Annual groundwater monitoring report for the Wellington region, 2006/07

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1. Introduction

Groundwater in the Wellington region is highly valued for a variety of uses. Groundwater under the Lower Hutt Valley alone supplies about a third of Wellington's[1] water supply. Otaki, Waikanae[2], Martinborough, Carterton[3] and Greytown[4] also rely on groundwater for public supply. In rural areas of the Kapiti Coast and the Wairarapa, groundwater is an important water source for domestic supply, stock water and irrigation. Groundwater is also an important water source for many springs and wetlands, and the successful protection of these groundwater dependant ecosystems requires careful management of groundwater use.

To assist with the sustainable management of groundwater resources in the Wellington region, Greater Wellington Regional Council (Greater Wellington) conducts regular monitoring of groundwater levels and quality. This report summarises the results of monitoring undertaken over the period 1 July 2006 to June 2007 inclusive. A report containing a detailed analysis of long-term trends is produced every six years (see Jones and Baker 2005).

As groundwater recharge in the region is strongly influenced by hydrological trends and events, it is recommended that this report is read in conjunction with the annual hydrology monitoring report for 2006/07 (Watts and Gordon 2007).

[1] Groundwater is usually used to supply Lower Hutt and supplements supplies to the Wellington's Central Business District, southern and eastern suburbs. It may also be used to supplement supplies to Upper Hutt and Porirua.
[2] In Waikanae, the Kapiti Coast District Council uses groundwater as a backup water supply to its surface water take from the Waikanae River.
[3] Primary supply to Carterton is from surface water.
[4] Primary supply to Greytown is from surface water.

2. Overview of the groundwater monitoring programme

There are three principal groundwater areas in the region: the Lower Hutt Valley, the Kapiti Coast and the Wairarapa valley. Secondary groundwater areas include Upper Hutt, Mangaroa valley, Wainuiomata valley and sections of the eastern Wairarapa coastline. Aquifers in all of these areas are found in unconsolidated alluvial, aeolian (wind blown) and beach sediments of varying grain size. Minor aquifers are also found in limestone and fractured greywacke in some areas of the region.

Groundwater management zones have been defined in all principal and some secondary groundwater areas (Figure 2.1). These have been used as a framework for describing groundwater areas in this report.

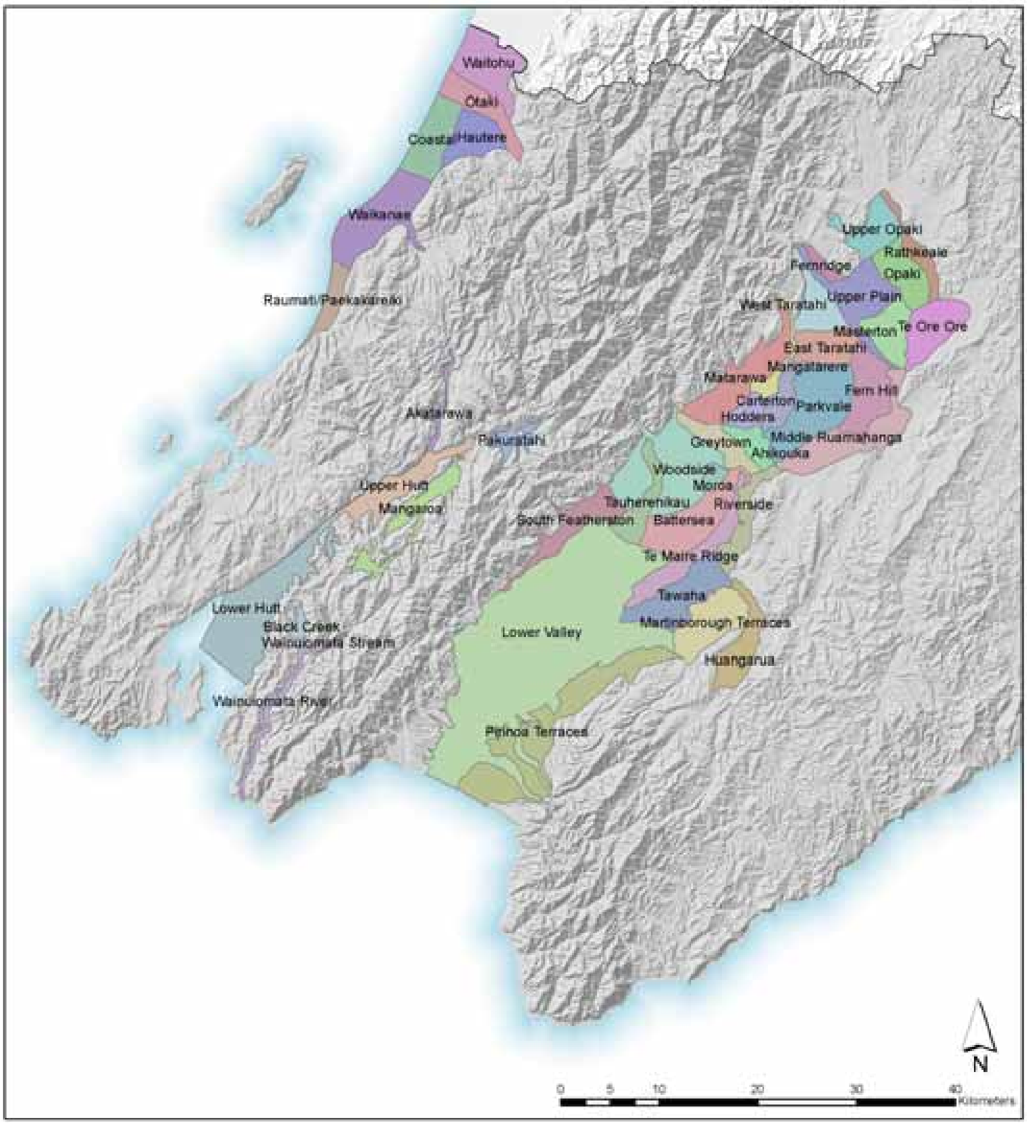

Figure 2.1: Groundwater management zones in the Wellington region

2.1 Objectives

The aims of Greater Wellington's groundwater monitoring programme are to:

- Provide information on the baseline quantity and quality of groundwater;
- Describe the current state of Greater Wellington's groundwater resource at a regional scale;
- Assist in the detection of spatial and temporal changes in groundwater quantity and quality;
- Determine the suitability of groundwater for designated uses; and
- Provide a mechanism to determine the effectiveness of policies and plans.

2.2 Monitoring network

Greater Wellington's monitoring network consists of a network of boreholes utilised for groundwater level and quality monitoring. This network utilises dedicated monitoring boreholes, un-used[5] privately owned boreholes and currently used[6] private boreholes. The groundwater level network currently consists of 58 automatic and 69 manually dipped[7] boreholes (Figure 2.2 and Appendix 1). The core groundwater quality network, referred to as the Groundwater State of the Environment (GW SoE) network, comprises 71 boreholes (Figure 2.3, Appendix 1), sampled quarterly for a wide range of physico-chemical and microbiological variables. Other selected groundwater level and quality monitoring is carried out on a project-specific basis.

A full list of variables monitored, together with details of field and analytical methods is provided in Appendix 2.

[5] Boreholes previously pumped for supply but no longer utilised for this purpose.
[6] Boreholes that are currently pumped for water supply, this pumping may have short term effects on water level readings.
[7] Boreholes are generally manually dipped to test depth to groundwater on a four or six week rotation.

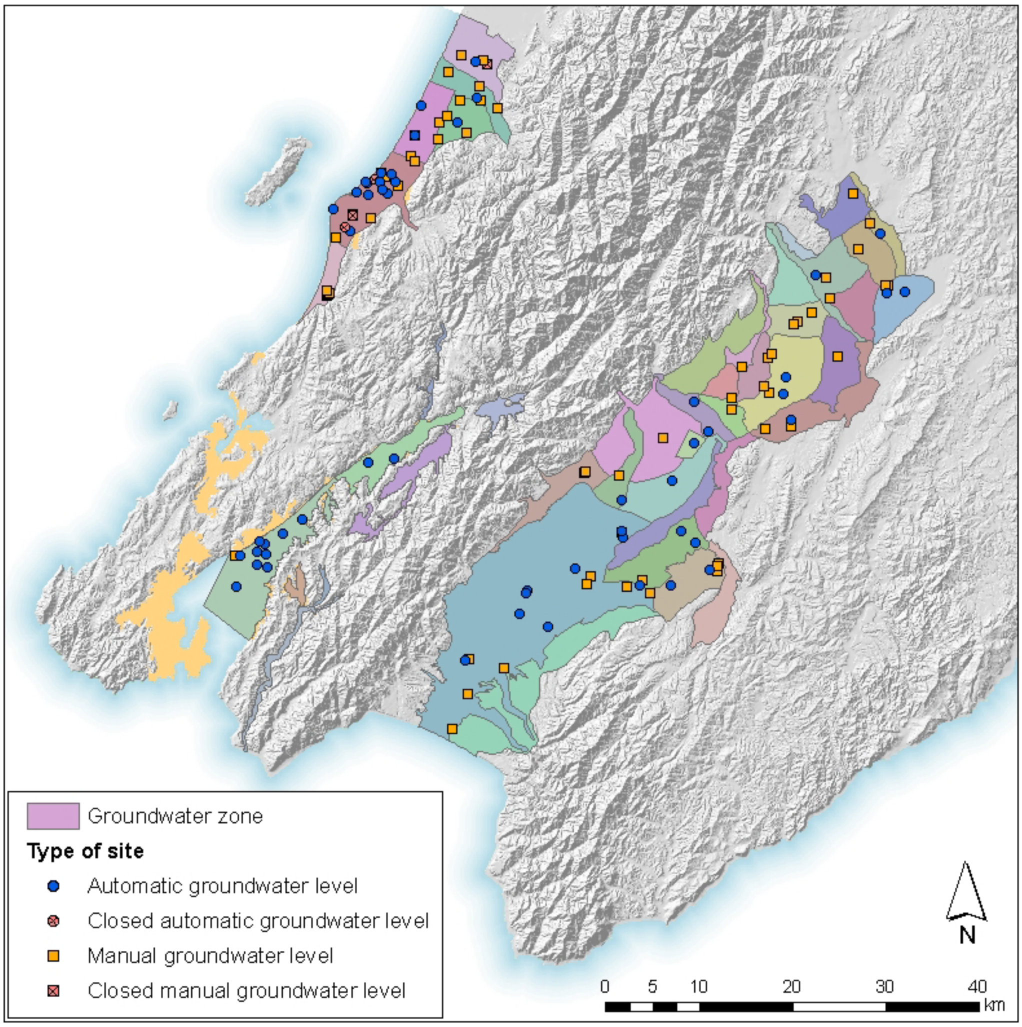

Figure 2.2: Location of groundwater level sites in the Wellington region, monitored over 1 July 2006 to 30 June 2007

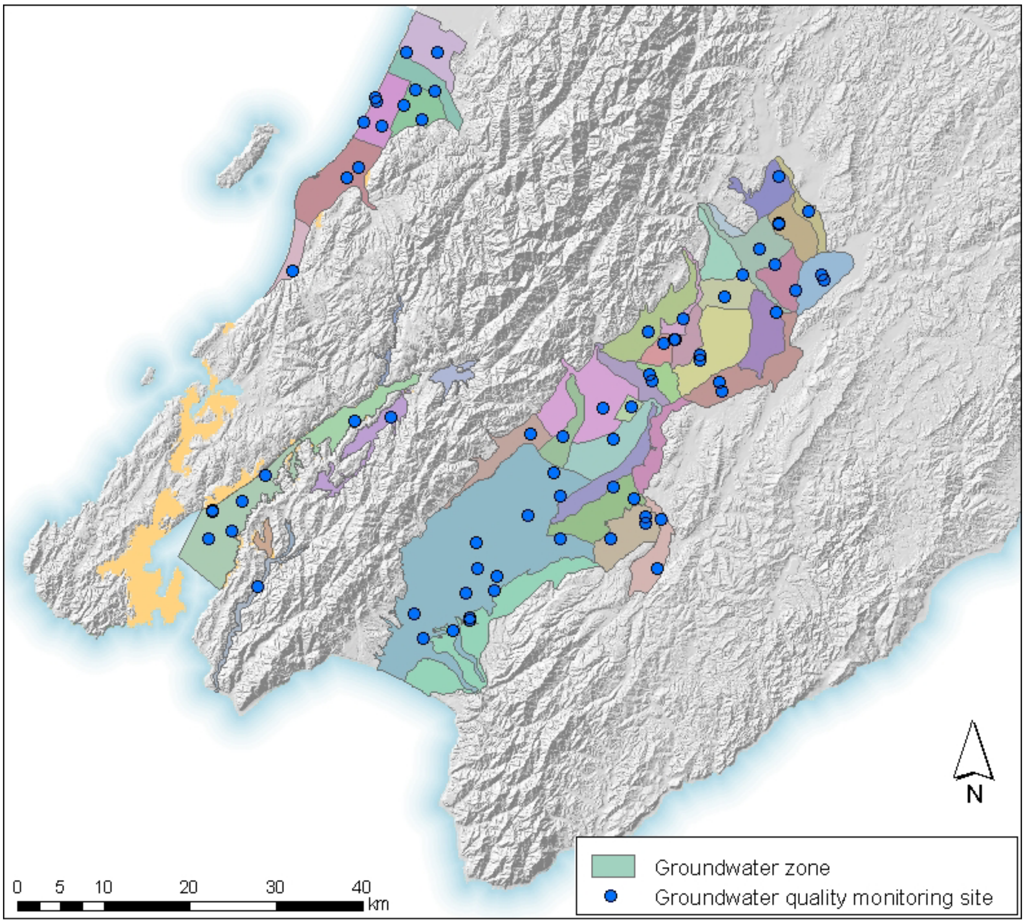

Figure 2.3: Location of routine groundwater quality monitoring sites in the Wellington region

2.2.1 Changes to the monitoring network in 2006/07

The following major changes to the groundwater monitoring network were made during the year:

- Two automatic groundwater level stations – Golf Tech (R26/6832) and Waikanae Golf Course (R26/6377) – were closed during the year due to the land being redeveloped. At this stage the Golf Tech well will not be replaced, with existing boreholes at Larch Grove (R26/6831) and Maclean Park (R26/6833) supplying sufficient data to monitor the shallow aquifer in this area.

- Two manual water level stations – Mazengarb Deep (R26/6558) and Hunt (S25/5320) – ceased to be read as technical problems were being incurred. At this stage there is no plan to replace these sites.

- Three new saline intrusion monitoring boreholes were constructed in the Lower Hutt Groundwater Zone at Petone. The boreholes located at McEwan Park and TS Tamatoa on the Petone foreshore were completed in April and May 2007 respectively. Logging equipment and telemetry is to be installed in these later in 2007.

3. Groundwater quantity

3.1 Groundwater levels

Aquifers across the region are recharged by either rainfall infiltration or leakage of water from rivers. In some cases aquifers may receive recharge from both sources in different proportions. For this reason the amount of rainfall and river flow directly influences groundwater levels in aquifers. This is particularly evident in shallow (unconfined) aquifers, but also has a subdued effect in deeper (confined) aquifers[8]. Examples of rainfall and river flow for Kapiti and the Wairarapa are shown in Figure 3.1 – for further information refer to Watts and Gordon (2007). Figures 3.2 and 3.3 show representative mean monthly groundwater levels against historic data for the main groundwater zones in the region.

July 2006 was an extremely wet month (Figure 3.1), resulting in higher than average recharge to rainfall-fed aquifers (Figure 3.2). This wet period also contributed to higher than average river flows (Figure 3.1). As a result shallow unconfined aquifers received above average recharge from both rainfall and river leakage (Figure 3.2, Figure 3.3).

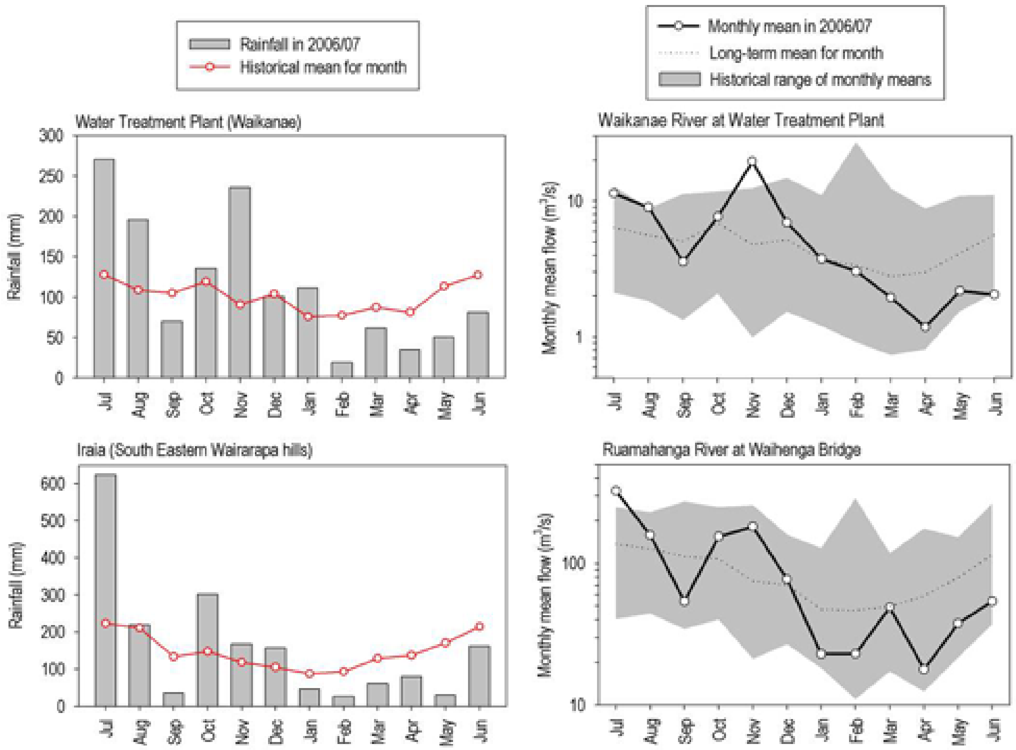

Figure 3.1: Representative monthly rainfall totals for 2006/07 (grey bars) compared to historical mean monthly rainfall (red line) at selected rainfall monitoring locations in the Wellington region. Representative monthly mean river flows for 2006/07 (black line) compared to historical mean monthly rainfall (dotted line) in the Wellington region. Grey area represents the range of historical monthly means.

[8] Deeper aquifers are recharge through the downward percolation of water from shallow aquifers

Above average groundwater levels can be seen for the rainfall fed aquifers in the Martinborough Terraces (Plot E, Figure 3.2) and Parkvale (Plot B, Figure 3.2) areas of the Wairarapa. The shallow river-recharged Greytown aquifer also showed above average levels over this period (Plot D, Figure 3.2). The mixed rainfall/river recharged shallow aquifers in the Waikanae area showed similar above average groundwater levels for this period (Plot A and Plot C, Figure 3.3).

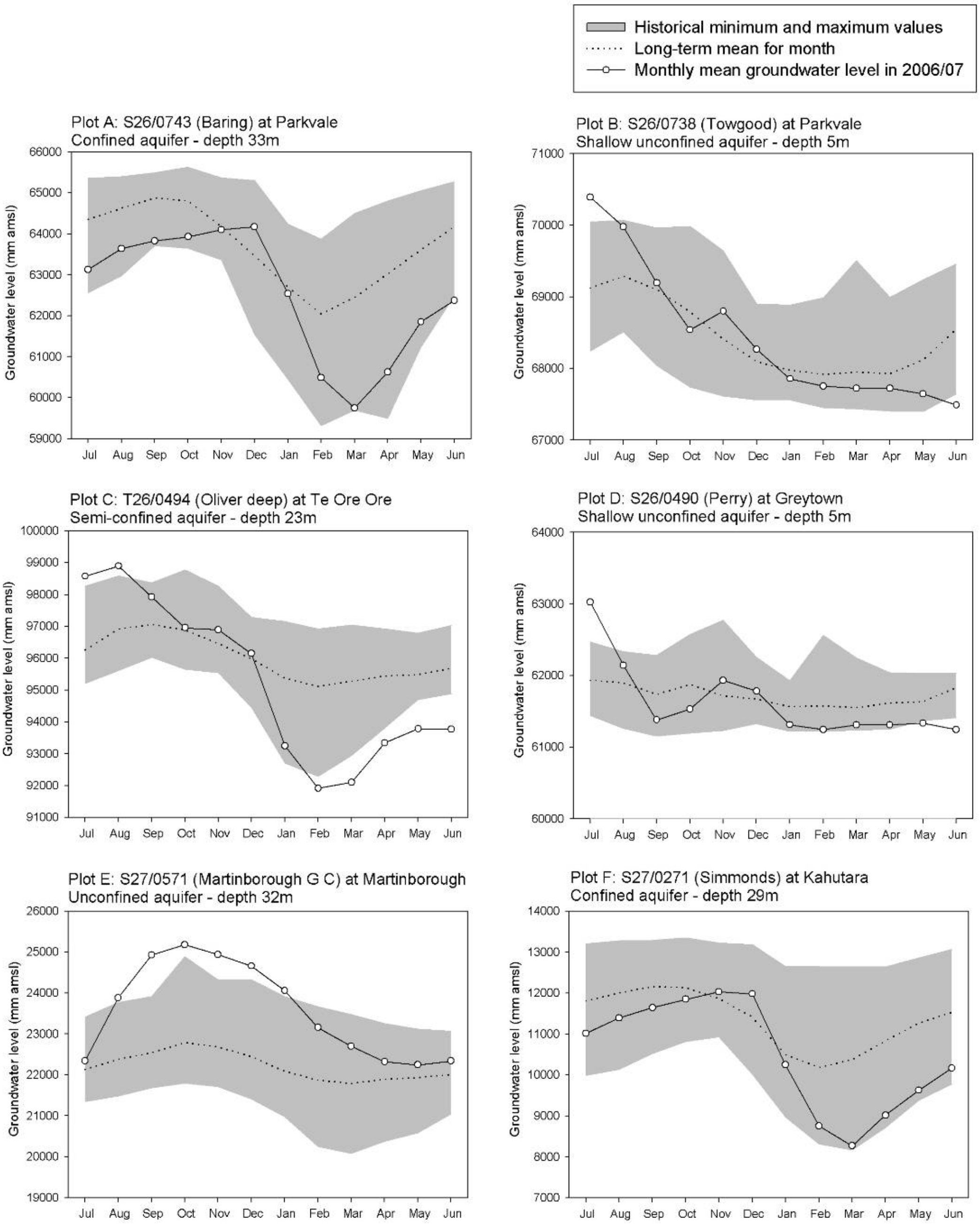

Figure 3.2: Monthly mean groundwater level for 2006/07 (black line) compared to historical mean monthly groundwater level (dotted line) at selected sites across the Wairarapa. Grey shaded area represents the range of historical minimum and maximum monthly mean groundwater levels.

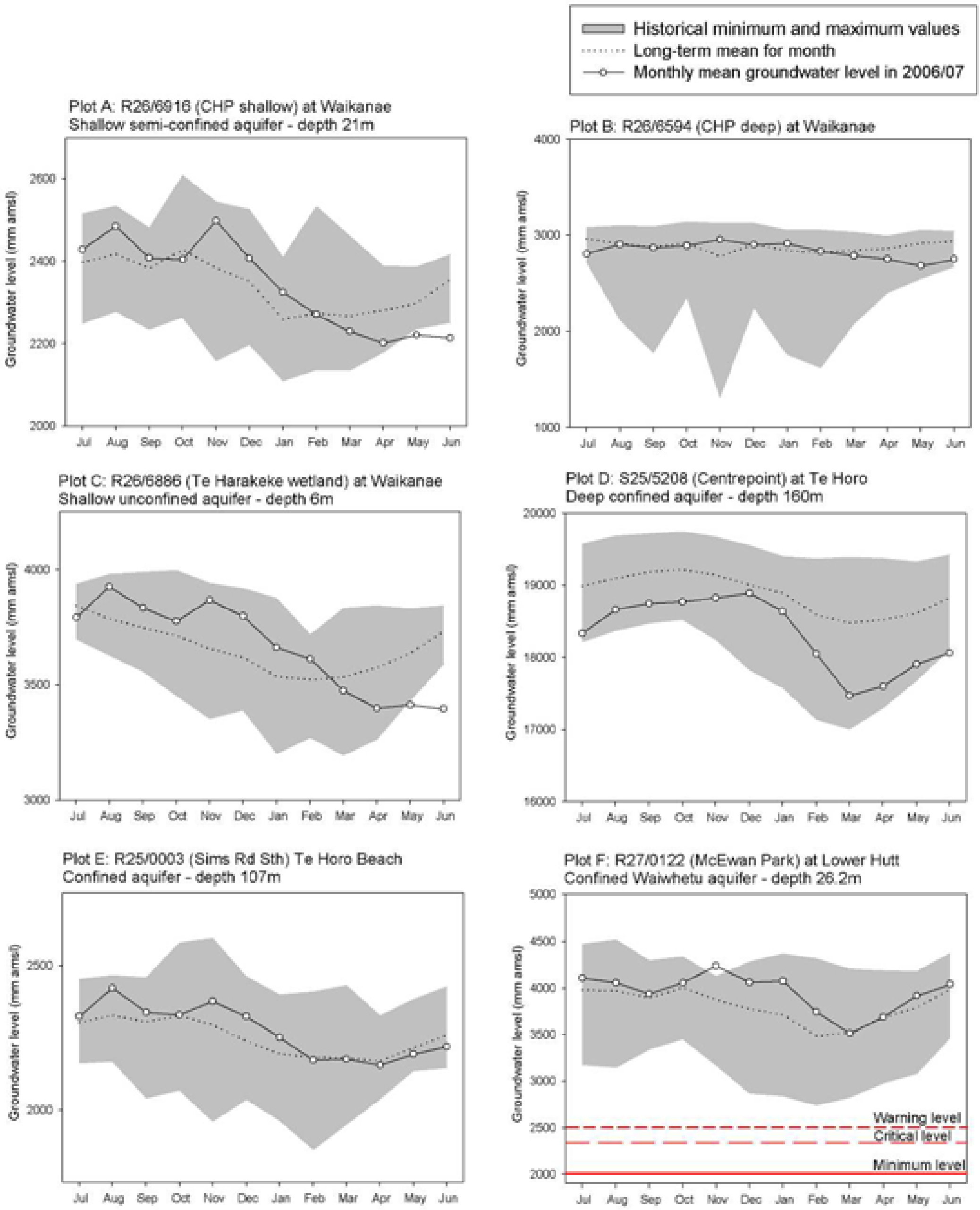

Figure 3.3: Monthly mean groundwater level for 2006/07 (black line) compared to historical mean monthly groundwater level (dotted line) at selected sites across the Kapiti Coast and Lower Hutt. Grey shaded area represents the range of historical minimum and maximum monthly mean groundwater levels.

With the exception of September, the remainder of the 2006 spring was cool and wet. This was particularly evident in borehole S27/0571 located in Martinborough (Plot E, Figure 3.2), where sustained above average groundwater levels were seen through to December 2006. Water levels in deeper (confined) aquifers across the region generally remained below average. This was particularly evident in the Parkvale and Kahutara areas (Plots A and F respectively, Figure 3.2).

In contrast, autumn 2007 (February to May) was drier than average. Groundwater monitoring in shallow (unconfined) and deeper (confined) aquifers showed below average levels throughout the second half of the year. Some levels were the lowest on record, such as T26/0494 in Te Ore Ore (Plot C, Figure 3.2). Levels within the Lower Hutt groundwater zone remained at or above average throughout the year (Plot F, Figure 3.3) and well above minimum management levels for the aquifer.

In general the Wairarapa aquifers showed the largest variations in water levels over the year. This is partially due to the extremes of weather seen throughout the year, but also a reflection of a high degree of abstraction from Wairarapa aquifers.

3.2 Wairarapa groundwater model

Groundwater in the Wairarapa valley is important for public water supply, domestic use, stock water and irrigation. There are also a number of groundwater dependent ecosystems in springs and wetlands throughout the valley.

The demand for groundwater irrigation in the Wairarapa valley has increased significantly in the last ten years, from around 200,000 cubic metres per day in 1996 to over 400,000 cubic metres in 2005. The increase in demand, coupled with full allocation in some groundwater zones and some groundwater level decline, has brought into question the appropriateness of the allocation limits specified in the Regional Freshwater Plan (RFP) and prompted Greater Wellington to undertake a valley-wide investigation of the Wairarapa groundwater system. The investigation has been designed to provide a sound scientific platform for the review of groundwater allocation limits and appropriate management objectives. The investigation has been underway for approximately two years, and involves two phases.

3.2.1 Phase 1

Phase One of the study was completed in December 2006 and summarised in a report by Jones and Gyopari (2006). The report describes a regional-scale revision of the geology and conceptual hydrogeology of the Wairarapa groundwater system. This revision has provided a context for local-scale information and identified information gaps.

Key findings from the Phase 1 report include:

- The groundwater and surface water system are essentially **one resource** and should be investigated as so. The majority of available and productive groundwater in the system discharges as surface water at some point in time.

- The shallow (<20 m in depth) aquifers across the region have strong interconnection with rivers, streams, springs and wetlands.

- River gauging studies show stretches of rivers gaining and losing water to the shallow aquifers.

- River water infiltrated to shallow groundwater often re-emerges back to rivers down valley or as springs. For example, the Waiohine River loses up to 30 – 40 % of its flow to groundwater north of Greytown to emerge at Papawai Springs and other spring systems south of Greytown.
- Groundwater flow is greater around present-day river systems.
- Although they have less connection to surface water systems, significant quantities of groundwater may be stored in aquifers >20m below ground level. Minor amounts of groundwater (from shallower aquifers) slowly percolate to these deeper aquifers.
- Tectonic movement (faulting) in the area means there is a complex regional groundwater system, with major barriers to groundwater flow (e.g., Te Marie Ridge, Tiffen Hill and Lansdowne Hill) and several sinking (subsiding) sub-basins (e.g., Te Ore Ore, Parkvale and Lake Wairarapa).

3.2.2 Phase 2

A second stage of advanced investigation was implemented in 2006/07 to build upon the geological and hydrogeological models developed to date. The key goal of the 'Phase 2' investigation is:

To provide a sound technical foundation for the practical and effective sustainable allocation of groundwater resources in the Wairarapa Valley.

Following the completion of Phase 1, the main sections of work carried out between December 2006 and June 2007 were as follows:

- River gauging studies to ascertain patterns in river loss and gain in connection with shallow aquifers.
- Groundwater level measurements in boreholes across the valley.
- Weekly measurement of selected borehole water meters.
- Development of a project to quantify the position of, and flow from, major spring systems across the valley.
- A geological workshop involving Greater Wellington and key Geological and Nuclear Sciences staff.
- Early stage development of a model to predict the volume of recharge entering the groundwater system across the valley from rainfall.

Gathered information and concepts are being combined into the first of three detailed model areas. The first area is located between Greytown and the Waingawa River (Figure 3.4).

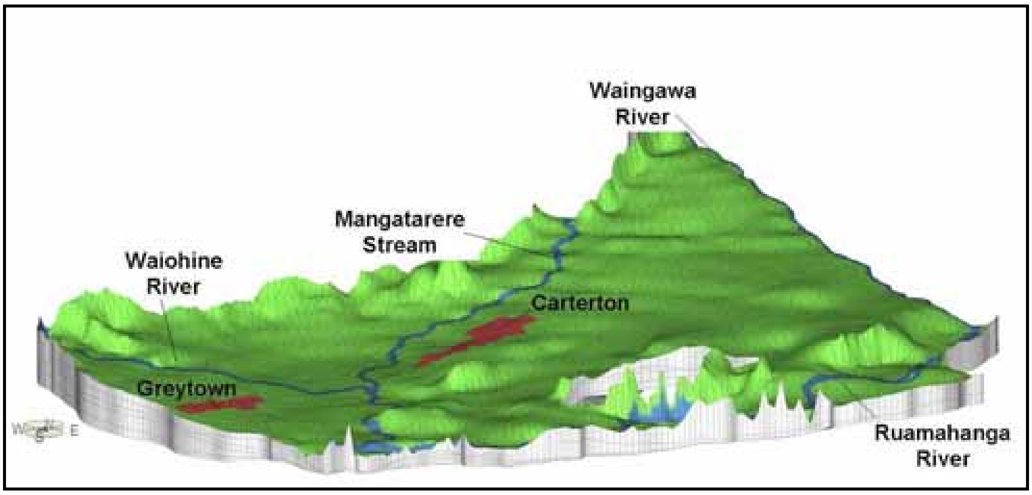

Figure 3.4: 3D simulation of the first of three detailed modelling areas between Greytown and the Waingawa River. Note the thickness of the aquifer system in the diagram has been stretched.

4. Groundwater quality

This section of the report provides a brief overview of the results of groundwater quality monitoring conducted in the Wellington region over 2006/07. This includes both routine groundwater state of the environment (GWSoE) monitoring and several targeted groundwater quality investigations.

Water 'quality' is a difficult concept to define, even though it is a commonly used term. The quality of groundwater can be described through the analysis of physical, chemical, and microbiological variables. The GWSoE programme incorporates a range of these variables, including dissolved oxygen, conductivity, pH, faecal bacteria, major ions, nutrients, and trace metals.

There are a number of anthropogenic factors that influence groundwater quality, notably land use (e.g., additional inputs of nutrients from agriculture, horticulture, effluent disposal) and in some cases water abstraction. However, natural variables such as the source of the water (rainfall or river), aquifer geology and residence time of water in the aquifer also influence the quality of an aquifer system.

4.1 GWSoE monitoring – summary points

GWSoE water quality sampling results for 2006/07 indicate no long term degradation of water quality occurring due to abstraction. Where groundwater systems discharge to the ocean, monitoring of water quality is critical; over abstraction of groundwater close to the sea may draw sea water inland effecting water quality for long periods of time. No significant deterioration was recorded through the year at any saline intrusion monitoring boreholes in the Lower Hutt or Kapiti aquifers[9].

Two of the main indicators of contamination of groundwater quality by landuse intensification and/or on-site wastewater disposal are nitrate-nitrogen and *Escherichia coli (E. coli)* bacteria. A brief review of nitrate-nitrogen and *E. coli* bacteria results for 2006/07 (four sampling rounds) is presented below.

4.1.1 Nitrate nitrogen

Elevated (>3.0 mg/L)[10] concentrations of nitrate-nitrogen were recorded at 23 of 71 (32%) GWSoE monitoring sites (Figure 3.5). Four of these sites, located in the Wairarapa, had concentrations greater than the Ministry of Health (2005) maximum acceptable value (MAV) of 11.3 mg/L, with 12.3 mg/L the maximum concentration recorded. While it appears from Figure 3.5 that areas of elevated nitrate nitrogen concentrations are spatially limited, this may be a reflection of the limited number of shallow sites in the GWSoE monitoring network. Further targeted nitrate nitrogen investigations have been undertaken, alongside GWSoE monitoring (see Section 4.2).

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9 The Wairarapa Valley aquifer system is not thought to have significant connection to the sea – therefore there is no need to report on potential saline intrusion for this system.

10 While most groundwater in New Zealand rarely has background nitrate-nitrogen concentrations exceeding 1.0 mg/L (Burden, 1982; Close 2001; Rosen 2001), in this report 3.0 mg/L NO_3-N is used as an indicator of anthropogenic influence in order to increase certainty caused by variability. A threshold concentration of 3.0 mg/L was also used by Madison and Brunett (1985) and Close (2001).

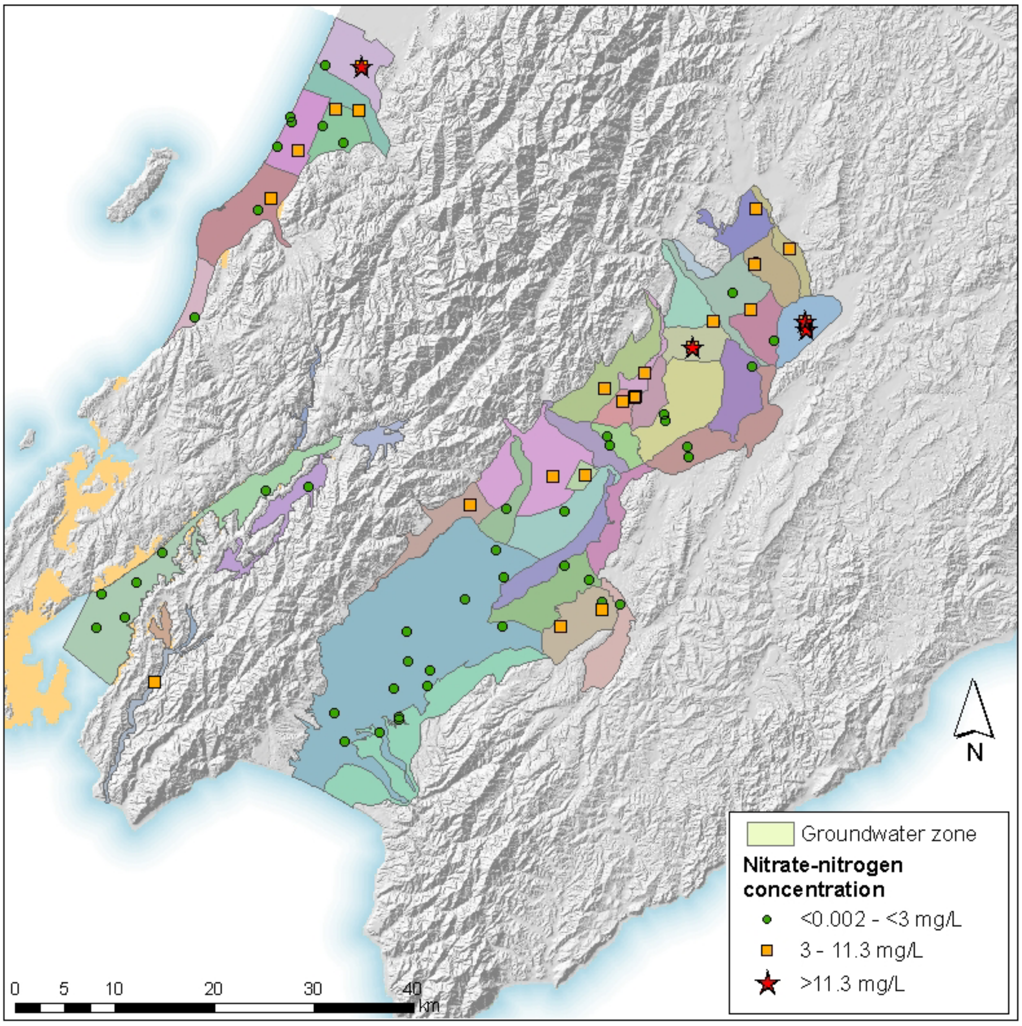

Figure 3.5: Maximum nitrate-nitrogen concentrations recorded at boreholes sampled on four occasions over 1 July 2006 to 30 June 2007 inclusive. A number of sites across the region had above background concentrations (i.e., >3 mg/L) although only four were above the Ministry of Health (2005) drinking water guideline value of 11.3 mg/L.

4.1.2 E. coli

In the Drinking Water Standards for New Zealand (Ministry of Health 2005), *E. coli* is used as an indicator of contamination of drinking water by faecal material[11]. For drinking water supplies, *E. coli* counts should be <1 cfu/100 mL.

Positive detects (generally >1 cfu/100 mL) for *E. coli* were made in nine bores on 12 occasions during four rounds of GWSoE sampling over 2006/07 (Figure 3.6). Noteworthy readings were 2,800 cfu/100mL (R25/ 5164) in the Coastal Zone in Kapiti, 840 and 700 cfu/100mL in Matarawa (S26/0439) and Moroa (S27/0202) in the Wairarapa, and 60 cfu/100mL (R27/6418) in the Wainuiomata valley.

[11] It is impracticable to monitor water supplies for all potential human pathogens, so surrogates are used to indicate possible contamination from such things as human and animal excrement, these being the most frequent causes of health-significant microbial contamination in drinking water supplies

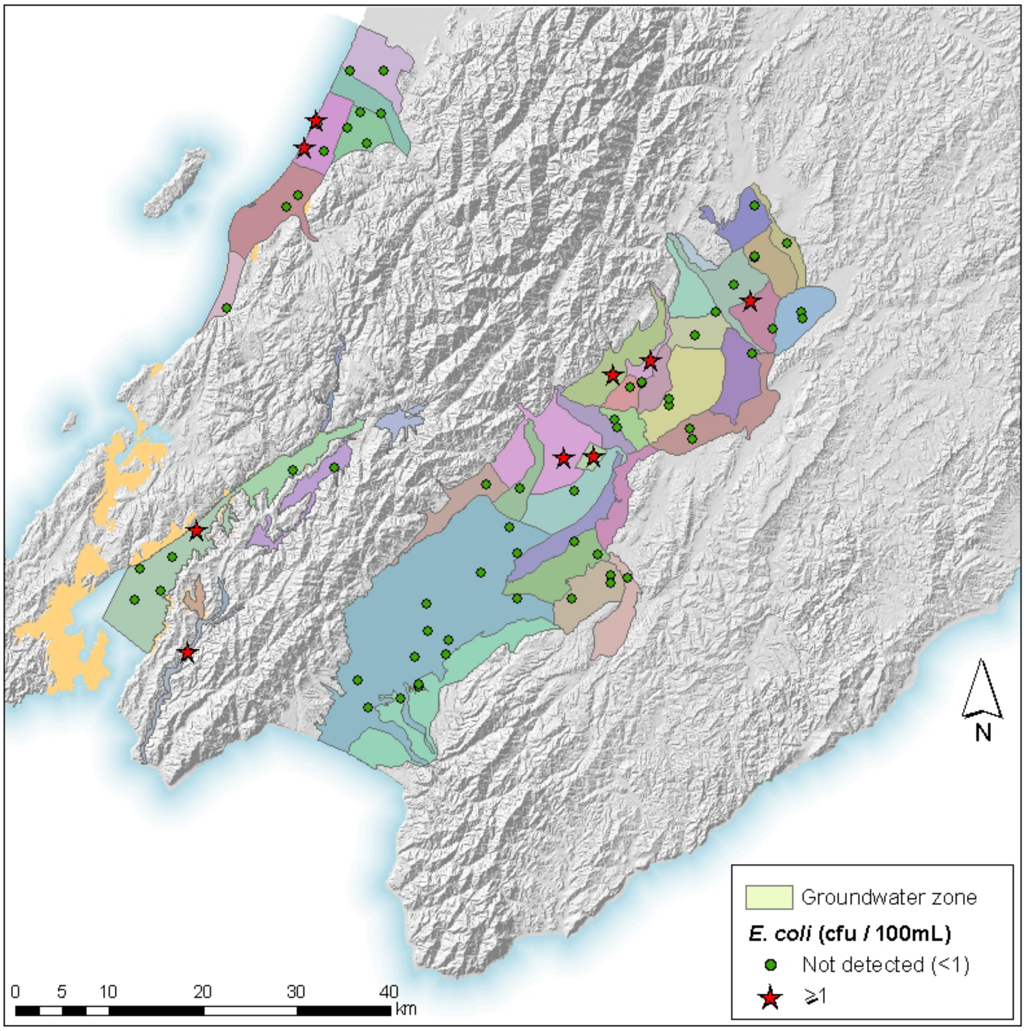

Figure 3.6: Maximum *E. coli* counts recorded at groundwater sites sampled on four occasions over 1 July 2006 to 30 June 2007 inclusive. Nine samples reported positive detects* for *E coli*.

*Note the level of analytical detection for 10 samples from 10 sites was greater than 1 cfu /100ml, ranging from <2 to <4 cfu/100 mL.

4.2 Targeted investigations

In addition to routine monitoring under the GWSoE programme, some specific groundwater quality investigations were also undertaken over 2006/07. These included:

- Monitoring the effects of on-site wastewater system discharges on groundwater quality at selected locations in the region, including Flat Point and Riversdale in the eastern Wairarapa. The groundwater aquifers in these areas are shallow and considered at risk of contamination, especially at Riversdale where there are already a number of discharges into the aquifer.

- Monitoring nitrate nitrogen concentrations, in 48 boreholes in the Carterton, Matarawa and South Featherston areas of the Wairarapa valley. This survey, undertaken over the 2006/07 summer, found elevated nitrate nitrogen concentrations, but only one result exceeded the Ministry of Health national drinking water standard of 11.3 mg/L.

- Collecting water samples for pesticide analysis from 17 boreholes across the region as part of Environmental Science and Research's (ESR) fifth national pesticides in groundwater survey. The results of the sampling – conducted in late 2006 – identified low concentrations of organonitrogen herbicides in two boreholes, one in Otaki (S25/5125; Norflurazon at 0.096µg/L) and one in Wainuiomata (R27/6418; Terbuthylazine at 0.12 µg/L). No pesticides were detected in any of the other boreholes sampled in the Wellington region.

Another investigation has recently commenced (mid 2007) looking at the effects of on-site wastewater discharges on the quality of groundwater under a developing intensive subdivision area along Norfolk Road in Carterton. The aquifer in this area is shallow, and unconfined or semi-confined, making the groundwater system particularly at risk of contamination. The results of the investigation, along with more a detailed account of the other nitrate investigations outlined above, will be the subject of a separate report in 2008.

5. Summary

Groundwater quantity in the Wellington region in 2006/07 was characterised by above average levels in the start of the year and a decline to average or below average levels in the end of the year. A wet spring 2006 resulted in above average recharge to both rainfall and river fed aquifers across the region.

Below average rainfall and river flows from January to June 2007 resulted in a decline in water levels in many areas to average or below average conditions. Deeper confined aquifers across the region showed some recovery from the wet start to the year but many declined in the second half of the year due to reduced recharge.

Routine SoE groundwater quality sampling over 2006/07 showed elevated results for nitrate-nitrogen and the presence of *E. coli* in a number of boreholes across the region. Some of the elevated results are possibly a result of changing land use practice such as more intensive farming practices and discharges of wastewater to land. Several targeted investigations have commenced throughout the year to assist with pin-pointing sources of contamination.

6. References

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Appendix 1: Groundwater monitoring networks

Table A1.1: Greater Wellington's automatic groundwater level monitoring network

Site Name	Site Number	Groundwater Zone	Start Date	Site Closed
Wairarapa Valley				
Simmonds /John	S27/0099	Battersea	10/12/1996	
Perry	S26/0490	Greytown	13/08/1990	
Hammond	S27/0225	Greytown	06/09/1994	
Simmonds - 6E/44/30/I	S27/0309	Kahutara	11/01/2002	
Simmonds - 6E/51/18/I	S27/0317	Kahutara	21/12/2001	
Green	S27/0467	Kahutara	29/11/2001	
Martinborough Golf Club	S27/0571	Martinborough Eastern Terraces	05/10/1998	
Duggan	S27/0522	Martinborough Western Terraces	01/12/2000	
Blundell	S26/0749	Middle Ruamahanga	17/12/1997	
Croad	S27/0202	Moroa	26/04/1988	
Luttrell/Shallow	S27/0587	Onoke	07/09/1990	
Towgood	S26/0738	Parkvale	03/08/1983	
Baring	S26/0743	Parkvale	06/11/1986	
Dry River Beef	S27/0481	Pukeo	19/09/1983	
Zyzalo	T26/0239	Rathkeale	26/08/1997	
Burt	S27/0330	Tauherenikau	30/11/2000	
Herrick	S27/0381	Tawaha East	09/03/1984	
Smith	S27/0346	Tawaha West	02/12/1983	
Wairoria	S27/0434	Te Hopai	02/02/1994	
Oliver - deep	T26/0494	Te Ore Ore	27/11/1991	
Oliver - shallow	T26/0501	Te Ore Ore	15/07/1983	
Robinson	S27/0442	Tuhitarata	30/08/2005	
Downing	S26/0033	Upper Plain	30/09/1983	
Wairio	S27/0428	Wairio	11/02/1983	
Hutt Valley				
HVMTC	R27/0120	Lower Hutt GW Zone	24/09/1968	
McEwan Pk#	R27/0122	Lower Hutt GW Zone	03/03/1971	
IBM No 1	R27/0320	Lower Hutt GW Zone	14/02/1974	
UWA 3	R27/1086	Lower Hutt GW Zone	24/12/1997	
Hutt Rec	R27/1115	Lower Hutt GW Zone	15/12/1967	
Mitchell Park	R27/1116	Lower Hutt GW Zone	24/09/1968	
Taita Intermediate	R27/1117	Lower Hutt GW Zone	24/09/1968	
Randwick	R27/1122	Lower Hutt GW Zone	22/07/1975	
Somes Island	R27/1171	Lower Hutt GW Zone	28/01/1969	
IBM No 2	R27/1265	Lower Hutt GW Zone	16/09/2004	
Marsden St	R27/6386	Lower Hutt GW Zone	01/05/2001	
South Pacific Tyres	R27/1137	Upper Hutt GW Zone	08/06/2006	
Trentham Memorial Park	R27/7004	Upper Hutt GW Zone	25/05/1973	
Kapiti Coast				
Sims Rd Sth	R25/0003	Coastal GW Zone	28/03/1985	
Housiaux 4	R26/6881	Coastal GW Zone	22/09/2004	
Centrepoint	S25/5208	Hautere GW Zone	19/12/1991	
Bettys	S25/5258	Otaki GW Zone	04/03/1993	
Waikanae Park	R26/6284	Waikanae GW Zone	14/07/2003	
Rangihiroa St	R26/6287	Waikanae GW Zone	16/12/2002	
Waikanae Golf Course	R26/6377	Waikanae GW Zone	18/11/2005	05/02/2007
Rutherford Drive	R26/6378	Waikanae GW Zone	13/09/2006	

Site Name	Site Number	Groundwater Zone	Start Date	Site Closed
Estuary Shallow	R26/6566	Waikanae GW Zone	18/02/2005	
Waikanae CHP Deep	R26/6594	Waikanae GW Zone	30/05/1994	
Taiata St Shallow	R26/6673	Waikanae GW Zone	18/02/2005	
Larch Grove	R26/6831	Waikanae GW Zone	01/03/2001	
Golf Tech	R26/6832	Waikanae GW Zone	13/10/2000	05/02/2007
Maclean Park	R26/6833	Waikanae GW Zone	03/04/2001	
Te Harakeke No 3	R26/6886	Waikanae GW Zone	18/11/2005	
Waikanae CHP Shallow	R26/6916	Waikanae GW Zone	10/08/1994	
Taiata St Deep	R26/6955	Waikanae GW Zone	18/02/2005	
Estuary Deep	R26/6956	Waikanae GW Zone	18/02/2005	
Nga Manu	R26/6991	Waikanae GW Zone	18/11/2005	
K6	R26/6992	Waikanae GW Zone	18/11/2005	
W1	R26/7025	Waikanae GW Zone	18/11/2005	
Taylors	S25/5332	Waitohu GW Zone	23/05/1995	

Table A1.2: Greater Wellington's manual groundwater level monitoring network

Site Name	Site No.	Groundwater Zone	Start Date	Site Closed
Wairarapa				
Craig /Deep	S26/0545	Ahikouka	03/08/1983	
Craig /Shallow	S26/0547	Ahikouka	03/08/1983	
Nicholson	S26/0223	East Taratahi	18/03/1998	
East Coast Fert./Dee	S26/0229	East Taratahi	14/05/1984	
Oldfield	S26/0236	East Taratahi	03/08/1983	
East Coast Fert./Shall	S26/0242	East Taratahi	03/08/1983	
McKay	T26/0326	Fern Hill	03/08/1991	
Simmonds /Jim	S27/0271	Kahutara	21/04/1982	
Awaroa /Deep	S27/0446	Kahutara	11/11/1982	
Awaroa /Shallow	S27/0465	Kahutara	20/04/1982	
Wither	S26/0658	Mangatarere	03/08/1983	
Wall	S27/0403	Martinborough Eastern Terraces	13/11/2001	
Collins/MacCullum	S27/0560	Martinborough Eastern Terraces	01/05/2002	
Te Kairanga/Deep	S27/0640	Martinborough Eastern Terraces	01/02/2002	
Transport Wairarapa	T26/0429	Masterton	10/02/1986	
Wenden	S26/0756	Middle Ruamahanga	29/05/1998	
Morrison	S27/0248	Middle Ruamahanga	03/08/1983	
Warren	S27/0594	Narrows	18/08/1981	
Luttrell /Deep	S27/0576	Onoke	29/11/1982	
Tocher/Lawrence	T26/0208	Opaki	26/01/1998	
Tulloch /Shallow	S26/0155	Parkvale	03/08/1983	
Denbee	S26/0568	Parkvale	17/08/1983	
Tulloch /Investigation	S26/0656	Parkvale	03/08/1983	
McNamara	S26/0675	Parkvale	30/10/1996	
Ness /Deep	S27/0484	Pukeo	07/12/1990	
Ness/Shallow	S27/0485	Pukeo	28/11/1995	
Stuart	S27/0517	Pukeo		
Hodgins	T26/0170	Rathkeale	24/11/1986	
Windy Farm /House	S27/0009	South Featherston	01/05/2002	
Windy Farm /Deep	S27/0012	South Featherston	03/08/1983	
Sth Featherston School	S27/0035	Tauherenikau	03/08/1983	
Butcher	S27/0542	Tawaha	21/12/1988	
Waicon	T26/0232	Te Ore Ore	19/09/1983	
Masterton District Council	T26/0243	Te Ore Ore	26/09/1988	

Site Name	Site No.	Groundwater Zone	Start Date	Site Closed
Annear	R28/0002	Turanganui	14/11/2001	
Lenton	T26/0003	Upper Opaki	02/04/1997	
Dick /Investigation	S26/0030	Upper Plain	24/07/1989	
Atkinson	S27/0618	Whangaehu / Tuhitarata	16/04/1982	
Carlisle	S27/0148	Woodside	03/08/1983	
Hutt Valley				
Nevis St	R27/1223	Lower Hutt GW Zone	03/03/1971	
Kapiti Coast				
Faith	R25/5123	Coastal GW Zone	26/02/1993	
Quinn	R26/6747	Coastal GW Zone	30/06/1982	
Housiaux 1	R26/6861	Coastal GW Zone	25/11/2004	
Housiaux 2	R26/6879	Coastal GW Zone	25/11/2004	
Housiaux 3	R26/6880	Coastal GW Zone	25/11/2004	
Housiaux 5	R26/6882	Coastal GW Zone	25/11/2004	
Housiaux 6	R26/6883	Coastal GW Zone	25/11/2004	
Jamieson	R25/5111	Hautere GW Zone	26/02/1993	
Windsor Park	R25/5135	Hautere GW Zone	30/06/1982	
Common Property	S25/5200	Hautere GW Zone	12/03/1993	
Penray	S25/5256	Hautere GW Zone	26/02/1993	
Rangiuru	R25/5228	Otaki GW Zone	08/04/1993	
Lutz	S25/5212	Otaki GW Zone	23/03/1993	
Andrews	S25/5228	Otaki GW Zone	26/02/1993	
Horowhenua Racing Club	S25/5287	Otaki GW Zone	12/03/1993	
QE Park No 3	R26/5102	Raumati/Paekak GW Zone	12/09/2001	
QE Park No 1	R26/6503	Raumati/Paekak GW Zone	26/02/1993	
QE Park No 2	R26/6520	Raumati/Paekak GW Zone	12/12/1994	
QE Park No 4	R26/6919	Raumati/Paekak GW Zone	12/09/2001	
QE Park No 5	R26/6920	Raumati/Paekak GW Zone	12/09/2001	
Weka Park	R26/6521	Waikanae GW Zone	26/02/1993	
Mazengarb	R26/6557	Waikanae GW Zone	26/03/1993	
Mazengarb Deep	R26/6558	Waikanae GW Zone	15/12/1995	01/02/2007
NZ Staff College	R26/6569	Waikanae GW Zone	26/02/1993	
McLaughlin	R26/6626	Waikanae GW Zone	26/02/1993	
McCardle	R26/6738	Waikanae GW Zone	26/02/1993	
Te Harakeke Bore 1	R26/6884	Waikanae GW Zone	14/05/2002	
Te Harakeke Bore 2	R26/6885	Waikanae GW Zone	14/05/2002	
Hunt	S25/5320	Waitohu GW Zone	12/03/1993	19/12/2006
Edhouse	S25/5322	Waitohu GW Zone	26/03/1993	
Laurensen	S25/5329	Waitohu GW Zone	26/03/0993	

Table A1.3: Greater Wellington's State of Environment groundwater quality monitoring network

Site No.	Site Name	Groundwater Zone
Wairarapa		
S26/0457	Palmer	Ahikouka
S27/0156	O'neale	Battersea
S26/0705	CDC South	Carterton
S26/0824	CDC North	Carterton
S26/0223	Nicholson	East Taratahi
T26/0332	Taratahi Shallow	Fern Hill
S26/0846	Druzianic	Greytown
S26/0467	Fitzgerald Shallow	Hodders
S27/0547	Campbell	Huangarua Lower Terraces
S27/0681	Te Kairanga Shallow	Huangarua Lower Terraces
S27/0268	Barton	Kahutara
S27/0283	Osbourne	Kahutara
S27/0299	Johnson	Lake Domain
S26/0117	Butcher, G	Mangatarere
S27/0389	Dimittina	Martinborough Eastern Terraces
S27/0571	Mtb Golf	Martinborough Eastern Terraces
S27/0522	Duggan	Martinborough Western Terraces
T26/0413	Seymour	Masterton
T26/0430	Trout Hatchery	Masterton
S26/0439	Rogers	Matarawa
S26/0756	Wendon	Middle Ruamahanga
S26/0762	Schaef	Middle Ruamahanga
S27/0202	Croad	Moroa
S27/0594	Warren	Narrows
S27/0585	Mccreary	Onoke
T26/0099	Butcher, M	Opaki
T26/0206	Thornton	Opaki
S26/0568	Denbee	Parkvale
S26/0576	Mcnamara	Parkvale
S27/0607	Findlayson	Pouawha
S27/0495	Bosch	Pukeo
T26/0259	Opaki Water Supply	Rathkeale
S27/0009	Donderman, A	South Featherston
S27/0070	Sth Fstn School	Tauherenikau
S27/0588	Swdc Pirinoa	Taunui
S27/0396	Swdc Martinborough	Tawaha East
S27/0344	George	Tawaha West
S27/0433	Mapuna Atea	Te Hopai
S27/0442	Robinson Transport	Te Hopai
T26/0489	Duffy	Te Ore Ore
T26/0538	Percy	Te Ore Ore
T26/0003	Lenton	Upper Opaki
T26/0087	Biss	Upper Plain
S27/0435	Wairio	Wairio
R25/5233	Op Trust	Waitohu
S25/5322	Edhouse	Waitohu
S26/0299	Graham	West Taratahi
S27/0602	Weatherstone	Whangaehu / Tuhitarata
S27/0614	Sorenson Southern	Whangaehu / Tuhitarata
S27/0615	Sorenson Northern	Whangaehu / Tuhitarata
S27/0136	Sugrue	Woodside

Site No.	Site Name	Groundwater Zone
Hutt, Mangaroa and Wainuiomata Valleys		
R27/0320	Ibm 1	Lower Hutt
R27/1171	Somes Island	Lower Hutt
R27/1180	Mahoe St/Willoughby St V	Lower Hutt
R27/1182	Seaview Wools	Lower Hutt
R27/1183	Avalon Studios	Lower Hutt
R27/1265	Ibm 2	Lower Hutt
R27/6833	Mangaroa	Mangaroa
R27/1137	South Pacific Tyres	Upper Hutt
R27/6418	Wainuiomata Golf Club	Wainuiomata River
Kapiti Coast		
R25/5100	O'Malley	Coastal
R25/5164	Card	Coastal
R25/5165	Salter	Coastal
R25/5190	Williams	Coastal
R25/5135	Windsor Park	Hautere
S25/5200	Common Property	Hautere
S25/5256	Penray	Hautere
S25/5125	Bettys/Andrews	Otaki
R26/6503	QE Park	Raumati/Paekakariki
R26/6587	Liddle Nurseries	Waikanae
R26/6624	Boffa	Waikanae

Appendix 2: Groundwater quality variables and analytical methods

Laboratory	Variable	Method Used	Detection Limit
N/A	Temperature	Field meter – ExStik DO600 (Extech Imstruments) and YSI 550A Meters	0.01 ˚C
N/A	Dissolved Oxygen	Field meter – ExStik DO600 (Extech Imstruments) and YSI 550A Meters	0.01 mg/L
N/A	Conductivity	Field meter – ExStik DO600 (Extech Imstruments) and YSI 550A Meters	0.1 µS/cm
N/A	pH	Field meter – ExStik DO600 (Extech Imstruments) and YSI 550A Meters	0.01 units
Hills	pH	pH meter APHA 4500-H+ B 21st ed. 2005.	0.1 pH units
Hills	Electrical Conductivity	Conductivity meter, 25°C APHA 2510 B 21st ed. 2005.	0.1 mS/m, 1 µS/cm
Hills	Total Alkalinity	Titration to pH 4.5 (M-alkalinity), Radiometer autotitrator. APHA 2320 B (Modified for alk <20) 21st ed. 2005.	1 mg/L as $CaCO_3$
Hills	Free carbon dioxide	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates r bicarbonates. APHA 4500-CO2 D 21st ed. 2005.	1 mg/L at 25°C
Hills	Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO2 D 21st ed. 2005.	1 mg/L at 25°C
Hills	Total Dissolved Solids	Filtration (GF/C, 1.2 µm), filtrate dried at 103 - 105 °C, Gravimetric. APHA 2540 C (modified from 180 °C) 21st ed. 2005.	10 mg/L
Hills	Dissolved Calcium	Filtered sample, ICP-MS APHA 3125 B 21st ed. 2005.	0.05 mg/L
Hills	Dissolved Magnesium	Filtered sample, ICP-MS APHA 3125 B 21st ed. 2005.	0.02 mg/L
Hills	Total Hardness	Calculation: from Dissolved Ca and Dissolved Mg APHA 2340 B 21st ed. 2005.	1 mg/L as $CaCO_3$
Hills	Dissolved Sodium	Filtered sample, ICP-MS APHA 3125 B 21st ed. 2005.	0.02 mg/L
Hills	Dissolved Potassium	Filtered sample, ICP-MS APHA 3125 B 21st ed. 2005.	0.05 mg/L
Hills	Total Ammoniacal-N	Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH4-N = NH4+-N + NH3-N) APHA 4500-NH3 F (modified from manual analysis) 21st ed. 2005.	0.01 mg/L
Hills	Nitrate-N + Nitrite-N (TON)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO3 - I (modified) 21sted. 2005.	0.002 mg/L
Hills	Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N.	0.002 mg/L

Laboratory	Variable	Method Used	Detection Limit
Hills	Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO3 - I (modified) 21st ed. 2005.	0.002 mg/L
Hills	Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 21st ed. 2005.	0.004 mg/L
Hills	Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500-Cl- E (modified from continuous-flow analysis) 21st ed. 2005.	0.5 mg/L
Hills	Bromide	Filtered sample. Ion Chromatography. APHA 4110 B 21st ed. 2005.	0.05 mg/L
Hills	Fluoride	Ion selective electrode APHA 4500-F- C 21st ed. 2005.	0.05 mg/L
Hills	Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 21st ed. 2005.	0.5 mg/L
Hills	Dissolved Boron	Filtered sample. ICP-MS APHA 3125 B 21st ed. 2005.	0.005 mg/L
Hills	Reactive Silica	Filtered sample. Heteropoly blue colorimetry. Discrete Analyser. APHA 4500-SiO2 F (modified from flow injection analysis) 21st ed. 2005.	0.1 mg/L as SiO_2
Hills	Total Organic Carbon (TOC)	Catalytic oxidation, IR detection, for Total C. Acidification, purging for Total Inorganic C. TOC = TC - TIC. APHA 5310 B (modified) 21st ed. 2005.	0.05 mg/L
Hills	Dissolved Iron	Filtered sample. ICP-MS APHA 3125 B 21st ed. 2005.	0.02 mg/L
Hills	Dissolved Manganese	Filtered sample. ICP-MS APHA 3125 B 21st ed. 2005.	0.0005 mg/L
Hills	Dissolved Lead	Filtered sample. ICP-MS APHA 3125 B 21st ed. 2005.	0.0001 mg/L
Hills	Dissolved Zinc	Filtered sample. ICP-MS APHA 3125 B 21st ed. 2005.	0.001 mg/L
Hills	Total Anions	Calculation: sum of anions as mEquiv/L [Includes Alk, Cl, NOxN & SO4]	0.07 mEquiv/L
Hills	Total Cations	Calculation: sum of cations as mEquiv/L [Includes Ca, Mg, Na, K, Fe, Mn, Zn & NH4N]	0.06 mEquiv/L
Hills	% Difference in Ion Balance	Calculation from Sum of Anions and Cations APHA 1030 E 21st ed. 2005.	0.1 %
ELS	Faecal Coliforms	APHA 21st Ed. Method 9222 D	1 cfu/100 mL
ELS	*E. coli*	APHA 21st Ed. Method 9222 G	1 cfu/100 mL