New Zealand National and Regional State of the Environment Aquifer Reporting

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ABSTRACT: Central and regional government agencies collaborate to monitor and report on the quality of New Zealand's groundwater resources. Measurements from around 1,100 water wells representing the main economic aquifers are collected each season and used to prepare regional or national reports on its state, and trends over time. New Zealand's groundwater quality is of a relatively high standard by international standards, but is influenced by human activities and can also be affected by naturally occurring degrading processes.

1 INTRODUCTION

New Zealand is located in the temperate latitudes and by international standards has an abundance of freshwater (MFE – 2007). However not all of it can be used as some needs to be left in rivers or lakes for ecological and natural character reasons.

In New Zealand, locally elected regional or catchment based councils issue consents to use freshwater under the auspices of the Resource Management Act (1991). Most of this consented water is used for crop irrigation in summer, followed in order of importance by municipal supply and then manufacturing. Small volumes for stock and domestic purposes are allowed as of right. A range of irrigated crops are grown in New Zealand including dairy pasture, horticulture, cereals, vegetables and grapes.

The majority of consents (66%) are sourced from groundwater, although volumetrically more water is drawn from rivers and lakes. Most of New Zealand's aquifers are associated with lowland river floodplains and are formed of alluvial gravels that are susceptible to surface contamination.

Groundwater quality remains high by world standards but is being influenced by intensive rural and urban landuses. Animal or human waste, fertilizers and urban stormwater runoff affect the quality of groundwater in these areas, although some is naturally of poor quality.

From a groundwater quantity or storage perspective, many of New Zealand's groundwater systems are approaching full allocation and careful management is needed to maintain consented use while providing for environmental flows.

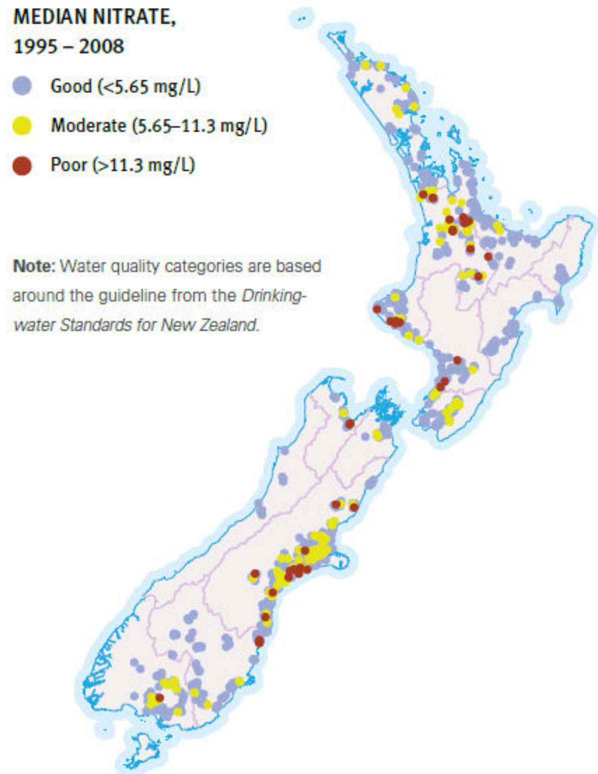

Fig. 1. Location of national groundwater sampling sites

2 BACKGROUND

Recognition of the importance of groundwater to New Zealand and increasing pressures on the resource, led to the first formal national report in 2007 on its state and trends over time. This was commissioned by the Ministry for the Environment and prepared by the Institute of Geological and Nuclear Sciences (GNS Science) to provide a national perspective.

It is based on information collected by the 15 regional councils responsible for water and environmental management, and represents a coordinated approach across all tiers of water resources management and research in New Zealand. This document was the first in a series that provide a national stocktake of the quality of New Zealand's groundwater resources.

To date the same level of analysis and reporting hasn't been applied at a national scale to the state and trends of groundwater storage or allocated use. The focus of this paper are the quality aspects of New Zealand's underground water resources.

3 GROUNDWATER QUALITY REPORTING IN NEW ZEALAND

State of the environment (SOE) reporting is now a commonly accepted method of evaluating environmental status at all levels of water management in New Zealand. It measures the performance of community plans and provides feedback so that practices affecting groundwater quality can be changed for the better. Resource information is key to sound water resource management.

Groundwater quality information originates from the National Groundwater Monitoring Programme (NGMP), and samples collected by regional councils for their local SOE reporting. It is a partnership between regional councils and GNS Science that started in 1990. Water quality is sampled at 1,100 wells representing New Zealand's main groundwater systems each season, where only the dissolved fraction is collected for analysis. Site locations are shown by Figure 1.

The advantages of this approach are standardized sampling procedures, analysis of samples at a single laboratory and reporting against thresholds that allow for a direct a comparison over time or between regions. The information is kept in perpetuity in a central archive that is available to the public. This is a successful template for an integrated approach to State of the Environment Reporting at all tiers.

4 METHODOLOGY

A base suite of 33 parameters are tested for each season across the NGMP network. Heavy metals, pesticides and other organic compounds are not measured as frequently. Murray Close, an environmental chemist at the Institute of Environmental Science and Research, coordinates the 4 yearly National Pesticide Survey (NPS).

Most regional councils participate in the NPS by collecting samples at vulnerable sites which are analysed at a central laboratory. Surveys began in 1990 and are designed to identify levels of pesticides in groundwater, trends over time and their risk factors for groundwater users.

In general pesticides have been detected at 20% of sites throughout the series of surveys, although the drinking water standards have only been exceeded on a few occasions. The most common type of pesticide detected are herbicides belonging to the Triazine family (Gaw, et al – 2008).

The quality of groundwater is determined by comparing the median measured value against two water quality guidelines. They are the Drinking Water Standards for New Zealand (DWSNZ), (Ministry of Health – 2005); and the Australia and New Zealand Environment Conservation Council (ANZECC) guidelines for fresh and marine water quality (Australia and New Zealand Environment Conservation Council – 2000).

Historically the quality of groundwater in New Zealand has focused on the water supply and human health aspects, but there is increasing weight on environmental thresholds, reflecting community aspirations. One of the difficulties from a national perspective of summarizing the quality of New Zealand groundwater systems is the diversity of natural chemical conditions, geology and landuses. For example nitrate-nitrogen levels are likely to be higher in shallow unconfined aquifers underlying dairy farms or market gardens, compared to deeper aquifers, where denitrification processes naturally reduce levels in groundwater.

5 NATIONAL STATE OF GROUNDWATER QUALITY

New Zealand groundwater chemistry is governed by both natural processes and human influences. In some cases human impacts from nutrients are disguised through natural degradation processes under some aquifer conditions.

Each of the recent reports commissioned by central government found that overall the quality of New Zealand groundwaters is similar to that of other countries, and identified two significant groundwater quality issues (MFE – 2007). They are:

1. Contamination with nitrate or microbial pathogens, especially in shallow unconfined aquifers
2. Naturally elevated concentrations of manganese, iron, arsenic or ammoniacal nitrogen, especially in deeper confined aquifers

(MFE – 2007) found that 39% of national monitoring sites showed significant levels of human influence, with the remainder either showing no evidence of human activities, or were oxygen poor aquifers with any influences degraded by natural processes. Naturally occurring problem species may also affect groundwater quality in this latter situation. These proportions are summarized in Figure 2.

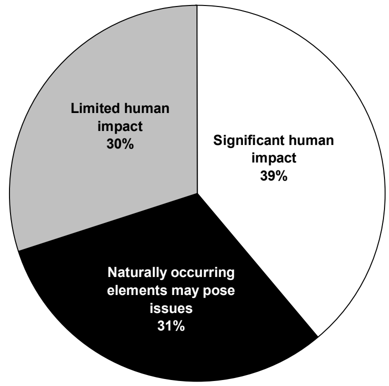

Fig. 2. Influences on New Zealand groundwater quality

(MFE – 2007) broke this down further based on the median concentration. Microbial contamination was present at 23% of sites, nitrate-nitrogen concentrations exceeded the ecological threshold (1.7 g/m^3) at 50% of sites, and at 5% of sites for the human drinking water standard (11.3 g/m^3).

Manganese levels exceeded the aesthetic guideline value (0.04 g/m^3) at 33% of sites and the human health limit (0.4 g/m^3) at 15% of wells sampled. Iron levels exceeded the aesthetic guideline (0.2 g/m^3) at 27% of sites, while ammoniacal-nitrogen exceeded the aesthetic threshold at around 4% of sites across the NGMP.

Measuring anomalies in groundwater quality is more straightforward than proving a link between its cause in terms of a particular landuse or source area. This reflects the isolating effect of aquifer confining layers from overlying landuses, and that underground water moves over large distances from where it may have acquired its chemical signature (Daughney et al – 2009).

6 NATIONAL TRENDS IN GROUNDWATER QUALITY

Time series of measurements from the National Groundwater Monitoring Programme allow trends in water quality to be quantified. Daughney & Randall (2009) found that groundwater quality at most sites is either constant over time or changing slowly as Figure 3 shows.

Rates of natural change in terms of median parameter values are small at less than 2-5% per year. Trends were identified using the Mann-Kendall test with a 95% confidence interval and the rate was assessed using Sen’s slope estimator (MFE – 2007).

More rapid change is linked to sites influenced by man-made impacts. Daughney & Randall (2009) found that the results appear similar to previous studies although the lack of uniformity made a direct comparison difficult. Quantifying trends has been complicated by some regional councils changing the makeup of their survey networks.

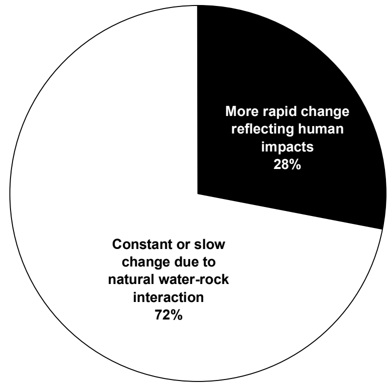

Fig. 3. Rates of national groundwater quality change

Daughney and Reeves (2005) devised a classification scheme for the drivers of change in New Zealand groundwater quality. Table 1 shows that the majority of sites exhibited little or no change and were dominated by natural processes.

The second category refers to the dilution of dissolved solids through younger groundwater being induced via pumping wells, and occurred at 10% of sites. An example of this will be described in the later section on Marlborough District groundwater quality.

The third category showed an improvement over time presumably due to reduced landuse contaminantion. The final class relates to a declining trend in groundwater quality and was seen at 12% of sites across the national network.

Table 1. National trend classification

Trend Category	**Rate of Change**	**Percentage of National Sites**
Natural water-rock interaction	No or slow rates of change	72%
Diluting	Decrease in total dissolved solids due to pumping induced changes	6%
Improving	Decreasing agricultural or human impact	10%
Degrading	Increasing human or agricultural impact	12%

Elevated levels of nitrate are linked with intensification of landuses in New Zealand, but MFE (2007) did not find a clear nationwide trend in nitrate concentration over time, with equal numbers of increasing and declining levels. However increasing trends in nitrate were more common in regions where intensification of agriculture was occurring.

7 STATE OF MARLBOROUGH DISTRICT GROUNDWATER QUALITY

We will now look at State of the Environment Reporting at a regional level, using Marlborough District as an example which is located at the top of the South Island as Figure 4 shows.

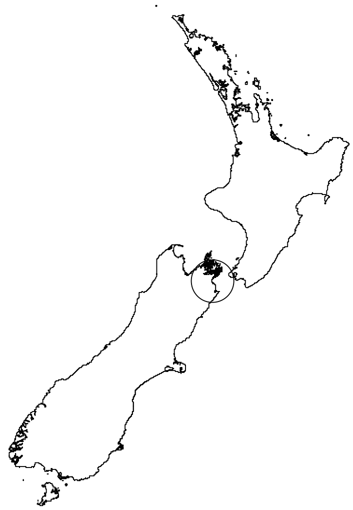

Fig. 4. Location map

Most of the economically important groundwater systems in Marlborough are formed of alluvial gravels with half representing insecure unconfined type aquifers, and the remaining confined aquifers. Hydrochemistry varies significantly from site to site. (Daughney - 2004).

The Marlborough District Council manages local freshwater resources and collects samples from 8 wells as part of the National Groundwater Monitoring Programme, alongwith a further 15 each season. Although groundwater quality information has been collected and reported on for decades, it is only now being formally reported to the Council in a quantitative way that mirrors the national template.

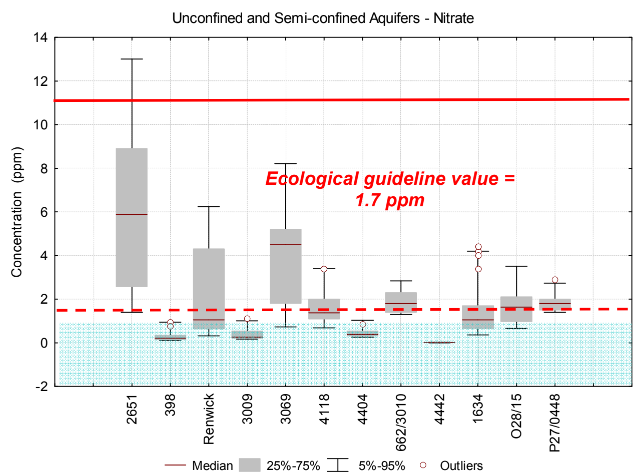

Fig. 5. Unconfined aquifer nitrate-nitrogen concentrations

The method used to assess groundwater quality involves comparing the median measured values across the regional sampling network with the two thresholds. Nitrate-nitrogen is used as an example in this paper because it has multiple thresholds, and behaves differently depending on aquifer type and the redox potential of local groundwater.

Figures 5 and 6 show the distribution of nitrate-nitrogen concentrations from unconfined and confined Marlborough aquifers respectively. The solid line represents the human health threshold (DWSNZ – 2005) and the dashed line the interim New Zealand derived ecological limit designed to protect the ecological values of aquifer fed springs (ECAN – 2009).

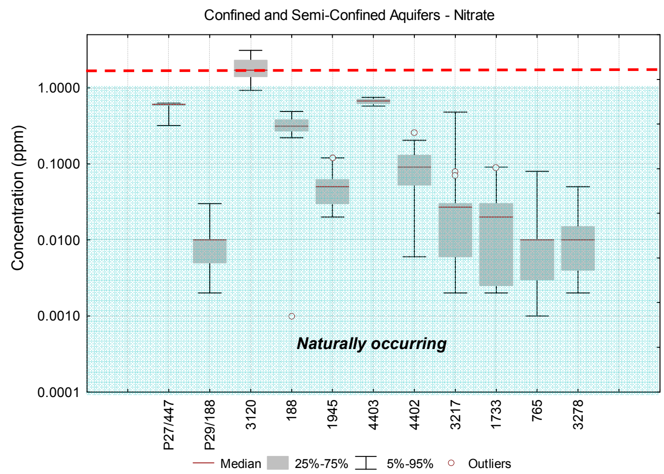

Fig. 6. Confined aquifer nitrate-nitrogen concentrations

Table 2 shows that the median concentration across all 23 Marlborough sites was below the maximum allowable value (MAV) of 11.3 g/m^3 in the Drinking Water Standards, and the groundwater is safe to drink. However 6 sites had median nitrate concentrations that exceeded the lower ecological concentration of 1.7 g/m^3. This can potentially cause eutrophication of hydraulically connected springs.

Table 2. Nitrate-nitrogen suitability summary

Year	DWSNZ 2005 Maximum allowable value = 11.3 g/m^3	ECAN 2009 Ecological protection guideline value = 1.7 g/m^3
	Number of sites exceeding	Number of sites exceeding
Up to 2009	0	6

Nitrate-nitrogen levels tend to become lower over time in confined aquifers due to natural denitrification processes, and occur at higher concentrations in unconfined type aquifers where the bulk of exceedances occur. The shading represents what is considered to be naturally occurring nitrate levels.

8 TRENDS IN MARLBOROUGH GROUNDWATER QUALITY

The level of Marlborough groundwater parameters such as nitrate-nitrogen appear to be relatively constant over time based on a small number of datasets, some with intermittent observations. This suggests that fertilizer application rates have not changed significantly following the widespread conversion to vineyard since the mid 1980's.

The approach used at a regional level was to first identify potential trends over time by graphing the results, and then using Sen's slope method to test whether it is significant at a 95% confidence level, and if so quantifying the magnitude of the change per year.

Nitrate-nitrogen levels are of special interest given the widespread pattern of conversion to vineyard in lowland Marlborough. Figure 7 shows a time series of nitrate-nitrogen concentrations taken from a well underlying irrigated vineyard over the period of a decade. While there is an apparent trend, the Time Trends (NIWA – 2009) analysis package showed it wasn't significant at a 95% confidence level.

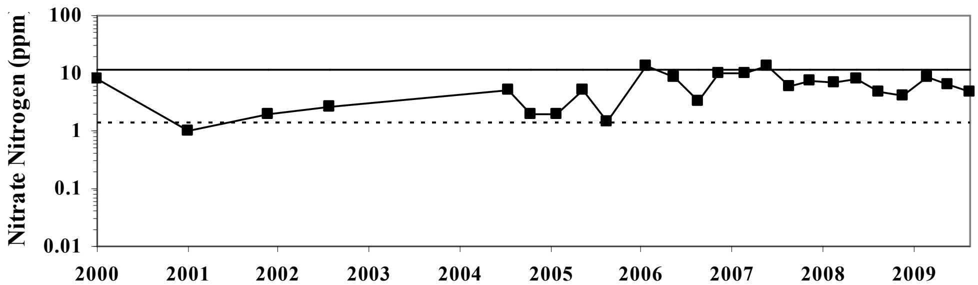

Fig. 7. Unconfined aquifer nitrate-nitrogen concentrations at well 2651

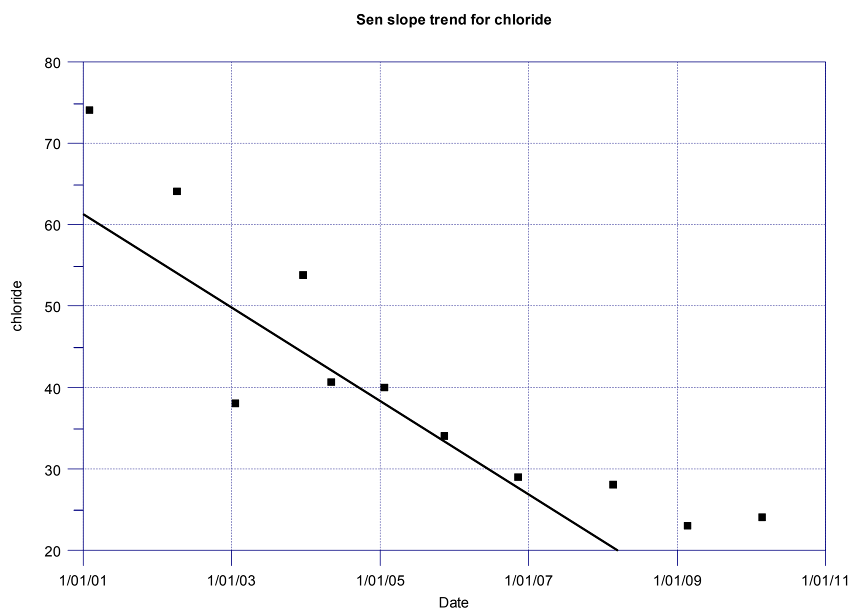

Fig. 8. Coastal confined aquifer chloride concentrations at well 3667

Another issue facing Marlborough District Council is seawater intrusion of coastal water wells and it operates a network of coastal sentinel wells to provide early warning. Figure 8 shows the variation in chloride concentration at a 40 metre deep well (3667) over a period of a decade from 2000.

Chloride is a prime indicator of seawater, and a statistically significant decline exists of about 5 g/m^3/year. This improvement in groundwater quality has been attributed to the significant increase in irrigation demand from this aquifer inducing younger water into this boundary area from the recharge zone.

9 CONCLUSIONS

SOE reporting relies on continuity of record at a stable number of monitoring sites. For information to be comparable between regions and eras, it must be collected in exactly the same manner over time. The template produced by GNS Science on behalf of MFE is useful for all tiers of government and the initial report provides a benchmark.

10 REFERENCES

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