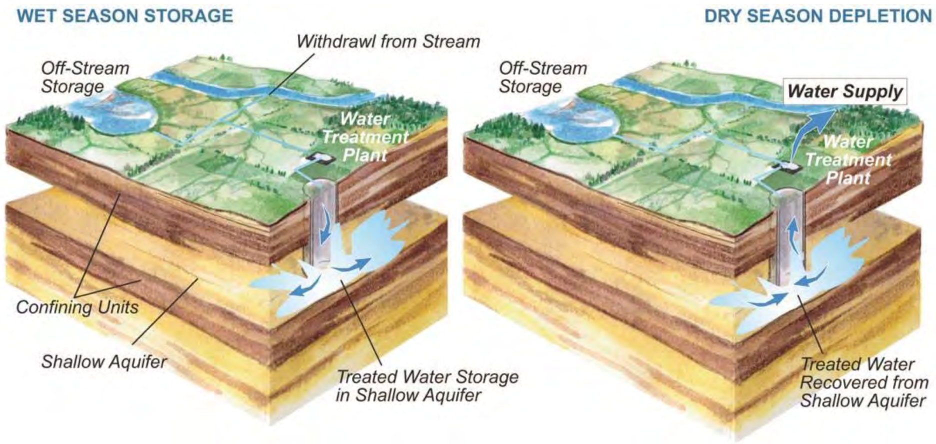
August 2014

POVERTY BAY GROUNDWATER MANAGEMENT

MAR Feasibility Assessment and Goldsim Groundwater Management Tool (Stage 1B)



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REPORT

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Executive Summary

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. A substantial proportion of the water used for irrigation across the Poverty Bay Flats is derived from groundwater. Reviews of groundwater levels in the Poverty Bay Flats area have identified declining groundwater pressure trends as an environmental and water supply issue. These trends are linked to increasing groundwater abstraction for irrigation purposes.

The GDC is investigating water management options to stabilize groundwater pressure trends and increase water supply reliability in the Poverty Bay area. One option under investigation is the use of Managed Aquifer Recharge (MAR), to replenish and sustain groundwater yields from aquifers beneath the Poverty Bay Flats. Golder Associates (NZ) Limited (Golder) was commissioned by GDC to undertake a feasibility assessment for a MAR program.

The key outcomes of the initial assessment were:

- The Makauri Aquifer is prospective candidate for a MAR pilot project due to its relatively high usage, declining groundwater pressure trends, broad extent and good transmissivity.
- The combination of treated water that is potentially available outside the irrigation season and existing infrastructure (e.g., Gisborne water supply reservoirs and delivery systems) provides an opportunity for a successful groundwater replenishment scheme.
- A system of direct water injection through bores is a clear option for Makauri Aquifer groundwater pressure management and is recommended for further design and pilot testing.
- Surface recharge using infiltration basins or other systems in the northern section of the Poverty Bay Flats area may also have potential; however the nature of the hydraulic connections between surface recharge and the Makauri Aquifer requires further assessment.
- The injection of treated surface water into the reduced geochemical environment of the Makauri Aquifer may present challenges requiring management with respect to injection well clogging.

The MAR feasibility assessment carried out by Golder included an evaluation of the challenges and needs for Poverty Bay water management, including source water options, direct injection and surface infiltration options and water quality management requirements.

A Groundwater Management Tool (GMT), incorporating a calibrated water balance model for the Makauri Aquifer, has been developed to a demonstration stage for the GDC using the Goldsim software package. The GMT is intended to support the GDC in assessing options for the management and replenishment of the Poverty Bay Flats groundwater supplies, within the framework of water management planning for the region.

Golder's feasibility analysis shows a groundwater replenishment scheme has the potential to:

- Stabilise current downward trends in groundwater levels within the Makauri Aquifer
- Restore groundwater pressures within the aquifer
- Enable the establishment of a sustainable yield for the aquifer that exceeds current usage

In summary, Managed Aquifer Recharge (MAR) has the potential to replenish and support sustainable groundwater yields from aquifers beneath the Poverty Bay Flats. The results from a risk-benefits analysis indicate that the further Stage II analysis, design and costing for a pilot injection MAR site is recommended.

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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. An ongoing water supply and demand study for the district (GDC 2013) indicated 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 partly depends on what limits and minimum flow criteria are set.

A substantial proportion of the water used for irrigation across the Poverty Bay Flats is derived from groundwater. Reviews of groundwater levels in the Poverty Bay Flats area have identified declining groundwater pressure trends as an environmental and water supply issue (Barber 1993, White et al. 2012). These reviews indicated the declining pressure trends are a consequence of historical over-abstraction through long term groundwater pumping.

For these reasons, the GDC is investigating water management options to increase reliability of water supplies in the Poverty Bay area into the future. One option under investigation is the use of Managed Aquifer Recharge (MAR), to replenish and sustain groundwater yields from aquifers beneath the Poverty Bay Flats.

The GDC, in conjunction with its Freshwater Advisory Group (FwAG), has commissioned Golder Associates (NZ) Limited (Golder) to undertake this feasibility assessment for a MAR program through a combination of funding sources including a medium advice grant (Envirolink Programme) from the Ministry of Science and Innovation and through the Community Irrigation Fund programme through the Ministry of Primary Industries. Funding was also provided by in-kind contributions by GDC and the FwAG project partners.

The combined funding sources provided support for a MAR feasibility and Go/No-go assessment, dividing these into two stages (1A and 1B). The outcomes of these stages of work are documented in:

- *Poverty Bay groundwater management: MAR feasibility stage 1A – conceptual model,* May 2014. (Golder 2014).
- *Poverty Bay groundwater management: MAR feasibility (Stage 1B) – technical assessment and Goldsim groundwater management tool,* August 2014 (this report).

The stage 1A report (Golder 2014) provides much of the background for the Stage 1 feasibility assessment. This report includes documentation of the data collection and compilation process, the background physical and environmental settings for the Poverty Bay aquifer system and the preliminary conceptual logic for the use of the Goldsim modelling package to develop a water management tool for the aquifer system.

This stage 1B report documents Golder's MAR Stage 1 feasibility assessment findings and recommendations as well as the development of the Goldsim *Poverty Bay Flats Groundwater Management Tool (PBGMT).* This tool has been developed specifically to support the FwAG and GDC in their work on a sustainable groundwater management strategy for this aquifer system. The tool has also been developed to enable the FwAG and GDC to evaluate the role MAR may play in stabilising and enhancing seasonal groundwater supplies across the Poverty Bay Flats.

This report is structured to provide a clear overview of the MAR feasibility assessment undertaken by Golder. Detailed technical information used to support development of the PBGMT is documented in Appendices attached to this report.

1.2 Stage 1A Assessment Outcomes

Stage 1A of the project included development of an appropriate MAR assessment methodology, a review and summary of previous groundwater assessments, a data collection and compilation process and development of a conceptual GoldSim model for the Poverty Bay aquifer system (Golder 2014). The work on Stage 1A was conducted through a collaborative technical partnership between GDC, Golder and the University of Waikato.

The main outcomes of the Stage 1A assessment are listed below.

- The Makauri Aquifer is highly prospective candidate for a potential MAR pilot project due to its relatively high usage, declining pressures and broad extent.
- The use of wells to inject treated water directly into the Makauri Aquifer 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 potential. The nature of the hydraulic connections between surface recharge and the Makauri Aquifer require further assessment.
- Water availability (non-irrigation season) and existing infrastructure (e.g., Gisborne water supply reservoirs and delivery systems) provides opportunity for a successful Groundwater Replenishment scheme.
- The injection of treated surface water into the reduced geochemical environment of the Makauri Aquifer presents challenges with respect to potential bore clogging that may require management.
- Overall, MAR has potential as a groundwater management tool for the Poverty Bay Flats area.

These conclusions were based on a preliminary assessment of the information available. The Stage 1A report therefore provided a 'first check' on the potential use of MAR in the Poverty Bay area and highlighted features of the aquifer system that would need further investigation.

1.3 Golder MAR Assessment Methodology

The decision matrix used in the Stage 1B assessment has been modified from Australia's MAR assessment guidelines. These guidelines are specifically designed for the purpose of investigating, developing and commissioning MAR projects (AGWR, 2009). The Australian guidelines generally describe a MAR development project as having four stages:

- Stage I – Conceptual model and desktop assessment
- Stage II – Viability and risk assessment with field testing (MAR pilot)
- Stage III – Further trials, validating conceptual models and viability of long term operations
- Stage IV – Groundwater Replenishment scheme[1] 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.

[1] Groundwater Replenishment scheme is defined as an operating MAR system which is operated similarly to an irrigation and/or public supply system. Scheme structure includes revenue mechanisms (e.g. targeted rate base system), consenting framework which might include opportunities for water banking and/or groundwater crediting. Operating examples include Orange County Water District (California, USA) which operates a replenishment programme for the City of Anaheim. (http://www.gwrsystem.com/)

Fundamental questions to be addressed in a MAR assessment as per the Australian Guidelines are set out below. An initial answer to each question is also provided below, together with references to the appropriate sections in the report.

- **Conceptual MAR model** – Is there potential for a clear understanding and expectations to be developed for the MAR objectives and goals? Are these realistically achievable based on Stage I available information?
  - This report is the basis on which a clear understanding of a Groundwater Replenishment scheme objectives and goals can be developed. Expectations can be managed through clear communication with and between the interested parties.
  - A Groundwater Replenishment scheme can potentially be used to stabilise, replenish and support a sustainable yield from the Makauri Aquifer groundwater resource (refer Section 4.0). A pilot trial is required to verify this expectation (refer Section 7.0).
- **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)?
  - Sufficient data are available through the GDC to support a pilot trial (refer Section 7.0).
- **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?
  - Data are summarised in Appendices A and C. Available information is sufficient to support the planning of a Groundwater Replenishment pilot trial.
- **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?
  - Data are available through the GDC (refer Section 2.0) to support a cost-benefit analysis.
- **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?
  - Potential Groundwater Replenishment pilot trial sites would be identified during Stage 2 design work. There is reasonable expectation that suitable sites can be identified and access arranged. A similar expectation applies for a full Groundwater Replenishment scheme.
- **Monitoring / modelling –** Will existing and / or readily installed project-specific monitoring systems be sufficient to provide adequate data for the evaluation of the pilot test programme? What kinds of modelling would be needed to help to evaluate and potentially manage the viability of a system-wide replenishment programme?
  - Existing monitoring systems operated by GDC can be adapted to monitor a pilot trial and for a full Groundwater Replenishment scheme. Additional monitoring systems can be installed as necessary.
- **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 (e.g., Mauri Compass).
  - Engagement has already been initiated through meetings with GDC, FwAG and other parties. Ongoing community engagement would be critical to the success of a MAR pilot and, if warranted, the development of a Groundwater Replenishment scheme.

- Engagement of local iwi through processes such as the proposed “Mauri Compass” between GDC and local Runanga is important to establish community engagement in the project.

- **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?
  - Stabilisation of Makauri Aquifer downtrend and provision of water for future growth aligns with FwAG recommendations for the draft GDC regional plan. Resource consents will be required for the MAR project under both the existing situation and under the Freshwater Plan that is currently being drafted. The recharge of groundwater would be considered as a discretionary activity and a comprehensive Assessment of Environmental Effects would be required.

1.4 Stage 1B Assessment - Report Scope

The purpose of this Stage 1B MAR assessment report is to provide three primary outcomes:

1) A technical analysis of the potential physical opportunities and obstacles of MAR for the Poverty Bay Flats area.

2) Document the development and calibration of the GoldSim Poverty Bay Groundwater Management Tool (*PBGMT)*. This modelling tool focuses on using MAR to actively supplement the replenishment of the Makauri Aquifer under various development and storage scenarios to meet broad economic and environmental objectives.

3) Provide a MAR feasibility analysis and a Go/No-Go summary of the opportunities and risks of a managed replenishment scheme. Provide a basis for communication and collaboration with FwAG and GDC staff regarding a pilot trail and scenarios for a managed replenishment scheme.

1.5 Report Structure

In addition to this introductory section, the Stage 1B report is set out in the following sections.

- Section 2.0 summarises the water management challenges and needs of the Poverty Bay Flats groundwater system.

- Section 3.0 documents the PBGMT, including the calibration process and baseline outcomes.

- Section 4.0 documents groundwater level projections for the Makauri Aquifer under current groundwater use. In addition, the outcomes of increased abstraction based on growth projections for groundwater use and already consented takes are provided. Similar projections for groundwater levels are provided, taking into account the application of a MAR system.

- Section 5.0 documents options for a MAR system, considering different recharge alternatives, locations, benefits and management requirements.

- Section 6.0 documents risks of instigating a MAR system and provides a matrix to support the decision making process.

- Section 7.0 outlines the needs for a Stage 2 investigation, leading up to and including a pilot-scale recharge trial.

- Section 8.0 provides conclusions with respect to the work completed to date and recommendations for the way forward.

Technical information used to support the findings of this study is attached in the appendices below.

Appendix A. **Derivation of Gisborne MAR model input factors**: Summarises the geology, hydrology and hydrogeology of the study area. In addition, the derivation of initial input factors for the GoldSim water balance model of the Makauri Aquifer is summarised in this appendix.

Appendix B. **Poverty Bay Flats Groundwater Management Tool:** Documentation of the Goldsim water balance model developed to evaluate current and future groundwater level trends and the benefits of MAR. This Appendix includes a guidance section for users of the PBGMT Player version available to GDC.

Appendix C. **Makauri Aquifer Geochemistry Assessment:** A summary of the water quality of the Makauri Aquifer, geochemical modelling of precipitation rates for the direct injection option and management options to control possible water chemistry issues.

Appendix D. **Makauri Aquifer Direct Injection Rating Matrix:** A review of the potential for developing a successful MAR project on the Poverty Bay Flats, following Golder's New Zealand modified version of the Australian MAR guidelines.

2.0 POVERTY BAY FLATS WATER MANAGEMENT CHALLENGES AND NEEDS

2.1 Background

The GDC, through guidance and input from the FwAG, has conducted a future water resource supply and demand study. This study reported that increasing water demand could be limited by declining or uncertain supplies. This limitation may lead to constrained economic growth and degraded environmental outcomes for the district.

Changing climate patterns are expected to lead to increased rainfall variability, including prolonged droughts and / or more frequent high intensity rain events. This expectation of increased rainfall variability makes proactive and longer-term planning a key element for water resource management.

Ongoing gains in irrigation efficiencies assist in the conservation of surface and groundwater resources. Using increasing efficiency as a sole management approach has, however, been shown to limit further opportunity. This is particularly true when water resources are deemed over allocated and declining, or when the opportunity to actively replenish supplies is deemed feasible and cost effective.

Studies have shown that improved management of water storage for the Poverty Bay Flats area will be needed. This improvement may be in the form of purpose built surface storage and / or through improved management of groundwater resources, or as a combination of the both in an integrated supply system.

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

- Declining seasonal 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 activities 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.

- Water is currently thought to be available for groundwater replenishment from three potential sources outside the irrigation season:
  - Waipaoa River, either supplied directly to a MAR system or through the Waipaoa supplementary water treatment plant.
  - Treated reservoir water from the Mangapoike Dams, provided through the Gisborne water supply network.
  - Other sources such as recycled water opportunities may also be developed in the future in the catchment.

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

2.2 Poverty Bay Water Usage

Water use data is collected through meter readings submitted by consent holders. Meter readings should be submitted each month. In practice, some water users submit readings in multi-month intervals or at the end of the season (GDC 2013).

Since 2008 GDC has been collecting metering data in the Poverty Bay Flats area. At the start of 2014 there were 156 different consents authorising water abstraction and use. Of that total, no water use was recorded against 56 of those consents for the 2012-2013 irrigation year (GDC 2013). For the Gisborne region, the 2012−13 drought was very similar to the El Niño drought of 1997−98. Both droughts were marginally shorter and less intense than the worst drought on record; the El Niño drought of 1982−83 (MPI 2013). This information suggests that only a small portion of allocated water is being used, even under severe drought conditions.

Irrigation of the Poverty Flats could triple within the next 50 years under some projections, with most of this growth expected over the next 25 years (Aqualinc 2013). From discussions with GDC staff (pers. comm. 22nd July 2014); current planning efforts are looking at reducing this over allocated situation through the consent renewal process with provisions being incorporated into upcoming water plans.

2.3 Economic Value of Water

Some of the highest unit prices for irrigated land in New Zealand occur in the Gisborne area (Doak et al. 2004). Consequently, irrigated horticulture is expanding over land previously used for dry-land sheep farming or other pasture uses.

The prevailing attitude often seems to be that the Poverty Bay Flats is too small an area to support a major surface 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 projected economic benefits per cubic metre of available water. Examples include pasture irrigation projects developed for yields of \$1/m^3 - to \$3/m^3 compared to important crops yielding \$5/m^3 to \$15/m^3 from irrigated land in the Poverty Bay Flats (GDC 2012).

Surface water resources for Poverty Bay Flats have been valued at about \$11.3 million (GDC 2012). Surface water use over the 2012-2013 irrigation season was approximately 1.8 M m^3, equating to an average value of \$6.25/m^3.

Assuming the value of groundwater is the same as surface water, the average value of water pumped from the Makauri Aquifer (refer Section 2.4) during the 2009-2013 period (average use of 1.06 M m^3/year) was \$6.6 million per year. The combined economic value of irrigation across the Poverty Bay Flats is in the order of \$18 million annually. Groundwater makes up a significant portion of the water needed to meet current and future demands in Poverty Bay Flats area. Managing growth with groundwater replenishment could help to improve upon these economic values with sustainable yields.

2.4 Makauri Aquifer Groundwater Abstraction

The water allocation record readily available from GDC has some gaps prior to 2008. The information provided however indicates total allocation of Makauri Aquifer water approximately doubled between 1998 and 2013, from 17,000 m^3/d to 34,000 m^3/d. This increase equates to an average growth rate of 5 % per year and can be linked to the expansion of irrigation systems over this period. Water metering information provided by GDC has clearly shown that actual abstraction (usage) from the Makauri Aquifer is significantly less than the allocated volumes.

At the start of 2014 there were 33 different consents authorising water abstraction from the Makauri Aquifer. No water use was recorded against six of those consents for the 2012-2013 irrigation year (GDC 2013). The combined daily consent limit for these six takes represents 3 % of the total Makauri Aquifer consented daily take.

Monthly Makauri Aquifer water use from December 2012 to February 2013 averaged 13,600 m^3/d, or about 20 % of the daily consent limit. Peak daily water use is estimated to have been about 50 % higher than the daily average over this period, or 20,000 m^3/d. This estimate is based on the relationship between peak daily and monthly average potential evapotranspiration data for the same period. This estimated peak water abstraction during a severe drought is approximately 30 % of the consented limit. Current groundwater abstraction from the Makauri Aquifer is therefore substantially less than the allocated limit. This difference has prompted concerns over the pressure that could be applied to the Makauri Aquifer water resource if groundwater use increased toward the currently allocated volumes.

2.5 Environmental Pressures

Discussions between Golder, GDC staff and the FwAG at a meeting on 23rd July 2014, noted that there are some concerns from the FwAG representatives around river flows, the drying up of coastal wetlands and the impacts of channelization on the Waipaoa River habitat, flows and channel incision. Of particular interest related to MAR was the potential environmental effects (e.g., flushing flows) of taking additional water during the non-irrigation season. It was noted that an environmental assessment of the non-irrigation seasonal flows should be considered in any further development of a MAR pilot project.

The other environmental effects that may arise from overuse of water from the Makauri Aquifer appear to be related to two main issues:

- The risk of inducing excessive downward leakage during the summer, leading to drawdown of groundwater levels in the overlying shallow aquifers and reduced flows in the Waipaoa River during periods when minimum flow environmental limitations are in force.
- The risk of inducing saline water intrusion to the Makauri Aquifer following drawdown of groundwater pressures in the aquifer close to the coast or beneath the ocean. At this stage, there is no indication that the Makauri Aquifer is hydraulically connected to the ocean; however this lack of evidence does not preclude the possibility.

2.6 Groundwater Level Trends

Barber (1993) reviewed groundwater levels in Makauri Aquifer monitoring wells between 1982 and 1992 and identified an ongoing drop in aquifer hydraulic head resulting from increased water abstraction. Barber concluded that the aquifer recharge rate was not keeping up with the rate of extraction.

In a review of groundwater level data from the Poverty Bay Flats, White et al. (2012) concluded that groundwater elevations in five out of eight wells exhibit a statistically-significant decreasing trend. The rate of decline identified ranged from -0.02 m to -0.1 m per year between the commencement of data collection and 2011. Aqualinc (2012) confirmed the declining trend observed in some bores screened in the Makauri Aquifer but indicated that the trend was not consistent. The rate of decline depended on the bore being monitored and could vary between different areas of the aquifer.

As part of this study Golder reviewed groundwater level trends for a selection of monitoring wells screened in the Makauri Aquifer. Some of the monitored wells were strongly affected by substantial seasonal drawdowns due to groundwater abstraction from those bores, or from bores very close by. Almost all of the datasets reviewed however showed similar trends and seasonal characteristics. These characteristics, exemplified in the groundwater level record from bore GPJ040 (Figure 1, Figure 2), include:

- A strong seasonal cycle with the lows corresponding to summer groundwater abstraction periods.
- An increasing amplitude in the seasonal cycle.
- The long term flat trend in seasonal peak groundwater levels since the early 1980's.
- The long term declining trend in seasonal lows since the mid 1980's.
- An overall decline in mean annual groundwater levels over the monitored period.
- A groundwater level recovery period of up to 8 years following the 1997-1998 El Niño drought, overprinted by the seasonal cyclic pattern.

Interpretation of these trends and other characteristics of the groundwater records (Appendix A) has led to a series of general conclusions summarised below.

A trend of increasing summer groundwater abstraction from the Makauri Aquifer is resulting in the long term declining trend in both overall groundwater pressures and seasonal lows. The trend is for more groundwater to be pumped from the aquifer, not only during the dry years but also during average and high rainfall years. The declines reflect a widening disparity between seasonal water use and aquifer recharge rates.

Although the overall trend in groundwater levels is declining, the flat trend in seasonal peaks indicates recharge to the aquifer is normally sufficient to enable groundwater levels to substantially recover during the following winter. During every seasonal cycle however summer pumping appears to start before the groundwater pressure in the Makauri Aquifer has fully recovered from the previous season's drawdown to a static groundwater level.

Increased abstraction during the 1997-1998 El Niño drought led to groundwater levels being drawn down further than had been previously recorded. The extended recovery period of up to 8 years (Figure 1) suggests that the Makauri Aquifer is reaching a limit in its capacity to recover following high demand years.

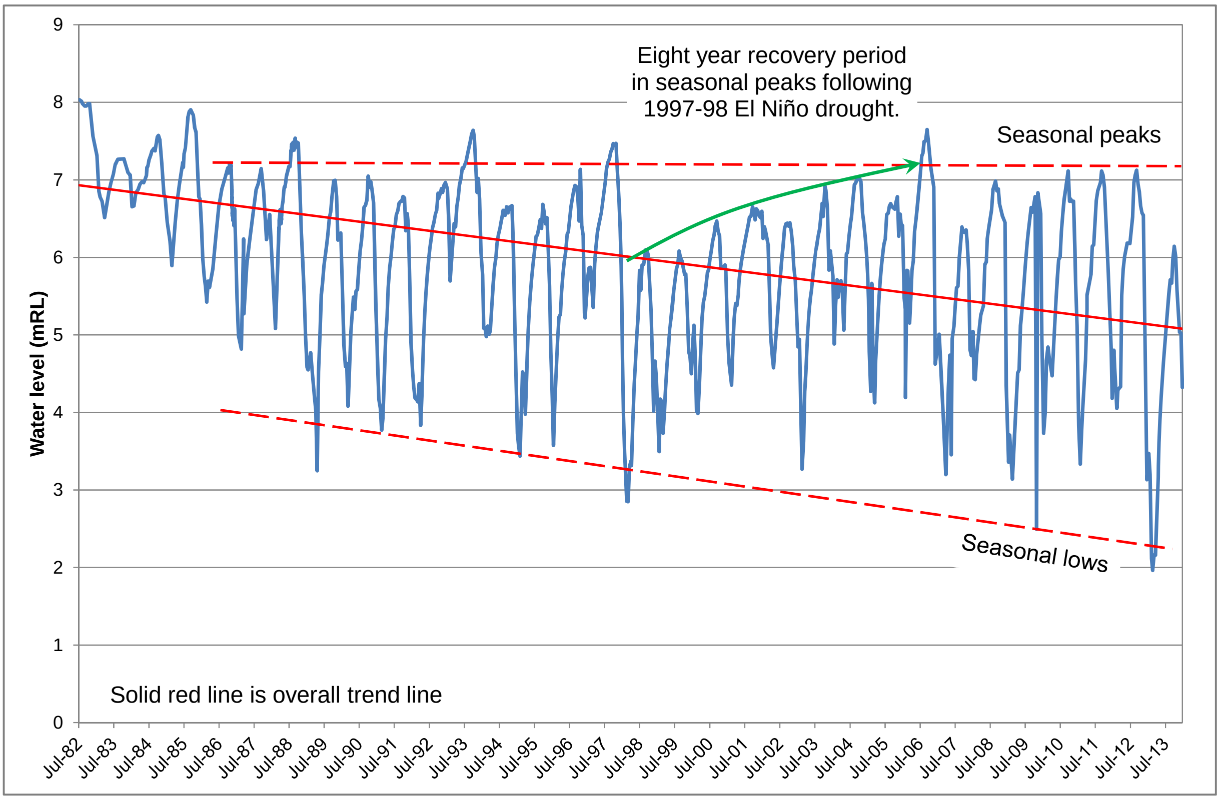


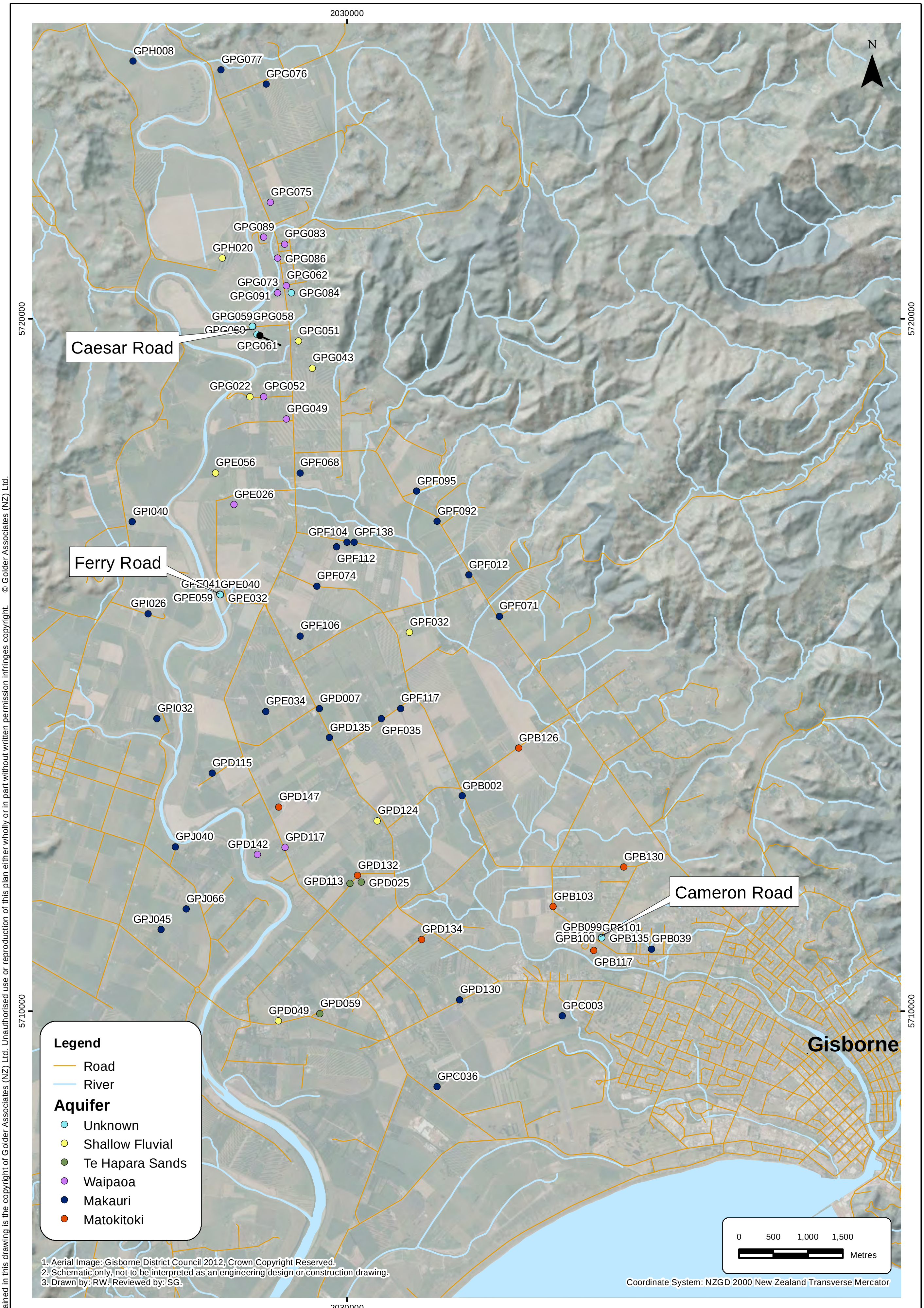
Figure 1: Groundwater level trends in Makauri Aquifer (bore GPJ040).

Groundwater levels recorded during the 2012-2013 drought period were generally the lowest recorded to date. The recovery in water levels during the following winter was less than would be expected following a normal irrigation season. This partial recovery is reminiscent of the delayed recovery following the 1997-1998 drought.

Groundwater level trends in the Makauri Aquifer indicate groundwater pumping over the past decade has been balanced by long-term inflows to the aquifer from the wider hydrological system including the Waipaoa gravel aquifer system. Abstracted volumes from the Makauri Aquifer during drought years already appear to exceed the annual recharge for the aquifer. The Makauri Aquifer is reaching a limit in its capacity to recover, as shown by the extended recovery period following drought seasons.

Water abstraction from the Makauri Aquifer is significantly less than the allocated volumes (refer Section 2.4). Further increases in water abstraction from the aquifer will lead to the observed declining trend in groundwater levels continuing. If the full allocation was used, the rate of long term groundwater pressure decline in the Makauri Aquifer would be higher than the observed rate (White et al. 2012, Aqualinc 2012).

A proactive management approach is required to stabilise groundwater pressures within the Makauri Aquifer, allow for future groundwater resource development, and associated economic growth whilst minimising seasonal stresses on the hydrological system by replenishing groundwater during the non-irrigation season.



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2. Schematic only, not to be interpreted as an engineering design or construction drawing.
3. Drawn by: RW. Reviewed by: SG.

Golder Associates

TITLE GROUNDWATER LEVEL MONITORING SITES POVERTY BAY AQUIFERS

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2.7 Managed Aquifer Recharge Benefits and Challenges

The existing private abstraction bores accessing the Makauri Aquifer represent a significant capital investment. This aquifer, when actively replenished and managed, should be able to act as an effective water distribution system linking these bores with a groundwater replenishment scheme (MAR system). Investment and operational costs for a groundwater replenishment scheme in the Poverty Bay area are therefore primarily linked to developing and maintaining either injection and / or infiltration systems.

The existing Gisborne water supply infrastructure, including reservoirs and water treatment plants (WTP), could be linked to a MAR system. Combining this infrastructure with a groundwater replenishment scheme can increase the total water storage capacity available for supply purposes. The drilling of additional city supply bores to access this water would need to be managed to limit the drawdown effects on neighbouring bores, however this can be incorporated within the current resource planning and consenting process. Subsequently the use of other aquifers (e.g., Matokitoki) as part of a groundwater replenishment scheme might also provide some additional options for water supplies.

A correctly operated MAR system should have limited environmental effects, provided the quality of the water injected or infiltrated to the aquifer is acceptable. The physical footprint of a MAR injection system for the Makauri Aquifer is potentially small, provided it is linked to existing water supply system (source water) and located to minimise geochemistry issues. If new water source and treatment systems need to be developed, the footprint and effects would need to be evaluated on a case-by-case basis. In general however the environmental and cultural effects of a new water source and injection system should be considerably less than, for example, a new water supply dam.

The benefits arising from installing a MAR system to improve water availability and reliability are not limited to economic outcomes. MAR systems can also be used to achieve ecological and social outcomes related to stream flows and ecology. The connection between groundwater levels and surface water flows is often not fully appreciated. The effects of groundwater over-abstraction on surface water flows may take time to be identified and measured.

Increasing groundwater levels in an over-used aquifer can be very beneficial to support environmental flows in local streams. Groundwater discharges are often the primary source of base-flows in streams, which is particularly important during summer low-flow periods. The aquifer system of the Poverty Bay Flats is not yet understood well enough to link the Makauri Aquifer with specific discharge zones and therefore with stream flows. The potential application of a MAR system to the shallow aquifers beneath the Poverty Bay Flats may however offer more opportunities in terms of supporting environmental stream and wetland flows.

The challenges that face groundwater replenishment schemes (MAR) are primarily:

- The physical issues around clogging (both surface infiltration and deep injection methods)
- The capture of available water and management of flow buffering systems
- Treating the water to a quality suitable for recharge
- Managing public perceptions or understanding of how MAR systems function
- Developing structures to fund the MAR construction and operation
- Developing structures for water allocation once a MAR system is in place

Should the Waipaoa River be used as a water source for a MAR system, timing of the water take from the river would be important. The take would need to be managed to minimise:

1) The risk of reducing river flows during seasonal low-flow periods.
2) Reducing the magnitude and frequency of storm flow events, which are part of the natural flow cycles in the river and necessary to maintain the health of the river.

Surface water storage often makes sense to the general public because they can see a reservoir and understand the concept of ‘stored’ water. Aquifers, while widely understood to be a dependable source of water, are less understood by the public and harder to visualise as an underground reservoir that needs to be actively managed.

In practice, a combination of surface and groundwater storage coupled with a flexible regulatory allocation framework may represent a cost effective and practical water management approach for the Poverty Bay area.

3.0 GROUNDWATER MANAGEMENT TOOL FOR MAR ASSESSMENT

3.1 Introduction

A decision management tool was required to support an informed decision making process regarding groundwater supplies across the Poverty Bay Flats. The Stage 1A and 1B work undertaken on this Gisborne MAR project has therefore been focused on developing the Poverty Bay Groundwater Management Tool (PBGMT) for this purpose.

The PBGMT has been developed using the Goldsim software package. Originally developed by Golder in the early 1990's, GoldSim is now a commercially available and widely used package. GoldSim is used internationally in decision-support roles for a wide range of water balance, water quality and water resource fields.

The core of the PBGMT consists of a calibrated water balance model incorporating the essential features of the Poverty Bay hydrogeological system. A range of water management options and water use scenarios have been structured around the model. A player file has been developed for the user interface. This player file enables any user to change water use and recharge factors within predefined ranges. The player file generates groundwater level and water value projections based on the scenario defined by the user. The water balance model, the associated option and scenario components and the player file form the PBGMT.

The purpose of the PBGMT is to:

1) Enable an increased understanding of the Makauri Aquifer water budget and how this budget influences historic and future groundwater level trends.

2) Support an assessment of groundwater management options and basic economic benefits of MAR.

It is important to recognise that the PBGMT is a highly adaptable tool that remains under development. As knowledge of the Poverty Bay aquifer system increases, the tool can be adapted correspondingly. The development and trial of a MAR pilot project would significantly help to improve upon the model accuracy. MAR pilots often provide an excellent method by which to calibrate such tools, through the controlled recharge of known quantities of water, under monitored experimental conditions.

The range of alternatives already incorporated should be expanded and assessed as the project proceeds. In addition, the outcomes from a MAR pilot trial proposed later in this report (refer Section 7.0) would be used to update some of the input factors applied in the water balance model.

3.2 Conceptual Model

The model in its current form is focused primarily on investigating the hydraulic behaviour of the Makauri Aquifer for the purpose of a MAR assessment. For this reason, other aquifers and hydrogeological features of the Poverty Bay Flats are simplified or combined.

The model incorporates two aquifers, broadly representing the Makauri Aquifer and the combined shallow aquifers of the Poverty Bay Flats. These aquifers are separated by a low permeability aquitard that permits limited leakage to occur, both upward and downward, between the two aquifers.

The Makauri Aquifer extent is based on maps derived from Barber (1993) and covers an area of approximately 6,000 ha beneath the Poverty Bay Flats, from Caesar Road in the north to the Gisborne city outskirts in the south (Figure 3).

Groundwater flows through the Makauri Aquifer from north to south during the winter and spring months, when abstraction rates are low (Appendix A). This hydraulic gradient indicates groundwater is discharging upward from the Makauri Aquifer in the lower flats area and / or the coastal zone. Isotope studies have indicated Makauri Aquifer may have discharged upward to the shallow fluvial aquifer layer in the Cameron Road area (Barber 1993). The Makauri Aquifer thins toward the coast. To date however, there is no clear evidence to confirm that the aquifer is blind (White et al. 2012).

During summer and early autumn months, high abstraction rates in the central area of the flats create a cone of groundwater depression. Groundwater flows across the Makauri Aquifer during these high use periods are radial inward toward the central flats area (Appendix A). Groundwater gradients beneath the coastal zone reverse, with groundwater flowing inland during these high use periods. This does not necessarily mean saline water intrusion is occurring during high use periods.

Groundwater drawdown and recovery patterns are remarkably consistent across the Makauri Aquifer, with a seasonal water level fluctuation generally between 2 m and 6 m. This consistency of pattern indicates the Makauri Aquifer is continuous and strongly hydraulically connected across the Poverty Bay Flats.

Interpolation of pumping test data results for Makauri Aquifer indicates transmissivity ranges from 500 m^2/day to 1,500 m^2/day across 80 % of the aquifer (Appendix A). This result supports the conclusion that the aquifer is strongly hydraulically connected across the Poverty Bay Flats. Makauri Aquifer storativity is expected to be in the range from 1×10^{-4} to 1×10^{-3}, indicative of a confined to leaky confined aquifer (Appendix A).

Recharge to the Makauri Aquifer beneath the Poverty Bay Flats (Appendix A) appears to be primarily derived from:

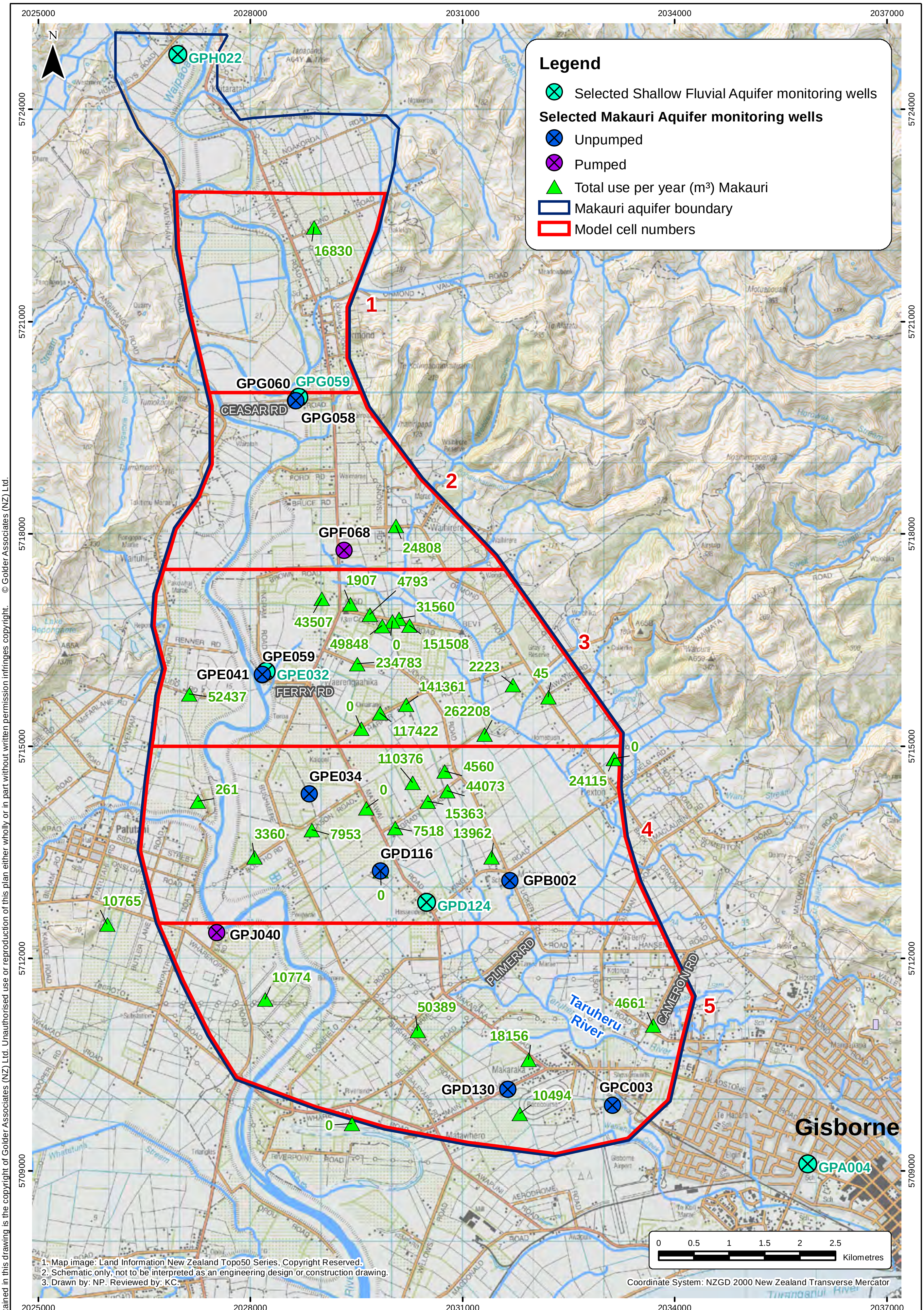
- Southward flows within the aquifer from the Waipaoa River valley. The source of this water is not fully understood, however, groundwater level records from bores north of Ormond do not indicate a strong hydraulic connection between the shallow aquifer in this area and the underlying Makauri Aquifer.
- Downward leakage from the Waipaoa Aquifer, other shallow aquifers and the Waipaoa River.

Both of these recharge components are incorporated in the water balance model.

Two other recharge components may also apply to the Makauri Aquifer:

- Upward leakage from the underlying Matokitoki Aquifer
- Lateral leakage into the aquifer from the basement rocks marking the northeastern and southwestern sides of the Poverty Bay Flats.

These two recharge components are either likely to be small or cannot be easily differentiated from other recharge sources. It was assumed for this study that recharge to the Makauri Aquifer via these routes is not significant or is fully represented through the downward leakage factor incorporated in the model.



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Re-analysis of data from two pumping test records (Appendix A) produced vertical hydraulic conductivity values for the aquitard overlying the Makauri Aquifer of between 2 x 10^{-2} m/day and 2 x 10^{-3} m/day. These values are indicative only as the leakage between the Makauri Aquifer and the underling Matokitoki Aquifer could not be evaluated separately.

Summer and winter groundwater level data from the upper flats area (Caesar Road) was used, together with the hydraulic conductivity values provided above, to provide a first indication of vertical leakage rates. Downward seepage rates, acting as recharge to the Makauri Aquifer, were estimated as being between 1 m^3/day/ha and 25 m^3/day/ha. This equates to recharge of 1,500 m^3/day to 37,500 m^3/day for the 1,500 ha aquifer footprint between Ferry Road and Caesar Road.

Upward seepage rate estimates for the lower flats (Ferry Road location) are 1 m^3/day/ha to 10 m^3/day/ha. If this seepage rate occurred across the estimated 4,700 ha Makauri Aquifer area south of Ferry Road, this would equate to an upward seepage rate of 4,700 to 47,000 m^3/d.

The recharge values provided above are broad estimates used to guide the water balance model calibration only. They are not intended for any other purpose.

3.3 Water Balance Model

The water balance model has been set up to operate on a monthly time step. This time step provides an acceptable simulation of the seasonal recharge patterns and pumping cycles in the Poverty Bay area. In addition, any MAR trial would presumably be carried out over a period of weeks to months rather than days. Historical groundwater abstraction data is also not available to support a model incorporating finer time steps.

The modelled area for the Makauri Aquifer is approximately 6,600 ha (Figure 3). This area comprises 5,900 ha of the flats to the south of Caesar Road and 700 ha in the Waipaoa River valley between Caesar Road and Bond Road.

For modelling purposes, the Makauri Aquifer is simulated as five connected reservoirs (Figure 3). The water levels in each cell vary on a monthly basis in response to changing inflows and outflows. Groundwater flows between cells are calculated using the Darcy equation and the pressure differential between adjacent cells.

Recharge to each cell is provided through vertical leakage from overlying shallow aquifer. In addition, recharge to the model as a whole is provided through lateral flows into the northernmost cell from further north in the Waipaoa River valley.

Discharges from each Makauri Aquifer cell are calculated on the basis of the water pressure difference between that cell and the overlying shallow aquifer. Water levels in the shallow aquifer system are represented using long term monitoring data from these units. Water is also removed from each cell based on recorded monthly pumping rates for wells located within the cell.

The key assumptions of the model are that:

- Future shallow groundwater levels follow similar seasonal trends to those observed in the past.
- The availability of water to the Makauri Aquifer from the north (Cell 1) is limited to represent a constant flux boundary, which would be influenced by the rate of abstractions versus recharge.
- Water exchange between the Makauri Aquifer and eastern and western boundaries and with the Matokitoki Aquifer is not significant.
- Water storage in the aquitard is adequately simulated through incorporation of the leakage parameter in the model.

Inputs for the water balance model included aquifer property data interpreted from pumping tests, aquifer geometry from well logs, groundwater level monitoring records and groundwater abstraction records. Abstraction records were only available from 2009 onwards. Historical abstraction rates were therefore estimated based on allocation data and an inferred relationship between water use and potential evapotranspiration.

Further details of the water balance model are provided in Appendix B. The model domain and model cell boundaries as well as the locations of monitoring wells that provided model input and calibration data are presented in Figure 3. The model logic is summarised in Figure 4.

3.4 Model Calibration

The water balance model was initially calibrated against Makauri Aquifer groundwater level data recorded from monitored wells between 2005 and 2013. The records from both of these bores are typical of the seasonal and longer trends across the full monitored area of the Makauri Aquifer. Calibration included optimisation of the model for:

- Northern boundary inflow rate
- Makauri Aquifer storativity and transmissivity
- The vertical hydraulic conductivity for the overlying confining layer.

The calibration was verified by extending the simulation period back a further 20 years without changing the calibrated parameters. The simulated groundwater levels in the Makauri Aquifer were compared to the 1985 to 2013 groundwater level record. An extract of the calibration results is provided in Figure 5, showing that the model provides a reasonable approximation of seasonal and long term water level trends in two monitoring wells within the cell boundaries. Further details of the model configuration and calibration are provided in Appendix B.

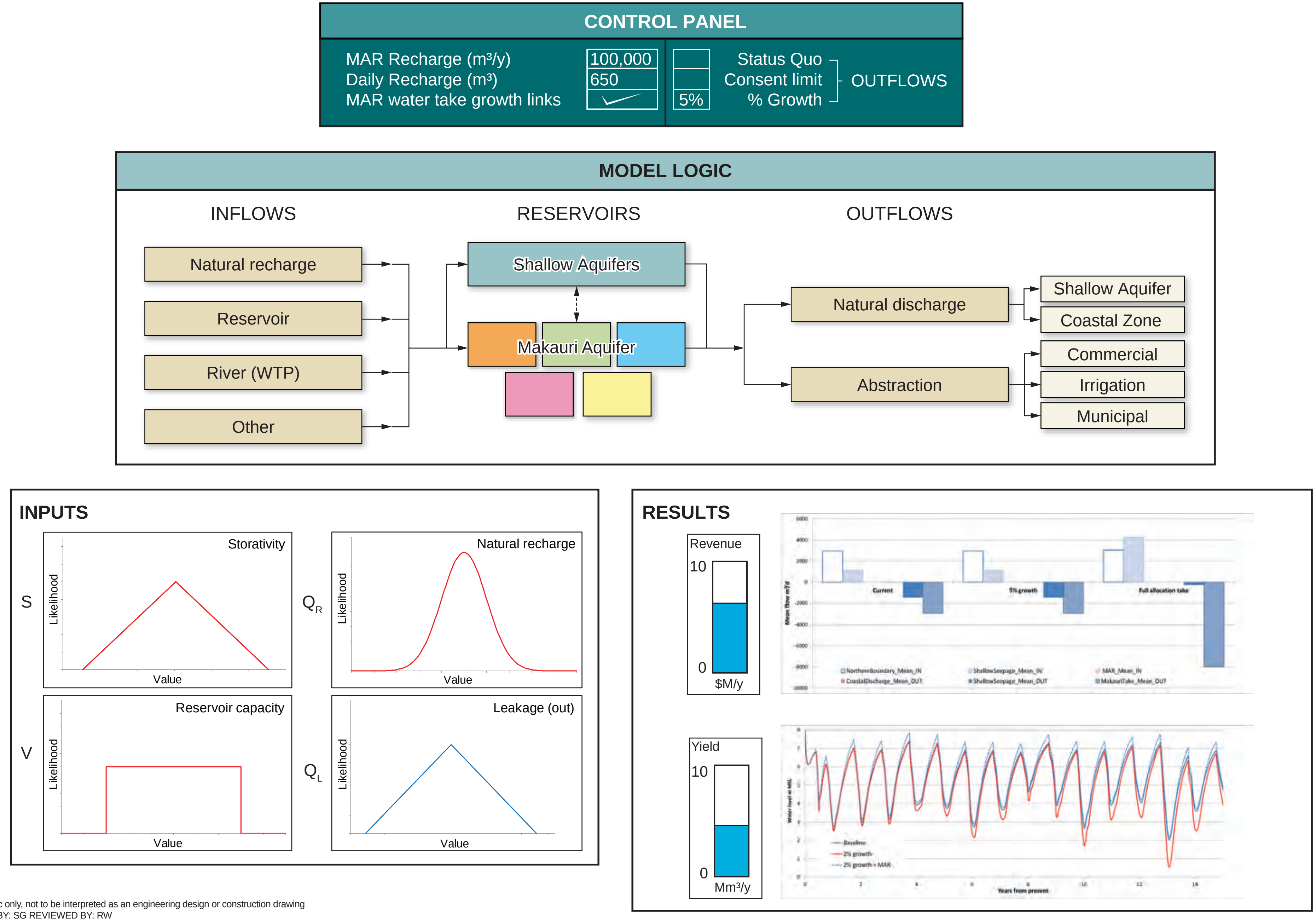
3.5 Player File Use and Limitations

The Makauri Aquifer water balance model provides an acceptable simulation of seasonal and long term groundwater pressures in the Makauri Aquifer. It is however important to recognise that the current model calibration is not a unique solution. Other combinations of input parameters can potentially generate similar solutions. When future water use scenarios are investigated using the PBGMT, different calibrated combinations of parameters would produce different projected outcomes. The differences may be slight but sufficient to affect decisions made on the basis of these outcomes.

As further information becomes available, confidence in the water balance model calibration will increase. Information gained from the planned MAR trial will be important in validating the model calibration and providing data to support further development of the PBGMT.

It is important to clearly state that the PBGMT, which incorporates the water balance model, is at the stage where general trends under a limited range of scenarios demonstrate the planned utility of the tool. It is **not yet developed to the stage that it can be used to support the GDC in making decisions on water supply options**. The PBGMT Player file provided to GDC with this report can be used to run a range of alternative scenarios. Instructions on use of the GMT are provided in Appendix B.

Most importantly, this tool provides the opportunity to consider the replenishment of groundwater supplies as part of the Poverty Bay Flats water management planning discussions. Replenishment coupled with reducing the current imbalance between consented allocation and actual usage will help the community consider a balanced set of options going forward.



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

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TITLE POVERTY BAY GROUNDWATER REPLENISHMENT MODEL SCHEMATIC

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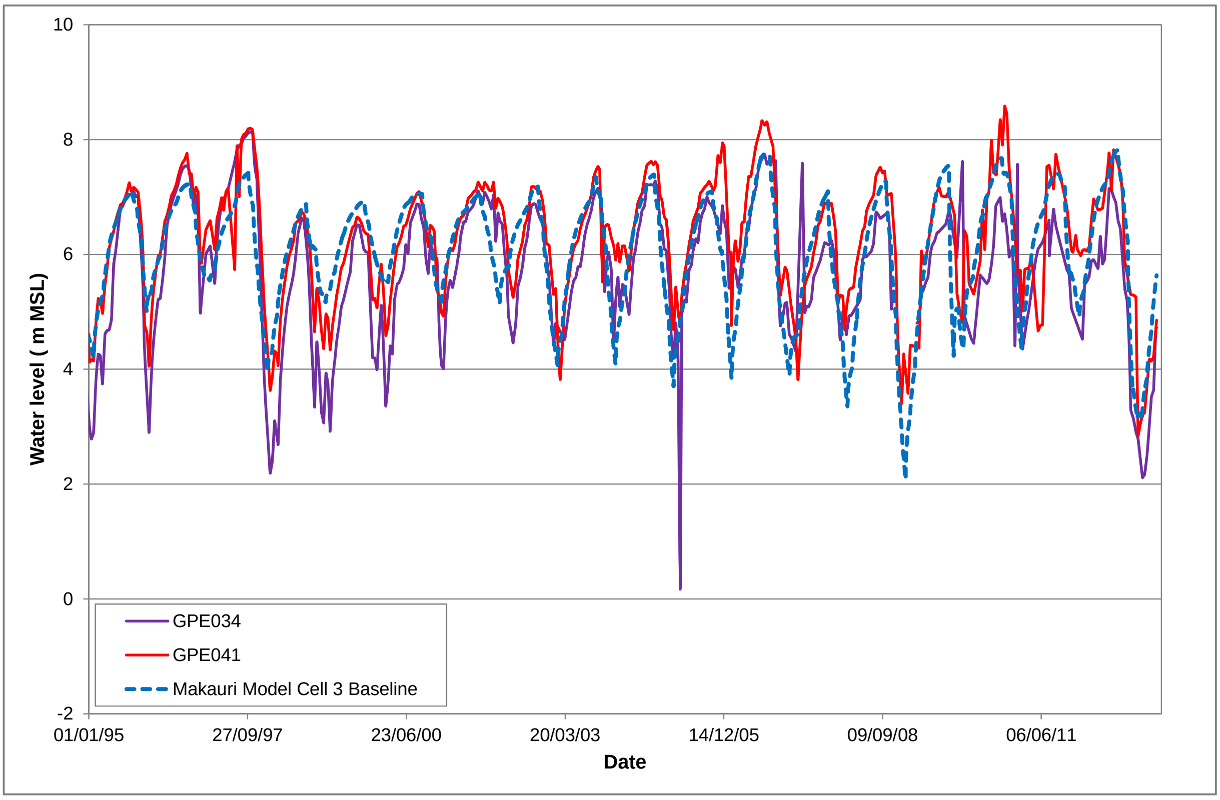

Figure 5: Model and measured groundwater levels from 1995 to 2013.

4.0 MAKAURI AQUIFER OUTLOOK AND MANAGEMENT

4.1 Introduction

Golder has developed a series of scenarios based on discussions with commercial users and GDC staff. A 'Do-nothing' scenario for groundwater management would imply an ongoing increase in groundwater use up to the currently consented limits. Golder notes that GDC is pursuing regulatory tools to begin to reduce these consented limits. Initial indications of future groundwater level trends for users within Cell 3 (highest density of usage) of the Makauri Aquifer under two water use scenarios are therefore presented in this report:

- 5 % annual increase in water abstraction
- Abstraction at the maximum consented rate

Details of the method used to generate synthetic water use records and projections from water metering data and climate records are provided in Appendix B.

4.2 5% Growth Scenario

Model outputs from the PBGMT, incorporating a 5 % annual increase scenario, are presented as groundwater pressure levels for the Makauri Aquifer in Figure 6. This simulation indicates that:

1) Seasonal groundwater drawdown would continue to increase
2) Pressure recovery takes longer than at present
3) The winter peaks gradually decline in comparison to the base case simulation, as the aquifer takes longer to recover from summer abstraction.
4) The median annual groundwater pressures would continue to decrease.

It is clear that the Makauri Aquifer can take several years to recover from increased water pumping during a drought year (refer Section 2.6). As previously stated, this implies that the aquifer is getting close to a tipping point in terms of its capacity to recover from seasonal pumping. For this reason we would expect that at some stage the winter peaks under the 5 % increase scenario would start to diverge substantially from the baseline. It is not clear that the divergence shown in Figure 6 is large enough to reflect this expectation. We therefore consider the recovery projections shown in Figure 6 to be optimistic. These outcomes would be updated following the completion of a MAR trial and analysis of the data.

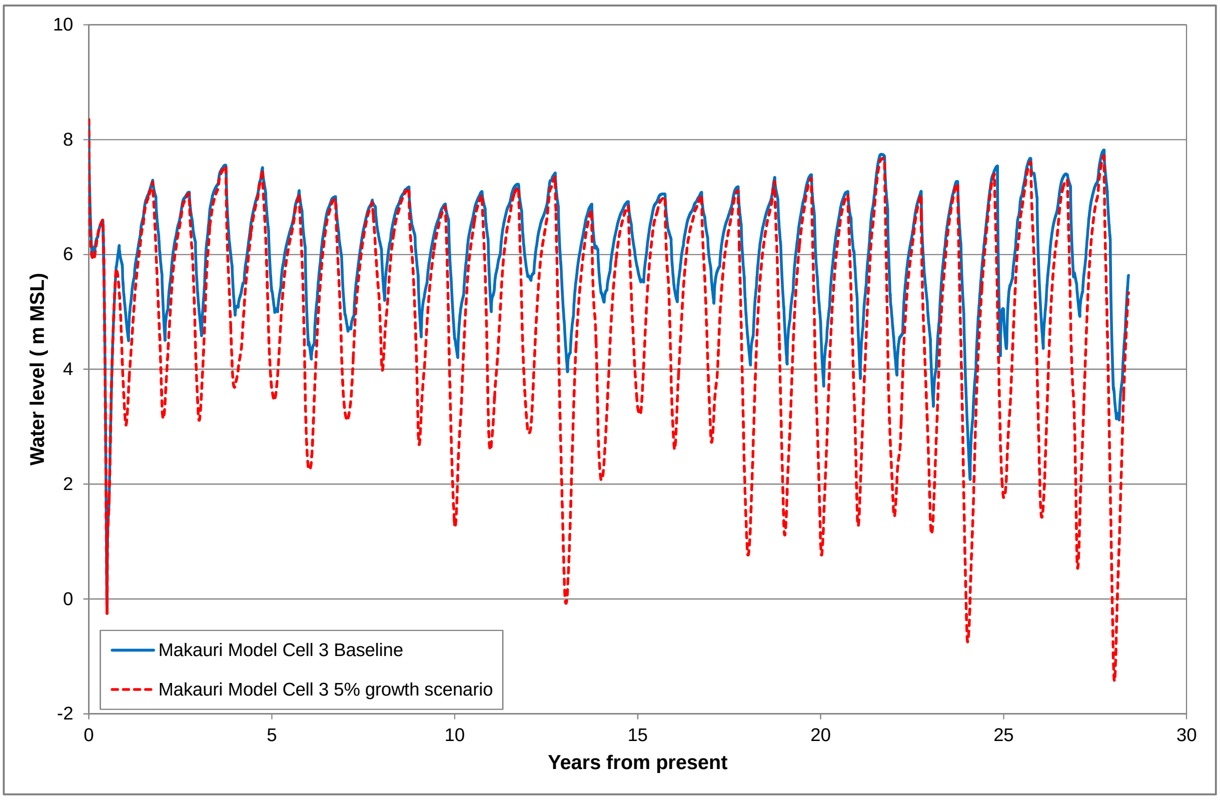

Figure 6: Makauri Aquifer model water levels – 5% annual growth water use scenario.

4.3 Maximum Consented Abstraction Scenario

The maximum consented water take scenario assumes that water will be used in the future, as required for irrigation purposes, up to the maximum daily volumes already authorised. This means that on peak irrigation days during a severe drought, the full daily water allocation would be used. Water use during average summer seasons would be correspondingly less, reflecting the greater rainfall and smaller soil moisture deficits. Overall, future water use under this scenario would be three times higher than current usage.

The outcomes from running this scenario using the PBGMT (Figure 7) indicate that Makauri Aquifer groundwater levels in Cell 3 would drop below mean sea level every year. In addition, the average groundwater level across this cell would frequently be at least 5 m deeper during the irrigation season. The peak winter groundwater levels are consistently lower than those for the baseline record.

As noted in Section 4.2, however, we consider the PBGMT is currently probably providing optimistic projections for seasonal recovery as the abstracted volumes increase. The same applies to the results for the maximum consented scenario presented in Figure 7. At these abstraction rates, it is likely that the winter peak groundwater levels in the Makauri Aquifer would be following a long term downward trend.

It is likely that the PBGMT currently overstates the potential downward leakage to the Makauri Aquifer from the shallow aquifer. Incorporation of outcomes from the planned MAR trial and an updated calibration for the water balance model should improve confidence in PBGMT outcomes for these higher abstraction rate projections.

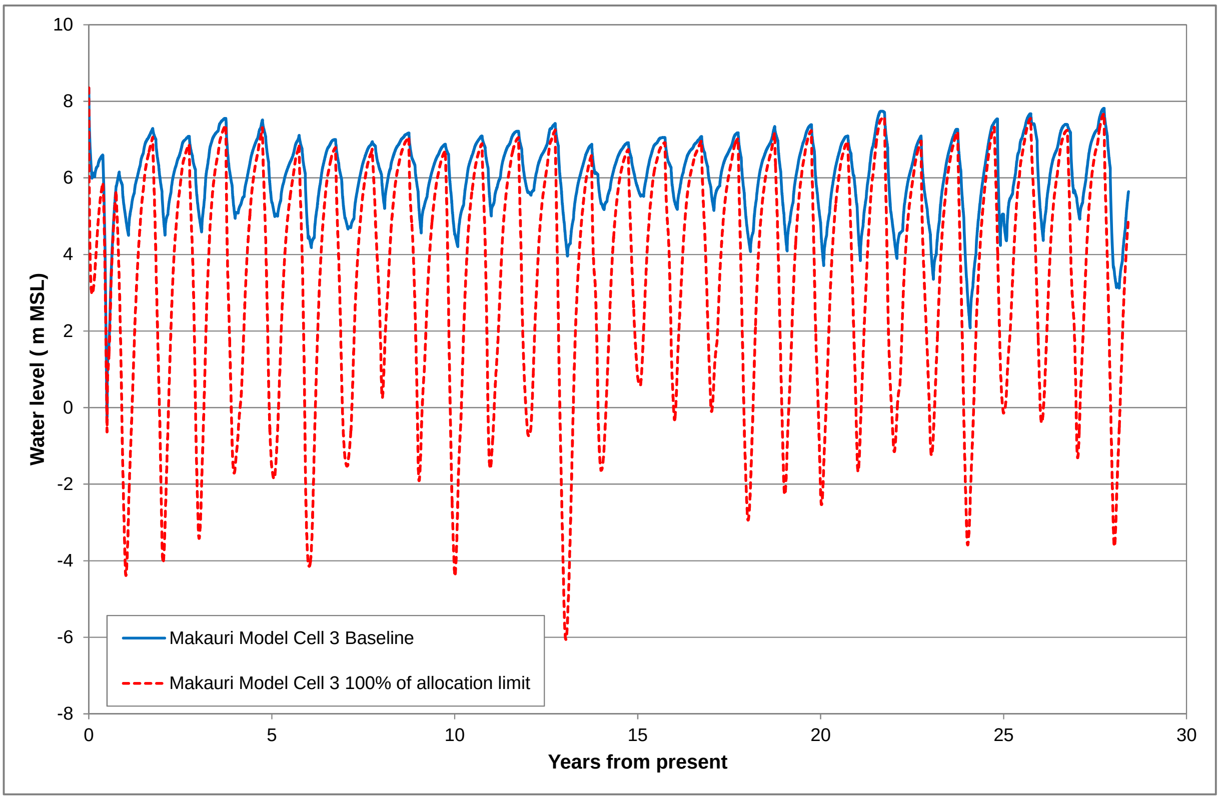

Figure 7: Makauri Aquifer model water levels – 100 % consented water use scenario.

4.4 MAR Scenarios

4.4.1 Objectives

The objectives of a designing a Groundwater Replenishment scheme would need to consider the stepwise process by which the community (through the FwAG and GDC) would develop a strategy to manage the current groundwater conditions in the Makauri Aquifer. Following a MAR pilot with results that indicate that the geochemical, logistical, environmental and economic costs of a Groundwater Replenishment scheme were feasible, the limit setting and planning strategy framework would need to be further developed. One potential strategy (Figure 8) could follow the logical progression:

1) **Stabilise –** Replenish Makauri Aquifer to stabilise the declining trends in groundwater levels. Note that 'stabilised' could entail a combination of replenishing the annual aquifer overdraught along with the continued annual increase in allocated usage.

2) **Restore** – Through community discussions and technical analysis a sustainable goal could be set to re-establish aquifer storage levels. This goal could be based on a number of potential considerations such as reducing the amount of leakage from the overlying gravel aquifer and in turn helping minimum flows in the Waipaoa River. Another goal could be to avoid the potential of saline intrusion along the coast. These community “Restore” goals should be considered adaptive, as the continued operation, and addition of MAR sites would likely continue to provide additional scientific knowledge about the system helping to better define its final achievable, sustainable yield.

3) **Manage for Sustainable Yield** – Forward on from these first two steps, the community could establish a longer term, sustainable aquifer yield. In this situation, groundwater replenishment could be matched with additional water usage to allow for a number of potential beneficial uses such as expanded economic growth of irrigation, additional access to stored emergency water supplies, and drought mitigation planning relative to a changing climate.

Figure 8: Potential Planning Framework for Implementing a Groundwater Replenishment Scheme.

A stepwise process that provides a vision for a Groundwater Replenishment scheme’s development is important not only for planning purposes, but also helps provide a framework by which a scheme can develop revenue and consenting mechanisms. If the opportunities for longer term growth and drought supplies can be integrated with the current need to stabilise and recover the aquifer, the opportunity to develop a groundwater crediting would help to incentivise the Groundwater Replenishment scheme.

These stepwise goals of Stabilise-Restore-Sustainable Yield would need to translate directly to specific hydrogeological triggers (e.g. pressure levels) in order to be successfully implemented. These trigger levels would also likely vary across the aquifer to take into account a number of spatial and temporal factors, including the natural hydraulic gradient toward the ocean.

There are at least four principal factors that would influence the setting of these target levels:

1) **Environmental effects management.** In the case of the Makauri Aquifer these effects may be related to minimising the risk of saline water intrusion at the southern end of the aquifer. As downward leakage is one component of the aquifer recharge, managing impacts on environmental flows through minimising leakage from overlying gravels and the river may also be an important community concern.

2) **Drought planning and management**. Climate change projections indicate the likelihood of more extended and more frequent droughts. Aquifer management should have one goal of ensuring water levels recover to the target level as rapidly as possible following a drought. Weather forecasting could also be used linking to longer term climate predictions (e.g. Southern Oscillation Index) to manage groundwater recharge and usage. By extension, this goal would allow for water availability through more frequent drought cycles.

3) **Growth.** The currently consented volumes for groundwater takes considerably exceed the amount of water actually pumped to date. Water use is however projected to grow over time. Aquifer management planning would need to incorporate projected growth rates. If abstraction rates start to regularly exceed the annual natural recharge capacity of the aquifer, this may mean matching the increases with equivalent off-season replenishment. The goal would be to allow growth without triggering compromises on the two factors presented above.

4) **Source water.** The availability of water to recharge the aquifer would play an important role in the development of the groundwater triggers and the potential recharge capacity of any replenishment scheme.

Setting aquifer target water levels that relate to sustainable yields developed through a community process such as the FwAG has potential for the Poverty Bay Flats. The community limit setting decision process could be informed through the use of the more refined and fully fit-for-purpose PBGMT. As previously stated, the tool is not yet at this stage of development, but does provide the community with a starting point by which to have these kinds of groundwater strategic discussions.

Overall, the Makauri Aquifer should be managed to sustain the yield while not compromising on environmental effects. Should a replenishment scheme be instigated, these levels and yields are very likely to be revised through time as our knowledge increases on how the aquifer reacts to artificial recharge testing.

4.4.2 Simulated MAR scenarios for establishment of Groundwater Replenishment scheme

The PBGMT has been used to simulate three aquifer scenarios that follow the stepwise conceptual development of a Groundwater Replenishment scheme as outlined in the previous section (Figure 8).

The first scenario (Stabilise) is one in which the current downward groundwater level trend has been stabilised through the installation of a MAR system offsetting the current over allocation with sufficient recharge to manage the declining trends (Figure 9). This is compared against the baseline or current state of the aquifer system.

Figure 10 shows the next two steps in the conceptual scheme development where the Stabilised scenario is recharged to a ‘Restore’ scenario level. In practice this would be a level developed through the community planning process, and is graphed purely for discussion purposes. This is then contrasted compared further with the Sustainable Yield scenario which matches growth in usage with the equivalent in offseason recharge with MAR. These scenarios were generated solely for providing conceptual understanding of scheme development and for discussion purposes. The further pilot testing of MAR and revisions to the PBGMT will allow this tool to be more accurate and support the groundwater management of the Makauri Aquifer system.

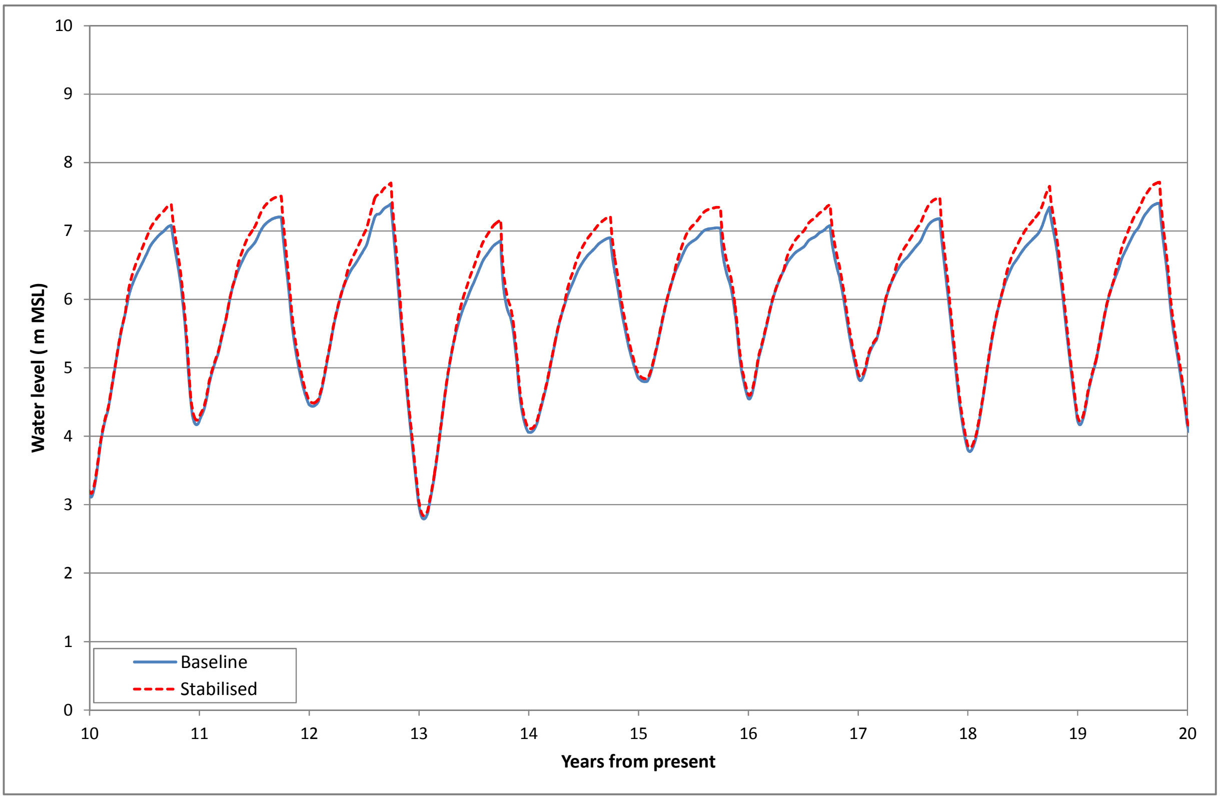

Figure 9: MAR scenarios showing comparison of Baseline (current conditions) to conceptual Stabilised.

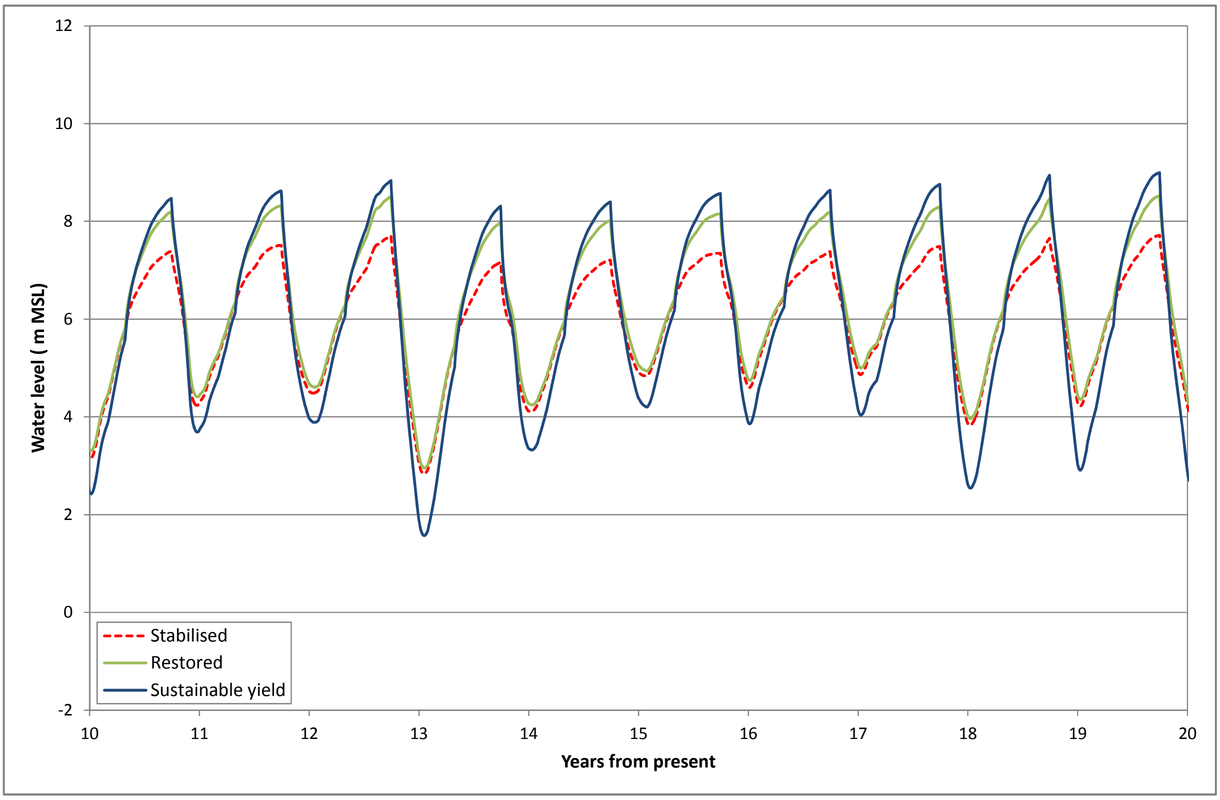

Figure 10: MAR scenarios showing comparison of conceptual Stabilised, Restored and Sustainable Yield.

5.0 MAR SOLUTIONS

5.1 Source and Recharge Options

Options for managed recharge of the Makauri Aquifer primarily comprise either direct injection via wells or surface infiltration via infiltration basins. An initial indication of areas where these types of recharge systems could be trialled is presented in Figure 11, although a full scale Groundwater Replenishment scheme may be viable in areas outside those identified in this figure. There are two primary sources of water that could potentially provide water for a MAR project: the Waipaoa River and the Mangapoike Dams via the Gisborne water supply network.

A surface recharge scheme would entail the construction of infiltration basins or equivalent systems together with water treatment systems to reduce the concentrations of suspended sediment in the water to be recharged. Infiltration basins are normally developed for a single use and are therefore not normally intended to be used as a direct water source themselves.

A direct injection well could be configured either as an Aquifer Storage and Recovery (ASR) type system or as an Aquifer Storage Transfer and Recovery (ASTR) system. The former would involve both injection and recovery of water via dedicated, and specially designed and installed with both injection pipework and valves and pumps for abstraction. Depending on the source of recharge water (e.g., treated water from reservoir) the recovery of groundwater back into the system would need to be managed to avoid untreated water being transferred back into the supply system. The ASTR system would rely on existing Makauri Aquifer bores for the recovery of the recharged water, and would not need to manage for source water protection measures. The final design of an injection system for the Makauri Aquifer would depend on a number of factors including costs and what entity (i.e., individual irrigator or part of Groundwater Replenishment scheme) might be injecting and recovering the water.

5.2 Surface Recharge

The Makauri Aquifer is confined beneath a significant thickness of low permeability silt and clay deposits across the Poverty Bay Flats south of Ford Road. It is unlikely a surface recharge system in this area would function to acceptably increase groundwater levels in the Makauri Aquifer. The review of potential surface recharge locations has therefore been confined to the Waipaoa River valley between Caesar Road and Kaitaratahi Bridge, using the Waipaoa River as a recharge source.

Key feasibility factors for a surface infiltration MAR system include water availability and quality, the vertical hydraulic conductivity of the near surface profile and hydraulic connections to the target aquifer, water table depth and the availability of land.

High water demand for surface water takes from the Waipaoa River during the summer months (typically October to March inclusive) and associated allocation restrictions mean that preferred period for aquifer recharge would be over the autumn and winter months.

A combination of highly erodible, steep and jointed bedrock, tephric soils and alluvium, episodically intense precipitation, seismic activity, and human disturbance contribute to rapid erosion of the Waipaoa watershed, and one of the highest suspended sediment yields in the world (Marden 2011). Suspended sediment concentrations remain high in the Waipaoa River in all but low flow conditions (Greg Hall, GDC, pers. comm.). Sediment removal would also be required before river water could be used for aquifer recharge via infiltration basins. This could potentially be achieved through riverbank filtration (gallery wellfield on riverbanks) or settling basins. Further work would be required to assess the feasibility of both of these options.

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An initial review of lithological logs from bores in the main recharge zone indicates that the upper 5 m to 15 m is generally dominated by fine grained deposits, typically silts and occasionally clay. Course grained deposits are recorded within 3 m of the surface in two wells (GPG059 and GPG061 at Caesar Road). These coarse deposits may provide a pathway to deliver enhanced recharge to the Waipaoa Aquifer.

The connectivity between the Makauri Aquifer and the Waipaoa Aquifer in the area of Caesar Road is uncertain. Groundwater monitoring records do not show any convincing data to confirm these two aquifers are hydraulically linked in this area. Furthermore, a net gaining reach of the Waipaoa River was identified in White (2012) between Caesar Road and Ford Road downstream. Whilst the limitations of the available river gauging data introduce some uncertainty to the aquifer-river interaction assessment, current understanding suggests that enhanced recharge of the Waipaoa Aquifer at Caesar Road would probably increase discharge flows back to the Waipaoa River instead of to the Makauri Aquifer.

A review of cross sections through the Waipaoa River valley between Caesar Road and Kaitaratahi Bridge indicates that the depth to water table in the postulated main Makauri recharge zone can vary between <1 m and 9 m. The depth to water at GPG059 (where gravels are present near surface) generally varies between 4 and 6 m bgl. Groundwater depths of 4 m or more are typically required to avoid groundwater mounding-related infiltration rate restrictions and on this basis the depth to groundwater is potentially sufficient for surface recharge.

This initial review of the potential for new river take option therefore indicates that:

- Surface infiltration would need to be undertaken in the winter months, when Waipaoa River water is available.
- Sediment removal and timing of recharge during lower flow periods would be required to minimise sediment concentrations in infiltration basins.
- The infiltration location would need to target those areas of the river valley where coarse sediment deposits are within close proximity of the surface and where the water table is relatively deep.
- Enhanced recharge of the Waipaoa Aquifer through surface infiltration could potentially discharge back to the river further downstream, and not achieve significant additional recharge of the Makauri Aquifer.
- Land availability for infiltration basins would need to be further assessed to determine the costs, locations and any other potential issues.

5.3 Direct Injection

Direct injection water could potentially be drawn from the Mangapoike Dams (via Waingake water treatment plant) or from the Waipaoa River. The latter could comprise either a new river take or water sourced from the Waipaoa Augmentation Plant.

For direct injection water with very low suspended sediment concentrations is required in order to control physical well clogging rates. Comprehensive (costly) water treatment would be required before water could be used for direct injection. A new river water take option is therefore not currently considered.

5.3.1 Mangapoike Dams

Golder understands that up to 100,000 m³ of water is potentially available from the Mangapoike Dams (Clapcott Dam and Williams Dam) between May and September, inclusive (Dennis Crone, pers. comm.) for the purposes of a potential MAR trial. This equates to an average daily flow during this period of approximately 650 m³/d or 7.5 L/s. It may be possible to extend this to October. It is also possible that additional water may be available when the dams are spilling. Further assessment will be required as part of a pilot trial design programme to confirm water availability.

Water from the dams is treated at the Waingake Water Treatment Plant (WTP) and conveyed via gravity flow (with boosting as required) through the reticulation system. This water can potentially be delivered as treated drinking water through the conveyance pipeline. Golder understands main pipeline capacity is sufficient to supply both existing users and a MAR system outside the irrigation season.

On this basis, sourcing water from the Mangapoike Dams is likely to be the preferred option for a MAR trial.

5.3.2 Waipaoa Augmentation Plant

The Waipaoa Augmentation Plant was commissioned in 1991 as an alternative / backup supply to augment the Waingake water supply, and could be used as a source of direct injection water for MAR. The plant has the ability to produce water volumes up to 720m^3/hr or 17,000m^3/day (GDC 2008). GDC holds resource consent to take up to 13,392 m^3/day from the Waipaoa River at the plant. The regional arm of council has established a minimum river flow of 600 L/s at the Matawhero Bridge and 1.3 m^3/s at the Kanakanaia Bridge, below which restrictions may be applied. These flows have not been observed to date and restrictions have never applied (GDC 2008). The minimum flows may be subject to change in a proposed Regional Water Plan due for notification in early 2015. The minimum flow at Matawhero is unlikely to be maintained whereas the minimum flow at Kanakanaia may remain in place following notification (Dennis Crone, pers comm.). Following development of the Regional Water Plan and increasing water demand, flow restrictions may apply in the future.

Golder understands that the operational costs of the Waipaoa Augmentation Plant are restrictively high because the intake pumps and treatment plant are powered by local diesel generators (Golder staff field tour, 23 July 2014).

On this basis the Waipaoa Augmentation Plant option has been limited from further consideration in this report. Future configurations of potential source water may utilise parts of this facility for the development of a Groundwater Replenishment scheme.

5.3.3 Other options

Other sources of recharge water may include the Te Arai River, springs (flow rate dependant) and downward transfer from shallow aquifers to the Makauri Aquifer. Each of these options should be revisited as part of the MAR pilot program design stage.

5.4 Water Quality Management Requirements

5.4.1 Introduction

A successful MAR system is based on efficient replenishment of aquifer water. Injection well efficiency is one management focus for direct injection schemes. Chemical, biological or physical clogging of injection surfaces or well screens is the most obvious problem encountered in any Groundwater Replenishment scheme (Martin 2013). Even a successful Groundwater Replenishment scheme will involve clogging, with appropriate management measures required. Where the selected Groundwater Replenishment scheme involves a dual use injection and recovery bore the risk of clogging is potentially greater.

Chemical, biological and physical injection well clogging can occur through a range of processes (Table 1). These are considered in turn below with reference to specific information for the Makauri Aquifer and potential injection water sources where available.

Table 1: Summary of clogging types and processes.

Clogging Type	Clogging Process
Chemical	• Geochemical reactions that result in the precipitation of minerals e.g. iron aluminium or calcium carbonate growth; • Aquifer matrix dissolution (can also work to increase hydraulic conductivity); • Ion exchange; • Ion adsorption; • Oxygen reduction. • Formation of insoluble scales. • Formation dissolution.
Physical clogging	• Accumulation / Injection of organic and inorganic suspended solids. • Velocity induced damage e.g. migration of interstitial fines such as illite or smectite. • Clay swelling (e.g. montmorillonite). • Clay deflocculation. • Invasion of drilling fluids (emulsifiers) deep into the formation. • Temperature.
Mechanical	• Entrained air/gas binding (includes nitrogen &/or methane from microbiological activity). • Hydraulic loading causing formation failure, aquitard failure or failure of casing around joints or seals.
Biological	• Algae growth and accumulation of biological flocs. • Microbiological production of polysaccharides. • Bacterial entrainment and growth.

Source: Russell 2013.

5.4.2 Chemical clogging

Local experience (Paul Murphy, pers. comm.) and a review of groundwater quality data completed for this study (Golder 2013) has highlighted elevated iron concentrations as a matter for consideration at the MAR feasibility assessment stage.

All bores screened in the Makauri Aquifer included in this review have produced water with dissolved iron elevated above ANZECC (2000) guidelines for long-term irrigation (>1.0 g/m^3). Iron concentrations are greatest in the southern half of the aquifer, with the highest median recorded in bore GPD147 (24 g/m^3).

Concentrations of manganese in bores to the northeast of Makaraka have also been elevated above ANZECC (2000) guidelines for manganese (also >1.0 g/m^3). Bores producing better water quality (i.e., lower iron and manganese concentrations) are located in the eastern half of the aquifer while bores to the south had the poorest water quality. Contour plots of recorded iron concentrations (Appendix C) provide information to support the identification of potential MAR pilot site locations with low ambient iron concentrations.

Geochemical modelling was undertaken using water data from two bores, one with relatively good water quality (lower salinity, iron, manganese and ammoniacal nitrogen concentrations), and one with “worst case” water quality (high iron, moderate salinity, moderate ammoniacal nitrogen). The results of this analysis (Appendix C) indicate that iron precipitation has the potential to occur when injected water is mixed with ambient Makauri Aquifer water at a ratio of 7 % and above. In an aquifer characterised by reducing conditions, iron oxyhydroxides can precipitate when oxygenated water is introduced to the aquifer.

Under an aquifer replenishment MAR configuration, injected surface water would gradually mix with ambient groundwater as it moves outward from the injection well(s). Installation of the injection well(s) a sufficient distance from the existing abstraction wells should ensure that iron precipitation would occur in the aquifer between the wells, and impacts on existing abstractions would be minimised.

Iron precipitation could initially form a low density floc with the potential to slightly reduce aquifer porosity and hydraulic conductivity. Over time, the floc will convert into a higher density hematite form so long term changes in the hydraulic properties of the aquifer due to iron precipitation are unlikely.

Preliminary analysis undertaken for this report indicates that under a simple piston flow model, the radius of influence around a MAR injection well would be approximately 200 m for a 100,000 m^3 injection season. The actual area of influence would however be greater due to mechanical dispersion and molecular diffusion along seepage flow paths from the injection well.

Possible water quality management measures are presented in Appendix C, the most promising of which is creation of a buffer zone or bubble around the injection wells. The buffer zone comprises a constantly maintained area of injected water around the well, which displaces native groundwater and prevents mixing of native and injected water from occurring within the injection well. This tried and tested approach is a successful means of minimising injection well clogging rates.

Groundwater flows under winter hydraulic gradient conditions have been estimated to be in the order of 0.5 m/d, or 180 m per year. On this basis, the water injected during one season may not be carried past the injection well before the following injection season starts. As this assessment does not take into account changes in hydraulic gradients resulting from abstraction, further evaluation of mixing zones would be required during the design process for a MAR trial. The outcomes would need to be taken into account when siting a trial injection well.

Chemical precipitation and clogging in existing abstraction wells has not been an issue in other Golder direct injection MAR projects. Management of the injection well has tended to be the main focus. Injection well efficiency testing coupled with a carefully designed baseline and trial stage water quality monitoring program would be required to evaluate and address this risk.

The risk of inducing additional precipitation rates in existing abstraction wells would be reduced if an ASR option was used, because the injected water is recovered via the ASR well(s). Injection and recovery using the same well would restrict the mixing zone for injected and ambient groundwater to an interface zone around the injection well. If a trial programme identified increased iron precipitation in existing abstraction wells as a matter for concern, risk mitigation through an ASR configuration could be investigated.

Water used for injection is usually treated to drinking water standards in order to minimise injection well clogging and protect aquifer water quality, especially when the aquifer is used for potable water supply. However, lower quality water can be used when the aquifer is not used for drinking water supply (Bouwer 2002). GDC has indicated that Mangapoike Dams water (via the Waingake water treatment plant) should be available for a MAR trial project. The dam water has low concentrations of metals and nutrients. Injection of this higher quality water into the Makauri Aquifer may improve the general groundwater quality in the area of the injection wells.

5.4.3 Biological clogging

Ammoniacal nitrogen concentrations were greater than ANZECC (2000) guidelines for nitrogen in long-term irrigation water (5 g/m^3) in the bores on the western and southern margins of the aquifer, but were typically <3 g/m^3 elsewhere. The ANZECC (2000) nitrogen guideline is based on prevention of bacterial growth in irrigator machinery. Relatively elevated nitrogen concentrations throughout the aquifer may therefore support bacterial growth within abstraction wells. Low concentrations of phosphorus (<0.004 g/m^3 dissolved reactive phosphorus (DRP)) in the receiving aquifer mean that growth rates will be limited by the availability of phosphorus. Nutrient concentrations in water from the Mangapoike Dams are low (<0.004 g/m^3 DRP,

<0.010 g/m^3 ammoniacal nitrogen) so injection of this water should not should not enhance biological growth in MAR injection wells.

Golder experience has shown that maintenance of a residual chlorine concentration of 1 g/m^3 to 2 g/m^3 can be to be an effective way of minimising biological growth rates in injection wells. Occasional shock chlorination coupled with backwash cycles and a targeted suite of injection well monitoring and maintenance measures may also be required to maintain injection well efficiencies. Further assessment during Stage IIA will be required to determine the concentrations of the Waingake WTP, at the source of injection.

5.4.4 Physical clogging

Water from the Mangapoike Dams is treated at the Waingake WTP. Use of this high quality source water will minimise the risk of physical clogging of injection wells due to suspended solids.

Physical clogging can also occur where clay minerals are present due to swelling processes. Where the aquifer comprises clean gravels with negligible clay content this issue is less likely to arise.

A regular backwash cycle and periodic mechanical rehabilitation of the injection wells may be required if injection well pressure monitoring data identify physical clogging-related reductions in well efficiency.

6.0 MAR FEASIBILITY ASSESSMENT

6.1 Introduction

Three assessment components are used to support a feasibility analysis for a MAR project. These stages are:

1) A preliminary viability and benefit assessment

2) An options assessment

3) A risk assessment

In this case, these components have been undertaken for a MAR project focused on the Makauri Aquifer and a project focused on the shallow aquifers. The approach taken broadly follows the AGWR Guidelines (2009), adapted to incorporate New Zealand-specific factors for this study.

6.2 Preliminary Viability Assessment

A preliminary viability assessment for a Poverty Bay MAR project has been undertaken and summarised in Table 2. This analysis does not incorporate a review of the economics of a full scale Groundwater Replenishment scheme, which would be undertaken as part of planning for a Stage 2 pilot program (refer Section 7.0)

Table 2: Preliminary viability assessment for a Poverty Bay Flats MAR project.

Attribute	Question	PVA outcome: assessed as viable? Yes / No	Comments
1. Intended water use	Is there an ongoing local demand or clearly defined environmental benefit for recovered groundwater that is compatible with local water management plans?	Yes	Projected growth in irrigation water demand. FwAG investigating water storage options to meet demand projections. Surface water resources fully allocated. Pressure on summer environmental low flows likely to arise.
2. Source-water availability and right of access	Is adequate source water available, and is harvesting this volume compatible with catchment water management plans?	Yes	The primary source option is the Mangapoike Dams. Secondary options include a new water take from the Waipaoa River during high flows and the Waipaoa Augmentation Plant. Harvesting is compatible provided it is focused on high flow winter periods.
3. Hydrogeological assessment	Is there at least one aquifer at the proposed managed aquifer recharge site capable of storing additional water?	Yes	Makauri Aquifer has capacity for additional storage. Matokitoki Aquifer and the shallow aquifers of the Poverty Bay Flats also have potential.
	Is the project compatible with groundwater management plans?	Yes	Stabilisation of Makauri Aquifer downtrend and provision of water for future growth aligns with FwAG management plans.
4. Space for water capture and treatment	Is there sufficient land available for capture and treatment of the water?	Yes / Uncertain for infiltration	Injection wells require minimal land and are not likely to be a limiting factor. Surface infiltration land availability has not been assessed. Further investigation is required during Stage 2 for either option.
5. Capability to design, construct and operate	Is there a capability to design, construct and operate a MAR project?	Yes	Through coupling national and international MAR expertise with local water management and operations capabilities.

In summary, Makauri Aquifer groundwater records show a long term downward trend in annual groundwater levels that corresponds to increasing demand for irrigation water. There is clear potential for irrigation water demand to continue to increase. Water is available during the off-season from the Mangapoike dams for a pilot trial and potentially directly (via a water treatment plant) or indirectly (via the shallow aquifer) from the Waipaoa River during high flow periods for a full scale Groundwater Replenishment scheme.

Such a scheme has the potential to:

- Stabilise current downward trends in groundwater levels within the Makauri Aquifer
- Restore aquifer water levels and help protect shallow / surface water resources from future depletion
- Enable the establishment of a sustainable yield for the aquifer that exceeds current usage

The Makauri Aquifer is a widespread, high yielding aquifer with good connectivity and available storage capacity. As such, it has good capacity to accept and distribute water introduced through MAR. These are key factors in establishing a Groundwater Replenishment scheme.

The preliminary analysis therefore indicates that a Groundwater Replenishment scheme could be viable. The next section in this report provides an assessment of MAR options for such a scheme.

6.3 Options Assessment

A complete options assessment for future Poverty Bay water supply and groundwater management process is outside the scope of this project. An initial assessment of options for the use of MAR as a management tool for the stabilisation of groundwater levels and supporting the long term sustainable use of groundwater for water supply purposes has however been undertaken.

Surface infiltration

A surface infiltration project using water diverted from the Waipaoa River during winter could potentially be used to enhance recharge to shallow aquifers across the Poverty Bay Flats. Two main issues arise that may limit the applicability of this type of system: land availability and subsurface permeability.

The availability of adequate land suitable for the construction of an infiltration system is likely to be an issue. Given the high suspended solids loads carried by the Waipaoa River, especially during high flows, the water would require treatment before being introduced to an infiltration system. Otherwise clogging of the system would be a significant issue. At a minimum, an infiltration project would probably need to incorporate one or more sediment settling ponds or wetlands in addition to an infiltration system.

Shallow subsurface permeability is likely to be low across much of the Poverty Bay Flats, due to silts and clays deposited across the flood plain of the Waipaoa River. An infiltration system would need to be located in an area where a shallow aquifer is not overlain by low permeability deposits. Site specific design of a specialised infiltration system would be an option, however further work would need to be undertaken to evaluate these possibilities.

Shallow aquifer replenishment is also not seen as the first priority as groundwater levels in these aquifers are directly linked to Waipaoa River or other surface water bodies. Groundwater records over the past 30 years do not indicate a substantial decline in groundwater levels in the shallow aquifers. This does not imply that drawdown in the shallow aquifers has not happened but rather that the magnitude is much less than that observed in the Makauri Aquifer.

Direct injection

Direct injection of water from the Mangapoike Dams, supplied through the existing water supply infrastructure is likely to be the most easily achievable option for a MAR pilot trial. The quality of water delivered through the Gisborne supply infrastructure is very good, with chlorine dosing reducing the risk of biological growth and fouling of the injection system.

The Makauri Aquifer appears to behave as a well-connected hydraulic system across the full extent of the Poverty Bay Flats. The choice of injection points is therefore more controlled by convenience of pipeline access at the surface. The opportunities to encourage rapid recovery of groundwater levels following summer pumping are however greatest in the areas where drawdown is also greatest.

The use of water from the Waipaoa River for injection into the Makauri Aquifer would face many of the same issues as a shallow infiltration project. The potential issues with clogging are likely to be greater as the infiltration systems would be focused on well screens. Any suspended sediment remaining in the injected water would probably lead to clogging and well maintenance issues. In addition, the water would need to be sterilised before injection, to reduce the risks of well screen biofouling. Although the Waipaoa Augmentation Plant should be able to achieve these objectives, the cost of running the plant for this purpose is likely to exceed the value of the benefits gained.

Most of the groundwater pumped for irrigation purposes across the Poverty Bay Flats is sourced from the Makauri Aquifer. Groundwater pressures in this aquifer are also in long term decline. For these two reasons alone, the Makauri Aquifer is seen as the most useful target for a Groundwater Replenishment scheme.

6.4 Risk Assessment

An analysis of risks and risk management options has been undertaken as part of this project. The outcomes of this analysis are summarised in Table 3.

The analysis indicates that low aquifer replenishment rates and potential issues associated with accessing land for infiltration basins or other infiltration systems are the main risks for a shallow aquifer replenishment project.

For a water injection program into the Makauri Aquifer the main risks relate to injection well clogging. Clogging risks relate to both biological and geochemical processes.

Management options to mitigate these risks have been rated to provide a basis for options assessment. Since injection well clogging is more readily manageable than low aquifer replenishment and land access risks, the analysis highlights that direct injection is the preferred option.

The difficulty of achieving the Poverty Flats MAR objectives using direct injection has been assessed using a complexity rating matrix Golder is developing for New Zealand, which is based on AGWR Guidelines (2009). The analysis results (Appendix D) indicate that the project complexity rating for direct injection is high. The key rating factors are source water and aquifer geochemistry, which give rise to physical and chemical clogging risks in the injection well. Management procedures would be planned and tested through undertaking a pilot injection program.

Table 3: MAR decision support matrix.

MAR option	Risk	Likelihood(1)	Consequence	Management options	Risk mitigation potential
Surface infiltration	Land availability	Medium	Insufficient land, low subsoil permeability limits recharge capacity	Investigation of infiltration rates and land availability, appropriate system design.	Limited
	Basin clogging	High	Low recharge rate	Source water treatment through bank filtration, basin maintenance	Medium
	Basin mounding	Medium (low)	Low recharge rate	Locate basins in deeper groundwater areas	Limited
	Loss of recharge water to surface water	High (medium / high)	Storage period and capacity reduced	Enhance shallow-deep aquifer connectivity – e.g. bores drilled to connect aquifers in recharge area. Good cost benefit analysis. Treat as environmental benefit.	Poor / medium
Direct injection	Injection well clogging	High (medium)	Reduced injection rates	Maintain residual Cl concentrations, sole use bores for injection, backwash cycle, physical and chemical maintenance and rehabilitation measures, careful monitoring of MAR trial	Good
	Low aquifer transmissivity and injection well efficiency	Medium (low)	Low injection capacity	Target high transmissivity areas for injection well(s). High quality well installation and development.	Good
	Loss of recharge water	Low – medium	Reduced Makauri Aquifer storage period and capacity reduced	Groundwater level monitoring during trial programme, improve understanding of aquifers, refine groundwater model for full-scale MAR design	Good

MAR option	Risk	Likelihood(1)	Consequence	Management options	Risk mitigation potential
	Abstraction well clogging	Low – medium (low)	Reduced well efficiencies / yields	Injection well site selection, careful monitoring during MAR trial, sole use injection wells, well maintenance	Good
General	Limited winter water availability for recharge	Medium (low)	Reduced recharge capacity during dry winters	Develop multiple water sources, off-river buffer storage capacity	Good
	Low public acceptance of MAR system	Low – medium (low)	Delays in setting up or expanding MAR system, consenting delays, public rejection of MAR	Clear public communication, successful and well documented trial	Good
	Consenting issues	Low – medium (low)	Delays in trial, delays in setting up full MAR system	Clear public communication, successful and well documented trial	Good

Notes: 1. Figures in brackets denote risk rating if management measures implemented.

7.0 STAGE 2 MAR PILOT PROGRAMME

Golder recommends a two stage pilot programme to progress the MAR feasibility assessment for the Poverty Flats. Stage 2A would comprise pilot programme detailed design and preparatory work. Stage 2B would comprise the trial itself including a monitoring period that would extend beyond the operational injection period, analysis of the results and recommendations for development of full-scale Groundwater Replenishment scheme, if appropriate.

7.1 Stage 2A

The Stage 2A programme would include:

- A detailed cost estimate for supply of water for winter injection for different source options (e.g., Waipaoa Augmentation Plant, Mangapoike reservoir water, Waipaoa River via riverbank filtration, shallow aquifer water). Included in the cost estimate would be a summary of any chemical dosing and water storage requirements. It is however, assumed that the most appropriate water source for the Stage II trial program will be the Mangapoike Dams, via the existing water supply infrastructure. This would include an hydrologic modelling assessment of non-irrigation flows in the Waipaoa River relative to protecting ecological functions (e.g., flushing flows).

- A detailed assessment of injection well site options using a GIS-based spatial analysis of source water infrastructure locations, groundwater chemistry, existing well locations, aquifer transmissivity, groundwater gradients and high water use areas.

- A detailed estimate of capex costs for injection well construction. Comparison of MAR capex costs to available surface water option cost estimates.

- An assessment of effects to support consent application. This would include an evaluation of Makauri Aquifer water use and the potential effects of trial injection on groundwater levels, well yields and water quality.

- An economic analysis comparing groundwater storage through the development of a Groundwater Replenishment Programme (MAR) and surface storage options using information from around New Zealand and existing work from the Gisborne District area. This analysis would include an integrated assessment where surface and groundwater storage were developed together to maximise their potential benefits and cost effectiveness.

- Pilot programme design including injection well location, water supply, baseline monitoring programme, injection well design, trial phase monitoring, methodology for assessment of outcome.

7.2 Stage 2B

Stage 2B would involve baseline monitoring, construction and testing of the injection well, undertaking a five month (non-irrigation season) injection trial and extensive monitoring of quality and quantity. Monitoring would include injection rates, groundwater level and groundwater quality. Data gathered during the trial would be analysed to determine the effects of injection on groundwater levels, the injection well efficiency over the trial period and a comprehensive assessment of MAR feasibility. The latter would include evaluation of infrastructure requirements, injection rates required to achieve specific environmental and economic outcomes, an updated option assessment and a cost / benefit analysis.

Based on the trial results the PBGWT could be refined and updated to provide a fit-for-purpose decision making tool. As the tool develops it could be used to develop further scenarios for planning and community educational purposes. If a scheme is deemed to be feasible, further development of a spatial model (such as Modflow) would be needed to model and manage some of the spatial and temporal issues related to siting and operating MAR sites.

The comprehensive data gathering and analysis programme undertaken for the MAR programme is likely to provide new insights into the behaviour and constraints of the aquifer system and local water resources. The final Stage 2B report would present these broad findings together with the MAR-specific outputs.

8.0 CONCLUSIONS AND RECOMMENDATIONS

1) The GDC is investigating water management options to increase reliability of water supplies in the Poverty Bay area into the future.

2) Managed Aquifer Recharge (MAR) has the potential to replenish and sustain groundwater yields from aquifers beneath the Poverty Bay Flats.

3) A two stage feasibility assessment has been carried out on the potential for a successful Groundwater Replenishment scheme to be established. This report represents the deliverable from stage (Stage 1B) of the project and is intended to be read in conjunction with the report documenting the outcomes from Stage 1A. Presented in this report is:

   - A technical analysis of the potential opportunities and obstacles to a Groundwater Replenishment scheme

   - Documentation of the Poverty Bay Groundwater Management Tool (PBGMT) under development to support the GDC in reaching decisions regarding development and storage scenarios to meet broad economic and environmental objectives

   - A MAR feasibility analysis and a Go/No-Go summary of the opportunities and risks of a managed aquifer replenishment scheme.

4) Makauri Aquifer groundwater records show a long term downward trend in annual groundwater levels that corresponds to increasing demand for irrigation water. The Makauri Aquifer is a widespread, high

yielding aquifer with good connectivity and available storage capacity. It has good capacity to accept and distribute water introduced through MAR. These are key factors in establishing a Groundwater Replenishment scheme.

5) There is clear potential for irrigation water demand to continue to increase. Water is available during the off-season from the Mangapoike Dams for a pilot trial and potentially directly (via a water treatment plant) or indirectly (via the shallow aquifer) from the Waipaoa River during high flow periods for a full scale Groundwater Replenishment scheme.

6) Golder's feasibility analysis shows a Groundwater Replenishment scheme has the potential to:

- Stabilise current downward trends in groundwater levels within the Makauri Aquifer
- Restore aquifer water levels and help protect shallow/surface water resources from future depletion
- Enable the establishment of a sustainable yield for the aquifer that exceeds current usage

7) The PBGMT will provide the opportunity to consider the replenishment of groundwater supplies as part of the Poverty Bay Flats water management planning discussions. Replenishment coupled with reducing the current imbalance between consented allocation and actual usage will help the community consider a balanced set of options going forward. The PBGMT is however not yet developed to the stage that it can be used to support the GDC in making decisions or setting allocation limits for water supply options.

8) A MAR pilot trial is required to provide data to support continuing development of the PBGMT and to verify the outcomes produced. Direct injection of water from the Mangapoike Dams, supplied through the existing water supply infrastructure, is likely to be the most easily achievable option for a trial.

9) The quality of water delivered through the Gisborne municipal supply infrastructure is very good, with very low sediment loads and chlorine dosing reducing the risk of biological growth and fouling of the injection system. Geochemical clogging resulting from mixing of injected water with ambient groundwater is an identified risk. Several management options are available to mitigate this risk, the most promising of which is creation of a buffer zone or bubble around the injection well(s).

Golder recommends:

1) Funding should be sought to enable a MAR pilot trial to be designed, planned and implemented, based on direct injection of water from the Mangapoike Dams into the Makauri Aquifer.

2) As water is only available on a seasonal basis, a pilot trial should be planned to proceed during the 2015 winter season, taking into account that focused baseline water level and water quality monitoring would need to be initiated well in advance of any trial injection being initiated.

3) Ongoing community engagement regarding a Groundwater Replenishment scheme for the Poverty Bay Flats should be sought and encouraged.

9.0 LIMITATIONS

Your attention is drawn to the document, "Report Limitations", as attached in Appendix E. 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.

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