State of the Environment Monitoring
Groundwater Levels
1989-2013

Technical Report 2014-126

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Executive summary

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

Groundwater is an extremely valuable resource for the Taranaki region, providing water supply for numerous agricultural, industrial and domestic needs. In addition, groundwater also sustains flows within rivers and streams and influences the quality of the water found within them. The Council recognises the importance of groundwater to the region and undertakes a significant amount of monitoring and assessment of groundwater quantity and quality as part of its overall state of the environment monitoring (SEM) programme. The data collected enables the Council to effectively manage the region's groundwater resources.

The groundwater levels programme incorporates nine groundwater level monitoring sites located across the Taranaki region. Monitoring sites are in the Taranaki volcanics (2), northern Marine Terraces (1), Whenuakura (2), Matemateaonga (3) and Tangahoe Formation aquifers (1). The data provided by the monitoring programme allows the Council to further develop its understanding of the hydrogeological characteristics of the monitored aquifers. By assessing water level data it is also possible to identify longer term trends in groundwater levels. Additional investigations can then be undertaken to assess whether any trends observed are a result of natural processes or human influences.

The following report summarises the results and findings of the groundwater levels monitoring programme from July 1989 to June 2013. This is the fourth SEM report written by the Council which specifically addresses the results of the groundwater levels monitoring programme.

The data collected shows that the region's shallow unconfined aquifers respond quickly to localised rainfall events and display a greater range of seasonal water level variation than the region's deeper aquifers. In general, groundwater levels across the region appear relatively stable; however five sites are displaying statistically significant trends in water level change. Three of these sites display positive trends, meaning water levels are increasing at these sites. The remaining two sites, GND0508 (Taranaki volcanics aquifer) and GND0708 (Whenuakura aquifer) display negative trends, meaning water levels are in decline. In all cases where significant trends are observable, the magnitude of the trends are extremely minor, with percentage annual change (PAC) values ranging from -0.4% to 0.05%. Given the low PAC values, the environmental significance of the trends observed is negligible. Data from these sites will continue to be closely monitored in coming years and further assessment undertaken to determine possible factors driving the trends observed.

This report presents a number of recommendations which, if adopted, will improve the spatial coverage of groundwater level monitoring sites across the region and the quality of data being collected. Additional changes to the reporting format and frequency are also proposed.

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1. Introduction

1.1 Background

Groundwater is an extremely valuable resource for the Taranaki region, providing water supply for numerous agricultural, industrial and domestic needs. In addition, groundwater also sustains flows within rivers and streams and influences the quality of the water found within them. The Taranaki Regional Council (the Council) recognises the importance of groundwater to the region and undertakes a significant amount of monitoring and assessment of groundwater quantity and quality as part of its overall state of the environment monitoring (SEM) programme. The data collected enables the Council to effectively manage the region's groundwater resources.

The Council's groundwater level monitoring network consists of nine sites, across five of the region's major aquifer systems. During the period being reported, water level measurements were generally obtained on a monthly basis, using an electronic water level meter. The data collected is used to assess the response of the region's aquifers to rainfall recharge and to determine whether there are any longer-term trends in groundwater level fluctuations.

The following report summarises the results and findings of the groundwater levels monitoring programme from July 1989 to June 2013.

1.2 Structure of the report

The following report contains eight sections as follows:

- Section 1 is an introductory and background section. It provides general information about groundwater monitoring undertaken by the Council.
- Section 2 provides specific details of the groundwater levels monitoring programme, including the objectives of the programme.
- Section 3 provides background information on the region's hydrogeological characteristics.
- Section 4 presents the data collected as part of the programme.
- Section 5 presents an interpretation of the results.
- Section 6 presents the main conclusions from the report based on the data gathered and the analysis of the data carried out by the Council.
- Section 7 provides information on the development and future direction of the groundwater levels monitoring programme.
- Section 8 concludes the report with recommendations to be implemented over the forthcoming monitoring period.

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

1.3 Statutory framework

The Resource Management Act 1991 (the RMA) requires the Council to monitor and report on the overall state of the environment within the Taranaki region. To meet this requirement, the Council undertakes a comprehensive programme of monitoring across all areas of the region's natural environment. The groundwater levels monitoring programme is part of Council's overall SEM programme.

Environmental monitoring is consistent with the purposes and principles of the RMA, the Regional Policy Statement and the Regional Freshwater Plan for Taranaki.

The Council also manages the impacts of abstractions on groundwater levels by regulating the taking of water through its policy framework and the resource consenting process.

The Council's *Regional Fresh Water Plan for Taranaki* (2001) contains an objective and policies for groundwater quantity and levels as follows:-

Objective

OBJ 6.4.1 To promote the sustainable management of groundwater resources by avoiding, remedying or mitigating any adverse effects of the taking and use of groundwater.

Policies

POL 6.4.1 The taking of water from shallow groundwater within close proximity of a surface water body may affect water levels and flows in the surface water body and accordingly any consideration of such an abstraction will take into account:

(a) the contribution of groundwater to surface flows;

(b) the effects of any abstraction on the surface water body at the location in question.

POL 6.4.2 The taking of groundwater will be limited to the sustainable yield of the aquifer to ensure that groundwater will be available for present and future generations. When assessing resource consents for the taking of groundwater, the Taranaki Regional Council will take into account the need to:

(a) maintain a sustainable yield of the aquifer;

(b) avoid the inflow of poor quality water into aquifers;

(c) avoid saltwater intrusion into aquifers;

(d) avoid significant interference with existing lawfully established and sustainable water uses.

The RFWP then discusses the objective and policies as follow:-

Policy 6.4.2 states that the groundwater resources of Taranaki will be managed on a sustainable yield basis. The concept of sustainable yield applies to both the quantity and quality aspects of groundwater. With respect to quantity, sustainable yield means ensuring that the abstraction rate does not cause long-term depletion of the groundwater resource…. The concept of sustainable yield is implemented through the standards, terms and conditions contained within regional rules

Through the procedures set out in the RFWP, the Council commits to:-

The monitoring of the effectiveness of the Plan will be carried out in conjunction with monitoring of the Regional Policy Statement for Taranaki and other regional plans. The following methods will be used to monitor fresh water and the effectiveness of the Plan.
…..
3. Continuation of the groundwater monitoring programme, including quality, nitrate and water level monitoring.

2. Groundwater levels monitoring Programme

2.1 Objectives

The groundwater levels monitoring programme aims to:

- Provide information on the current range of groundwater levels at a selected number of sites across the region's major aquifer systems;
- Identify natural and non-natural spatial and temporal trends in water level; and
- Assess the effectiveness of groundwater management objectives and policies for the region.

2.2 Programme overview

The groundwater levels monitoring programme is run as part of the Council's wider SEM programme for groundwater. Monitoring associated with the programme commenced in 1989 and this is the fourth report written by the Council specifically addressing the results.

The Council currently monitors groundwater levels at nine sites, across five of the region's major aquifer systems. There are no specific limits or guidelines to assess the data gathered against, but comparison against previous measurements and rainfall volumes can allow variations and trends in groundwater level to be interpreted.

2.3 Monitoring sites

The Council relies on being granted long-term access to privately owned wells or bores for the establishment of monitoring networks and is therefore restricted somewhat as to the location, design and construction of monitoring sites.

Currently, there are nine sites monitored as part of the programme, across five of the region's major aquifer systems. The sites include a mixture of wells and bores which tap both confined and unconfined aquifers.

The spatial distribution of the Council's groundwater level monitoring sites is summarised in Table 1 and illustrated in Figure 1. Summary information relating to each site is included in Table 2.

Table 1 Groundwater level monitoring coverage

Aquifer	Number of monitoring sites						
	North Taranaki	South Taranaki	East Taranaki	Central Taranaki	West Taranaki	Patea	Waverley
Volcanics (2)	1	1	0	0	0	X	X
Marine Terraces (1)	1	0	X	X	X	0	0
Whenuakura (2)	X	2	X	X	X	0	0
Matemateaonga (3)	2	1	0	0	X	X	X
Tangahoe (1)	0	1	X	X	X	X	X

X = Aquifer is not found in this area

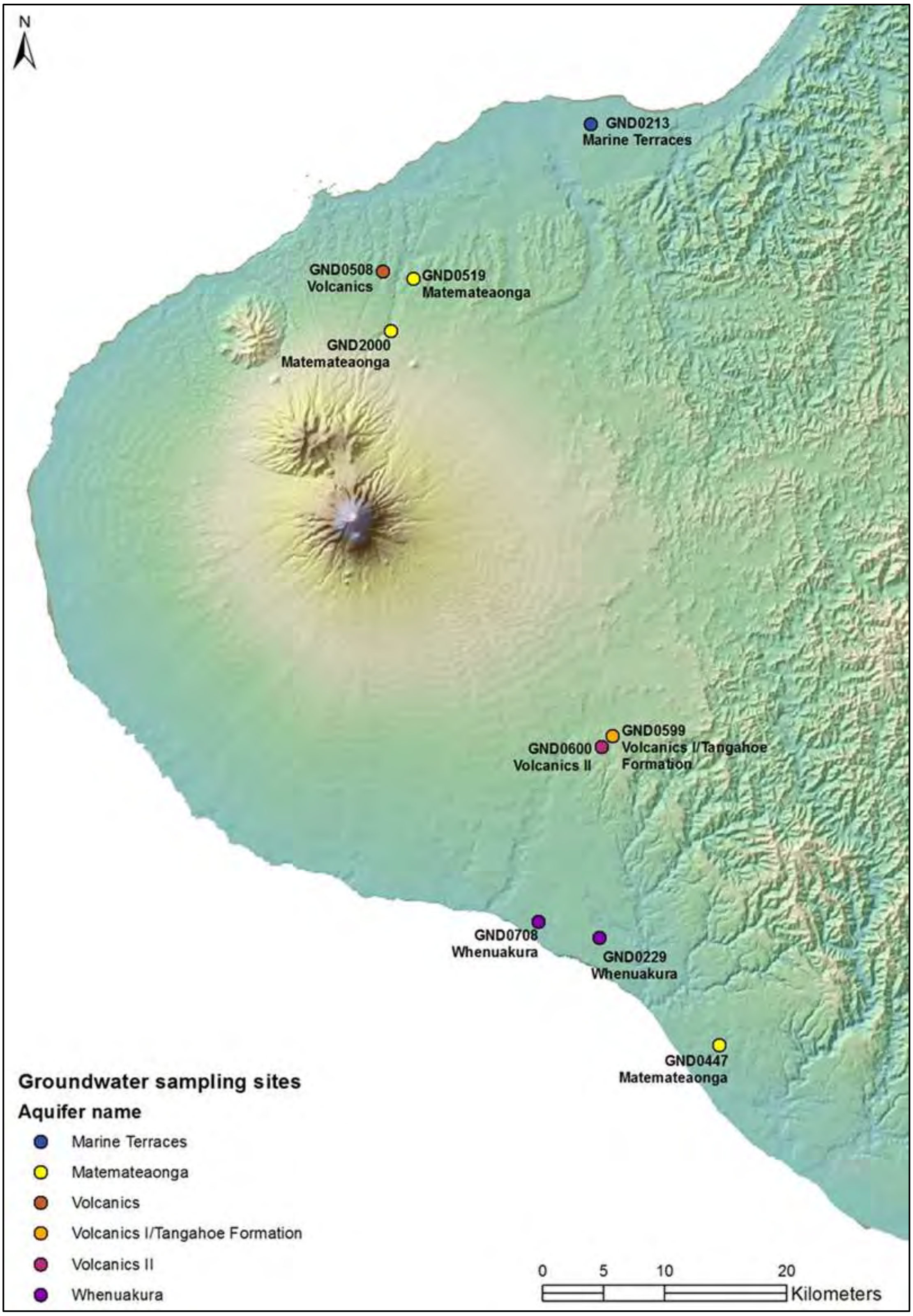

Figure 1 Monitoring site locations and aquifer unit intercepted

Table 2 Monitoring site details

Aquifer name	Aquifer type	Site code	Locality	Elevation (m AMSL)	Total depth (m BGL)	Screen depth (m BGL)		Screen depth (m AMSL)		Data record	
						Top	Bottom	Top	Bottom	From	To
Taranaki volcanics	Unconfined	GND0508	New Plymouth	120	14	8	14	112	106	Sep-94	Jun-13
		GND0600	Eltham	125	20	16	19	109	106	Nov-96	Jun-13
Marine Terraces	Unconfined	GND0213	Waitara	54.30	22	18	21	36.30	33.30	Jan-89	Jun-13
Whenuakura	Semi-confined/confined	GND0229	Whareroa	95	297	Unknown	Unknown	Unknown	Unknown	Oct-94	Jun-13
		GND0708	Hawera	70	94	82	94	-12	-24	Jul-98	Jun-13
Matemateaonga	Semi-confined/confined	GND0447	Manutahi	82.44	1,383	542	562	-459.56	-479.56	Oct-94	Jun-13
		GND0519	New Plymouth	145.18	795	644	766	-498.82	-620.82	Sep-94	Jun-13
		GND2000	Egmont Village	240	464	228 267	252 291	12 -27	-12 -51	Jan-09	Jun-13
Tangahoe	Semi-confined	GND0599	Eltham	125	83	79	82	46	43	Nov-96	Jun-13

2.4 Water level measurement and data collection

Groundwater levels at each monitoring site are generally obtained at monthly intervals. There has been significant variation in the frequency of measurements over the duration of the programme however, resulting in an intermittent data record. The length of data record is also variable by site, given that sites have been added and removed from the programme since its inception in 1989. The length of data records range from 4 years at site GND2000 to 24 years at site GND0213.

At site GND0213, water level measurements are recorded electronically at 15 min intervals using a pressure transducer. Water level measurements are then corrected for barometric pressure and data entered into the Council's data management system. To verify the electronic data record, manual water level measurements are obtained at monthly intervals using an electronic water level meter.

At the remaining eight monitoring sites, groundwater level measurements are obtained manually using an electronic water level meter. The groundwater levels are then entered into the Council's data management system.

All groundwater level measurements are referenced to a standard datum of metres above mean sea level (m AMSL) by subtracting depth to water measurements from the elevation of the point from which the measurement was taken (typically the top of the well casing) in m AMSL.

Photo 1 Measuring groundwater level at site GND0508

3. Regional hydrogeology

3.1 Rainfall

The Taranaki region receives regular rainfall throughout the year as a result of its westerly position, its mid-latitude location and topography. Average annual rainfall volumes across the region range from less than 1,000 mm along some southern coastal margins to in excess of 7,000 mm on the upper slopes of Mount Taranaki. Rainfall volumes also increase with elevation in the Taranaki hill country (Figure 2). The high rainfall volumes across Taranaki result in high rainfall surpluses being available to recharge the region's groundwater systems.

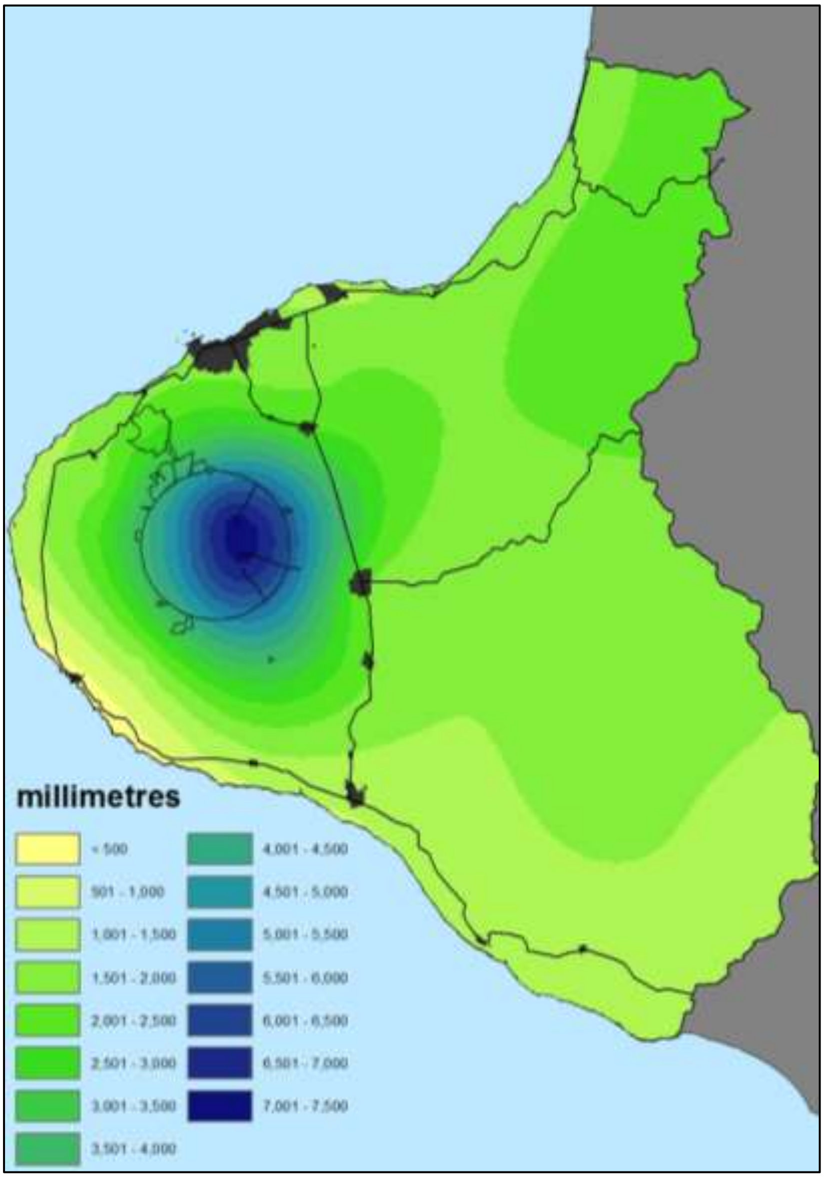

Figure 2 Average annual rainfall volumes for Taranaki 2008 to 2013

3.2 Groundwater systems

Groundwater resources within the Taranaki region can be differentiated between shallow unconfined aquifers and deeper confined/semi-confined aquifers. In unconfined aquifers, hydraulic heads fluctuate freely in response to changes in recharge and discharge. Groundwater levels measured in observation wells completed in the upper part of an unconfined aquifer help define the elevation of the water table, which is the top of the saturated zone. The major shallow aquifers within Taranaki are contained within the volcanic and Marine Terrace deposits.

In confined aquifers, water in the aquifer is confined under pressure by a geological layer that is considerably less permeable than the aquifer itself. Groundwater levels define an imaginary surface, referred to as the potentiometric surface, which represents the potential height to which water would rise in wells completed in the aquifer. In some instance this pressure potential exceeds the height of the overlying land surface. Wells drilled into such pressurised aquifers can flow freely without the use of pumps. Such wells are referred to as being artesian, or as having artesian flow. The major confined aquifers within Taranaki are contained within the Whenuakura and Matemateaonga Formations and to a lesser extent in the Tangahoe Formation.

The distribution and extent of geological formations across the Taranaki region is illustrated in Figure 3.

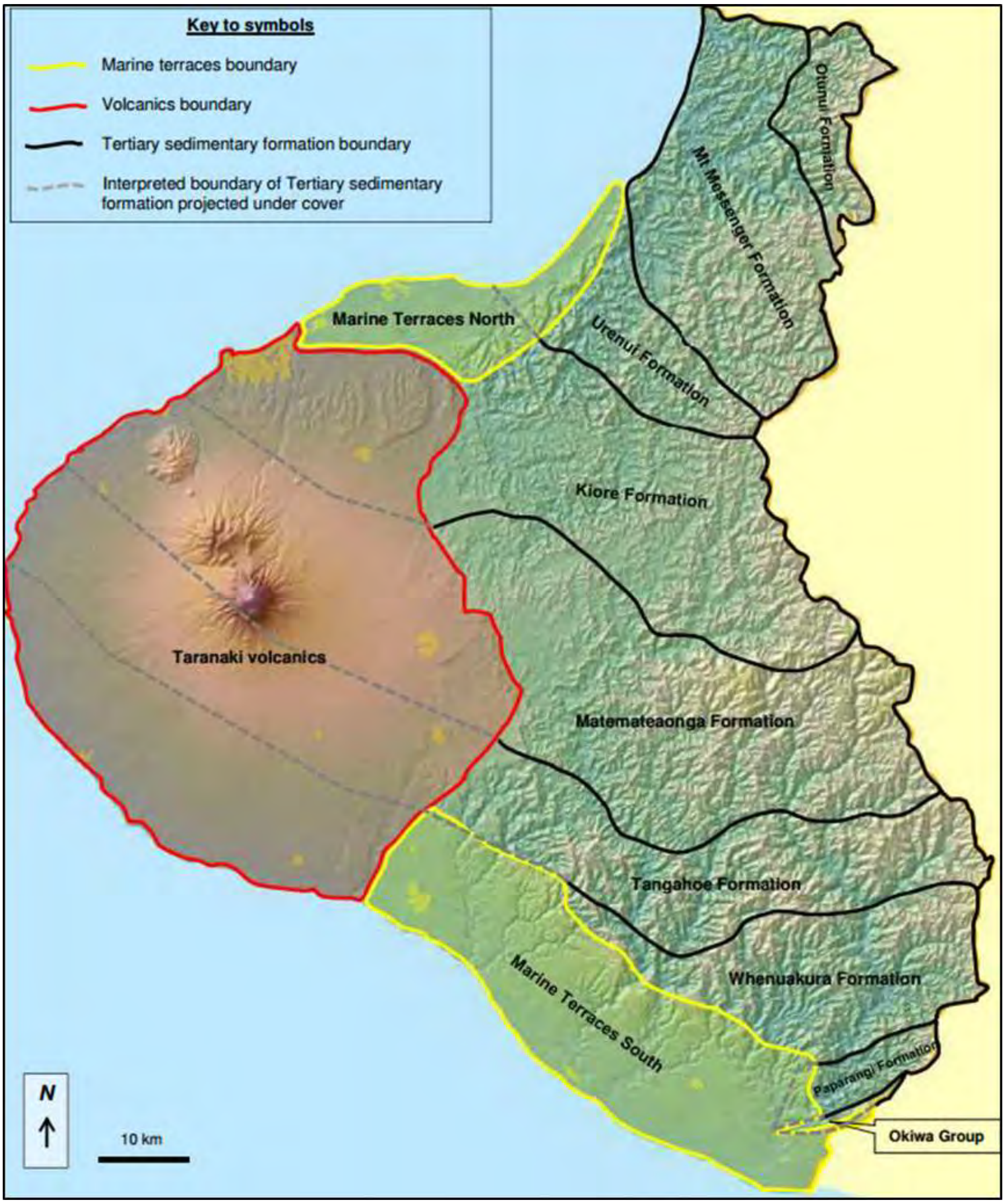

Figure 3 Major geological formations within the Taranaki region.

The hydrogeological architecture and water-bearing capacity of the region's major aquifer systems are highly variable. Further detail pertaining to each major aquifer unit is provided below.

3.2.1 Taranaki volcanics

Nearly all of the surficial geology of the Taranaki ring plain is comprised of volcanic products from the Egmont, Pouakai or Kaitake volcanic centres. The ring plain is constructed of successive accumulations of lahar, debris avalanche and air fall deposits from the volcanic centres, interbedded with river and swamp deposits. Coherent lava bodies occur in close proximity to the volcanic centres but are not represented in the volcanic deposits beyond the Egmont National Park boundary.

As a whole, the volcanics are complex in architecture and contain a range of aquifer types includeding unconfined, semi-confined, confined and perched aquifers. Aquifers are typically anisotropic and ash layers provide seals to more permeable volcanic materials. The volcanic deposits are hundreds of metres thick near the volcanic centres, thinning to metres thick at distal locations. Prevailing westerly winds have resulted in more ash being deposited in the east of the region than the west.

Recharge to the Taranaki volcanic aquifers is mainly by rainfall infiltration and percolation, with additional contributions from stream and river bed leakage. Groundwater within the shallow volcanics aquifers is thought to be relatively 'young' water due to the predominant recharge mechanisms. Tritium dating of shallow groundwater abstracted from wells within the unconfined Taranaki volcanic deposits indicates water in these locations is less than two years old.

The water table within the ring plain area is typically encountered within ten metres of the land surface. Seasonal variations in water table depth of up to five metres are not uncommon. Groundwater flow generally reflects surface topography and flows radially from Mount Taranaki.

Large numbers of shallow wells have been sunk in the volcanics for stock and domestic supply. Yields in the range of 0.5 to 2.5 L/s have been achieved from unconfined aquifers and up to 20 L/s from confined aquifers.

The Council monitors groundwater levels at two sites in the Taranaki volcanics, GND0508 and GND0600. Given the complexity and extent of the volcanics these sites will only reflect localised hydrogeologic conditions.

3.2.2 Marine Terraces

Marine Terraces comprising predominantly sandy, shelly marine sediments have developed along the both the southern and northern Taranaki coastlines. The terraces were formed as a result of sea level changes and tectonic uplift 680,000 to 60,000 years ago.

The marine terraces in North Taranaki are best developed from Waitara to Urenui and inland, along the coastal strip north of New Plymouth to Pukearuhe and from Tongaporutu to Awakino. Five Marine Terraces have been recognised in North

Taranaki but those in coastal ring plain areas are largely obscured by volcanic deposits from Mount Taranaki.

Terraced landforms in South Taranaki predominate along the coastal strip from Manaia to Wanganui, extending up to 15 km inland from the current coastline. Twelve terraces have been recognised in South Taranaki, but only the youngest are well preserved. While Hawera marks the approximate boundary between the volcanic ring plain deposits and the terraces, volcanic ash is a prominent component of the terraces for many kilometres further southeast.

The terraces range from tens to hundreds of metres in height and contain exclusively unconfined aquifers. Numerous shallow wells tap theses aquifers for stock and domestic supply, with yields in the range of 0.3 to 2.6 L/s being achieved.

The water table within the marine terraces generally lies within 15 metres of the land surface and generally follows a subdued reflection of surface topography toward the coastline. Seasonal variations in water table depth of up to five metres are not uncommon. Recharge to the Marine Terrace aquifers is primarily by rainfall infiltration and percolation. Groundwater within the marine terrace aquifers is also thought to be relatively ‘young’ water.

The Council monitors groundwater levels at one site in the northern Marine Terrace Formation, GND0213. No monitoring is currently carried out in the southern Marine Terrace Formation.

3.2.3 Whenuakura Formation

The Whenuakura Formation comprises Tertiary aged sequences of sandstone, siltstone and limestone. The formation is overlain by the Taranaki volcanic deposits north of Hawera and the Marine Terrace deposits to the south. It is underlain by the relatively impermeable Tangahoe Formation.

The formation contains multiple sandstone and shelly limestone layers which are the most productive in terms of water yields. Yields of up 10 L/s have been achieved in the Waverly and Patea areas and are utilised for a range of public supply, industrial, irrigation, stock and domestic purposes.

Recharge to the Whenuakura aquifers is not well understood. Some recharge may occur via the overlying volcanic and Marine Terrace deposits and where the formation is exposed in incised river valleys to the east.

The Council currently monitors groundwater levels at two sites in the Whenuakura Formation aquifers, GND0229 and GND0708.

3.2.4 Matemateaonga Formation

The Matemateaonga Formation is an alternating sequence of fine-grained sandstone, siltstone, limestone, and shell beds of Tertiary age, which underlies most of the region, except north of Urenui. The formation has a maximum thickness of about 1.1 km, but only the upper sections contain fresh groundwater. Groundwater is generally saline below about 800 m depth, although the freshwater-saline water interface may be significantly shallower or deeper in some areas. It is noted that deep connate groundwater produced during hydrocarbon exploration and production activities are injected into lower sections of the Matemateaonga Formation, below the freshwater-saline water interface depth.

Aquifers in the Matemateaonga Formation are generally confined and often thinly stratified. Where the formation can be accessed at depths that are not cost prohibitive, it has been tapped for public supply, industrial, commercial, stock and domestic purposes. Yields of up to 20 L/s have been achieved from the formation at Kapuni and Eltham.

Recharge to the Matemateaonga Formation aquifers is not well understood. It is thought that some recharge occurs via high rainfall zones on Mount Taranaki and subsequent leakage via the overlying volcanic deposits. In the south some leakage may occur via the overlying Marine Terrace deposits and where the formation is exposed in incised river valleys to the east.

The Council currently monitors groundwater levels at three sites in the Matemateaonga Formation aquifers, GND0447, GND0519 and GND2000.

Photo 2 Matemateaonga Formation monitoring well (GND 2000) at Scout Road, Egmont Village

3.2.5 Tangahoe Formation

The Tangahoe Formation underlies the Taranaki volcanic deposits in parts of central Taranaki and the Marine Terrace deposits to the South. The formation also dips below the Whenuakura Formation in parts of southern Taranaki. The Tangahoe Formation is predominantly comprised of impermeable siltstones and mudstones of Tertiary age.

While the formation is generally considered an extensive aquitard, there are records of a small number of wells accessing upper sections of the formation for water supply purposes. The upper sections contain thin sandstone laminations and occasional shell beds where bedding is pronounced.

The Council currently monitors groundwater levels at one site in the Tangahoe Formation, GND0599.

Photo 3 Coastal cliffs near Hawera exposing the Tangahoe Formation [1]

[1] Reference: GNS –REF: CN47444/16, courtesy of GNS Science

4. Results

A summary overview of the results in relation to each monitored site is provided below in Table 3. A more detailed outline of monitoring results by aquifer is provided in Sections 4.1 to 4.5.

Table 3 Summary groundwater level statistics for each monitoring site

Aquifer	Well	Max (m AMSL)	Min (m AMSL)	Median (m AMSL)	Range (m AMSL)	P-value	PAC (%)	Trend
Taranaki volcanics	GND0508	116.25	110.6	113.41	5.65	0.03	-0.04	▼
	GND0600	111.01	106.48	108.46	4.53	<0.01	0.03	▲
Marine Terraces (North)	GND0213	50.69	45.58	47.24	5.11	0.12	-0.02	■
Whenuakura	GND0229	38.44	37.53	38.13	0.91	<0.01	0.04	▲
	GND0708	33.26	30.92	32.27	2.34	0	-0.32	▼
Matemateaonga	GND0447	54.46	53.61	53.99	0.85	0	0.05	▲
	GND0519	69.87	69.47	69.645	0.40	0.68	0.01	■
	GND2000	199.29	198.65	199.02	0.28	N/A	N/A	N/A
Tangahoe	GND0599	99.61	97.77	98.46	1.84	0.66	0.01	■

▼ = reducing water level ▲ = increasing water level ■ = no trend N/A = data record not sufficient for statistical analysis

4.1 Taranaki volcanics

Groundwater levels are monitored at two sites within the Taranaki volcanics aquifer, GND0508 and GND0600. Groundwater levels respond quickly to local rainfall volumes at both sites, which also display a significant degree of seasonal water level variation. Given the shallow nature of the aquifer and its predominant recharge mechanisms this is to be expected.

The actual lag times between rainfall events and water level response does vary between the two monitored sites. The speed of groundwater level response to rainfall is dictated by the infiltration and percolation rates in the area of the monitoring site and more importantly, the depth of the well screen. At site GND0508, which is screened from 8 m BGL, groundwater level response to rainfall occurs quickly, generally within one month of rainfall events (Figure 4). Groundwater levels at GND0600, which is screened from 16 m BGL, shows a somewhat more delayed response to rainfall events, with peaks in groundwater level occurring approximately 2 to 3 months after major rainfall peaks (Figure 5).

Seasonal fluctuations in groundwater levels are also clearly evident in the data from sites GND0508 and GND0600, with respective fluctuations of up to 5.6 m and 4.5 m. Groundwater levels at site GND0508 generally peak in September and are at their lowest during April (Figure 6). At site GND0600, groundwater levels generally peak in October and are at their seasonal low during May (Figure 7).

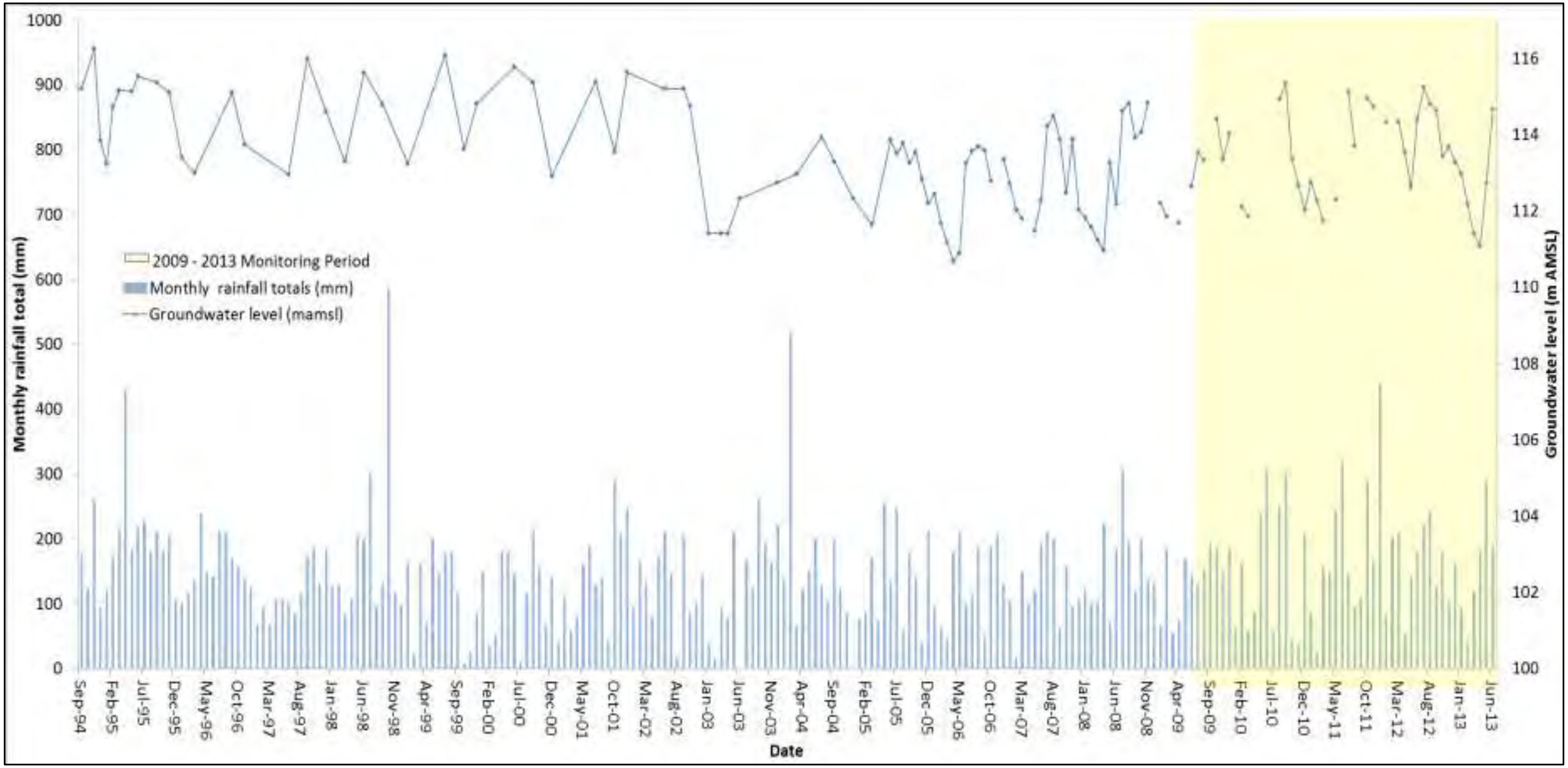

Figure 4 Groundwater level plotted against rainfall at site GND0508

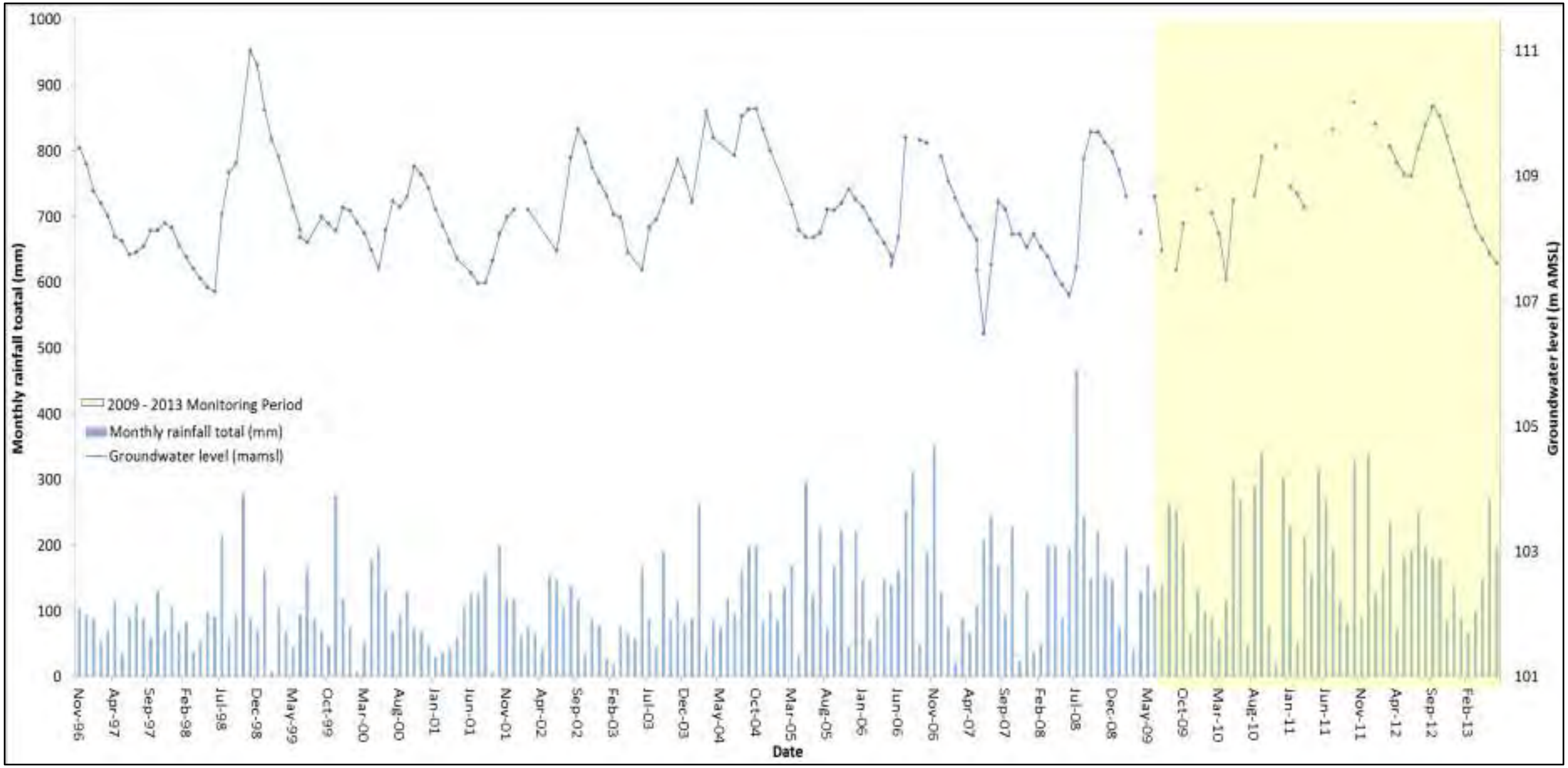

Figure 5 Groundwater level plotted against rainfall at site GND0600

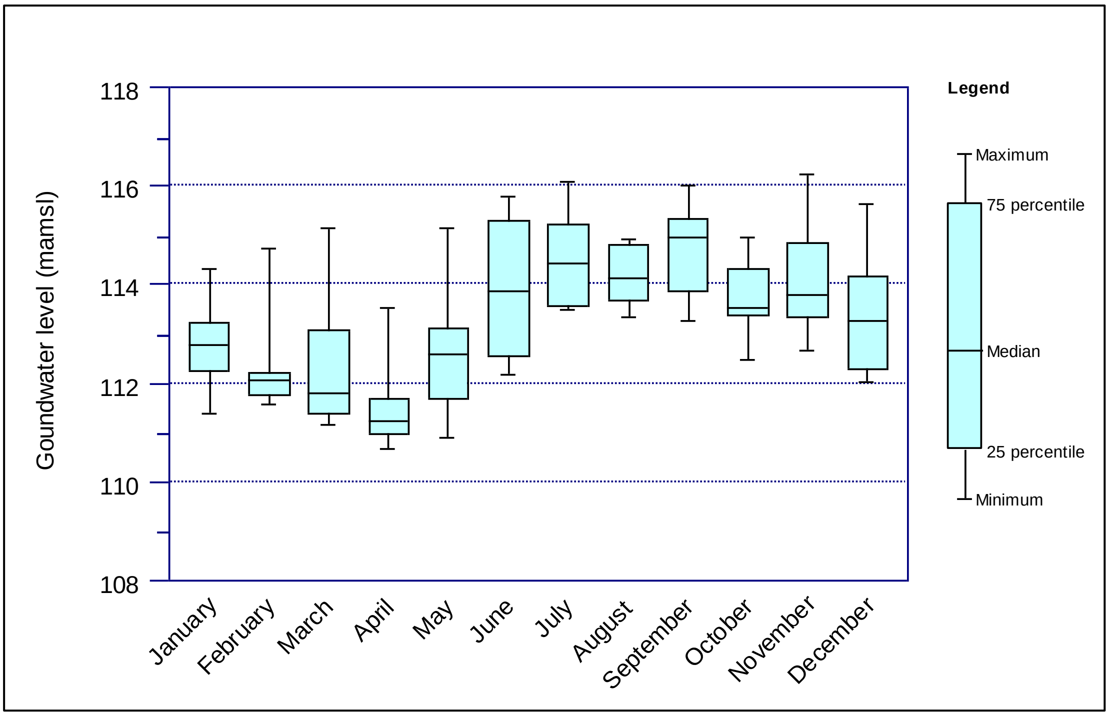

Figure 6 Summary of groundwater level measurements at site GND0508

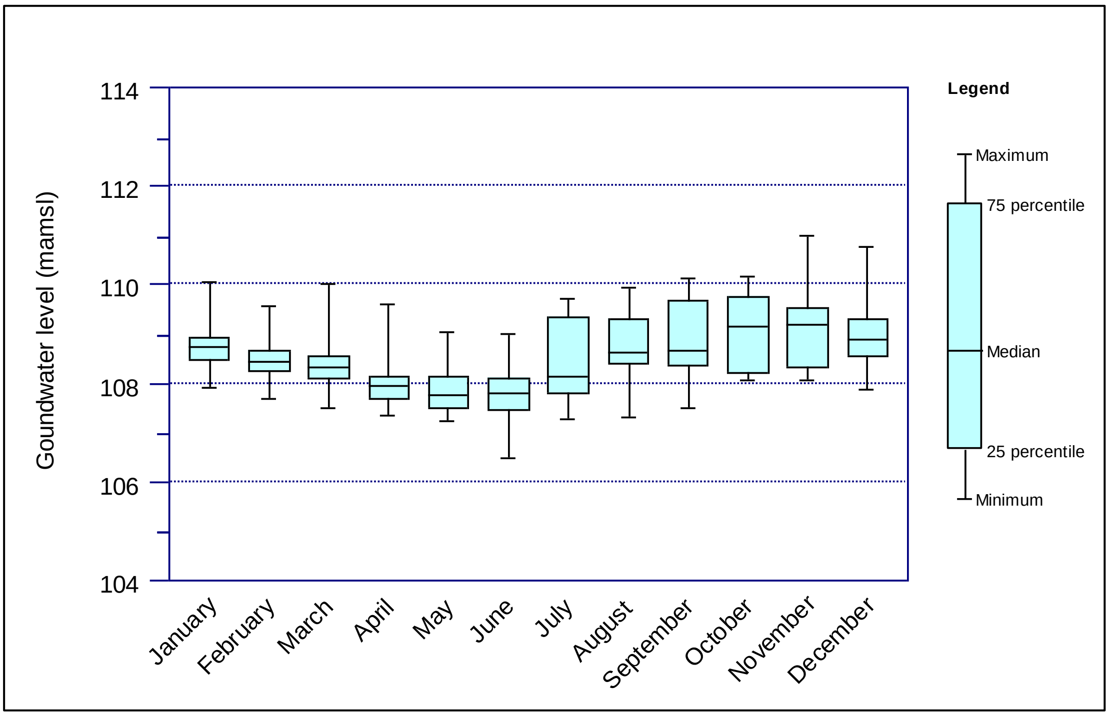

Figure 7 Summary of groundwater level measurements at site GND0600

The data collected at site GND0508 and GND0600 was analysed using Kendell test methods to determine if there are any statistically significant trends in groundwater levels at either site. For the purpose of this report, a trend is considered statistically significant when the calculated p-value is <0.05.

The trendline fitted to the time-series data from site GND0508 indicates that water levels at this site have followed a decreasing trend over the course of the monitoring record (Figure 8). The p-value associated with the trend a calculation is 0.03, meaning the trend is statistically significant. While a significant trend has been identified in the data, the magnitude of water level reduction is extremely low. The percentage annual change (PAC) in water levels at the site is only -0.04%. Typically trends are considered meaningful where PAC values exceed +/- 1%.

An analysis of time-series data at site GND0600 indicates a positive (increasing) trend in groundwater levels at the site (Figure 9). However, while the trend is statistically significant, the PAC is only 0.03%, meaning the magnitude of the increase in groundwater levels is also extremely low.

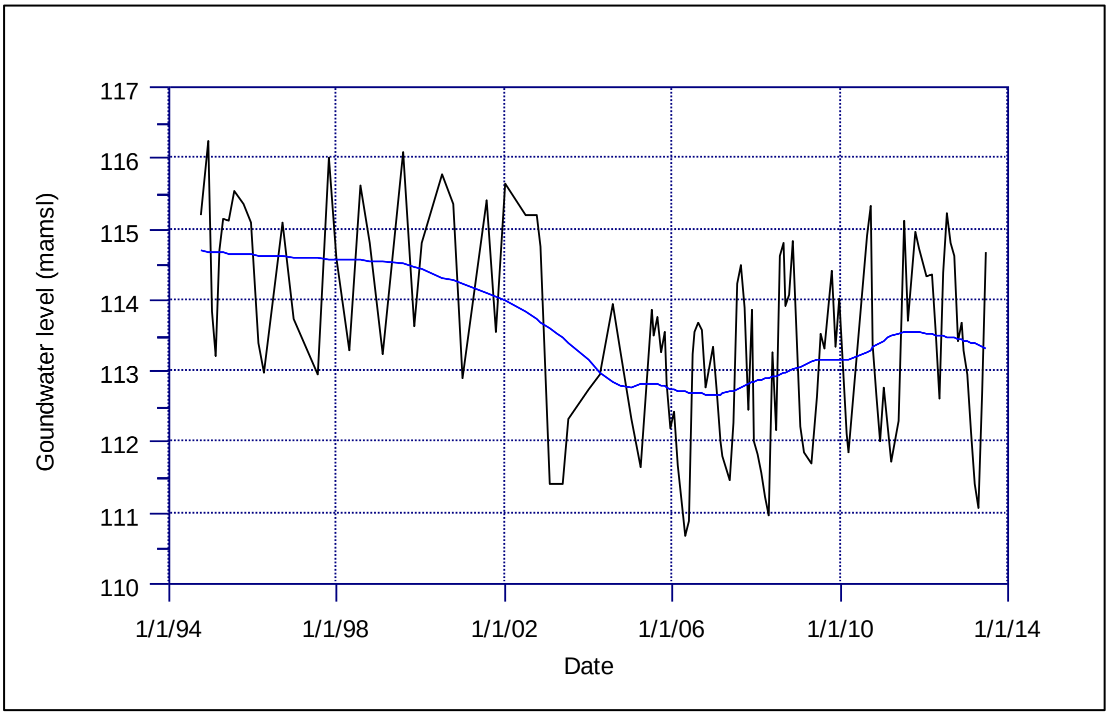

Figure 8 Trends in groundwater levels at site GND0508 (1994-2013)

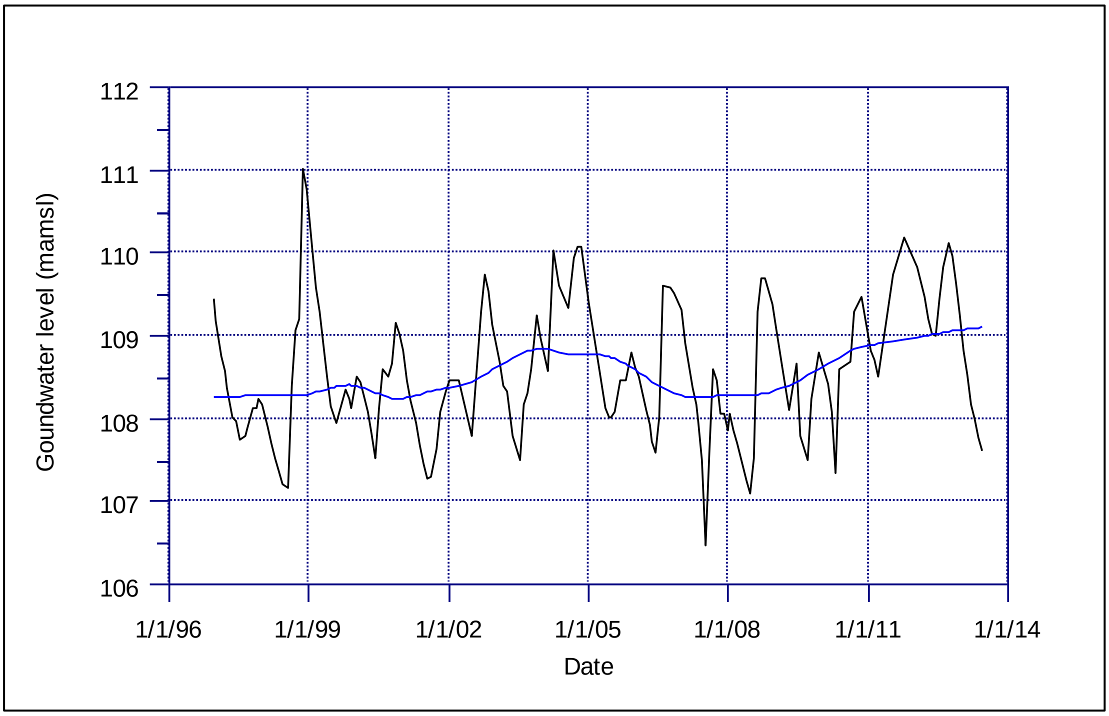

Figure 9 Trends in groundwater levels at site GND0600 (1996-2013)

4.2 Marine Terraces

The Council monitors groundwater levels in the northern Marine Terrace Formation aquifer at site GND0213. As detailed in Section 2.4, this is the only site in the groundwater level monitoring network where water levels measurements are recorded electronically. The data record from this site is therefore considered to be the most robust of all monitored sites.

The data collected indicates that groundwater levels in the northern Marine Terrace aquifer respond quickly to rainfall events, with peak groundwater level response occurring within one month of rainfall event peaks (Figure 10).

Groundwater levels in the northern Marine Terrace aquifer display seasonal variations of up to 5.1m. This is expected given the shallow, unconfined nature of the aquifer. Water levels generally peak in July and are at their lowest point during April (Figure 11). The aquifer responds quickly to peak rainfall events given the permeability of the marine sediments and shallow water table.

An analysis of the data collected from site GND0213 did not reveal any statistically significant trends in water level changes at the site.

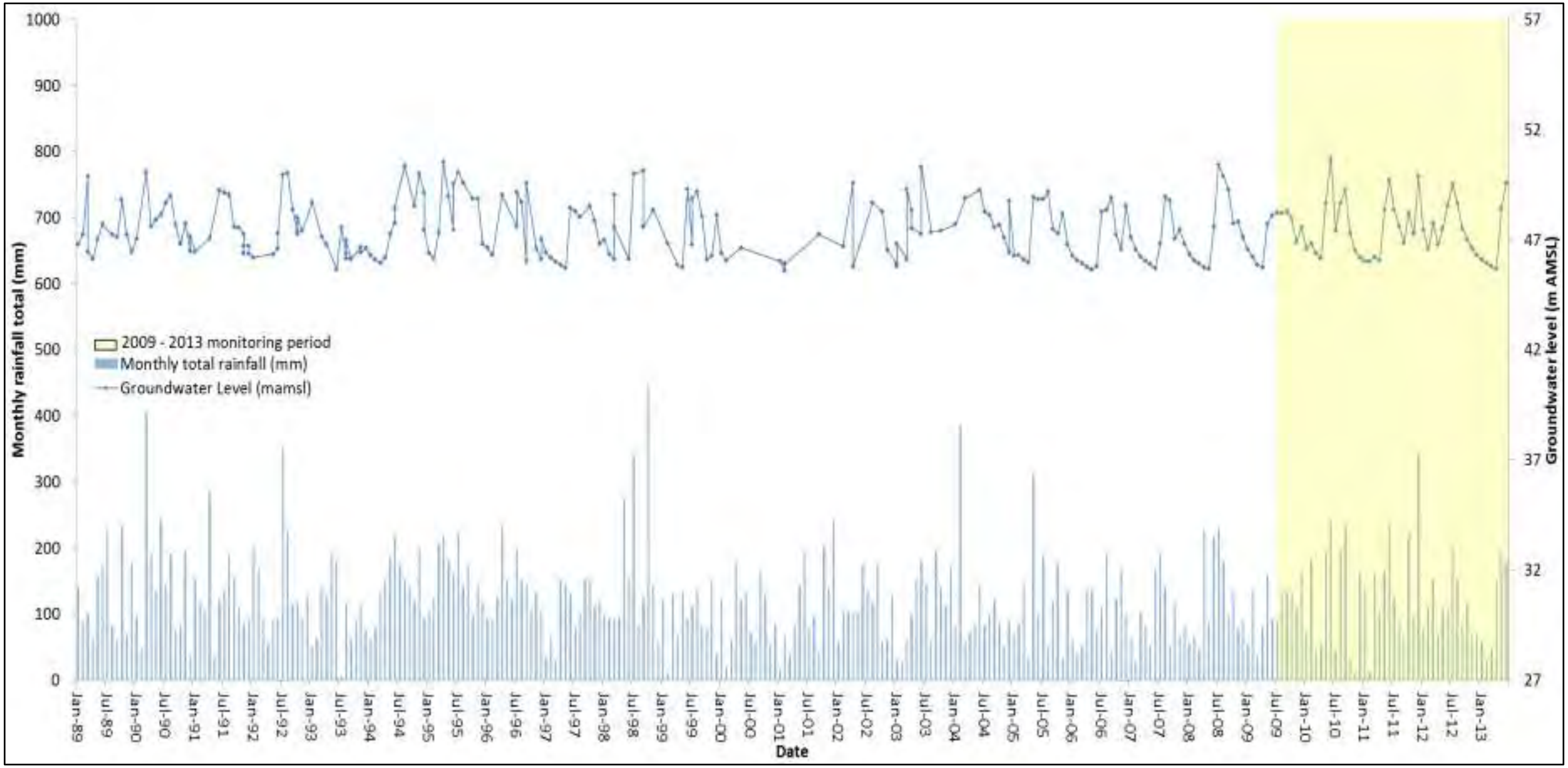

Figure 10 Groundwater level plotted against rainfall at GND0213

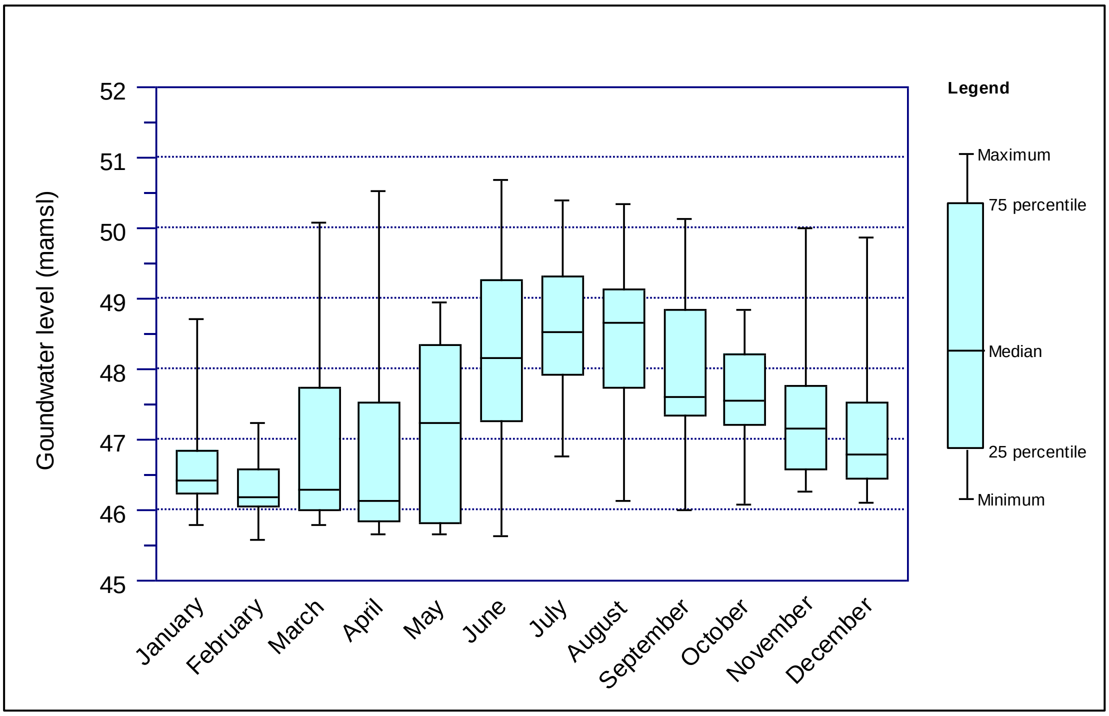

Figure 11 Summary of groundwater level measurements at site GND0213

4.3 Whenuakura Formation

The Council monitors groundwater levels at two sites in the Whenuakura Formation. The sites are located in areas where the formation is overlain by the southern Marine Terrace Formation. In these localities the Whenuakura Formation aquifers are confined. Given the aquifers confinement from overlying shallow groundwater systems, an assessment of the relationship between local rainfall and groundwater level responses is of little benefit. Recharge to the formation is thought to occur primarily where it is exposed in the Eastern Hill Country. It is rainfall volumes in these areas that exert the greatest control on water levels.

Given the confined nature of the formation and in the absence of any major abstraction pressures, groundwater level fluctuations at sites monitored are minor (Figures 12 & 13). The magnitude of the seasonal water level variation observed is much smaller than in the region's shallow unconfined aquifers.

The data collected from site GND0229 indicates a dramatic increase in groundwater levels between April and May 1998. This does not appear to be a result of natural processes and it is thought that a change in measurement datum occurred at this point and no correction was made in the data. Since May 1998 groundwater levels at the site have been extremely stable, varying by less the 0.6 m.

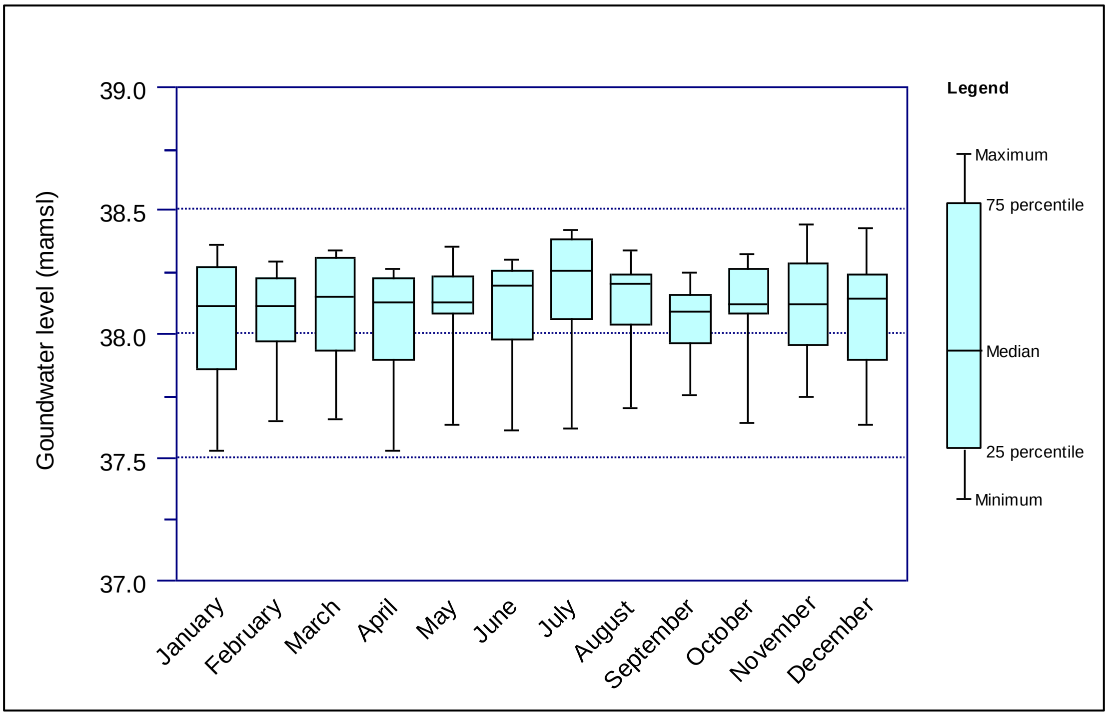

Figure 12 Summary of groundwater level measurements at site GND0229

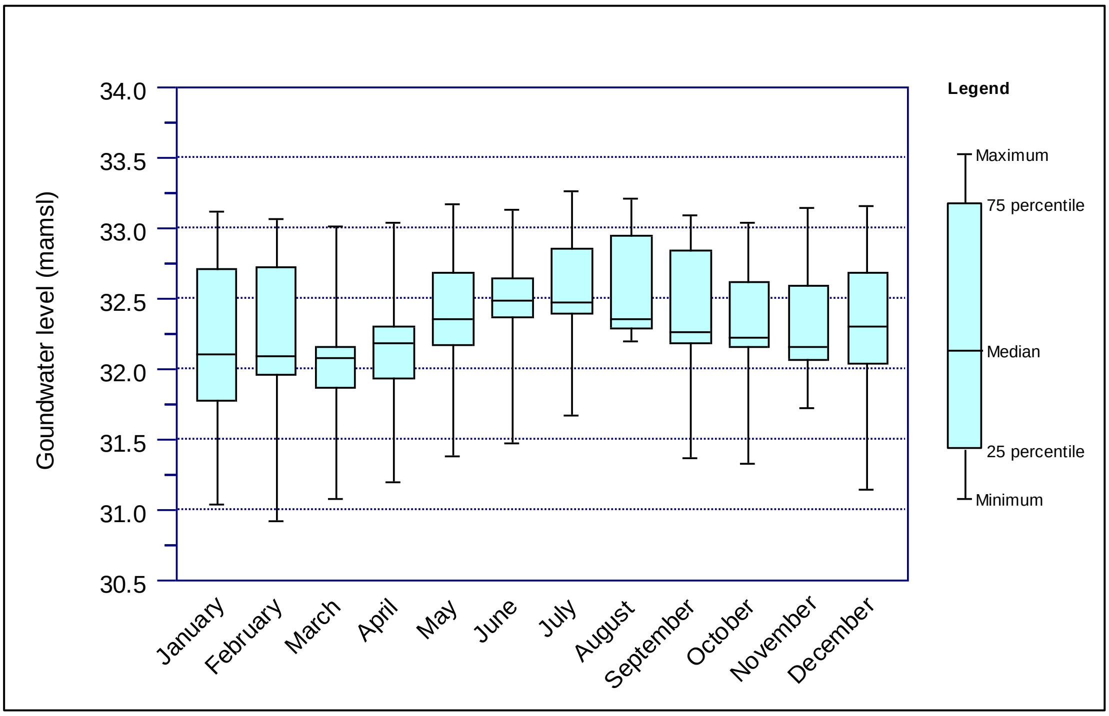

Figure 13 Summary of groundwater level measurements at site GND0708

The data collected at site GND0229 and GND0708 was analysed using Kendell test methods to determine if there are any statistically significant trends in groundwater levels at either site.

The trendline fitted to the time-series data from site GND0229 indicates that groundwater levels at this site have followed a positive (increasing) trend over the course of the data record (Figure 14). However, while the trend is also statistically significant, the PAC is only 0.04%, meaning the magnitude of the increase in groundwater levels is extremely low.

The trendline fitted to the time-series data from site GND0708 indicates that groundwater levels at this site have followed a decreasing trend over the course of the monitoring record (Figure 15). The trend is statistically significant. Groundwater levels at the site have decreased with PAC of -0.3%. While the magnitude of change is still minor, it is by far the highest for any monitored site displaying a statistically significant trend in water level elevation.

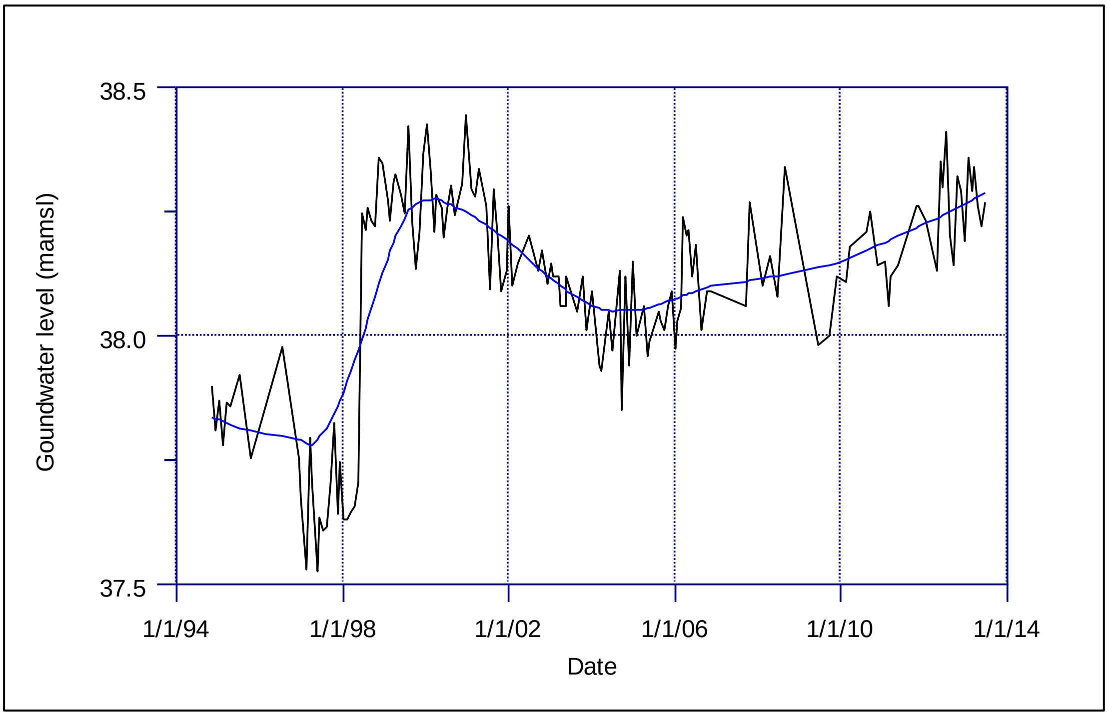

Figure 14 Trends in groundwater levels at site GND0229 (1994-2013)

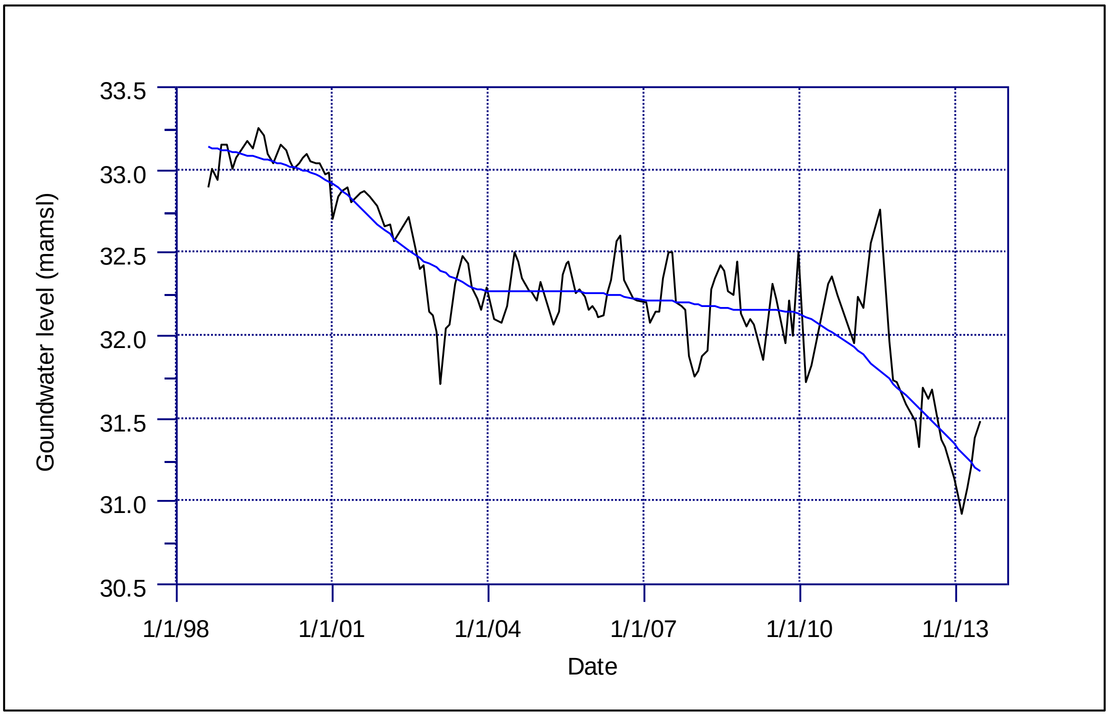

Figure 15 Trends in groundwater levels at site GND0708 (1998-2013)

4.4 Matemateaonga Formation

The Council monitors groundwater levels at three sites in the Matemateaonga Formation. These three sites are the deepest sites in the groundwater level monitoring network, with screened intervals ranging in depth from 228 m BGL to 766 m BGL. The sites are located in areas where the Matemateaonga Formation is confined by multiple overlying formations including the Taranaki volcanics in the north of the region and the Marine Terrace, Whenuakura and Tangahoe Formations in the south.

Given the formation's confinement from overlying shallow groundwater systems, an assessment of the relationship between local rainfall and groundwater level responses is of little benefit. Recharge to the formation is thought to occur primarily where it is exposed in the Eastern Hill Country. It is rainfall volumes in these areas that exert the greatest control on water levels.

Given the confined nature of the formation and in the absence of any major abstraction pressures, groundwater level fluctuations at the sites monitored are minor. The data collected from site GND0447 and GND2000 show very minor seasonal variations in groundwater levels (Figures 16 & 17). Site GND0519 also displays very minor seasonal variations in groundwater levels and also has the smallest monthly water level measurement range of any Matemateaonga Formation monitoring site (Figure 18).

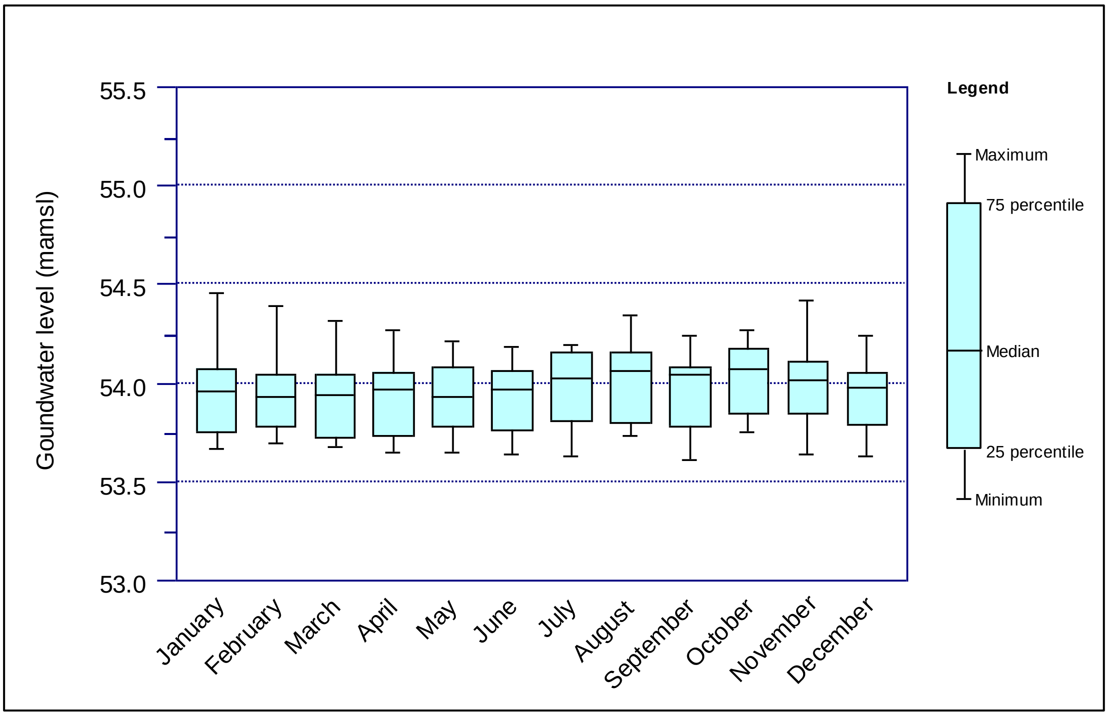

Figure 16 Summary of groundwater level measurements at site GND0447

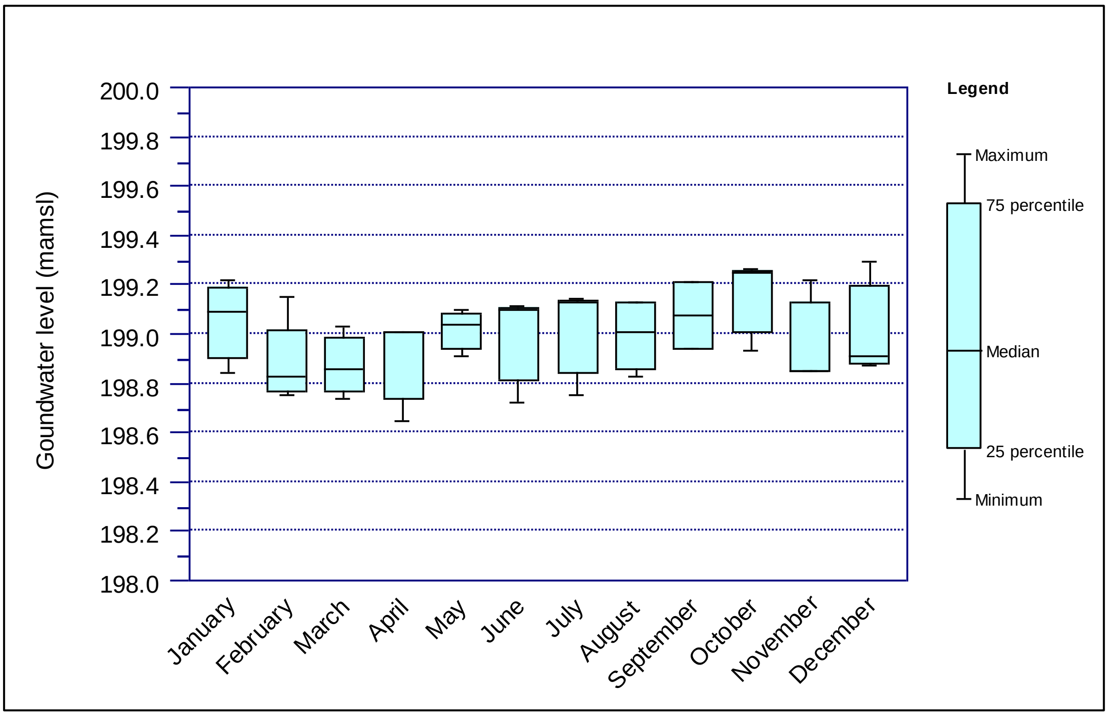

Figure 17 Summary of groundwater level measurements at site GND2000

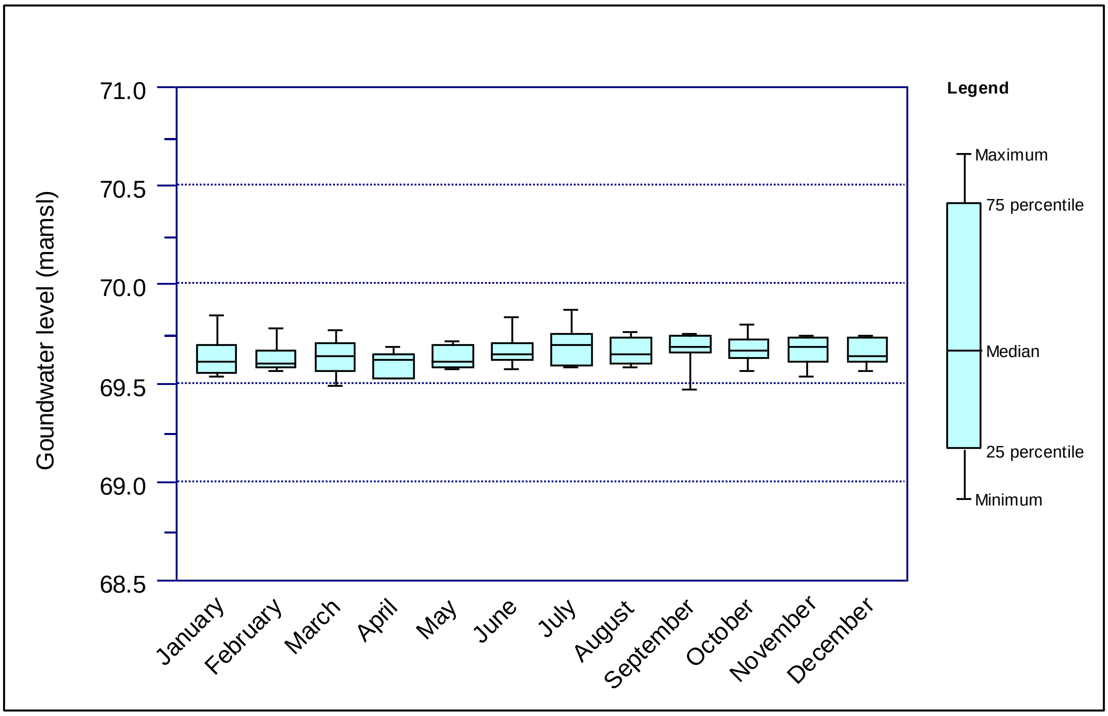

Figure 18 Summary of groundwater level measurements at site GND0519

The data collected at sites GND0447 and GND0519 was analysed using Kendell test methods to determine if there are any statistically significant trends in groundwater levels at either site. No analysis was undertaken on data from site GND2000 due to the short nature of the data record at that site.

The analysis revealed a statistically significant positive (increasing) trend in water level elevations at site GND0447 over the course of the data record (Figure 19). While the trend is statistically significant, the PAC is only 0.05%, meaning the magnitude of the increase in groundwater levels is extremely low.

No statistically significant trend was identified in the water level data from site GND0519.

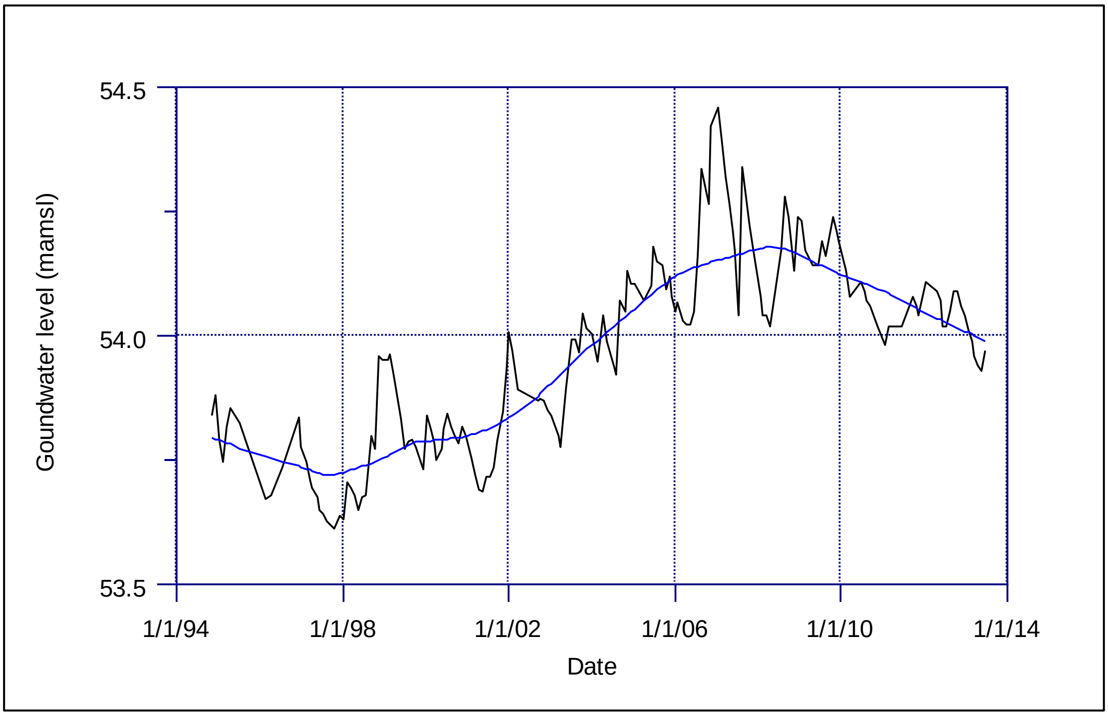

Figure 19 Trends in groundwater levels at site GND447 (1994-2013)

4.5 Tangahoe Formation

The Council monitors groundwater levels in the Tangahoe Formation at site GND0599. The aquifer is considered to be semi-confined but the data collected indicates that water levels in the formation respond quickly to local rainfall events (Figure 20). This response suggests that there is a degree of hydraulic connection between the aquifer monitored and the overlying shallow groundwater system.

Seasonal variation in water levels of up to 1.84 m is also evident in the data collected at site GND0599, with groundwater levels generally peaking in September and at their lowest during April (Figure 21).

An analysis of the data collected from site GND0599 did not reveal any statistically significant trends in water level changes at the site.

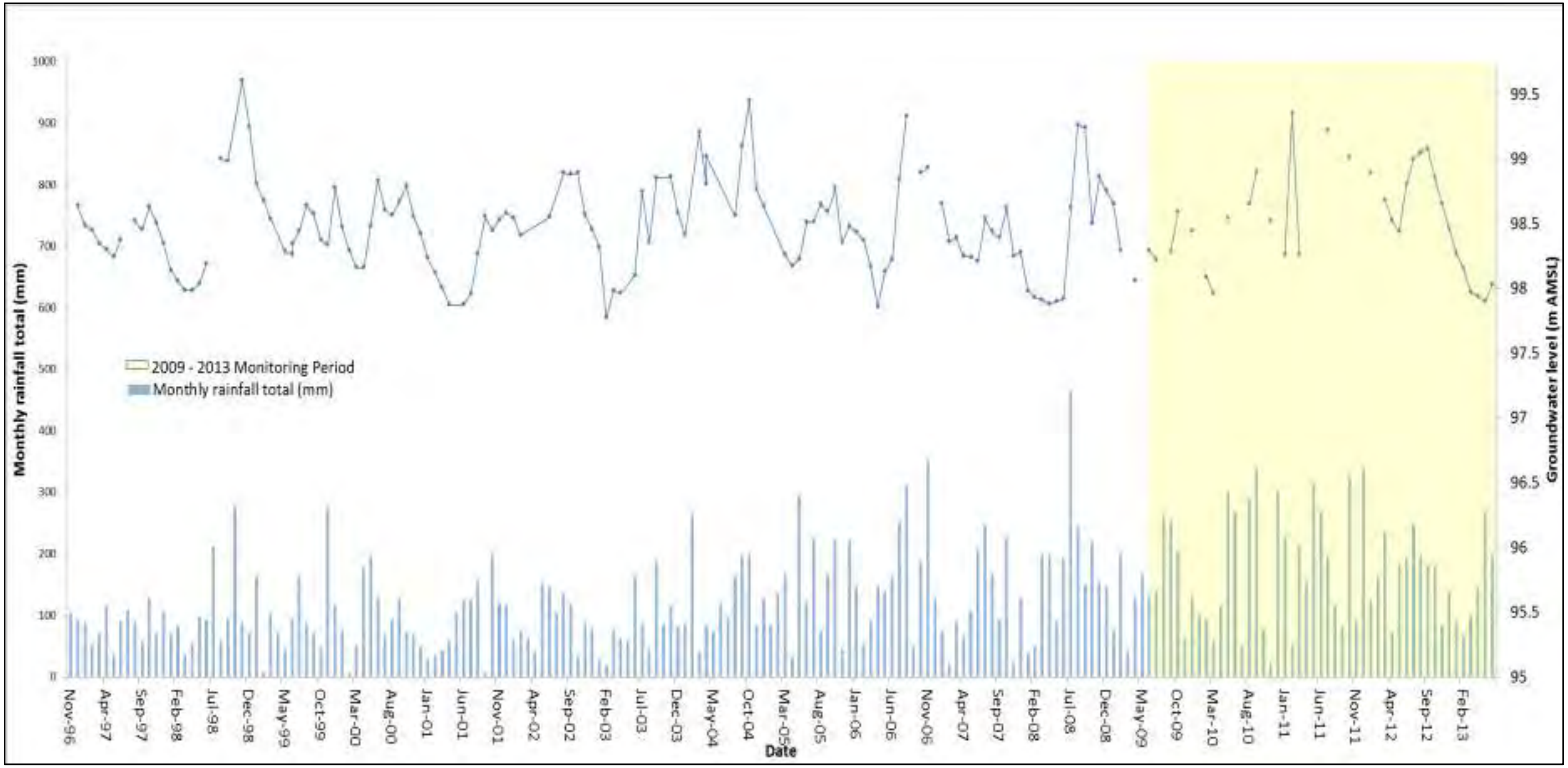

Figure 20 Groundwater level plotted against rainfall at GND0599

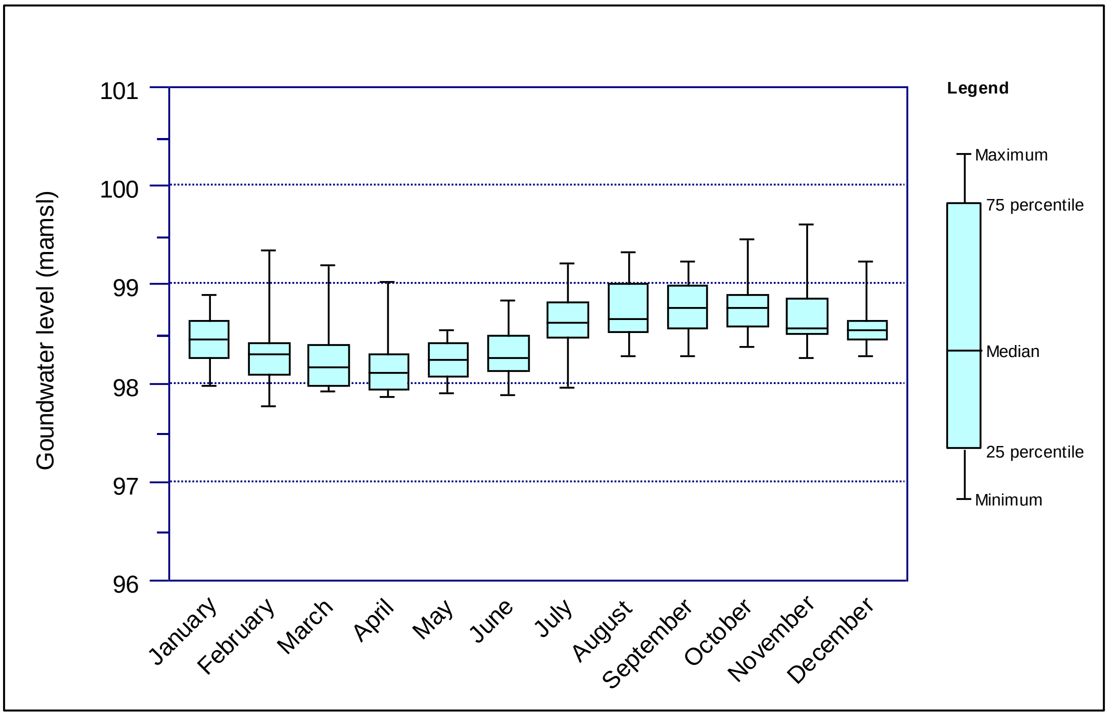

Figure 21 Summary of groundwater level measurements at site GND0599

5. Discussion

The Council monitors groundwater levels at nine sites across the Taranaki region. Sites are located in the Taranaki volcanics (2), northern Marine Terraces (1), Whenuakura (2), Matemateaonga (3) and Tangahoe Formation aquifer (1). The data provided by the monitoring programme allows the Council to further develop its understanding of the hydrogeological characteristics of the monitored aquifers. By assessing water level data it is also possible to identify longer term trends in groundwater levels. Additional investigations can then be undertaken to assess whether any trends observed are a result of natural processes or human influences.

The relationship between groundwater level and rainfall varies between the different aquifers. As expected, the shallower aquifers such as the Taranaki volcanics and northern Marine Terraces have a quicker and more pronounced reaction to rainfall events, whereas the deeper confined aquifers such as those in the Matemateaonga and Whenuakura Formations don't exhibit a response to individual rainfall peaks and troughs but correlate to the seasonal rainfall trends.

GND0213, screened in the northern Marine Terrace aquifer, exhibits the closest correlation between rainfall and groundwater level. The geological log for the borehole shows the underlying geology is composed of sandy silt, cobbles and gravel. These materials typically have a medium to high hydraulic conductivity and so rainwater infiltrating the subsurface would reach the water table, which ranges from approximately 5 to 7 m BGL, in a relatively short period of time.

The wells screened in the Taranaki volcanics also show a close correlation to rainfall. GND0508, which is screened between 2.2 and 8.6 m BGL, responds to changes in rainfall on a month by month basis. As the screen is so close to the surface, rainfall infiltrating into the subsurface will reach the groundwater table in a short period of time. Given the increased depth of the well screen at site GND0600, groundwater level at this site is not as responsive to rainfall, but still follows seasonal rainfall trends.

Site GND0599, which is screened in the Tangahoe formation, shows a very close correlation to rainfall throughout the monitoring period. This relationship indicates that localised rainfall events rapidly recharge the aquifer. This is somewhat surprising given that the well is screened between 78.5 and 81.5 m BGL and the log of the hole indicates that the screened interval is overlain layers of muddy sand, clay and peat, all of which should impede groundwater infiltration. The close relationship between rainfall and groundwater level in the area would therefore suggest that the low permeability material overlying the aquifer is not continuous and there is a hydraulic connection between overlying shallow groundwater and the aquifer being monitored in the vicinity of the site.

There is no relationship between local rainfall volumes and groundwater levels at sites monitored within the Whenuakura and Matemateaonga Formation aquifers. This is due to the depth at which groundwater is monitored in these aquifers, their confinement and recharge characteristics.

As expected, the greatest seasonal variations in groundwater level occur in the region's shallow unconfined aquifers. Data indicates seasonal variation in water level depths of up to 5.6 m in the Taranaki volcanics and up to 5.1 m in the Marine Terraces. While seasonal variations in water level are also apparent within the deeper Whenuakura, Matemateaonga and Tangahoe Formation aquifers, the level of variation is much smaller, ranging from 0.3 m to 2.3 m.

The groundwater level data collected at each site was analysed using statistical methods to identify if there were any long-term trends in water level variation at each site. Trend analysis was conducted for sites with more than 10 years of data to ensure a good sample size is available to analyse the data. It needs to be acknowledged that the sampling frequency varied from site to site and changes of methodology were implemented (from manual electronic water level meter to automatic pressure transducer) for groundwater level monitoring sites starting in 2013. Providing good consistency of data for all monitoring sites is essential to ensure interpretation of trend analysis is rigorous and robust.

Statistically significant trends in groundwater levels were identified at five of the nine sites monitored as part of the programme. Only two of the five sites, GND0508 (Taranaki volcanics) and GND0708 (Whenuakura) had negative (decreasing) water level trends.

While the reducing trends in groundwater levels at both sites GND0508 and GND0708 are statistically significant, the magnitude of the reduction in water levels must also be considered. At site GND0508, the PAC calculated is extremely low at -0.04%. The PAC calculated for site GND0708 was -0.4%. While this figure is also extremely low, it is the highest PAC calculated for any site with a statistically significant trend in groundwater level (positive or negative).

The magnitude of a trend value is important when considering the environmental significance of any trend identified. It is considered that the low PAC values for each of the downward trending sites mean the environmental significance of the trends is negligible.

The minor PAC values calculated indicate for both sites GND0508 and GND0708, in addition to the three sites showing positive trends in groundwater level, show that changes in groundwater level are occurring extremely slowly. This would suggest that factors influencing water level change are naturally occurring. If abstraction pressure were impacting groundwater storage volumes it would be expected that the reduction would be more pronounced and of greater magnitude.

A more detailed analysis of the potential links between groundwater abstraction and groundwater level decline will be possible in future reports as more comprehensive abstraction data becomes available through the implementation of the Resource Management (Measuring and Reporting of Water Takes) Regulations 2010.

6. Conclusions

The data collected shows that the region's shallow unconfined aquifers respond quickly to localised rainfall events and display a greater range of seasonal water level variation than the region's deeper aquifers. In general, groundwater levels across the region appear relatively stable; however five sites are displaying statistically significant trends in water level change. Three of these sites display positive trends, meaning water levels are increasing at these sites. The remaining two sites, GND0508 (Taranaki volcanics aquifer) and GND0708 (Whenuakura aquifer) display negative trends, meaning water levels are in decline. In all cases where significant trends are observable, the magnitude of the trends are extremely minor, with PACs ranging from -0.4% to 0.05%. Given the low PAC values the environmental significance of the trends is negligible. Data from these sites will continue to be closely monitored in coming years and further assessment undertaken to determine possible factors driving the trends observed.

7. Programme development

The Council commissioned an external review of its groundwater SEM programmes in 2011. The reviewer, Pattle Delamore Partners (PDP), identified several areas where the groundwater levels programme would benefit from further development and made the following recommendations:

- Additional monitoring sites be added to the programme. In the first instance these sites should be located in areas of greatest groundwater abstraction pressure and then in geographical areas where major aquifers are not currently monitored (Table 1).

- In order to develop a more comprehensive and robust dataset, groundwater levels should be monitored electronically using pressure transducers, set to take measurements every 15 minutes.

In addition to the recommendations made by PDP, it is proposed that the monitoring of groundwater levels be incorporated into a single 'groundwater pressures' programme, which will include presentation and assessment of water groundwater usage and demand across the region. Links between abstraction pressure and groundwater level response will be investigated as part of this programme, which will be reported on a biennial basis.

Recommendations to this effect are included in Section 8.

8. Recommendations

It is recommended:

1. THAT the results of the analysis presented in this report be noted for inclusion in the next 'State of the Environment' report to be prepared by the Council.

2. THAT the number of sites being monitored as part of the programme be increased over the forthcoming monitoring period to provide better spatial coverage across all of the region's major aquifer systems;

3. THAT pressure transducers be installed at all groundwater level monitoring sites to maintain a continuous record of groundwater level measurements at 15 minute intervals;

4. THAT the monitoring of groundwater levels and groundwater pressures/usage is integrated into a single SEM programme, with the results and interpretation of data collected incorporated into a single biennial report.

Glossary of common terms and abbreviations

The following abbreviations and terms are used within this report:

Anisotropic	The condition under which one or more of the hydraulic properties of an aquifer vary according to the direction of flow.
Aquifer	A permeable water-bearing geological formation through which water moves under natural conditions and which yields water to wells at a sufficient rate to be a practical source of water supply.
Bore	Bore means a hole drilled into the ground and completed for the abstraction of water or hydrocarbons to a depth of greater than 20 metres below the ground surface.
Confined aquifer	When an impermeable formation, such as clay, overlies an aquifer so that air and water are no longer in contact and the pressure is no longer equal to atmospheric pressure. Water in a well will stand at a different level to the water-table.
Impervious	To not allow fluid to pass through.
m AMSL	Metres above mean sea-level.
m BGL	Metres below ground level.
Objective	A statement of a desired and specific environmental outcome.
Outlier	An outlier is an observation point that is distant from other observations. An outlier may be due to variability in the measurement or it may indicate an error.
p-value	The p-value is a function of the observed sample results (a statistic) that is used for testing a statistical hypothesis. Before the test is performed, a threshold value is chosen, called the significance level of the test (e.g. <0.05).
PAC	Percentage annual change
Policy	A specific statement that guides or directs decision making. A policy indicates a commitment to a general course of action in working towards the achievement of an objective.
Recharge	The addition of water from other sources to an aquifer, e.g., seepage from rivers, percolation of rainfall.
Resource consent	Refer Section 87 of the RMA. Resource consents include land use consents (refer Sections 9 and 13 of the RMA), coastal permits (Sections 12, 14 and 15), water permits (Section 14) and discharge permits (Section 15).
RFWP	Regional Freshwater Plan for Taranaki (2001).
RMA	Resource Management Act (1991) and including all subsequent amendments.
RPS	Regional Policy Statement.
SEM	State of the environment monitoring
Unconfined aquifer	Groundwater which is freely connected to the atmosphere and which is free to rise and fall in the saturated zone, or water of an unconfined aquifer, or water under water table conditions.
Well	A hole dug, augured or drilled, tapping the water-table or springs to a depth of 20 metres or less below the ground surface.

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