High Country Environmental Monitoring Report 2005-06

David Norton[1], Dave Lucock[2], Diane Sage[1] and Mark Stevenson[3]
[1]School of Forestry, University of Canterbury, Private Bag 4800, Christchurch
[2]The Agribusiness Group, PO Box 4354, Christchurch
[3]The New Zealand Merino Company, PO Box 25-160, Christchurch

1 August 2007

ARGOS High Country Environmental Report No. 1

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

ARGOS

Contents

1. Introduction

This report documents the approach that has been taken for establishing land-cover, aquatic and soil monitoring on high country properties as part of the ARGOS (Agriculture Research Group on Sustainability) research project. As this is the first monitoring report no results are presented although each high country ARGOS property will receive individual reports detailing the location of monitoring sites and the data that was collected during the initial measurements. As monitoring is repeated in future years, summary analyses of observed trends will be compiled and circulated around all eight high country ARGOS properties, while individual farmers will receive detailed reports for their property.

ARGOS is an unincorporated joint venture between the Agribusiness Group, Lincoln University, and the University of Otago. It is funded by the Foundation for Research, Science and Technology, as well as various sector funders (e.g., Meat and Wool New Zealand). The ARGOS project is examining the environmental, social and economic sustainability of New Zealand's farming systems focusing on five farming sectors (sheep and beef, dairy, kiwifruit, high country, and Ngai Tahu farms). A better understanding of the environmental effects, and the social and economic consequences of different farming practices will help New Zealand farmers, and the broader New Zealand public, better understand the interdependencies that exist between farming and the environment, and thus contribute towards more sustainable farm management practices. The goal of ARGOS research is "to facilitate innovation and performance in primary production systems and to maintain or create multifunctional landscapes, where people and their actions are rooted in, rather than grafted on to, the New Zealand environment" (Moller et al. 2005).

The high country section of ARGOS is focused on the merino sector and involves the monitoring and analysis of eight eastern South Island high country properties from Marlborough to Otago (Figure 1).

The land-cover, aquatic and soil monitoring protocol for high country properties was developed and implemented during the 2005/06 summer. It has developed from the broader environmental monitoring programme that is being undertaken across all ARGOS study properties (Moller et al. 2005), but has been adapted to meet the specific requirements of the high country situation. Because of a funding shortfall, it was only possible to establish monitoring of all three variables (land-cover, aquatic and soil) on two of the eight study properties (Glenmore and Otematata Stations) but the work undertaken over this summer will result in a refinement to the monitoring procedure that will be applied in 2006/07 to the remaining six high country properties. Soil monitoring is being undertaken across all eight high country properties during the 2006 winter.

The primary goal of the high country monitoring is:

- To assess the response of high country ecosystems to (1) management inputs and (2) external perturbations such as climate change or species invasion.

Specifically, the monitoring aims to:

- Provide baseline information on trends in land-cover, stream health and soil conditions through time for a range of permanent sample sites representative of each high country property that the individual farmers can use to directly assess the effects of their farm management practices.

- Provide more detailed information on land-cover, stream health and soil conditions that can be used to test experimental hypotheses generated within the ARGOS project relating to the impacts of management inputs and external perturbations (e.g., climate change) on the resilience of high country ecosystems.

This report outlines the methods used to undertake land-cover, aquatic and soil monitoring, summarises the monitoring established over the 2005/06 summer and 2006 winter, and highlights changes to the monitoring protocol that will be implemented in 2006/07.

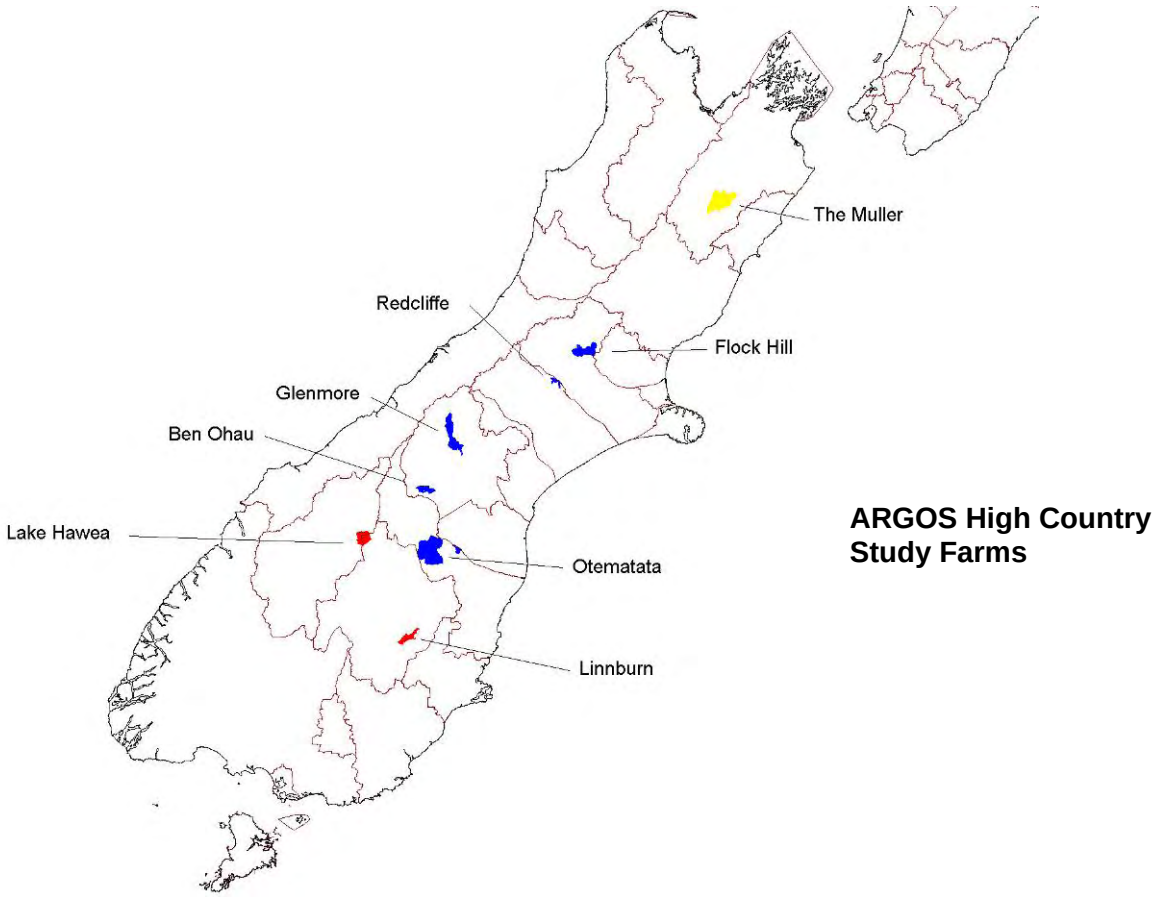

Figure 1. Location of high country study properties.

2. Land-cover monitoring

2.1 Introduction

High country properties are typically large, with those studied in this ARGOS project ranging up to ca. 40,000 ha. This presents a significant challenge for establishing monitoring that is representative of the whole property but is efficient to establish and re-measure. In particular, high country properties typically have substantial areas of higher altitude country that is accessible only by foot or helicopter. Monitoring therefore needs to be located in sites that have reasonable access, while still being representative of the range of environments present across the property. This section describes the methods used to establish land cover monitoring on Glenmore and Otematata Stations, outlines the monitoring established, and provides some suggestions on ways to improve land cover monitoring during the 2006/07 summer.

There is a long history of land-cover monitoring in the high country dating back to the pioneering work of Leonard Cockayne on montane tussock grasslands in the period 1918-1922 (e.g., Cockayne 1920). Since then, a range of organisations and individuals have undertaken different land-cover monitoring projects in the high country. Unfortunately, only a few of these have been long-term and followed through to the present day. Notwithstanding this, considerable information has been collected on the effects of different management inputs on high country land-cover (primarily plant cover), especially in assessing the effects of grazing versus no-grazing (e.g., Duncan et al. 2001, Meurk et al. 2002, Mark and Dickinson 2003), weed invasion (e.g., Scott 1993, Rose et al. 1995), and the fate over-sowing and fertiliser trials (Allan and Chapman 1987, Scott 2001).

A variety of methods have been used in these different monitoring programmes including counts of plant density and/or frequency, measurements of plant height, and various measures or estimates of cover abundance (Allen et al. 1983, Dickinson et al. 1992, Aspinall 1994, Allan et al. 1998). Photo-monitoring has also been successfully used in several studies to document trends in land-cover through time (Moore 1976, Mark 1978). All methods have their advantages and disadvantages and it is not proposed to review these in detail here. However, to be readily used by farmers as a land management tool, monitoring needs to be simple to undertake and interpret, but repeatable through time.

Based on the experience of previous monitoring projects, the need to obtain sound quantitative land-cover data, and the recognition that monitoring needs to be easily used by farmers, three elements were identified as underpinning land-cover monitoring here:

- Sites need to be permanently marked to enable reliable repeat measurements.
- Fixed photopoints provide a simple but interpretable tool for initial assessments.
- Plot based measurements provide quantitative data for detailed assessments.

These three elements provided the basis for the land-cover monitoring described below.

2.2 Monitoring site location

For this project monitoring sites were stratified across each property using the broad landform patterns present, coupled with farm management units as a basis for stratification, as follows:

1. Each property was initially divided into the major landform units present (e.g., flats, downlands, lower mountains, higher mountains).

2. Each of these units was further subdivided based on the presence of improvements, principally unimproved (native country) *versus* over-sown and top-dressed *versus* irrigated and/or cultivated.

This resulted in the identification of a number of landform/management units on each property (typically between 4 and 12 depending on the size of the property).

A number of monitoring sites was then assigned to each of these units. As an initial guide it was proposed to locate a minimum of 30 monitoring sites per property, with this increasing to no more than 60 for the largest properties. This number was considered reasonable in terms of the resources required to establish the monitoring sites and in remeasuring them, because it provides a reasonable density of monitoring sites across a property, and because it is of a size that farmers can relate to their farm management practices.

An attempt was made to keep the density of monitoring sites proportional to the area of each landform/management unit, although high mountainous areas (which were unimproved) were usually under-sampled relative to the more accessible and usually more developed lower parts of properties. This was done for partly pragmatic reasons (difficult access) and because the lower parts of properties are the areas that have the most development potential and are therefore likely to change most in the next 10-20 years. No permanent vegetation monitoring sites were located within regularly cultivated blocks, as the monitoring layout with permanently fixed metal standards is not compatible with cultivation.

Final site locations were then determined taking into account the following factors. Monitoring sites should be located:

- In an area of vegetation typical of the landform/management unit.
- In a site that is relatively uniform with respect to vegetation, landform and management regime, and preferably on the mid-slope.
- At least 20 m from a fence, water trough, tree/hedgerow, track or building.
- In a site that is not planned to be cultivated in the near future management.
- At a site that has reasonably easy access (e.g., not on the far side of a river), and preferably that can be driven to or within 500 m of a vehicle access point.

Monitoring site locations were entered onto a Geographical Information System[1] (GIS) map of the property and the sites location information (easting and northing; New Zealand Map Grid 1949 geodetic datum) extracted to facilitate field location using a Global Positioning System (GPS) unit.

2.3 Monitoring site establishment

A GPS unit was used to find the allocated site in the field. Final site location was then determined randomly from this point (direction and distance), taking into account the above considerations. A 1.8 m metal standard was then firmly hammered into the ground[2] and labelled using a numbered cattle ear tag[3]. A second metal standard was then positioned 25 m from the first, and was always located across the slope (along the contour). Once established the following information was recorded:

- GPS location and altitude (of the first standard), and date.
- Slope and aspect (perpendicular to the transect and recorded in the middle).

[1] MapInfo v8 was the GIS system used for this project.
[2] Stakes need to be firmly hammered into the ground to avoid cattle knocking them over.
[3] A list of field equipment required for establishing a monitoring site is provided in Appendix 1.

- A general location photo showing both standards and the landform the plot was located on (Figure 2).

Figure 2. Example of location photo for one vegetation monitoring site at Otematata Station.

Land cover measurements were then made within a transect located between the two metal standards (Figure 3). This transect involved ten 2x2 m contiguous plots that were centred along the centre-line between the two standards starting at 2.5 m from the first standard and finishing 2.5 m before the second standard.

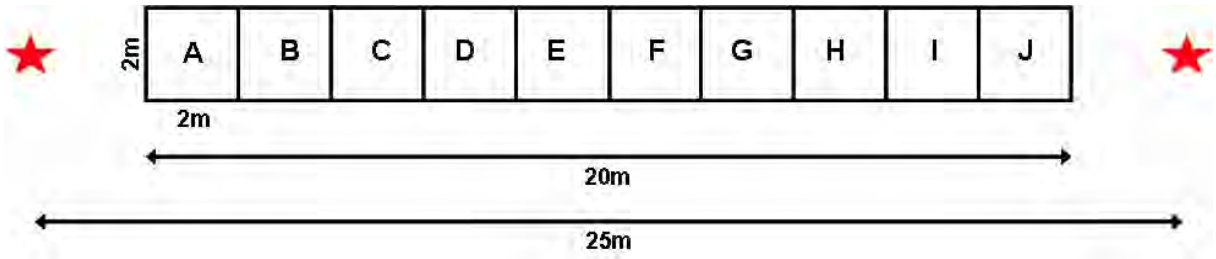

Figure 3. Monitoring transect layout. Red stars are the reference metal standards at each end of the transect.

The transect and plots were established by laying out two 30 m tapes 1 m either side of the centre-line (i.e., creating a 2 m wide belt transect) and then using one additional tape to mark off two 2x2 m plots starting at 2.5 m and 4.5 m from the first reference stake (plots A and B; Figure 3). The following were then recorded for each 2x2 m plot:

- The cover abundance class[4] of the following land cover types:
    - Individual tussock species (hard tussock, silver tussock, snow tussocks[5])
    - Any woody species (e.g., matagouri or sweet briar)
    - Hawkweed species (mouse-ear hawkweed, king-devil hawkweed, tussock hawkweed)

[4] Cover abundances classes were: 1, <1%; 2, 1-5%; 3, 6-10%; 4, 11-25%; 5, 26-50%; 6, 51-75%; 7, 76-100%.
[5] Where possible these were identified to species (*C. macra*, *C. rigida* and *C. rubra*).

- Clovers and exotic grasses (as one combined cover type)
- Other distinctive plant species (e.g., *Poa colensoi, Celmisia lyallii, Raoulia subsericea*)
- Bare ground, litter and rocks

This process was then repeated for the two 2x2 m plots at the far end of the transect starting at 18.5 m and 20.5 m from the first reference standard (plots I and J; Figure 3).

In addition to this the following were also recorded:

- One photo was taken from each end of the plot with the camera held immediately above the metal standard looking down the taped transect with the top of the second stake just visible in the distance (Figure 4). The tapes are left laid out for the photo and a white board with the plot number placed so as to be visible to the side of the transect.
- Cover abundance of tussocks or woody species for the remaining six 2x2 m plots in the middle of the transect (C, D, E, F, G and H; Figure 3)

Figure 4. Example of photograph taken from one end of the transect looking towards other end (Glenmore Station).

2.4 Subsequent data processing

The monitoring data was recorded into a field book and on return to the University of Canterbury the location information (easting, northing and altitude) were entered as a table into the GIS workspace for the property. GPS location data were not differentially corrected, so all locations typically had an error of 10-20 m associated with them. This was not considered a problem for relocation as all monitoring sites were marked on the ground by metal standards and location photographs were taken. The land-cover cover abundance data was entered into an Excel spread sheet. The photos were downloaded from the digital camera, labelled with the code for the property name and the monitoring site number, and stored.

2.5 Monitoring sites at Glenmore and Otematata Stations

During the 2005/06 summer, 48 monitoring sites were located on Glenmore Station and 57 monitoring sites on Otematata Station (including Avimore Station and the Awakino property; Figure 5).

The 48 land-cover monitoring sites at Glenmore Station were spread across seven landform/management units as follows:
Improved downlands – 12 monitoring sites
Unimproved downlands – 10 monitoring sites
Improved river flats – 2 monitoring sites
Unimproved river flats – 3 monitoring sites
Improved lower mountain slopes – 8 monitoring sites
Unimproved lower mountain slopes – 7 monitoring sites
Higher mountains (unimproved) – 6 monitoring sites

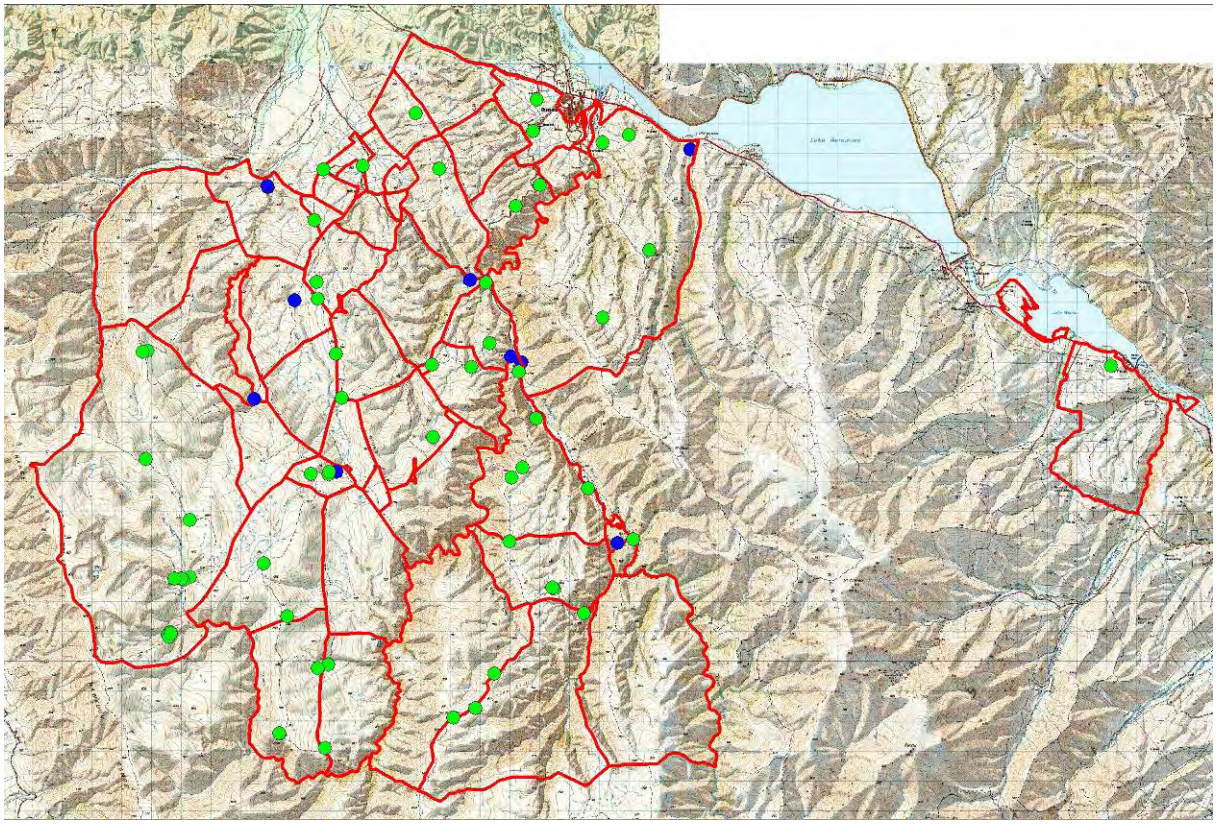

Figure 5. Location of land-cover (green circles) and aquatic (blue circles) monitoring sites at Otematata Station (including Avimore Station and the Awakino property).

The 57 land-cover monitoring sites at Otematata Station were spread across seven landform/management units as follows:
Improved low altitude Waitaki Valley slopes – 5 monitoring sites
Improved hill country – 19 monitoring sites
Improved river flats – 3 monitoring sites
Unimproved river flats (alpine) – 1 monitoring sites
Improved mountain slopes – 11 monitoring sites
Unimproved mountain slopes – 18 monitoring sites

2.6 Proposed changes to monitoring protocol

Overall, the establishment of monitoring sites during the 2005/06 summer was successful. Not withstanding this, a number of minor changes are proposed for establishing land-cover monitoring at the remaining high country properties over the 2006-07 summer namely:

- Recording the cover abundance of all vascular plant species in plots A, B, I and J, rather than just for the prominent species (information for Glenmore and Otematata will be updated when the first re-measurement occurs).
- Recording the cover abundance of both tussocks and woody plants (by species) in plots C, D, E, F, G and H, rather than just for tussocks or woody species (information for Glenmore and Otematata will be updated when the first re-measurement occurs).
- Ensuring that a photo is taken of the site label (the cattle ear tag) prior to taking the landscape or transect photos to ensure that all photos are correctly identified even if the whiteboard isn't clearly visible.
- Using three white-painted 2.5 m bamboo stakes to delineate the two 2 m plots at each end of the transect (rather than using a tape)

3. Aquatic monitoring

3.1 Introduction

Aquatic monitoring was of a far more limited extent than land-cover monitoring because aquatic ecosystems are of limited extent on high country properties and because of the limited resources available to sort and identify the invertebrate taxa collected during monitoring. Not withstanding these constraints, ten aquatic monitoring sites were established on each of the two high country properties worked on during the 2005/06 summer. This section describes the methods used to establish aquatic monitoring on Glenmore and Otematata Stations, outlines the monitoring established, and provides some suggestions on ways to improve aquatic monitoring during the 2006/07 summer.

Aquatic monitoring protocols have become largely standardised in recent years (Stark et al. 2001) and the methods used here follow these protocols. A simplified aquatic assessment method has been developed (SHMAK; Biggs et al. 1998) that requires far less time than the methods outlined in Stark et al. (2001) do. However, on advice from experienced freshwater biologists (Drs Jon Harding and Angus McIntosh, School of Biological Sciences, University of Canterbury), it was decided that use of the SHMAK approach would not provide data suitable for assessing long-term trends in stream health in high country ecosystems, especially because of the relatively unmodified nature of the stream ecosystems there, and this method was not used.

3.2 Establishment of monitoring sites

As with land-cover monitoring, selection of aquatic monitoring sites was stratified across individual high country properties. However, because sampling methods are different it was decided not to sample stationary water bodies (lakes and tarns) in 2005/06[6]. Aquatic systems were divided based on their size and source, with three main types recognised:

- Large (>5 m) streams/rivers with unstable beds[7].
- Smaller (<5 m) non-spring fed streams with more stable beds.
- Smaller (<5 m) spring fed streams with stable beds.

In addition, consideration was given to the type of land management occurring within the catchment of individual streams. In some instances aquatic sampling points were located immediately above and immediately below portions of the catchment that had been heavily developed (e.g., cultivated).

Selection of monitoring site location was also influenced by the need to:

- Have reasonably easy access (e.g., not on the far side of a river).
- If located below a culvert or ford, then sited at least 15 m downstream.

Aquatic monitoring sites were then selected to be representative of the differences in stream type and taking into account land management issues, and entered onto a GIS map of the property. The sites location information (easting and northing; New Zealand Map Grid 1949 geodetic datum) was then extracted to facilitate field location using a GPS unit.

[6] However, we will explore options for implementing monitoring of tarns during the 2006/07 summer.
[7] The largest rivers that could be practically sampled were 10 m in width.

3.3 Plot establishment

A GPS unit was used to find the allocated site in the field[8]. Once this position was located, the first section of stream immediately upstream from the GPS position that was relatively uniform for at least 10 m was selected for monitoring (the sampling reach). The upstream end of this reach was marked by a metal standard, with a second standard located 25 m downstream from this on the opposite bank. The standards were located in areas with stable river banks. All sampling was conducted in the sampling reach between these two standards.

Once the standards had been positioned, the following were recorded:

- GPS location and altitude (of the first standard), and date.
- Photographs were taken from both sides of the river, attempting to have the opposite stake in the photo[9] (Figure 6).

Figure 6. Aquatic monitoring site, Glenmore Station.

Within the sampling reach several physio-chemical variables were recorded. General physical characteristics of each site were recorded, including width, depth, velocity, and substrate size. Stream channel stability was assessed using the Pfankuch Channel Stability evaluation system. Fifteen features of the upper banks, lower banks and stream bottom were visually evaluated. These features covered a range of riparian and in-stream conditions, including such characteristics as; the degree of vegetation cover, bank undercutting, the occurrence of in-stream deposition zones, and the amount of substrate compactness Scores for each feature were summed to give a channel stability index which is interpreted as; <38 = excellent; 39-76 = good; 77-114 = fair; >114 = poor. Water temperature, pH, conductivity were measured at each site using a calibrated pH/conductivity meter (Oakton). A water sample was collected

[8] A list of field equipment required for aquatic monitoring is given in Appendix 2.
[9] It was not, however, possible to include the opposite metal standard in most photos because of dense stream-side vegetation.

and taken back to the laboratory to measure turbidity, while an additional water sample was collected for testing for phosphorous and nitrogen levels. Both water samples were stored under cool conditions before returning to the lab.

The benthic invertebrate fauna was then sampled in two ways; quantitative sampling (Protocol C3, Stark et al. 2001) and semi-quantitative sampling (Protocol C1, Stark et al. 2001).

The purpose of quantitative sampling is to estimate densities of invertebrates present within a sampling area. Sampling was based on the use of a Surber sampler, a net attached to a grid frame that enabled us to collect a sample over a known area (250x230 mm) of substrate. Sampling proceeds in an upstream direction, with the Surber placed on an undisturbed patch of stream bed. The operator then brushes all material from the upper surface of all cobbles in the stream bed within the frame. Then the cobbles are picked up and their sides and bottom also brushed. All the disturbed material is then swept downstream into the net. All collected invertebrates are transferred to a collecting jar and a preservative (90% ethanol) added. This process was then repeated four more times in the variety of stream habitat types present within the sampled reach of stream bed, giving five samples per monitored stream reach each stored in a separate jar.

Semi-quantitative sampling provides a broader sample of the benthic invertebrates present within the monitored reach of the stream and can be used to calculate species richness statistics. Sampling is based on a “kick net” and requires the operator to stand upstream of the net and disturb the stream bed sediments by kicking and scraping with their feet, as well as picking up rocks, rubbing stream banks and scuffing vegetation. The disturbed material is then swept down into the sampling net. This process is repeated for the full range of habitats present within the monitored stream reach, including substrates under stream banks. All collected invertebrates are transferred to a single collecting jar and a preservative (90% ethanol) added.

3.4 Subsequent analyses

Turbidity was measured in the laboratory using a standard turbidity meter (HACH Turbidmeter 2100P). The water chemistry samples were analysed for nitrate and nitrite nitrogen, and for dissolved reactive phosphorus (DAP). Nitrite-N was determined using automated azo dye colorimetry in a flow injector analyser (APHA 4500-NO_3^- I (proposed) 20th edition 1998). Nitrate-N + Nitrite-N (total oxidised nitrogen; TON) was determined using an automated cadmium reduction in a flow injection analyser (APHA 4500-NO_3^- I (proposed) 20th edition 1998). Nitrate-N was then calculated as TON – Nitrite-N. DAP was determined using Molybdenum blue colorimetry with a discrete analyser (APHA 4500-P E (modified from manual analysis) 20th edition 1998). All analyses were undertaken by Hill Laboratories, Hamilton, a fully accredited water chemistry laboratory.

The invertebrates collected through Surber and kick-net sampling were separated in the laboratory from sediments and detritus, and rinsed through a 500µm mesh sieve. Invertebrates were sorted and identified under a binocular microscope (x 6 magnification) using keys in Winterbourn *et al*. (2000) to the lowest possible taxonomic level. For the Surber samples, the abundance (number) of each invertebrate taxa was counted. For the kick-net samples, only the presence of invertebrate taxa was recorded.

For the Surber data, standard invertebrate indices were calculated including; the Macroinvertebrate Community Index (MCI) and Semi-quantitative MCI (SQMCI) which combine the pollution tolerance values of each taxa present to give an indication of overall stream "health" of the benthic community. Low MCI values indicate a polluted stream, whereas high values indicate streams with more natural communities. The scores are interpreted as; Clean water >120; Possible mild pollution 100-119; Probable moderate pollution 80-99; Severe pollution <80. The SQMCI is a modification of the MCI which incorporates the relative abundance of each species and is interpreted as; Clean water >6.00; Possible mild pollution 5.00-5.99; Probable mild pollution 4.00-4.99; Severe pollution <4.00. Additionally, the number of mayfly (Ephemeroptera), stonefly (Plecoptera) and caddisfly (Trichoptera), or EPT taxa, were calculated. Mayflies, stoneflies and caddisflies are widely used as indicators of stream health as these insects are frequently susceptible to poor water quality and pollution.

3.5 Monitoring sites at Glenmore and Otematata Stations

During the 2005/06 summer, 10 aquatic monitoring sites were located on Glenmore Station and 10 on Otematata Station (including Avimore Station; Figure 5). The sites were spread between the three main stream types discussed in Section 3.2 (Table 1), with one stream at Glenmore Station (Joseph Stream) sampled three times to assess the influence of management actions, upstream and downstream of a recently cultivated area, and downstream of a fenced off riparian planting.

Table 1. Aquatic monitoring sites according to stream types. Unimproved and improved refer to the catchment above the sample point and are relative.

	Glenmore		Otematata	
	Unimproved	Improved	Unimproved	Improved
>5 m, unstable	1	0	2	0
<5m, stable	4	3	6	2
<5m, spring fed	1	1	0	0

3.6 Proposed changes to monitoring protocol

The major alteration to the current aquatic monitoring protocol is to reduce from five to three the number of Surber samples collected per monitoring site in order to reduce the amount of time (and hence resources) required to sort the collected invertebrate samples. Because of resource constraints during the 2005/06 monitoring programme, five Surber samples were only analysed for 12 of the 20 Glenmore and Otematata sites, with three analysed at the remaining sites. Comparative analysis of three versus five Surber samples from these 12 monitoring sites (Appendix 3) indicates that for high country streams three samples provides a good representation of the invertebrate communities present.

4. Soil monitoring

4.1 Introduction

The broad approach to soil monitoring is the same across all ARGOS farming sectors (Moller et al. 2005), with only minor variations made to this approach in the high country relating primarily to the way soil monitoring sites were located.

4.2 Management unit selection

High country properties typically have three main zones reflecting the level of management inputs – (1) cultivated and often irrigated flats, (2) AOSTD (Aerial, Oversown, Top Dressed) lower hill country, and (3) undeveloped (native) higher hill country. These three zones form the basis for management unit (MU – block or paddock) selection for soil sampling. High country properties have been allocated 36 soil samples per property, with these arranged in 12 clusters of three samples located in different MUs. Given the above general framework for high country properties, the number of MUs sampled in each zone is as follows (Figure 7):

1. Cultivated and/or irrigated – 3 management units
2. AOSTD – 7 management units
3. Undeveloped/native – 2 management units

Based on typical high country property areas, these ratios over-sample the cultivated/irrigated and AOSTD management zones and under sample the undeveloped/native zone. The high sampling density on the AOSTD country in particular is justified as this is the area where farm management inputs are likely to increase in the future.

Within each of the three management zones, MUs were selected randomly. For Glenmore and Otematata where permanent land-cover monitoring sites (LCMS) are already present, selection will be based on the LCMS's with the proviso that only one LCMS can be selected within a MU. The selected LCMS were then used as the location for the first soil monitoring site (SMS). For the other properties, MUs were chosen randomly, and then the location of the first SMS chosen randomly within the selected MUs.

4.3 Monitoring site selection

Once the location within the MU of the first SMS had been selected, the following rules were followed to finalise this location.

1. For Otematata/Glenmore the first SMS was located within 25 m of the VMS transect (defined by two warratahs located 25 m apart). The exact location was determined by going a random direction and distance from the middle of the VMS transect, but with the 25 m radius limit, and ensuring that the site is on the same landform, aspect, slope and general vegetation type.
2. For the other properties, the first SMS was normally located within 25 m of the GPS coordinate. The only exception to this was when the GPS coordinate occurred on an atypical feature of the MU (e.g., sheep camp, wetland, dry ridge or rock outcrop). In this case, the observer moved to the nearest place that is typical of the dominant vegetation type in the MU. The exact location of the SMS was then determined by going a random direction and distance from the GPS location (or alternative location) but within the 25 m radius limit, and ensuring that the site is on the same landform, aspect, slope and general vegetation type.

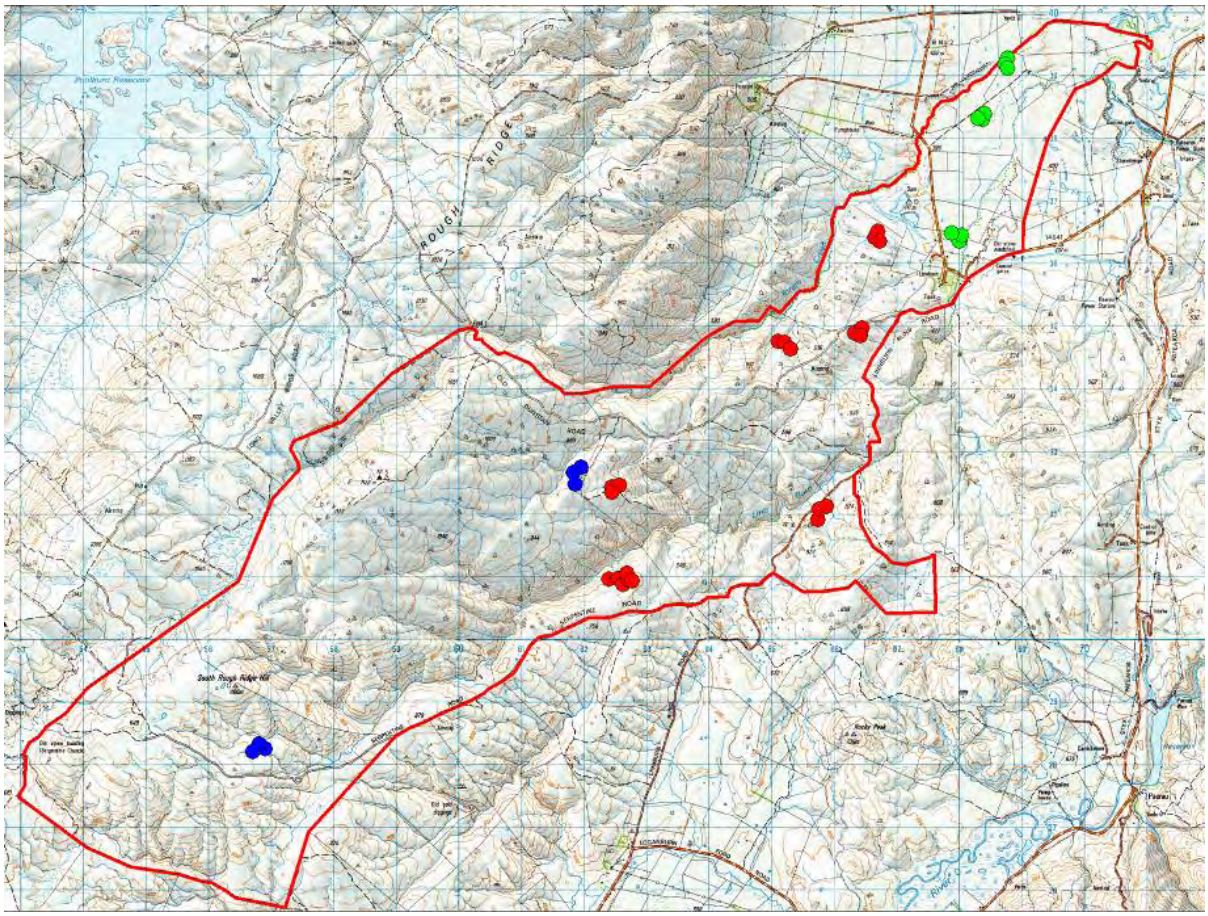

Figure 7. Soil monitoring site locations at Linnburn Station. Each cluster of three dots represents sampling within one MU. ● cultivated and/or irrigated, ●AOSTD (and some cultivation in this case as well), ● undeveloped/native.

Because high country property MUs can be large (several 100s ha) and heterogeneous, it was not considered feasible to locate all three SMSs randomly across a MU. Rather the three SMSs were located within the same area of the block (Figure 7). The procedure for selecting these was as follows:

1. From the first SMS a random point (direction and distance) within 100 – 200 m was selected. So long as the landform, aspect, slope and general vegetation type were the same as at the first SMS, then this became the location of the second SMS. If this site did not meet these criteria, then the nearest location to the random point that does was chosen.
2. The third SMS was selected in the same manner as the second, starting from the second SMS, with the restriction that it could not occur in the same quarter (90º directional bearing) as the first SMS.

Notwithstanding the above comments, SMSs were not located within 20 m of a fence, water trough, tree/hedgerow, track or building, and where practical they were located on the midslope (and not on ridges or hollows).

4.4 Field sampling

Once the SMS was selected the following were recorded[10]:

- GPS coordinates and altitude

Soil sampling then involved two components. First soil samples were collected for subsequent laboratory analysis for nutrients, microbial activity, bulk density and textural analysis. Then a visual soil description was completed that focused on the visible attributes of the soil profile.

Ten soil cores were collected from each SMS for subsequent analysis of nutrients and microbial activity. Individual soil cores were collected randomly from the area around the SMS (0-7.5 cm depth), with the 8x3 samples collected from each MU combined into a single bag and stored in a chilly bin/fridge until they could be couriered to the lab for subsequent analysis.

Soil profile samples were collected for textural analysis as follows:

- An auger was used to remove soil in 10 cm increments with samples laid out on a tarpaulin (Figure 8).
- The profile was divided into common layers based on colour and textural changes
- The depth of each layer was recorded.
- A subsample of each layer (approx 1 handful) was collected, avoiding gradational changes between layers, and packed into a labelled storage bag for subsequent analysis.

Figure 8. High country soil samples spread out on tarpaulin ready for sampling.

[10] A list of equipment required for soil sampling is given in Appendix 4.

Two soil cores were also collected for subsequent bulk density analysis. This involved the following steps:

- Removing excess vegetation without disturbing the soil
- Driving the corer into the soil to a depth of 15 cm
- Slicing the core in half (horizontally), and weighing each half in the field before placing into individual bags.
- Breaking up the soil sample in the bag and mixing well by shaking.
- Sub-sampling the soil sample by discarding roughly half back into the hole but keep all the non-soil material in the bag (e.g., stones, big roots etc).

Then a visual soil assessment was undertaken.

First inspect the soil surface and record the percentage area of (Figure 9):

- Bare ground not covered by living vegetation or dead residue (before raking away residue).
- Ground covered in living vegetation (after raking away residue).
- Crusted soil (and estimate thickness).
- Damaged soil surface (e.g. tractor marks, stock treading) and depth of damage.

			
i. Bare ground not covered by living vegetation or dead residue (before raking away residue)	ii. Ground covered in living vegetation (after raking away residue)	iii. Crusted soil and **estimate thickness**	iv. Damage to soil surface (e.g. tractor marks, stock treading) and depth of damage

Figure 9. Soil surface recording criteria.

Then dig a soil pit 15 cm x 15 cm in area, with straight sides to 20 cm deep. Using this pit, visual soil assessments are undertaken as follows (Figure 10):

- Thatch build-up - With a spade, collect a soil slice along the side of the hole. Inspect surface 10 cm of topsoil for thatching (build up of dead organic material, not incorporated)[11].
- Soil porosity - porosity affects water and air movement through the soil.
- Mottles and gleying - Caused by temporary or long term water logging and gives indication of how well soil is aerated. Mottles are orange. Gleying, caused by anaerobic conditions is a blue-grey colour
- Soil aggregation - Put soil onto tarpaulin and separate aggregates gently ALONG breakage lines. Spread out soil and compare to photographs.

[11] If soil recently ploughed, thatch may be buried at depth. Record depth and thickness as best you can (it wont be easy).

  	
i. No evidence of thatch build up. Organic matter well incorporated	ii. Thin thatch build up evident by dark band at soil surface.

			
i. Soil has many macro-pores between and within aggregates	Soil moderately consolidated with pores between aggregates, less within	iii. Soil quite consolidated with some pores between aggregates, few within	iv. Compact massive soil with little or no pores. Aggregates may have smooth faces with sharp angles

			
i. No mottling present	ii. Some mottling evident on a dark background	iii. Noticeable blotches of yellow orange (mottles) on a paler background.	iv. Gleying evident as the blue-grey colour. Orange mottles are forming where the soil has begun to drain.

Figure 10. Criteria for scoring soil profiles.

Finally, any earthworms and other macroinvertebrates present in the soil material removed from the profile hole were collected. This involved:

- Separating out any vegetation and shaking over tarpaulin to remove soil.
- Hand sorting vegetation to find worms and other macroinvertebrates, then discarding vegetation.
- Hand sorting soil twice and removing worms and other macroinvertebrates. The first sort involved thoroughly and methodically breaking up large soil aggregates and the second back sorting and taking particular note of the bottom layer.

- Recording whole and half worms numbers and total weight of worms (excluding other macroinvertebrates).
- Preserving all worms and other macroinvertebrateas collected in 70% ethanol.

4.5 Subsequent analyses

Subsequent soil analyses were undertaken by Peter Carey, Land Research Services Ltd, Christchurch. The following analyses were undertaken:

- Soil nutrient analyses included pH, Olsen-P, Resin - P, calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), P retention (ASC), anaerobic mineralisable-N (AMN), sulphate-S (SS), cation exchange capacity (CEC), % base saturation (%BS), weight/volume (w/v), and soil C and N.
- Soil respiration will be based on weighing and packing moist soil into PVC tubes and placing in an incubator. Respiration of CO_2 then being monitored after 24 hours by placing a sealed head space chamber over each tube and the gas evolved measured using an acoustic Trace Gas Analyser (TGA).
- Soil microbial biomass (SMB) is based on the conventional method of analysis of microbial cells exposed to chloroform vapour (24 hour fumigation) and extraction of the contents into 0.5 M K_2SO_4. Nutrients contained are determined by the difference between fumigated and unfumigated soils and applying a correction factor for unrecovered SMB. Analysis for C and N contained within the extracts will be performed by LU using TOC (C) and FIA (N) equipment.
- Bulk density will be determined by gravimetric analysis of each SMU hand-mixed but unsieved samples except where the presence of stones and/or significant root material is apparent.
- Soil texture will be determined using the classical hand rolled-ball technique and soil colour determination using the Munsell soil colour charts.

Full details on the methods used will be provided in the soil analysis reports prepared by Peter Carey, Land Research Services Ltd.

4.6 Proposed changes to monitoring protocol

No changes are proposed to the soil monitoring protocol for future remeasurements.

5. Future monitoring

Individual property monitoring reports on Glenmore and Otematata Stations have been prepared for the two families involved. These reports include detailed information on the location of land-cover and aquatic monitoring sites, plus a CD-rom with copies of all photographs taken and the spreadsheet data from each site.

It is planned, subject to sufficient funding being obtained, that land-cover and aquatic monitoring sites will be established on the remaining six ARGOS high country study properties (The Muller, Flock Hill, Redcliffe, Ben Ohau, Lake Hawea and Linnburn) over the 2006/07 summer.

It is proposed that land-cover and aquatic monitoring will be repeated on a three-year cycle, with Glenmore and Otematata re-measured during 2007/08, then three further properties in 2008/09 and the final three in 2009/10. The proposed changes to the monitoring protocols identified in the above sections will be implemented in 2006/07, and applied to Glenmore and Otematata Stations in their 2007/08 re-measurement.

Soil monitoring will be repeated every two years.

It is also planned to explore the potential of monitoring other aspects of the environment, especially rabbit and hare numbers. Standardised techniques such as spot-light counting are available for monitoring rabbits and hares (Aspinall 1994) and have been widely applied in the high country in the past. It is proposed to discuss with the farmers the possibility of their undertaking standardised rabbit and hare spot-light monitoring on their properties in autumn each year. If farmers were willing to do this, a standard monitoring protocol would be provided to assist with this monitoring which would be implemented in April/May 2007.

6. Acknowledgements

Thanks to Karl Schasching, Nigel Pink, Lachlan Kirk, Pam Moyle, Martin Emanuelsson and Nick Lucock for field and laboratory assistance, Peter Espie, Jon Harding, Jayson Benge, Henrik Moller and Andrea Pearson for assistance with designing the monitoring protocols, and Jon for assistance with invertebrate identifications, and to the owners/managers of the eight ARGOS high country properties for facilitating the field work.

7. Literature cited

Allan, D., Carter, A., Gibson, R., Mulcock, C. 1998. Land Condition Monitoring Reference Manual. Rural Futures Trust, Ashburton.

Allan, B.E., Chapman, H.M. 1987. Over sown tussock country; lessons from 30 years improvement and management on Tara Hills. *Proceedings of the New Zealand Grassland Association 48:* 77-81.

Allen, R.B., Rose, A.B., Evans, G.R. 1983. *Grassland survey manual: a permanent plot method.* Forest Research Institute Bulletin 43, New Zealand Forest Service, Christchurch.

Aspinall, J. (editor) 1994. *Farmer Resource Monitoring Kit*. High Country Committee Federated Farmers, Timaru.

Biggs, B, Kilroy, C., Mulcock, C. 1998. *New Zealand Stream Health Monitoring and Assessment Kit: Stream Monitoring Manual version 1*. Technical Report 40, NIWA, Christchurch.

Cockayne, L. 1920. An economic investigation of the montane tussock-grassland of New Zealand. XII The regrassing experiments in Central Otago Part II – objects, principles, and methods. New Zealand Journal of Agriculture 25: 82-94.

Dickinson, K.J.M., Mark, A.F., Lee, W.G. 1992. Long-term monitoring of non-forest communities for biological conservation. *New Zealand Journal of Botany 30*: 163-179.

Duncan, R.P., Webster, R.J., Jensen, C.A. 2001. Declining plant species richness in the tussock grasslands of Canterbury and Otago, South Island, New Zealand. *New Zealand Journal of Ecology 25:* 35-47.

Mark, A.F. 1978. Permanent photographic points for following vegetation changes. *Tussock Grasslands and Mountain Lands Institute Review 37*: 38-45.

Mark, A.F., Dickinson, K.J.M. 2003. Temporal responses over 30 years to removal of grazing from a mid-altitude snow tussock grassland reserve, Lammerlaw Ecological Region, New Zealand. *New Zealand Journal of Botany 41:* 655-668.

Meurk, C.D., Walker, S., Gibson, R.S., Espie, P. 2002. Changes in vegetation states in grazed and ungrazed Mackenzie Basin grasslands, New Zealand, 1990-2000. *New Zealand Journal of Ecology 26:* 95-106.

Moller, H., Wearing, A., Pearson, A., Perley, C., Steven, D., Blackwell, G., Reid, J., Johnson, M. 2005. Environmental monitoring and research for improved resilience on ARGOS farms. Unpublished ARGOS Working Paper No. 6, University of Otago, Dunedin.

Moore, L.B. 1976. *The Changing Vegetation of Molesworth Station 1944-1971*. Bulletin 217, DSIR, Wellington.

Rose, A.B., Platt, K.H., Frampton, C.M. 1995. Vegetation change over 25 years in a New Zealand short-tussock grassland: effects of sheep grazing and adventive invasions. *New Zealand Journal of Ecology 19:* 163-174.

Scott, D. 1993. Response of *Hieracium* in long term manipulative agricultural trials. *New Zealand Journal of Ecology 17:* 41-46.

Scott, D. 2001. Sustainability of New Zealand high-country pastures under contrasting development inputs. 7. Environmental gradients, plant species selection, and diversity. *New Zealand Journal of Agricultural Research 44:* 59-90.

Stark, J.D., Boothroyd, I.K.G., Harding, J., Maxted, J.R., Scarsbrook, M.R. 2001. Protocols for sampling macroinvertebrates in wadeable streams. New Zealand Macroinvertebrate Working Group Report No.1, Sustainable Management Fund Project 5103 report prepared for Ministry for the Environment.

Winterbourn, M.J., Gregson, K.L.D., Dolphin, C.H. 2000. Guide to aquatic insects of New Zealand. *Bulletin of the Entomological Society of New Zealand 13*: 1-102.

Appendix 1

Equipment required for establishing a land-cover monitoring site

2 x 1.5 or 1.8 m metal standards
1 x cattle ear tag (large size best)
1 x permanent tag pen for labelling tag
1 x 30 cm of lacing wire (to attach tag to standard)
1 x sledge hammer (long handle)
3 x 30 m tapes
2 x 3m retractable steel tapes
1 x compass
1 x clinometer
1 x GPS unit (Garmin eTrex or similar)
1 x whiteboard (ca. 50 x 30 cm)
1 x whiteboard pen
1 x camera (digital)
1 x field recording sheet

Appendix 2
Equipment required for establishing an aquatic monitoring site

2 x 1.5 or 1.8 m metal standards
1 x cattle ear tag (large size best)
1 x permanent tag pen for labelling tag
1 x 30 cm of lacing wire (to attach tag to standard)
1 x sledge hammer (long handle)
1 x 30 m tapes
1 x GPS unit (Garmin eTrex or similar)
1 x whiteboard (ca. 50 x 30 cm)
1 x whiteboard pen
1 x camera (digital)
1 x clipboard
1 x waders
4 x 200 ml pottles (Safe-a-Pak brand)
1 x 75 ml specimen jar (turbidity sample)
1 x water chemistry sample container (from Hill Laboratories)
1 x 250x230 mm Surber sampler (500 µm mesh)
1 x 300 mm kicknet (500 µm mesh)
1 x 500 ml Ethanol (90%)
5 x waterproof paper labels (to go into pottles)
1 x divers gloves
1 x stopwatch and cork
1 x meter ruler
1 x Oakton pH/conductivity meter
1 x Pfancuch index sheet
1 x “chilly bin” and “frozen slicker pad” to store samples

Appendix 3

Are three Surber samples sufficient to assess benthic invertebrate abundances?

Resource constraints during the 2005/06 monitoring programme, meant that five Surber samples were only analysed for 12 of the 20 Glenmore and Otematata aquatic monitoring sites, with three analysed at the remaining sites. Given the much larger number of samples planned for collection from the remaining six high country properties during the 2006/07 summer (60), it is again unlikely that we will have sufficient resources available to analyse all five Surber samples, with three a more realistic target. It was therefore decided to test how well a sub-sample of three Surber samples were at representing the species abundances recorded from the five samples. This appendix briefly presents the results of this comparison.

A correlation analysis (Pearson Product Moment) was undertaken comparing the total abundance of individual invertebrate taxa from a 3-sample subset of the data *versus* the full five samples for the 12 monitoring sites where five samples were analysed. The three samples were chosen randomly from the five available samples. Only those invertebrate taxa that were recorded in all five samples were included in the analysis. Each of the 12 sites was analysed individually. The r^2 value from the correlations ranged from 0.874 – 0.999 (Table A1), with a mean $r^2 = 0.949 \pm 0.013$ (SE). However, the 3-sample subset of the data underestimated the number of taxa in all 12 cases, with the number of species not detected in the 3-sample subsets ranging from 1 – 6 taxa (4 – 33 % of taxa).

Table A1. Ranked correlation coefficient r^2 values and species richness (S') calculated between 3-sample and 5-sample data sets for 12 Glenmore and Otematata Station aquatic monitoring sites.

Site code	r2	$S'_{3\text{-sample}}$	$S'_{5\text{-sample}}$
G4	0.874	17	19
G3	0.893	19	25
O9	0.898	13	14
G8	0.909	11	16
O8	0.931	16	17
O6	0.959	22	23
G6	0.972	13	18
G10	0.974	22	23
G7	0.987	18	19
G5	0.994	22	23
O10	0.998	13	15
G2	0.999	21	24

These results suggest that while three Surber samples will detect fewer benthic invertebrate taxa, they do provide an accurate assessment of invertebrate abundance for those taxa that are present. Furthermore, the kick-net samples do pick up a greater number of taxa and will account for most of the missing taxa. On balance, it is considered that the results obtained from five Surber samples does not offset the additional resources that are required to analyse the additional samples. It is therefore proposed that only three samples will be analysed in 2006/07.

Appendix 4

Equipment required for establishing soil monitoring sites

1 x Spear & Jackson border spade
1 x Bulk density tool
1 x Nutrient corer
1 x Soil auger
1 x Garmin
1 x Rawhide/copper hammer (no. 4)
1 x Tarpaulin
18 x Jars (worms)
1 x 20 litre water container
1 x Electronic scales
5 x Plastic bags (for soil samples) per soil monitoring site
1 x Compass
1 x Random number chart
Pre printed labels
Recording sheets, clipboard & pen
Nutrient soil bags