

Assessment of Environmental Effects: Groundwater Quality Assessment for the Hurunui Water Project

∴ Prepared for
Hurunui Water Project

∴ June 2009

Quality Control Sheet

TITLE **Assessment of Environmental Effects: Groundwater Quality
Assessment for the Hurunui Water Project**

CLIENT Hurunui Water Project

VERSION Final

DATE June 2009

JOB REFERENCE C02031500

SOURCE FILE(S) C02031500_R001Final.doc

Prepared by

SIGNATURE

Bas Veendrick Jeremy Sanson Andrew Brough

Directed, reviewed and approved by

SIGNATURE

Peter Callander

Limitations:

The report has been prepared for Hurunui Water Project, according to their instructions, for the particular objectives described in the report. The information contained in the report should not be used by anyone else or for any other purposes.

Table of Contents

SECTION		PAGE
1.0	Introduction	1
2.0	Description of Command Area	1
2.1	Location and Sub-Areas	1
2.2	Climate	2
2.3	Soils Water Holding Capacities	2
2.4	Existing Land Use	3
2.5	Change in Land Use Under Irrigation Scheme	4
3.0	Description of Potentially Affected Environment	4
3.1	Existing Groundwater Resource	4
3.2	Existing Groundwater Quality	6
4.0	Assessment of Actual and Potential Environmental Effects	8
4.1	Effects on Groundwater Quantity	8
4.2	Effects on Groundwater Quality	9
4.3	Effect of Irrigation on Structural Degradation of Soils	14
5.0	Management and Mitigation Measures	15
5.1	Groundwater Quality	15
5.2	Effects of Groundwater Quality Management and Mitigation Measures	16
5.3	Structural Degradation of Soils	16
6.0	Conclusion	17
7.0	References	17

Appendices

- Appendix A Figures
- Figure 1: Command Area
 - Figure 2: Soil Water Holding Capacities
 - Figure 3: Depth to Maximum Recorded Water Level
 - Figure 4: Depth of All Wells from Environment Canterbury Database
 - Figure 5: Piezometric Contours for Area Just North of HWP Command Area
 - Figure 6: Potentiometric Surface for Some Areas in the Waipara Basin
 - Figure 7: Existing Median Nitrate-Nitrogen Concentrations
 - Figure 8: Wells with Long-Term Nitrate-Nitrogen Records
 - Figure 9: Maximum Recorded *E. coli* Count
 - Figure 10: Maximum Recorded Faecal Coliform Count
- Appendix B Long-Term Nitrate-Nitrogen Trends

1.0 Introduction

Pattle Delamore Partners Ltd (PDP) has been engaged by the Hurunui Water Project (HWP) to assess the environmental effects resulting from the development of an irrigation scheme in the Hurunui and Upper Waipara catchment.

The proposed scheme seeks to irrigate an area of 42,180 ha located in the Amuri Basin, Omihi and Scargill Valley and includes the existing Balmoral Irrigation Scheme.

This assessment of environmental effects(AEE) report has been produced to technically support the HWP resource consent application. The applications to which this report relates are:

- Use of water for irrigation on a group of properties supplied by the proposed irrigation scheme

This report assesses the environmental effects of the proposed activities on groundwater and describes measures to mitigate any potentially adverse effects of the project.

A more detailed description of the scheme and command area can be found in the report 'Assessment of Environmental Effects: Hydrology and Irrigation Demand for the Hurunui Water Project'. That report also provides a more detailed description of climate, soils and water holding capacity information.

2.0 Description of Command Area

2.1 Location and Sub-Areas

The total area of the irrigation scheme covers a command area of approximately 51,686 ha as shown in Appendix A, Figure 1 with a net irrigable area of 42,180 ha as shown in Table 1 below.

Table 1: Gross and Net Irrigable Area		
Irrigation Area	Gross Irrigable Area (ha)	Net Irrigable Area (ha)
Existing Balmoral Scheme	5,500	5,240
Balmoral forest & adjacent area	9,150	7,320
Peaks	6,288	5,030
Hawarden south of Waitohi	11,200	8,960
Upper Waipara/Mason's Flat	6,888	5,510
Scargill Valley	5,880	4,700
Omihi	6,780	5,420
Total	51,686	42,180

Irrigation will be primarily spray irrigation with a small proportion (approximately 1900 ha) of the existing Balmoral Scheme being borderdyke irrigation.

2.2 Climate

The climate in this area is similar to the Canterbury Plains with a fairly consistent rainfall from month to month and a seasonal variation in temperature and evapotranspiration.

Table 2 shows the mean monthly rainfall, evapotranspiration and temperature for the command area.

Table 2: Monthly Rainfall and Evapotranspiration Data for the Command Area			
Month	Rainfall¹ (mm)	Potential Evapotranspiration¹ (mm)	Temperature² (°C)
January	47	133	17.25
February	49	105	16.89
March	58	83	14.66
April	51	48	11.68
May	50	29	8.36
June	57	20	5.75
July	66	20	5.27
August	65	32	6.80
September	57	56	9.32
October	60	88	11.34
November	53	108	13.05
December	55	127	15.86
Yearly Total	668	848	11.35 (yearly average)

- (1) Based on synthetic daily rainfall and PET data from 1972 to 2008 produced by NIWA on a 5km x 5km grid.
- (2) Based on data from Culverden climate station from 1983-2009 (NIWA agent number 4527)

2.3 Soils Water Holding Capacities

Soils in the command area have been classed into four different categories, using the plant available water (PAW) classification in the Land resource Inventory (LRIS), namely 60, 90, 120 and 150 mm. The spatial distribution and net areas for each irrigation area are shown in Appendix A, Figure 2 and Table 3.

Irrigation Area	Net Area in Each Soil WHC Category (ha)				
	60 mm	90 mm	120 mm	150 mm	Total
Existing Balmoral Scheme	400	3340	1500	0	5240
Balmoral forest & adjacent area	1210	6110	0	0	7320
Peaks	500	3620	850	60	5030
Hawarden south of Waitohi	2040	4380	1860	680	8960
Upper Waipara/Mason's Flat	2890	1960	480	180	5510
Scargill Valley	1450	1570	1680	0	4700
Omihi	840	3560	1020	0	5420
Total	9330	24540	7390	920	42180

2.4 Existing Land Use

Table 4 provides a table with the current land use in the command area. This table is derived from farmer questionnaires conducted by the Hurunui Water Project in 2006 and 2008.

Irrigation Area	Land Use (%)						
	Arable	Stock	Dairy	Dairy Support	Viti-Culture	Horti-Culture	Other
Existing Balmoral Scheme	0%	0%	58%	42%	0%	0%	0%
Balmoral Forest & Adjacent Area	0%	0%	0%	0%	0%	0%	100%
Peaks and Hawarden South of Waitohi	9%	77%	5%	8%	0%	0%	1%
Upper Waipara/Mason's Flat	4%	93%	0%	3%	0%	0%	0%
Scargill Valley	6%	88%	0%	3%	0%	0%	3%
Omihi	8%	84%	0%	4.0%	0%	0%	4%
Total	5%	66%	2%	4%	0%	0%	22%

Currently most of the areas have a mixture of land uses mainly consisting of Stock (Beef and Sheep), Arable and Dairy farming.

The existing Balmoral Irrigation Scheme mainly consists of irrigated Dairy and Dairy Support. The 100% 'other' land use for Balmoral Forest represents the current forestry practices of the Balmoral area.

2.5 Change in Land Use Under Irrigation Scheme

For the purpose of this assessment, it has been assumed that the HWP area will be used for dairying. In terms of this groundwater quality assessment this is considered a conservative assumption since it is likely that a proportion of the irrigable area will be used for crops, grazing of stock (beef and sheep) or viticulture, which on average will have lower concentrations of contaminants leaching to groundwater.

3.0 Description of Potentially Affected Environment

3.1 Existing Groundwater Resource

The geology and groundwater resource of the command area has been described by Brown (2002), Weeber (1984) and Close (1985). This description of the groundwater resource draws on information from these sources.

Within the Culverden Basin, gravels are estimated to be a maximum thickness of 100 m. These are underlain by terrestrial gravel lower Pleistocene – Pliocene Kowai Formation and marine sandstone and siltstone with conglomerate bands of the Bourne Formation. Groundwater is obtained from dug and drilled wells at shallow depths (between 7 and 30 m) in the gravels, and in small quantities (maximum 3 L/s), to provide farm domestic and stock water supplies. The highest yields (20 L/s) are obtained from shallow, large diameter (1000 mm) wells located adjacent to the Waitohi and Pahau riverbeds (Appendix A, Figure 3). Almost all wells appear to obtain water from the water table aquifer, with the depth of the water table generally at less than 5 metres below ground surface, although it can be up to 30 m depending on locality. Appendix A, Figure 3 shows a map with highest recorded water levels in the command area, sourced from the ECan GIS database. This map shows that most of the areas have their highest recorded water levels at more than 1 metre below ground level for most the command area. However, sub-area Hawarden south of Waitohi has a few wells with maximum recorded groundwater levels less than 1 metre below ground level. Some of these wells are located close to the river and are therefore influenced by the water level in the river.

No piezometric surveys or groundwater level monitoring have been conducted for the Culverden Basin. However, in 1954, NZGS established a network of water level monitoring wells which extends into the area of the Amuri irrigation scheme. Close (1985) constructed piezometric contours from this data indicating that groundwater flow in the southern half of the surveyed area is towards the Hurunui River (Appendix A, Figure 5). In the Culverden area, groundwater generally flows from west to east, sub-parallel to rivers that cross the basin and discharges into the major rivers at the eastern margin of the basin (Tonkin and Taylor, 1985).

Before the Amuri irrigation scheme was constructed, rainfall was the main recharge source for groundwater with some recharge derived from the Waitohi and Pahau rivers. Rainfall is the main influence on well water levels with winter highs and summer lows.

Flow gaugings along the Hurunui River did not locate any significant loss of surface flow and did not appear to affect groundwater levels.

Wells have been drilled in attempts to locate aquifers in deeper gravel aquifers for town water supply for Culverden and irrigation water supplies for farms. Widespread high yielding aquifers have not been located within explored depths of 120 m. A deep well at Hawarden (M33/0228) was in claybound gravels at 120m and screened between 75 and 114 m and the well pumped at 7 l/s with a drawdown of 58.6 m. A nearby well (M33/0215) drilled to 103 m and screened 66 to 72 m in a blue-grey free gravel, yielded 30.4 l/s with a drawdown of 29 m. This is the highest yielding well drilled in the Culverden basin.

There is very little information available with regard to the geohydrology of the Scargill Valley. A search through the ECan well database (Appendix A, Figure 4) shows that most wells are shallow and located in the vicinity of the Waikari River indicating that well yields are highest in the youngest and shallower strata. There are only two wells with recorded depth to water level measurements with measured maximum recorded water levels of 1.9 m and 4 m below ground level.

The Omihi basin gravels are estimated to range from 150 – 300 m and are mapped as Kowai Gravels, Teviotdale Gravels and Canterbury Gravels. The Kowai Gravels unconformably overlie the Tertiary marine derived sediments and are included with them in the Kowai formation with an age range from early Pliocene to early Quaternary. The Teviotdale and Canterbury gravels are correlated with late Quaternary and last glaciation outwash gravels. The Teviotdale and Canterbury gravels unconformably overlie the Kowai formation and form the basin surface.

Aquifers occur within the Kowai, Teviotdale and Canterbury gravels. Limestones are the most prospective for aquifers of the tertiary sediments. Domestic and stock supplies are generally available from gravel aquifers and permeability of the aquifers and well yields are lowest for the youngest and shallowest aquifer and increase with depth for the area (Loris 2000b). This is reflected in the high number of deep wells in the Omihi area (Appendix A, Figure 4)

Sparse water level data means that accurate determination of groundwater flow directions are difficult to establish. Appendix A, Figure 6 shows a map with the potentiometric surface for some areas in the Waipara Basin as interpreted from well logs by Loris (2000b). This indicates that the general flow direction in the southern part of the Omihi basin is in a south or southeast direction.

Chemical analyses of groundwater from wells indicate hard groundwater enriched in calcium bicarbonate and total dissolved solids, indicating the most likely source of recharge is the limestone hills located along the eastern and western margin of the basin.

3.2 Existing Groundwater Quality

Groundwater quality in the proposed scheme area has been studied with respect to its current state, as well as any trends that are observed up to May 2009. The focus of this analysis is on the parameters that may be affected by a change in land use from the proposed scheme.

Groundwater quality data was obtained from the Environment Canterbury (ECan) GIS database and from a groundwater quality report of the Culverden Basin (Abraham and Hanson, 2006).

3.2.1 Nitrate Nitrogen

The ECan GIS database revealed 48 wells with recorded nitrate-nitrogen concentrations in the proposed scheme area, with a total of 137 observations. Appendix A, Figure 7 shows the median nitrate-nitrogen concentration and the mid-screen depth for each well.

In the existing Balmoral Scheme there is a clear distinction between nitrate-nitrogen concentrations in shallow wells and deep wells. The two deep wells (63.5 m and 87.0 m deep) have median concentrations of 0.2 mg/L, whereas the shallow wells (less than 25 m deep) have median concentrations, ranging from 3.1 to 5.2 mg/L.

In the Peaks scheme area, median nitrate-nitrogen concentrations range from 0.2 to 8.4 mg/L. The two wells with a median concentration of 0.2 mg/L are located close to the Hurunui River, and their very low concentrations, despite their shallow depths (6.0 m and 23.3 m), may be attributed to recharge from the Hurunui River. The well with a median concentration of 8.4 mg/L has a mid-screen depth of 47.2 m. This relatively high median concentration in a deep well may be due to security issues around the well head. The remaining four wells in the Peaks area have median concentrations between 2.6 and 4.3 mg/L and mid-screen depths between 13.5 and 26.0 m. This suggests that there is not the same separation between nitrate-nitrogen concentrations in shallow and deep wells, as for the Existing Balmoral Scheme.

There are similar trends in the Hawarden south of Waitohi scheme area as for the Peaks scheme area. There are several shallow and deep wells, which have median concentrations less than 1 mg/L and these are generally located close to streams, and therefore experience recharge from the surface water bodies. There are three deep wells (37.0 to 56.0 m deep) which have median concentrations between 1.0 and 3.0 mg/L. Finally, there are two shallow wells (3.4 m and 5.5 m deep), which have very high median concentrations (14.9 and 10.2 mg/L, respectively). Given that this area is not currently irrigated (it is dry land farming) would indicate low concentrations of nitrate leaching to groundwater from farming practices. Consequently these high nitrate-nitrogen concentrations may be due to localised effects, such as contamination from on-site sewage discharges.

Most of the wells in the Omihi area have low median concentrations of nitrate-nitrogen, although there is one well (N34/0109) with a median concentration of 10.7 mg/L, which has a mid-screen depth of 22.0 m.

There were no available records of nitrate-nitrogen concentrations within the Balmoral Forest, Upper Waipara/Mason's Flat, and Scargill Valley scheme areas. It is expected that nitrate-nitrogen concentrations in these areas will be generally low; however, there may be some localised areas with higher concentrations.

The current nitrate-nitrogen groundwater concentrations for the shallow wells (wells with a depth of less than 25m) for the different sub-areas are tabulated in Table 5.

Area	Range (mg/l)	Average (mg/l)
Omihi Valley	0-10.7	2.53
Scargill Valley	No data	No data
Upper Waipara/Mason's Flat	No data	No data
Peaks - Hawarden South of Waitohi	<0.1-14.9	4.14
Balmoral Forest & Adjacent Area	No data	No data

Table 5 shows that current nitrate-nitrogen concentrations are highly variable throughout the area and are likely to reflect local variability in land use practices, groundwater recharge patterns or contamination by septic tanks.

Four wells within the command area have long-term (more than ten years) nitrate-nitrogen records; as shown in Appendix A, Figure 8 and Appendix B. The plots of nitrate-nitrogen concentrations over time show that the wells have different trends. For two of the wells (N33/0219 and N34/0109), the concentrations of nitrate nitrogen have been steady over time, one well (N33/0216) has an increasing trend, and in one well (N33/0194) the concentrations of nitrate-nitrogen have been decreasing over time. This suggests that specific changes in nitrate-nitrogen concentrations over time are localised and do not occur homogeneously throughout the command area.

3.2.2 E. coli and Faecal Coliform

There are 7 wells in the proposed command area with *E. coli* data, and a total of 75 observations. Appendix A, Figure 9 shows the maximum recorded *E. coli* count for these 7 wells. Two of the wells (N33/0194 and N33/0219), which are both located in the Existing Balmoral Scheme area, have had *E. coli* detections. Prior to around 2001, faecal coliforms were sampled instead of *E. coli*. Four wells in the command area have faecal coliform data and the maximum recorded faecal coliform count for these wells is shown in Appendix A, Figure 10. Appendix A, Figure 10 shows that all of these wells had a maximum recorded faecal coliform count of 1 cfu/100mL. The maximum acceptable

value (MAV) in the Drinking-water Standards for New Zealand for both *E. coli* and faecal coliform is less than one in 100 mL of sample.

4.0 Assessment of Actual and Potential Environmental Effects

4.1 Effects on Groundwater Quantity

The application of irrigation water to the command area will increase the drainage of water through the soil profile into the underlying aquifer compared with the land under its current use. This increase in drainage may impact on groundwater levels, especially during the irrigation season. Therefore the expected change in drainage is further quantified below together with the expected impact on groundwater levels.

For the proposed irrigation scheme actual irrigation practices need to be considered to determine the expected amount of drainage with the proposed scheme in place. Based on actual irrigation practices it is likely that soils with a Water Holding Capacity of 60mm will be irrigated using a centre pivot with a depth of application of 20 mm. Soils with a Water Holding Capacity of 90 mm or more will probably be irrigated using an irrigator (i.e. a Briggs Rotorainer) with a depth of application of 40-45 mm. This means that a parcel will be irrigated on a return period of typically 4 days for the Centre Pivots and 8 days for the Rotorainer. Modelling of drainage characteristics on these soils show the following dryland and irrigated average drainage for soils with Water Holding Capacities of 60 mm and 90mm or more (Table 6). It is considered that these values are representative for the command area of the HWP since climatic conditions are similar.

Soil WHC (mm)	Average Dryland Drainage (mm)	Average Dryland Drainage Forestry (mm)	Average Irrigation Drainage (mm)
60	167	84	255
>90	89	45	151

Since the amount of drainage for forested areas is less than other land use types we have included a separate estimate for this type of land use. It is assumed that drainage from the forested area is half of the amount of drainage from other dryland land uses. This compares with a measured and modelled drainage of 49 mm for a mature pine plantation west of Darfield (Watson et.al., 2004). At that site there was an estimated 148 mm of drainage from August 2000 to April 2003. Rainfall for this period was 1938 mm which is similar as the average yearly rainfall of the HWP command area.

An increase in drainage caused by the expected change in land use may adversely affect groundwater levels in areas which currently already have shallow groundwater levels. An

example is the Culverden area where, due to the Waiau Irrigation Scheme, drainage problems occurred from the borderdyke irrigation method.

As described earlier a search through the ECan database identified Hawarden South of Waitohi as an area with shallow groundwater. However limited data is available in this area to quantify the extent and periods when groundwater is near the surface and whether drainage problems are likely to occur. Some of the wells with shallow groundwater levels are located close to the river and are influenced by water level in the rivers and are therefore not likely to cause drainage problems. Generally the highest groundwater levels occur in winter when rainfall is high and evapotranspiration is low. The application of irrigation water is highest in summer when groundwater levels are naturally low. It is therefore not expected that the annual highest water levels will increase due to the proposed scheme.

Other areas within the command area typically show groundwater levels between 3-10m below ground level and it is therefore not expected that an increase in drainage of the magnitude described above will cause groundwater levels to rise close to ground levels. The increase in drainage due to irrigation may have beneficial effects on groundwater levels in areas where groundwater levels are naturally low during summer.

4.2 Effects on Groundwater Quality

The proposed use of water to irrigate land used for irrigated dairying could degrade water quality due to leaching of nitrates. This degradation of water quality may have adverse effects on other groundwater users and as a consequence of groundwater contamination, on surface waterways. Nitrate leaching occurs when there is an accumulation of nitrate-nitrogen in the soil that coincides with, or is followed by, a period of drainage through the soil to below the root zone where uptake occurs. Elevated nitrate-nitrogen concentrations in groundwater are a concern due to its harmful effects if ingested by humans. The main health concern is methaemoglobinaemia, commonly known as blue baby syndrome. The New Zealand Drinking Water Standard (MoH, 2005) for nitrate is 50 mg/L (which is equivalent to 11.3 g/m³ of nitrate-nitrogen). Elevated nitrate concentrations could also have an impact on water quality in spring-fed streams.

An increase in nitrate levels in groundwater could occur as a result of the proposed increase in the area used for irrigated dairy farming. Irrigation increases the potential for leaching nitrates from pasture into the ground and groundwater system. This section describes the likely change in drainage water quality based on the expected change in land use practices.

Since each sub-area in the command area differs in terms of current land use and geohydrology the likely change in nitrate-nitrogen leaching will be discussed separately.

4.2.1 Nitrate-Nitrogen

The Ministry for Agriculture and Forestry (www.maf.govt.nz/mafnet/rural-nz/sustainable-resource-use/) presents information on various work carried out under MAF contracts on

nitrate leaching. The work has included assessment of nitrate leaching from dairy farming and dryland arable farming. In terms of nitrate-nitrogen leaching from highly productive dairy farming in New Zealand this information indicates that the concentration of nitrate in leachate is relatively constant between regions with different hydrology but the mass leached per hectare depends on the amount of soil-water drainage. This is demonstrated in Figure 1 (Sourced from Bidwell, 2002).

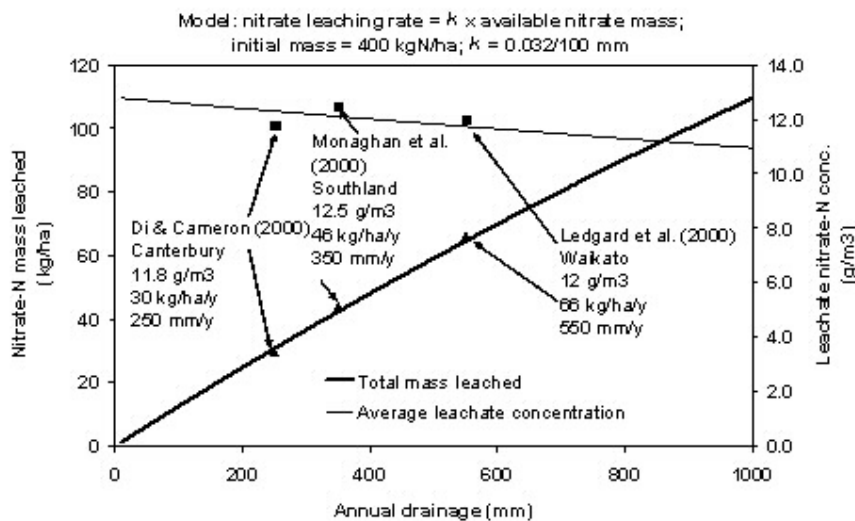


Figure 1: Nitrate-nitrogen mass leached and concentration of leachate in areas with different annual drainage.

The MAF website also makes recommendations for the typical concentration of nitrate-nitrogen in drainage for rural land uses which are reproduced in Table 7 below.

Land Use	Nitrate-Nitrogen Concentration (g/m³)
Dairy pasture	12
Cattle pasture	8
Sheep pasture	3
Forest	1

In the section on the MAF website titled "Implications of Groundwater Nitrate Standards for Agricultural Management: results" it describes the nitrogen losses from a "Typical" arable farm. This is summarised as a 5 year rotation of ryegrass seed, white clover seed, winter wheat, spring peas, spring barley. The leaching losses vary with the crop with an average leaching loss of 54 kg/ha/yr. This farm includes grazing of animals within the rotation. It is based on a non-irrigated scenario with average drainage of around 150 mm.

This compares with the dryland drainage ranging from 89 to 167 mm for the 60 mm and >90mm soil WHC assumed for the command area. Based on the average drainage and average leaching loss this represents an average concentration of nitrate-nitrogen in the drainage of 36 g/m³. With changes in farm management such as removing grazing and reducing fallow periods the report estimates that the nitrogen losses for this dryland farming scenario can be reduced to 25 to 30 kg/ha/yr. This would represent a concentration of nitrate-nitrogen of 16-20 g/m³. For horticulture and viticulture nitrate-nitrogen concentrations in leachate are typically low and for this assessment it is assumed that leachate concentrations are 1 g/m³.

Based on the considerations above the following nitrate-nitrogen leachate concentrations (Table 8) have been adopted for this assessment.

Table 8: Nitrate-Nitrogen Leachate Concentrations for Different Types of Land Use	
Land Use	Nitrate-Nitrogen Concentration
Arable	18 ¹
Stock	5.5 ²
Dairy	12
Dairy support	12
Viticulture	1
Horticulture	1
Other (i.e. Forest)	1
Notes: 1. Average between concentration of 16-20 g/m ³ 2. Average between cattle pasture and sheep pasture since no distinction was made in farmers questionnaire	

These concentrations, together with the amount of drainage from Table 5 and land use information from Table 4, have been used to calculate the nitrate-nitrogen mass leaching to the groundwater under the current land use and future land use scenario's for the sub-areas identified in Appendix A, Figure 1 (Table 8). This data is shown in Table 9.

Table 9 does not include the existing Balmoral Irrigation scheme since the current land use in this area will not change as a result of the proposed scheme. The majority of the existing Balmoral Irrigation Scheme is currently irrigated dairy farming.

Table 9: Annual Mass of Nitrate-Nitrogen Contributing to Groundwater				
Area	Net Irrigable Area, ha	Mass of Nitrate-Nitrogen (kg/year)		
		Current	Proposed	Increase
Omihi Valley	5420	35900	108700	72800
Scargill Valley	4700	33500	103300	69800
Upper Waipara/ Mason's Flat	5510	44300	135900	91600
Peaks - Hawarden South of Waitohi	13990	107090	285200	178100
Balmoral Forest & adjacent area	7320	3700	147700	144000

The most significant change in the amount of nitrate-nitrogen leaching to groundwater is for Balmoral Forest. As mentioned before forested areas leach very low concentrations to the groundwater and a change to irrigated dairy farming will significantly increase the mass of nitrogen leaching to groundwater.

This change in the mass of nitrogen in the drainage water is then mixed with other groundwater and rainfall and river recharge water to contribute to the nitrate concentrations measured in groundwater. It is difficult to predict how the concentrations will change. However the groundwater environment is similar to the existing Balmoral Scheme area where shallow groundwater nitrate-nitrogen concentrations of 3.1 -5.2 mg/L have been measured.

Section 3.2 describes the current water quality in the Peaks-Hawarden south of Waitohi area and in the Omihi area. Based on the current amount of nitrate nitrogen leaching to the groundwater the average concentration in the shallow groundwater is 4.14 mg/l for the Peaks – Hawarden South of Waitohi area and 2.53 mg/L for the Omihi area. Based on the expected increase in mass of nitrate nitrogen leaching to groundwater it is theoretically possible to see the existing concentrations for some of the shallow wells rise by 2-6 mg/l if no special management measures are put in place. This estimate is based on water quality modelling results from other irrigation schemes within the Canterbury area with a similar conversion of dryland farming (i.e. stock and crops) to irrigated dairy farming.

This expected rise in water quality would indicate that wells which currently have concentrations below 5 mg/l (the majority of the wells in the area) are not likely to exceed the drinking water standard of 11.3 mg/L. However wells that currently have concentration above 5 mg/L may exceed the drinking water standards if no special farm management practices were put in place.

Policy WQL9 of the NRRP aims to:

- (1) *Minimise the leaching of nutrients, chemical and microbiological contaminants to groundwater by requiring:*
 - (a) *The use of best management practices to:*
 - (i) *manage the input of nitrogen so that it matches plant requirements; and*
 - (ii) *prevent the accumulation of mineral nitrogen or other contaminants in the soil which have a high potential for leaching.*
 - (b) *that the use of water for irrigation:*
 - (i) *is in accordance with Policy WQN17; and*
 - (ii) *does not result in groundwater quality in any existing drinking water supply well, adjacent to, or down-gradient of the property being irrigated, being affected to the extent that the water in the well is no longer suitable for human consumption...*

Policy WQN9 also requires that measures be implemented to reduce the concentration of determinants in groundwater where groundwater quality has already declined and the concentrations do not meet Objective WQL2. Objective WQL2 of the NRRP states water quality outcomes for groundwater and contaminated land. One of these outcomes is for nitrate-nitrogen concentrations in groundwater to not rise by more than two milligrams per litre above maximum concentrations reported in 2002. As mentioned above there is a reasonable likelihood that the proposed activity may not be able to comply with this objective if no management measures are put in place to reduce nitrate leaching.

HWP intends to implement best management practices to minimise nitrogen leaching within the irrigated area which is further detailed in section 5.1.

Policy WQN9 also has provisions relating to areas where groundwater enters rivers or lakes. This policy aims to maintain river water quality if it already meets the water quality criteria of Table WQL5 of the NRRP, or improve river water quality if it fails to meet these criteria. Any increase of nitrate concentrations in the shallow groundwater is likely to lead to an increase of nitrate concentrations in spring-fed streams. However, nitrate is unlikely to be a limiting factor for algae growth in these streams and any potential effects will be balanced by the increased flows due to higher groundwater levels as a result of the irrigation, particularly in summer when lowland stream water quality is most impacted by low flows.

4.2.2 E. coli

High concentrations of microorganisms occur in faeces and urine from stock and when wastewater from milking sheds is applied to the land. Whilst there is potential for contaminating microorganisms to be carried through the soil to the underlying groundwater, studies have shown that this is unlikely to occur at adverse levels in well managed irrigation schemes. Provided irrigation is applied at rates that do not cause the soil to exceed its field capacity, then the following removal mechanisms prove to be very effective:

- ✦ Die-off of microorganisms at the ground surface;
- ✦ Filtering capacity of the soils;
- ✦ Die-off of microorganisms within the soil profile and in the unsaturated strata above the water table, where the conditions do not support their survival.

While E. Coli counts are observed in groundwater, common causes of E. Coli occurrences include septic tank discharge, wellhead contamination due to poorly constructed wellheads and seepage from rainfall runoff soakage pits. In a well designed and managed irrigation system, it is not expected that significant quantities of microorganisms will enter groundwater through irrigation drainage.

The supply of irrigation water via a community scheme provides an opportunity to raise the standards of irrigation practice to avoid contamination risks, such as those that might be created by overland flow to a poorly constructed wellhead.

4.2.3 Phosphorous

Phosphorous is readily absorbed into the soil and is not expected to migrate to groundwater through drainage, although it may enter surface waterways due to surface runoff. This could be an issue for irrigated land adjacent to surface waterways, but is readily addressed by good irrigation management and the use of riparian margins.

4.3 Effect of Irrigation on Structural Degradation of Soils

Some of the areas over which the irrigation is proposed to occur is covered by silt loams. These soils are classified as Fragic Pallic soils and these soils are more susceptible to structural degradation than other common sedimentary soil groups. A change from dryland grazing to intensive irrigated cattle grazing potentially decreases the soil physical quality (pugging) under wet soil conditions and as a consequence limits pasture growth and decreases infiltration rates. Consequently a higher proportion of water flow from these soils tends to occur as lateral drainage and/or overland flow. This degradation of the soil may have adverse effects on surface waters as the increased runoff from these soils results in the transfer of greater amounts of phosphorus, sediment and faecal micro-organisms from soil to surface waters.

5.0 Management and Mitigation Measures

5.1 Groundwater Quality

Rule WQL18 of the NRRP classifies the use of land that may result in the discharge of nitrate-nitrogen into groundwater in an unconfined or semi-confined aquifer as a permitted activity provided that the conditions are met. This rule is not currently active because the plan is not operative yet. However once it becomes operative this rule requires shareholder farmers to comply with the conditions. This rule requires nutrient budgeting calculations and best management practices to be implemented if nutrient leaching on farms where irrigation water is applied exceeds 8 grams per cubic metre of nitrate-nitrogen.

In addition, it is proposed to develop a code of farming practice that all farms taking water from the scheme will be required to adhere to. The estimated values for nitrate leaching presented in section 4.2 are based on typical farm management practices, but these can be considerably lowered by adopting best management practices that are aimed at reducing nitrate leaching. It is envisaged that these best management practices will include:

1. Recommendations as to how fertilisers should be applied to minimize the leaching of nitrogen from the fertiliser to the soil profile. These recommendations include:
 - A maximum amount of nitrogen per ha of N fertiliser per application and per year depending on soil type, climate and management.
 - Apply when soil temperature is above 4°C in spring and above 7°C in autumn (i.e. not too early in spring or too late in autumn).
 - Apply when pasture cover is 1,500 – 1,800 kg DM/ha.
 - Apply more frequently at rates which more closely match the growth requirements of the grass (e.g. fertigate using the irrigator).
2. Use Nitrification Inhibitors (NI's) which have lower concentrations of nitrogen which restrict the rate of conversion of nitrogen to nitrates meaning that the applied nitrogen can be better utilised by plants. Recent research has shown that NI's have the potential to significantly reduce the nitrate leaching from grazed pastures in New Zealand. For example two studies undertaken in Canterbury have reported annual reductions in nitrate leaching of 59% (Di and Cameron, 2002) and 74-76% (Di and Cameron, 2004) in irrigated grazed pastures treated with eco-n. These studies were undertaken on free draining (i.e. stony silt to deep sandy) soils which are typical of Canterbury conditions. Nitrification inhibitors are also effective on heavier soils. A two year study undertaken by AgResearch limited on a Southland dairy farm with heavy silty soils reported an annual reduction of nitrate leaching from pasture treated with DCn (a Nitrification Inhibitor by Balance

Agri Nutrients Limited) of 42%

(www.ballance.co.nz/Education/nitrification_inhibitors).

- It is proposed to develop a Groundwater Monitoring Plan. This would involve monitoring of some wells on a monthly basis and others on a six-monthly basis for parameters such as nitrate-nitrogen, ammonia-nitrogen, conductivity, pH and *E. coli* bacteria.

5.2 Effects of Groundwater Quality Management and Mitigation Measures

Given the research mentioned above there is enough data available to indicate that NI's can be an effective tool in mitigating nitrate leaching from grazed pastures in New Zealand. Table 10 shows the potential revised mass of nitrate-nitrogen potentially leaching to groundwater with best management practices in place. The calculated revised mass is based on a conservative assumption that NI's can reduce the leaching of nitrate-nitrogen to groundwater by 40%.

Table 10: Annual Mass of Nitrate-Nitrogen Contributing to Groundwater					
Area	Mass of nitrate-nitrogen (kg/year)				
	Current	Without Best Management Practices		With Best Management Practices (40% Reduction)	
		Proposed	Increase	Proposed	Increase
Omihi Valley	35900	108700	72800	65220	29300
Scargill Valley	33500	103300	69800	62000	28500
Upper Waipara/ Mason's Flat	44300	135900	91600	81500	37200
Peaks - Hawarden South of Waitohi	107090	285200	178100	171100	64010
Balmoral Forest & adjacent area	3700	147700	144000	88600	84900

Based on the calculated mass of nitrate-nitrogen with best management practices in place it is expected that nitrate-nitrogen in groundwater will not be as high as discussed in section 4.2.1. The scheme will be designed and managed in accordance with the requirements of policy WQL 9 and Rule WQL 18 to ensure that any adverse effects on groundwater quality are minimised.

5.3 Structural Degradation of Soils

The irrigation management of the shareholder farmers will use Best Management Practices (BMPs) such as optimal irrigation efficiency, decreased stock numbers during

wet periods to minimise soil animal treading damage and vegetative riparian buffer strips, that will provide effective mitigation against the risk of structural degradation and increased nutrient runoff from Fragic Pallic soils.

In addition to these BMPs the irrigation management of the farm will operate within the permitted activity limits of Rule WQL18 of the NRRP in order to avoid significant adverse water quality effects.

6.0 Conclusion

The assessment of effects described in this report are based on the current land use and estimates of future land use activities. Economic factors will provide a strong impetus to farmers as to which farming option is most viable to them. For instance recent drops in predicted returns for dairying and increased returns for sheep and beef could see a reduction in the increase in dairying used in this assessment.

Despite this, the information presented demonstrates that increases in nitrate-nitrogen concentrations are likely. These increases will be mitigated to some extent by dilution caused by increased drainage, the use of better farming practices such as targeted applications of nitrogen and use of new products such as nitrification inhibitors. As a result it is concluded that the use of irrigation water to increase farm production can be managed so not to result in significant, adverse, changes to groundwater quantity and quality.

7.0 References

- Abraham, P., Hanson, C. (2006). Groundwater quality investigation of the Culverden Basin. Environment Canterbury Report No. UO6/33.
- Bidwell, V.J. (2002). Groundwater protection: practical approaches to estimating the effects of land use. *New Zealand Hydrological Society Symposium Workshops, Blenheim, 3 December 2002.*
- Brown, L. J. 2001: Groundwaters of the Canterbury Region. Environment Canterbury Report R00/10.
- Close, M.E. 1985.: Simulating the effects of the Waiau Irrigation Scheme on recharge and groundwater level. *Journal of Hydrology (New Zealand) 24(2): 49-63.*
- Di and Cameron (2002). The use of a nitrification inhibitor, dicyandiamide (DCD) to decrease nitrate leaching and nitrous oxide emissions in simulated grazed and irrigated grassland. *Soil Use and Management 18: 395 – 403.*
- Di and Cameron (2004). Treating grazed pasture soil with a nitrification inhibitor, eco-n, to decrease nitrate leaching in a deep sandy soil under spray irrigation – a lysimeter study. *New Zealand Journal of Agricultural Research 47: 351-361.*

Loris, P. 2000b. Hydrogeology of the Waipara alluvial basin, North Canterbury, New Zealand. Unpublished MSc thesis lodged in the Library, University of Canterbury.

Watson et. al. 2004. Drainage to groundwater under a closed-canopy radiate pine plantation on the Canterbury Plains, South Island, New Zealand. *Journal of Hydrology, New Zealand*, 43:111-123.

Weeber, J.H., Talbot, .D. 1984. Preliminary report on the groundwater resource of the Culverden Plain. North Canterbury Catchment Board and regional Water Board unpublished report.

Tonkin and Taylor, 1985. Waiau Irrigation Scheme Drainage Study. Prepared for the Ministry of Works and Development.