Chapter 7 - Monitoring Groundwater Resources

Introduction

Because of its hidden nature, virtually everything that is known about Marlborough's aquifers comes from indirect observations made at wells. The only exceptions are where groundwater interacts with surface water, either through spring discharges or seepage losses into groundwater. In areas like the Wairau Plain there is no shortage of wells to help us understand what is happening below the surface, but in many other areas there are limited numbers of wells.

In Marlborough, regional authorities have supported the systematic monitoring of the regions main aquifers and targeted investigations into the hydrology of emerging or marginal groundwater systems since the 1970s. The aim of these programmes has been to understand and protect Marlborough's vital groundwater resources. This level of commitment reflects the region's high level of dependence upon groundwater resources, especially the residents of the Wairau Plain.

Many methods and techniques are used to understand and manage groundwater resources. New methods are constantly being developed, particularly in the fields of chemical or isotope tracers and computer models. However the most compelling information is generally the simplest. These involve observations of water levels in wells in conjunction with abstraction and associated spring or river flows.

Automatic measurement of water levels in selected wells shows how a resource is behaving and responding throughout any given season. If the same wells are monitored over a 50 to 100 year period, as the MDC intends, a very good appreciation of trends in relation to abstraction or climate will be established. This allows the Council to build a picture of cause and effect.

Another monitoring method is to dip a large number of wells across an aquifer to define the depth of the water table. From this information the directions and patterns of groundwater flow are mapped. This method, known as a peizometric survey, is appropriate where understanding larger scale flow patterns and who is affected downstream by groundwater use, is required.

At most permanent MDC aquifer monitoring sites, groundwater elevation information is recorded automatically at the well head and displayed on the Council website to keep water users and the public up to date on aquifer status from day to day. This is especially useful for those consent holders who can only pump groundwater under certain environmental conditions.

Regional monitoring network

The MDC operates a series of regional monitoring programmes, based on a fixed network of permanent wells in order to measure aquifer state and trends. The monitoring programmes have evolved over time in response to local issues, and will continue to be refined as new pressures on groundwater resources emerge.

A succession of regulatory bodies has contributed to the knowledge of the regions groundwater resources over the years. Each administration has fine-tuned the way aquifers are monitored. The current regional network developed by the MDC is the most comprehensive to date. The Wairau Plain has been, and is likely to remain, the geographic focus for the monitoring programmes.

In recent years the monitoring programme has been expanded and permanent sites have been added to aquifers that have had an increase in demand. This has included additional monitoring sites at Wairau Valley, Ward, Kaituna and the Tuamarina River Valley. This reflects the expansion of agriculture into non-traditional areas, poor natural water quality, agricultural landuse intensification and increased density of human settlement.

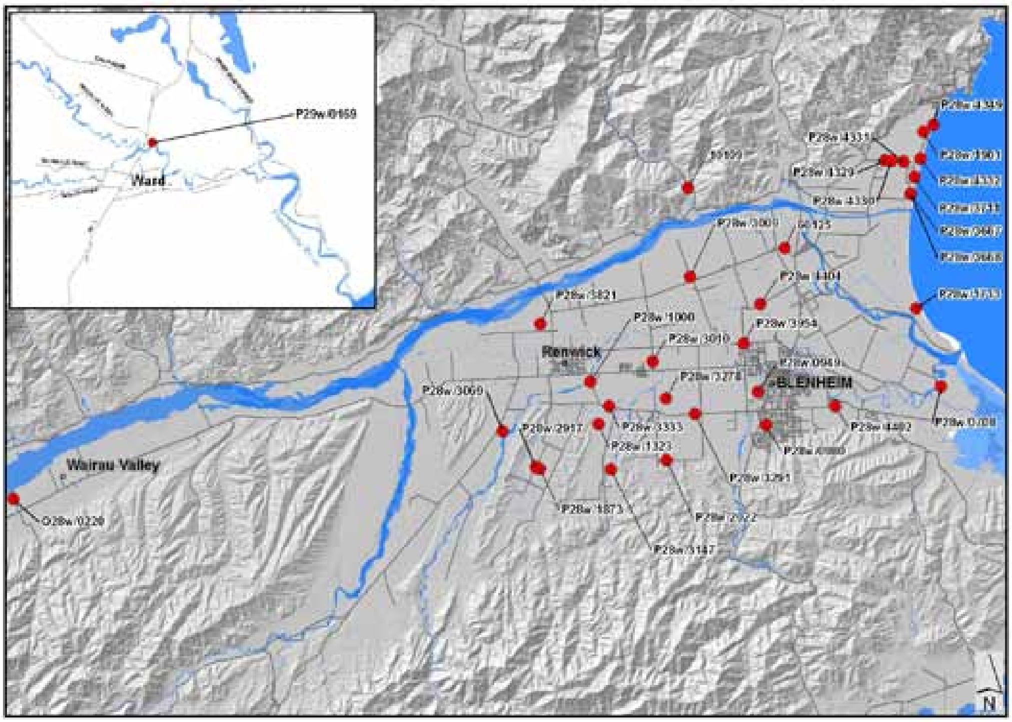

Figure 7.1: MDC groundwater level and Spring Creek flow monitoring network

Aquifer level

The MDC operates a permanent network of 33 monitoring wells which provide real-time information on aquifer status at sites throughout the district (Fig. 7.1). Instruments automatically record aquifer level or groundwater conductivity at 15 minute intervals and transmits them back to the MDC, via the telephone network, where they are archived and summarised on the Council website.

Permanent water level measuring instruments are typically housed in secure metal boxes straddling the well head (Fig. 7.2). Where artesian pressure results in groundwater levels being above ground level, the equipment may be raised above the water level on an extended well casing (Fig. 7.3).

Figure 7.2: Deep Wairau Aquifer monitoring well 3333 during the late 1990s

In addition to the permanent network of wells sites the MDC often has a series of temporary recorders operating to provide short term information on issues of current interest. Recent examples of temporary installations include hydrological studies of the Rarangi wetlands, Wairau Plain freshwater springs, Blenheim urban springs and the interaction between groundwater and flow in Doctors Creek.

Aquifer inputs and outputs

Measuring what is being added to or lost from groundwater systems is fundamental to an understanding of the natural water balance or budget. Aquifer inputs are often referred to as recharge.

Losses from rivers or streams provide most of the recharge to the Wairau Plain aquifers. Conversely, most lowland freshwater springs are fed from groundwater. Infiltrating rainfall is a major input to unconfined aquifers such as the Rarangi Shallow Aquifer.

The only part of the hydrological cycle that can be measured directly is water use. All other components are either estimated or indirectly measured. The Council has comprehensive water meter records for water short areas such as the Southern Valleys Aquifers dating back to the mid 1980s, but due to the lack of universal water metering, the picture is incomplete in most other areas.

Groundwater quality

As well as monitoring aquifer level, the MDC monitors the quality of groundwater at representative wells across the district. Most of the information collected is based on manual samples of groundwater taken at each site. There are also automated instruments at monitoring wells along the Cloudy Bay coastline (Fig. 7.4). These instruments automatically measure water conductivity, which is an indication of salinity.

The coastal monitoring wells along the Cloudy Bay coastline form what is known as the sentinel well network and provide early warning of changes in the natural interface between seawater and groundwater. Four of the sites monitor the Rarangi Shallow Aquifer. The remaining three sites monitor the deeper confined coastal Wairau Aquifer.

Each season samples of groundwater are taken for laboratory analysis at 23 wells representing each of the main aquifer systems (Fig. 7.5). Most of the monitored wells are owned by the MDC, although some long-standing sites or deep wells are privately owned. Samples are sent to a laboratory to analyse the concentration of the major ions in groundwater. This information is used to identify changes in quality. The chemical composition of groundwater tells us a number of things of community interest. First of

Figure 7.3: MDC recorder at Hospital well 0980

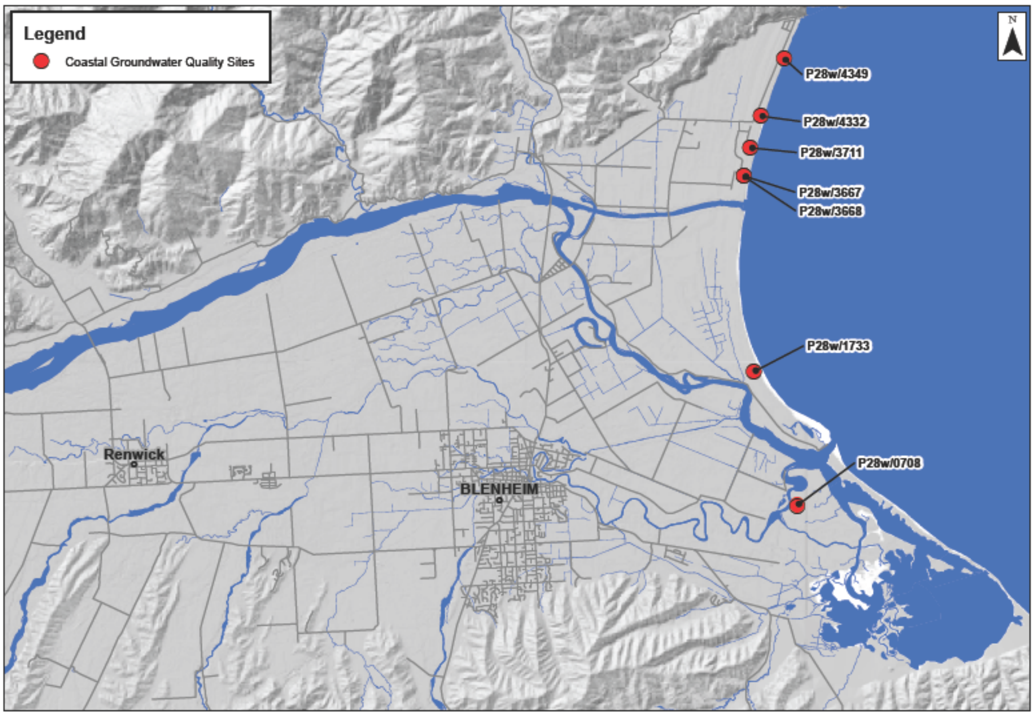

Figure 7.4: MDC coastal aquifer sentinel network

Three of these sites are also sampled on an annual basis including the RSA well 4442, the unconfined Wairau Aquifer well 3009 at Wratts Road, and well 4118 near Woodbourne. Their unconfined nature and current or historic landuses make these wells more likely to contain pesticides than elsewhere in the region.

Information acquired through the various MDC monitoring programmes is stored in an electronic archive in perpetuity for the community good. One of the guiding tenets of the programmes is continuity of record which means the same sites will still be operating in 100 years.

These records will become more powerful in the future for answering the questions of the day by providing a long term historical record to compare against current trends. The entire community has an interest in maintaining the availability of high quality groundwater as we are all shareholders in this valuable natural resource.

all is groundwater safe to drink? This is determined by comparing its quality in relation to human health thresholds specified in the government guidelines entitled: Drinking Water Standards NZ (2005). Secondly, are land uses affecting groundwater quality? Finally, what does the state or evolution of groundwater tell us about aquifer processes or the effects of water use? For example, abstraction for vineyard irrigation from the Wairau Aquifer at Rarangi appears to be changing local groundwater flow patterns. Knowledge of the groundwater chemistry helps us to refine understanding of aquifer behaviour and processes.

The MDC also carry out annual monitoring surveys to determine if pesticides or microbes are present. These surveys occur in spring when areas which are more susceptible to contamination are at maximum risk due to peak leaching rates.

Currently 17 wells are sampled for a broad spectrum of organic compounds as part of the National Pesticide Survey every four years.

The survey is coordinated by the Environmental and Scientific Research Ltd. (ESR) (Fig. 7.6).

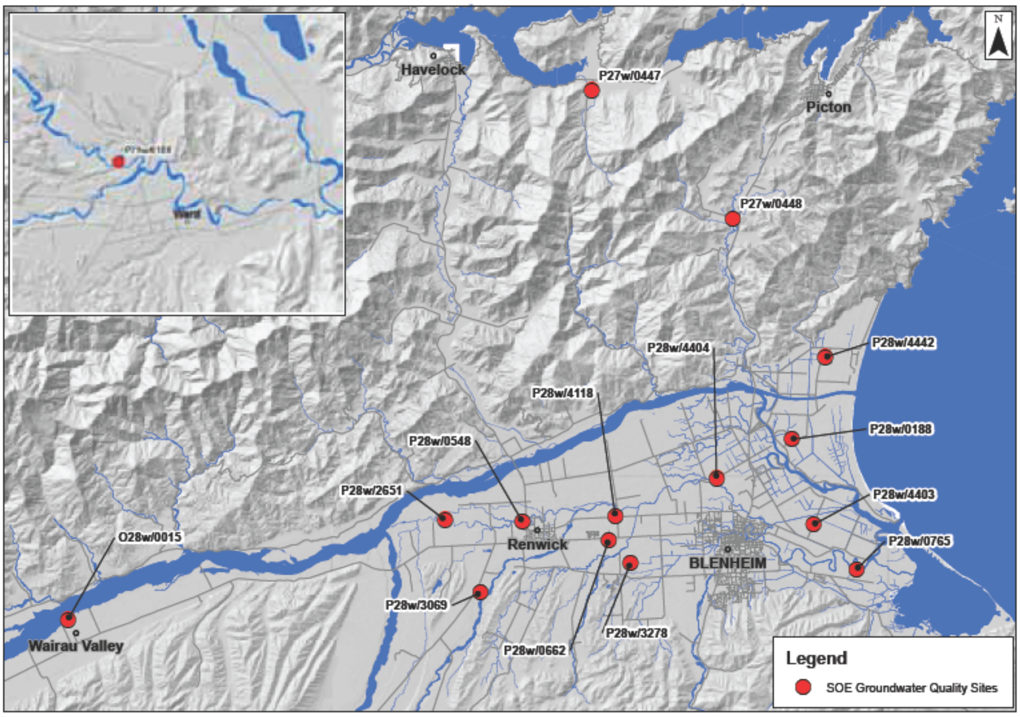

Figure 7.5: MDC seasonal state of the environment survey network

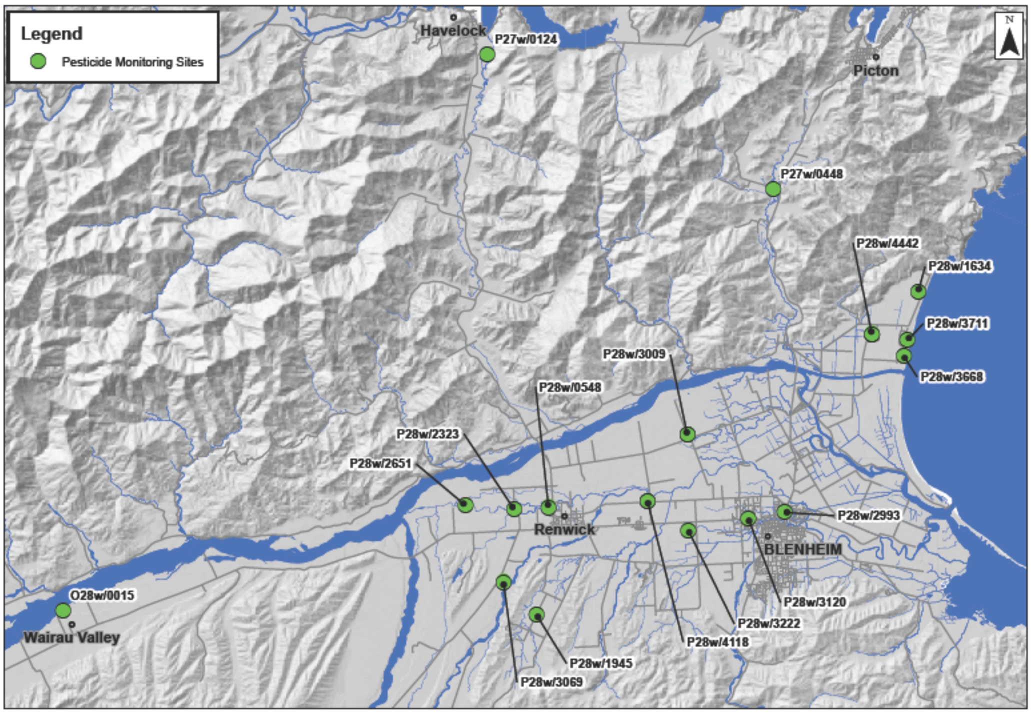

Figure 7.6: MDC groundwater pesticide survey network

Aquifer level changes and trends

We have described where and how Marlborough's groundwater resources are monitored physically and chemically. The following sections describe the seasonal and long-term patterns in aquifer levels and groundwater chemistry.

Variations in aquifer level occur both naturally and as a result of human activities. A long record of water levels in a single well over many years is very valuable. It indicates the nature of any short or long term variations, and also how the groundwater system has behaved over a number of seasons with varying climatic inputs or levels of abstraction (Fig. 7.7).

Over many years a considerable amount of water level information has been collected at various sites, particularly on the Wairau Plain. In the past well water levels were measured manually on a weekly basis. With the advent of automatic instruments, continuous information is now available on the state of all large aquifers in Marlborough.

Seasonal level variation

Rates of seasonal drainage, the response time of a well to a river flood or rainfall, and the drawdown of a well in response to a neighbouring well being pumped, all tell a story about the aquifer or efficiency of a well.

Over the period of a year, aquifer or well levels largely reflect the seasonal climatic and pumping cycles. They reflect the balance between "inputs" and "outputs" from an aquifer system. They are highest in winter or spring when rainfall or river flow peaks, and evapotranspiration or pumping is at a minimum. Conversely water levels are at a minimum in summer or autumn when water demand is highest and recharge is lowest. It is important to note that regardless of the season, natural gravity drainage affects most Marlborough aquifers.

Water levels represent the change in storage of an aquifer. If more water is entering than leaving an aquifer, wells will show a rising trend in spring or winter. If abstraction and natural drainage rates are higher than recharge, well levels will fall, as is typically the case in Marlborough, in late spring, summer and early autumn. In simple terms water tables or piezometric levels rise in autumn or winter, and fall in spring or summer.

Overall seasonal patterns in aquifer behaviour are largely predictable from year to year. The only differences are the rate, timing and extent of changes in water table levels, which depend on the nature of the season itself.

Much can be learnt about an aquifer from its seasonality, and in many cases the response is unique to each well. This is particularly true of Marlborough's smaller aquifers that have distinctive chemical and physical traits.

Figure 7.7: MDC Staff Amy Nicholson and Peter Davidson monitoring RSA groundwater levels 2007

Marlborough groundwater level seasonality - case studies

The way well levels vary seasonally and in response to pumping, rainfall or drought is often unique for each aquifer in Marlborough. These distinctive patterns help us understand how each aquifer works. To illustrate these differences and what causes them, the hydrographs for the most distinctive wells are shown as a series of case studies. The hydrographs presented here are known as envelope plots and need a minimum of five years record to make them meaningful.

All of the seasons on record are over plotted for each of the sites to show the local characteristics. A water year from July to June is shown along the horizontal axis. Groundwater elevation is in metres above mean sea-level in terms of the MDC Rivers and Drainage datum on the vertical axis. The outside of the grey shading shows the maximum and minimum water levels that have occurred on any particular date since the record began. The mean water level elevation is shown by the black line. The middle fifty percent of observations fall within the central yellow band.

The seasonal patterns in water table levels have practical implications when it comes to selecting the pump type to be used in a particular water well. For instance in the south-western area of the Wairau Plain where large changes in aquifer level occur from summer to winter, submersible pumps are the more appropriate type to install as surface type pumps may be limited by their lift capacity.

The first case study is for the unconfined Wairau Aquifer which is controlled by recharge from the Wairau River in the reach north-west of Renwick. Groundwater levels rise and fall in relation to Wairau River channel flow where the peaks correspond to flood events. Aquifer levels are effectively a subdued version of the river hydrograph with steep rises in level followed by a gradual recession. Groundwater levels peak in October at the same time as river flows peak (Fig. 7.8). Interestingly, some of the lowest levels have occurred in wetter months due to a lack of floods to top up recharge. While groundwater levels have varied by up to 3.5 metres since 1982, the moderating influence of recharge from the Wairau River generally maintains stable water levels in the aquifer.

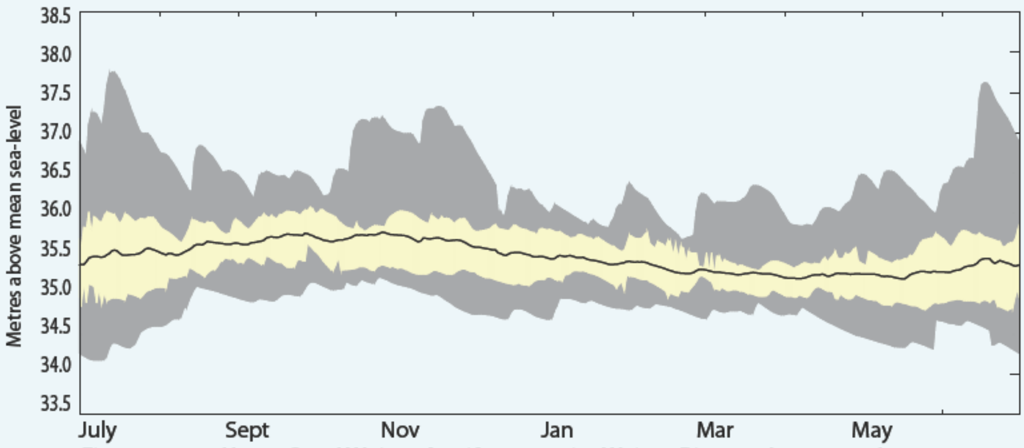

Figure 7.8: Unconfined Wairau Aquifer opposite Wairau River recharge reach

The second case study is for the Omaka River Aquifer. The Omaka River Aquifer behaves like an extension of the Omaka River with winter or spring Omaka River flood peaks. Water levels that have been recorded since 1997 show that typically the aquifer has a small variation of only 1.5 metres at well 3069 (Fig. 7.9) and for half of the time the variation is only 0.2 m.

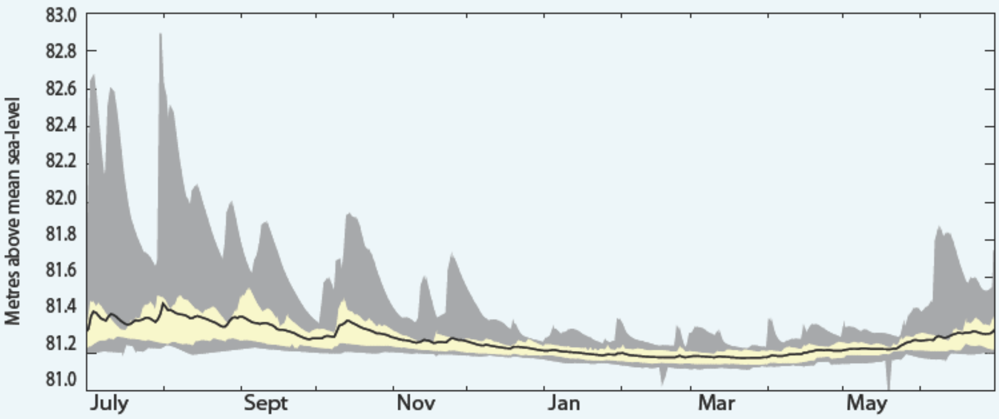

Figure 7.9: Unconfined Omaka River Aquifer shallow layer

The third case study is for the Coastal Wairau Aquifer. This confined aquifer is more distant from the river recharge source. This aquifer exhibits a small range in groundwater level, and the short term loading effects of Wairau River floods causing the distinctive spikes (Fig. 7.10). As a Wairau River floods passes by it compresses the clays that form the confining layer, momentarily raising the water level, before rebounding back to where it was previously. Six hourly fluctuations caused by the varying weight of the sea above the strata that confines the aquifer, are largely responsible for the spiky nature of the record, although nearby pumping also contributes.

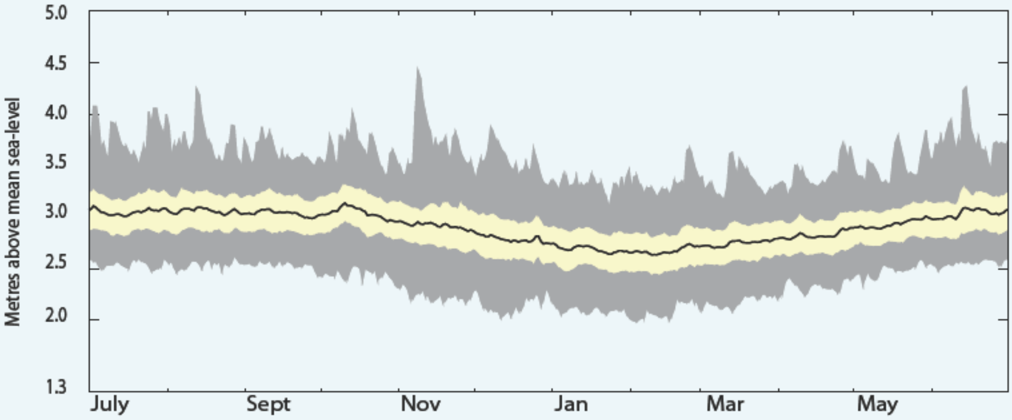

Figure 7.10: Confined Coastal Wairau Aquifer

The fourth case study shows the confined Riverlands Aquifer and the effect pumping has on water levels. The pumping effects are shown as intermittent spikes on the hydrograph. With more than one well operating, including the MDC Malthouse Road municipal supply well and Canterbury Meat Packers, together with 100 millimetre tidal change, the water levels can fluctuate dramatically (Fig. 7.11). The MDC Malthouse Road municipal supply well operates all year round and creates the largest drawdowns of around 400 millimetres. The drop in levels from January to May each year is due to the combined effect of many crop irrigation wells pumping. During the period between July and September the record is least affected by pumping as the meat processing plant is not operating and overall water demand is at its lowest.

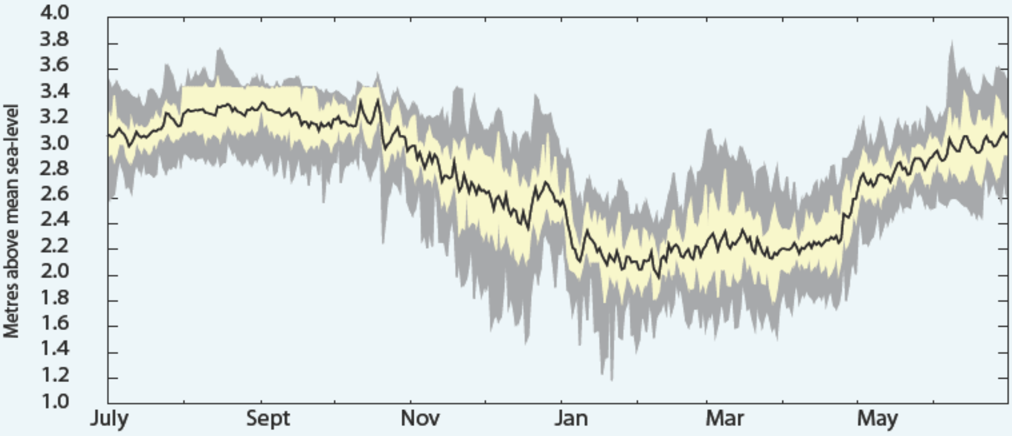

Figure 7.11: Inland confined Riverlands Aquifer

The next series of hydrographs illustrate the unique way in which aquifers along the drier, southern fringes of the Wairau Plain respond to pumping and ephemeral sources of river recharge. The first example shows the extraordinary 10 metre seasonal range in aquifer levels for the MDC monitoring well 1000 in Godfrey Road (Fig. 7.12). This behaviour is peculiar to deeper wells near Woodbourne and is largely a natural phenomenon caused by the seasonal disconnection of the deeper water bearing layer from its Omaka River recharge water source. Once this occurs in late spring, groundwater drainage is the dominant process until higher river flows return in June. Once a hydraulic connection between the river and the aquifer returns, water levels rise and the aquifer always fully recovers.

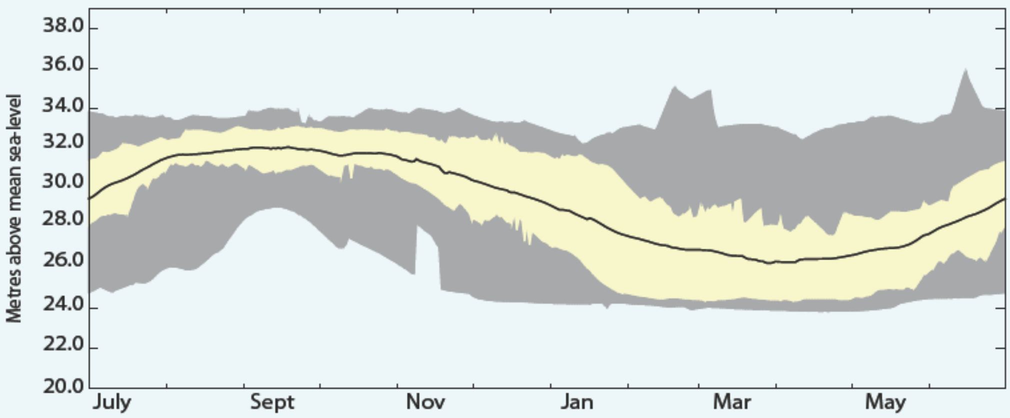

Figure 7.12: Semi-confined Omaka River Aquifer deep layer

The seasonal pattern is slightly different for the Fairhall River Gravels Aquifer which drains earlier in the year, but can be rejuvenated at any stage of the season (Fig. 7.13). This reflects the limited storage of this riparian type aquifer and the lower flows of the associated Fairhall River. In common with the deeper Omaka River Aquifer, groundwater levels can't fall below its impermeable base which in this case is at 70 metres elevation.

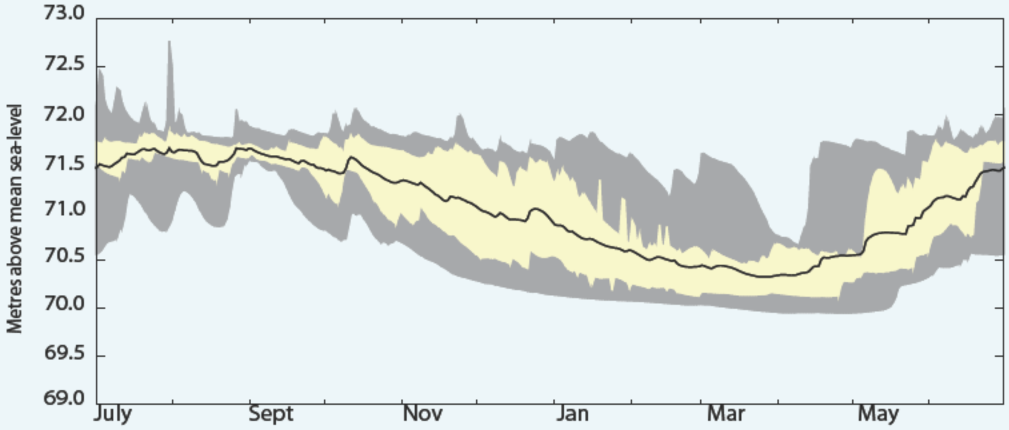

Figure 7.13: Unconfined riparian Fairhall River Gravels Aquifer

There are many riparian aquifers throughout Marlborough and the Needles Creek Gravels at Ward is typical (Fig. 7.14). For about half the year when Needles Creek is running continuously to the sea, the underlying shallow gravels are full of groundwater. In about December every year the rate of leakage from the channel is insufficient to meet the rate of groundwater throughflow, and well levels fall by about 1.5 metres due to drainage. Recovery normally occurs from May onwards.

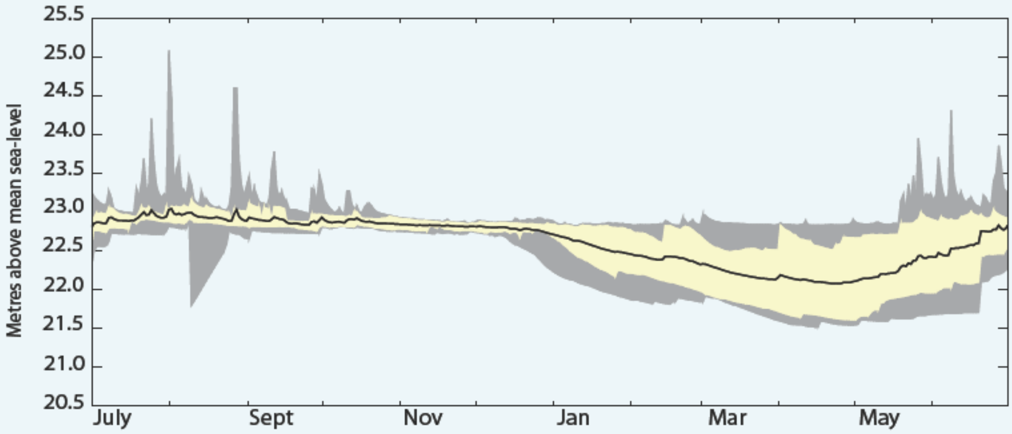

Figure 7.14: Unconfined Needles Creek Gravels Aquifer

The deeper Southern Valleys Aquifers are another group with characteristic hydrographs. Their distinguishing feature are large short-term changes in groundwater level caused by pumping. This reflects the low permeability of the local geological formations in relation to consented demand, and ephemeral sources of recharge. During the 1997/98 and 2000/01 droughts pumping caused some well levels to fall by as much as 15 metres in the Benmorven Aquifer (Fig. 7.15).

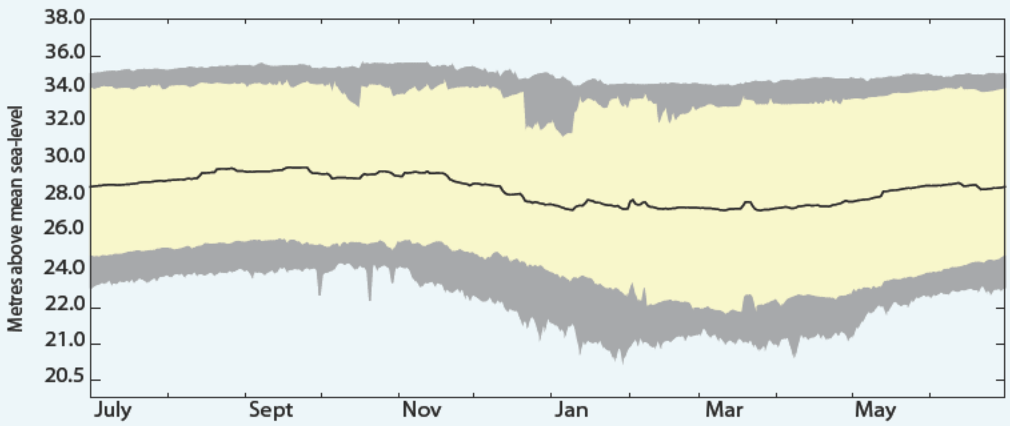

Figure 7.15: Confined Benmorven Aquifer

The isolating effect of the confining layer restricts the rate of recharge to the Benmorven Aquifer, with well levels only responding sluggishly to rainfall or Doctors Creek Flow. However water levels react instantly to pumping. By contrast the neighbouring Omaka Aquifer responded to the heavy rainfall received in winter 1998 and 2008 (Fig. 7.16). This reflects the more open structure of this aquifer, and demonstrates the uniqueness of Marlborough aquifers.

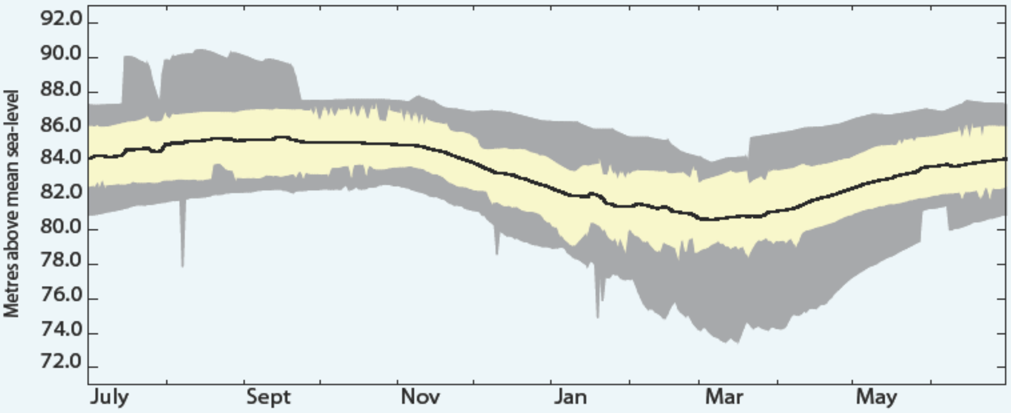

Figure 7.16: Semi-confined Omaka Aquifer

The final two case studies demonstrate the rapid response and drainage properties of the rainfall dominated unconfined Rarangi Shallow Aquifer. Examples of an inland and coastal well are used to demonstrate internal differences. The water table range is larger inland because this is closer to the source of recharge and groundwater drains more rapidly under the higher gradient (Fig. 7.17).

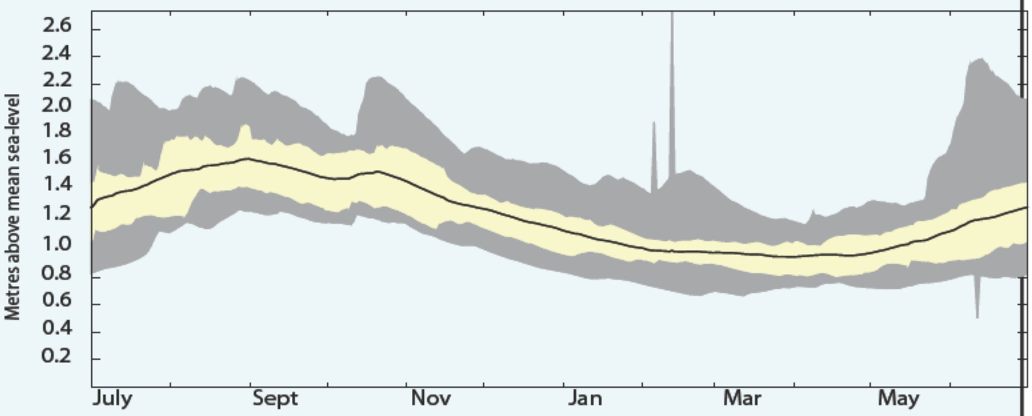

Figure 7.17: Inland unconfined Rarangi Shallow Aquifer

At the coast groundwater is closer to sea level and therefore there is a smaller gradient resulting in lower rates of drainage from the aquifer (Fig. 7.18). In effect shallow groundwater is dammed by the sea, especially at high tide, causing the regular peaks in Figure 7.18. This contrasts with the more conventional shape seen in Figure 7.17, where rises in water level are a result of rainfall recharge followed by a slow recession of the water table as the aquifer naturally drains.

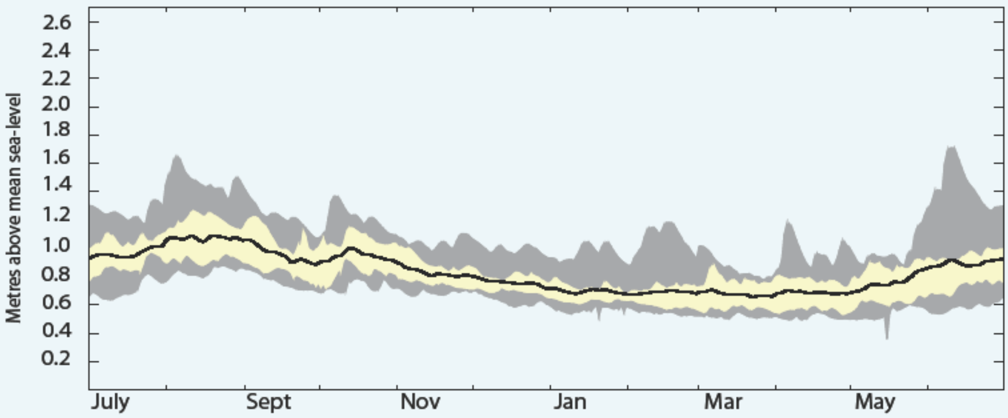

Figure 7.18: Coastal unconfined Rarangi Shallow Aquifer

Long-term level variation

Longer term fluctuations in observed water levels reflect shifts in demand or climate. These factors generally take much longer to detect in a monitoring record than seasonal changes. This is because their influence is more subtle, and must be isolated from medium term patterns.

Long-term responses vary across the province because of physical differences between aquifers and differing levels of demand. These changes can be split into the following two broad categories. Firstly, systems linked to perennially flowing large rivers such as the Wairau Aquifer, will always refill, but are subject to seasonal low levels. Secondly, lower yielding aquifers will tend to recharge more slowly, and take longer to recover, particularly if they have a confined structure.

To illustrate the diversity of responses, records from the longest standing monitoring sites are shown in Figures 7.19 to 7.27. The average daily elevation is shown in blue with a moving average line in black to identify the trends.

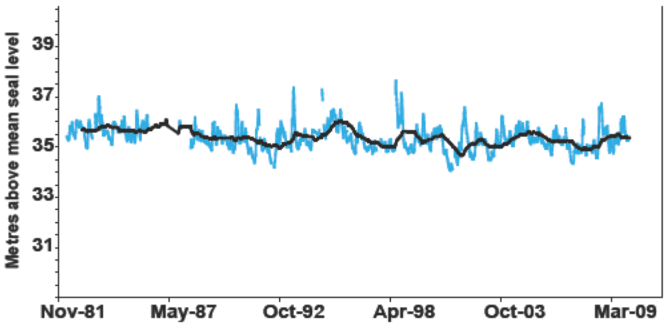

Figure 7.19: Wairau Aquifer recharge reach level variation

Levels have been monitored in the unconfined Wairau Aquifer, opposite the recharge reach, near Renwick, for 28 years. Water levels are relatively stable with a fall of just 0.5 metres over this period, which is a small proportion of the aquifer thickness of 20 to 30 metres (Fig. 7.19).

At the downstream end of the Wairau Aquifer at the Cloudy Bay coast, levels at well 1733 are largely unchanged over the period from 1988 to 2010 (Fig. 7.20).

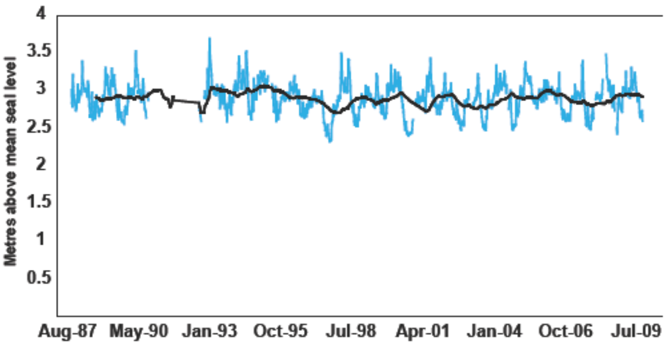

Figure 7.20: Coastal Wairau Aquifer level variation

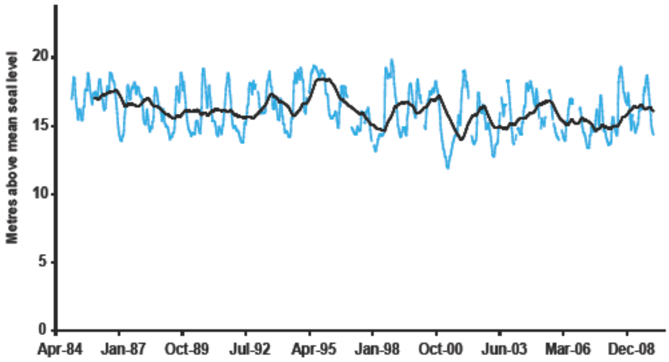

Figure 7.21: Woodbourne Sector level variation

Groundwater levels at Woodbourne are influenced by seasonal inputs from the Wairau River to the north, and the Southern Valleys catchments to the south. A drop in groundwater levels of around 1.25 metres over the past 25 years, which are thought to be largely due to changes in catchment runoff from the southern hills, has been observed (Fig. 7.21). The hydrograph is a composite record of manual weekly measurements at well 0594, and automatic observations at well 3010 in Jacksons Road from 1997 onwards.

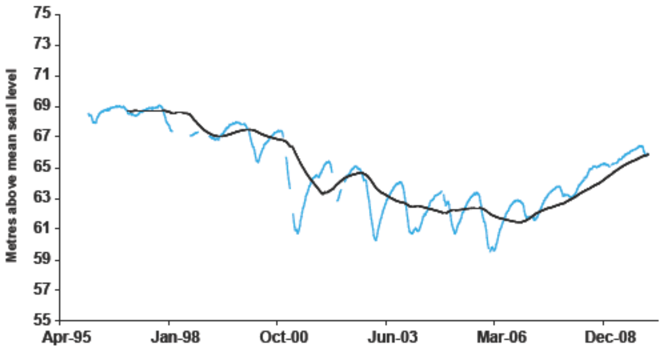

Figure 7.22: Deep Wairau Aquifer level variation

At great depth the Deep Wairau Aquifer is made up of many water bearing layers dispersed throughout a sequence of gravels several hundreds of metres thick. Groundwater levels fell significantly as a result of high rates of pumping and low recharge during the 1997/98 and 2000/2001 droughts (Fig. 7.22). Levels have been rebounding since winter 2006, following the introduction of the Southern Valleys irrigation scheme. Experience has shown that pumping has the largest influence on water levels due to the naturally low storage properties of these deeper aquifers. Their isolation from the surface sources of recharge also makes them naturally slow to recharge.

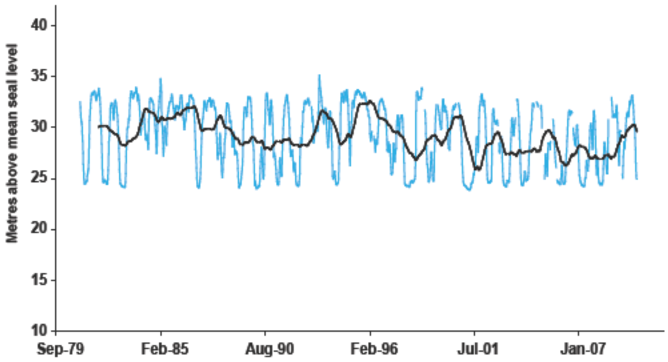

Figure 7.23: Omaka Aquifer deep layer level variation

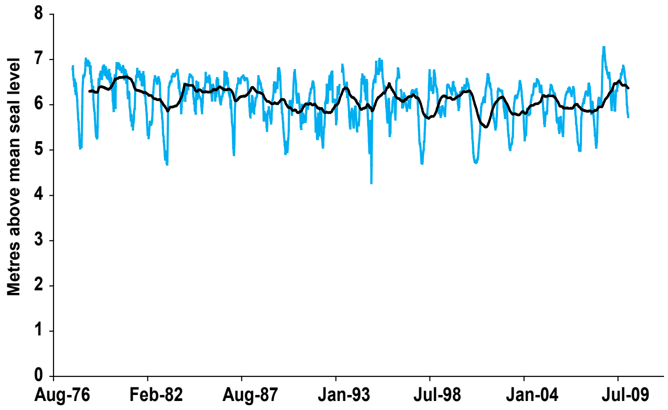

Figure 7.24: Taylor Fan Aquifer level variation

The Omaka River Aquifer is a multi layer system that lies to the south-west of Woodbourne. Groundwater levels over a period of three decades appears to follow the same seasonal pattern, although the average elevation has actually fallen by 2.5 metres. The hydrograph explanation lies in the fact that summer levels are staying lower for longer(Fig. 7.23).

The MDC long-term monitoring well 0949 at Athletic Park has been recording water levels for 33 years. This site represents the medium depth aquifers influenced by the Taylor River or the Southern Springs. Aquifer levels have fallen by a small amount which probably reflects changes in runoff from the Southern Valleys Catchments (Fig. 7.24).

The most significant changes in aquifer level have occurred in the Southern Valleys Catchments and in particular the Benmorven Aquifer, where falls of 15 metres have been experienced since 1990. The sharp falls in water level coincide with the 1997/98 and 2000/01 summer droughts (Fig. 7.25). Levels have stabilised through voluntary restrictions and the advent of the Southern Valleys Irrigation Scheme, but remain eight metres below 1990 elevations. This reflects the isolating effect of the confining layer that forms a lid on the Benmorven Aquifer, naturally slowing the rate of recharge.

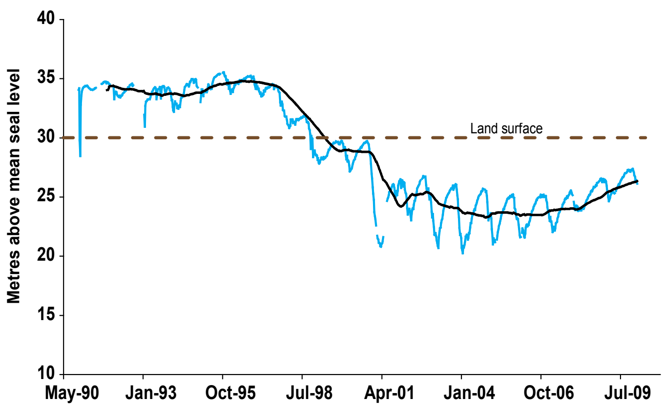

Figure 7.25: Benmorven Aquifer level variation

By contrast the Brancott Aquifer with its more open, semi-confined structure, had recovered fully by 2010, despite experiencing significant falls in level for the same reasons. These structural differences are reflected in older and more evolved groundwater at Benmorven where it is essentially trapped (Fig. 7.26).

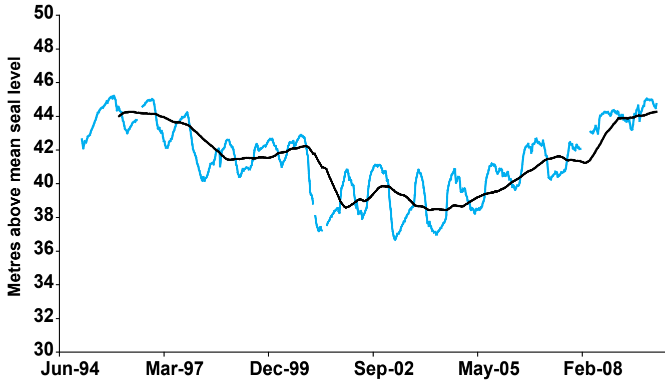

Figure 7.26: Brancott Aquifer level variation

Rarangi Shallow Aquifer levels have remained stable over the past 21 years of record for the Rarangi Golf Course well 1901 (Fig. 7.27). Unfortunately there are missing records during the mid 1990s. Low water levels correspond with the 1998 and 2001 droughts. While pumping and drought can cause seasonal low levels, the unconfined nature of the aquifer and its high water table means levels bounce back each winter or spring with the arrival of wetter conditions.

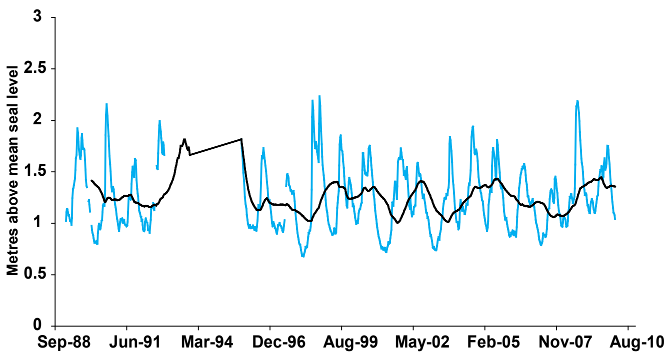

Figure 7.27: Rarangi Shallow Aquifer level variation

The above sequence of plots shows the value of collecting a long time series of aquifer behaviour to identify pumping or climatic patterns. What is missing, except in the case of the Southern Valleys Aquifers, are seasonal abstraction rates to complete the water balance and provide a clear picture of cause and effect.

Seasonal and long-term chemistry variation

Less information is available to describe corresponding changes in groundwater quality or chemistry than is available for groundwater levels.

A focus of current monitoring programmes is to provide definitive descriptions of the effect of landuse on groundwater quality.

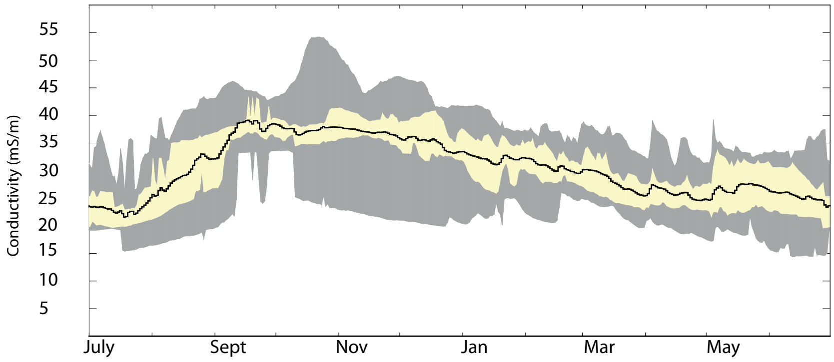

Figure 7.28: Coastal Rarangi Aquifer conductivity

Most water quality observations rely on field samples which are sent to a laboratory for analysis. This means that a site may only be sampled on a seasonal basis. One exception to this is conductivity, which is an indicator of overall water quality that can be monitored continuously with automated readings.

An area where a good conductivity record has been established through automatic readings, are the coastal aquifers. Groundwater conductivity records from shallow coastal sentinel wells show that levels rise naturally in spring. This is in response to higher rainfall and leaching of sea-spray that has accumulated in the sandy soils over the remainder of the year. So far there is no evidence of any inland movement of the sea-water interface due to over pumping (Fig. 7.28).

Groundwater temperature and conductivity are more difficult to measure automatically than water level and this is reflected in the greater variability of results.

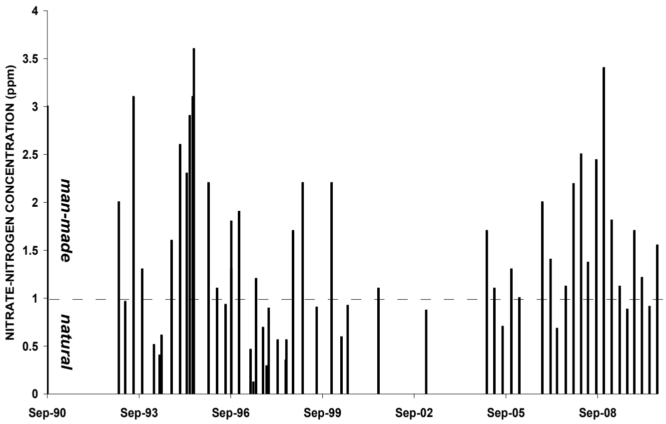

Figure 7.29: Woodbourne groundwater nitrate-nitrogen concentration

Nitrate-nitrogen concentrations are regularly measured throughout Marlborough's aquifers. This is because they are a good indicator of the impact of landuse on groundwater. The concentrations of nitrate-nitrogen often exceed the naturally occurring level of one part per million in Marlborough groundwaters.

Long term records of nitrate-nitrogen concentrations in groundwater exist for wells at Woodbourne from 1990 (Fig. 7.29). While there are some signs of man-made influences, there are no long-term upwards trends in groundwater nitrate levels in this intensively farmed mid plain area.

In the unconfined Wairau Aquifer and Rarangi Shallow Aquifers, spring rains, which tend to naturally leach nutrients down to the water table, are the cause of higher nitrate levels. For example, the peak value at Rarangi Golf Club well 1634 coincides with one of the wettest springs on record in late 2001 (Fig. 7.30).

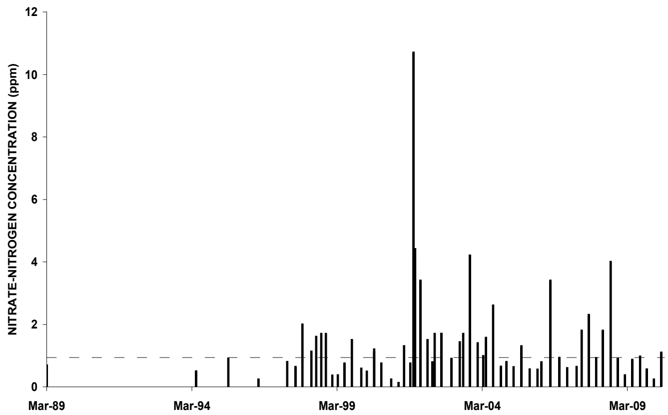

Figure 7.30: Rarangi Shallow Aquifer nitrate-nitrogen concentration

In common with other Wairau Plain sites with long-standing record, there is no apparent increase in nitrate levels over the past twenty years. While there are seasonal spikes, these don't appear to persist.

In other areas such as the mid Wairau Plain, the opposite appears to happen, with nitrate-nitrogen levels in groundwater peaking in summer. This is thought to reflect the dilution effects generated by greater groundwater throughflow in spring or winter. These uncertainties emphasise the importance of acquiring long and continuous records of groundwater quality rather than assuming the same process occurs in all of Marlborough's aquifers.

References

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