

State of the Environment
Groundwater chemical quality
1994 - 2007

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Executive summary

This is the second State of the Environment Monitoring Report by the Taranaki Regional Council to cover groundwater chemical quality. This report summarises the results and findings of monitoring from 1994 to June 2007.

The Council assesses the quality of groundwater in the region's three major freshwater aquifers through the participation in the National Groundwater Monitoring Programme (NGMP). General chemical quality has been monitored through the NGMP on a quarterly frequency since 1994 at five¹ sites. The programme aims among other things to identify spatial and temporal trends caused by either natural or anthropogenic effects.

The Resource Management Act 1991 (the RMA) under Section 35 requires that local authorities carry out environmental monitoring to determine the state of the environment of their region or district. The Taranaki Regional Council monitors the state of the environment in the region to the extent that enables it to effectively function under the Act. This report only covers general groundwater quality. Specific monitoring programmes for nitrates and herbicide and pesticide residues in groundwater are undertaken under different programmes and reported separately.

The NGMP started in 1990 and the Taranaki Regional Council joined in November 1994. Prior to 1994, there was no formal programme for monitoring baseline groundwater chemical quality in Taranaki. To date, there have been four particular reports on the results of the NGMP. The latest report has been the most complete to date regarding general groundwater quality.

The report shows that according to the analyses performed on the data gathered for the NGMP programme, there are no regional significant groundwater quality issues. It is noteworthy that the region's data show a stable or positive trend –decreasing concentrations- in groundwater quality in 93.75% of the trends analyses performed on the 17 parameters measured. Positive trends outnumber negative trends by a ration of 3 to 1. There has not been a negative regional trend in concentration of nutrients despite the increasing stock numbers and nitrogenated fertilizers over the last couple of decades. Taranaki's general groundwater quality is good for all the parameters analysed. Trend assessments based on data for the period from 1995 to 2006 reveal that the majority of the monitoring sites in Taranaki show increments in the general groundwater quality for most parameters. When water quality standards are used as a benchmark for comparison to the calculated median values, the health-related guidelines values for the parameters analysed (Drinking Water Standards for New Zealand - 2005) are not exceeded at any of the sites for which indicator data were available.

The groundwater quality data analysed for general quality provides evidence that the land-use activities in the region are not posing stresses on the groundwater quality more than natural complex aquifer chemical processes do.

This report includes recommendations for future monitoring. The next report is due after 30 June 2010.

¹ Bore GND0122, Eltham Dairy, a sixth sampled well site, collapsed in 2002

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1. Introduction

The Resource Management Act 1991 (the RMA) under Section 35 requires that local authorities carry out environmental monitoring to determine the state of the environment of their region or district. The Taranaki Regional Council monitors the state of the environment in the region to the extent that enables it to effectively function under the Act.

Environmental monitoring is consistent with the purpose and principles of the Act, the Regional Policy Statement and the Regional Freshwater Plan for Taranaki. The Council manages the quality of the region's groundwater resources through the monitoring the water quality in the major aquifers and by regulating activities that have the potential to contaminate groundwater.

In fulfilling its responsibility under Section 35 of the Act, the Council implements its State of the Environment Monitoring (SEM) programme for groundwater quality. The programme is set out in the Council's annual State of the Environment Monitoring Programme document, and comprises three independent but complimentary components that cover general groundwater quality, nitrates, and herbicides and pesticides. Currently, there is no structured specific programme to monitor groundwater bacterial quality, or saline intrusion in coastal aquifers; monitoring of saltwater intrusion is conducted in a case-by-case basis depending upon closeness to the coast of water bores considered to be abstracting more than minor volumes or rates of groundwater.

This report only covers general groundwater quality. Specific monitoring programmes for nitrates and herbicide and pesticide residues in groundwater are undertaken under different programmes and reported separately.

General groundwater quality is assessed through the participation in the National Groundwater Monitoring Programme (NGMP) which is coordinated by the Institute of Geological and Nuclear Sciences (IGNS) in conjunction with regional councils. The NGMP aims to assess the long-term trends in the water quality of New Zealand's significant aquifers and includes groundwater wells from 14 regions across New Zealand. Water quality samples are collected quarterly, in March, June, September and December and typically analysed for major cations and anions such as sodium, potassium, calcium, sulphate and alkalinity.

The Taranaki Regional Council joined the NGMP in December 1994 and has sampled groundwater at up to six sites deemed to be representative of the region's aquifers on a regular quarterly frequency since then. Prior to 1994, there was no structured monitoring of general groundwater quality in Taranaki. The programme monitors the region's three major freshwater aquifers (Volcanics, Matemateaonga, and Whenuakura) at locations that provide early warning of trends, although they are not within main recharge areas, or in pristine areas whose data can provide valuable baseline data that can be used to determine thresholds in groundwater quality.

General groundwater quality is assessed through the collection of samples for laboratory analysis; sampling is carried out in accordance with established NGMP protocol. The parameters that are chemically analysed include major anions and cations. These allow for the effects of human activity on groundwater quality to be assessed with a greater level of sensitivity than the analysis of only one or two indicator parameters, such as nitrate and ammonia (Rosen et al 2001).

This is the second State of the Environment Monitoring on general groundwater quality report by the Taranaki Regional Council, and summarises the results and findings of long term monitoring to 30 June 2007. The previous Council report on general groundwater quality was produced in 1998 (TRC 1998). Data analysed for this report encompass from 1994 to 2007.

1.1 Background

The physicochemical properties of an aquifer play a large part in determining whether contaminants discharged onto or into land will reach groundwater. The risk of groundwater contamination is usually greater for the shallowest unconfined aquifers (water table) than for deeper confined aquifers as the former lack an overlying impervious layer to impede the entry of contaminants.

Naturally occurring contaminants are present in soil, rocks and sediments. As groundwater flows through the soils, metals such as iron and manganese are dissolved and may later be found in high concentrations in groundwaters. While arsenic minerals are common in many volcanic rocks, particularly those which are hydrothermally altered, they are not common in the Taranaki volcanics.

In general, groundwater quality is judged by the amounts and types of materials that are present. Groundwater is not pure water; it contains a variety of dissolved substances including gases and ions. Some groundwater may also contain organic matter and suspended materials, such as silt.

International standards use the total dissolved solids (TDS) concentration in a water sample to classify water quality into one of the following categories: *Fresh water* is defined by TDS concentrations ranging from 0 to 1,000 milligrams per liter (mg/L). *Brackish water* contains 1,000 to 10,000 mg/L TDS, *saline water* contains 10,000 to 100,000 mg/L TDS, and *brine water* contains more than 100,000 mg/L TDS.

Commonly, good quality water is water that is safe for its intended use (human consumption, livestock, industrial uses or irrigation). Most substances dissolved in water do not adversely affect the taste, smell, appearance, or the hardness of the ground water. However, a few substances such as lead, arsenic, or nitrate, may be harmful to the human health. Listed in Table 1 are the most common substances measured in water. Included for each are the recommended drinking standards for public water supplies.

In Taranaki, because of its dairy farming industry, the concentration of sulphate, potassium, magnesium, nitrate, and possibly also calcium and ammonium in groundwaters are to be closely monitored. To date, no arsenic has been detected in Taranaki groundwaters.

This groundwater quality-monitoring programme consists of three annual surveys on five selected wells for a total of 15 water quality samples per year. The analytical results are compared to the Maximum Acceptable Value (MAV) and the Guideline Value (GV) in the drinking water standards (*Drinking Water Standards for New Zealand -DWSNZ-2005*). Any transgressions of the drinking water standards are highlighted in a letter and water quality report sent to the well owner.

While drinking water standards are widely used as a benchmark for determining water quality, it should be noted that these standards are not necessarily the most relevant and appropriate in every situation.

There is an endless list of chemical substances that can impact on groundwater. The impacts range from an unpleasant taste to imminent health hazards.

The main sources of groundwater contamination in Taranaki are:

- Industrial wastes
- Petrochemical activities
- Landfills
- Leaks from underground storage tanks
- Septic systems
- Agricultural wastes (livestock effluent, fertilisers, pesticides and agrichemicals)
- Underground injection wells



Figure 1 Sources of groundwater contamination²

In Taranaki, some of the activities that could cause adverse effects on groundwater quality might be:

² Courtesy of the UK Groundwater Forum

- The discharge of contaminants to land and water from point sources including, accidental chemical spills, septic tanks, offal pits, failures in well injection sites, and failed or poorly constructed water bores;
- The discharge of contaminants to land and water from diffuse sources including urbanisation, farm runoff and effluent irrigation;
- Unsustainable groundwater abstraction leading to the inflow of poor quality recharge water into an aquifer (salt water intrusion).

Activities of this nature within the region have their individual tailor-made monitoring programme with a component of groundwater monitoring.

Prevention of groundwater contamination is simpler and is much cheaper than the clean up of an aquifer. Once contaminated, an aquifer can be difficult and expensive to clean up; chemical substances may persist for many years. In this respect, effective monitoring of land use activities is essential, as is the strategic protection of aquifer recharge zones from contamination. Protection of the aquifer's recharge areas that supply public water systems is critical.

Degradation or depletion resulting from new or changed land use activities should be closely monitored due to the great susceptibility and vulnerability of the groundwater underlying these recharge areas. The Regional Fresh Water Plan (RFWP) for Taranaki contains provisions that relate to protection of groundwater quality.

Table 1 DWSNZ-2005 Guideline values (GVs) for aesthetic determinands

Determinand	GV	Units	Comments
aluminium	0.10	mg/L	Above this, complaints may arise due to depositions or discoloration
ammonia	1.5 0.3	mg/L	Odour threshold in alkaline conditions For control of chloramine formation in chlorinated water
calcium			See hardness
chloride	250	mg/L	Taste, corrosion
chlorine	0.6–1.0	mg/L	Taste and odour threshold (MAV 5 mg/L)
2-chlorophenol	0.0001 0.01	mg/L	Taste threshold Odour threshold
colour	10	TCU	Appearance
copper	1	mg/L	Staining of laundry and sanitary ware (PMAV 2 mg/L)
1,2-dichlorobenzene	0.001 0.002	mg/L	Taste threshold Odour threshold (MAV 1.0 mg/L)
1,4-dichlorobenzene	0.0003 0.006	mg/L	Odour threshold Taste threshold (MAV 0.4 mg/L)
2,4-dichlorophenol	0.0003 0.04	mg/L	Taste threshold Odour threshold
ethylbenzene	0.002 0.08	mg/L	Odour threshold Taste threshold (MAV 0.3 mg/L)

Determinand	GV	Units	Comments
hardness (total) (Ca + Mg) as CaCO ₃	200 100–300	mg/L	High hardness causes scale deposition, scum formation Low hardness (<100) may be more corrosive Taste threshold
hydrogen sulphide	0.05	mg/L	Taste and odour threshold
iron	0.2	mg/L	Staining of laundry and sanitary ware
magnesium			See hardness
manganese	0.04 0.10	mg/L	Staining of laundry Taste threshold (MAV 0.4 mg/L)
monochlorobenzene	0.01	mg/L	Taste and odour threshold (MAV 0.3 mg/L)
odour (threshold odour number)	3		Odour should be acceptable
pH	7.0–8.5		Should be between 7.0 and 8.0. Most waters with a low pH have a high plumbosolvency. Waters with a high pH: have a soapy taste and feel. Preferably pH <8 for effective disinfection with chlorine
sodium	200	mg/L	Taste threshold
styrene	0.004	mg/L	Odour threshold (MAV 0.03 mg/L)
sulphate	250	mg/L	Taste threshold
taste			Should be acceptable to most consumers
temperature			Should be acceptable to most consumers, preferably cool
toluene	0.03 0.04	mg/L	Odour Taste threshold (MAV 0.8 mg/L)
total dissolved solids	1000	mg/L	Taste may become unacceptable from 600–1200 mg/L.
trichlorobenzenes (total)	see below		(MAV 0.03 mg/L)
1,2,3-trichlorobenzene	0.01	mg/L	Odour threshold
1,2,4-trichlorobenzene	0.005	mg/L	Odour threshold
1,3,5-trichlorobenzene	0.05	mg/L	Odour threshold
2,4,6-trichlorophenol	0.002 0.3	mg/L	Taste threshold Odour threshold (MAV 0.2 mg/L)
turbidity	2.5	NTU	Appearance. For effective terminal disinfection, median turbidity <1 NTU, single sample <5 NTU
xylene	0.02	mg/L	Odour threshold (MAV 0.6 mg/L)
zinc	1.5	mg/L	Taste threshold. May affect appearance from 3 mg/L

1.1.1 Structure of this report

Section 1 of this report is an introductory and background section. It sets out general information about groundwater quality monitoring at the Council.

Section 2 outlines the groundwater quality monitoring programme in association with IGNS– National Groundwater Monitoring Programme. It discusses the results from reports generated during the period under review.

Section 3 discusses the results, their interpretation, and their significance for the environment.

Section 4 presents the main conclusions from the report based on the data processed by IGNS and the Council.

Section 5 concludes the report with recommendations to be implemented in the next monitoring period.

A glossary of common abbreviations and scientific terms, and a bibliography, are presented at the end of the report.

1.1.2 Groundwater quality and regional policy and plan framework

The Regional Policy Statement for Taranaki (RPS) promotes the sustainable management of groundwater so that adverse effects on groundwater quality can be avoided, remedied, or mitigated. The RPS also promotes land management practices that avoid or reduce groundwater contamination.

The Regional Freshwater Plan for Taranaki (RFP) outlines management practices aimed at maintaining and enhancing groundwater quality, by reducing both diffuse and point sources of contamination.

Policies 6.5.1 and 6.5.2 of the RFP relate to the siting, construction, and abandonment of wells and bores, while Policies 6.5.3 and 6.5.4 relate to the discharge of contaminants to land and water such that actual or potential adverse effects are avoided, remedied, or mitigated. Policy 6.5.5 of the RFP relates to the gathering of information to assist in the sustainable management of groundwater.

The application of agrichemicals is addressed in the RFP under Rules 32, 33, 34, and 43, and in the Regional Air Quality Plan (RAQP) under Rules 44 and 46. Guidance on good agrichemical spray management practices can be found in Appendix IV of the RAQP, and Appendix VI of the RFP. The Council will continue to promote the careful use of such chemicals in accordance with these rules and the manufacturers' instructions. Point source contamination from wells and bores can be minimised by adopting good siting, construction, abandonment practices, and well head protection.

To help promote sound management of groundwater resources in Taranaki, the Council requires drilling companies that operate in the region to carry out the drilling, construction, repair, or decommissioning of water wells and bores in accordance with the Environmental Standard for Drilling of Soil and Rock, NZS4411:2001.

1.1.3 Analytical data storage and handling

Groundwater quality analytical data are held in the Council's environmental databases, LABSYS (soon to be replaced by a state-of-the art database named WinLIMS) and ESAM (Environmental Sampling).

Data held in LABSYS come from sampling and analysis carried out by the Council at its laboratory and from analysis at other laboratories. Samples collected by the Council for analysis at the Taranaki Regional Council laboratory are registered on LABSYS at the time they are submitted. On receipt at the laboratory, a sample is given a unique number, which is referenced to the groundwater site it was collected from.

LABSYS also contains the results of groundwater samples collected by the Council for SEM purposes, but analysed at other laboratories. There are currently only two other laboratories that analyse samples for SEM purposes; these are the IGNS Water Gas Laboratory, Wairakei; and the ESR Laboratory, Christchurch. LABSYS contains groundwater quality results for a large number of sites sampled by the Council for purposes other than SEM too. These sample results are generally "one-offs" and are obtained at the request of well /bore owners to test for quite specific concerns. They are typically for a limited list of physico-chemical analytes, and may also include microbiological analysis. Additionally, LABSYS contains groundwater chemical quality results in relation to compliance monitoring of resource consents for a variety of activities, including industrial, and hydrocarbon exploration and production.

2. General groundwater quality – National Groundwater Monitoring Programme

2.1 Background

General groundwater chemical quality is assessed through the National Groundwater Monitoring Programme (NGMP), and is run in conjunction with the Institute of Geological and Nuclear Sciences (IGNS).

The programme aims to define hydrochemical facies³ for groundwaters in New Zealand based on the medians of fifteen chemical parameters, and identify spatial and temporal trends caused by either natural or anthropogenic effects.

The State of the Environment monitoring for groundwater aims to:

- Characterise the ambient groundwater quality on a regional scale.
- Identify significant groundwater quality issues, such as spatial or temporal trends in quality, which may result from pressure on the resource.
- Assess compliance with groundwater quality management objectives.
- Provide data to assess the effectiveness of groundwater management policies.

The NGMP started in 1990 and the Taranaki Regional Council joined in November 1994. Prior to 1994, there was no formal programme for monitoring baseline groundwater chemical quality in Taranaki. The general groundwater quality monitoring programme is set out in the Council's annual State of the Environment Monitoring Programme document.

2.2 Monitoring sites

The group of NGMP monitoring sites for Taranaki was selected to:

- represent the major aquifer systems;
- provide early warning of trends
- be accessible.

Figure 2 depicts the location of the NGMP wells and Appendix A shows a table with the description of each of these sampling sites.

2.2.1 Sample collection and analysis

As previously mentioned, sampling is carried out at quarterly intervals. Sample bottles are forwarded to the Council by the IGNS prior to each survey. Samples are analysed at the IGNS Water-Gas Laboratory at Wairakei.

At each site, unfiltered water is collected for alkalinity determinations, while field filtered (0.45 µm) acid preserved water is collected for cation and metal analysis, and field filtered unpreserved water is collected for anion and nutrient analysis.

Samples are analysed for the following parameters: nitrate (NO₃), nitrite (NO₂), ammonium (NH₄), dissolved reactive phosphorus (P), sodium (Na), potassium (K),

³ A rock or stratified body distinguished from others by its appearance or composition

calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), bromide (Br), fluoride (F-), chloride (Cl-), sulphate (SO₄), silica (Si), and alkalinity, pH and conductivity (field measurement of pH and conductivity began in December 2004). Water level ⁴and temperature are measured in the field.

Sampling methodology is conducted as prescribed by the IGNS in the “National Protocol for State of the Environment Groundwater Sampling in New Zealand” guidelines. The document describes a standardised protocol for the collection of groundwater samples in New Zealand for the purpose of State of the Environment (SOE) monitoring. The aim of the sampling protocol is to facilitate robust assessments of groundwater quality, particularly at an inter-regional and national scale. However, the protocol is not a mandatory requirement or an official national standard.

The Council is notified of results by email; results are then downloaded from the secure section of the IGNS website and entered into LABSYS (section 1.1.3).



Figure 1 Sampling well for NGMP programme

⁴ Where possible

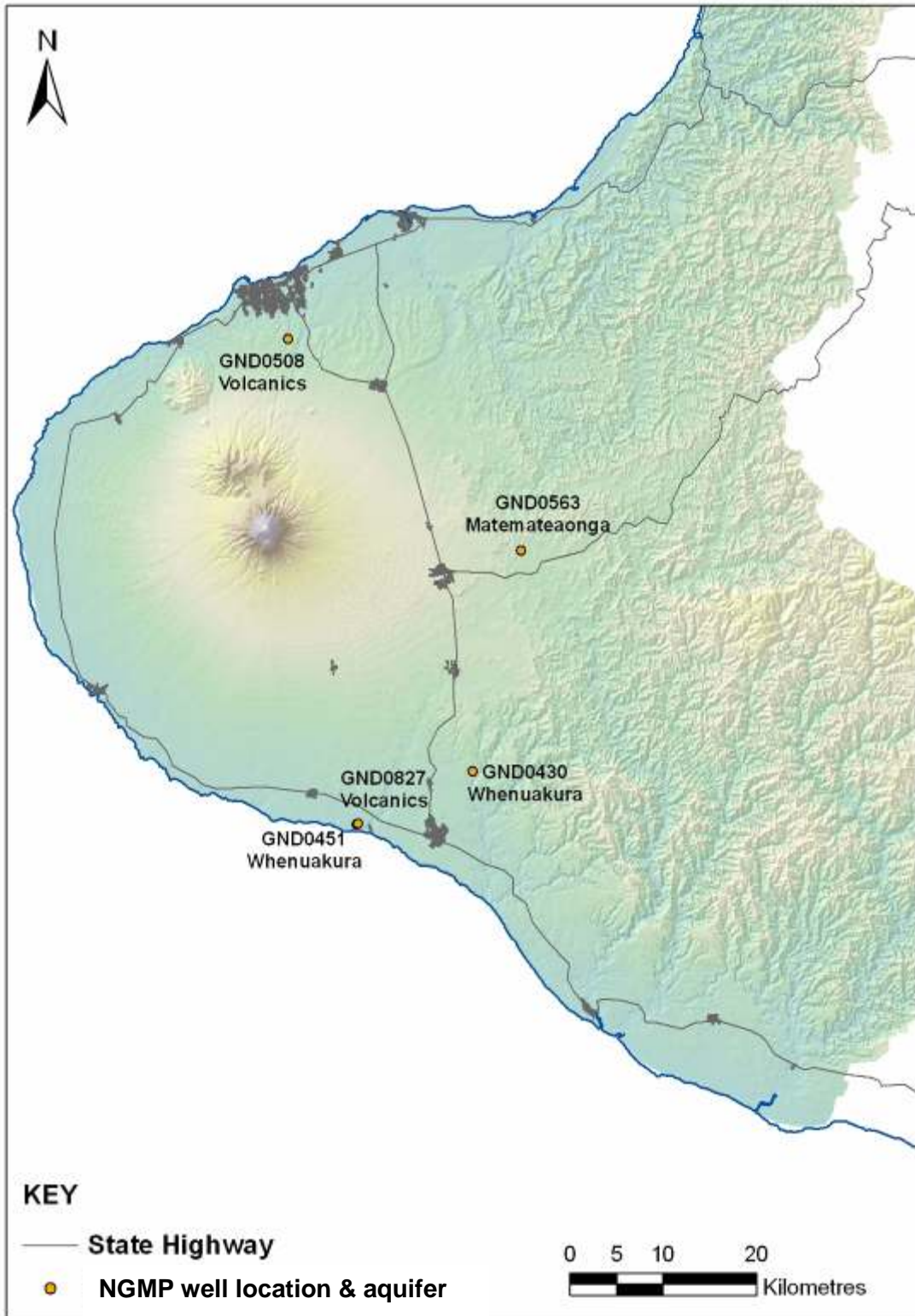


Figure 2 Well locations for NGMP programme

2.2.2 Results

To date, the IGNS has produced four reports on the results of the NGMP: Rosen (1997), Reeves (2001), and Daughney and Reeves (2003) and the latest report in August 2007 (Groundwater Quality in New Zealand, State and Trends 1995–2006).

Some of the most important findings of these reports are discussed below.

2.2.2.1 Report to 1997

Preliminary results for Taranaki (Rosen, 1997) indicated the following:

- Cation abundance distributions (on an equivalent basis) fell into the following groups:

Ca > Na > Mg > K > NH₄ for 3 wells

Na > Ca > Mg > K > NH₄ for 1 well

Na > Mg > Ca > K > NH₄ for 1 well

Na > Ca > Mg > NH₄ > K for 1 well

Ca > Na ≡ Mg > K > NH₄ for 1 well

Rosen found that sodium (Na) and chloride (Cl) results fell on or were close to the seawater concentration-dilution line (SCDL). The SCDL represents water with the same proportional concentration of Na and Cl as seawater. As water is evaporated from the sea, it contains dissolved salts in the same ratio as seawater, and as this water precipitates over land it contributes Na and Cl in the same ratio to aquifer recharge water. Therefore, groundwater collected closer to the sea will have Na: Cl ratios similar to seawater; this indicates that Taranaki groundwaters receive most Na and Cl from the sea, and is consistent with orographic weather patterns which prevail off the Tasman Sea.

Rosen also points out that where Na is enriched relative to Cl (ie. plots above the SDCL), it is a result of water-rock interaction (i.e. dissolution of volcanic glass, or pumice), or land use activities.

Anion abundance distributions fell into the following groups:

HCO₃ > Cl > SO₄ > NO₃ for 6 wells

Cl > HCO₃ > SO₄ > NO₃ for 1 well

The dominance of bicarbonate in solution (HCO₃) is thought to reflect the importance of exchange of CO₂ in soils, and the dissolution of calcite in some aquifer minerals (i.e. from shell rock, or volcanic soils).

In Taranaki, significant concentrations of ammonium (i.e. > 0.1 g/m³) typically occur in deeper bores that tap confined aquifers.

The concentration of ammonium together with the concentrations of dissolved iron (Fe) and manganese (Mn) can be used to indicate whether an aquifer has reducing or oxidising (REDOX) conditions. Sites with high NH₄-N concentrations typically also have high concentrations of dissolved Fe.

$\text{NH}_4\text{-N}$ greater than about 0.1 g/m^3 together with dissolved Fe and Mn can only occur under anaerobic (reducing) conditions. Mildly reducing conditions are characterised by an absence of dissolved oxygen and presence of hydrogen sulphide (H_2S or “rotten egg gas”). While Fe and Mn may be present under mildly reducing conditions, nitrogen species will be present as nitrate (NO_3). Under strongly reducing conditions, oxygen is absent and H_2S and methane (CH_4) are present. Under these conditions nitrate is reduced to ammonium.

Rosen (1997) suggested that increases in dissolved Fe or $\text{NH}_4\text{-N}$ concentrations with time may indicate changing aquifer conditions.

2.2.2.2 Report to 2001

The NGMP status report (Reeves, 2001) used parameters identified as primary aquifer state indicators (potassium, sulphate chloride, nitrate-N, and ammonium-N) to determine temporal trends in groundwater quality. These chemical parameters are considered to be indicators of the effects of land use activities on groundwater quality.

Reeves (2001) reported for most Taranaki NGMP sites, seasonal variations in nitrate-N concentrations of up to 3.3 g/m^3 amplitude, with highs occurring in June. Ammonium was detected at most sites, with concentrations relatively consistent with time, and Eltham Dairy (GND0122), showing the largest amplitude variations of 1.7 g/m^3 .

Reeves also reported the following trends for the period 1994-2001:

For the McCallum Well (GND0827):

- Increasing SO_4 concentrations at 1.5 g/m^3 year;
- Decreasing Cl concentrations at 2.2 g/m^3 year;
- Decreasing $\text{NO}_3\text{-N}$ concentrations at 0.2 g/m^3 year;

For the Carrington Road Well (GND0508):

- Seasonal variations in K concentrations of up to 2.3 g/m^3 amplitude, with highs occurring in September-December;
- Decreasing K concentrations at 0.3 g/m^3 year;
- Seasonal variations in $\text{NO}_3\text{-N}$ concentrations of up to 2.9 g/m^3 amplitude, with highs occurring in September-December;
- Decreasing $\text{NO}_3\text{-N}$ concentrations at 0.2 g/m^3 year;

In summary, temporal trends in the NGMP dataset for Taranaki to June 2001 were identified for only two of the five sites (GND0827 and GND0508). Both of these sites, in Table 2 and Appendix I, represent shallow wells tapping unconfined aquifers in the Taranaki Volcanics.

Table 2 Well codes and aquifers of the monitoring wells of the NGMP Programme

Well code	Aquifer	Depth
GND0430	Whenuakura	Deep Aquifer
GND0451	Whenuakura	Deep Aquifer
GND0563	Matemateaonga	Deep Aquifer
GND0827	Volcanics	Shallow Aquifer
GND0508	Volcanics	Shallow Aquifer

Well GND0827 showed a trend of increasing sulphate concentrations and decreasing chloride concentrations. Well GND0508 showed a trend of decreasing potassium concentrations, while both sites showed a trend of decreasing nitrate-N concentrations. Tables 3 and 4 give likely causes for the observed trends.

Table 3 Observed ranges of primary state indicator concentrations for Taranaki NGMP sites

Primary indicator	Minimum g/m ³	Maximum g/m ³
Potassium (K)	1.6	8.2
Nitrate-N (NO ₃ -N)	BD ⁵	6.86
Sulphate (SO ₄)	BD	47.7
Chloride (Cl)	7.2	124.5
Ammonium (NH ₄ -N)	BD	7.8

Table 4 Primary land use effect indicators and probable causes of contamination (Reeves 2001)

Primary indicator	Probable land use/contaminant
K	Fertiliser input, human and animal waste
SO ₄	Fertiliser input, pesticides
NO ₃ -N, NH ₄ -N, total-N	Fertiliser input, human and animal waste, landfill leachate, offal pits
Cl	Human and animal waste, saltwater intrusion (when with Na and Br)

2.2.2.3 Report to 2003

The 2003 report received from IGNS that relates to the NGMP programme (Daughney and Reeves 2003) discusses the role of hydrochemical facies in groundwater quality monitoring and management.

The definition of hydrochemical facies establishes background concentrations of key indicator parameters (analytes) at the monitoring sites. Departures in analyte concentrations from background levels (i.e. anomalies) can be used to identify the impacts of land use activities on groundwater chemical quality.

The concept of hydrochemical facies takes into account groundwater origin and evolution, together with processes that have affected a site in the past and may continue to do so in future. Daughney and Reeves made the following general comments for the five Taranaki NGMP sites in their 2003 report:

⁵ BD = below analytical method detection limit

Taranaki sites display a broad range of chemical composition;

- Most sites have shown little change in chemical composition since monitoring began. However, weak changes in REDOX sensitive parameters (Fe, Mn, and NH₄) may be evident which may suggest that REDOX potential is changing very slowly, if at all.
- Four sites (Bayly GND0563, Corrigan GND0430, Eltham Dairy GND0122, and McCallum-2 GND0451) showed evidence of low REDOX potential, mainly as the concentrations of NH₄ exceeded NO₃. Hydrochemical facies for these sites represent reduced sub-surface dominated systems with chemical compositions similar to the global average estimate for groundwater;
- The hydrochemical facies at the two remaining sites (Carrington Road, and McCallum Well) represent oxidised, surface-dominated systems with chemical compositions similar to the global average estimate for river water.

Daughney and Reeves concluded the following for Taranaki NGMP data to 2003:

For the Bayly site (GND0563):

- Groundwater chemistry in equilibrium with a carbonate rocks (Matemateaonga Formation), where Ca and HCO₃ > Na, K, Cl and SiO₂;
- Although the REDOX potential is low, Fe and Mn concentrations are not elevated, suggesting that either mineral containing these elements are not abundant in the aquifer, or organic matter necessary for their dissolution is scarce.
- A very slow decrease in groundwater NO₃ concentration over time is thought to reflect denitrification under reducing conditions.

For the Eltham Dairy site (GND0122) – sampling ceased after it collapsed in 2002:

- High ratio of Na: Ca in groundwater due to limited carbonate rocks in aquifer, despite being in Matemateaonga Formation.
- Higher concentrations of Mn and NH₄ in groundwater than other sites in the same hydrochemical facies.

For the McCallum-2 site (GND0451):

- Groundwater has the highest concentrations of Fe, NH₄ and SiO₂ of all Taranaki NGMP sites;
- A very slow decrease in groundwater NO₃ concentration over time is thought to reflect denitrification under reducing conditions.

For the Corrigan site (GND0430):

- The groundwater chemistry is similar to Bayly, but due to equilibration with feldspar minerals in the aquifer, has slightly higher proportions of Na and K;
- The aquifer has significant carbonate component;
- Slow decreases in Ca and Cl concentrations have occurred over time.

For the Carrington Road site (GND0508):

- The groundwater has high concentrations of K and SiO₂, which is consistent with the volcanic composition of the aquifer;
- The groundwater has a low concentration of total dissolved solids;

For the McCallum Well site (GND0827):

- The groundwater chemistry may be partially controlled by equilibration with carbonate minerals in the aquifer;
- Groundwater has anomalously high concentrations of Na, Cl and Br (bromide), which indicates a strong marine influence, either through infiltration or recharge;
- Groundwater has the highest concentration of nitrate-N of all of the Taranaki NGMP sites, indicating the effects of land use activities. Reeves (2001) also noted a decreasing trend in NO₃-N concentrations at this site.

Daughney and Reeves suggested that the Carrington Road and McCallum Well sites represent end members for freshly recharged un-impacted and impacted groundwaters.

2.2.2.4 Report to 2006⁶ - Groundwater Quality in New Zealand State and Trends

This report was prepared by the Institute of Geological and Nuclear Sciences Limited (GNS Science) the Ministry for the Environment. Taranaki Regional Council provided the data pertaining to the region for this report.

This report has been the most complete to date regarding general groundwater quality. The purpose of the IGNS 2007 report was to provide an assessment of the current state and trends in groundwater quality at a national scale. Results presented herein are those that relate to the Taranaki region extracted from the Nation wide report by Daughney and Reeves (IGNS 2006).

The assessment was based on data from the Regional Council's SOE monitoring programme, and from the National Groundwater Monitoring Programme (NGMP) operated by GNS Science. All data relate to the period between 1995 and 2006.

As more data has become available since the implementation of the NGMP, a national perspective on groundwater quality and the identification and interpretation of spatial and temporal trends in groundwater chemistry has been possible where analysis of changes over time in groundwater quality have started to be detectable for effective resource management. IGNS has undertaken trend analysis of time series data which allows for early detection of degrading groundwater quality, for differentiation of short-term fluctuations. The trend detection carried out involved analysis of time-series water quality data to determine patterns on the groundwater quality data.

In the 2007 study, IGNS used the seasonal Mann-Kendall test ($\alpha = 0.05$) to detect trends in selected water quality parameters at each NGMP site. The trending methods were used to detect and estimate trends on a per-analyte basis for 153 of the NGMP sites. For Taranaki, six MP sites were assessed. Trends were assessed for Br, Ca, Cl, F, Fe, HCO₃, K, Mg, Mn, Na, NH₄-N, NO₃-N, PO₄-P, SiO₂, SO₄, pH (field-measured), conductivity, (lab-measured) and temperature (field measured).

Daughney and Reeves (2006) developed a classification scheme for the NGMP in order to simplify the interpretation of groundwater quality trends at the national scale, Figure 3 and Table 5 explains the pre-defined classes.

⁶ Published in 2007

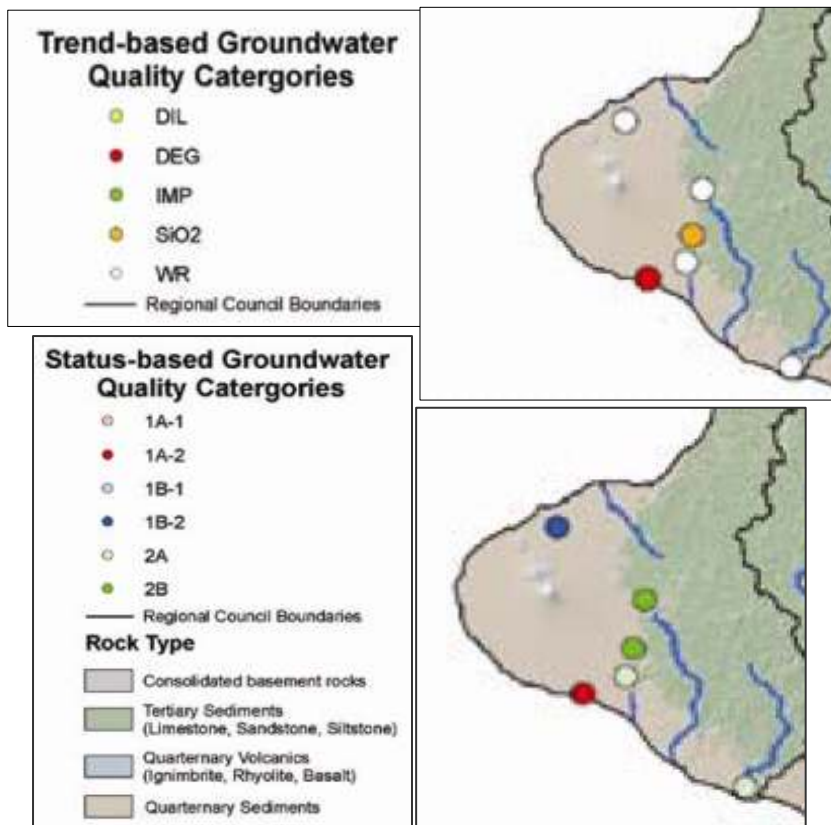


Figure 3 Assignment of Taranaki's SOE monitoring sites to status-based groundwater quality categories and (From Daughney and Reeves, 2006)

These categories cluster wells that share common characteristics as follows:

- 1A-2:** Most human influence. Water chemistry suggests water-rock interaction in a volcanic or volcanoclastic aquifer.
- 1B-2:** Water chemistry suggests water-rock interaction in a volcanic or volcanoclastic aquifer.
- 2A:** Moderately reduced, majority in unconfined aquifers. High TDS.
- 2B:** Highly reduced, majority in confined aquifers. Highest TDS.

In order to simplify the interpretation of groundwater quality data, the classification scheme allocates each monitoring site to a category and sub-category on the basis of measured concentrations multiple water quality parameters. These categorical assignments were based on groundwater chemistry only and do not particularly consider factors such as well depth, aquifer confinement or lithology.

Table 5 General characteristics of trend-based groundwater categories defined by Daughney and Reeves

Category	Characteristics	Possible causes	Comments
DIL (diluting)	Rapid decrease in Na, Ca, HCO ₃ and Cl over time	Change in pumping regime or hydrogeologic conditions; reduction of saltwater intrusion	<ul style="list-style-type: none"> Usually category 2 (see Figure 2) Median depth 95 m No significant relationship to lithology, confinement or surrounding land use
DEG (degrading)	Increases in Ca, Cl, K, Mg, Na, NO ₃ -N and/or SO ₄ over time	Increasing proportion of recharge from rainfall relative to river over time; increasing human or agricultural impact in recharge area	<ul style="list-style-type: none"> Usually category 1 (see Figure 2) Median depth < 10 m Most in unconfined aquifers No significant relationship to lithology or surrounding land use
SiO ₂	Rapid increase in SiO ₂ without accompanying changes in other analytes at a similar rate	Unknown	<ul style="list-style-type: none"> Only one NGMP site falls into this category, so its significance at the national scale is questionable
IMP (improving)	Decreases in K, Mg and/or NO ₃ -N over time, often with accompanying decreases in Ca, Na, Cl and/or SO ₄	Increasing proportion of recharge from rivers relative to rainfall over time; decreasing human or agricultural impact in recharge area	<ul style="list-style-type: none"> Usually category 1 (see Figure 2) No significant relationship to depth No significant relationship to lithology, confinement or surrounding land use
WR (water-rock interaction)	No or only slow changes in most parameters over time	Natural water-rock interaction	<ul style="list-style-type: none"> No relationship to water quality categories (see Figure 2) No significant relationship to depth No significant relationship to lithology, confinement or surrounding land use

The percentage of monitoring sites assigned by GNS to each trend-based groundwater quality category for Taranaki is given below.

Table 6 Classification of Taranaki's wells for trend analysis tests

Council	DIL	DEG	IMP	SiO ₂	WR
TRC	0.0%	14.3%	0.0%	14.3%	71.4%
Number of wells	0	1	0	1	4

The classification scheme for the NGMP was designed to simplify the interpretation of groundwater quality trends at the national scale. It, however, provides a convenient means of summarising the patterns of change among several different groundwater quality parameters. The authors acknowledge that the method followed does not specifically account for factors such as well depth or aquifer confinement.

Using an automated spreadsheet program developed by Daughney, (2005) descriptive statistics were computed for each of the parameter categories based on scientifically proven methods. Outliers were identified and excluded from subsequent calculations; if the remaining number of data-points did not withstand statistical analysis the calculations were not performed.

An important objective of many environmental monitoring programmes is to detect changes or trends in pollution levels over time. The purpose of the trend analysis in this particular case is to look for increased environmental pollution resulting from changing land use practices from changing or intensifying land uses.

The trend significance and magnitude were quantified for all trends that are detectable with the Mann-Kendal test at the 95% confidence interval; positive numbers indicate increasing trends and “N” indicates non-significant trends.

Declining trends (decreases in concentration) outnumbered increasing trends by a ratio of 3 to 1. There has not been an increasing regional trend in concentration of nutrients despite the increasing stock numbers and nitrogenated fertilizers over the last couple of decades.

Care must be taken when interpreting the results for the trend analysis. The categorisation followed in the study only provides an overview of groundwater quality at the big scale; it does not quantify the magnitude of any specific groundwater quality issues and does not tell much about the severity of the influence in the overall status of the groundwater quality for the region.

Magnitudes for significant trends for the region’s NGMP samples collected to June 2006 are given for each of the sampled wells in Table 7.

It is remarkable for the region to see that only 6.25% of all the trends performed on the 17 parameters for the Taranaki wells show an increasing (positive) trend, 93.75% of the trends performed on the data showed stability or a trend of decreasing concentrations.

Water quality standards were also used as a benchmark for comparison to the calculated median values; data collected and processed from 1999 to 2007 were compared to the Drinking-water Standards for New Zealand (DWSNZ) (Ministry of Health, 2005)

The DWSNZ defines health-related maximum allowable values (MAVs) and aesthetic guideline values (GVs) related to taste, odour or colour. Comparisons to these water-quality standards were performed on a per-parameter basis, to evaluate the region’s groundwater sampled sites in order to depict the sites at which calculated medians exceeded the relevant MAV’s and GV’s. A graphical representation of this analysis can be found in figures 4 to 14. Table 8 shows the average values for groundwater quality for SEM sites.

As noted earlier, the suitability of groundwater for particular uses should be assessed against the most applicable standard not only against the DWSNZ.

There are several published guidelines for water quality for livestock but these are often based on few data, with little information as to how the guidelines were formulated and how “acceptable” levels of water components and contaminants were defined.

The Australia and New Zealand Environment and Conservation Council (ANZECC) has developed “trigger values” (the level at which there is minimal risk to animal health, but if levels exceed the trigger value, the risk to stock should be investigated). In their 2000 review, ANZECC updated the information previously used in determining the guidelines for livestock drinking water (ANZECC 1992).

For example, high nitrate concentrations in the water supply may indicate that nitrate levels in locally-grown feed may also be elevated. Trigger values of 400 mg/litre nitrate and 30 mg/litre nitrite are recommended for livestock drinking water (ANZECC 2000). Depending on the nitrate content of feed, the type of livestock and other factors such as animal age and condition, concentrations up to 1500 mg/litre nitrate may be tolerated, at least for short-term exposure. These recommended trigger values are consistent with Livestock Production and Water Quality in the Canadian guidelines for livestock drinking water [100 mg/litre nitrate-N; 10 mg/litre nitrite-N] (CCREM 1987). (Literature Review Abacus Biotech Ltd for the MAF Sustainable Farming Fund 41)

Table 7⁷ Magnitudes for significant trends 1995-2006⁸

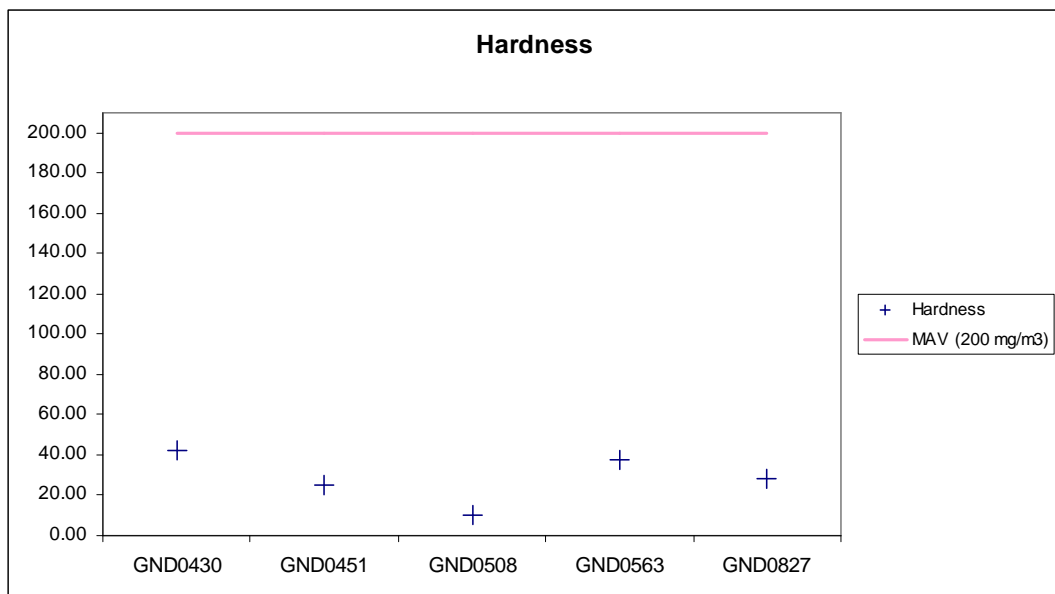
	GND0122	GND0430	GND0451	GND0508	GND0563	GND0827
Br	-0.0040	N	N	N	N	-0.0086
Ca	-0.8143	-0.1901	-0.2656	N	N	N
Cl	-0.1637	-0.0993	-0.1210	N	N	-2.8461
Cond	N	N	N	1.2555	N	-9.8716
F	N	N	N		N	N
Fe	N	N	0.2555	N	N	
HCO₃	N	0.6341	N	N	N	0.5882
K	-0.0855	-0.0413	N	N	N	N
Mg	-0.3310	N	-0.0792	N	-0.0942	N
Mn	-0.0170	N	-0.0113	N	N	
Na	N	N	N	N	N	-0.5419
NH₄-N	N	0.0263	N		N	
NO₃-N	N	N	-0.0014	N	-0.0015	0.0566
pH	N	-0.0248	N	N	N	-0.0325
PO₄-P	N	N	N		N	N
SiO₂	N	N	N	N	N	N
SO₄	N	N	N	N	N	2.8252

⁷ Data and information summarised in this spreadsheet was collated for the purposes of national state of environment reporting only. Data in this table is for the subset of data collected for the Taranaki sites. The accuracy of the data is subject to the limitations and constraints described in the report "Groundwater quality in New Zealand state and trends (1995-2006).

⁸ Units: mg/L per year for compounds, uS/cm per year for Cond, pH units per year for pH. N indicates that a trend calculation was performed, but found to be not significant

Table 8 Average values for groundwater quality for SEM sites 1999-2007

Parameter	GND0430	GND0451	GND0508	GND0563	GND0827
Ammoniacal nitrogen	0.27	1.20	0.01	0.56	0.01
Bicarbonate	169.39	138.91	37.25	180.97	55.85
Bromide	0.08	0.10	0.08	0.06	0.27
Calcium	30.25	17.52	7.42	28.49	17.19
Chloride	23.87	26.95	9.19	9.62	81.50
Conductivity @ 20°C	47.96	44.24	16.55	42.07	49.98
Fluoride	0.07	0.30	0.03	0.13	0.10
iron	0.02	3.15	0.16	0.14	0.03
Magnesium	11.98	7.19	3.13	9.42	11.31
<i>Hardness: Iron + Magnesium</i>	<i>42.23</i>	<i>24.71</i>	<i>10.55</i>	<i>37.91</i>	<i>28.49</i>
manganese	0.01	0.73	0.01	0.01	0.01
Nitrate nitrogen	0.23	0.04	1.75	0.03	2.33
pH	8.00	7.49	6.32	7.85	6.68
Potassium	2.60	7.48	2.70	1.81	5.52
silica	26.47	53.89	21.85	19.27	52.06
Sodium	22.92	30.49	9.19	21.07	52.61
Sulphate	5.23	2.00	6.42	0.12	41.64
Temperature	14.34	14.58	16.14	13.78	14.46

**Figure 4** Comparison of Hardness MAV values with average data for GNS-TRC monitoring sites for the period 1995 – 2007

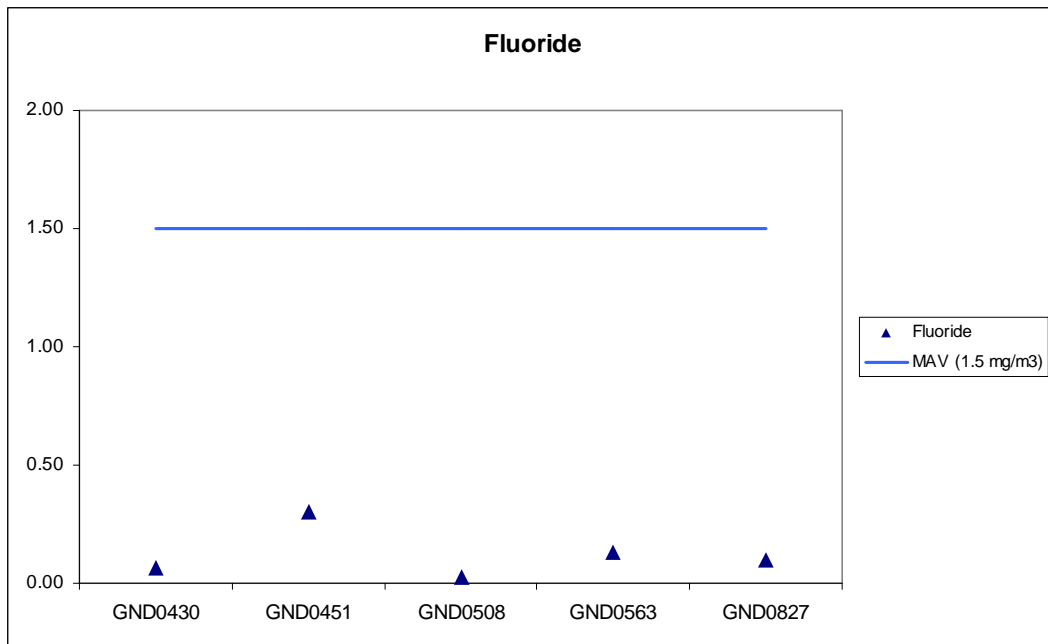


Figure 5 Comparison of Fluoride MAV values with average data for GNS-TRC monitoring sites for the period 1995 – 2007

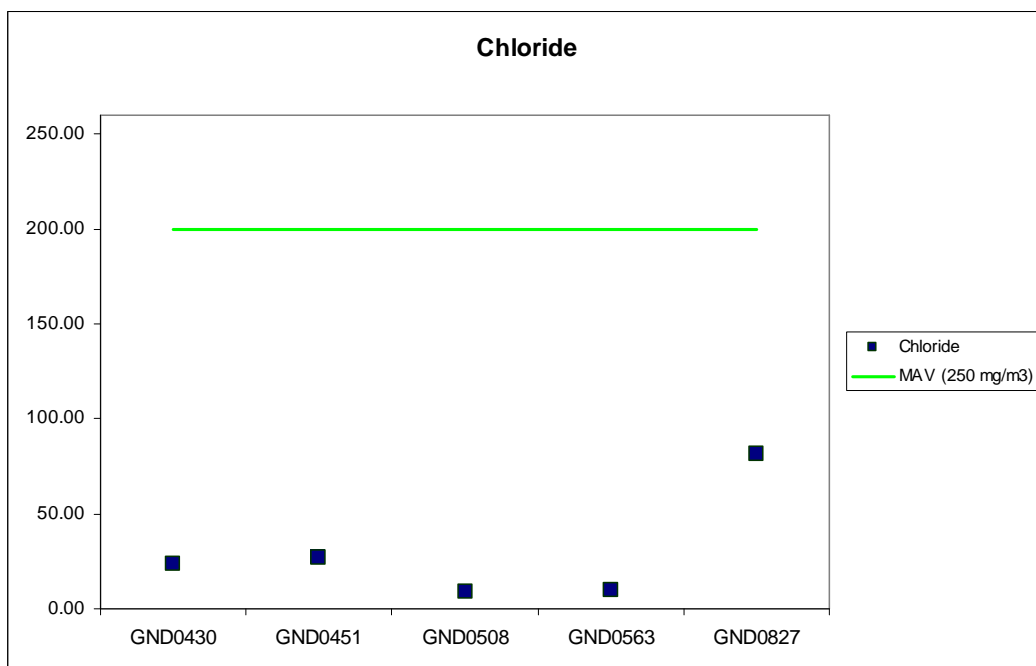


Figure 6 Comparison of Chloride MAV values with average data for GNS-TRC monitoring sites for the period 1995 – 2007

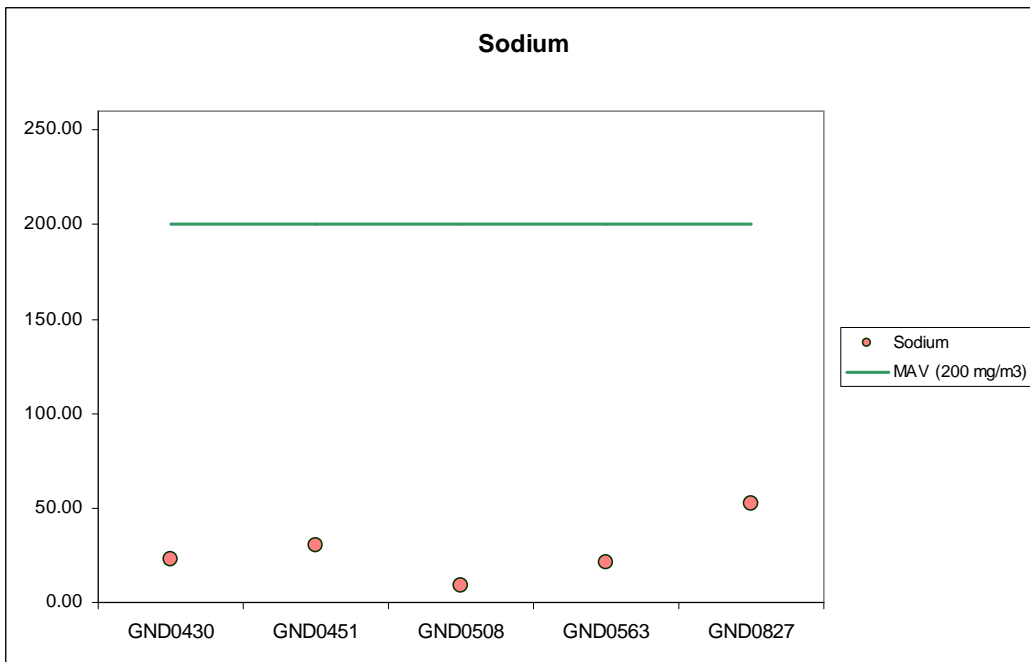


Figure 7 Comparison of Sodium MAV values with average data for GNS-TRC monitoring sites for the period 1995 – 2007

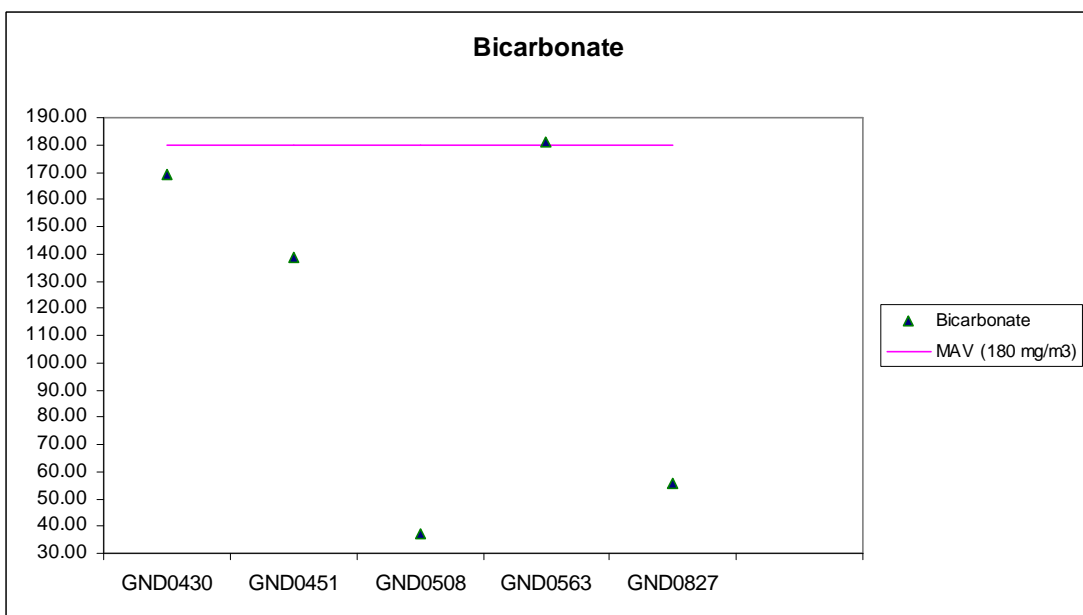


Figure 8 Comparison of Bicarbonate MAV values with average data for GNS-TRC monitoring sites for the period 1995 – 2007

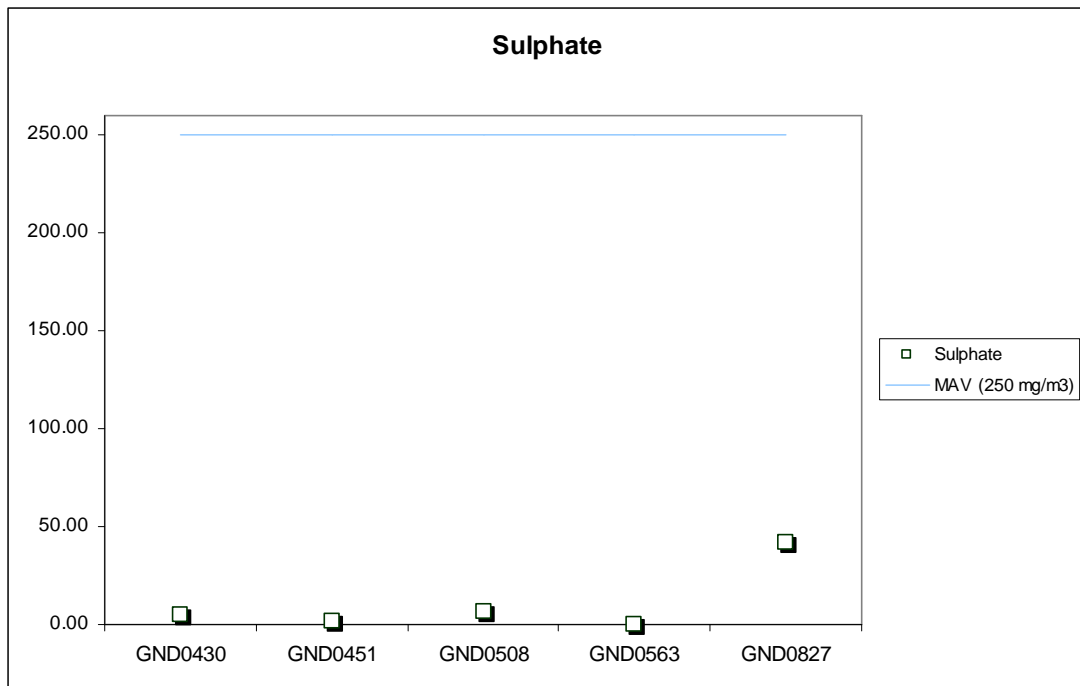


Figure 9 Comparison of Sulphate MAV values with average data for GNS-TRC monitoring sites for the period 1995 – 2007

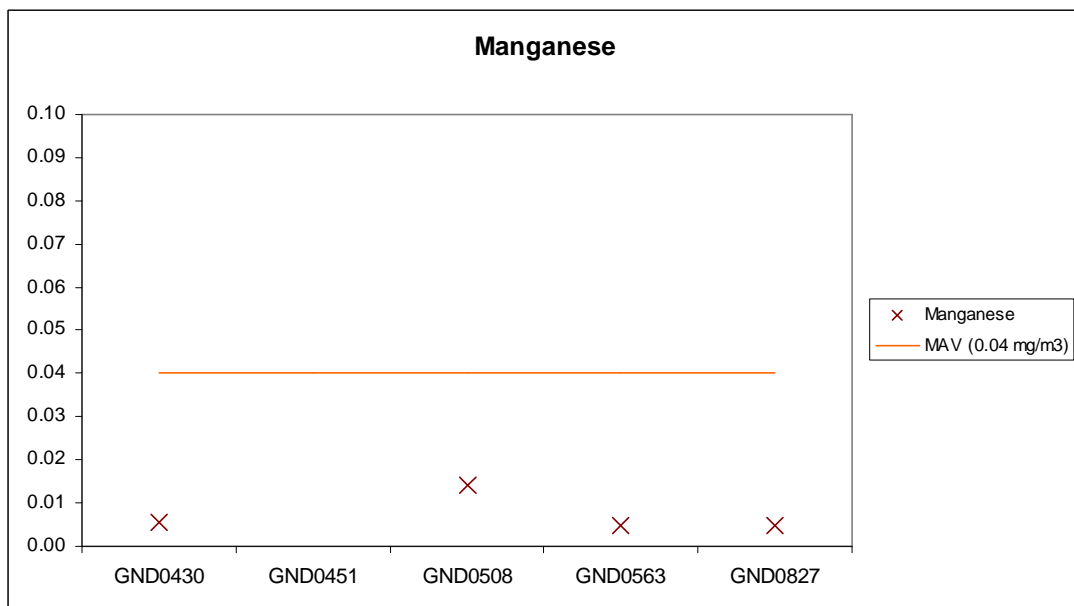


Figure 10 Comparison of Manganese MAV values with average data for GNS-TRC monitoring sites for the period 1995 – 2007

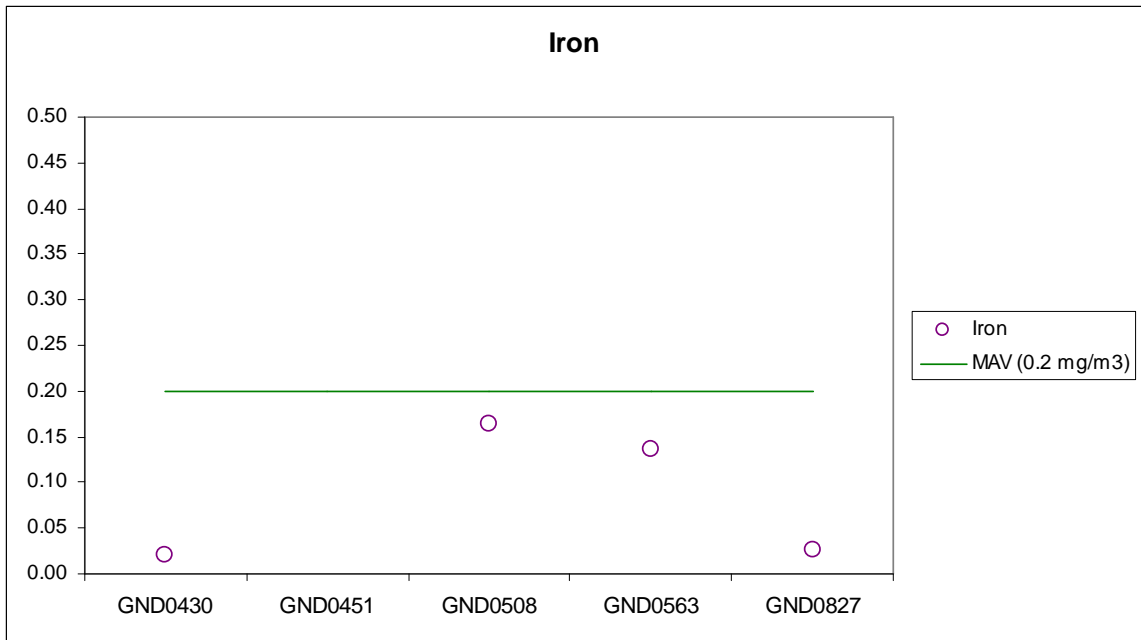


Figure 11 Comparison of Iron MAV values with average data for GNS-TRC monitoring sites for the period 1995 – 2007

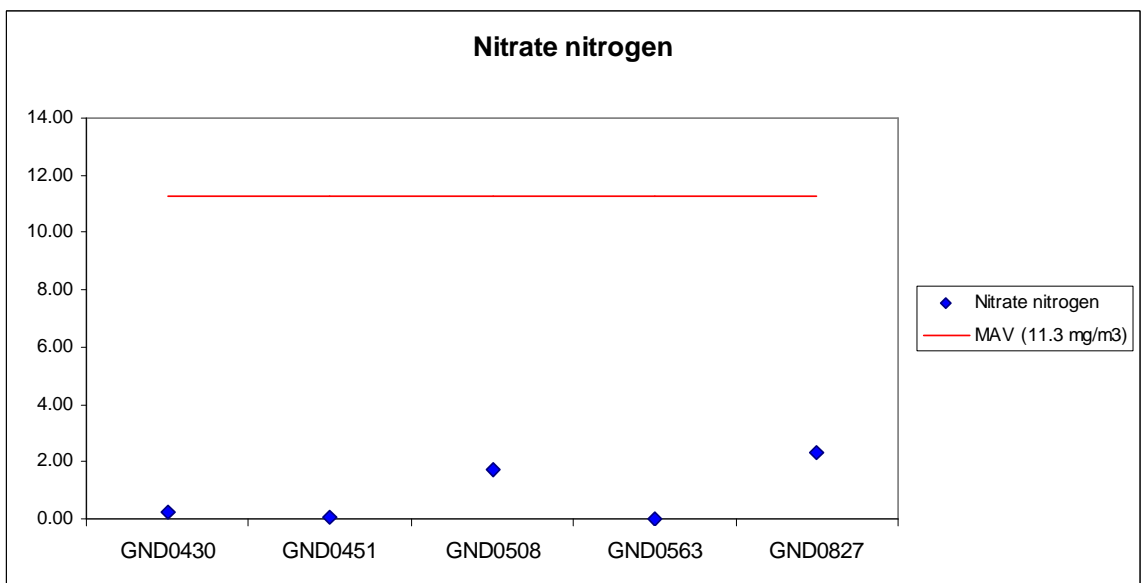


Figure 12 Comparison of Nitrate-nitrogen MAV values with average data for GNS-TRC monitoring sites for the period 1995 – 2007

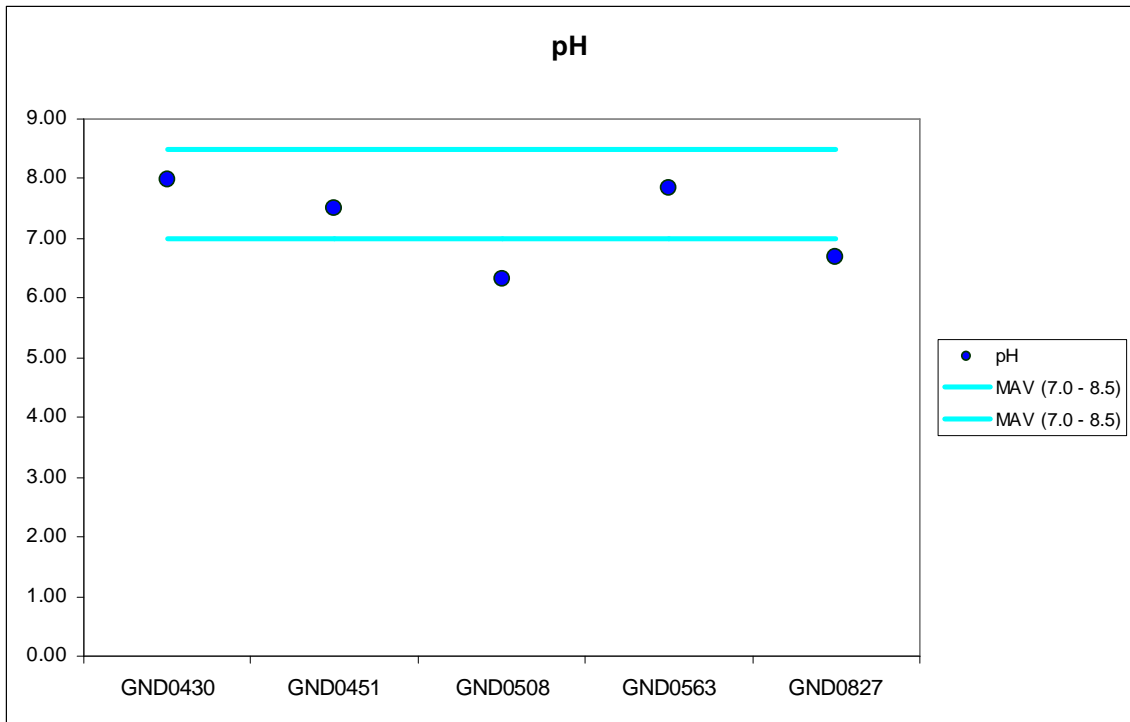


Figure 13 Comparison of pH MAV values with average data for GNS-TRC monitoring sites for the period 1995 – 2007

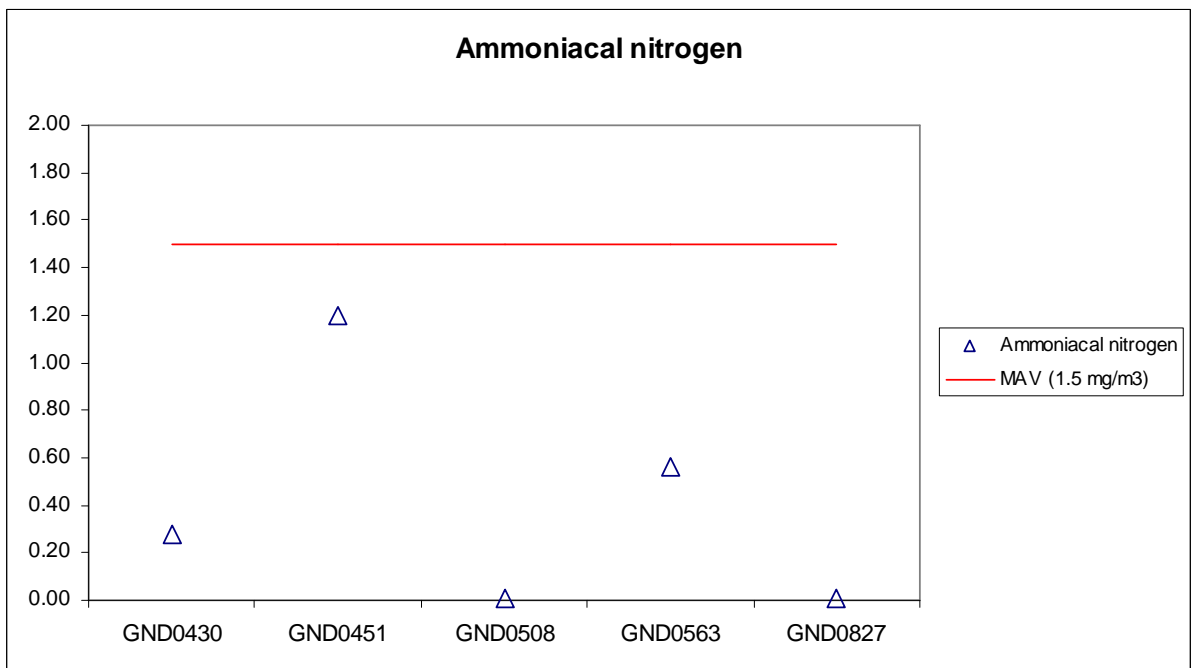


Figure 14 Comparison of Ammoniacal nitrogen MAV values with average data for GNS-TRC monitoring sites for the period 1995 – 2007

This analysis indicates that there are no regional significant groundwater quality issues, as it has been assumed that the selected sampling wells represent the major aquifer systems of the region as explained in Section 2.2

The Institute of Geological and Nuclear Sciences has also started to work on determining the age of groundwater at all NGMP sites. As there are only a limited number of analyses for the NGMP sites in Taranaki, only preliminary estimates can be made. In general, groundwater in the deepest aquifers in the region is older than 100 years. However, for several of the NGMP sites it is clear the groundwater is more than 140 years old while others sites' groundwater is less than 2 years old and therefore susceptible to changes in current land cover, land use and management. Table 9 shows the preliminary estimates of mean age for three of Taranaki's aquifers:

Table 9 Estimated groundwater age in Taranaki's aquifers

Well code	Aquifer	Estimated Age (Years)
GND0430	Whenuakura	144
GND0451	Whenuakura	152
GND0563	Matemateaonga	167
GND0827	Volcanics ⁹	2
GND0508	Volcanics	2

The age of groundwater is defined as the time that has elapsed since the water first entered the groundwater system. Rainfall that does not run off, gets evaporated or is captured by the vegetation on the surface, infiltrates into the soil and a portion of it percolates further until it reaches the water table. From the water table it continues to move through the aquifer systems at very slow velocities in processes that can take from days to thousands of years.

The age of the water is commonly measured to estimate the time lag between land-use intensification and the appearance of signs of land intensification on groundwater systems. Groundwater dating information is used to help define direction and velocities of the groundwater flow as it is valuable data to recognise recharge and discharge areas in groundwater-surface water systems for the characterisation of hydrogeologic environments that could be potentially affected by contamination.

⁹ Only moderate confidence on the groundwater dating for the Volcanic formation

3. Discussion

The SEM sites utilised for groundwater quality have been deemed as representative of the aquifers of the region for the most part. Over 68 wells have also been used for SEM monitoring of nitrates in the region but those have not been considered for the investigation of the general groundwater quality as they might represent more localised conditions that are dealt with more properly in a separate report (*Nitrates in shallow groundwater*, in preparation).

This report shows that Taranaki's general groundwater quality is good for all the parameters analysed. Trend assessments based on data for the period from 1995 to 2006 reveal that the majority of the monitoring sites in Taranaki show stability or improvements in the general groundwater quality for most parameters; the data suggests that natural water-rock interactions are the primary determinant of water quality (67% of the monitoring wells).

The 2007 report has been the most complete document regarding general groundwater quality in the region. To date, trending results provide an assessment of the current state in groundwater quality in Taranaki. Based on the latest study, there is no indication that human activities on the land are negatively affecting the general groundwater quality of the province. However, when nitrates are the only parameter to be analysed special attention will be focused on the shallowest unconfined aquifers, which are the most vulnerable to pollution from the land surface.

Previous studies in New Zealand have suggested that at the local scale land uses such as agriculture and horticulture are major sources of nitrate contamination of groundwater. Although in previous studies the levels of iron and manganese in groundwater in the volcanic formations have been reported as high, when the averaged data for these two elements is analysed and plotted against the MAV for human consumption, it can be seen that they do not surpass the allowable values. This further suggests that in general, most of the water in the region's aquifers is suitable for human and stock consumption.

The groundwater quality data analysed for general quality provides evidence that the land-use activities in the region are not posing stresses on the groundwater quality more than natural complex aquifer chemical processes do. However, groundwater that might have been potentially impacted by land-uses might not have had sufficient time to move all the way from the aquifer's recharge area to the monitoring well. So it is important that more precise information about the age and source of the groundwater monitored at the selected wells be gathered.

4. Conclusions

This study has reported on the data collected from 1994 until 2007 as part of the jointly programme for the State of the Environment between IGNS and TRC on general groundwater quality in Taranaki.

There are no major issues with the general groundwater quality in Taranaki to date based on the data gathered at the five monitoring wells that have been considered as representative for the region.

In spite of the Taranaki relatively high land use for dairying, at the totality of monitoring sites for this state of the environment programme there is currently no evidence of human influence in the fitness of groundwater.

Trend assessments based on data for the period from 1995 to 2006 reveal that remarkably for the region only 6.25% of all the trends performed on the 17 parameters for the five Taranaki wells show a positive trend (some deterioration); 93.75% of the trends performed on the data showed stability or improvement in water quality.

When water quality standards are used as a benchmark for comparison to the calculated median values, the health-related guidelines values for the parameters analysed (Drinking Water Standards for New Zealand - 2005) are not exceeded at any of the sites for which indicator data were available.

Previous trend analysis performed on groundwater data for the Council had been done only on nitrates in shallow groundwater. The trend analyses presented herein encompasses additional 16 parameters and shows a positive development in the general quality of the groundwater of the province. Nonetheless, some natural water–rock processes do affect groundwater quality in the region, so routine groundwater quality monitoring programmes should be continued.

The decreasing (improvement) long term trends in groundwater quality across the region is a sign that the implementation of Policy 6.3.1 of the Regional Freshwater Plan for Taranaki, which *promotes land use practices that avoid, remedy or mitigate adverse effects on fresh water quality*, has been effective until now as the data demonstrates.

Taranaki Regional Council's current monitoring groundwater quality programme, in association with IGNS should continue to be annually reviewed to make sure that it is addressing the questions that are important to the region's long-term resource management goals. IGNS recommends that a balanced number of shallow and deep sites be maintained in the region to ensure regional and national-scale representativeness.

From a management perspective, trend analysis should continue to be performed on all type of groundwater quality data in order to determine thresholds that can be used to identify quality issues.

5. Recommendations

It is recommended:

1. THAT the results of the analysis presented in this study be included in the 2008 TRC's State of the Environment report.
2. THAT in agreement with IGNS a review of the number of wells selected to date as representative be reviewed and that if the need arises to include more wells be included.
3. THAT the Council request from the Institute of Nuclear and Geological Sciences a biannual report on the status of Taranaki's general groundwater quality and that trend analysis on the data be also performed by the Council.
4. THAT the Council continues an appropriate level of groundwater quality monitoring for SEM and compliance monitoring purposes.

Glossary of common terms and abbreviations

The following abbreviations and terms are used within this report:

Agrichemicals	substances intended to control of plant growth (other than fertilisers or soil conditioners), bacteria, protozoa, fungi and viruses, vertebrates and invertebrate pests. Includes herbicides, algaecides, defoliants, or fruit setting hormones; bactericides, fungicides, viricides, nematocides, miticides, acricides, arachnicides, molluscides, insecticides, or other pesticides.
Analyte	a chemical substance that is the subject of a chemical analysis
Anthropogenic	caused or produced by humans
Anaerobic	pertaining to or caused by the absence of oxygen
Aerobic:	pertaining to or caused by the presence of oxygen
Aquifer	an underground geological formation able to store and yield water
Pathogenic	capable of producing disease
Unconfined	an aquifer in which the water table is at or near atmosphere pressure and is the upper boundary of the aquifer. Because the aquifer is not under pressure the water level in a well is the same as the water table outside the well
Carbonate	a mineral salt of carbonic acid
Confined	also known as artesian or pressure aquifers) exist where the groundwater is bounded between layers of impermeable substances like clay or dense rock. When tapped by a well, water in confined aquifers is forced up, sometimes above the soil surface. This is how a flowing artesian well is formed
Denitrification	to reduce (nitrates or nitrites) to nitrogen-containing gases, as by bacterial action on soil
Facies	a rock or stratified body distinguished from others by its appearance or composition
Hydrochemical	pertaining to the chemistry of the water
Physico-chemical	relating to both physical and chemical properties
Point source contamination	point source contamination of ground water refers to pollution from one place that is easy to identify, as this type of contamination is usually characterized by concentrated fertilizer or contamination plumes that are relatively localized

Diffuse source	Diffuse Pollution comprises true non point source contamination and contamination pollution arising from a multiplicity of dispersed, often individually minor, point sources
Recharge	Water added to an aquifer as when rainwater seeps into the ground. Recharge may occur artificially through injection wells or by spreading water over groundwater reservoirs
REDOX	Complementary chemical reactions characterized by the loss or gain, respectively, of one or more electrons by an atom or molecule

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TRC 2006. Taranaki Regional Council draft protocol for sampling groundwater. Unpublished standard operating procedure, February 2006. 151pp. TRC document number 117485.

Appendix I
Monitoring sites details

Site code	Site name	Locality	Well use	GPS reference		Aquifer name	Aquifer type	land uses within 1000 m radius of site	WQ data	
				East	North				From	To
GND0451	McCallum-2	Ohawe	irrigation	1701410	5617993	Whenuakura	Confined in sand	Dairy farming, some irrigated land. Some farm buildings & dwellings	Dec-94	Dec-07
GND0827	McCallum Well	Ohawe	domestic	1701591	5618033	Volcanics	Unconfined in sand		Dec-94	Dec-07
GND0563	Bayly	Toko	stock	1719027	5647305	Matemateaonga	Flowing artesian in sand	Dry stock & dairy farming, some farm buildings & dwellings	Dec-94	Dec-07
GND0430	Corrigan	Normanby	stock	1713802	5623656	Whenuakura	Confined in sand	Dairy farming, some farm buildings & dwellings	Dec-94	Dec-07
GND0508	Carrington Road	New Plymouth	monitoring	1694021	5669859	Volcanics	Unconfined in clay & alluvium	Dairy farming & horticultural some farm buildings & private dwellings	Dec-94	Dec-07
GND0122 ¹⁰	Eltham Dairy	Eltham	formerly dairy factory - <i>collapsed</i>	1715775	5632326	Matemateaonga	Confined in sand	Dairy farming, some farm buildings & dwellings	Dec-94	Apr-02

¹⁰ Well has been decommissioned since April 2002

