MARLBOROUGH DISTRICT COUNCIL

Groundwater Quantity State of the Environment Report

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Executive Summary

The health of Marlborough's aquifers, most of which are located beneath the Wairau Plain (Figure 1) is variable in terms of their state and the existence of trends. This reflects the influence of regionally significant stresses like earthquakes versus localised pressures like abstraction, the nature of aquifer boundaries and recharge processes.

In terms of current aquifer state, groundwater levels are low in the following areas: western areas of the Wairau Aquifer relative to Wairau River levels for recharge purposes, Riverlands Aquifer relative to sea-level and the potential for saltwater intrusion and the Benmorven Aquifer relative to historic levels and the potential for compaction.

Except for Wairau Aquifer recharge, these are potential threats only (Figure 2). No increase in actual abstraction is sustainable for the Riverlands Aquifer given the seasonal proximity of groundwater levels to Marlborough Environment Plan (MEP) seawater intrusion thresholds. The Riverlands Freshwater Management Unit (FMU) is overallocated and the MEP requires consented demand to be aligned with the volumetric limit.

Wairau Aquifer levels have been steadily declining for 50 years due to several factors which are currently being investigated as part of a national research programme. These include declining Wairau River channel levels and lower Wairau River summer flows (below 20 m^3/second), both of which affect the rate of recharge available from the Wairau River. Wairau Aquifer Recharge Sector well levels are more affected than coastal wells due to their proximity to the river.

The shallower strata of the Taylor River are classed as having relatively high levels currently, probably because of the 2016 earthquake raising land elevations in the Riverlands area and reducing rates of natural drainage.

Groundwater levels are relatively high in the deeper strata of the Southern Valleys Aquifers, except the Benmorven Aquifer where levels have rebounded, but have not fully recovered to where they were prior to the 1997/98 or 2000/01 droughts. The Benmorven FMU remains overallocated and the MEP requires reconciliation to bring consented demand into line with the plan limit.

All other aquifers and sectors are currently considered in a normal state. These include the Rarangi Shallow Aquifer, Omaka River Aquifer, eastern areas of the Wairau Aquifer, deeper layers of Taylor Fan Aquifer and Wairau Valley lower terrace groundwater (Figure 2).

In terms of trends in groundwater level, all Wairau Aquifer monitoring wells are exhibiting a declining trend varying in average magnitude from: 3 mm/year at the Cloudy Bay coast (Coastal Sector Bar well P28w/1733) to 22 mm/year inland at the Recharge Sector (Conders well P28w0398-3821) (Figure 3). This trend was first identified at the Conders well based on observations starting in the early 1970’s and confirmed by a similar trend in groundwater levels for two related wells in Wratts Road (including MDC well P28w/3009).

Spring Creek flow at Motorcamp has declined significantly since gauging's began in 1991 in line with the decline in Wairau Aquifer levels. Of concern is the potential for this trend to continue long term. Based on extrapolating the decline in Spring Creek flow, Wairau Aquifer springs may recede as far east as State Highway 1 by the year 2100. These include Spring Creek, Fulton Creek in Pollard Park, Murphys Creek and the baseflow of the Taylor River at Grove Road in Blenheim near the new library building.

Riverlands Aquifer levels have declined at a rate of 16 mm/year at the inland well P28w/4402 and 5 mm/year on average at the costal well 10346, which is relatively minor. These declines are likely to reflect the reduction in distant recharge from the Wairau River plus local pumping influences, especially larger seasonal drawdowns with time.

Interestingly Rarangi Shallow Aquifer (RSA) groundwater levels have shown a rising trend, although sea-level rise cannot account for the full amount with changes in natural water drainage patterns from the Hinepango Wetland likely to be a major part of the explanation.

Waikakaho River Gravels Aquifer groundwater levels are also showing a rising trend, although the period of record is much shorter than for other aquifers with the explanation uncertain at this stage. Possibly a combination of changes in rainfall and runoff linked to plantation forestry management cycles.

Omaka River Aquifer groundwater levels are stable over time except for the shallow well in the upper part of the lowland catchment (P28w/3069) where there has been a small, but steady decline since the late 1990's. The cause is most likely related to local abstraction for crop irrigation/filling dams.

Southern Valleys Aquifer levels have rebounded over the past 14 years due to reduced demand on local groundwater by irrigators, with Southern Valleys Irrigation Scheme (SVIS) water being used instead. While this is defined as an increasing trend, a more correct interpretation is a net increase in groundwater level over time.

The 2016 Kaikōura earthquake artificially raised groundwater levels of deep aquifers in a process like liquefaction where the seismic shaking reduced porosity causing water to rise. While it influences the observed trend, it is a temporary rise and levels are returning to their pre-earthquake levels.

The Taylor Fan well P28w/0980 has shown a rise consistent with the deeper aquifers in the Southern Valleys catchments, but MDC Athletic Park well P28w/0949 in the same aquifer does not have a significant time trend in groundwater level.

Shallow groundwater levels representing the lower terrace at Wairau Valley are stable over time (Figure 3), but showing recent seasonal summer declines whose causes are being investigated by MDC and NIWA hydrologists.

Wairau River flows measured at State Highway 1/Tuamarina in the lower catchment show a small declining trend since 1960, but no trend existed for Wairau River flow at Dip Flat in the upper catchment. This is consistent with the trend in Wairau Aquifer levels.

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1. Introduction

Marlborough District Council is required by its annual plan to produce annual State of the Environment (SoE) Reports across its science portfolios showing resource state and trends. This report describes the state and trends present for groundwater quantity across the district based on observations from the MDC permanent monitoring well network representing all the main aquifer systems in Marlborough. Effectively this is a stocktake of water stored in our underground reservoirs known as aquifers, and how these have changed with time.

The aim of this SoE report is to measure and improve Marlborough Environment Plan effectiveness. To do this the report compares aquifer state relative to Marlborough Environment Plan performance thresholds or hydrological criteria.

It also identifies any long-term trends present and explains their causes where possible. Shorter term patterns and cycles in groundwater level caused by changes in climate, demand or hydrology are less important for management purposes, but are discussed as part of evaluating aquifer health.

Most of Marlborough's groundwater resources are located beneath the Wairau Plain. Figure 1 is a map view of the Wairau Plain and Lower Wairau Valley showing the location of the MDC permanent groundwater quantity monitoring sites labelled with their MDC identification number. The groundwater quality monitoring network is more extensive and represents a greater number of Freshwater Management Units (FMU). The MDC groundwater quality monitoring network has been externally reviewed by GNS Science.

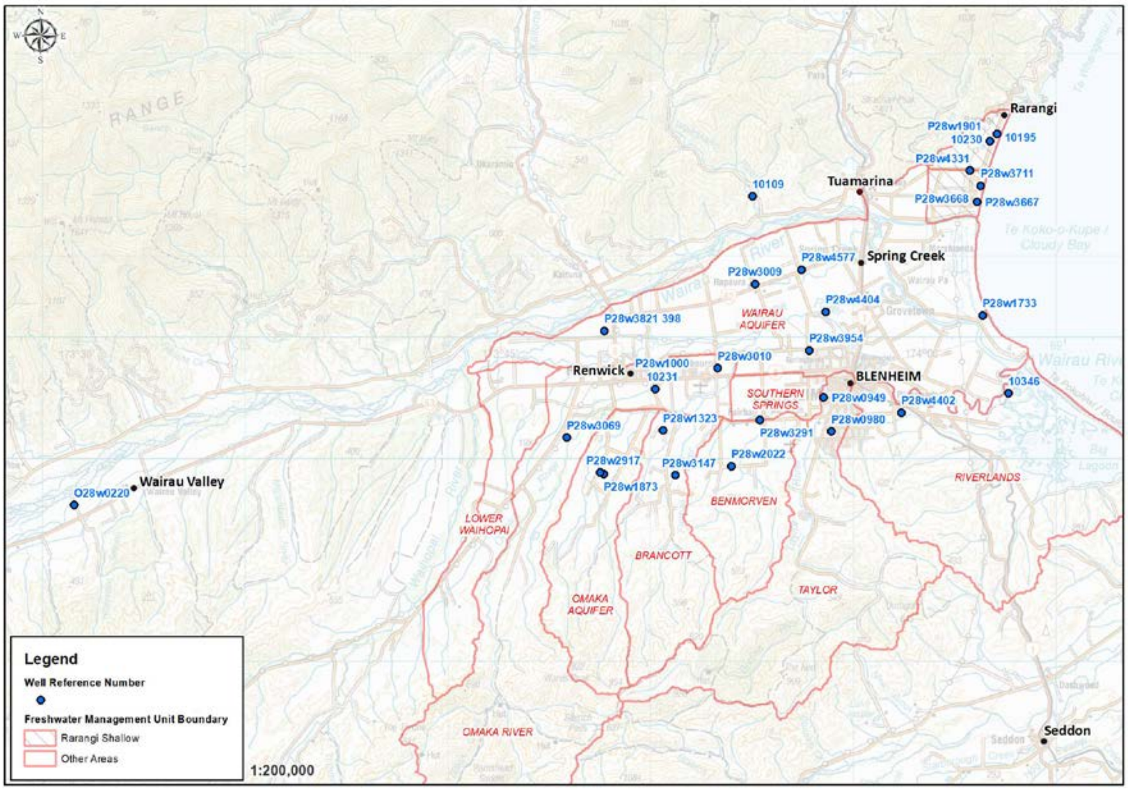

Figure 1: MDC groundwater quantity state of the environment permanent monitoring network

For resource management and limit setting purposes the Marlborough Environment Plan uses Freshwater Management Units (FMU) as the framework for defining hydrological units. FMU's are further subdivided into Sectors. Table 1 lists the FMU or Sector and how many MDC monitoring sites they are represented by. In some cases, there are multiple monitoring wells representing an FMU or Sector such as the Rarangi Shallow Aquifer.

This report focuses on the individual state of Marlborough's aquifers or sectors in the first instance to build a coherent overall regional picture of Wairau water resource health. Aquifer state/trend does not solely reflect Marlborough Environment Plan effectiveness or consenting practice with natural factors influencing behaviour too. A good example is the Wairau Aquifer recharge process affecting Wairau Aquifer level state/trend.

The report does not contain recommendations but does comment on the causes of state or trends, especially where these relate to consenting practice or Marlborough Environment Plan limits as these can be regulated unlike natural processes.

Table 1: Marlborough Environment Plan Freshwater Management Units and Sectors with SoE representative monitoring sites

Freshwater Management Unit	Management Sector	Number of MDC SoE monitoring well sites
Wairau Aquifer	Recharge, Springs, Lower Wairau, Coastal	6
Riverlands	-	2
Taylor	-	2
Benmorven	-	2
Brancott	-	2
Omaka	-	2
Omaka River	-	3
Rarangi	-	5

The explanation for some trends or aquifer behaviours remains uncertain and this reflects the fact that MDC still does not have perfect knowledge of all aquifer systems, but sufficient exists for management purposes and setting interim limits in the MEP. Aquifer mechanics are generally well understood but water budgets are still being developed.

Cumulative actual water use is the piece of the water budget that is still being assembled. It is the only component of the hydrological cycle that can be accurately measured. Measurements of rainfall and to a lesser extent river flow are only approximations of reality. This State of Environment Report uses observed changes in groundwater level at monitoring wells as the measure of aquifer response to consented demand and Marlborough Environment Plan limits.

Consented demand for an entire aquifer is not as physically relevant to aquifer response to stresses observed by the MDC SoE groundwater quantity network as actual use. To assess the cause-and-effect relationship between the fall in monitoring well level and actual pumping requires knowledge of cumulative daily metered water use for a whole FMU or aquifer sector. This information is currently being verified and assembled. Actual water use for the Riverlands Aquifer was available and used as part of this report with an allowance for consented demand that is not yet metered.

Bringing consented demand into line with actual use or sustainable limits is the aim of the MEP plan implementation process. Aquifer limits are likely to change as MDC knowledge is improved and this may affect individual water permits in some FMU's or management sectors in the future.

The workings are presented in the Appendix using a standardised scorecard format for uniformity purposes and to provide MDC with an easy to visualise appreciation of aquifer behaviour. The essence of the report is provided by Figure 2 and Figure 3 and conveys to the reader the regional pattern of aquifer wellbeing.

2. Methodology

Aquifer state is more difficult to assess than a trend in groundwater level. For the purposes of this report aquifer state was defined in terms of relativity to a physical threshold. For coastal aquifers and their monitoring wells, state was defined in terms of the risk of seawater intrusion occurring which in turn was depended on the relativity to an elevation threshold that avoids seawater intrusion from happening.

A similar approach was used for areas where spring recession or aquifer compaction was a potential threat. In all other cases the state of an aquifer was based on a review of groundwater level patterns in recent time relative to the long-term mean level and potential threats. The state at a certain date would not be representative especially for aquifers or wells where there are large changes in well level seasonally like the 10-metre annual range at Woodbourne (Omaka River FMU).

Trends were identified analytically using the Seasonal Kendall test. The Seasonal Kendall test was used because there is a seasonal variation in most of MDC's well level time series. A season was defined as one month because of the availability of continuous groundwater level data. Statistical significance was based on a confidence level of 95%. The statistic used in the Seasonal Kendall trend test to indicate the significance of a trend was P which had to have a value of less than 5% (0.05) to be significant.

This test showed the presence, direction, significance, and magnitude of trends in groundwater level, flow or electrical conductivity of waters. In some cases, the primary time series was adjusted using a covariant and loess was used for the correction. The trend is less meaningful where there have been large changes in level over short to medium term periods due to abrupt changes in abstraction or earthquakes, as is the case with the medium to deep Southern Valleys Aquifer systems. However, the trend rate was described in the report for completeness.

The input data used for analysing aquifer behaviour was mean daily groundwater levels for all MDC monitoring well sites. Mean daily and mean weekly flows were used for the analysis of Wairau River trends as the datasets were longer and Time Trends was unable to cope with the large file size.

Time series of groundwater elevation (level) were first plotted in XL to check for the existence of trends by automatically fitting a linear trend line to the dataset, and for some sites with more complex patterns or longer record, a moving mean line to understand the shorter-term patterns or cycles in well levels. Graphing the groundwater level or river flow is the essential first step for understanding the hydrology and drivers of change.

The Seasonal Kendall test was then applied to test the significance and magnitude of trends. The cumulative deviation from the mean groundwater elevation at a well or river flow or electrical conductivity (Cusum) was a check on whether a trend was present and significant. A decreasing trend was shown by the Cusum line plot being positive (above the zero line or high) and an increasing trend was identified by a negative line plot (below zero line or low).

The seasonality of groundwater levels at each site was assessed on a monthly basis using the Seasonality tool in Time Trends. The light blue inner portion represented 50% of values with the whiskers denoting the range of all observations. The seasonal variation was useful for understanding the dominant influences on an aquifer were natural processes like recharge and drainage versus human drivers like pumping.

The Time Trends suite of hydrological water quality analysis tools developed by Ian Jowett for Regional Councils was used for most of the trend and pattern analysis.

3. Results

Figure 2 and Figure 3 summarise aquifer state and trends. The scorecards in Appendix A provide details of how these were derived with discussion on each parameter and how they relate to other monitoring results from the same FMU. Much more could be written on the behaviour of each of Marlborough's aquifer systems, however the aim of this SoE report is to summarise aquifer state and trends.

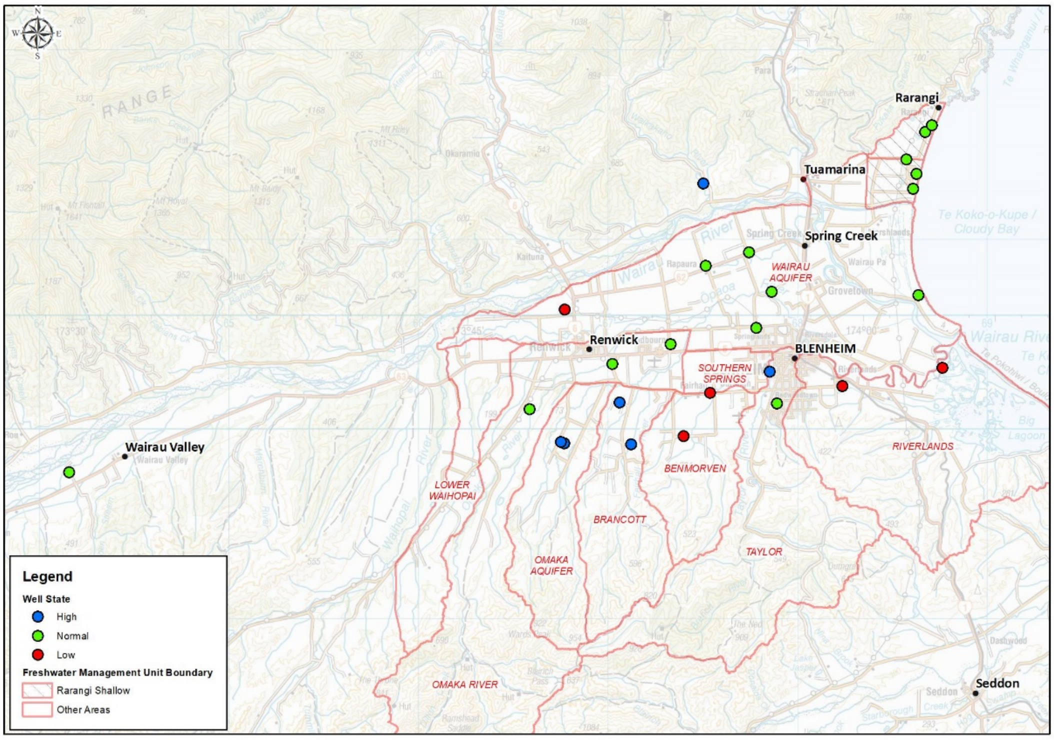

Figure 2: Aquifer State

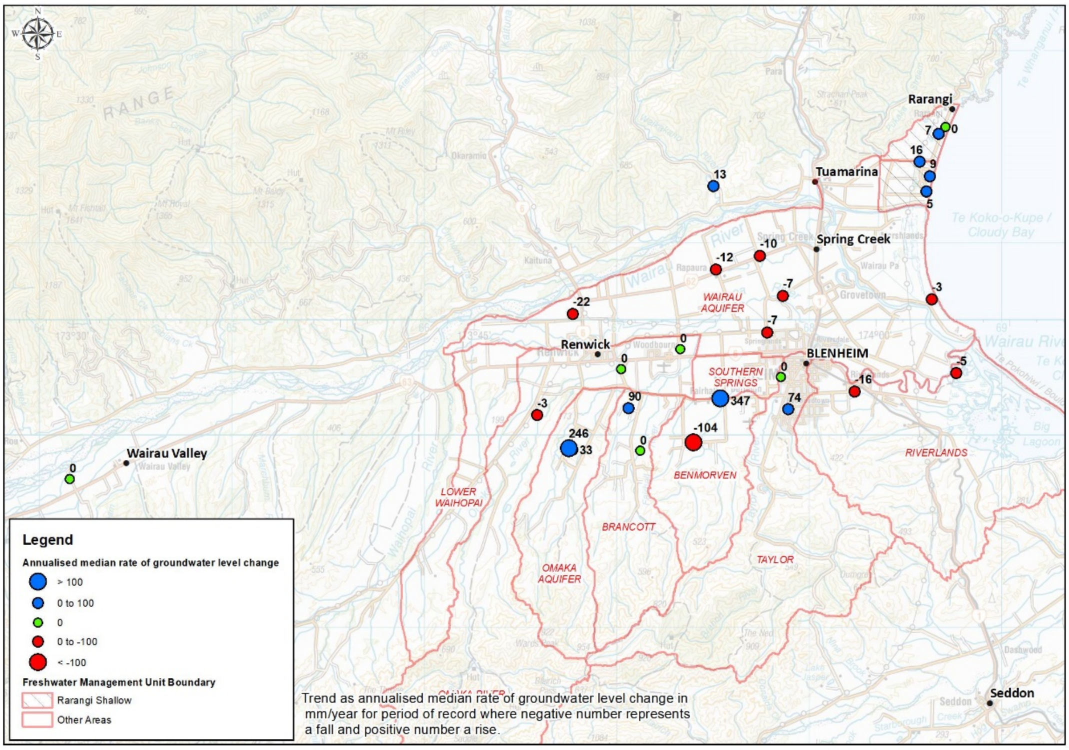

Figure 3: Aquifer Trends

4. Appendices

Appendix 1: SoE Network Monitoring Sites

This appendix contains the detailed analyses and discussion for each individual MDC SoE network monitoring site. This is the base information used to derive the overall picture of FMU state and trend in Figure 2 and Figure 3. Each monitoring site has a dedicated page providing the reader with a summarised appreciation of the assessment of aquifer health.

4.1. Wairau River Flow at Tuamarina

The Wairau River recharges all groundwater beneath the northern and eastern Wairau Plain. The largest and most significant aquifer in terms of the groundwater it provides for ecological, aesthetic, agricultural and municipal servicing, is the Wairau Aquifer. At moderate to high Wairau River flows, the Wairau Aquifer recharge rate is relatively constant. At low channel flows of less than 20 m^3/second however the recharge rate is likely to vary significantly. Because of this flow dependency, any reduction in Wairau River low flow has implications for Wairau Aquifer storage.

Mean daily, weekly, and monthly Wairau River flows were plotted to identify patterns and trends (Figure 4). The XL fitted linear trend line shows a decline of about 15 m^3/second over the past 61 years. The Seasonal Kendall test showed a decreasing trend was very likely and significant at the 95% confidence level for the mean weekly and monthly flows, but not mean daily flows (Figure 5). The P statistic values were: 0.03, 0.01 and 0.20 respectively. The median annual declines were 0.16 m^3/second/year for the mean weekly flows and 0.25 m^3/second/year for the mean monthly flows which equals 10 and 15 m^3/second over the 61 years of record. The reason for the lack of a significant trend in the mean daily dataset is uncertain as the number of observations used for all three analyses were similar. Interestingly Wairau River flow at Dip Flat showed an increasing trend since both 1950 and 1960.

Figure 6 shows the double peak of the Wairau River monthly flow regime. The Cusum analysis for Wairau River at Tuamarina showed a decreasing flow trend between 1960 and 2022 (Figure 7).

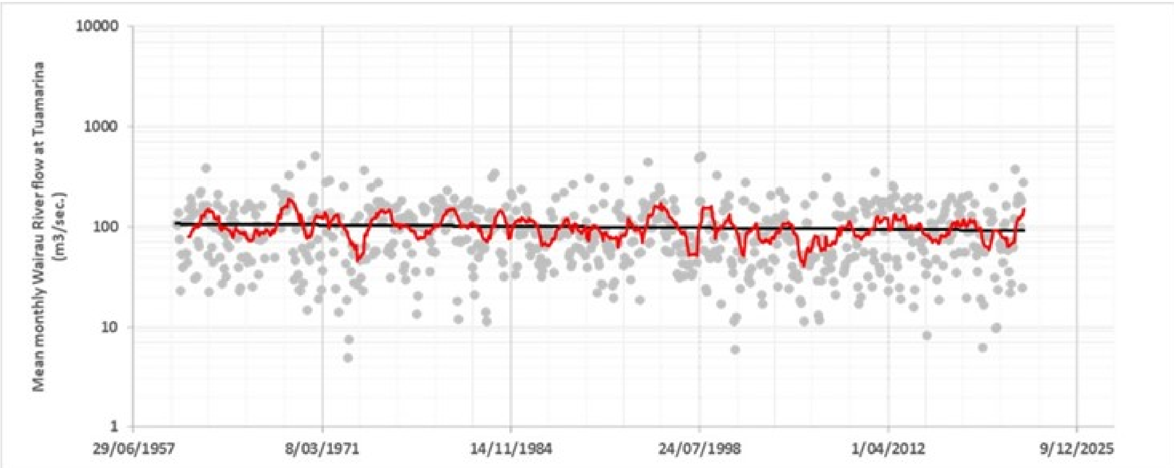

Figure 4: Groundwater elevation with linear trend & moving average for mean monthly flow at Tuamarina

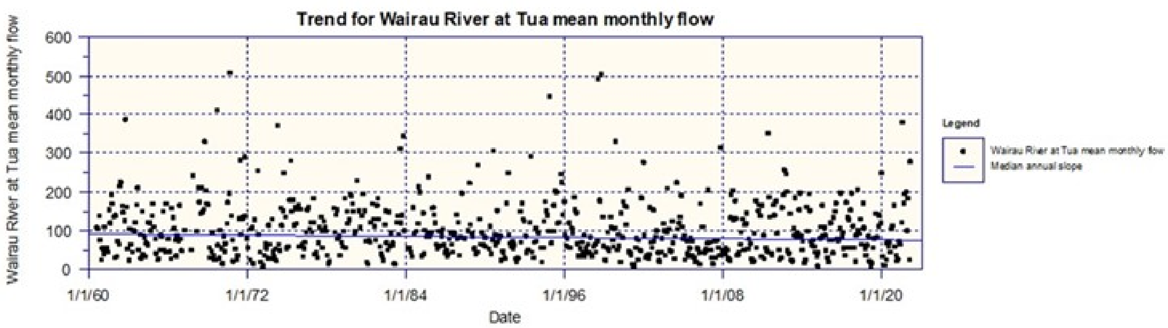

Figure 5: Seasonal Kendall test

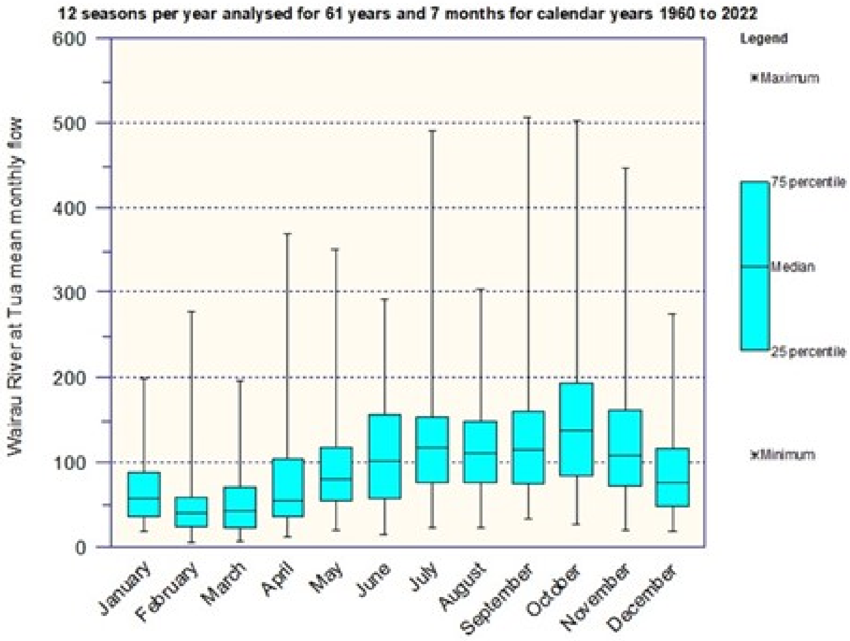

Figure 6: Seasonality

Figure 7: Cusum plot

4.2. Wairau River Electrical Conductivity at Tuamarina

Under natural conditions with the dilute type of water which characterises the Wairau River, flow is generally the inverse of the salt content of channel water. If there is a decrease in flow with time, there should be a corresponding increase in the electrical conductivity (EC) or salt content of channel water. Figure 8 shows a clear increasing trend in electrical conductivity of Wairau River water based on monthly samples at the State Highway 1/Tuamarina site. The black line is the XL fitted linear trend line and the red line is a moving average.

The Seasonal Kendall test confirmed an increasing trend is virtually certain at the 95% confidence level with a P value of 0.00 and a median annual increase in EC of 0.32 micro Siemens/cm/year (**Figure 9**). The cumulative change over 33 years is around 11 micro Siemens/cm or 18% of the mean EC value of Wairau River water. Figure 10 shows the monthly pattern of EC values is the roughly the opposite of channel flow.

Generally speaking, EC is highest in the drier months when catchment flows are lower, but the pattern is not clear-cut.

The Cusum analysis indicates an increasing trend in EC of Wairau River channel water (Figure 11).

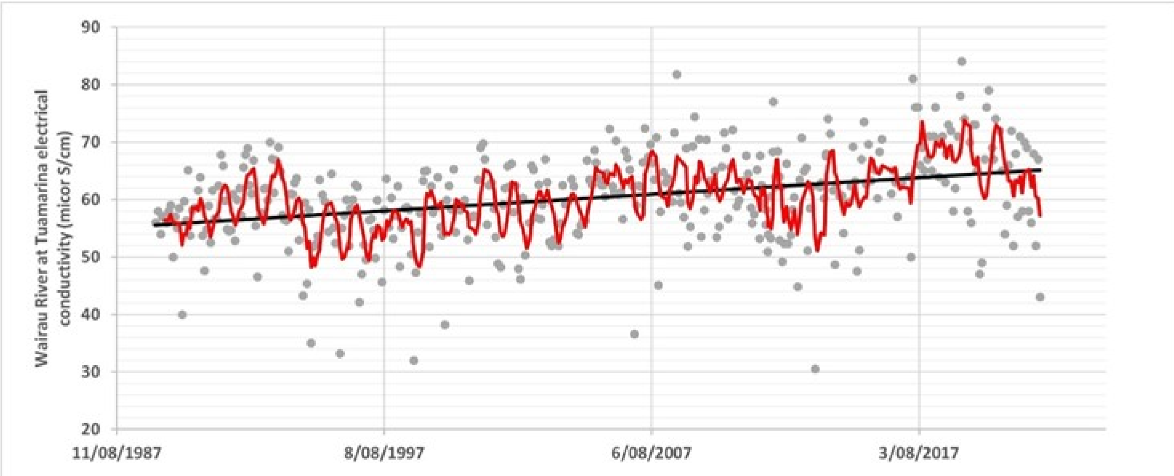

Figure 8: Wairau River electrical conductivity with trend line

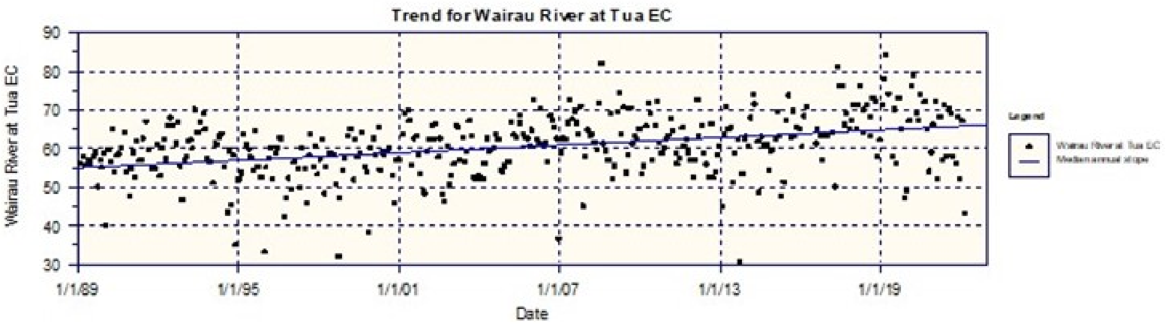

Figure 9: Seasonal Kendall test

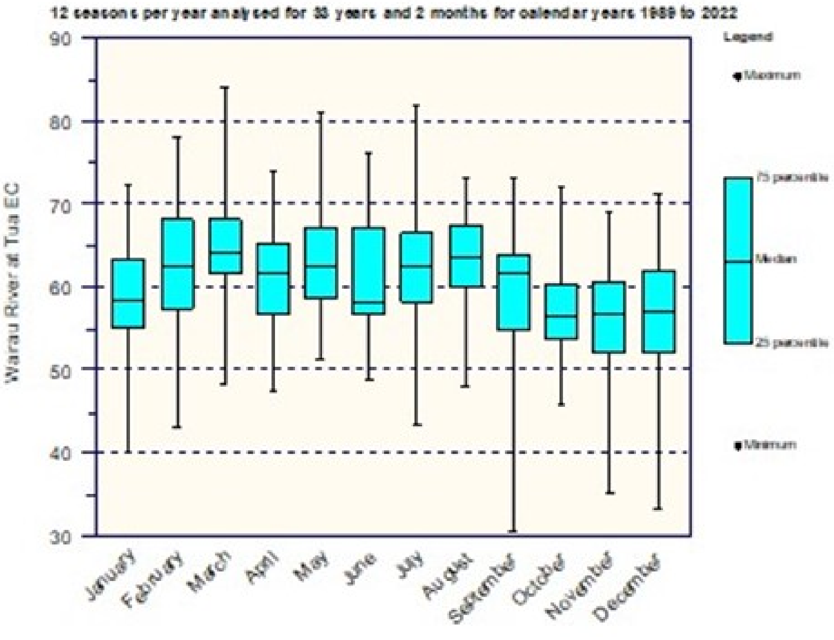

Figure 10: Seasonality

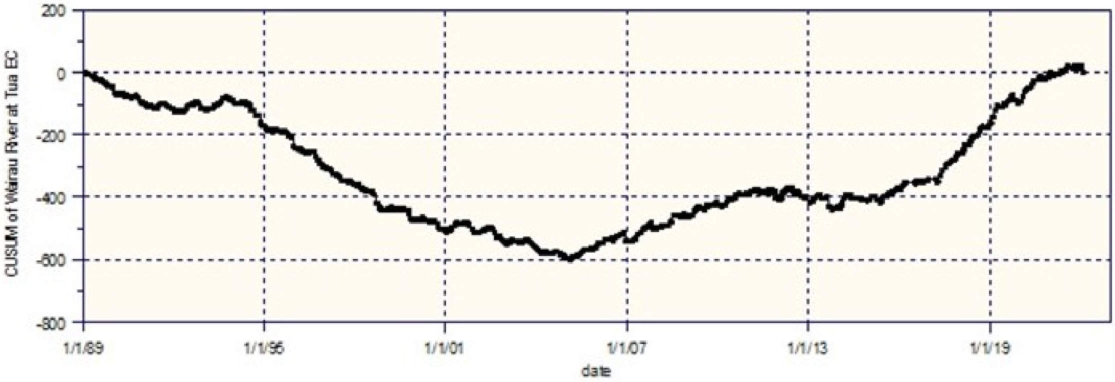

Figure 11: Cusum

4.3. Spring Creek-Awarua Flow at Motor-Camp

Most Wairau Aquifer groundwater leaves the aquifer as spring flow with only a minority remaining at depth and flowing towards the sea where it is likely to discharge offshore or exit as diffuse flow upwards to surface springs. Spring Creek has the largest flow of all these Wairau Aquifer fed springs.

Flow in Spring Creek is a good indicator of the rate of groundwater abstraction from the northern Wairau Aquifer.

MDC have measured the flow of Spring Creek in its lower reaches at the Motor-Camp site since 1996, although the frequency of gauging is lower now than historically. There has been an obvious decrease in flow between 1996 and 2022 (Figure 12). The Seasonal Kendall test confirmed a significant decreasing trend in flow exists at the 95% confidence level with a P value of 0.00 and an annual decline of 0.03 m^3/second or 0.92 m^3/second over nearly 31 years (Figure 13). The monthly fluctuation in flow shown in Figure 14 is very similar to that for the Wairau River flow at Tuamarina which is expected as most recharge originates as surface flow. Spring Creek flows appear to peak in August but rise again in October like the Wairau River.

Figure 15 shows a strong correlation exists between Spring Creek flow at Motor-Camp site on the vertical axis and groundwater elevation at MDC Wratts Road well 3009 nearby. 73% of the variation in Spring Creek flow is explained by change in groundwater level. The higher Spring Creek flow outliers reflect heavy rainfall during storms which increase channel flow without causing well levels to rise. The Cusum analysis indicated a decline in Spring Creek flow in line with the other tests (Figure 16). Based on an extrapolation of the current rate of flow recession, Spring Creek will recede to State Highway 1 by about the year 2100 and by association all of the springs including in Blenheim.

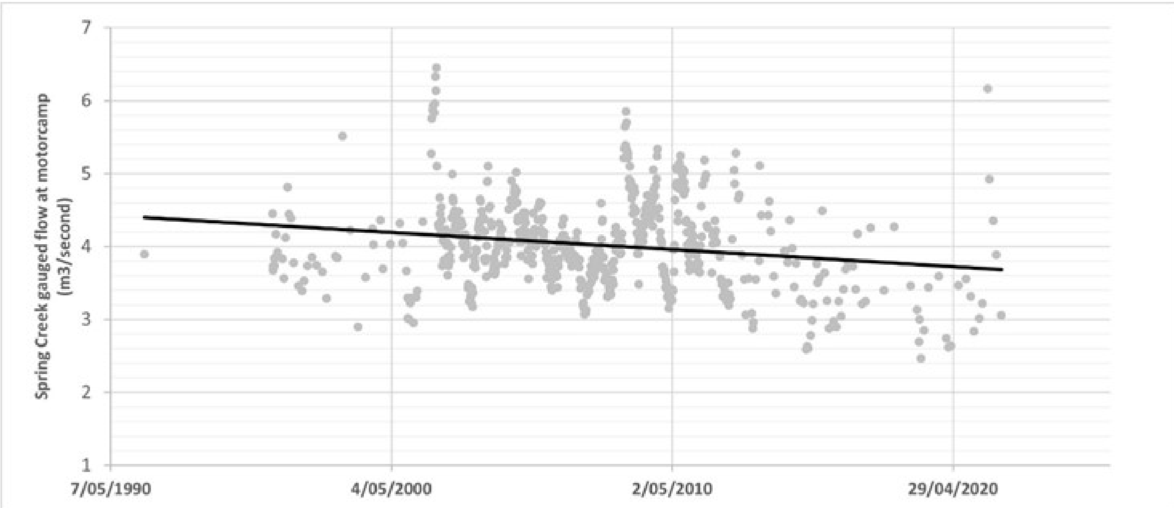

Figure 12: Gauged channel flow at Motor-Camp

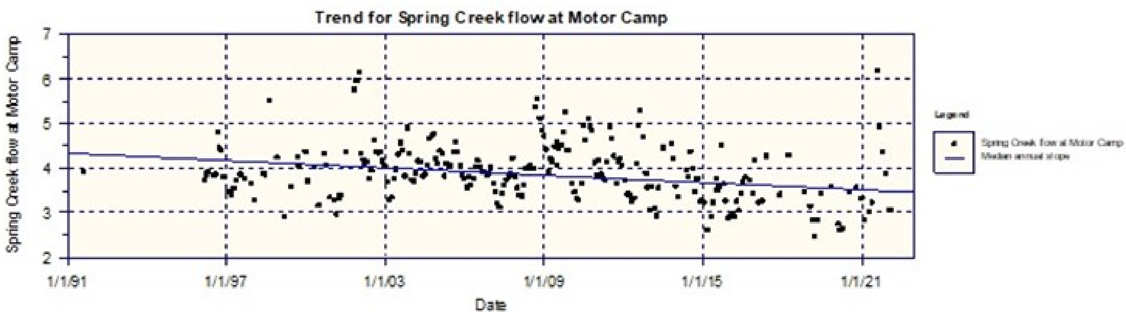

Figure 13: Seasonal Kendall test

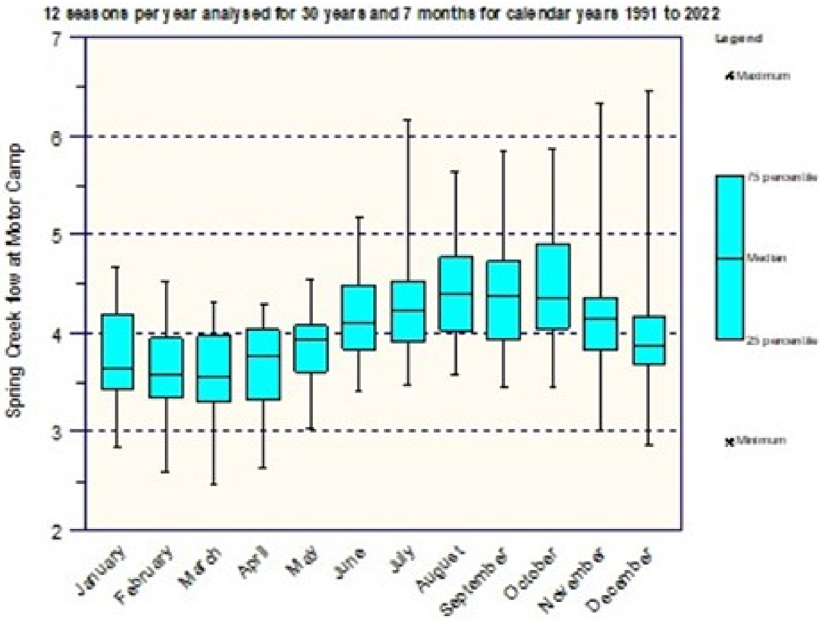

Figure 14: Seasonality

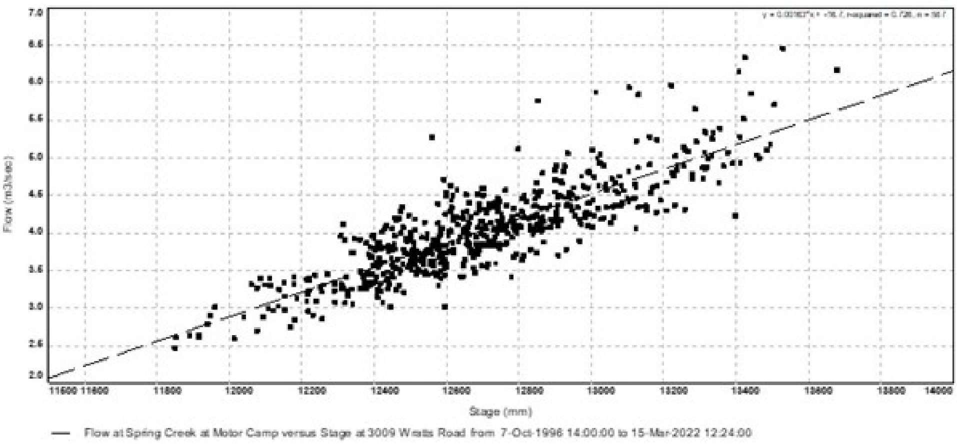

Figure 15: Correlation of Spring Creek flow versus groundwater nearby at MDC well 3009

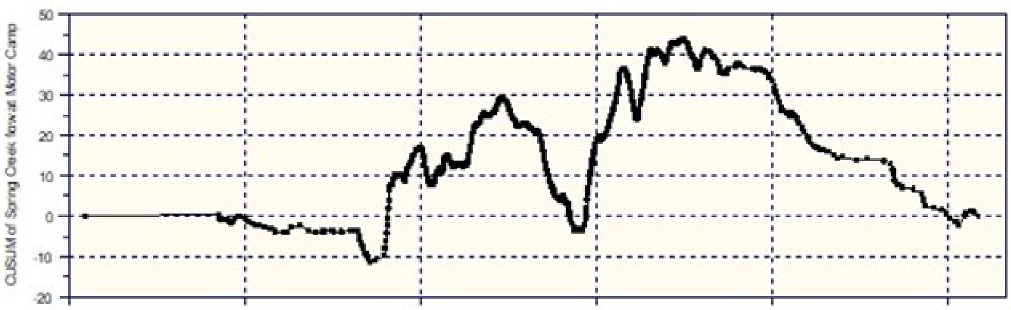

Figure 16: Cusum

4.4. Wairau Aquifer Recharge Sector

The Recharge Sector is the north-western area of the Wairau Aquifer where water naturally leaks from the braided Wairau River to the underlying alluvial gravels to become groundwater. An MDC monitoring well at Conders has been operating since the early 1970s with breaks in record but represents the longest time series at a single well available for studying trends in Wairau Aquifer levels, especially those associated with Wairau River processes.

The original well P28w/0398 was replaced in 2002 as water levels would periodically approach the bottom of the shallow well in most summers. Well 398 was replaced by a deeper well (3821) located two metres away. Figure 17 shows there is an obvious decreasing trend of around 1100 mm over 49 years or an average annual decline of 22 mm/year. Aquifer state is described as low based on groundwater levels relative to Wairau River channel source of recharge and the depth needed to lift water was now beyond a normal surface mounted pump in summer seasons. The Seasonal Kendall test found a decreasing trend was virtually certain at the 95% confidence level with a P statistic value of 0.00 (Figure 18). The median annual decline was 23 mm/year.

The seasonality plot (Figure 19) shows aquifer levels peak in September and fall to their annual minimum in March/April. The Cusum analysis identified a declining trend consistent with the other tests as Figure 20 shows.

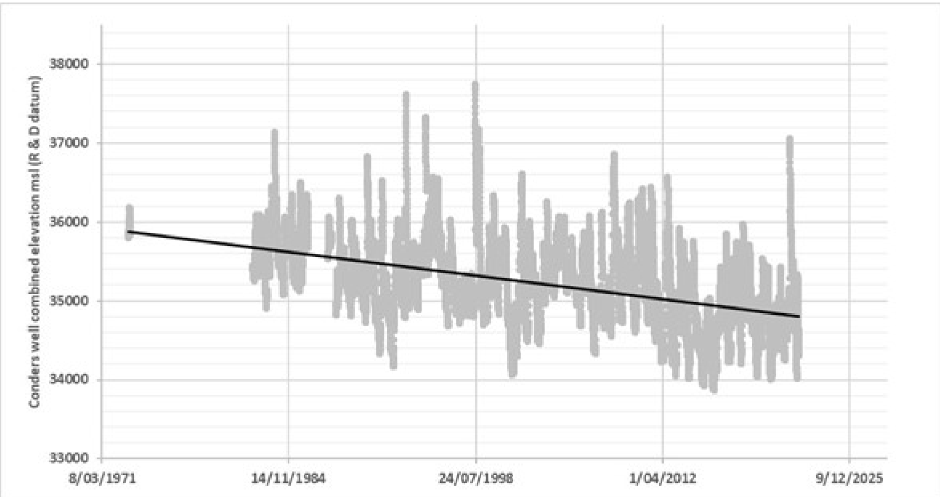

Figure 17: Groundwater elevation with trend line

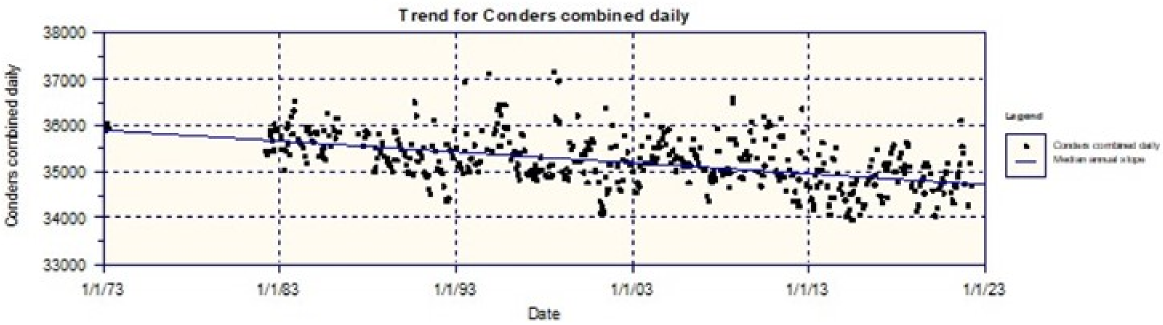

Figure 18: Seasonal Kendall test

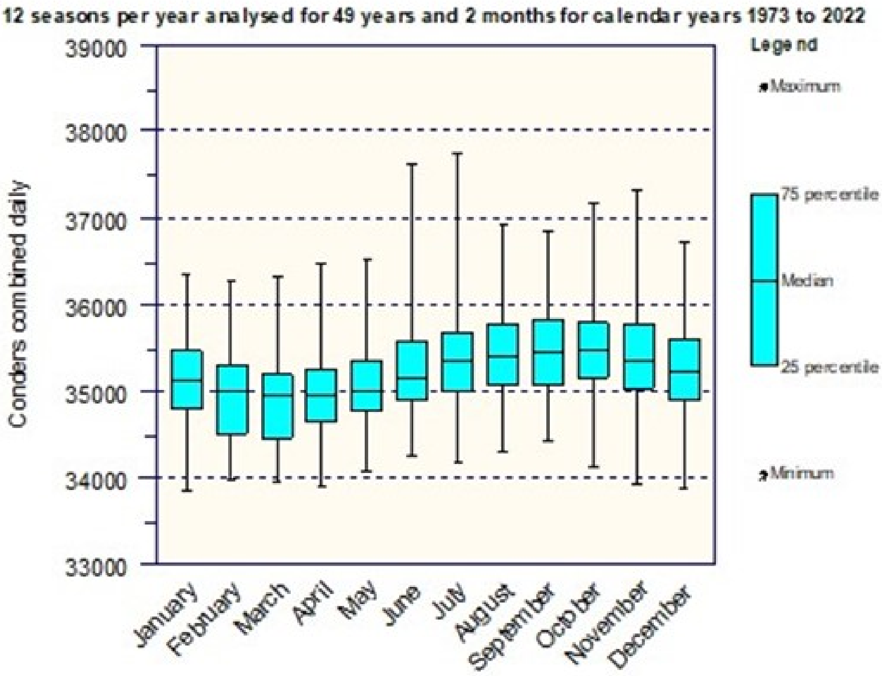

Figure 19: Seasonality

Figure 20: Cusum

4.5. Wairau Aquifer Recharge Sector

The Recharge Sector located north of Renwick is where water naturally seeps from the Wairau River channel to become unconfined Wairau Aquifer groundwater. The Wratts Road well is six meters deep and has been operating since 1996.

MDC monitoring well 3009 is located further from the Wairau River channel than the Conders well (398-3821), meaning it takes longer for well 3009 to respond to Wairau River recharge events. Well 3009 responds quickly to rainfall in winter/spring when most leaching of land surface material and nutrients like nitrate occurs.

There is a clear decreasing trend of around 270 mm over 26 years or an average annual decline of 10 mm/year (Figure 21). The Seasonal Kendall test showed a decreasing trend was virtually certain at the 95% confidence level with a P value of 0.00 and an annual median decrease of 12 mm/year (Figure 22).

Figure 23 shows aquifer levels peak from August to October and fall to their annual minimum in March. In terms of current aquifer state, the extent of Spring Creek-Awarua headwaters at the nearby tennis courts has visually receded slightly since 1998, however the effect is not significant yet. In terms of drivers of groundwater level change, MDC are still assembling the real-time telemetry water meter measurements to graph the cumulative effect of consented abstraction.

The Cusum analysis showed a declining trend consistent with other tests (Figure 24). Aquifer state is described as normal based on groundwater levels being sufficiently high to sustain springs.

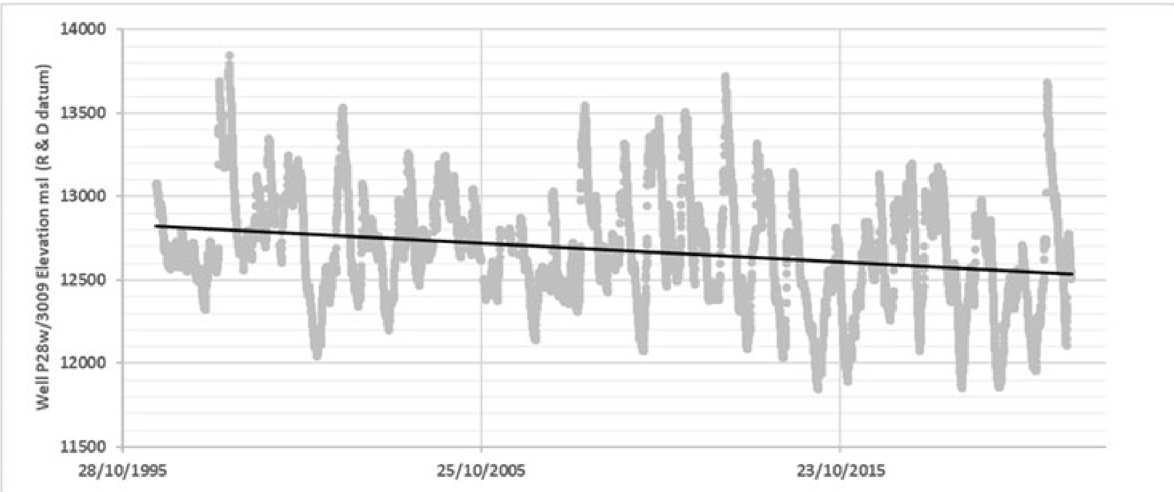

Figure 21: Groundwater elevation with trend line

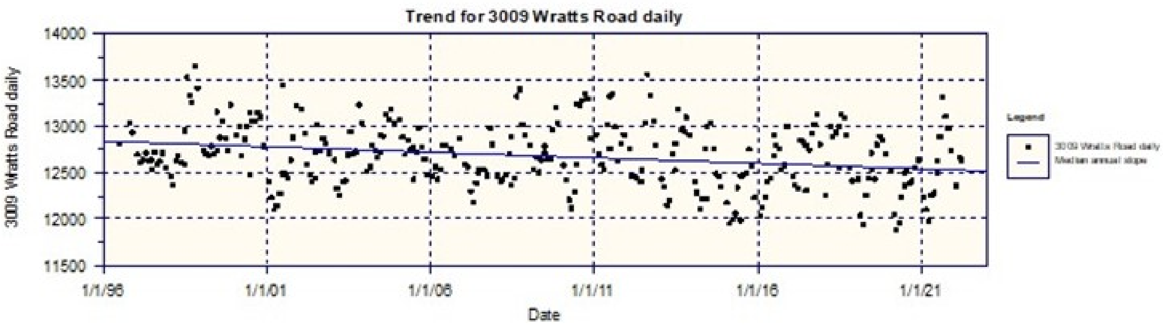

Figure 22: Seasonal Kendall test

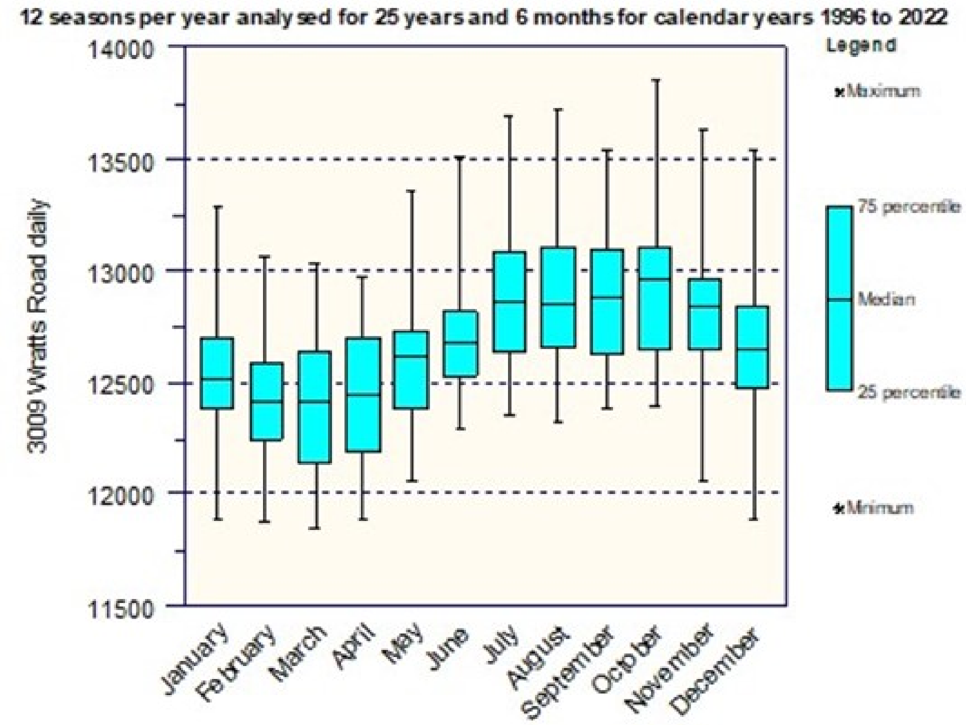

Figure 23: Seasonality

Figure 24: Cusum

4.6. Wairau Aquifer Southern Springs Sector

The Springs Sector of the Wairau Aquifer occupies the mid plains area near Blenheim where upwelling groundwater forms permanent springs. To represent aquifer and spring conditions, MDC operate two permanent groundwater level monitoring sites which automatically record at 15-minute intervals. The MDC Murphys Road well 3954 was established in 2002 and is located in the suburb of Springlands. Measurements represent the Blenheim urban spring flows, and the state of the aquifer which supplies about half of the municipal water to Blenheim.

The scatter plot (Figure 25) shows there has been a slight downwards trend in groundwater levels of around 130mm over 20 years or 7mm per year on average. A median annual declining trend of 7 mm/year was also identified by the Seasonal Kendall test. The declining trend was described as very likely with a P statistic value of 0.03 which is significant at the 95% confidence level (Figure 25). The annual magnitude of decline is consistent with the pattern exhibited by most other inland Wairau Aquifer monitoring sites. This area receives the majority of its recharge from the Wairau River, but because the site is distant from the channel, there are no apparent fluctuations in groundwater levels coinciding with floods, as they are attenuated. Levels do rise in response to rain and Ōpaoa River freshes. Groundwater levels peak in August and are lowest in March (Figure 27).

Aquifer state is described as normal based on groundwater levels being sufficiently high to sustain urban spring flows. The Cusum analysis results were consistent with the other trend analyses showing a fall in groundwater levels between 2002 and 2022 (Figure 28).

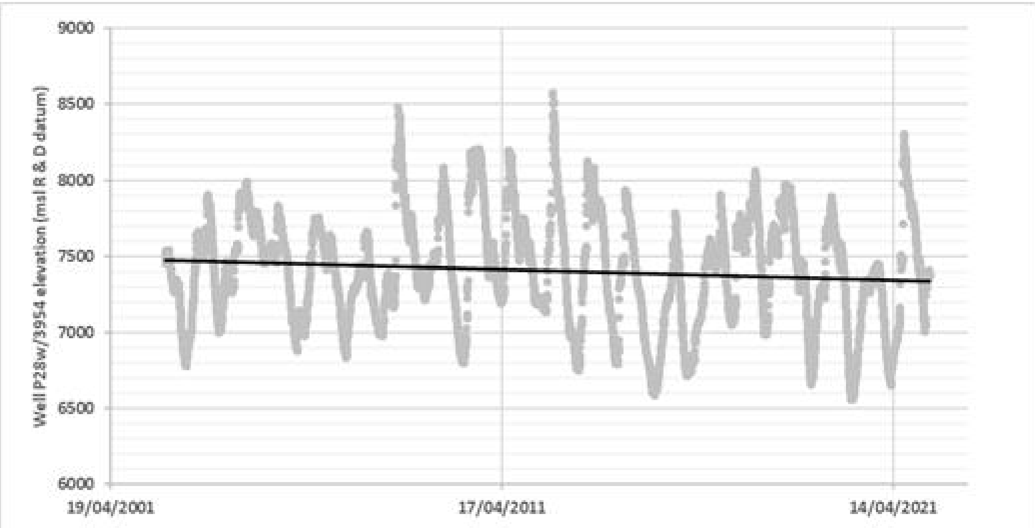

Figure 25: Groundwater elevation with trend line

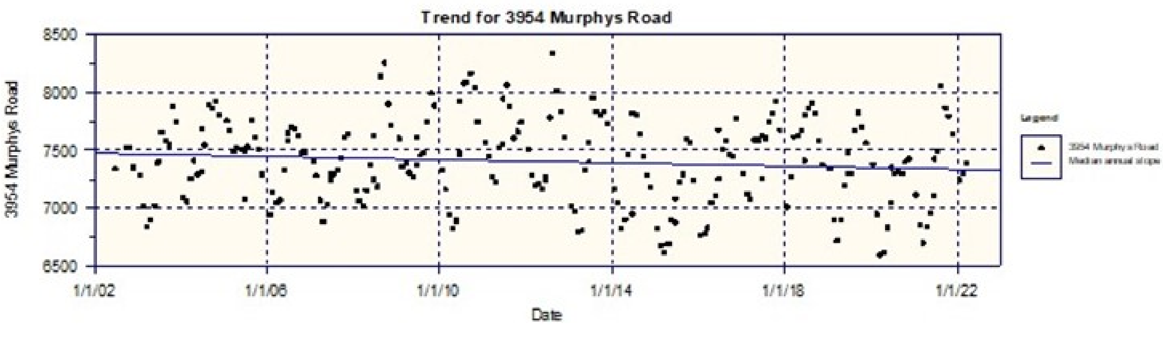

Figure 26: Seasonal Kendall test

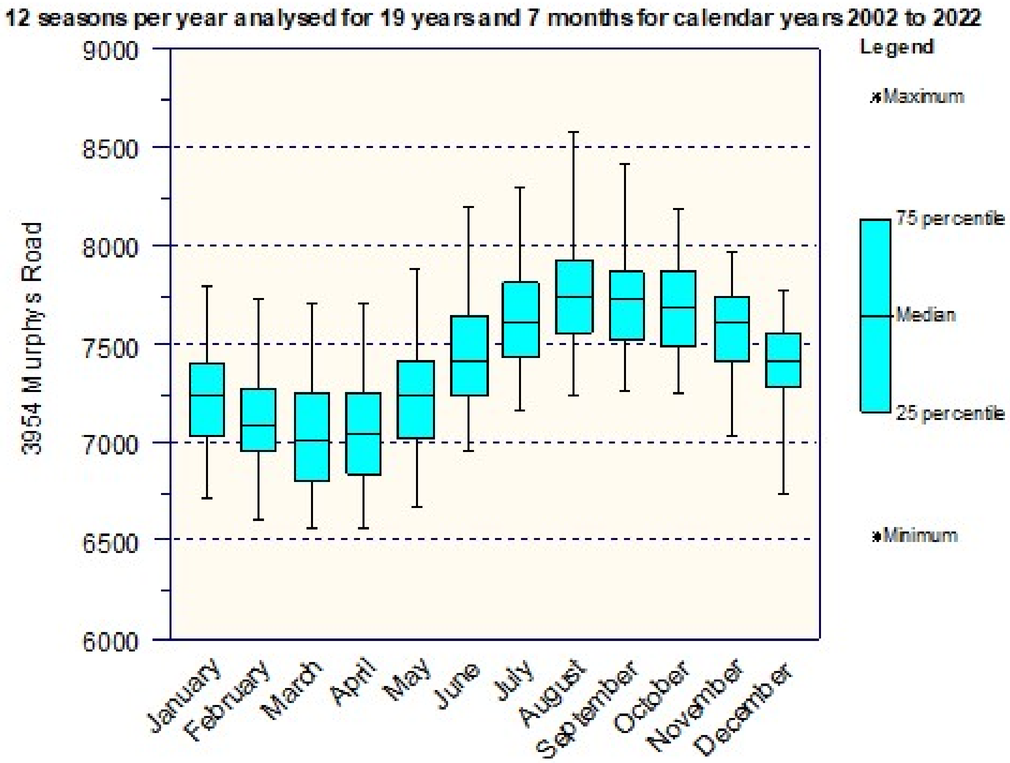

Figure 27: Seasonal Kendall test

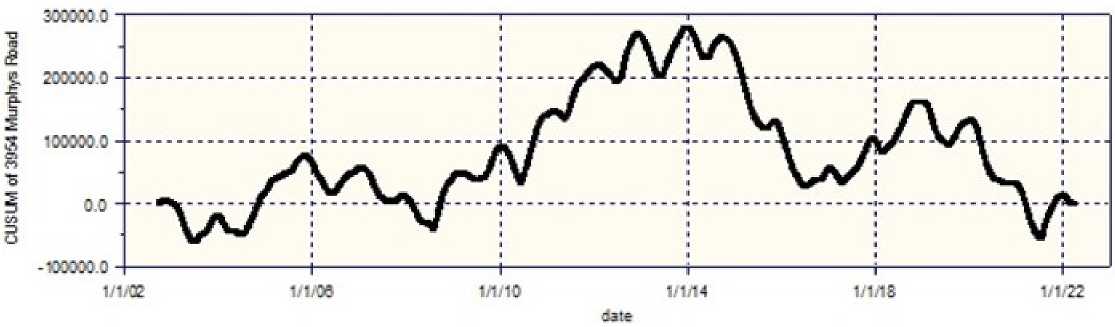

Figure 28: Cusum

4.7. Wairau Aquifer Northern Springs Sector

The MDC Selmes Road monitoring well P28w/4577 was established in 2010 to observe semi-confined aquifer response to Wairau River floods, and provide more sensitive measurements of groundwater level change versus nearby Spring Creek flows.

The scatter plot (Figure 29) shows a moderate downwards trend in groundwater levels of 110 mm over 11 years or ~ 10 mm per year on average. The decline is consistent with the pattern exhibited by all MDC SoE inland Wairau Aquifer monitoring sites. The Seasonal Kendall test showed a declining trend was virtually certain at the 95% confidence level with a P statistic of 0.00 (Figure 30). The median annual decrease was 7mm/year. Aquifer state is described as normal based on groundwater levels being sufficiently high to sustain spring flows. Groundwater levels peak in July and are lowest in March (Figure 31). This site receives the majority of its aquifer recharge from the Wairau River rather than local rainfall. The well taps relatively low porosity gravels meaning it responds instantaneously to pressure generated by Wairau River floods. The same compressible aquifer characteristics mean ocean tides are propagated 8.5 km inland from the Cloudy Bay coast, although the range is small at around 5 mm.

The Cusum test results were consistent with the other trend analyses showing a fall in groundwater levels between 2010 and 2022 (Figure 32).

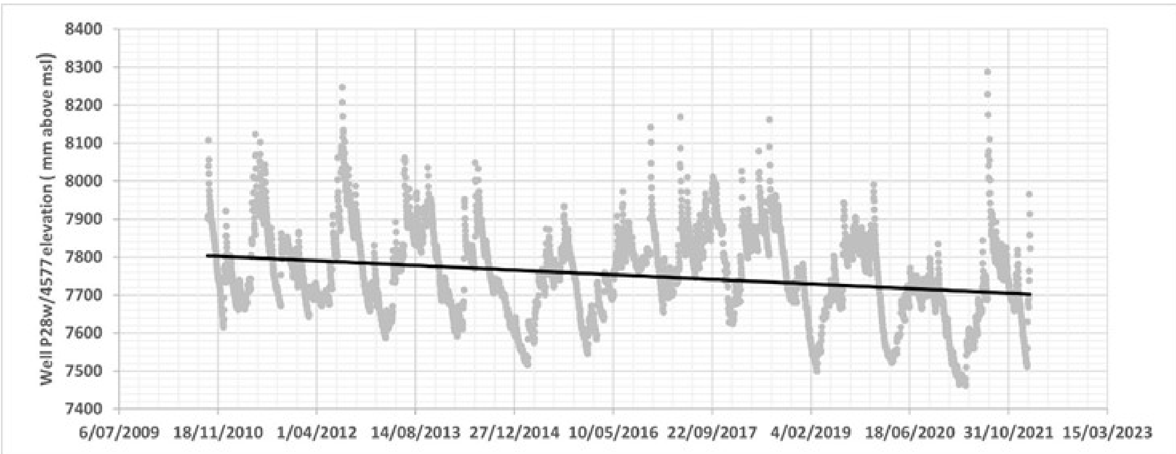

Figure 29: Groundwater elevation with trend line

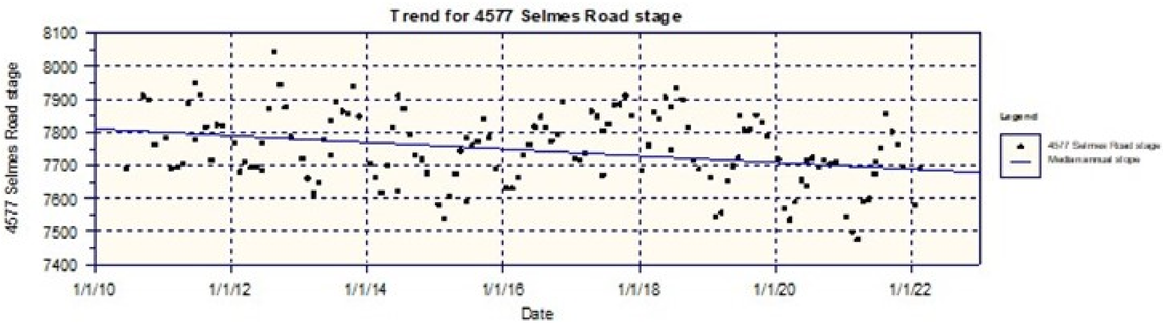

Figure 30: Seasonal Kendall test

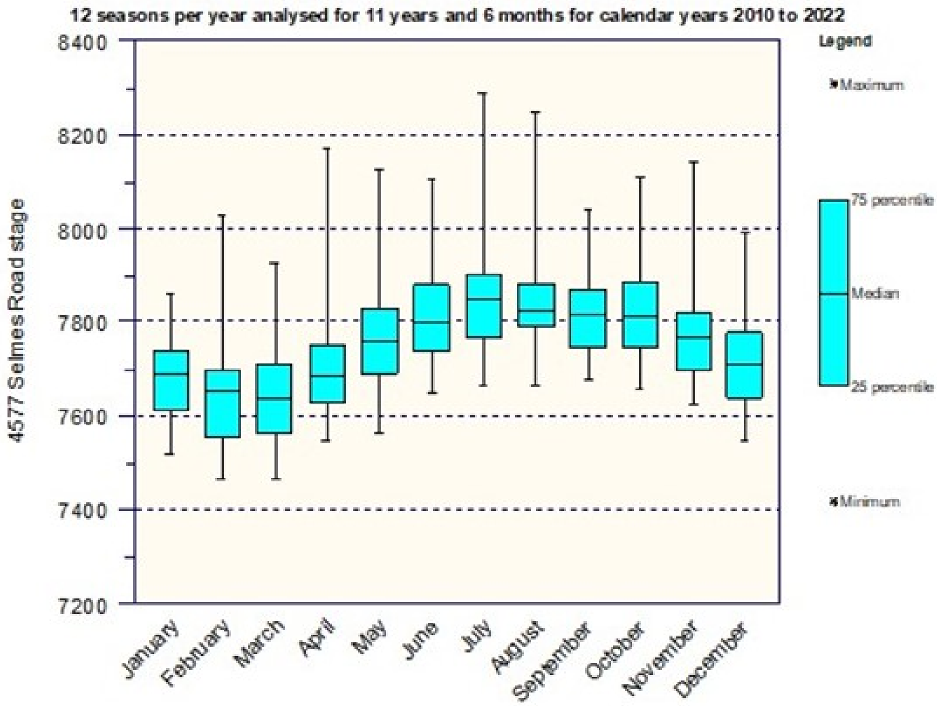

Figure 31: Seasonality

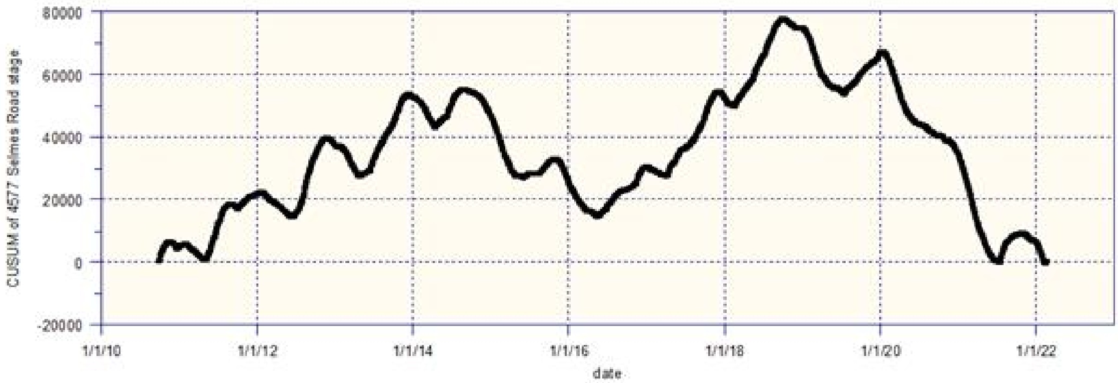

Figure 32: Cusum

4.8. Wairau Aquifer Central Springs Sector

MDC monitoring well P28w/4404 is located at the western end of Mills and Ford Road East near the Ōpaoa River channel. It is 14 metres deep and has been recording groundwater elevation continuously since 2009. The site represents shallow groundwater beneath the central Wairau Plain where sub-surface flow is highest. It also observes the effects of changes in Ruakanakana (Gibson) Creek flow on groundwater and spring emergence rates.

The scatter plot (Figure 33) shows a slight downwards trend in groundwater levels of around 100 mm over 13 years or 8mm per year on average.

The decline is consistent with the pattern exhibited by other Wairau Aquifer SoE sites. The Seasonal Kendall test analysis showed a decreasing trend was very likely with a P statistic value of 0.02 and a median annual decline of 7 mm/year (Figure 34). Groundwater levels peak in July/August and are lowest in March (Figure 35). Aquifer state is described as normal based on groundwater levels being sufficiently high to sustain spring flows. There is a close match between groundwater elevation at well 4404 and Ōpaoa River flow at Blicks Lane as expected, although not all of the well variation is explained by changing stream flow. This may reflect the semi-confined nature of the Wairau Aquifer in the area and the silting up of the base of the Wairau River channel which reduces rates of exchange in both directions.

The Cusum analysis indicated a net fall in groundwater levels between 2009 and 2022 (Figure 36).

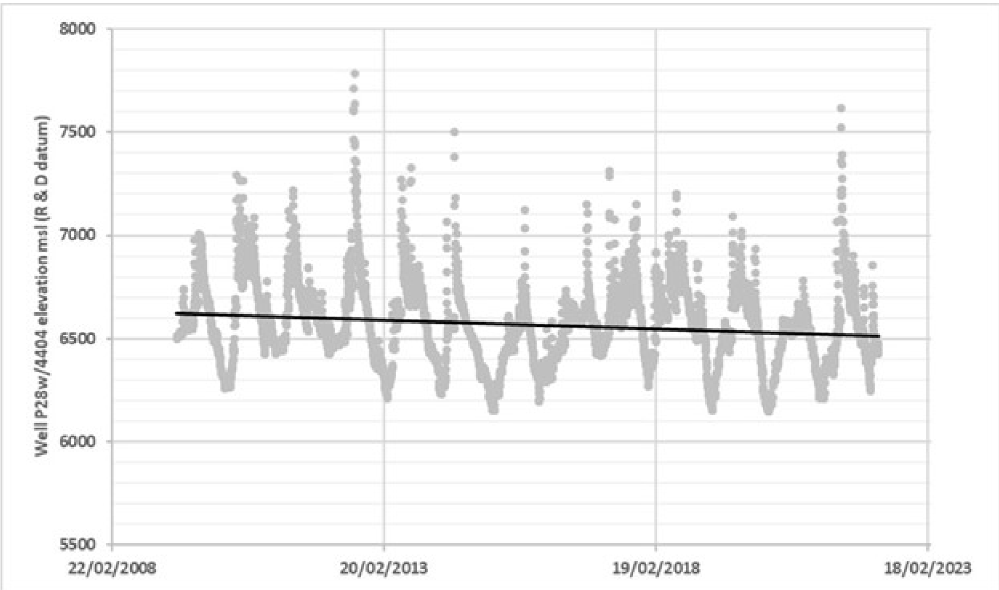

Figure 33: Groundwater elevation with trend line

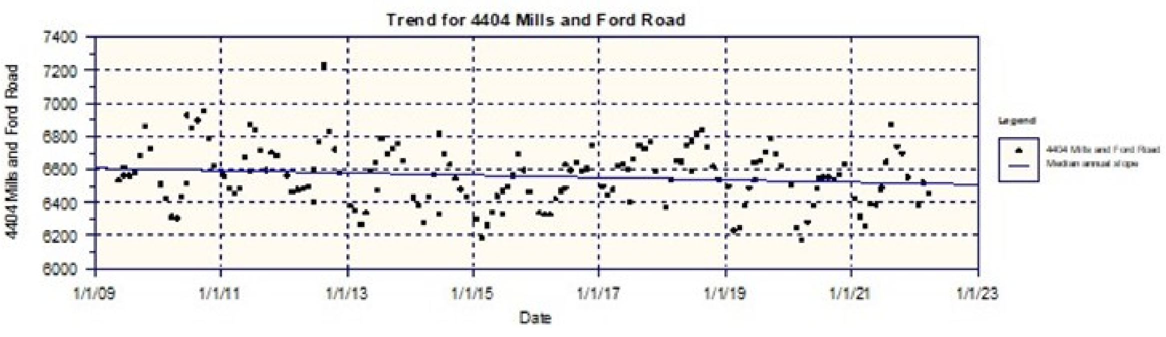

Figure 34: Seasonal Kendall test

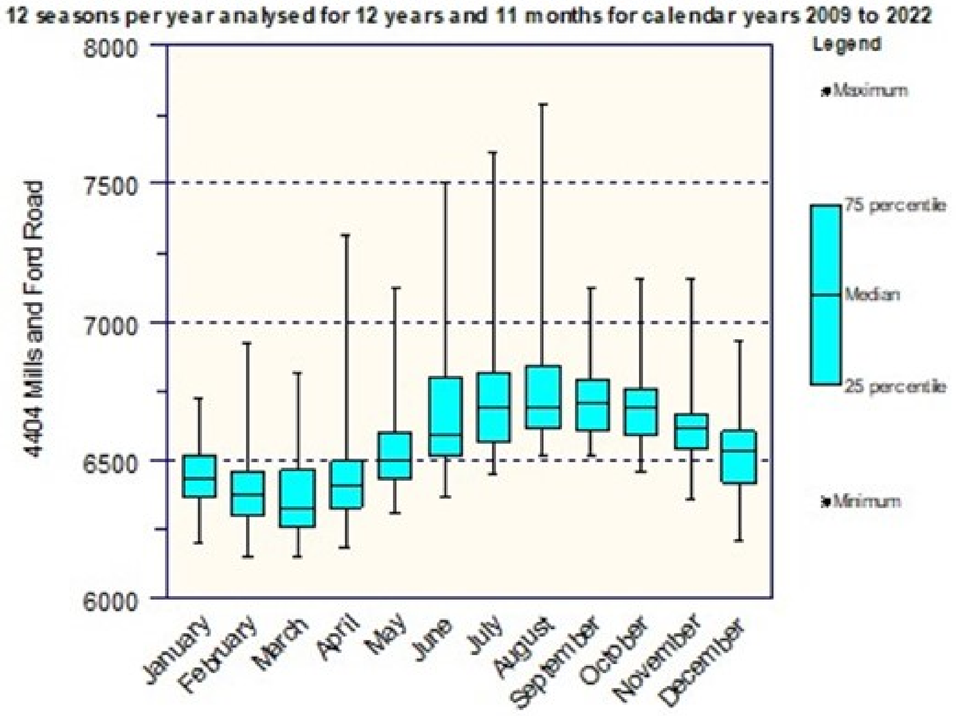

Figure 35: Seasonality

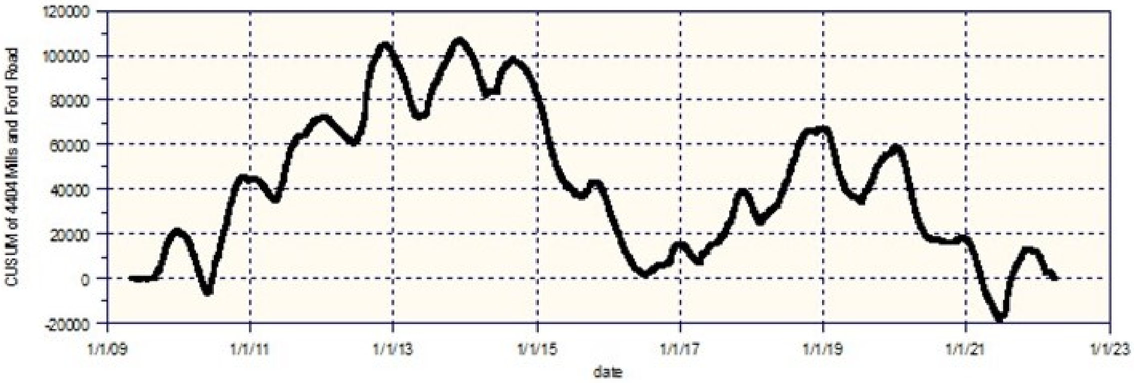

Figure 36: Cusum

4.9. Wairau Aquifer Coastal Sector

The Coastal Sector of the Wairau Aquifer is designated as the area where pumping from wells can directly affect groundwater pressures at the coast, potentially causing seawater intrusion. MDC monitor the risk of seawater intrusion at three permanent wells providing real time observations of groundwater electrical conductivity and level: Lagoon well 10346 (Riverlands Aquifer), Bar well P28w/1733 near the Wairau River mouth and Hinepango Deep well P28w/3667 north of the Diversion channel. Bar well 1733 is 50 m. deep and began recording in 1988. Groundwater level fell by 100 mm between 1988 and 2022 or an average of ~3 mm/year (Figure 37).

The Seasonal Kendall test also showed a decreasing trend of 3mm/year was virtually certain at the 95% confidence level with a P value of 0.00 (Figure 38). In absolute terms this is a small drop over this period though. The annual variation in Wairau Aquifer groundwater level is much smaller at the coast than inland near Renwick where the Wairau River recharges groundwater, generating a larger range. Figure 39 shows confined Wairau Aquifer levels at the coastal Bar well beneath the centre of the Wairau Plain peak in winter/early spring and reach a minimum in February. Drivers of groundwater level variation include pumping from wells which due to low aquifer storativity affects groundwater levels over large areas, loading of the Wairau River in flood and changes in barometric pressure. MDC are still verifying the cumulative abstraction based on water meters to correlate pumping versus aquifer drawdown. In terms of state, aquifer levels remain well above the 1.25 msl safety threshold.

A decreasing groundwater level trend is supported by the Cusum analysis (Figure 40).

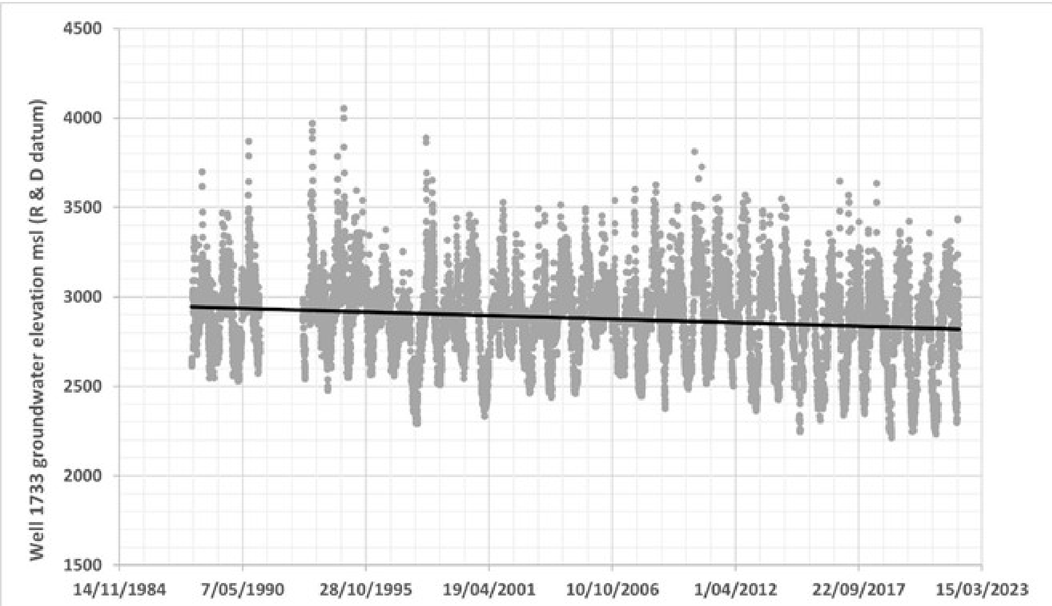

Figure 37: XL Groundwater elevation with trend line

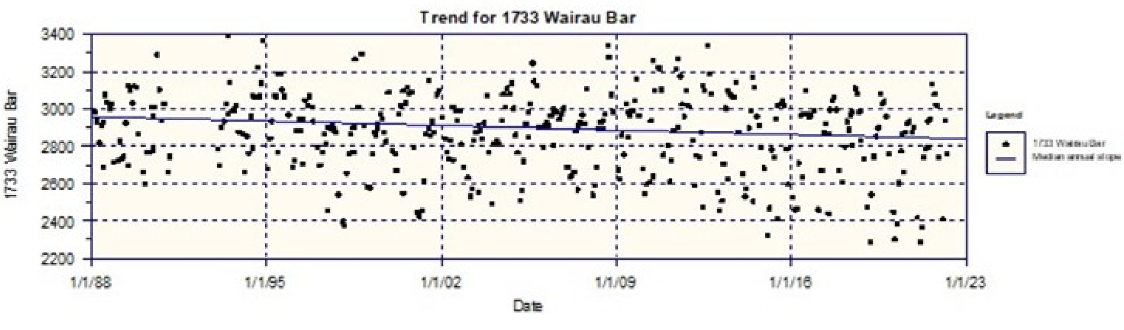

Figure 38: Seasonal Kendall test

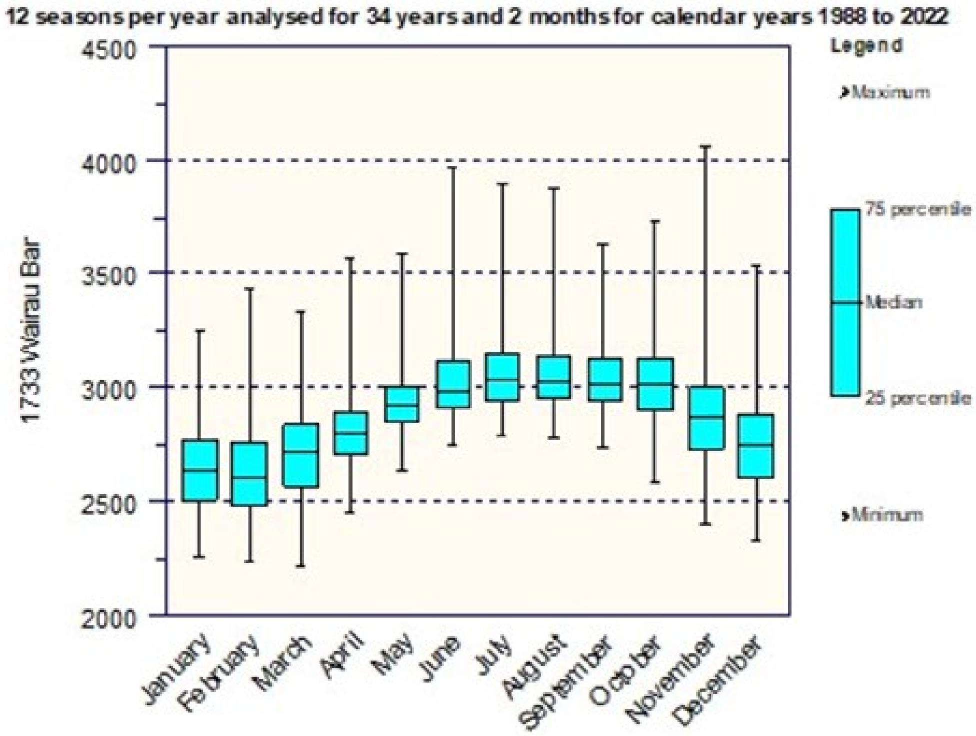

Figure 39: Seasonality

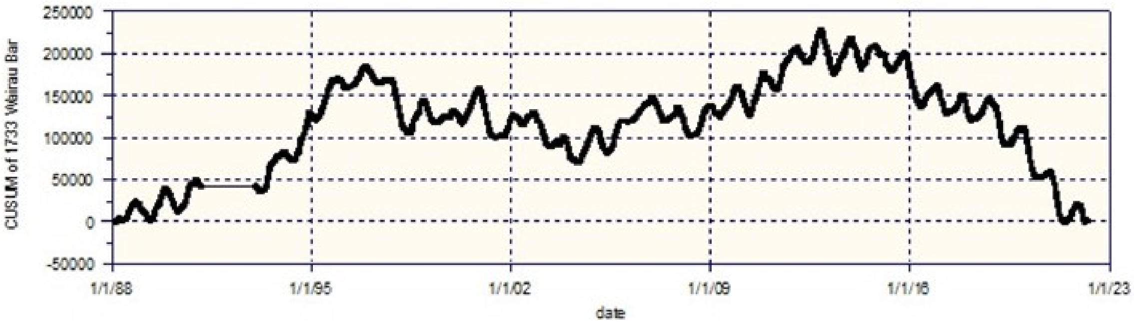

Figure 40: Cusum

4.10. Wairau Aquifer Coastal Sector

The Hinepango Deep well P28w/3667 is located north of the Diversion and around 150 metres inland from the sea. It is 40 metres deep, taps the confined Wairau Aquifer and began continuous recording in late 2000 in its role as a seawater intrusion early warning site. It represents the northern, lower yielding area of the Wairau Aquifer. There is no apparent trend in groundwater level based on the automatically fitted trendline in Figure 41.

The Seasonal Kendall test found that a trend was unlikely at the 95% confidence level with a P value of 0.77 (Figure 42). There is a larger range in groundwater levels in more recent times, representing larger summer drawdowns due presumably to higher rates of abstraction.

As expected, there is a strong correlation between groundwater levels at wells 1733 and 3667 with 90% of the level variation at well 3667 level explained by changes in well 1733 level (Figure 43). This shows natural Wairau Aquifer processes like recharge and drainage are less disturbed by irrigation pumping in this area than elsewhere.

Figure 44 shows groundwater levels peak between June and October with the lowest level in February. Levels plateau at near 3 metres above msl during the wetter months when there is little local abstraction. In terms of aquifer state, groundwater levels remain well above the restriction threshold of 1.25 metres elevation (Figure 41). In terms of drivers of groundwater level, there has been an obvious increase in summer lows due to increased abstraction.

The Cusum analysis shows no indication of a trend consistent with the findings of the other tests as Figure 45 shows.

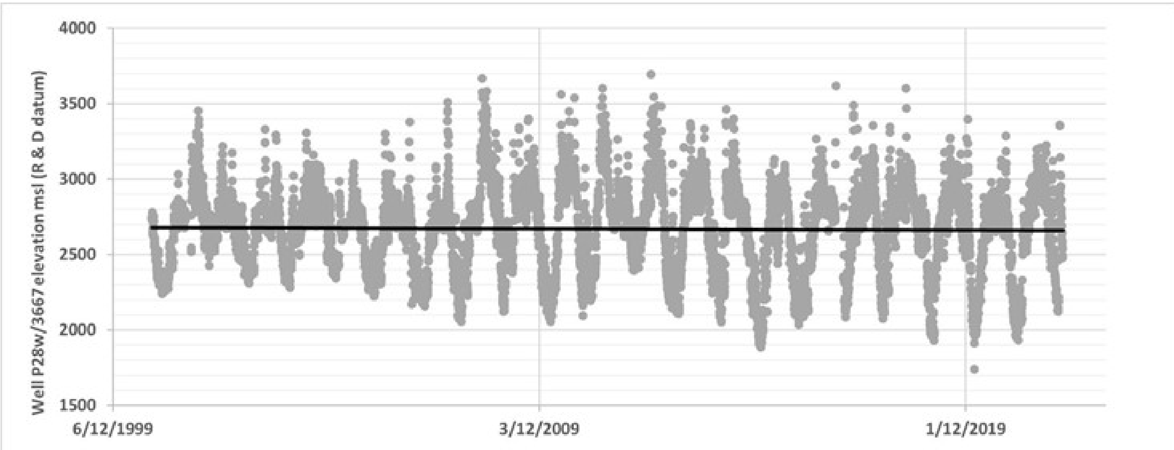

Figure 41: Groundwater elevation with trend line

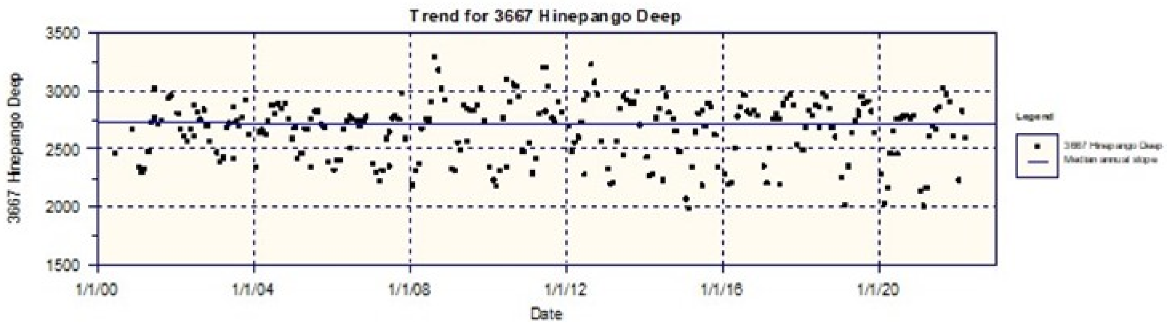

Figure 42: Seasonal Kendall test

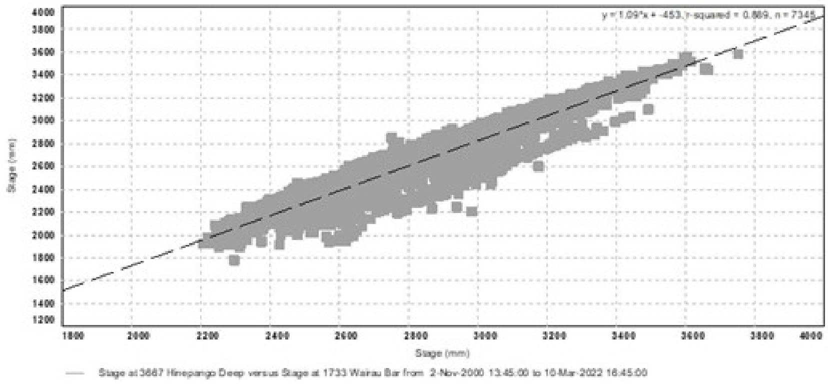

Figure 43: Correlation of groundwater elevation at well 1733 versus well 3667

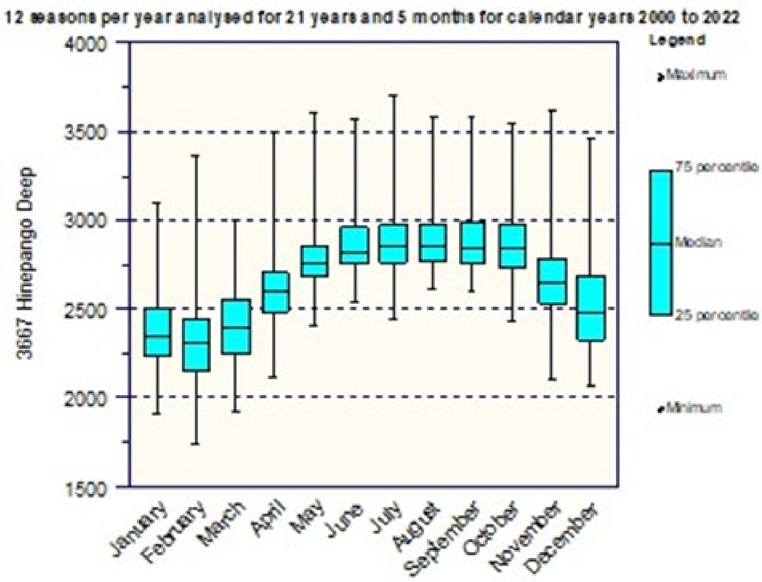

Figure 44: Seasonality

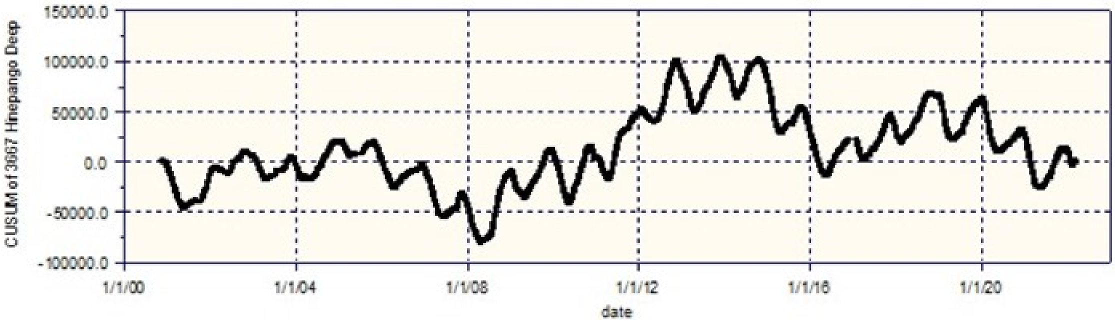

Figure 45: Cusum

4.11. Rarangi Shallow Aquifer

The Rarangi Shallow Aquifer (RSA) underlies the coastal settlement north of the Diversion and supplies most of the drinking water as well as maintaining the local Fen wetlands. MDC monitor coastal RSA groundwater level and electrical conductivity at two coastal wells: Hinepango Shallow well 3668 and Bluegums well 3711, both of which are 150 m. from coast and 10 metres. deep.

There is an overall upwards trend in groundwater level between 2001 and 2022 based on the XL fitted line (Figure 46). Interestingly there has been a downwards pattern since 2010. The Seasonal Kendall test indicated a virtually certain increasing trend at the 95% confidence level with an annual median rise of 5mm/year on average with a P value of 0.00 (Figure 47). In terms of drivers of groundwater level, there was no significant change in rainfall from 2010 onwards when records of rainfall at the Golf Club driving range started. This points to other influences, although the rise in groundwater level is too large to be explained by sea-level rise alone. In terms of aquifer state, groundwater levels remain well above the restriction threshold of 200 millimetres elevation above msl (Figure 46).

Groundwater levels peak in August and reach a minimum in February/March (Figure 48). The RSA has a pronounced seasonal range, dominated by natural recharge/drainage processes rather than pumping. The Cusum analysis also indicated an increasing trend in groundwater level since 2001 (Figure 49).

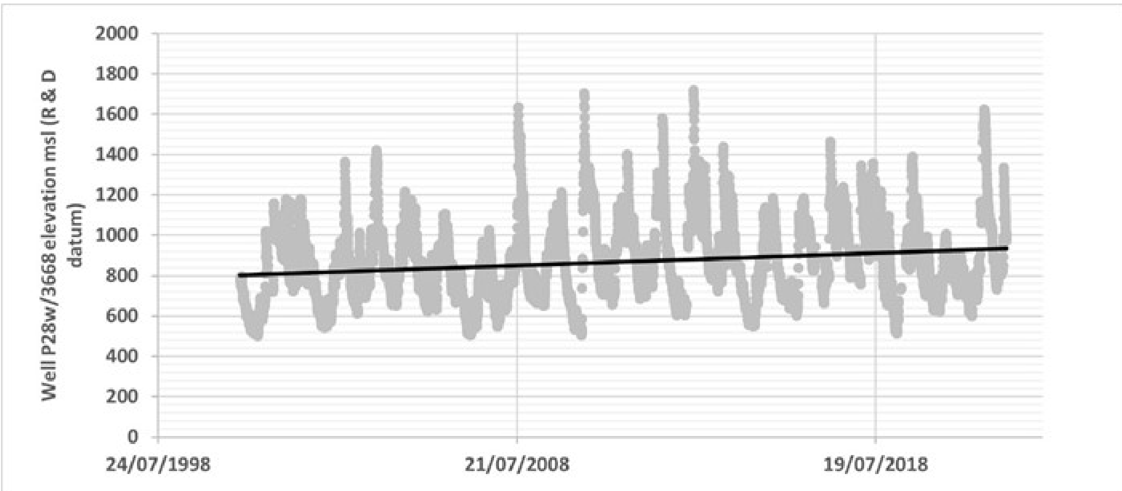

Figure 46: Groundwater elevation with trend line

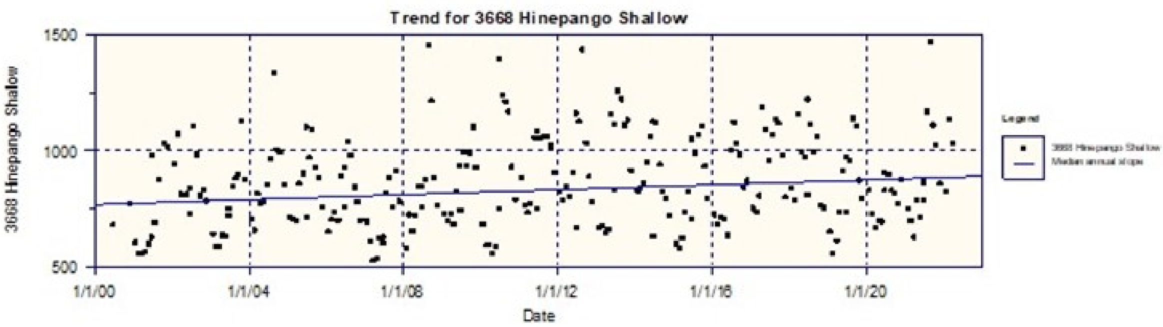

Figure 47: Seasonal Kendall test

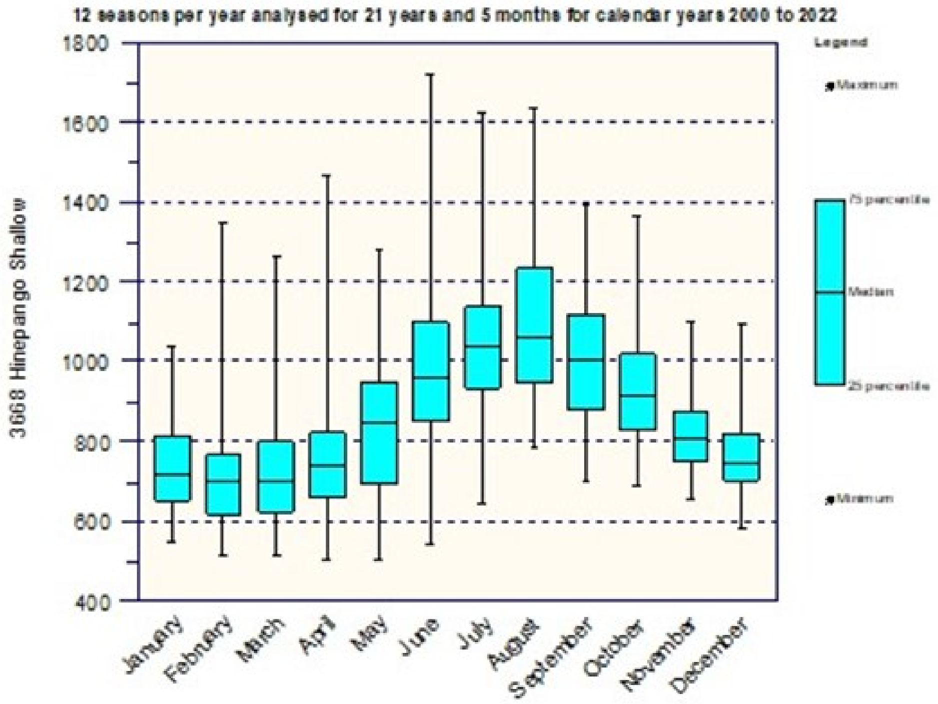

Figure 48: Seasonality

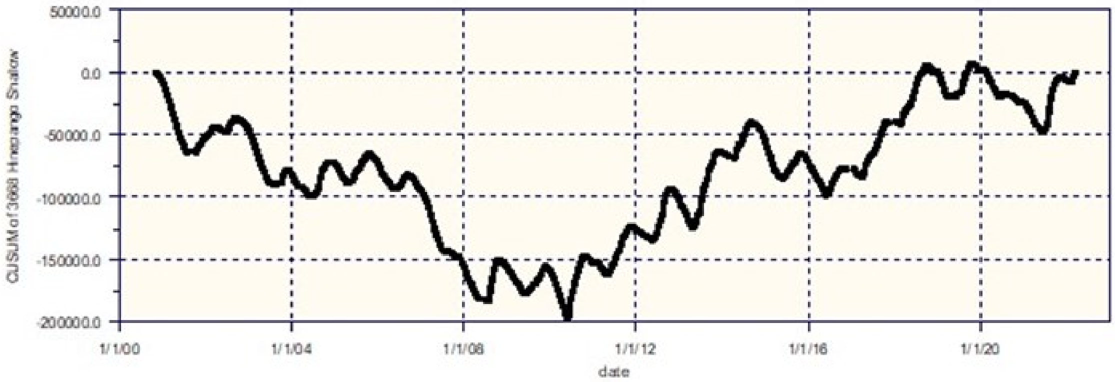

Figure 49: Cusum

4.12. Rarangi Shallow Aquifer

Like its neighbouring monitoring well 3668, Bluegums well 3711 is shallow. The prime role of these coastal wells is to provide early warning of seawater intrusion. The electrical conductance of RSA groundwater is also measured automatically at this well but was not analysed as part of this quantity review. Figure 50 shows there is a clear increasing trend of around 200 mm or an average of 9 mm/year.

The Seasonal Kendall test showed an increasing trend was virtually certain at the 95% confidence level with a P value of 0.00 and a median annual increase of 8.5 mm/year (Figure 51). The Rarangi Shallow Aquifer has an unconfined structure and effectively refills in winter and drains in summer to the sea. A contributing factor to the rising trend in groundwater level may be drainage rates have decreased over time through reduced losses via the wetland complex or the outlet to the Diversion floodway channel.

Figure 52 shows groundwater levels peak in August and reached a minimum in February/March as was the case for well 3668. The largest ranges in groundwater level are associated with the wetter months meaning change is due to drainage and recharge processes, not pumping induced. In terms of aquifer state, groundwater levels remain well above the restriction threshold of 300 millimetres above mean sea level (Figure 50).

The Cusum analysis showed an increasing trend in groundwater level consistent with the other tests (Figure 53).

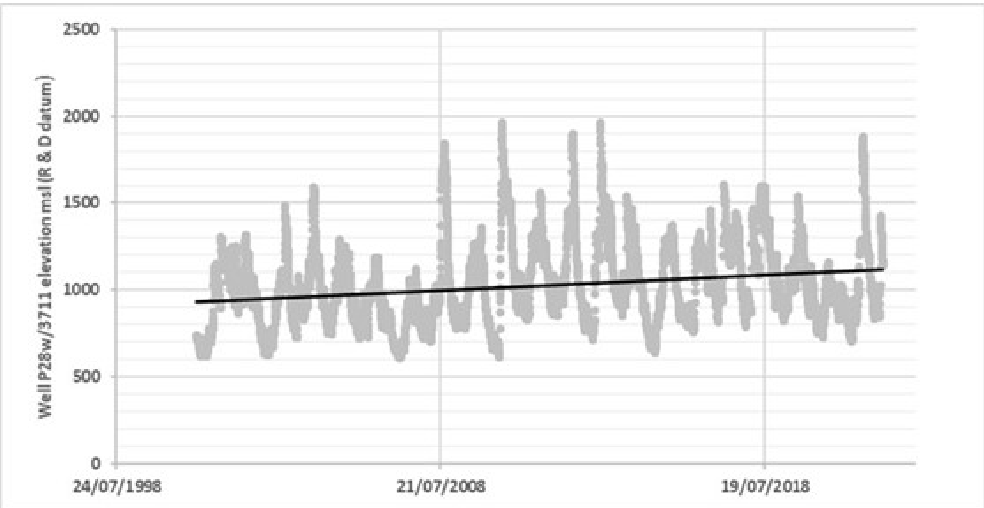

Figure 50: Groundwater elevation with trend line

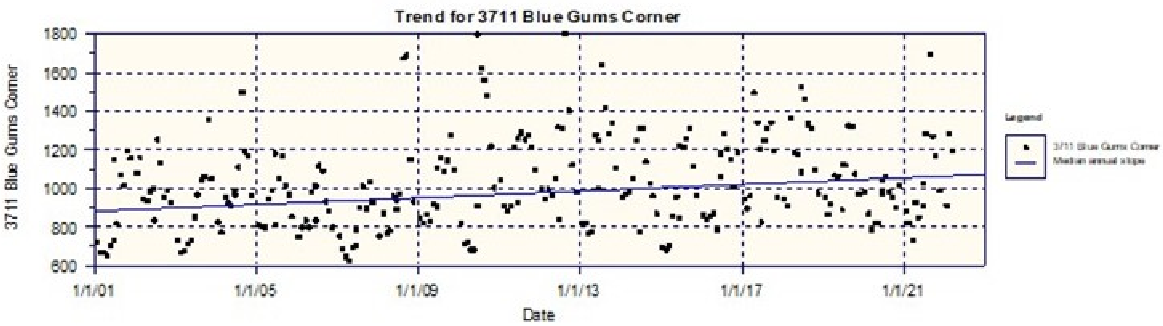

Figure 51: Seasonal Kendall test

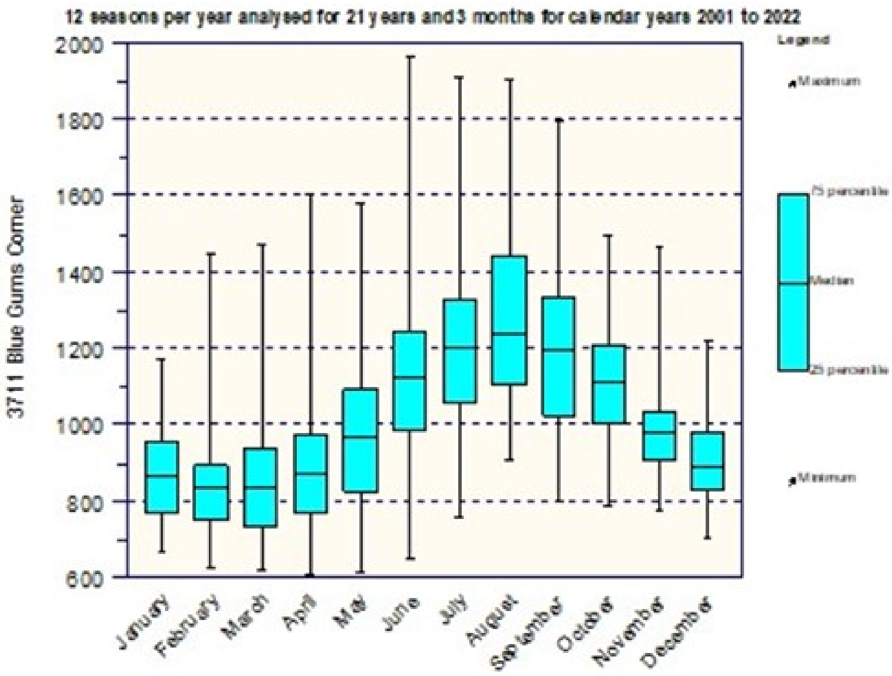

Figure 52: Seasonality

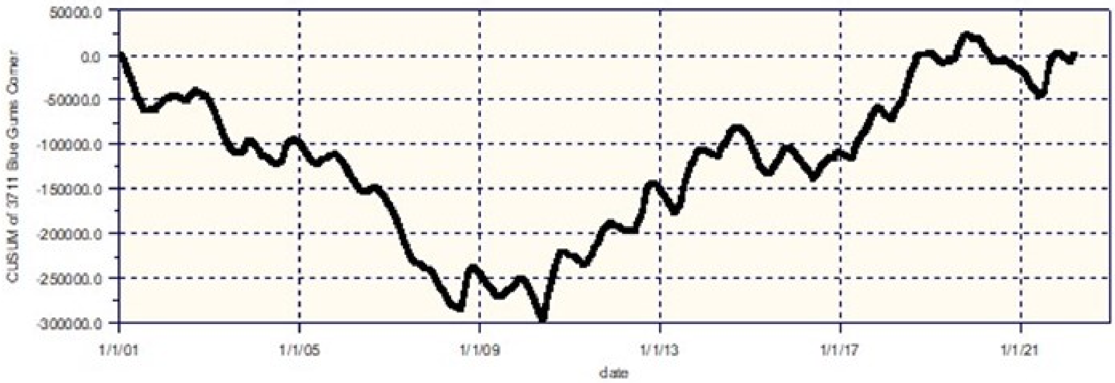

Figure 53: Cusum

4.13. Hinepango Wetland

MDC precise level surveys have shown the RSA and wetland water levels represent the same inter-connected water body. A key policy in the Marlborough Environment Plan for managing the Rarangi Shallow Aquifer is maintaining the health of the Fen wetland complex. MDC monitor the state of the Hinepango Wetland at shallow well P28w/4331 near where it crosses Rarangi Road. The water level in the well represents wetland state but is easier to measure than flow as channel weeds distort the true water volume.

Figure 54 shows an increasing trend in wetland/RSA level of around 350mm over 18 years or an average of 19mm/year. This is consistent with the increasing trends seen at the other RSA monitoring sites indicating a dominant hydrological or climatic influence affecting the entire dune aquifer system. The Seasonal Kendall test showed an increasing trend with an annual median rise of 16mm/year was virtually certain at the 95% confidence level with a P value of 0.00 (Figure 55). Wetland levels reach their annual maximum in August and minimum level in March (Figure 56). Because the channels take flood runoff during storms, levels fluctuate more than at the RSA wells distant from the wetlands including the coast. In terms of state, wetland levels have recently been well above the MEP 1.2 mean sea-level elevation threshold (Figure 54).

The Cusum analysis showed an increasing trend was present in line with the other tests (Figure 57).

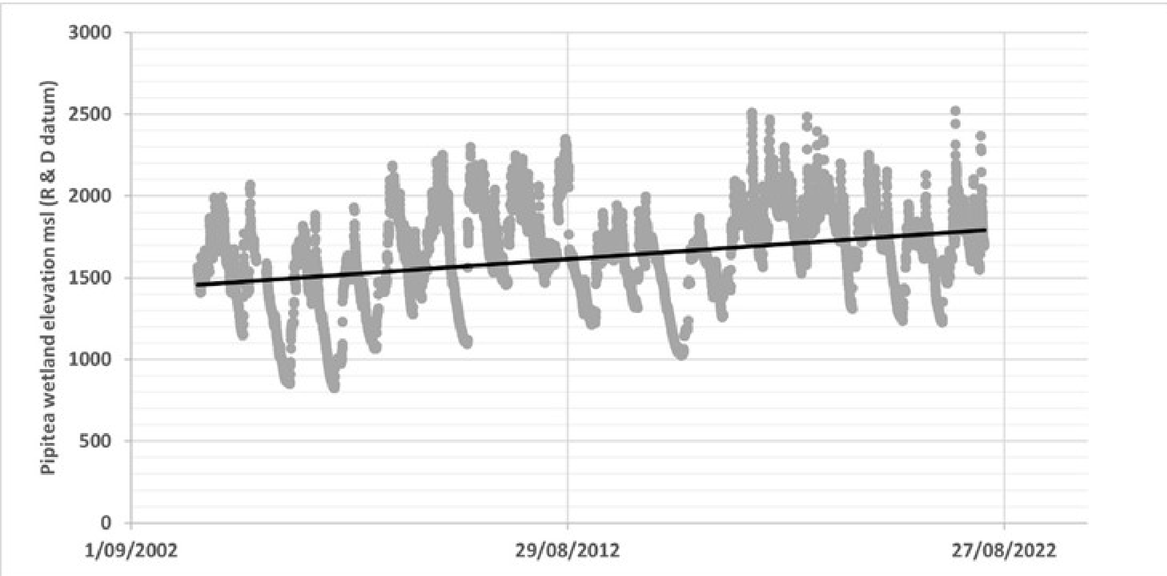

Figure 54: Groundwater elevation with trend line

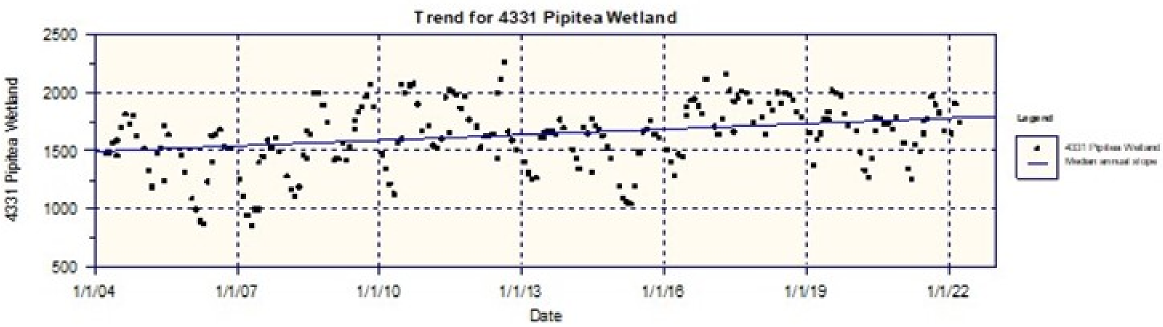

Figure 55: Seasonal Kendall test

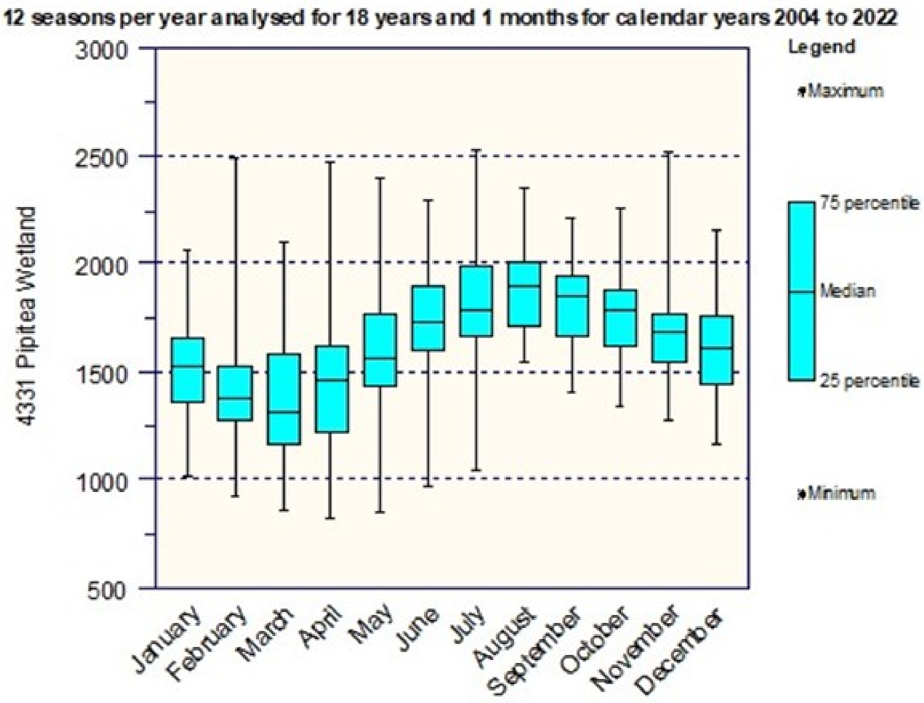

Figure 56: Seasonality

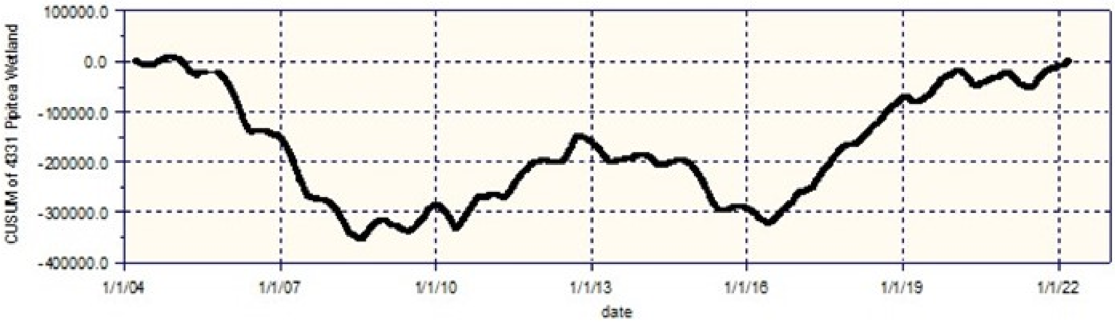

Figure 57: Cusum

4.14. Rarangi Shallow Aquifer Well

MDC permanently monitor well 10195 established by the Rarangi Golf Club in 2010 near Rarangi Beach Road to monitor consent conditions relating to seawater intrusion and interference with neighbouring domestic wells sourcing RSA groundwater. The site has 11 years of records which is significant for reporting purposes and a good check on the other RSA wells, but too short for identifying trends.

Figure 58 shows an apparent decreasing trend in RSA level of around 50mm since 2010 consistent with observations for this time period at other RSA monitoring sites, despite the long-term increasing trend. This highlights the presence of cycles in longer term trends. The Seasonal Kendall test showed no significant trend in groundwater level based on a P value of 0.21 which is greater than the 95% confidence limit value (0.05) (Figure 59). Groundwater levels peak in August and reach their annual minima in February/March (Figure 60). All five RSA sites analysed had peak levels in August but with an annual low in February or March. Aquifer state is described as normal based on groundwater level relative to mean sea-level (Figure 61).

Figure 61 shows the range in groundwater elevation for the 5 monitoring wells representing the different hydrological regions of the RSA. The similarity of the hydrographs demonstrates the interconnectedness of the RSA. The bottom plots are for lower elevation wells near coast. The Cusum analysis showed there was equal evidence for either an increasing or decreasing trend in groundwater level (Figure 62).

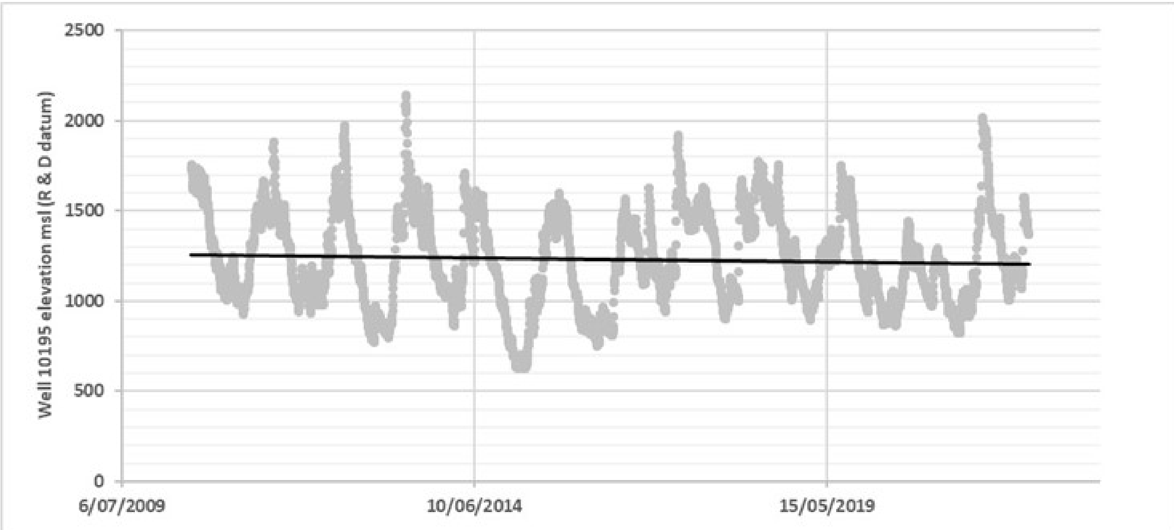

Figure 58: Groundwater elevation with trend line

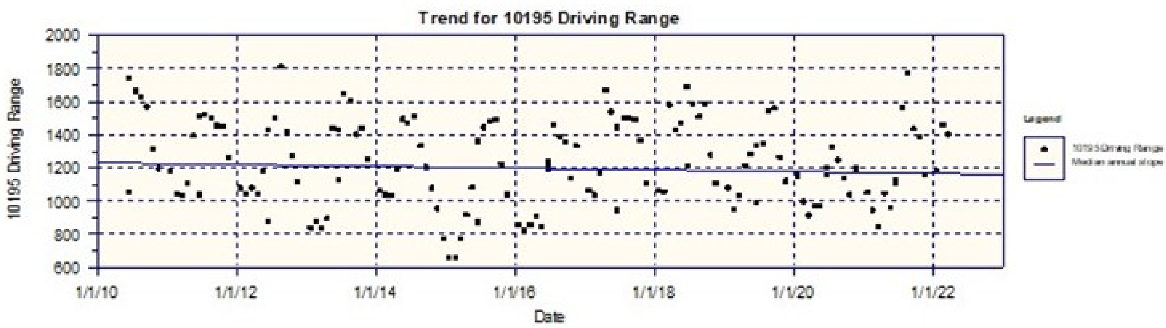

Figure 59: Seasonal Kendall test

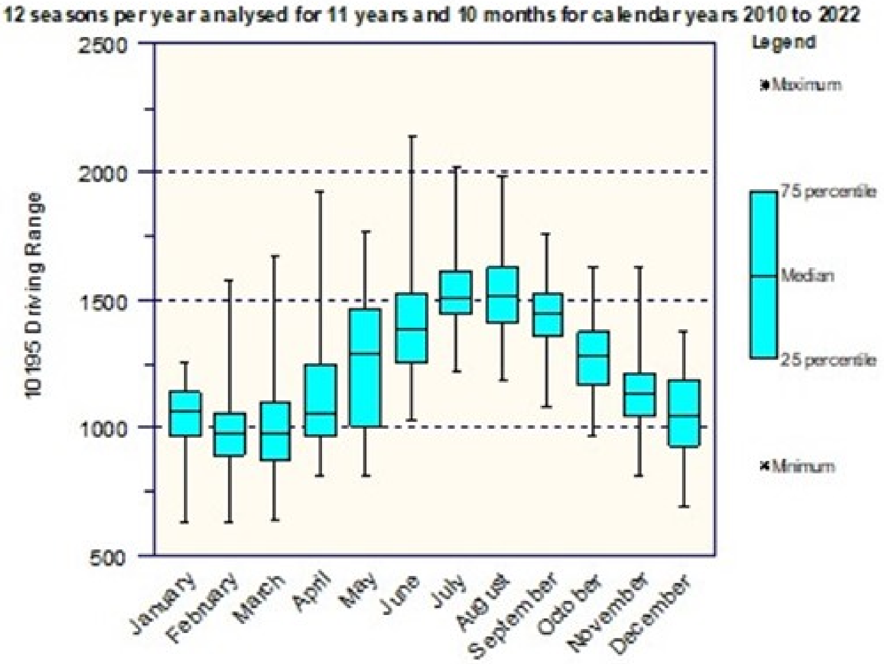

Figure 60: Seasonality

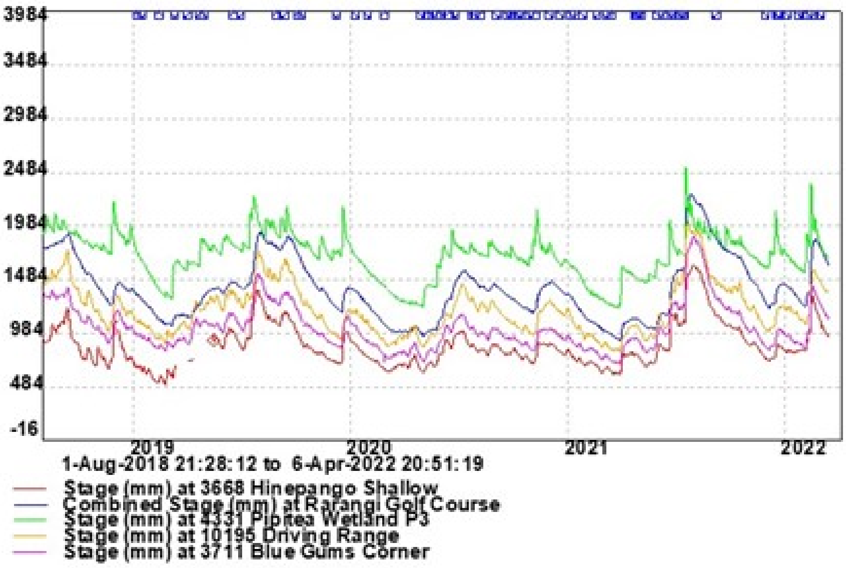

Figure 61: Combined plot of RSA groundwater level time series

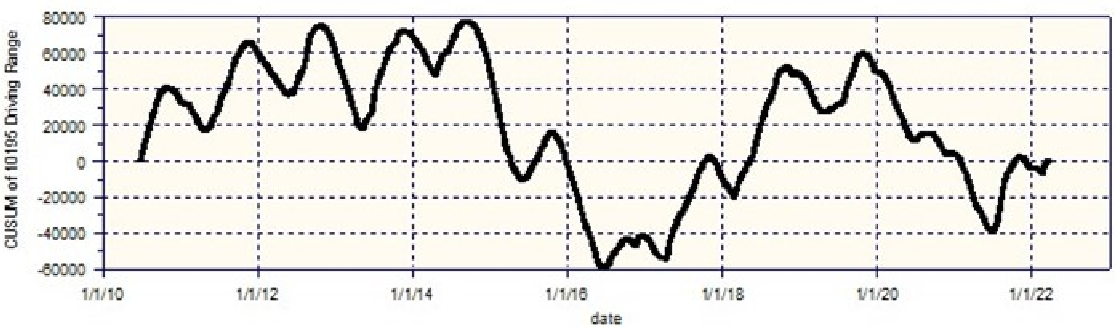

Figure 62: Cusum

4.15. Rarangi Shallow Aquifer Inland

The Rarangi Shallow Aquifer (RSA) situated at the coast north-east of Blenheim is the most intensively monitored aquifer in Marlborough with six permanent automatic instruments observing groundwater level. In addition, the electrical conductivity of groundwater is measured continuously at two coastal RSA sites. MDC also monitor RSA groundwater quality seasonally at three wells. The state and trends of four groundwater level monitoring sites will be analysed as part of this SoE report, but electrical conductivity record is not included. The longest running MDC RSA monitoring well is located at Rarangi Golf Club, 450 metres. inland from the sea where a recorder was first established in February 1989. The original large diameter well (P28w/1901) was replaced by a purpose-built steel cased well (10230) in 2010. There is a definite increasing trend in groundwater levels between 1989 and 2022 of around 200mm or an average of ~6mm/year (Figure 63). The Seasonal Kendall test also identified an average increasing trend of 7mm/year as being virtually certain with a P value of 0.00 which is significant at the 95% confidence level (Figure 64). This is consistent with the trends seen at the two MDC RSA coastal monitoring wells. There is a correlation between levels at the coastal and inland wells as Figure 65 demonstrates with 83% of the level variation in coastal well 3668 being explained by level changes at the inland Golf Club site. This shows the interconnectedness of the RSA. Well levels at this inland site peak in August and reach their minimum in March (Figure 66). The largest monthly variation occurs in June presumably due to rainfall-runoff recharge. In terms of aquifer state, groundwater levels at this inland site are sufficient to maintain an offshore flow. The Cusum analysis showed an increasing trend for the entire time series for the Rarangi Golf Club site (Figure 67).

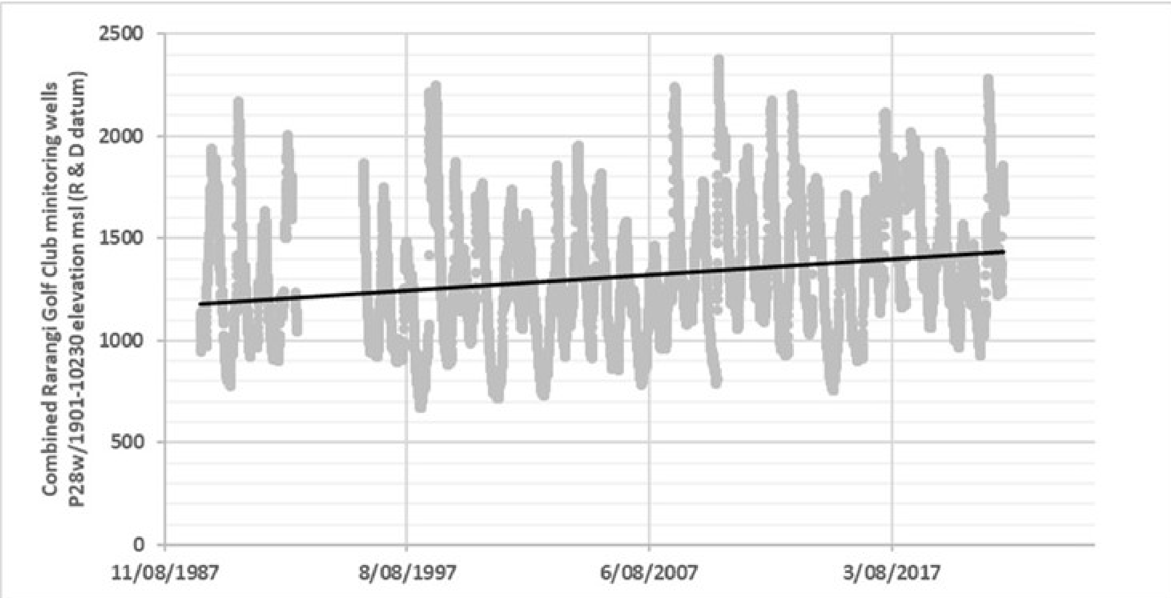

Figure 63: Groundwater elevation with trend line

Figure 64: Seasonal Kendall test

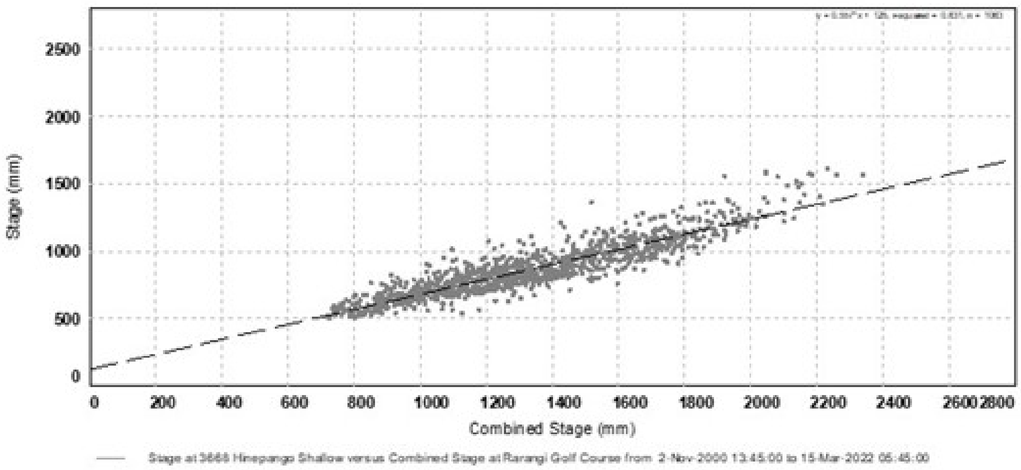

Figure 65: Correlation of groundwater level at well 3668 vs golf club

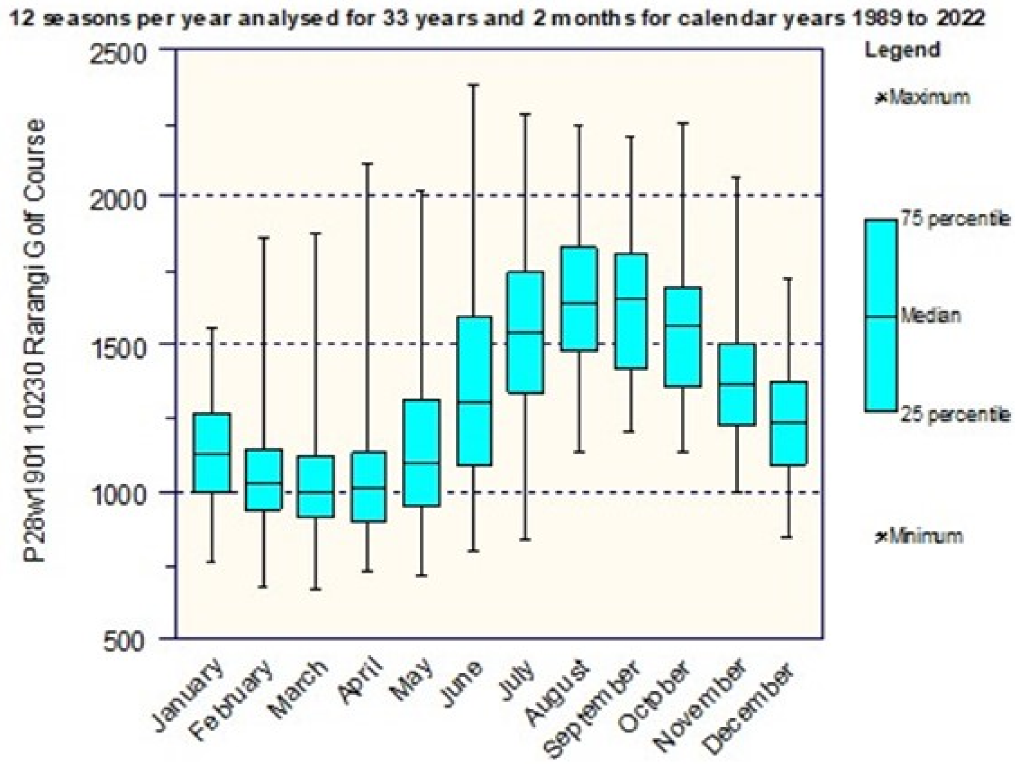

Figure 66: Seasonality

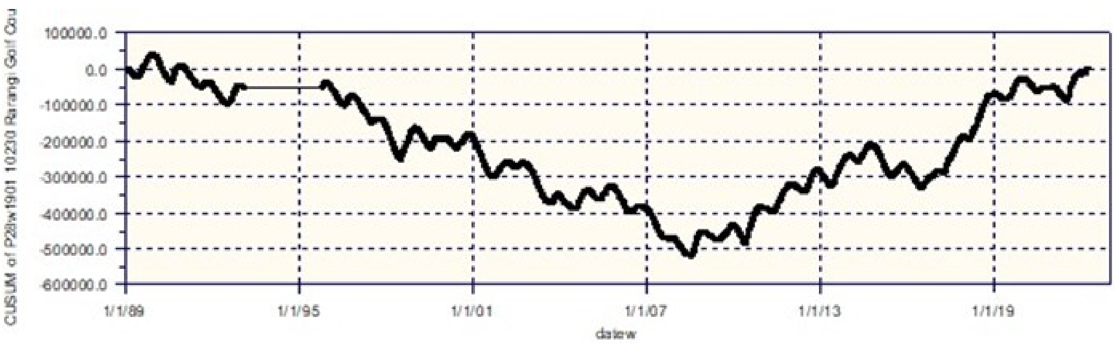

Figure 67: Cusum

4.16. Omaka River Aquifer

The Omaka River Aquifer is formed by the gravels of the Omaka River where the fan leaves its hill catchment at Tyntesfield Gorge, extending downstream as far north-east as Woodbourne. There are two aquifer layers: a Shallow (Upper) Layer and a Deep, (Lower) Layer.

Both layers are recharged by Omaka River water. Omaka River flow losses moderate Shallow Layer well levels explaining the small annual variation compared to the Deep Layer where levels vary by up to 10 metres per year as the Omaka River dries up (Figure 68). This annual range is one of the largest in New Zealand. Conversely the Shallow Layer has a very small annual range (Figure 68). Neither aquifer layer has significant storage, and both drain quickly due to steep hydraulic grades creating a high dependence on Omaka River flow to maintain well levels. Aquifer levels mimic Omaka River flow patterns but there are time lags between surface processes and groundwater level changes for the Deep Layer. MDC monitor Omaka River flow at the Gorge and groundwater level at three sites. The Shallow Layer is represented by well 3069 at Spy Valley Wines vineyard. The Deep Layer by well 10231 at Godfrey Road and well 3010 at Jacksons Road. Omaka River processes drive the aquifer. Figure 69 shows Omaka River flow at Gorge has been stable since 1993. The Seasonal Kendall test confirmed the lack of a trend in either channel flow or baseflow at the 95% confidence level with a P statistic value of 0.85 (Figure 70). While there was no overall trend between 1993 and 2022, there had been a slight increasing pattern in baseflow since 2001. The largest Omaka River flows occur in winter and spring with the river in recession for remainder of the year (Figure 71). The Cusum analysis showed no trend in flow over time (Figure 72).

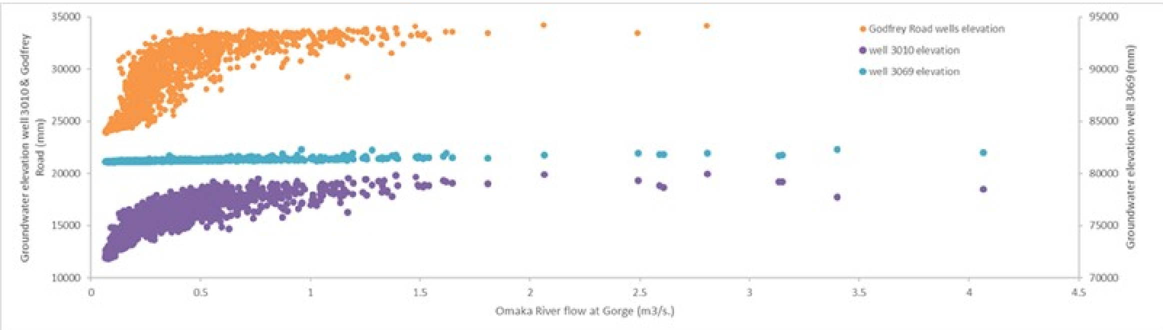

Figure 68: Omaka River flow versus groundwater level at 3 MDC monitoring wells

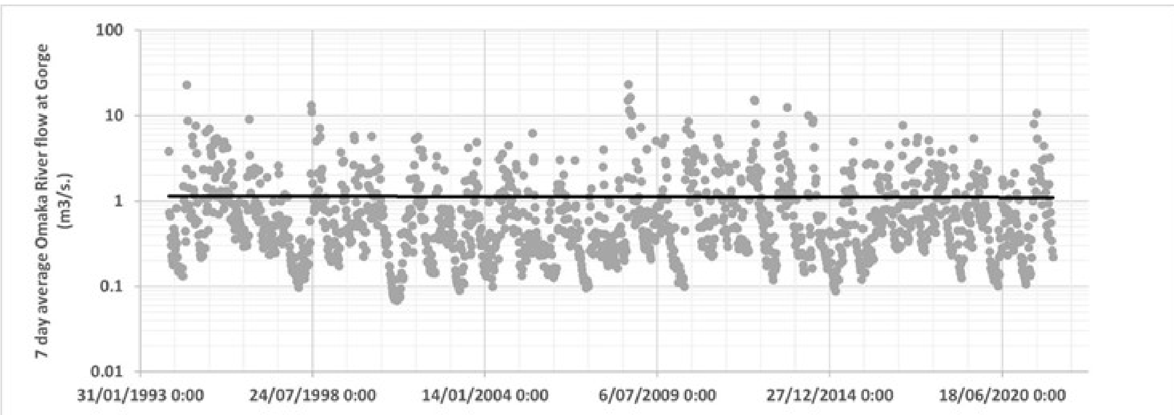

Figure 69: Omaka River flow with trend line

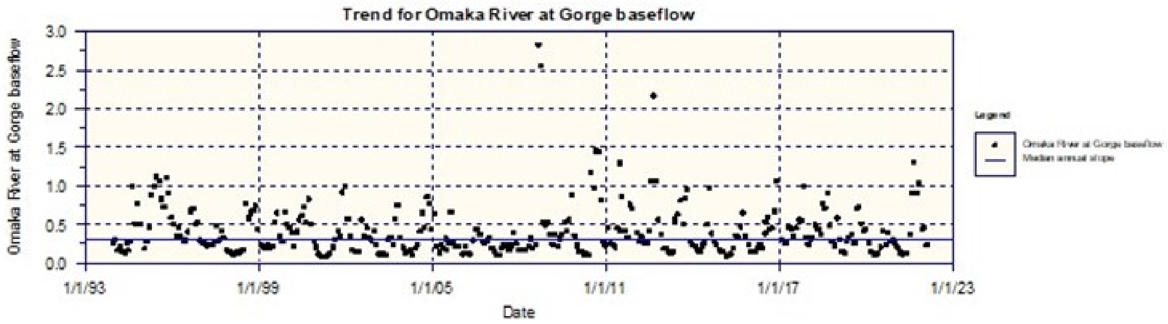

Figure 70: Seasonal Kendall test

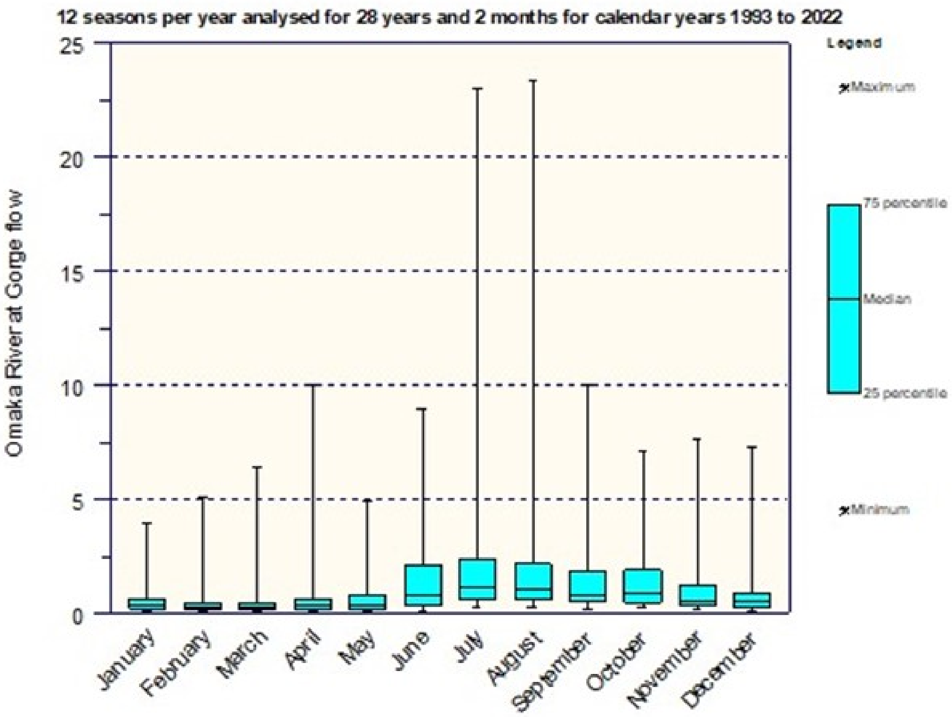

Figure 71: Seasonality

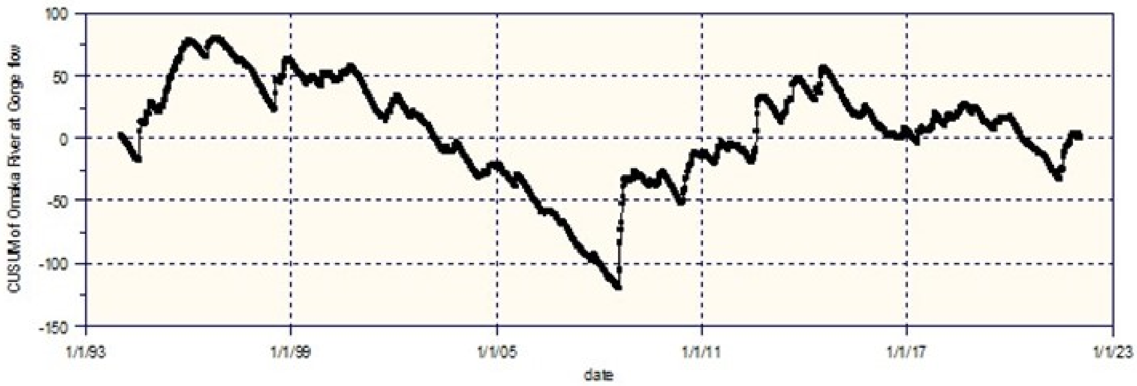

Figure 72: Cusum

4.17. Omaka River Aquifer Shallow (Upper) Layer

The Shallow (Upper) Layer of the Omaka River Aquifer is associated with the 10-metre-thick layer of sediments closest to the land surface. Shallow groundwater is in direct hydraulic connection with Omaka River channel flow which stabilises well levels, explaining the small seasonal variation compared to the Deep (Lower) Layer. MDC monitor the state and trends of Shallow Layer groundwater at MDC well 3069. Figure 73 shows an approximate 75mm decline in level over 25 years (~3 mm/year). This is a small drop in terms of the saturated aquifer thickness of around 10 metres, but its important to understand the causes. There is no corresponding fall in Omaka River baseflow so the explanation is related to demand, aquifer structure or changes in recharge. The 2016 Kaikōura earthquake did not affect this area, so it is not instrument or geology related. Unlike the MDC Jacksons Road and Godfreys Road wells, there is a definite declining trend in groundwater level for the Shallow Layer. There is a slight rising trend from 2015 onwards if records for the July 2021 storm are included showing how sensitive trends can be to extreme events.

The same magnitude downwards trend was identified by the Seasonal Kendall test (Figure 74). Adjusting for Omaka River baseflow accounted for 70% of the change in well level demonstrating the influence of river flow and increased the size of the downwards trend slightly from 3 to 3.5 mm/year (Figure 74). A decreasing trend is virtually certain based on the P value of 0.00 which is significant at the 95% confidence level. The other driver of well level change is water demand however total aquifer water meter figures are still being assembled. Figure 75 shows the small annual range in groundwater level. Groundwater levels peak in July/August coinciding with the largest monthly ranges and are lowest in March. The Cusum analysis indicated a small declining trend in well over the current period of record (Figure 76).

In terms of aquifer state there are no issues with sufficient aquifer saturated thickness despite the small fall in groundwater level to sustain wells and remain in connection with the Omaka River channel.

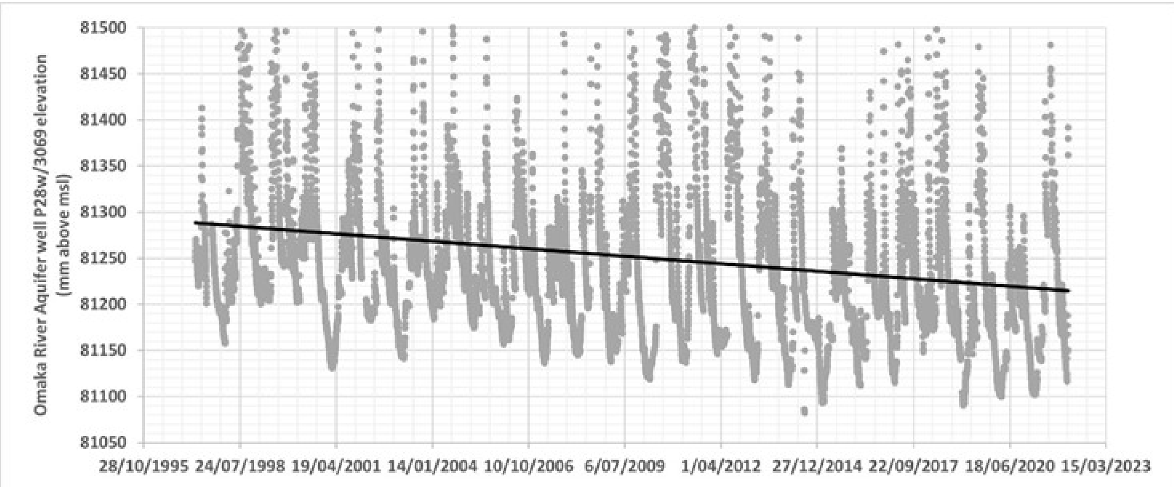

Figure 73: Groundwater elevation with trend line

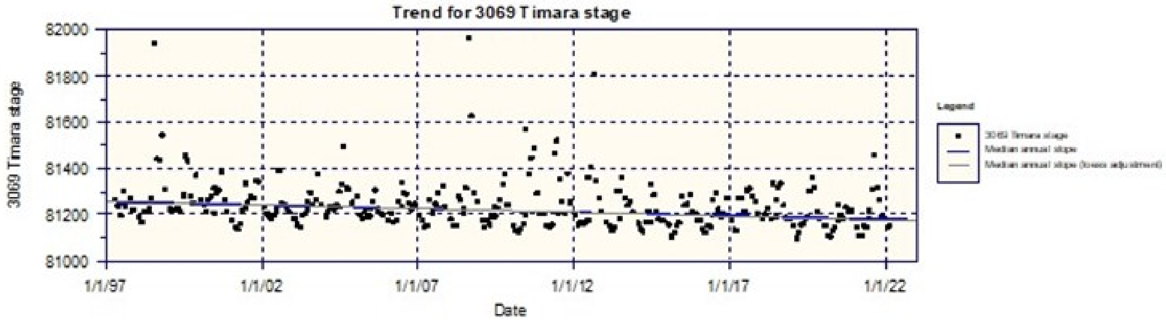

Figure 74: Seasonal Kendall test

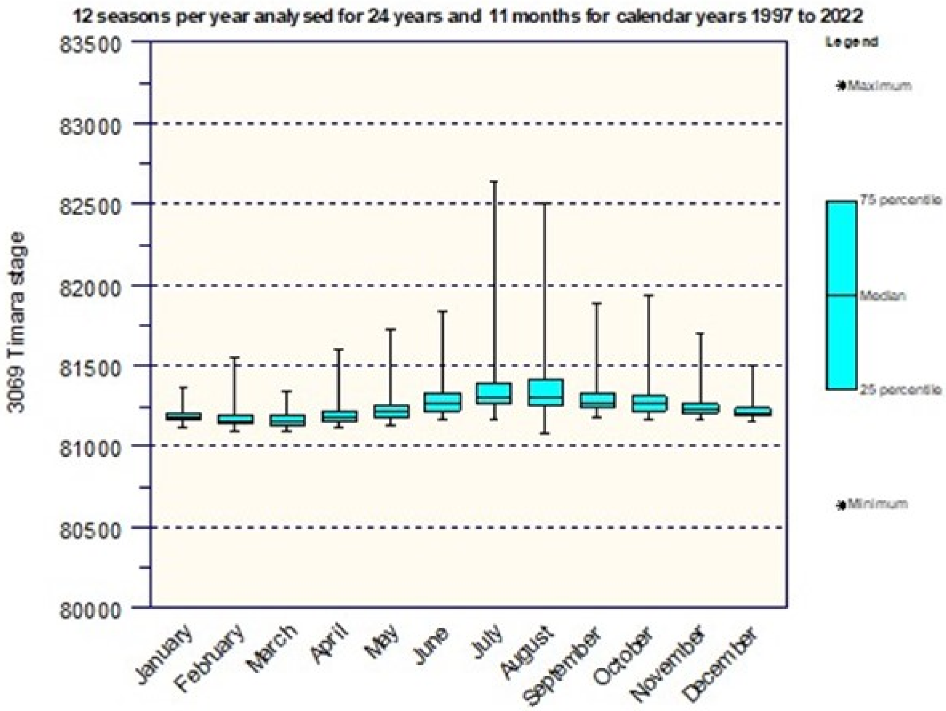

Figure 75: Seasonality

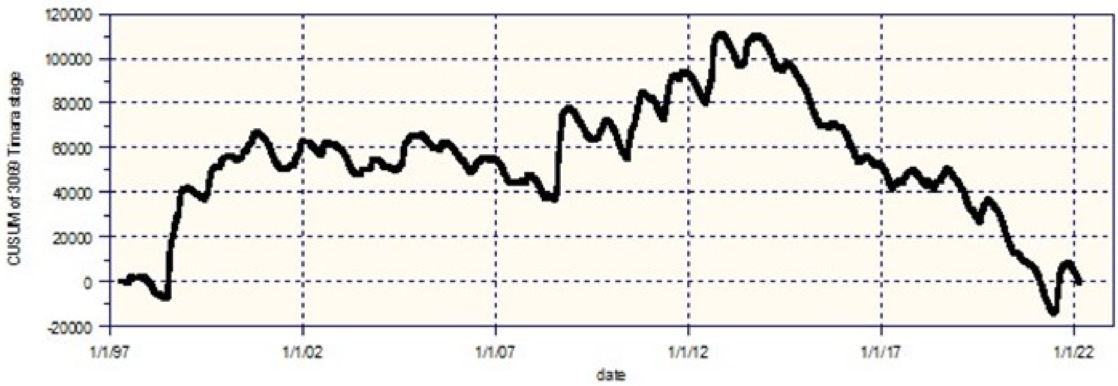

Figure 76: Cusum

4.18. Omaka River Aquifer Deep (Lower) Layer

The Deep layer of the Omaka River Aquifer is located at depths of greater than ~10 metres below the surface. Here groundwater is only indirectly linked to Omaka River channel flow and in summer it takes higher flows to recharge the Deep Layer by the equivalent amount than would be the case during wetter months. MDC have monitored groundwater level at this site in Godfrey Road since 1980 first at well P28w1000 which was 18 metres deep, and from 2010 at replacement well 10231 which is 25 metres deep. Figure 77 shows the XL linear trend line for the period 1980-2022 with a net decline over 42 years of around 400mm (~10 mm/year). Figure 78 shows the 8.5 month moving average of combined groundwater level with a declining trend up to about 2001, followed by an increasing trend since. The net effect is a slight decline over time but shows how trends consist of shorter time scale patterns also.

The Seasonal Kendall test showed a declining trend likely, but it was not statistically significant at the 95% confidence level. Adjusting for Omaka River baseflow accounted for 77% of the change in well level showing the significance of river recharge (Figure 79).

There was a possible increasing trend when groundwater level is adjusted for Omaka River baseflow but it was not significant at the 95% confidence level. Figure 80 shows Deep Layer aquifer levels at Godfrey Road peak in September with the minimum occurring in March. The largest range in groundwater level occurs in January when abstraction by irrigators and natural drainage rates are at their highest. While the Deep Layer can drain at any time of the year with levels falling by up to 10 metres, recovery has normally occurred by July. The reason for the possible decreasing pattern is unclear but reflects the trend in the Shallow Layer in the upper reaches of the Omaka River Valley, despite there being no long-term trend in Omaka River flow or baseflow.

A possible explanation is water stored in the gravels surrounding the Omaka River has declined over time due to pumping to dams. The Cusum analysis indicated a small declining trend in well levels (Figure 81). In terms of aquifer state groundwater levels are currently normal in historical terms.

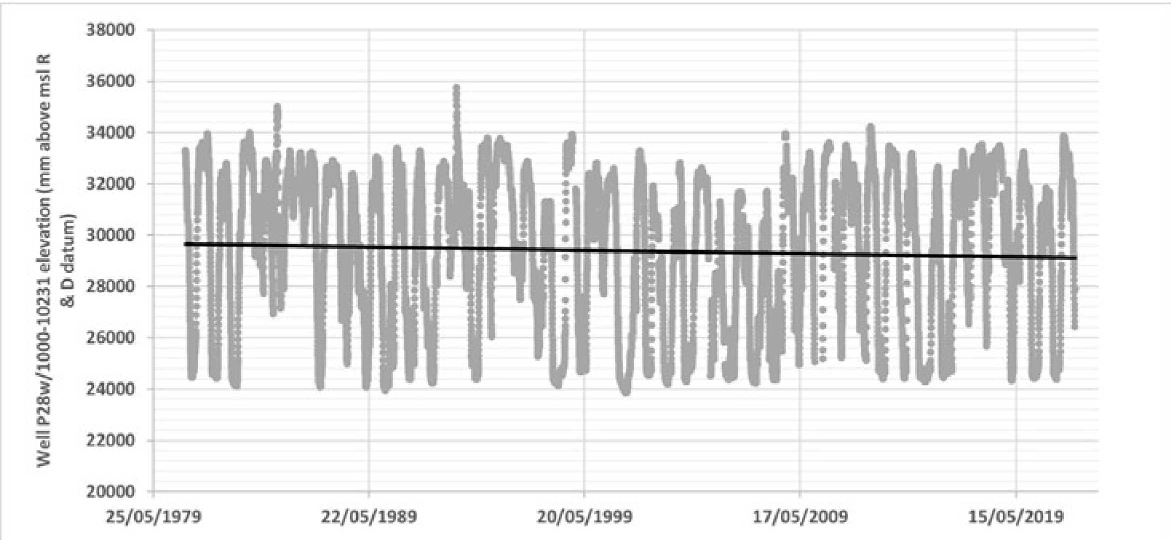

Figure 77: Groundwater elevation with linear trend & 8.5 month moving average trend line

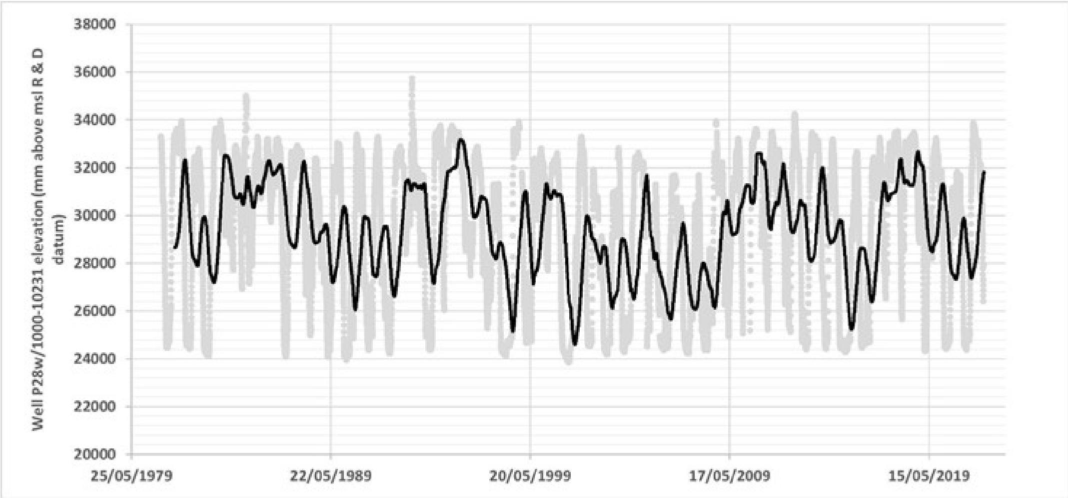

Figure 78: Groundwater elevation with linear trend & 8.5 month moving average trend line

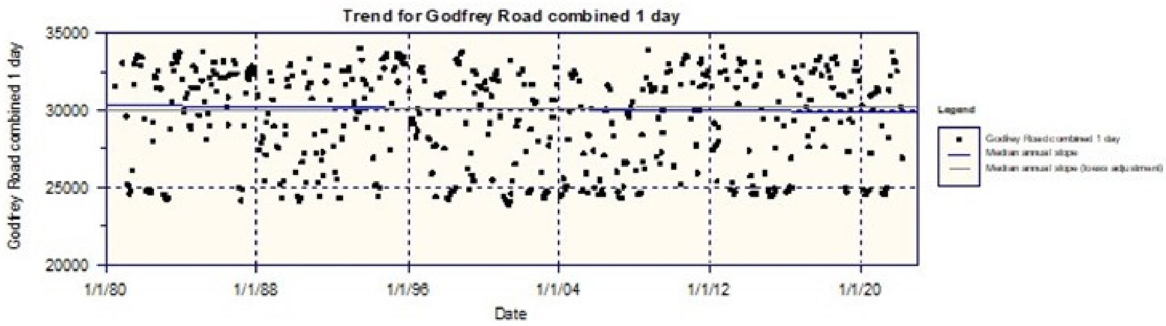

Figure 79: Seasonal Kendall test

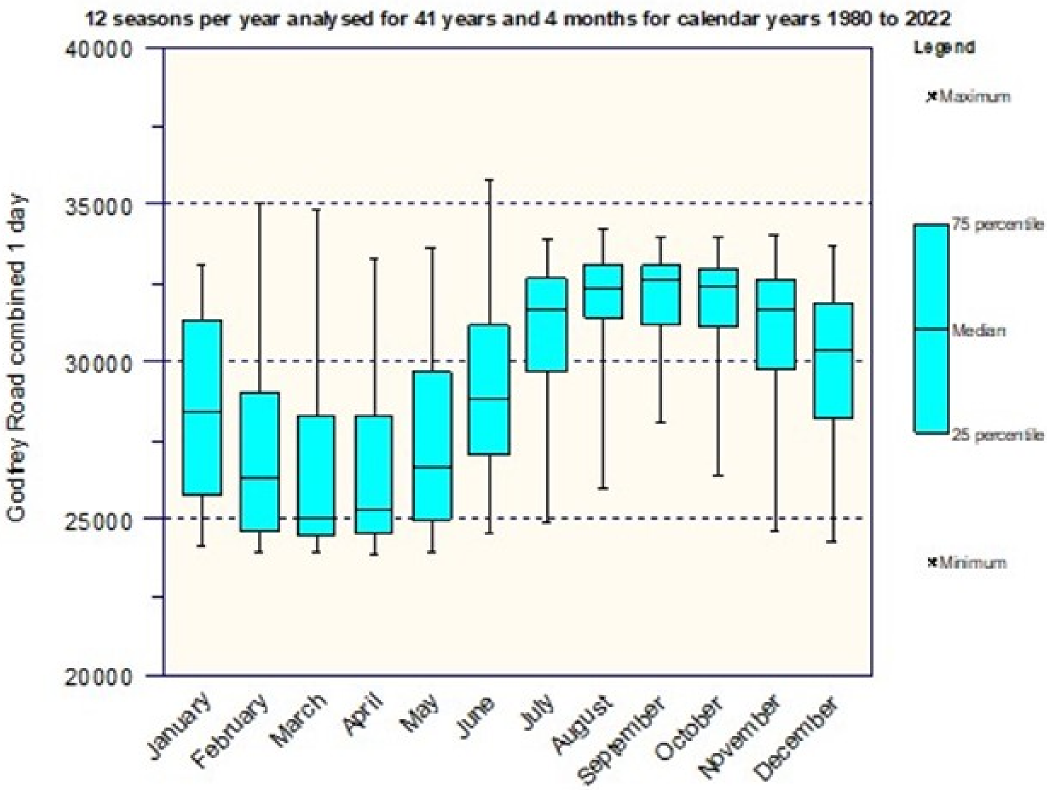

Figure 80: Seasonality

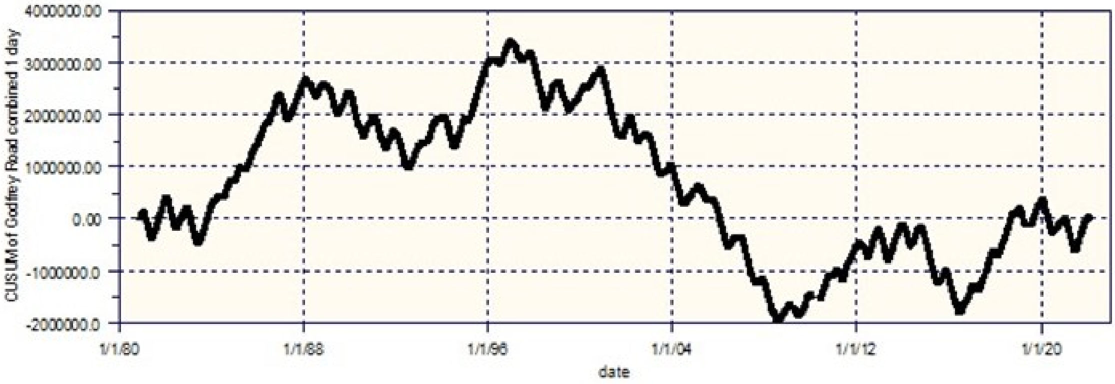

Figure 81: Cusum

4.19. Omaka River Aquifer (Woodbourne)

The Omaka River Aquifer extends from the foothills south-west of the Wairau Plain, downstream to Woodbourne. MDC well P28w/3010 is located in Jacksons Road and represents the Woodbourne area of the FMU where Southern Valleys catchments and Wairau Aquifer waters converge.

Well 3010 is shallower than the MDC Godfrey Road well at 13 metres depth and has been recording groundwater level since 1996. There is no apparent trend in groundwater level based on the trend line assigned by XL (Figure 82). The Seasonal Kendall test showed an increasing trend about as likely as not, but the P statistic value of 0.66 meant it was not statistically significant at the 95% confidence interval (Figure 83). There was no significant trend after adjusting well 3010 level for Omaka River or Wairau River baseflow. Omaka River flow accounted for more of the variation in well 3010 level (77%) than Wairau River flow (63%). In terms of aquifer state, groundwater levels are not far below historic values and appear stable at present due in part to the 2016 earthquake which induced uplift in the lower reaches, impeding drainage to the coast. The seasonality plot (Figure 84) shows aquifer levels peak in August and are lowest in March. Historic groundwater level observations dating back to 1971 show summer levels slightly lower today than in 1970s and 1980s based on observations from wells 3010 and nearby P28w/0594 (Figure 85). The Cusum analysis indicated no trend in groundwater levels at well 3010 (Figure 86). The aquifer state is currently normal.

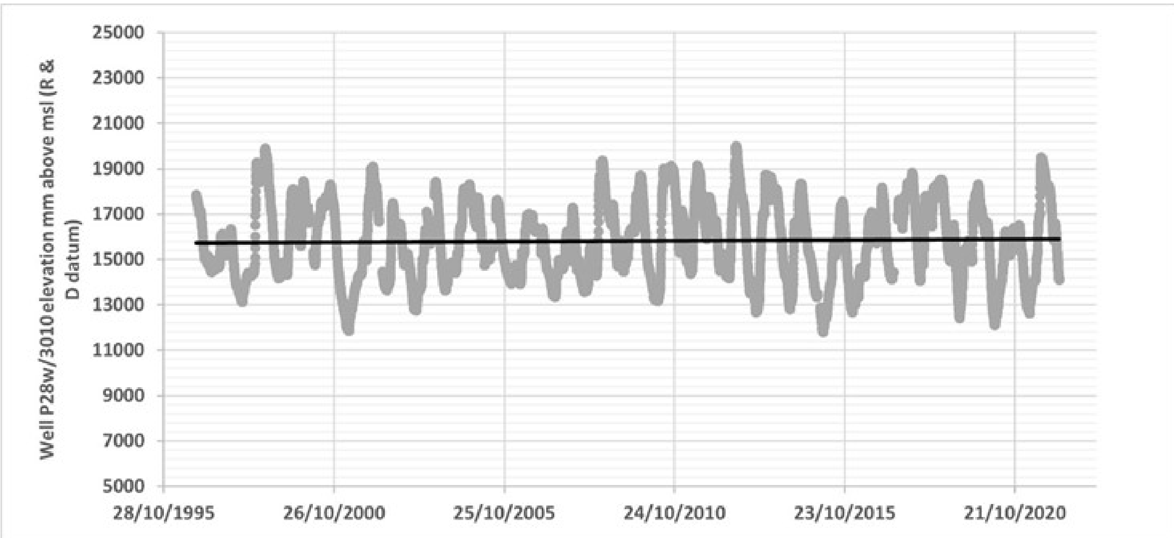

Figure 82: Groundwater elevation with trend line

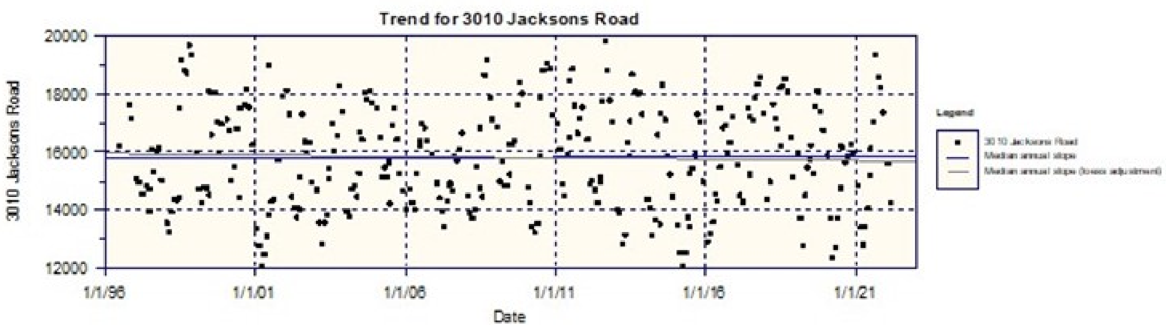

Figure 83: Seasonal Kendall test

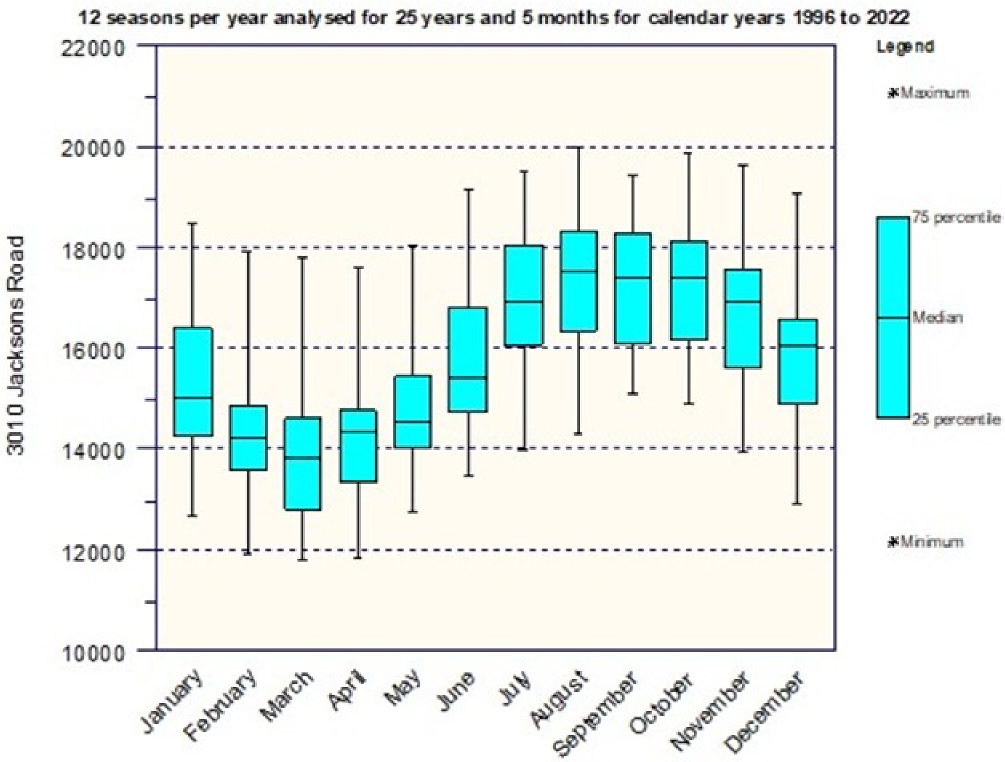

Figure 84: Seasonality

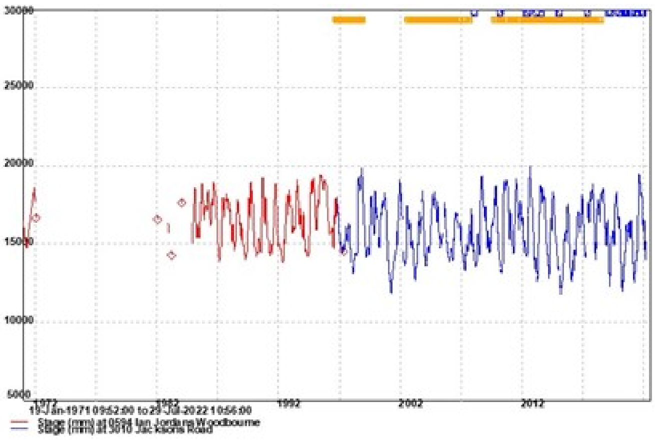

Figure 85: Groundwater elevation at Woodbourne wells P28w/594 & /3010: 1971-2022

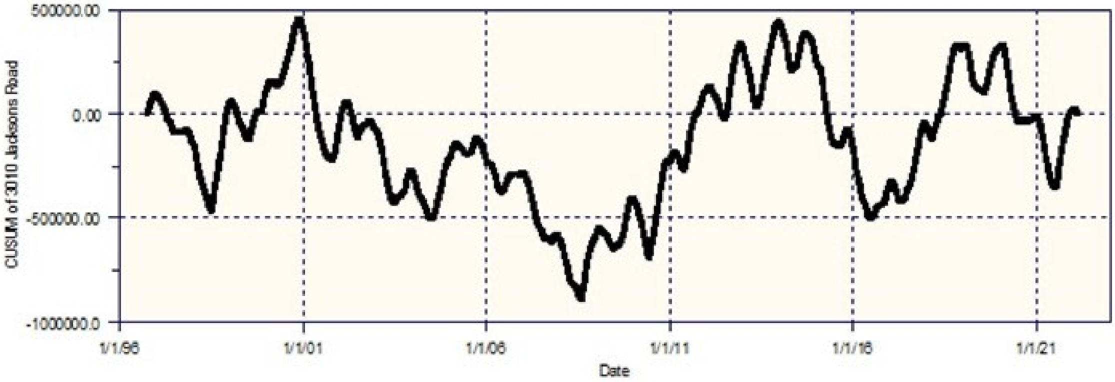

Figure 86: Cusum

4.20. Taylor Fan Aquifer Well

The age of groundwater beneath the Wairau Plain varies from very young to very old reflecting its stratified geology and depth. Residence times of days are typical for shallow groundwater near the surface, up to 39,500 years old for deeper groundwater from an 86 metre deep well drilled in 1916 as a water supply for Wairau hospital in Blenheim. This is the oldest dated groundwater in New Zealand. Deeper groundwater at 200 to 300 metres depth at Fairhall has 20,000-year-old groundwater. This deep groundwater is of very poor quality due to natural mineralisation processes, making it unsuitable for drinking.

Groundwater chemistry helps MDC understand the regional scale water circulation beneath the Wairau Plain. MDC began monitoring well 980 in early 1999, which was complicated by the high artesian water pressure at the time. Between 1999 and 2015 groundwater levels mimicked those of the wider Southern Valleys aquifers with a fall in levels due to pumping, followed by a recovery (Figure 87). The 2016 Kaikōura earthquake caused well 980 levels to rise by 5.5 metres, although they have now returned to pre-event levels (Figure 87). The event distorts the level time series and makes the increasing trend appear larger than it really is which is more like 40mm per year average increase. The Seasonal Kendall test analysis confirmed an increasing trend in groundwater level was virtually certain and significant at the 95% confidence level (Figure 88). Because the aquifer is relatively deep and isolated from surface processes, there is little difference in levels throughout the year with pumping effects being remote (Figure 89). Groundwater levels peak in January which is explained by the lag time between pumping effects further west and when they affect well 980 levels (Figure 89). The Cusum test also identified the apparent increasing trend in groundwater level as expected (Figure 90). Aquifer state is normal based on no net change over past 23 years of record.

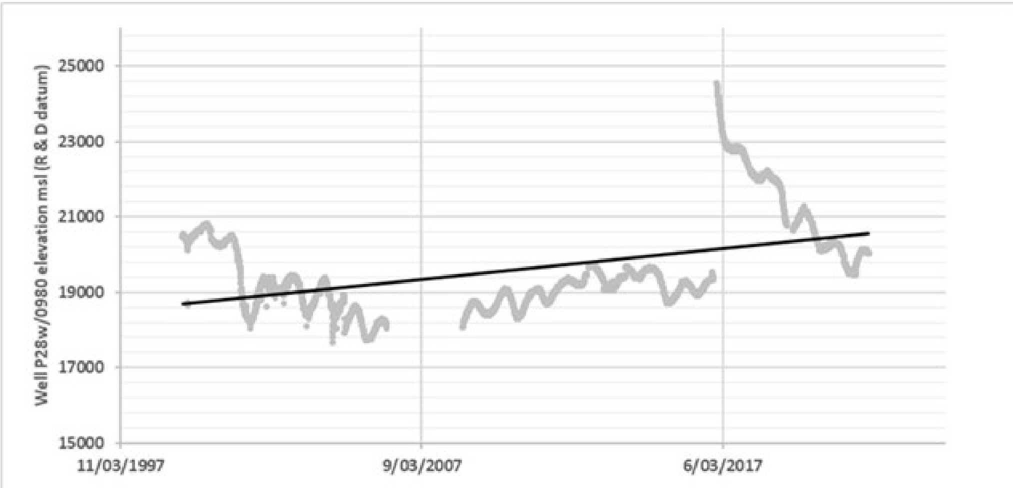

Figure 87: Groundwater elevation with trend line

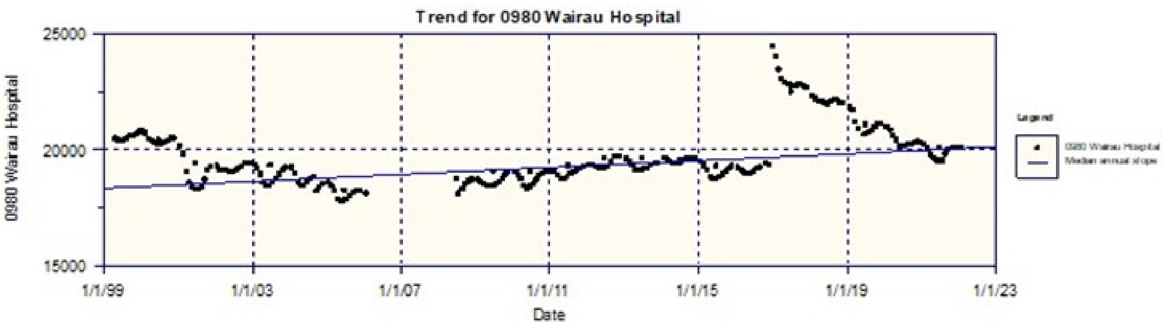

Figure 88: Seasonal Kendall test

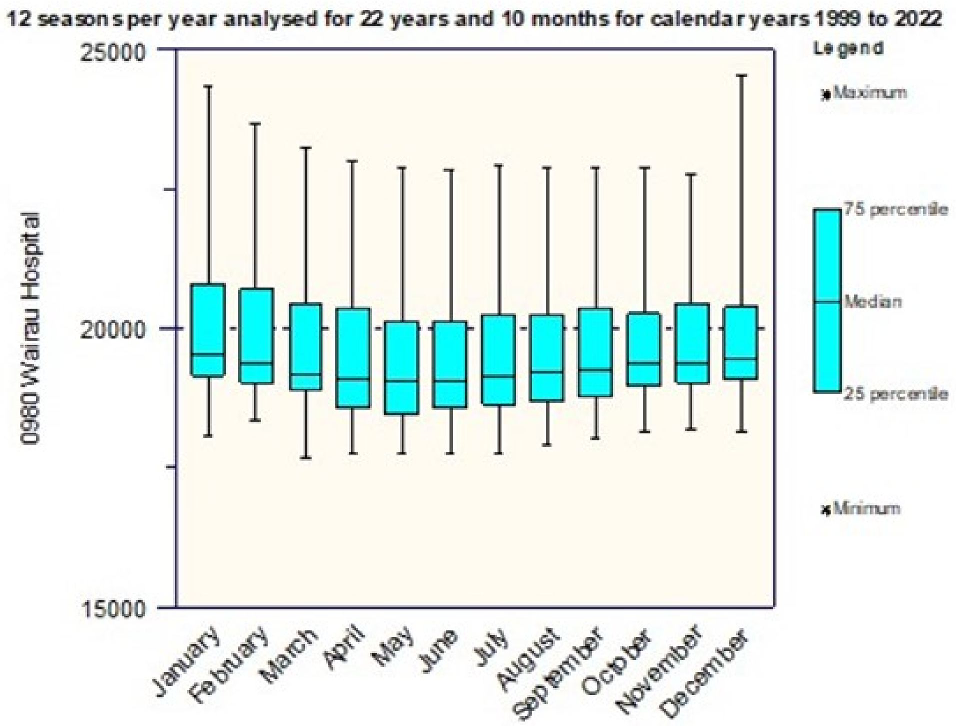

Figure 89: Seasonality

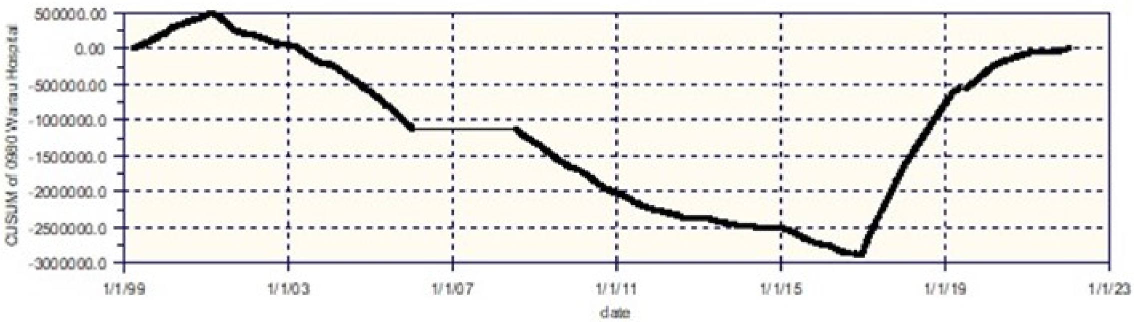

Figure 90: Cusum

4.21. Taylor Fan Aquifer Well

Two aquifers underlie the Taylor River catchment: a near surface, unconfined aquifer associated with the Taylor River channel called the Taylor River Gravels Aquifer (TRGA) and a deeper semi-confined/confined system known as the Taylor Fan Aquifer (TFA). MDC well P28w/0949 was originally a test bore finished off at a shallower depth of 22 metres below the surface and used as a monitoring well. Well 949 represents the Taylor Fan Aquifer and MDC have monitored groundwater levels there since 1977.

There is a slight decreasing in well level since 1977 of around 100mm or 2 mm/year on average as the black line shows (Figure 91). However, the moving average marked by the red line, shows there was a slight downwards pattern between 1977 and about 2001, followed by an increasing pattern since that time. The Seasonal Kendall test also indicates a decreasing trend possible however the P value of 0.27 means it is not significant at the 95% level (0.05) (Figure 92). In terms of drivers, land surface elevations downstream of this area rose due to the late 2016 earthquake which is likely to have reduced natural drainage rates to the sea, keeping groundwater levels higher. The aquifer is in a good state in terms of levels which in turn is maintaining the baseflow of the springs. This well was affected by nearby municipal abstraction up until the wellfield was deactivated in late 1990's. Groundwater levels peak in August or September and reach their minimum in March, which is also the month with the largest range in levels (Figure 93).

The Cusum analysis shows no net change between 1977 and 2022 in line with the other analyses (Figure 94).

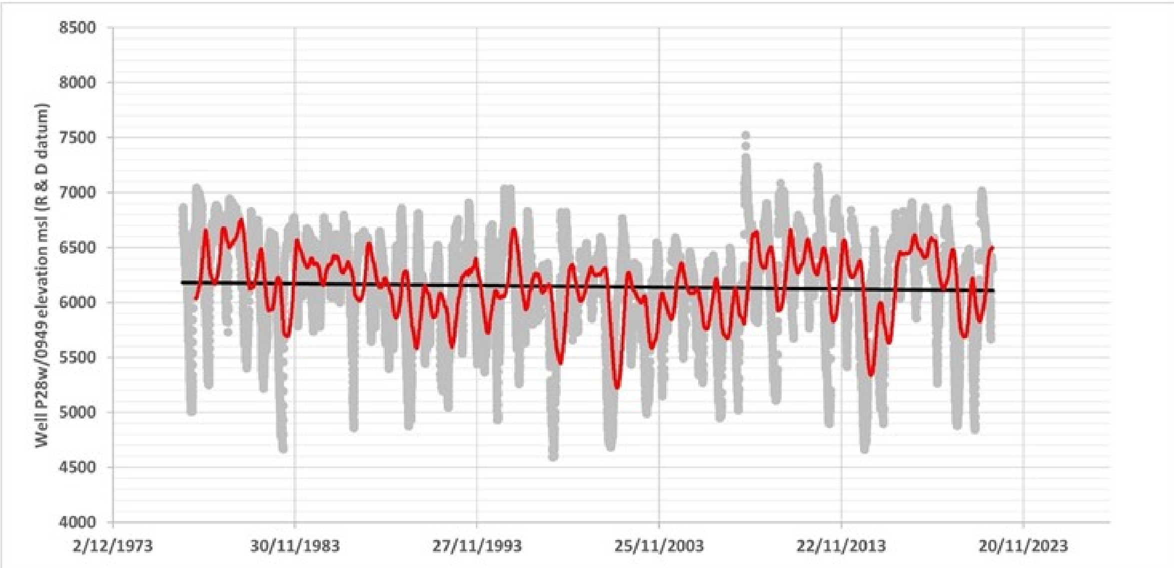

Figure 91: Groundwater elevation with trend line

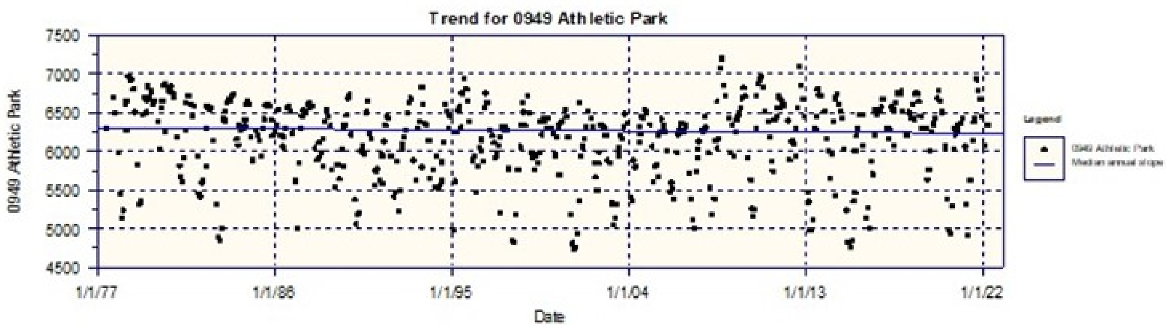

Figure 92: Seasonal Kendall test

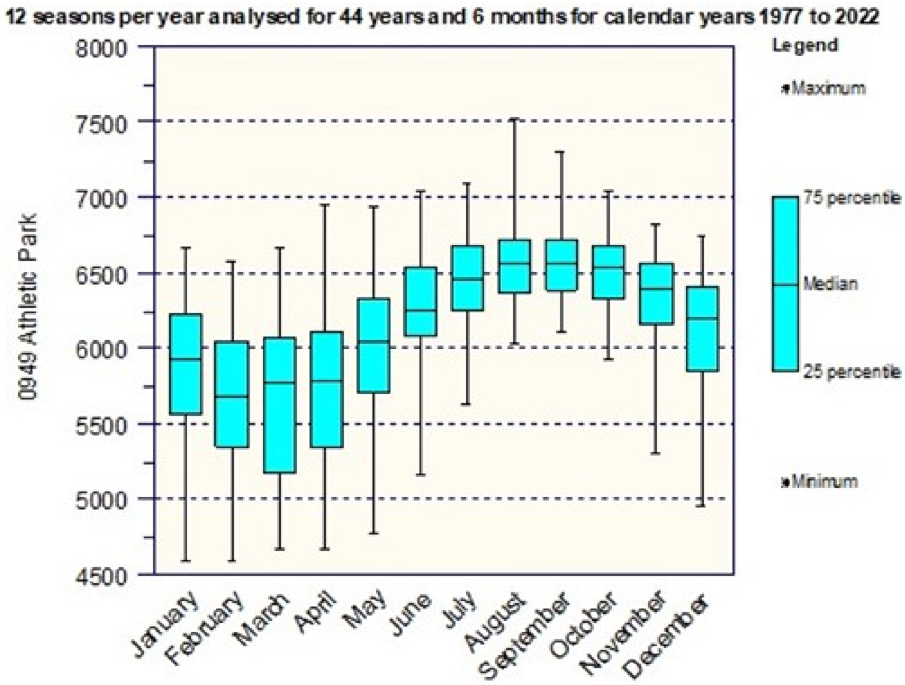

Figure 93: Seasonality

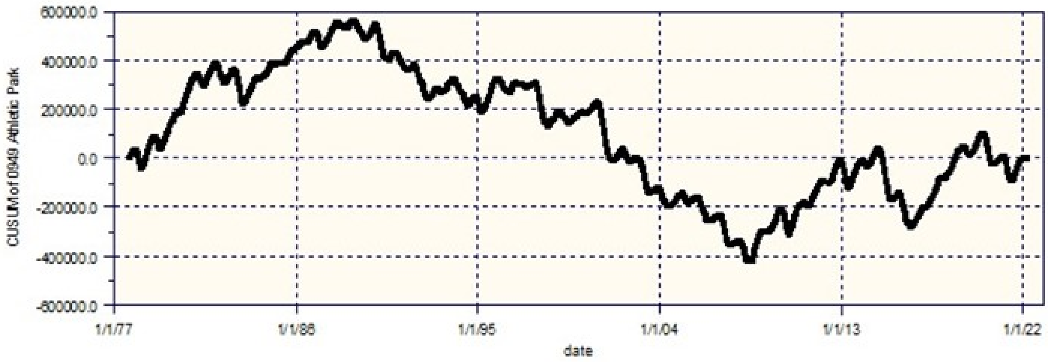

Figure 94: Cusum

4.22. Riverlands Aquifer (Inland) - Alabama Road

The Riverlands Aquifer underlies the south-eastern coastal area of the Wairau Plain and has a highly confined structure isolating it from surface activities. MDC operate two monitoring wells representing the Riverlands Aquifer. A coastal well near the Lagoon (P28w/0708-10346) and an inland well near Alabama Road (P28w/4402). The original Lagoon well P28w/0708 began recording coastal aquifer level and electrical conductivity in 2001. The inland well P28w/4402 was established later and began continuous measurements of aquifer level in 2006.

Groundwater sourced from the Riverlands Aquifer has a much broader range of end uses than other Wairau Plain aquifers meaning the timing of the demand is different from areas dominated by vineyard. For this report groundwater elevations are expressed in terms of NZVD 2016 for the two Riverlands well sites. Groundwater level observations were also corrected for the effects of the 2016 Kaikōura earthquake. Figure 95 shows a decreasing trend in groundwater level of around 200mm over 14 years or an average annual decline of 14 mm/year. The Seasonal Kendall test showed a decreasing trend was virtually certain with an annual median fall of 16mm/year significant at the 95% confidence level with a P statistic of 0.00 (Figure 96). Groundwater levels from 2016 to 2022 were adjusted for estimated pumping which accounted for 72% of the variation in well levels during that time. This is higher than for the Lagoon well and reflects the closer proximity to pumping wells. A slight decreasing trend, although not quite significant at the 95% confidence level (P=0.08), is reversed to become a statistically significant increasing trend with an annual median increase of 52 mm/year (Figure 97). Figure 98 shows groundwater levels peak in August and are lowest in February. The Cusum plot for the unadjusted data indicated a net decline (Figure 99).

In terms of state, Figure 95 shows aquifer levels at well 4402 are lower than at the coast by around 0.5 metres creating a seasonal reverse gradient. While an inland site, groundwater elevations are close to the acceptable minimum.

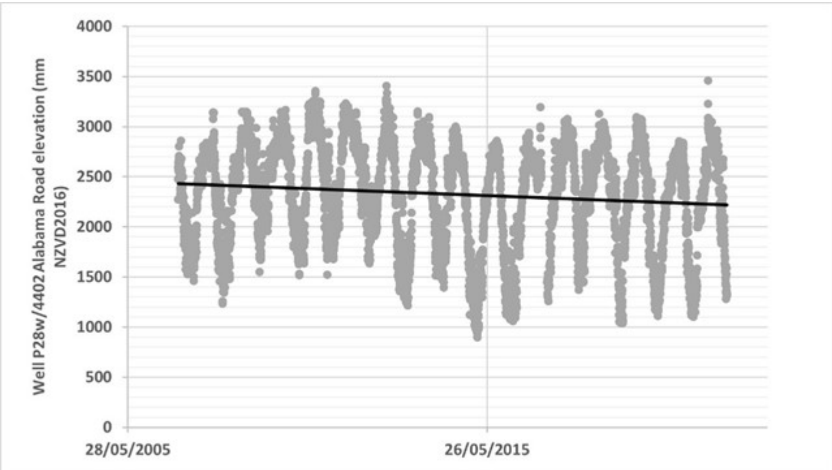

Figure 95: Groundwater elevation with trend line

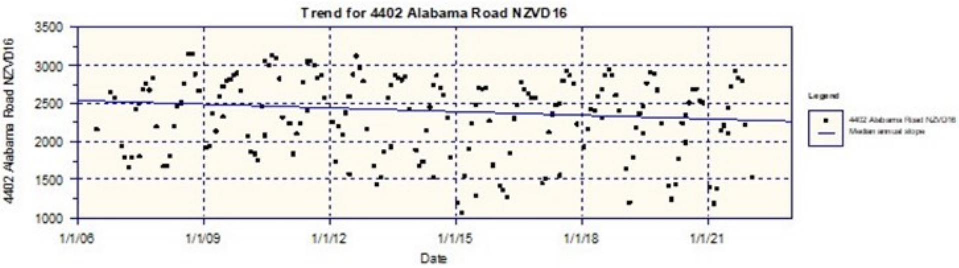

Figure 96: Seasonal Kendall test

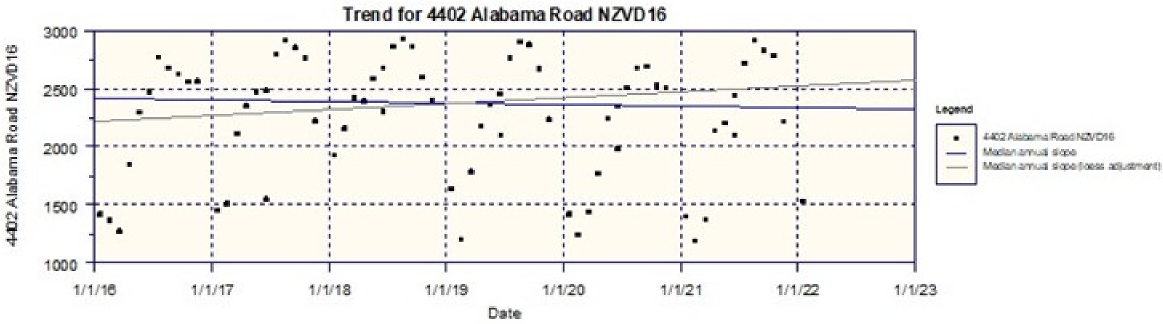

Figure 97: Seasonal Kendall test pumping adjusted

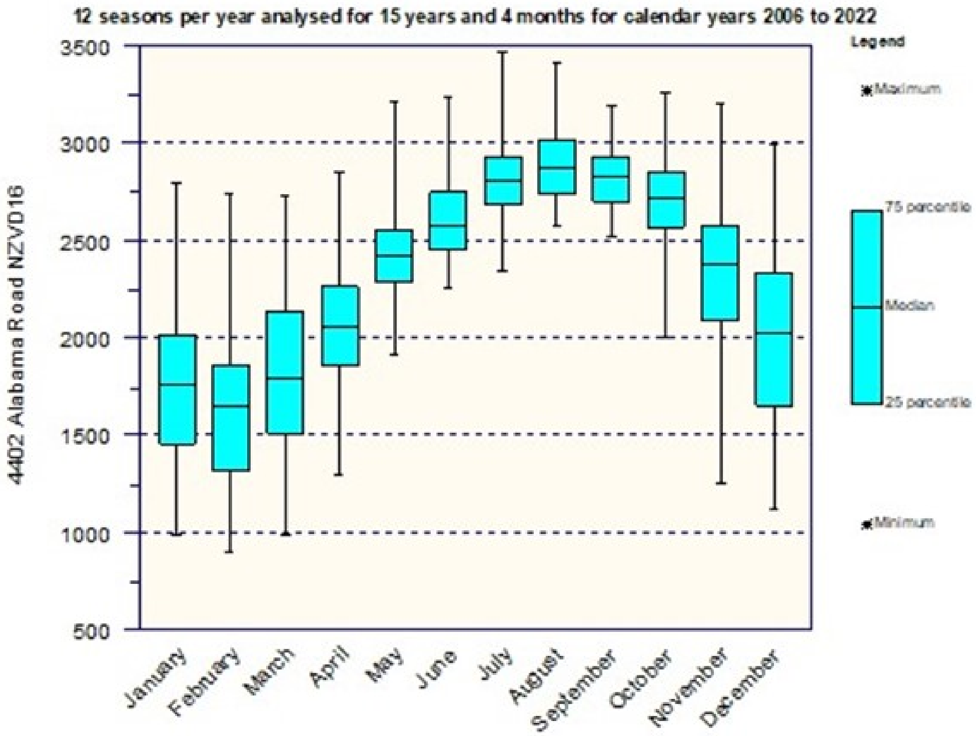

Figure 98: Seasonality

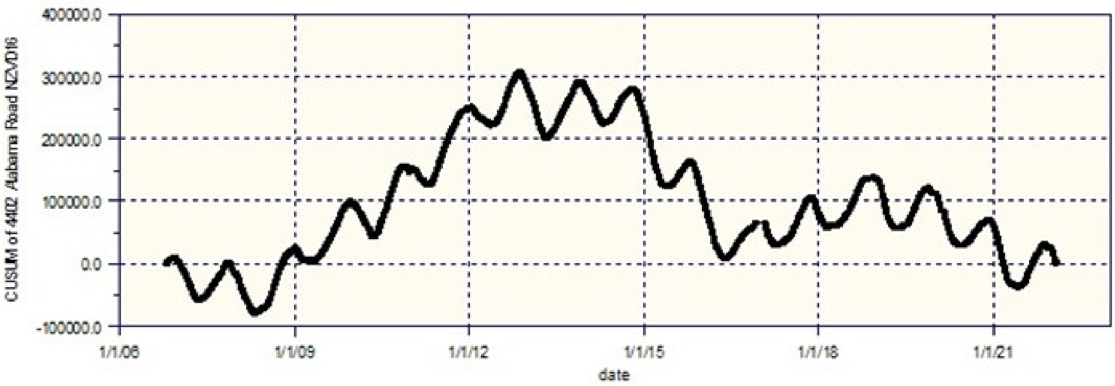

Figure 99: Cusum

4.23. Riverlands Aquifer (Coastal) Lagoon

The original Lagoon well (P28w/0708) was 43 metres deep and began automatic measurements of coastal groundwater elevation and electrical conductivity in 2001. Well 10346 was drilled by MDC in 2014 to replace well 708 and is 44 metres deep. Well levels were corrected to NZVD datum and at the same time corrected for the effects of the 2016 Kaikōura earthquake which significantly raised land at Riverlands and MDC level monitoring instruments making groundwater elevations appear to be lower than reality.

Figure 100 shows a slight decrease in aquifer levels between 2001 and 2022 of 100mm or an average of around 5mm/year based on the XL fitted trend line. The Seasonal Kendall test showed a declining trend was very likely based on a P statistic value of 0.02, which was significant at the 95% confidence level with a median annual slope of 5mm/year (Figure 101). When groundwater level is adjusted for estimated pumping for the period from 2016 to 2022, 62% of the variance in groundwater level is explained (Figure 102). This is quite high given the well is remote from direct pumping effects. The cumulative groundwater pumping rate was upscaled to allow for un-metered takes by adding a factor of 20% on top of measured use. Figure 102 shows that for this shorter period when level is adjusted for pumping, a slight decreasing trend which is not quite significant at the 95% confidence level (P=0.06), is reversed to become a statistically significant increasing trend with an annual median increase of 36mm/year.

Figure 103 shows the highest groundwater levels occur in August and lowest in February. The slight declining trend in the unadjusted groundwater level at well 10346 is apparent in the Cusum analysis also (Figure 104). In terms of aquifer state, Figure 100 shows groundwater levels at well 10346 approach the MEP cut-off threshold of 1250 mm elevation in most summer seasons and the aquifer cannot sustain any increase in actual use.

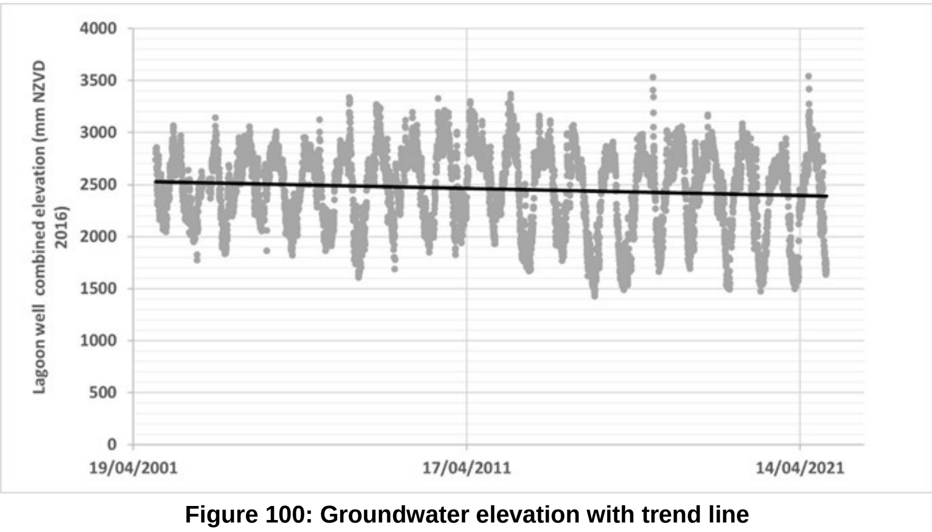

Figure 100: Groundwater elevation with trend line

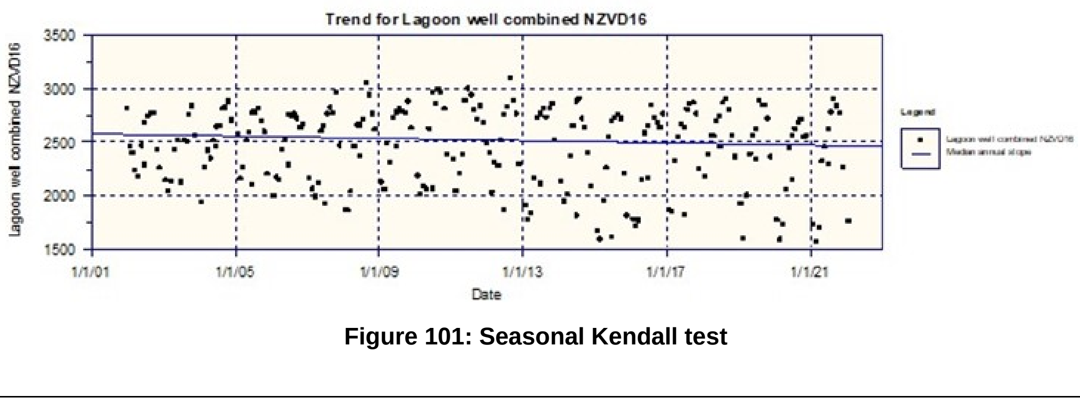

Figure 101: Seasonal Kendall test

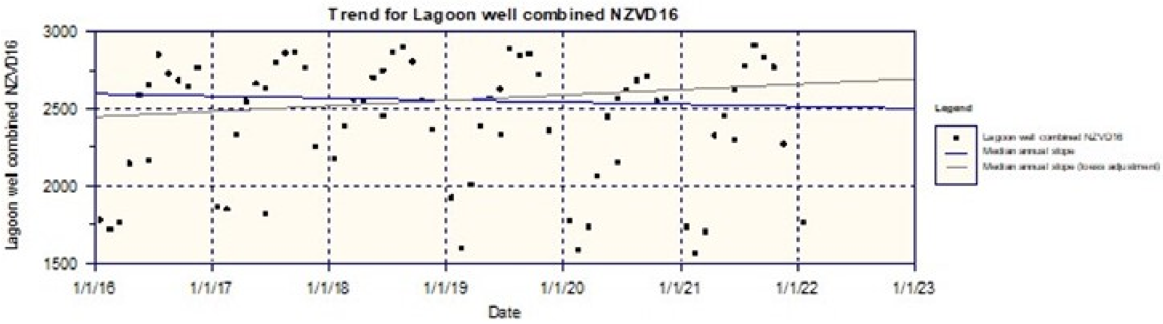

Figure 102: Seasonal Kendall test pumping adjusted

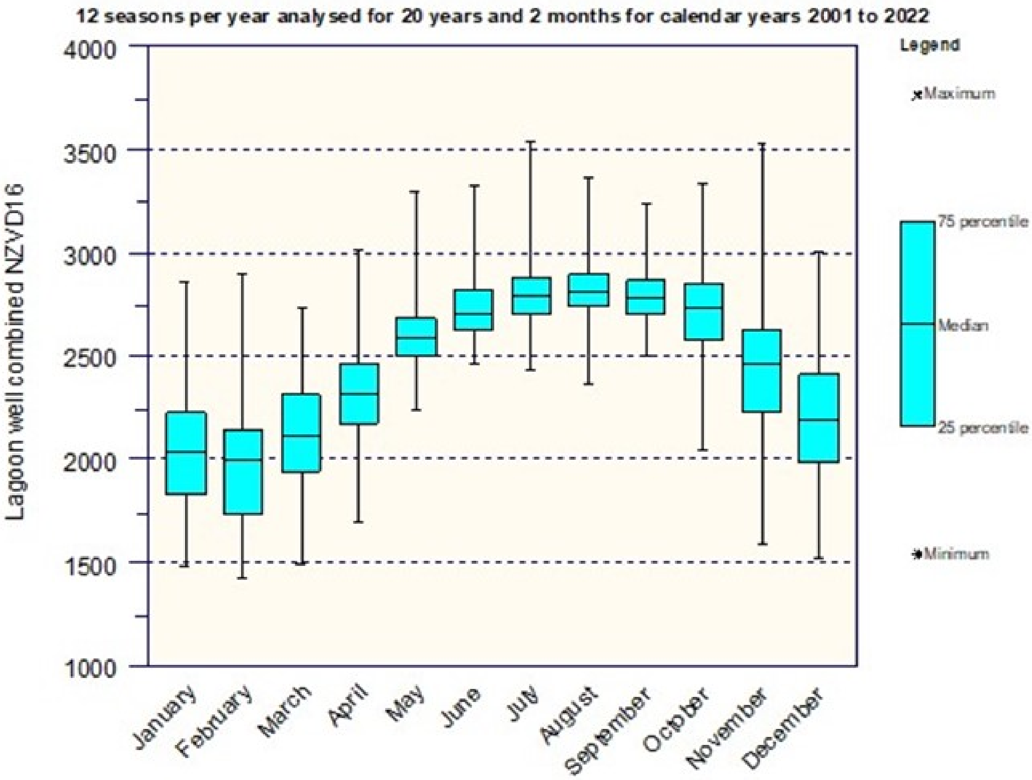

Figure 103: Seasonality

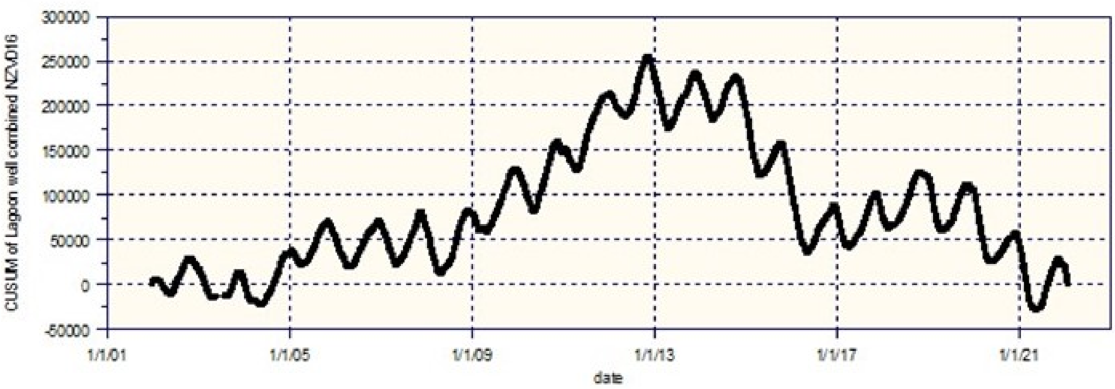

Figure 104: Cusum

4.24. Brancott Aquifer

The Brancott Aquifer is a low yielding system underlying the Fairhall-Brancott Valley at moderate depths and forming part of the Southern Valleys suite of catchments. The Brancott Aquifer is recharged by leakage from the Fairhall River channel and rainfall seepage. MDC monitor groundwater level in the Fairhall-Brancott Valley at two sites. The shallow riparian aquifer associated with the Fairhall River and known as the Fairhall River Gravels Aquifer is represented by shallow MDC well P28w/3147 at Bints Ford. The deeper Brancott Aquifer is represented by 54 metres deep well P28w1323 at the Pernod Ricard Vineyard halfway down the western side of the valley.

Figure 105 shows the large changes in groundwater level associated with irrigation pumping before the introduction of the Southern Valleys Irrigation Scheme (SVIS) in 2004.

Demand on the Brancott Aquifer has decreased significantly since the availability of SVIS water, with a rise in aquifer level of around seven metres. While there are still seasonal fluctuations in level due to natural variability in recharge or abstraction from bores in some summers when SVIS is unavailable, they are much smaller (around 1-2 metres) than pre-2004 when all water was sourced locally.

Figures 105 and 106 draw linear trend lines through the level data, however it is evident the large variations are pumping induced and there has been a net recovery in groundwater levels over time, with the aquifer is in a good state storage wise. Figure 107 shows the seasonality of Brancott Aquifer levels since 1983 is strongly influenced by pumping. The variation in the wetter months is a function of groundwater levels recovering. There is a poor correlation between Brancott Aquifer and Fairhall River Gravels Aquifer level as expected because of the lag time in drainage reaching deeper groundwater, but a reasonable correlation between Brancott Aquifer level and MDC Jacksons Road well 3010 level from 2010 onwards, when stable conditions existed.

In terms of drivers, the SVIS pumping rate was plotted to see if there was a strong inverse correlation between usage and Brancott Aquifer levels at well 1323 (Figure 108). The poor correlation probably reflects the total scheme usage rather than Brancott Aquifer only.

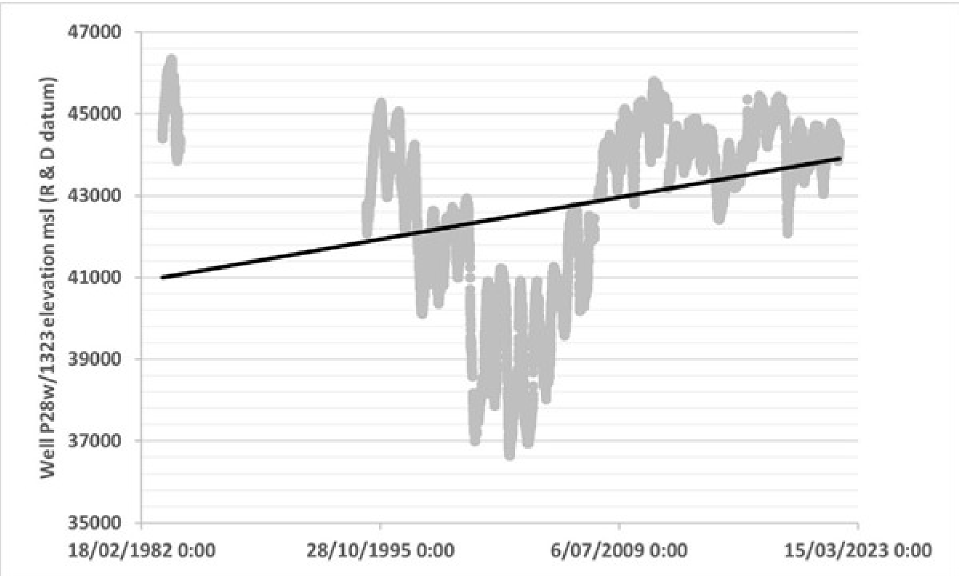

Figure 105: XL Groundwater elevation with trend line

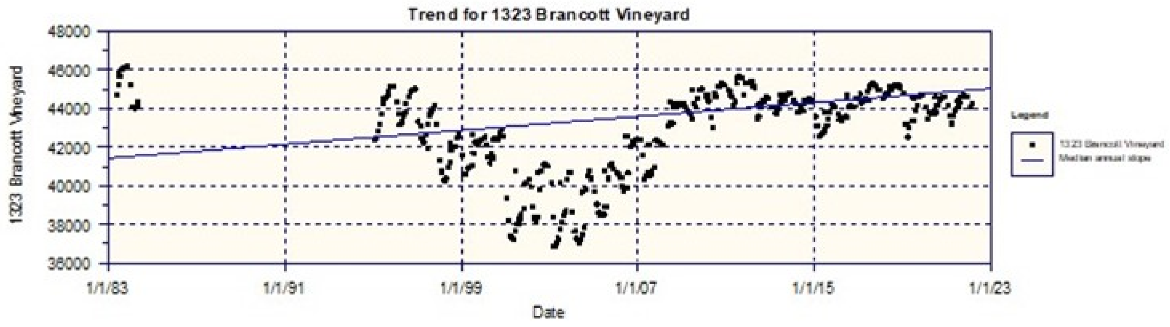

Figure 106: Seasonal Kendall test

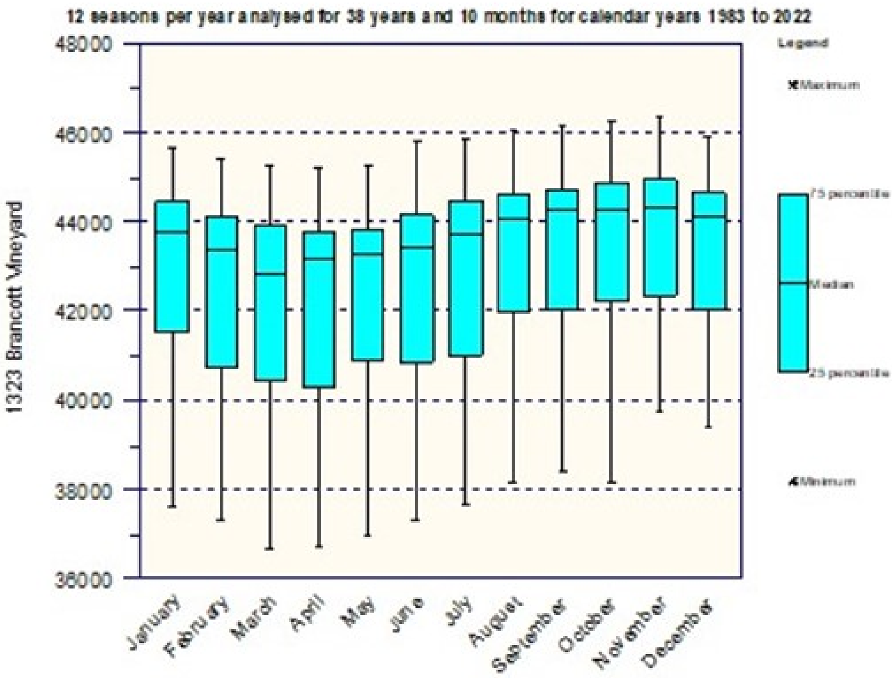

Figure 107: Seasonality

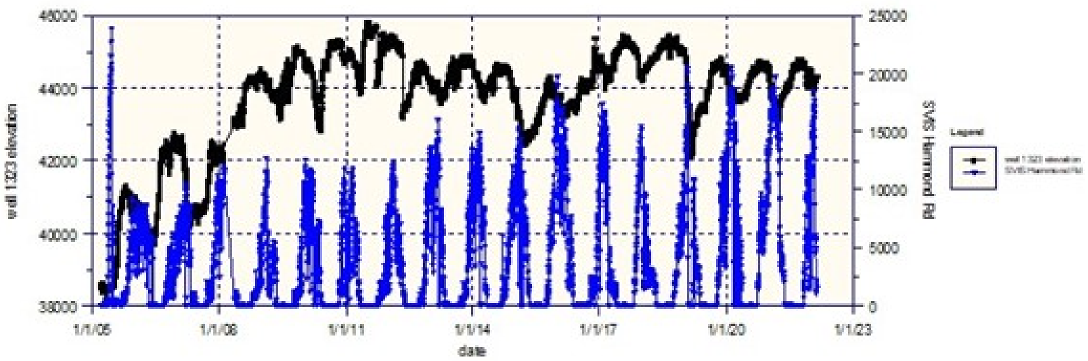

Figure 108: SVIS pumping rate versus well 1323 elevation

4.25. Fairhall River Gravels Aquifer

The Fairhall River Gravels Aquifer (FRGA) is the smaller of the two groundwater resources underlying the Fairhall-Brancott Valley. It is hosted by the permeable riparian gravels forming the Fairhall riverbed. It is high yielding when there is surface channel flow, but well productivity drops dramatically when the river recedes as the thin veneer of gravel has limited storage. During most summers, the gravels drain naturally in response to the drying up of the ephemeral Fairhall River. Historically pumping has accelerated this process.

Figure 109 shows the daily average groundwater level has increased between 1997 and 2022 by about 12mm/year based on the XL trendline. Summer minima are higher probably reflecting increased Fairhall River flows and less abstraction following the introduction of SVIS. Fairhall River flows are not measured continuously, however the Seasonal Kendall test showed an increasing trend was very likely, but not significant at the 95% confidence interval with a P value of 0.05 (Figure 110). The annual variation in shallow groundwater levels mimic channel flow, with a peak in July and a low in March (Figure 111). The largest changes in shallow groundwater occur in periods when the gravels are either draining or refilling, from November to June. The FRGA sits on a basement of clay bound gravels which constrains the seasonal variation in groundwater level, so levels do not go much lower regardless of rainfall-runoff rates. The Cusum analysis also indicates a net increasing trend in shallow groundwater level since 1997 consistent with the other analyses (Figure 112). Aquifer state is currently high.

The trend in Fairhall River Gravels Aquifer levels is consistent with that of the underlying Brancott Aquifer.

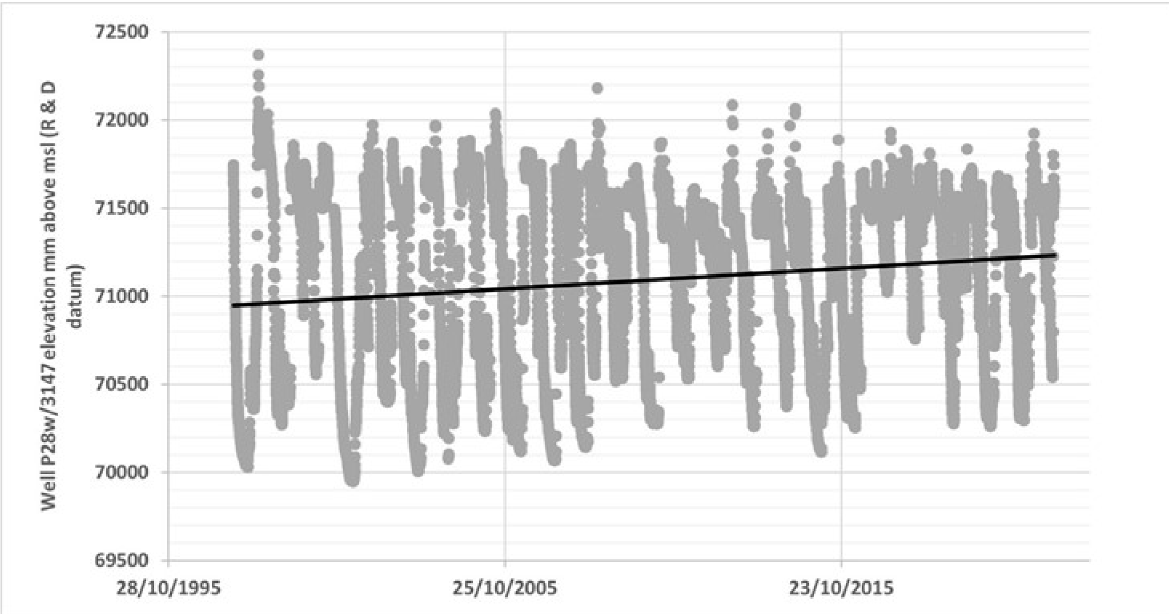

Figure 109: Groundwater elevation with trend line

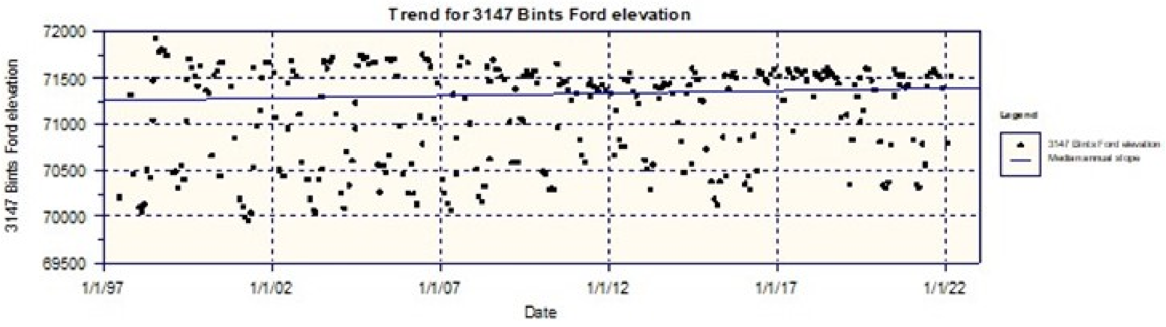

Figure 110: Seasonal Kendall test

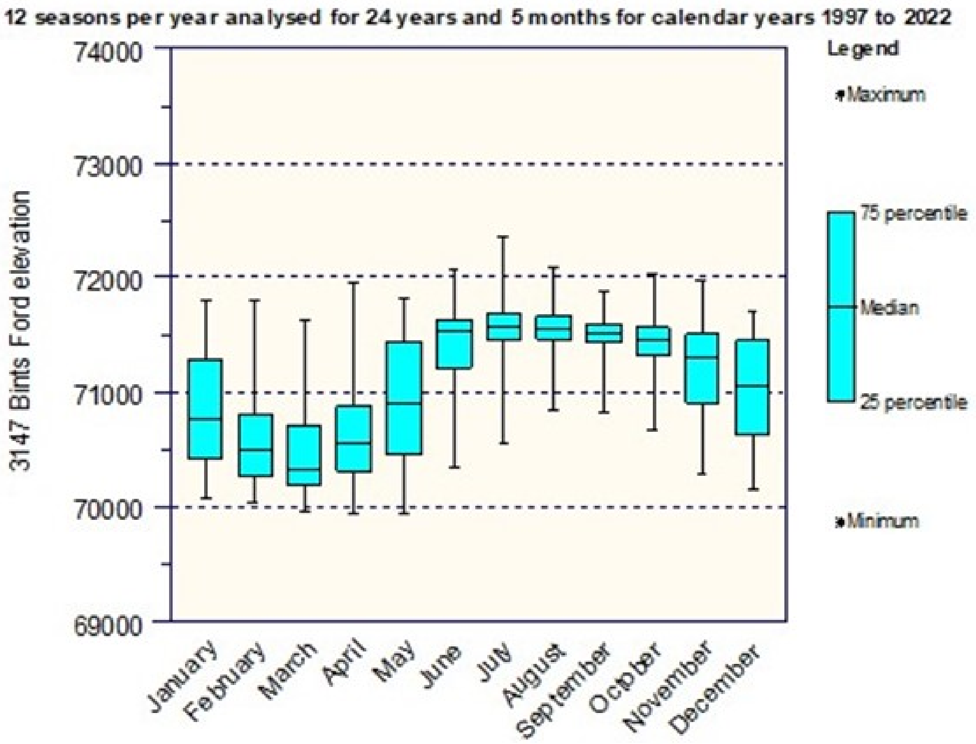

Figure 111: Seasonality

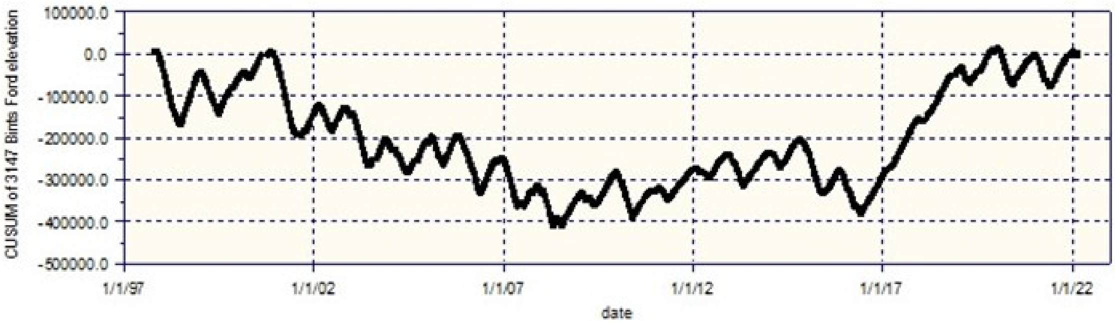

Figure 112: Cusum

4.26. Omaka Aquifer Medium Depth Layer

The Omaka Aquifer underlies the Omaka-Hawkesbury Valley and consists of multiple low yielding clay-bound gravel layers extending to a known depth of 405 metres below the surface. Well yields are very poor due to the low permeability aquifer sediments and low rates of rainfall recharge or leakage from Mill Creek. MDC monitor the state and trends in groundwater level at two sites. Well P28w/1873 at the Pernod Ricard vineyard in Hawkesbury Road representing the Medium Depth Layer and well 2917, the deepest well drilled to date in Marlborough, representing the Deep Layer. Both wells are located close together. In common with all deep Southern Valleys aquifers, well levels declined from the late 1990's due to over-pumping and only started recovering from 2006 onwards following the introduction of the Southern Valleys Irrigation Scheme in 2004 which reduced demand on local groundwater. Figure 113 shows the general pattern of decline reaching a minimum level during the 2000/01 drought and recovering within eight years to current stable levels. The trend is obvious, and the Seasonal Kendall test analysis shows the same long term upwards trend over the past 32 years (Figure 114). In terms of current state, the medium depth layer has good storage with levels similar to three decades ago, however potential demand could reduce the small volumes of water naturally stored in the system within a single season as demonstrated during the 2000/01 summer when abstraction dropped well levels by 10 metres (Figure 113). In terms of seasonality, Figure 115 shows the lowest levels occur in March and the highest in September. Figure 116 compares the variation in groundwater elevation between the two MDC monitoring wells from 1989 onwards for the same vertical scale. There are much larger changes in groundwater level at well 1873 representing the Medium Depth layer, compared with well 2917 representing the Deeper Layer. This response is consistent with most groundwater being abstracted from the Medium Depth Layer, and rises in groundwater caused by land surface recharge.

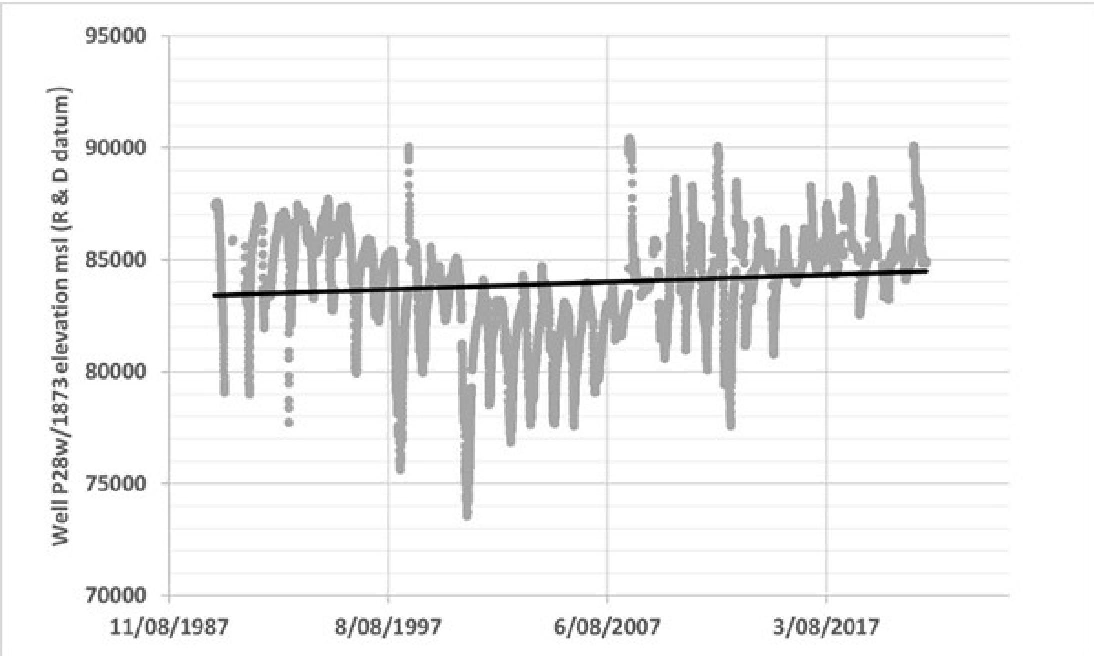

Figure 113: Groundwater elevation with trend

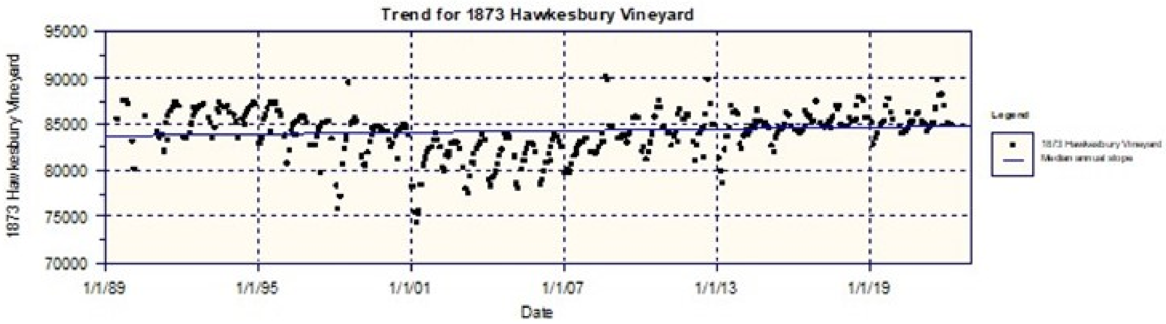

Figure 114: Seasonal Kendall test

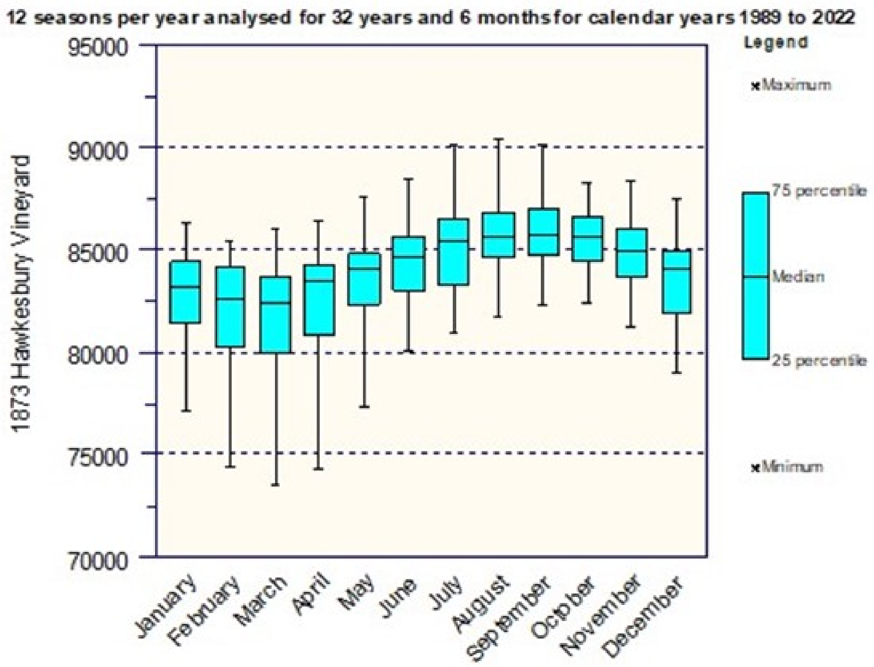

Figure 115: Seasonality

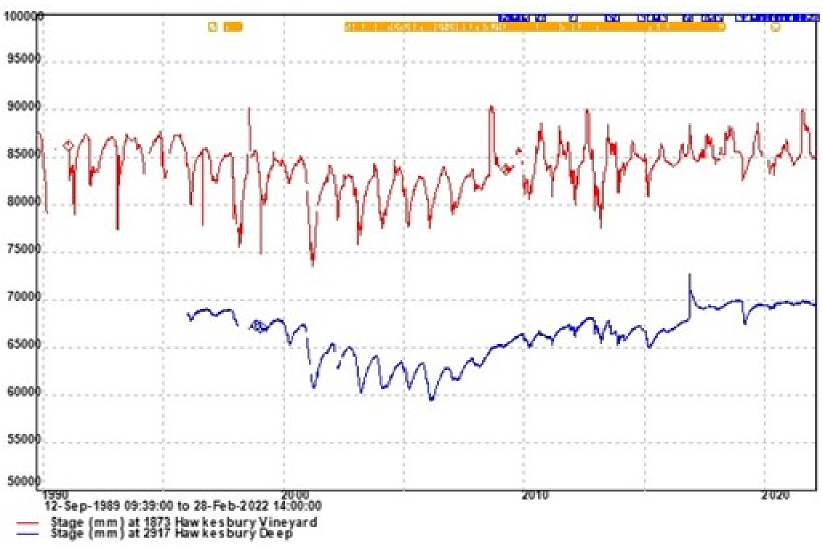

Figure 116: Groundwater level at MDC Omaka Aquifer monitoring wells

4.27. Omaka Aquifer Deep Layer

The Deep Layer of the Omaka Aquifer is the name given to water bearing strata at depths of between about 200 and 400 metres below the surface. MDC monitoring well P28w/2917 representing the Deep Layer, is the deepest well yet drilled in Marlborough and has a very long screen. The Deep Layer is far less productive than the Medium Depth Layer, with a transmissivity value an order of magnitude lower at 2 m^2/day. Figure 117 shows Omaka Aquifer Deep Layer levels exhibit the same demand driven pattern as for the Medium Layer, although the magnitude is smaller due to the relative remoteness from surface processes and pumping effects.

There is an obvious upwards trend reflecting bounce-back from pumping stress between the mid 1990’s and 2006. Demand on local groundwater was reduced with the switch to SVIS water from 2004 onwards. The same trend is shown by the Seasonal Kendall test (Figure 118). Figure 119 shows the lowest groundwater levels occur in March with peak levels in Spring, however there is not much difference between months. The seasonality plot is influenced by historical pumping although a more naturalised pattern is dominating in recent years. In terms of current state, Deep Layer levels are higher now than when MDC measurements first began in 1996. The very deep water bearing strata intercepted by MDC monitoring well 2917 are hydraulically connected to other deep layers extending further north and east beneath the Wairau Plain.

MDC have monitored the variation in groundwater level at several of these deep wells since their construction in the late 1990’s and all exhibit similar behaviour (Figure 120). The deep layer is overlain by a thick layer of clays and clay-bound gravels which are compressible and respond to changes in earth tides, seismic waves, pumping and barometric pressure. Figure 120 shows levels of all deep aquifer wells declined due to excessive demand until around 2006 and rose by several metres in response to the late 2016 Kaikōura earthquake, having only recently reached a new equilibrium.

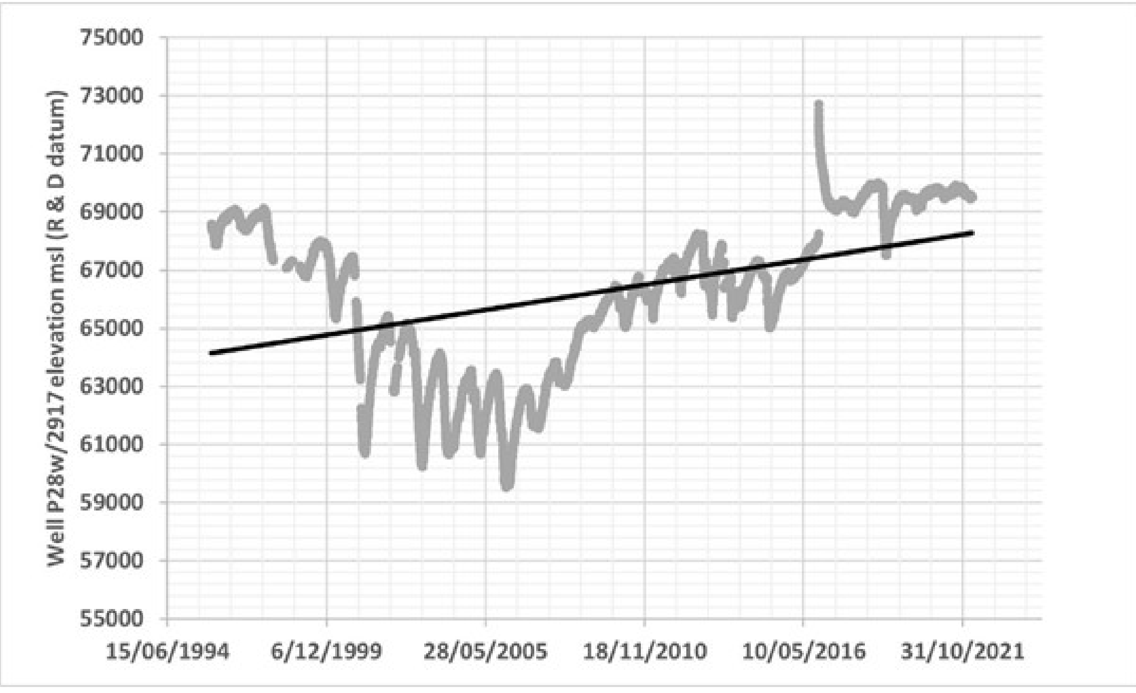

Figure 117: Groundwater elevation with trend line

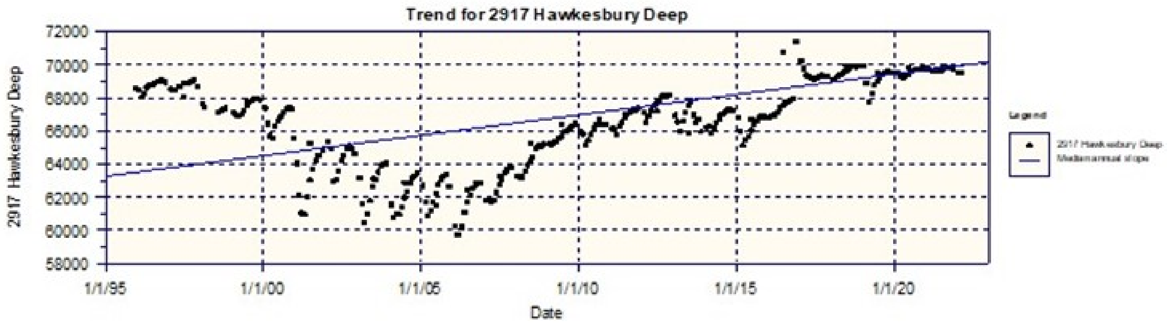

Figure 118: Seasonal Kendall test

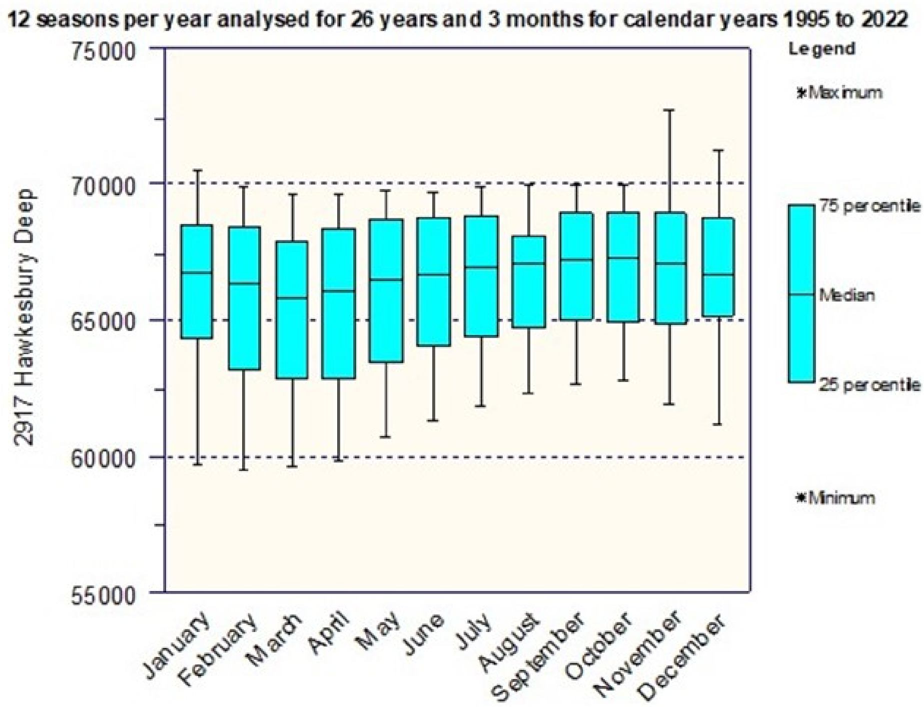

Figure 119: Seasonality

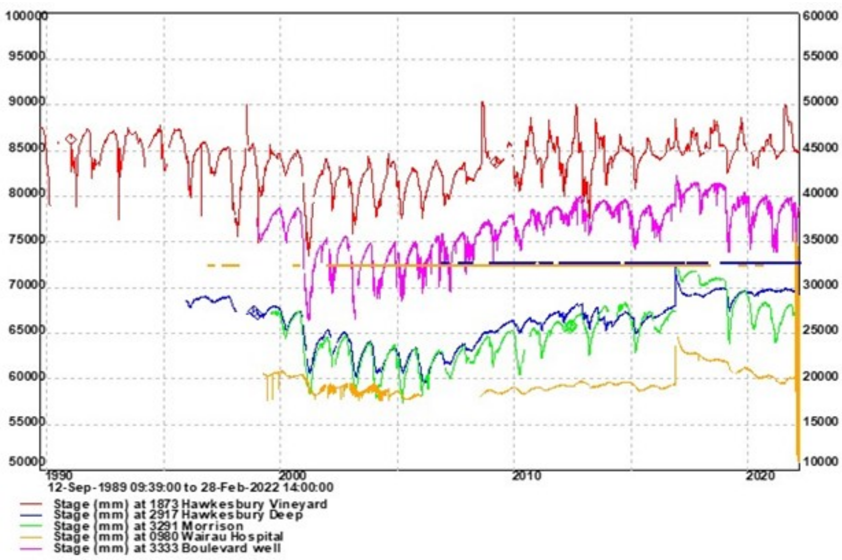

Figure 120: Wairau Plain deep groundwater strata elevation patterns

4.28. Benmorven Aquifer

The Benmorven Aquifer which forms part of the Southern Valleys Aquifer suite, is located south-west of Blenheim and is the most highly confined of the deeper aquifers. MDC monitor Benmorven Aquifer groundwater level at two sites: Morven Lane well P28w/2022 and deeper well P28w/3291 at Fairhall. Figure 121 shows a clear declining trend in groundwater level at well 2022 since continuous measurements started in 1990 of several metres.

This is not a simple unidirectional trend, but mimics the pattern seen in the neighbouring Brancott and Omaka Aquifers where excessive abstraction from the mid 1990's to 2001 caused large falls in levels. This was followed by a recovery from about 2008 onwards, due to the introduction of SVIS reducing demand on local aquifers. In terms of current state, aquifer levels remain around five metres lower than in 1996 which reflects the Benmorven FMU definition in the Marlborough Environment Plan as overallocated. Figure 121 shows the influence of the late 2016 Kaikōura earthquake which caused groundwater levels to rise by several metres, but levels have subsequently receded. Given its depleted state, the potential exists for current consented demand to cause groundwater levels to fall below cut-off thresholds in a single season and the FMU is cautiously managed on this basis. The Seasonal Kendall test shows a declining trend with a P value of 0.00 which is significant at the 95% (0.05) confidence level (Figure 122). The magnitude of the decline is less important as it is pumping induced. Figure 123 shows how groundwater level at the MDC well 2022 varies from month to month. The range since 1990 is around 15 metres which is very large and mostly reflects pumping not natural recharge/drainage processes. The natural range is probably around one metre/year based on the limited record in 1990 when use was low. The Cusum plot confirms an overall downwards trend although the influence of the bounce back post 2008 is evident (Figure 124).

In terms of drivers of groundwater level variation, abstraction dominates Benmorven Aquifer groundwater levels, although MDC are still building the real time, cumulative demand pattern. Benmorven Aquifer state is low.

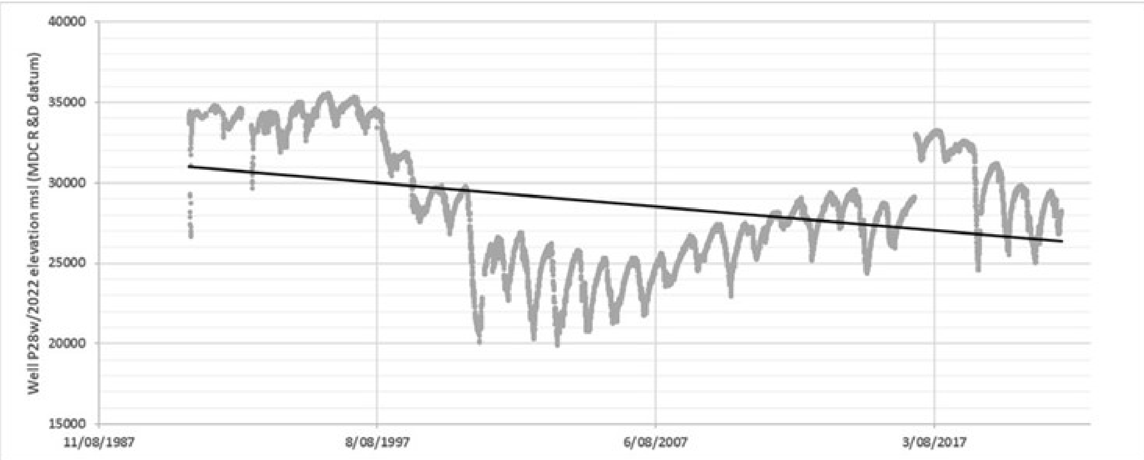

Figure 121: Groundwater elevation with trend line

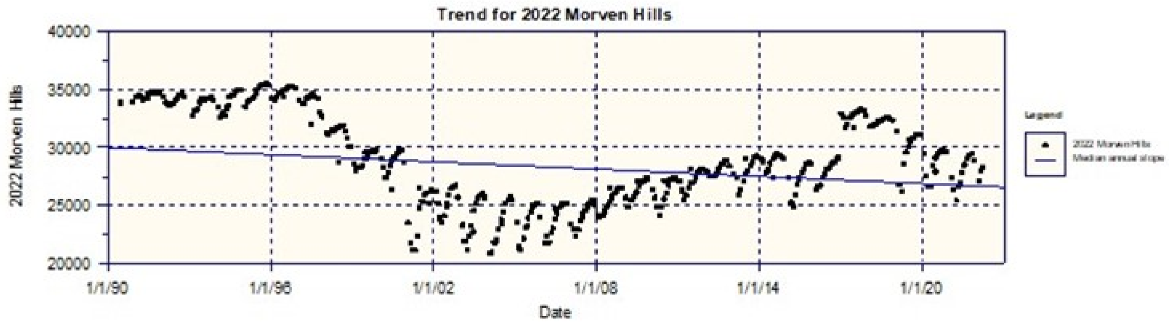

Figure 122: Seasonal Kendall test

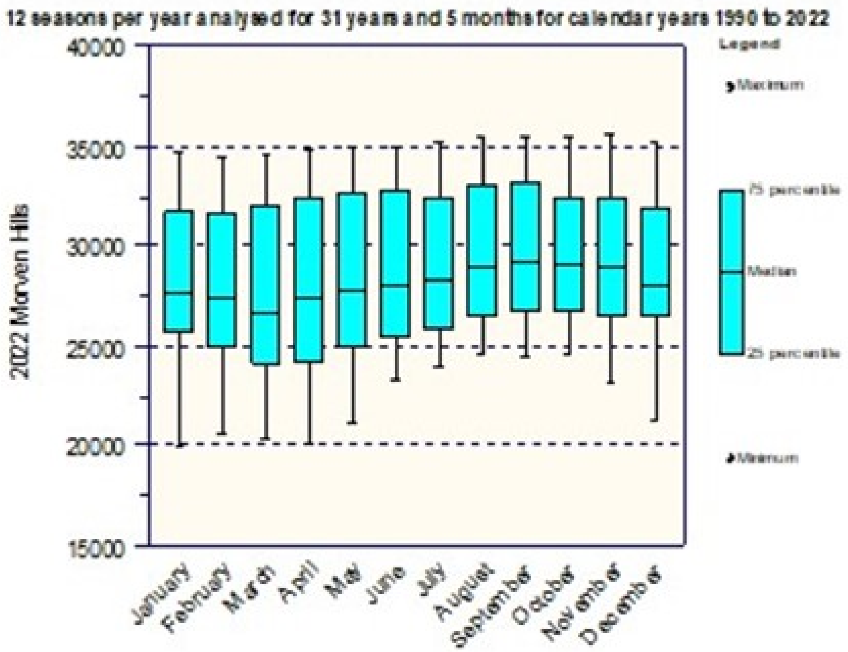

Figure 123: Seasonality

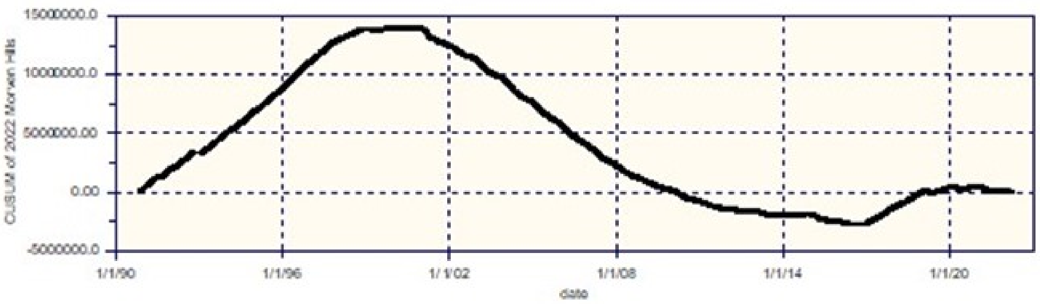

Figure 124: Cusum

4.29. Benmorven Aquifer

The deeper of the two MDC monitoring wells representing the Benmorven Aquifer is located near New Renwick Road, just east of Fairhall school. Well P28w/3291 is screened between 81 and 151 metres depth. Figure 125 shows well 3291 (grey) exhibits a similar variation in groundwater level to MDC monitoring well 2022 (orange). Because well 3291 was drilled and monitored around a decade later than 2022, the long-term pattern is not represented in Figure 125 and gives the impression that in terms of state, aquifer levels have risen above their start elevation. This is not the case with the Benmorven Aquifer remaining in a depleted state relative to its pre-pumping levels in 1990. In the case of well 3291 there is an evident rising pattern since about 2007 onwards, when pressure on the Benmorven Aquifer was relieved with the introduction of SVIS. The 2016 Kaikōura earthquake artificially raised aquifer levels by the order of metres, but no more water was added to the system. The Seasonal Kendall test confirms the obvious increasing trend. In terms of drivers of groundwater level variation, abstraction dominates the variation in Benmorven Aquifer level. MDC are still building the real time, cumulative picture of consented abstraction from the Benmorven Aquifer to relate cause and effect. Well 3291 levels peak in August and early Spring and reach their annual minimum in March at the tail end of the irrigation season (Figure 127).

The Cusum plot confirms the increasing trend in well 3291 levels with time.

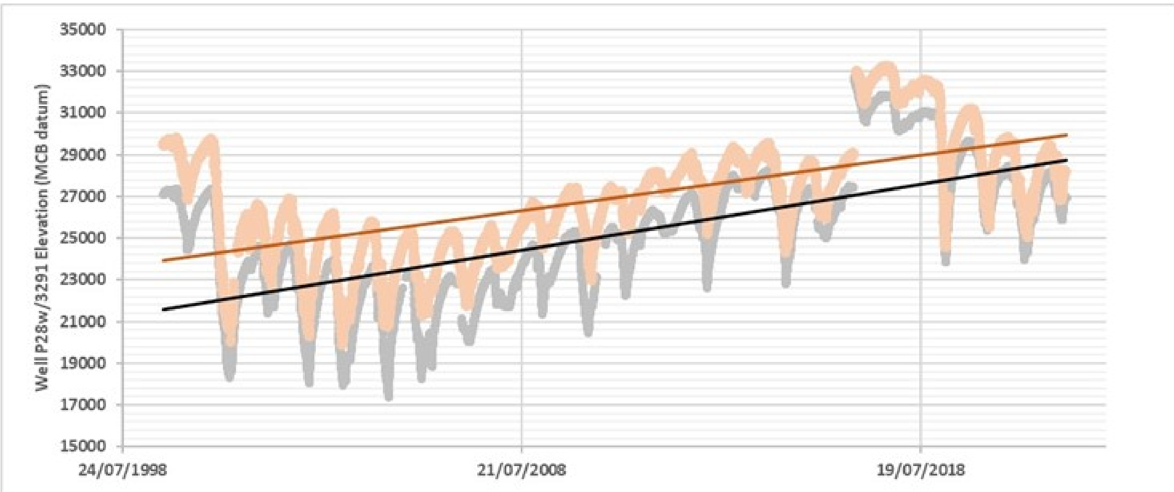

Figure 125: Groundwater elevation at wells 3291 & 2022 with trend lines

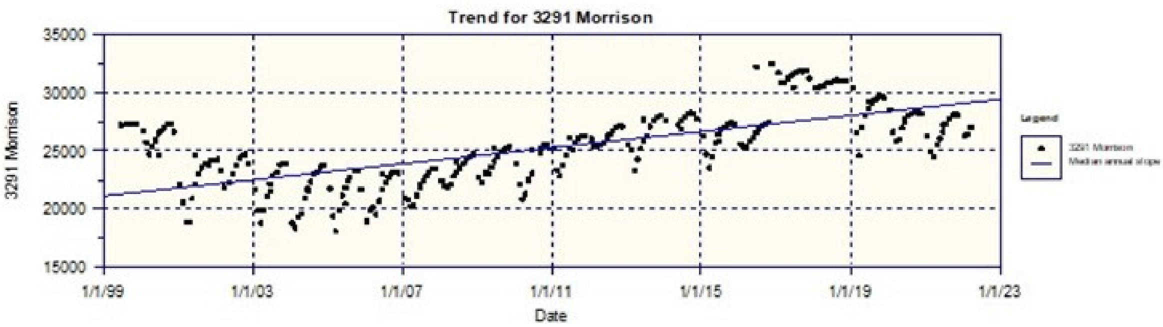

Figure 126: Seasonal Kendall test

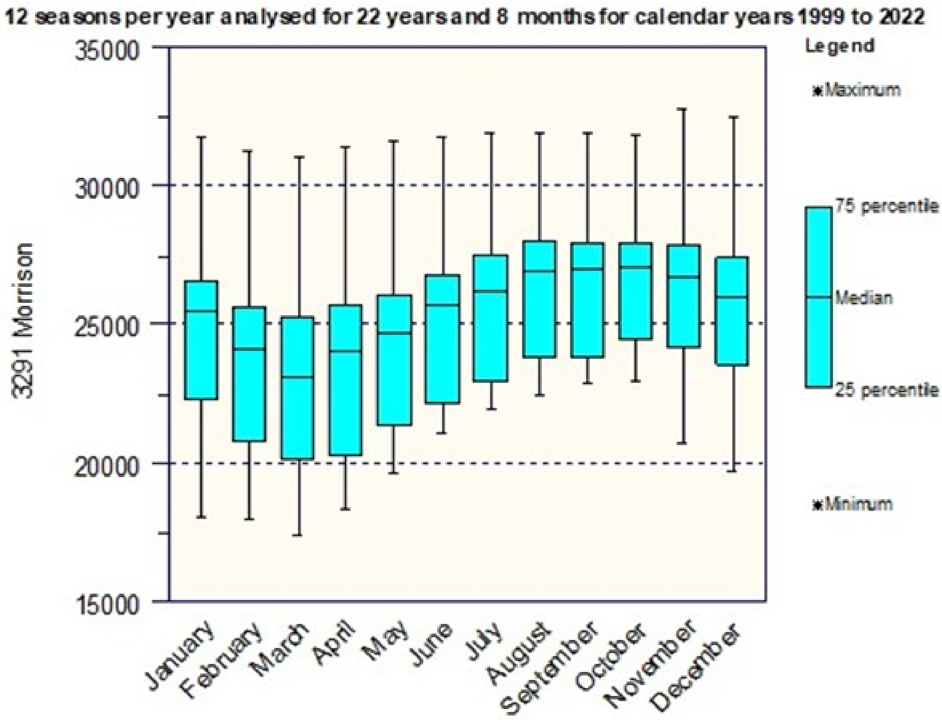

Figure 127: Seasonality

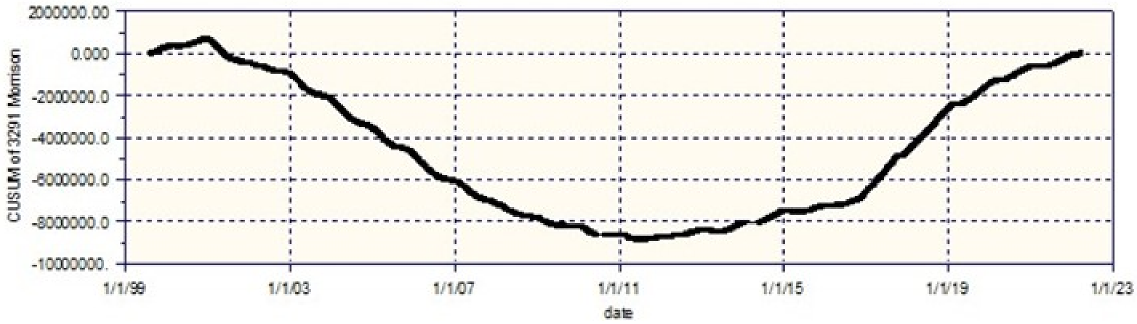

Figure 128: Cusum

4.30. Waikakaho River Gravels Aquifer

The Waikakaho River Gravels Aquifer is a riparian aquifer associated with the alluvium forming the valley floor surrounding the Waikakakho River on the North Bank of the Wairau River, west of Tuamarina. While not defined in the MEP yet or highly used, MDC operate a permanent water level recorder there as an indicator of total catchment flow (surface/ground). Another reason for MDC establishing the site was that little was known hydrologically about these North Bank catchments and valley floor aquifers.

There is an average upwards trend of around 15mm/year since 2009 (Figure 129). A virtually certain upwards trend of 13mm/year was identified by the Seasonal Kendall test at the 95% confidence level with a P value of 0.00 (Figure 130).

Due to the moderating effect of the hydraulic connection with the Waikakaho River, 50% of the time on a monthly basis groundwater levels vary by only 200mm or less (Figure 132). Groundwater levels peak in June and reach their minimum in March, although there is not a lot of difference between months. Figure 131 compares the spiky, river influenced hydrograph for well 10109 in late 2015, with the more subdued Wairau Aquifer Recharge Sector well 3821. The Cusum analysis also showed an upwards trend in groundwater level since 2009 (Figure 133). Aquifer state is described as high.

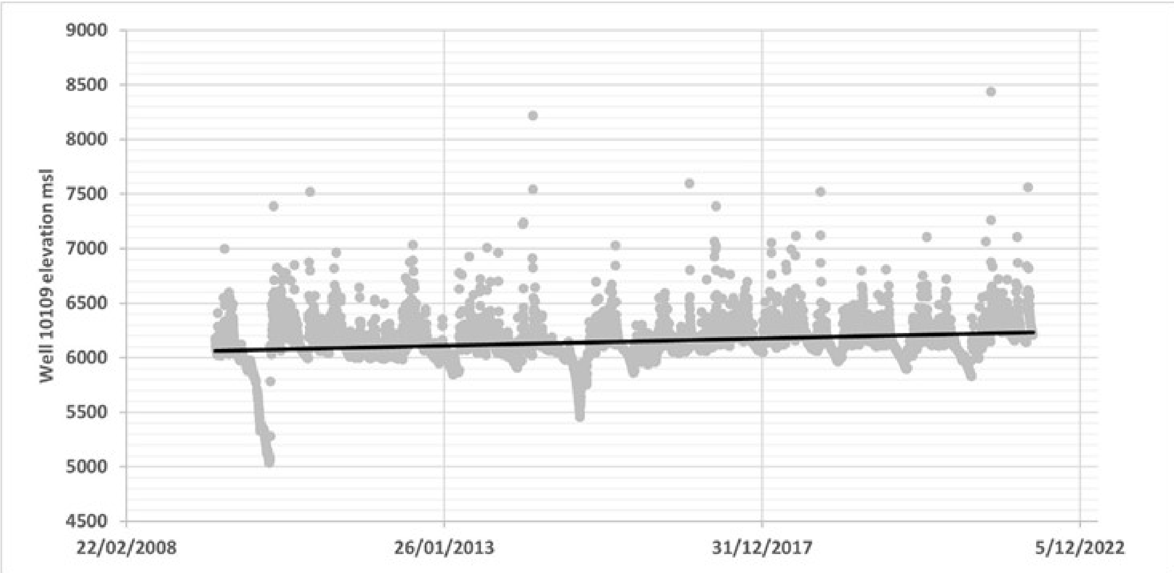

Figure 129: Groundwater elevation with trend line

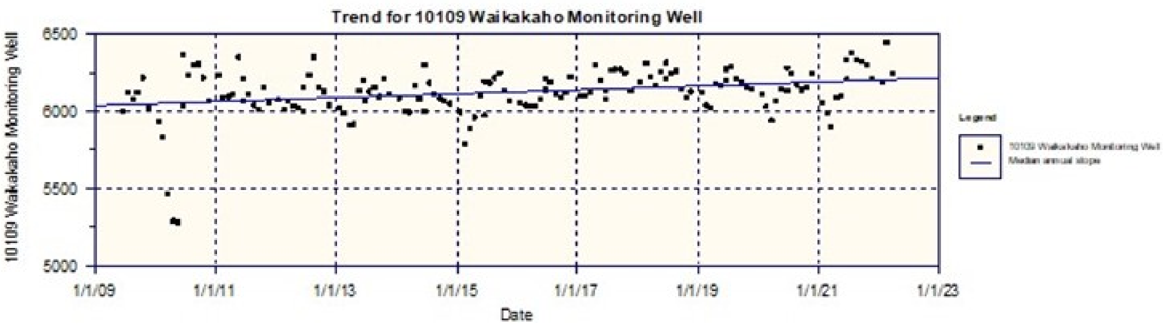

Figure 130: Seasonal Kendall test

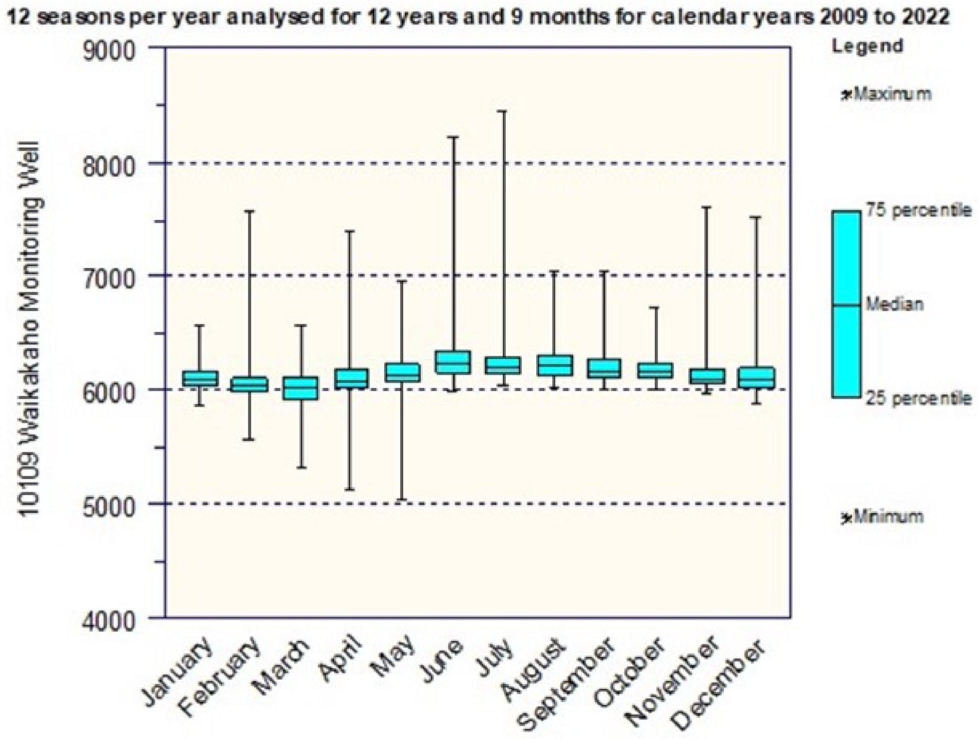

Figure 131: Seasonality

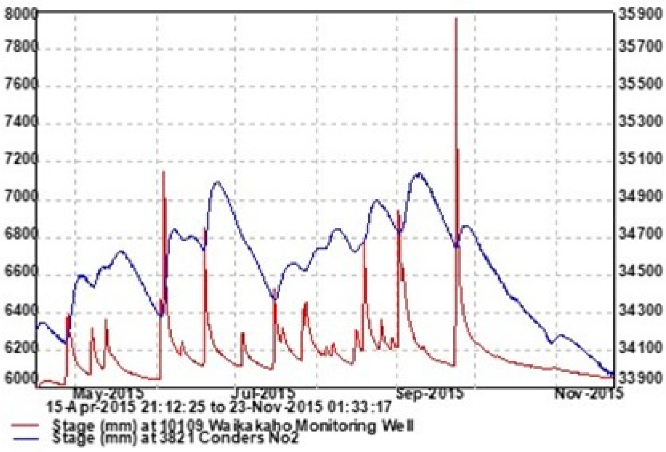

Figure 132: WRGA versus Wairau Aquifer groundwater elevation

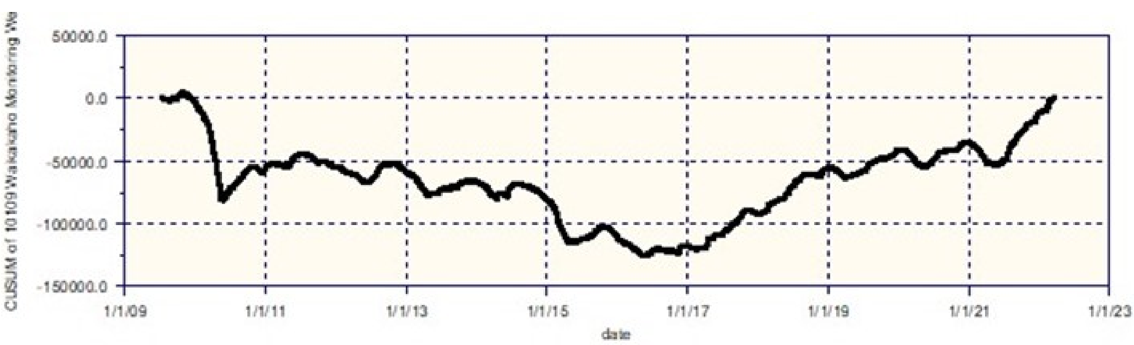

Figure 133: Cusum

4.31. Wairau Valley Lower Terrace

The intensively farmed terraces forming the Southbank of the Wairau Valley are underlain by locally important groundwater resources. The most productive is associated with the lower terrace closest to the Wairau River. Most drinking and stock water is supplied from shallow wells, but most crop irrigation water is pumped and piped from galleries near the Wairau River channel. MDC monitor Wairau Valley groundwater levels on the lower terrace at MDC shallow well O28w/0220 at Mill Road.

There appears to be a slight decreasing trend in groundwater levels since 2007 when the site was established by MDC and monitoring began (Figure 134). The Seasonal Kendall test showed a decreasing trend was possible but was not statistically significant at the 95% confidence level based on the P statistic value of 0.110 relative to the standard of 0.05 (Figure 135). The seasonality plot (Figure 136) shows peak aquifer levels are similar in winter through to spring and fall to their annual minimum in March. The 50-percentile groundwater elevation range is small compared to other aquifers. Most groundwater originates as rainfall-runoff from the southern hills based on stable isotope measurements, not the Wairau River, although it may have a damming effect on drainage. During the 2019/2020 summer there was a large fall in groundwater levels relative to previous recessions at this site. It may have reflected localised abstraction near the well, less recharge or a change in the boundary formed by the Wairau River channel.

It is fair to say the hydrology of the Wairau Valley area is still being investigated by MDC and a longer period of record is needed to draw firm conclusions and current aquifer state is classed as normal. The Cusum analysis indicated a declining trend as Figure 137 shows.

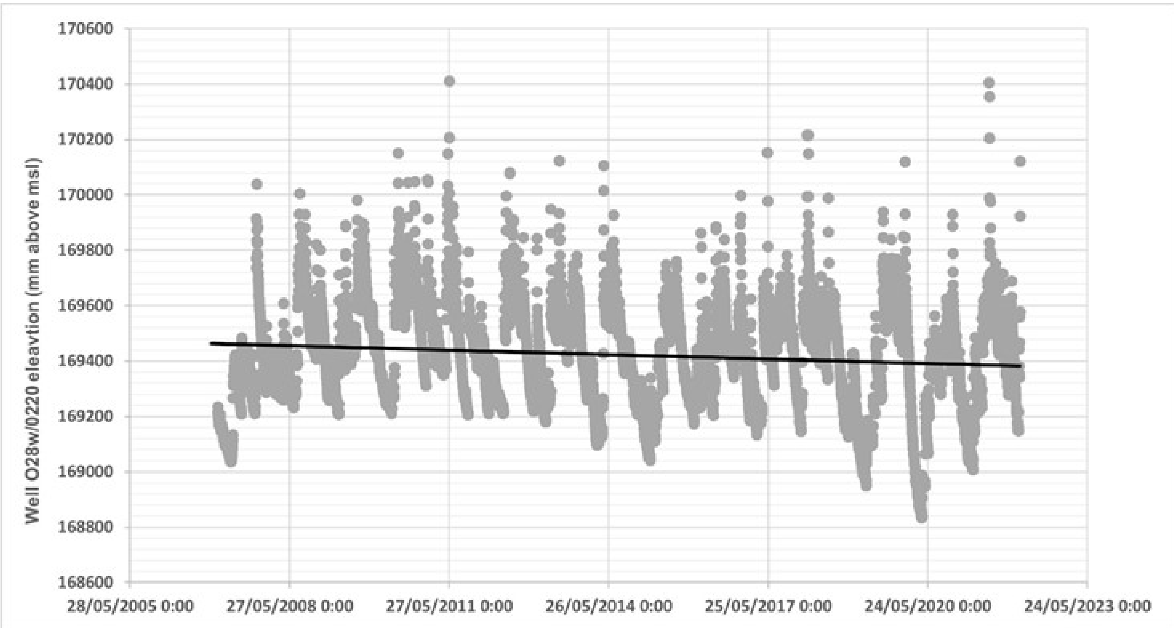

Figure 134: Groundwater elevation with trend line

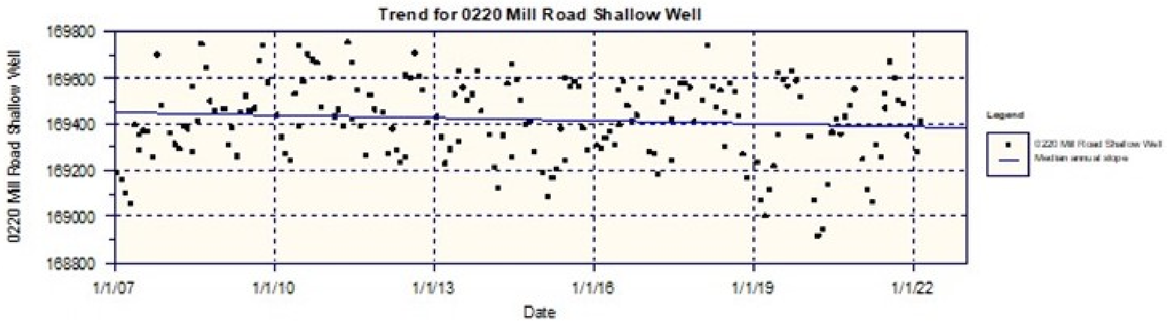

Figure 135: Seasonal Kendall test

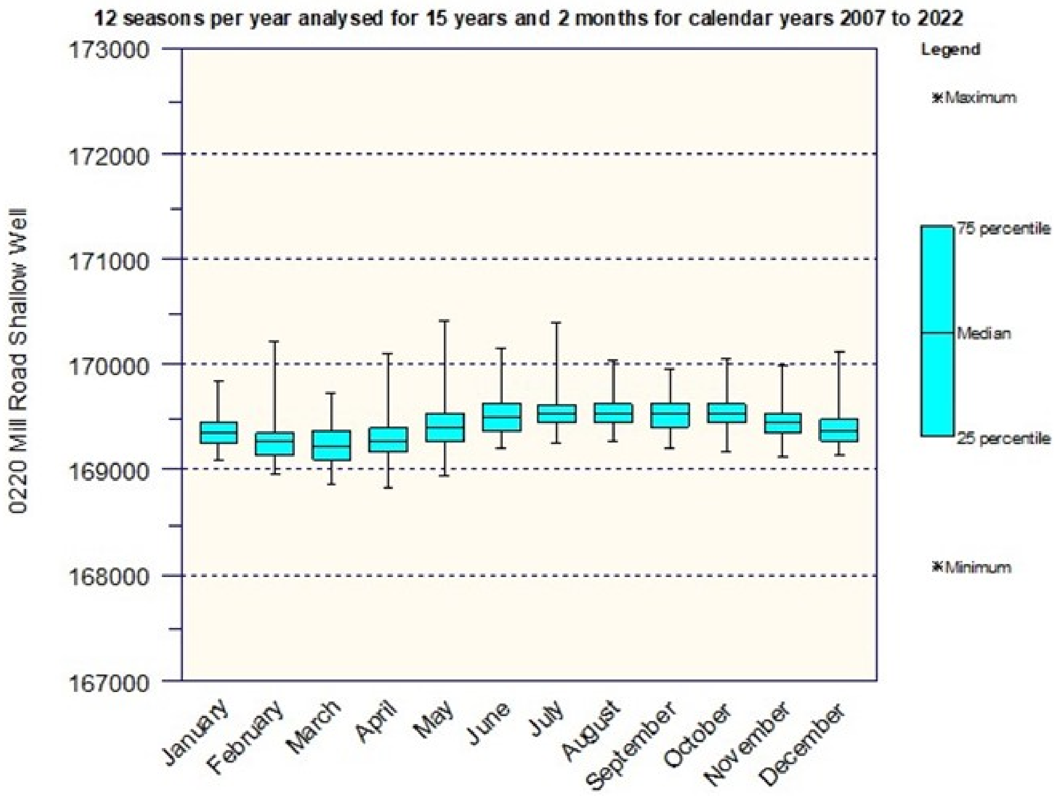

Figure 136: Seasonality

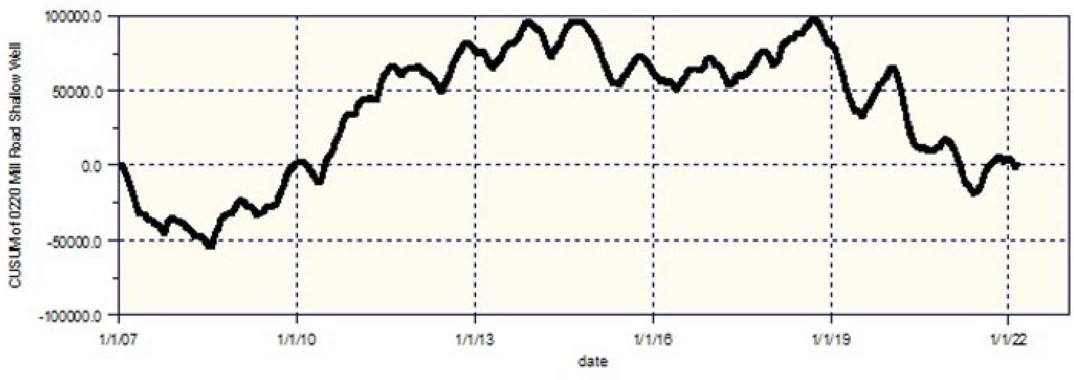

Figure 137: Cusum