Annual Groundwater Quality Survey 2015

Groundwater Science Section

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Facilitating sustainable development in the Canterbury region

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Introduction

What is the annual groundwater quality survey?

Each year in the spring, in the months from September to December, Environment Canterbury / Kaunihera Taiao ki Waitaha collects groundwater samples from wells across the region. The samples are analysed for a range of water quality parameters.

Why do we carry out an annual survey?

The survey provides data for evaluating long-term, regional-scale changes in groundwater quality. It also provides an annual snapshot of groundwater quality in the Canterbury region.

Why spring?

The composition of the groundwater can vary over the course of the year. Spring is when we generally see contaminant concentrations at their highest. Spring is also when groundwater levels tend to be highest, so wells are not dry and we can collect samples.

How do we sample the groundwater?

We collect samples according to Environment Canterbury's standard procedure for the collection of groundwater quality samples, which is consistent with the National Groundwater Sampling Protocol (MfE, 2006).

The procedure includes purging at least three well volumes before sampling, filtering samples for metals (cations) in the field and keeping the samples chilled (but not frozen) during transport to the laboratory. We measure field parameters (groundwater temperature, dissolved oxygen concentration, pH and conductivity) at each well during purging, immediately before collecting the sample.

Our groundwater samples are analysed by Hill Laboratories for major ion chemistry (sodium, potassium, calcium, magnesium, alkalinity, chloride and sulphate), ammonia and nitrate nitrogen, iron, manganese, silica, pH, conductivity and indicator bacteria (*E. coli* and total coliforms). In this year's survey, the samples were also analysed for dissolved reactive phosphorus.

What do we do with the data?

We use data from the annual surveys to determine the state of the groundwater resource and to assess changes in groundwater quality over time. We also use the data as a baseline to compare with results from other investigations.

We send the data to the Ministry for the Environment / Manatū Mō Te Taiao when the ministry compiles national statistics on the state of the environment in New Zealand.

In this report, we have used the results to compile a snapshot of Canterbury's groundwater quality in the spring of 2015.

All the data we collect are stored in our water quality database and are publicly available.

Glossary

Denitrification

Denitrification refers to a series of microbially assisted chemical reactions in which the nitrate anion is converted to other forms of nitrogen such as nitrous oxide or nitrogen gas. It occurs primarily in environments where there is no available oxygen (such as anoxic groundwater).

GV

GV stands for '*Guideline Value*'. It is set by the New Zealand Ministry of Health / Manatū Hauora as a threshold above which objectionable aesthetic effects may be observed, such as odour, taste, corrosion or staining problems (MoH, 2008). The GV is not a health-based limit.

MAV

MAV stands for '*Maximum Acceptable Value*'. It is set by the New Zealand Ministry of Health / Manatū Hauora to define water suitable for human consumption and hygiene (MoH, 2008). For most chemical parameters, the MAV is the highest concentration at which, based on present knowledge, the water is considered not to cause any significant risk to the health of the consumer over 70 years of consumption.

For two of the parameters that we test, nitrate and *E. coli*, the MAV is set a bit differently. For nitrate, the MAV is a short-term exposure limit established to protect bottle-fed infants against blue baby syndrome. For *E. coli*, a concentration above the MAV may cause a significant risk of contracting a waterborne disease.

Median

In statistics, the median is the middle value in a list of numbers. We use the median rather than the arithmetic mean (average) to summarise water quality because the mean may be biased by samples with very high or very low concentrations.

Nitrate nitrogen

This refers to the concentration of nitrate in water, calculated based on the mass of nitrogen in the nitrate anion. We record the concentration in milligrams of nitrogen per litre of water (mg/L).

The 2015 annual survey

From September to December 2015, we collected 343 samples (including 16 duplicate samples) from 327 wells across the Canterbury region.

Survey coverage

Figure 1 below shows the locations of the wells we sampled. The annual survey covered nine out of the ten Canterbury Water Management Strategy (CWMS) zones. The exception was Banks Peninsula, where water supplies are mainly derived from surface water resources. The Selwyn-Waihora and Ashburton zones are heavy users of groundwater, and these two zones together accounted for 40% of the wells in the survey.

Well depths

Of the wells we sampled in our survey, 138 wells (42% of the total) had depths of 20 m or less. We sampled 104 wells with depths between 20 and 50 m, 56 wells with depths between 50 and 100 m and 29 wells that were more than 100 m deep. The deepest well sampled in our survey was located in the Ashburton zone and was 252 m deep.

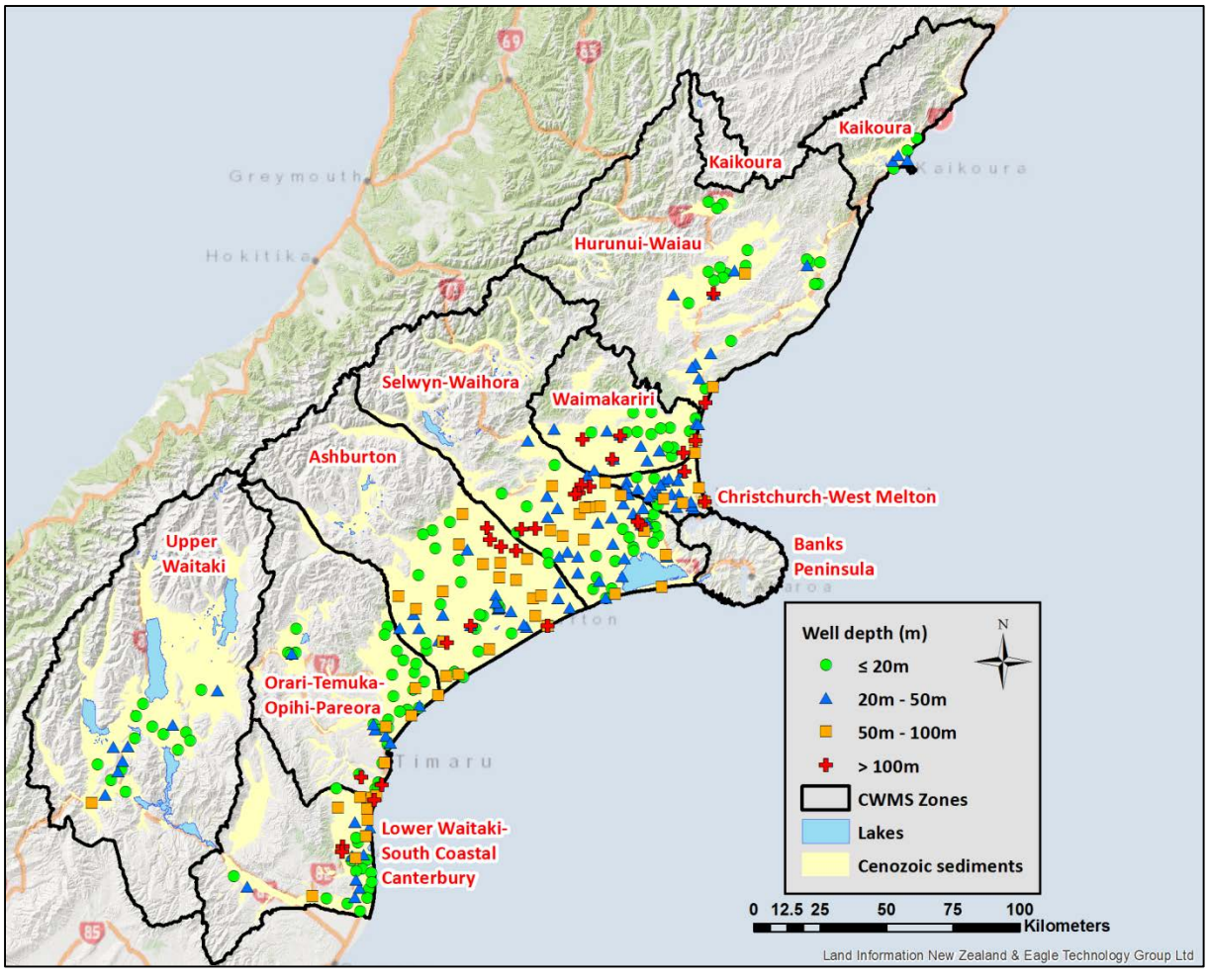

Figure 1: Locations and depths of wells sampled in the 2015 annual survey

Regional summary

Table 1: Summary of groundwater quality indicators collected in 2015 annual survey

Water Quality Parameters	Units	Annual Survey 2015 (327 wells)	
		Median	Range
Microbiological Indicators			
E. coli	MPN/100mL	<1	<1 to 1553
Total coliforms	MPN/100mL	<1	<1 to >2420
Anions			
Nitrate nitrogen	mg/L	3.7	<0.05 to 22
Bicarbonate (as HCO_3^-)	mg/L	62	7.7 to 270
Chloride	mg/L	7.6	<0.5 to 320
Sulphate	mg/L	8.1	<0.5 to 88
Cations			
Calcium	mg/L	17.8	1.01 to 89.5
Magnesium	mg/L	4.6	0.28 to 37
Sodium	mg/L	10.95	1.26 to 128
Potassium	mg/L	1.27	0.22 to 10
Ammonium nitrogen	mg/L	<0.01	<0.01 to 3.20
Iron	mg/L	<0.02	<0.02 to 11.2
Manganese	mg/L	0.0025	<0.0005 to 2.6
Other Parameters			
Silica (as SiO_2)	mg/L	16.8	5.0 to 45
Dissolved reactive phosphorus	mg/L	0.0063	<0.001 to 1.44
Total hardness (as $CaCO_3$)	mg/L	65	6.8 to 375
pH (field)*		6.6	5.3 to 8.2
pH (lab)		7.4	5.9 to 8.1
Conductivity (lab)	mS/m	19.7	2.1 to 133.8
Dissolved oxygen (field)	mg/L	6.92	0.1 to 15.57
Temperature (field)	^oC	12.4	6.5 to 18.3

** Based on our results, the pH of a sample appears to increase slightly when it is removed from the ground and transported to the lab.*

Comparison to New Zealand Drinking-water Standards

Canterbury groundwater is widely used as a source of untreated drinking water. We used the New Zealand Drinking-water Standards (MoH, 2008) to assess the groundwater quality. Table 2 summarises the number of wells in each CWMS zone, and in the region as a whole, which did not meet the standards.

Nitrate nitrogen and faecal contamination (indicated by *E. coli* bacteria counts) are the most common health-related contaminants in our groundwater.

Table 2: Number of wells not meeting the drinking-water standards for 2015 annual survey

Water quality parameter and drinking-water standards		Canterbury Region	CWMS Zone								
			Ashburton	Christchurch - West Melton	Hurunui - Waiau	Kaikōura	Lower Waitaki South Coastal Canterbury	Orari-Temuka-Opihi-Pareora	Selwyn - Waihora	Upper Waitaki	Waimakariri
Number of wells sampled		**327**	67	29	31	6	36	41	65	21	31
Health-based Maximum Acceptable Value (MAV) - numbers of wells that exceeded the standards											
E. coli	< 1 MPN / 100 ml	**22**	6	0	2	0	3	5	3	1	2
Nitrate nitrogen	11.3 mg/L	**22**	15	0	3	0	0	2	2	0	0
Manganese	0.4 mg/L	**7**	1	2	2	1	0	0	0	0	1
Arsenic (15 wells)	0.01 mg/L	**2**	0	1	1	0	0	0	0	0	0
Aesthetic-based Guideline Value (GV) - numbers of wells that exceeded the standards											
Ammonia-Nitrogen	1.2 mg/L	**3**	0	1	2	0	0	0	0	0	0
Chloride	250 mg/L	**1**	0	0	0	0	1	0	0	0	0
Hardness (as $CaCO_3$)	200 mg/L	**9**	0	0	3	0	4	2	0	0	0
Iron	0.2 mg/L	**26**	3	2	6	1	6	1	4	0	3
Manganese	0.04 mg/L	**35**	3	4	7	1	11	3	2	0	4
pH (lab)	7.0 - 8.5	**61**	17	0	6	1	12	14	1	2	8
Sodium	200 mg/L	**0**	0	0	0	0	0	0	0	0	0
Sulphate	250 mg/L	**0**	0	0	0	0	0	0	0	0	0

Nitrate nitrogen

Figure 2 below shows the distribution of nitrate nitrogen concentrations in Canterbury groundwater measured in the 2015 annual survey. Some laboratories will report the concentrations of the nitrate anion itself, but the nitrate nitrogen concentrations we report are calculated based on the mass of nitrogen in the nitrate anion.

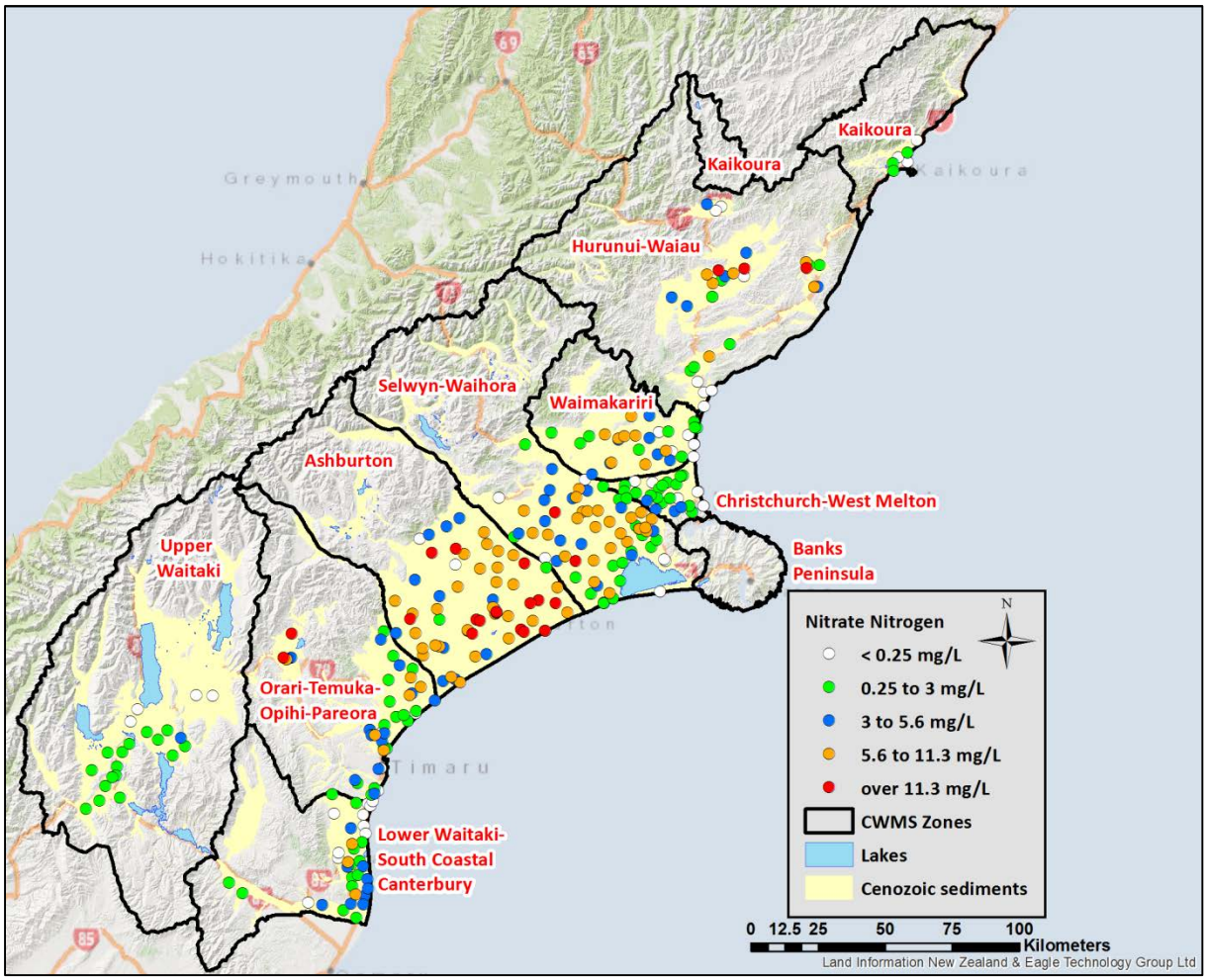

Figure 2: Distribution of nitrate nitrogen concentrations sampled in the 2015 annual survey

What we found:

- The samples from 157 wells (48% of the wells we sampled) had low nitrate nitrogen concentrations (≤ 3.0 mg/L, shown by blue dots).
- The samples from 22 (6.7%) wells had nitrate nitrogen concentrations above the MAV (> 11.3 mg/L and shown by red dots).
- In some places, concentrations of nitrate nitrogen leached from the soils can be decreased by dilution (especially adjacent to the major rivers) or by denitrification.
- Areas of intensive agricultural land use tend to have higher nitrate nitrogen concentrations in the groundwater than other areas.

Trends in nitrate nitrogen concentrations

Environment Canterbury conducts a statistical analysis each year to look for long-term trends in nitrate nitrogen concentrations. Hanson (2002) provides detail on the Mann-Kendall test that we use for the trend analysis. The results from a ten-year trend analysis on data collected each spring from 2006 to 2015 are presented in Figure 3.

Nitrate nitrogen trends in Canterbury groundwater:

- From the 327 wells we sampled this year, we had enough data to analyse trends in 224 wells.
- Over the past ten years, nitrate nitrogen concentrations have been increasing in 55 (about 25%) of those wells. The Selwyn-Waihora and Ashburton CWMS zones have the highest proportions of wells with increasing nitrate nitrogen trends.
- Nine wells (4%) showed decreasing concentrations.
- 160 (71%) of the wells in the annual survey had no decreasing or increasing trend in nitrate nitrogen concentrations.

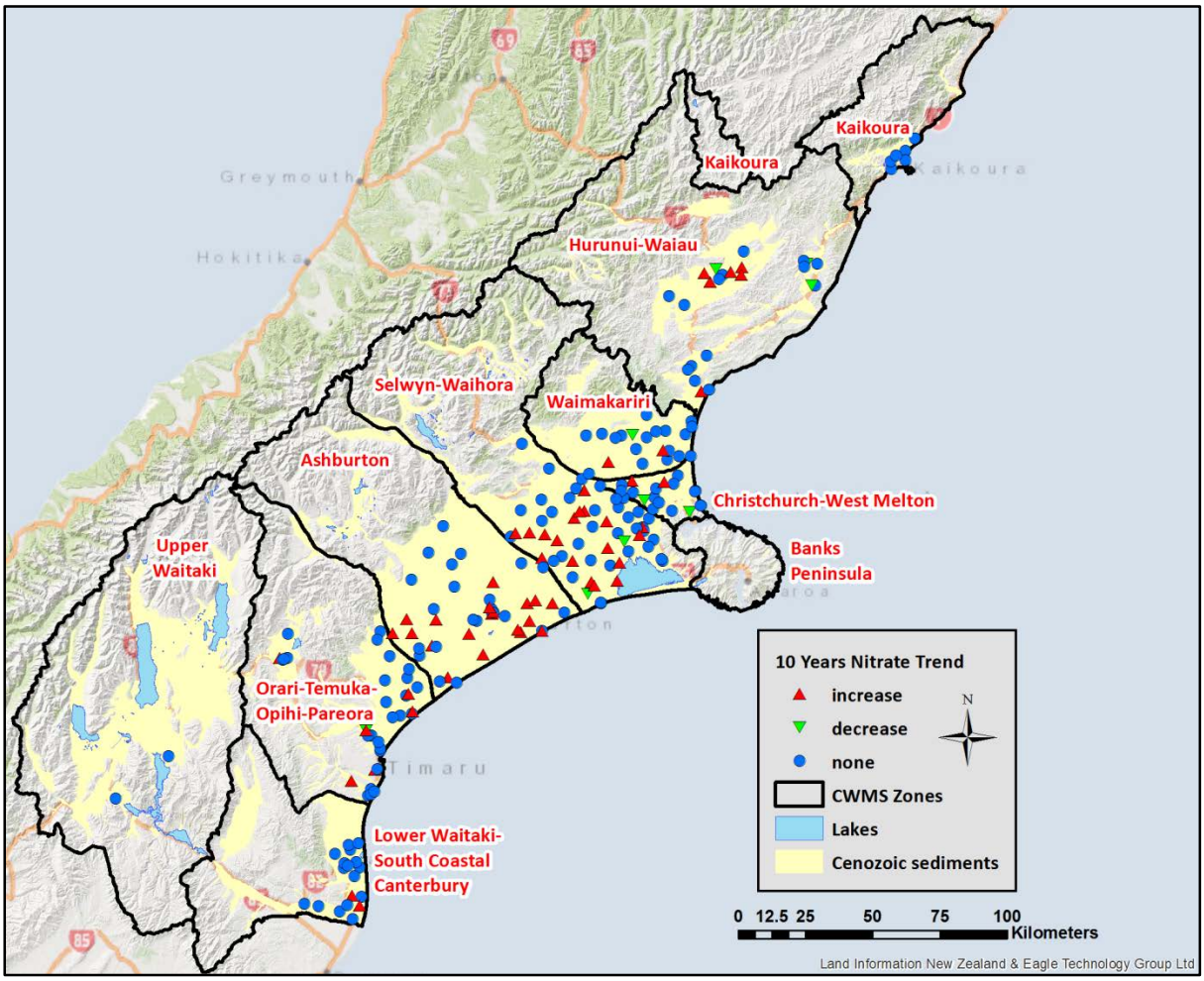

Figure 3: Ten-year trends (2006 to 2015) in nitrate nitrogen concentrations in annual survey wells

Dissolved Reactive Phosphorus

We added dissolved reactive phosphorus (DRP) to our list of parameters in the 2015 annual survey (Figure 4). DRP in groundwater could be coming from natural sources or from human activities such as farming or discharge of effluent. Elevated DRP is not a problem for drinking-water, but it may contribute to algae and plant growth if the groundwater feeds into surface waterbodies.

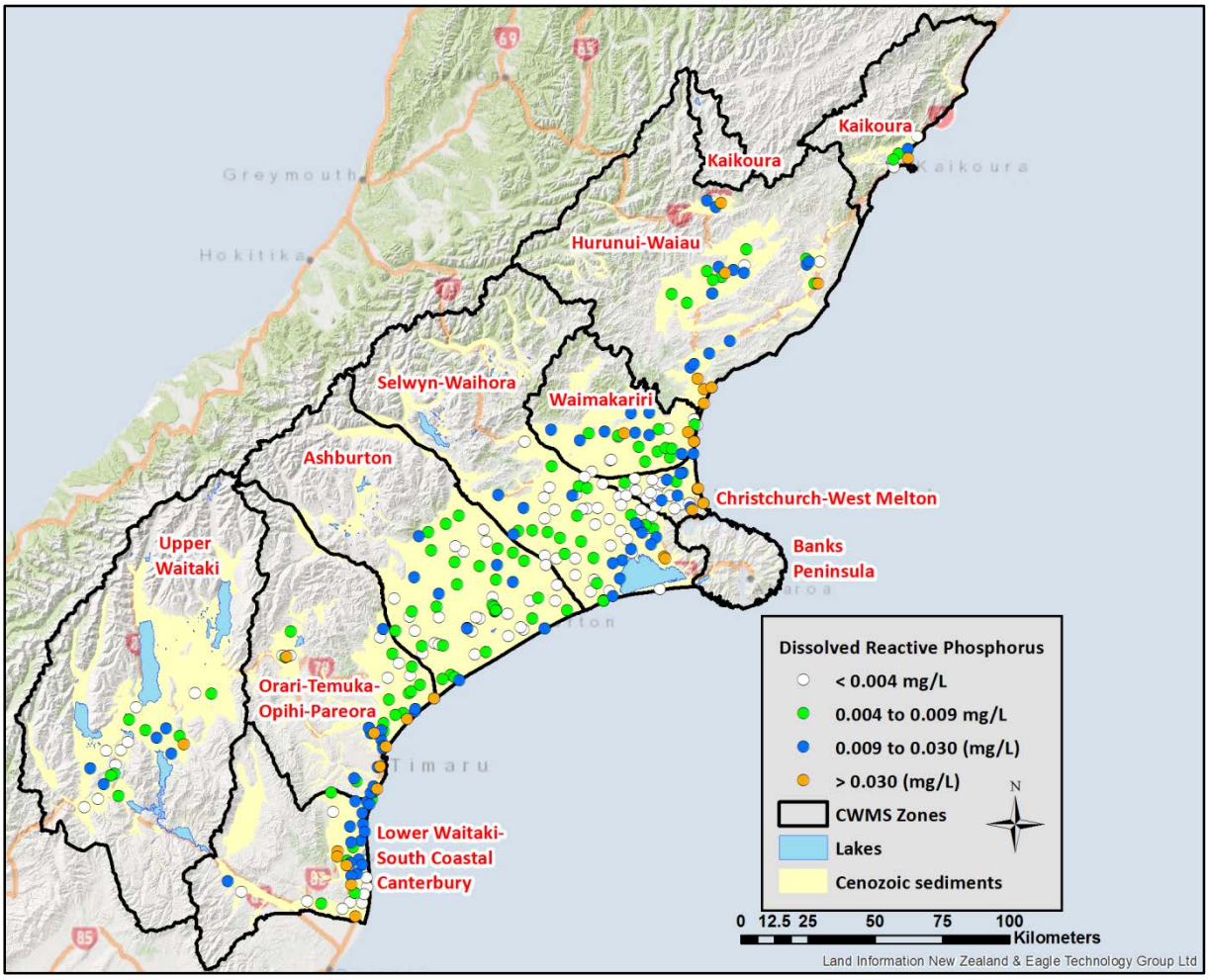

Figure 4: Distribution of dissolved reactive phosphorus concentrations sampled in the 2015 annual survey

What we found:

- Canterbury groundwater is generally unenriched to moderately enriched in phosphorus (concentrations less than 0.009 mg/L) as defined by surface water quality thresholds (Stevenson *et al*., 2010).
- The phosphorus in groundwater is likely to be natural in most cases, but some DRP could be coming from man-made sources.
- Groundwater in the coastal areas appears to have greater DRP concentrations than further inland, and the dissolved oxygen concentration seems to be the main controlling factor this.
- The highest DRP concentration recorded in 2015 survey was 1.44 mg/L, in a sample from a 5.2 m deep well at Hurunui-Waiau CWMS zone. This well also had high concentrations of ammonia, iron and manganese and no measured dissolved oxygen.

E. coli

We test for the bacteria *E. coli* as an indicator of contamination from faecal material. Detections of *E. coli* show no strong geographical pattern, but they are most common in shallower wells. Shallow groundwater throughout the region is vulnerable to faecal contamination. In the 2015 annual survey:

- *E. coli* was detected in 22 (6.7%) of the wells we sampled. This was a higher detection rate than the previous year (we detected *E. coli* in the samples from 12 wells in our 2014 survey), but still lower than 2011 to 2013, when we detected *E. coli* in more than 10% of the wells we sampled.
- 19 samples with *E. coli* detections came from wells less than 20 m deep, and only 3 samples with detections came from wells deeper than 20 m.
- We detected *E. coli* in one well that was 125 m deep. Detections in wells of such depth are rare. We have not detected *E. coli* in this well in the past.
- The highest *E. coli* count recorded in this survey was 1553 MPN/100 ml. This sample came from an 8 m-deep well located in the Lower Waitaki – South Coastal Canterbury CWMS zone. The well is located downgradient of a wastewater treatment plant.

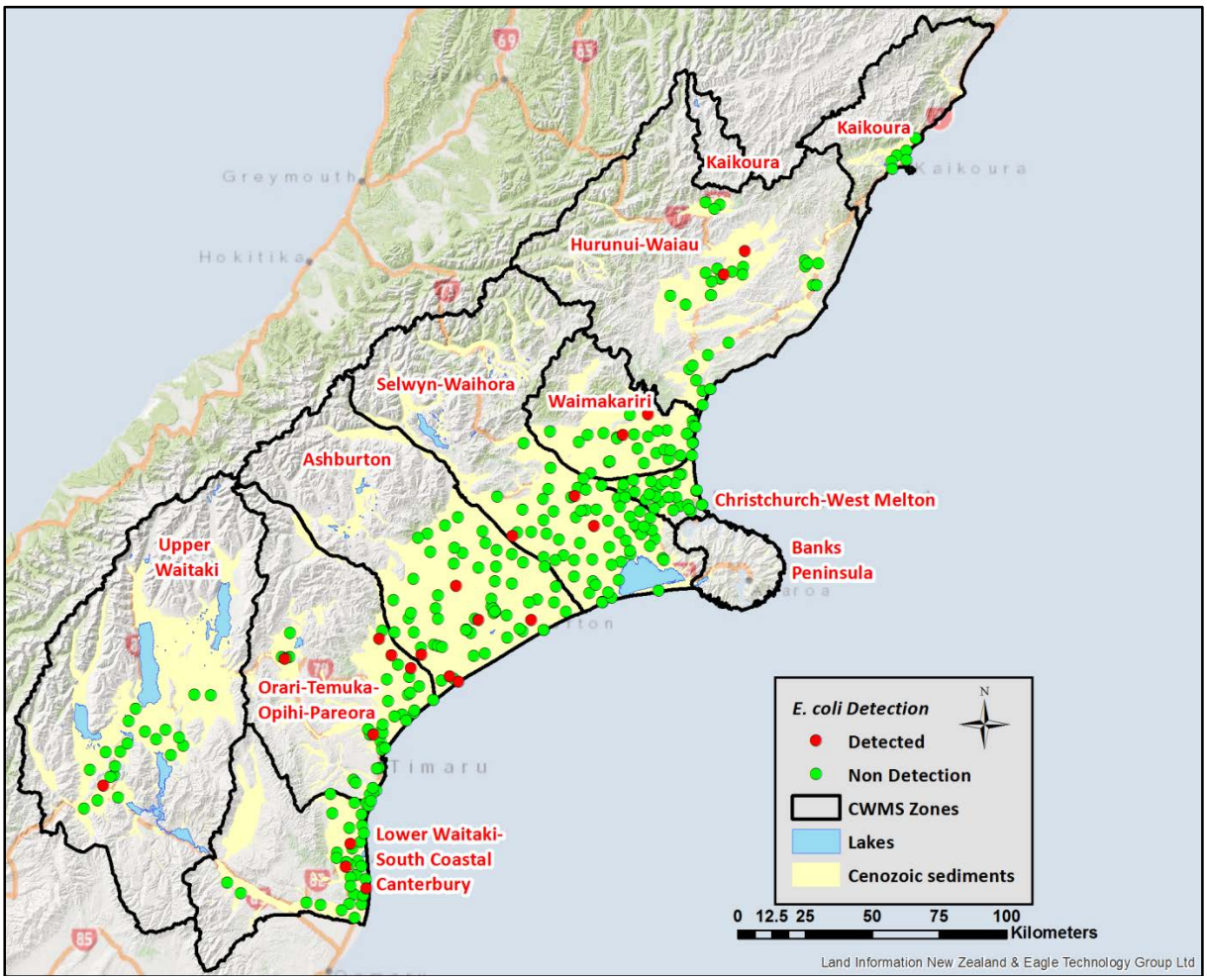

Figure 5: *E. coli* results from the 2015 annual survey

Manganese and iron

- Concentrations of iron and manganese were generally low (below the aesthetic limits stated in NZDWS) in most of the wells we sampled in the 2015 survey.
- Higher concentrations are generally natural, but they can also be related to old landfill sites.
- Seven sampled wells had manganese concentrations above the health-based MAV (0.4 mg/L).
- 35 wells had manganese concentrations above the GV (0.04 mg/L).
- 26 wells had iron concentrations above the GV (0.2 mg/L).
- 20 wells had both iron and manganese concentrations over the GV.

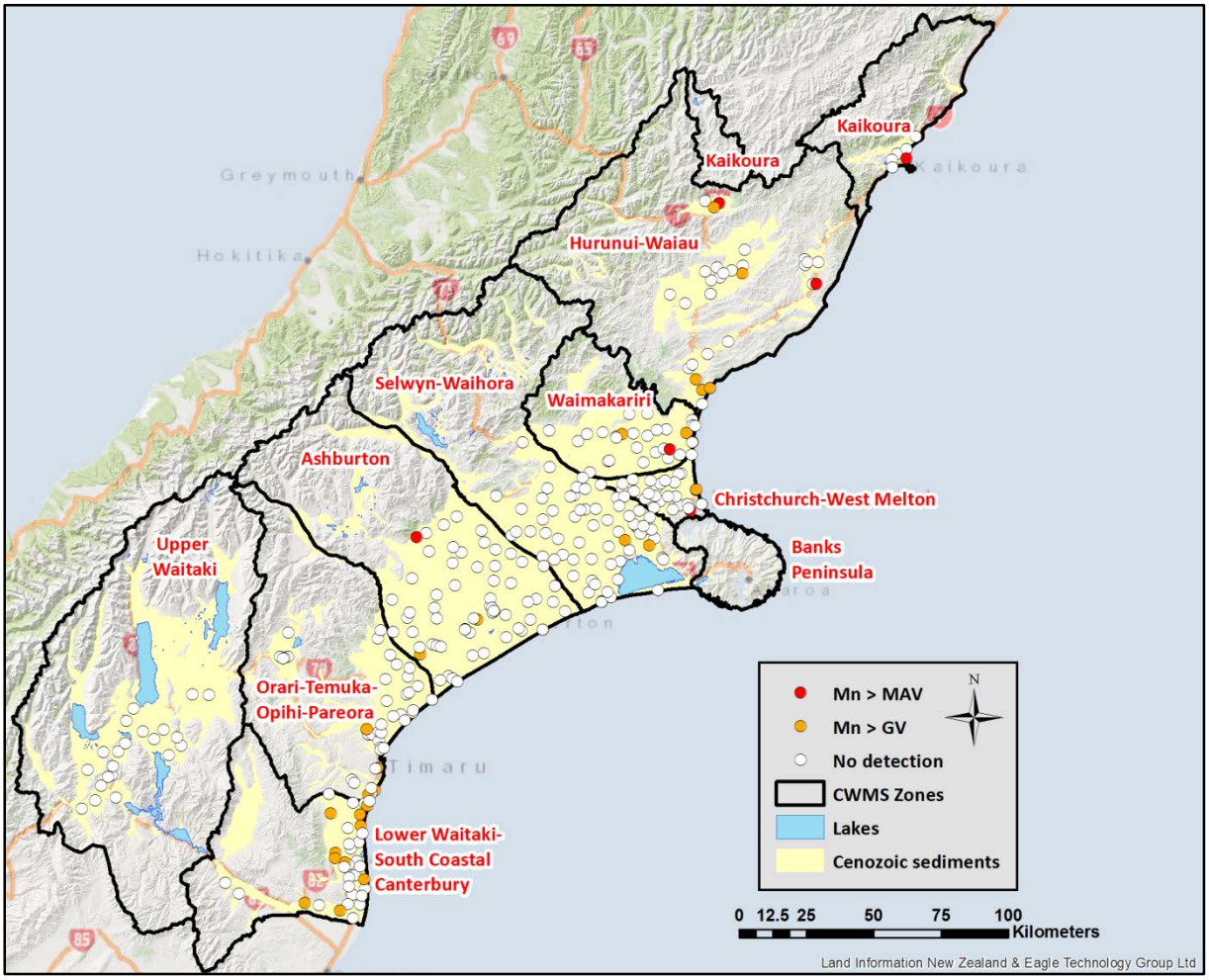

Figure 6: Distribution of manganese concentrations sampled from the 2015 annual survey

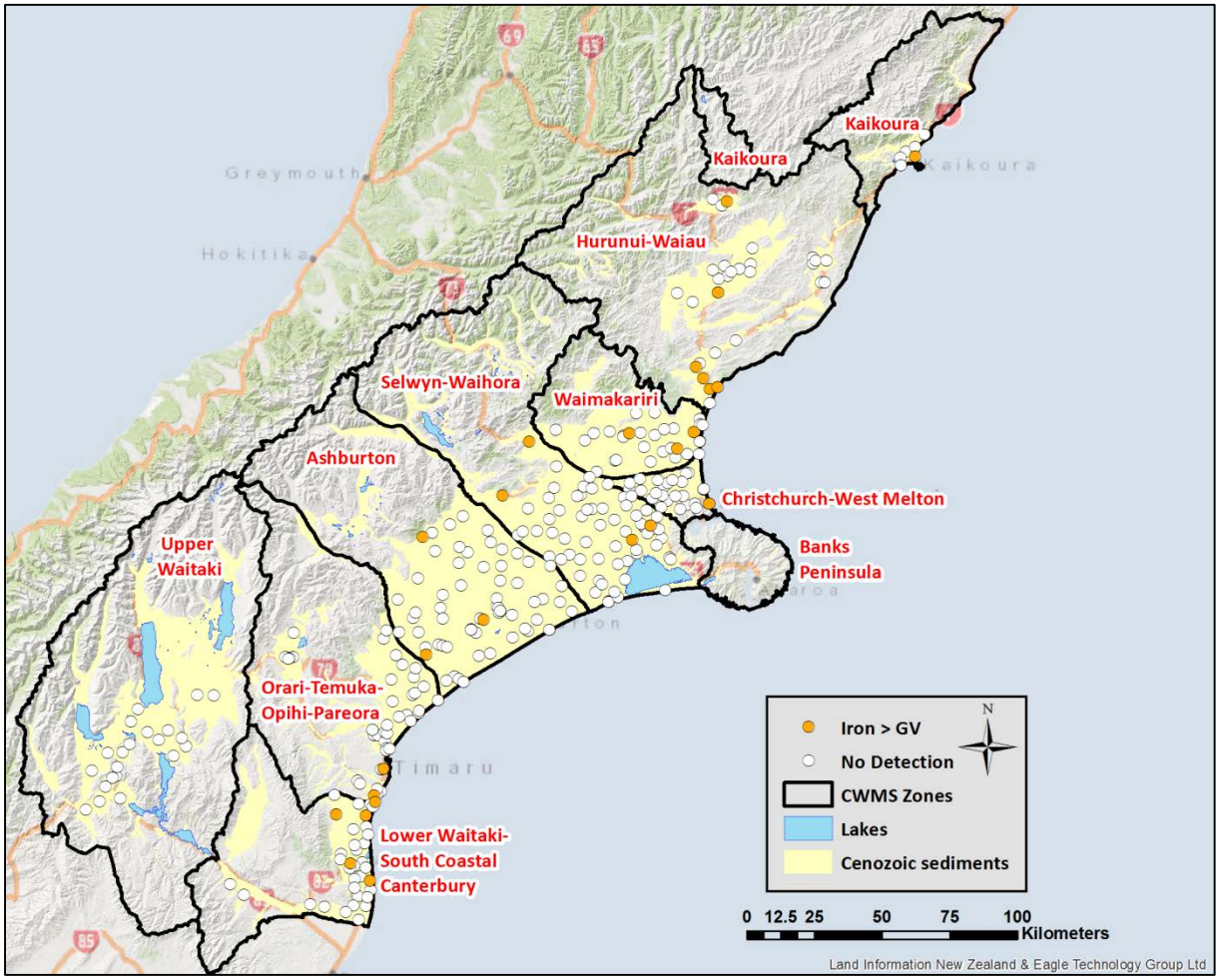

Figure 7: Distribution of iron concentrations sampled from the 2015 annual survey

Summary and Conclusion

- We sampled 327 groundwater wells across the Canterbury region in our 2015 annual groundwater quality survey.

- The samples from 22 wells (6.7%) had nitrate nitrogen concentrations above the health-based MAV. This was a decrease compared to the previous year's survey (25 wells). *E. coli* were detected in the samples from 22 wells, which was an increase from the previous survey (12 wells). *E. coli* and nitrate concentrations are generally higher in shallower wells.

- Most wells had low DRP concentrations (below 0.009 mg/L), and there are no strong correlations between the DRP concentrations and well depths.

- The samples from some wells did not meet the aesthetic GV for pH, hardness, iron, manganese, and ammonia. These results were very similar to previous surveys.

- We found increasing trends in nitrate concentrations in 25% of the wells where we could analyse trends over the past ten years. The concentrations in 71% of the wells showed no trends, while only 4% of the wells showed decreasing trends.

Acknowledgements

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