during which tile drain sites were observed to be flowing

The tile drains flowed on average 55% of the time, with little difference between the differing land uses (dairy 57% and sheep 52%). Four of the tiles flowed on at least 11 out of 12 sampling occasions. Figure 4-2 shows the percentage of tile drains flowing on a monthly basis. By comparing the data collected when the tiles were flowing to ORC's soil moisture site at Kelso, a general seasonal pattern can be observed with the exception of rainfall events (Figure 4-2).

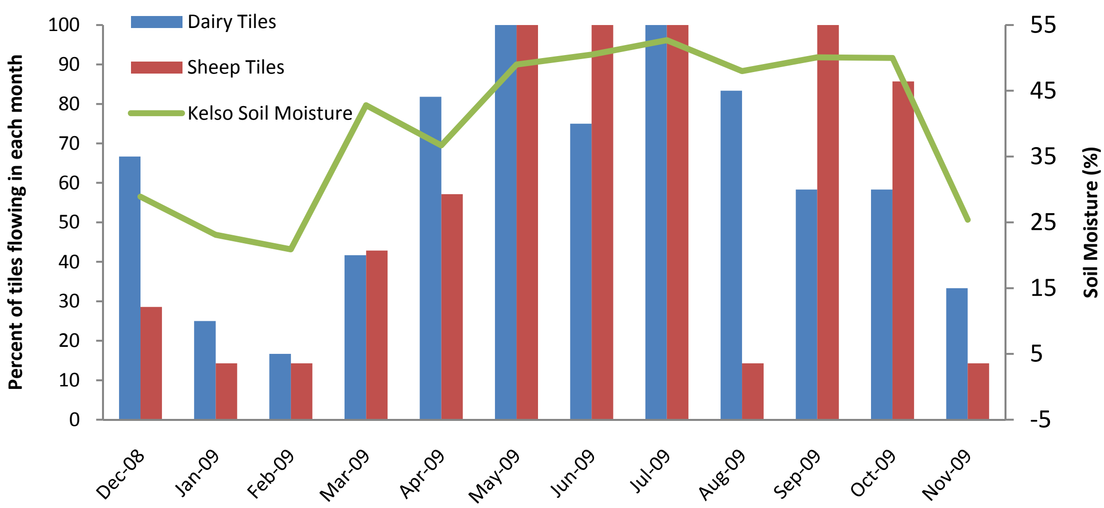


Figure 4-2 The percentage of individual tile drain sites observed to be flowing on a particular date relative to soil moisture recorded at Kelso

The concentrations of analytes were flow adjusted using the flow data that was continuously collected during the study. The data was flow adjusted because river flows can be variable between seasons and different-sized rivers have different dilution capabilities (i.e. a larger river such as the Pomahaka River has a larger dilution capacity than the Washpool Stream). Therefore, by flow adjusting, confounding factors such as differences in season, river size and flows are removed.

Tile-drain water chemistry

The graphs presented in this section represent two categories of tile drain: those for draining dairy pasture and those for draining sheep pasture. The results presented are flow-adjusted median values for each sampling occasion. Flow adjustment was used as it was for the streams. This was because, like streams, tile drains can have different flow characteristics, depending on the size of the catchment the tile drain collected drainage from and the rainfall that the tile drain catchment receives.

NNN was consistently higher in the dairy tile drains, compared to the sheep tile drains, with samples from dairy drains having median concentrations substantially above the guideline level (Figure 4-3). The sheep drains also exceeded this guideline 40% of the time. NNN concentrations appeared to reduce throughout summer and peaked in winter.

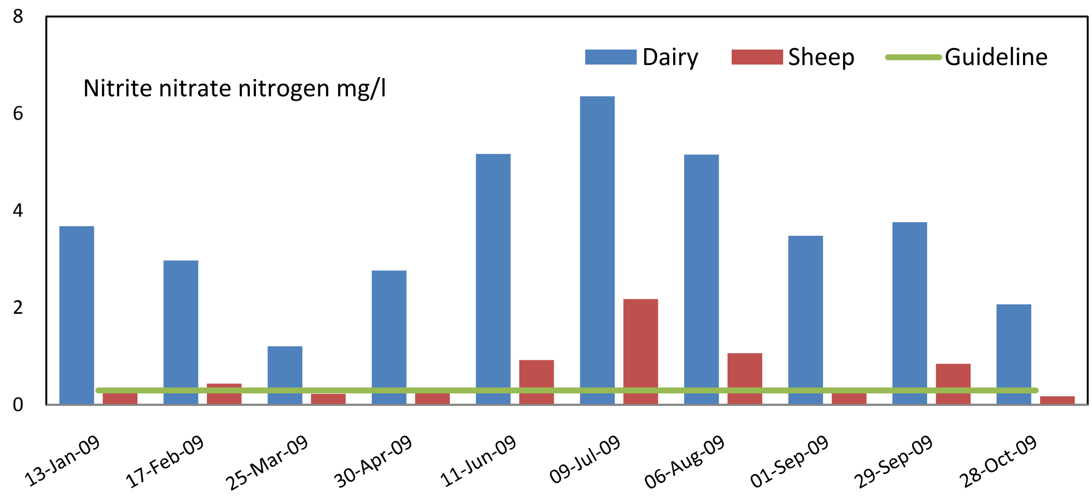


Figure 4-3 Median nitrite-nitrate nitrogen concentration for each sampling occasion

NH_4 was well below guideline values for both land uses, except for the dairy tile drains on 28 October (Figure 4-4). Concentrations in dairy tile drains appeared to be highest during spring, with another slight peak in autumn. NH_4 concentrations varied less in the sheep than in the dairy tile drains.

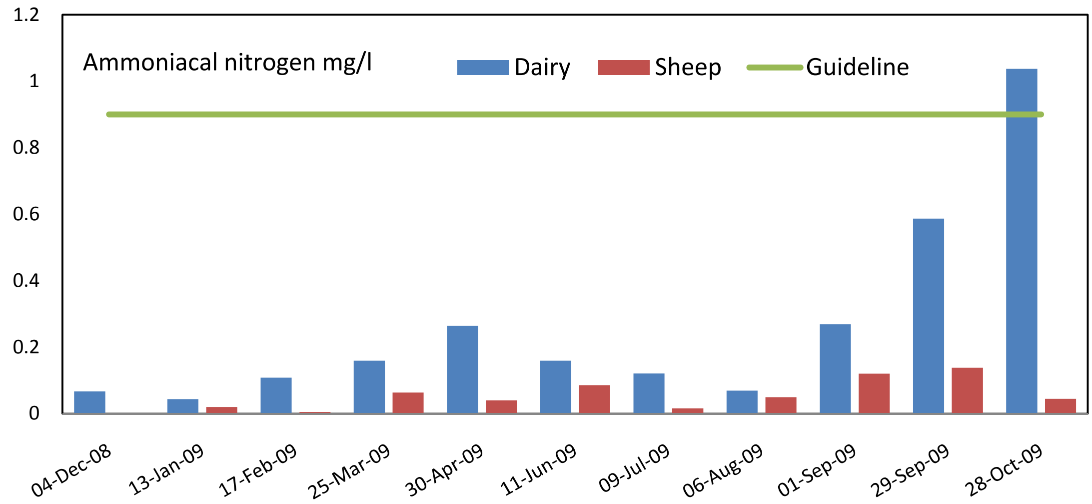


Figure 4-4 Median ammoniacal nitrogen concentration for each sampling occasion

DRP concentrations were highest in tile-drain discharges from dairy land and well above guideline values, especially during spring (Figure 4-5). DRP values from tile drains draining sheep farmland were noticeably lower than those that drained dairy, but they still exceeded the guideline for 20% of the samples. DRP levels in the sheep tiles drains were highest during summer and early autumn (Figure 4-5). While DRP concentrations in dairy tile drains were above the guideline for most of the year, the highest concentrations were recorded in early spring.

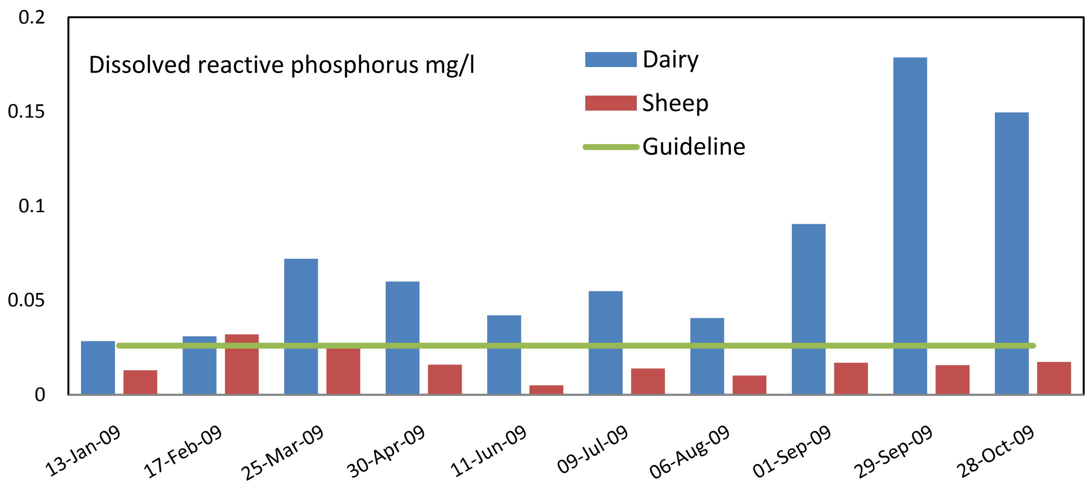


Figure 4-5 Median dissolved reactive phosphorus concentration for each sampling occasion

TN values were much higher for the dairy tile drains, with concentrations being well above the guideline and at least double the concentrations found in the sheep tile drains (Figure 4-6). The only pattern seems to be a drop in concentrations during the end of the summer period in dairy tile drains. For the sheep drains, the TN concentrations were highest in winter and early spring.

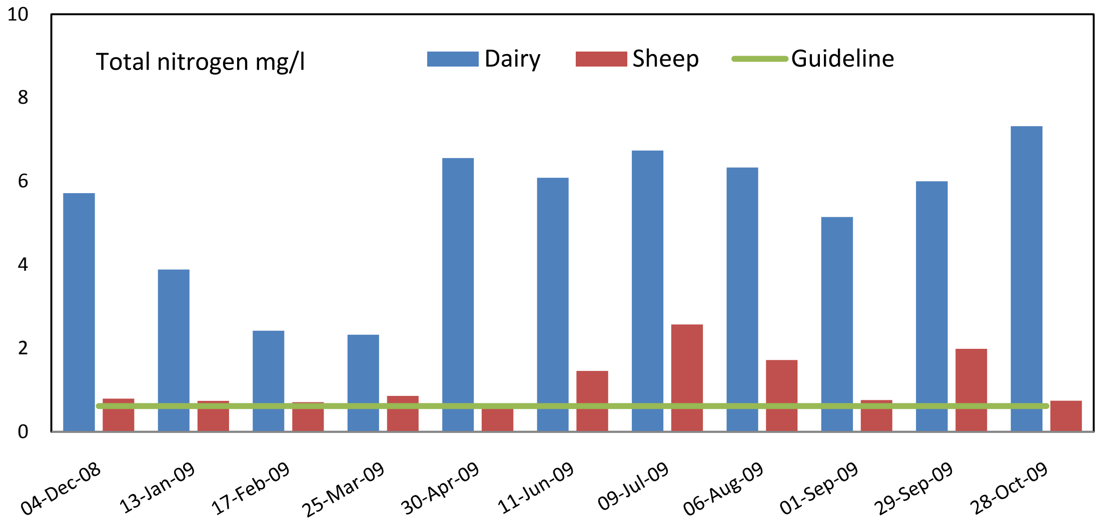


Figure 4-6 Median total nitrogen concentration for each sampling occasion

TP concentrations were higher in the dairy tile drains, and, in fact, they were much higher than found in the sheep tile drains, during spring (Figure 4-7). However, for the rest of the year, with the exception of April, the TP concentrations were similar.

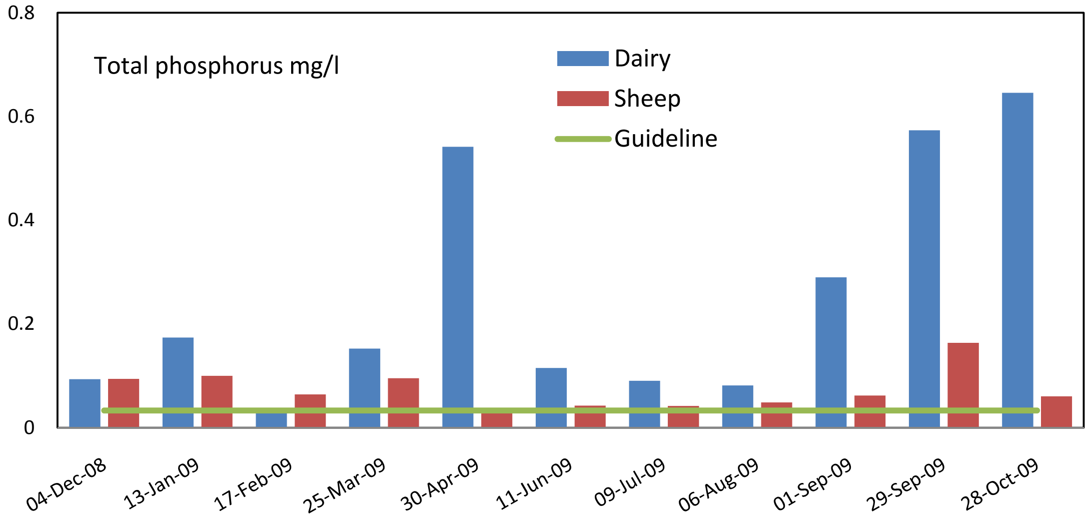


Figure 4-7 Median total phosphorus concentration for each sampling occasion

SS concentrations were generally higher in dairy tile drains, with the exception of July, when sheep tile drains were substantially higher. No seasonal trend was evident (Figure 4-8).

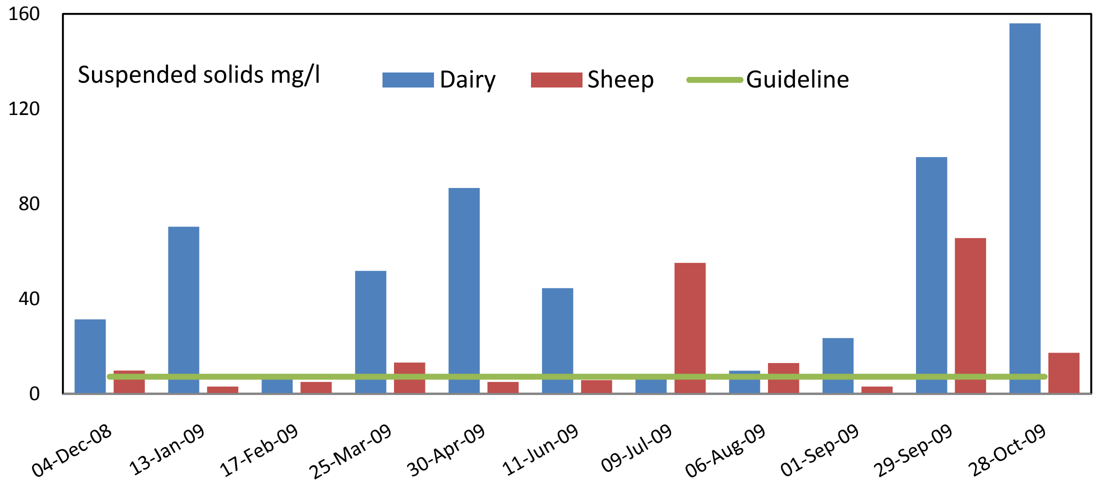


Figure 4-8 Median suspended solid concentration for each sampling occasion

Bacteria concentrations were generally similar in the sheep and dairy tile drains (Figure 4-9). *E.coli* levels were more often below the guideline levels considered safe for contact recreation for dairy tile drains when compared to those draining sheep farms. In six of the eleven sampling occasions, both the sheep- and dairy-drained pasture recorded *E.coli* concentrations below the 260 cfu/100mL guideline value. The highest concentrations were found in the spring/early summer period. These high concentrations were recorded after rain events (two days rain before 29 September 2009 and three days rain before 28 October 2009), which resulted in both sheep and dairy tile drains having high *E.coli* concentrations.

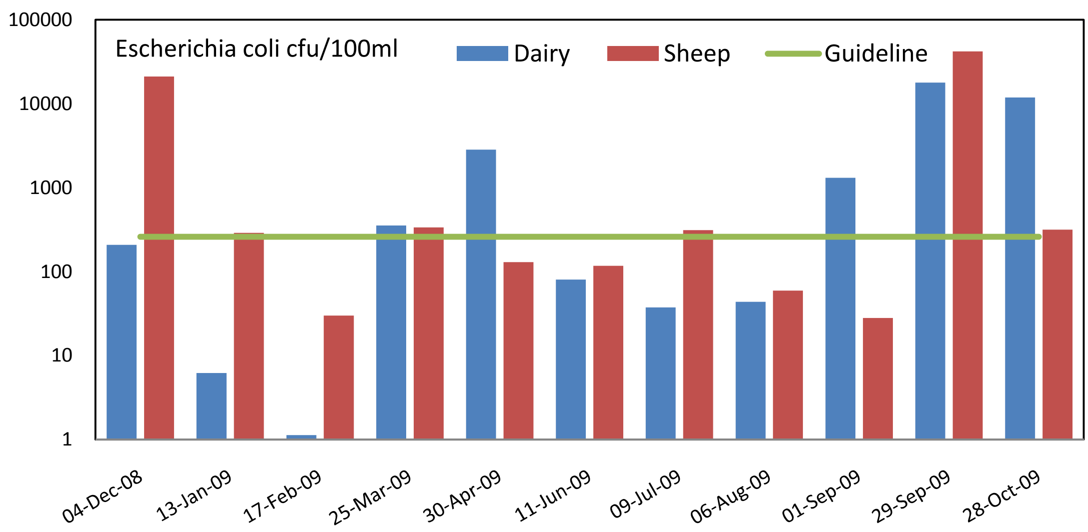


Figure 4-9 Median *E.coli* concentration for each sampling occasion

Tile-drain nutrient ranges

Figures 5.10-5.15 show the range of values recorded for sheep and dairy tile drains. These graphs provide more information than the median values and, in particular, indicate how high some values can get on individual days. Median values for NH_4 are only marginally higher for dairy tile drains than for sheep drains. However, there are many more outliers with higher concentrations in dairy tiles than in sheep tiles (Figure 4-10).

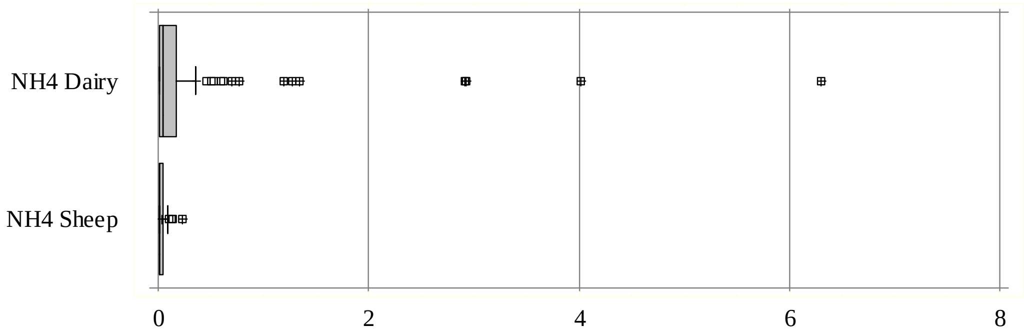


Figure 4-10 Range of measured concentrations between sheep and dairy tile drains for NH_4

Median concentrations for DRP were much higher in dairy tile drains, with outlying values being more than four times the value of dairy tile drains than sheep tile drains, in some instances (Figure Figure 4-11).

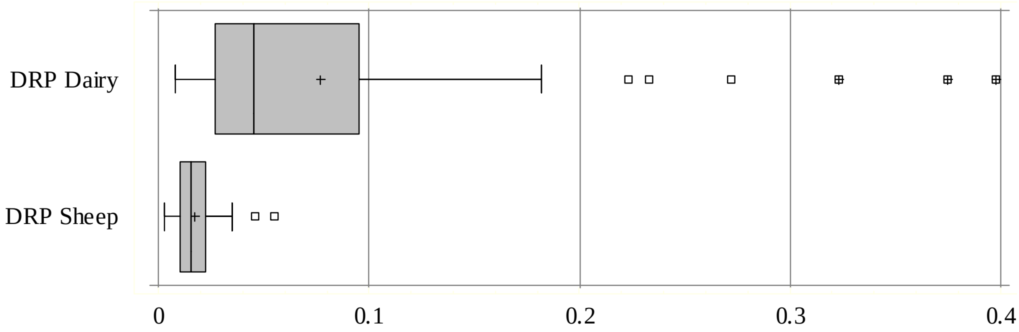


Figure 4-11 Range of measured concentrations between sheep and dairy tile drains for DRP

Median NNN values were higher in the dairy tile drains than in the sheep tile drains. However, sheep tile drains had two very high readings, both of which were the highest readings recorded in the study (Figure 4-12).

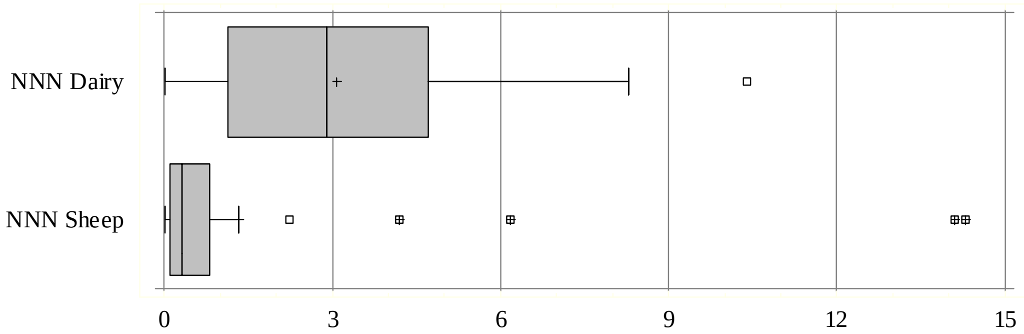


Figure 4-12 Range of concentrations from sheep and dairy tile drains for NNN.

The median concentration of TP was slightly higher in dairy tile drains compared to the sheep tile drains, with dairy tile drains having more extreme concentrations (Figure 4-13).

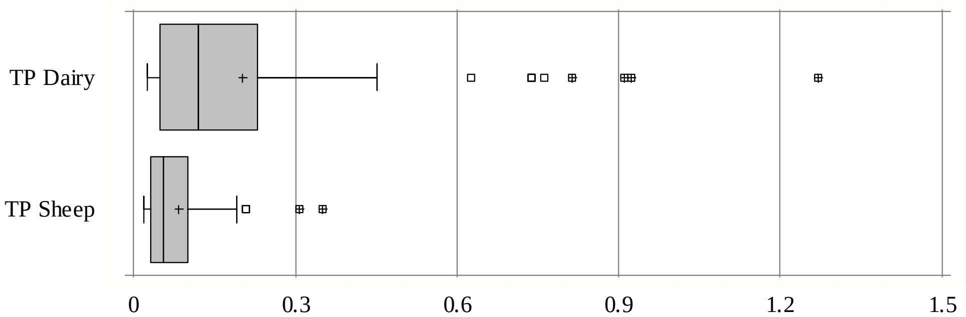


Figure 4-13 Range of concentrations from sheep and dairy tile drains for TP

Median concentrations of TN were substantially higher in the dairy tile drains than in the sheep tile drains. However, there were four outlying samples in sheep tile drains, two of which were the highest recordings (Figure 4-14).

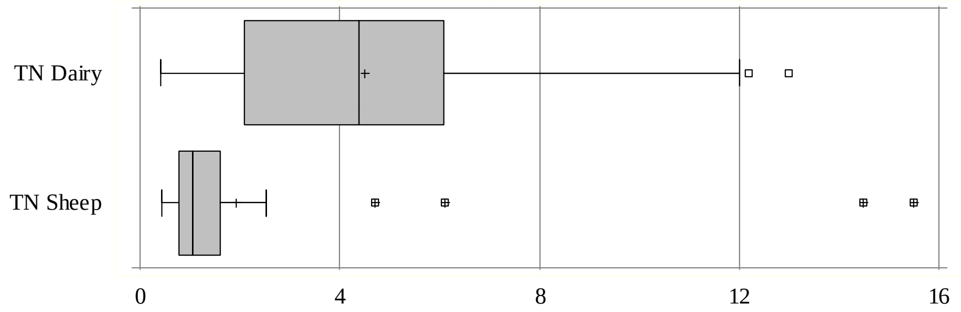


Figure 4-14 Range of concentrations from sheep and dairy tile drains for TN

Median *E.coli* samples had similar values between both land uses. There was only one extreme outlier from sheep tiles and that was the highest recorded value (Figure 4-15).

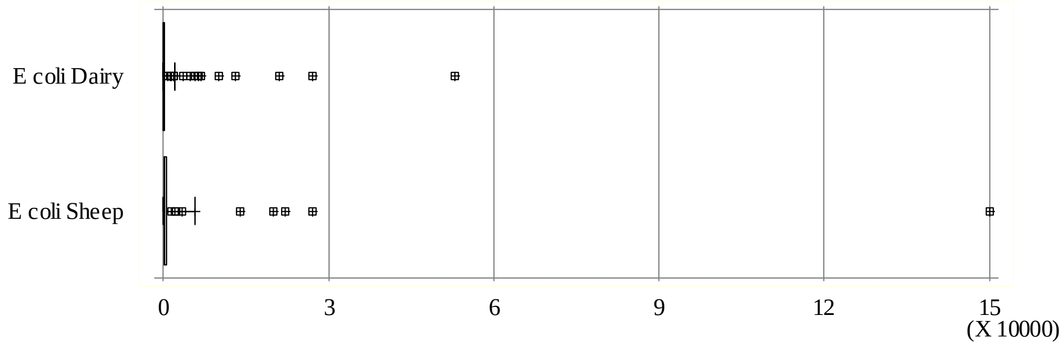


Figure 4-15 Range of concentrations for sheep and dairy tile drains for *E.coli*

Median values of SS were marginally higher in dairy tile drains. Tile drains from sheep farms had a higher range of SS concentrations, but dairy tile drains maintained the highest spot concentration of SS (Figure 4-16).

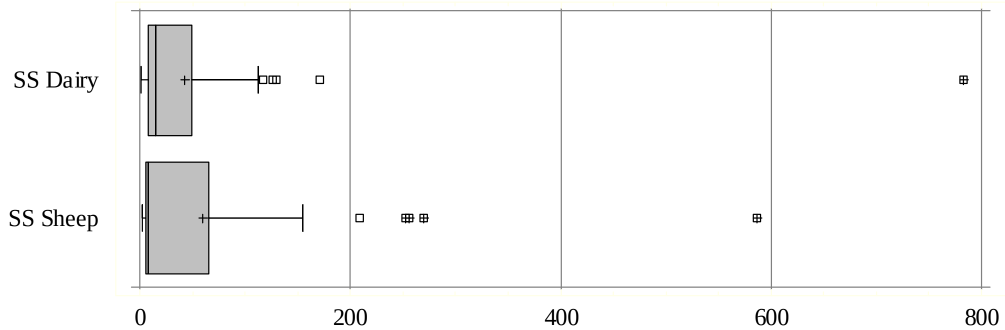


Figure 4-16 Range of concentrations for sheep and dairy tile drains for SS

The nutrient concentrations were generally significantly higher in dairy tile drains when compared to the sheep tile drains. This was confirmed with student t-tests, which were undertaken with the hypothesis that tiles draining dairy farms would have the same concentration of contaminants as those tiles draining sheep pasture (Table 4-1). In all cases, the hypothesis was untrue, and, generally, the drainage from tiles draining dairy pasture had a greater concentration of contaminants than the drainage from tiles from sheep pasture, with the exception of *E.coli*.

Table 4-1 Results from t-test analysis with the hypothesis that contaminants from tile drains from sheep pasture would be the same as those from dairy pasture. Results are significant (in bold) when $p < 0.05$.

	Sheep>Dairy	p value	Dairy>Sheep	p value
NH_4	NO	0.95	NO	0.47
DRP	NO	0.99	YES	0.003
E.coli	YES	0.002	NO	0.99
NNN	NO	0.99	YES	0.009
SS	NO	0.25	NO	0.74
TN	NO	0.99	YES	0.002
TP	NO	0.96	YES	0.03

4.2 Stream water quality

This section provides an assessment of the intensive monitoring of streams undertaken during the 12 months of this study, and compares this period to the long-term SOE monitoring data.

The concentrations of analytes were flow adjusted using the flow data that was continuously collected during the study. The data was flow adjusted to standardise the data by taking into account flow variability between seasons and the fact different-sized rivers have different dilution capabilities (i.e. a larger river such as the Pomahaka River has a larger dilution capacity than the Washpool Stream).

Nutrients

In this section, each graph has two bars. The blue bar shows the median value for all data (regardless of flow conditions), and the beige bar represents times of below median flow (i.e. when the river has its highest recreational use (e.g. fishing and swimming)). The extent and opportunity for plant growth depends largely on the time of year, and the growing season could also be represented by using below median flow conditions, as flows above median flow are not conducive to periphyton growth.

The two main nutrients available for plant growth are NNN and DRP, which are shown in Figure 4-17 and Figure 4-18. In Figure 4-17 it is immediately obvious that the control sites (Pomahaka Upper, Leithen Burn and Black Gully Upper) have very little available NNN. At median flows and below, the Spylaw Burn, Waikoikoi Stream and Washpool Stream also drop below the NZ Periphyton guideline level. DRP levels were generally below guideline levels (Figure 4-18). The exceptions to this were Washpool and Wairuna, which were substantially over the guideline value, while Black Gully Upper (a control site), Black Gully Lower and Crookston Burn were just slightly over the guideline.

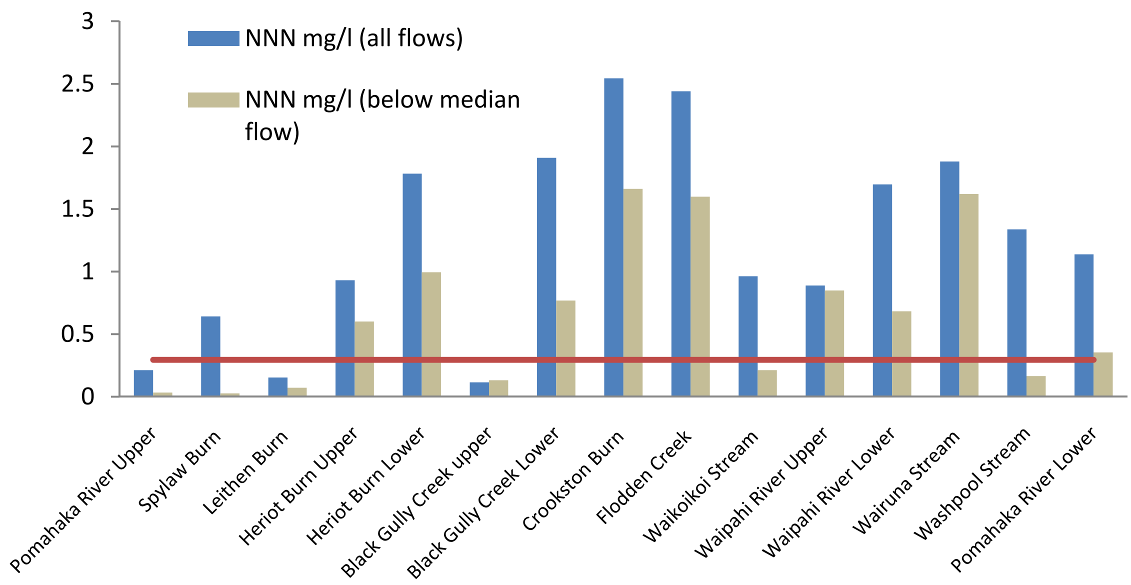


Figure 4-17 Median nitrite-nitrate nitrogen concentration at each stream site over the sampling period

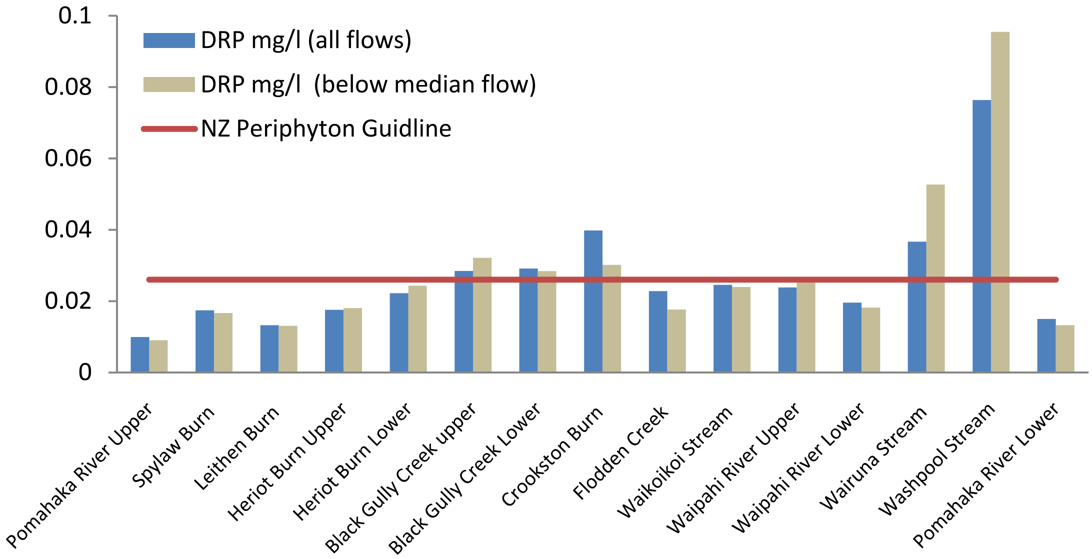


Figure 4-18 Median dissolved reactive phosphorus concentration at each stream site over the sampling period

TN concentrations were above the guideline value for the majority of the streams, except for the control sites and median flow concentrations at Pomahaka River Lower, Spylaw Burn and Waikoikoi. The Wairuna Stream had the highest median concentrations of TN (Figure 4-19).

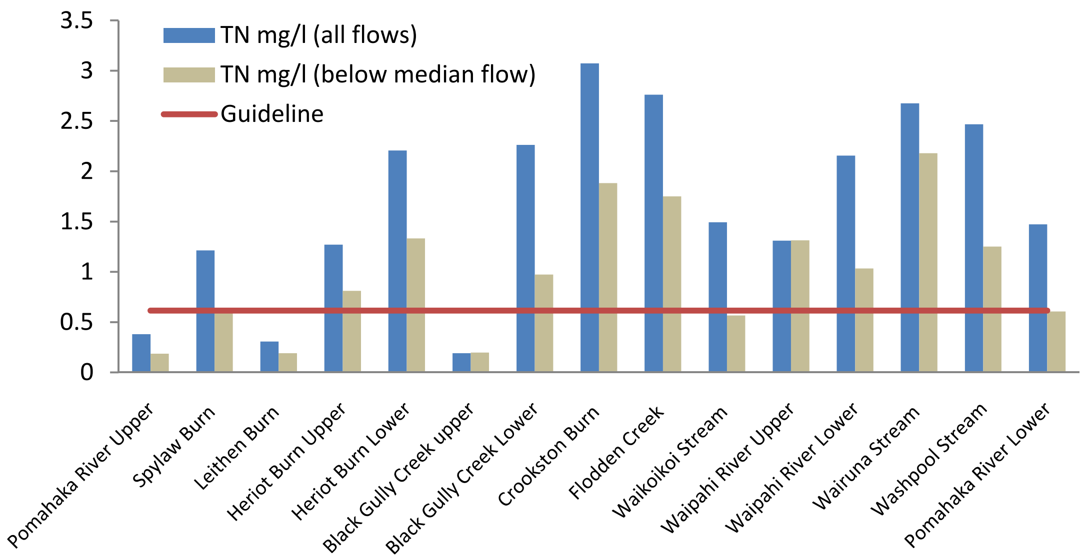


Figure 4-19 Median total nitrogen concentration at each stream site over the sampling period

TP concentrations were close to the guideline level at the control sites at median flow, with the rest of the sites being marginally higher than the control sites (Figure 4-20). The Wairuna stream and Washpool stream had the highest TP concentrations at median flow.

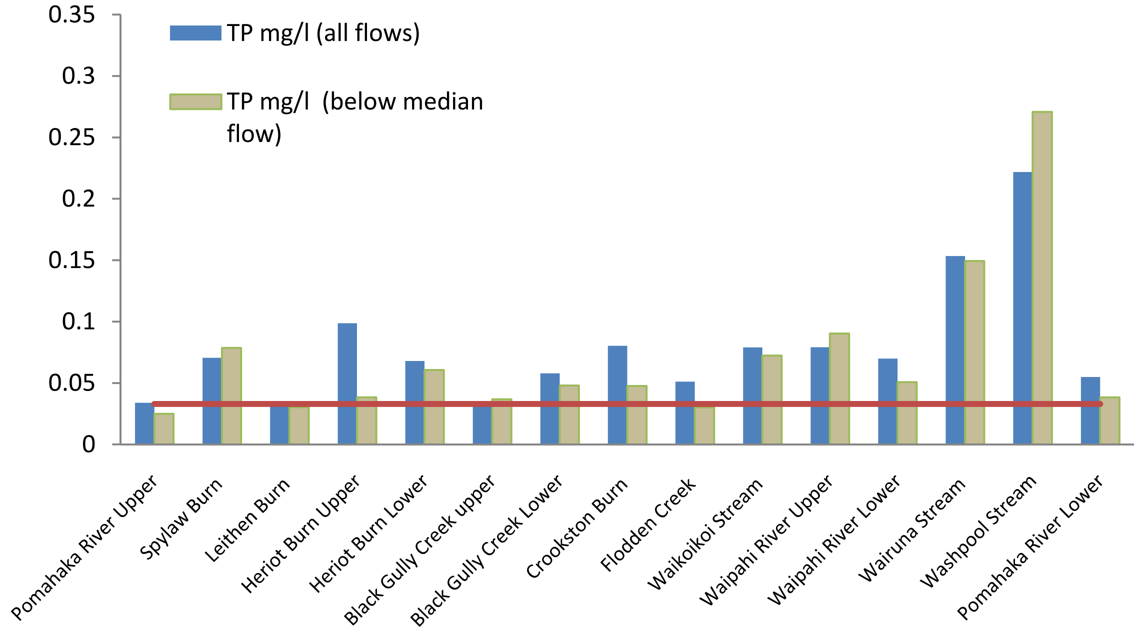


Figure 4-20 Median total phosphorus concentration at each stream site over the sampling period

NH_4 was the only parameter that did not exceed guideline levels (0.9 mg/l) at any of the stream sites (Figure 4-21).

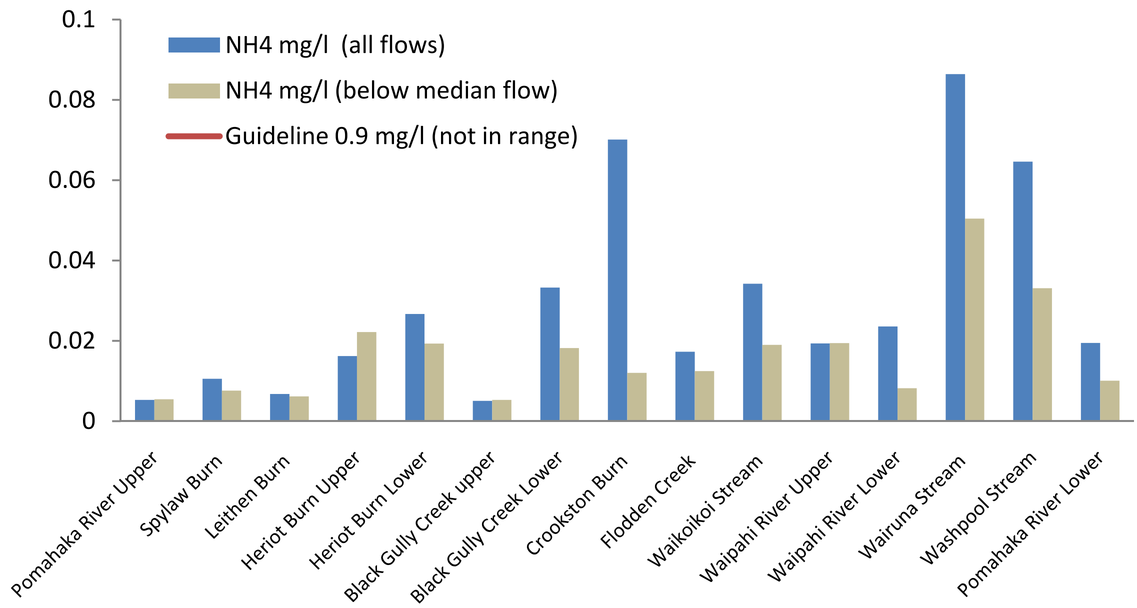


Figure 4-21 Median ammoniacal nitrogen concentration at each stream site over the sampling period

Bacteria

Two guideline values are shown for bacteria; the first is the ANZECC 1992 seasonal median of 126 cfu/100ml, the other is the MfE/MoH 2003 level of 260 cfu/100ml (generally used for spot samples, not median values).

Figure 4-22 shows that only the control site at Black Gully (upper) meets the ANZECC 1992 criteria. However, the Leithen Burn, Flodden Creek, Waipahi River Lower and the Pomahaka River Lower have a median value of less than the contact recreation standard (260 cfu/100ml). All the other sites recorded high median values, in particular the Wairuna and Washpool streams. Higher values are generally seen in the higher flows; however, guideline values are still exceeded at below median flows at the majority of sites.

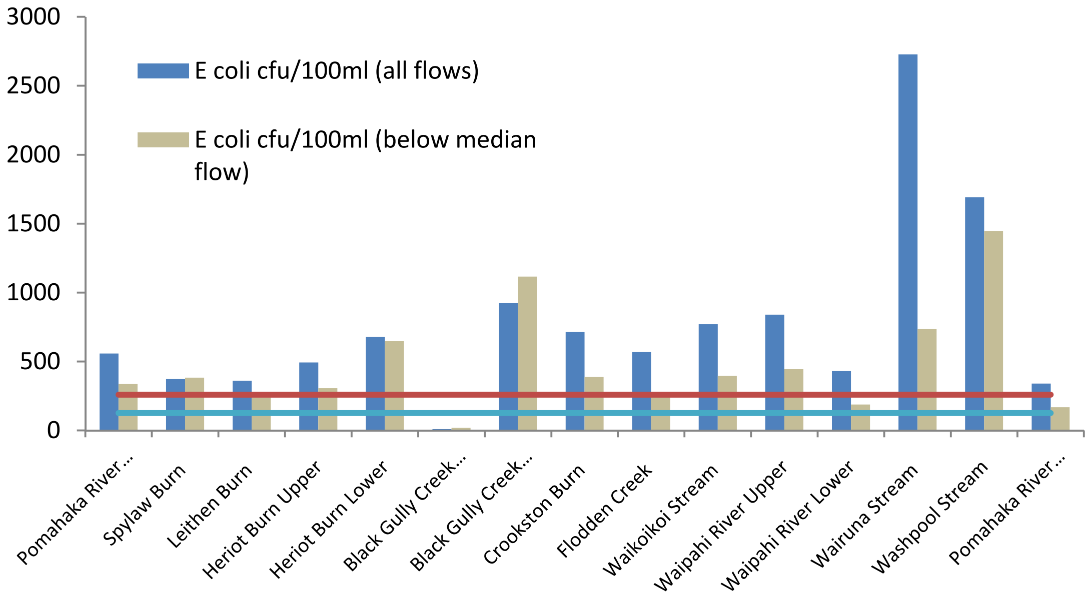


Figure 4-22 Median *E.coli* concentration at each stream site over the sampling period

Suspended Solids

SS concentrations at median flow were well above the guideline value at Waipahi Upper, while the Washpool stream was just above the guideline value (Figure 4-23). However, at normal flows, there are more sites with high sediment concentrations, particularly at Heriot Burn Upper and the Wairuna Stream.

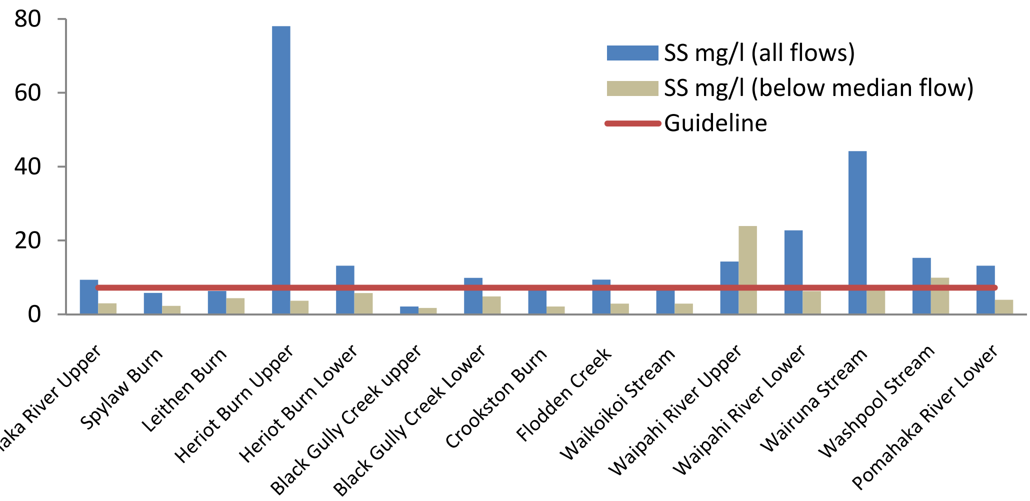


Figure 4-23 Median suspended solid concentration at each stream site over the sampling period

There is a considerable difference in water quality between the control sites located near headwater areas of the catchment, which generally have good water quality, and sites located in relatively low-lying areas, which have poorer water quality. Table 4-2 ranks the stream sites in order from good (number one) to poorest (number 15). The ranking is achieved by ranking each parameter from one to 15, and totaling the scores against each site (the higher the score (maximum score 105), the poorer the water quality). Typically, all waterways had nutrient and bacteria concentrations above guideline values.

Table 4-2 Stream sites are ranked in order of water quality from best (number 1) to poorest (number 15) for each contaminant and each site when flows were below median. Where numbers are coloured in green, the median value achieved guideline standards. Control sites are in bold.

Rank	Site	NH_4	DRP	E.coli	NNN	TN	TP	SS	Total
1	Pomahaka River (Upper)	2	1	7	2	1	1	6	20
2	Leithen Burn	3	2	4	3	2	3	9	26
3	Black Gully Creek(Upper)	1	13	1	4	3	4	1	27
4	Pomahaka River (Lower)	6	3	2	7	6	5	8	37
5	Spylaw Burn	4	4	8	1	5	12	3	37
6	Flodden Creek	8	5	5	13	13	2	4	50
7	Heriot Burn (Upper)	13	6	6	8	7	6	7	53
8	Waikoikoi Stream	10	8	10	6	4	11	5	54
9	Waipahi River (Lower)	5	7	3	9	9	9	12	54
10	Crookston Burn	7	12	9	15	14	7	2	66
11	Black Gully Creek (Lower)	9	11	14	10	8	8	10	70
12	Heriot Burn (Lower)	11	9	12	12	12	10	11	77
13	Waipahi River (Upper)	12	10	11	11	11	13	15	83
14	Washpool Stream	14	15	15	5	10	15	14	88
15	Wairuna Stream	15	14	13	14	15	14	13	98

The median values (at below median flow) were also assessed against water quality guidelines (Table 3-1) chosen, as appropriate, to protect local instream standards.

Table 4-3 shows how the grade was derived for each site. NH4 was not included in this assessment, as all sites passed the guideline value for this parameter. An excellent classification meant that all of the six other variables met guideline values, a score of four or five gave a good classification, a score of two or three meant the site was classified as fair and a score of one or less gave a poor classification.

Table 4-3 shows that the control sites all had excellent or good water quality. Flodden Creek also had good water quality and the rest of the sites were classified as having fair or poor water quality.

Table 4-3 Median results (flows below median) and resulting grades for each site (Results when flows are >median have been discarded.) Control sites are in bold.

Parameter	DRP	NNN	E.coli	SS	TP	TN	Grade	N or P
Guideline value (mg/l or cfu/100ml)	0.026	0.295	260	7.2	0.033	0.295		limited
Leithen Burn	0.013	0.072	240	4	0.030	0.190	Excellent	N
Pomahaka River (Upper)	0.009	0.033	336	3	0.025	0.185	Good	N
Black Gully Creek (Upper)	0.032	0.132	19	2	0.037	0.197	Good	N
Flodden Creek	0.018	1.598	251	3	0.030	1.750	Good	P
Pomahaka River (Lower)	0.013	0.354	169	4	0.038	0.606	Fair	P
Spylaw Burn	0.017	0.027	383	2	0.079	0.589	Fair	N
Waikoikoi Stream	0.024	0.212	395	3	0.072	0.566	Fair	N
Waipahi (Lower)	0.018	0.683	189	6	0.051	1.034	Fair	P
Heriot Burn (Upper)	0.018	0.602	307	4	0.038	0.810	Fair	P
Heriot Burn (Lower)	0.024	0.995	648	6	0.061	1.333	Fair	P
Waipahi River (Upper)	0.025	0.849	444	24	0.090	1.314	Poor	P
Black Gully Creek (Lower)	0.030	1.661	387	2	0.048	1.882	Poor	P
Crookston Burn	0.028	0.768	1116	5	0.048	0.972	Poor	P
Wairuna Stream	0.053	1.620	736	7	0.149	2.179	Poor	P
Washpool Stream	0.095	0.165	1447	10	0.271	1.252	Poor	N

4.3 Comparison of long-term and project monitoring

Five of the stream sites in the study have also been monitored in the ORC SOE monitoring programme. The sites are shown in Table 4-4, along with length of record.

Table 4-4 State of Environment (SOE) monitoring sites in the Pomahaka catchment

Site ID	Site	Start Date	End Date
OTA7520628	Pomahaka at Glenken (Upper)	30/4/97	To date
OTA 7520115	Pomahaka at Burkes Ford (Lower)	10/7/97	To date
OTA7520998	Waipahi at Cairns Peak (Upper)	21/10/95	To date
OTA7520540	Waipahi River at Waipahi (Lower)	15/7/97	To date
OTA7520512	Heriot Burn at SH90 (Upper)	26/3/99	To date

To determine whether water quality has improved or deteriorated, a Mann-Whitney (W) test was undertaken for two reporting periods: data prior to November 2008 and data taken after November 2008 (the sampling period for this report). The hypothesis was that the two sample medians would be equal.

As the data contained significant departures from normality, tests that compare standard deviations were invalidated. Therefore, in all cases, the Mann-Whitney W test was used as an alternative to the t-test to compare the medians of the two samples. This test is constructed by combining the two samples, sorting the data from smallest to largest, and comparing the average ranks of the two samples in the combined data. Table 4-5 gives the P-values for two-sided tests (alternative hypothesis). Where the P-value is less than 0.05, there is a statistically significant difference between the medians at the 95.0% confidence level.

Table 4-5 Showing which analytes have significantly different medians between the two reporting periods (i.e p-values is less than 0.05)

	Higher values prior to November 2008	Higher values post November 2008
Upper Pomahaka River	NH_4	DRP*
Lower Pomahaka River	NH_4, E.Coli	DRP, TP*
Upper Waipahi River		DRP, TN, TP*
Lower Waipahi River		DRP,TP*
Upper Herriot Burn	E.Coli	DRP,TP*

* Detection limits change from 0.01 mg/L to 0.05 mg/L in 2002

The samples taken between November 2008 and November 2009 show that DRP is significantly higher at all five sites, TN is significantly higher at one site, and TP is significantly higher at four of the sites (Table 4-5).

4.4 Physical habitat

Assessments of physical habitat structure were conducted at all 15 sites; this included estimations of fine sediment cover (<2 mm), measuring the longest axis from 100 pieces of substrate, as well as compactness and the shuffle index. From the median substrate-size class analysis, the results showed that control sites had very little fine sediment present and tended to have larger substrate size.

Leithen Burn and the Upper Pomahaka River had the largest substrate size, with a median Wolman particle size between 128-256 mm. Black Gully Upper (the other control site) had a lower median particle size class of between 64-128 mm. Sampling sites further down the catchment tended to have higher percentages of fine sediment and smaller median particle-size classes (Table 4-6). The two most notable sites were Black Gully Lower and Heriot Burn Lower, which had median particle sizes substantially smaller (8-16 each compared to 64-128 mm for Black Gully Upper and 32-64 mm for Heriot Burn Upper) (Table 4-6). Interestingly, despite the substrate-size class being larger at Heriot Burn Upper, this site had 26 % fine sediment build up, which was more than double that recorded at the lower site.

Despite Table 4-6 showing decreasing median substrate size and increasing proportions of fine sediment downstream, this trend was not shown in the two Pomahaka River sites, which had similar median substrate sizes and percentage of fine cover between the upper and lower reaches. The Waipahi River Lower site had a median particle size of 64-128 mm, compared to the upper site, with 16-32 mm, and a much higher percentage of fine cover (Table 4-6). The Washpool and Wairuna streams were the most degraded sites. The Washpool stream was smothered with 100 % fine sediment, which in some places was at depths of 15 cm. The Wairuna stream also had higher proportions of fine sediment cover (98%), despite it being a bedrock stream.

Table 4-6 Summary results of physical habitat assessment in the 15 streams

Site	Estimated fine sediment cover (%)	Median Wolman size class (mm)	Compactness	Shuffle index
Black Gully Upper	1	64-128	1	1
Black Gully Lower	12	8-16	1	4
Pomahaka Upper	2	128-256	1	2
Pomahaka Lower	5	128-256	2	3
Waipahi Upper	48	16-32	3	4
Waipahi Lower	7	64-128	1	2
Heriot Burn Upper	26	32-64	4	5
Heriot Burn Lower	11	8-16	1	4
Wairuna River	98	<2	Bedrock	4
Washpool Stream	100	<2	4	5
Crookston Burn	12	8-16	1	3
Flodden Creek	20	64-128	2	4
Waikoikoi	1	64-128	1	3
Spylaw Burn	40	64-128	2	3
Leithen Burn	0	128-256	1	2

Most sites had a compactness score of 1 or 2, with little difference between upstream and downstream locations. Interestingly, Heriot Burn Upper had a score of 4, compared to a 1 at the lower site, despite the upper site having a larger median substrate-size class. The Washpool also scored a 4 for compactness. The Waipahi continued the unusual trend between upstream and downstream, with compactness at the upper site being a 3, compared with 1 at the downstream site.

The shuffle index did show more differences between control sites and impacted sites and upstream/downstream comparisons. The control sites had scores of 1 or 2 (Table 4-6), while sites such as the Washpool and the Heriot Burn Upper had the highest shuffle index scores. The Heriot Burn Upper had a score of 5, which was slightly higher than the score recorded at the downstream site, while the Waipahi Upper had the higher score of the two Waipahi sites (Table 4-6).

4.5 Biological health

Macroinvertebrate communities

An individual kick-net sample was collected from each stream in late November during base-flow conditions. Macroinvertebrate health indices have shown that the highest MCI values were found in Leithen Burn, Black Gully upper and the upper Pomahaka

River Upper. All had a combination of mayfly species (*Deleatidium* sp., *Coloburiscus humeralis*, *Nesameletus* and *Oniscigaster*). Despite sampling sites being located within productive landscapes, Flodden Creek at SH90, Heriot Burn Upper and Crookston Burn at Walker Road still maintained good MCI scores (Figure 4-24), primarily due to the presence of mayflies and organic pollution sensitive caddisflies. The headwater site in the Upper Waipahi had a MCI score of 105, which is just above the good category threshold. The lower sites for Black Gully, Heriot Burn and the Pomahaka River only just made the good category. The Waikoikoi, Washpool, Lower Waipahi and Wairuna were the four worst sites in the study, with the Wairuna Stream rated as having poor macroinvertebrate communities, which suggests the likelihood of severe organic pollution. These four sites typically had macroinvertebrate communities comprising chironomids and other dipterans, molluscs and worms.

Figure 4-24 Macroinvertebrate Community Index (MCI) values for all streams

SQMCI indices provide different patterns for macroinvertebrate community structure. The Upper Black Gully site, where the stream emerges from forest, ranked the highest for SQMCI scores (Figure 4-25), as it supported high semi-quantitative abundances of mayflies (primarily *Deleatidium*) and stoneflies such as *Austroperla cyrene*, *Stenoperla* and *Zealandoperla* (Appendix 1). This site was closely followed by Flodden Creek and Crookston Burn, which were both dominated by a relatively high number of mayflies, and caddisflies, at Flodden Creek. Leithen Burn had a SQMCI score of 6.5, which fits into the good category, while the Upper Pomahaka River at Glenken had a SQMCI score just above the good threshold. With the exception of Wairuna, which maintains a poor macroinvertebrate community, the remaining sites had fair macroinvertebrate communities (Figure 4-25).

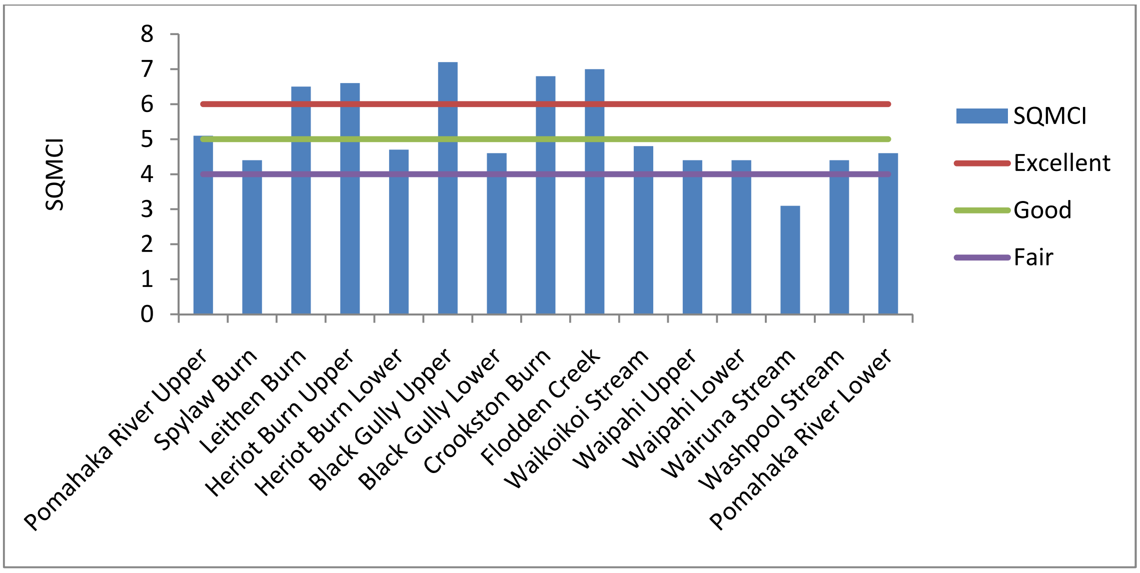


Figure 4-25 Semi-quantitative Macroinvertebrate Community Scores (SQMCI) for all streams

The percentage of the community comprising EPT taxa follows similar trends to the MCI and SQMCI graphs. The control sites and Flodden Creek represent healthy streams and support a high proportion (at least 55%) of EPT taxa (Figure 4-26). The lower sites in the Pomahaka River, Heriot Burn and Waipahi all support fewer EPT taxa; however, there was not much difference between the proportions of EPT taxa at Waipahi Upper (43%) and Waipahi Lower (41%) (Figure 4-26). The Washpool, Wairuna and lower Waipahi are consistently in the bottom four sites.

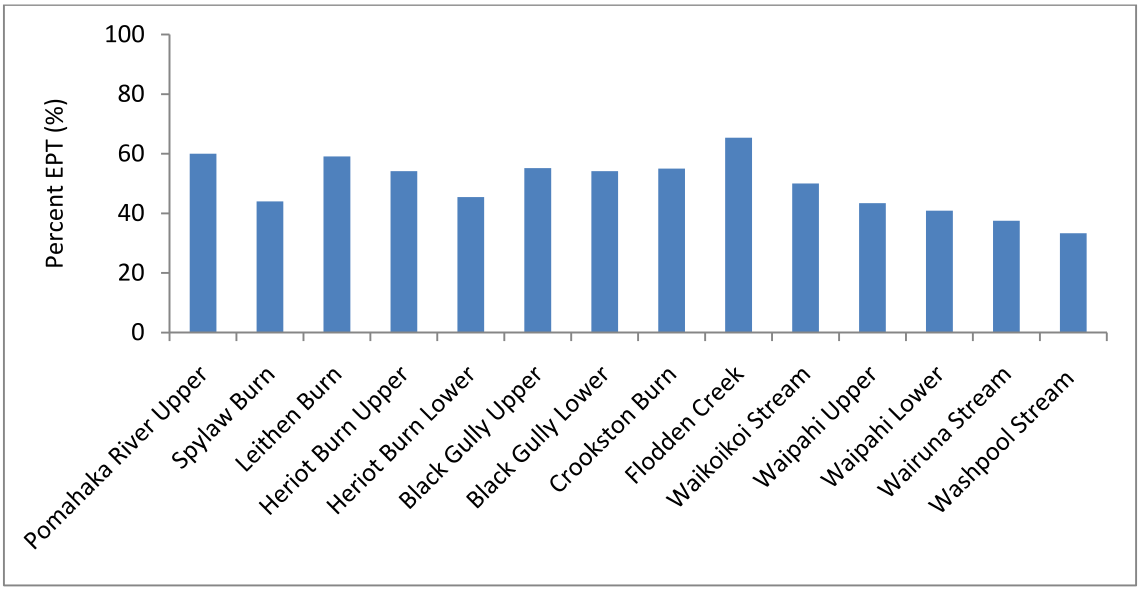


Figure 4-26 Percentage of macroinvertebrate community comprising Ephemeroptera (Mayflies), Plecoptera (Stoneflies) and Trichoptera (Caddisflies) (EPT) for all streams

To put the macroinvertebrate data into a regional context, the MCI scores of the three control sites were averaged. This figure was used as a surrogate for what a typical macroinvertebrate community should look like when not impacted by land management practises. The percentage deviation of the impacted stream MCI scores was calculated against the average control site score: the greater the percentage deviation, the greater the degradation in the macroinvertebrate community. Control sites had a very small percentage deviation from the mean MCI score of the three control sites. The Wairuna River and Washpool Stream had greatest percentage deviation from the mean MCI score of the control sites. The percentage deviation of macroinvertebrates from the mean MCI scores of the control sites revealed that control sites and some sites that maintained good macroinvertebrate assemblages, despite being in productive landscapes, had small deviations from the mean. However, the greater the deviation from the mean, the more the community moved away from a composition of mayflies, stoneflies and caddisflies to a community dominated by dipterans, worms, molluscs and crustaceans. Examples include Waikoikoi, Washpool, Waipahi Lower and Wairuna (Figure 4-27).

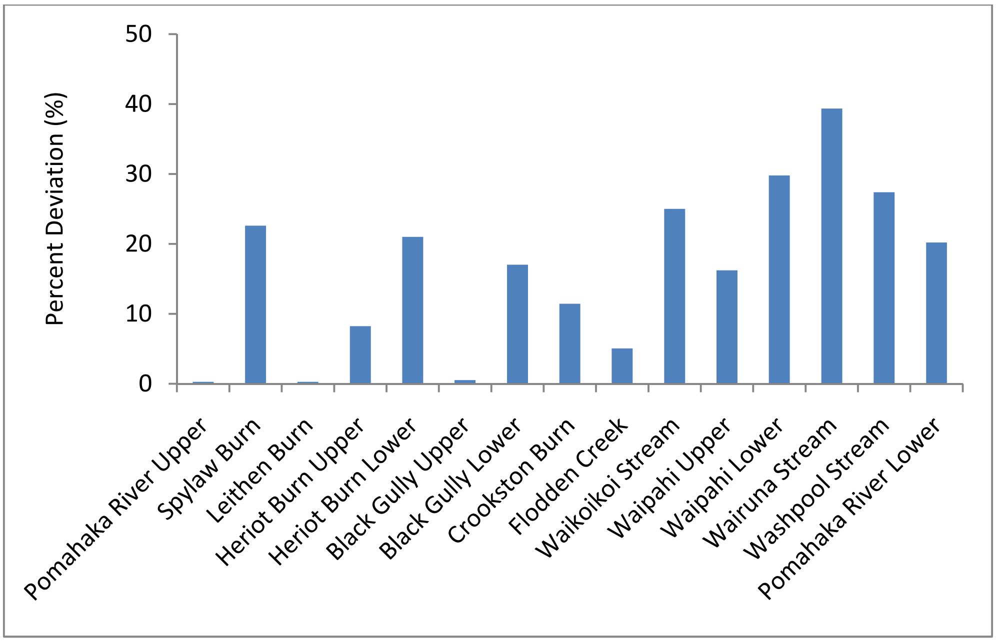


Figure 4-27 Percent deviation of macroinvertebrate community MCI scores from the mean MCI score of the three control streams

Fish communities

Electric fishing for density data was successfully completed in 13 tributaries of the Pomahaka River, with a further two sites in the Pomahaka River itself being electric fished in January and February 2010. Density data were only collected in 12 tributaries because the Pomahaka River (Upper and Lower) and Lower Waipahi were too wide to place stop nets effectively upstream and downstream. At each of the 12 sites, 100 m^2 sections were fished and between two and four fish species were present (Figure 4-28). While the maximum number of fish caught at any site was four, there was a total of five fish species caught, including Brown Trout, Longfin Eels, Upland Bullies and the non-migratory Clutha Flathead and Lamprey. Freshwater crayfish were also found in some streams, but these were not included in the fish diversity graph.

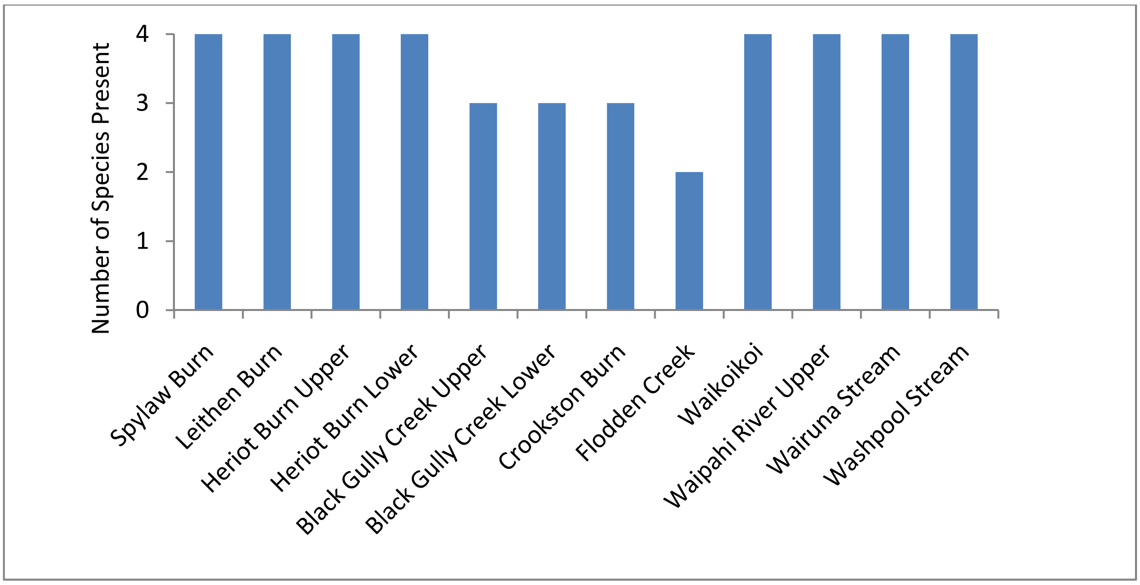


Figure 4-28 Number of fish species found at each sampling site

By sampling a known area (100m^2), density data were obtained showing total fish density was highly variable between sites (Figure 4-29). The Waikoikoi Stream and Spylaw Burn had the highest total densities of fish, with 1.81 and 1.31 fish per square metre, respectively, while the Wairuna stream had the lowest fish density (Figure 4-29).

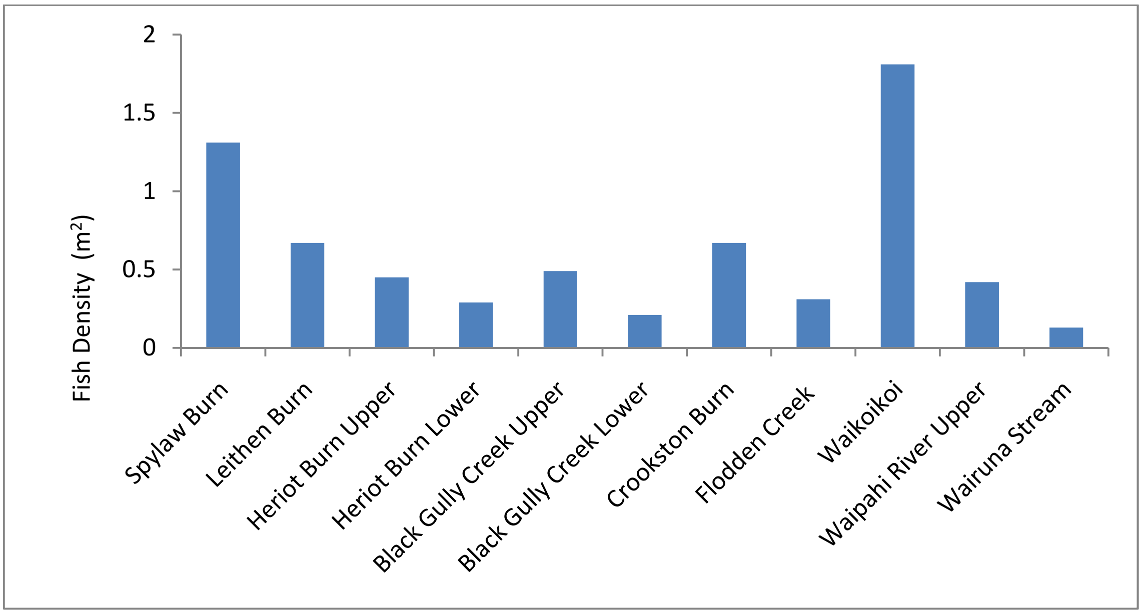


Figure 4-29 Total fish density (m^2) for tributary sites of the Pomahaka River

Native Fish

Native fish densities for this study were compared to densities calculated for all sites in the Clutha catchment from the New Zealand Freshwater Fish Database (NZFFD). The Waikoikoi stream, Spylaw Burn and Washpool Stream were all domianted by Upland Bullies and had densities that were above the excellent value, which represents the top 25% of native fish densites in the Clutha catchment (Figure 4-30). For the remaining sites where density data was collected, native fish densities were categorised as good.

The exception to this was Flodden Creek, which had densities in the bottom 50% of native fish densities (Figure 4-30).

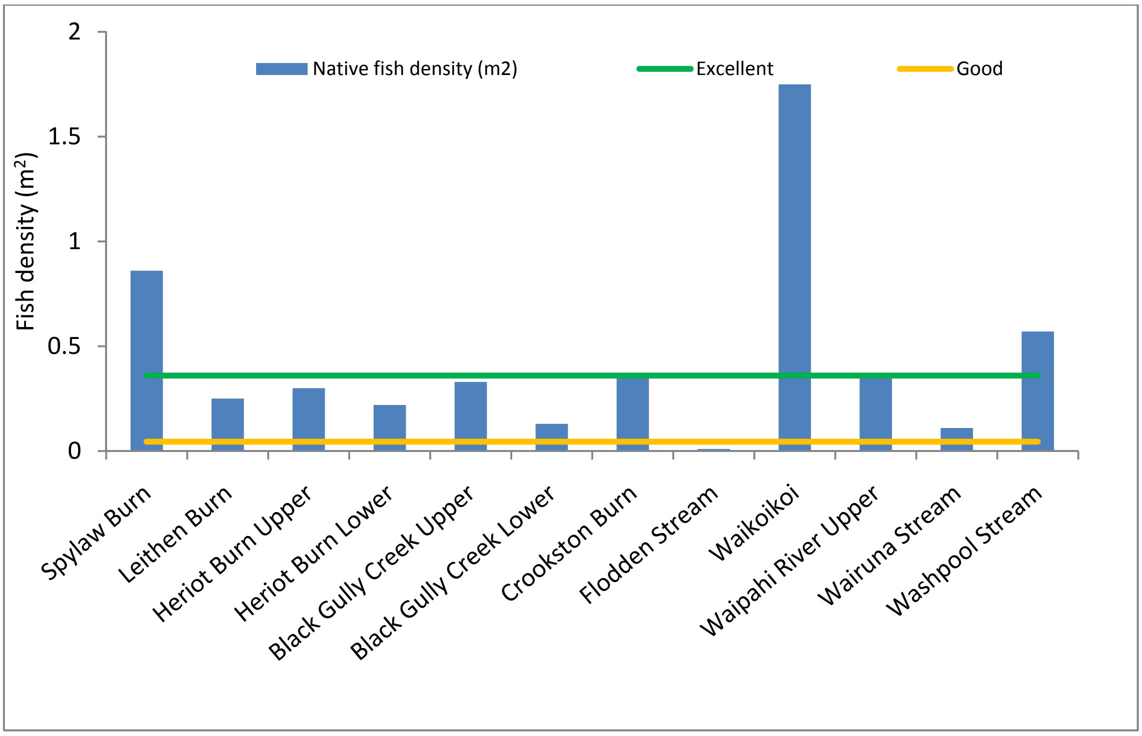


Figure 4-30 Native fish density (m^2) for tributary streams of the Pomahaka River relative to native fish density quartile's for the entire Clutha catchment

The only non-migratory galaxiid found in this study was the Clutha Flathead galaxiid (*Galaxias* Sp. D). Black Gully Creek Upper contained the highest densities of Clutha Flatheads (Figure 4-31), which were in the top 25th percentile of non-migratory fish densities for the Clutha catchment. The Washpool Stream, Leithen Burn, Spylaw Burn and Waipahi River Upper site all had relatively good densities of Clutha Flatheads, while the remaining sites had fair densities. Clutha Flatheads were absent from Crookston Burn, Flooden Creek and Lower Black Gully (despite being present in the Black Gully Upper site).

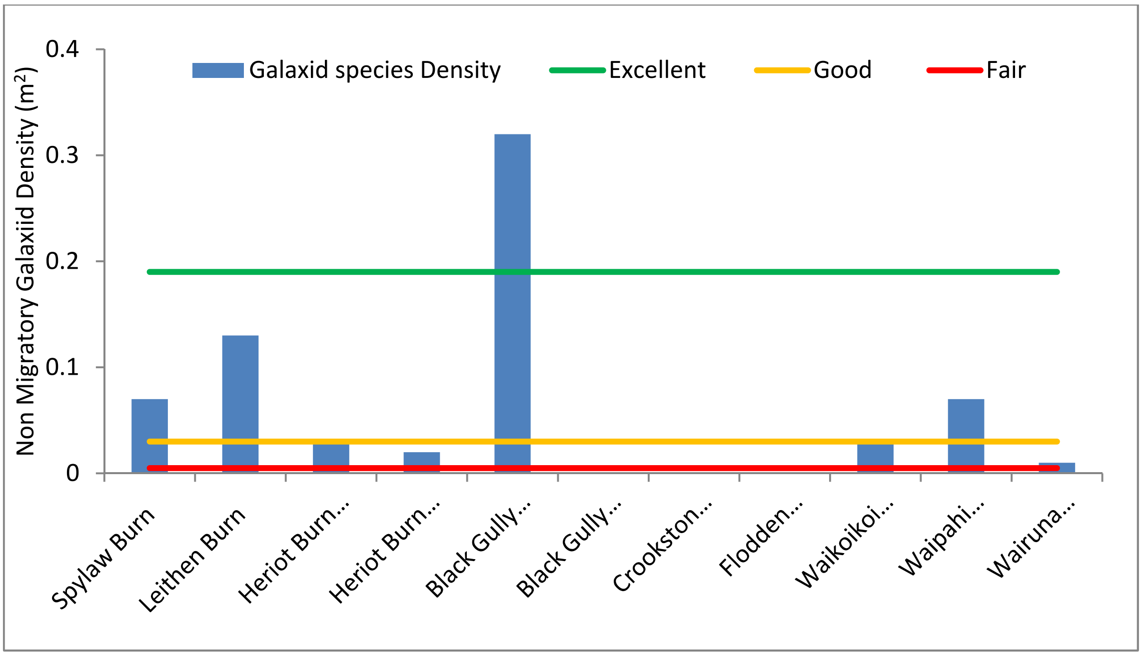


Figure 4-31 Clutha Flathead galaxiid densities (m^2) in tributaries of the Pomahaka River

Brown Trout

Brown Trout were present at all sites that were sampled for fish density. In addition to the density information, Brown Trout condition factors (K) were obtained for each stream (Table 4-3 and Figure 4-2). The condition factor of trout is a standardised measure commonly used to assess the health of trout and was obtained for 14 sites in the Pomahaka catchment (Figure 4-32). Using just trout condition, the only stream containing trout in excellent condition was the Washpool, although the Wairuna River, the Spylaw Burn and Leithen Burn were all close to being in the excellent condition category. No streams had extremely poor trout and the Upper Waipahi was only just above the poor category (Figure 4-32).

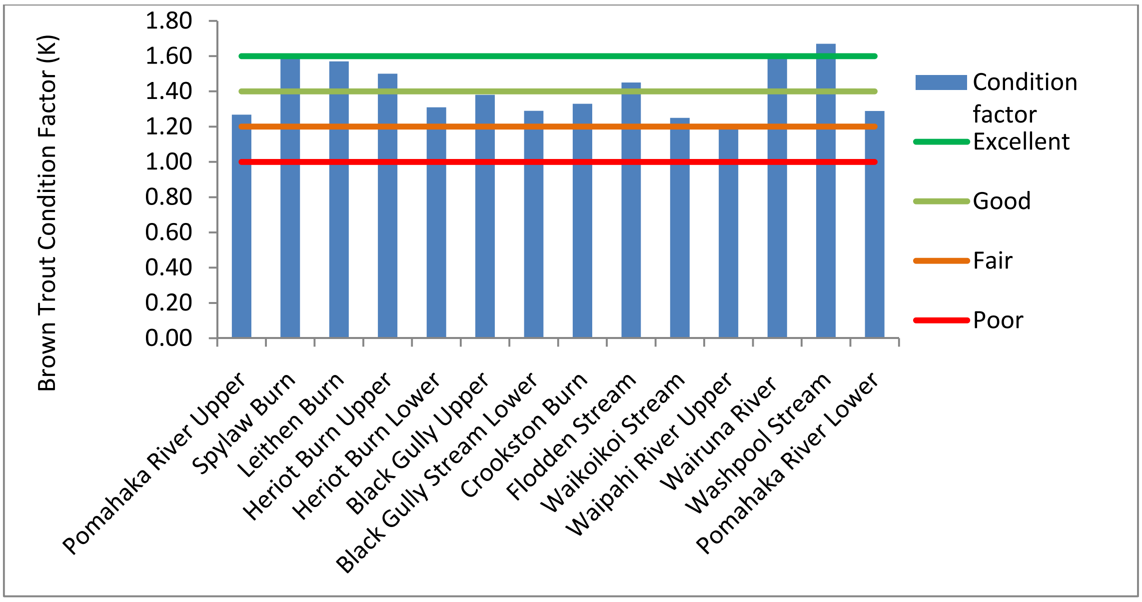


Figure 4-32 Median brown trout condition factors for the Pomahaka catchment

When trout density was considered, the Spylaw Burn and Leithen Burn had the highest densities of trout, which were considered to be excellent when compared to other trout densities in the Clutha catchment based on data from the NZFFD (Figure 4-33). The Crookston Burn and Flodden Stream both had good densities of trout, which were close to being excellent. The Washpool Stream and Wairuna River both had poor densities (Figure 4-33).

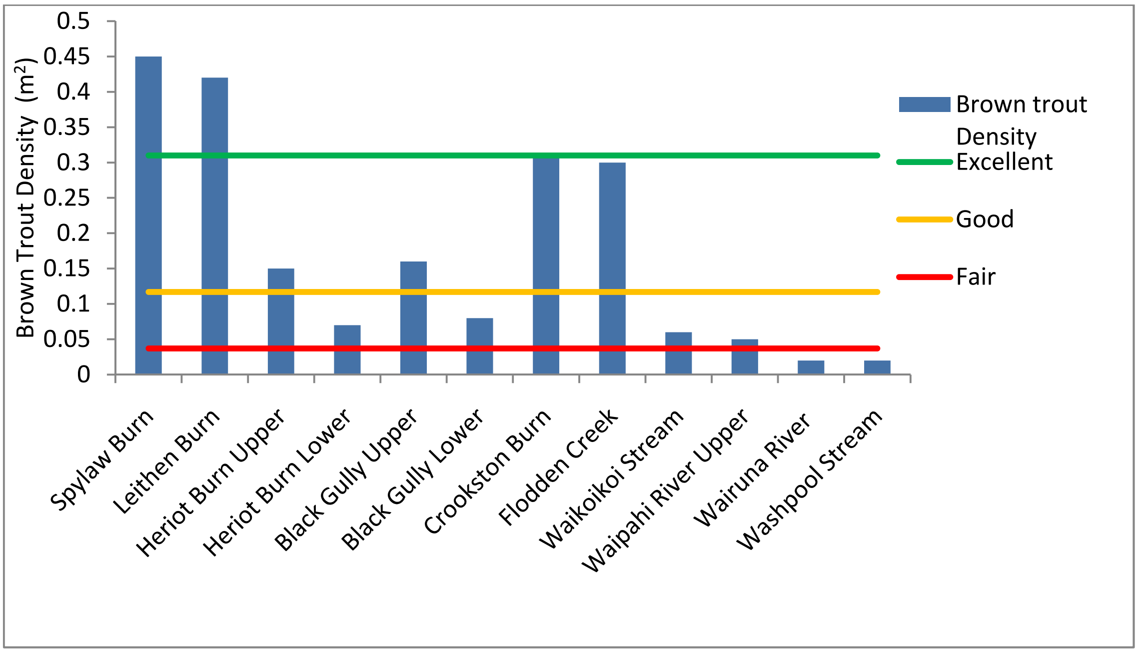


Figure 4-33 Brown trout density (m^2) for tributary streams of the Pomahaka River relative to trout density quartiles for the entire Clutha catchment

Assessing a stream just on brown trout condition or brown trout density can give conflicting results; for example, based on brown trout condition, the Washpool and Waiaruna Streams would be the best in the study, but, based on Brown Trout density per m^2, they are the worst (Figure 4-32 and Figure 4-33).

Ultimately, a high quality trout stream needs to contain high densities of excellent condition fish. To give a true representation of the quality of the brown trout fishery at each site, we assessed the condition factor for trout from each stream, along with the stream's density of Brown Trout per m^2 (Figure 5-34).

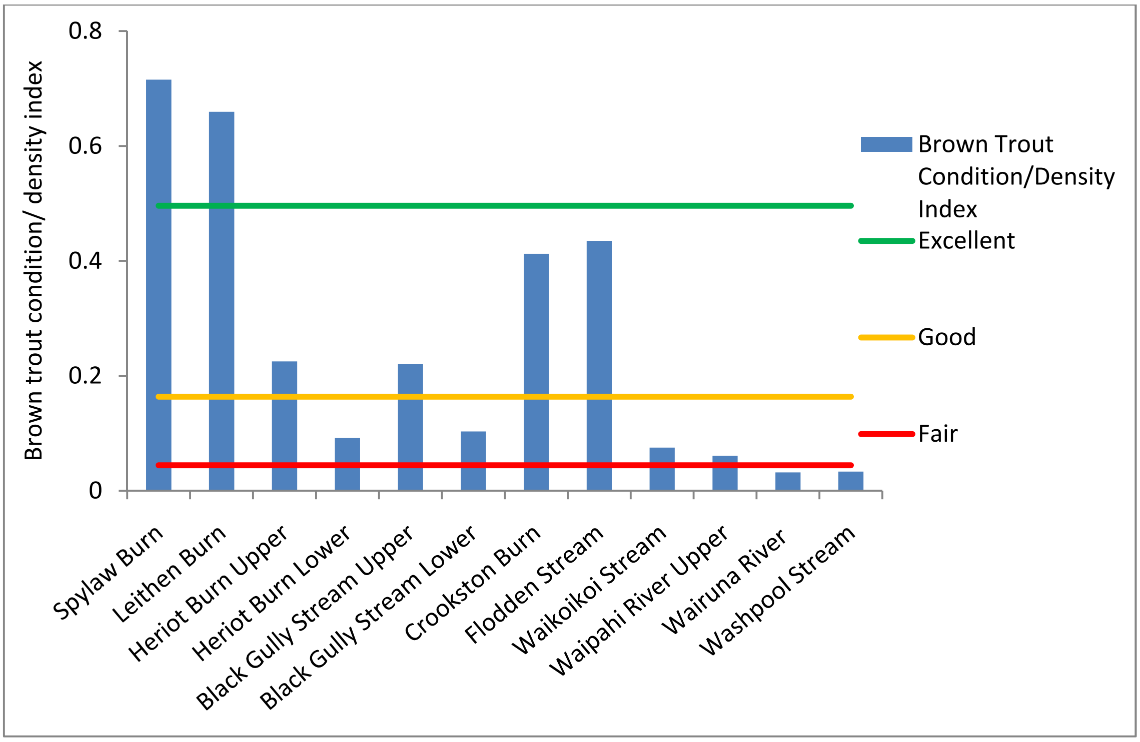


Figure 4-34 Brown trout density and condition factor index

Figure 4-34 simply ranks each stream as a brown trout fishery. Sites to the left side of the x-axis carry high numbers of trout in good/excellent condition, which indicates a good trout fishery. Sites at the right end of the x-axis either carry very low numbers of good conditioned or high numbers of poor conditioned trout; both scenarios suggest a poor trout fishery.

5 Discussion

This section discusses the findings of the tile drain and stream water quality, as well as the physical habitat and ecological values derived from the macroinvertebrate and fish sampling. Where appropriate, links have been made between degraded water quality and physical habitat as a result of agricultural development and the effect on ecological values. Case studies have also been used to highlight some significant issues in the catchment.

5.1 Tile drain water quality

Farming in the Pomahaka catchment relies on artificial drainage, predominantly in the form of tile drains. Unfortunately, subsurface drainage has been identified as a significant source of contaminants from grazed pastures to waterways (Wilcock *et al*. 1999, Monaghan *et al*. 2002a, Monaghan *et al*. 2002b). Tile drains influence water quality in the streams they discharge into, with the level of influence depending on several factors, including:

- the frequency and volume of flow from individual tile or mole drains
- the concentration of nutrients carried by the flowing drain
- the total number of flowing drains in the area
- land use and land management.

In this study, tile drains flowed on average 55% of the time, with little difference between the different land uses (dairy 57% and sheep 52%). Four of the tile drains flowed on at least 11 out of 12 sampling times. The total number of tile drains in the entire Pomahaka catchment is unknown. Data for when the tiles were flowing were compared to data from the ORC's soil moisture site at Kelso, showed a seasonal pattern to the flow regime (Figure 4-2). This information suggests that there are greater risks of agricultural pollution in the late autumn to early spring period, when soils are saturated and dairy herds return from their wintering locations.

Tile drain nutrients and suspended sediment

Concentrations of NNN, DRP, TP, TN and SS were much higher in tile drains draining dairy pasture than in the sheep pasture (Figure 4-3 to Figure 4-8). NNN and TN is likely to be related to the animal-stocking rate, effluent application and urine patches in dairy pasture, which can deliver the equivalent loads of 1000 kg N ha-1 (Monaghan, 2009). Since urea is completely water soluble, when applied to the soil surface it can easily move down the soil profile with rainfall to complete the urea to NH4 to NNN transformation. This process is much more rapid on land that is artificially drained by tile and mole drains.

The seasonal trends of NNN draining dairy farms showed that NNN begins to increase during the autumn period, which is probably the result of lower uptake rates of NNN by grass. (Grass growth rates reduce due to lower soil temperatures and increased soil moisture, allowing leaching of NNN via tile drains (Figure 4-3)).

With the exception of the October sample from dairy tile drains, NH4 is below the guideline value (Figure 4-4). However, NH4 concentrations are typically higher in tile drains draining dairy pasture, particularly in spring. This is probably due to the soil being close to or above saturation and effluent application rates being too high.

DRP and TP levels were highest in the dairy tile drains and were much higher than the guideline level of the tile drains used in the sheep farms (Figure 4-5 and Figure 4-7). In the dairy tile drains, TP concentrations increase greatly from September onwards (Figure 4-7). This increase coincides with the start of the milking season and the need to dispose of effluent. The application of dairy effluent on saturated soils can allow effluent to enter tile drains and end up in waterways (Monaghan and Snow, 2004). Houlbrooke et al. (2008) also found that P concentrations were between six and ten times higher in tiles discharging land plots that had had dairy effluent applied in mid-September on near saturated soils, compared to discharges when effluent had not been applied. To put this in context, during September 2009 at the Kelso soil moisture site, soil moisture exceeded 40% saturation (considered to be saturated) for the entire month.

Bacteria

E.coli concentrations showed that there were no major differences between tile drains draining dairy or sheep farms. *E.coli* was either well below, or well above, the guideline value for both land uses, depending on preceding rainfall (Figure 4-9). Following rain, both land uses contribute high levels of *E.coli*. The key exception was that, during dry periods, samples from some tiles draining dairy effluent application paddocks had high *E.coli* (refer to Case Study 1).

The highest risk from bacteria to recreational users would be during dry periods. High bacteria levels during high flows pose less of a risk because of fewer contact recreation activities during these periods.

Case Study 1: Effluent application over a tile drain

The ability of tile drains to transport both water and pollutants from land to stream is well documented (Houlbrooke, et al. 2003; Monaghan RM, Smith LC: 2004; Houlbrooke, et al. 2008). Results from this project further support the idea that tile drains themselves are not necessarily the cause of the problem, rather the practices which take place on tile-drained land are critical in determining the amount of nutrients passing into waterways via these drains.

An excellent example of this was found in the drain referred to in this study as Site-6. This site was surveyed five times during the dry weather period between December 2008 and April 2009.

On three of the five sampling occasions, the drain was not running (December, January and February). The two subsequent surveys in March and April found the tile flowing, with the sampling results showing poor water quality (Table 5-1). This was despite soil moisture levels being similar to the previous three visits.

Table 5-1 Results from drain number site-6 for March and April 2009

Date	DRP	NNN	TN	TP	E.coli	Tile flow(l/s)	Wairuna Stream flow (l/s)
25-Mar-09	0.073	1.2	2.38	0.154	380	0.45	360
30-Apr-09	0.093	1.34	8.11	0.923	6400	0.4	72

Results during the April survey were particularly poor, with E.Coli, DRP and NNN being 1160%, 358% and 454% above guideline levels, respectively (Table 5-1).

A subsequent conversation with the farmer confirmed that effluent had been applied with K-line the day prior to the April survey, and several days prior to the March survey, though application rates are unknown.

In this example, a single tile contributed no effects to the waterways most of the time, but a combination of natural events (moderate soil moisture) and a specific farming practice (application of effluent over tile drains) resulted in a particularly poor quality discharge continuously flowing at just under 0.5 l/s.

Individually, this is a relatively small flow from one tile; however, tile drains are numerous in the Pomahaka catchment and the cumulative effect of this activity may have significant negative effects on water quality.

Summary of tile drain water quality

- Tile drains from dairy farms have higher concentrations of DRP, SS, TN and NNN when compared to tile drains discharging from sheep farms.
- *E.coli* concentrations were high in both dairy and sheep tile drains, especially following rainfall.
- High levels of TN, TP and *E.coli* could be from inappropiate management of dairy shed effluent.

5.2 Stream water quality

Generally, the control sites for this study (Leithen Burn, Upper Pomahaka and Upper Black Gully) had the best water quality (Table 4-2). These control sites were dominated by sheep and beef farming and had at least 10% forest cover, with Black Gully Upper having 100% forest cover. In contrast, the worst streams for water quality (Washpool and Wairuna) had the highest proportions of dairy farming (79 and 51%, respectively) (Table 2-2).

Nutrients

For this study, comparisons have been made of nutrient concentrations for all flows and when rivers are at median flow or below. Overland flow from paddocks, tile drain contributions and increased catchment leaching from saturated soils are likely to be causing poorer water quality, but recreational use is less. Flows of less than median flow occur at times when rivers and streams are most likely to be used for angling and contact recreation. Flows exceeding median flow generally follow rainfall events. However, sediment during high flows needs to be managed, as these can have a lag effect within the system.

The control sites at Pomahaka River Upper and Leithen Burn had the lowest concentrations of DRP. However, the other control site (Black Gully Upper) had DRP levels above guideline values at median flow. This exceedence of the guideline value at a control site is thought to be natural and likely to be due to the sampling location, which had 100% forest cover and over 90% shading of the stream. The shading prevented photosynthesis; thus, algae were unable to grow and utilise the available DRP (Hudson *et al.* 2008). Furthermore, the break down of organic matter from forests generates phosphorus, hence the naturally high concentrations of DRP (Collier and

Winterbourn, 1987). The other sites to exceed the DRP guideline value were Black Gully, at Walker Road, Crookston Burn, at Walker Road, Wairuna Stream and Washpool Stream (Figure 4-18).

Nuisance algae growths are common in summer in waterways affected by excessive nutrient contamination. Growth conditions are optimal because of high water and air temperatures and lower water depths due to lower flows. Important to the proliferation of nuisance algae is the concept of nutrient limitation. Nutrient limitation occurs when one important nutrient is in limited supply, which means that algae can only grow until the limited nutrient supply is exhausted, regardless of the avaliability of other nutrients. Typically, in New Zealand waterways, the essential nutrients are the biological active component of N (NNN) and P (DRP).

In this study, we did not assess periphyton abundance, as there did not appear to be evidence of a widespread abundance of algal growths in summer low flows.

Using data collected below median flow, the results showed that the three control sites, as well as the Spylaw Burn, Waikoikoi Stream and the Washpool Stream, were N limited. However, the Waikoikoi and Washpool both have very high NNN and DRP concentrations, even after dense macrophyte mats had stripped out substantial amounts of nutrients, which suggests that these streams have abundant nutrient supplies, and that algal growth is not limited by nutrient availability.

TN concentrations also varied between sites; with the control sites having median concentrations well below the guideline during median flows and higher, and the rest recording median concentrations well above guideline values (Figure 4-19). This suggests that either dairy shed effluent or fertiliser is reaching the stream. Crookston Burn and Flodden Creek record the highest median concentrations of nutrients and both have over 30% of the catchment land area under dairy farming (Table 2-2). There was a noticeable increase at the lower Pomahaka site (Burkes Ford), compared to that at the upstream Pomahaka site, at Glenken, as the poor water quality tributaries discharge into the Pomahaka between the two sites (Figure 4-19).

Sites where high TP, DRP, NH_4, *E.coli* and low SS were recorded at median flows (when leaching and overland flow is at its lowest) suggest that there was effluent contamination via tile drains or direct stock access to streams. The Wairuna and Washpool streams show this pattern, while Black Gully Lower and Heriot Burn Lower also have elevated levels (Figure 4-20, Figure 4-18, Figure 4-21, Figure 4-22 and Figure 4-23).

Bacteria

The presence of bacteria in the water indicates the presence of faecal material and, with it, the possibility that other disease-causing organisms may be present. These organisms are able to enter water through a number of routes. In the Pomahaka catchment, this is likely to be mainly through runoff from pastoral farm land, tile drain discharges or wild life living in and around water bodies.

Bacteria concentrations at median flows are discussed, as recreation is unlikely to be undertaken during periods of high flows. The study has shown that only the control site at Black Gully Upper meets the ANZECC 1992 criteria; however, the Pomahaka River Upper, Crookston Burn at Walker Road, Flodden Creek at Tapanui, Waipahi River Lower and the Pomahaka River Lower have a median value of less than the contact recreation spot-reading standard (260 cfu/100ml) (Figure 4-22). All the other sites recorded high median values, in particular the Wairuna and Washpool streams, which have the highest proportions of land area under dairy farming (Figure 4-22, Table 2-2).

Suspended Solids

Sediment consists of particles of all sizes, including fine clay particles, silt, sand and gravel. Nutrients, in particular, may attach to sediment and then be transported into surface waters; they can then settle with the sediment or detach and become soluble in the water column. For this study, an effects-based guideline was used for SS of 7.2 mg/L (see Table 3-1). At median flows, the only sites to exceed the 7.2 mg/l value were the Washpool Stream and the Waipahi River Upper. At high flows, the Heriot Burn Upper was by far the worst site for SS, which was probably the result of bank erosion (Figure 4-23). Other sites to exceed the guideline value above median flows include Waipahi River Upper, Waipahi River Lower, Wairuna Stream, Washpool Stream and Pomahaka River Lower (Figure 4-23). Results at or below median flow occurred when ecological impacts are likely to be the greatest. However, SS that enters the stream during high flows will settle out as flows recede and then have potential significant ecological effects over a prolonged period.

Observations in the field suggest that unfenced streams and eroding banks are an issue in the Wairuna and Heriot Burn catchments. Furthermore, as P binds to SS particles, P can build up in the stream bed as sediment is deposited and be released at other times of the year (McDowell *et al.* 2008). *E.coli* is also capable of being stored in stream bed sediment and released slowly in summer, potentially increasing *E.coli* concentrations in summer when direct sources may be limited, and when waterways are being used for contact recreation.

Summary of stream water quality

- NH_4 levels (an indicator of raw effluent in waterways) were always well below the guideline value.
- DRP concentrations were only above the guidelines at five sites when at median flows or less. NNN concentrations are typically above guideline values, particularly for below median flows.
- Algal growth was possibly limited by DRP and any increase in this could lead to nuisance algal growth.
- Of significant concern were the high levels of SS, especially during times of below median flow. This is important as it can smother instream habitat, binds P and harbours *E.coli*.

5.3 Physical habitat condition

Habitat surveys revealed that there was degradation in habitat condition in many of the tributaries to the Pomahaka River. The control sites of Upper Black Gully (Figure 5-1), Pomahaka River Upper and Leithen Burn had the largest median substrate class, as did the Pomahaka River Lower, even though it was a downstream site. This similarity in substrate-size class was most likely the result of frequent flushing flows reducing fine sediment build up.

Figure 5-1 Good substrate size at the Upper Black Gully site. Median substrate size class category was 64-128 mm, but there were also frequent emergent boulders present.

The sampling sites located further downstream had smaller median substrate size, due to increased sedimentation. This was most noticeable in streams that had an upstream and downstream comparison, such as the Heriot Burn and Black Gully. The Heriot Burn was a very interesting site, in that the median substrate size decreased between the upper and lower sites, while the proportion of fine sediment was higher at the upper site. This higher proportion of fine sediment was patchy, and runs and riffles varied between clean cobbles that were in the 32-64 mm class, and sections which were smothered in fine sediment.

These sources of fine sediment most likely derived from the raw and/or steep banks, which showed active erosion. Stock access was identified as clearly a contributing factor (Figure 5-2), which helped provide a continual supply of fine sediment. Collapsed banks and pugging due to stock access can have significant negative ecological effects through the elimination of under cut banks, which are important native fish habitat, especially for eels (Figure 5-3).

Figure 5-2 Examples of stock access throughout the Pomahaka catchment

Figure 5-3 Examples of bank collapse and sedimentation in the Pomahaka catchment

The only stream which did not show increasing fine sediment cover downstream was the Waipahi, where the upper site had a higher proportion of fine sediment. Like the Pomahaka River, this was probably the result of flood flows, which had flushed the fine sediment out from the Lower Waipahi.

This upland stream, which showed sedimentation, was considered unusual, especially when it used to be an SOE monitoring control site. Further investigation revealed that the sedimentation was probabaly related to the drainage of the Cairn wetland and cattle grazing. (Refer to Case Study 2.)

The Washpool Stream contained the most sedimentation in the entire study, with an estimated 100% fine sediment cover. The main reasons are that the channel has been artifically straightened in the past and is now unstable as it tries to readjust to a natural form; also stock access destroys stream bank vegetation, puggs and ultimately causes stream banks to collapse.

Case Study 2: Cairn swamp wetland drainage

The loss of wetlands over a long-time scale and tracking the effects of wetland drainage on downstream water quality are difficult. This case study looks at the effects on downstream water quality after significant drainage works were undertaken on a large wetland in the Upper Waipahi catchment.

This study has shown a significant decline in water quality in the Upper Waipahi at the Cairn relative to the historical SOE data (Table 4-5). In August 2007, council staff noted that, between 2005 and 2007, substantial drainage had taken place within the Cairn Swamp wetland. A subsequent check of the March 2006 aerial photo showed large areas of drainage of the Cairn Swamp wetland (Figure 6.4).

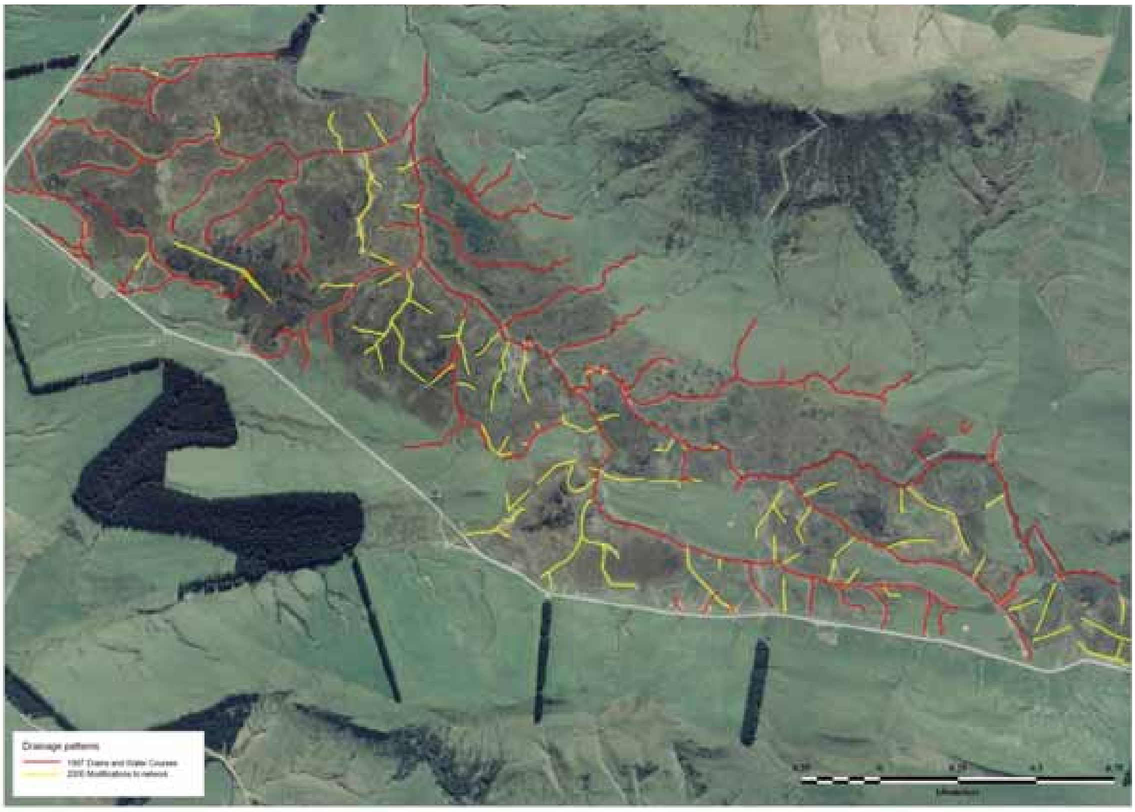
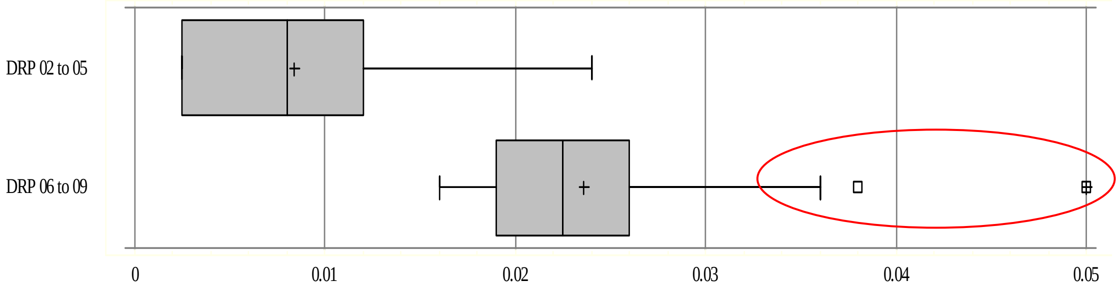


Figure 5-4 Cairn Swamp Wetland showing the increased drainage network comparing 1997(red line) to 2006 (yellow line)

The removal or degradation of wetlands often takes place over a prolonged period of time and it is rarely possible for SOE monitoring programs to detect and quantify the effect of wetland loss on water quality.

In the case of the Cairn Swamp wetland, TN, NNN, DRP, TP, *E.coli* and SS have been monitored downstream of the wetland since 2002. It is known that substantial drainage work occurred between 2005 and March 2006. This allowed a comparison of water quality at the SOE site to determine if there had been any change over time. For the purpose of this case study, it is assumed the effects of drainage on water quality have occurred from January 2006 onwards.



When comparing water quality for the pre-drainage period (2002 – December 2005) to the post- drainage period (January 2006 to October 2009), there has been no significant change in NNN, *E.coli* and SS. However, concentrations of DRP, TP and TN have increased significantly, as has the level of extreme values (Figure 6.5).

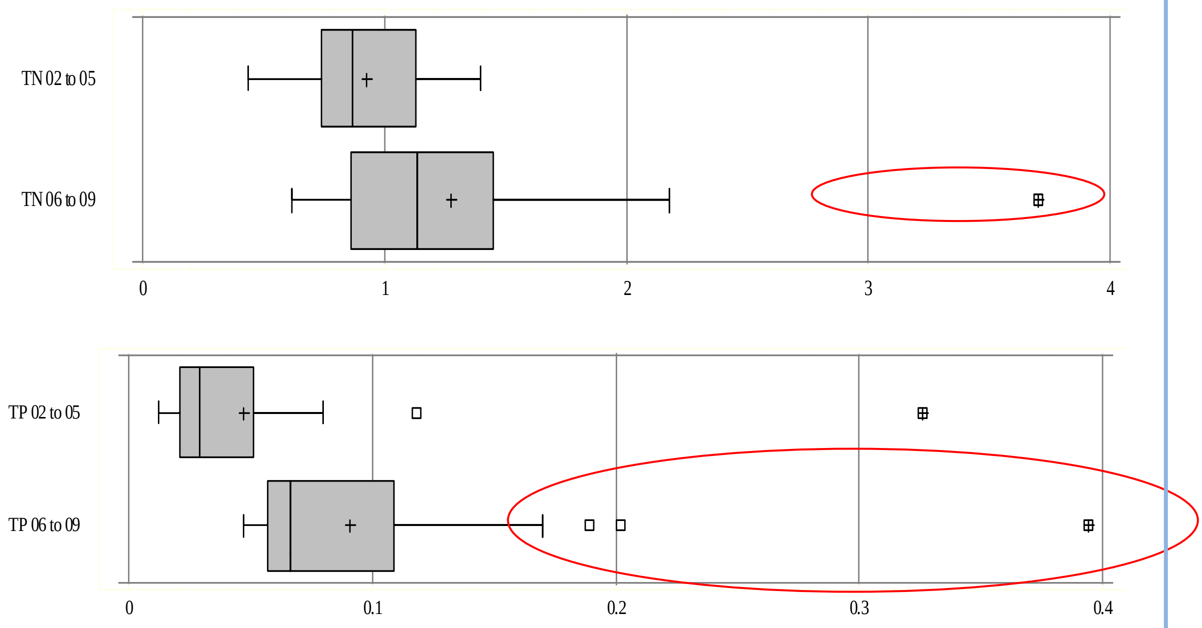


Figure 5-5 Box plots of the three significantly different analytes between 2002 and 2008. 2008 extreme values have been circled in red.

TP, TN and DRP have roughly doubled since drainage took place. Though median values are yet to reach or exceed effects-based guideline values, median values are significantly higher, extreme values have become more extreme and could possibly increase as land use intensifies or the drainage network is expanded. This is a typical symptom of wetland degradation, where the effects are often not fully experienced for a number of years after the fact.

Increased concentrations of TN and DRP could be the result of the use of phosphate fertiliser and these fertiliser applications binding to soil. Drainage channel erosion, due to probable stock access and natural process, has caused TP and DRP to increase. Increases in TN are the likely consequence of draining and drying the wetland. Ammonia or organic nitrogen that has built up in the wetland is exposed and goes through an aerobic conversion creating nitrate, which is leached into the streams and rivers. This has been the experience in Waikato, with the drainage of wetlands for primary pastoral farming (NWSCO 1978).

Summary of physical habitat

- The size of instream sediment decreased downstream. The largest substrate was found at the control sites.
- The sources of fine sediment are likely to be from unstable river banks that are naturally realinging, after straightening, and from stock access, particularly dairy and beef cattle and deer.

5.4 Land-use effects on ecological instream values

Water quality results are frequently reported as being above or below ANZECC guidelines. However, these guidelines do not neccessarily represent a threshold for detecting an ecological effect. They have limitations because they are broadly based on studies from New Zealand and Australia and do not always take into account regional differences. For this study, effects-based guidelines have been used for nutrients and sediment and health guidelines for bacteria, in addition to regionally derived guidelines for fishery values. This approach looks at mutiple stressors (chemical, physical and community structure) in tandem and therefore provides a more relevant ecological impact assesment. Each site has been graded as either Excellent, Good, Fair or Poor, for chemical, physical habitat, macroinvertebrate and trout fishery values (Table 5-2).

Table 5-2 Summary of categories for chemical, physical habitat, MCI and trout condition related-density for each stream. Control sites are in bold.

Site	% catchment dairy farm	Chemical	Physical habitat	MCI	Trout density/ condition
Leithen Burn	0	Excellent	Excellent	Excellent	Excellent
Pomahaka River Upper	0	Good	Excellent	Excellent	n/a*
Black Gully Upper	0	Good	Excellent	Excellent	Good
Spylaw Burn	1	Fair	Good	Fair	Excellent
Pomahaka River Lower	7	Fair	Good	Good	n/a*
Flodden Creek	26	Good	Good	Good	Good
Crookston Burn	44	Poor	Good	Good	Good
Heriot Burn Upper	12	Fair	Poor	Good	Good
Waikoikoi Stream	20	Fair	Good	Fair	Fair
Waipahi Lower	1	Fair	Good	Fair	n/a*
Heriot Burn Lower	15	Fair	Good	Fair	Fair
Waipahi Upper	0	Poor	Poor	Good	Fair
Black Gully Lower	36	Poor	Poor	Good	Fair
Washpool Stream	79	Poor	Poor	Fair	Poor
Wairuna Stream	51	Poor	Poor	Poor	Poor

- n/a means density data could not be collected, as the river was too wide to net effectively.

Table 5-2 shows degraded water quality does not neccessarily relate to degraded ecological values, as indicated by Crookston Burn at Walker Road, which had poor water quality, but good fishery values. This is because agricultural-chemical degradation does not generally have toxicological effects and is often correlated with other factors, such as sedimentation, changes in ecosystem function and structure, and the loss of riparian vegetation, all of which can affect the reproductive cycle of macroinvertebrates.

At the control sites, there was excellent or good water quality, excellent physical habitat structure, good or excellent macroinvertebrate communities and excellent fishery values (Table 5-2). Density data could not be collected in the Pomahaka River, at both the upper and lower sites, nor at the Waipahi Lower site, as the river was too wide to net off effectively. However, when collecting fish for trout condition in the Pomahaka River, their relative abundance did seem high. Despite good macroinvertebrate communities and physical habitat at Black Gully Upper, trout condition related density was only good. This is likely to be because this section was steep, with some large substrate; which suggests that flash flows come through periodically. Trout numbers are therefore likely to be limited by the lack of flood refuge habitat. The Washpool Stream and Wairuna Stream had poor water quality, physical habitat, macroinvertebrates (except at the Washpool) and poor fishery values. These results of severly degraded trout fishery values are probably the result of significant habitat degradation through sedimentation. In this case, trout would have limited habitat and food supplies, because macroinvetrebrates would also be habitat- limited due to sedimentation.

Trout in the best condition are often found in the highest densities in streams with a high number of mayfly species (Young and Hayes, 1999). This study showed that where there were diverse and abundant mayfly communities, there were also excellent trout density-related condition values (e.g. Leithen Burn, Black Gully Upper and to a lesser extent Heriot Burn Upper). The chemically degraded sites that still maintained reasonably good diversity and abundances of mayflies, such as Crookston Burn at Walker Road, had good trout fishery values, due to favourable physical habitat.

Sedimentation reduces habitat availability and can cause degraded macroinvertebrate and fishery values. Habitat availability is an important resource requirement for macroinvertebrates. Bank instability, because of the loss of riparian vegetation, and bank collapse, due to stock access and natural erosion, provides fine sediment that smothers substrate, thereby reducing substrate size, and thus reducing habitat availability for macroinvertebrates (Parkyn and Wilcock, 2004) (Figure 5-3). This relationship was most pronounced in the Wairuna, Heriot Burn Upper, Black Gully Lower and Washpool streams.

MCI values for this study show the Leithen Burn, Pomahaka Upper and Black Gully Upper have excellent scores, while the majority of streams fall into the good and fair category. The exception was the Wairuna River, which was classed as poor (Table 5-2). It should be noted that fair suggests probable moderate pollution.

Degraded habitat quality via sedimentation has negative impacts on macroinvertebrate communities and therefore fish populations. In this study, individual trout in most streams have at least a fair condition. A healthy trout stream will have high densities of healthy trout, while degraded streams will have only a small number of healthy trout. This is because the stream does not have the habitat availability or macroinvertebrate compositions or densities to support high numbers of healthy trout. The worst trout streams, based on trout condition and density, were the Wairuna and Washpool streams, while the Leithen Burn, Crookston Burn, Black Gully Upper and Flodden Creek had high densities of trout in good condition (Figure 4-34).

Coarse substrate and intersistitial space (the spaces between stones) are particuarly important for native NZ fish species because they are benthic dwelling and use the streambed for shelter, foraging and nesting (Jowett and Boustead 2001). In this study, it has been found that the highest densities of native fish were found in streams dominated by large substrate. In particular, the Waikoikoi had the highest Upland Bully densities, while Black Gully Upper had the highest abundances of Clutha Flathead galaxiids (Figure 4-30). This compliments several previous research papers (for example, Allibone and Townsend, 1997, and McDowell and Eldon, 1997). Despite the Washpool being severely degraded, native fish (Upland Bullies and non migratory galaxiids) are present where pockets of suitable habitat exists. Clutha Flathead galaxiids, which are generally the most threatened native fish species, were present in excellent numbers in the Upper Black Gully site, which is possibly the result of good habitat condition (Figure 4-31) and their ability to tolerate higher flood disturbance than trout.

Summary of land-use effects on ecological instream values

Ecological effects of poor water quality can be difficult to detect. This study has shown that the control sites had good water quality and high ecological values. Two streams (the Wairuna and Washpool streams) had the worst water quality and the poorest ecological vlaues.

The primary cause of ecological degradation in the Pomahaka catchment is the introduction of fine sediment, which is smothering the larger substrate that provides habitat and refuge for fish and macroinvertebrates. This situation can easily be rectified over the medium term with riparian fencing for all farms regardless of stock type.

6 Conclusions

1. Water quality data from surface water and tile drains have been collected and analysed. The sites were representative of different land uses; specifically sheep and beef; and dairy.
2. Upstream control sites generally had excellent water quality. Catchments with a high proportion of land under sheep and beef farming had good water quality, while catchments with an increasing proportion of dairy farms had increasingly poorer water quality. The exceptions to this were the Flodden Creek catchment (26% dairy), which maintained good water quality, and Waipahi River Upper (0% dairy), which had poor water quality. *E.coli* levels were generally above guideline levels throughout the catchment, but were higher in dairying areas during low to median flows.
3. All catchments with more than 30% of the catchment under dairy farming had poor water quality.
4. Tiles draining dairy farms had more DRP, SS, TN and NNN than those draining sheep farms.
5. *E.coli* levels were high in both dairy and sheep tile-drained land after rainfall (the highest two values recorded were from sheep farm drains). High *E.coli* values were also recorded from dairy farm tile drains during dry weather. However, in five of the 11 samples for sheep farms and six out of 11 samples for dairy farms, *E.coli* concentration was below the 260 cfu/mL guideline.
6. In-stream effects-based guidelines and an ecological value classification have been used to understand the effects of water quality degradation and habitat health. These have shown that the main issues of concern to the health of the river system are sediment, *E.coli* and DRP. Each of these is linked to poor land management practices.
7. NNN concentrations are only an ecological issue during summer low flows, as NNN is rapidly flushed from the system during high flows.
8. Results from this study indicate that sediment is an issue all year round, and at all flow levels. Sediment control is critical as it can smother habitat, harbour bacteria and bind P. P previously bound to sediment can be released back into the system during the low flow periods, potentially increasing algal growth. *E.coli* that has been harboured in sediment can be released by sediment disturbance at times of low flow, when contact recreational activities are most likely to occur.
9. The provision of stock drinking water, excluding all stock types of waterways and the use of native riparian vegetation, will result in improvements to physical habitat within the stream and ultimately improve instream values. Dairy farmers need to continue the improvements the industry has made in managing dairy shed effluent.
10. Water quality values from both the stream and tile sites provide the basis for calculating instream standards and tile-discharge standards. These could form the basis of community discussion prior to any future policy changes aimed at maintaining or improving ecological values.

7 Acknowledgements

We would like to acknowledge and thank all the farmers who provided us access to their property and allowed us to sample their drains. Without this co-operation, this project would never have eventuated. We would also like to thank the field staff from Regional Services who diligently collected all the data. Thank you to the staff at Fish and Game, who provided us with field assistance, site information and discussion. Finally, we would like to thank research staff from AgResearch's Invermary Research farm, who provided uselful guidance while we were establishing the study, and help with interpretation of water quality data.

8 References

ANZECC. 1992. Australian water quality guidelines for fresh and marine waters. National Water Quality Management Strategy Paper No. 4, Australian and New Zealand Environment and Conservation Council, Canberra.

ANZECC. 2000. Australia and New Zealand guidelines for fresh and marine water quality, Volume 1, The guidelines. Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Aqualinc Research Ltd, 2006. Evaluating strategic retention of artificial drainage flows for

nitrate-N reduction under Waikato conditions. *Prepared for Environment Waikato* (Report No H06005/1)

Roger, Y; Hayes, J. 1999. Trout Energetics and Effects of Agricultural land use on the Pomahaka Trout Fishery. Prepared for Fish and Game. February 1999.

Chapman, D.; Kimstach, V. 1998: Selection of water quality variables. In: Chapman, D. (ed.) Water quality assessments. 2nd ed. E & FN Spon, London.

Collier, K; Winterbourn, MJ. 1987. Faunal and chemical dynamics of some acid and alkaline New Zealand streams. Freshwater Biology, 18. 227-240.

Fonterra, 2003. Dairying and Clean Stream Accord. Electronic document, http://www.mfe.govt.nz/issues/land/rural/dairying-accord-may03.pdf

Houlbrooke, et al, 2003: The impact of intensive dairy farming on the leaching loses of nitrogen and phosphorus from a mole and pipe drained soil. Massey University, Palmerston North.

Houlbrooke, et al 2004: Minimizing surface water pollution resulting from farm-dairy effluent application to mole-pipe drained soils. I. An evaluation of the deferred irrigation system for sustainable land treatment in the Manawatu. New Zealand Journal of Agricultural Research, Vol. 47:405-415.

Houlbrooke, et al, 2008: Land application of farm dairy effluent to a mole and pipe drained soil: implications for nutrient enrichment of winter-spring drainage.

Hudson, JJ; Taylor, WD; Schindler, DW. 2000. Phosphate concentrations in lakes. Nature, 406, 54-56.

Larned, S.T.; Scarsbrook, M.R.; Snelder, T.H.; Norton, N.J.; Biggs, B.J.F. 2004. Water quality in low-elevation streams and rivers of New Zealand: recent state and trends in contrasting land-cover classes. New Zealand Journal of Marine and Freshwater Research, 34: 347-366.

Larned, S.T.; Scarsbrook, M.R.; Snelder, T.H.; Norton, N.J. 2005. Nationwide and regional state and trends in river water quality 1996-2002. National Institute of Water and Atmospheric Research, Christchurch.

Ministry for the Environment. 2000. New Zealand periphyton guideline: detecting, monitoring and managing enrichment of streams. Ministry for the Environment, Wellington.

Ministry for the Environment; Ministry of Health. 2003. Microbiological Water Quality Guidelines for Marine and Freshwater Recreation Areas. Ministry for the Environment, Wellington.

McDowell, RW; Houlbrooke, DJ; Muirhead, RW; Muller, K; Sheperd, M; Cuttle, SP (2008) Grazed pastures and surface water quality. Nova Science Publishers, Inc, New York.

Monaghan, RM; Paton, RJ; Drewey, JJ (2002a): Nitrogen and phosphorus losses in mole and tile drainage from a cattle-grazed pasture in eastern Southland. NZ Journal of Agricultural Research Vol.45:197-205.

Monaghan, RM Horne, D; Hedley, M; Nguyen, L (2002b); Subsurface drainage review - Water and contaminant loads from artificial subsurface drainage system in New Zealand. Prepared for Fonterra Research Centre. AgResearch Ltd.

Monaghan, R.M., 2009. Section 42A Report of Dr Ross Martin Monaghan on Behalf of Horizons Regional Council.

Monaghan RM, Smith LC: 2004. Minimizing surface water pollution resulting from farm-dairy effluent application to mole-pipe drained soils. II. The contribution of preferential flow of effluent to whole-farm pollutant losses in subsurface drainage from a West Otago dairy farm. New Zealand Journal of Agricultural Research, Vol. 47:417-428

National Institute of Water and Atmospheric Research (NIWA) 2008. New Zealand Freshwater Fish Database. http://fwdb.niwa.co.nz/

Nguyen, ML, Eynon-Richards, N; Barnett, J (2002): Nitrogen removal by a seepage wetland intercepting surface and subsurface flows from a diary catchment in Waikato. *In: Dairy farm soil management* (Eds L Currie and P Loganathan),Occasional Report No 15. Fertilizer and Lime Research Centre. Massey University. Palmerston North.

Otago Regional Council. 1998. Regional Policy Statement for Otago. Otago Regional Council, Dunedin.

Otago Regional Council. 2004. Regional Plan: Water for Otago. Otago Regional Council, Dunedin.

Otago Regional Council, 2007. State of the Environment Report: Surface Water Quality in Otago. Otago Regional Council, Dunedin.

Quinn, J.M.; Hickey, C.W. 1990. Characterisation and classification of benthic invertebrate communities in 88 New Zealand rivers in relation to environmental factors. New Zealand Journal of Marine and Freshwater Research, 24: 387-409.

Parkyn, S; Wilcock, B 2004. Impacts of agricultural land use in Harding, J; Mosley, P; Pearson, C; Sorrell, B. (eds) in *Freshwaters of New Zealand*. The Caxton Press, Christchurch.

Smith, D. G., and R. Maasdam, 1994. New Zealand's national water quality network. 1. Design and physicochemical characterisation. New Zealand Journal of Marine and Freshwater Research, 28: 19-35.

Snelder, T.; Biggs, B.; Weatherhead, M.; Niven, K. 2003. New Zealand River Environment Classification: a guide to concepts and use. Draft Report CHC 2003-034.

Stark, J.D. 1985. A macroinvertebrate community index of water quality for stony streams. Water & Soil Miscellaneous Publication 87. National Water and Soil Conservation Authority, Wellington.

Stark, J.D. 1993. Performance of the Macroinvertebrate Community Index: Effects of sampling method, sample replication, water depth, current velocity, and substratum on index values. New Zealand Journal of Marine and Freshwater Research, 27: 463-478. Published June 2002, updated June 2003.

Unwin, M.; Brown, S. 1998. The geography of angling in New Zealand – a summary of results from the 1994/96 national angling survey. NIWA Client Report No. CHC98/33. NIWA, Christchurch.

Unwin. M. & Image. K. 2003. Angler usage of lakes and river fisheries managed by Fish and Game New Zealand: Results from the 2001/02 National Angling Survey. NIWA Client Report CHC2003-114.

Wilcock, RJ; Nagels, JW; Rodda HJE; O'Conner MB; Thorrold BS; Barnett, JW (1999): Water quality of a lowland stream in a New Zealand dairy farming catchment. New Zealand Journal of Marine and Freshwater Research, 33:683-696.

NWSCO. 1978: A Survey of New Zealand Peat Resources. Water & Soil Technical Publication No. 14. National Water & Soil Conservation Organisation & University of Waikato, Hamilton.