STAFF REPORT

TO: Environment & Planning Committee

FROM: Glenn Stevens, Resource Scientist

REFERENCE: R10003

SUBJECT: **GROUNDWATER QUALITY IN TASMAN DISTRICT - REPORT REP10-12-09 -** Report prepared for meeting of 16 December 2010

A report on the groundwater quality across the Tasman District has been completed. It reports the results of Council's groundwater quality State of the Environment monitoring program where data has been regularly collected from 16 sites (with up to 20 years of data available at some sites). Ten of these sites are also included in the National Groundwater Monitoring Programme coordinated by the Institute of Geological and Nuclear Sciences. The report also includes other miscellaneous groundwater quality data collected and held by Council.

Two versions of the report have been prepared: a summary report (19 pages) and a full report (56 pages). The summary report is included in this EPC agenda. The full report is available upon request (please contact Glenn Stevens). The report covers information on the chemical characteristics of groundwater from the principal aquifers across the District, apparent trends in this data, and human influences on groundwater quality. The report does not cover the extent, use, availability and reliability of groundwater supplies.

Detail of continued work on the groundwater quality State of the Environment monitoring programme is included in the report.

RECOMMENDATION:

Council receive the report REP10-12-09 entitled "Groundwater Quality in Tasman District".

Glenn Stevens
Resource Scientist

Summary Report: Groundwater Quality in Tasman District

Document Status:

November 2010

This is a summary report of Tasman District Council's "State of the Environment" Groundwater Quality Monitoring Programme.

A larger more comprehensive technical report (TDC ref:R10003) is available which more comprehensively details the results of various monitoring data collected by Tasman District Council, including that collected for the National Groundwater Monitoring Programme.

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Tasman District Council Ref: R10004

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EXECUTIVE SUMMARY

Council monitors groundwater quality at 16 quarterly sampled sites for a range of parameters (the Groundwater State of the Environment Monitoring programme). In addition, Council collects other miscellaneous groundwater quality data across the District from time to time and as part of synoptic surveys.

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, residential, or other, the greater the likelihood of non-natural human influences to 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 since the 1970's in the Waimea plains has shown elevated nitrate concentrations in many places east of the Waimea River (both in the confined and unconfined aquifers). This contamination includes historic sources of nitrate which have been decreasing over time and may also include inputs occurring from current land uses.

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

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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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'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 and now comprises a total of 16 sites. Ten of these sites are also part of the New Zealand National Groundwater Monitoring Programme coordinated by the Institute of Geological and Nuclear Sciences.

The 16 SEM sites are distributed across a representative sample of the District's groundwater environments as follows (Figure 1).

- 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.

Other groundwater quality data is also collected by Council in the exercise of its various functions.

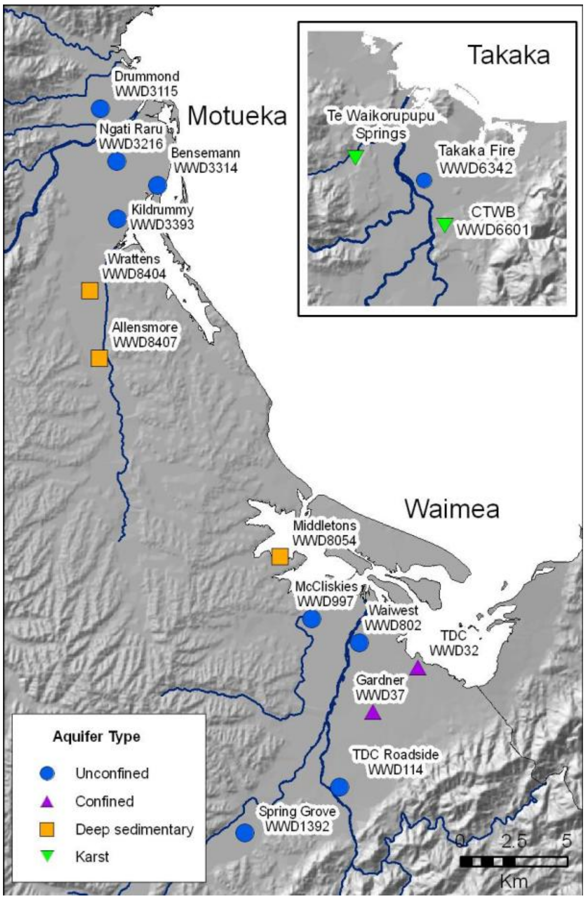

Figure 1 Groundwater quality monitoring programme sampling sites – Tasman District.

Characterisation of monitored groundwaters

Regional analysis and hierarchical cluster analysis

Regional analysis and hierarchical cluster analysis (Daughney (2005) identifies six clusters determined by up to three separation thresholds (summarised in Table 1). 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 thresholds are relatively small compared against all of the groundwaters from across the country assessed in the NGMP. This means that the 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. Three of the four sites in this cluster are from the Moutere aquifer where such conditions are expected.

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) WWD37 (Waimea, gravel, confined) 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)

TDS = Total dissolved solids

1 Nomenclature from Daughney 2005

Median concentrations

A tabulated summary of the median, median absolute deviation (MAD) and trends for the key geochemical parameters is presented in Appendix I.

By in large the median concentrations of most parameters reflect natural influences to the groundwater from the aquifer geology and the degree of groundwater / rock interaction that occurs as the groundwater moves through the subsurface. The observed median concentrations of some parameters, notably nitrates, reflect human influence occurring at some sites.

All three Golden Bay monitoring sites have higher calcium and bicarbonate concentrations than those of the Motueka and Waimea plains as a result of the 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 reflecting their respective aquifer lithologies.

A higher total dissolved solids concentration in the alluvial confined aquifers indicate a greater degree of groundwater-rock interaction than in the adjacent unconfined alluvial aquifers. The confined Moutere Gravel aquifers having the longest residence times and greater degree of groundwater/rock interaction have the highest total dissolved solid concentrations compared to the other monitored Tasman groundwaters.

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).

Comparison with groundwater elsewhere in New Zealand

Whilst in general most of the monitored parameters in Tasman have similar median concentrations to groundwaters as those of New Zealand as a whole, there are small variations attributable to the differences in geology of the aquifers and their catchments. Primarily, the marble and limestone geology in parts of Tasman (particularly Golden Bay) and the relatively common occurrence of basic igneous rocks from the Dun Mountain/Red Hills ultramafic mineral belt within the alluvial aquifers of the Waimea plains and the Motueka catchment.

Nitrate concentrations are discussed on page 7.

Comparison with New Zealand's drinking water standards

Overall, the median concentrations of the tested parameters at the 16 SEM sites are below (i.e. comply with) the relevant New Zealand drinking water maximum allowable values (MAV) and guideline values (GV) (contained in Ministry of Health 2005). The exceptions being:

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

The pH GV (that it falls between 7.0 and 8.5 pH units) 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) and one site with a median pH of 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 are of health concern. 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 hence have a MAV of 0.4 g/m^3. There is no MAV for iron. Only one SEM site (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.

Variability of monitored parameters

Relatively high variability[2] in the median concentrations is 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. However, caution is needed with parameters that have very low but otherwise stable median values as any measurable variability appears significant in comparison.

2 Daughney (2005) arbitrarily identifies sites with a low variability as ones where the MAD is less than 10% of its corresponding median. This measure of significance can be skewed where the median values are very low.

As expected the most secure SEM sites are the deeper confined aquifers and the less secure sites are the shallow unconfined gravel aquifers.

Te Waikoropupu Springs has considerable variation in the median values of a number of parameters as a result of the natural saline influence the spring's discharge (Thomas 2001), but is otherwise considered a secure groundwater site.

The Upper Confined Aquifer (UCA) of the Waimea plains, being a confined aquifer is expected to be a secure groundwater site. The apparent statistical variability in some parameters is a result of the strong decreasing trends observed in a number of parameters rather than a reflection of the site's security. However, as with the Lower Confined Aquifer (LCA), it has still been impacted by nitrate contamination.

Trends in monitored parameters

Most parameters at a majority of, but not all, sites are relatively stable and statistically are not showing significant trends[3]. The only statistically significant trends are increasing iron and manganese concentrations in WWD 3314. However, there have been problems with this bore and it has been subsequently decommissioned and replaced with a new bore located 120 metres to the west in late 2009. At the time of writing insufficient groundwater quality data is available from the new bore to comment further.

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

WWD 37 Gardner – Upper Confined Aquifer

Pervasive decreasing trends over a number of parameters (primarily calcium, magnesium and bicarbonate) indicative of a strong dilutional trend. The cause of this is not well understood and may be influenced by leakage occurring between the underlying LCA and the overlying unconfined aquifer at the land surface.

Nitrate concentrations are high but decreasing.

3 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. This measure of significance can be skewed where the median values are very low.

WWD 32 TDC – Lower Confined Aquifer

Slight increase in magnesium and bicarbonate concentrations. It is unknown if these increases are the result of mixing with groundwater from the overlying Upper Confined Aquifer.

Sulphate concentrations have been gradually increasing over time and nitrate concentrations slowly decreasing.

WWD 997 McCliskies and WWD 802 Waiwest – Unconfined aquifers

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

WWD 3393 Kildrummy – Unconfined aquifer

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.

Nitrates in Tasman's groundwater

Nitrates are an indicator of human influence to groundwater (MfE 2007). Nitrate inputs 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. Plots of the measured nitrate concentrations in the 16 SEM sites are shown in Figure 2.

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 influence:

- 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).

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).

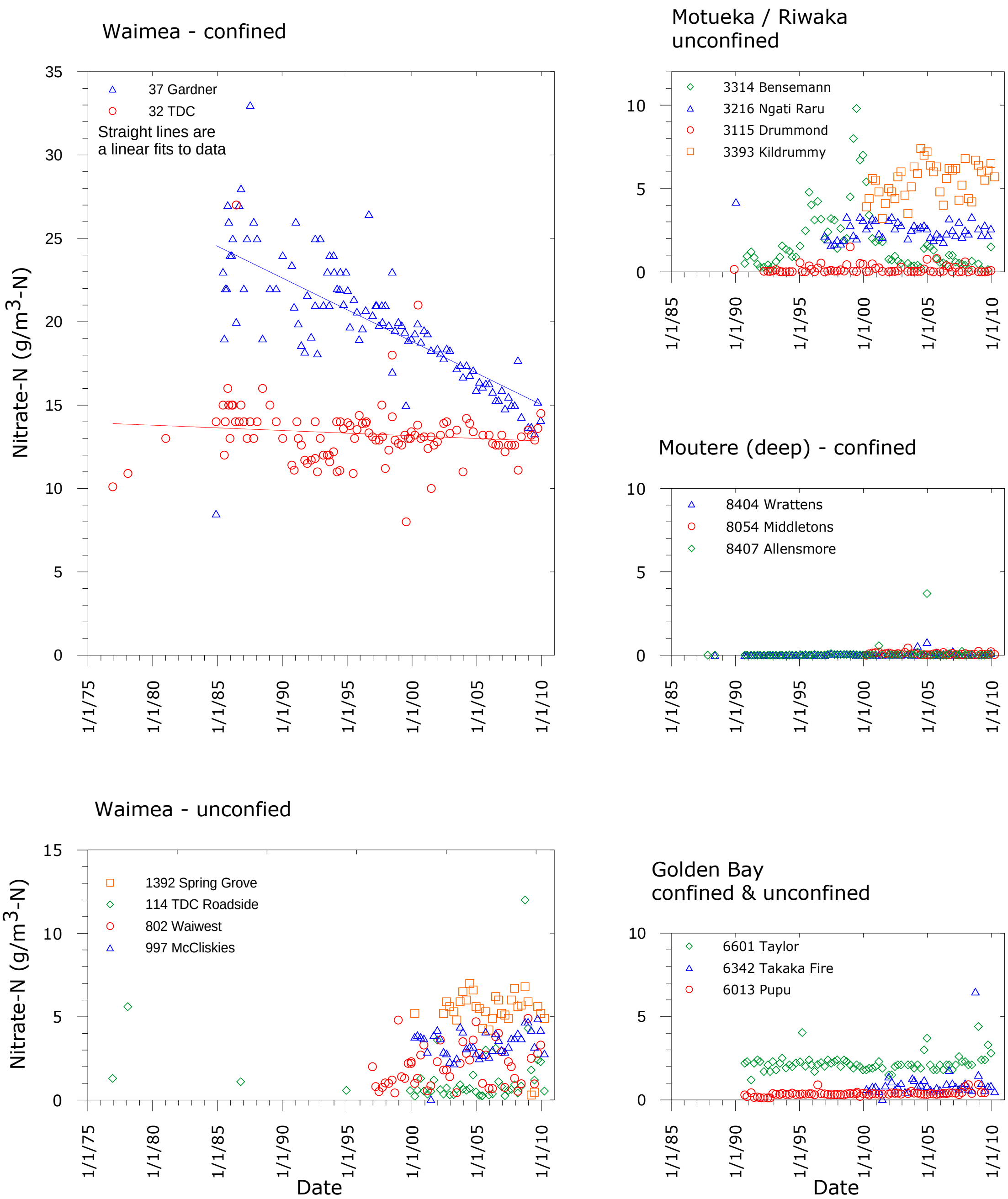

Figure 2 Nitrate-N concentrations in the groundwater quality State of the Environment monitoring sites.

In addition to the groundwater SEM programme 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.

Whilst much of these additional nitrate 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. Figure 3 shows the average of all data between 2000 and 2009 collected at a particular site across the District. However, in many cases it represents only a single sampling event.

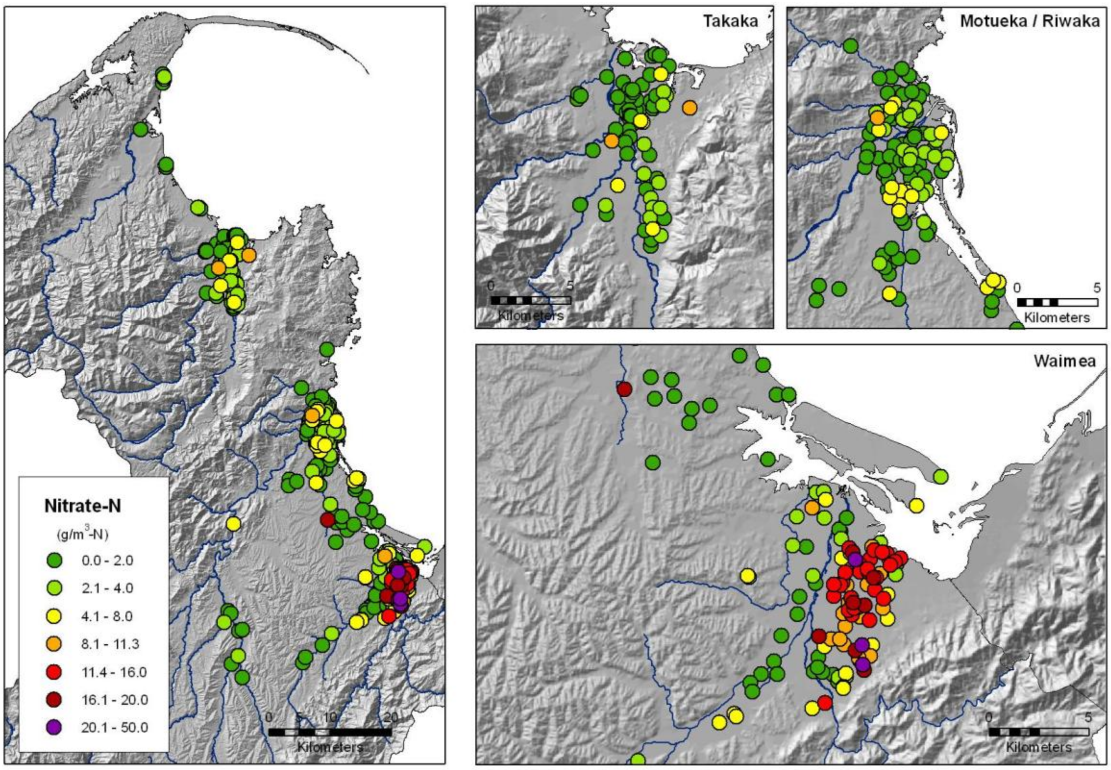

Figure 3 Nitrate-N concentrations across the Tasman District (average since 2000).

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 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 waters.

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.

Excluding the Waimea plains east of the Waimea River, the median nitrate concentrations for all sites across the District[4] since 2000 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.

Nitrates in the Waimea Plains

Since the 1970’s elevated nitrate concentrations have been found across the Waimea Plains and extensive monitoring 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 across the respective aquifers.

Data from the 2005 survey are presented in Figure 4. 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. The highest nitrate concentrations in the UCA were encountered along its eastern edge (up to 27 g/m^3-N in 2005) 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.

4 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.

At the northern end of the UCA in the vicinity of State Highway 60 and Swamp/Bartlett roads the aquifer becomes unconfined and merges into 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.

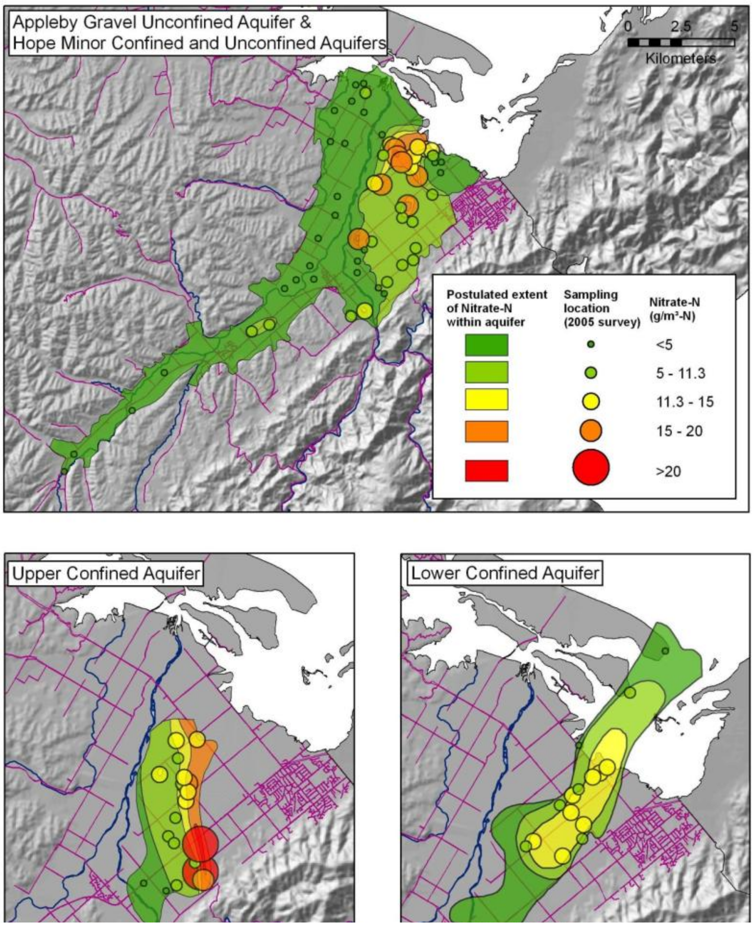

Figure 4 Nitrate-N concentrations in the aquifers of the Waimea Plains – winter 2005.

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 2 and Appendix II).

Pesticide Residue monitoring

Many land owners have in the past used, or still use, various pesticides5 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 2007).

In the most recent survey (2006) Pesticide residues were detected in only five of the 15 sites sampled (i.e. had concentrations above the detection limit of the laboratory analysis). In 2002 pesticide residues were detected at nine sites and in 1998 at ten sites. The sampled sites are all unconfined relatively shallow groundwaters. The sites represent a number of current and historic land uses.

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 relative to the drinking-water standard was for simazine (at WWD 4096) which was only 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.

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. However, 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 as elevated nitrate concentrations).

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

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. These are not necessarily indicative of widespread contamination. In most, but not all, cases it is the cumulative effects of such discharges that are of greater concern.

There is a large range of land use across the District, often within a relatively small area giving 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 etc.). As a consequence, groundwater quality at a particular 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.

Unfortunately 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. 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.

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 in the national groundwater pesticide monitoring programme.

- Completion of the isotope analysis of Waimea plains groundwater (for both age and nitrogen species). Envirolink funding has been recently approved to undertake this analysis.

- Review the establishment of an additional 1 to 2 groundwater SEM sites in an area 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 Long Term Plan, 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.

References

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. 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.

Stevens, G.J. 2007. 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

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

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

Site		***Silica (SiO_2)*** *g/m^3*			***Iron (Fe^{2+})*** *g/m^3*			***Manganese (Mn^{2+})*** *g/m^3*			***Ammonia-N (NH_4^+)*** *g/m^3-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 I(c) Summary of medians, median absolute deviation (MAD – a measure of variability) and trend for the 16 SEM sites (continued).

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															
	Guidelines							250 (aesthetic – taste, corrosion)			250 (aesthetic – taste)					

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

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					

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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.