

NERMN Groundwater Monitoring Report



Bay of Plenty Regional Council
Environmental Publication 2013/02

5 Quay Street
P O Box 364
Whakatane
NEW ZEALAND

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*Working with our communities for a better environment
E mahi ngatahi e pai ake ai te taiao*





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February 2013

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Cover Photo:
Installation of groundwater monitoring bore Lake Tikitapu. Photo by
A Lovett, GNS Science.

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How to read this report

This report has been constructed to read for both hard copy and electronic version. For electronic versions there are bookmarks embedded throughout the report that will link you to tables, maps and appendices referenced throughout the report. Click on the word and Ctrl+Click to follow link.

Executive summary

Bay of Plenty Regional Council (BOPRC) is required to undertake monitoring activities as part of its statutory responsibilities under the Resource Management Act 1991 (RMA). The monitoring data from the Natural Environment Regional Monitoring Network (NERMN) programme for groundwater has been collated and verified. This report provides an assessment of the groundwater level and groundwater quality of the aquifer systems we monitor.

The aquifer systems are informally named after the geological units they occur in. Aquifer systems are monitored for water quality and water level. However not all aquifers that are used are being monitored, or have only limited monitoring extent.

For the plains and low lying hill country the aquifer systems presently monitored are Tauranga Group sediments (river, estuary, marine); Volcanics like Waiteariki Ignimbrite; Aongatete Ignimbrite, and to a limited extent Mamaku Plateau Formation; Matahina Ignimbrite; and Minden Rhyolite/other volcanics. Those aquifers presently used but not monitored are Whitianga Group; Manawahe Volcano; Rotoiti Formation; and basement Greywacke.

For the Rotorua lake catchments the aquifer systems presently monitored are Mamaku Plateau Formation; Pokai and older volcanics; Pokai/Chimp Ignimbrite; and Tauranga Group sediments (lake sediments). The main focus of the lake monitoring is water quality in relation to land use and lake water quality.

Groundwater is part of the hydrological cycle and is therefore influenced by climatic change (Southern oscillation index; El Niño/La Niña). Rainfall partnered with the geology/soil type, topography and temperature can influence the amount of rainfall that percolates (recharges) to an aquifer system. Recharge to an aquifer system can be shown by a rise in bore water level.

Of the 54 water level monitoring bores assessed, 12 shows a decline in aquifer water level. These water level declines were localised and not widespread over the entire aquifer system. This indicates that use of groundwater in these areas exceeds that ability for the aquifer to recover before intensive pumping commences again.

There may be structural constraints within the aquifer at these locations that inhibits flow, so the effect in water level could be exaggerated because of the structural conditions. However without water use data or targeted hydraulic testing, the decline in water level cannot be determined.

Of the remaining 42 water level monitoring bores, water level is stable in 32 bores and increasing in 10. The stable trend indicates that groundwater use from the aquifer is sustainable; that in times of rest (no pumping) the aquifer can recover (replenished) so that recharge is meeting abstraction (use). The increasing trends probably indicate areas where over-use has occurred in the past.

It is considered that due to *Pseudomonas syringae pv. actinidiae* (Psa), climate change, land use change or maturity of crop, groundwater use has declined. Therefore less water is taken from the resource and the water level is able to recover to previous background levels. Water use data is crucial in understanding these trends. This information is lacking from the monitoring record.

Water quality data has been collected at varying intervals from 59 monitoring bores over the past twenty years. Presently 22 monitoring bores are used to provide water quality data. Twenty variables are assessed to determine any trend in water quality over time. Four of our bores are part of the National Groundwater Monitoring Program managed by GNS Science.

Groundwater quality in the region generally does not appear to be changing over time. Trend analysis found relatively few variables having statistically significant changes over time. However this can be due to the limited frequency of sampling, total number of samples and data gaps which can inhibit the ability to identify trends.

Groundwater quality concerns for the Bay of Plenty are:

- contamination by nutrients (nitrate, phosphate);
- contamination by microbial pathogens;
- risk of induced salt water intrusion;
- naturally elevated concentrations of iron, manganese, arsenic.

Aquifer properties of water level and groundwater quality have typically been seen as separate monitoring regimes. The importance of how each informs the other appears not to have been recognised. Only 15 of our monitoring bores have both water level and groundwater quality records. All others are either one or the other. This limits our ability to identify and understand any trends that may be present.

The findings of this report will be used to review and make recommendations to the NERMN groundwater monitoring programme. A review of the groundwater monitoring program is not within the scope of this report.

Contents

Acknowledgements	i
Executive summary	iii
Part 1: Introduction	1
1.1 Overview	1
1.2 Report purpose	1
1.3 Report scope	1
1.4 Report outline	1
Part 2: Groundwater monitoring and management in the Bay of Plenty region	3
2.1 Monitoring network overview	3
2.2 Monitoring regime	3
2.3 Monitoring protocols and methodologies	4
2.4 Management of groundwater allocation and quality	5
2.5 Current and future research and reporting	6
Part 3: Groundwater systems	9
3.1 Hydrogeological overview	9
3.2 Groundwater level	17
3.3 Groundwater quality	18
Part 4: Groundwater level assessment	19
4.1 Data management and trends	19
4.2 Discussion – factors influencing groundwater quantity	30
Part 5: Groundwater quality assessment	33
5.1 Data management and trends	33

5.2	Groundwater quality	33
Part 6: Conclusions		45
6.1	Overview	45
6.2	What is the monitoring telling us	45
6.3	Further work	46
Part 7: Recommendations		47
Part 8: References		49
Appendix 1 – Maps		53
Appendix 2 – Table of monitoring bores		67
Appendix 3 – Groundwater quality tables		73
Appendix 4 – Individual bore information sheets		95
List of Figures		
Figure 1	The natural water cycle	9
Figure 2	Southern oscillation Index	10
Figure 3	EarthVision 3-D western Bay of Plenty groundwater systems	12
Figure 4:	EarthVision cross-section western Bay of Plenty groundwater systems	12
Figure 5	EarthVision planar view western Bay of Plenty groundwater systems	13
Figure 6	Profile at Otakiri - Rangitaiki Plains	14
Figure 7	Cross-section through Otakiri - Rangitaiki Plains	14
Figure 8	Groundwater catchments and groundwater zones for sub-regional model	15
Figure 9	Concept of groundwater flow and allocation.	15
Figure 10	Consented groundwater take volume by purpose	17
Map 22	41	
Map 1	Regional distribution of NERMN groundwater bores	55

Map 2	NERMN water level bores and associated rainfall gauge sites	56
Map 3	Location of monitoring bores Western Bay of Plenty area	57
Map 4	Location of monitoring bores Tauranga area	58
Map 5	Location of monitoring bores Te Puke area	59
Map 6	Location of monitoring bores Rotorua area	60
Map 7	Location of monitoring bores Rangitāiki Plains area	60
Map 8	Location of monitoring bores Galatea area	62
Map 9	Location of monitoring bores Ōpōtiki area	62
Map 10	NERMN groundwater level monitoring and allocation	64
Map 11	NERMN groundwater level monitoring and allocation Waiteariki/ Aongatete Ignimbrite aquife	65

List of Tables

Table 1	Groundwater systems presently monitored.	11
Table 2	Summary of water level trends by aquifer	21
Table 4	Bore with groundwater quality concerns	35
Table 3	Bore with declining water level trends and groundwater quality monitoring	43

Part 1: Introduction

1.1 Overview

The Resource Management Act 1991 (RMA) section 35(2)(a) requires Council to monitor the environment to enable Council to effectively carry out its functions. This report forms part of Bay of Plenty Regional Council (BOPRC) responsibility under the RMA. The Natural Environment Regional Monitoring Network (NERMN) groundwater was initiated July 1990 and continues today providing longevity of record on our groundwater systems. The program includes bores that were monitored as far back as 1983. For the purpose of this report water level data and groundwater quality data up to January 2012 has been used to assess the groundwater resources of the region.

1.2 Report purpose

The purpose of the report is to consider all the monitoring data to date that Council has collected for groundwater level and groundwater quality over the last twenty years or so to determine if there are any trends of concern that need to be addressed.

The purposes of monitoring groundwater resources of the region are:

- to provide data on the properties of the groundwater systems;
- this data can inform matters that need to be covered by regional policy;
- assist with the sustainable management of the resource; and
- identify trends in groundwater level and quality that may affect groundwater availability and potential use.

1.3 Report scope

The scope of this report is to provide information on how the groundwater levels and groundwater quality of the region have behaved over the past decades of monitoring record.

The scope of the report is not to answer how trends are to be managed, but to identify concerns that may need attention.

During the process of drawing this report together, gaps and some deficiencies in our monitoring have been identified. The scope of this report is not to deal with these matters, but to refer them to the formal review of the NERMN groundwater program to be undertaken in the near future.

1.4 Report outline

The report looks at the current groundwater monitoring regime and management structure in policy. It provides a brief overview of the groundwater systems in the region and climatic influence the groundwater resources. Assessment is made of groundwater level and groundwater quality data to identify trends. These trends and observations are discussed. Conclusions and recommendations are made.

Part 2: Groundwater monitoring and management in the Bay of Plenty region

2.1 Monitoring network overview

Coverage of the entire groundwater monitoring network is shown in Appendix 1, where maps detail the bore location and type of monitoring undertaken. The region has been divided into seven mapping areas in order to better manage the amount of data requiring assessment.

Bore and groundwater monitoring information are tabled in Appendix 2 and relate to the maps found in Appendix 1. The present monitoring network comprises 56 bores; 34 measure water level, 7 measure quality, 15 measure both water level and groundwater quality.

Assessment of groundwater quality data is tabled in Appendix 3, with comprehensive information sheets for each monitoring bore provided in Appendix 4 (in numerical order). This includes the geological profiles, graphed water level data and graphed groundwater quality data (chemistry) for each monitoring bore. Discussion of the data is held in Part 4 (groundwater level) and Part 5 (groundwater quality) of this report.

There are several groundwater systems throughout the region. Not all of these systems are monitored. Presently there are eight aquifers that are part of the monitoring program (Table 1); some are better represented than others. Historically Council has relied on the good will of bore owners for the use of their bores for monitoring purposes. This does not always coincide with even coverage of the groundwater systems in use. Over the past twenty year monitoring period several bores have been removed from the monitoring program for various reasons (bore collapse, access to bore denied).

2.2 Monitoring regime

Groundwater level is measured continuously for eight of our monitoring bores. This provides the best data record for assessment of the dynamics of our groundwater systems. All other bores have their water levels measured quarterly, however this is loosely observed and monitoring does not occur at the same time each year. The data from these bores does not provide as clear a picture of the climatic and pumping influence on a groundwater system as the continuously recorded bores.

Groundwater quality monitoring occurs on an annual basis. Again this is loosely observed and monitoring does not occur at the same time each year. This frequency of monitoring does not provide for robust trend analysis on groundwater quality over time. Presently water is analysed for major cations and anions. This can provide information on the source of the groundwater (the geology it has passed through and land use) and provide limited trend analysis for changes in the groundwater quality due to pumping influence.

2.3 Monitoring protocols and methodologies

2.3.1 Groundwater quality

Environmental Data Services staff follows the national protocol for State of the Environment groundwater sampling in New Zealand (MfE, 2006) for the collection of groundwater quality samples wherever possible.

This involves:

- calibrating all field instruments at least daily on the sample day;
- sampling from the source before holding tanks and filters;
- purging the bore of at least three times the volume of water contained;
- continued purging until Temperature, pH and Conductivity have been measured on at least 4 occasions (one purge apart); and
- the differences between the last two measurements are within the following limits: Temperature $\pm 0.2^{\circ}\text{C}$, and Conductivity $\pm 3\%$, and pH ± 0.1 pH units.

Where this is not possible, it is noted why and the sampling procedure taken is detailed on the field sheet. Samples are chilled immediately and delivered to the BOPRC Laboratory on the same day and stored for analysis and/or distribution for analysis.

Presently water is analysed for major cations and anions; Alkalinity, Calcium, Chloride, Conductivity (ms/m), Fluoride, Iron, Potassium, Magnesium, Manganese, Sodium, Ammoniacal-N, Nitrate-N, pH, and Sulphate. In the past several other elements have been analysed for. These are listed on the front page of Appendix 3.

2.3.2 Groundwater level

Manual groundwater levels are measured from a known measure point. In some cases this level point has a reduced level, and in some cases this reduced level has been surveyed to Moturiki Datum. Where possible groundwater levels should not be measured within two days of rainfall, however as groundwater levels are measured quarterly, this is not always possible.

There is no provision to ensure the pump is off for at least 24 hours prior to the water level measurement being taken, to ensure that the static water level is measured. Most of the bores measured are privately owned production bores, some for domestic supply and others set up for irrigation programs. These takes are not interrupted for monitoring purposes. If the pump is on at the time of measurement it is noted on the field sheet. However it is not known the duration of time the pump has been off prior to the measurement. Therefore the reading could be the drawdown level of recovery rather than the static water level.

Telemetered groundwater levels are measured at least 15-minute intervals. Unless sooner due to issues, the site is visited at least every three months and a check is made of the recording sensor. If the recording sensors telemetered data is different to the manual measurement by more than ± 3 mm, the raw data is adjusted to the manual reading, creating processed data. A rating is applied to the processed data to convert it to Moturiki Datum. Telemetered sites are survey levelled annually from at least two benchmarks to within ± 3 mm. If there has been site movement greater than 3 mm within the year, the rating to apply Moturiki Datum is adjusted accordingly. When the Moturiki Datum for the area is updated by LINZ, BOPRC or other, the

rating is adjusted and backdated. Every few years (usually 3 to 5 years), the processed data is audited and checked externally.

2.4 **Management of groundwater allocation and quality**

Groundwater allocation and quality is currently managed under the

Bay of Plenty Regional Water and Land Plan (WLP), in particular Chapter 5: Water Quantity and Allocation. The RMA also provides permitted groundwater use for reasonable domestic and stock drinking water requirements under Section 14(3)(b).

Matters regarding the groundwater resource are set out in the WLP. In brief they are as follow:

- To allocate groundwater at a sustainable yield that avoids permanently or unsustainably lowering water levels, or degrading groundwater quality in aquifer systems, or streams/rivers where groundwater and surface water bodies are linked.
- Undertake surveys in areas of the region where water is at or near full allocation to identify water takes permitted under the RMA and WLP to establish an accurate water take record.
- Ensure the maintenance of high quality groundwater for recharge areas that contribute groundwater to aquifers that are pristine or used for public water supply, and to improve degraded groundwater quality where appropriate.
- Take appropriate action where there is significant adverse effect on groundwater quality, or there is a high risk that future development would adversely affect groundwater quality due to land use practices.
- Provide information to the public on the availability and quality of groundwater resources.
- Determine sustainable yields of groundwater systems.

The data from the NERMN groundwater program can be used to support some plan provisions in regard to allocation (water level) and groundwater quality. However we do not have the data to clarify impact due to abstraction pressure (allocation and actual use) on groundwater systems or related surface water systems.

Investigation of the groundwater resources of the Bay of Plenty is being carried out under the 'Sustainable Water and Geothermal Programme' of the Ten Year Plan. This work has been commissioned from GNS Science (GNS). Mass water balances are derived in these investigations to estimate the groundwater volumes available for allocation whilst ensuring surface waters are not compromised. In most areas groundwater and surface water are connected, with groundwater supplying the base flow for streams and rivers.

The groundwater allocation is provisionally set at no more than 35% of average annual recharge. This figure is taken from the Proposed National Environmental Standard on Ecological Flows and Water Level (the 'NES'). The NES is currently on-hold pending consideration of further advice to the NZ Government from the Land and Water Forum.

The groundwater available for allocation have been calculated against the NES to set an allocation volume for each groundwater catchment.

Actual groundwater use under resource consent is not recorded consistently across the region. Therefore an estimated actual groundwater use has been calculated. For this purpose the consented groundwater allocation is based on estimated actual use as follows:

- Frost protection water use for 30 days/year at the consented daily volume.
- Irrigation water use for five months/year at the consented daily volume.
- Municipal water use for 365 days/year at the consented daily volume

These figures help to inform consent and planning staff of areas in the region where potentially there are groundwater allocation concerns (see Map 10 and Map 11).

2.5 Current and future research and reporting

Evaluation of the groundwater resources of the Ōpōtiki area has recently been completed. Groundwater evaluation and conceptual models are presently under development for the greater Tarawera lakes catchment. The evaluation of the groundwater system of the Upper Rangitaiki is presently being scoped and will be initiated this year.

Two monitoring bores have been installed at Papamoa and Ōtamarākau for the purpose of measuring water level and corresponding groundwater quality change (Conductivity). The purpose is to identify any risk of salt water intrusion along the coast into freshwater aquifers if the groundwater levels decrease to a particular level due to pumping stress.

Three groundwater recharge monitoring stations (lysimeter) have been installed at existing BOPRC rainfall recorders. The three new sites complement the existing groundwater recharge monitoring station at Kaharoa. These sites are within groundwater catchments significant for rainfall recharge to extensive groundwater systems and groundwater catchments with high use. The monitoring stations are located at Kaharoa (Kaituna catchment), Mangorewa (Lower Kaituna catchment), Pongakawa (Pongakawa-Kaikokopo-Pokopoko-Wharere catchments), and Lower Kaimai (Wairoa catchment).

These sites will provide information to assess average annual rainfall recharge to the groundwater systems and under what climatic conditions does recharge occur. This data will help to inform groundwater allocation limits, which provisionally are set at 35% of average annual recharge (NES).

A drilling program has been initiated to develop a groundwater monitoring bore field at Oropi. The purpose is to intercept the three main groundwater systems that underlie this area and extend over large areas of the western Bay of Plenty providing a significant groundwater resource. The groundwater systems targeted are the Mamaku Formation, Waiteariki Ignimbrite and Aongatete Ignimbrite. The bore field will be set up with continuous water level monitoring and be regularly sampled for water quality (and possible isotope dating).

To help with assessing groundwater allocation staff have developed a numerical model to calculate estimated permitted takes under the RMA and WLP, for the region. This model has yet to be 'ground truthed' and tested, however work is progressing.

Considerable groundwater investigation has been undertaken in the greater Tarawera lake catchments to understand groundwater flow directions and groundwater quality in regard to anthropogenic impacts. This work is continuing with the development of a conceptual geological model and groundwater flow model and nutrient budget for better management of land use and potential impacts on groundwater quality and the lakes the groundwater discharges into.

Part 3: Groundwater systems

3.1 Hydrogeological overview

Groundwater is part of the hydrological cycle that is constrained by geology and influenced by climate (Figure 1). The groundwater systems of the Bay of Plenty region are predominantly found in volcanic deposits that form pumice gravel, sand and fractured rock layers that are capable of storing and releasing groundwater. There are also fluvial and marine deposits consisting of gravels and sands that can also provide a significant groundwater resource along the coastal areas of the region and within the Rangitaiki, Galatea, and Ōpōtiki plains.

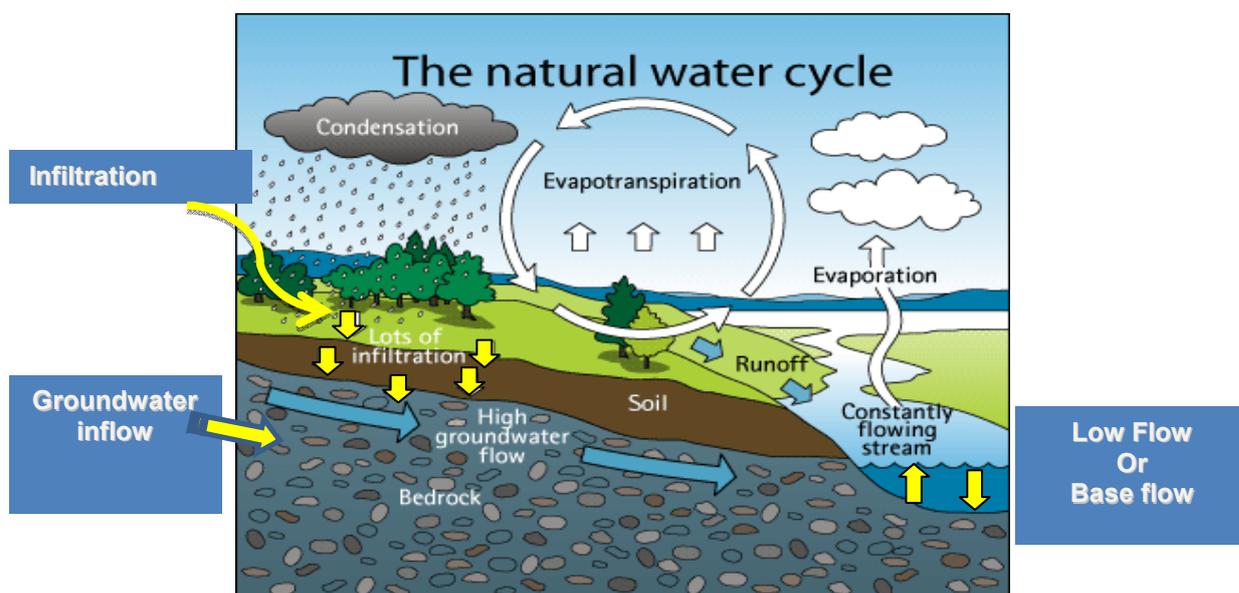


Figure 1 The natural water cycle

The groundwater resources are critically influenced by various pressures. These can include:

- Climatic conditions: rainfall and temperature.
 - Allocation: consented and permitted abstractions.
- Anthropogenic effect: land use activities and practices.

3.1.1 Rainfall and climate

The Bay of Plenty region experiences a range of rainfall due to topography and aspect. Lower lying coastal areas typically have annual totals around 1200mm, whereas double this amount can often be recorded at inland elevated locations. It is this high country rainfall that helps to recharge and sustain the groundwater systems.

The amount of rainfall the Bay receives and where it occurs is dependent on global and local weather patterns. Apart from regular seasonal change the most important global effect on our climate is the El Niño -Southern Oscillation (ENSO) cycle. This climate fluctuation occurs at times of "ocean warming". The cycle has two situations which are referred to as El Niño and La Niña. They are both characterised by variable levels of winds and rainfall in different parts of New Zealand (NIWA 2010).

These cycles of climate are shown over the decades in Figure 2. This influences the temperatures experienced over New Zealand and the location and amount of rainfall that occurs. El Niño in New Zealand typically experiences cooler temperatures while rainfall is typically above normal in the south and west, but below normal in the north and east. For La Niña, New Zealand typically experiences warmer than normal seasons with above normal rainfall in northern and north-facing regions and below normal rainfall in southern and south-western areas (NIWA 2010).



Figure 2 Southern oscillation Index

Other global weather patterns that impact on New Zealand climate are the Interdecadal Pacific Oscillation, a 20-30 year modulation in the behaviour of the ENSO cycle, and the Southern Annular Mode (SAM) that fluctuates every few weeks changing westerly wind direction and strength over New Zealand. A negative SAM situation is usually associated with unsettled and often wet conditions in parts of New Zealand.

3.1.2 Geology and aquifers

Rainfall recharges the groundwater systems. However the type of geology, soils and geomorphology also play a role in how much rainfall runs-off to surface water and how much percolates through the ground to the groundwater systems below.

Geology is the basis for identifying groundwater systems in the region. These geological units can be extensive covering large areas of the region. These units can be tens to hundreds of metres in thickness, and be gravel, sand or fracture rock.

For each monitoring bore the groundwater system can be identified by the geological unit, water level and groundwater quality. Identification can also be supported by isotope (signatures and age) and aquifer hydraulic properties (determined from pump testing data). The groundwater systems presently monitored in our region are listed in Table 1.

The groundwater systems occur in permeable geological units that are volcanic origin, with the exception of the Tauranga Group sediments; these being fluvial, marine or lake deposits that have generally been derived from the volcanic material.

Table 1 Groundwater systems presently monitored.

Groundwater system	Water level only	Groundwater quality only	Both water level and groundwater quality
Tauranga Group sediments	16	2	8
Waiteariki Ignimbrite	6	4	1
Aongatete Ignimbrite	5	0	1
Waiteariki/Aongatete Ignimbrite	6	0	0
Mamaku Plateau Formation	1	0	1
Whitianga Group	0	1	0
Pokai and older volcanics	0	0	1
Matahina Ignimbrite	0	0	1
Minden Rhyolite/other volcanics	0	0	2
Total	34	7	15

3.1.3 Conceptual model of groundwater systems - EarthVision

Investigation of the groundwater resources of the Bay of Plenty has been progressively carried out since 2006, beginning with the Rotorua Lake catchment. These investigations have been commissioned from GNS Science (GNS) and are foundation works to better understand the extent and depth of groundwater systems in the region. The conceptual geological models of groundwater systems are created in a model package called 'EarthVision' that is maintained by GNS.

To date conceptual models of the groundwater systems have been completed for the Western Bay of the Plenty area, the Lower Rangitaiki plains area, and Lake Rotorua catchment, and initiated for the Opotiki area and the greater Tarawera lakes catchment. The focus of the Western Bay, Rangitaiki and Opotiki work was on groundwater volumes and available allocation, whereas the focus for the Rotorua and Tarawera work is groundwater quality. The NERMN groundwater program plays an important role in understanding how the aquifer systems are behaving to abstraction pressure for parts of the region.

EarthVision is a 3-D model, so screenshots of the model are presented (Figures 3, 4 and 5) to show the versatility of the model and its ability to show groundwater extent and depth. These particular examples are from the sub-regional model of the western Bay of Plenty from Waihi to Maketu and back to the Rotorua lakes.

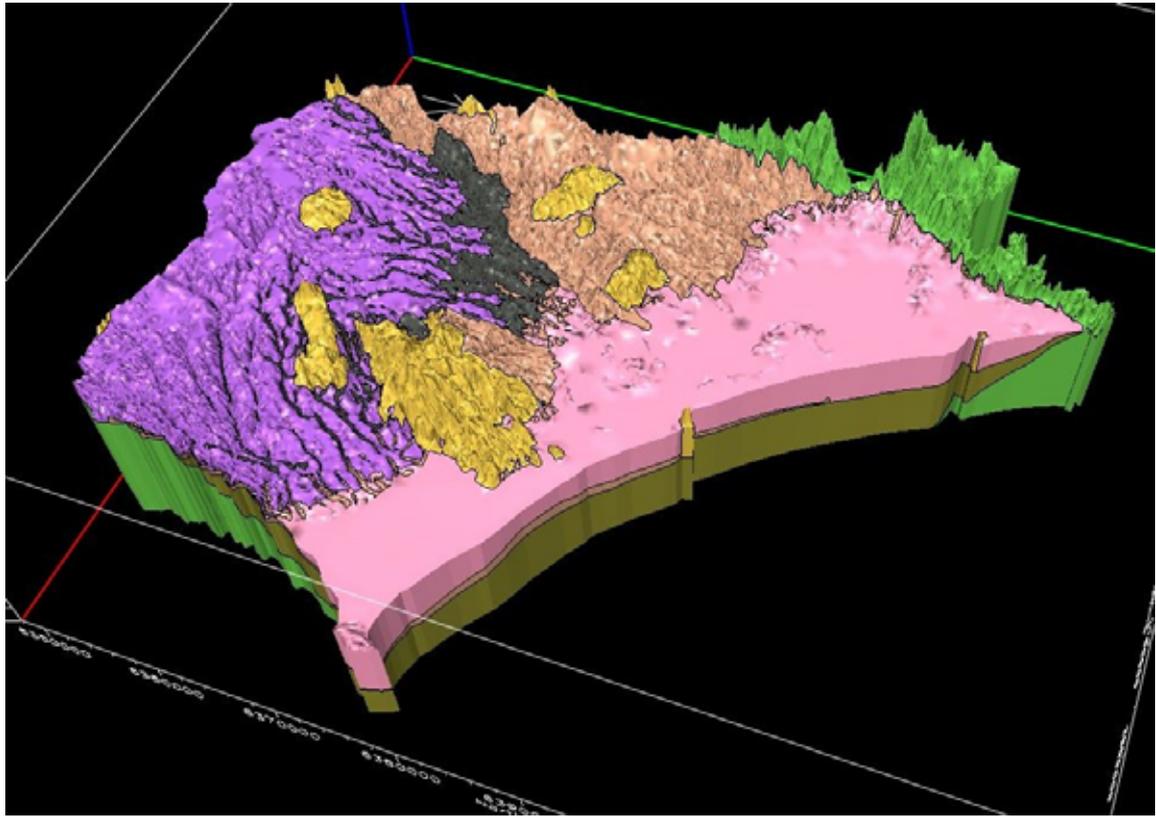


Figure 3 EarthVision 3-D western Bay of Plenty groundwater systems

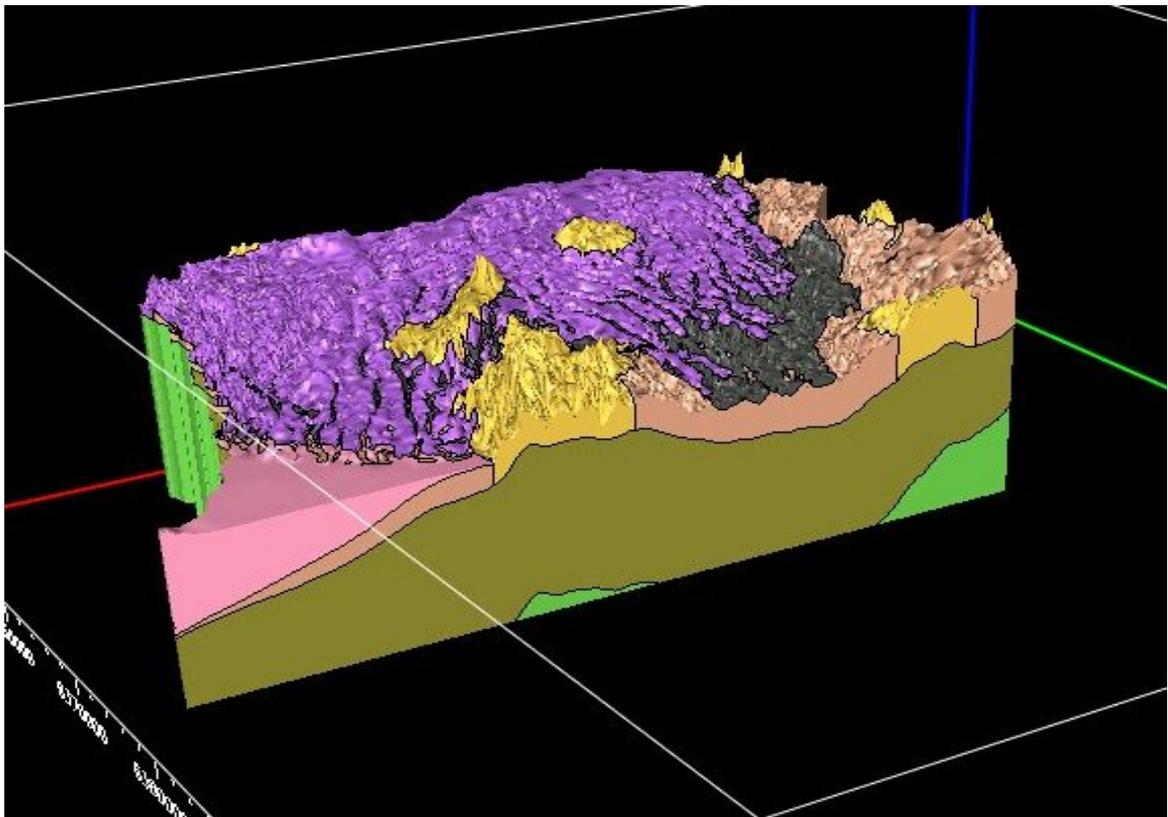


Figure 4: EarthVision cross-section western Bay of Plenty groundwater systems

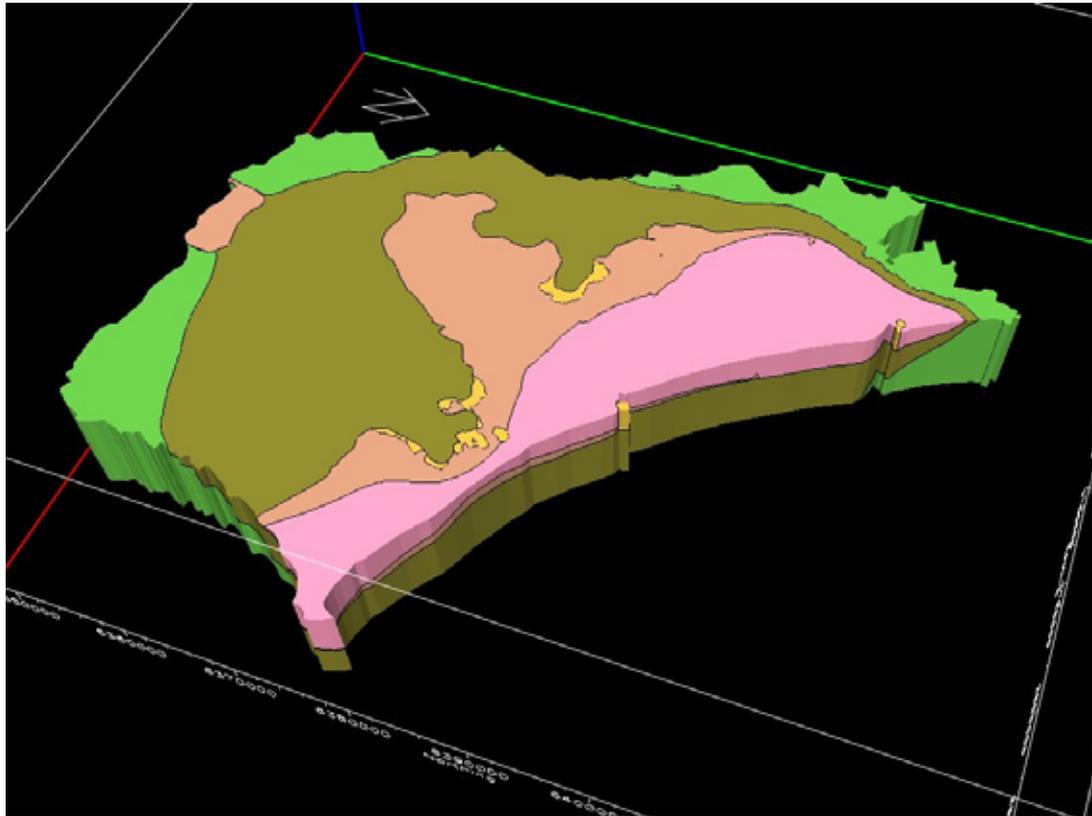


Figure 5 EarthVision planar view western Bay of Plenty groundwater systems

Key for EarthVision groundwater systems:

Geological colour key	
	Tauranga Group sediments
	Mamaku Plateau Formation
	Pokai Formation (Waimakariri Ignimbrite)
	Waiteariki Ignimbrite
	Whitianga Group (Minden Rhyolite & Ōtawa Volcanics)
	Aongatete Ignimbrite
	Basement rock

3.1.4 Conceptual model of groundwater systems - Earth beneath our feet

The 3-D model has been adapted to a 2-D model so that the public can easily assess the groundwater information via the web. This adapted model is called Earth Beneath Our Feet. This is a webpage that is presently being developed by GNS. Simply enter your location, or select an area and the program will construct a geological profile (Figure 6) or cross-section (Figure 7) of the area you are interested in. Information about groundwater quality and potential yields are also being developed. The aim is to provide a useful tool for both staff and public to access information on groundwater systems in the region.

Geological Model Profile
 Location of Profile: 2839024, 6347976

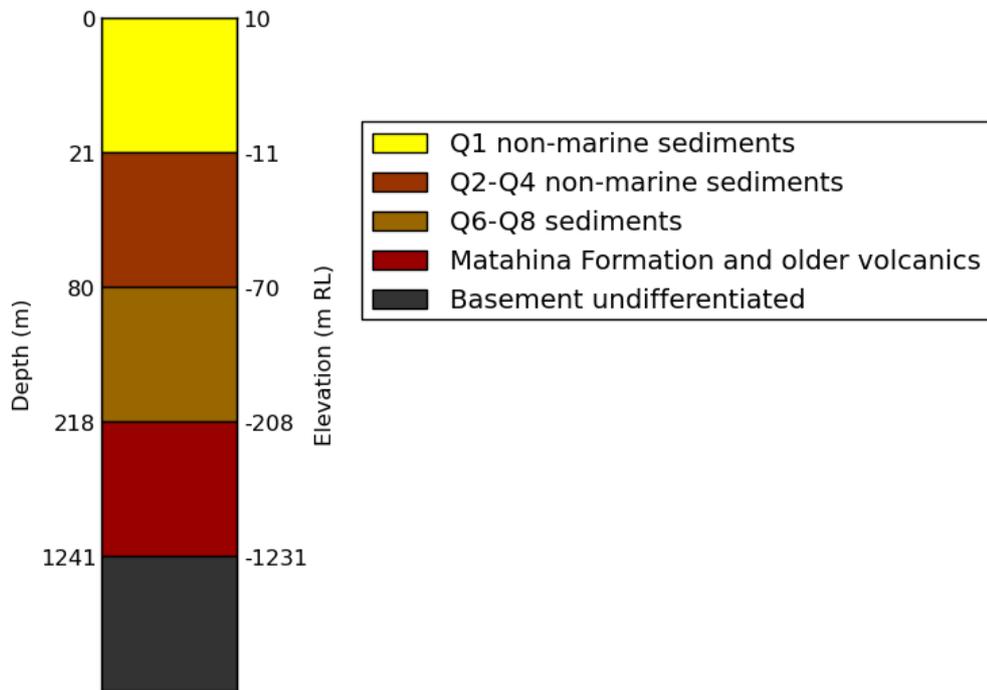


Figure 6 Profile at Otakiri - Rangitaiki Plains

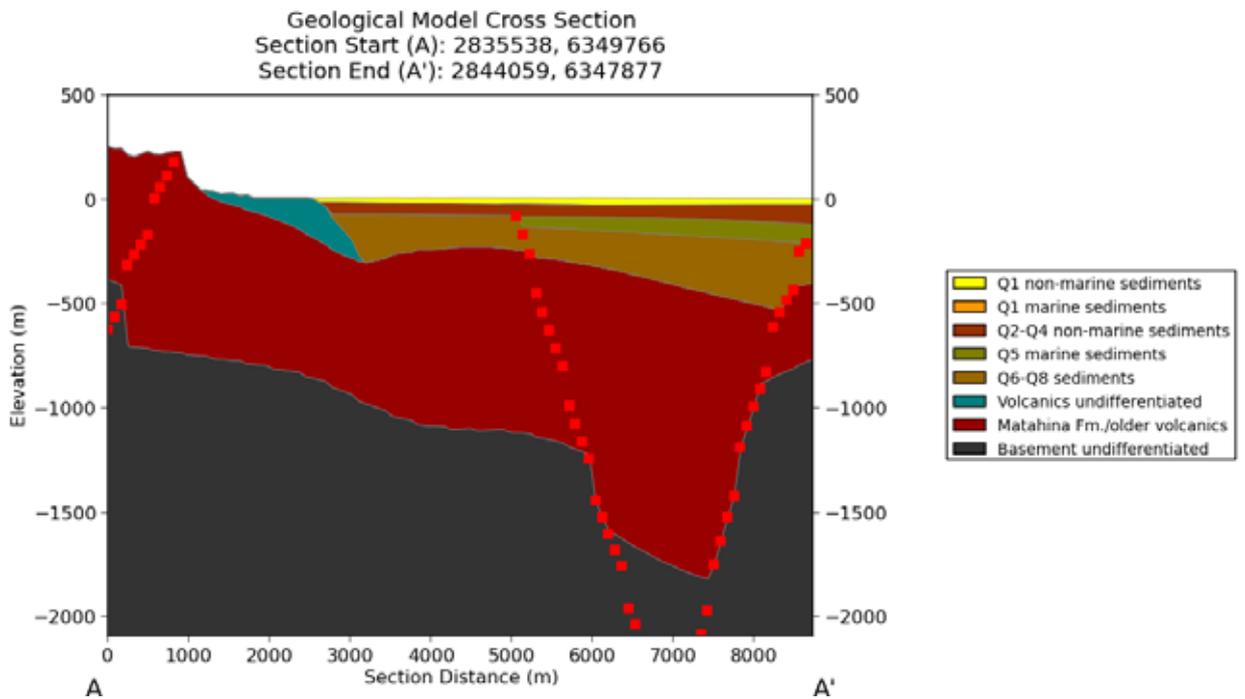


Figure 7 Cross-section through Otakiri - Rangitaiki Plains

3.1.5 Groundwater management areas

Presently the groundwater models have been developed in a sub-regional manner. Within each sub-region the areas have been divided into groundwater catchments (where surface water and groundwater are strongly connected) and groundwater zones (where groundwater is separated from the surface water in the area). Figure 8 is an illustration of the western Bay of Plenty sub-regional model showing the location of groundwater catchment boundaries (A) and coloured groundwater zones (B).

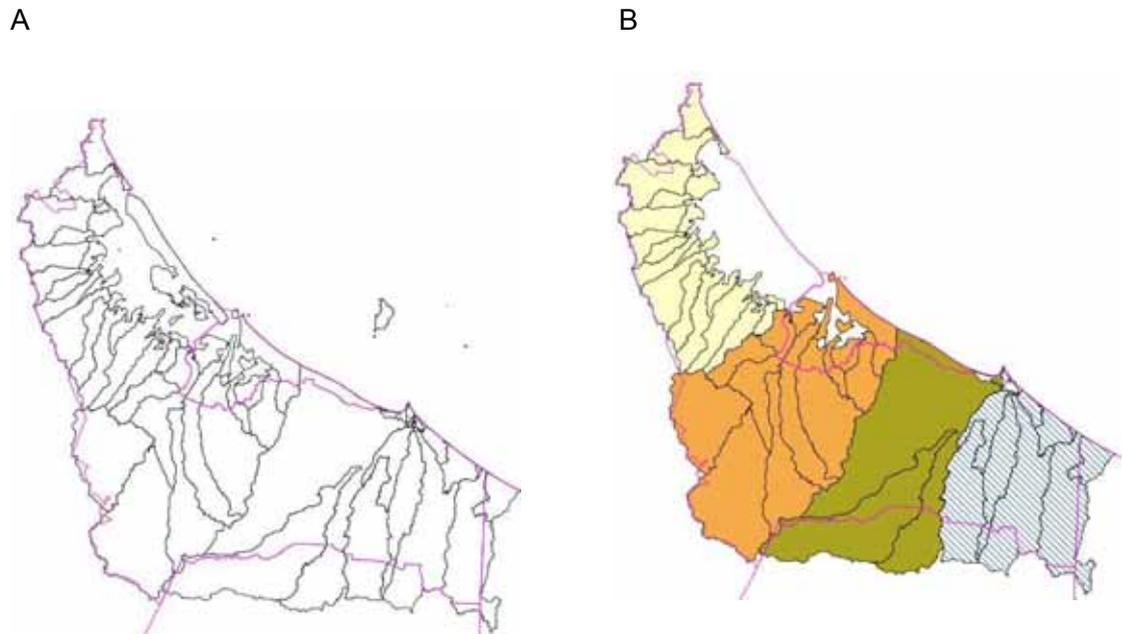


Figure 8 Groundwater catchments and groundwater zones for sub-regional model

For each of these groundwater catchments and zones groundwater available for allocation has been calculated. Groundwater flow and allocation considers three groundwater needs: to maintain spring flows (base flow) for streams, to maintain the aquifer itself (quality and water level), and provide water for use (abstraction). This is illustrated in Figure 9.

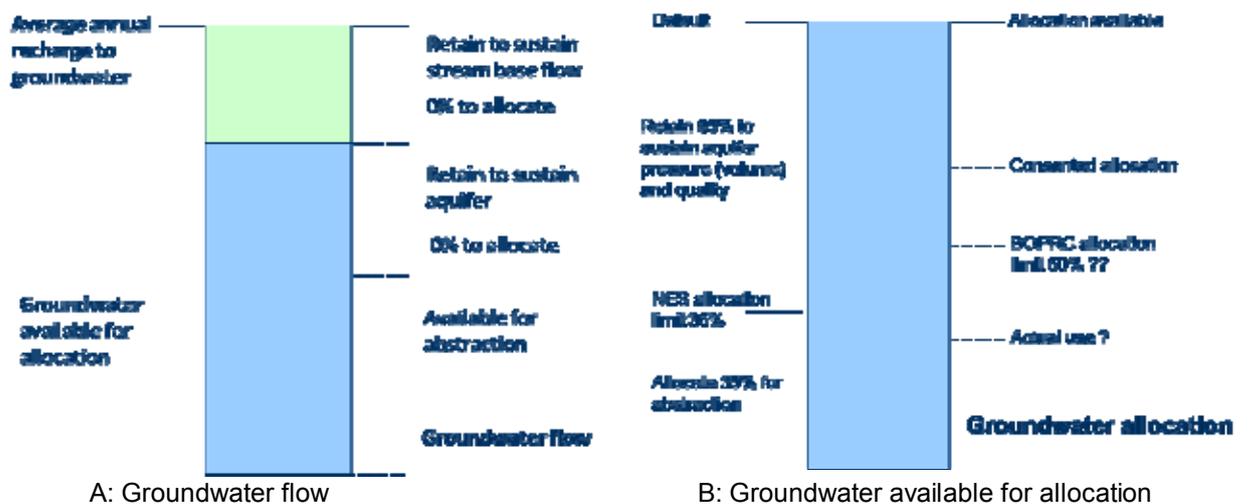


Figure 9 Concept of groundwater flow and allocation.

The present water level status of the monitoring bores has been mapped against the groundwater allocation status for the groundwater catchments/zones in Appendix 1 Map 10 and Map 11.

This is discussed in more detail in Part 4 of the report.

In order to better understand the volumes of groundwater actually being used requires a different approach to what we have presently. Under resource consent the allocation of groundwater can appear huge, however just because it is allocated does not mean that the resource is taken at its maximum allowable allocation on a daily or seasonal basis. The actual volumes used will vary with the climatic conditions experienced for that year and also the type of land use and practices that may now be in favour in the region.

Apart from attempting to estimate permitted use volumes for our groundwater catchments, it is crucial that actual use data is collected in a timely manner to effectively manage and allocate groundwater resources.

3.1.6 Pressures on the groundwater resource

To manage the groundwater resources, any take that exceeds volumes that are permitted under the RMA and WLP require resource consent from the Regional Council. This provides information on the amounts of water that have been legally allocated from a groundwater system.

Although the groundwater systems are extensive it is the actual and potential connection with surface water bodies that has dictated available allocation volumes from the groundwater systems. Groundwater allocation is now being considered in the framework of groundwater catchments, in keeping with surface water catchments.

It is only the confined groundwater systems (those that do not interact with surface water bodies above) that are dealt with differently as groundwater zones within the groundwater system.

Over the past 30 years land use and practices have changed and intensified. This can be illustrated by a regional overview of the amount of groundwater resources that have been approved under resource consent over the past decades. Figure 10 provides a snapshot of the volumes of groundwater allocated under resource consent at each decade 1980, 1990, 2000, and 2010. This broadly illustrates the changes in land use practices over the groundwater monitoring duration.

Resource consent is issued for a purpose. These are clumped into five categories: summer irrigation; frost protection; farm use; community/municipal; and commercial/industrial. Although these are not actual groundwater use figures they do show where the main pressure for groundwater is being driven from. In the 1980's most groundwater was being taken to develop the green kiwifruit industry in the region. As the vines matured less groundwater was needed.

However, by 2010 there had been a substantial shift in the kiwifruit industry with the introduction of Gold fruit that required irrigation to become established and continued irrigation for cropping. Gold fruit were also sensitive to frost, requiring protection. This saw a substantial increase in groundwater consents to provide security (an insurance) under which crops could be saved from inclement weather. Also over this time there was a boom in the dairy industry with the advent of pasture irrigation for sustained production and increased milk yields. Both frost protection and dairy irrigation require huge volumes of groundwater to meet the needs of the farmer.

Municipal supply has also increased its take from groundwater, as surface water became over-allocated based on the WLP policies. Groundwater is considered a secure supply of fresh water for growing communities, particularly in the Western Bay of Plenty.

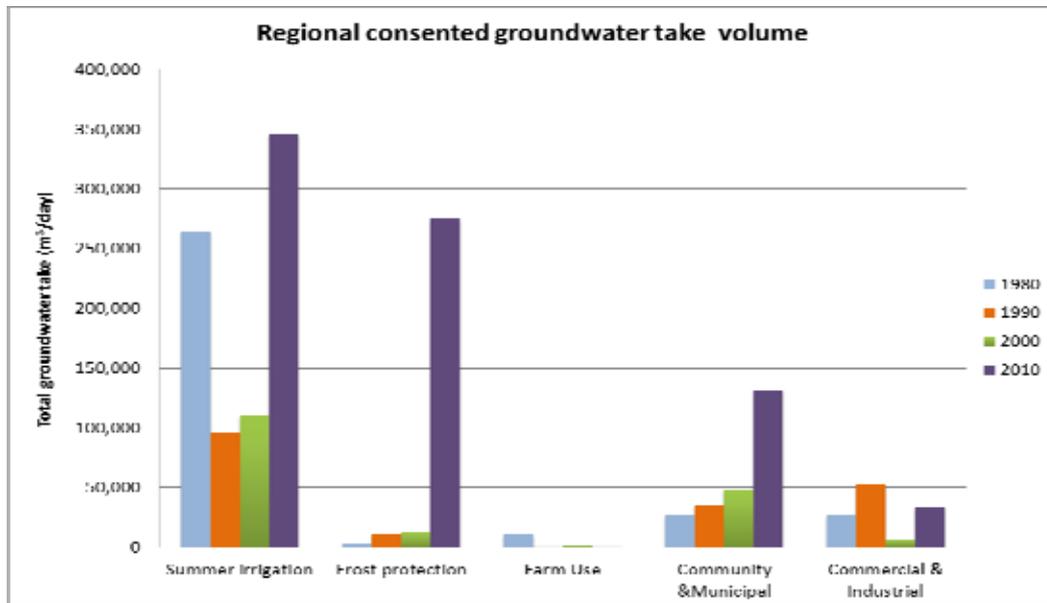


Figure 10 Consented groundwater take volume by purpose

3.2 Groundwater level

Long-term groundwater level monitoring records are valuable to help determine the behaviour of an aquifer; recharge zones, pumping impact, and flow direction. Other important data sets are rainfall, to identify climatic change and variance in recharge to groundwater systems, allocation and actual use data to determine the changes in water level on groundwater systems that are human induced. Typically groundwater is taken seasonally; irrigation in summer, heating in winter, frost protection in spring, the exceptions are municipal and commercial/industrial use, which is year round.

When the groundwater system is at rest the water level can determine how well the groundwater system recharges (replenishes) after intensive use. This data can identify trends of stress (depletion) on a groundwater system under certain pumping regimes (allocation and land use practices). It can show how the groundwater system responds to pumping stress and whether the allocation is sustainable.

Water level change in a groundwater system can influence groundwater quality. Abstraction can influence groundwater quality as pumping can change the flow directions and aquifer water levels. This provides for groundwater to flow from one area to another or from an aquifer to another (leakage), drawing varying quality of groundwater into areas. Leakage from other aquifers, or intercepting a recharge boundary i.e. a surface water source, may draw in better quality 'cleaner' water.

3.3 **Groundwater quality**

Groundwater is a large and reliable source of fresh water. In some areas the required volume of groundwater is available, however due to the quality of the water it may not be used. Groundwater quality needs to be monitored to identify high quality systems to be retained and deteriorated quality systems to be improved where possible.

For some groundwater systems the natural state will exclude them from use e.g. high iron or arsenic. However other groundwater systems can show human impacts to groundwater quality due to changes in water level (pumping) and/or impact from land use.

For some groundwater systems near the coast managing the water level of the system is necessary to avoid salt water intrusion from the sea into the fresh water groundwater system. Also a change in water level can draw poorer groundwater quality from one part of an aquifer into another.

Groundwater is largely replenished by rainfall; that is rainfall that percolates down through the soil to the groundwater system. Any soluble material on the ground surface can be moved into the groundwater systems by rainfall infiltration. Therefore managing land use in groundwater recharge areas is relevant to groundwater quality.

Part 4: Groundwater level assessment

4.1 Data management and trends

All monitoring bore data for water level has been verified, graphed and assessed. The primary purpose of this section is to identify any trends and pressures on the various groundwater systems. This will help assess if current allocation is sustainable; are the groundwater systems recovering from pumping stress.

4.1.1 Data quality

The majority of the bores monitored are done so on a manual basis. There are 48 manual water level monitoring sites. These bores are typically monitored every three months (four times per year). However this can occur at varying intervals over the years and is not consistent. The data collected over any year usually represents two lower and two higher water levels, for when the aquifer is under pumping stress and at rest (recovery) respectively. Pumping produces 'noise' in the data that needs to be assessed and removed where necessary, so the data is not skewed and causing a bias result.

Recording pumped levels is a problem in the water level monitoring program. Static water levels need to be recorded. This requires that the bore to be monitored is at rest for at least 24 hours before the water level is taken.

The limited data points that result from the manual water level monitoring program mean that seasonal variance and changes in static water levels are not clearly shown.

There are eight data-logged long term monitoring bores for water level; these are bore numbers 461, 2060, 2328, 2504, 2533, 2541, 2822, and 3043. These sites provide a frequent and continuous monitoring record of the fluctuations in water level during seasons and over years. These provide the most comprehensive water level data we have. However two of these bores (2328 and 2541) are actively pumped, therefore recording pumping water levels rather than static water levels.

Forty-nine of the monitoring bores are actively pumped at various volumes and therefore show pumping influence in the water level record. The monitoring bores also intercept aquifers that are pumped regularly either during summer (irrigation), autumn (frost protection) or winter (heating).

4.1.2 Approach to analysis

The pumped water level data influences the trend line of the static water level. For this reason the water level data required editing to remove outliers caused by pumping to gain a better understanding of the overall water level trend on the aquifer. The outliers were identified by visual/qualitative judgement. In Appendix 4 both graphs are presented; the raw data and edited data. Each bore has been surveyed to Moturiki datum and the data calculated to reduced level to standardise the data for assessment.

At least two high water level data points have been retained for each year. The trend line can then be applied (linear regression) without skewing the data. An example of how pumping can impact trend is shown at Bore 90 below.

The water level trend line for each bore has been assessed and put into three categories; stable, increase, decline. If the slope change is +/- 0.5m, over the duration of monitoring, then it is determined that there is a trend; + increase, - decline.

- **Stable:** there is fluctuation of the water levels over the years but the overall use does not exceed the ability for the aquifer to recover to background levels.
- **Increase:** could mean that the groundwater level had already been influenced by human impact prior to monitoring being initiated and we are now seeing a recovery on this system. Also there are periods where abstraction exceeds the ability of the aquifer to recover to background water levels. These sustained high use periods have caused the water levels to decline over time and not recover to background level. An increase trend is the recovery of the water levels to natural levels. This could be due to high rainfall years; land use change, and/or reduced abstraction.
- **Decline:** could mean that groundwater use exceeds recharge volumes for this aquifer. This can be influenced by low rainfall years; land use change, or high demand in localised areas.

The background water level is that recorded at the time monitoring began at the bore. Some aquifers had been in use for some years before any monitoring of water level began. So in some cases we are seeing a recovery of these systems to levels prior to when monitoring began e.g. Bore 729.

Water level trends have been derived for each bore. These are set out in stating whether the overall water level trend is stable, has increased or is in decline.

Table 2 key:

A:	Aongatete ignimbrite
W:	Waiteariki ignimbrite
WA:	Waiteariki/Aongatete ignimbrite
TGS:	Tauranga Group sediments
Q1:	Non-marine sediments (Tauranga Group)
Q1m:	Marine sediments (Tauranga Group)
Q2-Q4:	Non-marine sediments (Tauranga Group)
Q6-Q8:	Sediments (Tauranga Group)
Mnd:	Minden Rhyolite
Pk:	Pokai and other volcanics
Mmk:	Mamaku Plateau Formation
Mhn:	Matahina and other volcanics

Table 2 Summary of water level trends by aquifer

Bore	Aquifer	Status	Location	Data range	Duration	Water level change (m/year)	Water level change over duration (m)
51	A	Stable	Tauranga	1990 to 2011	21	-	-0.2
90*	A	Increase	Katikati	1986 to 2011	25	+0.32	+8.0
90	A	Decline	Katikati	1992 to 2011	19	-0.094	-1.8
93	A	Decline	Wairoa	1990 to 2011	21	-0.033	-0.7
94	W	Stable	Oturu	1990 to 2011	21	-	+0.4
851	W	Stable	Katikati	1987 to 2011	24	-	+0.2
1018	W	Stable	Maketu	1993 to 2011	18	-	-0.05
1386	A	Decline	Tauranga	1999 to 2011	13	-0.46	-6.0
1468	WA	Stable	Otumoetai	1995 to 2011	16	-	+0.48
1566	WA	Stable	Apata	1987 to 2011	24	-	+0.46
1670	W	Decline	Tauranga	1990 to 2011	21	-0.033	-0.70
1686	W	Stable	Waipapa	1990 to 2011	21	-	-0.3
2024	W	Stable	Te Puke	1990 to 2011	21	-	-0.05
2328	A	Increase	Katikati	1987 to 2011	24	+0.30	+7.2
2344	W	Stable	Waimapu	1990 to 2011	21	-	0
2533	WA	Stable	Te Puna	1990 to 2011	21	-	-0.08
2829	A	Decline	Athenree	1988 to 2011	23	-0.078	-1.8
2838	A	Increase	Katikati	1988 to 2011	23	+0.065	+1.5
3026	W	Increase	Te Puke	1990 to 2011	21	+0.095	+2
2519\2	?WA	Stable	Katikati	1986 to 2011	25	-	+0.2
2519\3	?WA	Stable	Katikati	1986 to 2011	25	-	+0.4
2520\3	?WA	Stable	Katikati	1986 to 2011	25	-	-
2521\1	?WA	Decline	Katikati	1990 to 2011	21	-0.104	-2.2
2521\3	?WA	Decline	Katikati	1986 to 2011	21	-0.138	-2.9
2522\3	?WA	Stable	Katikati	1986 to 2011	25	-	-
2523\2	?WA	Stable	Katikati	1986 to 2011	25	-	+0.25
1319	TGS	Stable	Galatea	1991 to 2011	20	-	-
1520	TGS	Stable	Maketu	1990 to 2011	21	-	-0.3
1535	TGS	Stable	Te Puke	1990 to 2011	21	-	+0.4
1690	TGS	Stable	Maketu	1990 to 2011	21	-	-0.42
2330	TGS	Stable	Katikati	1987 to 2011	24	-	-0.4
2504	TGS	Stable	Otumoetai	1983 to 2011	28	-	+0.35
2728	TGS	Stable	Te Puke	1990 to 2011	21	-	+0.3
2847	TGS	Stable	Maungatawa	1975 to 2009	35	-	-0.20
2913	TGS	Stable	Galatea	1990 to 2009	19	-	-0.25
3032	TGS	Increase	Waihī	1990 to 2011	21	+0.095	+2.0
3034	TGS	Stable	Maketu	1990 to 2011	21	-	+0.30
3036	TGS	Decline	Opotiki	1990 to 2011	21	0.038	-0.80
3038	TGS	Stable	Opotiki	1990 to 2011	21	-	-
3043	TGS	Stable	Maketu	1990 to 2011	21	-	+0.10
3301	TGS	Stable	Ohope	1996 to 2011	15	-	+0.40
3463	TGS	Stable	Otumoetai	1995 to 2011	16	-	+0.35
461	Q1	Stable	Rangitāiki Pl.	1988 to 2011	23	-	+0.005
845	Q6-Q8	Increase	Rangitāiki Pl.	1989 to 2011	22	-	+0.5
729	Q1m	Increase	Rangitāiki Pl.	1987 to 2011	24	-	+0.5
2060	Q2-Q4	Decline	Rangitāiki Pl.	1988 to 2011	23	-	-0.5
2541	Q6-Q8	Increase	Rangitāiki Pl.	1986 to 2011	25	+0.077	+2.0
410	Mnd	Stable	Paengaroa	1998 to 2011	13	-	-0.2
951	Mnd	Stable	Paengaroa	1990 to 2011	21	-	+0.25

Bore	Aquifer	Status	Location	Data range	Duration	Water level change (m/year)	Water level change over duration (m)
2822	Mnd	Decline	Pongakawa	1990 to 2011	21	-0.05	-1.1
1561	Mmk	Stable	Rotorua	1995 to 2011	16	-	-0.2
3470	Mmk	Stable	Rotorua	1996 to 2011	15	-	+0.1
4005	Mmk	Increase	Rotorua	1995 to 2011	16	+0.03	+0.5
4006	Mmk	Stable	Rotorua	1995 to 2011	16	-	-0.2
3469	PK	Increase	Rotorua	1996 to 2011	15	+0.1	+1.5
4007	PK	Increase	Rotorua	1995 to 2011	16	+0.03	+0.5
2509	Mhn	Decline	Rangitāiki Pl.	1996 to 2011	15	-0.333	-5.0

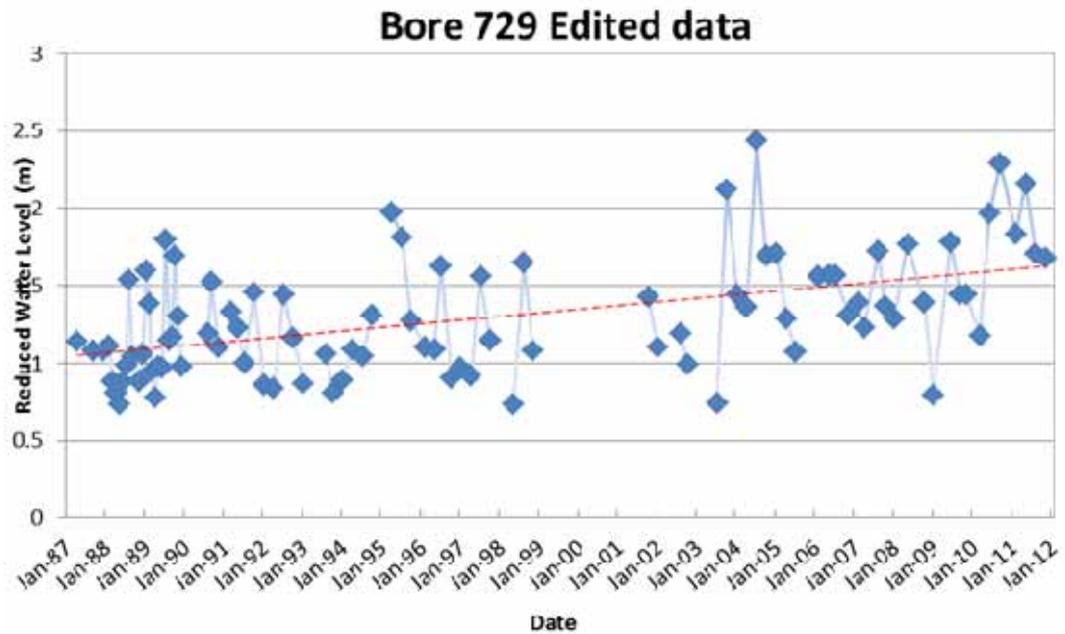
4.1.3 Bores with increasing water level trends

There are eleven monitoring bores that show an increasing water level trend (Bore 90 is included) over the monitoring duration. The overall water level trend is now higher than initial water level records. To help determine the reasons for an increase water level trend it is necessary to know abstraction volumes from a system. However no records of groundwater use have been kept. Groundwater was being abstracted prior to monitoring of the water levels began. Therefore we do not have a true background groundwater level, the static water level of the groundwater system prior to human impact by pumping. So the earliest record could be showing pumping effect. Therefore it is assumed that the increase water level trend is due to less groundwater being abstracted from these areas than previously.

Of the water level bores we monitor eleven show varying states of water level increase. These bores are within the Aongatete Ignimbrite (3), Waiteariki Ignimbrite (1), Mamaku Ignimbrite (1), Pokai Volcanics (2) and the Tauranga Group sediments (4). Examples of three of these water level trends are provided for bores 729, 2328 and 4005.

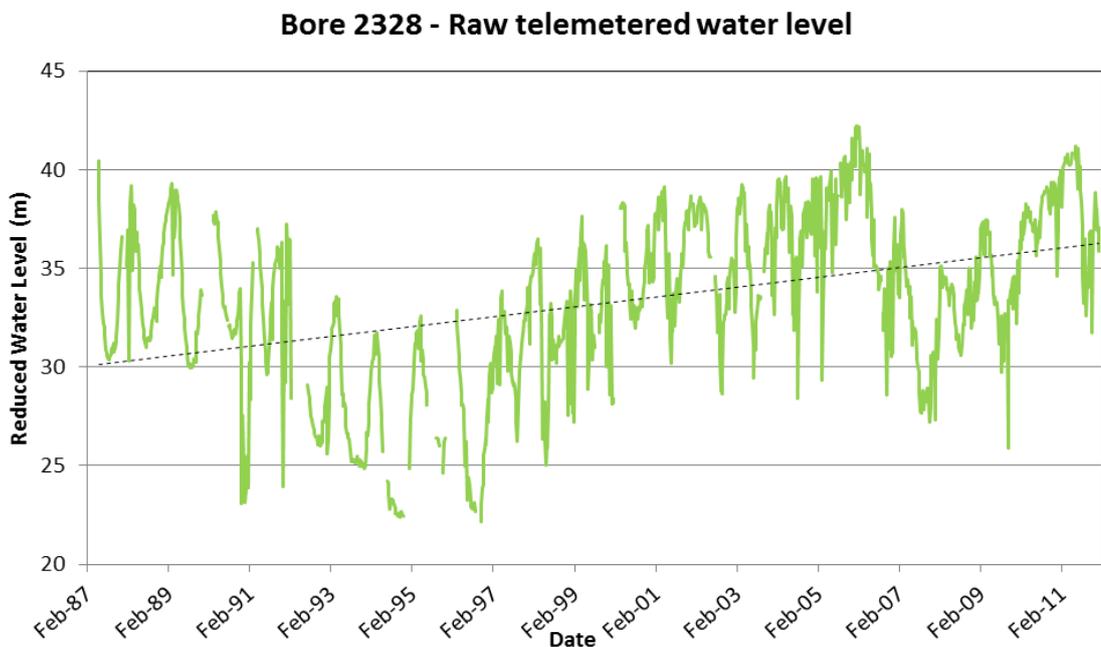
4.1.4 Bore 729 [page 124]

This bore intercepts the Tauranga Group sediments on the Whakatāne coastal plains and is 12.8 m deep. There appears to be an overall long term increasing water level trend of 0.02 m/year (0.5 m increase over 24 year period).



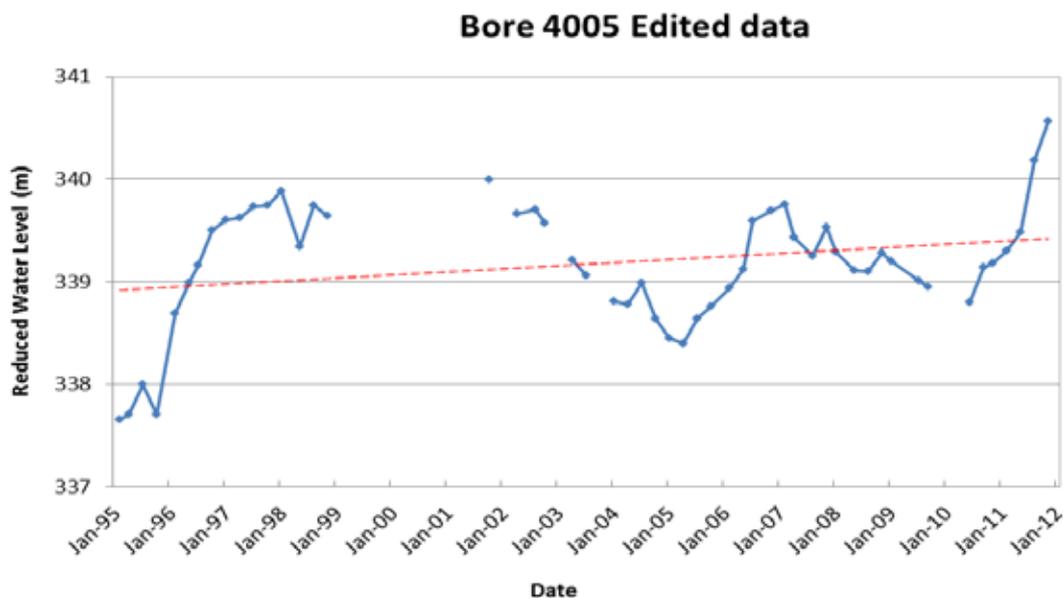
4.1.5 Bore 2328 [page 180]

This bore intercepts the Aongatete Ignimbrite near Katikati and is 454m deep. There appears to be an overall long term increasing water level trend of 0.30m/year (7.2m increase over 24 year period). This bore is also a production bore used for irrigation, so the extreme water level drops occur with pumping during the summer. This pumping effect provides a greater increase in water level trend than if it were not present.



4.1.6 Bore 4005 [page 278]

This bore intercepts the Mamaku Ignimbrite in the Rotorua lake catchment and is 180m deep. There appears to be an overall long term increasing water level trend of 0.03m/year (0.5m increase over 16 year period). The water use records for this aquifer are no known, but it is assumed that there was already a pumping effect on this data. The bore is used regularly to provide domestic supply all year round and irrigation in summer. Again it could be the pumping effect of this production bore that has skewed the data to show an overall increase in water level trend.



4.1.7 Bores with declining water level trends

Fluctuations in water level occur, however it is the over-all trend that is of interest; of particular concern is an overall declining trend. To help determine the reasons for a decline trend it is necessary to know abstraction volumes from a system. Although we can calculate the volumes for consented water takes, we are reliant on models to determine permitted take effects. Also the consented volumes are the maximum volumes rather than actual use. Just because consent provides for a set volume does not mean this total volume is used. Therefore it is assumed that the decline trend is due to use exceeding recharge.

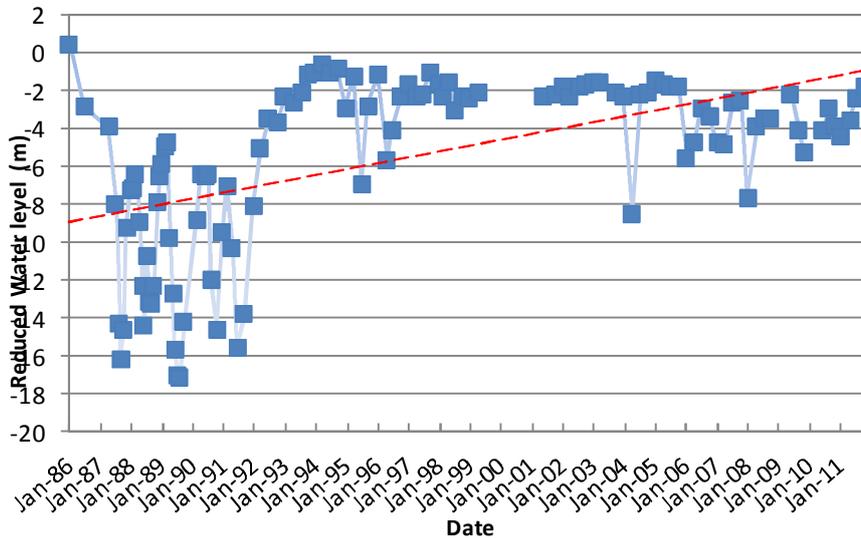
Of the water level bores we monitor eleven show varying states of water level decline. These bores are within the Aongatete Ignimbrite (5), Waiteariki Ignimbrite (2), Minden Rhyolite (1), Matahina Ignimbrite (1) and the Tauranga Group sediments (2).

4.1.8 Bore 90 [page 104]

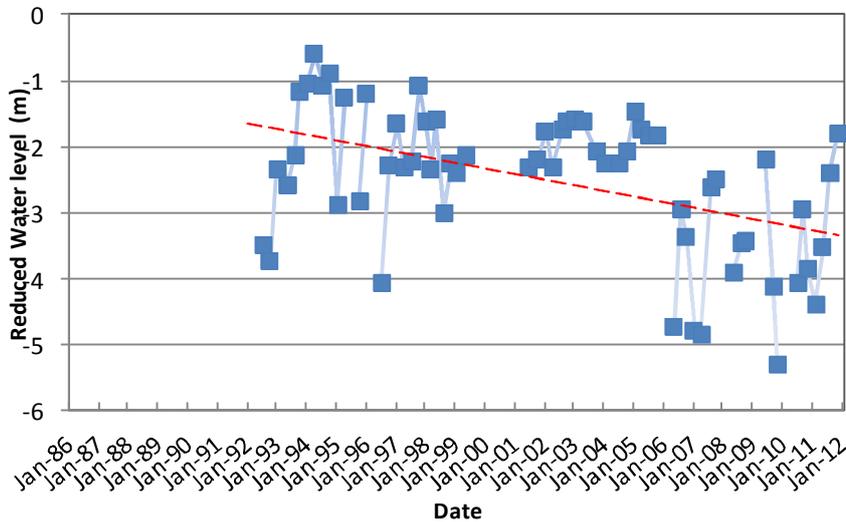
This bore intercepts the warm water of the Aongatete Ignimbrite aquifer in the Athenree area and is 329m deep. The highest water level recorded was in 1986 at the beginning of water level monitoring program (Graph A). Intensive pumping at the bore up to 1992 kept the overall water level down and recovery was only partial. However it appears as use decreased from 1992 that the water levels did recover, but not to the extent of the initial water level reading in 1986.

If the intensive pumping data is retained in the data record the over-all trend on the aquifer is increasing (Graph A). However if the pumping data is removed from 1987-1991 (retaining the initial 1986 level) then the water level shows an overall decline (Graph B). Background water levels have not been reached since 1994 with a steady groundwater level decline, particularly from winter 2005 to winter 2010. For Graph B there is a declining water level trend of 0.1m/year (1.8m drop over 19 year period).

Graph A: Bore 90 Raw Data



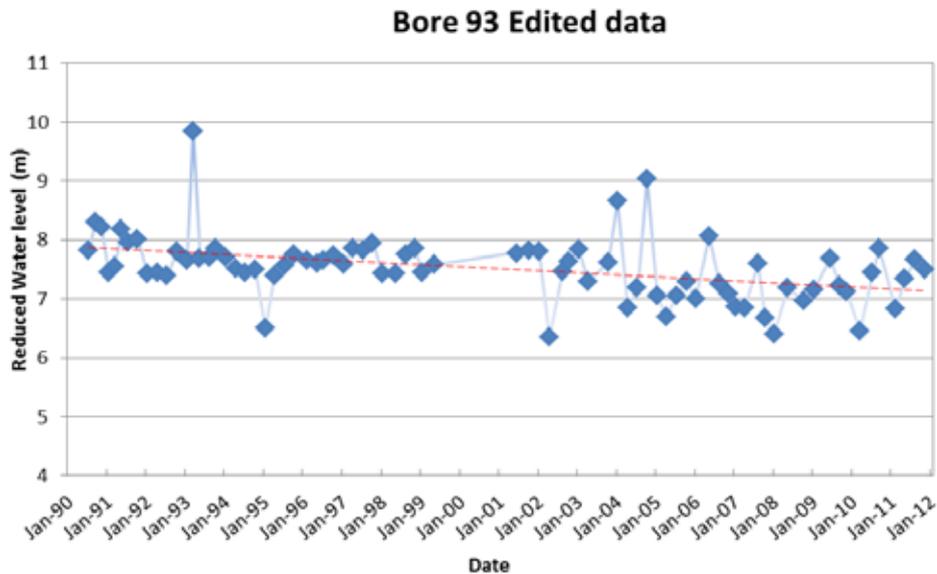
Graph B: Bore 90 Edited data



Bore 90 is near the coast and has a water level that is below sea level. This is a confined layer that extends out to sea. However the extent off shore is not known. It is recommended that groundwater quality monitoring is initiated at least twice annually for groundwater quality (particularly conductivity), to identify any risk of salt water intrusion.

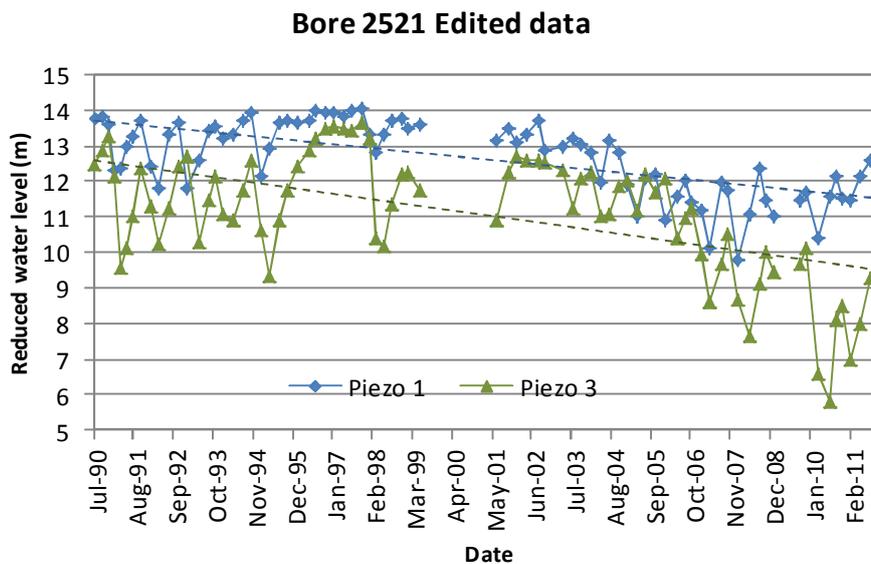
4.1.9 Bore 93 [page 104]

This bore intercepts the Aongatete Ignimbrite in the Te Puna area and is 460m deep. There appears to be an overall long term declining water level trend of 0.033m/year (0.7m drop over 21 year period).



4.1.10 Bore 2521\1 [pages 205] and 2521\3 [page 209]

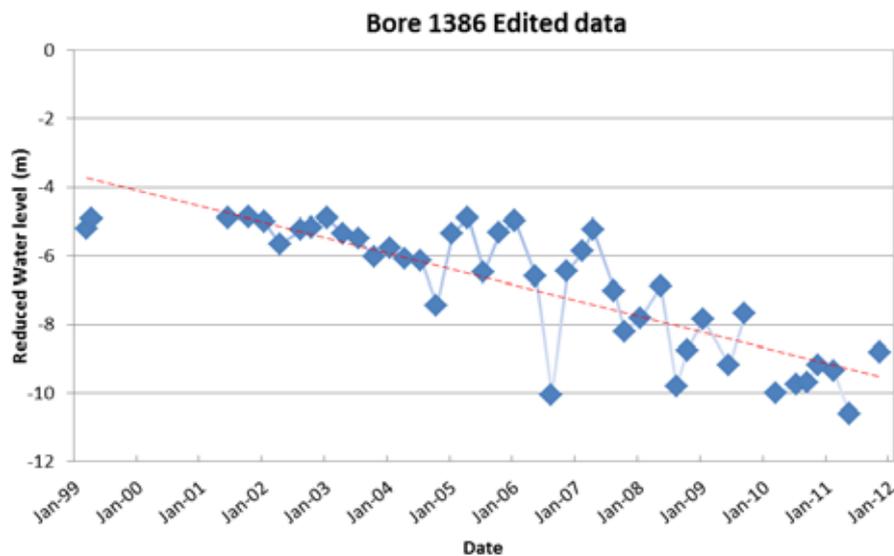
In the early 1980's several monitoring bores were installed north of Tauranga. Each bore intercepted several aquifers, and each aquifer was set with a piezo so that the separate aquifers could be monitored. However it is not known what piezo intercepts which aquifer. Few of these piezo remain functional and the data can be ambiguous. This bore is 157m deep and probably intercepts the Whaiteariki and/or Aongatete Ignimbrite aquifer system. There is an overall declining water level trend of 0.104m/year (2.2m drop over a 21 year period) and 0.138m/year (2.9m drop over a 21 year period) respectively for bore 2521/1 and 2521/3.



4.1.11 Bore 1386 [page 142]

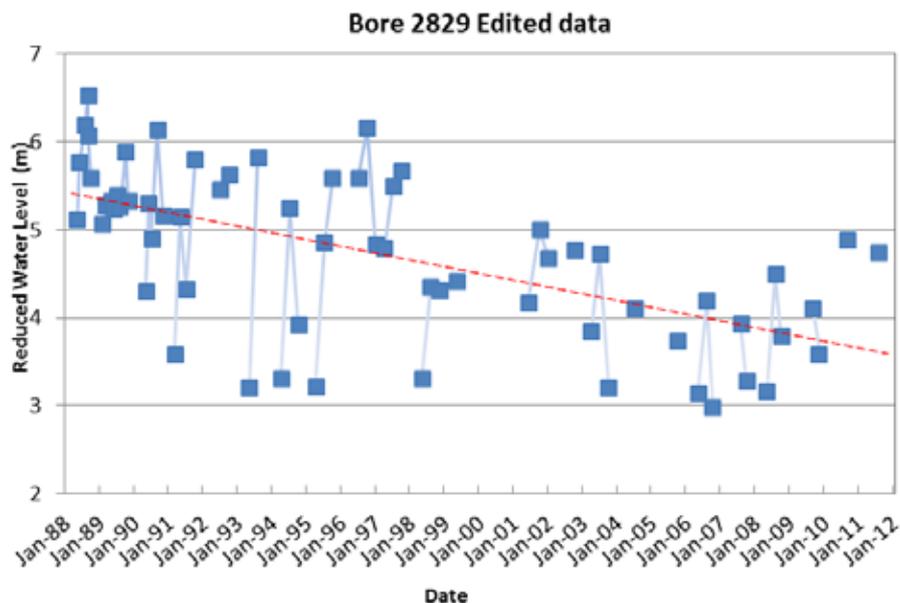
This bore intercepts warm water of the Aongatete Ignimbrite in the Tauranga city area and is 466m deep. There appears to be an overall long term declining water level trend of 0.46m/year (6m drop over 13 year period). The water permit for this bore states it is used for commercial heating. Drawdown tends to occur in the colder months.

Bore 1386 is inland of the coast but near the harbour. It has a water level that is below sea level. This is a confined layer that extends out to sea. It is recommended that groundwater quality monitoring is initiated at least twice annually for groundwater quality (particularly conductivity), to identify any risk of salt water intrusion.



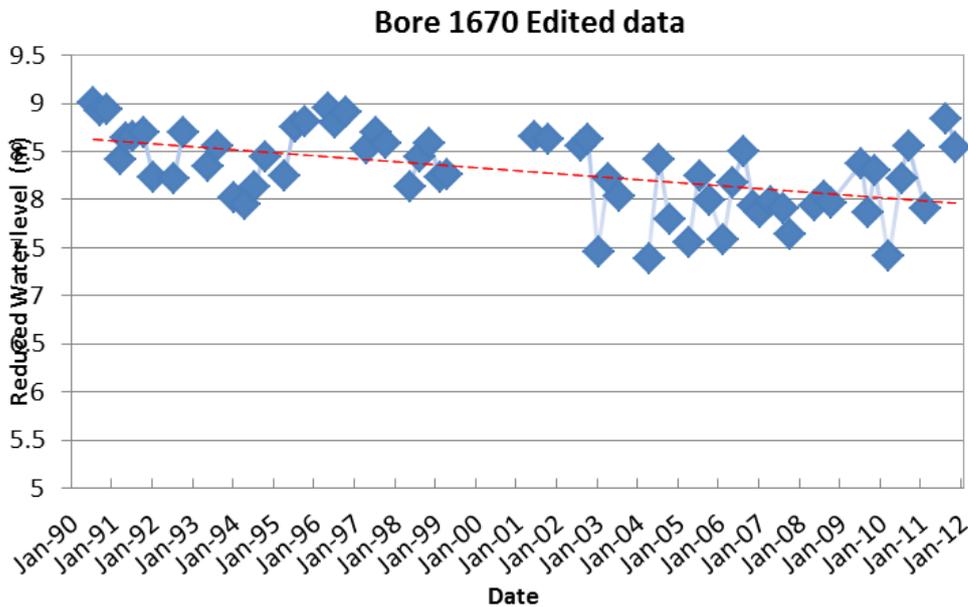
4.1.12 Bore 2829 [page 227]

This bore intercepts the warm water of Aongatete Ignimbrite in the Katikati area and is 216m deep. There appears to be a decline on groundwater levels since 1997. There is a declining water level trend of 0.078m/year (1.8m drop over a 23 year period).



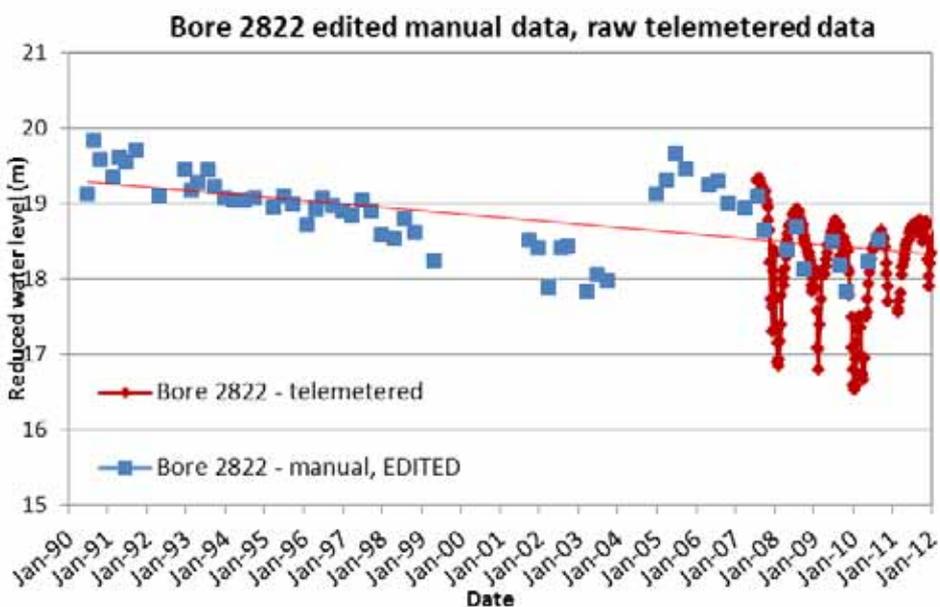
4.1.13 Bore 1670 [page 160]

This bore intercepts the Waiteariki Ignimbrite in the Tauranga city area and is 103m deep. There appears to be an overall long term declining water level trend of 0.033m/year (0.7m drop over a 21 year period).



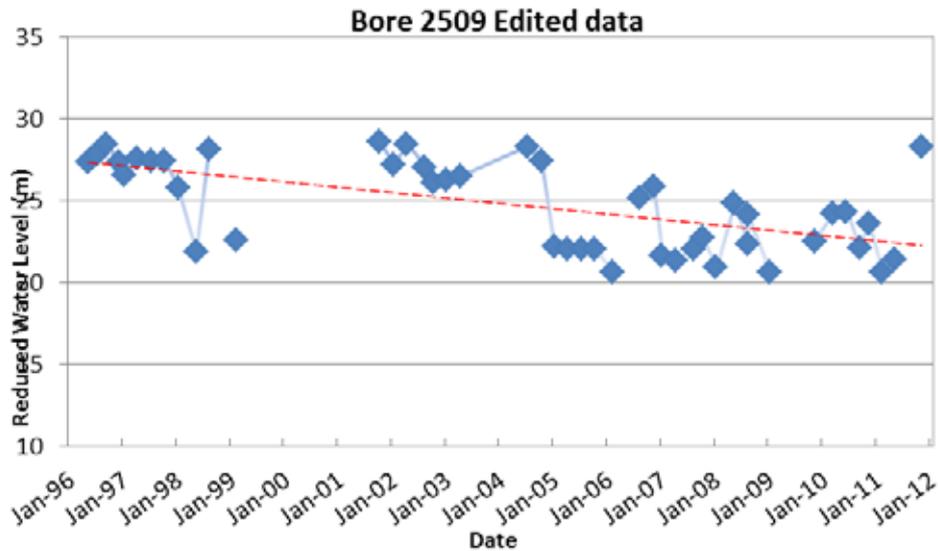
4.1.14 Bore 2822 [page 223]

This bore intercepts the Minden Rhyolite near Pongakawa and is 121m deep. The water levels were recorded manually until 2007 when the site was telemetered. The telemetered data provides more data and a clearer understanding of the overall drawdown on the aquifer system and its recharge levels over the years than what is provided for with the manually recorded data. There appears to be an overall long term declining water level trend of 0.05m/year (1.1m drop over 21 year period). This is not an extensive aquifer and is localised to this geological unit.



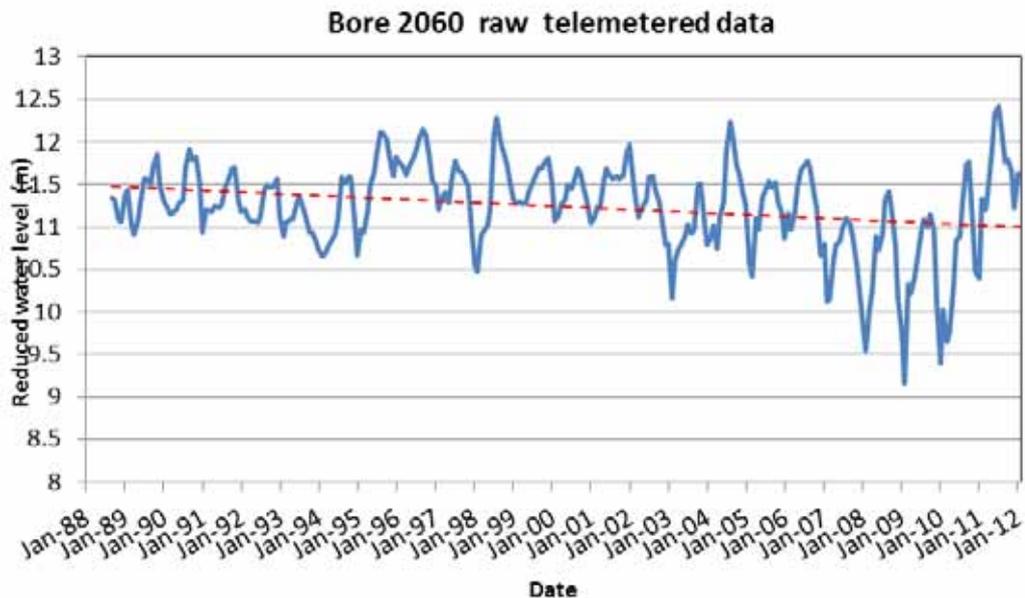
4.1.15 Bore 2509 [page 198]

This bore intercepts the Matahina and older volcanics on the Rangitaiki Plains and is 319m deep. A steady groundwater level decline occurs from 2004 to 2010, with a rise in groundwater levels in 2011. There is an overall declining water level trend of 0.3m/year (5m drop over a 15 year period).



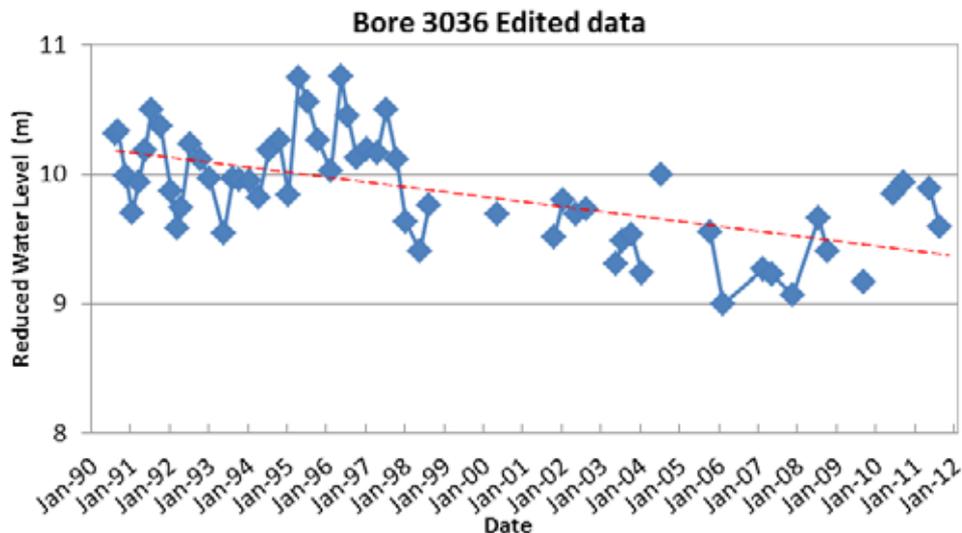
4.1.16 Bore 2060 [page 170]

This bore intercepts Tauranga Group sediments on the Rangitāiki Plains and is 61m deep. There appears to be an overall long term declining water level trend of 0.02m/year (0.5m drop over a 23 year period). However this comprehensive record also shows decline and recovery cycles between 1989-1995, 1998-2004, 2004-2011. These cycles could be related to climatic change (rainfall), land use change, or in later years the arrival of Psa in the region.



4.1.17 Bore 3036 [page 245]

This bore intercepts the Tauranga Group sediments near Opotiki and is 30m deep. This is the main aquifer for the Ōpōtiki Plains. There is an overall declining water level trend of 0.038m/year (0.80m drop over a 21 year period).



4.2 Discussion – factors influencing groundwater quantity

Eleven of the bores indicated a decline in groundwater levels relative to background levels. These bores are highlighted in Table 2. Seven of these are within the confined groundwater system of the Waiteariki and Aongatete Ignimbrites around the Tauranga Harbour. These show intensive use areas of the aquifer system. The entire aquifer however is not in decline. In the high use areas recharge cannot meet the volume of water being taken from the system.

The other decline groundwater trends are identified in localised unconfined, leaky or confined groundwater systems. These systems are the Tauranga Group sediments, Minden Rhyolite and Matahina aquifers respectively, of the Ōpōtiki Plains, Te Puke and Rangitāiki area. The remainder of the aquifer systems are either stable or showing an increase water level trend, due to recharge to the systems.

To put these trends in context with allocation status for the region see Map 10 and Map 11. Evaluation of the groundwater systems and preliminary water balance for the water resources have been completed for western Bay of Plenty and Rangitāiki Plains area. This work was commissioned from GNS Science. The reports calculated a rough volume of water available for allocation from the groundwater systems. This was off-set by estimated actual use based on consented use i.e. what is being taken from the groundwater for irrigation, frost protection, municipal/industrial/commercial use (this does not include any calculation for permitted takes). At present the WLP provides a general direction, but not a specific method on how to allocate the groundwater resource.

The Ministry for the Environment have had a draft proposed groundwater allocation systems since 2009, but this document has not progressed to an operative document and remains the Proposed National Environmental Standard on Ecological Flows and Water Levels (NES). This sets an allocation for groundwater of no more than 35% of average annual recharge or 15% of average annual recharge for shallow coastal aquifers (predominantly sand). However 'coastal aquifer' is not defined, therefore the 35% has been used as an allocation limit to assess allocation pressure in regard to consented use (estimated actual use).

Estimated actual use has been calculated for the groundwater systems for Western Bay of Plenty area and Rangitāiki Plains. How much of the groundwater resource that has been allocated is mapped against the 35% NES criteria. This identifies areas that are within allocation and those that are near full allocation (Map 10 and Map 11).

For Map 10 the Otumoetai and Kaituna catchments allocation is calculated as high, yet the monitoring bores are showing a stable trend (sustainable); pumping does not exceed recharge to the system. However for the Rangitāiki Plains decline trends are identified in catchment with allocation concerns.

For Map 11 for the groundwater zones of the Waiteariki/Aongatete ignimbrite aquifer the high allocation area is not showing decline and the medium to low allocation areas are showing decline trend in specific areas. This could be due to localised specific use and/or the structure of the geology in these areas affecting recharge.

For the majority of monitoring bores the water level recovers to above sea level. During pumping stress water levels can drop below sea level for period of time. When the pumping stress is off the aquifer we are seeing the water levels recover above sea level. There are three monitor bore where the background water level is below sea level. These are bores 90, 461 and 1386.

Two bores that show water level decline are bores 90 and 1386. Both bores draw groundwater from the geothermal resource that underlies the Tauranga harbour area.

For bores 90, 461 and 1386 groundwater quality sampling is recommended to identify any risk of salt water intrusion into the freshwater resource of the aquifer, and temperature monitoring for bores 90 and 1386 to determine any temperature loss with water level decline.

Rainfall recharge to unconfined groundwater systems typically is rapid. For other systems that are leaky (semi-confined, semi-unconfined) or confined the water level response from rainfall recharge can take days, weeks or months to show.

In Appendix 4 the telemetered bore data has also been plotted over residual monthly rainfall. The rainfall data used is from the closest rain gauge site to the bore Map 2. This was an attempt to assess any influence of rainfall on groundwater levels. These graphs are located on the information sheet for each of the telemetered bores (461, 2060, 2328, 2504, 2533, 2541, 2822, and 3043) in Appendix 4.

Human impact on the water level of the aquifer system is difficult to assess because the actual use (the annual or seasonal volume of water taken from an aquifer) is not recorded. Although estimated actual use has been calculated It can only be surmised why the water level of the systems behave the way they do.

To provide actual use (abstraction volumes) all consented water takes require a record of actual water use in real-time. This information coupled with rainfall, climate and hydraulic flow data will allow a better understanding and interpretation of the groundwater data and how the aquifer systems are behaving.

Part 5: Groundwater quality assessment

5.1 Data management and trends

Groundwater quality data has been collected from 59 monitoring bores over the years. Presently 22 monitoring bores are used to provide groundwater quality data. Only 15 of these also include water level data. However the water level and groundwater quality monitoring does not correspond to each other (undertaken at different times). Groundwater quality monitoring only occurs annually. Therefore no trend assessment can be done on the quality of the water, as to whether it changes under pumping stress and improves with recovery (recharge) or visa-versa.

5.1.1 Data quality

Twenty variables are assessed to determine any trend in groundwater quality over the entire monitoring regime. Four of our bores are presently part of the National Groundwater Monitoring Program managed by GNS Science (Bore numbers 2509, 3301, 4007, and 4364). No change to groundwater quality trend has been identified over the monitoring duration.

5.1.2 Approach to analysis

Groundwater quality has been assessed against Drinking Water Standards for New Zealand 2005 (revised 2008) (DWSNZ); ANZECC guidelines 2000; and anthropogenic nitrogen levels (Daughney & Reeves 2005). Although the standards and guidelines are not strictly applicable to ambient groundwater quality they serve as a reference for comparison and indicators of change.

In most cases the groundwater quality is within the maximum acceptable (MAV) or guideline value (GV) set in DWSNZ. The DWSNZ defines health-related maximum acceptable values (MAV) and aesthetic guideline values (GV). The ANZECC guidelines define trigger levels (TV) based on specified protection levels for aquatic ecosystems. This report uses TV that corresponds to the 95% protection level for freshwater ecosystems.

5.2 Groundwater quality

Maintaining good groundwater quality is crucial for the longevity of the fresh water resource. Regional concerns for groundwater quality relate to:

- contamination with nitrate and/or phosphate (nutrients);
- contamination with microbial pathogens;
- naturally elevated concentrations of iron, manganese, arsenic;
- risk of induced salt water intrusion.

Groundwater quality in the region generally does not appear to be changing over time. There is little evidence of trend. The frequency of sampling, total number of samples and data gaps may hinder the ability to recognise any annual (seasonal) or long term trends.

5.2.1 Key groundwater quality indicators

Over the years our groundwater systems have been analysed for various parameters. These are listed in Appendix 3. Of these parameters some have been assigned limits based on health, environmental and aesthetic effects (Table A3-1, A3-2, A3-4).

Nitrate-nitrogen ($\text{NO}_3\text{-N}$) is monitored for health and environmental reasons. Work undertaken by Daughney & Reeves (2005) has provided figures for $\text{NO}_3\text{-N}$ in groundwater to help determine status in regard to human impact:

- median concentration of 0.7g/m^3 for pristine oxidised groundwater
- median concentrations above 1.6g/m^3 probably indicate anthropogenic effects,
- median concentrations above 3.5g/m^3 indicate human impact on groundwater.

Nitrogen in oxygen-rich groundwater exists predominantly as $\text{NO}_3\text{-N}$, but under oxygen-poor conditions nitrogen is converted to ammoniacal-nitrogen ($\text{NH}_4\text{-N}$) by natural processes. The level of $\text{NH}_4\text{-N}$ is useful as it shows whether the absence of $\text{NO}_3\text{-N}$ is due to oxygen-poor water (conversion) or a lack of human or agricultural impact on groundwater quality. Low values of $\text{NO}_3\text{-N}$ and greater values of $\text{NH}_4\text{-N}$, Fe and Mn indicate oxygen-poor groundwater. Thus nitrogen exists as $\text{NH}_4\text{-N}$ rather than $\text{NO}_3\text{-N}$ (Daughney & Reeves 2005).

Dissolved iron (Fe) can impart an unpleasant taste to drinking water, but is not a health or ecosystem risk. Fe can cause problems with staining and is precipitated on contact with surface oxygen, which can cause blockages in screen/pump works. Elevated concentrations of dissolved Fe in groundwater indicate oxygen-poor conditions, so complements $\text{NH}_4\text{-N}$ to understand measured concentrations of $\text{NO}_3\text{-N}$.

Dissolved manganese (Mn) can impart an unpleasant taste to drinking water and cause staining. It can also be a risk to human health and freshwater ecosystems. Mn is soluble in oxygen-poor groundwater. Oxidised Fe and Mn can precipitate in the bore screen causing clogging. Before use the groundwater can be filtered to reduce the oxidised Fe and Mn from the water.

Escherichia coli (E. coli) are a species of bacteria that indicates the presence of faecal matter in groundwater. This can be due to lack of containment at bore head works or proximity to septic tank or dairy shed waste.

Electrical conductivity (conductivity) provides a measure of the total dissolved solids (TDS) concentration and provides a useful indicator of changes in quality, particularly with abstraction, like salt water intrusion and recharge.

5.2.2 Groundwater quality observations

To undertake trend analysis for groundwater quality requires at least quarterly data for several years. Due to the lack of monitoring frequency and inconsistency of sampling intervals trend analysis could not be performed for individual calendar years. Even the overall monitoring it is difficult to ascertain any changes in quality due to abstraction because of the lack of monitoring frequency and interval variation. Therefore medium and maximum have been considered in relation to standards, guidelines and trigger levels.

Groundwater quality data from the monitoring bores has been assessed and set out in tables (Appendix 3). The tables display the median and maximum figures for certain parameters against recognised standards, guidelines and trigger values.

In the tables the groundwater quality result is highlighted if the parameter exceeds a DWSNZ threshold or ANZECC TV. However this does not necessarily indicate a threat to human health, because some DWSNZ guidelines are purely aesthetic, and ANZECC TV do not necessarily lead to adverse ecological consequences in adjacent surface waters. Water treatment methods can often be employed to remove or reduce the concentration of the parameter of concern to meet health-related standards. Whereas groundwater discharging to a lake, stream, river, mixes with the surface water and can lead to dilution and a reduction of the contaminant concentration.

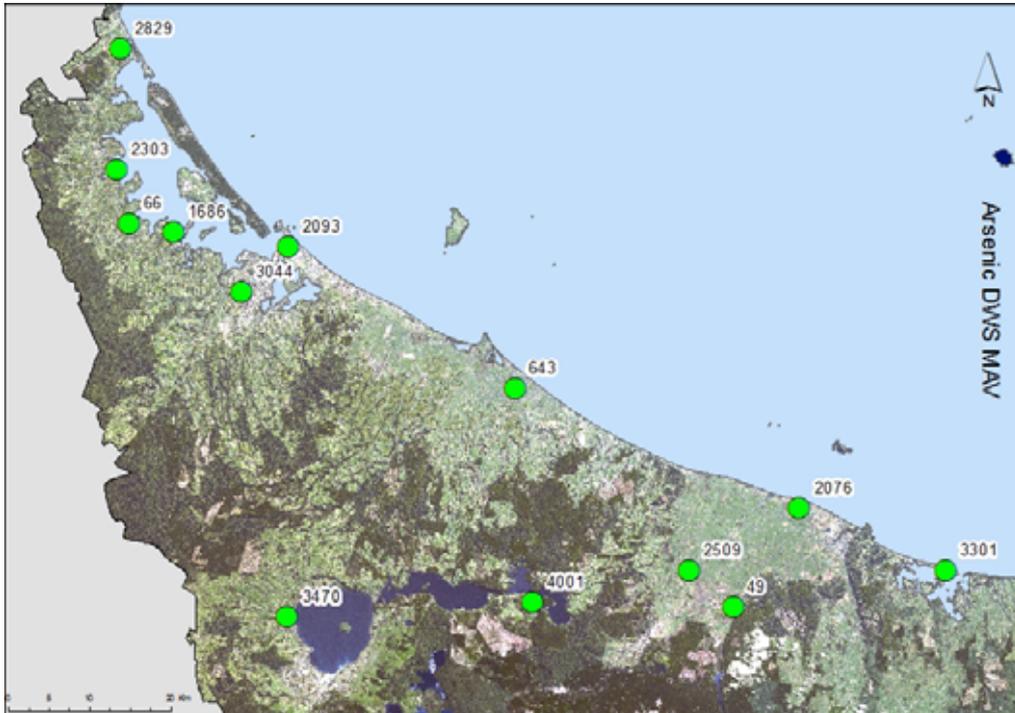
The median groundwater quality results for each bore have been assessed and tabled to show those with a tendency to exceed limits and guidelines. These bores and the parameters of concern are listed in Table 4 and shown on Maps 12 to 24.

Table 4 Bore with groundwater quality concerns

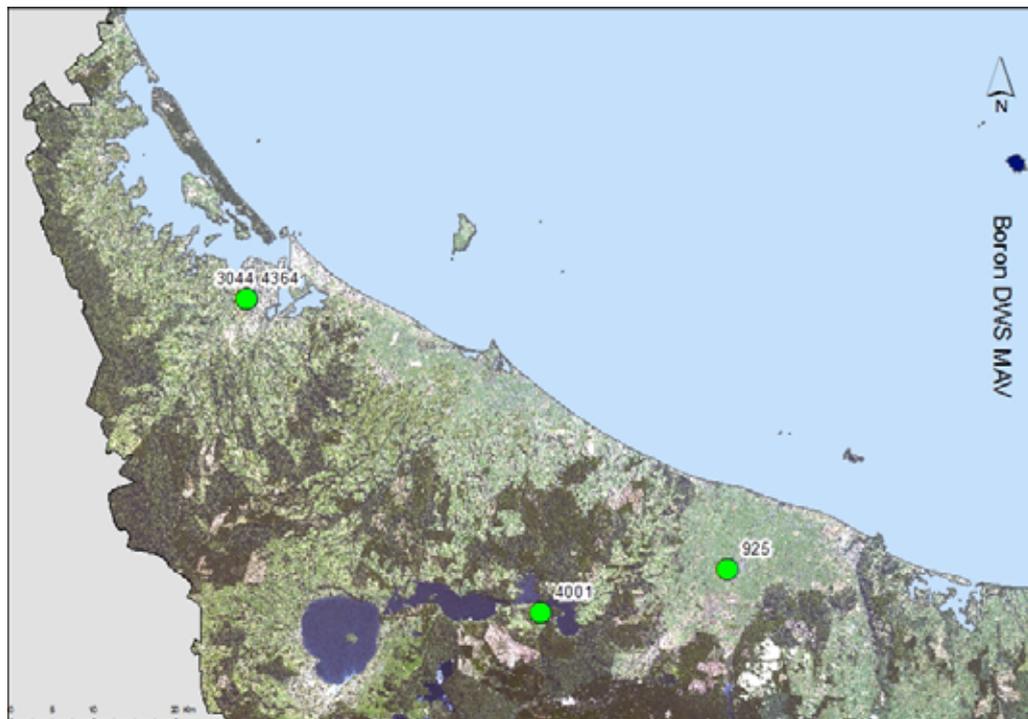
Above DWSNZ Health Related MAV	Bore number	Map
Arsenic	49, 66, 643, 1319, 1686, 2076, 2093, 2303, 2509, 2829, 3044, 3301, 3470, 4001	12
Boron	925, 3044, 4001, 4364	13
Manganese	410, 643, 925, 951, 1319, 1690, 2362, 2822, 3272, 3470, 4001, 4364,	14
ENT/FC	1, 49, 643, 3301, 3566	15
Ammoniacal-nitrogen	49, 466	16
Above DWSNZ Aesthetic Guideline	Bore number	
Aluminium	49, 1686, 2847	17
Hardness	49, 2707, 3272	18
Iron	1, 196, 410, 466, 490, 643, 845, 851, 925, 951, 1018, 1319, 1686, 1690, 2362, 2728, 2822, 2829, 2847, 3036, 3044, 3470, 4001, 4002, 4364,	19
Manganese	1, 49, 196, 410, 466, 490, 643, 845, 851, 925, 951, 1018, 1319, 1586, 1686, 1690 2303, 2362, 2728, 2822, 2847, 3036, 3044, 3272, 3470, 4001, 4002, 4364,	20
Sodium and Chloride	2093, 3044, 3272, 4001	21
Sulphate	3272	22
Above ANZECC TV	Bore number	
Ammoniacal-nitrogen	1, 2847, 3272, 3470	23
Anthropogenic nitrate effect	Bore number	
	3034, 3566, 4968	24

Also included in the groundwater quality analysis is a table of trace elements recorded Table A3-3. For data integrity and to determine accuracy of the groundwater quality results an Ion Balance data check was undertaken; Table A3-5 Major Ions and Table A3-6 Ion Balance of bore samples.

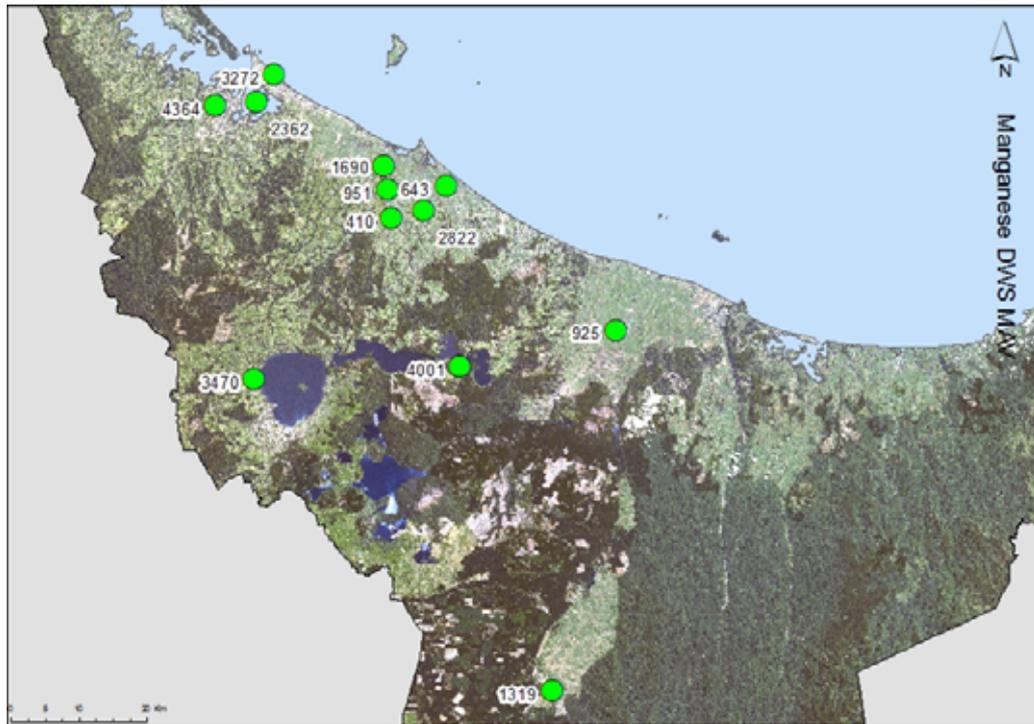
The review of outliers and charge balance (Table A3-6) errors indicates that data quality is generally acceptable; not greater than +/-10%. In general the bores are sampled on an annual basis. Some years no sample is collected. Therefore monitoring data is limited with regard to trend analysis. There could be quality changes occurring over the year (due to water level rise and fall) that are not shown due to low monitoring frequency. Time series plots of variables are produced for all bores to help visualise the data (Appendix 4).



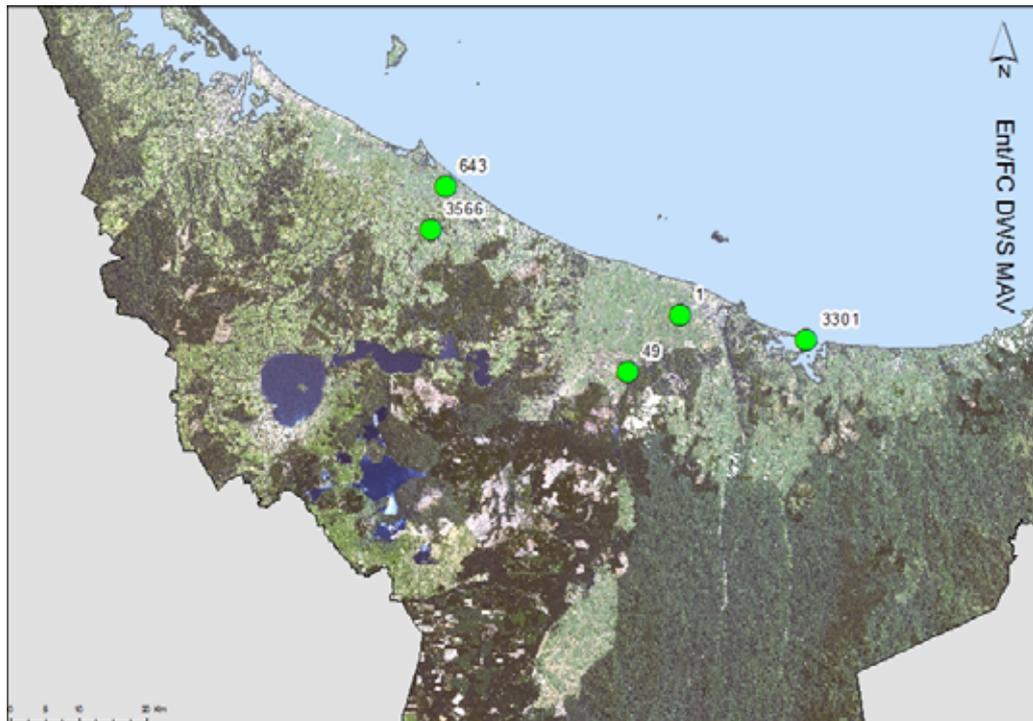
Map 12



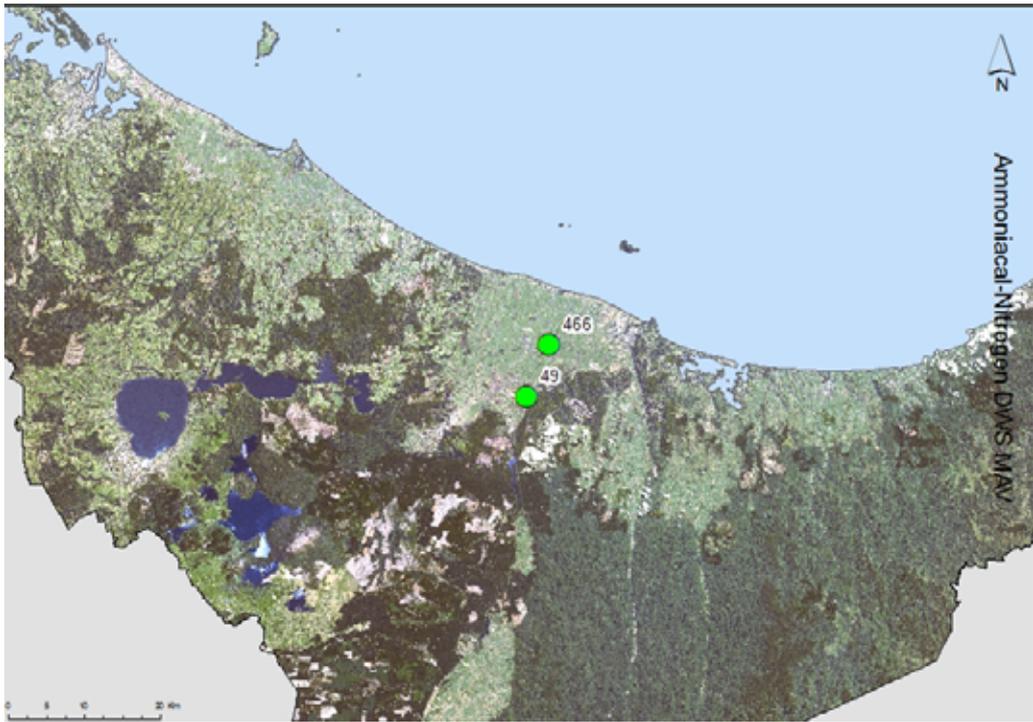
Map 13



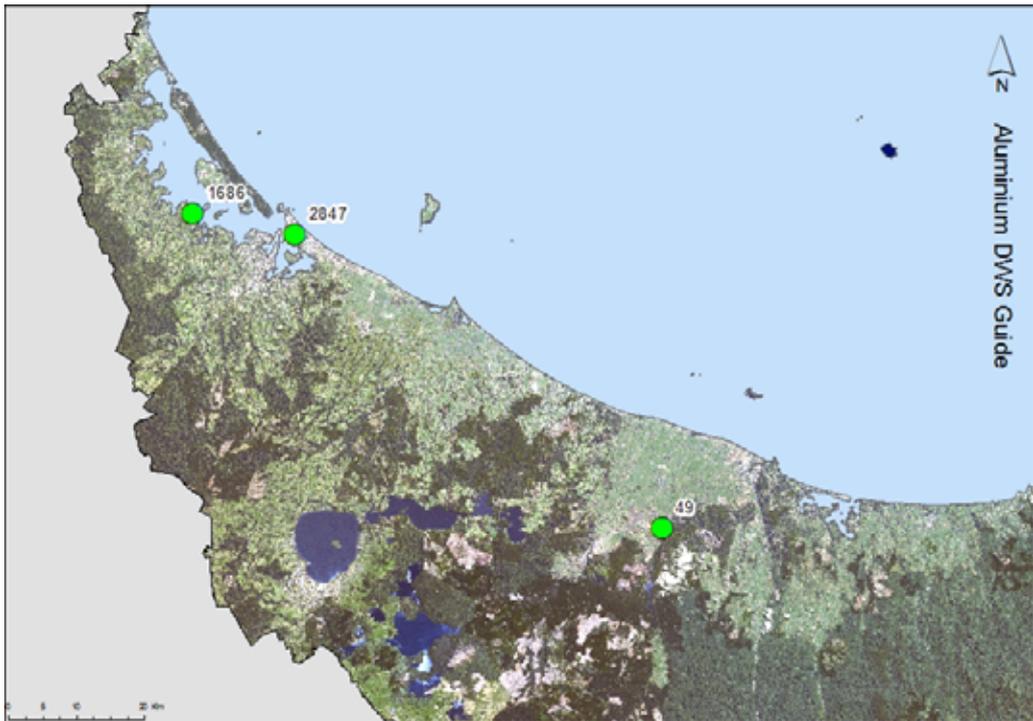
Map 14



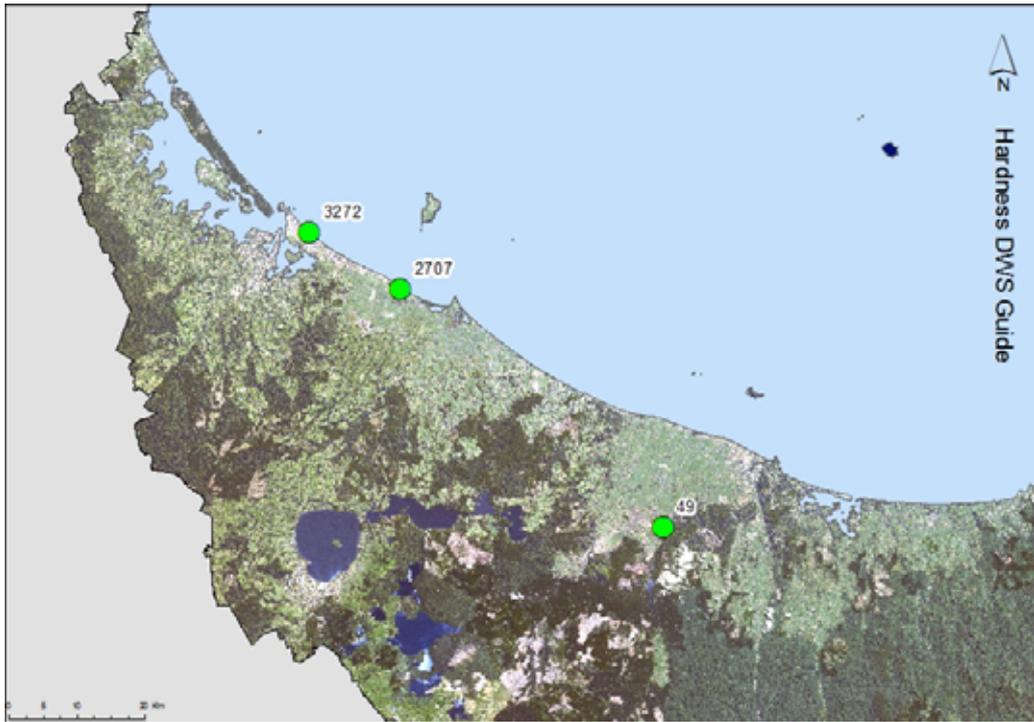
Map 15



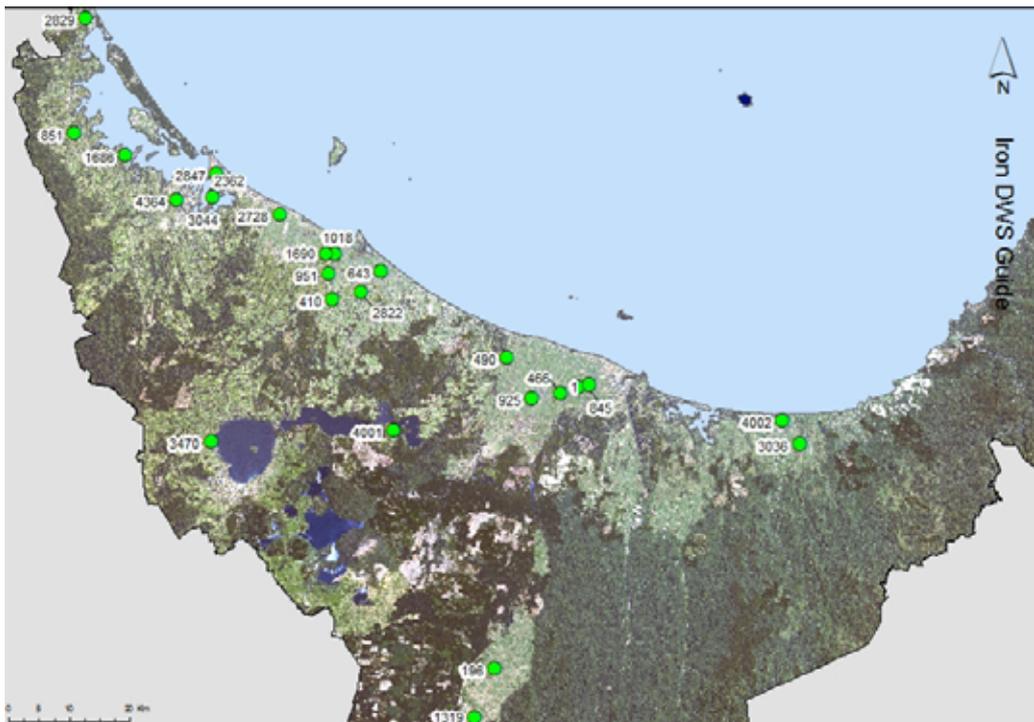
Map 16



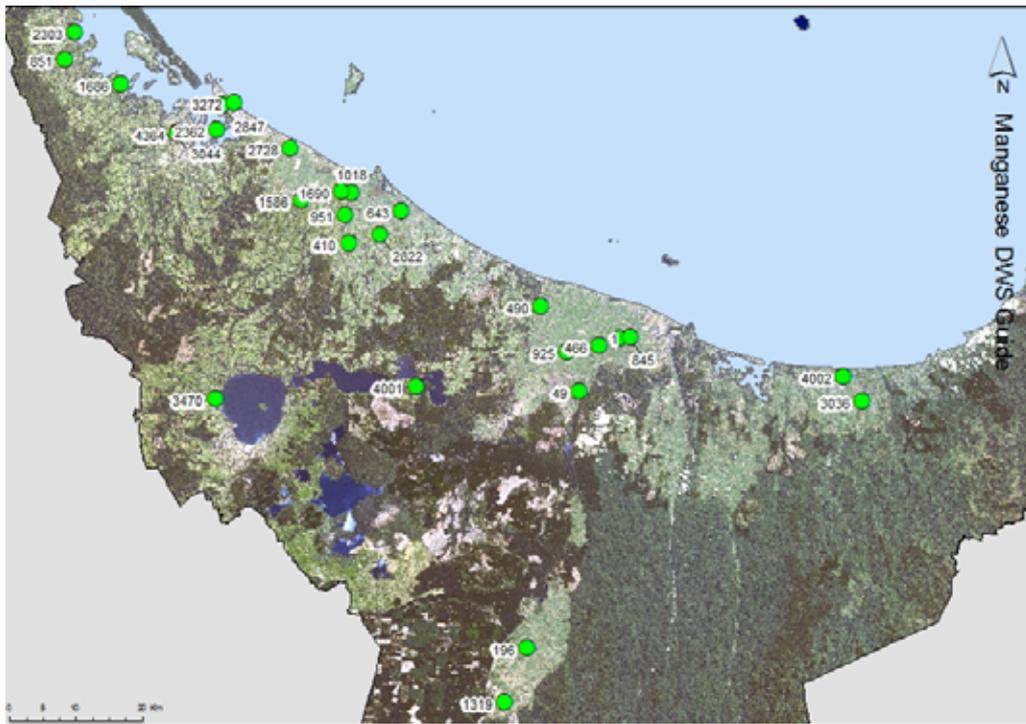
Map 17



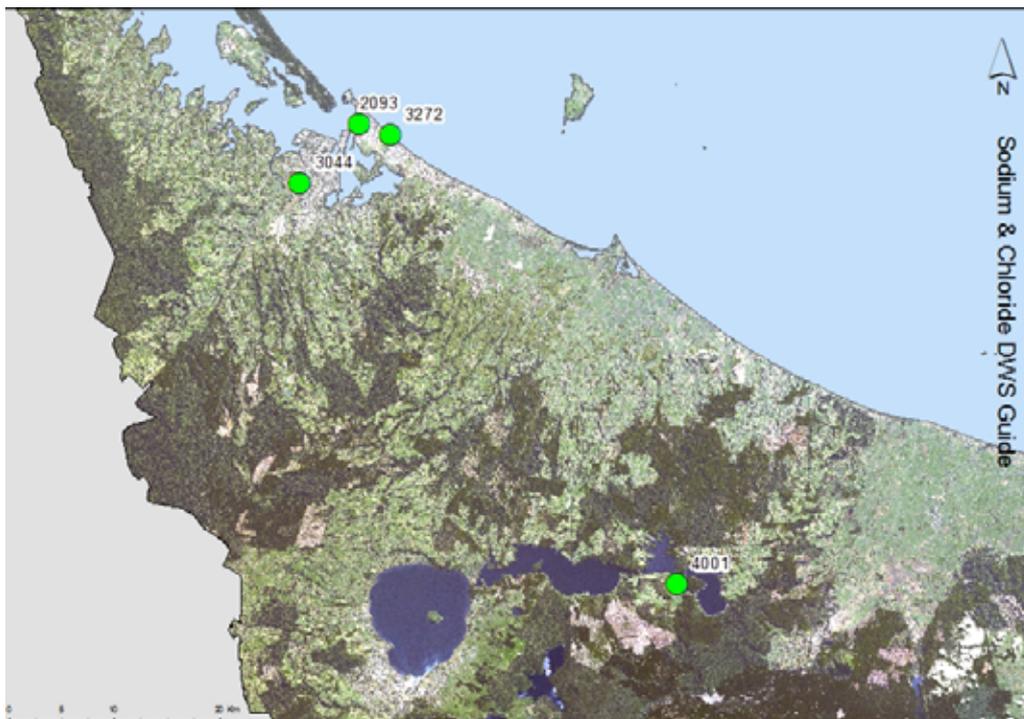
Map 18



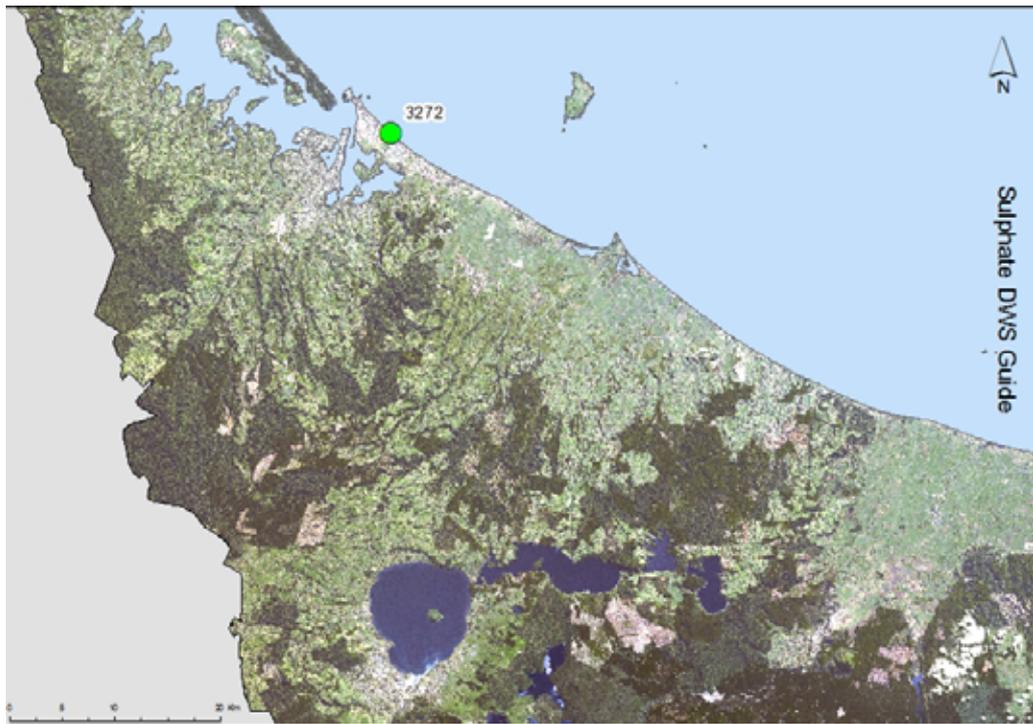
Map 19



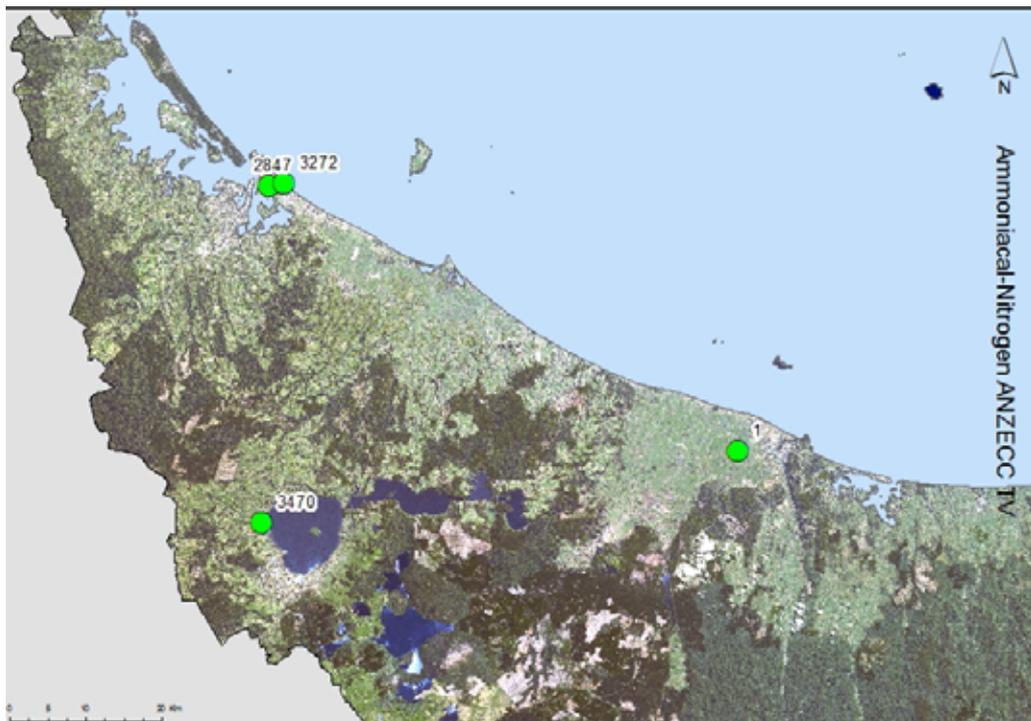
Map 20



Map 21



Map 22



Map 23

Map 24



5.2.3 Groundwater quality observations for bores with declining water level trends

With any water level drop there is the potential for water to move toward the lower water level area of the groundwater system. This means that the quality of the water moving into a low water level area could be the same, better or poorer in quality than what is already there. For declining water level bores (Table 3) that are not already part of the water quality monitoring regime, it is proposed that these bores are included in the water quality monitoring program to assess if there is any water quality change over time.

Table 3 Bore with declining water level trends and groundwater quality monitoring

Bore number	Aquifer	Water quality monitored	Groundwater quality trend
90	Aongatete Ignimbrite	No	
93	Aongatete Ignimbrite	No	
2521/1	Waiteariki/ Aongatete Ignimbrite	No	
2521/3	Waiteariki/ Aongatete Ignimbrite	No	
1386	Aongatete Ignimbrite	No	
2829	Aongatete Ignimbrite	Yes	Does not indicate groundwater quality decline.
1670	Waiteariki Ignimbrite	No	
2822	Minden Rhyolite	Yes	Does not indicate groundwater quality decline.
2509	Matahina Ignimbrite	Yes	Does not indicate groundwater quality decline.
2060	Tauranga Group sediments	No	
3036	Tauranga Group sediments	Yes	Does not indicate groundwater quality decline.

Part 6: Conclusions

6.1 Overview

Of the 54 water level monitoring bores assessed, 12 shows a decline in aquifer water level. These water level declines were localised and not widespread over the entire aquifer system. This indicates that use of groundwater in these areas exceeds that ability for the aquifer to recover before intensive pumping commences again.

There may be structural constraints within the aquifer at these locations that inhibits flow, so the effect in water level could be exaggerated because of the structural conditions. However without water use data (allocation) or targeted hydraulic testing, determination for the decline in water level can only be postulated.

Of the remaining 42 water level monitoring bores, the water level is stable in 32 bores and increasing in 10. The stable trend indicates that groundwater use from the aquifer is sustainable; that in times of rest (no pumping) the aquifer can recover (replenished) so that recharge is meeting abstraction (use). The increasing trends probably indicate areas where over-use has occurred in the past.

Groundwater quality data has been collected from 59 monitoring bores over the years. Presently 22 monitoring bores are used to provide groundwater quality data. Twenty variables are assessed to determine any trend in groundwater quality over time. Four of our bores are part of the National Groundwater Monitoring Program managed by GNS Science.

Groundwater quality in the region generally does not appear to be changing over time. Trend analysis found relatively few variables having statistically significant changes over time. However this can be due to the limited frequency of sampling, total number of samples and data gaps which can inhibit the ability to identify trends.

Aquifer properties of water level and groundwater quality have typically been seen as separate monitoring regimes. The importance of how each informs the other appears not to have been recognised. Only 15 of our monitoring bores have both water level and groundwater quality records. All others are either one or the other. This limits our ability to identify and understand any trends that may be present.

The findings of this report will be used to review and make recommendations to the NERMN groundwater monitoring programme. A review of the groundwater monitoring program is not within the scope of this report.

6.2 What is the monitoring telling us

Two separate monitoring regimes form the groundwater monitoring program; water level and groundwater quality. These regimes would better inform the state of the groundwater systems if they occurred sequentially and at regular intervals throughout the year.

The data available provides some information on the health of the groundwater systems. Apart from naturally occurring groundwater quality parameters (arsenic, iron/manganese) that can make the groundwater unsuitable for certain purposes (potable water), there are minor contamination concerns identified by nutrients, bacteria and increased conductivity (possible salt water intrusion). These tend to be localised and are not wide spread. To determine the actual reason for these contaminants would require further investigation of the containment of the bore, land use and bore management.

The water level of the groundwater systems can influence the movement of groundwater quality through an aquifer. However the monitoring regime does not presently provide for this.

The water level of the groundwater systems has in the past shown pumping stress. There have been periods where for many years the aquifer has maintained a decline water level trend, only to recover in recent years. It is not clear if this is due to better rainfall recharge to an area, less groundwater use, land use change or efficiency of resource use in recent times.

Those groundwater systems in decline tend to be in localised areas and do not extend over the entire aquifer. However the Tauranga Harbour deep aquifer is showing decline, particularly to the north and near Tauranga. Abstraction of groundwater exceeds the ability for the groundwater to recharge (flow) into these areas. It is also of concern due to the proximity to the coast, and that two bores have water levels that are below sea level (risk of salt water intrusion).

The monitoring program does not provide information on water use; what a consent holder is actually taking and what volumes are being abstracted under the permitted provisions of the RMA and WLP. Therefore it is not known what abstraction volumes cause decline water level trends, or how rainfall-recharge can offset this effect.

The taking of groundwater does not lower the water levels to where they are unsustainable or cause decrease in groundwater quality.

- Determine sustainable yields for groundwater systems.
- Investigate the linkages between groundwater and surface water where there are large abstractions of groundwater in the recharge areas of springs used for municipal water supply.

6.3 Further work

This report provides a comprehensive assessment of the current groundwater monitoring regime and an overview of the region.

This information will be used to inform a future review of the groundwater monitoring network to determine:

- which monitoring sites are of value - providing useful information
- what monitoring improvements are needed to the network
- provide direction on where information is required to fill information gaps
- identify areas that require further study.

Part 7: Recommendations

It is recommended that the groundwater monitoring regime be reviewed to better align monitoring objectives with the information necessary to assess the state of this resource over the region, and inform the implementation of the WLP.

It is suggested that the monitoring program be developed into modules for a specific purpose, with appropriate monitoring frequency and parameters to meet set objectives. Such modules could be:

- Groundwater system(s) water level and quality
- Tauranga geothermal
- Lake catchment groundwater
- Risk of salt water intrusion
- Recharge zones
- Surface water-Groundwater interaction

The modules can provide reasonable coverage over the region to ensure adequate information on the groundwater systems can be determined from the data.

At present monitoring of water level and groundwater quality are undertaken separately and at different intervals and frequency. This does not allow for any correlation to be made between changes in water level and change to water chemistry within the groundwater systems. This needs to be rectified to make better use of the data collected to provide information on the behaviour of the groundwater system under pumping stress and recharge (recovery).

Crucial data on water use and allocation is not readily available at present. This is a substantial gap in our information and inhibits our ability to understand and manage the groundwater resource. Support and resourcing is needed for Consents, Compliance and Data Services staff to allow information to be efficiently collected, stored and retrieved.

There is a separate groundwater program for geothermal groundwater in Rotorua. The groundwater program includes monitoring of bores that are geothermal within the Tauranga area. It is recommended that a monitoring module for these bores is developed and includes temperature measurements and temperature profiles. It is postulated that a decline in water level can also result in a decline in temperature. This needs to be monitored for assessment and management of the Tauranga geothermal resource.

At present there are three rainfall recharge monitoring stations that are gathering information on the infiltration of rain water through the soils to the groundwater systems (recharge). For the future the aim is to assess this data against water level over an aquifer system and actual use from the system to determine what influence pumping stress or climate has of the water levels of the system. The present assumption is that decline on the water levels of the groundwater systems are due to abstraction however it is not known what portion of this water drop is due also to climatic influences (changes in rainfall: El Niño/La Niña).

Data management, storage and retrieval require improvement. Presently it is dis-jointed and time consuming. The data required to undertake this NERMN groundwater assessment has been sourced from separate systems:

- Wells database
- Consents database
- LabStar (water quality database)

- HydroTel
- Archival hard files for groundwater quality and bore log data

Each of these data storage systems are managed separately, under different sections of Council. Verification of the data is slow and arduous. Data has been queried from the respective data storage systems and extracted into excel spreadsheets. Here it has been collated and verified where possible.

It is imperative that for Council to undertake its function effectively that data storage, management and retrieval is seamless. The systems at present are disseminated and clumsy for information retrieval and assessment of data.

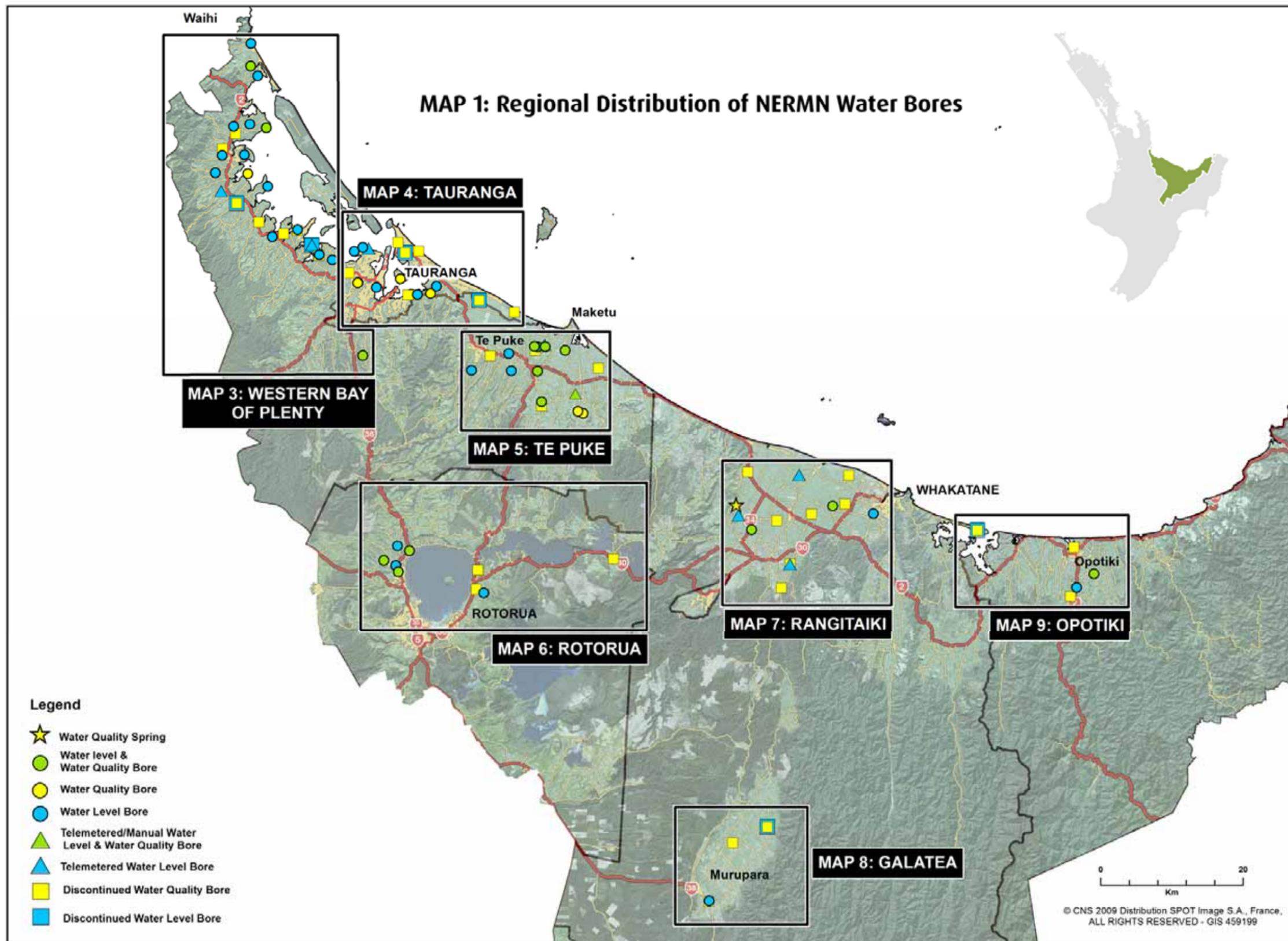
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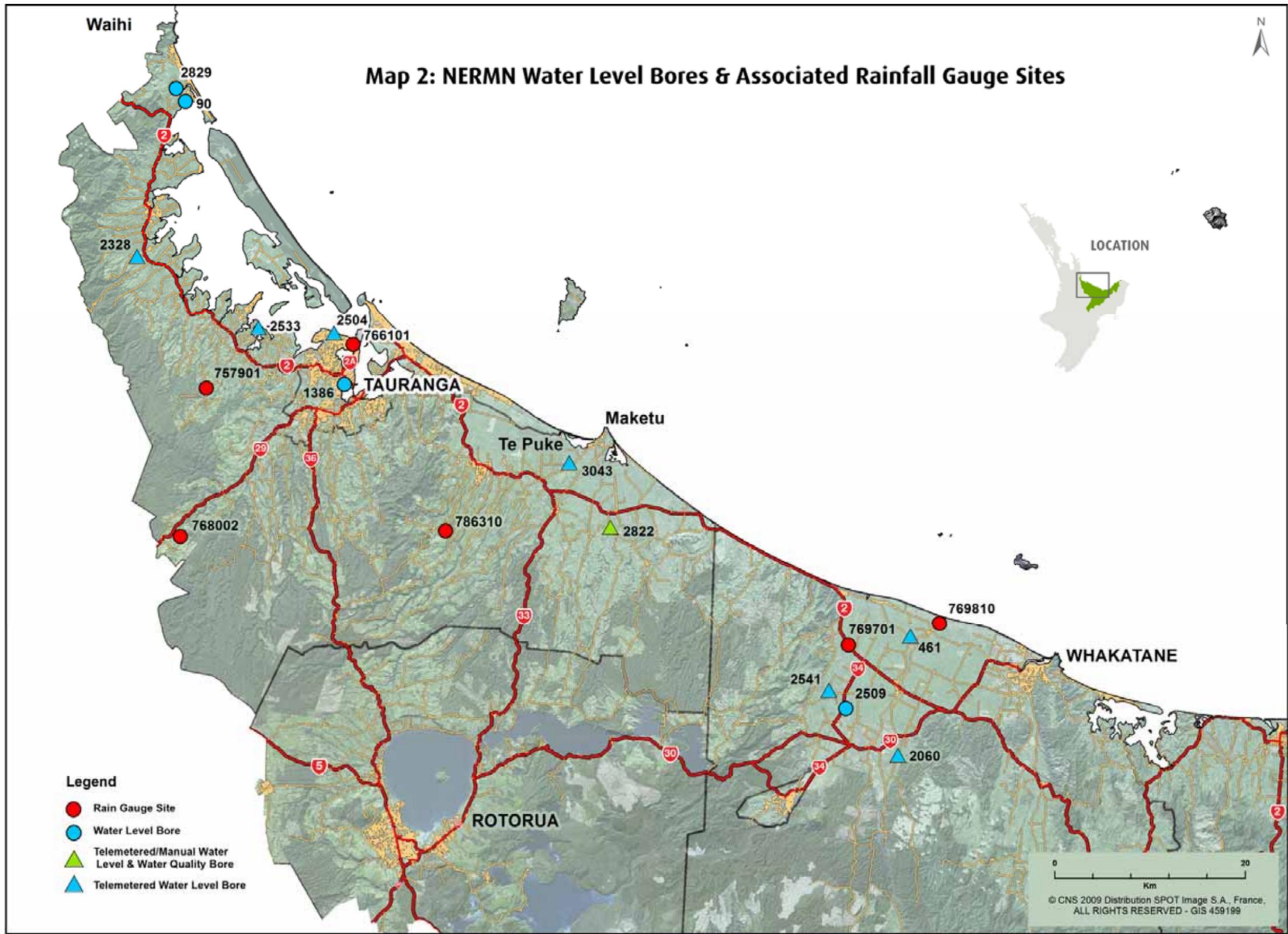
Appendices

Appendix 1 – Maps

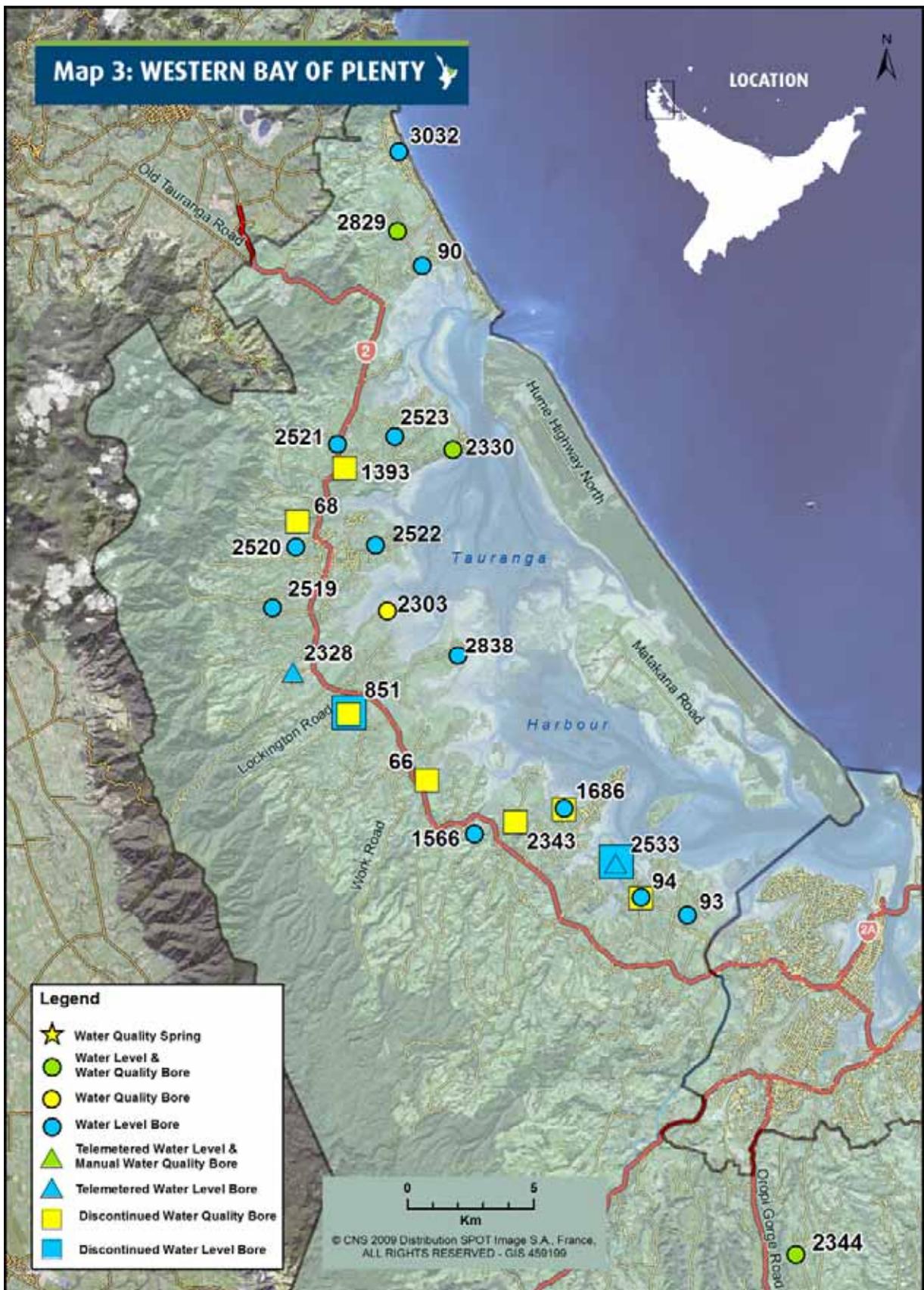
- Map 1 Regional distribution of NERMN groundwater bores
- Map 2 NERMN water level bores and associated rainfall gauge sites
- Map 3 Location of monitoring bores Western Bay of Plenty area
- Map 4 Location of monitoring bores Tauranga area
- Map 5 Location of monitoring bores Te Puke area
- Map 6 Location of monitoring bores Rotorua area
- Map 7 Location of monitoring bores Rangitaiki Plains area
- Map 8 Location of monitoring bores Galatea area
- Map 9 Location of monitoring bores Ōpōtiki area
- Map 10 NERMN groundwater level monitoring and allocation
- Map 11 NERMN groundwater level monitoring and allocation Waiteariki/Aongatete
Ignimbrite aquifer



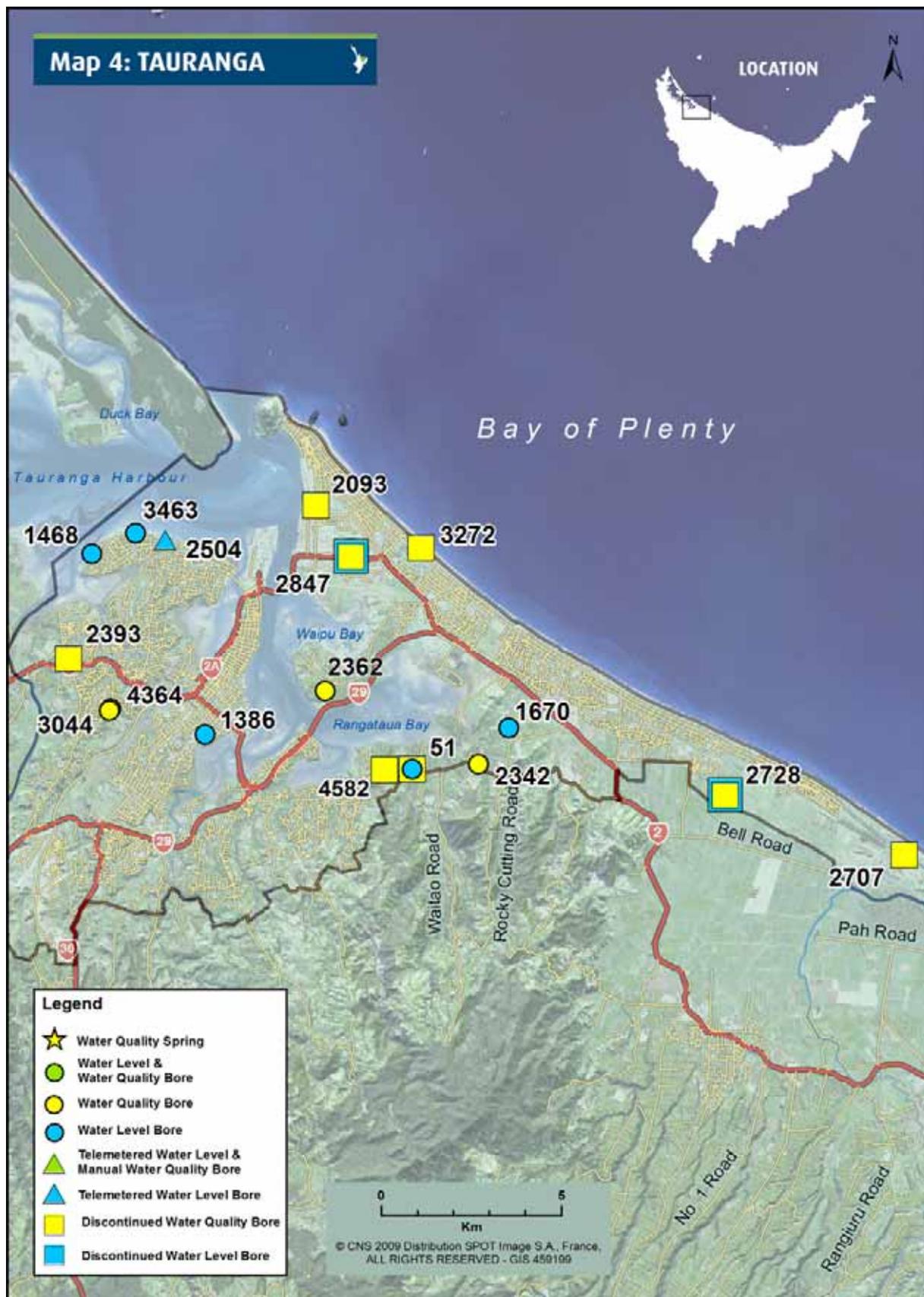
Map 1 Regional distribution of NERMN groundwater bores



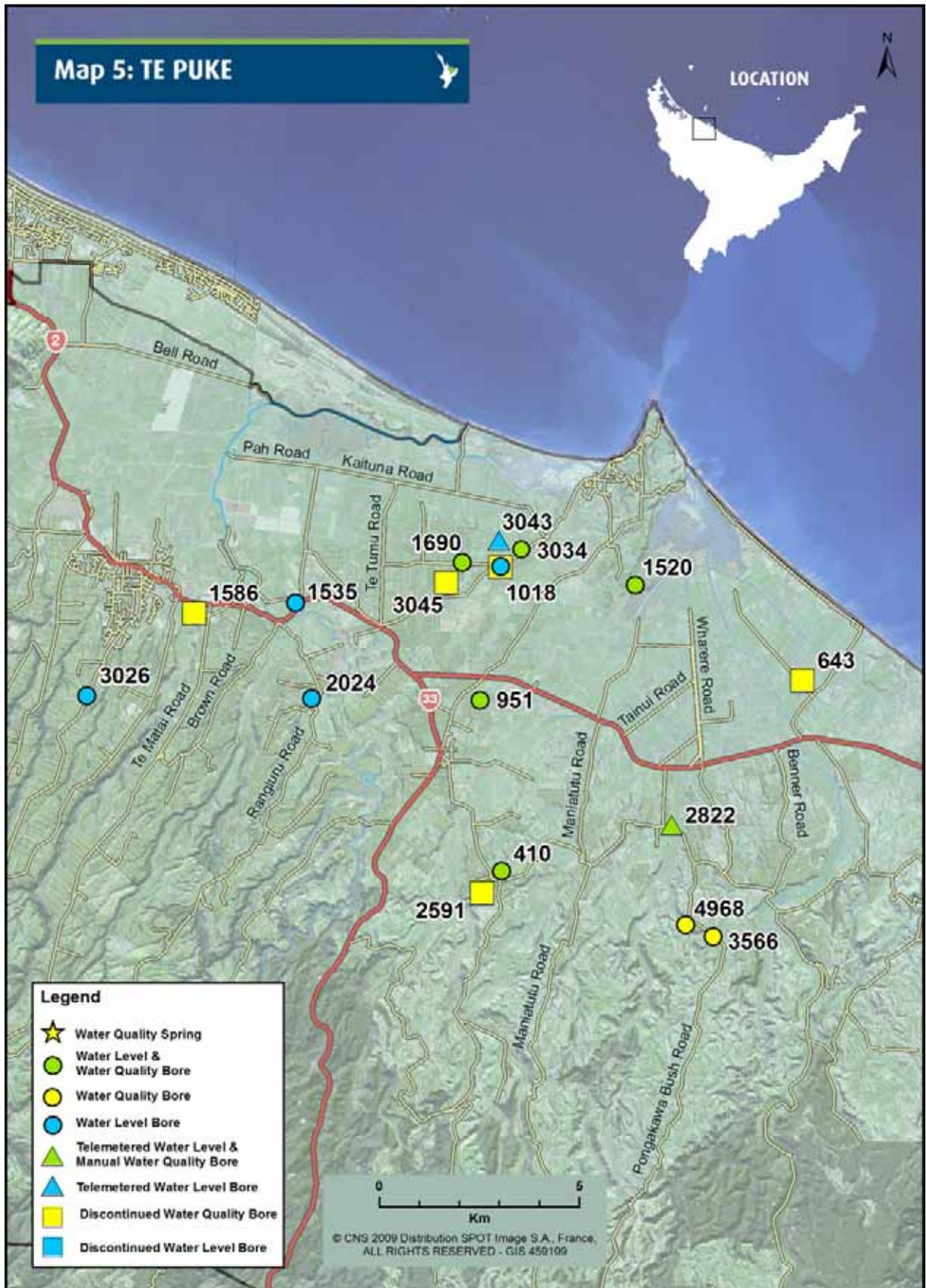
Map 2 NERMN water level bores and associated rainfall gauge sites



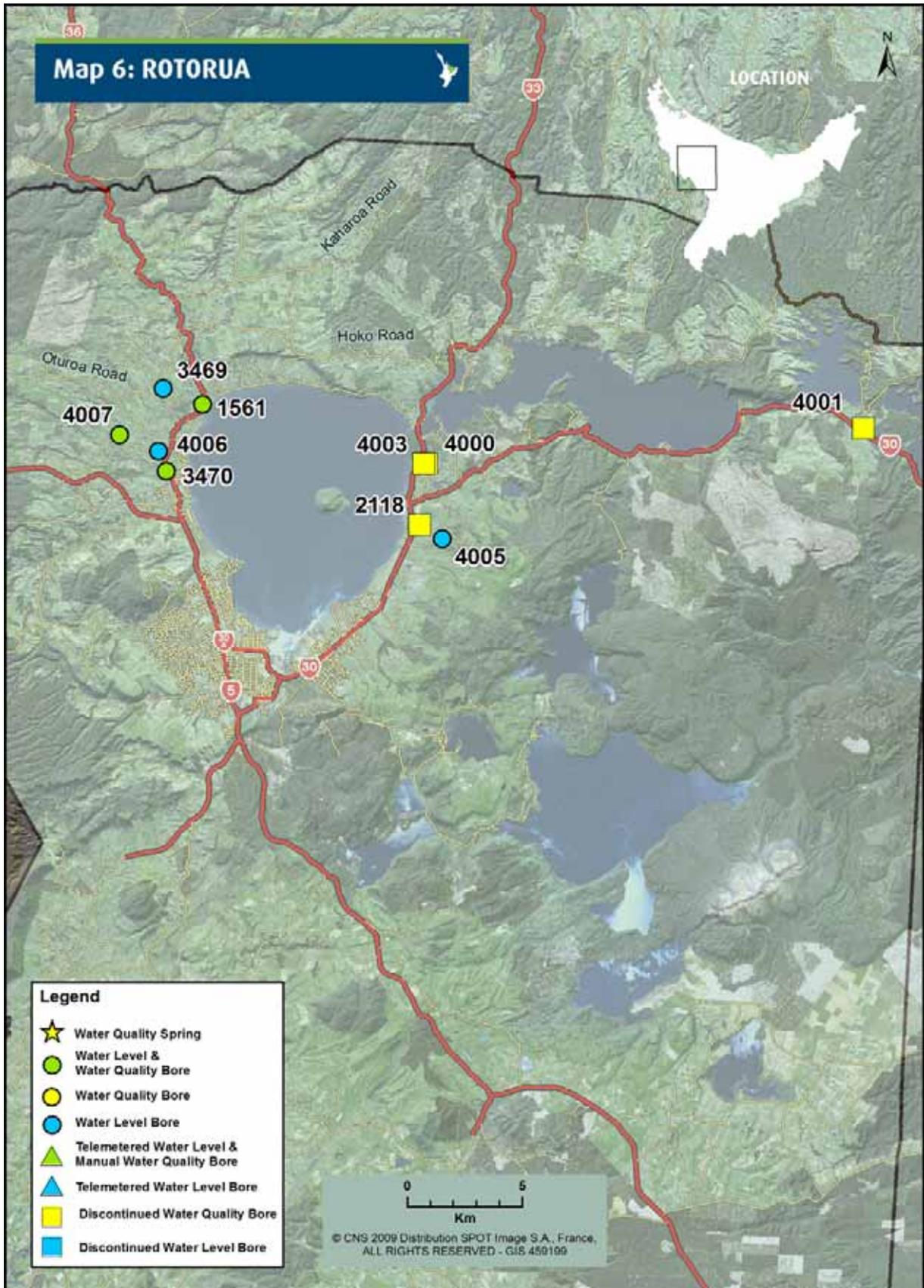
Map 3 Location of monitoring bores Western Bay of Plenty area



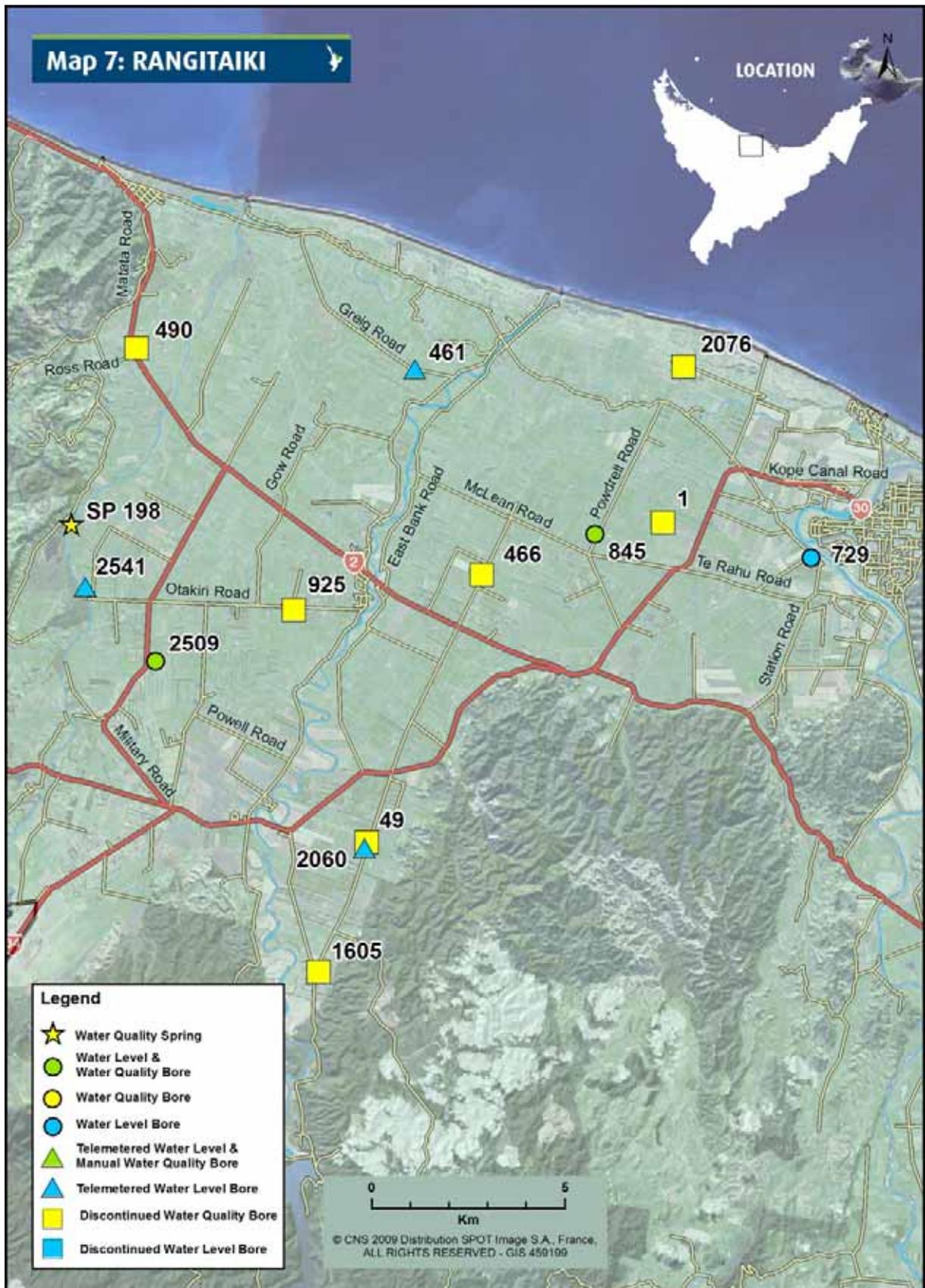
Map 4 Location of monitoring bores Tauranga area



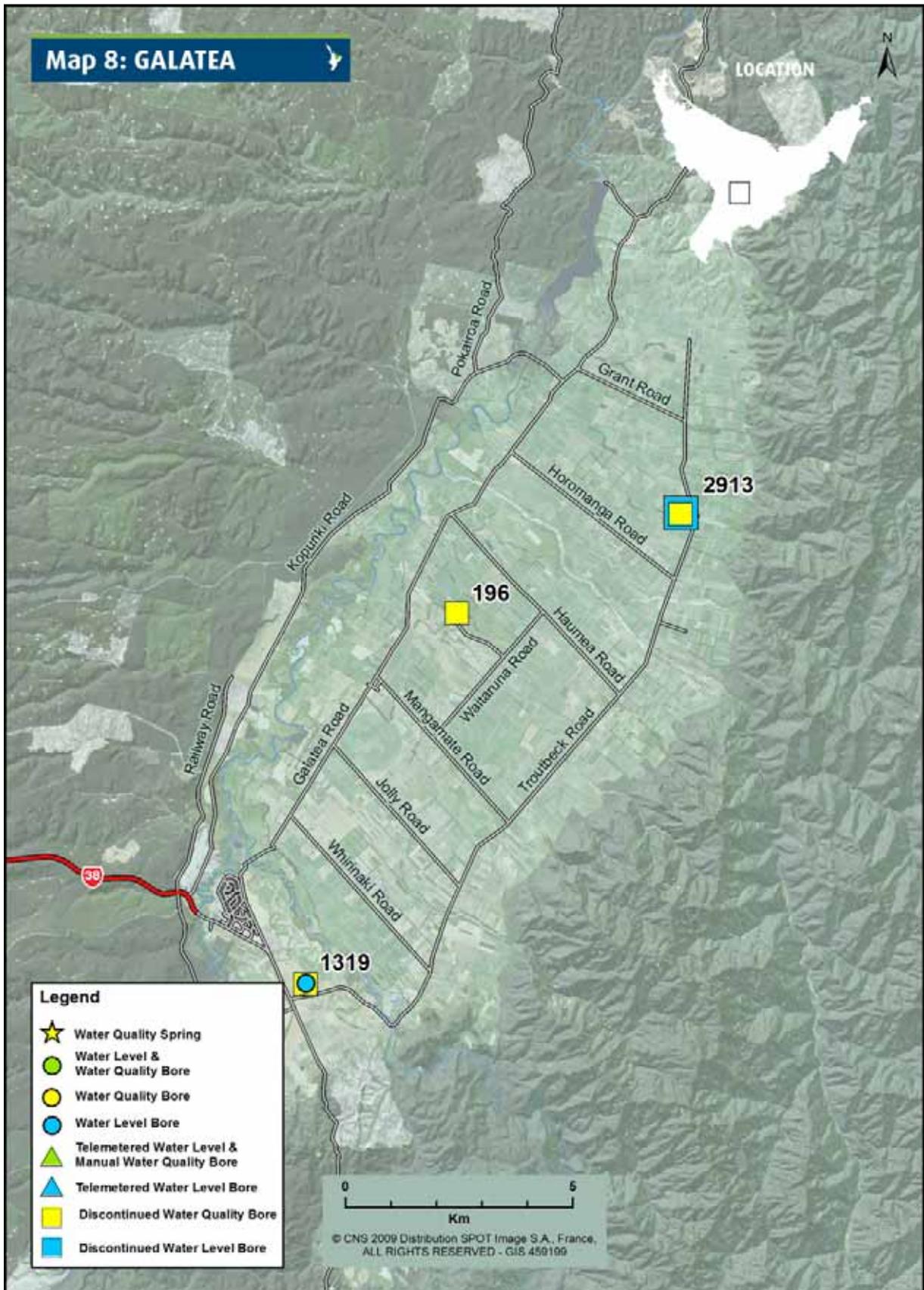
Map 5 Location of monitoring bores Te Puke area



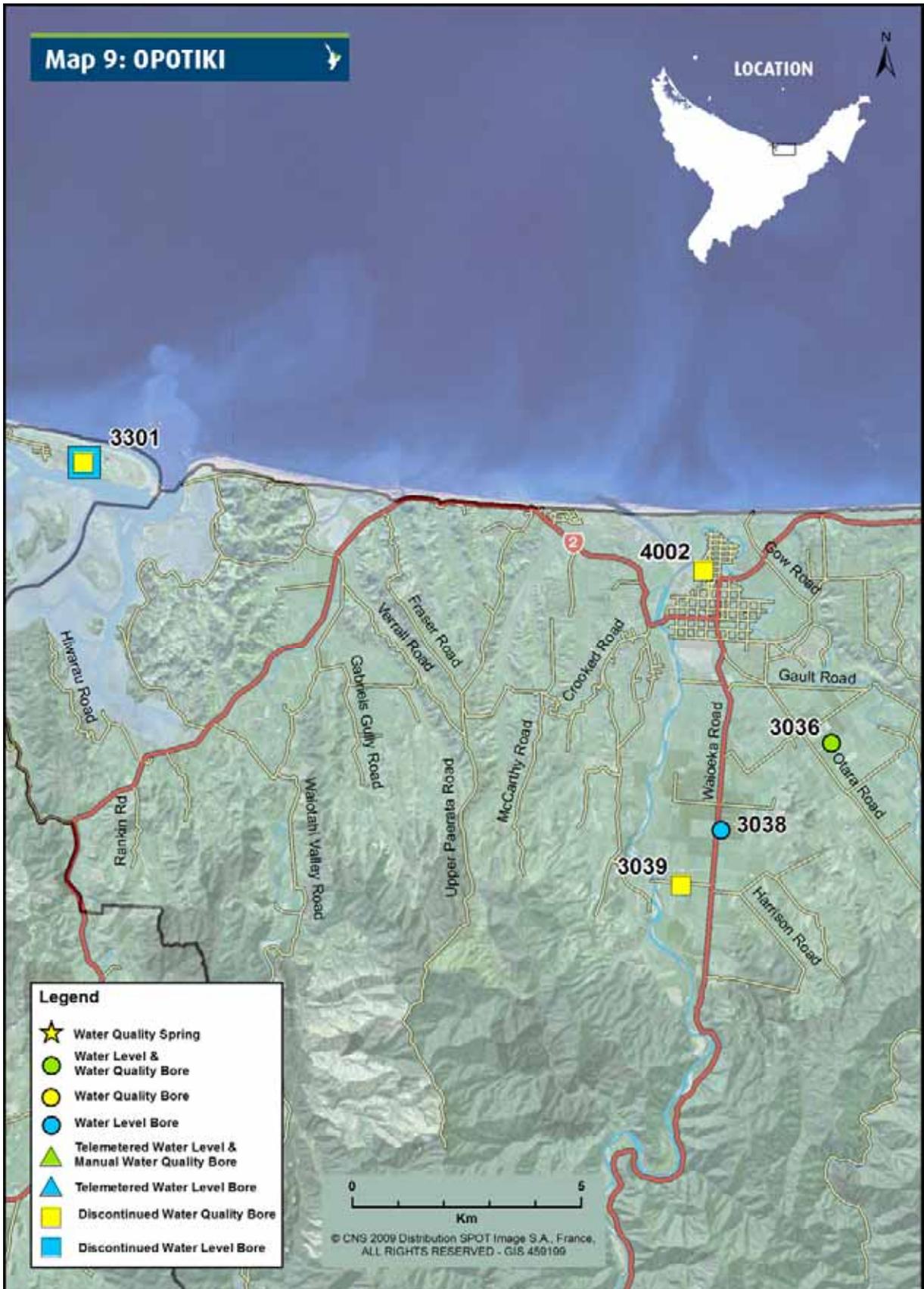
Map 6 Location of monitoring bores Rotorua area



Map 7 Location of monitoring bores Rangitāiki Plains area



Map 8 Location of monitoring bores Galatea area



Map 9 Location of monitoring bores Ōpōtiki area