Assessment of groundwater quality in the West Coast:

West Coast Regional Council State of the Environment groundwater monitoring report

February 2009

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EXECUTIVE SUMMARY

The West Coast Regional Council (WCRC) commissioned the Institute of Geological and Nuclear Sciences (GNS) to prepare a report of the state of the environment for groundwater in the West Coast Region, including a summary of groundwater level and groundwater quality, a brief analysis of preliminary groundwater age dating work, and a brief commentary on results from previous reports written by GNS in 2005 and 2007.

This study is based on groundwater quality data collected quarterly since 1998 from ten sites included in the National Groundwater Monitoring Programme (NGMP), which is operated in the West Coast region by GNS in collaboration with WCRC. Microbiological indicator parameters have also been measured at the NGMP sites quarterly since 2000. WCRC also routinely monitors groundwater level at 27 monitoring wells.

The results of this investigation show that groundwater quality in the West Coast region is comparatively good at present, particularly in relation to NGMP sites in other regions of New Zealand. However, specific groundwater quality issues are evident at certain sites and at certain times, namely elevated concentrations of nitrate-nitrogen, manganese, iron or microbiological indicator parameters.

Specific findings of this report were:

- Median nitrate-nitrogen concentrations are relatively low at most sites (ca. 2 mg/L or less) in comparison with the Maximum Allowable Value of 11.3 mg/L based on the New Zealand Drinking Water Standards (New Zealand Ministry of Health, 2005). However, at three sites in the West Coast region (GR17, GR24 and GR02), the median nitrate-nitrogen concentrations exceed 3 mg/L, which is an almost certain indicator of human impact (cf. Daughney and Reeves, 2003). At two of these sites and during the period 2005-2008, the nitrate-nitrogen concentrations occasionally approached or exceeded the Trigger Value of 7.2 mg/L set for protection of freshwater ecosystems (Australia and New Zealand Environment and Conservation Council, 2000).

- At one site (GR02), during the period 2005-2008, the concentration of manganese constantly exceeded the aesthetic guideline value of 0.05 mg/L and occasionally exceeded the health-related Maximum Allowable Value of 0.5 mg/L defined in the New Zealand Drinking Water Standards (New Zealand Ministry of Health, 2005). It is presently unclear what causes the elevated concentrations of manganese at this site.

- At three sites (HK31, BU01 and GR04), during the period 2005-2008, concentrations of iron occasionally exceeded the aesthetic guideline value of 0.2 mg/L defined in the New Zealand Drinking Water Standards (New Zealand Ministry of Health, 2005). The elevated concentrations of iron at these sites result from naturally low levels of oxygen in the aquifers, and carry no associated health risks.

- For bacterial indicator parameters, frequent transgressions of the Drinking Water Standards occurred in the period 2005-2008. At all but one NGMP site in the West Coast region, the bacterial counts exceeded the health-related Maximum Allowable Value (1 cfu/100 ml) for roughly one third of samples. During the period of 2005-2008, no bacterial contamination was observed at the HK25 site. The bacterial contamination is probably associated with agricultural land use, and poses a health risk if the bores are used for drinking water supply. However, bacterial contamination of groundwater typically results from localised leaching of bacteria down around poorly constructed wells, and it can generally be alleviated by deepening the bore and by improving well-head protection.

- Groundwater age determination demonstrated that the mean residence time of groundwater at the NGMP sites in the West Coast region ranged from 1.5 years to 45 years. Sites with young groundwater are expected to respond rapidly to land use changes, and the nitrate-nitrogen concentrations measured at these sites reflect the current level of land use intensity. At sites with long groundwater mean residence times, breakthrough of nitrate from past human/agricultural activities may not yet have occurred, meaning that an increase in measured nitrate concentration might take place in the future. In the West Coast region, three sites have groundwater with mean residence times of several decades (GR04, HK34 and GR02). At one of these sites (GR02), nitrate concentrations have significantly increased during recent years, and the comparatively long mean residence time suggests that nitrate concentrations may continue to rise for some time even if the level of human impact remains constant or is reduced.

- Typically shallow bores and highly permeable aquifers in the West Coast region mean that groundwater in the West Coast region is particularly vulnerable to contamination. Although the groundwater quality at the NGMP sites in the West Coast region is presently relatively good, there are indications that it is deteriorating with time. Since 1998, several NGMP monitoring sites have shown significant increasing trends in the concentrations of nitrate-nitrogen, chloride and/or sulphate. Together with frequently observed presence of 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. These indicator parameters should therefore be considered as evidence of a threat to the current quality of groundwater in the region and appropriate management strategies should be adopted as soon as possible to prevent continued degradation of groundwater quality.

Recommendations from this review are:

- The increasing trends of some indicator parameters demonstrate that continued quarterly monitoring is warranted at all NGMP sites in the West Coast region. Quarterly monitoring will allow the rapid detection of nitrate or bacterial contamination, and will enable the assessment of the degree of human/agricultural impact. In addition, continued quarterly monitoring will also ensure compliance with the protocols of the NGMP, where the West Coast bores provide valuable perspective in the national context, in particular with respect to the hydrochemistry of aquifers that exhibit (presently) relatively little human/agricultural impact.

- Despite the additional chemical analyses conducted on groundwaters from other bores in the West Coast region as recommended by previous State of the Environment reports, the spatial distribution of sites with known groundwater chemistry is too sparse to identify relationships between hydrochemistry and surrounding land use, or to provide a reliable estimate of baseline (i.e. ‘normal’ or natural) hydrochemistry. At present, most sites where groundwater chemistry data are available are used for dairy, and collecting additional data from as many sites as possible on a one-off basis, targeting various land uses, and analysing for a broad array of water quality parameters, would add considerable value to the knowledge on the relations between land use and groundwater quality in the West Coast region. Furthermore, no information on bacterial contamination presently exists at site HK34B, and so it is recommended to conduct analysis for bacterial indicator parameters on groundwater from this site.

- Where the degree of confidence for the mean residence times of groundwaters has been determined as moderate, additional analysis for tritium may be warranted to remove the ambiguity of these results. In addition, groundwater age determination on groundwater from the GR24 site is recommended. This will help to determine if the high nitrate-nitrogen concentrations measured at this site can be expected to further rise in the future due to the delayed arrival of nitrate associated with past land uses.

1.0 INTRODUCTION

The West Coast Regional Council (WCRC) commissioned the Institute of Geological and Nuclear Sciences (GNS) to prepare a report of the state of the environment for groundwater in the West Coast Region. It was agreed that this report would provide the following information as proposed by GNS in a letter to the WCRC on the 3rd of December 2008:

1. A summary of groundwater level and groundwater quality in the West Coast region, using all available data;
2. An analysis and presentation of any extra information for WCRC derived from the National Groundwater Monitoring Programme (NGMP), including a brief analysis of preliminary groundwater age dating work;
3. A brief commentary on results from previous reports written by GNS in 2005 and 2007, with relevance to this report.

It was also agreed that GNS would work collaboratively with WCRC staff on this project and that WCRC would provide all available data and information for a preliminary chapter of the report giving a resource overview for the West Coast Region.

The work envisioned above has been completed and this report has been prepared to provide the resulting information.

2.0 RESOURCE OVERVIEW[1]

2.1 Groundwater general background

Groundwater is simply defined as that water occurring in the “interconnected pores below the water table in an unconfined aquifer or located in a confined aquifer” (Fetter, 1994). Aquifers are various types of geologic formations (e.g., unconsolidated sediments like sands and gravels or consolidated rocks such as limestone) that are “saturated and sufficiently permeable to transmit economic quantities of water to wells and springs” (Driscoll, 1986 and Fetter, 1994). Figure 1 illustrates the general case involving an unconfined or water table aquifer underlain by a confined aquifer. Note that the confined aquifer is sandwiched between confining layers of relatively impermeable geologic materials, one of which also separates it from the unconfined aquifer.

As is also shown in Figure 1, access to groundwater is generally provided by wells drilled into and screened within aquifers. Except in relatively rare cases where a well is screened in a confined aquifer under sufficient pressure that it is Artesian (i.e., groundwater flows above ground from the wellhead without pumping), pumps must be installed in wells to bring the water to the surface for use.

2.2 West Coast region groundwater resources

The West Coast Region occupies most of the west coast of the South Island of New Zealand and includes three districts. From south to north these are the Westland, Grey, and Buller

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[1] This chapter was provided by WCRC staff working in collaboration with GNS and is reproduced from Zemansky et al. (2005).

Districts. Locations of the Districts within the West Coast Region and the West Coast Region itself are indicated in Figure 2.

Groundwater is an important source of water for drinking and other purposes to many communities and individuals living in the West Coast Region. It is used by communities for public water supply, by agriculture for irrigation and watering stock, for washing, processing, and producing bottled water by industry, and by tourists.

The WCRC has only a partial understanding of the region's aquifer systems. This is a result of the fact that most West Coast Region communities have historically relied on surface water resources for their water supply and that many of the wells in the Region have been developed as a permitted activity or in shallow alluvial aquifers without producing logs to record the geologic materials involved.

Most identified West Coast Region aquifers are located in the alluvial materials adjacent to the Region's streams and rivers. These aquifers are the product of tectonic influence, most notably the Alpine Fault (a sharp western boundary to the Southern Alps), periods of extensive glaciation, high rainfall, and the erosive force of the Region's streams and rivers. The relatively high erosion rates have deposited alluvial material across the majority of lowlands to the west of the mountainous Southern Alps.

The thickness of the alluvial gravels is typically 20 to 40 metres, but can be as much as 70 to 80 metres in parts of the Grey Valley. The basement of these aquifers is sandstone, mudstone (in particular the Kaita Bluebottom Group), and conglomerate. Most current groundwater abstraction in the West Coast Region is from such shallow aquifers with water tables on the order of 5 to 12 metres below ground level (BGL). In addition, uplifted marine limestones are also important aquifers. These are often associated with karstic landforms, caverns, and spring flow features in the West Coast Region.

A number of low temperature-tectonic geothermal systems, expressed at the ground surface in warm springs or seeps, are also associated with the tectonic setting of the Southern Alps. Such systems that have been identified are indicated in Figure 6 from Mosely (1992). These systems contain mainly meteoric waters that having fallen as rain and snow on the ground surface have then percolated downwards and been heated at depths as great as 5 km. The warm waters subsequently rise along high permeability pathways such as faults. These systems have temperatures in the range of about 20 to 100^{o}C.

2.3 Abstraction of groundwater in the West Coast region

The WCRC maintains a Groundwater Bore Inventory of bores and wells in the Region. However, as the WCRC does not require a resource consent be obtained prior to drilling a bore, the database does not contain the details of all bores and wells in the region. As a consequence, knowledge of aquifers in the Region is limited.

There are currently 450 bores listed in the Groundwater Bore Inventory. The majority of these are located in the Hokitika River and Grey River valley areas.

The Resource Management Act in 1991 required that all existing water rights be renewed within 10 years. For that reason, there was a notable increase in the number of resource consents to take groundwater granted during 2001. Thirteen of the 26 resource consents granted in that year were for existing school and community water supplies. Other than that perturbation, there is no discernable trend in the allocation of groundwater by resource consent in the West Coast Region.

Of the 100 resource consents that were processed to take groundwater during the 1997 to 2004 period, nearly half were within the Grey District. The distribution of these was 29, 47, and 22 percent for the Westland, Grey and Buller Districts, respectively.

Unlike some other areas of New Zealand, overuse of groundwater aquifers has not been an issue to date in the West Coast Region. Operators of shallow unconfined bores note seasonal fluctuations in groundwater levels and other changes related to precipitation events recharging these aquifers; however, when necessary, water supply can generally be secured by drilling a deeper well into a more extensive confined aquifer.

2.4 Groundwater management in the West Coast region

2.4.1 General concerns

A number of issues related to impacts on groundwater quality and, therefore, groundwater management have arisen in the West Coast Region. These may require further investigation and education in the future. They include:

1. Potential contamination from agricultural operations (e.g., fertilizer and cattle faeces);
2. Potential diversion of springs away from spring-fed creeks;
3. Potential increase in fines (i.e., very fine sediments) carried by groundwater from anthropogenic activities in the immediate vicinity of poorly protected bores; and
4. Other general groundwater protection issues.

2.4.2 Policy

The WCRC has developed a Proposed Water Plan and a Discharge to Land Plan. These plans include policies and rules for the management of groundwater resources. Essentially, they provide for the allocation of groundwater at sustainable yields to ensure both quality and quantity are maintained.

2.4.3 Monitoring

Currently, the WCRC routinely monitors groundwater levels at 27 sites in the West Coast Region. The WCRC has assigned alphanumeric identification codes to these wells. The first two letters of each well code indicate the drainage involved (i.e., BU for Buller River, GR for Grey River, HK for Hokitika River, and IN for Inanganua River). All of these sites are located in the areas of higher groundwater use of the Grey River and Hokitika River valleys. Water level readings are manually taken at each of these sites approximately every six weeks. This program commenced in the year 2000 in order to provide monitoring data regarding the possible seasonality of groundwater levels and the effect of precipitation on them.

In addition to the 27 wells comprising the WCRC groundwater level monitoring network, chemical and biological groundwater quality parameters are monitored in eight wells. Two of these have been changed for nearby wells in response to well decommissions. These sites are listed in Table 1 (with east-north coordinates and a map reference for each) and their locations are displayed in Figure 3. This program was established in September 1998 to provide data pertinent to the effects of various land uses on groundwater quality and to determine trends in groundwater quality in the West Coast Region. The monitoring network is a component of the National Groundwater Monitoring Programme (NGMP) operated by GNS in collaboration with the regional councils. The NGMP sites are sampled on a quarterly basis (i.e., every three months). GR04 was replaced by well GR24, and HK34 was replaced by HK34B.

2.4.4 Education

The potential for groundwater contamination can be reduced by the appropriate design and installation of wells with particular attention to measures for wellhead protection. Such measures ensure that the wellhead and well casing are sealed to prevent contaminants from directly entering groundwater in close proximity to the well. The WCRC, in a joint venture with a number of other regional councils, is promoting education in this area through use of an information brochure titled “Secure Your Well-Head.” This brochure was first produced in 2001.

Contaminants can readily enter wells that are not properly installed and managed. For example, precipitation, irrigation, and flood waters can move bacteria, viruses, and toxic substances (e.g., pesticides and trace metals) overland and down the sides of well cases into the groundwater supply when wells have not been properly constructed. It is important to seal the area around the wellhead with concrete that is sloped so that surface water from precipitation will drain away from the well. It is equally important to seal the annular space between the well casing and surrounding soil from the surface to the top of the well screen to eliminate that potential pathway for contaminant migration. It is also important to keep this area clear of rubbish, pesticides, fertilizer, offal, compost, and animals. Sometimes people used older out of service wells to dispose of rubbish or other wastes. Contaminants moving down the well bore into groundwater in such cases can migrate underground and contaminate wells being used to supply water. All wells need to be protected, whether in use or not, and older wells no longer in use should be plugged. Other recommendations for the protection of wells are presented in the brochure “Secure Your Well-Head”.

Contaminants may also enter groundwater as a result of various human activities (i.e., anthropogenic sources). A major concern in this regard is anthropogenic sources of nitrogen that can result in the contamination of groundwater with nitrates. These typically occur as a function of waste disposal (e.g., the application to land surfaces of human and animal wastes or from underground discharges of septic tank effluents) or agricultural operations that concentrate grazing animal populations in relatively small areas, but they can also occur from other agricultural practices (e.g., the use of nitrogen containing fertilizers). Nitrate contamination of New Zealand groundwaters from sources of this type have been well documented (Close, et al., 2001). This potential source of nitrate contamination is particularly relevant in the West Coast Region at this time because of intensification of dairying operations. Relatively low concentrations of nitrates from groundwaters may enter associated surface water systems and thereby contribute to eutrophication. Nitrates at sufficiently high concentrations may also be toxic to humans consuming the water.

3.0 REVIEW OF PREVIOUS REPORTS

This section provides a brief overview of the main conclusions and selected recommendations from previous reports that have assessed the groundwater resources of the West Coast region, including:

- Daughney, C., 2004. Assessment of groundwater quality in the West Coast Regional Council State of the Environment Monitoring Programme to March 2004. Client Reoprt 2004/156, Institute of Geological and Nuclear Sciences, 48 pp.

- Zemansky, G., Bowis, S. and Horrox, J. 2005. Groundwater state of the environment report. Client Report 2005/85, Institute of Geological and Nuclear Sciences, December, 104 pp.

- Zemansky, G. and Horrox, J., 2007a. Groundwater Nutrient Movement: Inchbonnie Catchment. GNS Science Report 2007/35, 77 pp.

- Zemansky, G. and Horrox, J., 2007b. Kowhitirangi and Kokatahi Plains groundwater assessment. GNS Science Report 2007/34, 62 pp.

Daughney (2004), in an examination of the groundwater quality data collected from the West Coast region between 1998 and 2004, suggested that the groundwater quality at the NGMP sites in the West Coast region is overall relatively good, especially if compared to the groundwater quality in other regions of New Zealand. For most water quality parameters, no statistically significant trends were detected over the period from 1998 to 2004. However, increasing trends were observed for chloride, nitrate-nitrogen and sulphate in six NGMP wells. Furthermore, bacterial indicator parameters exceeded the health-related Maximum Allowable Value (MAV) of 1 cfu/100ml for about one third of the groundwater samples considered in the study, attributed to the impact of increasing human/agricultural activity in the West Coast region. In order to monitor this inferred threat from leaching of manure, sewage effluent or fertilizer to groundwater resources in the West Coast region, Daughney (2004) suggested a continuation of the quarterly monitoring of the NGMP sites. In addition, a synoptic survey of groundwater chemistry from other bores in the West Coast region on a one-off basis was recommended to improve the knowledge of groundwater quality in the West Coast region and for allowing a robust statistical analysis of the relation between hydrogeochemistry and surrounding land use. Daughney (2004) also suggested conducting age dating on the groundwaters from the NGMP sites to examine the time lag between land use intensification and the observed impact on groundwater chemistry.

Zemansky et al. (2005) reviewed the groundwater state of the environment in the West Coast region and also confirmed that the groundwater quality in most of the sampled wells of the West Coast region is generally good in comparison to the New Zealand Drinking Water Standards. However, the report also identified bacterial contamination of groundwater in all wells except one as an issue. In agreement with previous reports, Zemansky et al. (2005) also suggested that intensifying agricultural operations in the West Coast region are responsible for the statistically significant increasing trends of chloride, nitrate-nitrogen and sulphate observed at several NGMP sites. An examination of the link between groundwater level data and groundwater chemistry by Zemansky et al. (2005) identified missing data (e.g. water samples had only been taken for approximately 35% of the quarters between

September 1998 and March 2004) as a limitation to the usefulness of the data sets. In addition, the authors noted that field and laboratory quality control and quality assurance measures are poorly documented. In order to improve the groundwater quality monitoring in the West Coast region, Zemansky et al. (2005) recommended implementation of the suggestions made by Daughney (2004), specifically age-dating of groundwater from NGMP sites and completion of a one-off synoptic survey of groundwater chemistry at non-NGMP sites around the West Coast region. Furthermore, Zemansky et al. (2005) recommended the introduction of several measures to reduce or eliminate missing data and improve the general quality of the analyses and field data (e.g. strictly following standard sampling guidelines and a review of the quality assurance procedures).

Zemansky and Horrox (2007a) assessed the movement of nutrients in surface water and groundwater in the Lake Brunner area. This study allowed for determination of mass fluxes of nitrogen and phosphorus through the catchment via various pathways. The study showed that nitrate-nitrogen flux through the groundwater component of the hydrologic cycle is a significant component of the overall nitrogen flux through the catchment, whereas in contrast phosphorus flux through the catchment is predominantly via the surface water pathway.

Zemansky and Horrox (2007b) conducted additional groundwater analyses of primarily non-NGMP wells in the Kowhitirangi and Kokatahi Plains in order to study groundwater flow paths and obtain a more comprehensive view of the effect(s) of land use on groundwater quality in the study area, following from recommendations made by Daughney (2004) and Zemansky et al. (2005). This follow-up study by Zemansky and Horrox (2007) confirmed the link between land use and nitrate contamination of groundwater, and also indicated that precipitation-facilitated downward migration of nitrate-nitrogen and sulphate from anthropogenic sources (e.g. farming operations) results in minor changes of concentrations between the dry and wet seasons.

4.0 METHODS

4.1 Groundwater monitoring sites

There are eight routinely monitored NGMP sites in the West Coast region. Since the completion of the last State of the Environment report (Zemansky et al., 2005), two monitoring sites (HK34B and GR24; Table 3) have been added to the NGMP in the West Coast region to replace the GR04 and HK34 sites, which have remained inactive since 2006. The hydrogeology of the monitoring sites is generally poorly constrained because well drillers do not record details such as hydraulic conductivity, storativity or transmissivity. Bore logs for four of the sites are available, but they are not detailed. Most of the sites tap shallow gravel or sand aquifers from alluvial deposits (Rosen, 2001; see also Baker, 2004; Zemansky and Horrox, 2007a). Site characteristics are summarised in Table 2 and presented in more detail in Appendix 1 (modified from James, 1998 and Daughney, 2004). Groundwater level data were available from 27 additional sites and microbiological parameter data were available from 9 sites.

4.2 Sample Collection

Samples for the chemical analysis of the NGMP monitoring sites were collected in quarterly intervals by WCRC staff following standard sampling protocols described by Rosen (1997) and Rosen et al. (1999). Where possible, the water level in each well was measured prior to sample collection and the well was then purged of three well volumes of standing water. Conductivity, pH, temperature, dissolved oxygen concentration and/or oxidation-reduction potential were monitored during purging, and samples were collected when these parameters had stabilised. Unfiltered, filtered (0.45 μm), and filtered and acidified (nitric acid) samples were collected using plastic bottles provided by GNS. All samples were placed on ice in chilly bins immediately after collection and for the duration of their transportation to the GNS Analytical Facility in Wairakei.

Samples for microbiological analysis were collected from each site after collection of samples for chemical analysis. Samples were collected in sterile 120 ml bottles supplied by the Cawthron Institute, and then immediately placed in a chilly bin with cold packs. Samples were transported to the Cawthron Institute and analysed within 24 hours of collection.

4.3 Analytical methods

4.3.1 Major and minor ion analysis and bacterial indicators

Names, abbreviations and units for all parameters analysed for the NGMP sites in the West Coast region are shown in Table 2.

Field measurements were made at the site using portable meters. Parameters measured in the field include electric conductivity, pH, dissolved oxygen concentration, oxidation-reduction potential and water temperature. Some of these parameters were also measured separately in the laboratory; for example, the tables in this report list separate values for “pH field” and “pH lab”.

Most laboratory chemical analyses were conducted at the GNS Water-Gas Lab in Wairakei. Concentrations of Mg, Ca, Fe, Mn and SiO_2 were measured in the filtered acidified samples using a Thermo Jarrell Ash inductively coupled plasma optical emission spectrometer. Concentrations of Na and K were measured in the filtered acidified sample using a Perkin-Elmer 1100 atomic absorption spectrophotometer. Concentrations of Cl, SO_4, NO_3-N, Br, F and PO_4-P were measured in the filtered, unacidified sample using a Dionex ion exchange chromatograph. Alkalinity measurements (to pH 4.5) were made with a Metrohm autotitrator. The conductivity of each unfiltered, unacidified sample was measured in the laboratory at 25ºC using a conductivity meter, and the pH of each unfiltered, unacidified sample was measured in the laboratory using a pH meter with automatic temperature compensation. NH_4-N was measured in the filtered unacidified samples by RJ Hill Laboratories, using an automated phenohypochlorite method.

Microbiological analyses were performed at Cawthron Institute. The samples for microbiological analysis were enumerated for faecal coliforms and for *Escherichia coli* using membrane filtration and mFC selective agar medium. Results were reported in colony forming units (cfu) per 100 ml.

4.3.2 Groundwater age determinations

Aquifers in the West Coast region are mostly unconfined and are composed of permeable sands and gravels. Because of the nature of the aquifers and the high rainfall in the West

Coast region, recharge rates are expected to be high and groundwaters relatively young. Tritium (half-life of 12.3 years), chlorofluorocarbons (CFCs) and sulphur hexafluoride (SF_6) are the tracers most commonly applied to date young groundwaters (Cook and Solomon, 1997; Kazemi et al., 2006), and these tracers have therefore been applied to determine the age of groundwater at NGMP sites in the West Coast region. Samples were collected from seven different sites during the period 2001-2008. For most sites, only one sample was collected for each tracer. For the HK25 site, however, a time-series of tracer measurements was obtained to remove ambiguity in the age determination that can arise under certain hydrogeological conditions (see Daughney et al., 2009).

Tritium was analysed in 1 L unfiltered and unpreserved samples at GNS in Lower Hutt using 70-fold electrolytic enrichment prior to ultra-low level liquid scintillation spectrometry following the method described by Morgenstern and Taylor (2005). The detection limit for tritium is 0.03 TU (tritium units), and the reproducibility of a standard enrichment is 2%. Samples for CFC and SF_6 were collected in 125 mL and 1 L bottles, respectively. The samples were analysed at GNS in Lower Hutt following the methods described by van der Raaij (2003).

4.4 Quality assurance of chemical data/charge balance errors

All waters are electrically neutral, meaning that the sum of concentrations (equivalents per litre) of all positive ions (cations) must be equal to the sum of concentrations of all negative ions (anions). Thus computation of the charge balance error (CBE) can be used as a measure of the analytical accuracy of water quality data. CBE was calculated for each sample collected from each WCRC monitoring site, following the method of Freeze and Cherry (1979):

$$CBE = \frac{\sum zm_c - \sum zm_a}{\sum zm_c + \sum zm_a} \times 100\%$$

where z is the absolute value of the ionic valance, m_c is the molarity of the cationic species and m_a is the molarity of the anionic species. The following ionic species were considered in the calculation of CBE: Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{2+}, Mn^{2+}, NH_4^+, HCO_3^-, Cl^-, NO_3^-, PO_4^{3-} and SO_4^{2-}. In all cases, results below the analytical detection limit were assigned values of ½ the detection limit to permit calculation of CBE.

The acceptable limits for the CBE for each sample were calculated by propagation of analytical uncertainties through the CBE equation. The analytical uncertainty (two standard deviations around the mean) for each ion was related to its concentration as described by Daughney and Reeves (2003). In general, the analytical uncertainties for most ions were between 2 and 5% over the range of concentrations relevant to the West Coast groundwater samples, though uncertainties would be expected to increase to roughly 20% at the analytical detection limit. Using this method, the acceptable limits for CBE for the WCRC samples could be as low as 5.3% or as high as 6.5% for samples with very high or very low concentrations of total dissolved solids, respectively. These values for acceptable *CBE* are slightly higher than the value of ±5%, suggested by Freeze and Cherry (1979), due to the dilute nature of most WCRC groundwaters.

4.5 Assessment of groundwater chemistry by analyte

The median, median absolute deviation (MAD) and trend were assessed on a per-site and per-analyte basis as described in the following paragraphs. These distributional and statistical parameters were calculated for the entire historical data record, and using only the data collected after January 2005. The statistical results were compared to the results described by Daughney (2004) to identify any changes. Where no analyses were available or if a calculation could not be performed (e.g. because 100% of the results were below the detection limit), then median, MAD and trend were recorded as ND, indicating "Not Determined". Samples identified as outliers were excluded from these calculations. Outliers were defined as having concentrations more than four times the MAD away from the median (Helsel and Hirsch, 1992). Samples with CBE outside the acceptable limits were not excluded during the calculation of the median, MAD or trend.

The median concentration of each analyte was calculated at each monitoring site, because it is less sensitive to extreme values in the dataset than the mean and thus provides a more resistant measure of central tendency than the average (Helsel and Hirsch, 1992). Estimation methods are often required for calculation of median values for water quality data, because the dataset typically includes “censored” values reported as being less than some detection limit. In this analysis, a log-probability regression method (Helsel and Cohn, 1988) was employed to calculate the median. This method provides a reasonable estimate of the median even when up to 70% of the available results are reported as being below some detection limit. Median values of all parameters were compared to their respective Maximum Allowable Values (MAVs) or aesthetic guideline values based on the Drinking Water Standards for New Zealand (New Zealand Ministry of Health, 2005) and to Trigger Values (TVs) set for protection of aquatic ecosystems (Australia and New Zealand Environment Conservation Council, 2000)

The median absolute deviation (MAD) was calculated for each analyte at each monitoring site as a means of assessing variability around the median. The MAD is a measure of the spread of analytical results and is analogous to the standard deviation, but the MAD is less subject to biasing by extreme values (Helsel and Hirsch, 1992). The MAD can be compared to the median to provide a measure of groundwater security. For example, Close et al. (2000) suggested that if the standard deviation is more than 5% of the average for certain analytes (this is analogous to the MAD as a percentage of the median), then the site is likely non-secure and affected by significant seasonal variation, groundwater abstraction, land use change, or some similar process.

The rate of change of each analyte was assessed statistically at each site. In this study, the term ‘trend’ is used to describe a continual increase or decrease in a parameter over time. It is important to note that an analyte may show significant variation over time, as manifested by a relatively large MAD, but if the variation does not follow a consistent direction over time, then a significant trend will not exist. Trends were identified using the Mann-Kendal test (Helsel and Hirsch, 1992) with a confidence interval of 95%. If a trend in any parameter at any site was significant at the 95% confidence interval, then the magnitude of the trend was quantified with Sen’s slope estimator. This method was employed to determine the median rate of change in the analyte (units per year) for the entire historical record available for the site in question. Trends that are not significant at the 95% level are tabulated with an assigned value of zero.

The statistical approaches outlined above were also applied to the biological data (faecal coliform and E. coli), although certain limitations with this approach exist, as discussed by Daughney (2004). First, the statistical calculations apply to a shorter time interval than other parameters, because bacterial indicator data were available only for the period July 2001 to December 2008. Secondly, for most sites, analytical results were below the detection limit on several occasions, which makes determination of the median, MAD and trend less robust. This latter point should be kept in mind when comparing medians to the drinking water guidelines, because the analytical detection limit is actually equal to the health related Maximum Allowable Value (<1 cfu/100 ml) based on the New Zealand Drinking Water Standards (New Zealand Ministry of Health, 2005).

4.6 Assessment of groundwater chemistry in relation to land use

Box-whisker plots and the Kruskal-Wallis test were employed to test for significant differences in the medians, MADs and trends of monitored parameters between sites with different surrounding land use. The Kruskal-Wallis test is non-parametric, and thus it does not require the assumption that the parameters being assessed follow the normal distribution (Helsel and Hirsch, 1992). In this regard, the Kruskal-Wallis test is more robust than analysis of variance (ANOVA), which is often used for a similar purpose. The land use category at each monitoring site in each is as follows:

Well	Land use	Well	Land use
HK34	Dairy	GR04	Dairy
HK25	Urban	BU01	Dairy
HK39	Dairy	HK34B	Unknown
HK31	Rural-residential	GR24	Unknown
GR17	Dairy		

4.7 Assessment of temporal groundwater level trends

Water level data for 28 groundwater wells (7 NGMP sites and 21 other WCRC sites) were provided by WCRC. Frequent (approximately quarterly) water level readings were only available for the period since 2000. All groundwater level data were obtained using an electric-tape water level meter with the top of the well casing as a reference point. Hydrographs showing the water level time-series plots were prepared and examined to identify water level trends. In addition, trend analyses using the nonparametric Sen's slope estimator were conducted as described above to detect and quantify significant time trends.

5.0 RESULTS

5.1 Groundwater quality

5.1.1 Charge balance error

CBE could be calculated for 207 groundwater samples collected since the commencement of sampling NGMP wells in the West Coast Region in 1998. Of these 207 samples, 203 (98%) were within acceptable limits, 1 (<0.5%) was 'High' (cation excess), and 3 (<1.5%) were 'Low' (anion excess) (Table 3). A histogram shows that the data approximate the ideal normal distribution with a mean of zero (Figure 4). Previous reports (Daughney, 2004; Zemansky et al., 2005) suggested that the CBE decreased slightly from 1998 to 2000 due to improvements in analytical methodology, and has remained near constant since 2000. A scatter plot (Figure 5) shows that from 2005-2008, all samples for which CBE could be calculated were within the acceptable limits of ±5%. A box-whisker plot demonstrates that the CBE does not vary significantly between the different NGMP sites in the West Coast region (Figure 6). The results obtained for CBE from the NGMP sites in the West Coast region are in good agreement with previous reports (Rosen, 2001; Daughney, 2004; Zemansky et al., 2005), and are similar to values obtained in other regions of New Zealand (Daughney and Reeves, 2003, Daughney, 2004).

5.1.2 Median concentrations of monitored parameters and comparison to water quality guidelines

As shown in Table 4, at most sites, the median values of most analytical parameters are below the respective health-related Maximum Allowable Value (MAV) or aesthetic guideline value (GV) based on the Drinking Water Standards for New Zealand (New Zealand Ministry of Health, 2005), or the Trigger Value (TV) based on the 95% level of protection for freshwaters (Australia and New Zealand Environment and Conservation Council, 2000) (MAVs, GVs and TVs). However, for bacterial indicators, systematic transgression of the guideline values at all bores could be observed (discussed further below).

A comparison of the median values calculated for the most recent years (2005-2008) with the entire historical data record (1998-2008) (Table 4) shows that there is a good overall agreement, suggesting that the controls on the hydrogeochemistry have remained unchanged since 1998. For some parameters, however, a considerable deviation from the long-term trend could be observed. For example, increasing median concentrations of NO_3-N are observed at a number of sites (HK31, HK39, GR04, GR02 and HK25) where no trend was detected pre-2005 (Daughney, 2004). In addition, median values of NO_3-N in groundwater from the two sites (GR24 and HK34B) which have been incorporated into the NGMP in the West Coast region since the completion of the last groundwater state of the environment report (Zemansky et al., 2005) also show statistically significant trends of increasing NO_3-N values over the period 2005 to 2008. By contrast, the median NO_3-N concentration at the GR17 bore, where an increase in median NO_3 was observed in previous reports (Daughney, 2004), has decreased during the last four years (2005-2008) of analysis, probably showing that the level of land use has stabilised or decreased at this site. The health-related TV for NO_3-N based on the 95% level of protection for freshwaters is 7.3 mg/L, and the MAV for NO_3-N is 11.3 mg/L. Daughney (2004) noted that the median concentrations of NO_3-N across all NGMP sites in the West Coast Region is 1 mg/L for the period of 1998 to 2004, which has risen to median concentrations of 1.32 mg/L across all NGMP sites in the WCRC for the years 2005 to 2008. Despite these increasing NO_3-N trends observed for certain NGMP sites in the West Coast region since 2005, the NO_3-N concentration of groundwaters at most sites are relatively low and are generally below the MAV for NO_3-N (Figure 7). However, since 2005, NO_3-N concentrations occasionally approached or exceeded the TV for NO_3-N at the GR02 and the GR24 bores (Figure 7). By contrast, NH_4-N concentrations remain consistently low at all NGMP sites in the West Coast region, related to the oxic redox state of most groundwaters in the West Coast region.

Trends of increasing median NO_3-N concentration in West Coast groundwaters have also been noted by James (2001), Rosen (2001), Blake (2004) and Daughney (2004). To address the recommendations of the state of the environment report in 2005 (Zemansky et al., 2005), Zemansky and Horrox (2007b) collected additional samples from bores in the Kowhitirangi and Kokatahi Plains. NO_3-N concentrations in the groundwaters from the (mostly non-NGMP) bores in the Kowhitirangi and Kokatahi Plains were mostly ca. 1 mg/L, slightly lower than for the NGMP bores in the present report, possibly reflecting dilution from low concentration stream water or rapid recharge from rainfall.

Table 5 shows an overview of the number of times groundwaters from each NGMP site in the West Coats region were analysed for bacterial indicator parameters (E. coli or faecal coliforms) and how many times the groundwaters exceeded the health-related MAV of 1 cfu/100 ml (there are no GVs or TVs for bacterial parameters). Since 2000, most bores have been sampled and analysed for these microbiological indicator parameters more than 20 times and with the exception of the HK34B site where no data exist at present, counts of faecal coliforms or E. coli in excess of the MAV (Table 5) were frequent at all sites. During the entire period of data record (2000-2008), the percentage of all samples collected in excess of the MAV of 1 cfu/100 ml varies from about 22-65% at the different monitoring sites (Table 5). During the most recent years (2005-2008), this percentage has dropped for most sites (HK31s, HK39, GR17, HK34, BU01s and HK25). Notably, no bacterial counts of faecal coliforms or E. coli in excess of the MAV were detected during 11 analyses conducted at the HK25 site from 2005-2008. By contrast, an increase in bacterial contamination could be observed at the GR04 site and the GR02 site.

Bacterial contaminants at the NGMP sites in the West Coast region are probably derived from manure associated with dairying, although Sinton (2001) states that bacterial contamination of groundwater can also be caused by septic tank systems, effluent irrigation, land application of sludge, offal pits and landfills. Where bacterial contamination of groundwater is caused by leaching of manure, the effects are often localised, and often affect poorly constructed wells. Sinton (2001) also states that bacterial transport and survival in groundwater is enhanced in porous or gravely soils and under saturated conditions. Overall then, bacterial contamination at the NGMP sites in the West Coast region is probably facilitated by high rainfall, shallow water tables and shallow bore depths, and may also be affected by lack of adequate well-head protection. The frequency of bacterial contamination could be reduced by deepening bores and by ensuring adequate well head protection. This would result in improved protection for drinking water supplies.

The occurrence of elevated concentrations of Fe and/or Mn in groundwater is usually indicative of reduced (anoxic) conditions in the aquifer. Based on the drinking water standards, Fe and Mn have aesthetic GVs of 0.2 mg/L and 0.05 mg/L, respectively, and Mn has a health-related MAV of 0.5 mg/L (New Zealand Ministry of Health, 2005). Based on the 95% level of protection for freshwaters, Mn has a TV of 1.9 mg/L (Australia and New Zealand Environment and Conservation Council, 2000). Notably, high Mn concentrations in excess of the MAV for Mn of 0.5 mg/L could be observed at the GR02 well, particularly since 2005. The co-occurrence of high concentrations of nitrate (which is not stable under anoxic conditions) and O_2 demonstrate that conditions in the aquifer at this location are not anoxic. Daughney (2004) noted that elevated Fe and/or Mn concentrations can also result from corrosion of metal pipes and cylinders that are in contact with the water before it is sampled and elevated concentrations of Fe or Mn may thus reflect inadequate purging time prior to sampling. It is at present unclear if this is the cause of the high Mn concentrations at the GR02 site. The median Fe concentration at the BU01 bore also exceeded the aesthetic guideline value of 0.2 mg/L for the period from 2000-2004 (Daughney, 2004), indicating that the BU01 bore shows characteristics of anoxia. During the most recent years of analysis (2005-2008), the median Fe concentration at the BU01 site has dropped below the GV of 0.2 mg/L, but the continuously low concentrations of NO_3-N and O_2 support the assumption that the elevated Fe and/or Mn concentrations at this site arise from naturally low levels of oxygen in the aquifer. The GR04 bore also displays variable elevated concentrations of Fe and/or Mn, although the median values are below the aesthetic GVs. The GR04 bore is cased in PVC, and so the observed concentrations of Fe and Mn probably reflect naturally low levels of oxygen in the aquifer.

As NO_3-N is not introduced into groundwater as a result of natural water-rock interactions, the increasing concentrations of NO_3-N observed at most NGMP sites in the West Coast region can be attributed to the effect of intensifying human/agricultural activity (further discussed in Section 5.1.4). This is consistent with the relatively high number of sampling events where counts of faecal coliform or E. coli were detected in groundwaters from the West Coast region, attributed also to the effect from dairy shed effluent and urine and dung patches on pasture (Baker, 2004).

5.1.3 Variability of monitored parameters

Figure 7 and Table 4 show that the variability of most analytes at most NGMP sites in the West Coast region is relatively low, with MAD typically below 10% of the corresponding median. Comparing the MADs calculated from the entire historical record with the MADs calculated from only the most recent years of data (2005-2008) shows that these are in good agreement for most parameters (Table 4). This suggests that the potential controls on the groundwater hydrochemistry (e.g. seasonality, temporal trends) have remained fairly constant since the implementation of sample collection in 1998. The most notable change has occurred at the GR02 bore, where the MADs of most parameters are higher for the period from 2005-2008 than before. By contrast, decreases in the MADs of several parameters (e.g. Cl, NO_3-N, SO_4 and HCO_3) occurred at the GR17, GR04 and HK34 sites (for the latter two sites fewer than five samples had been analysed in the period from 2005-2008). The high relative variabilities in certain analytes at some sites reflect significant increasing or decreasing trends of these parameters, and the high relative variabilities in Cl and NO_3-N observed at some bores are at least partially also related to non-security (cf. Close et al., 2000). The HK31 and GR04 bores display the highest relative variabilities in groundwater temperature, which is diagnositic of seasonal fluctuations. In turn this suggests that the variabilities in Cl and NO_3-N at these bores are at least partially controlled by seasonal effects related to recharge volume and flushing of salts and nutrients from the soil zone.

At the GR02 bore, the high MADs are accompanied by a substantial increase in NO_3-N and Mn concentrations. The GR17 site, by contrast, has experienced a considerable increase in NO_3-N concentrations from 1.6 to 4.1 mg/L between 1998 and 2004 (Figure 7), but has now stabilised at concentrations of about ~3.2 mg/L. this suggests that the level of human/agricultural impact has stabilised or decreased at this site (see Section 5.1.4). This same effect is also at least partially responsible for the high relative variabilities of NO_3-N at the GR04 and HK34 bores and the high relative variabilities in Cl at the GR17 and HK34 bores, and in SO_4 at the HK31, HK34, GR04 and BU01 bores. The two sites (GR24 and

HK34B) incorporated into the NGMP since the completion of the last state of the environment report have high relative MADs for NO_3-N and SO_4, demonstrating that the level of human/agricultural impact has not yet stabilised at these sites.

In other instances, several monitored parameters have high relative variabilities simply because their median values are very low, causing the high relative variabilities of Br, F, Fe, Mn and/or NH_4 at several NGMP sites in the West Coast region. The same effect is also responsible for the high relative variabilities of bacterial indicator parameters at NGMP sites, since on many occasions the analytical results are below the detection limit.

5.1.4 Temporal trends in monitored parameters

For most groundwater monitoring sites in the West Coast region, trends in major cations (Ca, Mg, Na, K), SiO_2, pH and conductivity are not statistically significant at the 95% confidence level (Figure 7, Table 4).

However, the HK31, HK39, HK34B, GR04, GR24, GR02 and HK25 bores show significant increasing trends for NO_3-N and other analytes (e.g. Cl and/or SO_4) (Figure 7, Table 4). As NO_3-N is not introduced into groundwater during natural water-rock interaction, it can be concluded that the increasing trends are due to increased leaching of manure, sewage effluent and/or nitrogen fertilisers into the aquifer (Close et al., 2001). Increases in Cl and SO_4 co-occurring with increases in NO_3-N occur as expected, since these substances are also present in manure, sewage effluent and fertiliser (Close et al., 2001). The NGMP sites in the West Coast region are typically shallow with water levels less than 5 m below the ground surface, and shallow water tables are generally more susceptible to groundwater contamination because travel times through the unsaturated zone are comparatively low and recharge is rapid. The increasing concentrations in NO_3-N observed at the NGMP sites in the West Coast region therefore provide convincing evidence for the impact of human activities on groundwater quality.

For most analytes at most sites, the trends calculated using the entire historical record are in good agreement with the trends calculated using only the most recent three years of data (Table 4), but there are several notable exceptions. For example, NO_3-N has increased significantly at the GR17 site since 1998, but has stabilised and decreased in the most recent measurements since January 2005. This pattern suggests that the human/agricultural activities that caused these trends have either stabilised or abated in the last few years, although future monitoring is required to confirm this. By contrast, looking at the entire historical record from the HK31 bore does not reveal a significant increasing trend in NO_3-N, but an increasing trend was detected in the most recent four years of data (2005-2008). Future monitoring is warranted to observe the future development of nitrate concentrations at this site. The most notable changes occur at the GR02 bore, where all major ions (and consequently also the conductivity) have increased since 2004. At several other sites changes in the trends in Ca or HCO_3 have occurred over the last four years (Table 4, Figure 7). For the GR04 and the HK34 sites, the meaning of the observed increase in Ca and decrease in HCO_3 is unclear due to the small number of analytical results available for 2005-2008 (due to exclusion of these bores from the NGMP in 2006). The cause and importance of similar trends in Ca or HCO_3 at other bore locations is at present unclear.

5.1.5 Groundwater chemistry in relation to land use

With the available data, it is impossible to determine whether or not the medians, MADs or trends of the monitored parameters differ significantly in relation to land use. Primarily, this is because the urban and rural-residential categories contain only one site each, and there is no evidence to prove that these sites are truly representative of their respective land use categories. With only one site in the urban and rural-residential categories, statistical tests have very little power. Although Baker (2004) studied groundwater quality at 19 non-NGMP sites in the West Coast region, all of the sites were at or near dairy farms. In order to reliably test for differences in hydrochemistry caused by surrounding land use, results from other urban and rural-residential monitoring sites in WCRC would need to be considered.

A second problem arises because the capture zone of each well is presently unknown. The capture zone encompasses the area around the well where land use activities could potentially impact its groundwater quality. For the NGMP wells in the West Coast region, it is likely that the capture zones are fairly small, because the bores are shallow, the water table is generally within a few meters of the surface, and rates of groundwater flow are probably relatively high. As a result, it is quite possible that the groundwater quality represents the land use in the immediate vicinity of the bore, but would provide little information that could be generalised or extended to the entire West Coast region.

Despite the obvious limitations in the data set, box-whisker plots showing the variation of selected analytes between the three land use categories are presented in Figure 8. These plots, along with the Kruskal-Wallis test, suggest that the median concentrations of Ca, Mg, K, Na, SiO_2, HCO_3, NO_3-N and Cl differ significantly (95% confidence interval) between the land use categories. However, as stated above, this conclusion is applicable only to the land use immediately around the bores in question, and cannot be generalised or applied to the entire West Coast region.

5.2 Groundwater levels

The comparison and classification of bore hydrographs and their response to rainfall events provides important insights into the characteristics of an aquifer and the impact of land use or climate changes on water level elevations. Time-series graphs of groundwater levels (hydrographs) show responses to rainfall events over seasonal, decadal or long-term time-scales (Healy and Cook, 2002). The magnitude of the hydrograph recession varies depending on factors such as the relative position of the well location along the hydraulic gradient and the depth of the screened interval. Shallow bores and particularly bores in unconfined sections of permeable aquifers are typically more affected by seasonal variations of rainfall and potential evapotranspiration. The WCRC provided GNS with an Excel file containing all available water quality and water level data from wells within the region. These data, derived from the WCRC database, are presented in Appendix 2. Water level data were collected from September 1998 to September 2008 for a total of 28 sites (including all NGMP wells and selected non-NGMP wells). Although the intended sampling frequency was quarterly, Zemansky et al. (2005) noted that substantial data gaps existed for the period from 1998 to 2004 where data were only available for about 65% of the quarters involved for most wells. However, for the period 2005-2008, data were collected more regularly for the NGMP wells. For the wells not included in the NGMP, no corresponding water quality data were available.

All groundwater level data were obtained using an electric-tape water level indicator. All depth measurements are taken using the top of the well casing as a reference point. The top of all well casings is within 10 centimetres of ground level. Top of casing elevations have not been determined by survey. However, ground level elevations have been estimated from 1:50,000 topographic maps using well coordinates and topographic contours.

Hydrographs of groundwater level data from the West coast region were prepared for 28 sites (Figure 9). Most wells in the West Coast region have shallow water tables with static water levels (SWL) typically less than 5 meters below ground surface. Visual examination of the hydrographs shows that there is considerable variation of water levels over time for most sites, but there is no indication of any systematic seasonal trends. The absence of such seasonal patterns of groundwater levels probably reflects the lack of a distinct seasonal pattern of rainfall and potential evapotranspiration in the West Coast region. Orographic rainfall resulting from the prevailing north-westerly winds and the location of the Southern Alps is high, generating excess rainfall over evapotranspiration for every month of the year (Figure 10).

A comparison of the bore hydrographs with the monthly rainfall data (Figure 9) indicates that there is no detectible time lag between rainfall events and the response of water levels in bores, suggesting that the unconfined and highly permeable nature of aquifers in the West Coast region facilitates rapid recharge. For the Kowhitirangi and Kokatahi Plains in the West coast region, Zemansky and Horrox (2007b) noted that there is no evidence for substantial seasonal changes for most ions. However, concentrations of NO_3-N and SO_4 appeared to change marginally between dry and wet seasons, attributed to precipitation-facilitated downward migration from anthropogenic sources.

In addition to the graphical examination of the groundwater, data from the same wells were also analysed using Sen's slope estimator to calculate the true slope in order to detect if there is any evidence for medium to long term trends of the water level elevation.

Results of trend testing are presented in Table 6. A negative trend means that the water table elevation is decreasing over time (i.e., the depth to the water level measured below from the top of well casing is increasing). Depression of water table elevations can result from a changed pumping regime or a change in climatic patterns. For the entire period covered by the water level elevation data (2000-2008), a small negative trend was recorded for 16 out of 28 wells, whereas 11 out of 28 wells showed a small positive trend and the GR17 bore revealed no trend. The median calculated from the trends from all 28 sites for 2000-2008 showed a decline of the water table elevation of 1 cm/year. During the most recent years (2005-2008), the median trend calculated from all wells showed a decline of the water table elevation of 3 cm/year. While this indicates that there is a small drop of the water table elevation in most bores, the magnitude of the trend is small and there is considerable variation in the data. Nevertheless, continuous monitoring is recommended to observe the future development of the water table elevations in the West Coast region.

5.3 Groundwater ages

Groundwater age or mean residence time (MRT) of groundwater is the difference between the time a water drop has entered the catchment and when it is observed in a well (Kazemi et al., 2006). If the groundwater residence time in an aquifer is in the range of decades, nitrogen concentrations in groundwater could continue to increase further even though no intensification of farming practises may occur at present. This is due to the progressive arrival of water recharged after the catchment development started. Conducting groundwater age determinations can therefore help to determine if there is a lag between land use intensification and the arrival of contaminants derived from land use at any particular well or receiving water body such as a lake or stream.

Although tritium dating is a robust tool for dating young groundwaters, there can be ambiguity in age interpretations in certain cases (see Daughney et al., 2009). Complementary dating tools such as SF_6 and CFCs can help to resolve this ambiguity. In addition, conducting multiple tritium analyses over a longer time interval can also help to remove ambiguous results.

In the West Coast region, groundwaters from seven NGMP sites were sampled for tritium, SF_6 and CFCs between 2001 and 2008 (Table 7). The MRT estimated for the groundwaters from the tracer measurements ranges from 1.5 to 45 years (Table 7). The degree of confidence ranges from moderate to high, and where the degree of certainty is only moderate, additional tritium measurements may be warranted in the future to obtain tritium time-series data which will help to remove the present ambiguity in interpreted groundwater age. The youngest groundwaters (HK31 and GR17) can be expected to respond rapidly to any local changes in land use, as their capture zones (recharge area) are limited to the immediate surroundings. This means that at such locations, the residence times of NO_3-N in the unsaturated zone or in the aquifer up-gradient of the sampling locations are generally short, and it can be concluded that the present groundwater NO_3-N concentrations reflect the current land use practices. Decreasing NO_3-N and a short mean residence time of groundwater in the GR17 bore, for example, suggest that less intense land use practises have been used in the recent past, whereas the slightly increasing trend of NO_3-N medians observed at the HK31 site may indicate that an intensification of land use practises has occurred. The trend analysis (section 5.1.4) demonstrated that no statistically significant trend at the 95% level could be detected for the BU01 bore (MRT of 10 years; Table 7) and only a moderately increasing trend was observed at the HK25 sites (MRT of 7 years; Table 7). The age determination therefore places the MRT of these two groundwaters within a similar range as the time covered by the historic record of measurements of nitrate at these NGMP sites, and the absence of strong trends for these groundwaters therefore suggests that the level of land use has remained relatively stable at these sites since the start of data recording. Where the age determination showed that groundwaters have a MRT of several decades (HK34 bore, GR04 bore and GR02 bore), NO_3-N concentrations may increase further in the future as a result of the delayed arrival of NO_3-N from human/agricultural activities. These relatively long MRTs observed for the GR02 and the GR04 bores suggest that these groundwaters have a larger capture zone and are part of a larger groundwater flow system. This may explain the increasing trend of groundwater NO_3-N concentrations, and suggests that NO_3-N concentrations may continue to increase for some time even if the land use remains constant or becomes less intense. To remove further ambiguity with regards to the MRTs of groundwaters with moderate confidence, it may be advisable to conduct further groundwater age dating in the future. In addition, it is warranted to conduct age determinations on groundwaters from the new NGMP bores (HK34B and GR24) to determine if groundwater NO_3-N loadings can be expected to further increase in the future.

6.0 COMPARISON OF WEST COAST GROUNDWATER QUALITY PATTERNS WITH OTHER REGIONS IN NEW ZEALAND

A comparison of the 25th, 50th (=median) and 75th percentiles from the NGMP sites in the West Coast region with all NGMP sites throughout New Zealand (Table 8) shows that most monitored parameters at the West Coast Region NGMP sites have significantly lower concentrations than for NGMP sites across New Zealand as a whole. Likewise, the 25th and 75th percentile (interquartile range) and the total range of values indicate that the data from West Coast Region NGMP sites cover a narrower range of compositions than NGMP sites across New Zealand as a whole. This simply means that the relatively dilute groundwaters of the NGMP wells in the West Coast Region are geochemically similar to one another compared to NGMP wells across New Zealand as a whole.

Daughney and Reeves (2004) defined six different “groundwater types” (i.e. hydrochemical facies) for all NGMP sites across New Zealand (Table 9). Of these six hydrochemical facies defined for all of New Zealand as a whole, groundwaters from all NGMP sites in the West Coast Region (including the new sites GR24 and HK34B) fell into two classifications: 1B-1 or 1B-2. These classifications are both described as “Little Human Impact, Low Total Dissolved Solids (TDS)”. In comparison, across all regions of New Zealand, 42 percent of NGMP sites are classified as being 1A-1 or 1A-2 (“Signs of Human Impact, Moderate TDS”), 32 percent are classified as being 1B-1 or 1B-2 (like all the West Coast Region sites), and 26 percent are classified as being 2A or 2B (“Reduced Confined Aquifer, Higher TDS”). A comparison of the NO_3-N concentrations of NGMP groundwaters in the West coast region versus the entire NGMP (groundwater chemistry data from across New Zealand) shows that the median values for the West Coast region (1.2 mg/L) are higher than for all NGMP sites (0.615 mg/L). This reflects the mostly oxic redox state of groundwaters in the West Coast region where nitrate is the dominant form of nitrogen, whereas the NGMP across New Zealand includes numerous anoxic groundwaters where NO_3-N is not stable. In addition, the higher median NO_3-N concentrations in the West Coast region may also be a result of the relatively small capture zones and high recharge rates (as documented by comparatively young groundwater ages). While small capture zones, high recharge rates and relatively short groundwater flow paths result in a rapid increase of groundwater NO_3-N concentrations at the NGMP sites in the West Coast region, other areas in New Zealand which are part of larger groundwater flow systems may take longer to respond to intensification of land use. This means that despite the overall good groundwater quality in the West Coast region, continuous monitoring is essential to observe the future evolution of groundwater quality (and in particular nitrate concentrations) in the West Coast Region).

7.0 CONCLUSIONS

Groundwater quality in the West Coast region is comparatively good at present, in particular if compared with other regions in New Zealand which are subjected to intensive land use/agricultural practises. In general, median concentrations of groundwater NO_3-N do not exceed maximum allowable values for drinking water or for ecosystem protection. However, during the most recent years (2005-2008), groundwater NO_3-N concentrations at two NGMP monitoring sites (GR24 and GR02) have approached or were in excess of the guideline value set for ecosystem protection (7.2 mg/L). In addition, bacterial indicator parameters exceeded the health-related guideline value of 1 cfu/100 ml on several occasions at all but one monitoring sites between 2005-2008 (no bacterial counts were detected at the HK25 sites during this period). In addition, Mn concentrations at the GR02 site exceeded the health-related guideline value (0.5 mg/L). The co-occurring high concentrations of NO_3-N with high Mn concentrations at this site suggest that the elevated concentrations of Mn are may be associated with corrosion of metal pipes and cylinders that are in contact with the water before it is sampled. Alternatively, inadequate purging time prior to sampling could be responsible for the high Mn concentrations in this bore and further clarification with regards to the well construction is required.

All NGMP sites in the West Coast region are shallow wells with shallow water tables, and the aquifers are composed of porous and highly permeable materials. This configuration makes groundwaters collected from these wells susceptible to bacterial and NO_3-N contamination from the immediate surroundings of the bore. Age determinations on groundwaters from the NGMP sites in the West Coast region had mean groundwater residence times as short as 1.5 years for some bores, suggesting that their capture zones are small and limited to the immediate surroundings of the sites. For those NGMP sites where young groundwater ages were observed, no significant future increase in nitrogen mass loading is to be expected unless further land use intensification occurs (e.g. increased leaching from manure, sewage effluent or fertiliser). By contrast, the recent trends of increasing NO_3-N concentrations of some groundwaters with comparatively long mean residence times of up to 45 years in the West Coast region suggest that even if the present level of land use is maintained in the capture zones of these sites, groundwater nitrate concentrations may continue to increase in the future due to the delayed arrival of land use-impacted water.

8.0 RECOMMENDATIONS

The increasing trends of NO_3-N and the frequent detection of bacterial contamination indicators show that continued quarterly monitoring at all NGMP sites is warranted. This ensures that further increases in these contaminants are detected rapidly and measures can be taken to prevent further contamination. The high NO_3-N concentrations co-occurring with high Mn concentrations and an increase in the concentrations of other parameters at the GR02 site requires clarification. In particular, an inspection of the well casing should be conducted to rule out that corrosion of the well piping is responsible for this observation. In addition, purging of at least three bore volumes prior to sampling is required.

Where the level of certainty of groundwater ages is presently low, additional tritium analyses are recommended to obtain time-series data which will help to resolve groundwater age more accurately.

Groundwater NO_3-N concentrations at the new HK34B site are relatively high. In order to gain a better understanding of the size of the capture zone and to estimate if a further increase in NO_3-N concentration is to be expected due to a time lag between intensification of land use and the arrival of nitrate loadings, groundwater dating should be conducted at this site.

While Zemansky and Horrox (2007b) addressed the recommendations by Daughney (2004) and Zemansky et al. (2005) to conduct an additional survey of groundwater chemistry in the West Coast region, it would be helpful to obtain additional data on water quality from more bores. In particular, it would be useful to get more information of groundwaters associated with different forms of land use in order to conduct a robust statistical analysis.

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FIGURES

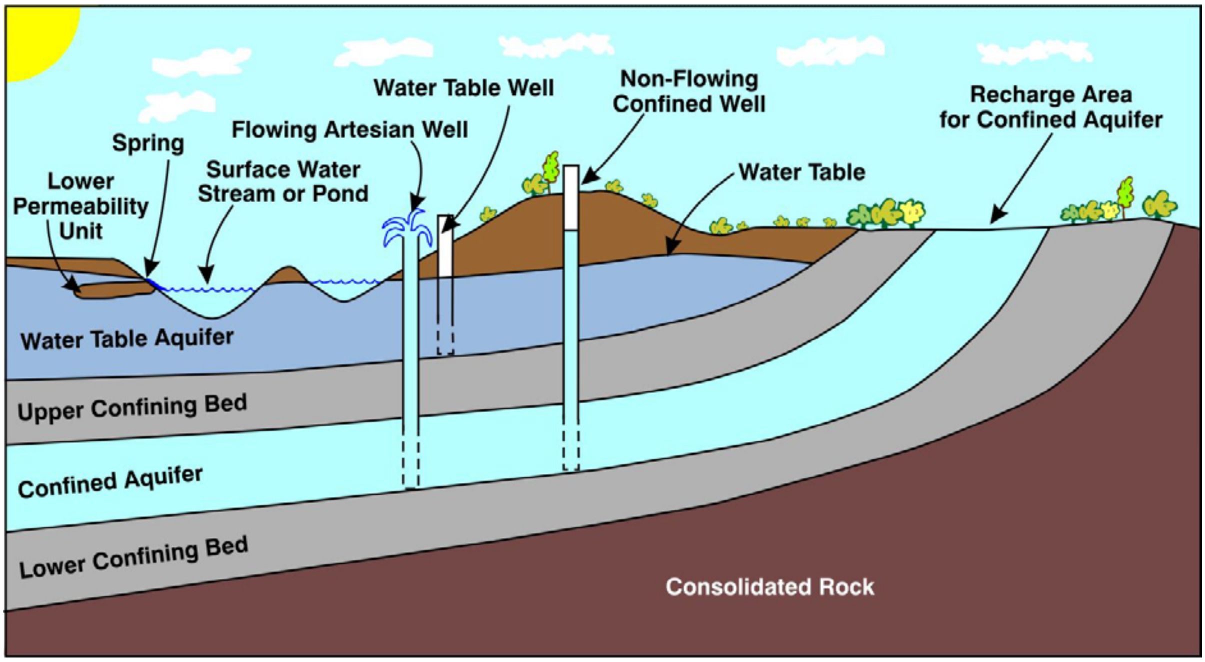

Figure 1 Generalised groundwater aquifer system (Zemansky et al., 2005).

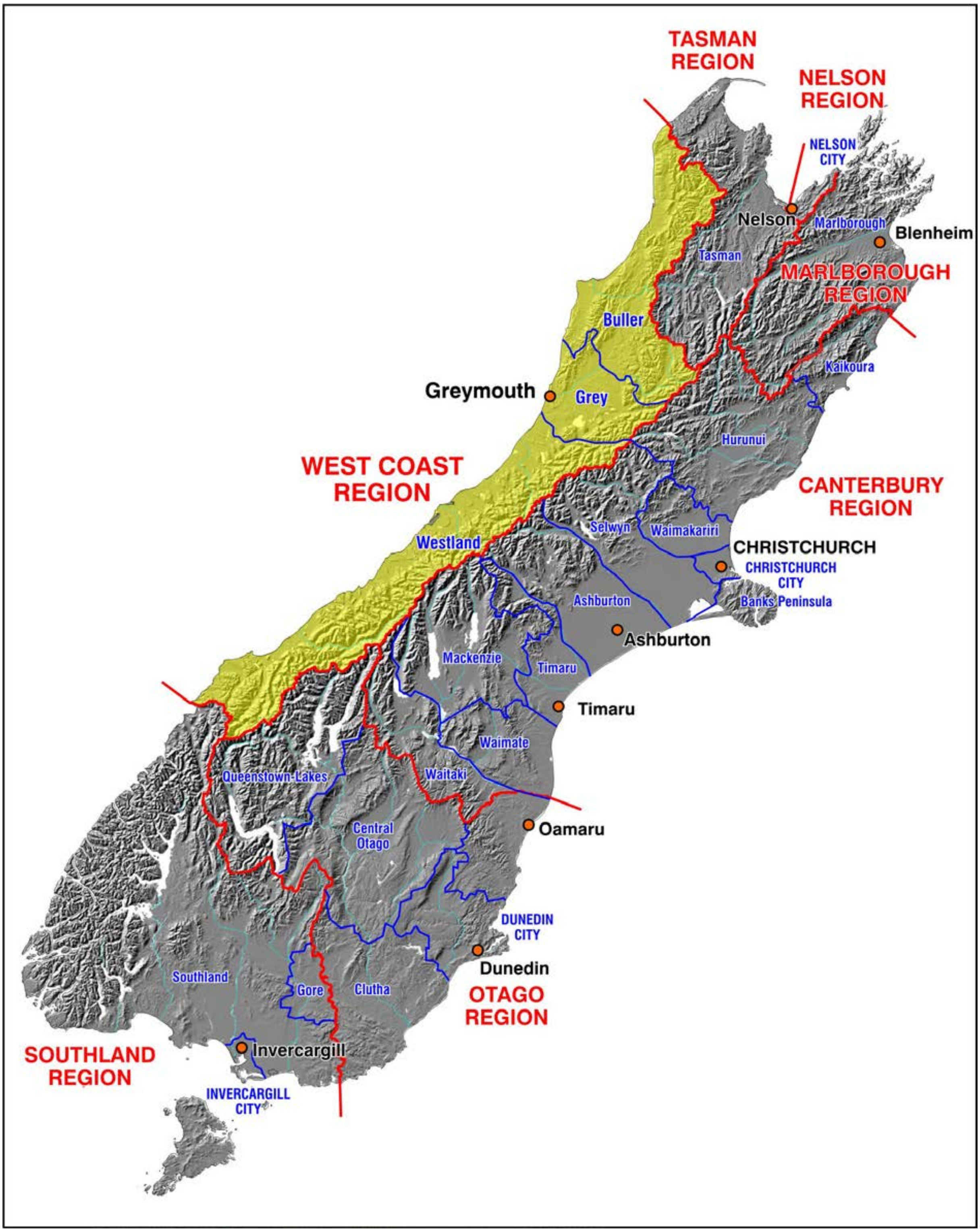

Figure 2 Overview of the West Coast region and districts (Zemansky et al., 2005).

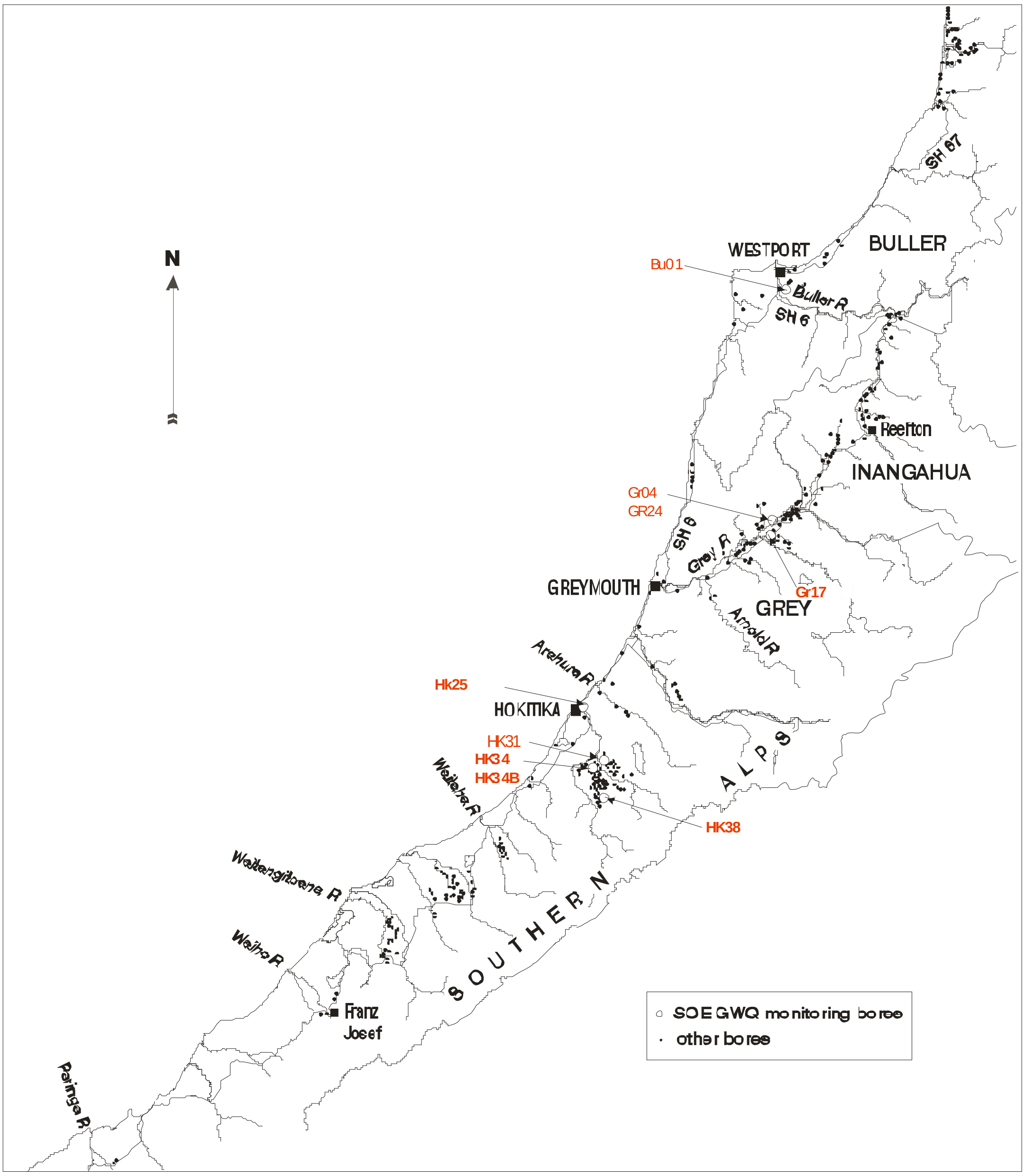

Figure 3 Location of NGMP wells in the West Coast region (modified from Daughney, 2004).

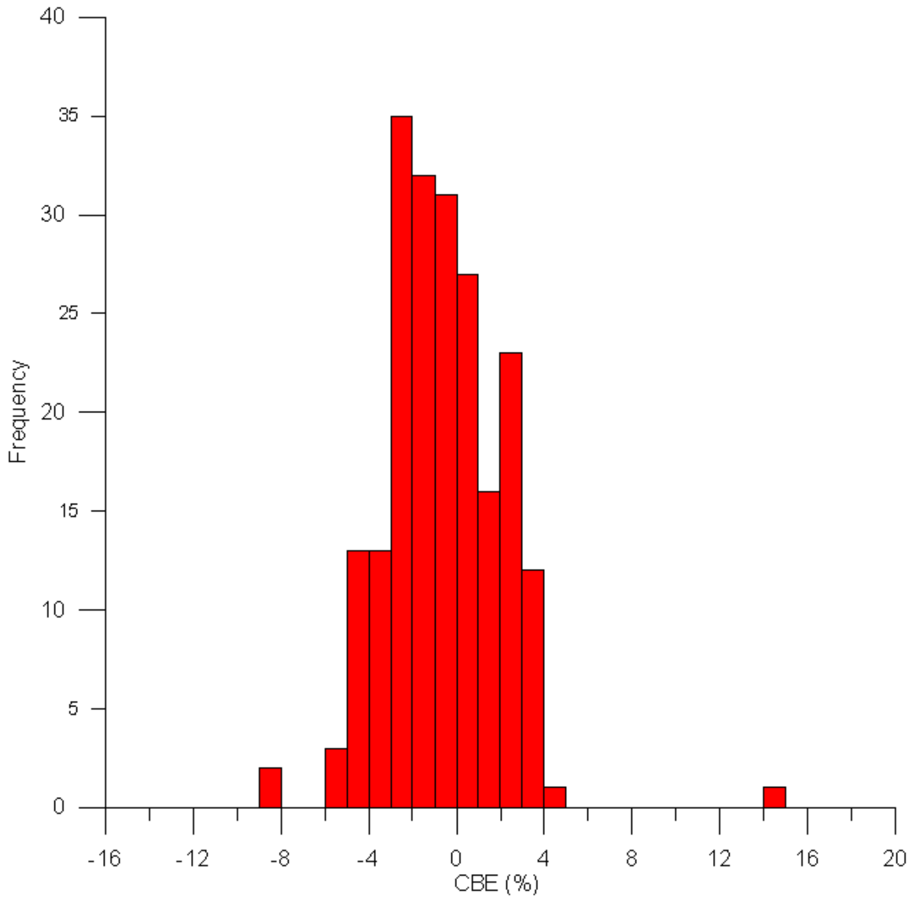

Figure 4 Histogram of charge balance error (CBE) percentage for all samples collected from NGMP sites in the West Coast region. The ideal value for CBE is zero.

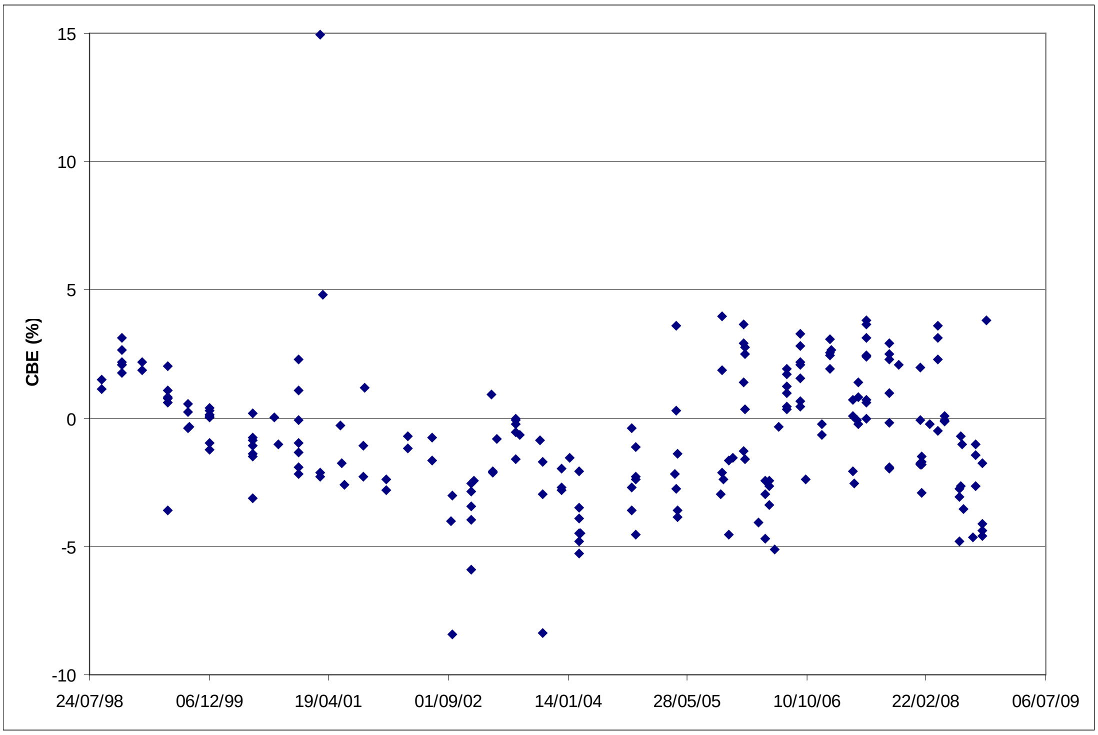

Figure 5 Scatter plot of charge balance error over time for all samples from NGMP sites in the West Coast region.

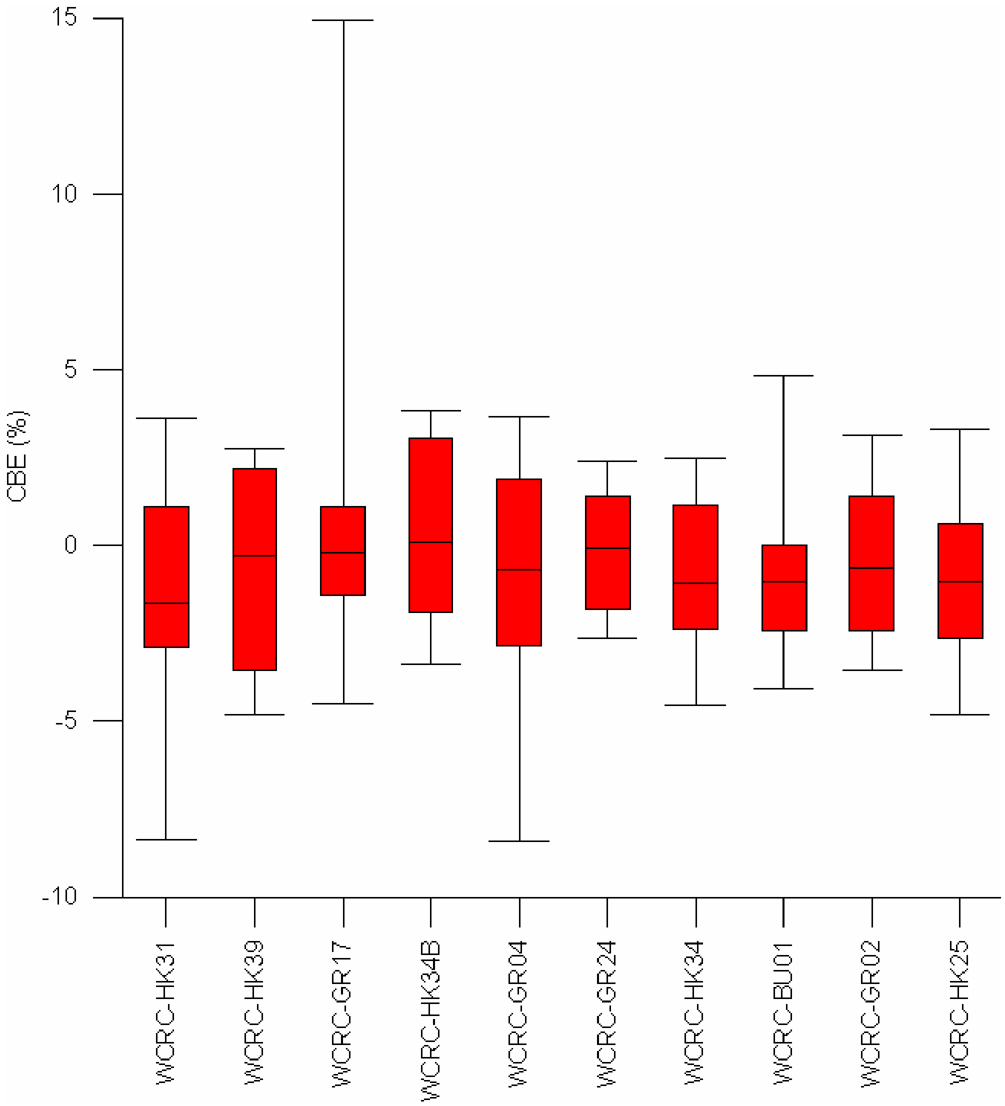

Figure 6 Box-whisker plot showing the variation of charge balance error (%) on a per-site basis for all NGMP sites in the West Coast region.

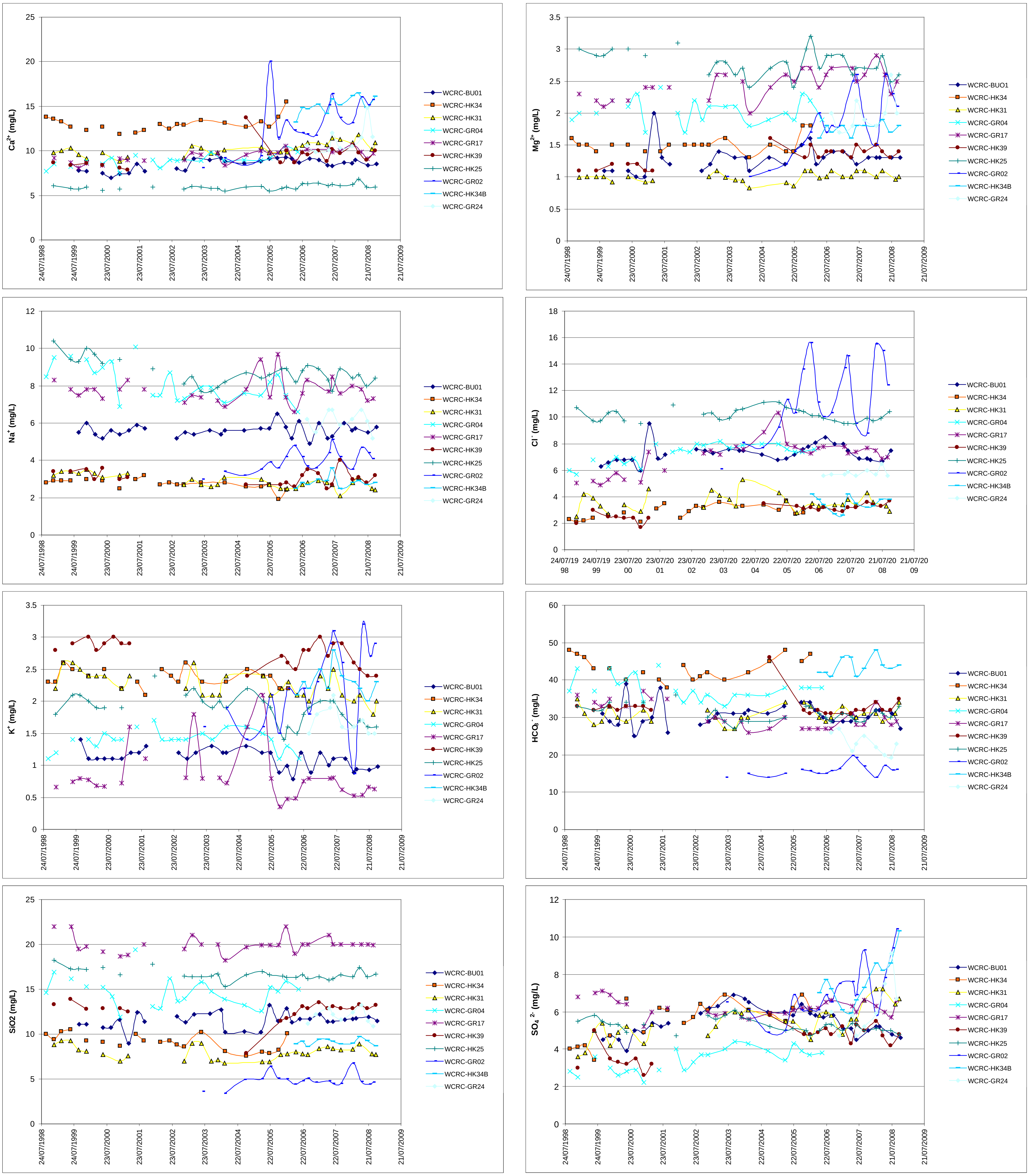

Figure 7 Time-series plots for selected water quality parameters on a per-site basis.

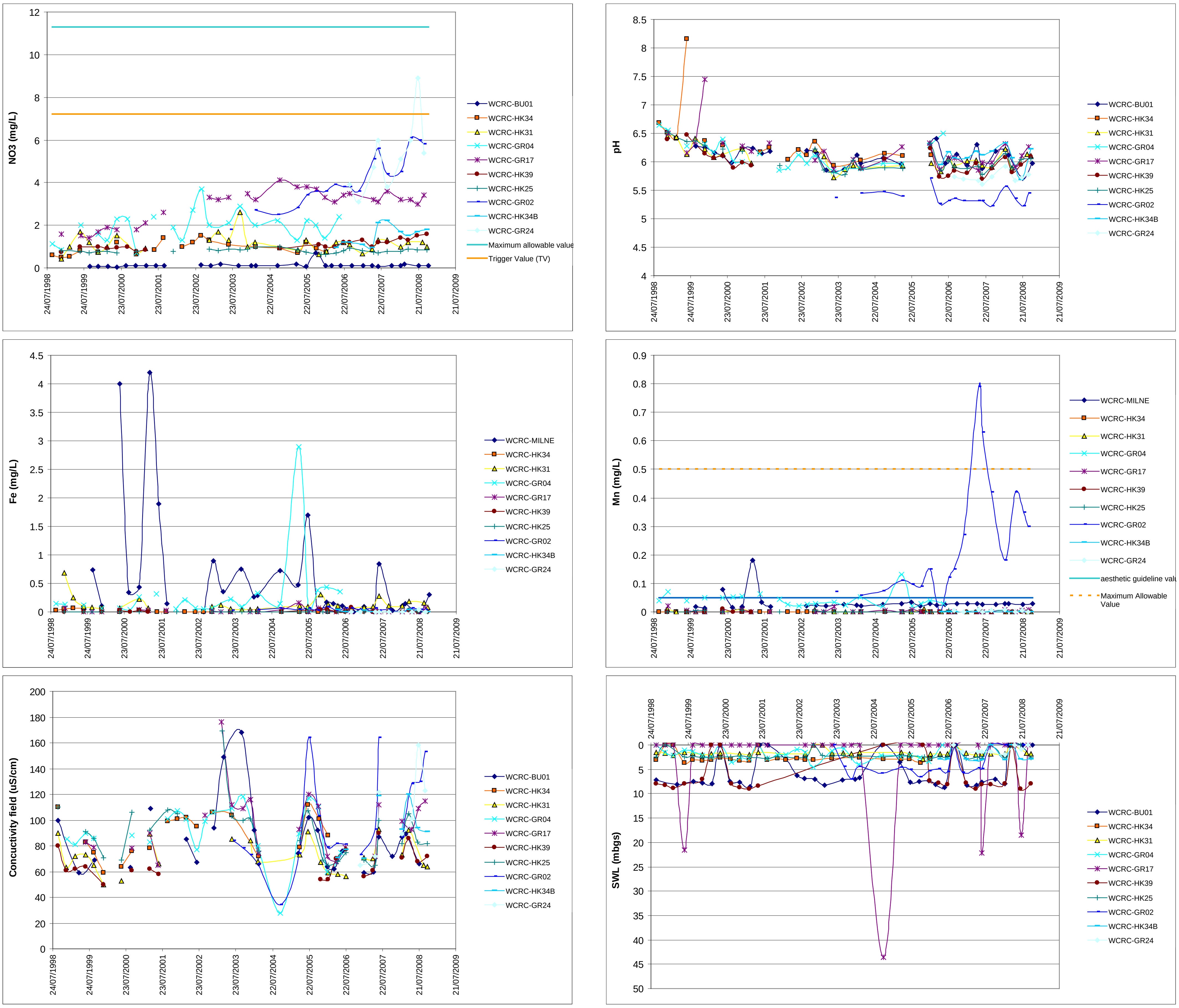

Figure 7 continued Time-series plots for selected water quality parameters on a per-site basis.

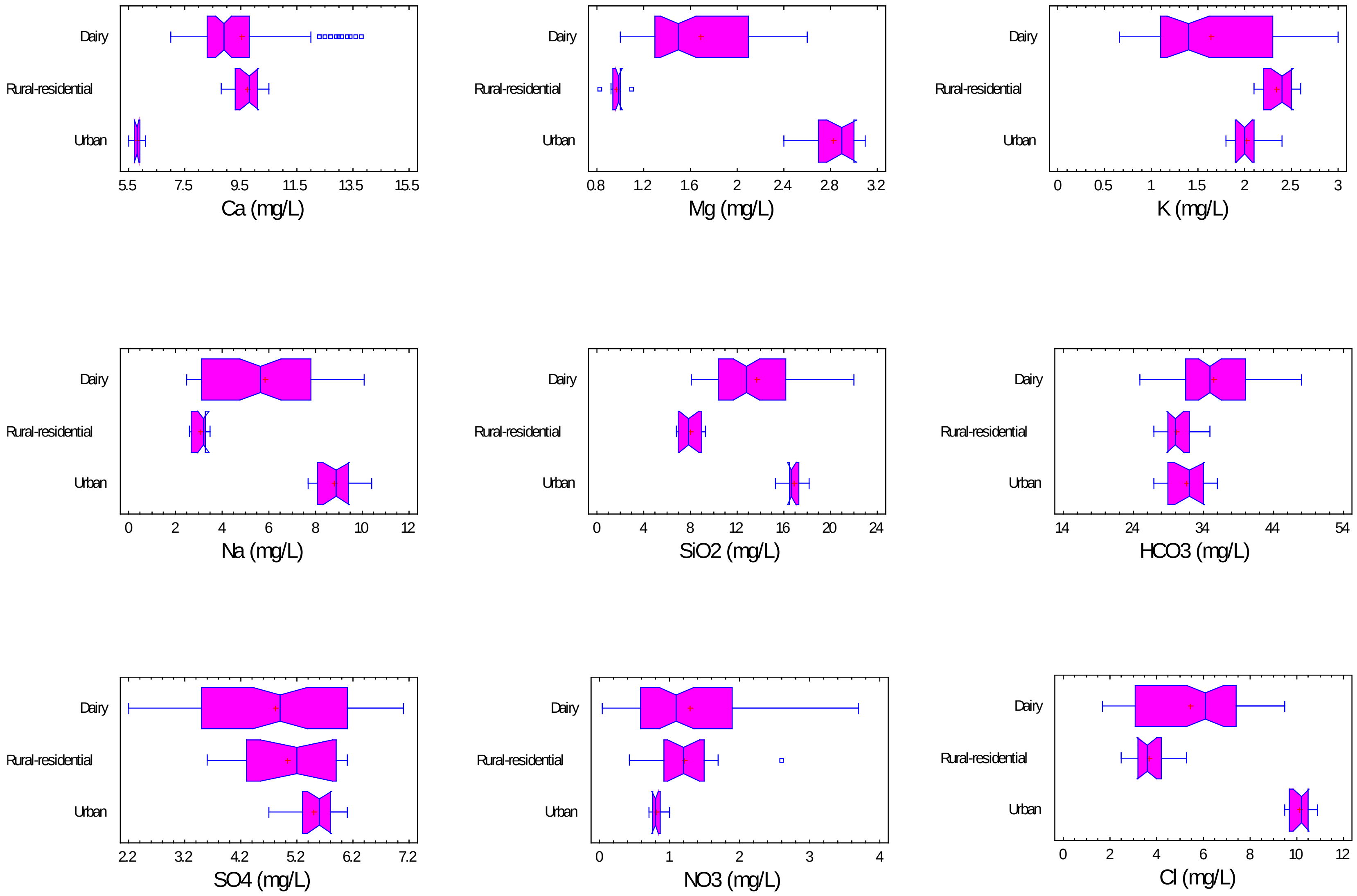

Figure 8 Box-whisker plot showing variations in selected water quality parameters as a function of land use for the NGMP sites in the West Coast region.

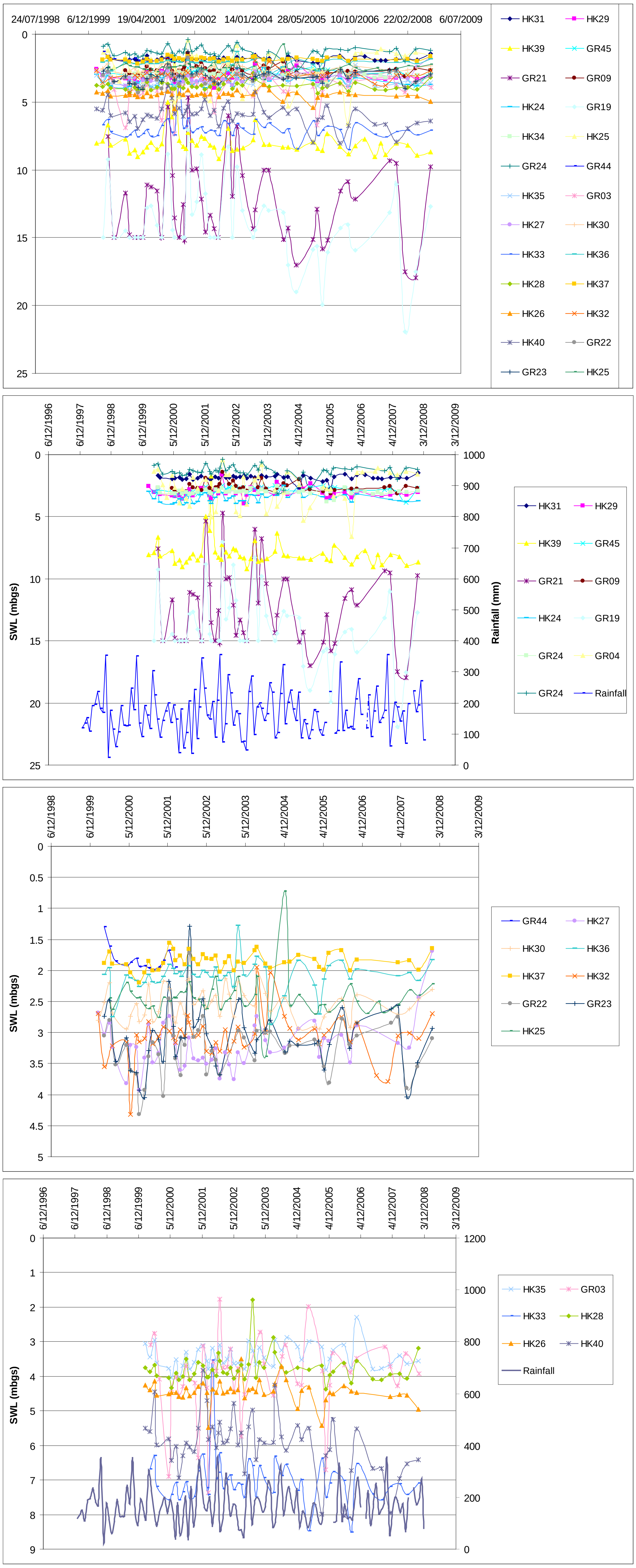

Figure 9 Bore hydrographs showing the static water level (SWL) trends in the West Coast region.

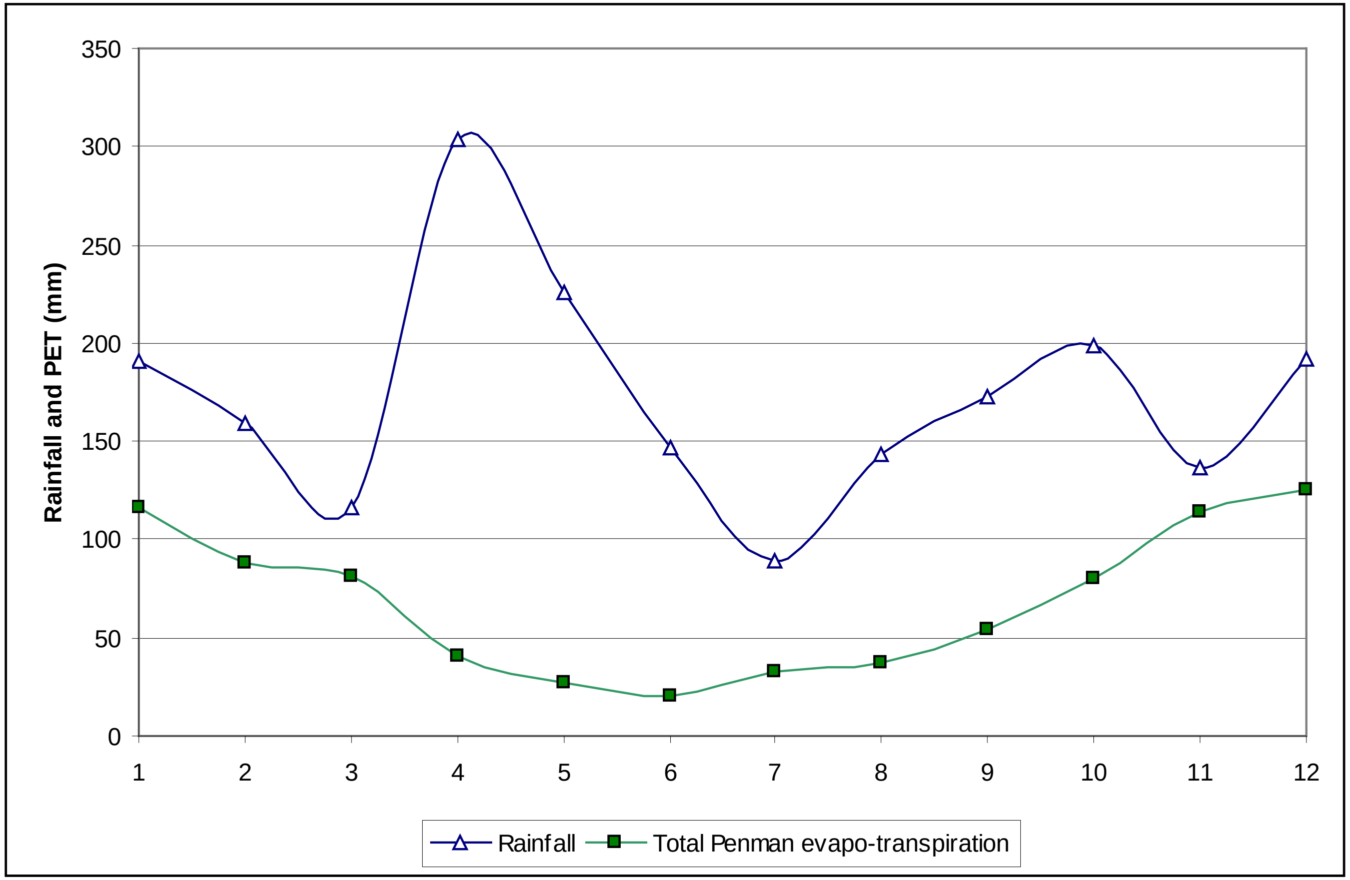

Figure 10 Seasonal variation of rainfall and potential evapotranspiration at Westport in 2000 (data courtesy of NIWA).

TABLES

Table 1 Details of NGMP wells in the West Coast region (extracted from James, 1998).

Well ID	Map name and Grid reference	Well Depth*	Depth to Water table*	Screen depth*	Bore log available
	Hokitika area				
HK34	J33 KANIERE 468146	~7-10 m	3.0 - 3.5 m	Last 2 metres	No
HK25	J33 KANIERE 432303	13 m	1.5 - 3.0	11-13 m	Yes
HK39	J33 KANIERE 496080	~7-10 m	8 m	Unknown	No
HK31	J33 KANIERE 499171	3 m	~1.5 m	Unknown	No
	Grey River area				
GR04	K31 AHAURA 910765	5 m	0.5 - 1 m	Unknown	Yes
GR17	K31 AHAURA 909736	37 m	24.7 m	35-37 m	Yes
	Westport-Buller River area				
BU01	K29 WESTPORT 945330	18 m pre-June 1999 24m post June 1999	7-8 m	16-18 m pre-June 1999 22-24m post June 1999	Yes
GR02	K31 AHAURA	Unknown	Unknown	Unknown	No?

Table 2 Analytical parameters, and their units, considered in this review.

Parameter	Abbreviation	Units
Bromide	Br	mg/L
Calcium	Ca	mg/L
Chloride	Cl	mg/L
Conductivity, Field	Cond Field	uS/cm
Conductivity, Lab	Cond Lab	uS/cm
Escherichia coli	E coli	cfu/100 ml
Fluoride	F	mg/L
Faecal Coliforms	Faecal Coliforms	cfu/100 ml
Iron	Fe	mg/L
Bicarbonate	HCO_3	mg/L
Potassium	K	mg/L
Magnesium	Mg	mg/L
Manganese	Mn	mg/L
Sodium	Na	mg/L
Ammoniacal nitrogen	NH_4-N	mg/L
Nitrate-nitrogen	NO_3-N	mg/L
Dissolved oxygen	O_2 Field	mg/L
Oxidation-reduction potential	ORP	mV
pH, Field	pH Field	pH units
pH, Lab	pH Lab	pH units
Phosphate	PO_4-P	mg/L
Silica	SiO_2	mg/L
Sulphate	SO_4	mg/L
Total Dissolved Solids, Field	TDS Field	mg/L
Total Dissolved Solids, Lab	TDS Lab	mg/L
Temperature, Field	Temp Field	degrees C

Table 3 Charge balance error calculations on a per-site basis. The labels OK, Low and High indicate the number of samples collected from each site that are within acceptable limits, below acceptable limits (anion excess) or above acceptable limits (cation excess), respectively. ND indicates charge balance was “not determined” because the sample had not been analysed for one or more of the major ions.

Monitoring Site Name	Total Number of samples	Charge Balance Results			
		OK	High	Low	ND
WCRC-HK31	33	25	0	3	5
WCRC-HK39	25	20	0	0	5
WCRC-GR17	35	26	1	1	8
WCRC-GR04	27	19	0	2	6
WCRC-HK34	25	19	0	0	6
WCRC-BU01	35	29	0	0	6
WCRC-GR02	20	17	0	0	3
WCRC-HK25	35	28	0	0	7
WCRC-GR24	9	9	0	0	0
WCRC-HK34B	11	11	0	0	0

Table 4 Summary of medians, median absolute deviations (MADs) and trends (units per year) on a per-site and per-analyte basis. Medians that exceed water quality guidelines are shown in bold red text. MADs and trends that exceed 10% of the corresponding median are shown in bold orange and bold red text, respectively. Medians, MADs and trends that are based on fewer than eight measurements are shown in italics. ND indicates No Data. The 'from' and 'to' columns describe the length of the data record, and pertain to the date of collection of the earliest and most recent sample, respectively. The columns '#', 'CBE Calc' and 'CBE OK' describe the total number of samples collected from each site, the number of samples for which the charge balance error can be calculated, and the number of samples for which the charge balance error is within acceptable limits. Water Type is based on the molar concentrations of major cations and anions, and was determined using AquaChem. 'Facies' describes hydrochemical categories defined based on data from the entire NGMP (see Section 4).

Site				Location					Data Record					Hydrochemistry		Br			Ca			Cl		
RC	ID	Name	Type	Easting	Northing	Depth (m below ground level)			From	To	#	CBE Calc	CBE OK	Water Type	Facies	Dissolved, mg/L			Dissolved, mg/L			Dissolved, mg/L		
						Screen Top	Screen Bottom	Bore Depth								Med	MAD	Trend	Med	MAD	Trend	Med	MAD	Trend
WCRC	380	WCRC-HK31	bore	2349941	5817046			3	09/98	03/04	15	14	12	Ca-HCO3	1B-2	<0.03	ND	ND	9.80	0.40	0.00	3.60	0.55	0.00
									09/98	01/09	33	28	25	Ca-HCO3	1B-2	<0.1	ND	ND	10.20	0.40	0.17	3.40	0.40	0.00
									01/00	03/04	10	9	7	Ca-HCO3	1B-2	<0.1	ND	ND	9.80	0.50	0.00	3.80	0.60	0.00
									01/05	01/09	15	15	15	Ca-HCO3	1B-2	<0.1	ND	ND	10.7	0.4	0.42	3.4	0.2	0.00
	383	WCRC-HK39	bore	2349530	5808062			10	09/98	06/01	8	6	6	Ca-Na-HCO3	1B-1	*<0.03*	*ND*	*ND*	*8.40*	*0.25*	*-0.35*	*2.40*	*0.05*	*0.00*
									09/98	01/09	22	22	20	Ca-Na-HCO3	1B-1	<0.1	ND	ND	9.30	0.70	0.15	3.05	0.30	0.11
									01/00	06/01	5	3	3	Ca-HCO3	1B-2	*<0.03*	*ND*	*ND*	*8.10*	*0.20*	*-0.65*	*2.40*	*0.00*	*0.00*
									01/05	01/09	13	13	13	Ca-HCO3	1B-2	<0.1	ND	ND	9.8	0.2	0.15	3.2	0.1	0.13
	382	WCRC-GR17	bore	2391364	5872750	7.2	9	9	09/98	03/04	14	13	12	Ca-Na-Mg-HCO3	1B-2	0.04	0.01	0.00	9.00	0.40	0.00	5.90	0.94	0.55
									09/98	01/09	29	29	26	Ca-Na-Mg-HCO3	1B-2	<0.1	ND	0.00	9.65	0.55	0.15	7.40	0.40	0.21
									01/00	03/04	10	9	8	Ca-Na-Mg-HCO3-Cl	1B-2	0.05	ND	0.00	9.00	0.60	0.00	7.25	0.45	0.55
									01/05	01/09	14	14	14	Ca-Na-Mg-HCO3-Cl	1B-2	<0.1	ND	ND	9.9	0.2	0.00	7.60	0.20	-0.28
	381	WCRC-GR04	bore	2392648	5877766			5	09/98	03/04	17	16	15	Ca-Na-HCO3-Cl	1B-2	0.05	0.00	0.00	8.90	0.35	0.00	7.40	0.60	0.41
									09/98	01/09	23	22	19	Ca-Na-HCO3-Cl	1B-2	0.03	0.00	0.00	8.95	0.35	0.20	7.40	0.50	0.22
									01/00	03/04	13	12	11	Ca-Na-HCO3-Cl	1B-2	0.05	0.00	0.00	9.00	0.10	0.00	7.60	0.40	0.37
									01/05	01/09	5	5	5	Ca-Na-HCO3-Cl	1B-2	*0.048*	*ND*	*0*	*9.8*	*0.6*	*1.44*	*7.60*	*0.20*	*-0.38*
	379	WCRC-HK34	bore	2346916	5814612	8	10	10	09/98	03/04	15	15	15	Ca-HCO3	1B-1	0.02	0.00	0.00	12.90	0.40	0.00	2.80	0.50	0.25
									09/98	01/09	20	19	19	Ca-HCO3	1B-1	0.02	0.00	0.00	12.95	0.40	0.08	2.85	0.45	0.16
									01/00	03/04	10	10	10	Ca-HCO3	1B-2	<0.1	ND	ND	12.80	0.30	0.37	3.15	0.30	0.00
									01/05	01/09	4			Ca-HCO3	1B-2	*<0.04*	*ND*	*ND*	*13.55*	*0.55*	*3.32*	*2.90*	*0.15*	*-0.42*
	378	WCRC-BU01	bore	2394615	5932928	18	20	20	09/98	03/04	15	14	14	Ca-Na-HCO3-Cl	1B-2	0.02	0.00	0.00	7.80	0.35	0.35	7.20	0.40	0.23
									09/98	01/09	31		29	Ca-Na-HCO3-Cl	1B-2	0.02	0.00	0.00	8.60	0.50	0.12	7.20	0.40	0.08
									01/00	03/04	13	12	12	Ca-Na-HCO3-Cl	1B-2	0.02	0.00	0.01	7.90	0.55	0.45	7.25	0.35	0.20
									01/05	01/09	14	14	14	Ca-Na-HCO3-Cl	1B-2	<0.1	ND	ND	8.8	0.3	-0.20	7.50	0.60	-0.07
	1993	WCRC-GR02	bore	2389380	5882150				06/03	03/04	2	2	2	Ca-Na-HCO3-Cl-SO4	1B-2	*0.20*	*0.02*	*-0.06*	*8.65*	*0.55*	*0.00*	*7.10*	*1.00*	*0.00*
									09/98	01/09	18		17	Ca-Na-HCO3-Cl-SO4	1B-2	0.14	0.04	0.01	12.70	2.40	1.44	10.70	2.25	1.20
									01/00	03/04	2	2	2	Ca-Na-HCO3-Cl-SO4	1B-2	*0.20*	*0.02*	*-0.06*	*8.65*	*0.55*	*0.00*	*7.10*	*1.00*	*0.00*
									01/05	01/09	15	15	15	Ca-Na-HCO3-Cl-SO4	1B-2	0.12	0.05	0.04	13.4	1.7	1.30	11.30	2.10	0.66
	384	WCRC-HK25	bore	2343256	5830228			13	09/98	03/04	13	13	13	Na-Ca-Mg-HCO3-Cl	1B-2	0.05	0.00	0.00	5.80	0.10	0.00	10.20	0.40	0.00
									09/98	01/09	30		28	Na-Ca-Mg-HCO3-Cl	1B-2	0.01	0.00	0.00	5.90	0.20	0.04	10.10	0.40	-0.03
									01/00	03/04	9	9	9	Na-Ca-Mg-HCO3-Cl	1B-2	0.05	ND	0.00	5.80	0.10	0.00	10.20	0.40	0.00
									01/05	01/09	15	15	15	Na-Ca-Mg-HCO3-Cl	1B-2	0.044	ND	0	6.1	0.2	0.12	9.90	0.40	-0.39
	2103	WCRC-GR24	bore	2346910	5814600				09/98	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									09/98	01/09	9	9	9	Ca-HCO3	1B-2	<0.1	ND	ND	10.6	0.7	0.76	5.7	0.1	0.11
									01/00	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									01/05	01/09	9	9	9	Ca-HCO3	1B-2	<0.1	ND	ND	10.6	0.7	0.76	5.70	0.10	0.11
	2069	WCRC-HK34B	bore	2392748	5877766				09/98	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									09/98	01/09	11	11	11	Ca-HCO3	1B-2	<0.1	ND	ND	15.1	0.7	0.93	3.5	0.3	0.00
									01/00	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									01/05	01/09	11	11	11	Ca-HCO3	1B-2	<0.1	ND	ND	15.1	0.7	0.93	3.50	0.30	0.00

Table 4 Continued.

Site				Location					Data Record					Hydrochemistry		F			Fe			HCO3		
RC	ID	Name	Type	Easting	Northing	Depth (m below ground level)			From	To	#	CBE Calc	CBE OK	Water Type	Facies	Dissolved, mg/L			Dissolved, mg/L			Total, mg/L		
						Screen Top	Screen Bottom	Bore Depth								Med	MAD	Trend	Med	MAD	Trend	Med	MAD	Trend
WCRC	380	WCRC-HK31	bore	2349941	5817046			3	09/98	03/04	15	14	12	Ca-HCO3	1B-2	0.04	0.01	0.00	0.06	0.02	0.00	30.00	1.00	0.00
									09/98	01/09	33	28	25	Ca-HCO3	1B-2	0.04	0.01	0.00	0.09	0.03	0.00	30.00	1.00	0.00
									01/00	03/04	10	9	7	Ca-HCO3	1B-2	0.04	0.00	0.00	0.06	0.01	0.00	30.00	1.00	0.00
									01/05	01/09	15	15	15	Ca-HCO3	1B-2	0.04	0.01	0.00	0.10	0.02	0.00	31.00	1.50	0.00
	383	WCRC-HK39	bore	2349530	5808062			10	09/98	06/01	8	6	6	Ca-Na-HCO3	1B-1	*0.05*	*0.02*	*0.00*	*<0.02*	*ND*	*ND*	*33.00*	*0.00*	*0.00*
									09/98	01/09	22	22	20	Ca-Na-HCO3	1B-1	0.04	0.01	0.00	0.00	0.00	0.00	32.00	1.00	0.00
									01/00	06/01	5	3	3	Ca-HCO3	1B-2	*0.05*	*0.02*	*0.00*	*0.02*	*0.01*	*0.00*	*33.00*	*0.00*	*0.00*
									01/05	01/09	13	13	13	Ca-HCO3	1B-2	0.04	0.00	0.00	0.01	0.00	0.00	32.00	1.00	0.53
	382	WCRC-GR17	bore	2391364	5872750	7.2	9	9	09/98	03/04	14	13	12	Ca-Na-Mg-HCO3	1B-2	0.04	0.01	0.00	<0.02	ND	ND	33.00	3.00	-1.47
									09/98	01/09	29	29	26	Ca-Na-Mg-HCO3	1B-2	0.04	0.01	0.00	0.01	0.01	0.00	29.00	2.00	-0.64
									01/00	03/04	10	9	8	Ca-Na-Mg-HCO3-Cl	1B-2	0.05	0.01	0.00	0.01	0.01	0.00	30.00	3.00	-2.66
									01/05	01/09	14	14	14	Ca-Na-Mg-HCO3-Cl	1B-2	0.04	0.01	0.00	0.01	0.01	0.00	28.00	1.00	0.53
	381	WCRC-GR04	bore	2392648	5877766			5	09/98	03/04	17	16	15	Ca-Na-HCO3-Cl	1B-2	0.06	0.00	0.00	0.11	0.05	0.00	37.00	3.00	-1.02
									09/98	01/09	23	22	19	Ca-Na-HCO3-Cl	1B-2	0.06	0.00	0.00	0.13	0.08	0.02	37.00	1.00	-0.20
									01/00	03/04	13	12	11	Ca-Na-HCO3-Cl	1B-2	0.06	0.00	0.00	0.06	0.01	0.00	36.00	2.00	0.00
									01/05	01/09	5	5	5	Ca-Na-HCO3-Cl	1B-2	*0.05*	*0.00*	*-0.03*	*0.38*	*0.06*	*-0.13*	*38.00*	*0.00*	*0.00*
	379	WCRC-HK34	bore	2346916	5814612	8	10	10	09/98	03/04	15	15	15	Ca-HCO3	1B-1	0.02	0.00	0.00	<0.02	ND	ND	42.00	2.00	-1.06
									09/98	01/09	20	19	19	Ca-HCO3	1B-1	0.03	0.01	0.00	0.00	0.00	0.00	43.00	3.00	0.00
									01/00	03/04	10	10	10	Ca-HCO3	1B-2	0.03	0.01	0.00	<0.02	ND	ND	40.50	1.00	0.00
									01/05	01/09	4			Ca-HCO3	1B-2	*0.03*	*0.00*	*-0.01*	*<0.02*	*ND*	*ND*	*47.00*	*1.00*	*-1.30*
	378	WCRC-BU01	bore	2394615	5932928	18	20	20	09/98	03/04	15	14	14	Ca-Na-HCO3-Cl	1B-2	0.01	0.01	0.00	0.35	0.23	0.00	29.00	2.00	0.00
									09/98	01/09	31		29	Ca-Na-HCO3-Cl	1B-2	0.03	0.01	0.00	0.27	0.22	-0.06	30.50	1.50	0.00
									01/00	03/04	13	12	12	Ca-Na-HCO3-Cl	1B-2	0.03	0.02	0.00	0.35	0.15	0.00	30.00	2.00	0.00
									01/05	01/09	14	14	14	Ca-Na-HCO3-Cl	1B-2	0.03	0.00	0.00	0.11	0.08	-0.03	30.50	1.50	-1.04
	1993	WCRC-GR02	bore	2389380	5882150				06/03	03/04	2	2	2	Ca-Na-HCO3-Cl-SO4	1B-2	*<0.03*	*ND*	*ND*	*0.03*	*0.00*	*0.00*	*14.50*	*0.50*	*0.00*
									09/98	01/09	18		17	Ca-Na-HCO3-Cl-SO4	1B-2	0.00	0.00	0.00	0.04	0.01	0.00	15.70	0.70	0.50
									01/00	03/04	2	2	2	Ca-Na-HCO3-Cl-SO4	1B-2	*<0.03*	*ND*	*ND*	*0.03*	*0.00*	*0.00*	*14.50*	*0.50*	*0.00*
									01/05	01/09	15	15	15	Ca-Na-HCO3-Cl-SO4	1B-2	0.01	0.00	0.00	0.04	0.01	0.00	15.95	0.95	0.40
	384	WCRC-HK25	bore	2343256	5830228			13	09/98	03/04	13	13	13	Na-Ca-Mg-HCO3-Cl	1B-2	0.10	0.02	0.00	<0.02	ND	ND	32.00	2.00	-0.78
									09/98	01/09	30		28	Na-Ca-Mg-HCO3-Cl	1B-2	0.08	0.01	0.00	0.04	ND	0.00	31.00	2.00	-0.70
									01/00	03/04	9	9	9	Na-Ca-Mg-HCO3-Cl	1B-2	0.10	0.02	-0.01	<0.02	ND	ND	30.00	2.00	-1.66
									01/05	01/09	15	15	15	Na-Ca-Mg-HCO3-Cl	1B-2	0.08	0.00	0.00	0.04	ND	0.00	30.50	1.00	0.00
	2103	WCRC-GR24	bore	2346910	5814600				09/98	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									09/98	01/09	9	9	9	Ca-HCO3	1B-2	0.05	0.01	0.01	0.13	ND	0	23	2	-2.75
									01/00	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									01/05	01/09	9	9	9	Ca-HCO3	1B-2	0.05	0.01	0.01	0.04	ND	0.00	23.00	2.00	-2.75
	2069	WCRC-HK34B	bore	2392748	5877766				09/98	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									09/98	01/09	11	11	11	Ca-HCO3	1B-2	0.03	0	0	0.01	0.01	0	43	1	0.86
									01/00	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									01/05	01/09	11	11	11	Ca-HCO3	1B-2	0.03	0.01	0.00	0.01	0.01	0.00	43.00	1.00	0.86

Table 4 Continued.

Site				Location					Data Record					Hydrochemistry		K			Mg			Mn		
RC	ID	Name	Type	Easting	Northing	Depth (m below ground level)			From	To	#	CBE Calc	CBE OK	Water Type	Facies	Dissolved, mg/L			Dissolved, mg/L			Dissolved, mg/L		
						Screen Top	Screen Bottom	Bore Depth								Med	MAD	Trend	Med	MAD	Trend	Med	MAD	Trend
WCRC	380	WCRC-HK31	bore	2349941	5817046			3	09/98	03/04	15	14	12	Ca-HCO3	1B-2	2.40	0.20	-0.07	0.99	0.01	0.00	<0.005	ND	ND
									09/98	01/09	33	28	25	Ca-HCO3	1B-2	2.20	0.20	-0.04	1.00	0.05	0.00	0.00	0.00	0.00
									01/00	03/04	10	9	7	Ca-HCO3	1B-2	2.30	0.10	0.00	0.95	0.04	0.00	<0.005	ND	ND
									01/05	01/09	15	15	15	Ca-HCO3	1B-2	2.10	0.10	-0.09	1.00	0.09	0.00	0.01	ND	0.00
	383	WCRC-HK39	bore	2349530	5808062			10	09/98	06/01	8	6	6	Ca-Na-HCO3	1B-1	*2.90*	*0.05*	*0.00*	*1.10*	*0.00*	*0.00*	*<0.005*	*ND*	*ND*
									09/98	01/09	22	22	20	Ca-Na-HCO3	1B-1	2.80	0.10	-0.03	1.30	0.10	0.03	0.01	ND	0.00
									01/00	06/01	5	3	3	Ca-HCO3	1B-2	*2.90*	*0.00*	*0.00*	*1.15*	*0.05*	*0.00*	*<0.005*	*ND*	*ND*
									01/05	01/09	13	13	13	Ca-HCO3	1B-2	2.70	0.20	-0.09	1.40	0.10	0.00	<0.005	ND	ND
	382	WCRC-GR17	bore	2391364	5872750	7.2	9	9	09/98	03/04	14	13	12	Ca-Na-Mg-HCO3	1B-2	0.76	0.05	0.00	2.30	0.10	0.00	<0.005	ND	ND
									09/98	01/09	29	29	26	Ca-Na-Mg-HCO3	1B-2	0.75	0.08	-0.01	2.50	0.10	0.04	0.00	0.00	0.00
									01/00	03/04	10	9	8	Ca-Na-Mg-HCO3-Cl	1B-2	0.76	0.06	0.00	2.40	0.20	0.00	<0.005	ND	ND
									01/05	01/09	14	14	14	Ca-Na-Mg-HCO3-Cl	1B-2	0.65	0.15	0.00	2.60	0.10	0.00	0.00	0.00	0.00
	381	WCRC-GR04	bore	2392648	5877766			5	09/98	03/04	17	16	15	Ca-Na-HCO3-Cl	1B-2	1.40	0.00	0.00	2.05	0.15	0.00	0.04	0.01	0.00
									09/98	01/09	23	22	19	Ca-Na-HCO3-Cl	1B-2	1.40	0.10	0.00	2.00	0.10	0.00	0.04	0.01	0.00
									01/00	03/04	13	12	11	Ca-Na-HCO3-Cl	1B-2	1.40	0.00	0.00	2.10	0.15	0.00	0.04	0.01	0.00
									01/05	01/09	5	5	5	Ca-Na-HCO3-Cl	1B-2	*1.30*	*0.20*	*-0.35*	*2.00*	*0.10*	*-0.04*	*0.03*	*0.01*	*-0.01*
	379	WCRC-HK34	bore	2346916	5814612	8	10	10	09/98	03/04	15	15	15	Ca-HCO3	1B-1	2.30	0.10	0.00	1.50	0.00	0.00	<0.005	ND	ND
									09/98	01/09	20	19	19	Ca-HCO3	1B-1	2.35	0.10	0.00	1.50	0.05	0.00	<0.02	ND	ND
									01/00	03/04	10	10	10	Ca-HCO3	1B-2	2.30	0.10	0.00	1.50	0.00	0.00	<0.005	ND	ND
									01/05	01/09	4			Ca-HCO3	1B-2	*2.30*	*0.10*	*-0.31*	*1.60*	*0.20*	*0.63*	*<0.005*	*ND*	*ND*
	378	WCRC-BU01	bore	2394615	5932928	18	20	20	09/98	03/04	15	14	14	Ca-Na-HCO3-Cl	1B-2	1.20	0.10	0.00	1.10	0.10	0.00	0.02	0.00	0.00
									09/98	01/09	31		29	Ca-Na-HCO3-Cl	1B-2	1.10	0.10	-0.02	1.30	0.10	0.02	0.03	0.00	0.00
									01/00	03/04	13	12	12	Ca-Na-HCO3-Cl	1B-2	1.20	0.10	0.00	1.20	0.10	0.00	0.02	0.00	0.00
									01/05	01/09	14	14	14	Ca-Na-HCO3-Cl	1B-2	0.99	0.10	-0.03	1.30	0.10	0.00	0.03	0.00	0.00
	1993	WCRC-GR02	bore	2389380	5882150				06/03	03/04	2	2	2	Ca-Na-HCO3-Cl-SO4	1B-2	*1.75*	*0.15*	*0.00*	*1.00*	*0.00*	*0.00*	*0.06*	*0.01*	*-0.02*
									09/98	01/09	18		17	Ca-Na-HCO3-Cl-SO4	1B-2	2.15	0.55	0.31	1.75	0.35	0.29	0.15	0.08	0.07
									01/00	03/04	2	2	2	Ca-Na-HCO3-Cl-SO4	1B-2	*1.75*	*0.15*	*0.00*	*1.00*	*0.00*	*0.00*	*0.06*	*0.01*	*-0.02*
									01/05	01/09	15	15	15	Ca-Na-HCO3-Cl-SO4	1B-2	2.20	0.50	0.34	1.80	0.30	0.29	0.18	0.09	0.09
	384	WCRC-HK25	bore	2343256	5830228			13	09/98	03/04	13	13	13	Na-Ca-Mg-HCO3-Cl	1B-2	2.00	0.10	0.00	2.90	0.10	-0.07	<0.005	ND	ND
									09/98	01/09	30		28	Na-Ca-Mg-HCO3-Cl	1B-2	1.90	0.10	-0.04	2.80	0.10	-0.03	0.00	0.00	0.00
									01/00	03/04	9	9	9	Na-Ca-Mg-HCO3-Cl	1B-2	2.00	0.10	0.00	2.80	0.20	-0.15	<0.005	ND	ND
									01/05	01/09	15	15	15	Na-Ca-Mg-HCO3-Cl	1B-2	1.80	0.20	0.00	2.70	0.20	-0.09	0.00	0.00	0.00
	2103	WCRC-GR24	bore	2346910	5814600				09/98	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									09/98	01/09	9	9	9	Ca-HCO3	1B-2	1.6	0.1	-0.14	2	0.2	0.16	0	0	0
									01/00	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									01/05	01/09	9	9	9	Ca-HCO3	1B-2	1.60	0.10	-0.14	2.00	0.20	0.16	0.01	0.00	0.00
	2069	WCRC-HK34B	bore	2392748	5877766				09/98	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									09/98	01/09	11	11	11	Ca-HCO3	1B-2	2.3	0.1	0	1.8	0	0	<0.005	ND	ND
									01/00	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									01/05	01/09	11	11	11	Ca-HCO3	1B-2	2.30	0.10	0.00	1.80	0.00	0.00	<0.005	ND	ND

Table 4 Continued.

Site				Location					Data Record					Hydrochemistry		Na			NH4-N			NO3-N		
						Depth (m below ground level)										Dissolved, mg/L			Dissolved, mg/L as N			Dissolved, mg/L as N		
RC	ID	Name	Type	Easting	Northing	Screen Top	Screen Bottom	Bore Depth	From	To	#	CBE Calc	CBE OK	Water Type	Facies	Med	MAD	Trend	Med	MAD	Trend	Med	MAD	Trend
WCRC	380	WCRC-HK31	bore	2349941	5817046			3	09/98	03/04	15	14	12	Ca-HCO3	1B-2	3.20	0.20	-0.12	<0.01	ND	ND	1.20	0.27	0.00
									09/98	01/09	33	28	25	Ca-HCO3	1B-2	2.80	0.30	-0.02	0.00	0.00	0.00	1.15	0.17	0.00
									01/00	03/04	10	9	7	Ca-HCO3	1B-2	3.05	0.25	0.00	<0.01	ND	ND	1.25	0.26	0.00
									01/05	01/09	15	15	15	Ca-HCO3	1B-2	2.70	0.20	0.00	0.00	0.00	0.00	1.10	0.20	0.05
	383	WCRC-HK39	bore	2349530	5808062			10	09/98	06/01	8	6	6	Ca-Na-HCO3	1B-1	*3.40*	*0.20*	*0.00*	*<0.01*	*ND*	*ND*	*0.92*	*0.08*	*0.00*
									09/98	01/09	22	22	20	Ca-Na-HCO3	1B-1	3.10	0.30	-0.03	0.00	0.00	0.00	1.00	0.17	0.05
									01/00	06/01	5	3	3	Ca-HCO3	1B-2	*3.00*	*0.00*	*0.00*	*0.01*	*0.01*	*0.00*	*0.90*	*0.05*	*0.00*
									01/05	01/09	13	13	13	Ca-HCO3	1B-2	3.00	0.30	0.14	0.01	ND	0.00	1.20	0.10	0.16
	382	WCRC-GR17	bore	2391364	5872750	7.2	9	9	09/98	03/04	14	13	12	Ca-Na-Mg-HCO3	1B-2	7.65	0.20	-0.16	<0.01	ND	ND	2.00	0.55	0.41
									09/98	01/09	29	29	26	Ca-Na-Mg-HCO3	1B-2	7.70	0.30	0.00	0.00	0.00	0.00	3.20	0.30	0.18
									01/00	03/04	10	9	8	Ca-Na-Mg-HCO3-Cl	1B-2	7.45	0.35	-0.20	<0.01	ND	ND	2.90	0.50	0.42
									01/05	01/09	14	14	14	Ca-Na-Mg-HCO3-Cl	1B-2	7.65	0.35	-0.22	0.00	0.00	0.00	3.35	0.20	-0.17
	381	WCRC-GR04	bore	2392648	5877766			5	09/98	03/04	17	16	15	Ca-Na-HCO3-Cl	1B-2	8.50	1.00	-0.35	0.03	0.02	0.00	2.00	0.40	0.21
									09/98	01/09	23	22	19	Ca-Na-HCO3-Cl	1B-2	7.90	0.70	-0.23	0.03	0.02	0.00	2.00	0.40	0.10
									01/00	03/04	13	12	11	Ca-Na-HCO3-Cl	1B-2	7.90	0.80	0.00	0.03	0.01	0.00	2.10	0.30	0.00
									01/05	01/09	5	5	5	Ca-Na-HCO3-Cl	1B-2	*7.50*	*0.70*	*-1.11*	*0.05*	*0.02*	*-0.03*	*2.00*	*0.40*	*0.44*
	379	WCRC-HK34	bore	2346916	5814612	8	10	10	09/98	03/04	15	15	15	Ca-HCO3	1B-1	2.80	0.10	0.00	<0.01	ND	ND	1.00	0.27	0.14
									09/98	01/09	20	19	19	Ca-HCO3	1B-1	2.80	0.10	-0.50	0.00	0.00	0.00	0.91	0.23	0.05
									01/00	03/04	10	10	10	Ca-HCO3	1B-2	2.80	0.10	0.00	<0.01	ND	ND	1.15	0.15	0.00
									01/05	01/09	4			Ca-HCO3	1B-2	*2.50*	*0.15*	*-0.40*	*0.03*	*0.01*	*-0.10*	*0.83*	*0.10*	*-0.29*
	378	WCRC-BU01	bore	2394615	5932928	18	20	20	09/98	03/04	15	14	14	Ca-Na-HCO3-Cl	1B-2	5.50	0.10	0.00	<0.01	ND	ND	0.10	0.02	0.00
									09/98	01/09	31		29	Ca-Na-HCO3-Cl	1B-2	5.60	0.20	0.02	0.00	0.00	0.00	0.11	0.01	0.00
									01/00	03/04	13	12	12	Ca-Na-HCO3-Cl	1B-2	5.50	0.10	0.00	<0.01	ND	ND	0.10	0.01	0.00
									01/05	01/09	14	14	14	Ca-Na-HCO3-Cl	1B-2	5.70	0.30	-0.04	0.02	ND	0.00	0.11	0.01	0.00
	1993	WCRC-GR02	bore	2389380	5882150				06/03	03/04	2	2	2	Ca-Na-HCO3-Cl-SO4	1B-2	*3.20*	*0.20*	*0.00*	*0.03*	*ND*	*0.00*	*2.25*	*0.45*	*0.00*
									09/98	01/09	18		17	Ca-Na-HCO3-Cl-SO4	1B-2	7.40	0.40	0.24	0.00	0.00	0.00	3.80	0.85	0.75
									01/00	03/04	2	2	2	Ca-Na-HCO3-Cl-SO4	1B-2	*3.20*	*0.20*	*0.00*	*0.03*	*ND*	*0.00*	*2.25*	*0.45*	*0.00*
									01/05	01/09	15	15	15	Ca-Na-HCO3-Cl-SO4	1B-2	4.20	0.50	0.17	0.00	0.00	0.00	3.90	0.50	0.79
	384	WCRC-HK25	bore	2343256	5830228			13	09/98	03/04	13	13	13	Na-Ca-Mg-HCO3-Cl	1B-2	8.90	0.70	-0.42	<0.01	ND	ND	0.80	0.06	0.03
									09/98	01/09	30		28	Na-Ca-Mg-HCO3-Cl	1B-2	8.65	0.45	-0.11	0.00	0.00	0.00	0.79	0.06	0.01
									01/00	03/04	9	9	9	Na-Ca-Mg-HCO3-Cl	1B-2	8.20	0.50	-0.39	<0.01	ND	ND	0.86	0.04	0.05
									01/05	01/09	15	15	15	Na-Ca-Mg-HCO3-Cl	1B-2	8.60	0.30	-0.12	0.00	0.00	0.00	0.79	0.06	0.05
	2103	WCRC-GR24	bore	2346910	5814600				09/98	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									09/98	01/09	9	9	9	Ca-HCO3	1B-2	6.2	0.5	-0.11	<0.01	ND	ND	5.10	0.90	1.31
									01/00	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									01/05	01/09	9	9	9	Ca-HCO3	1B-2	6.20	0.50	-0.11	<0.01	ND	ND	5.10	0.90	1.31
	2069	WCRC-HK34B	bore	2392748	5877766				09/98	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									09/98	01/09	11	11	11	Ca-HCO3	1B-2	2.8	0.1	0	<0.01	ND	ND	1.50	0.30	0.33
									01/00	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									01/05	01/09	11	11	11	Ca-HCO3	1B-2	2.80	0.10	0.00	<0.01	ND	ND	1.50	0.30	0.33

Table 4 Continued.

Site				Location					Data Record					Hydrochemistry		PO4-P			SiO2			SO4		
RC	ID	Name	Type	Easting	Northing	Depth (m below ground level)			From	To	#	CBE Calc	CBE OK	Water Type	Facies	Dissolved, mg/L as P			Dissolved, mg/L as SiO2			Dissolved, mg/L		
						Screen Top	Screen Bottom	Bore Depth								Med	MAD	Trend	Med	MAD	Trend	Med	MAD	Trend
WCRC	380	WCRC-HK31	bore	2349941	5817046			3	09/98	03/04	15	14	12	Ca-HCO3	1B-2	<0.05	ND	ND	7.90	0.90	-0.34	5.20	0.70	0.31
									09/98	01/09	33	28	25	Ca-HCO3	1B-2	0.00	0.00	0.00	7.80	0.60	0.00	5.50	0.55	0.21
									01/00	03/04	10	9	7	Ca-HCO3	1B-2	<0.05	ND	ND	7.00	0.10	0.00	5.25	0.60	0.28
									01/05	01/09	15	15	15	Ca-HCO3	1B-2	0.00	0.00	0.00	7.80	0.40	0.34	5.80	0.60	0.50
	383	WCRC-HK39	bore	2349530	5808062			10	09/98	06/01	8	6	6	Ca-Na-HCO3	1B-1	*<0.04*	*ND*	*ND*	*12.90*	*0.25*	*0.00*	*3.20*	*0.20*	*0.00*
									09/98	01/09	22	22	20	Ca-Na-HCO3	1B-1	0.00	0.00	0.00	12.90	0.25	0.01	4.80	0.50	0.19
									01/00	06/01	5	3	3	Ca-HCO3	1B-2	*<0.04*	*ND*	*ND*	*12.90*	*0.00*	*0.00*	*3.25*	*0.05*	*0.00*
									01/05	01/09	13	13	13	Ca-HCO3	1B-2	0.01	0.00	0.00	12.90	0.20	0.40	4.80	0.20	0.00
	382	WCRC-GR17	bore	2391364	5872750	7.2	9	9	09/98	03/04	14	13	12	Ca-Na-Mg-HCO3	1B-2	0.05	0.00	0.00	19.80	0.60	0.00	6.10	0.40	-0.27
									09/98	01/09	29	29	26	Ca-Na-Mg-HCO3	1B-2	0.01	0.01	0.00	20.00	0.15	0.00	6.20	0.30	-0.02
									01/00	03/04	10	9	8	Ca-Na-Mg-HCO3-Cl	1B-2	<0.05	ND	ND	19.50	0.50	0.00	5.95	0.25	-0.20
									01/05	01/09	14	14	14	Ca-Na-Mg-HCO3-Cl	1B-2	0.02	0.01	0.00	20.00	0.05	0.00	6.20	0.20	0.05
	381	WCRC-GR04	bore	2392648	5877766			5	09/98	03/04	17	16	15	Ca-Na-HCO3-Cl	1B-2	<0.1	ND	ND	14.70	1.05	0.00	3.00	0.50	0.31
									09/98	01/09	23	22	19	Ca-Na-HCO3-Cl	1B-2	0.07	ND	0.00	14.80	1.05	-0.12	5.90	0.60	0.18
									01/00	03/04	13	12	11	Ca-Na-HCO3-Cl	1B-2	<0.1	ND	ND	14.10	1.05	0.00	3.30	0.50	0.46
									01/05	01/09	5	5	5	Ca-Na-HCO3-Cl	1B-2	*<0.004*	*ND*	*ND*	*15.00*	*0.20*	*1.77*	*3.80*	*0.10*	*0.05*
	379	WCRC-HK34	bore	2346916	5814612	8	10	10	09/98	03/04	15	15	15	Ca-HCO3	1B-1	<0.05	ND	ND	9.30	0.60	-0.25	5.70	0.80	0.47
									09/98	01/09	20	19	19	Ca-HCO3	1B-1	<0.1	ND	ND	9.20	0.80	-0.25	6.00	0.55	0.32
									01/00	03/04	10	10	10	Ca-HCO3	1B-2	<0.1	ND	ND	9.10	0.35	0.00	6.10	0.35	0.00
									01/05	01/09	4			Ca-HCO3	1B-2	*<0.004*	*ND*	*ND*	*8.10*	*0.15*	*1.88*	*6.15*	*0.35*	*1.59*
	378	WCRC-BU01	bore	2394615	5932928	18	20	20	09/98	03/04	15	14	14	Ca-Na-HCO3-Cl	1B-2	<0.04	ND	ND	11.35	0.65	0.00	5.40	0.80	0.54
									09/98	01/09	31		29	Ca-Na-HCO3-Cl	1B-2	0.00	0.00	0.00	11.55	0.45	0.07	5.40	0.50	0.00
									01/00	03/04	13	12	12	Ca-Na-HCO3-Cl	1B-2	<0.04	ND	ND	11.50	0.80	0.00	5.40	0.80	0.58
									01/05	01/09	14	14	14	Ca-Na-HCO3-Cl	1B-2	0.01	ND	0.00	11.70	0.20	0.06	5.20	0.60	-0.43
	1993	WCRC-GR02	bore	2389380	5882150				06/03	03/04	2	2	2	Ca-Na-HCO3-Cl-SO4	1B-2	*<0.05*	*ND*	*ND*	*3.50*	*0.10*	*-0.29*	*6.30*	*0.20*	*-0.58*
									09/98	01/09	18		17	Ca-Na-HCO3-Cl-SO4	1B-2	0.00	ND	0.00	4.75	0.25	-0.06	6.70	0.70	0.78
									01/00	03/04	2	2	2	Ca-Na-HCO3-Cl-SO4	1B-2	*<0.05*	*ND*	*ND*	*3.50*	*0.10*	*-0.29*	*6.30*	*0.20*	*-0.58*
									01/05	01/09	15	15	15	Ca-Na-HCO3-Cl-SO4	1B-2	0.00	ND	0.00	4.80	0.30	-0.16	6.90	0.80	1.08
	384	WCRC-HK25	bore	2343256	5830228			13	09/98	03/04	13	13	13	Na-Ca-Mg-HCO3-Cl	1B-2	<0.05	ND	ND	16.70	0.50	-0.25	5.60	0.20	0.00
									09/98	01/09	30		28	Na-Ca-Mg-HCO3-Cl	1B-2	0.00	0.00	0.00	16.60	0.20	-0.08	5.30	0.30	-0.05
									01/00	03/04	9	9	9	Na-Ca-Mg-HCO3-Cl	1B-2	<0.05	ND	ND	16.50	0.10	0.00	5.60	0.20	0.00
									01/05	01/09	15	15	15	Na-Ca-Mg-HCO3-Cl	1B-2	0.02	0.00	0.00	16.40	0.20	0.00	5.00	0.10	0.00
	2103	WCRCGR24	bore	2346910	5814600				09/98	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									09/98	01/09	9	9	9	Ca-HCO3	1B-2	0.01	ND	0	12.2	0.7	-0.13	5.9	0.8	1.38
									01/00	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									01/05	01/09	9	9	9	Ca-HCO3	1B-2	0.01	ND	0	12.20	0.70	-0.14	5.90	0.80	1.39
	2069	WCRC-HK34B	bore	2392748	5877766				09/98	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									09/98	01/09	11	11	11	Ca-HCO3	1B-2	0.01	ND	-0.01	9.2	0.2	0.05	7.3	0.9	1.19
									01/00	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									01/05	01/09	11	11	11	Ca-HCO3	1B-2	0.01	ND	-0.01	9.20	0.20	0.05	7.30	0.90	1.20

Table 4 Continued.

Site				Location					Data Record					Hydrochemistry		pH Lab			pH Field			Conductivity Lab		
RC	ID	Name	Type	Easting	Northing	Depth (m below ground level)			From	To	#	CBE Calc	CBE OK	Water Type	Facies	pH units			pH units			uS/cm		
						Screen Top	Screen Bottom	Bore Depth								Med	MAD	Trend	Med	MAD	Trend	Med	MAD	Trend
WCRC	380	WCRC-HK31	bore	2349941	5817046			3	09/98	03/04	15	14	12	Ca-HCO3	1B-2	6.13	0.15	-0.10	5.96	0.14	0.00	81.00	9.00	0.00
									09/98	01/09	33	28	25	Ca-HCO3	1B-2	6.06	0.14	0.00	5.94	0.17	0.00	87.00	6.00	1.13
									01/00	03/04	10	9	7	Ca-HCO3	1B-2	6.03	0.12	0.00	5.87	0.19	0.00	87.50	2.50	0.00
									01/05	01/09	15	15	15	Ca-HCO3	1B-2	5.99	0.07	0.03	5.87	0.16	0.13	91.00	3.00	0.54
	383	WCRC-HK39	bore	2349530	5808062			10	09/98	06/01	8	6	6	Ca-Na-HCO3	1B-1	*6.09*	*0.13*	*-0.24*	*5.56*	*0.04*	*0.00*	*80.00*	*0.00*	*0.00*
									09/98	01/09	22	22	20	Ca-Na-HCO3	1B-1	5.98	0.13	-0.03	5.66	0.10	0.00	80.00	1.00	0.00
									01/00	06/01	5	3	3	Ca-HCO3	1B-2	*5.99*	*0.08*	*0.00*	*5.52*	*0.00*	*0.00*	*80.00*	*0.00*	*0.00*
									01/05	01/09	13	13	13	Ca-HCO3	1B-2	5.88	0.13	0.04	5.67	0.04	0.08	85.00	3.00	1.52
	382	WCRC-GR17	bore	2391364	5872750	7.2	9	9	09/98	03/04	14	13	12	Ca-Na-Mg-HCO3	1B-2	6.18	0.15	-0.10	6.07	0.27	0.00	110.00	1.00	0.00
									09/98	01/09	29	29	26	Ca-Na-Mg-HCO3	1B-2	6.16	0.17	-0.03	5.97	0.24	-0.04	110.50	4.50	0.40
									01/00	03/04	10	9	8	Ca-Na-Mg-HCO3-Cl	1B-2	6.18	0.15	-0.12	6.14	0.22	0.00	111.00	3.00	0.00
									01/05	01/09	14	14	14	Ca-Na-Mg-HCO3-Cl	1B-2	6.07	0.19	-0.05	5.85	0.13	-0.01	113.50	3.00	-5.83
	381	WCRC-GR04	bore	2392648	5877766			5	09/98	03/04	17	16	15	Ca-Na-HCO3-Cl	1B-2	6.11	0.21	-0.12	5.77	0.27	-0.11	110.00	8.50	0.00
									09/98	01/09	23	22	19	Ca-Na-HCO3-Cl	1B-2	6.11	0.19	-0.04	5.75	0.27	-0.08	110.00	7.00	0.82
									01/00	03/04	13	12	11	Ca-Na-HCO3-Cl	1B-2	6.00	0.12	-0.07	5.74	0.24	0.00	110.00	8.50	0.00
									01/05	01/09	5	5	5	Ca-Na-HCO3-Cl	1B-2	*6.40*	*0.27*	*0.46*	*5.69*	*0.25*	*-0.66*	*111.00*	*ND*	*ND*
	379	WCRC-HK34	bore	2346916	5814612	8	10	10	09/98	03/04	15	15	15	Ca-HCO3	1B-1	6.24	0.13	-0.10	5.97	0.08	0.00	100.00	0.00	0.00
									09/98	01/09	20	19	19	Ca-HCO3	1B-1	6.22	0.13	-0.06	5.97	0.12	-0.04	100.00	0.00	1.42
									01/00	03/04	10	10	10	Ca-HCO3	1B-2	6.19	0.09	0.00	5.97	0.09	0.00	100.00	0.00	0.00
									01/05	01/09	4			Ca-HCO3	1B-2	*6.12*	*0.02*	*0.03*	*5.85*	*0.13*	*-0.37*	*108.00*	*ND*	*ND*
	378	WCRC-BU01	bore	2394615	5932928	18	20	20	09/98	03/04	15	14	14	Ca-Na-HCO3-Cl	1B-2	6.16	0.08	-0.04	5.85	0.23	0.00	80.00	0.00	0.00
									09/98	01/09	31		29	Ca-Na-HCO3-Cl	1B-2	6.13	0.12	-0.01	5.87	0.16	0.00	90.00	10.00	2.61
									01/00	03/04	13	12	12	Ca-Na-HCO3-Cl	1B-2	6.14	0.06	0.00	5.84	0.14	0.00	90.00	10.00	0.00
									01/05	01/09	14	14	14	Ca-Na-HCO3-Cl	1B-2	6.13	0.17	-0.12	5.90	0.13	0.05	95.50	4.00	-0.34
	1993	WCRC-GR02	bore	2389380	5882150				06/03	03/04	2	2	2	Ca-Na-HCO3-Cl-SO4	1B-2	*5.41*	*0.04*	*0.00*	*5.18*	*0.70*	*0.00*	*82.00*	*ND*	*ND*
									09/98	01/09	18		17	Ca-Na-HCO3-Cl-SO4	1B-2	5.36	0.09	-0.03	5.13	0.08	0.00	132.00	17.00	14.71
									01/00	03/04	2	2	2	Ca-Na-HCO3-Cl-SO4	1B-2	*5.41*	*0.04*	*0.00*	*5.18*	*0.70*	*0.00*	*82.00*	*ND*	*ND*
									01/05	01/09	15	15	15	Ca-Na-HCO3-Cl-SO4	1B-2	5.34	0.07	-0.04	5.13	0.06	0.02	139.00	8.50	14.46
	384	WCRC-HK25	bore	2343256	5830228			13	09/98	03/04	13	13	13	Na-Ca-Mg-HCO3-Cl	1B-2	6.18	0.19	-0.13	6.00	0.33	0.00	100.00	0.00	0.00
									09/98	01/09	30		28	Na-Ca-Mg-HCO3-Cl	1B-2	5.98	0.13	-0.03	5.87	0.20	-0.02	103.00	3.00	0.13
									01/00	03/04	9	9	9	Na-Ca-Mg-HCO3-Cl	1B-2	5.94	0.13	0.00	6.04	0.46	0.00	101.50	1.50	0.00
									01/05	01/09	15	15	15	Na-Ca-Mg-HCO3-Cl	1B-2	5.92	0.09	0.01	5.79	0.15	0.07	104.50	2.00	-2.33
	2103	WCRC-GR24	bore	2346910	5814600				09/98	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									09/98	01/09	9	9	9	Ca-HCO3	1B-2	5.73	0.04	0.02	5.54	0.05	0	113.5	3.5	7.08
									01/00	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									01/05	01/09	9	9	9	Ca-HCO3	1B-2	5.73	0.04	0.02	5.55	0.05	-0.01	113.50	3.50	7.08
	2069	WCRC-HK34B	bore	2392748	5877766				09/98	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									09/98	01/09	11	11	11	Ca-HCO3	1B-2	6.12	0.06	0.03	5.95	0.04	0.06	112	4	6.74
									01/00	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									01/05	01/09	11	11	11	Ca-HCO3	1B-2	6.12	0.06	0.04	5.96	0.04	0.06	112.00	4.00	6.74

Table 4 Continued.

Site				Location					Data Record					Hydrochemistry		Conductivity Field			Temperature			O2		
RC	ID	Name	Type	Easting	Northing	Depth (m below ground level)			From	To	#	CBE Calc	CBE OK	Water Type	Facies	uS/cm			Degrees C			Dissolved, mg/L		
						Screen Top	Screen Bottom	Bore Depth								Med	MAD	Trend	Med	MAD	Trend	Med	MAD	Trend
WCRC	380	WCRC-HK31	bore	2349941	5817046			3	09/98	03/04	15	14	12	Ca-HCO3	1B-2	70.00	10.50	0.00	12.91	1.23	0.00	5.15	1.55	-0.81
									09/98	01/09	33	28	25	Ca-HCO3	1B-2	70.00	7.00	0.10	13.07	1.45	-0.08	4.56	1.56	-0.19
									01/00	03/04	10	9	7	Ca-HCO3	1B-2	76.00	9.50	0.00	12.86	1.46	0.00	4.19	1.19	0.00
									01/05	01/09	15	15	15	Ca-HCO3	1B-2	70.00	6.00	-0.36	13.82	1.30	-0.52	4.18	1.58	0.37
	383	WCRC-HK39	bore	2349530	5808062			10	09/98	06/01	8	6	6	Ca-Na-HCO3	1B-1	*61.50*	*0.50*	*0.00*	*13.09*	*0.21*	*0.00*	*5.21*	*1.11*	*0.00*
									09/98	01/09	22	22	20	Ca-Na-HCO3	1B-1	62.00	8.00	1.04	13.00	0.15	-0.01	4.97	0.72	-0.17
									01/00	06/01	5	3	3	Ca-HCO3	1B-2	*61.00*	*1.00*	*0.00*	*13.15*	*0.17*	*0.00*	*5.85*	*1.35*	*0.00*
									01/05	01/09	13	13	13	Ca-HCO3	1B-2	70.00	9.00	6.18	12.97	0.07	0.01	4.94	0.44	-0.46
	382	WCRC-GR17	bore	2391364	5872750	7.2	9	9	09/98	03/04	14	13	12	Ca-Na-Mg-HCO3	1B-2	92.00	17.00	0.00	13.10	0.68	0.00	8.56	1.57	0.00
									09/98	01/09	29	29	26	Ca-Na-Mg-HCO3	1B-2	93.00	18.00	1.21	13.19	0.34	0.03	8.16	1.14	-0.13
									01/00	03/04	10	9	8	Ca-Na-Mg-HCO3-Cl	1B-2	104.00	14.00	0.00	13.10	0.65	0.00	8.20	1.62	0.00
									01/05	01/09	14	14	14	Ca-Na-Mg-HCO3-Cl	1B-2	96.00	16.50	3.09	13.19	0.26	0.17	7.91	0.51	-0.55
	381	WCRC-GR04	bore	2392648	5877766			5	09/98	03/04	17	16	15	Ca-Na-HCO3-Cl	1B-2	94.50	11.50	0.00	12.99	1.08	0.00	3.82	1.72	0.00
									09/98	01/09	23	22	19	Ca-Na-HCO3-Cl	1B-2	89.00	12.00	1.34	12.99	1.03	-0.05	3.80	2.05	-0.32
									01/00	03/04	13	12	11	Ca-Na-HCO3-Cl	1B-2	101.00	8.00	0.00	13.08	1.18	0.00	2.79	1.01	0.00
									01/05	01/09	5	5	5	Ca-Na-HCO3-Cl	1B-2	*89.00*	*21.00*	*-33.02*	*13.20*	*0.94*	*0.56*	*2.94*	*1.64*	*3.51*
	379	WCRC-HK34	bore	2346916	5814612	8	10	10	09/98	03/04	15	15	15	Ca-HCO3	1B-1	89.00	14.00	0.00	13.51	0.34	0.00	3.68	0.71	0.00
									09/98	01/09	20	19	19	Ca-HCO3	1B-1	91.00	13.00	3.07	13.41	0.38	-0.03	3.39	0.46	-0.09
									01/00	03/04	10	10	10	Ca-HCO3	1B-2	97.00	8.00	0.00	13.60	0.33	0.00	3.60	0.62	0.00
									01/05	01/09	4			Ca-HCO3	1B-2	*89.00*	*21.00*	*-33.02*	*13.31*	*0.19*	*-0.49*	*3.16*	*0.17*	*1.19*
	378	WCRC-BU01	bore	2394615	5932928	18	20	20	09/98	03/04	15	14	14	Ca-Na-HCO3-Cl	1B-2	88.50	21.00	0.00	14.38	0.34	0.00	1.20	0.80	0.00
									09/98	01/09	31		29	Ca-Na-HCO3-Cl	1B-2	76.00	13.00	-1.10	14.28	0.59	-0.05	1.58	1.18	-0.03
									01/00	03/04	13	12	12	Ca-Na-HCO3-Cl	1B-2	92.00	25.00	0.00	14.41	0.29	0.00	1.27	0.96	0.00
									01/05	01/09	14	14	14	Ca-Na-HCO3-Cl	1B-2	74.00	13.00	-1.54	13.95	0.95	-0.13	1.80	1.40	0.20
	1993	WCRC-GR02	bore	2389380	5882150				06/03	03/04	2	2	2	Ca-Na-HCO3-Cl-SO4	1B-2	*75.50*	*5.50*	*-24.88*	*12.35*	*1.13*	*0.00*	*3.65*	*0.25*	*-1.19*
									09/98	01/09	18		17	Ca-Na-HCO3-Cl-SO4	1B-2	83.00	10.00	9.04	12.80	0.50	0.18	2.22	1.36	-0.37
									01/00	03/04	2	2	2	Ca-Na-HCO3-Cl-SO4	1B-2	*75.50*	*5.50*	*-24.88*	*12.35*	*1.13*	*0.00*	*3.65*	*0.25*	*-1.19*
									01/05	01/09	15	15	15	Ca-Na-HCO3-Cl-SO4	1B-2	93.00	19.00	10.11	13.04	0.60	0.09	2.16	1.33	-0.42
	384	WCRC-HK25	bore	2343256	5830228			13	09/98	03/04	13	13	13	Na-Ca-Mg-HCO3-Cl	1B-2	100.00	8.00	0.00	14.60	0.23	0.00	3.87	1.91	-0.90
									09/98	01/09	30		28	Na-Ca-Mg-HCO3-Cl	1B-2	86.00	17.00	-1.53	14.40	0.20	-0.04	3.24	1.44	-0.08
									01/00	03/04	9	9	9	Na-Ca-Mg-HCO3-Cl	1B-2	102.00	3.50	0.00	14.60	0.21	0.00	3.10	1.24	-1.41
									01/05	01/09	15	15	15	Na-Ca-Mg-HCO3-Cl	1B-2	82.00	13.00	3.60	14.29	0.14	0.05	3.20	1.47	0.38
	2103	WCRC-GR24	bore	2346910	5814600				09/98	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									09/98	01/09	9	9	9	Ca-HCO3	1B-2	101	22	33.48	13.33	1.31	-1.26	4.87	0.2	-0.08
									01/00	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									01/05	01/09	9	9	9	Ca-HCO3	1B-2	101.00	22.00	33.48	13.34	1.32	-1.26	4.87	0.26	0.10
	2069	WCRC-HK34B	bore	2392748	5877766				09/98	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									09/98	01/09	11	11	11	Ca-HCO3	1B-2	92	18	9.54	13.31	0.74	-0.23	4.12	0.49	-0.95
									01/00	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									01/05	01/09	11	11	11	Ca-HCO3	1B-2	92.00	18.00	9.54	13.32	0.75	-0.23	4.13	0.49	-0.95

Table 4 Continued.

Site				Location					Data Record					Hydrochemistry		ORP Field			E. coli			Faecal Coliforms		
RC	ID	Name	Type	Easting	Northing	Depth (m below ground level)			From	To	#	CBE Calc	CBE OK	Water Type	Facies	mV			cfu/100 ml			cfu/100 ml		
						Screen Top	Screen Bottom	Bore Depth								Med	MAD	Trend	Med	MAD	Trend	Med	MAD	Trend
WCRC	380	WCRC-HK31	bore	2349941	5817046			3	09/98	03/04	15	14	12	Ca-HCO3	1B-2	205.80	129.50	0.00	0.08	0.08	0.00	0.25	0.24	0.00
									09/98	01/09	33	28	25	Ca-HCO3	1B-2				0.73	0.66	0.00	0.73	0.66	0.00
									01/00	03/04	10	9	7	Ca-HCO3	1B-2	69.70	ND	ND	0.08	0.08	0.00	0.25	0.24	0.00
									01/05	01/09	15	15	15	Ca-HCO3	1B-2				0.04	0.04	0.00	0.04	0.04	0.00
	383	WCRC-HK39	bore	2349530	5808062			10	09/98	06/01	8	6	6	Ca-Na-HCO3	1B-1	*268.00*	*100.70*	*0.00*	*<5*	*ND*	*ND*	*<5*	*ND*	*ND*
									09/98	01/09	22	22	20	Ca-Na-HCO3	1B-1				5.00	0.00	ND	3.45	0.68	0.00
									01/00	06/01	5	3	3	Ca-HCO3	1B-2	*ND*	*ND*	*ND*	*<5*	*ND*	*ND*	*<5*	*ND*	*ND*
									01/05	01/09	13	13	13	Ca-HCO3	1B-2				5.00	0.00	ND	2.87	0.91	0.00
	382	WCRC-GR17	bore	2391364	5872750	7.2	9	9	09/98	03/04	14	13	12	Ca-Na-Mg-HCO3	1B-2	216.70	24.70	-10.9	0.50	0.00	0.00	2.32	0.00	0.00
									09/98	01/09	29	29	26	Ca-Na-Mg-HCO3	1B-2				0.95	0.68	0.00	0.80	0.58	0.00
									01/00	03/04	10	9	8	Ca-Na-Mg-HCO3-Cl	1B-2	192.00	ND	ND	0.50	0.00	0.00	2.32	0.00	0.00
									01/05	01/09	14	14	14	Ca-Na-Mg-HCO3-Cl	1B-2				0.01	0.01	0.00	0.01	0.01	0.00
	381	WCRC-GR04	bore	2392648	5877766			5	09/98	03/04	17	16	15	Ca-Na-HCO3-Cl	1B-2	160.90	60.20	-29.0	0.47	0.12	0.00	0.29	0.23	0.00
									09/98	01/09	23	22	19	Ca-Na-HCO3-Cl	1B-2				3.50	1.84	0.00	3.50	1.84	0.00
									01/00	03/04	13	12	11	Ca-Na-HCO3-Cl	1B-2	69.50	ND	ND	0.47	0.12	0.00	0.29	0.23	0.00
									01/05	01/09	5	5	5	Ca-Na-HCO3-Cl	1B-2				*5.00*	*2.65*	*-1.69*	*5.00*	*2.65*	*-1.69*
	379	WCRC-HK34	bore	2346916	5814612	8	10	10	09/98	03/04	15	15	15	Ca-HCO3	1B-1	126.30	101.70	0.00	0.01	0.01	0.00	0.00	0.00	0.00
									09/98	01/09	20	19	19	Ca-HCO3	1B-1				0.15	0.15	0.00	0.15	0.15	0.00
									01/00	03/04	10	10	10	Ca-HCO3	1B-2	56.60	ND	ND	0.01	0.01	0.00	0.00	0.00	0.00
									01/05	01/09	4			Ca-HCO3	1B-2				*2.49*	*0.81*	*0.00*	*2.49*	*0.81*	*0.00*
	378	WCRC-BU01	bore	2394615	5932928	18	20	20	09/98	03/04	15	14	14	Ca-Na-HCO3-Cl	1B-2	135.30	72.20	0.00	2.07	0.71	0.00	1.13	0.55	0.00
									09/98	01/09	31		29	Ca-Na-HCO3-Cl	1B-2				0.13	0.13	0.00	0.13	0.13	0.00
									01/00	03/04	13	12	12	Ca-Na-HCO3-Cl	1B-2	135.30	72.20	0.00	2.07	0.71	0.00	1.13	0.55	0.00
									01/05	01/09	14	14	14	Ca-Na-HCO3-Cl	1B-2				0.01	0.01	0.00	0.01	0.01	0.00
	1993	WCRC-GR02	bore	2389380	5882150				06/03	03/04	2	2	2	Ca-Na-HCO3-Cl-SO4	1B-2	*96.00*	*ND*	*ND*	*0.50*	*0.00*	*0.00*	*0.50*	*0.00*	*0.00*
									09/98	01/09	18		17	Ca-Na-HCO3-Cl-SO4	1B-2				0.33	0.30	0.00	0.33	0.30	0.00
									01/00	03/04	2	2	2	Ca-Na-HCO3-Cl-SO4	1B-2	*96.00*	*ND*	*ND*	*0.50*	*0.00*	*0.00*	*0.50*	*0.00*	*0.00*
									01/05	01/09	15	15	15	Ca-Na-HCO3-Cl-SO4	1B-2				0.69	0.49	-0.14	0.69	0.49	-0.14
	384	WCRC-HK25	bore	2343256	5830228			13	09/98	03/04	13	13	13	Na-Ca-Mg-HCO3-Cl	1B-2	151.40	100.85	0.00	0.50	0.00	0.00	0.50	ND	0.00
									09/98	01/09	30		28	Na-Ca-Mg-HCO3-Cl	1B-2				0.11	0.10	0.00	0.13	0.12	0.00
									01/00	03/04	9	9	9	Na-Ca-Mg-HCO3-Cl	1B-2	70.80	ND	ND	0.50	0.00	0.00	0.50	ND	0.00
									01/05	01/09	15	15	15	Na-Ca-Mg-HCO3-Cl	1B-2				<1	ND	ND	<1	ND	ND
	2103	WCRC-GR24	bore	2346910	5814600				09/98	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									09/98	01/09	9	9	9	Ca-HCO3	1B-2				0.62	0.51	0	0.62	0.51	0
									01/00	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									01/05	01/09	9	9	9	Ca-HCO3	1B-2				0.62	0.51	0	0.62	0.51	0
	2069	WCRC-HK34B	bore	2392748	5877766				09/98	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									09/98	01/09	11	11	11	Ca-HCO3	1B-2				n/a	n/a	n/a	n/a	n/a	n/a
									01/00	03/04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
									01/05	01/09	11	11	11	Ca-HCO3	1B-2				n/a	n/a	n/a	n/a	n/a	n/a

Table 5 Bacterial indicator parameters for entire time of data records and the most recent years (2005-2008).

Site	Number of analyses for Faecal coliforms or E. coli 2000-2008	Number of times faecal coliforms or E. coli ≥ 1 (2000-2008)	Percentage	Number of analyses for Faecal coliforms or E. coli 2005-2008	Number of times faecal coliforms or E. coli ≥ 1 (2005-2008)	Percentage
HK31s	25	7	28	13	3	23
HK39	11	4	36	9	3	33
GR17	27	10	37	14	3	21
HK34	23	10	43	11	3	27
GR04	20	13	65	7	5	71
GR24	-	4		8	4	50
BU01s	20	6	30	13	3	23
GR02	20	9	45	16	8	50
HK25	23	5	22	11	0	0

Table 6 Results of trend testing for groundwater level measurements (change in water level, expressed in meters below ground level per year) for entire period of data record and most recent data (2005-2008). A negative trend means that the water table elevation is decreasing over time (i.e., the depth to the water level measured below from the top of well casing is increasing).

Site ID	1998-2008	2005-2008
HK31	-0.01	-0.08
HK29	0.01	0.03
HK39	0.06	0.09
GR45	-0.05	0.13
GR21	0.03	-1.43
GR09	0.00	-0.08
GR16	0.00	0.00
GR17	0.02	-0.05
HK24	-0.02	0.10
GR19	0.14	-1.18
HK34	0.00	0.00
GR04	-0.06	-0.86
GR24	-0.01	-0.10
GR44	0.09	ND
HK35	-0.01	0.06
GR03	-0.06	-0.08
HK27	-0.03	-0.14
HK30	-0.01	-0.17
HK33	0.01	0.03
HK36	-0.01	-0.03
HK28	-0.01	-0.06
HK37	-0.01	0.00
HK26	0.01	0.05
HK32	-0.02	0.02
HK40	0.11	0.21
GR23	-0.03	-0.02
GR23/1	-0.02	-0.05
HK25	0.00	-0.06

Table 7 Groundwater age determinations for West Coast region (Daughney et al., 2009).

Well ID (NGMP number)	Local ID	Sample Date	Well depth (mbgs[1])	Tritium		Calculated atmospheric partial pressures					Groundwater age from Tracer measurements	
						CFC-11[3]		CFC-12[4]		SF6[5]	Mean Residence Time (MRT) in years	Confidence
				TR[2]	±TR	ppt	±	ppt	±	ppt		
378	BU01	14/07/2005	24	1.4	0.04	ND	ND	ND	ND	ND	10	Moderate
378	BU01	19/06/2007	24	ND	ND	1.22	1.12	125.23	0.21	5.1		
379	HK34	12/07/2005	~7-10	1.81	0.05	ND	ND	ND	ND	ND	35	High
379	HK34	18/06/2007	~7-11	ND	ND	199.74	2.2	473.72	1.97	4.84		
380	HK31	12/07/2005	3	1.68	0.04	ND	ND	ND	ND	ND	1.5	High
380	HK31	18/06/2007	3	ND	ND	200.36	5.89	891.71	36.37	5.61		
381	GR04	30/05/2006	5	1.67	0.05	ND	ND	ND	ND	ND	45	Moderate
381	GR04	18/06/2007	5	ND	ND	131.09	9.36	383.75	19.89	4.64		
382	GR17	20/07/2005	37	1.69	0.04	ND	ND	ND	ND	ND	1.5	Moderate
383	HK39	18/06/2007	~7-10	ND	ND	1.54	unknown	418	unknown	4.78	40	Low
384	HK25	5/07/2001	13	ND	ND	194.78	ND	663.11	ND	ND	7	Moderate
384	HK25	12/05/2005	13	1.41	0.06	ND	ND	ND	ND	ND		
384	HK25	12/05/2005	13	ND	ND	112	ND	20000	ND	2.71		
384	HK25	12/07/2005	13	1.51	0.04	ND	ND	ND	ND	ND		
384	HK25	18/06/2007	13	ND	ND	3971.84	100.14	5691.33	93.87	4.42		
384	HK25	18/06/2007	13	ND	ND	154.28	4.39	418.05	8.57	4.78		
384	HK25	5/05/2008	13	1.47	0.05	ND	ND	ND	ND	ND		
1993	GR02	19/07/2005	Unknown	1.93	0.04	ND	ND	ND	ND	ND	35	High
1993	GR02	18/06/2007	Unknown	ND	ND	79.26	13.19	339.62	35.8	3.32		

1 = meters below ground surface

2 = Tritium units

3 = Chlorofluorocarbon 11 in units of parts/trillion by volume

4 = Chlorofluorocarbon 12 in units of parts/trillion by volume

5 = Sulfur hexafluoride in units of parts/trilltion by volume

ND = No data

Table 8 Comparison of percentiles of major ion concentrations for NGMP sites in the West Coast region and the whole of New Zealand (there are ten NGMP sites in the West Coast region and 110 NGMP sites across all of New Zealand).

	Ca (mg/L)		**Mg (mg/L)**		**K (mg/L)**		**Na (mg/L)**		**Fe (mg/L)**		**Mn (mg/L)**		**HCO3 (mg/L)**	
	WCRC	All NGMP	WCRC	All NGMP	WCRC	All NGMP	WCRC	All NGMP	WCRC	All NGMP	WCRC	All NGMP	WCRC	All NGMP
Range	5.9-15.1	2.2-408	1.0-2.85	0.08-204.35	0.75-2.8	0.41-59.3	2.8-8.7	2.0-1311	0.02-0.155	0.003-16.7	0.005-0.103	0.0-2.6	15-43	14-1070
25th percentile	8.8	8.5	1.3	3.5	1.4	0.98	2.85	9.9	0.02	0.02	0.005	0.005	30	45
50th percentile	9.85	15.075	1.75	6.05	2	1.6	4.65	18.36	0.02	0.02	0.005	0.005	30.5	73.5
75th percentile	12	30	2	8.8	2.25	3.45	7.7	28	0.081	0.28	0.027	0.13	37	144

	Cl (mg/L)		**SO4 (mg/L)**		**NO3-N (mg/L)**		**NH4-N (mg/L)**		**Br (mg/L)**		**TDS (mg/L)**	
	WCRC	All NGMP	WCRC	All NGMP	WCRC	All NGMP	WCRC	All NGMP	WCRC	All NGMP	WCRC	All NGMP
Range	2.85-10.3	0.5-2468	3.6-7.2	0.004-321	0.11-4.7	0.00-33.5	0.01-0.03	0.005-10.7	0.0-0.12	0.0-1.1	59.96-87.68	54-2512
25th percentile	3.4	8.9	5.3	2.9	0.915	0.01	0.01	0.01	0	0.02	69.8	138
50th percentile	6.45	17.2	5.6	6.1	1.125	0.615	0.01	0.01	0.01	0.04	76.65	190
75th percentile	7.5	30	6.2	11.1	3.3	2.6	0.01	0.03	0.02	0.105	85.47	310

Table 9 Description of hydrochemical facies (based on Daughney and Reeves, 2003)

Cluster at Threshold 1	Facies Description	Cluster at Threshold 2	Facies Description	Cluster at Threshold 3	Facies Description
1	Surface-dominated Oxidised Unconfined aquifer Low to moderate TDS Ca-Na-Mg-HCO_3 water	1A	Signs of human impact Moderate TDS Na-Ca-Mg-HCO_3-Cl water	1A-1	Moderate human impact Carbonate or clastic aquifer Ca-Na-Mg-HCO_3-Cl water
				1A-2	Most human Impact Volcanic or volcaniclastic aquifer Na-Ca-Mg-HCO_3-Cl water
		1B	Little human impact Low TDS Ca-Na-HCO_3 water	1B-1	Carbonate or clastic aquifer Ca-HCO_3 water
				1B-2	Volcanic or volcaniclastic aquifer Na-Ca-Mg-HCO_3-Cl
2	Groundwater-dominated Reduced Confined aquifer Higher TDS Ca-Na-HCO_3 water			2A	Moderately Reduced High TDS
				2B	Highly Reduced Highest TDS