State of the Environment Report

GROUNDWATER QUALITY IN TASMAN DISTRICT 2010

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October 2010

A technical report presenting results of the Tasman District Council's "State of the Environment" Groundwater Quality Monitoring Programme. The report draws on various monitoring data collected by Tasman District Council, including that collected for the Institute of Geological and Nuclear Sciences Ltd as part of the National Groundwater Monitoring Programme.

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EXECUTIVE SUMMARY

The Resource Management Act (1991) requires Council to monitor and report on the state of the environment within its territorial boundaries. This report presents the findings of Council's groundwater quality State of the Environment Monitoring (SEM) programme.

Council's groundwater quality SEM programme commenced in 1990 with seven sites and now comprises 16 sites that are sampled quarterly (every 3 months) for a range of standard parameters. In addition, Council collects other miscellaneous groundwater quality data across the District from time to time. These data have also been incorporated into this report.

Overall, groundwater across the District is of high quality and reflects natural variations in the respective geological composition and settings of the various aquifers.

However, in places groundwater quality also reflects influences from human activities. In general, the more intense the land use, be it agricultural, horticultural or residential, the greater the likelihood of non-natural human influences on groundwater quality being apparent. Typically this is observed as elevated nutrient concentrations (primarily nitrates). In all bores sampled since 2000 across the District, but excluding those on the Waimea plains east of the Waimea River, the median nitrate concentration is 1.1 g/m^3-N which is below the national median of 1.7 g/m^3-N.

Monitoring of groundwaters in the Waimea plains east of the Waimea River since the 1970's has shown elevated nitrate concentrations in many places (both in the confined and unconfined aquifers). The median nitrate concentration of the sampled bores in the Waimea plains east of the Waimea River is 11.0 g/m^3-N. This contamination includes historic sources of nitrate which has been decreasing over time. However, the continuing elevated nitrate concentrations may mask inputs occurring from current land uses.

Most parameters at most of the 16 regularly monitored SEM sites are relatively stable and statistically not showing any significant trends. There are decreasing trends over a number of parameters, including nitrate, in the Upper Confined Aquifer of the Waimea plains indicating a strong dilutional trend. In the Lower Confined Aquifer of the Waimea plains there appears to be a corresponding increase in measured concentrations in a number of parameters, though nitrate concentrations show a weak decreasing trend. Three other SEM sites (all shallow unconfined gravel aquifers) showe some increases in nitrates and/or sulphates though with much variability.

Naturally elevated iron and manganese concentrations are present at a number of sites across the District. Such concentrations are typical of much groundwater throughout New Zealand and reflect a combination of minerals rich in these elements and reducing (anaerobic) conditions within the aquifer.

Bacterialogical contamination of groundwater across the District is low. Where present, such sites are generally in shallow unconfined aquifers with inappropriate surrounding land use and/or inadequate separation distances from potential contaminate sources such as chicken coups, stock water troughs (where animals congregate) or wastewater disposal facilities etc.

Pesticide monitoring has been undertaken at 15 sites. The most recent survey (2006) shows very low concentrations (i.e. considerably lower than the respective drinking water standards) present at five sites. At the remaining 10 sites no pesticide residues were detected.

That Council continues with its groundwater SEM programme is a recommendation of this report.

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LIST OF ABBREVIATIONS

ESR	Environmental Science and Research Ltd
GNS	Institute of Geological and Nuclear Sciences Ltd
NGMP	National Groundwater Monitoring Programme
RMA	Resource Management Act
SEM	State of the Environment Monitoring
TDC	Tasman District Council
TRMP	Tasman Resource Management Plan

AGUA	Appleby Gravel Unconfined Aquifer
LCA	Lower Confined Aquifer
UCA	Upper Confined Aquifer

Br	Bromide
Ca	Calcium
Cl	Chloride
DRP	Dissolved reactive phosphorus
E. coli	a faecal indicator bacteria
Fe	Iron
HCO_3	Bicarbonate
K	Potassium
Mg	Magnesium
Mn	Manganese
Na	Sodium
NH_4-N	Ammonium nitrogen
NO_3-N	Nitrate nitrogen
SO_4	Sulphate
TDS	Total Dissolved Solids

STATEMENT OF DATA VERIFICATION AND LIABILITY

Tasman District Council recognises the importance of good quality data. This assessment of groundwater quality across the District's principal aquifers provides interpretation of results from the Council's groundwater quality monitoring programme and other relevant data available at time of producing the report. Data collection and management systems follow systematic quality control procedures. International Accreditation New Zealand (IANZ) laboratories carried out sample analysis excluding field analysis.

While every attempt has been made to ensure the accuracy of the data and information presented, Tasman District Council does not accept any liability for the accuracy of the information. It is the responsibility of the user to ensure the appropriate use of any data or information from the text, tables or figures. Not all available data or information is presented in the report. Only information considered reliable, of good quality and of most importance to the readers has been included.

1 Introduction

Groundwater is an important resource in Tasman District. It is extensively used for drinking water supplies, irrigation, stock water and industry. Groundwater provides an important contribution to surface water bodies being the major contributor to base flows in rivers and streams. At some locations natural groundwater discharges occur via flowing springs, an obvious example being Te Waikoropupu Springs in Golden Bay.

The usefulness of a particular groundwater for a particular purpose is not only determined by its availability, but also by its quality. Obviously drinking water needs to be of potable quality, but other groundwater uses, such as irrigation, can have differing water quality requirements.

Tasman District Council (the Council) monitors groundwater quality to fulfil its responsibilities under the Resource Management Act (RMA 1991) and the Tasman Resource Management Plan (TRMP). Section 30 of the RMA (1991) imparts to Regional Authorities, which includes Unitary Authorities such as Tasman, a function of maintaining and enhancing the quality of natural waters (including groundwater) and directs councils to gather information so that they can effectively carry out these functions (Section 35).

The TRMP identifies the potential degradation of groundwater quality as an issue and seeks to maintain and improve groundwater quality.

Council's groundwater quality monitoring programme aims to gather appropriate data to fulfil these responsibilities. The groundwater quality monitoring programme forms part of the Council's broader State of the Environment Monitoring programme (SEM).

The specific aims of the groundwater quality monitoring programme include:

1. To determine the chemical quality of groundwaters in the District's aquifers with reference to accepted standards and comparison to groundwater from elsewhere in New Zealand.

2. Where data allows, identify trends over time in groundwater quality.

3. Where data allows, identify spatial variations in groundwater quality.

4. To identify factors that may cause changes in groundwater water quality.

5. To better understand the nature of groundwater quality issues and the factors that may cause changes in groundwater water quality in order to facilitate better management of the District's land and water resources. This may include input to reviews of Council resource management plans, regulations, and resource consent conditions.

6. To identify new issues and monitoring requirements.

1.1 Groundwater Quality

The quality of a particular groundwater is the result of the groundwater's movement from the surface into and through the sub-surface and is a reflection of the chemical influences that occur along the way. This includes natural processes as well as influences from human activities and land use.

Human influences typically result from land use and surface activities in the groundwater recharge areas. The extent that a particular groundwater environment is susceptible to surface influences will depend on the nature of the aquifer (including its depth) and its degree of confinement.

Natural processes are dominated by the types of rock that make up the aquifer and their respective chemical compositions and how long the groundwater remains in contact with the rock material.

Natural processes within the aquifer are primarily reflected by changes in the total dissolved solids concentrations, the cation and anion ratios and the groundwaters redox state (i.e. its oxidation−reduction potential). Whereas human influences on groundwater quality are usually indicated by elevated concentrations of nitrate and sometimes relatively high concentrations of potassium, sulphate and/or chloride (MfE 2007). Bacteriological contamination can also be an indicator of human influence on groundwater.

2 Tasman's Principal Groundwater Environments

Groundwater is found in a range of different subsurface environments across the District. It is not the intention of this report to provide a detailed physical description of the District's aquifer systems. Rather, the following is a broad categorisation of the principal groundwater environments found in the Tasman District, namely:

- Unconfined alluvial aquifers
- Confined alluvial aquifers
- Sedimentary rock aquifers
- Karst aquifers

Figure 1 shows the locations of bores across the District (as recorded on Council's database). The distribution of the bores gives a good indication of where groundwater is used. Majority of the bores shown are in unconfined aquifers.

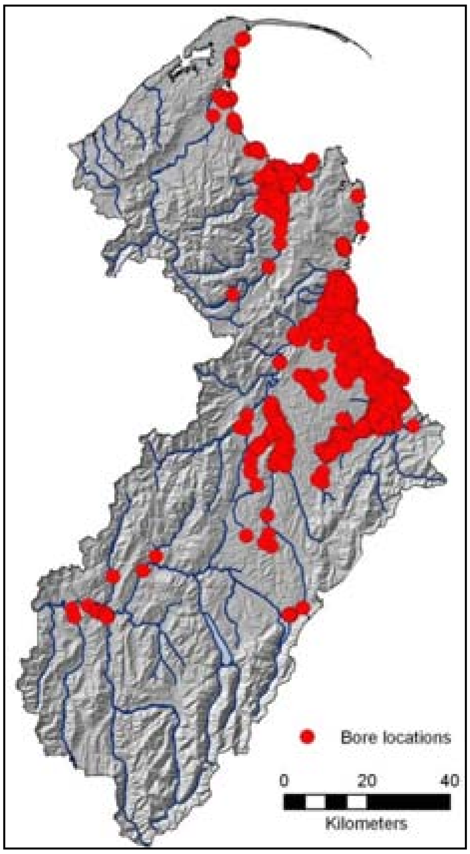


Figure 1 Bore locations across the Tasman District.

2.1 Alluvial Aquifers

The flood plains adjacent to the lower reaches of the principal rivers in the District contain extensive alluvial gravel and sand deposits. Groundwater is present within these strata in varying quantities depending on the extent and permeabilities of the respective strata.

2.1.1 Unconfined Alluvial Aquifers

An unconfined aquifer is where permeable strata are open to the ground surface. Rainfall can soak down directly though the soil layers recharging the underlying groundwater. Consequently, land use activities above such aquifers can influence the quality of the groundwater below. Extensive use (such as for irrigation, stock water, domestic supply) is made of groundwater from the unconfined alluvial aquifers across the District.

Unconfined groundwater is also found elsewhere in the District, such as within the accumulated silts and sands of valley floors (e.g. the Moutere valley) and the sandy coastal plains of Tasman and Golden bays, typically at depths of less than 10 metres. However, whilst present, such groundwater may not always be available in usable quantities. Use of these shallow unconfined aquifers is often for domestic supply and/or stock water rather than irrigation.

2.1.2 Confined Alluvial Aquifers

A confined aquifer is where permeable water bearing strata is separated from the land's surface above by an impermeable layer (typically silt and/or clay layers). As such, confined aquifers are not directly affected by land use activities directly above them. Confined aquifers will have an unconfined recharge area somewhere and hence can still be influenced by surface activities to some extent. The longer flow paths from the recharge areas result in longer residence times for groundwater within confined aquifers. This in turn allows the groundwater to be subject to greater chemical interaction with the rocks of the aquifer formation. The Waimea plains contain two essentially confined alluvial aquifers, the Upper Confined Aquifer (UCA) and Lower Confined Aquifer (LCA) though the confining layers can be somewhat leaky in places. In Golden Bay the deep karst aquifers, whose discharge includes Te Waikoropupu Springs, are confined. The deep sedimentary aquifers of the Moutere Gravels are also confined.

2.2 Sedimentary Rock Aquifers

Usable quantities of groundwater are found in some of the District's sedimentary rocks. In particular, the Moutere Gravel formation (clay bound gravels with deeply weathered clasts) contains several deep confined aquifers. The Moutere Gravel formation differs from the more recent alluvial gravel and sands of the rivers and their floodplains in that they are geologically older and have weathered and consolidated over time into a relatively cohesive rock unit. Their permeability is limited to that of the clayey matrix that surrounds the gravels. In contrast the more recent alluvial gravels and sands are only loosely consolidated, if at all, and are significantly more permeable.

Whilst other sedimentary rocks present in the District such as Tertiary sandstones and mudstones may contain groundwater, it is typically not in useable quantities and, for all intents and purposes, not utilised.

2.3 Karst Aquifers

Karst aquifers are formed within limestone and marble rocks. Karst aquifers have a significant secondary porosity as a result of fractures and gradual solution processes enlarging fissures and passageways through the rock mass (including the formation of cave systems). Groundwater movement is dominated by flow through these enlarged pathways rather than diffuse flow through the rock matrix (the primary porosity). Consequently, karst aquifers typically have shorter residence times and high through flow rates. Recharge can be rapid such as where surface streams flow directly into cave systems. Karst aquifers can be confined and unconfined. Te Waikoropupu Springs and the Riwaka resurgence are examples of natural discharges from karst aquifers.

3 Tasman's Groundwater Quality Monitoring Programme

Tasman District Council's groundwater quality State of the Environment Monitoring program (SEM) comprises quarterly monitoring of 16 sites across the District. Monitoring commenced in 1990 with seven sites. Another site was added in 1992 and two more in 1996. The programme was further expanded in 2000 with the addition of a further six sites bringing the total to 16. Ten of these 16 sites are also part of the New Zealand National Groundwater Monitoring Programme coordinated by the Institute of Geological and Nuclear Sciences.

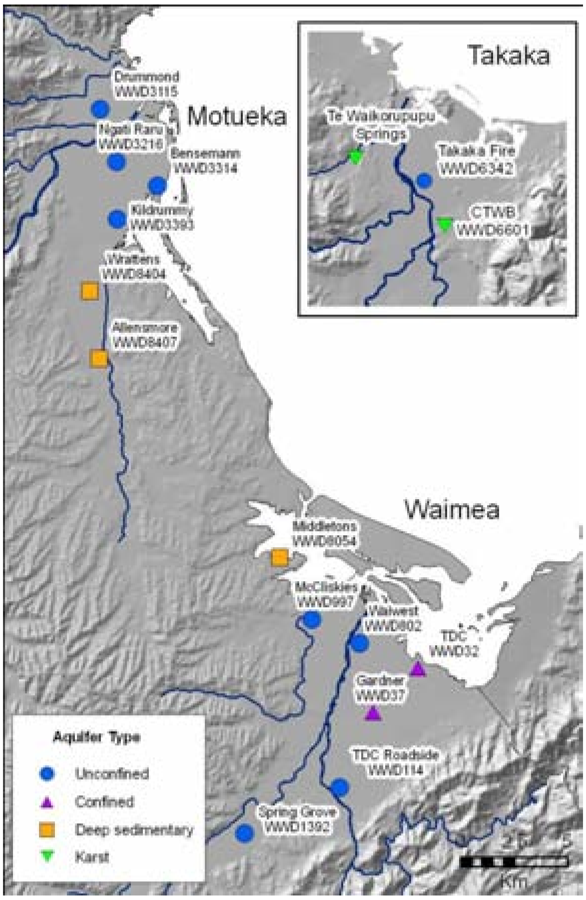


Figure 2 Groundwater quality monitoring programme sampling sites – Tasman District.

The 16 SEM sites are distributed across the District's groundwater environments as follows (Figure 2):

- unconfined alluvial aquifers (9 sites);
- confined alluvial aquifers (2 sites);
- confined sedimentary aquifers (3 sites); and
- karst aquifers (2 sites).

Groundwater at these sites is sampled quarterly and analysed for a range of standard water quality parameters (listed in Appendix I). Graphs of the measured concentrations over time for selected parameters are contained in Appendix III.

Previously, GNS have reviewed and analysed the data collected up until December 2004 from all 16 quarterly monitored SEM sites (Daughney 2005). This review included a regional analysis based on the chemical characteristics of the groundwater and a hierarchical cluster analysis which allowed the 16 sampled groundwaters to be grouped based on their various statistical thresholds.

Also a number of distributional parameters were calculated, namely:

- median
- median absolute deviation (MAD)
- trend
- deviation in the trend

The results were compared with other groundwaters throughout the country that are part of the NGMP.

For this report the distributional parameters have been recalculated to include subsequent data (up to December 2009) using an automated spreadsheet specifically developed by GNS (Daughney 2007) to undertake such calculations on water quality data. A tabulated summary of the median, MADs and trends for the key geochemical parameters is presented in Appendix II.

3.1 Regional Analysis and Hierarchical Cluster Analysis – SEM Sites

The groundwater type was determined by GNS (Daughney 2005) based on the median concentrations of the major cations and anions and a hierarchical cluster analysis to partition the 16 sites into various categories. This partitioning is based solely on the chemical characteristics of the groundwater and is independent of the physical setting of the site (i.e. the particular aquifer characteristics). The determined partitions are summarised in Table 1 (adapted from Daughney 2005).

A total of six clusters were identified determined by up to three separation thresholds. At the highest separation threshold, the 16 sites are separated into two groups, essentially based on their redox potential. That is, groundwaters characterised by aerobic (oxidising) conditions (12 sites) and groundwaters characterised by anoxic (reducing) conditions (4 sites). Further separation thresholds, though less distinct, are also identified.

Daughney (2005) notes that all three separation thresholds are relatively small compared against all of the groundwaters across the country assessed in the NGMP. This means that the 16 Tasman SEM sites overall are characterised by relatively similar groundwater chemistry compared to the variations seen nationally.

The sites characterised by anoxic conditions typically have elevated dissolved iron and manganese concentrations. Nitrogen does not persist in the form of nitrate under such conditions, but rather accumulates in the form of ammonium. Of the four sites that are in this cluster, three are from the Moutere aquifer. This is not unexpected as the Moutere aquifers are deep, confined and their groundwaters are typically slow moving with long residence times.

The fourth site (WWD 3115 Drummond), an unconfined gravel aquifer on the Riwaka plains, is where the immediate surrounds were historically dominated by swamps and peaty deposits. The decay of organic matter is likely to have contributed to the anoxic conditions encountered there.

Table 1: Hierarchical cluster analysis for the 16 Tasman groundwater SEM sites

Cluster[1]	Cluster characteristics		SEM site (aquifer type)
TDC-1A-1	Anaerobic (oxidised) groundwaters	• moderate TDS (approx 150 g/m^3), • relatively high concentrations of Cl, Mg, Na, SiO_2, SO_4 in response to aquifer lithology (gravels in Motueka and the Waimea Plains), • evidence of human/agricultural impact with NO_3-N concentrations typically above 2 g/m^3.	WWD114 (Waimea, gravel, unconfined) WWD997 (Waimea, gravel, unconfined) WWD1392 (Waimea, gravel, unconfined) WWD3314 (Motueka, gravel, unconfined) WWD3393 (Motueka, gravel, unconfined)
TDC-1A-2		• moderate TDS (approx 150 g/m^3), • relatively high concentration of HCO_3, perhaps due to greater degree of water-rock interaction.	WWD32 (Waimea, gravel, confined - LCA) WWD37 (Waimea, gravel, confined - UCA) WWD802 (Waimea, gravel, unconfined) WWD3216 (Motueka, gravel unconfined)
TDC-1B		• moderate TDS (approx 150 g/m^3), • relatively high concentrations of Ca and HCO_3 in response to aquifer lithology (carbonates in the Takaka sub-region).	WWD6342 (Takaka, gravel, unconfined) WWD6601 (Takaka, limestone, confined)
TDC-1C		• high TDS (>400 g/m^3) – significant saline water influence.	Te Waikoropupu Springs (Takaka, marble, confined)
TDC-2A	Anoxic (reduced) groundwaters	• slightly lower TDS (than cluster TDC-2B).	WWD8054 (Moutere, sedimentary, confined) WWD8407 (Moutere, sedimentary, confined)
TDC-2B		• slightly higher TDS (than cluster TDC-2A), • slightly higher concentrations of Fe, Mn and NH_4-N (than cluster TDC-2A).	WWD3115 (Motueka, gravel, unconfined) WWD8404 (Moutere, sedimentary, confined)

[1] Nomenclature from Daughney 2005

3.2 Median Concentrations – SEM Sites

The median values of the various parameters (Appendix II) by in large reflect the characteristics of the respective aquifer geology and the degree of groundwater / rock interaction. The observed median concentrations of some parameters, notably nitrates, reflect human influence at some sites.

All three Golden Bay monitoring sites have higher calcium and bicarbonate concentrations than those of the Motueka and Waimea plains. This is attributed to a greater proportion of carbonate rocks present within the Golden Bay aquifers. Conversely, the monitoring sites in the Motueka and Waimea plains have higher concentrations of chloride, magnesium, sodium, silica and sulphate which are a reflection of their respective aquifer lithologies.

WWD 3314 has a relatively high median sulphate concentration, largely due to elevated concentrations that occurred for a period in the late 1990's and early 2000's during a period when the surrounding land was redeveloped with land use changed from kiwi fruit to residential. Subsequent sulphate data is now similar to the other Motueka SEM sites.

Groundwater discharging from Te Waikoropupu Springs is distinctive for its higher chloride, sodium and total dissolved solids concentrations due to saline water influence. It is postulated that a degree of mixing occurs due to a venturi effect with deeper saline groundwater (Thomas 2001).

The Moutere Gravel aquifers with their longer residence times, and hence greater degree of groundwater/rock interaction, typically have higher total dissolved solid concentrations compared to the other monitored Tasman groundwaters.

The total dissolved solids and bicarbonate concentrations in the alluvial confined aquifers (WWD 37 Gardner and WWD 32 TDC) indicate a greater degree of groundwater-rock interaction than in the adjacent unconfined alluvial aquifers.

3.2.1 Median Nitrate Concentrations – SEM Sites

Nitrate inputs to Tasman groundwaters most likely occur from fertiliser use in excess of plant/soil needs and/or the discharge of nutrient rich effluents (such domestic wastewater or farm dairy effluent) to land in a manner where leaching to the underlying aquifer may occur. Intensive stocking rates (such as with dairy farming) can also result in elevated nitrate inputs to underlying aquifers.

In New Zealand nitrate concentrations over 1.6 g/m^3-N are probably indicative of human influence and concentrations above 3.5 g/m^3-N are almost certainly indicative of human impact (Daughney and Reeves 2005). On this basis the following Tasman SEM sites are considered to have median nitrate concentrations that reflect human activities:

- WWD 37 Gardner (19.8 g/m^3-N)
- WWD 32 TDC (13.1 g/m^3-N)
- WWD 1392 Spring Grove (5.6 g/m^3-N)
- WWD 3393 Kildrummy (5.6 g/m^3-N).

WWD 32 (LCA) and WWD 37 (UCA) are confined alluvial aquifers within the Waimea plains. The observed nitrate concentrations may reflect historic point source contamination (a piggery and intensive market gardening were historically located in the recharge area of the UCA). The current land use surrounding WWD 1392 and WWD 3393 is pasture and orcharding respectively.

Also showing a lesser impact, but one still likely to reflect a degree of human influence are:

- WWD 997 McCliskies (3.7 g/m^3-N)
- WWD 3216 Ngati Raru (2.5 g/m^3-N)
- WWD 6601 CTWB (2.1 g/m^3-N)
- WWD 802 Waiwest (2.0 g/m^3-N).

With the exception of WWD 6601 these are all surrounded by intensive horticulture (orcharding), though WWD 802 may also reflect to some extent market gardening and glass houses located to the south.

WWD 6601 is a karst aquifer where groundwater movement is expected to be dominated by conduit flow through fractures and/or cavities within the rock mass, often unrelated to the surface topography. This can make identifying the specific recharge area of a particular site problematic. The immediate vicinity of WWD 6601 the aquifer is confined by a layer of mudstone. However, it is possible that the groundwater encountered in WWD 6601 has rapidly travelled from some distance away. Whilst dairying is the predominant surrounding land use, there are a number of residential houses in the more immediate vicinity. Sewage reticulation was only extended to these houses in 2005. It is not possible to comment further on potential sources of the observed nitrate concentrations in WWD 6601 without additional investigation.

The remaining eight SEM sites have median nitrate concentrations consistent with groundwater unaffected by human activities. Four of these sites encounter anaerobic (reduced) groundwater conditions where if nitrate were present in the aquifer it will be readily converted to ammonium via denitrification processes.

Three of these four anaerobic sites (WWD 8054, WWD 8404 and WWD 8407) are in the deep Moutere Aquifers and, given the groundwater's long residence time and the historic land use in the recharge area (extensive pastoral farming and forestry), are expected to be un-impacted by human influences.

The fourth site (WWD 3115) is shallow unconfined groundwater where the surrounding land use is orcharding. Historically the immediate surrounds of this site were dominated by swamps and peaty deposits. The decay of organic matter within the surrounding aquifer is the most like contributor to the observed anoxic groundwater conditions. Whilst only low nitrate concentrations are observed at this site, it is possible that it is influenced to some extent by human activities and that such impacts are masked by denitrification processes.

Whilst overall WWD 3314 has a low median nitrate concentration (0.9 g/m^3-N), there was a period during the late 1990's where it was measured at concentrations as high as (9.8 g/m^3-N). This coincided with a period when the surrounding kiwi fruit was removed and the area redeveloped for residential land use. Since this time nitrate concentrations have returned to low concentrations.

3.2.2 Comparison of Tasman District's Median Concentrations to other New Zealand Groundwaters – SEM Sites

Daughney (2005) has compared the 16 monitored sites in Tasman District with the other groundwaters in New Zealand that are sampled as part of the NGMP. In general, most of the monitored parameters in Tasman have similar median concentrations to groundwaters across New Zealand as a whole.

Median concentrations of calcium, magnesium and bicarbonate are slightly higher in the Tasman SEM sites compared to the NGMP sites as a whole, whereas the median concentrations of sodium and chloride are slightly lower. This is attributed to the greater prevalence of carbonate-dominated groundwaters arising from the marble and limestone geology present in parts of Tasman compared to the NGMP sites.

The Tasman SEM sites also have higher magnesium-to-calcium ratios than most groundwaters sampled through the NGMP. This is probably due to the relatively common occurrence of basic igneous rock clasts within the alluvial aquifers of the Waimea Plains and the Motueka catchment. Sources of such rock clasts include the Dun Mountain/Red Hills ultramafic mineral belt in the Richmond Ranges.

The median nitrate concentration of all the Tasman SEM sites (2.1 g/m^3-N) is higher than the national median of the NGMP (1.7 g/m^3-N, Daughney and Randle 2009). However, the median for Tasman District is skewed by the particularly high nitrate concentrations encountered in two sites (WWD 32 and WWD 37). When these two sites are excluded, the median nitrate concentrations from the remaining Tasman SEM sites is 1.0 g/m^3-N (and less than the national median).

3.2.3 Comparison of Tasman's Median Concentrations with New Zealand's Drinking Water Standards – SEM Sites

The Ministry of Health's NZ Drinking Water Guidelines (2005) provide maximum allowable values (MAV) and guideline values (GV) for drinking water in New Zealand for various parameters. The MAVs are health based and the GVs are typically aesthetic based (odour or taste) and/or seek to avoid nuisance effects such as staining, the build up of scale or excessive corrosion of pipes.

Overall, the median concentrations of the tested parameters at the 16 SEM sites are below (i.e. comply with) the respective drinking water MAVs and GVs. The exceptions being:

- pH (8 sites)
- Iron (4 sites)
- Manganese (3 sites)
- Nitrate (2 sites)

The NZ drinking water GV for pH is that it falls between 7.0 and 8.5 pH units. This is primarily for aesthetic reasons, which include the avoidance of corrosion of plumbing. There are seven sites that have median pH values below 7.0 (with the lowest median pH being 6.4). There was one site with a median pH marginally above the maximum guideline (WWD 8407, 8.1).

Groundwaters with a pH of less than 7.0 are not uncommon in New Zealand. A national review of New Zealand groundwater quality (Daughney and Randle 2009) note that 71% of sampled groundwaters in New Zealand do not meet the NZ drinking water GV for pH. Whilst such pH values may be problematic for some water supplies, they are not considered a pervasive environmental issue.

Elevated dissolved iron and manganese concentrations in groundwater present a nuisance issue long before they present a health issue. The GVs for iron and manganese for New Zealand drinking water are 0.2 and 0.04 g/m^3 respectively and seek to avoid the staining of laundry and sanitary ware. Higher concentrations of manganese can present a health risk and have a MAV of 0.4 g/m^3. There is no MAV for iron. WWD1392 (0.7 g/m^3), WWD3115 (1.3 g/m^3), WWD3314 (1.2 g/m^3) and WWD8404 (3.2 g/m^3) all had median iron concentrations above the GV. WWD 3115 (2.6 g/m^3) had a median manganese concentration higher than the health based MAV.

There were two sites, WWD 32 (13.1 g/m^3-N) and WWD 37 (19.8 g/m^3-N), where the median nitrate concentrations exceed the drinking water MAV of 11.3 g/m^3-N. There are another two sites, WWD 1392 and WWD 3393 (both 5.6 g/m^3-N) with median nitrate concentrations close to 50% of the MAV.

3.2.4 Variability of Median Values – SEM Sites

The median absolute deviation (MAD) is a measure of the variability in the sampled data from its median value. Appendix II contains a list of selected parameters and their respective MADs and the trend over time of the medians for the 16 SEM sites.

Daughney (2005) arbitrarily identifies sites with a low variability as ones where the MAD is less than 10% of its corresponding median, noting there are three situations that give rise to high relative variability. These are discussed in turn.

Firstly, a number of parameters display high variability simply because they have very low median concentrations such that any measurable variability appears significant in comparison. This is the case for iron, manganese, ammonium, bromide, fluoride, nitrate, phosphate, and to a lesser extent potassium, at most sites.

Secondly, and more importantly, is where relatively high variabilities are indicative of non-secure groundwater sites. That is, sites whose groundwater chemistries are readily influenced by surface water, climate, and/or adjacent land use activities.

Of the 16 SEM sites, both WWD 802 (Waiwest) and WWD 3314 (Bensemann) stand out as having a number of parameters whose median concentrations display relatively high variability (in particular calcium, magnesium, potassium, sodium, chloride, sulphate, bicarbonate and electrical conductivity). Both of these bores are shallow (8.0 and 6.2 m deep respectively) and penetrate unconfined gravel aquifers. As noted subsequently in section 3.3 WWD 3314 has been deteriorating over time and it has now been replaced with a newly installed bore.

The third cause of variability is only seen at Te Waikoropupu Springs and is a reflection of the natural saline influence (high and variable sodium and chloride concentrations) in the spring's discharge (Thomas 2001). All other attributes of the Te Waikoropupu Springs discharge indicate that it is a secure groundwater site.

Other bores that show lesser, but still significant, variability in their monitored parameters are:

- WWD 114 TDC Roadside
- WWD 1392 Spring Grove
- WWD 3115 Drummond
- WWD 3393 Kildrummy
- WWD 3216 Ngati Raru

These are all relatively shallow (9.4 to 14.5 m deep) bores in unconfined alluvial gravel aquifers.

The data from two of the sites in confined aquifers (WWD 37 Gardner and WWD 6601 CTWB) similarly show lesser, but still significant, variability in their monitored parameters. WWD 37 is in the Upper Confined Aquifer of the Waimea plains and being a confined aquifer it is expected to be a secure groundwater site. The apparent variability in some parameters (calcium, magnesium and bicarbonate in particular) is more likely a reflection of the strong decreasing trends in some parameters (see Section 3.3) occurring over time rather than an indication of the site's security.

WWD 6601 (CTWB) is a 54.6 m deep bore penetrating overlying impermeable mudstone into the limestone aquifer below. However, whilst the immediate surrounds of the site are confined, karst aquifers typically have significant secondary porosities and fast through flow rates. Consequently, such a site may not be as secure as a similarly confined alluvial gravel aquifer.

The bores that show the least variability, which would indicate that they are more secure, are:

- WWD 8054 Middletons
- WWD 8404 Wrattens
- WWD 8407 Allensmore
- WWD 32 TDC

The first three of these sites are deep confined aquifers with long residence times within the Moutere Gravels. The latter is in the Lower Confined Aquifer of the Waimea plains. Whilst seemingly secure, this site has still been impacted by nitrate contamination (see section 3.2.1).

3.3 Trends in Monitored Parameters – SEM Sites

A measure of the trends over time in the monitored parameters for the 16 SEM sites is included in Appendix II. Similar to the MADs, Daughney (2005) arbitrarily identifies a trend as significant where it is more than 10% of the corresponding median and significant at the 95% confidence level. However, as with the MADs, this measure of significance can be skewed when the median values are low. This is the case for iron, manganese, ammonia, bromide, fluoride and phosphate at most sites. A number of sites show differing degrees of variability (see Section 3.2.4). This should not necessarily be interpreted as a pervasive trend over time.

Most parameters at a majority of, but not all, sites are relatively stable and statistically are not showing significant trends. The only statistical trends that are significant (as described above) are increasing iron and manganese concentrations in WWD 3314, however, as noted below there has been problems with this bore and it has been subsequently replaced.

There are other less significant, but observable, trends present at other sites and these are described below.

WWD 37 Gardner

Decreasing nitrate, calcium, magnesium and bicarbonate.

The pervasive decreasing trends over a number of parameters, including nitrate, in WWD 37 is indicative of a strong dilutional trend. The cause of this is not well understood. WWD 37 is in the Upper Confined Aquifer and located at a point where the Lower Confined Aquifer lies directly below. The observed dilutional trend may be influenced by leakage occurring between the two aquifers and the overlying unconfined aquifer at the land surface.

WWD 32 TDC

Increasing sulphate, magnesium and bicarbonate.

Where WWD 37 is showing a decrease in magnesium and bicarbonate concentrations, there appears to be an increase in these parameters in WWD 32 which is in the Lower Confined Aquifer. It is unknown if these increases are a result of mixing with groundwater from the Upper Confined Aquifer.

Sulphate concentrations have been gradually increasing over time in WWD 32.

WWD 3314 Bensemann

Increasing iron, manganese and bicarbonate.
Decreasing nitrate and sulphate.

The WWD 3314 monitoring site has been progressively deteriorating over time becoming more and more difficult to obtain groundwater samples from (bore would pump dry before it could be flushed sufficiently to sample). There is no bore log and it is unknown what sort of screen is installed.

The sampling site was decommissioned and replaced with a new bore located 120 metres to the west in late 2009. At the time of writing no groundwater quality data is available from the new bore.

It is possible that the observed increases in iron and manganese and the decreases in nitrate and sulphate are a result of increasing stagnation and the onset of anaerobic conditions exacerbated by insufficient flushing occurring in the old bore.

WWD 997 McCliskies and WWD 802 Waiwest

Both of these sites show increasing sulphate concentrations, however, the median concentrations are not unusual for groundwater. The cause of this increase is unknown. A possible source is the use of sulphate based fertilisers. Nitrate concentrations in these two bores, whilst indicating minor human impacts (i.e. low median concentrations), do not show a statistically significant increasing trend.

WWD 3393 Kildrummy

Nitrate concentrations at this site are gradually increasing over time. This site has median nitrate concentrations indicative of a degree of human influence. The surrounding land use is orcharding.

4 Other Groundwater Quality Data

Whilst the 16 quarterly monitored SEM sites are the cornerstone of Council's long term groundwater quality monitoring programme, Council collects numerous other groundwater quality data in the exercise of its various functions. This includes systematic surveys carried out across the various catchments. There is also a significant amount of one off sampling data, typically collected following the drilling of a new bore by the bore owner with the groundwater quality results forwarded to Council.

Data is also collected by various resource consent holders as part of their compliance requirements (e.g. monitoring of discharges to land). Whilst most of this data relates to groundwater that is likely to be locally impacted, it often includes up gradient control sites which reflect ambient background groundwater quality.

All groundwater quality data collected by, or provided to, Council is kept on the Council's environmental database.

Whilst these data are not collected regularly and hence trends over time are unable to be discerned, they do provide a useful insight into the variation of groundwater quality across a much larger area of the District. Figures 3 to 11 show the distribution of selected parameters over parts of Tasman District. The data presented is the average[2] of all data collected at a particular site, however, in most cases it represents only a single sampling event. The nitrate data are the average between 2000 and 2009.

These figures do need to be interpreted with care. They present very much a broad brush picture of spatial variations in selected parameters across wide areas. They do not take into account different sampling depth (i.e. they may show data from different aquifers at the same surface location) and they include data collected at differing times (i.e. may reflect seasonal influences). The observed spatial variations can also be expected to be influenced by differing combinations of natural variation and human influences.

[2] Average values (rather than median values) were used because of constraints with the software used for the analysis.

Whilst much groundwater quality data has been collected, only nitrate, ammonia, sulphate, iron, manganese and Eschericia coli are presented as these are considered key indicators of groundwater quality (Daughney and Randall 2009 and MfE 2007).

4.1 Nitrates across the Entire Region

Council has surveyed nitrate concentrations across the District's principal aquifers at various times. This has primarily focused on the Waimea plains where data has been collected since the 1970's and includes four plains wide nitrate surveys undertaken since 1986. Other surveys have also been undertaken, including the Motueka and Riwaka plains, upper Motueka valley, Moutere, Takaka plains and coastal Golden Bay settlements. In addition there are various miscellaneous nitrate data available from throughout the District.

With the exception of the Waimea plains east of the Waimea River, nitrate concentrations across the District's principal aquifers are, in general, relatively low being either at or close to expected background concentrations. The median nitrate concentration for all sites across the District[3] since 2000, but excluding the Waimea plains east of the Waimea River, is 1.1 g/m^3-N with 75% of these sites being below 2.7 g/m^3-N. The median nitrate concentration for all of New Zealand is 1.7 g/m^3-N with 75% of samples being below 4.7 g/m^3-N (Daughney and Randle 2009). The median nitrate concentration of all sites on the Waimea plains east of the Waimea River is 11.0 g/m^3-N with 75% of these sites being below 15.0 g/m^3-N.

The unconfined aquifers adjacent to the principal river systems, where they are regularly recharged from the river water, typically have low nitrate concentrations similar to that of the respective river water.

Nevertheless, there are some areas where the nitrate concentrations reflect a degree of human influence (concentrations that exceed expected background levels) on intensively used land. Also isolated "hot spots" are present across the District but these are not necessarily indicative of wide spread contamination. Rather, they likely represent point source discharges close to the sampling site such as wastewater systems, offal pits, chicken coups etc.

[3] Where more than one sample has been collected the maximum recorded value since 2000 has been used. Where samples are below the detection limit of the analysis method used they were assumed to be equal to the detection limit.

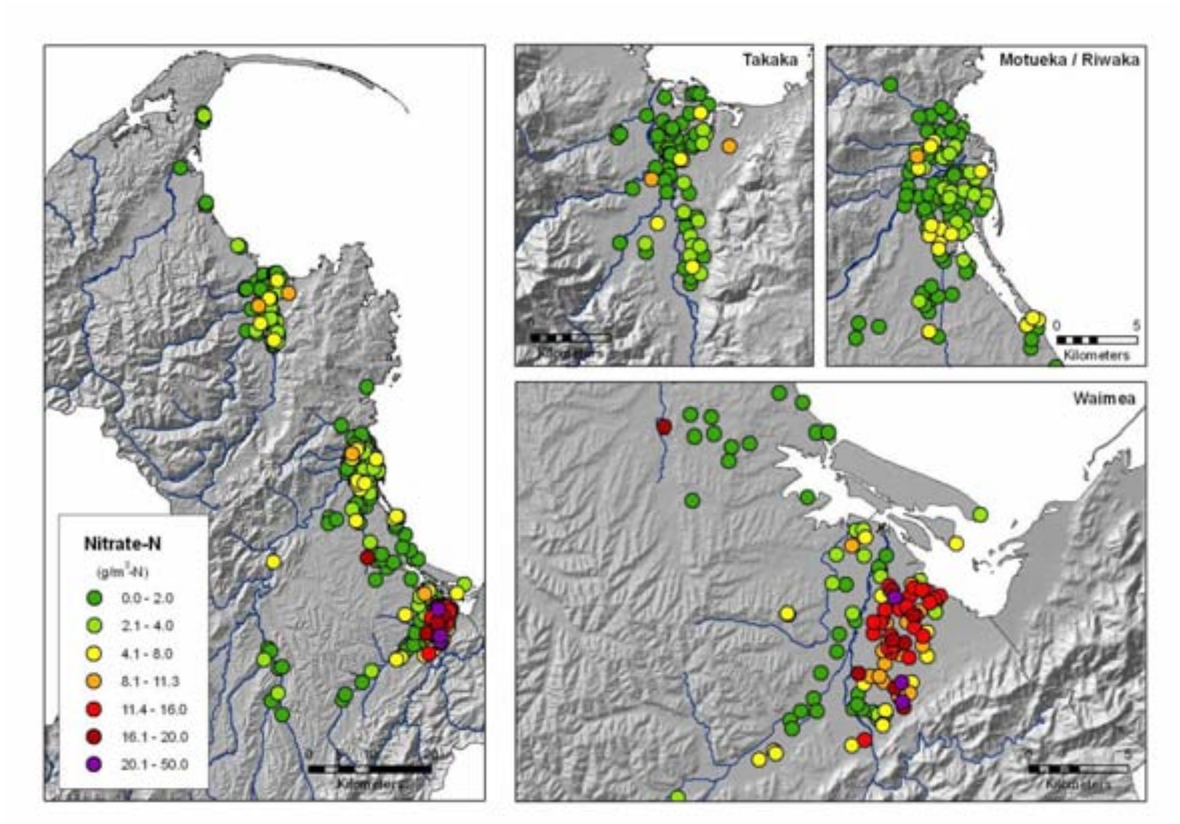


Figure 3 Nitrate-N concentrations across the Tasman District since 2000.

4.2 Nitrates in the Waimea Plains

Elevated nitrate concentrations across the Waimea Plains have been measured since the 1970's. Extensive monitoring of nitrate concentrations across the Waimea plains has been undertaken since this time (Dicker *et al*., 1992). Of note are four plains wide surveys undertaken in 1986 (63 sites), 1994 (64 sites) 1999 (82 sites) and 2005 (93 sites). This has enabled a snapshot of the spatial distribution of nitrate concentrations to be determined in the respective aquifers.

Nitrate concentrations encountered in the Waimea plains from the 2005 survey are presented in Figure 5. At the up gradient (southern) ends of the Upper Confined Aquifers (UCA) and the Lower Confined Aquifer (LCA), close to where they are both recharged via leakage from the Wairoa River bed, nitrate concentrations are relatively low (less than 3 g/m^3-N). With distance along these aquifers (i.e. away from the Wairoa River) increasing nitrate concentrations are encountered.

As well as recharge from the Wairoa River some recharge to the UCA occurs along its eastern edge from the overlying Hope Minor Confined and Unconfined Aquifers near the foothills of the Barnicoat range. During the 2005 nitrate survey the highest concentrations encountered in the UCA were along its eastern edge (up to 27 g/m^3-N) in what appears to be a plume extending towards the north from the Aniseed Valley Road and Patons Road area. This plume has similarly been identified in the previous nitrate surveys. Historically this area has extensively been used of intensive horticulture (including market gardens), though less so in recent times. A piggery was previously located in this area (reportedly prior to the 1970's) and, historically at least, has likely contributed to the observed nitrate concentrations.

At the northern end of the UCA in the vicinity of State Highway 60 and Swamp/Bartlett roads the overlying confining layer thins out and the aquifer is unconfined, essentially lying directly below and in contact with, the Appleby Gravel Unconfined Aquifer (AGUA). Elevated nitrate concentrations, similar to that observed the lower UCA, are present in the AGUA in this area.

In the LCA elevated nitrate concentrations (11 to 15 g/m^3-N measured during the 2005 survey) are encountered from the Ranzau Road area to the Waimea estuary. The Ranzau Road area is also where the UCA passes over the top of the LCA. Bore logs indicate that in this vicinity the LCA and UCA are separated by as little as 4 metres, but more typically 6 to 10 metres, of strata (clay bound gravels). Further down gradient in the LCA, which extends north at least as far as Rabbit Island, the measured nitrate concentrations decrease.

Drilling logs for some of the older bores where UCA passes over the top of the LCA show that the casing may have penetrated through, and be screened across, both aquifers. It is unknown how wide spread the practise of screening multiple aquifers was, however, Council has not allowed this practise since the late 1980s. It is also possible that natural pathways exist in places through the confining layers allowing leakage to occur as suggested by White and Reeves' (1999) modelling work.

The regularly monitored SEM site in the UCA (WWD 37 Gardner) shows a strong decreasing trend in nitrate concentrations. In the LCA (WWD 32 TDC) the trend is a much more gradual decrease over time (Figure 4 and Appendices II and III).

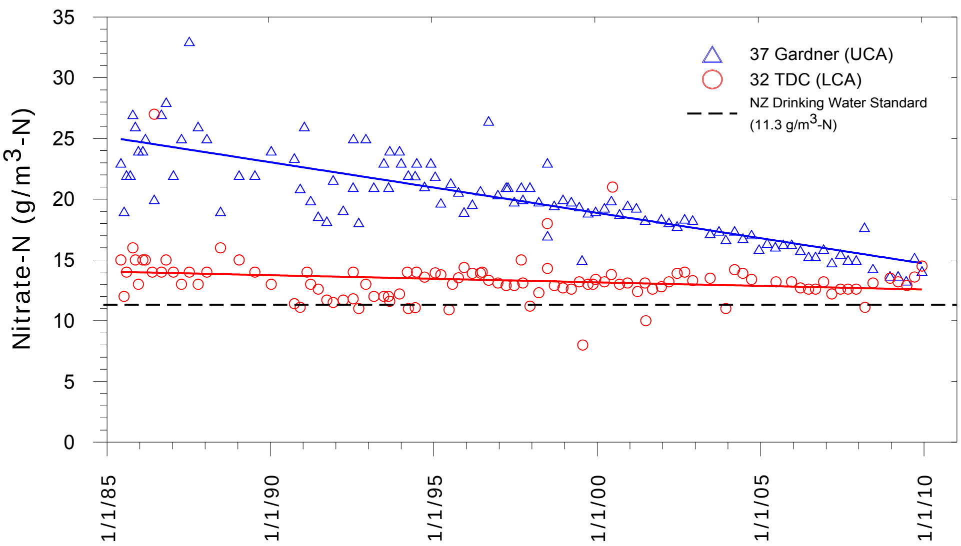


Figure 4 Nitrate-N concentrations in the Upper Confined Aquifer (UCA) and Lower Confined Aquifer (LCA) as measured at their respective SEM monitoring sites. Straight lines are a linear fit.

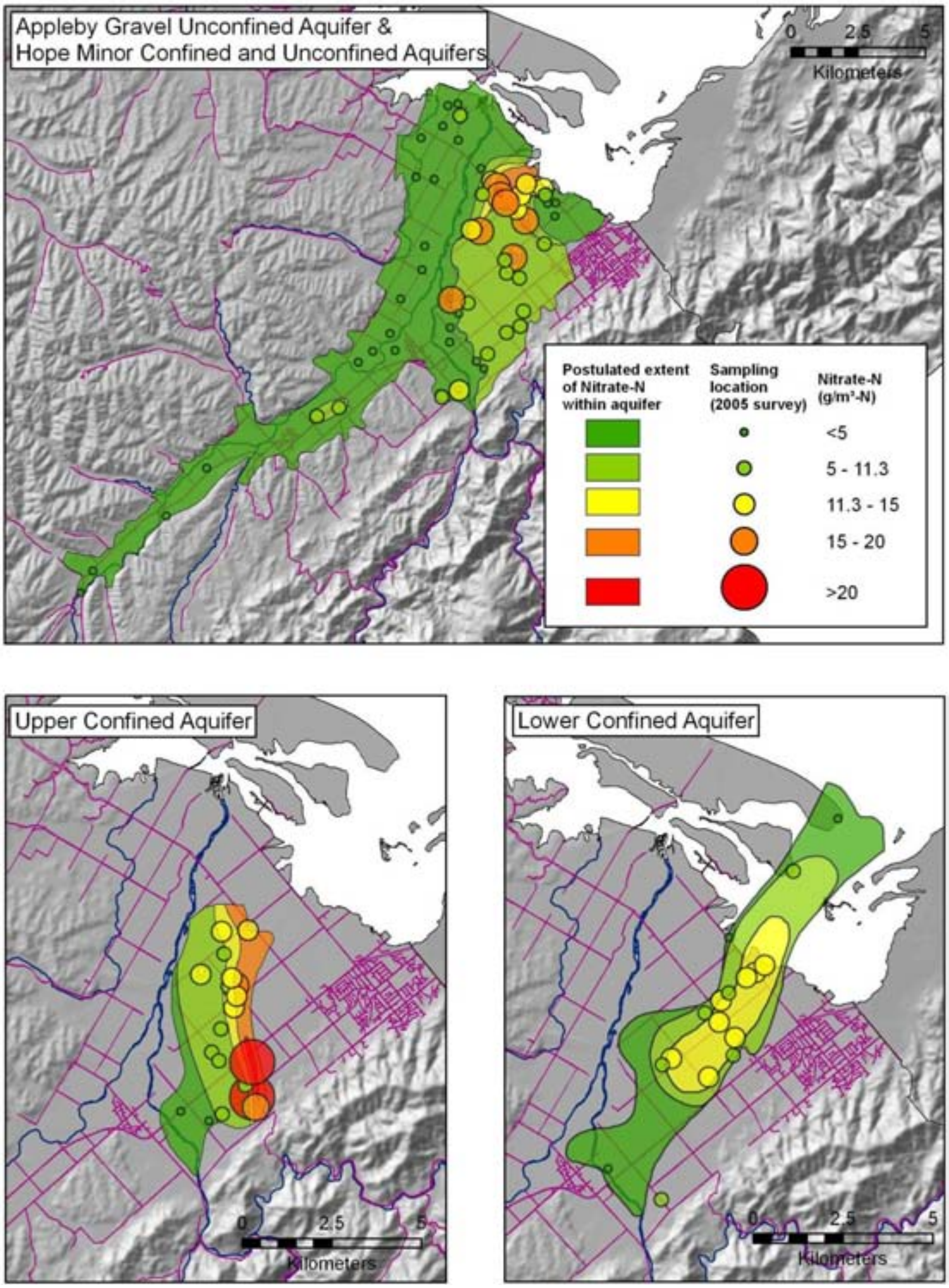


Figure 5 Nitrate-N concentrations in the aquifers of the Waimea Plains – winter 2005.

4.3 Ammonia

Ammonia readily oxidises to nitrate under aerobic conditions, only accumulating where groundwaters are oxygen poor (anaerobic). As much of Tasman's groundwaters are aerobic ammonia concentrations are generally low.

Groundwaters where anaerobic conditions occur, such as the deep sedimentary Moutere aquifers or bores penetrating old swampy areas containing decaying organic matter and may have naturally elevated ammonia concentrations.

Elevated ammonia concentrations in groundwater can also occur where there are high nitrogen loadings, such as from point source discharges of effluent. Such localised "hot spots" could occur anywhere across the district. Similar to nitrates, such "hot spots" are not necessarily indicative of widespread contamination.

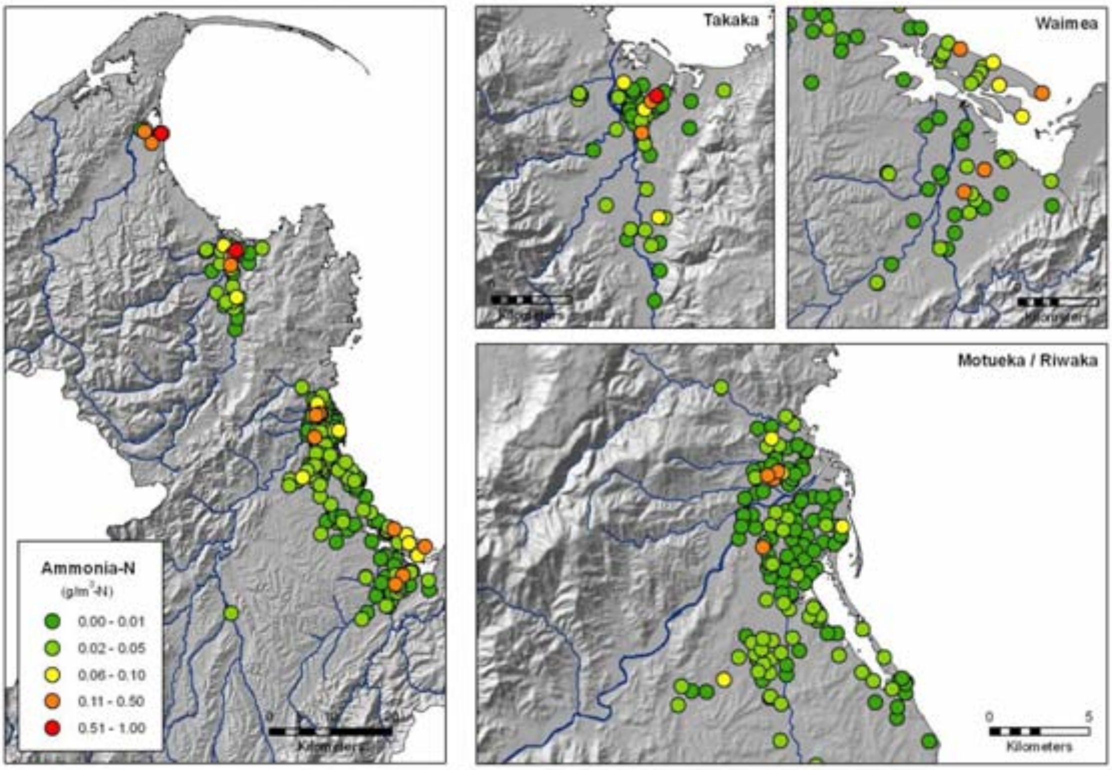


Figure 6 Ammoniacal nitrogen concentrations across the Tasman District.

4.4 Sulphates

Sulphate is often indicative of human influence on groundwater quality (MfE 2007) as it is a component of many fertilisers. However, it can occur naturally from groundwater interaction with parent rocks, particularly where they contain sulphides and/or decaying organic material (such as old peat and swamp deposits). Sulphate in groundwater can also be derived from sea spray at sites subject to such coastal influences (Rosen 2001). Figure 7 shows sulphate concentrations in the gravel aquifers across the District. The NZ drinking water guideline value (aesthetic) for sulphate is 250 g/m^3 and no samples exceeded this concentration. There is no health based MAV for sulphate in NZ drinking water.

Of note are the observed sulphate concentrations across the Motueka/Riwaka plains where relatively high concentrations are present to the north of the Motueka River and moderate concentrations south of the Motueka River. South of the Motueka River the sulphate concentrations show an increasing trend with distance away from the river towards the southeast.

The Motueka River provides considerable recharge to the aquifer system with groundwater flowing generally to the southeast. Groundwater will increase in age away from the recharge area. Therefore, close to the river groundwater quality will be strongly influenced by river water quality. As distance increases from the river there is more groundwater / rock interaction as well as a longer period of time for surface land use activities to influences to occur (i.e. fertiliser use). This is consistent with the observed sulphate concentrations in Figure 7.

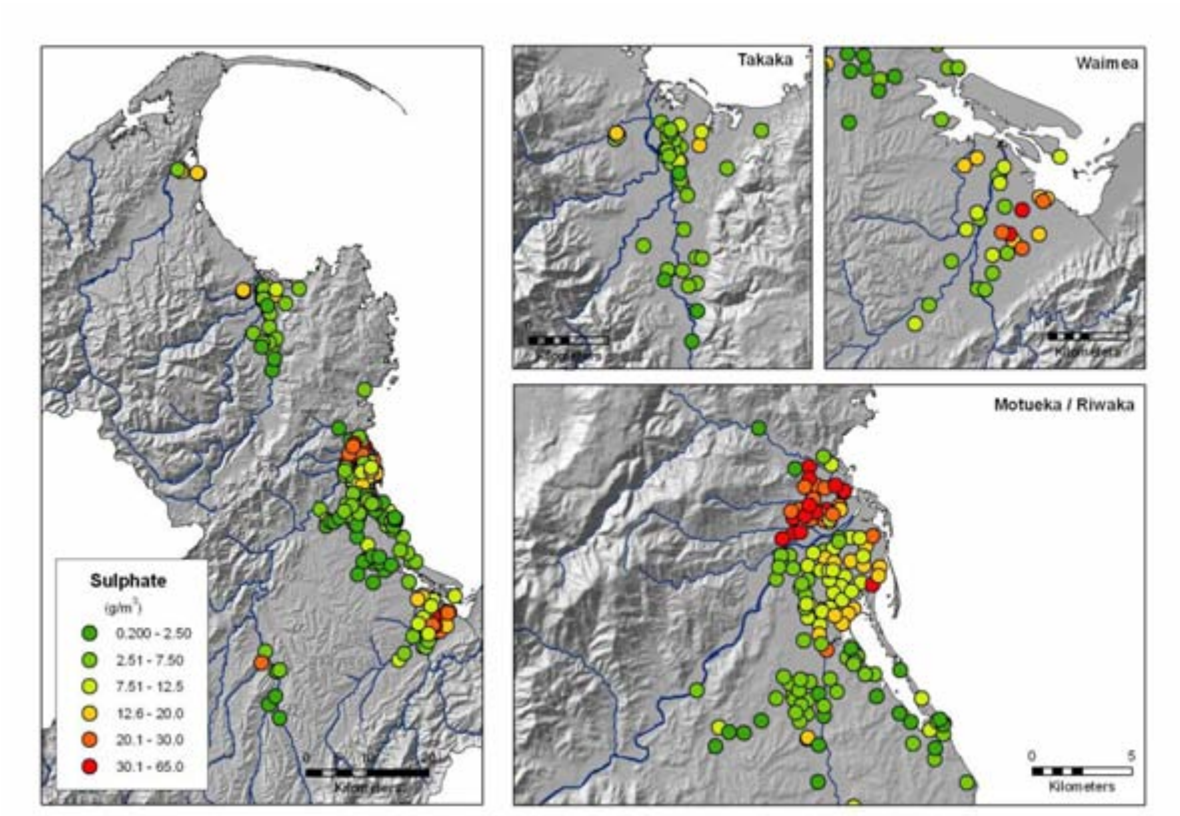


Figure 7 Sulphate concentrations across the Tasman District.

To the north of the Motueka River, groundwater through flow rates are less than those to the south (i.e. there is much less flushing with river water). This area contains old peat and swamp deposits (including decaying organic material) and is underlain and bounded by granite geology, all of which could contribute to increased sulphate concentrations.

Sulphates can enter groundwater as a result of leeching from excessive use of sulphate based fertilisers. Land use to both the north and south of the Motueka plains is similar, namely intensive horticulture. Consequently, fertiliser use is expected to be similar across these areas. Whilst this intensive land use may contribute to the observed sulphate concentrations, the spatial variations observed are more likely to be influenced by the fore mentioned natural processes (principally dilution with recharging river water) irrespective of the sulphate source.

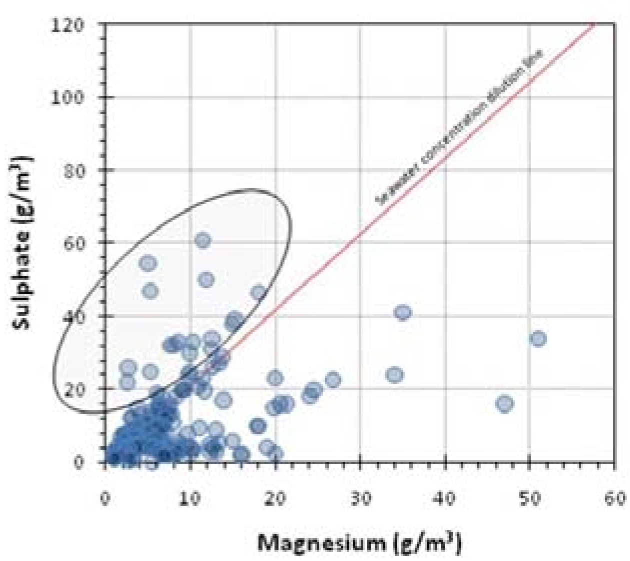


Figure 8 Average sulphate concentrations plotted against average magnesium concentrations across the Tasman District.

Figure 8 shows average sulphate concentrations plotted against average magnesium concentrations. The straight line is the seawater concentration-dilution line (SCDL). That is, the line showing the ratio of sulphate and magnesium found in seawater. Rainfall from evaporated seawater will have the same ratio. Therefore, as groundwater ages and interacts with its surroundings changes in the sulphate concentration will result in a movement away from the SCDL. Wells with significant additional inputs of sulphates will plot above (and to the left) of the SDCL.

Most bores in the District fall below and to the right of the SCDL indicating that their sulphate concentrations are at or below what would be expected if all sulphate was derived from seawater. However, some clearly plot above and to the left of the SCDL indicating enrichment in sulphate. Majority of these bores are located on the Motueka Riwaka plains north of the Motueka River where, as noted previously, appreciable natural sulphate inputs are likely.

4.5 Iron and manganese

Elevated iron and manganese concentrations are often a consequence of iron and manganese rich minerals contained in the aquifer rocks coupled with reducing (anaerobic) conditions (Daughney 2003). Such reducing conditions typically occur in older confined aquifers or where biological decomposition results in low oxygen concentrations in the groundwater, particularly where through flow rates and flushing are low.

The observed distribution of iron and manganese across the District is consistent with this (Figure 9 and Figure 10). Elevated concentrations are typically in the confined Moutere Gravel aquifers, the alluvial aquifers north of the Motueka River and in numerous unconfined coastal aquifers. Elevated iron and manganese concentrations are likely to exist elsewhere across the District, however, no suitable data is available to verify this.

The presence of elevated iron and manganese concentrations generally presents a nuisance or aesthetic concern (typically rust coloured staining, clogging of filters and pipe work, etc.) long before it presents a health hazard.

In Tasman there are a total of 129 sites where dissolved iron concentrations have been measured. Of these, 40% are below (i.e. comply with) the NZ drinking water aesthetic guideline of 0.2 g/m^3. This compares with 21% nationally (Daughney and Randall 2009). The aesthetic guideline value for manganese is 0.04 g/m^3 and 59% of the 82 sites tested in Tasman are below this (compared to 73% nationally). The heath base drinking water standard for manganese is 0.4 g/m^3 and 15% of the sites failed to meet this standard (compared to 10% nationally).

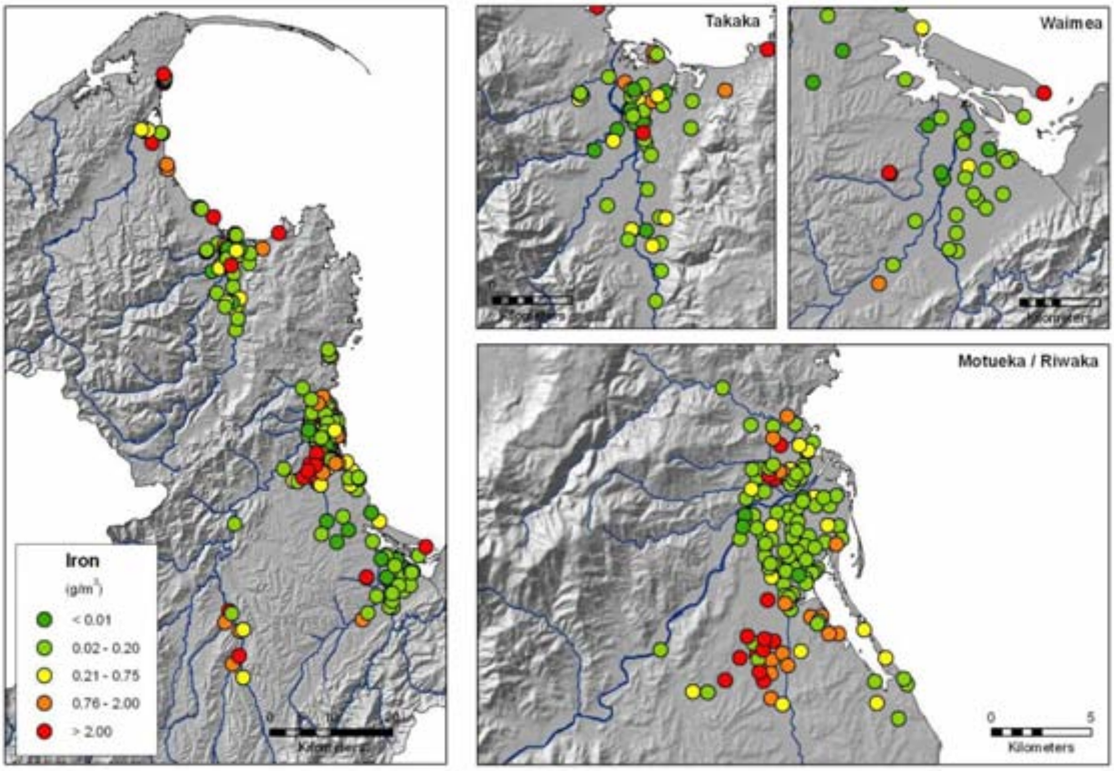


Figure 9 Iron concentrations across the Tasman District (average of all data collected).

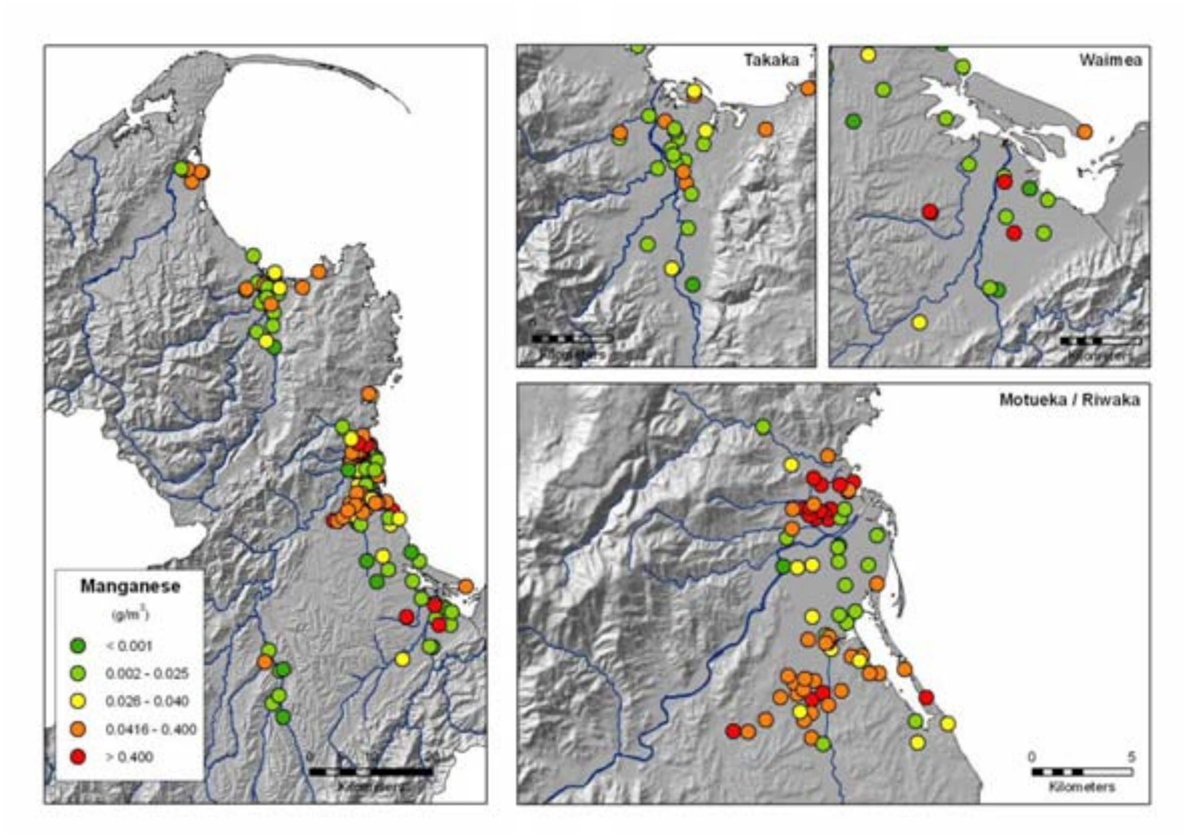


Figure 10 Manganese concentrations across the Tasman District (average of all data collected).

4.6 Bacteriological Contaminants

Only limited bacteriological data has been collected for natural groundwaters across the District. Generally low concentrations are encountered, however, some sites are elevated (Figure 11). There is insufficient data to draw any strong conclusions regarding the distribution of sites where elevated bacteriological concentrations were encountered.

Monitoring of some Golden Bay coastal settlements encountered elevated bacteriological contamination at a number of sites. These were typically shallow wells in unconfined aquifers, in residential areas (coastal bach settlements) that rely on onsite wastewater treatment and disposal (Stevens 2007a). The highest concentration shown in Figure 11 is from a shallow large diameter domestic well at Pakawau. The contamination is most likely to originate from a wastewater disposal system located very close to the well.

Elevated bacteriological concentrations encountered at other sites included shallow wells close to areas where stock congregate (such as a water trough), chicken coups, wastewater disposal facilities, etc.

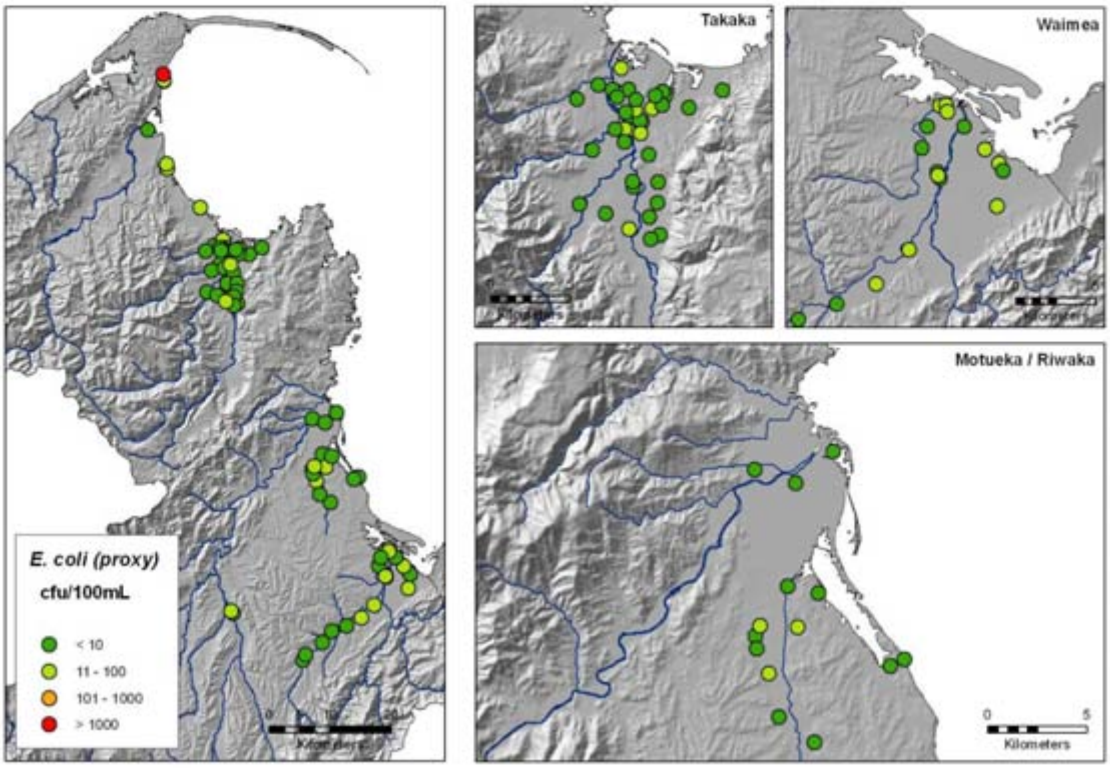


Figure 11 Bacteriological concentrations across the Tasman District (average of all data collected). Data is for *E. coli* where available otherwise faecal coliforms or total coliform data is used as a proxy.

5 Pesticide Residue Monitoring

Many land owners have in the past used, or still use, various pesticides[4] to control pests and weeds in their horticultural and agricultural operations. If pesticides are used inappropriately residues can persist in the soil and potentially leach down into underlying groundwater.

The Institute of Environmental Science & Research Limited (ESR) has coordinated national surveys of pesticides in New Zealand groundwaters at four yearly intervals since 1990. The Council has contributed to this project with surveys occurring in 1998, 2002 and 2006. The 2006 survey comprised the sampling of 15 unconfined groundwater sites across the Waimea, Moutere and Motueka plains (Stevens 2007b). A list of the pesticides and pesticide residues tested for and their detection limits is included in Appendix IV.

Pesticide residues were detected in only five of the 15 sites sampled (i.e. had concentrations above the detection limit of the laboratory analysis). Previously, there were nine sites in 2002 and ten sites in 1998 where pesticide residues were detected. The results of the pesticide residue monitoring are summarised in Figure 12 and detail of the surrounding land use is provided in Table 2.

The sampled sites are all unconfined relatively shallow groundwaters. The sites represent a number of current and historic land uses (see Table 2).

Overall the pesticide residues detected are at low concentrations and considerably below the respective NZ drinking water standards. In the 2006 sampling round the highest concentration compared to the respective drinking water standard was at WWD 4096 where simazine was detected at 1.3% of the maximum allowable value.

The five sites where pesticide residues were detected in the 2006 survey also showed low levels of pesticide residues when tested during both previous surveys (1998 and 2002).

There are three sites where no pesticides have been detected during all three surveys and a further two sites where pesticide residues were only detected in the original 1998 survey.

The pesticide residues detected during the 2006 sampling round are:

Simazine	a pre-emergence herbicide (half life[5] in soil of 30 – 100 days).
Metalaxyl	an organo-nitrogen fungicide (half life in soil in the order of 20 days and 20 – 30 days in water). Its use is restricted to the asparagus industry.

In addition to simazine, the previous sampling rounds in 1998 and 2002 have also detected the following:

[4] The term pesticide is taken to include the various insecticides, herbicides, fungicides and related substances used in horticultural and agricultural land use.

[5] Soil half life data from the *New Zealand Agrichemical Manual* 2004.

Diazinon	an organo-phosphate insecticide, used to control a wide range of common pests.
Terbuthylazine	a herbicide for grass and broadleaf weed control (half life in biologicaly active soils of 30- 60 days).
Endosulfan	an organo-chloride broad spectrum insecticide (half life in soil of 30-70 days).
Propazine	an organo-nitrogen herbicide (half life in soil of 80 – 100 days).

(Metalaxyl was only detected in the 2006 sample round)

Pesticide residues continue to be encountered at some locations across the District, all at very low levels. Given only three sample rounds have been undertaken it is not possibly to conclusively determine any trends over time. However, none of the sampled sites are showing any significant increases in pesticide residues compared to the previous results.

The possible exception is site WWD 524. Whilst pesticide residues have been detected in this well during previous surveys, traces of metalaxyl were encountered for the first time during the 2006 survey. Metalaxyl is used as a fungicide. The land use surrounding this well includes market gardening and glass houses.

The concentration of metalaxyl encountered in well WWD 524 (0.056 mg/m^3) is not significantly above the detection limit of 0.01 mg/m^3, particularly when compared to the NZ drinking water standard of 100 mg/m^3. Given that metalaxyl has only been detected in a single result and at a low concentration, it is difficult to draw any firm conclusions.

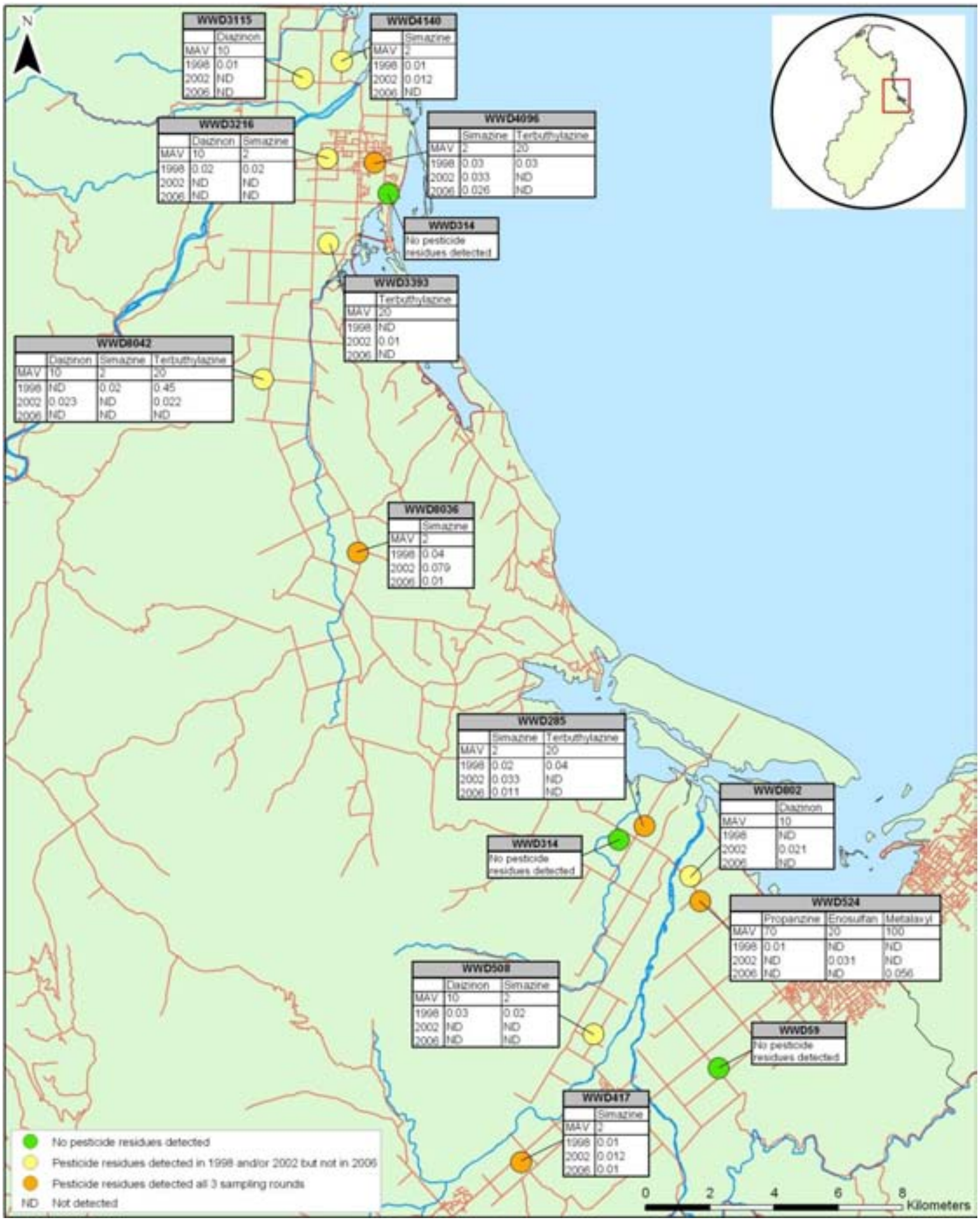


Figure 12 Location of sample sites and results of pesticide residue monitoring (all concentrations in mg/m^3).

Table 2 Summary of surrounding land use for the pesticide residue monitoring sites.

	Bore	Current Land Use	Previous Land Use*
Sites where pesticide residues have been detected on all three sampling rounds (i.e. 1998, 2002 and 2006)	WWD4096	Residential (urban fire bore)	Residential (1978)
	WWD8036	Pasture	Horticulture (berry fruit?) and possibly including tobacco (1978)
	WWD285	Viticulture	Pasture (1971)
	WWD524	Glasshouses / industrial wastewater irrigation field	Orchard (1971)
	WWD417	Pasture/grazing (though within curtilage of a dwelling)	Pasture/grazing (1971)
Sites where no pesticide residues have been detected during the latest sampling round (2006) but some pesticide residues were detected during previous sampling rounds.	WWD4140	Orcharding – some residential (fire bore)	Tobacco (old tobacco kiln located on opposite side of road) (1978)
	WWD3216	Kiwi fruit	Cropping/market garden? (1978)
	WWD3393	Orcharding	Pasture/grazing (1978)
	WWD8042	Orcharding	Orcharding (1978)
	WWD802	Orcharding – market gardening across road (up-gradient)	Pasture/grazing (1971)
	WWD3115	Orcharding	Orcharding (1978)
	WWD508	Orcharding/kiwi fruit	Pasture? (possibly cropping/market gardening) (1971)
Sites where no pesticide residues have been detected during all three previous sampling rounds	WWD3314	Residential (bore surrounded by rose garden)	Orcharding (1978) Kiwi fruit (1980s & 90s)
	WWD997	Orcharding	Pasture? (possibly cropping/market gardening) (1971)
	WWD59	Market gardening/ plant nursery (including glasshouses)	Market gardening/ glasshouses (Orcharding next door) (1971)

* Land use inferred from aerial photography. Date of photography in brackets.

6 Summary

Groundwater is an important and well utilised resource in Tasman District.

Overall, groundwater quality is high and, as expected, reflects natural variations in the respective geological composition and settings of the aquifers. Nevertheless, in places it reflects a degree of human influence. Most notably the Waimea plains east of the Waimea River, where elevated nitrate concentrations are prevalent in many places.

Throughout the District there are isolated localised areas of impacted groundwater. Typically these are from point sources such as wastewater treatment discharges, offal pits, historic land uses (such as automotive repair, timber treatment, storage of hazardous substances) etc. In most, but not all, cases it is the cumulative effects of such discharges that are of greater concern.

Overall, the more intense the land use, be it agricultural, horticultural or residential, the greater the likelihood of non-natural human influences on groundwater quality being apparent. Typically this is reflected as elevated nitrate concentrations.

A large range of land use across the District and within such a relatively small area gives the productive plains a patchwork pattern. Furthermore, land use changes occur over time (e.g. fruit trees giving way to market gardening, viticulture or residential). As a consequence, groundwater quality at a monitoring site can be influenced by multiple land uses, both current and historic. This makes identifying specific impacts to groundwater quality arising from specific land use practices problematic.

Any discharges to land, including human and animal effluents, need to be appropriately treated and managed. Fertiliser use needs to be undertaken in a manner that avoids leaching. Accurate nutrient budgeting of fertiliser use should be encouraged where possible. Once contaminated, groundwater can be very difficult, if possible at all, to remedy and the contamination can persist for long periods of time. The best solution is to avoid contamination of groundwater in the first place.

6.1 Unconfined Alluvial Aquifers

Overall, groundwater in the District's unconfined alluvial aquifers is of good quality. Chemically the unconfined alluvial groundwaters are very similar. The primary differences are the level of human and agricultural impacts and the degree of rock/groundwater interaction.

With the exception of the Waimea plains east of the Waimea River, human influences on the groundwater quality are overall relatively modest. As is typical of shallow unconfined alluvial aquifers, they are often insecure and readily influenced by surface conditions and land use activities.

As a consequence, continued intensive land use over the unconfined aquifers needs to be undertaken in a manner that limits the discharge of contaminants into groundwater or to land where it may impact groundwater.

6.2 Confined Alluvial Aquifers

The District's confined alluvial aquifers, the Upper Confined Aquifer (UCA) and Lower Confined Aquifer (LCA), are found beneath the Waimea Plains. Both of these aquifers are used extensively for irrigation and a lesser amount for drinking water supplies (including the Richmond municipal supply).

The groundwater from the UCA and LCA are chemically similar to each other and the adjacent unconfined aquifers. This reflects both aquifers having similar geology and, in places, sharing similar recharge areas. They exhibit a greater degree of groundwater-rock interaction than the nearby unconfined alluvial aquifers reflecting longer residence times of the groundwater within the aquifers.

Both aquifers show significant human impact with elevated nitrate concentrations. Nitrate concentrations remain high but are rapidly decreasing in WWD 37 Gardner. In WWD 32 TDC nitrate concentrations are slightly lower and show no discernable trend. Both sites do not comply with the NZ drinking water standard for nitrate. Whilst this contamination includes historic sources of nitrate which have been decreasing over time, the continuing elevated concentrations may mask inputs occurring from current land uses to some extent.

The UCA (as monitored at WWD 37 Gardner) exhibits decreasing concentrations of most major ions (principally magnesium, bicarbonate and nitrate, and to a lesser extent, calcium, sodium and chloride) indicating a strong dilutional trend. Whereas the LCA (as monitored at WWD 32 TDC) displays slightly increasing TDS concentrations (principally sulphate and bicarbonate, and to a lesser extent, magnesium, calcium, and chloride).

The sampled groundwaters from both confined aquifers (at the two SEM monitoring bores) are oxidised suggesting relatively fast through flow rates and low residence times to this point within the aquifers. The LCA may be less oxidised at its northeastern extension offshore and beneath Rabbit Island.

6.3 Sedimentary Rock Aquifers

The Deep Moutere Aquifers occur within the thick sequence of clay bound gravels (the Moutere Gravels). These aquifers are confined and characterised by slow moving groundwater with long residence times. As a consequence these aquifers have higher TDS concentrations than other Tasman groundwaters reflecting a greater degree of groundwater - rock interaction.

These groundwaters are typically depleted of dissolved oxygen (i.e. anaerobic) which is reflected by elevated iron and manganese, and to a lesser extent, ammonium concentrations coupled with low nitrate concentrations.

The regularly monitored bores in the Deep Moutere Aquifers show no evidence of human influence on their groundwater quality.

6.4 Karst Aquifers

The two karst aquifers in the District that are regularly monitored are the Takaka Limestone aquifer (WWD 6601 CTWB) and the Waikoropupu Arthur Marble aquifer (Te Waikoropupu Springs), both in Golden Bay. Both aquifers have good groundwater quality with their geochemistries reflecting the presence of carbonate rocks (elevated calcium concentrations and, with Te Waikoropupu Springs in particular, elevated bicarbonate concentrations). Their groundwaters are oxidised. Te Waikoropupu Springs also show high sodium and chloride concentrations contributing to a high total dissolved solids concentration. This is a reflection of the naturally occurring saline water influence to the spring's discharge.

There is no apparent human influence in Te Waikoropupu Springs where nitrate concentrations are low (typically < 0.4 g/m^3-N). However, WWD 6601 CTWB shows a moderate level of human impact with a median nitrate concentration of 2.1 g/m^3-N. The measured nitrate concentrations in WWD 6601 have remained remarkably steady over the entire period data has been collected (since 1990).

7 Future Programme

- Maintain the quarterly monitoring of the existing 16 SEM sites (including continuing participation in the National Groundwater Monitoring Programme).

- Periodic synoptic groundwater quality surveys that include monitoring for nitrate continue to be undertaken across the principal aquifers.

- Continued participation of the national groundwater pesticide monitoring programme.

- Completion of the isotope analysis of Waimea plains groundwater (for both age and nitrogen species). Environlink funding has been recently approved to undertake this analysis. Additional isotope sampling to complement the existing data should be undertaken if necessary.

- Review the establishment of an additional 1 to 2 groundwater SEM sites that reflects dairying land use as this land use is currently not well represented in the groundwater quality monitoring programme.

- Subject to obtaining suitable funding in the LTCCP, undertake fate and transport contaminant modelling of the Waimea plains (utilising the existing Waimea groundwater model) to gain a better understanding of the effects of potential nitrate sources (both historic and current). In particular, to gain a better understanding of the "plume" of elevated nitrate concentrations observed in the UCA and how it interacts with the underlying LCA and overlying AGUA.

8 References

Daughney, C.J. 2003. Iron and Manganese in New Zealand's Groundwater. In *Journal of Hydrology (NZ) 42(1)*, New Zealand Hydrological Society.

Daughney, C.J. 2005. Review of data from the Tasman District Council state of the environment groundwater monitoring programme. Institute of Geological & Nuclear Sciences Ltd client report 2008/69.

Daughney, C.J. 2007. Spreadsheet for automatic processing of water quality data: 2007 Update. GNS Science report 2007/17.

Daughney, C. and Randall, M. 2009. National Groundwater Quality Indicators Update: State and Trends 1995-2008, *GNS Science Consultancy Report 2009/145*. Prepared for the Ministry for the Environment, Wellington, New Zealand.

Daughney, C.J. and Reeves, R.R. 2005. Definition of Hydrochemical Facies in the New Zealand Groundwater Monitoring Programme. In *Journal of Hydrology (NZ) 44(2)*, New Zealand Hydrological Society.

Dicker, M. J. I., Fenemor, A.D. and Johnston, M. R. 1992. Geology and Groundwater Resources of the Waimea Plains, Nelson. New Zealand Geological Survey Bulletin 106, DSIR Geology & Geophysics.

Ministry for the Environment, 2007. Groundwater Quality in New Zealand State and Trends 1995–2006, report prepared by the institute of Geological and Nuclear Sciences Ltd. Publication number: ME 831.

Ministry of Health, 2005. Drinking-water Standards for New Zealand 2005, Ministry of Health.

New Zealand Agrichemical Manual 2004.

Rosen, M.R. 2001. Hydrochemistry of New Zealand's Aquifers. In *Groundwaters of New Zealand*. Rosen, M.R. and White, P.A. eds. New Zealand hydrological Society Inc

Stevens, G.J. 2007a. Groundwater Quality of Coastal Settlements, Golden Bay. Report EP07/06/02. Unpublished internal report, Tasman District Council.

Stevens, G.J. 2007b. Monitoring Of Pesticides Residues in Shallow Groundwater, Tasman District. Report EP07/09/05. Unpublished internal report, Tasman District Council.

Thomas, J. 2001. Tasman. In *Groundwaters of New Zealand*. Rosen, M.R. and White, P.A. eds. New Zealand hydrological Society Inc.

White P.A. and Reeves, R.R. 1999. Waimea Plains Aquifer Structure as Determined by Three-Dimensional Computer Modelling. In *Journal of Hydrology (NZ) 38(1)*, New Zealand Hydrological Society.

Appendix I

Standard analyses for Tasman District's Groundwater Quality State of the Environment Monitoring Programme.

National Groundwater Monitoring Programme (10 sites)

Alkalinity
Ammonia-N
Bromide
Calcium
Chloride
Fluoride
Iron
Magnesium
Manganese
Nitrate-N
Potassium
pH
Silica
Sodium
Sulphate

Tasman District Council Groundwater Monitoring Programme (6 sites)

Acidity
Alkalinity
Ammonia-N
Bromide
Calcium
Chloride
Conductivity
Dissolved reactive phosphorus
Fluoride
Free carbon dioxide
Hardness
Iron
Magnesium
Manganese
Nitrate-N
pH
Potassium
Silica
Sodium
Sulphate

Appendix II

Summary of medians, median absolute deviation (MAD – a measure of variability) and trend for the 16 SEM sites

Appendix II(a): Summary of Medians, Median Absolute Deviation (MAD – a measure of variability) and Trend for the 16 SEM Sites

Site		Calcium (Ca^{2+}) g/m^3			Magnesium (Mg^{2+}) g/m^3			Potassium (K^+) g/m^3			Sodium (Na^+) g/m^3		
		Median	**MAD**	**Trend**	**Median**	**MAD**	**Trend**	**Median**	**MAD**	**Trend**	**Median**	**MAD**	**Trend**
WWD 32	TDC	19.2	0.60	0.06	27.0	1.35	0.30	0.62	0.05	0.00	9.90	0.30	0.02
WWD 37	Gardner	10.0	1.00	-0.17	50.5	**5.10**	-0.97	0.81	0.05	0.00	10.6	0.50	-0.09
WWD 114	TDC Roadside	10.0	0.70	0.00	8.50	0.50	0.05	0.60	**0.10**	-0.01	7.40	0.50	0.10
WWD 802	Waiwest	16.5	**2.15**	0.23	11.0	**1.60**	0.15	0.56	**0.09**	0.00	7.80	0.40	0.06
WWD 997	McCliskies	12.0	0.00	0.00	12.0	1.00	0.00	1.20	0.10	0.00	11.0	0.00	0.00
WWD 1392	Spring Grove	18.0	1.00	0.00	6.00	0.20	0.03	1.30	0.10	-0.02	11.0	0.00	0.00
WWD 3115	Drummond	14.6	0.50	0.10	12.7	0.80	0.12	1.10	0.10	0.00	5.80	0.20	0.00
WWD 3216	Ngati Raru	23.0	1.00	0.00	7.31	0.30	0.01	1.10	0.10	-0.01	4.80	0.20	-0.03
WWD 3314	Bensemann	20.5	**2.50**	0.08	10.3	1.00	0.01	4.60	**0.60**	0.05	6.95	0.50	-0.04
WWD 3393	Kildrummy	17.0	1.00	0.00	6.20	0.35	0.03	0.90	0.05	0.00	6.00	0.20	0.04
WWD 8054	Middletons	27.0	1.00	0.00	9.60	**1.00**	0.22	1.10	0.10	0.00	33.0	1.00	0.00
WWD 8404	Wrattens	16.2	0.50	0.00	6.30	0.30	0.02	1.10	0.10	0.00	20.0	0.55	0.00
WWD 8407	Allensmore	30.0	1.00	0.08	6.80	0.25	0.06	0.60	**0.08**	0.00	25.0	1.00	-0.03
Te Waikoropupu Springs		61.9	2.90	-0.17	7.95	**0.85**	-0.03	4.60	0.30	-0.01	59.0	**6.75**	-0.22
WWD 6342	Takaka Fire	15.0	1.00	0.00	2.10	0.10	0.00	0.80	**0.10**	0.00	3.20	0.20	0.00
WWD 6601	CTWB	44.0	3.00	0.12	2.80	0.20	0.01	0.76	**0.09**	0.00	4.80	0.20	0.00
NZ Drinking Water	Standards												
	Guidelines										200 (aesthetic – taste)		

Italic = Analyses where more than 70% of samples are below the detection limit of the method used (used to signify lower confidence in results).
bold orange = MADs greater than 10% of the corresponding median (used as an identifier relative variability).
bold red = Medians that do not comply with NZ drinking water standards or guidelines.

Trends that are not significant at the 95% level are assigned the value of zero.

Appendix II(b): Summary of Medians, Median Absolute Deviation (MAD – a measure of variability) and Trend for the 16 SEM Sites (cont'd)

Site		Silica (SiO_2) g/m³			Iron (Fe^{2+}) g/m³			Manganese (Mn^{2+}) g/m³			Ammonia-N (NH_4^+) g/m³-N		
		Median	**MAD**	**Trend**	**Median**	**MAD**	**Trend**	**Median**	**MAD**	**Trend**	**Median**	**MAD**	**Trend**
WWD 32	TDC	28.5	0.50	0.00	*0.00*	*0.00*	*0.00*	*<0.005*	*ND*	*ND*	*<0.01*	*ND*	*ND*
WWD 37	Gardner	36.0	1.00	-0.02	*0.01*	*0.00*	*0.00*	*<0.005*	*ND*	*ND*	0.01	0.00	0.00
WWD 114	TDC Roadside	13.0	0.00	0.00	0.02	**0.01**	0.00	0.002	**0.001**	0.00	0.005	**0.002**	0.00
WWD 802	Waiwest	15.6	0.60	0.02	*0.01*	*0.00*	*0.00*	*<0.005*	*ND*	*ND*	*<0.01*	*ND*	*ND*
WWD 997	McCliskies	20.0	1.00	0.29	0.01	0.00	0.00	*<0.001*	*ND*	*ND*	0.004	**0.002**	0.00
WWD 1392	Spring Grove	16.0	1.00	0.00	**0.71**	**0.11**	-0.01	0.027	**0.005**	0.00	0.027	**0.008**	0.00
WWD 3115	Drummond	24.0	1.00	0.00	**1.30**	**0.15**	0.00	**2.60**	0.100	0.00	0.06	**0.01**	0.00
WWD 3216	Ngati Raru	14.2	0.40	0.01	*0.01*	*ND*	*0.00*	*<0.005*	*ND*	*ND*	*<0.01*	*ND*	*ND*
WWD 3314	Bensemann	15.8	0.70	-0.05	**1.15**	**0.60**	0.11	**0.190**	**0.080**	0.02	*<0.01*	*ND*	*ND*
WWD 3393	Kildrummy	15.0	1.00	0.22	0.01	**0.01**	0.00	*<0.001*	*ND*	*ND*	0.005	**0.002**	0.00
WWD 8054	Middletons	26.0	2.00	0.66	0.02	**0.01**	0.00	0.007	**0.002**	0.00	0.004	**0.002**	0.00
WWD 8404	Wrattens	64.8	1.75	0.00	**3.15**	0.25	0.00	**0.310**	0.020	0.00	0.02	**0.01**	0.00
WWD 8407	Allensmore	23.7	0.95	0.10	0.03	**0.03**	0.00	0.013	**0.004**	0.00	0.02	**0.01**	0.00
Te Waikoropupu Springs		6.40	0.40	-0.03	*0.00*	*0.00*	*0.00*	*0.002*	***0.001***	*0.00*	*0.01*	*ND*	0.00
WWD 6342	Takaka Fire	5.60	0.20	0.06	0.01	0.00	0.00	*<0.001*	*ND*	*ND*	<0.005	ND	ND
WWD 6601	CTWB	10.1	0.60	-0.05	*0.01*	*0.00*	*0.00*	*<0.005*	*ND*	*ND*	*<0.01*	*ND*	*ND*
NZ Drinking Water	Standards							0.4					
	Guidelines				0.20 (aesthetic – staining).			0.04 (aesthetic – staining) 0.10 (aesthetic – taste)			1.4 (Odour in alkaline conditions)		

Italic = Analyses where more than 70% of samples are below the detection limit of the method used (used to signify lower confidence in results).
bold orange = MADs greater than 10% of the corresponding median (used as an identifier relative variability).
bold red = Medians that do not comply with NZ drinking water standards or guidelines.

Trends that are not significant at the 95% level are assigned the value of zero.

Appendix II(c): Summary of Medians, Median Absolute Deviation (MAD – a measure of variability) and Trend for the 16 SEM Sites (cont'd)

Site	Bromide (Br^-) g/m^3			Fluoride (F^-) g/m^3			Chloride (Cl^-) g/m^3			Sulphate (SO_4^{2-}) g/m^3			Bicarbonate (HCO_3^-) g/m^3		
	Med	MAD	Trend	Med	MAD	Trend	Med	MAD	Trend	Med	MAD	Trend	Med	MAD	Trend
WWD 32 TDC	0.05	**0.02**	-0.01	0.02	**0.01**	0.00	16.7	0.70	0.08	22.0	2.00	0.55	107	3.00	0.72
WWD 37 Gardner	*0.02*	***0.01***	*0.00*	0.04	**0.01**	0.00	17.0	0.60	-0.12	33.0	1.00	-0.17	151	15.00	-2.66
WWD 114 TDC Roadside	*<0.15*	*ND*	*ND*	0.06	**0.02**	*-0.01*	11.0	**1.15**	0.18	4.95	**1.10**	0.15	56	3.50	0.22
WWD 802 Waiwest	*0.02*	***0.01***	*0.00*	0.03	**0.01**	0.00	12.6	1.15	0.07	9.10	**2.70**	0.33	87	**9.00**	0.92
WWD 997 McCliskies	*<0.15*	*ND*	*ND*	0.07	**0.02**	0.00	14.0	1.00	0.00	20.0	1.00	0.28	53	2.00	-0.01
WWD 1392 Spring Grove	*<0.15*	*ND*	*ND*	0.06	**0.01**	0.00	19.0	**2.00**	0.17	10.0	0.95	0.20	39	3.00	-0.84
WWD 3115 Drummond	*0.01*	*0.00*	*0.00*	0.05	**0.01**	0.00	7.65	0.65	0.10	26.0	1.50	0.00	87	3.00	0.76
WWD 3216 Ngati Raru	0.01	**0.01**	0.00	0.01	0.00	0.00	6.60	0.50	0.05	14.4	1.20	0.20	85	1.07	0.00
WWD 3314 Bensemann	0.04	**0.01**	0.00	0.02	**0.01**	0.00	10.0	**1.45**	-0.15	50.6	**16.45**	-1.50	51	**6.00**	1.83
WWD 3393 Kildrummy	*<0.15*	*ND*	*ND*	*<0.05*	*ND*	*ND*	8.70	0.80	0.13	17.0	1.00	0.00	36	2.00	0.00
WWD 8054 Middletons	*<0.15*	*ND*	*ND*	0.43	0.03	0.01	18.0	1.00	0.24	3.20	0.20	0.00	150	0.00	0.00
WWD 8404 Wrattens	*0.00*	*0.00*	*0.00*	0.35	0.03	0.00	4.90	0.20	-0.01	2.60	0.20	-0.01	127	1.00	0.00
WWD 8407 Allensmore	*0.03*	*0.00*	*0.00*	0.18	0.01	0.00	5.70	0.20	0.00	1.80	**0.20**	0.00	179	4.00	0.76
Te Waikoropupu Springs	0.22	**0.09**	-0.02	0.03	**0.01**	0.00	96.0	**12.00**	-0.23	16.6	**1.80**	-0.02	205	7.00	0.22
WWD 6342 Takaka Fire	*<0.15*	*ND*	*ND*	*<0.05*	*ND*	*ND*	3.50	0.10	-0.03	4.10	0.20	0.04	46	3.00	0.23
WWD 6601 CTWB	*0.01*	*0.00*	*0.00*	0.04	**0.01**	0.00	6.20	0.40	0.04	4.20	0.20	0.03	135	8.00	0.50
NZ Drinking Water – Standards															
NZ Drinking Water – Guidelines							250 (aesthetic – taste, corrosion)			250 (aesthetic – taste)					

Italic = Analyses where more than 70% of samples are below the detection limit of the method used (used to signify lower confidence in results).
bold orange = MADs greater than 10% of the corresponding median (used as an identifier relative variability).
bold red = Medians that do not comply with NZ drinking water standards or guidelines.

Trends that are not significant at the 95% level are assigned the value of zero.

Appendix II(d): Summary of Medians, Median Absolute Deviation (MAD – a measure of variability) and Trend for the 16 SEM Sites (cont'd)

Site		Nitrate-N (NO_3^-) g/m^3-N			Total Phosphorus g/m^3-P			Dissolved Reactive Phosphorus g/m^3-P			pH			Conductivity (uS/cm)		
		Med	MAD	Trend	Med	MAD	Trend	Med	MAD	Trend	Med	MAD	Trend	Med	MAD	Trend
WWD 32	TDC	**13.10**	0.82	-0.02	*0.00*	*0.00*	*0.00*	-	-	-	7.61	0.09	0.00	368	10.75	2.36
WWD 37	Gardner	**19.80**	**2.20**	-0.45	*0.03*	*ND*	*0.00*	-	-	-	7.60	0.19	0.02	473	40.75	-8.87
WWD 114	TDC Roadside	0.59	**0.23**	0.00	-	-	-	0.01	0.00	0.00	7.20	0.10	0.05	153	12.10	1.42
WWD 802	Waiwest	2.00	**1.00**	0.10	*0.03*	*ND*	*0.00*	-	-	-	7.05	0.23	0.02	210	**24.80**	2.50
WWD 997	McCliskies	3.65	**0.55**	0.06	-	-	-	0.02	0.00	0.00	**6.40**	0.10	0.04	217	10.80	2.75
WWD 1392	Spring Grove	5.60	0.40	0.00	-	-	-	0.00	0.00	0.00	**6.50**	0.20	0.06	211	4.00	0.85
WWD 3115	Drummond	0.01	**0.01**	0.00	*<0.05*	*ND*	*ND*	-	-	-	**6.53**	0.10	0.01	212	9.50	1.42
WWD 3216	Ngati Raru	2.50	**0.37**	0.01	*<0.05*	*ND*	*ND*	-	-	-	**6.89**	0.19	0.01	200	10.00	0.10
WWD 3314	Bensemann	0.89	**0.50**	-0.03	*<0.05*	*ND*	*ND*	-	-	-	**6.39**	0.13	0.01	247	**26.70**	0.08
WWD 3393	Kildrummy	5.60	**0.80**	0.13	-	-	-	0.01	0.00	0.00	**6.60**	0.20	0.04	180	5.50	1.44
WWD 8054	Middletons	0.052	**0.02**	0.00	-	-	-	0.02	0.00	0.00	7.50	0.10	0.00	331	15.95	3.47
WWD 8404	Wrattens	0.005	0.00	0.00	*<0.05*	*ND*	*ND*	-	-	-	7.00	0.13	0.01	220	5.00	0.52
WWD 8407	Allensmore	0.003	0.00	0.00	*0.00*	*0.00*	*0.00*	-	-	-	**8.06**	0.06	0.00	290	6.95	0.47
Te Waikoropupu Springs		0.36	0.03	0.00	*0.01*	*0.00*	*0.00*	-	-	-	7.70	0.10	0.01	650	50.00	-1.47
WWD 6342	Takaka Fire	0.80	**0.20**	0.00	-	-	-	0.00	0.00	0.00	**6.70**	0.20	0.08	111	4.15	0.00
WWD 6601	CTWB	2.10	0.20	0.00	*0.01*	*0.00*	*0.00*	-	-	-	7.50	0.18	0.00	253	14.30	0.76
NZ Drinking Water	Standards	11.3														
	Guidelines										Should be between 7.0 and 8.0					

Italic = Analyses where more than 70% of samples are below the detection limit of the method used (used to signify lower confidence in results).
bold orange = MADs greater than 10% of the corresponding median (used as an identifier relative variability).
bold red = Medians that do not comply with NZ drinking water standards or guidelines.

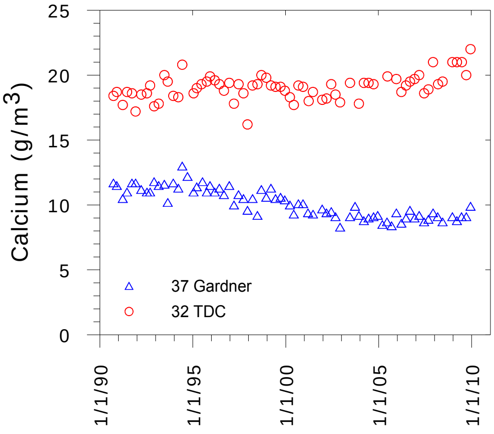
Trends that are not significant at the 95% level are assigned the value of zero.

Appendix III

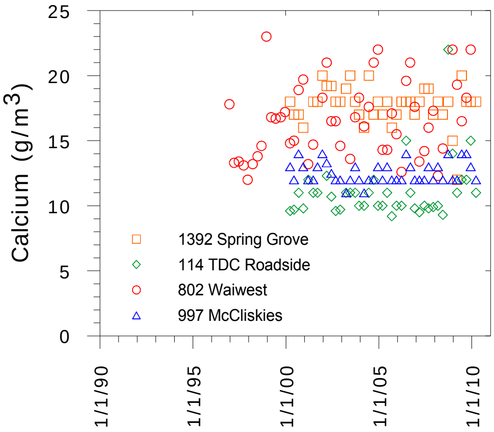
Plots of key groundwater quality parameters for the 16 SEM sites

Calcium (Ca^{2+})

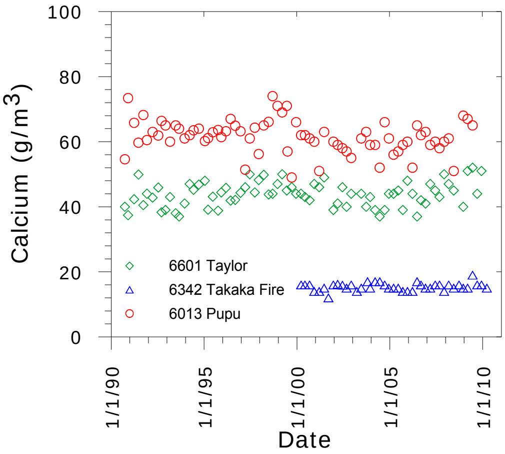
Waimea - confined



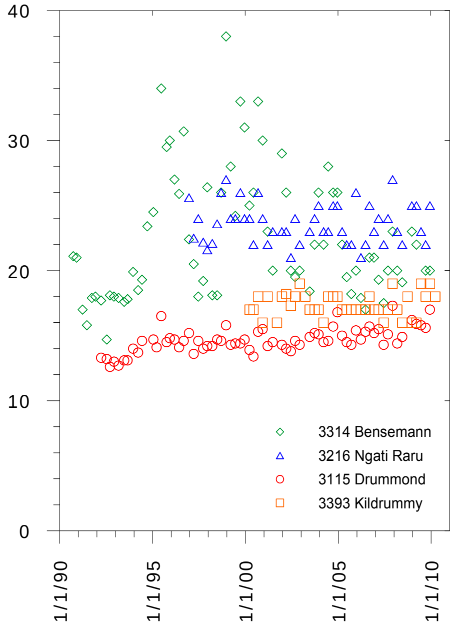
Waimea - unconfied



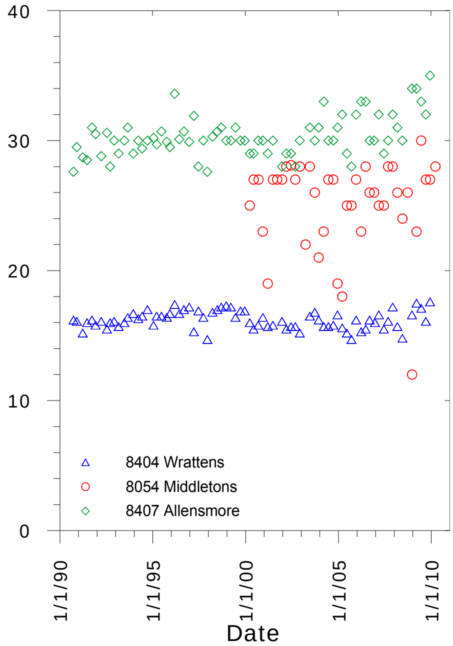
Golden Bay
confined & unconfined



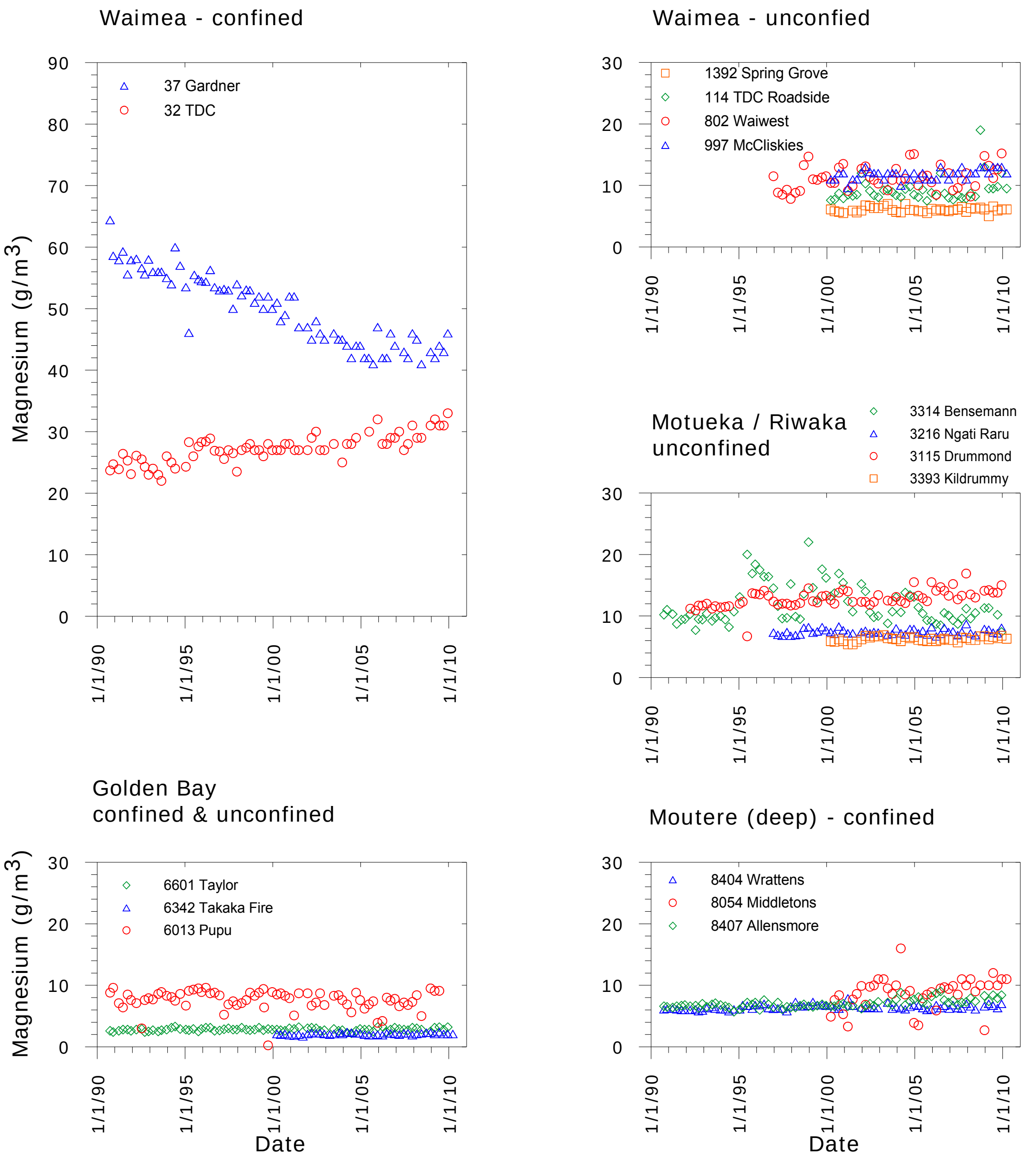
Motueka / Riwaka
unconfined



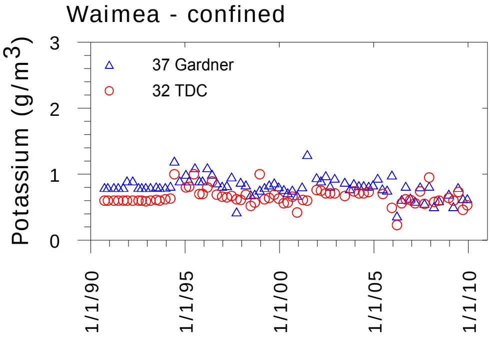
Moutere (deep) - confined

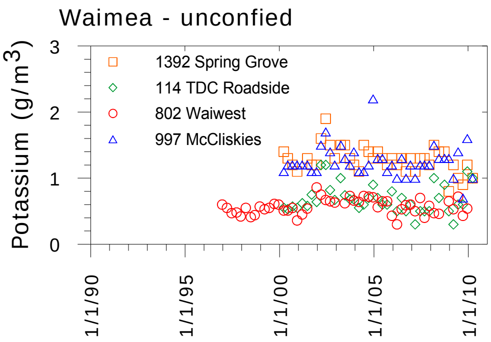


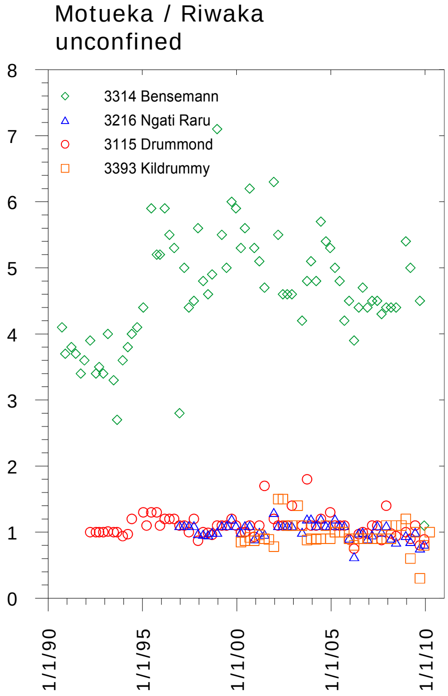
Magnesium (Mg^{2+})

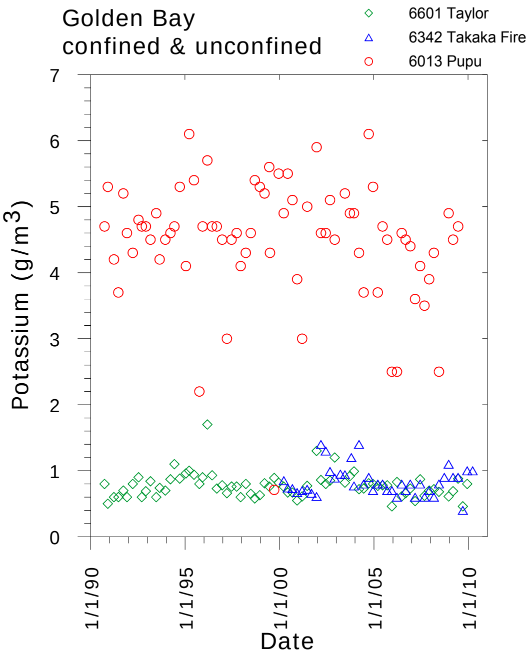


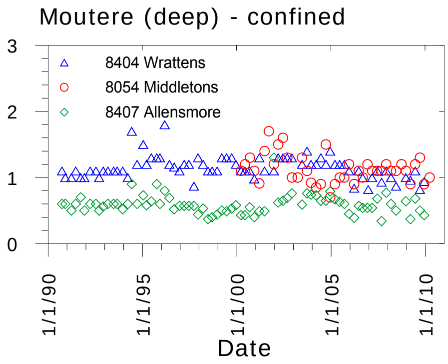
Potassium (K^+)


Waimea - confined
Potassium (g/m3)
37 Gardner
32 TDC
0
1
2
3
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10


Waimea - unconfied
Potassium (g/m3)
1392 Spring Grove
114 TDC Roadside
802 Waiwest
997 McCliskies
0
1
2
3
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10

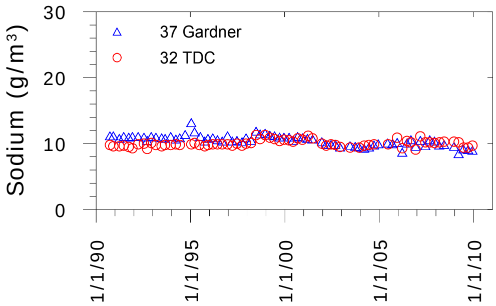

Motueka / Riwaka
unconfined
3314 Bensemann
3216 Ngati Raru
3115 Drummond
3393 Kildrummy
0
1
2
3
4
5
6
7
8
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10


Golden Bay
confined & unconfined
6601 Taylor
6342 Takaka Fire
6013 Pupu
Potassium (g/m3)
0
1
2
3
4
5
6
7
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10
Date

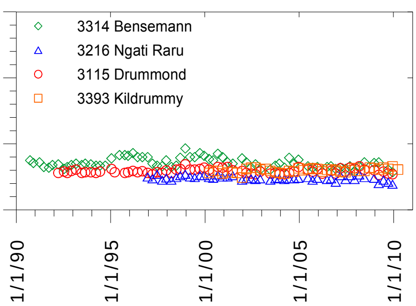

Moutere (deep) - confined
8404 Wrattens
8054 Middletons
8407 Allensmore
0
1
2
3
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10
Date

Sodium (Na^+)

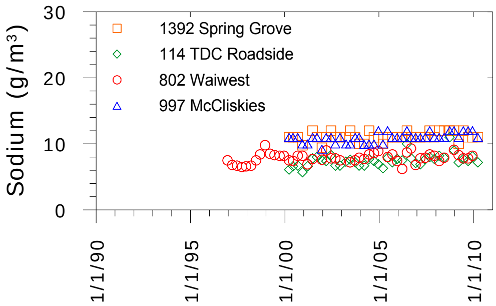
Waimea - confined



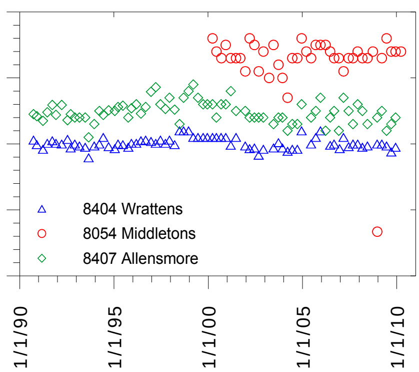
Motueka / Riwaka unconfined



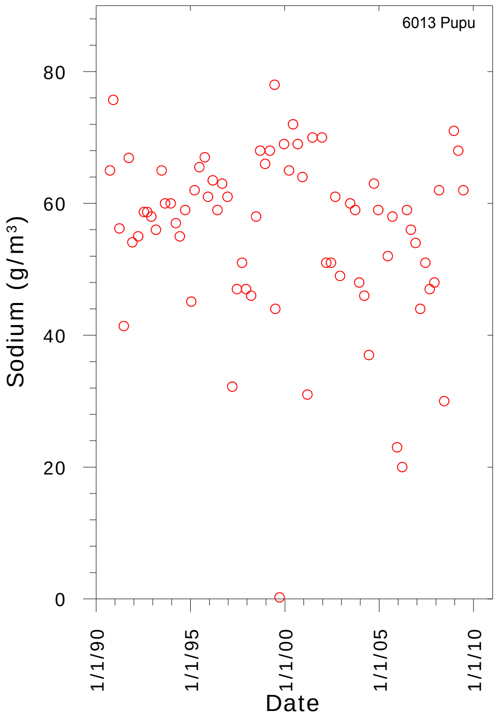
Waimea - unconfied



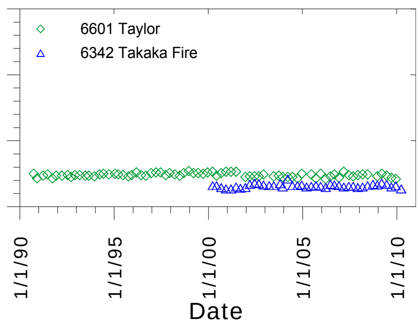
Moutere (deep) - confined



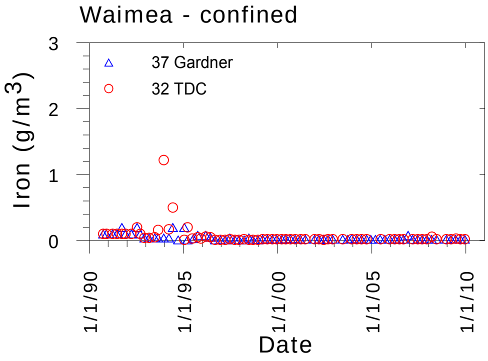
Golden Bay
Pupu Springs (confined)

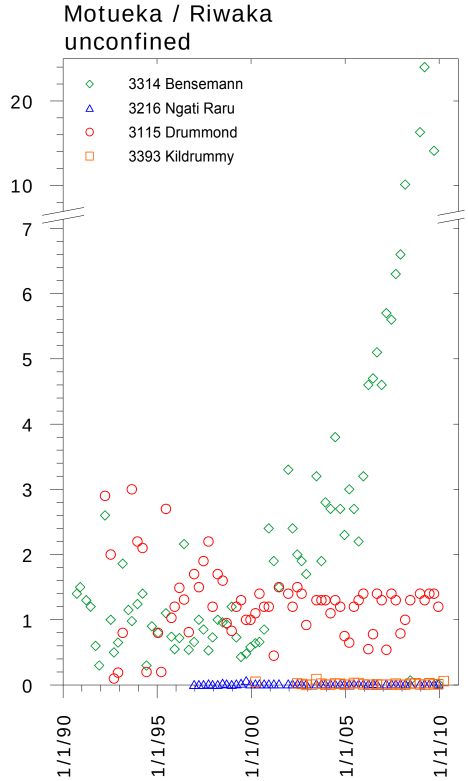


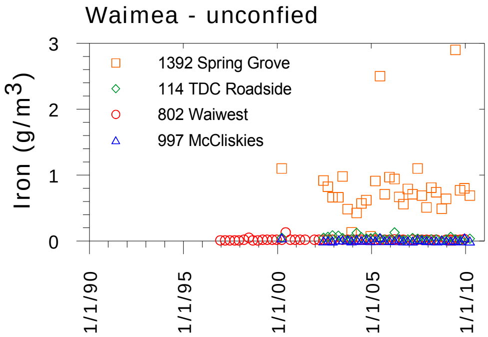
Golden Bay
confined & unconfined

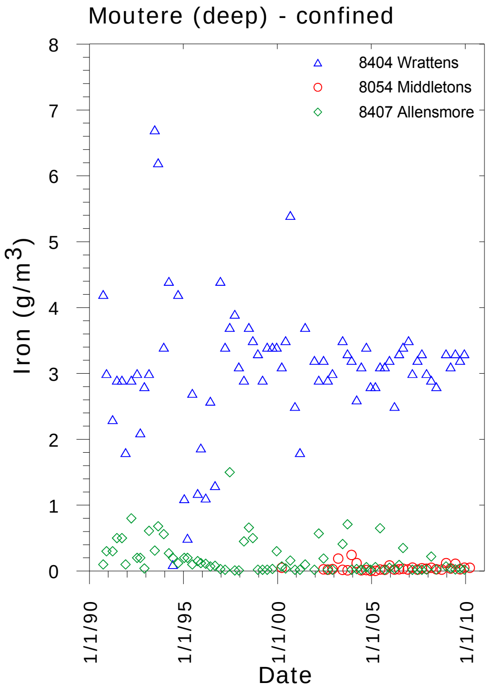


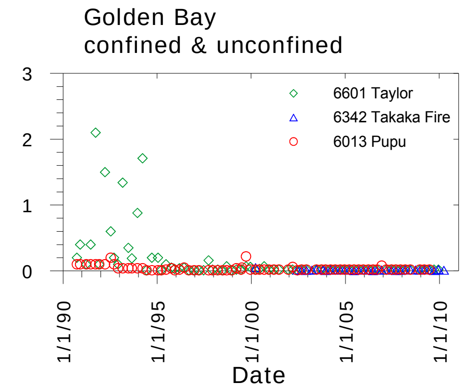
Iron (Fe^{2+})


Waimea - confined
Iron (g/m3)
37 Gardner
32 TDC
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10
Date

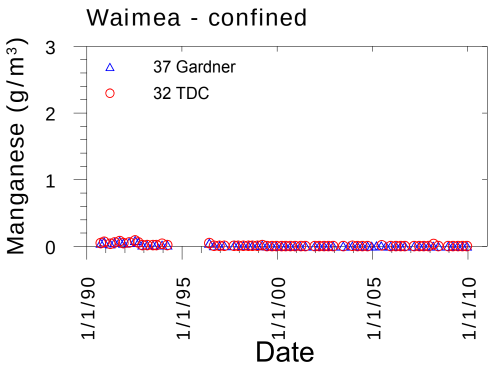

Motueka / Riwaka unconfined
3314 Bensemann
3216 Ngati Raru
3115 Drummond
3393 Kildrummy
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10

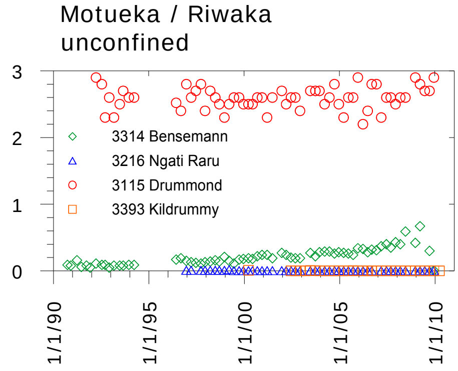

Waimea - unconfied
Iron (g/m3)
1392 Spring Grove
114 TDC Roadside
802 Waiwest
997 McCliskies
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10

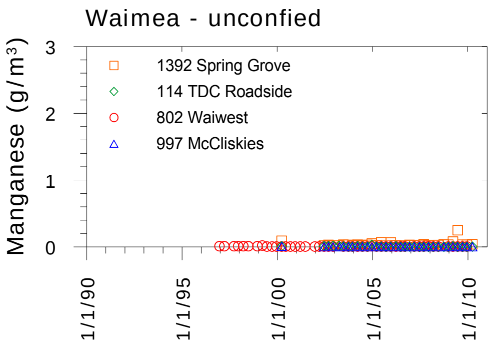

Moutere (deep) - confined
Iron (g/m3)
8404 Wrattens
8054 Middletons
8407 Allensmore
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10
Date

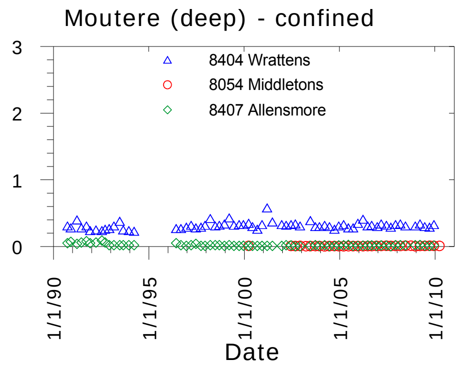

Golden Bay confined & unconfined
6601 Taylor
6342 Takaka Fire
6013 Pupu
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10
Date

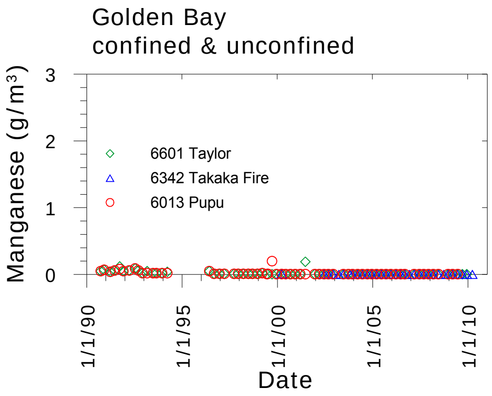
Manganese (Mn^{2+})



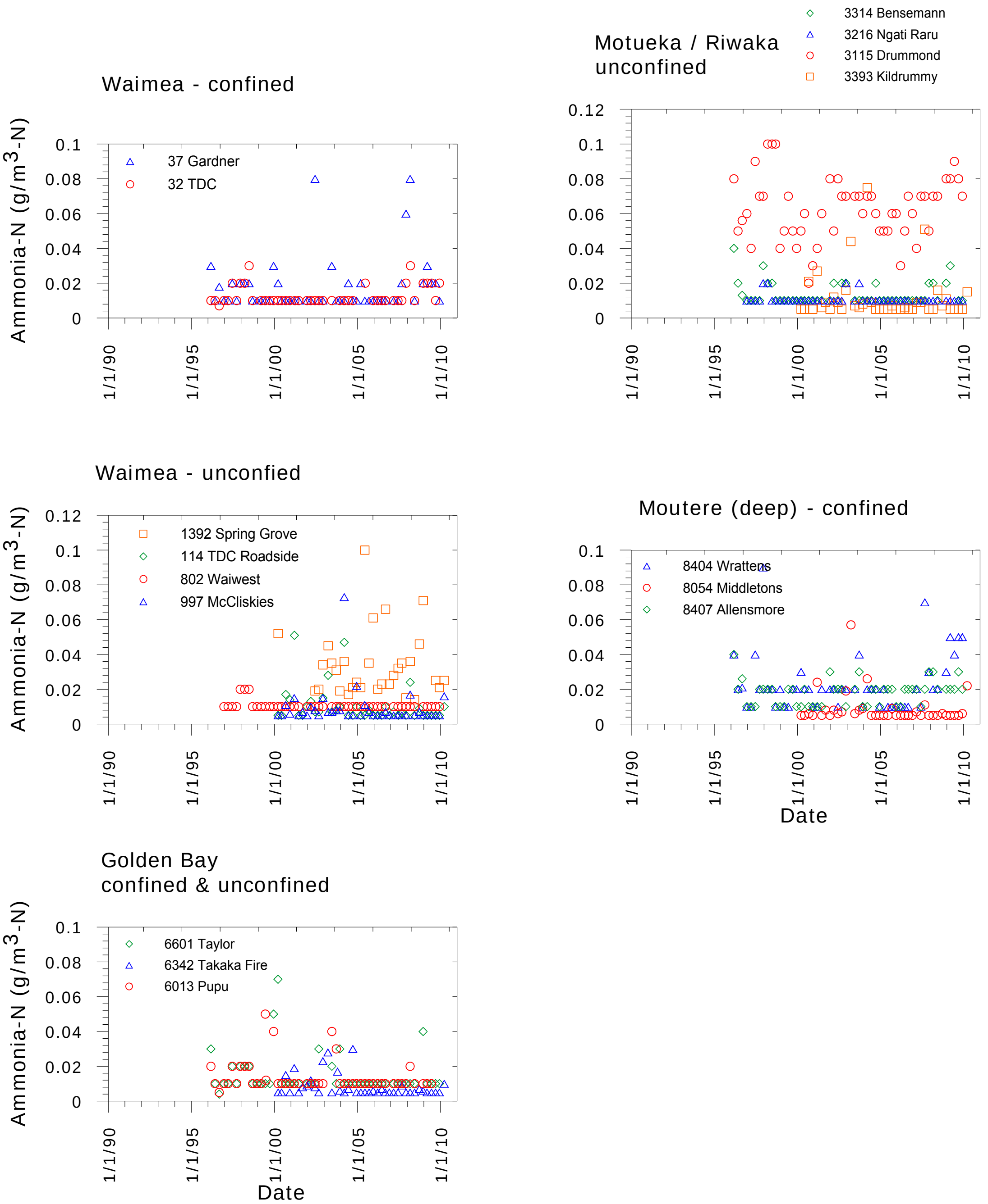




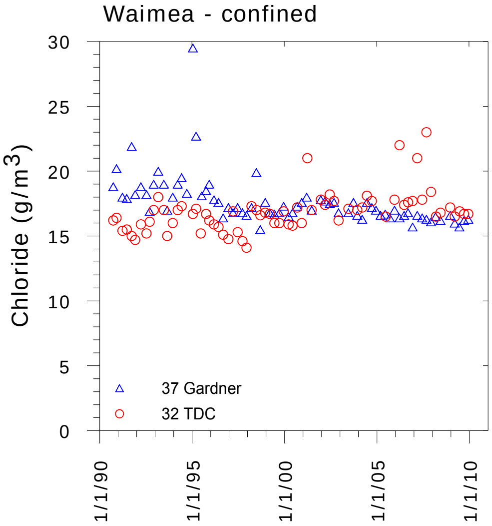




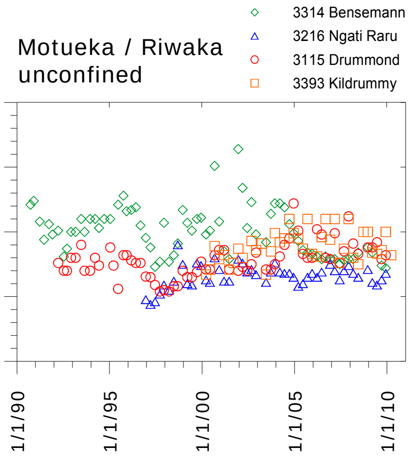
Ammonia - nitrogen ($NH_4^-N^+$)



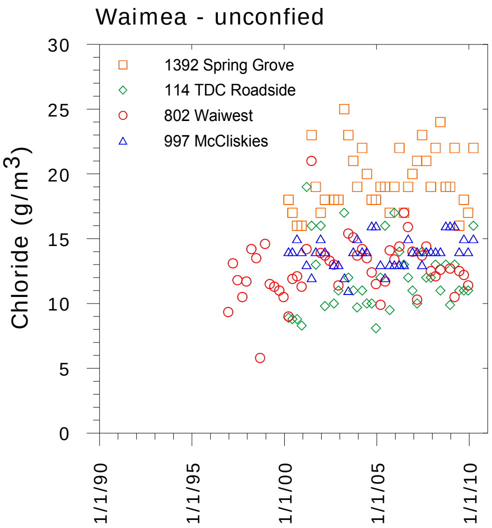
Chloride (Cl^-)



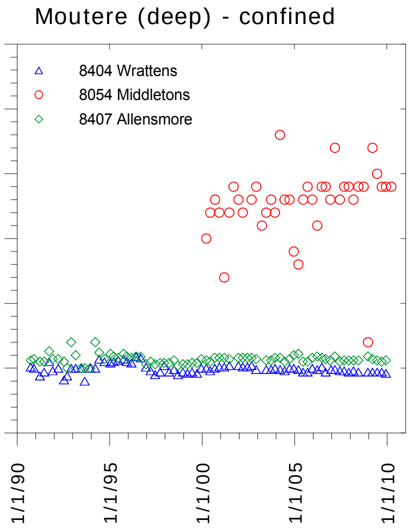
Waimea - confined
Chloride (g/m3)
30
25
20
15
10
5
0
37 Gardner
32 TDC
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10



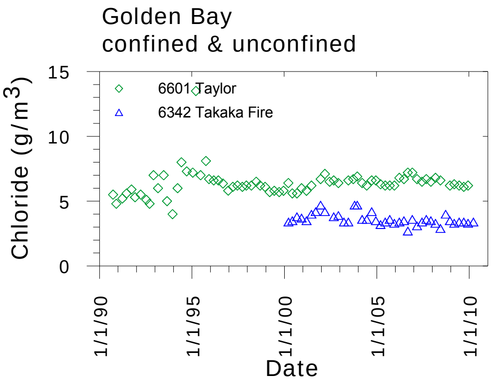
Motueka / Riwaka unconfined
3314 Bensemann
3216 Ngati Raru
3115 Drummond
3393 Kildrummy
20
15
10
5
0
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10



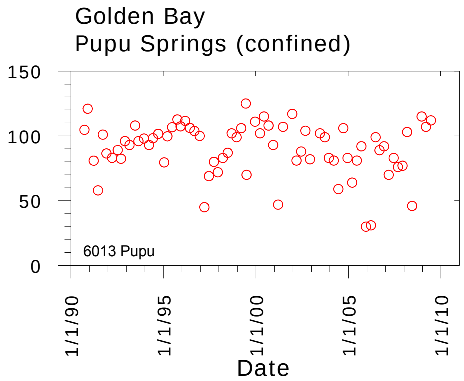
Waimea - unconfied
Chloride (g/m3)
30
25
20
15
10
5
0
1392 Spring Grove
114 TDC Roadside
802 Waiwest
997 McCliskies
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10



Moutere (deep) - confined
30
25
20
15
10
5
0
8404 Wrattens
8054 Middletons
8407 Allensmore
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10



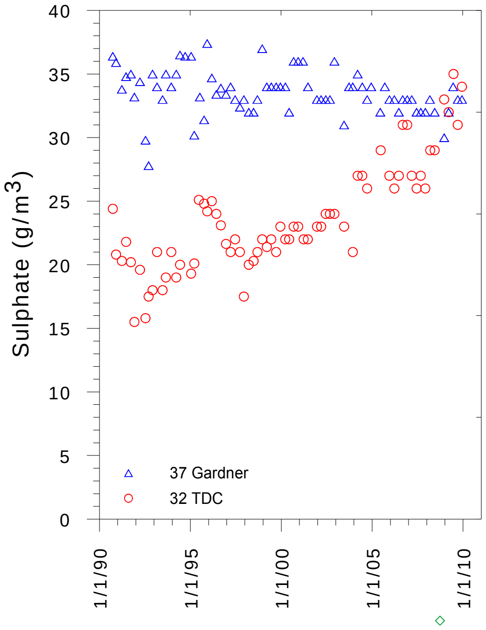
Golden Bay confined & unconfined
Chloride (g/m3)
15
10
5
0
6601 Taylor
6342 Takaka Fire
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10
Date



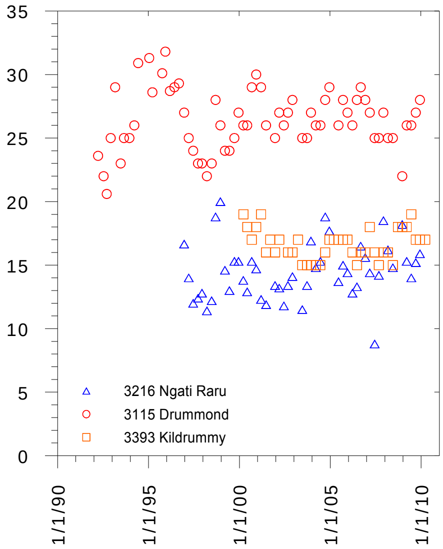
Golden Bay Pupu Springs (confined)
150
100
50
0
6013 Pupu
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10
Date

Sulphate (SO_4^{2-})

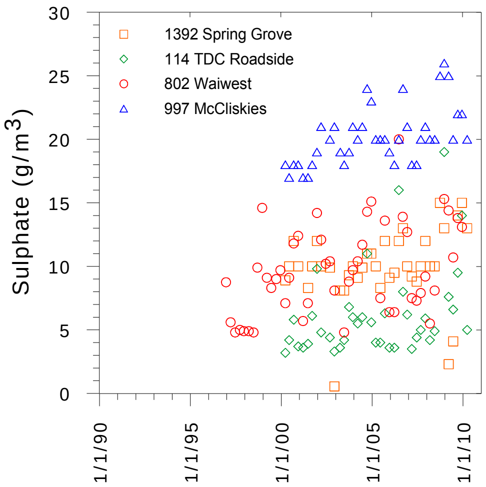
Waimea - confined



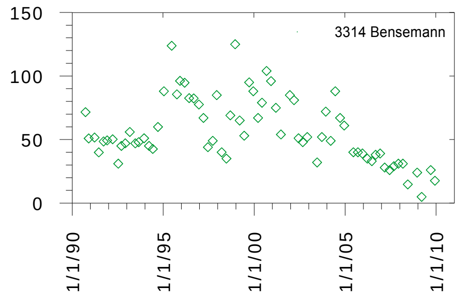
Motueka / Riwaka
unconfined



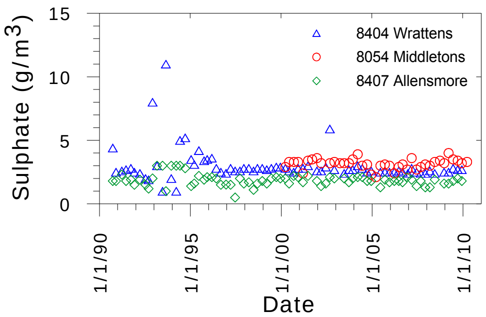
Waimea - unconfined



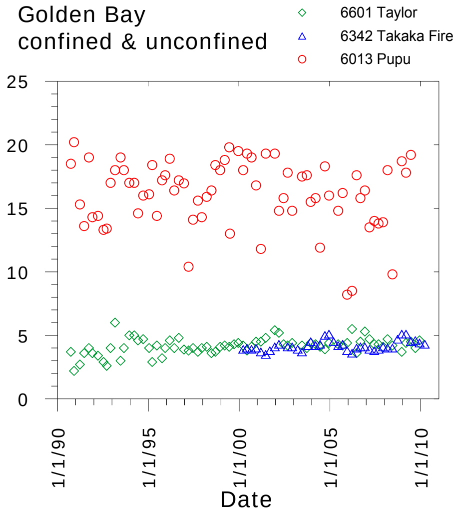
Motueka / Riwaka
unconfined



Moutere (deep) - confined

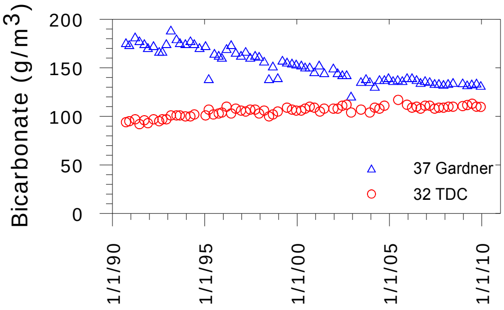


Golden Bay
confined & unconfined

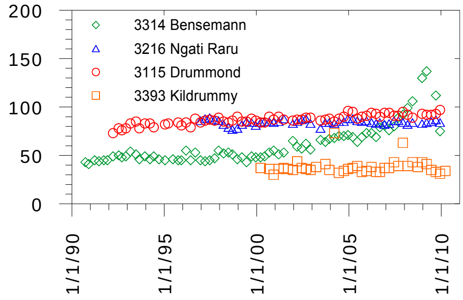


Bicarbonate (HCO_3^-)

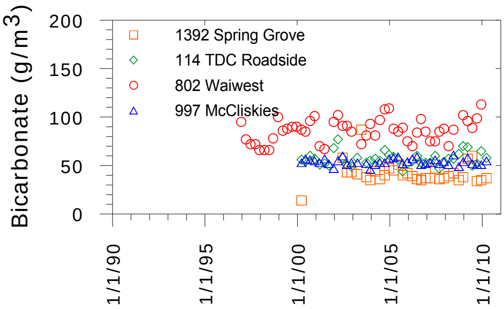
Waimea - confined



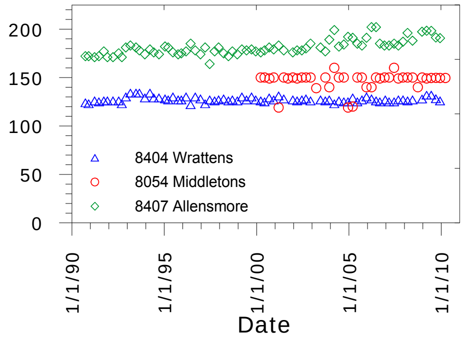
Motueka / Riwaka
unconfined



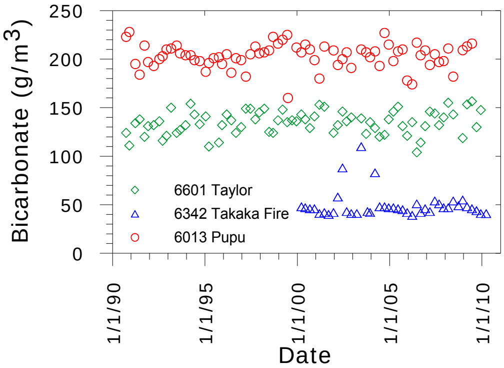
Waimea - unconfied



Moutere (deep) - confined

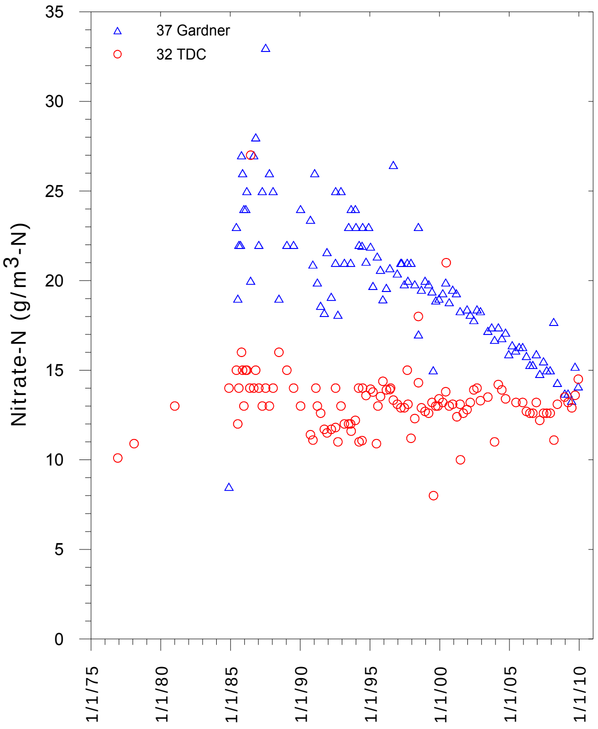


Golden Bay
confined & unconfined

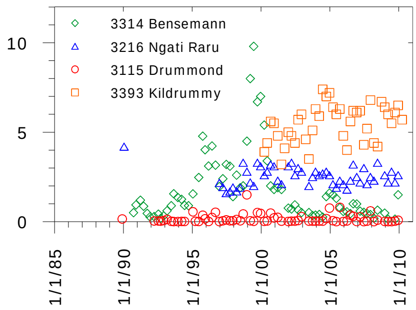


Nitrate-nitrogen (NO_3^-)

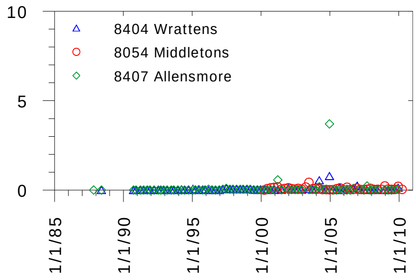
Waimea - confined



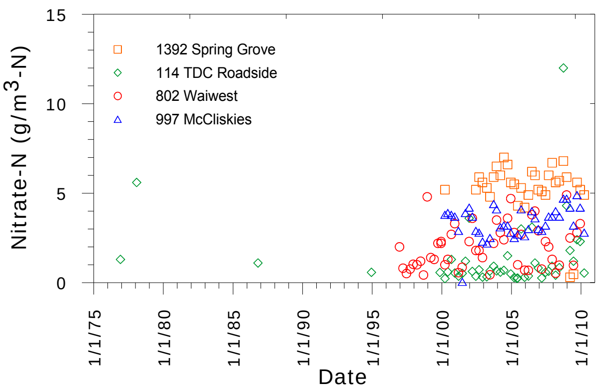
Motueka / Riwaka
unconfined



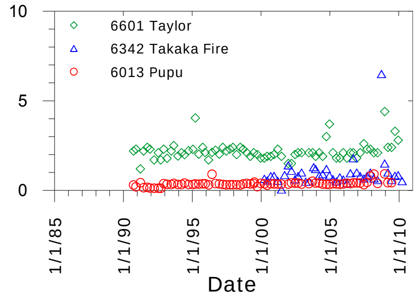
Moutere (deep) - confined



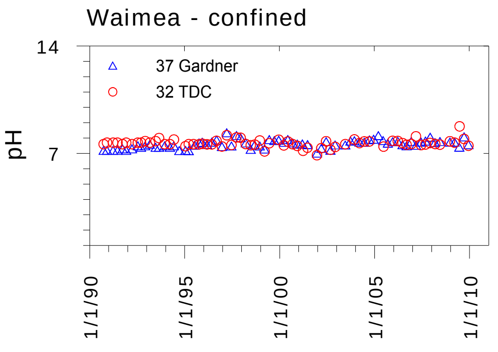
Waimea - unconfied



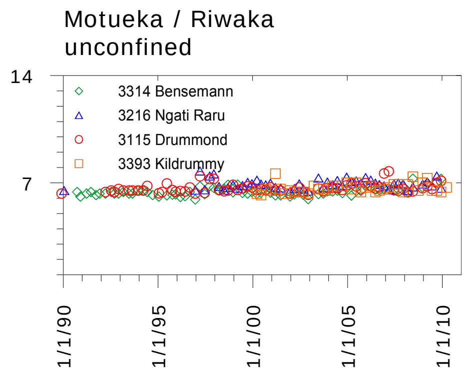
Golden Bay
confined & unconfined



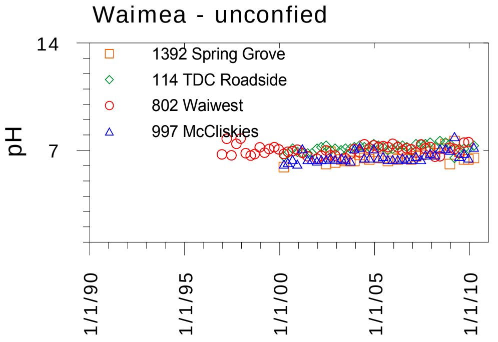
pH



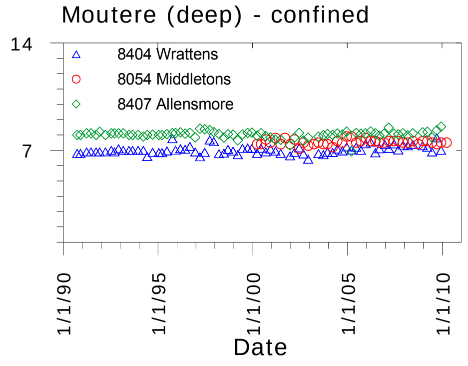
Waimea - confined
14
7
pH
37 Gardner
32 TDC
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10



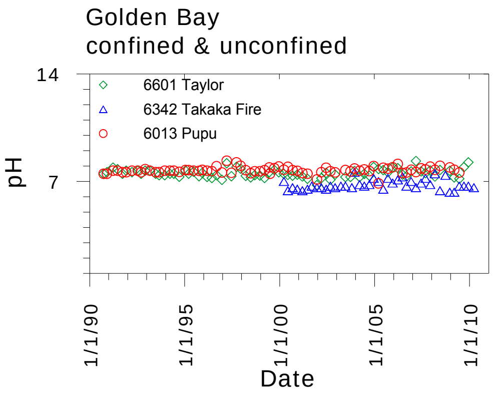
Motueka / Riwaka
unconfined
14
7
3314 Bensemann
3216 Ngati Raru
3115 Drummond
3393 Kildrummy
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10



Waimea - unconfied
14
7
pH
1392 Spring Grove
114 TDC Roadside
802 Waiwest
997 McCliskies
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10

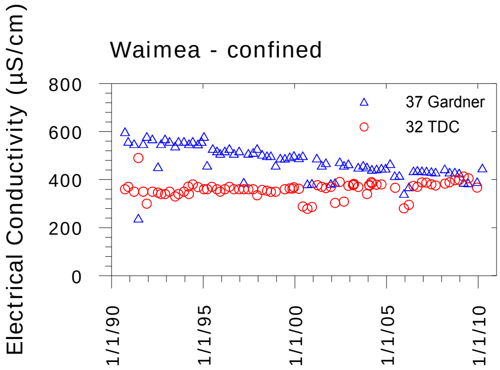


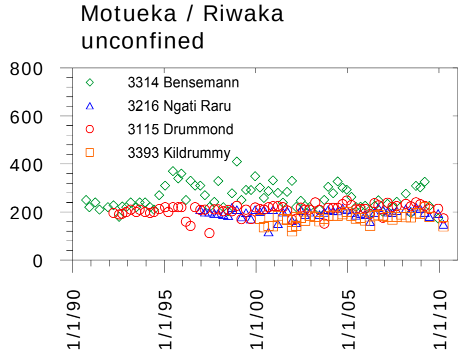
Moutere (deep) - confined
14
7
8404 Wrattens
8054 Middletons
8407 Allensmore
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10
Date

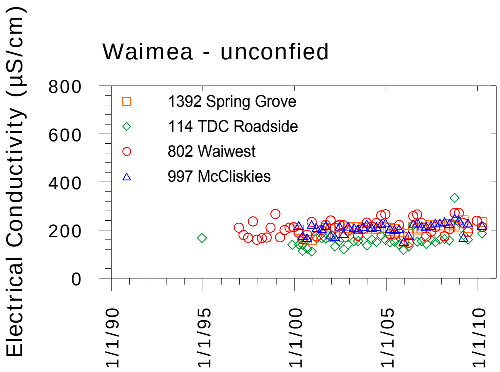


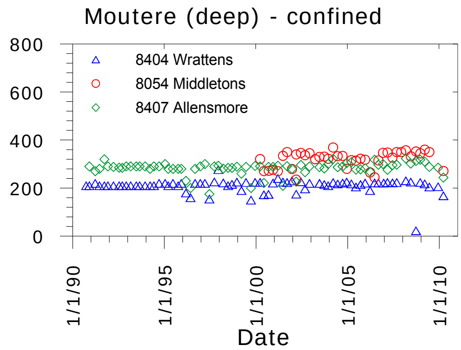
Golden Bay
confined & unconfined
14
7
pH
6601 Taylor
6342 Takaka Fire
6013 Pupu
1/1/90
1/1/95
1/1/00
1/1/05
1/1/10
Date

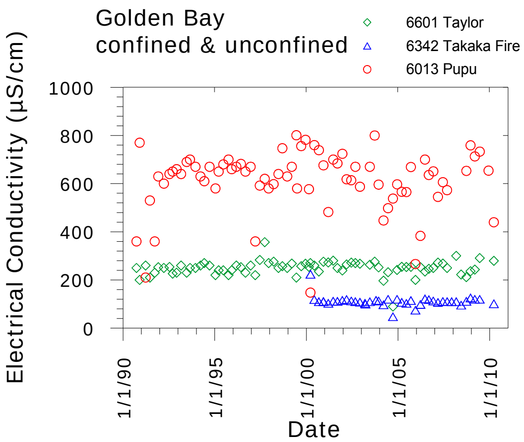
Electrical Conductivity











Appendix IV

List of pesticides tested for and the limits of detection for each method in the 2006 pesticide monitoring programme. Units are mg/m^3 (ppb).

Organo-chlorine pesticides:

lindane	0.01	*cis* permethrin	0.01
heptachlor	0.02	*trans* permethrin	0.01
heptachlor epoxide	0.03	vinclozin	0.02
aldrin	0.02	endosulfan I	0.02
procymidone	0.02	endosulfan II	0.04
α-chlordane	0.02	endosulfan sulphate	0.02
γ-chlordane	0.02	endrin	0.02
dieldrin	0.02	endrin aldehyde	0.04
methoxychlor	0.02	endrin ketone	0.04
BHC	0.01		

p,p′-dichlorodiphenyldichloroethylene (DDE)	0.01
p,p′-1,1-dichloro-2,2-bis(4-chlorophenyl)ethane (DDD)	0.01
p,p′-1,1,1-trichloro-2,2-bis(4-chlorophenyl)ethane (DDT)	0.01

Organo-phosphorus pesticides:

azinphos methyl	0.4	pirimiphos methyl	0.02
diazinon	0.01	chlorpyrifos	0.02

Organo-nitrogen herbicides:

trifluralin	0.02	metribuzin	0.02
simazine	0.01	bromacil	0.03
atrazine	0.01	oryzalin	2.0
propazine	0.01	linuron	0.04
terbuthylazine	0.01	hexazinone	0.02
desethyl atrazine	0.02	norflurazon	0.02
desisopropyl atrazine	0.1	metalaxyl	0.01
propanil	0.02	acetochlor	0.02
alachlor	0.02	oxadiazon	0.01
metolachlor	0.02	cyanazine	0.02
pendimethalin	0.02	terbacil	0.02
molinate	0.02		

Acid herbicides:

mecoprop	0.1	triclopyr	0.1
MCPA	0.1	2,4,5-T	0.1
MCPB	0.1	2,4-DB	0.1
Acifluorfen	0.1	bentazone	0.1
Bromoxynil	0.1	fenoprop	0.1
Dicamba	0.1	picloram	0.1
dichlorprop	0.1	3,5-dichlorobenzoic acid	0.1
dinoseb	0.1	pentachlorophenol	0.1
2,4-D	0.1		