MARLBOROUGH
DISTRICT COUNCIL

# Groundwater Quality State and Trends 2014

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Report Prepared by:
**Peter Davidson**
Groundwater Scientist
Environmental Science & Monitoring Group

Marlborough District Council
Seymour Square
PO Box 443
Blenheim 7240
Phone: 520 7400
Website: www.marlborough.govt.nz

Acknowledgements:

Amy Nicholson – Senior Environmental Monitoring Officer

# Executive Summary

1. The quality of Marlborough's groundwater remains high in terms of nitrate-nitrogen content.

2. Of the median nitrate-nitrogen concentration across the 14 unconfined aquifer sites, all meet the drinking water standard of 11.3 g/m$^3$.

3. Out of the 14 unconfined aquifers only two of these currently would not meet the proposed surface water target of 2.4 g/m$^3$, to protect in-stream values, and a further two other sites approached the threshold.

4. Most unconfined aquifers exhibited a large seasonal variation in nitrate-nitrogen with peak concentrations coinciding with Spring rains which leach land surface contaminants downwards to the water table.

5. In three cases the peak nitrate-nitrogen concentration exceeded 10 g/m$^3$ , and in one case exceeded the human drinking water standard for short periods.

6. This seasonal nitrate-nitrogen pattern appears stable suggesting current land uses are in equilibrium with water resources.

7. There are only short time delays before land surface contaminants appear in groundwater after spring rains.

8. Lysimeter results show the slowest part of the flow path is vertical drainage through the soil, with relatively rapid horizontal flow in groundwater once it encounters the water table.

9. Nitrate-nitrogen concentrations are relatively low under vineyard. This is also a function of the rate of groundwater through-flow which varies between systems and within individual aquifers or sectors.

10. Most wells showed a rising pattern in nitrate-nitrogen values around 2008 followed by a fall again about 2011 which was attributed to higher rainfall leaching. This may not be the only explanation however as land uses weren't stable across all catchments during this period.

11. There was a slight long-term upwards trend in nitrate-nitrogen concentration at two sites, but actual values are low with slow rates of change.

12. Conclusions have been made on the basis of 5 to 25 years of results. Some sites have yet to experience the full spectrum of weather conditions or overlying land uses are still in transition meaning the full range of nutrient values may not yet have been observed.

13. Concentrations of nitrate-nitrogen dissolved in groundwater or surface water translate into the average equivalent land use load across the catchment area of between 1 and 47 kg/ha/year.

# Contents

# 1. Introduction

Marlborough and especially the Wairau Plain is heavily dependant on underground water for its everyday existence, economic prosperity and maintaining the ecologic habitat of groundwater dependant streams like Spring Creek or the Taylor River.

All of the main settlements rely on groundwater for their public drinking water and many rural dwellers have water wells. The Blenheim hinterland relies on groundwater as its prime source of freshwater for irrigating crops. Processing of the grape vintage uses groundwater because of its higher quality.

The quality of groundwater is just as important as having enough of it in the right place at the right time. Groundwater is accorded the highest grading of any natural freshwater body because it is primarily used for human consumption.

## 1.1. Marlborough groundwater quality

Marlborough groundwater quality continues to be of a generally high standard. This is especially true of the free-flowing aquifers underlying the northern Wairau Plain which tend to dilute the concentration of any contaminants generated at the surface.

The focus of this report is on nutrient levels in groundwater and associated surface waters. Nutrients are mostly a byproduct of human activities. As the New Zealand population grows and agriculture intensifies, nutrients are of increasing interest to central government as they may limit new economic activities.

The most commonly occurring nutrient in groundwaters is nitrogen and because most aquifer systems susceptible to land surface activities are oxygen rich, the most common form of nitrogen locally is nitrate. At high concentrations nitrate-nitrogen is harmful to human health and at lower concentrations may affect the biological health of rivers and wetlands.

The purpose of this report is to provide an update on levels of nitrate-nitrogen in Marlborough ground waters and their associated springs or related surface waterways. The analysis is based on nitrate-nitrogen records dating from 1992 in some cases.

## 1.2. Monitoring methodology & network

To identify groundwater potential threats and to improve understanding of aquifer processes, the Marlborough District Council (MDC) and its predecessors have actively monitored groundwater quality in some shape or form since the 1970s.

The programme has evolved over time to reflect the issues of the day and monitoring resources or staff levels. Major reviews occurred in 1998 when it became part of the National Groundwater Monitoring Programme (NGMP) and again in 2004 when these standards were incorporated across all sites and the network was enlarged to its current size.

Every 5 years a more detailed assessment is made to see if groundwater quality is improving, deteriorating or is stable, along with possible causes. This is based around analysing for time trends.

While the MDC groundwater monitoring network covers a representative range of locations and threats to groundwater, it is primarily a regional scale tool and may not detect local spills or contamination issues. The MDC still relies on reports from well owners to identify these smaller scale issues and the performance standards of permitted activities to avoid problems.

Most of the sites used for sampling groundwater are MDC monitoring wells with a smaller number of privately owned wells. Dedicated sites are preferred because they provide security of tenure and continuity of information. The aim is to produce long term records of 50 years or more to identify any trends in groundwater quality in relation to land-uses or environmental changes.

In the past many different sites have been sampled rather than a fixed group. This provided a snap-shot of groundwater chemistry, but not the uninterrupted record needed to see what if any trends exist. To ensure continuity of record, the current network will be maintained or added to, but no sites will be removed.

Geographically the focus has always been the Wairau Plain where the main population is based and the highest rates of groundwater use occur to support the most intensive land uses and largest settlements. The network has evolved over time and includes a reasonably representative series of aquifer types and land-uses. A site representing the upper Rai-Pelorus catchment was added in 2012 to complete the district-wide coverage.

Monitoring for laboratory analysis involves taking samples of groundwater at a network of 24 wells chosen to represent the main water supply aquifers, their vulnerability to pollution, depth and the type of overlying land-use.

The results from this project are applied for managing the risk to human health of drinking groundwaters, developing management policy and providing general information to water users on aquifer processes. Water chemistry and hydrology are indivisible and increasingly one is revealing the nature of the other.

The overall monitoring programme is made-up of five separate surveys each with specific aims. The most frequently conducted survey is for state of the environment monitoring of general chemical parameters and is conducted each season. This includes measurements of nitrate-nitrogen.

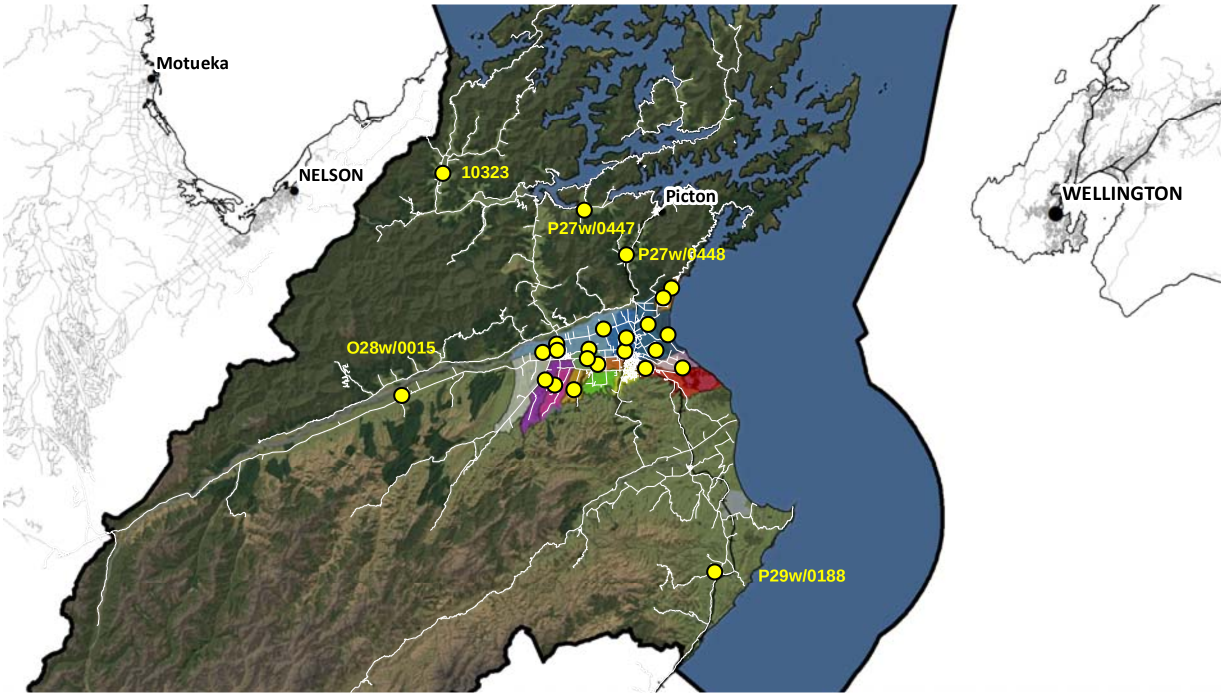


**Figure 1: District scale SOE/NGMP sample sites**

It involves sampling 16 wells and analysing for a general range of metals, nutrients and commonly occurring constituents of Marlborough groundwaters. This is referred to as the Marlborough State of the Environment programme.  The location of the wells sampled is shown in Figure 1.

A further eight well sites are sampled each season for a similar group of parameters as part of the NGMP. Coordinated by the Crown Research Institute GNS Science Ltd and involving most regions of New Zealand, the results provide a national perspective of groundwater quality.

The MDC first participated in the programme in 1998 and continues to support it. The mutual benefits to Marlborough district and New Zealand are a nationally consistent set of measurement and reporting guidelines.

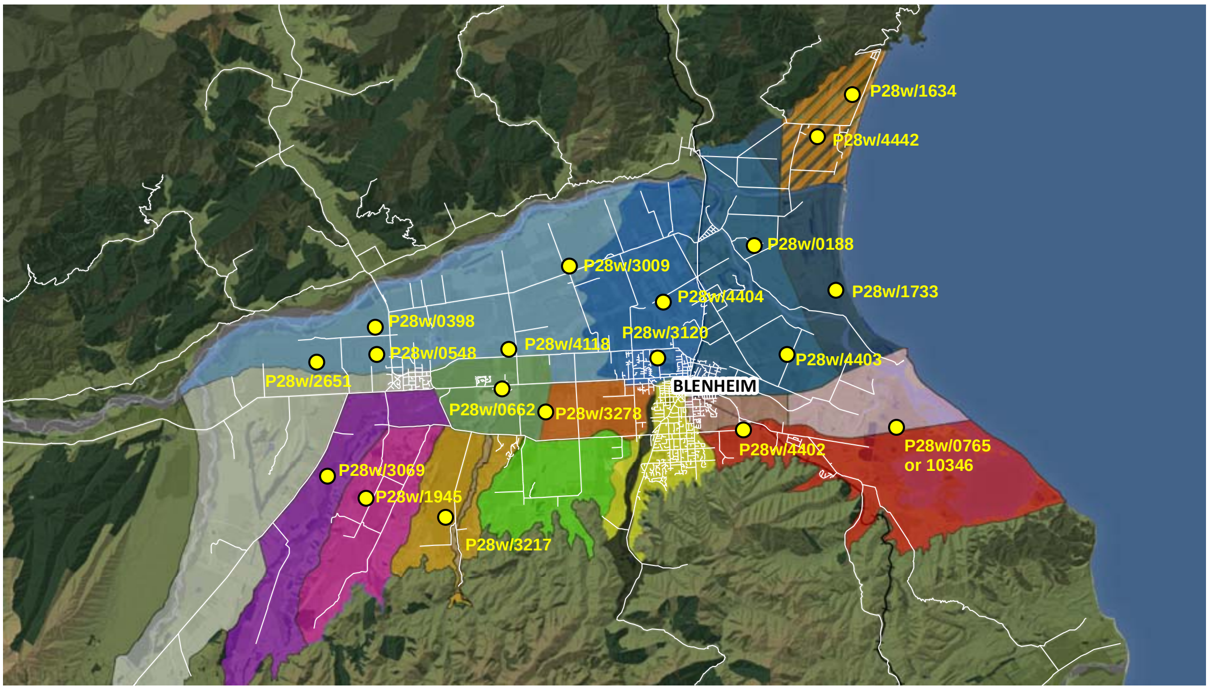


**Figure 2: Wairau Plain SOE/NGMP sample sites & aquifers or sectors**

There are also surveys of coastal aquifer salinity in relation to seawater intrusion and of pesticides and microbes in groundwater. The results are reported to MDC and contribute to the national state of the environment reports the most recent of which was produced by the Ministry for the Environment in 2007. The various aquifers underlying the Wairau Plain are shaded in different colours (Figure 2).

## 1.3. Water quality standards & suitability thresholds

Measuring the chemical or microbial composition of groundwater is of little practical use unless it is compared to thresholds that show its fitness for a certain use. The primary measure of groundwater quality in New Zealand is its fitness for human consumption or its potability.

The Drinking Water Standards for New Zealand were prepared by the Ministry of Health and specify the maximum allowable values of health significance for each of the common parameters in groundwater. This document also contains guidelines to avoid aesthetic issues. These are not life threatening but cause nuisance problems depending on their concentrations such as staining, odours, smells or residues.

Ecological standards also exist to gauge the threat to the normal biological functioning of wetlands or surface waters. These are specified in the 2014 National Policy Statement, for surface waterways but indirectly relate to aquifers which are hydraulically connected. For instance the majority of Spring Creek flow and the baseflow of the Taylor River is Wairau Aquifer groundwater.

The maximum nitrate-nitrogen concentration has yet to be set by the MDC for freshwater management units (FMU) here in Marlborough, but for many groundwater dependant streams it is likely to be 2.4 $g/m^3$ and this has been used in this report to compare with measured values as a measure of fitness.

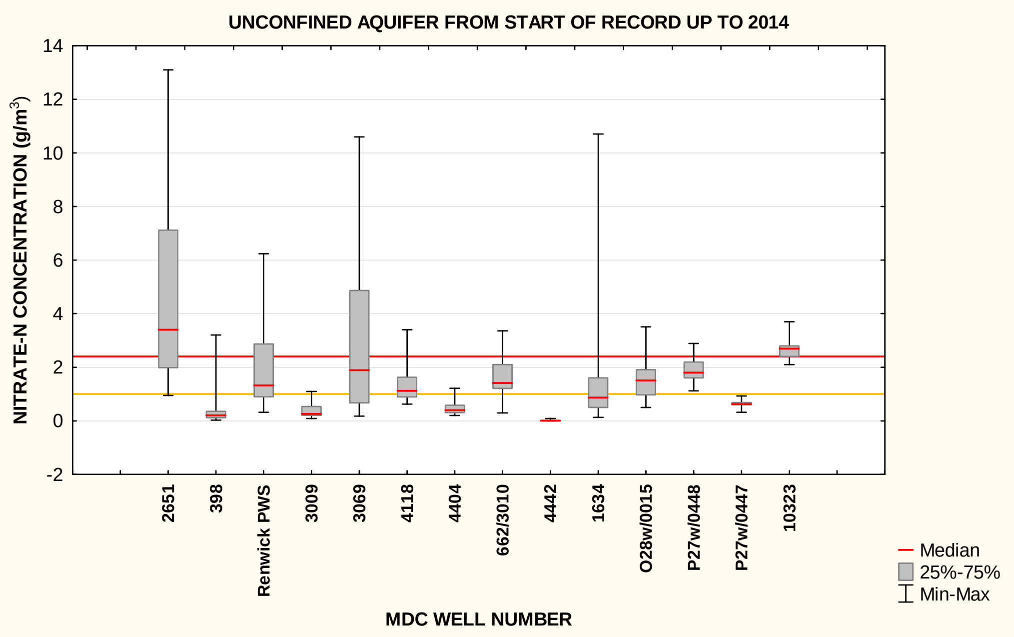


**Figure 3 : Median nitrate-nitrogen concentrations for unconfined aquifers**

Nitrate-nitrogen values are sensitive to aquifer structure and this explains the large range in values between unconfined and confined aquifers. Exceedances only occur at sites representing unconfined aquifers. This reflects their vulnerability to surface activities and conversely the denitrifying capacity of many deeper, confined aquifer systems which act as nutrient sinks. Sulphates which are most commonly derived from land surface activities are also consumed in confined aquifers.

Figure 3 shows the results for the 14 sites sampled in unconfined aquifers with the median value marked by the red line and the middle fifty percent of values in the grey shaded band. Nitrate-nitrogen levels exceeded the 2.4 g/m$^3$ possible ecological threshold at two wells. These sites are located at Rai Valley and south west of Renwick.

The large range in nitrate-nitrogen concentration at several sites can be explained by a combination of intensive land uses overlying shallow soils that easily leach any surface nutrient in conjunction with aquifers that have limited throughflow to dilute contaminants. It is fair to say that every site has a unique combination of factors giving rise to nutrient levels in groundwater which can also vary over time.

# 2. Hydrogeochemical background

It is useful to provide some hydrological background on Marlborough's groundwater systems as natural factors have as much influence on levels of nutrients as do human activities, even in intensively farmed areas like the Wairau Plain.

The spatial distribution of nitrate-nitrogen concentrations in Wairau Plain groundwater is well described based on measurements taken at many wells since the 1970s, but the reasons for the pattern are still being figured out (Figure 4).

Values are lowest in the north nearest the Wairau River, in parts of the Southern Valleys Aquifers and by the Cloudy Bay coast. There is a band of intermediate concentrations extending from Renwick through Woodbourne to Blenheim. The highest values are found in the Southern Valleys Aquifers.

Because current land use is the same across the Wairau Plain, differences must either relate to the aquifer properties, soils or climate. It is assumed that there is no residual nitrate from previous land uses. Climate is similar but there are big differences in soil types and aquifer characteristics.

Soils tend to be shallower and are more likely to leach in western areas of the Wairau Plain, while those in the east or south are deeper with finer grains meaning drainage is slower and nutrients are less likely to leach. There is no apparent correlation between groundwater nitrate concentrations and these broad soil classes. Groundwater through flow rates and chemical conditions can explain the differences very well.

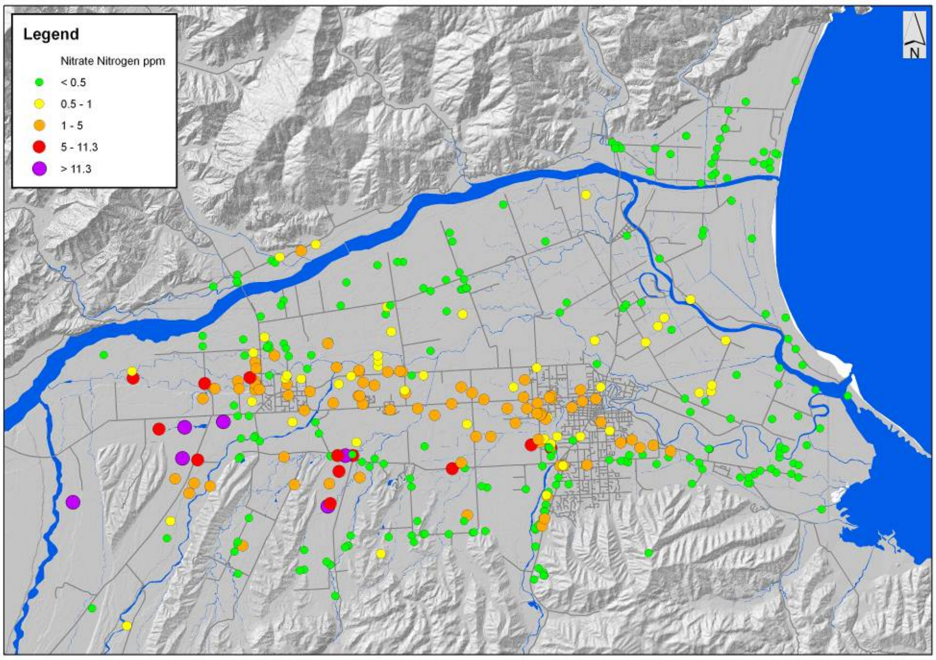


**Figure 4 : Median nitrate-nitrogen concentrations**

The most important determinant of nitrate levels in groundwater appears to be the rate of aquifer flow which is expressed as an aquifers transmissivity. The most transmissive gravels are closest to the Wairau River while the lowest form the Southern Valleys Aquifers (Figure 5).

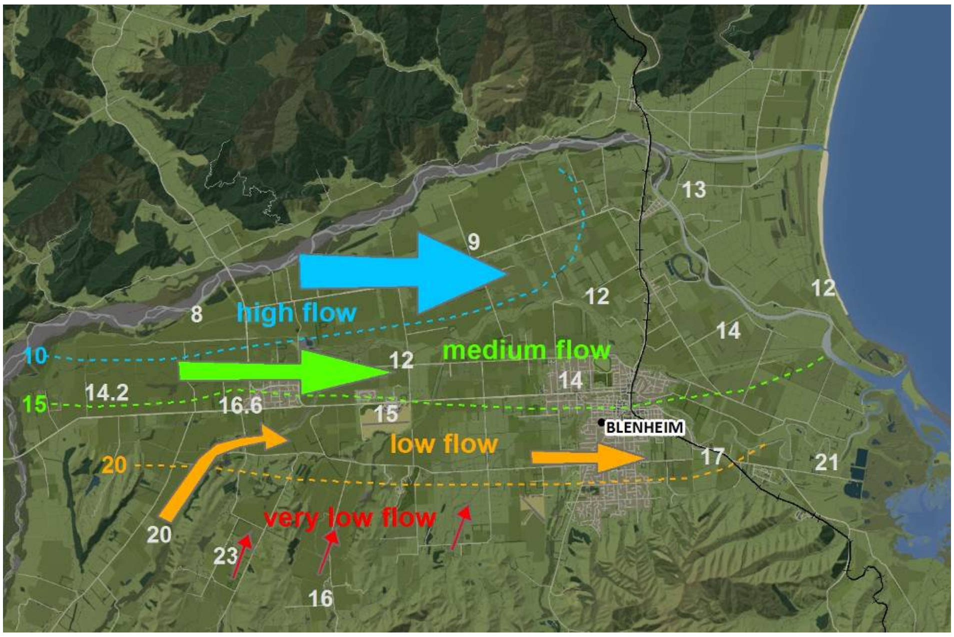


**Figure 5 : Median silica concentration & relative aquifer flow rate**

Figure 5 splits the Wairau Plain aquifers into four broad groups using transmissivity based on pump test or well productivity results. If rates of underground flow are slower you would expect the water to be older and this is the case based on median silica concentrations in groundwater measured by MDC over many years at wells forming its monitoring network (Figure 5). The highest values indicate older water and the pattern of median silica values shown by the white figures in parts per million align well with the flow classes.

Higher throughflow rates tend to dilute land use contaminants and lower the concentrations of nitrate-nitrogen in groundwater. There are some anomalies in Figure 5 which throughflow alone doesn't account for. The very low nitrate-nitrogen concentrations in parts of the Southern Valleys and coastal area where transmissivity rates are lower are caused by chemical reduction of nitrate-nitrogen due to the naturally low oxygen levels of these deep, confined aquifers.

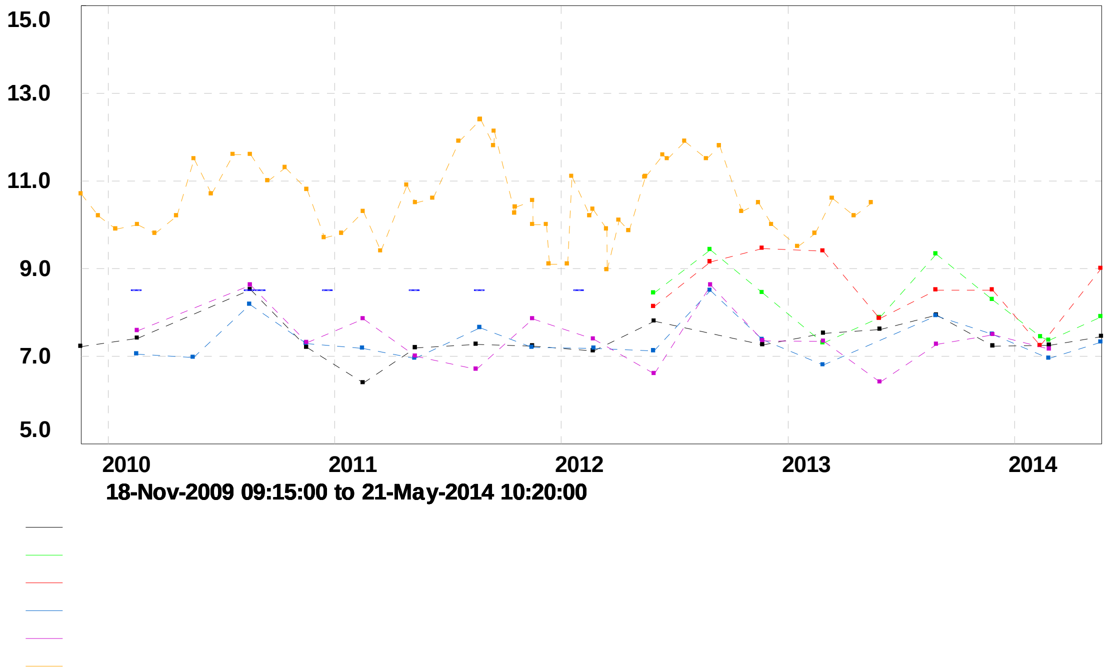


**Figure 6 : Dissolved oxygen concentration in g/m³ for most transmissive aquifer sites**

Figure 6 shows the variation in dissolved oxygen concentration in groundwater at various MDC monitoring wells across the Wairau Plain versus the Wairau River at Tuamarina, which is the main source of recharge for these sites.

The time series from 2010 to 2014 shows Wairau River water in orange has the highest oxygen content as expected, followed by the groundwater at the two most northern wells P28w/0398 at Conders and P28w/3009 at Wratts Road, which are also the youngest waters (marked green and red respectively).

The series of sites with lower oxygen levels represent wells located further away from the Wairau River recharge source which have longer residence times, although water tables are closer to the surface in some cases.

# 3. Land use impacts on groundwater quality

Naturally occurring nitrate-nitrogen concentrations in New Zealand groundwaters are generally considered to be 1 g/m³ or less based on recent research by GNS Science across the country (Figure 7). Because of the lower rate of groundwater flow compared to rivers, dissolved concentrations of nitrogen are usually higher than in surface waters.

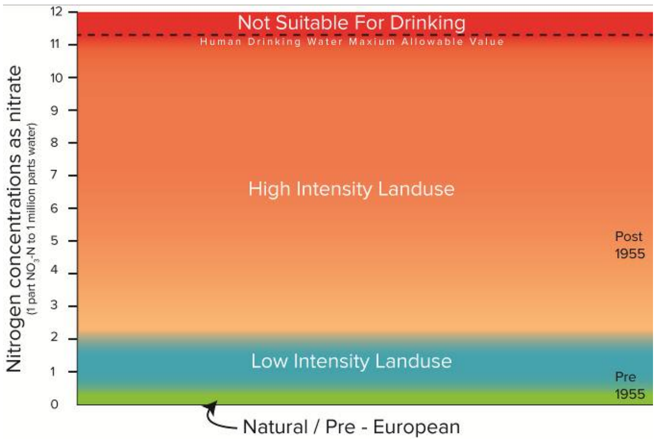


**Figure 7 : Historical changes in New Zealand nitrate levels**

The four main factors controlling nutrient concentrations in Marlborough aquifers are depicted in Figure 8. Current land use is the easiest factor to identify but MDC doesn't have a time indexed series of land use prior to 2001. However we can still rely on experience of local farmers to a large degree to fill in the gaps over the past century.

Wairau Plain land uses have changed dramatically since 1974 following the introduction of grape plants and now irrigated vineyard is the predominant crop. This simplifies things when it comes to isolating the causes of changes in nutrients as this factor is stable assuming there are no residual nutrients held up in the soil profile from historical activities.

In the case of the larger catchments where it may take 5 to 10 years for runoff water to transit to the sea, there may not be clear or direct correlations between rainfall, land use change and water quality. This is why water residence times are being measured to define lag times where they exist.

In shallow free draining soils, knowing what the historical land use and nutrient rates were is less important because it appears that nutrients are flushed from the soil layer quickly with no accumulation between seasons.

Land surface activities generate wastes which can either drain downwards or runoff sideways and the first barrier they meet are soils. In general terms deep, fine grained soils will tend to impede and assimilate nutrients more than thin, coarse soils which are free draining and not much of a physical or biochemical barrier. Higher rainfall or drainage which may include irrigation, will tend to leach more nutrients down to the water table. Having passed through the soil any remaining nutrients enter groundwater or surface water where their concentration is often diluted because the flow of water is higher.

Figure 8 emphasises vertical processes and doesn't show the situation where nutrients originating from a neighbouring property or catchment can add nutrients to those generated locally. A local example of this is runoff from the Southern Valleys Catchments entraining nutrients and increasing levels in the Woodbourne or southern fringes of the Wairau Aquifer. Some of the higher values in Figure 4 can probably be attributed to this process.

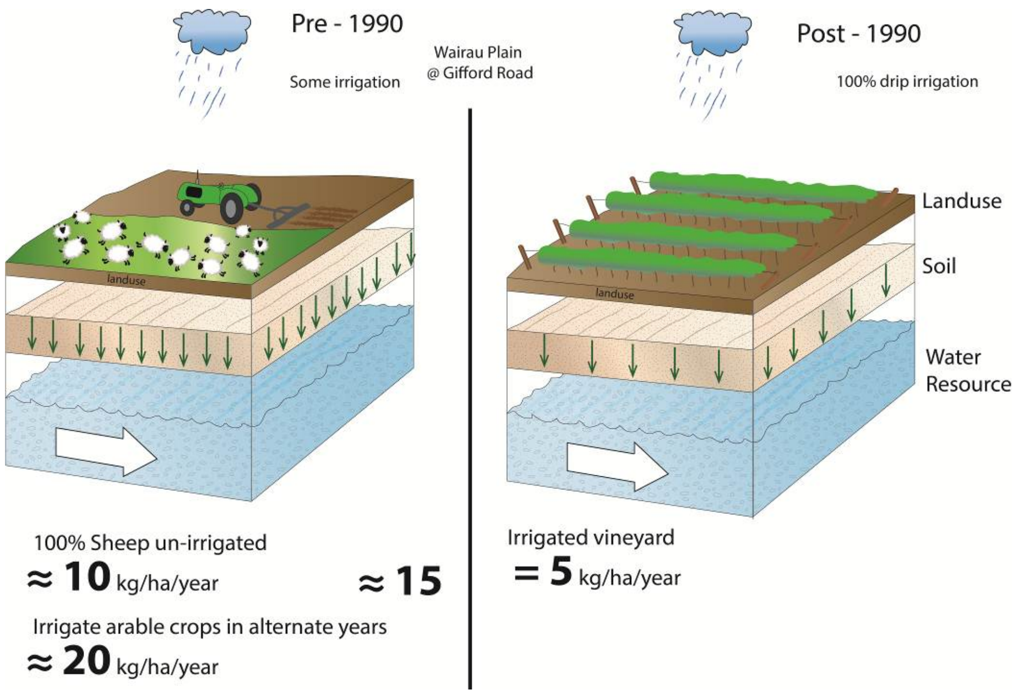


**Figure 8 : Four main drivers of aquifer nutrient leaching rates**

There is a question mark over the leaching rate of historic Wairau Plain land uses. Assessing the leaching rate is complicated by the fact that there was a greater diversity of crops and land uses in the 1960s to1980s than there is now and unlike vineyards which are fixed in time and space, the same paddock was used for different crops in successive seasons or years. The main historic land uses in very broad terms was dryland sheep farming with arable rotation.

Based on the Environment Canterbury Technical Report No. R14/19 – Estimated nitrate-nitrogen leaching rates under rural landuses in Canterbury (updated), average rates for unirrigated sheep grazing are around 10 and for irrigated arable crops is 20 kg/ha/year which giving a net figure of 15 kg/ha/year.

If we assume that prior to 1990 land uses were a combination of these two activities, the net nitrate load was probably around 15 kg/ha/year or in other words nitrate-nitrogen values could have been three times higher than what is currently observed.

This is a very crude approximation and will vary depending on soil type and rainfall also. The important message is that nitrate leaching rates are likely to have decreased over time and are now lower under vineyard despite being irrigated and having sheep grazing the inter-row for some of the year.

Since 2011 Plant & Food Research and MDC have been measuring the actual rate of leaching under vineyard on a medium depth soil at Giffords Road on the Northern Wairau Plain. Rates are very low compared to other land-uses such as arable cropping or dairying and over the two seasons measured to date have been around 5 kg/ha/year.

The purpose of this report is to explain trends in nutrient levels in groundwater. To do this we need to know how the leaching rate of the different land uses in Marlborough change over time. Also the rates of soil drainage from irrigation or rainfall over time as this mobilises surface contaminants. As was discussed earlier, the nutrient generating ability of a unit area of a particular land use is the same, but the flow of a aquifer can substantially modify nitrate-nitrogen concentrations.

# 4. Long-term trend in nitrate-nitrogen levels

MDC is fortunate to have collected several long time series of nitrate-nitrogen levels in groundwater at the same site which mirror the transition in land uses. One of these wells is situated near the corner of Old Renwick and Jacksons Roads. Because upstream land uses have changes over this time some of the variation in nitrate-nitrogen will reflect differences in these activities while some of the variation will be explained by differences in rainfall or irrigation leaching rates (Figures 9 & 10).

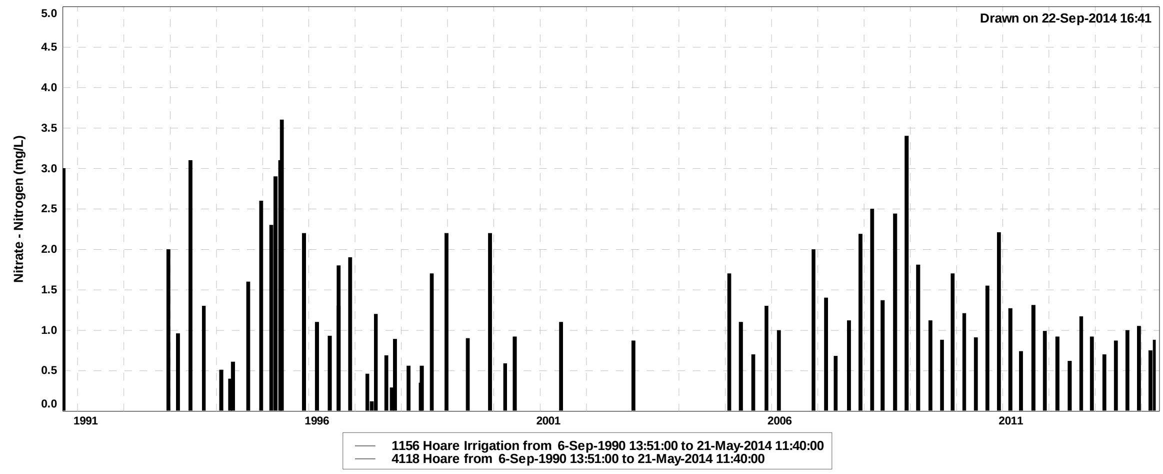


**Figure 9 : Nitrate-nitrogen concentration 1993-2014**

Interestingly there doesn't appear to be significantly higher nitrate-nitrogen levels during the early 1990s when mixed farming and cropping which are known to generate more nutrients byproducts than current land uses would have been more widespread. Peak concentrations occurred in the mid 1990s and in 2008 which coincided with higher rainfall periods (Figure 10).

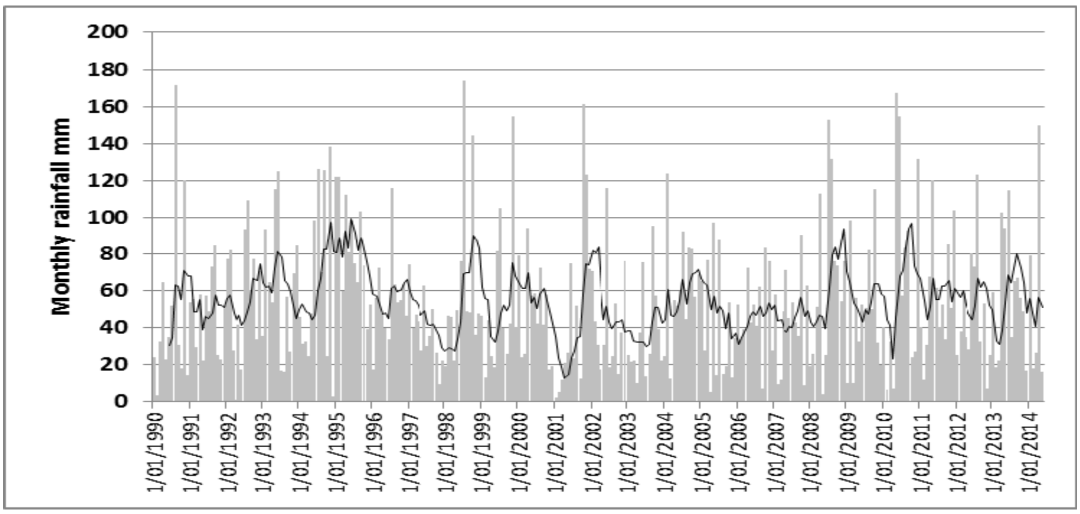


**Figure 10: Monthly rainfall 1990-2014**

# 5. Comparison of nitrate-nitrogen levels across Marlborough district

The nitrate-nitrogen concentration for groundwater was compared with the value for surface water in the same catchment where one existed, to see what that tells us about localised differences in land use, runoff patterns, degree of hydraulic connection and flow paths.

As part of the 2014 NPS on freshwater management, MDC is required to define so called freshwater management units (FMU) for the purpose of specifying water quality and quantity limits or thresholds. The analysis of surface water and groundwater quality measurements required to prepare this report was very useful for identifying linkages better water bodies and the degree of homogeneity or mixing in catchments or possible FMUs.

## 5.1. Aquifers located outside the Wairau Plain

### 5.1.1. Mill Creek Catchment – Wairau Valley

MDC measure the quality of both surface water and groundwater on the lower terrace closest to the Wairau River at Wairau Valley at two sites about 1 kilometre apart. Well O28w/0015 is 10 metres deep and located close to Mill Creek in its lower reaches, upstream of the Wairau River (Figure 11). The quality of Mill Creek water is measured upstream of Ormond Aquaculture at the MDC flow recorder site.

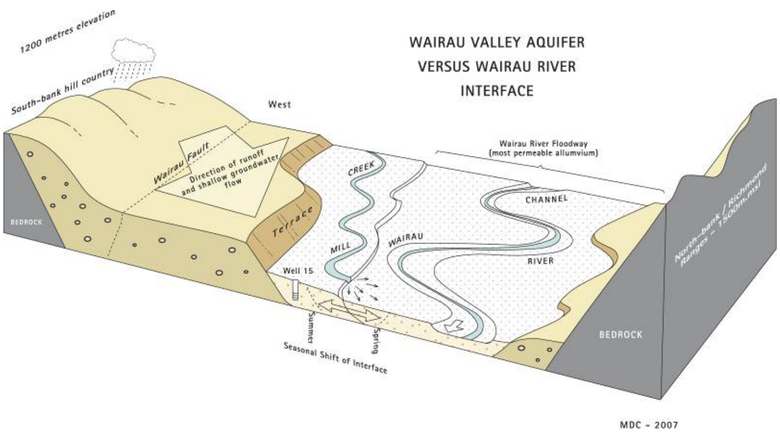


**Figure 11: Location of water quality sampling sites**

The main land uses in the catchment which receives runoff from the south-bank ranges and at a tangent across the upper terrace are: plantation forestry, mixed farming and dairy farming. The similarity between all parameters measured by MDC in surface water and groundwater indicates an interconnected water body with any differences explained by local land uses. Figure 12 shows the close match between nitrate-nitrogen levels in groundwater and surface water. The median groundwater nitrate-nitrogen concentration is 1.5 g/$m^3$ with peak values of 3.5 g/$m^3$ to date.

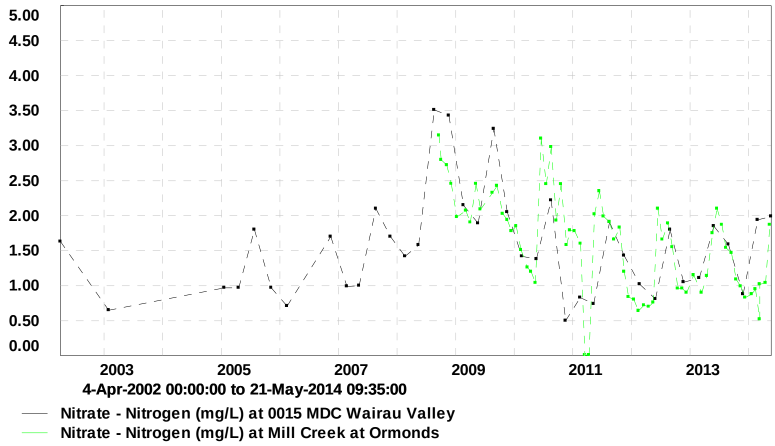


**Figure 12: Nitrate-nitrogen concentration 2002-2014**

Nitrate-nitrogen values are moderately high and peak in winter or spring in both groundwater and surface water (Figure 12). There was an increasing trend between 2002 and 2008, followed by a decline through to 2014. This pattern can't be explained by rainfall patterns alone and may reflect land use influences upstream. Peak values coincide with the highest oxygen values in groundwater which are associated with young runoff water draining from the surface and bringing with it nutrients (Figure 13). The percentage saturation of oxygen in groundwater is shown on the left hand vertical axis.

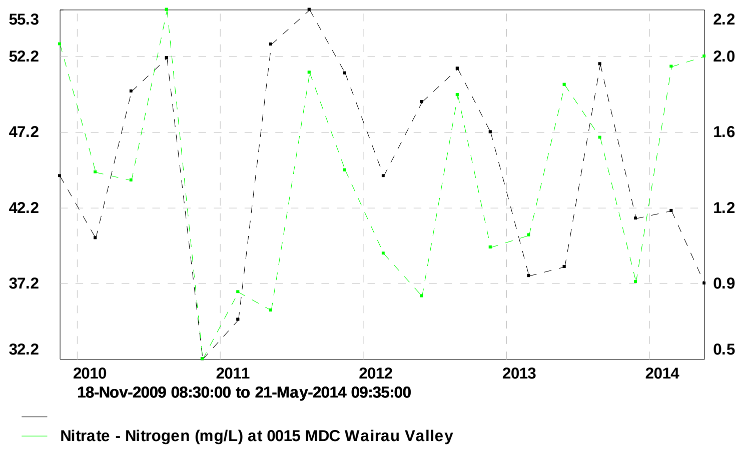


**Figure 13: Nitrate-nitrogen versus dissolved oxygen at well O28w/0015**

The estimated average nitrate-nitrogen bulk loading per hectare derived from the concentration in groundwater draining the catchment is 11 kg/year (Table 1).

| Catchment | Catchment Area generating significant nutrient (ha) | Mean Mill Stream flow at Ormond Aquaculture ($m^3$/s.) | Mean residence time of groundwater & surface water (years) | Median $NO_3$- nitrogen concentration ($g/m^3$) | Groundwater chemical environment & dissolved oxygen as % saturated | Calculated $NO_3$-N leaching load (kg/ha/year) |
|---|---|---|---|---|---|---|
| Wairau Valley shallow groundwater at well O28w/0015 | Estimated 2300 ha catchment or nutrient generating area of semi-extensive or pastoral farming | 0.427 | Surface water & groundwater of similar recent age | 1.8 (groundwater)<br>1.5 (Mill Stream at Ormond Aquaculture) | Moderately low oxygen levels<br>44% | Nitrate loading based on surface water flow & groundwater nitrate content<br>11 |

**Table 1 : Calculated land use loadings**

## 5.1.2. Upper Rai-Pelorus River & terrace gravel aquifer

This is the most recently established groundwater quality sampling site in the MDC nework. Well 10323 is located on a terrace elevated above the Rai River channel to the south of the area school (Figure 14). Lowland areas occupying the valley floors are mostly used for dairy farming with semi-extensive grazing on the lower hills, with native bush or plantation forestry on the steeper slopes.

The well was drilled in 2012 and there are too few data to form any firm conclusions at this stage about nutrient level patterns or interconnections between rivers or wells. Surface water quality is measured at several sites in the catchment but for the purposes of this report Rai Falls values are used as a comparison.

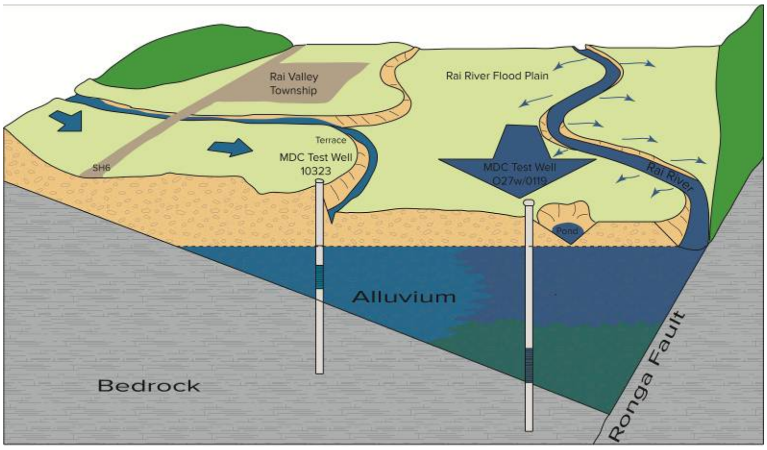


**Figure 14 : Well 10323 location relative to Rai River**

Nitrate-nitrogen values are about five times higher in groundwater at this site compared to Rai River levels at the Falls. The difference can probably be explained by the greater diluting capacity of the river compared to the throughflow of groundwater and localised factors. The median nitrate-nitrogen concentration in groundwater from well 10323 is 2.7 g/m$^3$ (Figure 15). Values are moderately high in groundwater and surprisingly low in surfacewater.

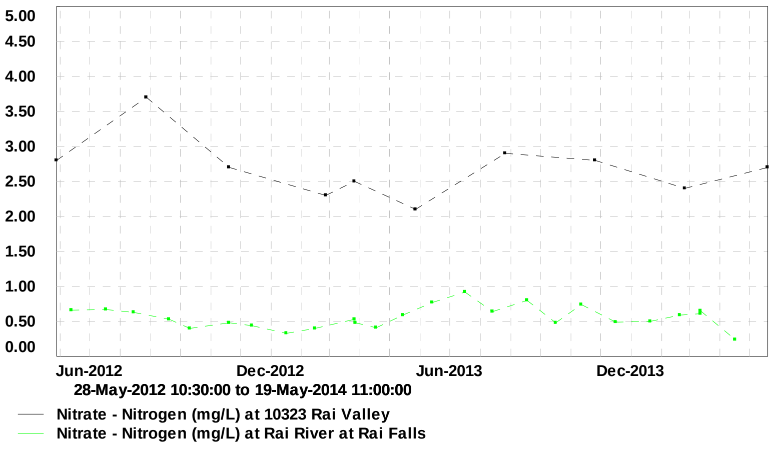


**Figure 15 : Nitrate-nitrogen concentration 2012-2014**

MDC still has a plenty to learn about the relationship between land use, runoff and the geochemistry of this large catchment. The residence time of groundwater from well 10323 was 2.5 years and the average time for rainfall runoff to transit the catchment is around 3 years. This means that the water quality of the Rai River at any point in time is likely to reflect the cumulative contribution of runoff over the previous 3 years.

| Catchment | Upstream catchment area generating significant nutrient (ha) | Mean Rai River flow at Falls ($m^3$/s.) | Mean residence time of groundwater (years) | Median $NO_3$-nitrogen concentration ($g/m^3$) | Groundwater chemical environment & dissolved oxygen as % saturated | Calculated $NO_3$-N leaching load (kg/ha/year) |
|---|---|---|---|---|---|---|
| Rai River terrace aquifer at well 10323 | Approximately 5000 upstream | 12 | 2-4 | 2.7 (groundwater)<br>0.62 (Rai River at Falls) | 39% | 47<br>based on $NO_3$-nitrate in surface water |

**Table 2 : Calculated land use loadings**

The estimated average nitrate-nitrogen loading per hectare in the catchment upstream of the Rai Falls is calculated to be about 47 kg/year (Table 2).

### 5.1.3. Cullen Creek & gravels aquifer (western Linkwater)

MDC measures groundwater quality in the Cullen Creek area of the Linkwater catchment at well P27w/0447 located south of the Cullensville Road. MDC also monitors surface water quality at Cullen Creek where it crosses Queen Charlotte Drive. Linkwater is an alluvial fan connecting Mahakipawa Sound with Queen Charlotte Sound (Figure 16).

**Figure 16 : Aerial view looking towards Linkwater and Havelock from Queen Charlotte Sound**

Well P27w/0447 is 17 metres deep and located approximately 50 metres east of Cullen Creek. Nitrate-nitrogen concentrations are higher in groundwater compared to surface water probably because of localised leaching in conjunction with lower dilution rates associated with groundwater (Figure 17). Concentrations are of the same order and peak or low values occur at the same time in each water body which reinforces the view of a relatively connected system hydrologically based on earlier studies.

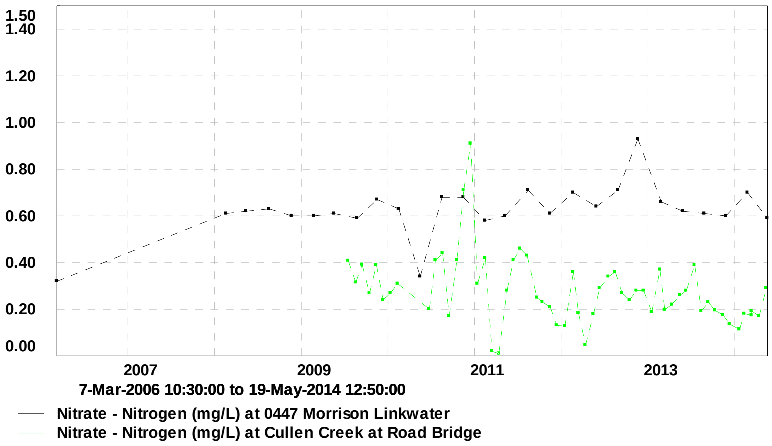


**Figure 17 : Nitrate-nitrogen concentration 2006-2014**

Dairy farming and cropping are the main land-uses on the lowland areas surrounding the well. Upland areas of the catchment are dominated by plantation forestry or native bush which contribute relatively low levels of nitrogen to water bodies. Nitrate-nitrogen concentrations are low compared to other intensively farmed and high rainfall areas.

There is insufficient length of record covering a spectrum of weather conditions to come to any conclusions about time trends at this stage. Table 3 shows the estimated average nitrate-nitrogen loading per hectare in the catchment of 36 kg/year which is in line with other areas with similar characteristics.

| Catchment | Catchment Area generating significant nutrient (ha) | Cullen Creek mean flow estimated by NIWA virtual climate calculator ($m^3$/s.) | Mean residence time of groundwater (years) | Median $NO_3$-nitrogen concentration ($g/m^3$) | Groundwater chemical environment & dissolved oxygen as % saturated | Calculated $NO_3$-N leaching load (kg/ha/year) |
|---|---|---|---|---|---|---|
| Cullen Creek Gravels Aquifer at well P27w/0447 | Approximately 150 | 0.64 | 3-6 | 0.624 (groundwater)<br>0.269 (Cullen Creek) | 53% | 36 based on $NO_3$-nitrate in surface water |

**Table 3 : Calculated land use loadings**

## 5.1.4. Upper Tuamarina River & Tuamarina River Gravels Aquifer

The quality of Tuamarina River surface water is measured at a site above the confluence with the Wairau River which may not be representative of runoff and land uses upstream of the Para wetland. MDC also monitors groundwater quality at the MDC Speeds Road Picton municipal wellfield which is located halfway between Picton and the Wairau Plain, representing land-uses and runoff from the northern half of the catchment through to the Elevation (Figure 18).

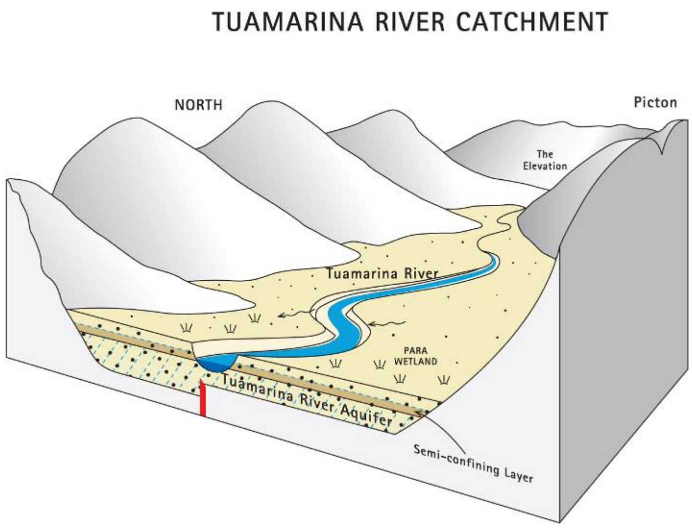


**Figure 18 : Conceptual model of Tuamarina River & Gravels Aquifer**

The median nitrate-nitrogen concentration is 1.8 g/m$^3$ between 2005 and 2014 (Figure 19). Interestingly, maximum concentrations often occur in summer whereas in most other groundwater systems values peak in winter or spring. The reason why isn't clear yet but may be related to pasture irrigation or linked to the operation of the municipal supply well-field pumping.

The mean residence time of groundwater is 13 years which is high for the type of alluvial aquifer and part of the reason may involve mixing and travel times. The main upstream land uses contributing nutrients to the Speeds Road area are dairying on the valley floors, lifestyle blocks or settlements, a golf course and plantation forestry or native bush on the hills.

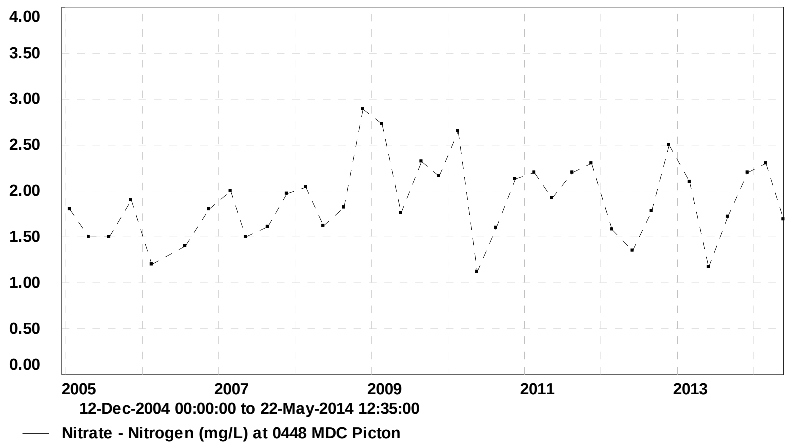


**Figure 19 : Nitrate-Nitrogen concentration 2005-2014**

Nitrate-nitrogen concentrations are stable and there are no apparent trends between 2005 and 2014 (Figure 19). There is a large seasonal range and values are moderately high.

The estimated land use loading based on the median dissolved nitrate-nitrogen concentration and mean flow of the Tuamarina River at Para Road is 45 kg/ha/year (Table 4). Unfortunately there are only occasional nitrate-nitrogen measurements for the Tuamarina River opposite the well-field at Para Road to compare with groundwater levels, but those available appear to indicate lower values in surface water which is normally the case.

| Catchment | Catchment Area generating significant nutrient (ha) | Mean Tuamarina River flow at Para Road ($m^3$/s. ) | Mean residence time of groundwater (years) | Median $NO_3$-nitrogen concentration in groundwater ($g/m^3$) | Groundwater chemical environment & dissolved oxygen as % saturated | Calculated $NO_3$-N leaching load (kg/ha/year) |
|---|---|---|---|---|---|---|
| Tuamarina River Valley Aquifer at well P27w/0448 | 2000 | 1.514 | 13 | 1.9 | Moderately reducing conditions 27% | 45 |

**Table 4 : Calculated land use loadings**

## 5.1.5. Needles Creek Gravels Aquifer & Flaxbourne River

MDC monitors groundwater quality in the Flaxbourne River catchment at well P29w/0188 which is used for small scale irrigation on a lowland farm upstream of SH1 at Ward. Well 188 is 6 metres deep and within 40 metres of Needles Creek. Land uses in the upstream catchment are mostly traditional semi-extensive pastoral farming with some vineyard on the lower lying flats (Figure 20).

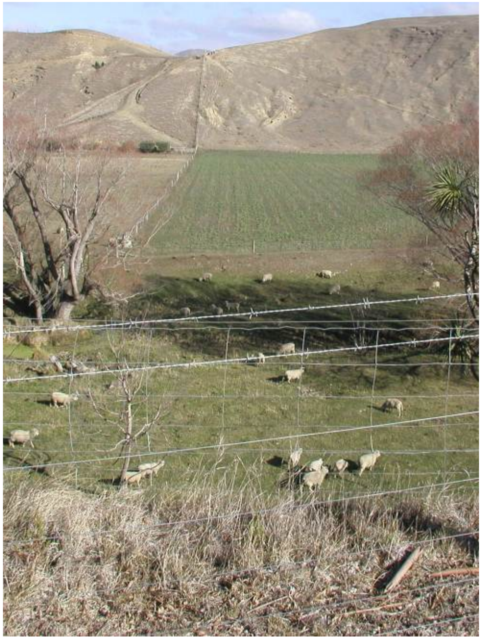

**Figure 20 : Middle reaches of Needles Creek with channel in foreground**

Nitrate-nitrogen concentrations in groundwater are very low with a median value between 2012 and 2014 of just 0.002 $g/m^3$. (Figure 21). Concentrations are significantly higher for parts of the year in Flaxbourne River water at the quarry site which is downstream of where the Needles Creek joins the main channel.

All groundwater parameters MDC measure indicate that well P29w/0188 taps an isolated aquifer dominated by old water and reduced chemical conditions. As a consequence most nitrogen is in its ammoniacal rather than nitrate form. Whether groundwater quality at well 188 is representative of the wider catchment remains to be seen and it may reflect localised conditions although the 2007 GNS Science report shows the existence of aerobic conditions in several wells and wetlands.

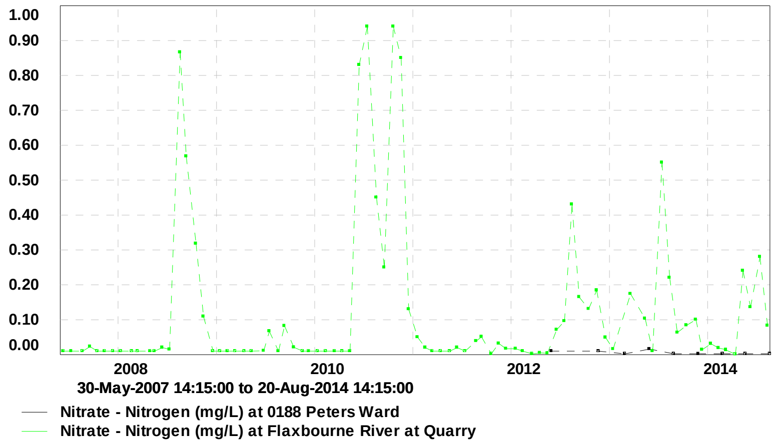


**Figure 21 : Nitrate-nitrogen concentration 2007-2014**

There is a large seasonal variation in Flaxbourne River nitrate-nitrogen values from very low in summer to moderately high in the wetter months. Groundwater levels are by comparison very low due to the denitrifying processes associated with the aquifer which is why a nitrate-nitrogen loading can't be calculated reliably because much of what may have existed would be consumed.

## 5.2. Mid Wairau Plain aquifers

### 5.2.1. Omaka River & Omaka River Aquifer

MDC monitors groundwater quality at well P28w/3069 located halfway between the bridges at Hawkesbury and Tyntesfield Roads. The well is located on a low terrace elevated above the Omaka River channel (Figure 22). Surface water and groundwater hydrology is known to be dominated by Omaka River flows.

**Figure 22 : MDC well P28w/3069**

The MDC monitoring well 3069 at Timara Wines is located 300 metres west of the Omaka River channel, but levels in the well are moderated by river flows based on the small variation in groundwater elevation since 1998.

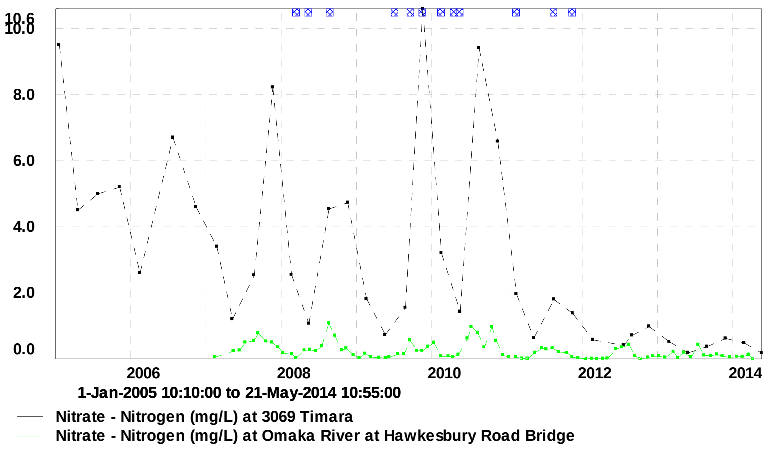


**Figure 23 : Nitrate-nitrogen concentration 2005-2014**

Well P28w/3069 is located within a large vineyard of mature plantings and there is a strong seasonal pattern of peak nitrate-nitrogen concentrations coinciding with spring rains. Nitrate-nitrogen concentrations in well P28w/3069 samples have a large range from a minimum of 0.2 to a maximum of 10.6 g/m$^3$. The median value is 1.9 g/m$^3$ (Figure 23).

Groundwater values mostly peak in spring but occasionally winter, whereas concentrations in Omaka River water peak slightly earlier in winter. There has been an abrupt and significant decline in nitrate-nitrogen concentrations in groundwater since 2011. It is thought that this change reflects a reversion to natural equilibrium conditions based on the premise that groundwater provides the summer baseflow of the Omaka River.

The earlier higher values are thought to show the effects of increased runoff between 2008 and 2011 leading to more leaching of surface nutrients to groundwater. The same pattern doesn't occur in surface water which points to local influences also including inputs of nutrients from further south around Tyntesfield Road draining towards well 3069.

The estimated average nitrate-nitrogen loading per hectare is calculated to be very low at 1 kg/year based on dissolved levels in the Omaka River in conjunction with the mean flow of the river and and likely nutrient contributing area (Table 5).

| Catchment | Catchment Area generating significant nutrient (ha) | Mean Omaka River flow at gorge ($m^3$/s.) | Mean residence time of groundwater (years) | Median $NO_3$-nitrogen concentration ($g/m^3$) | Groundwater chemical environment & dissolved oxygen as % saturated | Calculated $NO_3$-N leaching load (kg/ha/year) |
|---|---|---|---|---|---|---|
| Omaka River Valley Aquifer at well P28w/3069 | 4000 semi-extensive upland pastoral farming + 1500 lowland intensive farming | 1.16 | - | 1.89 (groundwater)<br>(0.14) Omaka River at Hawkesbury Rd bridge | 82% | Nitrate loading based on surface water nitrate content & flow<br>1 |

**Table 5 : Calculated land use loadings**

### 5.2.2. Woodbourne Sector & Doctors Creek

MDC monitors groundwater quality at well P28w/0662 at RNZAF Base Woodbourne south of Middle Renwick Road near Blenheim airport. Well 662 is 18 metres deep. Woodbourne is defined as a separate aquifer management sector because it is influenced by both Wairau Aquifer and Southern Valleys recharge water, with the proportion depending on the season.

This is illustrated by Figure 24 showing contours of groundwater table elevation at Woodbourne for November 1982. The blue arrows show the direction of groundwater flow with contributions from both the

Wairau Aquifer and Southern Valleys catchments. At other times there is minimal flow coming from the Southern Valleys. These flow patterns have implications for water quality.

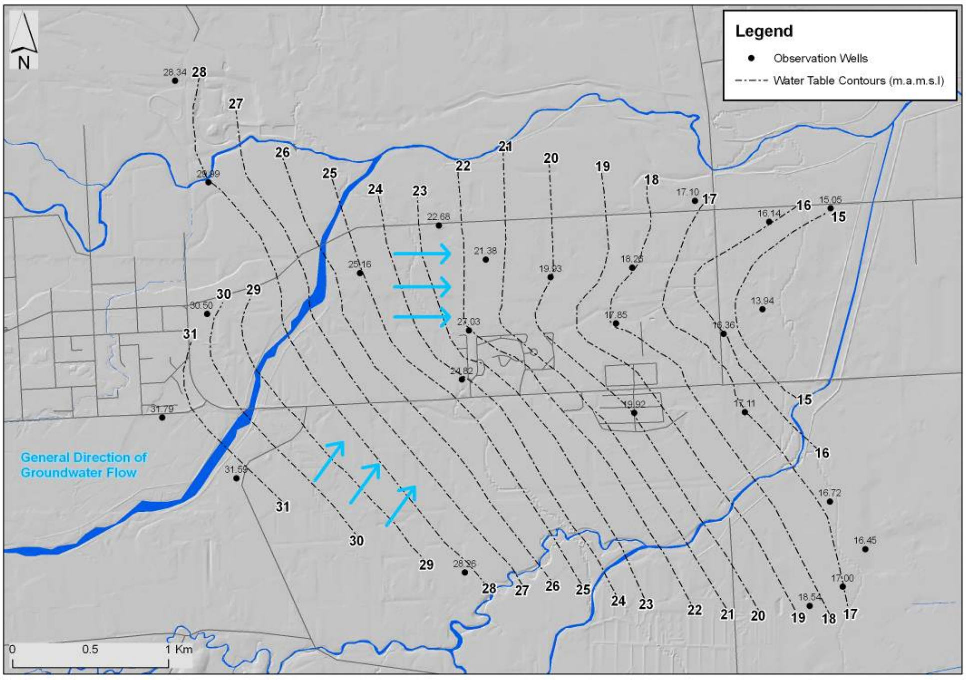


**Figure 24 : Contours of measured groundwater elevation for November 1982**

Nitrate-nitrogen concentrations are moderately high in groundwater from well 662 with a median value of 1.5 g/m$^3$ (Figure 25). There are gaps in the MDC record since the first samples were taken in 1977 but nitrate-nitrogen concentrations appear to have been reasonably stable since at least 1987. Levels have been declining since a peak in 2008 which coincided with the highest annual Omaka River mean flow.

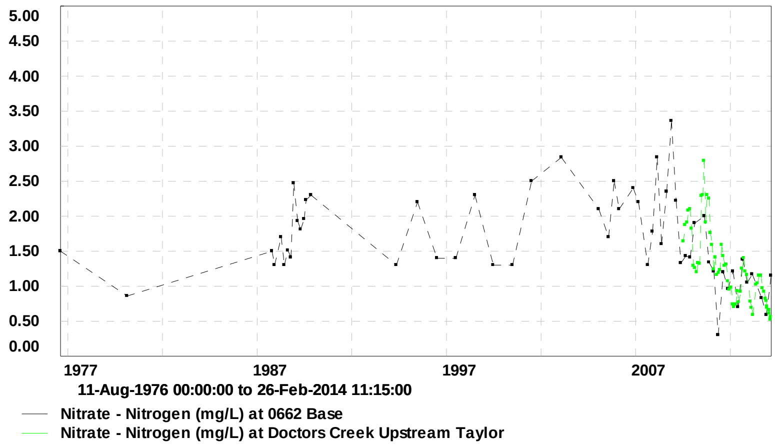


**Figure 25 : Nitrate-nitrogen concentration 1977-2014**

There is a good match between nutrient values in groundwater underlying the middle areas of the Wairau Plain and those measured in Doctors Creek upstream of the Taylor River. The reason is that the same water dominates both surface and groundwater. Omaka River water is lost to the gravels and flows towards Blenheim bringing with it nutrients from the Woodbourne area as well as inputs from the Southern Valleys.

## 5.3. Northern Wairau Aquifer

Nutrient levels in groundwater can be traced along its flowpath from where it leaves the Wairau River as recharge water between the Waihopai River and opposite Wratts Road, to where it exits as spring flow or enters the confined aquifer. This is effectively the same water and changes in quality reflect land use inputs as there are only minor changes in flow along the underground stream from rainfall leaching minus abstraction from wells.

### 5.3.1. Wairau Aquifer recharge sector (north-western area)

MDC samples groundwater quality as part of the central NGMP at well P28w/0398 in the Pernod Ricard vineyard on the eastern side of SH6 before the Nelson road bridge. Well 398 is 10 metres deep and located 1.5 kilometres from the Wairau River in terms of the travel path of groundwater flows.

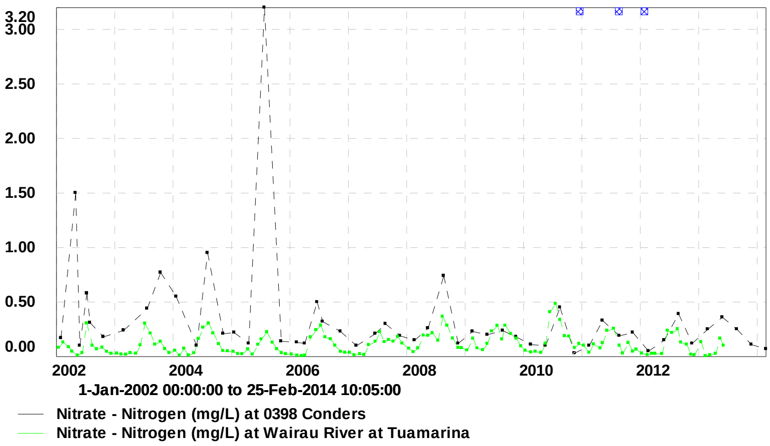


**Figure 26 : Nitrate-nitrogen concentration 2002-2013**

Since 2006 nitrate-nitrogen concentrations in groundwater have been the same as the content of Wairau River water, which provides the bulk of aquifer recharge. The spikes prior to this reflect rainfall leaching of surface nutrients downwards to the water table, but it is unclear why they haven't occurred since that time. It may be due to differences in local vineyard fertiliser or irrigation practices. Well 398 was deepened in 2012 to improve its well head security, but the trend starts before this time.

Concentrations are low and stable except for the occasional leaching spikes. This reflects the influence of the Wairau River baseflow water entering the aquifer at a relatively constant rate and moderating nutrient levels at well 398. It follows that the water quality of the Wairau River is translated directly to groundwater in areas close to the channel. The median nitrate-nitrogen concentration is 0.21 g/m$^3$ but short term peaks can be an order of magnitude higher (Figure 26). Latterly groundwater nitrate-nitrogen concentrations have exactly matched those of the Wairau River showing there are minimal land use influences on underground flows.

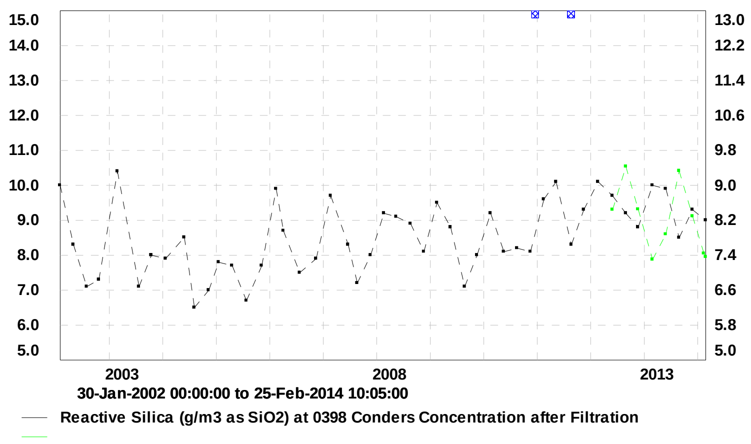


**Figure 27 : Silica & dissolved oxygen concentration (ppm)**

There is a regular seasonal pattern in concentrations of silica in groundwater at well 398 shown by the black line in Figure 27. High silica generally indicates older more evolved groundwater and the cycle implies younger recharge water in the wetter months and older water in summer or autumn. Dissolved oxygen concentrations have been overplotted in green and confirm the pattern of more oxygenated younger water entering the aquifer in the months with higher rainfall or runoff.

### 5.3.2. Spring Creek Catchment & Wairau Aquifer Springs Sector

MDC monitors the quality of groundwater at well P28w/3009 in Wratts Road located upstream of the headwaters of Spring Creek. Surface water quality is measured in the lower reaches of Spring Creek at the floodgates before it flows into the Wairau River.

Groundwater at well 3009 has entered the aquifer downstream of the SH6 bridge and flowed underground for approximately 3.5 kilometres. Because it is located further from the Wairau River than the Conders well, well 3009 water has higher nutrient levels than Wairau River recharge water. Groundwater quality changes as water moves beneath the Rapaura area and emerges as Spring Creek, are very informative both about the hydrology and land use impacts.

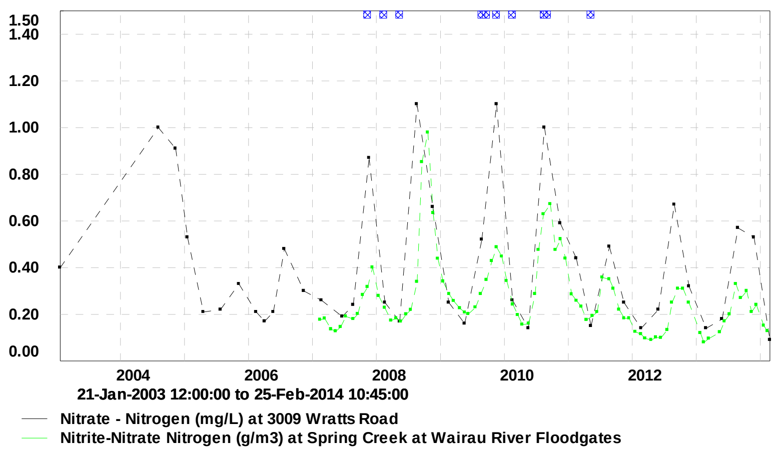


**Figure 28 : Nitrate-Nitrogen concentration 2003-2014**

The range and seasonality of nitrate-nitrogen concentrations is very similar between well 3009 and Spring Creek water samples. This supports the existing understanding that they are a single interconnected water body with surface flow mostly representing upwelling groundwater (Figure 28). Groundwater sulphate concentrations exhibit the same pattern (Figure 29).

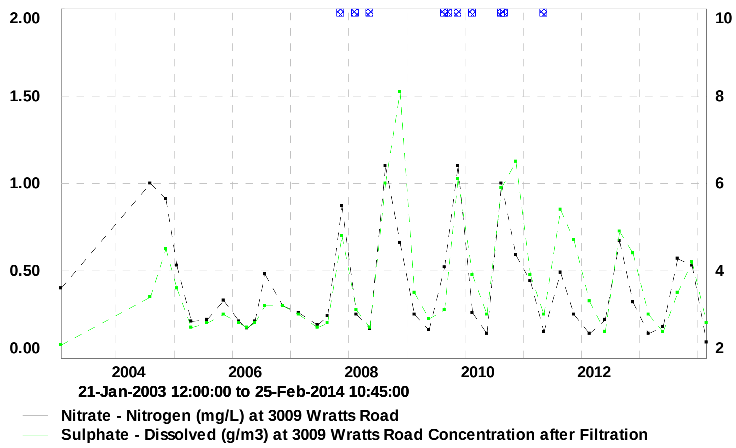


**Figure 29 : Nitrate-nitrogen versus sulphate concentration 2003-2014**

The median nitrate-nitrogen concentration in groundwater is 0.26 g/m$^3$. There is a consistent pattern of low nitrate-nitrogen in autumn representing Wairau River recharge water, which provides the bulk of aquifer recharge, interspersed with pulses of mainly rainfall mobilised land based nutrients in winter or spring.

There is also a close match between the seasonal variation in the groundwater table and dissolved nitrate-nitrogen levels (Figure 30). A rising water table may also bring nitrate-nitrogen into contact with the shallow screen in well 3009 and is a good indicator of rainfall recharge in this area where the water table is close to the surface in spring.

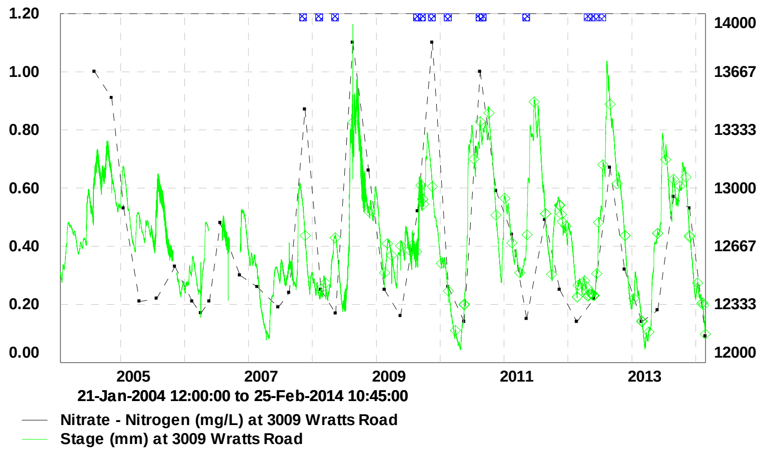


**Figure 30 : Nitrate-nitrogen concentration versus groundwater level 2004-2014**

Apart from the pronounced seasonal pattern there is no apparent trend over the period of sampling since 2004. Land uses have been stable over that time with vineyard predominating. Historically the area upstream was used for arable and mixed farming but it is likely that accumulated nutrients are flushed through reasonably quickly within one to two seasons. The estimated average nitrate-nitrogen load per hectare is 13 kg/year (Table 6).

| Catchment | Catchment Area generating significant nutrient (ha) | Mean groundwater throughflow ($m^3$/s.) | Mean residence time of groundwater (years) | Median $NO_3$-nitrogen concentration ($g/m^3$) | Groundwater chemical environment & dissolved oxygen as % saturated | Calculated $NO_3$-N leaching load (kg/ha/year) |
|---|---|---|---|---|---|---|
| Wairau Aquifer at well P28w/3009 | 2000 vineyard | 4 | Less than 5 | 0.2 after correction for Wairau River recharge component<br><br>(0.16) Spring Creek at Floodgates upstream of confluence | Moderately oxygenated<br><br>85% | 13 |

**Table 6 : Calculated land use loadings**

## 5.3.3. Wairau Aquifer Springs Sector & Opawa River

MDC monitors groundwater quality at well P28w/4404 located in Mills and Ford Road, just east of the Opawa River (Figure 31). The Wairau Aquifer is semi-confined in this area meaning it is leaky and there is commonly a good hydraulic connection between groundwater and surface water. Well 4404 was drilled by MDC in 2004 to represent the groundwater quality in the mid plains area and to measure stream depletion parameters in relation to local aquifer fed springs.

**Figure 31 : Well P28w/4404 looking west with Opawa River in background by willow trees**

The median nitrate-nitrogen concentration in groundwater is 0.39 g/m$^3$. A similar pattern exists to the other Wairau Aquifer monitoring sites with seasonal peaks in nitrate-nitrogen normally in spring, but no strong trends at this stage (Figure 32).

Levels of nitrate-nitrogen in Opawa River water are more variable and unravelling the causes is difficult because of the number of rivers which contribute flow including the Omaka River, Wairau River, Waihopai River via Gibson Creek; along-with groundwater and local runoff. The very low summer values which fall below those of groundwater baseflow are caused by algal consuming the nitrate.

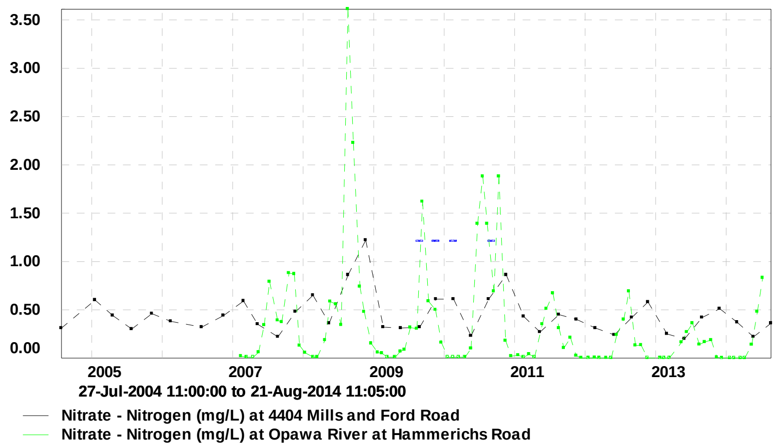


**Figure 32 : Nitrate-nitrogen concentration 2004-2014**

## 5.3.4. Wairau Aquifer Lower Wairau Sector

Most Wairau Aquifer water exits the system as Spring Creek flow with only a small proportion entering the confined aquifer where its velocity slows considerably. MDC samples groundwater from well P28w/0188 at Dicks Road on the eastern side of the Wairau River. Well 188 is 25 metres deep and for most of the year it is able to free-flow because of naturally high artesian pressures (Figure 33).

**Figure 33 : Well P28w/0188 free flowing naturally during MDC sampling**

The purpose for sampling at this location is to measure the transition in quality as water moves from the unconfined aquifer where it is exposed to land uses, to the confined aquifer which is isolated from surface processes with reducing chemical conditions that actively remove nitrate-nitrogen from solution.

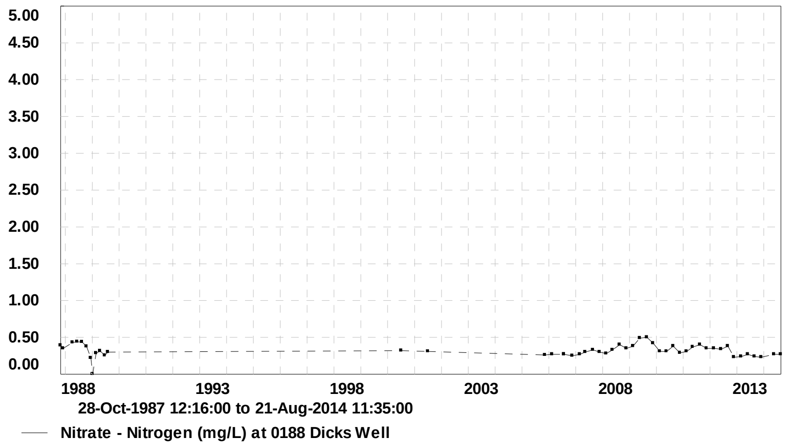


**Figure 34 : Nitrate-nitrogen concentration 1988-2014**

Nitrate-nitrogen levels are low and appear stable based on the good number of samples in 1988 to compare with recent values. However the gaps do raise questions as to what happened in those seasons (Figure 34).

Interestingly median nitrate levels are higher in well 188 groundwater than for wells further west in the Wairau Aquifer. Peak values are lower as there is less leaching due to the confined nature of the aquifer here, but minimum levels are higher because there is less flow to dilute the same concentration of nutrient inherited from upstream land uses.

### 5.3.5. Summary

The pattern of nitrate-nitrogen content in groundwater along the northern flow path is shown in Figure 35 for a series of wells all tapping the same stream tube. The process starts with inputs of what is essentially Wairau River recharge water with low nitrate because of dilution, and characterised by well 398 levels shown in green.

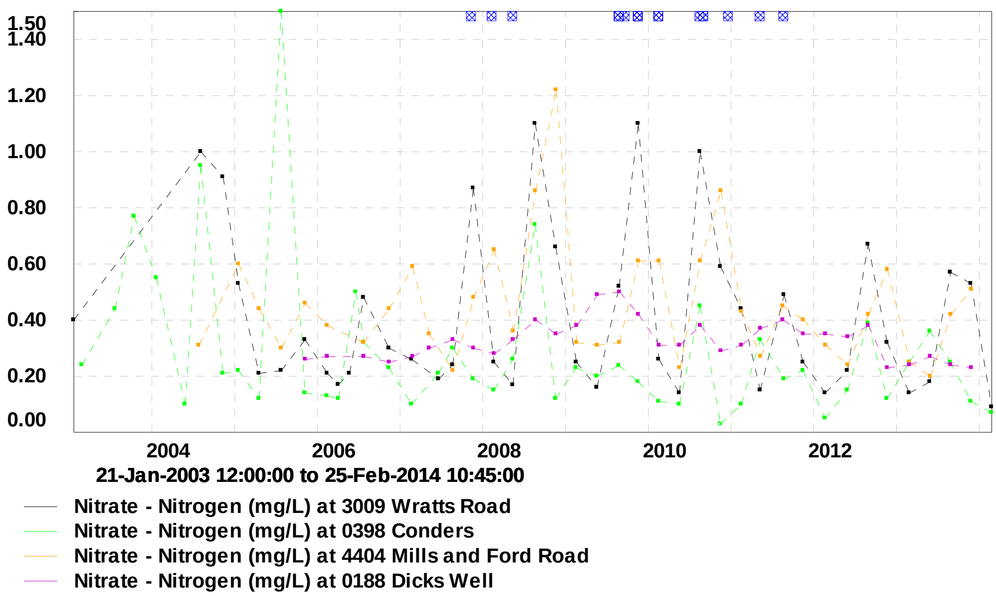


**Figure 35 : Nitrate-nitrogen concentration 2003-2014 northern Wairau Aquifer**

Groundwater flows eastwards under the force of gravity, slowly accumulating nutrients draining from the overlying land uses which are leached in Spring each year. This pattern is best seen at well 3009 in black. Peaks are high, but levels return to low levels quickly due to the diluting effect of the relatively large groundwater baseflow.

Further east again at Mills and Ford Road, both minimum and peak concentrations are higher than upstream wells showing the assimilative capacity of groundwater is being matched by land surface effects. This is the orange trace.

Finally at the most easterly site in the northern stream tube at Dicks Road where groundwater enters the confined portion of the aquifer, the maximum median nitrate value is seen. This increase is caused by a drop in the diluting capacity of the aquifer as it becomes confined which in turn lessens the external influences and inputs from land uses.

## 5.4. Southern Wairau Aquifer groundwaters

The boundary between the northern and southern stream tubes of the Wairau Aquifer roughly coincides with Old Renwick Road. South of this line aquifer transmissivity declines rapidly and groundwater is influenced by nutrients draining from the Southern Valleys Catchments or aquifers as well as those from overlying land uses.

Groundwater originates as Wairau River losses in the recharge reach upstream of the SH6 bridge in the west, and ends up beneath the Morgans Road area in the east. This groundwater flow is less homogeneous than the more northerly Wairau Aquifer flow, especially in wetter seasons because of Southern Valleys inputs. Leakage from the Opawa River is another source of dilution and also nutrients for groundwater in this southern part of the Wairau Aquifer.

### 5.4.1. Wairau Aquifer Recharge Sector – (south-western area)

MDC samples groundwater from well P28w/2651 which is located about 200 metres north of the terrace marking the southern boundary of the Wairau Aquifer, and midway between Renwick and the Waihopai River, as part of the seasonal state of the environment monitoring. Well 2651 is 12 metres deep and surrounded by mature vineyard (Figure 36).

Higher nitrate-nitrogen concentrations have been observed here over the past 15 years. The most likely explanation is a combination of the lower groundwater throughflow further away from the Wairau River, and extra nutrient loads originating from drainage of the Lower Waihopai River Valley land on top of those contributed by local land uses near the sample well.

**Figure 36 : Well P28w/2651**

Peak nitrate-nitrogen values reached the very high value of 13 g/$m^3$ in 2006 and 2007 which is in excess of the human health drinking water guideline. Peak values were observed at other wells over this time which suggests it is at least partly climate related, but local factors such as low groundwater flushing also play a part. The median nitrate-nitrogen concentration between 1999 and 2014 was 3.4 g/$m^3$ (Figure 37).

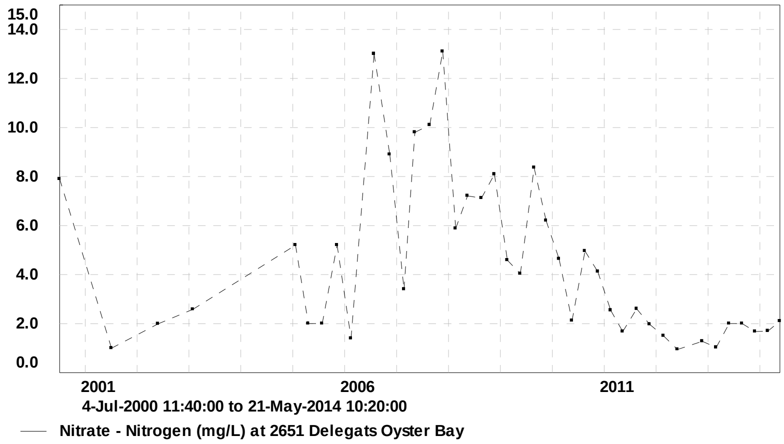


**Figure 37 : Nitrate-nitrogen concentration 2000-2014**

## 5.4.2. Wairau Aquifer recharge sector (Renwick area)

MDC samples groundwater from the Renwick municipal well-field well P28w/0548 each season. Well 548 is screened between 12 and 27 metres depth. The site is outside the direct influence of Wairau River recharge flows but is affected by both Gibson Creek flow leakage and rainfall recharge, which entrain nutrients (Figure 38).


**Figure 38 : MDC Renwick well-field location map**

Because well 548 is close to the terrace it is highly likely that runoff from the Delta area will contribute extra nitrate-nitrogen to groundwater which would explain the higher nitrate-nitrogen values than those measured in nearby wells affected by overhead or local vineyard leaching rates alone.

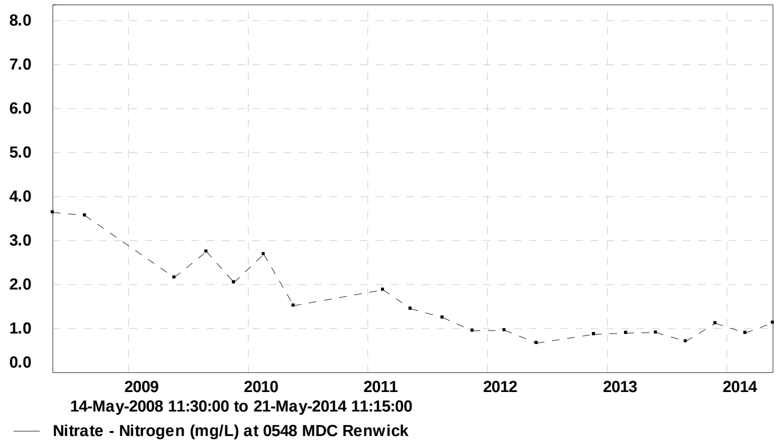


**Figure 39 : Nitrate-nitrogen concentration 2008-2014**

Nitrate-nitrogen concentrations show a declining pattern since 2008 from moderate to low levels (Figure 39). The median concentration is 1.25 $g/m^3$. The fall in nitrate-nitrogen since 2009 is too short to call a trend but is likely to be the same pattern that is seen at well 2651 and caused by some of the same drivers.

## 5.4.3. Wairau Aquifer Recharge Sector (central area)

MDC monitors groundwater at well P28w/4118 which is a privately owned irrigation well located near the intersection of Old Renwick and Jacksons Roads. This is near the southern boundary of the most productive part of the Wairau Aquifer, and the northern boundary with the Woodbourne sector, which is prone to seasonal drought.

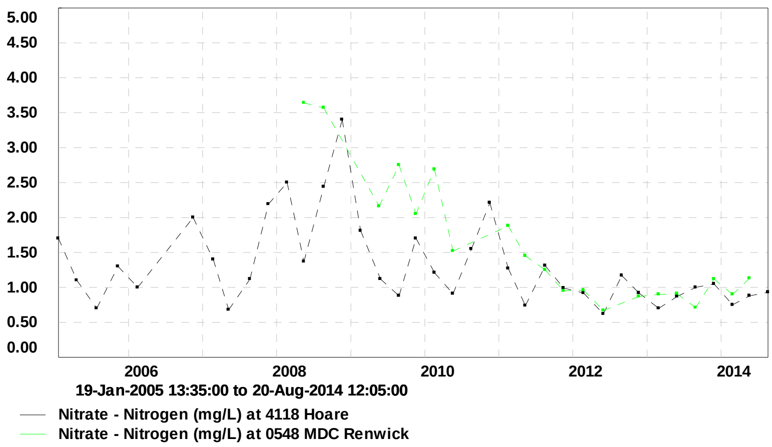


**Figure 40 : Nitrate-nitrogen concentration 2005-2014 at wells 4118 & 548**

This is a very important site for monitoring the effects of land uses on groundwater quality because an interrupted record dates back to 1990 at well 4118, and its predecessor and neighbouring well 1156. Well 4118 is 22 metres deep, and well 1156 which it replaced was screened at 14 metres.

The median nitrate-nitrogen concentration is 1.12 $g/m^3$ for well 4118 and 1.1 $g/m^3$ for well 1156. Nitrate-nitrogen concentrations exhibit the same seasonality as the other unconfined, shallow Wairau Aquifer sites. It also shows the rise in levels around 2008 which is a regional pattern (Figure 40).

As you move further south and further from the recharge influence of the Wairau River, the minimum nitrate-nitrogen levels in groundwater rise, presumably because the aquifer throughflow and hence assimilative capacity is less.

Peak nitrate-nitrogen values are higher for the same soil type and similar upstream land uses as at the Wratts Road well 3009, although there is a factory for processing crops 1 kilometre upstream which may add extra nutrients than under vineyard alone. The green line in Figure 40 shows the variation in nitrate-nitrogen concentration for the same time at well 548 which is within the same groundwater flow stream as 4118 and values are similar. Nutrient levels appear to have reached a low equilibrium since 2012.

### 5.4.4. Wairau Aquifer Spring Sector (Blenheim) & Murphys Creek

MDC monitors groundwater quality at well P28w/3120 which forms part of the municipal supply well-field at Middle Renwick Road near the intersection with Colemans Road. Surface water quality of nearby Murphys Creek water is sampled where it crosses Nelson Street (Figure 41). Murphys Creek is mainly groundwater fed and any differences in water chemistry are likely to reflect surface runoff or local influences.


**Figure 41 : MDC Blenheim water sampling sites**

Well 3120 is 25 metres deep. Apart from several high spikes, concentrations of nitrate-nitrogen are very similar in groundwater between well P28w/3120 and surface water from neighbouring Murphys Creek. The median nitrate-nitrogen concentration in groundwater is 1.45 g/m$^3$, but peaks can be as high as 3.5 g/m$^3$ (Figure 42).

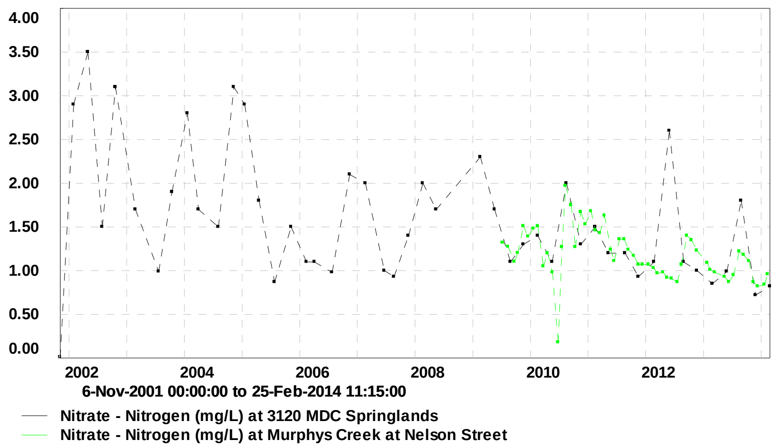


**Figure 42 : Nitrate-nitrogen concentration 2002-2014**

A much longer record of nitrate-nitrogen exists for well P28w/3120 than Murphys Creek and shows an overall declining pattern in concentrations since 2002 with pronounced seasonal peaks. Being the same interconnected water, it follows that nitrate-nitrogen concentrations in Murphys Creek will mimic those of groundwater. This means that Murphys Creek nitrate-nitrogen levels probably reached similar values in 2002 as groundwater.

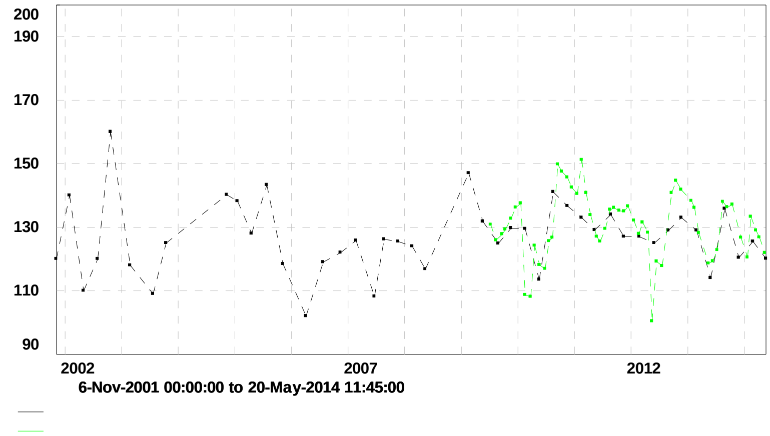


**Figure 43 : Electrical conductivity (microS/cm) 2002-2014**

The electrical conductivity of water represents the sum of all dissolved chemicals. Electrical conductivity values of Murphys Creek and well P28w/3102 water match which supports the notion of an interconnected water body (Figure 43). This means it makes sense to manage it as a single entity.

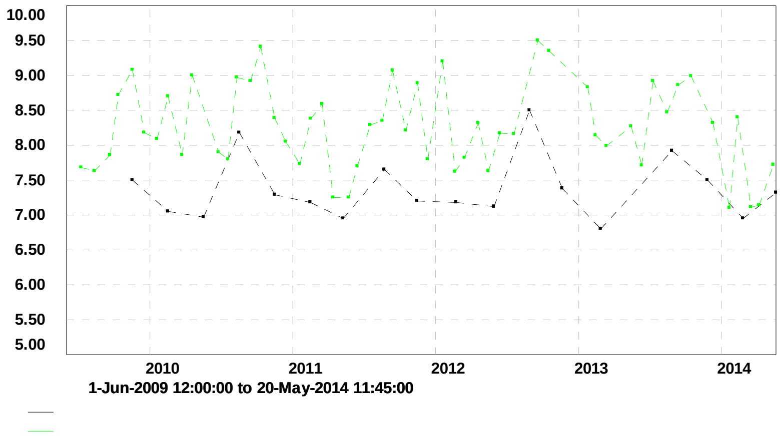


**Figure 44 : Dissolved oxygen concentration (ppm) 2009-2014**

As expected, dissolved oxygen levels are higher in Murphys Creek at Nelson Street than groundwater except in the headwaters where groundwater emerges into contact with the atmosphere (Figure 44). Dissolved oxygen levels were the same in the summer of 2014 implying most surface water flow consisted of groundwater base flow.

Interestingly during the dry late summer conditions experienced by the Taylor River in 2013, Murphys Creek dissolved oxygen levels didn't match those of groundwater which it should have if all baseflow was maintained by aquifer inputs as gaugings showed.

Care is needed when interpreting dissolved oxygen results from well P28w/3120 because turbulence is generated by the well pump and also there are 3 month gaps between measurements so we may not be seeing the entire story. Continuous observations are really needed. Groundwater measurements are in black and surface water values in green.

### 5.4.5. Wairau Aquifer Lower Wairau Sector

MDC samples groundwater from well P28w/4403 at Morgans Road just south of where it intersects Roses Overflow. Well 4403 was drilled by MDC in 2004 specifically to fill a gap in knowledge of Wairau Aquifer flow in the Lower Wairau area and for calibrating the Riverlands Aquifer flow model. Well 4403 is screened within the confined Wairau Aquifer over a depth of between 34 to 37 metres below the surface.

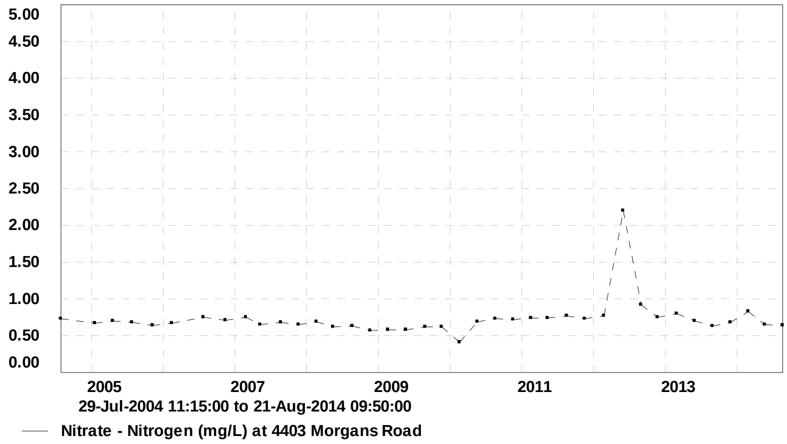


**Figure 45 : Nitrate-nitrogen concentration 2004-2014**

The median nitrate-nitrogen concentration is 0.69 g/m$^3$ which is low by groundwater standards (Figure 45). There is a very slight upwards trend in levels over the past decade but it is uncertain if this relates to recent land uses, or if there is a delay as groundwater flow velocities are slower here than further west due to the lower hydraulic grade and transmissivity.

**Figure 46 : land uses surrounding monitoring well 4403 have changed over time**

Because the aquifer is fully confined at this location there is likely to be some natural denitrification happening to explain the decline in nitrate-nitrogen levels between well 4403 and those in Blenheim wells. However reducing conditions aren't advanced based on oxygen levels and concentrations of iron or manganese.

Figure 46 shows well 4403 being drilled in 2004 with arable crops in the background which have been replaced by vineyard more recently. However with a confined aquifer it is not the immediate overlying land use that can impart nutrients to grounwdater, but those 4 kilometres or more to the west and upgradient of the well. This is because groundwater in the area is pressurised so land use leachates can't physically drain downwards.

### 5.4.6. Summary

Nutrient concentrations in the southern sector are higher because there is less groundwater throughflow than further north in the Wairau Aquifer to dilute land surface contaminants and there are higher nutrient inputs. In addition to leaching of nitrate-nitrogen from the same land uses that overlie the northern Wairau Aquifer, groundwater receives extra runoff from the neighbouring Southern Valleys catchments including the Lower Waihopai Valley. In short it has less assimilative capacity and a larger nutrient load per hectare.

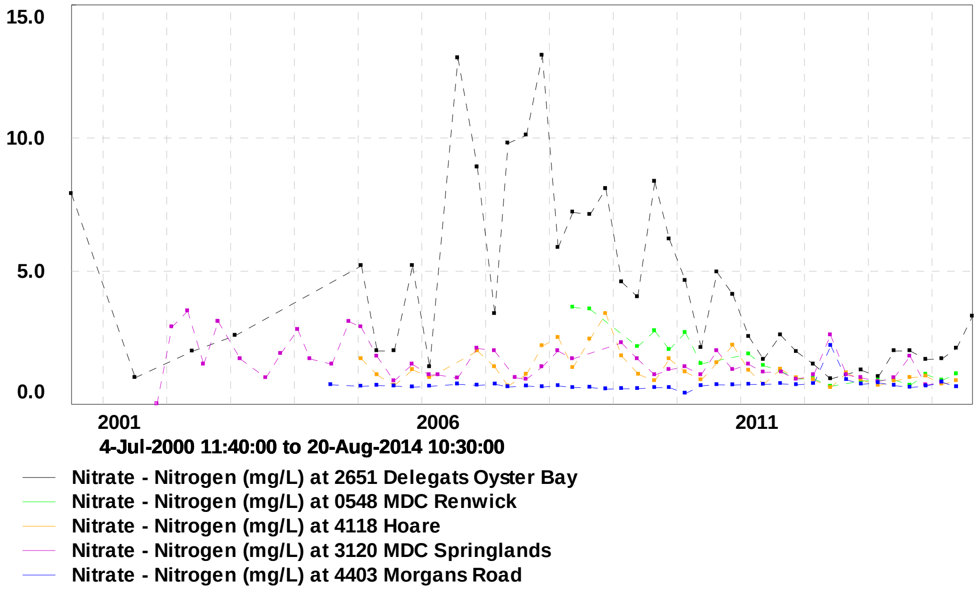


**Figure 47 : Nitrate-nitrogen concentration 2001-2014 for southern Wairau Aquifer**

The other phenomena to explain which is peculiar to this stream of the Wairau Aquifer is the rise in nitrate levels from around 2006 and the rapid decline in about 2011. One explanation is that the low levels represent the baseflow nutrient levels of Wairau Aquifer groundwater while the higher values are caused by increased leaching due to the heavier rains over this period (Figure 47).

This is consistent with a similar pattern of rising nutrient levels at multiple Wairau Plain sites. However local effects can’t be ruled out as every vineyard has different fertiliser and irrigation practices and this may play a part too.

## 5.5. Groundwater systems isolated from land use processes

This section deals with Marlborough’s deeper aquifers as a group because they generally have low nutrient concentrations in groundwater. This is explained by the isolating effect of large thicknesses of sediments that are a physical barrier for leachates. The existence of a confining layer leads to naturally depleted oxygen levels which in turn causes chemical denitrification. These deep aquifers are effectively nitrate sinks and of less relevance to land use impacts on water resources.

### 5.5.1. Riverlands Aquifer

MDC samples two wells to characterise the quality and chemistry of the Riverlands Aquifer. Well P28w/0765 is located near the MDC Hardings Road well-field and oxidation ponds in the south-eastern corner of the Wairau Plain and is 39 metres deep (Figure 48). In the future the new Lagoon monitoring well 10346 will be used instead for sampling. Well 10346 is 43.5 metres deep and taps the same confined aquifer layer and is free-flowing artesian most of the time.

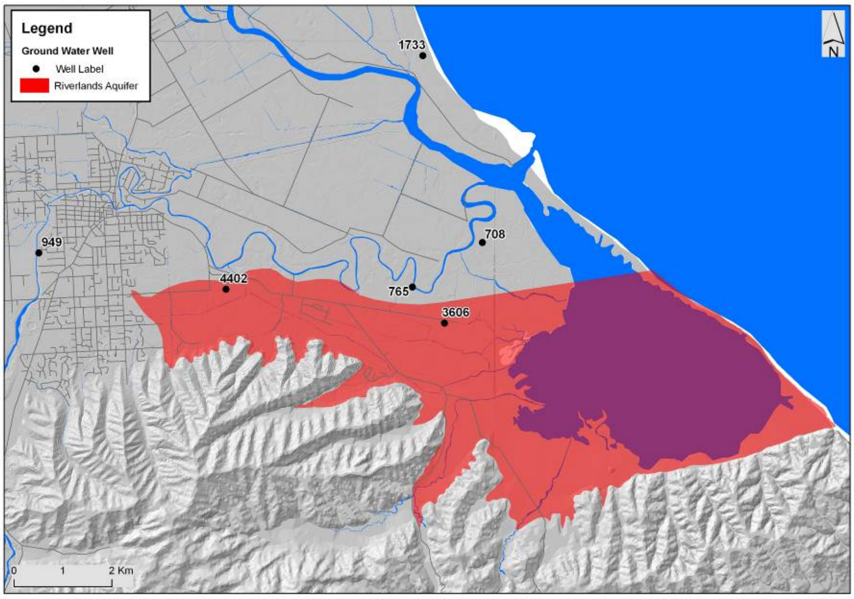


**Figure 48 : Riverlands Aquifer Plan**

The area of the Riverlands Aquifer is shaded red in Figure 48. Well 765 is located outside of the aquifer but in the hydraulically connected transition sector.

**Figure 49 : New MDC monitoring well 10346 with old Lagoon well 708 in background**

Nitrate-nitrogen levels are slightly higher than other deep wells or confined aquifers but are very low by groundwater standards. They are physically constrained by the reducing chemical conditions of the aquifer (Figure 50). The median concentration is 0.01 $g/m^3$ and until recent times when higher spikes have been measured, concentrations were reasonably stable.

The cause of these elevated values is uncertain but may be related to changing pumping patterns which can induce groundwater from other areas in this low storage aquifer. There have also been some major changes in land use upstream of the Riverlands area and these may take some time to develop or showup in water quality results.

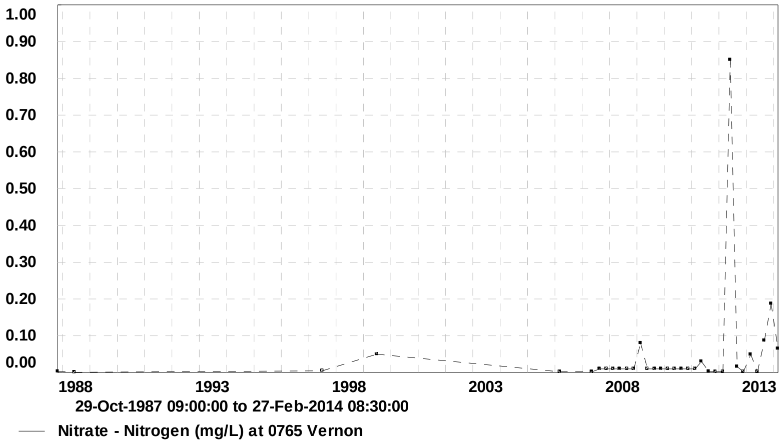


**Figure 50 : Nitrate-nitrogen concentration 1988-2014**

The second well that MDC samples for water quality monitoring purposes is located within the Riverlands Aquifer proper at the Huia vineyard off the end of Alabama Road. Well P28w/4402 was drilled by MDC in 2004 as a permanent site for monitoring aquifer pressures in this heavily committed aquifer area (Figure 51).

**Figure 51 : MDC permanent monitoring well 4402 looking south-west towards Wither Hills**

Well 4402 is screened between 22 and 26 metres depth and has almost permanent artesian pressures hence the reason why the casing is elevated above ground-level (Figure 51). Since 2000 the dominant local land use has been vineyard, and lifestyle or industrial uses upgradient to the west. Runoff from the Blenheim urban area carrying with it nutrients may also affect groundwater quality at Riverlands.

Nitrate-nitrogen concentrations are low by groundwater standards. The consistent rise each winter or spring shows the aquifer does receive local nutrients from not to far away suggesting it isn't as highly confined as first thought or isolated from surface processes. Nitrate-nitrogen levels have increased over the past 7 years (Figure 52). The median concentration is very low at only 0.125 g/m$^3$.

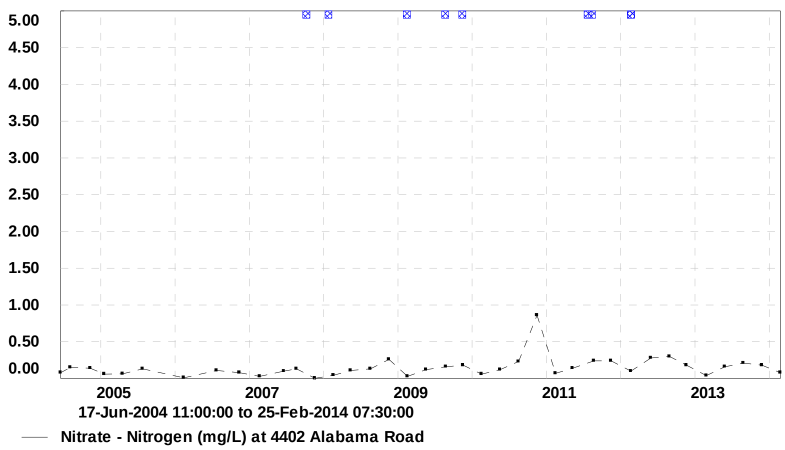


**Figure 52 : Nitrate-nitrogen concentration 2005-2014**

### 5.5.2. Wairau Aquifer Coastal Sector

MDC samples groundwater from well P28w/1733 situated around 2 kilometres north of the Wairau River mouth and 150 metres inland from the Cloudy Bay coast (Figure 53). Well 1733 is 45 metres deep. It is used to sample groundwater quality and has been a permanent groundwater level monitoring site since 1988. Instruments at the base of the well measure the electrical conductivity of groundwater to provide advance warning of seawater intrusion.

**Figure 53 : MDC Bar well P28w/1733 looking north towards Rarangi and Cloudy Bay coast**

While well 1733 does at times a free flow depending on the state of the tide and season, for sampling purposes it is pumped to purge the casing of stagnant water and provide a representative sample of aquifer water.

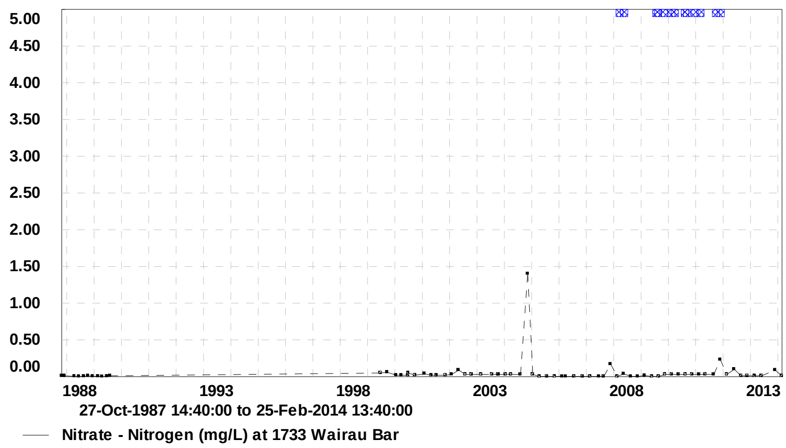


**Figure 54 : Nitrate-nitrogen concentration 1988-2014**

While there is a gap in record of several years between 1990 and 1999, it is fair to say that levels of nitrate-nitrogen are consistently low and not showing any signs of a trend up or down. The cause of the spike is uncertain but is unlikely to be related to land uses because the aquifer in this area is confined meaning the closest land surface activities that could affect groundwater would be west of SH1.

The naturally occurring reducing conditions associated with confined aquifers normally mean any nitrate has been denitrified and this is the case with groundwater sampled at well 1733 where there are noticeable levels of hydrogen sulphide. Hydrogen sulphide is a breakdown product of the chemical reduction of sulphate and occurs at the same redox potential as nitrate reduction. The gas is a sure sign that both processes are happening.

## 5.5.3. Brancott Aquifer

MDC samples groundwater from well P28w/3217 in the southern part of the Brancott Aquifer near Wrekin Road. Well 3217 is screened between 55 and 140 metres depth meaning it gathers groundwater from a range of layers and residence times and this mixture of inputs needs to be considered when reporting on levels and time trends in nitrate-nitrogen concentrations (Figure 55).

**Figure 55 : Typical upper Fairhall-Brancott Valley land use predating introduction of irrigated vineyards**

The overlying land use has been vineyard since the late 1980s and prior to this sheep grazing with cropping in some seasons at some properties (Figure 55). Interpreting the time series of groundwater chemistry parameters is complicated by the long screen as we don’t know where precisely the groundwater is originating within the strata.

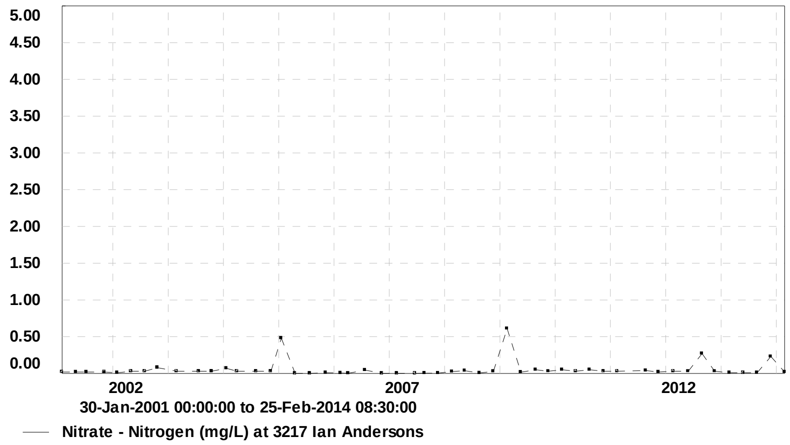


**Figure 56 : Brancott Aquifer Nitrate-Nitrogen Concentration 2001-2014**

Since 2001 levels of nitrate-nitrogen are barely detectable and stable, except for occasional higher spikes (Figure 56). Groundwater conductivity rose sharply in 2008 in line with chloride which could mean older water is being induced into the well. But this conclusion is at odds with a decline in concentrations of silica which is an indicator of younger groundwater age (Figure 57).

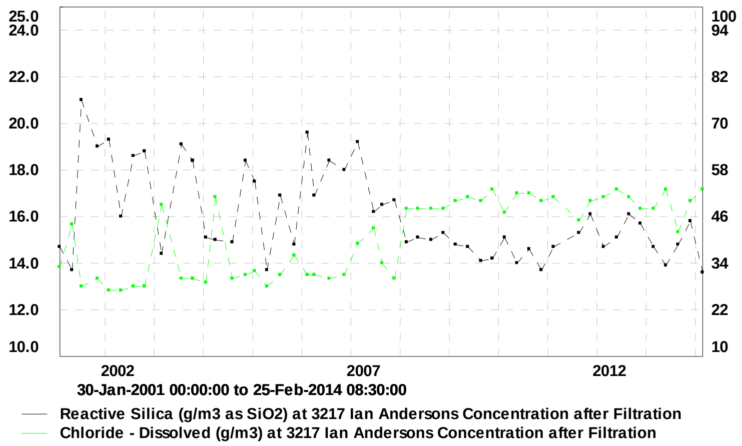


**Figure 57 : Silica and chloride concentrations 2001-2014**

Sulphate concentrations rose over this period which indicates a land use influence. One explanation is that the upper levels of the well screen are intercepting young water with older groundwater dominating the deeper strata.

## 5.5.4. Omaka Aquifer

MDC samples groundwater at well P28w/1945 belonging to Pernod Ricard in Hawkesbury Road. The well is screened between 15 and 60 metres depth. The predominant land use in the area since the late 1980s has been irrigated viticulture on the flats and lifestyle blocks, with pastoral farming on the ridges.

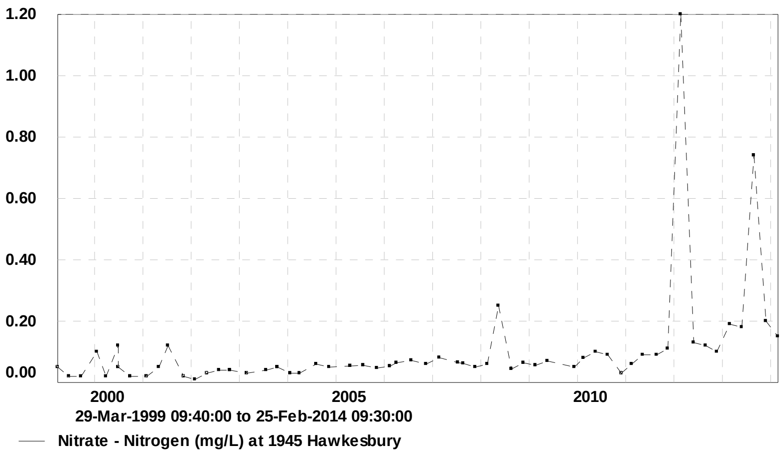


**Figure 58 : Nitrate-nitrogen concentration 1999-2014**

Nitrate-nitrogen concentrations are low in common with other deep aquifer systems in the Southern Valleys Aquifer suite and of little concern, but show an increasing trend over time and higher spikes are occurring more often (Figure 58).

Well 1945 sources groundwater over a long section of strata just like the Brancott Aquifer well and some may originate from closer to the surface. The increase may also indicate the arrival of nutrients that have been delayed by the very low Omaka Aquifer flow velocities. Median concentrations remain low, but MDC will keep watch on patterns in the Southern Valleys generally for signs of increasing trends in nutrients in groundwater.

## 5.5.5. Deep Wairau Aquifer

MDC monitors the chemistry of the Deep Wairau Aquifer system at well P28w/3278 belonging to Pernod Ricard at their Fairhall Estate vineyard. Well 3278 is screened between 100 and 189 metres depth below the surface and is by Marlborough standards a very deep production irrigation water well.

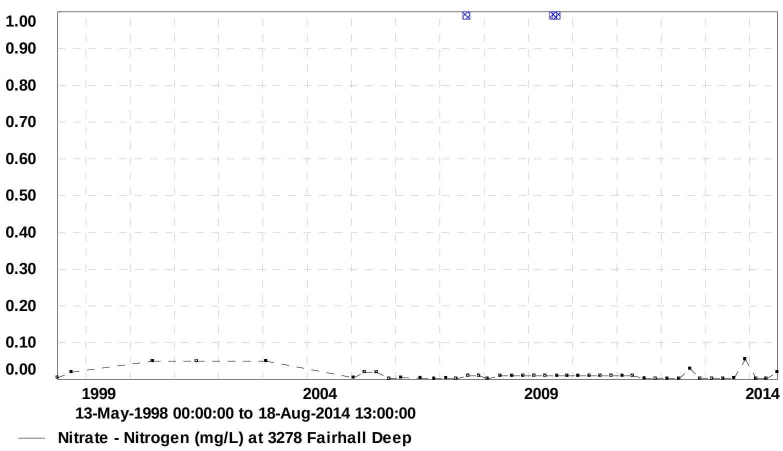


**Figure 59 : Nitrate-nitrogen concentration 1998-2014**

MDC analyses well 3278 groundwater to see if its chemistry is changing over time as more groundwater is pumped from it. Changes in water age or chemistry may provide a clue as to the size of the resource and if hydraulic connection exists with an active surface recharge source or whether the aquifer is blind. Nitrate-nitrogen levels are very low which is consistent with all of the other parameters measured (Figure 59).

**Figure 60 : Well P28w/3278**

The age of groundwater from well 3278 has been measured at 20,000 years meaning that is how long ago it was recharged and it is possible that no nitrate has entered the system since that time, but if it has it may have subsequently been naturally denitrified. Groundwater contains naturally high levels of salts that have originated as minerals forming the gravels of the aquifer. These have been dissolved and cause corrosion (Figure 60).

## 5.6. Localised Marlborough groundwater systems

There are a number of smaller aquifers that MDC monitors to provide a district wide perspective of the spectrum of land uses, geology, climate and aquifer structure or behaviour that are encountered. Most are located outside of the Wairau Plain and are used by small numbers of water users relative to the Wairau Plain aquifer systems. Notwithstanding this these water resources are vital to local communities and ecosystems that depend on them.

### 5.6.1. Rarangi Shallow Aquifer

The quality of surface water at Rarangi isn't monitored, but MDC takes seasonal samples of groundwater from well P28w/1634 at Rarangi Golf Club. The local community rely on the underground resource for all of their drinking water and it provides the baseflow for wetlands, as well as the irrigation of the local golf course. More recently samples have also been taken at well P28w/4222 south of the new subdivisions on the corner of Rarangi and Neal Roads in relation to natural arsenic investigations.

A very long record exists for water quality at the Golf Club well dating from the mid 1990s and show a clear seasonal pattern with peak nitrate values coinciding with spring rains which leach nutrients accumulating in the soil downwards to the water table (Figure 61). A similar leaching pattern is observed in groundwater at the Rarangi Shallow Aquifer coastal sentinel wells with marine salts.

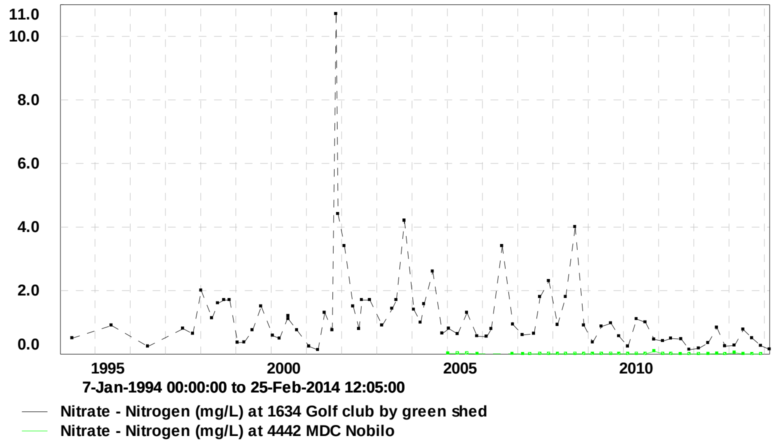


**Figure 61 : Rarangi Shallow Aquifer Nitrate-Nitrogen Concentration 1994-1995**

By contrast nitrate-nitrogen concentrations at well 4222 are extremely low and shown by the green dots in Figure 61. The differences can be explained by naturally occurring differences in the chemistry of groundwater between sites, and to a lesser extent local land use practices.

Land surrounding the Golf Club well receives artificial fertilisers and because local groundwater is oxygenated for most of the year, the nitrate persists in the aquifer. By contrast any nitrate-nitrogen that is applied on the vineyard near well 4222 undergoes natural denitrification due to the reducing conditions. This is also the reason why this groundwater contains high levels of arsenic.

Areas of wetland tend to have reducing chemical conditions which lead to high levels of natural arsenic and low nitrate-nitrogen, whereas sand dunes or land elevated above the water table have relatively oxygen abundant groundwater and nutrients persist. This broad pattern is reflected in the distribution of nitrate-nitrogen (Figure 62).

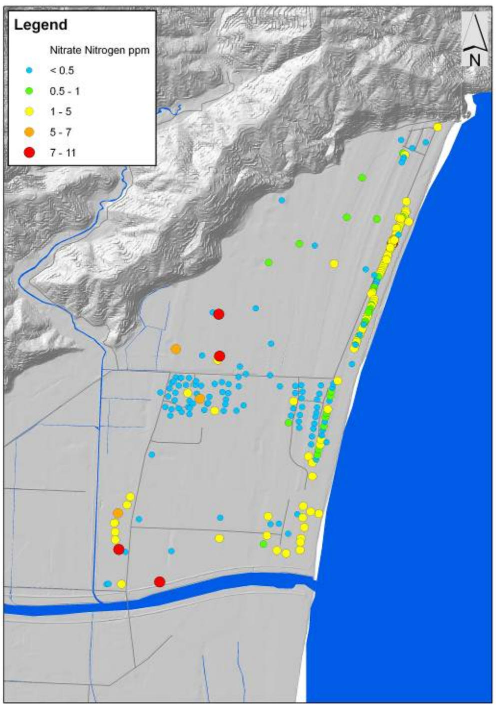


**Figure 62 : Median nitrate-nitrogen concentrations in Rarangi Shallow Aquifer**