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SOUTHLAND

Balfour Nitrate Hotspot

REPORT PREPARED FOR ENVIRONMENT SOUTHLAND

- Final
- 30 June 2008

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1. Background

Over the last 30 years land use on the Waimea Plains between Balfour and Lumsden has generally comprised a mix of sheep, beef and arable farming. However, recent changes in land use in this area mirror that occurring in other parts of Southland with increasing areas of land being converted to dairying and dairy support.

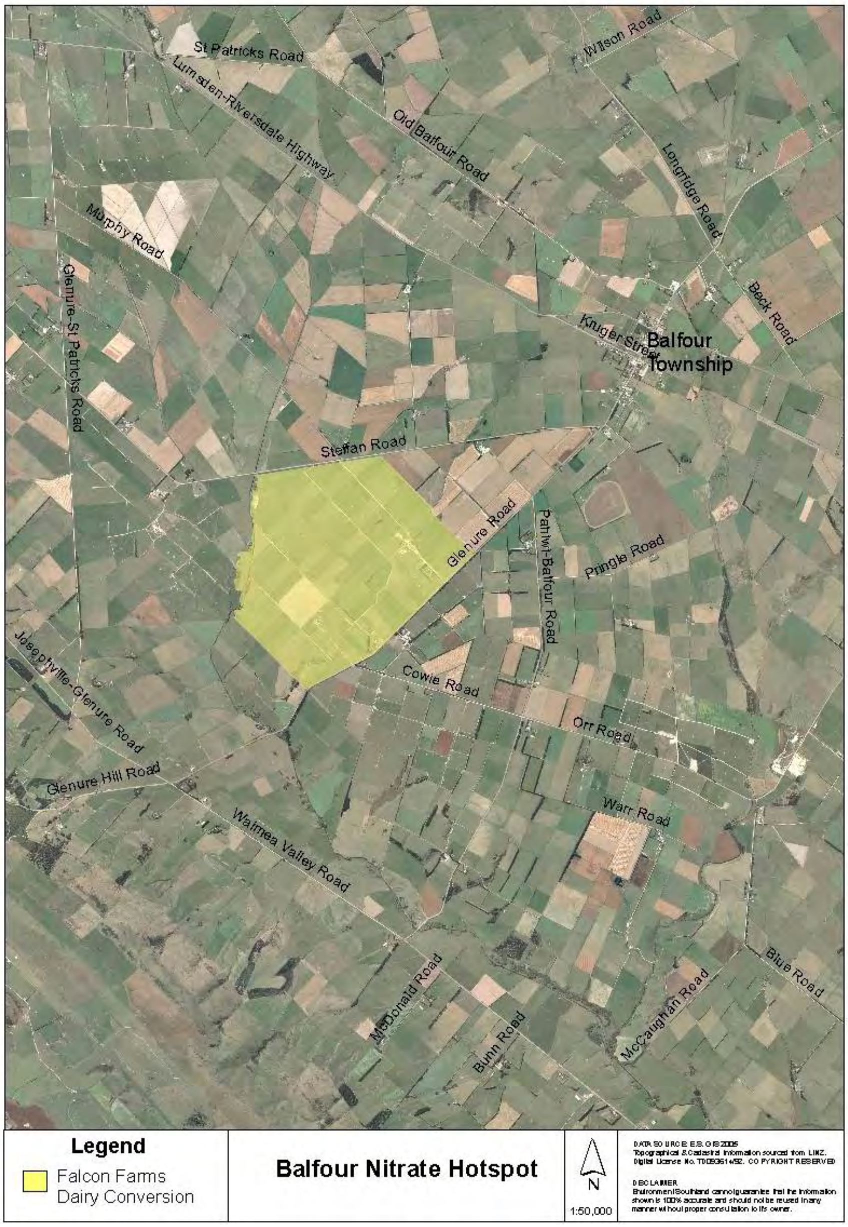
In 2001 a property extending over approximately 500 Hectares between Balfour-Dipton Road and Steffan Road was converted to two separate dairy units known as Falcon Farms 1 and Falcon Farms 2. These dairy units were granted resource consent by Environment Southland (Consent Nos. 200314 and 200349 respectively) for land application of farm dairy effluent and commenced milking in the 2001-02 season. Table 1 shows details of the relevant land parcels.

- **Table 1. Land parcel details**

Dairy Unit	Legal Description
Falcon Farms 1	Lot 1 DP3414
	Lot 5A DP716
Falcon Farms 2	Pt Section 351 Hokonui SD
	Pt Section 353 Hokonui SD

Figure 1 shows the location of the Falcon Farms dairy units in relation to the wider Waimea Plains area. The main channel of the Waimea streams runs roughly north-south over the area shown and forms the western boundary of the Falcon Farms property. A smaller tributary of the Waimea Stream also flows south-southeast across the property and joins the main channel near the Balfour-Dipton Road.

Following concern expressed by a neighbouring landowner in regard to potential impacts of dairy conversion on groundwater quality, Environment Southland commenced regular monitoring of groundwater quality and levels in E44/0036, a bore located approximately 50 metres east of the newly converted property in early 2001. Initial groundwater quality results showed groundwater nitrate concentrations of approximately 10 g/m^3. With no localised nitrate source identified near the sample point, these elevated nitrate levels were attributed to the cumulative impacts of land use across the surrounding area.



- **Figure 1. Location Map**

Compliance monitoring samples collected from E44/0046 and E44/0047, farm supply bores on the respective dairy units indicated groundwater nitrate concentrations close to, or above, New Zealand Drinking Water Standard (NZDWS) when first measured in January 2003. Combined with the elevated nitrate levels observed in E44/0036 these results prompted concern regarding the potential extent and magnitude of elevated groundwater nitrate levels in this area, given both the use of groundwater for potable supply in the local area and the contribution of groundwater discharge to baseflow in the Waimea Stream.

1.1. Land Use

The aerial photograph shown in Figure 1 was flown during the 2001-02 year. The exact timing of the photograph is uncertain however, the areas of cereal cropping (light brown areas) and clearly identifiable trough lines on the Falcon dairy units (partially obscured) indicate it is likely to have been taken in early 2002. The photograph clearly illustrates the relatively extensive areas of cereal cropping in the local area surrounding the Falcon Farms dairy units at this time.

Numerous technical papers are available describing typical nitrate leaching losses from arable farming operations (e.g. MAF, 2000). These data typically show relatively high leaching from arable farming areas with high rates of leaching occurring due to a combination of mineralisation of organic nitrogen in the soil profile and organic fertiliser inputs. Most investigations report nitrate leaching losses for arable farming in excess of 60 kg N/ha/year with many studies indicating significantly higher rates depending on individual farm management practice. In comparison, similar investigations indicate nitrate leaching losses from dairying typically range from 35 to 50 kg N/ha/year.

Based on typical nitrate leaching losses reported for arable farming and dairying, it was concluded that the Falcon Farms dairy conversion was unlikely to increase groundwater nitrate concentrations provided farming operations on the new dairy conversion were undertaken in line with best management practice (e.g. stocking rates, effluent disposal and fertiliser application).

2. Physical Setting

The Falcon Farms dairy units are located in the Waimea Plains groundwater zone approximately 2 kilometres south west of the Balfour township. This area is relatively flat-lying with a general slope of 1 to 2 degrees to the southeast following the topographic gradient of the Waimea Plain.

Mean annual rainfall in the Balfour area is 870 mm/year while potential evapotranspiration measured at Gore is around 770 mm/year giving an annual water surplus of approximately 100 mm. Monthly rainfall totals are generally lowest during winter and highest during summer although examination of available records also indicates frequent dry spells in excess of one month duration during the summer months.

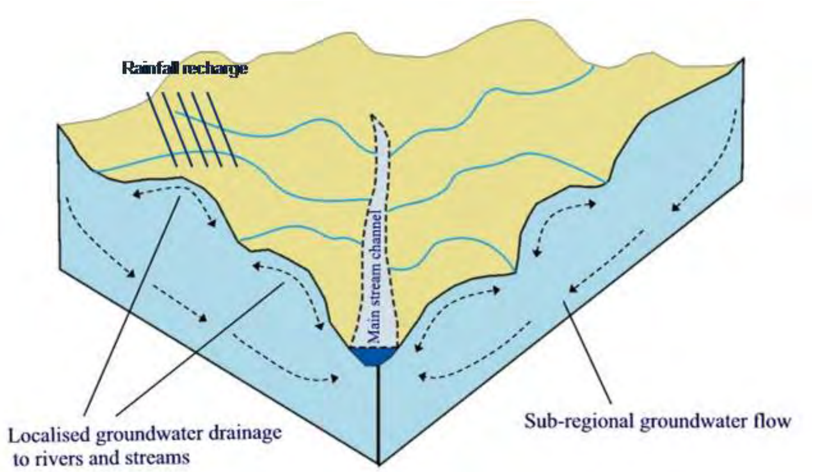
2.1. Hydrogeology

The near-surface geology of the Balfour area generally comprises poorly sorted Quaternary alluvial gravel deposits. These alluvial gravels are generally moderately weathered with abundant clay and silt in the gravel matrix, with frequent silt and clay lenses also encountered. These gravels form a thin, relatively low permeability unconfined aquifer system.

Bore logs in the Balfour area generally show basement rock (interpreted to be Tertiary mudstone and/or sandstone sediments of the East Southland Group) lies between 10 to 20 metres below ground surface. In E44/0386, a bore drilled immediately east of the Falcon Farms property, the base of the alluvial gravel sediments was encountered at a depth of approximately 15.5 metres below ground. Given groundwater levels in this area lie between 3 to 5 metres below ground, the typical saturated thickness of the unconfined aquifer is interpreted to be in the range of 10 to 12 metres.

The Tertiary sediments underlying the alluvial gravels may contain groundwater. However, due to the low permeability of the thick mudstone deposits the upper surface of these sediments is generally assumed to form the effective groundwater basement in the area with limited groundwater movement occurring between these units.

The Waimea Plains groundwater zone is classified as a Lowland aquifer. Figure 2 shows a schematic illustration of the typical hydrogeology of this aquifer type. The figure shows groundwater recharge occurs exclusively from infiltration of local rainfall. A significant proportion of this recharge drains locally to numerous closely-spaced first and second order streams. A more limited component of groundwater flows through deeper levels of the aquifer following the general pattern of catchment drainage. This conceptual model is consistent with known hydrogeological characteristics of the Waimea Plains groundwater zone.



- Figure 2. Conceptual hydrogeological model of a lowland aquifer

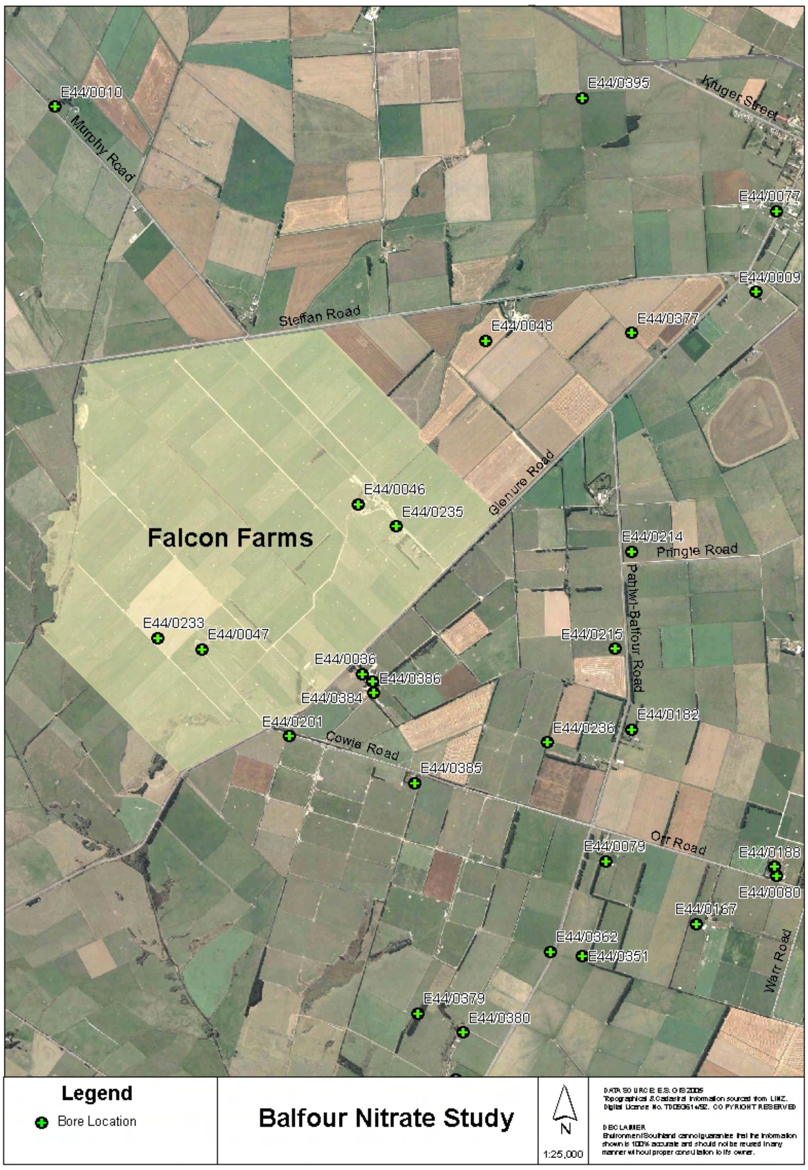
2.1.1. Bore Locations

Significant use of groundwater for both domestic and farm supply occurs in the Waimea Plains groundwater zone. Most bores are shallow (less than 10 metres) and relatively low yielding (less than 1 L/s). Figure 3 shows the location of bores in the vicinity of the Falcon Farms property currently recorded on the Environment Southland WELLS database.

The figure shows the location of E44/0046 and E44/0047 which are the supply bores for the individual Falcon Farms dairy units. Resource consents (200315 and 200350) are currently held for these bores to individually abstract up to 126 m^3/day of groundwater for dairy supply.

Figure 3 also shows E44/0214 and E44/0215 located adjacent to Pahiwi-Balfour Road. These bores are currently utilised for horticultural irrigation. Under resource consent 202279 these bores are able to be pumped at a combined rate of 900 m^3/day.

Bores E44/0036 on Balfour-Dipton Road and E44/0010 on Murphys Road are currently included in the Environment Southland baseline groundwater quality and level monitoring programs.



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- **Figure 3. Bores in the vicinity of the Falcon Farms property**

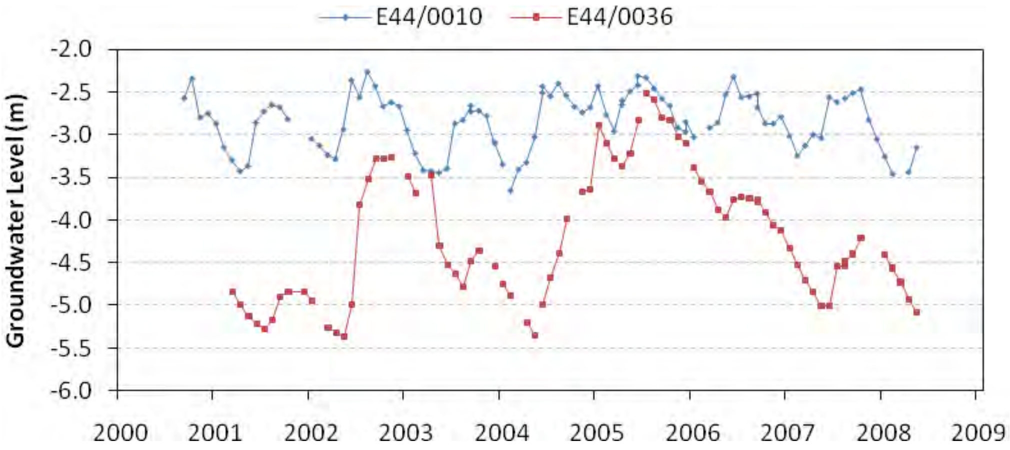
2.1.2. Groundwater Levels

Figure 4 shows a plot of monthly groundwater levels measured in E44/0010 and E44/0036 since early 2001. These data show different temporal variations in groundwater level in the respective bores over the period of record available.

In E44/0010 groundwater levels show a regular seasonal variation of approximately 1 metre with a peak between July and August and generally reach a minimum between March and April. The data from this site indicate rapid aquifer recharge during the winter months once soil moisture reaches field capacity. Groundwater levels then decline in a relatively linear fashion during summer and autumn reflecting progressive drainage of groundwater by the Waimea Stream and tributaries. Overall the data indicate little long-term variation in groundwater storage between seasons.

The groundwater level record from E44/0036, although showing a similar response to seasonal variation in soil moisture, suggests a significant carry-over of aquifer storage between seasons. This is particularly evident in the magnitude of seasonal variation observed during winter 2002 and spring 2004 when groundwater levels increased by up to 3 metres due to above average rainfall. These significant increases in groundwater level were evident for at least one to two years following.

The observed differences in groundwater levels response between E44/0010 and E44/0036 suggest a significant difference in local hydrogeological conditions between these two sites. The reason for this variation is unclear by may reflect a combination of both the local drainage pattern and the influence of local geology on groundwater flow



- **Figure 4. Groundwater levels recorded at E44/0010 and E44/0036, 2001-2008**

2.1.3. Aquifer Hydraulic Characteristics

Limited data is available to describe the hydraulic characteristics of the unconfined aquifer in the vicinity of Balfour. Aquifer testing undertaken on E44/0214 and E44/0215 for resource consent 202279 indicate the unconfined aquifer has a relatively low permeability. Although aquifer test information is somewhat inconclusive the available data indicate an aquifer transmissivity of the order of 200 to 300 m^2/day.

Similarly, an aquifer test undertaken by Environment Southland in 2007 on E44/0351 indicated an aquifer transmissivity of the order of 300 to 400 m^2/day. The test data indicated a low storage coefficient for the aquifer indicating at least partial confinement. It is uncertain if the low storage value derived from the test indicates localised aquifer confinement or is an artefact of the data collected (possible due to the degree of heterogeneity and weathered nature of the alluvial gravel materials).

2.1.4. Groundwater Flow

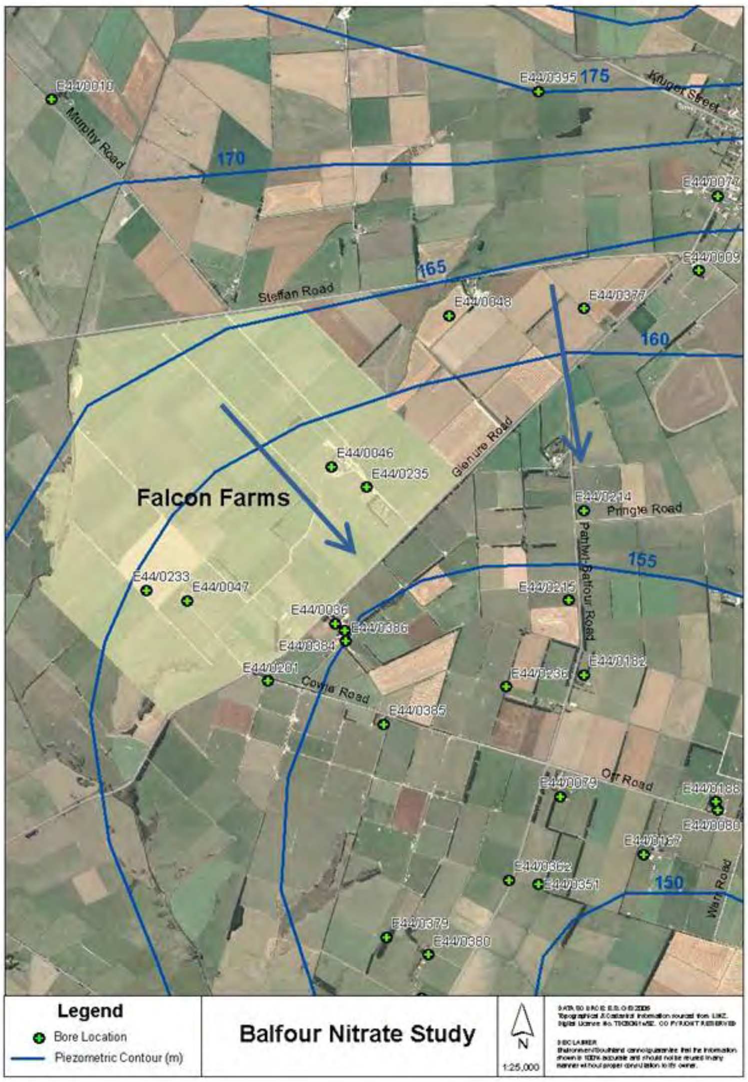
In February 2002 Environment Southland undertook a piezometric survey across the Waimea Plains. This survey included measurement of reduced groundwater elevation in approximately 120 bores distributed from Mandeville to Lumsden. In the Balfour area survey results indicate a relatively complex picture with groundwater flow strongly influenced by a combination of topography and geology in the Longridge area.

Figure 5 shows piezometric contours interpreted in the Balfour area. These data indicate groundwater flow in a south easterly direction in the vicinity of the Falcon Farms dairy units with a gradient of approximately 0.004.

Assuming an average saturated thickness of 10 metres and an aquifer transmissivity of 300 m^2/day, representative hydraulic conductivity is estimated to be of the order of 30 m/day. Combining this estimate with the interpolated piezometric gradient of 0.004 and a porosity of 0.25, seepage velocity through the unconfined aquifer is calculated applying Darcy’s Law at 0.48 metres per day (or approximately 175 metres per year).

This velocity represents an estimate of the bulk flow rate through the aquifer system whereas, in reality, there is likely to be significant difference in seepage velocity due to heterogeneity within the alluvial gravel aquifer system. However it does provide an indication that the bulk rate of groundwater flow through this section of the Waimea groundwater zone is relatively slow. This suggests that groundwater quality impacts resulting from land use will migrate downgradient (i.e. in a south easterly direction) at a relatively low rate.

The low rate of groundwater flow increases the vulnerability of the unconfined aquifer to the cumulative impacts of surrounding land use due to the low rate of dilution available within deeper levels of the unconfined aquifer. This is illustrated by the sub-regional component of groundwater flow shown in Figure 2.



■ Figure 5. Piezometric contours and interpreted groundwater flow direction in the Balfour area.

2.1.5. Groundwater Isotope Studies

Groundwater isotope samples were collected in May 2002 from E44/0010 and E44/0036. Samples were analysed for both oxygen-18 ($\delta^{18}O$) nitrogen-15 ($\delta^{15}N$) stable isotopes.

Oxygen occurs naturally in two stable isotopic forms; Oxygen-16 and Oxygen-18. Both isotopic forms occur naturally as constituents of water molecules however, the ratio between the two forms is affected by atmospheric temperature which in turn is strongly influenced by altitude. As a result, the ratio between the two isotopic forms can be used to distinguish precipitation from different altitudes and assist identification of recharge sources.

Results of the $\delta^{18}O$ measurements show consistent values of -8.44 in E44/0010 and -8.36 in E44/0036. These results are similar to other values derived from shallow bores on the Waimea Plain and indicate local rainfall recharge is the predominant recharge source.

Similarly nitrogen naturally occurs in two isotopic forms; Nitrogen-14 and Nitrogen-15 and the ratio between these forms can be used as a general indicator to distinguish nitrogen source. As a general rule, $\delta^{15}N$ values in groundwater <5 reflect input from artificial fertiliser while values between 5 to 10 reflect soil mineralisation (breakdown of organic material within the soil zone) and values >10 indicate an animal effluent source.

$\delta^{15}N$ values observed across the Waimea Plain were generally in the range of 5 to 7 indicating soil mineralisation possibly with some fertiliser input as the main nitrogen sources. The $\delta^{15}N$ value of 5.7 observed at E44/0036 was consistent with this pattern while the value of 20.0 at E44/0010 indicated an animal source (groundwater nitrate levels at the time of sampling were 10.0 g/m^3 in E44/0036 and 1.6 g/m^3 in E44/0010).

A later $\delta^{15}N$ sample collected from E44/0036 in March 2007 showed a value of 4.3. This value is slightly lower than that recorded in May 2002. It is uncertain if the difference in $\delta^{15}N$ values between the two samples reflects natural variability or the transition to a more fertiliser dominated N source following the conversion to dairying on the Falcon Farms property.

A tritium sample collected from E44/0036 in March 2007 indicated a groundwater residence time of 3 to 7 years. This suggests that the minimum time between changes in land use and corresponding variations in groundwater quality in this area is likely to be in excess of 5 years.

Overall, the limited stable isotope data available indicate recharge to the Waimea Plains groundwater zone is exclusively derived from local rainfall while nitrogen sources are generally consistent with a combination of pastoral and arable land use in the area.

2.2. Soil Types

The Topoclimate soil map of the Balfour area is shown in Figure 6 below. The map shows the bulk of the soils on the Falcon property are Crookston soils with Waikoikoi soils present toward the southern property boundary. Dipton soils are also present adjacent to the main stem of Waimea Stream and the tributary that flows north-south across the eastern margin of the property. The main physical properties of these soils are summarised in Table 2.

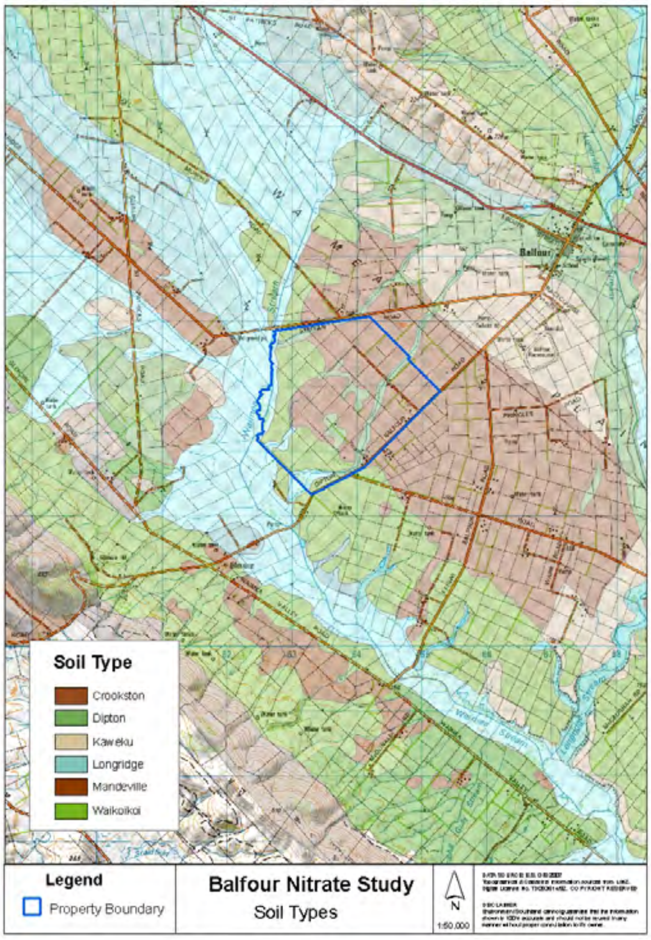


Figure 6. Soil map of the Balfour area

Table 2. Summary of physical characteristics of soils present on the Falcon property

Soil Type	Texture	Physical Characteristics	Vulnerability
Crookston	Light silt loam	Well drained soil with compact subsoil which may cause short-term waterlogging after heavy rainfall	Moderate vulnerability to structural compaction and nutrient leaching
Dipton	Heavy silt loam	Shallow soils with firm clay-enriched subsoil that is slowly permeable resulting in poor internal drainage and perching of water	Severe structural compaction and waterlogging risk, slight nutrient leaching risk
Waikoikoi	Silt loam	Poorly drained soil with a dense fragipan that restricts internal drainage	Very severe structural compaction risk, severe waterlogging risk, slight leaching risk

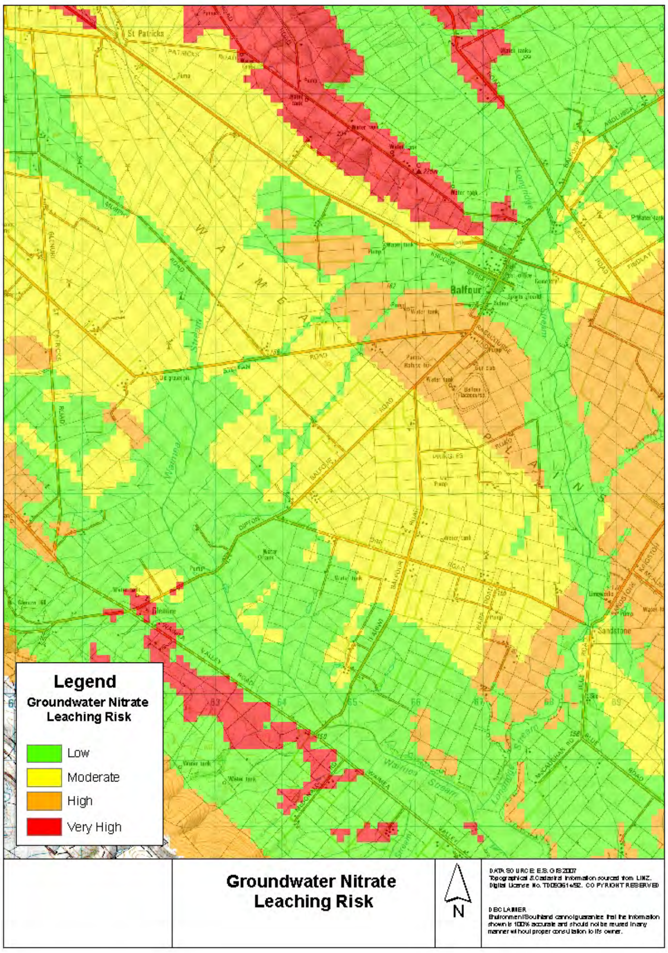
The main soil physical characteristic of note on the Falcon property is the well drained nature of the Crookston soils. The lack of internal drainage restriction in this soil type means soil moisture infiltrates relatively readily from the land surface to the underlying aquifer meaning there is limited requirement for artificial drainage by mole and tile drains which is likely to be required on the relatively restricted areas of poorly drained Dipton (and possibly restricted areas of Waikoikoi) soils adjacent to the Waimea Stream. The internal drainage characteristics of these soil types have two main implications for land use activities on the Falcon property:

- The lack of surface drainage and the relatively well drained nature of the Crookston soils increase the potential for nutrients (in particular nitrate) to be leached through the soil profile into underlying groundwater; and,
- The lack of surface drainage and limited areas requiring artificial drainage reduces the potential for microbial contaminants and phosphorus to be transported to the Waimea Stream.

2.3. Groundwater Leaching Risk

In 2007 Environment Southland completed a regional assessment of groundwater nitrate risk associated with land application of farm dairy effluent (FDE) as part of a combined assessment of potential groundwater and surface water quality risks associated with FDE disposal.

This assessment combined factors relating to source risk (nitrate leaching vulnerability), transport risk (soil moisture variability) and receiving environment risk (hydrogeological characteristics and historic land use) to produce a weighted ranking in GIS format. Figure 7 shows the final groundwater nitrate risk ranking for the Balfour area. This identifies a majority of the area where elevated groundwater nitrate have been identified as moderate risk.



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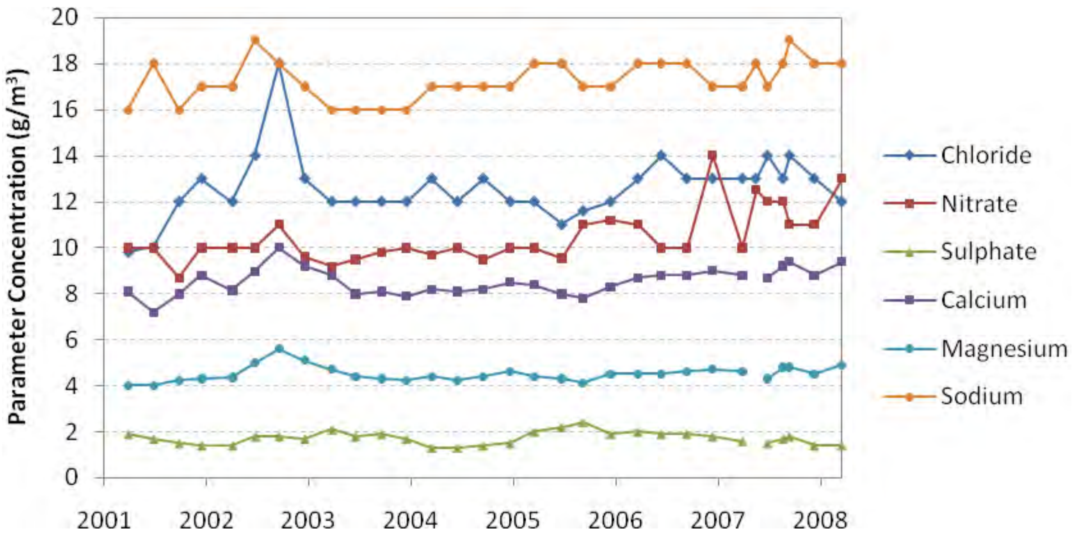
- **Figure 7. Groundwater nitrate leaching risk in the Balfour area**

3. Groundwater Quality Monitoring

3.1. Baseline Groundwater Quality Monitoring

Groundwater quality has been monitored on a quarterly basis at E44/0036 since early 2001. As shown in Figure 8, the concentrations of major ions over this period have remained relatively stable. In general, groundwater quality at this site is typical of much of the Waimea Plains groundwater zone. The concentrations of major ions are generally low, with groundwater characterised as sodium-bicarbonate type waters, typical of groundwater with a low residence time in relatively inert aquifer media.

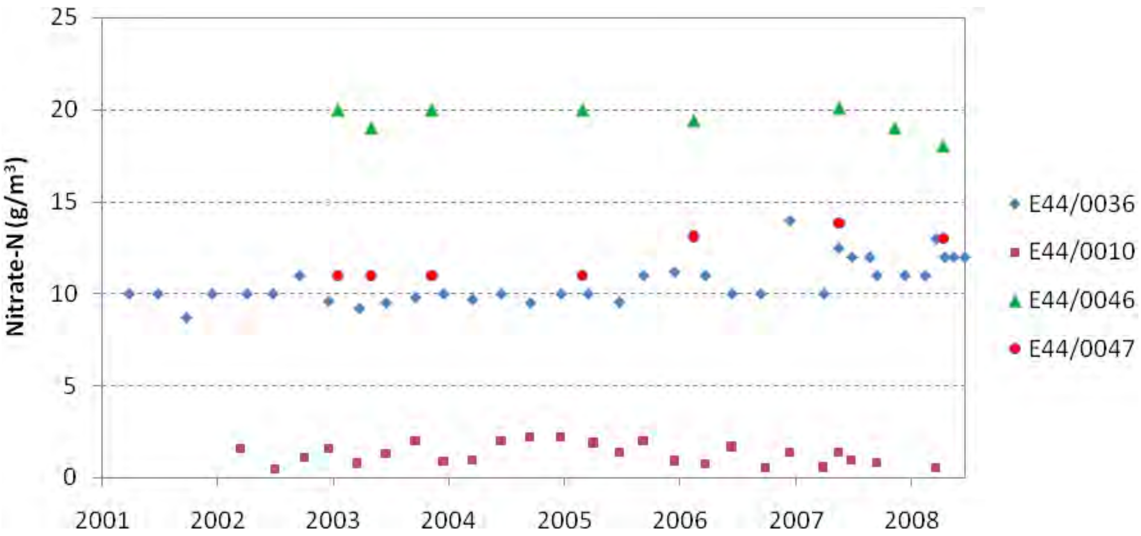


- **Figure 8. Groundwater quality at E44/0036, 2001-2008**

The main feature of observed groundwater quality in E44/0036 is the elevated nitrate-nitrogen concentration which, since late 2005 has increased from 10 g/m^3 to around 12 g/m^3 in recent samples (peaking at 14 g/m^3 in December 2006). Recent analysis indicates this variation represents a statistically significant increasing trend of between 0.25 to 0.3 g/m^3/year.

3.1.1. Groundwater nitrate concentrations

In addition to E44/0036, quarterly groundwater nitrate concentrations have been measured in E44/0010 since early 2002. Groundwater nitrate data are also available at semi-regular intervals from E44/0046 and E44/0047, the dairy supply bores on the Falcon 1 and Falcon 2 dairy units respectively. These data are shown in Figure 9 below.



- **Figure 9. Nitrate-Nitrogen concentrations in groundwater surrounding Falcon Farms**

The data show groundwater nitrate concentrations are significantly elevated above NZDWS MAV (11.3 g/m^3) in E44/0046 located on the Falcon 1 (northern) dairy unit. Concentrations in this bore were generally between 19-20 g/m^3 from 2003 to 2007, although recent data indicate a slight decline to around 18 g/m^3. Nitrate concentrations in E44/0036 and E44/0047 (the Falcon 2 dairy unit) show a similar temporal variation with relatively stable concentrations of approximately 10 g/m^3 between 2001 to 2005 increasing to around 12 g/m^3 by mid-2007. Nitrate concentrations in the remaining bore (E44/0010) remained less than 2 g/m^3 over the period 2002 to 2008. None of the bores measured (with the possible exception of E44/0010) show any clear seasonal variations in groundwater nitrate concentrations.

Overall the nitrate monitoring data indicate groundwater nitrate concentrations close to or above NZDWS in three of the four bores regularly monitored in this area. Some temporal changes in nitrate concentrations are observed in E44/0036 and E44/0047 with levels (and variability) appearing to have increased by up to 2 g/m^3 between 2005 and 2007.

3.1.2. Snapshot nitrate survey

In order to improve definition of the extent and magnitude of elevated groundwater nitrate levels Environment Southland undertook a snapshot survey in May 2007. This survey involved collection of samples from 6 bores in the local area along with samples from the Waimea Stream at Murphys Road and Balfour-Dipton Road. Results are shown in Figure 10 below.

■ **Figure 10. Groundwater snapshot survey results, May 2007.**

Results of the survey showed groundwater nitrate levels were less than 2 g/m^3 in bores E44/0010 and E44/0076 located northwest and southwest of the Falcon Farms property respectively. In contrast, nitrate levels were measured at around 12 g/m^3 in E44/0036 and E44/0236 located up to 1 kilometre east of the Falcon Farms property.

Water quality samples collected from Waimea Stream also show considerable downstream variation. Samples at Murphys Road showed a nitrate concentration of 1.6 g/m^3 and a chloride concentration of 12 g/m^3. These concentrations almost doubled to 2.8 and 26 g/m^3 respectively at Balfour-Dipton Road, approximately 4.5 kilometres downstream. The downstream chloride concentration are higher than that typically observed in Waimea Plains groundwater but consistent with values observed in the Falcon Farms bores. These data indicate that groundwater discharge is a major influence on surface water quality in this section of the Waimea Stream.

3.2. Summary

Based on the observed spatial and temporal variation in groundwater quality and the interpreted hydrogeology of the local area, the following conclusions are reached with regard elevated nitrate concentrations in groundwater in the Balfour area:

- The area affected by elevated groundwater nitrate levels appears to be extend from Steffan Road in a south-easterly direction at least as far as the Cowie Road/Pahiwi-Balfour Road corner, a downgradient distance of approximately 4 kilometres;
- The nitrate 'hotspot' appears to be bounded to the west by the main stem of the Waimea Stream. The northern extent of the affected area does not appear to extend north of the Steffan Road/Balfour-Dipton Road corner as groundwater quality samples from E44/0007 collected between 2000-04 show groundwater nitrate concentrations in the range of 3 to 6 g/m^3;
- Samples taken from E44/0036 in 2001, prior to the dairy conversion on the Falcon Farms property, indicate elevated groundwater nitrate concentrations (approximately 10 g/m^3) in the area. These concentrations are assumed to reflect the impact of existing land use (cereal cropping) in the upgradient area;
- Groundwater nitrate levels appear to increase in E44/0036 in mid-2005. If this change is attributed to the impact of dairy transition on the Falcon Farms property, it appears unlikely that the nitrate level of 11.9 g/m^3 observed in E44/0236 in May 2007 can be attributed to the same source. These bores are located in excess of 1 kilometre apart and (at an average seepage velocity of 175 m/year) it is likely to take in excess of 5 years for groundwater to travel over the intervening distance. It is therefore inferred that the nitrate concentration in E44/0236 is likely to reflect either the impact of landuse prior to the Falcon Farms dairy conversion or localised groundwater contamination;
- The groundwater nitrate concentration in E44/0046 has remained at approximately 20 g/m^3 since first monitored in early 2003. It would appear unlikely that the nitrate concentration in this bore could have reached such elevated levels less than 2 years after dairy conversion and

remained constant for the remaining period if it reflects short-term effects of surrounding land use. This may suggest that nitrate levels in this bore again either reflect localised contamination or land use effects prior to dairy conversion;

- Groundwater nitrate concentrations in the area have remained relatively stable over the period 2001-05, the major change observed over the subsequent period being an increase from approximately 10 g/m^3 to 12 g/m^3 observed in E44/0036 and E44/0047;
- The limited temporal (and seasonal) variability in observed nitrate concentrations indicates that groundwater quality in the local area is relatively insensitive to short-terms variations in land use and aquifer recharge. It is noted that the observed variation in groundwater quality in E44/0036 and E44/0047 in late 2005 occurs approximately 4 years after the conversion of the Falcon Farms property to dairying;
- The observed variation in groundwater nitrate levels in E44/0036 and E44/0047 also corresponds to a period of high aquifer recharge (late 2004 and early 2005) and subsequently elevated groundwater levels. This increased groundwater recharge may have resulted in increased leaching rates and resulted in greater circulation of water via sub-regional groundwater flow illustrated in Figure 2;
- Water quality in the Waimea Stream appears to be significantly influenced by groundwater inputs.

Overall, the Balfour nitrate ‘hotspot’ represents an area in excess of 10 square kilometres in the Waimea Plains groundwater zone where groundwater nitrate levels in the shallow unconfined aquifer are close to, or above, drinking water standards.

The occurrence of elevated nitrate levels in this area appears to reflect the impact of historical arable farming on groundwater quality and pre-dates large-scale dairy conversion in the area. The impact of more recent dairy conversion on groundwater nitrate levels is uncertain. Increases in nitrate concentrations observed since 2005 may reflect the impact of the nearby dairy conversions (in particular increased nitrate leaching during the transition period) or, alternatively, result from changes in the rate of groundwater recharge and aquifer throughflow in early 2005.

4. Discussion

The following section discusses a range of observations that may be drawn from the Balfour nitrate hotspot example. These observations include the application of existing monitoring and information management tools as well as ways to potentially manage land use to avoid, remedy or mitigate similar occurrences elsewhere in the Southland Region.

4.1. Assessment of groundwater nitrate leaching risk

In 2007 Environment Southland completed an assessment regional scale assessment of the potential groundwater leaching risk associated with land application of farm dairy effluent. This risk assessment was derived from a weighted overlay of factors contributing to source risk (mainly soil characteristics), transport risk (mainly related to soil moisture variability) and receiving environment risk (hydrogeology and historical land use).

In the Balfour area, while the receiving environment risk was calculated as being high to very high, the overall groundwater nitrate leaching risk was moderated to moderate by the source risk and transport risk components of the assessment. This illustrates the limitations of applying a regional-scale assessment to estimation of localised risk where, in this case, the receiving environment risk may contribute more to the overall nitrate leaching risk than in other physical and hydrogeological settings.

4.2. Impact of historical land use on existing groundwater quality

The Balfour hotspot provides a useful example of the potential time-lags observed between land use and resulting impacts on groundwater quality. In this case it appears that groundwater nitrate levels were elevated in response to a long history of arable farming in the local area. Due to the relatively low rate of groundwater circulation through deeper parts of the unconfined aquifer the resulting impacts may remain for an extended period. As a result it is not clear from the available data of the observed nitrate concentrations reflect historical (cropping) or recent land use (dairying) or a combination of the two.

The potential time-lag between land use and resulting impacts on groundwater quality has been observed elsewhere in Southland. Groundwater age dating undertaken in 2002 suggested the mean residence time for groundwater sampled in a majority of baseline groundwater monitoring sites was in excess of 10 years. Based on this data it is assumed that impacts of recent land use intensification (dairy conversion, dairy support and horticulture) are yet to be observed in many regional monitoring bores.

4.3. Land use transition

In terms of potential nitrate sources, both arable farming and dairying have the potential to result in significant nitrate leaching losses depending on farm management practices adopted. However, whereas a significant component of leaching losses from arable farming occurs through soil mineralisation, those occurring from dairying are more result from urine patches deposited by grazing animals or fertiliser application. As a result, the transition from arable farming to dairying may represent a particularly high risk period for nitrogen leaching with continued losses from dairy farming operations added to ongoing soil mineralisation.

4.4. Identification of potential nitrate hotspot areas

In the Balfour area the main factors contributing to elevated nitrate levels observed are interpreted to be:

- The lowland aquifer setting - a low permeability unconfined aquifer recharged exclusively by local rainfall infiltration with relatively low rates of groundwater circulation through deeper levels of the aquifer; and,
- A relatively long history of intensive land use (in this case cereal cropping and more recently intensive dairying).

It is interesting to note that in regard these factors the Balfour nitrate hotspot appears to be similar in origin and nature to that observed in the Oreti Plains area. In both cases, elevated groundwater nitrate levels measured in bores screened below the seasonal water table appear to reflect historical land use with some possible input from more recent land use.

These observations may suggest that the potential for elevation of nitrate concentrations in shallow groundwater may be increased in situations where underlying aquifers are relatively low permeability, groundwater recharge occurs exclusively from local rainfall infiltration and there is a history of intensive land use (particularly cereal cropping but into the future dairying) in the surrounding area.   This observation illustrates the importance of having good land use data to enable characterisation of groundwater nitrate leaching risk. The lack of historical land use data was one of the limiting factors identified in the regional groundwater nitrate leaching risk assessment completed in early 2007.

In terms of overall risk assessment, both the Balfour and Oreti nitrate hotspot examples may also indicate that an increased weighting on receiving environment risk is required for lowland aquifers.

As an interim measure it is therefore recommended that consideration of the potential nitrate leaching risk in lowland aquifers is based on the calculated receiving environment risk with particular emphasis on areas where there has been historical high intensity land use in the local area. When considering applications for land use or effluent discharge, areas identified as high risk should be verified by the collection of groundwater quality samples prior to determination of the ultimate receiving environment quality.

4.5. Management response

The Balfour nitrate hotspot illustrates the potential for different land uses including both cereal cropping and dairying to have a significant impact on groundwater nitrate levels. As a result, management of areas where elevated nitrate levels are identified requires management controls which can be applied across a range of land use types. These management controls are required to ensure that existing groundwater nitrate issues are not exacerbated by current and future land use.

It is therefore recommended that policy be developed to enable an appropriate management response were an area is identified as either having an existing groundwater nitrate issue or where the risk of potential groundwater nitrate leaching is determined to be high (i.e. vulnerable hydrogeological setting but where historical land use has been relatively low intensity). Such policy should apply to all land use activities that may contribute to the problem (rather than be restricted to the land disposal of FDE) and require landowners in the affected are to submit to the Regional Council:

- A nutrient budget detailing relevant the impact of aspects of farm operation in terms of potential nitrate leaching;
- A farm management plan detailing management of farming operations to ensure leaching losses are maintained at a level which will result in groundwater nitrate levels remaining (or reducing to within) required standards. Measures covered may include stocking rates, timing of cultivation, fertiliser usage, use of supplements,

These measures should apply to all land uses including arable farming, drystock farming and dairying and require updating if there is any significant change in land use. Particular attention is required where there is a transition from one intensive land use type to another to ensure suitable farm management practices are adopted to avoid elevated nitrate leaching losses during the transition period.

Overall it is suggested that to effectively manage the potential for land use impacts on groundwater quality that Environment Southland develop appropriate policy and associated technical tools to identify and manage nitrate hotspot areas. This may involve:

- Refinement of technical tools (and/or monitoring) to identify high risk areas;
- Confirmation of environmental risk in high risk area by on-site investigations including groundwater quality sampling and soil assessments
- Identification of required performance standards for agricultural and horticultural operations in high risk areas;

- Requirements for landowners in affected areas to prepare nutrient budgets and farm management plans to mitigate potential nitrate leaching impacts particularly during the transition phase between alternative high intensity land use; and
- Ongoing monitoring of groundwater quality to ensure management controls adopted effectively avoid or remedy any significant elevation of groundwater nitrate concentrations.

4.6. Groundwater quality impacts on surface water

Data collected during the May 2007 snapshot survey as well from more regular monitoring undertaken by Environment Southland clearly indicate that groundwater quality has a direct impact on water quality in the Waimea Stream. This information clearly demonstrates changes in groundwater quality as a result of land use are likely to have a corresponding impact on surface water quality. As a result, management of groundwater quality in terms of relevant objectives outlined in the Regional Freshwater Plan (i.e. within New Zealand Drinking Water Standards) may not be consistent with equivalent policy objectives for surface water which seek to avoid any deterioration in water quality.

5. Summary

Identification and management of existing and future land use impacts on groundwater quality presents a significant resource management challenge due to both the time lags involved and uncertainty associated with the heterogeneity inherent in all aquifer systems. However, failure to place appropriate management controls on existing land use risks potential future impacts on groundwater quality, particularly in high risk hydrogeological settings.

The Balfour nitrate hotspot provides a useful example of the issues surrounding the management of land use impacts on groundwater quality. In this case a pre-existing land use (cereal cropping) appears to have resulted in significant elevation of groundwater nitrate concentrations over a relatively large area. This situation may have been exacerbated by the relatively recent transition from arable farming to dairying over part of the affected area.

This situation highlights the need for Environment Southland to have in place appropriate policy and technical tools to:

- Identify areas vulnerable to land use impacts on groundwater quality;
- Characterise the receiving environment (soil and groundwater) and identify appropriate performance standards for agricultural and horticultural land use; and,
- Place appropriate controls on land management to ensure resulting environmental impacts are consistent with stated policy objectives; and,
- Ensure sufficient recognition of the potential for changes in groundwater quality to impact on surface water quality.

6. References

Environment Southland & SKM (2007); *Farm Dairy Effluent: Water Quality Risk Assessment.* Publication number 2007-06

MAF (2000); *Implications of Groundwater Nitrate Standards for Agricultural Management*. MAF Technical Paper 2000/15, May 2000.

Ministry of Health (2005); *Drinking Water Standards for New Zealand*