Implications of Irrigation and Land Use Changes in a High Country Valley - The Hakataramea Valley

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Abstract

There have been major changes to the farming practices across Canterbury in the past 50 years, with the biggest changes seen in the previous two decades. These changes in farming practices, namely dairy farming and irrigation, have lead to declining water quality in the region. The changes that have been experienced on the Canterbury plains are now being seen in the hill and high country settings, such as the Hakataramea Valley.

This study found that the waterways in the Hakataramea Valley are susceptible to nutrient enrichment following a rainfall event that caused soil runoff. Wind erosion also occurrs in the valley and was believed to be the major source of nutrient transport in the waterways, however, this was proven to be not as significant as soil runoff. The valley showed a range in water quality, with the river generally being of a higher quality than the tributaries. One tributary in particular stood out as being lower in quality than the others, this was Rocky Point stream. It was identified that the tributary catchments that had extensive farming systems and no irrigation present (Grampians Stream and Rocky Point Stream) were of a lower quality than the tributary that had irrigation (Padkins Stream). This was due to the fact that waterways in this catchment were fenced, and on farm stockwater systems were in place, stopping stock from accessing the waterway.

The OVERSEER modelling of the future scenarios presented showed that if the agriculture in the valley was to continue to develop and intensify, the water quality would decline. If the valley became completely irrigated this decline could potentially be large enough to result in a level that would become unsafe for recreational use and human and animal consumption.

The future of the Hakataramea Valley and its waterways depends on improved management processes that focus on specific areas of the catchment and the catchment as a whole.

Acknowledgements

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1. INTRODUCTION

Irrigation is needed in large areas of New Zealand including; Waikato, Taranaki, Hawkes Bay, Marlborough, Canterbury, Otago and Southland, with the latter locations comprising the majority of the national irrigation water take. These areas have dry hot summers and it is a necessity to apply water to the land to make the increasingly intensified farming practices profitable. Irrigation is sourced from both underground freshwater aquifers and surface waterways. The aquifers are utilised by drilling a well and then pumping the water to the surface while the surface water schemes use a myriad of different technologies to utilise the water.

1.1 Irrigation in New Zealand

The earliest irrigation schemes in New Zealand date back to the early 1900's but were few until the 1970s (Prou, 2007). Since the 1970s there has been a slow steady increase in the area irrigated, until the 1980's (Doak, 2005). When between 1985 and 2005 the total irrigated area in New Zealand doubled (***Figure 1.1***).

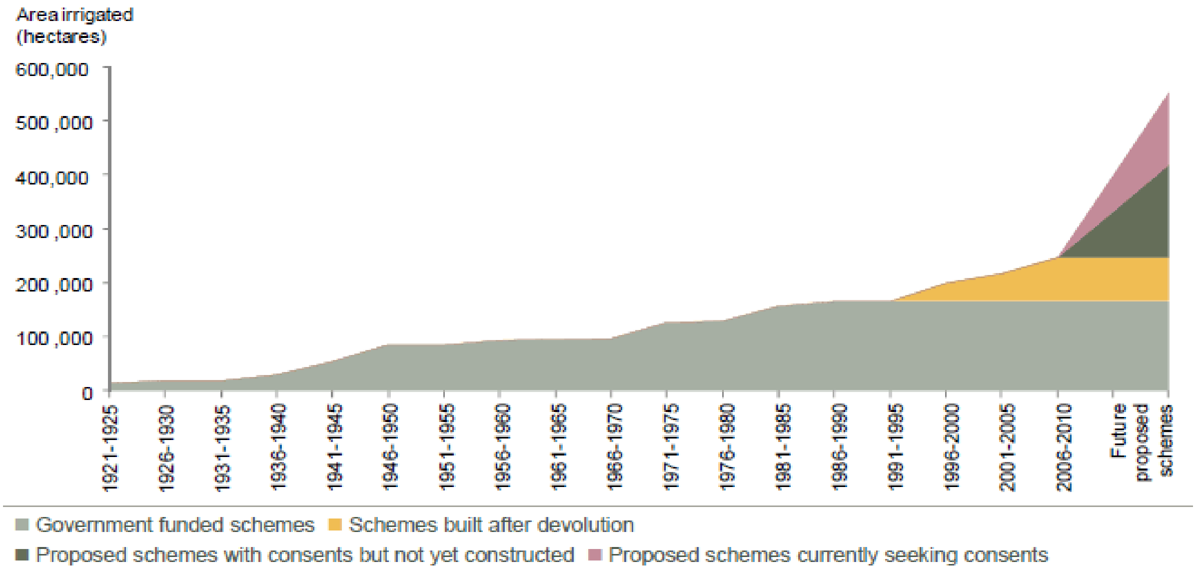


Figure 1. 1 Estimated cumulative area (total hectares) irrigated by schemes in New Zealand - existing and proposed (excludes private on farm irrigation not linked to a formal scheme) (National Infrastructure Unit, 2010)

The majority of this irrigated land was in the form of individual farm water takes, with only two large community schemes (to irrigate greater than 5000ha) in place, both these in Canterbury (Ministry for the Environment, 2000). Since the arrival of the Resource Management Act (1991 (RMA)) there has been greater focus by the government to control the allocation of water for irrigation, especially in Canterbury which comprises around 61% of the country's total irrigation take. However in the past the irrigation in Canterbury has mainly been focussed on the plains. Now with recent advances in irrigation systems, pasture quality and engineering technologies, irrigation is available to agricultural areas that were once considered unprofitable. In the Canterbury region irrigation has recently spread to areas that were once dominated by dry land farms; an example of this is in the upper Waitaki basin (Glasson, 2009). Agriculture remains an important component of New Zealand's economy making up the largest portion of all exports in 2012 (***Figure 1.2***) (AgriBusiness Limited, 2012).

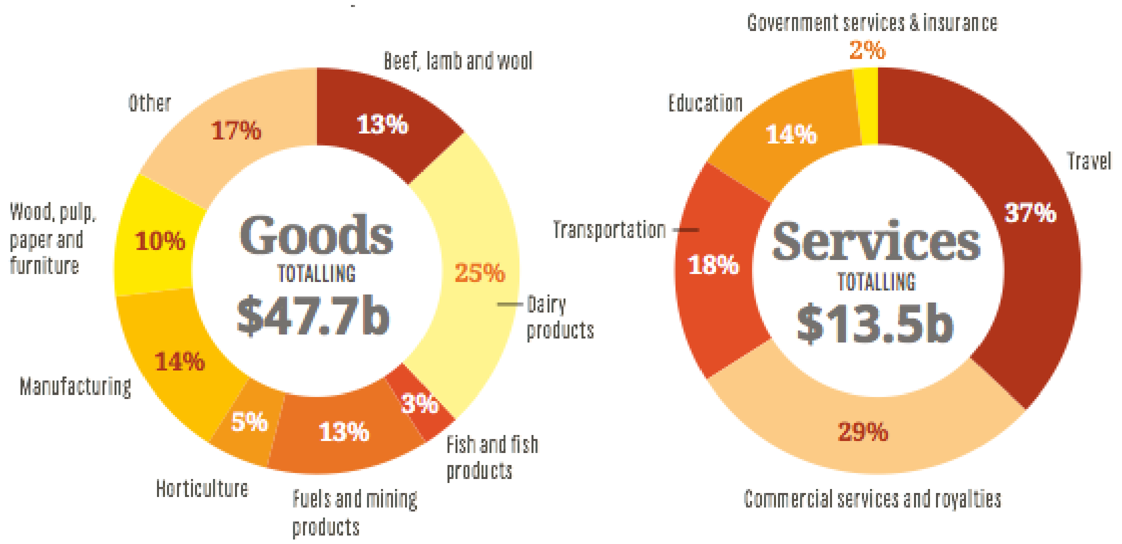


Figure 1. 2 New Zealand's Exports by Industry in 2012 (Idealog, 2012)

With the advancement of irrigation, Canterbury is the largest agricultural exporter in New Zealand, exporting the equivalent of 862,650ha of land/year; the second largest agricultural exporter is Otago which exports the equivalent of 658,250ha of land/year (McDonald, 2003). This was in 1998 before the dairy boom in Canterbury so this figure would have increased greatly.

1.1.1 Potential Impacts of Irrigation on the Ground and Surface Water

Studies conducted internationally and nationally on the potential impacts of irrigation on the environment include; Dougherty & Hall (1995); Carpenter et al, (1998); Houlbrooke et al, (2004); Brown & Harris (2005); Wilcock et al, (2006); Zemansky et. al, (2006); Monaghan et al, (2007 a); Monaghan et al, (2007 b), . The negative impacts are often focussed on, and do outweigh the positive impacts in most instances. Potential negative effects include; an increase in nutrients in both surface and groundwater systems (Carpenter e.t al. 1998; Houlbrooke et. al. 2004); decrease in surface water levels (Brown & Harris, 2005 & (Zemansky et. al, 2006); increase in water tables (Brown & Harris, 2005); potential increase in soil salinity (Dougherty & Hall 1995); decrease in available aquifer water for human consumption (Monaghan et. Al. 2007a); land subsidence (not common in New Zealand) (Dougherty, 1995), and adverse economic impacts on downstream users. Many of these impacts affect people that have no direct contact with or benefit from irrigation. Positive effects or benefits include; encouraging better plant cover therefore decreasing soil erosion; decreasing stock access to streams due to stock water systems being installed; replenishing groundwater levels during seasonal lows; and decreasing certain nutrient loads in surface waters (rare). Irrigation leads to an increase in farm exports; increase in national exports; and increase in income for many farmers. The majority of studies that have been conducted on impacts of irrigation on surface and groundwaters, have focussed on low lying, flat lands, such as the Canterbury plains. It has not been until recent years that irrigation has begun to be used on sloping land and in foothill and high country settings. Hence the shortage in literature on the effects of irrigation on waterways in such settings.

1.1.2 Aims and Objectives of the Study

This study aims to address the lack of knowledge on the effects of irrigation on a high country setting by focussing on one high country river catchment that is undergoing irrigation growth, the **Hakataramea Valley**. The objectives of this research are to;

- Identify the current situation in the valley in terms of water quality, climatic conditions, soil quality and farming practices
- Quantify how the current situation could potentially change with irrigation
- Determine how future changes may impact the ground and surface water quality, and what these changes mean for the future of the valley
- Relate the results found from this valley to similar valleys in New Zealand

1.2 The Characteristics of Hakataramea Valley

Response of the catchment to irrigation will depend on a number of characteristics including; the location; climate; geology; soils; hydrology; and land use. These are explained in detail in this section.

1.2.1 Location of the valley

The Hakataramea Valley is located in the Waimate region of South Canterbury, with the closest town being Kurow. Kurow is located around 110 kilometres from Timaru. The heart of the Hakataramea Valley is located a further 40km up the Hakataramea Valley Road (***Figure 1.3***).

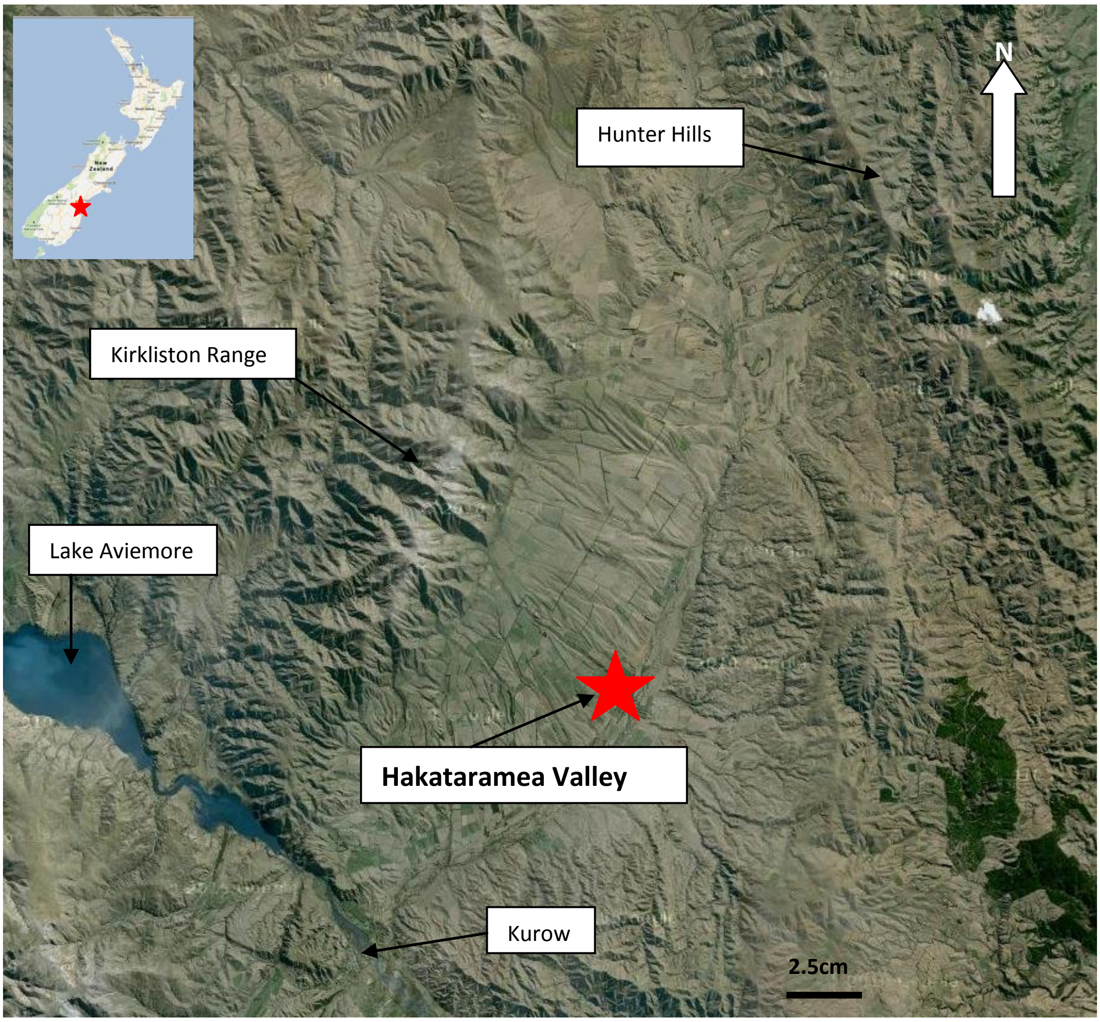


Figure 1. 3 Location of the Hakataramea Valley (Yellow Pages Group , 2009)

The Hakataramea catchment spans from the Waitaki River in the south to the Hakataramea pass in the north. The catchment is bounded in the west by the Kirkliston Range and in the east by the Hunter Hills (***Figure 1.3***). The valley is around 56km long with an average width of 21km and drains an area of around 890km^2 (Hanning (1996); Lower Waitaki South Coastal Canterbury Zone Committee (2012)). The Hakataramea River is the largest tributary of the lower Waitaki River (below lakes Benmore, Aviemore and Waitaki dams).

1.2.2 Climate

This catchment like so many high country basins in New Zealand experiences extremes in the weather. During the winter months it is not uncommon for the temperatures to drop as low as -10°C, during the summer months the temperature can climb as high as 35°C. The Hakataramea Valley experiences on average 528mm of rainfall per annum, this can drop below 300mm during a typical drought year, which is common in the valley. Altitude does play a big role in precipitation levels; at 520m.a.s.l. the rainfall can be as high as 700 mm/yr while lower down the valley at 350m.a.s.l. there may only be 400mm/yr (National Institute of Water and Atmospheric Research Ltd. (NIWA)). The western extent of the valley receives more rainfall (due to dominant North West winds) than the eastern extent. Heavy rainfall events in some areas of the valley result in soils becoming water logged, leading to surface water runoff. The NIWA rain gauge (Cliflo site number 36209) located (GPS point S 44°21'19.33" E 170°38'09.32") at the top of the valley experienced several events where as much as 70.8mm of rain has fallen in 24 hours particularly during spring and summer when the North West winds are in full effect. These events can lead to soil erosion if there is no plant cover present. This along with the topography makes the average valley rainfall misleading. The NIWA weather station (Cliflo site number 36209) shows wind velocity during the summer months (December to February) averages 2.47m/s, and on average there are between two and three wind events of 6m/s or more. This is considered the wind speed at which soil erosion occurs if adequate plant cover on certain soils is not present (Roose, 1996). Other basins in New Zealand experience similar climates to the Hakataramea valley, including; the upper Waitaki basin and Culverden basin (National Institute of Water and Atmospheric Research Ltd. (NIWA)). Climate data of reference to this study is in ***Appendix 1***.

1.2.3 Geology of the catchment

The topography of the Hakataramea Valley began to form during the Miocene (15mya). Faults contributed to the creation of the ranges (Kirkliston, Dalgety and the Hunters Hills) which enclose the valley (Zemansky et. al., 2006). These faults are the; Kirkliston; Hunters; Dalgety; Stonewall; Clarkesfield; and the Dryburgh faults (***Figure 1.4***). The Kirkliston fault zone to the west and Hunters fault to the east are the most influential (Institute of Geological and Nuclear Science, 2004).

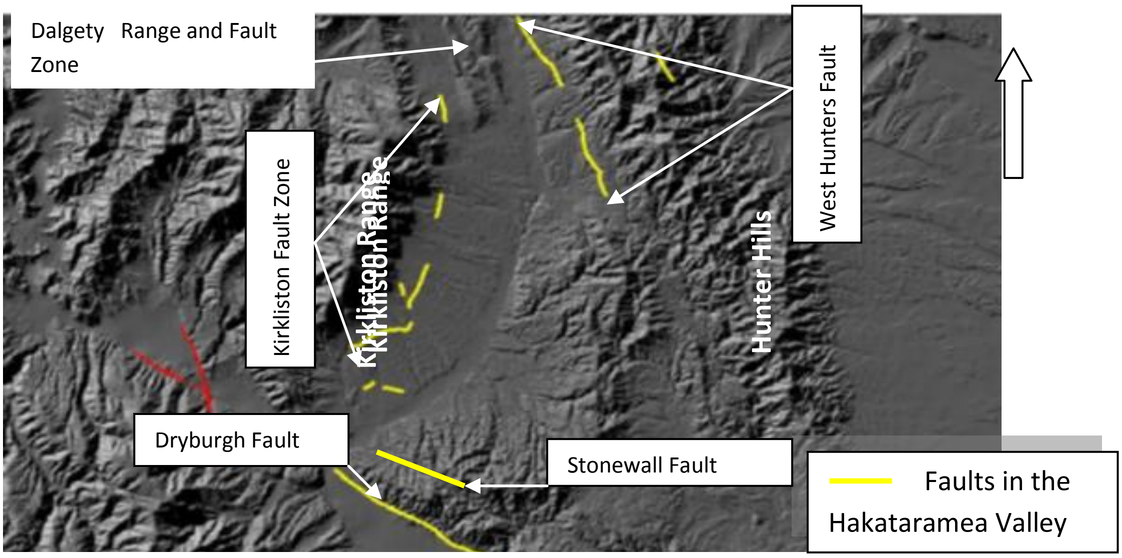


Figure 1. 4 Hakataramea Faults and Ranges (GNS, 2004)

All of the faults within the valley have a reverse sense of motion, where the hanging wall is being forced up and the footwall down, resulting in compression of the earth at these points (California Geological Survey, 1992). In New Zealand this type of fault is relatively common, especially in the formation of valleys that take on a similar appearance to the Hakataramea Valley. Valleys such as Culverden and Taieri have all been formed by reverse faults (Mould, (1992) and Cox & Lyttle, (2003)). There are currently only two faults within the valley that can be considered active, these being the Kirkliston fault zone and the West Hunters fault to the east (***Figure 1.4***). The Kirkliston fault has a recurrence interval of between 3500 and 5000 years, with a low slip rate and a moderate displacement per single event (Forsyth, 2001). The West Hunters fault is believed to be active but there has been inadequate research done on this to define the recurrence interval, slip rate and the displacement per event (GNS, 2004). The basement rock in the valley is a Greywacke of Mesozoic age, inter-bedded with sandstones and mudstones (argillite) (Forsyth, 2001). The ranges surrounding the valley are of similar material. On top of this greywacke, Tertiary aged sediments including; greensands; quartz sandstones; limestone; mudstone; and conglomerate have been deposited (***Table 1.1***) (Forsyth, 2001). Running parallel to the Hakataramea River there are unconsolidated alluvial sediments, mainly alluvial gravels. Similar sediments are also seen along the flanks of the many river tributaries (Zemansky et. al., 2006). In the higher terraces alongside the river (older as they are higher) more clay is found in the units, creating a semi impermeable gravel layer. The presence of this layer is a good indicator of the little known aquifers below. These clay rich sediments are of mid to late Quaternary age (Zemansky et al, 2006).

Table 1. 1 Geological Units of the Hakataramea Valley (Forsyth, 2001)

Principal Geological Units of the Hakataramea Valley			
Geological Material	Summary Description	Approximate Age	Comments and Groundwater Relationships
Late Quarternary river alluvial gravel	Well rounded, sandy greywacke gravel. Some weathering in the deposits forming the highest (oldest) of the Late Quarternary terraces	0 to 125ka	Youngest gravels that form lowest terraces or floodplains are likely to be cleanest/least compact. Excellent potential as aquifers, though may be closely connected with surface water.
Late Quarternary fan alluvial gravel	Sub angular silty greywacke gravel. Some weathering in the deposits forming the highest (oldest) of the Late Quarternary terraces	0 to 125ka	Youngest gravels that form lowest terraces or floodplains are likely to be cleanest/least compact. Moderate potential as aquifers, though may be closely connected with surface water.
Mid to Early Quarternary Alluvial Gravel	Weathered sandy or silty greywacke gravel, at least in part clay plugged.	125ka to 1.8Ma	Generally compact and clay bound, of lesser potential as aquifers. May contain stringers of cleaner gravel (buried channels) with localised aquifer potential
Tertiary Sediments	(From youngest to oldest): well consolidated greywacke conglomerate; marine sandstone or siltstone; limestone greensand; marine quartz sandstone or mudstone; white quartz sandstone locally silica cemented	1.8Ma to 55Ma	The generally compact, or in places indurated, nature of sediments inhibits their potential as aquifers.
Greywacke and Semischist	Very hard, fractured, greywacke sandstone and argillite mudstone; locally passing into slightly fissile greywacke/argillite semischist.	200Ma to 275Ma	May have potential as fracture controlled aquifers, especially close to fault lines.

1.2.4 Soils of the Catchment

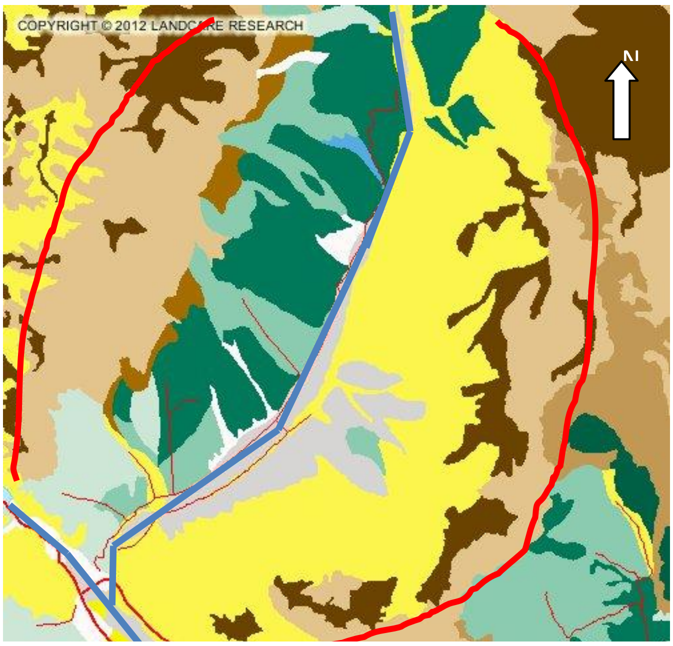
Soils in the Hakataramea Valley range from fertile to dry semi arid type soils, with four main soil types found. These soil types are; Pallic, Recent, Gley, and Semi Arid (Landcare Research, 2012). These soils have been split into categories (***Table 1.2***) on suitability for agriculture by Webb, (2005).

Table 1. 2 Descriptions of the Four soil categories in the Hakataramea Valley (Webb, 2005)

Soil Name	**Description**	**Suitability for Agriculture**			
		Sheep/Beef/Deer	Dairy	Arable	Orchard
Pallic	Deep to shallow, well drained soil on flat to very gently sloping land	1-3	2-3	1-3	1-3
Recent	Predominantly well drained stony soils on flat to rolling land	2-3	2	2-3	2-3
Gley	Predominantly moist moderately drained soils on flat to rolling land	1-3	3	2	3
Semi Arid	Very stony excessively drained soils with shallow stony sandy soils on flat to very gently sloping land	3	3	4	3

1 = Good 2 = Moderate 3 = Poor 4 = Unsuitable

Not all soils of the valley are suited to agricultural practices (***Table 1.2***); Pallic soils are the best soils in the valley for agriculture. This soil class does vary considerably with category one representing a small percentage of the total land in the valley covered by Pallic soils. Pallic soils comprise the largest area of the valley, followed by Recent, Semi Arid and Gley.



LEGEND

Orthic Recent

Orthic Brown

Immature Pallic

Allophanic Brown

Fragic Pallic

Aged Argillic Semi Arid

Argillic Pallic

Hakataramea Valley Outline

River

Figure 1. 5 Distribution of Soil Classes in the Hakataramea Valley (Landcare

"Pallic" soils typically have low contents of iron oxides, and a weak structure but a high bulk density. They form in climates that are often dry in the summer and wet in the winter, like the Hakataramea Valley. These soils have a moderately slow permeability rate with limited rooting depth, and are susceptible to erosion due to a high slaking potential. They have naturally high nutrient contents (except sulphur), and low organic matter content, so produce good crops and have the capability to yield high levels of pasture if there is enough water applied to them during the summer months. This soil class contains six sub groups; Perch-Gley, Duric, Fragic, Laminar, Argillic and Immature. The Hakataramea Valley contains the Argillic, Immature, Laminar and Fragic Pallic groups (Landcare Research, 2012). This soil class covers the second largest area of land in the Hakataramea Valley and includes 80% of the irrigated land in the valley.

"Recent" soils are weakly developed, with limited signs of soil forming processes taking place. There is often distinct topsoil present but a B horizon is usually not present. These soils have a variable texture and a large spatial variation. They are usually deep rooting, so if there is enough water present, these soils can yield high pasture levels or crops. Natural fertility is often high due to the high concentration of nutrients. This soil class has six sub classes; Hydrothermal, Rocky, Sandy, Fluvial, Tephric and Orthic. The Hakataramea Valley contains the Orthic and Fluvial subgroups. These soils are typical of 'young' land surfaces throughout NZ, such as floodplains and moderate to steep slopes, they cover around 6% of NZ (Landcare Research, 2012). This soil class covers over half of the valley, but only comprises a very small percentage of the irrigated land in the valley.

"Semiarid" soils are dry for most of the growing season, with rain not being significant enough (350 to 500mm per annum) to leach through the soil horizon. Lime, salts and other nutrients tend to accumulate in the top portion of this class. Nutrient levels are relatively high but for the soil to produce any pasture or crop; large volumes of water have to be applied to the land. They have a high slaking and dispersion potential, with moderate to high bulk densities. The high slaking and dispersion potential in these soils makes them typically weak and easily erodible. These soils have low organic matter, cation exchange and low iron and aluminium oxide contents; they tend to have high nutrient and salt levels. The soils tend to have a low biological activity due to their potential to suffer from drought; also the low organic matter does not promote biological activity. There are four sub groups to these soils; Aged-Argillic, Solonetzic, Argillic, and Immature, the Hakataramea valley contains the Aged Argillic and Argillic sub group soils (Landcare Research, 2012).These soils are found in inland Otago and South Canterbury, and cover 1% of New Zealand.

"Gley" Soils are strongly affected by water logging. Water logging occurs typically in winter and spring. These soils have shallow rooting depths and a high bulk density. Organic matter and natural nutrient concentrations are usually high. The biological activity in these soils is limited due to the lack of oxygen from high groundwater levels. This soil series contains six sub classes; Sulphuric, Sandy, Acid, Oxidic, Recent and Orthic (Landcare Research, 2012). These soils are not common in the valley with Orthic being the only subclass found in a very small area.

The soils of the Hakataramea valley have a typical permeability ranging from moderately slow to rapid (Landcare Research, 2012). These values aid in determining how good the soil is for agricultural use, with a value in the moderate range optimum (Turenne, 2012).

Table 1. 3 Typical Permeability Rates of New Zealand Soils (Turenne, 2012)

Very slow	less than 1.5 mm/hr (36mm/day)
Slow	1.5 to 5 mm/hr (36-120 mm/day)
Moderately slow	5 to 15 mm/hr (120-360 mm/day)
Moderate	15 to 50 mm/hr (360-1200 mm/day)
Moderately rapid	50 to 150 mm/hr (1200-3600 mm/day)
Rapid	150 to 510 mm/hr (3600-12240 mm/day)
Very rapid	more than 510 mm/hr (12240 mm/day)

The main soil classes in the valley fall into the moderately slow (Pallic) to very rapid classes (***Table 1.3***) (Recent and Semiarid) (Turenne, 2012).

1.2.5 Hydrology

Surface Waters

The Hakataramea valley includes both streams that flow year round, and others that flow seasonally, all of which are tributaries of the greater Hakataramea River. Stream and river flows are seasonally low, due to the low summer rainfall with water temperatures reaching more than 18°C. Both the small tributaries and the river itself may also gain recharge from groundwater sources, but this is not confirmed as there has not been adequate investigation (Zemansky et. al, 2006).

Sub Surface Waters

There is very limited information about groundwaters in the valley, with only five wells in the valley from which data have been collected (ECan, 2012). Groundwater reserves in the region are not immense, and are subject to over abstraction during the height of the summer (Zemansky et. al. 2006). With the limited data that is available the hydraulic conductivity has been calculated as 0.62 cm/second, and the storage volume as 907 million m^3 (Sinclair Knight Merz, 2004). Although relatively large, the low groundwater flow means that any further groundwater abstraction will have a direct affect on the flow of the Hakataramea River and tributaries (Sinclair Knight Merz, 2004).

The recharge for the basin has been calculated using the equation;

$$\mathbf{Rc = SL + RI + EII}$$

Where Rc is recharge, SL is stream leakage, RI is rainfall infiltration, and EII is excess irrigation infiltration (all units in mm^3/annum). For the Hakataramea basin this gives 424 L/s or a total of 13.4million m^3/year.

1.2.6 Land use in the Valley

60% of the total 890km^2 valley area is considered profitable to farm. Of this farmed land there has only been enough water granted to irrigate 6000 hectares and currently only 55-60% is being irrigated. Historically the region has been dominated by dryland sheep grazing, with dryland beef grazing being the second most common agricultural activity (Land Resource Inventory, 2011). A minor component of cropping and deer farming is also present. These four farming types were all considered to be semi extensive to extensive practices. In recent years the valley has seen the introduction of irrigation, and more intensified agricultural practices that require irrigation.

1.2.7 Aquatic Ecology

The Hakataramea River is the largest tributary of the Waitaki River below the hydroelectricity dams (excluding the Mackenzie lakes and their tributaries), and it is also the most important spawning river for the Chinook salmon (*Oncorhynchus tshawytscha*). ***Figure 1.6*** shows the number of spawning salmon returning to the river between 1993 and 2008 and how this relates to flow. With the exception of 1994/96, the overall trend of salmon returning to spawn is decreasing with a decreasing flow. The electric fishing of the river (2010-2011) also revealed that there are a number of other native and exotic fishes present including; Brown Trout (*Salmo trutta*), Rainbow Trout (*Oncorhynchus mykiss*), Canterbury Galaxid (*Galaxias vulgaris)*, Common Bully (*Gobiomorphus cotidianus*), Upland Bully (*Gobiomorphus breviceps*), and Long Finned Eel (*Anguilla dieffenbachia*). There is also a large range and number of macroinvertebrates in the river (***Appendix 3***) that will be directly and indirectly affected from decreased flow levels and the subsequent increased temperatures.

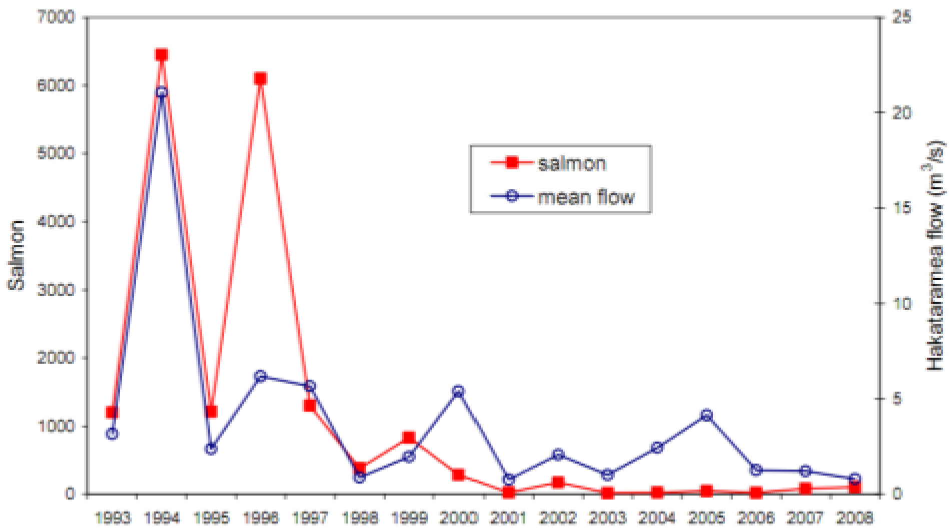


Figure 1. 6 Salmon Spawning Counts from 1993 to 2008 (Webb, 2008)

1.2.8 Social importance

The valley has undergone a large population decrease in recent years. Due to the declining population, two schools, a pub and a church have all closed in the last two decades (Sutton, 2008). Consequently it is becoming harder and harder for the valley to attract new people, and in some instances it has become difficult for large farms to find employees (Sutton, 2008). Due to the lack of community facilities, the river acts as a social hub for much of the community who use it for swimming, camping and barbequing. The river is also important to freshwater fishermen in the Central South Island region and all over New Zealand, supporting 1,600 to 1,900 days of angling effort per season, or on average about 10 anglers fishing for each day of the season. With 60% of seasonal activity occurring in November and December, before the river levels inevitably become low in summer (Unwin and Brown 1998, Unwin and Image 2003). Anglers travel from as far abroad as Australia and Germany to fish this once iconic fishing river (Ministry for the Environment, 2004).Historically the valley was very important to local Maori, acting as home for a large population of Maori and as a source of speargrass (King, 2006). The valley was also home to the Whekau (laughing owl), which was used as a source of food, and the skin of these owls was used as a bag material. There were many wetlands in the valley that were used as fishing grounds for; Tuna (*eels*), Kokopu (*galaxias*), Koura (freshwater crayfish), Waikakahi (freshwater mussel) and Putakitaki (Paradise duck). The valley is not used as much now by the local Maori, due to changes in their lifestyle but still acts as a link to their heritage (King, 2006).

1.3 Future Changes in the Hakataramea Valley

Irrigation use in New Zealand is predicted to increase in the future, as the population of the country and world increases. Inevitably, there will be irrigation in high country areas such as the Hakataramea Valley (Brown & Harris, 2005). With this comes the need for a greater understanding of the processes acting in the soils and how changes in these processes may influence the quality of the surface waters in the catchment. It is evident that while there has been research on irrigation on flat land areas, with a large portion related to groundwater, this literature cannot be considered relevant for high country surface water settings. It is therefore paramount that research is carried out in steeper catchments that will potentially be irrigated in the future.

1.3.1 Nitrogen and Phosphorus

Nitrogen and phosphorus are the two main nutrients that have the potential to alter the quality of any waterway. These two nutrients have the potential to change it individually or by working together.

Nitrogen

There are 3 forms of nitrogen that are commonly measured in water bodies: ammonium, nitrates and nitrites, each of these make up a distinct quantity of the total nitrogen (***Figure 1.7***).

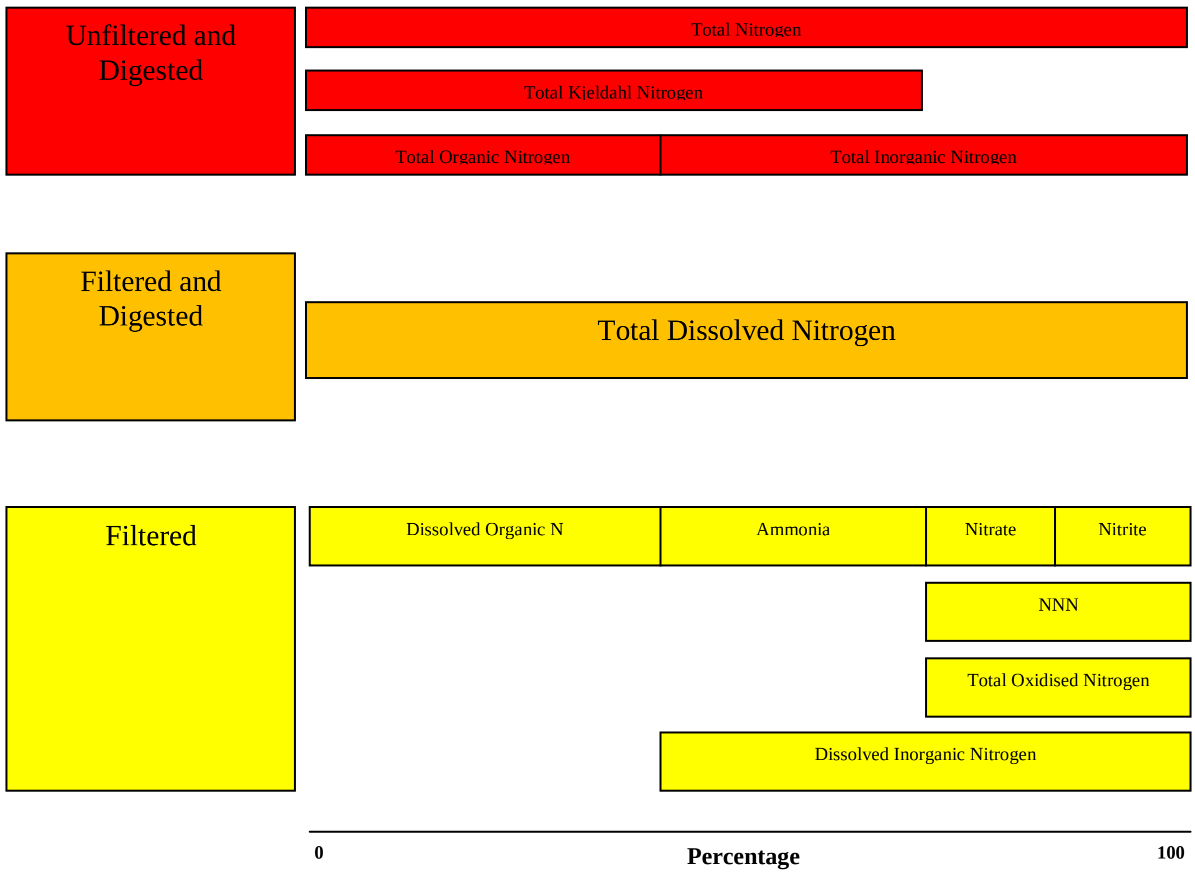


Figure 1.7 Nitrogen Species and the Percent these make up of the total nitrogen Faction

Revised from Environmental Laboratory Services (2004)

The major nitrogen species that have the ability to directly affect water quality are the three that fall under dissolved inorganic nitrogen (DIN), these are; ammonium (NH_4^+), nitrate (NO_3^-), and nitrite (NO_2^-). NO_3 and NH_4 are the most common and problematic inorganic N species in New Zealand agricultural systems (ELS, 2004). These two species can cause a number of implications, including; toxicity to fish; acidification of freshwater; eutrophication of aquatic ecosystems; increased algal growth; increase detrimental aquatic plant life (macrophytes); human health risks; and economic implications (ELS, 2004; Camargo & Alonso, 2006).

Phosphorus

There are 4 forms of phosphorus that are commonly measured in water bodies throughout NZ, these are: dissolved reactive phosphorus (DRP); total dissolved phosphorus (TDP); total phosphorus (TP); and total reactive phosphorus (TRP), each of these make up a distinct quantity of the sample TP (***Figure 1.8***).

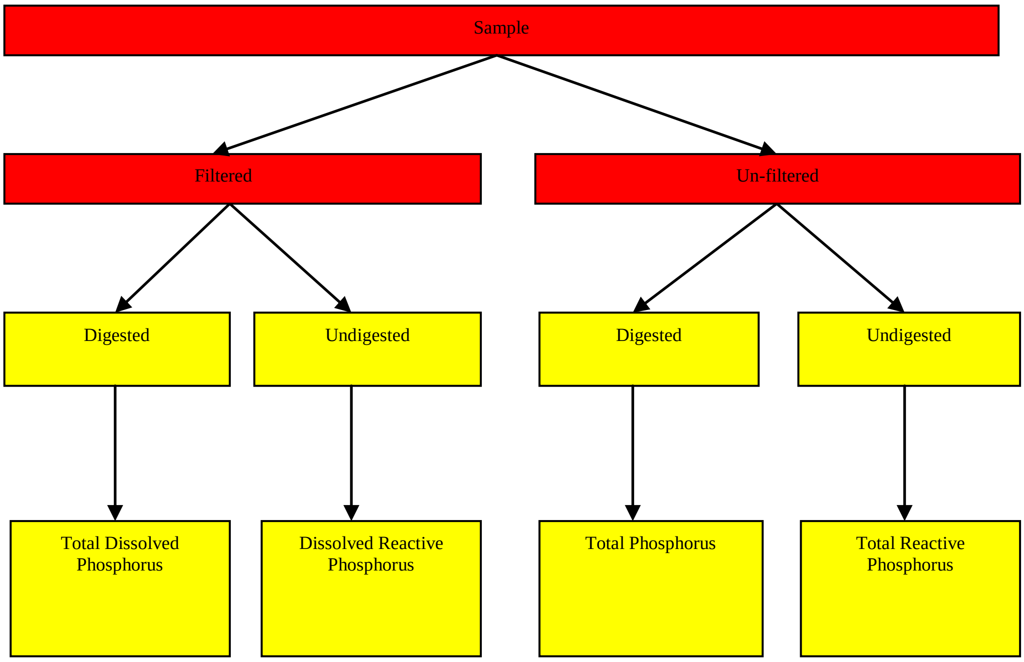


Figure 1.8 Phosphorus Species and the quantity these make up of the total Sample phosphorus

Revised from Environmental Laboratory Services (2004)

This study sampled TP and DRP from the waterways. These two forms of P have many adverse effects on the environment. These include; increased algal growth; increase detrimental aquatic plant growth (macrophytes); human health risks; and eutrophication of aquatic ecosystems; (ELS, 2004; Camargo & Alonso, 2006; Lenntech, 2012).

2. METHODOLOGY

This thesis used a number of methods to come up with a set of results. Methods used included; surveys of the valley (Land Resource Inventory or LRI), monthly water quality sampling over a 12 month period, quarterly ecological monitoring over the same 12 month period, monthly groundwater sampling, soil sampling and analysis of 9 sites during late autumn.

2.1 Monitoring Sites

Water and soil sampling sites were chosen (***Figure 2.1***) to be a good representation of overall catchment conditions. These sites were chosen in conjunction with Environment Canterbury and Irricon Resource Solutions (who supported this research).

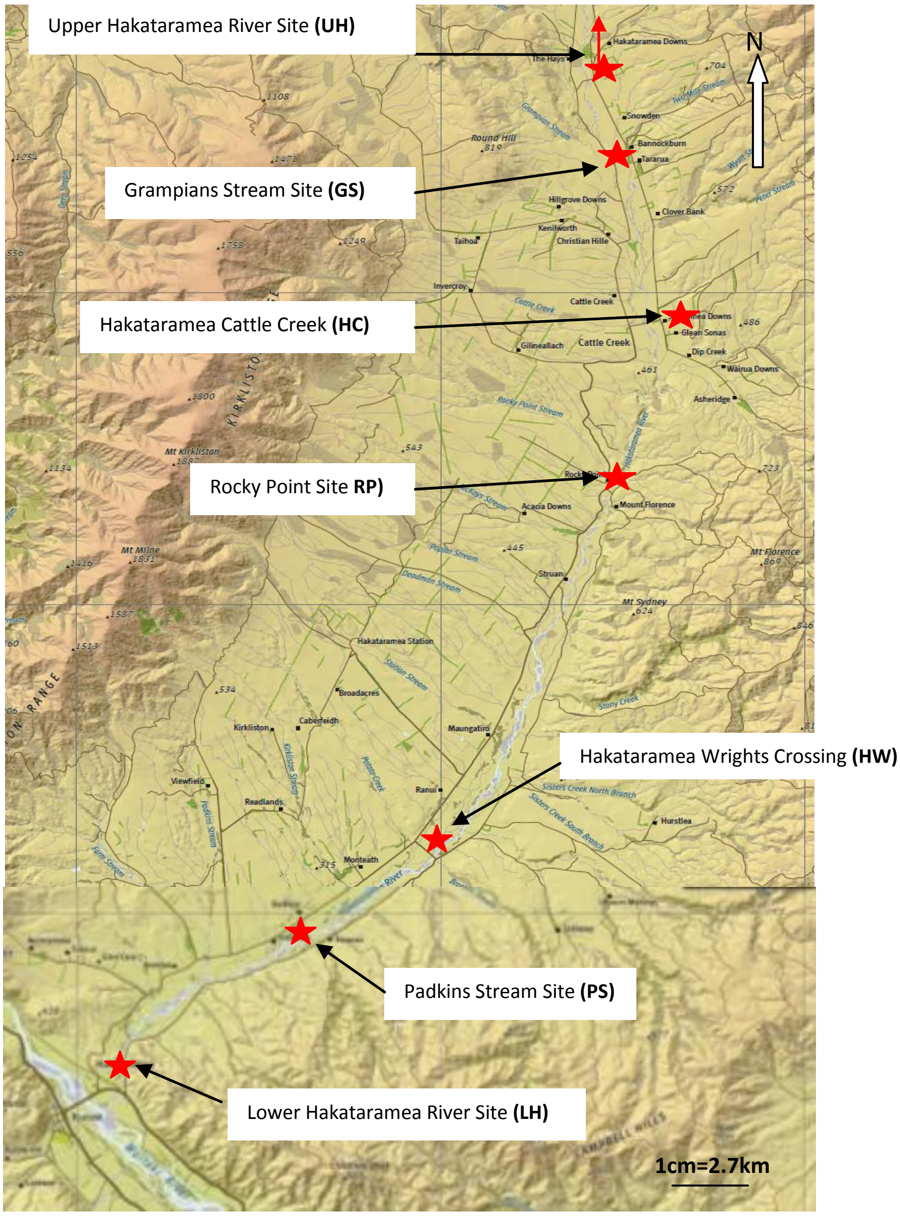


Figure 2. 1 Locations of Surface Water Sampling Sites

2.1.1 Surface River Water Monitoring Sites

The four surface water monitoring sites (***Figure 2.1***) were chosen to give a good indication of the changing water quality in the river as it progressed downstream. These sites spanned the length of the valley with the furthest downstream site located at the state highway 82 bridge crossing of the Hakataramea River (just upstream of the confluence with the Waitaki River, GPS: S 44°43’31.64” E 170°29’26.25”) and the furthest upstream being located 60km up the Hakataramea Valley Road at the NIWA rain gauge (NIWA weather station 36209, GPS: S 44°21’20.21” E 170°38’10.91”). The two sites in between were at Wrights Crossing (GPS: S 44°39’34.62” E 170°36’03.51”) and Cattle Creek (GPS: S 44°30’27.63” E 170°40’51.01”).

Upper Hakataramea (UH) River (GPS: S 44°21’20.21” E 170°38’10.91”).

This site was the furthest upstream site where water and ecological monitoring took place. At this site there have been very few improvements of pastures for agriculture, which is dominated by sheep and beef. Any agriculture in this region is considered extensive. Fertiliser is applied to this area by aerial topdressing; however this does not occur often. The river is not fenced from stock here, as it is used as the main source of stock water. There are very low numbers of stock located this far up the valley, so stock access to the river is not a major problem. The river bed here is dominated by coarse gravel to a cobble substrate with the occasional boulder (***Table 2.1***).

Table 2. 1 Grain Size Distribution Chart (Read, Millar, Luxford, & Olsen, 2005)

<table>
<tr><th rowspan="3">TYPE</th><th colspan="8">COARSE</th><th colspan="2">FINE</th><th>ORGANIC</th></tr>
<tr><td>Boulders</td><td>Cobbles</td><td colspan="3">Gravel</td><td colspan="3">Sand</td><td rowspan="2">Silt</td><td rowspan="2">Clay</td><td rowspan="2">Organic Soil</td></tr>
<tr><td></td><td></td><td>Coarse</td><td>Medium</td><td>Fine</td><td>Coarse</td><td>Medium</td><td>Fine</td></tr>
<tr><td>Size Range (mm)</td><td colspan="10">200 60 20 6 2 0.6 0.2 0.06 0.002</td><td></td></tr>
</table>

There are areas where greywacke bedrock formed obstructions in the river. At the monitoring site the river was on average 11.8m wide and had an average depth of 32cm. At the monitoring site the stream flowed gently across its bed but immediately upstream and downstream there were significant rapids. The surrounding environment (stream banks and immediate paddocks) consisted of rolling hill country, semi improved agricultural land, matagouri (*Discaria toumatou*), and native tussock (***Figure 2.2***).

Figure 2. 2 Looking Upstream at the Upper Hakataramea River Monitoring Site

Hakataramea at Cattle Creek (HC) (GPS S 44°30'27.63" E 170°40'41.01")

The Cattle Creek site was located immediately upstream of "Scott's Bridge" which spans the river. This site has a lot more agriculture surrounding it than the upper site but is still not intensively farmed. There was no irrigation located here with dry land sheep being the most prominent form of farming seen, followed by dry land beef. The pastures in this region do receive fertilisers, mainly in the form of land application by trucks. The agriculture seen here can be considered semi extensive to extensive for most of the year. Stock do have access to the river in areas as this is the main source of stock water, stock water systems are not common this far up the valley. The river bed here is dominated by coarse gravel to rocky substrate. There is the occasional boulder seen in the river. Further upstream from the monitoring site the river changes in nature from a fast flowing rapid dominated system to a gently flowing stream across a limestone substrate. Bedrock is present but not as prominent as at the upper site. The river was on average 10.8m wide and had an average depth of 38cm. The surrounding environment (stream banks and immediate paddocks) consisted of flat land, improved pastures, matagouri (*Discaria toumatou*), exotic trees (willow (*Salix spp.*) and poplar (*Populas spp.*)), and a small wetland at the confluence of Cattle Creek just downstream of the monitoring site.

Figure 2. 3 Looking Downstream toward Scott's Bridge from the Monitoring Site

Hakataramea at Wrights Crossing (HW) (GPS S 44°39'34.62" E 170°36'03.51")

The Wrights Crossing site was located 80m upstream of the bridge at "Wrights Crossing". This site was more intensively farmed than the sites upstream. There was a small amount of irrigation located in the surrounding area. Dry land sheep is still the dominant form of farming, followed by dry land beef. The pastures receive fertilisers via trucks when needed. The agriculture seen here was extensive to semi intensive. Stock do have access to the river in areas as this is still the main source of stock water and in cases the only source of stock water. The river bed here was dominated by coarse to fine gravel. The river channel was choked by willow trees (*Salix spp.*) (***Figure 2.4***). In areas these trees forced the water to funnel through small shoots. The river was on average 10.8m wide and had an average depth of 42cm. At this location there was one bank of the river that consisted of river gravels, the other bank was made up of Pallic soil. The surrounding environment (stream banks and immediate paddocks) consisted of flat farm land, improved pastures, matagouri (*Discaria toumatou*) and exotic trees (willow (*Salix spp.*)).

Figure 2. 4 Looking Upstream at the Wrights Crossing Monitoring Site

<u>Hakataramea at State Highway 82 (LH) (GPS S 44°43’31.64” E 170°29’26.25”)</u>

This site was located directly upstream of the state highway 82 bridge. At this site there was no farming located in the immediate surroundings as there are two roads and a number of houses. Not far from this site there were semi intensive dry land sheep and beef farms with a low level of irrigation. The pastures down this low in the valley receive greater fertiliser inputs than the other areas. The agriculture seen here was considered semi intensive. Stock do not have direct access to the river in most areas. The river bed here is dominated by coarse to fine gravel with the occasional small cobble. The river channel was surrounded by willow trees (*Salix spp.*). The river was on average 11.8m wide, but as wide as 23m in areas with an average depth of 46cm. The immediately surrounding environment (stream banks and immediate paddocks) consisted of flat farm land, improved pastures, matagouri (*Discaria toumatou*) and exotic trees (willow (*Salix spp.*) and poplar (*Populas spp.*)). Further upstream the Hakataramea River Gorge started, this area is surrounded by hill country (***Figure 2.5***).

Figure 2. 5 Looking Upstream at the State Highway 82 Monitoring Site

2.1.2 Surface Tributary Monitoring Sites

The tributary sites were located between the UH site and the LH site (***Figure 2.1***). These three sites were chosen to give a representation of three different quality streams (good, medium and poor). The three sites chosen were (from upper to lower); Grampians stream (GS) (GPS S 44°27’35.26” N 44°40’07.05”); Rocky Point stream (RS) (GPS S 44°33’15.23” E 170°40’02.00”); and Padkins stream (PS) (GPS S 44°41’19.09” E 170°31’18.95”). These sites were chosen to identify how the various tributary catchments in the valley influence the waters of the Hakataramea River.

Grampians Stream (GS) – Good Quality Site (GPS S 44°27’35.26” N 44°40’07.05”)

This site was located 30m upstream from the bridge that crosses the stream on the Hakataramea Valley Road. The Grampians stream catchment was dominated by dry land sheep and beef farming. At current there is no irrigation in the catchment, this is due to change in the future. The pastures here have been improved and receive fertilisers via trucks; the upper areas of the catchment receive fertiliser via aerial top dressing. The agriculture here was considered semi extensive to extensive. Stock do have access to the stream as this is the primary source of water. The stream bed here was dominated by coarse to fine gravel (***Table 2.1***). The banks of the stream are surrounded by willow (*Salix spp.*) and poplar trees (*Populas spp.*). The stream was on average 3m wide and had an average depth of 39cm (***Figure 2.6***). The surrounding environment (stream banks and immediate paddocks) consisted of flat to rolling farm land, improved pastures, matagouri (*Discaria toumatou*) and exotic trees (willow (*Salix spp.*)).

Figure 2. 6 Looking Upstream at the Grampians Stream Monitoring Site

Rocky Point Stream (RS) – Poor Quality Site (GPS S 44°33’15.23” E 170°40’02.00”)

The Rocky Point stream site was located 30m upstream from the bridge that crosses the stream on the Hakataramea Valley Road. The Rocky Point stream catchment is dominated by dry land semi extensive to extensive sheep and beef farming. There was no irrigation in this catchment; this will change in the future with a small area set to be converted to irrigation. There have been improvements made to the pastures in this region and they do receive fertiliser via trucks. Stock do have access to the stream as this is the primary source of stock water. The stream bed is dominated by fine sand to fine gravel with areas of medium gravel further upstream. The stream bed is often covered in a root mass from the mass of willow trees (*Salix spp.*) that choke the stream (***Figure 2.7***). The stream was on average 5.4m wide with an average depth of 23cm, this was as low as 5cm in the lower monitoring section. The surrounding environment (stream banks and immediate paddocks) consisted of flat to rolling farm land, improved pastures, matagouri (*Discaria toumatou*) and exotic trees (willow (*Salix spp.*)).

Figure 2. 7 Looking at the Rocky Point Stream Monitoring Site

Padkins Stream (PS) – Medium Quality Site (GPS S 44°41’19.09” E 170°31’18.95”)

The PS site was located directly upstream of the bridge that crosses the stream on Hakataramea Valley Road. This catchment is still dominated by dry land farming but does consist of a lot more irrigation than the other monitoring sites. The pastures in this catchment are much more improved and receive greater levels of nutrients via fertiliser. The agriculture here was considered semi intensive for periods of the year, but mainly semi extensive to extensive. The stock have access to the stream in areas, however this catchment consists of the most fencing out of all the tributaries. The stream bed was dominated by coarse to fine gravel. The stream was on average 5.8m wide with an average depth of 16cm. The surrounding environment (stream banks and immediate paddocks) consisted of flat farm land, improved pastures, matagouri (*Discaria toumatou*); bush lawyer (*Rubus cissoids*) and exotic trees (willow (*Salix spp.*)).

Figure 2. 8 Looking Upstream at the Padkins Stream Monitoring Site

2.1.3 Groundwater Monitoring Sites

Four groundwater monitoring sites were chosen from a limited number of bores, all located in the lower reaches of the valley. The data collected from these bores was to provide insight into the quality of the groundwater in the valley, and the affect it may have on surface water. The bores monitored were (in order from the northern end of the valley) (***Figure 2.9***); Bore I40/0780, 0004, 0040 and 0440.

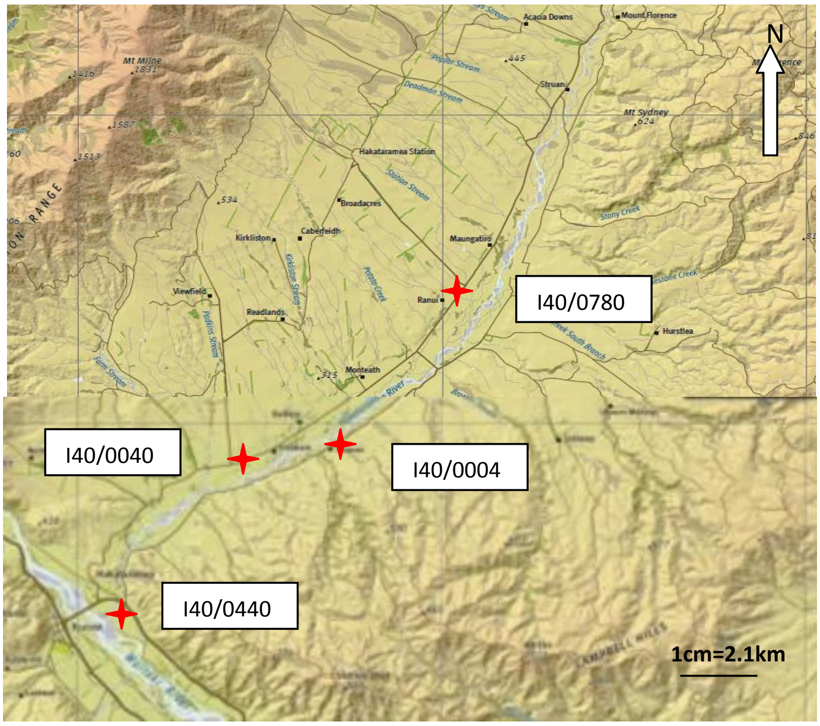


Figure 2. 9 Location of Groundwater Monitoring Sites

2.1.4 Soil Sampling Sites

To gain an understanding of the soil composition and quality in the valley a number of soil sites were sampled (***Figure 2.10***). Soil samples were taken from both dry land farming areas and from irrigated areas, to determine any differences. Since the irrigation is primarily being applied to the Pallic soil group this is where the soil sampling was focussed. ***Table 2.2*** shows the code names used for the study.

Table 2. 2 Code Names Used for the Soil Sampling Sites

Description	**Code**
Dry Immature Pallic	IP1
Irrigated Immature Pallic	IP2
Lower Fragic Pallic	FP1
Mid Fragic Pallic	FP2
Irrigated Fragic Pallic	FP30
Argillic Pallic	AP
Orthic Gley	OG
Upper Fragic Pallic	FP4
Orthic Brown	OB

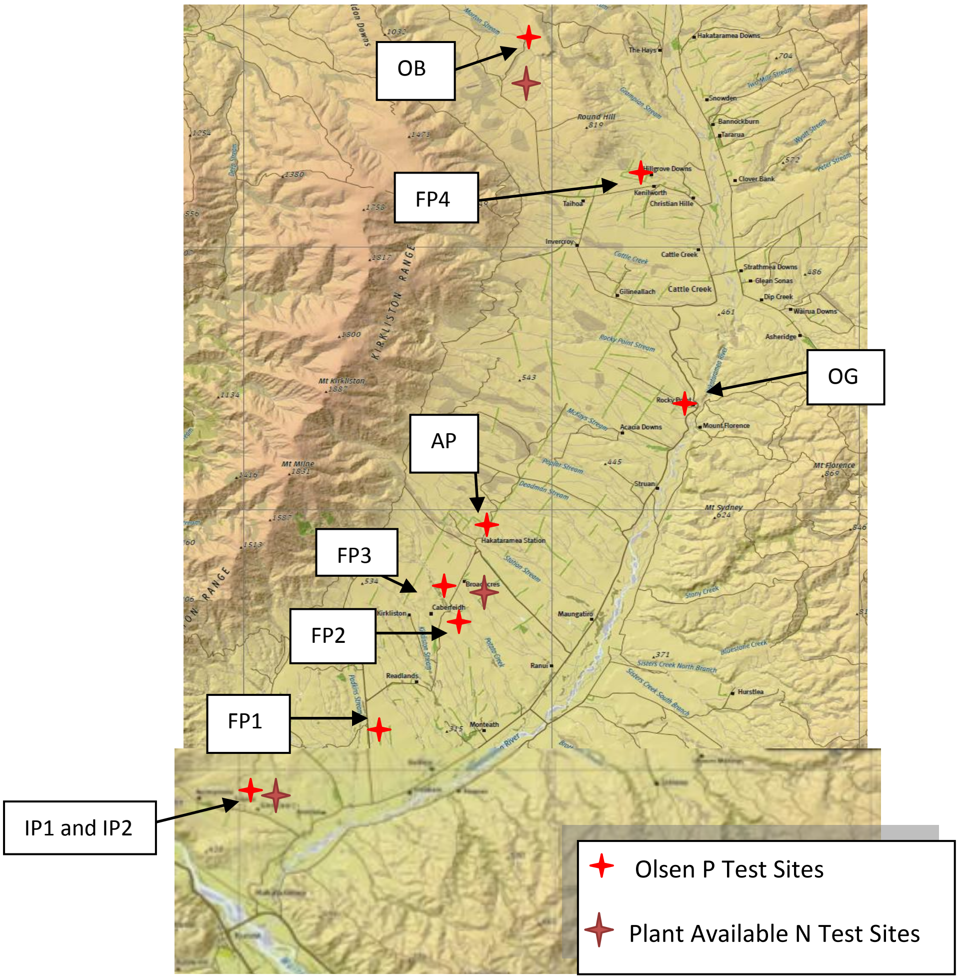


Figure 2.10 Location of soil sampling sites

IP1 Site (GPS S 44°40'41.03" E 170°28'47.78")

This site was located in the lower section of the valley and was an improved dry land mixed sheep and beef farm site. The soils at the site have been improved but there was not a very good pasture cover on the soils (***Figure 2.11***). The topography at this site was gently rolling to flat with the occasional cobble on and under the surface. There was a stream located in the vicinity of this site and groundwater was also evident seeping out of the gullies in the paddock.

Figure 2.11 IP1 Soil Sampling Site

IP2 Site (GPS S 44°40'39.82" E 170°28'55.92")

This site was located not far from the IP1 site and the topography was of a similar nature. There was no groundwater located in the vicinity of this site, but there was k-line irrigation. The soils have been improved with a nice cover of lush rye grass maintained (***Figure 2.12***).

Figure 2.12 IP2 Soil Sampling Site

FP1 Site (GPS S 44°39’32.91” E 170°32’01.02”)

This site was located around 5km (straight line) up the valley from the IP sites. The topography was flat. There were no surface waterways or ground water seepage (spring) sites located near the sampling site and there was no irrigation. The soils in this area have been improved and the area has in the past been in crop (Lucerne) (***Figure 2.13***). The property this site was located on was mixed sheep and beef.

Figure 2.13 FP1 Soil Sampling Site

FP2 Site (GPS S 44°37’31.93” E 170°34’47.54”)

This site was 7km (straight line) up the valley from the FP1 site. The topography was again flat. There were no surface waterways or ground water springs located in the vicinity. The soils here have been improved but there was not a great pasture cover (***Figure 2.14***). This site was located on a mixed sheep and beef site.

Figure 2. 14 FP2 Soil Sampling Site

FP3 Site (GPS S 44°36’23.28” E 170°33’03.22”)

This site was just over the road from the FP2 site. This site was irrigated by a centre pivot and the soils had been greatly improved. Both of these factors determined the high pasture yield that was evident (***Figure 2.15***). This site was again flat. There were no surface waterways or groundwater springs in the area of the sampling. This site was located on a mixed sheep and beef property.

Figure 2.15 FP3 Soil Sampling Site

AP Site (GPS S 44°35’16.79” E 170°34’50.06”)

This site was located 2km (straight line) up the valley from the FP3 site. There was no irrigation at this site. The soils had been semi improved but were covered with a thick poor quality grass yield (***Figure 2.16***). The topography at this site was rolling to steep. There was a stream located 150m down gradient from the sampling site but no springs or surface waterways were in the immediate vicinity. This site was located on predominantly a sheep station but there was also beef present.

Figure 2.16 AP Soil Sampling Site

OG Site (GPS S 44°33’11.42” E 170°39’45.25”)

This site was located 10km up the valley from the AP site. The topography here was a mix of flat plateaus and rolling land. The sampling area was on one of these flat plateaus. There was no irrigation at this site. The soils here had been improved but did not have a good pasture cover (***Figure 2.17***). There were no springs or surface waterways located in the vicinity of the sampling site. This site was located on a mixed sheep and beef property.

Figure 2.17 OG Soil Sampling Site

FP4 Site (GPS S 44°28’22.06” E 170°39’54.72”)

This site was located 10km up the valley from the OG site. The topography here was rolling. There were no surface waterways or springs located near the sampling site, however some of the depressions between the peaks were considerably damper than the overall sampling site. There was no irrigation at this site. The soils here have been improved and had a moderate but poor quality pasture cover (***Figure 2.18***). The property the site was located on was mixed sheep and beef with areas of cropping.

Figure 2.18 FP4 Soil Sampling Site

OB Site (GPS S 44°26’20.61” E 170°35’36.97”)

This site is located 7km up the valley on the same property as the FP4 site. At this location there was more cropping than the other site but sheep and beef were still the dominant agricultural type. There was no irrigation here but the soils were naturally damper than the other site. There were no springs evident at this site but there was a surface waterway located around 100m down gradient. The soils here have had more improvements made to them than the other site and this is shown in the pasture cover, although ***Figure 2.19*** shows a relatively new planting.

Figure 2.19 OB Soil Sampling Site

2.2 Sample Collection and Analysis

The water monitoring for this study was done by the author and Mr Al McCabe of Irricon Resource Solutions. Data and sample collection techniques used met the requirements set out by the Ministry for the Environment (MfE) in “A Technical Guide to New Zealand’s Environmental Indicators” (2012) as specified in Bartram & Balance (1996) and Chapman (1996). Water quality results were considered in conjunction with daily data collected on; air temperature; rainfall; wind speed and direction, from the NIWA weather station (Cliflo reference 36209) located at the top of the valley. Data from this weather station has been collected as far back as November 2010.

2.2.1 Surface Water

The various surface water parameters were collected over the same 150 metre stretch of water each month. This 150 metre stretch is referred to as the monitoring site and consists of fifteen 10m transects to make the testing easier. Both the ground and surface water samples were analysed by two different labs. The Environment Canterbury Laboratory was the first lab used, following the Christchurch earthquakes of February this lab was shut down, the samples were then sent to McMIllans Drilling Ltd. Laboratory. The samples were not analysed by the author as the sample results were also used in a terms of consent report and one of the terms was that the samples had to be analysed by an Environment Canterbury (ECan) approved laboratory. This was also the case for the ecological samples.

<u>Monthly</u>

Collection of; dissolved inorganic nitrogen (DIN); dissolved organic nitrogen (DON); dissolved reactive phosphorous (DRP); total phosphorous (TP); total suspended sediment (TSS); conductivity; pH; temperature; dissolved oxygen (DO); clarity/turbidity/absorbance; E.coli/F.coli; and periphyton percentage cover were collected monthly. Samples of total phosphorous (TP), dissolved reactive phosphorous (DRP), dissolved inorganic nitrogen (DIN), dissolved organic nitrogen (DON) and total suspended sediment (TSS) were analysed by ECan and McMillans Drilling Ltd, both are International Accreditation New Zealand (**IANZ**) and International Laboratory Accreditation Corporation (**ILAC**) members. The methods used by McMillans Drilling Laboratory for analysis were;

- Total phosphorus: total phosphorus digestion with ascorbic acid and analysed photo colorimetrically with a discrete analyser, APHA 4500-PE analyser (modified).

- Dissolved reactive phosphorus: filtered sample with molybdenum blue and analysed photo colorimetrically with a discrete analyser, APHA 4500-E (modified).

- Dissolved inorganic nitrogen and ammonium-N: filtered sample with phenol/hypochlorite and analysed photo colorimetrically with a discrete analyser, APHA 4500-NH3F (modified).

- Total oxidised nitrogen (nitrate and nitrite nitrogen): automated cadmium reduction technique measured with flow injection analyser, APHA 4500-No. 3 (modified).

- Dissolved organic nitrogen: total nitrogen digestion, total Kjeldahl digestion techniques with phenol/hypochlorite and analysed photo colorimetrically with a discrete analyser, APHA 4500-NH3 F (modified).

- Total Suspended Sediment: dried at 103-105°C and analysed with a discrete analyser APHA 2540.

Variables that did not require water samples to be collected (flow depth, velocity, periphyton percentage cover, conductivity, pH, temperature, dissolved oxygen and clarity) were measured using multi metres and instruments by the author and other relevant people. The Orion 5 star multi meter was used in the testing of conductivity, pH, temperature, and dissolved oxygen.

Meters were calibrated against buffer solutions to ensure accurate readings. The turbidity was measured using a smack tube. This method is similar to the black disk method but does not take as much time and is able to be used in shallow water which was a must for this study (***Figure 2.20***).

Figure 2. 20 Using the Smack Tube to Determine Clarity (Chajes, 2011) Photo by Jerry Kaufman

Flow volume and depth measurements were made by Mr Dave Pierce (Boraman Consultants Limited) using traditional hydrological measurement techniques of flow gauging and velocity measurement. Periphyton percentage cover was sampled using a 300 millimetre squared quadrant placed on top of the stream bed. The percent cover of periphyton in this quadrant was estimated and recorded along with the thickness; colour; filament percent cover and length; and didymo percent cover. This process was undertaken five times across the width of the stream and in each of the 15 transects.

Quarterly (Ecological Monitoring)

The quarterly surface water monitoring was focussed on ecological monitoring and was conducted by the author and Ms Melissa Anthony (GHD New Zealand Limited). The ecological monitoring was conducted in conjunction with the monthly river and stream monitoring. This allowed comparison between water quality and ecological health. The ecological monitoring focussed on fish counts, macro invertebrate counts and percent cover of periphyton. The electric fishing followed MfE guidelines and all adequate safety procedures were followed. This was carried out on all four river sites, along with all three tributary sites. To gain an in-depth understanding into the fish numbers in the waterway there was 150m of each site sampled, this was cut into 15 transects of 10m each (same as the other surface water monitoring). This gave the best possible catch rate and ensured the safety of the fish caught as they were not kept in captivity for extended periods of time. The fishing was completed across the full width of the waterway, excluding deep pools, swift rapids, or areas enclosed by overhanging willows with a Kainga 300 backpack electro-fishing machine. Areas that were not fished were noted down. The species of fish were identified with reference to “The Reed Field Guide to New Zealand Freshwater Fishes” (McDowall, 1990 revised 2010). As with the electric fishing the macro-invertebrate sampling was completed over the same 150m stretch of river or stream. The samples were simply collected using a kicknet. Following the completion of the sampling, debris and large shingle was cleaned out. The samples were then placed in sealable plastic containers with a quantity of white spirit (isopropyl alcohol) covering the entire sample. The samples were then sent to John Stark of Stark Environmental in Nelson for analysis. The results were obtained by using the Ministry for the Environment Protocol P2. This method is completed in the laboratory and gains a 200 fixed count of macro-invertebrates per sample with a scan for rare taxa (Stark et. al., 2001). From this, macro-invertebrate community index (MCI), quantitative macro-invertebrate community index (QMCI) and %EPT (Ephemeroptera (mayflies), Plecoptera (Stoneflies), and Trichoptera (Caddisflies)) abundance and taxa were calculated. The MCI and QMCI systems were developed from the British Biological Monitoring Working Party score system of 1978. The MCI score relies on prior allocation of scores between 1 and 10 to each macro-invertebrate, the higher the score the more sensitive the taxa are to pollutants. The following calculation is used to then define the score;

$$MCI = \frac{site\ score}{\#\ of\ scoring\ taxa} \times 20$$

(Stark J. , 1985)

The site score is the sum of the individual taxon score for all taxa present in the sample, 20 is a scoring factor (Kumar, Bohra, & Singh, 2003). The QMCI score is the quantitative equivalent of the MCI and instead of giving the overall score it gives the average taxa score value (1-10). The QMCI is calculated using the equation;

$$QMCI = \sum_{i=1}^{i=s} \frac{n_i \times a_i}{N}$$

(Stark J. , 1985)

Where ‘s’ is the total number of taxa in the sample, ‘n_i’ is the number of individuals in the scoring taxon, ‘a_i’ is the score of the i-th taxon, and ‘N’ is the total number of coded abundances in the entire sample.

These two systems give the health of the waterway by coming up with scores, in general the higher the score the healthier the waterway, although there are some exceptions. The scores of each of the taxa can be seen in ***Appendix 3***. The %EPT abundance and taxa are another way of identifying the health of a waterway. These two use counts of Ephemeroptera (mayflies), Plecoptera (Stoneflies), and Trichoptera (Caddisflies) as these three groups are considered the most sensitive to pollutants; the higher the percentage the healthier the waterway.

2.2.2 Groundwater

The methods of groundwater sampling met the MfE protocols and guidelines; A National Protocol for State of the Environment (Daughney et. al., 2006). The groundwater was sampled monthly for total nitrogen (TN), total phosphorous (TP), and *E.coli* at each of the sampling sites identified in ***Figure 2.9***. The time that each well was purged was based on the calculation presented by Daughney et. al. (2006).

Volume: = (3.14(Depth of Well - Depth to Water)*(Radius of Well) ^2*1000)*

Time: = Purge Volume (as above) / max pump rate (L/second)

Daughney et. al. (2006)

By using this calculation an adequate purge was achieved with three to five times the volume of standing water in the well being removed allowing for fresh non stale water to enter the well column and thus giving a fresh sample.

2.2.3 Soil

The soil samples were collected from 9 different sites throughout the valley; predominantly in the areas where irrigation is going to be added and has already been added, on the western side of the river in the Pallic soils. These sites were chosen after looking at the current and future irrigation consents in the valley. The soils were sampled using approved methods as set out in the document “Site Investigation and Analysis of Soils, Contaminated Land Management Guidelines number five” (Ministry for the Environment, 2004). The sampling followed the systematic technique as stated in this paper. There were between 15 and 20 samples taken per site (one every 10m) in a zig zag fashion.

Figure 2.21 Soil Sampling Gear Used in the Collection of Samples

2.3 Soil Analysis

The soil samples were not part of the “terms of consent study”. Collecting these samples and analysing them will allow for modelling of the potential changes in nutrient concentrations and flows. Samples were analysed for; pH, water content, total porosity, bulk density, plant available N (ammonium and NO_x) and plant available phosphorus. Each of these tests was based on the methods of Blakemore, et al. (1987).

pH

There are many different soil pH tests, the test used in this analysis was to represent what happens in nature so a water based pH test was used, following Blakemore, et al. (1987). The test procedure is as follows;

1.) Weigh 10g of soil (air dried and sieved to <2mm) into a 100 mL beaker and add 25 mL of deionised water.
2.) Stir vigorously with a homogeniser or high speed stirrer.
3.) Leave to stand overnight (Note: record the ratio of soil to suspension).
4.) Thoroughly wash the electrodes or bulb of the pH metre with deionised water.
5.) Position the soil sample on the instrument so that either electrodes or the bulb are well covered by the soil solution.
6.) Without stirring, measure and record the pH.
7.) Carry out duplicate determinations on separate subsamples. Replicate determinations should give results within 0.1 pH.

Water Content (Moisture Factor)

Most soil moisture content tests are reported on an oven dry basis, this is not exactly representative of the natural environment and there are a number of chemical changes that occurr in such testing processes. For this test the soils were to be air dryed to combat this problem. The soils were dried at no more than 30°C. At the final stage of this test it is then possible to convert these results to an oven dried basis by applying a moisture factore in the calculation of the results. The technique that was used in the moisture factor test was based off the technique described by Blakemore et al. (1987).

The test procedure is as follows;

1.) Weigh a number of dishes (one for each of the samples) and record
2.) Sieve the soils to <2mm, air dry the soils
3.) Weigh accurately a 10-20g sample, add this to the already weighed dish (record the dish number and sample location)
4.) Dry in an oven at 105°C for 8-24 hours minus the lid.
5.) Remove from the oven, cool and weigh as soon as the sample is at a respectable heat to handle.
6.) Record the results.

Following on from the recording of the weights a moisture factor is then calculated, this calculation is;

$$\frac{wt\ moist\ soil(g) - wt\ oven\ dried\ soil\ (g)}{wt\ oven\ dry\ soil\ (g)} = Moisture\ Factor\ (g/g\ 3dp)$$

$$multiply\ the\ above\ by\ 100\ to\ get\ the\ water\ content\ as\ a\ percentage$$

$$wt = weight$$

(Blakemore, Searle, & Daly, 1987)

Bulk Density

Soil bulk density was measured using the equation;

$$Soil\ Bulk\ Density\ (g/cm^3) = \frac{Oven\ Dry\ wt\ of\ soil}{volume\ of\ soil}$$

(Blakemore, Searle, & Daly, 1987)

The volume of soil was calculated when collected in the field using the sampling equipment shown in ***Figure 2.21***, this was noted down. The soil dry weight was simply found by drying the sample collected in the field for 24 hours at 110°C then weighing it.

Soil Porosity (%)

The soil porosity or void fraction is a measure of the pores/void spaces in soil. These pores allow water to pass through the soil (Asare, Rudra, Dickinson, & Fenster, 2001). The porosity of soil can be affected by compaction (compact soils have a lower porosity) which in turn determines clover growth and N fixation.

$$Total\ Soil\ Porosity\ (\%) = 100 \times (1 - \left(\frac{Bulk\ Density}{Particle\ Density}\right))$$

(Asare, Rudra, Dickinson, & Fenster, 2001)

The particle density was assumed at 2.65g/cm^3 which is considered a good value for a generic mineral soil (Freeze & Cherry, 1979).

Plant Available Phosphorus (Olsen P)

There are many different phosphorus tests available, each of which has a specific use. These tests allow different phosphorus parameters including; plant available; soluble; organic; total; and phosphate retention to be found. This study is looking into how changes in farming practices with the addition of water will alter the soil and water quality so plant available phosphorus was tested for. The Truog, Olsen, Resin, Mehlic 3 and Bray 2 are all used in analysing this parameter. In New Zealand the Truog test was considered the standard plant available P test up until the mid 1970s where the Olsen test took over and is still used today. The Olsen test used follows the directions set out by Blakemore et al. (1987) and also Gavlak et al. (2003).

Reagents:

1.) Deionised water.

2.) Sodium bicarbonate extracting solution (0.5N $NaHCO_3$ at pH - 8.50). Dissolve 42.01g of $NaHCO_3$ in 900mL of deionised water. Adjust the pH to 8.50 ± 0.05 with 2.0N NaOH before diluting with deionised water to 1,000mL.

3.) Modified Reagent A (Watanabe and Olsen, 1965).

- Ammonium Molybdate: Dissolve 12.0g of [(NH4)6$Mo_7O_{24}.4H_2O$] in 250 mL of deionised water.
- Antimony Potassium Tartrate: Dissolve 0.291g of antimony potassium tartrate [K(SbO).C $C_4H_4O_6$.½ H_2O] in 100 mL of deionised water.
- Add both of the dissolved reagents to 1,000mL of 5.76NH_2SO_4 (160mL of concentrated sulphuric acid per litre (Self and Rodriguez, 1996)) mix thoroughly and make to 2,000mL.

4.) Reagent B, ascorbic/molybdate reagent (Watanabe and Olsen, 1965). Dissolve 1.32g of ascorbic acid ($C_6H_4O_6$) in 250mL of modified Reagent A and mix well.

5.) Phosphorus Calibration Standards. From a standard solution containing 1,000mg/L PO_4-P, prepare 100mL of standard in 0.5N $NaHCO_3$ containing 100mg/ L PO_4-P. Then, using the 100 mg/L PO_4-P standard, prepare 7 calibration solutions of 100mL each in 0.5N $NaHCO_3$ with PO_4-P concentrations of 0.00, 0.25, 0.50, 0.75, 1.00, 2.00, and 4.00 mg/L.

Extracting Procedure:

1.) Weigh 2.00 ± 0.02g of air dried soil pulverized to pass through <2 mm sieve in a 125mL plastic extraction Erlenmeyer flask.

2.) Add 40.0mL of 0.5N $NaHCO_3$ extraction solution. Include a method blank and standard quality control samples.

3.) Place extraction vessels on oscillating mechanical shaker for 30mins.

4.) Filter suspension immediately through 11µm filter paper (within 1min, re-filter if filtrate is cloudy).

Phosphorus Analysis:

1.) Pipette a 3.0mL aliquot of standard or soil extract into an Erlenmeyer flask.

2.) Add 9.0mL of deionised water.

3.) Add 3.0mL of Reagent B (ascorbic/molybdate reagent).

4.) Add 1.5mL of concentrated H_2SO_4.

5.) When effervescence has ceased, pour into a suitable spectrometer tube and run analysis.

4.) Read absorbance at a wavelength of 882nm after 30mins of adding the Reagent B. Adjust the 0.000 absorbance using the 0.00 standard. Determine absorbance of a method blank, standards and unknown samples.

5.) Once the standards have been determined plot these as a phosphorus versus absorbance calibration curve graph. Subtract the blank absorbance reading off the unknown sample reading and plot on the standard curve (***Figure 2.22***).

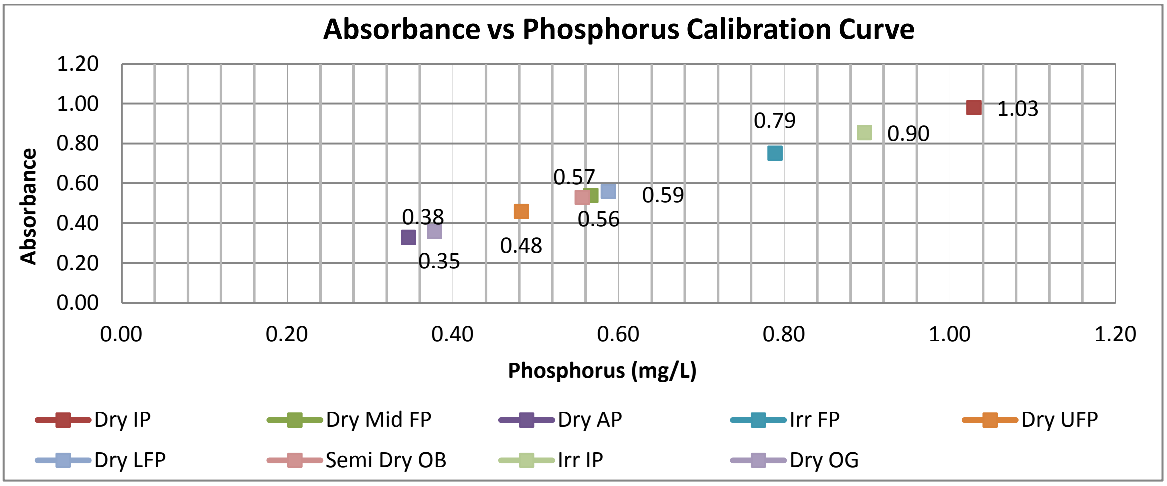


Figure 2.22 Absorbance vs. Phosphorus Calibration Curve for the samples collected from the Hakataramea Valley

Calculations:

$$\mu\ \mathrm{P/mL\ (in\ extract)} \times 20 \times 1.08 = \mathrm{Olsen\ P\ (\mu g/g)}$$

(Blakemore, et al. (1987) & Gavlak, et al. (2003))

NOTE: The 1.08 factor is to correct for dilution introduced by adding 1.5mL of concentrated H_2SO_4.

Report the phosphorus readings to the nearest 0.1mg/kg.

Plant Available Nitrogen (Ammonium and Nitrate) (Modified KCl Extraction)

There are many different methods used in the testing of the different forms of nitrogen. This study is looking at how irrigation and agricultural changes will affect the waterways and soils so the tests that are used will relay this. This test is the modified ammonium and nitrate nitrogen potassium chloride (KCl) extraction method. This method involves the extraction of quantitative nitrate (NO_3-N) and semi quantitative ammonium (NH_4-N) from soils using 2N KCl. Nitrate is found by reduction to nitrite (NO_2-N) via an auto analyser spectro-photometrically at 520nm. The procedure outlined follows the method described by Keeney and Nelson (1982) and can also be found in Gavlak et al. (2003). These two papers give a modified version of the original test in which 25mL of KCl and 5g of soil is used instead of 100mL and 10g of soil and extending the shaking period to 30mins with 2N KCl (Bremner et.al.1965). The method detection limit is approximately 0.5mg/kg (on a dry soil basis).

Reagents:

1.) Deionised water.

2.) Potassium chloride extracting solution, 2N KCl: Dissolve 150g of reagent grade KCl in 500mL deionised water and dilute to 1000mL.

3.) Standard calibration solutions of NO_3-N. Prepare 6 calibration standards ranging from 0.1-20.0mg/L concentration, diluted in 2N KCl extraction solution prepared from 1000mg /L NO_3-N standard solution.

Procedure:

1.) Weigh 5.0 ± 0.05g of air-dried soil pulverized to pass through <2mm sieve into extraction vessel. Add 25.0mL of 2N KCl extraction reagent using repipette dispenser. Include a method blank.

2.) Place extraction vessels on reciprocating mechanical shaker for 30mins.

3.) Filter extract through 11µm filter paper, re filter if filtrate is cloudy.

4.) Nitrate-N content of the extract is determined using a spectrophotometer. Calibrate using standard calibration solutions. Determine nitrate concentration of KCl extract, method blank and unknown samples and record results as mg/L of plant available N in extract solution.

Calculation:

$$\text{Available N/kg} = (\text{Available N mg/L in filtrate} - \text{method blank}) \times 5$$

Report soil nitrate concentration to the nearest 0.1mg/kg.

(Gavlak, Horneck, Miller, & Kotuby-Amacher, 2003)

2.4 Data Analysis

Basic statistical analytical methods were used in the analysis of the data, including; mean values, median values, ranges, accuracy, precision, bias and standard deviation. These methods were based on that presented by Van Reeuwijk (1998) and ensured that the data entered into the various graphs was accurate. The graphs presented in the Results Chapter (chapter 3) followed basic techniques that have been described in Wenner (2004), Krzanowski (2000) and Cleveland, (1985).

2.4.1 Modelling

Following on from the completion of the various water quality and soil quality tests modelling of the future of the valley will be performed. There are many different systems used by farm consultants and fertiliser companies for modelling, including; OVERSEER; SPASMO (Soil-Plant-Atmosphere System Model); NPLAS (Nitrogen and Phosphorus Load Assessment System); EcoMod; LUCI (Land Use Change and Intensification); and APISM (Agricultural Production Systems Simulator). OVERSEER version 6 programme developed by MAF, FertResearch and AgResearch was used in this study as it is commonly used by farm consultants and fertiliser companies and allows modelling of nutrient flows and nutrient budget calculations. The OVERSEER programme uses inputs of; animal numbers; stocking rates; pasture types; supplements imported and exported; area in wetlands; topography; soil properties; soil nutrients; and fertiliser application. This model has been used with success and has been proven to be successful in many studies including; Wheeler, et al. (2003); Monaghan, et al. (2007a); Monaghan, et al. (2007b) & Cichota & Snow (2009). To model the valley there were six different scenarios presented that could represent future farming practices in the valley. These scenarios were;

1.) Dry land sheep grazing across the entire valley
2.) Mixed dry land sheep and beef grazing across the entire valley
3.) The lower valley becomes heavily irrigated with mixed sheep and beef grazing, while the upper valley remains dry with mixed sheep and beef grazing
4.) The lower valley becomes heavily irrigated with beef and dairy grazing, while the upper valley remains dry with mixed sheep and beef grazing
5.) The entire valley becomes irrigated with mixed sheep and beef grazing
6.) The entire valley becomes irrigated with beef and dairy grazing

By having these six scenarios it gave a good representation of how the valley could potentially change in the future. The Olsen P and nitrate-nitrogen values given to each scenario can be seen in ***Table 2.3***. These values were chosen after going over results collected in the past in the valley and other similar valleys and from data the author collected.

Table 2. 3 Scenarios Used in the OVERSEER Modelling of the Potential Future in the Hakataramea Valley

Scenario Number	Description of the Scenario	Stocking Rate per Hectare	Olsen P (ppm) Level Used	Plant Available Nitrogen Level Used (mg/kg)
1	Dry land sheep over the entire valley	1.5 (100% sheep)	8	16.5
2	Mixed dry land sheep and beef grazing over the entire valley	5 (70% sheep 30% beef)	10	16.5
3	Lower valley becomes irrigated with mixed sheep and beef grazing while upper valley is dry	11 (65% sheep, 35% beef)	16	19
4	Lower valley becomes irrigated with beef and dairy grazing while upper valley is dry land sheep and beef grazing	15 (8.7% sheep, 65% beef, 26.3% dairy grazing)	19	24
5	Entire valley becomes irrigated with mixed sheep and beef grazing	12 (60% sheep 40% beef)	16	19
6	Entire valley becomes irrigated with beef and dairy grazing	18 (70% beef 30% dairy grazing)	20	24

The stocking rates (units) used were sourced from Dalton (2009). The values given for each stock type are seen in ***Table 2.4***. A stock unit is based off a 40kg ewe suckling one lamb (one stock unit) and consuming 520kg of dry matter feed a year.

Table 2. 4 Stock Type and the Corresponding Stock Unit, Based off a 40kg Ewe Suckling One Lamb (One Stock Unit) **(Dalton, 2009)**

Stock Type	Stock Unit Equivalent
Ewe with a lamb, pre winter hogget	1
Angus: Beef heifer (350-400kg), steer, bull (200-400kg)	3.7
Dairy Grazing Jersey Yearling (180-320 kg)	3.5
Dairy Grazing Friesian Yearling (225-430 kg)	4.5
Dairy Grazing (dry) Cow (400 kg)	6

Assumptions made in the modelling of the valley included;

1.) A mean average rainfall of 452mm across the entire valley.
2.) When referring to the lower valley, this constitutes the block of land to the west of the river from Rocky Point east 4.5km and south to the Waitaki River, a total area of 14,900ha.
3.) When referring to the upper valley, this constitutes the block of land on the western side of the river from Rocky Point east 4.5km and north 10.5km to the OB soil sampling site, a total area of 7,600ha.
4.) An even application of irrigation was used across the valley of 450mm/yr.
5.) That the farms in the lower valley were flat, with some farms in the upper valley being rolling.
6.) That nutrient levels applied via irrigation were constant across the valley.
7.) The dry land soils in the lower valley had a bulk density of 1.03 g/cm^3.
8.) The irrigated soils in the upper and lower valley had a bulk density of 0.95 g/cm^3.
9.) The dry land soils in the upper valley had a bulk density of 0.78 g/cm^3.
10.) The QT (ppm) K (7), Ca (7), Mg (21), Na (8) values were constant across the entire valley.
11.) The fertiliser application rate in the upper and lower valley was constant and fertiliser was applied in July.
12.) There were no supplements imported or exported from the property.
13.) The pasture cover was ryegrass and white clover mix, with more clover under irrigated land.
14.) The stocking rate is unchanged throughout the year.
15.) When referring to ewes this is actually referring to Perendale ewes as these are the most common in the valley. The average weight used is 60kg.

3. RESULTS

This chapter shows the results that were collected from the surface and groundwater sites, soil sites and the daily monitoring site. The water quality samples were collected by the author, but these were analysed by both McMillans Drilling Ltd and Environment Canterbury Laboratories. This was necessary as stated in the terms of conditions for the consent that this project arose from. The ecological testing was completed by Melissa Anthony (GHD) and the author, and the samples were sent away to John Stark (Stark Environmental) for analysis, as required in the terms of conditions for the consent. Both sets of results were sent to the author for interpretation. The results of the daily monitoring of the climate were collected from the NIWA weather station with Cliflo reference 36209. The soil sampling and analysis was undertaken by the author. A Land Resource Inventory (LRI) survey was carried out on ten properties in the valley by the author. This survey was conducted by the author through Irricon Resource Solutions, but the results were made available for this study. The ten properties have, or will have in the future, irrigated land. These results will be used in the modelling of the nutrient flows and budgets in the valley using the OVERSEER programme. ***Appendices 1, 2*** and ***3*** show the raw data results for the climate and monitoring data.

3.1 Daily Monitoring Climate Results

The daily climate monitoring identified how the climate extremes (heavy rainfall or high wind velocities) affected water quality and soil quality results, any relationships were quantified, if possible. The climate results were collected from the NIWA weather station located in the valley (Cliflo 36209), for wind velocity, rainfall, and temperature and then analysed using common statistical methods (Cleveland & McGill, 1985). The climate data will aid in determining whether any irregularities or spikes in the water quality data are natural, or human induced. All the raw data presented in this section is given in ***Appendix 1***.

3.1.1 Rainfall

Graphs and tables of monthly, annual seasonal, and average seasonal rainfall were prepared (***Figures 3.1, 3.2, & 3.3***). These show when rainfall was highest (Spring and Summer) and just how much it varies throughout the year and from year to year (February 2010 with 12.2mm compared to February 2011 with 105.2mm). Seasonal data has been displayed in place of monthly data. In doing this it allows for easier comparison with stock movements throughout the properties (stock move seasonally not monthly).

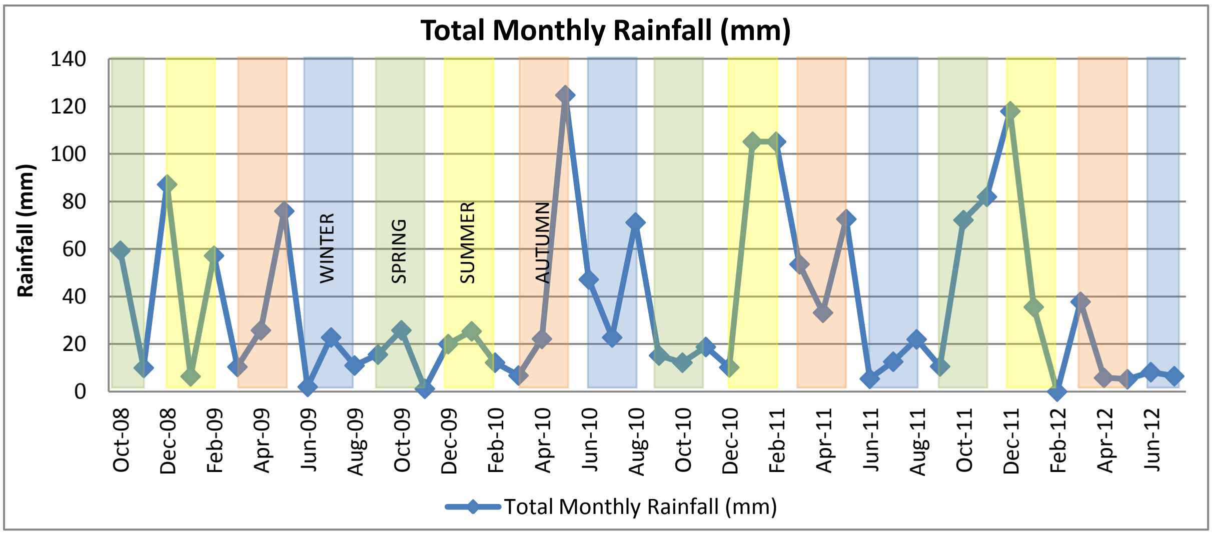


Figure 3. 1 Total Monthly Rainfall in the Hakataramea Valley (October 2008 to July 2012)

During the irrigation season (September; October; November; December; January; February; March, April and depending on the season early May (***Figure 3.2***) (Rangitata Diversion Race Management Limited, 2012), the rainfall appeared often to be greater than during the non-irrigation season. This can be misleading as during the non irrigation season (winter) precipitation falls mainly as snow which stays in the upper catchment until spring. Also, during the irrigation season, evapotranspiration (water lost to the atmosphere) is far greater than during the winter, resulting in a net loss of water.

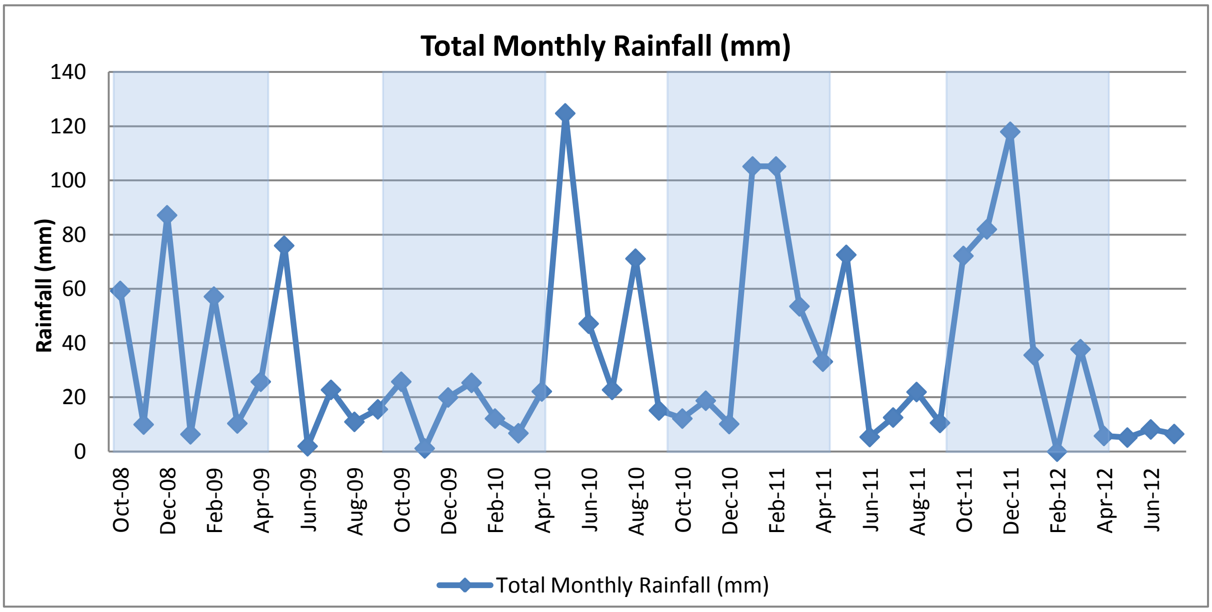


Figure 3. 2 Monthly Rainfall in the Hakataramea Valley with the Typical Canterbury Irrigation Season Overlain

Figure 3.3 shows the average seasonal rainfall from October 2008 to July 2012 (16 seasons in total). As stated above the rainfall in the catchment is greatest during the hottest months (summer and autumn), which coincides with the irrigation season.

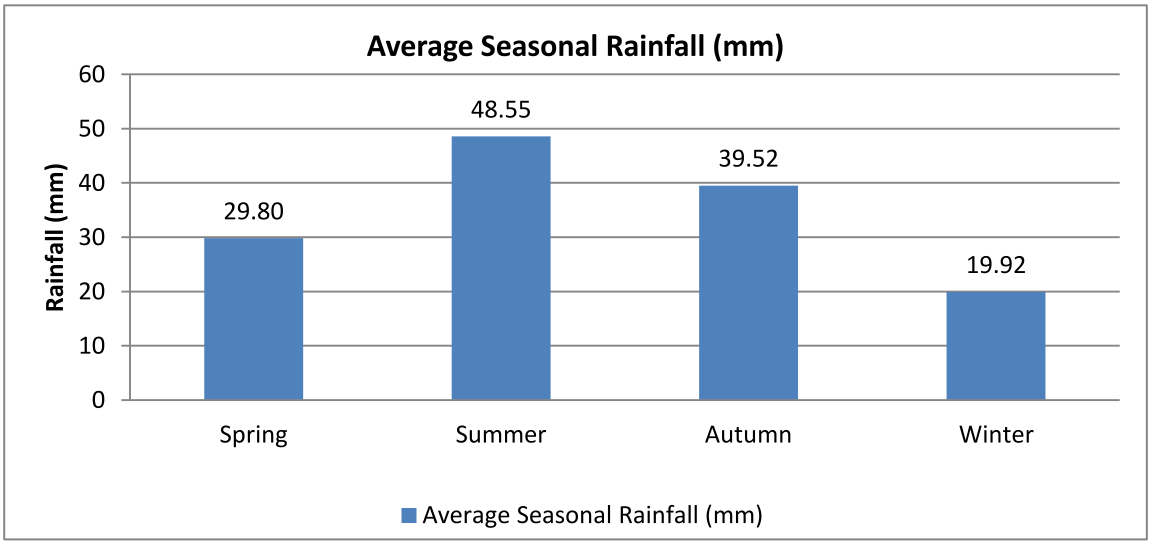


Figure 3. 3 Average Seasonal Rainfall 2008-2012

National Institute of Water and Atmospheric Research (NIWA), 2012)

3.1.2 Wind

Wind data was sourced from the NIWA weather station (Cliflo 36209) covering the period from December 2008 to July 2012, over this time period wind from the west accounted for

49% of all wind. Of the westerly winds, the south westerly winds were the most prevalent comprising 24%. Surprisingly NW wind only accounted for 12% of the wind experienced during this period (***Figure 3.4***).

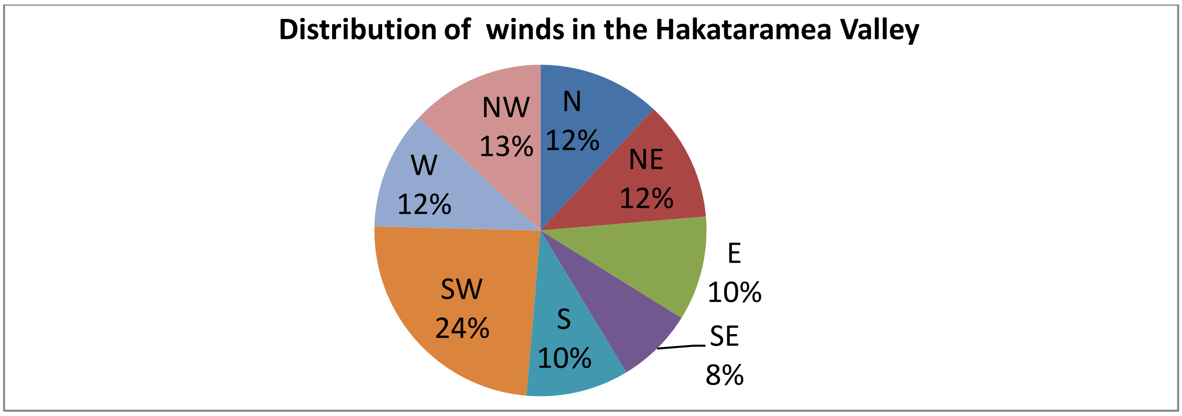


Figure 3. 4 Percentage Distribution of Total Wind Experienced in the Hakataramea Valley between December 2010 and July 2012

By comparing wind speed data and distribution of wind direction it allows for quantification on which wind direction is the main cause of high velocity events and what season these events typically occur in. A velocity of over 6m/s is connected with soil erosion (Roose, 1996) so this is the velocity at which “high” refers too. The average seasonal velocity of the wind in the valley ranges considerably with the lowest average velocity coming in autumn and the highest average velocity coming in winter (***Figure 3.5***). Higher average seasonal wind velocity translates to more wind events with a velocity greater than 6m/s (***Figure 3.6***).

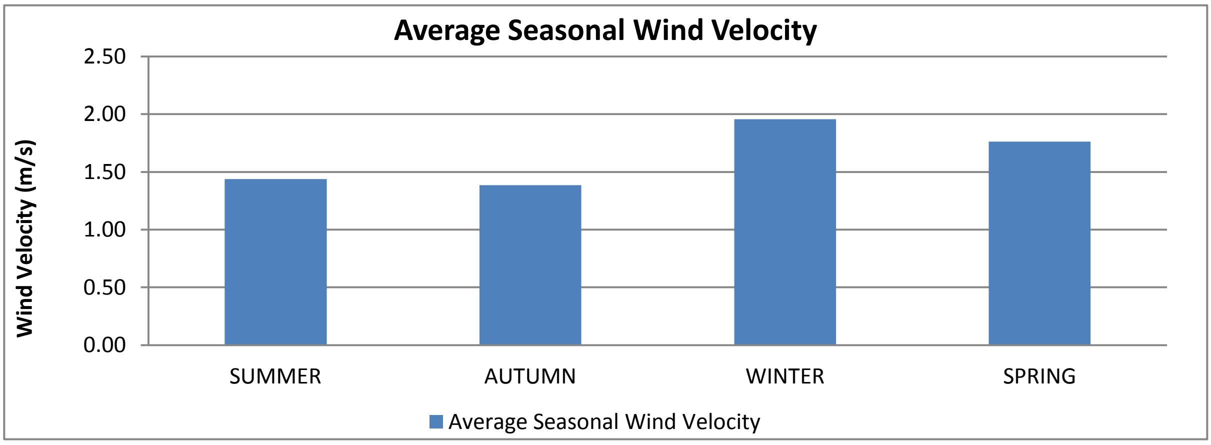


Figure 3. 5 Average Seasonal Wind Velocities for the Hakataramea Valley, spanning the period between December 2010 and July 2012.

Over the data time period winter and spring were the seasons that had the greatest number of high velocity wind days (***Figure 3.6***). With these events being at these times of year there is a high risk of wind erosion occurring sue to the lack of pasture cover.

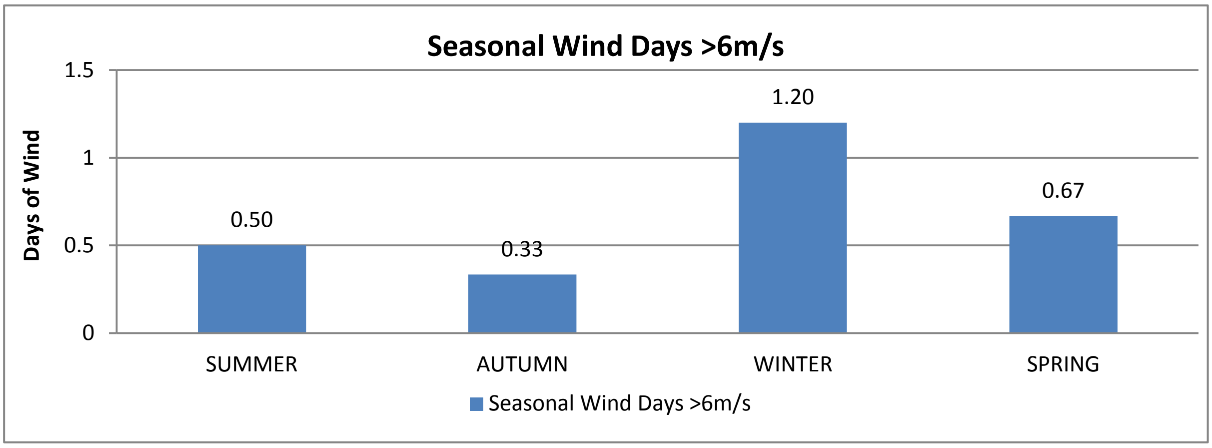


Figure 3.6 Seasonal Wind Days >6m/s

The high velocity wind events are most commonly originating from the east and north east (***Figure 3.7***). These wind directions are subsequently more common during the winter months.

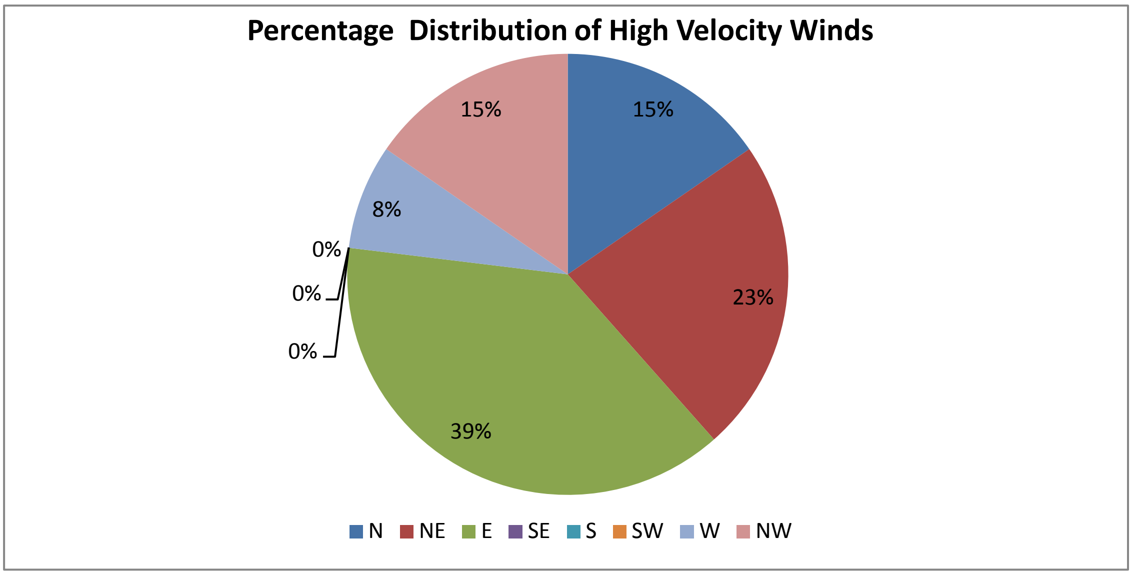


Figure 3. 7 Percentage Distribution of Wind Direction for the High Velocity Wind Events

3.1.3 Temperature

This data was sourced from the NIWA weather station located in the valley (Cliflo 36209) and covers the time period from October 2008 to July 2012. The results are displayed in seasonal format and are presented in full in ***Appendix 1***. The atmospheric temperature directly influences the water temperature. This in turn is one of the largest contributing factors to a number of adverse effects that could potentially take place within the valley. As was expected the temperature data shows that the summer months are by far the warmest and as a result have the highest evapotranspiration levels, hence the need for irrigation during the wettest months.

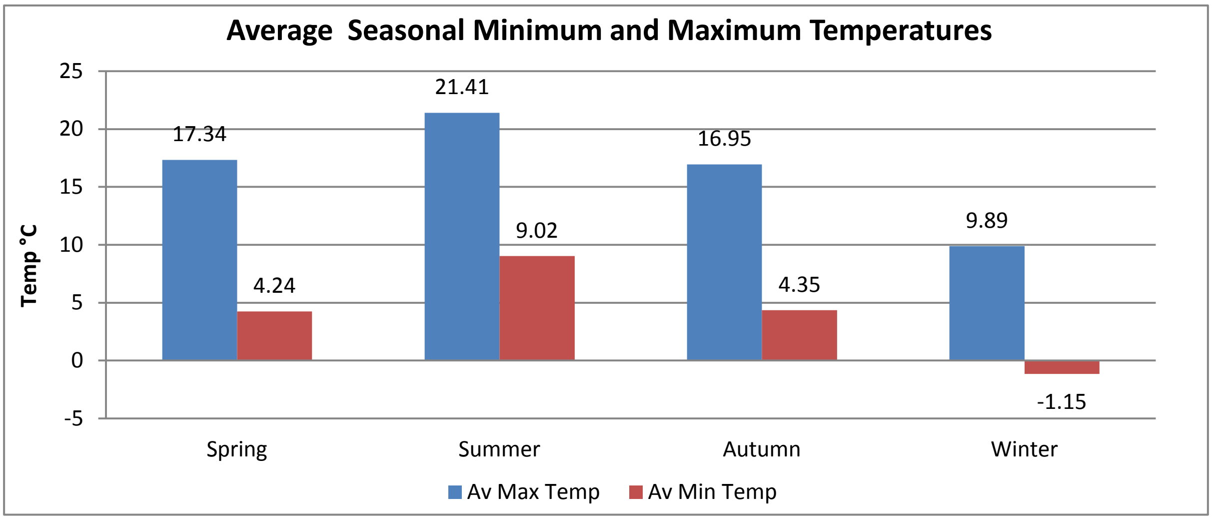


Figure 3. 8 Average Seasonal Minimum and Maximum Temperatures for the Hakataramea Valley. These are directly related to the amount of evapotranspiration occurring.

(National Institute of Water and Atmospheric Research, 2012)

3.2 Monthly Monitoring Raw Data Results (Water Quality)

The monthly monitoring was focussed solely on water quality, with the main focus being on surface water (***Figure 2.1***). Groundwater was also collected at a limited number of sites (***Figure 2.9***). Data (***Appendix 2***) was collected for; flow volumes; pH; conductivity; dissolved oxygen; temperature; clarity; total suspended sediment; dissolved inorganic nitrogen; total nitrogen; total ammoniacal nitrogen; nitrate-nitrite; total kjeldahl nitrogen; dissolved reactive phosphorus; and *E.coli*. Water samples were collected at the same time every month (second week of the month) by the author and colleagues (Chapter 2). The data collection began in the 2011 summer (December 2010) and ceased in November 2011, this gave a full year of data covering all the months and seasons of the year and ensured a full set of data was available as a baseline for this study.

3.2.1 Surface Water

Some samples were analysed for; total suspended sediment (TSS); dissolved inorganic nitrogen (DIN); total nitrogen (TN); total ammoniacal nitrogen (TAN); nitrate-nitrite (NO_x); total kjeldahl nitrogen (TKN); dissolved reactive phosphorus (DRP); and *E.coli*, at an ECan approved laboratory as stated in the terms of consent. Two laboratories were used in the analysis due to the Christchurch earthquake, which shut down the laboratory facilities at ECan in February 2011. The other parameters collected were; dissolved oxygen (DO), clarity, temperature, flow volumes, pH, and conductivity were collected in the field. The results were compiled by the author (***Appendix 2***).

Physical Parameters and Dissolved Oxygen

<u>Flow Volumes</u>

Figure 3.9 illustrates the different sizes of the waterways tested and also how much variation is seen annually. This data shows high flow periods in February, May and October) which will ultimately influence water quality results due to soil runoff.

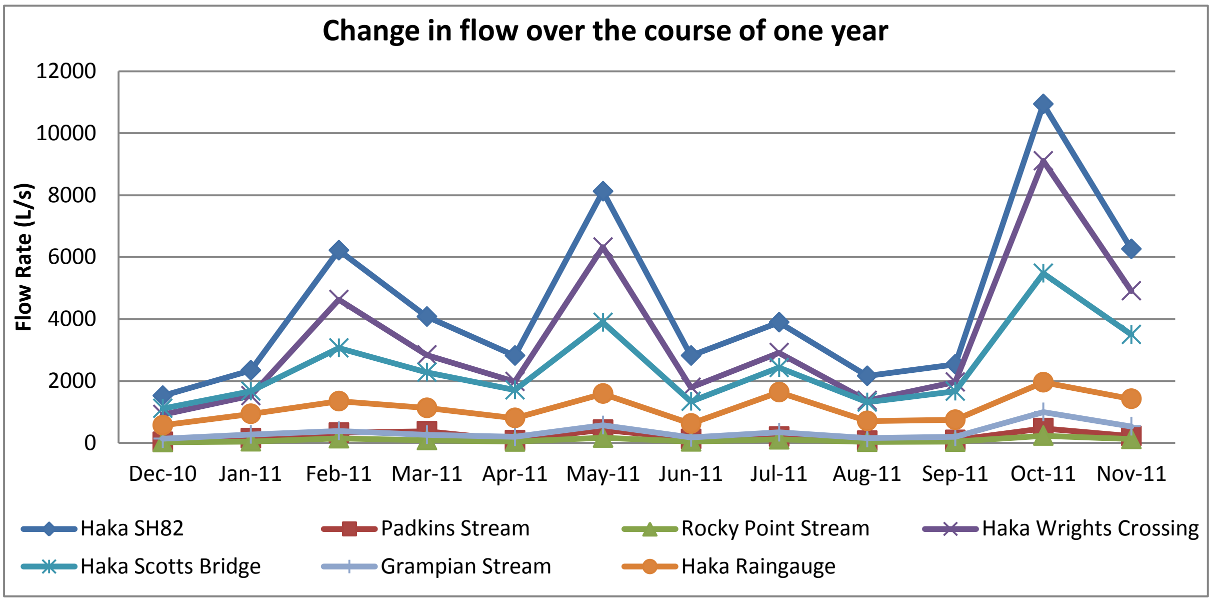


Figure 3. 9 Flow Volumes of the Surface Water Monitoring Sites in the Hakataramea Valley over the course of the monitoring period (December 2010 to November 2011)

Conductivity

Conductivity in the valley varies considerably. The lower valley sites (Padkins stream, Hakataramea River at State Highway 82, and Rocky Point Stream) show higher readings than the other sites. The higher the conductivity the more dissolved ions (nutrients) the waters has. This is what was expected in the valley as the lower valley has more intensive farming systems in place with greater nutrient inputs.

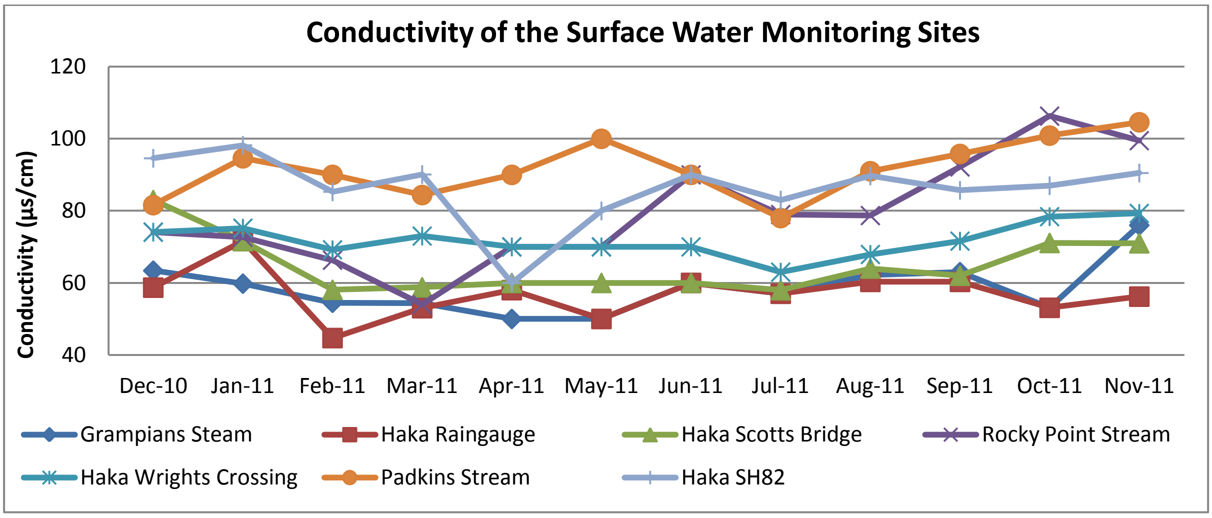


Figure 3. 10 Conductivity of the Surface Water Monitoring Sites in the Hakataramea Valley

pH

The pH levels in the valley are relatively stable across all the sites monitored all falling within the excepted range for New Zealand freshwater, with March 2011 being an exception (***Figure 3.11***). The readings of pH in March were conducted with a different multi metre as the one used previously was unavailable. This metre was obviously not calibrated correctly.

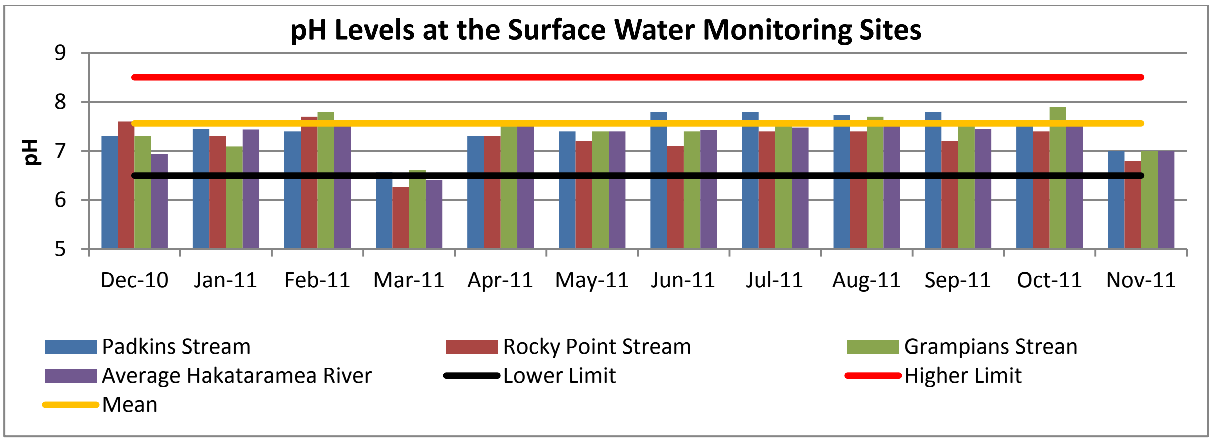


Figure 3. 11 pH of the Surface Water Monitoring Sites

Dissolved Oxygen

The readings of DO at the sites were expected and are all acceptable readings. The lowest readings were acquired in the summer (warmer) and highest in the winter (coldest).

Rocky Point stream showed lower levels of DO throughout the study until September 2011 (***Figure 3.12***). This stream had a different bed substrate than the others and was choked by willow tree roots and macrophytes.

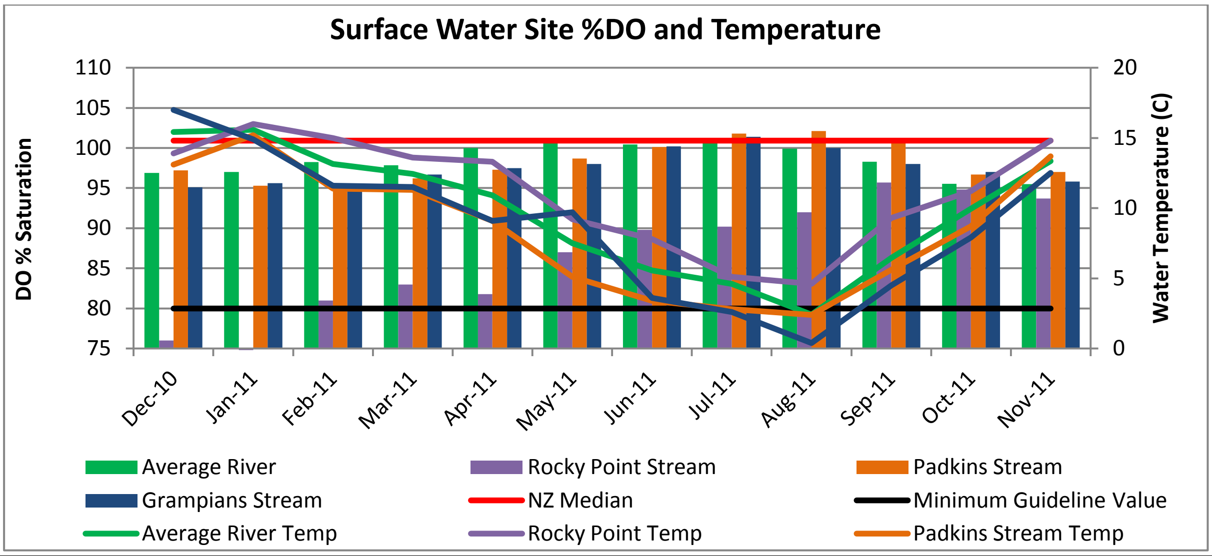


Figure 3. 12 Dissolved Oxygen Percent Saturation of the Surface Water Monitoring Sites in the Hakataramea Valley

Clarity

The clarity of the surface waters was collected with a smack tube, hence the highest readings being 1m. The clarity at any of the sites (minus Rocky Point Stream) rarely dropped lower than 1m. The one site where it was common for this to be lower, was at Rocky Point Stream, here the clarity was less than 1m for 8 of the 12 months monitored.

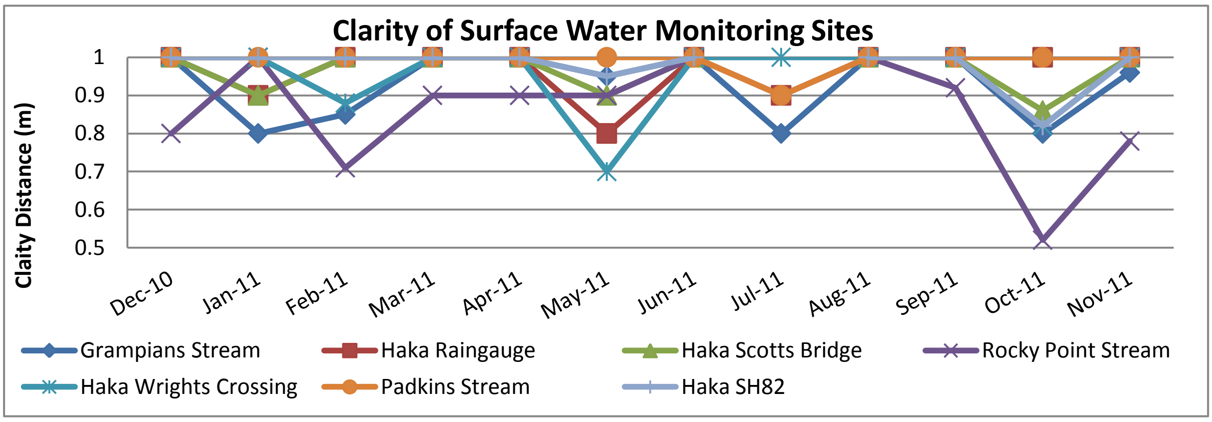


Figure 3. 13 Clarity of the Surface Water Monitoring Sites in the Hakataramea Valley

Temperature

The temperature at the sites was pretty similar throughout the year (***Figure 3.14***). The highest flow volume sites (river sites) did not climb as high and did not get as low as the lower flow volume sites (tributaries). The high readings seen in summer (December 2010) in the tributaries are a cause for concern as these high readings are great enough to start putting considerable pressure on the aquatic life in the waterways by lowering the % saturation of DO, and increasing the risk of algal blooms.

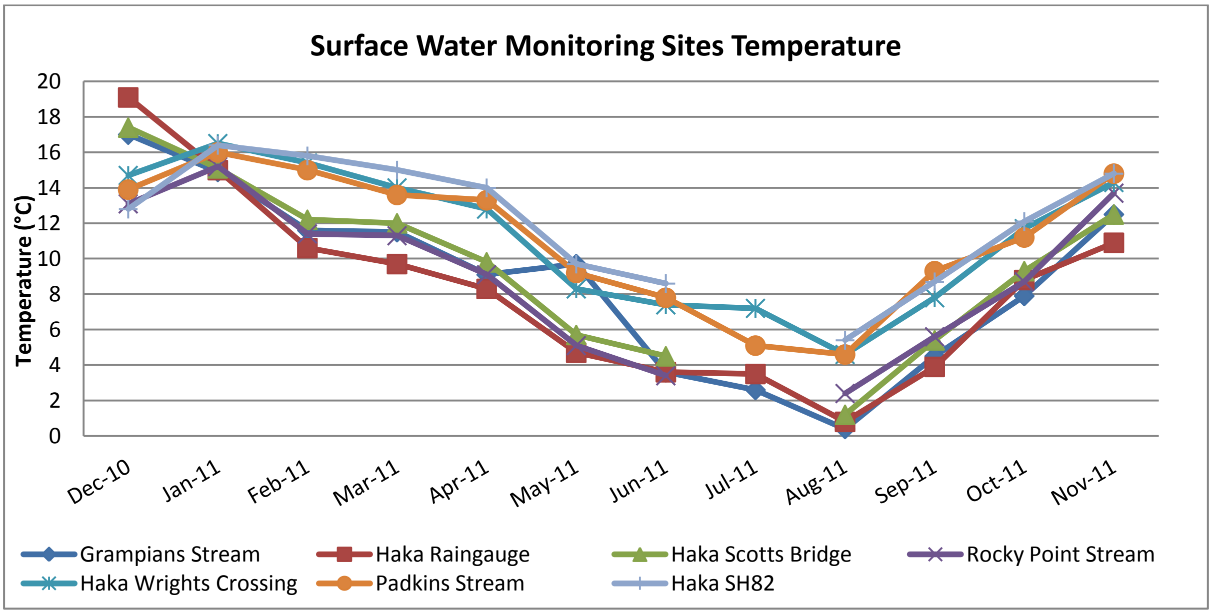


Figure 3. 14 Temperature of the Surface Water Monitoring Sites

Nutrients

Nitrogen Species

The five forms of N monitored were; Total Nitrogen (TN), Dissolved Inorganic Nitrogen (DIN), Oxidised Nitrogen (NO_x) and Total Ammoniacal Nitrogen (TAN), (NO_x comprises nitrate (NO_3) and nitrite (NO_2)). These are all commonly sampled and monitored in NZ waterways. NO_x and TAN are the most significant species where algal and aquatic plant growth is a potential problem. TN is the total concentration of all the N species (***Figure 1.7***); the majority of this is unavailable to plant life and is bound to organic matter. NO_x and TAN are the two forms of N that are commonly available for plant life to absorb. These two forms only account for 2-3% of the TN but are the most important (Fert Research 2007a).

DIN is the total plant available portion of N and is the most important N species when talking about algal and aquatic plant growth. The DIN concentrations in the valley showed a large range. From December 2010 to April 2011 the concentrations were very low with the greatest concentration being 0.048mg/L. From May 2011 on the concentrations increased drastically with the greatest concentration being 0.58mg/L (***Figure 3.15***).

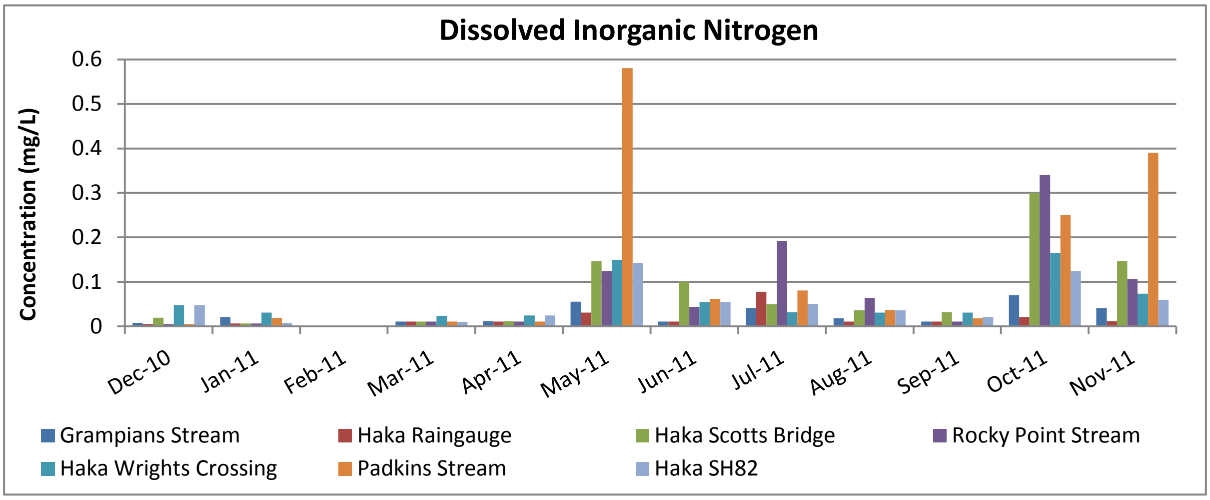


Figure 3. 15 Dissolved Inorganic Nitrogen of the Surface Water Monitoring Sites in the Hakataramea Valley

TN throughout the valley varies during each sampling session with Rocky Point Stream constantly experiencing the highest readings. The high readings are also experienced in the spring time (October and November) with the exception of the May readings (***Figure 3.16***).

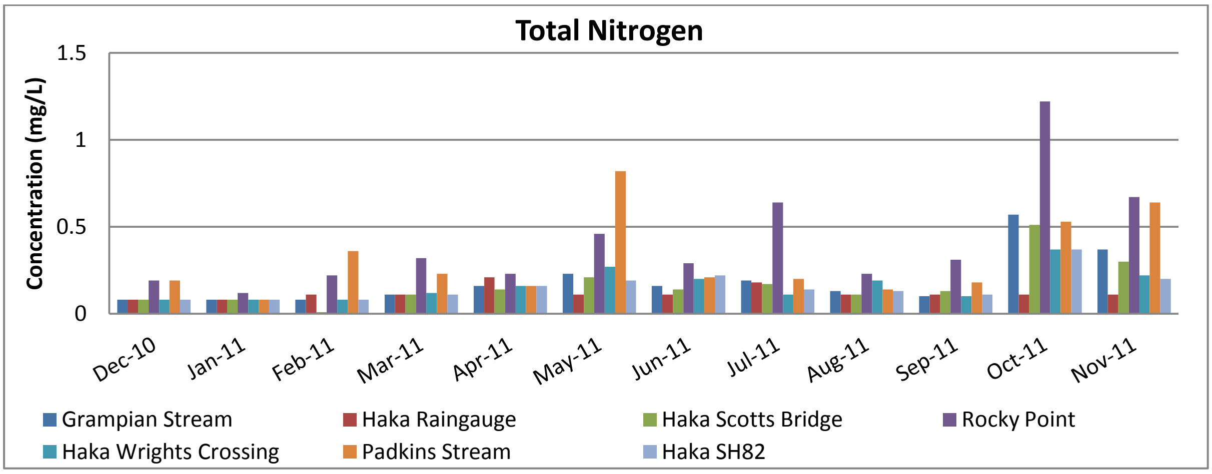


Figure 3. 16 Total Nitrogen of the surface water monitoring sites in the Hakataramea Valley

TAN as stated above is one of the subspecies of DIN that is available to plant life for absorption. TAN can not be studied with too much detail as the laboratories testing them had a detection limit set to the ANZECC guidelines (2000) and for the majority of the time the waterways were under this value (***Figure 3.17***). The only data that can be accurately read off ***Figure 3.17*** are the few readings that exceeded this guideline value (April, July, August, October and November). Four out of the seven values was exceeding the guidelines came from Grampians Stream; this is concerning, as this stream was considered the "good quality" tributary before the study began. The highest readings were from the spring period (October and November).

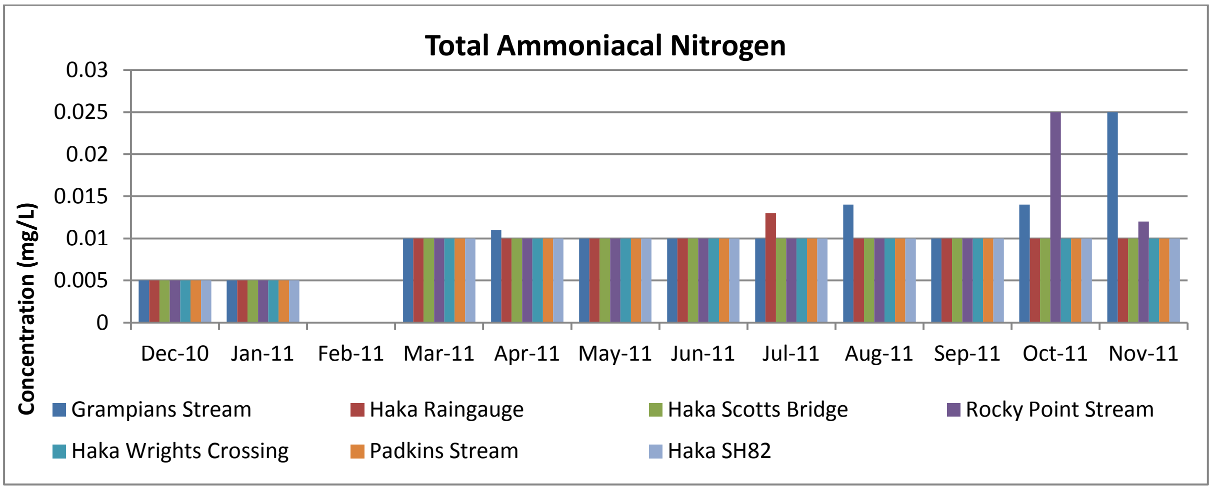


Figure 3. 17 Total Ammoniacal Nitrogen of the surface water monitoring sites in the Hakataramea Valley

The other sub specie of DIN that is available for plant life to absorb is nitrate (NO_3) (***Figure 3.18***). This form of N is very important as it is one of the primary N species that is present in common fertilisers. As with TAN, NO_x can influence the algal and macrophyte growth in waterways. There were three months where abnormally high readings were collected for NO_x, two in spring (October and November) and the other in May.

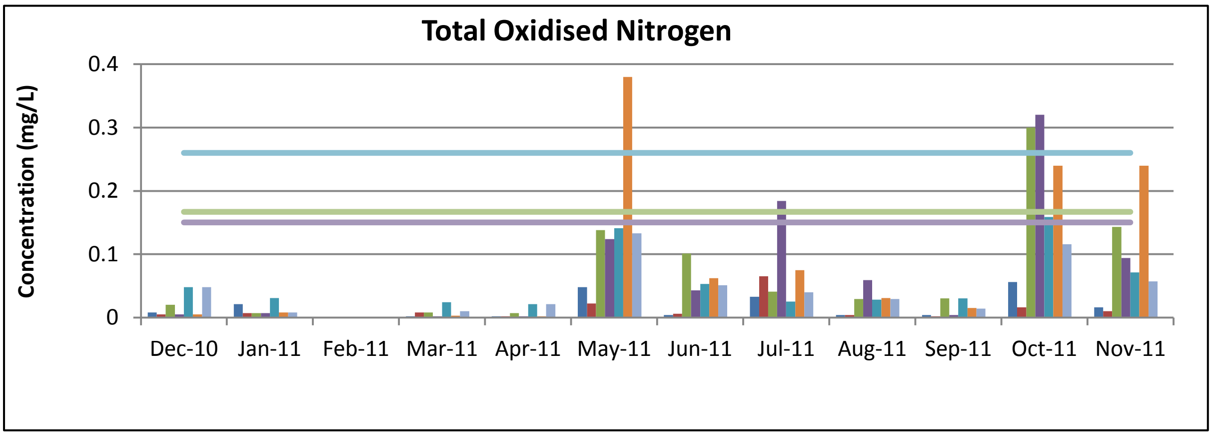


Figure 3. 18 Total Oxidised Nitrogen of the Surface Water Monitoring Sites in the Hakataramea Valley

Phosphorus Species;

Total Phosphorus (TP) and Dissolved Reactive Phosphorus (DRP) were both sampled for. TP is the total quantity of P in the sample. The majority of this is bound to organic matter like N, and only a small portion is available for uptake by plants (McLarren & Cameron, 1990). High readings of TP were experienced at different times of the year (December, January, July, October and November, ***Figure 3.19***). Trends in these high readings do not seem evident at first but when comparing the concentrations with the irrigation season, the majority of the high readings occur in this time (September to March).

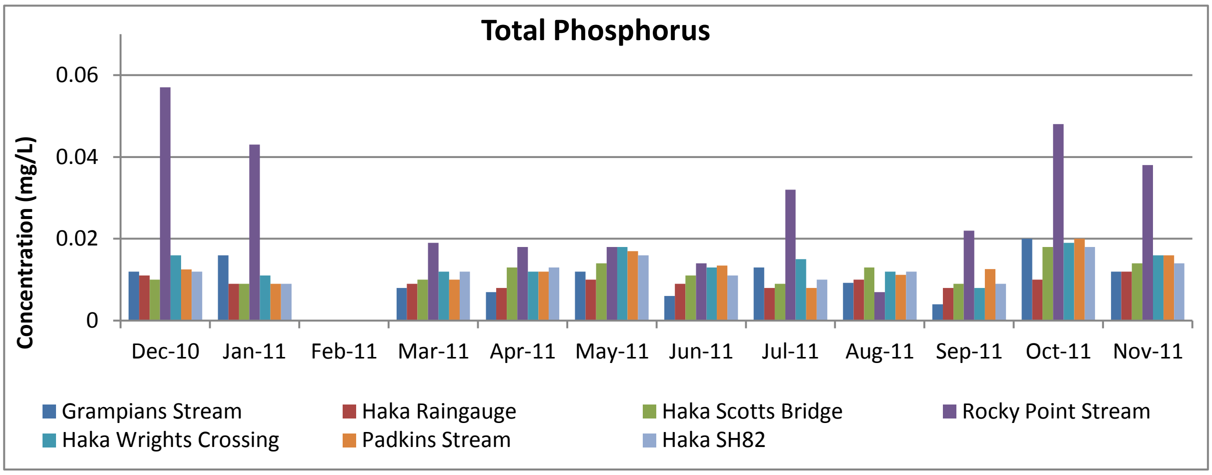


Figure 3. 19 Total Phosphorus of the surface water monitoring sites in the Hakataramea Valley

DRP is a P species that is commonly available to plants for uptake. This form of P is one of the most significant factors in algal and aquatic plant growth and is also commonly found in fertilisers throughout NZ. For this reason it is very important to monitor it. As with TP there are no real trends seen in the high readings of DRP, with the two biggest readings coming in December from Padkins and Rocky Point streams.

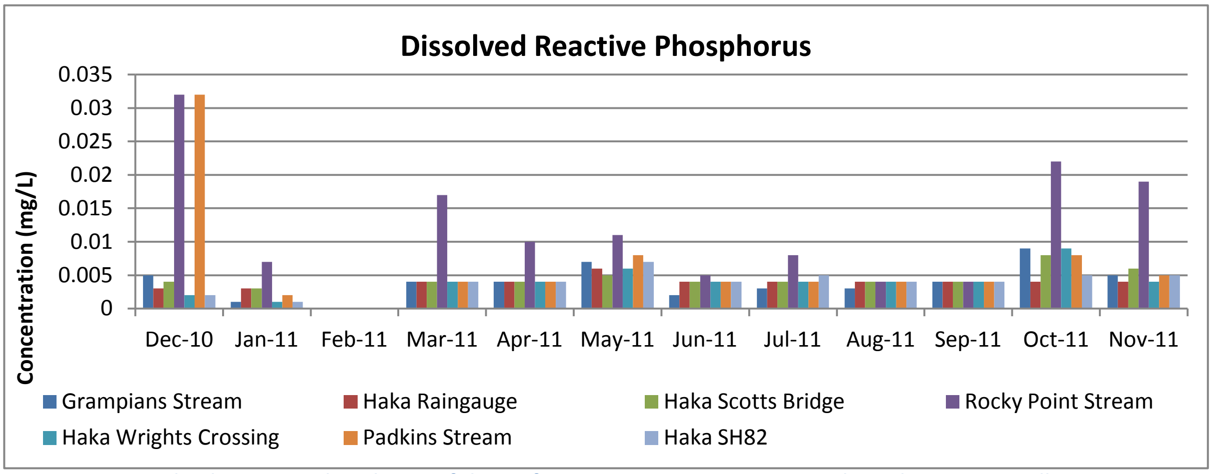


Figure 3. 20 Dissolved Reactive Phosphorus of the surface water monitoring sites in the Hakataramea Valley

Sewage Indicators

E.coli (*Escherichia coli*) is an indicator of faecal matter concentrations in waterways and is therefore a good indicator of stock (animal) interactions with the waterways. E.coli in the valley varies considerably, with the Tributary sites (minus Padkins Stream) experiencing the greatest concentrations. The highest readings are typically seen from late spring through summer (***Figure 3.21***).

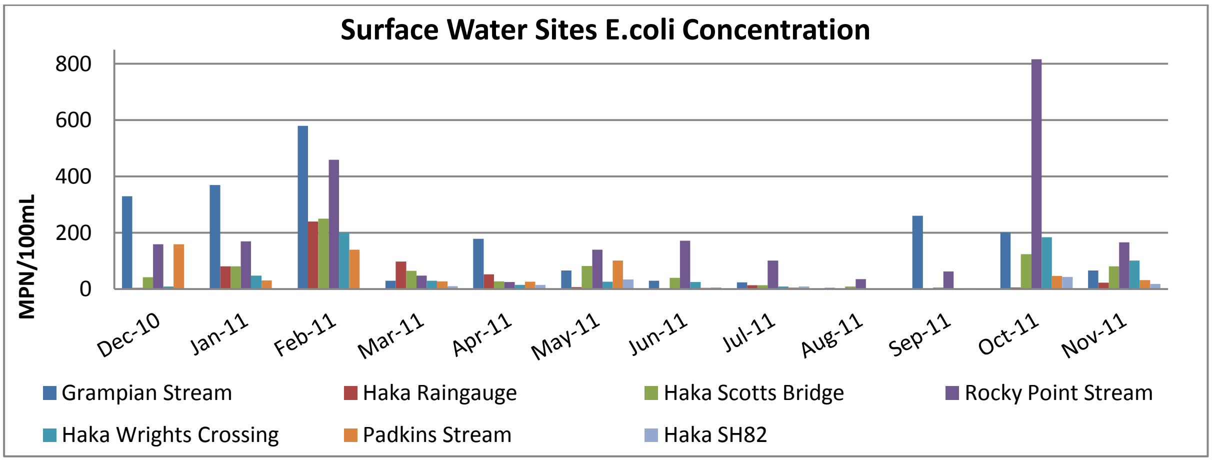


Figure 3. 21 E.coli Concentrations of the Surface Water Monitoring Sites in the Hakataramea Valley

3.2.2 Groundwater

As with the surface water sampling sites the samples collected were sent to the relevant laboratory for analysis. The results were then compiled by the author. Data was collected on *E.coli*, total nitrogen, and total phosphorus monthly from the bores shown in ***Figure 2.9***, and is shown in ***Figures 3.22-3.24***.

TN in the groundwater of the valley is considerably greater than in the surface and varies considerably, with the highest reading being 3.07mg/L (I40/0780) and the lowest reading being 0.08mg/L (I40/0004). All the bores were located in the lower portion of the valley (***Figure 2.9***). No real trends can be easily identified from these graphs, but with a combination of graphs trends can be found.

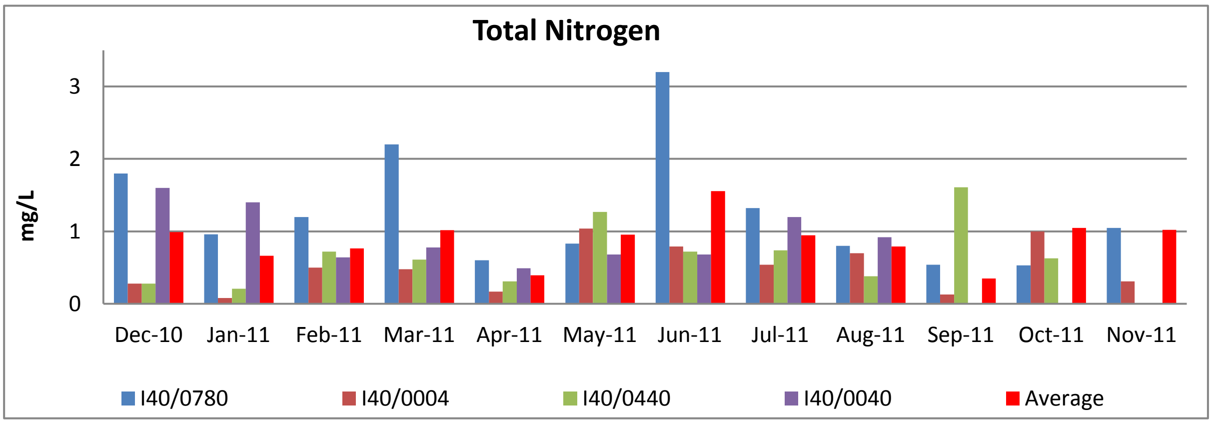


Figure 3. 22 Total Nitrogen of the Groundwater Monitoring Sites in the Hakataramea Valley

"E.coli" in the groundwater varies considerably, between 290MPN/100mL and less than 1MPN/100mL. The highest readings are seen in bores I40/0040 and 0780 and all occur from late spring (October) to late summer (March). Over the winter the readings at all the bores are very low.

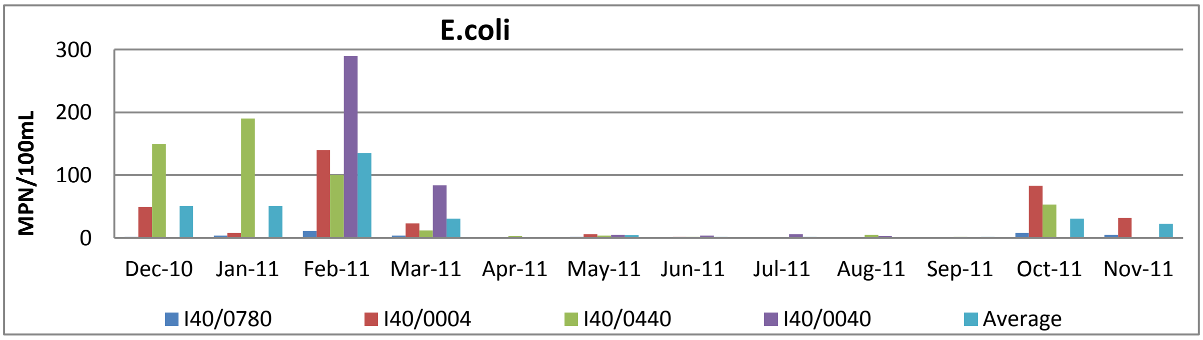


Figure 3. 23 E.coli concentrations of the groundwater monitoring sites in the Hakataramea Valley

The groundwater "TP" experiences a large range in concentrations as does the other groundwater data. The highest readings again come from bore I40/0040 (***Figure 3.24***). No obvious trends can be identified in the data presented other than the average concentrations.

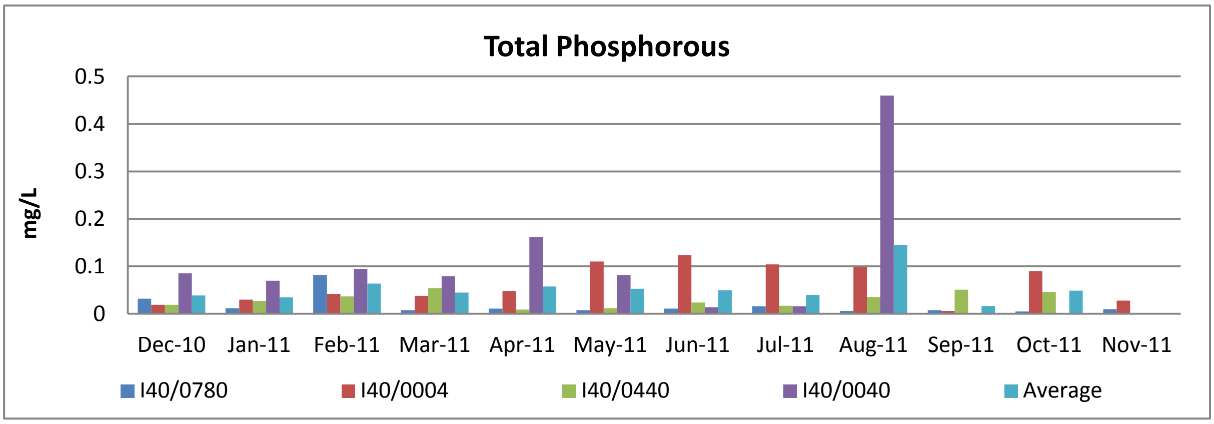


Figure 3. 24 Total Phosphorus at the groundwater monitoring sites in the Hakataramea Valley

3.3 Ecological Monitoring

Quarterly ecological monitoring at seven surface water (four river and three tributary) sites (***Figure 2.1***) included; periphyton percentage covers; fish counts; and macro invertebrate counts. This testing was completed at the same time as the monthly monitoring in; December 2010; March 2011; June 2011; and September 2011. The raw data (***Appendix 3***) was used to calculate; Macroinvertebrate Community Index Score (MCI); Quantitative MCI score (QMCI); percent Ephemeroptera, Plecoptera and Trichoptera (%EPT) groups (mayflies, stoneflies and caddisflies) taxa; percent EPT abundance; total number of taxa; total number of rare taxa and periphyton scores.

3.3.1 MCI

The MCI score refers to the whole macro-invertebrate population, and gives a different score to each of the various taxa depending on their sensitivity to pollution, the higher the score the higher the sensitivity to pollution. A MCI score of <80 indicates poor aquatic health and a score >119 indicates excellent aquatic health (Ministry for the Environment, 2009). The sites monitored show a large range of scores (127 to 73) with the river sites in general having higher scores than the tributaries (***Figure 3.25***). Rocky Point stream is the only stream with low scores; this stream does not have the same bed substrate as the others so cannot be used as a comparison.

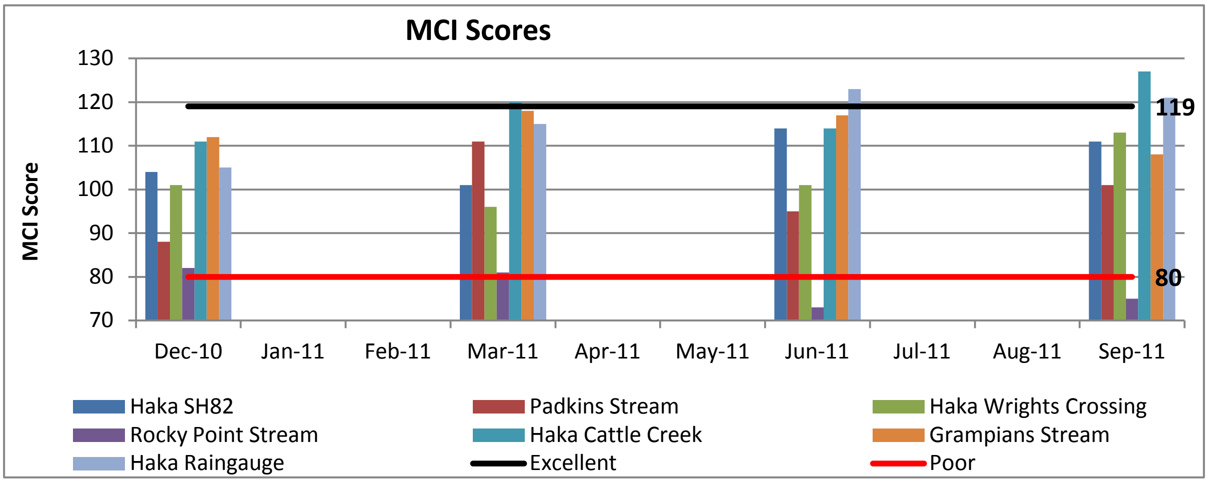


Figure 3. 25 Surface Water Monitoring Sites MCI Scores in the Hakataramea Valley. The Poor and Excellent Values are set using MfE 2009 Guidelines

3.3.2 QMCI Score

This is similar to the MCI score but gives the mean value of the taxa scores, and gives a better indication of the structure of the MCI score. The MCI score may be high but the QMCI (***Figure 3.26***) score may be low, suggesting that there are large numbers of low scoring pollutant resistant taxa in the waterway and the aquatic health is in fact poor. This score is the average score of the sample collected and is found using the equation;

$$QMCI = \sum_{i=1}^{i=s} (n_i * a_i) / N$$

S=total number of taxa in the sample

n_i=abundance of the *i*th scoring taxa in the sample

ai=tolerance scoring value for the *i*th taxon

N=total number of taxa in the sample (Stark & Maxted, 2007)

The scores range from 0 (extremely poor quality with nothing living) to 10 (excellent quality with a large number of pollution sensitive taxa present). All the surface water monitoring sites in the valley (minus Rocky Point stream) fall above the poor value set by the MfE in 2009. The excellent value was surpassed 12 times, with the majority of these being from the river sites. The readings in December (2010) were on average lower than the other three monitoring periods.

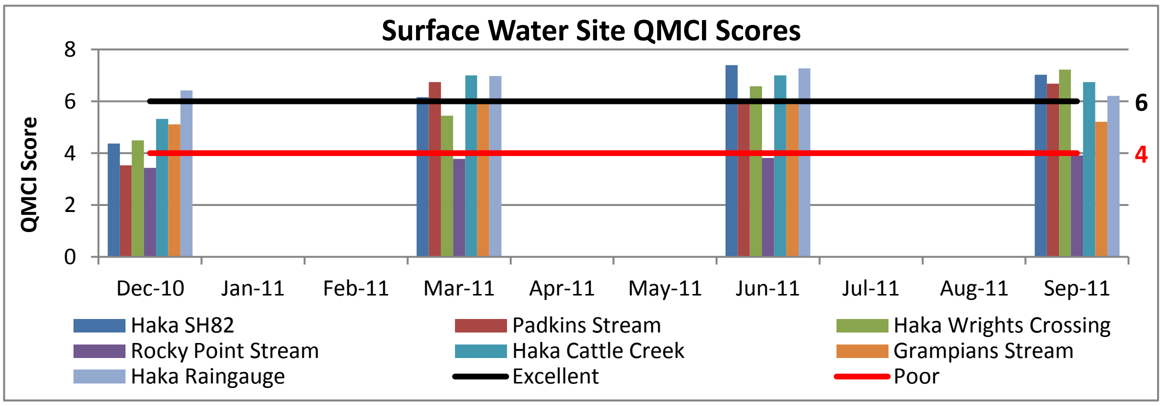


Figure 3. 26 Surface Water Monitoring Sites QMCI Scores in the Hakataramea Valley

3.3.3 %EPT taxa (Ephemeroptera, Plecoptera, and Trichoptera)

The percent EPT taxa assesses the most sensitive macro-invertebrate groups; Ephemeroptera (mayflies), Plecoptera (Stoneflies), and Trichoptera (Caddisflies). A low

%EPT indicates poor aquatic health and a high %EPT indicates good aquatic health (Ministry for the Environment, 2009). The Hakataramea Valley comprises a large range of scores from 21.05%EPT to 66.67%EPT, with the highest scores generally seen in the river monitoring sites and the lowest scores seen in Rocky Point stream. This stream has a soft bottom and has a limited suitability for the EPT taxa.

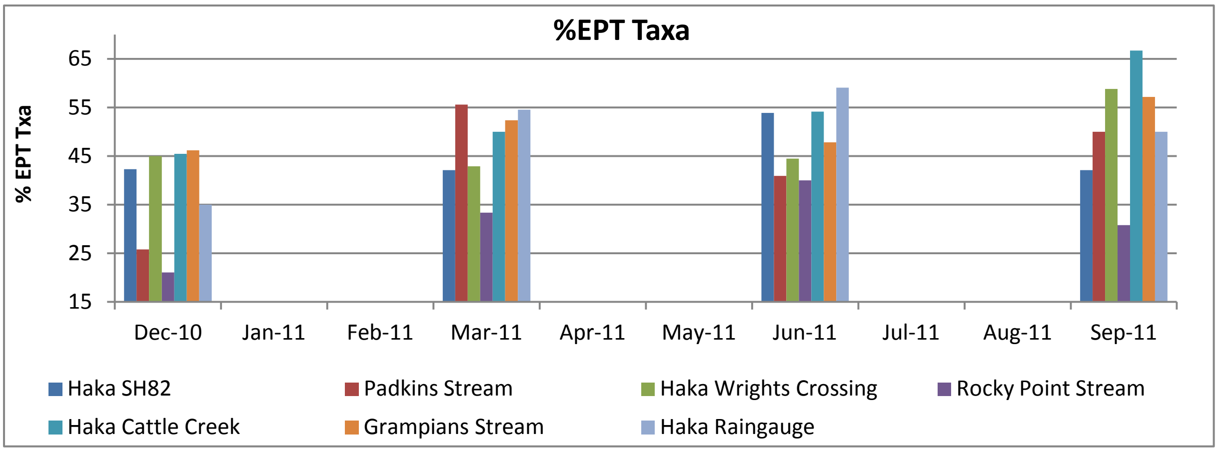


Figure 3. 27 % EPT Taxa of the surface water monitoring sites in the Hakataramea Valley

The %EPT abundance is similar to the %EPT but shows how abundant these taxa are in each sample. This version is easier to relate back to the MCI score and gives a good indication of how many EPT taxa are actually present.

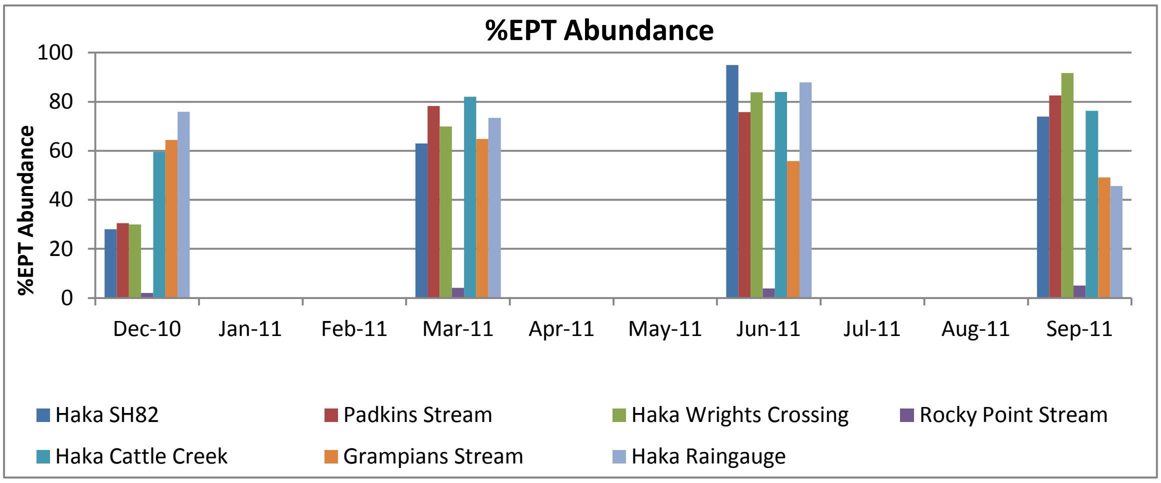


Figure 3. 28 Surface Water Monitoring Sites % EPT Abundance

3.3.4 Total number of taxa and Rare taxa

The total taxa is the number of taxa that make up the MCI score per sample. This is not ideal for determining aquatic health as there may be large numbers of pollutant resistant taxa present. Padkins stream experiences the highest reading but the MCI score is not the highest, so this indicates that pollutant resistant taxa are abundant.

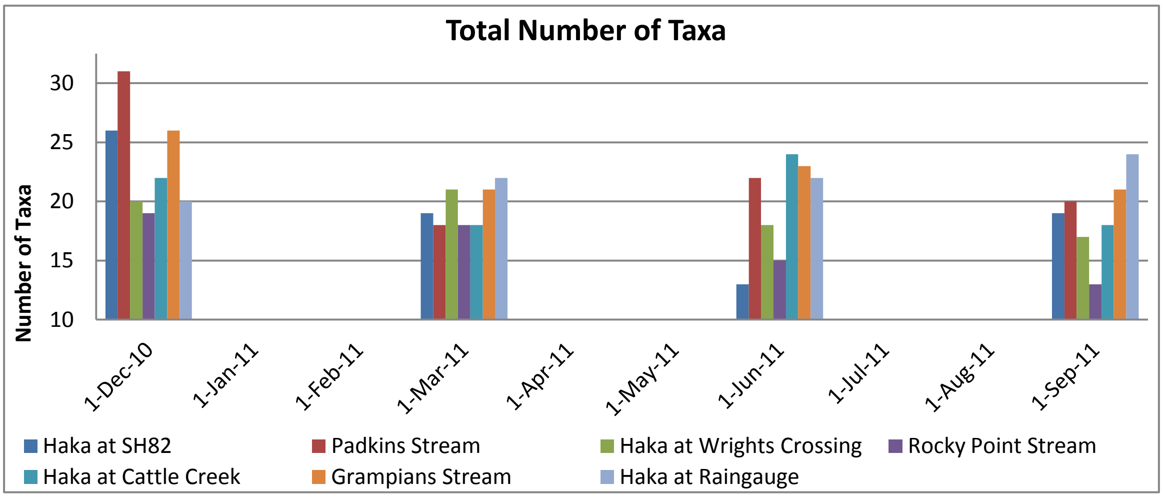


Figure 3. 29 Total Number of Taxa at the surface water monitoring sites in the Hakataramea Valley

The total number of rare taxa is better for determining the aquatic health of waterways as these taxa are sensitive to pollutants. The highest number of rare taxa coincides with the highest QMCI scores.

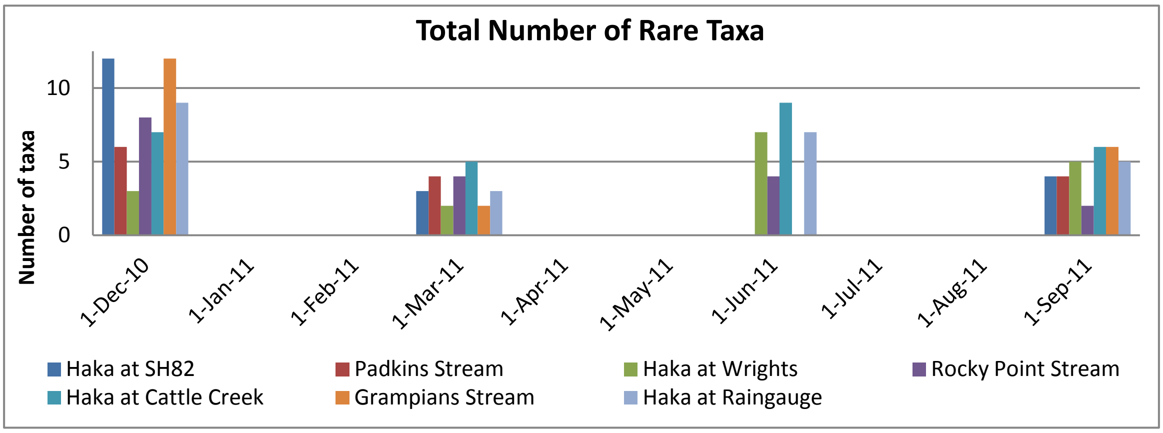


Figure 3. 30 Surface Water Monitoring Sites Total Number of Rare Taxa

This method of assessing aquatic health can be more accurate than chemical water quality testing in certain instances, as it allows assessment of what has occurred over a longer time period, and not just at a single point in time.

3.4 Soil Testing

Soil sampling was carried out on the western side of the river, where 90% of the foreseeable future irrigation will be added in the valley, at nine sites (***Figure 2.10*** and ***Table 3.1***).

Two sites were irrigated, one was naturally damp and farmed as if it was irrigated, and the rest were current dry land sites.

Table 3. 1 Name and Corresponding Abbreviations of the Soil Sampling Points in the Hakataramea Valley

Dry Immature Pallic	**Dry IP**
Dry Middle Fragic Pallic	**Dry Mid FP**
Dry Argillic Pallic	**Dry AP**
Irrigated Fragic Pallic	**Irr FP**
Dry Upper Fragic Pallic	**Dry UFP**
Dry Lower Fragic Pallic	**Dry LFP**
Semi Dry Orthic Brown	**Semi Dry OB**
Irrigated Immature Pallic	**Irr IP**
Dry Orthic Gley	**Dry OG**

Dryland site farmed as if it was irrigated

By sampling soils from each land use (irrigated and un-irrigated) a time specific insight into how the soils react to irrigation was found. Analysis was carried out on pH, soil moisture, bulk density, plant available N (ammonium and nitrate using the modified KCl extraction test) and plant available P (using the Olsen P test).

Plant available phosphorus was extensively tested for, but due to the limited irrigation in the valley a comprehensive comparison between un-irrigated and irrigated land was unable to be made. This was the same for nitrate-nitrogen (not tested for extensively due to this) which was taken at three points (Dry IP, Dry UFP and Semi Dry OB) throughout the valley to get a base level.

3.4.1 Plant Available P (Olsen P)

The plant available P was calculated from the P in the extraction following the method of Blakemore et. al. (1987) using the equation;

$$\text{Olsen P}(\mu\text{g/g}) = \mu\ \text{P/mL}\,(\text{in extract}) \times 20 \times 1.08$$

(Blakemore, et al., 1987)

There is a large range of Olsen P levels in the valley with the highest reading being 22.23 and the lowest being 7.49 (***Figure 3.31***). The highest Olsen P levels came from the lower valley and irrigated sites; this was expected as these areas are more intensely farmed.

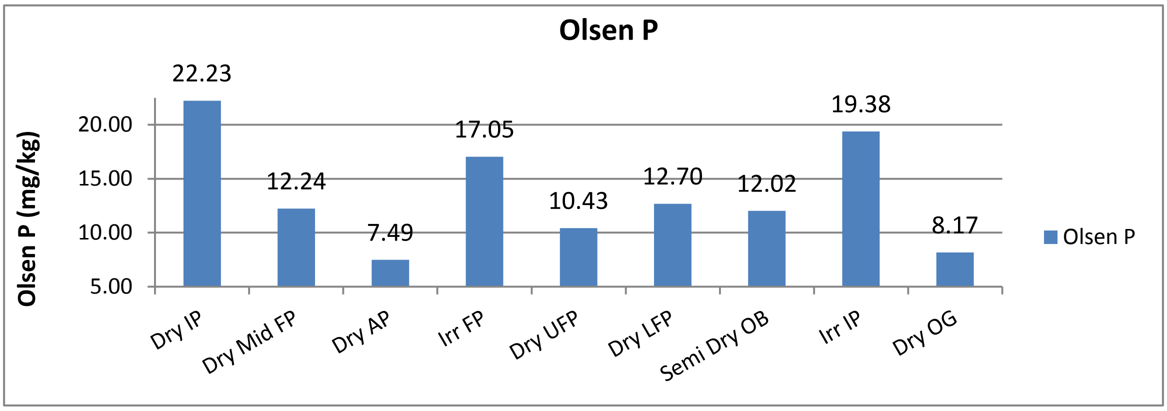


Figure 3. 31 Olsen P Levels at the Soil Sampling Sites in the Hakataramea Valley.

3.4.2 Plant Available Nitrogen (Ammonium and Nitrate)

Plant available N refers to the amount of N that is available for plant life to absorb and is made up of ammonium and nitrate; this is typically 1-2 % of the total nitrogen (Mclaren & Cameron, 1990).

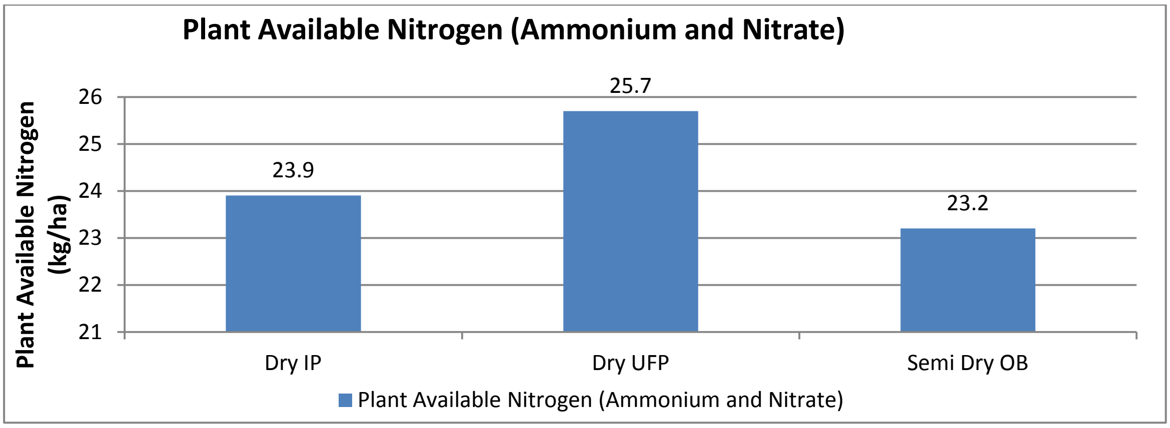


Figure 3. 32 Plant Available Nitrogen of the Soil Sampling Sites in the Hakataramea Valley

The levels of plant available N (ammonium and nitrate) ranged from 23.2 to 25.7kg/ha, these levels were expected in the Hakataramea valley (***Figure 3.32***). In New Zealand a typical plant available N concentration is between 10 and 250 kg/hectare depending on the land use, farm location and climate. (NZFMA Ltd, 1999). The samples collected from the valley are at the low end of this range. The mg/kg readings can be converted to mg/hectare using the equation;

$$N\ (kg\ per\ ha) = N\ (mg\ per\ kg) \times BulkDensity\ (0.98) \times \left(\frac{soil\ depth\ (15cm)}{10}\right)$$

(Australian Centre for International Agricultural Research, 2002)

3.4.3 Other Soil Parameters

Soil pH, moisture, bulk density and total porosity parameters were collected. This data influences soil productivity and are the physical properties required for OVERSEER modelling.

3.4.4 pH

In NZ and Canterbury, the optimum pH level for pasture growth is between 5.8 and 6.0 (Allan, 2007). In the Hakataramea Valley there were three sites where the pH levels were below 5.8 and one above 6.0. The low pH sites came from sites that, had been indicated by the farmers prior to sampling, and were due a lime application of 5 to 10 tonne/ha, to raise the soil pH by 0.5-1 unit, within the next year (Land Resource Inventory, 2011). The opposite is also true for the high reading site. This site had undergone a lime application within the last three months.

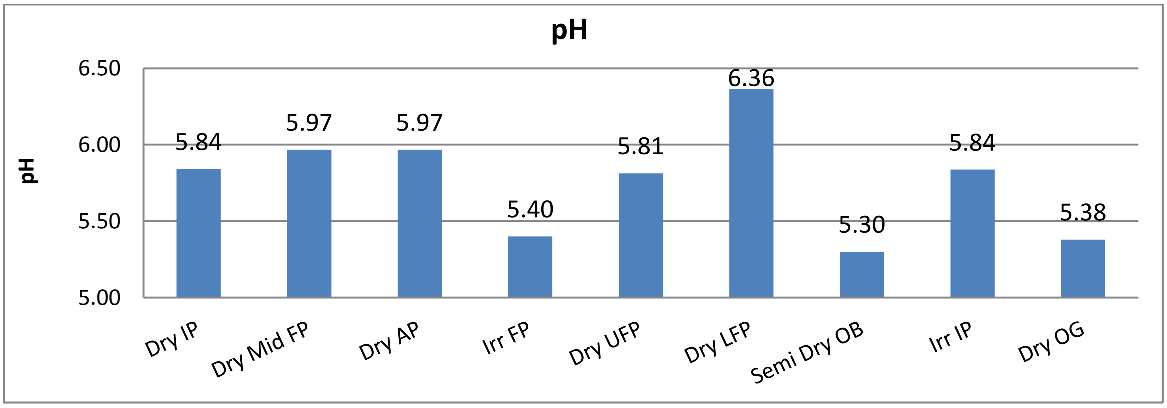


Figure 3. 33 pH Readings from the soil sampling sites in the Hakataramea Valley

3.4.5 Soil Water Content

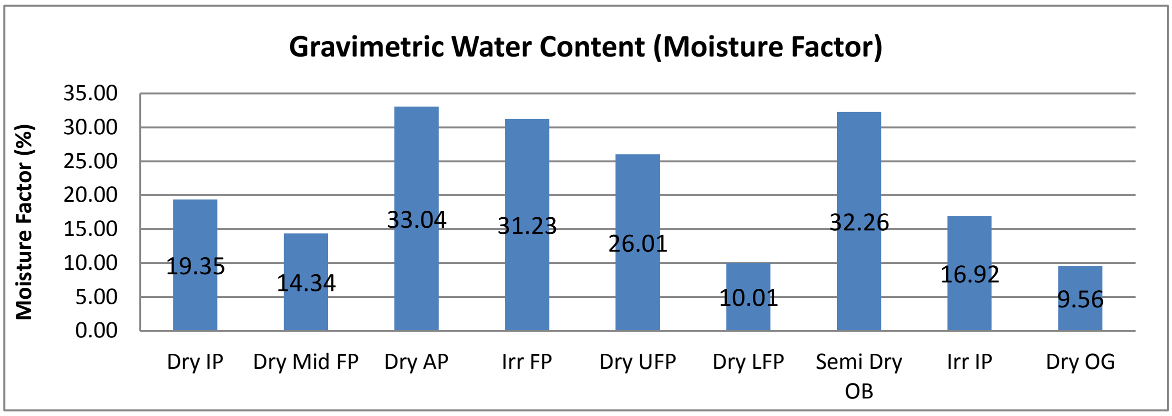


Figure 3. 34 Soil Gravimetric Water Content of the Samples collected in the Hakataramea Valley

The gravimetric soil water content is the percentage of a sample that is occupied by water. It is found by weighing a moist field sample, drying the sample and then reweighing it, this is also known as the moisture factor. There is no difference between the irrigated and non irrigated sites (***Figure 3.34***) because the samples were collected at the end of July and the soils had not been irrigated for three months. For optimum plant growth to take place a gravimetric water content of 15-30 % is required. This depends on the type of soil, as it is best to have this value below the field capacity and above the wilting level (Zotarelli, et al., 2010).

3.4.6 Bulk Density Data

For plant growth to be unobstructed in soils, a bulk density of less than 1.4g/cm^3 is targeted. If the bulk density is higher, it becomes hard for plant roots to expand, no sites are too high. If the value is too low (Dry IP and Irr FP), it becomes hard for the plant to absorb adequate levels of nutrients (United States Department of Agriculture, 2008).

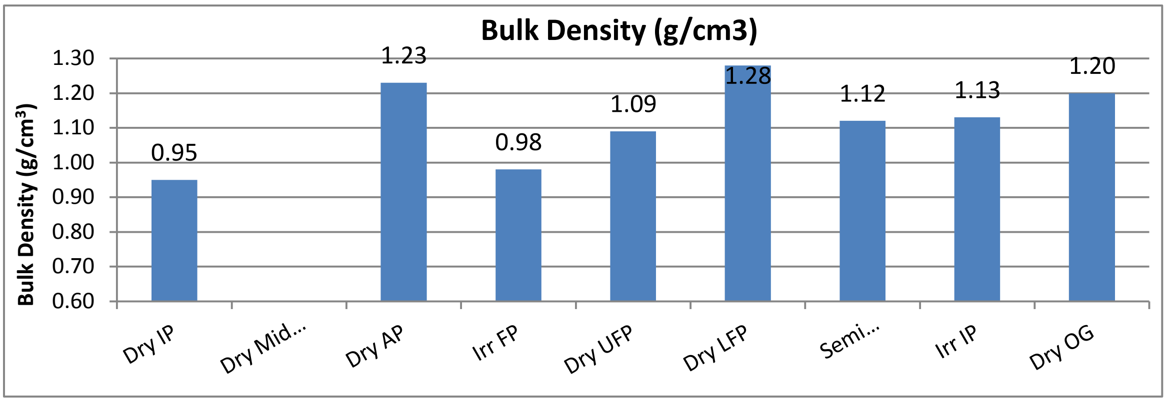


Figure 3. 35 Bulk Densities of the Soil sampling sites in the Hakataramea Valley.

The bulk densities of the Hakataramea Valley soils collected were all relatively low at 0.95 – 1.28g/cm^3 with the average bulk density for NZ being 0.9-1.3 g/cm^3 (Sparling, et. al, 2008). These values are low compared to the values presented by Sparling, et al (2008) in ***Table 3.2***.

Table 3. 2 Typical Bulk Densities of NZ Soils (Sparling, et al., 2008)

Typical Bulk Density Ranges of NZ Soils (g/cm^3)						
Soil Type	Very Loose	Loose	Adequate	Semi Compact	Compact	Very Compact
Semiarid, Pallic, Recent	0.3	0.7	0.9	1.3	1.4	1.6

3.4.7 Total Porosity

Total porosity is a measure of the total pore space of a soil sample. This pore space is the area that is available for water to occupy and indicates how water passes through the soil and how well the soil holds water. A higher total porosity can (at times during rain periods) indicate higher gravimetric water contents.

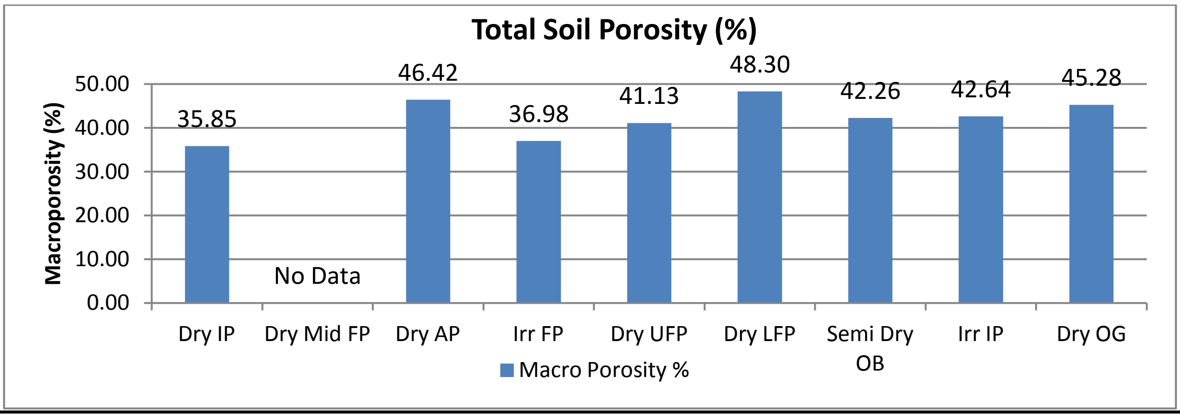


Figure 3. 36 Total Soil Porosity of the soil samples collected from the Hakataramea Valley

The total soil porosity of the soils sampled ranged from 35.85 - 48.30 %. Typical porosity values for soil materials range anywhere from 25-70% (Freeze & Cherry, 1979). The soils of the Hakataramea Valley fit within the expected range for silty to fine sand soils (***Table 3.3***).

Table 3. 3 Typical Soil Total Porosity Ranges for New Zealand Soils (Freeze & Cherry, 1979)

Material	Total Porosity Values (%)
Gravel	25-40
Sand	25-50
Silt	35-50
Clay	40-70
Shale	0-10
Sandstone	5-30

This is important as it gives vital information needed for modelling of the valley with added irrigation. This will ultimately dictate how the soil nutrients in the valley will react to higher moisture levels.

3.5 Land Resource Inventory

A land resource inventory (LRI valley questionnaire) was carried out during the terms of consent study by Irricon Resource Solutions to gain a basic understanding of the stock types and numbers, fertiliser application rates and frequency, property sizes, crop and grass types, and environmental concerns about each property and/or the valley. This data is needed in the OVERSEER modelling.

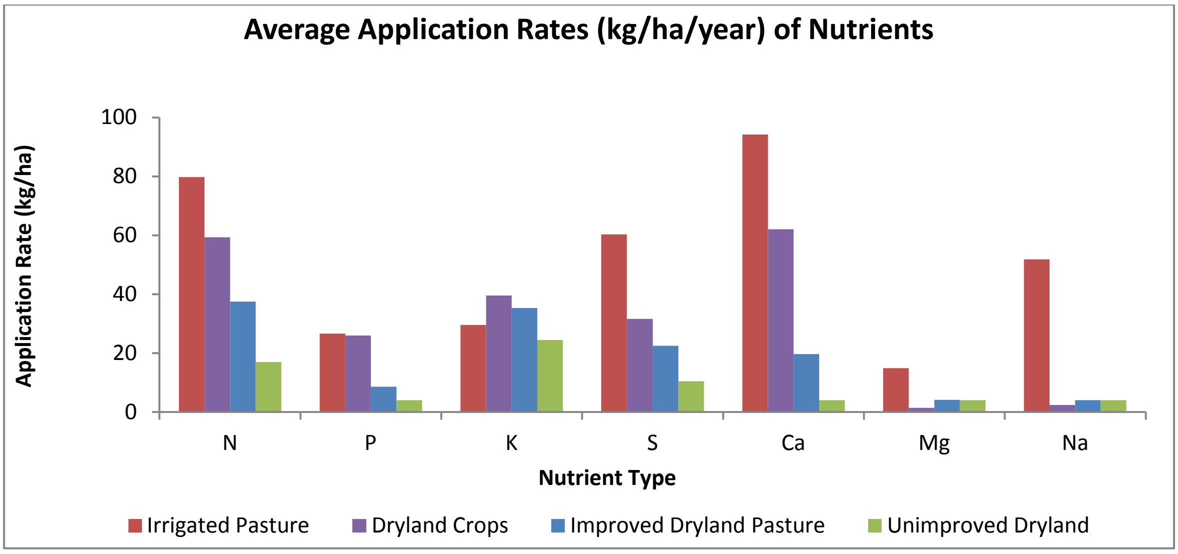


Figure 3. 37 Average Application Rates of Nutrients for Different Land Use Types in the Hakataramea Valley

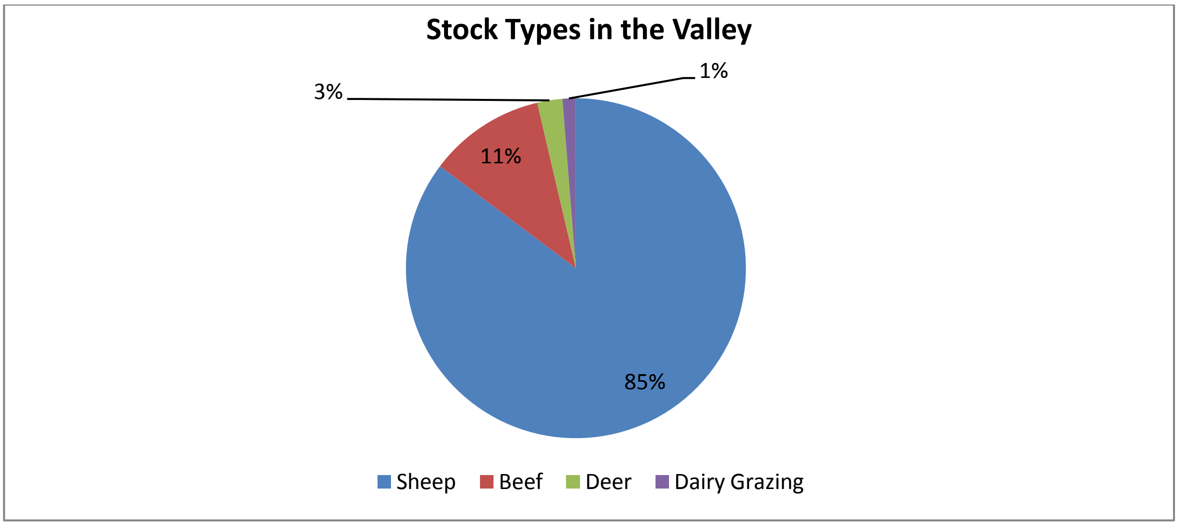


Figure 3. 38 Percentage Distribution of Each Stock Type in the Valley

Land use in the valley is dominated by sheep (85%) with beef being the second most common stock type (***Figure 3.38***). This is typical of a pastoral high/hill country setting in New Zealand.

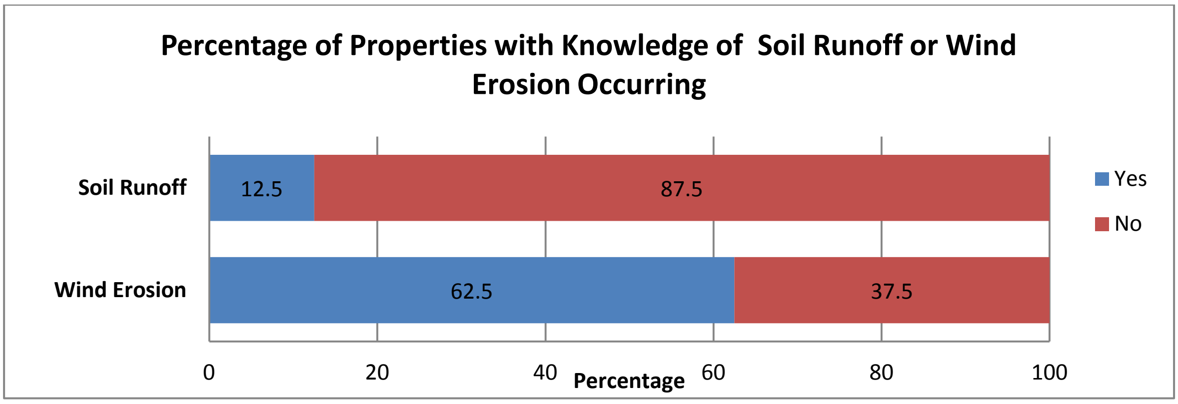


Figure 3. 39 Percentages of Properties Surveyed with Knowledge of Soil Runoff or Wind Erosion

In response to a question about various erosion types on the properties in the catchment it was indicated that wind erosion is the biggest problem (***Figure 3.39***). The integrity of these responses can be questioned as it was following on from a question on irrigation and most farmers realise that wind erosion can be minimised with irrigation but soil runoff can be enhanced.

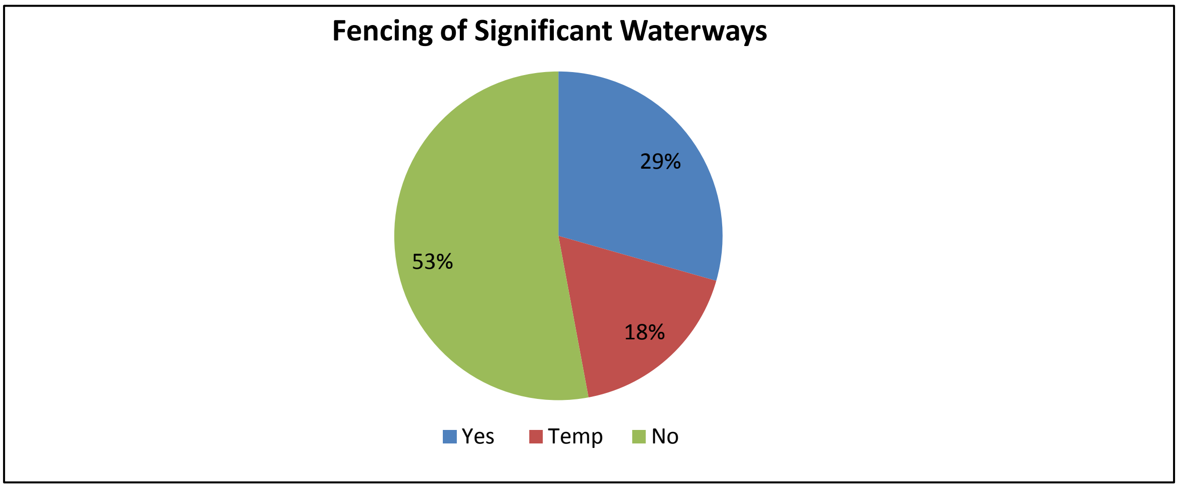


Figure 3. 40 Fencing of Waterways within the Hakataramea Valley

The degree of fencing along significant waterways is shown in ***Figure 3.40***. A significant waterway was defined as one that flows for the majority of the year and not just after a high rainfall event, and has some degree of natural appeal to it. From both site visits and this survey it was evident that the majority of the significant waterways were unfenced.

The number of unfenced waterways is likely to decrease with the addition of irrigation as stock will access water for from a stock water system. It is also in the consent conditions for the properties that are going to be receiving irrigation that the waterways be fenced.

3.6 OVERSEER Modelling

By modelling potential future irrigation and farming scenarios in the valley it becomes possible to predict future water quality in the river and tributaries. Chapter 2 describes how and why each scenario was chosen. The modelling gave outcomes that included nutrients lost to water and atmosphere, and the change in soil pools. The soil pools display the change in amount of nutrients found in the soil. Higher changes result in higher nutrient concentrations and ultimately higher loss of nutrients to water.

3.6.1 Scenario Assessment

Scenario 1 (Current) - Dry land sheep grazing across the entire valley

Table 3. 4 Scenario 1 – Dry land sheep grazing across the valley nutrient budget

Kg/ha/yr	N	P	K	S	Ca	Mg	Na
Nutrients Added							
Fertiliser, lime & other	3	8	15	15	18	4	4
Rain/clover N fixation	11	0	1	2	1	1	3
Irrigation	0	0	0	0	0	0	0
Nutrients Removed							
As Products	1	0	0	0	0	0	0
Exported Effluent	0	0	0	0	0	0	0
As supplements and crop residues	0	0	0	0	0	0	0
To atmosphere	3	0	0	0	0	0	0
To water	2	0	4	16	9	1	1
Change in Scenario Pools							
Standing Plant Material	0	0	0	0	0	0	0
Organic pool	9	5	0	1	0	0	0
Inorganic mineral	0	0	-20	0	-1	-2	-2
Inorganic soil pool	0	3	32	0	11	6	8

Scenario 2 (Current) - Mixed dry land sheep and beef grazing across the entire valley

Table 3. 5 Scenario 2 - Mixed dry land sheep and beef grazing across the valley nutrient budget

Kg/ha/yr	N	P	K	S	Ca	Mg	Na
Nutrients Added							
Fertiliser, lime & other	3	8	15	15	18	4	4
Rain/clover N fixation	19	0	1	2	1	1	3
Irrigation	0	0	0	0	0	0	0
Nutrients Removed							
As Products	2	0	0	0	0	0	0
Exported Effluent	0	0	0	0	0	0	0
As Supplements and crop residues	0	0	0	0	0	0	0

To atmosphere	7	0	0	0	0	0	0
To water	2	0	5	16	9	1	1
Change in Scenario Pools							
Standing Plant Material	0	0	0	0	0	0	0
Organic Pool	11	6	0	1	0	0	0
Inorganic mineral	0	0	-20	0	-1	-2	-2
Inorganic soil pool	0	4	32	0	11	6	8

Scenario one and two are very similar with the only difference being the stock types, stocking rates and nutrient input. These two scenarios are considered to be the current situation in the valley. These two scenarios indicate that there is likely to be very little nutrient runoff into waterways as the nutrients lost to water are near zero. The inorganic soil pools are the most significant as they include plant available forms of nutrients. The levels experienced in scenarios 1 and 2 are within acceptable guideline values incorporated in the OVERSEER programme.

Scenario 3 – Irrigated lower valley with mixed sheep and beef grazing, while the upper valley remains dry

Table 3. 6 Scenario 3 - Irrigated lower valley with mixed sheep and beef grazing, while the upper valley remains dry

Kg/ha/yr	N	P	K	S	Ca	Mg	Na
Nutrients Added							
Fertiliser, lime & other	23	19	25	25	54	10	30
Rain/clover N fixation	53	0	1	2	1	1	3
Irrigation	7	0	5	7	28	7	28
Nutrients Removed							
As Products	4	0	0	1	0	0	0
Exported Effluent	0	0	0	0	0	0	0
As supplements and crop residues	0	0	0	0	0	0	0
To atmosphere	17	0	0	0	0	0	0
To water	3	0.1	6	33	10	1	1
Change in Scenario Pools							
Standing plant material	0	0	0	0	0	0	0
Organic pool	60	8	0	1	0	0	0
Inorganic mineral	0	2	-18	0	-1	-2	-2
Inorganic soil pool	0	9	42	0	70	18	62

Scenario 4 - Irrigated lower valley with beef and dairy grazing while the upper valley remains dry mixed sheep and beef grazing

Table 3. 7 Scenario 4 - Irrigated lower valley with beef and dairy grazing while the upper valley remains dry mixed sheep and beef grazing

Kg/ha/yr	N	P	K	S	Ca	Mg	Na
Nutrients Added							
Fertiliser, lime & other	23	25	28	30	54	10	30
Rain/clover N fixation	79	0	1	2	1	1	3
Irrigation	7	0	5	7	28	7	28
Nutrients Removed							
As Products	4	0	0	1	0	0	0
Exported Effluent	0	0	0	0	0	0	0
As supplements and crop residues	0	0	0	0	0	0	0
To atmosphere	24	0	0	0	0	0	0
To water	3	0.1	7	37	10	1	1
Change in Scenario Pools							
Standing plant material	0	0	0	0	0	0	0
Organic pool	70	9	0	1	0	0	0
Inorganic mineral	0	2	-17	0	-1	-2	-2
Inorganic soil pool	0	12	44	0	74	18	62

Scenario 3 and 4 are the most plausible future irrigation scenarios presented, splitting the valley into a lower irrigated area and upper dry area. These scenarios show that with the irrigation changes in the lower valley there are more nutrients lost to the atmosphere and water (***Tables 3.6 & 3.7***). These levels are still high (with the exception of S) but have certainly increased from scenarios 1 and 2. The inorganic soil pools of both these scenarios have increased, this has the potential to allow further nutrients to be lost to water via runoff or wind erosion.

Scenario 5 - Irrigated upper and lower valley with mixed sheep and beef grazing

Table 3. 8 Scenario 5 - Irrigated upper and lower with mixed sheep and beef grazing across the valley

Kg/ha/yr	N	P	K	S	Ca	Mg	Na
Nutrients Added							
Fertiliser, lime & other	42	27	32	30	98	17	56
Rain/clover N fixation	50	0	1	2	1	1	3
Irrigation	11	0	7	11	42	10	43
Nutrients Removed							
As Products	3	0	0	1	0	0	0

Exported Effluent	0	0	0	0	0	0	0
As supplements and crop residues	0	0	0	0	0	0	0
To atmosphere	20	0	0	0	0	0	0
To water	6	0.3	6	41	12	1	1
Change in Scenario Pools							
Standing plant material	0	0	0	0	0	0	0
Organic pool	74	9	0	1	0	0	0
Inorganic mineral	0	2	-16	0	-1	-2	-2
Inorganic soil pool	0	15	50	0	128	29	102

Scenario 6 - Irrigated upper and lower valley with beef and dairy grazing

Table 3. 9 Scenario 6 - Irrigated upper and lower valley with beef and dairy grazing

Kg/ha/yr	N	P	K	S	Ca	Mg	Na
Nutrients Added							
Fertiliser, lime & other	42	27	32	35	98	17	56
Rain/clover N fixation	75	0	1	2	1	1	3
Irrigation	11	0	7	11	42	10	43
Nutrients Removed							
As Products	0	0	0	0	0	0	0
Exported Effluent	0	0	0	0	0	0	0
As supplements and crop residues	0	0	0	0	0	0	0
To Atmosphere	27	0	0	0	0	0	0
To water	8	0.3	7	47	14	1	1
Change in Scenario Pools							
Standing plant material	0	0	0	0	0	0	0
Organic pool	93	10	0	1	0	0	0
Inorganic mineral	0	2	-16	0	-1	-2	-2
Inorganic soil pool	0	17	50	0	129	29	102

Scenario 5 and 6 are provided to show how much the nutrient balance of the valley would change if irrigation became a common feature. These levels of nutrients lost to water could definitely pose a significant risk to the health of the waterways in the valley. The inorganic soil pools have both risen significantly and pose a risk for soil runoff and wind erosion.

3.6.2 Nutrients Lost to Water

All nutrients have increased across the scenarios presented (***Figure 3.41 – 3.43***, except Mg and Na) with the two most significant changes (not necessarily the biggest) coming in the form of N and P. These two nutrients are the dominant nutrients in determining water quality and aquatic health. The largest change was experienced in sulphate. Sulphate does not pose the same risk to the waterways in the valley but can at times contribute to increases in nutrients such as N and P by increasing the mobilisation of these nutrients.

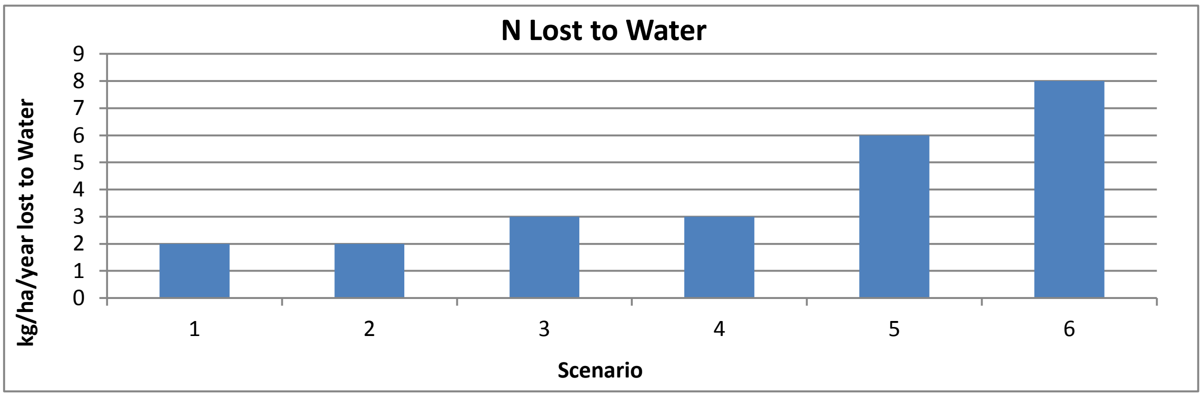


Figure 3. 41 Nitrogen Lost to Water after Modelling of Each Scenario

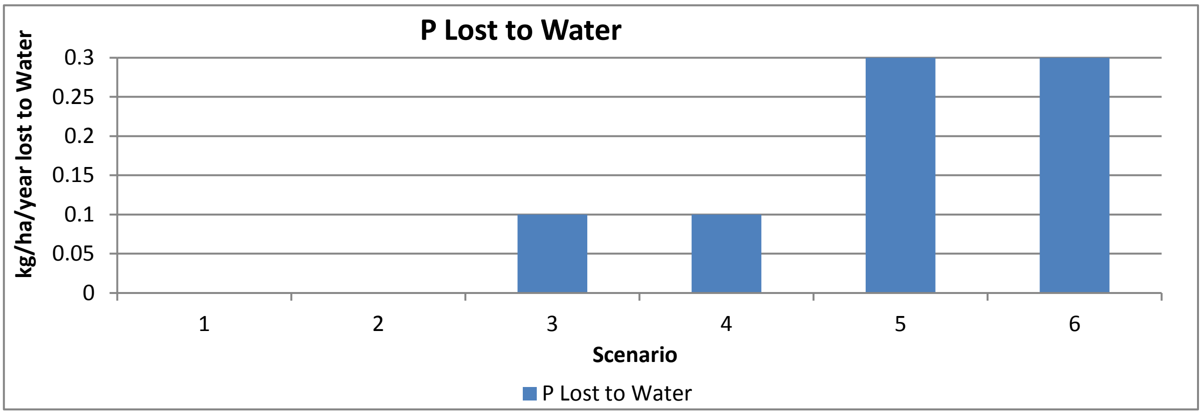


Figure 3. 42 Phosphorus Lost to Water after Modelling of Each Scenario

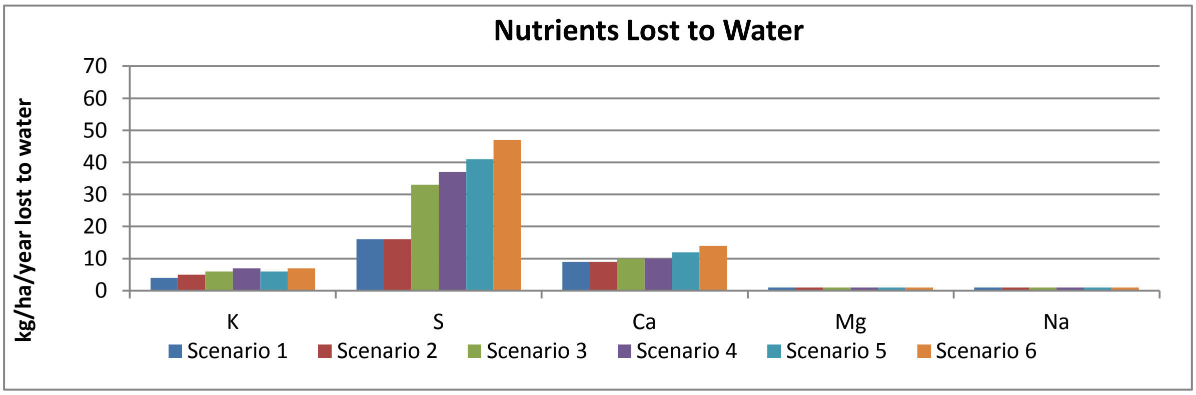


Figure 3. 43 K, S, Ca, Mg, Na Lost to Water after Modelling of Each Scenario

3.6.3 Changes to Soil

Both the organic (***Figure 3.44***) and inorganic soil nutrients pools (***Figure 3.45***) have increased throughout the scenarios. The most significant soil pool is the inorganic soil pool; this includes the plant available fractions of the nutrients. This soil pool has experienced the largest changes of the two with the most environmentally detrimental changes being in the form of N and P.

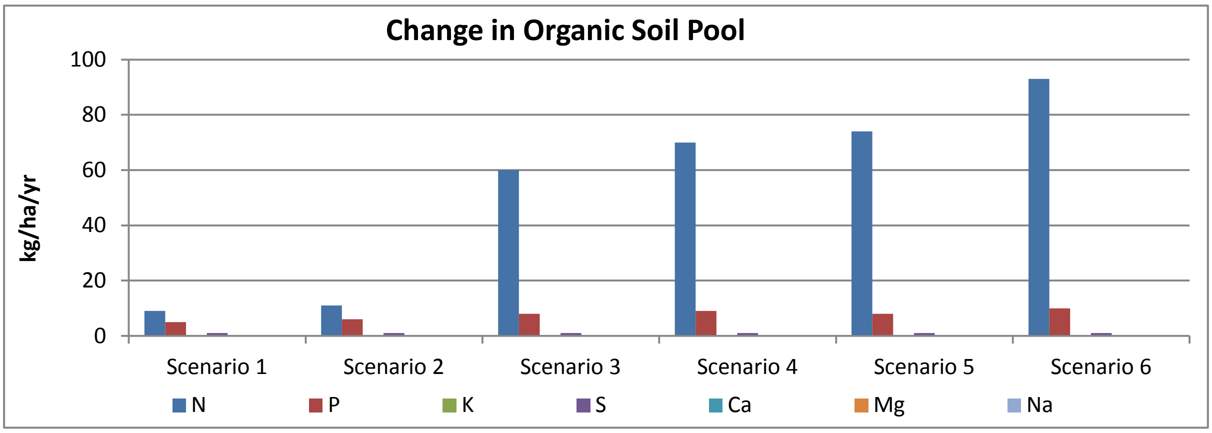


Figure 3. 44 Change in the Organic Soil Pool after Modelling of Each Scenario

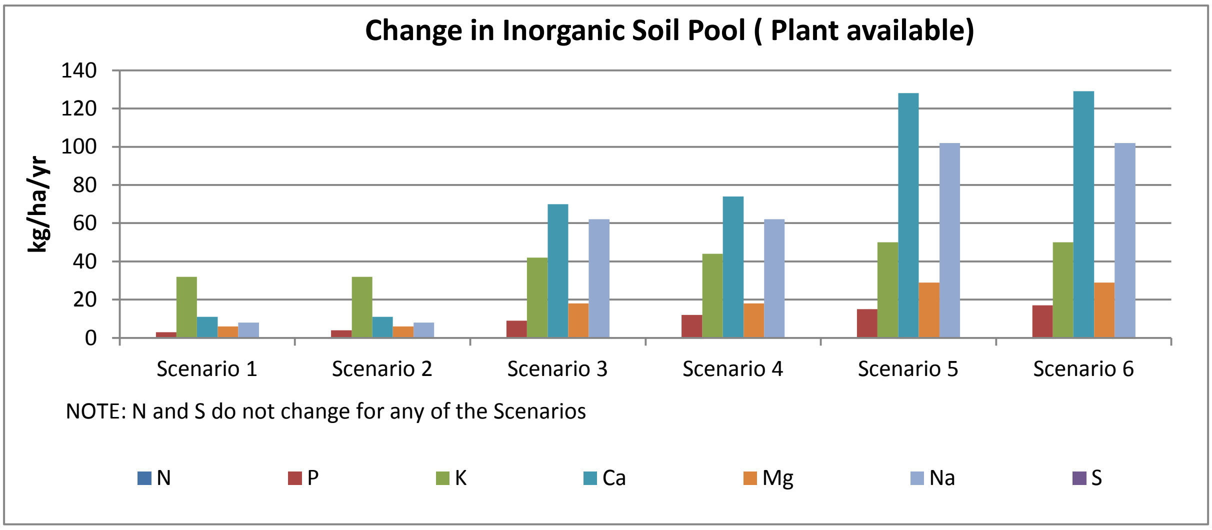


Figure 3. 45 Change in the Inorganic Soil Pool after Modelling of Each Scenario

4. DISCUSSION

The objectives of this study were to gain a better understanding of how irrigation in a hill/high country river valley will impact the water and soil quality. To achieve this four key focuses were set. These were to;

- Identify the current situation in the valley in terms of water quality, climatic conditions, soil quality and farming practices
- Quantify how the current situation could potentially change with irrigation
- Determine how future changes may impact the ground and surface water quality, and what these changes mean for the future of the valley
- Relate the results found from this valley to similar valleys in New Zealand

4.1 Current Situation in the Hakataramea Valley

The current situation refers to the time period covered by the study and the sampling, and is represented in the OVERSEER modelling scenarios 1 and 2. These scenarios assume that the upper and lower portions of the valley will remain predominantly dry with no (very little) irrigation. Both these scenarios use low stocking rates and nutrient inputs.

4.1.1 Flow in Waterways of the Hakataramea Valley

Flows in the various waterways currently relate directly to the amount of rainfall in the valley (***Figure 4.1a-b***). This is evident when comparing rainfall with river and tributary flow recordings.

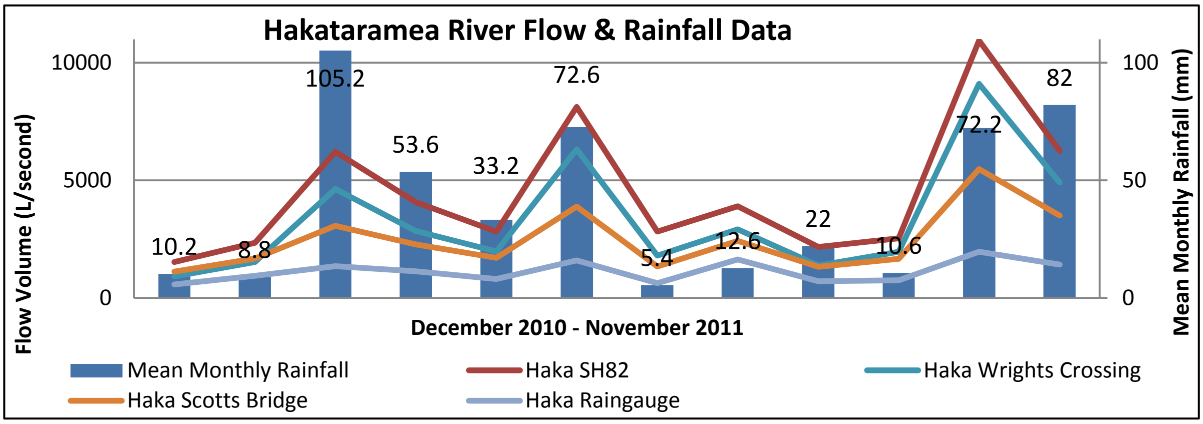


Figure 4. 1a Monthly Flow Volumes of the Hakataramea River in Relation to the Monthly Hakataramea Valley Rainfall

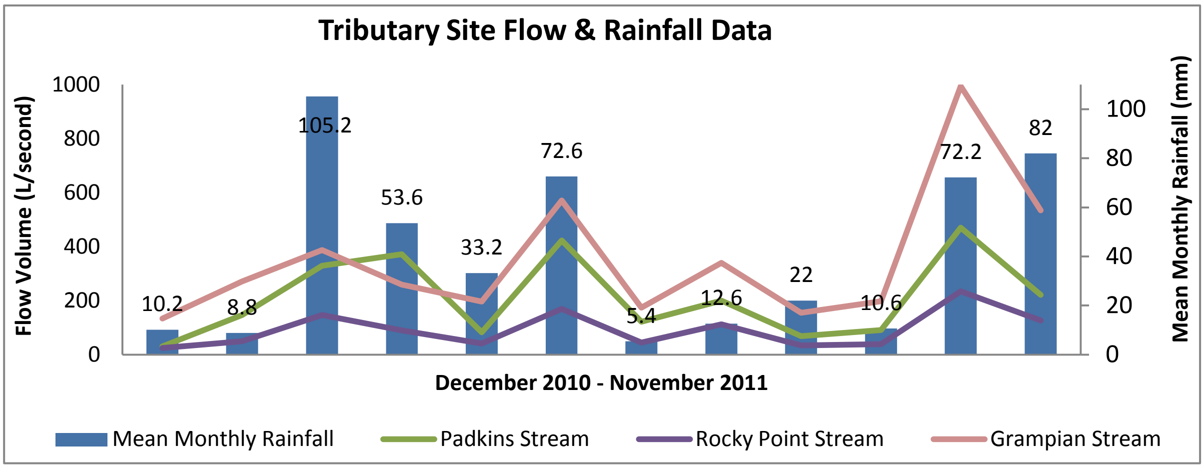


Figure 4.1b Monthly Flow Volumes of the Tributary Monitoring Sites in Relation to the Monthly Hakataramea Valley Rainfall

4.1.2 Farming Practises and Soil Quality

Currently there is very little irrigation in the valley. Dryland farming is predominant with an extensive (low stock density) mix of sheep (85%) and beef (11%) (***Figure 3.40***). The average stocking rate in the valley is 5 stock units/ha. With such a low density style of farming (shown by the stocking rate) and small amount of irrigation, there are very few stock water systems in place. This was confirmed in the LRI where 82% of properties indicated they rely on naturally flowing waterways for stock consumption; this will change in the future with the introduction of irrigation.

Soil samples were collected at the end of July; this influenced the results as no irrigation had taken place for three months not allowing for any easily identifiable trends to be recognised. From the samples collected and other data available on the soils in the valley, similar results (pH, gravimetric water content, bulk density, and porosity) to a semi improved dry NZ Pallic soil are seen. Soil pH levels (***Figure 3.35***) were in general within the target range of 5.8-6.0 (Allan, 2007), with no spatial trend evident for areas of the valley with high or low pH levels. The lowest readings were from both irrigated and un-irrigated farm properties, which were due for an application of lime, as stated in the LRI by the relevant farmers. Moisture properties of the soil ranged from 9.56% water content to 33.04% (***Figure 3.36***). For the type of soil in the valley, water content in the range of 15-30% is required for optimum plant growth (Department of Primary Industries, 2012). Again there were no differences identified between dry land and irrigated land, with a dryland site having the highest water content. The Bulk Density of the soils ranged from 0.95-1.28g/cm^3. There are no differences between irrigated and un-irrigated soils; as for moisture content. The values seen in the valley fall into the adequate to semi compact range (***Table 3.6***) and will potentially hinder plant growth if too compact (Sparling et. al, 2008). Total Porosity values in the valley ranged from 35.85-48.30% (***Figure 3.38***). The results collected again show no identifiable trends. All the sites sampled fell within an acceptable range for total porosity (Freeze & Cherry, 1979).

The low density farming systems and lack of irrigation ultimately results in low nutrient application rates (***Figure 3.39***). The LRI quantifies this in the response to a question on nutrients added to the soils (***Figure 3.37***). The two major nutrients this project focussed on were phosphorus and nitrogen. The Olsen P levels in the valley showed a range of 14.74, with the highest level being 22.23 and the lowest level being 7.49 (***Figure 3.31***). The highest levels came from the irrigated land as well as the lower valley where soil and pasture species had been highly improved; the lowest levels came from the middle of the valley in very dry, unimproved soils and pastures. The upper valley (naturally higher rainfall) showed higher Olsen P readings than the middle of the valley, this was expected. For improved pasture and soil in the Canterbury region, Olsen P levels should be in the vicinity of 20 to 30, and close to 10 for native or poor quality introduced pasture. These concentrations allow near maximum pasture production (90-95% of relative pasture production, ***Figure 4.2***) (Mackay, et al., 2010; Mackay, et al., 2011; Department of Primary Industries, 2012). The majority of the soils in the Hakataramea Valley (dry mid FP, dry AP, dry UFP, and dry OG) sampled, fall into the “native/poorer introduced species” bracket. The only soils that are close too, or fall within the “improved pasture” bracket are the irrigated soils and the soil from the lowest sampling site in the valley. The Dry AP and Dry OG soils were from agricultural areas that did not receive much stock pressure and were unimproved, so their Olsen P levels were outside the range specified in ***Figure 4.2***.

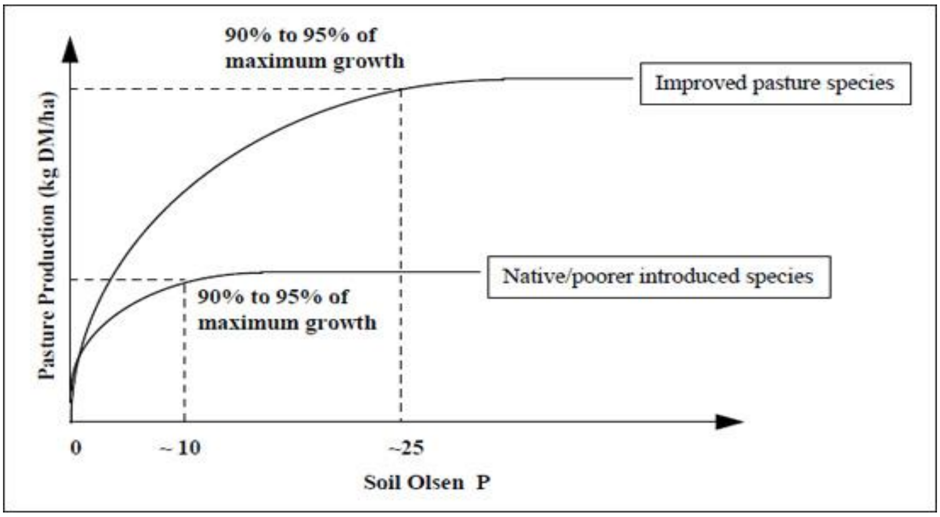


Figure 4. 2 Near Maximum Pasture Yield Olsen P Target Ranges for Soils in the Canterbury Region

(Department of Primary Industries, 2012)

At the three sites where soil nitrogen (ammonium and nitrate) was tested, the levels ranged from 23.2 to 25.7 kg/ha. In New Zealand, plant available N can range from 10 to 250 kg/ha (McLaren & Cameron, 1990; Morton & Roberts, 1999) so the valley is at the very low end of this, therefore is naturally low in plant available N which is conveyed in the water quality results where the concentrations exceed the New Zealand median or the ANZECC guideline values very few times (refer to section 4.1.5). Modelling of scenarios 1 and 2 (current conditions) showed the organic and inorganic soil pools (***Figure 4.3 & 4.4***) increased between each scenario, with the largest increases seen in the organic soil pool. Of the two soil pools the inorganic one is the most relevant and important in terms of potential altering of water quality, as it contains the readily available portions of the nutrients. In this soil pool N does not change from scenario 1 to 2. P experienced a slight increase from 3kg/ha/yr to 4kg/ha/yr from scenario 1 to 2; this is due to the slightly higher stocking and fertiliser application rates.

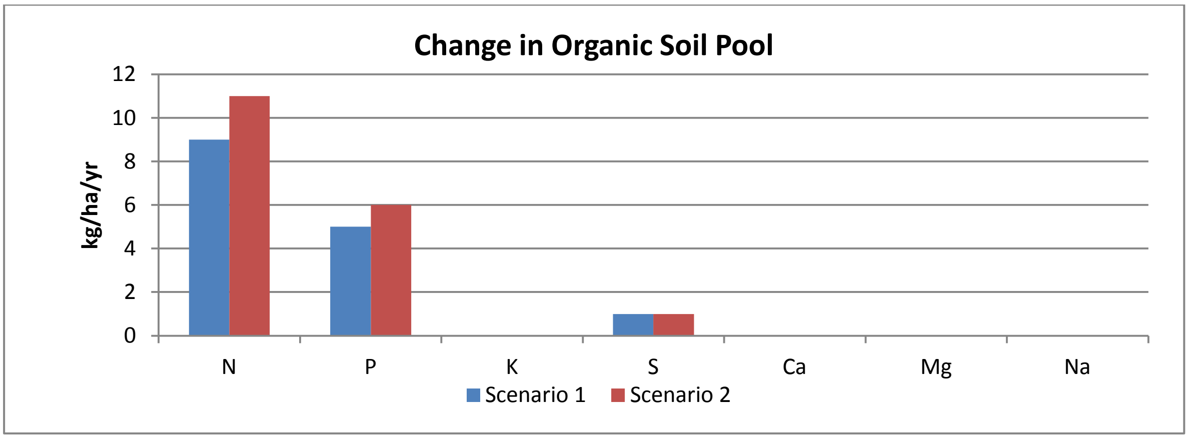


Figure 4. 3 Change in the Organic Soil Pool each year in the Hakataramea Valley with current farming operations

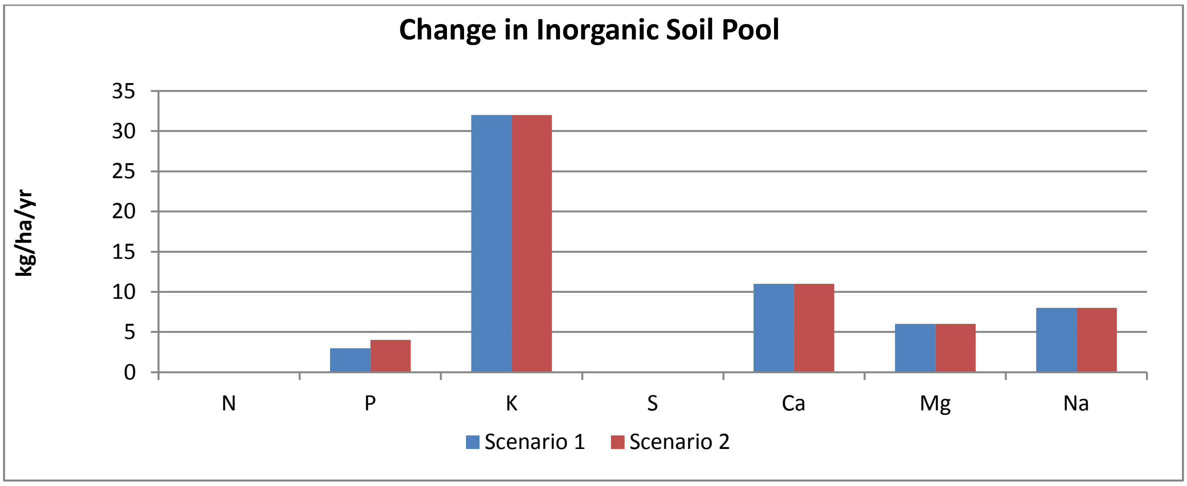


Figure 4. 4 Change in the Inorganic Soil Pool each year in the Hakataramea Valley with current farming operations

4.1.3 Water Quality

After modelling the two scenarios that represent the current situation (scenario 1 and 2) the nutrients lost to water were identified (***Figure 4.5***). This data, along with the soil data (section 4.1.2), water sampling data and infield monitoring data determines the quality of the surface water in the catchment.

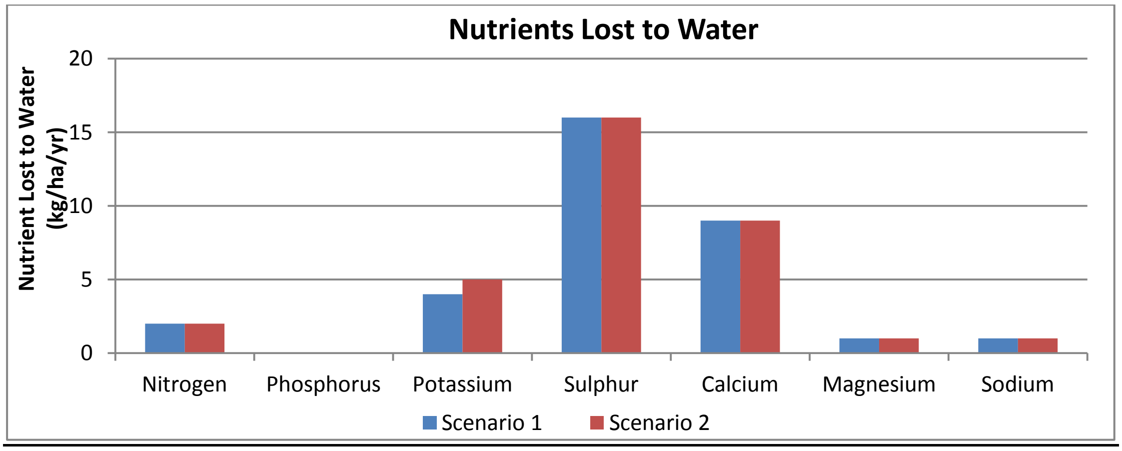


Figure 4. 5 Nutrients Lost to water after the modelling of the current situation (scenarios 1 and 2) in the Hakataramea Valley

The two nutrients of greatest interest are N and P, as these have the highest potential to alter the water quality. Trigger stressor values have been set for these nutrients by ANZECC (Australian and New Zealand Environment and Conservation Council, 2000). These values are used to assess the threat a waterway is under (***Table 4.1***). In 2007 the Ministry for the Environment (MfE) reported the median concentrations of the various forms of N and P in NZ rivers (***Table 4.1***).

Table 4. 1 ANZECC Nitrogen Specie Trigger Stressor Nutrient Concentrations and NZ River Mean/Median Nutrient Concentrations (ANZECC, 2000; MfE, 2007)

Nitrogen ANZECC Trigger Stressor Concentrations			
Nutrient		Concentration (mg/L)	
Total nitrogen (TN)		0.295	
Oxidised nitrogen (NO_x)		0.167	
Ammonium (NH_4^+)		0.01	
NZ Average and Median Concentrations			
	Total Nitrogen (TN)	Oxidised Nitrogen	Total Ammoniacal
Average	0.41	0.26	0.011
Median	0.33	0.15	0.007
Phosphorus ANZECC Trigger Stressor Concentrations			
Nutrient		**Concentration (mg/L)**	
Total phosphorus (TP)		0.026	
Dissolved reactive phosphorus (DRP)		0.0095	
NZ Average and Median Concentrations			
	TP	DRP	
Average	0.04	0.011	
Median	0.03	0.006	

Nutrient concentrations recorded in the Hakataramea River and tributary monitoring sites varied considerably, with some nutrient concentrations often exceeding the ANZECC guideline values, and at times the NZ median values. From the P and N samples collected, N was more likely to exceed the ANZECC guideline values, with TN exceeding them more often than NO_x and TAN (***Figure 4.6***). TN exceeds the ANZECC levels 16 times in the valley; 4 in the river and 12 times in the tributaries. NO_x only exceeds the levels 6 times; 5 in the tributary sites (especially Padkins Stream) and once in the river when the flow was extremely high. TAN exceeds the levels 7 times, 6 times in the tributaries and once in the river. From this data it is evident that the tributary sites are more nitrogen enriched than the river sites, with Rocky Point stream being the worst of the tributary sites, closely followed by Padkins Stream. The reason for the tributary sites experiencing higher nitrogen enrichment is due to the water from the tributaries entering the river and becoming mixed, therefore diluted. It is also evident that the nitrogen concentrations in the tributaries are more responsive to high rainfall rates than the river sites (***Figure 4.6***).

Padkins Stream is the only tributary catchment within the valley that comprises a significant area of irrigation. It would be expected that this stream would suffer from higher nitrogen enrichment than the others, this is not the case. The major reason is that the streams in the Padkins stream catchment are fenced from stock as the conditions of the consents require. These properties also make up the 18% of properties that have on farm stock water systems in place, therefore stock do not need to access the waterways for water. October and November continuously experience the highest nutrient concentrations; this is due to stock drinking more water while suckling young.

TAN levels in the tributaries and river cannot be used for detailed analysis as two different laboratories were used with two different detection limits. The first laboratory was at ECan which had a detection limit of 0.005mg/L. This laboratory shut down after the Christchurch earthquakes in February. McMillans drilling limited (Southbridge, Canterbury) then took over; this laboratory had a detection limit set to the ANZECC trigger stressor values (0.01mg/L). The only data that can be accurately referred to are the 7 samples that exceeded the detection limits (***Figure 4.6***).

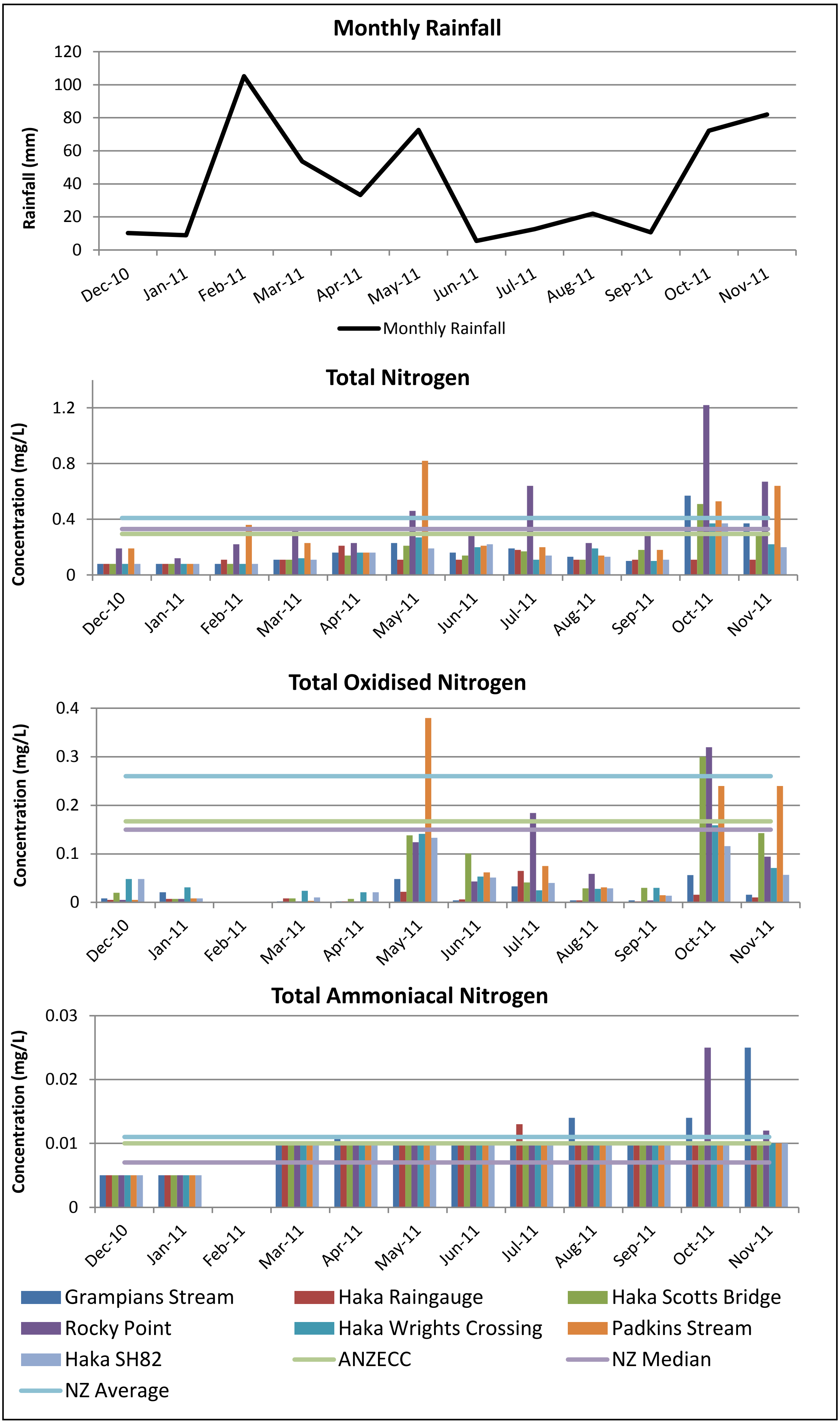


Figure 4.6 Nitrogen Species Concentrations at the Surface Water Monitoring Sites in Relation to the Average Monthly Rainfall

P is not as mobile as N and enters the waterways via soil transport (wind or rain) (McLaren & Cameron, 1990). Soil testing showed low concentrations of P, this resulted in P not exceeding the ANZECC guideline or the NZ median concentrations as often as N (***Figure 4.7***). None of the DRP or TP concentrations measured in the river come close to exceeding the ANZECC concentrations or the NZ average concentrations. The only surface water monitoring site that exceeded the ANZECC and NZ median concentrations for both TP and DRP was Rocky Point stream. This stream exceeded the ANZECC and NZ median TP concentrations 5 times and the DRP concentrations 6 times, none of the other sites came close. The reason Rocky Point stream was the only waterway monitored that showed high readings was due to its setting. The immediate surroundings and in the stream itself are also densely populated with willow trees, these trees can also be a source of nutrients (Kasco Marine Inc. 2006). Another contributing fact was that a farm yard was located above the monitoring site. To access this yard the stream was forded several times a day, at this location spray rigs also filled up their tanks.

The groundwater sampling results showed very high concentrations of N, while the P concentrations were not all that different to the surface water concentrations (***Figures 3.21 & 3.23***). The highest TN concentration seen was 3.2mg/L; this is well above the NZ median concentration of 1.7mg/L (Daughney & Randall, 2009). No trend was identifiable as to what time of year the highest readings took place, but they did occur after high rainfalls. This is normal as an increased rate of leaching and runoff into surface waters would have occurred. The best explanation as to why the groundwater TN concentrations are higher than the surface water concentrations is that surface waters receive nutrients from a local setting compared to groundwater, which receives nutrients across the entire catchment. The bores monitored were all shallow and located close to high use areas such as roads, farm tracks, stock yards and farm yards, all of which would experience higher concentrations of nutrients than more remote areas. P concentrations in groundwater were similar to the surface water with one major exception; this is the high reading in August of 0.46mg/L (***Figure 3.24***). The reason P was not vastly different to the surface water concentrations, unlike N, is that P is not as mobile as N, and is bound to soil particles and is not easily leached (McLaren & Cameron, 1990).

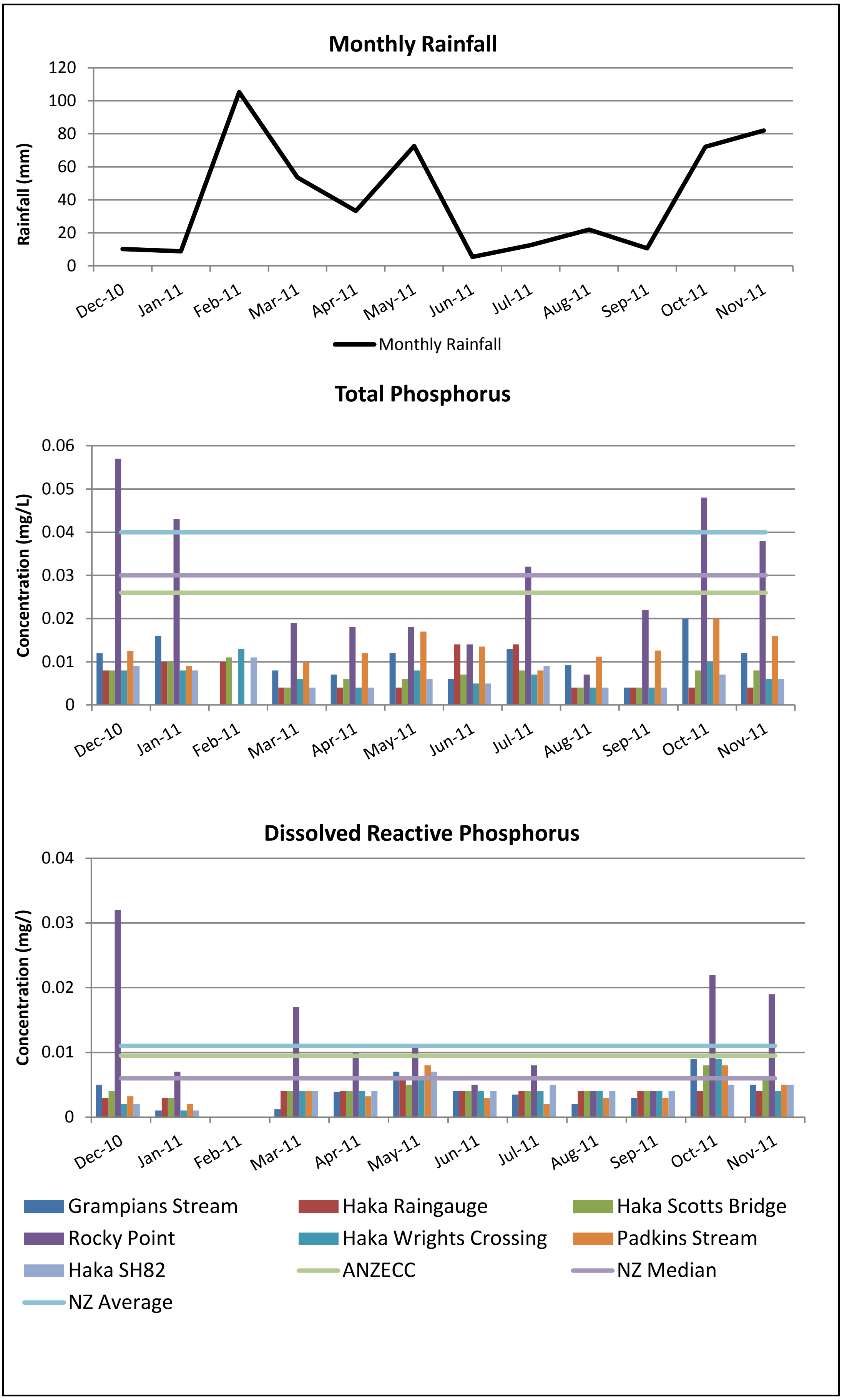


Figure 4.7 Phosphorus Species Concentrations at the Surface Water Monitoring Sites in Relation to the Average Monthly Rainfall

E.coli concentrations in the river monitoring sites and tributary sites were vastly different, with none of the river sites exceeding any alert levels set by the MfE in 2008 (***Figure 4.8***). The tributary sites however, exceeded both the amber alert (260MPN/100mL) and the red alert (550MPN/100mL) levels 6 times, with two of these exceeding the red alert level (***Figure 4.9***). Grampians stream contributed to 3 amber alerts and one red alert, the only other tributary to breach any of the values was Rocky Point. This stream exceeded the amber alert and the red alert one time each. These high values are all experienced during the warmer months (summer and spring) when the stock gather near permanently flowing waterways as a large number of the smaller waterways dry up. The extremely high value seen in October 2011 coincides with the beginning of lambing and calving. During these months stock are beginning to suckle young and need to consume greater volumes of water. In a study completed at Lincoln, it was shown that a dry Angus cow consumed on average 15L of water a day, while lactating this increased to 31L/day. The same was true for sheep which increased from 2L/day to 4.5L/day (Harrington, 1980). It is therefore extremely important for stock to have access to permanently available freshwater over the Spring and Summer.

Grampians and Rocky Point Streams do not have vast areas of land being irrigated and as high stocking rates as the land surrounding Padkins Stream but the E.coli levels are greater. A large portion of the tributaries of Padkins Stream and Padkins Stream itself are now fenced (due to consent conditions) stopping stock from entering them. There are also permanent stock water systems in place on these properties. This is not the case in the Rocky Point and Grampians stream catchments where stock can access streams directly for water. Due to this phenomenon irrigation causes the opposite affect to what was expected for E.coli concentrations.

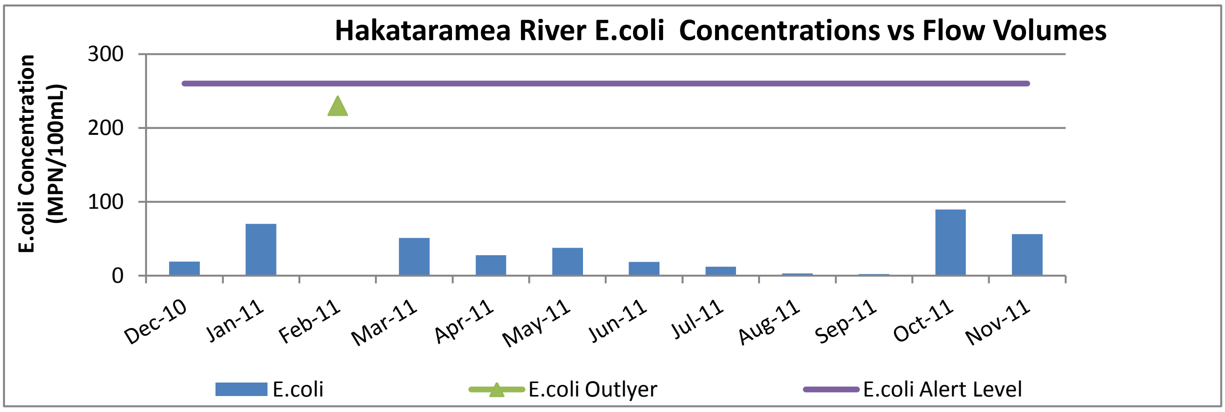


Figure 4. 8 Monthly E.coli Concentrations in the Hakataramea River

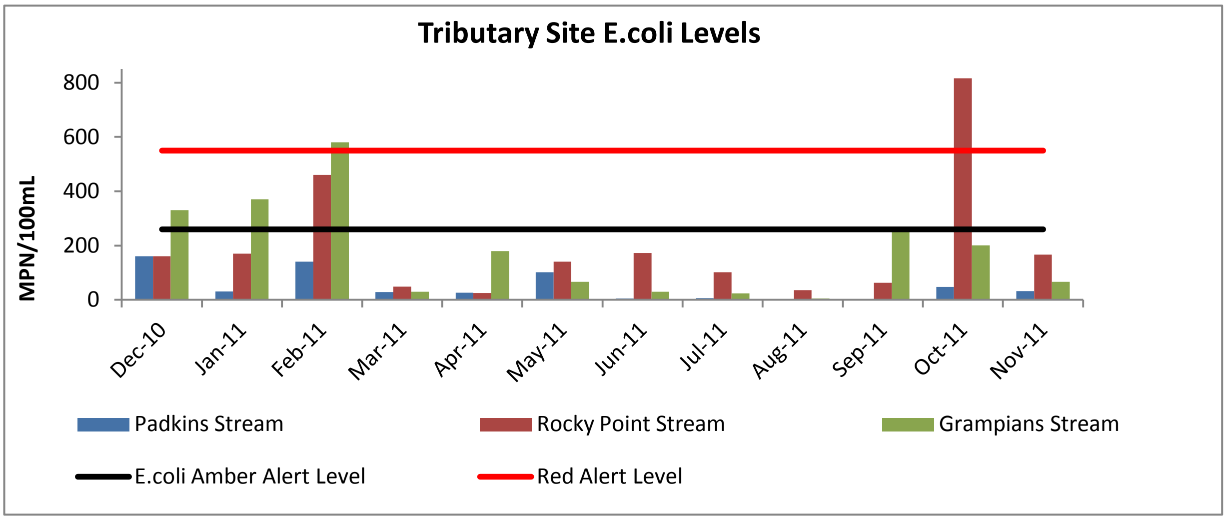


Figure 4. 9 Monthly E.coli Concentrations of the Tributary Monitoring Sites

The results collected in the field (physical parameters) all show the water quality at the surface water monitoring sites (minus Rocky Point stream) to be within the various guideline values set (***Figures 3.9 to 3.13***). There are no differences between the river sites and the two tributary sites, Grampians and Padkins streams. Rocky Point stream shows substantially worse readings than any of the other sites. This stream had a bed substrate unlike any of the other sites that was dominated by willow roots and a silty/muddy bottom, compared to the coarser substrates found at the other sites.

4.1.4 Aquatic Health

N and P concentrations in waterways are one of the most influential factors that dictate the aquatic health of a waterway. The major problem with elevated N and P concentrations in waterways is algal blooms. For optimum algal growth a mole ratio of between 4 and 20 N to 1 P (Ausseil, 2011) is required (***Figure 4.10***). All the sites monitored in the study show the valley is low in P (P limited), this was backed up in the soils which indicated low Olsen P levels (***Figure 3.31***). There were no algal blooms experienced during the monitoring period but periphyton did have a thick cover at times.

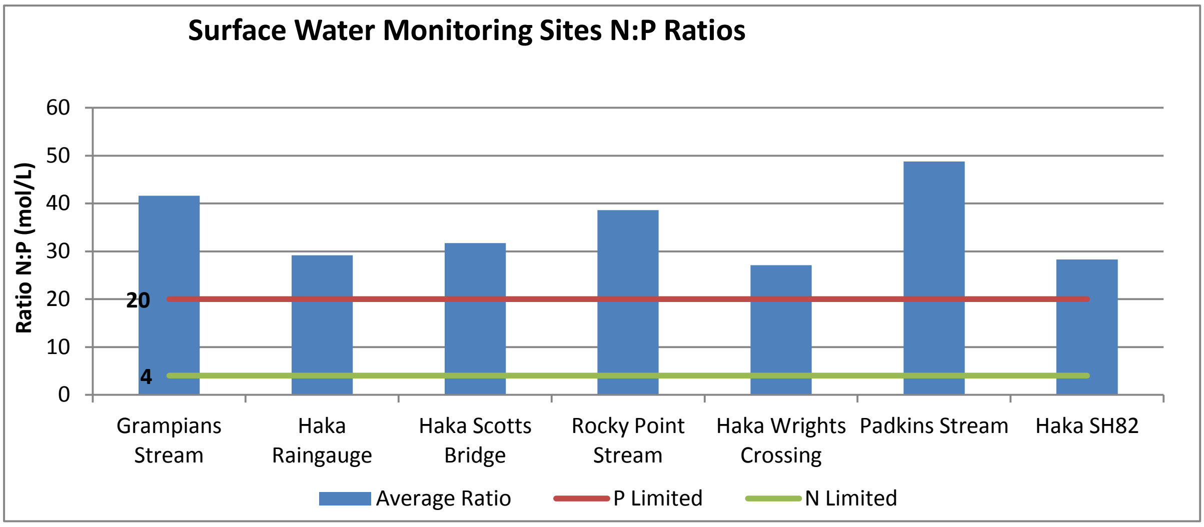


Figure 4.10 Surface Water Monitoring Sites N:P Ratios and the Limiting Nutrients

The further up the valley the monitoring locations, the higher the MCI, QMCI, %EPT, and %EPT abundance scores were. This was expected as there is not as much human interference. In general the Hakataramea River showed higher bio indices scores than the tributary sites.

The river had an average MCI score of 111 (105 at the lower two sites and 117 at the upper sites), an average QMCI score of 6.35, and showed an average of 49% EPT taxa (***Figures 3.24 – 3.26***). These results are all around the NZ and Canterbury averages; MCI 109; %EPT of 45 to 65; and a QMCI of 5.9 (MfE, 2007 & Burrell, 2009) and put the river into the excellent category (***Table 4.2***).

Rocky Point stream cannot be compared to any of the other sites (including the river sites) as the stream substrate was entirely different (soft bottom opposed to a gravel bottom). This site showed the lowest scores for MCI, QMCI, total number of taxa and %EPT taxa of any of the sites (***Figures 3.25-3.29***). Using Padkins and Grampians streams for comparison with the river sites it is evident that the tributaries do not have scores as high as the river. The average MCI score for the tributaries sites was 106 (***Figure 3.25***), below the New Zealand average of 109. The %EPT taxa was 47% (***Figure 3.27***); this was at the lower limit of the NZ average. The QMCI average score for Padkins and Grampians streams was 5.66 (***Figure 3.26***), with Rocky Point stream having a QMCI score of just 3.74. Although the MCI, QMCI, and %EPT taxa scores were not as high as the river sites they were still in the good to excellent range (***Table 4.2***). The tributary sites were expected to be lower than the river sites as stock use these for drinking water and the catchments of the tributaries are also more directly involved in agriculture than the river.

Table 4. 2 Interpretation of Biotic Indices Scores in Relation to Water Quality

(Stark & Maxted, 2007)

Quality	Description	MCI Score	QMCI Score
Excellent	Clean water	> 119	> 5.99
Good	Possible mild pollution	100-119	5.00-5.99
Fair	Probable moderate pollution	80–99	4.00-4.99
Poor	Probable severe pollution	< 80	< 4.00

4.2 Situation after Modelling the Future Scenarios

Each scenario modelled shows the potential future of the valley. Scenarios 1 and 2 (current situation) have been explained above. Scenario 3 and 4 are the most likely cases for the Hakataramea Valley. While scenarios 5 and 6 are unlikely to take place in the valley, they help in showing the extreme impacts of irrigation and changing farm practices. By modelling each scenario the quality of the surface water, ground water and aquatic health of the valley will be determined. However, this will only be an estimate as there are many outside factors that cannot be predicted that would influence the outcomes in real life. Each scenario showed a direct link between nutrients added to the soil and nutrients lost to water. The modelling scenarios all showed an increase in nutrients added to the soils and lost to water from scenarios 1 and 2 (***Figures 4.11 & 4.12***).

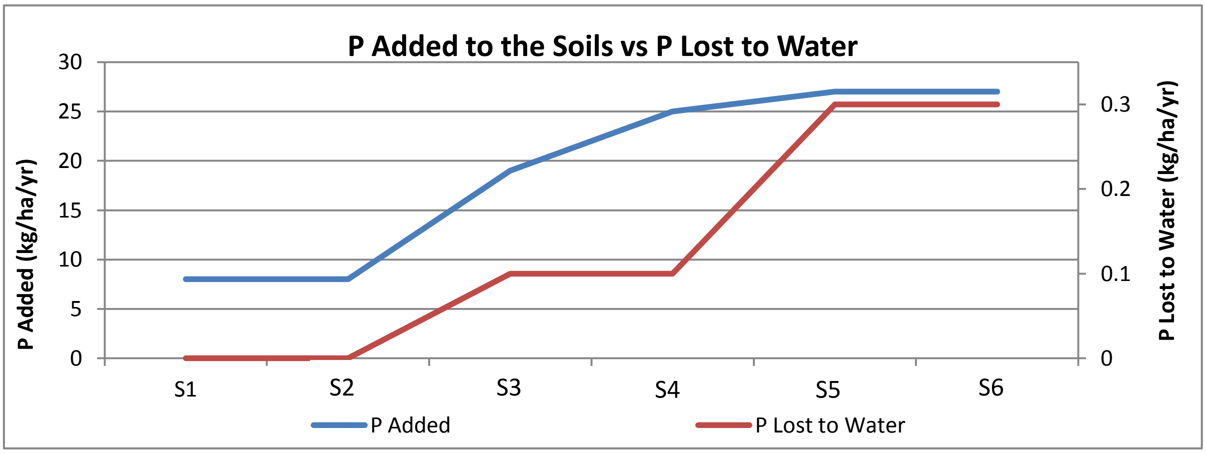


Figure 4. 11 Phosphorus Added to the Soils in Relation to the Phosphorus Lost to Water in the Hakataramea Valley after the OVERSEER Modelling

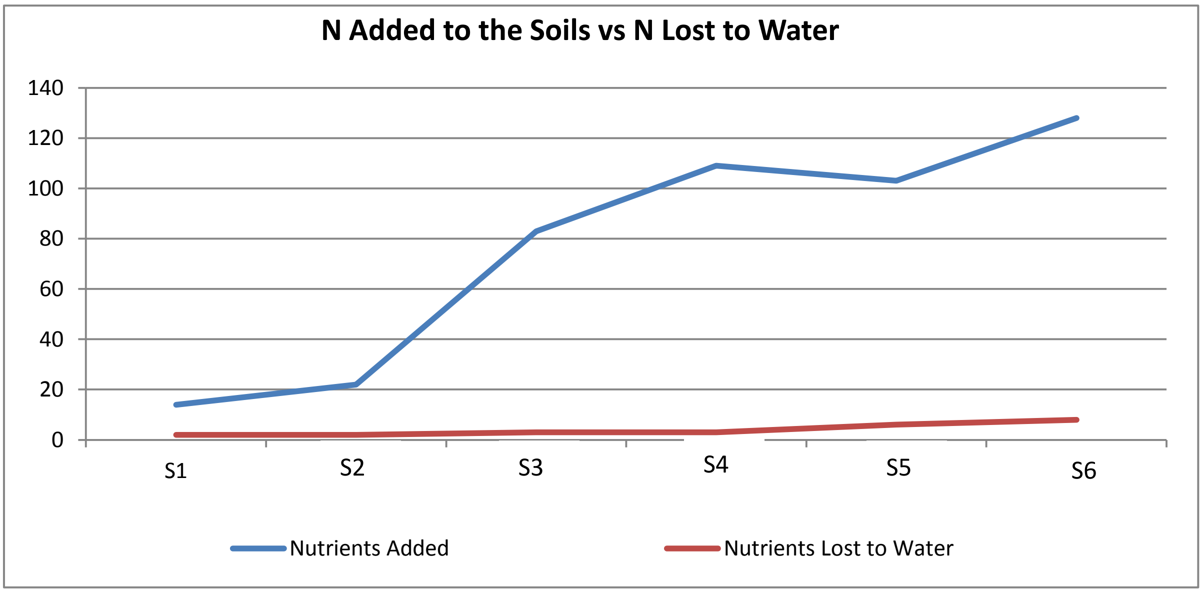


Figure 4. 12 Nitrogen Added to the Soils in Relation to the Nitrogen Lost to Water in the Hakataramea Valley after the OVERSEER Modelling

The increased nutrients added to the soils also resulted in increased organic and inorganic nutrient soil pools, with the biggest increases coming from the inorganic soil pool (***Figure 3.42 & 3.43***).

4.2.1 Scenario 3

This scenario did not see any drastic changes in the farming practises used in the valley. The area of land irrigated in the lower valley increased while the upper valley remained dry. The irrigated land experienced an increase in fertiliser application rates, allowing for an increase in stock density, which increased to 11su/ha with more beef stock present, however sheep were still dominant. One positive change would be the introduction of more on farm stock water systems and the fencing of waterways. The various changes in farming practises resulted in an increase in the soil pools (***Figures 3.42 & 3.43***). Increased nutrient soil pools are potentially harmful to the waterways in the valley as they result in more soil nutrients available to be transported via wind or rain into waterways. The most potentially harmful nutrients are N and P, these both show increased levels. The nutrients lost to water increased, with the exception of Mg and Na (***Table 4.3***). With both P and N increasing it is unlikely the N:P ratio would get closer to the optimum range for algal growth (***Figure 4.10***).

Table 4. 3 Nutrients Lost to Water after the Modelling of Scenario 3 and 4 in the Hakataramea Valley

Nutrients lost to water (kg/ha/yr)	Scenario 3	Scenario 4
Nitrogen	3	3
Phosphorus	0.1	0.1
Potassium	6	7
Sulphur	33	37
Calcium	10	10
Magnesium	1	1
Sodium	1	1

Sulphur experienced the only large increase (17 kg/ha/yr (***Figure 3.41***)). There are three major risks that arise from an increase of S in waterways, these are; acidification, mobilisation of P and S toxicity (Lenntech, 2011). Oxidised N (nitrate constitutes 90% of plant available N (Brown et. al, 1993)) and DRP nutrient concentrations in the waterways increased as a result of the changes to the farming practises. These two nutrients are the most significant in terms of altering the aquatic health of a waterway as they dictate the algal growth. Oxidised N has been estimated to be 0.070mg/L and DRP to be 0.007mg/L. Total ammoniacal N could not be estimated as there was insufficient data on the levels of this in the waterways during the current period.

E.coli is not easy to predict for future scenarios as it has been identified during the monitoring that the levels of E.coli are lower in irrigated catchments. This is due to fencing of waterways and the installation of stock water systems on the properties. The periphyton scores would not change drastically as P would still be the limiting factor in this scenario. The aquatic ecosystems would show small changes (***Table 4.4***) but cannot be predicted easily due to the vast array of unpredictable processes acting. The %EPT taxa would be in the range of 35 to 40%; this drop is due to the sensitive taxa dying as a result of the slight increase in nutrient concentrations. The MCI score may not change all that much. This is due to the fact that some macro invertebrates are able to cope better with increased nutrient levels, including; *Austrosimulium* (sand fly), *Orthocladiinae* (midge) and *Potamopyrgus* (snail) which are all present in the waterways. The MCI score is likely to be in the range of 100 to 105. The most relevant change would come from the QMCI scores; these would be expected to drop slightly but would still be in the lower excellent to upper good range (5.8 - 7.0).

Table 4. 4 Predicted Aquatic Bio Indices scores after the OVERSEER Modelling of Scenario 3 in the Hakataramea Valley

	Hakataramea River	Tributary Sites (minus Rocky Point)
MCI	100-105	100-105
QMCI	5.8-7.0	5.25-5.50
%EPT taxa	35-40	35-45
E.coli		
Periphyton Scores	8-8.5	8.0-8.5

4.2.2 Scenario 4

The farming practises in the valley under this scenario would experience small changes from scenario 3, especially in the lower valley. The stock density increased to 15su/ha, with much more beef and the introduction of dairy animals; sheep are no longer the dominant animal in the valley. The lower valley would see the introduction of more on farm stock water systems and more fencing of waterways due to the change in farm type. Dairy farms would also be introduced to the valley, bringing different farming systems; more intensification and fertiliser application rates. The irrigated area remains the same as scenario 3. The various increases resulted in the soil nutrient pools to increase. Currently after every large storm event (wind or rain) there is an increase in nutrients in the waterways in at least one location, the frequency and size of these increases will become greater with larger soil nutrient pools. The change in soil pools resulted in an increase of K, S, and Ca entering the waterways. The N, P, Mg, and Na lost to water did not change (***Figures 3.39 – 3.41***). The concentrations of nutrients in the water has experienced a slight increase, this is due to higher stock numbers over the valley. Oxidised N was estimated to be 0.09mg/L and DRP was estimated to be 0.008mg/L.

The aquatic health of the waterways would not change drastically from scenario 3 with an MCI score in the range of 95 to 100 likely (***Table 4.5***). The biggest change would be the QMCI scores which would decrease as the high scoring sensitive taxa (mayflies, caddis flies and stoneflies) die off and are replaced by lower scoring taxa (flies, midges and snails). This change would not be large as the nutrient levels have not risen extensively form scenario 3, a QMCI score in the bracket of 5.5 to 6.0 would be expected (***Table 4.5***).

Table 4. 5 Predicted Aquatic Bio Indices scores after the OVERSEER Modelling of Scenario 4 in the Hakataramea Valley

	River	Tributary Sites (minus Rocky Point)
MCI	95-100	95-100
QMCI	5.5-6.0	5.0-5.25
%EPT taxa	30-35	25-35
E.coli		
Periphyton Scores	7.5-8.0	7.5-8.0

4.2.3 Scenario 5

This scenario saw the loss of dairy stock, but the introduction of irrigation and semi intensified farming in the upper valley as well as the lower valley. This would result in an increase in stock water systems and number of fenced streams. The stocking rate dropped from 15 (scenario 4) to 12, but this is across the entire valley so the number of stock in the valley will be far greater than scenario 4. Sheep are again the predominant stock type in the valley constituting 60%, with beef making up the remainder (40%). The changes in farming practises expected in the valley would result in increased soil pools for all nutrients bar Mg (***Figures 3.42-3.43***). N does not show any change in the inorganic soil pool, P does. P has increased from 12kg/ha/yr to 15kg/ha/yr; this change is significant and will result in minor changes in the concentrations seen in the waters. N and P lost to water experienced increases, N increased to 6kg/ha/yr, this is a 3kg/ha/yr increase and P increased to 0.3kg/ha/yr, a 0.2kg/ha/yr increase (***Table 4.6***).

Table 4. 6 Nutrients Lost to Water after the Modelling of Scenario 5 and 6 in the Hakataramea Valley

Nutrients lost to water (kg/ha/yr)	Scenario 5	Scenario 6
Nitrogen	6	8
Phosphorus	0.3	0.3
Potassium	6	7
Sulphur	41	47
Calcium	12	14
Magnesium	1	1
Sodium	1	1

These increases will change the quality of the waters in the valley in various ways. The river water quality will have degraded to a level that is undesirable and close to becoming unsafe for recreation use and consumption (***Figure 4.13***). The N:P molar ratio has not fallen within the optimum range for periphyton growth as both N and P have increased. Oxidised N increased to 0.14mg/L and DRP to 0.0126mg/L.

A rise in algal growth would occur with nutrient levels becoming this high, with algal blooms becoming more common during the summer. The QMCI, MCI, %EPT taxa, periphyton scores would all relay a decrease in water quality from the previous scenarios (***Table 4.7***). The QMCI and MCI scores would have lowered significantly from scenarios 3 and 4 and would now be in the "fair bracket" (***Table 4.2***).

Table 4. 7 Predicted Aquatic Bio Indices scores after the OVERSEER Modelling of Scenario 5 in the Hakataramea Valley

	River	**Tributaries (minus Rocky Point)**
MCI	90-95	90-95
QMCI	5.0-5.5	4.5-5.00
%EPT taxa	25-30	20-25
Periphyton Scores	7.0-7.5	7.0-7.5

4.2.4 Scenario 6

This scenario would see the reintroduction of dairy stock to the valley and the loss of sheep altogether. Under this scenario the entire valley would be irrigated with dairy and beef farming. The farming systems would change completely and would resemble that of a factory style farm of the Canterbury plains. The fertiliser application rate increased allowing for greater grass growth, as would be necessary with the increase in stock density, now 18su/ha up from 12 (scenario 5) and 15 (scenario 4). This has major implications on the water qualities and aquatic health of the valley. These increases naturally resulted in an increase in the soil pools (***Figures 3.42 & 3.43***) with the highest concentration of nutrients experienced in the inorganic soil pool. These increases have an impact on the nutrients lost to water. Out of the two most harmful nutrients, N is the only one to increase. The nutrients lost to water were the highest of any scenarios; this ultimately resulted in the highest nutrient concentrations in the waterways. NO_x (0.188mg/L) and DRP (0.0126mg/L) concentrations in the waterways were the highest of any scenarios and pose a definite risk to the quality of the water in the river. The quality of the river water would be well below desirable if the valley did progress to a similar state as described in scenario 6 (Chapter 2), and will have become unsafe for recreation and consumption (***Figure 4.14***).

Due to the highest nutrient levels out of any scenario the lowest bio indices scores were seen (***Table 4.8***). The nutrient levels in the waterways have risen so high the QMCI scores have dropped right down and would be in the poor to fair range. The MCI scores have dropped from the other scenarios but are still above the poor value set in Stark & Maxted (2007). If the nutrient concentrations in the river stayed at these levels for prolonged periods the bio indices scores would be expected to decrease even further.

Table 4. 8 Predicted Aquatic Bio Indices scores after the OVERSEER Modelling of Scenario 6 in the Hakataramea Valley

	River	**Tributaries (minus Rocky Point)**
MCI	85-95	85-90
QMCI	4.5-5.0	4.0-4.5
%EPT taxa	<25	15-20
E.coli		
Periphyton Scores	6.5-7.0	6.0-7.0

4.2.5 Ground Water

The groundwater in the valley would relay the changes seen in the surface water. It is hard to predict how much the ground water would have deteriorated due to the soils and subsurface materials. There is very little known about the groundwater and aquifer properties in the Hakataramea Valley currently. Using the little knowledge there is it can be predicted that the nutrient levels would increase at each scenario. The groundwater has shown that it is more susceptible to changes in farming practices than the surface water (higher readings currently). Using this knowledge an average TN concentration >0.9mg/L and a TP concentration >0.08mg/L would be expected.

4.2.6 Summary

Changes to the farming practises in the Hakataramea Valley, including; increased irrigated land; increased stock density; change in stock types; and increased fertiliser application rates would inevitably result in higher average nutrient concentrations that would exceed the ANZECC concentrations far more regularly (***Figure 4.13***). The modelling showed that dairy stock are the major player in heightened nutrient concentrations, even with fencing of streams and stock water systems. These higher nutrient concentrations would lead to a decrease in the aquatic health of the river. A decrease in the aquatic health would ultimately result in a river system that has decreased social, cultural, recreational and economical appeal.

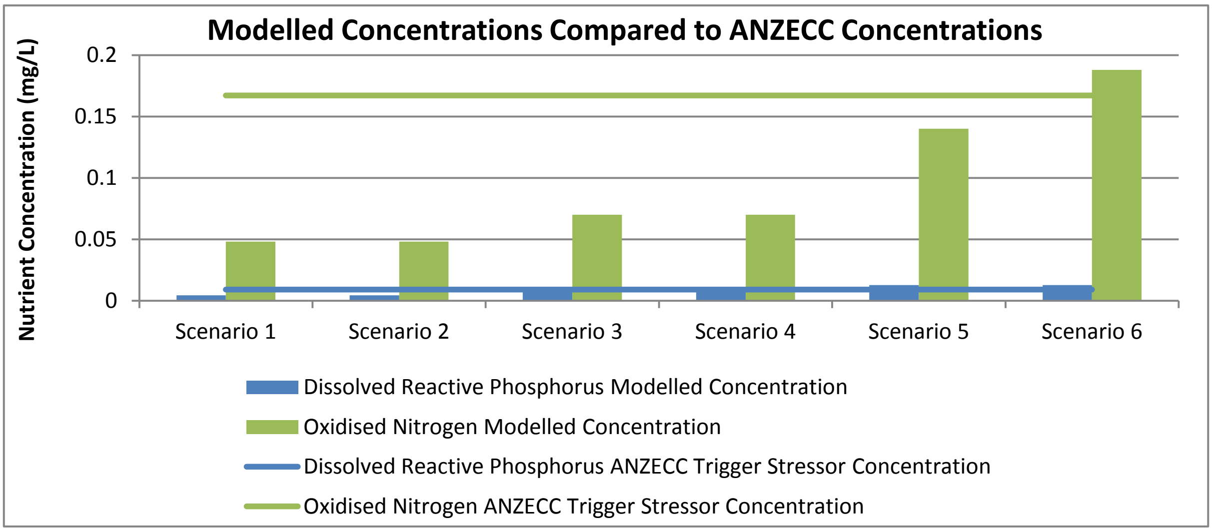


Figure 4. 13 Modelled DRP and NO_x Concentrations in Relation to the ANZECC Trigger Stressor Concentrations for the Hakataramea River

4.3 How the Hakataramea Valley Relates to Similar Valleys

There are many valleys within New Zealand that show similar characteristics (climate, topography, geology, farming systems, economic benefits for New Zealand, and recreational values) as the Hakataramea River Valley. The south island valleys/basins/catchments including; the Ashburton Lakes area, Upper Rakaia River (Lakes) area, Upper Rangitata River area, Upper Mackenzie Basin, Upper Waimakariri River area, and the Upper Waiau River area, all show very similar climatic, topographic, farming and soil characteristics to the Hakataramea Valley. Throughout these valleys the mean maximum temperature was calculated to be 17.16°C with the mean minimum temperature as 4.37°C, with an average rainfall of 670mm/yr (NIWA, CliFlo, 2012). These valleys all have similar topographies with high mountain ranges enclosing the valley floors (DOC, 2012). The soils in these valleys are dry and do not maintain a good pasture cover if water is not applied, this in turn dictates the extensive style of farming seen, with sheep again being the dominant stock type (Landcare Research, 2012). These, like the Hakataramea Valley, are all located in Canterbury, and have all experienced a degree of change over the past century, with the Culverden basin experiencing the largest agricultural changes. New irrigation systems are being installed in the Ashburton Lakes area, Upper Mackenzie basin (Reid, K.G. & Marks, H.G., 2009), and Lake Coleridge area (ECan, 2012). Along with the irrigation being installed, future systems are always being proposed for these areas.

This change is now nearing the most crucial stage, as the need for these high country farms to become more profitable increases.

4.3.1 Implications for the Wider NZ Area

The results from the modelling of the Hakataramea Valley give a very small insight as to how changes in farming systems brought about by the introduction of irrigation can potentially alter the water quality adversely. Valleys similar to the Hakataramea Valley don’t just add to New Zealand’s agricultural exports but also to the tourism and recreation sectors (Relph, 2007; Brownie, 2012; New Zealand Tourism Guide, 2012). If these valleys are continuously improved (even with strict rules in place) it is highly likely that the waterways in these areas will diminish and with this the other economical benefits from these areas (tourism and recreation) will also be lost, such was the case with the lowland Lake Ellesmere area. It is therefore imperative that the relevant authorities carry out further in-depth study into similar areas throughout New Zealand to gain a greater understanding of how these valleys will react to the unavoidable changes that are coming.

5. CONCLUSIONS & RECOMMENDATIONS

5.1 Current Nutrient Situation in the Hakataramea Valley

Nutrient concentrations in both soils and waterways are increasing across New Zealand, with the Canterbury region showing some of the biggest increases in recent times. These increases have been put down to changes in farming systems (more intensified) and an increase in irrigated land. The majority of research done in this field has been completed in a lowland plains setting which does not relate well to a hill/high country sensitive river valley. The aim of this research was to determine how an increase in irrigated land area and more intensified farming systems would alter the nutrient concentrations in soils and waterways in a high country river valley and what these changes would do to the aquatic health of the surface waterways.

5.1.1 Achieving the Aims

Seven surface water sites (four Hakataramea River and three tributaries to the river) and four groundwater bores were monitored monthly over a twelve month period for; dissolved inorganic nitrogen (DIN); dissolved organic nitrogen (DON); dissolved reactive phosphorous (DRP); total phosphorous (TP); total suspended sediment (TSS); conductivity; pH; temperature; dissolved oxygen (DO); clarity/turbidity/absorbance; E.coli/F.coli; and periphyton percentage cover. Monitoring on the aquatic health was carried out quarterly for fish counts, macrophyte presence, percentage cover of periphyton, and macroinvertebrate counts. From this data a range of aquatic bio indices scores were calculated. The monitoring sites were distributed throughout the valley and ranged from those that were believed to be poor quality to those that were believed to be good quality. The monitoring of these sites gave an insight into the chemical and aquatic quality of the waterways over the course of the project.

Nine soil sites were sampled at the end of August for a number of physical and chemical properties, including; pH; water content; total porosity; bulk density; plant available N, and plant available phosphorus. This sampling was to give an insight into the current nutrient concentrations in the soils. These soils sampling sites covered both dry and irrigated land in the anticipation it would allow trends to be identified. The sites were located on the western side of the river and spatially spread throughout the land that is in the future going to, (or most likely to) have irrigation applied.

5.1.2 Summary of the Results

Water quality in the valley varied considerably within and between each of the sampling sites over the course of the monitoring period, with the river monitoring sites showing better quality than the tributary sites. All the sites bar one were similar to the New Zealand median values collected from 77 sites throughout New Zealand (MfE, 2007). However when compared to the ANZECC (2000) values the sites exceeded the concentrations on occasions. Over the course of the project the chemical water quality of all the surface water monitoring sites showed a slight deterioration in quality, with the ANZECC values being exceeded more often later in the monitoring period, indicating waterway degradation. It was found during the modelling that soil runoff was the major process acting in transportation of nutrients to the waterways.

The aquatic health bio indices scores, including; MCI; QMCI, and %EPT taxa of the waterways (minus one site) all fell within the good to excellent range of scores set by the MfE. There appeared to be no decline in the bio indices scores throughout the monitoring period, with the lowest scores coming in the summer sampling period (December 2010), this was expected due to the low and warm water levels. The bio indices scores indicated that the lower valley aquatic health was not as good as the upper valley, indicating a declining chemical water quality further down the valley. This was not the case as the chemical water quality in the lower valley was not vastly different to the upper valley; the major difference was in the stream habitat being better up the valley.

The soils in the valley were only sampled at one time over the project, simply to give an insight into the properties. The sampling sites identified that the soils were low in nutrient levels with no evident trends between the irrigated and non irrigated land. This was partially due to the timing of the sampling which took place at the end of autumn when the soils had not been irrigated for two to three months. The middle of the valley showed the lowest nutrient concentrations and the poorest physical properties. This was expected as the middle of the valley is the driest (upper valley receives rain from the winds and the lower valley has more irrigation).

5.2 Future Nutrient Situation in the Hakataramea Valley

Following on from the twelve monthly sampling and monitoring in the valley, modelling of the potential changes in the chemical and aquatic health of the river was undertaken. Using the OVERSEER programme, different scenarios were presented that used varying inputs of stock numbers, stocking rate, irrigation application rates, and nutrient application rates. The future modelling did not seem to change all that much at first (scenario 3), but then when dairy cows and more irrigated land was introduced, the changes experienced were much greater. This is in part due to the higher level of soil runoff that would be experienced following a high rainfall event. The aquatic health of the waterways in the valley showed large declines as more nutrients were applied to land resulting in greater concentrations in the waterways.

5.3 Recommendations

Due to the two very different waterways in the valley (the river and the tributaries), two different management approaches are needed, one for the tributaries, and one for the river. These two approaches need to address the issue of stock movements within waterways, irrigation application rates, stock types, nutrient application rates, nutrient runoff and soil erosion, but still be flexible to allow for the properties to operate economically. The valley then needs to be looked at as three separate areas (lower flat to rolling, upper flat to rolling, and hill country). By doing this it would allow for each of these very different areas to be managed in a way that would be best suited for them. Actions that could stop the waterways in the valley from declining to a no return level include; fertiliser and irrigation management for all properties, fencing of significant waterways, riparian planting, sensible location of stock at certain times of year, the introduction of on farm stock water systems, and the possible use of nitrate and phosphate binding chemical (last resort).

5.4 Suggested Further Research

The research conducted in this study has identified that high country river valleys are sensitive to farming changes and the surface waterways are susceptible to increased nutrient inputs resulting in a decline in water quality. If changes to these high country river valleys continue unopposed, then the aquatic health and chemical quality of these areas will undoubtedly decline, lowering the recreational, economic, and aesthetic appeal of these valleys. However the modelling of the future scenarios presented in this study can only be used as estimates as there are many more external forces in place that can easily change the outcome of the future. It is therefore paramount that further research be done on such valleys. Areas of possible future research are;

Groundwater Analysis

There is very little known about the movements of groundwater in the valley, there has been minimal work carried out by Sinclair Knight Merz (2004), but this study stated that further in-depth research was needed, this is challenging in the valley due to the limited number of bores. The knowledge on groundwater in the valley needs to improve as farming systems in these valleys change to keep up with demand. The groundwater needs to be analysed for; aquifer depth, recharge/connectivity with surface water, chemical content, biological content, and allocation limits. With in-depth data on these parameters more accurate predictions on how the surface waterways may react to changes in farming systems would be possible. It would also allow for groundwater changes to be identified and modelled, which would ultimately influence the surface water quality.

Isotope Analysis

By carrying out isotope analysis (nitrogen or oxygen-18 ($\delta^{18}O$)) on the different aquifers in the valley more reliable determinations on the source of the contamination and whether this is a human or natural source, would be achieved. By achieving this it would allow for management to be focussed on the source of the contamination, resulting in faster positive changes to be seen.

Nutrient Recycling

The recycling of nutrients is a relatively new problem experienced in farming systems. The problem has arisen from irrigation. It is basically the reusing of water for application to land that has already been applied to land and has therefore got higher nutrient concentrations. This is definitely a potential problem in the valley as irrigation becomes more common. If nutrient recycling was taking place in the valley, the implications of this could have varying detrimental effects, including; economical, environmental and social.

Assessment of Management Options for a River Basin/Valley

Management of valleys, such as the Hakataramea, is a comprehensive process, and for this to occur a great deal more research is needed in the valley. This study has briefly outlined a number of potential management approaches for the valley; nevertheless further in-depth investigation is needed before any management plans can be proven to work.

5.5 Concluding Statement

The waterways within the Hakataramea Valley have experienced a slight decline in quality over the course of this project. This decline could be due to seasonal differences but the historic data shows that the decline has been increasing in recent years. These increases have lead to the ANZECC guidelines being exceeded more frequently and the valley falling below the mean New Zealand values. With the farming practices in the valley changing to keep up with demand for food, the nutrient levels in the valley will undoubtedly increase, as has been shown in the modelling of the future scenarios. Without careful management processes and adequate rules and regulations applied to the valley by the regional council, the decline in water quality would continue. The decline in water quality within the valley would not just be devastating to the Hakataramea Valley, but to the greater South Canterbury area, including the Waitaki River which is one of New Zealand's largest rivers. If the changes in the Hakataramea Valley were significant, it would change the appearance and state of the Waitaki River, and potentially destroy the lower Waitaki economy which is dependent on tourism.

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Appendices

For **Appendix 1** please refer to the NIWA national climate database CliFlo (http://cliflo.niwa.co.nz/). The climate data came from the station with the reference number 36209 and covered the period from 25th October 2008 to 20th July 2012.

GRAMPIANS STREAM									
	Flow		Conductivity		Dissolved Oxygen		Temp	Clarity	TSS
DATE	L/s	pH	us/cm	ms/m	mg/L	%	C	m	mg/L
Dec-10	134	7.3	63.4	6.34	8.65	81.7	17	1	4.7
Jan-11	271	7.09	59.8	5.98	8.46	79.9	14.9	0.8	1.9
Feb-11	387	7.8	54.5	5.45	9.47	89.5	11.6	0.85	1.8
Mar-11	259	6.61	54.4	5.44	9.95	94	11.5	1	3
Apr-11	197	7.5	50	5	9.81	92.7	9.1	1	3
May-11	571	7.4	50	5	9.55	90.2	9.7	0.95	3
Jun-11	174	7.4	60	6	8.82	83.3	3.6	1	3
Jul-11	340	7.5	57	5.7	9.74	92	2.6	0.8	13
Aug-11	155	7.7	62.2	6.22	10.20	96.4	0.4	1	3
Sep-11	198	7.5	63	6.3	10.37	98	4.5	1	3
Oct-11	995	7.9	53.1	5.31	9.72	91.8	7.9	0.8	3
Nov-11	534	7	76	7.6	9.64	91.1	12.5	0.96	3

GRAMPIANS STREAM									
	DIN	TN	NH4+	NOx	TKN	DRP	TP	E.coli	
DATE	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN/100mL	
Dec-10	0.008	0.08	0.005	0.008		0.005	0.012	330	
Jan-11	0.021	0.08	0.005	0.021		0.001	0.016	370	
Feb-11		0.08					0.02	580	
Mar-11	0.011	0.11	0.01	0.002	0.1	0.004	0.004	30	
Apr-11	0.012	0.16	0.011	0.002	0.16	0.004	0.007	179	
May-11	0.056	0.23	0.01	0.048	0.18	0.007	0.012	66	
Jun-11	0.011	0.16	0.01	0.004	0.16	0.004	0.006	30	
Jul-11	0.041	0.19	0.01	0.033	0.16	0.004	0.013	24	

Aug-11	0.018	0.13	0.014	0.004	0.12	0.004	0.004	5
Sep-11	0.011	0.1	0.01	0.004	0.1	0.004	0.004	261
Oct-11	0.07	0.57	0.014	0.056	0.51	0.009	0.02	201
Nov-11	0.041	0.37	0.025	0.016	0.35	0.005	0.012	66

Hakataramea Rain gauge

	Flow		Conductivity		Dissolved Oxygen		Temp	Clarity	TSS
DATE	**(L/s)**	**pH**	**us/cm**	**ms/m**	**mg/L**	**%**	**(C)**	**m**	**mg/L**
Dec-10	568	6.8	58.7	5.87	8.46	79.9	19.1	1	1.1
Jan-11	936	7.44	71.6	7.16	8.73	82.5	15	0.9	0.5
Feb-11	1345	7.6	44.7	4.47	9.36	88.4	10.6	1	1.1
Mar-11	1127	6.84	53	5.3	9.87	93.3	9.7	1	3
Apr-11	803	7.8	58	5.8	9.72	91.8	8.3	1	3
May-11	1590	7.5	50	5	9.54	90.1	4.7	0.8	3
Jun-11	623	7.5	60	6	8.82	83.3	3.6	1	3
Jul-11	1637	7.5	57	5.7	9.02	85.2	3.5	0.9	3
Aug-11	706	7.8	60.3	6.03	10.09	95.3	0.8	1	3
Sep-11	744	7.9	60.3	6.03	10.41	98.4	3.9	1	3
Oct-11	1955	7.9	53.1	5.31	10.27	97	8.8	1	3
Nov-11	1422	7.3	56.2	5.62	10.35	97.8	10.9	1	3

Hakataramea Rain gauge

	DIN	TN	NH4+	NOx	TKN	DRP	TP	E.coli	
DATE	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**MPN/100mL**	
Dec-10	0.005	0.08	0.005	0.005		0.003	0.008	5	
Jan-11	0.007	0.08	0.005	0.007		0.003	0.01	81	
Feb-11		0.11					0.01	240	
Mar-11	0.011	0.11	0.01	0.008	0.1	0.004	0.004	98	
Apr-11	0.011	0.21	0.01	0.002	0.21	0.004	0.004	53	
May-11	0.031	0.11	0.01	0.022	0.1	0.006	0.004	7	
Jun-11	0.011	0.11	0.01	0.006	0.1	0.004	0.004	3	
Jul-11	0.078	0.18	0.013	0.065	0.11	0.004	0.014	14	
Aug-11	0.011	0.11	0.01	0.004	0.1	0.004	0.004	0	
Sep-11	0.011	0.11	0.01	0.002	0.01	0.004	0.004	1	
Oct-11	0.021	0.11	0.01	0.016	0.1	0.004	0.004	6	
Nov-11	0.012	0.11	0.01	0.01	0.1	0.004	0.004	23	

Hakataramea Scots Bridge

	Flow		**Conductivity**		**Dissolved Oxygen**		**Temp**	**Clarity**	**TSS**
DATE	**L/s**	**pH**	**us/cm**	**ms/m**	**mg/L**	**%**	**C**	**m**	**mg/L**
Dec-10	1113	6.9	83	8.3	8.66806	81.9	17.4	1	1.1
Jan-11	1669	7.44	71.6	7.16	7.58852	71.7	15.1	0.9	0.5
Feb-11	3063	7.7	58.1	5.81	9.64177	91.1	12.2	1	1.9
Mar-11	2281	6.18	58.8	5.88	10.1286	95.7	12	1	3
Apr-11	1707	7.6	60	6	9.98044	94.3	9.8	1	3
May-11	3889	7.4	60	6	9.63118	91	5.7	0.9	3
Jun-11	1339	7.5	60	6	8.90091	84.1	4.5	1	3
Jul-11	2429	7.5	58	5.8	0				3

Aug-11	1314	7.5	64	6.4	10.3826	98.1	1.2	1	3
Sep-11	1666	7.5	62	6.2	10.4885	99.1	5.4	1	3
Oct-11	5476	7.6	71.1	7.11	10.298	97.3	9.3	0.86	3
Nov-11	3497	7	71	7.1	10.2133	96.5	12.5	1	3

Hakataramea Scotts Bridge

	DIN	TN	NH4+	Nox	TKN	DRP	TP	E.coli	
DATE	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**MPN/100mL**	
Dec-10	0.02	0.08	0.005	0.02		0.004	0.008	42	
Jan-11	0.007	0.08	0.005	0.007		0.003	0.01	81	
Feb-11		0.008					0.011	250	
Mar-11	0.011	0.11	0.01	0.008	0.1	0.004	0.004	65	
Apr-11	0.012	0.14	0.01	0.007	0.13	0.004	0.006	28	
May-11	0.146	0.21	0.01	0.138	0.1	0.005	0.006	82	
Jun-11	0.101	0.14	0.01	0.101	0.1	0.004	0.007	40	
Jul-11	0.05	0.17	0.01	0.041	0.13	0.004	0.008	14	
Aug-11	0.036	0.11	0.01	0.029	0.1	0.004	0.004	10	
Sep-11	0.032	0.13	0.01	0.03	0.1	0.004	0.004	6	
Oct-11	0.3	0.51	0.01	0.3	0.21	0.008	0.008	124	
Nov-11	0.147	0.3	0.01	0.143	0.16	0.006	0.008	81	

Rocky Point Stream

	Flow		Conductivity		Dissolved Oxygen		Temp	Clarity	TSS
DATE	**L/s**	**pH**	**us/cm**	**ms/m**	**mg/L**	**%**	**C**	**m**	**mg/L**
Dec-10	24	7.6	74.1	7.41	7.017	66.3	13.1	0.8	4.1
Jan-11	49	7.31	72.7	7.27	6.99584	66.1	15.2	1	2.4
Feb-11	147	7.7	66.3	6.63	8.67865	82	11.4	0.71	2.4
Mar-11	90	6.27	54	5.4	8.90091	84.1	11.3	0.9	3

Apr-11	41	7.3	70	7	8.68923	82.1	9.1	0.9	3
May-11	169	7.2	70	7	9.32425	88.1	5.1	0.9	3
Jun-11	45	7.1	90	9	8.45639	79.9	3.4	1	3
Jul-11	112	7.4	79	7.9	0				3
Aug-11	34	7.4	78.7	7.87	9.53593	90.1	2.4	1	3
Sep-11	39	7.2	92.2	9.22	10.171	96.1	5.6	0.92	3
Oct-11	234	7.4	106.3	10.63	10.0228	94.7	8.7	0.52	7
Nov-11	126	6.8	99.5	9.95	9.93811	93.9	13.7	0.78	4

Rocky Point Stream

	DIN	**TN**	**NH4+**	**Nox**	**TKN**	**DRP**	**TP**	**E.coli**	
DATE	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**MPN/100mL**	
Dec-10	0.005	0.19	0.005	0.005		0.032	0.057	160	
Jan-11	0.007	0.12	0.005	0.007		0.007	0.043	170	
Feb-11		0.22					0.043	460	
Mar-11	0.011	0.32	0.01	0.002	0.32	0.017	0.019	48	
Apr-11	0.011	0.23	0.01	0.002	0.23	0.01	0.018	25	
May-11	0.124	0.46	0.01	0.124	0.34	0.011	0.018	140	
Jun-11	0.044	0.29	0.01	0.043	0.25	0.005	0.014	172	
Jul-11	0.192	0.64	0.01	0.184	0.46	0.008	0.032	102	
Aug-11	0.064	0.23	0.01	0.059	0.17	0.004	0.007	36	
Sep-11	0.011	0.31	0.01	0.004	0.3	0.004	0.022	63	
Oct-11	0.34	1.22	0.025	0.32	0.9	0.022	0.048	816	
Nov-11	0.106	0.67	0.012	0.094	0.58	0.019	0.038	166	

Hakataramea Wrights Crossing									
	Flow		Conductivity		Dissolved Oxygen		Temp	Clarity	TSS
DATE	L/s	pH	us/cm	ms/m	mg/L	%	C	m	mg/L
Dec-10	914	7.2	74.1	7.41	7.49327	70.8	14.7	1	0.9
Jan-11	1520	7.06	75.2	7.52	8.33997	78.8	16.5	1	0.5
Feb-11	4627	7.5	69.2	6.92	8.53048	80.6	15.4	0.88	2.1
Mar-11	2841	6.32	73	7.3	9.96986	94.2	14	1	3
Apr-11	1979	7.3	70	7	9.65235	91.2	12.8	1	3
May-11	6321	7.3	70	7	9.37717	88.6	8.3	0.7	3
Jun-11	1793	7.2	70	7	8.66806	81.9	7.4	1	3
Jul-11	2914	7.3	63	6.3	8.80565	83.2	7.2	1	3
Aug-11	1368	7.4	67.9	6.79	10.0969	95.4	4.6	1	3
Sep-11	1963	7	71.6	7.16	10.245	96.8	7.8	1	3
Oct-11	9107	7.3	78.4	7.84	9.80052	92.6	11.7	0.82	3
Nov-11	4910	6.8	79.3	7.93	9.78994	92.5	14.3	1	3

Hakataramea Wrights Crossing									
	DIN	TN	NH4+	Nox	TKN	DRP	TP	E.coli	
DATE	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN/100mL	
Dec-10	0.048	0.08	0.005	0.048		0.002	0.008	10	
Jan-11	0.031	0.08	0.005	0.031		0.001	0.008	48	
Feb-11		0.08					0.013	200	
Mar-11	0.024	0.12	0.01	0.024	< 0.1	0.004	0.006	30	
Apr-11	0.025	0.16	0.01	0.021	0.14	0.004	0.004	15	
May-11	0.15	0.27	0.01	0.141	0.13	0.006	0.008	27	
Jun-11	0.055	0.2	0.01	0.053	0.14	0.004	0.005	25	
Jul-11	0.032	0.11	0.01	0.025	< 0.1	0.004	0.007	10	

Aug-11	0.031	0.19	0.01	0.028	0.16	0.004	0.004	0	
Sep-11	0.031	0.1	0.01	0.03	< 0.1	0.004	0.004	1	
Oct-11	0.165	0.37	0.01	0.159	0.21	0.009	0.01	185	
Nov-11	0.074	0.22	0.01	0.071	0.15	0.004	0.006	102	

Padkins Stream

	Flow		Conductivity		Dissolved Oxygen		Temp	Clarity	TSS
DATE	**L/s**	**pH**	**us/cm**	**ms/m**	**mg/L**	**%**	**C**	**m**	**mg/L**
Dec-10	30	7.3	81.6	8.16	9.09141	85.9	13.9	1	4.1
Jan-11	147	7.45	94.6	9.46	8.95382	84.6	16	1	0.9
Feb-11	329	7.4	90	9	9.93811	93.9	15	1	0.7
Mar-11	372	6.56	84.4	8.44	11.0494	104.4	13.6	1	3
Apr-11	83	7.3	90	9	10.9753	103.7	13.3	1	3
May-11	423	7.4	100	10	9.8111	92.7	9.2	1	3
Jun-11	122	7.8	90	9	9.46184	89.4	7.8	1	3
Jul-11	200	7.8	78	7.8	9.98044	94.3	5.1	0.9	3
Aug-11	68	7.74	91	9.1	10.7848	101.9	4.6	1	3
Sep-11	91	7.8	95.8	9.58	10.9647	103.6	9.3	1	3
Oct-11	471	7.5	100.9	10.09	10.2768	97.1	11.2	1	3
Nov-11	221	7	104.6	10.46	10.3615	97.9	14.8	1	3

Padkins Stream

	DIN	TN	NH4+	Nox	TKN	DRP	TP	E.coli	
DATE	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**MPN/100mL**	
Dec-10	0.005	0.19	0.005	0.005		0.032	0.057	160	
Jan-11	0.019	0.08	0.005	0.008		0.002	0.009	31	
Feb-11		0.36					0.015	140	

Mar-11	0.011	0.23	0.01	0.003	0.23	0.004	0.004	28	
Apr-11	0.011	0.16	0.01	0.002	0.16	0.004	0.004	26	
May-11	0.58	0.82	0.01	0.57	0.24	0.008	0.006	101	
Jun-11	0.062	0.21	0.01	0.062	0.15	0.004	0.004	5	
Jul-11	0.081	0.2	0.01	0.075	0.12	0.004	0.008	6	
Aug-11	0.037	0.14	0.01	0.031	0.11	0.004	0.004	0	
Sep-11	0.018	0.18	0.01	0.015	0.16	0.004	0.004	3	
Oct-11	0.25	0.53	0.01	0.24	0.29	0.008	0.006	47	
Nov-11	0.39	0.64	0.01	0.39	0.25	0.005	0.006	32	

Hakataramea SH82

	Flow		**Conductivity**		**Dissolved Oxygen**		**Temp**	**Clarity**	**TSS**
DATE	**L/s**	**pH**	**us/cm**	**ms/m**	**mg/L**	**%**	**C**	**m**	**mg/L**
Dec-10	1521	6.86	94.6	9.46	8.16005	77.1	12.8	1	0.9
Jan-11	2342	7.8	98.2	9.82	9.98044	94.3	16.4	1	0.5
Feb-11	6217	7.7	85.3	8.53	9.39834	88.8	15.8	1	0.6
Mar-11	4075	6.31	90.1	9.01	10.4038	98.3	15	1	3
Apr-11	2817	7.5	60	6	10.2556	96.9	14	1	3
May-11	8122	7.4	80	8	9.54651	90.2	9.7	0.95	3
Jun-11	2817	7.5	90	9	8.82682	83.4	8.6	1	3
Jul-11	3893	7.6	83	8.3	0				3
Aug-11	2161	7.825	89.7	8.97	10.3932	98.2	5.4	1	3
Sep-11	2534	7.4	85.7	8.57	10.4567	98.8	8.7	1	3
Oct-11	10940	7.4	87	8.7	9.91694	93.7	12.1	0.82	3
Nov-11	6260	6.9	90.5	9.05	10.0757	95.2	14.8	1	3

Hakataramea SH82									
	DIN	TN	NH4+	Nox	TKN	DRP	TP	E.coli	
DATE	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN/100mL	
Dec-10	0.048	0.08	0.005	0.048		0.002	0.008		
Jan-11	0.008	0.08	0.005	0.008		0.001	0.008		
Feb-11		0.08					0.011		
Mar-11	0.01	0.11	0.01	0.01	0.1	0.004	0.004	11	
Apr-11	0.025	0.16	0.01	0.021	0.14	0.004	0.004	15	
May-11	0.142	0.19	0.01	0.133	0.1	0.007	0.006	34	
Jun-11	0.055	0.22	0.01	0.051	0.17	0.004	0.005	6	
Jul-11	0.051	0.14	0.01	0.04	0.1	0.005	0.009	10	
Aug-11	0.036	0.13	0.01	0.029	0.1	0.004	0.004	2	
Sep-11	0.021	0.11	0.01	0.014	0.1	0.004	0.004	1	
Oct-11	0.124	0.37	0.01	0.116	0.25	0.005	0.007	43	
Nov-11	0.06	0.2	0.01	0.057	0.14	0.005	0.006	19	

December 2010 Ecology

	200 Fixed Count	MCI TV	Hakataramea @ SH82	Padkins Stream	Hakataramea @ Wrights Crossing	Rocky Point Stream	Hakataramea @ Cattle Ck	Grampians Stream	Hakataramea @ rain gauge (top)
Mayflies									
Austroclima		9	-	-	-	-	1	-	-
Coloburiscus		9	-	-	-	-	1	1	-
Deleatidium		8	95	5	35	-	34	27	92
Nesameletus		9	-	-	-	-	-	1	1
Stoneflies									
Stenoperla		10	-	-	-	-	-	-	-
Zelandobius		5	-	-	-	-	-	-	-
Zelandoperla		10	-	-	-	-	-	-	-
Dobsonflies									
Archichauliodes		7	1	-	-	1	1	1	1
Beetles									
Berosus		5	-	-	-	-	-	-	-
Elmidae		6	33	6	22	1	23	5	37
Hydraenidae		8	-	-	-	-	-	1	-
Staphylinidae		5	-	3	-	-	-	-	-
Water Bugs									
Saldula		5	-	-	-	-	1	1	-
Sigara		5	-	-	1	1	-	-	-
True Flies									
Anthomyiidae		3	-	2	1	-	2	1	1
Aphrophila		5	-	-	-	-	-	1	-

Austrosimulium	3	9	13	93	1	42	45	5
Chironomus	1	-	1	-	1	-	-	-
Corynoneura	2	-	1	-	-	-	-	-
Dolichopodidae	3	-	1	-	-	-	-	-
Empididae	3	-	1	-	-	-	1	-
Ephydrella	4	-	1	-	-	-	-	-
Eriopterini	9	1	1	-	-	1	-	2
Hexatomini	5	-	-	-	-	1	-	-
Maoridiamesa	3	-	1	-	-	-	-	-
Orthocladiinae	2	10	38	13	1	9	2	2
Parochlus	8	-	1	-	-	-	-	-
Podonominae	8	-	-	-	-	-	-	-
Polypedilum	3	-	-	-	-	-	-	-
Stictocladius	8	-	-	-	-	-	-	1
Stratiomyidae	3	-	1	-	-	-	-	-
Tabanidae	3	1	-	-	-	-	-	1
Tanypodinae	5	-	6	2	-	1	1	1
Tanytarsus	3	2	12	10	-	1	4	1
Caddisflies								
Aoteapsyche	4	14	1	7	-	13	20	1
Beraeoptera	8	-	-	-	-	-	-	-
Costachorema	7	-	-	-	-	-	1	-
Helicopsyche	10	-	-	-	-	-	4	-
Hudsonema	6	1	-	1	1	-	1	-
Hydrobiosis	5	2	5	9	1	2	5	2
Neurochorema	6	1	-	-	-	1	1	-
Olinga	9	2	7	5	-	15	11	5
Oxyethira	2	-	47	-	2	-	-	-
Plectrocnemia	8	-	-	2	-	-	-	-

Polyplectropus	8	-	-	1	-	-	-	-
Psilochorema	8	-	2	2	1	1	1	1
Pycnocentria	7	1	1	-	-	1	-	-
Pycnocentrodes	5	10	2	5	-	55	66	71
Crustacea								
Copepoda	5	-	1	-	4	-	-	-
Ostracoda	3	-	1	3	45	1	-	-
Paracalliope	5	1	1	-	-	-	-	-
Phreatogammarus	5	-	-	-	-	-	-	-
Mites	5	-	1	1	1	-	1	-
Worms	1	4	1	1	32	1	1	1
Flatworms	3	-	-	-	-	-	-	-
Hirudinea								
Placobdelloides	3	-	-	-	-	-	-	-
Snails								
Gyraulus	3	-	-	-	-	-	-	-
Physa	3	2	-	-	4	-	-	-
Potamopyrgus	4	13	65	10	141	-	12	1
Sphaeriidae	3	-	-	-	1	-	-	-
Proboscis worms	3	-	-	-	-	-	-	-
Round worms	3	-	-	-	2	-	-	-
Horse-hair worms	3	-	1	-	-	-	-	1
Collembola	6	-	-	-	1	-	-	-
Total number of taxa		19	31	20	19	22	26	20
Number of rare taxa		3	6	3	8	7	12	9
Number of individuals (incl. rare taxa)		200	230	224	242	208	216	228
Number of individuals (excl. rare taxa)		200	224	221	234	201	204	219
MCI		101	88	101	82	111	112	105
QMCI		6.16	3.54	4.50	3.43	5.33	5.12	6.42

%EPT$_{taxa}$	42.11	25.81	45.00	21.05	45.45	46.15	35.00
%EPT$_{taxa}$ (excl. Hydroptilidae)	42.11	22.58	45.00	15.79	45.45	46.15	35.00
%EPT$_{abundance}$	63.00	30.43	29.91	2.07	59.62	64.35	75.88
%EPT$_{abundance}$ (excl. Hydroptilidae)	63.00	30.43	28.57	2.07	59.62	64.35	75.88

March 2011 Ecology

	200 Fixed Count	MCI TV	Hakataramea @ SH82	Padkins Stream	Hakataramea @ Wrights Crossing	Rocky Point Stream	Hakataramea @ Cattle Ck (Scotts Bridge Rd)	Grampians Stream	Hakataramea @ rain gauge (top)
Mayflies									
Austroclima		9	-	-	-	-	1	-	-
Coloburiscus		9	-	-	-	-	1	4	-
Deleatidium		8	95	140	68	4	123	59	115
Nesameletus		9	-	-	-	-	-	-	-
Stoneflies									
Stenoperla		10	-	1	-	-	-	-	1
Zelandobius		5	-	-	-	1	-	-	2
Zelandoperla		10	-	-	-	-	-	1	1
Dobsonflies									
Archichauliodes		7	1	1	1	-	1	1	3
Beetles									
Berosus		5	-	-	1	-	-	-	-
Elmidae		6	33	3	14	1	20	21	44
Hydraenidae		8	-	-	-	-	-	1	-
Staphylinidae		5	-	-	-	-	-	-	-
Water Bugs									
Saldula		5	-	-	-	-	-	-	-
Sigara		5	-	-	-	-	-	-	-
True Flies									

Anthomyiidae	3	-	-	1	-	-	-	-
Aphrophila	5	-	-	-	-	1	2	-
Austrosimulium	3	9	8	-	-	6	9	2
Chironomus	1	-	-	-	-	-	-	-
Corynoneura	2	-	-	-	-	-	-	-
Dolichopodidae	3	-	-	-	-	-	-	-
Empididae	3	-	-	-	-	-	-	1
Ephydrella	4	-	-	-	-	-	-	-
Eriopterini	9	1	2	-	-	1	-	3
Hexatomini	5	-	-	-	-	-	-	-
Maoridiamesa	3	-	-	-	-	-	-	1
Orthocladiinae	2	10	-	22	1	1	-	4
Parochlus	8	-	-	-	-	-	-	-
Podonominae	8	-	-	-	-	-	-	-
Polypedilum	3	-	-	-	-	-	-	-
Stictocladius	8	-	-	-	-	1	-	2
Stratiomyidae	3	-	-	-	-	-	-	-
Tabanidae	3	1	-	-	-	-	-	1
Tanypodinae	5	-	-	6	-	-	-	-
Tanytarsus	3	2	2	7	-	-	-	1
Caddisflies								
Aoteapsyche	4	14	3	7	-	4	13	12
Beraeoptera	8	-	-	-	-	-	-	1
Costachorema	7	-	-	-	-	-	-	-
Helicopsyche	10	-	-	-	-	-	1	-
Hudsonema	6	1	1	3	1	4	3	1
Hydrobiosis	5	2	2	7	1	1	3	1
Neurochorema	6	1	-	-	-	-	-	-
Olinga	9	2	1	2	-	20	29	13

Oxyethira	2	-	1	11	1	-	-	2
Plectrocnemia	8	-	-	-	-	-	-	-
Polyplectropus	8	-	-	-	-	-	-	-
Psilochorema	8	-	4	1	2	1	2	3
Pycnocentria	7	1	1	1	-	-	10	-
Pycnocentrodes	5	10	19	42	-	28	22	11
Crustacea								
Copepoda	5	-	-	-	-	-	-	-
Ostracoda	3	-	1	-	12	-	1	-
Paracalliope	5	1	-	-	-	-	-	-
Phreatogammarus	5	-	-	1	-	-	-	-
Mites	5	-	-	-	1	-	-	-
Worms	1	4	1	3	14	1	12	-
Flatworms	3	-	-	-	3	-	1	-
Hirudinea								
Placobdelloides	3	-	-	-	-	-	-	-
Snails								
Gyraulus	3	-	-	-	15	-	-	-
Physa	3	2	-	1	3	-	-	-
Potamopyrgus	4	13	34	5	184	13	33	-
Sphaeriidae	3	-	-	-	1	-	-	-
Proboscis worms	3	-	-	-	2	-	1	-
Round worms	3	-	-	-	3	-	-	-
Horse-hair worms	3	-	-	1	-	-	-	-
Collembola	6	-	-	-	-	-	-	-
Total number of taxa		19	18	21	18	18	21	22
Number of rare taxa		3	4	2	4	5	2	3
Number of individuals (incl. rare taxa)		200	221	203	246	223	227	222
Number of individuals (excl. rare taxa)		200	221	203	246	223	227	222

MCI	101	111	96	81	120	118	115
QMCI	6.16	6.74	5.45	3.78	7.00	6.12	6.98
%EPT$_{taxa}$	42.11	55.56	42.86	33.33	50.00	52.38	54.55
%EPT$_{taxa}$ (excl. Hydroptilidae)	42.11	50.00	38.10	27.78	50.00	52.38	50.00
%EPT$_{abundance}$	63.00	78.28	69.95	4.07	82.06	64.76	73.42
%EPT$_{abundance}$ (excl. Hydroptilidae)	63.00	78.28	69.95	4.07	82.06	64.76	73.42

June 2011 Ecology

	200 Fixed Count	MCI TV	Hakataramea @ SH82	Padkins Stream	Hakataramea @ Wrights Crossing	Rocky Point Stream	Hakataramea @ Cattle Ck (Scotts Bridge Rd)	Grampians Stream	Hakataramea @ rain gauge (top)
Mayflies									
Austroclima		9	-	-	-	-	2	-	1
Coloburiscus		9	-	-	-	-	1	1	-
Deleatidium		8	244	72	130	3	150	69	161
Nesameletus		9	-	-	-	-	-	-	1
Stoneflies									
Stenoperla		10	-	-	-	-	-	-	-
Zelandobius		5	-	-	-	-	1	-	4
Zelandoperla		10	-	-	-	-	1	1	1
Dobsonflies									
Archichauliodes		7	-	1	-	-	1	1	1
Beetles									
Berosus		5	-	-	-	-	-	-	-
Elmidae		6	2	-	5	-	3	11	3
Hydraenidae		8	-	-	-	-	-	-	-
Staphylinidae		5	-	-	-	-	-	-	-
Water Bugs									
Saldula		5	-	-	-	-	-	-	-
Sigara		5	-	-	-	-	-	-	-
True Flies									

Anthomyiidae	3	-	-	1	-	-	-	-
Aphrophila	5	-	-	1	-	1	3	1
Austrosimulium	3	1	18	24	2	25	73	10
Chironomus	1	-	-	-	-	-	-	-
Corynoneura	2	-	-	-	-	-	-	-
Dolichopodidae	3	-	-	-	-	-	-	-
Empididae	3	-	2	-	-	-	-	5
Ephydrella	4	-	-	-	-	-	-	-
Eriopterini	9	1	1	1	-	-	-	2
Hexatomini	5	-	-	-	-	-	-	-
Maoridiamesa	3	-	1	-	-	1	1	-
Orthocladiinae	2	-	8	1	1	1	2	1
Parochlus	8	-	-	-	-	-	-	-
Podonominae	8	-	-	-	-	-	1	-
Polypedilum	3	-	1	-	-	-	-	-
Stictocladius	8	-	-	-	-	1	1	3
Stratiomyidae	3	-	1	-	-	-	-	-
Tabanidae	3	-	-	-	-	-	-	-
Tanypodinae	5	-	-	-	-	-	-	-
Tanytarsus	3	-	1	-	-	-	-	-
Caddisflies								
Aoteapsyche	4	23	6	12	1	7	3	3
Beraeoptera	8	-	-	-	-	-	-	1
Costachorema	7	-	-	-	-	1	-	-
Helicopsyche	10	-	-	-	-	-	1	-
Hudsonema	6	-	16	3	1	-	1	-
Hydrobiosis	5	3	7	1	1	6	5	7
Neurochorema	6	-	-	-	-	1	-	1
Olinga	9	4	7	1	-	13	56	2

Oxyethira	2	-	4	-	4	-	-	1
Plectrocnemia	8	-	-	-	-	-	-	-
Polyplectropus	8	-	-	-	-	-	-	-
Psilochorema	8	1	5	3	-	2	3	6
Pycnocentria	7	1	8	1	-	5	10	-
Pycnocentrodes	5	9	22	41	1	9	18	8
Crustacea								
Copepoda	5	-	-	-	-	-	-	-
Ostracoda	3	-	-	1	9	1	-	-
Paracalliope	5	1	2	-	-	-	-	-
Phreatogammarus	5	-	-	-	-	-	-	-
Mites	5	-	1	-	-	-	-	-
Worms	1	1	1	1	3	1	8	-
Flatworms	3	-	-	-	12	-	1	-
Hirudinea								
Placobdelloides	3	-	-	-	-	-	-	-
Snails								
Gyraulus	3	-	-	-	18	-	-	-
Physa	3	-	-	1	6	-	-	-
Potamopyrgus	4	9	9	1	220	2	28	1
Sphaeriidae	3	-	-	-	-	-	-	-
Proboscis worms	3	-	-	-	1	1	3	-
Round worms	3	-	-	-	-	-	-	-
Horse-hair worms	3	-	-	-	-	-	-	-
Collembola	6	-	-	-	-	-	-	-
Total number of taxa		13	22	18	15	24	23	22
Number of rare taxa		0	0	7	4	9	0	7
Number of individuals (incl. rare taxa)		300	194	229	283	237	301	224
Number of individuals (excl. rare taxa)		300	194	222	279	228	301	217

MCI	114	95	101	73	114	117	123
QMCI	7.40	6.00	6.50	3.82	7.00	5.89	7.27
%EPT$_{taxa}$	53.85	40.91	44.44	40.00	54.17	47.83	59.09
%EPT$_{taxa}$ (excl. Hydroptilidae)	53.85	36.36	44.44	33.33	54.17	47.83	54.55
%EPT$_{abundance}$	95.00	75.77	83.84	3.89	83.97	55.81	87.95
%EPT$_{abundance}$ (excl. Hydroptilidae)	95.00	73.71	83.84	2.47	83.97	55.81	87.50

September 2011 Ecology

	200 Fixed Count	MCI TV	Hakataramea @ SH82	Padkins Stream	Hakataramea @ Wrights Crossing	Rocky Point Stream	Hakataramea @ Cattle Ck (Scotts Bridge Rd)	Grampians Stream	Hakataramea @ rain gauge (top)
Mayflies									
Austroclima		9	-	-	-	-	1	-	-
Coloburiscus		9	-	-	-	-	-	1	-
Deleatidium		8	122	141	154	8	110	81	66
Nesameletus		9	-	-	-	-	-	-	1
Stoneflies									
Stenoperla		10	-	-	-	-	1	-	1
Zelandobius		5	1	-	-	-	-	-	1
Zelandoperla		10	-	-	-	-	1	-	1
Dobsonflies									
Archichauliodes		7	1	-	1	-	-	1	1
Beetles									
Berosus		5	-	-	-	-	-	-	-
Elmidae		6	37	1	1	-	24	17	81
Hydraenidae		8	-	-	-	-	-	-	-
Staphylinidae		5	-	-	-	-	-	-	-
Water Bugs									
Saldula		5	-	-	-	-	-	-	-
Sigara		5	-	-	-	-	-	-	-
True Flies									

Anthomyiidae	3	-	-	-	-	-	-	-
Aphrophila	5	-	1	-	-	1	1	1
Austrosimulium	3	4	30	12	17	19	62	10
Chironomus	1	-	-	-	-	-	-	-
Corynoneura	2	-	-	-	-	-	-	-
Dolichopodidae	3	-	-	-	-	-	-	-
Empididae	3	-	-	-	-	-	-	1
Ephydrella	4	-	-	-	-	-	-	-
Eriopterini	9	2	1	1	1	-	-	1
Hexatomini	5	-	-	-	-	-	-	-
Maoridiamesa	3	1	1	-	-	-	-	1
Orthocladiinae	2	1	2	1	5	-	2	17
Parochlus	8	-	-	-	-	-	-	-
Podonominae	8	-	-	-	-	-	-	-
Polypedilum	3	-	-	-	-	-	-	-
Stictocladius	8	1	-	-	-	3	-	12
Stratiomyidae	3	-	-	-	-	-	-	-
Tabanidae	3	3	1	-	-	-	-	1
Tanypodinae	5	-	-	-	-	-	1	-
Tanytarsus	3	-	1	-	-	-	-	3
Caddisflies								
Aoteapsyche	4	7	1	1	-	1	1	2
Beraeoptera	8	-	-	-	-	-	1	1
Costachorema	7	-	-	-	-	1	1	1
Helicopsyche	10	-	-	-	-	-	1	-
Hudsonema	6	-	4	3	-	1	1	-
Hydrobiosis	5	3	24	1	1	3	2	1
Neurochorema	6	-	-	1	-	-	-	-
Olinga	9	5	4	6	-	3	7	6

Oxyethira	2	-	1	-	2	-	-	-
Plectrocnemia	8	-	-	-	-	-	-	-
Polyplectropus	8	-	1	1	-	-	-	-
Psilochorema	8	1	1	2	1	1	1	3
Pycnocentria	7	2	3	1	-	5	8	-
Pycnocentrodes	5	12	9	29	-	30	13	25
Crustacea								
Copepoda	5	-	-	-	-	-	-	-
Ostracoda	3	-	-	-	6	-	1	-
Paracalliope	5	-	-	-	-	-	-	-
Phreatogammarus	5	-	-	-	-	-	-	-
Mites	5	1	-	-	-	-	-	1
Worms	1	1	1	1	3	1	31	-
Flatworms	3	-	-	-	-	-	-	-
Hirudinea								
Placobdelloides	3	-	-	-	-	-	-	-
Snails								
Gyraulus	3	-	-	-	6	-	-	-
Physa	3	-	-	-	1	-	-	-
Potamopyrgus	4	2	1	1	186	-	6	-
Sphaeriidae	3	-	-	-	-	-	-	-
Proboscis worms	3	-	-	-	-	-	-	-
Round worms	3	-	-	-	3	-	-	-
Horse-hair worms	3	-	-	-	-	-	-	-
Collembola	6	-	-	-	-	1	-	-
Total number of taxa		19	20	17	13	18	21	24
Number of rare taxa		4	4	5	2	6	6	5
Number of individuals (incl. rare taxa)		207	229	217	240	207	240	239
Number of individuals (excl. rare taxa)		203	225	212	238	201	234	234

MCI	111	101	113	75	127	108	121
QMCI	7.03	6.68	7.22	3.92	6.75	5.21	6.21
%EPT$_{taxa}$	42.11	50.00	58.82	30.77	66.67	57.14	50.00
%EPT$_{taxa}$ (excl. Hydroptilidae)	42.11	45.00	58.82	23.08	66.67	57.14	50.00
%EPT$_{abundance}$	73.91	82.53	91.71	5.00	76.33	49.17	45.61
%EPT$_{abundance}$ (excl. Hydroptilidae)	73.91	82.10	91.71	4.17	76.33	49.17	45.61