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POVERTY BAY MANAGED AQUIFER RECHARGE

Pilot Trial Options Analysis

Submitted to:
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REPORT

Golder Associates

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List of Abbreviations and Units

Abbreviation/Unit	Name
DBP	Disinfection by-product
g/m^3	Grams per cubic metre
GDC	Gisborne District Council
Golder	Golder Associates (NZ) Limited
MAR	Managed Aquifer Recharge
TSS	Total suspended solids
µm	Micrometre

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

The GDC is investigating water management options in the Poverty Bay region with the aim of improving water security for all users against a background of declining groundwater level trends in response to increased demand and predicted future climate change.

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 pre-feasibility assessment (Golder 2014) concluded that MAR, using excess water taken during high winter flow periods has the potential to replenish the Makauri Aquifer beneath the Poverty Bay Flats to support sustainable groundwater use.

GDC is now seeking to proceed with a pilot injection trial to the Makauri Aquifer (the "Pilot Trial"). Golder Associates (NZ) Limited (Golder) has been commissioned by GDC to assist with technical support for the MAR Pilot Trial. Golder has completed a technical report (Golder 2015a) to support the assessment of environmental effects for the Pilot trial and submitted this report to GDC.

The pre-feasibility study and initial technical assessment was based on the direct injection of water sourced from the Wainake Water Treatment Plant into the Makauri Aquifer. An alternative source water option was identified during initial planning for the Pilot trial. This option entails using water sourced from the Waipaoa River and treated in the Waipaoa Augmentation Plant prior to injection.

In November 2015, the Kaiaponi infiltration gallery, which is positioned beneath the Waipaoa River, was identified as a further source water supply option for the MAR Pilot Trial. This gallery provides water to a distribution pipe network, which services the Kaiaponi Farm irrigation system. This is a private water supply system providing water for a single farm. Golder understands water from this system could be available for the Pilot Trial during periods outside the irrigation season.

Golder understands that GDC is now looking to proceed with the most suitable of the options for the consent application process. This will help to reduce the complexity of the application and any confusion around these multiple options. In order to make a decision on the preferred option, GDC have requested a short report comparing the details of the two options at Bushmere and a third at the Kaiaponi site.

1.2 Pilot Trial Options

The three Pilot Trial options under consideration are summarised below.

- **Option #1 - Bushmere Site - Waingake water source:** Install an injection bore into the Makauri Aquifer at the Waipaoa Augmentation Plant on Bushmere Road. The water for the Pilot Trial would be treated drinking water sourced from the **Waingake Water Treatment Plant** and provided to the injection bore through the town water supply pipe line.
- **Option #2 - Bushmere Site - Waipaoa River water source:** Install an injection bore into the Makauri Aquifer at the Waipaoa Augmentation Plant on Bushmere Road. The water for the Pilot Trial would be sourced from the Waipaoa River, processed to drinking water standard and provided to the injection bore through the town water supply pipe line.
- **Option #3 - Kaiaponi Site - Waipaoa River water source**: Install an injection bore on Kaiaponi Farm. The water for the Pilot Trial would be sourced from the Waipaoa River, abstracted through the Kaiaponi infiltration gallery. The water would be treated through the use of an existing cyclone and filter bank

system, with the potential for additional treatment considered in this report, and transferred through the Kaiaponi Farms irrigation water distribution network to the injection bore.

1.3 Scope of Work

Golder has been tasked with providing GDC with a comparative assessment of the three MAR Pilot Trial options, as described in Section 1.2. This comparative assessment is required by GDC to enable informed decisions to be reached on the final Pilot Trial site and water source. GDC has requested that the cost comparison focus primarily on:

a) The differences in source water treatment requirements and costs.

b) The monitoring costs required of the three Pilot Trial options.

The costs and construction factors associated with drilling and installing the injection bore, the injection flow control system and the drilling and installing of a nearby monitoring well are expected to be similar for each of the three options. For this reason, these components of the Pilot Trial are not a factor in the comparative assessment.

This report outlines the factors assessed and compares the three options through summarising:

- Costs associated with treatment of the injection water, if required.
- Costs associated with connecting the injection bore to the source water delivery pipeline.
- The monitoring program required for each site, together with the associated costs.
- A comparison of the benefits and limitations of the three options.

This report has been produced to support GDC in making decisions with respect to the final Pilot Trial site and water source. For this reason, the costs presented are indicative only and provided to support a comparison of the options identified. These costs are not intended to reflect the overall cost of the Pilot Trial. Detailed cost estimates and quotes will be obtained once a decision has been reached regarding the site location and water source.

2.0 TREATMENT AND MONITORING COSTS

2.1 Treatment and Transport of Source Water

2.1.1 Option 1: Bushmere - Waingake

The treatment of Waingake source water to a drinking water standard is included in the water supply costs provided by GDC for treating and transporting the water to the site (Table 1). The treatment process would provide a very stable and high quality water supply to the injection bore.

A commercial style off-take from the public water supply pipeline, including a non-return flow system, would need to be installed at the Bushmere site by GDC. The planned injection bore is located very close to the public water supply pipeline so the costs of additional piping are low.

The water in the public supply system is chlorinated, with low levels of residual chlorine being present in the pipeline at Bushmere. The presence of residual chlorine in the source water is not considered to be an issue for the Pilot Trial. If necessary however the concentrations of residual chlorine in the water supplied by GDC could be managed through exposure to sunlight. Clear plastic tanks at the injection site could be used to reduce chlorine levels to required concentrations. Given the rapid breakdown of any potential disinfection by products (DBP) in the reduced conditions of the Makauri Aquifer, this level of treatment is not considered by Golder to be a requirement. An initial cost indication to install a system for this purpose is however provided in Table 1, should a reduction in residual chlorine concentrations in the injection water become a consent condition.

Table 1: Relative indicative costs for source water connection, monitoring and treatment.

Factor [1,2]	Option #1 Bushmere- Waingake		Option #2 Bushmere- Waiapoa		Option #3 Kaiaponi- Waipaoa	
	From	To	From	To	From	To
GDC water supply costs (treatment to drinking water standard)	$ 121,000	$ 121,000	$ 121,000	$ 121,000		
GDC water supply costs (connection to public supply system)	$ 16,000	$ 24,000	$ 16,000	$ 24,000		
Optional: Residual chlorine reduction	$ 0	$ 3,000	$ 0	$ 3,000		
Kaiaponi water supply system (connection to system)					$ 3,000	$ 5,000
Kaiaponi additional source water treatment [3]					$ 22,000	$ 65,000
Kaiaponi water supply system (system maintenance costs) [4]					$ 0	$ 3,000
Electricity connection for Pilot Project control system [5]	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000	$ 8,000
Water quality monitoring for Pilot Trial (source water only) [6]	$ 2,000	$ 3,000	$ 2,000	$ 3,000	$ 7,000	$ 8,000
Total	**$ 147,000**	**$ 159,000**	**$ 147,000**	**$ 159,000**	**$ 40,000**	**$ 89,000**

Notes: 1) Summary notes on cost derivation provided in Appendix B. Capital expenditure (CAPEX(and operational expenditure (OPEX) not separated as trial is for a limited time. Costs relate to Pilot Trial only, not to any ongoing process following the completion of the trial. Values provided rounded to nearest $1,000.

2) Costs for drilling and installation of injection bore, injection flow control system and drilling and installation of monitoring well are expected to be similar for each option. These costs therefore not incorporated in this table.

3) Lower end of range assumes Arkal filter is positioned upstream from injection bore and no additional filtration or treatment required. Upper cost limit involves the installation of a UV water treatment system to manage pathogen concentrations in the source water. Intermediate cost options include chlorine disinfection systems.

4) General maintenance and running costs including possible clearance of soils around intake gallery, filter replacement, operating costs.

5) Connection costs partially dependent on exact location of injection bore.

6) Groundwater quality monitoring costs similar for all three options.

2.1.2 Option 2: Bushmere - Waipaoa

The operational costs of treating Waipaoa River water using the Augmentation Plant are large as the plant would need to be run at a greater flow rate than required for the Pilot trial. The minimum flow rates through the Augmentation Plant are much greater than the flow rates required for the Pilot trial. The excess water would therefore presumably be used to supply Gisborne. The plant is usually only run by GDC for a few weeks each year in spring. Therefore, the additional operational period for the Augmentation Plant is considered to be an operational cost for the Pilot Trial.

A commercial style off-take from the public water supply pipeline, including a non-return flow system, would need to be installed at the Bushmere site by GDC. The planned injection bore is located very close to the public water supply pipeline so the costs of additional piping are low.

As with Option 1, the water in the public supply system is chlorinated, with low levels of residual chlorine being present in the pipeline at Bushmere. An initial cost indication to install a system for the reduction in chlorine concentrations in the water prior to injection is provided in Table 1, should a reduction in residual chlorine concentrations in the injection water become a consent condition.

2.1.3 Option 3: Kaiaponi - Waipaoa

The water treatment system presently installed on the Kaiaponi Farms irrigation supply line consists of:

- An infiltration gallery installed behind the river bank, which is expected to remove most sand, silt and clay together with much of the bacterial load from the river water.
- A cyclone filter installed close to the river intake gallery to remove coarser solids.
- Several banks of Arkal 120 µm filters situated throughout the distribution scheme.

The levels of bacteria and other microorganisms in the water sourced from the gallery are generally expected to be low, due to natural filtering provided by the soils around the infiltration gallery. This natural water treatment capacity is one reason why infiltration galleries are installed as the first treatment stage in many water supply plants (Ray et al. 2002). In addition, the concentrations of suspended sediment derived from the river water are expected to be low for the same reason. Source water quality monitoring is planned to confirm this expectation.

Initial monitoring indicates the TSS concentration up-stream and down-stream from the first bank of Arkal filters is at or below the laboratory detection limit of 3 g/m^3. However, the intake water supply quality may vary due to changes in sediment loads in the Waipaoa River during and following storm events. Detailed monitoring of source water quality is planned and changes in sediment loads in the injection water can be accommodated through operational management of the trial.

The cyclone and Arkal filters are designed to remove suspended solids down to a size of 120 µm, which is a very fine sand. Residual silt and clay size particles, bacteria and other microorganisms that enter the pipeline from the infiltration gallery would not be removed by these filters.

The presence of fine sediment in the injected water could affect the hydraulic efficiency of the injection bore and is therefore an operational issue for the trial. The installation of additional filters for the trial will be recommended if the outcomes of the pre-trial source water quality monitoring program show significant increases in suspended sediments. Any sediment in the injected water would not affect the permeability of the wider aquifer or water supplies for other users as it would be captured by the injection well gravel pack or in the aquifer immediately surrounding the injection well screen.

Pathogens and microorganisms are present in the Waipaoa River water. Aquifers are however generally very efficient at removing pathogens and other microorganisms from groundwater seepage flows (Pang et al. 1998, Page et al 2015). In order to validate expectations regarding the aquifer's pathogen removal efficiency, Golder recommends that a Pilot Trial at the Kaiaponi site be divided into two phases. Each Phase would involve injecting approximately half the source water volume (50,000 m^3).

1) Phase 1 involves injecting filtered water without further treatment to the aquifer, with careful monitoring and triggers to ensure safe operation. This phase is planned to provide critical information needed to confirm the attenuation rates of bacteria introduced to the conditions within the Makauri Aquifer.

2) Phase 2 involves injecting filtered water that has been treated to remove pathogens and thereby provide a proof of concept for MAR sites using treated water. This will provide important information helping establish how this treatment approach might be progressed in the future and monitoring will allow assessment of geochemical responses in the aquifer.

A two-phase trial is recommended as the results of the trial would need to be scaled-up to support planning of a wider groundwater replenishment scheme. The division of the Pilot Trial into two phases as described above enables the aquifer behaviour and water quality changes under both treated and untreated water supply scenarios to be confirmed.

During the Pilot Trial it would be useful to accept low bacterial levels in the injection water in order to track their appearance in seepage passing the adjacent monitoring well through the water quality sampling program. Analysis of this breakthrough data would provide valuable information on the rates of pathogen removal by the aquifer, to support the planning of a possible future groundwater replenishment scheme. Triggers designed to protect groundwater users (Golder 2015b) have been developed and are summarised below.

1) The *E.coli* concentration in the injected water should initially not exceed 100 cfu, which is considered to be a conservatively low concentration for the protection of water quality in the aquifer.

2) The *E.coli* data from the planned nearby monitoring bore (10 m away) shall be used to calculate an attenuation rate for bacteria in the aquifer. This attenuation rate shall be used to confirm that *E.coli* concentrations in the groundwater will decrease to below the detection limit within a radius of 100 m from the injection bore.

3) Once the attenuation rate for *E.coli* has been confirmed, the initial trigger concentration may be adjusted to enable the attenuation rate to be tested under a range of injection concentrations and recharge rates.

Should the E.coli loads in the source water exceed the trigger levels, the trial can be either temporarily halted or Phase 1 can be brought to a close and Phase 2 brought forward. As Phase 2 of the Pilot Trial involves the chlorination of the source water to manage bacterial concentrations, and the equipment will already be available on site, this should not result in significant cost increases or issues with respect to the management of the trial.

Source water treatment is not expected to be required at all future groundwater replenishment scheme sites, especially where local groundwater is not used for drinking water supply or irrigation of particular horticultural crops. Adding treatment to the Pilot Trial, allows it to be used as an example of future MAR sites which may require treatment based on their proximity to identified drinking water sources. None of the three potential Pilot Trial sites are located in proximity to any known drinking water supply bore or any known drinking water supply source that could potentially be affected by the MAR Pilot Trial. In the future, GDC could use policies under the National Objective Framework to define sections of the Makauri Aquifer as separate Freshwater Management Units with water quality objectives based on the beneficial use of the local aquifer.

2.2 Monitoring

The effort required to monitor groundwater quality and levels is similar in each of the Pilot Trial options. A similar number of monitoring bores will be developed for the Kaiaponi site as has been carried out for Bushmere. During Phase 1 when injecting un-treated water disinfection by-product monitoring will not be required at the nearest monitoring well.

The differences in monitoring costs between the three options are primarily related to the sampling and analysis of the source water at the Kakaponi site. Groundwater quality monitoring costs are therefore not

included for comparison purposes in Table 1. A source water monitoring program for the Kaiaponi site is provided in Appendix A, with the expectation that this program is flexible and would probably change through the trial.

3.0 BENEFITS AND LIMITATIONS SUMMARY

To support GDC in comparing the three options listed in Section 1.2, a summary of the benefits and limitations associated with each Pilot Trial option is presented in Table 2. In evaluating the information provided in Table 2:

- **Green text** indicates benefits.
- **Red text** indicates limitations.
- **Black text** indicates information that is not beneficial or limiting, or is provided for general advice only.

Optional components to the proposed Pilot Trial related to the treatment of source water have been incorporated in Table 2. At present ultra-violet treatment is considered to be unnecessary for the trial, however it has been included in the comparison table for completeness.

4.0 DISCUSSION AND RECOMMENDATION

The three options have various limitations and benefits, as summarised out in Table 2. Golder considers that the main benefits of Option 1 Bushmere- Waingake includes good source water quality of a consistent standard, a site that could easily be managed by GDC in the future and could provide a secure water source for the town supply. The main limitation is uncertainty for source water supply for the Pilot Trial given water storage requirements at Mangapoike Dams (Waingake). Option 2 Bushmere- Waiapoa is limited by the costs and practicalities of operating the plant at the flow rates required for the Pilot Trial.

Golder recommends that the Option 3 Kaiaponi- Waipaoa be accepted as the preferred option for the Pilot Trial for the following reasons:

- This site provides for a reliable water supply throughout the irrigation off-season at rates suitable for the trial.
- This site provides a source water setup that is easily scalable for a possible future groundwater replenishment scheme.
- A trial focused at this site could be separated into two phases with different source water treatment options: filtered water only and filtered treated water. This two-phase trial offers substantial benefits for the planning of a future groundwater replenishment scheme through providing valuable information on the rates of pathogen removal by the aquifer.
- Use of the Kaiaponi water does not require the source water protection systems, including backflow prevention, that would be necessary at the other two sites (Golder 2015a).
- There is a significant cost benefit to using the Kaiaponi site compared to using either of the other two sites.

Table 2: Benefits and limitations of Pilot Trial options.

Factors	Option #1 Bushmere- Waingake	Option #2 Bushmere- Waiapoa	Option #3 Kaiaponi- Waipaoa
Land ownership	■ GDC land ownership	■ GDC land ownership	■ Private land ownership ■ Ownership of bore and equipment following completion of trial needs to be negotiated.
Capital costs	**Well drilling and installation** costs are effectively the same for each option. Injection control system costs also the same for each option. Electrical connection costs assumed to be the same for each option at this stage – costs for Option 3 will depend partially on exact location of injection bore.		
	■ Moderate water supply pipeline connection costs. ■ Backflow protection required due to connection to public water supply system.	■ Moderate water supply pipeline connection costs. ■ Backflow protection required due to connection to public water supply system.	■ Low water supply pipeline connection costs. ■ Backflow protection is not required as it is not connected to the drinking water supply. ■ Moderate costs for additional treatment if required.
Operational costs	Trial management, field oversight, data assessment and documentation costs are effectively the same for each option.		
	■ The cost of water treated to drinking water standard is high (Table 1).	■ The cost of water treated to drinking water standard is very high (Table 1). Operating the full treatment plant to provide 10 L/s for the Trial is inefficient.	■ Operational costs low - little more than normal operating costs for Kaiaponi Farms irrigation system. Treatment to drinking water standard not required.
Source water availability	■ Uncertainty about supply of source water for a full season as water only available once dams are at capacity.	■ A change to treatment plant may be required to enable the supply of water for a full season trial.	■ Water supply reliable. Possible flow limitations due to river flow levels and unusable water during high flow storm events (turbidity). ■ Water only available outside irrigation season.
Source water quality	■ Very stable and drinking water standard.	■ Very stable and drinking water standard.	■ Likely to generally be good. May vary in response to seasonal and storm driven variations in river water quality.
Additional source water treatment	■ Residual chlorine levels may need to be managed before injection (on-site tanks and monitoring required).	■ Residual chlorine levels may need to be managed before injection (on-site tanks and monitoring required).	■ The planning and performance of the trial in two phases can enable the attenuation of bacteria in the aquifer to be confirmed and also provide a proof of concept study for treatment of the injection water using chlorination.

Factors	Option #1 Bushmere- Waingake	Option #2 Bushmere- Waiapoa	Option #3 Kaiaponi- Waipaoa
Aquifer location suitability for trial.	■ Good site location at appropriate distance from abstraction pressure area in Makauri Aquifer.	■ Good site location at appropriate distance from abstraction pressure area in Makauri Aquifer.	■ Close to main area of groundwater use and pressure on resource. Potential interference from nearby groundwater abstraction on monitoring long term responses. Additional time for analysis required.
Operational flexibility	■ Provided reservoir water available, a high level of flexibility available for injection management. ■ Increased flows may not be available if aquifer proves to be highly permeable.	■ Once trial has started, the Augmentation Plant should continue operating until trial injection finished. Shut down periods during trial would therefore be costly as treatment plant would continue to operate.	■ High degree of operational flexibility available.
Scalability (Application of trial information to other sites.)	■ Can be scaled up but new water supply options may require additional geochemical assessment for mixing with aquifer water.	■ Directly scalable to other sites using water sourced from Waipaoa River	■ Directly scalable to other sites using water sourced from Waipaoa River
Potential for Pilot Trial program to be directly incorporated into a regional groundwater replenishment scheme.	■ Can be incorporated into a full operational scheme however water supply costs may prove prohibitive.	■ Unlikely to be directly incorporated into a full operational scheme due to water treatment costs. ■ Modifications to site can be made to support a permanent MAR site.	■ Can be immediately incorporated in full operational scheme. ■ Water users are highly involved in trial and have ownership. This could lead well into future scheme.
	■ Would be operated by GDC if incorporated in full scheme.	■ Would be operated by GDC if incorporated in full scheme.	■ Unsure who would operate, maintain project going forward.
Other factors	■ Due to land ownership and the source of recharge water, this option may provide a potential secure water supply for Gisborne through a future Aquifer Storage and Recovery (ASR) scheme as it is already integrated with the existing GDC water supply network.	■ Due to land ownership and the source of recharge water, this option may provide a potential secure water supply for Gisborne through a future Aquifer Storage and Recovery (ASR) scheme as it is already integrated with the existing GDC water supply network.	■ At Kaiaponi site GDC would be enabling the framework for a future regional groundwater replenishment scheme. ■ Trial site demonstrates integration with existing irrigation operations.

Notes: Benefits = green text. Limitations = red text. Black text indicates neutral implications or general information only.

5.0 SUMMARY

This report summarises the benefits and limitations associated with the various establishment and operational factors involved at each of the three Poverty Bay MAR Pilot Trial options. This information has been developed to support the GDC in finalising a decision on the location of the trial injection well.

In addition, a summary of indicative costs for factors that differ from one site to the next is provided. These estimated costs are indicative only, based on limited cost estimates from providers. These costs are provided for general cost comparison purposes only and actual costs may vary from those provided in this report. For this reason, the costs provided should not be used for detailed budgeting purposes.

Golder recommends that the Poverty Bay MAR Pilot Trial be undertaken at the site described under Option 3 Kaiaponi- Waipaoa.

6.0 LIMITATIONS

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

7.0 REFERENCES

Golder 2014. Poverty Bay groundwater management. MAR feasibility assessment and Goldsim groundwater management tool (Stage 1B). Report prepared for Gisborne District Council by Golder Associates (NZ) Limited. Golder report 1378110136-006. August 2014.

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APPENDIX A

Cost Summary Notes

Table A1: Relative indicative costs of monitoring and treatment requirements.

Options	Factors considered[1]	Indicative costs (excluding GST)
Option 1: Bushmere-Mangapoike	■ To drinking water standard currently carried out for public water supply. ■ Reduction of residual chlorine concentrations pre-injection using large storage tanks optional. ■ Off-take connection to water supply pipe line required with backflow protection. ■ Electrical connection for flow management and control equipment.	■ $100,000 (GDC water treatment and supply) ■ $3,000 initial estimate ■ $20,000 (establish off-take for commercial supply) +/- 20% ■ $8,000 (Electricity connection/control equipment)
	■ As carried out for town water supply requirements, with additional sampling for Dissolved Organic Carbon (DOC) and Total Organic Carbon (TOC) each month. ■ Allowance for specific sampling and analysis in QA/QC.	■ Additional DOC and TOC sampling 5 x $60 (per month) of up to $1,800 over trial month period. ■ $500
Option 2: Bushmere-Waiapoa	■ To drinking water standard currently carried out for public water supply. ■ Reduction of residual chlorine concentrations pre-injection using large storage tanks optional. ■ Off-take connection to water supply pipe line required with backflow protection. ■ Electrical connection for flow management and control equipment.	■ $100,000 (GDC water treatment and supply) ■ $3,000 initial estimate ■ $20,000 (establish off-take for commercial supply) +/- 20% ■ $8,000 (Electricity connection/control equipment)
	■ As carried out for town water supply requirements, with additional sampling for Dissolved Organic Carbon (DOC) and Total Organic Carbon (TOC) each month. ■ Allowance for specific sampling and analysis in QA/QC.	■ Additional DOC and TOC sampling 5 x $60 (per month) of up to $1,800 over trial month period. ■ $800
Option 3: Kaiaponi - Waipaoa	■ Off-take connection to water supply pipe line required with backflow protection. ■ Electrical connection for flow management and control equipment.	■ $3,000 initial estimate plus potential $2,000 for additional sampling and other connections. ■ $8,000 (Electricity connection/control equipment).
	■ Additional TSS filtering equipment if required. OPTIONAL ■ Chlorination of injection water, including dosing system, automated water monitoring for chlorine concentrations and control system. Chlorination OPEX costs include up to 3 kg of hypochlorite per day. OPTIONAL ■ UV treatment of injection water.	■ $22,000 filtering equipment and $3,000 installation[2]. ■ $22,000 chlorination equipment and $3,000 installation[2]. Hypochlorite solution approximately $45 per month or $270 for a 6 month period. ■ $65,000 UV plant costs. $3,000 [2] installation. Electricity costs TBA.

	■ Water quality sampling and analysis costs. Sampling as per schedule and parameters listed in Appendix B. Includes pre-trial sampling and sampling during trial. Assume 44 samples in total.	■ Approximately $8,000, rounded up.

Note: 1) Some of the factors listed are considered to be optional and are described as such in the body of the report.
2) The allowance for installation is highly dependent on site layout and well head structures.

APPENDIX B

Source Water Monitoring Summary

Table B1: Source water quality monitoring.

Source water monitoring	Irrigation season	Pre-trial	During Trial
Option 1: Bushmere-Mangapoike	Dissolved Organic Carbon (DOC) and Total Organic Carbon (TOC) each month.		
Option 2: Bushmere-Waiapoa	Dissolved Organic Carbon (DOC) and Total Organic Carbon (TOC) each month.		
Option 3: Kaiaponi - Waipaoa	4 – 5 samples at different flow rates.	At least three intensive sampling periods linked to high flow river events 5 samples per event, total of 15 samples.	Weekly sampling for laboratory analysis Weekly measurements for field parameters to match laboratory sampling schedule.

Source water monitoring parameters for program set out in Table B1:

- Laboratory analysis:
  - E-coli
  - TSS and turbidity (NTU)
  - Major ions (including sulfate & carbonate)
  - NO_3-N, NO_2-N NH_4-N, Total N
  - Dissolved iron
  - Dissolved arsenic
  - pH
- Field monitoring parameters (Strict equipment calibration procedures):
  - pH, Eh and temperature
  - Electrical conductivity
  - Dissolved oxygen
  - Turbidity (NTU)

APPENDIX C

Report Limitations

Report Limitations

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

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