Ruawai Aquifer Management Zone Bore Survey and Preliminary Hydrogeological Study

REPORT PREPARED FOR
NORTHLAND REGIONAL COUNCIL

- Rev D - Final Report
- 16/12/2003

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Executive Summary

The hydrogeology of the Ruawai Plains is currently poorly defined, even though the underlying aquifer is an important source of water for public water supply, dairy shed washdown, stock drinking water and irrigation.

This study was commissioned to increase the level of understanding of the Ruawai aquifer hydrogeology and to assess some of the issues that are of concern to Northland Regional Council, including:

- flowing artesian bores;
- effect of land uses on shallow groundwater (including dairying and horticulture);
- occurrence of poor water quality in some bores, especially elevated salinity, iron, and manganese.
- sustainability of groundwater pumping (quantity available).

To achieve the study objectives, staff from SKM and NRC conducted a four day bore survey of as many properties as could be visited in the time available. The bore survey involved a questionnaire regarding bore ownership, history and landuse, and taking physical measurements of location (GPS), depth, diameter and general condition/integrity. During the survey a number of bores were identified as being suitable for test pumping to determine the aquifer's hydraulic characteristics. Three of these bores were subsequently visited and hydraulically tested over a three day period.

Following the field survey and testing phase, existing information was compiled and reviewed from NRC and other sources. Based on this information and data from the field testing, an analysis of the aquifer hydrogeology was undertaken.

The main findings from the study include:

Hydrogeology - The Ruawai aquifer consists of 45 to 60 m of undifferentiated alluvium comprising alternating successions of mud, clay, silt, peat, sand and gravels associated with various phases of shallow marine and terrestrial fluvial activity in a deltaic setting. Nearer the Kaipara Harbour in the south of the plains there is a higher occurrence of estuarine muds and silts.

An 8-20 m thick sand to gravel layer at depths of 40 to 60 m occurs relatively consistently in borelogs across the plains. The lithological succession appears to coarsen downwards, which implies that aquifer permeabilities and groundwater yields are likely to be greater with depth. In addition, the shallow layers provide a degree of confinement that creates artesian pressures over wide expanses of the plains.

Groundwater Chemistry/Quality – Data from previous bore water quality testing indicated that no water quality parameters exceed the Maximum Acceptable Value for health, however exceedance of aesthetic guideline values indicates that the groundwater in some bores have an unpleasant taste and appearance. The problems that have been experienced at Ruawai range from 'rusting' of pipework due to high iron & manganese, scale deposition due to high total hardness, and 'salty' water due to high sodium and chloride.

The elevated parameters are a function of the hydrogeology of the Ruawai Plains, specifically the proximity to coastal waters, nature of in-situ (iron and manganese) and surrounding sedimentary rocks (possibly high connate salts), and faulting, which may act as a conduit for poorer quality water on the eastern margin of the plain. In addition, bore construction and condition is likely to be a major determinant of water quality especially where water quality has changed markedly during the lifetime of the bore.

Implications – Current surface activities within the Ruawai area are unlikely to affect the deeper aquifer (>30 m) that is used for drinking water because of:

a) the stratified and generally lower permeability characteristics of the upper aquifer; and
b) the upward groundwater pressures from the underlying aquifer, which act to withhold downward percolation of groundwater – providing a form of hydrogeological security against contamination.

However, landuse activities in the future do have the potential to alter the hydrogeological security of the deeper aquifer if significant groundwater pressure reductions occur. In this respect it is important to gain an understanding of the deeper aquifers flow characteristics and an improved understanding of the sustainable yields under varying climatic conditions and pumping rates so that regulation of the amount of abstraction to mitigate such effects occurring can be achieved.

Contamination of the shallow groundwater is likely to be occurring as a result of land use activities in the area. As the shallow groundwater is likely to discharge into the surface waters (drains) in the area, such contamination will also influence the water quality of the surface waters.

Sustainable Yields - Preliminary estimates of annual average sustainable yield from the Ruawai aquifer are in the order of 10,000 m^3/day for the shallow aquifer and 27,000 m^3/day for the deeper aquifer. This has been estimated from the calculated aquifer discharge volumes from the shallow and deeper aquifer zones of approximately 25,000 m^3/day and 70,000 m^3/day, respectively.

The preliminary sustainable yield figures indicate that the existing groundwater allocation from the Ruawai aquifer of approximately 1,200 m^3/day is significantly less than what is potentially available.

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Recommendations - Based on the findings from this study, and without knowledge of NRC's priorities and statutory obligations, SKM recommend that the following activities and studies are undertaken:

- Begin real-time groundwater pressure monitoring in at least two bores screened within the deeper aquifer to facilitate assessment of the dynamic response of the aquifer. This will allow a more definitive assessment of sustainable yield and the potential for surface contamination;
- Carry out quarterly groundwater quality monitoring in both the shallow and deeper aquifer for all major anions and cations, nutrients and metals.
- Initiate the development of a groundwater model to assess dynamic groundwater flow rates and sustainable yields of the aquifer and assess water chemistry transport from surficial sources, in accordance with the principles of adaptive management.
- Investigate shallow groundwater and surface water interaction.
- Consider management options to address the issue of flowing artesian and uncapped bores in the Ruawai area.

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Contents

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1. Introduction

The hydrogeology of the Ruawai Plains is currently poorly defined, although the underlying aquifer is an important source of water for public water supply, dairy shed washdown, stock drinking water and irrigation.

Over much of the Plains the groundwater table is close to the ground surface, being a low-lying region with land surface elevations generally less than 10 m above mean sea level. Artesian groundwater (groundwater pressures above the ground surface) exists in some bores – usually those screened at reasonable depths (>20 m). Water quality issues such as high iron, manganese and salinity are also known to prevail in certain localities.

Because of the shallow groundwater table there is the possibility that landuse practices in the Ruawai Plain area, which comprise predominantly dairying and kumara growing, are likely to impact on shallow groundwater quality. Knowledge of this occurring is currently poorly understood.

Given the high reliance on groundwater and various other issues discussed above, the Northland Regional Council (NRC) initiated investigations into the groundwater resource in order to facilitate more informed and proactive management of the aquifer system. As such, NRC commissioned Sinclair Knight Merz Ltd (Environmental and Engineering Consultants) in June 2003 to carry out a bore survey of the region and preliminary investigations to assess the characteristics of the groundwater and hydrogeological setting.

To this end, Sinclair Knight Merz (SKM) have conducted field investigations in the Ruawai area to verify the:

- depth of groundwater across the plains;
- typical specifications of bores (depth, diameter) drilled;
- groundwater usage patterns;
- hydraulic properties of the underlying aquifers; and
- water quality characteristics and issues.

Following this, analyses of the field data and other data provided by NRC was carried out to form a conceptual understanding of the aquifer system. The report contained herein documents both the field investigation and analyses.

2. SKM/NRC Bore Survey

A media release was published in the Dargaville & District News on 6 August and posted on the NRC web site advising the public and seeking cooperation with a four day bore survey. A copy of the article is provided in Appendix A. The objectives of the bore survey were to obtain information on as many bores in the Ruawai Plains area as possible in the time available. The survey did not set out to investigate all properties in the area, but rather to obtain a representative spread of samples across the area.

The bore survey was undertaken by SKM Hydrogeologist Donna Jones and NRC Monitoring Technician George Skuse between 11 –14 August 2003. During the four day period 71 properties were visited, with the following details recorded at each site:

- Property owner;
- Whether a bore existed on the property and if so;
- Coordinates from a Global Positioning System (GPS);
- Date the bore was installed;
- Bore depth and diameter;
- Bore condition and type of pump;
- Landuse and bore water use;
- Information on the water quality from owners;
- Photograph of bore headworks;
- Groundwater level measurement (where access down bore permitted);
- Water quality field parameters (pH, EC, TDS, temperature) were taken from bores where access to the discharge water was available;
- Assessment of whether the bore would be suitable for hydraulic testing.

In total 81 bores were surveyed from the 71 properties visited[1]. Following the survey, the information was compiled by SKM and added to the NRC database. Only 26 existing NRC bores were matched to bores from the survey, which suggests that 55 bores either have not been registered on the NRC database, or that inaccurate coordinates have been provided on the bore logs.

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[1] Note: Most properties had more than one bore. Generally only the main pumping bore was surveyed. The maximum number of bores on any single property surveyed was seven.

Appendix B provides photographs and data sheets for each of the bores surveyed and Appendix C provides a hardcopy of the NRC bore database with SKM data appended.

Bores that have damaged casings or where the top of the casing is at or close to ground level pose a possible risk of contamination to the aquifer. These bores have potential to permit surface water to directly enter the aquifer. Six of the surveyed bores had negligible casing stick-up and/or were free-flowing artesian (e.g. SKM Bore 66 in Appendix C). It is thought that the number of bores that could result in surface connection with the underlying aquifer(s) is much higher than the proportion identified during the survey, as most properties had secondary or older bores that were not surveyed. In most cases, the owners said that these bores were unused and uncapped. Bores that are unused should be sealed permanently.

The following sections of this report describe the physical setting and hydrogeological characteristics of the area based on a combination of existing background information and information gained from the bore survey.

3. Locality & Setting

The Ruawai Plains area is a low-lying alluvial floodplain bordering the eastern banks of the Northern Wairoa River approximately 15 km south of Dargaville at the northern end of the Kaipara Harbour (Figure 1).

The Ruawai Plains comprise an area of approximately 89.8 km^2, with lateral extents of approximately 6.5-8 km east-west and 13 km north-south. The topography across the plains is flat and low-lying, varying from sea level to approximately 10 metres above mean sea level (mAMSL), with much of the land only slightly above sea level. Being so low-lying the plains require protection against flooding by a system of drains, canals, floodgates and stop-banks.

- **Figure 1. Locality Plan – Ruawai Plains**

  (see A3 attachment at rear).

4. Regional Geology

The geology of the Ruawai Plains area is described on the 1:250,000 Geological Map Sheet for Whangarei.

As with most coastal New Zealand settings, the geology of Ruawai Plains has been shaped by water and tectonics. The impacts of water include fluvial processes associated with the Wairoa River and marine processes associated with rise and fall of sea levels, resulting in erosion and deposition. The tectonic impacts have included both vertical and horizontal movement along fault lines on a local and regional scale.

In geologically recent times, the Wairoa River is likely to have meandered across what is now the Ruawai Plains depositing sedimentary materials eroded from the Northland hinterland. During times of flood, river banks were breached and overbank deposits laid down, with coarser grained materials (gravels and sands) occurring closer to the river and finer grained materials (clays and silts) deposited at greater distance from the source. The process was repeated, along with periods of erosion and quiet times where layers of peat, silt and clay were laid down under swampy conditions. While these sedimentary processes were happening, movement was also occurring along numerous faults, adding another level of complexity to the geological record. As a consequence, the Ruawai Plains as we now know them, are a down-faulted coastal plain comprising low swampy flats of undifferentiated Holocene alluvium consisting of alternating layers of fine to coarse materials.

The surrounding areas to the north and east are broadly described as tablelands of disordered sedimentary basement rocks; with sporadic isolated hill-ranges and sharp peaks of igneous rocks rising conspicuously (Figure 2).

- **Figure 2. Regional Geology – Ruawai Plains**
  (see A3 attachment at rear).

The sedimentary rocks underlying the Ruawai Plains and exposed east of the area, include from oldest to youngest:

- Mangakahia Group– Late Cretaceous-Palaeocene concretionary, micaceous sandstone with carbonaceous material, and hard, dark grey, siliceous shale.
- Opahi Formation– Eocene greensands, argillaceous limestone, and green and chocolate shale with flints.
- Motatau Group– Oligocene argillaceous and minor crystalline limestone (Whangarei Limestone) and argillaceous limestone with glauconitic sandstone bands.

The sporadic igneous rocks, most noticeable of which is Mt. Tokatoka to the immediate north of the Ruawai Plains, comprise basic pillow lavas, basalt breccias and intrusions of the Tangihua Volcanics and andesitic agglomerate, pumice breccia, pillow lavas and dikes of the Manukau Breccia.

5. Hydrogeology

The NRC bore database contains approximately 140 bores in the Ruawai Plains area, where drillers borelogs and other bore information is available. Figure 3 shows the approximate location of these bores. The available borelogs contain limited detailed geological information, partly because the favoured drilling technique is mud-rotary, which is not conducive to accurate geological logging unless the materials encountered are consolidated or coarse sand/small gravels, and partly because of limited details entered by the drillers. However, it can be seen that the underlying aquifers typically comprise alternating layers of silts, clays, peaty materials, black running sands, grey sands and gravels, and grey marine muds (typically in the west and south of the area), with underlying grey or white clays (interpreted as soft limestone), limestone, green sandstone and mudstone, and volcanic rocks in localised areas. This sequence of geological materials indicates a typical succession of alternating fluvial and shallow marine/estuarine deposits (alluvium), overlying more regional sedimentary basement rocks.

There is a trend apparent from review of the borelogs of coarsening downward through the alluvium profile. The implications of this are:

- shallow confining or semi-confining layers;
- increasing permeability (groundwater yields) with depth;
- potential for artesian heads in the deeper aquifer and upward groundwater gradients;
- deeper aquifer has low vulnerability from surface contamination under the current artesian conditions.

- **Figure 3. NRC Borelogs – Ruawai Plains**

  (see A3 attachment at rear).

Groundwater is found in varying quantity and quality within the alluvium, and is described on the geology map as being negligible in the underlying rocks (sedimentary rocks of Cretaceous and Arnold series).

Drillers' air lift tests indicate that the groundwater yields typically increase with depth within the alluvium, which tends to correspond to more frequent sand and gravel layers. Yields are typically in the range of 0.025-5 L/s with the majority of bore yields falling below 1 L/s. These yields are satisfactory for domestic, stock drinking water and shed washdown purposes, but probably insufficient for large scale irrigation or other high usage applications.

Groundwater pressures in the area are generally close to ground level and in many cases above ground level (artesian). The high groundwater table/pressures are due to the:

- lowlying nature of the area and surrounding hills which may impart lateral pressure into the plains, and
- finer grained lower permeability muds, silts, and clays forming confining beds within the top layers of the alluvium.

Flowing artesian bores are of concern for a number of reasons (Table 5-1). These issues require careful thought when considering capping these bores.

- **Table 5-1. Summary of flowing artesian bore issues.**

Do Nothing	Cap Flow
Reduces the amount of groundwater in the aquifer available to other users and dependent downstream ecosystems currently and in the future (depending on aquifer characteristics).	Where the bores have been flowing for a long time, capping the flow may destroy wetlands, streams and/or aquatic ecosystems that have developed or become dependent on the water.
Increases the risk of aquifer contamination from the surface (relative to natural condition) by reducing aquifer pressures.	

Groundwater quality within the deeper Ruawai Plains aquifer is generally considerably better than the surface waters, which are tidally influenced. However, there are problems in some bores with elevated aesthetic determinants such as manganese and iron, and saline groundwater in some places especially in the southeast adjacent to the Awaroa River and in the east. The elevated salt content is possibly due to:

- saline intrusion from the harbour;
- migration of seawater along the faultline that delineates the eastern boundary of the plains;
- connate salt derived from the underlying marine sedimentary rocks on the landward side of the plains.

It is important to note that there is no clear trend in groundwater quality across the site due to the many variables that are likely to contribute to the water quality in a bore. Some of these variables are listed below:

- bore construction techniques (varying screen depths, bore security, grout seals, casing type);
- bore integrity (age of bore, casing materials);
- bore location (aquifer geology, proximity to septic tanks, offal holes etc.);
- groundwater demand in area (over demand can cause reduction in water quality);
- interaction with surface water;
- saline intrusion.

5.1 Bore Drilling History

The NRC Database for the Ruawai area contains 138 bores that have been sunk over the last 38 years. An assessment was conducted of these records to determine any trends in the number of bores drilled and variation in construction technique each decade since the 1960's. As shown in Table 5-2, there is no trend evident, which is probably partly explained by the fact that until 1998 bore details were only forwarded to the council on an informal basis.

- **Table 5-2. Bore log data for the Ruawai region from 1965-2002**

Decade drilled	1960-79	1970-79	1980-89	1990-99	2000-02	not dated
No. of bores	1	2	22	6	3	104
Mean bore depth (m)	45	28	29	33	23	32
Mean casing diameter (mm)	100	Not given	85	100	Not given	53

5.2 Groundwater Take Consents

It is a "permitted activity" under the NRC Revised Proposed Regional Water and Soil Plan to abstract up to 30 m^3/day of groundwater for reasonable stock drinking needs or 2 m^3/day for reasonable domestic purposes, and five cubic metres of any other purpose. There are currently 8 consents for groundwater takes above this limit, varying from 50 to 450 m^3/day and comprising a total allocation from the Ruawai Aquifer Management Zone (not including "permitted activity" abstractions) of 1,185 m^3/day (Table 5-3). The position of the current consents is shown in Figure 4.

- **Figure 4. Existing Groundwater Consents.**

  (see A3 attachment at rear).

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- **Table 5-3. Exiting resource consents to take groundwater.**

NRC Consent Number	Owner	Allocation (m^3/day)	Bore Depth (m)	Expiry Date	Use
19970832601	G A Alexander	30		30-Jun-10	Pasture/Crop Irrigation
19990516301	B H Crompton	50	59.0	30-Jun-10	Horticultural Irrigation.
19920442901	Kevin Murray Reid	50		31-Dec-49	Other Livestock Farming
19960798201	McKinley Partnership	75	66.7	30-Jun-06	Horticultural Irrigation.
19960806702	James Leonard Simpson	100	48.0	30-Jun-10	Crop Irrigation
19960806703	James Leonard Simpson	100		30-Jun-10	Pasture/Crop Irrigation
20000395302	Kaipara Produce Limited	360		Renewal application in process	Public Water Supply
20010218701	Kaipara District Council	450	60.0	Renewal application in process	Public Water Supply
TOTAL		1,215			

5.3 Artesian Flowing Bores

One of the objectives of this study was to gain a better understanding of the extent and potential loss of groundwater in the Ruawai area as a result of uncapped flowing artesian bores.

During the bore survey 25 bores inspected were identified as artesian and of those six were flowing artesian. However, as previously stated in Section 2, the majority of properties visited have secondary or older bores that were not surveyed and in most cases the owners indicated that these bores were unused and uncapped. Assuming that the properties where the artesian bores were inspected have one additional uncapped bore that is also flowing to waste, the number of flowing artesian bores over the entire Ruawai Plains is estimated at approximately 32. This figure was derived from the area of the properties visited (2,557 hectares) over the entire area of the Ruawai Plains (8,976 hectares) (i.e., 28% divisor).

Based on the Wallace bore flowing artesian discharge (24.3 m^3/day) and slow drawdown rate, the rate of discharge for each flowing artesian bore is estimated at approximately 20 m^3/day (0.23 L/s). Therefore, the total discharge from flowing artesian bores within the Ruawai Plains is estimated at approximately 640 m^3/day (233,760 m^3/annum).

Although this is a very rough estimation it does suggest that there is the potential for a large volume of water to be flowing to waste in the Ruawai Plains area.

6. Rainfall & Evaporation

An understanding of the meteorological regime of an area, and in particular the difference between rainfall and evaporation, provides an indication of the surplus or deficits in water at various times of the year. When rainfall is significantly greater than evaporation, local streams are likely to have good flow and soil moisture deficits will be reducing. This results in more water available to recharge aquifers (groundwater) and as rising groundwater tables as a consequence of this.

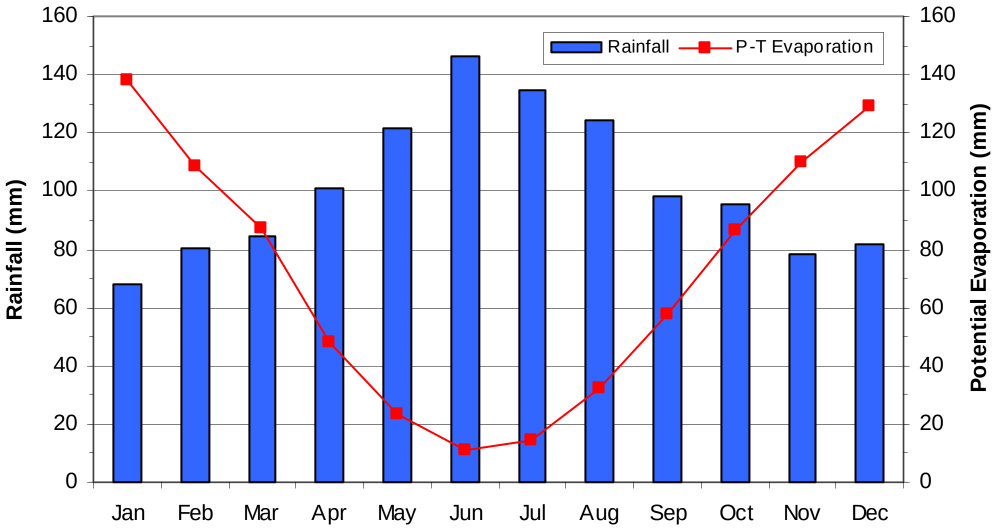

Figure 5. Mean Monthly Rainfall and Evaporation – Ruawai.

Figure 5 indicates that rainfall is greatest when evaporation is lowest in winter, and vice versa. Further analysis indicated that for six months of the year from April to September, rainfall is significantly greater than evaporation. Conversely, the six months from October to March, evaporation is equal to or greater than rainfall, indicating that in average years significant soil moisture deficits could develop during the summer months.

The implication for groundwater resources of this temporal pattern is the predominance of aquifer recharge during the winter months (April to September). This is a fairly uniform trend across much of the upper North Island.

7. Soils & Landuse Characteristics

The soils of the Ruawai area have been mapped by the now defunct Department of Scientific and Industrial Research (DSIR) and are shown on the NZ Land Inventory Map Sheet 290 Series. Gley Organic and Saline Soils are the principle soils in the area, with Kaipara clays the main type of gley soil. The Kaipara clays have a slight wetness limitation with high water tables and drainage is generally required. The soils are reasonably fertile and are utilised for vegetable growing and intensive grazing, and are considered the most versatile in the Kaipara Region.

Landuse characteristics were noted during the bore survey and compiled into the GIS plan shown in Figure 6. Please note that this figure is intended as indicative only, given that the survey did not visit every property in the region.

- **Figure 6. Landuse – Ruawai Plains.**

  (see A3 attachment at rear).

Dairy farming and kumara growing are the two primary landuse activities in the Ruawai region. Dairy farming has been established since the early 1900’s when the Northern Wairoa Dairy Company was first established. Approximately 90% of the total New Zealand kumara crop are also grown in the Ruawai region. The rich sand-loam of the alluvial flats and warm sub-tropical weather conditions make it conducive to growing excellent kumara. Kumara are grown using limited fertiliser, pesticide and herbicides compared with the majority of other horticultural crops. Qualitatively, this has a positive implication for water quality of both shallow surface water and groundwater resources.

8. Aquifer Conceptualisation

8.1 Hydrogeological Cross-Sections

Two hydrogeological cross sections (A-A’, B-B') as shown in Figure 7 have been produced for the Ruawai Plains. Cross section A-A’ is orientated roughly north to south and B-B' is orientated west to east. The section positions are indicated in plan view on Figure 4.

- **Figure 7. Hydrogeological Cross Sections – Ruawai Plains.**

  (see A3 attachment at rear).

The cross sections have been compiled from the drillers logs along or close to the respective transect lines, and from extrapolation of information from the 1:250,000 Geological Map Sheet for Whangarei. Due to the difficulty in interpreting the drillers logs and the lack of detail provided (as discussed in Section 5) the hydrogeological sections are indicative only. Hashed black lines represent interpolation or inferred geological boundaries, while hashed red lines are assumed groundwater equipotential lines (lines of equal groundwater pressure).

8.1.1 Aquifer Lithology

The Ruawai aquifer lithology comprises 45 to 60 m of undifferentiated alluvium typically consisting of alternating successions of mud, clay, silt, peat, sand and gravel associated with various phases of shallow marine and terrestrial fluvial activity in a deltaic setting. The soft and unconsolidated nature of the sediments makes it very difficult to separate out the various units while drilling using the rotary-mud techniques, which is favoured in this area. There is a relatively consistent occurrence of a 8-20 m thick, sand to gravel layer that appears to coarsen downwards at depths of between 40 to 60 m across the plains. This layer is the main groundwater yielding aquifer and is currently tapped by the Ruawai township water supply bores, the Ruawai Bowling Club and various others.

Although only a few bores penetrate the entire thickness of the alluvium and provide borelogs with enough details to assess the geology with reasonable confidence, it is likely that argillaceous limestone and glauconitic sandstone underlie the alluvium within the Ruawai Plains area.

8.1.2 Aquifer Flow Regime

The assumed groundwater equipotential lines and groundwater flow direction arrows shown in Figure 7 provide a preliminary conceptual understanding of the aquifer flow regime. This understanding has been developed based on measured groundwater pressures at various screened intervals (depths) within the aquifer, knowledge of artesian areas and hydrogeological intuition in areas where data is lacking or unreliable due to bore construction issues (over much of the area). The conceptual understanding of the aquifer flow regime should thus be treated as preliminary in the absence of more detailed groundwater monitoring data.

Similar groundwater flow geometry is shown on both cross sections, comprising three bulk aquifer flow zones that consist of:

- a recharge zone to depths of approximately 10-20 m (shallow aquifer);
- a lateral flow zone at depths of 20-40 m (intermediate aquifer); and
- an upwelling zone at depths greater than 40 m (deeper aquifer).

Areal groundwater recharge (downward movement) occurs over much of the floodplain. The downward vertical movement of groundwater becomes progressively more horizontal with depth, with the horizontal flow in a downgradient direction towards the river and harbour depending on position within the plains (i.e., north to south and east to west). Within the sand and gravel zone in the lower portion of the alluvial aquifer and in the underlying sedimentary aquifer, groundwater pressures are greater than the overlying aquifer indicating upwelling.

A progressive transition from surface recharge to surface discharge zones is evident towards the river and harbour and this conforms to the standard hydrogeological model. Convergence of groundwater at the Wairoa River from both sides of the valley is demonstrated in Section B-B'.

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8.2 Piezometric Surface Distribution

Depth to groundwater varies from ground level (artesian pressures) to 14 metres below ground level, although some of this variation is due to the different screen depths of the bores. Bearing this in mind, Figure 8 shows the depth to groundwater contours across the Plains. The zones of artesian pressures cover an extensive area (highlighted blue) and generally occur along the coastline and Wairoa River bank, and on the eastern side of the plain. Under times of higher groundwater pressures some of the areas shown in the blue-grey shade are also likely to be artesian.

Groundwater pressures above or near the ground surface are likely to be a function of i) the lowlying nature of the area and consequent poor drainage and ii) upward groundwater pressures from the underlying aquifer.

Figure 9 shows the piezometric surface geometry calculated from the depth to groundwater and estimated land surface elevation. The piezometric surface was constructed using groundwater pressure data for all bores situated within the alluvium. The groundwater pressures range from -6 mAMSL near the southeastern edge of the Plain to 20 mAMSL near the northern edge. The groundwater flow direction is from the higher ground at the northern and eastern boundaries of the Plains towards the Wairoa River and harbour.

- **Figure 8. Depth to Groundwater – Ruawai Plains.**

  (see A3 attachment at rear).

- **Figure 9. Piezometric Surface – Ruawai Plains.**

  (see A3 attachment at rear).

8.3 Aquifer Hydraulic Properties

Information on aquifer properties is available from test pumping exercises conducted on the Ruawai town supply bores during 1987 by Cook Costello Ltd[2]. The test pumping results are summarised in Table 8-1. Transmissivity is estimated as 110 m^2/day and hydraulic conductivity is estimated as 18 m/day. The hydraulic conductivity value is consistent with publicised valued for clean and silty sands (Freeze and Cherry, 1979).

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[2] Cook Costello Ltd, 1987. Report to Otamatea County Council on Ruawai Water Supply. Report dated 5 October 1987.

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Table 8-1. Summary of Town Supply Bore Aquifer Properties.

Bore	Analysis method	Transmissivity (m^2/day)	Saturated thickness (m)	Hydraulic conductivity (m/day)	Discharge (m^3/day)
Bore 2A	Jacob	109.8	6.0	18.3	300

Additional information on aquifer hydraulic properties was obtained from test pumping exercises conducted by SKM personnel on three bores during September 2003.

Table 8-2 summarises the details of the bores assessed, while Appendix D provides the aquifer test field observations and calculations.

Table 8-2. Aquifer Test Pumping Bore Details.

Bore Owner	NRC Bore No.	Depth (m)	Diameter (mm)	Screen depth (m)	Distance from pumping bore (m)
R. & C. Antonio – pumping bore	208378	11	100	8	-
R. & C. Antonio – observation well	-	4	1200	4	10
P. Flood		70	100	64	-
H. Wallace	-	20	75	Unknown	-

The bores were pumped at a constant rate for between 7 and 30 hours. Discharge was measured using a bucket and stopwatch. The shorter tests conducted on the Flood and Wallace pumping bores ended prematurely (7 and 10 hours, respectively) as the pump automatically switched off.

Table 8-3 provides a summary of test pumping results and indicates that transmissivity varies from 14 to 132 m^2/day, which are similar to results obtained from pumping tests conducted on the Ruawai town water supply bores. Hydraulic conductivity varies from 4.6 to 22 m/day, which are at thigh high end of published values for silty sands and low end of values for clean sands (Freeze and Cherry, 1979).

Further assessment of the hydraulic test data from all sources indicates a trend of increasing hydraulic conductivity with increasing bore depth. This supports the conceptual hydrogeological model of a coarsening downwards alluvial sequence.

A storativity (specific yield) value of 0.13 was determined from the observation bore of the Antonio bore test. All other tests provided unreliable storativity values because observation bores were not available.

- **Table 8-3. Summary of SKM Test Pumping Results.**

Bore	Analysis method	Transmissivity (m^2/day)	Saturated thickness (m)	Hydraulic conductivity (m/day)	Discharge (m^3/day)
Antonio – pumping	Jacob	29.0	3.0	9.7	86.4
Antonio – obs.	Jacob	18.0	3.0	6.0	-
Flood	Jacob	131.8	6.0	22.0	86.4
Wallace	Jacob	13.8	3.0	4.6	24.2

8.4 Groundwater Chemistry/Quality

The NRC database contains water quality information for seven bores in the Ruawai area. Table 8-4 summarises the latest sampling results for these bores. Also included in Table 8-4 are groundwater quality data for Town Supply Bore 1, sourced from Duffill Watts & King Ltd[3].

Values in Table 8-4 that exceed the Drinking Water Standards for New Zealand[4] (DWSNZ) are highlighted in red. Exceedances occur for the following list of parameters (guideline value in brackets), which are all aesthetic determinants under the DWSNZ:

- Chloride (250 mg/L)
- Ammonia (1.5 mg/L)
- Total hardness (200 mg/L)
- Iron (0.2 mg/L)
- Manganese (0.05 mg/L)
- pH (7.0 - 8.5)
- Sodium (200 mg/L)
- Turbidity (2.5 NTU)

None of the above parameters exceed the Maximum Acceptable Value for health, however exceedance of the aesthetic guideline values indicates that the groundwater in some bores have an unpleasant taste and appearance. The problems that have been experienced at Ruawai range from

[3] Duffill Watts & King Ltd., 2003. Attachment to letter sent to Sinclair Knight Merz 26 May 2003.

[4] Ministry of Health, 2000. Drinking Water Standards for New Zealand 2000. Ministry of Health, Wellington.

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'rusting' of pipework due to high iron & manganese, scale deposition due to high total hardness, and 'salty' water due to high sodium and chloride.

The elevated parameters listed above are a function of the hydrogeology of the Ruawai Plains, specifically the proximity to coastal waters, nature of surrounding sedimentary rocks (possibly high connate salts), and faulting, which may act as a conduct for poorer quality water on the eastern margin of the plain. In addition, bore construction and condition is likely to be a major determinant of water quality especially where water quality has changed markedly within a bore.

- **Table 8-4. Summary of Groundwater Quality Results.**

Parameter (mg/L)	Town Supply Bore 1	Town Supply Bore 2	Town Supply Bore 3	Harris Farm	Kaipara Products	Tearooms	Lugtigheid	Preston Farms
NRC Sampling Site No.	-	102111	102110	105206	106134	106135	106693	106920
Date sampled	20/02/03	15/01/03	22/05/03	22/05/03	30/10/02	30/10/02	22/05/03	22/05/03
Chloride	-	104	131	1860	140	149	224	137
Conductivity (µS/cm)	-	562	410	444	-	-	1020	571
Dissolved Oxygen	-	7.5	-	-	-	-	-	-
E. coli (cfu/100 mL)	<1	<1	<10	<10	-	-	<10	<10
TON	-	<0.002	-	-	-	-	-	-
Ammonium	-	-	0.1	5.49	-	-	0.7	0.26
Nitrate	-	-	<0.002	0.003	-	-	<0.002	<0.002
Nitrite	-	-	<0.002	0.033	-	-	<0.002	<0.002
DRP	-	-	0.056	0.030	-	-	0.021	0.013
pH (pH units)	7.0	6.4	7.7	6.6	-	-	-	-
Sodium	-	-	71	397	-	-	175	73.4
Potassium	-	-	3.87	22.2	-	-	5.86	3.11
Magnesium	-	-	6.35	-	-	-	18.9	6.91
Sulphate	-	-	7.3	<0.5	-	-	6.8	1.6
Calcium	-	-	-	-	-	-	-	34.9
Alkalinity	-	118	135	125	-	-	364	128
COD	-	<6	-	-	-	-	-	-
Total Hardness	-	115	113	899	-	-	215	116
Total Iron	5.57	0.2	-	-	-	-	-	-
Total Manganese	0.308	0.122	-	-	-	-	-	-
Total Sulphide	-	<0.002	-	-	-	-	-	-
Turbidity (NTU)	25	0.35	-	-	-	-	-	-

Water quality field parameters (pH, electrical conductivity (EC), total dissolved solids, and temperature) were measured for a number of bores during the bore survey. Appendix C contains the measurements recorded. In general, the variation in water quality across the plains was not significant, with the exception of EC, which is shown in Figure 10. Generally (poor bore construction aside), bores that are shallow have higher EC. Most of the sampled bores near the harbour that had lower EC were drilled to greater than 50 m and were artesian. These observations are consistent with the discussion of the conceptual aquifer understanding in Section 8.1.

- **Figure 10. Electrical Conductivity Distribution – Ruawai Plains.**

  (see A3 attachment at rear).

EC varied from 180 to 7,300 µS/cm, and was generally lowest near the Wairoa River and highest towards the eastern boundary of the plains and in particular places where surface water drainage is poorest. Possible mechanisms for this trend could include combinations of the following, although further research and consideration of bore integrities would be required to confirm this:

- runoff or throughflow of more saline waters from the marine sedimentary rocks of the eastern hills;
- saline intrusion from the harbour in the south of the plains area;
- migration of sea water along the fault on the eastern boundary of the plains; and
- high degree of flushing of the aquifer in areas adjacent to the fresh water drainage courses.

8.5 Groundwater Age

An assessment of groundwater age has been conducted for the Ruawai town water supply to satisfy age criteria specified in the DWSNZ for public water supplies for determining the vulnerability of the aquifer to contamination. Samples taken from Town Supply Bore No. 1 during January 2003 were analysed for CFC and tritium concentrations by the Institute of Geological & Nuclear Sciences[5].

The concentration of CFC's in the atmosphere has been steadily increasing since production of CFC's began in the 1940's. Incorporation of the CFC's into water molecules and subsequently into surface recharge allows the age of the groundwater to be determined. Likewise, tritium is incorporated into rainwater from small quantities naturally present in the atmosphere. Tritium is a radioactive isotope of hydrogen and is found at low levels (< 10 tritium units) in groundwater older than 1954. Groundwater systems with recharge occurring after the 1950's will have elevated tritium levels as a result of nuclear weapons testing.

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[5] IGNS, 2003. Age Dating of Groundwater. Letter from Institute of Geological & Nuclear Sciences Limited to Duffill Watts & King dated 5 May 2003.

The average age of the groundwater sampled from the deep Ruawai town water supply bore was estimated conservatively as >100 years. The young fraction of the water (water with age less than one year) was less than 0.005 %. As the residence time of the groundwater in the aquifer is greater than one year the aquifer from which the town supply bore is abstracting from is not considered to be vulnerable to contamination by pathogenic organisms under existing bore construction conditions

8.6 Implications of Conceptual Aquifer Understanding

The implications of the conceptual understanding of the aquifer flow regime in terms of groundwater age and quality is hypothesised as follows:

Shallow Aquifer Zone

- groundwater in this zone is likely to be significantly younger than that residing in the deep aquifer zone;
- the lack of a strong groundwater flow gradient on to the eastern backs of the Wairoa River indicates that surface water quality in this area is likely to be influenced by mixing with tidal water from the river;
- vulnerability to contamination as a result of land surface activities is considered reasonably high for the following reasons;
  a) downward flow direction and reasonably high hydraulic conductivity of the materials at approximately 5-10 m/day (see Section 8.3) indicates the potential to readily accept surface water into the aquifer;
  b) reduction and then reversal in pressure gradient with depth coupled with poor surface drainage (i.e., weak groundwater gradients) means flushing rates are low and contaminants movement slow.

Deeper Aquifer Zone

- groundwater within the deeper aquifer zone (sand and gravel layers) is old water (>50 years) comprised from waters sourced predominantly from lateral recharge and upwelling from the hinterland sedimentary basement rocks, with some vertical recharge from the plains above;
- due to the natural filtering through rock and sediments water quality is likely to be generally good, although faulting may provide a conduit for transmission of poorer quality water, so there may be localised patches of poorer quality water;
- the vulnerability of the deeper zone to surface contamination is considered low.

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9. Sustainability of Groundwater Abstractions

Based on the above conceptual understanding of the aquifer, a preliminary assessment of the sustainability of groundwater abstraction has been carried out. The assessment considers the shallow and deeper aquifers as separate bulk systems, although in practice there is no discrete boundary, with the bulk change in aquifer properties likely to be gradational. The hydraulic gradient has been used in the calculation based on the assumption that the hydraulic gradient reflects the imposed aquifer stresses (recharge and discharge processes, including free flowing artesian bores), given known aquifer hydraulic conductivity.

The following data and assumptions have been used in the calculation:

- **Table 9-1. Summary of Aquifer Discharge Preliminary Estimate.**

	Average Hydraulic Gradient (m/m)	Average Hydraulic Conductivity (m/day)	Storativity (-)	Discharge Area (m^2)	Discharge Volume (m^3/day)
Shallow Aquifer	0.0006	7.5	0.13	19 km x 30 m	25,650
Deeper Aquifer	0.0006	20	0.13	19 km x 30 m	68,400
TOTAL					94,050

The calculated aquifer discharge volumes from the shallow and deeper aquifer zones are approximately 25,000 m^3/day and 70,000 m^3/day, respectively. To provide a ballpark check on the combined discharge volume for the aquifer, a calculation was performed using average rainfall (1,200 mm/year) over the aquifer (8,976 hectares) and a recharge coefficient of 30%. This calculation resulted in a discharge volume of 88,470 m^3/day, which is similar to the total aquifer discharge of 94,000 m^3/day in Table 9-1. This indicates that the mass balance calculation is reasonable.

In the absence of a more dynamic assessment of aquifer sustainability and as a rough rule of thumb, 30% of the aquifer discharge volume is set aside for sustaining environmental ecosystems. In addition to this, a volume (say 30%) should be set aside for stock drinking water and for mitigating issues such as loss of artesian pressures. On this basis, sustainable yields from the Ruawai are in the order of 10,000 m^3/day for the shallow aquifer and 27,000 m^3/day for the deeper aquifer. These figures indicate that the existing total groundwater allocation of approximately 1,200 m^3/day is significantly less than what is potentially available.

10. Summary & Conclusions

10.1 Groundwater Issues

The main issues potentially affecting the quantity and quality of groundwater on the Ruawai Plains include:

- ***Bore integrity*** **-** there are a number of bores with unsecured wellheads, which have the potential to allow contaminants to enter the aquifer during times of lowered groundwater pressures due to pumping or seasonal influences.
- ***Free-flowing artesian bores*** – these bores depressurise the aquifer and reduce the volume of groundwater for future use. However, before capping consideration must be given to the aquatic ecosystems that the free-flowing bores may be supporting.
- ***High dissolved salts*** – the concentration of dissolved salts increases across the Plains from west to east, and is also relatively high in the southeast. This is possibly due to saltwater intrusion from the harbour, seawater migrating along the eastern boundary fault line, and possibly poorer quality water from the marine sedimentary rocks within the eastern hills seeping into the Ruawai aquifer.
- ***Iron, manganese and total hardness*** – elevated concentrations of these parameters occur in some locations, which is typical of fluvial aquifers.
- ***Landuse issues*** – fertilisers, dairy effluent, and kumara excavation pits are likely to be contributing to elevated levels of bacteria, nitrogen and phosphorus in surface water and shallow groundwater.

10.2 Conceptual Hydrogeology

The Ruawai aquifer comprises 45 to 60 m of undifferentiated alluvium consisting of alternating successions of mud, clay, silt, peat, sand and gravel. The material has been deposited under alternating terrestrial fluvial and marine conditions in a deltaic setting during the Holocene period. An 8-20 m thick layer of coarsening-downwards sand to gravel is consistently found across the plains at the base of the alluvium. Underlying the alluvial aquifer is a hardrock aquifer of glauconitic sandstone and limestone of significantly lower permeability.

In summary, the Ruawai alluvial aquifer is comprised of three bulk aquifer flow zones that consist of:

- a recharge zone to depths of approximately 10-20 m (shallow aquifer);
- a lateral flow zone at depths of 20-40 m (intermediate aquifer); and
- a zone of high groundwater pressure (artesian) at depths greater than 40 m (deeper aquifer).

Groundwater pressures generally increase with depth, which indicates that the shallow aquifer materials of generally of lower permeability and provide a degree of confinement. The occurrence of coarsening downward sand and gravel unit at the base of the alluvial aquifer suggests that in general the aquifer permeabilities generally increase with depth.

10.3 Implications of Hydrogeology

The implications of the conceptual understanding of the aquifer flow regime in terms of groundwater age and quality is summarised as follows:

Shallow Aquifer Zone

- groundwater in this zone is likely to be significantly younger than that residing in the deep aquifer zone;
- the lack of a strong groundwater flow gradient towards the Wairoa River indicates that surface water quality in this area is likely to be influenced by mixing with tidal water from the river;
- vulnerability to contamination from land surface activities is considered reasonably high, and
- interaction with surface water bodies (drains) means that surface water will also be vulnerable to contamination.

Deeper Aquifer Zone

- groundwater within the deeper aquifer zone (sand and gravel layers) is old water (>50 years);
- due to the natural filtering through rock and sediments water quality is likely to be generally good, although faulting may provide a conduit for transmission of poorer quality water;
- the vulnerability of the deeper zone to surface contamination is considered low under current demand and landuse activities.

Current surface activities within the Ruawai area are unlikely to affect the deeper aquifers (>20 depth) because of:

a) the upward groundwater pressures from the underlying aquifer which act to withhold downward percolation of groundwater – providing a form of hydrogeological security against contamination, and

b) the stratified and generally lower permeability characteristics of the shallow aquifer.

However, landuse activities in the future (i.e., increased groundwater abstraction associated with more intensive dairying and/or horticulture) have the potential to alter the hydrogeological security of the deeper aquifer if significant groundwater pressure reductions occur. The most significant concerns with regard to vulnerability to contamination exist for the top few meters of the aquifer.

This shallow groundwater is likely to discharge into the surface water networks on the Ruawai Plains. Therefore, current land use activities in the Ruawai area, such as dairying, have the potential to result in bacterial and nutrient (nitrogen and phosphorus) contamination of the surface water resources in the area.

10.4 Sustainability of Groundwater Abstractions

Preliminary estimates of annual average sustainable yield from the Ruawai aquifer are in the order of 10,000 m^3/day for the shallow aquifer and 27,000 m^3/day for the deeper aquifer. This has been estimated from the calculated aquifer discharge volumes from the shallow and deeper aquifer zones of approximately 25,000 m^3/day and 70,000 m^3/day, respectively.

The preliminary sustainable yield figures indicate that the existing groundwater allocation from the Ruawai aquifer of approximately 1,200 m^3/day is significantly less than what is potentially available.

However, this assessment is considered very preliminary based on the limited real time groundwater monitoring data and reliable drillers logs available. In this respect, it will be important to gain an improved understanding of the groundwater response to seasonal fluctuations, shifts in climate and groundwater pumping, to enable a more dynamic and accurate assessment of aquifer sustainable yields. The following section provides recommendations that will facilitate this.

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11. Recommendations

Based on the findings from this study, without knowledge of NRC's priorities and statutory obligations, SKM recommend the following activities and studies are undertaken:

- Undertake a workshop with local drillers to highlight/demonstrate through case studies the importance of detailed drilling information, especially detailed lithological logs, air lift water flow rates, drawdown levels etc.
- Begin real-time groundwater pressure monitoring in at least two bores screened within the deeper aquifer, and located at opposite sides of the plains. It would also be useful to monitor a shallow bore at each location to enable comparisons and assessment of aquifer coupling. Existing bores have been identified for this monitoring at the following locations:

Owner	NRC No.	Easting	Northing	Depth
West				
P Wilson	-	2601473	6563607	42
KDC Town Supply Bore	208297	2602500	6562100	61
East				
T Brcich	208151	2605660	6564903	52

- Carry out quarterly groundwater quality monitoring in both the shallow and deeper aquifer for all major anions and cations, nutrients and metals. A control site with a shallow and deep bore pair would be preferred. : Unfortunately, no bore pairs were identified during the bore survey as not all bores on each property were visited.
- In accordance with the principles of adaptive management, initiate the development of a groundwater model to assess the groundwater flow rates and sustainable yield of the aquifer, and assess water chemistry transport from surficial sources.
- Investigate shallow groundwater contamination and the shallow groundwater and surface water interaction.
- Consider management options to address the issue of flowing artesian and uncapped bores in the Ruawai area.

Appendix A Media Release

The following is the media release advertising the SKM/NRC field survey.

NORTHLAND REGIONAL COUNCIL

Phone: (09) 438-4639

Fax: (09) 438-0012

MEDIA RELEASE

Number of Pages: 2

Date: 30 July, 2003

FOR IMMEDIATE RELEASE

PUBLIC HELP SOUGHT FOR RUAWAI PLAINS GROUNDWATER SURVEY

People with bores on Kaipara's Ruawai Plains are being asked for their help as the Northland Regional Council studies the area's valuable groundwater resource.

A new Council study aims to determine how much groundwater can safely be taken from the Ruawai aquifer system.

As part of the study, bores will be surveyed to work out;

- The depth of groundwater across the plains
- The typical depths and diameters of bores drilled there
- The permeability of underlying aquifers.

The bore survey will involve staff from the Council and Auckland-based environmental and engineering consultants Sinclair Knight Merz Ltd.

Regional Council Groundwater Management Officer Susie Osbaldiston says staff taking part in the study plan to visit as many properties as possible between Monday 11 August and Friday 15 August.

"However, due to the limited time available, we anticipate that some properties may not be visited. This is most likely to occur in areas where a relatively high concentration of bores are located and a neighbouring bore was surveyed."

Ms Osbaldiston says it should take no more than 30 minutes at each property to take measurements and photograph the bore. "We would really appreciate locals' cooperation in allowing us access to their properties to do this."

Ms Osbaldiston says once the bore survey has been done and the collected data reviewed, the Council intends to select two bores to conduct test pumping exercises.

"This would involve running the bores at a continuous rate for 24 hours, and monitoring the groundwater level drawdown in the bores and any neighbouring bores. Results from these tests will provide information about the aquifer's ability to transmit water.

Members of the public with questions are asked to contact either ***Susie Osbaldiston*** at the Northland Regional Council on (09) 438 4639 or ***Donna Grimshaw*** at Sinclair Knight Merz on (09) 913 8999 ext. 8802.

ENDS

MEDIA: For further information, contact Northland Regional Council Groundwater Management Officer Susie Osbaldiston, ph (09) 438 4639.

G/Drive, ECO-Team, "Ruawai bores July 03"

Appendix B Bore Survey Data Sheets

Appendix C NRC Bore Database with SKM Data Appended

Appendix D Aquifer Test Results