Grey Lynn Tunnel

Groundwater Effects Assessment

MCMILLEN JACOBS ASSOCIATES

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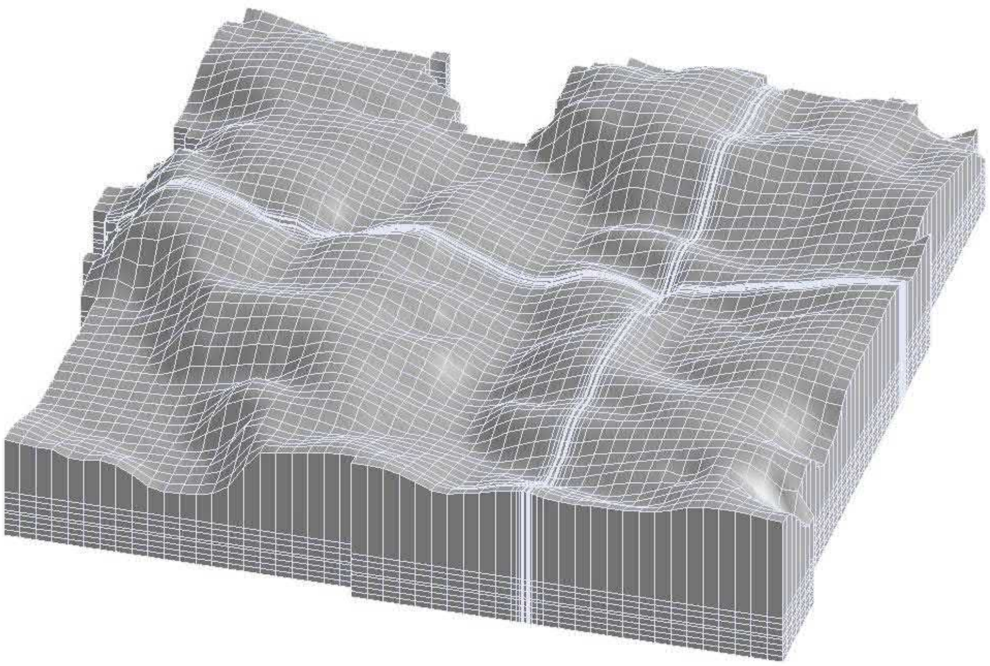

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Contents

Executive Summary

Project Overview

Williamson Water & Land Advisory (WWLA) has been commissioned by Watercare Services Limited (Watercare) to undertake a numerical modelling analysis and assessment of groundwater effects report for the proposed construction of new shafts at the termination of Tawariki Street in Grey Lynn, Auckland.

The groundwater effects assessment criteria for the proposed shafts used in this analysis are based on those included in Section E7.8 of the Auckland Unitary Plan (Operative in Part) (AUP(OP)). Additional consideration has been given to the potential impact of groundwater drainage on the construction process. These considerations can be summarised as follows:

- Estimation of seepage into the shaft during the construction process under various temporary lining conditions;
- An estimate of regional drawdown of groundwater levels during construction and groundwater recovery following project completion;
- Potential impact on surface water features, specifically streams; and
- Potential impact on neighbouring groundwater users.

The proposed Secondary Shaft will be constructed a minimum of 2.5 years after the competition of the Main Shaft. At this time any groundwater impacts from the Main Shaft would have fully recovered. The configuration of the Secondary Shaft is slightly smaller than the Main Shaft, so any new groundwater impacts of the Secondary Shaft will be less than for the Main Shaft. Therefore, separate modelling of the groundwater effects from the Secondary Shaft were not undertaken. However, the effects assessment is relevant to both shafts. Reference to “shaft” within this report is reference to the shaft under construction at the time.

The groundwater effects of the tunnel construction will be minimal as the construction proceeding involved an earth pressure balance tunnel boring machine, which limits groundwater ingress to the tunnel and prevents any groundwater related impacts from occurring.

Numerical Modelling

A calibrated numerical groundwater flow model was developed using MODFLOW to determine the potential impact of shaft construction on regional groundwater and to estimate the rate of groundwater drainage into the shaft during and following construction.

A two-year simulation was run to establish baseline conditions (**Scenario 1**). Six transient simulations were subsequently run, which included four simulations of various lining scenarios to the full depth of the shaft using different permeability assumptions. In the other two scenarios the shaft lining was simulated to extend to 7 m below ground level (mBGL), and a higher material conductivity was tested in Model Layer 1 in the final scenario:

- ***Scenario 2*** - no shaft lining;
- ***Scenario 3*** - 10^{-8} m/s shaft lining;
- ***Scenario 4*** - 10^{-9} m/s shaft lining;
- ***Scenario 5*** - 10^{-10} m/s shaft lining;
- ***Scenario 6*** - 10^{-9} m/s shaft lining extending to 7 m BGL; and
- ***Scenario 7*** - 10^{-9} m/s shaft lining extending to 7 m BGL and increased Layer 1 permeability.

Scenario 4 was considered to be the most representative of long-term conditions while Scenario 6 was considered to represent the temporary conditions during the construction period prior to the installation of the full shaft lining. Scenario 2 (unlined shaft) was considered to be the most conservative scenario from the perspective of demonstrating an upper envelope of potential effects.

Model Results

Drainage into the shaft is predicted to reach a peak 7 to 10 days into the shaft excavation process and rapidly decline at the end of the construction period, approaching a pseudo constant rate as conditions stabilize around the shaft. In Scenario 2, with no lining on the shaft wall, drainage is predicted to peak at 32 m^3/day. This reduces to 30, 24, and 23 m^3/day in Scenarios 3, 4, and 5 with progressively decreasing lining permeabilities, respectively. The rate of steady state drainage into the shaft after construction is 5.6 m^3/day in Scenario 2, 4.0 m^3/day in Scenario 3, and approximately 2 m^3/day in Scenario 4 and 5. Scenarios 6 and 7 are effectively the same as Scenario 2 in terms of peak and steady state drainage into the shaft.

The model results demonstrated that barrier permeability has a stronger influence on the long term rate drainage into the shaft, whereas the peak drainage includes a strong component of vertical inflow that limits the effect of the lining which is only applied on the sides of the shaft.

The predicted impact on surface drainage was minimal, with less than 0.07 m^3/day (0.0008 L/s[1]) of flow reduction predicted in Cox's Creek in the most extreme case (i.e. Scenario 2 – Unlined Shaft). Groundwater drawdown was greatest directly around the shaft location, but widespread impact on groundwater levels was not predicted as there are no current groundwater users within the range of impact. This is consistent with our expected result, due to the very low hydraulic conductivity of the rock formation, and the finite duration of dewatering.

Predicted drawdown in Scenario 2, with no shaft lining, was 5.5 m at a distance of 10 m from the shaft but only 0.6 m at 100 from the shaft. Measurable drawdown (>5 cm) was predicted to extend to approximately 420 m from the shaft location in the model layer corresponding to the bottom of the shaft. Drawdown in the shallow layer where settlement could occur was under 0.2 m in all scenarios other than Scenario 7.

Greater drawdown was predicted in Scenario 7 where a higher conductivity for the Tauranga Group/upper ECBF was assumed, however this Scenario was run to assess model sensitivity and did not apply calibrated parameters. In Scenario 7, approximately 7.2 m of drawdown was predicted at a distance of 10 m from the shaft and 2.9 m was predicted at 100 m from the shaft.

All other scenarios where the shaft wall was lined resulted in the prediction of significantly less drawdown than for Scenario 2. Drawdown was predicted to be under 0.5 m at 100 m distance from the shaft in Scenarios 3-5 and Scenario 6 was effectively the same as Scenario 2. Drawdown was not predicted to extend to the coast in any scenario, therefore shaft construction is therefore not predicted to induce saline intrusion into the aquifer. The model results all indicated a less than a minor impact on regional groundwater. Groundwater monitoring is recommended for a three-month period prior to construction and a maximum of one-year period following construction (with potential to reduce this period if the actual maximum drawdown level is less than predicted) to assure impacts are not beyond the expected levels.

Recommendations

The following is a list of recommendations based on model results and regional groundwater conditions:

1. The shaft should be lined to minimize the risk of impacting local groundwater levels and inducing ground settlement using a material, with a permeability of no greater than $1x10^{-8}$ m/s.
2. Monitoring existing boreholes at time periods and frequency as indicated in Recommendation 2-4 at CIE-BH04, CIE-BH05, and CIE-BH06 adjacent to the shaft, as well monitoring the borehole CIE-BH01 or CIE-BH02, located along the proposed route of the Grey Lynn Tunnel approximately 500 m from the shaft to confirm that the actual drawdown levels are not beyond the maximum expected levels.
3. Weekly monitoring of groundwater levels at all boreholes installed for the Grey Lynn Tunnel project is recommended for a three-month period prior to construction to document baseline conditions.

[1] To place this in context, a garden hose has a typical peak flow rate of 0.2 L/s.

4. Weekly monitoring of all boreholes installed for the Grey Lynn Tunnel project in accordance with a Groundwater Monitoring and Contingency Plan is recommended during shaft construction to alert managers if there is any change in groundwater level that may incur risk to structures or the environment.
5. Monthly groundwater monitoring in accordance with a Groundwater Monitoring and Contingency Plan is recommended for a one-year period following construction to assure impacts are not beyond the expected levels and that groundwater levels recover to pre-construction conditions.

1 Introduction

Watercare Services Limited ("Watercare") is the water and wastewater service provider for Auckland. Watercare is proposing to construct a wastewater interceptor from Tawariki Street, Grey Lynn to Western Springs ("Grey Lynn Tunnel"). The Grey Lynn Tunnel will connect to the Central Interceptor at Western Springs.

1.1 Project Overview

The Grey Lynn Tunnel involves the elements shown in the drawings and outlined in more detail in the reports which form part of the application. These elements are summarised as follows.

1.1.1 Grey Lynn Tunnel

The Grey Lynn Tunnel involves construction, operation and maintenance of a 1.6km gravity tunnel from Western Springs to Tawariki Street, Grey Lynn with a 4.5m internal diameter, at an approximate depth of between 15 to 62m below ground surface, depending on local topography. The tunnel will be constructed north-wards from Western Springs using a Tunnel Boring Machine ("TBM"). The Grey Lynn Tunnel will connect to the Central Interceptor at Western Springs via the Western Springs Shaft Site.

1.1.2 Tawariki Street Shaft Site

The Grey Lynn Tunnel also involves construction, operation and maintenance of two shafts and associated structures at Tawariki Street, Grey Lynn ("Tawariki Street Shaft Site").

The Tawariki Street Shaft Site will be located at 44-48 Tawariki Street where the majority of the construction works will take place. Construction works will also take place within the road reserve at the eastern end of Tawariki Street and a small area of school land (St Paul's College) bordering the end of Tawariki Street (approximately 150m^2).

The Tawariki Street Shaft Site will involve the following components:

1.1.3 Main Shaft

- A 25m deep shaft, with an internal diameter of approximately 10.8m, to drop flow from the existing sewers into the Grey Lynn Tunnel;
- Diversion of the Tawariki Local Sewer to a chamber to the north of the shaft. This chamber will be approximately 12m long, 5m wide and 5m deep below ground, and will connect to the shaft via a trenched sewer;
- Diversion of the Orakei Main Sewer to a chamber to the south of the shaft. This chamber will be approximately 10m long, 5m wide and 11m deep below ground;
- Construction of a stub pipe on the western edge of the shaft to enable future connections (that are not part of this proposal) from the CSO network;
- Construction of a grit trap within the property at 48 Tawariki St to replace the existing grit trap located within the Tawariki Street road reserve. The replacement grit trap will be approximately 16m long, 5m wide and 13m deep below ground;
- Permanent retaining of the bank at the end of Tawariki Street to enable the construction of the chamber for the Orakei Main Sewer. The area of the bank requiring retaining will be approximately 44m long, 3m wide and 2m high; and
- An above ground plant and ventilation building that is approximately 14m long, 6m wide and 4m high. An air vent in a form of a stack will be incorporated into the plant and ventilation building and discharge air vertically via a roof vent. The vent stack will be designed with a flange to allow future extension of up to 8m in total height and approximately 1m in diameter in the unexpected event of odour issues.

1.1.4 Tawariki Connection Sewer Shaft – Secondary Shaft

A secondary shaft will be constructed at the Tawariki Street Shaft Site to enable the connection of future sewers (that are not part of this proposal) from the Combined Sewers Overflows ("CSO") network. This will involve the following components:

- A 25m deep drop shaft with an internal diameter of approximately 10.2m; and
- A sewer pipe constructed by pipe-jacking to connect the secondary shaft to the main shaft.

1.2 Assessment

Williamson Water & Land Advisory (WWLA) has been commissioned by McMillan-Jacobs to undertake a numerical modelling analysis of the groundwater impact of constructing the proposed shaft at the Tawariki Street Shaft Site and of the effects of the tunnel construction. The shaft is to be used during construction as an access point for the machinery required to excavate the sewage tunnel and the shaft itself. Following construction, the shaft will remain in place as an access point for ongoing tunnel operation and maintenance.

Figure 1 shows the extent of the study area, defined as the model boundary, as well as the major features within the study area as related to this assessment.

Figure 1. Overview of study area (see A3 attachment at rear).

The primary components of this assessment are:

- Estimation of seepage into the shaft during the construction process under lined and unlined conditions
- An estimate of regional drawdown of groundwater levels during construction and groundwater recovery following project completion
- Potential impacts on surface water features, specifically streams
- Potential impacts on groundwater users
- Assessment of consolidation settlements resulting from groundwater drawdown is provided in a separate effects assessment report.

Report Structure

The report is divided into seven primary sections with each section sub-divided into specific topics to provide further detail as needed:

- **Considerations for Assessment:** Potential impacts on groundwater, relevant evaluation criteria, geological and hydro-geological setting (**Section 2**).
- **Conceptual Hydrogeological Model:** Regional geology and hydrogeology, hydraulic testing, groundwater recharge and flow characterisation (**Section 3**).
- **Groundwater Model development:** grid discretization, parameterization, conceptual model setup, boundary conditions (**Section 4**).
- **Model Calibration:** Observed groundwater conditions, calibrated model parameters, calibrated model groundwater budget (**Section 5**).
- **Predictive Simulations:** Scenario setup, transient model inputs, model results evaluated against baseline conditions **(Section 6).**

- **Assessment of Effects:** Model output evaluated against consent criteria, monitoring and reporting approach **(Section 7).**
- **Summary and conclusions:** Summary of predicted impact of shaft construction on groundwater conditions and groundwater flow into shaft, recommendations for groundwater management as related to shaft construction (**Section 8**).

2 Considerations for Assessment

2.1 Potential Effects of Shaft Construction

The construction of the proposed shafts brings several considerations for groundwater management during the construction process and for long-term impacts on local groundwater conditions. Groundwater inflows that occur during the shaft excavation process will require management throughout the construction period. Inflowing water will have to be removed by pumping and subsequent disposal into stormwater facilities provided the volume is manageable. The shafts will effectively act as a drain on local groundwater and an associated drawdown on local groundwater levels can be expected.

Groundwater drawdown has potential to deplete stream flows by reducing baseflow and initiate land settlement as underlying geologic material becomes desaturated. Land settlement is not in the scope of this study and is being evaluated separately, however the drawdown estimates derived from this study are used to inform land settlement calculations.

The development of a numerical model based on measured field hydraulic properties is used as a tool for estimating the rate of groundwater drainage into the shaft and the depth and extent of groundwater drawdown.

The shafts will be excavated and supported by a temporary system, consisting of secant piles, sheet piles or similar methods in thick soil layers above rockhead, and rockbolts, shotcrete and/or mesh in competent bedrock below overburden soils. Following shaft excavation, a concrete liner will be installed to support ground loads, house the sewer hydraulic drop structures and minimize groundwater leakage into the shafts.

The proposed Secondary Shaft will be constructed a minimum of 2.5 years after the completion of the Main Shaft. At this time any groundwater impacts from the Main Shaft would have fully recovered. The configuration of the Secondary Shaft is slightly smaller than the Main Shaft, so any new groundwater impacts of the Secondary Shaft will be less than for the Main Shaft. Therefore, separate modelling of the groundwater effects from the Secondary Shaft was not undertaken. However, the effects assessment is relevant to both shafts. Reference to “shaft” within this report is reference to the shaft under construction at the time.

2.2 Potential Impacts of Tunnel Construction

The proposed Grey Lynn Tunnel between Western Springs and the Tawariki Street Shaft Site will be constructed using the same tunnel boring machine (TBM) as the Central Interceptor mainline tunnel. Project specifications require that this tunnel must be constructed by an Earth Pressure Balance (EPB) TBM which limits groundwater ingress into the tunnel during construction. In the long-term, the precast tunnel lining limits long-term water ingress.

With the use of the EPB TBM construction method, the excavation is sealed from groundwater ingress, and minimal groundwater impacts are expected to occur. Nevertheless, an assessment of groundwater impacts due to EPB TBM tunnelling for the mainline tunnel are assessed in the Central Interceptor project report “Assessment of Potential Groundwater Drawdown due to Shaft Construction” (Ref. PWCIN-DEL-REP GT-J-100236). This report concluded that groundwater ingress to the tunnel was approximately 0.006 L/s per meter of tunnel. This is equivalent to a teaspoon of water per second, which is a very slow flow rate noting a garden hose has a typical flow of 0.2 L/s, which is 33 times greater. The same tunnel construction and control assumptions employed in the Central Interceptor mainline tunnel groundwater assessment apply to the Grey Lynn Tunnel, and the geological conditions are similar. Therefore, the potential groundwater impacts of the Grey Lynn Tunnel construction are considered to be negligible.

2.3 Relevant Statutory Provisions

Planning provisions related to the construction and potential groundwater impacts of the shaft are provided in the Auckland Unitary Plan – Operative in Part (AUP-OP) (Auckland Council, 2016). As explained in more detail in the Assessment of Effects, Section E7 (taking, using, damming and diversion of water), classifies the activity as restricted discretionary. Assessment criteria for groundwater impacts associated with restricted discretionary activities are addressed in Section E.7.8 of the AUP. **Table 1** summarises the specific matters of discretion considered for evaluating restricted discretionary activities with regard to groundwater impacts.

Table 1. AUP matters of discretion for evaluation of restricted discretionary activities with regard to groundwater impacts.

Criteria Number		Matters of Discretion	Comment
E7.8.1 (6a)	i)	How the proposal will avoid, remedy or mitigate adverse effects on the base flow of rivers and springs	Potential impacts on surface streams are addressed in **Section 6.2.3** and included in the assessment of effects provided in **Section 7.1**
	ii)	How the proposal will avoid, remedy or mitigate adverse effects on levels and flows in wetlands	Potential impacts on wetlands are addressed in **Section 6.2.3** and included in the assessment of effects provided in **Section 7.1.8**
	iii)	How the proposal will avoid, remedy or mitigate adverse effects on lake levels	Potential impacts on lakes are addressed in **Section 6.2.3** and included in the assessment of effects provided in **Section 7.1.2**
	iv)	How the proposal will avoid, remedy or mitigate adverse effects on existing lawful groundwater takes and diversions	Potential impacts on other groundwater takes are addressed in **Section 6.2.4** and included in the assessment of effects provided in **Section 7.1.3**
	v)	How the proposal will avoid, remedy or mitigate adverse effects on groundwater pressures, levels or flow paths and saline intrusion	Potential impacts along the coast are addressed in **Section 6.2.4** and included in the assessment of effects provided in **Section 7.1.4**
	vi)	How the proposal will avoid, remedy or mitigate adverse effects from ground settlement on existing buildings, structures and services including roads, pavements, power, gas, electricity, water mains, sewers and fibre optic cables	Not relevant to the technical scope of this report. Will be addressed in the Ground Settlement Report.
	vii)	How the proposal will avoid, remedy or mitigate adverse effects arising from surface flooding including any increase in frequency or magnitude of flood events	Not relevant to the technical scope of this activity (groundwater dewatering of an excavation)
	viii)	How the proposal will avoid, remedy or mitigate adverse effects from cumulative effects that may arise from the scale, location and/or number of groundwater diversions in the same general area	Potential cumulative impacts from groundwater extraction is addressed in **Section 6.2.4** and included in the assessment of effects provided in **Section 7.1.6**
	ix)	How the proposal will avoid, remedy or mitigate adverse effects from the discharge of groundwater containing sediment or other contaminants	Groundwater discharge into the shaft is addressed in **Section 6.2.1** and included in the assessment of effects provided in **Section 7.1.7**
	x	How the proposal will avoid, remedy or mitigate adverse effects on any scheduled historic heritage place	Not relevant to the technical scope of this report. May be addressed elsewhere.
	xi)	How the proposal will avoid, remedy or mitigate adverse effects on terrestrial and freshwater ecosystems and habitats	Not relevant to the technical scope of this report. Will be addressed in the ecology report
E7.8.1 (6c	i)	How the proposal will address monitoring and reporting requirements incorporating, but not limited to the measurement and recording of water levels and pressures	Recommendations for groundwater monitoring and reporting are provided in **Section 7.2**

3 Conceptual Hydrogeological Model

3.1 Regional Geology

The Grey Lynn Tunnel will be located within the Waitemata Basin, which formed between 24 and 18 million years ago as a subsiding shallow marine environment filled with sediments eroding from landforms. Sediments deposited in the Basin were predominantly interbedded silts and muddy sands with some coarser-grained volcaniclastic sands and conglomerates. Collectively, the sediments are known as the Waitemata Group.

Following deposition, the Waitemata Group sediments were unconformably overlain by Puketoka Formation sediments (2 million to 340,000 years ago) and undifferentiated alluvium (<14,000 years ago) of the Tauranga Group, and by basalt, scoria, lapilli and ash deposits belonging to the Auckland Volcanic Field (250,000 to 500 years ago) (Tuhono, 2011). The Regional geology of the Auckland area has been described in detail in the Groundwater and Surface Settlement report prepared by Tonkin and Taylor (2012).

The spatial distribution of geologic units in the study area is shown in **Figure 2**.

Figure 2. Study area geologic units (see A3 attachment at rear).

The primary materials present in the study area defined in **Section 1.2** are:

- **East Coast Bays Formation (ECBF)** – The primary geologic unit present around the shaft location and surrounding the tunnel alignment. The ECBF is a member of the Waitemata Group rocks characterised by alternating, graded sandstones, and siltstones with facies of volcanic-rich and volcanic-poor material. ECBF deposits are typically grey to greenish grey, very poorly-sorted to moderately-sorted materials with laminated or convoluted beds 0.1 to 1.4 m (median 0.5 m) thick (Tuhono, 2011). Within the ECBF there are zones of highly weathered material (wECBF) and a sub-unit recognized as the Parnell Grit (PG). The wECBF typically occurs in the upper five meters of the ECBF profile and is comprised of residual soils and weathered silts and clays from the ECBF with variable sand content. With depth, the relict structure of the original rock mass is evident.
- **Parnell Grit (PG)** - Volcanoclastic gravity flow deposits originating as submarine lahars. PG materials are comprised of a poorly sorted pebble to boulder size conglomerate in a compacted and cemented muddy to sandy matrix. PG units are difficult to predict the in location and extent because they are vertically and laterally variable, ranging from less than a meter to 20 meters in thickness and occurring at irregular intervals. Due to the units strength and lower clay content, joints can remain open and have a greater persistence than the ECBF allowing localised pathways for groundwater flow (Jacobs, 2016).
- **Auckland Volcanic Field Basalts (AVFB)** – Located to south and southwest of the tunnel alignment and Tawariki Street Shaft Site abutting the ECBF outside of the model boundary. AVFB consist of basalt, scoria, lapilli and ash deposits typically associated with volcanic cones. The basalt is described as grey to very dark grey, dense, fine-grained. Scoria deposits consist of red or red-brown to dark grey or black, angular to sub-rounded, poorly-sorted, and vesicular to very vesicular pebble to boulder size ejecta of basalt composition. Ash and lapilli deposits consist of unconsolidated beds of dark grey to black, very angular to rounded, well-sorted, dense to very vesicular, basalt fragments.
- **Tauranga Group Alluvium (TGA)** – Collectively the Puketoka Formation and recent alluvium and colluvium make-up the TGA. The recent TGA deposits are late Pleistocene to Holocene in age, having been deposited within low lying drainage channels and topography. These deposits are comprised of light grey to orange-brown, well sorted, bedded (2 to 20 mm) silts or clays with variable sand and gravel content and clasts of rhyolite pumice and weathered rock. On the Auckland Isthmus the alluvium is typically derived directly from the weathering and erosion of ECBF (Institute of Geological and Nuclear Sciences, 2001).

3.1.1 Material Hydrogeological Characteristics

The shaft will be situated primarily within the ECBF formation with thin wECBF or TG deposits overlaying at the land surface. There are thin deposits of the TGA material at the land surface adjacent along Motions Creek, a stream which forms the western model boundary. These deposits are considered to have negligible influence on groundwater impacts from shaft construction because they are hydraulically similar to the ECBF (i.e. both of low permeability) and only occur near the land surface. Therefore, only the ECBF was considered for groundwater dewatering modelling purposes.

Geological evolution, including both depositional environment and subsequent morphological processes have a strong influence on the hydrological characteristics of materials. The primary aspects for hydrogeological assessment include the lateral and vertical distribution of materials. Hydrogeological characteristics of these materials have been documented in previous studies and are summarised in **Table 2** and as follows:

- **ECBF:** Typically, low permeability in the range from $1x10^{-8}$ to $3x10^{-6}$ m/s, with an average across Auckland Isthmus of approximately $2.3x10^{-7}$ m/s. Hydraulic conductivity can be greater in areas where fracture zones are present. Strong anisotropy with horizontal conductivity 40 to 250 times greater than vertical conductivity.
- **wECBF:** Lower hydraulic conductivity relative to ECBF due to the influence of colloidal clay from weathering, with a range from $1x10^{-8}$ to $8x10^{-8}$.
- **TGA:** Low to moderate hydraulic conductivity, ranging from $5x10^{-8}$ to $2.5x10^{-5}$ m/s with somewhat greater storage characteristics with specific yields <0.1 in the unconfined areas, and storativity typically found to be around $1x10^{-3}$.

Table 2. Hydraulic parameters within the Auckland Isthmus.

Material	Parameter	Watercare[1.]	Tuhono[2.]	PDP[3.]	Tonkin & Taylor[4.]
		Central Interceptor Phase 1	Waterview Connection	St Marys Bay & Mansfield Beach WQ Improvement Project	Central Interceptor Project Effect on GW and Surface Settlement
ECBF	K_h (m/s)	$7.5x10^{-6}$	$2.3x10^{-7}$	$2.6x10^{-6}$	$2.0x10^{-7}$
	Storativity (1/m)	$1.9x10^{-3}$	$9.0x10^{-6}$	NA	NA
ECBF-Weathered	K_h (m/s)	$8.3x10^{-7}$	$1.0x10^{-8}$	$5.3x10^{-7}$	$2.0x10^{-7}$
	Storativity (1/m)	$3.8x10^{-3}$	$1.0x10^{-3}$	$2.5x10^{-3}$	NA
TGA	K_h (m/s)	$1.3x10^{-7}$	$5.0x10^{-8}$	$2.5x10^{-5}$	$2.0x10^{-7}$
	Storativity (1/m)	NA	$1.0x10^{-3}$	NA	NA
	Specific Yield (m)	$8x10^{-1}$	$1.0x10^{-2}$	$1.3x10^{-1}$	NA

Notes: Table states mean value where reported values were a range. NA = Not Available.

References. 1. Watercare Services LTD, 2013. 2. Tuhono Consortium, 2011. 3. Pattle Delamore Partners LTD, 2018. 4. Tonkin & Taylor, 2012.

3.1.2 Hydraulic Testing

Site specific investigations were performed as a part of the development and planning process for the Grey Lynn Tunnel. Six bores (CIE-BH1 to CIE-BH6) were drilled for the purpose of installing monitoring piezometers and are shown in **Figure 3**. Bore logs documenting geological materials encountered in the drilling process are presented in **Appendix A**. Vibrating wire piezometers were installed in CIE-BH04 and CIE-BH05 and a standpipe monitoring piezometer was installed in CIE-BH06.

Figure 3. Location of Phase 1 and Phase 2 monitoring bores (see A3 attachment at rear).

Hydraulic testing was performed by WWA in all monitoring boreholes. Three slug tests were performed at CIE-BH04, CIE-BH05, and CIE-BH06, respectively, where a volume of water was removed from the open borehole (CIE-BH4 and CIE-BH05) or piezometer (CIE-BH6) using a 2.1 m pipe sealed on one end. Water level recovery was monitored with a data logger.

The rate of water level recovery was evaluated using the Hvorslev method, which entails fitting the slope and offset parameters of a best-fit line to normalised drawdown data over one log interval of time to calculate an estimate of hydraulic conductivity within the test interval of the bore. **Table 3** provides a summary of the slug tests performed and the estimated hydraulic conductivity as determined by water level recovery. Data and analysis details are provided in **Appendix B**.

Table 3. Slug test results.

Borehole ID	Location	Slug Test-Hydraulic Conductivity (m/s)		
		Test 1	Test 2	Test 3
CIE-BH04	46 Tawariki St.	$1.10x10^{-6}$	$1.07x10^{-6}$	$1.04x10^{-6}$
CIE-BH05	44 Tawariki St.	$1.84x10^{-7}$	$4.01x10^{-7}$	$3.92x10^{-7}$
CIE-BH06	Fisherton/Richmond St.	$1.05x10^{-7}$	$1.49x10^{-7}$	$1.06x10^{-7}$

Packer tests (aka Lugeon tests) were performed at all boreholes. These tests involve isolating a section of the borehole using an inflatable packer and then pumping clean water into the bore for five-minute intervals at increasing, and then decreasing pressures, with flow rate monitored during each interval.

Data was subsequently analysed by WWA using the Richter and Lillich (1975) method as described in NZTA (2016) to classify the flow response and estimate hydraulic conductivity. **Table 4** summarises the packer tests performed, testing intervals, and resulting hydraulic conductivity. Estimated hydraulic conductivities derived from packer tests were generally low when compared to slug test and findings from other studies. Testing details, results, and complete analysis are provided in **Appendix C**.

Table 4. Packer (Lugeon) test results.

Borehole	Test Interval		Test result	Permeability (m/s)
	Top (mBGL)	Bottom (mBGL)		
CIE-BH01	17.0	21.5	Void Filling	9.7x10-8
CIE-BH02	18.7	21.5	Laminar	7.3x10-8
CIE-BH03	20.0	24.5	Dilation	5.3x10-8
CIE-BH04	9.8	12.0	Dilation	2.9x10-8
CIE-BH04	19.5	22.5	Laminar	6.5x10-8
CIE-BH04	28.5	31.5	Laminar	1.1x10-7
CIE-BH05	11.0	13.5	Dilation	9.0x10-8
CIE-BH05	19.0	21.0	Wash out	7.1x10-8
CIE-BH05	28.5	31.5	Dilation	2.6x10-7
CIE-BH06	27.0	30.0	Dilation	2.8x10-8
CIE-BH06	50.3	52.5	No Flow	NA
CIE-BH06	56.25	58.5	Dilation	4.2x10-8
CIE-BH06-High pressure	54.5	63.5	Dilation	2.9x10-8

3.2 Groundwater Recharge

The aquifer system in the study area is recharged by rainfall. Recharge along with material characteristics drives the development of hydraulic gradients and head elevations, hence an understanding of the rate and distribution of recharge is essential for estimating groundwater flow rate and volume.

Annual recharge volume varies depending on climate and geology. Geologic parent material governs soil infiltration rate, which in turn controls the partitioning of rainfall into surface runoff and groundwater recharge. Geology also determines the rate of percolation of soil water to groundwater.

Ground surface recharge is relatively high in areas where high permeability basalt is present, estimated to be 15-20% of mean annual precipitation (approximately 190 to 250 mm/year). Recharge is comparatively low in areas where ECBF is the dominant material, ranging from 25-50 mm/year or 2 to 4 % of mean annual rainfall (Tuhono, 2011).

For this study groundwater recharge in the ECBF has been assumed to be 3% of mean annual precipitation.

3.3 Groundwater Flow Direction

Monitoring bore data from Auckland Council and bore installation records from the Grey Lynn Tunnel were assessed and an estimated piezometric surface for the shallow aquifer is presented in **Figure 4**. Based on this analysis, groundwater is presumed to flow from southeast to northwest with an average gradient of approximately 1.5 percent. The groundwater table (shallow aquifer) geometry generally mimics regional topography, with areas of localized perching likely along ridge lines.

Groundwater discharges to surface water at several locations within or adjacent to the study area including Western Springs, Meola Creek, Motions Creek, and Cox's Creek, and is likely drained into local stormwater facilities in several additional locations where local drainage is concentrated.

Figure 4. Estimated piezometric surface (see A3 attachment at rear)

4 Groundwater Modelling Methodology

The MODFLOW (2005) Regular Grid, developed by the United States Geological Survey (USGS), was utilised within the GMS10.2 modelling platform to construct the groundwater flow model for the Tawariki Street Shaft. The discretisation of the model domain with decreasing cell size around the shaft area provides increases the resolution for areas of maximum interest (the shaft) and decreases resolution in other areas, thereby increasing the efficiency in model computation compared to a similarly constructed structured MODFLOW grid.

4.1 Model Domain

The study area, as defined by the model boundary, covers an area of 6.4 km^2 and was constructed based on nine layers, with a total of 35,028 active cells. The model was discretised using a global grid spacing of 50 m with a finer resolution grid spacing of down to 1.5 m in the shaft area. The same grid layout was used for each of the model layers. This spatially varying discretisation approach reduced model computational time while improving model resolution in the area of interest (**Figure 5**).

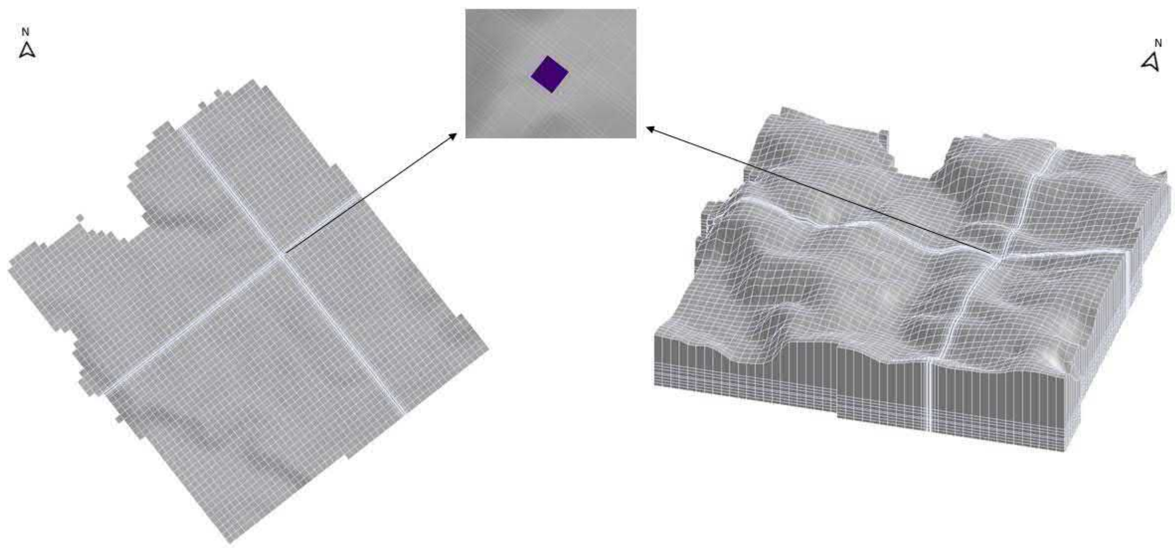

Figure 5. MODFLOW-USG grid in plan view with shaft area detail and orthogonal view with vertical magnification of 5.

The surface elevation used for the model was determined using the 1 m Lidar digital elevation model data available through the Land Information New Zealand (LINZ) service. Surface elevation for the model area is shown in **Figure 6**.

Figure 6. Model area ground surface elevation (see A3 attachment at rear).

4.1.1 Constant Head Boundaries

The northwest model boundary follows the coastline and was assigned a constant head boundary condition (CHB) of 0 m AMSL for model Layer 1 to represent the mean hydraulic head of the ocean at these locations.

4.1.2 General Head Boundaries

A general head boundary (GHB) is typically used to simulate the flow interaction between groundwater and external water sources to the model domain. The cells along the coastline from Layer 2 through 9 were also assigned with GHBs. The head values for all the cells were assigned as 0 mAMSL and the conductance value of each layer decreasing with the depth to reflect the progressively increasing disconnection with the free water surface of the ocean (i.e. the impedance of flow to the ocean floor increases with depth) and also the resistance of higher-density seawater offshore.

4.1.3 No-Flow Boundaries

No-flow boundaries were assigned to cells located on the northeast, southwest, and southeast boundaries of the model domain. Ridgelines along the northeast and southeast boundaries are expected to act as local groundwater divides with recharging water following local topography down slope.

Shallow groundwater along the southwest model boundary discharges into Motions Creek while deeper groundwater flows parallel to groundwater in the model area toward the Waitemata Harbour.

The base of the model was set significantly below the depth of the Tawariki Street Shaft or Grey Lynn Tunnel so that lower boundary conditions would not impact the simulation. A no-flow boundary condition was then assigned to the lower model boundary on the basis that groundwater at this depth has negligible bearing on the overall flow budget of the portion of the aquifer system impacted by the Tawariki Street Shaft.

4.1.4 Drain Boundaries

Drains in the model area were identified from the River Environment Classification (REC) database New Zealand.

The primary surface drains are Motions Creek, which forms the western model boundary discharging into Waitemata Harbour and Cox's Creek, which drains the central portion of the model area discharges into Cox's Bay. A subsurface drain passes below Tawariki Street, adjacent to the shaft location and discharging into Cox's Creek. The surface and sub-surface drains in the model area are included in **Figure 1** (attached at rear).

Drain boundaries were assigned in the model to simulate the groundwater discharged to the streams within the model area, subsurface drains, and perennial wet areas where they occur within the model area. The drain bed elevations were derived from the Digital Elevation Model (DEM) generated from LiDAR data, with specific depth determined through the model calibration process and based on the type of drain feature. Cells within the Tawariki Street Shaft were also assigned as drain boundaries with drain elevations decreasing with time over the construction period to simulate the increasing depth of the shaft. Following the construction period, the shaft drain elevations remain level with the bottom of the shaft.

- ***Surface streams*** – DEM minus 2.0 m;
- ***Subsurface drains*** – DEM minus 2.0 m;
- ***Inundated areas*** – Equal to DEM elevation
- ***Shaft Drains*** – Increasing depth to -13 mAMSL

The conductance value of the drains was set relatively high to reflect limited impedance to water removal (or drain functionality) where surface discharge was expected.

4.1.5 Horizontal Flow Barrier

A horizontal flow barrier (HFB) was assigned to the cells around the Tawariki Street Shaft location for model layers one through four encompassing the vertical extent of the completed shaft. The conductance of the barrier was varied to simulate a range of liner permeabilities. The HFB was only used in the transient simulations and was not included in the 'No-Barrier' scenario.

4.1.6 Well Boundaries

No wells were simulated in the model as there are no major groundwater users within the model area.

4.1.7 Sparse Matrix Solver

The Sparse Matrix Solver (SMS) package was utilised to solve linear and non-linear equations. A maximum head change of 0.01 m between iterations was set as the model convergence criteria. Default values were used for the maximum number of iterations for linear and non-linear equations.

4.2 Model Layer Configuration

4.2.1 Layer Geology

The model comprises nine layers that are used to represent the geologic strata and allow for the flow restrictions that would naturally occur in a stratified and vertically variable formation such as the ECBF. The ECBF material type was assigned for each model layer based on a review of the borelogs included in **Appendix A** and the findings of other geologic investigations within the Auckland Isthmus. TGA deposits in the model area were lumped with ECBF because the two materials have a largely overlapping range of hydraulic parameters and are therefore functionally the same for modelling purposes.

Model Layer 1 encompasses all the material within the model area from the ground surface to 1.0 m below mean sea level (-1 mAMSL). This value was selected to avoid numerical errors that can occur along the coastal margins where surface elevations were approximately 0 mAMSL.

The bottom elevation for each model layer was assigned as a uniform elevation with the specific elevation of Layer 4 determined to be 1 m below the bottom elevation of the Tawariki Street Shaft. The elevation configuration of the model layers is shown in **Table 5**.

Table 5. Model layer elevation configuration.

Model Layer	Top Elevation (mAMSL)	Bottom Elevation (mAMSL)
1	LINZ LiDAR Elevation	-1
2	-1	-4
3	-4	-9
4	-9	-14
5	-14	-16
6	-16	-20
7	-20	-24
8	-24	-28
9	-28	-32

5 Model Calibration

The model calibration was primarily conducted by manually changing the model hydraulic parameters to achieve an acceptable fit to measured groundwater levels. Drain elevation for surface streams relative to the DEM were tested at several levels and specific adjustments were made to match groundwater level observations. Groundwater recharge was not considered a calibration parameter.

5.1 Observation Points

Water level measurements obtained from six boreholes installed in preparation for shaft and tunnel development were used to guide model calibration. The boreholes used for calibration of the model are as shown in **Figure 3** and the key properties of the boreholes relevant to model calibration are summarised in **Table 6**.

Three of the boreholes are located directly around the planned shaft location on Tawariki Street. All but one of the boreholes are constructed on relatively low-lying areas situated between 9 and 13 mAMSL with the exception being the CIE-BH06 which is on a ridge at 48 mAMSL. It is notable that this borehole had the lowest conductivity of those tested.

The borehole screen intervals ranged from approximately -7 to -20 mAMSL corresponding to model Layers 3 through 6. Vibrating wire piezometers were installed in CIE-BH04 and CIE-BH05 however the water levels used for these boreholes were obtained prior to piezometer installation when the boreholes were uncased therefore the water levels were considered to be representative of the bottom elevation of the borehole.

Table 6. Summary of borehole information used in calibration.

Borehole ID	Location	Surface Elevation (mAMSL)	Borehole Depth (m)	Bottom Elevation (mAMSL)	Top of Screen (mAMSL)	Bottom of Screen (mAMSL)	Model Layer	Water Level (mAMSL)
CIE-BH01	28 Cockburn St.	13.31	25.5	-12.19	-3.19	-8.69	3	12.45
CIE-BH02	Hakanoa Reserve	9.68	25.5	-15.82	-7.32	-12.32	4	11.82
CIE-BH03	41 Tawariki St.	13.00	27.5	-14.50	-6.51	-11.51	4	15.04
CIE-BH04	46 Tawariki St.	11.94	31.5	-19.56	Vibrating wire piezometer (26 mBGL)		5	10.91
CIE-BH05	44 Tawariki St.	11.02	31.5	-20.48	Vibrating wire piezometer (26 mBGL)		6	13.79
CIE-BH06	Fisherton/Richmond St.	47.55	63.5	-15.95	0.35	-6.95	3	44.39

5.2 Steady-State Calibration

A steady-state model was developed and calibrated to validate the conceptualisation of the groundwater flow model. The objective of the calibration was to determine hydraulic parameters such that simulated groundwater head matched observations as accurately as possible, and to obtain initial heads for transient model simulation.

The six water level observations were used as the calibration targets. The simulated head is plotted against observations in **Figure 7**. The steady-state simulation has a mean head residual of 1.19 m, and root mean square error (RMSE) of 2.4 m, which is approximately 7% of the range of observations. A simulated RMSE of less than 10% of the measured range is considered a good calibration.

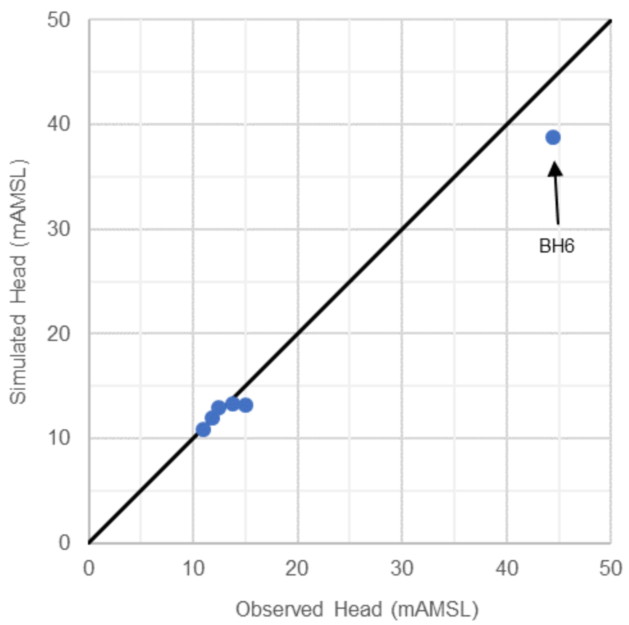

Figure 7. Simulated head versus observed head

The RMSE is strongly influenced by the observation at CIE-BH06. This bore is a relative anomaly compared to the other bores as it is the only observation obtained from a bore located on a ridge. The observed water level at CIE-BH06 was under simulated by the model by 5.6 m. Several methods were attempted to obtain a calibration that would match CIE-BH06 without losing the calibration at the other boreholes. This included varying hydraulic conductivity and vertical anisotropy within the range considered appropriate for ECBF material. It was apparent that reducing conductivity sufficiently to match the observed water level at CIE-BH06 generated an error over 10 m at the other boreholes.

Another approach was to vary conductivity with elevation based on the concept consistent with the geologic evolution of the landscape that ridges tend to be composed of more resistant material than valleys. This approach generated a good match for computed versus observed head at all boreholes for the model layers corresponding to the respective observations however the simulated head in Model Layer 1 was far above realistic values indicating widespread flooding over the model area.

Finally, to partially compensate for the high observed head at CIE-BH06 a low permeability zone was incorporated into the model over the ridge where CIE-BH06 is located. This represents an area where the parent rock is more resistant and less permeable that than what is present at the other boreholes and is supported by the low conductivity measured during hydraulic testing at CIE-BH06.

The simulated water levels obtained through the model calibration process are presented in **Table 7**.

If the water level observation at CIE-BH06 is disregarded, the RMSE is reduced to 0.89 m, representing 1% of the range of observations and mean head residual is reduced to 0.32 m.

Table 7. Observed and simulated water levels from steady state calibrated model

Borehole ID	Model Layer	Observed Water Level (mAMSL)	Simulated Water Level (mAMSL)	Residual (m)
CIE-BH0 01	3	12.45	12.92	-0.46
CIE-BH0 02	4	11.82	12.03	-0.21
CIE-BH0 03	4	15.04	13.15	1.88
CIE-BH0 04	5	10.91	10.92	-0.02
CIE-BH0 05	6	13.79	13.38	0.41
CIE-BH0 06	3	44.39	38.83	5.56

5.2.1 Calibrated Model Parameters

The calibrated model parameters are shown in **Table 8**. The calibrated model parameters are consistent with hydraulic parameters obtained in other investigations of ECBF material as shown in **Table 2**.

Table 8. Calibrated model hydraulic parameters

Material	Hydraulic Conductivity (m/s)	Vertical Anisotropy	Specific Storage (Layers 2-9)	Specific Yield (Layer 1)
ECBF	$3.0x10^{-7}$	30	0.0005	0.25
ECBF-Low permeability zone	$1.0x10^{-8}$	10	0.0005	0.25

The calibrated model hydraulic conductivity for the ECBF was $3.0x10^{-7}$ m/s with a vertical anisotropy of 30. Calibrated conductivity in the low permeability zone was over an order of magnitude lower at $1.0x10^{-8}$ m/s possibly indicating a highly compacted, unstratified area within the formation.

5.2.2 Model Flow Budget

Table 9 provides the long-term average water budget for the steady state calibration model. Groundwater recharge accounts for the entire model inflow.

The predominant discharge components from the model are the combined stream baseflow, which accounts for 61% of the model outflow. Coastal boundary outflows comprise 21% of the total model outflow with the majority occurring below the surface layer; largely because Layer 1 is very thin along the coastal margin so there is little material available through which outflow can occur. Approximately 19% of the model area groundwater outflow is predicted to occur at Western Springs in the southwest portion of the model area.

Table 9. Calibrated model groundwater flow budget

Mass balance	Components	Flow (m^3/d)	Percentage of Flow (%)
Inflow	Recharge	633	100
	Total inflow	633	100
Outflow	Shallow Coastal Discharge (CH)	-10	-1.6
	Deep Coastal Discharge (GHB)	-103	-16.2
	Stream Baseflow (Drain)	-520	-82.2
	Total outflow	633	100
Percentage discrepancy		0.03%	

6 Predictive Simulations

6.1 Scenario Setup

The numerical groundwater model was developed to assess the effect of construction of the shaft on local groundwater conditions. This assessment included a range of construction alternatives in the form of differing shaft liner permeability. In testing a range of liner permeabilities the model results can also be interpreted as a sensitivity analysis for liner permeability on groundwater impact. Aside from incorporating the Tawariki Street Shaft, all transient model variations applied the same boundary conditions as were used in the steady state calibration model.

The specified construction approach to the shaft is as follows:

- Temporary excavation support through soil materials and ECBF material shall consist of either secant piles, sheet piles, ring beams with lagging, steel liner plate, precast segmental rings, caisson or similar, and will be designed to be near-watertight to limit groundwater drawdown.

- Linings constructed of permanent concrete (precast or cast -in-situ), or potentially other corrosion resistant materials will be installed to support ground and groundwater loads in the long-term, provide a conduit for sewer hydraulic drop structures, and limit groundwater infiltration per to NZS 3106, *Design of Concrete Structures for the Storage of Liquids*, (tightness class 2).

The seven predictive model scenarios can be summarised as follows:

- ***Scenario 1: Basecase*** – The steady state calibration model was run as a transient model for the same time period as other scenarios. The shaft was not included in the model.
- ***Scenario 2: No Barrier*** – The shaft was incorporated into the steady state calibration model. Construction of the shaft proceeded at a rate of 2 m/day, reaching completion at 25 mBGL after 13 days. The model was run for a one year time period. No HFB was applied around the shaft.
- ***Scenario 3: Moderate Permeability Flow Barrier*** (***10^{-8} m/s)*** – The simulation was set up identically to Scenario 1 with the inclusion of the shaft and the addition of a HFB boundary applied around the shaft. The permeability of the HFB was assumed to be $1x10^{-8}$ m/s.
- ***Scenario 4: Low Permeability Flow Barrier*** (***10^{-9} m/s)*** – The simulation was set up identically to Scenario 1 with the inclusion of the shaft and the addition of a HFB boundary applied around the shaft. The permeability of the HFB was assumed to be $1x10^{-9}$ m/s.
- ***Scenario 5: Extra Low Permeability Flow Barrier*** (***10^{-10} m/s)*** – The simulation was set up identically to Scenario 1 with the inclusion of the shaft and the addition of a HFB boundary applied around the shaft. The permeability of the HFB was assumed to be $1x10^{-10}$ m/s.
- ***Scenario 6: Low Permeability Flow Barrier to 7 m BGL*** – The simulation was set up identically to Scenario 1 with the inclusion of the shaft and the addition of a HFB boundary applied around the shaft extending to 7 m BGL. The permeability of the HFB was assumed to be equal to Scenario 4 ($1x10^{-9}$ m/s).
- ***Scenario 7: Low Permeability Flow Barrier to 7 m BGL-High Conductivity Material*** – The simulation was set up identically to Scenario 6; however, conductivity of the upper model layer was increased to $1x10^{-6}$ m/s to evaluate the sensitivity of predicted shaft drainage and drawdown to material conductivity
- Based on the specified construction methods for the shafts, Scenario 6 best approximates the temporary condition during construction, while Scenario 4 approximates the long-term condition during operations.

6.1.1 Construction Sequence

The shaft was excavated to a depth of 1 m on the first day of the simulation and then proceeded at a rate of 2 m/day thereafter until the terminal depth of 25 m was reached. The construction period totalled 13 days and the shaft depth remained constant for the rest of the simulation (**Figure 8**).

The simulation was run with a daily time step for the first month, after which it converted to a weekly time step as model input conditions were constant and simulated conditions approached steady state.

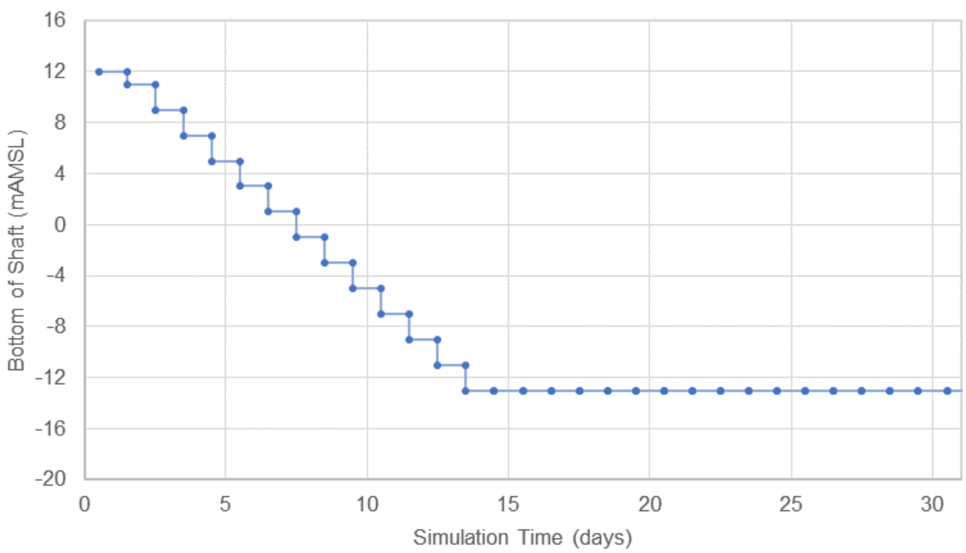

Figure 8. Elevation at bottom of shaft for first month of simulation.

6.1.2 Shaft and Liner Details

The thickness and depth of the flow barrier was 0.5 m and 25 m, respectively. This depth equates to an RL at the shaft of -13 mAMSL, which is 1 m above the bottom of Layer 4 in the model.

6.1.3 Boundary Conditions

An HFB was assigned to the cells around the shaft location for model Layers 1 through 4 encompassing the vertical extent of the completed shaft. The conductance of the barrier was varied to simulate the range of liner permeabilities tested in Scenario 1 through Scenario 3. The HFB was not included in the Scenario 1 (Baseline) or Scenario 2 (No Barrier).

The cells inside of the HFB and on the bottom of the shaft were assigned as drains where drainage was tracked over the course of the simulation with the resulting values representing drainage into the shaft.

6.1.4 Stress Periods and Time Steps

The model was simulated in transient mode for two years from 1 October 2018 to 30 September 2020. The simulation was subdivided into 131 stress periods where imposed stresses remain constant. Each day was considered a stress period for the first month of the simulation to capture the hydrologic changes that may occur during the shaft construction period. After the first simulation month weekly stress periods were applied as the rate of change in groundwater conditions was expected to decline and eventually approach steady state.

Each stress period consisted of ten time steps, with head and flow volume in each model cell evaluated at the end of each time step.

6.1.5 Initial Conditions

The transient model used the steady-state model heads as the starting condition.

6.1.6 Model Hydraulic Parameters

The calibrated model hydraulic parameters shown in **Table 8** were applied in all of the transient models.

6.2 Model Results

As described above, at completion of construction, the base of the shaft will be at -13 mAMSL (25 mBGL) corresponding to Layer 4, which is where the maximum impact on groundwater is expected to occur. For this reason, results are reported for Layer 4 to reflect the full impact of the shaft on groundwater conditions.

As previously stated, the shaft construction period was assumed to proceed at 2 m per day though 1 m was assumed for the first simulation day assuming some start up time. In all simulations a rapid change in groundwater level was predicted over the construction period and for the following days, however the rate of change slowed significantly by the end of the first month. After one year groundwater conditions had reached a quasi-steady state. Model results are reported for one month and one year after the initiation of shaft construction.

6.2.1 Drainage into Shaft

Simulated drainage into the shaft during and following construction for Scenarios 2 through 5 is presented in **Figure 9**. The greatest level of drainage is predicted to occur in scenarios where the shaft is unlined, i.e. Scenario 2, Scenario 6, and Scenario 7. The lining in Scenarios 6 and 7 had an impact when the shaft excavation was above the level of the liner material, producing the results virtually identical to Scenario 4 which had the same liner permeability. Once the excavation was below the liner level, seepage into the shaft increased in both scenarios relative to Scenario 2 where the liner was absent altogether. Once the additional seepage had drained the scenarios behaved identically to the Scenario 2 because conditions were the same. The higher permeability material tested in Scenario 7 had virtually no influence on drainage into the shaft as flow was controlled by the liner material.

The rate of seepage into the shaft is predicted to decline as the permeability of liner materials is decreased in Scenarios 3 through 5. However, there is negligible difference in the predicted drainage for Scenarios 4 and 5 indicating that the majority of flow in these scenarios is emerging through the floor of the shaft where there is no flow barrier. This indicates that a barrier with a permeability of 10^{-9} m/s, as is applied in Scenario 4, would be an effective barrier to prevent groundwater draining through the shaft walls.

Table 10 presents the predicted peak and steady state rate of drainage into the shaft. When no flow barrier is used in Scenario 2, a peak of 31.6 m^3/day is predicted, reducing to 30.3 m^3/day in Scenario 3. The more impermeable barriers used in Scenarios 4 and 5 reduce predicted peak flow into the shaft to 24.0 and 22.8 m^3/day, respectively.

A greater peak drainage is predicted in Scenario 6 and 7 because water that is initially detained by the flow barrier drains quickly after the excavation level falls below the barrier on day 5 of the simulation. In Scenario 6 the maximum drainage was 32.1 m^3/day and in Scenario 7 the peak flow was 32.0 m^3/day. Reducing barrier permeability has a limited impact on reducing drainage during excavation because of the limited penetration of the lining. Groundwater readily flows up through the bottom of the shaft where there is no lining.

Seepage increases sharply during the first week of shaft excavation in all scenarios, levelling off during the latter half of the excavations and then declining rapidly after the shaft excavation is complete and groundwater levels are reduced. As opposed to peak drainage, steady state drainage into the shaft is reduced significantly by decreasing the permeability of the liner.

The steady state drainage rate predicted follows a similar pattern with Scenario 2 generating 5.6 m^3/day of drainage into the shaft, which reduces to 4.0 m^3/day in Scenario 3. A drainage rate of approximately 2.2 m^3/day is predicted for Scenario 4 and 1.8 m^3/day for Scenario 5. This shows only a minor reduction in drainage is achieved by reducing the permeability of the barrier from 10^{-9} to 10^{-10} m/s. Scenarios 6 and 7 are essentially the same as Scenario 2 once the excavation level drops below the barrier.

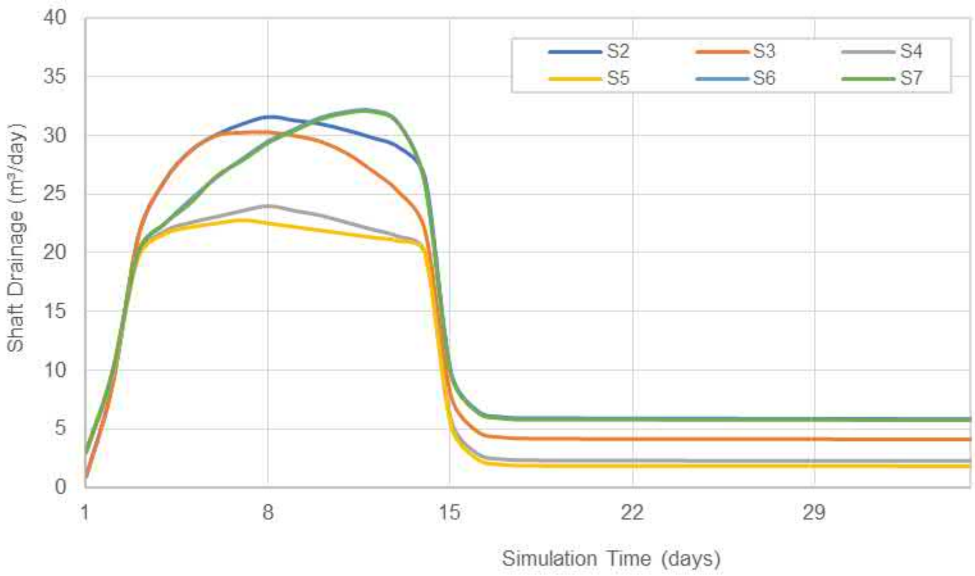

Figure 9. Simulated groundwater drainage into shaft during and immediately following construction.

Table 10. Model predicted peak and steady state groundwater drainage into shaft.

Scenario	Drainage Into Shaft-30 vertical anisotropy	
	Peak (m^3/day)	Steady State (m^3/day)
S2	31.6	5.6
S3	30.3	4.0
S4	24.0	2.2
S5	22.8	1.8
S6	32.1	5.6
S7	32.0	5.5

6.2.2 Mass Balance

A comparison of the average flow budget between the scenarios one year after the initiation of shaft construction is presented in **Table 11**. At this point in time the simulated groundwater conditions have reached steady state in all model scenarios. The purpose for providing this information is to demonstrate that the simulated water budget is internally balanced and reflects the expected hydrological conditions in the model area.

Table 11. Average flow budget one year after initiation of shaft construction.

Components	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6		Scenario 7	
	Flow (m3/d)	% of Flow	Flow (m3/d)	% of Flow	Flow (m3/d)	% of Flow	Flow (m3/d)	% of Flow	Flow (m3/d)	% of Flow	Flow (m3/d)	% of Flow	Flow (m3/d)	% of Flow
Recharge	632.7	99.9	632.7	99.5	632.7	99.7	632.7	99.9	632.7	99.9	632.7	99.5	632.7	99.5
Storage	0.6	0.1	3.2	0.5	2.0	0.3	0.8	0.1	0.6	0.1	3.2	0.5	3.2	0.5
Total inflow	633.3	100	635.9	100	634.7	100	633.6	100	633.3	100	635.9	100	636.0	100
Storage	0.7	0.1	0.6	0.1	0.6	0.1	0.7	0.1	0.7	0.1	0.6	0.1	0.5	0.1
Shallow Coastal Discharge (CH)	9.8	1.6	9.8	1.5	9.8	1.5	9.8	1.5	9.8	1.6	9.8	1.5	26.7	4.2
Deep Coastal Discharge (GHB)	102.7	16.2	102.7	16.1	102.7	16.1	102.7	16.2	102.7	16.2	102.7	16.1	89.2	14.0
Surface/Sub-surface Drainage	521.6	82.2	518.8	81.4	519.3	81.6	519.8	81.8	520.0	81.9	518.8	81.4	515.2	80.9
Shaft Drainage	0.0	0.0	5.6	0.9	4.0	0.6	2.2	0.3	1.8	0.3	5.6	0.9	5.2	0.8
Total outflow	635	100	638	100	636	100	635	100	635	100	638	100	637	100

Key observations from **Table 11** include:

- Recharge accounts for virtually all of the model inflow in all scenarios though there is a small influx from groundwater storage predicted in the scenarios where the shaft is included.
- The influx from storage is a result of increased groundwater gradient where there is a cone of depression in the immediate vicinity of the shaft, increasing with the permeability of the barrier.
- Stream flow accounts for 82% of model outflow under baseline conditions (Scenario 1) with a significant portion of groundwater outflow emerging at Western Springs in the southwest part of the model area.
- With the shaft included in the model, a small amount of groundwater that would otherwise flow into surface streams or subsurface drains seeps into the shaft.
- The maximum amount of drainage into the shaft is in Scenario 2 where no barrier is applied.
- In Scenario 2, 1% (6 m^3/day) of groundwater outflow in the model area is predicted to flow into the shaft. This declines to 0.6% (4 m^3/day) in Scenario 3, and with more impermeable barriers in scenarios 4 and 5 the portion of groundwater outflow into the shaft falls to approximately 0.3% or 2 m^3/day.
- Groundwater that drains into the shaft proportionally reduces the amount of groundwater discharging to surface water; however, the maximum reduction is 2.8 m^3/day with the exception of Scenario 7 where a slightly greater reduction is predicted but this is due to the different material properties applied and does not signify an impact related to the shaft.
- The shaft is not predicted to impact coastal discharge.

6.2.3 Stream Flows

An analysis of the predicted impact of shaft construction on streamflow was undertaken. There was no measurable impact predicted for either Motions Creek or Cox's Creek (<0.01 L/s).

It should be noted that the model only reflects flow in Motions Creek originating from the east side of the stream as the area to the west is outside of the model boundary; therefore flow in Motions creek is underestimated and effects estimated here are conservative.

6.2.4 Aquifer Drawdown Effects

Groundwater drawdown within the aquifer adjacent to the shaft was calculated by subtracting predicted groundwater head for Scenarios 2 to 6 in Layers 1 to 4 from the corresponding head in the baseline model (Scenario 1). Layers beneath Layer 4 are not impacted by drawdown because they are below the bottom of the shaft. Model results from two years after the initiation of shaft construction were used for the calculations to allow groundwater conditions to reach steady state in all scenarios.

Predicted groundwater drawdown resulting from construction of the shaft are presented in **Table 12** using distances of 1, 10, and 100 m from the shaft for reference.

The greatest drawdown is predicted in Scenario 2 where no flow barrier is applied in the shaft and in Scenario 6 where the completed shaft extends 18 m below the lining. At a distance of 1 m from the shaft, drawdown in Layer 4 is 9.7 m whereas 5.5 m of drawdown is predicted 10 m away and 0.6 m is predicted 100 m away.

With a relatively permeable barrier installed, as in Scenario 3, the predicted drawdown in Layer 4 declines to 6.2 m, 3.7 m, and less than 0.5 m at distances of 1, 10, and 100 m from the shaft. The less permeable barriers used in Scenarios 4 and 5 decrease predicted Layer 4 drawdown at 10 m from the shaft to 1.6 and 1.1 m, respectively.

Figure 10 shows simulated groundwater head in Layer 4 at 10 and 100 m from the shaft for Scenario 2, where predicted drawdown is relatively high due to the unlined shaft, and Scenario 4 where a relatively impermeable liner is used as the expected long term condition. At 10 m from the shaft, groundwater head declines by approximately 5.5 m in Scenario 2. In Scenario 4 this impact is reduced to approximately 1.6 m. The simulated decline in groundwater head at 100 m form the shaft minimal in Scenario 2 and negligible in Scenario 4.

Table 12. Model predicted groundwater drawdown one year after the initiation of shaft construction.

Distance from Shaft (m)	Model Layer	Predicted Drawdown (m)				
		Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
1	Layer 1	0.02	0.02	0.01	0.01	0.02
	Layer 2	1.35	0.93	0.46	0.34	1.35
	Layer 3	2.73	1.83	0.84	0.60	2.73
	Layer 4	9.71	6.19	2.30	1.36	9.71
10	Layer 1	0.02	0.02	0.01	0.01	0.02
	Layer 2	1.30	0.89	0.45	0.34	1.30
	Layer 3	2.45	1.66	0.79	0.58	2.45
	Layer 4	5.50	3.66	1.62	1.13	5.50
100	Layer 1	0.11	0.10	0.08	0.08	0.11
	Layer 2	0.42	0.32	0.20	0.17	0.42
	Layer 3	0.54	0.40	0.24	0.21	0.54
	Layer 4	0.64	0.47	0.29	0.24	0.64

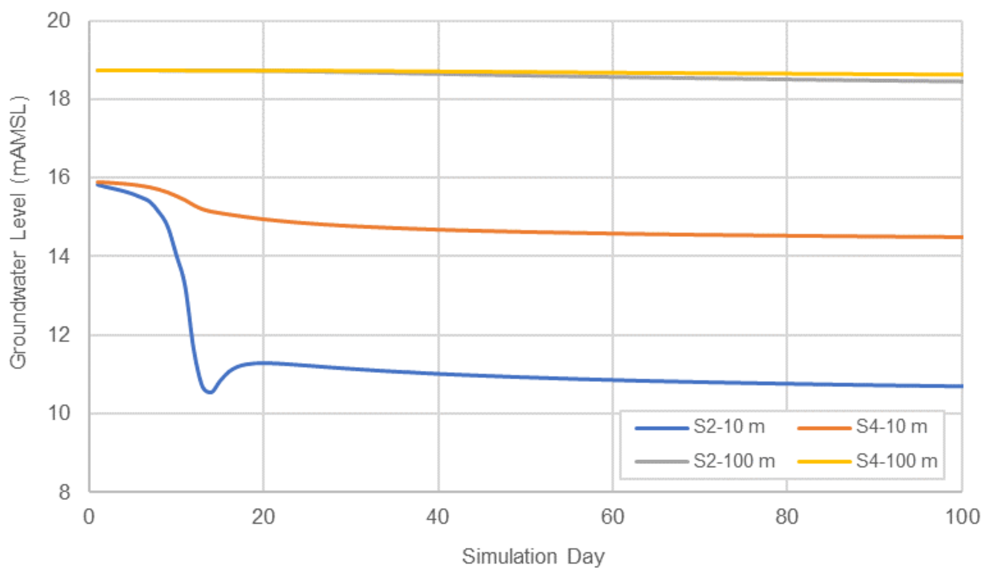

Figure 10. Simulated groundwater head in Layer 4 for the first 100 days in Scenario 2 and Scenario 4

Predicted drawdown in Scenario 4, considered to represent the long term condition after shaft construction, is shown for model Layer 2 in **Figure 11** and for model Layer 4 in **Figure 12**. Less than 0.2 m of drawdown was simulated in model Layer 1 throughout the model area. Model Layer 2 was selected to show expected drawdown at a level relatively near the surface. Model Layer 4 corresponds to where the bottom of the shaft is located and where maximum drawdown is expected to occur, though it is below the area where structures or infrastructure will be affected.

Scenario 6 is considered to represent the conditions during construction and prior to installation of the full shaft lining. Predicted drawdown for model Layer 2 is shown in **Figure 13** and for Layer 4 in **Figure 14**. The extent of drawdown in Scenario 6 is greater than in Scenario 4 because the temporary shaft lining only extends to 7 m BGL, allowing a greater cone of depression to form around the shaft prior to the full liner installation.

The lateral extent of predicted drawdown from Scenario 4 and Scenario 2 two years after the initiation of shaft construction is presented in **Table 13**. Scenario 2 represents the greatest potential drawdown among the scenarios that applied calibrated hydraulic parameters, while Scenario 4 is the most likely long-term condition.

Model results were assessed to determine the extent where drawdown was predicted to be 5 cm or more for each model layer and the maximum drawdown outside of the shaft. The maximum distance from the shaft where 5 cm of drawdown was predicted in Layer 1 was approximately 300 m, though the maximum drawdown in Layer 1 was 0.2 m in the unlined scenario and 0.1 m with a lined shaft. The maximum distance where 5 cm of drawdown was predicted was 420 m from the shaft in Scenario 2, Layer 4.

The maximum drawdown in Layer 4 (9.8 m in Scenario 2) was directly adjacent to the shaft and was reduced to 2.3 m in with a lined shaft as in Scenario 4. Maximum drawdown in shallower layers was significantly less than in Layer 4. It is evident that the impact of drawdown is relatively limited and does not reach the coast or any significant surface water features.

Table 13. Lateral extent and maximum predicted drawdown in select model layers for Scenario 4 and Scenario 6.

Model Layer	Extent of Drawdown (m)		Maximum drawdown outside of shaft (m)	
	Scenario 4	Scenario 2	Scenario 4	Scenario 2
1	300	300	0.1	0.2
2	340	395	0.5	1.4
4	365	420	2.3	9.8

Figure 11. Predicted drawdown after one year in Layer 2 from Scenario 4 (see A3 attachment at rear)**.**

Figure 12. Predicted drawdown after one year in Layer 4 from Scenario 4 (see A3 attachment at rear)**.**

Figure 13. Predicted drawdown after one year in Layer 2 from Scenario 6 (see A3 attachment at rear)**.**

Figure 14. Predicted drawdown after one year in Layer 4 from Scenario 6 (see A3 attachment at rear)**.**

7 Assessment of Effects

The following discussion is an assessment of potential groundwater related effects from construction of the shaft and with consideration for the relevant provisions of the Auckland Unitary Plan as referenced in **Section 2.3**.

Construction of the secondary shaft, to be built directly adjacent to the shaft, will be initiated a minimum of 2.5 years after the initial construction period for the shaft. This time frame will allow for a full recovery of groundwater levels following the construction of the shaft. The secondary shaft will be the same depth as the main shaft and slightly less in diameter, therefore groundwater effects from the secondary shaft will be within the envelope of (albeit slightly less than) the effects from construction of the main shaft, as described herein.

7.1 Potential Environmental Impacts

The following items are addressed based on the stated criteria for groundwater impacts related to restricted discretionary activities as defined in the AUP. The items addressed in the following sub-sections are those within the scope of this report considered relevant to construction of the proposed shaft, as defined in **Section 2.2**.

7.1.1 Stream Baseflow

A reduction of 0.6 m^3/day (0.007 L/s) is predicted on baseflow for Cox's Creek of 211 m^3/day. This represents an impact of 0.28% on baseflow and is considered less than minor. No impact on baseflow is predicted on Motions Creek.

7.1.2 Lake Levels

The closest lake is Western Springs, which is 1,800 m from the Tawariki Street Shaft Site. There are no adverse impacts predicted on Western Springs lake as the cone of depression does not extend to the lake. The shaft is predicted to only cause measurable drawdown (> 0.05 m) within 420 m of the Tawariki Street Shaft Site if unlined. With a lined shaft, similar to Scenario 4, this distance drops to under 350 m.

7.1.3 Existing Groundwater Takes

There are no groundwater takes in the area impacted by the shaft construction. The closest consented groundwater take is a 150 mm bore used for irrigating the sports ground at Eden Park, which is 2.5 km south of the Tawariki Street Shaft Site whereas the radius of worst case expected drawdown is 420 m.

7.1.4 Saline Intrusion

The reduction in groundwater level is, at worst, predicted to extend 420 m from the Tawariki Street Shaft Site. The area of anticipated reduction in groundwater level does not extend to the ocean, so there are no adverse effects related to saline intrusion predicted.

7.1.5 Surface Flooding

Changes in groundwater levels or flow patterns resulting from the shaft construction will not generate any increase in the frequency or magnitude of flood events. Depressurisation only serves to reduce moisture content of waterlogged materials and flooding.

7.1.6 Cumulative Effects of Groundwater Diversions

Cumulative effects are not applicable because there will not be any additional projects diverting groundwater within the study area.

7.1.7 Discharge of Contaminated Groundwater

Groundwater that drains into the shaft will be collected and routed to Watercare's own water treatment facilities.

7.1.8 Surface Water Effects

The Tawariki Street Shaft Site will be constructed on what is currently an urban residential street. Existing land and stormwater drainage is routed into subsurface pipes and diverted through the area. The anticipated hydrological flow regime impact from the proposed shaft construction is predicted to be less than minor.

Residual uncertainty regarding the potential impact of shaft construction on groundwater will be addressed in the following recommendations for the monitoring of, and reporting on, groundwater conditions.

7.1.9 Potential Settlement

Potential consolidation settlements due to groundwater drawdown are addressed in a separate assessment report.

7.2 Recommendations for Groundwater Monitoring and Reporting

Recommendations for groundwater monitoring prior to, during, and following shaft construction are based on the conditions stated in the consent for the Central Interceptor Main Works as provided by Watercare (2013) and consideration of specific site conditions at the proposed location of the shaft at the Tawariki Street Shaft Site. The monitoring protocol recommended below will provide information to confirm that the magnitude of impact, if any, associated with the development of the shaft is no greater than predicted in this AEE, and to inform management decisions should ground settlement triggers be reached where preventative action is required.

1. Groundwater monitoring boreholes shall be installed prior to construction to enable the establishment of baseline groundwater conditions. At least one of these boreholes shall be within 100 m of the shaft location and the another approximately 500 m from the shaft location adjacent to the proposed Grey Lynn Tunnel.

   Note: Six boreholes have been installed for monitoring groundwater along the proposed route of the Grey Lynn Tunnel and the two closest boreholes CIE-BH04 and CIE-BH05 located less than 10 and 29 m respectively from the shaft construction site have been outfitted with vibrating wire piezometers for high frequency data collection. CIE-BH01 and CIE-BH02 can be used as the monitoring boreholes 500 m from the shaft location.

2. To give effect to Recommendation 1, a monitoring program of at least three months in duration within boreholes CIE-BH04 and CIE-BH05 is recommended. Data shall be recorded to an accuracy of at least ±5 mm at an interval of no greater than one week during this time.

3. Groundwater monitoring records at CIE-BH04 and CIE-BH05 shall be collected from their respective vibrating wire piezometers and reviewed no less than weekly during shaft construction and no less than monthly for one year following shaft construction. Data records shall be compiled and submitted to Auckland Council Consents Manager.

4. In the event of land settlement reaching trigger levels defined in the Ground Settlement Report, the measured drawdown from the groundwater monitoring data should be compared to anticipated drawdown from the groundwater model. Any significant discrepancy shall be considered cause to review site management of groundwater pumping that is generating the drawdown.

5. After 12 months monitoring activities may cease in any borehole where water levels have recovered to within 2 m of pre-construction conditions. Monitoring activities shall continue if groundwater levels are not recovering from construction effects and there is a risk of adverse impacts related to dewatering.

6. Preparation of a Groundwater and Ground Settlement Monitoring and Contingency Plan that describes the monitoring suggested above, analysis of this data, and actions to be implemented should certain settlement outside of the anticipated range be triggered.

8 Summary and Conclusion

The Grey Lynn Tunnel is an infrastructure project being developed in Auckland to increase regional capacity for managing sewage flows and stormwater. The tunnel construction and subsequent operation and maintenance will require a shaft to be constructed on Tawariki Street in Grey Lynn.

A numerical groundwater flow model was developed to determine the potential impact of shaft construction on regional groundwater and estimate the rate of groundwater drainage into the shaft during and following construction. Regional geology around the shaft location is dominated by the ECBF formation which typically has permeability on the order of $3x10^{-7}$ m/s.

Site specific investigations found the geological and hydrogeological conditions to be typical for the area based on testing performed at six monitoring boreholes that were installed in preparation for shaft and tunnel construction. Three of these boreholes were located on Tawariki Street adjacent to the proposed shaft site.

Regional groundwater generally flows from higher elevation areas toward the Waitemata Harbour and the major surface drains are Motions Creek and Cox's Creek.

Model Development and Calibration

A numerical groundwater model was developed using a MODFLOW unstructured grid with a 50 m grid spacing and enhanced resolution around the shaft location where grid spacing was reduced to under 0.5 m. The model was calibrated using water levels measured at the six monitoring boreholes. Accurate calibration of groundwater levels was achieved at four of the boreholes with a final calibrated hydraulic conductivity of $5x10^{-7}$ m/s.

Groundwater recharge in the model originates from rainfall. Based on calibrated model results 79% of groundwater outflows in the model area go to surface and subsurface drains with the remainder discharging into Waitemata Harbour.

Predictive Simulations and Results

A one-year simulation was run using calibrated parameters from the steady state model to establish baseline conditions (Scenario 1). Four transient simulations were then run which included the shaft being installed over a 13-day period at the beginning of the simulation. These scenarios simulated a range of construction alternatives by varying permeability of the shaft lining and testing an unlined shaft. The permeabilities tested were, no lining (Scenario 2), 10^{-8} m/s (Scenario 3), 10^{-9} m/s (Scenario 4), and 10^{-10} m/s (Scenario 5).

Two additional scenarios were devised where the shaft was lined to a depth of 7 m with a permeability equal to 10^{-9} m/s. In Scenario 6 model parameters were the same as for the other scenarios, whereas in Scenario 7 increased conductivity of the ECBF material was applied as a sensitivity test.

Scenario 4 was considered to be the most representative of long-term conditions while Scenario 6 was considered to represent the temporary conditions during the construction period prior to the installation of the full shaft lining. Scenario 2 (unlined shaft) was considered to be the most conservative scenario from the perspective of demonstrating an upper envelope of potential effects.

Drainage into the shaft was predicted peak during construction as the shaft was excavated below the pre-existing groundwater level and decline to a constant rate as groundwater conditions stabilized once the shaft was completed. In Scenario 2, with no lining, drainage into the shaft was predicted to peak at 32 m^3/day. This reduced to 30, 24, and 23 m^3/day in Scenarios 3, 4, and 5, respectively. Scenarios 6 and 7 where the shaft was only lined to 7m BGL were similar to Scenario 2 in terms of predicted drainage, though the peak occurred slightly later in the construction process after the excavation level had dropped below the liner. After construction drainage into the shaft dropped off significantly, approaching steady state in following weeks. The rate of steady state drainage into the shaft after construction is approximately 6 m^3/day in Scenario 2; 4 m^3/day in Scenario 3; and approximately 2 m^3/day in Scenario 4 and 5. Scenarios 6 and 7 were effectively equal to Scenario 2 in terms of the steady state drainage into the shaft.

The predicted impact on surface drainage was negligible. In the most extreme case, with an unlined shaft (Scenario 2), less than 0.01 L/s of flow reduction was predicted in Cox's Creek and no impact was predicted on Motions Creek.

Groundwater drawdown was significant directly around the shaft location, but widespread impact was not predicted. The greatest drawdown was predicted in Layer 4 of Scenario 2 where there was no shaft lining. In this case, 5.5 m of drawdown was predicted at 10 m from the shaft while 0.6 m was predicted 100 m from the shaft. Drawdown was significantly less in shallower model layers and below 0.2 m in Layer 1 which extends to -1 m AMSL, making damage to structures or other infrastructure unlikely.

In Scenario 2 measurable drawdown (5 cm) was predicted to extend to approximately 420 m from the shaft location. All scenarios where the shaft wall was lined yielded a lesser extent of drawdown and significantly lower maximum drawdown predictions. Drawdown was predicted to be under 0.5 m at 100 m distance from the shaft in scenarios 3 through 5. Drawdown was not predicted to extend to the coast in any scenario therefore shaft construction is not predicted to induce saline intrusion into the aquifer.

Model results indicate a less than a minor impact on regional groundwater. The following list of recommendations was developed based on the criteria for evaluating restricted discretionary activities outlined in the Auckland Unitary Plan and with consideration of model results.

The following is a list of recommendations based on model results and regional groundwater conditions:

1. The Tawariki Street Shaft shall be lined in the permanent case to minimize the risk of impacting local groundwater levels and inducing ground settlement using a material with a permeability of no greater than $1x10^{-8}$ m/s.
2. Monitoring existing boreholes CIE-BH04, CIE-BH05, and CIE-BH06 adjacent to the shaft as well monitoring the borehole CIE-BH01 or CIE-BH02, located along the proposed route of the Grey Lynn Tunnel approximately 500 m from the shaft to confirm that groundwater impacts are minimal, if any.
3. Weekly monitoring of groundwater levels at all boreholes installed for the Grey Lynn Tunnel project is recommended for a three month period prior to construction to document baseline conditions.
4. Weekly monitoring of all boreholes installed for the Grey Lynn Tunnel project in accordance with the Groundwater and Settlement Monitoring and Contingency Plan is recommended during shaft construction to alert managers if there is any change in groundwater level that may incur risk to structures or the environment.
5. Monthly groundwater monitoring in accordance with the Groundwater Monitoring and Contingency Plan is recommended for a one year period following construction to assure impacts are not beyond the expected levels and that groundwater levels recover to pre-construction conditions.

9 References

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Tonkin and Taylor, 2012. Effect on Tunnel on Groundwater and Surface Settlement, s.l.: s.n.

Tuhono Consortium (2011). Hydrogeological Assessment Report for the Waterview Connection Tunnels and Great North Road Interchange. Contract Number NZTA CA3466.

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Appendix A. Borelogs

Jacobs in association with AECOM and McMillen Jacobs Associates		Preliminary Log of Investigation
Project: **Grey Lynn Tunnel CIGI5**		**Borehole**
Location: **29 Cockburn Street, Grey Lynn**	Project No: **AE04725**	Hole ID: **CIE-BH01**
Client: **Watercare**		Date: **14/03/2018**

Started:	14/03/2018	Remarks	Co-ordinates:
Finished:	19/03/2018	All hand vane results corrected, correction factor = 1.412 Packer Test at 17.00 - 21.50 m Piezometer dipped 28/05/2018. Water level = 0.86m. Hole location determined by Survey.	5919643.48mN 1754735.36mE
Driller:	McMillan		Elevation: 13.68mRL
Plant:	Rig N107 (McMillan)		Inclination: -90°
Logged:	A. Coutts		
Checked:	CS		Log cover page

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: Grey Lynn Tunnel CIGI5

Borehole

Location: 29 Cockburn Street, Grey Lynn — **Project No:** AE04725

Hole ID: CIE-BH01

Client: Watercare

Date: 14/03/2018

R.L. (m)	Depth (m)	Drilling Method	TCR (SCR) [RQD] %	In-Situ Testing	Description of Strata	Defect Description	Comments	Geological Unit
13.68	0.00	VAC EX	0		Vacuum Excavation: Infer fill material - gravelly SILT with some clay observed during vacuum excavation.			MG
	1.60	HQ3	100	I_{vp}40/I_{vr}13	SILT with some clay and minor gravel; dark greyish brown streaked dark brown. Firm, wet, high plasticity, moderately sensitive. Gravel is fine to coarse, subangular, basalt and sandstone.			
	2.00	SPT	93	SPT_s 1,2,3 N=5	CLAY with some silt and trace gravel and rootlets; light grey streaked brownish orange. Firm, wet, high plasticity. Gravel is medium to coarse, subangular, basalt.			Tp
	2.40	HQ3	100	I_{vp}51/I_{vr}17	Interbedded silty fine SAND; yellowish orange, and silty CLAY; light grey streaked yellowish orange. Loose/Firm to stiff, moist, low plasticity. Beds are thin to moderately thin. *2.70m to 2.75m: Becomes wet.* *3.00m to 3.10m: Silty sand becomes brownish grey, wet.*			
	3.10	SPT	100	SPT_s 0,0,1 N=1	Silty fine SAND with minor clay and trace organics; dark grey mottled bluish black. Very loose, wet. Organics are amorphous. *3.72m to 3.78m: Becomes banded grey and yellowish orange. Laminated relict beds.*			
	4.00	HQ3	57		Silty fine SAND with trace clay; grey. Medium dense, moist.			Wwc
	4.05			UTP_c	CORE LOSS.			
	4.50	SPT	100	SPT_s 6,11,13 N=24	Interbedded clayey SILT; dark grey and silty fine SAND; dark grey. Stiff and medium dense, moist, clayey silt is non plastic. Beds are thin to moderately thin.			
	5.26	HQ3	88 (61) [61]		Moderately weathered, dark grey, interbedded medium grained SANDSTONE and MUDSTONE. Very weak. Beds are laminated to moderately thin, steeply inclined.		5.36m: Core breaks along bedding planes on handling.	Wuw
	5.87	SPT	0	SPT_c 29,50 N>50 50/120	CORE LOSS. *6.00m to 6.27m: Core loss due to solid cone SPT. Infer highly weathered mudstone and sandstone.*			
	6.27	HQ3	100 (67) [62]		Moderately weathered, dark grey, interbedded medium grained SANDSTONE and MUDSTONE. Very weak. Beds are laminated to moderately thin, steeply inclined. *7.15m: Beds become moderately thin.*	6.47-6.56: Jt 65° R, P, Vn, C. 6.74-6.84: Jt 35° R, P, Mw, Si of silty fine to coarse gravel; sandstone. 6.98-7.04: Jt 35° Sm, P, Vn, Si of fine sand. 7.11-7.14: Jt 0° R, P, Mw, Si of silty fine to coarse gravel; sandstone.		
	7.50	SPT	0	SPT_c 18,32,19 N>50 51/225	CORE LOSS - Solid cone SPT. Infer moderately weathered mudstone/sandstone.			
	7.88	HQ3	94 (88) [81]		Moderately weathered, dark grey, interbedded medium grained SANDSTONE and MUDSTONE. Very weak. Beds moderately thin, steeply inclined. *8.50m: Very thin, steeply inclined, black carbonaceous bed.*	8.00-8.15: Jt 40° Sm, P, W, Si of fine to coarse gravel rock fragments.		
	9.00	SPT	0	SPT_c 11,19,30 N=49	CORE LOSS - Solid cone SPT. Infer highly weathered mudstone and sandstone.			
	9.45				Highly weathered, dark grey, interbedded medium grained SANDSTONE and MUDSTONE. Very weak. Beds are moderately thin, steeply inclined. *9.67m to 9.90m: Becomes moderately weathered, SANDSTONE bed.*	9.57-9.61: Jt 40° Sm, P, Vn, Si of silty sand.		Wwnc

Shift details & standing water level: 13/03/2018 3:00:00 PM; 14/03/2018 5:00:00 PM; 15/03/2018 7:45:00 AM (Water depth 2.7m)

Flush Type: Water — Flush Colour: Grey

Started: 14/03/2018
Finished: 19/03/2018
Driller: McMillan
Plant: Rig N107 (McMillan)
Logged: A. Coutts
Checked: CS

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations

Remarks
All hand vane results corrected, correction factor = 1.412
Packer Test at 17.00 - 21.50 m
Piezometer dipped 28/05/2018. Water level = 0.86m.
Hole location determined by Survey.

Co-ordinates:
5919643.48mN
1754735.36mE
Elevation: 13.68mRL
Inclination: -90°

Jacobs in association with AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: Grey Lynn Tunnel CIGI5

Borehole

Location: 29 Cockburn Street, Grey Lynn **Project No:** AE04725

Hole ID: CIE-BH01

Client: Watercare

Date: 14/03/2018

Columns: R.L. (m) | Depth (m) | Shift Details & Standing Water Level / Drilling Method | Drilling Flush Return (%) (25 50 75) | TCR (SCR) [RQD] % | Spacing of Natural Defects (mm) (500 100 50 10) | Relative Strength (EW VW W MS S VS EW) | Weathering Grade (UW SW MW HW CW RW) | Sampling | In-Situ Testing | Geology Legend | GroundWater | Description of Strata | Defect Description | Comments | Geological Unit | Backfill / Installation

BOUNDARY: Well defined; Gradational; Poorly defined

Defect Description key:

TYPE: CS Clay seam; C Cleavage; CR Crushed zone; DZ Decomposed zone; DB Drilling induced fracture; FL Foliation; FZ Fracture zone; IF Incipient fracture; JT Joint; SC Schistosity; SH Shear; SZ Shear Zone; SL Sill; VN Vein; VO Void

SURFACE: C Clean; Mc Mineral coat; Si Soil infill; Sn Surface stain; V Veneer

PLANARITY: P Planar; St Stepped; U Undulating

ROUGHNESS: R Rough; Ss Slickensided; Sm Smooth

APERTURE: T 0mm; Vn 0-2mm; N 2-6mm; Mn 6-20mm; Mw 20-60mm; W 60-200mm; Vw >200mm

R.L. scale: 3, 2, 1, 0, -1, -2, -3, -4, -5, -6. Depth scale: 11, 12, 13, 14, 15, 16, 17, 18, 19, 20.

Flush Type: **Water**; Flush Colour: **Grey**

Drilling Method	TCR (SCR) [RQD] %	In-Situ Testing
HQ3	89 (43) [43]	
SPT	0	SPT$_c$ 8,14,14 N=28
HQ3	86	
SPT	100	SPT$_s$ 7,13,19 N=32
HQ3	100	
SPT	100	SPT$_s$ 8,14,22 N=36
HQ3	95	
SPT	100	SPT$_s$ 12,22,30 N>50 52/280
HQ3	100	
SPT	100	SPT$_s$ 11,21,29 N>50 50/285
HQ3	100	
SPT	100	SPT$_s$ 11,21,29 N>50 50/275
HQ3	100 (14) [14]	
SPT	100	SPT$_s$ 12,24,26 N>50 50/255

Description of Strata

Very weak.

Highly weathered, dark grey interbedded fine medium grained SANDSTONE and MUDSTONE. Extremely weak. Beds are thin to moderately thin, steeply inclined. Sandstone recovered as silty fine SAND; Medium dense, moist. Mudstone recovered as SILT with minor clay and sand; Firm, moist, low plasticity. Sand is fine.

CORE LOSS.
10.50m to 10.95m: Core loss due to solid cone SPT. Infer highly weathered interbedded mudstone and sandstone. Extremely weak.

Highly weathered, dark grey, interbedded fine grained SANDSTONE and MUDSTONE. Extremely weak. Sandstone beds are thin to moderately thick, steeply inclined. Mudstone beds are very thin to thin, steeply inclined. Sandstone recovered as fine to medium SAND with some silt; Medium dense, moist. Mudstone recovered as clayey SILT; Hard, moist.

CORE LOSS.

Highly weathered, dark grey, interbedded fine grained SANDSTONE and MUDSTONE. Extremely weak. Sandstone beds are thin to moderately thick, steeply inclined. Mudstone beds are very thin to thin, steeply inclined. Sandstone recovered as fine to medium SAND with some silt; Medium dense, moist. Mudstone recovered as clayey SILT; Hard, moist, silt has low plasticity.
12.22m to 12.26m: Laminated, steeply inclined, very dark brown carbonaceous bed.

Completely weathered, dark grey, massive, fine to medium grained SANDSTONE. Extremely weak. Recovered as fine to medium SAND with some silt. Dense, moist.
13.92m to 13.95m: Thin, steeply inclined, black carbonaceous bed.

14.42m: Thin, steeply inclined, black carbonaceous bed.
14.50m: Thin, steeply inclined, black carbonaceous bed.
14.70m: Becomes very dense.

15.97m: Very thin, steeply inclined, black carbonaceous bed.

16.94m to 16.97m: Becomes silty fine SAND with minor clay.

19.35m to 19.50m: Becomes moderately weathered, SANDSTONE. Very weak.
19.37m to 19.45m: Moderately thin, steeply inclined, grey speckled speckled black, discontinuous carbonaceous bed.

Comments: 14.25m: Flush return turned black.

Geological Unit: Wwnc(Contd.)

Started: 14/03/2018
Finished: 19/03/2018
Driller: McMillan
Plant: Rig N107 (McMillan)
Logged: A. Coutts
Checked: CS

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations

Remarks
All hand vane results corrected, correction factor = 1.412
Packer Test at 17.00 - 21.50 m
Piezometer dipped 28/05/2018. Water level = 0.86m.
Hole location determined by Survey.

Co-ordinates:
5919643.48mN
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Elevation: 13.68mRL
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Jacobs in association with AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: **Grey Lynn Tunnel CIGI5**

Borehole

Location: **29 Cockburn Street, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH01**

Client: **Watercare**

Date: **14/03/2018**

R.L. (m)	Depth (m)	Shift Details & Standing Water Level / Drilling Method	Drilling Flush Return (%) 25 50 75	TCR (SCR) [RQD] %	Spacing of Natural Defects (mm) 500 100 50 10	Relative Strength EW VW W MS S VS	Weathering Grade UW SW MW HW CW RW	Sampling	In-Situ Testing	Geology Legend	GroundWater	Description of Strata	Defect Description	Comments	Geological Unit	Backfill / Installation
-7	21	HQ3	Flush Type: Water; Flush Colour: Clear, slightly cloudy	100 (98) [98]								Moderately weathered, dark grey, massive, fine to medium grained SANDSTONE. Very weak. *20.63m to 20.65m: Becomes silty fine SAND with minor clay.*			Wuw	
		SPT		100					SPT$_s$ 16,28,29 N>50 57/235			Highly weathered, dark grey, massive, fine to medium grained SANDSTONE. Extremely weak. Recovered as fine to medium SAND with some silt. Very dense, moist. *21.39m to 21.42m: Becomes silty fine SAND with some clay; dark grey. Very dense, moist.*		21.39m: Short run for packer test.	Wwnc	
-8	22	HQ3		100								Highly weathered, grey speckled green, dark grey and trace reddish brown flecks, massive, fine to medium volcaniclastic SANDSTONE, very weak. With trace fine gravel sized, subrounded to subangular mudstone and sandstone clasts. *21.52m: Very thin, steeply inclined, black carbonaceous bed.*	21.65-21.68: Jt 40° Sm, P, N-Mn, Sn of silty sand. 21.71-21.81: Jt 40° Sm, P, W, Si of clayey sand. 22.20-22.26: Jt 0° Sm, P, W, Si of clayey sand.	21.5m: Pulled rods back to 16.5m for packer test.	Wpvc	
		HQ3; 16/03/2018 2:40:00 PM (Water depth 0.4m); 19/03/2018 7:30:00 AM (Water depth 2.8m)		84 (80) [80]								Highly weathered, dark grey, massive, fine to medium grained SANDSTONE. Extremely weak to very weak. Recovered as fine to medium SAND with some silt; Very dense, moist.			Wwnc	
-9	23	SPT		100					SPT$_s$ 15,28,24 N>50 52/225			CORE LOSS.				
		HQ3	Flush Type: Water; Flush Colour: Grey	61 (61) [61]								Highly weathered, dark grey, massive, fine to medium grained SANDSTONE. Extremely weak. Recovered as fine to medium SAND with some silt; Very dense, moist.	23.20: Jt 25° R, P, N, Si of clayey coarse sand.		Wpvc	
-10												Moderately weathered, grey speckled green, dark grey and trace reddish brown flecks, massive, medium to coarse volcaniclastic SANDSTONE. Very weak. With trace fine gravel sized, subrounded to subangular mudstone and sandstone clasts.				
	24											CORE LOSS.				
		SPT		100					SPT$_s$ 9,21,33 N=54			Moderately weathered, dark grey, massive, fine to medium grained SANDSTONE. Extremely weak. Recovered as fine to medium SAND with some silt; Very dense, moist.			Wuw	
-11	25	HQ3		90 (90) [90]								Slightly weathered, massive, grey speckled green, dark grey and trace reddish brown flecks, medium to coarse volcaniclastic SANDSTONE, very weak. With trace fine gravel sized, subrounded to subangular mudstone and sandstone clasts. *24.90m: Laminated, steeply inclined, black carbonaceous bed.* *24.93m: Becomes fine to medium grained.*			Wpvc	
												CORE LOSS.				
												CIE-BH01 terminated at 25.50m. Target Depth				

BOUNDARY
Well defined
Gradational
Poorly defined

TYPE
CS Clay seam
C Clevage
CR Crushed zone
DZ Decomposed zone
DB Drilling induced fracture
FL Foliation
FZ Fracture zone
IF Incipient fracture
JT Joint
SC Schistosity
SH Shear
SZ Shear Zone
SL Sill
VN Vein
VD Void

SURFACE
C Clean
Mc Mineral coat
Si Soil infill
Sn Surface stain
V Veneer

PLANARITY
P Planar
St Stepped
U Undulating

ROUGHNESS
R Rough
Ss Slickensided
Sm Smooth

APERTURE
T 0mm
Vn 0-2mm
N 2-6mm
Mn 6-20mm
Mw 20-60mm
W 60-200mm
Vw >200mm

Started: 14/03/2018
Finished: 19/03/2018
Driller: McMillan
Plant: Rig N107 (McMillan)
Logged: A. Coutts
Checked: CS

Groundwater Observations

No. Struck (m) Date Standing (m) Observations

Remarks
All hand vane results corrected, correction factor = 1.412
Packer Test at 17.00 - 21.50 m
Piezometer dipped 28/05/2018. Water level = 0.86m.
Hole location determined by Survey.

Co-ordinates:
5919643.48mN
1754735.36mE
Elevation: 13.68mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with AECOM and McMillen Jacobs Associates	**Preliminary Log of Investigation**
Project: **Grey Lynn Tunnel CIGI5**	**Borehole**
Location: **Hakanoa Reserve, Grey Lynn** Project No: **AE04725**	Hole ID: **CIE-BH02**
Client: **Watercare**	Date: **19/03/2018**

Started: 19/03/2018 Finished: 22/03/2018 Driller: McMillan Plant: Rig N107 (McMillan) Logged: A. Coutts Checked: CS	Remarks All hand vane results corrected, correction factor = 1.412 Packer Test at 18.70-21.50 m Artesian piezometer, low pressure gauge installed. Pressure reading on 25/05/2018 was 20 kPa. Hole location determined by Survey.	Co-ordinates: 5919692.99mN 1754644.56mE Elevation: 10.11mRL Inclination: -90° Log cover page

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with
AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: Grey Lynn Tunnel CIGI5

Borehole

Location: Hakanoa Reserve, Grey Lynn **Project No:** AE04725

Hole ID: CIE-BH02

Client: Watercare

Date: 19/03/2018

Column headings: R.L. (m) | Depth (m) | Shift Details & Standing Water Level / Drilling Method | Drilling Flush Return (%) | TCR (SCR) [RQD] % | Spacing of Natural Defects (mm) | Relative Strength | Weathering Grade | Sampling | In-Situ Testing | Geology Legend | GroundWater | Description of Strata | Defect Description | Comments | Geological Unit | Backfill / Installation

BOUNDARY: Well defined; Gradational; Poorly defined

Defect Description key — TYPE: CS Clay seam, C Cleavage, CR Crushed zone, DZ Decomposed zone, DB Drilling induced fracture, FL Foliation, FZ Fracture zone, IF Incipient fracture, JT Joint, SC Schistosity, SH Shear, SZ Shear Zone, SL Sill, VN Vein, VO Void. SURFACE: C Clean, Mc Mineral coat, Si Soil infill, Sn Surface stain, V Veneer. PLANARITY: P Planar, St Stepped, U Undulating. ROUGHNESS: R Rough, Ss Slickensided, Sm Smooth. APERTURE: T 0mm, Vn 0-2mm, N 2-6mm, Mn 6-20mm, Mw 20-60mm, W 60-200mm, Vw >200mm.

Drilling Method	TCR %	Sampling	In-Situ Testing	Description of Strata	Comments	Geological Unit
HA	100			SILT with minor rootlets and clay; dark brown. Stiff, moist, low plasticity.		MG
HA	100			Silty CLAY with minor rootlets; brownish orange mottled dark orange and light greyish brown. Stiff, moist, low plasticity. *0.90m: Becomes light grey mottled dark orange.* *1.20m: Trace rootlets.* *1.40m: Becomes moderate plasticity.*	1.3m: Cased to 1.3 m.	Tp
19/03/2018 3:30:00 PM HQ3; TBX 20/03/2018 8:00:00 AM HQ3	100					Tp
	80	TW		PUSH TUBE: Material at top and bottom comprises: Silty CLAY; light grey mottled dark orange. Stiff, moist, low plasticity. 400mm recovered.		Tp
HQ3	100		I_{vp}59/I_{vr}14	Silty CLAY with trace rootlets; light grey mottled dark orange. Firm, moist, high plasticity.		Tp
SPT	100		SPT_s 0,0,0 N<1	Silty CLAY with minor sand and trace rootlets; light greyish brown. Very soft, moist, high plasticity. Sand is fine. *3.45m: Minor organics. Brown mottled bluish black and yellowish brown. Organics are amorphous and fibrous decaying wood fragments.*	3m: Difficulty with circulation. 3.45m: Drilled without water.	Tp
HQ3	43			CORE LOSS.		Tp
SPT	100		SPT_s 0,0,3 N=3	Silty CLAY with some organics and minor sand; dark greyish brown speckled black and light brown. Firm, wet, high plasticity. Organics are amorphous and fibrous decaying wood fragments. Sand is fine.		Tp
				Silty fine to medium SAND with minor clay and trace fibrous decaying wood fragments; light grey. Loose, wet.		Tp
HQ3	100			Highly weathered, grey speckled white, dark grey, green and trace reddish brown flecks, massive, fine to medium grained SANDSTONE. Extremely weak. Recovered as fine to medium SAND with some silt, trace gravel and clay; Medium dense, moist. Gravel is fine, subrounded mudstone and sandstone. *5.05m: Becomes medium dense, moist.*		Wpvc
SPT	100		SPT_s 8,15,23 N=38			Wpvc
HQ3	95			Moderately weathered, grey speckled white, dark grey, green and trace reddish brown flecks, massive, fine to medium grained SANDSTONE. Very weak. With trace gravel. Gravel is fine, subrounded mudstone and sandstone. *6.95m: Becomes very weak.*		Wpvc
SPT	100		SPT_s 12,24,26 N>50 50/250	*7.96m: Laminated, sub-horizontal, black carbonaceous bed.*		Wpvc
HQ3	90					Wpvc
SPT	100		SPT_s 16,37,14 N>50 51/180	CORE LOSS.		Wpvc
SPT	100			Highly weathered, grey speckled white, dark grey, green and trace reddish brown flecks, massive, fine to medium grained SANDSTONE. Extremely weak. Recovered as fine to medium SAND with some silt and trace gravel; Very dense, moist. Gravel is fine, subrounded mudstone and sandstone.		Wwhc
HQ3	94			Moderately weathered, grey speckled white, dark grey, green and trace reddish brown flecks, massive, fine to medium grained SANDSTONE.	9.33m: Core oxidises to greenish	Wpvc

Flush Type: Water
Flush Colour: Grey

Started:	19/03/2018
Finished:	22/03/2018
Driller:	McMillan
Plant:	Rig N107 (McMillan)
Logged:	A. Coutts
Checked:	CS

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations

Remarks
All hand vane results corrected, correction factor = 1.412
Packer Test at 18.70-21.50 m
Artesian piezometer, low pressure gauge installed.
Pressure reading on 25/05/2018 was 20 kPa.
Hole location determined by Survey.

Co-ordinates:
5919692.99mN
1754644.56mE
Elevation: 10.11mRL
Inclination: -90°

Jacobs in association with AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: **Grey Lynn Tunnel CIGI5**

Borehole

Location: **Hakanoa Reserve, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH02**

Client: **Watercare**

Date: **19/03/2018**

R.L. (m)	Depth (m)	Drilling Method	TCR (SCR) [RQD] %	In-Situ Testing	Description of Strata	Defect Description	Comments	Geological Unit
0			(92) [92]		Very weak. Base of unit is steeply inclined. *9.42m: Laminated, steeply inclined, black carbonaceous bed.*		grey.	Wpvc(Contd.)
		SPT	0	SPT$_c$ 36 N>50 36/150 bouncing	Moderately weathered, grey speckled white, dark grey, green and trace reddish brown flecks, massive, coarse volcaniclastic SANDSTONE. Very weak. With trace fine to medium gravel, subrounded mudstone and sandstone.	10.30-10.39: Jt 65° Sm, P, T-Vn, Si of clay.		
-1	11	HQ3	87 (87) [87]		Slightly weathered, grey speckled white, dark grey, green and trace reddish brown flecks, massive, fine to medium grained SANDSTONE. Very weak.			
					CORE LOSS - Solid cone SPT. Infer highly weathered sandstone.			
					Slightly weathered, grey speckled white, dark grey, green and trace reddish brown flecks, massive, fine to medium grained SANDSTONE. Very weak. *10.86m to 11.22m: Becomes coarse grained. 11.56m to 11.58m: Some white, subrounded fine gravel grains.*			
-2	12	SPT	0	SPT$_c$ 48 N>50 48/150 bouncing	CORE LOSS. *12.00m to 12.15m: Core loss due to solid cone SPT. Infer highly weathered sandstone.*			
					Slightly weathered, grey speckled white, dark grey, green and trace reddish brown flecks, massive, fine to medium grained SANDSTONE. Very weak.			
-3	13	HQ3	74 (74) [74]		Slightly weathered, grey speckled white, dark grey, green and trace reddish brown flecks, massive, coarse volcaniclastic SANDSTONE. Very weak. With trace fine gravel, subrounded mudstone and sandstone.		12.6m: Core biscuiting with drilling.	Wwnc
					Highly weathered, grey, massive, fine to medium grained SANDSTONE. Very weak.			
					CORE LOSS.			Wwuw
					Slightly weathered, grey, massive, fine to medium grained SANDSTONE. Very weak.			Wpvc
-4	14	HQ3	83 (83) [83]		Slightly weathered, grey speckled white, dark grey, green and trace reddish brown flecks, massive, coarse volcaniclastic SANDSTONE. Very weak. With trace fine gravel, subrounded mudstone and sandstone.			Wuw
					Moderately weathered, grey, interbedded, fine grained SANDSTONE and MUDSTONE. Very weak. Beds are very thin to thin, sub-horizontal. *14.05m to 14.60m: Moderately thick, sandstone bed. 14.46m: Laminated, sub-horizontal, black carbonaceous bed.*			
-5	15				CORE LOSS.			
					Slightly weathered, grey, massive, fine to medium grained SANDSTONE. Very weak. *15.54m to 15.70m: Becomes extremely weak. Recovered as fine to medium SAND with some silt; Very dense, moist. 15.76m to 15.95m: Moderately thin, sub-horizontal, grey speckled black carbonaceous bed. 16.12m to 16.17m: Thin, sub-horizontal, grey speckled black, discontinuous carbonaceous bed.*			
-6	16	HQ3	93 (87) [87]		CORE LOSS.			
					Silty SAND with minor clay; dark grey. Very dense, wet.			
-7	17	HQ3	97		Slightly weathered, grey, interbedded, fine to medium grained SANDSTONE and MUDSTONE. Extremely weak. Beds are very thin to moderately thin, sub-horizontal. Sandstone recovered as fine to medium SAND with minor silt; Very dense, Mudstone recovered as CLAY; Hard.			
-8	18				Slightly weathered, massive, grey speckled white, dark grey, green and trace reddish brown flecks, fine to medium grained SANDSTONE. Extremely weak to very weak. Recovered as fine to medium SAND; Very dense. *18.23m: Laminated, sub-horizontal, black carbonaceous bed. 18.32m to 18.40m: Becomes coarse grained. Trace coarse gravel, subrounded mudstone. 18.33m: Laminated, sub-horizontal, black carbonaceous bed. 18.68m to 18.77m: Moderately thin, sub-horizontal, grey speckled black, discontinuous carbonaceous bed.*			Wpvc
-9	19	HQ3	90		CORE LOSS.			
	20				Slightly weathered, grey speckled white, dark grey, green and trace reddish brown flecks, massive fine to medium grained SANDSTONE. Very weak. With minor coarse sand, and trace fine gravel, subrounded, mudstone.			

Drilling Flush Return (%): Flush Type: Water; Flush Colour: Grey

Column headings: R.L. (m); Depth (m); Shift Details & Standing Water Level / Drilling Method; Drilling Flush Return (%) 25 50 75; TCR (SCR) [RQD] %; Spacing of Natural Defects (mm) >500 >100 >50 >10; Relative Strength EW VW W MS S VS; Weathering Grade EW VW MW HW CW RW; Sampling; In-Situ Testing; Geology Legend; GroundWater; Description of Strata; Defect Description; Comments; Geological Unit; Backfill / Installation

BOUNDARY: Well defined; Gradational; Poorly defined

Defect Description

TYPE: CS Clay seam; C Clevage; CR Crushed zone; DZ Decomposed zone; DB Drilling induced fracture; FL Foliation; FZ Fracture zone; IF Incipient fracture; JT Joint; SC Schistosity; SH Shear; SZ Shear Zone; SL Sill; VN Vein; VD Void

SURFACE: C Clean; Mc Mineral coat; Si Soil infill; Sn Surface stain; V Veneer

PLANARITY: P Planar; St Stepped; U Undulating

ROUGHNESS: R Rough; Ss Slickensided; Sm Smooth

APERTURE: T 0mm; Vn 0-2mm; N 2-6mm; Mn 6-20mm; Mw 20-60mm; W 60-200mm; Vw >200mm

Started: 19/03/2018
Finished: 22/03/2018
Driller: McMillan
Plant: Rig N107 (McMillan)
Logged: A. Coutts
Checked: CS

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations

Remarks
All hand vane results corrected, correction factor = 1.412
Packer Test at 18.70-21.50 m
Artesian piezometer, low pressure gauge installed.
Pressure reading on 25/05/2018 was 20 kPa.
Hole location determined by Survey.

Co-ordinates:
5919692.99mN
1754644.56mE
Elevation: 10.11mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with
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Preliminary Log of Investigation

Project: Grey Lynn Tunnel CIGI5

Borehole

Location: Hakanoa Reserve, Grey Lynn **Project No:** AE04725

Hole ID: CIE-BH02

Client: Watercare

Date: 19/03/2018

R.L. (m)	Depth (m)	Drilling Method	TCR (SCR) [RQD] %	Description of Strata	Comments	Geological Unit
-10		HQ3	91 (91) [91]			
-11	21			CORE LOSS.		
		HQ3	94	Moderately weathered, grey speckled white, dark grey, green and trace reddish brown flecks, massive, fine to medium grained SANDSTONE. Extremely weak. Recovered as fine to medium SAND with trace coarse sand and fine gravel; Very dense. *21.10m to 21.30m: Very thin, sub-horizontal, grey speckled black carbonaceous bed. 21.50m to 22.32m: Becomes slightly weathered.*	21.5m: Core biscuiting with drilling.	Wpvc(Contd.)
-12	22	HQ3	82	CORE LOSS - infer sand washed away from drilling.		
				Moderately weathered, grey speckled white, dark grey, green and trace reddish brown flecks, massive, fine to medium grained SANDSTONE. Extremely weak. Recovered as fine to medium SAND with trace coarse sand and fine gravel; Very dense.		
-13	23	HQ3	73	Moderately weathered, interbedded, fine to medium grained SANDSTONE and MUDSTONE. Extremely weak. Beds are very thin to moderately thin, gently inclined. Sandstone recovered as silty fine to medium SAND; Very dense. Mudstone recovered as CLAY; Hard.		Wuw
				CORE LOSS - infer sand washed away from drilling.		
-14	24	HQ3	75	Moderately weathered, grey, massive, fine to medium grained SANDSTONE. Extremely weak. Recovered as fine to medium SAND with some silt; very dense.	24m: Short run to improve recovery.	WpWpvc
				Slightly weathered, grey, interbedded medium grained SANDSTONE and MUDSTONE. Extremely weak. Beds are very thin, gently inclined. Sandstone recovered as silty fine to medium SAND; Very dense. Mudstone recovered as CLAY; Hard.		
-15	25	HQ3	80 (80) [80]	CORE LOSS.		
				Slightly weathered, grey, interbedded, medium grained SANDSTONE and MUDSTONE. Very weak. Beds are very thin to moderately thin, sub-horizontal.		
				CORE LOSS.		
				CIE-BH02 terminated at 25.50m. Target Depth		

Drilling Flush: *Flush Type:* Water, *Flush Colour:* Clear, slightly cloudy; *Flush Type:* Water, *Flush Colour:* Grey

Shift details & standing water level: 21/03/2018 3:30:00 PM; 20/03/2018 (Water depth 0m); 21/03/2018 6:00:00 PM (Water depth …); 22/03/2018 8:00:00 AM (Water depth 0m); 22/03/2018 1:45:00 PM (Water depth -1.35m)

Defect Description key — TYPE: CS Clay seam, C Cleavage, CR Crushed zone, DZ Decomposed zone, DB Drilling induced fracture, FL Foliation, FZ Fracture zone, IF Incipient fracture, JT Joint, SC Schistosity, SH Shear, SZ Shear Zone, SL Sill, VN Vein, VO Void. SURFACE: C Clean, Mc Mineral coat, Si Soil infill, Sn Surface stain, V Veneer. PLANARITY: P Planar, St Stepped, U Undulating. ROUGHNESS: R Rough, Ss Slickensided, Sm Smooth. APERTURE: T 0mm, Vn 0-2mm, N 2-6mm, Mn 6-20mm, Mw 20-60mm, W 60-200mm, Vw >200mm.

BOUNDARY: Well defined, Gradational, Poorly defined

Started:	19/03/2018
Finished:	22/03/2018
Driller:	McMillan
Plant:	Rig N107 (McMillan)
Logged:	A. Coutts
Checked:	CS

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations

Remarks
All hand vane results corrected, correction factor = 1.412
Packer Test at 18.70-21.50 m
Artesian piezometer, low pressure gauge installed.
Pressure reading on 25/05/2018 was 20 kPa.
Hole location determined by Survey.

Co-ordinates:
5919692.99mN
1754644.56mE
Elevation: 10.11mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

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AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: **Grey Lynn Tunnel CIGI5**			**Borehole**
Location: **41 Tawariki Street, Grey Lynn**	Project No: **AE04725**		Hole ID: **CIE-BH03**
Client: **Watercare**			Date: **23/03/2018**

Started: 23/03/2018	Remarks	Co-ordinates:
Finished: 27/03/2018	Packer Test at 20.00-24.50 m	5920068.77mN
Driller: McMillan	Artesian piezometer, low pressure gauge installed..	1754833.35mE
Plant: Rig N101 (McMillan)	Pressure reading on 25/05/2018 was 21 kPa.	Elevation: 13.34mRL
Logged: A. Coutts	Hole location determined by Survey.	Inclination: -90°
Checked: CS		Log cover page

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

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Preliminary Log of Investigation

Borehole

Project: **Grey Lynn Tunnel CIGI5**

Location: **41 Tawariki Street, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH03**

Client: **Watercare**

Date: **23/03/2018**

Column headings
R.L. (m)
Depth (m)
Shift Details & Standing Water Level / Drilling Method
Drilling Flush Return (%) 255075
TCR (SCR) [RQD] %
Spacing of Natural Defects (mm) 500 100 50 10
Relative Strength EW VW W MS S VS EW
Weathering Grade UW SW MW HW CW RW
Sampling
In-Situ Testing
Geology Legend
GroundWater
Description of Strata
Defect Description
Comments
Geological Unit
Backfill / Installation

BOUNDARY: Well defined; Gradational; Poorly defined

Defect Description key — TYPE: CS Clay seam; C Cleavage; CR Crushed zone; DZ Decomposed zone; DB Drilling induced fracture; FL Foliation; FZ Fracture zone; IF Incipient fracture; JT Joint; SC Schistosity; SH Shear; SZ Shear Zone; SL Sill; VN Vein; VO Void. SURFACE: C Clean; Mc Mineral coat; Si Soil infill; Sn Surface stain; V Veneer. PLANARITY: P Planar; St Stepped; U Undulating. ROUGHNESS: R Rough; Ss Slickensided; Sm Smooth. APERTURE: T 0mm; Vn 0-2mm; N 2-6mm; Mn 6-20mm; Mw 20-60mm; W 60-200mm; Vw >200mm.

R.L. scale: 13, 12, 11, 10, 9, 8, 7, 6, 5, 4. Depth scale: 1–10 m.

Drilling methods (top to bottom): VAC EX; HQ3 (23/03/2018 8:00:00 AM); TBX (23/03/2018); HQ3; SPT; TBX; HQ3; SPT; HQ3; SPT; HQ3; SPT; HQ3; SPT (Water depth 1.8m, 23/03/2018 3:00:00 PM, 26/03/2018 9:00:00 AM); HQ3.

Flush Type: Water. Flush Colour: Grey.

TCR (SCR) [RQD] % (top to bottom): 0; 100; 70; 100; 100; 100; 100; 78; 81 (74) [74]; 100; 92 (92) [92]; 0; 75 (75) [75]; 0; 100 (100).

Sampling: TW; TW; TW.

In-Situ Testing:
- SPT$_s$ 3,7,13 N=20
- SPT$_s$ 13,14,33 N=47
- SPT$_s$ 19,40 N>50 40/150 bouncing
- SPT$_c$ 34,33 N>50 33/75 bouncing
- SPT$_c$ 44 N>50 44/150 bouncing

Description of Strata:
- Vacuum Excavation.
- Silty CLAY with minor rootlets; light grey mottled orange and dark brown. Very soft, saturated, high plasticity. *1.70m: Becomes minor sand. Sand is fine.* *1.90m: Becomes dark grey.*
- PUSH TUBE: Material at top and bottom comprises: CLAY with minor silt and trace fine sand; dark grey mottled light brownish grey. Soft, saturated, low plasticity.
- CORE LOSS.
- CLAY with some silt; dark grey mottled light brownish grey. Soft, wet, high plasticity.
- SILT with minor clay and trace sand and rootlets; dark grey mottled orange. Very stiff, moist, low plasticity. Sand is fine.
- PUSH TUBE: Material at top is too deep in tube to obtain sample. Material at base is: Sandy SILT; dark grey. Hard, moist. Sand is fine.
- Highly weathered, dark grey, massive, fine grained SANDSTONE. Extremely weak. Recovered as fine SAND with some silt; Dense, moist. *4.48m to 4.50m: Becomes silty CLAY. Hard, moist, low plasticity.* *4.70m to 4.77m: Becomes SILT. Hard, moist, low plasticity.*
- CORE LOSS.
- Highly weathered, dark grey, massive, fine grained SANDSTONE. Extremely weak. Recovered as fine SAND with some silt; Dense, wet.
- Moderately weathered, interbedded, grey MUDSTONE and grey speckled white, green with trace red flecks SANDSTONE. Very weak. Mudstone beds are laminated to thin, sandstone beds are thin to moderately thin, sub-horizontal. With minor laminated to thin carbonaceous beds. *5.15m to 5.00m: Thin, sub-horizontal, grey speckled black, discontinuous carbonaceous bed.*
- Moderately weathered, grey speckled white, green with trace red flecks, massive, medium grained SANDSTONE. Very weak. With trace coarse sand and fine gravel, subrounded, mudstone.
- CORE LOSS.
- Moderately weathered, grey speckled white, green with trace red flecks, massive, medium grained SANDSTONE. Very weak. With trace coarse sand and fine gravel, subrounded, mudstone. *6.30m: Becomes slightly weathered.* *6.40m to 6.50m: Very thin, moderately inclined carbonaceous bed.*
- Slightly weathered, grey, massive, fine grained SANDSTONE. Very weak.
- Slightly weathered, grey, medium grained SANDSTONE. Extremely weak. Recovered as fine to medium SAND with some silt; Very dense.
- CORE LOSS.
- Slightly weathered, grey speckled white, green with trace red flecks, massive, medium grained SANDSTONE. Very weak. With minor coarse sand grains and trace fine gravel, subrounded, mudstone.
- CORE LOSS.
- Slightly weathered, grey speckled white, green with trace red flecks, medium grained SANDSTONE. Very weak. With minor coarse sand grains and trace fine gravel, subrounded, mudstone.
- Slightly weathered, grey speckled white and green with red flecks, massive, fine to coarse volcaniclastic SANDSTONE, very weak. With trace fine gravel sized, subrounded to subangular mudstone and

Comments:
- 2.7m: Rods sinking under own weight.
- 3.45m: Push tube could only be pushed 250mm, too hard.
- 6.3m: Core biscuiting with drilling.

Geological Unit (top to bottom): MG; Tp; Wwc; Wwnc; Wuw; Wpvc; Wuw; Wpvc; Wuw; Wpvc.

Started:	23/03/2018
Finished:	27/03/2018
Driller:	McMillan
Plant:	Rig N101 (McMillan)
Logged:	A. Coutts
Checked:	CS

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations

Remarks
Packer Test at 20.00-24.50 m
Artesian piezometer, low pressure gauge installed..
Pressure reading on 25/05/2018 was 21 kPa.
Hole location determined by Survey.

Co-ordinates:
5920068.77mN
1754833.35mE
Elevation: 13.34mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with
AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: **Grey Lynn Tunnel CIGI5**

Borehole

Location: **41 Tawariki Street, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH03**

Client: **Watercare**

Date: **23/03/2018**

Columns: R.L. (m) | Depth (m) | Shift Details & Standing Water Level / Drilling Method | Drilling Flush Return (%) | TCR (SCR) [RQD] % | Spacing of Natural Defects (mm) | Relative Strength | Weathering Grade | Sampling | In-Situ Testing | Geology Legend | GroundWater | Description of Strata | Defect Description | Comments | Geological Unit | Backfill / Installation

BOUNDARY: Well defined; Gradational; Poorly defined

Defect legend:
TYPE: CS Clay seam; C Clevage; CR Crushed zone; DZ Decomposed zone; DB Drilling induced fracture; FL Foliation; FZ Fracture zone; IF Incipient fracture; JT Joint; SC Schistosity; SH Shear; SZ Shear Zone; SL Sill; VN Vein; VD Void
SURFACE: C Clean; Mc Mineral coat; Si Soil infill; Sn Surface stain; V Veneer
PLANARITY: P Planar; St Stepped; U Undulating
ROUGHNESS: R Rough; Ss Slickensided; Sm Smooth
APERTURE: T 0mm; Vn 0-2mm; N 2-6mm; Mn 6-20mm; Mw 20-60mm; W 60-200mm; Vw >200mm

Flush Type: Water
Flush Colour: Grey

Depth (m)	Drilling Method	TCR (SCR) [RQD] %	In-Situ Testing	Description of Strata
10.0		[100]		sandstone clasts.
				Moderately weathered, grey, interbedded, fine grained SANDSTONE and MUDSTONE . Very weak. Sandstone beds are thin to moderately thin, gently inclined. Mudstone beds are laminated to thin, gently inclined.
10.5	SPT	0	SPT$_c$ 51 N>50 51/125 bouncing	*10.05m to 10.15m: Moderately thin, sub-horizontal, grey speckled black, discontinuous carbonaceous bed.*
				CORE LOSS.
11–12	HQ3	100 (100) [100]		Slighlty weathered, grey, bedded, medium grained SANDSTONE. Very weak. Beds are thin to moderately thin, gently inclined. With trace laminated, gently inclined, black carbonaceous beds.
12.0	SPT	0	SPT$_c$ 55 N>50 55/125 bouncing	CORE LOSS.
12–13.5	HQ3	96 (96) [96]		Slightly weathered, grey, interbedded, medium grained SANDSTONE and MUDSTONE. Very weak. Sandstone beds are thin to moderately thin, gently inclined. Mudstone beds are laminated to thin, gently inclined.
13.5–15	HQ3	93 (87) [87]		*13.92m: Very thin, gently inclined, black carbonaceous bed.*
				14.67m: Laminated, sub-horizontal, grey speckled black, discontinuous carbonaceous bed.
				CORE LOSS.
15–16.5	HQ3	93 (93) [93]		Slightly weathered, grey speckled white, green with trace red flecks, massive, medium grained SANDSTONE. Very weak. With minor coarse sand grains and trace fine gravel, subrounded, mudstone.
				Moderately weathered, grey speckled white and green with red flecks, massive, fine to coarse volcaniclastic SANDSTONE, very weak. With trace fine gravel sized, subrounded to subangular mudstone and sandstone clasts.
				15.32m to 15.52m: Coarse gravel sized, subrounded mudstone clasts.
				Moderately weathered, grey speckled white, green with trace red flecks, massive, medium grained SANDSTONE. Very weak. With minor coarse sand grains and trace fine gravel, subrounded, mudstone.
				15.49m: Very thin, gently inclined, black carbonaceous bed.
16.5–18	HQ3	93 (93) [93]		*15.95m to 16.15m: Becomes extremely weak. Recovered as fine to medium sand; Very dense.*
				16.20m: Very thin, moderately inclined carbonaceous bed.
				CORE LOSS.
				Highly weathered, grey speckled white and green with red flecks, massive, medium grained SANDSTONE, very weak. With trace fine gravel sized, subrounded to subangular mudstone and sandstone clasts and trace fine to medium gavel sized carbonaceous clasts.
				CORE LOSS.
18–19.5	HQ3	100 (100) [100]		Slightly weathered, grey, speckled white and green with red flecks, massive, fine to medium grained SANDSTONE, very weak. With trace fine to medium gravel sized, subrounded to subangular mudstone and sandstone clasts.
				18.47m to 18.54m: Moderately thin, sub-horizontal, grey banded and speckled black, discontinuous carbonaceous bed.
				18.90m to 19.00m: Becomes fine grained with carbonaceous clasts.
19.5–20	HQ3	100		*19.56m: Very thin, gently inclined, black carbonaceous bed.*

Depth scale: 11, 12, 13, 14, 15, 16, 17, 18, 19, 20. R.L. scale: 3, 2, 1, 0, -1, -2, -3, -4, -5, -6.

Defect Description

- 10.05: Jt 15° R, P, Vn, C.
- 10.97: Jt 5° Sm, P, T-Vn, C.
- 13.09: Jt 10° R, U, Vn, C.
- 13.20: Jt 5° Sm, P, T-Vn, C.
- 13.61: Jt 0° Sm, P, N, Si of clay.
- 14.35-14.45: Jt 75° Sm, U, Vn, C.
- 14.47-14.51: Jt 75° Sm, St, Vn, C.
- 16.61: Jt 5° Sm, U, Vn, C.
- 16.99-17.03: Jt 85° Sm, P, T-Vn, C.
- 18.38: Jt 0° Sm, P, N, Si of clay.

Comments

10.63m: Very closely spaced to closely spaced driling induced fractures.

Geological Unit: Wuw (to c. 15.0 m); Wpvc (below)

Started: 23/03/2018
Finished: 27/03/2018
Driller: McMillan
Plant: Rig N101 (McMillan)
Logged: A. Coutts
Checked: CS

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations

Remarks
Packer Test at 20.00-24.50 m
Artesian piezometer, low pressure gauge installed..
Pressure reading on 25/05/2018 was 21 kPa.
Hole location determined by Survey.

Co-ordinates:
5920068.77mN
1754833.35mE
Elevation: 13.34mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with
AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: **Grey Lynn Tunnel CIGI5**

Borehole

Location: **41 Tawariki Street, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH03**

Client: **Watercare**

Date: **23/03/2018**

Depth (m)	R.L. (m)	Drilling Method	TCR (SCR) [RQD] %	Description of Strata	Defect Description	Comments	Geological Unit
20.0–21.3	-7	HQ3	90 (70) [70]		20.08: Jt 0° R, P, Vn, C. 20.43-20.53: Jt 85° R, P, Vn, C. 20.55-20.61: Jt 85° R, P, Vn, C. 21.14-21.19: Jt 0° R, P, Mw, Si of rock fragments. 21.22: Jt 0° R, P, Mn, Si of clay.		Wpvc(Contd.)
21.3	-8	HQ3		CORE LOSS.			
21.4–22.4		HQ3	94 (94) [94]	Slightly weathered, grey speckled white and green with red flecks, massive, fine to medium grained SANDSTONE, very weak. With trace fine to medium gravel sized, subrounded to subangular mudstone and sandstone clasts.			
22.4	-9			CORE LOSS.			
22.5–24.3	-10	HQ3	100 (53) [53]	Slightly weathered, grey speckled white and green with red flecks, massive, medium grained SANDSTONE, very weak. With trace fine to medium gravel sized, subrounded to subangular mudstone and sandstone clasts. *23.30m to 24.00m: Becomes extremely weak. Recovered as fine to medium SAND with minor silt; Very dense.*			
24.3–24.6	-11	HQ3	42 (26) [26]	CORE LOSS. Infer sandstone broke and washed away while trying to recover run.		24m: Difficulty recovering run. Third attempted recovered with fingered catcher. 24.47m: Dipped hole for packer test. Replaced mud pit with fresh water.	
24.6–25.4		HQ3	92 (92) [92]	Slightly weathered, grey speckled white and green with red flecks, massive, fine to coarse grained SANDSTONE, very weak. With trace fine gravel sized, subrounded mudstone and sandstone clasts.			
25.4–25.9	-12			Slightly weathered, interbedded, medium grey speckled white, green and flecks of red, medium grained SANDSTONE and dark grey MUDSTONE . Very weak. Sandstone beds are thin to moderately thin, mudstone beds are laminated to thin, gently inclined. *25.30m: Very thin, sub-horizontal, black carbonaceous bed.* *25.63m to 25.88m: Beds become steeply inclined.*			Wuw
25.9				CORE LOSS.			
26.0–26.8	-13	HQ3	100 (100) [100]	Slightly weathered, grey, massive, medium grained SANDSTONE. Very weak.			
26.8–27.5	-14			Slightly weathered, grey speckled white, green and flecks of red, massive, medium grained SANDSTONE. Very weak.			Wpvc

CIE-BH03 terminated at 27.50m. Target Depth

Shift Details & Standing Water Level: 26/03/2018 4:00:00 PM; 27/03/2018 8:00:00 AM(Water depth 0.9m); 27/03/2018 2:00:00 PM(Water depth 0.9m); 28/03/2018 9:15:00 AM(Water depth 0.7m)

Drilling Flush Return: Flush Type: Water, Flush Colour: Clear, slightly cloudy; Flush Type: Water, Flush Colour: Grey

Started: 23/03/2018
Finished: 27/03/2018
Driller: McMillan
Plant: Rig N101 (McMillan)
Logged: A. Coutts
Checked: CS

Groundwater Observations
No. Struck (m) Date Standing (m) Observations

Remarks
Packer Test at 20.00-24.50 m
Artesian piezometer, low pressure gauge installed..
Pressure reading on 25/05/2018 was 21 kPa.
Hole location determined by Survey.

Co-ordinates:
5920068.77mN
1754833.35mE
Elevation: 13.34mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with **AECOM and McMillen Jacobs Associates**	**Preliminary Log of Investigation**
Project: **Grey Lynn Tunnel CIGI5**	**Borehole**
Location: **46 Tawariki Street, Grey Lynn** Project No: **AE04725**	Hole ID: **CIE-BH04**
Client: **Watercare**	Date: **5/07/2018**

Started: 5/07/2018	Remarks		Co-ordinates:
Finished: 10/07/2018	Packer Test 1 at 9.75-12.00 m, Packer Test 2 at 19.25-22.50 m, Packer Test 3 at 28.50-31.50 m. Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.1 m RL. Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0. Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946 Hole location determined by Survey.		5920092.60mN
Driller: McMillan			1754813.92mE
Plant: Rig N111 (McMillan)			Elevation: 12.29mRL
Logged: S. Burgess			Inclination: -90°
Checked: LD			Log cover page

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: Grey Lynn Tunnel CIGI5

Borehole

Location: 46 Tawariki Street, Grey Lynn **Project No:** AE04725

Hole ID: CIE-BH04

Client: Watercare

Date: 5/07/2018

Columns: R.L. (m) | Depth (m) | Shift Details & Standing Water Level / Drilling Method | Drilling Flush Return (%) (25 50 75) | TCR (SCR) [RQD] % | Spacing of Natural Defects (mm) (500, 100, 50, 10) | Relative Strength (EW, VW, W, MS, S, VS) | Weathering Grade (UW, SW, MW, HW, CW, RW) | Sampling | In-Situ Testing | Geology Legend | GroundWater | Description of Strata | Defect Description | Comments | Geological Unit | Backfill / Installation

BOUNDARY: Well defined; Gradational; Poorly defined

Defect Description key

TYPE		SURFACE		APERTURE	
CS	Clay seam	C	Clean	T	0mm
C	Clevage	Mc	Mineral coat	Vn	0-2mm
CR	Crushed zone	Si	Soil infill	N	2-6mm
DZ	Decomposed zone	Sn	Surface stain	Mn	6-20mm
DB	Drilling induced fracture	V	Veneer	Mw	20-60mm
FL	Foliation			W	60-200mm
FZ	Fracture zone	**PLANARITY**		Vw	>200mm
IF	Incipient fracture	P	Planar		
JT	Joint	St	Stepped		
SC	Schistosity	U	Undulating		
SH	Shear				
SZ	Shear Zone	**ROUGHNESS**			
SL	Sill	R	Rough		
VN	Vein	Ss	Slickensided		
VD	Void	Sm	Smooth		

Drilling Method / Core Recovery

Drilling Method	TCR (SCR) [RQD] %
VAC EX	0
SPT	33
HQ3	81
SPT	100
HQ3	59
SPT	100
HQ3	95 (35) [35]
SPT	0
HQ3	98 (71) [95]
SPT	0
HQ3	100 (100) [100]
SPT	0
HQ3	96 (96)

Shift details: 5/07/2018 4:00:00 PM(Water depth 0m); 6/07/2018 7:30:00 AM(Water depth 1.33m)

Flush Type: **Water** *Flush Colour:* **Grey**

In-Situ Testing

Test	Blows	Result
SPT_s	0,0,0	N<1
SPT_s	2,6,10	N=16
SPT_s	8,17,20	N=37
SPT_c	50	N>50 50/140
SPT_c	26,35,15	N>50 50/220
SPT_c	50	N>50 50/110

Description of Strata

Description of Strata	Geological Unit
Vacuum Excavation.	MG
Silty SAND, trace rootlets, gravel; brown, homogeneous. Very soft, moist, insensitive; one angular gravel clast (50 mm).	MG
Silty SAND to CLAY with some organics, trace gravel; brown and grey, mixed. Very soft, moist, low plasticity, debris found throughout including sharp metal fragments and gravel. Soil is uncontrolled fill and randomly changes from silty sand to clay throughout this depth. *2.60m: Metal Fragment.*	MG
CORE LOSS. *3.45m: Vitrified clay cobble (60mm).* *3.55m: 3 basalt/brick gravel sized fragments (50mm).*	MG
Silty SAND to CLAY with some organics, trace gravel; brown and grey mixed. Very soft, moist, low plasticity, debris found throughout including sharp metal fragments and gravel. Soil is uncontrolled fill and randomly changes from silty sand to clay throughout this depth.	MG
Residually weathered, SANDSTONE. Silty fine SAND, with some clay; dark grey, homogeneous. Soft, moist, low plasticity, moderately sensitive. *4.59m to 4.65m: Residual Mudstone bed. Dark grey CLAY* *5.20m to 5.30m: Residual Mudstone bed. Dark grey CLAY*	Wwc
Highly weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Extremely weak. Bedding is gently inclined, sandstone beds are moderately thin, mudstone beds are thin. Sandstone has occasional red flecks. Black carbonaceous beds approx 5mm thick present throughout deposit at very widely spaced intervals. *6.58m: Becomes moderately weathered and weak.* *7.45m to 7.50m: Fracture zone.* *9.50m: Becomes very weak*	Wwnc

Defect Description

- 6.85: Jt 90° R, P, Vn, C.
- 7.03: Jt 45° R, St, Vn, C.
- 7.05: Jt 70° R, P, Vn, C.
- 7.21: Jt 70° R, St, Vn, C.
- 7.33: Jt 45° R, St, Vn, C.
- 7.40: Jt 70° R, P, Vn, Si of clay.
- 7.45-7.50: Sz.
- 9.30: Jt 90° R, P, Vn, C.

Comments: 3m: Cased to 3.0 m.

Started:	5/07/2018
Finished:	10/07/2018
Driller:	McMillan
Plant:	Rig N111 (McMillan)
Logged:	S. Burgess
Checked:	LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	-3.78	14/09/2018		Midday WL

Remarks

Packer Test 1 at 9.75-12.00 m, Packer Test 2 at 19.25-22.50 m, Packer Test 3 at 28.50-31.50 m. Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.1 m RL.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946
Hole location determined by Survey.

Co-ordinates: 5920092.60mN 1754813.92mE
Elevation: 12.29mRL
Inclination: -90°

Jacobs in association with AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: Grey Lynn Tunnel CIGI5 | **Borehole**

Location: 46 Tawariki Street, Grey Lynn | **Project No:** AE04725 | **Hole ID:** CIE-BH04

Client: Watercare | **Date:** 5/07/2018

Depth (m)	TCR (SCR) [RQD] %	Description of Strata	Defect Description	Geological Unit
10.00–10.05	[96]	CORE LOSS.		Wwnc(Contd.)
10.05–10.85		Moderately weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Extremely weak. Bedding is sub-horizontal, sandstone beds are moderately thin, mudstone beds are thin. Sandstone has occasional red flecks. Black carbonaceous beds approx 5mm thick present throughout deposit at very widely spaced intervals.	10.17: Jt 70° R, P, Vn, C. 10.68: Jt 85° R, U, Vn, C. 10.75: Jt 85° R, U, Vn, C. 10.77: Jt 85° R, U, Vn, C.	Wwnc(Contd.)
10.85–11.65	100 (94) [94]	Highly weathered, dark grey, homogeneous, fine grained SANDSTONE. Extremely weak.		Wwnc(Contd.)
11.65–12.30		Highly weathered, dark grey, homogeneous, medium grained SANDSTONE. Extremely weak. *11.83m to 11.85m: Very thin, sub-horizontal, black carbonaceous bed.*		Wpvc
12.30–12.70	47 (23) [23]	CORE LOSS.		Wwnc
12.70–13.05		Completely weathered, dark grey, homogeneous, fine grained SANDSTONE. Recovered as fine silty SAND, trace clay.Tightly packed, moist.		Wwnc
13.05–13.60		CORE LOSS.		Wwnc
13.60–14.05		Completely weathered, dark grey, homogeneous, fine grained SANDSTONE. Recovered as fine silty SAND, trace clay.Tightly packed, moist.		Wwnc
14.05–16.40	90 (87) [87] 97 (97) [97]	Highly weathered, dark grey, homogeneous, fine grained SANDSTONE. Extremely weak. Minor white clasts present throughout matrix (1mm). Silty SAND. Loosely packed, moist. *15.05m to 15.55m: Trace green clasts (1-3 mm)* *15.10m: Becomes moderately weathered* *15.45m to 15.50m: Thin, sub-horizontal, black carbonaceous bed.*		Wwnc
16.40–16.85		Highly weathered, dark grey, homogeneous, fine to medium grained SANDSTONE. Extremely weak. Minor white clasts present throughout matrix (1mm). Silty SAND. Loosely packed, moist.		Wpvc
16.85–17.00		CORE LOSS.		Wwnc
17.00–20.00	83 (83) [83] 100 (100) [100]	Moderately weathered, dark grey, interbedded, fine to coarse grained SANDSTONE and MUDSTONE. Very weak. Bedding is sub-horizontal, sandstone beds are moderately thin, mudstone beds are thin. Black carbonaceous beds, laminated to thin, present throughout deposit at widely spaced intervals. *18.13m to 18.15m: Thin, sub-horizontal, black carbonaceous bed.* *18.70m to 19.30m: Laminated to thin, sub-horizontal, black carbonaceous beds.*	17.45: Jt 85° R, P, Vn, C. 18.00: Jt 85° R, St, Vn, C. 18.72: Jt 85° R, P, Vn, C. 18.94: Jt 85° R, P, Vn, C. 19.30: Jt 85° R, St, Vn, C. 19.43: Jt 85° R, St, Vn, C.	Wuw

R.L. (m): 2, 1, 0, -1, -2, -3, -4, -5, -6, -7

Drilling Method: HQ3

Shift Details & Standing Water Level: 6/07/2018 4:00:00 PM HQ3 9/07/2018 7:30:00 AM(Water depth 2m)

Drilling Flush Return (%): Flush Type: Water, Flush Colour: Grey

Started: 5/07/2018
Finished: 10/07/2018
Driller: McMillan
Plant: Rig N111 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	-3.78	14/09/2018		Midday WL

Remarks

Packer Test 1 at 9.75-12.00 m, Packer Test 2 at 19.25-22.50 m, Packer Test 3 at 28.50-31.50 m. Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.1 m RL.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946
Hole location determined by Survey.

Co-ordinates: 5920092.60mN 1754813.92mE
Elevation: 12.29mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

R.L. (m)	Depth (m)	Drilling Method	TCR (SCR) [RQD] %	Description of Strata	Defect Description	Geological Unit
-8	20–21	HQ3	93 (93) [93]		20.30: Jt 75° R, P, Vn, C.	Wuw(Contd.)
	~20.8			CORE LOSS.		
-9	21–22	HQ3	100 (96) [96]	Moderately weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Very weak. Bedding is gently inclined, sandstone beds are moderately thin, mudstone beds are thin. Black carbonaceous beds, laminated to thin, present throughout deposit at widely spaced intervals. *21.45m to 21.48m: Fracture zone. Coal.*	21.20: Jt 75° R, P, Vn, C. 21.39: Jt 75° R, P, Vn, C. 21.45-21.48: Sz Vn, C, Highly fractured coal. 21.58: Jt 50° R, U, Vn, C. 21.97: Jt 75° R, P, T, C. 22.14: Jt 75° R, U, Vn, C.	Wuw(Contd.)
-10 / -11	22–24	HQ3	100 (100) [100]	Moderately weathered, dark grey, homogeneous, medium grained SANDSTONE. Very weak. Minor white clasts present throughout matrix (1mm), trace dark brownish green mudstone clasts (2-6 mm). Local, very thin mudstone beds are present.		Wpvc
-12 / -13	24–25.5	HQ3	100 (100) [100]	Moderately weathered, dark grey, homogeneous, fine grained SANDSTONE. Very weak. Minor white clasts present throughout matrix (1mm). Local, very thin mudstone beds are present. *24.30m: Becomes medium grained.* *24.68m: Becomes fine grained.* *24.82m: Thin, gently inclined, grey speckled black, discontinuous carbonaceous bed.* *24.92m: Becomes medium grained.* *25.11m to 25.22m: Mudstone bed.* *25.68m to 25.71m: Mudstone bed.*	24.82: Jt 75° R, P, Vn, C.	Wuw
-14	26–27	HQ3	93 (93) [93]			Wuw
	~26.6			CORE LOSS.		
-15	27–28	HQ3	96 (96) [96]	Moderately weathered, dark grey, homogeneous, medium grained SANDSTONE. Very weak. Minor white clasts present throughout matrix (1mm), trace dark brownish green mudstone clasts (2-6 mm). *27.16m to 27.18m: Mudstone bed.*		Wuw
-16	27.5–28.8			Moderately weathered, dark grey, homogeneous, medium grained SANDSTONE. Very weak. Minor white clasts present throughout matrix (1mm), trace dark brownish green mudstone clasts (2-6 mm). *28.05m to 28.25m: Becomes coarse grained.*		Wpvc
	~28.8			CORE LOSS.		
-17	29–30	HQ3	95 (95) [95]	Moderately weathered, dark grey, homogeneous, medium grained SANDSTONE. Very weak. Minor white clasts present throughout matrix (1mm), trace dark brownish green mudstone clasts (2-6 mm). *28.90m: Becomes extremely weak.* *29.27m: Becomes slightly weathered and strong.* *29.47m: Becomes moderately weathered and very weak.*	29.37: Jt 30° R, P, T, C.	Wpvc

Shift Details & Standing Water Level: 9/07/2018 1:45:00 PM(Water depth 0.97m); 9/07/2018 4:00:00 PM; 10/07/2018 7:30:00 AM(Water depth 0.6m)

Drilling Flush Return: 255075 — Flush Type: Water, Flush Colour: Grey

Legend: BOUNDARY — Well defined, Gradational, Poorly defined. TYPE: CS Clay seam, C Cleavage, CR Crushed zone, DZ Decomposed zone, DB Drilling induced fracture, FL Foliation, FZ Fracture zone, IF Incipient fracture, JT Joint, SC Schistosity, SH Shear, SZ Shear Zone, SL Sill, VN Vein, VO Void. SURFACE: C Clean, Mc Mineral coat, Si Soil infill, Sn Surface stain, V Veneer. PLANARITY: P Planar, St Stepped, U Undulating. ROUGHNESS: R Rough, Ss Slickensided, Sm Smooth. APERTURE: T 0mm, Vn 0-2mm, N 2-6mm, Mn 6-20mm, Mw 20-60mm, W 60-200mm, Vw >200mm.

Started: 5/07/2018
Finished: 10/07/2018
Driller: McMillan
Plant: Rig N111 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	-3.78	14/09/2018		Midday WL

Remarks

Packer Test 1 at 9.75-12.00 m, Packer Test 2 at 19.25-22.50 m, Packer Test 3 at 28.50-31.50 m. Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.1 m RL.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946
Hole location determined by Survey.

Co-ordinates: 5920092.60mN 1754813.92mE
Elevation: 12.29mRL
Inclination: -90°

Jacobs in association with
AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: **Grey Lynn Tunnel CIGI5**

Borehole

Location: **46 Tawariki Street, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH04**

Client: **Watercare**

Date: **5/07/2018**

R.L. (m)	Depth (m)	Shift Details & Standing Water Level / Drilling Method	Drilling Flush Return (%)	TCR (SCR) [RQD] %	Description of Strata	Defect Description
-18		HQ3	Flush Type: Water; Flush Colour: Grey		CORE LOSS.	
	31			94 (94) [94]	Moderately weathered, dark grey, homogeneous, medium grained SANDSTONE. Very weak. Minor white clasts present throughout matrix (1mm), trace dark brownish green mudstone clasts (2-6 mm).	30.47: Jt 30° P, T, C. 30.54: Jt 30° P, T, C. 30.61: Jt 30° P, T, C. 30.68: Jt 30° P, T, C. 30.75: Jt 30° P, T, C.
-19					*31.06m to 31.11m: Mudstone bed.*	

Geological Unit: Ww

CIE-BH04 terminated at 31.50m. Target Depth

10/07/2018 4:00:00 PM

17/07/2018 7:30:00 AM(Water depth 0.8m)

Key — Boundary: Well defined; Gradational; Poorly defined. Type: CS Clay seam; C Cleavage; CR Crushed zone; DZ Decomposed zone; DB Drilling induced fracture; FL Foliation; FZ Fracture zone; IF Incipient fracture; JT Joint; SC Schistosity; SH Shear; SZ Shear Zone; SL Sill; VN Vein; VO Void. Surface: C Clean; Mc Mineral coat; Si Soil infill; Sn Surface stain; V Veneer. Planarity: P Planar; St Stepped; U Undulating. Roughness: R Rough; Ss Slickensided; Sm Smooth. Aperture: T 0mm; Vn 0-2mm; N 2-6mm; Mn 6-20mm; Mw 20-60mm; W 60-200mm; Vw >200mm.

Started: 5/07/2018
Finished: 10/07/2018
Driller: McMillan
Plant: Rig N111 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	-3.78	14/09/2018		Midday WL

Remarks
Packer Test 1 at 9.75-12.00 m, Packer Test 2 at 19.25-22.50 m, Packer Test 3 at 28.50-31.50 m. Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.1 m RL.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946
Hole location determined by Survey.

Co-ordinates:
5920092.60mN
1754813.92mE
Elevation: 12.29mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with AECOM and McMillen Jacobs Associates		Preliminary Log of Investigation
Project: **Grey Lynn Tunnel CIGI5**		**Borehole**
Location: **44 Tawariki Street, Grey Lynn**	Project No: **AE04725**	Hole ID: **CIE-BH05**
Client: **Watercare**		Date: **11/07/2018**

Started: 11/07/2018 Finished: 13/07/2018 Driller: McMillan Plant: Rig N111 (McMillan) Logged: S. Burgess Checked: LD	Remarks Packer Test 1: 11.00 - 13.50 m, Packer Test 2: 19.00 - 21.00 m, Packer Test 3: 28.50 - 31.50 m. Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.0 m. Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0. Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946 Hole location determined by Survey.	Co-ordinates: 5920115.28mN 1754793.05mE Elevation: 11.59mRL Inclination: -90° Log cover page

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with
AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: Grey Lynn Tunnel CIGI5

Borehole

Location: 44 Tawariki Street, Grey Lynn **Project No:** AE04725

Hole ID: CIE-BH05

Client: Watercare

Date: 11/07/2018

R.L. (m)	Depth (m)	Drilling Method	TCR (SCR) [RQD] %	In-Situ Testing	Description of Strata	Comments	Geological Unit
11.59–9.59	0.0–2.0	VAC EX	0		Vacuum Excavation		MG
	2.0	SPT	100	SPT 1,2,2 N=4	Silty CLAY; light grey mottled orange. Very soft, moist, high plasticity, not dilatant.		T
		HQ3 (11/07/2018 7:30:00 AM (Water depth 0.3m))	100		*2.25m: Becomes brown grey with some wood fragments. Soft.* *2.70m: Becomes firm.*		T
	3.0	TBX	100		Push Tube. Material change at 3.1m from silty CLAY to silty clayey SAND.	3m: Cased to 3.0 m.	Wwc
		SPT	100	SPT 0,0,1 N=1	Residually weathered, SANDSTONE. Clayey silty fine SAND; dark grey, homogeneous. Soft, moist, low plasticity, low dilatancy.		Wwc
		HQ3	100				
		TBX	100		Push Tube. *4.50m: Becomes firm.*		
		SPT	100	SPT 6,11,12 N=23	Residually weathered, SANDSTONE. Clayey silty fine SAND; dark grey, homogeneous. Firm, moist, low plasticity, Insensitive		
					CORE LOSS.		
		HQ3	77 (77) [77]		Highly weathered, fine grained SANDSTONE. Extremely weak. Clayey silty fine SAND; dark grey, homogeneous. Dense, moist.		
		SPT	100	SPT 5,9,11 N=20	*6.45m to 6.80m: Recovered as Silty fine SAND*		
		HQ3	67 (33) [33]		CORE LOSS.		
		SPT	100	SPT 8,12,19 N=31	Highly weathered, fine grained SANDSTONE. Extremely weak. Silty fine SAND, some clay; dark grey, homogeneous. Dense, moist.		Wwnc
		HQ3 (11/07/2018 4:00:00 PM)	71 (65) [65]		Highly weathered, dark grey, BRECCIA with fine to medium gravel sized, angular to sub-rounded mudstone clasts in a well cemented fine sandstone matrix. Extremely weak.		Wwnc
					Core loss. Infer BRECCIA and a mudstone clast blocked catcher.		
					Highly weathered, dark grey, BRECCIA with fine to medium gravel sized, angular to sub-rounded mudstone clasts in a well cemented fine sandstone matrix. Extremely weak.		
		SPT (12/07/2018 7:30:00 AM (Water depth 0.2m))	100	SPT 12,20,30 N>50 50/290	Highly weathered, fine grained SANDSTONE. Extremely weak. Silty fine SAND, some clay; dark grey, homogeneous. Very dense, moist.		
	10.0				Highly weathered, dark grey, BRECCIA, fine to medium gravel sized, sub- rounded mudstone and fine grained sandstone clasts in a fine		Wwc

Drilling Flush: *Flush Type: Water, Flush Colour: Grey*

Column headings: R.L. (m); Depth (m); Shift Details & Standing Water Level / Drilling Method; Drilling Flush Return (%) (25 50 75); TCR (SCR) [RQD] %; Spacing of Natural Defects (mm) (500 100 50 10); Relative Strength (EW VW W MS S VS); Weathering Grade (RS SW MW HW CW EW); Sampling; In-Situ Testing; Geology Legend; GroundWater; Description of Strata; Defect Description; Comments; Geological Unit; Backfill / Installation

BOUNDARY: Well defined; Gradational; Poorly defined

Defect Description

TYPE: CS Clay seam; C Cleavage; CR Crushed zone; DZ Decomposed zone; DB Drilling induced fracture; FL Foliation; FZ Fracture zone; IF Incipient fracture; JT Joint; SC Schistosity; SH Shear; SZ Shear Zone; SL Sill; VN Vein; VO Void

SURFACE: C Clean; Mc Mineral coat; Si Soil infill; Sn Surface stain; V Veneer

PLANARITY: P Planar; St Stepped; U Undulating

ROUGHNESS: R Rough; Ss Slickensided; Sm Smooth

APERTURE: T 0mm; Vn 0-2mm; N 2-6mm; Mn 6-20mm; Mw 20-60mm; W 60-200mm; Vw >200mm

Started: 11/07/2018
Finished: 13/07/2018
Driller: McMillan
Plant: Rig N111 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	-4.39	13/09/2018		End of Day WL

Remarks
Packer Test 1: 11.00 - 13.50 m, Packer Test 2: 19.00 - 21.00 m, Packer Test 3: 28.50 - 31.50 m.
Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.0 m RL.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946 Hole location determined by Survey.

Co-ordinates:
5920115.28mN
1754793.05mE
Elevation: 11.59mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with
AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: **Grey Lynn Tunnel CIGI5**

Borehole

Location: **44 Tawariki Street, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH05**

Client: **Watercare**

Date: **11/07/2018**

Columns: R.L. (m) | Depth (m) | Shift Details & Standing Water Level / Drilling Method | Drilling Flush Return (%) | TCR (SCR) [RQD] % | Spacing of Natural Defects (mm) | Relative Strength | Weathering Grade | Sampling | In-Situ Testing | Geology Legend | GroundWater | Description of Strata | Defect Description | Comments | Geological Unit | Backfill / Installation

BOUNDARY: Well defined; Gradational; Poorly defined

Defect Description key – TYPE: CS Clay seam; C Cleavage; CR Crushed zone; DZ Decomposed zone; DB Drilling induced fracture; FL Foliation; FZ Fracture zone; IF Incipient fracture; JT Joint; SC Schistosity; SH Shear; SZ Shear Zone; SL Sill; VN Vein; VO Void. SURFACE: C Clean; Mc Mineral coat; Si Soil infill; Sn Surface stain; V Veneer. PLANARITY: P Planar; St Stepped; U Undulating. ROUGHNESS: R Rough; Ss Slickensided; Sm Smooth. APERTURE: T 0mm; Vn 0-2mm; N 2-6mm; Mn 6-20mm; Mw 20-60mm; W 60-200mm; Vw >200mm

Drilling Flush Return (%): 25 50 75. Spacing of Natural Defects (mm): 500, 100, 50, 10. Relative Strength: EW, VW, W, MS, S, VS, ES. Weathering Grade: RS, CW, HW, MW, SW, UW.

Flush Type: Water. Flush Colour: Grey

Shift details: 12/07/2018 4:00:00 PM; 13/07/2018 7:30:00 AM(Water depth 0m)

Drilling Method	TCR (SCR) [RQD] %
HQ3	58 (25) [25]
SPT	100
HQ3	76 (48) [48]
SPT	100
HQ3	89 (89) [87]
SPT	0
HQ3	91 (91) [91]
SPT	0
HQ3	92 (92) [92]
HQ3	83 (83) [83]
HQ3	97 (97) [97]

In-Situ Testing:
- SPT$_s$ 10,16,25 N=41
- SPT$_s$ 13,24,26 N>50 50/280
- SPT$_c$ 50 N>50 50/120
- SPT$_c$ 50 N>50 50/82

Description of Strata:

- grained sandstone matrix. Recovered as clasts with silty fine SAND; dense.
- Highly weathered, dark grey, interbedded, moderately thinly bedded fine grained SANDSTONE and thinly bedded MUDSTONE. Sub-horizontal bedding. Extremely weak. Mudstone has trace black carbonaceous material.
- CORE LOSS. Infer residual BRECCIA from 10.2m. Clast blocked catcher.
- Completely weathered, dark grey, BRECCIA recovered as a silty CLAY with subangular mudstone clasts (5-10mm). Soft, moist, low plasticity.
- Highly weathered, dark grey, BRECCIA with fine to coarse gravel sized, sub-angular to sub-rounded mudstone clasts and some wood fragments in a fine grained sandstone matrix. Very weak. *11.57m: Recovered as clasts only; infer matrix washed out.*
- CORE LOSS.
- Highly weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Sandstone beds are moderately thin, sub-horizontal. Mudstone beds are thin to moderately thin, sub-horizontal. Very weak.
- CORE LOSS.
- Highly weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Sandstone beds are moderately thin, moderately inclined. Mudstone beds are thin to moderately thin, moderately inclined. Very weak.
- CORE LOSS.
- Highly weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Sandstone beds are moderately thin, moderately inclined. Mudstone beds are thin to moderately thin, moderately inclined. Very weak. *14.70m to 15.00m: Becomes interbedded with laminated carbonaceous beds (black). 14.77m: Becomes weak. 15.12m to 15.33m: Moderately weathered, moderately thick SANDSTONE bed. Moderately strong.*
- Moderately weathered, dark grey, homogeneous fine grained SANDSTONE.Weak, moderately inclined. *15.83m: Becomes medium grained with white and cream fine gravel sized clasts and black speckles inferred as trace carbonaceous material.*
- CORE LOSS.
- Moderately weathered, dark grey, homogeneous, fine grained SANDSTONE. Weak, moderately inclined. Minor white clasts present throughout matrix (1mm).
- Moderately weathered, dark grey, homogeneous, fine to medium grained SANDSTONE. Weak. Minor white clasts present throughout matrix (1mm). *17.10m to 17.45m: Extremely weak.*
- CORE LOSS.
- Slightly weathered, dark grey, fine to medium grained SANDSTONE. Strong. Matrix has some sand to fine gravel sized white and cream clasts and discontinuous black carbonaceous beds.
- Moderately weathered, dark grey, fine to medium grained SANDSTONE. Very weak. Minor white clasts present throughout matrix (1mm). *18.26m: Becomes extremely weak 18.50m: Becomes very weak.*
- Moderately weathered, dark grey, medium to coarse grained SANDSTONE. Extremly weak. Minor white clasts present throughout matrix (1mm).

Defect Description:

- 12.43: Jt 90° Sm, P, Vn, C.
- 12.45: Jt 90° Sm, P, Vn, C.
- 12.67: Jt 90° R, St, Vn, C.
- 13.37: Jt 70° R, P, Vn, C.
- 13.65: Jt 70° Sm, U, Vn, Si of sandy clay.
- 13.95: Jt 70° R, P, Vn, C.
- 14.90: Jt 70° R, St, Vn, C.
- 15.34: Jt 70° R, P, Vn, C.
- 16.15: Jt 70° R, P, Vn, C.
- 18.55: Jt 10° Sm, P, T, C, joint is displaced by 10mm.

Geological Unit: Wwc(Contd.); Wwnc; Wwc; Wuw; Wpvc

Depth (m): 11, 12, 13, 14, 15, 16, 17, 18, 19, 20. R.L. (m): 1, 0, -1, -2, -3, -4, -5, -6, -7, -8

Started: 11/07/2018
Finished: 13/07/2018
Driller: McMillan
Plant: Rig N111 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	-4.39	13/09/2018		End of Day WL

Remarks
Packer Test 1: 11.00 - 13.50 m, Packer Test 2: 19.00 - 21.00 m, Packer Test 3: 28.50 - 31.50 m.
Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.0 m RL.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946 Hole location determined by Survey.

Co-ordinates:
5920115.28mN
1754793.05mE
Elevation: 11.59mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: **Grey Lynn Tunnel CIGI5**

Borehole

Location: **44 Tawariki Street, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH05**

Client: **Watercare**

Date: **11/07/2018**

Depth (m)	Drilling Method	TCR (SCR) [RQD] %	Description of Strata	Defect Description	Comments	Geological Unit
20.0–21.0	HQ3	93 (93) [93]	Moderately weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Very weak, moderately inclined. Sandstone beds are moderately thick, mudstone beds are thin. With trace laminated to thin carbonaceous beds.	20.75: Jt 70° R, P, Vn, C.	20m: Borehole becomes artesian.	Wuw(Contd.)
			CORE LOSS.			
21.0–22.5	HQ3	87 (87) [87]	Moderately weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Very weak, moderately inclined. Sandstone beds are moderately thick, mudstone beds are thin. With trace laminated to thin carbonaceous beds. *21.23m to 21.53m: Moderately thick sandstone bed.* *22.01m to 22.65m: Thick sandstone bed.*	21.08: Jt 70° R, P, Vn, C. 21.30: Jt 70° R, P, Vn, C. 21.45: Jt 70° R, P, Vn, C. 21.69: Jt 70° R, P, Vn, C.		
			CORE LOSS.			
22.5–24.0	HQ3	96 (96) [96]	Moderately weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Very weak, moderately inclined. Sandstone beds are moderately thick, mudstone beds are thin. With trace laminated to thin carbonaceous beds. *23.24m to 23.41m: Slightly weathered, moderately thick, fine grained sandstone bed. Strong.* *23.41m to 24.20m: Moderately thick medium grained sandstone bed.*	22.79: Jt 70° R, U, Vn, C. 23.15: Jt 70° R, P, Vn, C. 23.48: Jt 70° R, P, Vn, C. 24.00: Jt 70° R, P, Vn, C. 24.25-24.30: Fz R, St, Mw, Si of rock fragments and sandy clay. 24.27: Jt 70° R, P, Vn, C.		
24.0–25.5	HQ3	87 (76) [76]	Moderately weathered, grey with trace white speckles, fine grained to coarse SANDSTONE. Very weak. With trace fine gravel sized mudstone clasts.			
			Moderately weathered, dark grey, BRECCIA with fine to medium gravel sized, angular to sub-rounded mudstone clasts in a fine sandstone matrix. Extremely weak.	25.13: Jt 70° R, U, Vn, C.		
			CORE LOSS.			
25.5–27.0	HQ3	93 (93) [93]	Moderately weathered, dark grey speckled white, coarse grained SANDSTONE. Very weak. With trace fine to medium gravel sized, sub-angular mudstone clasts. *25.82m: Becomes weak.* *26.20m to 26.35m: Moderately thick medium grained sandstone bed.*	26.39: Jt 70° R, U, Vn, C.		Wpvc
			CORE LOSS.			
27.0–28.5	HQ3	83 (83) [83]	Moderately weathered, dark grey speckled white, coarse grained SANDSTONE. Very weak. With trace fine to medium gravel sized, sub-angular mudstone clasts.	27.20: Jt 50° R, P, Vn, C. 27.34: Jt 70° R, P, Vn, C. 27.86: Jt 70° R, P, Vn, C.		
			CORE LOSS.			
28.5–30.0	HQ3	100 (100) [100]	Moderately weathered, dark grey speckled white, coarse grained SANDSTONE. Very weak. With trace fine to medium gravel sized, sub-angular mudstone clasts. *29.48m to 29.54m: Moderately thin bed of discontinuous carbonaceous material.*	29.42: Jt 70° R, P, Vn, C.		

Flush Type: **Water** Flush Colour: **Clear**

R.L. (m): -9 to -18 (depth 20–30 m)

Started: 11/07/2018
Finished: 13/07/2018
Driller: McMillan
Plant: Rig N111 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	-4.39	13/09/2018		End of Day WL

Remarks
Packer Test 1: 11.00 - 13.50 m, Packer Test 2: 19.00 - 21.00 m, Packer Test 3: 28.50 - 31.50 m.
Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.0 m RL.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946 Hole location determined by Survey.

Co-ordinates:
5920115.28mN
1754793.05mE
Elevation: 11.59mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: Grey Lynn Tunnel CIGI5

Borehole

Location: 44 Tawariki Street, Grey Lynn **Project No:** AE04725

Hole ID: CIE-BH05

Client: Watercare

Date: 11/07/2018

R.L. (m)	Depth (m)	Drilling Method	Drilling Flush Return (%)	TCR (SCR) [RQD] %	Description of Strata	Geological Unit
-19	31	HQ3	Flush Type: Water; Flush Colour: Clear	93 (93) [93]	Moderately weathered, dark grey speckled white, coarse grained SANDSTONE. Very weak. With trace fine to medium gravel sized, sub-angular mudstone clasts. *30.78m to 30.96m: Strong bed.*	Wpac (Contd.)
					CORE LOSS.	
					Moderately weathered, dark grey speckled white, coarse grained SANDSTONE. Very weak. With trace fine to medium gravel sized, sub-angular mudstone clasts.	
					CIE-BH05 terminated at 31.50m. Target Depth	

Shift Details & Standing Water Level: 13/07/2018 4:00:00 PM; **18/07/2018 7:30:00 AM(Water depth -2.9m)**

Boundary: Well defined; Gradational; Poorly defined

Defect Description key — TYPE: CS Clay seam, C Cleavage, CR Crushed zone, DZ Decomposed zone, DB Drilling induced fracture, FL Foliation, FZ Fracture zone, IF Incipient fracture, JT Joint, SC Schistosity, SH Shear, SZ Shear Zone, SL Sill, VN Vein, VO Void. SURFACE: C Clean, Mc Mineral coat, Si Soil infill, Sn Surface stain, V Veneer. PLANARITY: P Planar, St Stepped, U Undulating. ROUGHNESS: R Rough, Ss Slickensided, Sm Smooth. APERTURE: T 0mm, Vn 0-2mm, N 2-6mm, Mn 6-20mm, Mw 20-60mm, W 60-200mm, Vw >200mm.

Started: 11/07/2018
Finished: 13/07/2018
Driller: McMillan
Plant: Rig N111 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	-4.39	13/09/2018		End of Day WL

Remarks

Packer Test 1: 11.00 - 13.50 m, Packer Test 2: 19.00 - 21.00 m, Packer Test 3: 28.50 - 31.50 m.
Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.0 m RL.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946 Hole location determined by Survey.

Co-ordinates: 5920115.28mN 1754793.05mE
Elevation: 11.59mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with AECOM and McMillen Jacobs Associates	**Preliminary Log of Investigation**
Project: **Grey Lynn Tunnel CIGI5**	**Borehole**
Location: **1A Fisherton St, Grey Lynn** Project No: **AE04725**	Hole ID: **CIE-BH06**
Client: **Watercare**	Date: **27/06/2018**

Started: 27/06/2018 Finished: 3/07/2018 Driller: McMillan Plant: Rig N102 (McMillan) Logged: S. Burgess Checked: LD	Remarks Packer Test 1 at 27.00-30.00m, Packer Test 2 at 50.25-52.50m, Packer Test 3 at 56.25-58.50m, Packer Test 4 at 54.5-63.50m. Piezometer dipped 10/07/2018; water level 1.8mbgl. Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0. Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946 Hole location determined by Survey.	Co-ordinates: 5919179.64mN 1754450.92mE Elevation: 48.00mRL Inclination: -90° Log cover page

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with
AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: **Grey Lynn Tunnel CIGI5**

Borehole

Location: **1A Fisherton St, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH06**

Client: **Watercare**

Date: **27/06/2018**

Depth (m)	Drilling Method	TCR (SCR) [RQD] %	In-Situ Testing	Sampling	Description of Strata	Comments	Geological Unit
0.00–1.50	VAC EX	0			Vacuum Excavation.		MG
1.50–2.00	SPT	100	SPT, 0,2,3 N=5		Silty CLAY; blueish grey with some mottled yellow (oxidation). Firm, moist, low plasticity.		
2.00–3.00	HQ3	100			*2.55m to 2.70m: Changes to Silty CLAY with some well graded fine grained angular sand*		
3.00–3.50	TBX	100		TW	Push tube.		
3.50–4.00	SPT	100	SPT, 2,2,4 N=6		Sandy Silty CLAY; blueish grey mottled heavily with yellow (oxidation). Soft, moist, low plasticity, Insensitive.		
4.00–4.50	HQ3	100			SILT with minor clay and trace sand; brownish grey and brownish orange, mixed. Soft, moist, low plasticity, Insensitive, heavily oxidised.	4m: Cased to 4.0 m.	Wwc
4.50–5.00	SPT	100	SPT, 1,2,4 N=6		*4.50m to 4.95m: Changes to trace fine sand*		
5.00–6.00	HQ3	76			*4.95m: Changes to some clay, no sand; grey.*		
~5.80–6.05					CORE LOSS.		
6.00–6.50	SPT	100	SPT, 3,8,9 N=17		Residually weathered SANDSTONE/SILTSTONE. SILT with minor clay and trace sand; dark grey, homogeneous. Firm, moist, low plasticity, Insensitive.		
6.50–7.50	HQ3	100					
7.50–8.00	SPT	100	SPT, 2,4,4 N=8				
8.00–9.00	HQ3	62			Completely weathered, SILTSTONE. SILT with some clay; dark grey, homogeneous. Very stiff, moist, low plasticity, Insensitive. Residual joints present. *8.40m to 8.60m: Becomes firm.*		
~8.60–9.00					CORE LOSS.		
9.00–9.50	SPT	100	SPT, 3,5,8 N=13		Completely weathered, SILTSTONE. SILT with some clay; dark grey, homogeneous. Very stiff, moist, low plasticity, Insensitive. Residual joints present.		

Shift details: 27/06/2018 4:00:00 PM (Water depth 1.9m); 28/06/2018 7:30:00 AM (Water depth 0.3m)

Flush Type: Water; Flush Colour: Grey

RL (m): 47 at 1 m, 46 at 2 m, 45 at 3 m, 44 at 4 m, 43 at 5 m, 42 at 6 m, 41 at 7 m, 40 at 8 m, 39 at 9 m, 38 at 10 m

Started: 27/06/2018
Finished: 3/07/2018
Driller: McMillan
Plant: Rig N102 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	1.8	10/07/2018		
2	2.1	28/08/2018		

Remarks
Packer Test 1 at 27.00-30.00m, Packer Test 2 at 50.25-52.50m, Packer Test 3 at 56.25-58.50m, Packer Test 4 at 54.5-63.50m.
Piezometer dipped 10/07/2018; water level 1.8 mbgl.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946
Hole location determined by Survey.

Co-ordinates:
5919179.64mN
1754450.92mE
Elevation: 48.00mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with
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Preliminary Log of Investigation

Project: **Grey Lynn Tunnel CIGI5**

Borehole

Location: **1A Fisherton St, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH06**

Client: **Watercare**

Date: **27/06/2018**

R.L. (m)	Depth (m)	Drilling Method	TCR (SCR) [RQD] %	In-Situ Testing	Description of Strata	Defect Description	Geological Unit
		HQ3	100				Wwc(Contd.)
		SPT	100	SPT 3,6,9 N=15			
37	11	HQ3	95 (95) [95]		Highly weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Extremely weak, moderately inclined. Silty SAND, some clay. Medium dense, moist.		Wwnc
36	12	SPT	100	SPT 6,9,14 N=23			
35	13	HQ3	100 (62) [62]		*12.80m to 13.20m: Recovered as crushed zone.*		
		SPT	100	SPT 7,12,16 N=28			
34	14	HQ3	100 (100) [100]		*14.10m: Thin, moderately inclined, black carbonaceous bed.*	14.70: Jt 70° Sm, P, Vn, C.	
33	15	SPT	100	SPT 8,13,19 N=32			
32	16	HQ3	90 (90) [90]		*16.04m: Thin, moderately inclined, black carbonaceous bed.*		
		SPT	100	SPT 8,12,17 N=29	CORE LOSS.		
31	17				Highly weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Extremely weak, moderately inclined. Silty SAND, some clay. Medium dense, moist.		
		HQ3	90 (90) [90]		CORE LOSS.		
30	18	SPT	100	SPT 8,12,15 N=27	Highly weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Extremely weak, moderately inclined. Silty SAND, some clay. Medium dense, moist.	17.80: Jt 70° R, P, Vn, C.	
					CORE LOSS.		
29	19	HQ3	86 (86) [75]		Highly weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Extremely weak, moderately inclined. Silty SAND, some clay. Medium dense, moist.		
		SPT	100	SPT 7,10,14 N=24			
28	20						

Drilling Flush Return: *Flush Type: Water; Flush Colour: Grey*

Started: 27/06/2018
Finished: 3/07/2018
Driller: McMillan
Plant: Rig N102 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	1.8	10/07/2018		
2	2.1	28/08/2018		

Remarks
Packer Test 1 at 27.00-30.00m, Packer Test 2 at 50.25-52.50m, Packer Test 3 at 56.25-58.50m, Packer Test 4 at 54.5-63.50m.
Piezometer dipped 10/07/2018; water level 1.8mbgl.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946
Hole location determined by Survey.

Co-ordinates:
5919179.64mN
1754450.92mE
Elevation: 48.00mRL
Inclination: -90°

Jacobs in association with
AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: **Grey Lynn Tunnel CIGI5**

Borehole

Location: **1A Fisherton St, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH06**

Client: **Watercare**

Date: **27/06/2018**

R.L. (m)	Depth (m)	Drilling Method	TCR (SCR) [RQD] %	In-Situ Testing	Description of Strata	Defect Description	Geological Unit
					CORE LOSS.		Wwnc(Contd.)
		HQ3	57 (57) [53]		Highly weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Extremely weak, moderately inclined. Silty SAND, some clay. Very dense, moist. *20.45m to 20.50m: Thin, black carbonaceous bed.*	20.55: Jt 30° R, U, Vn, C.	
27	21	SPT	100	SPTs 16,21,29 N>50 50/270	Moderately weathered, dark grey, indistinctly bedded, fine grained SANDSTONE. Extremely weak, moderately inclined. Silty SAND, some clay. Very dense, moist. *21.20m: Thin, black carbonaceous bed.*		Wuw
26	22	HQ3	100 (100) [100]				
		SPT	0	SPTc 35,50 N>50 50/90	*22.30m: Thin, black carbonaceous bed.*	22.30: Jt 70° R, U, Vn, C.	
25	23	HQ3	92 (92) [92]		CORE LOSS.		
					Moderately weathered, dark grey, indistinctly bedded, fine grained SANDSTONE. Extremely weak, moderately inclined. Silty SAND, some clay. Very dense, moist.		
24	24	SPT	0	SPTc 50,50 N>50 50/45			
23	25	HQ3	100 (100) [100]		*24.59m: Thin, black carbonaceous bed.*		
					Moderately weathered, dark grey, MUDSTONE. Extremely weak.		
22	26	HQ3	100 (100) [100]		Moderately weathered, dark grey, indistinctly bedded, fine grained SANDSTONE. Extremely weak, steeply inclined. Trace red flecks. Silty SAND, some clay. Very dense, moist.		
21	27				*26.80m to 27.50m: Very weak.*		
20	28	HQ3	100 (100) [100]				
19	29	HQ3	100 (100) [100]				
18	30						

Shift details: 28/06/2018 4:00:00 PM; 29/06/2018 7:30:00 AM (Water depth 1.2m)

Flush Type: Water
Flush Colour: Grey

Started: 27/06/2018
Finished: 3/07/2018
Driller: McMillan
Plant: Rig N102 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	1.8	10/07/2018		
2	2.1	28/08/2018		

Remarks
Packer Test 1 at 27.00-30.00m, Packer Test 2 at 50.25-52.50m, Packer Test 3 at 56.25-58.50m, Packer Test 4 at 54.5-63.50m.
Piezometer dipped 10/07/2018; water level 1.8mbgl.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946
Hole location determined by Survey.

Co-ordinates:
5919179.64mN
1754450.92mE
Elevation: 48.00mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with
AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: **Grey Lynn Tunnel CIGI5**

Borehole

Location: **1A Fisherton St, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH06**

Client: **Watercare**

Date: **27/06/2018**

R.L. (m)	Depth (m)	Drilling Method	TCR (SCR) [RQD] %	Description of Strata	Geological Unit
17	31	HQ3 (29/06/2018 1:45:00 PM (Water depth 0.6m); 2/07/2018 7:30:00 AM (Water depth 1.05m))	100 (100) [100]	*30.00m: Becomes slightly weathered, very weak. Trace black clasts (2mm)*	Wuw (Contd.)
16	32	HQ3	100 (100) [100]		
15	33			*32.75m to 32.80m: Thin, steeply inclined, black carbonaceous bed.*	
14	34	HQ3	100 (100) [100]		
13	35	HQ3	100 (100) [100]	Slightly weathered, dark grey, MUDSTONE. Very weak, steeply inclined. *34.66m to 34.76m: Laminated, steeply inclined, black carbonaceous beds.*	
				Slightly weathered, dark grey, homogeneous, fine grained SANDSTONE. Very weak. Trace red flecks, trace black clasts (2mm)	
				Slightly weathered, dark grey, MUDSTONE. Very weak, steeply inclined.	
12	36			Slightly weathered, dark grey, homogeneous, fine grained SANDSTONE. Very weak. Trace red flecks, trace black clasts (2mm)	
				Slightly weathered, dark grey, homogeneous, fine to medium grained SANDSTONE. Very weak. Trace red flecks, trace light and dark grey clasts (2mm)	Wpvc
11	37	HQ3	100 (100) [100]	Slightly weathered, dark grey, homogeneous, fine grained SANDSTONE. Very weak. Trace red flecks, trace black clasts (2mm)	Wuw
10	38	HQ3	100 (100) [100]	Slightly weathered, dark grey, homogeneous, fine to medium grained SANDSTONE. Very weak. Trace red flecks, trace light and dark grey clasts (2mm)	Wpvc
9	39			Slightly weathered, dark grey, homogeneous, fine grained SANDSTONE. Very weak. Trace red flecks, trace black clasts (2mm)	Wuw
8	40	HQ3	100 (100) [100]		

Flush Type: Water; Flush Colour: Grey

Started: 27/06/2018
Finished: 3/07/2018
Driller: McMillan
Plant: Rig N102 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	1.8	10/07/2018		
2	2.1	28/08/2018		

Remarks
Packer Test 1 at 27.00-30.00m, Packer Test 2 at 50.25-52.50m, Packer Test 3 at 56.25-58.50m, Packer Test 4 at 54.5-63.50m.
Piezometer dipped 10/07/2018; water level 1.8mbgl.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
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5919179.64mN
1754450.92mE
Elevation: 48.00mRL
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Jacobs in association with
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Preliminary Log of Investigation

Project: **Grey Lynn Tunnel CIGI5**

Borehole

Location: **1A Fisherton St, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH06**

Client: **Watercare**

Date: **27/06/2018**

R.L. (m)	Depth (m)	Drilling Method	TCR (SCR) [RQD] %	Description of Strata	Defect Description	Geological Unit
7	41	HQ3	100 (100) [100]			Wuw(Contd.)
6	42	HQ3	100 (100) [100]			
5	43	HQ3	100 (100) [100]			
4	44	HQ3	100 (100) [100]		44.74: Jt 30° R, U, Vn, C.	
3	45					
2	46	HQ3	100 (100) [100]		46.23: Jt 45° R, U, Vn, C.	
1	47	HQ3	100 (100) [100]	Slightly weathered, dark grey BRECCIA. Very weak. Medium to coarse SANDSTONE matrix, trace white subangular clasts (2mm), with SILTSTONE clasts. Submarine landslide feature.		
				Slightly weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Very weak. Beds are closely spaced, steeply inclined. Weak, laminated to thin black carbonaceous beds are present in the mudstone.	47.58: Jt 45° R, P, Vn, C.	
0	48				48.22: Jt 45° Sm, St, Vn, C. 48.63: Jt 45° Sm, P, Vn, C.	
-1	49	HQ3	100 (95) [91]	*49.04m to 49.12m: Fracture zone. Intersecting joints. Dominant joint set is the steeply inclined bedding plane.*	49.04-49.12: Sz. 49.20: Jt 45° R, U, Vn, C.	
				Slightly weathered, dark grey, homogeneous, fine grained SANDSTONE. Very weak.		
-2	50					

Flush Type: Water; Flush Colour: Grey

Started: 27/06/2018
Finished: 3/07/2018
Driller: McMillan
Plant: Rig N102 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	1.8	10/07/2018		
2	2.1	28/08/2018		

Remarks
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Piezometer dipped 10/07/2018; water level 1.8mbgl.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
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Hole location determined by Survey.

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5919179.64mN
1754450.92mE
Elevation: 48.00mRL
Inclination: -90°

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Columns: R.L. (m) | Depth (m) | Shift Details & Standing Water Level / Drilling Method | Drilling Flush Return (%) 255075 | TCR (SCR) [RQD] % | Spacing of Natural Defects (mm) 500 100 50 10 | Relative Strength | Weathering Grade | Sampling | In-Situ Testing | Geology Legend | GroundWater | Description of Strata | Defect Description | Comments | Geological Unit | Backfill / Installation

BOUNDARY: Well defined; Gradational; Poorly defined

TYPE: CS Clay seam; C Cleavage; CR Crushed zone; DZ Decomposed zone; DB Drilling induced fracture; FL Foliation; FZ Fracture zone; IF Incipient fracture; JT Joint; SC Schistosity; SH Shear; SZ Shear Zone; SL Sill; VN Vein; VD Void

SURFACE: C Clean; Mc Mineral coat; Si Soil infill; Sn Surface stain; V Veneer

PLANARITY: P Planar; St Stepped; U Undulating

ROUGHNESS: R Rough; Ss Slickensided; Sm Smooth

APERTURE: T 0mm; Vn 0-2mm; N 2-6mm; Mn 6-20mm; Mw 20-60mm; W 60-200mm; Ww >200mm

R.L. (m)	Depth (m)	Drilling Method	TCR (SCR) [RQD] %
-3	51	HQ3	100 (100) [100]
-4	52	HQ3	100 (85) [80]
-5	53	HQ3 (2/07/2018 1:45:00 PM(Water depth 0m); 3/07/2018 7:30:00 AM(Water depth 1m))	100 (100) [100]
-6	54		
-7	55	HQ3	100 (100) [100]
-8	56	HQ3	86 (86) [86]
-9	57		
-10	58	HQ3	100 (90) [90]
-11	59	HQ3	100 (91) [91]
-12	60		

Flush Type: Water
Flush Colour: Grey

Description of Strata

Slightly weathered, dark grey, MUDSTONE. Very weak, steeply inclined. Laminated black carbonaceous beds are present.

Slightly weathered, dark grey, homogeneous, fine grained SANDSTONE. Very weak.

Slightly weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Very weak. Beds are moderately widely spaced, steeply inclined.
51.00m to 51.10m: Fracture zone. Completely fractured, fragments 10-50 mm.

52.08m to 52.20m: Fracture zone. Fragments 10-70 mm.

Slightly weathered, dark grey, homogeneous, coarse grained SANDSTONE. Weak.

Slightly weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Very weak. Beds are closely spaced, steeply inclined. Sandstone beds are moderately thin, mudstone beds are thin.

54.10m to 56.80m: Bedding is moderately widely spaced. Sandstone beds are moderately thick, mudstone beds are moderately thin. Minor speckled black, discontinuous carbonaceous beds. At 55.60 m gravel sized coal deposit (30 mm)

CORE LOSS.

57.00m to 57.15m: Recovered as crushed zone due to drilling.

Slightly weathered, dark grey, homogeneous, fine grained SANDSTONE. Very weak.

Highly weathered, dark grey, homogeneous, coarse grained SANDSTONE. Extremely weak. White clasts present, likely Silica (2mm).
59.58m to 60.10m: Becomes fine grained.

Defect Description

- 50.83: Jt 45° R, U, Vn, C.
- 51.00-51.10: Sz.
- 52.08-52.20: Sz.
- 52.37: Jt 45° R, U, T, C.
- 52.92: Jt 45° R, U, Vn, C.
- 53.76: Jt 45° R, U, Vn, C.
- 54.82: Jt 45° R, P, Vn, C.

Geological Unit: Wuw(Contd.); Wwnc; Wuw; Wwnc

Started:	27/06/2018
Finished:	3/07/2018
Driller:	McMillan
Plant:	Rig N102 (McMillan)
Logged:	S. Burgess
Checked:	LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	1.8	10/07/2018		
2	2.1	28/08/2018		

Remarks
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Piezometer dipped 10/07/2018; water level 1.8mbgl.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946
Hole location determined by Survey.

Co-ordinates:
5919179.64mN
1754450.92mE
Elevation: 48.00mRL
Inclination: -90°

Jacobs in association with
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Preliminary Log of Investigation

Project: **Grey Lynn Tunnel CIGI5**

Borehole

Location: **1A Fisherton St, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH06**

Client: **Watercare**

Date: **27/06/2018**

R.L. (m)	Depth (m)	Drilling Method	Drilling Flush Return (%)	TCR (SCR) [RQD] %	Description of Strata	Defect Description	Comments	Geological Unit	Backfill / Installation
-13	61	HQ3	Flush Type: Water; Flush Colour: Grey	100 (100) [100]	Slightly weathered, dark grey, homogeneous, fine grained SANDSTONE. Very weak. Widely spaced thin black carbonaceous beds.			Ww	
-14	62	HQ3		100 (100) [100]					
-15	63	HQ3		100 (100) [100]					
		3/07/2018 4:00:00 PM			CIE-BH06 terminated at 63.50m. Target Depth				

Started: 27/06/2018
Finished: 3/07/2018
Driller: McMillan
Plant: Rig N102 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	1.8	10/07/2018		
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Remarks
Packer Test 1 at 27.00-30.00m, Packer Test 2 at 50.25-52.50m, Packer Test 3 at 56.25-58.50m, Packer Test 4 at 54.5-63.50m.
Piezometer dipped 10/07/2018; water level 1.8mbgl.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946
Hole location determined by Survey.

Co-ordinates:
5919179.64mN
1754450.92mE
Elevation: 48.00mRL
Inclination: -90°

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Appendix B. Slug Test Analyses

Borehole Variable Head Permeability Test

Borehole ID

BH4_test 1

Project Details

Project Name	Grey Lynn Tunnel
Project Number	WWA047
Test Date	17/7/1018
Tested	JNS
Checked	

Test Parameters

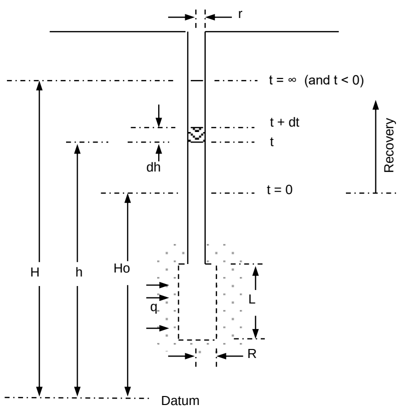
Top of screen	25.000 m
Bottom of Screen	31.500 m
Screen Length, *L*	6.500 m
Static Water Level, *H*	1.030 m
Initial Water Level, H_0	1.300 m
Hole Radius, *R*	0.060 m
Casing Radius, *r*	0.050 m

Note: If the datum is above the hole, the height/depth readings do not have to be negative numbers - as long as they are either all negative or all positive, the answer will be correct.

Result

Hydraulic Conductivity	
K =	1.10E-06 m/s

Test Schematic



Hvorslev (1951) method:

$$F = \frac{2\pi L}{\ln(L/R)}$$

$$K = \frac{\pi r^2}{F T_0}$$

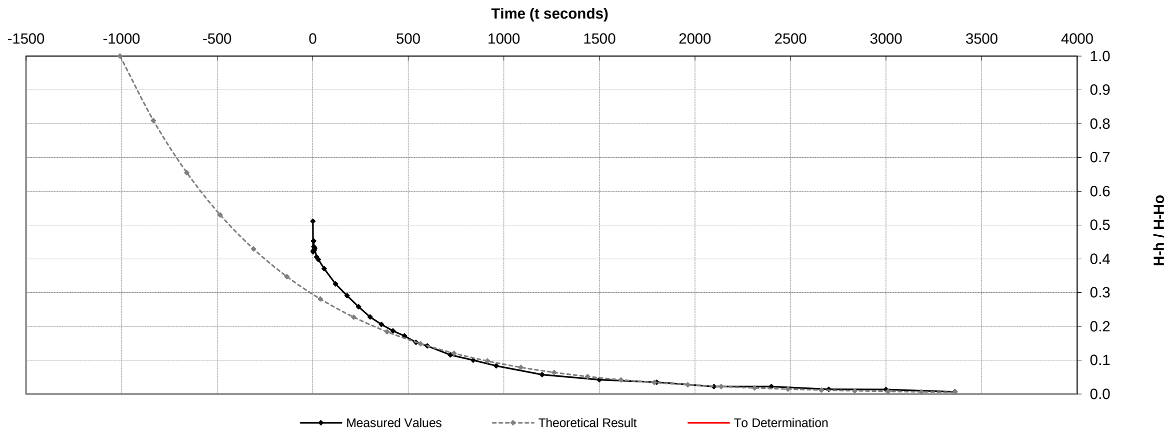
Calibrated Parameters

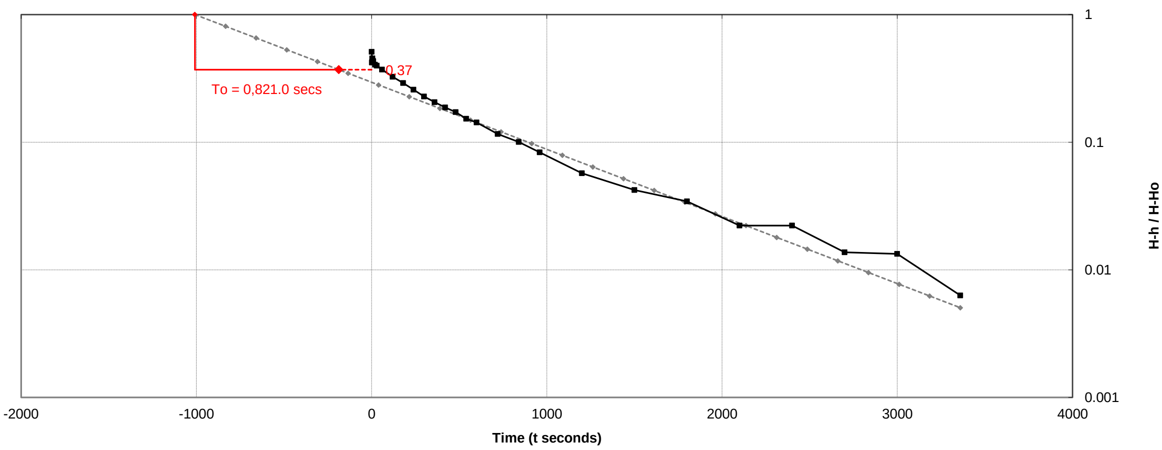
Intake factor, *F*	8.72
Time Factor, T_0	821.0

Measured Data

Time (Secs)	Depth (h) (m)	H - h (m)	H-h / H-H0
1	1.168	0.14	0.51
2	1.144	0.11	0.42
3	1.144	0.11	0.42
4	1.152	0.12	0.45
5	1.152	0.12	0.45
6	1.148	0.12	0.44
7	1.145	0.12	0.43
8	1.145	0.12	0.43
9	1.147	0.12	0.43
10	1.146	0.12	0.43
20	1.140	0.11	0.41
30	1.137	0.11	0.40
60	1.130	0.10	0.37
120	1.118	0.09	0.33
180	1.109	0.08	0.29
240	1.100	0.07	0.26
300	1.092	0.06	0.23
360	1.086	0.06	0.21
420	1.081	0.05	0.19
480	1.076	0.05	0.17
540	1.071	0.04	0.15
600	1.069	0.04	0.14
720	1.061	0.03	0.12
840	1.057	0.03	0.10
960	1.053	0.02	0.08
1200	1.045	0.02	0.06
1500	1.041	0.01	0.04
1800	1.039	0.01	0.03
2100	1.036	0.01	0.02
2400	1.036	0.01	0.02
2700	1.034	0.00	0.01
3000	1.034	0.00	0.01
3360	1.032	0.00	0.01

Graphs of Hvorslev Piezometer Test (top graph has normal axes and bottom graph has a log H-h/H-Ho axis)





Note: Hvorslev method is based on the slope of the best-fit line. This is calculated by taking the elapsed time, T_0, over 1 natural log interval of the graph, i.e. normalised head between 1 and 0.37.

Borehole Variable Head Permeability Test

Borehole ID

BH4_test 2

Project Details

Project Name	Grey Lynn Tunnel
Project Number	WWA047
Test Date	17/7/1018
Tested	JNS
Checked	

Test Parameters

Top of screen	25.000 m
Bottom of Screen	31.500 m
Screen Length, *L*	6.500 m
Static Water Level, *H*	1.030 m
Initial Water Level, H_0	1.300 m
Hole Radius, *R*	0.060 m
Casing Radius, *r*	0.050 m

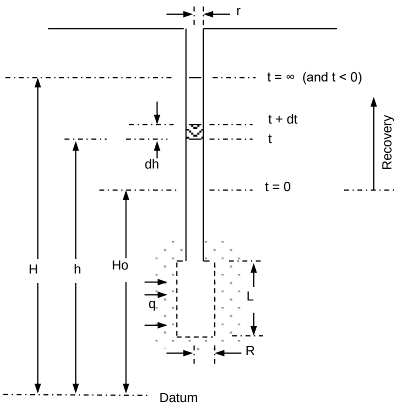
Note: If the datum is above the hole, the height/depth readings do not have to be negative numbers - as long as they are either all negative or all positive, the answer will be correct.

Result

Hydraulic Conductivity

K **= 1.07E-06 m/s**

Test Schematic



Hvorslev (1951) method:

$$F = \frac{2\pi L}{\ln(L/R)} \qquad K = \frac{\pi r^2}{FT_0}$$

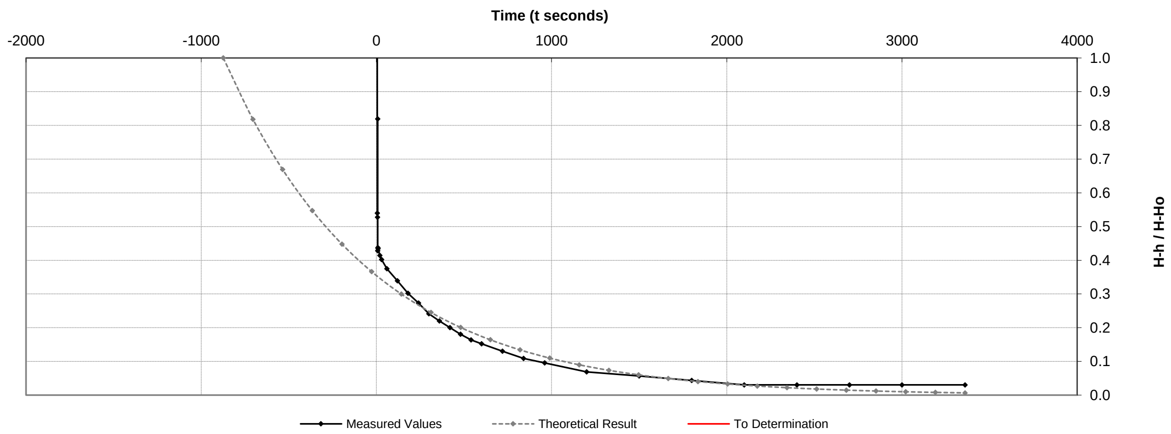
Calibrated Parameters

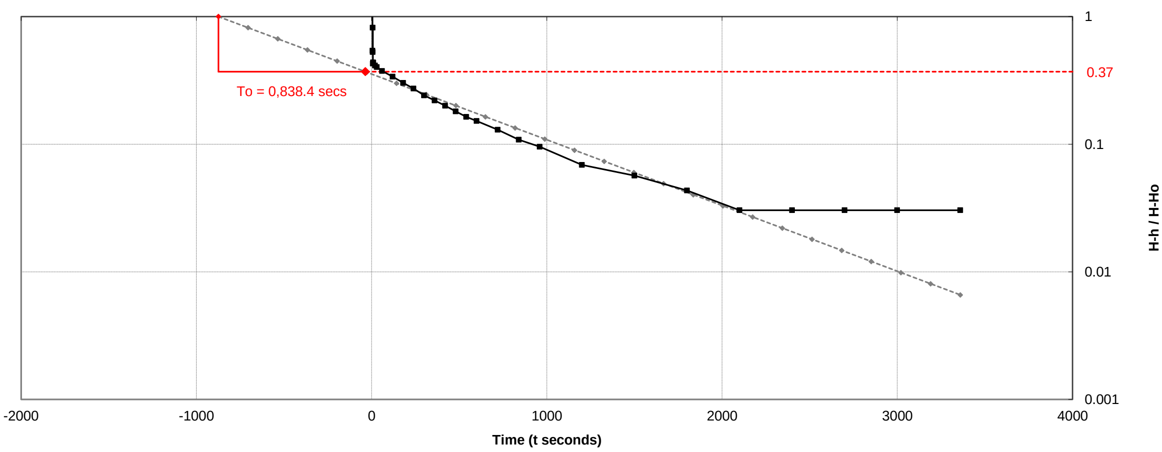
Intake factor, *F*	8.72
Time Factor, T_0	838.4

Measured Data

Time (Secs)	Depth (h) (m)	H - h (m)	H-h / H-H0
1	2.823	1.79	6.64
2	2.765	1.74	6.43
3	2.700	1.67	6.19
4	1.686	0.66	2.43
5	1.176	0.15	0.54
6	1.172	0.14	0.53
7	1.251	0.22	0.82
8	1.146	0.12	0.43
9	1.148	0.12	0.44
10	1.147	0.12	0.43
20	1.142	0.11	0.41
30	1.139	0.11	0.40
60	1.131	0.10	0.37
120	1.122	0.09	0.34
180	1.112	0.08	0.30
240	1.104	0.07	0.27
300	1.095	0.07	0.24
360	1.089	0.06	0.22
420	1.084	0.05	0.20
480	1.079	0.05	0.18
540	1.074	0.04	0.16
600	1.071	0.04	0.15
720	1.065	0.04	0.13
840	1.059	0.03	0.11
960	1.056	0.03	0.10
1200	1.049	0.02	0.07
1500	1.045	0.02	0.06
1800	1.042	0.01	0.04
2100	1.038	0.01	0.03
2400			
2700			
3000			
3360			

Graphs of Hvorslev Piezometer Test (top graph has normal axes and bottom graph has a log H-h/H-Ho axis)





Note: Hvorslev method is based on the slope of the best-fit line. This is calculated by taking the elapsed time, T_0, over 1 natural log interval of the graph, i.e. normalised head between 1 and 0.37.

Borehole ID

BH4_test 3

Project Details

Project Name	Grey Lynn Tunnel
Project Number	WWA047
Test Date	17/7/1018
Tested	JNS
Checked	

Test Parameters

Top of screen	25.000 m
Bottom of Screen	31.500 m
Screen Length, *L*	6.500 m
Static Water Level, *H*	1.030 m
Initial Water Level, H_0	1.300 m
Hole Radius, *R*	0.060 m
Casing Radius, *r*	0.050 m

Note: If the datum is above the hole, the height/depth readings do not have to be negative numbers - as long as they are either all negative or all positive, the answer will be correct.

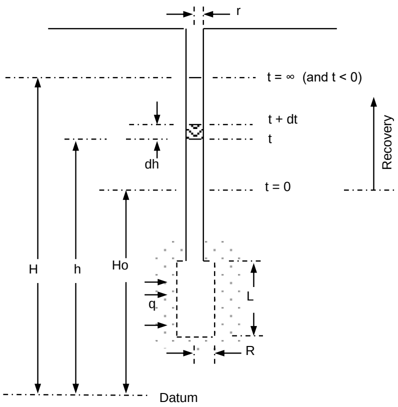
Result

Hydraulic Conductivity

***K* = 1.04E-06 m/s**

Borehole Variable Head Permeability Test

Test Schematic



Hvorslev (1951) method:

$$F = \frac{2\pi L}{\ln(L/R)} \qquad K = \frac{\pi r^2}{F T_0}$$

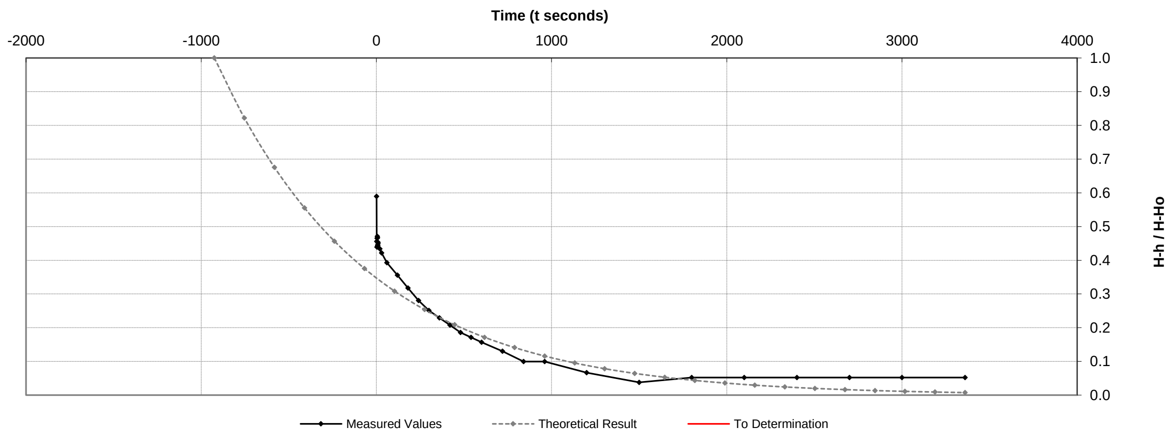
Calibrated Parameters

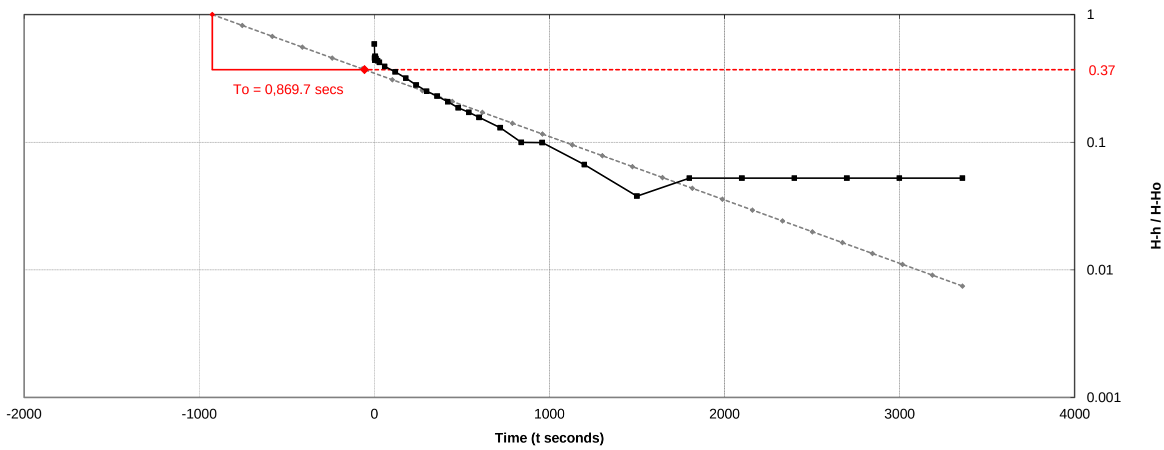
Intake factor, *F*	8.72
Time Factor, T_0	869.7

Measured Data

Time (Secs)	Depth (h) (m)	H - h (m)	H-h / H-H0
1	1.189	0.16	0.59
2	1.153	0.12	0.46
3	1.149	0.12	0.44
4	1.156	0.13	0.46
5	1.157	0.13	0.47
6	1.156	0.13	0.47
7	1.150	0.12	0.45
8	1.150	0.12	0.44
9	1.152	0.12	0.45
10	1.152	0.12	0.45
20	1.147	0.12	0.43
30	1.144	0.11	0.42
60	1.136	0.11	0.39
120	1.126	0.10	0.36
180	1.116	0.09	0.32
240	1.106	0.08	0.28
300	1.098	0.07	0.25
360	1.092	0.06	0.23
420	1.086	0.06	0.21
480	1.080	0.05	0.19
540	1.076	0.05	0.17
600	1.072	0.04	0.16
720	1.065	0.04	0.13
840	1.057	0.03	0.10
960	1.057	0.03	0.10
1200	1.048	0.02	0.07
1500	1.040	0.01	0.04
1800	1.044	0.01	0.05
2100			
2400			
2700			
3000			
3360			

Graphs of Hvorslev Piezometer Test (top graph has normal axes and bottom graph has a log H-h/H-Ho axis)





Note: Hvorslev method is based on the slope of the best-fit line. This is calculated by taking the elapsed time, T_0, over 1 natural log interval of the graph, i.e. normalised head between 1 and 0.37.

Borehole Variable Head Permeability Test

Borehole ID

BH5_test 1

Project Details

Project Name	Grey Lynn Tunnel
Project Number	WWA047
Test Date	17/7/1018
Tested	JNS
Checked	

Test Parameters

Top of screen	25.000 m
Bottom of Screen	31.500 m
Screen Length, *L*	6.500 m
Static Water Level, *H*	-2.773 m
Initial Water Level, H_0	-2.358 m
Hole Radius, *R*	0.060 m
Casing Radius, *r*	0.050 m

Note: If the datum is above the hole, the height/depth readings do not have to be negative numbers - as long as they are either all negative or all
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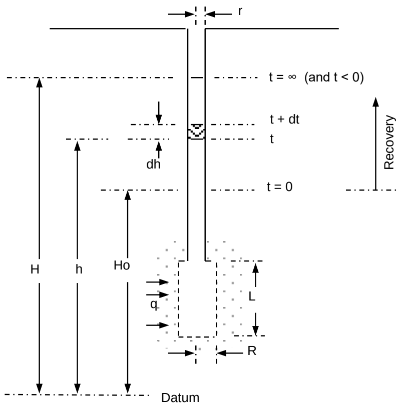
Result

Hydraulic Conductivity

***K* = 1.84E-07 m/s**

Test Schematic



Hvorslev (1951) method:

$$F = \frac{2\pi L}{\ln(L/R)} \qquad K = \frac{\pi r^2}{F T_0}$$

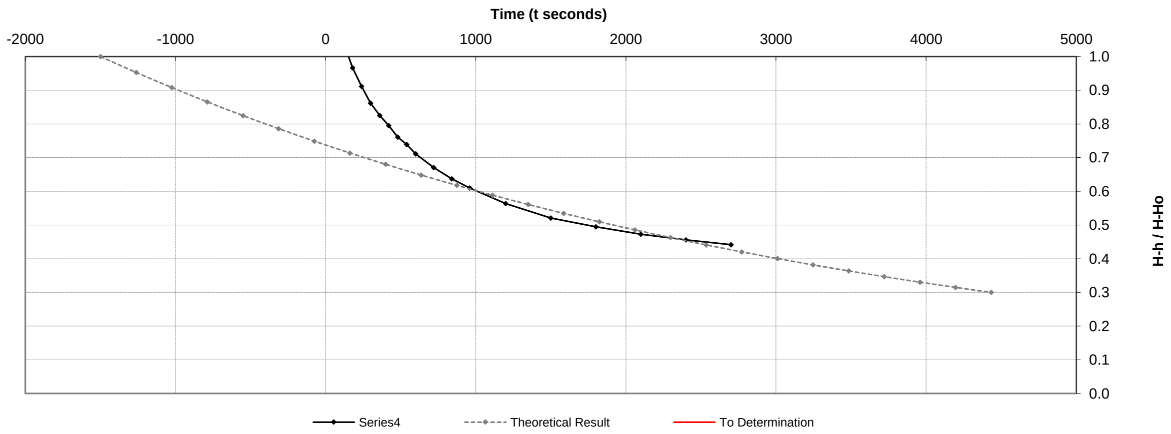
Calibrated Parameters

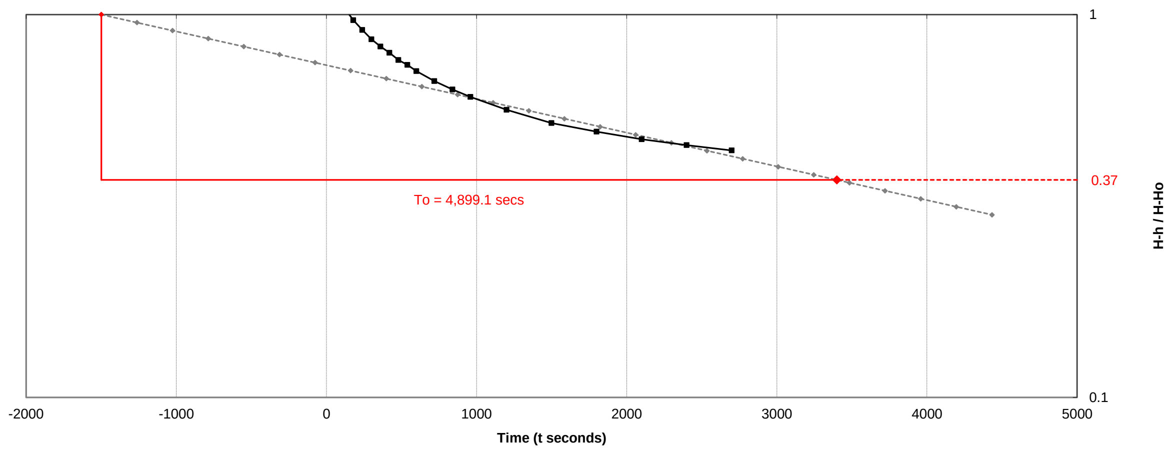
Intake factor, *F*	8.72
Time Factor, T_0	4,899.1

Measured Data

Time (Secs)	Depth (h) (m)	H - h (m)	H-h / H-H0
1	-2.248	0.53	1.27
2	-2.248	0.52	1.26
3	-2.252	0.52	1.25
4	-2.253	0.52	1.25
5	-2.254	0.52	1.25
6	-2.256	0.52	1.25
7	-2.257	0.52	1.24
8	-2.259	0.51	1.24
9	-2.261	0.51	1.23
10	-2.261	0.51	1.23
20	-2.272	0.50	1.21
30	-2.282	0.49	1.18
60	-2.305	0.47	1.13
120	-2.341	0.43	1.04
180	-2.372	0.40	0.97
240	-2.395	0.38	0.91
300	-2.415	0.36	0.86
360	-2.430	0.34	0.83
420	-2.443	0.33	0.79
480	-2.457	0.32	0.76
540	-2.466	0.31	0.74
600	-2.478	0.30	0.71
720	-2.495	0.28	0.67
840	-2.509	0.26	0.64
960	-2.520	0.25	0.61
1200	-2.539	0.23	0.56
1500	-2.557	0.22	0.52
1800	-2.568	0.21	0.49
2100	-2.577	0.20	0.47
2400	-2.584	0.19	0.46
2700	-2.590	0.18	0.44
3000			
3360			

Graphs of Hvorslev Piezometer Test (top graph has normal axes and bottom graph has a log H-h/H-Ho axis)





Note: Hvorslev method is based on the slope of the best-fit line. This is calculated by taking the elapsed time, T_0, over 1 natural log interval of the graph, i.e. normalised head between 1 and 0.37.

Borehole Variable Head Permeability Test

Borehole ID

BH5_test 2

Project Details

Project Name	Grey Lynn Tunnel
Project Number	WWA047
Test Date	17/7/1018
Tested	JNS
Checked	

Test Parameters

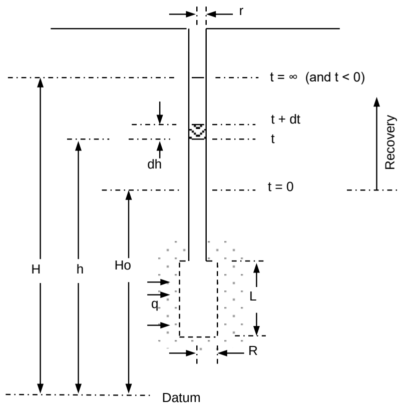
Top of screen	25.000 m
Bottom of Screen	31.500 m
Screen Length, *L*	6.500 m
Static Water Level, *H*	-2.773 m
Initial Water Level, H_0	-2.358 m
Hole Radius, *R*	0.060 m
Casing Radius, *r*	0.050 m

Note: If the datum is above the hole, the height/depth readings do not have to be negative numbers - as long as they are either all negative or all \

Result

Hydraulic Conductivity
***K* = 4.01E-07 m/s**

Test Schematic



Hvorslev (1951) method:

$$F = \frac{2\pi L}{\ln(L/R)} \qquad K = \frac{\pi r^2}{F T_0}$$

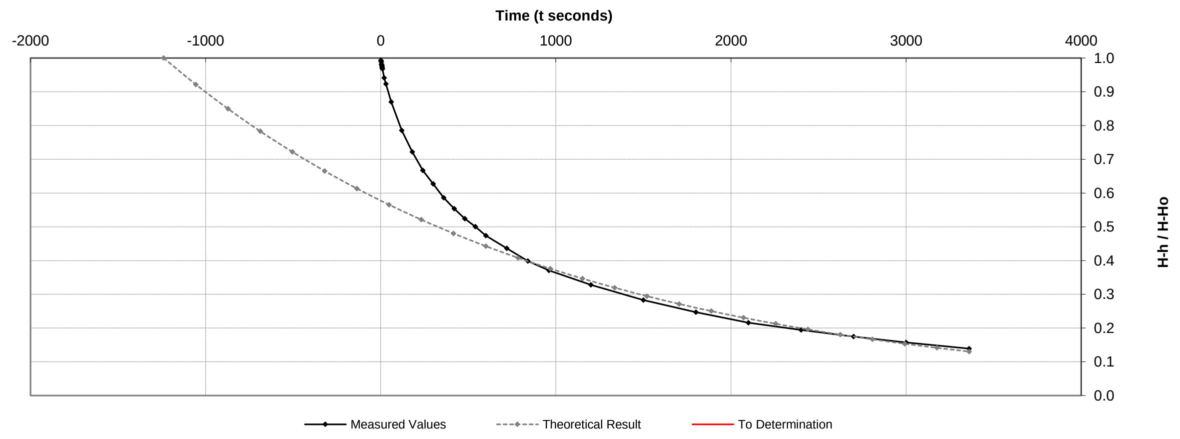
Calibrated Parameters

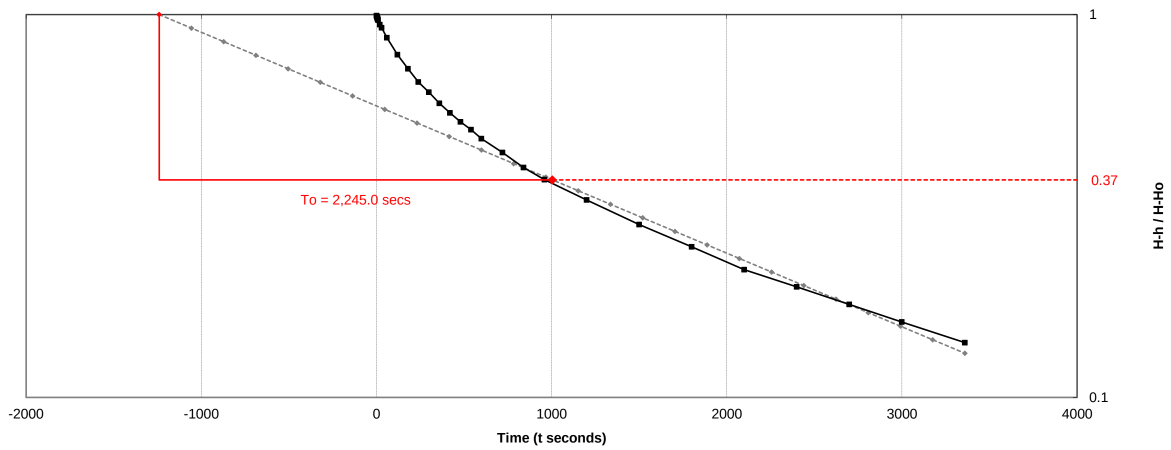
Intake factor, *F*	8.72
Time Factor, T_0	2,245.0

Measured Data

Time (Secs)	Depth (h) (m)	H - h (m)	H-h / H-H0
1	-2.361	0.41	0.99
2	-2.362	0.41	0.99
3	-2.363	0.41	0.99
4	-2.366	0.41	0.98
5	-2.366	0.41	0.98
6	-2.367	0.41	0.98
7	-2.368	0.41	0.98
8	-2.370	0.40	0.97
9	-2.370	0.40	0.97
10	-2.372	0.40	0.97
20	-2.383	0.39	0.94
30	-2.390	0.38	0.92
60	-2.412	0.36	0.87
120	-2.447	0.33	0.79
180	-2.473	0.30	0.72
240	-2.496	0.28	0.67
300	-2.513	0.26	0.63
360	-2.530	0.24	0.59
420	-2.543	0.23	0.55
480	-2.555	0.22	0.52
540	-2.565	0.21	0.50
600	-2.576	0.20	0.47
720	-2.592	0.18	0.44
840	-2.608	0.17	0.40
960	-2.619	0.15	0.37
1200	-2.637	0.14	0.33
1500	-2.656	0.12	0.28
1800	-2.670	0.10	0.25
2100	-2.684	0.09	0.22
2400	-2.692	0.08	0.19
2700	-2.700	0.07	0.17
3000	-2.708	0.07	0.16
3360	-2.715	0.06	0.14

Graphs of Hvorslev Piezometer Test (top graph has normal axes and bottom graph has a log H-h/H-Ho axis)





Note: Hvorslev method is based on the slope of the best-fit line. This is calculated by taking the elapsed time, T_0, over 1 natural log interval of the graph, i.e. normalised head between 1 and 0.37.

WILLIAMSON WATER ADVISORY

Borehole Variable Head Permeability Test

Borehole ID

BH5_test 3

Project Details

Project Name	Grey Lynn Tunnel
Project Number	WWA047
Test Date	17/7/1018
Tested	JNS
Checked	

Test Parameters

Top of screen	25.000 m
Bottom of Screen	31.500 m
Screen Length, *L*	6.500 m
Static Water Level, *H*	-2.773 m
Initial Water Level, H_0	-2.358 m
Hole Radius, *R*	0.060 m
Casing Radius, *r*	0.050 m

Note: If the datum is above the hole, the height/depth readings do not have to be negative numbers - as long as they are either all negative or all
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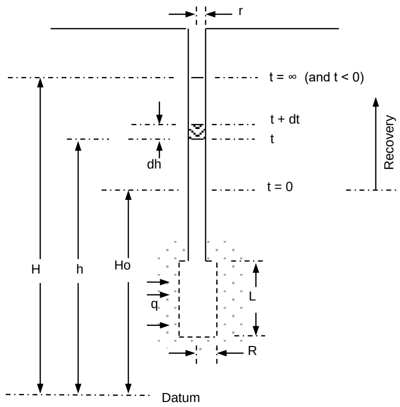
Result

Hydraulic Conductivity
***K* = 3.92E-07 m/s**

Test Schematic



Hvorslev (1951) method:

$$F = \frac{2\pi L}{\ln(L/R)} \qquad K = \frac{\pi r^2}{F T_0}$$

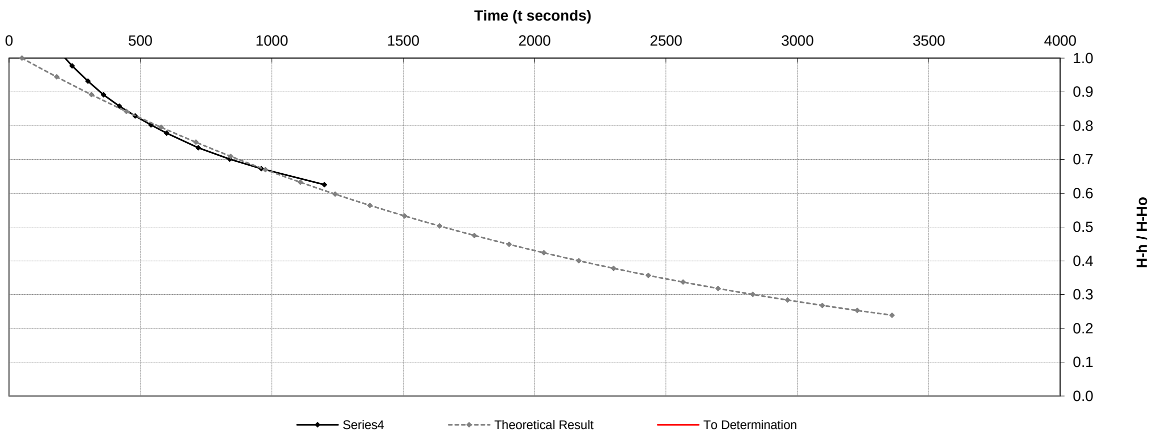
Calibrated Parameters

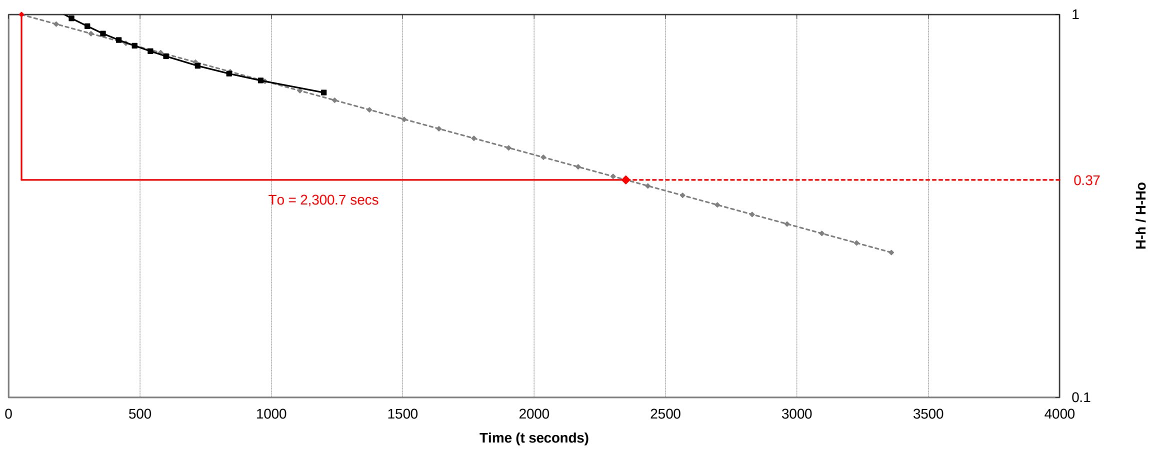
Intake factor, *F*	8.72
Time Factor, T_0	2,300.7

Measured Data

Time (Secs)	Depth (h) (m)	H - h (m)	H-h / H-H0
1	-2.221	0.55	1.33
2			
3	-2.228	0.55	1.31
4	-2.232	0.54	1.30
5	-2.234	0.54	1.30
6	-2.235	0.54	1.30
7	-2.236	0.54	1.29
8	-2.237	0.54	1.29
9	-2.239	0.53	1.29
10	-2.240	0.53	1.28
20	-2.250	0.52	1.26
30	-2.260	0.51	1.24
60	-2.283	0.49	1.18
120	-2.318	0.45	1.10
180	-2.346	0.43	1.03
240	-2.368	0.41	0.98
300	-2.386	0.39	0.93
360	-2.403	0.37	0.89
420	-2.417	0.36	0.86
480	-2.429	0.34	0.83
540	-2.440	0.33	0.80
600	-2.450	0.32	0.78
720	-2.468	0.30	0.73
840	-2.482	0.29	0.70
960	-2.494	0.28	0.67
1200	-2.513	0.26	0.63
1500			
1800			
2100			
2400			
2700			
3000			
3360			

Graphs of Hvorslev Piezometer Test (top graph has normal axes and bottom graph has a log H-h/H-Ho axis)





Note: Hvorslev method is based on the slope of the best-fit line. This is calculated by taking the elapsed time, T_0, over 1 natural log interval of the graph, i.e. normalised head between 1 and 0.37.

Borehole Variable Head Permeability Test

Borehole ID

BH6_test 1

Project Details

Project Name	Grey Lynn Tunnel
Project Number	WWA047
Test Date	17/7/1018
Tested	JNS
Checked	

Test Parameters

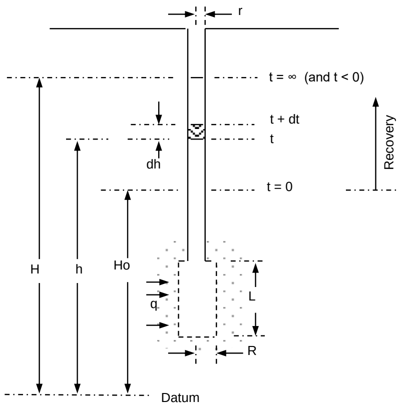
Top of screen	47.200 m
Bottom of Screen	54.500 m
Screen Length, *L*	7.300 m
Static Water Level, *H*	3.300 m
Initial Water Level, H_0	4.750 m
Hole Radius, *R*	0.050 m
Casing Radius, *r*	0.025 m

Note: If the datum is above the hole, the height/depth readings do not have to be negative numbers - as long as they are either all negative or all positive, the answer will be correct.

Result

Hydraulic Conductivity
K **= 1.05E-07 m/s**

Test Schematic



Hvorslev (1951) method:

$$F = \frac{2 \pi L}{\ln(L / R)} \qquad K = \frac{\pi r^2}{F T_0}$$

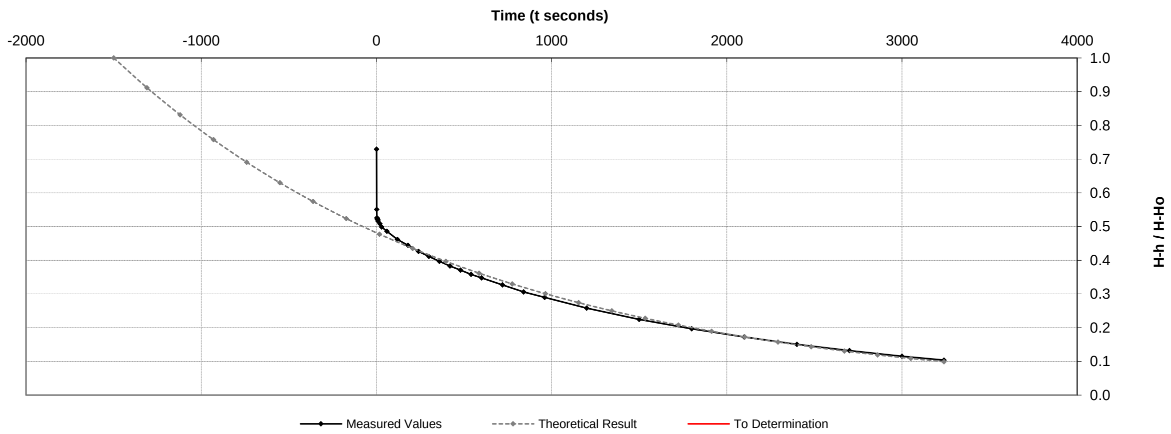
Calibrated Parameters

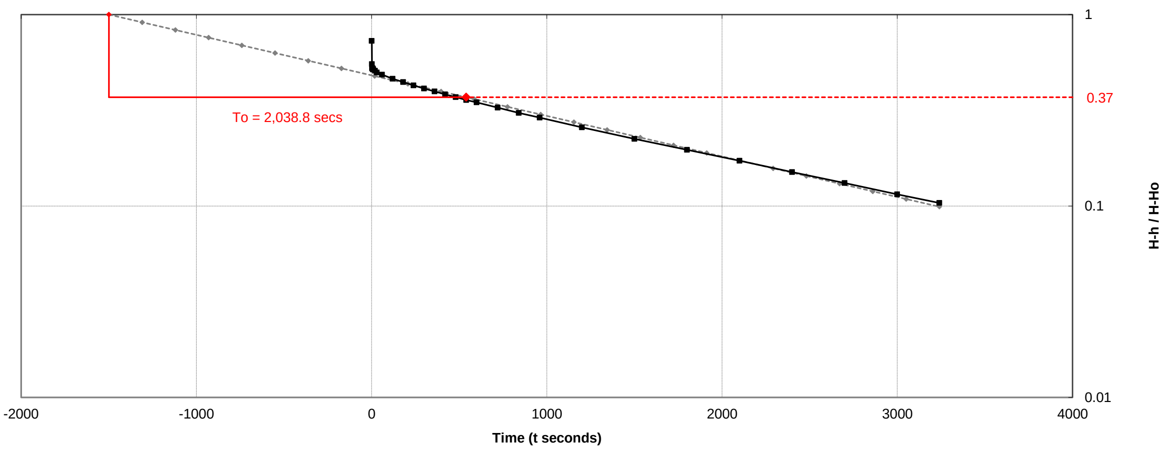
Intake factor, *F*	9.20
Time Factor, T_0	2,038.8

Measured Data

Time (Secs)	Depth (h) (m)	H - h (m)	H-h / H-H0
1	4.358	1.06	0.73
2	4.099	0.80	0.55
3	4.062	0.76	0.53
4	4.059	0.76	0.52
5	4.061	0.76	0.52
6	4.056	0.76	0.52
7	4.054	0.75	0.52
8	4.057	0.76	0.52
9	4.053	0.75	0.52
10	4.048	0.75	0.52
20	4.037	0.74	0.51
30	4.023	0.72	0.50
60	4.004	0.70	0.49
120	3.970	0.67	0.46
180	3.944	0.64	0.44
240	3.918	0.62	0.43
300	3.897	0.60	0.41
360	3.876	0.58	0.40
420	3.855	0.56	0.38
480	3.837	0.54	0.37
540	3.819	0.52	0.36
600	3.804	0.50	0.35
720	3.774	0.47	0.33
840	3.744	0.44	0.31
960	3.720	0.42	0.29
1200	3.674	0.37	0.26
1500	3.625	0.33	0.22
1800	3.585	0.29	0.20
2100	3.550	0.25	0.17
2400	3.518	0.22	0.15
2700	3.491	0.19	0.13
3000	3.467	0.17	0.12
3240	3.450	0.15	0.10

Graphs of Hvorslev Piezometer Test (top graph has normal axes and bottom graph has a log H-h/H-Ho axis)





Note: Hvorslev method is based on the slope of the best-fit line. This is calculated by taking the elapsed time, T_0, over 1 natural log interval of the graph, i.e. normalised head between 1 and 0.37.

Borehole Variable Head Permeability Test

Borehole ID

BH6_test 2

Project Details

Project Name	Grey Lynn Tunnel
Project Number	WWA047
Test Date	17/7/1018
Tested	JNS
Checked	

Test Parameters

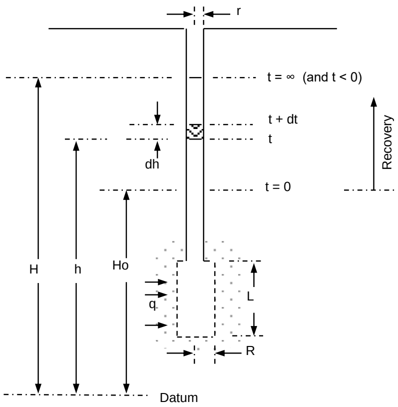
Top of screen	47.200 m
Bottom of Screen	54.500 m
Screen Length, *L*	7.300 m
Static Water Level, *H*	3.300 m
Initial Water Level, H_0	4.750 m
Hole Radius, *R*	0.050 m
Casing Radius, *r*	0.025 m

Note: If the datum is above the hole, the height/depth readings do not have to be negative numbers - as long as they are either all negative or all positive, the answer will be correct.

Result

Hydraulic Conductivity
***K* = 1.49E-07 m/s**

Test Schematic



Hvorslev (1951) method:

$$F = \frac{2\pi L}{\ln(L/R)}$$

$$K = \frac{\pi r^2}{F T_0}$$

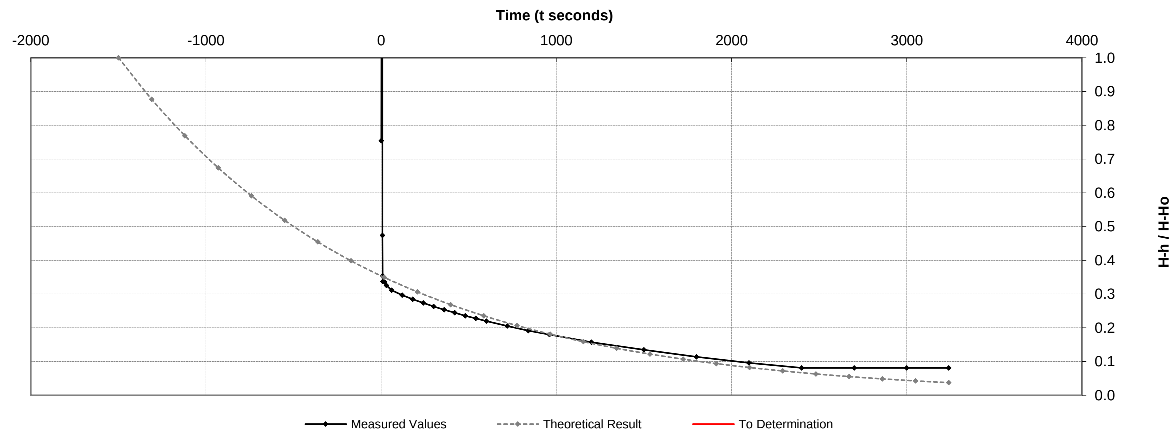
Calibrated Parameters

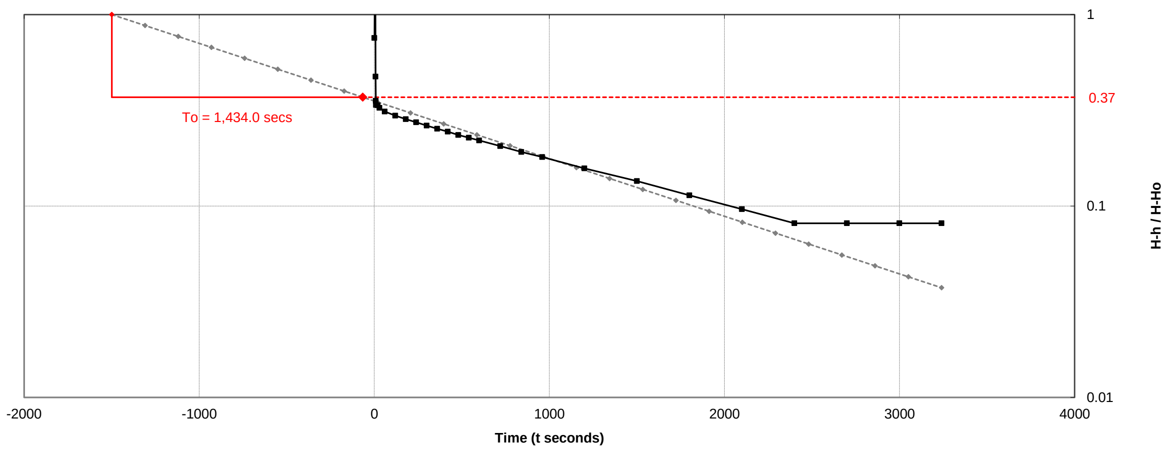
Intake factor, *F*	9.20
Time Factor, T_0	1,434.0

Measured Data

Time (Secs)	Depth (h) (m)	H - h (m)	H-h / H-H0
1	4.394	1.09	0.75
2	4.960	1.66	1.15
3			
4			
5			
6			
7			
8	3.987	0.69	0.47
9	3.814	0.51	0.35
10	3.789	0.49	0.34
20	3.787	0.49	0.34
30	3.772	0.47	0.33
60	3.752	0.45	0.31
120	3.730	0.43	0.30
180	3.713	0.41	0.28
240	3.697	0.40	0.27
300	3.682	0.38	0.26
360	3.668	0.37	0.25
420	3.655	0.35	0.24
480	3.641	0.34	0.24
540	3.630	0.33	0.23
600	3.619	0.32	0.22
720	3.598	0.30	0.21
840	3.578	0.28	0.19
960	3.561	0.26	0.18
1200	3.528	0.23	0.16
1500	3.496	0.20	0.13
1800	3.465	0.17	0.11
2100	3.440	0.14	0.10
2400	3.418	0.12	0.08
2700			
3000			
3240			

Graphs of Hvorslev Piezometer Test (top graph has normal axes and bottom graph has a log H-h/H-Ho axis)





Note: Hvorslev method is based on the slope of the best-fit line. This is calculated by taking the elapsed time, T_0, over 1 natural log interval of the graph, i.e. normalised head between 1 and 0.37.

Borehole Variable Head Permeability Test

Borehole ID

BH6_test 3

Project Details

Project Name	Grey Lynn Tunnel
Project Number	WWA047
Test Date	17/7/1018
Tested	JNS
Checked	

Test Parameters

Top of screen	47.200 m
Bottom of Screen	54.500 m
Screen Length, *L*	7.300 m
Static Water Level, *H*	3.300 m
Initial Water Level, H_0	4.750 m
Hole Radius, *R*	0.050 m
Casing Radius, *r*	0.025 m

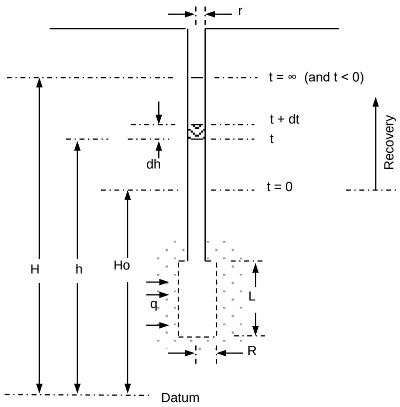
Note: If the datum is above the hole, the height/depth readings do not have to be negative numbers - as long as they are either all negative or all positive, the answer will be correct.

Result

Hydraulic Conductivity

***K* = 1.06E-07 m/s**

Test Schematic



Hvorslev (1951) method:

$$F = \frac{2\pi L}{\ln(L/R)} \qquad K = \frac{\pi r^2}{F T_0}$$

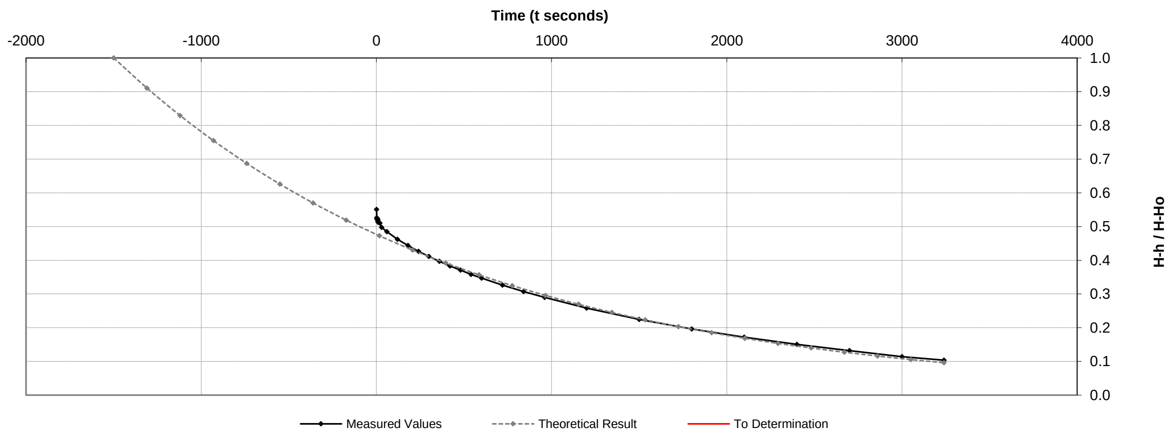
Calibrated Parameters

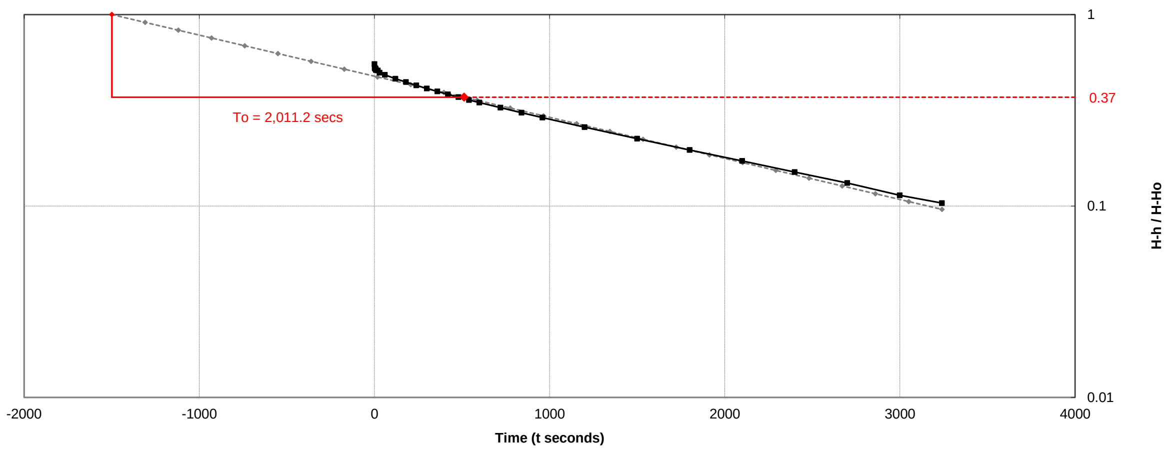
Intake factor, *F*	9.20
Time Factor, T_0	2,011.2

Measured Data

Time (Secs)	Depth (h) (m)	H - h (m)	H-h / H-H0
1	4.099	0.80	0.55
2	4.062	0.76	0.53
3	4.059	0.76	0.52
4	4.061	0.76	0.52
5	4.056	0.76	0.52
6	4.054	0.75	0.52
7	4.057	0.76	0.52
8	4.053	0.75	0.52
9	4.048	0.75	0.52
10	4.044	0.74	0.51
20	4.040	0.74	0.51
30	4.021	0.72	0.50
60	4.003	0.70	0.48
120	3.971	0.67	0.46
180	3.944	0.64	0.44
240	3.919	0.62	0.43
300	3.896	0.60	0.41
360	3.875	0.58	0.40
420	3.856	0.56	0.38
480	3.837	0.54	0.37
540	3.819	0.52	0.36
600	3.803	0.50	0.35
720	3.773	0.47	0.33
840	3.745	0.45	0.31
960	3.720	0.42	0.29
1200	3.674	0.37	0.26
1500	3.626	0.33	0.22
1800	3.584	0.28	0.20
2100	3.549	0.25	0.17
2400	3.518	0.22	0.15
2700	3.491	0.19	0.13
3000	3.465	0.17	0.11
3240	3.450	0.15	0.10

Graphs of Hvorslev Piezometer Test (top graph has normal axes and bottom graph has a log H-h/H-Ho axis)





Note: Hvorslev method is based on the slope of the best-fit line. This is calculated by taking the elapsed time, T_0, over 1 natural log interval of the graph, i.e. normalised head between 1 and 0.37.

Appendix C. Packer Test Analyses

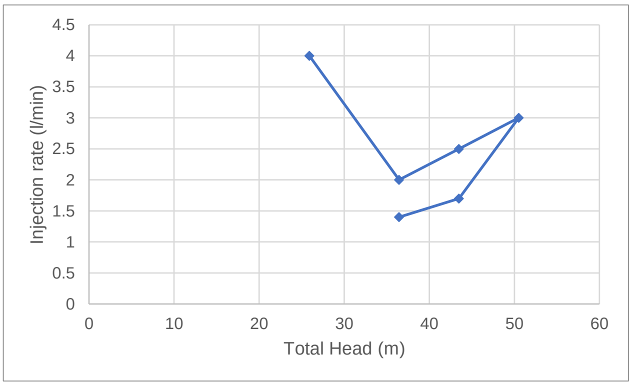
Packer Test Analysis

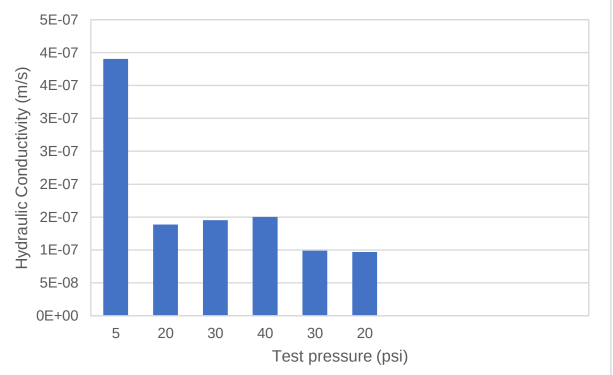
Project Name	Grey Lynn Tunnel	**Client**	Watercare
Borehole ID	CIE-BH01	**Contractor**	McMillans Drilling Group Ltd
Hole Diameter (m)	0.123	**Test Date**	16/03/2018
Top of test interval (mBGL)	17	**Collar Point (mAGL)**	1
Bottom of test interval (mBGL)	21.5	**Static WL (mBTC)**	2.6
Length of test interval (m)	4.5	**Gauge Height (m)**	0.9
		Static Pressure (m)	22.4

Test step	Time elapsed	Water Take			Gauge Pressure		Net Test Pressure	Total Head	Injection Rate	Take	Lugeon Value	K[1]
	(min)	Flow 1 (L)	Flow 2 (L)	Total flow	(psi)	(kPa)	(kPa)	(m)	(L/min)	(L/min/m)		(m/s)
1	10	200	240	40	5	34	254	25.91	4	0.89	3.50	3.90E-07
2	20	240	260	20	20	138	358	36.46	2	0.44	1.24	1.39E-07
3	30	265	290	25	30	207	427	43.49	2.5	0.56	1.30	1.45E-07
4	40	290	320	30	40	276	496	50.51	3	0.67	1.35	1.50E-07
5	50	330	347	17	30	207	427	43.49	1.7	0.38	0.89	9.89E-08
6	60	350	364	14	20	138	358	36.46	1.4	0.31	0.87	9.71E-08
7												
8												
9												
10												
											Mean	**1.7E-07**

1. K is hydraulic conductivity. The relationship between K and Lugeon Units was defined by Richter and Lillich (1975).

Representative hydraulic conductivity (m/s):	9.71E-08
Test flow behaviour:	Void Filling
Comments:	Highest flow at low pressure indicates void filling. Final permeability used as representative value.





Lugeon Value	Conductivity classification	Rock discontinuity condition
<1	Very low	Very tight
1-5	Low	Tight
5-15	Moderate	Few partly open
15-50	Medium	Some open
50-100	High	Many open
>100	Very high	Open closely spaced or voids

Ref. http://www.geotechdata.info/geotest/Lugeon_test.html

Key
Background data to be entered
Test data
Spreadsheet calculation (do not change)
Hydraulic conductivity result

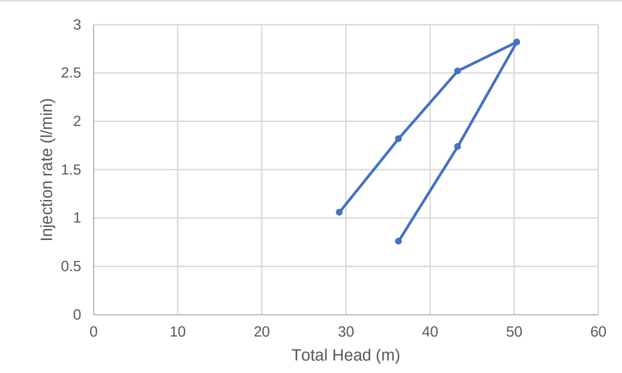
Packer Test Analysis

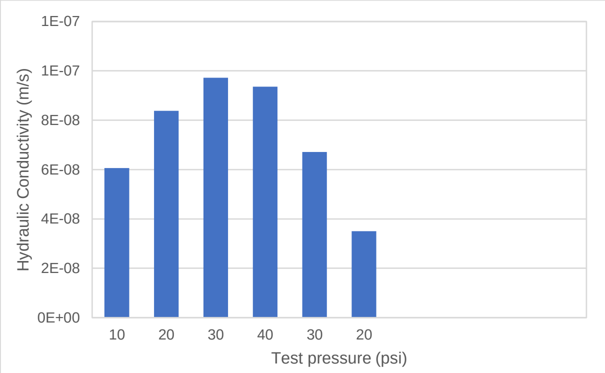
Project Name	Grey Lynn Tunnel	**Client**	Watercare
Borehole ID	CIE-BH02	**Contractor**	McMillans Drilling Group Ltd
Hole Diameter (m)	0.96	**Test Date**	21/03/2018
Top of test interval (mBGL)	18.7	**Collar Point (mAGL)**	0.7
Bottom of test interval (mBGL)	21.5	**Static WL (mBTC)**	6.2
Length of test interval (m)	2.8	**Gauge Height (m)**	0.7
		Static Pressure (m)	22.2

Test step	Time elapsed	Water Take			Gauge Pressure		Net Test Pressure	Total Head	Injection Rate	Take	Lugeon Value	K[1]
	(min)	Flow 1 (L)	Flow 2 (L)	Total flow	(psi)	(kPa)	(kPa)	(m)	(L/min)	(L/min/m)		(m/s)
1	10	935	945.6	10.6	10	69	287	29.23	1.06	0.38	1.32	6.06E-08
2	10	948	966.2	18.2	20	138	356	36.26	1.82	0.65	1.83	8.38E-08
3	10	970	995.2	25.2	30	207	425	43.29	2.52	0.90	2.12	9.72E-08
4	10	998	1026.2	28.2	40	276	494	50.31	2.82	1.01	2.04	9.36E-08
5	10	1029	1046.4	17.4	30	207	425	43.29	1.74	0.62	1.46	6.71E-08
6	10	1047	1054.6	7.6	20	138	356	36.26	0.76	0.27	0.76	3.50E-08
7												
8												
9												
10												
											Mean	**7.3E-08**

1. K is hydraulic conductivity. The relationship between K and Lugeon Units was defined by Richter and Lillich (1975).

Representative hydraulic conductivity (m/s):	7.29E-08
Test flow behaviour:	Turbulent
Comments:	Laminar flow because of small range of permeability values. Average permeability was used.





Lugeon Value	Conductivity classification	Rock discontinuity condition
<1	Very low	Very tight
1-5	Low	Tight
5-15	Moderate	Few partly open
15-50	Medium	Some open
50-100	High	Many open
>100	Very high	Open closely spaced or voids

Ref. http://www.geotechdata.info/geotest/Lugeon_test.html

Key
Background data to be entered
Test data
Spreadsheet calculation (do not change)
Hydraulic conductivity result

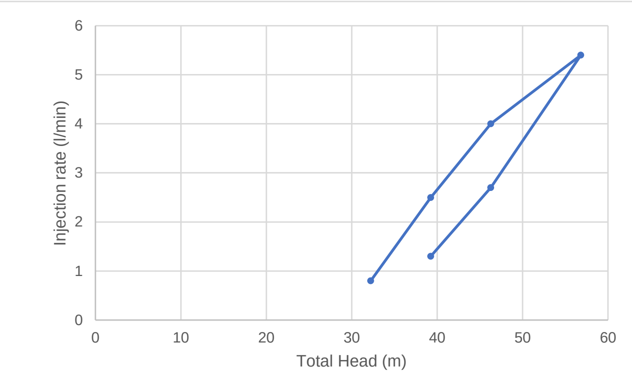
Packer Test Analysis

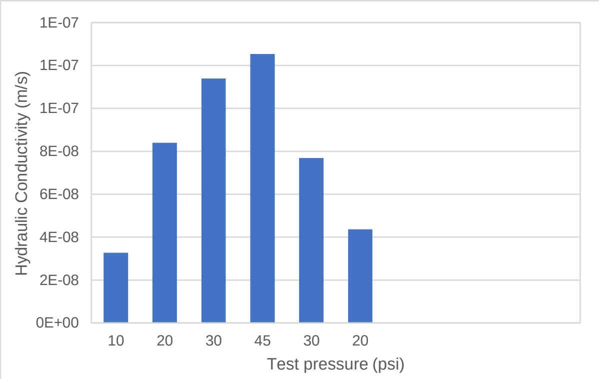
Project Name	Grey Lynn Tunnel	**Client**	Watercare
Borehole ID	CIE-BH03	**Contractor**	McMillans Drilling Group Ltd
Hole Diameter (m)	0.96	**Test Date**	27/03/2018
Top of test interval (mBGL)	20	**Collar Point (mAGL)**	0
Bottom of test interval (mBGL)	24.5	**Static WL (mBTC)**	0.9
Length of test interval (m)	4.5	**Gauge Height (m)**	0.7
		Static Pressure (m)	25.2

Test step	Time elapsed	Water Take			Gauge Pressure		Net Test Pressure	Total Head	Injection Rate	Take	Lugeon Value	K[1]
	(min)	Flow 1 (L)	Flow 2 (L)	Total flow	(psi)	(kPa)	(kPa)	(m)	(L/min)	(L/min/m)		(m/s)
1	10	65	73	8	10	69	316	32.23	0.8	0.18	0.56	3.27E-08
2	10	76	101	25	20	138	385	39.26	2.5	0.56	1.44	8.40E-08
3	10	104	144	40	30	207	454	46.29	4	0.89	1.96	1.14E-07
4	10	154	208	54	45	310	557	56.83	5.4	1.20	2.15	1.25E-07
5	10	212	239	27	30	207	454	46.29	2.7	0.60	1.32	7.69E-08
6	10	241	254	13	20	138	385	39.26	1.3	0.29	0.75	4.37E-08
7												
8												
9												
10												
											Mean	**7.9E-08**

1. K is hydraulic conductivity. The relationship between K and Lugeon Units was defined by Richter and Lillich (1975).

Representative hydraulic conductivity (m/s):	5.35E-08
Test flow behaviour:	Dilation
Comments:	Partial dilation occurred at 20 psi, increasing with pressure. Average of lower pressure values used as representative permeability.





Lugeon Value	Conductivity classification	Rock discontinuity condition
<1	Very low	Very tight
1-5	Low	Tight
5-15	Moderate	Few partly open
15-50	Medium	Some open
50-100	High	Many open
>100	Very high	Open closely spaced or voids

Ref. http://www.geotechdata.info/geotest/Lugeon_test.html

Key
Background data to be entered
Test data
Spreadsheet calculation (do not change)
Hydraulic conductivity result

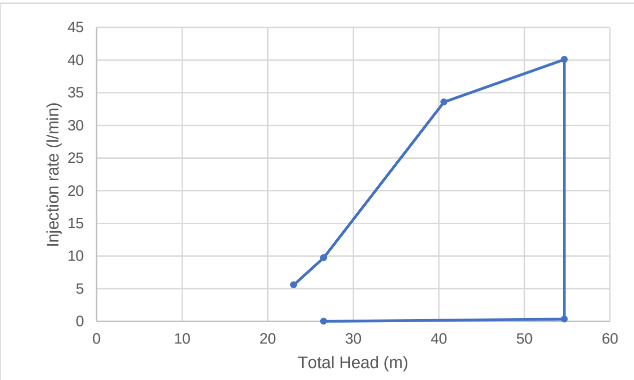
Packer Test Analysis

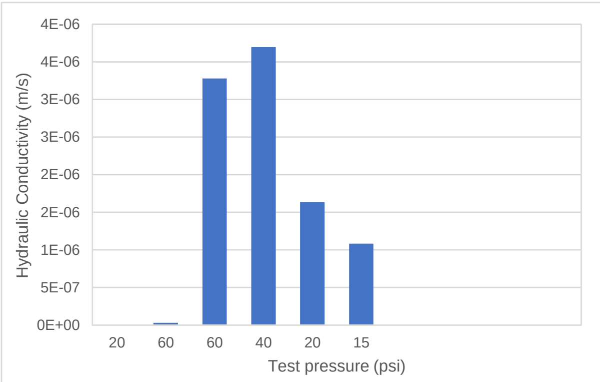
Project Name	Grey Lynn Tunnel	**Client**	Watercare
Borehole ID	CIE-BH04	**Contractor**	McMillans Drilling Group Ltd
Hole Diameter (m)	0.101	**Test Date**	6/07/2018
Top of test interval (mBGL)	9.75	**Collar Point (mAGL)**	1.2
Bottom of test interval (mBGL)	12	**Static WL (mBTC)**	1.13
Length of test interval (m)	2.25	**Gauge Height (m)**	0.5
		Static Pressure (m)	12.5

Test step	Time elapsed	Water Take			Gauge Pressure		Net Test Pressure	Total Head	Injection Rate	Take	Lugeon Value	K[1]
	(min)	Flow 1 (L)	Flow 2 (L)	Total flow	(psi)	(kPa)	(kPa)	(m)	(L/min)	(L/min/m)		(m/s)
1	5	16727.3	16727.3	0	20	138	261	26.56	0	0.00	0.00	0.00E+00
2	5	16727.6	16729.4	1.8	60	414	536	54.67	0.36	0.16	0.30	2.95E-08
3	5	16730.1	16930.5	200.4	60	414	536	54.67	40.08	17.81	33.21	3.28E-06
4	5	16945	17112.8	167.8	40	276	398	40.61	33.56	14.92	37.44	3.70E-06
5	5	17123.6	17172.2	48.6	20	138	261	26.56	9.72	4.32	16.58	1.64E-06
6	5	17174.5	17202.4	27.9	15	103	226	23.04	5.58	2.48	10.97	1.08E-06
7												
8												
9												
10												
											Mean	**1.6E-06**

1. K is hydraulic conductivity. The relationship between K and Lugeon Units was defined by Richter and Lillich (1975).

Representative hydraulic conductivity (m/s):	2.95E-08
Test flow behaviour:	Dlation
Comments:	Dilation occurred after attempting to increase to 90 psi, then losing pressure and returning to 60. First 60 psi increment used.





Lugeon Value	Conductivity classification	Rock discontinuity condition
<1	Very low	Very tight
1-5	Low	Tight
5-15	Moderate	Few partly open
15-50	Medium	Some open
50-100	High	Many open
>100	Very high	Open closely spaced or voids

Ref. http://www.geotechdata.info/geotest/Lugeon_test.html

Key
Background data to be entered
Test data
Spreadsheet calculation (do not change)
Hydraulic conductivity result

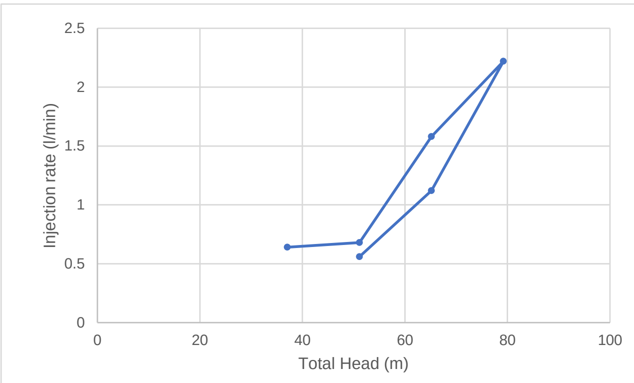
Packer Test Analysis

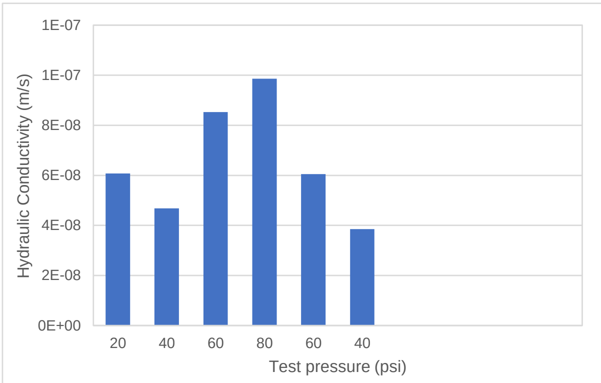
Project Name	Grey Lynn Tunnel	**Client**	Watercare
Borehole ID	CIE-BH04	**Contractor**	McMillans Drilling Group Ltd
Hole Diameter (m)	0.112	**Test Date**	6/07/2018
Top of test interval (mBGL)	19.5	**Collar Point (mAGL)**	1.85
Bottom of test interval (mBGL)	22.5	**Static WL (mBTC)**	0.97
Length of test interval (m)	3	**Gauge Height (m)**	0.5
		Static Pressure (m)	23.0

Test step	Time elapsed	Water Take			Gauge Pressure		Net Test Pressure	Total Head	Injection Rate	Take	Lugeon Value	K[1]
	(min)	Flow 1 (L)	Flow 2 (L)	Total flow	(psi)	(kPa)	(kPa)	(m)	(L/min)	(L/min/m)		(m/s)
1	5	213.2	216.4	3.2	20	138	364	37.06	0.64	0.21	0.59	6.08E-08
2	5	219.8	223.2	3.4	40	276	501	51.11	0.68	0.23	0.45	4.68E-08
3	5	226.1	234	7.9	60	414	639	65.17	1.58	0.53	0.82	8.53E-08
4	5	236	247.1	11.1	80	552	777	79.23	2.22	0.74	0.95	9.86E-08
5	5	249.1	254.7	5.6	60	414	639	65.17	1.12	0.37	0.58	6.05E-08
6	5	255	257.8	2.8	40	276	501	51.11	0.56	0.19	0.37	3.86E-08
7												
8												
9												
10												
											Mean	**6.5E-08**

1. K is hydraulic conductivity. The relationship between K and Lugeon Units was defined by Richter and Lillich (1975).

Representative hydraulic conductivity (m/s):	6.51E-08
Test flow behaviour:	Laminar
Comments:	Laminar flow because of small range of permeability values. 40 psi appears to be an outlier. Average permeability was used.





Lugeon Value	Conductivity classification	Rock discontinuity condition
<1	Very low	Very tight
1-5	Low	Tight
5-15	Moderate	Few partly open
15-50	Medium	Some open
50-100	High	Many open
>100	Very high	Open closely spaced or voids

Ref. http://www.geotechdata.info/geotest/Lugeon_test.html

Key
Background data to be entered
Test data
Spreadsheet calculation (do not change)
Hydraulic conductivity result

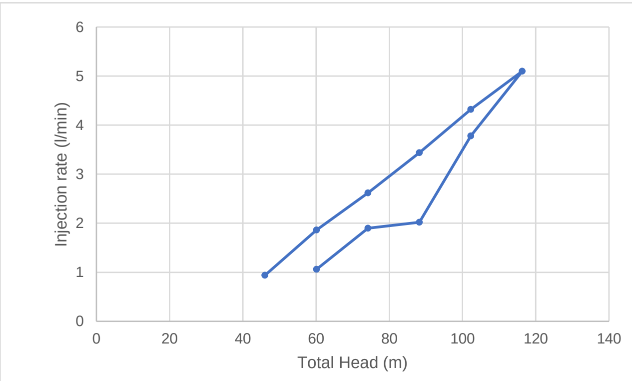
Packer Test Analysis

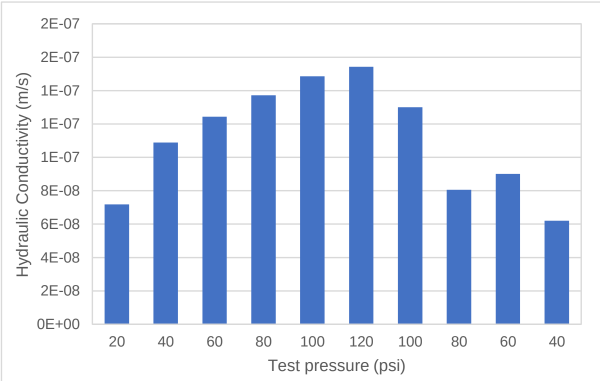
Project Name	Grey Lynn Tunnel	**Client**	Watercare
Borehole ID	CIE-BH04	**Contractor**	McMillans Drilling Group Ltd
Hole Diameter (m)	0.112	**Test Date**	10/07/2018
Top of test interval (mBGL)	28.5	**Collar Point (mAGL)**	1.85
Bottom of test interval (mBGL)	31.5	**Static WL (mBTC)**	0.9
Length of test interval (m)	3	**Gauge Height (m)**	0.5
		Static Pressure (m)	32.0

Test step	Time elapsed	Water Take			Gauge Pressure		Net Test Pressure	Total Head	Injection Rate	Take	Lugeon Value	K[1]
	(min)	Flow 1 (L)	Flow 2 (L)	Total flow	(psi)	(kPa)	(kPa)	(m)	(L/min)	(L/min/m)		(m/s)
1	5	274.3	279	4.7	20	138	452	46.06	0.94	0.31	0.69	7.18E-08
2	5	280.5	289.8	9.3	40	276	590	60.11	1.86	0.62	1.05	1.09E-07
3	5	292.2	305.3	13.1	60	414	728	74.17	2.62	0.87	1.20	1.24E-07
4	5	308.4	325.6	17.2	80	552	866	88.23	3.44	1.15	1.32	1.37E-07
5	5	328.7	350.3	21.6	100	689	1003	102.28	4.32	1.44	1.44	1.49E-07
6	5	359.3	384.8	25.5	120	827	1141	116.34	5.1	1.70	1.49	1.54E-07
7	5	400	418.9	18.9	100	689	1003	102.28	3.78	1.26	1.26	1.30E-07
8	5	420.9	431	10.1	80	552	866	88.23	2.02	0.67	0.78	8.06E-08
9	5	435.1	444.6	9.5	60	414	728	74.17	1.9	0.63	0.87	9.01E-08
10	5	445	451	5.3	40	276	589.712	60.11	1.06	0.3533333	0.60	6.21E-08
											Mean	**1.1E-07**

1. K is hydraulic conductivity. The relationship between K and Lugeon Units was defined by Richter and Lillich (1975).

Representative hydraulic conductivity (m/s):	1.11E-07
Test flow behaviour:	Laminar
Comments:	Laminar flow because of small range of permeability values. Average was used.





Lugeon Value	Conductivity classification	Rock discontinuity condition
<1	Very low	Very tight
1-5	Low	Tight
5-15	Moderate	Few partly open
15-50	Medium	Some open
50-100	High	Many open
>100	Very high	Open closely spaced or voids

Ref. http://www.geotechdata.info/geotest/Lugeon_test.html

Key
Background data to be entered
Test data
Spreadsheet calculation (do not change)
Hydraulic conductivity result

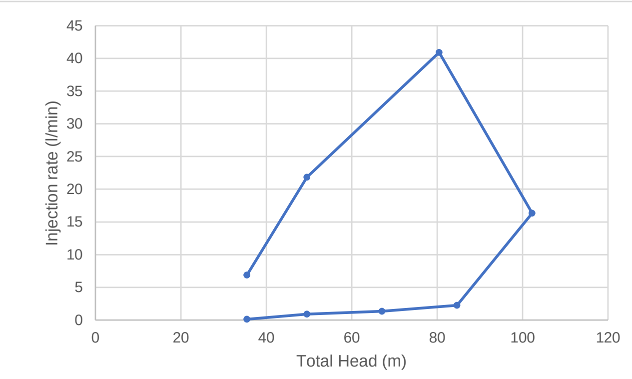
Packer Test Analysis

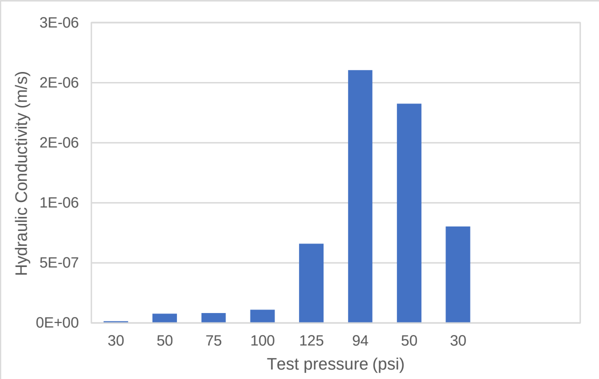
Project Name	Grey Lynn Tunnel	**Client**	Watercare
Borehole ID	CIE-BH05	**Contractor**	McMillans Drilling Group Ltd
Hole Diameter (m)	0.101	**Test Date**	12/07/2018
Top of test interval (mBGL)	11	**Collar Point (mAGL)**	1.1
Bottom of test interval (mBGL)	13.5	**Static WL (mBTC)**	0.2
Length of test interval (m)	2.5	**Gauge Height (m)**	0.9
		Static Pressure (m)	14.4

Test step	**Time elapsed**	**Water Take**			**Gauge Pressure**		**Net Test Pressure**	**Total Head**	**Injection Rate**	**Take**	**Lugeon Value**	**K[1]**
	(min)	**Flow 1 (L)**	**Flow 2 (L)**	**Total flow**	**(psi)**	**(kPa)**	**(kPa)**	**(m)**	**(L/min)**	**(L/min/m)**		**(m/s)**
1	5	3.84	4.46	0.62	30	207	348	35.49	0.124	0.05	0.14	1.45E-08
2	5	5.1	9.69	4.59	50	345	486	49.54	0.918	0.37	0.76	7.67E-08
3	5	11.1	17.75	6.65	75	517	658	67.11	1.33	0.53	0.81	8.20E-08
4	5	21.11	32.41	11.3	100	689	831	84.68	2.26	0.90	1.09	1.10E-07
5	5	37.5	119.1	81.6	125	862	1003	102.25	16.32	6.53	6.51	6.61E-07
6	5	135.3	339.9	204.6	94	648	789	80.47	40.92	16.37	20.74	2.10E-06
7	5	355.3	464.5	109.2	50	345	486	49.54	21.84	8.74	17.98	1.82E-06
8	5	474.8	509.2	34.4	30	207	348	35.49	6.88	2.75	7.91	8.02E-07
9												
10												
											Mean	**7.1E-07**

1. K is hydraulic conductivity. The relationship between K and Lugeon Units was defined by Richter and Lillich (1975).

Representative hydraulic conductivity (m/s):	8.97E-08
Test flow behaviour:	Dilation
Comments:	Dilation occurred at 125 psi. Average of 50-100 psi test used as representative permeability.





Lugeon Value	**Conductivity classification**	**Rock discontinuity condition**
<1	Very low	Very tight
1-5	Low	Tight
5-15	Moderate	Few partly open
15-50	Medium	Some open
50-100	High	Many open
>100	Very high	Open closely spaced or voids

Ref. http://www.geotechdata.info/geotest/Lugeon_test.html

Key
Background data to be entered
Test data
Spreadsheet calculation (do not change)
Hydraulic conductivity result

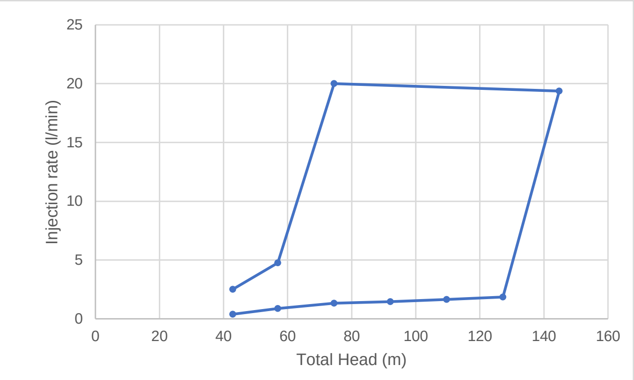
Packer Test Analysis

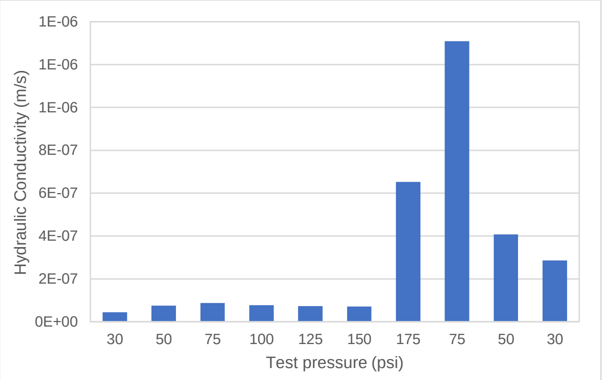
Project Name	Grey Lynn Tunnel	**Client**	Watercare
Borehole ID	CIE-BH05	**Contractor**	McMillans Drilling Group Ltd
Hole Diameter (m)	0.101	**Test Date**	13/07/2018
Top of test interval (mBGL)	19	**Collar Point (mAGL)**	1.1
Bottom of test interval (mBGL)	21	**Static WL (mBTC)**	-2.77
Length of test interval (m)	2	**Gauge Height (m)**	0.8
		Static Pressure (m)	21.8

Test step	Time elapsed	Water Take			Gauge Pressure		Net Test Pressure	Total Head	Injection Rate	Take	Lugeon Value	K[1]
	(min)	Flow 1 (L)	Flow 2 (L)	Total flow	(psi)	(kPa)	(kPa)	(m)	(L/min)	(L/min/m)		(m/s)
1	5	0.85	2.79	1.94	30	207	421	42.89	0.388	0.19	0.46	4.41E-08
2	5	4.54	8.93	4.39	50	345	559	56.94	0.878	0.44	0.79	7.52E-08
3	5	9.86	16.51	6.65	75	517	731	74.51	1.33	0.67	0.91	8.71E-08
4	5	18.59	25.84	7.25	100	689	903	92.08	1.45	0.73	0.80	7.68E-08
5	5	27.29	35.54	8.25	125	862	1076	109.65	1.65	0.83	0.77	7.34E-08
6	5	38.27	47.52	9.25	150	1034	1248	127.23	1.85	0.93	0.74	7.09E-08
7	5	50.02	146.9	96.88	175	1207	1420	144.80	19.376	9.69	6.82	6.53E-07
8	5	161.6	261.61	100.01	75	517	731	74.51	20.002	10.00	13.68	1.31E-06
9	5	271.15	294.94	23.79	50	345	559	56.94	4.758	2.38	4.26	4.08E-07
10	5	298	311	12.56	30	207	420.702	42.89	2.512	1.256	2.99	2.86E-07
											Mean	**3.1E-07**

1. K is hydraulic conductivity. The relationship between K and Lugeon Units was defined by Richter and Lillich (1975).

Representative hydraulic conductivity (m/s):	7.09E-08
Test flow behaviour:	Wash out
Comments:	Wash out occurred at 175 psi, highest Lugeon value before wash out used as representative permeability.





Lugeon Value	Conductivity classification	Rock discontinuity condition
<1	Very low	Very tight
1-5	Low	Tight
5-15	Moderate	Few partly open
15-50	Medium	Some open
50-100	High	Many open
>100	Very high	Open closely spaced or voids

Ref. http://www.geotechdata.info/geotest/Lugeon_test.html

Key
Background data to be entered
Test data
Spreadsheet calculation (do not change)
Hydraulic conductivity result

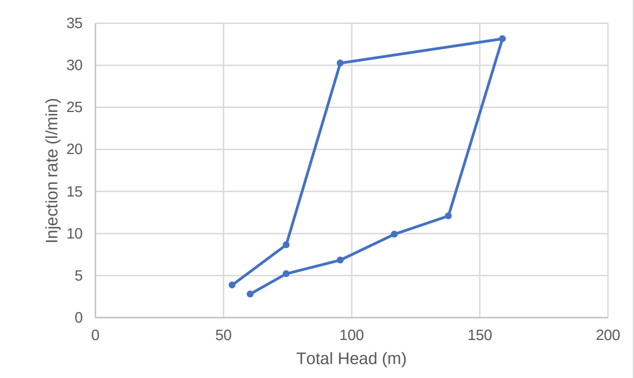
Packer Test Analysis

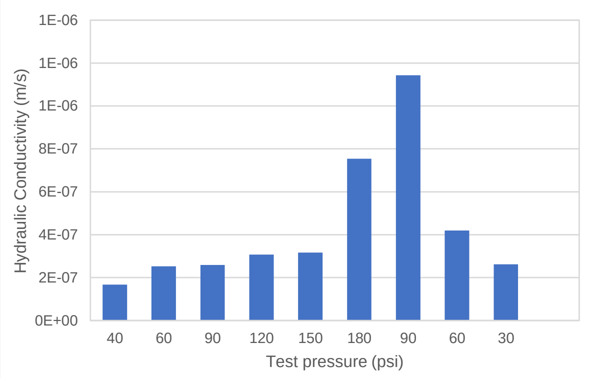
Project Name	Grey Lynn Tunnel	**Client**	Watercare
Borehole ID	CIE-BH05	**Contractor**	McMillans Drilling Group Ltd
Hole Diameter (m)	0.101	**Test Date**	13/07/2018
Top of test interval (mBGL)	28.5	**Collar Point (mAGL)**	1.1
Bottom of test interval (mBGL)	31.5	**Static WL (mBTC)**	-2.77
Length of test interval (m)	3	**Gauge Height (m)**	0.8
		Static Pressure (m)	32.3

Test step	Time elapsed	Water Take			Gauge Pressure		Net Test Pressure	Total Head	Injection Rate	Take	Lugeon Value	K[1]
	(min)	Flow 1 (L)	Flow 2 (L)	Total flow	(psi)	(kPa)	(kPa)	(m)	(L/min)	(L/min/m)		(m/s)
1	5	7.29	21.31	14.02	40	276	593	60.41	2.804	0.93	1.58	1.68E-07
2	5	30.59	56.67	26.08	60	414	731	74.47	5.216	1.74	2.38	2.53E-07
3	5	76.31	110.54	34.23	90	621	937	95.56	6.846	2.28	2.43	2.59E-07
4	5	118.57	168.17	49.6	120	827	1144	116.64	9.92	3.31	2.89	3.07E-07
5	5	191.84	252.29	60.45	150	1034	1351	137.73	12.09	4.03	2.98	3.17E-07
6	5	271.76	437.55	165.79	180	1241	1558	158.81	33.158	11.05	7.09	7.54E-07
7	5	479.7	631.02	151.32	90	621	937	95.56	30.264	10.09	10.76	1.14E-06
8	5	667.25	710.56	43.31	60	414	731	74.47	8.662	2.89	3.95	4.20E-07
9	5	716.89	736.27	19.38	30	207	524	53.39	3.876	1.29	2.47	2.62E-07
10												
											Mean	**4.3E-07**

1. K is hydraulic conductivity. The relationship between K and Lugeon Units was defined by Richter and Lillich (1975).

Representative hydraulic conductivity (m/s):	2.61E-07
Test flow behaviour:	Dilation
Comments:	Dilation occurred at 180 psi, average of values prior to dilation was used as representative permeability.





Lugeon Value	Conductivity classification	Rock discontinuity condition
<1	Very low	Very tight
1-5	Low	Tight
5-15	Moderate	Few partly open
15-50	Medium	Some open
50-100	High	Many open
>100	Very high	Open closely spaced or voids

Ref. http://www.geotechdata.info/geotest/Lugeon_test.html

Key
Background data to be entered
Test data
Spreadsheet calculation (do not change)
Hydraulic conductivity result

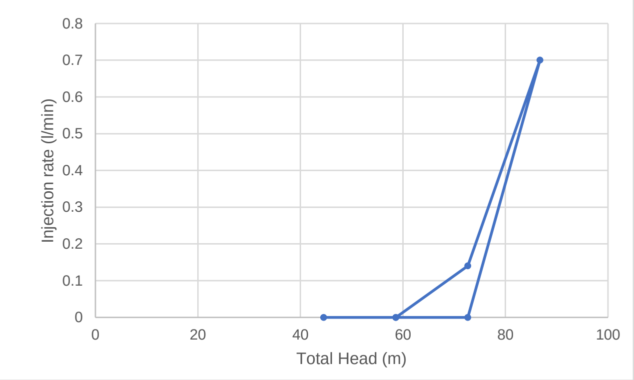
Packer Test Analysis

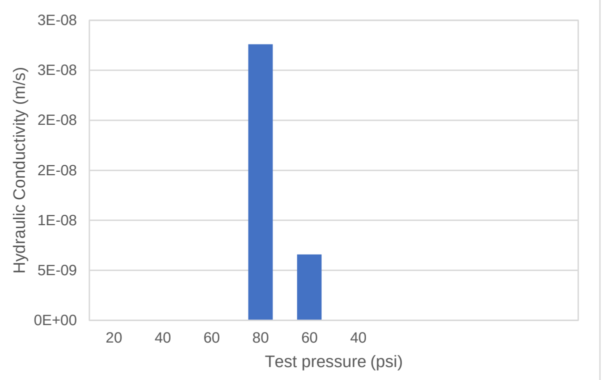
Project Name	Grey Lynn Tunnel	**Client**	Watercare
Borehole ID	CIE-BH06	**Contractor**	McMillans Drilling Group Ltd
Hole Diameter (m)	0.125	**Test Date**	29/06/2018
Top of test interval (mBGL)	27	**Collar Point (mAGL)**	1.2
Bottom of test interval (mBGL)	30	**Static WL (mBTC)**	0.6
Length of test interval (m)	3	**Gauge Height (m)**	0.5
		Static Pressure (m)	30.5

Test step	Time elapsed	Water Take			Gauge Pressure		Net Test Pressure	Total Head	Injection Rate	Take	Lugeon Value	K[1]
	(min)	Flow 1 (L)	Flow 2 (L)	Total flow	(psi)	(kPa)	(kPa)	(m)	(L/min)	(L/min/m)		(m/s)
1	5	16644.2	16644.2	0	20	138	437	44.56	0	0.00	0.00	0.00E+00
2	5	16644.2	16644.2	0	40	276	575	58.61	0	0.00	0.00	0.00E+00
3	5	16644.2	16644.2	0	60	414	713	72.67	0	0.00	0.00	0.00E+00
4	5	16653.9	16657.4	3.5	80	552	851	86.73	0.7	0.23	0.27	2.76E-08
5	5	16657.6	16658.3	0.7	60	414	713	72.67	0.14	0.05	0.07	6.59E-09
6	5	16658.3	16658.3	0	40	276	575	58.61	0	0.00	0.00	0.00E+00
7												
8												
9												
10												
											Mean	**5.7E-09**

1. K is hydraulic conductivity. The relationship between K and Lugeon Units was defined by Richter and Lillich (1975).

Representative hydraulic conductivity (m/s):	2.76E-08
Test flow behaviour:	Dilation
Comments:	Flow did not occur until 80 psi. 80 psi used as representative permeability value.





Lugeon Value	Conductivity classification	Rock discontinuity condition
<1	Very low	Very tight
1-5	Low	Tight
5-15	Moderate	Few partly open
15-50	Medium	Some open
50-100	High	Many open
>100	Very high	Open closely spaced or voids

Ref. http://www.geotechdata.info/geotest/Lugeon_test.html

Key
Background data to be entered
Test data
Spreadsheet calculation (do not change)
Hydraulic conductivity result

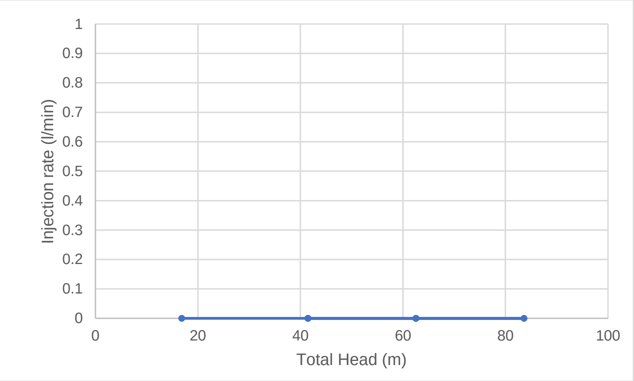
Packer Test Analysis

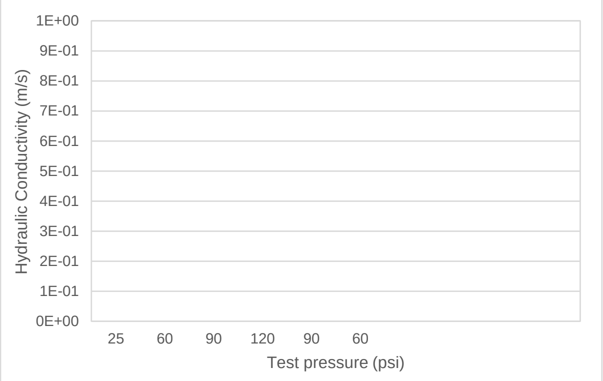
Project Name	Grey Lynn Tunnel	**Client**	Watercare
Borehole ID	CIE-BH06	**Contractor**	McMillans Drilling Group Ltd
Hole Diameter (m)	0.125	**Test Date**	2/07/2018
Top of test interval (mBGL)	50.25	**Collar Point (mAGL)**	1.2
Bottom of test interval (mBGL)	52.5	**Static WL (mBTC)**	0
Length of test interval (m)	2.25	**Gauge Height (m)**	0.5
		Static Pressure (m)	-0.7

Test step	Time elapsed	Water Take			Gauge Pressure		Net Test Pressure	Total Head	Injection Rate	Take	Lugeon Value	K[1]
	(min)	Flow 1 (L)	Flow 2 (L)	Total flow	(psi)	(kPa)	(kPa)	(m)	(L/min)	(L/min/m)		(m/s)
1	5	16664.9	16664.9	0	25	172	166	16.87	0	0.00	0.00	0.00E+00
2	5	16664.9	16664.9	0	60	414	407	41.47	0	0.00	0.00	0.00E+00
3	5	16664.9	16664.9	0	90	621	614	62.56	0	0.00	0.00	0.00E+00
4	5	16664.9	16664.9	0	120	827	821	83.64	0	0.00	0.00	0.00E+00
5	5	16664.9	16664.9	0	90	621	614	62.56	0	0.00	0.00	0.00E+00
6	5	16664.9	16664.9	0	60	414	407	41.47	0	0.00	0.00	0.00E+00
7												
8												
9												
10												
											Mean	**0.0E+00**

1. K is hydraulic conductivity. The relationship between K and Lugeon Units was defined by Richter and Lillich (1975).

Representative hydraulic conductivity (m/s):	0.00E+00
Test flow behaviour:	No flow
Comments:	No Flow





Lugeon Value	Conductivity classification	Rock discontinuity condition
<1	Very low	Very tight
1-5	Low	Tight
5-15	Moderate	Few partly open
15-50	Medium	Some open
50-100	High	Many open
>100	Very high	Open closely spaced or voids

Ref. http://www.geotechdata.info/geotest/Lugeon_test.html

Key
Background data to be entered
Test data
Spreadsheet calculation (do not change)
Hydraulic conductivity result

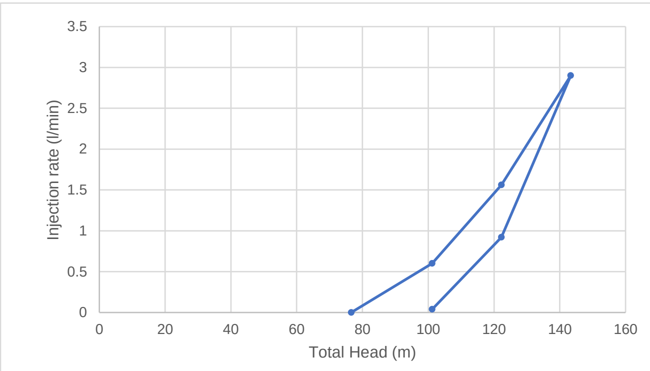
Packer Test Analysis

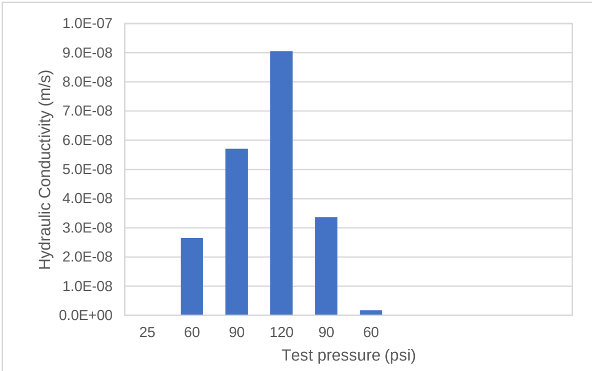
Project Name	Grey Lynn Tunnel	**Client**	Watercare
Borehole ID	CIE-BH06	**Contractor**	McMillans Drilling Group Ltd
Hole Diameter (m)	0.101	**Test Date**	3/07/2018
Top of test interval (mBGL)	56.25	**Collar Point (mAGL)**	1.2
Bottom of test interval (mBGL)	58.5	**Static WL (mBTC)**	0.25
Length of test interval (m)	2.25	**Gauge Height (m)**	0.5
		Static Pressure (m)	59.0

Test step	Time elapsed	Water Take			Gauge Pressure		Net Test Pressure	Total Head	Injection Rate	Take	Lugeon Value	K[1]
	(min)	Flow 1 (L)	Flow 2 (L)	Total flow	(psi)	(kPa)	(kPa)	(m)	(L/min)	(L/min/m)		(m/s)
1	5	16674.8	16674.8	0	25	172	751	76.57	0	0.00	0.00	0.00E+00
2	5	16675.7	16678.7	3	60	414	992	101.17	0.6	0.27	0.27	2.65E-08
3	5	16679.9	16687.7	7.8	90	621	1199	122.26	1.56	0.69	0.58	5.71E-08
4	5	16688.7	16703.2	14.5	120	827	1406	143.34	2.9	1.29	0.92	9.05E-08
5	5	16704.4	16709	4.6	90	621	1199	122.26	0.92	0.41	0.34	3.37E-08
6	5	16709.1	16709.3	0.2	60	414	992	101.17	0.04	0.02	0.02	1.77E-09
7												
8												
9												
10												
											Mean	**3.5E-08**

1. K is hydraulic conductivity. The relationship between K and Lugeon Units was defined by Richter and Lillich (1975).

Representative hydraulic conductivity (m/s):	4.18E-08
Test flow behaviour:	Dilation
Comments:	Dilation occurred at 120 psi. Average of 60 and 90 psi used as representative values.





Lugeon Value	Conductivity classification	Rock discontinuity condition
<1	Very low	Very tight
1-5	Low	Tight
5-15	Moderate	Few partly open
15-50	Medium	Some open
50-100	High	Many open
>100	Very high	Open closely spaced or voids

Ref. http://www.geotechdata.info/geotest/Lugeon_test.html

Key
Background data to be entered
Test data
Spreadsheet calculation (do not change)
Hydraulic conductivity result

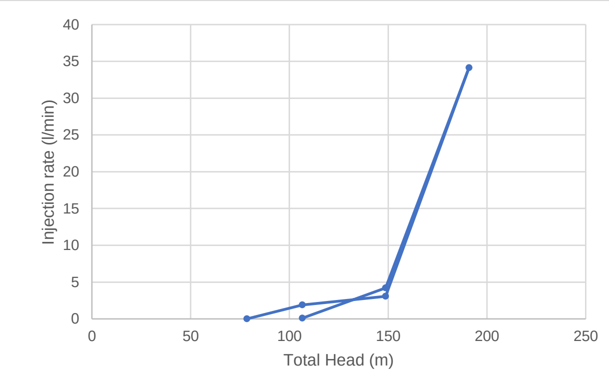
Packer Test Analysis

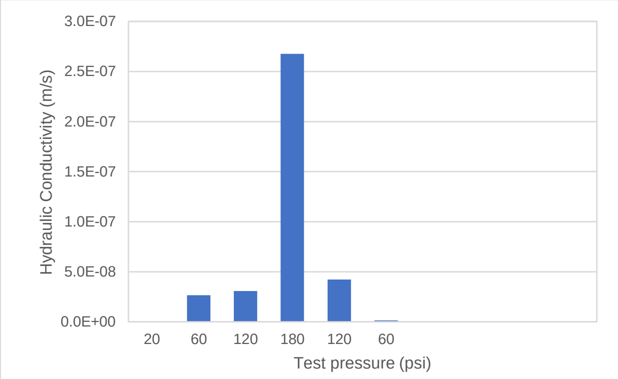
Project Name	Grey Lynn Tunnel	**Client**	Watercare
Borehole ID	CIE-BH06	**Contractor**	McMillans Drilling Group Ltd
Hole Diameter (m)	0.112	**Test Date**	10/07/2018
Top of test interval (mBGL)	54.5	**Collar Point (mAGL)**	1.3
Bottom of test interval (mBGL)	63.5	**Static WL (mBTC)**	1.8
Length of test interval (m)	9	**Gauge Height (m)**	0.9
		Static Pressure (m)	64.4

Test step	**Time elapsed**	**Water Take**			**Gauge Pressure**		**Net Test Pressure**	**Total Head**	**Injection Rate**	**Take**	**Lugeon Value**	**K[1]**
	(min)	**Flow 1 (L)**	**Flow 2 (L)**	**Total flow**	**(psi)**	**(kPa)**	**(kPa)**	**(m)**	**(L/min)**	**(L/min/m)**		**(m/s)**
1	5	30.17	30.17	0	20	138	770	78.46	0	0.00	0.00	0.00E+00
2	5	31.6	41.07	9.47	60	414	1045	106.57	1.894	0.21	0.20	2.66E-08
3	5	50.35	65.62	15.27	120	827	1459	148.74	3.054	0.34	0.23	3.07E-08
4	5	76.31	247	170.69	180	1241	1873	190.91	34.138	3.79	2.03	2.68E-07
5	5	275.9	296.9	21	120	827	1459	148.74	4.2	0.47	0.32	4.23E-08
6	5	298.6	299.07	0.47	60	414	1045	106.57	0.094	0.01	0.01	1.32E-09
7												
8												
9												
10												
											Mean	**6.1E-08**

1. K is hydraulic conductivity. The relationship between K and Lugeon Units was defined by Richter and Lillich (1975).

Representative hydraulic conductivity (m/s):	2.87E-08
Test flow behaviour:	Dilation
Comments:	Dilation occurred at 180 psi. Average of 60 and 120 psi used as representative value.





Lugeon Value	**Conductivity classification**	**Rock discontinuity condition**
<1	Very low	Very tight
1-5	Low	Tight
5-15	Moderate	Few partly open
15-50	Medium	Some open
50-100	High	Many open
>100	Very high	Open closely spaced or voids

Ref. http://www.geotechdata.info/geotest/Lugeon_test.html

Key
Background data to be entered
Test data
Spreadsheet calculation (do not change)
Hydraulic conductivity result

Map Title:

Project Area Overview

Project:

Grey Lynn Tunnel

Client:

Watercare Services Limited

★ **Tawariki shaft location**

Model boundary

Drainage Network

Data Provenance

Topographic Data derived from Land Information New Zealand

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QGIS by:

WILLIAMSON WATER ADVISORY

Figure 1.

Map Title:

Study Area Geology

Project:

Grey Lynn Tunnel

Client:

Watercare Services Limited

★ **Tawariki shaft location**

Model boundary

Model area drains (surface & sub-surface)

Geologic Units

- **East Coast Bays Formation**
- **Tauranga Group**
- **Auckland Basalts**
- **Puketoka Formation**
- **Fill**

Data Provenance

Topographic Data derived from Land Information New Zealand

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Figure 2.

Map Title:
Monitoring bore locations

Project:
Grey Lynn Tunnel

Client:
Watercare Services Limited

- **model boundary_final**
- **Model area drains (surface & sub-surface)**
- **Monitoring bore locations**

Data Provenance

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Figure 3.

Map Title:

Estmiated water table surface

Project:

Grey Lynn Tunnel

Client:

Watercare Services Limited

Model boundary

- Tawariki shaft location
- Boreholes
- Model Boundary
- Drainage network
- Water table elevation contours

Data Provenance

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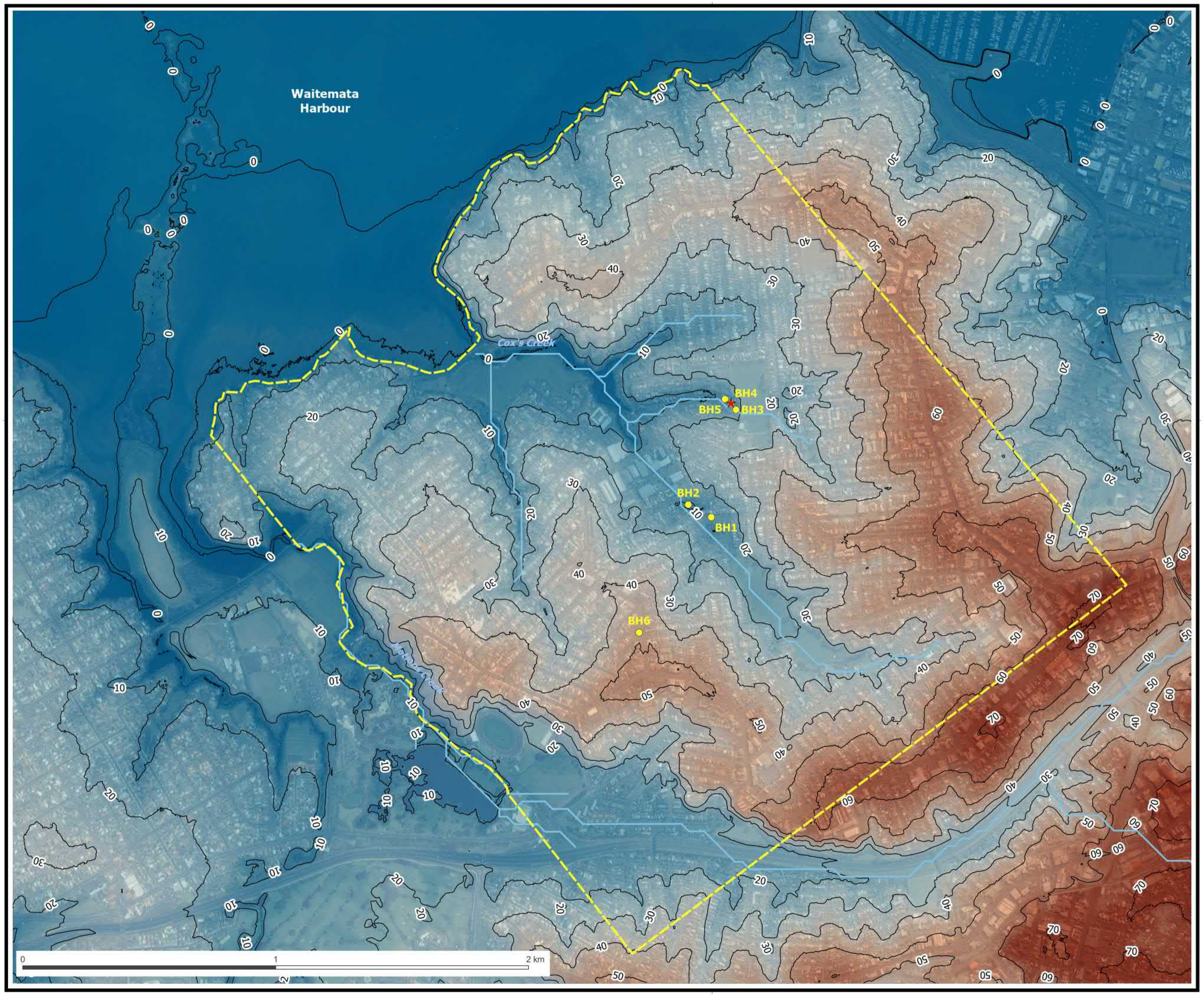
Figure 4.



Map Title:

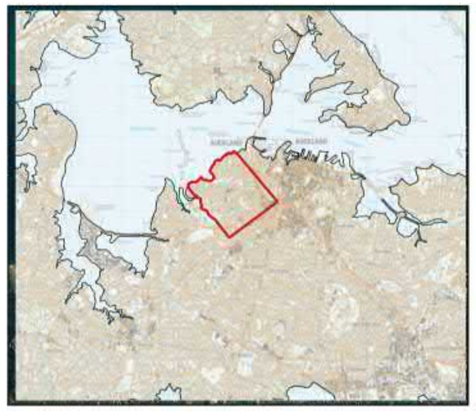
Study area surface elevation

Project:

Grey Lynn Tunnel

Client:

Watercare Services Limited



★	**Tawariki shaft location**
	Model boundary
●	**Monitoring bore locations**
—	**Drainage network**

Surface elevation (mAMSL)

- **0**
- **10**
- **20**
- **30**
- **40**
- **50**
- **60**
- **70**

Data Provenance

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Figure 6.

Map Title:

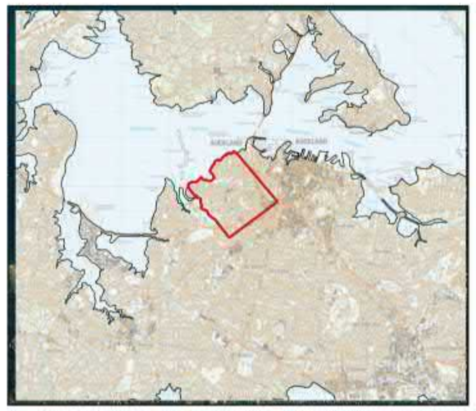
Predicted drawdown following shaft installation: Scenario 4-Layer 2

Project:

Grey Lynn Tunnel

Client:

Watercare Services Limited



★ Tawariki shaft location

Drawdown contour (m)

Data Provenance

Topographic Data derived from Land Information New Zealand

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Figure 11.

Map Title:

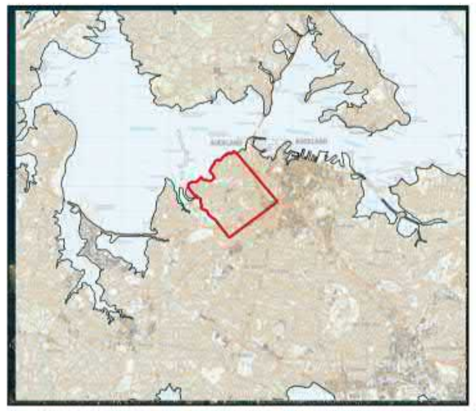
Predicted drawdown following shaft installation: Scenario 4-Layer 4

Project:

Grey Lynn Tunnel

Client:

Watercare Services Limited



★ **Tawariki shaft location**

Drawdown contour (m)

Data Provenance

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Figure 12.

Map Title:

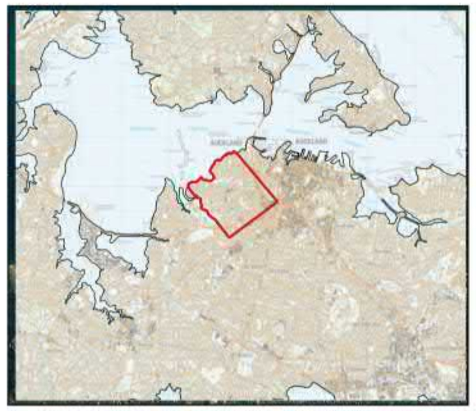
Predicted drawdown following shaft installation: Scenario 6-Layer 2

Project:

Grey Lynn Tunnel

Client:

Watercare Services Limited



★ **Tawariki shaft location**

— **Drawdown contour (m)**

Data Provenance

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Figure 13.

Map Title:

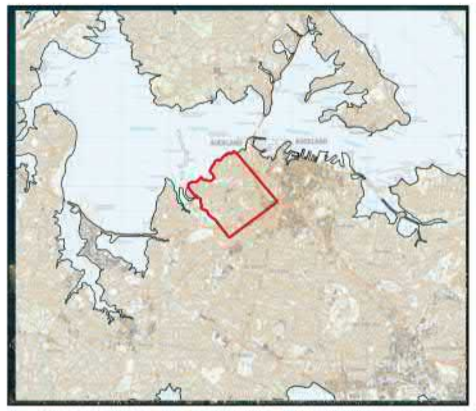
Predicted drawdown following shaft installation: Scenario 6-Layer 4

Project:

Grey Lynn Tunnel

Client:

Watercare Services Limited



★ Tawariki shaft location

Drawdown contour (m)

Data Provenance

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Figure 14.