# West Coast State of the Environment report: groundwater quality 1998–2024

M Moreau

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## DISCLAIMER

## BIBLIOGRAPHIC REFERENCE

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M Moreau, GNS Science, Private Bag 2000, Taupo 3352, New Zealand

www.gns.cri.nz

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# ABSTRACT

The West Coast Regional Council (WCRC) commissioned GNS Science (GNS) to prepare a report of the State of the Environment (SoE) for groundwater quality in the region. This report includes: a summary of groundwater resources in the West Coast region and their monitoring, an update on the state of and trend in groundwater quality in the region from the previous report (Moreau 2019), a state and trend assessment script for WCRC use, and recommendations for future monitoring.

This study is based on groundwater quality data regularly collected by WCRC that contained over 19 analytical variables, including microbial indicators. It also includes data collected as part of the National Groundwater Monitoring Programme (Moreau and Cameron 2023); results from the 2022 national Pesticides Survey led by ESR (Close and Banasiak 2023) and from a regional characterisation study (Moreau et al. 2021). Statistical trend analysis was performed using R software (version 3.6.2, NADA and LWP-Trends libraries). Time periods considered for the analysis were: 2019 to 2024 for State and Exceedances; and 2014–2024, 2004–2024 and 1999–2024 for Trends. Following the removal of sites due to minimum data point requirements. State was assessed at 48 groundwater quality sites. Exceedances were assessed at 21 sites, and Trends were assessed at 29 groundwater quality sites.

Groundwater quality remains relatively dilute, with median conductivities ranging from 66 to 250 μS/cm (5th and 95th percentiles). Nitrate concentrations (<0.01 to 6.9 mg/L as N) are higher than previously reported (0.18 to 5.8 mg/L as N) over the 2012–2017 period (Moreau 2019). However, unlike previously reported, there were no occurrences of exceedance of the drinking-water Maximum Acceptable Value (MAV) of 11.3 mg/L as N (Water Services 2022). The 2022 screen for trace inorganic variables identified occasional occurrence of aluminium, barium, chromium, cobalt, copper, strontium, vanadium and zinc, at or close to the detection limit, which can be explained by natural sources. Microbial contamination remains a groundwater quality issue for WCRC groundwaters, with *E.coli* detected above the MAV at 70% of the monitoring bores. The 2022 pesticides screen only yielded two isolated detections (clopyralid and picloram herbicides) at low concentrations. Concurrent trends were a common pattern at monitoring sites and highlight localised dynamics in each hydrogeological system. The long-term monitoring sites showed trending variables consistent with possible indication of increasing temperature and carbon uptake, which may be related to climate change and/or human activity.

Recommendations from this report are to:

- Continue monitoring of groundwater quality inorganic and microbial variables, including low-frequency groundwater age and quantity. Suggestions for monitoring variables and frequencies are provided.
- Continue seizing opportunities to align with research programmes to enhance the regional dataset and understanding.
- Analyse at least once for dissolved oxygen, dissolved iron, dissolved manganese, and sulphate at the 15 SoE sites where the redox status assessment could not be performed to assess whether nitrate concentrations should be reported against the nitrate reference value for unimpacted groundwater for oxic aquifers.
- Continue to engage with the national framework to enhance the representativeness, transparency and efficiencies of the current monitoring programmes.
- Continue to refine the region’s hydrogeological systems together with GNS by providing expert knowledge and feedback. These systems have been used in this report as spatial reporting units.

# KEYWORDS

Groundwater quality, West Coast, monitoring, State of the Environment

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# 1.0 Introduction

## 1.1 West Coast Groundwater Resources

Groundwater is an essential part of our environment and our economy. In the environment, groundwater naturally occurs as springs and seeps supporting river flows, lakes and wetlands, especially through drier periods. Baseflow to rivers is essential to aquatic health. Groundwater is hosted in geological formations that may be qualified as: aquifer, aquitard or aquiclude.

In this report, aquifers are defined as hydrogeological units that are geological formations containing sufficient saturated permeable material to yield significant quantities of water to wells and springs. Aquitards are hydrogeological units defined as saturated but poorly permeable stratum that impedes groundwater movement and does not yield water freely to wells. They may, however, transmit appreciable quantities of water to or from adjacent aquifers and, where sufficiently thick, may constitute an important groundwater storage zone; sandy clay is an example. Aquicludes are hydrogeological units defined as saturated but relatively impermeable material that does not yield appreciable quantities of water to wells. The concept of aquifers, aquitards and aquicludes is relative; for instance, what is regarded as an aquifer in one region may be regarded as an aquitard where more productive lithologies occur.

West Coast aquifers are mostly hosted between the coast and the foothills of the Southern Alps within Holocene fan deposits (typically 20–40 m thick) adjacent to streams and rivers. These deposits are underlain by low-permeability Tertiary deposits (mudstone or siltstone dominated). Localised, Tertiary karstic limestones occur in Karamea and between Charleston and Punakaiki, and may provide local supplies (Moreau et al. 2021). In the region, the Alpine Fault, which occurs along the western side of the Southern Alps, acts as a hydraulic seal between groundwater held in Holocene unconfined fan and alluvial gravel deposits near the coast and the Triassic schist mountains (often producing warm to hot springs) (Figure 1.1).

Hydrogeological systems represent geographical areas with broadly consistent hydrogeological properties, and similar resource pressures and management challenges (Moreau et al. 2019b). The region is divided into 15 large basin-type systems (over 100 km$^2$ in area). Ten systems are mapped as coastal basins (from north to south): Karamea, Stockton, Westport, Charleston, Hokitika, Okarito, Whakapohai, Fox, Jackson and Cascade (Figure 1.2). The remaining five are inland basins (from north to south): Murchinson, Mokihinui, Reefton, Maruia and Middle Grey. Generally, systems drain towards the sea, with inland systems feeding coastal systems (e.g. Middle Grey into Hokitika), with the exception of the Maruia system, which drains north towards the Tasman region (Figure 1.2). The remaining systems are small, often hydraulically disconnected, and can be aggregated into four types: coastal independent, inland river valley, basement infill and basement hard rock. The latter is regarded in New Zealand as an aquiclude and hydrogeological basement (Moreau et al. 2019b).

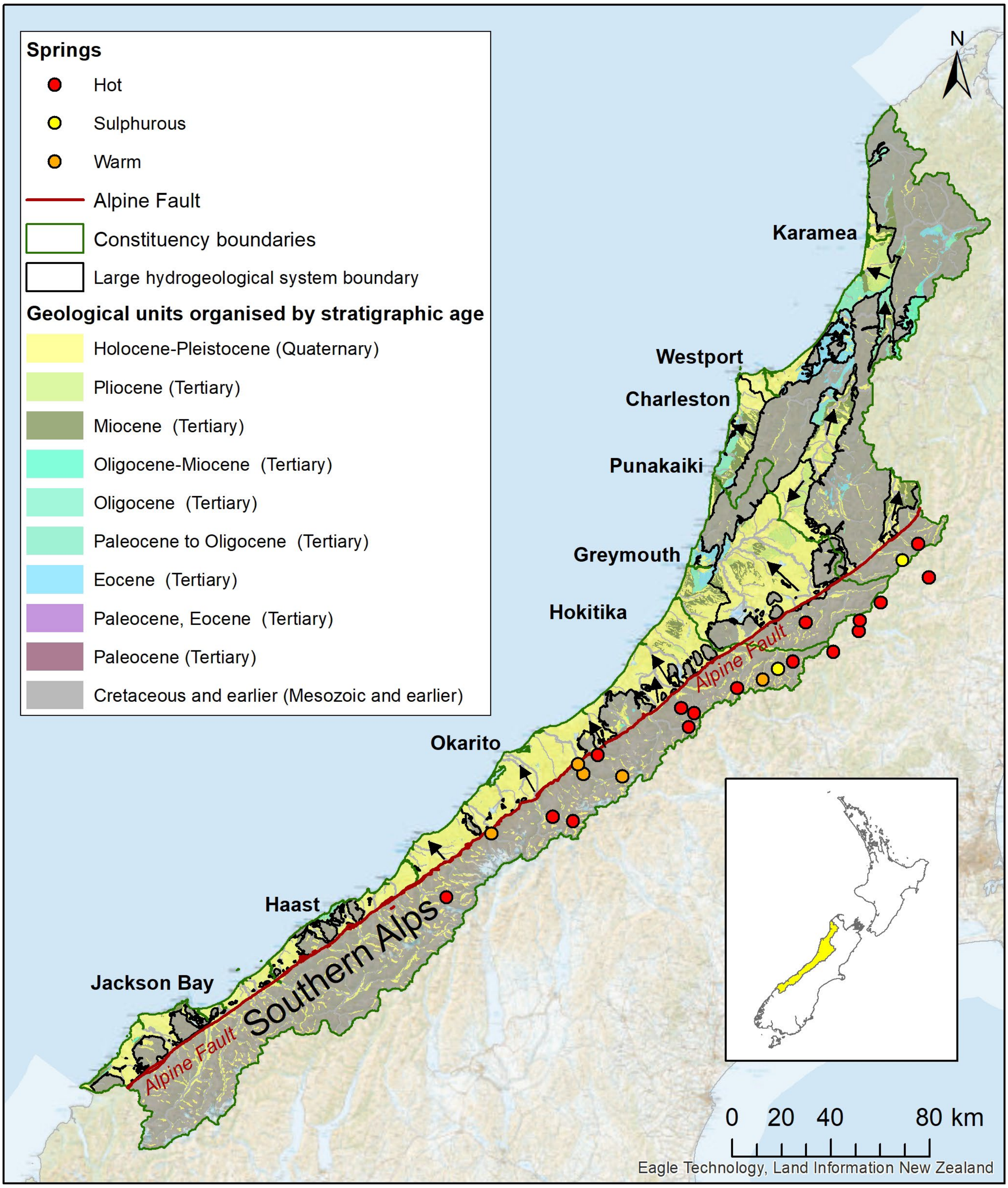

Figure 1.1 Regional geology of the West Coast with large hydrogeological system boundaries and indicative groundwater flow direction (black arrows) (adapted from Moreau et al. 2019b). Reported thermal spring locations are also shown near the Alpine Fault (Mongillo and Clelland 1984).

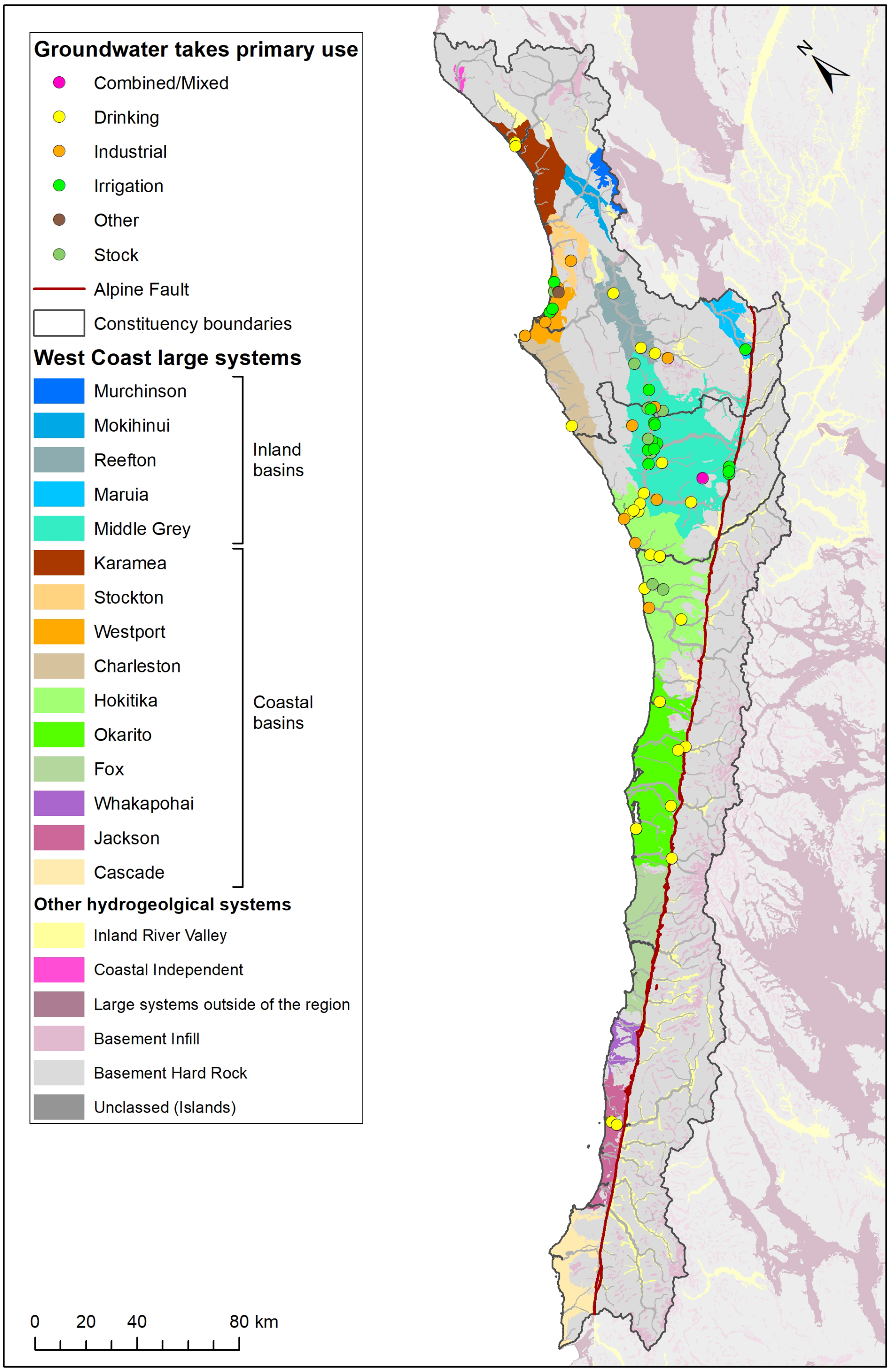

Figure 1.2 West Coast larger hydrogeological system types and consented takes (2017–2018) where the primary source is groundwater (Moreau et al. 2019b; Booker and Henderson 2019). Coastal and inland basin systems are large systems where the dominant outcropping units are of sedimentary origin. Coastal and inland volcanic systems are large systems where the dominant outcropping units are of volcanic origin. Inland river valleys are small systems that contribute to larger systems. Coastal independent systems are smaller systems that discharge at the coast and do not contribute water to a larger system. Basement infill systems are small systems that are fully enclosed within basement. In this classification, basement is defined as Cretaceous and older geological units, and is generally associated with very low hydraulic permeability. Basement hard rock systems depicted in light grey are regarded as an aquiclude at the national scale.

## 1.2 Groundwater Quality Monitoring

State of the Environment (SoE) groundwater quality monitoring is undertaken at the national scale through two programmes: (1) the National Groundwater Monitoring Programme (NGMP), co-ordinated by GNS Science (GNS), which focuses on inorganic chemistry; and (2) the Pesticides Survey, co-ordinated by the Institute of Environmental Science Research (ESR), which focuses on man-made compounds. Both programmes are long-standing collaborations with regional and district councils, initiated in 1990. It is worthwhile to note that monitoring for man-made compounds comprises pesticides and compounds of emerging concern, the latter being an active research area and, as a result, the list of monitored compounds is growing. The occurrence, transport and fate of these compounds, and therefore the need for long-term monitoring at smaller scales, remains largely undetermined and the object of current research (e.g. Hadfield 2017; Moreau et al. 2019a).

West Coast Regional Council (WCRC) manages a dedicated SoE monitoring programme since 1998, which currently consists of 32 sites. Ten of these sites have been shared with the national programme since inception. The network was reviewed in 2010 by WCRC, which resulted in an increase in monitoring sites to a size similar to that of today. The distribution of sites generally reflects aquifer location and groundwater use (Figure 1.2; Table 1.1). For a given year, the number of monitored sites may vary due to unforeseen circumstances (e.g. if the bore pump is not working on the day of the visit).

As part of the monitoring, groundwater samples are collected according to a sampling protocol that has been used in New Zealand since 1999, although it has been subsequently updated to be consistent with National Environmental Monitoring Standards (Rosen et al. 1999; Daughney et al. 2006; Milne 2019). Quality assurance methods vary between networks, but generally include the collection of field blanks, sample replicates and the comparison of results with historical records. Quality assurance is part of the Standards and applied by all SoE monitoring agencies. Collected data are publicly accessible from WCRC and through the freely accessible Geothermal Groundwater (GGW) database for NGMP sites. State and Trends at selected SoE sites are also made publicly available on the LAWA website, grouped by “groundwater zones”.

Table 1.1 West Coast hydrogeological systems and associated number of monitoring sites included in this report.

| System Type | System Name | Number of Monitoring Sites | Area % | Area (km$^2$) |
|---|---|---|---|---|
| Inland Basin | Maruia | 3 | 0.8% | 194 |
| | Middle Grey | 10 | 8.2% | 1908 |
| | Mokihinui | - | 0.6% | 139 |
| | Murchinson | - | 0.4% | 100 |
| | Reefton | 4 | 1.9% | 452 |
| Coastal Basin | Cascade | - | 1.8% | 420 |
| | Charleston | 1 | 1.9% | 447 |
| | Fox | - | 2.5% | 572 |
| | Hokitika | 5 | 5.5% | 1292 |
| | Jackson | - | 1.4% | 333 |
| | Karamea | 3 | 1.9% | 432 |
| | Okarito | - | 4.8% | 1129 |
| | Stockton | - | 0.8% | 194 |
| | Westport | 1 | 1.0% | 240 |
| | Whakapohai | - | 0.5% | 122 |
| Inland River Valley | West Coast (aggregated system) | 1 | 5.0% | 1160 |
| Coastal Independent | Grey (aggregated system) | - | 0.1% | 31 |
| Basement Infill | Basement Infill (aggregated system) | - | 5.3% | 1237 |
| Basement Hard Rock | Basement Hard Rock (aggregated system) | - | 55.3% | 12894 |

## 1.3 Current Collaborative Nationwide Review of SoE Monitoring

Three recent independent reviews have identified shortcomings in current groundwater monitoring programmes:

1. An independent review of New Zealand's environmental monitoring concluded that environmental monitoring data are inconsistently collected and remain difficult to access (Parliamentary Commissioner for the Environment 2019). Our environmental monitoring systems were described as a passive harvesting system (i.e. designed around what is available rather than purposefully), largely fragmented, and having multi-objectives (e.g SoE and policy development and implementation). Recommendations included the development of a comprehensive environmental monitoring system enabling a representative national monitoring network to ensure systematic, coordinated, consistent and accessible monitoring nationwide.
2. An independent review of the 2020 Groundwater Quality Indicator demonstrated unresolved challenges in building a consistent national picture by aggregating regional data (Moreau 2023). Indicator reports are data-driven technical publications from Statistics New Zealand (Stats NZ) that inform independent regular reports on the state of New Zealand's environment under the Environmental Reporting Act. The review highlighted spatial bias and inconsistencies in site and variable selection, attributed to inconsistent and multipurpose data collection objectives. Recommendations included the review and consolidation of existing national programmes in collaboration with regional councils.
3. A technical review was also undertaken on how fit for purpose New Zealand SoE data are for informing policy effectiveness (Etheridge et al. 2023). The report was focussing on nitrate concentration reduction, which is a long-standing, widespread issue in New Zealand's groundwater. The work showed that an improvement to a 2.4 mg/L target nitrate-nitrogen level would only be detected with a suitable degree of confidence at 40% of the SoE wells over New Zealand's network.

To address these shortcoming, collaborative work to develop a national groundwater quality framework is underway, led by Waikato Regional Council and GNS. This work involves all organisations responsible for groundwater quality monitoring at the regional scale (i.e. Groundwater Forum Special Interest Group, which brings together New Zealand regional and unitary council groundwater science teams, Stats NZ and the Ministry for the Environment) and national scale (GNS for inorganic variables monitoring and ESR for organic compounds monitoring). The national monitoring framework was established in 2024 by agreeing on common monitoring aims. These are to: develop national views consistent with regional views through national programmes; foster knowledge transfer across regions and research institutes; and clarify trade-offs between resourcing and monitoring at regional and national scales (Moreau 2024). A key change within this framework is the intentional distinction between Surveillance (long-term, representative of diversity) and Evaluative (policy or management question driven) monitoring. It is acknowledged by all participating agencies that implementation under the current resourcing system will require an iterative approach (i.e. making incremental changes) and multiple years to stage reviews between regions.

At the time of writing this report, a pilot case study for the Waikato Region is underway, aiming to provide a pragmatic and transparent review of the current networks to be transitioned into Surveillance and Evaluative programmes (scheduled completion in June 2025). The work is conducted with progress updates to a Working Group from the Groundwater Forum Special Interest Group. Greater Wellington and Northland regional councils have indicated a willingness to start reviewing their networks starting July 2025. The long-term goal is to review every region, therefore recommendations for WCRC are provided at the close of this report.

## 1.4 This Report

This report aims to present an update for groundwater quality State and Trends from the previous report (Moreau 2019), and includes:

- A brief overview of West Coast groundwater resources and SoE monitoring.
- A state and trend assessment of groundwater quality data from the following sources: regularly collected data as part of regional and national monitoring operations; 2020 regional hydrogeology characterisation (Moreau et al. 2021); 2022 dissolved metals survey at NGMP sites (Moreau and Cameron 2023) and the national Pesticides Survey (Close and Banasiak 2023) (Figure 1.3).
- Development of a toolkit enabling WCRC to undertake state and trend assessments internally using the methods presented in this report.
- Recommendations for future monitoring, including opportunities for WCRC through the national monitoring framework.

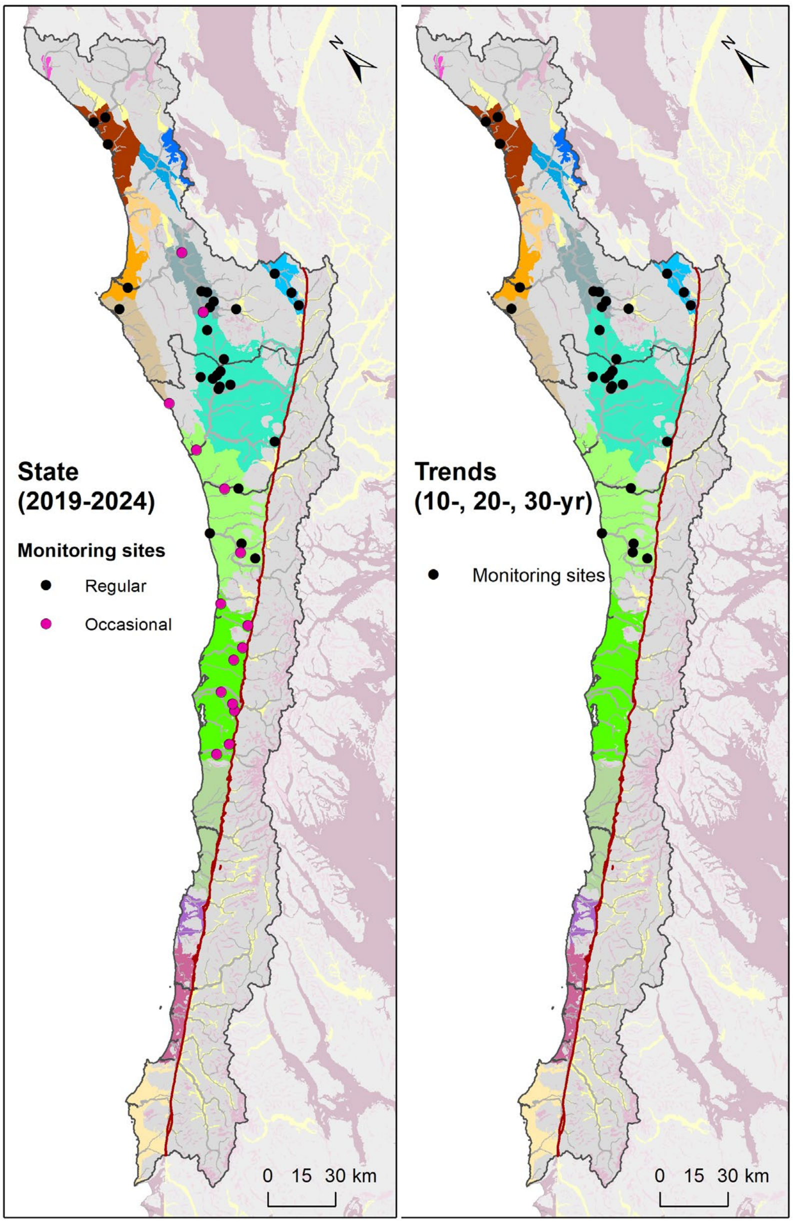

Figure 1.3 Location of groundwater quality monitored sites presented in this report. Note that some sites belong to multiple networks (national and regional).

# 2.0 Methods

The reported statistics, methods and statistical analysis outlined in this section have been updated from previous reports (Moreau 2019) and are consistent with the latest national reporting methods for groundwater and surface quality (Moreau et al. 2025 [and references therein]). The confidence thresholds used for reporting are also consistent with those used by the Intergovernmental Panel on Climate Change and Stats NZ reporting (Stocker et al. 2013).

## 2.1 Data Processing

Groundwater quality and site data were collated from WCRC and GNS. The following steps were undertaken to aggregate and cleanse the dataset:

- Reformatting from wide to long format.
- Site mapping to develop consistent naming for each dataset. There were instances where unique site IDs were generated by GNS as part of the processing because source data did not include a unique ID field.
- Variable mapping to develop consistent naming and enable aggregation (Table 2.1).
- Data harmonisation and cleansing. Once the dataset was aggregated, values below the detection limit were reformatted using customised R scripts and the LWP library (Snelder et al. 2021). To remove nonsensical values and avoid statistical bias induced by the collection of replicate groundwater samples on a daily basis, the following rules were applied:
    - Removal of readings of ‘zero’ concentration, except for dissolved oxygen.
    - Removal of readings of nonsensical dissolved oxygen concentration (>14 mg/L, which is equivalent to 100% saturation).
    - Identification and removal of replicate analyses for the same variable, site and day. Where available, sample IDs from source data were used, elsewhere IDs were created and the selection was based on the analysis that contained the larger number of results.

Table 2.1 Variable aggregation used in this report.

| Type | Variable(s) | Reported Forms |
|---|---|---|
| Physical | Conductivity (also denoted as specific conductance), dissolved oxygen, pH, temperature | Field measurement only. |
| Major | Bicarbonate, calcium, carbonate, chloride, magnesium, nitrate, potassium, sodium, sulphate | Aggregated dissolved and total. |
| Major | Silica | Aggregated dissolved and dissolved reactive. |
| Minor | Boron, ammonia | Aggregated dissolved and total. |
| Minor | Bromide, fluoride, iron, manganese | Dissolved form only. |
| Minor | Dissolved reactive phosphorous | Dissolved reactive form only. |
| Trace | Aluminium, arsenic, barium, cadmium, chromium, cobalt, lead, nickel, nitrite, selenium, strontium, vanadium, zinc | Dissolved form only. |
| Micro | *E.coli* | mpn per 100ml, cfu per 100mL |
| Man-made compounds | 25 organochlorine pesticides, 88 organonitrogen and phosphorus pesticides, 25 acid herbicides and 57 multiresidue pesticides | Dissolved form only. |

## 2.2 Reported Statistics

The following statistics are reported for the dataset, in accordance with national reporting (Moreau et al. 2025 [and references therein]):

- Percentage of censoring: censored results are measurements reported below the detection limit. Multiple censoring levels are common in long-term datasets, as measurement resolution improves with technology. This mostly affects variables present in very low quantities, such as minor variables, trace metals and man-made compounds. Where censoring occurs, there is a reduction in the ability to derive descriptive statistics or detect trends, especially if multiple censoring levels affect the time series.
- Median and Median Absolute Deviation (MAD): the median is a measure of central tendency. It is a more resistant 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.
- Percentiles (5th, 25th, 50th, 75th, 95th): these also inform on the data spread around the median. The median is the 50th percentile.
- Number of exceedances for all time periods: this statistic provides context for state and trend descriptive metrics with regard to published environmental guidance relevant to ecosystem or human health. Individual measurements or calculated median measurement values are compared with a defined threshold. Exceedances are reported against: the New Zealand drinking water MAVs (Water Services 2022); the drinking-water Aesthetic Values (AVs), which apply to total form (Taumata Arowai 2022) and, for nitrate-nitrogen only, reference conditions estimated using the 90th percentiles defined for New Zealand oxic groundwaters (Daughney et al. 2023).
- Statistical test p-values: data-calculated probability value (p-value), for which an acceptable error rate is arbitrarily set to reject or accept a statistical hypothesis. In this report, several statistical tests were conducted to assess either the statistical significance of a trend (Mann-Kendall test) and seasonality (Kruskal-Wallis). For each test, a hypothesis is formulated and test statistics are calculated. 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.
- Trend magnitudes: the rate of change in each parameter. In this report, the trend magnitudes are provided as Sen's slopes, which is commonly used for environmental reporting, and as percentage annual change in slope. The latter 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.
- Trend category: the decreasing or increasing trend diagnostic is informed by levels of confidence applied to the probability that the trend is decreasing (Cd), as calculated using the Mann-Kendall trend test. Descriptors are assigned using the following thresholds: "Very likely decreasing" ($Cd < 0.90$), "Likely decreasing" ($0.66 < Cd \leq 0.90$), "Indeterminate" ($0.33 \leq Cd \leq 0.66$), "Likely increasing" ($0.10 \leq Cd < 0.33$) and "Very likely increasing" ($Cd < 0.01$).
- Sen slope confidence interval and confidence that the trend is decreasing: the first metric informs on whether the true trend slope differs from zero and the second qualifies the confidence on the trend direction.

## 2.3 Statistical Analysis Settings and Implementation

Four time-periods were defined: five years to define State (March 2019 to February 2024) and 10-year (March 2014 to February 2024), 20-year (March 2004 to February 2024) and 30-year (March 1994 to February 2024) periods to define Trends.

Descriptive statistics indicative of State were derived from uncensored and censored time series combining the R standard package (version 3.6.2) with the Non-Detects and Data Analysis (NADA version 1.6–1.1) library (Helsel et al. 2020). Median, MAD and percentiles were estimated using statistical formulas for uncensored values. For time series affected by less than 25% censoring, median and MAD were estimated using Regression on Order Statistics (ROS) models and percentiles were calculated using statistical formulas. Above 25% and below 80% censoring, no percentiles were calculated; and median and MAD were computed using ROS models. At and above 80% censoring, no estimates were made of median, MAD or percentiles; and values are shown as below the highest detection limit. Where the MAD generated by ROS models was null, it was replaced by a "not available", as it is unlikely that no variations occur for a given variable at a site.

In this report, Trends were identified on the complete dataset (i.e. no outlier removal) by applying levels of confidence to a decreasing trend direction metric calculated as part of the Mann-Kendall trend test. This method is a recent alternate approach to identifying statistically significant trends via a confidence threshold on the Mann-Kendall test p-value (McBride 2019; Helsel et al. 2020). It is consistent with the most recent river quality state and trend assessments in New Zealand and Stats NZ methods (Whitehead et al. 2022; Stats NZ 2024). The Kruskal-Wallis seasonality tests, Mann-Kendall trend test and Sen's slope estimations were performed using R and the LWP-Trends library (version 2101; Snelder et al. 2021). The number of seasons considered for in the Kruskal-Wallis test was four (autumn, winter, spring and summer). The annual time period commenced on 1 March of the first year (the start of autumn). The Mann-Kendall and Sen slope tests were seasonally adjusted based on the result of the Kruskal-Wallis test. For time series where censoring occurred, a filter was applied to replace all observations below the highest detection limit by the highest detection limit (Whitehead et al. 2022).

Minimum data point requirements were set as follows:

- Descriptive statistics: no minimum requirements were applied, as one aim of this report was to include low-frequency monitored variables, such as cadmium or chromium.
- Kruskal-Wallis test: all seasons must have at least one observation, and individual seasons require at least two data points.
- Mann-Kendall test and Sen's slope estimator: the time series must contain at least eight data points, and the maximum censored values must be smaller than the maximum observed values. Data requirements set within the LWP library also applied: greater than three unique values, greater than five uncensored values and greater than two data points per unique season.
- Trend analysis: the time series must contain at least eight data points per 10-year time window to avoid temporal bias. This means that sites at which a 30-year trend is calculated must have eight data points for each of the 10-year intervals.

# 3.0 Results

## 3.1 State

In this section, summary statistics from all sites are presented and grouped into characteristics, groundwater processes and man-made compounds. The time period defined for State is 2019–2024. Cleaned and processed groundwater quality datasets are provided as enclosures to this report (Appendix 2).

### 3.1.1 In-Situ Physico-Chemical Conditions

Field-measured variables informing on aquifer conditions consist of temperature, pH, electrical conductivity and dissolved oxygen. Laboratory-measured variables include dissolved iron, manganese, arsenic and ammonia. Aquifer physico-chemical conditions determined the mobility of these variables (e.g. arsenic is only mobile in anoxic environments).

In low-oxygen or reduced aquifers, these variables are highly mobile and may occur in significant concentrations. Conversely, in oxygen-rich groundwaters, these variables tend to bind to sediments or precipitate. It is worth noting that nitrogen can be present in different forms depending on the aquifers' oxygen levels: as nitrate in oxygen-rich aquifers and as ammonia in reduced aquifers. This natural nitrogen conversion is naturally facilitated by microbial respiration within the aquifer. The full range of oxygenated conditions (from anoxic to oxygenated) occur in West Coast groundwaters. This is demonstrated by the occurrence of low dissolved oxygen sometimes concurrent with high dissolved iron concentrations (Table 3.1). A range of oxygenated conditions is also observed nationally (Moreau et al. 2025).

Groundwater median temperatures range from 10.3°C to 16.4°C, which is consistent and slightly lower than national values and significantly lower than the reported thermal spring temperatures (27 to 82°C) (Mongillo and Clelland 1984) occurring east of the Alpine Fault. Most groundwater temperatures (88%) are below the AV (15°C). Median pH ranges from 5.5 to 7.7 pH units, with 93% of the sites within the AV range (7.0–8.5 pH units), which is more frequent than nationally.

Conductivity is a measure of the total dissolved solids content in groundwaters. A narrower range was measured in the West Coast (19.5–359 uS/cm) compared to nationwide (100 to several 1,000 uS/cm). Naturally, groundwater conductivity increases with prolonged contact with aquifer minerals and lack of dilution by rainfall. The relative dilute nature of West Coast groundwaters is consistent with high recharge (rainfall or river) and shorter travel times (mean residence times are commonly measured below 10 years; Moreau et al. 2021). Note that isolated older groundwaters occur locally, likely associated with swamp deposits close to the coast. The higher national values are likely to be associated with either long residence time and increased water-rock interaction or saltwater intrusion in coastal areas.

The above summary statistics are consistent with previously reported values (from the 2012–2017 time period) (Moreau 2019), with a slightly larger range in conductivity. This likely reflects the larger geographical site distribution capturing more hydrogeological systems.

Table 3.1 Calculated percentiles and maximum values for inorganic chemistry groundwater variables based on site-specific median values for the period 2019–2024. “Censoring” refers to the percentage of times a variable was reported below the detection limit. National values were obtained from a national dataset (Moreau et al. 2025).

| | | West Coast | | | | | | | | | National | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Variable Type** | **Variable** | **n** | **Censoring** | **5th** | **25th** | **50th** | **75th** | **95th** | **Max.** | **MAD** | **n** | **50th** | **Max.** |
| Field | Conductivity (uS/cm) | 48 | 0% | 66 | 86 | 114 | 150 | 250 | 359 | 46 | - | 224 | 36100 |
| | Dissolved oxygen (mg/L) | 30 | 0% | 0.47 | 3.5 | 4.2 | 6.6 | 9.2 | 9.8 | 2.7 | - | 4.4 | 13 |
| | ph (pH units) | 28 | 0% | 5.5 | 5.8 | 6.1 | 6.4 | 7.1 | 7.7 | 0.42 | - | 6.7 | 11 |
| | Temperature (deg C) | 45 | 0% | 11 | 13 | 13 | 14 | 15 | 16 | 1.0 | - | 14 | 51 |
| Major | Bicarbonate (mg/L) | 46 | 0% | 18 | 25 | 31 | 36 | 89 | 139 | 9.3 | - | 68 | 1500 |
| | Calcium (mg/L) | 46 | 0% | 4.1 | 7.4 | 12 | 16 | 32 | 47 | 5.8 | - | 19 | 1140 |
| | Chloride (mg/L) | 32 | 0% | 1.4 | 2.7 | 4.1 | 6.5 | 23 | 29 | 2.9 | - | 14 | 14400 |
| | Magnesium (mg/L) | 46 | 0% | 0.90 | 1.3 | 1.8 | 2.5 | 4.0 | 6.0 | 0.89 | - | 5.5 | 890 |
| | Nitrate (mg/L) | 31 | 0% | 0.015 | 0.28 | 0.95 | 2.4 | 4.7 | 6.9 | 1.2 | - | 1.1 | 28 |
| | Potassium (mg/L) | 46 | 0% | 0.57 | 1.1 | 1.9 | 3.0 | 8.6 | 23 | 1.4 | - | 1.6 | 280 |
| | Silica (mg/L) | 24 | 0% | 5.3 | 8.6 | 13 | 16 | 39 | 39 | 5.5 | - | 20 | 146 |
| | Sodium (mg/L) | 46 | 0% | 2.1 | 2.8 | 4.4 | 7.1 | 15 | 20 | 2.7 | - | 15 | 7100 |
| | Sulphate (mg/L) | 31 | 0% | 0.53 | 3.9 | 5.9 | 8.4 | 22 | 37 | 4.0 | - | 7.1 | 2100 |
| Minor | Ammonia (mg/L) | 46 | 46% | 0.0025 | 0.0030 | 0.0050 | 0.0050 | 0.10 | 0.28 | 0.0030 | - | 0.0060 | 25 |
| | Bromide (mg/L) | 24 | 11% | 0.020 | 0.020 | 0.020 | 0.030 | 0.039 | 0.040 | 0 | - | 0.060 | 32 |
| | Dissolved reactive phosphorous (mg/L) | 31 | 29% | 0.0035 | 0.0040 | 0.0040 | 0.020 | 0.075 | 0.090 | 0.0015 | - | 0.012 | 4.5 |
| | Fluoride (mg/L) | 24 | 14% | 0.020 | 0.030 | 0.050 | 0.093 | 0.21 | 0.28 | 0.030 | - | 0.097 | 2.9 |
| | Iron (mg/L) | 46 | 29% | 0.0041 | 0.0065 | 0.020 | 0.030 | 0.50 | 11 | 0.019 | - | 0.030 | 168 |
| | Manganese (mg/L) | 46 | 17% | 0.0010 | 0.0010 | 0.0045 | 0.025 | 0.19 | 0.32 | 0.0052 | - | 0.0030 | 23 |
| Trace | Aluminium (mg/L) | 8 | 42% | <0.02 | <0.02 | 0.02 | 0.0275 | 0.102 | 0.13 | - | 508 | 0.0010 | 5.3 |
| | Antimony (mg/L) | 8 | 100% | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | - | 98 | <0.001 | <0.001 |
| | Arsenic (mg/L) | 8 | 100% | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - | 906 | 0.0002 | 0.8 |
| | Boron (mg/L) | 8 | 0% | 0.0027 | 0.0062 | 0.013 | 0.02 | 0.02 | 0.02 | 0.010 | 720 | 0.023 | 33.0 |
| | Barium (mg/L) | 8 | 100% | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | - | 98 | 0.010 | 4.6 |
| | Cadmium (mg/L) | 8 | 100% | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | - | 351 | <0.001 | 0.0 |
| | Chromium (mg/L) | 8 | 94% | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | 0.001 | - | 382 | <0.001 | 0.1 |
| | Cobalt (mg/L) | 8 | 50% | <0.001 | 0.001 | 0.001 | 0.001 | 0.00165 | 0.002 | - | 98 | 0.006 | 0.01 |
| | Copper (mg/L) | 8 | 0% | 0.001 | 0.00175 | 0.002 | 0.005 | 0.0076 | 0.009 | 0.001 | 644 | 0.001 | 0.3 |
| | Lead (mg/L) | 8 | 100% | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - | 403 | <0.005 | 0.006 |
| | Lithium (mg/L) | 8 | 100% | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - | 130 | 0.004 | 2.0 |
| | Nickel (mg/L) | 8 | 75% | <0.001 | <0.001 | <0.001 | 0.001 | 0.00295 | 0.004 | - | 227 | 0.000 | 0.0 |
| | Nitrite (mg/L) | 7 | 70% | 0.00047 | 0.001 | 0.001 | 0.0042 | 0.011 | 0.012 | - | 973 | 0.001 | 5.4 |
| | Selenium (mg/L) | 8 | 100% | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | - | 98 | <0.005 | <0.005 |
| | Strontium (mg/L) | 8 | 0% | 0.0335 | 0.0475 | 0.055 | 0.075 | 0.116 | 0.13 | 0.022 | 98 | 0.120 | 1.8 |
| | Vanadium (mg/L) | 8 | 63% | 0.001 | 0.001 | 0.001 | 0.00125 | 0.00265 | 0.003 | - | 98 | 0.001 | 0.03 |
| | Zinc (mg/L) | 8 | 25% | 0.001 | 0.001 | 0.001 | 0.00525 | 0.01615 | 0.02 | - | 778 | 0.004 | 1.3 |

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### 3.1.2 Groundwater Processes

Groundwater quality naturally evolves along the flow paths via a range of hydrochemical processes, such as mineral dissolution, mineral precipitation, mixing, ion exchange and leaching of land surface contaminants, such as nutrients (nitrogen, phosphorous). Variables indicative of groundwater processes include most of the major (bicarbonate, calcium, chloride, magnesium, potassium, silica and sulphate), minor (ammonia, bromide, dissolved reactive phosphorous, fluoride, iron and manganese) and trace inorganic variables (aluminium, antimony, arsenic, boron, barium, cadmium, chromium, cobalt, copper, lead, lithium, nickel, nitrite, selenium, strontium, vanadium, zinc).

Typically, major variables' concentrations are lower in the West Coast than nationally; for instance, the median concentration for bicarbonate is 31 mg/L in the West Coast compared with 224 mg/L nationally (Table 3.1; Figure 3.1). This is consistent with the dominant aquifer material (gravels) and the combination of high recharge and shorter flow paths. Concentrations of major variables were similar between 2019 and 2024 and the previous reporting period of 2012 to 2017 (Moreau 2019) (Appendix 2).

The chemical composition of groundwater varies between hydrogeological systems, reflecting local conditions and geology (Figure 3.2). For instance, the Okarito System exhibits the widest range of concentrations, consistent with thick gravel deposits in an active erosion environment facilitating water-rock interaction. The relatively higher sodium chloride concentrations at Charleston and Karamea may be linked to sea spray in the rainfall recharge. The maximum iron concentration (10.6 mg/L) demonstrates localised occurrence of reducing conditions, which are likely to be naturally occurring within old swamp deposits in and around estuaries (e.g. Karamea, Okarito) (Moreau et al. 2021). Available SoE monitoring data did not exhibit signs of saltwater intrusion at the coast (i.e. elevated sodium and chloride concentrations).

*E.coli* bacteria originates from the gut of warm-blooded animals. It is monitored as a proxy for pathogens, although it may not adequately represent viruses. Once outside bodies, *E.coli* counts will decline with time, as the bacteria dies, which means that natural filtration within aquifer materials is closely linked to their hydraulic permeability and groundwater velocity. However, *E.coli* may also enter aquifers more rapidly through anthropogenic pathways, for instance if a wellhead is not adequately protected by a cap, raised entry and concrete pad. During the 2019–2024 time period, *E.coli* MAV exceedances (1 mpn per 100 mL) were common (70% of 30 sites, at least on one occasion) in the West Coast and nationwide (Table 3.2). This indicates that pathogens may occur commonly in groundwater, particularly where surface water connections are important.

Concentrations of most minor and trace variables were low, close to the detection limit (e.g. cadmium, fluoride, lithium). There were no exceedances of the MAV for drinking-water for median values and only for manganese concentrations on one or more occasions (4.3% of 46 sites) (Table 3.2). There are two AVs for manganese: one for the staining of laundry (0.04 mg/L) and a higher threshold for taste (0.1 mg/L). Manganese concentrations exceeded these thresholds at 39.1% and 3.9% of the sites at least on one occasion, respectively. Manganese is naturally occurring and ubiquitous in the environment. Median iron concentrations exceeded the AV for staining of laundry at 26.0% of the sites at least on one occasion but otherwise remained low. This is consistent with localised low ammonia concentrations and reducing conditions.

Trace metals analysed during the 2022 December NGMP survey highlighted detectable (close to or at the detection limit) concentrations of aluminium, barium, chromium, cobalt, copper, strontium, vanadium and zinc. Most of these occur naturally in rock-forming minerals (low solubility and reactivity) and have also been detected in other New Zealand regions at similar concentrations.

Table 3.2 Percentage of West Coast and nationwide groundwater quality monitoring sites at which the Maximum Acceptable Value (MAV), Acceptable Value (AV) and/or Reference Value (REF) was exceeded at least on one occasion and by the median value calculated for the period 2019–2024. Thirty-two pesticide compounds with a MAV but no detection in any of the 183 tested sites during the 2022 survey were omitted from this table. Sources are indicated by * (with citations at the bottom of the table) and NA stands for Not Available.

| | West Coast | | | | New Zealand**** | |
|---|---|---|---|---|---|---|
| **Variable** | **# samples** | **MAV* (AV**) [REF**]** | **Sites Exceeding (one or more occasion) (%)** | **Sites Exceeding (median values) (%)** | **n** | **Sites Exceeding (one or more occasion) (%)** |
| **Physical** | | | | | | |
| pH (pH unit) | 25 | (7.0–8.5) | (88) | (93) | 716 | (5.3) |
| Temperature (°C) | 45 | (≤15) | (30) | (11.1) | 1174 | (45) |
| **Inorganic Chemistry** | | | | | | |
| Aluminium (mg/L) | 8 | 1 (0.1) | 0 (12.5) | 0 (12.5) | 508 | 1 (0.1) |
| Ammonia (mg/L) | 46 | NA (1.5) | NA (2.2) | 0 | 1144 | NA (1.5) |
| Arsenic (mg/L) | 8 | 0.01 | 0 | 0 | 906 | 0.01 |
| Boron (mg/L) | 8 | 2.4 | 0 | 0 | 720 | 2.4 |
| Cadmium (mg/L) | 8 | 0.004 | 0 | 0 | 351 | 0.004 |
| Chloride (mg/L) | 32 | NA (250) | NA | 0 | 1144 | NA (250) |
| Chromium (mg/L) | 8 | 0.05 | 0 | 0 | 906 | 2 (1) |
| Copper (mg/L) | 8 | 2 (1) | 0 | 0 | 1165 | 0.05 |
| Fluoride (mg/L) | 24 | 1.5 | 0 | 0 | 749 | 1.5 |
| Iron (mg/L) | 46 | NA (0.3) | NA (26.0) | 0 | 351 | NA (0.3) |
| Lead (mg/L) | 8 | 0.01 | 0 | 0 | 1151 | 0.01 |
| Manganese (mg/L) | 46 | 0.4 (0.01, 0.4) | 4.3 (39.1, 3.9) | 0 (17.4, 10.9) | 1065 | 0.4 (0.01, 0.4) |
| Nickel (mg/L) | 8 | 0.08 | 0 | 0 | 227 | 0.08 |
| Nitrate (mg/L) | 31 | 11.3 [1.97] | 0[29] | 0 [25] | 1173 | 11.3 [41.2] |
| Nitrite (mg/L) | 7 | 3 | 0 | 0 | 973 | 3 |
| Sodium (mg/L) | 46 | NA (200) | NA | 0 | 1184 | NA (200) |
| Sulphate (mg/L) | 31 | NA (250) | NA | 0 | 1170 | NA (250) |
| Zinc (mg/L) | 8 | NA (1.5) | NA | 0 | 778 | NA (1.5) |

| | **West Coast** | | | | **New Zealand****** | |
|---|---|---|---|---|---|---|
| **Variable** | **# samples** | **MAV* (AV**) [REF**]** | **Sites Exceeding (one or more occasion) (%)** | **Sites Exceeding (median values) (%)** | **n** | **Sites Exceeding (one or more occasion) (%)** |
| **Microbiology** | | | | | | |
| *E.coli* (mpn or cfu) | 30 | 1 | 70 | NA | 1007 | 46 |
| **Pesticides** | | | | | | |
| Alachlor (µg/L) | 18 | 0.02 | 0 | NA | 183 | 0.5 |
| Dieldrin (µg/L) | 18 | 0.00004 | 0 | NA | 182 | 1.1 |
| Metolachlor (µg/L) | 18 | 0.01 | 0 | NA | 183 | 0.5 |
| Metribuzin (µg/L) | 18 | 0.07 | 0 | NA | 183 | 0.5 |
| Picloram (µg/L) | 18 | 0.2 | 11.1 | NA | 182 | 1.1 |
| Terbuthylazine (µg/L) | 18 | 0.008 | 0 | NA | 178 | 3.3 |

* Water Services 2022

** Taumata Arowai 2022

*** Daughney et al. 2023

**** Moreau et al. 2025

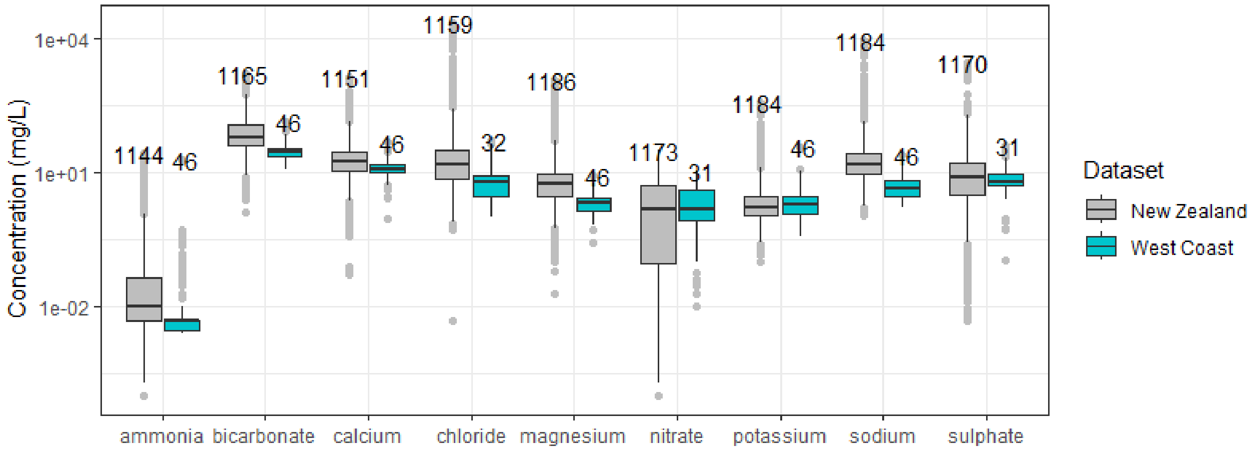

Figure 3.1 Box plot of concentrations for selected variables at State of the Environment (SoE) groundwater quality monitoring sites (2019–2024). The numbers above the boxplot indicate the number of sites.

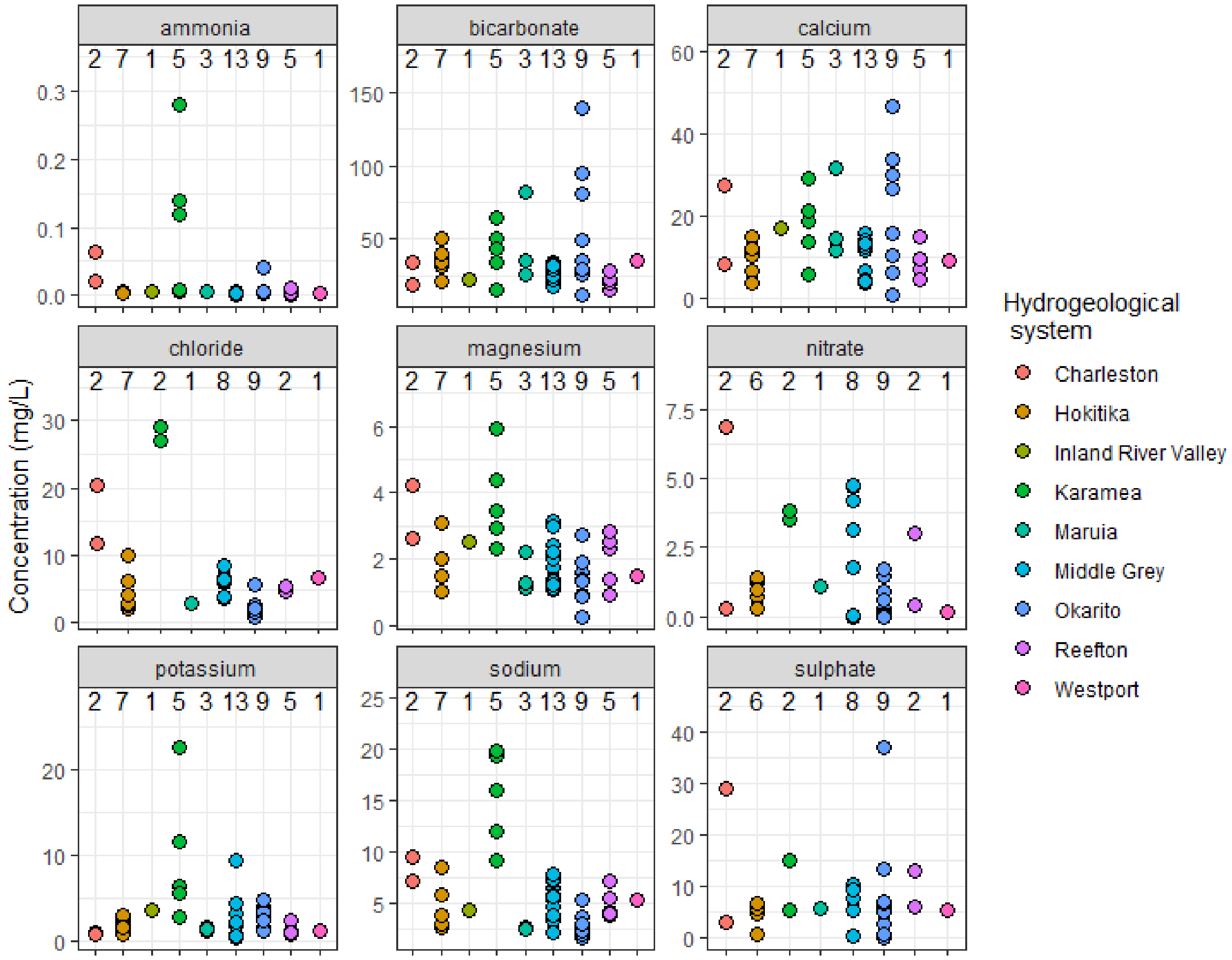

Figure 3.2 Median concentrations for selected variables organised per hydrogeological system. The numbers indicate the number of sites.

### 3.1.3 Human Influence

In New Zealand, the onset of industrial agriculture in the 1950s is correlated with anthropogenic impacts on groundwater quality (Morgenstern and Daughney 2012). Contamination by other anthropogenic sources may lead to localised elevated concentrations of other variables that are not picked up by SoE sites. For instance, localised arsenic contamination in many areas of New Zealand has been found to be associated with timber treatment plants, old sheep dip sites, old orchards (from use of lead arsenate sprays), sulphide mine drainage and leaching from treated timber posts in orchards and vineyards (Piper and Kim 2006).

The main variable indicative of diffuse agricultural activity influence is nitrate, which is sometimes accompanied by relatively high concentrations of calcium, bicarbonate, potassium, sulphate and/or chloride. Anthropogenic sources of nitrate or nitrite include fertilisers, urine and septic tank waste, livestock manure and erosion of natural deposits.

Between 2019 and 2024, median nitrate concentrations in the region ranged from below the detection limit (<0.01 mg/L) to 6.9 mg/L (as N), which is higher than previously reported (maximum of 5.8 mg/L over the 2012–2017 period). Elevated concentrations occurred in the Middle Grey, Hokitika and Charleston hydrogeological systems. The reference value for unimpacted groundwaters (1.97 mg/L as N) was exceeded at 11% of the sites (median values). There were no exceedances of the drinking-water MAV. Over the same time period, elevated nitrate concentrations were widespread in New Zealand, with a maximum median nitrate concentration of 28 mg/L (as N), and 6.2% of 1173 sites exceeded the MAV.

It should be noted that nitrogen is present in the form of nitrate in oxygen-rich groundwaters, whereas, in oxygen-poor groundwaters, nitrogen exists as ammonia. The conversion from one form to another occurs under natural processes. Where microbial fauna exists, nitrate can be removed by microbial respiration (denitrification). It is therefore possible that nitrate leachate may affect more sites but may be naturally removed or converted to ammonia. The reduction/oxidation framework, based on dissolved oxygen, nitrate-nitrogen, dissolved iron and manganese, and sulphate concentrations can only be applied at 33 sites from the medians dataset (McMahon and Chapelle 2008; Chapelle et al. 2009). In this framework, oxic conditions are met at 26 sites. Anoxic conditions, where the predominant process is nitrate reduction, were not identified at any sites. This classification could not be applied at 15 sites.

The 2022 Pesticides Survey involved sampling at 18 wells in the region and another 166 wells nationwide. Wells were selected using multiple factors, including: the relative regional importance of an aquifer, the known application and storage of pesticides in the area, and the perceived aquifer vulnerability to pesticide contamination. In this context, unconfined aquifers are preferably selected as they are more vulnerable to surface contamination (Close and Banasiak 2023). Samples were collected using a dedicated sampling protocol, and each sampling survey included the collection of duplicate samples for quality assurance (7.6% of the wells). The list of tested compounds included 25 organochlorine pesticides, 88 organonitrogen and phosphorus pesticides, 25 acid herbicides and 57 multiresidue pesticides (full list provided in Appendix 1). The 2022 survey was a timely repeat from the initial 1998 survey, where 67 compounds were tested. No pesticides were detected in the 1998 survey at the three wells located in the West Coast (Close and Banasiak 2023).

Only two compounds were detected in the 2022 Pesticide Survey out of the 195 tested compounds in the region, clopyralid and picloram, which are both acid herbicides regarded as having a high leaching potential to groundwater. The detection limit for clopyralid and picloram are reported as 0.4 ug/L. Clopyralid was measured at 1.1 ug/L at a single well in Okari. Picloram was measured at two wells (Okari and Maimai) at concentrations of 0.3 and 0.7 ug/L, respectively. Nationwide, 29 detections were reported at 17 wells. Isolated MAV exceedances were recorded in other regions for alachlor, dieldrin, metolachlor, metribuzin, picloram and terbuthylazine (Table 3.2). Detections are generally isolated and of low concentration. The maximum concentration of the national survey was that of clopyralid, measured in the West Coast. There is no MAV or AV associated with clopyralid in New Zealand, but, for context, the Australian Drinking Water Guideline is less than 2 mg/L (i.e. 2000 ug/L) for human consumption (NHMRC; NRMMC 2011).

## 3.2 Trends

Trend assessments for the 10-, 20- and 30-year periods show that, at most sites, the quantity of monitored variables are either increasing or decreasing (Table 3.3; Figure 3.3). The large detection of trends represents a departure from previously reported trends (Moreau 2019), due to the change in trend assessment method (Section 2.4).

Most sites exhibited concurrent increasing and decreasing variables, which is not surprising as a range of hydrochemical processes (e.g. dilution, water-rock interaction) occur along the flow paths and may affect variables differently. Increases were more frequent, with the notable exception of sodium and iron concentrations (Figure 3.3). Generally, the likelihood of trends were stronger over the longer time periods, although the number of monitoring sites decreases. The seemingly dominant decrease in ammonia concentrations is likely to be an artefact of the lowering of the detection limit over time.

Conductivity exhibited a range of patterns, from increases up to 6.5 uS/cm per year (10-year period, site #511) to decreases as rapid as -18.5 uS/cm per year (10-year period, site #143) (Table 3.3). All of the Reefton monitoring sites exhibited concurrent decreases in conductivity (0.07–3.95 uS/cm per year) and sodium concentrations (mg/L), but these changes were not accompanied by other variables. This suggests a local effect rather than system-wide. Conductivity trends were variable within each of the remainder of the monitored systems.

Nitrate concentration trends were contrasted amongst the 14 long-term monitoring sites, with both long-standing increases (e.g. sites #203 and #288) and decreases (e.g. sites #104 and #487), generally mimicked by sulphate trends (Figure 3.4). Drivers of changing nitrate concentrations are likely to be multiple and site specific (e.g. increased leaching from soils, land use management, oxygenation of the aquifer). Trend reversals in nitrate concentrations occurred at sites #104, #203, #288 and #291A around 2018. The fastest long-term increase was recorded at Site #511 at a rate of 0.11 mg/L per year over the 10-year period. Conversely, the fastest decrease was 0.10 mg/L at Site #496 over the 10-year period.

The most consistent trends over the three time periods were (Figure 3.5): increases in bicarbonate, fluoride and silica concentrations and decreases in dissolved oxygen concentrations. These sustained, long-term trends are confirmed by graphical examination at seven sites (#134, #288, #289, #290, #291A, #292 and #487 – Figure 3.5). Available age data indicate that these sites draw young groundwater (mean residence time of up to four years) from shallow, unconfined aquifers located in the Middle Grey (Grey Valley area), Charleston (Westport) and Hokitika (Hokitika and Kowhitirangi areas) systems. The main source of silica in groundwater is water-rock interaction (Hem 1985). Increasing air temperatures and carbon dioxide have been linked to increased breakdown of soil organic matter, facilitating microorganism growth, which can lower the groundwater pH and dissolved oxygen concentrations (Dao et al. 2024). These changes in aquifer conditions may trigger the dissolution of calcite or silicates (Niedhardt and Shao 2023; Schmidt et al. 2024). Five of the seven sites (#134, #289, #290, #292 and #487) exhibited increases in conductivity, calcium, potassium, silica concentrations and groundwater temperature concurrent with decreases in dissolved oxygen and pH over the 20-year period. At Site #288, a similar pattern is observed, although no significant trend was identified for bicarbonate concentrations and pH. At Site #291A, the silica increase is paired with a long-term pH and conductivity increase, and a dissolved oxygen concentration decrease. It is therefore possible that the observed long-term silica increases are linked to the changing climate or anthropogenic factors.

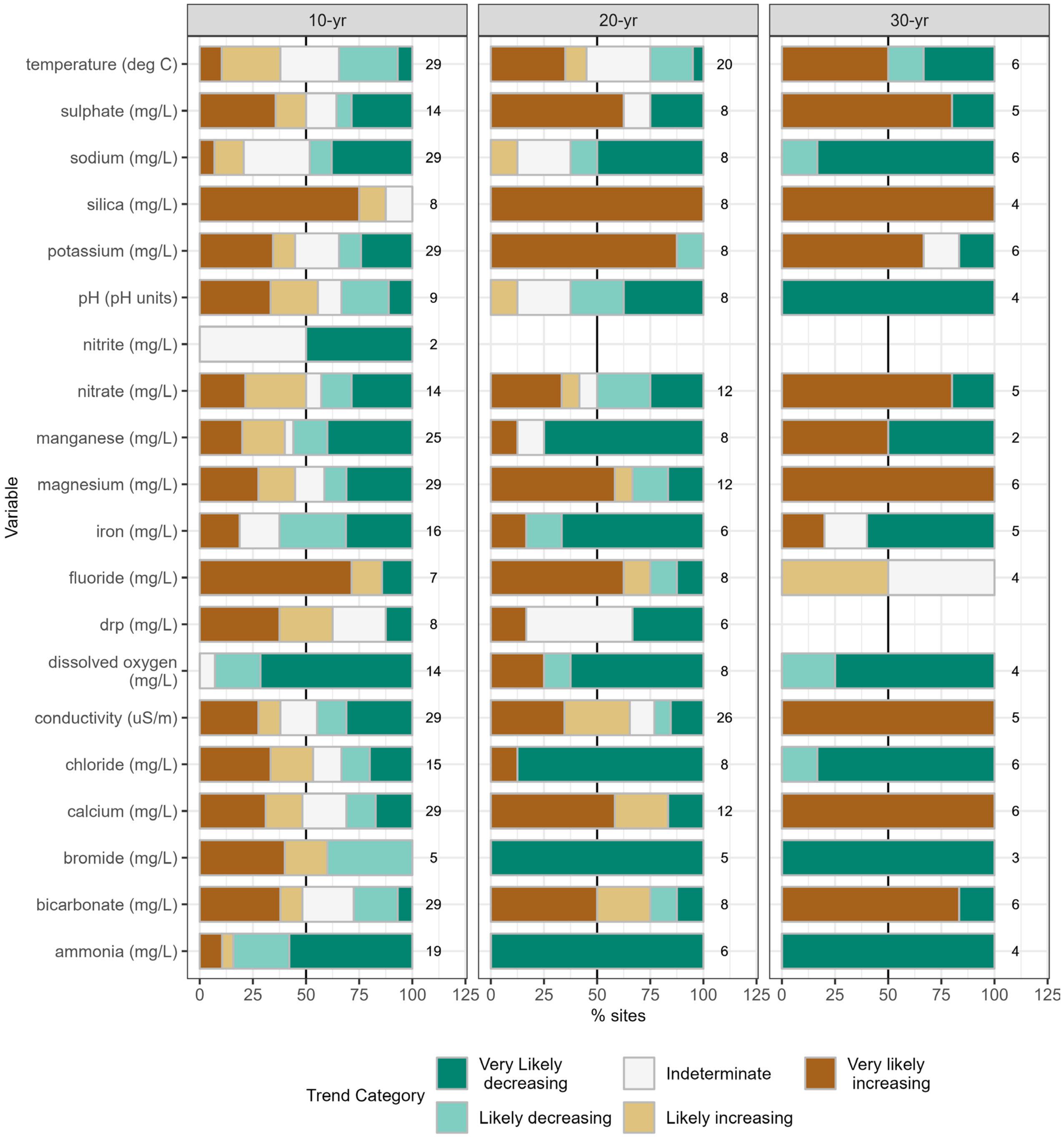

Figure 3.3 Percentage of significant trends at monitoring sites across the West Coast at which trend tests could be performed for the 10-, 20- and 30-year periods. The numbers shown on each portion of the bar graph represent the number of sites per category per variable.

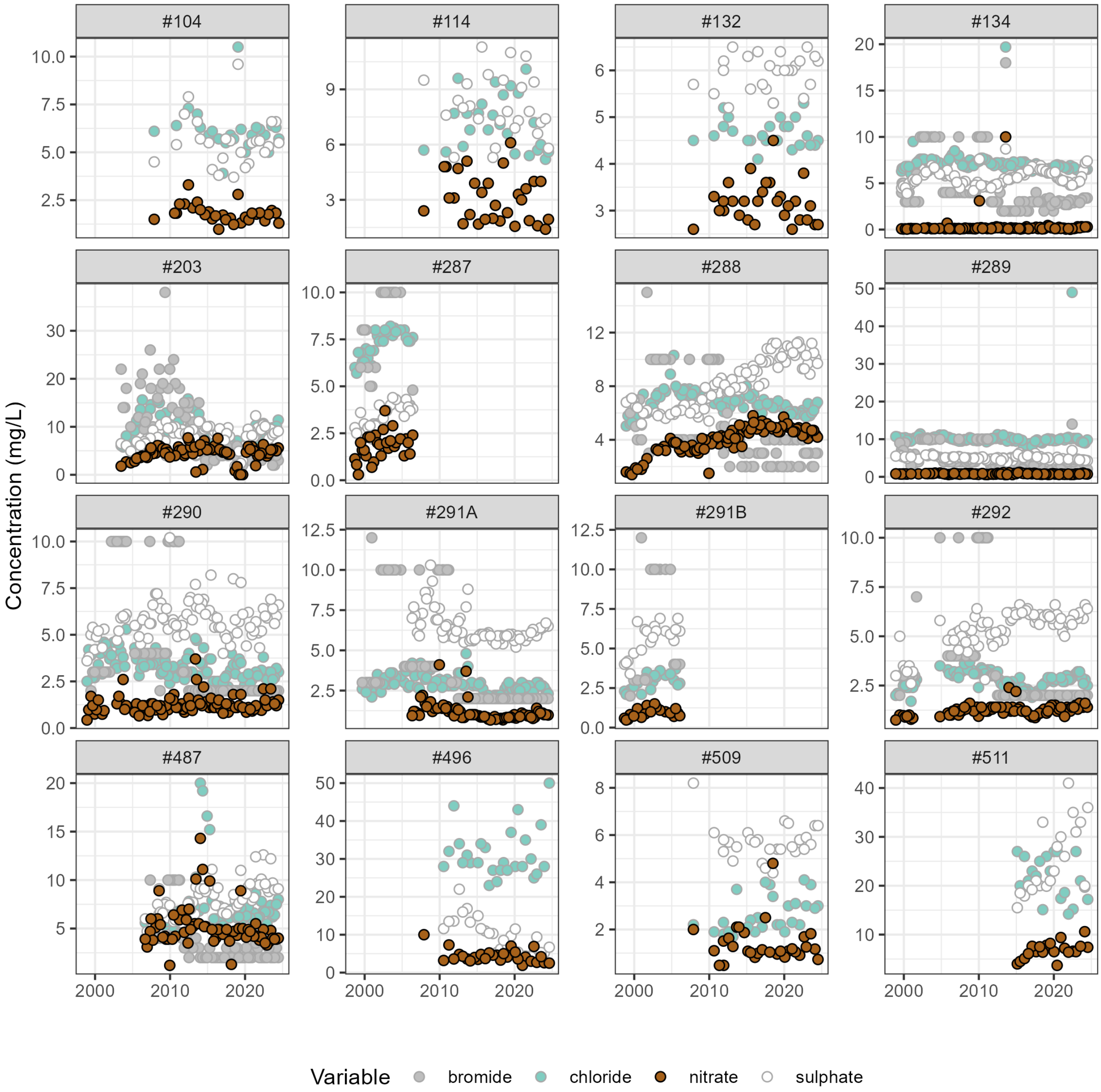

Figure 3.4 Nitrate, bromide, chloride and sulphate concentrations at long-term monitoring West Coast Regional Council (WCRC) sites. In this figure, bromide concentrations were multiplied by a factor of 10 to enable comparison.

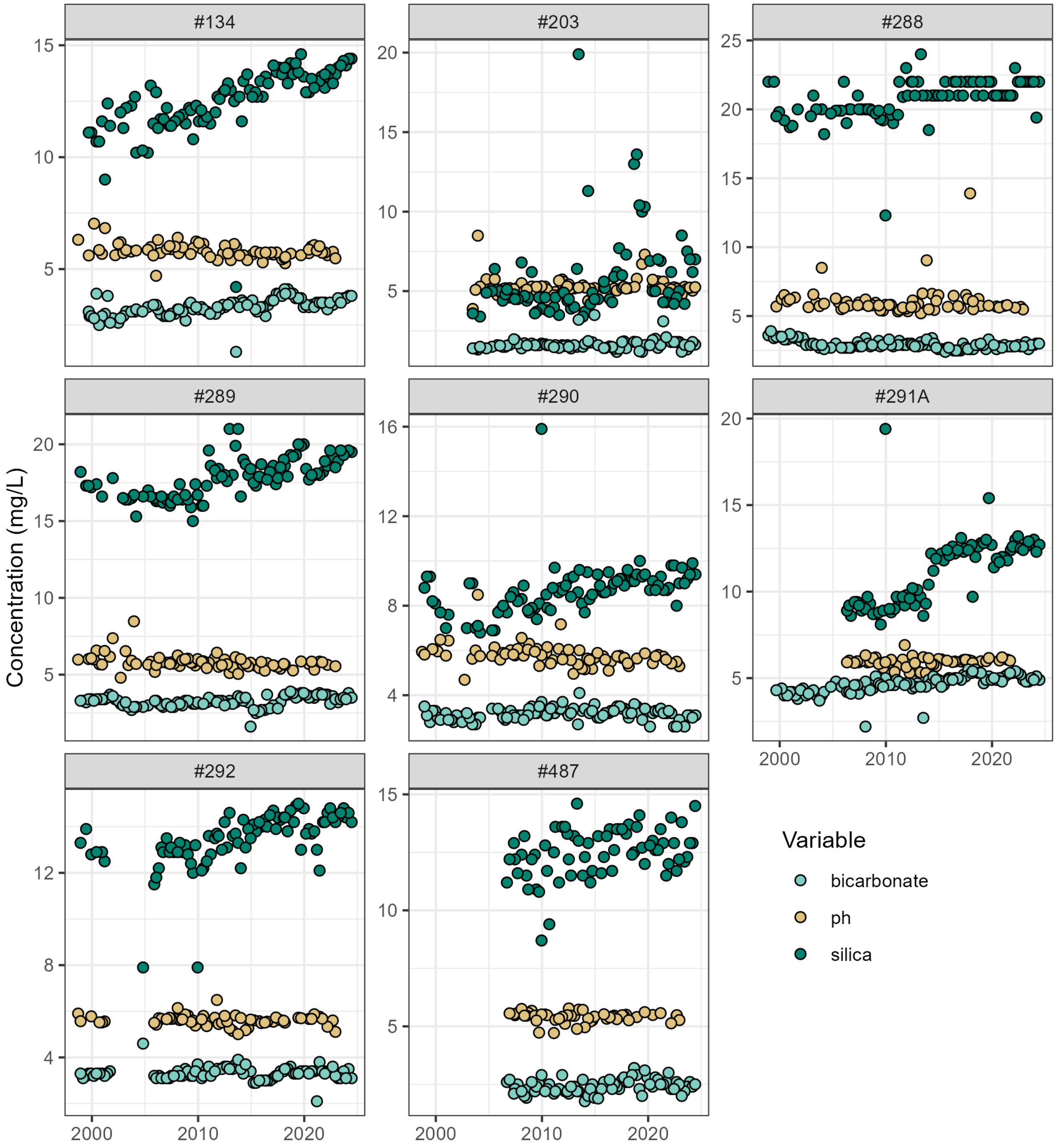

Figure 3.5 Measured pH, bicarbonate and silica concentrations at National Groundwater Monitoring Programme (NGMP) sites located in the West Coast since 2000. In this figure, bicarbonate concentrations were divided by a factor of 10 to enable comparison.

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Table 3.3 Absolute trend magnitude for significant increases and decreases at monitoring sites across the region for the 10-year period (2014–2024). Decreases are highlighted with a grey background.

| Hydrogeological System Name | Site ID | Ammonia (mg/L) | Bicarbonate (mg/L) | Bromide (mg/L) | Calcium (mg/L) | Chloride (mg/L) | Conductivity (uS/cm) | Dissolved Oxygen (mg/L) | Dissolved Reactive Phosphorous | Fluoride (mg/L) | Iron (mg/L) | Magnesium (mg/L) | Manganese (mg/L) | Nitrate (as N mg/L) | pH (pH units) | Potassium (mg/L) | Silica (mg/L) | Sodium (mg/L) | Sulphate (mg/L) | Temperature (°C) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Charleston | #511 | 0.0078 | 0.256 | - | 1.28 | -0.50 | 6.52 | -0.161 | - | - | -0.043 | -0.033 | -0.019 | 0.333 | 0.011 | 0.079 | - | - | 1.874 | 0.079 |
| Hokitika | #186 | 0.0000 | - | - | 0.05 | - | - | - | - | - | 0.000 | 0.015 | 0.000 | - | - | - | - | -0.020 | - | - |
| Hokitika | #289 | -0.0002 | 0.664 | 0.000 | 0.03 | 0.07 | 0.29 | -0.153 | - | 0.000 | - | 0.014 | 0.000 | -0.019 | - | 0.000 | 0.126 | 0.122 | -0.119 | -0.033 |
| Hokitika | #290 | -0.0003 | -0.316 | - | -0.16 | 0.00 | -0.94 | -0.174 | - | 0.000 | -0.020 | -0.017 | 0.000 | 0.000 | -0.008 | -0.017 | 0.047 | 0.000 | - | 0.097 |
| Hokitika | #291A | -0.0003 | 0.171 | - | - | 0.02 | 0.25 | -0.226 | 0.000 | - | -0.002 | -0.011 | -0.001 | 0.021 | 0.028 | 0.000 | 0.069 | - | 0.050 | 0.042 |
| Hokitika | #292 | -0.0002 | 0.147 | - | 0.03 | 0.07 | 0.29 | -0.083 | - | 0.000 | 0.001 | - | 0.000 | 0.025 | 0.020 | 0.011 | 0.050 | 0.000 | -0.022 | 0.013 |
| Karamea | #143 | -0.0407 | -2.495 | - | -1.99 | - | -18.55 | - | - | - | - | -0.990 | -0.004 | - | - | - | - | -1.110 | - | - |
| Karamea | #150 | - | -0.224 | - | 0.46 | - | 2.90 | - | - | - | - | 0.075 | 0.008 | - | - | 0.369 | - | 0.086 | - | 0.102 |
| Karamea | #378 | 0.0160 | 0.428 | - | - | - | -3.30 | - | - | - | 0.779 | - | 0.010 | - | - | 0.040 | - | -1.412 | - | - |
| Karamea | #496 | 0.0000 | 2.069 | - | 0.63 | 0.20 | 1.85 | -0.301 | 0.006 | - | - | 0.068 | 0.000 | -0.103 | - | 0.201 | - | 0.214 | -0.786 | -0.117 |
| Maruia | #507 | - | 0.404 | - | 0.28 | - | 1.45 | - | - | - | - | 0.028 | - | - | - | - | - | - | - | - |
| Maruia | #509 | - | -0.247 | - | - | 0.10 | - | - | - | - | - | 0.000 | 0.000 | 0.015 | - | 0.037 | - | - | - | - |
| Maruia | #510 | - | 0.794 | - | 0.47 | - | 1.60 | - | - | - | -0.001 | 0.038 | - | - | - | 0.018 | - | 0.039 | - | 0.054 |
| Middle Grey | #104 | - | 0.124 | - | 0.11 | 0.04 | 0.83 | -0.054 | 0.000 | - | - | 0.023 | 0.000 | 0.019 | - | 0.008 | - | - | 0.157 | - |
| Middle Grey | #109 | - | 0.634 | - | - | - | - | - | - | - | - | 0.000 | 0.000 | - | - | - | - | -0.066 | - | 0.073 |
| Middle Grey | #114 | - | -0.372 | - | -0.23 | -0.24 | -1.54 | -0.138 | 0.000 | - | - | -0.029 | - | - | - | 0.036 | - | -0.187 | -0.034 | 0.066 |
| Middle Grey | #116 | 0.0000 | - | - | 0.15 | - | 1.28 | - | - | - | - | 0.045 | 0.000 | - | - | -0.030 | - | - | - | -0.165 |
| Middle Grey | #125 | -0.0036 | -0.483 | - | - | - | -1.30 | - | - | - | - | -0.050 | -0.003 | - | - | -0.109 | - | - | - | 0.000 |
| Middle Grey | #203 | -0.0002 | - | 0.000 | 0.08 | 0.21 | - | -0.156 | - | -0.001 | 0.000 | 0.015 | -0.001 | -0.063 | 0.000 | -0.067 | - | - | 0.048 | 0.062 |
| Middle Grey | #288 | -0.0002 | 0.248 | 0.000 | 0.00 | -0.14 | -0.32 | -0.296 | 0.000 | 0.000 | - | -0.020 | 0.000 | -0.050 | -0.074 | -0.008 | 0.000 | -0.030 | 0.196 | - |
| Middle Grey | #310 | 0.0000 | - | - | -0.10 | - | - | - | - | - | 0.000 | -0.021 | - | - | - | -0.013 | - | -0.110 | - | - |
| Middle Grey | #487 | -0.0003 | - | 0.000 | -0.10 | 0.03 | -1.20 | -0.002 | 0.000 | 0.000 | -0.001 | -0.029 | 0.000 | -0.101 | 0.015 | -0.044 | 0.059 | -0.053 | 0.175 | 0.050 |
| Middle Grey | #92 | - | -0.621 | - | - | - | -2.31 |  | - | - | - | - | - | - | - | -0.143 | - | 0.000 | - | -0.049 |
| Reefton | #130 | 0.0000 | 0.638 | - | -0.34 | - | -3.95 | - | - | - | 0.000 | -0.073 | 0.002 | - | - | -0.014 | - | -0.100 | - | -0.076 |
| Reefton | #132 | - | 0.168 | - | 0.03 | - | -0.07 | -0.087 | - | - | - | - | 0.003 | -0.049 | - | - | - | -0.038 | 0.023 | -0.123 |
| Reefton | #231 | 0.0000 | - | - | -0.09 | - | -0.70 | - | - | - | 0.000 | -0.010 | 0.001 | - | - | - | - | -0.042 | - | 0.052 |
| Reefton | #451 | -0.0006 | -0.555 | - | 0.06 | - | -0.58 | - | - | - | - | 0.000 | -0.004 | - | - | 0.003 | - | -0.033 | - | -0.064 |
| West Coast | #127 | - | - | - | 0.11 | - | 0.64 | - | - | - | - | 0.045 | 0.001 | - | - | 0.134 | - | -0.073 | - | -0.067 |
| Westport | #134 | -0.0010 | 0.118 | 0.001 | -0.06 | -0.04 | -0.71 | -0.105 | - | 0.000 | 0.006 | 0.000 | 0.003 | 0.005 | 0.016 | -0.024 | 0.079 | - | -0.087 | -0.024 |

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Exceedances of *E.coli* have remained a common occurrence across non-basement systems and remain broadly consistent through time (Figure 3.6). As monitoring increased in site numbers and sampling frequencies, the number of exceedances decreased; however, these exceedances remain frequent. *E.coli* MAV exceedances also occurred at the national scale (between 20% and 67%) (Moreau et al. 2025).

Figure 3.6 Occurrence of *E.coli* Maximum Acceptable Value (MAV) exceedances at monitored sites per five-year time window from 1999 to 2024, grouped by hydrogeological system type.

### 3.3 State and Trends Assessment Toolkit

To enable future state and trend assessments using the methods described in this report, an annotated R script was developed by GNS and released during a two-hour participative workshop open to regional councils (Presentation material is provided in Appendix 2). The workshop objectives were twofold: first, to introduce recent changes in trend detection and reporting methods that are used for national reporting; and second, to walk through the R script as a training session to perform state and trend analysis using these methods. Two workshops were facilitated by GNS, one targeting regional councils (1 May 2025 online, with 42 attendees from 13 councils) and one dedicated to WCRC (24 June 2025 online, with 15 WCRC participants from the Science teams to policy, planning and hazards).

The assessment toolkit (*GNS SR2025-08_toolkit.zip*) comprises the following files and was sent to WCRC by separate email:

- *GNS SR2025-08_trend_analysis_for_SOE_reporting.R*: the annotated R script, which enables the user to undertake state and trend assessment of groundwater quality time series using the methods described in this report and an example time series dataset as an input file. Although the script includes comments for guidance on its use, these were not generated to any publishing standard and therefore this script is not suitable to disseminate for general public use as is.
- *gwq_timeseries_example.csv*: groundwater quality time series example input file.
- *LWPTrends_v2101.R*: Land and Water People Trends library version 2021. The library was developed by LandWaterPeople and was available from their website until March 2025. A new version was released (version number 2502), however, the newer version does not work as is with the developed R script as some function and data formats were modified for the 2025 release. The library release occurred after the script was developed and tested by GNS.

# 4.0 Recommendations and Conclusions

This technical report summarises data collected by WCRC as part of State of the Environment regular monitoring operations (regional and national programmes), complemented by a recent regional characterisation investigation undertaken by WCRC and GNS. The aggregated dataset consisted of time series for 19 variables (field, major, minor chemistry variables) collected at up to 48 sites between 1999 and 2024; 17 trace variables measured in December 2022 at eight sites; and 195 man-made pesticides compounds measured at 18 sites in 2022. Statistical trend analysis was undertaken using recently updated methods, reflecting current best-practice. State was defined as the 2019–2024 time period and characterised using up to 48 sites, depending on variables. Trends were characterised for three time periods, 1999–2024, 2004–2024 and 2014–2024 at up to 29 sites.

Groundwaters in the West Coast have a low total dissolved solids content with median conductivities ranging from 66 to 250 µS/cm (5th and 95th percentiles). The region's groundwaters are generally low pH, colder and more dilute than most groundwaters elsewhere in the country. This is consistent with high recharge combined with relatively short flow paths with mean residence times of less than 10 years. A range of oxic to anoxic aquifer conditions occur throughout the region. The 2022 screen for trace inorganic variables identified occasional occurrences of aluminium, barium, chromium, cobalt, copper, strontium, vanadium and zinc, at or close to the detection limit, which can be explained by natural sources.

In terms of rates of change for most variables, concurrent trends were a common pattern at monitoring sites and highlighted localised dynamics in each hydrogeological system. The long-term monitoring sites showed trending variables consistent with possible indications of increasing temperature and carbon uptake, which may be related to climate change and/or human activity.

Microbial contamination remains a regular occurrence in groundwaters of the region: *E.coli* drinking-water exceedances occurred at 70% of the 30 monitoring sites. It is worthwhile to note that *E.coli* detections were less frequent in the last five years than previously. Although nitrate concentrations in the region are low compared with national values and did not exceed the Drinking Water Standards, they can be locally as high as 6.9 mg/L and the national reference condition for unimpacted groundwater was exceeded at 11% of the sites. Both increases and decreases in nitrate concentrations were detected, and some increasing trends showed recent (c.2018) signs of trend reversal. The 2022 pesticides screen only yielded two detections at low concentrations (clopyralid and picloram herbicides). Although the clopyralid detection was low, it was the highest in the nationwide survey.

Monitoring data provides independent observations that can be used to develop understanding, calibrate/validate models, and assist with designing and monitoring outcomes of management interventions to restore/sustain freshwater quality and quantity. The existing cumulative dataset has successfully enabled characterisation of multiple groundwater bodies and groundwater quality issues. Long-term data collection is required to monitor changes and identify arising issues, including potential climate-change impacts on freshwater. Therefore, recommendations from this report are to:

- Continue monitoring groundwater quality, including repeating the collection of groundwater age samples at monitoring sites at low frequency (e.g. every three years). It is recommended to continue monitoring using the same frequency and standard variable suite (field, major and minor variables). To maintain efficiencies, pesticides and trace inorganic variables may be monitored at a lower frequency (e.g. five- or 10-yearly) to check conditions remain stable in alignment with national surveys. Considering the number of hydrogeologically distinct systems, it is also recommended to assess the feasibility of undertaking synoptic groundwater quality and quantity surveys (i.e. focusing sampling in a particular system), rotating between systems on a quarterly or biannually basis to ensure each system where groundwater is used is monitored at lower frequencies. Collected data could also be used to engage with local communities.

- Continue seizing opportunities to align with research programmes to enhance the regional dataset and understanding.
- Analyse at least once for dissolved oxygen and dissolved iron, dissolved manganese and sulphate at the 15 SoE sites where the redox status assessment could not be performed. This characterisation will allow to ascertain whether the nitrate reference value should be applied for future SoE reporting. Acquiring time series for these variables would be informative in a context of changing climate.
- Continue to review wellhead conditions of the SoE network regularly and engage with well owners to communicate on the associated health risks if the bores are used as a drinking water source. 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.
- Continue to engage with the national framework to enhance the representativeness, transparency and efficiencies of the current monitoring programmes. Activities may include: review of the regional network, sharing research findings or tools, and assessing opportunities to align monitoring with drinking-water suppliers (district, schools) to fill in data spatial gaps.
- Continue the collaborative refinement of the hydrogeological systems to incorporate WCRC’s knowledge in the region. For example, a draft classification of aquifer systems was developed for the Waikato region to review and prioritise monitoring, clarifying differences between regional and national scale monitoring (Hadfield et al. 2024). This classification was derived from combining hydrogeological systems and groundwater use, an approach consistent with the UK groundwater protection classification (Environment Agency 2024; Hadfield et al. 2024). A similar approach may be used in the West Coast to review sites shared with the national network and sites to be used for national reporting.

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# APPENDICES

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## APPENDIX 1 2022 Pesticides Survey Test Compounds

Samples for the pesticide analysis suites were sent to Hill Laboratories. The acid herbicide analysis involved liquid chromatography with tandem mass spectrometry (LC-MS-MS). The organo-chlorine, organo-phosphorus and organo-nitrogen pesticides were analysed using liquid-liquid extraction gas chromatography mass spectrometry (LLE-GC-MS). For the full list of compounds, please see the following file attached to the PDF version of this report:

- *GNS 2025-08_Appendix 1_2022 Pesticides Survey Test Compounds.pdf*

## APPENDIX 2 Cleaned and Processed Dataset (2019–2024)

The groundwater quality time series cleaned raw and processed dataset used in this assessment are attached to the PDF version of this report as the following files:

- *GNS 2025-08_Appendix 2_Groundwater_quality_time_series.csv*
- *GNS 2025-08_Appendix 2_Groundwater_quality_state_trends.csv*

## APPENDIX 3 State and Trends Assessment Online Workshop Presentation Material

The slides presented during the online workshops for the State and Trends Assessment are attached to the PDF version of this report in the following files:

- *GNS 2025-08_Appendix 3_WCRC_workshop material_part1.pdf*
- *GNS 2025-08_Appendix 3_WCRC_workshop material_part2.pdf*

1 Fairway Drive, Avalon 5011
PO Box 30368, Lower Hutt 5040

**gns.**cri.nz