Groundwater

GROUNDWATER

Drilling a well on the lower Wairau plain.

In addition to Marlborough's surfacewater resources of rivers, lakes and streams and rainfall, there is also a network of underground water resources as varied and as essential as any of the surfacewater systems. Groundwater flows underground within cracks in rocks or through pores in deposits such as gravel and sands. The layers of rocks or sediment that contain groundwater in sufficient quantities for human use are called aquifers.

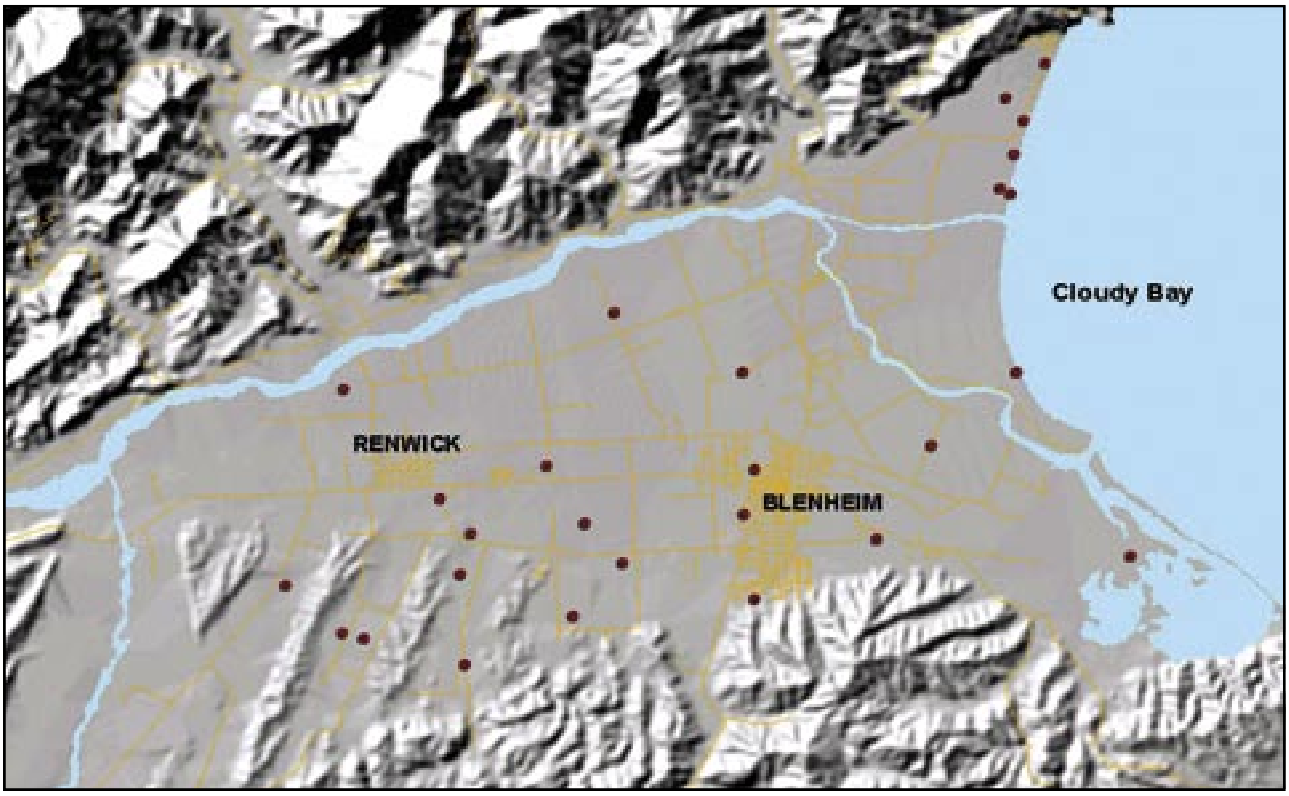
Marlborough has a number of aquifers, the most significant of which are located beneath the Wairau Plain. These include the Wairau Aquifer, the Southern Valley Aquifers and the Deep Wairau Aquifer. In other areas of Marlborough, groundwater is of less significance, either because the geological structure of these areas does not provide large areas capable of holding water, or because there is no significant source of water for recharge.

Two major issues in managing groundwater are contamination (quality) and availability (quantity). Managing groundwater quality and quantity at sufficient levels has long been important to the economic and social wellbeing of the Marlborough community. As the groundwater resource can be potentially affected in a large number of ways, the Council is continuing with its current monitoring efforts and developing initiatives aimed at protecting the groundwater resource for future generations.

WAIRAU PLAIN AQUIFER TRENDS

The Council maintains a regional network of observation wells, which allow the monitoring of short-term seasonal and long-term aquifer level trends to ensure that current allocation is sustainable. Figure 9 shows the current network of 27 wells across the Wairau Plain that are used by the Council to observe trends and provide a indicator of aquifer health. Some sites have been operating for over 20 years and are providing valuable information on long-term trends in aquifer behaviour. (Information from most sites will be accessible through the Council's website by the end of 2005.)

Figure 9: Wairau Plain monitoring network



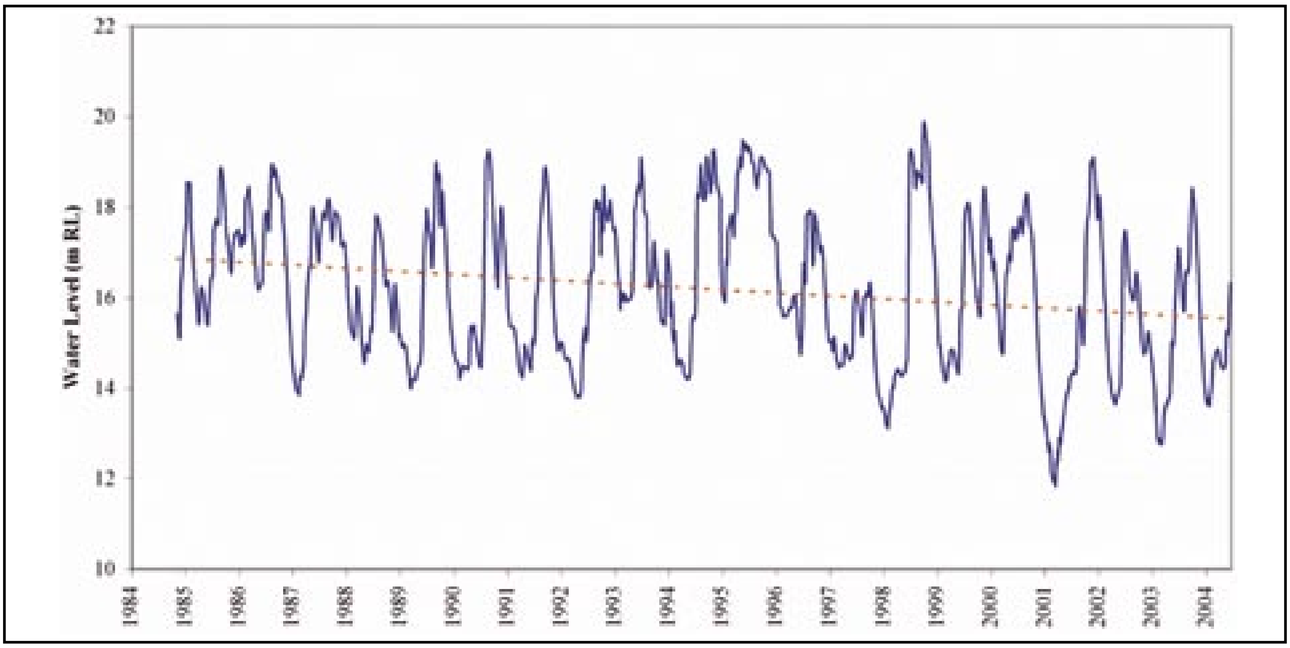


Figure 10: Water level in Woodbourne monitoring well at Jacksons Road

Groundwater levels in the Wairau Aquifer are changing over time. Average groundwater levels have dropped by 0.5m at Conders, 1.3m at Woodbourne and 0.1m at the Wairau Bar, since the time that records were first gathered from these sites; 22 years, 20 years and 16 years respectively. This trend is shown by the dotted line in Figure 10, which is the Woodbourne monitoring well. Irrigation demand, recharge from the Wairau River and land drainage work all affect annual and long term trends in groundwater levels.

If the aquifer is still being topped up each year by recharge it reassures us that we are not overabstracting or 'mining' the Wairau Aquifer. Summer irrigation demand is being replenished by recharge during wetter months. However, if summer aquifer levels continue to trend downwards, there is potential for depletion of spring flows, and in particularly dry years, for depletion of river flows. This indicates that we need to focus on managing irrigation demand to maintain spring and river flows during drier periods.

FLAXBOURNE CATCHMENT SHALLOW GROUNDWATER

Flaxbourne River flow measurement site at Corrie Downs

Land use changes have been a common trend in lowland areas of Marlborough and have often been accompanied by an increase in demand for irrigation water. The Flaxbourne area in South Marlborough is a good example of an area where demand for water outstrips supply during normal summers, and where there is a lack of hydrological information on which to make long-term allocation decisions. Land use in the lower parts of the catchment has traditionally consisted of extensive pastoralism. However, there has been a trend toward more intensive land uses requiring irrigation, including viticulture.

More than 15 water permits have been granted for the taking of both surface water and groundwater for irrigation, including recent proposals to take and store high flows in dams. In recent years, there have been community concerns about the effects of abstraction on the Flaxbourne River. The River provides water for stock and domestic supply as well as for two community water schemes, the Ward and Taimate schemes.

The Flaxbourne River has a significant hill country catchment to the west of Ward. This means that while the area experiences low rainfall, the Flaxbourne retains a permanent flow. However, certain reaches of its tributaries, Needles Creek and Tachalls Creek, do dry up most summers. The link between surface water and groundwater resources in this area is an important factor in managing water use in the catchment but is not yet well understood.

Confluence of Tachells (left) and Needles Creeks

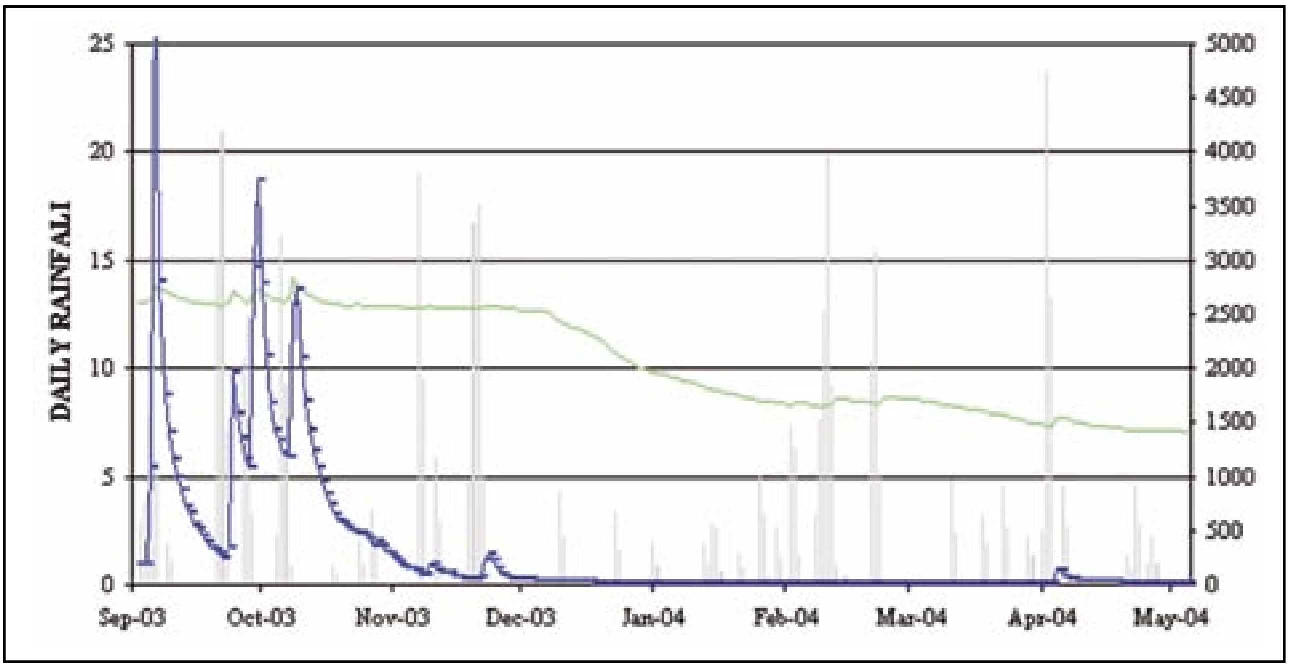
The Council has installed permanent recorders for Flaxbourne River flow and Needles Creek Gravel Aquifer levels to provide baseline hydrological information. In addition a water user group has been established and a review of water allocation in the Flaxbourne catchment is underway. Information is flowing to the community and strategies for managing water are being developed. This process was assisted by an independent review of water resources in the area in 2003 by Pattle Delamore Partners Ltd.

Figure 11 shows the relationship between the Flaxbourne River flow (blue), rainfall (grey) and shallow groundwater level in the Needles Creek Gravel Aquifer (green), since September 2003. Daily rainfall in millimetres is shown on the left hand vertical axis, with Flaxbourne River flow in litres per second and aquifer level in millimetres above a local datum on the right hand axis.

There is a clear interconnection between these factors, especially during spring. When aquifer levels are high river flows are very responsive to rainfall. However, during February, March and April of 2004 when aquifer levels fell below 2500mm, although similar amounts of rainfall fell in the catchment, river flows remained very low. It appears that river flows are only significantly influenced by rainfall when the aquifer level is above 2500mm.

Further work is planned to learn more about the age and turnover of Flaxbourne Catchment water, to add to the information already provided by the hydrological recording stations.

Figure 11: Relationship between Flaxbourne River flow, rainfall and groundwater levels



VINE PLANTING DENSITY AND WATER DEMAND

Not only has there been an expansion of the vineyard area in Marlborough, there has also been an increase in planting density. Historically, vineyard rows were 3 metres wide and grape plants were planted at 1.8 metre intervals. Over time the conventional row width has reduced to 2.4 metres and in some instances to 1.8 metres. The obvious aim of the closer plantings is to maximise production. The practice raises the question of what is the corresponding increase in water demand and will this affect the sustainability of water supply from Marlborough's aquifers?

In the 2002/2003 Update, it was reported that HortResearch Ltd was carrying out some work to determine what the demand for water might be with varying grape densities. The conclusion from this desktop modelling study is that an increase in planting density will only have a small influence (<10%) on vine water demand. Water users are not justified in seeking substantially more water for irrigation on the grounds of an increased planting density. Variation in the ability of the soil to hold water was considered likely to have a much greater influence on annual water demand than the effect of different vine densities. Soils with good water holding capacity need much less irrigation than free draining soils.

Sensors measuring light intercepted by vines

IRRIGATION WATER USE EFFICIENCY

Heat pulses measure water movement in a grape plant

Defining the reasonable water needs of a grape plant has been an evolving process, which started back in the 1970s with experiments by the Marlborough Research Centre and private growers. Today this kind of information is quite significant, given the area of the Wairau Plain covered in vineyards and the need to use water more efficiently.

The Council is currently involved with two local irrigation trials, both of which aim to identify the optimum level of irrigation needed to produce premium quality wine under Marlborough conditions. The 2002/2003 Update report described the Regulated Deficit Irrigation (RDI) trial being undertaken at Squire Estate, near Blenheim. This trial has now been running for several seasons and preliminary results suggested that lower irrigation rates than conventionally used do not adversely affect grape production or quality. The trial at Squire Estate has clearly demonstrated over the past three seasons that vines irrigated at 60 % of evapotranspiration, produced as much fruit as vines irrigated at the full rate of evapotranspiration. Not only was productivity unaffected but fruit was also of a similar quality based on berry weight, soluble sugars, titratable acids and pH.

The trial is set to continue for at least another season.

Weed growth in streams interferes with water levels

WAIRAU PLAIN SPRING FLOW MONITORING

Flow is being monitored at a number of springs on the Wairau Plain so that the effects of groundwater abstraction on springs can be measured. This is because one of the consequences of ongoing abstraction from the Wairau Aquifer is the potential for the network of springs on the Plain, to recede or dry up. The springs most at risk are likely to be those that are farthest from the Wairau River, which is the primary source of recharge.

The underlying Wairau Aquifer sustains spring flows at a generally steady rate although floods do have a short-term influence.

Weekly gaugings of Spring Creek were started back in 1996 to measure long-term trends in flow and identify depletion effects associated with aquifer abstraction. While a long record of water level in Spring Creek exists, this has been affected to some extent in recent years by weed blooms displacing water over summer. In response to this, the Council has increased the frequency of monitoring to gain a more accurate picture of spring flow.

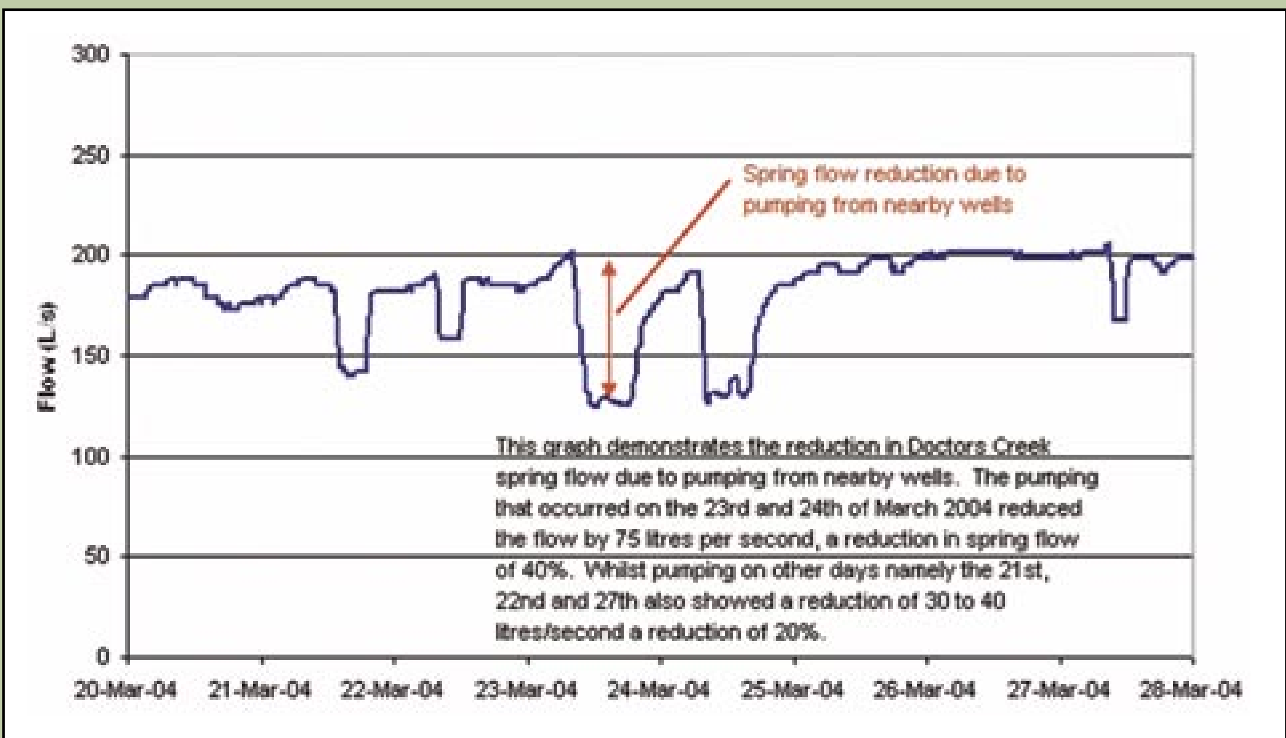
This record has been complemented by weekly flow gaugings of Fultons Creek, Doctors Creek and Murphys Creek above their confluence with the Taylor River. These latter springs are potentially most at risk from depletion because of their distance from the Wairau River, which is the primary source of summer baseflow recharge.

The only spring that appears to be adversely affected by seasonal pumping from nearby wells at this stage is Doctors Creek - see Figure 12.

The lowest Spring Creek gauged flow of 2.9 m3/second occurred in late summer 2001 during a major drought event and interestingly, equalled the Wairau River flow at the Tuamarina River for the same period.

There is the potential for further demand on the aquifer to lead to depletion of spring flows. The investigations are ongoing and may contribute to the development of sustainable flow regimes for the Wairau Plain springs.

Figure 12: Effect on Doctors Creek spring flow from pumping nearby wells



DOCTORS CREEK SPRINGS CATCHMENT

The "Doctors Creek springs catchment", which includes Doctors Creek, Yelverton Stream, and the Fairhall Co-op Drain, is an area of groundwater springs found between Blenheim and Woodbourne, south of Middle Renwick Road. These springs flow into the Taylor River near the end of Brook Street, in Blenheim. During the summer, the Taylor River does not flow into Blenheim above the Doctors Creek confluence. This means, therefore, that the Doctors Creek catchment is an important source of water for the Taylor River during summer.

Doctors Creek at confluence of Taylor River

The point at which springs emerge above ground is where the slope of the land and the water table intersect. How far west Doctors Creek, Yelverton Stream, and the Fairhall Coop Drain extend changes throughout the year as groundwater levels fluctuate. The slope of the ground surface and the water table are very low in this area, so a small drop in the groundwater level can cause the springs to recede a large distance.

In the area between Middle and New Renwick Roads the Wairau and Southern Valleys aquifers come together. In the winter, Southern Valleys streams flow north of New Renwick Road and recharge gravels in the Woodbourne area. Aquifer recharge is considerably less in the summer when the Southern Valleys streams are not flowing. During summer some minor recharge may be sourced from Wairau Aquifer to the northwest.

The location of the Doctors Creek spring catchment, at the convergence between the two main aquifer systems has important implications for how groundwater is managed in this area. Figure 13 shows how there is a greater seasonal variability in spring flow at Doctors Creek compared to the Wairau Aquifer springs of Fultons Creek and Murphys Creek to the north. Because the Woodbourne - Doctors Creek aquifer has a lower yield and storage capacity compared to the Wairau Aquifer, pumping in the Doctors Creek spring catchment can significantly reduce flow to the springs. This is in contrast to the Spring Creek catchment area, where aquifer yield and storage capacity is so good that a strong flow is maintained throughout the summer despite considerable pumping.

The Council has been measuring flow in Doctors Creek, just upstream from the Taylor confluence, on a weekly basis since October 2002. The length of record is not enough to observe any long-term trends, but we can use groundwater levels as an indicator of spring flow.

Monitoring ground water levels

This is because springs are the surface expression of groundwater. Monitoring wells upstream and downstream of the Doctors Creek spring catchment can be used to determine if Doctors Creek spring flows are falling over time.

As previously described earlier in this chapter and shown in Figure 10, groundwater levels in the Woodbourne area have fallen on average 1.3m since 1984. This general decline in aquifer levels supports anecdotal accounts of summer spring recession and a general reduction in flow over time in the Doctors Creek springs catchment.

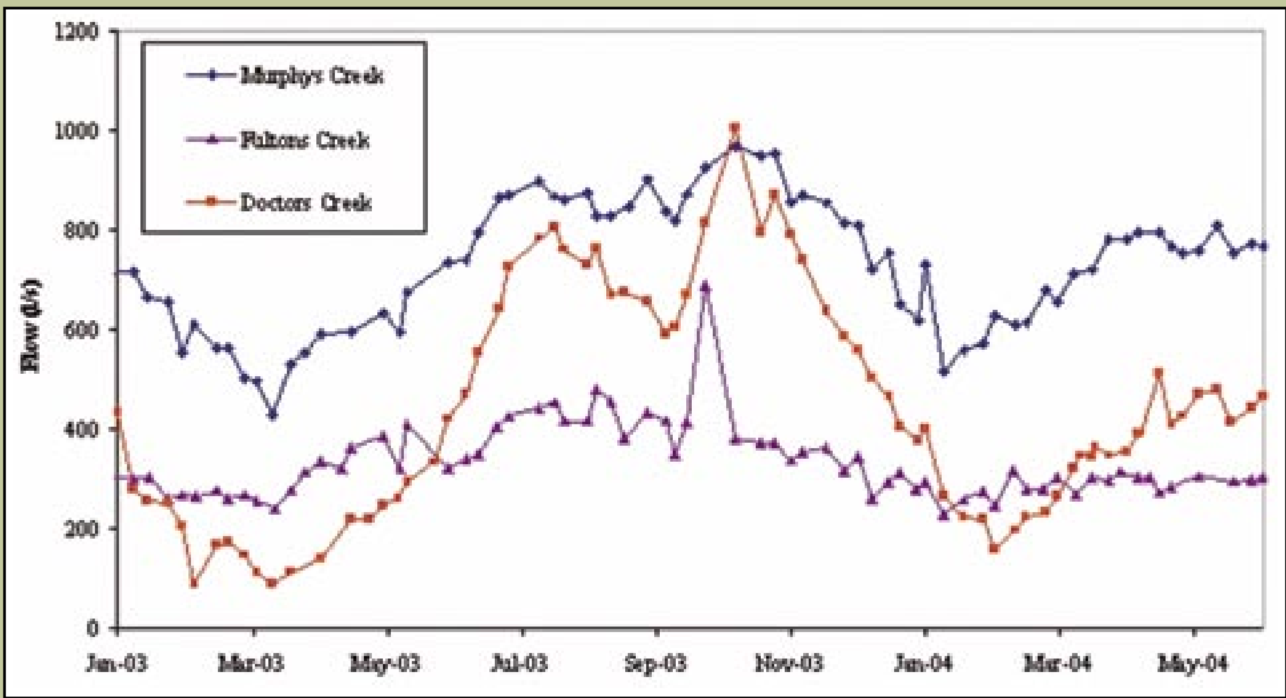


Figure 13: Comparative Flows for Spring-Fed Tributaries of the Taylor River

RARANGI WATER ISSUES

Rarangi is an area of Marlborough experiencing rapid land use change. Historic land uses like semi-extensive pastoralism are being replaced by vineyard and rural residential developments. Water quality and quantity are issues for these new developments as well as for existing land uses.

The coastal margin of the Wairau Plain contains two important groundwater resources:

- The Rarangi Shallow Aquifer; and
- The coastal margin of the Wairau Aquifer.

The Rarangi Shallow Aquifer extends east from the Pukaka River, and from the Pukaka Hills in the north (also the source of recharge) to the mouth of the Wairau River in the south. Water from the aquifer is used predominantly for domestic water supply and is used for community water schemes or through bores on individual properties. The water level in the aquifer varies due to changes in topography, but ranges from 5 metres below ground level to just above ground level in the ecologically significant Pipitea Wetlands. It also varies seasonally, reflecting rainfall patterns in the Pukaka Hills.

Partially underlying the Rarangi Shallow Aquifer is the Wairau Aquifer, separated by a confining layer of fine silts. The Wairau Aquifer is a substantial aquifer that extends from the confluence of the Wairau and Waihopai Rivers through to the coast. Water taken from the Wairau Aquifer along the coastal margin is predominantly used for pasture and vineyard irrigation because the yields are higher than the Rarangi Shallow Aquifer.

With an overlying land area of only 12 km2, the Rarangi Shallow Aquifer is the most sensitive of the Wairau Plain aquifer systems, given it's small storage volume of freshwater in close proximity to the Pacific Ocean. A significant amount of work has occurred at Rarangi over the past year to resolve a series of high profile issues.

The Cloudy Bay coast looking south from Rarangi

ARSENIC CONCENTRATIONS IN GROUNDWATER

The discovery of high arsenic levels in a large number of domestic water supply wells at Rarangi during 2003 generated a series of investigations into it's source, distribution, health risks and treatment options.

Figure 14 summarises the results of the winter 2003 survey in relation to the human health guideline for arsenic in the Drinking Water Standards for New Zealand 2000, of 0.01 parts per million. 68% of samples had low concentrations of arsenic, 14% had elevated levels, which means concentrations were above half the guideline, while the remaining 18% of samples had high levels of arsenic i.e. exceeded the guideline.

Wells that draw water from the Wairau Aquifer were also tested for arsenic concentrations - see Figure 15. While a higher number of samples from the Rarangi Shallow Aquifer had concentrations above the drinking water guideline than

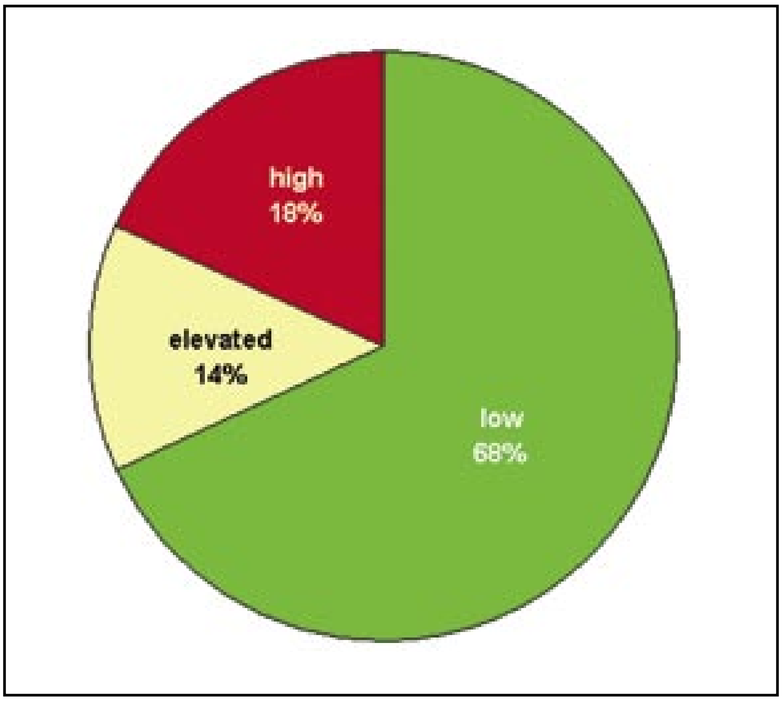
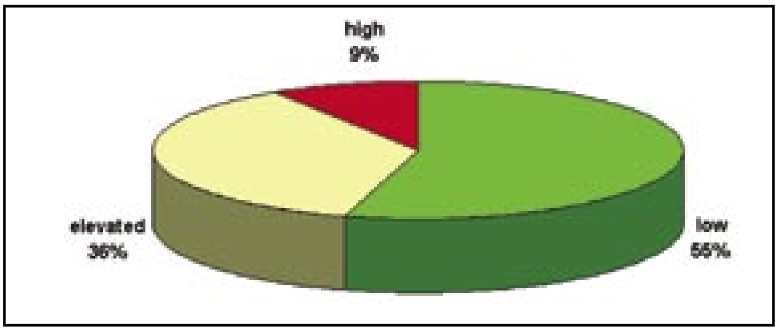


Figure 14: Arsenic Concentrations in Rarangi Groundwaters

Figure 15: Wairau Aquifer Arsenic Concentrations



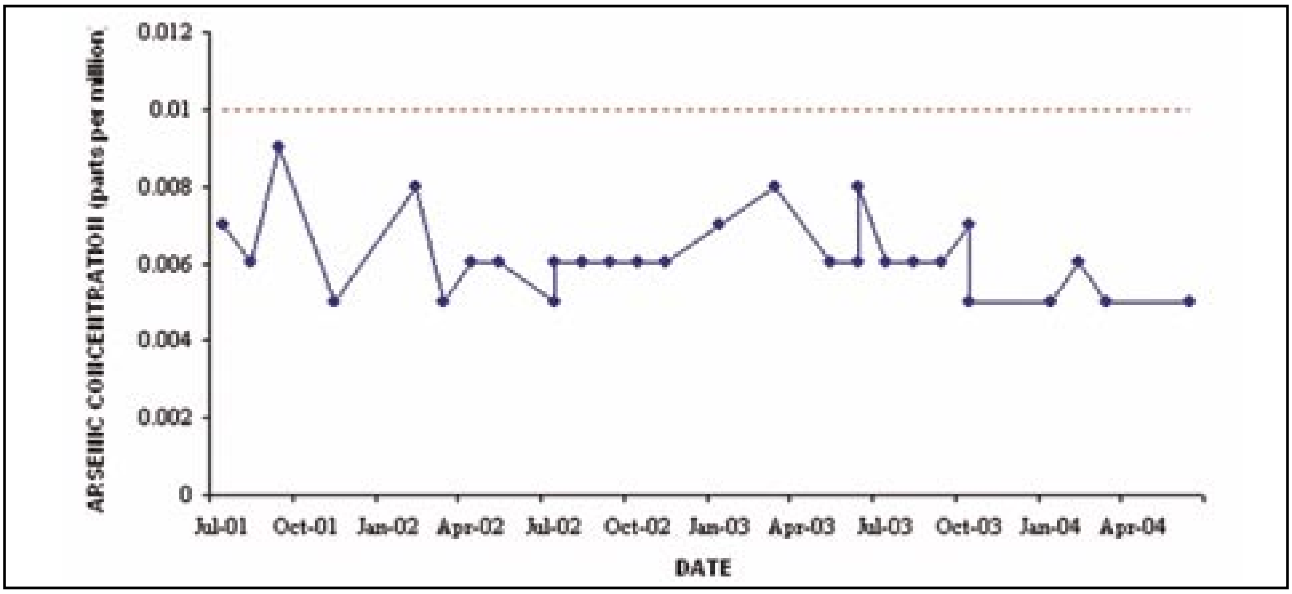
from the Wairau Aquifer, there were a significant number of samples that had elevated levels of arsenic.

While the results tell us that arsenic occurs in both aquifers underlying Rarangi, it is unclear whether levels are changing over time. Figure 16 shows the variation in arsenic concentration in a Rarangi Shallow Aquifer well from July 2001 through to June 2004. The dashed red line represents the health threshold for arsenic of 0.01 parts per million with arsenic concentration in parts per million on the vertical axis and date along the horizontal axis. Currently this is the only record of how arsenic concentrations in local groundwater vary seasonally. There is no apparent correlation between season or aquifer levels and arsenic concentration at this stage, although this site may not be representative.

While the widespread occurrence of arsenic in Rarangi groundwater suggests a natural origin, potential sources such historic sheep dips and chromium-copper-arsenic (CCA) preserved vineyard posts have also been surveyed as part of a systematic approach to understanding this issue.

The survey work looked at arsenic (As), chromium (Cr) and copper (Cu) in soil and post wood at five sites across the Wairau Plain, not just Rarangi. Figure 17 summarises some of the results of the survey.

Figure 16: Variation in Arsenic Concentration



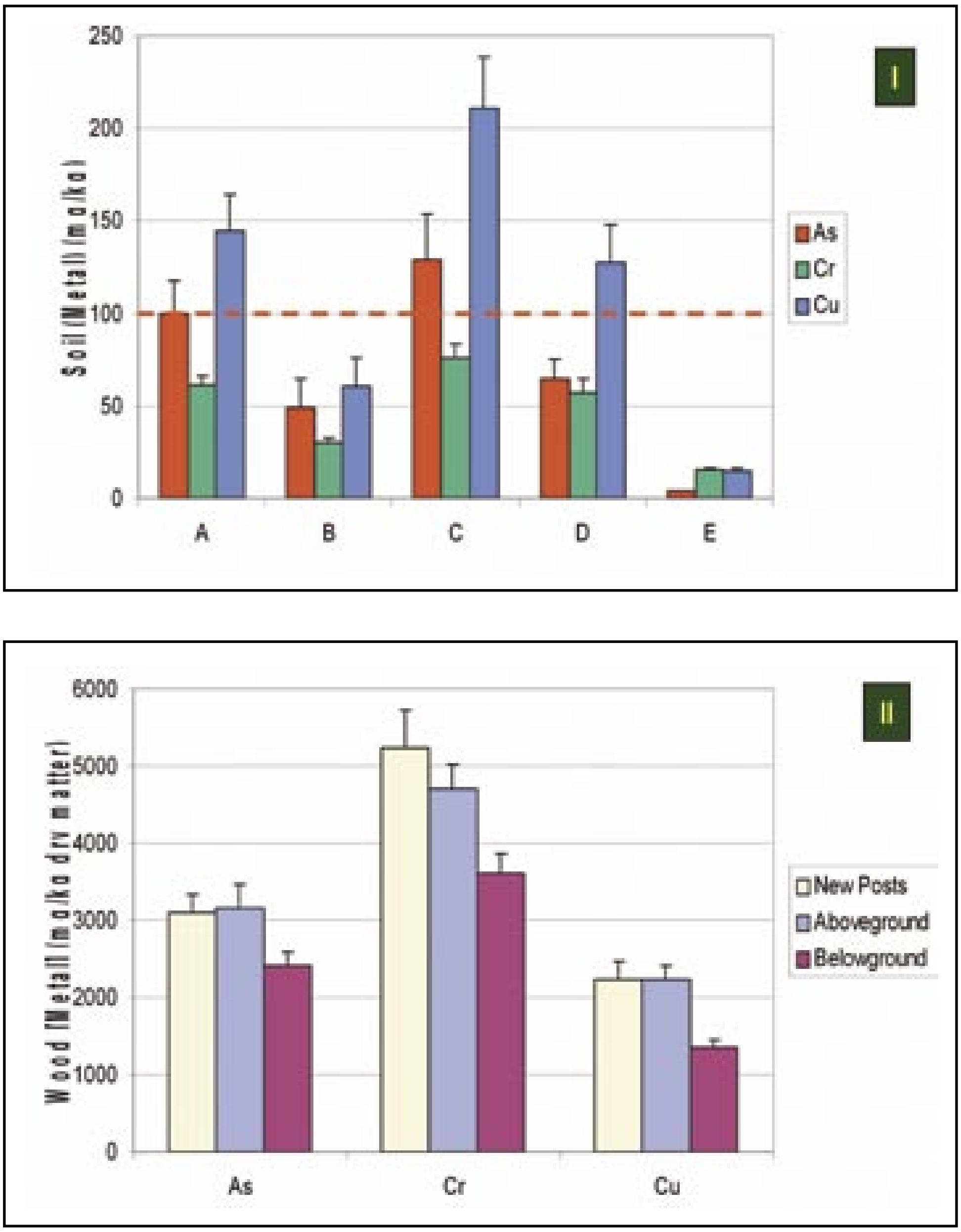


Figure 17: Average soil concentration of the metals within 100 mm of the posts (I) and average concentrations of the metals in new posts, post wood above ground, and post wood below ground (II)

The upper graph, I, shows average soil concentration of the metals within 100 mm of the posts. The dashed horizontal line shows the Australian National Environmental Protection Council guideline for arsenic in soil (1999). The lower graph, II, shows average concentrations of the metals in new posts, post wood above ground, and post wood below ground. Arsenic concentrations were lower in below ground and new post samples suggesting higher transfer rates to the environment.

As expected, the preliminary results confirmed that small concentrations of timber preservatives accumulate in close proximity to the post. However, the CCA treated posts associated with recently established vineyards at Rarangi were very unlikely to be responsible for the observed levels of arsenic in shallow groundwater, given the flushing effect of aquifer through flow and young age of existing posts.

Current investigations are looking at the processes that control the occurrence and mobility of arsenic in groundwater. Of particular interest is how stable are the levels monitored so far, and whether they represent the highest or lowest values that will occur naturally. A number of tools including environmental isotopes and geochemistry indicators are being used as part of this project.

Pipitea wetland south of Rarangi Beach Road

PIPITEA WETLAND

The Council has been monitoring water levels in and around the Pipitea wetland, south of Rarangi Beach Road, since September 2003. The purpose of the monitoring is to get a better understanding of how groundwater interacts with the wetland.

During the winter, because of high rainfall on the surrounding hills, excess groundwater in the northern part of the Rarangi Shallow Aquifer drains into northern part of the wetland. The wetland then acts as a channel to recharge the aquifer along the southern margin of the Rarangi Shallow Aquifer, around Flaxmill Drive. During the summer, when there is little recharge, the northern part of the wetland acts as a storage reservoir, and slowly drains into the aquifer as water levels drop.

The aquifer drains to the south and into the Wairau Diversion through the wetland. Prior to the cutting of the Wairau Diversion, the water level in the southern part of the wetland would have been maintained during the summer.

The monitoring of water levels in the Pipitea wetland has shown how important wetlands can be in storing and distributing water on a seasonal basis across an aquifer. The Council intends to study the wetland-groundwater interaction further by installing continuous recorders in the wetland. This will show us how the aquifer and wetland respond to individual rainfall events.

RARANGI FRESHWATER-SEAWATER INTERFACE

Groundwater naturally flows towards the coast where it discharges to the sea. The two water bodies, freshwater and seawater, meet each other at a position called the saltwater or saline interface. The relative densities of freshwater and seawater, and the difference between ground water and sea level, determine the position of the interface. In general, seawater is found in the aquifer slightly inland from the coastline because saltwater has a higher density. If groundwater abstractions in the aquifer are excessive, particularly near the coastline, the saline interface can move inland. If this occurs, the aquifer can become contaminated with salty water.

In December 2003, a survey was carried out to locate the exact location of the saline interface within the Rarangi Shallow Aquifer. The technique involves sending a small electric charge into the earth, which is recorded by a series of electrodes, inserted into the ground at constant spacings. This gives us a picture, or profile, of the aquifer, which is like a slice through the earth taken at right angles to the shore. Salty water is much more conductive (able to carry an electrical current) than freshwater, so we can easily locate the presence of salty water in the profiles.

Surveys were carried out at northern, central and southern Rarangi Beach. All three profiles showed that the inland toe of the saline interface is situated less than 40 metres from the mid-tide mark. This is approximately 20 metres further seaward than had been estimated by modelling. The base of the Rarangi Shallow Aquifer is also shown as being quite saline, presumably because it is composed of marine silts.

The results of this survey can be used to help in future modelling work, and will act as a benchmark to assess the sustainability of abstractions of water from the Rarangi Shallow Aquifer.

LOWLAND CROP INVENTORY

In recent times, the main trend for the Wairau Plain has been a change in land use from pastoral activities, cropping and orchards, to viticulture. Knowing what the future trends in land use might be, helps in managing natural and physical resources, and especially in trying to determine what future water demands could be.

The Council has been using satellite imagery for mapping land use types to identify trends. However, this imagery (the National Land Cover Database), cannot precisely distinguish vineyards at this stage. The Council's staff, therefore, have refined the accuracy of the land cover database for the Wairau Plain and Lower Awatere Valley, by ground-truthing an area of around 20,000 hectares since 2001. The aim of the project is to map irrigated crops, define trends and eventually characterise the satellite signature of a vineyard to help with future interpretation of satellite imagery.

Around 11,000 hectares of the Wairau Plain is now occupied by vineyard, with the largest concentration in the area west of Selmes Road or Fairhall. In looking at the potential for additional demand for irrigation water in this area, it is considered this will not be significant given the amount of land that is already planted in vineyard.

An area that was believed to have potential for an increase in the demand for water, given the current trend of converting land to vineyard from more traditional crops, is the Lower Wairau area.

In 2004 the Council commissioned a study of the likely future trend in water demand in this area, which has some of the best soils on the Plain. Traditional land uses in this area have been intensive farming systems, some horticultural use, vegetable production, a small amount of dairying and some less intensive pastoral production. The current breakdown of crop type in this area is shown in Figure 18.

Approximately 450 hectares of land were considered unlikely to ever be planted in vines because of soil salinity issues. This land is currently stocked with low numbers

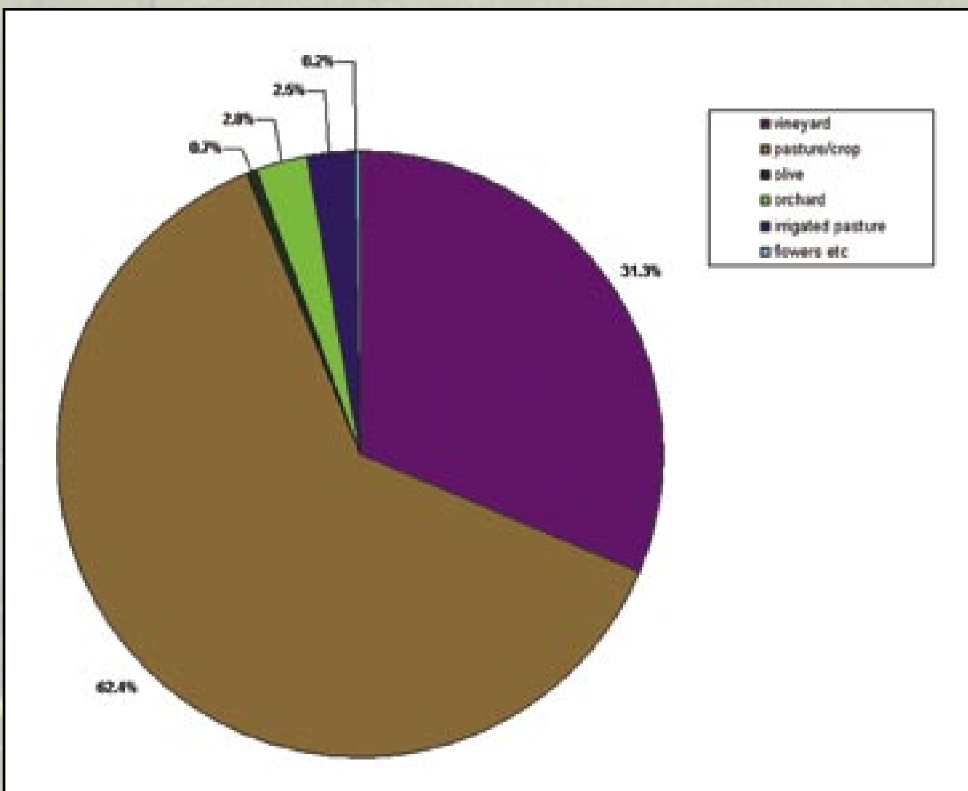


Figure 18: Lower Wairau Crop Type

Lower Wairau Plain

of sheep and some cattle and this is not likely to change. In general however, the soils within the study area are deeper with higher water holding capacities than elsewhere on the Wairau Plain. (The survey noted that there are a number of vineyards planted in this area that have no permanent irrigation system.)

Approximately 70% of the land able to be irrigated is already subject to a resource consent for water abstraction for irrigation purposes. While more land could be, and is likely to be, converted to viticulture, the study concluded that there would not be a significant increase in demand for water, based on an assessment of current levels of water applied to vines. The heavier nature of the soils within the Lower Wairau area and their water holding capacities indicate that the amount of water that would be applied to vines in this area would not be as great as elsewhere in the district.

Monitoring groundwater levels

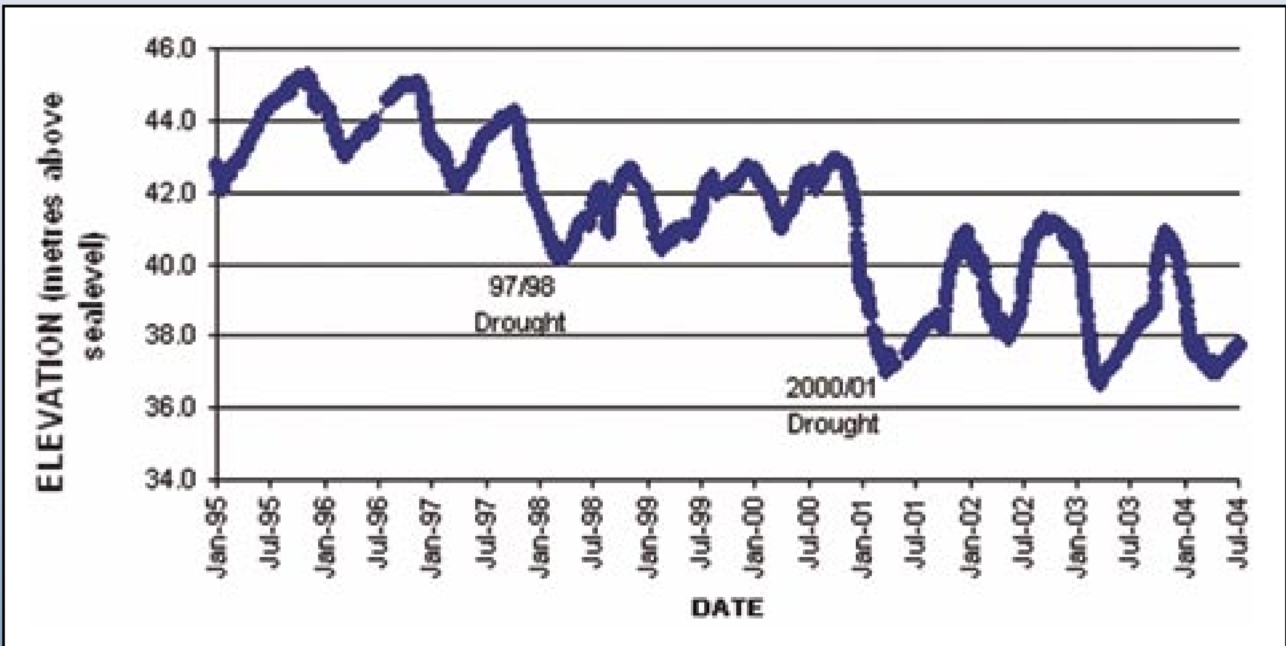
SOUTHERN VALLEYS AQUIFER TRENDS

Historically the Southern Valleys aquifers have been the most heavily committed, but lowest yielding, of all the aquifer systems the Council has had to manage. This past summer has been no different, with nearly 600,000 m^3 of water being used for irrigation. This compares with 650,000 m^3 in 2002/03, 320,000 m^3 in 2001/02 and 950,000 m^3 during the 2000/01 drought.

The Council uses a well on the Brancott Aquifer as one of its regional monitoring wells to indicate overall aquifer health. Figure 19 shows the variation in Brancott Aquifer levels from 1995 through to the present day, with water level elevation in metres on the vertical axis. Aquifer levels have stabilised at around the 2000/01 drought minimum, following voluntary restrictions over the past three summer seasons. These restrictions have been in place since the 2001/2002 summer season, following agreement with local well owners.

It is anticipated that the demand for groundwater in this area will be significantly reduced following the introduction of the Southern Valleys Irrigation Scheme in late 2004/2005. An exception to this may be when the irrigation scheme water is unavailable. In any event, the Council will be closely monitoring how the Southern Valleys aquifers reacts once the irrigation scheme is in use.

Figure 19: Brancott Aquifer Well showing trend in aquifer levels from 1995 to 2004



PESTICIDE RISK REDUCTION

Monitoring groundwater levels

Pesticides assist in the production of high quality crops in New Zealand. However some pesticides have the ability to build-up in the soil or leach downwards to groundwater. The risk of this occurring in any given situation depends upon the pesticide used, the soil type, crop type and climate. A national project involving the Agrichemical Education Trust, regional councils, agrichemical producers, primary producer groups and HortResearch Ltd set out to provide a tool for farmers to make decisions about the best pesticides to use on their properties, to minimise risk to soil quality, and particularly to groundwater.

HortResearch Ltd used a computer model to simulate what would happen with typical spray regimes for a range of pesticides used in the major crop growing areas of New Zealand. Around 16,000 scenarios involving combinations of soil, climate and typical spray regimes were simulated and stored on a CD called the GROWSAFE CALCULATOR.

Farmers can now use this tool to predict the relative risk of pesticide build up in the soil or leaching to groundwater and select the most environmentally suitable product for their property.

Further work is needed to determine the build up of pesticide in soils under Marlborough conditions. While regular surveys of groundwater quality have shown that, at a regional scale, there is no widespread occurrence of pesticides in groundwater, there have been some isolated incidents. The Council will continue to work with industry to improve agrichemical practice and monitor levels of pesticides in the environment as part of its state of the environment monitoring programme.

REFERENCES

CH2M BECA. April 2004. **Rarangi Arsenic Treatment Options.**

Horticulture and Food Research Institute of NZ Ltd. February 2004. **An Assessment of Vineyard Planting Density and the Water Demand of Grapes.**

Horticulture and Food Research Institute of NZ Ltd. February 2004. **Interim Report on Squire Estate Regulated Deficit Irrigation Trial.**

Horticulture and Food Research Institute of NZ Ltd. May 2004. **Results of an Initial Survey of the Leaching from Treated Posts in Vineyards in the Marlborough Region.**

Ingham, Malcolm, Victoria University of Wellington. February 2004. **Measurement of the Saline/Fresh Water Interface at Rarangi Using DC Resistivity Traversing.**

Institute of Environmental Science and Research Ltd. October 2003. **Arsenic Groundwater Contamination in the Rarangi Area, Marlborough**

Pattle Delamore Partners. July 2003. **Comments on Arsenic Occurrences in Marlborough Groundwater.**

Pattle Delamore Partners. August 2003. **Ward Water Resources Investigation.**

Pattle Delamore Partners. June 2004. **Rarangi Sheep Dip Assessment.**

PRIMAC Ltd. June 2004. **Lower Wairau Crop and Water Demand Trends.** Report prepared for the Marlborough District Council.

The New Zealand Agrichemical Trust, producer groups, The Sustainable Farming Fund, regional and territorial local authorities. January 2004. **GrowSafe Calculator CD ROM.**