CANTERBURY REGIONAL COUNCIL

Kaunihera Taiao ki Waitaha

Annual Groundwater Quality Survey
2019

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Introduction

What is the annual groundwater quality survey?

Each year, 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. We generally conduct the survey in the springtime, during the months of September to December.

Why do we care about groundwater quality?

Communities in Canterbury want access to safe drinking-water sources and healthy waterways. Groundwater is the major source of drinking-water supply in Canterbury and provides the baseflow to streams and lakes.

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.

The wells we sample are a mix of public and privately-owned wells used for a range of purposes. They give us an indication of the quality of *untreated* source water and baseflow to surface water across the region. We don't specifically monitor drinking-water supplies – this is the responsibility of the water supplier.

How do we conduct our annual groundwater quality survey?

Every year Environment Canterbury field officers visit the same wells across Canterbury to collect water samples. We sample in the spring months (September to December), after the higher groundwater recharge which generally happens over winter.

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) and the National Environmental Monitoring Standard for groundwater quality sampling (NEMS, 2019).

The process includes purging wells by pumping out at least three well volumes or by pumping the well at a low flow rate with the pump intake at the level of the well screens. We take the samples using our own pump or from a sampling tap as close to the wellhead as we can get when the well is already equipped for pumping.

We measure field parameters to ensure that the wells are purged and the samples are representative of the local groundwater. Our groundwater samples are tested by an IANZ-accredited laboratory for major ion chemistry (sodium, potassium, calcium, magnesium, alkalinity, chloride, and sulphate), nutrients (ammonia nitrogen, nitrate-nitrogen, and dissolved reactive phosphorus), boron, iron, manganese, reactive silica, pH, electrical conductivity, and indicator bacteria (*E. coli* and total coliforms). In 2019, we also tested for bromide, copper, and zinc.

What do we do with the data?

All the data we collect are stored in our water quality database and are publicly available on Environment Canterbury's website via the Well Search or Data Catalogue functions.

As well as analysing and presenting the data in reports like this one, we also 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. Some of these data (chloride, dissolved reactive phosphorus, *E. coli*, electrical conductivity, and nitrate-nitrogen) will be added to the new groundwater quality module on the LAWA – Land, Air, Water Aotearoa – website (www.lawa.org.nz). Our monitoring also supplements results from other investigations and is used for resource management decisions, such as regional planning and processing resource consent applications.

Glossary

Baseflow

Baseflow is sustained low flow in a river during dry or fair-weather conditions, contributed mainly by the discharge of groundwater in springs.

Denitrification

Denitrification refers to a series of microbially assisted chemical reactions in which the nitrate anion is converted to other forms 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, colour, corrosion, or staining problems (MoH, 2018). 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. 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 a 70 kg consumer over 70 years of consumption (MoH, 2018).

For two of the parameters that we test, nitrate-nitrogen and *E. coli*, the MAV is set a bit differently. For nitrate-nitrogen, 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 an ordered 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-nitrogen in water, calculated based on the mass of nitrogen in the nitrate anion. Our standard convention is to record the concentration of nitrate-nitrogen in milligrams per litre of water (mg/L).

The 2019 annual survey

From September to December 2019, we collected samples from 328 wells across Canterbury.

Survey coverage

Figure 1 shows the locations of the wells we sampled. They cover the areas in Canterbury where groundwater is used. The annual survey covered nine out of the ten Canterbury Water Management Strategy (CWMS) zones. The exception was Banks Peninsula, where there is not much groundwater resource potential and water supplies are derived mainly from surface water resources. The Selwyn-Waihora and Ashburton zones are heavy users of groundwater, and these two zones together account for 36% of the wells in the survey.

Well depths

Aquifers are three-dimensional systems, so we try to sample groundwater from a range of depths as well as different locations. Most of the wells draw groundwater from the upper part of the groundwater system near the water table where groundwater is easier to access. We also sample some deeper wells and some artesian flowing wells where the groundwater has travelled through deeper parts of the system. The shallowest well in our network is 3 m deep and the deepest is 251 m deep. Figure 1 shows the depths of the wells in this survey as sample depth below the water table.

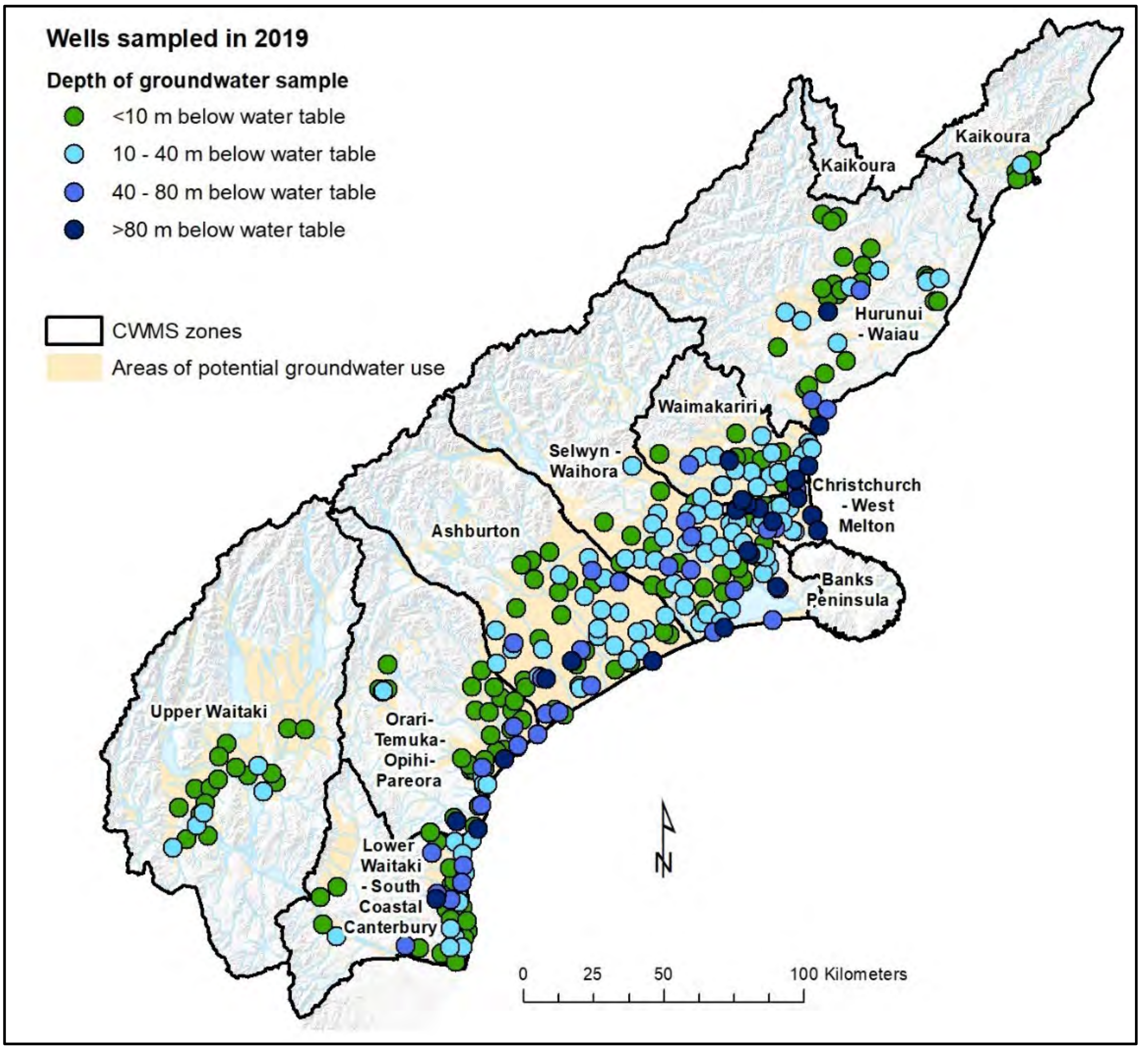

Figure 1: Locations and depths of groundwater samples in the 2019 annual survey

Regional summary

Table 1: Summary of groundwater quality indicators collected in 2019 annual survey

Water Quality Parameters	Units	Annual Survey 2019 (328 wells)	
		Median	Range
Microbiological indicators			
E. coli	MPN/100mL	<1	<1 to 61
Total coliforms	MPN/100mL	<1	<1 to >2420
Nutrients			
Nitrate-nitrogen	mg/L	3.4	<0.05 to 23
Ammonia nitrogen	mg/L	<0.010	<0.010 to 3.3
Dissolved reactive phosphorus	mg/L	0.0065	<0.0010 to 1.19
Cations (dissolved metals)			
Total hardness (Ca + Mg as $CaCO_3$)	mg/L	71	9.3 to 310
Calcium	mg/L	19.6	1.19 to 95
Sodium	mg/L	10.6	1.29 to 117
Magnesium	mg/L	4.8	0.33 to 27
Potassium	mg/L	1.26	0.19 to 10.5
Iron	mg/L	<0.02	<0.02 to 10.5
Zinc	mg/L	0.0052	<0.0010 to 0.27
Manganese	mg/L	0.0014	<0.0005 to 5.0
Copper	mg/L	0.0008	<0.0005 to 0.026
Anions			
Bicarbonate alkalinity (as HCO_3^-)	mg/L	63	12.6 to 320
Chloride	mg/L	8.6	<0.5 to 210
Sulphate	mg/L	8.1	<0.5 to 135
Bromide	mg/L	0.032	<0.005 to 0.86
Other parameters			
Specific conductance at 25°C (lab)	mS/m	20.4	2.6 to 103.3
pH (lab)	Unitless	7.3	5.9 to 8.3
pH (field)*	Unitless	6.6	5.0 to 8.5
Temperature (field)	^{o}C	12.4	6.5 to 19.6
Oxidation Reduction Potential (field)	mV	+139	-180 to >+300
Dissolved oxygen (field)	mg/L	6.9	0.0 to 16.7
Reactive silica (as SiO_2)	mg/L	16.7	5.0 to 43
Boron	mg/L	0.021	<0.005 to 0.152

** 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 drinking-water standards for New Zealand (MoH, 2018) to assess the groundwater quality. Table 2 summarises the number of wells in each CWMS zone, and in the whole region, that did not meet the standards.

Table 2: Number of wells not meeting the drinking-water standards for 2019 annual survey

Water quality parameter and drinking-water standards		Canterbury Region	CWMS Zone								
			Kaikoura	Hurunui-Waiau	Waimakariri	Christchurch-West Melton	Selwyn-Waihora	Ashburton	Orari-Temuka-Opihi-Pareora	Lower Waitaki-South Coastal Canterbury	Upper Waitaki
Number of wells sampled		328	5	36	34	33	63	55	42	39	21
Health-based maximum acceptable value (MAV) - numbers of wells that exceeded the standards											
Nitrate-nitrogen	11.3 mg/L	30	0	5	0	0	5	16	1	3	0
E. coli	< 1 MPN / 100 ml	20	0	2	2	1	4	5	2	4	0
Manganese	0.4 mg/L	7	0	3	0	1	0	1	0	2	0
Arsenic[1]	0.01 mg/L	2	-	1	0	1	-	-	-	-	-
No wells exceeded the maximum acceptable values for Boron (1.4[2] mg/L) or Copper (2 mg/L).											
Aesthetic-based guideline value (GV) - numbers of wells that exceeded the standards											
pH (lab)	7.0 - 8.5	86	1	13	15	0	5	16	17	18	1
Manganese	0.04 mg/L	35	0	8	4	4	3	4	2	10	0
Iron	0.2 mg/L	30	0	7	6	2	4	4	1	6	0
Hardness (measured as $CaCO_3$)	200 mg/L	10	0	3	0	0	0	1	2	4	0
Ammonia nitrogen	1.2 mg/L	4	0	2	0	1	1	0	0	0	0
No wells exceeded the aesthetic guideline values for Chloride (250 mg/L), Copper (1 mg/L), Sodium (200 mg/L), Sulphate (250 mg/L), or Zinc (1.5 mg/L).											

[1] Arsenic tested for 6 wells only. Dash indicates no wells tested in the zone.
[2] The WHO guideline value is 0.5 mg/L, which was also not exceeded by any wells.

Drinking water quality

E. coli

Groundwater is vulnerable to contamination by microorganisms, some of which can cause diseases. Faecal bacteria from livestock, onsite wastewater discharges, stormwater, and other sources can contaminate groundwater, especially after heavy rainfall. We have been testing for the presence and quantity of *E. coli* bacteria in water as an indicator of faecal contamination in groundwater for the past 20 years. Any detection of 1 or more *E. coli* bacterium per 100 ml exceeds the New Zealand Drinking-water Standards (MoH, 2018).

Current state of *E. coli* in groundwater (2019)

- *E. coli* were detected in 20 (6%) out of 328 wells we tested in spring 2019. The rate of detection varies from year to year, but 2019 was below average for all the years we have been testing for *E. coli*.
- Fifteen samples with *E. coli* detections came from groundwater sampled less than 10 m below the water table; five samples between 10 and 40 m below the water table and zero samples from more than 40 metres below the water table.

Long-term patterns in *E. coli* detections (2000 - 2019)

A single water sample does not always reliably show the risk of contamination because concentrations can be highly variable over time. We therefore went back to look at historical data for the wells we sampled in 2019. As an indicator of the pathogen risk to untreated drinking-water, we have summarised the proportion of groundwater samples with *E. coli* present from all the data collected from this survey and past surveys from 2000 to 2019.

Figure 2 shows how often *E. coli* have been detected for 206 wells where we have more than 20 samples on record, arranged by CWMS zone. Light blue squares indicate wells in our monitoring network at low risk of faecal contamination. These wells have had *E. coli* present in less than 5% of all the samples that have been collected. The risk is higher for wells indicated by light orange/brown squares (5 to 50% of samples affected by *E. coli*). Red squares represent wells where more than half of the samples contained *E. coli.* These wells are at very high risk and are likely to be located near sources of faecal pollution.

We also plotted the long-term data for *E. coli* detections by groundwater sample depth below the water table in Figure 3. Because faecal bacteria are carried to groundwater from the surface and are filtered out or die-off over time as they travel through the aquifer, it is common that we see more detections near the water table.

We recommend that all owners of private water supply wells test their water regularly for *E. coli*, especially after heavy rain. If *E. coli* are detected, all water for consumption should be boiled or disinfected.

> Groundwater throughout the region is vulnerable to faecal contamination. Detections of *E. coli* are found in all CWMS zones. They show no strong geographical pattern, but they are most common in shallower wells.

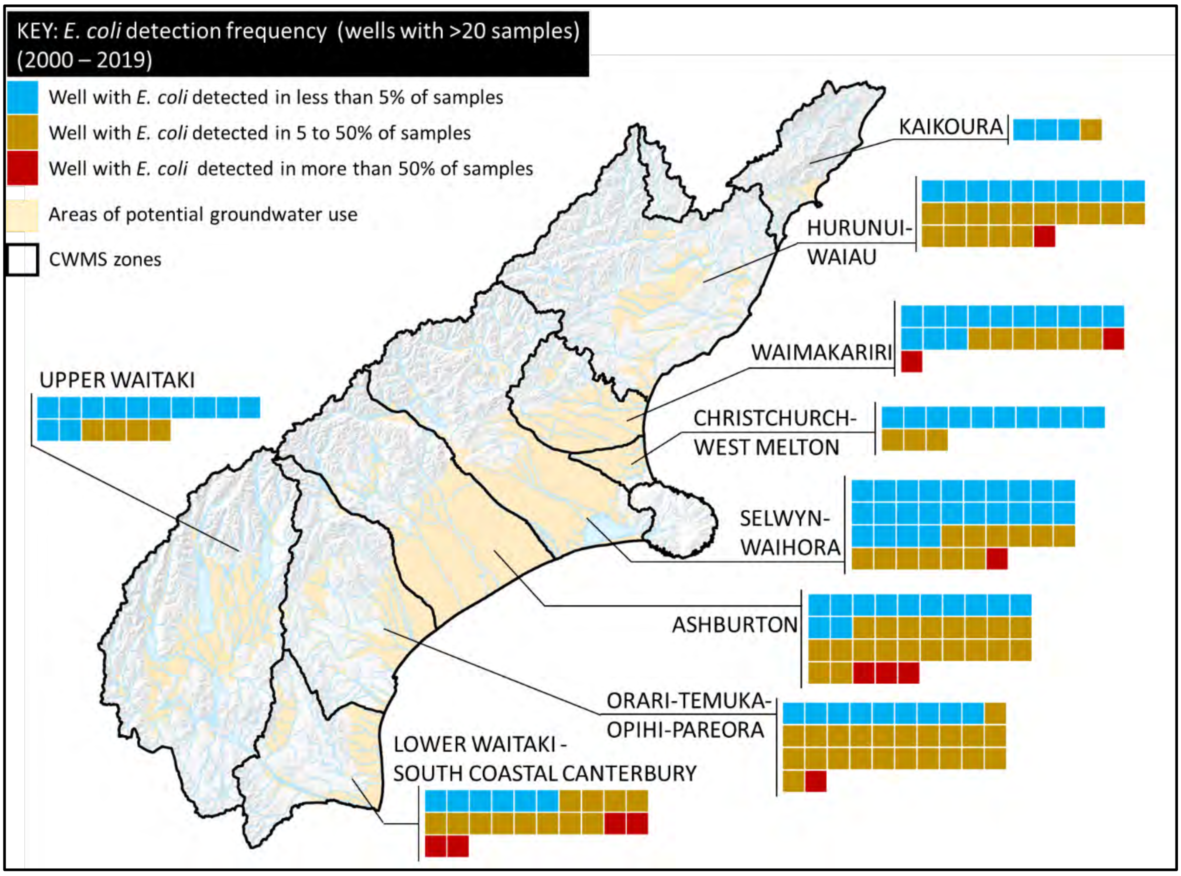

Figure 2: **Frequency of *E. coli* detection in long-term monitoring wells (wells sampled in 2019 with data for more than 20 *E. coli* tests in the period 2000 to 2019)**

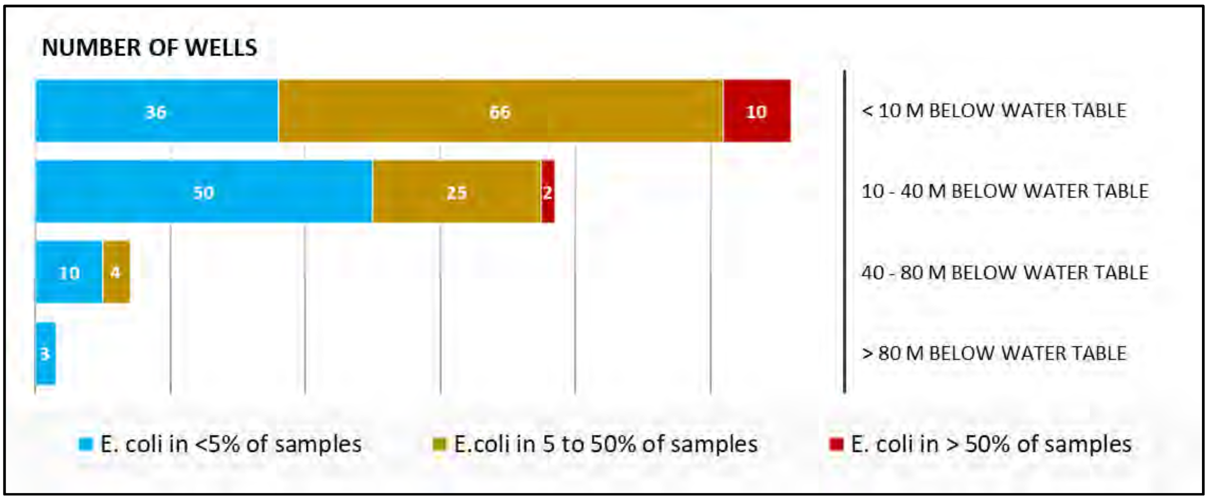

Figure 3: **Summary of long-term *E. coli* detection frequency by groundwater sample depth (for wells with 20 or more samples including the 2019 annual survey sample)**

Nitrate-nitrogen

Nitrate-nitrogen in groundwater can affect its quality for drinking-water supply. The New Zealand drinking-water standards set a Maximum Acceptable Value (MAV) for nitrate at 50 mg/L (equivalent to nitrate-nitrogen of 11.3 mg/L), based on a risk to bottle-fed babies (MoH, 2018). Community and Public Health recommends applying this value to bottle-fed babies less than six months old and to pregnant women.

Current state of nitrate-nitrogen in groundwater (2019)

Figure 4 summarises the nitrate-nitrogen concentrations found in our 2019 groundwater quality survey by CWMS zone. In this map we only display the spring 2019 data, which we compare with health-based thresholds from the Drinking-Water Standards for New Zealand. Each blue or green square represents a sample with a concentration below half the MAV. Green squares indicate concentrations at or above 3 mg/L; these values are above the expected concentrations for natural conditions (MfE, 2019). Yellow squares show concentrations above half of MAV and red squares represent concentrations that exceeded the MAV.

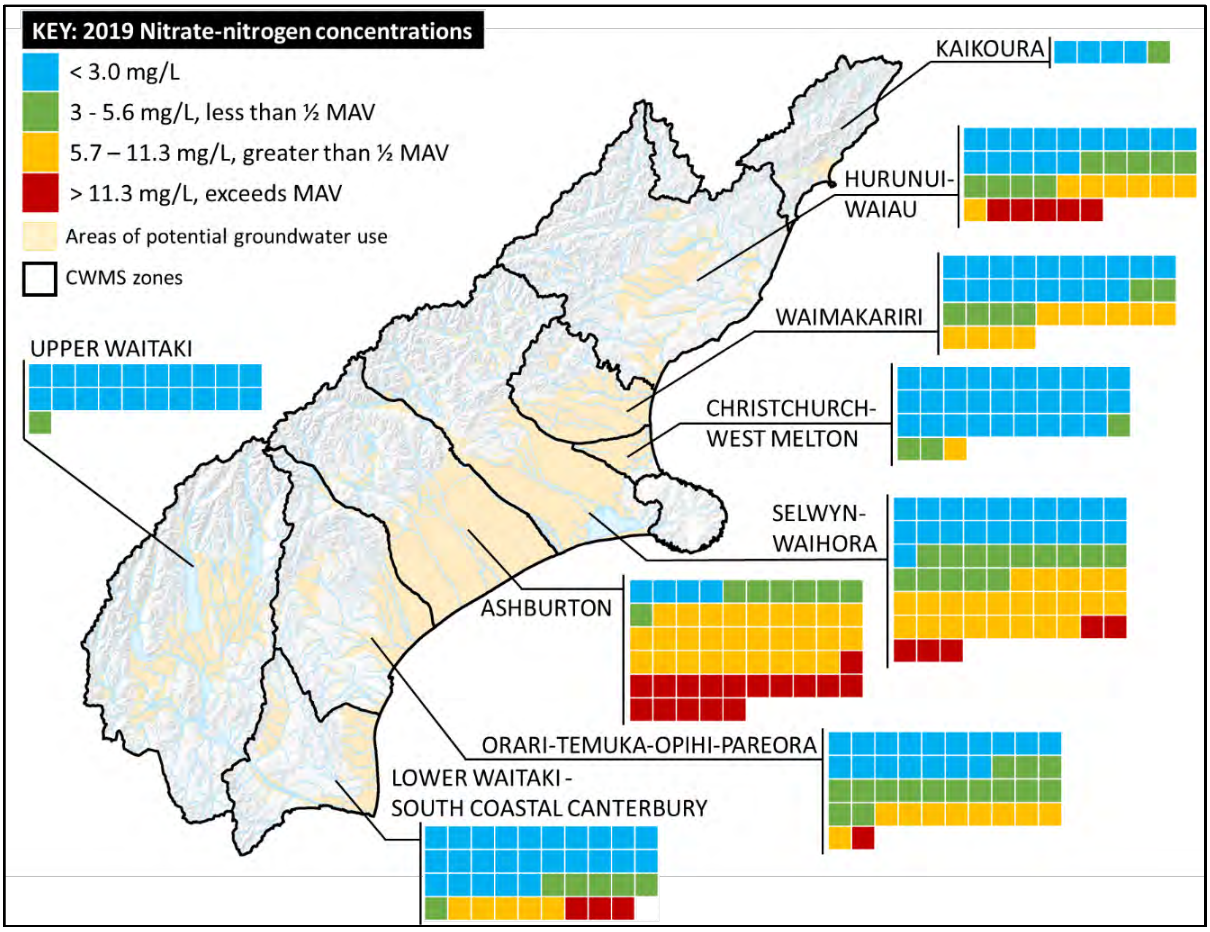

Figure 4: Summary of nitrate-nitrogen concentrations sampled in the 2019 annual survey for each CWMS zone

Areas around and downstream of intensive agricultural land use tend to have higher nitrate-nitrogen concentrations in the groundwater than other areas. 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.

In the 2019 annual survey we found:

- the samples from 153 wells (47% of the wells we sampled) had nitrate-nitrogen concentrations below 3.0 mg/L (shown by blue squares).
- the samples from 62 (19%) wells had nitrate-nitrogen concentrations greater than or equal to 3.0 mg/L but less than half of the MAV (5.65 mg/L; shown by green squares).
- the samples from 83 (25%) wells had nitrate-nitrogen concentrations above half of the MAV (5.65 mg/L) but less than or equal to the MAV (11.3 mg/L; shown by yellow squares).
- the samples from 30 (9%) wells had nitrate-nitrogen concentrations above the MAV (> 11.3 mg/L; shown by red squares).

In general, we have seen that nitrate-nitrogen concentrations tend to decrease with depth when we compare samples from different depths in an area that has concentrations above the expected values for natural conditions. At a regional scale, this pattern becomes less clear, as shown in Figure 5.

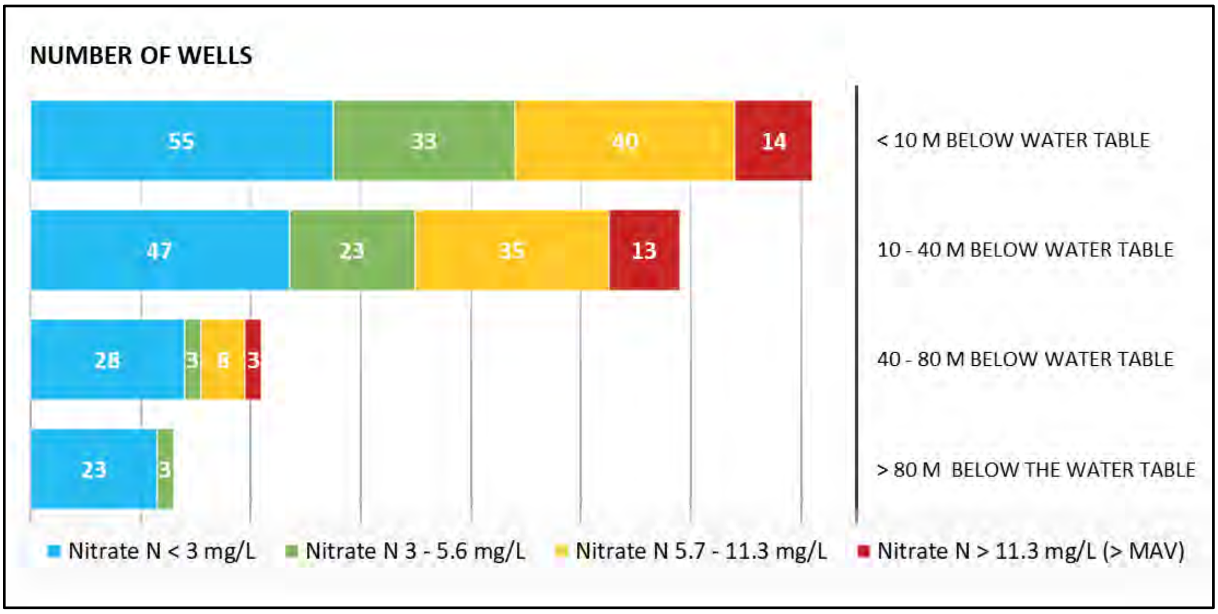

Figure 5: **Summary of nitrate-nitrogen concentration by sample depth below water table in the 2019 annual survey**

Long-term trend of nitrate-nitrogen in groundwater (2010 – 2019)

Environment Canterbury conducts a statistical analysis each year to look for long-term trends in nitrate-nitrogen concentrations. For this year's report, we have adopted a different method to the one we've used in previous years. Instead of the Mann-Kendall analysis that we've used in the past, we now follow the methodology developed by LWP (Snelder & Fraser, 2019) and used for the new groundwater quality module on the LAWA – Land, Air, Water Aotearoa – website (www.lawa.org.nz). Table 3 shows how the likelihood of a decreasing trend is categorised into graduated expressions of confidence. Additional details of this methodology can be found on the LAWA website.

Table 3: Trend categories from likelihood of decreasing trend

Trend category	Likelihood of decreasing trend
Very likely decreasing	90-100%
Likely decreasing	67-90%
No trend in nitrate-nitrogen	33-67%
Likely increasing	10-33%
Very likely increasing	0-10%

From the 2010 to 2019 annual surveys we found:

- 234 of the 328 wells sampled in 2019 had enough data to analyse trends (at least 8 samples each from the last ten years).
- 70 wells (30%) showed 'very likely increasing' trends in nitrate-nitrogen concentrations
- 41 wells (17%) showed 'likely increasing' trends in nitrate-nitrogen concentrations
- 36 wells (15%) showed 'likely decreasing' trends in nitrate-nitrogen concentrations
- 20 wells (9%) showed 'very likely decreasing' nitrate-nitrogen concentration trends.
- 67 wells (29%) had no decreasing or increasing trend in nitrate-nitrogen concentrations.

The results are mapped in Figure 6. Compared with previous years, the results this year show many more wells with trends. In our 2018 report (Scott, 2019), we reported that 77% of the wells we analysed had no decreasing or increasing trend in nitrate-nitrogen concentrations. This year, that number is only 29%. This is because of the additional trend categories; the trends in the 2018 report would have all been included in the "very likely" trend categories.

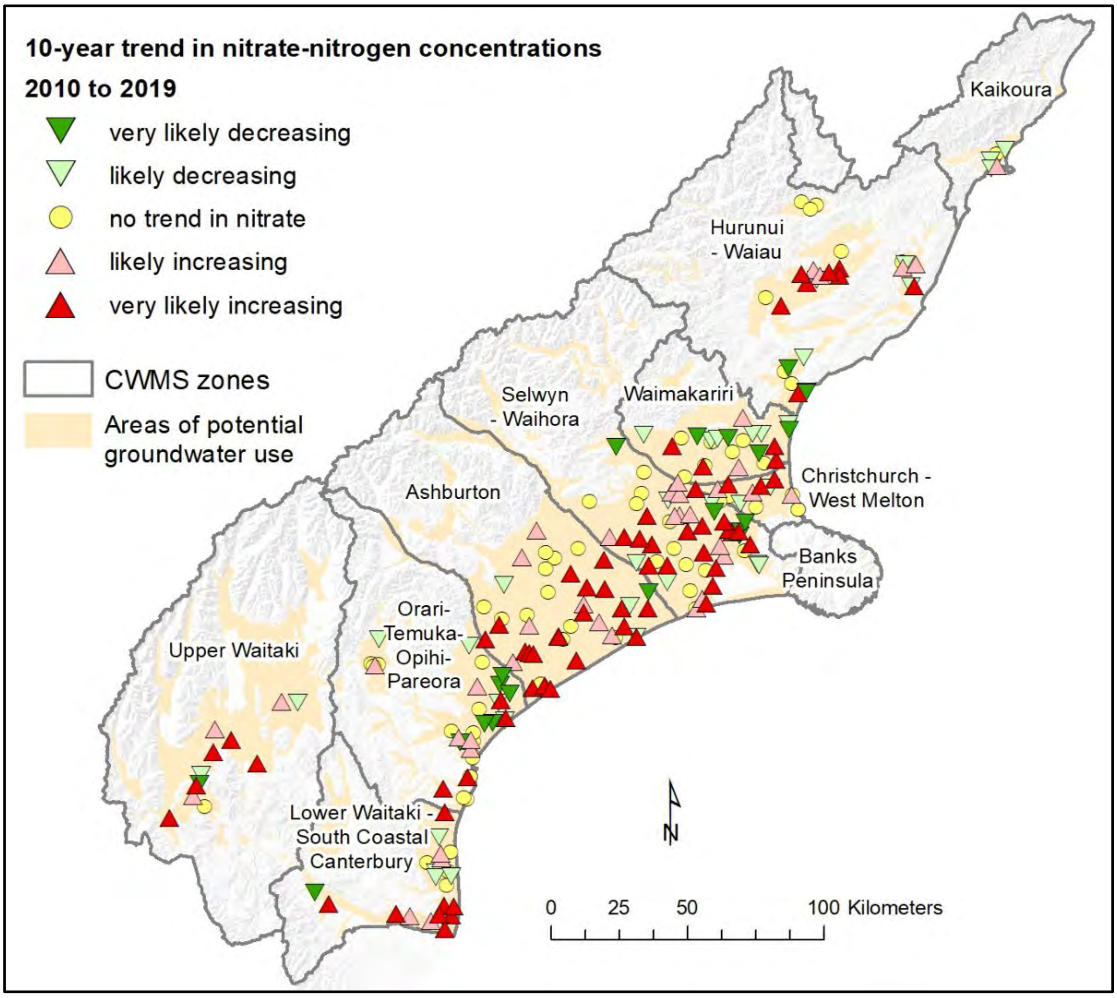

Figure 6: Ten-year trends (2010 to 2019) in nitrate-nitrogen concentrations in annual survey wells

There are some differences between our results and those shown on LAWA, even though the analytical method is the same. There are two key reasons for this:

1) *different time periods*: in this report, we present trends calculated over the period 2010-2019, whereas LAWA presents trends calculated over the period 2009-2018
2) *different sampling frequencies*: the trends in this report are based on annual data, whereas LAWA trends were calculated using quarterly data.

The greatest difference between them is the number of wells analysed. For this report, we calculated trends for 234 of the 328 wells in our survey. In contrast, LAWA shows data for 125 wells that we sample quarterly, and of those, only 39 met the data requirements for trend analysis. A second significant difference is that the quarterly data used in LAWA has more data points and therefore increases certainty in the trend. This causes some sites that show 'no trend' or a 'likely' trend in this report to have a 'very likely' trend on LAWA.

Other contaminants

Health risks

Very localised health risks may be present from drinking groundwater exceeding the MAV for arsenic and manganese in Canterbury. These substances tend to occur naturally in areas of anoxic groundwater (i.e. water with little or no dissolved oxygen). Figure 7 shows the results for manganese and arsenic graded by aesthetic and health-based concentrations in 2019. Pink dots indicate wells where the manganese concentrations are high enough to cause potential staining of laundry (above 0.04 mg/L) and dark purple indicates potential health risks from long-term consumption of water with manganese above 0.4 mg/L.

We only monitored arsenic in 6 selected wells in areas where we have found high arsenic in the past: Hurunui-Waiau (Amberley), Waimakariri (Woodend), and coastal wells in Christchurch. Arsenic is also known to be present in groundwater near Kaikoura, Culverden, Woodend-Waikuku and Greenpark as well as other localised areas. The red squares in Figure 7 show two wells where arsenic was above the MAV of 0.01 mg/L in the 2019 survey. Note that in Southshore, Christchurch, arsenic was also tested but not detected in a deeper well at the same location as the well that was above the MAV.

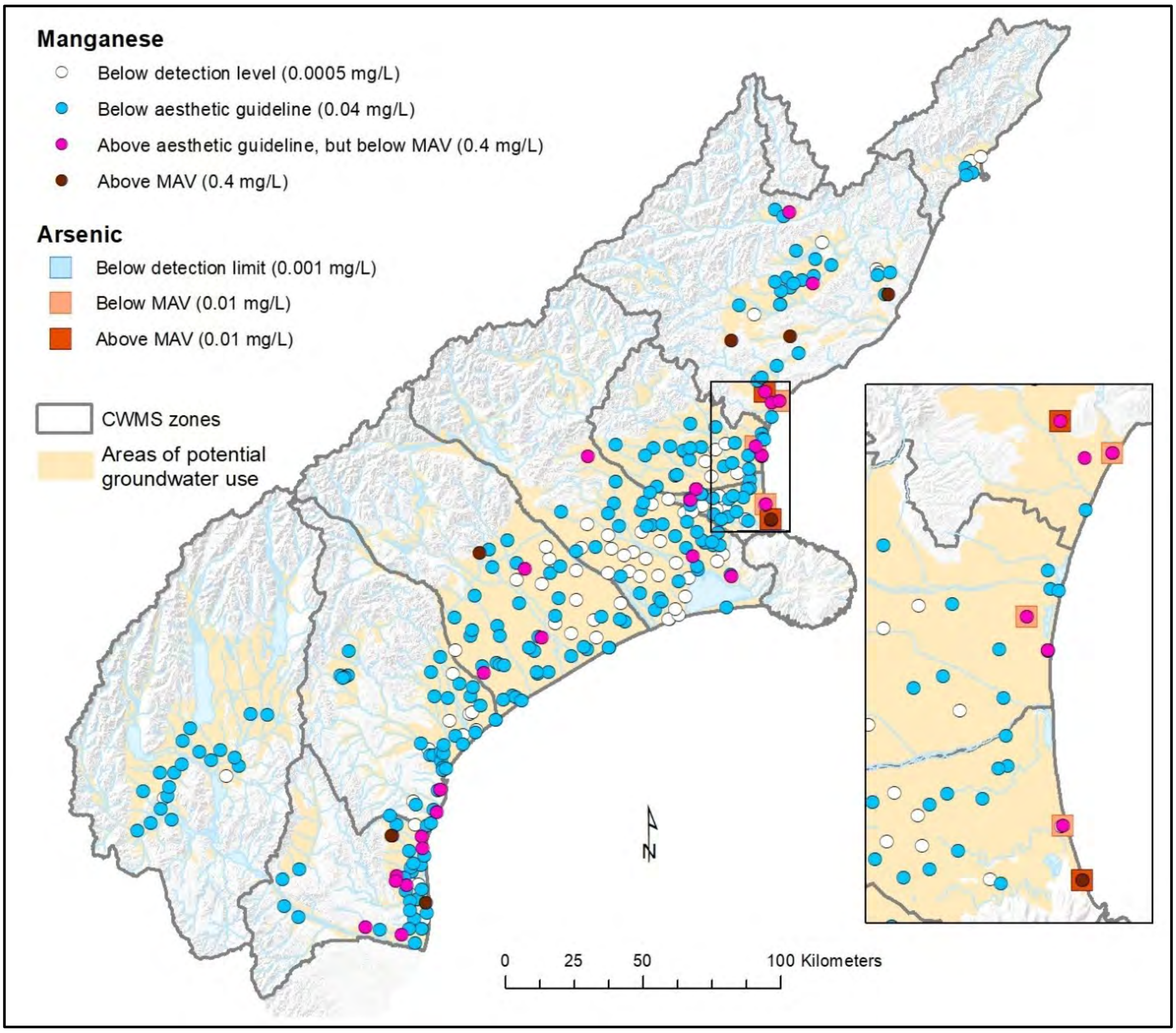

Figure 7: **Manganese and arsenic concentrations in groundwater from the 2019 annual survey assessed relative to drinking-water standards**

Aesthetic properties

Occasionally groundwater quality does not meet guideline values for contaminants that affect its aesthetic properties, including pH, iron, manganese, and hardness (see Table 2). These contaminants do not pose a health risk, but they may be a nuisance because of corrosiveness, staining, poor taste, scale build-up or scum formation with certain types of soaps. The drinking-water standard categorises this type of water as potable, but not 'wholesome'.

pH is the most common indicator that does not meet drinking-water guideline values. The pH of most Canterbury groundwater is mildly acidic. This is a natural effect from dissolved gases in the recharge and the low buffering capacity of our aquifer sediments. Water with a pH below 7 can pose a risk of dissolving metals from plumbing pipes.

Healthy waterways

Nitrate-nitrogen

Many of our streams and lakes are fed by groundwater. Dissolved nutrients (nitrogen and phosphorus) transported via groundwater pose a threat to the health of these waterways. Nitrate can be directly toxic to fish or, together with phosphorus, can cause the growth of plants and algae that deplete oxygen.

To assess our groundwater monitoring results in this context, we have used nitrate-nitrogen toxicity thresholds for ecosystem health in rivers from the National Policy Statement for Freshwater Management (NPS-FM, MfE, 2017). We must note, though, that for surface water, these thresholds are based on annual median concentrations. Our groundwater results are based on single samples, so they can only indicate potential effects on rivers, particularly where groundwater is the dominant source of flow in the river.

In Figure 8, we apply the nitrate-nitrogen toxicity thresholds to results from a subset of 114 of our shallower monitoring wells located in areas where groundwater may be discharging to surface water. The criteria we have selected to indicate potential connectivity with surface water are wells less than 20 m deep and water levels less than 6 m below surface or artesian groundwater.

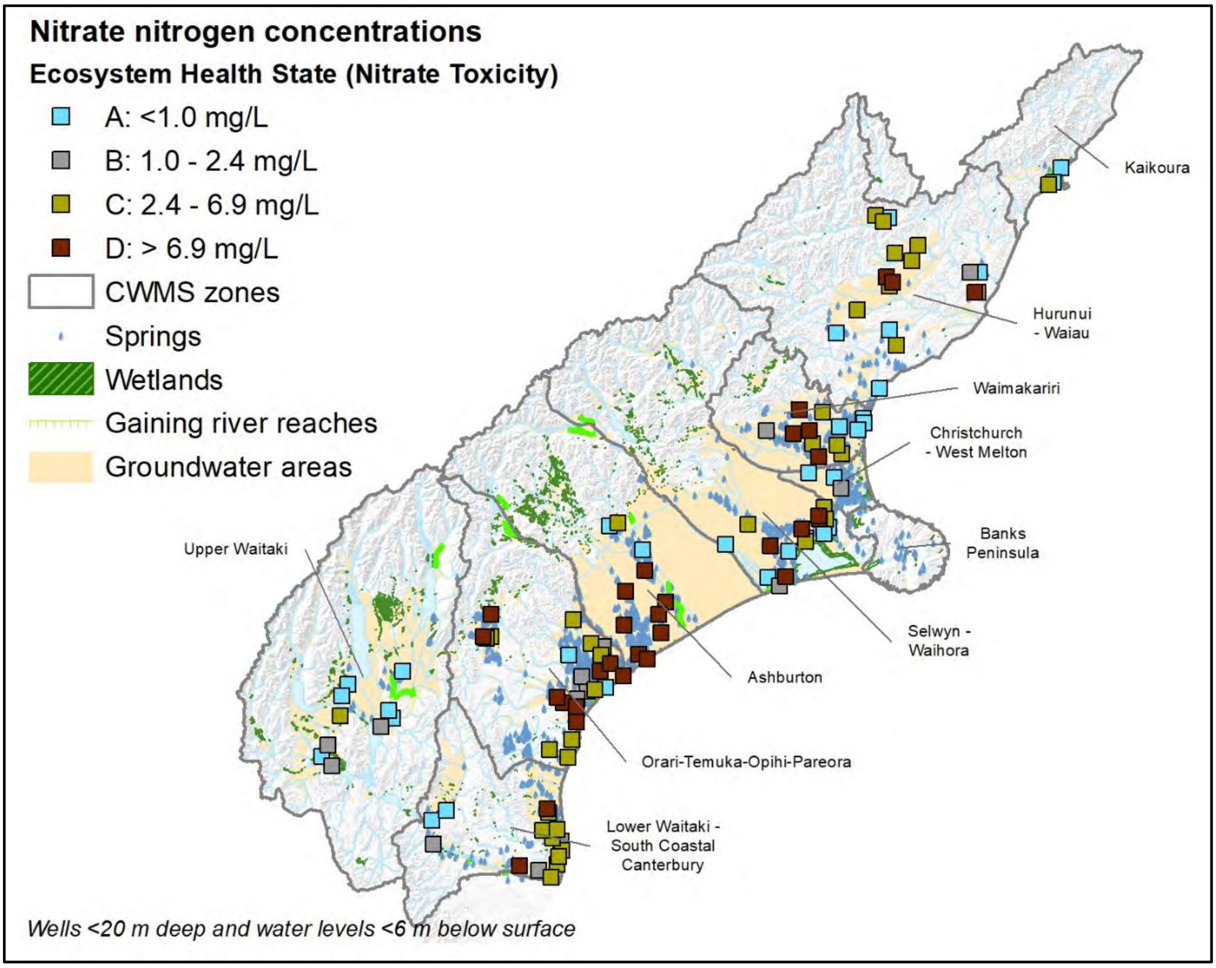

Figure 8: Groundwater nitrate-nitrogen concentrations from the 2019 annual survey, grouped by NPS-FM nitrate-nitrogen toxicity thresholds in areas where groundwater potentially discharges to surface water

In the 2019 annual survey we found:

- The samples from 31 shallow wells (27%) had low nitrate-nitrogen concentrations (≤ 1.0 mg/L) shown by light blue squares. In rivers an annual median nitrate-nitrogen concentration below 1.0 mg/L would be classed as band A – unlikely to cause effects even on sensitive species.
- 31 of the groundwater samples (27%) had nitrate-nitrogen concentrations greater than 6.9 mg/L shown by the brown squares. Annual median nitrate-nitrogen concentrations of greater than 6.9 mg/L in rivers exceed the NPS-FM National Bottom Line (band D) for ecosystem health, with potential impacts on the growth of multiple aquatic species.
- Concentrations from 14 wells (12%) are equivalent to band B (grey squares, some growth effects on up to 5% of species) and 38 wells (33%) to band C (green squares, growth effects on up to 20% of species, mainly sensitive species).

Phosphorus

High concentrations of nutrients in surface water bodies can cause excessive plant growth rates. With the exception of Banks Peninsula rivers, and possibly the Waipara and Pareora catchments, phosphorus is considered the main limiting nutrient for aquatic plant growth in Canterbury rivers (Hayward *et al*., 2009). Surface runoff is widely recognised to be the major source of phosphorus in rivers, but where groundwater contributes to stream flow, the phosphorus concentration in the groundwater has the potential to affect the concentration in the stream. Phosphorus in groundwater could be coming from several sources, either natural or from human activities such as farming or discharge of effluent.

Phosphorus does not have assessment criteria in the NPS-FM like nitrate-nitrogen does. In Figure 9 we have compared dissolved reactive phosphorus (DRP) concentrations to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000) trigger value for filterable reactive phosphorus (equivalent to DRP) in New Zealand lowland rivers and to other thresholds from surface water reporting (Stevenson *et al*., 2010). Blue squares are all below the ANZECC guideline. The higher concentration classes (shown by green and brown squares) could have greater potential for causing excessive plant growth and affecting the recreational quality of streams. Again, we have only plotted data for wells less than 20 m deep in areas where the groundwater table is less than 6 m deep because of the potential for groundwater to affect surface water quality.

In the 2019 annual survey we found:

- Around two thirds of the wells (77 wells, 68%) in areas of potential connection to surface water had DRP concentrations below the ANZECC trigger level of 0.01 mg/L.
- high DRP concentrations in some of the wells are probably from phosphorus-bearing rocks or sediments, especially in Hurunui-Waiau zone and the downlands of South Canterbury.

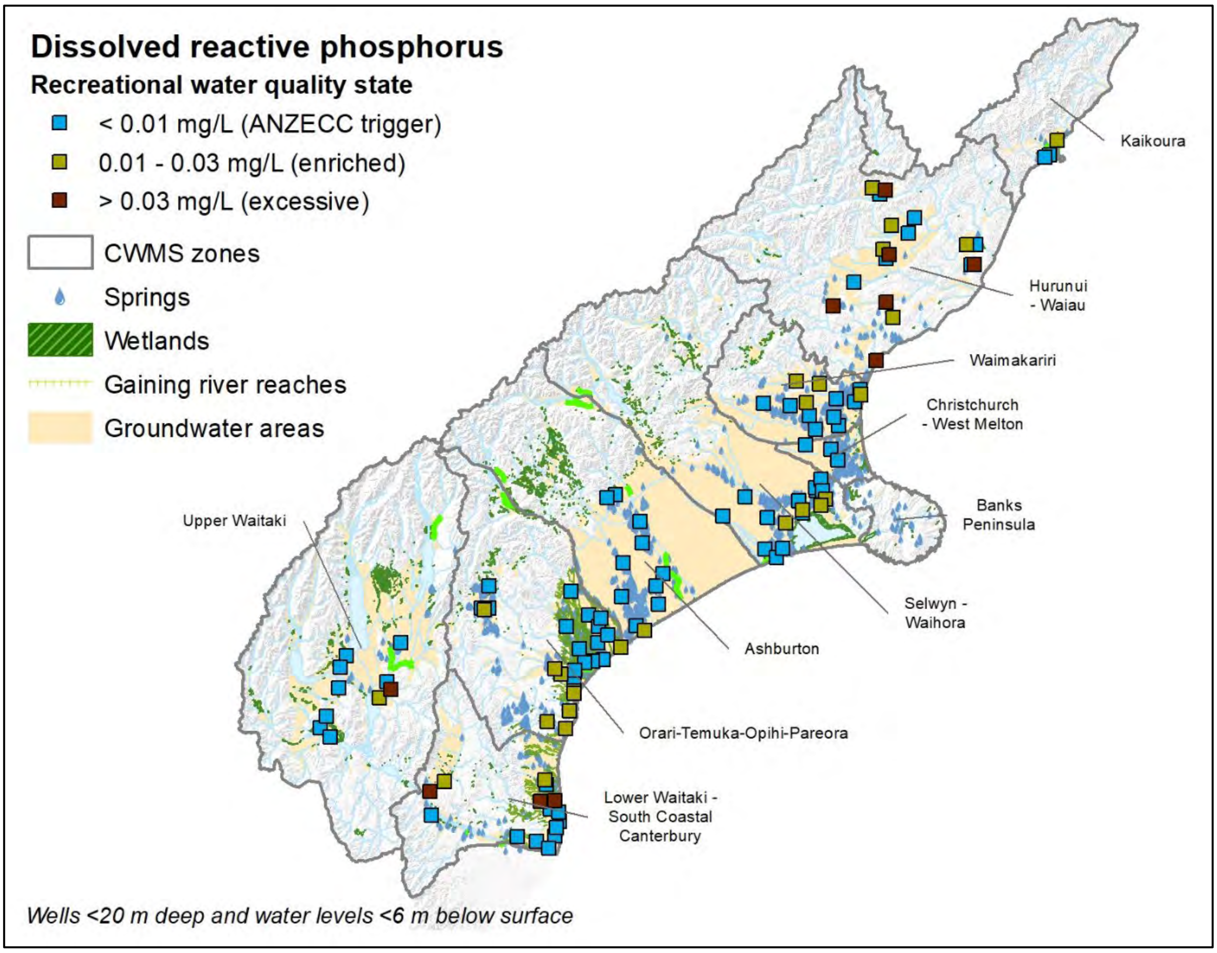

Figure 9: Distribution of dissolved reactive phosphorus concentrations from the 2019 annual survey near areas where groundwater may be discharging to surface water

Summary and conclusion

- We sampled groundwater from 328 wells across the Canterbury region in our 2019 annual groundwater quality survey.

- The samples from 30 wells (9%) had nitrate-nitrogen concentrations above the health-based Maximum Acceptable Value (MAV). This was slightly higher than the previous year's survey (22 wells or 7% of sampled wells). *E. coli* were detected in the samples from 20 wells (6%), which was a decrease from the previous survey (34 wells or 11% of sampled wells with *E. coli* in 2018).

- We found increasing trends in nitrate-nitrogen concentrations in 47% (30% very likely, 17% likely) of the wells with enough data to analyse trends over the past ten years. The concentrations in 29% of the wells showed no trends, while 24% of the wells showed decreasing trends (9% very likely, 15 % likely).

- Just over one quarter (27%) of the groundwater samples in areas where there is likely high connectivity with surface water had nitrate-nitrogen concentrations greater than 6.9 mg/L. Baseflow from such groundwater could contribute to some lowland rivers failing to meet the National Bottom Line concentrations (of 6.9 mg/L annual median nitrate-nitrogen).

- About two-thirds (67%) of the wells in the survey in areas where there is likely high connectivity with surface water had dissolved reactive phosphorus (DRP) concentrations below 0.01 mg/L.

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

Acknowledgements

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