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Review of groundwater quality monitoring results from the Heenans Corner nested piezometer site

1.   Introduction

Environment Southland installed a nested (multi-level) piezometer well on the Westlake property at Heenans Corner as a permanent groundwater monitoring site in early 2005. The piezometer was constructed to allow groundwater quality sampling at discrete depth intervals between 3 and 15 metres below ground. The objective of this monitoring was to investigate temporal variations in groundwater quality through the upper levels of a typical lowland aquifer system in order to provide a better understanding of the relationship between intensive land use and resulting impacts on groundwater quality.

Since 2005 the piezometers have been sampled on a regular basis for nutrients and major ion chemistry with the intention of developing a data set that can be used to assess the impacts of land use on groundwater quality, particularly with regard groundwater nitrate concentrations.

2.   Physical Setting

The site is located is located on the Central Southland Plains near Heenans Corner. The surrounding area comprises gently undulating topography with minimal topographic relief. Land use is relatively typical for the area and includes mainly non-irrigated dairy farming with some dryland sheep and cattle grazing. The monitoring well is situated on within an area of grazed dairy pasture understood to be subject to a typical fertilisation regime (150 to 200 kg N/ha/yr plus maintenance applications of lime and trace minerals) with a stocking rate of slightly over 3 cows/hectare. **Figure 1** shows the location of the Heenans Corner monitoring site (E44/0330).
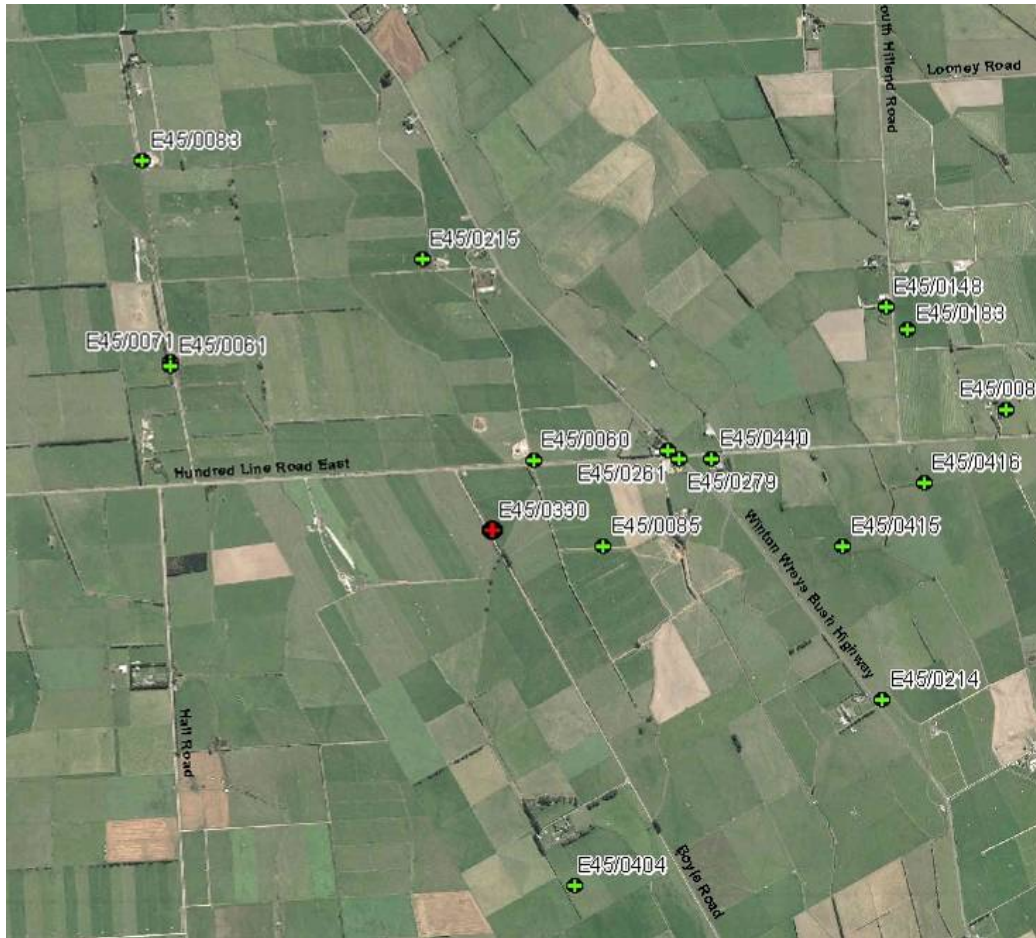
■ **Figure 1. Location of Heenans Corner monitoring site (E44/0330) and surrounding bores**

The sampling site is located in the Central Plains groundwater zone. This area is classified as a Lowland aquifer system and is typical of many of the intensively farmed areas across the Southland and Waimea Plains. The subsurface geology consists of a typical sequence of poorly sorted sand and gravel deposits with varying amounts of silt and clay present within the gravel matrix. These sediments host a shallow unconfined aquifer system which is recharged from local rainfall and in turn discharges water to the numerous first and second order streams that cross the area.

Figure 2 shows a plot of groundwater level measured in the shallowest (3 metre) piezometer, as well as with rainfall recorded at the Heenans Corner site since late 2005. These data show a seasonal groundwater level variation of up to 1.2 metres and indicate a relatively rapid increase in groundwater levels following individual rainfall, events particularly during winter and spring when soil moisture levels are close to field capacity.
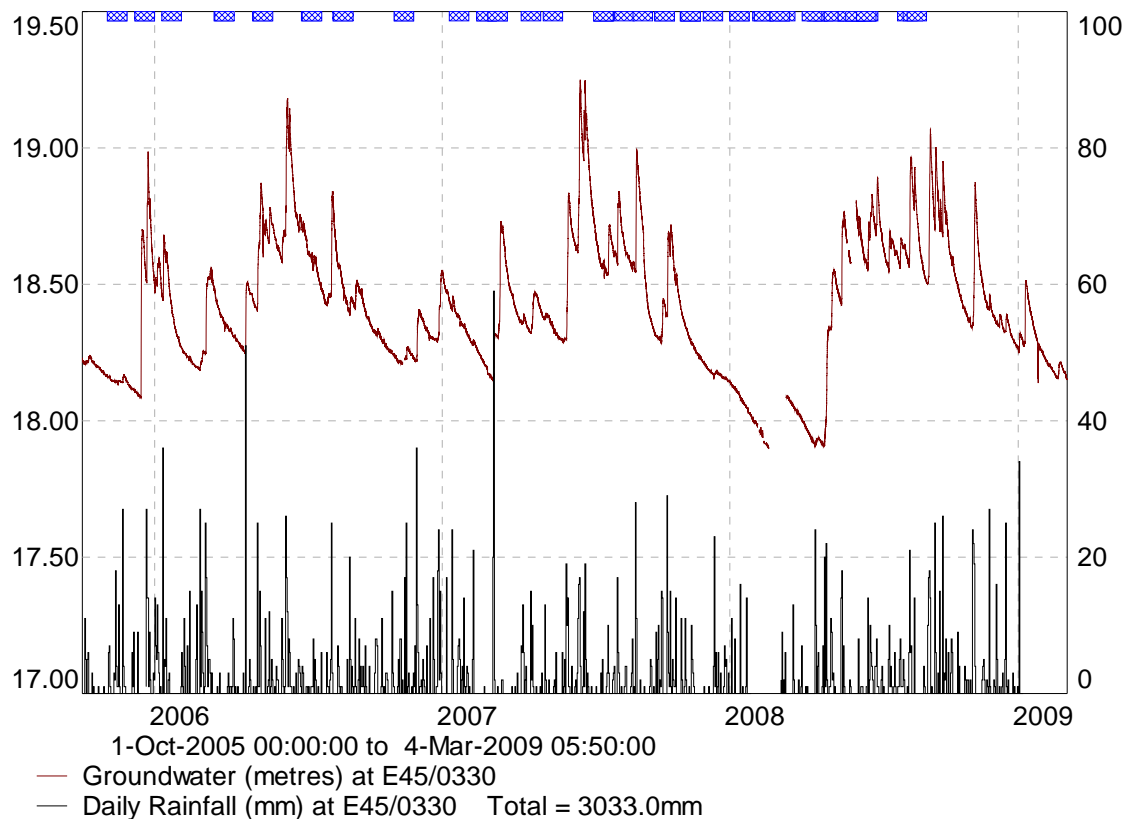
Figure 2. Daily rainfall totals and groundwater level in the 3 metre piezometer at the Heenans Corner monitoring site, 2005-2009

Figure 2 also shows periods of steady decline in groundwater levels during summer and autumn. The progressive decline in groundwater levels during this period is interpreted to reflect groundwater discharge to local streams such as the un-named tributary of Terrace Creek which flows approximately 100 metres south of the Heenans Corner site.

3. Background to the Investigation

The observed temporal variations in groundwater level observed at the Heenans Corner site are consistent with the conceptual model developed for Lowland Aquifers. As shown in **Figure 3** this model suggests two main components of groundwater flow in this hydrogeological setting:

▪ Localised drainage of shallow groundwater to rivers and streams representing a significant component of the overall aquifer water budget; and,

▪ Sub-regional groundwater flow through deeper parts of the aquifer system comprising a relatively minor component of the aquifer water budget.
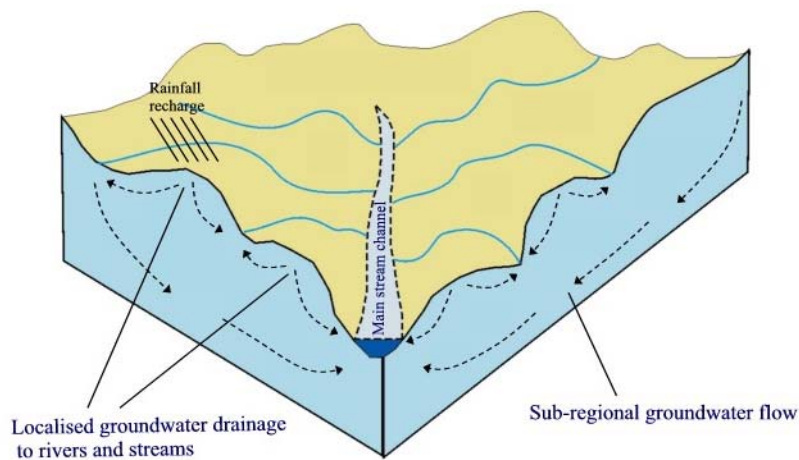
- **Figure 3. Conceptual model of groundwater flow in a Lowland aquifer system**

In terms of groundwater quality it was anticipated that while shallow groundwater in Lowland aquifers would reflect the effects of land use intensification on a relatively short-term basis, deeper levels of the aquifer system would show an increasing time lag between land use and resulting impacts on groundwater quality due to the relatively slow circulation of groundwater through deeper levels of the saturated aquifer.

The overall intention of the Heenans Corner investigation was collect field data improve understanding of the relationship between changes in land use and resulting impacts on groundwater quality. It was anticipated that monitoring results would contribute to an improve understanding of the nature of groundwater flow in an aquifer system typical of many of the more intensively farmed areas of Southland. In particular, it was hoped that data would assist characterisation of the conceptual hydrogeological model in regard the rate of groundwater circulation through various depths of the aquifer system.

4. Well Construction and Sampling Details

4.1 Well Construction

The well completion report[1] indicates that the mutil-level sampling well at Heenans Corner was constructed using five 75 mm diameter PVC piezometers installed into a 600 mm diameter bore hole to depths of 3 m, 6 m, 9 m, 12 m and 15 m below ground level (bgl) respectively. Each piezometer is screened across a 1 metre interval at the base of the well and the screens covered with filter cloth. The annulus surrounding the screened intervals was packed with clean filter media (Walton Park gravel) and a 1.5 metre betonite clay plug placed between each screened interval to prevent vertical flow.

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[1] Report on Heenans Corner Nested Piezometer. Report for Environment Southland prepared by MWH, April 2005.

4.2 Groundwater Sampling

Sampling of the piezometers has been undertaken since May 2005 through to the present, with a data set consisting of up to 18 data points for each piezometer. Analysis has been undertaken for major ions and nutrients including nitrate, ammonium and dissolved reactive phosphorus. In the data provided by Environment Southland there were 49 samples with complete set of major ion analysis and a further 26 samples with partial analysis.

The sampling methodology developed by Environment Southland indicates that, on the day prior to sampling, each well is purged of at least three bore volumes of water to ensure the water in the wells is representative of in situ groundwater. Purging is achieved by pumping and during this process the water level in each well is not allowed to drop within 2 m of the screen. This is done to avoid any geochemical changes that might occur in the aquifer as a result of exposure to the atmosphere. On the day following purging, sampling is undertaken by pumping from each interval at a low rate to avoid disturbance of the water column and minimise sediment entrainment. Prior to sampling the pump is run for an extended period to the potential for minimise cross-contamination between the piezometers via the pump and sampling tube.

4.3 Data Quality (Charge Balance Error)

Charge balance error was determined for the major ion chemistry of each sample by comparing total cations with total anions after the reported concentrations were converted to milli-equivalents using the standard formula:

$$\text{Error (\%)} = ((\textstyle\sum \text{cations} - \sum \text{anions}) / (\sum \text{cations} - \sum \text{anions})) \times 100 \qquad \text{(Eq. 1)}$$

Results of this analysis indicate samples with a complete set of major ionic data have charge balance errors ranging from 5 to 25 %, with an average value of 16 % (compared to the generally accepted limit of +/- 5 %). With the exception of one sample, the magnitude of the charge balance error was above the acceptable limit in all analyses. As shown in **Figure 4,** all samples show an overbalance in favour of the cations, which suggests that not all significant anions are represented in the ion balance calculation. This suggests that either there is a significant anion that is not included in the major ion analysis suite, or that there is a consistent data quality issue related to sample storage or laboratory analysis.
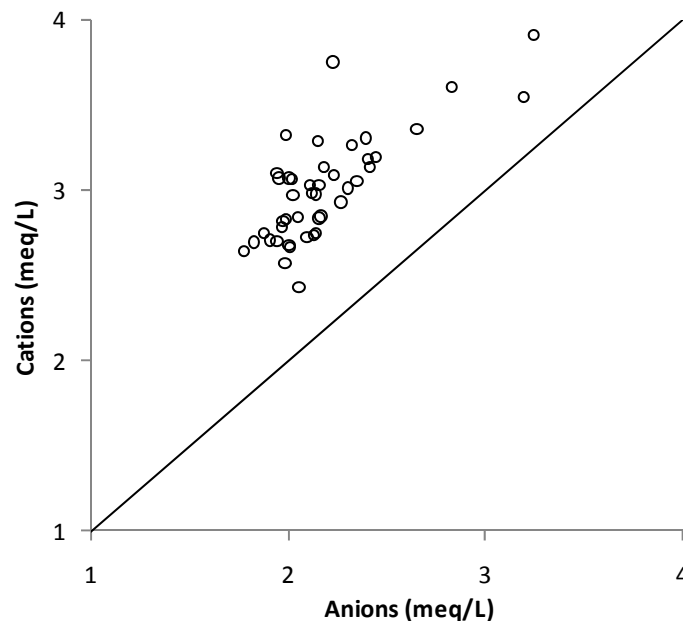
■ **Figure 4. Calculated ion balance for samples from the five piezometers installed in E45/0330. The solid line represents equal contributions from cations and anions.**

5. Results and Discussion

The following sections are intended to provide a summary and basic interpretation of groundwater quality monitoring results from E45/0330. The discussion is not intended to provide a detailed analysis of geochemistry at the site but rather provide an assessment with regard the overall objectives of the sampling program.
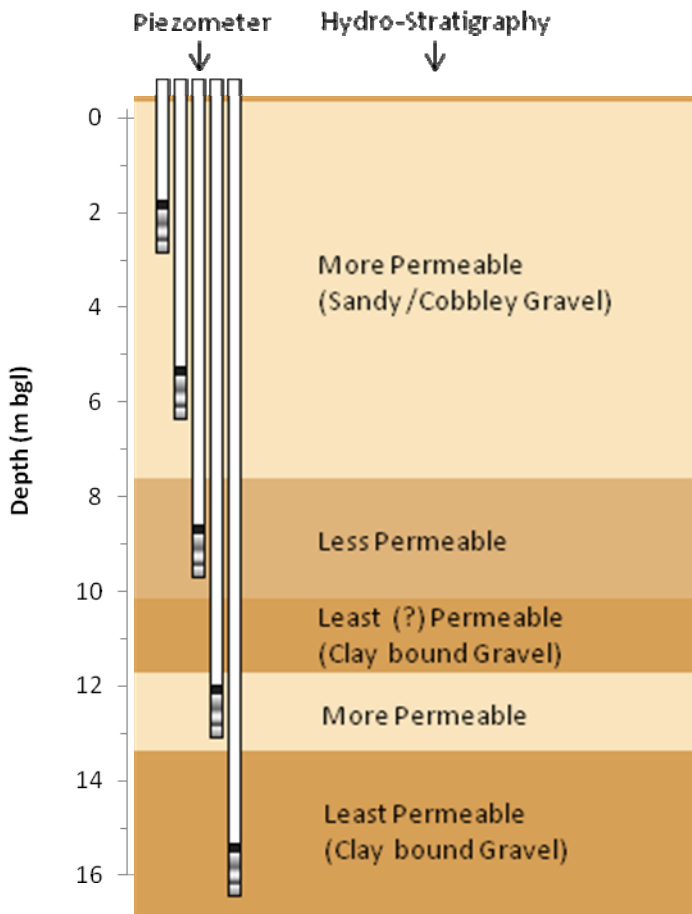
5.1 Hydro-Stratigraphy

Figure 5 presents a cross-section diagram showing the piezometer construction details and interpreted hydro-stratigraphy, in terms of sediment types and aquifer properties.

The drillers log for E45/0330 indicates that the subsurface geology at the site consists of the sandy to cobbley gravels in a silt and clay matrix, typical of the Quaternary gravel deposits which cover much of the Southland Plains. The relative proportion of finer-grained materials appears to increase from around 9.5 metres below ground to the end of the hole at 15 mbgl. Sediments became more compacted with depth, grading from loose in the upper 4.8 m to dense or very dense ('firmer') in the lower sections of the profile. The groundwater table was encountered at approximately 1.5 mbgl during piezometer installation.

Information collected during purging of the piezometers prior to sampling provides a basic indication of the relative permeability of the aquifer materials surrounding the screened intervals. These data suggest sediments surrounding the 3, 6 and 12 metre piezometers are relatively permeable with water

levels recovering rapidly following pumping. The rate of water level recovery is relatively slow in the 9m interval and very slow in the 15m interval suggesting the presence of low permeability sediments at these depths. This interpretation suggests that there is more layering in the profile than is recorded in the driller's log and that material permeability may be highly variable and influenced by the relative proportion of clay and silt matrix materials rather than the overall sediment texture.


Figure 5. Piezometer completion details and interpreted hydro-stratigraphy.

5.2   Groundwater Levels

Figure 6 shows a plot of groundwater levels recorded in the individual piezometers. The data show a well defined seasonal variation of around 0.6 to 0.7 m in response to the climate regime, with highest water levels during winter and lowest levels in autumn. Relative groundwater levels tend to decrease with depth, with average depths to groundwater of 1.68 m bgl in the 3m interval compared to 1.92 m bgl in the 15 m piezometer. At any given time there is a 0.2 to 0.4 m difference in the water levels between the shallowest and deepest piezometers with levels in the 6, 9 and 12 metre piezometers standing at intermediate levels.

While the similarity in temporal water level variations indicate all 5 piezometers are screened in a single hydraulic unit the observed differences in standing water level suggest a downward vertical piezometric gradient at the site. This suggests that the Heenans Corner site is located in a groundwater recharge area and that there is a component of groundwater circulation through deeper (>15 metre) levels of the unconfined aquifer in this area.
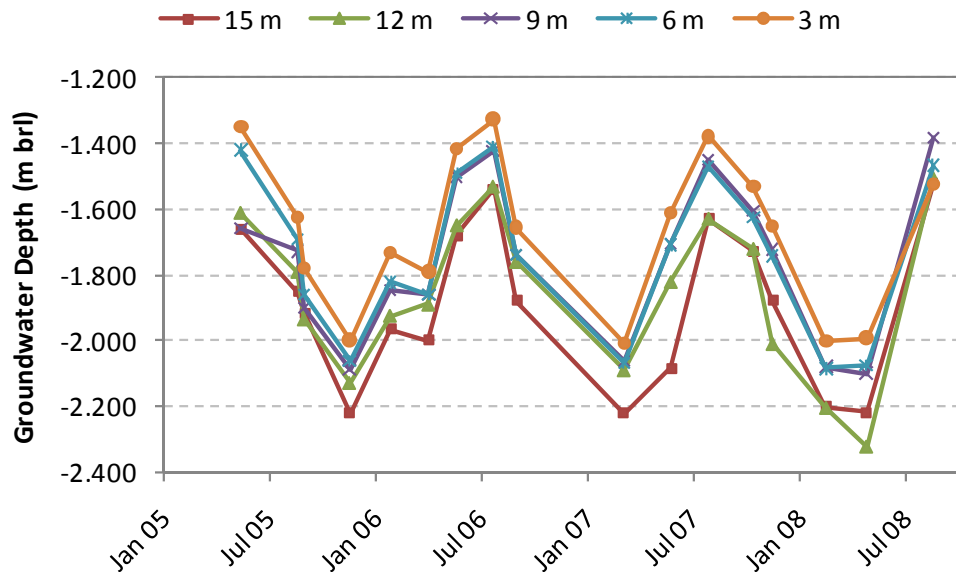

■ **Figure 6. Groundwater levels recorded in the Heenans Corner piezometers.**

5.3 Major Ion Chemistry

The major ion chemistry data from the Heenans Corner site have been used to assist in developing an understanding of groundwater movement and evolution through the upper 15 metres of the unconfined aquifer at this site.

Figure 7 shows a plot of the relative contribution of major ions to the total dissolved solids. These data show bicarbonate, chloride and sulphate are the dominant anions while magnesium calcium and sodium are the dominant cations. The data also show that the relative contribution of bicarbonate far exceeds the contribution of any other ionic constituent. Other trace ions present above method detection limits include potassium, iron, manganese, ammonia and dissolved reactive phosphorus (DRP). These ions make a relatively minor contribution to the overall total ion concentration.

Relative Ionic Contributions to TDS
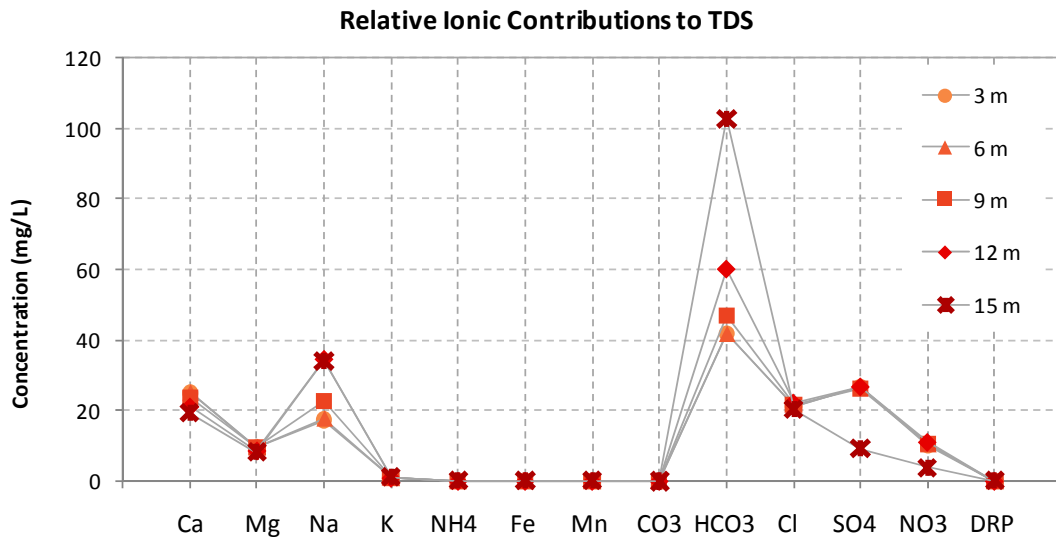
■   **Figure 7. Average ionic contributions to total dissolved solids in each sample interval.**

Table 1 lists the average major ion concentrations in the five sample intervals. Overall the data show major ion concentrations are relatively low although some notable variations in individual parameter concentrations are observed between the individual piezometers.

■   **Table 1. Average major ion concentrations measured in the Heenans Corner piezometers.**

Depth (m)	EC (µS/cm)	NO_3-N (g/m^3)	Cl (g/m^3)	Alkalinity (g/m^3)	SO_4 (g/m^3)	Na (g/m^3)	Ca (g/m^3)	Mg (g/m^3)	TDS (g/m^3)
3	290	11.5	22.8	42	27	17	26	9.7	153
6	295	12.0	23.3	41	27	18	26	9.9	154
9	309	12.2	23.3	50	27	22	25	9.7	162
12	332	12.1	23.7	64	28	33	21	8.7	185
15	293	5.1	21.2	98	12	33	21	8.8	199

In order to better illustrate the vertical variation in groundwater quality, the data outlined in **Table 1** are presented graphically on **Figures 8** and **9** below.

Figure 8 shows electrical conductivity (EC) shows a steady increase between the 3 and 12 metre intervals from 290 to 332 µS/cm before declining to 293 µS/cm in the 15 metre piezometer. This figure also shows alkalinity (bicarbonate) values are relatively similar in the upper three sample intervals but increase in two deepest piezometers. Reflecting bicarbonate as the dominant ion, total dissolved solids (TDS) concentrations follow a similar trend with roughly equal values in the upper three piezometers followed by a steady increase to the 15 metre interval.
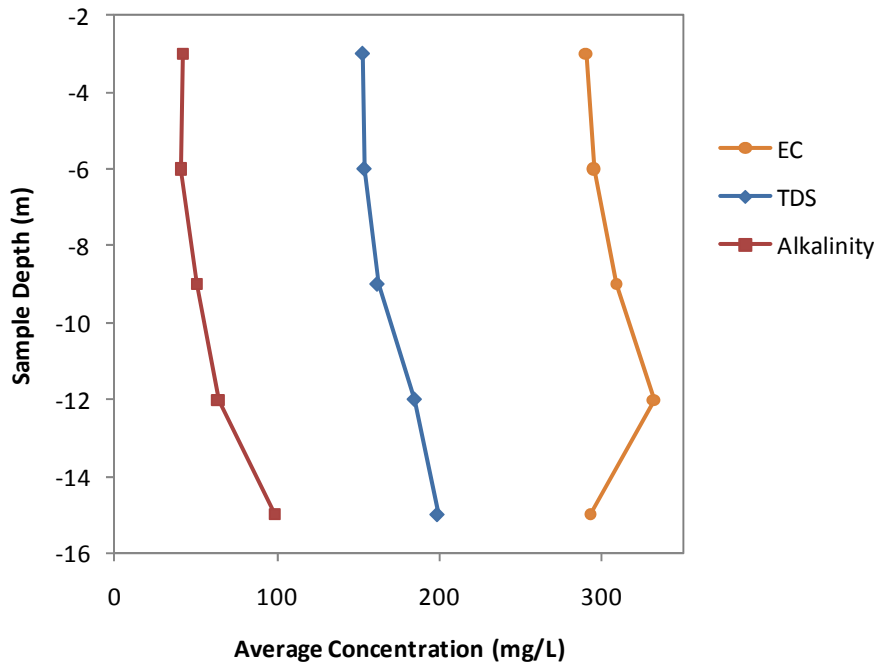
- **Figure 8. Plot of average major cation and anion concentrations observed in the Heenans Corner piezometers.**

Concentrations of other major anions (chloride, sulphate and magnesium) are relatively constant in the 3, 6, 9 and 12 metre piezometers but decline in the deeper (15 m) piezometer. The large decline in sulphate concentration may reflect the onset of reducing (low oxygen) conditions in the unconfined aquifer below 12 metres. This observation is supported by the hydrogen sulphide odour frequently noted during purging of the 15 metre piezometer.

In terms of the major cations, calcium concentrations decline slightly down the profile while magnesium remains relatively constant. In contrast, sodium concentrations show a marked increase with depth. These variations are thought to the reflect water-rock interaction within the aquifer. These reactions include the weathering of carbonate minerals[2] due to the formation of carbonic acid (H_2CO_3) as a result of the interaction between infiltrating recharge and carbon dioxide near the water table along with preferential substitution of higher charged ions (e.g. Al^{3+} and Ca^{2+}) onto clay minerals within the aquifer matrix at the expense of species carrying a lower charge (e.g. Na^+) as well as the weathering of silicate minerals[3] at deeper levels in the aquifer. These observations are consistent with the observed increase in alkalinity at depth.

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[2] Carbonate weathering ($CaCO_3 + H_2CO_3 = Ca2+ + 2HCO_3$ i.e. calcium and bicarbonate concentrations increase)

[3] Silicate weathering (e.g. $NaAlSi_3O_{8(albite)} + H_3CO_3 = {}^9/_2H_2O = Na^+ + HCO_3 + 2H_4SiO_4 + {}^1/_2AlSi_2O_5(OH)_{4(kaolinite)}$ i.e. sodium and bicarbonate concentrations increase)
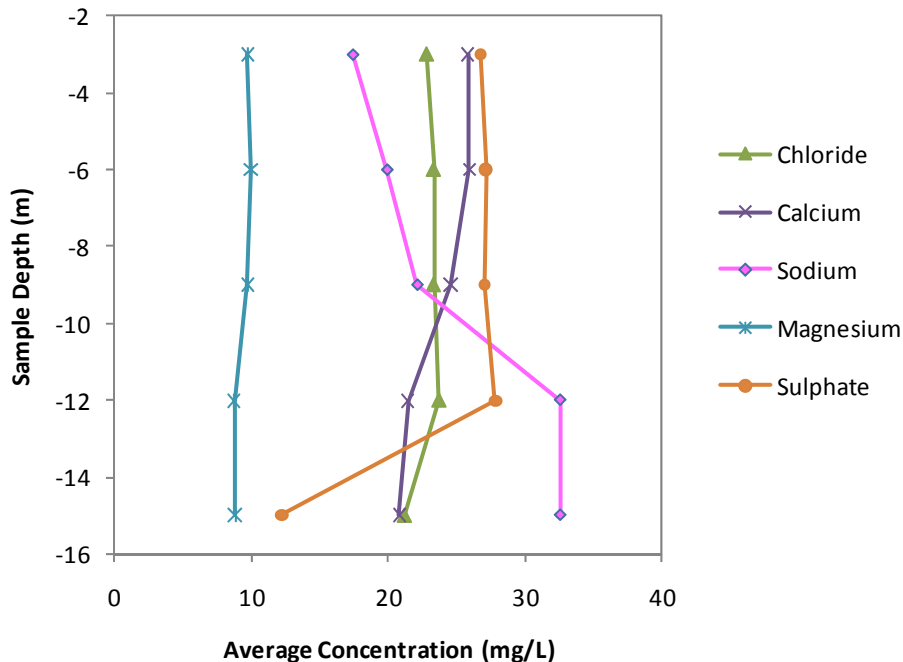
- **Figure 9. Plot of average alkalinity, electrical conductivity and total dissolved concentrations in the Heenans Corner piezometers.**

The geochemical evolution of groundwater through the depth profile at Heenans Corner is well illustrated by the piper plot shown in **Figure 10**. This diagram clearly shows a gradual evolution in groundwater chemistry with depth as the relative contributions of sodium and bicarbonate increase with depth. This type of pattern would typically be expected in a groundwater system where groundwater residence time increases with depth. Given the similarity between geochemistry in the upper three sample intervals, these data tend to support the initial conceptual hydrogeological model for the site which involves a majority of groundwater circulation occurring through the upper levels of the saturated zone with a relatively low rate of groundwater circulation at depth.

Overall, when plotted on the piper diagram, the groundwater quality analyses from the 15 metre piezometer appear to represent the end point (of the depths sampled) in terms of cation evolution. However, data from this interval show a distinct break from the other sample intervals in terms of the anions present. This is interpreted to reflect a transition between the more oxidising conditions above the 12 metre interval and reducing conditions below this depth.
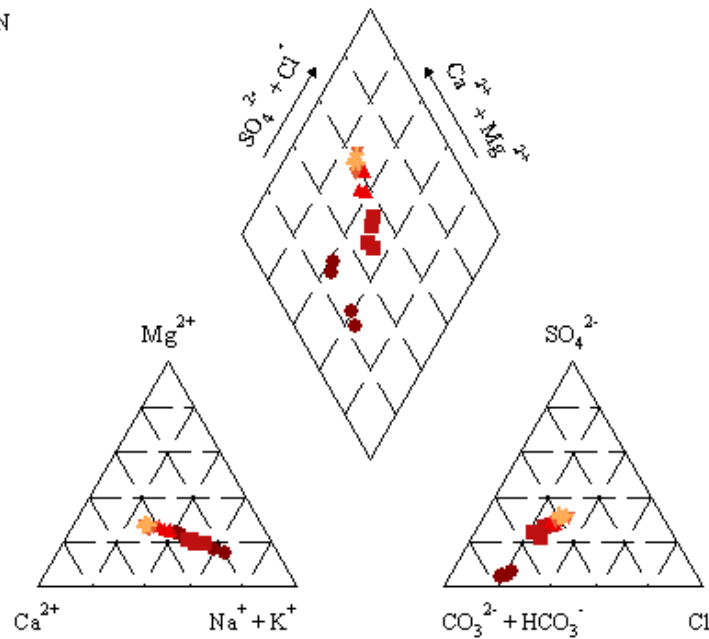
Figure 9. Piper diagram showing relative percentage contribution of each major ion for the Heenans Corner piezometers.

5.4 Nutrients

One of the main objectives for the Heenans Corner site was to provide an improved understanding of the impact of land use (particularly in terms of nitrate) on groundwater quality.

Monitoring data indicate elevated nitrate concentrations in all five piezometers. Average concentrations in the upper four sample intervals are relatively constant at between 11.5 and 12.2 mg/L. These values are above the New Zealand Drinking Water Standard Maximum Acceptable Standard (MAV) of 11.3 g/m^3 and significantly in excess of the ANZECC 95% protection trigger value for freshwater of 0.7 g/m^3. Observed groundwater nitrate concentrations therefore suggest that:

- Land use in the contributing recharge area has resulted in the accumulation of elevated groundwater nitrate concentrations;

- There relatively even distribution of groundwater nitrate across the upper portion of the unconfined aquifer suggests either a relatively constant nitrate input to groundwater or that there is a significant degree of vertical mixing within the upper portion of the saturated zone;

- The lower groundwater nitrate values in the 15 metre piezometer may suggest either a change in redox conditions at this depth or a break in the rate of groundwater circulation at depth (i.e. water in the 15 metre piezometer is older and therefore reflects historical lower intensity land use); and,

- Groundwater discharge to surface water will result in significant nutrient loadings in surface waterways.

Figure 10 shows a plot of the average groundwater nitrate concentrations across the five sample intervals. These data show the marked difference in groundwater nitrate concentration in the 15 metre piezometer compared to the remaining sample intervals.

However, ammonia concentrations do not show any clear trend with depth. Concentrations above detection limits (0.01 g/m^3) are observed in approximately 45 percent of samples (7 out of 16) from all piezometers except the 6 metre interval which shows only a single sample above detection limits. This pattern is not entirely consistent with the observed decrease in nitrate concentration in the 15 metre piezometer reflecting a change in redox state as this would be expected to increase ammonia concentrations.

Dissolved reactive phosphorus concentrations are generally low in all samples (<0.035 g/m^3) but do appear to show a slight increasing trend with depth.
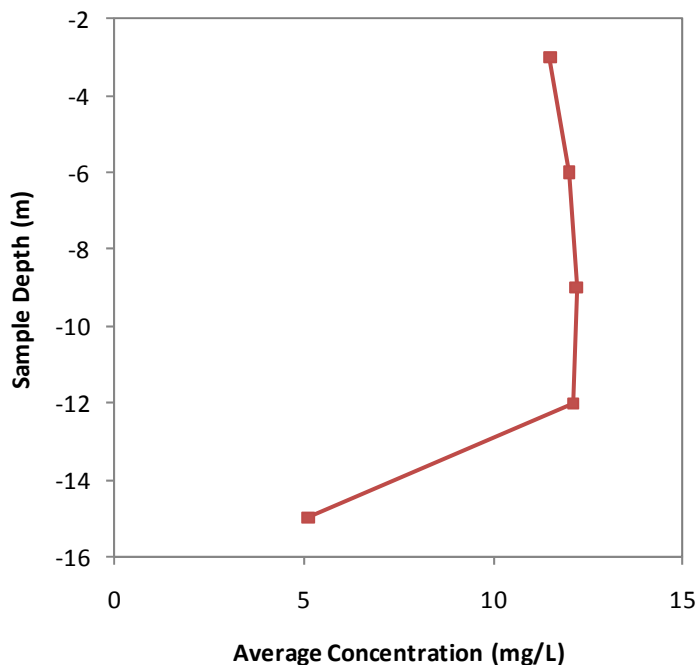

- **Figure 10. Vertical distribution of average groundwater nitrate concentrations.**

5.5 Temporal groundwater quality variations

The following section includes a series of graphs illustrating the observed temporal variation in groundwater quality in the Heenans Corner site. These data suggest groundwater quality varies significantly between individual ions in the respective piezometers.

Figure 11 shows the temporal variation in electrical conductivity. Initial samples show extremely high (up to 600 µS/cm) and variable values through to mid-2006, particularly in the 9 and 12 metre intervals. The cause of this variability is uncertain although it appears to correspond with similarly high alkalinity and sodium values recorded over the same period. From mid-2006, electrical conductivity values stabilise then show a gradual increase of between 20 to 40 µS/cm through to 2009. The data show electrical conductivity values are very similar in the 3, 6 and 9 metre intervals with values in the 12 metre interval consistently the highest observed. Values from the 15 metre interval are generally low although recent samples show similar values to those observed in the upper three piezometers.
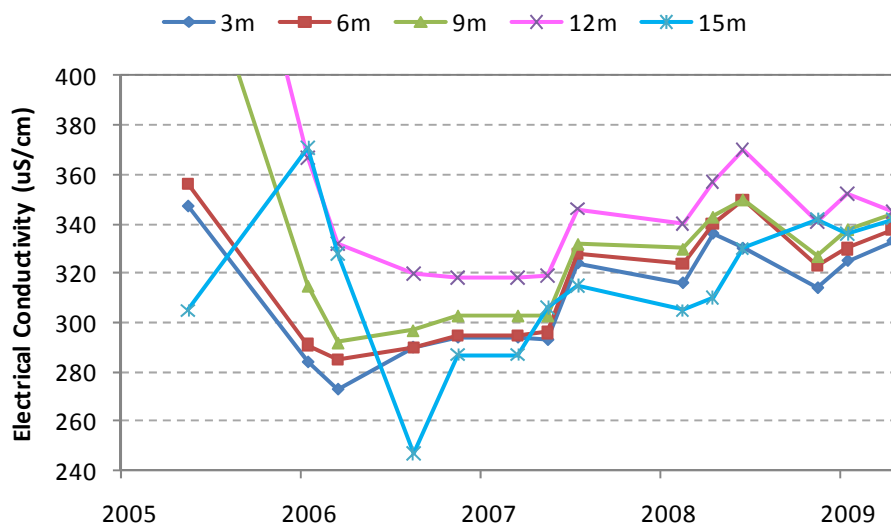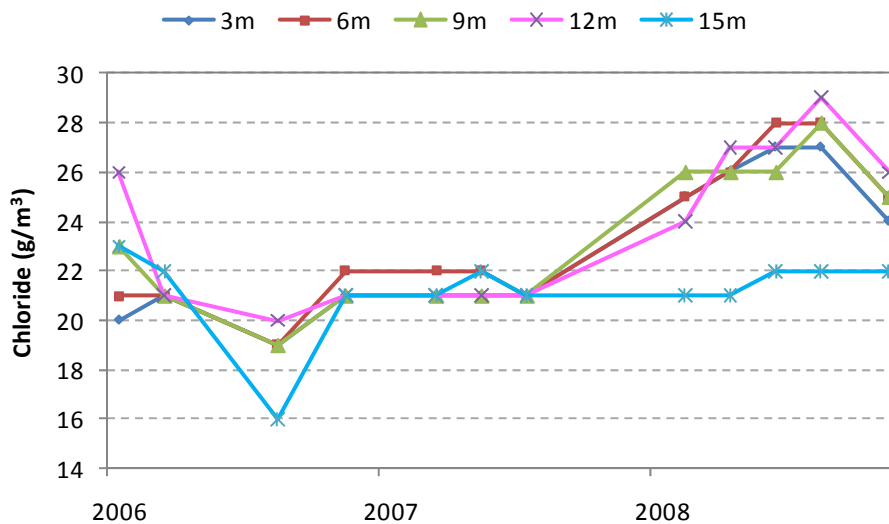

- **Figure 11. Temporal variability in Electrical Conductivity values.**

Figure 12 shows a plot of recorded chloride concentrations. Chloride is a conservative ion (i.e. relatively unaffected by geochemical processes within the saturated zone) so observed concentrations are generally interpreted to reflect recharge input concentrations which at the Heenans Corner site include the aerosol concentration in rainfall (generally around 20 to 25 g/m³ near the coast) as well as losses from overlying land use.

The data indicate that chloride concentrations remained relatively stable at around 20 to 22 g/m³ (with the exception of the August 2006 sample round) until early 2008. After this time concentrations in the 3, 6, 9 and 12 metre intervals increase markedly while the concentration in the 15 metre interval remained stable. It is uncertain if the post-2008 changes in chloride concentrations reflect the effects

of overlying land use or variations in recharge or a combination of both. The data do however suggest that the changes impacting the shallower sample interval did not impact on the 15 metre interval. This may suggest limited mixing of water through deeper levels (>12 metres) of the aquifer.
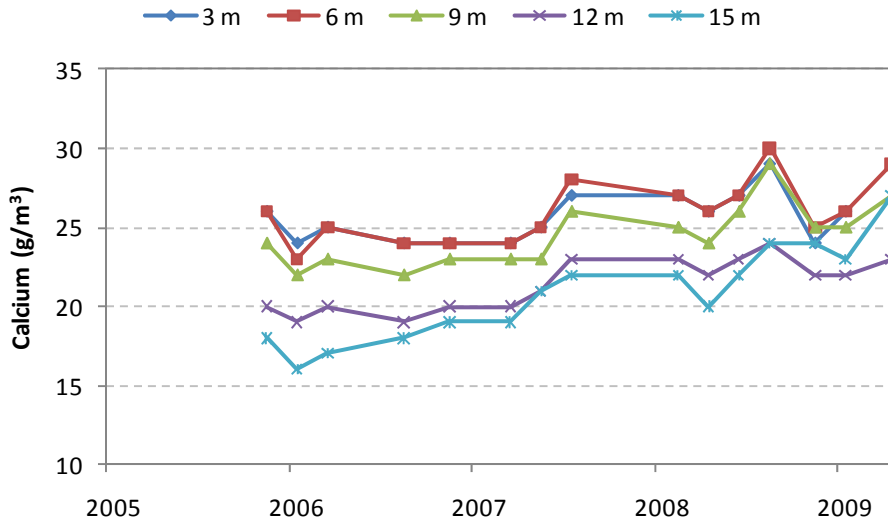

- **Figure 12. Temporal variability in Chloride concentrations.**

Figures 13 and **14** show plots of the observed temporal variation in Calcium and Sodium concentrations. The data show the observed decrease in calcium concentration with depth remained relatively constant over the period of record. Concentrations in the 3 and 6 metre piezometers are virtually identical then decrease progressively to the 15 metre interval which exhibits concentrations generally between 5 to 7 g/m^3 lower than upper levels of the aquifer. The data also show a progressive increase in calcium concentrations across all sample intervals since early 2006. The cause of this change is uncertain as calcium concentrations in rainfall recharged groundwater are generally influenced by the interaction with carbonate minerals in the aquifer materials.

In contrast, sodium concentrations remained relatively stable (the high concentrations in the 12 and 15 metre piezometers to mid-2006 excepted) and show a clear increase with depth of approximately 10 g/m^3 between the 3 and 15 metre sample intervals. It is also noted that these data show virtually identical sodium concentrations in the 3 and 6 metre piezometers again indicating a high degree of mixing in the shallow portion of the unconfined aquifer.

Overall, the observed decrease in calcium and increase in sodium with depth are consistent with the typical geochemical groundwater evolution observed in many aquifer systems where there is an observed transition from calcium to sodium as the dominant cation with depth due to the water-rock interaction described in Section 5.3. At shallow depths the geochemistry is dominated by weathering of carbonate minerals which increase calcium and bicarbonate concentrations. However, at depth, the preferential substitution of calcium ions onto clay minerals and or weathering of silicate minerals have a greater influence on groundwater geochemistry. The observed change in dominant cation with

depth does however suggest that groundwater movement through the aquifer system is relatively slow, allowing sufficient time for these geochemical changes to occur.

■ **Figure 13. Temporal variability in Calcium concentrations.**
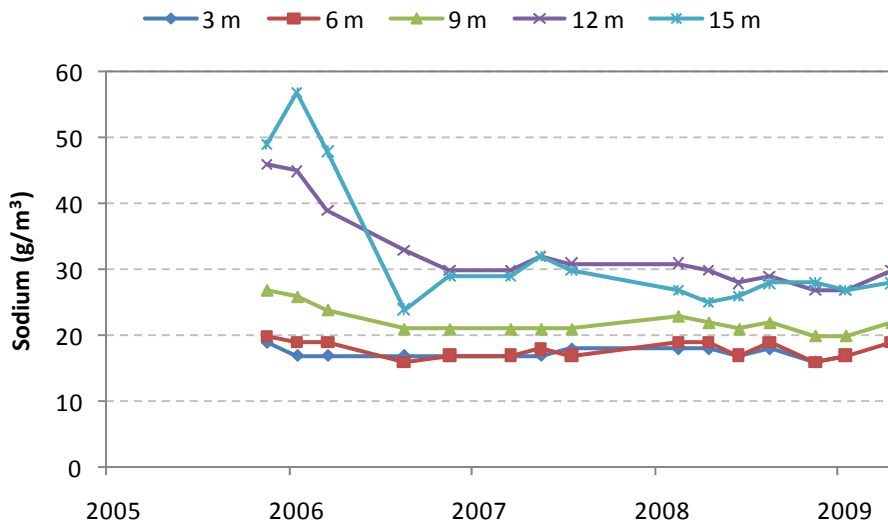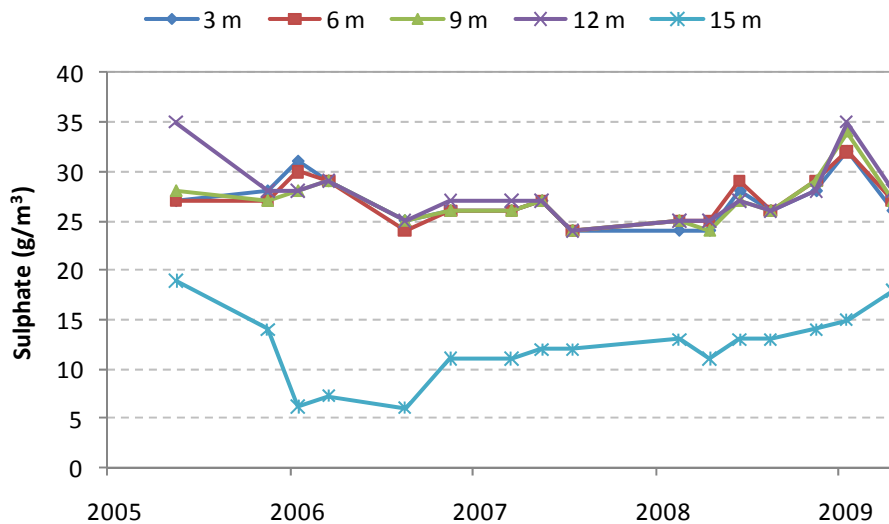

■ **Figure 14. Temporal variability in Sodium concentrations.**

Figure 15 shows a plot of sulphate concentrations over time. The most noticeable features of this graph are the clear differentiation in concentrations between the 15 metre piezometer and those at shallower depths along with the virtually identical concentrations across the upper 10 metres of the

saturated zone. Given the hydrogen sulphide odour noted in the 15 metre interval, one explanation for the contrast in sulphate concentration observed in the 15 metre piezometer is that there is a significant change in redox potential at this depth. This means that a portion of the sulphate in the groundwater at 15 metres has been reduced to hydrogen sulphide as a result of the low dissolved oxygen content of water at this depth.

■   **Figure 15. Temporal variability in Sulphate concentrations.**

As shown in **Figure 16**, groundwater nitrate concentrations exhibit a similar pattern to sulphate in that concentrations are virtually identical in the upper four sample intervals but decline markedly in the 15 metre piezometer. However, a change in redox potential as the primary cause of this observed variation is uncertain as concentrations of ammonia do not exhibit any appreciable increase in the deeper piezometer.
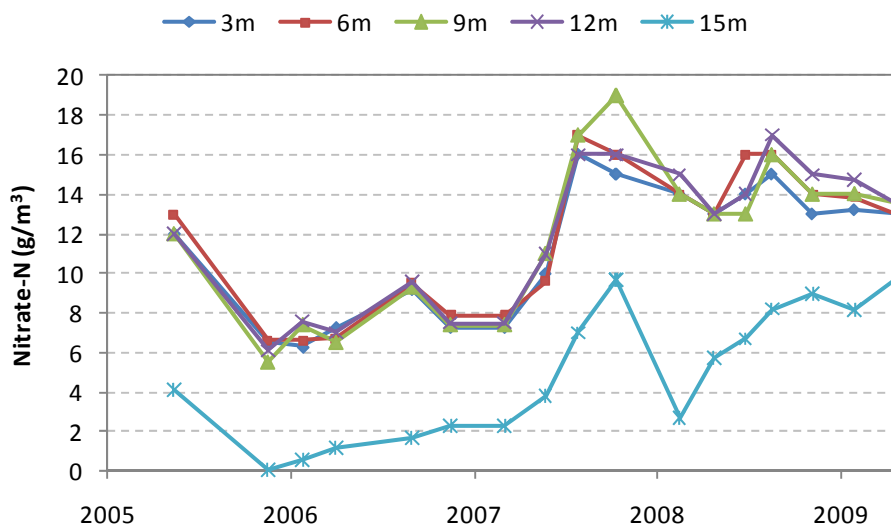
Figure 16. Temporal variability in Nitrate concentrations.

In terms of temporal variation, groundwater nitrate concentrations show a high degree of variability with concentrations in the upper four piezometers ranging from 6 to 16 g/m^3 over a relatively short period. Interestingly, concentrations in the 15 metre piezometer track those in the upper levels of the saturated zone with no apparent time lag. Given that the major ion chemistry suggests a relatively slow rate of groundwater circulation through the unconfined aquifer to account for observed geochemical changes, the cause of the relatively equal variations in nitrate concentration across the entire profile are uncertain.

The results indicate groundwater nitrate concentrations at the Heenans corner site have increased significantly since 2005. However, the limited time lag between variations in observed nitrate concentration in the upper four piezometers suggests a rapid vertical mixing of recharge input concentrations which is not supported by other water quality analyses. As a result, it is not possible to determine if the observed nitrate concentrations reflect the impact of overlying land use or have occurred in response to some alternative (as yet unknown) cause.

As previously noted, sample contamination seems unlikely to be the cause of the observed changes in groundwater nitrate concentrations. Field notes indicate that water levels in adjacent piezometers are unaffected by purging indicating hydraulic separation between the respective sampling intervals. Similarly, the groundwater sample methodology adopted (e.g. low rate sampling, purging etc) as well as the overall consistency of results suggests that sample collection methodology is unlikely to be the primary cause of the observed temporal variation in nitrate concentration.

6.   Summary

The Heenans Corner nested piezometer site was installed to collect groundwater quality data to enable verification of the conceptual hydrogeological model for Lowland aquifers and improve understanding of the relationship between changes in land use and resulting impacts on groundwater

quality. Based on the review of groundwater sampling results to date it appears that the success of the site in achieving these objectives is variable as there remain an number of uncertainties with regard to data interpretation.

Some data quality issues are apparent in the sample results including the consistent bias toward cations in the ion balance and the seemingly anomalous sodium and bicarbonate concentrations (with consequent impacts on electrical conductivity, TDS and total hardness) in initial samples. However, these effects do not appear to have had any major impact on the data set and its utility for analysis of groundwater quality.

In terms of the conceptual hydrogeological model the water quality results (with the exception of nitrate) indicate:

- Major ion chemistry varies with depth generally following the standard geochemical evolution sequence. These changes are interpreted to reflect water-rock interaction and redox processes and suggest progressively lower rates of groundwater circulation at depth;

- The upper two piezometers (3 and 6 metre sample intervals) show very similar water quality results suggesting a high degree of mixing in the upper portion of the saturated zone; and

- Variation in some major ion concentrations (particularly anions subject to redox reactions) suggest a significant change in redox conditions between the 12 and 15 metre piezometers. This again may suggest a significant reduction in the rate of groundwater throughflow through deeper levels of the unconfined aquifer which is consistent with the conceptual hydrogeological model.

However, interpretation of sample results is less certain with regard to the potential impacts of surrounding land use on groundwater quality. Groundwater nitrate concentrations in the 3, 6, 9 and 12 metre piezometers are extremely high and occur at levels generally only seen in areas of Southland that have been significantly impacted by historical land use. In addition, observed temporal variations in groundwater nitrate concentration are large and occur rapidly across the entire profile (including in the 15 metre piezometer). This is not consistent with the observed aquifer permeability or major ion chemistry and therefore remains largely unexplained.

Overall, data from the Heenans Corner multi-level piezometer has yielded useful data to improve and validate the conceptual understanding on groundwater flow in Lowland aquifer systems. However, because of the apparent disparity between major ion chemistry and nutrient concentrations, the site would appear to have limited value in determining land use impacts on groundwater quality. It is uncertain if this relates to the physical set-up of the nested piezometer or reflects some peculiarities with regard the local hydrogeological setting or historical land use.

7. Recommendations

In order to better understand the observed groundwater quality variations there it is recommended that Environment Southland continue to sample the Heenans Corner piezometers. However, it may be possible to reduce the frequency of sample collection to six monthly over the long-term without

adversely impacting on the overall utility of the data set. Alternatively, the current sampling frequency (~quarterly) could be maintained but the analysis suite reduced to include the main indicator parameters (e.g. EC, alkalinity, chloride, sulphate, nitrate, calcium, sodium and magnesium) with the balance of the current parameters sampled on an annual basis.

Sampling for other parameters such as tritium should only be continued if there is some benefit (e.g. estimate of groundwater residence time) that can be derived from a realistic number of samples. However, one parameter that warrants further investigation is redox potential (Eh) as this parameters appears to have a significant influence on a number of important groundwater quality parameters and may assist explanation of the seemingly anomalous groundwater nitrate concentrations at the Heenans Corner site.

From the available data appears there may be some merit in the installation of additional multi-level piezometer sites elsewhere in Southland. Data derived from such installations would enable improved understanding of aquifer geochemistry and aid conceptualisation of groundwater flow in alternative hydrogeological settings. An additional installation would at least confirm data from the Heenans Corner site with regard the rate and magnitude of changes in groundwater nitrate concentrations and implications this may have for the management of land use change impacts.

However, if an additional multi-level sampling site were to be considered it would be worth investigating alternative construction methods such as the installation of closely-spaced piezometers to varying depths in separate drillholes. This would enable a multi-level sampling installation to be developed around an existing bore with known temporal variations in water quality and reduce some of the uncertainty around observed groundwater nitrate concentrations that complicate interpretation of data from the Heenans Corner site.

Yours Sincerely

Brydon Hughes
Hydrogeologist