

**REVIEW OF DEEP WAIRAU AQUIFER
- GROUNDWATER CHEMISTRY
ASPECTS**

July 2008

Client Report
CSC0806

**REVIEW OF DEEP WAIRAU AQUIFER
- GROUNDWATER CHEMISTRY
ASPECTS**

for the
Marlborough District Council

by
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July 2008

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TABLE OF CONTENTS

EXECUTIVE SUMMARY and RECOMMENDATIONS	i
INTRODUCTION	1
GROUNDWATER CHEMISTRY OF DEEP WAIRAU AQUIFER	2
TEMPORAL TRENDS IN GROUNDWATER CHEMISTRY	4
DISCUSSION.....	10
RECOMMENDATIONS FOR FUTURE WORK	11
REFERENCES	12

EXECUTIVE SUMMARY AND RECOMMENDATIONS

The Deep Wairau Aquifer was discovered about 10 years ago following drilling of a series of very deep wells in the New Renwick Road area. These wells were screened at depths between 150 and 300 metres below the surface. An initial assessment was carried out at the time considering piezometric data, groundwater chemistry and isotope information. Water in the aquifer was very old and there was no information about whether the aquifer was still being recharged or still connected to present day recharge sources. It was recommended that the aquifer be pumped over the next few years and monitored to determine whether recharge was occurring and, if possible, the source of any recharge.

This EnviroLink project is to review the monitoring data collected over the past 10 years. This includes the pumping volumes, water level responses, groundwater chemistry and isotope data. This report focuses on the groundwater chemistry data but the other information is also considered.

The pH values of the Deep Wairau Aquifer wells were usually greater than 8, with associated high levels of alkalinity (130 - 180 mg/L as HCO₃). Levels of nitrate-N (all < 0.2 mg/L), sulphate (all < 8 mg/L), calcium (all < 20 mg/L) and magnesium (all < 7 mg/L) were all reasonably low in the Deep Wairau Aquifer. There was significant variability between wells in chloride levels (35 - 130 mg/L), sodium (68 - 110 mg/L) and conductivity (35 - 71 mS/m). The Deep Wairau Aquifer wells have a lot more sodium and chloride than wells in the shallow Wairau aquifers and would be characterised as a sodium-bicarbonate-chloride water.

A total of 18 samples have been taken from well 3278 over the past 10 years. Concentrations of all parameters for showed fairly constant levels with time. There is a slight indication of a decrease in levels in 2000/01 for sodium, potassium and magnesium but otherwise the time series indicate little change in groundwater chemistry over the 10 year period. The decrease in concentrations of some ions in 2000/01 occurred at the same time as the maximum pumping and drawdown in well 3278 and may reflect water being drawn into the well from a slightly different location or depth.

As discussed in the earlier report (Close, 1999), the high levels of chloride, alkalinity and sodium compared to likely sources (Wairau or Waihopai Rivers) indicate that significant chemical evolution of the groundwater chemistry has occurred. The high levels of these elements would have resulted from extensive contact with the aquifer media. This is consistent with the groundwater being old as indicated by the radio-isotope data. The relatively constant groundwater chemistry over the last 10 years is also consistent with this being very old groundwater.

The groundwater chemistry results do not distinguish between either the Wairau, Waihopai, or Omaka rivers as recharge sources, and the groundwater chemistry would be consistent with any of these as recharge sources. Environmental isotope results indicate a high altitude source implying either the Wairau or Waihopai Rivers as a recharge source, although the age of the water means that the altitude of the recharging water is less certain as climatic conditions and rainfall patterns could be different. Both the chemistry and the environmental isotope data indicate that the water is old.

The amount of pumping combined with the annual recovery of water levels implies that the Deep Wairau Aquifer is being recharged to some extent and/or the aquifer is larger than previously thought. The reasonably constant groundwater chemistry does not indicate a source of recent recharge but suggests that any recent recharge has not, at this stage, been intercepted by any of the sampled wells.

Recommendation 1: The recovery of water levels in the Deep Wairau Aquifer indicates that either recharge is occurring or the aquifer is very large. It is probable that more consents for more pumping could be granted without negatively affecting this aquifer. The possibility of interference effects with other hydraulically-connected aquifers needs to be considered.

Recommendation 2: Continue annual sampling of wells 980, 3278 and 3291. Review the data in a further 10 years time.

Recommendation 3: Continue monitoring of groundwater levels and recording of pumping from the Deep Wairau Aquifer.

Recommendation 4: Carry out further isotope sampling and analysis in 5 years time. A sample for water chemistry should be taken at the same time.

INTRODUCTION

The Deep Wairau Aquifer was discovered about 10 years ago following drilling of a series of very deep wells in the New Renwick Road area. These wells are screened at depths between 150 and 300 metres below the surface. It is currently known to occur beneath the Fairhall, Woodbourne and Southern Valleys Aquifer areas. An initial assessment was carried out at the time considering piezometric data, groundwater chemistry and isotope information. Water in the aquifer was very old and there was no information about whether the aquifer was still being recharged or still connected to present day recharge sources. It was recommended that the aquifer be pumped over the next few years and monitored to determine whether recharge was occurring and whether there was any information about the source of any recharge and the sustainable yield of this aquifer.

This EnviroLink project is to review the monitoring data collected over the past 10 years. This includes the pumping volumes, water level responses, groundwater chemistry and isotope data. This report focuses on the groundwater chemistry data but the other information is also considered. A companion report by GNS, focuses on the isotope data (Morgenstern et al., 2008). MDC has summarised the hydrological data for the Deep Wairau Aquifer, including metered well use and continuous water level recording (Davidson, 2008). The groundwater chemistry of the Deep Wairau Aquifer was characterised, based the available data at the time by ESR in 1999 (Close, 1999). That report also compared the groundwater chemistry of the Deep Wairau Aquifer to that of other aquifer systems in the Wairau Plains to see if there were similar chemistries, and hence similar recharge sources, and similar levels of chemical evolution.

The aquifer systems in the Wairau Plains are briefly summarised. The most productive aquifer is the Wairau River Aquifer, which is a shallow aquifer system, recharged by the Wairau River. It flows east towards the sea and changes from unconfined to semi-confined to confined as it progresses down the valley. Along the coast is the shallow Rarangi Aquifer. The Kaituna Aquifer is on the north bank of the Wairau River and would be recharged by the Wairau River, similar to the Wairau-unconfined Aquifer. The next group of aquifers are known as the southern valley aquifers and consist of a series of aquifers which proceed out of the valleys to the south of the Wairau Plains. These are the Waihopai, Omaka River Valley, Omaka, Brancott, Benmorven and Taylor-Burleigh Aquifers. These are less productive systems with higher levels of chemical parameters, reflecting the lower levels of recharge in the southern valleys. The Woodbourne Aquifer is at the boundary of the Wairau River Aquifer and some of the southern valley aquifers. Below these aquifers are deeper aquifers which have been called the Deep Wairau Aquifer (focus of this investigation), Deep Wairau/Benmorven Aquifer and the Brancott - Deep Aquifer. These aquifers are less well known and their extent, properties, and interactions are currently under investigation.

This report focuses on the groundwater chemistry monitoring data from the Deep Wairau Aquifer. Further groundwater chemistry sampling has taken place for 3 wells over the past 10 years, in particular for well 3278. The objectives of this report are to :

- analyse the groundwater chemistry monitoring data to determine any trends since pumping began around 1998,
- integrate the groundwater chemistry data with other monitoring data to infer a likely source of recharge and reservoir characteristics.

GROUNDWATER CHEMISTRY OF DEEP WAIRAU AQUIFER

Extensive surveys of most of the Wairau Plains aquifer systems were undertaken for major ion chemistry during 1994 and 1995 (Close, 1994, 1995). These results were used to characterise these aquifer systems and were combined with more recent sampling and analysis of the deeper aquifer systems to provide a comparison by Close (1999). Continued sampling has taken place for three wells from the Deep Wairau Aquifer, wells 980, 3278 and 3291. Unfortunately other wells from the Deep Wairau Aquifer were not able to be monitored, generally because suitable pumps were not available or would have been too expensive to install for a single sample collection. The full results of chemical samples from the Deep Wairau Aquifer taken between 1998 and 2008 are given in Table 1. A total of 7 wells have been identified as belonging to the Wairau Deep Aquifer. The mean chemical concentrations for all the Wairau aquifers, including the Deep Wairau Aquifer, are given in Table 2. Where there was more than one sample per well, averages were taken for each well before calculating the average for the aquifer. This ensures that the average estimates for the aquifer are not skewed in favour of wells that have had more sampling occasions. The locations for the Deep Wairau Aquifer wells with chemical data are given in Figure 1. The details for each well from the Deep Wairau Aquifer are given in Appendix 1.

Ion balances were calculated for each sample. The ionic balances were generally good. There were three exceptions for well 3278. The ionic balance for the sample taken in January 2003 was too high for the cations and too low for the anions with the measured conductivity about equal to the calculated value. An exchange of the Cl and Na values (which were lower and higher, respectively, than other Cl and Na values from that well, would have improved the ionic balance. However these were the values on the laboratory sheets so any exchange would have happened at the laboratory and cannot be further checked. The conductivity values for samples taken in July and November 2005 were significantly higher (71 and 65 mS/m) than those calculated from the measured ions (55 and 54 mS/m). The estimated conductivity values of 55 and 54 mS/m are probably correct. The ionic balance for well 2917 was unsatisfactory. Considering the ionic and conductivity balance the chloride concentration was probably in error and was estimated as 50 mg/L. Occasionally there were missing data from the analysis. Where there were only one or two missing analyses these were estimated from the ionic balance and this is indicated in Table 1 with an asterisk.

The Deep Wairau Aquifer wells are dominated by sodium, bicarbonate, and chloride and would be characterised as a sodium-bicarbonate-chloride water. They are most similar to the Benmorven wells. The pH values of the Deep Wairau Aquifer wells were usually greater than 8 (well 3333 had widely varying values for pH of 7.3 and 8.6 on the two sampling occasions). All other aquifers in the Wairau Plains have pH values less than 8.0, although Benmorven is near this with a value of 7.9 (Table 2). Alkalinity was high, ranging between 130 and 180 mg/l as HCO₃ which is consistent with the high pH. Levels of nitrate-N (all < 0.2 mg/l), sulphate (all < 8 mg/l), calcium (all < 21 mg/l) and magnesium (all < 7 mg/l) were all reasonably low in the Deep Wairau Aquifer. There were variable but generally low levels of iron and manganese detected in these wells. Ammonia levels were around 0.25 mg/L in well 980 but were around the 0.05 mg/L for the other wells in the Deep Wairau Aquifer (Table 1). Boron levels ranged from 0.08 mg/L in well 3291 to 0.9 mg/L in well 980. Well 980 is

weakly artesian but there is no pumping from this well. It is located furthest to the east and has the

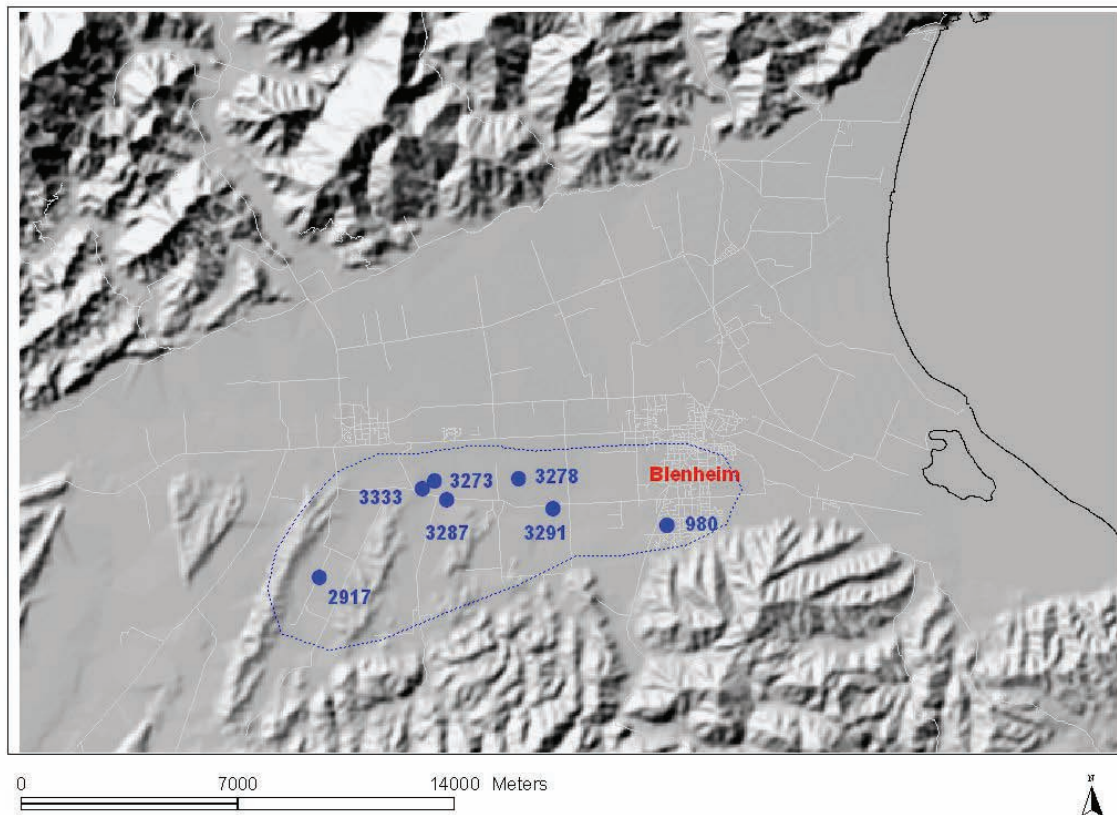


Figure 1: Location of Deep Wairau Aquifer wells.

oldest groundwater age. It is possible that there may be upwelling of water from greater depths into this well as the well depth is relatively shallow compared to other wells in the Deep Wairau Aquifer. The low nitrate and sulphate values indicate that there has been reduction of these parameters, presumably because of redox conditions.

There was more variability between wells for chloride, sodium and conductivity (Table 1) with these variables being highly correlated. Mean chloride levels for each well ranged from 35 to 137 mg/L, mean sodium levels for each well ranged from 43 to 113 mg/L, and mean conductivity levels for each well ranged from 35 to 71 mS/m. Well 980 had the highest values followed by well 3278, with the remaining wells having reasonably similar, lower values. The levels of these parameters were generally higher for the Deep Wairau Aquifer than in other aquifer systems in the Wairau Plains.

The variability between wells for chloride, sodium and conductivity appears to be related to the distance along the valley towards the east (or coast) and the depth of the well screen(s). This is discussed more fully by Close (1999) and is briefly summarised here. There was a slight positive relationship between groundwater chemistry and screen depth, but there is significant variability in this relationship (Close 1999). Some of this is probably the result of the very long screen lengths and multiple screens that occur in some of the wells which makes

it difficult to determine what depth the water is coming from. There was a much better relationship between groundwater chemistry and distance down the valley. The distance down the valley is likely to be related to travel distance and time. This would be consistent with a conceptual model of the Deep Wairau Aquifer where the water was moving slowly down the valley, with little variation in movement with respect to depth.

The groundwater chemistry results do not distinguish between either the Wairau, Waihopai, or Omaka rivers as recharge sources, and the groundwater chemistry would be consistent with any of these as recharge sources (Close 1999). Environmental isotope results indicate a high altitude source implying either the Wairau or Waihopai Rivers as a recharge source. However, the effect of the age of the water on implied recharge altitude should be noted as 10,000 years ago the climate was colder and the rain was more negative compared to present day conditions (Morgenstern et al., 2008). This makes the implication of a high altitude source less certain. Both the chemistry and particularly the environmental isotope data available in 1999 indicated that the water is old. The water chemistry is still similar and would confirm that the water is old and reasonably similar to that sampled 10 years ago. The piezometric heads indicate that, if the recharge source is the Wairau or Waihopai Rivers, the recharge area must be some distance upstream.

TEMPORAL TRENDS IN GROUNDWATER CHEMISTRY

The main recommendation from the initial study that assessed the Deep Wairau Aquifer was to pump from the aquifer and monitor any effects on the water levels, water chemistry and isotopes. This section examines temporal changes in groundwater chemistry over the last 10 years. Multiple groundwater samples have been collected over the last 10 years from 3 wells, 980 (3 samples), 3291 (2 samples), and 3278 (18 samples).

The three samples from well 980 show consistent water chemistry over time for all the parameters that were measured (Table 1). There is a slight increase in the iron value for the sample collected in 2001 but the levels in 2008 are the same as in 1999, indicating that the slightly higher iron value was probably a sampling artefact in 2001.

There are some significant differences in water chemistry between the 2 samples from well 3291. The chloride value is much higher in 1998 (51 mg/L) compared to 2008 (18 mg/L), as is the Na and conductivity values (Table 1). This well has 3 well screens (82 – 86 m; 116 – 127 m; 133 – 151 m). Downhole logging indicated that most of the water was coming from the top and bottom screens (P Davidson, MDC, pers. comm.). It is possible that the variation in water chemistry results from varying proportions of water from the differing screen depths.

Most of the groundwater chemistry monitoring over the past 10 year is from well 3278 and the remainder of this section focuses on data from that well. The time series are shown for pH and conductivity (Figure 2); sodium and calcium (Figure 3); potassium and magnesium (Figure 4) and alkalinity, chloride and sulphate (Figure 5). The two points that show the most variation for conductivity (July and November 2005) are the same points that have already been discussed as probably being in error based on the ionic balance. The conductivity values calculated based on the concentrations of ions in the samples were 55 and 54 mS/m for the July and November 2005, respectively. These would be similar to other conductivity values

and would indicate that conductivity values in well 3278 were fairly constant over the 10 year period.

Table 1: Summary of Chemistry data from Deep Wairau Aquifer

Well #	Date	pH	Alkalinity as HCO ₃	Conductivity mS/m	Cl (mg/L)	NO ₃ -N (mg/L)	SO ₄ (mg/L)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Fe (mg/L)	Mn (mg/L)	B (mg/L)	NH ₃ (mg/L)
980	Jun-99	8.0	180	71	130	<0.05	<0.2	110	1.0	16	6.7	0.29	0.18	0.90	0.25
	Jul-01	8.2	180	70	140	<0.05	<0.2	110	1.0	18	6.6	0.72	0.18		
	Jan-08	8.0	180	71	140	0.002	0.002	120	1.1	16	6.7	0.23	0.19	0.96	0.26
2917	Sep-95	8.1	155	41	50*	0.02	7.5	70	0.9	19	0.9	0.2	0.02		
3273	Jun-99	8.2	150	37	39	<0.05	3.7	51	0.8	21	3.3	<0.05	0.02		<0.04
3278	May-98	8.3	130*	56	110	<0.05	7.7	90	0.7	17	0.5	0.06	0.02	0.59	
	Sep-98	8.3	146	58*	110	0.02	1.8	100	0.7	17	0.7				
	Jun-99	8.5	150	58	110	<0.05	1.4	98	0.6	18	0.5	<0.05	0.011	0.58	0.06
	Jul-00	8.5	140	59	110	<0.05	1.5	83	0.5	17	0.4	<0.05	0.012		
	Jul-01	8.5	140	57	100	<0.05	1.7	89	0.5	18	0.5	0.05	0.013		
	Jan-03	8.3	142	56	86#	<0.05	1.1	111#	0.7	20	0.6	<0.05	0.016	0.67	<0.05
	Jan-05	8.5	134	58	100	0.005	1.9	98	0.5	18	0.6	0.01	0.015	0.68	0.053
	Apr-05	8.4	146	56	98	<0.02	2.0	92	0.7	17	0.6	0.02	0.016	0.65	0.055
	Jul-05	8.4	146	71#	100	<0.02	1.9	98	0.4	17	0.5	0.02	0.013	0.64	0.058
	Nov-05		146	65#	100	<0.002	1.9	93	0.5	17	0.6	0.015	0.013	0.65	0.066
	Feb-06		150	54*	100	0.005	1.9	92	0.8	16	0.6	0.019	0.015	0.68	0.063
	Nov-06	8.3	160	56	100	0.004	1.8	95	0.7	17	0.5	0.009	0.015	0.71	0.057
	Feb-07	8.5	150*	56	97	0.002	1.7	89	0.7	17	0.6	0.009	0.015	0.70	0.042
	May-07		130	55*	100	0.004	1.8	99	0.9	19	0.6	0.013	0.014	0.74	0.064
	Jul-07	8.4	150	56	99	<0.002	1.9	93	0.7	18	0.6	0.034	0.014	0.70	0.068
	Aug-07	8.6	144	56	102	<0.01	1.7	95	0.7	18	0.6	0.023	0.014	0.72	0.050
	Nov-07	8.7	131	56	104	<0.01	1.7	111	0.6	17	0.5	0.013	0.012	0.69	0.060
	Jan-08	8.5	150	55	99	<0.002	3.1	95	0.6	17	0.5	0.013	0.014	0.70	0.054
3287	Apr-98	8.5	146	35	35	0.16	4.3	70*	0.5*	8.4	0.26	0.43	<0.01		
3291	Nov-98	7.5	146*	41	51	0.05	4	49	1.3	21	8.6	0.06	0.15		
	Jan-08	7.7	160	32	18	0.007	3.9	36	1.3	19	7.2	0.25	0.04	0.08	<0.05
3333	Aug-98	7.3	144	42	56	0.078	5.1	68	0.9	14	4.9	0.56	0.05		
	Jun-99	8.6	180	44	55	<0.05	1.2	80	0.5	8.9	1.4	0.11	0.02	0.22	0.05

Note: * These values were estimated from the ion balance; # The ionic balance indicates that these values may be in error

Table 2: Mean chemical concentrations for aquifers in the Wairau Plains

Aquifer	pH	Acidity as CO ₂	Alkalinity as HCO ₃	Conductivity mS/m	Cl	NO ₃ -N	SO ₄	Na	K	Ca	Mg	Fe	Mn
Wairau- unconfined	6.8	9.2	35	7.5	4.2	0.6	3.8	4.8	0.8	8.2	2.0	0.23	0.00
Wairau- semiconfined	7.0	9.8	54	11.5	4.8	1.5	5.7	8.0	1.0	12.2	3.5	0.43	0.01
Wairau- confined	7.2	7.3	52	11.1	6.9	0.8	4.0	10.1	1.3	9.1	3.1	0.02	0.02
Kaituna	6.8	7.5	20	4.9	6.1	0.1	1.9	4.6	0.7	4.8	1.2	0.00	0.00
Rarangi	7.4	10.0	153	26.3	12.6	0.4	9.7	13.3	1.4	41.0	5.5	0.83	0.07
Waihopai	6.6	12.7	24	12.3	3.4	7.3	9.4	9.2	0.8	9.9	3.0	0.00	0.00
Omaka River Valley	7.1	7.7	58	10.7	2.5	0.8	4.9	6.5	0.7	13.3	2.9	0.03	0.00
Omaka	7.3	11.4	104	18.8	7.6	2.5	6.7	21.1	0.9	14.7	7.0	0.01	0.08
Brancott- Shallow	6.6	18.7	42	22.2	15.7	9.6	18.3	18.1	1.6	16.4	5.7	0.10	0.00
Brancott-Deep	7.5	9.5	170	41.9	56.0	0.5	9.1	40.0	1.2	24.0	21.4	0.20	0.00
Woodbourne	7.0	11.3	61	12.2	4.8	1.7	6.3	8.2	0.9	14.6	3.7	0.03	0.00
Benmorven	7.9	4.5	190	53.4	78.5	0.0	1.2	66.5	0.9	26.0	12.2	0.20	0.26
Taylor- Burleigh	6.5	53.0	126	28.7	21.7	3.5	8.7	17.7	1.7	32.5	9.6	0.30	0.01
Deep Wairau	8.1	0.9	156	46	59	0.0	3.5	74	0.9	16.3	3.2	0.22	0.05

Note: Samples with values < DL were set to zero for calculation of means.
Wells with multiple samples were averaged before taking aquifer mean values.

The pH values varied between 8.3 and 8.66. There was a slight positive trend in the pH values but it was not statistically significant and the slope depended almost entirely on the 2 values of 8.55 and 8.66. All the other time series showed fairly constant levels with time. There is a slight indication of a decrease in levels in 2000/01 for sodium, potassium and magnesium but otherwise the time series indicate little change in groundwater chemistry over the 10 year period. The slight change in water chemistry around 2000/01 is similar to a slight change in the C-13 and C-14 data at that time (Morgenstern et al., 2008) and indicates contribution of a different source of water to the well. It correlates with heavy pumping from well 3278 at that time (Table 3) and the drawdown in groundwater level. This probably reflects water being drawn into the well from a slightly different location or depth. This is consistent with the spatial variation in water chemistry between different wells in the Deep Wairau Aquifer (Table 1), where mean conductivity in a particular well ranges from 35 to 71 mS/m and mean Na ranges from 43 to 113 mg/L. Most of the variation in water chemistry between the wells is correlated with the age of the water for the wells that have an age determined from C-14 measurements (Morgenstern et al., 2008).

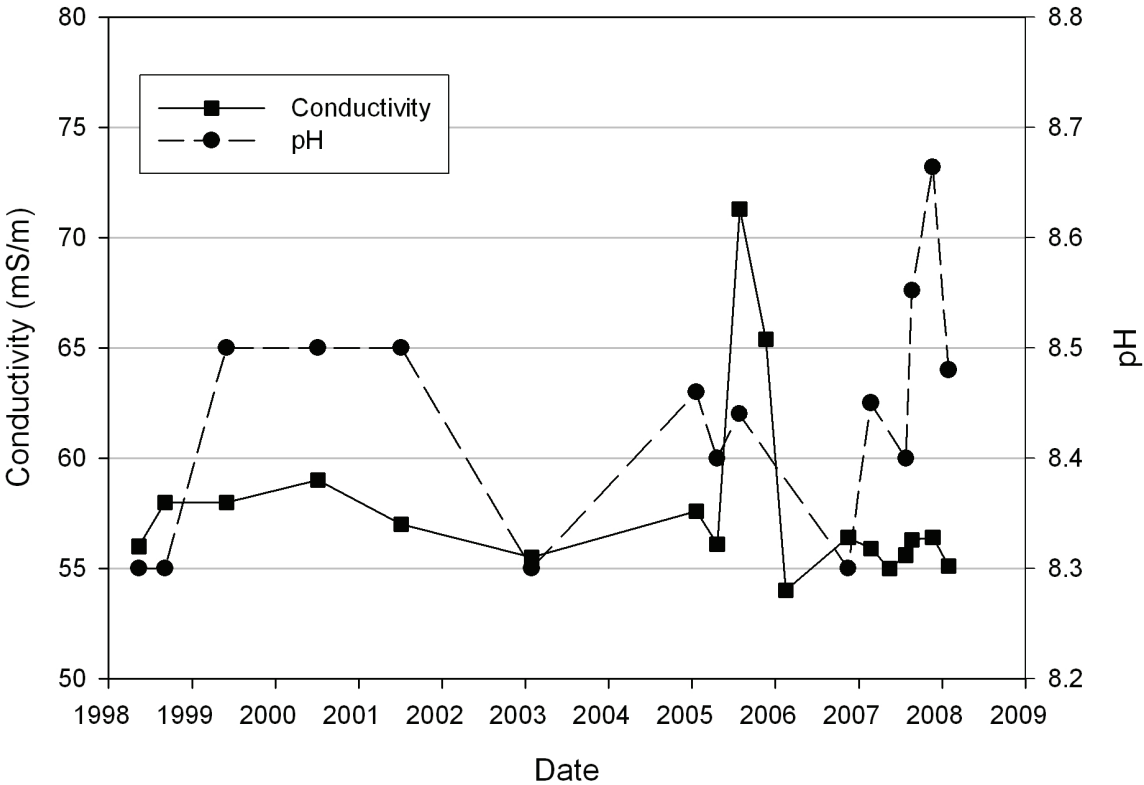


Figure 2: Variation of pH and conductivity with time for well 3278. Note that the high conductivity values of 71 and 65 mS/m are probably 55 and 54 mS/m, respectively, based on the ionic balance.

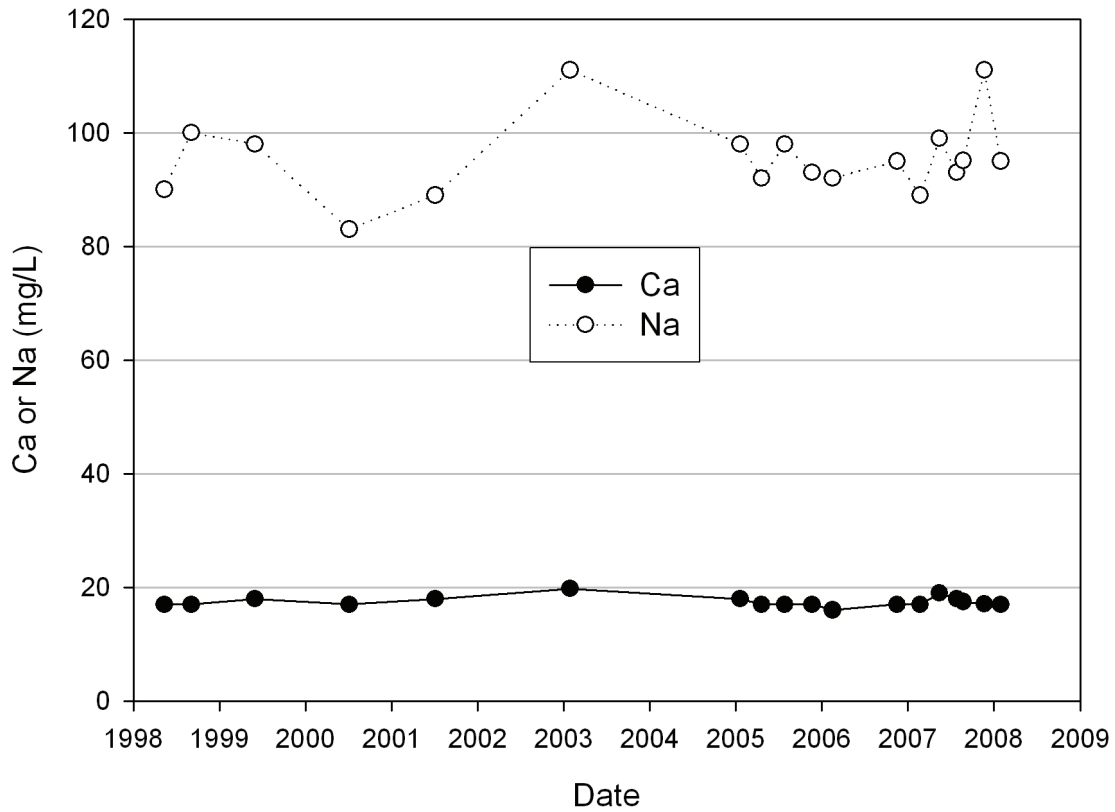


Figure 3: Variation of sodium (Na) and calcium (Ca) with time for well 3278.

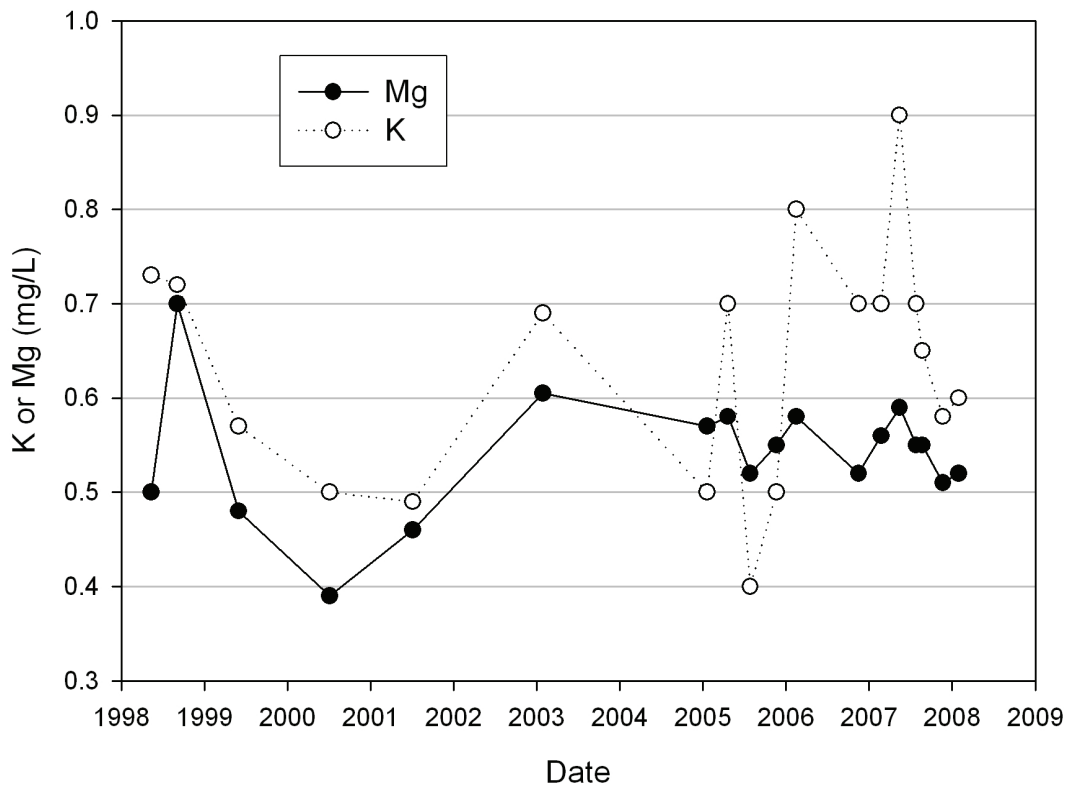


Figure 4: Variation of potassium (K) and magnesium (Mg) with time for well 3278.

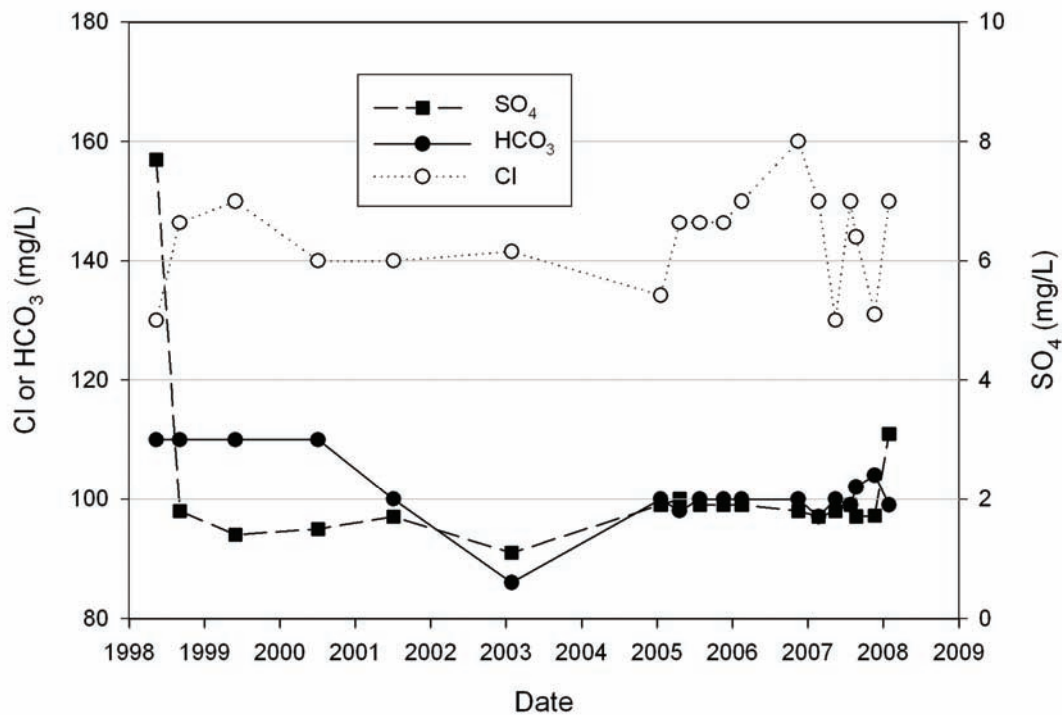


Figure 5: Variation of alkalinity (as HCO₃), chloride (Cl), and sulphate (SO₄) with time for well 3278.

Table 3: Annual pumping amount (000 m³) from well 3278

Year	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08
Volume	114	46	84	70	80	72	25	7.1

As discussed in the earlier report (Close, 1999), the high levels of chloride, alkalinity and sodium compared to likely sources (Wairau or Waihopai Rivers) indicate that significant chemical evolution of the groundwater chemistry has occurred. The high levels of these elements would have resulted from extensive contact with the aquifer media. This is consistent with the groundwater being old as indicated by the radio-isotope data. The relatively consistent groundwater chemistry over the last 10 years is also consistent with this being very old groundwater.

DISCUSSION

The key management question for the Deep Wairau Aquifer centres on whether the Deep Wairau Aquifer represents a significant natural water reservoir in terms of volume and whether it is linked to an active source of recharge to sustain current or increased rates of withdrawal (Davidson, 2008). The relatively constant groundwater chemistry indicates that the volume of the reservoir is significant compared to the amounts of withdrawal that have taken place over the last 10 years. Based on meter readings (Table 3) it is estimated that approximately 500,000 m³ of water has been pumped from the Deep Wairau Aquifer (Davidson 2008). He calculates that the drawdown required to release that volume of water would be about 35 m. This assumes an area of 150 km² and a storativity of 1x10⁻⁴ (Davidson 2008). The actual decrease in groundwater levels has been about 5 m and there is an annual recovery of water level following the cessation of pumping (Figure 3 – Davidson 2008). This implies that the Deep Wairau Aquifer is being recharged to some extent and/or the aquifer is larger than previously thought. The reasonably constant groundwater chemistry does not indicate a source of recent recharge but suggests that any recent recharge has not, at this stage, been intercepted by any of the sampled wells. There is some variation in the chemistry of the old water that is being extracted from well 3278, which may relate to the amount of pumping. The variable pumping may result in water being drawn from different depths that have slightly different chemistries.

The recent isotope results show that the water is still very old and indeed is getting older for well 980. As well 980 has the oldest water (currently about 38,000 years) and the age of water generally increases towards the coast, this may indicate that water is being drawn back from this direction towards the pumping wells. The plots of groundwater chemistry versus age of water indicate a generally increasing concentration in conductivity, bicarbonate, sodium and chloride as age increases. pH levels for all Deep Wairau Aquifer wells were fairly constant around 8.0 but are significantly higher than young water around 6 - 7. There was little increase observed with age for F, Ca, Mg and silica indicating that the groundwater has reached equilibration with the mineral phases that are present.

It would be useful if some of the other wells that were sampled in 1998/99 could be re-sampled for water chemistry and isotopes. This would assist in the assessment of the extent of the Deep Wairau Aquifer.

RECOMMENDATIONS FOR FUTURE WORK

- The recovery of water levels in the Deep Wairau Aquifer indicates that either recharge is occurring or the aquifer is very large. It is probable that more consents for more pumping could be granted without negatively affecting this aquifer. The possibility of interference effects with other hydraulically-connected aquifers needs to be considered.
- Continue annual sampling of wells 980, 3278 and 3291. Review the data in a further 10 years time.
- Continue monitoring of groundwater levels and recording of pumping from the Deep Wairau Aquifer.
- Carry out further isotope sampling and analysis in 5 years time. A sample for water chemistry should be taken at the same time.

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