Potential impacts of irrigation on groundwater nitrate in the Hakataramea River catchment

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CONTENTS

FIGURES

TABLES

APPENDICES

ENCLOSURES

EXECUTIVE SUMMARY

Environment Canterbury (ECAN) is concerned about the possible water quality impacts or irrigation development in the Hakataramea River catchment (Figure 1.1). For that reason, ECAN commissioned a “desk top” study to assess the potential impact of current land use activities on the nutrient status of ground and surface waters in the Hakataramea River catchment and to assess the likely impact of increased irrigation in the area.

ECAN has issued consents allowing irrigation on lands of some farms located within the Hakataramea River catchment. Farms in the catchment have also applied to ECAN for new consents to irrigate.

ECAN requested that GNS Science develop estimates of the impact of nitrate-nitrogen leaching loss on groundwater from four scenarios:

- Scenario 1 - Existing irrigated land uses. This scenario involves estimation of nitrogen leaching losses as a result of irrigation under the **current** consents. ECAN provided data allowing the lands involved to be identified.

- Scenario 2 – Irrigation at a level considered economically viable for irrigation at this time. This scenario involves estimation of the incremental additional nitrogen leaching losses that would result if **new** consents were to be granted to all those who have applied. The combination of losses from currently issued consents (Scenario 1) and new consents has been defined by ECAN as a level of irrigation that is economically viable at this time.

- Scenario 3 - Irrigation of all potentially irrigable land in the Hakataramea River catchment. This has been defined by ECAN as the **community scheme**. ECAN provided delineation of community scheme lands. Lands involved in Scenarios 1 and 2 outside of the community scheme were identified and included in Scenario 3.

- Scenario 4 - Fully dry land without irrigation. This scenario provides estimates for nitrogen leaching losses under **dryland sheep** conditions for each of the lands defined in Scenarios 1, 2, and 3.

GNS Science modeled these four scenarios and developed estimates of nitrate leaching and water drainage losses. Nitrate-nitrogen concentrations in soil solutions were calculated assuming complete mixing. Such concentrations represent maximum nitrate-nitrogen levels at the point of entry to groundwater and would be diluted by natural upgradient groundwater flow.

The following nitrate-nitrogen and water drainages losses, respectively, for the above four scenarios, and calculated soil solution nitrate-nitrogen concentrations were estimated:

- Scenario 1, Current irrigation - 106 tonnes/year of nitrate-nitrogen and 3.2 million m^3/year of drainage water. These estimates yield a mean nitrate-nitrogen concentration of 32.7 mg/L.

- Scenario 2, New irrigation - 47 tonnes/year of nitrate-nitrogen and 1.4 million m^3/year of drainage water. These estimates yield a mean nitrate-nitrogen concentration of 33.4 mg/L.

- Scenario 3, Community scheme irrigation - 537 tonnes/year of nitrate-nitrogen and 15.4 million m^3/year of drainage water. These estimates yield a mean nitrate-nitrogen concentration of 34.8 mg/L.

- Scenario 4, Dryland sheep –

  a. Land currently irrigated – 14 tonnes/year of nitrate-nitrogen and 1.2 million m^3/year of drainage water. These estimates yield a mean nitrate-nitrogen concentration of 11.2 mg/L.

  b. Land to be irrigated in new consent applications – 6 tonnes/year of nitrate-nitrogen and 0.6 million m^3/year of drainage water. These estimates yield a mean nitrate-nitrogen concentration of 9.77 mg/L.

  c. Land for irrigation under community scheme - 89 tonnes/year of nitrate-nitrogen and 5.6 million m^3/year of drainage water. These estimates yield a mean nitrate-nitrogen concentration of 15.8 mg/L.

1.0 INTRODUCTION

Environment Canterbury (ECAN) is concerned about the possible water quality impacts from irrigation development in the Hakataramea River catchment (Figure 1.1). For that reason, ECAN commissioned a "desk top" study to assess the potential impact of current land use activities on the nutrient status of ground and surface waters in the Hakataramea River catchment and to assess the likely impact of increased irrigation in the area.

ECAN has issued consents allowing irrigation on lands of some farms located within the Hakataramea River catchment. Currently issued consents allow the use of about 6,998,400 m^3 of water a year to irrigate 2,580 hectares. Additional farms in the catchment have also applied to ECAN for new consents to irrigate. If all of these application were granted, it would result in an approximately 60 percent increase in the volume of irrigation water that could be applied annually. These applications involve an increase of 54 percent in irrigated land area over farmland currently covered by the existing consents that have been issued.

This was a joint project involving GNS Science and NIWA. Specific GNS Science tasks were as follows (see copy of pertinent parts of contract between ECAN and GNS Science provided as Appendix A):

1. The development of land use scenarios based on four existing and potential irrigation scenarios –

    a. Scenario 1 – Existing irrigated land uses. This scenario involves estimation of nitrogen leaching losses as a result of irrigation under the **current** consents that have been issued.

    b. Scenario 2 – Irrigation at a level considered economically viable for irrigation at this time. This scenario involves estimation of the incremental additional nitrogen leaching losses that would result if **new** consents were to be granted to all those who have applied. The combination of losses from currently issued consents (Scenario 1) and new consents has been defined by ECAN as a level of irrigation that is economically viable at this time.

    c. Scenario 3 – Irrigation of all potentially irrigable land in the Hakataramea River catchment. This has been defined by ECAN as the "community scheme." In practice, since some of the land being irrigated in Scenario 1 at this time or to be irrigated in Scenario 2 should new consent applications be granted are outside of ECAN's defined "community scheme" areas, this scenario involves all of the areas that would be irrigated in Scenarios 1 and 2 combined with the "community scheme."

    d. Scenario 4 – Fully dry land without irrigation. This scenario provides three estimates for nitrogen leaching losses in the event that the same land areas considered under Scenarios 1, 2, and 3 above were to be farmed for the production of sheep without irrigation (i.e., dryland sheep).

2. Gather and review published or unpublished information on groundwater resources and potential land use practices in the Hakataramea River catchment.

3. Identify the potential area of irrigable land in the Hakataramea River catchment.

4. Estimate nitrate and phosphorous leaching losses to groundwater under the above land use scenarios.

This study was limited to existing published and unpublished information and no additional field work or data collection was carried out. This study uses the same methodology of a prior study of water quality impacts from irrigation development in the Upper Waitaki River catchment reported by White, et al. (2004).

Provision of this report to ECAN summarizing methods, assumptions, and results constitutes the completion of this work by GNS Science. Findings will also be provided to NIWA for incorporation into the consolidated project report.

2.0 GEOLOGY AND SOILS

2.1 Geology

The Hakataramea catchment occupies a broad tectonic depression (Figures 1.1 and 2.1). The geologic units present are summarized in Table 2.1. The basement rock of the region is Mesozoic-age greywacke rock, comprising hard, typically closely fractured, sandstones and mudstones, the latter often being referred to as “argillite.” In places, particularly towards the northeast part of the catchment, the greywacke has been metamorphosed into fissile semischist (Forsyth, 2001 and Cox and Barrell, 2006; see Figure 2.1). Greywacke/argillite and/or semischist rock forms the ranges and much of the hill country within the catchment and at depth underlies the valley floor. Tertiary-age sediments, including quartz sandstones, greensands and limestone, mudstones and conglomerates, were originally laid down on top of the greywacke/schist rock. They are now preserved in a broad down-fold that underlies the valley floor, though are largely obscured by overlying Quaternary sediments. Elsewhere, the Tertiary sediments have been eroded off the uplifted ranges and hill country, exposing the originally underlying greywacke/semischist. The full sequence of Tertiary sediments has a total thickness of approximately several hundred metres (Field, et al., 1989).

Quaternary sediments, generally comprising unconsolidated alluvial gravel with minor sand and mud, are preserved extensively along the axis and flanks of the Hakataramea River valley. The sediments are of two principal types; river alluvial gravels and fan alluvial gravels. The river alluvial gravels have been deposited by the Hakataramea River, and are found within low-gradient terraces flanking the river, as well as under the modern floodplain. The river gravels are typically well-rounded and are relatively clean and sandy. Fan alluvial gravels have been deposited by tributary streams draining to the Hakataramea River, and are found within moderate to high-gradient alluvial fan terraces that occupy the overlapping distributary lobes of these streams, as well as under the modern stream floodplains. The fan gravels are typically poorly-rounded and commonly have a silty matrix that partly plugs the pore spaces in the gravel. In the higher, older, river and fan terraces (Early to Mid-

Quaternary in age), there is an increasing degree of clay-binding within the matrix, and coupled with an associated increasing degree of weathering and weakening of the gravel clasts, gives the older gravels greater compactness and less permeability than younger, cleaner, gravels. The thickness of Quaternary sediments may vary from a veneer no more than a few metres thick resting on older rocks, through to voluminous deposits many tens of metres thick. Generally, the thickest deposits are likely to be found on the mid-part of alluvial fans, while river alluvial terrace deposits are more likely to occur as veneers over older rocks.

The younger of the Quaternary sediments (i.e. Late Quaternary) are the most important with regard to groundwater (Table 2.1), as they are likely to host the most potentially productive aquifers and are the unit through which much aquifer recharge occurs. Sandstones in the Tertiary sediments may have some potential as aquifers, although transmissivities are likely to be very low. Fracture-zones within the greywacke/schist rock may potentially form localised aquifers, especially in conjunction with seams of clayey crushed rock in fault zones that are potential aquitards.

The margins of the valley are formed in part by faults (Figure 2.1). Faults have thrust up greywacke/semischist rock that forms the Kirkliston, Grampian and Dalgety ranges, as well as the Round Hill and Mt. MacGregor ridges on the western side of the valley. The contact between greywacke/semischist and Tertiary sediments on the eastern side of the Hakataramea River valley is partly controlled by fault lines. In very broad terms, bedding within the Tertiary sediments on the eastern side of the valley dips towards the valley axis, although there are many local complexities due to folding or faulting of the sediments.

The general landscape of the Hakataramea River catchment has evolved to its present form over the past 15 million years or so, due to the progressive effects of fault movements, folding, episodes of alluvial gravel deposition and erosion. The ongoing nature of the geological evolution is indicated by surface-rupture fault scarps (“active faults”), probably associated with earthquakes, of the Kirkliston and West Hunters faults in the geologically recent past.

2.2 Soils

Landcare Research provided identification of soils for the Upper Waitaki River Basin (the Hakataramea River catchment is within this basin). Soils data were derived from existing soils surveys (Landcare Research, 2005; NWSCO, 1975-1979; and Webb, 1992). Data from all of these surveys were merged into a single database.

Landcare research classified all soils within the Upper Waitaki River Basin (including those within the Hakataramea River catchment) under irrigation, or having potential for irrigation, into four groups based on the attributes of soil depth (i.e., depth to underlying gravels), stoniness, profile available water capacity, occurrence of dense slowly permeable subsoil pans, drainage class, and slope angle. The four soil group classifications used and their descriptions were as follows (Webb, 2005):

Class	Soil Name	Description
1	Deep to shallow	Deep to shallow, well to imperfectly drained soils, on flat to very gently sloping land.
2	Stony and rolling	Predominantly well drained stony soils on flat to rolling land.
3	Very stony	Very stony, excessively drained soils, and shallow and stony sandy soils with very low profile available water storage, on flat to very gently sloping land.
4	Impeded	Soils with impeded drainage including soils with subsoil pans on flat to rolling land and poorly drained soils on flat land.

In variable map units, in which two or more soils were recorded, classification was done on the basis of the soil occupying the largest area of the map unit, or more rarely on a subdominant soil, if this soil was considered to affect the quality of most of the unit.

Landcare Research had the following comments with regard to the soils involved (Webb, 2005):

> "Stony and very stony soils in the Upper Waitaki Basin have very sandy textures making them prone to drought and to leaching nutrients. Soils of the same stoniness class are of poorer quality than the equivalent stoniness class on the Canterbury Plains. This is due to their extremely thin topsoils and high percentage of sand in the fine fraction. Stony and very stony soil types on the Canterbury Plains would be rated one suitability class higher than those in the Upper Waitaki Basin. It may be possible to achieve high pasture yields on these soils but they would require high application of fertilizer and frequent irrigation to achieve these yields. This would have consequent impacts on leaching of nutrients."

> "Impeded soils have potential for high pasture yields but have significant management limitations in winter and wet periods. They also have significant potential for runoff of water and contaminants to surface streams."

Landcare Research took into account the suitability of the soils involved for agricultural land uses in making its classifications. It's judgements in that regard are indicated in Table 2.2 (Webb, 2005).

As a part of this project, Landcare Research expanded on its soil classifications for the Hakataramea River catchment to ensure that all soils within the areas covered by the irrigation scenarios were covered. The resulting map of its classifications was provided as a GIS shape file (Figure 2.2). Figure 2.2 shows five classifications. The fifth classification, shown as green in Figure 2.2, is that land occurring on moderate slopes. This land "had been considered too steep to irrigate but can now be irrigated with K-line." Landcare Research indicated that this "hilly" land falls within the "stony and rolling" classification of Class 2 (Webb, 2006).

Landcare Research indicated that certain alluvial areas bordering the mainstem of the Hakataramea River were “mainly stony soils” that could also be considered as Class 2 soils (Webb, 2006). However, these soils are not shown within any soil classification illustrated in Figure 2.2.

3.0 HYDROLOGY

3.1 Surface Water

3.1.1 Precipitation

There are two rainfall gages located within the Hakataramea River catchment (Figure 1.1). These are the Mt. Florence gage (site number 450601) located about mid-catchment near Rocky Point and a second gage located at the north end of the catchment near McRaes Gorge (site number 403601).

All available data from these rainfall gages are presented in Table 3.1. The periods of record in each case are relatively short (i.e., parts of 12 and 22 years, respectively) and because of missing months there are even fewer complete years (i.e., two and nine years, respectively). Considering only the complete years, the Mt. Florence and McRaes Gorge gages shows annual median rainfalls of 444 mm and 640 mm, respectively. The mean of these two values is 542 mm. This value is similar to that of 528 mm which, as noted in Section 4.2 below, was used part of the input for the SPASMO computer model.

Data for the McRaes Gorge rainfall gage appears to indicate a greater degree of rainfall than occurs at the Mt. Florence gage location and perhaps greater seasonal and annual variability. There are no strictly comparable complete years for these two gages. However, rainfall for the sum of the incomplete months during 2004 at the McRaes Gorge gage of 740 mm was much larger than for the complete year at the Mt. Florence gage of 491 mm. Additionally, while the mean of the minimum monthly values for both gages is the same, the means of median, mean, and maximum values for all months at both gages are higher for the McRaes Gorge gage than for the Mt. Florence gage. This may reflect the McRaes Gorge gage’s location in more mountainous terrain near the north end of the catchment. In view of the location of the McRaes Gorge gage near the north end of the catchment, the Mt. Florence gage is probably more representative of rainfall over the catchment as a whole than the McRaes Gorge gage because it is located near the catchment’s centre.

3.1.2 Sreamflow

The Hakataramea River is a tributary of the Waitaki River. The Waitaki River is a major South Island river. It’s catchment area is illustrated in a Ministry for the Environment (MfE) figure (Figure 1 in Appendix A). The headwaters of the Waitaki River are Lakes Benmore, Aviemore, and Waitaki, which in turn are fed by the large glacial lakes Pukaki, Tekapo, and Ohau. The Waitaki flows east-southwest approximately 110 km to enter the Pacific Ocean between Timaru and Oamaru.

The Hakataramea River is a “shallow braided river with mid channel islands and large open cobble and shingle areas” (MfE, 2005b). The Hakataramea River catchment and subcatchments within it are shown in Figure 1.1. It is approximately 70 km long, has a basin area of 336 km^2 and flows south and southwest to enter the Waitaki near the junction of State Highways 82 and 83 (SH82 and SH83) a short distance below the town of Kurow and about 60 km upstream of the mouth of the Waitaki (Wikipedia, 2005 and SKM, 2004). The relative size of these streams is illustrated by their mean annual flows of 373 m^3/sec for the Waitaki at Kurow and 6 m^3/sec for the Hakataramea above the main highway bridge (MHBR in Figure 1.1) (ECAN, 2001). However, the ecological importance of the Hakataramea in this drainage exceeds what would be indicated by its relative size alone. It serves as “high value habitat” for several species of trout and salmon, for purposes that include spawing (MfE, 2005b) and is reputed to be the “principal salmon spawning river for the Waitaki” catchment (ECAN, 2005).

There are a number of small tributaries to the Hakataramea River. These and the limited information readily available on their catchment areas and flows are listed in Table 3.1.

3.2 Groundwater

Specific data on groundwater resources in the Hakataramea River catchment are very limited. ECAN has records of five well logs within the catchment and one just downstream of the mouth of the River outside of it (Figure 1.1). Their identification numbers, coordinates, and lithology are listed in Table 3.3. The logs show a variety of unconsolidated materials typical of alluvial and terrace locations from relatively permeable sandy gravels to much less permeable claybound gravels, silts, and clays. However, despite evidence that larger particle sizes are present (i.e., sands, gravels, cobbles, and even boulders), they also indicate the relatively low permeability greywacke and fines (i.e., clay and silt). Fines in such cases can result in lower permeabilities even when larger size fractions are present (e.g., “claybound” gravels).

Reportedly, an aquifer test was performed within the catchment in 1983. However, the location and methods used are “unclear” (Atchison-Earl, 2005). The results of this test indicated a transmissivity on the order of 8,000 m^2/day. The saturated thickness for the area involved was not noted. If a saturated thickness of 15 m is assumed, this would yield a hydraulic conductivity of 0.62 cm/sec. Such a value would be consistent with the low end of the range for gravel or the high end of the range for clean sand (Freeze and Cherry, 1979).

Assuming a mean saturated thickness of 15 m and a storativity of 0.2, the Hakataramea River catchment would have an estimated groundwater storage volume of 907 million m^3 (SKM, 2004). If rainfall-recharge occurred at a rate of 40 mm/year on the surface area of this basin, the long term mean input would be 13.4 million m^3/year or 425 L/sec (SKM, 2004). This recharge would be balanced against groundwater pumping for domestic water supply and irrigation and leakage into streams. Since it is believed that streams in the Hakataramea River catchment gain from groundwater, increases in groundwater abstraction for other purposes would be expected to result in reduced streamflow (SKM, 2004).

Very limited groundwater static water level (SWL) data are available for the Hakataramea River catchment. A catchment-wide estimate has been made of the depth below ground level (BGL) to groundwater (SKM, 2004 Figure 4B in Appendix A). This estimate indicates shallow groundwater in alluvial areas near the mainstem of the Hakataramea River, on the order of several metres or less, and increasing depth to groundwater with distance away from the mainstem, reaching a maximum of 15 to 30 metres on the west side of the Hakataramea River valley.

Potentiometric surface contours have been fit to the very limited groundwater SWL data (SKM, 2004 Figure 5B in Appendix A). Estimated groundwater level contours on the west side of the valley are nearly parallel to the main axis of the river and bend around to intersect the river in a “V” pattern with the base of the “V” pointing upstream. This indicates that the Hakataramea River is a gaining stream with groundwater to the west of the river generally flowing from the higher mountainous terrain directly toward the river before entering it at a relatively steep angle (i.e., on the order of 70^{o}). In contrast, on the east side of the river the contours indicate that groundwater flows at a shallower angle into the river. Under such conditions, nitrate leached to groundwater from irrigated farmland on either side of the Hakataramea River will ultimately discharge to the river.

4.0 FARM NITROGEN GENERATION

4.1 Background

As noted by Kirchmann, et al. (2002), “Nitrate leaching is a complex function of land use, cropping system, soil type, climate, topography, hydrology, animal density and nutrient management.” The complexity is evident when the nature of the nitrogen cycle and nitrogen transformations in soil are considered (Close, et al., 2001 Figure 8.1 in Appendix B).

There are a variety of sources of nitrogen to the soil system in agricultural areas. These include biological fixation of dinitrogen gas (mainly by such legumes as clover) from the atmosphere to ammonia, atmospheric deposition of mineral nitrogen (ammonia/ammonium-nitrogen and nitrate-nitrogen), wastes from grazing animals (urine and dung containing organic nitrogen, urea, and ammonia/ammonium-nitrogen) or land disposal of wastewater, and nitrogen fertilizers (ammonia/ammonium is commonly used for this purpose). Pasture systems in New Zealand are often comprised of a mixture of ryegrass and white clover. The rate of plant nitrogen uptake “is influenced by soil moisture, temperature, and extent of grazing” with higher uptakes in the spring and lower uptakes in the winter. In an ungrazed system, clover biomass decomposes and contributes organic nitrogen to the soil which subsequently slowly mineralizes. Under grazed conditions, nitrogen in clover is ingested by animals and excreted as dung and urine. This results in relatively rapid mineralization (Selvarajah, 1996 and Close, et al., 2001).

Organic nitrogen in unsaturated aerobic soil systems sequentially undergoes ammonification and nitrification to produce nitrate-nitrogen. This process usually takes several weeks to occur from the time of entry into the soil system. During this process some ammonia-nitrogen may be volatilized to the atmosphere. Because nitrate-nitrogen is negatively charged, it “is very mobile in soil and can be leached below the rhizophere to groundwater during high rainfall or irrigation” (Selvarajah, 1996) Under reducing conditions, nitrate-nitrogen may also undergo denitrification to nitrous oxide and/or dinitrogen gas (Selvarajah, 1996 and Close, et al., 2001).

Nitrate-nitrogen leaching rates for different land uses and conditions vary considerably (Table 4.1). It should be noted that the leaching rate of nitrogen from crop land (e.g., ryegrass or white clover) can be increased by approximately 30 Kg/ha as a result of grazing animals (MAF, 2006). It is also noteworthy to consider that the amount of nitrogen applied in a sheep urine patch is “commonly” 500 Kg-N/ha and that this urine nitrogen “is rapidly converted” to ammonia nitrogen which “in turn is either lost to the atmosphere, immobilised into soil organic forms or converted to nitrate” (MAF, 2006).

4.2 SPASMO Computer Model

The potential for nitrate leaching as a function of land use and irrigation in the Upper Waitaki River catchment (which includes the Hakataramea River) has been assessed under a range of non-irrigated and irrigated scenarios by Hort Research using the SPASMO computer model (Green, 2005). Model outputs were obtained in the form of mean annual loadings (i.e., kg N/ha/year) and average nitrate concentrations (mg/L NO_3-N).

SPASMO “links the mechanisms of soil water flow through the root zone, with the complex nitrogen transformations that result from both natural processes, and those consequent upon the application of nitrogen fertilizer and the returns of dung and urine from grazing animals” (Green, 2005). For modelling purposes, animal returns are assumed to be applied uniformly across the whole field and issues associated with “patches” are not considered. SPASMO addresses “the balance between inputs (rainfall and irrigation) and losses (plant uptake, evaporation, runoff and drainage) of water and nutrients (nitrogen) from the root-zone soil” of a ryegrass/clover sward. SPASMO models “nitrogen-transformations during hydrolysis (urea to ammonium), nitrification (ammonium to nitrate) and denitrification (nitrate to nitrous oxide and dinitrogen gas)” using first-order rate constants depending on soil temperature and moisture. The movement of nitrogen species leaching below the root-zone in soil is calculated assuming that urea and nitrate move freely as non-reactive solutes present only in the soil solution but that ammonium is retarded by sorption to soil cation-exchange sites. Ammonium sorption is modelled using a linear isotherm with K_D of 2.5 L/kg. This value comes from measurement in a free-draining Manawatu fine sand (Clothier, et al., 1977).

Further discussion of SPASMO modelling assumptions, inputs, and outputs is as follows:

1. Soils -

   The soils of the Upper Waitaki River catchment are generally stony, poorly developed, and free-draining with underlying gravel-dominated deposits (see Section 2.0 above). Soil physical and hydraulic properties were taken from Landcare Research’s soils database. Five soil types were utilized. These were an Edwards moderately deep silt loam, a Pukaki moderately deep sandy loam, and three variants of a McKenzie sandy loam (shallow, stony, and very stony).

2. Farm types and irrigation regimes -

   SPASMO modelling addressed five farm types. These were intensive farming of beef, dairy, deer, and sheep on irrigated pasture and extensive farming of sheep under non-irrigated conditions. Irrigation scenarios applied 18 mm of irrigation on those days when root-zone moisture levels in pastures declined “below a certain fraction” unless daily rainfall exceeded 5 mm. The “fraction” triggering irrigation was half of the normal “total available water” (TAW) content of the soil.

3. Climate inputs -

Climate inputs to the SPASMO model were from the long-term climate station at Tara Hills, Omarama (having a period of record of 1972-2003). The mean annual rainfall at this station is 528 mm.

4. Pasture transpiration, irrigation, and drainage -

Mean annual evapotranspiration for dry land and irrigated pastures was estimated at 510 mm and 865 mm, respectively, using the modified Penman-Monteith equation.

The annual irrigation requirement determined by the model is listed for the different soil groups in Table 4.2. It was estimated to range between 432 and 450 mm for deeper soils (Edwards and Pukaki series) with a 10 percent probability of the irrigation requirement exceeding 558 mm one year in 10. The irrigation season for these soils would typically be the warmer months of October through April. Stonier soils (McKenzie series) generally require more irrigation due to their lower water holding capacities (i.e., in the range of 468 to 540 mm/year). The irrigation season for these soils likely starts a month earlier (i.e., in September) than for other soils. SPASMO assumes that 100 percent of applied irrigation water enters the soil and disregards application losses, although they can reach 30 percent of more.

Typically, soil drainage peaks in the winter months whether under irrigation or not. However, substantial drainage also occurs during summer months for the stonier McKenzie soils. Median annual drainage results are listed for the different soil groups in Table 4.2. They were in the range of 4 to 5 mm from the non-irrigated deeper soils (Edwards and Pukaki) while median drainage from non-irrigated stonier soils (McKenzie) was in the 34 to 95 mm range. In contrast, median drainage from irrigated deeper soils was in the 57 to 82 mm range while it was in the 108 to 184 mm range for stonier soils.

5. Pasture nitrate leaching losses -

Because nitrate is mobile in mineral soils, “all other factors being equal” nitrate leaching increases with increases in drainage losses. Average annual nitrate leachate losses predicted by SPASMO were a function of soil type and irrigation. Median model results for the different soil groups and land uses are listed in Table 4.2. In summary, the ranges of nitrate leaching losses from soil were:

Use	Nitrate Losses (kg N/ha/yr)
Dryland sheep	2 – 7
Irrigated arable crops	14 - 28
Irrigated sheep	27 – 35
Irrigated beef	24 – 48
Irrigated dairy	23 – 47
Irrigated deer	27 – 62

5.0 CONSENTS DATA

In December 2005 Environment Canterbury (ECAN) provided a geographic information system (GIS) shape file indicating locations of current consents that have been issued in the Hakataramea River catchment (Miller, 2005). This shape file was updated by new data provided in the form of Excel workbooks (Miller, 2006a and Miller, 2006b). ECAN also provided a GIS shape file indicating locations for which applications for new irrigation consents in the Hakataramea River catchment exist.

5.1 Locations/Areas

5.1.1 Current Consents

Relevant information on current irrigation consents in the attribute table of the GIS shape file, as modified by information in Excel spreadsheets subsequently provided by ECAN (Miller, 2006a and Miller, 2006b), is presented in Table 5.1. There are a total of 32 different parcels of land (i.e., separate GIS polygons) on 23 properties (see “Prop_ID” column) for which 35 consents have been issued. Also listed in Table 5.1 are the source of the water involved, the area of each polygon (“Total_A”), the area of each polygon to be irrigated (“Irr_A”), the agricultural activity taking place on each polygon when the consent was applied for, the actual current agricultural practice based on recent interviews, information on the amount of take, a grid reference, and information on land slope within the polygon. The 23 properties involved and their shapes are shown in green in Figure 5.1. In some cases, where the properties involved are composed of more than one polygon, the polygons are arbitrarily identified by an “A,” “B,” or “C” placed after the property number (Prop_ID).

The intersect feature of ArcMap 9.0 was used with ECAN current irrigation consents and the Landcare Research soil group (Section 2.0 of this report) shape files to determine areas for each of the four soil groups (identified as “Soil_Gr”) within each of the 32 current irrigation polygons split between 23 properties (identified by Prop_IDs). These are listed in Table 5.2 as “Gr_A” (the soil group area for each polygon) along with the total area of each property (“Total_A”) and the relevant irrigated area of the consent (“Irr_A”). For Prop_IDs with multiple polygons, the combined total of each property, rounded off to the nearest whole number, is also listed in Table 5.2 (i.e., Comb_A). This is a check for consistency with the Total_A column and matches within rounding error. In most cases, Irr-A is less than and fits within Total_A for the polygon or Comb_A for the property. However, there were some anomalies that required the exercise of judgement in order to proceed with this analysis. In consultation with ECAN (Miller, 2006c), it was decided that the distribution of irrigation water would be handled as follows:

For Prop_IDs 6, 7, 8, 16, and 20 where there was a mismatch between the area of each soil group (i.e., Gr_A) and Irr_A for some soil groups but the sum of soil group areas (i.e., Comb_A) was greater than the sum of irrigated areas within them (i.e., Total Comb_A>Total Irr_A) for each Prop_ID, the sum of Irr_A was distributed over all polygons in proportion to Gr_A. Irr_A was multiplied by the ratio of Gr_A to Comb_A to accomplish this. For Prop_IDs 19 and 27 where Irr_A was very close to or exceeded Comb_A, it was assumed that all land was irrigated.

The resulting irrigation distribution (GrIrr_A) for each soil group in each polygon is listed in Table 5.2. The non-irrigated (NonIrr_A) area is also listed.

5.1.2 New Consent Applications

Relevant information on applications that have been submitted for new irrigation consents from the attribute table associated with that GIS shape file, as modified by information in an Excel spreadsheet subsequently provided by ECAN (Miller, 2006a), is presented in Table 5.3. A total of 7 consent applications are before ECAN from the owners of 9 properties (see "Prop ID" column) covering 16 different parcels of land. Table 5.3 presents the same categories of information for new consent applications provided in Table 5.1 for current irrigation. The 9 properties involved and their shapes are shown in orange in Figure 5.2. In some cases, where the properties involved are composed of more than one polygon, the polygons are arbitrarily identified by an "A," "B," "C," or "D" after the property number (Prop_ID).

As with current irrigation, the intersect feature of ArcMap 9.0 was used with ECAN new irrigation and the Landcare Research soil group (see Section 2.0 of this report above) shape files to determine areas for each of the four soil groups within each of the 16 current irrigation polygons. These are listed in Table 5.4 along with the total area of each polygon ("Total_A") and the relevant irrigated area of the consent ("Irr_A"). For Prop_IDs with multiple polygons, the combined total of each is also listed in Table 5.4 (i.e., Comb_A). In most cases, Irr-A is less than and fits within Total_A or Comb_A. However, there were some anomalies that required the exercise of judgement in order to proceed with this analysis. In consultation with ECAN (Miller, 2006c), it was decided that they would be handled as follows:

For Prop_IDs 2 and 24 where there was a mismatch between Gr_A and Irr_A for some soil groups but Comb_A was greater than the sum of Irr_A (i.e., Comb_A>Irr_A) for each Prop_ID, the sum of Irr_A was distributed over all polygons in proportion to Gr_A. Irr_A was multiplied by the ratio of Gr_A to Comb_A to accomplish this. For Prop_IDs 11 and 13, where Irr_A exceeded Comb_A, it was assumed that all land was irrigated.

The resulting calculated irrigated land to be irrigated for each soil group in each polygon (GrIrr_A) and the non-irrigated area (NonIrr_A) are listed in Table 5.4.

5.2 Agricultural Practices

5.2.1 Current Consents

Agricultural practices, when current consents were authorized, are listed in the "Agricultural Activity" column of Table 5.1. These generally involved irrigation to provide pasture for grazing animals including cattle (listed as "beef"), deer, or sheep or some combination of those and/or the growing of unspecified crops. In some cases, the crop involved may be pasture for grazing animals. To obtain more detailed information, particularly with regard to indicated multiple uses, farmers were queried regarding actual current practice. The data obtained from this query is listed in the "Actual Current Practice" column of Table 5.1. This information gives a much better indication of the distribution of grazing animals in cases of multiple uses. It was also indicated in many cases that crops of one kind or another were being grown and that sometimes these crops are for the purpose of providing grazing pasture or silage.

Based on information in the "Actual Current Agricultural Practice" column of Table 5.1, assumptions regarding agricultural use in modelling were made. These are shown in the far right column of Table 5.5. These were applied to the total area for each soil group of each property polygon. Nitrate leaching losses were then calculated as the product of the areas of each soil group for each type land use and the unit value of nitrate leaching loss for each type land use from Table 4.2.

5.2.2 New Consent Applications

The activities involved with consent applications are listed in the "Activity" column of Table 5.3. Although no fractional distribution was specified in those cases of multiple uses (e.g., splits between beef and sheep), these were relatively straight-forward. Where beef and sheep were the listed activity, the primary case, a distribution of 20% beef and 80% sheep was assumed. There were some cases where the specified activity included crops along with beef and sheep. In these cases, in the absence of clarifying information, the conservative assumption was made that beef and sheep would be the effective use.

Assumptions used in modelling are shown in the far right column of Table 5.6. These were applied to the irrigated area for each soil group of each property polygon. Nitrate leaching losses were then calculated as the product of the areas of each soil group for each type land use and the unit value of nitrate leaching loss for each type land use from Table 4.2.

6.0 MODEL SCENARIOS

ECAN specified that modelling be performed for four scenarios. These were further defined in terms of the specific data available as follows:

1. Scenario 1 – Existing irrigated land uses. This scenario involves estimation of nitrogen leaching losses as a result of irrigation under the current consents that have been issued. The locations of irrigated areas are indicated in Figure 5.1. These areas were mapped by ECAN from records and following discussions with

Hakataramea irrigators (10 October 2005). These mapped areas do not necessarily equate with areas specified on resource consents and an adjustment has been required. Information on current consents (see Tables 5.1 and 5.2) was used to define the properties, soil groups on them, current practice, areas involved, and nitrate leaching losses (see Table 4.2) for currently irrigated areas.

2. Scenario 2 – An increase in irrigation to a level considered economically viable for irrigation at this time. This scenario involves estimation of the incremental additional nitrogen leaching losses that would result if new consents were to be granted to all those who have applied. The combination of losses from this increase and currently issued consents (Scenario 1) has been defined by ECAN as a level of irrigation that is economically viable at this time. The locations of irrigated areas are indicated in Figure 5.2. These areas were mapped by ECAN from information with the resource consent applications and following discussions with Hakataramea irrigators (10 October 2005). These mapped areas do not necessarily equate with areas specified on resource consent applications and an adjustment has been required. Information on applied for new consents to irrigate (see Tables 5.3 and 5.4) was used to define the properties, soil groups on them, proposed practice, areas involved, and nitrate leaching losses for requested new irrigation areas.

3. Scenario 3 – Irrigation of all potentially irrigable land in the Hakataramea River catchment. This has been defined by ECAN as the "community scheme." The delineation of the community scheme areas was accomplished in two GIS shape files splitting the area involved into north and south segments (community schemes 1 and 2, respectively). Because small portions of land with current irrigation and new consent applications (Scenarios 1 and 2, respectively) fell outside of the community scheme areas, it was necessary to also include them in addition to ensure that this scenario covered the maximum area irrigation case. The areas covered by the community scheme and those portions of current irrigation and new consent applications falling outside the community scheme are indicated in Figure 6.1.

4. Scenario 4 – Fully dry land without irrigation. This scenario provides three estimates for nitrogen leaching losses in the event that the same land areas considered under Scenarios 1, 2, and 3 above were to be farmed for the production of sheep without irrigation (i.e., dryland sheep).

6.1 Scenario 1 - Current Irrigation

Estimates of nitrate-nitrogen leaching and water drainage losses were prepared for farms with current irrigation consents. These locations are shown in Figure 5.1. GrIrr_A values from Table 5.2, assumptions about land use from Table 5.5, and soil group nitrate-nitrogen leaching loss per unit area from Table 4.2 are also listed in Table 6.1a for current irrigation. In addition, ratios of total irrigated (T-Irr_A) to total areas (Total_A) for each property were calculated. These varied considerably. Ratios were 0.74 for the sums of all areas (i.e., totals for T-Irr_A divided by Total_A) and 0.75 for the mean of all properties (i.e., the mean of the individual area T-Irr_A divided by Total_A values). It should be noted that due to rounding and assumptions regarding irrigation areas, as discussed in Section 5.1.1, land area column totals in Tables 5.1, 5.2, and 6.1a are very close but not identical.

Nitrate-nitrogen leaching losses per year by soil group for irrigated land on each property calculated from this information are listed in the four columns on the right side of Table 6.1a as well as a current irrigation total for all soil groups combined. In addition to estimates of nitrate-nitrogen leaching presented in Table 6.1a, estimates of water drainage for irrigated areas were also prepared. These are presented in Table 6.1b. SPASMO water drainage losses in mm/year from Table 4.1 were applied to the irrigated areas listed in Table 6.1b to arrive at these estimates.

Estimates of both nitrate-nitrogen leaching and water drainage losses are shown as split into two geographic groups. Wright's Crossing is used as the dividing line to delineate the split. Farms located to the north of a line perpendicular to the river and extending to either side of it at Wright's Crossing are the first group. This group includes properties with identification numbers (Prop_IDs) less than 12 in the various tables (e.g., Tale 5.1). Farms located to the south of that line, between Wright's Crossing and where the main highway bridge (MHBR) for SH82 crosses the Hakataramea River a short distance from its mouth (i.e., near the Waitaki River), are the second group. Stream gaging site data are available for both of these locations.

These estimates indicate that 51,034 Kg of nitrate-nitrogen/year leach to groundwater from currently irrigated land north of Wright's Crossing and 55,163 Kg between Wright's Crossing and the MHBR or a total of 106 tonnes/year. They also indicate that approximately 1.5 million m^3/year of water drainage loss carries this nitrate-nitrogen into groundwater from irrigated farms north of Wright's Crossing and 1.7 m^3/year does between Wright's Crossing and the MHBR or a total of 3.2 million m^3/year. Assuming complete mixing, these masses of nitrate-nitrogen in such volumes of water would result in mean nitrate-nitrogen concentrations of 33.1, 32.4, and 32.7 mg/L for currently irrigated land north and south of Wright's Crossing and for all currently irrigated land combined, respectively.

6.2 Scenario 2 – New Consent Applications

Estimates of nitrate-nitrogen leaching and water drainage losses were prepared for farms which have applied for new consents to irrigate. These locations are shown in Figure 5.2. GrIrr_A values from Table 5.4, assumptions about land use from Table 5.6, and soil group nitrate-nitrogen leaching loss per unit area from Table 4.2 are also listed in Table 6.2a for new applications to irrigate. In addition, ratios of total irrigated (T-Irr_A) to total areas (Total_A) for each property were calculated. These varied considerably. Ratios were 0.55 for the sums of all areas and 0.67 for the mean of all individual properties. It should be noted that due to rounding and assumptions regarding irrigation areas, as discussed in Section 5.1.2, land area column totals in Tables 5.3, 5.4, and 6.2a are very close but not identical.

Nitrate-nitrogen leaching losses per year by soil group for land to be irrigated on each property calculated from this information are listed in the four columns on the right side of Table 6.2a as well as a current irrigation total for all soil groups combined. In addition to estimates of nitrate-nitrogen leaching presented in Table 6.2a, estimates of water drainage for areas subject to new applications to irrigate were also prepared. These are presented in Table 6.2b. SPASMO water drainage losses in mm/year from Table 4.2 were applied to the irrigated areas listed in Table 6.2b to arrive at these estimates.

As with current irrigation, estimates of both nitrate-nitrogen leaching and water drainage losses are shown split into two groups (i.e., north of Wright's Crossing and between Wright's Crossing and the MHBR). The group north of Wright's Crossing includes properties with property identification numbers (Porp_IDs) less than 13.
These estimates indicate that 41,351 Kg of nitrate-nitrogen/year would leach to groundwater if the new applications are approved from farms north of Wright's Crossing and 5,760 Kg between Wright's Crossing and the MHBR or a total of 47 tonnes/year. They also indicate that 1.2 million m^3/year of water drainage loss would carry this nitrate-nitrogen into groundwater from irrigated farms north of Wright's Crossing and 211,040 m^3/year between Wright's Crossing and the MHBR or a total of 1.4 million m^3/year. Assuming complete mixing, these masses of nitrate-nitrogen in such volumes of water would result in mean nitrate-nitrogen concentrations of 34.5, 27.3, and 33.4 mg/L for irrigated lands north and south of Wright's Crossing and for all farms combined, respectively.

6.3 Scenario 3 – Community Scheme

The community scheme includes the areas indicated in Figure 6.1. The soil group areas involved for current and new property areas outside of community scheme areas were identified using GIS files and are listed in Table 6.3.

It was assumed that only 75 percent of community scheme soil group areas available for irrigation would actually be irrigated. This allows for the existence of roads, farm structures, and other areas that would not be irrigated and is close to the ratio of the actual irrigated to total area found from data for the current irrigation scenario (see Table 6.1a). This information was coupled with SPASMO nitrate-nitrogen leaching loss values per unit area from Table 4.2 to calculate annual leaching loss for irrigation. In doing so, it was further assumed that pasture land use would be in the proportion of 20 percent beef and 80 percent sheep. As can be seen in Tables 5.1 and 5.3, this ratio of use is common for both current irrigation and for new irrigation consent applications.

Nitrate leaching and drainage loss estimates for the community scheme scenario are presented in Tables 6.4a and 6.4b. These indicate that approximately 379 tonnes of nitrate-nitrogen/year would leach to groundwater under community scheme 1 (from irrigated land north of Wright's Crossing) and 158 tonnes under community scheme 2 (between Wright's Crossing and the MHBR) or a total for the Hakataramea River valley of 537 tonnes/year. They also indicate that approximately 10.9 million m^3/year of water drainage loss would carry this nitrate-nitrogen into groundwater from irrigated land north of Wright's Crossing and 4.6 million m^3/year between Wright's Crossing and the MHBR or a total of 15.4 million m^3/year. Assuming complete mixing, these masses of nitrate-nitrogen in such volumes of water would result in mean nitrate-nitrogen concentrations of 34.9, 34.5, and 34.8 mg/L for irrigated land north and south of Wright's Crossing and for all irrigated land combined, respectively.

6.4 Scenario 4 – Dryland Sheep

Dryland sheep land use was modelled for irrigated land associated with each of the above scenarios. Results for dryland scenarios are presented in Tables 6.4 and 6.5. In summary, these indicate the following:

1. Scenario 4a – Dryland sheep on current irrigated land (Tables 6.5a and 6.5b). Annual nitrate-nitrogen leaching loss was estimated at a total of 14 tonnes and annual drainage loss was estimated at approximately 1.2 million m^3/year. Assuming complete mixing, this mass of nitrate-nitrogen in such a volume of water would result in a mean nitrate-nitrogen concentration of 11.2 mg/L.

2. Scenario 4b – Dryland sheep on land that would be irrigated if new applications for consents were granted (Tables 6.5c and 6.5d). Annual nitrate-nitrogen leaching loss was estimated at a total of 6 tonnes and annual drainage loss was estimated at 615,760 m^3/year. Assuming complete mixing, this mass of nitrate-nitrogen in such a volume of water would result in a mean nitrate-nitrogen concentration of 9.77 mg/L.

3. Scenario 4c – Dryland sheep on land that would be irrigated under the community scheme (Table 6.4). Annual nitrate-nitrogen leaching loss was estimated at a total of approximately 89 tonnes and annual drainage loss was estimated at 5.6 million m^3/year. Assuming complete mixing, this mass of nitrate-nitrogen in such a volume of water would result in a mean nitrate-nitrogen concentration of 15.8 mg/L.

6.5 Comparison of Results

Results for all scenario runs are presented in Table 6.6 for comparison. This includes a breakdown by the “upper” Hakataramea River catchment (i.e., irrigated land north of Wright’s Crossing) and “lower” Hakataramea River catchment (i.e., irrigated land between Wright’s Crossing and the MHBR) and the combined sum of both for nitrate-nitrogen leaching loss in Kg/year and for water drainage loss in m^3/year. In addition, calculated concentrations in mg/L based on these data are also presented.

Comparison are most readily made by uses factors indicating the ratio of one scenario to another. For example, estimated nitrate-leaching loss to groundwater for the various land uses practiced on currently irrigated land was larger by a factor of 6.2 (i.e., 6.2 times) than what it would be for the dryland sheep use on the same areas. Water drainage loss is also a factor of 1.9 (i.e., 1.9 times) greater for the irrigated compared to the dryland case. In general, using combined figures, it appears that nitrate-nitrogen leaching loss is 6.1 to 7.8 times greater on irrigated land than nitrate-nitrogen leaching loss from dryland sheep use on the same areas. Similarly, estimates of water drainage loss are 2.3 to 2.8 times greater with irrigated land use than for the dryland sheep scenario.

It is also possible to see the relative impact of regulatory changes when comparing estimates in Table 6.6. For example, approval of all new consent applications would result in an estimated 44 percent increase in nitrate-leaching loss to groundwater over current irrigation and roughly the same increase in water drainage loss (mostly in the upper Hakataramea River catchment north of Wright's Crossing). The community scheme represents the maximum irrigation case. Estimated combined nitrate-nitrogen leaching loss to groundwater would increase by a factor of 5.1 (i.e., 5.1 times) and estimated water drainage loss would increase by a factor of 4.8 with irrigation of community scheme land as compared to currently irrigated land.

Mean concentrations of nitrate-nitrogen as unsaturated zone drainage water entering groundwater can also be estimated assuming complete mixing and that the mass involved as nitrate-nitrogen leaching loss is contained in the water drainage loss from these farms. These concentrations would represent the levels of nitrate-nitrogen in unsaturated zone soil solutions as they enter groundwater. They indicate a maximum level nitrate-nitrogen concentration at the point of entry to groundwater because natural upgradient groundwater will result in dilution. These calculations indicate nitrate-nitrogen concentrations of approximately 30 mg/L under irrigated farms and 10 mg/L under the same farms for the dryland sheep use without irrigation (for current irrigated land and for new irrigation consent application scenarios). This amounts to a factor of three increase for farms going from dryland sheep to various irrigated uses. For the community scheme scenario, the estimates indicate closer to a factor of two increase for this change in land use.

To place the nature of water drainage loss volumes into perspective, they can also be compared with other volumes of water. Such comparisons indicate that the volume of water drainage loss from irrigation is small in comparison to the flow of the Hakataramea River but is likely to constitute a substantial portion of the water used for irrigation. For example, the long term mean flow rate of the Hakataramea River at the MHBR gaging station prior to entry into the Waitaki River over the 1964-2004 period of record is 5.872 m^3/sec (MfE, 2005) or 185,179,392 m^3/year. Estimated annual water drainage loss from currently irrigated land (3,243,092 m^3 under Scenario 1) is approximately 1.8 percent of that volume. Alternatively, drainage volumes can also be compared to irrigation volumes. The sum of daily average flows in consents for currently irrigated land is 900 L/sec. Assuming this flow occurs for 60 percent of the time over 150 days a year (Miller, 2006c), it would amount to an annual total of 6,998,400 m^3/year. This value would be approximately 3.8 percent of the mean annual flow of the Hakataramea River at the MHBR gaging station while the estimate of combined water drainage loss for currently irrigated land throughout the catchment would be approximately 46 percent of this calculated irrigation flow. This comparison indicates that estimates of water drainage loss are reasonable in terms of current consents for irrigation.

Figure 1.1 Hakataramea River catchment.

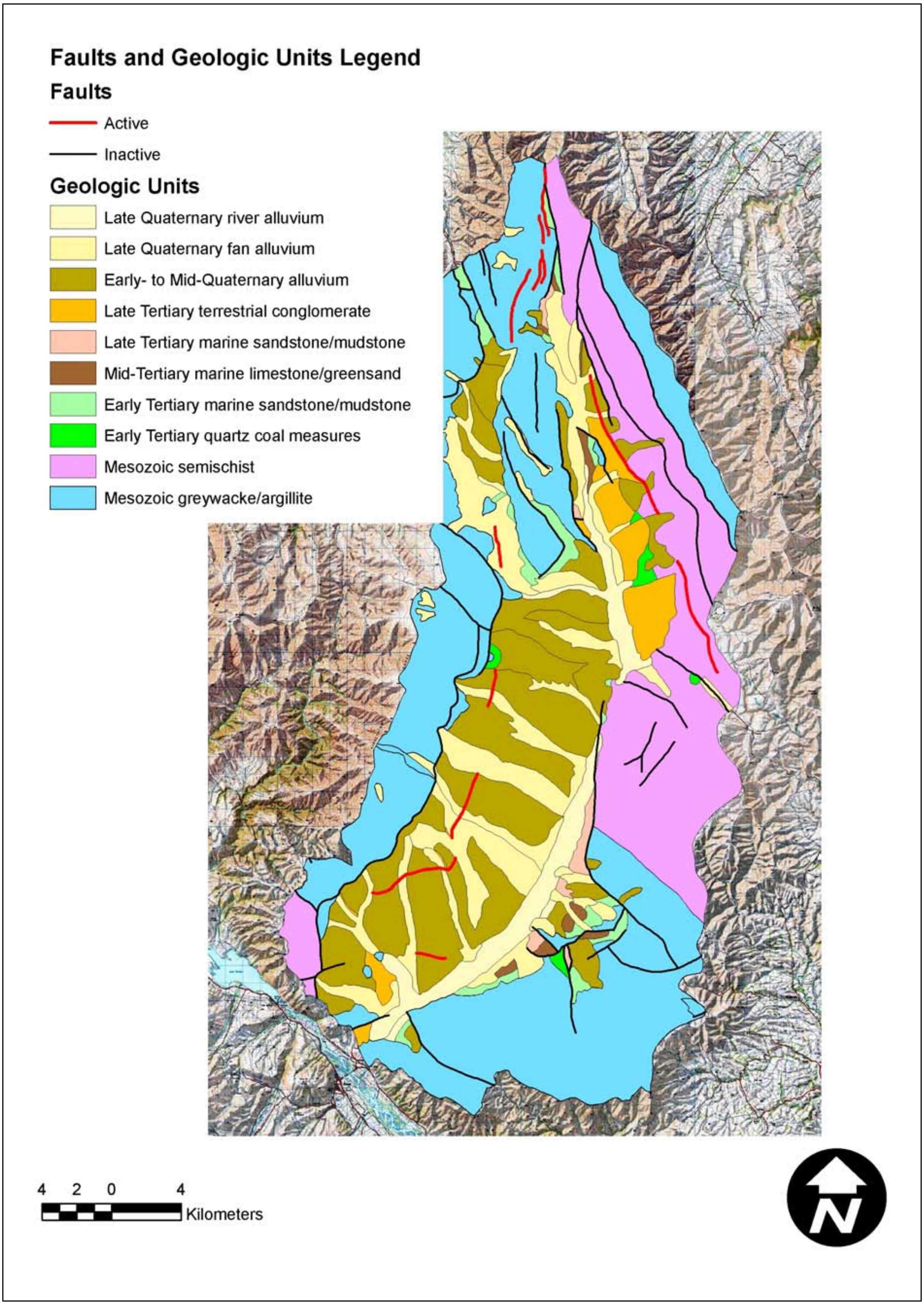

Figure 2.1 Geology of the Hakataramea River Valley.

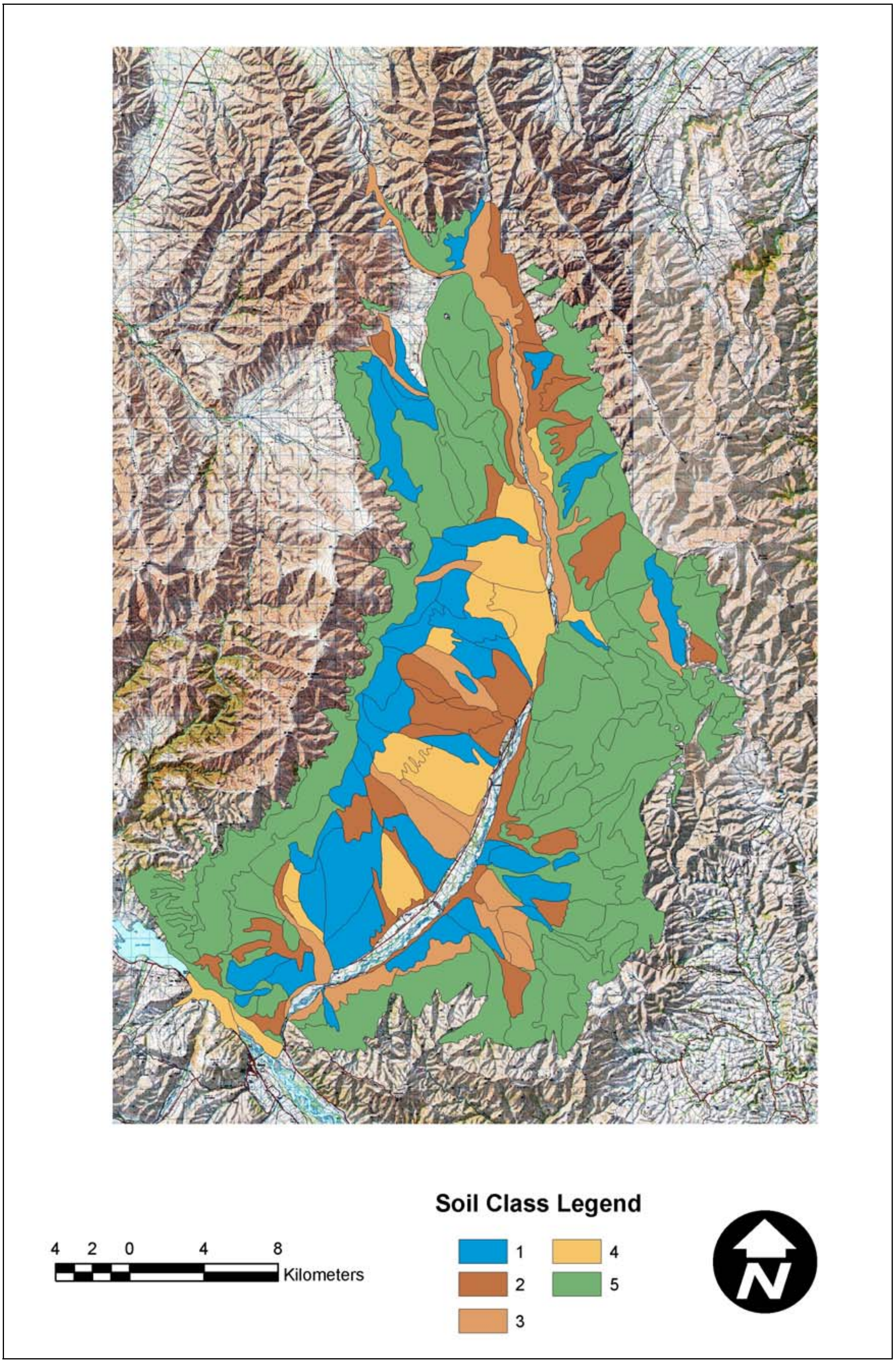

Figure 2.2 Soils of the Hakataramea River Valley.

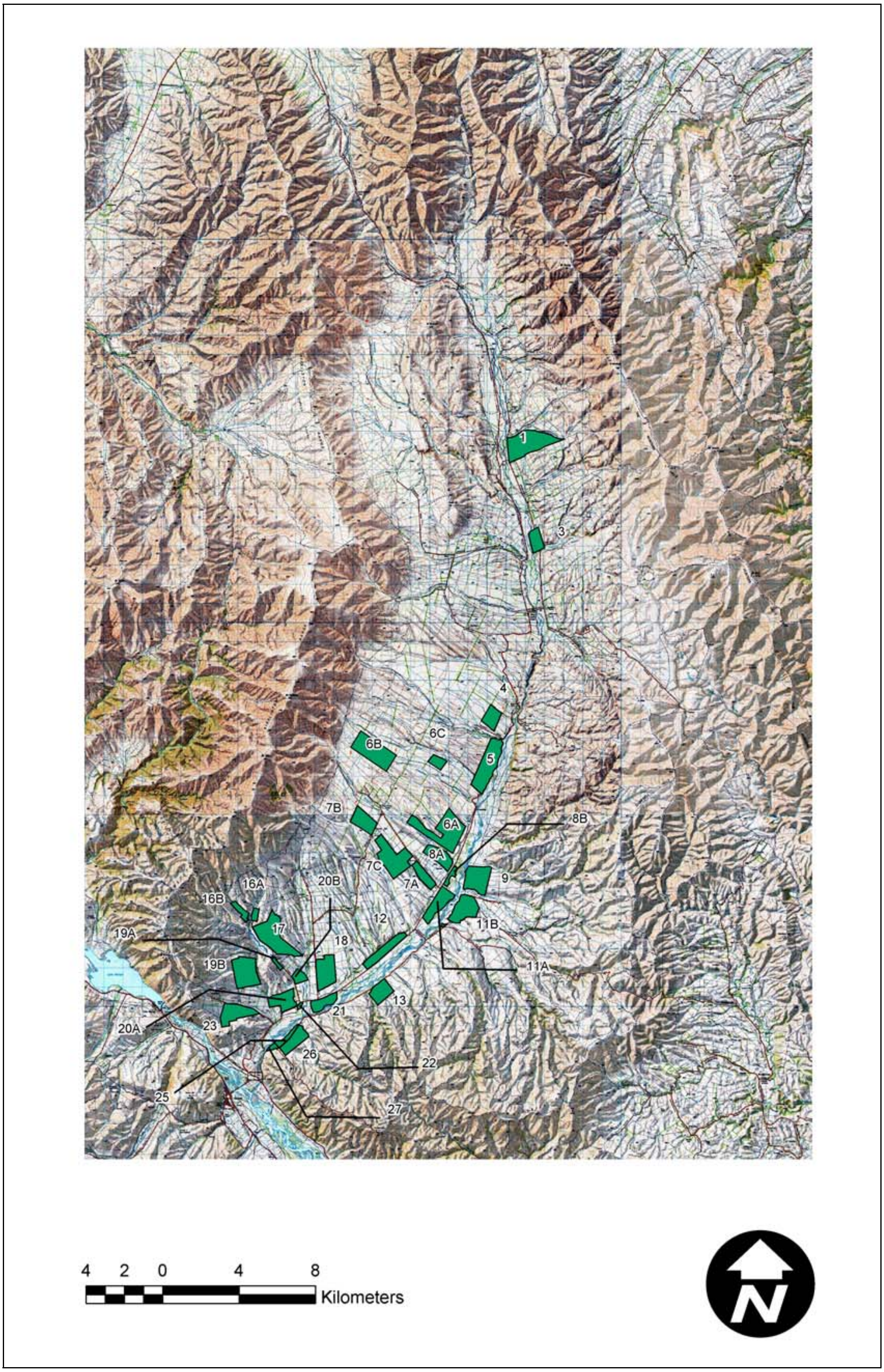

Figure 5.1 Current consents for irrigation.

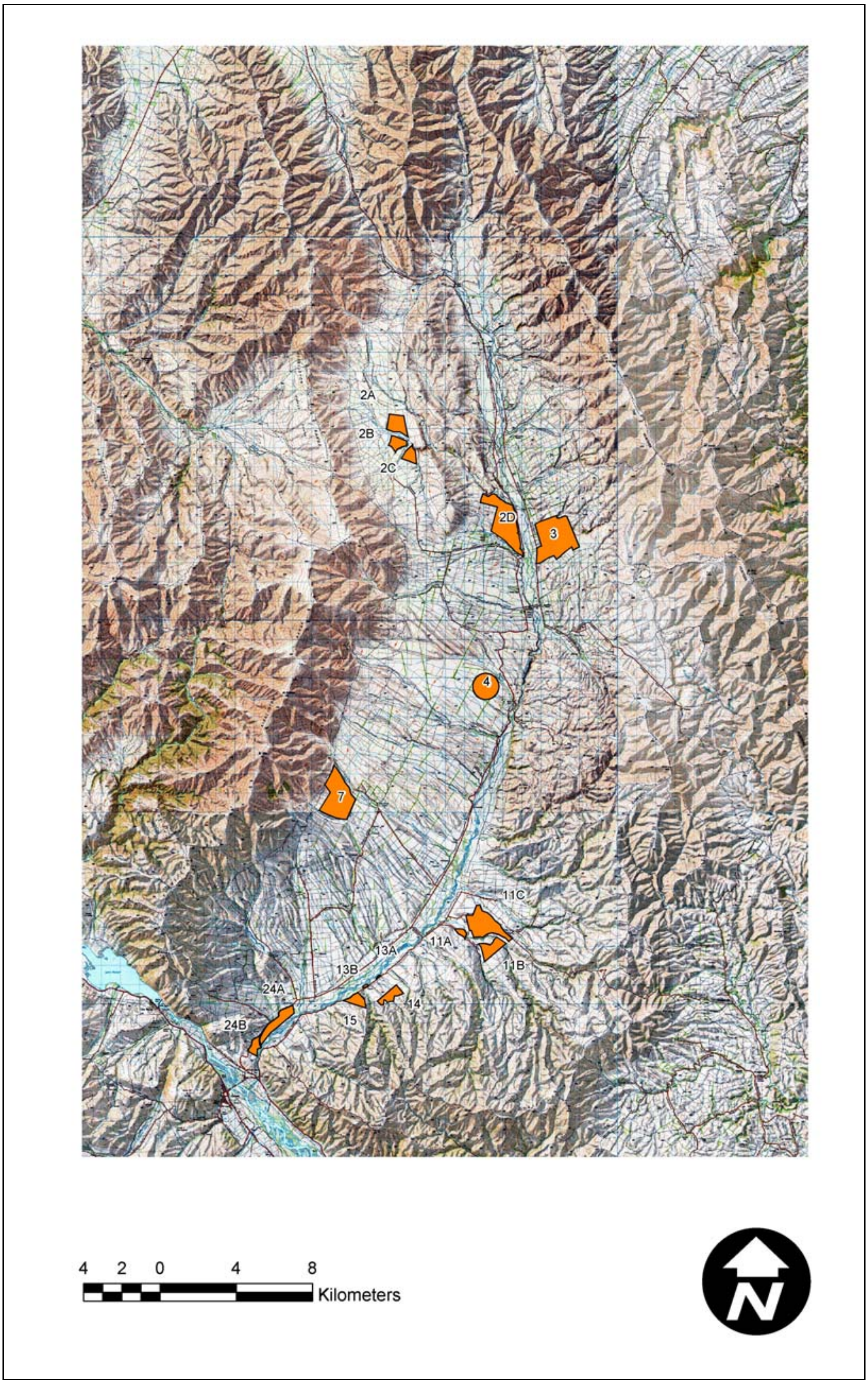

Figure 5.2 New applications for irrigation.

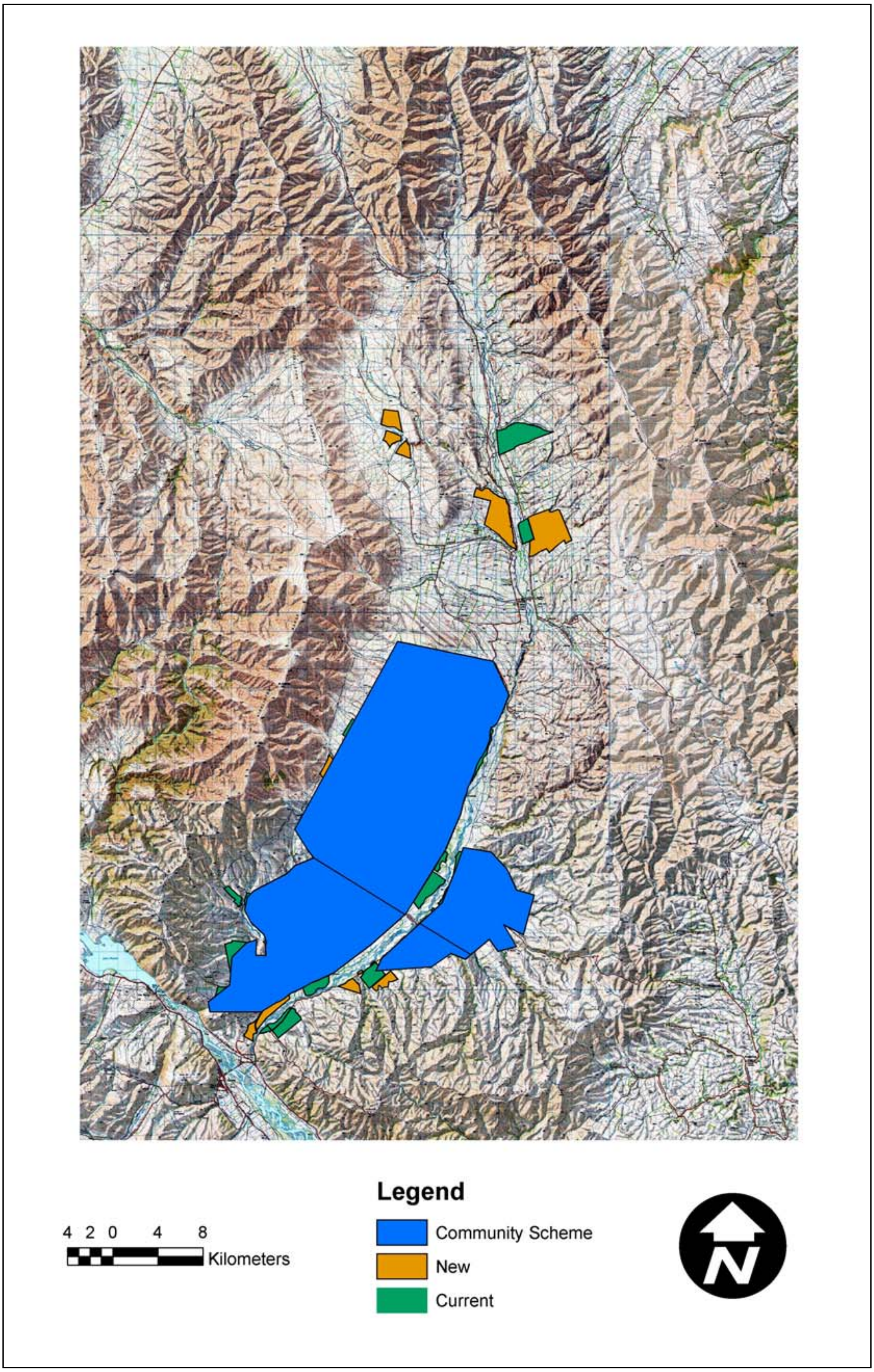

Figure 6.1 Community Scheme Irrigation.

Table 2.1 Principal geological units in the Hakataramea River Valley.

Principal Geological Units in the Hakataramea River Valley[1]			
Geological Material	Summary Description	Approximate Age[2]	Comments and Groundwater Relationships
Late Quaternary river alluvial gravel	Well-rounded sandy greywacke gravel. Some weathering in the deposits forming the highest (oldest) of the Late Quaternary terraces.	0 to 125 ka	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 Quaternary fan alluvial gravel	Sub-angular silty greywacke gravel. Some weathering in the deposits forming the highest (oldest) of the Late Quaternary terraces.	0 to 125 ka	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 Quaternary alluvial gravel	Weathered sandy or silty greywacke gravel, at least in part clay-plugged.	125 ka to ~1.8 Ma	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.	~1.8 Ma to ~55 Ma	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.	~200 to ~275 Ma	May have potential as fracture-controlled aquifers, especially close to fault lines.

1. *Forsyth (2001) and Cox and Barrell (2006).*
2. *1 ka = 1,000 years before present. 1 Ma = 1 million years before present.*

Table 2.2 Suitability of soils for agricultural land uses.

Suitability of Soils for Agricultural Land Uses[1]					
		Use Description			
Soil Class	Name	Beef/Deer/Sheep	Dairy	Arable	Orchard
1	Deep to shallow	1	1	1	1
2	Stony	2	2	3	2
3	Very stony	3	3	4	3
4	Impeded	2	2	2	3

1. *Suitability codes: 1 = Good; 2 = Moderate; 3 = Poor; and 4 = Unsuitable. From Webb (2005).*

Table 3.1 Rainfall gage data for the Hakataramea River Catchment.

Rainfall Gage Data for the Hakataramea River Catchment[1]													
	Monthly Rainfall												Annual
Site/Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Hakataramea River at Mt. Florence (#450601)													
1995	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	16	43	88	53	110	-
1996	124	40	39	65	23	33	38	**ND**	6	65	39	47	-
1997	35	15	30	63	**ND**	**ND**	30	23	19	17	16	**ND**	-
1998	**ND**	**ND**	**ND**	**ND**	33	41	30	11	4	70	17	30	-
1999	22	32	**ND**	27	4	37	53	5	12	15	64	79	-
2000	101	11	48	69	29	**ND**	**ND**	**ND**	56	18	32	**ND**	-
2001	60	12	1	16	28	20	59	17	10	45	27	**ND**	-
2002	80	20	14	67	18	60	14	23	14	21	68	**ND**	-
2003	**ND**	30	12	14	34	12	14	12	67	39	17	12	-
2004	88	26	29	15	47	9	5	46	16	46	65	99	491
2005	33	72	44	14	24	8	17	21	37	38	25	65	396
2006	60	19	6	-	-	-	-	-	-	-	-	-	-
Min	22	11	1	14	4	8	5	5	4	15	16	12	396
Median	70	26	30	27	28	27	30	17	16	39	32	65	444
Mean	68	29	27	39	27	27	29	19	26	42	38	63	444
Max	124	72	48	69	47	60	59	46	67	88	68	110	491
Hakataramea River at McRaes Gorge (#403601)													
1985	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	33	31	77	121	-
1986	46	113	196	17	63	33	88	195	46	42	70	3	912
1987	75	117	179	31	67	54	33	14	26	48	37	47	728
1988	64	51	10	37	32	42	56	**ND**	**ND**	**ND**	**ND**	43	-
1989	79	85	**ND**	29	97	48	18	13	24	61	**ND**	**ND**	-
1990	58	99	40	31	91	17	41	151	34	112	19	21	714
1991	41	80	14	**ND**	**ND**	41	57	108	89	33	101	61	-
1992	7	68	18	12	56	47	84	58	58	99	83	50	640
1993	49	33	66	**ND**	**ND**	**ND**	2	28	86	46	62	137	-
1994	89	101	197	16	**ND**	**ND**	**ND**	28	106	12	87	20	-
1995	63	36	68	66	22	93	29	63	99	**ND**	69	119	-
1996	72	74	73	110	43	59	67	27	17	88	68	70	768
1997	54	49	41	90	17	19	74	49	31	51	37	69	581
1998	16	**ND**	86	28	48	45	59	40	21	114	22	35	-
1999	**ND**	**ND**	64	39	8	**ND**	71	26	14	35	90	49	-
2000	144	10	72	107	46	**ND**	**ND**	**ND**	94	38	60	72	-
2001	49	15	12	25	77	38	77	30	13	71	72	67	546
2002	139	44	29	40	20	71	21	26	26	28	85	25	554
2003	46	49	22	31	46	28	34	32	119	47	31	18	503
2004	167	95	**ND**	9	110	26	14	67	26	51	39	136	-
2005	**ND**	84	69	13	49	14	62	26	**ND**	44	24	65	-
2006	66	45	10	-	-	-	-	-	-	-	-	-	-
Min	7	10	9.5	9	8	14	2	13	13	12	19	3	503
Median	63	68	64	31	48	42	57	31	33	47	68	56	640
Mean	70	66	67	41	52	42	49	55	51	55	60	61	661
Max	167	117	197	110	110	93	88	195	119	114	101	137	912

1. *Data provided by Gabites (2005) and Gray (2006). All values in mm (monthly and annually). "**ND**" denotes no data provided for month involved. This can indicate no data at all were available or that data for the month involved were incomplete. "-" under "Annual Total" column denotes incomplete data for the year involved. When under any monthly column, "-" denotes data not yet available (i.e., for year 2006).*

Table 3.2 Surface stream information.

Surface Stream Information[1]			
Stream-Location	Drainage Area (km^2)	Flow	
		MALF[3] (m^3/sec)	Mean (m^3/sec)
Waitaki River at Kurow[2]	9,760.	-	373.
Hakataramea River Mainstem:			
At Above MHBR (SH82)	896.	1.126	5.872
Wrights Crossing	717.2	0.425	4.802
Rocky Point[4]	433.6	0.786	4.039
McRaes Gorge[4]	84.	0.485	1.744
Hakataramea River Tributaries:			
West Side -			
Padkins Stream	41.3	0.082	0.192
Kirkliston Stream	5.9	-	-
Potato Creek	-	-	-
Station Stream	7.3	0.077	0.224
Deadman Stream	-	-	-
Poplar Stream	-	-	-
McKays Stream	29.2	0.049	-
Rocky Point Stream	-	-	-
Cattle Creek	16.5	0.099	0.495
Gorman Stream	-	-	-
Grampian Stream	71.1	0.106	-
Dunstan Stream	10.	0.	-
MacGregor Stream	-	-	-
Dalgety Stream	30.9	0.134	-
East Side -			
Brothers Stream	16.4	0.002	0.014
Homestead Stream	39.8	0.006	0.161
Sisters Creek	8.8	0.001	-
Bluestone Creek	14.4	0.	0.027
Stoney Creek	-	-	-
Peter Stream	9.2	0.009	-
Two Mile Stream	-	-	-
Scour Stream	10.5	0.009	-
Two Legged Stream	-	-	-
Nessing Stream	-	-	-
Longden Stream	-	-	-
Massack Stream	-	-	-

1. *Unless otherwise noted, area and flow data from MfE (2005a). Hakataramea River listed for west and east side of river in order of location starting at the River's mouth picked off of topographic map.*
2. *Waitaki River area and flow from ECAN (2001).*
3. *"MALF" means natural mean annual low flow.*
4. *Rain gages located in vicinity of stream gages (Mt. Florence near Rocky Point and McRaes Gorge near McRaes Gorge).*

Table 3.3 Hakataramea River Catchment well logs.

Hakataramea River Catchment Well Logs[1]				
	NZMG Coordinates		Depth	
Well ID[2]	Easting	Northing	(m BGL)	Lithoology
I40/0019	2317130	5612020	0-3	Greywacke gravels, boulders
			3-6	Greywacke gravels, cobbles
			6-15	Sandy greywacke gravels, cobbles
I40/0024	2314580	5614310	0-0.30	Brown earth
			0.3-3.50	Brown clay
			3.5-16.79	Claybound gravel
			16.79-27.50	Brown clay with some gravel
			27.50-83.00	Claybound gravel
I40/0001	2311533	5605129	0-2.80	Wrights Crossing Bridge fill to mixed gravels and sand
			2.80-3.50	Large gravels and silt
			3.50-5.19	Small to medium brown gravel and clay
			5.19-5.59	Brown silt, clay
			5.59-15.00	Mudstone, black sand
I40/0025	2319800	5613600	0-.30	Earth - sandy, some gravels
			0.30-1.50	Very sandy gravel
			1.50-3.90	Freeish gravel with some staining
			3.90-19.20	Brown clay
			19.20-25.79	Brown clay, sandstone
			25.79-83.00	Grey clay, sandstone with some iron
I39/0003	2319820	5622320	0-0.30	Topsoil
			0.30-1.60	Brown silty clay
			1.60-9.80	Brown silt and brown and grey weathered gravels
			9.80-11.40	Brown silt, claybound brown-grey weathered gravels, odd pebble, scattered cobbles, dribble moist
			11.40-32.59	Brown silt, claybound brown-grey weathered gravels, odd pebble, scattered cobbles, dribble water
			32.59-43.50	Brown silt, claybound brown-odd grey weathered gravels, dribble water
			43.50-47.20	Brown silt, claybound brown-odd grey weathered gravels, lost water
			47.20-72.00	Brown silty clay, brown weathered gravels, odd pebbles
I40/0382	2321650	5615670	0-0.29	Olive-brown silty sand, with minor clay. Sand is fine, weak, no mottles
			0.29-0.45	Light brown silty fine sand with minor clay, weak, no mottles
			0.45-0.55	Light olive brown fine-coarse sand, med-coarse gravel with rare clay and some silt, weak consistency
			0.55-0.8	Olive sandy gravels, gravel medium-coarse, firm/tight
			0.8-1.5	Olive sandy medium-very coarse gravels, slightly firm

1. *Data provided by Atchison-Earl (2005 and 2006).*
2. *See location of wells by well IDs shown in Figure 1.1.*

Table 4.1 Typical soil nitrogen leaching losses

Typical Soil Nitrogen Leaching Losses			
Reference[1]	Land Use	Leaching[2] (Kg N/ha/Yr)	Remarks
HBRC (2003)	Dryland Sheep	6	-
HBRC (2003)	Irrigated Sheep	20	-
HBRC (2003)	Dryland Beef	7	-
HBRC (2003)	Irrigated Beef	16	-
HBRC (2003)	Dairy	43	-
HBRC (2003)	Maize	20	-
HBRC (2003)	Grape Production	41	-
Di, et al. (1998)	Dairy Shed Effluent	8-25	Templeton fine sandy loam soil pasture with mix of ryegrass and white clover near Christchurch. Two applications/year at rate of 200 Kg N/application. Pasture irrigated. Herbage harvested.
Di, et al. (1998)	Ammonia Fertilizer	28-48	Templeton fine sandy loam soil pasture with mix of ryegrass and white clover near Christchurch. Two applications/year at rate of 200 Kg N/application. Pasture irrigated. Herbage harvested.
MAF (2006)	Ryegrass	5-73	Based on newly established grazed crop. Grazing contributes ~ 30 Kg N/Ha.
MAF (2006)	White Clover	40-50	Winter leaching losses from grazed crop. Grazing contributes ~ 30 Kg N/ha.
MAF (2006)	Winter Wheat	60-80	Winter leaching losses from wheat crop only.
MAF (2006)	Spring Barley	60-70	Winter leaching losses on fallow land following a grain legume crop.

1. *See references cited for complete citation.*
2. *Primary form of leached nitrogen is as nitrate-nitrogen.*

Table 4.2 Median SPASMO results.

Median SPASMO Results[1]												
Soil Group			Water (mm/year)			Leaching Losses (Kg NO_3-N/hectare/year)[5]						
			Irr	Drainage Losses[4]		Non-Irr	Irrigated					
#	Webb (2005) Name	Green (2005) Name	Required[3]	Non-Irr	Irr	Sheep	Arable[6]	Beef	Dairy	Deer	Sheep
-	-	Pukaki Sandy Loam	450	4	82	2	17	32	31	35	35
-	-	McKenzie Shallow	468	34	108	5	15	25	25	31	31
1	Deep to shallow	Mean[2]	459	19	95	4	16	29	28	33	33
2	Stony and rolling	McKenzie Stony	522	66	145	7	25	42	40	50	53
3	Very stony	McKenzie Very Stony	540	95	184	7	28	48	47	62	62
4	Impeded	Edwards Silt Loam	432	5	57	3	14	24	23	27	27

1. *All values are SPASMO modelling output results from Green (2005).*
2. *Mean of Pukaki sandy loam and McKenzie shallow (White, et al., 2004).*
3. *Irrigation (Irr) requirements (required) based on single irrigation of 18 mm applied each time root-zone water deficit exceeds 50% of total available water.*
4. *Drainage looses in mm/year from non-irrigated (Non-Irr) and irrigated (Irr) pasture.*
5. *Nitrate-nitrogen leaching losses in Kg-N/hectare/year under use for non-irrigated sheep or irrigated arable crops, beef, dairy, deer, or sheep.*
6. *May vary depending on type of crops and other factors. Assumed as mean of non-irrigated sheep and irrigated beef (White, et al., 2005).*

Table 5.1 Current irrigation by property parcel/polygon.

Current Irrigation By Property Parcel/Polygon[1,2,3]																
		Total_A				Irr_A			Max Rate	Max Vol	Consec	Daily Avg		Slope		
#	Prop_ID	ha	Source	Consent #	Name	ha	Agricultural Activity[4]	Actual Current Agricultural Practice[5]	L/sec	m^3	Days	L/sec	Grid Ref	Min	Mean	Max
1	1	254.91	Anderson Stream	CRC020842.1	R H & J Robertson Family Trust	140	Beef and sheep	Deer	70	60,480	10	70	I39:2737-4000	0	3.57	17
2	3	69.25	Hakataramea River	CRC050940	Pringle R G & Z L	50	Beef and sheep	20% beef/80% sheep, 67% lucerne	14	4,234	7	7	I39:253-346 I39:255-341 I39:256-338	0	0.95	6
3	4	76.14	MacKays Stream	CRC950464.1	Hakataramea Station 1990 Ltd	50	Deer	Deer	15	9,100	7	15	I39:174-276	0	1.85	7
4	5	221.30	MacKays Stream	CRC931009	G K & J L Taylor Partnership	120	Beef and sheep	20% beef/80% sheep, two annual lucerne crops over 20%	60	36,288	7	60	I39:221-243	0	3.43	27
5	6	224.56	Poplar Stream	CRC950460.1	New Zealand Deer Farms Ltd	80	Deer	Two annual lucerne crops over 67%, 90% deer/10% sheep over 33%	40	24,200	7	40	I39:157-250	0	3.04	14
6	6	41.80	Deadmans Stream	CRC950462.3	New Zealand Deer Farms Ltd	30	Deer	Same as Item #6 (Property ID #5)	15	9,100	7	15	I39:180-229	0	1.48	4
7	6	269.86	Station Stream	CRC950458.1	New Zealand Deer Farms Ltd	320	Deer	100% pasture - 20% beef/80% sheep	45	3,888	1	45	I39:150-232	0	2.95	25
8	7	106.00	Station Stream	CRC951776.4	Star Holdings Ltd	80	Deer	100% pasture - 20% beef/80% sheep	43	3,716	1	43	I39:1515-2290	0	2.08	8
9	7	214.96	Station Stream	CRC951698.1	Star Holdings Ltd	150	Beef, sheep, and crops	100% pasture - 20% beef/80% sheep	30	2,592	1	30	I39:170-205	0	2.76	19
10	7	69.51	Station Stream	CRC951804.1	Star Holdings Ltd	75	Beef, sheep, and crops	45 ha pasture - 20% beef/80% sheep and 20 ha two annual crops lucerne	30	2,592	1	30	I39:170-205	0	2.21	12
11	8	99.66	Station Stream	CRC931005	Maungatiro Partnership	120	Beef, sheep, and crops	30% lucerne/70% grass, pasture - 100% sheep	45	27,216	7	45	I40:199-187	0	1.44	4
12	8	24.72	Station Stream	CRC931005	Maungatiro Partnership	0	Beef, sheep, and crops	Same as Item #10 (Property ID #7)	0	0	0	0	I39:170-205	0	0.74	3
13	9	160.71	Hakataramea River	CRC930942.2	Mr A Pasquale	48	Sheep	Pasture for silage, then 100% sheep	30	12,000	7	20	I40:218-164	0	4.69	33
14	10	122.58	Hakataramea River	CRC051768	RPNZ Properties Ltd	40	Beef, deer, and sheep	Pasture for silage, then 100% sheep	26	10,000	7	17	I40:2077-1569	0	0.67	3
15	11	146.50	Hakataramea River	CRC950602.2	Foveran	136	Deer	Deer	45	3,888	1	45	I40:213-154	0	2.73	28
16	11	3.09	Hakataramea River	CRC950602.2	Foveran	0	Deer	Deer	0	0	0	0	I40:106-144	0	2.30	10
17	12	110.14	Kirkliston Stream	CRC980915	Montara Properties Ltd	60	Beef and sheep	20% beef/80% sheep	25	10,800	17	7	I40:172-128	0	1.11	11
18	13	93.58	Hakataramea River	CRC950601.2	Foveran	80	Deer	Deer	26	2,247	1	26	I40:168-109	0	5.18	16
19	16	35.26	Farm Stream	CRC951082.1	Taramea Trust Ltd	50	Beef and sheep	10% beef/90% sheep	25	22,680	21	13	I40:106-144	0	9.41	32
20	16	20.38	Farm Stream	CRC951082.1	Taramea Trust Ltd	0	Beef and sheep	10% beef/90% sheep	0	0	0	0	I40:1163-0776	1	4.29	10
21	17	240.46	Farm Stream	CRC950493.2 CRC010048.1 CRC961543.1	Mr Timothy B Petrie	195	Beef and sheep	45 ha barley/wheat, 150 ha 100% sheep (took one 40 ha cut for silage)	59	0	0	52	I40:1215-1305 I40:137-135 I40:118-146	0	3.99	29
22	18	153.84	Padkins Creek	CRC950409.4	Star Holdings Ltd	151	Beef and sheep	42 ha lucerne (three crops), 109 ha - 45% beef/55% sheep	100	8,640	1	100	I40:138-138	0	1.47	7
23	19	183.75	Unnamed	CRC980513.1	RW and ME Sutton	140	Beef and sheep	70 ha lucerne (two cuts), 15 ha barley, then 5% beef/95% sheep	44	38,016	14	31	I40:101-132	0	6.25	27
24	19	15.08	Farm Stream	CRC980514	RW and ME Sutton	60	Beef, sheep, and crops	5% beef/95% sheep	30	21,600	10	25	I40:1061-1363	0	7.14	27
25	20	38.57	Farm Stream	CRC950995.1	Mr Graham Stuart Hay	120	Beef and sheep	Sheep	60	5,184	1	60	I40:120-124	0	1.58	7
26	20	108.86	Farm Stream	CRC950995.1	Mr Graham Stuart Hay	0	Beef and sheep	6 ha crop, 102.86 ha sheep	0	0	0	0	I40:168-109	0	3.20	20
27	21	73.39	Hakataramea River	CRC051769 CRC0428491	RPNZ Properties Ltd	44	Deer	Not yet developed. When developed expect pasture and beef	20	12,096	7	20	I40:1446-1035	0	0.96	4
28	22	6.20	Hakataramea River	CRC030278	Mr & Mrs C R A & G N Hay	6	Beef, sheep, and crops	Sheep	5	3,024	14	3	I40:1328-0940	0	1.51	3
29	23	133.00	Waitaki River	CRC021158	Normanvale Ltd	130	Beef and sheep	30 ha lucerne (2-3 crops), then 20% beef/80% sheep	50	77,760	18	50	I40:0829-0862	0	4.54	18
30	25	30.49	Hakataramea River	CRC040309	Davenport Holdings Ltd	12	Beef and sheep	Not currently used. Will use for pasture.	110	2,000	7	3	I40:129-091	0	1.02	4
31	26	96.53	Hakataramea River	CRC931003.4	Mr & Mrs J R D & M M Clarke	58	Beef and sheep	100% lucerne crop (3 or 4 crops/year)	110	15,500	7	26	I40:129-091	0	5.91	28
32	27	12.91	Hakataramea River	CRC020875.2	Woodrow Ltd	34	Crops	Sheep	19	1,915	14	2	I40:1163-0776	0	1.91	13
Total:		3,457.97				2,579			1,191	430,756		900				

1. *All irrigation via spray irrigation. "#" is a sequential parcel or polygon list. "Prop_ID" is number identifying property. "Total_A" is the total area of the parcel or polygon. "Irr_A" is that portion of the property parcel or polygon irrigated.*
2. *"Max Rate" (maximum rate allowed L/sec), "Max Vol" (annual take allowed in m3), "Consec Days" (consecutive days of take allowed), and "Daily Avg" (daily average take allowed in L/sec).*
3. *"Min" (minimum), "Mean," and "Max" (maximum) land slope of property involved. Slope specified in units of degrees.*
4. *Activity listed as "mixed farming" has been changed to "beef, sheep, and crops." "Crops" assumed to be barley or similar. "Cattle" assumed to be same as "beef."*
5. *Actual current practice as reported in recent interviews (Miller, 2006b).*

Table 5.2 Current irrigation by soil group.

Current Irrigation By Soil Group									
								Gr Distribution	
Prop_ID	Soil_Gr	Total_A	Gr_A	Name	Grid Ref	Comb_A	Irr_A	GrIrr_A	NonIrr_A
1	2	254.91	176.71	R H & J Robertson Family Trust	I39:2737-4000			97	80
	3		36.60	R H & J Robertson Family Trust	I39:2737-4000			20	17
	4		41.54	R H & J Robertson Family Trust	I39:2737-4000	255	140	23	19
3	2	69.25	8.84	Pringle R G & Z L	I39:253-346			6	3
	3		60.41	Pringle R G & Z L	I39:253-346	69	50	44	16
4	2	76.14	76.14	Hakataramea Station 1990 Ltd	I39:174-276	76	50	50	26
5	1	221.30	26.82	G K & J L Taylor Partnership	I39:221-243			15	12
	2		194.47	G K & J L Taylor Partnership	I39:221-243	221	120	105	89
6A	3	269.86	118.83	New Zealand Deer Farms Ltd	I39:150-232			95	24
6A	4		151.03	New Zealand Deer Farms Ltd	I39:150-232	270	320	121	30
6B	1	224.56	140.13	New Zealand Deer Farms Ltd	I39:157-250			112	28
6B	2		28.57	New Zealand Deer Farms Ltd	I39:157-250			23	6
6B	4		55.85	New Zealand Deer Farms Ltd	I39:157-250	225	80	45	11
6C	1	41.80	36.75	New Zealand Deer Farms Ltd	I39:180-229			29	7
6C	2		5.05	New Zealand Deer Farms Ltd	I39:180-229	42	30	4	1
Total						536	430	430	106
7A	1	69.51	7.09	Star Holdings Ltd	I39:170-205			6	2
7A	3		62.42	Star Holdings Ltd	I39:170-205	70	75	49	14
7B	2	106.00	106.00	Star Holdings Ltd	I39:1515-2290	106	80	83	23
7C	1	214.96	170.57	Star Holdings Ltd	I39:170-205			133	37
7C	2		9.38	Star Holdings Ltd	I39:170-205			7	2
7C	3		35.00	Star Holdings Ltd	I39:170-205	215	150	27	8
Total						390	305	305	85
8A	3	99.66	99.66	Maungatiro Partnership (S W Taylor)	I40:199-187	100	0	96	4
8B	2	24.72	24.72	Maungatiro Partnership (S W Taylor)	I40:199-187	25	120	24	1
Total						124	120	120	4
9	1	160.71	149.78	Mr A Pasquale	I40:218-164			45	105
	2		10.93	Mr A Pasquale	I40:218-164	161	48	3	8
10	2	122.58	122.58	RPNZ Properties Ltd	I40:2077-1569	123	40	40	83
11A	2	3.09	3.09	Foveran	I40:213-154	3	0	0	3
11B	2	146.50	64.07	Foveran	I40:213-154			59	5
11B	3	146.50	82.43	Foveran	I40:213-154	147	136	77	5
Total						150	136	136	14
12	2	110.14	110.13	Montara Properties Ltd (J W & H R Benny)	I40:172-128	110	60	60	50
13	1	93.58	75.15	Foveran	I40:168-109			64	11
	2		7.45	Foveran	I40:168-109			6	1
	3		10.98	Foveran	I40:168-109	94	80	9	2
16A	2	20.38	20.38		-	20	0	18	2
16B	2	35.26	35.26	Taramea Trust Ltd	I40:106-144	35	50	32	3
Total						56	50	50	6
17	1	240.46	38.74	Mr Timothy B Petrie	I40:1215-1305			31	8
	2		26.21	Mr Timothy B Petrie	I40:1215-1305			21	5
	3		17.67	Mr Timothy B Petrie	I40:1215-1305			14	4
	4		157.84	Mr Timothy B Petrie	I40:1215-1305	240	195	128	30
18	1	153.84	153.84	Star Holdings Ltd	I40:138-138	154	151	151	3
19A	2	15.08	8.60	RW ME Sutton	I40:1061-1363			9	0
19A	3		6.48	RW ME Sutton	I40:1061-1363	15	60	6	0
19B	1	183.75	9.41	Mr & Mrs R W & M E Sutton	I40:101-132			9	0
19B	2		174.34	Mr & Mrs R W & M E Sutton	I40:101-132	184	140	174	0
Total						199	200	199	0
20A	1	108.86	91.96	Mr Graham Stuart Hay	-			75	17
20A	2		7.72	Mr Graham Stuart Hay	-			6	2
20A	3		9.18	Mr Graham Stuart Hay	-	109	0	7	2
20B	1	38.57	3.71	Mr Graham Stuart Hay	I40:120-124			3	1
20B	3		33.88	Mr Graham Stuart Hay	I40:120-124			28	6
20B	4		0.98	Mr Graham Stuart Hay	I40:120-124	39	120	1	0
Total						147	120	120	27
21	1	73.39	0.42	RPNZ Properties Ltd	I40:1446-1035			0	0
	2		72.05	RPNZ Properties Ltd	I40:1446-1035			43	29
	3		0.91	RPNZ Properties Ltd	I40:1446-1035	73	44	1	0
22	3	6.20	6.20	Mr & Mrs C R A & G N Hay	I40:1328-0940	6	6	6	0
23	1	133.00	98.81	Normanvale Ltd	I40:0829-0862			97	2
	2		34.19	Normanvale Ltd	I40:0829-0862	133	130	33	1
25	2	30.49	8.70	Davenport Holdings Ltd	I40:129-091			3	6
	3		21.79	Davenport Holdings Ltd	I40:129-091	30	12	9	13
26	1	96.53	14.72	Mr & Mrs J R D & M M Clarke	I40:129-091			9	6
	2		31.99		I40:129-091			19	13
	3		49.82	Mr & Mrs J R D & M M Clarke	I40:129-091	97	58	30	20
27	2	12.91	0.28	Woodrow Ltd	I40:1163-0776			0	0
	3		12.62	Woodrow Ltd	I40:1163-0776	13	34	13	0
Total						3458	2579	2555	902

1. *"Prop_ID" means property identification number. "Soil_Gr" means soil group. "Total_A" means total area of Prop_ID in ha. "Gr_A" means area of soil group in ha for Prop_ID. "Comb_A" means combined area of all soil groups in same polygon in ha rounded off to nearest whole number. "Irr_A" means area irrigated within polygon in ha.*
2. *"GrIrr_A" under "Gr Distribution" means irrigated area in ha proportionally distributed between all soil groups and polygons based on product of ratio of Gr_A to Comb_A times Irr_A. "NonIrr_A" under "Gr Distribution" means difference between "Gr_A" and that portion of the total that is irrigated ("GrIrr_A").*

Table 5.3 Applications for new Irrigation by property parcel/polygon.

Applications for New Irrigation By Property Parcel/Polygon[1,2,3]															
		Total_A				Irr_A		Max Rate	Max Vol	Consec	Daily Avg		Slope		
#	Prop_ID	(ha)	Source	Consent #	Name	(ha)	Activity[4]	L/sec	m^3	Days	L/sec	Grid Ref	Min	Mean	Max
1	2	82.33	Grampians Stream	CRC040988	Small NJ	200	Beef, sheep, and crops	275	0	0	0	-	0	2.34	12
2	2	45.64	Grampians Stream	CRC040988	Small NJ	0	Beef, sheep, and crops	0	0	0	0	-	0	2.15	9
3	2	43.13	Grampians Stream	CRC040988	Small NJ	0	Beef, sheep, and crops	0	0	0	0	-	0	3.37	12
4	2	300.24	Grampians Stream	CRC040988	Small NJ	0	Beef, sheep, and crops	0	0	0	0	-	0	2.78	26
5	3	373.32	Peter Stream	CRC050957	Pringle R G & Z L	120	Beef and sheep	35	0	0	35	I39: 260-337	0	7.14	37
6	4	147.02	McKays Stream	CRC981376	Hakataramea Station 1990 Ltd	140	Deer	60	36,000	7	60	I39: 180-275	0	2.04	13
7	7	289.69	Station Stream	CRC021585	Star Holdings Ltd	120	Deer	600	0	0	60	I39: 1515-2290	0	6.37	31
8	11	201.41	Homestead Stream	CRC032220	Foveran Deer Park (FDP)	690	Beef, deer, and sheep	320	27,648	1	320	I40: 210-142	0	3.48	37
9	11	15.28	Homestead Stream	CRC032220	Foveran Deer Park	0	Deer	0	0	0	0	I40: 210-142	0	5.98	28
10	11	76.92	Homestead Stream	CRC032220	Foveran Deer Park	0	Deer	0	0	0	0	I40: 210-142	0	2.71	18
11	13	1.89	Hakataramea River	CRC031592	Robertson R H & J Family Trust (FDP)	50	Deer	52	0	0	52	I40: 210-142	2	3.71	6
12	13	3.19	Hakataramea River	CRC031592	Robertson R H & J Family Trust (FDP)	0	Deer	0	0	0	0	I40: 210-142	2	3.43	7
13	14	56.11	Hakataramea River	CRC031592	Robertson R H & J Family Trust (FDP)	0	Deer	0	0	0	0	I40: 210-142	0	7.37	22
14	15	46.02	Hakataramea River	CRC031592	Nowell BW	40	Horticulture/grapes	7	605	0	7	I40: 1636-1050	0	9.47	29
15	24	99.01	Hakataramea River	Pending	Neave	42	Beef and sheep	20	1,632	1	19	I40: 1636-1050	0	1.55	12
16	24	36.62	Hakataramea River	Pending	Neave	0	Beef and sheep	0	0	0	0	I40: 1636-1050	0	5.51	26
Total		1,817.83				1,402		1,369	65,885		553				

1. All irrigation via spray irrigation. "Prop_ID" is number identifying property. "Irr_A" is portion of property parcel or polygon irrigated.
2. "Max Rate" (maximum rate allowed L/sec), "Max Vol" (annual take allowed in m3), "Consec Days" (consecutive days of take allowed), and "Daily Avg" (daily average take allowed in L/sec).
3. "Min" (minimum), "Mean," and "Max" (maximum) land slope of property involved. Slope specified in units of degrees.
4. Activity listed as "mixed farming" has been changed to "beef, sheep, and crops." "Crops" assumed to be barley or similar. "Cattle" assumed to be same as "beef".

Table 5.4 Applications for new irrigation by soil group.

Applications for New Irrigation By Soil Group[1,2]									
								Gr Distribution	
Prop_ID	Soil_Gr	Total_A	Gr_A	Name	Grid Ref	Comb_A	Irr_A	Irr_A	NonIrr_A
2A	1	82.33	81.61	Small NJ	-	82	200	35	47
2A	2		0.72	Small NJ	-			0	1
2B	2	43.13	43.13	Small NJ	-	43	0	18	25
2C	2	45.63	45.64	Small NJ	-	46	0	19	27
2D	2	300.23	8.80	Small NJ	-	300	0	4	5
2D	3		6.07	Small NJ	-			3	3
2D	4		285.36	Small NJ	-			121	164
Total						471	200	200	271
3	1	373.32	22.13	Pringle R G & Z L	I39:260-337			7	15
	2		241.94	Pringle R G & Z L	I39:260-337			78	164
	3		109.25	Pringle R G & Z L	I39:260-337	373	120	35	74
4	1	147.02	13.75	Hakataramea Station 1990 Limited	I39:180-275			13	1
	2		133.27	Hakataramea Station 1990 Limited	I39:180-275	147	140	127	6
7	1	289.69	222.67	Star Holdings Limited	I39:1515-2290			92	131
	2		53.70	Star Holdings Limited	I39:1515-2290			22	32
	3		13.32	Star Holdings Limited	I39:1515-2290	290	120	6	7
11A	2	15.27	0.58	Foveran Deer Park	-	15	0	1	0
11A	3		14.70	Foveran Deer Park	-			15	0
11B	3	76.91	76.92	Foveran Deer Park	-	77	0	77	0
11C	1	201.41	16.32	Foveran Deer Park	I40:210-142	201	690	16	0
11C	2		10.94	Foveran Deer Park	I40:210-142			11	0
11C	3		174.15	Foveran Deer Park	I40:210-142			174	0
Total						294	690	294	0
13A	2	1.88	1.88	Robertson R H & J Family Trust (FDP)	-	2	50	2	0
13B	2	3.19	3.19	Robertson R H & J Family Trust (FDP)	-	3	0	3	1
14	1	56.11	20.45	Robertson R H & J Family Trust (FDP)	-	56	0	17	4
	2		5.48	Robertson R H & J Family Trust (FDP)	-			4	1
	3		30.18	Robertson R H & J Family Trust (FDP)	-			25	6
Total						61	50	50	11
15	2	46.02	7.17	Nowell BW	I40:1636-1050			6	1
	3		38.77	Nowell BW	I40:1636-1050	46	40	34	5
24A	1	99.01	7.80	Neave	-	99	42	2	6
24A	2		54.32	Neave	-			17	37
24A	3		36.89	Neave	-			11	26
24B	2	36.61	34.01	Neave	-	37	0	11	23
24B	3		2.58	Neave	-			1	2
Total						136	42	42	94
Total						1818	1402	1006	812

1. *"Prop_ID" means property identification number. "Soil_Gr" means soil group. "Total_A" means total area of Prop_ID in ha. "Gr_A" means area of soil group in ha for Prop_ID. "Comb_A" means combined area of all soil groups in same polygon in ha rounded off to nearest whole number. "Irr_A" means area irrigated within polygon in ha.*
2. *"GrIrr_A" under "Gr Distribution" means irrigated area in ha proportionally distributed between all soil groups and polygons based on product of ratio of Gr_A to Comb_A times Irr_A. "NonIrr_A" under "Gr Distribution" means difference between "Gr_A" and that portion of the total that is irrigated ("GrIrr_A").*

Table 5.5 Modeling assumptions for current agricultural practice.

Modeling Assumptions for Current Agricultural Practice[1]					
#	Prop_ID	Total_A ha	Stated Activity	Actual Current Practice	Assumption Used In Modeling[2]
1	1	254.91	Beef and sheep	Deer	100% Deer
2	3	69.25	Beef and sheep	20% beef/80% sheep, 67% lucerne	20% Beef, 80% Sheep
3	4	76.14	Deer	Deer	100% Deer
4	5	221.30	Beef and sheep	20% beef/80% sheep, two annual lucerne crops over 20%	20% Beef, 80% Sheep
5	6A	269.86	Deer	100% pasture - 20% beef/80% sheep	20% Beef, 80% Sheep
6	6B	224.56	Deer	Two annual lucerne crops over 67%, 90% deer/10% sheep over 33%	67% Arable, 30% Deer, 3% Sheep
7	6C	41.80	Deer	Same as Item #5 (Property ID #6)	67% Arable, 30% Deer, 3% Sheep
8	7A	69.51	Beef, sheep, and crops	45 ha pasture - 20% beef/80% sheep and 20 ha two annual crops lucerne	20% Beef, 80% Sheep
9	7B	106.00	Deer	100% pasture - 20% beef/80% sheep	20% Beef, 80% Sheep
10	7C	214.96	Beef, sheep, and crops	100% pasture - 20% beef/80% sheep	20% Beef, 80% Sheep
11	8A	99.66	Beef, sheep, and crops	30% lucerne/70% grass, pasture - 100% sheep	100% Sheep
12	8B	24.72	Beef, sheep, and crops	Same as Item #10 (Property ID #7)	20% Beef, 80% Sheep
13	9	160.71	Sheep	Pasture for silage, then 100% sheep	100% Sheep
14	10	122.58	Beef, deer, and sheep	Pasture for silage, then 100% sheep	100% Sheep
15	11A	3.09	Deer	Deer	100% Deer
16	11B	146.50	Deer	Deer	100% Deer
17	12	110.14	Beef and sheep	20% beef/80% sheep	20% Beef, 80% sheep
18	13	93.58	Deer	Deer	100% Deer
19	16A	20.38	Beef and sheep	10% beef/90% sheep	10% Beef, 90% Sheep
20	16B	35.26	Beef and sheep	10% beef/90% sheep	10% Beef, 90% Sheep
21	17	240.46	Beef and sheep	45 ha barley/wheat, 150 ha 100% sheep (took one 40 ha cut for silage)	45 ha Arable, remainder Sheep
22	18	153.84	Beef and sheep	42 ha lucerne (three crops), 109 ha - 45% beef/55% sheep	42 ha Arable, remainder 45% Beef, 55% Sheep
23	19A	15.08	Beef, sheep, and crops	5% beef/95% sheep	5% Beef, 95% Sheep
24	19B	183.75	Beef and sheep	70 ha lucerne (two cuts), 15 ha barley, then 5% beef/95% sheep	85 ha Arable, remainder 55 Beef, 95% Sheep
25	20A	108.86	Beef and sheep	6 ha crop, remainder sheep	6 ha Arable, remainder Sheep
26	20B	38.57	Beef and sheep	Sheep	100% Sheep
27	21	73.39	Deer	Not yet developed. When developed expect pasture and beef	100 Beef
28	22	6.20	Beef, sheep, and crops	Sheep	100% Sheep
29	23	133.00	Beef and sheep	30 ha lucerne (2-3 crops), then 20% beef/80% sheep	30 ha Arable, 20% Beef, 80% Sheep
30	25	30.49	Beef and sheep	Not currently used. Will use for pasture.	20% Beef, 80% Sheep
31	26	96.53	Beef and sheep	No current information	20% Beef, 80% Sheep
32	27	12.91	Crops	Sheep	100% Sheep
Total		3457.97			

1. *All columns except far right extracted from Table 5.1.*
2. *Far right column shows assumptions based on actual current practice used in modeling.*

Table 5.6 Modeling assumptions for new consent applications.

Modeling Assumptions for New Consent Applications[1]				
#	Prop_ID	Total_A (ha)	Activity	Assumption Used In Modeling[2]
1	2A	82.33	Beef, sheep, and crops	20% Beef, 80% Sheep
2	2B	43.13	Beef, sheep, and crops	20% Beef, 80% Sheep
3	2C	45.64	Beef, sheep, and crops	20% Beef, 80% Sheep
4	2D	300.24	Beef, sheep, and crops	20% Beef, 80% Sheep
5	3	373.32	Beef and sheep	20% Beef, 80% Sheep
6	4	147.02	Deer	100% Deer
7	7	289.69	Deer	100% Deer
8	11A	15.28	Deer	100% Deer
9	11B	76.92	Deer	100% Deer
10	11C	201.41	Beef, deer, and sheep	20% Beef, 20% Deer, and 60% Sheep
11	13A	1.89	Deer	100% Deer
12	13B	3.19	Deer	100% Deer
13	14	56.11	Deer	100% Deer
14	15	46.02	Horticulture/grapes	100% Arable
15	24A	99.01	Beef and sheep	20% Beef, 80% Sheep
16	24B	36.62	Beef and sheep	20% Beef, 80% Sheep
Total		1817.83		

1. *All columns except far right extracted from Table 5.3.*
2. *Far right column shows assumptions based on current practice and application data used in modeling.*

Table 6.1a Current irrigation nitrate leaching loss by soil group - scenario 1.

Current Irrigation Nitrate Leaching Loss By Soil Group - Scenario 1																			
	Area Currently Irrigated (ha)										Leaching Losses ($Kg\ NO_3$-N/ha/yr)				Leaching Losses ($Kg\ NO_3$-N/yr)				
		GrIrr_A (Irrigated Areas by Soil Group)					Total	Ratio											
#	Prop_ID	1	2	3	4	Total_A	GrIrr_A	Irr/Total	Assumption Used In Modeling	Use	1	2	3	4	1	2	3	4	Total
1	1	0	97	20	23	255	140	0.55	100% Deer	Deer	33	50	62	27	0	4,850	1,240	621	6,711
2	3	0	6	44	0	69	50	0.72	20% Beef, 80% Sheep	Beef	29	42	48	24	0	50	422	0	473
										Sheep	33	53	62	27	0	254	2,182	0	2,437
3	4	0	50	0	0	76	50	0.66	100% Deer	Deer	33	50	62	27	0	2,500	0	0	2,500
4	5	15	105	0	0	221	120	0.54	20% Beef, 80% Sheep	Beef	29	42	48	24	87	882	0	0	969
										Sheep	33	53	62	27	396	4,452	0	0	4,848
5	6A	0	0	95	121	270	216	0.80	20% Beef, 80% Sheep	Beef	29	42	48	24	0	0	909	582	1,490
										Sheep	33	53	62	27	0	0	4,695	2,617	7,312
6	6B	112	23	0	45	225	180	0.80	67% Arable, 30% Deer, 3% Sheep	Arable	16	25	28	14	1,199	382	0	418	1,999
										Deer	33	50	62	27	1,113	344	0	363	1,820
										Sheep	33	53	62	27	111	36	0	36	184
7	6C	29	4	0	0	42	34	0.80	67% Arable, 30% Deer, 3% Sheep	Arable	16	25	28	14	314	68	0	0	382
										Deer	33	50	62	27	292	61	0	0	353
										Sheep	33	53	62	27	29	6	0	0	36
8	7A	6	0	49	0	70	54	0.78	20% Beef, 80% Sheep	Beef	29	42	48	24	32	0	469	0	501
										Sheep	33	53	62	27	146	0	2,421	0	2,568
9	7B	0	83	0	0	106	83	0.78	20% Beef, 80% Sheep	Beef	29	42	48	24	0	696	0	0	696
										Sheep	33	53	62	27	0	3,515	0	0	3,515
10	7C	133	7	27	0	215	168	0.78	20% Beef, 80% Sheep	Beef	29	42	48	24	774	62	263	0	1,098
										Sheep	33	53	62	27	3,522	311	1,358	0	5,190
11	8A	0	0	96	0	100	96	0.96	100% Sheep	Sheep	33	53	62	27	0	0	5,952	0	5,952
12	8B	0	24	0	0	25	24	0.96	20% Beef, 80% Sheep	Beef	29	42	48	24	0	202	0	0	202
										Sheep	33	53	62	27	0	1,018	0	0	1,018
13	9	45	3	0	0	161	48	0.30	100% Sheep	Sheep	33	53	62	27	1,485	159	0	0	1,644
14	10	0	40	0	0	123	40	0.33	100% Sheep	Sheep	33	53	62	27	0	2,120	0	0	2,120
15	11A	0	0	0	0	3	0	0.00	100% Deer	Deer	33	50	62	27	0	0	0	0	0
16	11B	0	59	76	0	147	136	0.93	100% Deer	Deer	33	50	62	27	0	2,964	4,728	0	7,692
17	12	0	60	0	0	110	60	0.55	20% Beef, 80% sheep	Beef	29	42	48	24	0	504	0	0	504
										Sheep	33	53	62	27	0	2,544	0	0	2,544
18	13	64	6	9	0	94	80	0.85	100% Deer	Deer	33	50	62	27	2,111	317	580	0	3,007
19	16A	0	18	0	0	20	18	0.90	10% Beef, 90% Sheep	Beef	29	42	48	24	0	76	0	0	76
										Sheep	33	53	62	27	0	859	0	0	859
20	16B	0	32	0	0	35	32	0.91	10% Beef, 90% Sheep	Beef	29	42	48	24	0	134	0	0	134
										Sheep	33	53	62	27	0	1,526	0	0	1,526

Current Irrigation Nitrate Leaching Loss By Soil Group - Scenario 1

	Area Currently Irrigated (ha)										Leaching Losses (Kg NO_3-N/ha/yr)				Leaching Losses (Kg NO_3-N/yr)				
		GrIrr_A (Irrigated Areas by Soil Group)					Total	Ratio											
#	Prop_ID	1	2	3	4	Total_A	GrIrr_A	Irr/Total	Assumption Used In Modeling	Use	1	2	3	4	1	2	3	4	Total
21	17	31	21	14	128	240	195	0.81	45 ha Arable, remainder Sheep	Arable	16	25	28	14	116	123	93	414	746
										Sheep	33	53	62	27	799	868	685	2,664	5,016
22	18	151	0	0	0	154	151	0.98	42 ha Arable, remainder 45% Beef, 55% Sheep	Arable	16	25	28	14	672	0	0	0	672
										Beef	29	42	48	24	1,436	0	0	0	1,436
										Sheep	33	53	62	27	1,997	0	0	0	1,997
23	19A	0	9	6	0	15	15	1.00	5% Beef, 95% Sheep	Beef	29	42	48	24	0	19	14	0	33
										Sheep	33	53	62	27	0	453	353	0	807
24	19B	9	174	0	0	184	184	1.00	85 ha Arable, remainder 5% Beef, 95% Sheep	Arable	16	25	28	14	70	2,013	0	0	2,083
										Beef	29	42	48	24	7	197	0	0	204
										Sheep	33	53	62	27	159	4,723	0	0	4,882
25	20A	75	6	7	0	109	88	0.81	6 ha Arable, remainder Sheep	Arable	16	25	28	14	82	10	13	0	105
										Sheep	33	53	62	27	2,306	296	404	0	3,007
26	20B	3	0	28	1	39	32	0.82	100% Sheep	Sheep	33	53	62	27	99	0	1,736	27	1,862
27	21	0	43	1	0	73	44	0.60	100% Beef	Beef	29	42	48	24	0	1,806	48	0	1,854
28	22	0	0	6	0	6	6	1.00	100% Sheep	Sheep	33	53	62	27	0	0	372	0	372
29	23	97	33	0	0	133	130	0.98	30 ha Arable, 20% Beef, 80% Sheep	Arable	16	25	28	14	358	190	0	0	549
										Beef	29	42	48	24	433	213	0	0	646
										Sheep	33	53	62	27	1,970	1,076	0	0	3,046
30	25	0	3	9	0	30	12	0.40	20% Beef, 80% Sheep	Beef	29	42	48	24	0	25	86	0	112
										Sheep	33	53	62	27	0	127	446	0	574
31	26	9	19	30	0	97	58	0.60	20% Beef, 80% Sheep	Beef	29	42	48	24	52	160	288	0	500
										Sheep	33	53	62	27	238	806	1,488	0	2,531
32	27	0	0	13	0	13	13	1.00	100% Sheep	Sheep	33	53	62	27	0	0	806	0	806
Total		781	926	531	318	3,460	2,557	0.74		Total (North of Wright's Crossing)					8,016	18,470	19,911	4,637	51,034
Mean								0.75		Total (MHBR to Wright's Crossing)					14,388	25,528	12,142	3,105	55,163
Median								0.80		Combined					22,404	43,998	32,053	7,742	106,197

Table 6.1b Current water drainage loss by soil group - scenario 1.

Current Water Drainage Loss By Soil Group - Scenario 1																			
	Area Currently Irrigated (ha)																		
		Irr_A By Soil Group					Total	Ratio	Water	Water Drainage Losses (mm/Year)				Water Drainage Losses (m^3/Year)					
#	Prop_ID	1	2	3	4	Total_A	GrIrr_A	Irr/Total	Use	1	2	3	4	1	2	3	4	Total
1	1	0	97	20	23	255	140	0.55	Irrigated	95	145	184	57	0	140,650	36,800	13,110	190,560
2	3	0	6	44	0	69	50	0.72	Irrigated	95	145	184	57	0	8,700	80,960	0	89,660
3	4	0	50	0	0	76	50	0.66	Irrigated	95	145	184	57	0	72,500	0	0	72,500
4	5	15	105	0	0	221	120	0.54	Irrigated	95	145	184	57	14,250	152,250	0	0	166,500
5	6A	0	0	95	121	270	216	0.80	Irrigated	95	145	184	57	0	0	174,182	69,062	243,245
6	6B	112	23	0	45	225	180	0.80	Irrigated	95	145	184	57	106,797	33,234	0	25,539	165,570
7	6C	29	4	0	0	42	34	0.80	Irrigated	95	145	184	57	28,008	5,874	0	0	33,883
8	7A	6	0	49	0	70	54	0.78	Irrigated	95	145	184	57	5,268	0	89,821	0	95,088
9	7B	0	83	0	0	106	83	0.78	Irrigated	95	145	184	57	0	120,201	0	0	120,201
10	7C	133	7	27	0	215	168	0.78	Irrigated	95	145	184	57	126,725	10,637	50,364	0	187,726
11	8A	0	0	96	0	100	96	0.96	Irrigated	95	145	184	57	0	0	176,640	0	176,640
12	8B	0	24	0	0	25	24	0.96	Irrigated	95	145	184	57	0	34,800	0	0	34,800
13	9	45	3	0	0	161	48	0.30	Irrigated	95	145	184	57	42,750	4,350	0	0	47,100
14	10	0	40	0	0	123	40	0.33	Irrigated	95	145	184	57	0	58,000	0	0	58,000
15	11A	0	0	0	0	3	0	0.00	Irrigated	95	145	184	57	0	0	0	0	0
16	11B	0	59	76	0	147	136	0.93	Irrigated	95	145	184	57	0	85,950	140,322	0	226,271
17	12	0	60	0	0	110	60	0.55	Irrigated	95	145	184	57	0	87,000	0	0	87,000
18	13	64	6	9	0	94	80	0.85	Irrigated	95	145	184	57	60,760	9,188	17,201	0	87,149
19	16A	0	18	0	0	20	18	0.90	Irrigated	95	145	184	57	0	26,100	0	0	26,100
20	16B	0	32	0	0	35	32	0.91	Irrigated	95	145	184	57	0	46,400	0	0	46,400
21	17	31	21	14	128	240	195	0.81	Irrigated	95	145	184	57	29,905	30,875	26,416	73,102	160,298
22	18	151	0	0	0	154	151	0.98	Irrigated	95	145	184	57	143,450	0	0	0	143,450
23	19A	0	9	6	0	15	15	1.00	Irrigated	95	145	184	57	0	13,050	11,040	0	24,090
24	19B	9	174	0	0	184	184	1.00	Irrigated	95	145	184	57	8,940	252,793	0	0	261,733
25	20A	75	6	7	0	109	88	0.81	Irrigated	95	145	184	57	71,250	8,700	12,880	0	92,830
26	20B	3	0	28	1	39	32	0.82	Irrigated	95	145	184	57	2,850	0	51,520	570	54,940
27	21	0	43	1	0	73	44	0.60	Irrigated	95	145	184	57	0	62,350	1,840	0	64,190
28	22	0	0	6	0	6	6	1.00	Irrigated	95	145	184	57	0	0	11,040	0	11,040
29	23	97	33	0	0	133	130	0.98	Irrigated	95	145	184	57	92,150	47,850	0	0	140,000
30	25	0	3	9	0	30	12	0.40	Irrigated	95	145	184	57	0	4,350	16,560	0	20,910
31	26	9	19	30	0	97	58	0.60	Irrigated	95	145	184	57	8,550	27,550	55,200	0	91,300
32	27	0	0	13	0	13	13	1.00	Irrigated	95	145	184	57	0	0	23,920	0	23,920
Total		781	926	531	318	3,460	2,557	0.74	Total (North of Wright's Crossing)					281,047	544,046	608,767	107,711	1,541,572
Mean								0.75	Total (MHBR to Wright's Crossing)					460,605	799,305	367,939	73,672	1,701,520
Median								0.80	Combined					741,652	1,343,351	976,706	181,383	3,243,092

Table 6.2a New consent nitrate leaching loss by soil group - scenario 2.

New Consent Nitrate Leaching Loss By Soil Group - Scenario 2																			
	New Irrigated (ha)																		
		Irr_A By Soil Group					Total	Ratio			Leaching Losses (Kg NO_3-N/ha/yr)				Leaching Losses (Kg NO_3-N/yr)				
#	Prop_ID	1	2	3	4	Total_A	GrIrr_A	Irr/Total	Assumption Used in Modeling	Use	1	2	3	4	1	2	3	4	Total
1	2A	35	0	0	0	82	35	0.43	20% Beef, 80% Sheep	Beef	29	42	48	24	203	0	0	0	203
										Sheep	33	53	62	27	924	0	0	0	924
2	2B	0	18	0	0	43	18	0.42	20% Beef, 80% Sheep	Beef	29	42	48	24	0	151	0	0	151
										Sheep	33	53	62	27	0	763	0	0	763
3	2C	0	19	0	0	46	19	0.41	20% Beef, 80% Sheep	Beef	29	42	48	24	0	160	0	0	160
										Sheep	33	53	62	27	0	806	0	0	806
4	2D	0	4	3	121	300	128	0.43	20% Beef, 80% Sheep	Beef	29	42	48	24	0	34	29	581	643
										Sheep	33	53	62	27	0	170	149	2,614	2,932
5	3	7	78	35	0	373	120	0.32	20% Beef, 80% Sheep	Beef	29	42	48	24	41	655	336	0	1,032
										Sheep	33	53	62	27	185	3,307	1,736	0	5,228
6	4	13	127	0	0	147	140	0.95	100% Deer	Deer	33	50	62	27	429	6,350	0	0	6,779
7	7	92	22	6	0	290	120	0.41	100% Deer	Deer	33	50	62	27	3,036	1,100	372	0	4,508
8	11A	0	1	15	0	15	15	1.00	100% Deer	Deer	33	50	62	27	0	50	930	0	980
9	11B	0	0	77	0	77	77	1.00	100% Deer	Deer	33	50	62	27	0	0	4,774	0	4,774
10	11C	16	11	174	0	201	201	1.00	20% Beef, 20% Deer, 60% sheep	Beef	29	42	48	24	93	92	1,670	0	1,856
										Deer	33	50	62	27	106	110	2,158	0	2,373
										Sheep	33	53	62	27	317	350	6,473	0	7,139
11	13A	0	2	0	0	2	2	1.00	100% Deer	Deer	33	50	62	27	0	100	0	0	100
12	13B	0	3	0	0	3	3	1.00	100% Deer	Deer	33	50	62	27	0	150	0	0	150
13	14	17	4	25	0	56	46	0.82	100% Deer	Deer	33	50	62	27	561	200	1,550	0	2,311
14	15	0	6	34	0	46	40	0.87	100% Deer	Deer	16	25	28	14	0	150	952	0	1,102
15	24A	2	17	11	0	99	30	0.30	20% Beef, 80% Sheep	Beef	29	42	48	24	12	143	106	0	260
										Sheep	33	53	62	27	53	721	546	0	1,319
16	24B	0	11	1	0	37	12	0.32	20% Beef, 80% Sheep	Beef	29	42	48	24	0	92	10	0	102
										Sheep	33	53	62	27	0	466	50	0	516
Total		182	323	381	121	1,817	1,006	0.55		Total (North of Wright's Crossing)					5,333	14,197	18,626	3,194	41,351
Mean								0.67		Total (MHBR to Wright's Crossing)					625	1,922	3,212	0	5,760
Median								0.62		Combined					5,958	16,120	21,839	3,194	47,111

Table 6.2b New consent water drainage loss by soil group - scenario 2

New Water Drainage Loss By Soil Group - Scenario 2																			
	New Irrigated (ha)								Water Use	Water Drainage Losses (mm/Year)				Water Drainage Losses (m^3/Year)					
		Irr_A By Soil Group				Total_A	Total GrIrr_A	Ratio Irr/Total											
#	Prop_ID	1	2	3	4					1	2	3	4	1	2	3	4	Total
1	2A	35	0	0	0	82	35	0.43	Irrigated	95	145	184	57	33,250	0	0	0	33,250
2	2B	0	18	0	0	43	18	0.42	Irrigated	95	145	184	57	0	26,100	0	0	26,100
3	2C	0	19	0	0	46	19	0.41	Irrigated	95	145	184	57	0	27,550	0	0	27,550
4	2D	0	4	3	121	300	128	0.43	Irrigated	95	145	184	57	0	5,800	5,520	68,970	80,290
5	3	7	78	35	0	373	120	0.32	Irrigated	95	145	184	57	6,650	113,100	64,400	0	184,150
6	4	13	127	0	0	147	140	0.95	Irrigated	95	145	184	57	12,350	184,150	0	0	196,500
7	7	92	22	6	0	290	120	0.41	Irrigated	95	145	184	57	87,400	31,900	11,040	0	130,340
8	11A	0	1	15	0	15	15	1.00	Irrigated	95	145	184	57	0	1,450	27,600	0	29,050
9	11B	0	0	77	0	77	77	1.00	Irrigated	95	145	184	57	0	0	141,680	0	141,680
10	11C	16	11	174	0	201	201	1.00	Irrigated	95	145	184	57	15,200	15,950	320,160	0	351,310
11	13A	0	2	0	0	2	2	1.00	Irrigated	95	145	184	57	0	2,900	0	0	2,900
12	13B	0	3	0	0	3	3	1.00	Irrigated	95	145	184	57	0	4,350	0	0	4,350
13	14	17	4	25	0	56	46	0.82	Irrigated	95	145	184	57	16,150	5,800	46,000	0	67,950
14	15	0	6	34	0	46	40	0.87	Irrigated	95	145	184	57	0	8,700	62,560	0	71,260
15	24A	2	17	11	0	99	30	0.30	Irrigated	95	145	184	57	1,900	24,650	20,240	0	46,790
16	24B	0	11	1	0	37	12	0.32	Irrigated	95	145	184	57	0	15,950	1,840	0	17,790
Total		182	323	381	121	1,817	1,006	0.55	Total (North of Wright's Crossing)					154,850	406,000	570,400	68,970	1,200,220
Mean								0.67	Total (MHBR to Wright's Crossing)					18,050	62,350	130,640	0	211,040
Median								0.62	Combined					172,900	468,350	701,040	68,970	1,411,260

Table 6.3 Irrigated areas outside of community scheme.

Irrigated Areas Outside of Community Scheme													
									Irr_A Outside Community Scheme				
Prop_ID	Soil_Gr	Total_A	Gr_A	Comb_A	Irr_A	Inside	Outside	Irr_A Outside	1	2	3	4	Total
CURRENT:													
1	2	255	177		97	0	All	97	0	97	20	23	140
	3	255	37		20	0	All	20					
	4	255	42	255	23	0	All	23					
3	2	69	9		6	0	All	6	0	6	44	0	50
	3	69	60	69	44	0	All	44					
6B	1	225	140		112	124	16	13	13	0	0	0	13
	2	225	29		23	29	0	0					
	4	225	56	225	45	56	0	0					
9	1	161	150		45	141	9	3	3	2	0	0	5
	2	161	11	161	3	4	6	2					
11A	2	3	3	3	0	1	2	0	0	0	0	0	0
11B	2	147	64		59	56	8	8	0	8	0	0	8
	3	147	82	147	77	82	0	0					
13	1	94	75		64	4	71	60	60	6	9	0	75
	2	94	7		6	0	7	6					
	3	94	11	94	9	0	11	9					
16A	2	20	20	20	18	0	All	20	0	20	0	0	20
16B	2	35	35	35	32		All	32	0	32	0	0	32
19A	2	15	9		9	6	2	2	0	2	0	0	2
	3	15	6	15	6	6	0	0					
19B	1	184	9		9	9	0	0	0	68	0	0	68
	2	184	174	184	174	106	68	68					
23	1	133	99		97	87	12	11	11	0	0	0	11
	2	133	34	133	33	34	0	0					
25	2	30	9		3	0	All	3	0	3	9	0	12
	3	30	22	30	9	0	All	9					
26	1	97	15		9	0	All	9	9	19	30	0	58
	2	97	32		19	0	All	19					
	3	97	50	97	30	0	All	30					
Total (North of Wright's Crossing)				859	554	493		215	16	113	64	23	216
Total (MHBR to Wright's Crossing)				608	528	254		281	80	150	48	0	278
Combined				1,467	1,083	747		496	96	263	112	23	494
NEW:													
2A	1	82	82	82	35	0	All	35	35	0	0	0	35
2B	2	43	43	43	18	0	All	18	0	18	0	0	18
2C	2	46	46	46	19	0	All	19	0	19	0	0	19
2D	2	300	9	300	4	0	All	4	0	4	3	121	128
	3	300	6		3	0	All	3					
	4	300	285		121	0	All	121					
3	1	373	22		7	0	All	7	7	78	35	0	120
	2	373	242		78	0	All	78					
	3	373	109	373	35	0	All	35					
7	1	290	223		92	198	24	10	10	1	0	0	11
	2	290	54		22	51	3	1					
	3	290	13	290	6	13	0	0					
13A	2	2	2	2	2	0	All	2	0	2	0	0	2
13B	2	3	3	3	3	0	All	3	0	3	0	0	3
14	1	56	20	56	17	0	All	17	17	4	25	0	46
	2	56	5		4	0	All	4					
	3	56	30		25	0	All	25					
15	2	46	7		6	0	All	6	0	6	34	0	40
	3	46	39	46	34	0	All	34					
24A	1	99	8	99	2	8	0	0	0	17	6	0	23
	2	99	54		17	0	54	17					
	3	99	37		11	17	20	6					
24B	2	37	34	37	11	0	All	11	0	11	1	0	12
	3	37	3		1	0	All	1					
Total (North of Wright's Crossing)				1134	440	262		331	52	120	38	121	331
Total (MHBR to Wright's Crossing)				243	132	25		126	17	43	66	0	126
Combined				1,377	572	287		457	69	163	104	121	457

Table 6.4a Community scheme nitrate leaching loss - scenarios 3 and 4c.

Community Scheme Nitrate Leaching Loss - Scenarios 3 and 4c															
	Irr_A Outside Community Scheme					Leaching Losses (Kg NO_3-N/yr) - Irrigated					Leaching Losses (Kg NO_3-N/yr) - Dryland Sheep				
Prop_ID	1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total
COMMUNITY SCHEME 1:															
Current Outside															
1	0	97	20	23	140	0	4,928	1,184	607	6,719	0	679	140	69	888
3	0	6	44	0	50	0	305	2,605	0	2,910	0	42	308	0	350
6B	13	0	0	0	13	419	0	0	0	419	52	0	0	0	52
9	3	2	0	0	5	97	102	0	0	198	12	14	0	0	26
11A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11B	0	8	0	0	8	0	406	0	0	406	0	56	0	0	56
Total	16	113	64	23	216	515	5,740	3,789	607	10,652	64	791	448	69	1,372
New Outside															
2A	35	0	0	0	35	1,127	0	0	0	1,127	140	0	0	0	140
2B	0	18	0	0	18	0	914	0	0	914	0	126	0	0	126
2C	0	19	0	0	19	0	965	0	0	965	0	133	0	0	133
2D	0	4	3	121	128	0	203	178	3,194	3,575	0	28	21	363	412
3	7	78	35	0	120	225	3,962	2,072	0	6,260	28	546	245	0	819
7	10	1	0	0	11	322	51	0	0	373	40	7	0	0	47
Total	52	120	38	121	331	1,674	6,096	2,250	3,194	13,214	208	840	266	363	1,677
Community Scheme															
	3,572	3,485	2,183	1,979	11,219	86,273	132,787	96,906	39,179	355,145	14,289	24,397	15,278	5,936	59,900
COMMUNITY SCHEME 2:															
Current Outside															
13	60	6	9	0	75	1,932	305	533	0	2,770	240	42	63	0	345
16A	0	20	0	0	20	0	1,016	0	0	1,016	0	140	0	0	140
16B	0	32	0	0	32	0	1,626	0	0	1,626	0	224	0	0	224
19A	0	2	0	0	2	0	102	0	0	102	0	14	0	0	14
19B	0	68	0	0	68	0	3,454	0	0	3,454	0	476	0	0	476
23	11	0	0	0	11	354	0	0	0	354	44	0	0	0	44
25	0	3	9	0	12	0	152	533	0	685	0	21	63	0	84
26	9	19	30	0	58	290	965	1,776	0	3,031	36	133	210	0	379
Total	80	150	48	0	278	2,576	7,620	2,842	0	13,038	320	1,050	336	0	1,706
New Outside															
13A	0	2	0	0	2	0	102	0	0	102	0	14	0	0	14
13B	0	3	0	0	3	0	152	0	0	152	0	21	0	0	21
14	17	4	25	0	46	547	203	1,480	0	2,231	68	28	175	0	271
15	0	6	34	0	40	0	305	2,013	0	2,318	0	42	238	0	280
24A	0	17	6	0	23	0	864	355	0	1,219	0	119	42	0	161
24B	0	11	1	0	12	0	559	59	0	618	0	77	7	0	84
Total	17	43	66	0	126	547	2,184	3,907	0	6,639	68	301	462	0	831
Community Scheme															
	3,010	903	450	551	4,914	72,695	34,416	19,979	10,911	138,001	12,041	6,323	3,150	1,653	23,167

SPASMO MODEL ASSUMPTIONS:

	Leaching Losses (Kg NO_3-N/ha/yr)			
Use	1	2	3	4
Beef	29	42	48	24
Sheep	33	53	62	27
Assume 20% Beef and 80% Sheep				
Dryland Sheep	4	7	7	3

TOTALS:

	Irrigated	Dryland Sheep
Community Scheme 1	379,011	62,949
Community Scheme 2	157,678	25,704
Combined	536,688	88,653

Table 6.4b Community scheme water drainage loss - scenarios 3 and 4c.

Community Scheme Water Drainage Loss - Scenarios 3 and 4c															
	Irr_A Outside Community Scheme					Water Drainage Losses (m3/Year) - Irrigated					Water Drainage Losses (m3/Year) - Dryland Sheep				
Prop_ID	1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total
COMMUNITY SCHEME 1:															
Current Outside															
1	0	97	20	23	140	0	140,650	36,800	13,110	190,560	0	64,020	19,000	1,150	84,170
3	0	6	44	0	50	0	8,700	80,960	0	89,660	0	3,960	41,800	0	45,760
6B	13	0	0	0	13	12,350	0	0	0	12,350	2,470	0	0	0	2,470
9	3	2	0	0	5	2,850	2,900	0	0	5,750	570	1,320	0	0	1,890
11A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11B	0	8	0	0	8	0	11,600	0	0	11,600	0	5,280	0	0	5,280
Total	16	113	64	23	216	15,200	163,850	117,760	13,110	309,920	3,040	74,580	60,800	1,150	139,570
New Outside															
2A	35	0	0	0	35	33,250	0	0	0	33,250	6,650	0	0	0	6,650
2B	0	18	0	0	18	0	26,100	0	0	26,100	0	11,880	0	0	11,880
2C	0	19	0	0	19	0	27,550	0	0	27,550	0	12,540	0	0	12,540
2D	0	4	3	121	128	0	5,800	5,520	68,970	80,290	0	2,640	2,850	6,050	11,540
3	7	78	35	0	120	6,650	113,100	64,400	0	184,150	1,330	51,480	33,250	0	86,060
7	10	1	0	0	11	9,500	1,450	0	0	10,950	1,900	660	0	0	2,560
Total	52	120	38	121	331	49,400	174,000	69,920	68,970	362,290	9,880	79,200	36,100	6,050	131,230
Community Scheme															
	3,572	3,485	2,183	1,979	11,219	2,545,311	3,790,190	3,011,936	845,905	10,193,343	509,062	1,725,190	1,555,076	74,202	3,863,530
COMMUNITY SCHEME 2:															
Current Outside															
13	60	6	9	0	75	57,000	8,700	16,560	0	82,260	11,400	3,960	8,550	0	23,910
16A	0	20	0	0	20	0	29,000	0	0	29,000	0	13,200	0	0	13,200
16B	0	32	0	0	32	0	46,400	0	0	46,400	0	21,120	0	0	21,120
19A	0	2	0	0	2	0	2,900	0	0	2,900	0	1,320	0	0	1,320
19B	0	68	0	0	68	0	98,600	0	0	98,600	0	44,880	0	0	44,880
23	11	0	0	0	11	10,450	0	0	0	10,450	2,090	0	0	0	2,090
25	0	3	9	0	12	0	4,350	16,560	0	20,910	0	1,980	8,550	0	10,530
26	9	19	30	0	58	8,550	27,550	55,200	0	91,300	1,710	12,540	28,500	0	42,750
Total	80	150	48	0	278	76,000	217,500	88,320	0	381,820	15,200	99,000	45,600	0	159,800
New Outside															
13A	0	2	0	0	2	0	2,900	0	0	2,900	0	1,320	0	0	1,320
13B	0	3	0	0	3	0	4,350	0	0	4,350	0	1,980	0	0	1,980
14	17	4	25	0	46	16,150	5,800	46,000	0	67,950	3,230	2,640	23,750	0	29,620
15	0	6	34	0	40	0	8,700	62,560	0	71,260	0	3,960	32,300	0	36,260
24A	0	17	6	0	23	0	24,650	11,040	0	35,690	0	11,220	5,700	0	16,920
24B	0	11	1	0	12	0	15,950	1,840	0	17,790	0	7,260	950	0	8,210
Total	17	43	66	0	126	16,150	62,350	121,440	0	199,940	3,230	28,380	62,700	0	94,310
Community Scheme															
	3,010	903	450	551	4,914	2,144,722	982,333	620,984	235,585	3,983,624	428,944	447,131	320,617	20,665	1,217,357

SPASMO MODEL ASSUMPTIONS:

	Water Drainage Losses (mm/Year)			
Use	1	2	3	4
Irrigation	95	145	184	57
Dryland Sheep	19	66	95	5

TOTALS:

	Irrigated	Dryland Sheep
Community Scheme 1	10,865,553	4,134,330
Community Scheme 2	4,565,384	1,471,467
Combined	15,430,937	5,605,798

Table 6.5a Dryland sheep current nitrate leaching loss - scenario 4a.

Dryland Sheep Current Nitrate Leaching Loss - Scenario 4a																		
	Area Currently Irrigated (ha)																	
		Irr_A By Soil Group						Irr_A	Water	Leaching Losses (Kg NO_3-N/ha/yr)				Leaching Losses (Kg NO_3-N/yr)				
#	Prop_ID	1	2	3	4	Total_A	Irr_A	Total_A	Use	1	2	3	4	1	2	3	4	Total
1	1	0	97	20	23	255	140	0.55	Dryland Sheep	4	7	7	3	0	679	140	69	888
2	3	0	6	44	0	69	50	0.72	Dryland Sheep	4	7	7	3	0	42	308	0	350
3	4	0	50	0	0	76	50	0.66	Dryland Sheep	4	7	7	3	0	350	0	0	350
4	5	15	105	0	0	221	120	0.54	Dryland Sheep	4	7	7	3	60	735	0	0	795
5	6A	0	0	95	121	270	216	0.80	Dryland Sheep	4	7	7	3	0	0	663	363	1,026
6	6B	112	23	0	45	225	180	0.80	Dryland Sheep	4	7	7	3	450	160	0	134	745
7	6C	29	4	0	0	42	34	0.80	Dryland Sheep	4	7	7	3	118	28	0	0	146
8	7A	6	0	49	0	70	54	0.78	Dryland Sheep	4	7	7	3	22	0	342	0	364
9	7B	0	83	0	0	106	83	0.78	Dryland Sheep	4	7	7	3	0	580	0	0	580
10	7C	133	7	27	0	215	168	0.78	Dryland Sheep	4	7	7	3	534	51	192	0	777
11	8A	0	0	96	0	100	96	0.96	Dryland Sheep	4	7	7	3	0	0	672	0	672
12	8B	0	24	0	0	25	24	0.96	Dryland Sheep	4	7	7	3	0	168	0	0	168
13	9	45	3	0	0	161	48	0.30	Dryland Sheep	4	7	7	3	180	21	0	0	201
14	10	0	40	0	0	123	40	0.33	Dryland Sheep	4	7	7	3	0	280	0	0	280
15	11A	0	0	0	0	3	0	0.00	Dryland Sheep	4	7	7	3	0	0	0	0	0
16	11B	0	59	76	0	147	136	0.93	Dryland Sheep	4	7	7	3	0	415	534	0	949
17	12	0	60	0	0	110	60	0.55	Dryland Sheep	4	7	7	3	0	420	0	0	420
18	13	64	6	9	0	94	80	0.85	Dryland Sheep	4	7	7	3	256	44	65	0	366
19	16A	0	18	0	0	20	18	0.90	Dryland Sheep	4	7	7	3	0	126	0	0	126
20	16B	0	32	0	0	35	32	0.91	Dryland Sheep	4	7	7	3	0	224	0	0	224
21	17	31	21	14	128	240	195	0.81	Dryland Sheep	4	7	7	3	126	149	100	385	760
22	18	151	0	0	0	154	151	0.98	Dryland Sheep	4	7	7	3	604	0	0	0	604
23	19A	0	9	6	0	15	15	1.00	Dryland Sheep	4	7	7	3	0	63	42	0	105
24	19B	9	174	0	0	184	184	1.00	Dryland Sheep	4	7	7	3	38	1,220	0	0	1,258
25	20A	75	6	7	0	109	88	0.81	Dryland Sheep	4	7	7	3	300	42	49	0	391
26	20B	3	0	28	1	39	32	0.82	Dryland Sheep	4	7	7	3	12	0	196	3	211
27	21	0	43	1	0	73	44	0.60	Dryland Sheep	4	7	7	3	0	301	7	0	308
28	22	0	0	6	0	6	6	1.00	Dryland Sheep	4	7	7	3	0	0	42	0	42
29	23	97	33	0	0	133	130	0.98	Dryland Sheep	4	7	7	3	388	231	0	0	619
30	25	0	3	9	0	30	12	0.40	Dryland Sheep	4	7	7	3	0	21	63	0	84
31	26	9	19	30	0	97	58	0.60	Dryland Sheep	4	7	7	3	36	133	210	0	379
32	27	0	0	13	0	13	13	1.00	Dryland Sheep	4	7	7	3	0	0	91	0	91
Total		781	926	531	318	3,460	2,557	0.74	Total (North of Wright's Crossing)					1,363	3,510	2,850	567	8,290
Mean								0.75	Total (MHBR to Wright's Crossing)					1,759	2,975	866	388	5,988
Median								0.80	Combined					3,123	6,485	3,716	955	14,278

Table 6.5b Dryland sheep current water drainage loss - scenario 4a.

Dryland Sheep Current Water Drainage Loss - Scenario 4a																		
	Area Currently Irrigated (ha)								Water Use	Water Drainage Losses (mm/Year)				Water Drainage Losses (m^3/Year)				
		Irr_A By Soil Group						Irr_A Total_A										
#	Prop_ID	1	2	3	4	Total_A	Irr_A			1	2	3	4	1	2	3	4	Total
1	1	0	97	20	23	255	140	0.55	Dryland Sheep	19	66	95	5	0	64,020	19,000	1,150	84,170
2	3	0	6	44	0	69	50	0.72	Dryland Sheep	19	66	95	5	0	3,960	41,800	0	45,760
3	4	0	50	0	0	76	50	0.66	Dryland Sheep	19	66	95	5	0	33,000	0	0	33,000
4	5	15	105	0	0	221	120	0.54	Dryland Sheep	19	66	95	5	2,850	69,300	0	0	72,150
5	6A	0	0	95	121	270	216	0.80	Dryland Sheep	19	66	95	5	0	0	89,931	6,058	95,989
6	6B	112	23	0	45	225	180	0.80	Dryland Sheep	19	66	95	5	21,359	15,127	0	2,240	38,727
7	6C	29	4	0	0	42	34	0.80	Dryland Sheep	19	66	95	5	5,602	2,674	0	0	8,275
8	7A	6	0	49	0	70	54	0.78	Dryland Sheep	19	66	95	5	1,054	0	46,375	0	47,428
9	7B	0	83	0	0	106	83	0.78	Dryland Sheep	19	66	95	5	0	54,712	0	0	54,712
10	7C	133	7	27	0	215	168	0.78	Dryland Sheep	19	66	95	5	25,345	4,842	26,003	0	56,190
11	8A	0	0	96	0	100	96	0.96	Dryland Sheep	19	66	95	5	0	0	91,200	0	91,200
12	8B	0	24	0	0	25	24	0.96	Dryland Sheep	19	66	95	5	0	15,840	0	0	15,840
13	9	45	3	0	0	161	48	0.30	Dryland Sheep	19	66	95	5	8,550	1,980	0	0	10,530
14	10	0	40	0	0	123	40	0.33	Dryland Sheep	19	66	95	5	0	26,400	0	0	26,400
15	11A	0	0	0	0	3	0	0.00	Dryland Sheep	19	66	95	5	0	0	0	0	0
16	11B	0	59	76	0	147	136	0.93	Dryland Sheep	19	66	95	5	0	39,122	72,449	0	111,571
17	12	0	60	0	0	110	60	0.55	Dryland Sheep	19	66	95	5	0	39,600	0	0	39,600
18	13	64	6	9	0	94	80	0.85	Dryland Sheep	19	66	95	5	12,152	4,182	8,881	0	25,215
19	16A	0	18	0	0	20	18	0.90	Dryland Sheep	19	66	95	5	0	11,880	0	0	11,880
20	16B	0	32	0	0	35	32	0.91	Dryland Sheep	19	66	95	5	0	21,120	0	0	21,120
21	17	31	21	14	128	240	195	0.81	Dryland Sheep	19	66	95	5	5,981	14,053	13,639	6,412	40,086
22	18	151	0	0	0	154	151	0.98	Dryland Sheep	19	66	95	5	28,690	0	0	0	28,690
23	19A	0	9	6	0	15	15	1.00	Dryland Sheep	19	66	95	5	0	5,940	5,700	0	11,640
24	19B	9	174	0	0	184	184	1.00	Dryland Sheep	19	66	95	5	1,788	115,064	0	0	116,852
25	20A	75	6	7	0	109	88	0.81	Dryland Sheep	19	66	95	5	14,250	3,960	6,650	0	24,860
26	20B	3	0	28	1	39	32	0.82	Dryland Sheep	19	66	95	5	570	0	26,600	50	27,220
27	21	0	43	1	0	73	44	0.60	Dryland Sheep	19	66	95	5	0	28,380	950	0	29,330
28	22	0	0	6	0	6	6	1.00	Dryland Sheep	19	66	95	5	0	0	5,700	0	5,700
29	23	97	33	0	0	133	130	0.98	Dryland Sheep	19	66	95	5	18,430	21,780	0	0	40,210
30	25	0	3	9	0	30	12	0.40	Dryland Sheep	19	66	95	5	0	1,980	8,550	0	10,530
31	26	9	19	30	0	97	58	0.60	Dryland Sheep	19	66	95	5	1,710	12,540	28,500	0	42,750
32	27	0	0	13	0	13	13	1.00	Dryland Sheep	19	66	95	5	0	0	12,350	0	12,350
Total		781	926	531	318	3,460	2,557	0.74	Total (North of Wright's Crossing)					64,759	330,977	386,758	9,448	791,942
Mean								0.75	Total (MHBR to Wright's Crossing)					83,571	280,480	117,520	6,462	488,033
Median								0.80	Combined					148,330	611,456	504,277	15,911	1,279,975

Table 6.5c Dryland sheep new nitrate leaching loss - scenario 4b.

Dryland Sheep New Nitrate Leaching Loss - Scenario 4b																		
	New Irrigated (ha)								Water	Leaching Losses (Kg NO_3-N/ha/yr)				Leaching Losses (Kg NO_3-N/yr)				
		Irr_A By Soil Group						Irr_A	Use									
#	Prop_ID	1	2	3	4	Total_A	Irr_A	Total_A		1	2	3	4	1	2	3	4	Total
1	2A	35	0	0	0	82	35	0.43	Dryland Sheep	4	7	7	3	140	0	0	0	140
2	2B	0	18	0	0	43	18	0.42	Dryland Sheep	4	7	7	3	0	126	0	0	126
3	2C	0	19	0	0	46	19	0.41	Dryland Sheep	4	7	7	3	0	133	0	0	133
4	2D	0	4	3	121	300	128	0.43	Dryland Sheep	4	7	7	3	0	28	21	363	412
5	3	7	78	35	0	373	120	0.32	Dryland Sheep	4	7	7	3	28	546	245	0	819
6	4	13	127	0	0	147	140	0.95	Dryland Sheep	4	7	7	3	52	889	0	0	941
7	7	92	22	6	0	290	120	0.41	Dryland Sheep	4	7	7	3	368	154	42	0	564
8	11A	0	1	15	0	15	15	1.00	Dryland Sheep	4	7	7	3	0	7	105	0	112
9	11B	0	0	77	0	77	77	1.00	Dryland Sheep	4	7	7	3	0	0	539	0	539
10	11C	16	11	174	0	201	201	1.00	Dryland Sheep	4	7	7	3	64	77	1,218	0	1,359
11	13A	0	2	0	0	2	2	1.00	Dryland Sheep	4	7	7	3	0	14	0	0	14
12	13B	0	3	0	0	3	3	1.00	Dryland Sheep	4	7	7	3	0	21	0	0	21
13	14	17	4	25	0	56	46	0.82	Dryland Sheep	4	7	7	3	68	28	175	0	271
14	15	0	6	34	0	46	40	0.87	Dryland Sheep	4	7	7	3	0	42	238	0	280
15	24A	2	17	11	0	99	30	0.30	Dryland Sheep	4	7	7	3	8	119	77	0	204
16	24B	0	11	1	0	37	12	0.32	Dryland Sheep	4	7	7	3	0	77	7	0	84
Total		182	323	381	121	1,817	1,006	0.55	Total (North of Wright's Crossing)					652	1,960	2,170	363	5,145
Mean								0.67	Total (MHBR to Wright's Crossing)					76	301	497	0	874
Median								0.62	Combined					728	2,261	2,667	363	6,019

Table 6.5d Dryland sheep new water drainage loss - scenario 4b.

Dryland Sheep New Water Drainage Loss - Scenario 4b																		
	New Irrigated (ha)								Water	Water Drainage Losses (mm/Year)				Water Drainage Losses (m^3/Year)				
		Irr_A By Soil Group						Irr_A	Use									
#	Prop_ID	1	2	3	4	Total_A	Irr_A	Total_A		1	2	3	4	1	2	3	4	
1	2A	35	0	0	0	82	35	0.43	Dryland Sheep	19	66	95	5	6,650	0	0	0	6,650
2	2B	0	18	0	0	43	18	0.42	Dryland Sheep	19	66	95	5	0	11,880	0	0	11,880
3	2C	0	19	0	0	46	19	0.41	Dryland Sheep	19	66	95	5	0	12,540	0	0	12,540
4	2D	0	4	3	121	300	128	0.43	Dryland Sheep	19	66	95	5	0	2,640	2,850	6,050	11,540
5	3	7	78	35	0	373	120	0.32	Dryland Sheep	19	66	95	5	1,330	51,480	33,250	0	86,060
6	4	13	127	0	0	147	140	0.95	Dryland Sheep	19	66	95	5	2,470	83,820	0	0	86,290
7	7	92	22	6	0	290	120	0.41	Dryland Sheep	19	66	95	5	17,480	14,520	5,700	0	37,700
8	11A	0	1	15	0	15	15	1.00	Dryland Sheep	19	66	95	5	0	660	14,250	0	14,910
9	11B	0	0	77	0	77	77	1.00	Dryland Sheep	19	66	95	5	0	0	73,150	0	73,150
10	11C	16	11	174	0	201	201	1.00	Dryland Sheep	19	66	95	5	3,040	7,260	165,300	0	175,600
11	13A	0	2	0	0	2	2	1.00	Dryland Sheep	19	66	95	5	0	1,320	0	0	1,320
12	13B	0	3	0	0	3	3	1.00	Dryland Sheep	19	66	95	5	0	1,980	0	0	1,980
13	14	17	4	25	0	56	46	0.82	Dryland Sheep	19	66	95	5	3,230	2,640	23,750	0	29,620
14	15	0	6	34	0	46	40	0.87	Dryland Sheep	19	66	95	5	0	3,960	32,300	0	36,260
15	24A	2	17	11	0	99	30	0.30	Dryland Sheep	19	66	95	5	380	11,220	10,450	0	22,050
16	24B	0	11	1	0	37	12	0.32	Dryland Sheep	19	66	95	5	0	7,260	950	0	8,210
Total		182	323	381	121	1,817	1,006	0.55	Total (North of Wright's Crossing)					30,970	184,800	294,500	6,050	516,320
Mean								0.67	Total (MHBR to Wright's Crossing)					3,610	28,380	67,450	0	99,440
Median								0.62	Combined					34,580	213,180	361,950	6,050	615,760

Table 6.6 Comparison of scenario model results.

Comparison of Scenario Model Results[1]									
	NO_3-N Leaching Loss (Kg/Year)			Water Drainage Loss (m^3/Year)[4]			NO_3-N Concentration (mg/L)		
Scenario-Use	Upper	Lower	Combined	Upper	Lower	Combined	Upper	Lower	Combined
Model Estimates[2]:									
Current Irrigated Areas									
Irrigated Various Uses (Scenario 1)	51,034	55,163	106,197	1,541,572	1,701,520	3,243,092	33.1	32.4	32.7
Dryland Sheep (Scenario 4)	8,290	5,988	14,278	791,942	488,033	1,279,975	10.5	12.3	11.2
New Irrigation Applications (Scenario 2)									
Irrigated Various Uses (Scenario 2)	41,351	5,760	47,111	1,200,220	211,040	1,411,260	34.5	27.3	33.4
Dryland Sheep (Scenario 4)	5,145	874	6,019	516,320	99,440	615,760	10.0	8.8	9.8
Community Scheme (Scenario 3)									
Irrigated Beef and Sheep (Scenario 3)	379,011	157,678	536,688	10,865,553	4,565,384	15,430,937	34.9	34.5	34.8
Dryland Sheep (Scenario 4)	62,949	25,704	88,653	4,134,330	1,471,467	5,605,798	15.2	17.5	15.8
Comparison of Estimates[3]:									
Irrigated:Dryland									
Current Irrigation (Factor)	6.2	9.2	7.4	1.9	3.5	2.5	3.2	2.6	2.9
New Irrigation (Factor)	8.0	6.6	7.8	2.3	2.1	2.3	3.5	3.1	3.4
Community Scheme (Factor)	6.0	6.1	6.1	2.6	3.1	2.8	2.3	2.0	2.2
Increase in Irrigation									
New Over Current (Percent for loss, factor for concentration)	81	10	44	78	12	44	1.0	0.8	1.0
Community Scheme Over Current (Factor)	7.4	2.9	5.1	7.0	2.7	4.8	1.1	1.1	1.1

1. *"Upper" indicates farm areas north of Wright's Crossing while "Lower" indicates farm areas south of Wright's Crossing to the MHBR. "Combined" is the sum of both.*
2. *Summary of results from Tables 6.1, 6.2, 6.4, and 6.5.*
3. *Comparison of irrigated to dryland alternatives for same farm areas presented as factors (e.g., current irrigation results in an increase in nitrate-nitrogen leaching loss by a factor of 6.2 for the upper Hakataramea River catchment). Increase in irrigation given as a percent increase for "New" farm areas over "Current" or as a factor for "Community Scheme" over "Current." Calculated nitrate-nitrogen concentrations for irrigation drainage would be similar in all cases (i.e., factors close to one) and and much greater for the various irrigated uses than for dryland sheep case (factors between two and greater than three).*
4. *For comparison, the mean annual flow of the Hakataramea River for the 1964 through 2004 period of record at the MHBR gaging station is 5.872 m3/sec. At that flow rate, the flow for one 365 day year would be 185,179,392 m3. The estimated combined water drainage loss for current irrigation (Scenario 1) would be approximately 1.8 percent of that flow. Using the sum of the average daily flow rates listed for current irrigation in Table 5.1 of 900 L/sec and assuming 60 percent of this flow for 150 days as a representative value of annual irrigation (Miller, 2006c), the total annual flow rate for current irrigation would be 6,998,400 m3. This is approximately 3.8 percent of the mean annual flow for the Hakataramea River at the MHBR gaging station.*

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8.0 ACKNOWLEDGEMENTS

The cooperation and assistance of Malcolm Miller and other Environment Canterbury staff in the provision of the relevant data necessary to perform this analysis and prepare this report is gratefully acknowledged. Trevor Webb of Landcare Research provided invaluable assistance with regard to soil classification in the Hakataramea River valley and Steve Green of HortResearch provided the nitrate-nitrogen and water drainage loss factors from SPASMO modelling that were used in making these estimates.

APPENDIX A – ECAN – GNS SCIENCE CONTRACT

Environment Canterbury
Your regional council

CONTRACT FOR SERVICES

PROJECT: Water quality impacts from irrigation development in the Hakataramea catchment. Part 1 – to be undertaken by GNS

SCOPE AND NATURE OF THE SERVICES:

1. To assess the extent of the effect of current landuse activities on groundwater quantity and quality and the discharge of nitrogen to surface water from groundwater in the Hakataramea catchment
2. Given possible irrigation scenarios, determine the effects on groundwater quality and quantity and the discharge of nitrogen and phosphorus nutrients to surface water from groundwater and runoff in the Hakataramea catchment.

(More details are included in the accompanying Work Brief - Water Quality Impacts from Irrigation Development in the Hakataramea Valley.)

Outputs: 1: Provide a written report.
2: If required, present findings to Council.

PROGRAMME FOR THE SERVICES:

This is to be carried out in three stages. Stage 1 is to categorise the existing and future nutrient loads from irrigation development scenarios. Stage 2 is to determine the effects of existing and irrigation development scenarios on the groundwater system. Stage 3 is to determine the effects of existing and future irrigation development scenarios on surface waters. Stages 1 and 2 will be completed by **GNS** (principally tasks 2, 3 and 4A). Stage 3 will be completed by **NIWA** and **AgResearch** (principally tasks 4B, 5, 6, 7, and 8). All stages are to be brought together in one report by NIWA with ECan assistance.

FEES AND TIMING OF PAYMENTS (GST exclusive):

Fees to be determined prior to commencement of this work. Initial payment will be upon delivery of acceptable draft report; final payment will be on completion.

INFORMATION OR SERVICES TO BE PROVIDED BY ENVIRONMENT CANTERBURY :

Environment Canterbury staff will provide data on water quality, existing and potential irrigation scenarios; and will review the draft report and provide comment.

Environment Canterbury engages the Consultant to provide the services described above and the Consultant agrees to perform the services for the agreed fees. Both parties agree to be bound by the provisions of the General Conditions of Engagement. Once signed, this Contract, together with any attachments, will replace all or any relevant contract previously reached between the parties.

Signed on behalf of Canterbury Regional Council:	Signed on behalf of the Consultant:
	Company name: **GNS**
Name:...	Name:...
Designation:..	Designation:...
Signature:...	Signature:...
Date:	Date:

Page *1 of 6*

Environment Canterbury Work Brief - Water Quality Impacts from Irrigation Development in the Hakataramea Valley *16/06/2006*

Environment Canterbury
Your regional council

General Conditions of Engagement

for the provision of services to

Environment Canterbury

1. The Consultant shall perform the services and provide the outputs by the agreed date as described in the attached documents.
2. In providing the services the Consultant shall exercise the degree of skill, care and diligence normally exercised by consultants in similar circumstances. The Consultant shall not have any conflict of interest that would prevent the impartial provision of services.
3. Environment Canterbury shall provide all agreed relevant information held by Environment Canterbury to the Consultant, free of cost, as soon as practicable following any request.
4. Environment Canterbury shall pay the Consultant the amount of fees for services at the times and in the manner set out herein.
5. Amounts due to the Consultant shall be paid in full and within twenty (20) working days of the date of receipt of any account.
6. For all reimbursable costs, and where services are carried out on a time charge basis, the Consultant shall maintain up to date records which clearly identify relevant time and expenses incurred in providing the services to Environment Canterbury.
7. Environment Canterbury may suspend all or part of the services or terminate the Contract by written notice to the Consultant who shall immediately make arrangements to stop the services and minimise further expenditure. Suspension or termination shall not prejudice or affect the accrued rights or claims and liabilities of the parties.
8. Environment Canterbury may request variations to the services in writing or may request the Consultant to submit proposals for variation to the services.

CRC		Consultant	

9. The ownership of data and information collected by the Consultant and paid for by the CRC shall, after payment by Environment Canterbury, lie with Environment Canterbury. The Consultant may, with the written approval of Environment Canterbury, use the data/information for public good purposes and may publish the data/information, and such approval shall not be unreasonably withheld or delayed. In all other respects the Consultant shall not disclose any information obtained as a consequence of the contract to any person not being a party to this Contract. Environment Canterbury shall have no right to use any of the data/information where any or all of the fees payable to the Consultant have not been paid in accordance with this Contract.

10. The Consultant, pursuant to Section 114 of the Copyright Act 1994, assigns to Environment Canterbury all copyright now and in the future, held by the Consultant in the report(s) prepared for the Environment Canterbury for the full term of such copyright.

11. All reports prepared as part of the contract shall be prepared as a Environment Canterbury report in accordance with the applicable parts of Environment Canterbury report "Environmental Management Technical Reports: Guidelines for Preparation and Review" Report No. U94(16), November 1994. The title page shall **not** include the name of the Consultant responsible for the report. The individual author(s) or Consultant may be identified on the publication reference page only. The report shall be cited as an Environment Canterbury report, and may acknowledge the role of the Consultant.

    A disclaimer shall be included on the publication reference page stating "The information in this report is accurate to the best of the knowledge and belief of the Consultant acting on behalf of Environment Canterbury. While the Consultant has exercised all reasonable skill and care in the preparation of information in this report, neither the Consultant nor Environment Canterbury accept any liability in contract, tort or otherwise for any loss, damage, injury or expense, whether direct, indirect or consequential, arising out of the provision of information in this report.".

    It is agreed, in any event what so ever, the consultant's sole liability for this contract shall be limited to $100,000.

12. Disputes shall first be referred to conciliation for settlement. Unresolved disputes shall be referred to arbitration in accordance with the Arbitration Act 1996.

Signed on behalf of Canterbury Regional Council:	Signed on behalf of the Consultant:
	Company name: **GNS**
Name:...	Name:..
Designation:..	Designation:...
Signature:...	Signature:...
Date:	Date:

Page 3 of 6

Environment Canterbury Work Brief - Water Quality Impacts from Irrigation Development in the Hakataramea Valley 16/06/2006

Environment Canterbury Work Brief:

Water Quality Impacts from Irrigation Development in the Hakataramea Valley

Background

The Hakataramea River is the principal salmon spawning river for the Waitaki River but this role could be jeopardised by pressure for further abstraction for irrigation, and by the impacts of land use on water quality.

An estimated 1.060 cumecs is currently allocated from the Hakataramea River and its tributaries to irrigate 2108 hectares of land in the Hakataramea Valley. An additional area of 7000 hectares is the subject of applications that are on hold while the Waitaki Allocation Plan is developed. (This includes the application to take 4.0 cumecs from the Waitaki River and to pump it into the Hakataramea Valley to irrigate 6,000 – 9,000 hectares). The 1982 Waitaki water and soil management plan indicated an area in excess of 20,000 hectares as being suitable for irrigation in the Hakataramea Valley (generally below 300 metres and with slopes of less than 10°). The Canterbury Strategic Water Study 2002 estimated that there is a gross irrigable area of 8,077 hectares in the Hakataramea riparian area. While the river is limited in the amount of water it can supply in a run of river situation there is significant interest in storage as a method for providing more water for irrigation use.

There are indications that land use activities are causing nutrient enrichment of the lower reaches of the river. The actual and potential effects of current intensive landuse practices on water quality of the river need to be determined, and the effects of further irrigation understood.

Environment Canterbury has completed a water quality sampling programme of most of the tributaries of the Hakataramea River over the 2004 /05 summer period (5 sampling occasions).

Study Objectives:

1. To undertake a "desk top" study, to assess the potential effect of current landuse activities on the nutrient status of groundwater and surface water in the Hakataramea catchment, and to compare this against recent water quality data.

2. To also determine the likely effect of increased irrigation and land use intensification on groundwater and surface water quality. In particular to determine likely changes in nutrient concentrations and the effects of this on stream ecology in the Hakataramea catchment.

Tasks

Specific tasks are:

Irrigation / dry-land land use

1. Develop land use scenarios based on existing and potential irrigation as follows:
    a. Scenario I - existing dry-land and irrigated land uses – no further development;
    b. Scenario 2 - irrigation area of land that is currently economically viable to irrigate;
    c. Scenario 3 – assuming all potentially irrigable land was developed;

d. Scenario 4 - fully dry-land no irrigation

Groundwater

2. Gather and review published or unpublished information on groundwater, surface water resources, current and potential land use practices and potential areas suitable for irrigation in the Hakataramea Catchment.

3. From published or unpublished information of potential irrigation schemes, and distribution of soil types, identify the potential area of irrigable land in the Hakataramea catchment.

4A Estimate nitrate nutrient leaching losses to groundwater under the land use scenarios developed in Task 1.

4B Estimate phosphorous losses to groundwater and surface water under the land use scenarios developed in Task 1

Surface water

5. Assess with respect to national water quality guidelines, the current state of surface water quality, including nutrient determinands, trophic status, and algal biomass, in the Hakataramea under existing land uses and river flows.

6. Assess with respect to national water quality guidelines, the potential changes to surface water quality under the land use scenarios developed in Task 1. Describe the potential impacts of this on the aquatic ecosystem and other values.

7. Describe the cumulative changes, if any, to the water quality of the lower Waitaki River if the land use scenarios developed in Task 1 were to proceed in combination with the irrigation scenarios identified for the upper Waitaki catchment for the Meridian/NIWA water quality study. Describe the potential impacts of this on aquatic ecosystem and other values.

8. Consolidate reports into one document including executive summary.

Assumptions

1. The study would be limited to existing published and unpublished information. No additional fieldwork or data collection would be carried out.
2. Within the constraints of 1), the same methodology as used in the study for Meridian Energy on water quality impacts from irrigation development in the Upper Waitaki would be used.

Outputs:

1. Provide the findings to NIWA as soon as practical for them to apply when carrying out their tasks.
2. Provide a draft written report for staff to comment on by early October. This to include methods, assumptions, results, etc of the work carried out, and to include a summary that can be readily imported into the consolidated report. (The full report is to be appended to the report completed by NIWA)
3. Provide a bound final report, an unbound final report and an electronic version on CD.
4. Participate if required in a workshop with Council to discuss the findings and recommendations.

Timetable

1. Draft to be completed by early October 2005. A meeting will be arranged following this with Environment Canterbury staff to consider any amendments.
2. Final Report to be completed by early November 2005.

Environment Canterbury Assistance

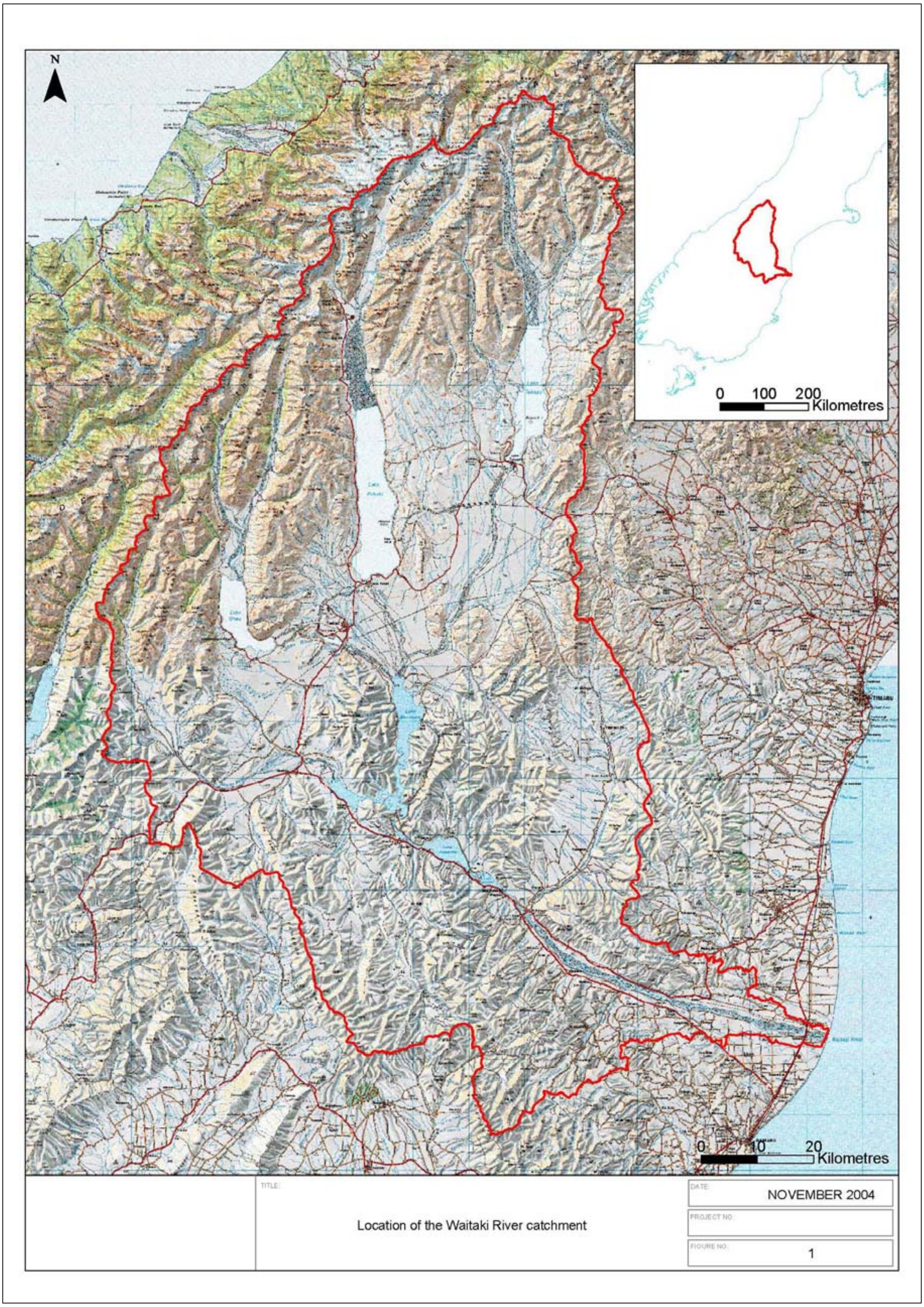
Staff will provide assistance in determining estimates of irrigation potential, water quality results, and other information or support as required. Staff will provide comment on the draft report when submitted and will meet with consultants to discuss these as required.

Project Management

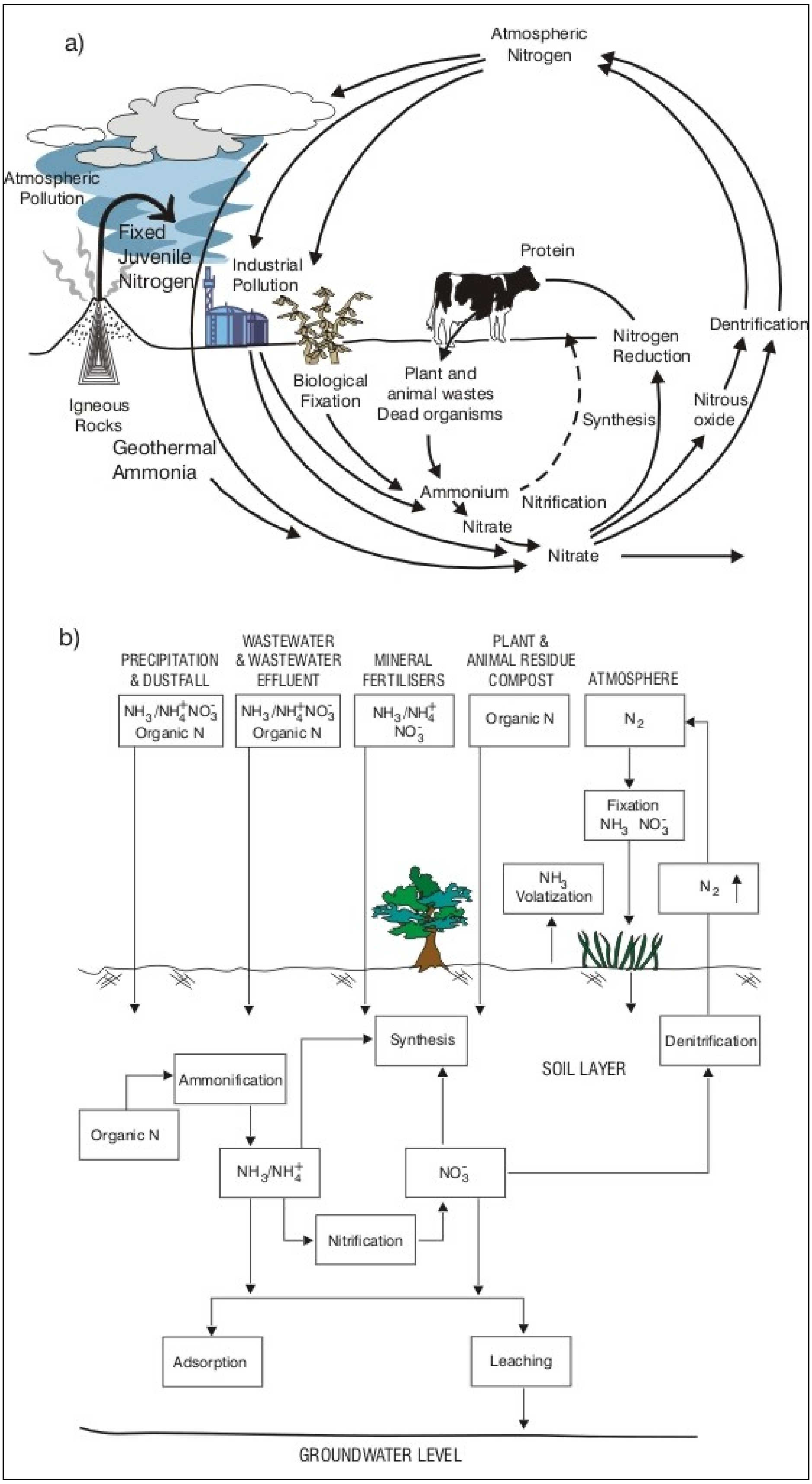
Malcolm Miller will oversee and manage the contracts for Environment Canterbury.

APPENDIX B – FIGURES FROM OTHER SOURCES/REPORTS

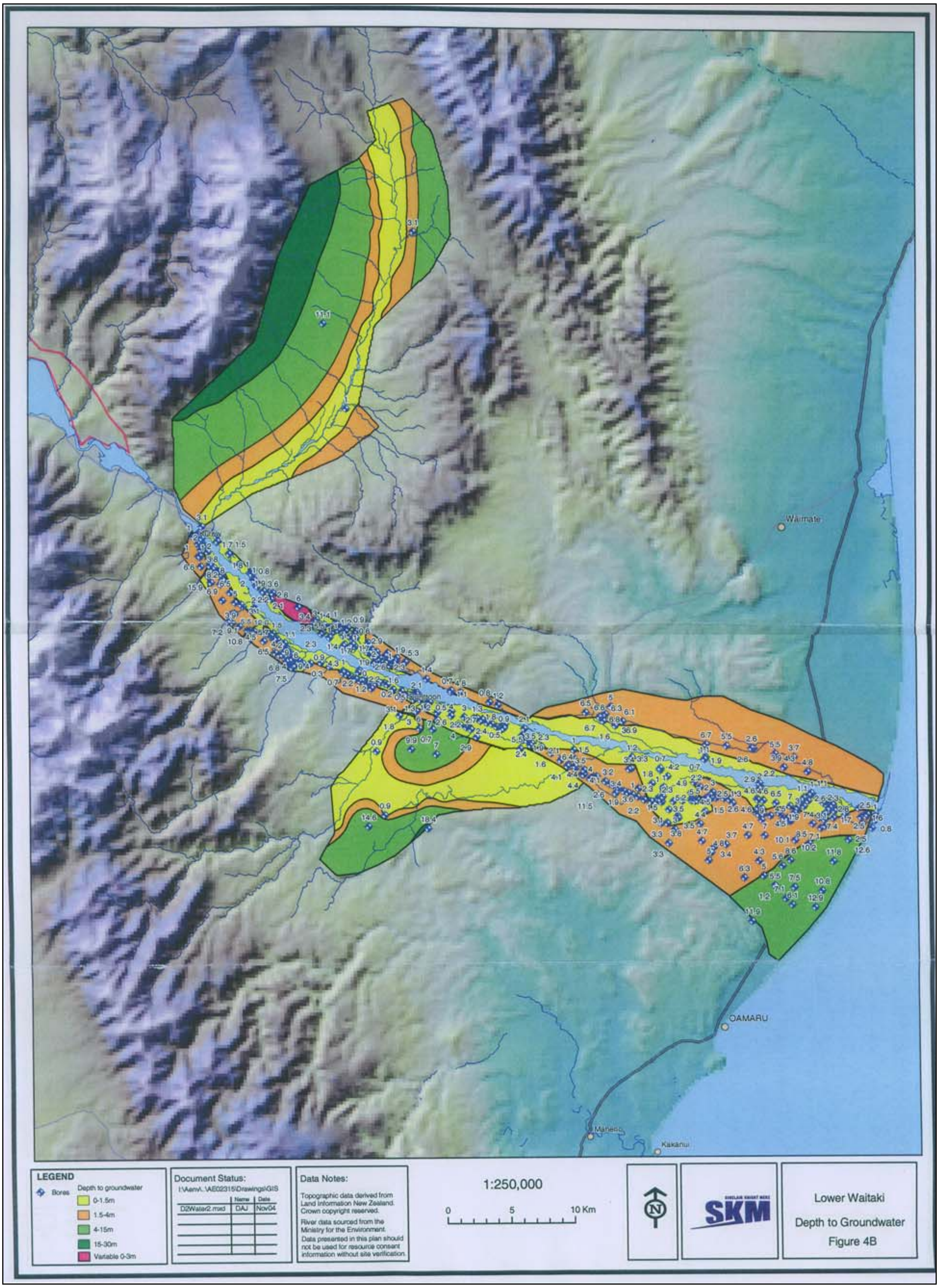
- MfE (2005a) Figure 1 – Location of the Waitaki River catchment
- Close, et al. (2001) Figure 8.1 – Nitrogen cycle
- SKM (2004) Figure 4B – Lower Waitaki depth to groundwater
- SKM (2004) Figure 5B – Lower Waitaki piezometric contours, springs and wetlands



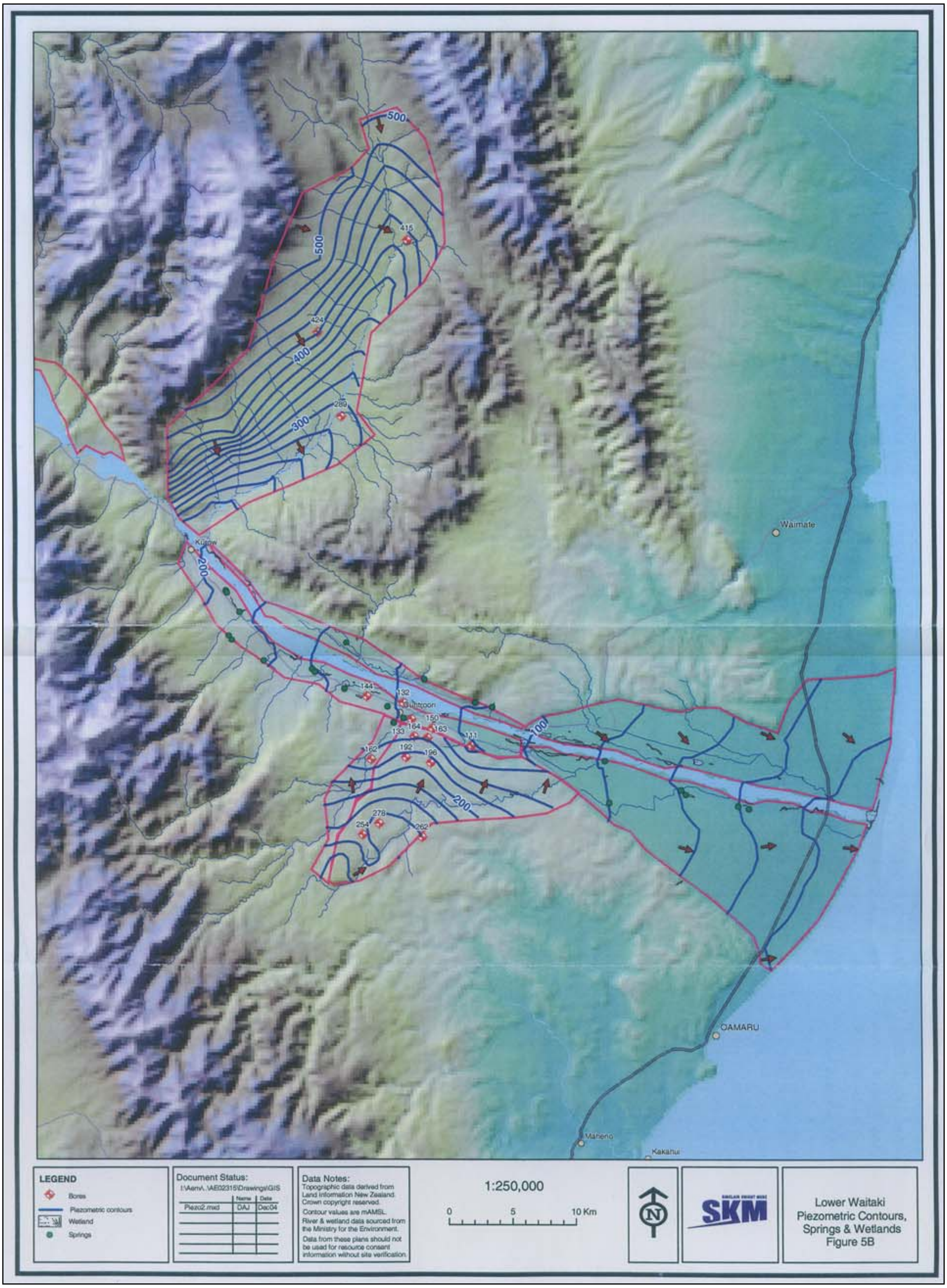
MfE (2005a) Figure 1 – Location of the Waitaki River catchment



Close, et al. (2001) Figure 8.1– Nitrogen cycle



SKM (2004) Figure 4B – Lower Waitaki depth to groundwater



SKM (2004) Figure 5B – Lower Waitaki piezometric contours, springs and wetlands.

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