West Coast Regional Council State of the Environment groundwater monitoring report 2018

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ABBREVIATIONS

ANZECC	Australia and New Zealand Environment and Conservation Council
Br	Bromide
Ca	Calcium
Cl	Chloride
DO field	Dissolved oxygen, measured in the field
DRP	Dissolved reactive phosphorous
E. coli	Escherichia Coli
EC	Electrical conductivity
F	Fluoride
Fe	Iron (dissolved form)
GNS	GNS Science
GV	Guideline value
HCO_3	Bicarbonate
K	Potassium
MAD	Median absolute deviation
MAV	Maximum Allowable Value
Mg	Magnesium
Mn	Manganese (dissolved form)
Na	Sodium
NGMP	National Groundwater Monitoring Programme
NH_3-N	Ammonia-nitrogen
NO_3-N	Nitrate-nitrogen
NZ	New Zealand
NZDWS	New Zealand Drinking Water Standards
NZTM	New Zealand Transverse Mercator
pH field	Groundwater pH, measured in the field
SiO_2	Dissolved reactive silica
SOE	State of the Environment
SO_4	Sulphate
T field	Groundwater temperature, measured in the field
TV	Trigger value
WCRC	West Coast Regional Council

EXECUTIVE SUMMARY

The West Coast Regional Council (WCRC) commissioned GNS Science (GNS) to prepare a report of the State of the Environment (SOE) for groundwater in the West Coast Region. This report includes a summary of groundwater levels (indicative of groundwater quantity) and groundwater quality; a brief analysis of preliminary groundwater age dating work; and a brief commentary on results from previous reports (2004, 2005 and 2009).

This study is based on monitored groundwater quality and quantity data collected by WCRC that contained over 20 analytical parameters, including microbial indicators. It included quarterly samples collected at National Groundwater Monitoring Programme (NGMP) bores since 1998. Statistical trend analysis was performed using R software (version 3.5.0, NAD and LWP-Trends libraries). Time periods considered for the analysis were: 2012 to 2017 for State and Exceedances; 2007 to 2017 and 1997 to 2017 for Trends. Following the removal of sites due to minimum data point requirements: State was assessed at 8 groundwater quality sites and 23 groundwater quantity sites; Exceedances were assessed at 21 sites; Trends were assessed at 31 groundwater quality sites and 44 groundwater quantity sites.

Groundwater quality remains relatively dilute, with median conductivities close to 100 μS/cm. NO_3-N concentrations (0.18 to 5.8 mg/L) are higher than previously reported (0.11 to 5.1 mg/L) over the 2005-2009 period (Raiber and Daughney, 2009). At three sites, these concentrations exceed both the maximum naturally occurring NO_3-N concentrations and land use impact thresholds established through two independent studies (Daughney and Reeves, 2005; Morgenstern et al. 2012). Low NH_3-N concentrations (0.003 to 0.01 mg/L) are consistent with low Fe (<0.02 to 0.31 mg/L) and Mn (0.04 to 0.09 mg/L) concentrations, although mixed oxygenated conditions are encountered at the monitoring bores (median DO field range from 0.88 to 8.68 mg/L). Concurrent significant (i.e., low statistical uncertainty) trends at given wells were observed for up to twelve parameters, mostly decreases for Cl and field pH, accompanied with increasing Ca, Mg, K, SiO_2 and SO_4. Microbial contamination remains a groundwater quality issue for WCRC groundwaters, with *E.coli* and faecal coliforms detected above the NZDWQ MAV at 62% and 40% of the monitoring bores, respectively.

At most bores, groundwater level remains relatively stable through time, with medians from 0.77 to 11.98 m below the top of casing between 2012 and 2017. Significant (i.e., low uncertainty) depth to groundwater decreasing trends (i.e., water level decline) was observed at seven sites for both the longer periods.

Recommendations from this report are:

- Continued monitoring for microbial indicators is recommended at all sites. Where the bores are used as drinking water supply this poses a health risk. Deepening the bores and improving bore-head protection may be considered to improve abstracted groundwater quality.
- NO_3-N concentrations are higher than previously reported and indicative of land use impact: it is recommended to continue quarterly monitoring for the same suite of chemical parameters to monitor this change.
- Where the degree of confidence for the mean residence times of groundwaters has been determined as moderate to low: additional sampling and analysis for tritium is recommended to improve confidence of these results.
- For some bores, the lack of detailed bore construction and site information prevents the conversion from “depth to groundwater” to “groundwater elevation”: the capture of detailed bore information for all bores will enable a comparison of groundwater elevation between sites and may provide information on aquifer connectivity.

1.0 INTRODUCTION

1.1 Scope

GNS was commissioned by WCRC to complete a Groundwater SOE report incorporating historical and recent relevant WCRC groundwater level and groundwater quality data. This report is an update of previous Groundwater SOE reports completed by GNS (Daughney 2004; Zemansky et al. 2005; Raiber and Daughney, 2009) using the most current information available, and includes:

- A brief overview of relevant results from previous GNS groundwater SOE reports for WCRC.
- Summary and incorporation of available and relevant groundwater level and quality data, for the West Coast region.
- Analysis and presentation of additional information for WCRC derived from the NGMP, including a brief analysis of preliminary groundwater age data.
- This report, provided to WCRC with accompanying cleaned and processed datasets in electronic format.

2.0 SOE MONITORING

2.1 Why is groundwater monitored

In 2009-2010, West Coast Region's annual (1 July 2009 – 30 June 2010) water allocation for consumptive use amounted to 243 Mm^3/yr, with 14.2% of this coming from groundwater resources. This important resource is used by communities for drinking-water, agriculture, processing and bottled water production (Raiber and Daughney, 2009; West Coast Regional Council, 2018). Nationally, groundwater annual allocation for consumptive use over the same time period represented 12.4%, or a total of 26,936 Mm^3/yr, of the annual volume of freshwater allocated for consumptive use (Aqualinc Research Ltd, 2010). It is also recognised that the contribution of groundwater irrigation to the New Zealand economy is significant (estimated at $2 billion per annum; Corong et al. 2014).

In the West Coast Region, groundwater is mainly hosted in alluvial material (e.g., sand, gravel), typically 20 to 40 m thick adjacent to streams and rivers. The maximum recorded depth for these deposits is 80 m in the Grey Valley. These aquifers were formed by long-term erosional processes associated with the uplifting of the Southern Alps and glacial processes. Although WCRC maintains a Groundwater Bore inventory, a resource consent was not required by the council to undertake bore drilling until approximately 2009, which limits the available knowledge of the aquifers (Raiber and Daughney, 2009).

Other important sources of groundwater in the West Coast Region are uplifted marine limestones, which are often associated with karstic landforms (e.g., sinkholes, caverns) and springs (Raiber and Daughney, 2009). In addition, low-temperature (20 to 100°C) geothermal springs and seeps occur in the region, likely linked to faulting associated with the Alpine Fault (Mosley, 1992).

2.2 Current network

WCRC current SOE monitoring network consists of:

- 21 dedicated SOE groundwater quality sites (Appendix 1; Figure 2.1), monitored for 35 parameters annually or bi-annually (Table 2.1). Sixteen of these bores were commissioned in 2007, and therefore have not yet been included in previous reporting.
- 8 groundwater quality bores are shared with the National Groundwater Monitoring Programme (NGMP; operated in collaboration with GNS). The NGMP bores are sampled quarterly for 23 variables (Table 2.1) and have been monitored since 1998 (except for Bore 203, which was added in 2003). Additionally, Bore 291B was replaced by Bore 291A, and Bore 287 was replaced by Bore 487; the last samples recorded for these bores were collected in July 2005 and September 2006, respectively. The NGMP bores have a bore depth range between 3 and 37 m, however, aquifer information is unknown (Appendix 1, Figure 2.1). For all bores, the surrounding land use is dominated by dairy activities. Microbiological indicator parameters have also been measured at the NGMP sites quarterly since 2000 (Raiber and Daughney, 2009).
- 39 groundwater quantity bores (Figure 2.1), which include NGMP sites. The number of monitoring bores significantly increased in 2010. The monitoring frequency of groundwater depth varies from 3-yearly to monthly.

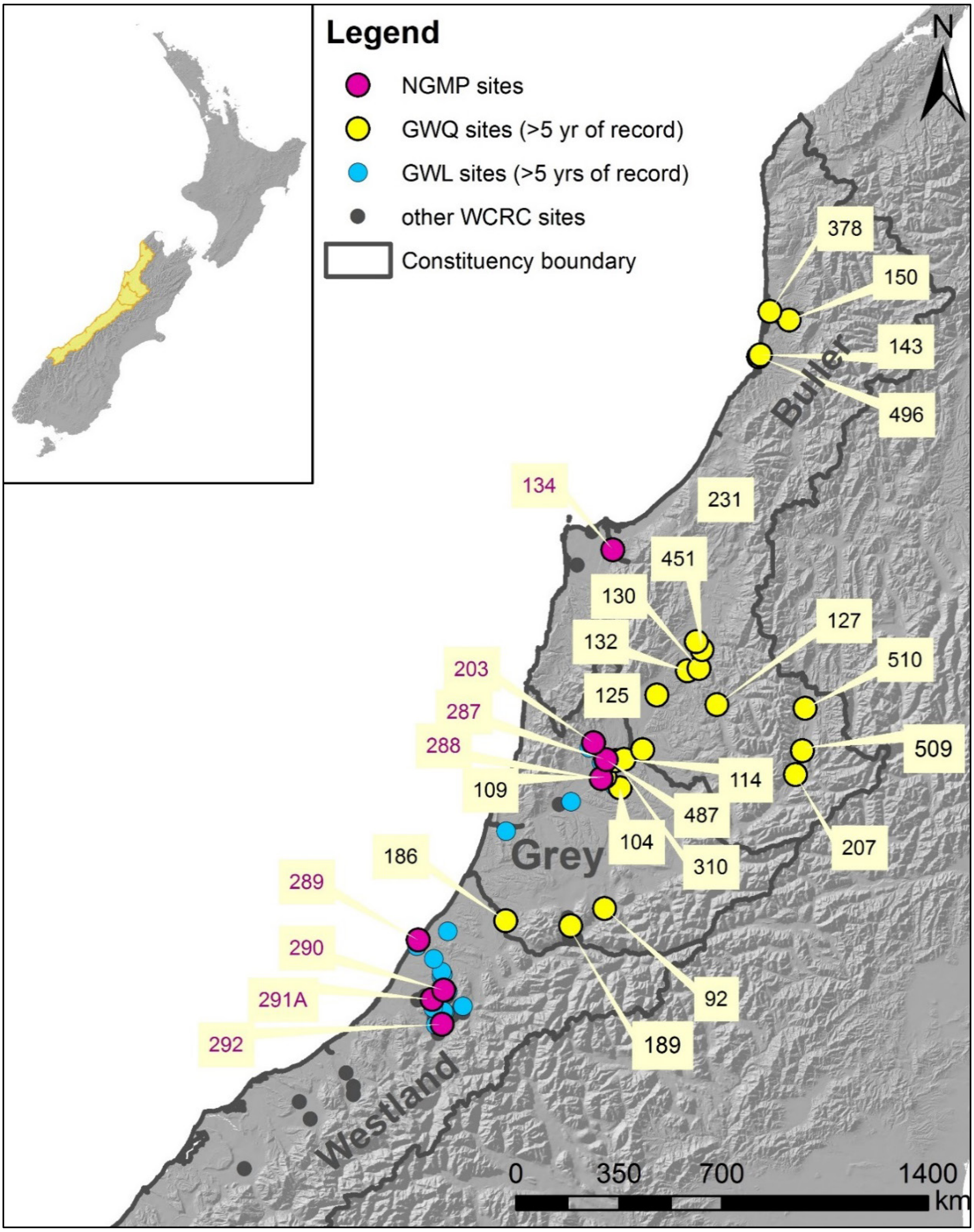

Figure 2.1 Location of groundwater quality (GWQ; NGMP) and water level (GWL) sites in the West Coast region.

Table 2.1 Current list of parameters monitored at WCRC SOE and NGMP sites.

Parameter	Units	SOE analytical method	NGMP analytical method
Alkalinity (total, as HCO_3)	mg/L as $CaCO_3$	Titration, APHA 2320 B (modified)	Titration APHA 2320B
Bicarbonate	mg/L at 25˚C	Calculation: from alkalinity and pH, APHA 4500-CO_2 D	
Bromide (dissolved)	mg/L		Ion Chromatography APHA 4110B
Calcium (dissolved)	mg/L	Filtered sample, ICP-MS, trace level. APHA 3125 B	Induced Coupled Plasma -Optical Emission Spectrometry, APHA 3120B
Calcium (total)	mg/L	Induced Coupled Plasma -Mass Spectrometry, trace level, APHA 3125 B	
Carbonate Alkalinity	g/m_3 as $CaCO_3$	Calculation: from alkalinity and pH, APHA 4500-CO_2 D	
Chloride (dissolved)	mg/L	Ion Chromatography, APHA 2 4110 B (modified)	Ion Chromatography APHA 4110B
Dissolved Reactive Phosphorus (dissolved)	mg/L	Molybdenum blue colorimetry, Flow injection analyser. APHA 4500-P G	Flow Injection Analyser APHA 4500-P G (modified)
E.coli (Mem. Filtration)	cfu/100mL	Membrane filtration, APHA 9222 G	
E.coli (MPN)	MPN/100mL	MPN count, APHA 9221 B, 9221 F (modified)	MPN count, APHA 9221 B, 9221 F (modified)
Fluoride (dissolved)	mg/L		Ion Chromatography APHA 4110B
Iron (dissolved)	mg/L	Induced Coupled Plasma -Mass Spectrometry, APHA 3125 B	Induced Coupled Plasma -Optical Emission Spectrometry, APHA 3120B
Iron (total)	mg/L	Induced Coupled Plasma -Mass Spectrometry, trace level, APHA 3125 B	
Magnesium (dissolved)	mg/L	Filtered sample, ICP-MS, trace level. APHA 3125 B	Induced Coupled Plasma -Optical Emission Spectrometry, APHA 3120B
Magnesium (total)	mg/L	Induced Coupled Plasma -Mass Spectrometry, trace level, APHA 3125 B	
Manganese (dissolved)	mg/L	Filtered sample, ICP-MS, trace level. APHA 3125 B	Induced Coupled Plasma -Optical Emission Spectrometry, APHA 3120B
Nitrate (dissolved)	mg/L	Calculation: (Nitrate-N + Nitrite-N) - NO_2N.	Ion Chromatography APHA 4110B
Nitrate + Nitrite (dissolved)	mg/L	Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3-I (modified)	
Nitrite (dissolved)	mg/L	Automated Azo dye 2 colorimetry, Flow injection analyser. APHA 4500-NO_3-I	
Nitrogen (total)	mg/L	Calculation: TKN + Nitrate-N + Nitrite-N.	
Nitrogen Kjeldahl	mg/L	Sulphuric acid digestion with copper sulphate catalyst.	
pH field	pH	N/A	N/A
Phosphorous (total)	mg/L	Colorimetry, Discrete analyser, APHA 4500-P B & E (modified)	
Potassium (dissolved)	mg/L	Filtered sample, ICP-MS, trace level. APHA 3125 B	Induced Coupled Plasma -Optical Emission Spectrometry, APHA 3120B
Potassium (total)	mg/L	Induced Coupled Plasma -Mass Spectrometry, trace level, APHA 3125 B	
Silica (dissolved)	mg/L		ICP-OES APHA 3120B
Sodium (dissolved)	mg/L	Filtered sample, ICP-MS, trace level. APHA 3125 B	Induced Coupled Plasma -Optical Emission Spectrometry, APHA 3120B
Sodium (total)	mg/L	Induced Coupled Plasma -Mass Spectrometry, trace level, APHA 3125 B	
Specific Conductance	µS/cm	N/A	N/A
Sulphate (dissolved)	mg/L	Ion Chromatography, APHA 2 4110 B (modified)	Ion Chromatography APHA 4110B
Sum of anions	meq/L	Calculation, APHA 1030 E	
Sum of Cations	meq/L	Calculation, APHA 1030 E	
Total ammonia (dissolved)	mg/L	Phenol/hypochlorite 2 colorimetry. Flow injection analyser, APHA 4500-NH_3 H	Flow Injection Analyser APHA 4500-NH_3-N
Total hardness	mg/L as $CaCO_3$	Calculation from Calcium and Magnesium. APHA 2340 B	
Water Temperature	°C	N/A	N/A

2.3 Previous SOE reports

Based on groundwater quality data collected at NGMP sites between 1998 and 2009, West Coast groundwater is generally of relatively good quality compared to other regions of New Zealand (Daughney, 2004; Zemansky et al. 2005) and to the New Zealand Drinking Water Standards (NZDWS; Zemansky et al. 2005; Raiber and Daughney, 2009).

During the period 2005-2008, median NO_3-N concentrations were relatively low at NGMP sites (ca. 2 mg/L or less) in comparison with the NZDWS MAV of 11.3 mg/L (Ministry of Health, 2008). However, it was noted that at three sites (bore 203, 285 and 454), median NO_3-N concentrations exceed 3 mg/L, which is an almost certain indicator of human impact (Morgenstern and Daughney, 2012). At two of these sites, the NO_3-N concentrations occasionally approached or exceeded the ANZECC TV of 7.2 mg/L set for protection of freshwater ecosystems (Australia and New Zealand Environment and Conservation Council, 2000) during the period 2005-2008. Elevated Mn concentrations were measured constantly above the aesthetic guideline value (GV) of 0.05 mg/L at Bore 454 during the period 2005-2008, and occasionally exceeded the health-related NZDWS MAV of 0.5 mg/L (Ministry of Health, 2008). Occasionally, Fe concentrations were measured at three locations (bores 134, 287 and 290) above the NZDWS aesthetic GV of 0.2 mg/L (Ministry of Health, 2008). Elevated Fe concentrations at the NGMP sites result from naturally low levels of oxygen in the aquifers, and carry no associated health risks.

Bacterial contamination is a recurring issue in WCRC groundwaters—a third of the groundwater samples collected at six NGMP bores between 1998 and 2004 exceeded the NZDWS MAV (<1 cfu/100mL). More recently, contamination at all NGMP sites, except one, was reported (Zemansky et al. 2005; Raiber and Daughney 2009). The shallow depth of the bores, combined with the likely unconfined nature of the monitored aquifers, makes these groundwaters very vulnerable to surface contamination.

Since 1998, several NGMP monitoring sites have shown significant increasing trends in the concentrations of NO_3-N, Cl and/or SO_4. Together with frequent transgression of the NZDWS for bacterial indicator parameters, the increasing concentrations of these substances in groundwater are likely the result of increased leaching from manure, sewage effluent or fertiliser associated with intensification of land use (Zemansky et al. 2005; Raiber and Daughney 2009).

Groundwater age determination at NGMP sites yielded mean residence times ranging from 1.5 years to 45 years. At sites where residence time is less than 2 years, a rapid response in groundwater quality to land use changes is expected. In contrast, a delayed breakthrough of nitrate from past human/agricultural activities is expected at sites with older (several decades) groundwater mean residence times. This could mean that NO_3-N concentrations at these sites may continue to rise for some time even if the level of human impact remains constant or is reduced within the bore's capture zone (Raiber and Daughney 2009).

Groundwater monitoring and data management at WCRC were reviewed in 2005, highlighting issues around documenting field and laboratory quality control and quality assurance measures. It was also recommended to collect groundwater samples following the New Zealand sampling protocol (Daughney et al. 2006). At present, NGMP and SOE samples are being consistently collected following the New Zealand sampling protocol.

Two local groundwater studies were conducted in 2007, one in the Lake Brunner area (Zemansky and Horrox, 2007a) and the other in the Kowhitirangi and Kokatahi Plains (Zemansky and Horrox, 2007b). The Lake Brunner area study aimed to assess the nutrient pathways in surface water and groundwater. Mass fluxes of nitrogen and phosphorus through the catchment were estimated, and it was shown that groundwater contributed significantly to the NO_3-N flux through the catchment, whereas in contrast, phosphorus migrated predominantly via surface water. The Kowhitirangi and Kokatahi Plains study involved the collection and analyses of groundwater samples at non-NGMP bores to gain insight on groundwater flow paths and assess the local impact of land use on groundwater quality. High nitrate concentrations were associated with intensive land use activities. Minor changes of concentrations between the dry and wet seasons were associated with precipitation-facilitated downward migration of NO_3-N and sulphate from anthropogenic sources (e.g., farming operations).

3.0 STATE AND TREND ASSESSMENT

3.1 Data selection

Groundwater quality and level data was provided to GNS by WCRC staff in eight data files in the form of Excel spreadsheets. All spreadsheets were aggregated into a single file. The spreadsheets included data from additional sites that are not part of the routinely monitored sites described in Section 2.2.

Duplicated groundwater level records were identified through a matching combination of site name, date (truncated to the day) and groundwater level measurement value, and were subsequently removed.

In total, groundwater quality and level data were provided for 85 and 77 sites respectively, with some overlap. The aggregated dataset was edited as follows:

- 139 individual results were edited to address anomalous values (e.g., faecal coliform measurement of 0 replaced by the higher detection limit for this parameter, <5) or data format issues during processing (e.g., removal of space character for measurement below detection limits);
- 200 chemical analyses and 23 groundwater level recordings were removed because they were duplicated;
- where a sufficient number of parameters was available, a calculation of the charge balance error and/or ionic sum was performed. This quality assurance measure ensures that the electroneutrality of a sample is verified. The calculation details can be found in previous SOE reports (e.g., Raiber and Daughney, 2009). This check resulted in the further removal of 26 analyses.

3.2 Reported statistics

In this report, three time-periods were used: a 5-year period defines State (2012-2017); and two periods, 10-year (2007-2017) and 20-year (1997-2017), defined short-term and long-term Trends. State and Trend statistics are reported using the following metrics, in accordance with previous SOE and national reporting (Raiber and Daughney 2009; Moreau and Daughney 2015):

- median and median absolute deviation (MAD): the median is a measure of central tendency. It is a more robust measure than mean values because it is not affected by outliers. The MAD gives an indication of the data spread around the median; it is likewise more robust than the standard deviation, particularly to long distribution tails (Helsel and Hirsch 2002)
- percentiles (5th, 25th, 50th, 75th, 95th): these also inform the data spread around the median. The median is the 50th percentile (Helsel and Hirsch 2002).
- trend magnitudes: the rate of change in each parameter. In this report, the trend magnitudes are based on Sen's slope estimator, which is commonly used for environmental reporting (Helsel and Hirsch 2002).
- number of exceedance: this indicator provides context to state and trend descriptive metrics with regards to published environmental guidance relevant to ecosystem or human health. It is limited to groundwater quality data and consists of a comparison between either individual measurements or calculated median measurement values and a defined threshold. Exceedances are reported against the following thresholds for State

assessment: NZDWS maximum admissible and guideline values (Ministry of Health, 2008); the ANZECC guidelines (Australia and New Zealand Environment Conservation Council. 2000; note that at the time of writing, these guidelines are currently in revision); and referenced groundwater quality baseline values where applicable (Daughney and Reeves 2005). For trends, exceedances are reported against groundwater quality baseline trend values, where applicable (Daughney and Reeves 2006).

- statistical test p-values: in this report, several statistical tests were conducted to assess either the statistical significance of a trend, seasonality or distribution difference. For each test, a hypothesis is formulated and test statistics are calculated. An acceptable error rate is arbitrarily set to reject or accept the hypothesis, based on a data-calculated probability value (p-value). For this report, the significance level was arbitrarily set as $\alpha=0.05$ for all tests, which is a common threshold used in environmental statistics reporting. Detailed information about the use of hypothesis tests in general and the tests used in this report can be found in Helsel and Hirsch (2002).

3.3 Statistical tests selection and implementation

The Mann-Kendall test, seasonally adjusted where relevant, was used for trend detection of temporal trends in groundwater quality. The Mann-Kendall test has a long history of use in water quality studies in general (Helsel and Hirsch 2002) and has been applied in previous investigations of groundwater quality in New Zealand (Raiber and Daughney 2009; Moreau and Daughney 2015). Seasonality was tested using the Kruskall-Wallis test, an equally widely used statistical test for environmental data analysis (Helsel and Hirsch 2002). Trend magnitudes are estimated using the Sen slope estimator, which robustly handles typical groundwater quality data, i.e., non-normally distributed time series containing missing and censored values (Snelder and Fraser, 2018).

Previous WCRC SOE groundwater quality and quantity reports used the NGMP Calculator (Daughney 2007, 2010) to perform state and trend analysis. For this report, SOE monitoring data was processed through the R software (version 3.5.0) using the LWP-Trends (version 1804) and NADA (version 1.6-1) libraries. The change in method reflects recent advances in handling of censored data (Helsel, 2012) that supersede methods used by the NGMP Calculator (Table 3.1). The NADA library implements the statistical methods to handle censored values. It is used here to calculate medians and median absolute deviations for time series with left-censored values. The LWP-Trends library was used to compute all statistical tests, on censored and uncensored time series that have been processed with NADA methods, however, it does not output either median or median absolute deviations. This library also provides new trend descriptors (Snelder and Fraser, 2018):

- **Trend category**. The decreasing or increasing trend diagnostic is no longer informed by the sole comparison of the trend test p-value to an arbitrarily defined confidence level. Instead, a symmetric confidence interval around the trend is calculated. If this interval contains zero, the trend is described as “uncertain”. If this interval does not contain zero, this interval is “established with confidence” and assigned either a “decreasing” or “increasing” descriptor. This method was recently developed and applied to river quality state and trend assessments (Larned et al. 2016; McBride 2018).
- **Trend direction**. This is a descriptive category based on the sign of the Sen slope. Possible values are: “increasing”, “decreasing”, “undetermined”.
- **Percentage annual change in slope**. The annual change is calculated by dividing the Sen slope by the median. In this instance, the median is calculated over the same time period as the slope and is subject to the same minimum data requirement.

- **Lower and upper confidence interval bounds** for the Sen slope.
- **Sen slope probability**. In this report, the mean probability of all inter-observation slopes that are equal to zero. It informs on whether the true trend slope differs from zero.

To calculate meaningful state and trend metrics, minimum data point requirements were set as follows:

- Descriptive statistics (indicative of state over the 2012-2017 time period): where more than half of the measurements are recorded below the detection limit (i.e., above a censoring level of 50%), median and trend metrics are reported as “non-determined”. For censoring levels between 25% and 50% percentiles, data is insufficient to derive these values with confidence and these values will be reported as “non-determined”.
- Kruskall-Wallis test (includes seasonal, both trend time periods): the number of seasons considered for the analysis is four (Autumn, Winter, Spring and Summer). The annual time period commences on 1st March of the first year (start of Autumn). To enable seasonality state and trend assessments, all seasons must have at least one observation and individual seasons require at least two data points.
- Mann-Kendall test and Sen Slope estimator (includes seasonal, and both trend time periods): the time series must contain at least 10 data points, the maximum censored values must be smaller than the maximum observed values, and for each time series at least 5 unique observations must be required.

Table 3.1 Comparison of handling of censored values between the NGMP Calculator and the LWP-Trends and NADA R libraries. Sources: Daughney (2007 and 2010) and Snelder and Fraser (2018).

Statistics type	LWP-Trends	NADA	NGMP Calculator
Descriptive	Not applicable	Below 80% censoring, imputation using the robust regression on order statistics.	Below 80% censoring, imputation using lognormal regression (Helsel and Cohn 1988)
Sen slope estimator (includes seasonal)	Removal	Not applicable	Substitution to half the detection limit
Mann-Kendall (includes seasonal)	Left and right censored values are treated as two distinct ties groups. Test statistics calculations are adjusted when censoring levels are multiple.	Not applicable	Substitution to half the detection limit
Kruskall-Wallis	Censored values and values less than the highest non-detect (<) are assigned the same low value and treated as ties (i.e., repeated values, which have the same rank). If the censored values are > then all non-detects and values higher than the lowest non-detect (>) are assigned the same high value and are treated as ties.	Not applicable	Substitution to half the detection limit

4.0 RESULTS

4.1 Data output

Groundwater quality time series at 85 sites were provided by WCRC. This included 50 sites at which groundwater quality was measured for less than a year in 2007 and five sites at which measurements were collected over a 1 to 5-year period. Forty-six of these sites consisted of less than 5 years of record. Data included one of the decommissioned NGMP sites. State and trends over the 1997-2017 period was calculated for 8 and 31 sites respectively, owing to minimum data point requirements.

Groundwater level time series were provided for 77 sites for the 1997-2017 period. This included 26 sites at which groundwater depth was measured for less than a year in 2007 and four sites at which measurements were collected over a 1 to 5-year period. Another four sites exhibited almost 10 years of record, however, measurements ended in 2009. State and trends over the 1997-2017 period was calculated for 23 and 44 sites respectively, owing to minimum data points requirements.

Raw, cleaned and processed data are compiled in a digital data file accompanying the report (CR 2018-109 Data output, xls format), in the following worksheets:

- “Site_information”: contains site specific information where available, such as bore ID, bore number, location, monitoring network information, bore depth, surrounding land use.
- “Clean_data”: contains groundwater quality and level data provided by WCRC, including both unedited and edited values, as bore as an indication of whether this data was excluded from calculations.
- “State_per_site_per_param”: contains groundwater quality and level state metrics per site, per parameter, calculated over the 2012-2017 time-period. Site and parameter combinations included in this report are tagged “yes” in the “reported” column, which indicate that more than 10 data points were available for the state assessment. This additional data was provided for WCRCs convenience, as the application of a minimum data requirement reduced the number of quality sites from 31 to 8.
- “Trends_per_site”: contains groundwater quality and level trend metrics, calculated over the 1997-2017 and 2007-2017 time-periods, for sites and parameters at which more than 10 data points were available during the time period. The exception is dissolved reactive phosphorous (DRP), where trend assessment was provided without a minimum data point requirement. This is because DRP is monitored annually at NGMP sites due to budget restrictions, and this sampling frequency is incompatible with the minimum data point requirement. DRP trend assessment is tagged “no” in the “reported” column;
- “Exceedance_per_site”: contains a summary table per site for parameters where thresholds were exceeded in the 2012-2017 time period.

4.2 State

4.2.1 Groundwater quality

Groundwater quality state was established at eight monitoring locations for 20 parameters (T field, pH field, DO field, EC, microbiological indicators (E. coli and faecal coliforms), Br, Ca, Cl, F, Fe, HCO_3, K, Mg, Mn, NH_3-N, Na, NO_3-N, SiO_2 and SO_4).

T field at the NGMP bores ranged from 12.5 to 14.8°C, with a seasonal pattern observed at bores 290, 487 and 203. Median pH field ranged from 5.2 to 6.1 pH units. Do range from less than 1 to 8.68 mg/L.

Median EC at WCRC bores exhibited a narrow range, from 90 μS/m (Bore 292) to 140 μS/m (Bore 203). The lowest MAD (2.96 μS/m) was observed where median conductivity was lowest and conversely for the highest MAD (19.27 μS/m at bore 203). The highest conductivity coincided with the highest Br, Ca, K, NO_3-N and SO_4 concentrations.

Median Cl concentrations ranged from 2.6 mg/L (Bore 292) to 9.9 mg/L (Bore 511). The lowest MAD (3 mg/L) was observed where median conductivity was lowest and conversely for the highest MAD (19.27 μS/m at bore 203). The highest Cl concentration did not coincide with the highest EC. Median Ca, Mg, K and Na concentrations at WCRC bores were low (overall medians 11.7, 2.08, 2.1 and 4.7 mg/L, respectively) with MADs of less than 1.8 mg/L. Median SO_4 concentrations ranged from 5.15 mg/L (Bore 511) to 9.0 mg/L (Bore 203). Median SiO_2 concentrations ranged from 4.5 mg/L (Bore 203) to 21.0 mg/L (Bore 288).

Nitrogen is mostly present in West Coast groundwaters in the form of NO_3-N. At the eight NGMP bores, median NO_3-N concentrations ranged between 0.14 mg/L (Bore 134) to 5.8 mg/L (Bore 203), with all but one value below 1.00 mg/L. Median NO_3-N concentrations were previously reporter at lower level (0.11 and 5.1 mg/L range between the 2005 and 2009; Raiber and Daughney, 2009).NH_3-N concentrations ranged from 0.003 to 0.01 mg/L. Nitrogen species may occur naturally from nitrogen-rich bedrock and natural soil leaching, however, an elevated concentration of nitrogen is a potential indicator of land use impact on groundwater quality (e.g., from sewage and fertiliser). Based on multivariate statistics, Daughney and Reeves (2005) established NO_3-N threshold values of 1.6 and 3.5 mg/L, respectively, for “probable” and “almost certain” land use impact on New Zealand groundwaters (affecting 41% and 29% of the SOE bores nationally, respectively). In another study linking groundwater chemistry and mean residence time, an intermediate threshold value of 2.5 mg/L of NO_3-N was proposed as an indication of land use intensity (Morgenstern and Daughney, 2012). Three out of the eight WCRC monitoring bores are above all three thresholds. A comparison between the 2012-2017 median NO_3-N concentrations and medians for the 2007-2012 and 1997-2017 periods clearly indicate an upward shift (Figure 4.1), which is also observed with other possible indicators of land use impact (Na, K, Mg, Ca, NO_3-N and NH_3-N) in Southland (Rissmann et al. 2012), and nationally (Daughney and Reeves, 2006).

The low NH_3-N concentrations are consistent with low Fe (<0.02 to 0.31 mg/L) and Mn (0.04 to 0.09 mg/L) concentrations, which indicate oxygenated conditions at the monitoring bores.

Phosphorous can be naturally derived from rock interaction or decomposition of plant and animal tissue, or originate from organic waste. It is also a land use impact indicator, as fertilisers, manure and composted material contain phosphorous. DRP concentrations at WCRC’s SOE bores remain low, with a range from 0.002 to 0.02 mg/L.

E.coli detection occurred at all sites for 40 to 60% of the samples. The two largest *E.coli* counts were measured at Bore 487, with 1600 MPN/100 mL on 19/05/2014 and 920 MPN/100 mL on 20/04/2017. The current NZDWS MAV is a single detection (1 CFU/100mL).

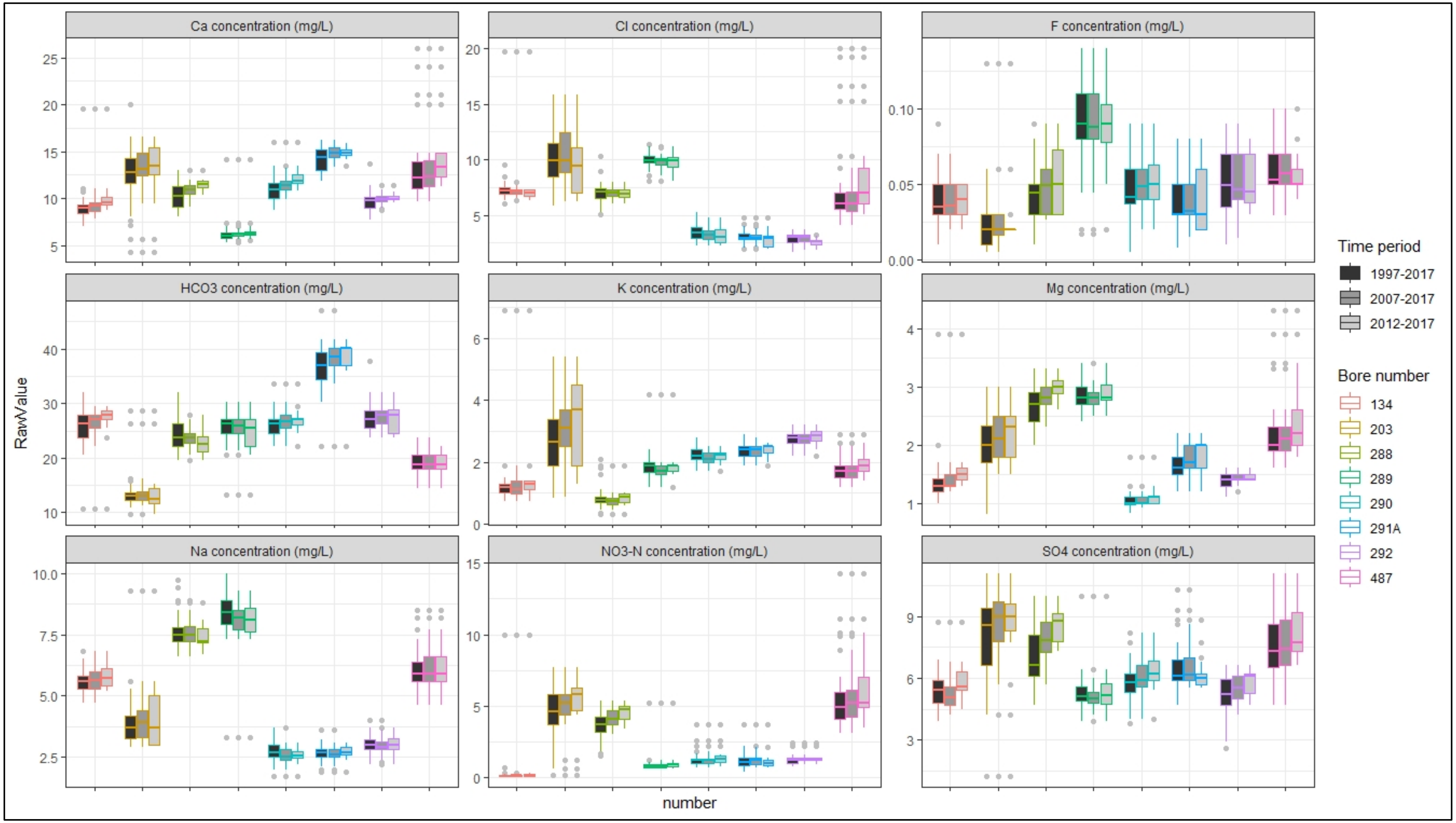

Figure 4.1 Boxplot concentrations of Ca, Cl, F, HCO_3, K, Mg, Na, SiO_2, SO_4 at WCRC NGMP bores between 1997 and 2017.

4.2.2 Exceedances

Over the 2012-2017 time-period, time series for 29 sites were assessed with regard to threshold exceedances. At all sites, pH values below the recommended pH range of 6.5 to 8.5 were recorded (Table 4.1, Ministry of Health, 2008).

NO_3-N concentrations exceeded the ANZECC GV (0.2 mg/L) at all sites, occasionally the higher ANZECC TV (7.3 mg/L) at 10 sites, and the NZDWS MAV (11.3 mg/L) at 3 sites once or twice. Maximum naturally occurring concentrations for a range of parameters are available at 7 of the 8 NGMP sites. Natural baseline concentration for NO_3-N was exceeded almost all the time at bore 288 and 487, and once at bores 134, 290 and 291A. Median pH field at NGMP bores range from 5.2 to 6.1 pH units. At Bore 125, the NH_3-N NZDWS GV (1.2 mg/L) and ANZECC TV (0.7 mg/L) was exceeded on a couple of occasions.

Fe concentrations exceeded the NZDWS aesthetic GV of 0.2 mg/L and 0.04 mg/L, respectively at 14% and 41% of the bores. Where available, natural baseline Fe concentration was exceeded every second measurement at all but Bore 289. There was no exceedance of NZDWS or ANZECC guidelines for F, Mn and SO_4 concentrations.

Microbial contamination continues to be a groundwater quality issue for WCRC groundwaters. *E.coli* and faecal coliforms analytical methods are a combination of colony-forming unit (CFU) and most probable number (MPN) estimates for a sample volume of 100 mL, preventing a direct comparison with the, which uses only CFU/100mL NZDWS (Ministry of Health, 2008). However, the MAV is set as no detection for microbial indicator. Therefore, *E.coli* and faecal coliforms CFU and MPN estimates were aggregated to investigate detection. Over the 2012-2017 period, *E.coli* were detected at 62% of the monitored bores and faecal coliforms were detected at 40% of the bores.

4.2.3 Groundwater depth

Groundwater quantity state for the 2012-2017 time-period was established at 23 monitoring locations (Figure 4.2). Median groundwater depth ranged from 0.77 to 11.98 m below the top of casing. The largest variations were observed in Bore 104 with a median absolute deviation of 3.79 m. The second largest groundwater level variations were observed in Bore 203, with a median absolute deviation of 1.3 m. Only three bores (292, 104, 611) exhibited statistically significant seasonal variations.

Table 4.1 Exceedances in groundwater quality observed at WCRC bores over the 2012-2017 period.

		Bore number	290	496	292	104	114	288	451	310	130	291	127	116	487	378	143	150
		Baseline reference	1B2		1B1			1B2				1B1			1B2			
NO_3-N concentration (mg/L)		n	20	9	20	9	8	20	9	8	8	19	9	8	21	7	7	8
		NZDWS GV																
	11.3	NZDWS MAV													1			2
	0.16	ANZECC GV	20	9	20	9	8	20	6	8	8	19	9	8	21	1	7	8
	7.3	ANZECC TV									6		1		5		5	4
		Natural baseline	1					20				1			21			
Fe concentration (mg/L)		n	40	12	40	12	12	40	12	10	10	38	14	14	42	8	8	10
	0.04	NZDWS GV	31		1						2	8				8		
	0.4	NZDWS MAV	4								1					4		
		ANZECC GV																
	1.9	ANZECC TV																
		Natural baseline	23		19			9				21			12			
NH_3-N concentration (mg/L)		n	20	9	20	9	8	20	9	7	8	19	8	7	21	7	7	8
	1.23	NZDWS GV																
		NZDWS MAV																
		ANZECC GV																
	0.74	ANZECC TV																
		Natural baseline																
E.coli (cfu/100mL or MPN/100mL)		n	20	9	20	9	8	20	10	8	9	19	10	8	20	7	7	8
		NZDWS GV																
	1	NZDWS MAV	8		9			8	1	3	2	6			10		2	
		ANZECC GV																
		ANZECC TV																
Faecal coliform (cfu/100mL or MPN/100mL)		n	20	9	20	9	8	20	11	9	10	19	11	9	20	7	7	8
	1	NZDWS GV																
		NZDWS MAV	1	1	2				2	1		2		1				
		ANZECC GV																
		ANZECC TV																

Table 4.1 Exceedances in groundwater quality observed at WCRC bores over the 2012-2017 period. (continued)

		Bore number	509	109	134	231	510	132	125	92	207	186	203	289	511
		Baseline reference			1B2									1A1	
NO_3-N concentration (mg/L)		n	8	9	19	8	7	8	9	8	9	8	19	20	3
		NZDWS GV													
	11.3	NZDWS MAV							1						
	0.16	ANZECC GV	8	9	8	8	6	8	9	6	9	8	19	20	3
	7.3	ANZECC TV		2	1				3				2		1
		Natural baseline			1										
Fe concentration (mg/L)		n	8	14	38	10	8	10	12	8	12	10	38	40	4
	0.04	NZDWS GV			14	2	1		1		1		3		4
	0.4	NZDWS MAV													1
		ANZECC GV													
	1.9	ANZECC TV													
		Natural baseline			17										
NH_3-N concentration (mg/L)		n	8	9	19	8	7	8	9	8	9	8	19	20	3
	1.23	NZDWS GV							1						
		NZDWS MAV													
		ANZECC GV													
	0.74	ANZECC TV							2						
		Natural baseline													
E.coli (cfu/100mL or MPN/100mL)		n	8	9	19	9	8	9	9	8	10	8	19	20	3
		NZDWS GV													
	1	NZDWS MAV	2	3	6	1	2		2		5		11	7	
		ANZECC GV													
		ANZECC TV													
Faecal coliform (cfu/100mL or MPN/100mL)		n	9	9	19	10	9	10	10	9	11	9	19	20	3
	1	NZDWS GV													
		NZDWS MAV	2	1					1		2			1	
		ANZECC GV													
		ANZECC TV													

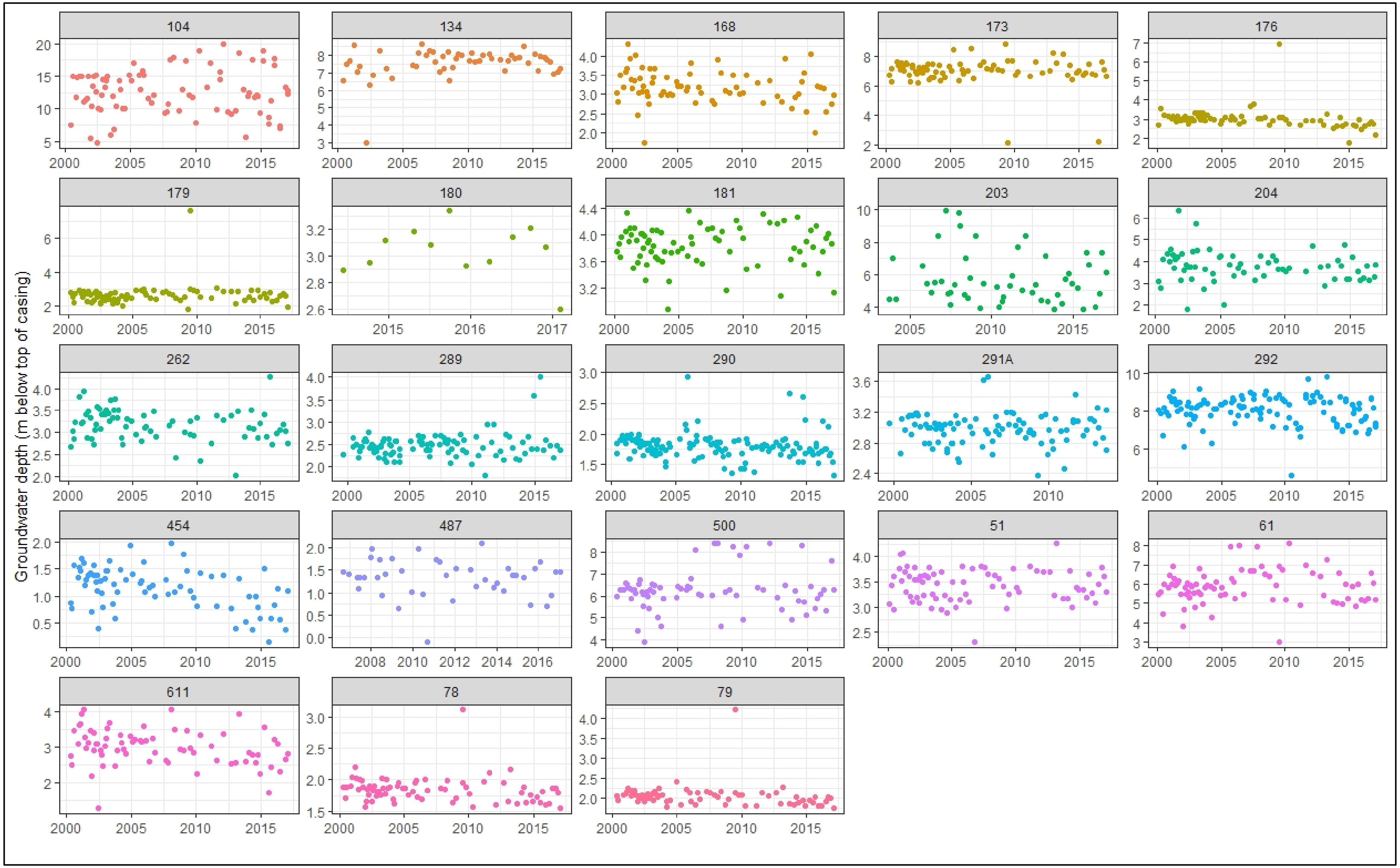

Figure 4.2 Groundwater depth time series at selected WCRC bores.

4.3 Trends

4.3.1 Groundwater quality

Groundwater quality trends were established with confidence at 13 sites, including the observation of concurrent trends at 12 sites that combined increases and decreases for different parameters (Table 4.2). Generally, the detected trends at individual sites are consistent in direction and magnitude for both time periods.

The most frequent increases were observed simultaneously at 10 sites for Ca, Mg, K, SiO_2 and SO_4 concentrations. Ca and SiO_2 trend magnitudes were of the order of 0.1 mg/L per year, whereas for K and Mg these increases are about an order of magnitude less. The most frequent decreases are for Cl concentrations and field pH with rates ranging between -0.04 and -0.53 mg/L per year for Cl, and between -0.01 and -0.1 pH unit per year for field pH.

NO_3-N increases affects 5 sites (bore 130, 203, 289, 288, and 292) at rates ranging from 0.01 to 0.47 mg/L per year. The fastest rate exceeds the threshold for naturally increasing trends for defined using all NGMP bores (0.3 mg/L, Daughney and Reeves, 2006). However, NO_3-N is decreasing at two bores (207 and 291A) at rates of 0.1 to 0.2 mg/L per year.

4.3.2 Groundwater depth

Over the 2007-2017 period, groundwater depth decreases were established with confidence at 7 bores, with rates ranging from -0.016 to -0.113 m per year at bores 61,78,79,173,176,454 and 611. There were no instances of groundwater depth increase established with confidence. Uncertain decreases were detected at 26 bores, while uncertain increases were detected at the 4 remaining bores.

Over the 1997-2017 period, groundwater depth decreases were established with confidence at 7 bores (78,79,168,176,262,454 and 611) at rates ranging from -0.008 to -0.034 m per year. There were two instance of increasing groundwater depth, with magnitudes of 0.183 m per year (bore 288) and 0.198 m per year (bore 105). Uncertain decreases were detected at 24 bores, while uncertain increases were detected at the 11 remaining bores.

4.3.3 Additional information derived from the NGMP programme.

Concentrations of tritium shows latitudinal variation in concentrations across the country. In addition, tritium in rain near the coast can potentially be diluted by direct input of low-tritium oceanic moisture, while high-altitude rain is less diluted by direct input of low-tritium oceanic moisture. Rain in the valleys behind mountain ranges is somewhat sheltered from the direct influence of oceanic air masses and is expected to have the signature of high altitude meteoric water and the resulting higher tritium concentration. Therefore, a rain collector was installed in Greymouth at location 144988 (Easting, NZTM) 5293299 (Northing, NZTM) as part of the NGMP programme in 2009 to monitor tritium and isotope input. Tritium in rain was measured from April 2009 to October 2011. The results showed a lower tritium input into West Coast hydrologic systems by a factor 0.91, compared to Kaitoke near Wellington. The tritium sampler has since been moved to Hawkes Bay (Bridge Pa).

Groundwater age determination at NGMP sites was refined through repeated sampling in 2011. Revised mean residence time ranged from 1.5 to 45 years, with three sites at which the interpretations of age are still ambiguous (former monitoring Bore 291B, active monitoring bores 134 and 487). The collection of additional samples is currently planned for the three sites.

Table 4.2 Trend magnitude for selected parameter at WCRC sites. Negative trends represent a decrease whereas positive trends indicate an increase. Trend magnitude is expressed in pH unit per year for field pH, deg. C per year for temperature and elsewhere in mg/L per year.

Bore number	Period	pH field	T field	Br	Ca	Cl	DO field	F	Fe	HCO_3	K	Mg	Mn	NH_3-N	Na	NO_3-N	SiO_2	SO_4
290	1997-2017	-0.04	-0.04		0.17	-0.07	-0.17		0.01	0.16	-0.01	0.01			-0.04		0.09	0.07
	2007-2017	-0.05			0.12	-0.07	-0.47		0.03		0.03			0.00			0.10	
292	1997-2017	-0.01			0.10	-0.04						0.02		0.00		0.02	0.11	0.17
	2007-2017	-0.04				-0.13	0.07		0.00		0.03		0.00	0.00		0.00	0.18	0.15
288	1997-2017			0.00	0.20					-0.27		0.05				0.17	0.12	0.22
	2007-2017				0.20	-0.07			0.00	-0.36	0.03	0.05	0.00	0.00	-0.06	0.20	0.17	0.34
130	1997-2017				0.65											0.47		
	2007-2017				0.65											0.47		
291	1997-2017		-0.04		0.18					0.40		0.03			-0.01		0.14	
	2007-2017		-0.07			-0.11				0.40	0.03	0.03				-0.11	0.44	-0.14
127	1997-2017					-0.18					0.10	0.05			0.09			0.57
	2007-2017					-0.18					0.10	0.05			0.09			0.57
287	1997-2017	-0.10			0.25	0.18		0.00							-0.16			0.23
487	1997-2017	-0.02			0.37	0.14	-0.22				0.04	0.04		0.00			0.10	0.27
	2007-2017	-0.02			0.35	0.15	-0.22				0.04	0.04		0.00			0.11	0.24
134	1997-2017	-0.03	-0.04	0.00	0.14		-0.11		-0.01	0.27		0.02	0.00			0.00	0.13	
	2007-2017	-0.05			0.20	-0.04	-0.24		-0.01	0.33	0.05	0.03	0.01				0.23	0.19
132	1997-2017	-0.05			0.09													
	2007-2017	-0.05			0.09													
92	1997-2017						-0.18											
	2007-2017						-0.18											
207	1997-2017	-0.06			-0.43		-0.47				0.02					-0.21		
	2007-2017	-0.06			-0.43		-0.47				0.02					-0.21		
203	1997-2017			-0.01	0.20	-0.20	0.24		0.00		0.18	0.08	-0.01	0.00		0.23		0.26
	2007-2017			-0.02		-0.53	0.30		0.00	-0.19			-0.03	0.00	-0.06			
289	1997-2017	-0.02	0.02		0.03	-0.05	-0.18	0.00		-0.12	-0.01				-0.08		0.07	-0.03
	2007-2017	-0.03	0.05				-0.25				0.03	0.02	0.00	0.00		0.02	0.21	

5.0 CONCLUSION AND RECOMMENDATIONS

Statistical trend analysis for WCRC SOE bores was undertaken by GNS Science to report on groundwater quality and quantity State (2012-2017) and Trends (2007-2017 and 1997-2017). State was assessed at 8 groundwater quality sites and 23 groundwater quantity sites for the 2012-2017 period. Exceedances were assessed at 21 sites for the same time period. Trends were assessed at 31 groundwater quality sites and 44 groundwater quantity sites for the 2007-2017 and 1997-2017 periods.

Groundwater in the West Coast remains relatively dilute with median conductivities close to 100 μS/cm. However, concentrations are rising for several parameters (C, K, Mg, Cl, NO_3-N) often associated with land use impact. For instance, NO_3-N concentrations over the 2012-2017 period ranged from 0.14 to 5.8 mg/L (reported range of 0.11 to 5.1 mg/L between 2005 and 2009). At three bores, concentrations exceed both the maximum naturally occurring NO_3-N concentrations and published land use impact thresholds (c. 3 mg/L; Daughney and Reeves, 2005; Morgenstern et al. 2012).

In terms of rates of change for various parameters, concurrent trends were observed at 12 bores were observed for up to twelve parameters, mostly decreases for Cl and field pH, accompanied with increasing Ca, Mg, K, SiO_2 and SO_4.

Microbial contamination remains a groundwater quality issue for West Coast groundwaters. *E.coli* and faecal coliforms detection, which are transgression of the NZDWS MAV occurred at at 62% and 40% of 21 bores. Increasing NO_3-N concentrations were detected at 5 bores with rates up to 0.47 mg/L per year (Bore 130), at a rate faster than naturally occurring increases (Daughney and Reeves, 2006).

At most bores, groundwater depth remains relatively stable through time, with medians from 0.77 to 11.98 m below the top of casing. Decreasing groundwater depth (i.e., water level decline) was observed at seven sites for both time periods.

Recommendations from this report are:

- Bacterial contamination is probably associated with agricultural land use and poses a health risk if the bores are used as drinking water source. It is recommended at these locations to review the condition of the borehead and to delineate the well capture and protection zones for improved management (Moreau et al. 2014a and 2014b). Deepening the bores at these locations would improve groundwater quality only if a confining layer, which may provide a barrier to direct surface contamination is encountered. Continued monitoring for microbial indicators is recommended at all sites.
- NO_3-N concentrations are higher than previously reported and indicative of land use impact: it is recommended to continue quarterly monitoring for the same suite of chemical parameters to monitor these multi-parameter rises.
- Where the degree of confidence for the mean residence times of groundwaters has been determined as moderate to low: additional analysis for tritium may be warranted to improve confidence in these results.
- For some bores, the lack of detailed bore construction and site information prevents the conversion from groundwater depth to groundwater elevation: the capture of detailed bore information for all bores will enable a comparison of groundwater elevation between sites and may provide information on aquifer connectivity. The information required consists of: ground elevation relative to sea level (e.g., RTK GPS or hand-held GPS, recording accuracy), measurement of the relative distance between the casing top and the ground, use of a groundwater depth sign convention and record of this in metadata (e.g., above ground is negative), and bore depth (this can be measured retrospectively using a manual dip meter if no submersible pump is installed).

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APPENDICES

APPENDIX 1: BORE INFORMATION FOR GROUNDWATER MONITORING SITES INCLUDED IN THIS REPORT

Note that the bore numbers correspond to WCRC bore reference numbers, which have been sourced by WCRC (West Coast Regional Council GIS Server, 2018) and through the Land, Air, Water Aotearoa collaboration (LAWA, 2018). At the time of writing, these reference numbers are not available for all bores. The * indicates were NZTM coordinates were sourced from LAWA and converted from latitude and longitude coordinates.

Bore number	ID used in previous reports	Easting (NZTM)	Northing (NZTM)	Depth (m)	Diameter (mm)	Screem top (m below TOC)	Screen bottom (m below TOC)	TOC to ground (cm)	Land use	Height asl (from toc)	TOC to ground (cm)	Network	Groundwater quality monitoring period	Groundwater quantity monitoring period
290	HK31	1439978	5255423	2.95	100			0.04	Rural	20.76	0.5	NGMP	1998 - 2017	2000 - 2017
180		1439735	5259514							13.37	18		2007 - 2007	2000 - 2014
180		1439735	5259514							13.37	18			2014 - 2017
496		1522894	5422132	10	500				Rural			SOE	2010 - 2017	2010 - 2017
292	HK39	1439560	5246443	7 to 10	100				Rural			NGMP	1998 - 2017	2000 - 2017
170		1440907*	5253622*							27.98	1		2007 - 2007	2007 - 2007
NA		1456374	5297244											2000 - 2009
104		1486424	5308665	20.4				0.43	Rural			SOE	2007 - 2017	2000 - 2017
114		1487439	5316136	10.24	250			0.6	Rural			SOE	2007 - 2017	2000 - 2017
288	GR17	1481417	5311122	37	200	35	37		Rural			NGMP	1998 - 2017	1999 - 2016
NA		1482391	5311591											2009 - 2009
500		1482391	5311591											2000 - 2017
451		1507985	5345072	11.5	125			0	Rural			SOE	2007 - 2017	2007 - 2017
275		1441090	5270866											2000 - 2009
105		1485029	5309011											2000 - 2016
310		1485177	5315812						Rural			SOE	2007 - 2017	2007 - 2017
166		1433236*	5252861*							24.91	7.5		2007 - 2007	2007 - 2007
130		1507211	5340114	6	200				Rural			SOE	2007 - 2017	2007 - 2017
497		1479102*	5376096*										2007 - 2010	2007 - 2010
291B	HK34	1436945*	5252983*	7 to 10	100	8	10		Rural	26.51	15	exNGMP	2007 - 2007	2007 - 2007
291A	HK34B	1436947	5253002		100				Rural	26.52	23	NGMP	1999 - 2017	1999 - 2013
81		1438346*	5250072*							32.72	4		2007 - 2007	2007 - 2007
490		1439244*	5256208*										2007 - 2007	2007 - 2007
NA		1485339*	5315848*										2000 - 2000	
56		1437820*	5249189*										2007 - 2007	2007 - 2007
NA		1485321*	5315834*										2000 - 2000	
41		1416252*	5230030*										2007 - 2007	2007 - 2007
127		1511904	5330588	~50	200				Rural			SOE	2007 - 2017	2007 - 2017
498		1472837*	5274507*										2007 - 2007	
189		1473387*	5272351*							107.15			2000 - 2008	
57		1437584*	5247950*							42.54	-8		2007 - 2007	2007 - 2007
499		1387548*	5208433*										2007 - 2007	

Bore number	ID used in previous reports	Easting (NZTM)	Northing (NZTM)	Depth (m)	Diameter (mm)	Screem top (m below TOC)	Screen bottom (m below TOC)	TOC to ground (cm)	Land use	Height asl (from toc)	TOC to ground (cm)	Network	Groundwater quality monitoring period	Groundwater quantity monitoring period
194		1474931*	5268907*							135.39			2007 - 2007	
192		1473171*	5270186*							122.01			2007 - 2007	
116		1492352	5318672	33	150				Rural			SOE	2007 - 2017	
485		1416264*	5227990*										2007 - 2007	2007 - 2007
287	GR04	1482688	5316128	5	200				Rural			exNGMP	1998 - 2006	1999 - 2009
487	GR24	1482786	5316122	~5.5	255				Rural			NGMP	2006 - 2017	2006 - 2017
454		1481559	5315352											2000 - 2017
83		1437486*	5251906*							30.08	11		2007 - 2007	2007 - 2007
378		1525893	5434050	3.79	0				Rural			SOE	2008 - 2017	2010 - 2017
143		1523333	5422642	10	500				Rural			SOE	2007 - 2017	2007 - 2017
150		1530909	5431788	6	125				Rural			SOE	2007 - 2017	2007 - 2017
193		1473170*	5269168*							128.98			2007 - 2007	
501		1470502	5304297											2000 - 2002
509		1534429	5318461						Rural			SOE	2007 - 2017	
51		1437244	5250742							33.06	0		2007 - 2007	2000 - 2017
204		1478283	5319128											2000 - 2017
167		1435145*	5253873*							21.04	1		2007 - 2007	2007 - 2007
262		1437397	5263665											2000 - 2017
109		1482457	5311527	9.5	300				Rural			SOE	2007 - 2017	2007 - 2017
134	BU01	1484550	5371338	24	140	22	7	0.08	Rural			NGMP	1998 - 2017	2000 - 2017
231		1506512	5347160						Rural			SOE	2007 - 2017	2007 - 2017
69		1439300*	5248346*							40.22	13		2007 - 2007	2007 - 2007
70		1440166*	5247616*							42.97	50		2007 - 2007	2007 - 2007
172		1444286*	5251219*							46.7	43		2007 - 2007	2007 - 2007
177		NA	NA							23.52	2		2007 - 2007	2007 - 2007
163		1438727*	5252174*							26.82	11		2007 - 2007	2007 - 2007
179		1439420	5259010							13.29	3		2007 - 2007	2000 - 2017
510		1535085	5329624						Rural			SOE	2007 - 2017	2010 - 2017
173		1445065	5251199							49.82	39		2007 - 2007	2000 - 2017
NA		1485447*	5315895*										2000 - 2000	
79		1439904	5249819							33.95	8		2007 - 2007	2000 - 2017
132		1504177	5339516	15	250				Rural			SOE	2007 - 2017	2007 - 2016
63		1438648*	5244047*							65.6	59		2007 - 2007	2007 - 2007
125		1496138	5333101	5	90				Rural			SOE	2007 - 2017	2007 - 2017
181		1439508	5260284							12.84	20		2007 - 2007	2000 - 2017

Bore number	ID used in previous reports	Easting (NZTM)	Northing (NZTM)	Depth (m)	Diameter (mm)	Screem top (m below TOC)	Screen bottom (m below TOC)	TOC to ground (cm)	Land use	Height asl (from toc)	TOC to ground (cm)	Network	Groundwater quality monitoring period	Groundwater quantity monitoring period
26		1402085*	5226051*										2007 - 2007	2007 - 2007
78		1440176	5249577											2000 - 2017
434		1473145*	5271413*							111.89			2007 - 2007	
191		1473874*	5270734*							118.46			2007 - 2008	
92		1482344	5276933	~10	75				Rural			SOE	2007 - 2017	2007 - 2017
253		1485363*	5315974*										2000 - 2000	
428		1485637*	5315754*										2000 - 2000	
190		1473954*	5271901*							110.42			2007 - 2008	
437		1432980	5266976											2000 - 2009
207		1532622	5312168						Rural			SOE	2007 - 2017	2007 - 2017
74		1445183*	5249530*							51.86			2007 - 2007	2007 - 2007
176		1441063	5255088							25.19	45		2007 - 2007	2000 - 2017
61		1437896	5246284							50.14			2007 - 2007	2000 - 2017
48		1414314*	5233649*										2007 - 2007	2007 - 2007
186		1456366	5273648	6	100				Rural			SOE	2007 - 2017	2007 - 2017
37		1404940*	5221544*										2007 - 2007	2007 - 2007
NA		1485175*	5315810*										1998 - 2000	
168		1473485	5305001											2000 - 2017
611		1473487	5305002											2000 - 2017
203	GR02	1479420	5320505	15	200				Rural			NGMP	2000 - 2017	2003 - 2017
11		NA	NA										2007 - 2007	
75		1442376*	5248686*							46.62	0 to 5		2007 - 2007	2007 - 2007
76		1441388*	5249098*							39.56	0		2007 - 2007	2007 - 2007
289	HK25	1433302	5268616	13	200	11	13		Urban			NGMP	1998 - 2017	1999 - 2017
511		1475214	5367323						Rural			SOE	2015 - 2017	2015 - 2017

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