May 2014

POVERTY BAY GROUNDWATER MANAGEMENT

MAR Feasibility Stage 1A - Conceptual Model

Submitted to:
Dennis Crone
Gisborne District Council
Water Conservation Team Leader
15 Fitzherbert Street
Gisborne
New Zealand 4010

REPORT

Report Number: 1378110136-003

Table of Contents

1.0 INTRODUCTION 1

1.1 Background 1

1.2 Report Scope and Structure 1

2.0 MAR ASSESSMENT METHODOLOGY 2

3.0 POVERTY BAY MAR STAGE IA ASSESSMENT 3

3.1 Introduction 3

3.2 Summary of Water Management Challenges and Needs 3

3.3 Data Collection and Compilation 5

4.0 PHYSICAL AND ENVIRONMENTAL SETTING 5

4.1 Introduction 5

4.2 Geology 5

4.3 Hydrogeology 7

4.3.1 Aquifer structure 7

4.3.2 Shallow Fluvial Aquifer 9

4.3.3 Waipaoa Gravel Aquifer 9

4.3.4 Te Hapara Sand 9

4.3.5 Makauri Gravel Aquifer 9

4.3.6 Matokitoki Aquifer 12

4.3.7 Other aquifers 12

4.4 Hydrology 12

4.4.1 Introduction 12

4.4.2 Aquifer recharge 14

4.4.3 Source water – availability and timing 14

4.5 Water Quality 14

4.5.1 Potential source water 14

4.5.2 Potential receiving water 15

4.6 Water Use 15

5.0 POVERTY FLATS GROUNDWATER REPLENISHMENT MODEL 16

5.1 Introduction 16

5.2 GoldSim for Poverty Flats 19

5.3 User Interface – Control Panel 19
5.4 Model Logic and Inputs 21
5.5 Model Results 21
5.6 Model Extensions 21
6.0 CONCLUSIONS 21
7.0 LIMITATIONS 22
8.0 REFERENCES 22

TABLES

Table 1: Poverty Flats aquifer water usage. 16

FIGURES

Figure 1: Poverty Bay Flats location map. 6
Figure 2: Conceptualisation of groundwater flow in Poverty Bay Flats (White et al 2012). 7
Figure 3: Surface geology and bores with lithological logs. 8
Figure 4: Map of transmissivity values in the five main Poverty Bay aquifers. 10
Figure 5: Location of groundwater pressure monitoring locations for the Poverty Bay aquifers. 11
Figure 6: Irrigation and surface water monitoring location map. 13
Figure 7: Map of allocated groundwater takes by aquifer. 17
Figure 8: Map of measured groundwater takes by aquifer. 18
Figure 9: Preliminary Poverty Bay groundwater replenishment model schematic. 20

APPENDICES

APPENDIX A
Groundwater Pressure Records

APPENDIX B
Water Quality Data

APPENDIX C
Report Limitations

1.0 INTRODUCTION

1.1 Background

The Gisborne District Council (GDC) has identified long term water availability in the Poverty Bay area as being a potentially limiting factor in future regional development. For this reason the council is investigating water management options to sustain and potentially increase water availability in the future.

The management of groundwater storage using Managed Aquifer Recharge (MAR) is being assessed for the lower portion of the Waipaoa River catchment in the Poverty Bay Flats groundwater system. The GDC through its' Freshwater Advisory Group (FwAG) has commissioned the exploration of groundwater replenishment through medium advice grant funding (Environlink Programme) from the Ministry of Science and Innovation (MSI).

Groundwater pressure declines measured in portions of the Poverty Bay Flats aquifer system, clearly indicate historical over abstraction through long term groundwater pumping (Barber 1993, White et al. 2012). The use of MAR to help groundwater systems stabilise, recover and then be proactively managed for increased sustainable water yields is an internationally recognised water management approach. For this reason the GDC and FwAG are interested in MAR as one potential component of the long term water management system for the Poverty Bay area.

This report represents the deliverable from the first stage (Stage 1A) of a two part project to:

1) Outline a "Go/No-Go" risk assessment process leading to a MAR pilot project
2) Provide a preliminary summary of the data collection and analysis relevant to MAR
3) Present a conceptual overview for a GoldSim water balance model for the Poverty Bay Flats groundwater system

1.2 Report Scope and Structure

Stage 1A of the project was conducted through a collaborative technical partnership between GDC, Golder Associates (NZ) Limited and the University of Waikato (UW). A UW student internship was created at GDC (December 2013 through February 2014) to support the data assembly, initial analysis and compilation component of Stage 1A. Golder technical staff utilised the compiled information to develop the draft conceptual groundwater model presented in this report.

Stage 1B of the project will focus on development and calibration of a model of the Poverty Bay aquifer system using the GoldSim numerical modelling package. The report from Stage 1B will also present the MAR risk assessment and recommendations for a Stage 2 pilot project (if deemed viable).

This report is structured to:

1) Introduce a method whereby MAR projects may be assessed (Section 2.0).
2) Provide background information on historical groundwater assessment and outcomes for the Poverty Bay Flats aquifer system (Section 3.1).
3) Identify some of the challenges and needs with respect to water management in the Poverty Bay area (Section 3.2).
4) Summarise the process of data collection and compilation (3.3).
5) Summarise the physical and environmental setting of the Poverty Bay aquifer system (Section 4.0).
6) Set out the conceptual GoldSim model for the Poverty Bay aquifer system (Section 5.0).
7) Provide conclusions with respect to the work completed to date that lead into Stage 1B of the project (Section 6.0).

2.0 MAR ASSESSMENT METHODOLOGY

The decision matrix that will be used in Stage 1B is modified from Australia's assessment guidelines, which are specifically designed for the purpose of investigating, developing and commissioning MAR projects (NMRCC 2009, Dillon et al 2009). The Australian guidelines generally describe MAR assessment as a four stage assessment process:

- Stage I – Conceptual model and desktop assessment
- Stage II – Viability and risk assessment with field testing
- Stage III – Further trials, validating conceptual models and viability of long term operations
- Stage IV – Groundwater replenishment scheme development and verification, including development of further site(s), revenue and consenting structures, long term sustainable management goals

While the Australian guidelines provide a good basis with which to assess MAR, they do not include some factors relevant to the unique cultural, social and physical environments of New Zealand. Golder has therefore refined the guidelines to be more applicable to New Zealand conditions. These refinements will be covered further in the Stage 1B report.

Fundamental questions to be addressed in a MAR assessment as per the Australian Guidelines are set out below.

- **Conceptual MAR model** – Is there potential for a clear understanding and expectations to be developed for the MAR objectives and goals and whether these are realistically achievable based on Stage I available information?
- **Infrastructure / physical settings / logistics** – Are potential MAR test site(s) favourable for the capture, delivery, percolation or injection and operational management of a pilot project?
- **Source water** – Are data available or readily collected on the source water (to be recharged) with respect to quality, availability (timing / volumes), infrastructure (delivery), consenting and operations (e.g., willing water purveyors)?
- **Target aquifer(s)** – Are data available or readily collected on the target storage aquifer(s) for parameters such as storage capacity (e.g., freeboard), hydrogeological conditions (e.g., unconfined or confined, aquifer hydraulic parameters), geochemistry, existing water quality and any potential concerns, consenting?
- **Environmental / economic –** Are data available or readily collected on the likely groundwater-dependent environmental influences of a MAR project(s) as well as an assessment of economic drivers (e.g., water demand exceeds supply) and cost-benefit analysis favouring project development?
- **Monitoring / modelling –** Will existing and/or readily installed project-specific monitoring systems be sufficient to adequate data for the evaluation of the pilot test program? What kinds of modelling would be needed to help to evaluate and potentially manage the viability of a system-wide replenishment programme?
- **Collaboration / partnerships –** Community, governmental, water management agencies, water purveyors and other stakeholders (e.g., iwi, environmental, etc.) will need to be informed and engaged regarding the development of MAR relative to their specific needs and regulatory requirements.
- **Regulatory / consenting –** Are local, regional and/or national water plans and regulations favourable or can they be modified to provide for MAR pilot tests and eventually potential groundwater replenishment scheme development?

Information pertinent to these questions and topics is set out in this report. These questions are to be addressed in the Stage 1B report.

3.0 POVERTY BAY MAR STAGE IA ASSESSMENT

3.1 Introduction

In 1993, an assessment (Barber 1993) of the Poverty Bay Flats aquifer system in the Waipaoa River catchment indicated that groundwater pressure levels in the Makauri aquifer were in decline. The report stated groundwater did not recover to previous levels even following a wet summer with assumed relatively low seasonal water demand.

Nearly 20 years later, a GNS report commissioned by GDC re-evaluated the main shallow and deeper aquifers of the Poverty Bay flats and concluded that groundwater pressures have continued to decline (White et al 2012). This conclusion is consistent with GDC's techincal staff assessment of the groundwater situation (Paul Murphy, per comm, April 2014). This report indicated groundwater pumping was the primary cause of the decline. Data presented in this report indicated Poverty Bay's deeper gravel aquifers (Makuri and Matokitoki) were the most utilised in this area. Both showed statistically-significant pressure declines ranging from 0.02 m/year to 0.1 m/year over a period of more than 25 years between the early-mid 1980s and 2011. The absence of corresponding climate trends during this period (GDC 2011) support the conclusion reached by White et al. (2012) that an abstraction overdraft was likely the major driver in declining groundwater storage.

An assessment of groundwater geochemistry (White et al 2012) indicates that seaward-directed groundwater flow rates in the Makauri and Matokitoki aquifers are likely to be very low. This conclusion is consistent with a groundwater budget developed for the system and documented in the same report. Concerns over the sustainable groundwater availability and the potential for saline water intrusion (from groundwater over-pumping) were also expressed. The report by White et al (2012) concludes that groundwater allocation policies are crucial for the sustainable management of this aquifer system.

GDC staff and the FwAG members identified that the use of groundwater replenishment with MAR should also be explored as part of the potential mitigations. Hence, the commissioning of this project and assessment reporting.

3.2 Summary of Water Management Challenges and Needs

The GDC is currently conducting a water supply and demand study, which FwAG members believe will quantify what they already expect to be true:

- That the current uncertain reliability of water supply will be a constraint on the future economic growth of the region.
- Some water resources in the region, if not already over-allocated, soon will be, although this depends on what limits and minimum flow criteria are set (GDC 2013).

Factoring in the expected variability of a changing climate is likely to make water supply even less reliable for the region. On-going gains in irrigation efficiency will assist toward managing groundwater systems within allocation limits. There can however, be little doubt that improved management of water storage, either as purpose built surface or in groundwater supplies, will be needed. The FwAG is considering multiple options for these storage needs as part of formulating the water plan for the catchment.

FwAG members have in the past looked at ways of increasing water availability through storage. They have found the prevailing attitude often seems to be that the Poverty Bay Flats is too small an area to support a major water storage initiative. This area is also apparently not nationally significant enough to attract Central Government support. Other regions have however, managed to justify such projects on much lower economic benefits per cubic metre of available water (e.g., \$1-3/m^3 for pastoral uses) than would be achieved from irrigation on the Poverty Bay Flats where there are a number of important crops yielding \$5/m^3 to \$15/m^3 (GDC 2012).

Previous work has indicated the monetary value of water in the Gisborne area (Doak et al. 2004). Specifically, surface water resources have been valued at about $11.3 million (GDC 2012). Annual consented surface water use is equivalent to 1.7 m^3/s (Aqualinc 2013). Assuming that the proportion of actual use to consented allocation is approximately 30 % (GNS 2012), the actual surface water use is likely equivalent to a flow of 500 L/s. Assuming that the price of groundwater is the same as for surface water, then the corresponding value of groundwater actual use, a flow of about 300 L/s, may be upwards of $7 million. On this basis, the estimated value of surface and groundwater used is around $18 million per annum.

The ongoing decline in groundwater levels threatens the sustainability of the resource and the economic activity dependent upon it. Furthermore, an aquifer system that relies solely on controlling abstractions for the management of groundwater storage (levels) is not taking advantage of the potential of MAR.

Most surface storage projects currently being assessed around NZ have focused on dam construction. Dam storage can be more capital intensive and less efficient (due to evaporative losses and sedimentation) than to replenish and better utilise the natural groundwater storage capacity. In addition, dams and the associated reservoirs often prove to be environmentally and culturally controversial. In practice, a combination of both surface and groundwater storage coupled with a flexible regulatory framework is likely to represent the most cost effective and practical water management approach.

The report by Doak et al. (2004) on the economic value of irrigation indicates some of the highest unit prices for irrigated land in New Zealand occur in the Gisborne area. This report also indicated that squash, sweet corn and lettuce would probably be grown on irrigated areas that would previously have been supporting dry-land sheep.

The FwAG also highlighted that the potential for the use of Mar to improve water supply reliability is not just based on the issue of economic outcomes. Discussions about ecological and social outcomes are generally focussed on surface water flows. The connection between groundwater and surface water flows is not always fully appreciated. Increased groundwater storage can be very beneficial to environmental flows as groundwater is often the primary driver of base-flows, which is particularly important during critical low-flow times of the year. An increase in the sustainable abstraction of groundwater without prejudicing the minimum flows in the Waipaoa River can potentially be achieved through the application of MAR.

Factors associated with the Poverty Bay Flats area relevant to the groundwater replenishment project include:

- Declining aquifer storage at current abstraction rates.
- Tighter limits likely on surface water abstraction, with these affected by groundwater levels (and vice versa).
- Increasing water demand by existing users.
- Potential for further investment in high value productive uses provided greater reliability of water supply is achieved.
- Catchments characterised by highly erodible sediments resulting in silt-laden rivers and geotechnical and siltation problems for dam storage.
- Reliable surface water flows potentially available for MAR during the irrigation off-season.
- Waipaoa supplementary water treatment plant generally held in reserve (used only 1 day per year). This plant abstracts water from the river to supplement the Gisborne city municipal supply. The plant could provide a source of clean water for a MAR program.

This information provides the background against which MAR is to be assessed for the Poverty Bay Flats area.

3.3 Data Collection and Compilation

During the summer of 2013-2014, an intern student collected and collated spatial and time series data related to the Poverty Bay Flats aquifer system, water use in the area and climate patterns in the area. The collated data was assembled in the form of Excel spreadsheets suitable for input into a GIS database developed for this project.

GIS data provided by GDC including local water supply system layouts, groundwater and surface water monitoring points were also accessed by the intern and incorporated in the project database. In addition, publically available data including geological maps from the Institute of Geological and Nuclear Sciences (IGNS), topographic data from Land Information New Zealand (LINZ) and rainfall data from the National Institute for Water and Atmospheric Research (NIWA) has been accessed and incorporated in the project database.

The information collected by the intern student constitutes the primary dataset from which the GoldSim water balance model for the Poverty Bay Flats aquifers will be developed. A summary of the data collated is presented in Section 4.0.

4.0 PHYSICAL AND ENVIRONMENTAL SETTING

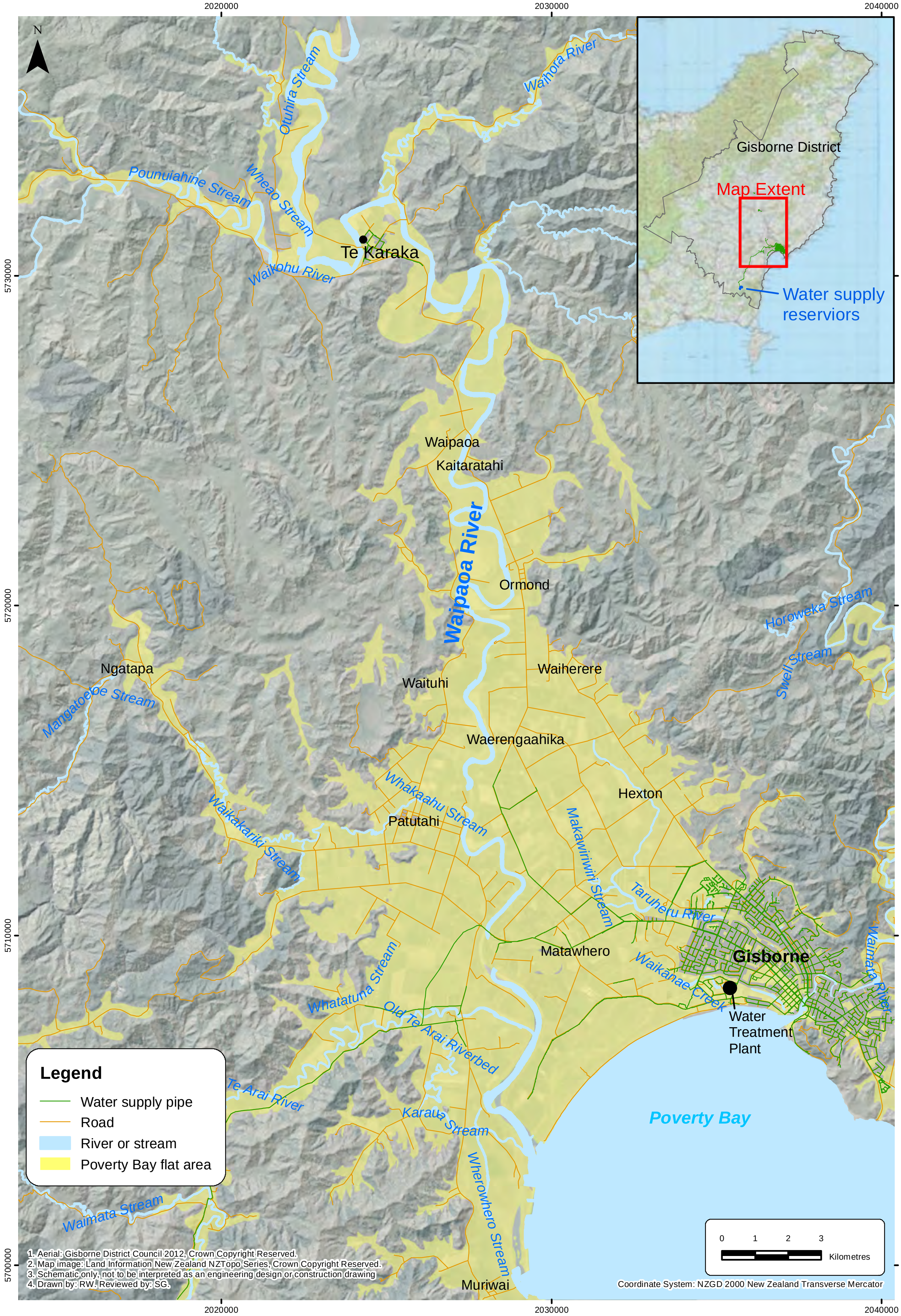
4.1 Introduction

The aquifer system beneath Poverty Bay Flats consists of a series of sand or gravel units within Quaternary age sediments infilling a sedimentary basin to the west and northwest of Gisborne City (Figure 1). Five main aquifers have been identified from surface mapping and drilling. These aquifers are used extensively for irrigation and commercial purposes, and domestic supply. In 2012, the GDC commissioned GNS to complete a report summarising the Poverty Bay Flats groundwater system (White et al 2012). The conceptual model developed for the purposes of water budgeting in that report is presented in Figure 2.

Relative to the assessment of MAR for this area, there are two primary aquifers of interest. The first is the Makauri aquifer where a large majority of the irrigation pumping is concentrated and where groundwater pressures have shown declines. The second focus aquifer is the Matokitoki aquifer, which has less overall usage than the Makauri but also shows declines in groundwater pressures. This aquifer also is used by Gisborne City for emergency supplies and is important part of their long term water supply planning (GDC 2010). The characteristics of these aquifers are outlined more fully in the following sections.

4.2 Geology

The basement rocks of the Poverty Bay area consist of Tertiary age sandstone and siltstone (Figure 3). Tectonic tilting and deformation of the basement rocks has led to the development of a sedimentary basin beneath the Poverty Bay Flats. The basement depth was provisionally interpreted by GNS (White et al 2012) to be relatively shallow in the area west of the Waipaoa River (40 m to 50 m below mean sea level (bmsl)) and within the Gisborne urban area (35 m bmsl). In the central basin area the basement rocks are interpreted to be located at depths of at least 225 m bmsl based on the geological log from bore GPC008.



Golder Associates

TITLE POVERTY BAY FLATS LOCATION MAP

MAY 2014

PROJECT 1378110136

1

S:\GIS\Projects-Numbered\2013\13781\10\1378110_136_LeaderBrand_MAR_Stage1\MapDocuments\Fig01_SiteLocation_A4P_GIS.mxd

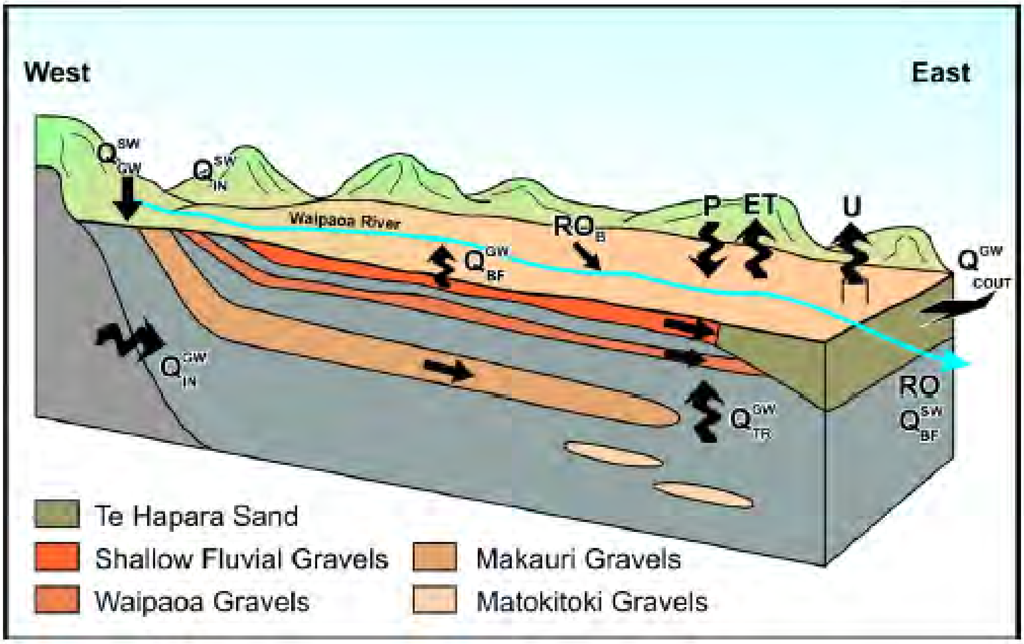


Figure 2: Conceptualisation of groundwater flow in Poverty Bay Flats (White et al 2012).

Most of the fluviatile and deltaic sandy gravel deposits in-filling the basin have been deposited since the last glaciation (70,000-14,000 years BP), when the sea level was about 120 m lower that current levels and the coast was 30 km further to the east (Taylor 1994). Since that glaciation, the beach front has retreated inland (9,000-7,000 years BP) preventing the fluviatile gravels from being deposited through to the modern day coast.

Along the coast sand deposits have been deposited to depths of approximately 20 m. An extensive estuary was present behind the dunes, reaching inland as far as Ormond. Swamp and estuarine deposits from this time (8,000 BP) form a low permeability silt layer over the previously deposited delta gravels (White et al. 2012). Rivers subsequently cut down into and reworked some of the sediments. In addition, volcanic ash deposits from the Taupo Volcanic Zone are inter-bedded within the alluvium.

4.3 Hydrogeology

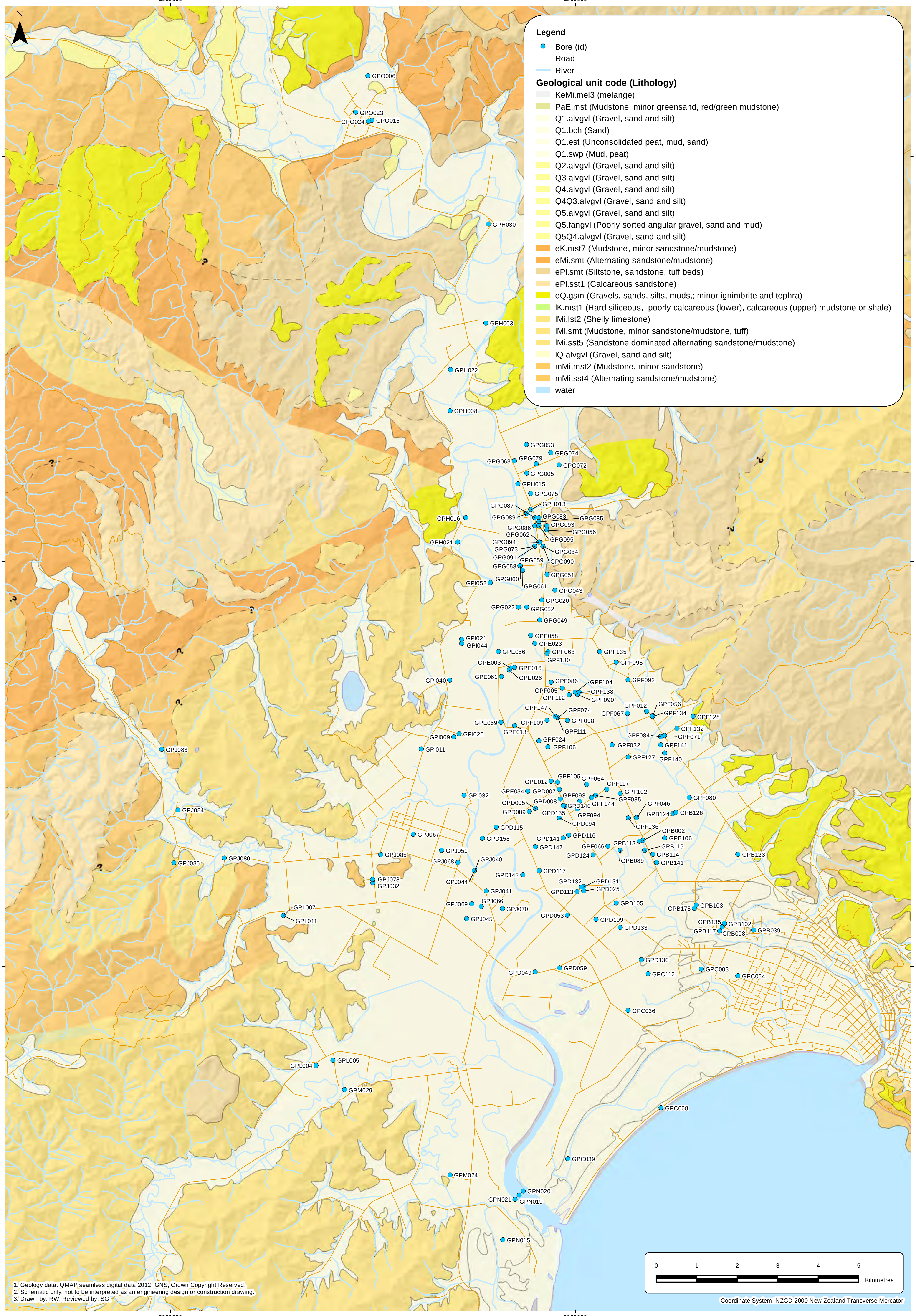
4.3.1 Aquifer structure

Five main aquifers have been delineated within the Quaternary deposits. These include three shallow aquifers which are hydraulically linked to surface water bodies and two deeper aquifers.

Based on the geological interpretation set out in Section 4.2, it appears likely that the fluviatile gravel deposits will constitute lenses of more permeable sediments dispersed within finer grained sedimentary deposits. If this is the case, gravel beds intersected at similar depths in different bores may not be directly hydraulically connected. Care therefore needs to be taken, if designing a MAR system focused on the gravel aquifers, to ensure that the water injection and abstraction points are hydraulically connected.

Toward the coast, the geological interpretation indicates the aquifers will be predominantly sandy rather than a continuation of the gravel deposits. The gravel aquifers may therefore not have a strong hydraulic connection to the ocean.

Also the thick low permeability sediments from the former estuary act to restrict the hydraulic connection between the shallow aquifers and the deeper aquifers. This restriction also presumably limits the potential for artificial surface recharge to influence water storage in the deeper aquifers.



Golder Associates

TITLE SURFACE GEOLOGY AND BORES WITH LITHOLOGICAL LOGS

MAY 2014

PROJECT 1378110136

3

S:\GIS\Projects-Numbered\2013\13781\10\1378110_136_LeaderBrand_MAR_Stage1\MapDocuments\Fig03_Geology_A3P_GIS.mxd

4.3.2 Shallow Fluvial Aquifer

The Shallow Fluvial Aquifer is an unconfined aquifer consisting of pumice, sand and gravel deposits up to 10 m thick. This aquifer is hydraulically connected to and locally recharged from the Waipaoa River. The Shallow Fluvial Aquifer and the less extensive Waipaoa Gravel Aquifer are often considered as one aquifer system (White et al. 2012).

4.3.3 Waipaoa Gravel Aquifer

The Waipaoa Gravel Aquifer consists of localised fluviatile gravel deposits from the Waipaoa River, approximately 10 m to 30 m below the ground surface. The aquifer is considered to have formed during a time of river down-cutting during a coastal advance (7,000 to 4,000 years BP). At its southern end, this aquifer therefore inter-fingers with the Te Hapara Sand. The Waipaoa Gravel aquifer is considered to be recharged from the river, and possibly from rainfall and deeper aquifers (White et al. 2012).

4.3.4 Te Hapara Sand

A beach and dune sand deposit forms an unconfined aquifer in the southern area of the Poverty Bay Flats. The sands were initially deposited during a coastal advance (7,000 to 4000 years BP) and are up to 20 m thick. This aquifer is predominantly recharged by rainfall with some through-flow from the Shallow Fluvial Aquifer and the Waipaoa Gravel Aquifer (Taylor 1994). Isotope analysis results have confirmed recharge to the Te Hapara Sand Aquifer from locally infiltrating rainwater (Taylor 1994). Groundwater pressures in this aquifer rise during winter storm events followed by a recession curve during the summer (Appendix A).

4.3.5 Makauri Gravel Aquifer

The Makauri Aquifer constitutes a series of gravel layers covering most of the Poverty Bay Flats area and extending up the Waipaoa Valley past Kaitaratahi. The gravel layers are considered to have been deposited as delta deposits (7,000 – 9,000 years old) when the river was down cutting into gravel terrace deposits upstream of Te Karaka (Taylor 1994).

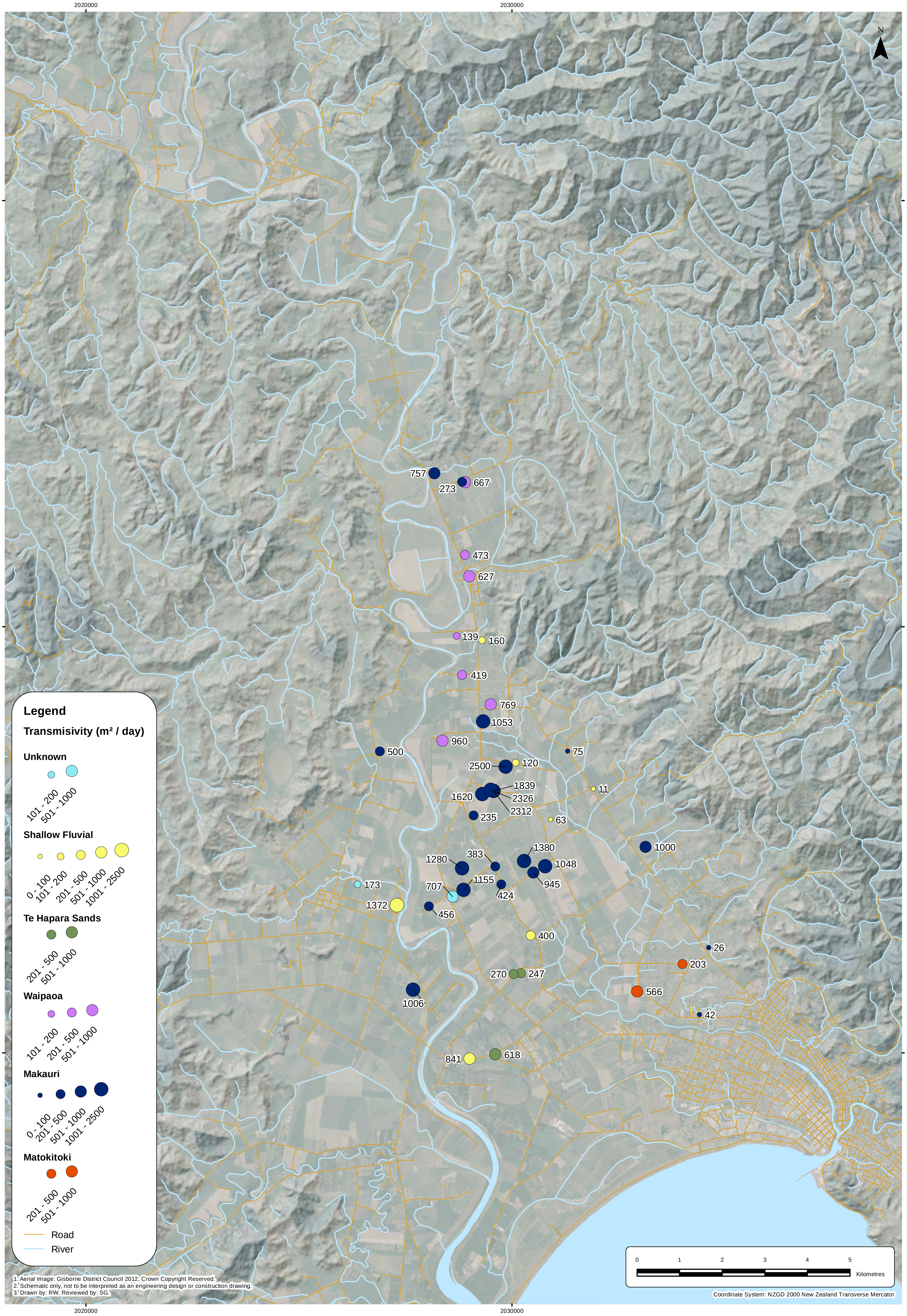
The aquifer is shallower beneath the northern edge of the flats (45 m bmsl at Ormond) dipping down to 60 m bmsl in the middle of the basin (White et al 2012). The aquifer has a thickness of 5 m – 20 m, with the thickest gravel layers in the middle of the basin and thinning towards the coast. Although the aquifer was at one time considered to thin out completely before reaching the coast, lithological logs from bores near the coast indicate a thin gravel layer is locally present in this area at approximately 66 m below ground level (White et al. 2012).

The Makauri Gravel Aquifer is most extensive of the five main aquifers. Hydraulic testing of the Makauri Gravel Aquifer has produced relatively high transmissivity results in the central plains area (750 m^2/day to 2,500 m^2/day; Taylor 1994) compared to the other aquifers (Figure 4).

A downward hydraulic gradient has been measured between the overlying Waipaoa Gravel Aquifer and the Makauri Aquifer at Ceasor Road (Ormond), indicating that this could be a recharge area for the Makauri Aquifer (Appendix A). By Ferry Road (Figure 5) the measured pressure gradient appears to be reversed and the Makauri Aquifer may have a higher static water pressure than the Waipaoa Gravel Aquifer (Appendix A).

Taylor (1994) indicated that recharge to the Makauri Aquifer could be from the Waipaoa River, upstream of Kaitaratahi, during high flows, with some additional recharge from the eastern margins of the flats. He considered that water recharged to the older gravels within the narrow valley flows slowly downstream towards Kaitaratahi where it 'spills over' into the deeper Makauri Aquifer beneath the flats. Taylor also considered that the Makauri Aquifer is not deriving its predominant recharge by general seepage from the shallower aquifer, despite the favourable pressure difference in the upper area of the flats.

Isotope analysis results from samples obtained from Makauri Gravel Aquifer bores situated between Ormond and Waerengaahika, close to the river, have indicated that recharge could occur at a relatively steep angle directly under the river where the river emerges onto the flats just north of Kaitaratahi (Taylor 1994). Further downstream the river recharges the Waipaoa and Shallow Fluvial aquifers. He suggested all these recharge processes are so slow that the water has lost essentially all its tritium through decay before reaching the Makauri Gravels.



Golder Associates

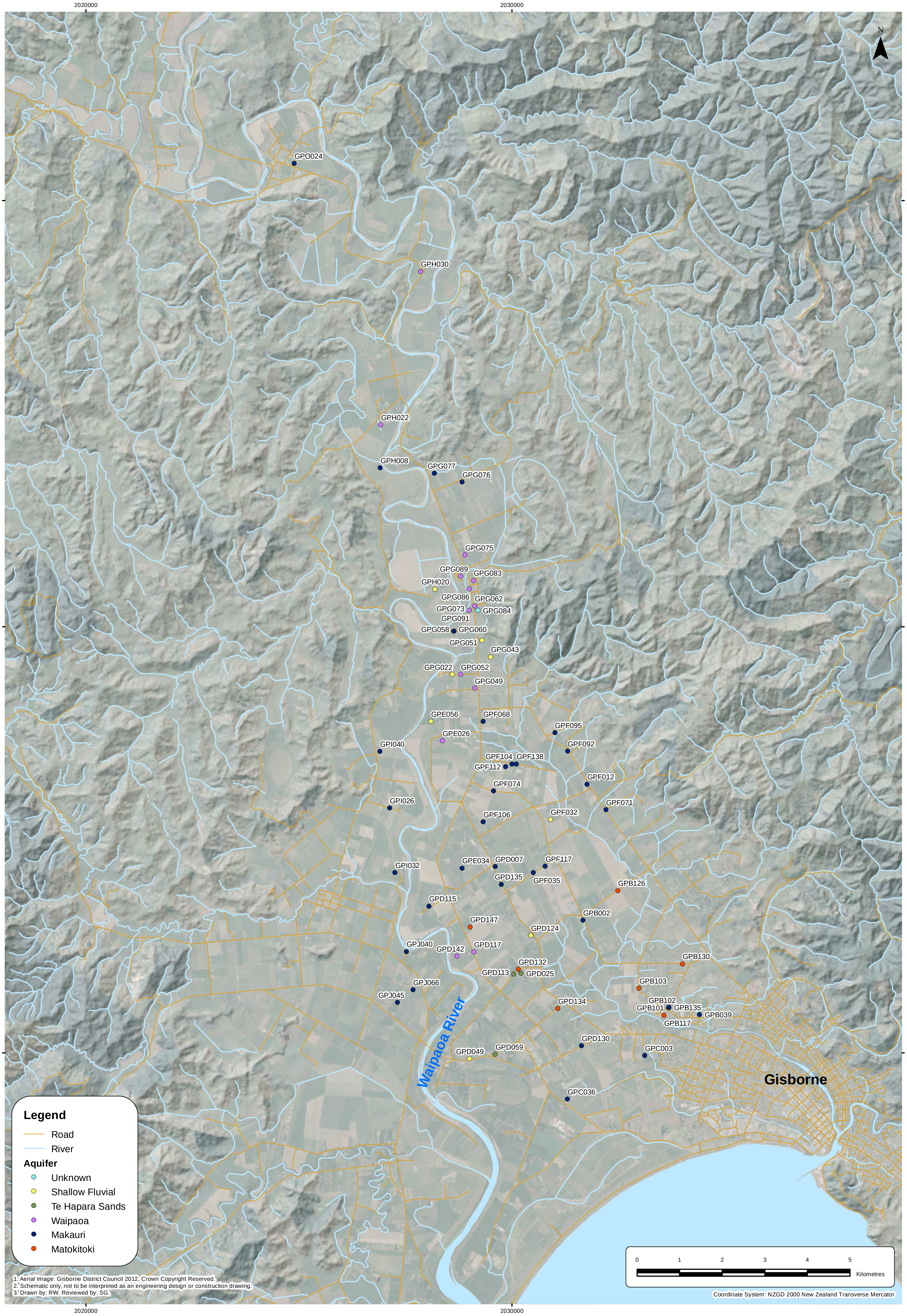
TITLE MAP OF TRANSMISSIVITY VALUES IN THE FIVE MAIN POVERTY BAY AQUIFERS

MAY 2014

PROJECT 1378110136

4

S:\GIS\Projects-Numbered\2013\13781\10\1378110_136_LeaderBrand_MAR_Stage1\MapDocuments\Fig04_Transmissivity_A3P_GIS.mxd



Golder Associates

TITLE LOCATION OF GROUNDWATER PRESSURE MONITORING LOCATIONS FOR THE POVERTY BAY AQUIFERS

MAY 2014

PROJECT 1378110136

5

S:\GIS\Projects-Numbered\2013\13781\10\1378110_136_LeaderBrand_MAR_Stage1\MapDocuments\Fig05_WaterLevel_A3P_GIS.mxd

Although appearing to be a blind aquifer, Taylor (1994) considered that the Makauri Gravel Aquifer must discharge at its coastward end, most likely into the poorly permeable overlying silts under the influence of artesian pressure. He concluded from the water quality data, that natural flow and discharge of water in the Makauri Aquifer occurs on a timescale in the order of 100 years.

4.3.6 Matokitoki Aquifer

The Matokitoki Aquifer consists of a deep gravel layer (100 m to 200 m below ground surface) deposited during the last glaciation. In some places the gravels lie directly upon basement rocks (Taylor 1994). The aquifer has an unknown extent and may actually occur as a series of disconnected gravel lenses rather than a continuous feature (White et al. 2012). The silts that act as aquitards overlying the aquifer appear to thin toward the north. The aquitard may become leakier inland, allowing water recharge from the overlying Makauri Aquifer (Aqualinc 2012).

Water from the Matokitoki Aquifer at its southern limit near Gisborne City has been estimated to have an approximate age of 4,300 years old (Taylor 1994). This age implies that the groundwater is very slow moving and the aquifer is potentially blind.

During 1987 and 1988 there was a short pumping period from the Gisborne City Emergency bore, which accesses the Matokitoki Aquifer. Groundwater drawdown plots from that period suggested a long recovery time of approximately four years (Barber 1993). Aqualinc (2012) refers to the groundwater level response record from one of the Matokitoki bores (GPB102) as showing effects of pumping and slow recovery (Appendix A). Slow pressure recovery following pumping would suggest a low recharge rate to the Matokitoki aquifer in the area close to Gisborne.

Some shallower bores (40 m deep) near Gisborne are considered by Taylor (1994) to have a water chemistry signature which indicates they have groundwater closely associated with the Matokitoki Aquifer. This may imply groundwater is moving up from the deeper aquifer to shallower aquifers near the coast, or indicate a steep dip to the aquifer in the Gisborne area.

4.3.7 Other aquifers

There are localised aquifers of gravel, pumice sand and beach deposits along the eastern and western edges of the alluvial basin. Analysis of water samples from these aquifers indicates the water quality is similar to that of the Waipaoa Gravel Aquifer.

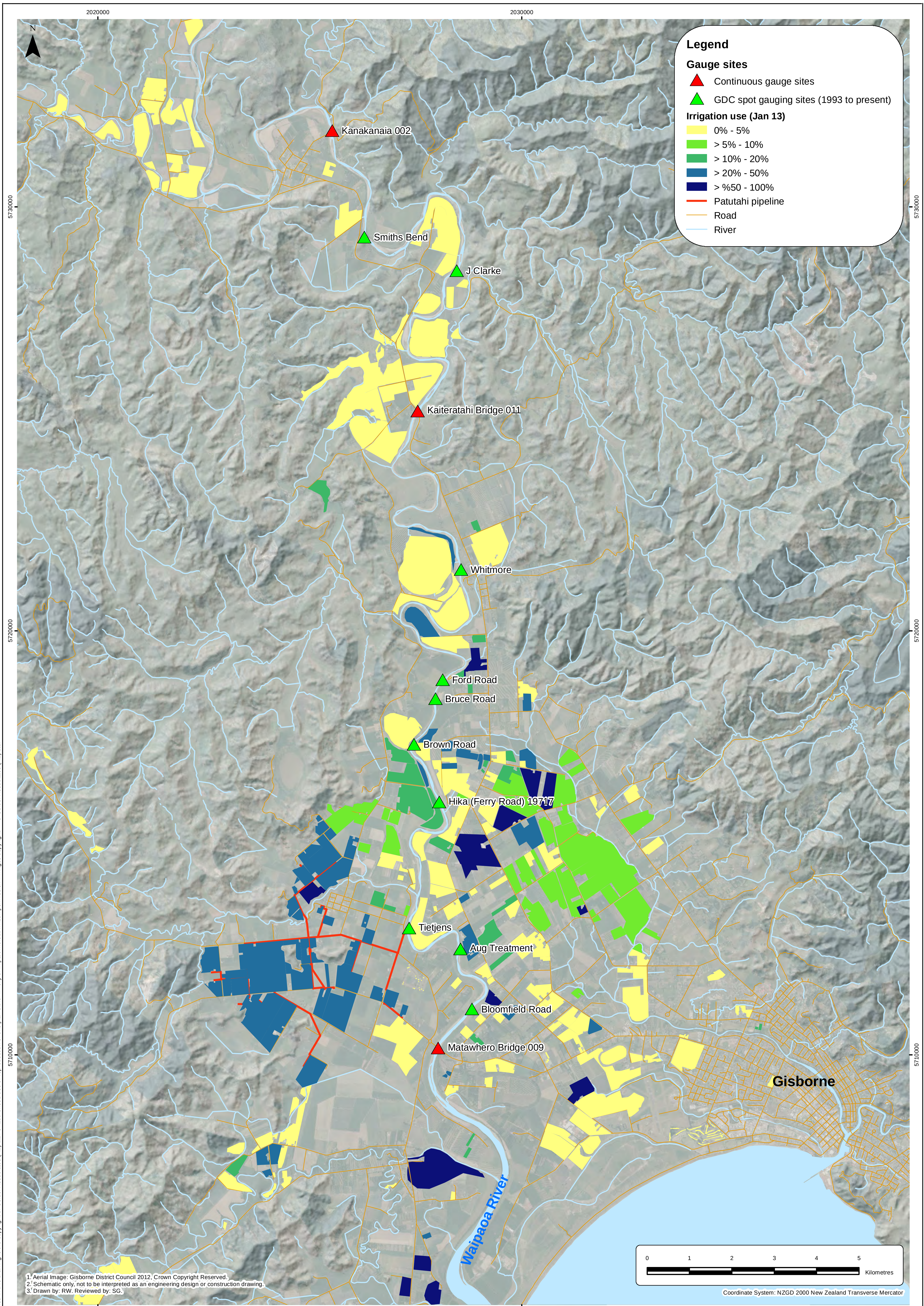
Inflow to the Poverty Bay Flats aquifer system from the western and eastern edges has been interpreted as being negligible (White et al. 2012). This conclusion was reached based on an interpretation of low recharge and through flow within the Tertiary basement rocks as observed in the low flow from the one monitored spring (Brewery Spring). For this reason it was not included in the water budget documented in that report. Taylor (1994) similarly considered that the eastern and western edges of the basin contain only isolated aquifers. Lithological logs from bores support this conclusion, indicating low permeability clays and silts in the shallow sediments (down to 15 m to 20 m below ground level) in the western and eastern areas.

4.4 Hydrology

4.4.1 Introduction

When evaluating the hydrology of a catchment relative to the application of MAR, and for the development of a hydrogeologic model, there are a number of factors that need to be considered. Firstly, relative to the development of system water budget the areas of groundwater recharge (e.g., river beds, rainfall, etc.,) must be identified and quantified. It is important to understand spatially where natural recharge (e.g., Waipaoa River) may occur for each aquifer system to help identify potential locations for some methods of artificial recharge (e.g., infiltration). Secondly, the areas where groundwater is likely to discharge (e.g., subsurface ocean outfall, baseflow to rivers, etc.,) in the catchment need to be assessed.

Flow information for the Waipaoa River is available from a number of sources including GDC and NIWA. Continuous gauge sites are maintained by GDC at Kanakanaia, Kaiteratahi, and Matawhero bridges (Figure 6) while GDC has collected spot gaugings between Whitmore Road and Brown Road since 1993.



1. Aerial Image: Gisborne District Council 2012, Crown Copyright Reserved.
2. Schematic only, not to be interpreted as an engineering design or construction drawing.
3. Drawn by: RW. Reviewed by: SG.

Golder Associates

TITLE IRRIGATION AND SURFACE WATER MONITORING LOCATION MAP

MAY 2014

PROJECT 1378110136

6

S:\GIS\Projects-Numbered\2013\13781\10\1378110_136_LeaderBrand_MAR_Stage1\MapDocuments\Fig06_Irrigation_A3P_GIS.mxd

4.4.2 Aquifer recharge

Focusing firstly on the Makauri Aquifer, Taylor (1994) found using isotopic compositions of dissolved inorganic carbon, and ground-water age analysis results that recharge occurs from the Waipaoa River near to or upstream from Kaitaratahi (Figure 6). The results suggested that both direct recharge under the river and the migration of recharged water away from the river in the shallow aquifer before infiltrating to the Makauri Aquifer was occurring. In analysis of spot gauging information from NIWA and GDC, White et al. (2012) found the largest consistent river losses (groundwater recharge) were near the Kaitaratahi gauge site (between Kaitaratahi and Bond Road). Barber (1993) reported small Waipaoa River losses (150 L/s – 400 L/s) further up the catchment (between Waipaoa Station and Kanakanaia Bridge) however, this was not consistent with the findings from White et al. (2012).

An initial review of GDC spot gauging information for the Waipaoa River has been undertaken. Review of low flow spot gaugings taken between November and March (1993 – 2014) suggests that groundwater recharge from the river can also occur further downstream, at the upper end of the Poverty Bay catchment between Whitmore Road to Brown Road. It is not yet clear which aquifer(s) may receive recharge water from this area. This is an area that will be explored further during the next stage of the project.

The connection of the Waipaoa River recharge to the Matokitoki Aquifer is likely extremely limited. A combination of much older (4,300 years) groundwater ages (Taylor 1994) and the aquifer slow pressure recoveries following pumping (Aqualinc 2012) implies that the groundwater is slow moving and not strongly linked to overlying aquifers.

4.4.3 Source water – availability and timing

There are two primary sources of water that could potentially provide water for a MAR project. The first is the Waipaoa River. Flows in the river are extremely limited during the summer irrigation season. These low summer flows suggest that sourcing water from the river for a MAR scheme would probably need to occur during the off-season. The second source of potential recharge water may be the Mangapoike Dams (2) (GDC 2011) through the Gisborne water supply network. While this water can only be delivered as treated drinking water through the conveyance pipeline (more costly), the availability of water outside the irrigation season also has potential. Other sources of recharge water may include the Te Arai River however, this option would need further analysis during Stage 1B.

4.5 Water Quality

4.5.1 Potential source water

An important factor needing to be managed if water from the Waipaoa River is to be used for managed recharge, is the concentration of suspended solids in the water. Suspended solids can relate directly the likelihood of having to manage MAR clogging both for infiltration and injection style systems. Total suspended solids concentrations in the Waipaoa River water vary on a seasonal basis and in response to flow rates in the river (Appendix B). Peak concentrations occur during the winter when river water is potentially available for a MAR operation The solids loads are higher upstream at Kanakanaia than at Matawhero, the median concentrations at both sites being approximately 100 g/m^3 or more.

Nitrate, dissolved reactive phosphate and sulfate concentrations are very similar at both the Kanakanaia and Matawhero monitoring sites. These types of indicators are often checked regarding the reinjection of water and the protection of drinking water supplies. The calcium hardness in the river water is substantially higher at Matawhero than at Kanakanaia.

The dissolved oxygen concentrations follow similar trends at both of the monitoring. Oxygen concentrations in solution vary in response to temperature changes, with the highest concentrations corresponding to low temperatures during the winter months (Appendix B). Dissolved oxygen will likely be a key issue if MAR injection is to be further pursued.

The biological oxygen demand (BOD) of the river water is higher in samples from Matawhero than in those from Kanakanaia. This difference has only appeared since 2008. Prior to that time there was little difference between the two sites. BOD is a critical parameter to understand for the potential of biological clogging of MAR sites.

Faecal coliform counts measured in water samples from both sites have historically been moderate to high (between 100 CFU/100mL and 10,000 CFU/100mL). There has overall been little observed difference between the two sites. Like nutrients, enteric bacterial indicators are key to protecting human health and potable water supply.

4.5.2 Potential receiving water

Water quality data for the Waipaoa Gravel Aquifer, the Makauri Aquifer and the Matokitoki Aquifer provided by GDC is summarised in Appendix B. General observations with respect to the water quality in each of the aquifers are provided below.

The Waipaoa Gravel Aquifer has generally better water quality for irrigation and domestic use than other aquifers in the area. The groundwater quality data from wells in the Waipaoa Aquifer generally indicates oxidised conditions. The average electrical conductivity is 800 µS/cm, iron, manganese and nitrate concentrations are low (White et al. 2012).

The water in the Te Hapara Sand Aquifer has lower average electrical conductivity, iron and manganese concentrations than the other aquifers (White et al. 2012). This water quality is consistent with an oxidised environment in an unconfined aquifer.

The Makauri Aquifer water contains high levels of salinity, iron, manganese and chloride in the south western area of the aquifer, rendering the aquifer in this area unsuitable as a water source for irrigation or domestic use (Emsley et al. 1984). These high concentrations are considered to be due to the inter-bedding of the aquifer with marine aquitard deposits (Emsley et al. 1984). Sulphate concentrations measured are low and although there is a slight increase in concentration with distance inland, values are still well within the limits recommended for domestic use. Phosphorus and nitrate-nitrogen concentrations measured are also acceptable for domestic use. The mean electrical conductivity indicates water which may be greater than 100 – 200 years old (White et al. 2012).

Some of the monitored bores in the Makauri Aquifer show improved water quality during times of pumping. This improvement suggests that water is being recharged from shallower aquifers during pumping (White et al. 2012).

Water from the Matokitoki Aquifer is characterised by high electrical conductivity, reduced conditions with very high dissolved iron, manganese and ammonia concentrations (White et al. 2012). A large range of water quality has been detected from this aquifer, which may reflect varying degrees of reducing conditions (White et al. 2012).

During the Stage 1B portion of this project, comparisons and chemical modelling relating the potential source waters, treatment options and likely receiving water interactions will be a key part of the analysis. Golder geochemistry staff will provide a detail analysis of these issues as part of the final Stage 1 reporting.

4.6 Water Use

Groundwater in the Poverty Bay is used for irrigation and domestic supply and the majority of the abstraction is for irrigation. The total groundwater allocation is 70,457 m^3/day, based on the maximum daily consented volumes. The total rate allocation is 1,040 L/s, based on the maximum rate allocation. Over an irrigation season the total annual use will vary depending on climate and soil requirements. Groundwater use for the 2012-2013 irrigation season totalled 1.9 million m^3/year (Table 1). Maps are presented showing the locations of consented groundwater takes (Figure 7) and measured groundwater takes (Figure 8).

Table 1: Poverty Flats aquifer water usage.

Aquifer	Consented volume	Consented Rate of take	Total use	Daily consented x 120 days	Use compared to allocation
	(m^3 per day)	(L/sec)	(m^3/year)	(m^3/year)	%
Shallow Fluvial	8,975	156	112,119	1,077,000	19
Te Hapara	5,846	111	80,890	701,520	17
Waipaoa	2,747	48	116,380	329,640	25
Makauri	33,794	491	1,472,020	4,055,220	33
Matokitoki	18,350	222	77,664	2,202,000	7
Unknown	745	12	24,312	89,400	38
Total	**70,457**	**1,040**	**1,883,386**	**8,454,780**	**25**

Note: Source GDC (2014).

To compare the allocated daily volumes to actual use, an assumed number of abstraction days can be applied. If it is assumed the annual seasonal abstraction period is 120 days, the total annual allocation would be approximately 8.5 million m^3/year. Previous studies have used groundwater allocation rates as high as 11.5 million m^3/year (NIWA 2010).

Groundwater abstraction has predominantly been allocated from the Makauri Aquifer (48 %, Table 1). The predominant use for the allocated irrigation water is for growing vegetables, kiwifruit and citrus. There is also a significant allocation set aside for emergency water supply to the Gisborne urban area for domestic use (GDC 2013). The actual recorded use of groundwater for the 2012-2013 irrigation season was approximately 25 % of the allocated volume (GDC 2013). Recorded annual groundwater use and allocation is predominantly from the Makauri Aquifer.

The Makauri Aquifer responds to pumping during the irrigation season each year. Groundwater levels decline over the irrigation season and then recover during winter to reach a peak in September.

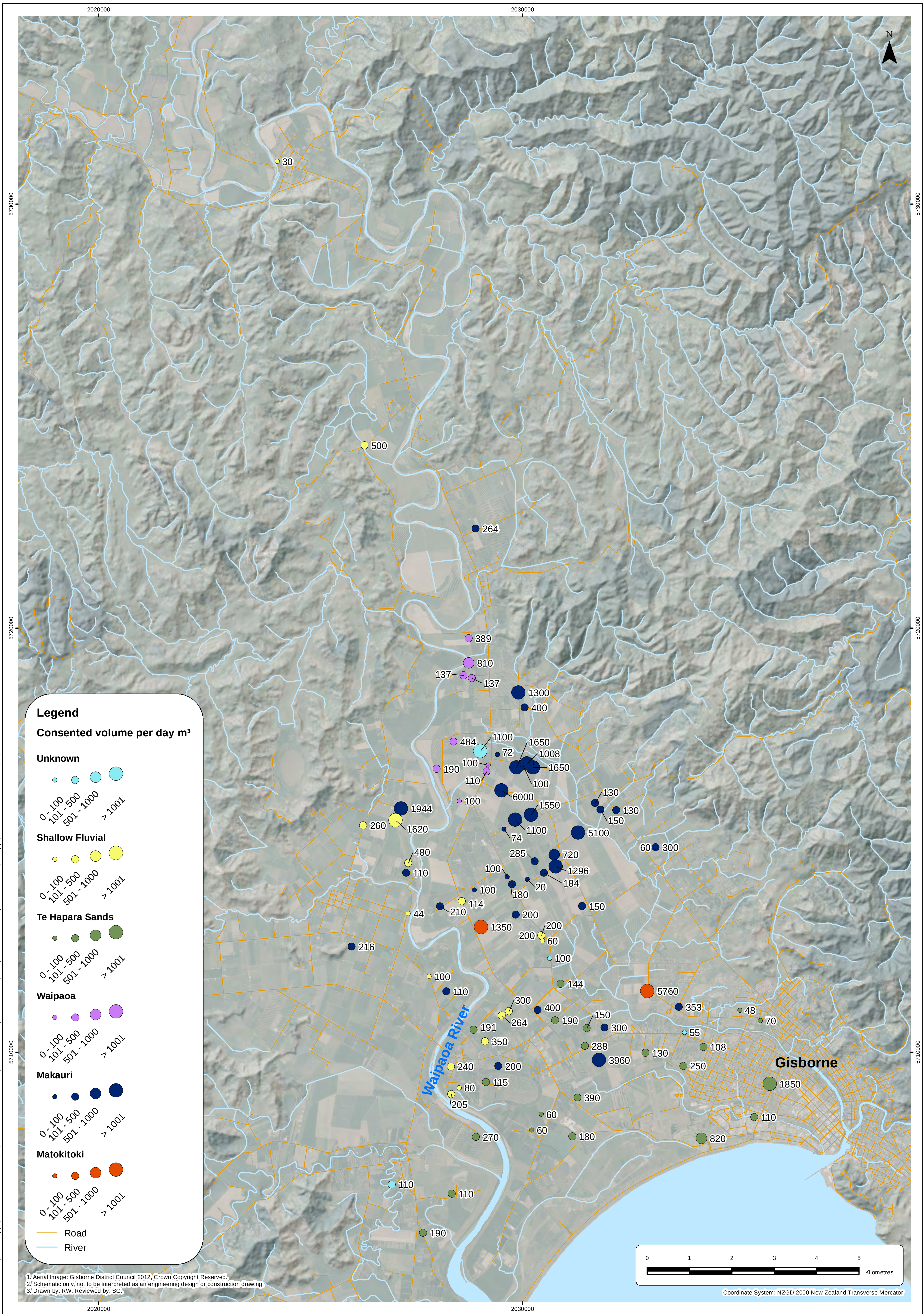
Aqualinc (2013) indicates there could be a 160% increase in water use over the coming 50 year period.

5.0 POVERTY FLATS GROUNDWATER REPLENISHMENT MODEL

5.1 Introduction

This section provides an overview of the preliminary model design and proposed functionality of the GDC Poverty Flats Groundwater Replenishment (GWR) GoldSim model. This summary discusses the preliminary main components of the model only. The model will be refined and the functionality increased during the development and calibration phase (Stage 1B). Consultation with GDC staff and FwAG members will help inform the final structure, features and outputs of the model.

The purpose of the GoldSim model is to provide a tool for assessment of the potential benefits of developing a groundwater replenishment scheme using MAR to increase the sustainable yield from groundwater resources in the Poverty Bay Flats aquifer system. The principal components of the model are a control panel, the model logic, model inputs and results.



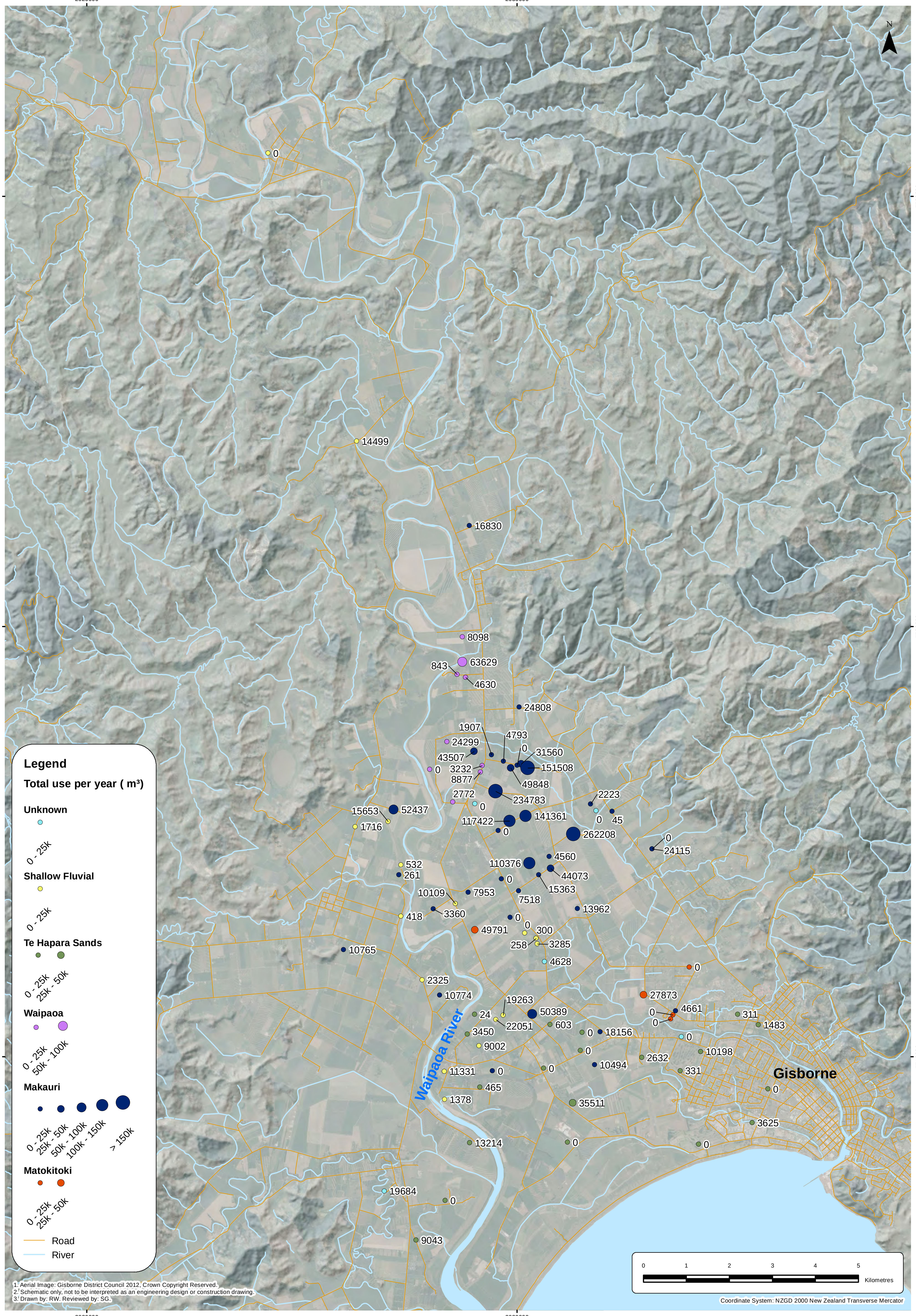
Golder Associates

TITLE MAP OF ALLOCATED GROUNDWATER TAKES BY AQUIFER

MAY 2014

PROJECT 1378110136

7



Golder Associates

TITLE MAP OF MEASURED GROUNDWATER TAKES BY AQUIFER

MAY 2014

PROJECT 1378110136

8

S:\GIS\Projects-Numbered\2013\13781\10\1378110_136_LeaderBrand_MAR_Stage1\MapDocuments\Fig08_WaterUse_A3P_GIS.mxd

5.2 GoldSim for Poverty Flats

GoldSim is a dynamic probabilistic simulation package which provides a visual and hierarchical modelling environment. GoldSim supports decision and risk analysis by simulating future performance while quantitatively representing the uncertainty and risks inherent in all complex systems. The software enables users to construct models by adding “elements” that represent data, equations, processes or events, and link them together into graphical representations. Influence arrows are automatically drawn when elements are referenced by other elements to show connections/flows through the model. Visual representations and hierarchical structures help users to build large, complex models that can still be clearly explained to interested stakeholders (e.g., government regulators, elected officials, and the public) (GoldSim 2014).

The principal components of the model are a control panel, the model logic, model inputs and results (Figure 9). These components are set out in more detail below. The preliminary model design information provided in the following sections is indicative only. It is highly likely that some features of the model will be modified as it is developed, initial outcomes are reviewed and evaluated against the stated objectives and our understanding of the groundwater system improves.

The completed GWR model will be exported as a Player File, which can be used by anyone via a free Player File software download[1]. The objectives in providing a Player File to the end users are to enable the user to:

1) Change certain input parameters, such as MAR recharge rates or groundwater demand projections, and view the consequences on groundwater supply reliability projections.

2) Develop a feel for how the groundwater supply system functions through running different scenarios within pre-defined realistic input value ranges.

The overall model structure will not be able to be modified using the Player File and the input values that may be applied will be limited to a realistic potential range.

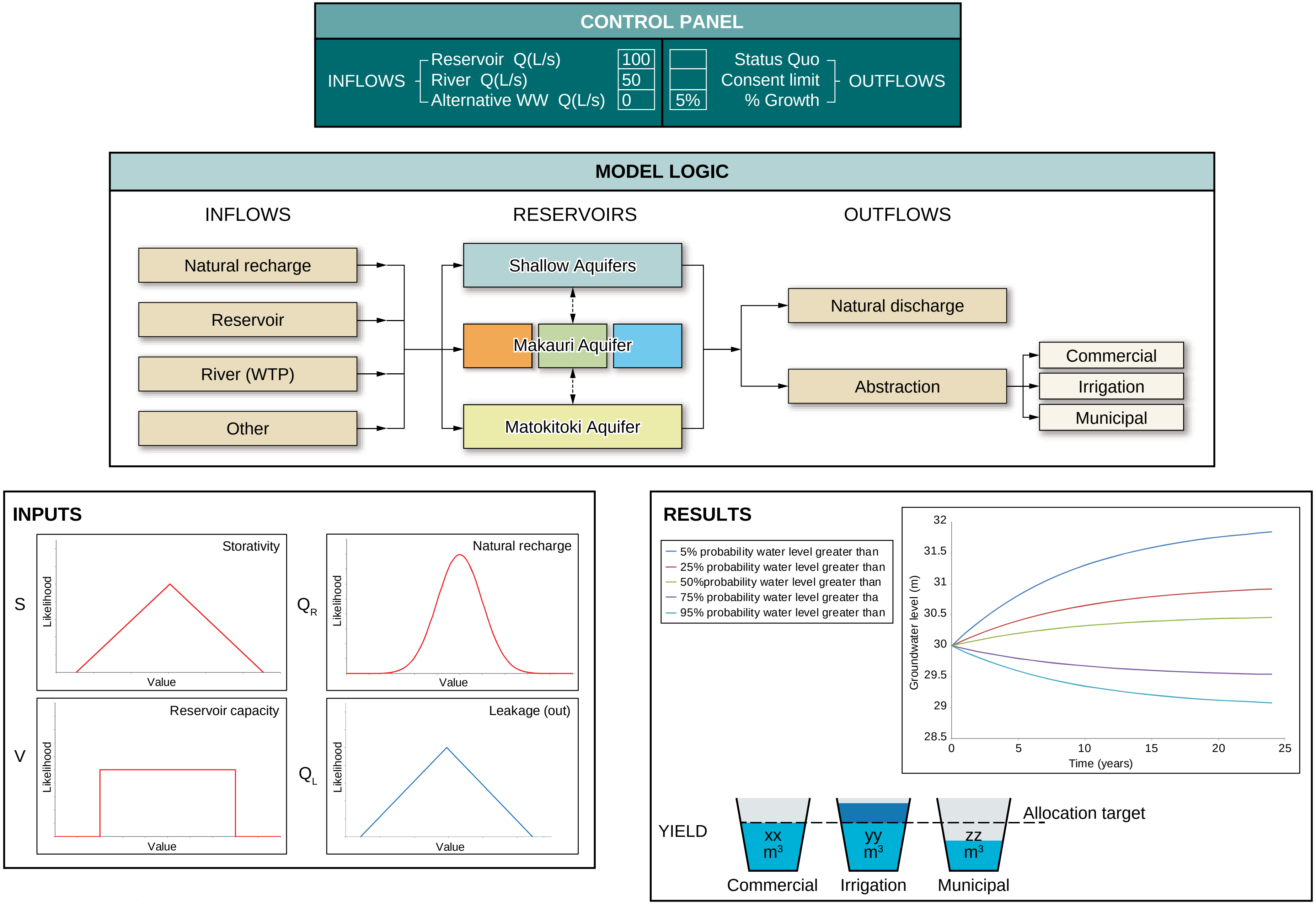
5.3 User Interface – Control Panel

The control panel provides an accessible, user-friendly interface for model end-users. Through this interface an end-user may define appropriate parameters (e.g., inflows and outflows) to simulate operational management of a potential GWR scheme.

User-defined inflows for the Gisborne MAR model consist of water availability and recharge rates from potential sources including the Mangapoike dam(s), Waipaoa River (via the Waipaoa Water Treatment Plant) and from other yet to be identified sources (e.g., Te Arai River).

Golder proposes up to three potential outflow scenarios that can be selected by the user. The *Status Quo* scenario is used to validate the model by comparing modelled and measured declining groundwater levels. Projections made using this scenario constitute base-case outcomes representing the current groundwater abstraction and recharge rates continued into the future. The *Consented Limit* scenario can be selected to show the expected decline in groundwater levels if all existing groundwater takes were operated at their consented limits. The *% Growth* scenario allows the model user to define an annual percentage increase in the various types of groundwater abstraction rates, above those defined for the *Status Quo scenario*. This scenario can be used, in combination with the user-defined inflows, to assess the impact on groundwater levels associated with a range of MAR management options and water demand growth scenarios (e.g., injecting 100 ML/year of recharge from the Waipaoa River via the Waipaoa Augmentation Plant and increasing groundwater abstraction by 5% per year).

[1] http://www.goldsim.com/forms/playerdownload.aspx



1. Schematic only, not to be interpreted as an engineering design or construction drawing
2. DRAWN BY: SG REVIEWED BY: RW

Golder Associates

TITLE PRELIMINARY POVERTY BAY GROUNDWATER REPLENISHMENT MODEL SCHEMATIC

MAY 2014

PROJECT 1378110136

9

S:\Graphics\Projects-numbered\2013\13781x\10xxx\1378110_136_LeaderBrand_MAR_Stage1\May14

5.4 Model Logic and Inputs

The heart of the model logic is a series of aquifer reservoir elements which represent groundwater resources in the Gisborne District. The model calculates the volume of water stored in these reservoirs over time, based inflows and outflows defined by the model builder and the model user. Figure 9 shows the two likely primary target aquifers for MAR (Makuari and Matokitoki) as distinctive elements. The Makauri is likely to be divided into more than one element as the hydrogeologic properties vary across the aquifer. Higher localised groundwater usage coupled with source water accessibility would be some of the parameters used to define the extent and nature of each element.

In this draft version the model inputs comprise four physical parameters defined by the model builder: the aquifer storage coefficient, the aquifer (reservoir) capacity, the natural groundwater recharge rate and the natural groundwater leakage (discharge) rate. Because each of these inputs are spatially variable and subject to uncertainty due to data limitations, they are defined in the model as probability functions. These define the expected range of values for each parameter and the likelihood that any given value within that range will occur in reality. The physical parameters are controlled via a technical dashboard and are based on analysis of hydrogeological data and research. Although the physical parameter inputs are generally not accessible to the model end-user, the technical dashboard could be exported as a Player File for technical end users if required.

5.5 Model Results

This draft version of the model will provide two sets of results: the water yield for irrigation, commercial and municipal water takes, based on the user defined inputs and status-quo water demand values, and the model groundwater levels over time. Groundwater levels will be plotted as a time series graph showing groundwater levels and confidence intervals (e.g., the graph could show a 95 % confidence estimate that groundwater levels after 5 years of MAR will be greater than 10 m below ground level).

The development of a managed allocation target level (dependent on MAR testing results, source water supply relative to changing climate, and other physical hydrogeologic constraints) could be one approach to sustainable management. The model results could be used to support an assessment of allocation limits based on compliance with acceptable groundwater pressures in the aquifers.

5.6 Model Extensions

The model structure has been designed to accommodate additional modules if required during later phases of the MAR project, such as a financial module and a water quality module. The financial module could provide estimates of GWR capital and operating costs and economic benefits (e.g., revenue associated with increased irrigated area) for a given operational scenario. A water quality module could be developed to indicate possible water quality changes in the aquifer due to recharge of water from the various potential water sources.

6.0 CONCLUSIONS

This report represents the deliverable from the first stage (Stage 1A) of a two part project. It provides the methodology being used to assess MAR for the potential targeted aquifers. Golders' preliminary analyais of the data collected from GDC staff coupled with reviews of existing literature indicates both some opportunities and challenges for the Stage 1B portion of the project.

Through discussions with GDC and FwAG staff it is clear that there is uncertainty around the reliability of future water supply, which may constrain economic growth and sustainable water supplies. Additionally, some water resources in the region are soon to be (if not already are) over allocated. Portions of the Poverty Bay aquifer system are showing the effects of over abstraction from groundwater pumping.

Golders' review of the overall status of this aquifer system indicates that two primary aquifers (Makuari and Matokitoki) should be further evaluated for MAR. Of these two aquifers, Golder believes that the Makuari Aquifer is the best candidate for a potential pilot project due a number of factors including its relatively high usage, declining pressures and potentially easier accessibility.

The Makuari Aquifer appears to have two primary options for replenishment. The direct injection of treated water using a bore to a portion of the aquifer with both high usage and declining pressures appears to have potential. The use of surface recharge (e.g., infiltration basins) in the upper portion of the Poverty Bay Flats area may also have some potential. Both of these options need considerable further work before they can be recommended.

The conceptual GoldSim model has been outlined which will be further refined through collaboration with GDC and FwAG members. The model is to be constructed as a tool to not only to help evaluate MAR options but also as a broader groundwater management tool for the council.

In looking at the potential for MAR overall, water availability (non-irrigation season) and existing infrastructure (e,g., Waipaoa Augmentation plant, existing bores, etc.,) appear to provide ample opportunities for a successful MAR scheme. However, the geochemistry of the target aquifers (reduced geochemical environment) relative to the injection of fresh, oxygenated surface water presents challenges with respect to potential bore clogging if direct injection is pursued.

Overall, MAR appears to have potential as a groundwater management tool for the Poverty Bay Flats area. This potential will be explored further during the second stage of the project (Stage 1B).

7.0 LIMITATIONS

Your attention is drawn to the document, "Report Limitations", as attached in Appendix C. The statements presented in that document are intended to advise you of what your realistic expectations of this report should be, and to present you with recommendations on how to minimise the risks to which this report relates which are associated with this project. The document is not intended to exclude or otherwise limit the obligations necessarily imposed by law on Golder Associates (NZ) Limited, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

8.0 REFERENCES

Aqualinc 2012. Review of "Groundwater in the Poverty Bay Flats", prepared by Aqualinc Research Limited for Horticulture New Zealand, report C09069/13, 14 p.

Aqualinc 2013. Strategic water study into the supply and demand options for the four main catchments within the Gisborne District. Report prepared for Gisborne District Council by Aqualinc Research Ltd. Report No H13000/3. October 2013.

Barber JL 1993. Groundwater of the Poverty Bay Flats: a brief synopsis. Gisborne District Council report, 43 p.

Doak M, Parminter I, Horgan G, Monk R, Elliot G 2004. The economic value of irrigation In New Zealand. Ministry of Agriculture and Forestry Technical Report 04/01, 65 p.

Dillon P, Kumar A, Kookana R, Leijs R, Reed D, Parsons S, Ingleton G 2009. Managed aquifer recharge - risks to groundwater dependent ecosystems – a review. Water for a healthy country flagship report series. Published by Land & Water Australia, 119 p.

Elmsley TA, Brown LL, Turnpenny BW 1984. Poverty Bay Flats groundwater geochemistry report. Report prepared for East Cape Catchment Board and Regional Water Board.

GDC 2010. Water Supply Activity Management Plan. Report prepared by Gisborne District Council, 2010. 136 p.

GDC 2011. Water demand forecasting – Gisborne water supply, Appendix 1. Report prepared by Gisborne District Council, December 2011, 11 p.

GDC 2012. An assessment of the economic value of irrigation on the Poverty Bay Flats. Report prepared for Gisborne District Council and Horticulture New Zealand by The AgriBusiness Group, February 2012.

GDC 2013. Groundwater and surface water use and allocation. Memorandum prepared by Julie Van de Valk and Dennis Crone for the Freshwater Advisory Group, dated 12 June 2013.

Goldsim 2014. GoldSim Technology Group website. http://www.goldsim.com

NIWA 2010. Review of groundwater information for the Poverty Bay Aquifers. Report produced for Gisborne District Council by the National Institute for Water and Atmospheric Research. NIWA client report CHC2010-022, April 2010.

Taylor CB 1994. Hydrology of the Poverty Bay Flats aquifers, New Zealand: recharge mechanisms, evolution of the isotopic composition of dissolved inorganic carbon, and ground-water ages. Journal of Hydrology 158: 151-185.

White P, Moreau-Fournier M, Tschritter C, Murphy P 2012. Groundwater in the Poverty Bay flats. GNS Science Report 2012/106, 68 p.

APPENDIX A

Groundwater Pressure Records

GROUNDWATER LEVEL GRAPHS

Groundwater levels are recorded in metres above mean sea level (m amsl). The bore number, aquifer, and depth of the monitoring bores below ground level are presented in the legend to each chart.

Multi-level sites

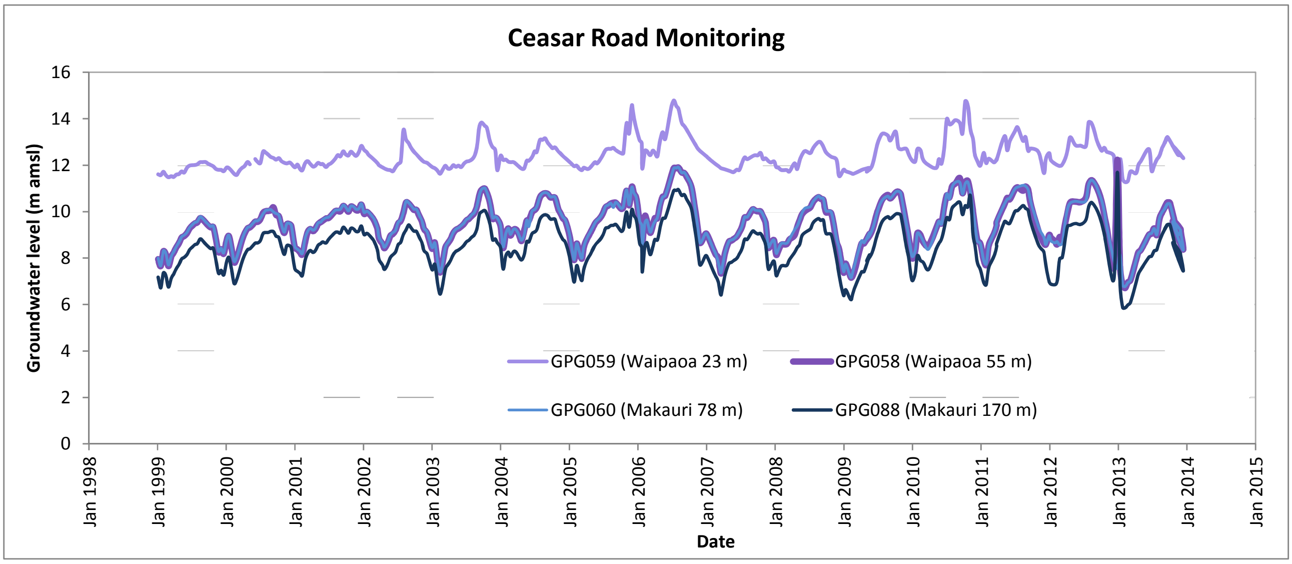


Figure A1: Caesar Road groundwater pressure monitoring 1999 to 2014.

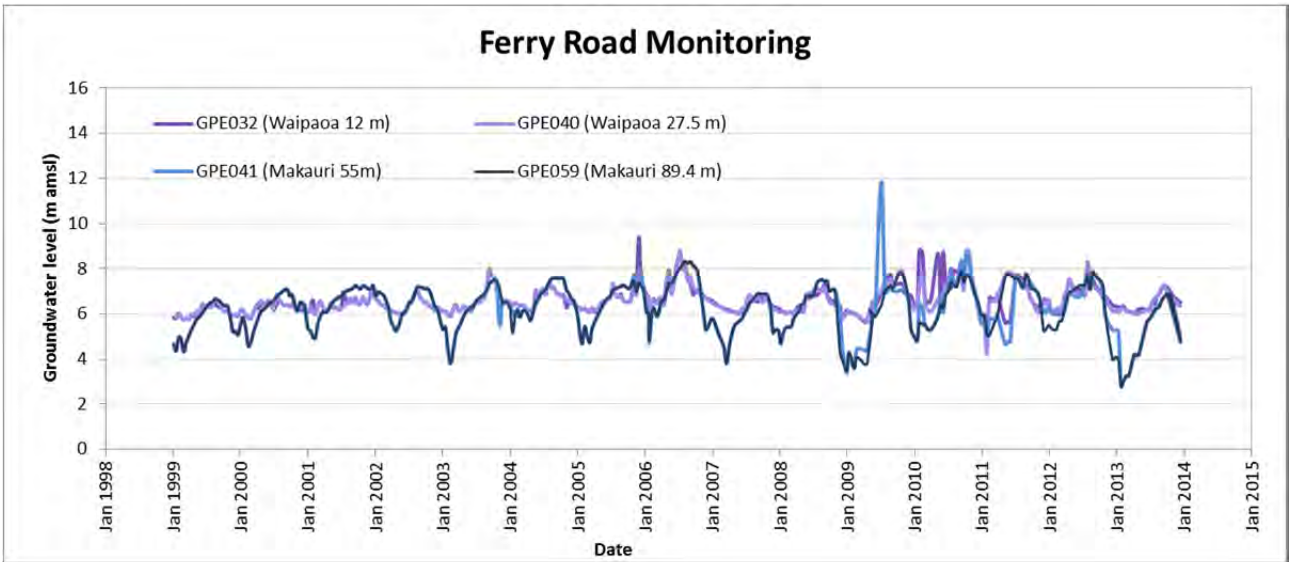


Figure A2: Ferry Road groundwater pressure monitoring 1999 to 2014.

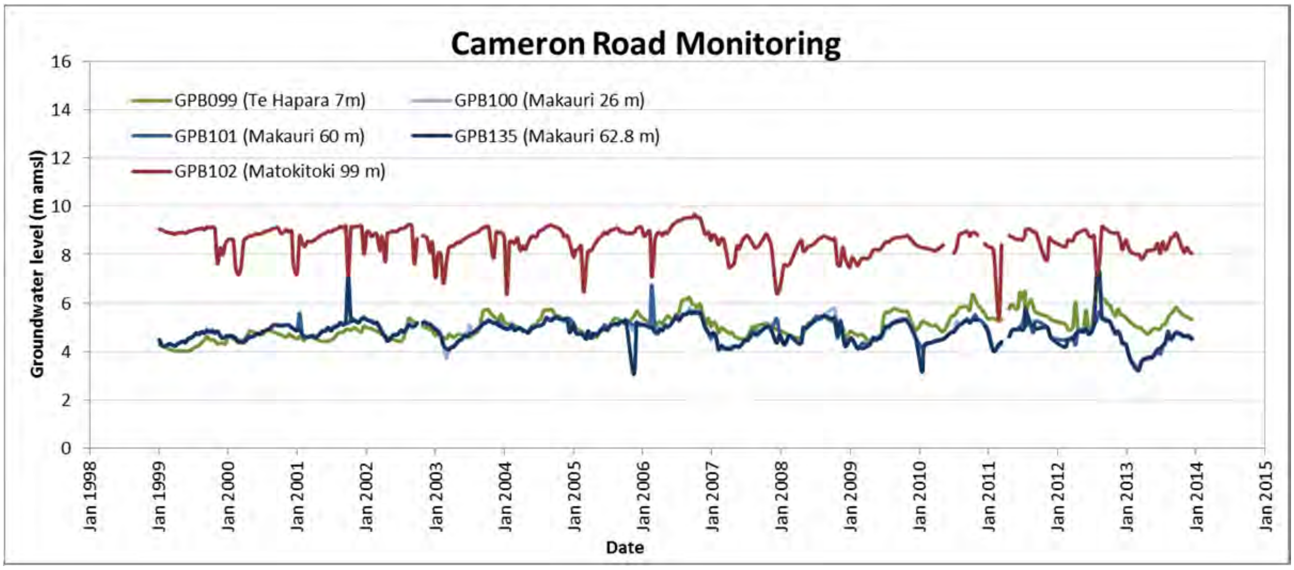


Figure A3: Cameron Road groundwater pressure monitoring 1999 to 2014.

Makauri Aquifer Examples

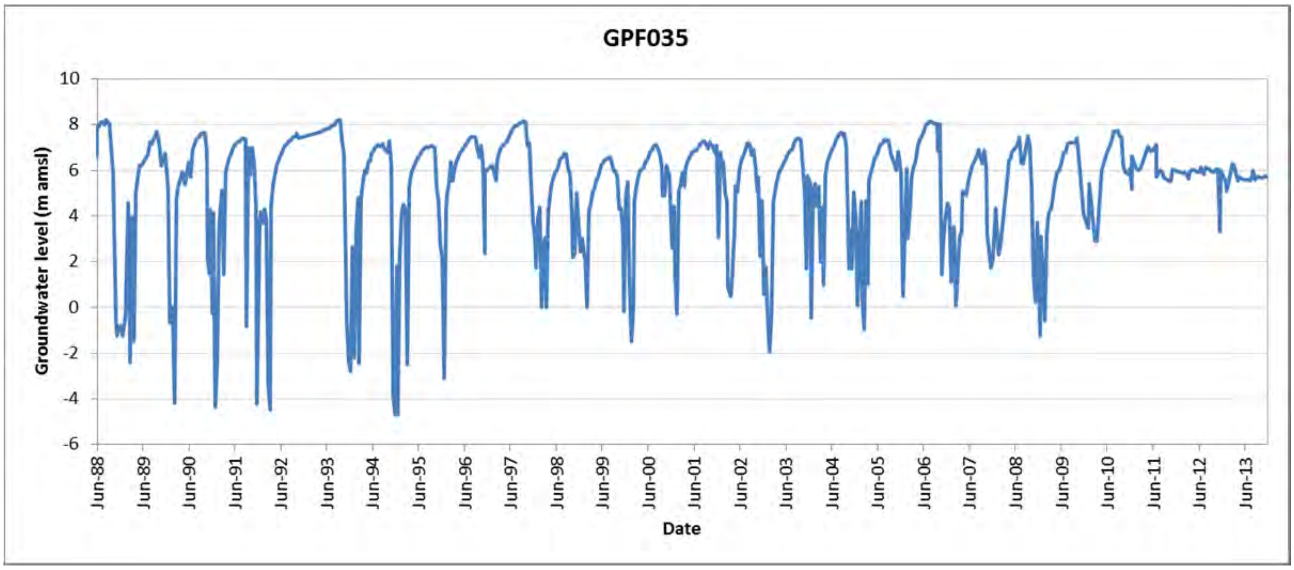


Figure A4: Groundwater pressures in GPF035, central Makauri Aquifer, 1988 to 2013.

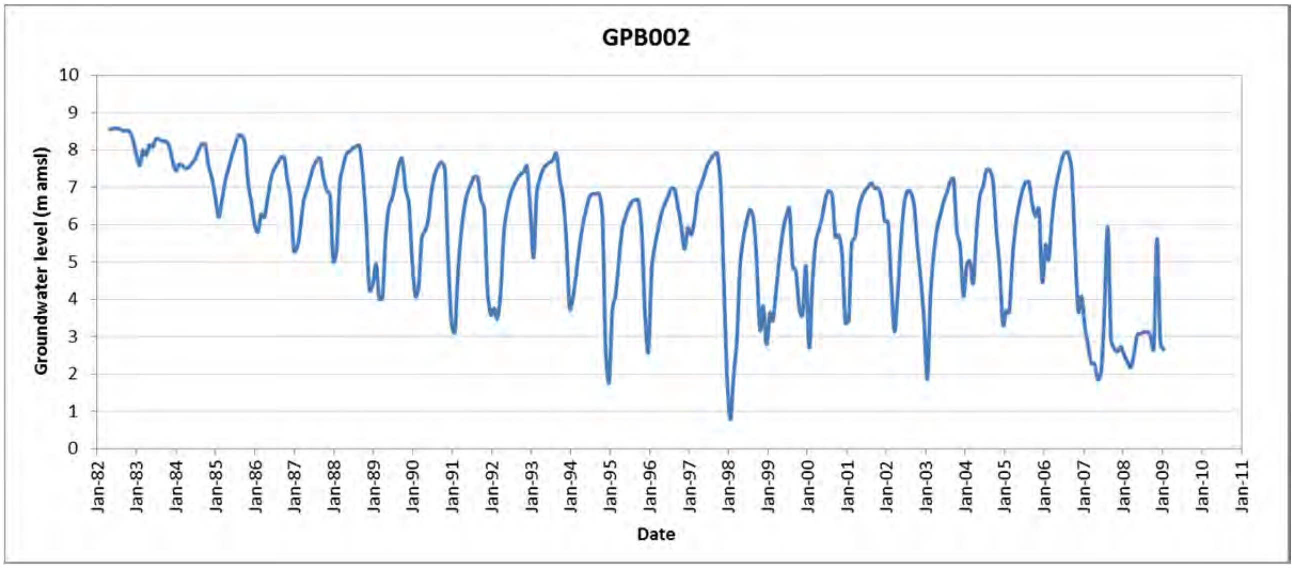


Figure A5: Groundwater levels in GPB002, central Makauri Aquifer, 1982 to 2009.

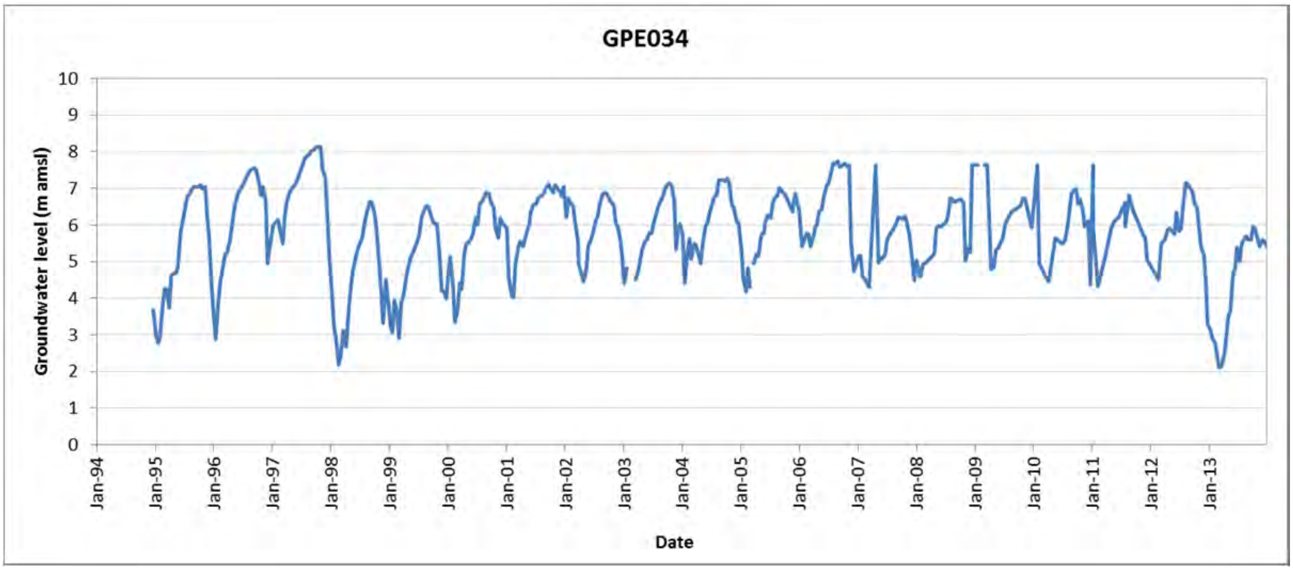


Figure A6: Groundwater levels in GPE034, central Makauri Aquifer, 1995 to 2013.

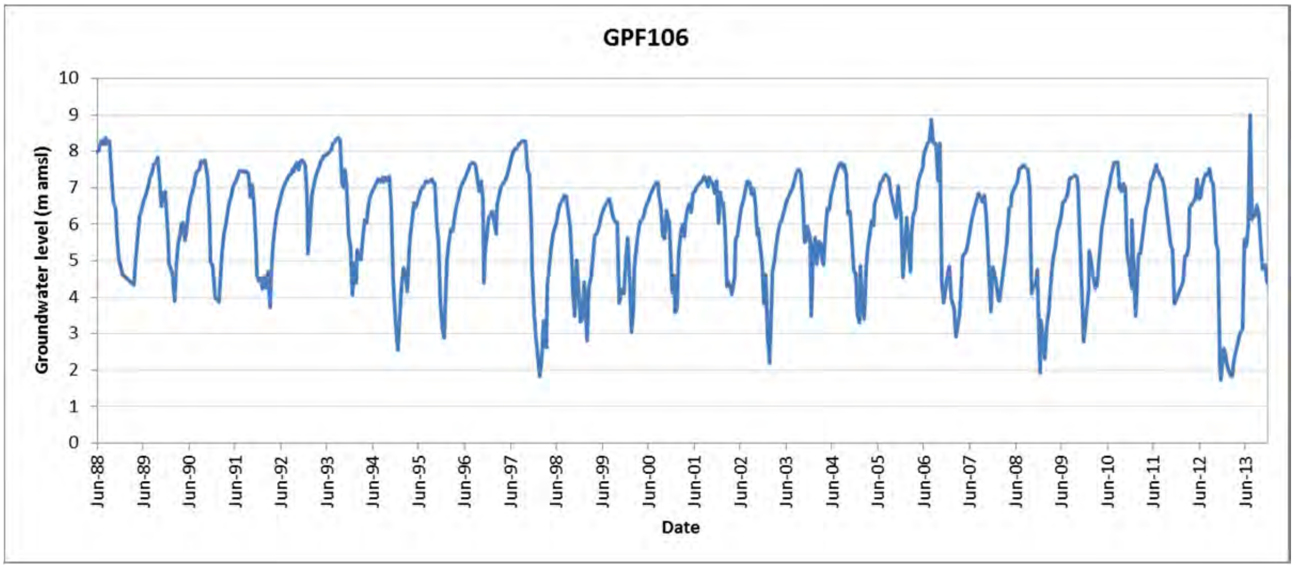


Figure A7: Groundwater levels in GPF106, central Makauri Aquifer, 1988 to 2013.

Matokitoki Aquifer Examples

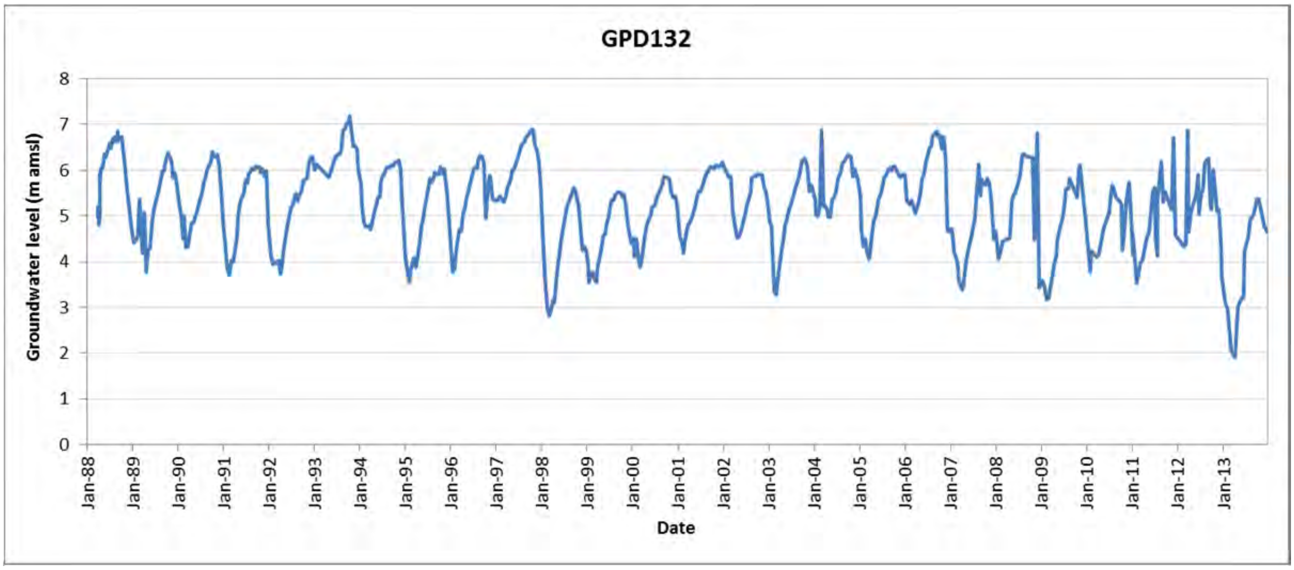


Figure A8: Groundwater levels in GPD132, central Matokitoki Aquifer, 1988 to 2013.

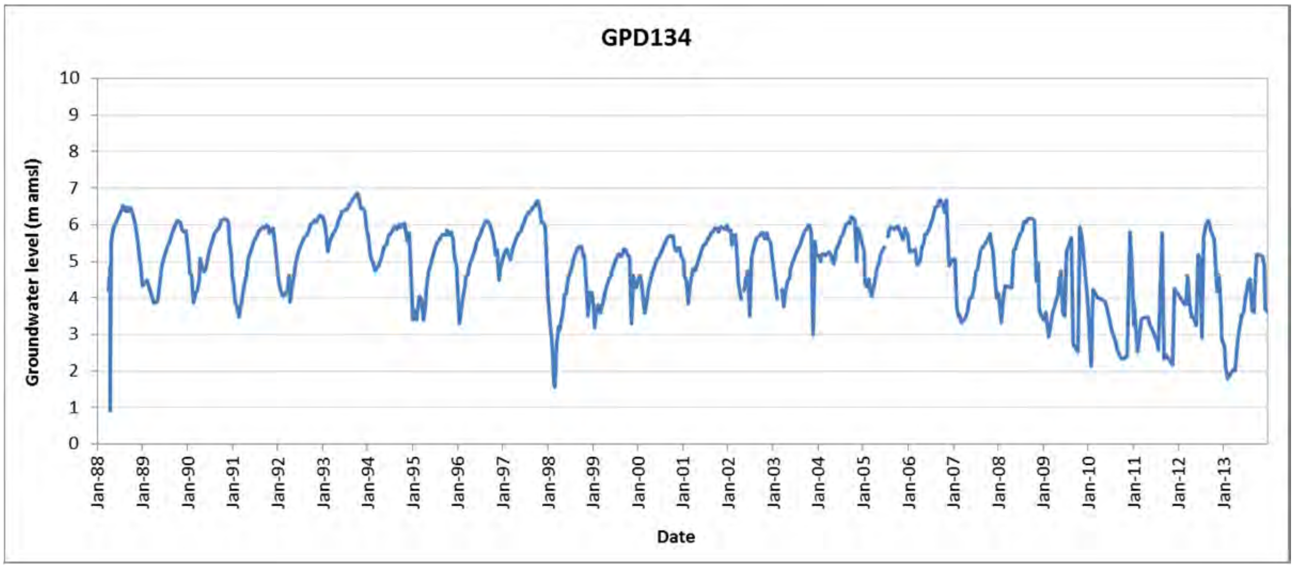


Figure A9: Groundwater levels in GPD134, central Matokitoki Aquifer, 1988 to 2013.

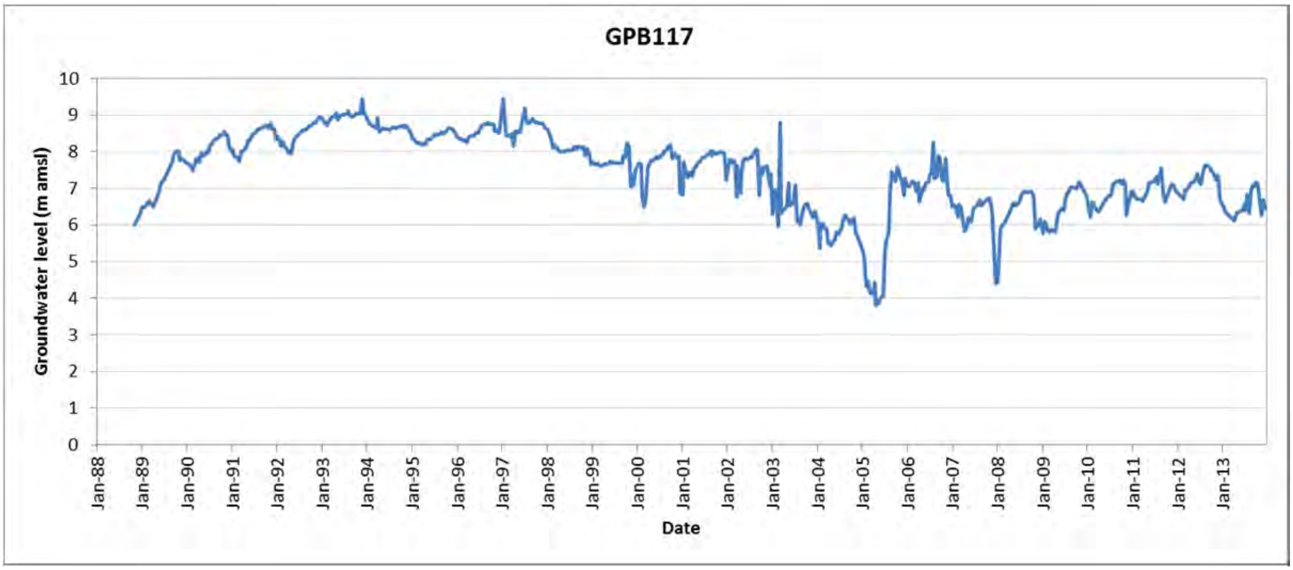


Figure A10: Groundwater levels in GPB117, central Matokitoki Aquifer, 1988 to 2013.

i:\projects-numbered\13781x\10xxx\1378110_136_leaderbrand_mar_stage1\reports (golder)\stage 1a environlink report\1378110136-003-r-appa gw levels.docx

APPENDIX B

Water Quality Data

INTRODUCTION

The raw water quality data presented in this appendix has been sourced from Gisborne District Council records. A formal quality control assessment of the data has not been undertaken at this stage however, a few clearly anomalous individual data points that are probably incorrect have been removed from the data in the interest of providing a clearer picture of general water quality conditions.

WAIPAOA RIVER

Total suspended solids concentrations in the river water vary on a seasonal basis and in response to flow rates in the river (Table B1, Figure B1, Figure B2)

Nitrate (Figure B3) and dissolved reactive phosphate (Figure B4) concentrations in the river water vary on a seasonal basis and in response to flow rates in the river. The seasonality of sulfate concentrations in the river is less pronounced although still present (Figure B5).

The measured concentrations of the parameters presented in this appendix are very similar between Kanakanaia and Matawhero, with the exception of calcium hardness (Figure B6). Calcium hardness analysis results have generally been higher at Matawhero than at Kanakanaia.

Dissolved oxygen concentrations in the river water vary on a seasonal basis (Figure B7), in response to temperature changes Figure B8. The biological oxygen demand (BOD) from samples obtained from both monitoring sites was similar until about 2009. Following that time the BOD in water at Matawhero has generally been higher than at Kanakanaia. Faecal coliform counts vary greatly in the river water at both sites (Figure B10).

A statistical summary of selected water quality monitoring result from the Waipaoa River is presented in Table B2.

Table B1: Waipaoa River total suspended solids statistical summary.

Parameter	Kanakanaia (1)	Matawhero (1)
Number of samples	143	127
Mean (g/m^3)	405	379
Median (g/m^3)	120	99
Maximum (g/m^3)	11,000	6,400
Minimum (g/m^3)	2	2

Note: 1) All data included in statistics – no anomalous data points.

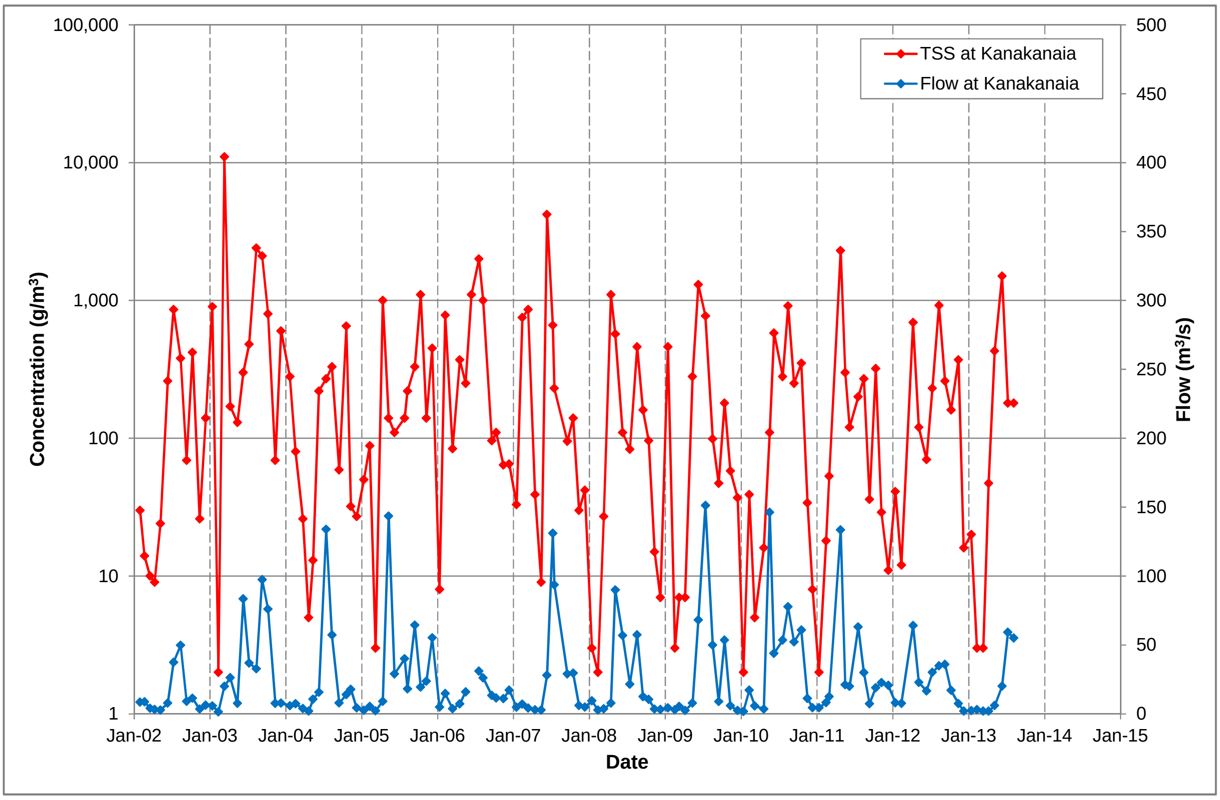


Figure B1: Waipaoa River total suspended solids concentrations and flow rates at Kanakanaia.

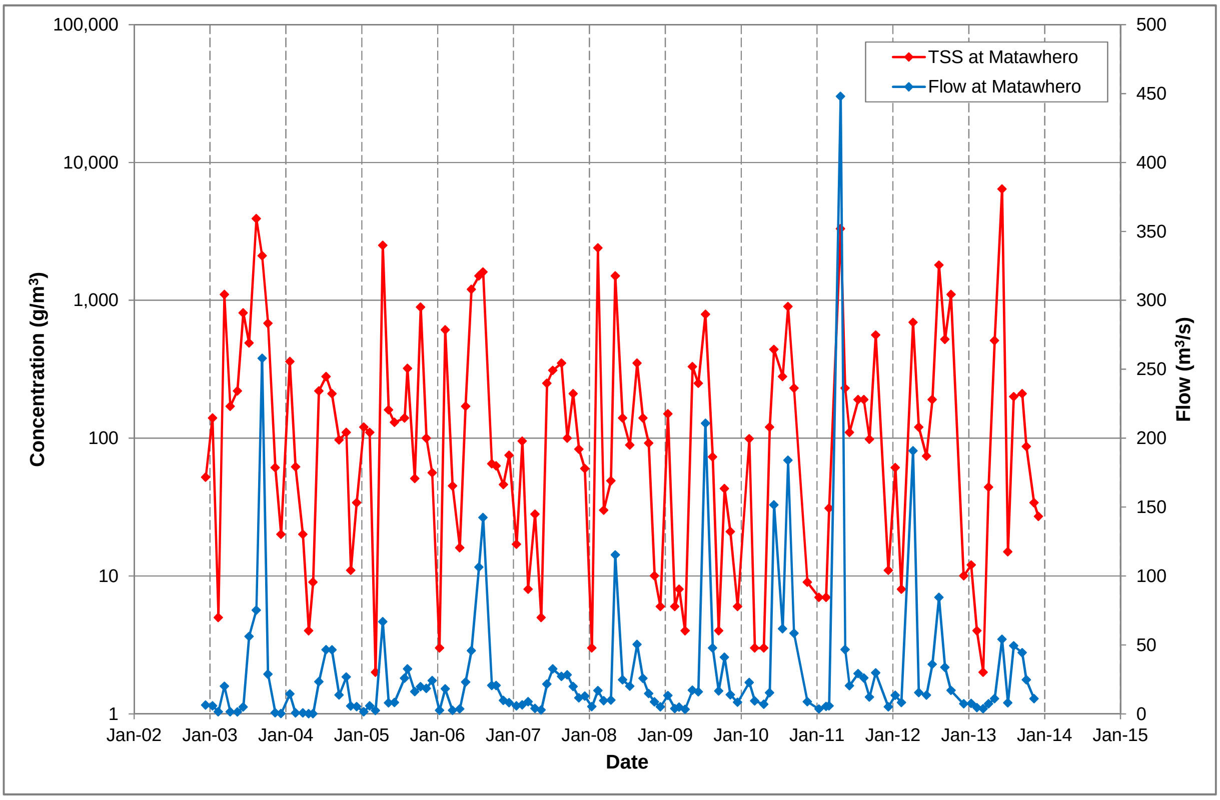


Figure B2: Waipaoa River total suspended solids concentrations and flow rates at Matawhero.

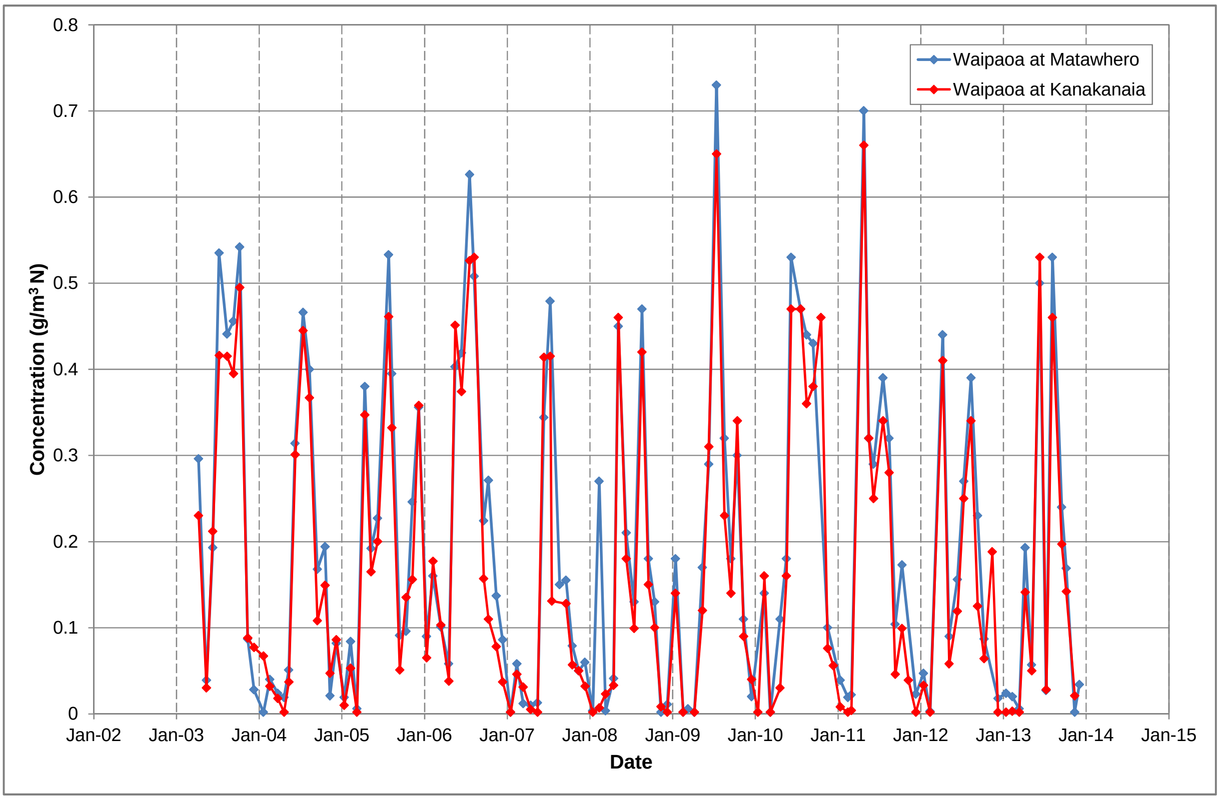


Figure B3: Waipaoa River nitrate-N concentrations at Matawhero and Kanakanaia.

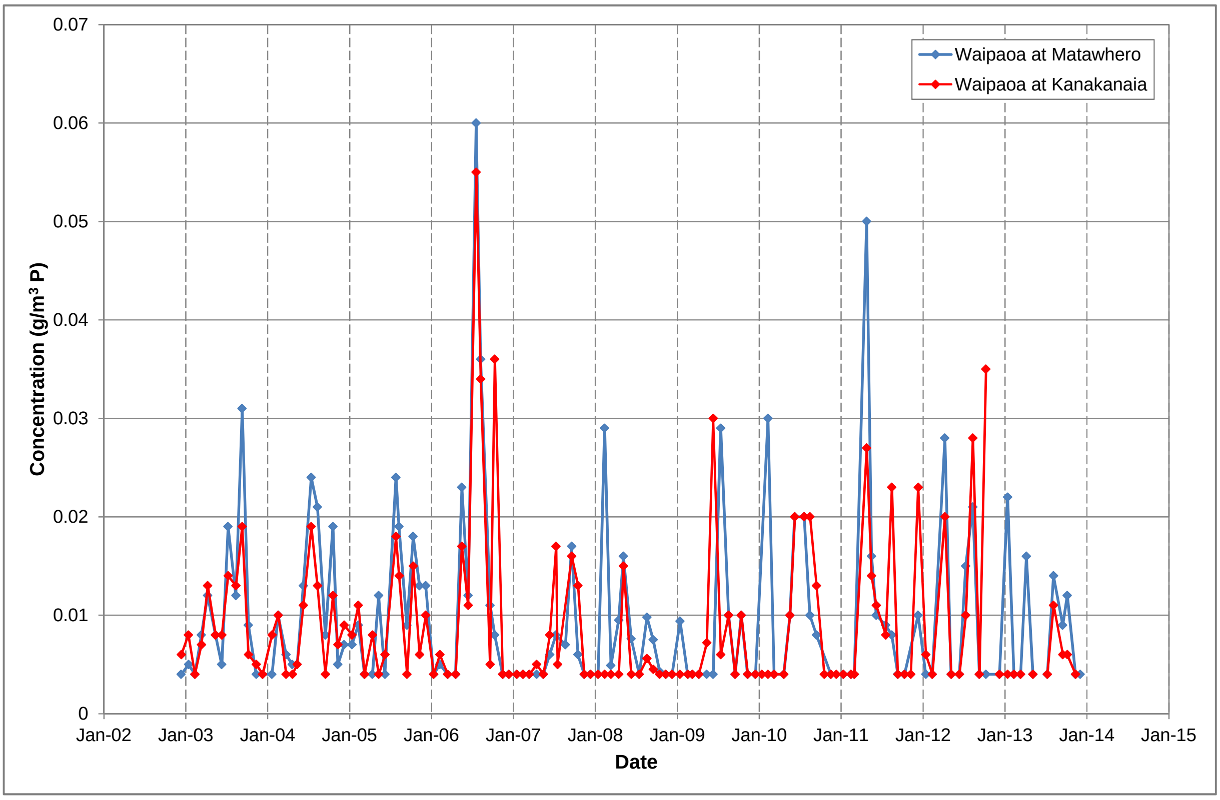


Figure B4: Waipaoa River dissolved reactive phosphate-P concentrations at Matawhero and Kanakanaia.

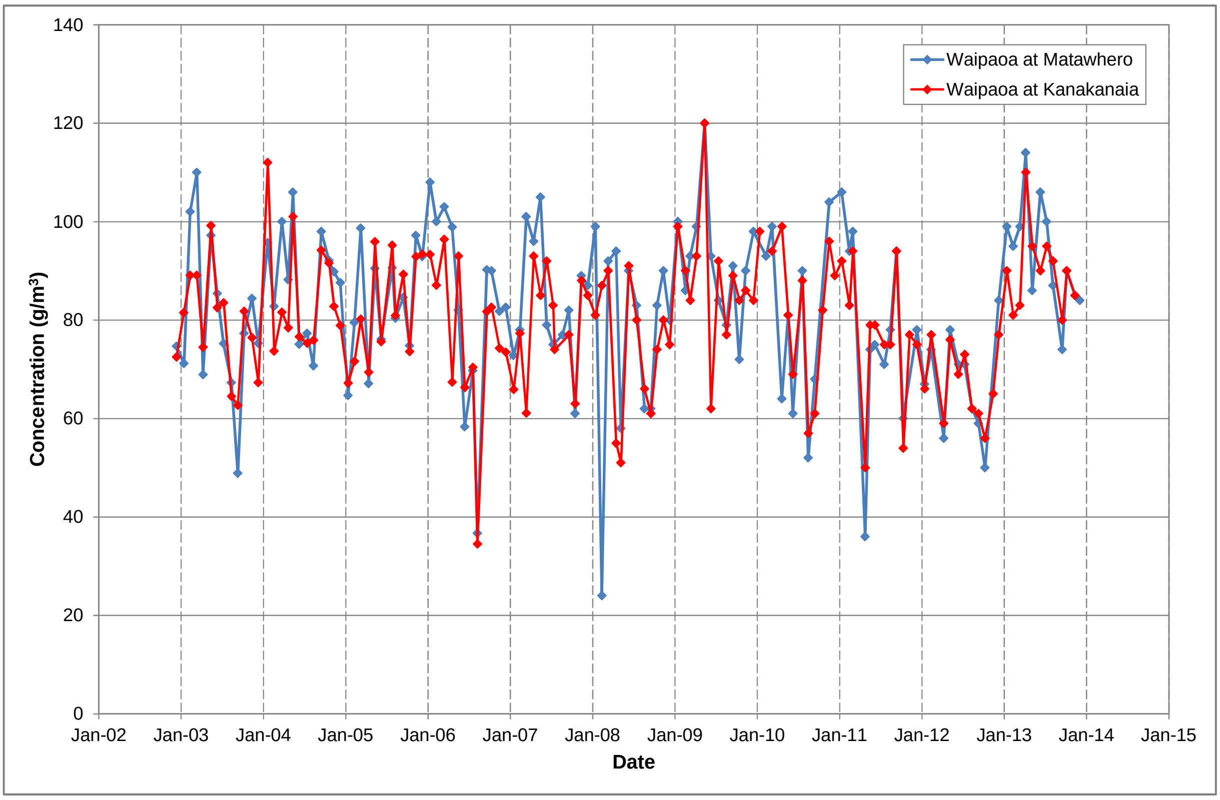


Figure B5: Waipaoa River sulfate concentrations at Matawhero and Kanakanaia.

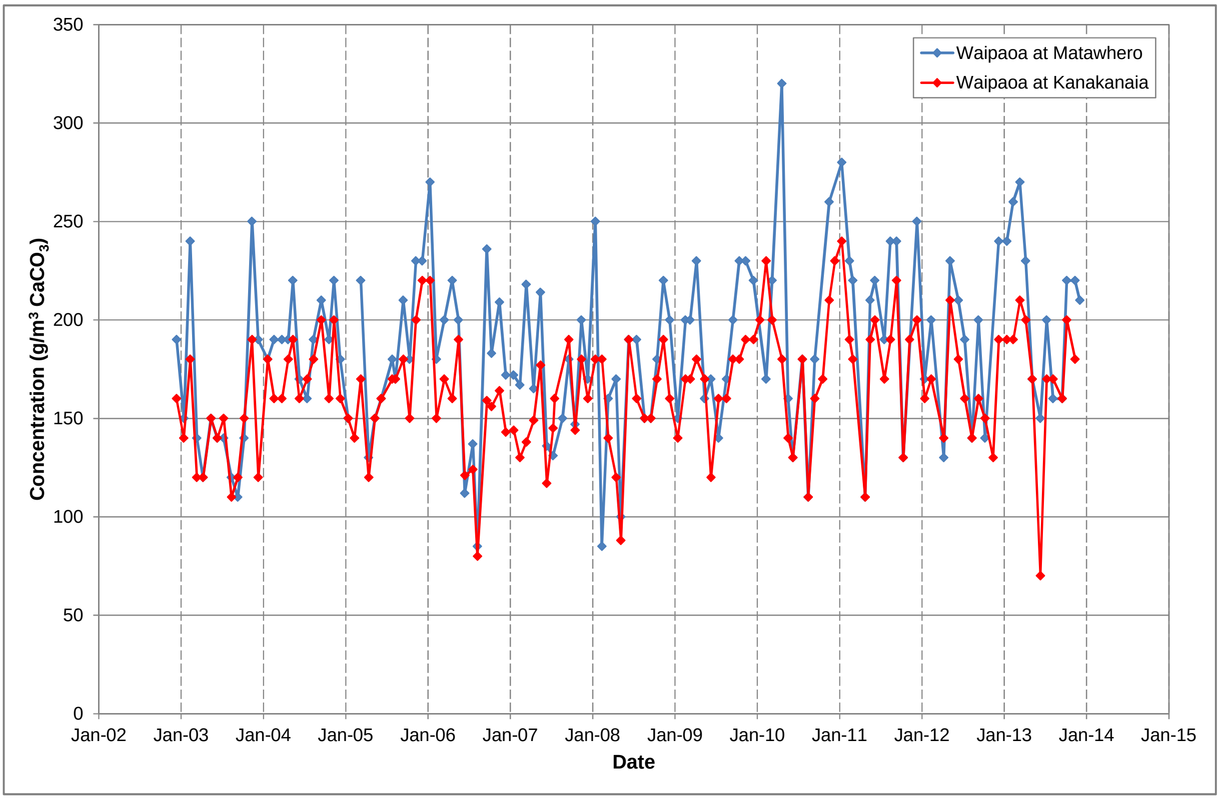


Figure B6: Waipaoa River calcium hardness at Matawhero and Kanakanaia.

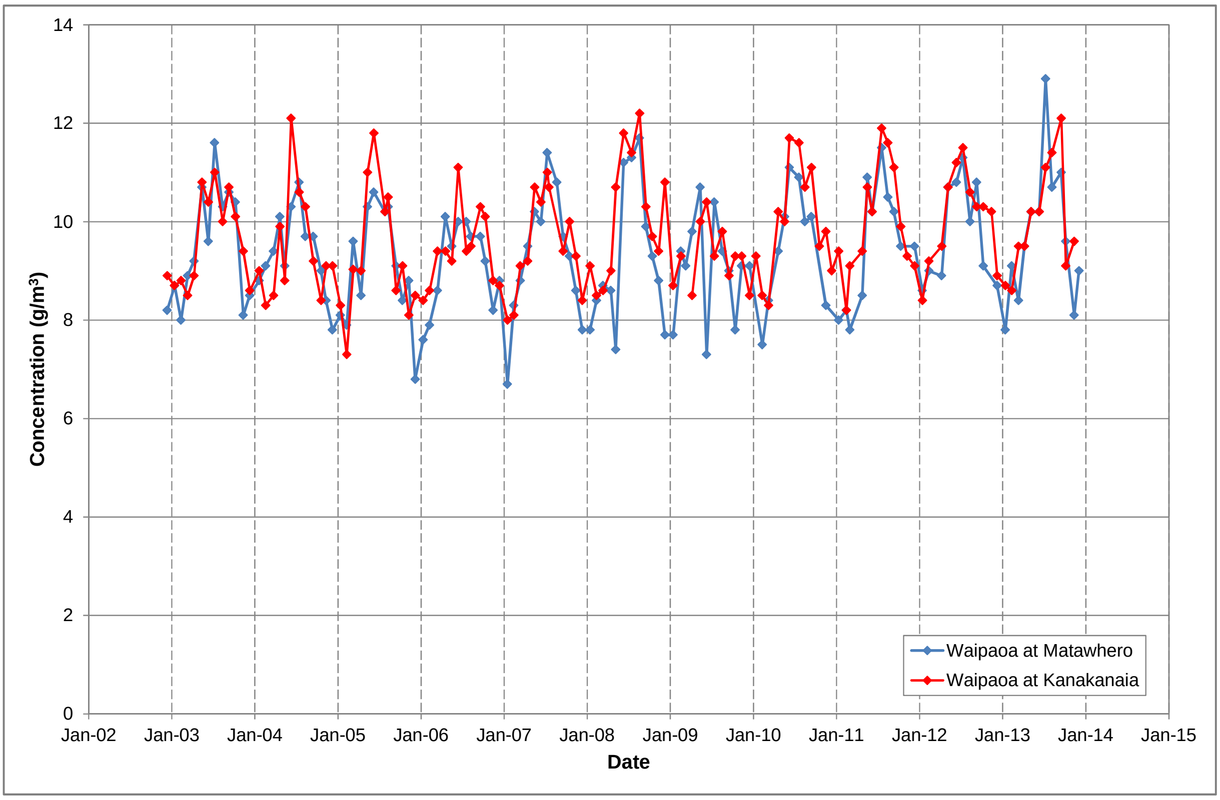


Figure B7: Waipaoa River dissolved oxygen concentrations at Matawhero and Kanakanaia.

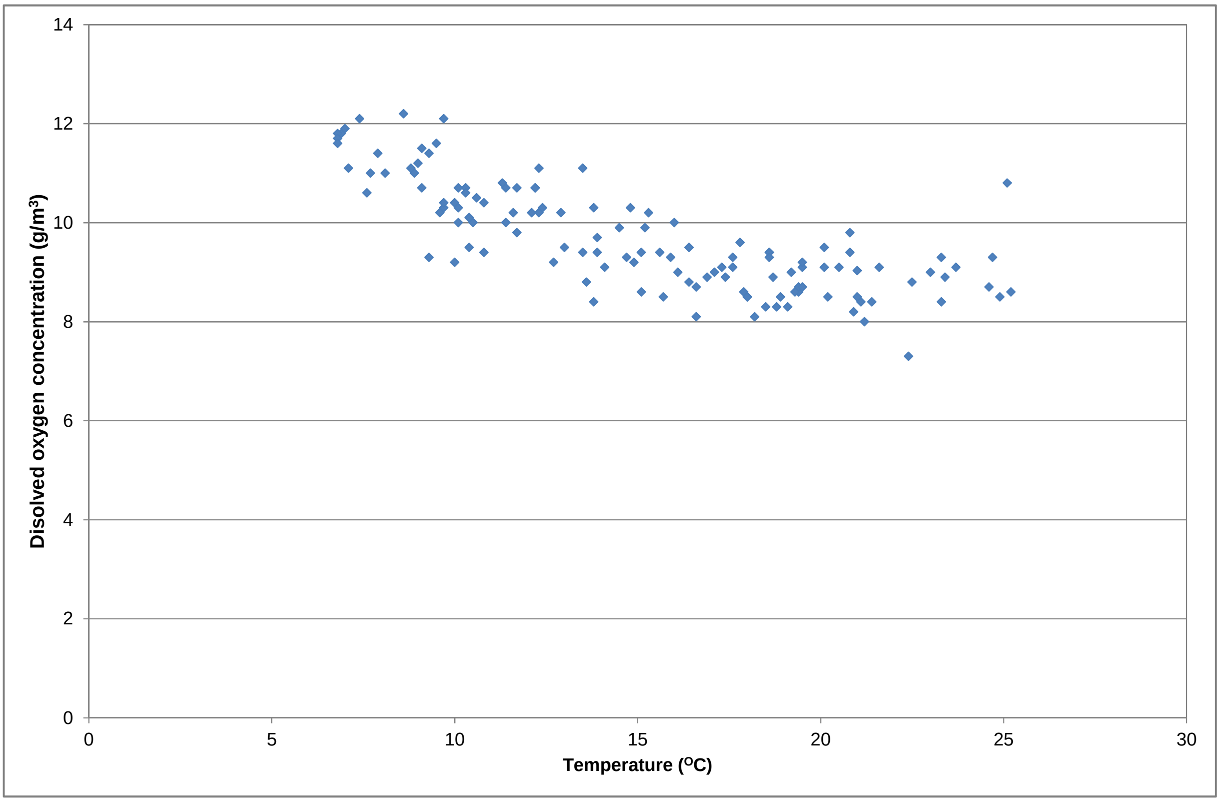


Figure B8: Waipaoa River dissolved oxygen concentrations at Kanakanaia compared to water temperature.

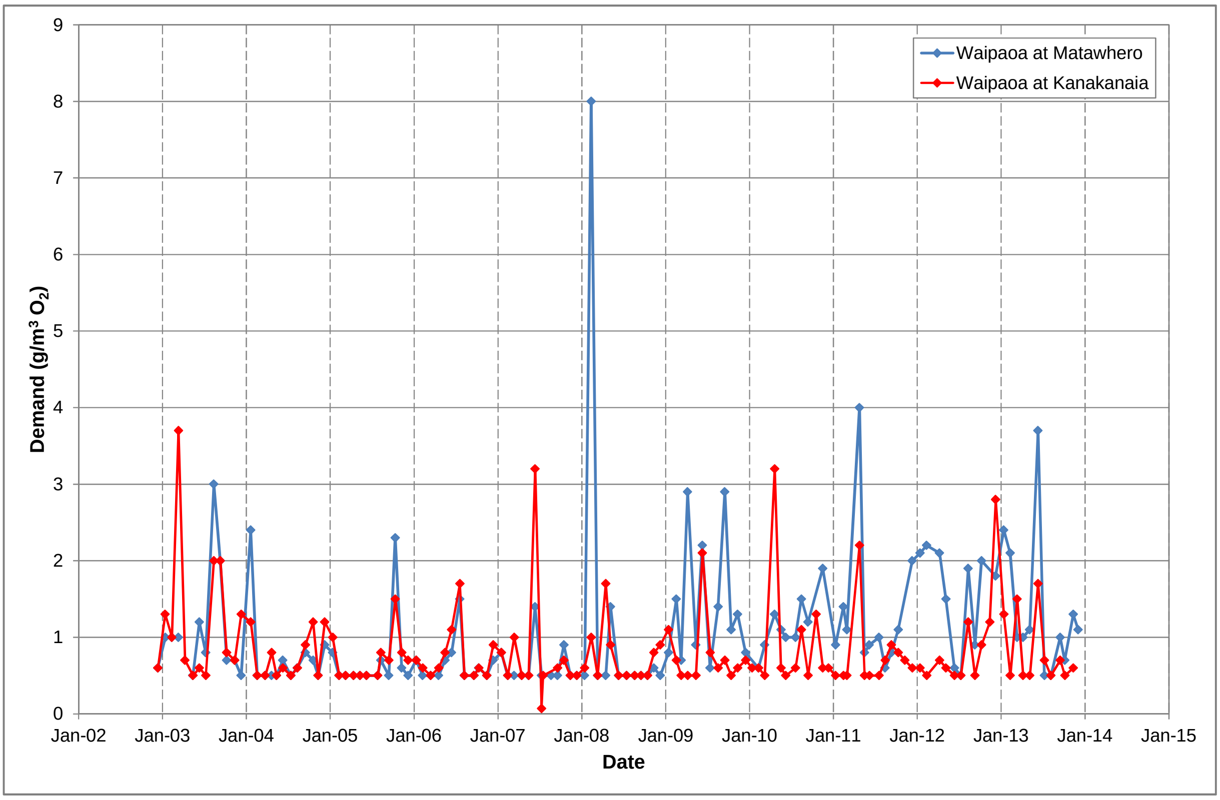


Figure B9: Waipaoa River biological oxygen demand at Matawhero and Kanakanaia.

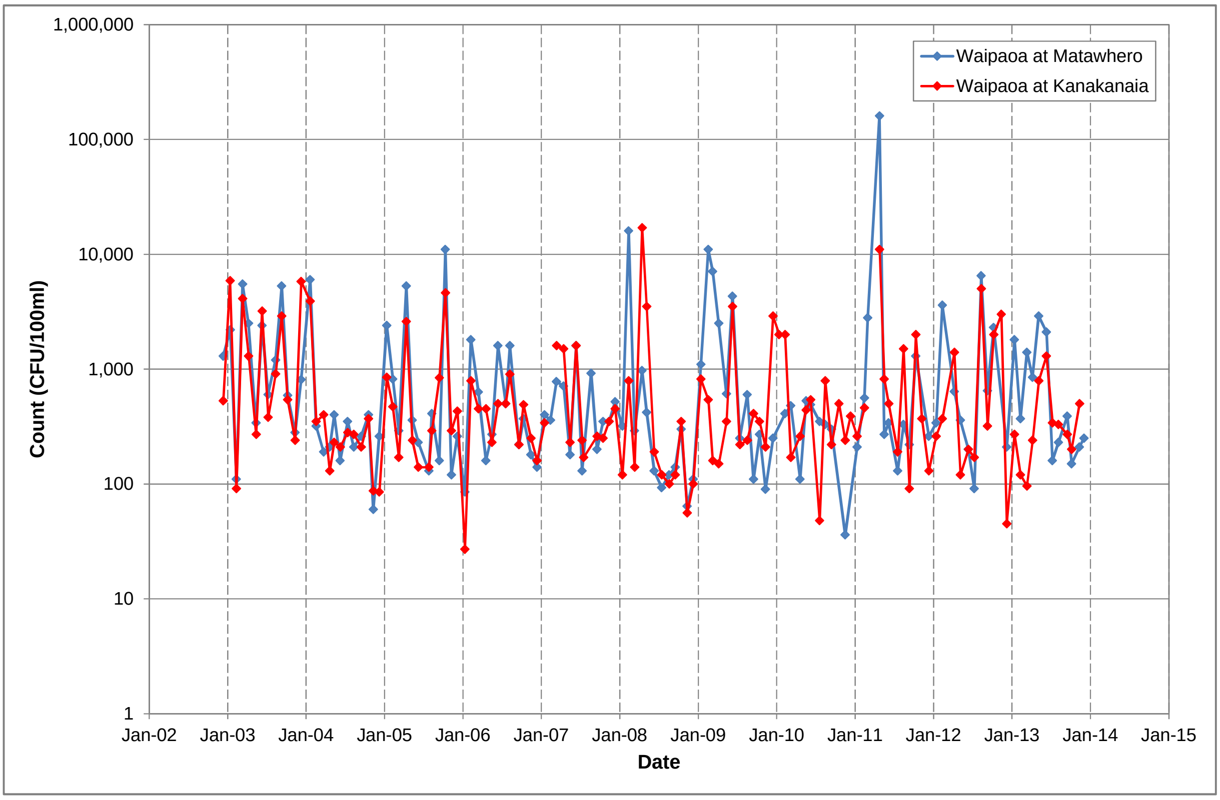


Figure B10: Waipaoa River faecal coliform counts at Matawhero and Kanakanaia.

Table B2: Waipaoa River water quality parameter statistical summary.

Parameter	Nitrate-N	DRP-P	Sulfate	Calcium hardness	Dissolved oxygen	Biological oxygen demand	Faecal coliforms
Units	g/m^3-N	g/m^3-P	g/m^3	g/m^3	g/m^3	g/m^3	CFU/100 mL
Kanakanaia							
Number of samples	126	128	130 (1)	131	130 (1)	131	130
Mean	0.172	0.009	80	164.4	9.7	0.83	1003
Median	0.109	0.005	81	164	9.4	0.60	345
Maximum	0.66	0.055	120	240	12.2	3.7	17,000
Minimum	0.002	0.004	34.5	70	7.3	0.07	0
Matawhero							
Number of samples	123	126	127	126 (1)	127	126 (1)	127
Mean	0.20	0.010	83	185	9.4	1.1	2,439
Median	0.15	0.006	84	187	9.3	0.8	350
Maximum	0.73	0.06	120	320	12.9	8	160,000
Minimum	0.002	0.004	24	85	6.7	0.5	36

Note: 1) One value removed from summary as being highly anomalous and probably incorrect.

GROUNDWATER

The water quality information presented below is based on raw data provided by GDC from their environmental monitoring database. Although a limited quality control process to check the data has been undertaken, this was limited to identifying and removing highly anomalous or clearing incorrect data.

Waipaoa Gravel Aquifer

Dissolved iron, manganese and ammonia concentrations in groundwater from wells intersecting the Waipaoa Aquifer appear to be fairly consistent over time within any single bore, however across the aquifer there is a substantial range of results (Figure B11, Figure B12, Figure B14). A limited amount of dissolved aluminium data for bore water is available, with the results varying greatly even from the same bore (Figure B13). The water quality is evidence of a reducing geochemical environment in the aquifer.

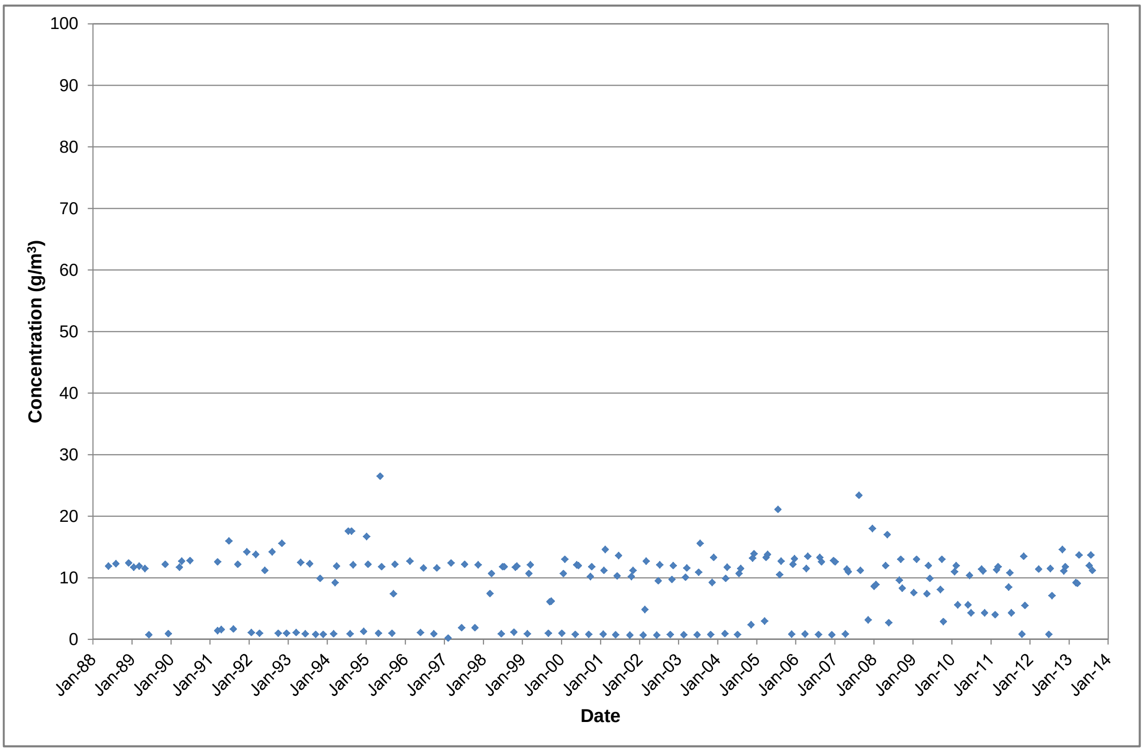


Figure B11: Waipaoa Aquifer dissolved iron concentrations.

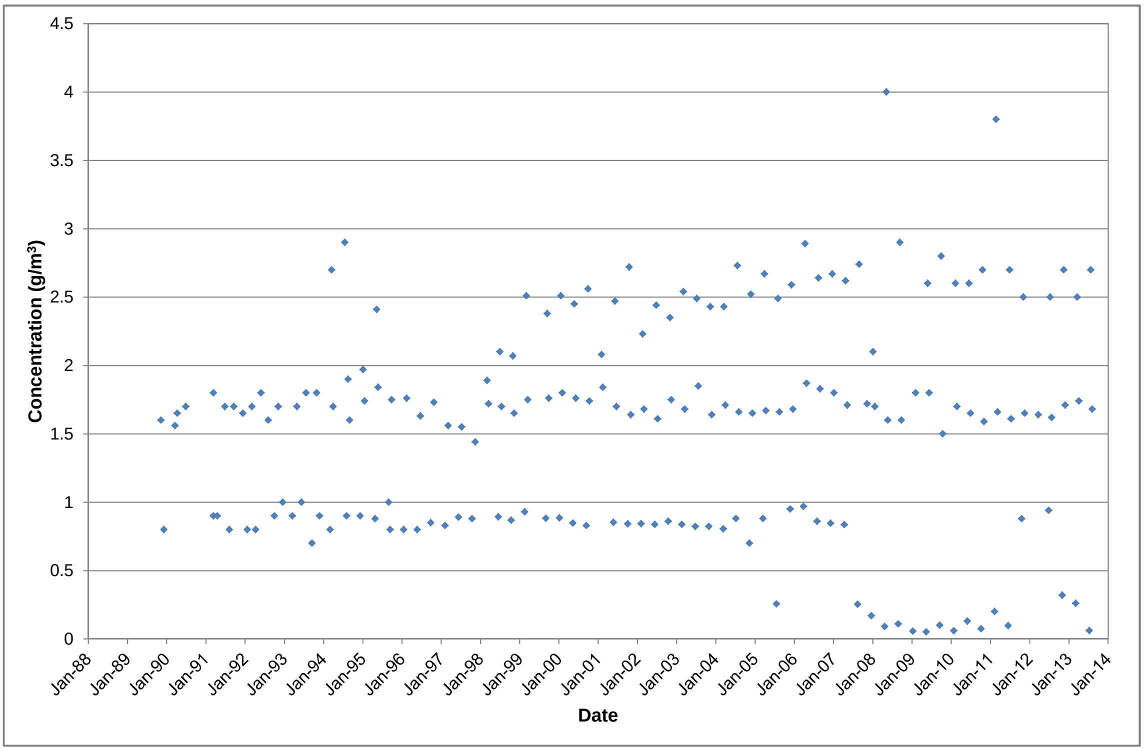


Figure B12: Waipaoa Aquifer dissolved manganese concentrations.

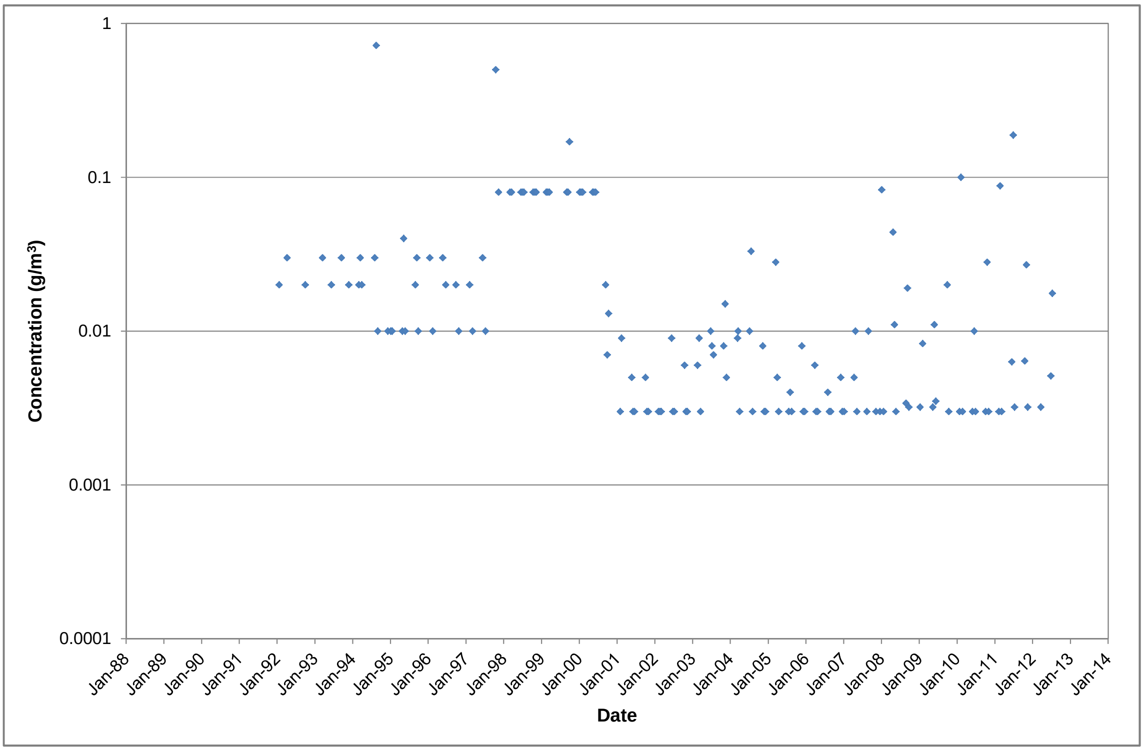


Figure B13: Waipaoa Aquifer dissolved aluminium concentrations.

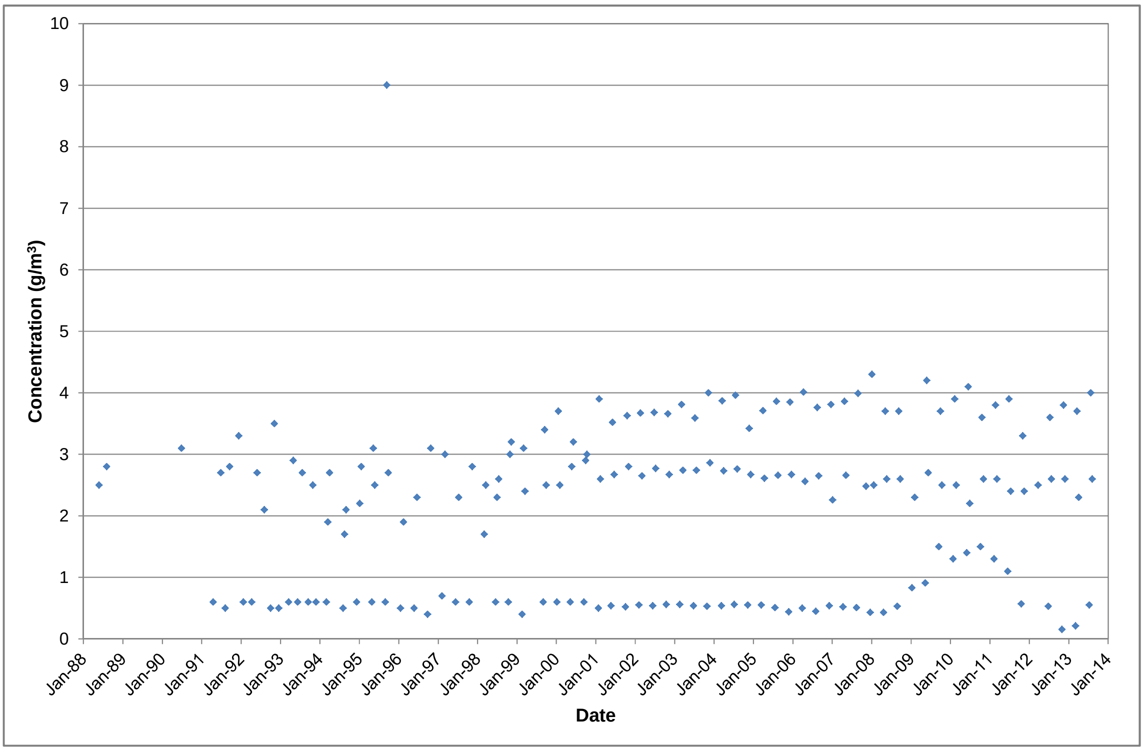


Figure B14: Waipaoa Aquifer ammonia-N concentrations.

Makauri Gravel Aquifer

As with the Waipaoa Aquifer, dissolved iron, manganese and ammonia concentrations in groundwater from wells intersecting the Makauri Aquifer appear to be fairly consistent over time within any single bore, however across the aquifer there is a substantial range of results (Figure B15, Figure B16, Figure B18). More dissolved aluminium data is available for the Makauri Aquifer, however the range of results is similar to that of the Waipaoa Aquifer (Figure B17). The water quality is evidence of a reducing geochemical environment in the aquifer.

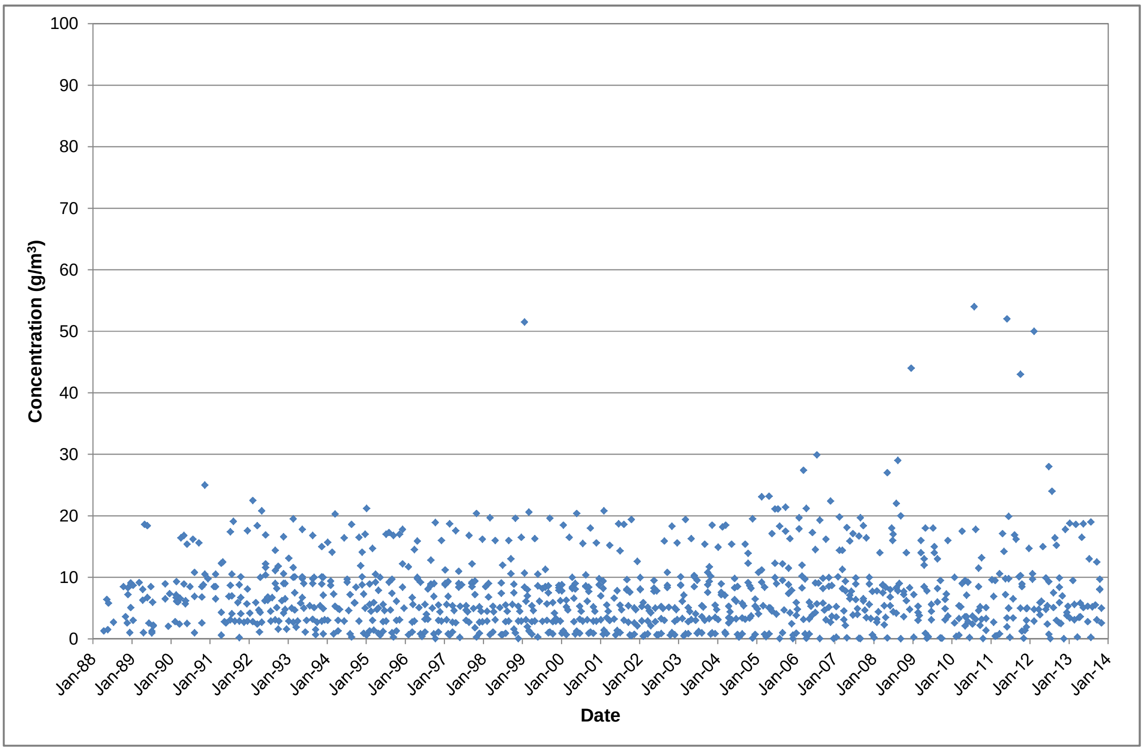


Figure B15: Makauri Aquifer dissolved iron concentrations.

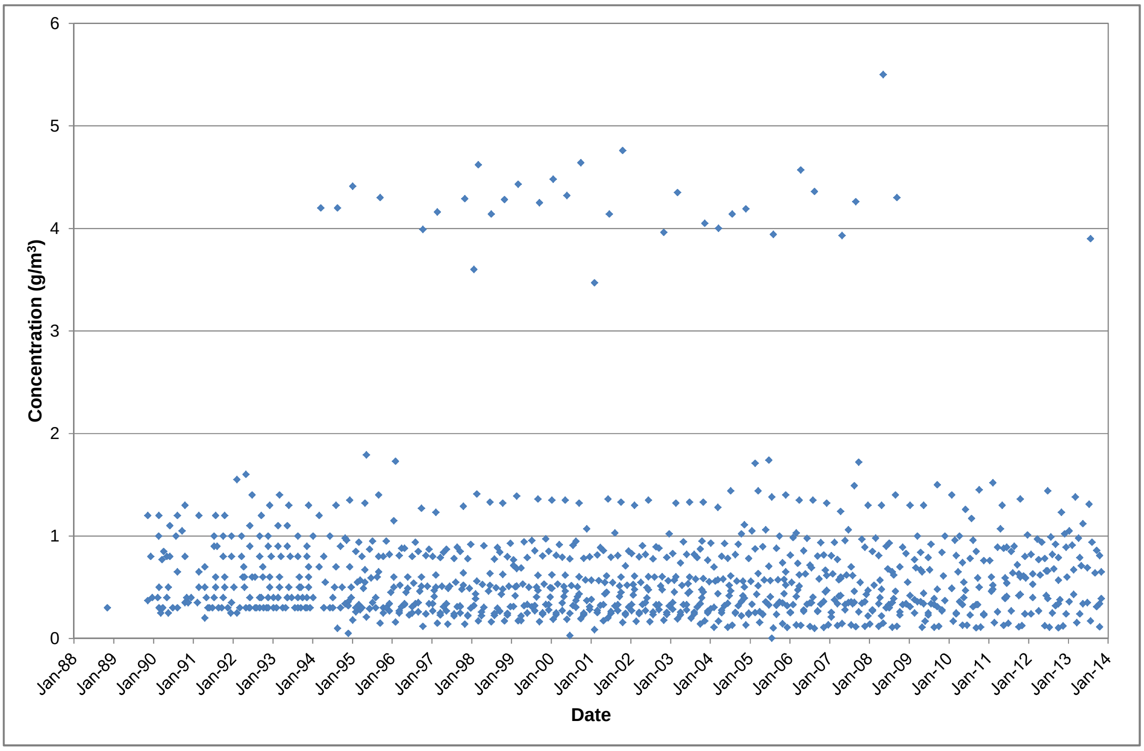


Figure B16: Makauri Aquifer dissolved manganese concentrations.

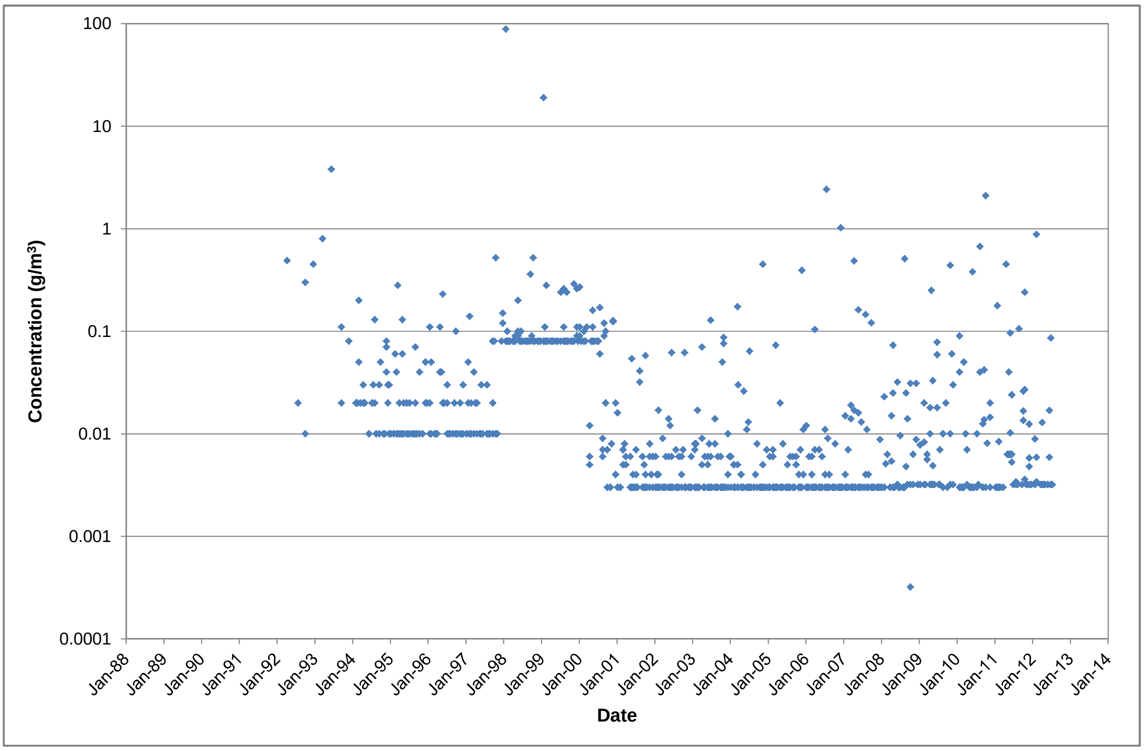


Figure B17: Makauri Aquifer dissolved aluminium concentrations.

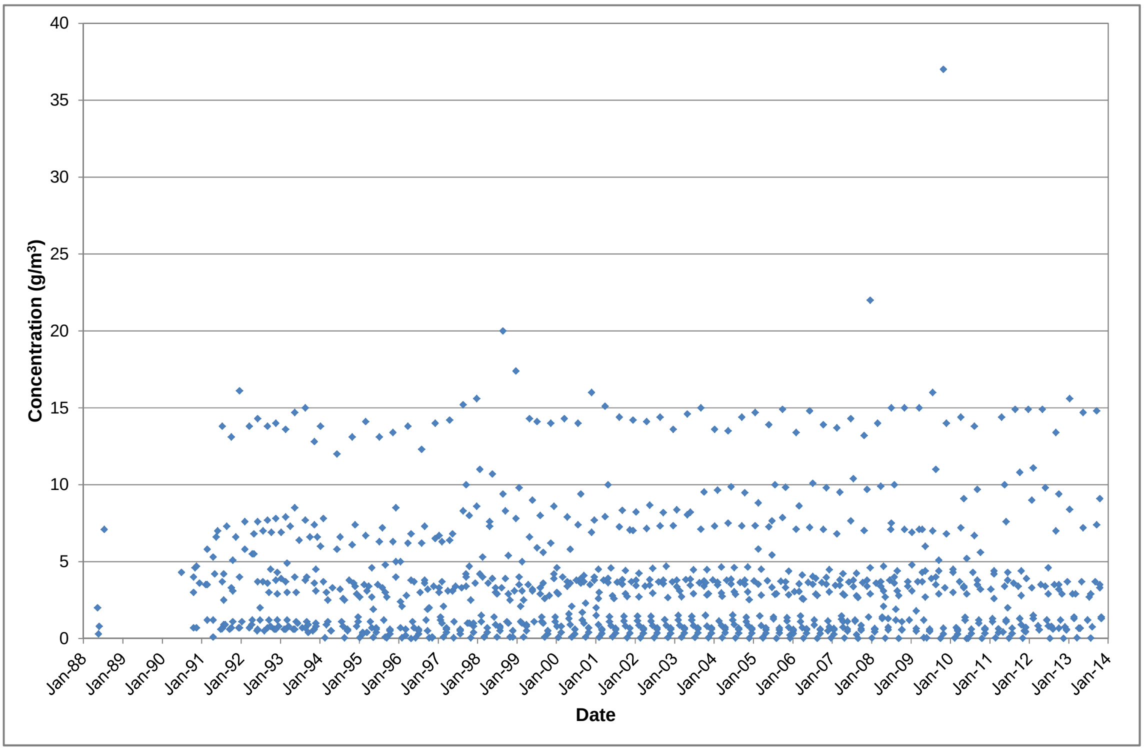


Figure B18: Makauri Aquifer ammonia-N concentrations.

Matokitoki Aquifer

As with the Waipaoa Aquifer, dissolved iron, manganese and ammonia concentrations in groundwater from wells intersecting the Matokitoki Aquifer appear to be fairly consistent over time within any single bore, however across the aquifer there is a substantial range of results (Figure B19, Figure B20, Figure B22). The range of results for dissolved aluminium is similar to that of the Waipaoa Aquifer (Figure B21). The water quality is evidence of a reducing geochemical environment in the aquifer.

A statistical summary of selected water quality data from groundwater monitoring bore installed in the Poverty Bay aquifers is presented in Table B3.

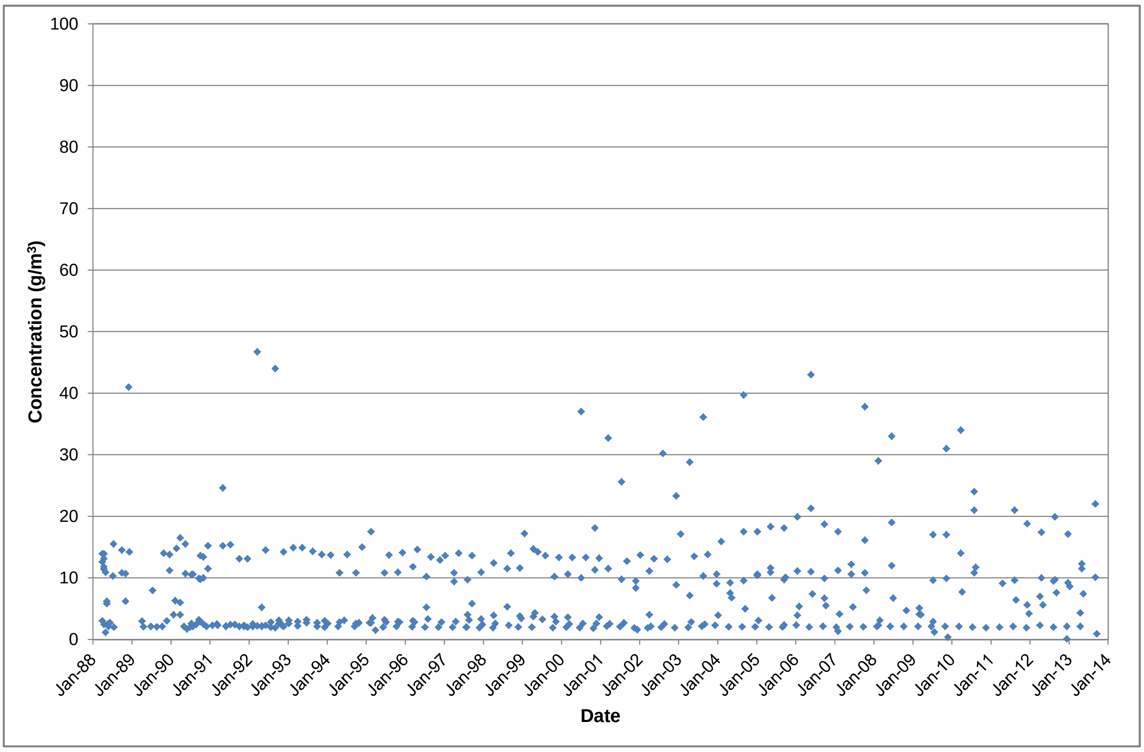


Figure B19: Matokitoki Aquifer dissolved iron concentrations.

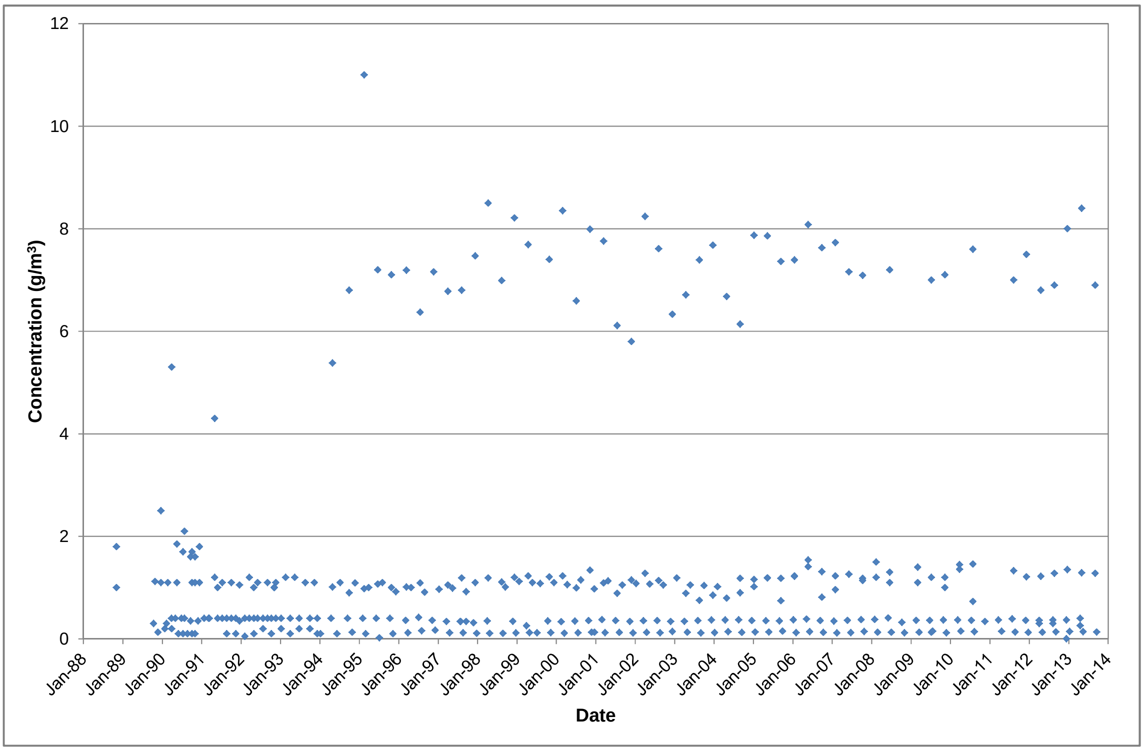


Figure B20: Matokitoki Aquifer dissolved manganese concentrations.

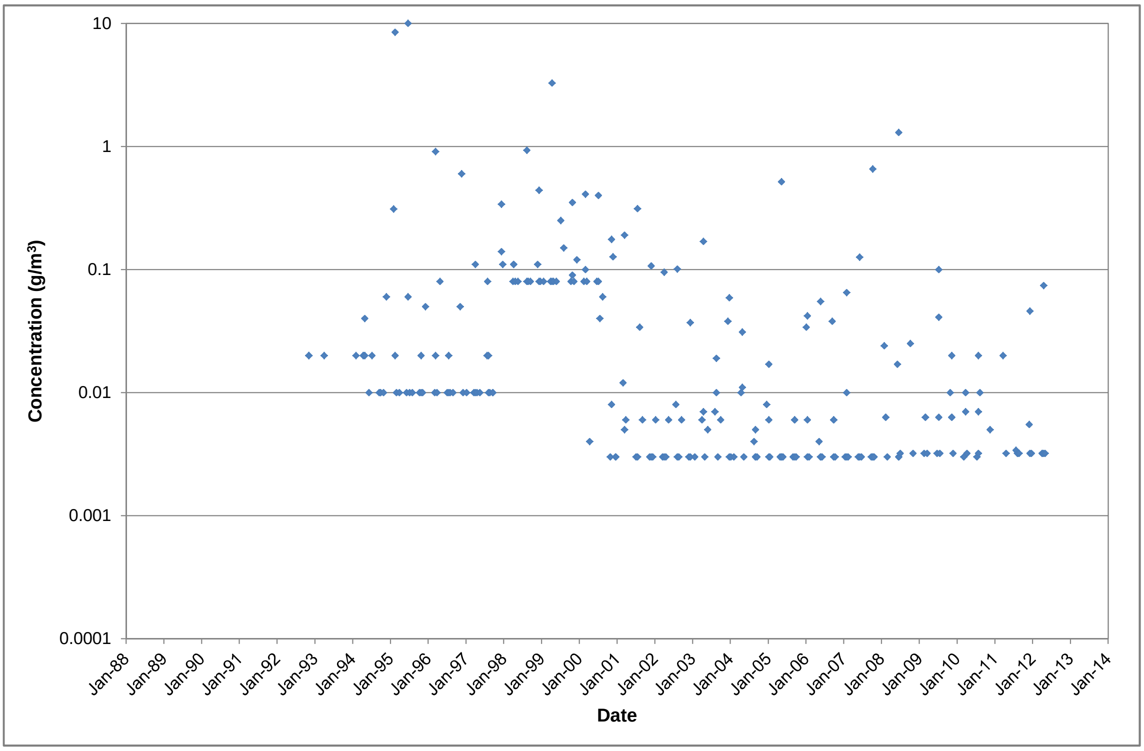


Figure B21: Makauri Aquifer dissolved aluminium concentrations.

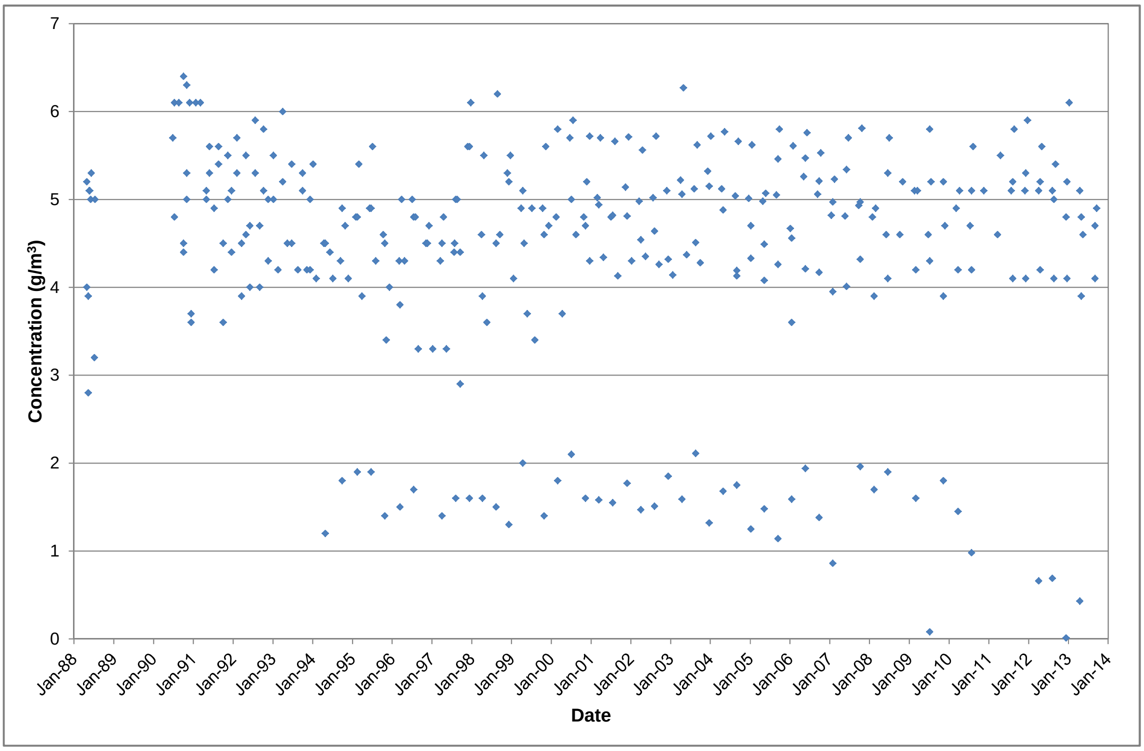


Figure B22: Makauri Aquifer ammonia-N concentrations.

Table B3: Aquifer water quality parameter statistical summary.

Parameter	**Dissolved iron**	**Dissolved manganese**	**Dissolved aluminium**	**Calcium hardness**	**Dissolved reactive phosphorus**	**Ammonia**
Units	g/m^3	g/m^3	g/m^3	g/m^3 $CaCO_3$	g/m^3-P	g/m^3 NH_4-N
Waipaoa Aquifer						
Number of samples	193	185	153	197	184	180
Mean	8.7	1.6	0.031	356	0.020	2.2
Median	11	1.66	0.01	370	0.007	2.5
Maximum	26.5	4.0	0.72	470	0.472	9
Minimum	0.2	0.051	0.003	72	0.004	0.15
Standard Deviation	5	0.78	0.08	69	0.05	1.35
Makauri Aquifer						
Number of samples	959	952	770	1001 (1)	942 (2)	939
Mean	7.8	0.69	0.19	399	0.034	3.79
Median	5.9	0.5	0.0093	350	0.009	2.91
Maximum	287	5.5	88.5	1,200	4.7	37
Minimum	0.023	0.003	0.00032	7	0.001	0.005
Standard Deviation	11	0.75	3.27	153	0.20	4.1
Matokitoki Aquifer						
Number of samples	391	346 (1)	246	400	357 (3)	334 (3)
Mean	8.5	1.6	0.15	517	0.047	4.3
Median	4.7	0.83	0.01	380	0.015	4.7
Maximum	106	11	10	2,400	3.9	6.4
Minimum	0.10	0.0029	0.003	10	0.001	0.01
Standard Deviation	9.4	2.4	0.86	260	0.22	1.4

Note:
1) One value removed from summary as being highly anomalous and probably incorrect.
2) Eight values of 0 removed from statistical summary.
3) Two values of 0 or highly anomalous values removed from statistical summary.

APPENDIX C

Report Limitations

Report Limitations

This Report/Document has been provided by Golder Associates (NZ) Limited (“Golder”) subject to the following limitations:

i) This Report/Document has been prepared for the particular purpose outlined in Golder’s proposal and no responsibility is accepted for the use of this Report/Document, in whole or in part, in other contexts or for any other purpose.

ii) The scope and the period of Golder’s Services are as described in Golder’s proposal, and are subject to restrictions and limitations. Golder did not perform a complete assessment of all possible conditions or circumstances that may exist at the site referenced in the Report/Document. If a service is not expressly indicated, do not assume it has been provided. If a matter is not addressed, do not assume that any determination has been made by Golder in regards to it.

iii) Conditions may exist which were undetectable given the limited nature of the enquiry Golder was retained to undertake with respect to the site. Variations in conditions may occur between investigatory locations, and there may be special conditions pertaining to the site which have not been revealed by the investigation and which have not therefore been taken into account in the Report/Document. Accordingly, if information in addition to that contained in this report is sought, additional studies and actions may be required.

iv) The passage of time affects the information and assessment provided in this Report/Document. Golder’s opinions are based upon information that existed at the time of the production of the Report/Document. The Services provided allowed Golder to form no more than an opinion of the actual conditions of the site at the time the site was visited and cannot be used to assess the effect of any subsequent changes in the quality of the site, or its surroundings, or any laws or regulations.

v) Any assessments, designs and advice made in this Report/Document are based on the conditions indicated from published sources and the investigation described. No warranty is included, either express or implied, that the actual conditions will conform exactly to the assessments contained in this Report/Document.

vi) Where data supplied by the client or other external sources, including previous site investigation data, have been used, it has been assumed that the information is correct unless otherwise stated. No responsibility is accepted by Golder for incomplete or inaccurate data supplied by others.

vii) The Client acknowledges that Golder may have retained subconsultants affiliated with Golder to provide Services for the benefit of Golder. Golder will be fully responsible to the Client for the Services and work done by all of its subconsultants and subcontractors. The Client agrees that it will only assert claims against and seek to recover losses, damages or other liabilities from Golder and not Golder’s affiliated companies. To the maximum extent allowed by law, the Client acknowledges and agrees it will not have any legal recourse, and waives any expense, loss, claim, demand, or cause of action, against Golder’s affiliated companies, and their employees, officers and directors.

viii) This Report/Document is provided for sole use by the Client and is confidential to it. No responsibility whatsoever for the contents of this Report/Document will be accepted to any person other than the Client. Any use which a third party makes of this Report/Document, or any reliance on or decisions to be made based on it, is the responsibility of such third parties. Golder accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this Report/Document.

At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australia & NZ	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

AUCKLAND

Tel +64 9 486 8068
Fax +64 9 486 8072

Level 2
Nielsen Centre
129 Hurstmere Road
Takapuna
Auckland 0622

PO Box 33-849
Takapuna 0740

HAMILTON

Tel +64 7 859 2356
Fax +64 9 486 8072

Room 31 in the Homestead
Ruakura Research Centre
10 Bisley Road
Hamilton 3214

PO Box 19-479
Hamilton 3244

NELSON

Tel +64 3 548 1707
Fax +64 3 548 1727

Level 3
295 Trafalgar Street
Nelson 7010

PO Box 1724
Nelson 7040

CHRISTCHURCH

Tel +64 3 377 5696
Fax +64 3 377 9944

Level 1
214 Durham Street
Christchurch 8011

PO Box 2281
Christchurch 8140

DUNEDIN

Tel +64 3 479 0390
Fax +64 3 474 9642

Level 9A
John Wickliffe House
265 Princes Street
Dunedin 9016

PO Box 1087
Dunedin 9054

Golder Associates