Douglas Links Well Aquifer Pump Test Report and AEE

765 Muhunoa West Road, Ohau

for
Grenadier Developments Limited
c/- Land Matters Ltd
RD1
Otaki 5581

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Project No. BGS258_02
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CONTENTS

FIGURES

TABLES

EXECUTIVE SUMMARY

Grenadier Developments Limited (the Applicant) are proposing to construct a Links golf course called Douglas Links on a 107-ha coastal property at 765 Muhunoa West Road, Ohau. The development will include a clubhouse and accommodation facilities, along with an Owner's residence, carparking and maintenance sheds. To establish and maintain the fairways and greens, groundwater is required for irrigation, along with water for landscaping and beautification of the property to establish it as one of the premier links in the country. It is understood that the Applicant requires 1500 to 2000 m^3/day in order to irrigate 38.76 to 51.68 ha comprising 18 greens, 36 tees and a practice tee with an estimated volume of 168,060 to 224,806 m^3/year. The property lies centrally within the Horowhenua lowlands, across NNE-SSW-trending marine deposits elevated some 5 to 40 m above sea level, formed sub-parallel to the western coastline north of Paekakariki. The Holocene marine and marginal marine terraces mantle the project area, adjacent to alluvium deposited by the Ohau River that drains westward to the coast approximately 250 m south of Well that has been drilled on the site.

Due to the absence of existing groundwater bores in the area, a 150 mm Well was drilled from November 2020 to February 2021 on the western side of the property, using cable-tool technology for sand conditions. The Well was drilled to 104.60 m depth below top of casing (toc), and is screened from 96.91 – 102.91 toc (6 m) across sandy gravel aquifer with trace shell material and an initial SWL of -11.22 m toc. The bore log records series of sand units above the gravel aquifer, with upper confinement provided by low permeability silty sand fining to clay, with traces of shell (79.10 – 93.0 m toc); clay, peat and wood (48.7-49.10 m toc), and occasional clay beds, with predominantly fine to medium sand with occasional clay layers to the surface.

Following well development, a Step Test was performed in May 2021 at flow rates of 4.75, 6.94, 9.25, 11.56, 13.75 and 16.07 l/s for 60 minutes each step, where a maximum drawdown of 16.29 m was recorded at 16.07 l/s (transmissivity (T) = 134.30 m^2/day), with a Recovery T value of 107.60 m^2/day. We understand from the driller that the maximum flow rate of the test (16.071/s) was a result maximum performance of the pump rather that aquifer limitations.

A 4-day (5760 min) Pump Test was conducted from 10 – 14 May 2021, at a constant rate of 16.07 l/s. The well maintained the flow rate over the test period, with a maximum drawdown of 18.92 m (at 5685 mins) which was 2.53 m less than that predicted based on the Step Test analysis. The Well pump test drawdown data was initially matched against the Cooper-Jacob (1946) curve with a transmissivity T = 108.90 m^2/day; and a match to the Neuman-Witherspoon the Neuman-Witherspoon (1969) solution for leaky confined aquifers determined a low T = 25.11 m^2/day. Manual calculations of Recovery data (using MS Excel and Aqtesolv software) determined values ranging from T = 103.85 to 105.00 m^2/day. A summary of transmissivity values determined from pump test analysis is provided in the table below:

Aquifer Pump Test Analysis Results for Douglas Links Well				
Well No.	**Test**	**Method**	**Drawdown Data T (m^2/day), Theis (1935)**	**Recovery Data T (m^2/day), Theis (1935)**
Well	Step Test	Manual data (Aqtesolv)	134.30	107.60
	Constant Flow	Manual data (Aqtesolv)		103.85
		Electronic data (Aqtesolv)	126.90	105.00
		Drawdown Data T (m^2/day) Cooper-Jacob (1946)		
		Electronic data (Aqtesolv)	108.90	
		Drawdown Data T (m^2/day) Neuman-Witherspoon (1969)		
		Electronic data Aqtesolv)	25.11	

The pump test plan, data analysis and reporting were prepared in accordance with 2008 Aquifer Test Guidelines Environment Canterbury report (Aitchison-Earl & Smith) and Guidelines for the Assessment of Groundwater Abstraction Effects on Stream Flow (PDP and Environment Canterbury, 2000). Manual and electronic monitoring of the pumped well and four relatively shallow neighbouring bores (Tahamata Irrigation, Tahamata Farm, Bryant, Monitoring (wet-well) Bore) was completed prior to, during and post (Recovery) pumping period; however, no measurable well interference effects were recorded in the Monitoring bores which displayed water level fluctuations of less than 100 mm over the monitoring period attributed to tidal flux and barometric pressure responses. The Monitoring (wet-well) Bore was installed to 2.6 m depth between the pumped well and close to the Ohau River to monitor any indirect surface water level fall as a result of pumping. However, the water level rose approximately 0.420 m over the pumping duration, likely due to persistent rainfall.

A conservative transmissivity value, T = 105 m^2/day determined from Recovery data is used for long-term well interference effects predictions, along with an adopted storativity value, s = 0.0001 reflecting confined aquifer conditions. The Aqtesolv software and Drawdown.xls program (Scott, 2001) estimates conservative long-term well interference effects of approximately 4.72 m and 3.88 m within the same aquifer at distances of 2km and 3 km, respectively, based on pumping 24/7 for 150 days at 16.07 l/s. However, the aquifer response displays a 'leaky' component with vertical contribution, potentially reducing the predicted well interference response in neighbouring wells.

An assessment of the potential for stream deletion was completed using the Hunt (2003) model, which estimated stream depletion effects of approximately 4% when pumping the Well at 16.07 l/s over 100 days. This is considered to be low when referencing the Horizons 'One Plan', Table 16.1 classification. In addition, the Ghyben–Herzberg ratio was used to calculate the potential for saline intrusion upon pumping the Well, whereby the saltwater-freshwater interface is 40 times the elevation of the water table above mean sea level (amsl). The water table of approximately 14.76 m amsl determined the interface at about 590 m depth bgl. The confined nature of the aquifer producing from a deep gravel unit and the relatively low flow rate (16.06 l/s) resulting in moderate drawdown suggests that the risk of saline intrusion would be low.

Laboratory analysis of water samples collected from the Well deep gravel aquifer was completed by Hill Laboratories (Hamilton) who provided the following assessment: *The parameters Turbidity, Total Iron and Total Manganese did NOT meet the guidelines laid down in the publication 'Drinking-water Standards for New Zealand 2005 (Revised 2018)' published by the Ministry of Health for water which is suitable for drinking purposes*. The Land Air Water Aotearoa (LAWA) website reveals a State of the Environment (SOE) monitoring bore No. 362001 about 4.5 km east of the Well. The 100 mm diam. bore is very shallow (16.30 m depth) in comparison to the Well and results suggest that it is susceptible to near-surface activities and potential contaminants in shallow groundwater such as E. coli, which is not expected within the deep Well site.

The Horowhenua Groundwater Management Zone (HGMZ) groundwater allocation limit is set at 27 Mm^3/year, based on 5% of annual rainfall (Horizons). Information from Horizons to June 2021 indicates that allocations total 18,963 m^3/day (3,458,853 m^3/year) which amounts to 12.8% of the allocatable volume.

The Pump Test analysis indicates a 'leaky' confined aquifer, with a typical drawdown response of a confined aquifer that exhibits a degree of vertical leakage, providing recharge. The cone of influence generated by pumping a confined aquifer is large and may extend several kilometres; however, the effects at this site are predicted to be less as a result of pumping the Well given the vertical contribution. It is considered that pumping the Applicant's Well at a constant rate of 16.07 l/s over 150 days is likely to result in tolerable well interference effects in deep gravel aquifer bores due to the available head of water, and effects on the environment are considered no more than minor. It should be noted that there are no other wells at this depth within the near vicinity of the pumped Well and therefore adverse effects on nearby bores is not expected.

1. INTRODUCTION

Grenadier Developments Limited (the Applicant) has proposed to develop coastal land totaling 107 ha near the end of Muhunoa West Road, Ohau into a Links golf course called Douglas Links. Critical to the project is water for irrigation of the course fairways and greens, along with water to establish landscaping and beautification of the property to establish it as one of the premier links in the country. It is understood that the Applicant requires 1500 m^3 to 2000 m^3/day in order to irrigate 38.76 to 51.68 ha comprising 18 greens, 36 tees and a practice tee with an estimated volume of 168,060 to 224,806 m^3/year. The development will also include a clubhouse and accommodation facilities along with an Owners residence, carparking and maintenance sheds.

A feasibility study completed by Lattey Group (Lattey) in 2020 identified potential groundwater resources from reviewing surrounding bore data provided by Horizons Regional Council (HRC). The majority of the surrounding wells are screened across shallow brown sand and deeper blue and brown sand to depths ranging from 10 to 45.80 m bgl. A deep gravel is also identified as a productive aquifer.

No productive groundwater bores exist across the project site, and subsequently Neville Webb Welldrilling commenced water well drilling in October, 2020. The Levin-based welldrillers have extensive expertise in constructing water bores in the area, and the deep Well was drilled using cable-tool technology, best suited for the coastal sediment conditions. The Well was drilled to a total depth of 104.90 m below top of casing (toc) on 3 February 2021, following which the well was developed using surging and bailing methods for 36.50 hours. A static water level (SWL) of -11.22 m toc was recorded within the well. Aquifer testing including a Step Test and a 4-day Constant Flow test were completed on the Well in May 2021, at a rate of 16.07 l/s from which a relatively moderate transmissivity value was calculated.

2. SITE INFORMATION

The property is located off Muhunoa West Road, Ohau, across gently sloping to rolling coastal dunes, bound to the south by the Ohau River and coastline to the west (refer Figure 1).

Figure 1. Topo map showing project area off Muhunoa West Road, Ohau (Topomap nz)

The Well is located centrally within the block. The closest surface water feature is the nearby Ohau River which drains westward into the sea about 250 m south of the Well.

2.1 Geological Setting

The project site near the mouth of the Ohau River is located within the Horowhenua lowlands that extend from the coast, approximately 10 km inland to the foot of the bounding Tararua Ranges. The Ohau River mouth lies along the southwestern margin of the NNE-trending South Wanganui Basin, the structural development of which resulted in a progressively subsiding basin accumulating Pliocene and Pleistocene sediments (Anderton, 1981).

The Horowhenua Plains have been comprehensively studied in the past, resulting in interpretations of geological processes over the past 400,000 years which formed the NNE-SSW-oriented coastal lowlands basin, fault-bound by the Tararua Ranges to the east (Begg and Johnston, 2000). Cyclic climate change along with tectonic uplift resulted in sequences of alluvial and marine sediments (Jones and Gyopari, 2005) as illustrated in Figure 2.

During the late Pleistocene penultimate (Waimea) glaciation, deep erosion in the ranges resulted in significant thickness of gravels within the valleys and fanning out across the western plains. During the succeeding interglacial period (between 130,000 and 70,000 BP), sea level rose and cut beach platforms in the coastal hills. The subsequent sea level fall (after 70,000 years BP) resulted in massive scree and debris flows filling in valleys and west-facing wash out plains with gravel, sand and silt (Parata Gravels). Following the end of the last glaciation (10,000 to 11,000 years BP), sea level rise and fall eroded the coastline, with progradation of the coast forming extensive lagoons and swamps and retreat of the sea to its present level.

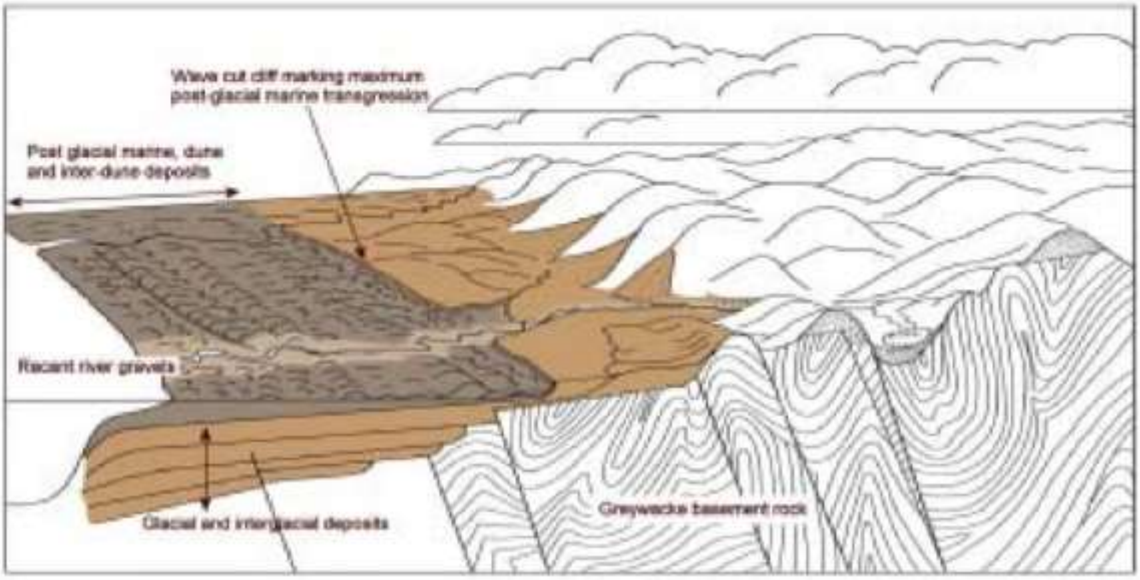

Figure 2. Diagrammatic cross section through the Waikanae area

The geology across the coastal belt comprises Holocene-aged aeolian and active dunes ('*Q1d*' on the geological map) that extend north from Paekakariki northward, beyond Foxton (refer Figure 3). The sand was initially transported southward, parallel to the coast by longshore drift, then blown inland by prevailing westerly winds to form NW-SE-oriented low foredunes. The dunes overlie beach sediments comprising alternating layers of sand, gravel, and mud.

Further inland, rivers across the Tararua Catchment flow the short distance to the ocean, depositing Holocene alluvial sediments (‘*Q1a*’) described as well-sorted floodplain gravels; and older alluvium (‘*Q2a*’) comprising poorly- to moderately-sorted gravel with minor sand or silt underlying aggradational and degradational terraces; and (‘*Q3a*’) consisting of weathered, poorly- to moderately-sorted gravel underlying loess-covered, commonly eroded aggradational surfaces.

Older terraces lie at higher elevations further east, which are mapped as beach deposits (‘*Q5b*’) consisting of marine gravel with sand, commonly underlying loess and fan deposits; and older weathered, loess-covered alluvial and fan gravel deposits (‘*mQa*’ and ‘*uQa*’), with greywacke basement strata (‘*Tt*’) forming the ranges.

Figure 3. **GNS 1:250,000 Geological Qmap across the project area (Begg and Johnston, 2000).**

A review of published geological maps reveals an active fault across the eastern periphery of the plains, oriented SSW-NNE which is downthrown to the east (Begg and Johnston, 2000). The southern extent of the fault trends toward the west just south of Otaki River, but appears to terminate or is not clearly identified as it tracks west beneath the accumulated beach sediments.

Similarly, no faults are mapped across the sand dunes of the project area, although an active fault is shown on the GNS active fault database (data.gns.cri.nz/af) transecting Muhunoa West Road approximately 4 km east of the project site (refer Figure 4). The Poroutawhao Fault is described as reverse with a low slip rate and moderate displacement that last moved during the Holocene with an IV Recurrence Interval (>5,000 to <= 10,000 years).

Figure 4. GNS Active Faults database map across the southern Levin area ((data.gns.cri.nz/af).

3. IRRIGATION REQUIREMENTS

The Applicant's property at 765 Muhunoa West Road totals 107 ha; however, the area to be irrigated is likely to be less. A Feasibility Study by Lattey Group (2020) provides details as to the likely water use across the property and it is understood that a daily irrigation volume 1,500 to 2,000 m^3/day is required which equates to flow rates of 17.36 and 23.15 l/s, respectively.

The 2020 study calculates daily and annual irrigation requirements using the IRRICALC (Irrigation NZ) and SPASMO (Plant and Food Research Limited), with the latter preferred by Horizons Regional Council (HRC). The two soil types evenly distributed across the property are described as the Himitangi and Foxton Black Sand. Based on the SPASMO model, a calculated demand of 4,140 m^3/day (47.92 l/s) and annual volume of 465,450 m^3 is required across the 107-ha block (Lattey, 2020) as displayed in the table of Irrigation Demands (refer Table 1).

It is understood that initially, the Applicant requires 1500 m^3 to 2000 m^3/day in order to irrigate 38.76 to 51.68 ha comprising 18 greens, 36 tees and a practice tee, with an estimated volume of 168,060 to 224,806 m^3/year. The development will also include a clubhouse and accommodation facilities along with an Owners residence, carparking and maintenance sheds.

Table 1. Irrigation Demand Calculations (Lattey Group)

Soil Type	Land Area (Ha)	Peak Monthly Rate (mm)	+20% for Distribution Inefficiencies	Peak Daily Rate (mm)	Peak Daily volume (m3)	28-day Rate	28-day Volume (m3)
Foxton Black sand	53.5	100	120	3.87	2,070	108	57,780
Himatangi Sand	53.5	100	120	3.87	2,070	108	57,780
Totals	107				**4,140**		**115,560**
Soil Type	**Land Area (Ha)**	**Annual Rate (mm)**	**+20% for Distribution inefficiencies**	**Annual Volume (m3)**			
Foxton Black sand	53.5	350	420	224,700			
Himatangi Sand	53.5	375	450	240,750			
Totals	107			**465,450**			

4. HYDROGEOLOGY OF THE PROJECT AREA

The property lies centrally within the Horowhenua lowlands, across NNE-SSW-trending marine deposits formed sub-parallel to the western coastline north of Paekakariki. The zone is elevated some 5 to 40 m above sea level, and published geological and topographic maps clearly display the stable inland dune formations, and mobile coastal dunes oriented NW-SW, formed perpendicular to the coast by longshore drift (Begg and Johnston, 2000).

Holocene beach deposits and marginal marine terraces mantle the project area, adjacent to alluvium deposited by the Ohau River that drains westward to the coast approximately 250 m south of the Well. A review of bore logs from nearby wells revealed five bores within 1.5 km radius of the Well as displayed in Figure 5. It is noted that there are no bores within 1 km of the project site, likely due to intensive development of flat land cropping and horticulture further to the east. The bore logs reveal fine to medium brown sand aquifers particularly in the near-surface and shallow depths; with deeper coarse blue and brown sand aquifers; and a productive gravel aquifer identified in a nearby bore, below 25 m depth.

Figure 5. Map showing bores within a 4 km radius of the project area (Lattey)

The near surface and upper sequence of Holocene dune sands adjacent to the coast, where groundwater is extensively found, however the homogenous, fine grained nature of the strata results in relatively low yields with transmissivity values calculated from 8 to 11 m^2/day. The dunes overlie highly permeable gravel and sands alluvial deposits in an unconfined to semi-confined system, with water abstracted for municipal and irrigation supplies. Transmissivity values are much higher (up to 2,750 m^2/day at Otaki) due to the re-worked nature of the sediments. The deeper sediments are interpreted as alluvial deposits accumulated during the Waimea (penultimate) glacial period when extensive alluvial fans were building out from the foothills.

Representative hydraulic properties for hydrostratigraphic units in the Otaki groundwater zone are described by Gyopari et al (2014) and detailed in Table 2. Although the number of available aquifer pump tests was limited, the transmissivity values indicate a significant difference in hydraulic properties for the highly permeable shallow alluvium (and reworked Otaki River floodplain gravels) and the lower permeability near surface dune sand and late Quaternary deep gravels and alluvium.

Results from aquifer pump tests on the deeper gravels determined transmissivity values of about 144 to 200 m^2/day and storage coefficient of 6×10^{-5} and 1.2×10^{-4}. Pump test data analysis for one of the tests however, displayed a departure from the ideal curve, which infers vertical leakage from overlying water-bearing layers in response to pumping (Ingham et al, 2006; Gyopari et al, 2014).

Table 2. Representative hydraulic properties for hydrostratigraphic units in the Otaki groundwater zone (Gyopari et al, 2014).

Unit	T m2/day	K m/day	S	Geological Description
Q1 sand	10	~1	0.2	Fine to medium sand and silt with occasional gravels and peat layers
Q1 Alluvium	4,500	~250 - 500	0.2	Coarse sand and gravel
Q2 Alluvium	5,000 250	~250 - 500 5 - 20	? - 0.25 0.1	Coarse sand and gravel Claybound gravel and sand
Q5 Sand	350	1 - 10	0.0001	Fine sand and silt containing occasional waters of weathered gravel and organics
Q6 Alluvium	200	1 - 10	0.0001	Weathered gravels containing a high percentage of silt and sand

4.1 Aquifer Parameters of Nearby Bores

Six nearby wells were identified in the Feasibility Report (Lattey, 2020), the pump test data for which provided detail on aquifer parameters and characteristics. The aquifer pump test data for Bores 361021, 361041 and 361051 provided transmissivity values of 23, 41 and 86 m^2/day, respectively. Although the values are low, the reported transmissivities are consistent with a sand aquifer.

4.1.1 Bore No. 361063 Pump Test data

The nearby Tahamata irrigation Bore No. 361063 located to the south of the Ohau River was reviewed, the bore log for which reveals the well produces from a gravel aquifer from 26.70 to 33.90 m top of casing (toc) overlain by peat and clay to 22 m depth, and cemented sand and silt to the surface (Lattey, 2020). The well recorded flowing artesian conditions with a SWL of +2.46 m above toc inferring a confined aquifer system.

A two-day aquifer pump test was conducted on Bore No. 361063 at a rate of 43.60 l/s with responses from an observation well located 400 m distant and indications of tidal flux suggesting a level of confinement. The transmissivity value for the gravel aquifer was reported as 5200 m^2/day, and storativity of 1.1E-4, with a relatively low leakage coefficient of K'/B' of 1.3E-4. The aquifer parameters suggest a highly transmissive, leaky confined aquifer. Re-analysis using the aquifer test data by PDP, further quantified the potential for stream depletion and concluded that stream leakage was equivalent to about 5% of the pumped volume after 10 days' pumping. The impact of the leakage was determined to be minor under the One Plan (Policy 16-6) and below the threshold requiring management based on river flows and surface water allocation (Lattey, 2020).

5. DETAILS OF PUMPED DOUGLAS LINKS WELL

In November 2020, Neville Webb Welldrilling commenced drilling a 150 mm diameter Test Well using a cable-tool rig, best suited for the predicted sandy stratigraphy. The Well site is located approximately 250 m north of the Ohau River and 230 m west of the eastern boundary as shown in Figure 6. Additional photos are included in Appendix A. The well was spudded on 17 November, 2020 and reached a total depth of 104.9 m toc on 13 February, 2021.

Figure 6. The Neville Webb Welldrilling cable-tool rig drilling the new Well. View southwest toward the Ohau River, and coastline to the west.

The cable-tool drilling rig was used to ensure detailed formation location identification and accurate sampling, which allows a comprehensive bore log to be generated (Neville Webb Welldrilling, 2020). The Well bore log is included as Appendix B which reflects well drilling depths and formation identification.

A SWL is typically recorded when a water-bearing formation is penetrated and identified. In addition, water quality samples were collected at selected intervals to be analysed by Hill Laboratories (refer Appendix C). The results should be compared to the NZ Ministry of Health Drinking Water Standards.

5.1 Well Details

Well drilling results indicate the Well intercepted a series of sand zones, with medium brown sand from the surface to 12.00 m depth. Below this, zones of predominantly medium grained, silty blue sand with shell material (to 21.10 m toc) and some clay layers present to 71.90 m depth.

A brown clay layer with peat and wood was logged from 48.70 to 49.10 m bgl, and it is noted that the underlying sand intervals included traces of gravel. The interval is described as a ‘dry’ zone.

Traces of gravel are logged within sand intervals from 65.90 to 68.00 m toc and from 71.90 and 79.10 m toc which are described as water bearing. From 79.10 to 93.00 m toc fine silty sand is logged containing traces of shell.

A sandy gravel interval is described from 93 to 103.40 m toc which exhibits traces of shell, overlain by medium sand to at least the base of the 104.90 metre-deep bore hole, which became increasingly gravelly when drilling ceased.

The SWL recorded during drilling (no screen) to 03.12.20 is detailed as follows:

- casing at 13.80 m toc: SWL = -11.65 m below ground level (bgl)
- casing at 38.00 m toc: SWL = -13.38 m bgl
- casing at 44.00 m toc: SWL = -10.80 m bgl

Bore hole logging also identifies potentially productive strata during drilling and thus far, water bearing zones described as 'Good' (G) and 'Very Good' (VG) are recorded at the following depths:

- 21.10 – 44.90 m toc: blue, silty, fine to medium sand with traces of silty clay (G);
- 44.90 – 48.70 m toc: blue medium sand with layers of very sandy clay (G);
- 49.10 – 53.50 m toc: blue, medium sand (G);
- 53.50 – 65.90 m toc: blue, medium/coarse sand with thin clay layers (G);
- 68.00 – 71.90 m toc: blue, fine to medium sand (VG);
- 71.90 – 79.10 m toc: blue, medium sand with trace clay and gravel (G); and,
- 93.00 – 103.40 m toc: blue gravel, sandy with trace shell. (VG). SWL = -11.22 m toc.

The 150 mm slotted screen was installed across the deep gravel interval from 96.91 to 102.91 m toc.

6. WELL STEP TEST

A Step Test was undertaken by Neville Webb & Son Welldrilling on 7 May 2021 following Environment Canterbury (ECAN) guidelines prepared by Aitchison-Earl and Smith (2008). Step Test data analysis was completed using methodology as outlined in Kruseman and de Ridder (2000) with the Eden-Hazel (1973) method for confined aquifers. The Eden-Hazel (1973) method is used noting the following assumptions:

1) *The aquifer is confined;*
2) *The aquifer has a seemingly infinite areal extent;*
3) *The aquifer is homogeneous, isotropic, and of uniform thickness over the area influenced by the test;*
4) *Prior to pumping, the piezometric surface is horizontal (or nearly so) over the area that will be influenced by the test;*
5) *The aquifer is pumped step-wise at increased discharge rates;*
6) *The well penetrates the entire thickness of the aquifer and thus receives water by horizontal flow;*
7) *The flow to the well is in an unsteady state;*
8) *The non-linear well losses are appreciable and vary according to the expression CQ^2;*
9) *$u < 0.01$;*
10) *The non-linear well losses are appreciable and vary according to the expression CQ^P.*

6.1 New Well Step Test (7 May 2021)

Once the new Well was drilled and developed, a Step Test was completed on 7 May 2021 at six steps of 59 mins duration each step, along with 60 mins Recovery time in order to determine well losses and transmissivity values for the pumped aquifer, used to determine a sustainable flow rate for the 4-day Constant Flow Pump Test.

The Step Test comprised six flow rates of 4.75, 6.94, 9.25, 11.56, 13.75 and 16.07 l/s for 60 minutes each step, plus 60 mins' Recovery time. The manual water level data (as presented in Appendix D) was recorded by the welldrillers and provided to Bay Geological Services Ltd. for processing and analysis.

Each step was completed at the designated flow rate, and results indicate that the early steps appeared to approach stabilisation; although this was not observed at the higher rate Steps 3 to 6. The maximum drawdown of 16.29 m was recorded at the end of the final Step 6 (at 16.07 l/s) as detailed in Table 3.

Table 3. Summary of Well Step Test results

Step	1	2	3	4	5	6	Recovery
Pump step rates (l/s)	***4.75***	***6.94***	***9.25***	***11.56***	***13.75***	***16.07***	***0***
Step duration (mins)	59	59	59	59	59	59	60
Elapsed Time (mins)	59	118	177	236	295	354	414
Maximum actual DD (m)	3.37	5.66	8.49	10.86	13.35	16.29	-1.49 *(not fully recovered)*

The results were analysed using the Aqtesolv (Duffield, 2007) software which provided a range of T values by matching best fit to the drawdown and recovery data as shown in Figure 7, with the full graphs presented in Appendix D. The pumped Douglas Links Well Step Test results are:

- Drawdown data T = 134.30 m^2/day
- Recovery data, T = 107.60 m^2/day

An average transmissivity value, T = 120.9 m^2/day is adopted to determine drawdown within the pumped Well following 4 days (5760 mins) flow testing at a constant rate of 16.07 l/s (1388.45 m^3/day). Using the constant rate of 16.07 l/s over 96 hours, a drawdown of 21.40 m was predicted within the pumped well. However, upon cessation of pump testing, the drawdown within the pumped Well was recorded as 18.87 m. This is 2.53 m less than that estimated from analysis of the Step Test data, and suggests additional availability of groundwater upon longer term pumping.

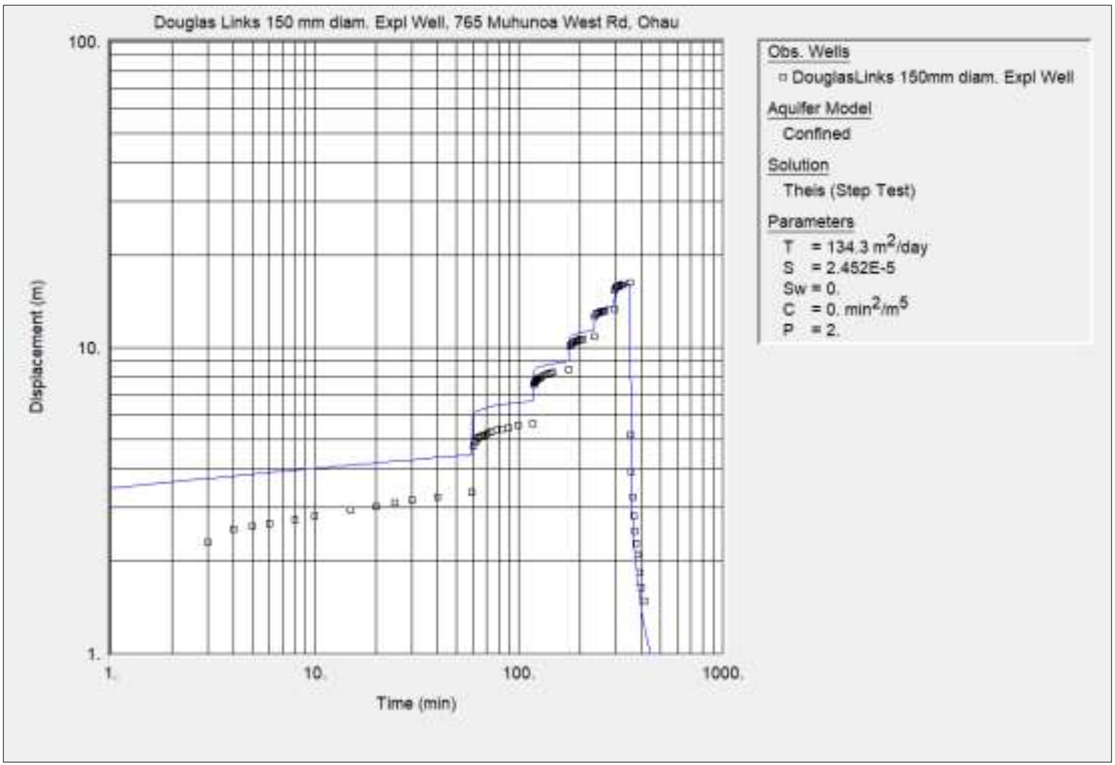

Figure 7. Pumped Well Step Test AQTESOLV Drawdown and Recovery plot (using Theis (1935)).

7. CONSTANT FLOW AQUIFER PUMP TEST

After performing several short-term pump tests on shallow sand intervals, a long-term pump test was scheduled for May 2021 to test the sustainability of the deep gravel aquifer at a constant flow rate of 16.07 l/s for an extended period of time. Using conservative step test aquifer parameters, an Aqtesolv (Duffield, 2007) Forward Solution estimated a long-term drawdown of approximately 21.40 m in the pumped well after 4 days pumping at 16.07 l/s (1388.45 m^3/day).

7.1 Details for Monitor Wells

In order to observe potential drawdown as a result of pumping the Well, in discussion with the welldrillers, neighbouring bores were investigated for monitoring suitability and included in a Pump Test Plan. Three nearby wells were selected as Monitor Bores, including the two pumped wells located on the neighbouring Tahamata farm as displayed in Figure 8.

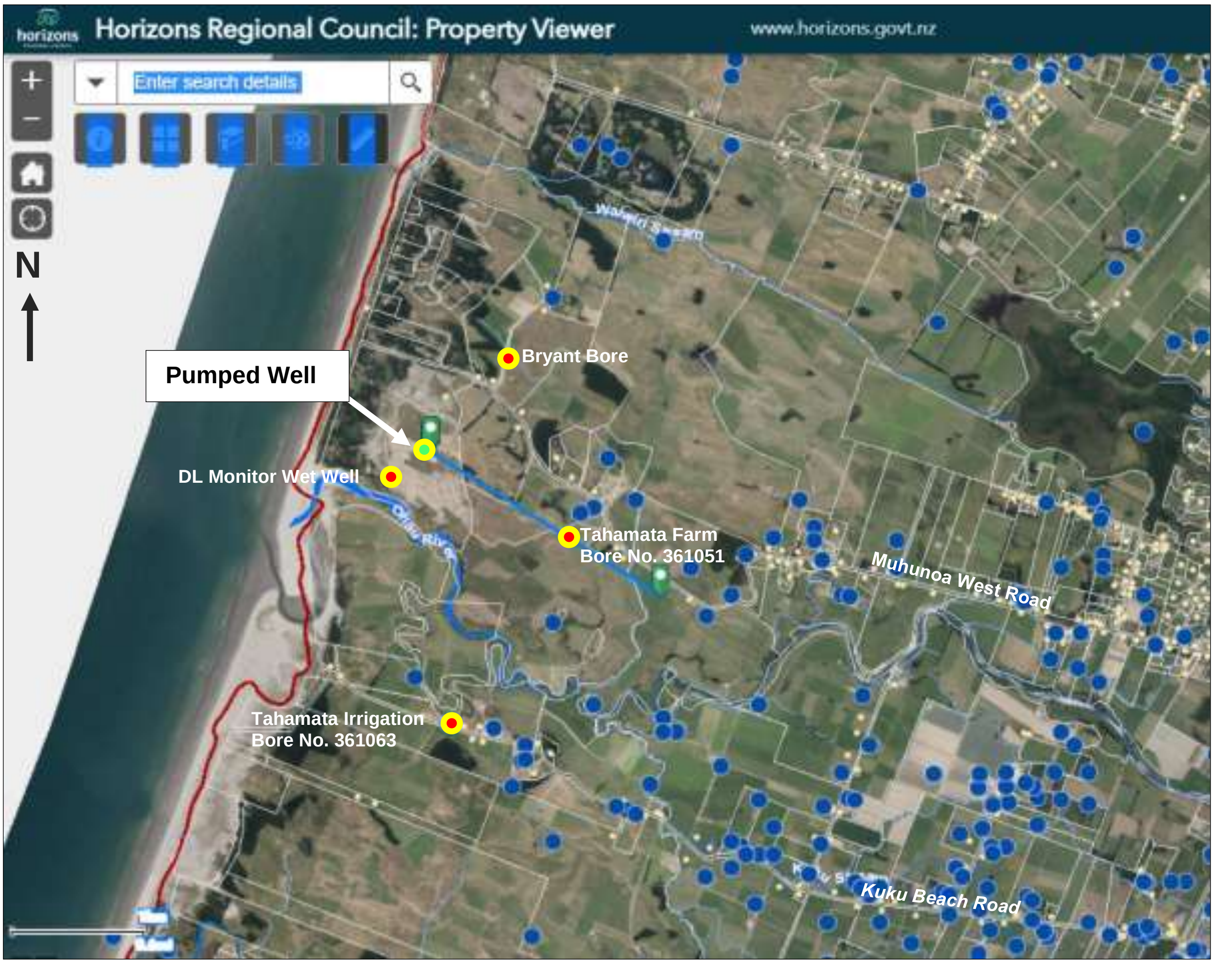

Figure 8. Horizons Wells map displaying pumped Well and nearby Monitor Bore locations.

The water level data was collected electronically on pre-programmed dataloggers installed within the pumped Well and Monitor Bores several days prior to the Step Test being performed. The dataloggers remained in the bores, recording data until after the pump test Recovery period had ended, having collected water level data from 5 – 17 May, 2021. Manual recording of water level data was also undertaken by the welldrillers, resulting in a generally very good correlation between the two datasets.

7.2 Surface Water Monitoring

A Monitoring ‘wet well’ Bore was installed adjacent to the nearby Ohau River in order to monitor water level fluctuations prior to, during and after the pump testing period without possible influence of discharged groundwater from the pumped well. The Monitoring Bore was drilled to 1.1 m depth with a SWL of -2.04 m toc with near-surface sediments logged as follows:

- 0.00 – 0.05 m toc: topsoil;
- 0.05 – 0.60 m toc: brown sand;
- 0.06 – 2.60 m toc: blue sand.

Locations of the pumped well, monitor bores and stream site are shown in Figure 8, with details included in Table 4 and Section 8. Bore logs for the Monitor Bores are presented in Appendix E.

Table 4. Details of pumped Well and Monitoring Bores

Well Description	Well No.	Landowner	Distance from Test Well (m)	Grid ref (NZMG) Easting	Northing	Approx Elevation (m	Depth (m toc)	Screen (m) (aquifer)	SWL (m toc)
Pumped Exploration Well (Douglas Links 150 mm)	TBA	Douglas Links	0	2693344	6059649	8 - 10 m amsl	104.90	98.60-102.91 (Gravel)	-11.22
Monitor (Wet Well)	N/A	Douglas Links	201 (S)	2693191	6059518	-3-5 m bmsl	2.60	0 - 2.6 (blue Sand)	-2.04
Bryant Monitor Bore (100 mm diam.)	N/A	Bryant	730 (NE)	2694699	6059345	9.16 m amsl	36.70	33.67-36.00 (blue Sand)	-2.60
Tahamata Monitor Bore (150 mm dia,)	361051	Tahamata Corp	1304 (SE)	2694600	6059300	20 m amsl	45.80	40.89-45.80 (brown c-m Sand)	-0.85
Tahamata Irrigation Monitor Bore (250 mm diam.)	361063	Kuku Beach Rd, Tahamata Farm	1908 (S)	2693650	6057766	5 m amsl	35.11	28.71 - 33.21 (Gravel)	+2.039

7.3 Diversion of pumped discharge

Due to the depth of the pumped well and confined nature of the aquifer, the groundwater discharge is not likely to re-enter the productive gravel aquifer.

Furthermore, groundwater pumped from the Well during the constant flow aquifer test was piped away, in order that the shallow Monitoring (Wet Well) Bore did not experience recharge as a result of infiltrating discharge.

7.4 Groundwater Level Response to External Influences

Under certain conditions, groundwater levels can be influenced by non-rhythmic regular fluctuations such as atmospheric pressure and unique changes such as heavy rain (Kruseman and de Ridder, 2000). Barometric fluctuations represent areal (planar) stress applied directly at land surface and to the open well water level surface (Spane, 2002). Dependent upon the level of confinement and hydraulic characteristics of the aquifer, variable responses will result due to atmospheric pressure changes. In certain circumstances, fluctuations in groundwater levels often mirror changes in barometric pressure; for example, when barometric pressure increases, a measurable decline in groundwater levels is observed (Kruseman and de Ridder, 2000). As stated in Hare and Morse (1997), greater barometric pressure changes can be observed within wells in unconfined aquifers than those typically observed for wells in confined aquifers.

Significant rainfall is also considered an external influence on unconfined aquifers, particularly if the aquifer is hydraulically connected to nearby surface water bodies. The pumping effect in the Well would be significant however, and be likely to overwhelm slight variations in water level as a result of changes in atmospheric pressure or rainfall; although such measurable changes are often observed in monitor wells.

Barometric pressure data recorded by the Barologger was downloaded by the welldrillers and provided to Bay Geological Services Ltd. for processing. The electronic data collected from the pumped and monitor wells was corrected for barometric changes during the monitoring period. The pressure and temperature data recorded by the Barologger are presented as Figure 9 which also shows Pump Test start and stop.

The graph displays slightly elevated barometric pressure conditions (103.50 kPa) three days prior to pumping which fell to 102.2 kPa the day before the start of the constant flow pump test on 10 May 2021. The first day of pumping initially experienced relatively stable pressures at around 102.25 kPa, which fell to 101.8 kPa by the start of the second day. Day two conditions experienced a fall (to 101.35 kPa) followed by a sharp pressure increase (to 102.2 kPa). During the third day of pumping the pressure increase continued to 102.85 kPa; and then fell during day four to 102.0 kPa.

Generally, the barometric pressure fell then rose during the testing period; then experienced almost the same pressure as at commencement of pumping. At the end of the Pump test, during the Recovery period, the pressure falls sharply to just below 100 kPa, followed by a small rise to 101.25 kPa and fell again to just below 100 kPa.

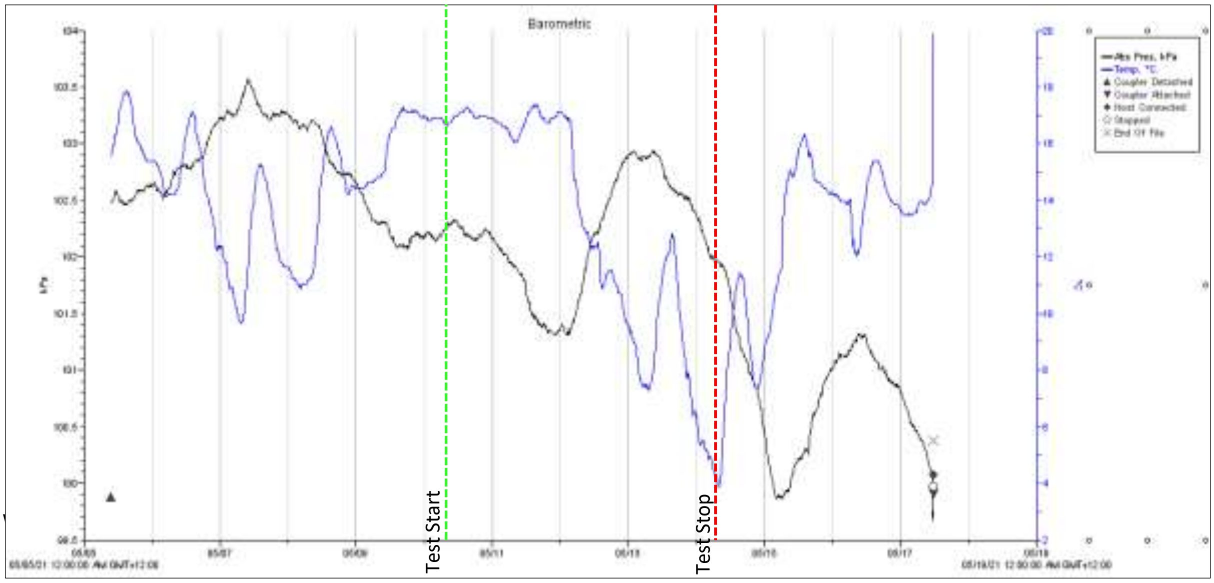

Figure 9. Barotroll data graph displaying pressure and temp fluctuations prior to, during and after the pumping period.

In certain circumstances, the fluctuations in well water levels often mirror changes in barometric pressure; for example, when the barometric pressure increases, a measurable decline in groundwater levels is observed (Kruseman and de Ridder, 2000), although this was initially thought more typical in confined aquifers (Hare and Morse, 1997). As stated in Hare and Morse (1997), greater barometric pressure changes can be observed within wells in unconfined aquifers than those typically observed for wells in confined aquifers.

Significant rainfall is also considered an external influence on unconfined aquifers, particularly if the aquifer is hydraulically connected to nearby surface water bodies. The pumping effect in the pumped well would be significant however, and overwhelm slight variations in water level as a result of changes in atmospheric pressure or rainfall; although such changes are often critically observed in monitor wells.

8. AQUIFER PUMP TEST RESULTS

The manual and electronic data collected during the pump testing of the Well and three monitor bores were provided by Neville Webb and Son Ltd. welldrillers. The electronic data was successfully downloaded and converted to MS Excel format, and analysed using Aqtesolv Pro version 4.0 (Duffield, 2007) software and manual calculations on MS Excel.

8.1 Pumped Doulas Links Well

Pump Test Summary details:

Well No.: Pumped Douglas Links Well
Depth: 104.90 m toc
Pump Depth:
Screen: 98.91 – 102.91 m toc
Max Drawdown: 18.92 m (at t = 5685 mins)

Casing Diameter: 150 mm
SWL: - 11.22 m toc
Aquifer: fine sandy, blue gravel
Drawdown: immediate upon pumping
Recovery: to within 150 mm after 3210 mins (2.2 days into Recovery Period).

Drawdown at Pump Stop: 18.87 m (at t = 5760 mins)

The pumped 150 mm diam. Well is 104.90 m toc deep, and is screened from 98.91 – 102.91 m toc across a fine sandy blue gravel with traces of shell material and increasing gravels to the base of the unit. The bore stratigraphy is recorded by the drillers which reveals upper confinement above the screened gravel aquifer provided by low permeability silty sand fining to clay, with traces of shell. The drillers recorded a SWL of -11.22 m toc following well development in February 2021.

The manual and electronic logger water level data from the 4-day (5760 min) aquifer pump test were plotted as Residual Drawdown (m) against Time (mins), with the results presented as Figure 10. It is noted that tidal fluctuations are evident in the pump test Drawdown and Recovery data, reflecting confined aquifer condtions.

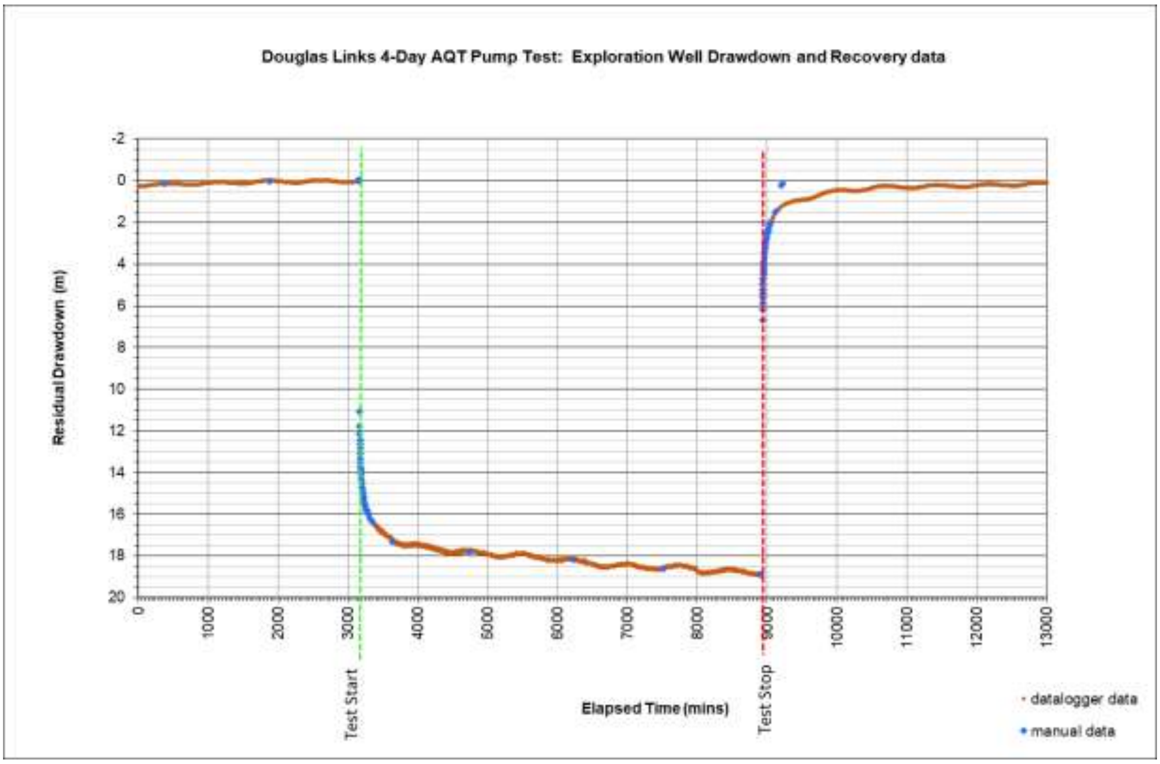

Figure 10. Pumped Well AQT Test Residual Drawdown v Time graph

The plotted data shows an immediate response in the water level to commencement of pumping with measurable drawdown of 15.35 m after 60 mins. The water level steadied relatively quickly with a drawdown of 15.73 m at 90 mins and 17.23 m at 460 mins which slowed but did not approach stabilisation. The maximum drawdown was calculated as 18.86 m at cessation of pumping after 5760 mins.

The initial assessment of the Drawdown data was completed by comparing the data to the Cooper-Jacob (1946) solution for pumping a confined aquifer which is based on a straight-line approximation of the Theis (1935) equation for unsteady flow to a fully penetrating well in a confined aquifer. The solution assumes a line source for the pumped well and therefore neglects wellbore storage. Analysis of the data shows a good match to the straight-line solution until approximately Time (t) = 700 mins when a flow boundary was intercepted, and actual drawdown fell below the ideal linear solution as shown in Figure 11. The Cooper-Jacob (1946) method is used noting the following assumptions:

- aquifer has infinite areal extent;
- aquifer is homogeneous, isotropic and of uniform thickness;
- pumping well is fully penetrating;
- flow to pumping well is horizontal;
- aquifer is confined;
- flow is unsteady;
- water is released instantaneously from storage with decline of hydraulic head;
- diameter of pumping well is very small so that storage in the well can be neglected;
- values of *u* are small (i.e., *r* is small and *t* is large).

The solution provides an initial transmissivity value of 108.90 m^2/day which is slightly less than that determined from the Step Test data (average 120.90 m^2/day).

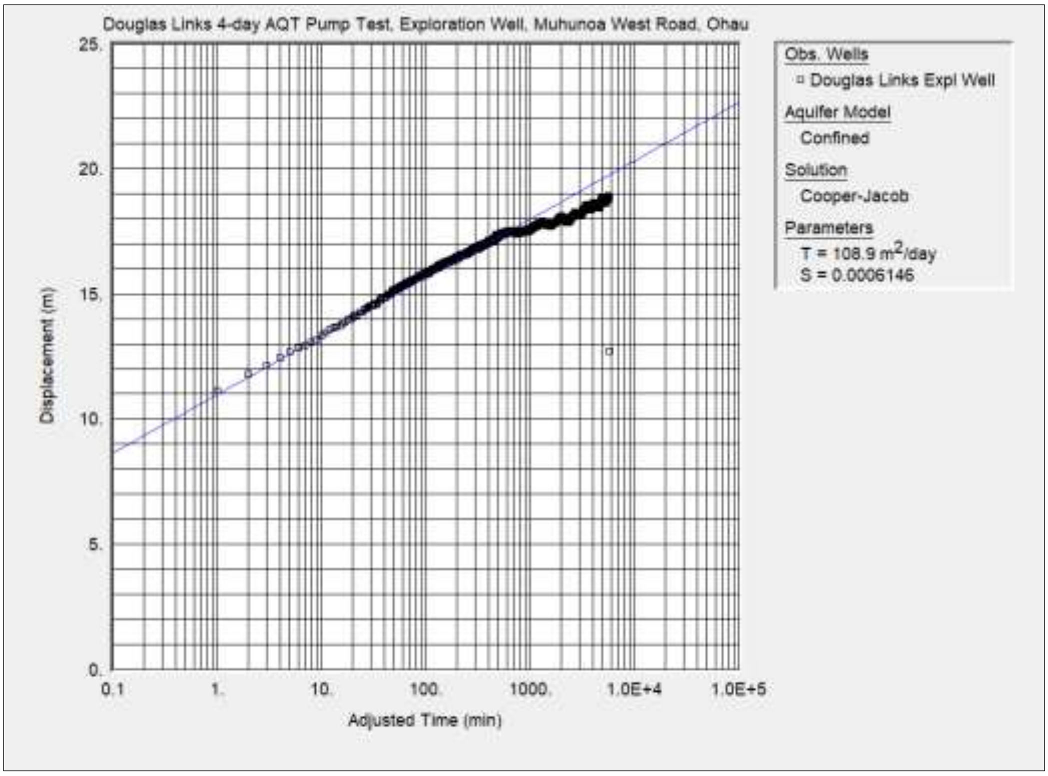

Figure 11. Cooper-Jacob modelling of pumped Well Residual Drawdown v Time data using Aqtesolv

Analysis of the pump test results focused on the Recovery data which is considered a true reflection of aquifer conditions, as the pump is switched off and down-hole turbulence has ceased. The data exhibits rapid recovery of the water level to within 6.70 m of the initial water level after 1 min of the pump stopping. After 40 mins of Recovery time, the well has recovered to within 3.15 m of the initial water level, and within 1.0 m after 430 mins of Recovery time. However, it is noted that full recovery (to within 150 mm of the initial SWL) did not occur until after 3210 mins (2.2 days into the Recovery Period) taking into consideration the effect of tidal fluctuations.

The Recovery electronic data is plotted using Aqtesolv (Duffield, 2007) software and the Theis (1935) solution for confined aquifers (the default recovery curve). Initial analysis of the plotted data determines a transmissivity value of 105.0 m^2/day as displayed in Figure 12. The values are in line with those reported in the Step Test data. The assumptions for the Theis (1935) solution are:

- prior to pumping, the potentiometric surface is approximately horizontal (No slope);
- the aquifer is confined and has an "apparent" infinite extent;
- the aquifer is homogeneous, isotropic, of uniform thickness over the area influenced by
- pumping;
- the well is pumped at a constant rate;
- the well is fully penetrating;
- water removed from storage is discharged instantaneously with decline in head; and,
- the well diameter is small so that well storage is negligible.

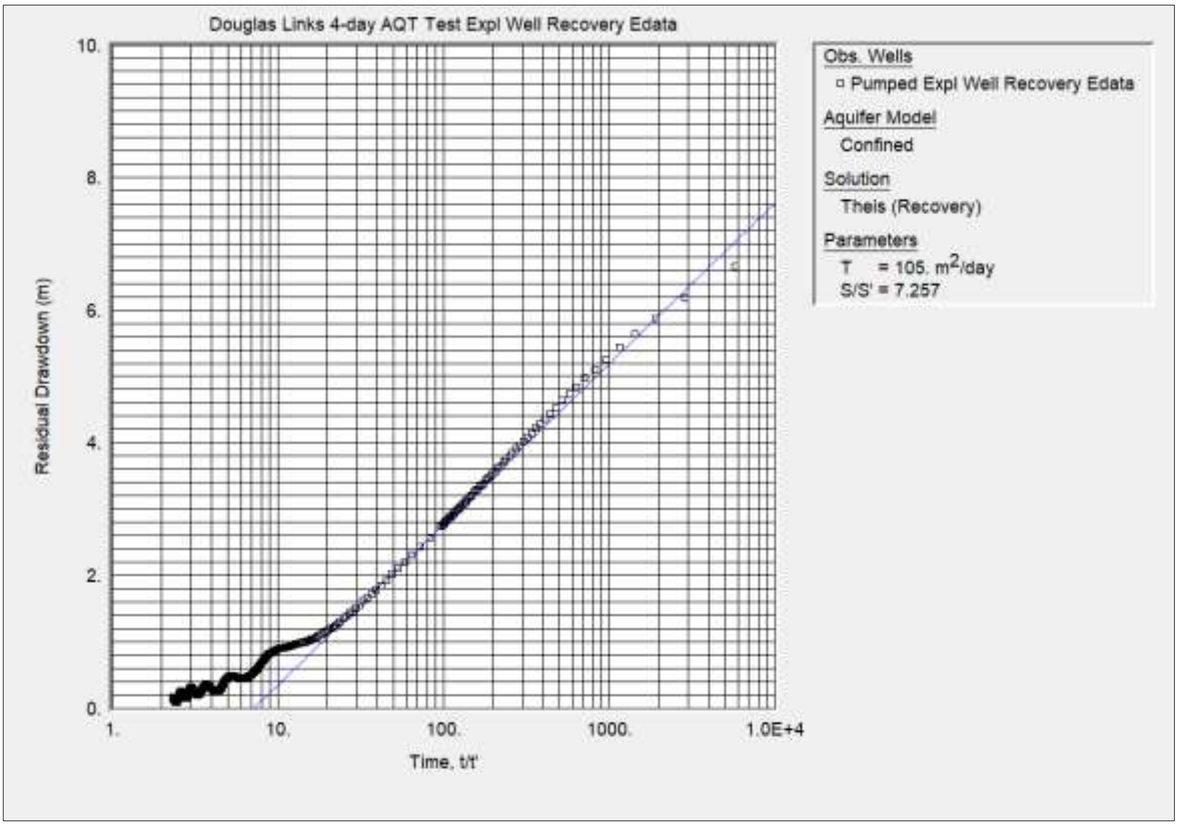

Figure 12. Pumped Well AQT Pump Test AQTESOLV Theis (1935) Recovery plot.

The electronic Drawdown and Recovery data was then matched to the Theis (1935) solution for confined aquifers, plotted on a log-log displacement-time Aqtesolv (Duffield, 2007) graph.

The Drawdown data generally fit the solution, although fell slightly below the theoretical curve during the later-time Recovery period. A transmissivity value of T = 126.90 m^2/day is determined from the solution which is similar to that determined from the Step Test data analysis.

A better fit is provided by the Neuman-Witherspoon (1969) solution for pump testing a leaky aquifer, modelling unsteady flow to a fully penetrating well in a confined two-aquifer system. The assumptions for the solution are as follows:

- aquifer has infinite areal extent;
- aquifer is homogeneous, isotropic and of uniform thickness;
- pumping well is fully penetrating;
- flow to pumping well is horizontal;
- aquifer is leaky confined;
- flow is unsteady;
- water is released instantaneously from storage with decline of hydraulic head;
- diameter of pumping well is very small so that storage in the well can be neglected;
- confining bed(s) has infinite areal extent, uniform vertical hydraulic conductivity, storage coefficient and thickness; and,
- flow is vertical in the aquitard(s).

The electronic Drawdown and Recovery data is plotted on an Aqtesolv (Duffield, 2007) log-log displacement-time graph with a fit to the Neuman-Witherspoon (1969) solution (refer Figure 13). A transmissivity value of T = 25.11 m^2/day is matched to the curve, which is significantly lower than the other data analysis methods.

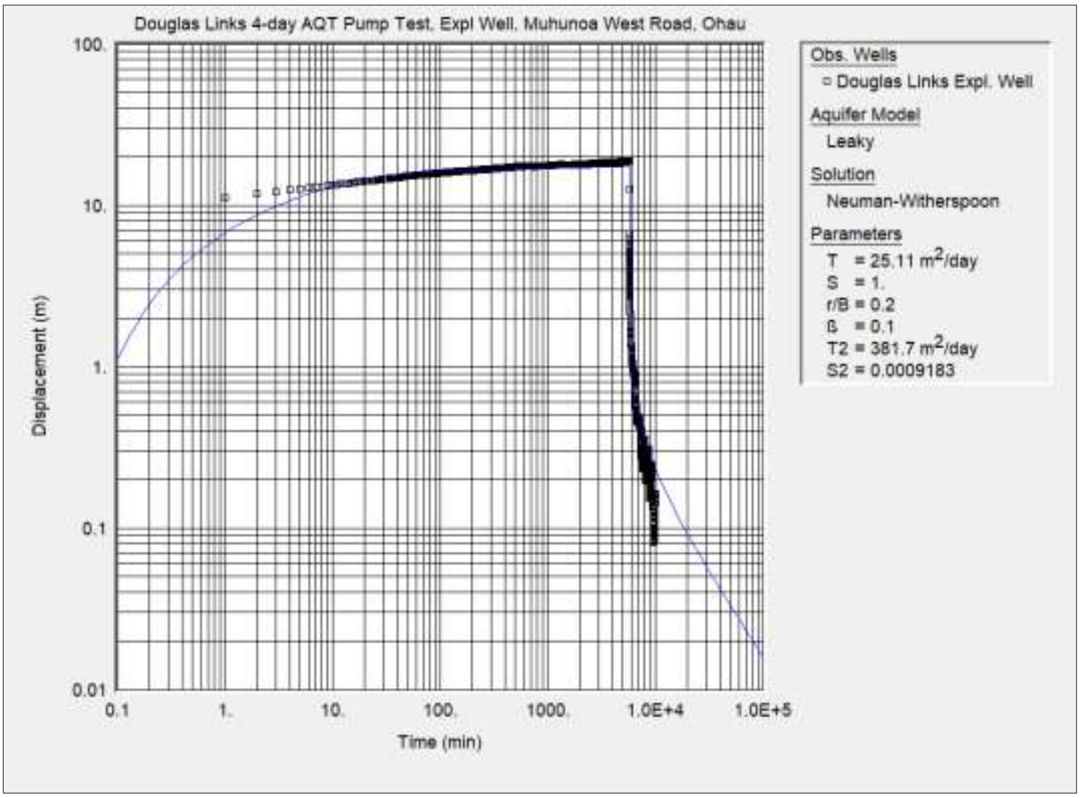

Figure 13. Pumped Well AQT Test AQTESOLV Drawdown and Recovery plot using Theis (1935) solution for confined aquifers.

Full Aqtesolv (Duffield, 2007) log-log and semi-log graphs of the pumped Well Manual and Electronic Drawdown and Recovery data are presented in Appendix G.

A summary of aquifer parameters determined from the pumped Well aquifer testing is presented in Table 5.

Table 5. Summary of Aquifer Parameters from pumped Well data analysis

Aquifer Pump Test Analysis Results for Douglas Links Well		
Aqtesolv (Duffield, 2007), MS Excel	**Drawdown analysis Transmissivity (m^2/day)**	**Recovery data Analysis (Theis, 1935) Transmissivity (m^2/day)**
Manual data		103.85
Electronic data	108.90 *(Cooper-Jacob, 1946)* 25.11 *(Neuman-Witherspoon, 1969)* 126.90 *(Theis, 1935)*	105.00

The similar transmissivity values determined from the majority of the Drawdown and Recovery data solutions infers moderate well efficiency. However, the low transmissivity value provided by the Neuman-Witherspoon (1969) solution suggests greater water availability from the overlying confined sand and gravel aquifer (from 68.00 to 79.10 m depth toc) which presents a transmissivity value of 381.70 m^2/day.

The lithology log recorded for the Well reveals a fine sandy blue gravel interval is screened from 96.91 – 102.91 m toc, which is overlain by almost 18 m of confining layers including fine silty sand and clay with traces of shell, sequences of interbedded predominantly fine to coarse sand with layers of clay, clay peat and wood, and medium dune sand with shell material. In particular, medium sand and gravel intervals logged from 68.00 to 79.10 m toc are described as ‘good’ to ‘very good’ water bearing units, and are inferred to provide a level of recharge to the underlying deep gravel unit via vertical leakage.

8.2 Tahamata Irrigation Monitor Bore No. 361063

Pump Test Summary details:

Well No.: 361063
Depth: 35.11 m toc
Aquifer Depth: 26.70-33.86 m toc
Screen Depth: 27.71-33.21 m toc
Distance from pumped well: 1908 m
Drawdown at Pump Stop: 0.047 m
Continued Drawdown after Pump Stop: N/A

Casing Diameter: 250 mm
SWL: +2.039 m toc
Aquifer: blue Gravel
Drawdown: Not attributed to pumped Well
Recovery: N/A
Max Drawdown: 0.313 m (at t =7600 mins) (370 mins into pumping)

The Tahamata Irrigation Monitor Bore No. 361063 is located approximately 1.9 km south of the pumped well. The stratigraphy of the 35.11 m toc deep (toc) irrigation bore is described as near surface brown sand to 5 m depth (toc) overlying blue cemented and very silty sand to 22.00 m, below which is a 4.7-m thick layer of peat and clay. From 26.70 to 33.86 m depth, blue gravel is logged, overlying silty blue sand to at least the base of the bore hole. The bore is screened from 27.71-33.21 m toc across the water-bearing blue gravel interval, and is the closest bore that produces from a gravel aquifer.

The Drawdown v Time graph for Monitor Bore No. 361063 is included as Appendix H which plots water levels prior to, during, and following the pumping period, with the Pump Test start at t = 7230 mins. It is important to note the tidal flux evident within the bore water level data which averages 100 mm, along with the Monitor Bore continuing to pump during the test period.

The drawdown data shows a maximum water level drawdown of 0.313 m (including tidal flux) during the pumping period which is considered minor. Following the pump test period, the monitor well water level rose slightly before a gradual decline and another rise, overall amounting to approximately 30 mm. It is noted that the well water level was recorded 20 mm lower than the initial SWL by the end of the 5760 min pump test.

The inverse of the barometric effect is overlaid across the water level data plotted on the Drawdown v Time graph, which provides an approximate match to significant increases and falls in water levels. This infers that water level changes are also influenced as a result of barometric influences.

8.3 Tahamata Farm Monitor Bore No. 361051

Pump Test Summary details:

Well No.: 361051
Depth: 45.80 m toc
Aquifer Depth: 39.80-45.80 m toc
Screen Depth: 40.89-45.80 m toc
Distance from pumped well: 1304 m
Drawdown at Pump Stop: 0.076 m

Casing Diameter: 150 mm
SWL: -0.85 m toc
Aquifer: brown, coarse to medium Sand
Drawdown: Not attributed to pumped Well
Recovery: N/A
Max Drawdown: 4.69 m (at t =10105 mins) (2905 mins into pumping)

Continued Drawdown after Pump Stop: N/A

The Tahamata Farm Monitor Bore No. 361063 is located approximately 1.3 km east of the pumped well. The bore log indicates near-surface brown and blue sand to 7.00 m toc, overlying 50 mm of blue clay, and blue medium to coarse sand with minor gravel to 20.30 m depth toc. A 3.5 m thick layer of clay was then logged, above blue gravel with some coarse sand to 32.20 m toc. Below this is brown, medium sand to 39.20 m toc, and peat with medium sand to 39.80; below which is the productive brown medium to coarse sand to at least the base of the bore hole.

The bore is screened from 40.89 – 45.80 m toc across the water-bearing, brown medium to coarse sand unit.

The Drawdown v Time graph for Monitor Bore No. 361051 is included as Appendix H which plots water levels prior to, during, and following the pumping period, with the Pump Test start at t = 7200 mins. The Monitor Bore was pumped during the pump test as displayed by the scatter of water level data plotted on the graph, which also exhibits sinuosity due to the influence of tides, the magnitude of which is difficult to determine due to the pumping effect.

The drawdown data shows a maximum water level drawdown of 4.689 m (including tidal flux) during the pumping period; however, this is considered as a result of pumping the Monitor Bore. A reduced axis graph is also displayed in Appendix H which also shows a close match between the overlay of barometric pressure fluctuations and water levels.

8.4 Bryant Monitor Bore No. unknown

Pump Test Summary details:

Well No.: unknown
Depth:
Aquifer Depth:
Screen Depth:
Distance from pumped well: 730 m
Drawdown at Pump Stop: 0.007 m
Continued Drawdown after Pump Stop: N/A

Casing Diameter: 100 mm
SWL: -2.60 m toc
Aquifer:
Drawdown: Not attributed to pumped Well
Recovery: N/A
Max Drawdown: 0.042 m (at t =11830 mins)
(4660 mins into pumping)

No bore log is available for the 100 mm diam. Bryant Monitor Bore, and the well location is not shown on the Horizons map presented as Figure 5. The bore is located approximately 730 m north of the pumped well and records a SWL of -2.60 m toc.

The Drawdown v Time graph for Monitor Bore No. 361051 is included as Appendix H which plots water levels prior to, during, and following the pumping period, with the Pump Test start at t = 7170 mins. The Monitor Bore was pumped during the pump test as displayed by the scatter of water level data plotted on the graph, which also exhibits a level of sinuosity due to the influence of tides, the magnitude of which is difficult to determine due to the pumping effect.

The drawdown data shows a maximum water level drawdown of 0.042 m (including tidal flux) during the pumping period at t = 11830 mins on the plot; however, this is considered as a result of pumping the Monitor Bore.

8.5 Douglas Links Monitoring (Wet Well) Bore

Pump Test Summary details:

Well No.: unknown
Depth: 2.60 m toc
Aquifer Depth: 0 – 2.60 m toc
Screen Depth: 0 – 2.60 m toc
Distance from pumped well: 201 m
Drawdown at Pump Stop: +0.420 m
Continued Drawdown after Pump Stop: yes
(water level rose to +0.436 m, 270 mins into Recovery Period)

Casing Diameter: 100 mm
SWL: -2.04 m toc
Aquifer: blue Sand
Drawdown: Not attributed to pumped Well
Recovery: N/A
Max Drawdown: No drawdown

The Monitoring (‘wet-well’) Bore was purpose-drilled approximately 200 m south of the pumped Well, between the nearby Ohau River and the new Well. The Monitor Bore lithology log indicates fine brown sand was encountered to 0.6 m depth toc, overlying coarse blue sand to at least the base of the 2.60 m deep bore hole at which time the SWL was -1.1 m toc. Prior to the pump test, the bore recorded a SWL of -2.60 m toc.

The Drawdown v Time graph for the Monitoring (wet-well) Bore is included in Appendix H which plots water levels prior to, during, and following the pumping period, with the Pump Test start at t = 7170 mins. In the days before the pump test, the water level data reflected a very gentle decline of 0.05 m, along with minor tidal fluctuation sinuosity. On the day prior to the pump test, the water level began to rise and continued to increase over the duration of the pump test, peaking just after cessation of pumping, after which the water level began to slowly fall.

The welldrillers noted significant rain at this time, which appear to have affected water levels within the well. The drawdown data shows a maximum water level rise of 0.436 m (including tidal flux) during the pumping period at t = 11830 mins on the plot (270 mins into the Recovery Period).

9. ASSESSMENT OF EFFECTS ON THE ENVIRONMENT

9.1 Long Term Well Interference Predictions

The Applicant initially requires volumes of 1500 to 2000 m^3/day (17.36 to 23.15 l/s continuous pumping) in order to irrigate 38.76 to 51.68 ha, comprising 18 greens, 36 tees and a practice tee, with an estimated volume of 168,060 to 224,806 m^3/year.

An estimate of well interference effects within neighbouring bores as a result of pumping the Applicant's new Well at 16.07 l/s, is based on 150 days, being a typical irrigation season over the summer months. The aquifer parameters determined from the pump test Recovery data analysis are used in the analysis, along with an adopted storativity value appropriate for confined aquifers. The aquifer parameters are applied to the Aqtesolv (Duffield, 2007) Forward Solution graph using the Theis (1935) solution for confined aquifers as displayed in Figure 14, which provide a conservative estimate of well interference effects as it does not take leakage into consideration. It is noted that no bores were identified within 2 km of the pumped well that produce groundwater from the deep gravel aquifer.

The solution and Aqtesolv forward modeling provide conservative Displacement (drawdown) v. Radial distance (m) well interference estimates within bores screened across a similar gravel aquifer, as a result of pumping the Well continuously on a 24/7 basis. A conservative Recovery data transmissivity value, T = 105 m^2/day is used and adopted storativity value, s = 0.0001 reflecting confined aquifer conditions. As shown in Figure 14, when using the Theis (1935) solution, the Aqtesolv Forward Solution predicts up to almost 11 m drawdown within a 100 m radius of the pumped well. The full Aqtesolv graph is presented in Appendix I.

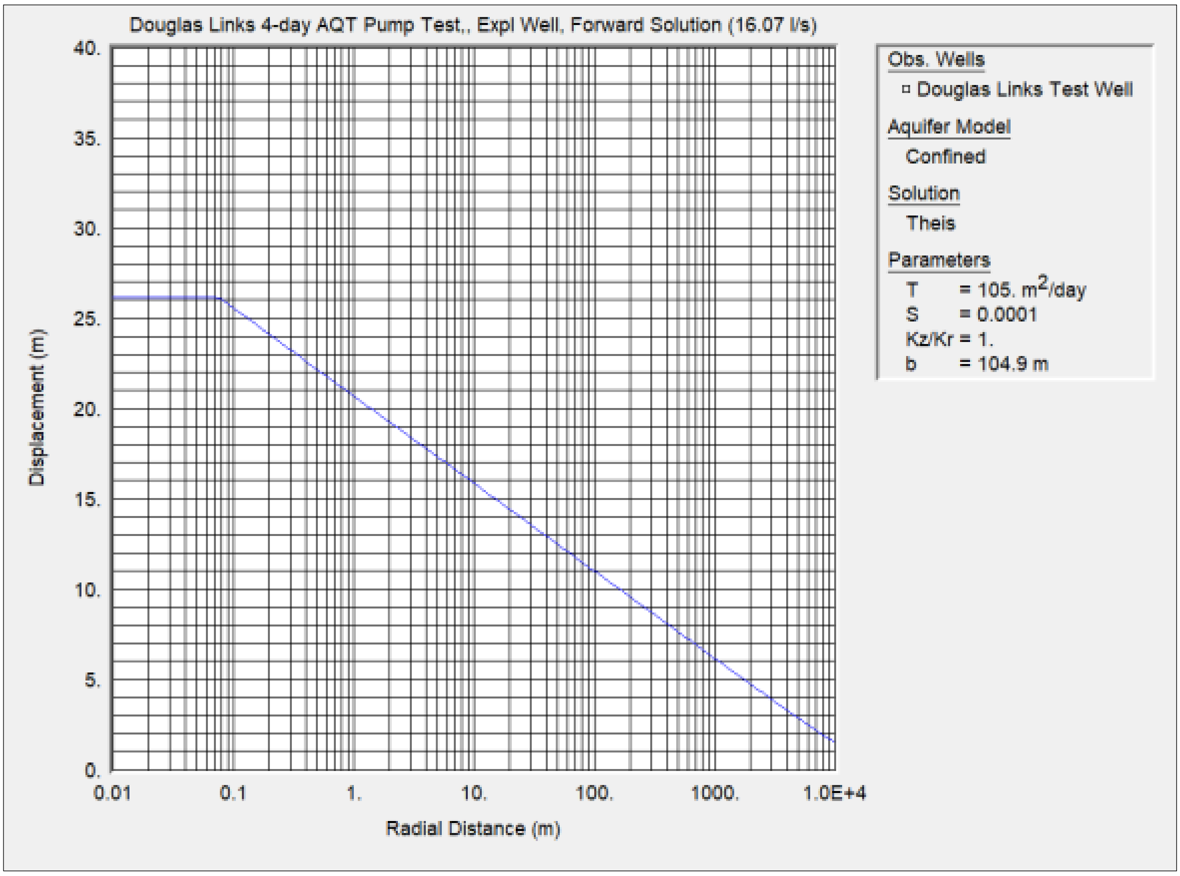

Figure 14. Pumped Well Aqtesolv Forward Solution graph at 16.07 l/s for 150 days (Theis, 1935)

At distances of 1 km, 1.5 km and 2 km from the pumped bore, the well interference effects are predicted to be estimated as 6.18 m, 5.33 m and 4.72 m respectively should the Douglas Links Well be pumped continuously (on a 24/7 basis) at a rate of 16.07 l/s for 150 days as detailed in Table 1. The predicted well interference is also estimated as 3.88 m and 3.28 m at distances of 3 and 4 km respectively, as the confined nature of the deep aquifer results in observable well interference at greater distances from the pumped well in comparison to an unconfined aquifer. Table 6 displays predicted well interference effects in bores screened across the same deep gravel aquifer.

Table 6. Predicted well interference as a result of pumping Well over 150 days

Predicted Well Interference as a result of pumping Well (T = 105 m^2/day, s = 0.0001)					
Pumping Rate	**Duration (days)**	**1 km radius**	**2 km radius**	**3 km radius**	**4 km radius**
16.07 l/s	150	6.18	4.72	3.88	3.28

In addition, the Drawdown.xls program using the Theis (1935) solution (created by D Scott, Environment Canterbury (2001) presented in Appendix I details predicted well interference effects at selected radii.

The well interference assessment is deemed conservative as it does not consider aquifer leakage and models pumping being undertaken 24-hours per day, rather than factoring in times when irrigation is not required. It must be noted that periodic or no-pumping allows for recharge of groundwater levels, which is assessed as moderately rapid in line with the transmissivity value as determined. A review of surrounding bores indicate that no deep gravel bores are recorded within 2 km of the pumped Well, and furthermore, the depth of the gravel aquifer infers a greater total water column within bores screened across the same unit, therefore, potential well interference estimates are considered tolerable.

9.2 Stream Depletion Assessment

The new Well is located approximately 250 north of the major Ohau River which flows about 1 km south, then west into the South Taranaki Bight. The Hunt (2003) method states that abstracting water from a well beside a stream also depletes water from the stream. A series of solutions provided by Hunt (2003, 2012) describe the level stream depletion over time as a result of pumping a nearby well as shown in Figure 15. Each solution is formulated for a specific scenario and provides an ability to predict stream depletion as a function of time for any given well abstraction. This enables pumping schedules to be managed in order to control the level of environmental effects occurring in the stream.

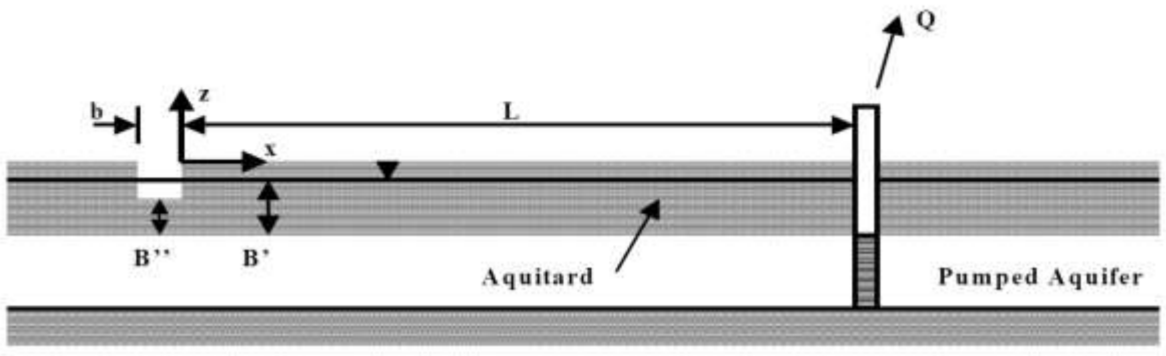

Fig. 6 Geology for the stream depletion problem.

Figure 15. The Hunt (2003) schematic depicting the Stream Depletion Problem.

The Horizons 'One Plan' was reviewed, particularly Policy 16-6: Effects of groundwater takes on surface water bodies. The Policy states the following:

The effects of groundwater takes on surface water bodies, including wetlands, must be managed in the following manner:

(a) An appropriate scientific method must be used to calculate the likely degree of connection between the groundwater and surface water at the location of the groundwater take.

(b) Subject to (a), the potential adverse effects of groundwater takes on surface water depletion must be managed in accordance with Table 16.1.

The Policy 16-6, Table 16.1 is presented below (refer Table 7) which provides a classification for varying levels of depleting effects on surface water, from Riparian to Low, where the latter is described as:

The surface water depletion effect is calculated as less than 20% of the groundwater pumping rate after 100 days of pumping.

Table 7. Horizons One Plan Policy 16-6, Table 16.1 Surface water depletion classification (Horizons).

Table 16.1 Surface water^ depletion

Classification of Surface Water^ Depletion *Effect*^	Magnitude of Surface *Water*^ Depletion *Effect*^	Management Approach
Riparian	Any groundwater take screened within the geologically recent bed strata of a surface *water body*^.	The groundwater take is subject to the same restrictions as a surface water^ take, unless there is clear hydrogeological evidence that demonstrates that the *effect*^ of pumping will not impact on the surface *water body*^.
High	The surface *water*^ depletion *effect*^ is calculated as 90% or greater of the groundwater pumping rate after seven days of pumping, or 50% or greater of the average groundwater pumping rate after 100 days of pumping.	The groundwater take is subject to the same restrictions as a surface *water*^ abstraction.
Medium	The surface *water*^ depletion *effect*^ is calculated as 20% or greater and less than 50% of the groundwater pumping rate after 100 days of pumping.	The calculated loss of surface *water*^ is included in the surface *water*^ allocation regime, but no specific minimum flow restrictions are imposed on the groundwater take.
Low	The surface *water*^ depletion *effect*^ is calculated as less than 20% of the groundwater pumping rate after 100 days of pumping.	The calculated loss of surface *water*^ is not included in the surface *water*^ allocation regime and no specific minimum flow restrictions are imposed on the groundwater take.

The Application AEE for the Tahamata Irrigation Monitor Bore 361063 located to the south of the Ohau River reported a transmissivity value of 5,200 m^2/day; and included an assessment of the potential for stream depletion using Hunt (2003) at a distance offset of 100 m.

The aquifer parameters calculated from pump testing and flow rate of 43.6 l/s were applied to the solution, along with storativity of 0.0001, K'/B' value of 0.00013, specific yield of 0.1 and streambed conductance of 0.1 m/d. The method determined that leakage was approximately 6% when pumping at 43.6 l/s over 100 days (Lattey, 2020) which was deemed to be low using the One Plan, Table 16.1 classification.

An assessment of the potential effects on nearby surface water bodies as a result of pumping the new Well was carried out. The closest surface water feature is the Ohau River at a distance of approximately 250 m south of the new well. It is considered that the degree of confinement afforded by the upper layers including blue and brown clay layers, it is unlikely that pumping the new well at the required rate will affect the surface water features.

The Hunt (2003) solution provides a quantification of the depletion over 100 days, along with the modelled Theis (1935) curve and actual drawdown data from the pumped Well. The streambed conductance (0.1 m/d) and specific yield (0.1) are adopted from the assessment for Bore No. 361063; and a storativity value of 0.0001 is considered appropriate for the confined aquifer conditions.

The graph in Figure 16 shows the solution when K'/B' is 0.01 (K'/B' = 0.0003) based on a flow rate of 16.07 l/s, which determines after 100 days a depletion of 20 mm (using Hunt (2003)) which is considered low.

Parameters		
T	105	(m^2/d)
S	0.0001	(-)
K'	0.01	(m/d)
B'	14	(m)
K'/B'	0.0007	(d^{-1})
L	250.00	(m)
T_0	350	(m^2/d)
sigma	0.1	(-)
Q	16.1	(l/s)
Q	1388	(m^3/d)
radius	2000	(m)

Only change figures in yellow cells

Water table Drawdown/Pumped Aquifer Drawdown		
time (d)	Water table drawdown	Pumped aquifer drawdown
0.0007	0.00	0.00
0.0014	0.00	0.00
0.0021	0.00	0.00
0.0028	0.00	0.00
0.0035	0.00	0.00
0.0042	0.00	0.00
0.0049	0.00	0.00
0.0056	0.00	0.00
0.0063	0.00	0.00
0.0069	0.00	0.00
0.0076	0.00	0.00
0.0083	0.00	0.00
0.0090	0.00	0.00
0.0097	0.00	0.00
0.0104	0.00	0.00
0.0340	0.00	0.00
0.0347	0.00	0.00
0.0354	0.00	0.00

DL Expl Well		
Time (min)	Time(day)	Drawdown
1	0.0007	11.12
2	0.0014	11.804
3	0.0021	12.128
4	0.0028	12.453
5	0.0035	12.666
6	0.0042	12.825
7	0.0049	12.953
8	0.0056	13.069
9	0.0063	13.167
10	0.0069	13.344
11	0.0076	13.43
12	0.0083	13.546
13	0.0090	13.62
14	0.0097	13.669
15	0.0104	13.699
49	0.0340	15.125
50	0.0347	15.161
51	0.0354	15.167

Theis Curve				
		Time(day)		Drawdown
t	105.00	0.01	3.6E-45	0.000
s	0.00010	0.02	3.42E-24	0.000
q	1388.45	0.03	3.97E-17	0.000
r	2000.00	0.05	2.13E-11	0.000
		0.10	5.57E-07	0.000
		0.15	1.92E-05	0.000
		0.20	0.000121	0.002
		0.25	0.000379	0.005
		0.30	0.000833	0.011
		0.35	0.001485	0.020
		0.40	0.002321	0.031
		0.45	0.003316	0.044
		0.50	0.004443	0.059
		0.55	0.005677	0.075
		0.60	0.006997	0.093
		0.65	0.008383	0.111
		0.70	0.009821	0.130
		0.75	0.011296	0.149
		0.80	0.012798	0.169
		0.85	0.014318	0.189
		0.90	0.015849	0.210
		0.95	0.017385	0.230
		1.00	0.018921	0.250
		1.05	0.020454	0.270
		1.10	0.02198	0.291
		2.10	0.049368	0.653
		3.10	0.070675	0.935
		4.10	0.087697	1.160
		5.10	0.101795	1.346
		6.10	0.113804	1.505
		7.10	0.124255	1.643
		8.10	0.133503	1.765
		9.10	0.141794	1.875
		10.10	0.149305	1.974
		11.10	0.156172	2.065
		12.10	0.162495	2.149
		13.10	0.168353	2.226
		14.10	0.173811	2.298
		15.10	0.178919	2.366
		16.10	0.183719	2.429
		17.10	0.188247	2.489
		18.10	0.192531	2.546
		19.10	0.196597	2.600
		20.10	0.200465	2.651
		21.10	0.204154	2.700
		22.10	0.20768	2.746
		23.10	0.211057	2.791
		24.10	0.214296	2.834
		25.10	0.217408	2.875
		26.10	0.220403	2.914
		27.10	0.22329	2.953

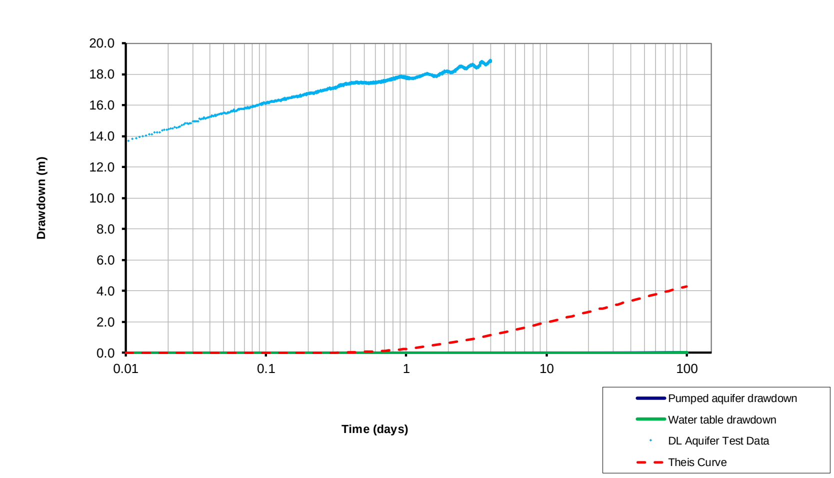

Figure 16. Sreadsheet and graph using Hunt solution (2003)

An additional adoption of the Hunt (2003) solution to determine the rate of stream depletion is displayed in Figure 17 which utilises the Environmental Canterbury spread sheet. The aquifer parameters calculated from pump testing and flow rate of 16.07 l/s were applied to the solution, along with storativity of 0.0001, K'/B' value of 0.0007, specific yield of 0.1 and streambed conductance of 0.03 m/d. The method determined that leakage was approximately 4% when pumping at 16.07 l/s over 100 days which is deemed to be low using the Table 16.1 classification in the Horizons 'One Plan'.

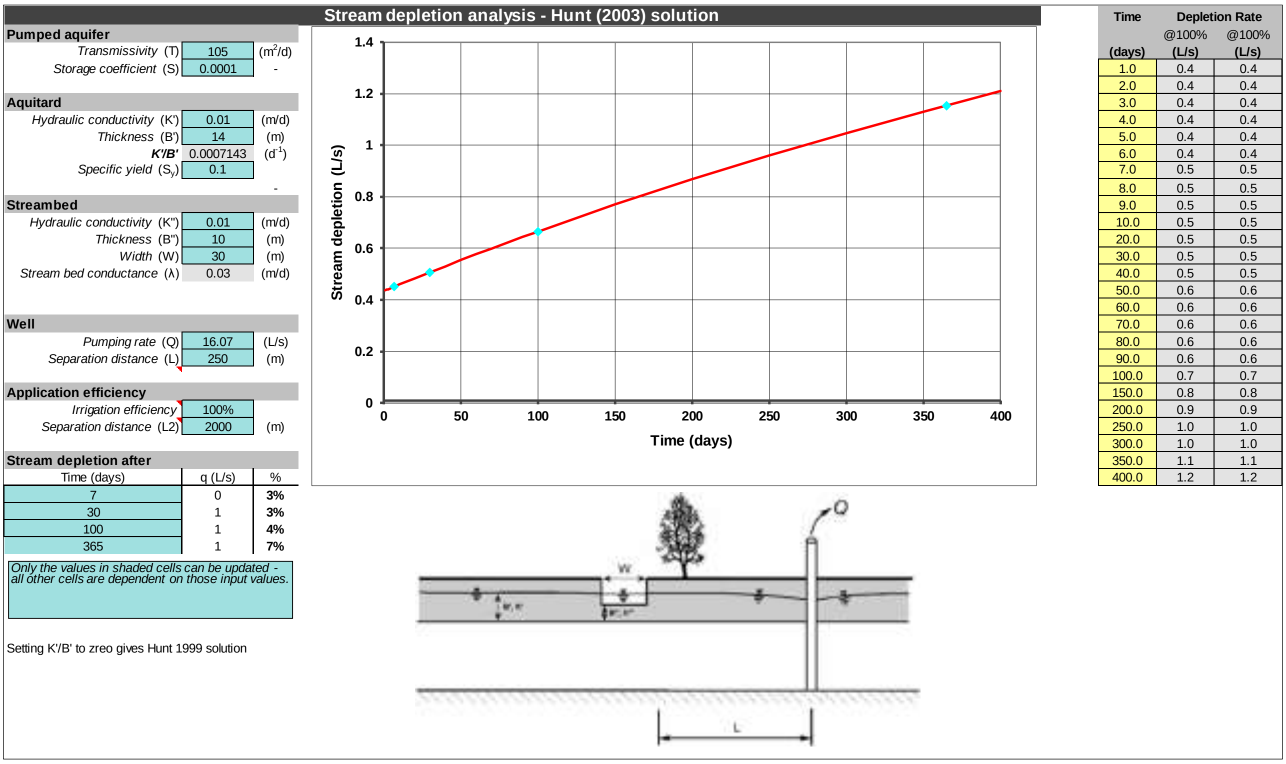

Figure 17. Environment Canterbury Stream Depletion method using Hunt (2003).

A geochemistry study by GNS in 2019 on the Ohau and Waikawa catchments modelled groundwater interactions with surface water including recharge and discharge, using groundwater age, chemistry, gas, and isotope tracers (Morgenstern et al, 2019). The study revealed high radon concentrations along the lower reaches of the Ohau River and Waikawa Stream, indicative of significant groundwater discharge into the surface waterways just upstream of the confluence, beyond which surface water flows across the Quaternary sands. The sands exhibit low permeability, inhibiting groundwater discharge to the sea, instead, it discharges to surface water bodies once it reaches the coastal end of the transmissive Quaternary gravel beds.

9.3 Aquifer Sustainability

Horizons have set an allocation limit for the Horowhenua Groundwater Management Zone (HGMZ), of 27 Mm³/year which is based on 5% of annual rainfall (Horizons). Information from Horizons as at June 2021, indicates that groundwater volumes totaling 18,963 m³/day (3,458,853 m³/year) have been allocated, which is 12.8% of the allocatable volume. This suggests that significant allocation is still available within the HGMZ.

9.4 Tidal Effects

The new Well is located approximately 865 m east of the mean sea level near the Ohau River mouth. An approximate 12-hourly sinuous response is observed in the pumped Well and majority of the Monitor Bores' water level data, as a result of tidal flux.

The Ghyben-Herzberg principal provides a theoretical estimate of the saltwater-freshwater boundary for small discharges (Verruijt, 1968), where the interface is approximately 40 times the elevation of the water table above mean sea level (amsl) as illustrated in Figure 18. The equation based on static hydraulic conditions, can be used to provide a range of groundwater level pressures above which no sea water intrusion problems should occur.

However, if groundwater pressures fall below the values where the Ghyben-Herzberg solution indicates the risk of saline intrusion increases, targeted monitoring of groundwater quality should be considered.

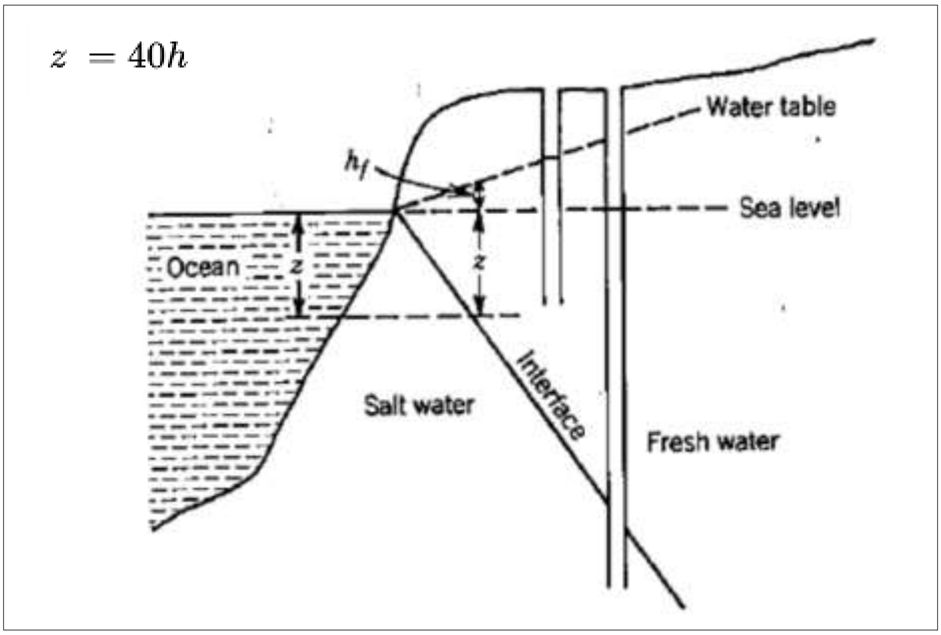

Figure 18. Ghyben-Herzberg relationship of the interface position (from Domenicoand Schwartz, 1990 *in* PDP, 2011)

The Ghyben–Herzberg ratio states that, for every meter of fresh water in an unconfined aquifer above sea level, there will be forty meters of fresh water in the aquifer below sea level.

The autumn SWL of the pumped Well recorded prior to the pump test is -11.31 m toc (-10.24 m bgl), and the approximate elevation of the site is estimated as 25 m amsl (referenced from the LINZ topomap). Therefore, if the water table is approximately 14.76 m amsl, then the saltwater-freshwater interface is inferred to be about 590 m depth bgl. During the winter, the water table rises due to groundwater recharge and lower demands, and accordingly, the interface will move to a deeper elevation with the inverse occurring during dry summer months.

Using the Step Test data (Section 7) and aquifer parameters as discussed in Section 8.1, the AQTESOLV Forward Solution modelling over a 150-day irrigation period, when pumping at 16.07 l/s estimates a drawdown within the pumped well to approximately 28.50 m (a water level of 39.72 m toc)

The confined nature of the aquifer producing from a deep gravel unit and the relatively low flow rate (16.06 l/s) resulting in moderate drawdown suggests that the risk of saline intrusion would be low.

10. WATER QUALITY MONITORING

10.1 Sea Water Intrusion Monitoring

Saline intrusion as a result of high levels of groundwater abstraction has been identified as a risk in western coastal areas of the Horizons region. To provide advanced warning of possible sea water intrusion, a series of bores were installed along the west coast as a monitoring network (PDP, 2011) as shown in Figure 19.

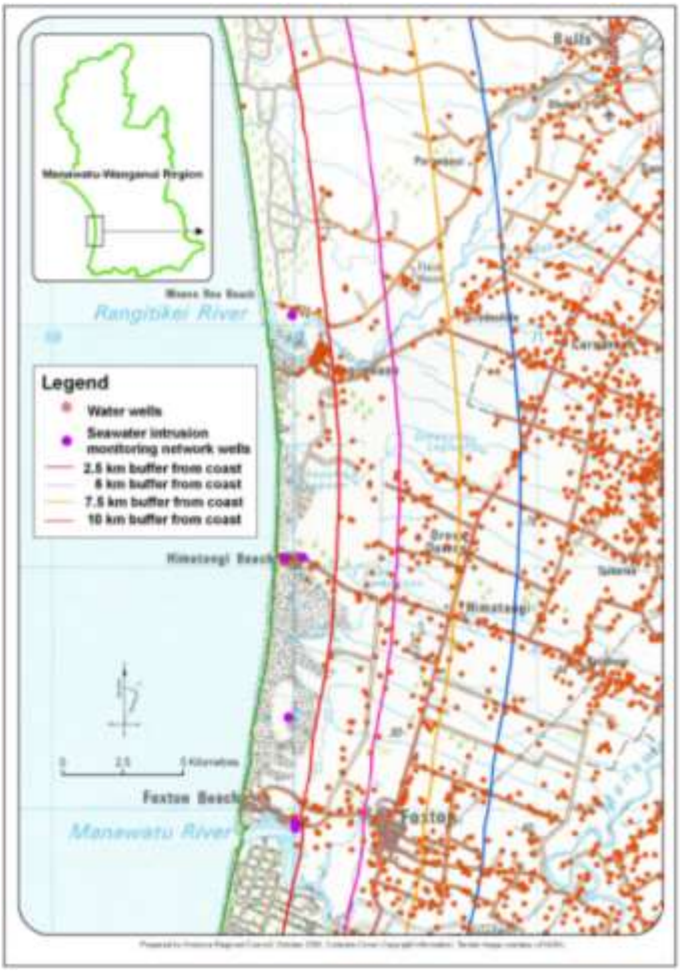

Figure 19. Horizons Regional Council Seawater Intrusion Monitoring Network (Horizons, 2011)

The Horizons State of the Environment (SOE) report discusses environmental conditions across the region including the risk of saline intrusion. As of 2019, the report states that bore monitoring has shown no significant signs of seawater intrusion, and regional council studies generally consider the risk to be low for the majority of the region.

10.2 SOE Groundwater Monitoring Bores

New Zealand's Regional and Unitary Councils regularly monitor groundwater quality in SOE wells. The data collected from these wells is typically made available on council websites and can also be accessed on the Land Air Water Aotearoa (LAWA) website.

A review of the LAWA website and maps displaying monitoring bores across the Horowhenua region, shows that Bore No. 362001 lies approximately 4.5 km east of the pumped Well. The shallow 100 mm diam. monitor bore is drilled to 16.3 m deep with a top screen at 12.3 m depth and recorded SWL of -4.9 m below datum. The bore is monitored for the following components: chloride, electrical conductivity, dissolved reactive phosphorus (DRP), nitrate-nitrogen (N-N) and E.coli, the results for which are detailed in Table 8.

Table 8. Bore No. 362001 Groundwater Quality Indicators (LAMA)

Groundwater Quality Indicators (mg/L). *Source LAMA.*					
Indicator	**Chloride**	**Electrical conductivity**	**DRP**	**NN**	***E.coli***
Result	25 (mg/L)	340 (uS/cm)	0.07 (mg/L P)	6.4 (mg/L N)	detected
Trend	*not assessed*	*very likely degrading*	*not assessed*	*likely improving*	*not assessed*

The monitored bore is very shallow in comparison to the pumped Well and would be susceptible to near-surface activities and potential contaminants in shallow groundwater, which is not expected within the deep Well site.

11. GROUNDWATER QUALITY

Many aquifers within the basin comprise heterogeneous accumulation of sediments ranging from gravels, sandstone, pumice and limestone which affects the hydrochemistry of the groundwater. The multi-layered aquifer systems often exhibit a level of confinement, and subsequently the longer residence time groundwater hydrochemistry is influenced by the lithology of the host strata. This results in variable hydrochemistry, gas and age tracer concentrations within discrete subsurface groundwater. These accumulations are further affected by varying degrees of abstractions and recharge.

11.1 Groundwater quality sampling

In order to assist in the understanding of connectivity of across aquifers penetrated by the recent exploratory drilling, a series of water quality sampling and analysis was carried out during the drilling of significant intervals within the new Well.

Groundwater samples were collected by the welldrillers typically during the drilling process following purging of the well bore, with samples couriered to Hill Laboratories for analysis. A suite of nutrients, metals and other criteria was tested for in each groundwater sample, with the results provided to the welldrillers.

A groundwater sample abstracted from the deep gravel unit within the pumped Well on 9 February 2021 was submitted for water quality analysis at Hill Laboratories Ltd. The results for the test analyses are presented in Appendix C.

A review of the results against Drinking Water Standards New Zealand 2005 (Revised 2008) was not completed as it is outside the scope of Bay Geological Services Ltd; however, the following observations are noted by the laboratory:

- ***pH:*** *The pH of this water (8.3) is within the NZ Drinking Water Guidelines, the ideal range being 7.0 to 8.0. With the pH and alkalinity levels found, it is unlikely this water will be corrosive towards metal piping and fixtures. The high alkalinity of this water may cause an increase in the pH in the root zones of plants which are irrigated using this water.*
- ***Hardness/Total Dissolved Salts Assessment:*** *The water contains a moderate amount of dissolved solids and would be regarded as being slightly hard.*
- ***Nitrate Assessment:*** *Nitrate-nitrogen at elevated levels is considered undesirable in natural waters as this element can cause a health disorder called methaemaglobinaemia. Very young infants (less than six months old) are especially vulnerable. The Drinking-water Standards for New Zealand 2005 (Revised 2018) suggests a maximum permissible level of 11.3 g/m^3 as Nitrate-nitrogen (50 g/m^3 as Nitrate). Nitrate-nitrogen was not found in this water.*
  For household use, it is important that the water is not contaminated with human or animal wastes (e.g., from septic tanks or effluent ponds). Bacteriological analyses may be required if such contamination could exist. For further details, please contact this laboratory.
- ***Boron Assessment:*** *Boron may be present in natural waters and if present at high concentrations can be toxic to plants. Boron was found at a low level in this water but would not give any cause for concern.*
- ***Metals Assessment:*** *Iron and manganese are two problem elements that commonly occur in natural waters. These elements may cause unsightly stains and produce a brown/black precipitate. Iron is not toxic but manganese, at concentrations above 0.5 g/m^3, may adversely affect health. At concentrations below this it may cause stains on clothing and sanitary ware.*
  Iron was found in this water at a significant level.
  Manganese was found in this water at a significant level.
  Treatment to remove iron and/or manganese may be required.
- ***Final Assessment:*** *The parameters Turbidity, Total Iron and Total Manganese did NOT meet the guidelines laid down in the publication 'Drinking-water Standards for New Zealand 2005 (Revised 2018)' published by the Ministry of Health for water which is suitable for drinking purposes.*

12. SUMMARY AND CONCLUSIONS

In February 2021, Grenadier Developments Limited (the Applicant) installed a new 150 mm diam. Well on a 107-ha coastal property at 765 Muhunoa West Road, Ohau which is to be developed into a Links golf course called Douglas Links. It is understood that the Applicant requires 1500 to 2000 m^3/day in order to irrigate 38.76 to 51.68 ha comprising 18 greens, 36 tees and a practice tee with an estimated volume of 168,060 to 224,806 m^3/year. The property lies centrally within the Horowhenua lowlands, across NNE-SSW-trending marine deposits elevated some 5 to 40 m above sea level, formed sub-parallel to the western coastline north of Paekakariki. The Holocene marine and marginal marine terraces mantle the project area, adjacent to alluvium deposited by the Ohau River that drains westward to the coast approximately 250 m south of the pumped Well.

The new Douglas Links Well was drilled to 104.60 m toc, and is screened from 96.91 – 102.91 toc (6 m) across sandy gravel aquifer with trace shell material and an initial SWL of -11.22 m toc. The bore log records upper confinement above the screened gravel aquifer provided by low permeability silty sand fining to clay, with traces of shell, with predominantly fine to medium sand with occasional clay layers to the surface.

The Horizons online maps show five bores within 1.5 km radius of the Well, although no bores within 1 km of the project site. The bore logs reveal fine to medium brown sand units as near-surface aquifers; with shallow coarse blue and brown sand aquifers above 50 m depth, and a gravel aquifer identified in the nearby 35.11 m deep Tahamata Irrigation Bore No. 361063.

The new Well was developed and Step Tested in February 2021 at flow rates of 4.75, 6.94, 9.25, 11.56, 13.75 and 16.07 l/s for 60 minutes each step, plus 60 mins' Recovery time. Transmissivity values from Drawdown data T = 134.30 m^2/day and Recovery data, T = 107.60 m^2/day were determined. This was followed by constant flow Pump Testing in May 2021 over a 4-day (5760 min) period at 16.07 l/s (1388.45 m^3/day) followed by a 3-day (4320 min) Recovery period. Manual and electronic monitoring of the pumped well and four relatively shallow neighbouring bores (Tahamata Irrigation, Tahamata Farm, Bryant, Monitoring (wet-well) Bore) was completed prior to, during and post (Recovery) pumping period.

The pumped Well exhibited a rapid and measurable drawdown, with a maximum drawdown of 18.92 m at t = 5685 mins (2.53 m less than that predicted based on the Step Test analysis), reflecting steady drawdown from the first minute of the test which approached stabilisation before pumping stopped. The Recovery response upon cessation of pumping was instantaneous and the well returned to within 150 mm of the initial SWL after 3210 mins Recovery. The effects of tidal fluctuation are observed on the water level data. No measurable well interference effects were recorded in the Monitoring bores which displayed water level fluctuations of less than 100 mm over the monitoring period attributed to tidal flux and barometric pressure responses.

In conclusion:

- A new Douglas Links Well was drilled in November – February 2021, to 104.60 m toc, screened from 96.91 – 102.91 m toc (6 m) across a sandy gravel aquifer with trace shell material, with an initial SWL of -11.22 m toc;
- Constant flow aquifer testing of the pumped Well was carried out from 10 to 14 May 2021 at a rate of 16.07 l/s (1388.45 m^3/day) for 5760 mins, followed by a 4320 min Recovery period;
- The maximum recorded drawdown in the pumped Well was 18.92 m after 5685 mins pumping, following which drawdown approached stabilisation;
- The Recovery response upon cessation of pumping was instantaneous and the well returned to within 150 mm of the initial SWL after 3210 mins' Recovery;

- Four shallow to intermediate depth bores within 2 km of the pumped well were monitored during pumping and recovery periods, which did not did not experience measurable drawdown attributed to pumping;
- The pumped Well drawdown data was initially matched using the Cooper-Jacob (1946) curve with a transmissivity T = 108.90 m^2/day; and the Neuman-Witherspoon (1969) solution for leaky confined aquifers with T = 25.11 m^2/day were found using Aqtesolv (Duffield, 2007);
- Transmissivity values ranging from T = 103.85 to 105.00 m^2/day were calculated using MS Excel and the Recovery data, along with the Aqtesolv software;
- Aquifer parameters of T = 105 m^2/day and adopted storativity, s = 0.0001 (reflecting confined aquifer conditions) are considered appropriate for well interference calculations;
- Analysis of pump test data reveals a leaky confined aquifer with a degree of vertical contribution from an overlying aquifer, logged as a fine to medium sand from 68.0 to 79.1 m toc;
- An instantaneous flow rate of 16.07 l/s and volume of 1500 to 2000 m^3/day (17.36 to 23.15 l/s), and 168,060 to 224,806 m^3/year is sought to develop and irrigate the new Links course;
- The Aqtesolv (Duffield, 2007) software and Drawdown.xls program (Scott, 2001) estimates conservative long-term well interference effects of approximately 4.72 and 3.88 m within the same aquifer at distances of 2km and 3 km respectively, based on pumping 24/7 for 150 days at 16.07 l/s (using the Theis (1935) solution for confined aquifers). However, the aquifer response displays a 'leaky' component with vertical contribution, potentially reducing the predicted well interference response in neighbouring wells;
- The Hunt (2003) model was used to estimate stream depletion of approximately 4% when pumping the new Well at 16.07 l/s over 100 days which is deemed to be low using the Table 16.1 classification in the Horizons 'One Plan';
- Using the Ghyben–Herzberg ratio, and water table measurement of approximately 14.76 m amsl, then the saltwater-freshwater interface is inferred to be about 590 m depth bgl. The confined nature of the aquifer producing from a deep gravel unit and the relatively low flow rate (16.06 l/s) resulting in moderate drawdown suggests that the risk of saline intrusion would be low;
- Water quality testing of the pumped aquifer was completed by Hill Laboratories, who provided the following Final Assessment: *The parameters Turbidity, Total Iron and Total Manganese did NOT meet the guidelines laid down in the publication 'Drinking-water Standards for New Zealand 2005 (Revised 2018)' published by the Ministry of Health for water which is suitable for drinking purposes*;
- The Land Air Water Aotearoa (LAWA) website reveals a monitor bore about 4.5 km east of the Well. The 100 mm diam. bore is very shallow (16.30 m depth) in comparison to the new Well and results suggest that it is susceptible to near-surface activities and potential contaminants in shallow groundwater such as *E. coli*, which is not expected within the deep pumped Well;
- Of the 27 Mm^3/year allocation limit set for the Horowhenua Groundwater Management Zone (HGMZ), approximately 12.8% (3,458,853 m^3/year, and 18,963 m^3/day) has been allocated as at June 2021, which suggests sufficient allocation is available within the HGMZ.

This result indicates a 'leaky' confined aquifer with the typical drawdown response of a confined aquifer, that also exhibits a degree of vertical leakage providing aquifer recharge. Therefore, pumping the Well is likely to affect surrounding wells screened within the same deep gravel aquifer at similar depths, however to a lesser extent than a fully confined well given the vertical contribution.

It is considered that pumping the Applicant's Well at a constant rate of 16.07 l/s over 150 days is likely to result in tolerable well interference effects in deep gravel aquifer bores (of which there are none within 2 km) due to the available head of water; and effects on the environment are considered *no more than minor*. Given the nature of the aquifer, it is considered that the Well would be able to sustain a greater abstraction rate without resulting in significant adverse effects; however, this assumption would need to be tested through a similar regime of assessment covered in this report.

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Report Limitations

This report is written based on conditions as reported by third party contractors at the time of the desktop study, and there is no interpretation made on potential changes that may occur across the site or be reported incorrectly. Subsurface conditions may exist across the site that are not able to be detected or revealed by the investigation within the scope of the project, and are therefore not taken into account in this report. Furthermore, statements included within this report are assumptions made for the purposes of providing interpretations of well drilling and aquifer pump testing analysis.

APPENDICES

APPENDIX A

Site Photographs

Figure A1: Douglas Links new Well site (view southwest)

Figure A2: Douglas Links 150 mm diam. Pumped Well

Figure A3: Tahamata Irrigation Monitor Bore No. 361063

Figure A4: Tahamata Farm Monitor Bore No. 361051

Figure A5: Bryant Monitor Bore

Figure A6: Douglas Links Monitoring Wet Well

APPENDIX B

Well Bore Log

Screened Interval: 96.91 – 102.91 m bgl

(Neville Webb Welldrilling, 2020)

horizons regional council

Groundwater Archive (GWARC)

WATER WELL LOG FORM

Council use only:

Well Number: ☐☐☐-☐☐☐

Catchment: ______

Aquifer: ______

Completion date: 0 3 / 0 2 / 2 0 2 1

Driller: Nevill Webb & Son Ltd

Property Info:

Valuation No:	1481011204	(e.g. 1472000302)
Lot No:	Lots 1 & 2	(e.g. Lot 1)
DP No:	DP 51446	(e.g. DP 2560)
Fonterra No:		(e.g. 44044)
Street Address:	765 Muhunoa West Road Ohau LEVIN	

Owner's Info:

Name:	Grenadier Limited
Phone:	(021) 995 777
Fax:	(021)
Email:	hamish@douglaslinks.co.nz
Postal Address: (If different from property address)	1 Ishii Lane Arrowtown 9371

Well Intended Use (please tick all applicable):

- ☐ Public Supply
- ☐ Domestic Supply
- ☐ Farm Supply
- ☐ Irrigation
- ☐ Industrial Supply
- ☐ Resource Investigation/Testing
- ☑ Other (specify: Golf Club House Supply)

Target maximum abstraction: ______ m³/day

Well Location/elevation:

New Zealand Map Grid (NZMG) Ref: ☐☐☐:☐☐☐-☐☐☐

Easting:	*Northing:*	*Positioning data source:* (Please circle one)
2 6 9 3 4 4 6 m	6 0 5 9 6 2 0 m	Estimated / GPS / SGPS / Survey
Ground level:	*Casing height above ground:*	*Elevation data source:* (Please circle one)
☐☐☐☐.☐☐ masl	☐. 8 5 6 m	Estimated / GPS / SGPS / Survey

Well Access Directions:

Location Sketch:

Well Sketch:

Well Construction & Completion

Council use only:
Well Number: ☐☐☐-☐☐☐

Drilling Method:

From (m)	To (m)	Ø (mm)	Method & Fluid
0	104.9	150	Cable Tool

Casing:

From (m)	To (m)	Ø (mm)	Type
-.856	97.792	150	

Screen:

From (m)	To (m)	Ø (mm)	Type	Slot (thou)
96.91	102.91	150TS	Stainless Steel	4mm

Annular Fill (filter pack, grout, etc):

From (m)	To (m)	Fill Volume (m^3)	Description

Well Development):

Method: Surging/Bailing
Duration: 36.5 hours
Chemicals used: Nil

Static Groundwater Level (after well completion):

Measurement point (please specify/describe): ____________

Date: 03 / 02 / 2021 Water level: 11.22 m ☑ below ☐ above measurement point
(please tick one)

Well Yield & Drawdown:

Estimated maximum well yield/stabilised artesian flow rate: 16.07 LPS (please specify units)

Approximate stabilised pumping water level: 29.920 m ☑ below ☐ above measurement point
(please tick one)

Testing (please tick all applicable and attach data /results):

- ☑ Constant rate pumping test (aquifer test)
- ☑ Step-drawdown test (well efficiency test)
- ☑ Recovery test
- ☐ Slug test
- ☐ Water quality field measurements
- ☑ Water quality lab analysis

Wellhead Completion (please describe below):

Slip Over Well Cap

Remarks:

Lithological Well Log

(Page 1/2)

Council use only:

Well Number: ☐☐☐-☐☐☐

Lithological log:

From (m)	To (m)	Colour	Lithology	Description	Water Depth (m)*	W B**
0.00	0.20	Black		Sandy Topsoil		D
.20	12.0	Brown		Sand, Medium		D
12	15.5	Blue		Sand, Medium W/B		M
15.5	17.3	Blue		Sand, Medium with shell fragments W/B		M
17.3	17.8	Blue		Sand,Medium. Less shell fragments, silty with traces of clay W/B		VP/D
17.8	21.1	Blue		Sand medium,small traces of shell fragments, silty formation W/B		VP
21.1	44.9	Blue		Sand, medium to fine, quite silty. Traces of silty clay W/B		G
44.9	48.7	Blue		Sand, medium layers of sandy clay W/B		G
48.7	49.1	Brown		Clay, peat & wood		D
49.1	53.5	Blue		Sand, medium. Layers of sandy clay W/B		G
53.5	65.9	Blue		Sand, medium/coarse. Thin layers of clay W/B		G
65.9	68	Blue		Silty sand,coarse. Layers of clay & traces of gravel W/B		M
68	71.9	Blue		Sand, medium/fine W/B		VG
71.9	79.1	Blue		Sand, medium. Traces of clay & gravel W/B		G
79.1	93	Blue		Silty sand, fine. Slowhing phasing into clay. Traces of shell W/B		VP
93	103.4	Blue		Gravel. Sandywith tracels of shell. Good traces of gravels to bottom. W/B		VG
103.4	104.9	Blue		Sand,medium. Slowing fading back to gravel		
				Still in this when stopped drilling		

* **Depth to water:** is negative if below measurement point, and positive if above it (artesian).
** **Water-bearing: V** = very good, **G** = good, **M** = moderate, **P** = poor, **D** = dry

APPENDIX C

Water Quality Testing

(Hill Laboratories, Hamilton)

Hill Laboratories
TRIED, TESTED **AND TRUSTED**

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Client:	Nevill Webb Welldrilling	**Lab No:**	2524491	DWAPv1
Contact:	Catlin Goldsmith	**Date Received:**	10-Feb-2021	
	PO Box 1155	**Date Reported:**	15-Feb-2021	
	Levin 5540	**Quote No:**		
		Order No:		
		Client Reference:	Douglas Links Test Bore	
		Submitted By:	Catlin Goldsmith	

Sample Type: Aqueous

	Sample Name:	Douglas Links 09-Feb-2021 1:20 pm	**Guideline Value**	**Maximum Acceptable Values (MAV)**
	Lab Number:	2524491.1		
Routine Water Profile				
Turbidity	NTU	4.7	< 2.5	-
pH	pH Units	8.3	7.0 - 8.5	-
Total Alkalinity	g/m³ as $CaCO_3$	177	-	-
Free Carbon Dioxide	g/m³ at 25°C	1.7	-	-
Total Hardness	g/m³ as $CaCO_3$	81	< 200	-
Electrical Conductivity (EC)	mS/m	56.1	-	-
Electrical Conductivity (EC)	µS/cm	561	-	-
Approx Total Dissolved Salts	g/m³	380	< 1000	-
Total Arsenic	g/m³	< 0.0011	-	0.01
Total Boron	g/m³	0.26	-	1.4
Total Calcium	g/m³	22	-	-
Total Copper	g/m³	0.00125	< 1	2
Total Iron	g/m³	0.33	< 0.2	-
Total Lead	g/m³	0.00025	-	0.01
Total Magnesium	g/m³	6.3	-	-
Total Manganese	g/m³	0.093	< 0.04 (Staining) < 0.10 (Taste)	0.4
Total Potassium	g/m³	6.2	-	-
Total Sodium	g/m³	85	< 200	-
Total Zinc	g/m³	0.0143	< 1.5	-
Chloride	g/m³	76	< 250	-
Nitrate-N	g/m³	< 0.05	-	11.3
Sulphate	g/m³	< 0.5	< 250	-

Note: The Guideline Values and Maximum Acceptable Values (MAV) are taken from the publication 'Drinking-water Standards for New Zealand 2005 (Revised 2018)', Ministry of Health. Copies of this publication are available from https://www.health.govt.nz/publication/drinking-water-standards-new-zealand-2005-revised-2018

The Maximum Acceptable Values (MAVs) have been defined by the Ministry of Health for parameters of health significance and should not be exceeded. The Guideline Values are the limits for aesthetic determinands that, if exceeded, may render the water unattractive to consumers.

Note that the units g/m³ are the same as mg/L and ppm.

Routine Water Assessment for Sample No 2524491.1 - Douglas Links 09-Feb-2021 1:20

pH/Alkalinity and Corrosiveness Assessment

The pH of a water sample is a measure of its acidity or basicity. Waters with a low pH can be corrosive and those with a high pH can promote scale formation in pipes and hot water cylinders.
The guideline level for pH in drinking water is 7.0-8.5. Below this range the water will be corrosive and may cause problems with disinfection if such treatment is used.

The alkalinity of a water is a measure of its acid neutralising capacity and is usually related to the concentration of carbonate, bicarbonate and hydroxide. Low alkalinities (25 g/m³) promote corrosion and high alkalinities can cause problems with scale formation in metal pipes and tanks.

The pH of this water is within the NZ Drinking Water Guidelines, the ideal range being 7.0 to 8.0.
With the pH and alkalinity levels found, it is unlikely this water will be corrosive towards metal piping and fixtures.
The high alkalinity of this water may cause an increase in the pH in the root zones of plants which are irrigated using this water.

Hardness/Total Dissolved Salts Assessment

The water contains a moderate amount of dissolved solids and would be regarded as being slightly hard.

Nitrate Assessment

Nitrate-nitrogen at elevated levels is considered undesirable in natural waters as this element can cause a health disorder called methaemaglobinaemia. Very young infants (less than six months old) are especially vulnerable. The Drinking-water Standards for New Zealand 2005 (Revised 2018) suggests a maximum permissible level of 11.3 g/m³ as Nitrate-nitrogen (50 g/m³ as Nitrate).

Nitrate-nitrogen was not found in this water.

For household use, it is important that the water is not contaminated with human or animal wastes (e.g. from septic tanks or effluent ponds). Bacteriological analyses may be required if such contamination could exist. For further details, please contact this laboratory.

Boron Assessment

Boron may be present in natural waters and if present at high concentrations can be toxic to plants.
Boron was found at a low level in this water but would not give any cause for concern.

Metals Assessment

Iron and manganese are two problem elements that commonly occur in natural waters. These elements may cause unsightly stains and produce a brown/black precipitate. Iron is not toxic but manganese, at concentrations above 0.5 g/m³, may adversely affect health. At concentrations below this it may cause stains on clothing and sanitary ware.

Iron was found in this water at a significant level.
Manganese was found in this water at a significant level.
Treatment to remove iron and/or manganese may be required.

Final Assessment

The parameters Turbidity, Total Iron and Total Manganese did NOT meet the guidelines laid down in the publication 'Drinking-water Standards for New Zealand 2005 (Revised 2018)' published by the Ministry of Health for water which is suitable for drinking purposes.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Routine Water Profile		-	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) 23rd ed. 2017.	-	1
Turbidity	Analysis by Turbidity meter. APHA 2130 B 23rd ed. 2017 (modified).	0.05 NTU	1
pH	pH meter. APHA 4500-H^+ B 23rd ed. 2017. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (modified for Alkalinity <20) 23rd ed. 2017.	1.0 g/m^3 as $CaCO_3$	1
Free Carbon Dioxide	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 23rd ed. 2017.	1.0 g/m^3 at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 23rd ed. 2017.	1.0 g/m^3 as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23rd ed. 2017.	0.1 mS/m	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23rd ed. 2017.	1 µS/cm	1
Approx Total Dissolved Salts	Calculation: from Electrical Conductivity.	2 g/m^3	1
Total Arsenic	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m^3	1
Total Boron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.0053 g/m^3	1
Total Calcium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.053 g/m^3	1
Total Copper	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00053 g/m^3	1
Total Iron	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.021 g/m^3	1
Total Lead	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00011 g/m^3	1
Total Magnesium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.021 g/m^3	1
Total Manganese	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.00053 g/m^3	1
Total Potassium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.053 g/m^3	1
Total Sodium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.021 g/m^3	1
Total Zinc	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017 / US EPA 200.8.	0.0011 g/m^3	1
Chloride	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m^3	1
Nitrate-N	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.05 g/m^3	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B (modified) 23rd ed. 2017.	0.5 g/m^3	1

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 11-Feb-2021 and 15-Feb-2021. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

K Harrison

Kim Harrison MSc
Client Services Manager - Environmental

APPENDIX D

Douglas Links pumped Well Step Test Data

(07.05.21)

- **Manual Data Sheets (Neville Webb & Son Ltd well drillers)**
- **Drawdown and Recovery Graphs (using MS Excel and Aqtesolv (Duffield, 2007)).**

APPENDIX D1: Step Test manual data for Douglas Links Well (Neville Webb Welldrilling Ltd.)

Douglas Links (Grenadier) STEP DRAW DOWN TEST			
Bore Name:	Production Well		
Location:	365 Muhunoa West Road, Ohau		
GPS:	E 2693349	N 6059640	Company Mapping System
Data Logger S/N:	1066924		
SWL (m):	**11.375m**		
SWL Date:	7/05/2021	**SWL Time:**	8.57am

Manual Readings (Datum 1.072m)

Step Draw Down Test

Date	Time/Minutes	Water Level (m)	Adjustments
5/05/2021			
Pump Test Rate: 4.75 L/sec (6 inch pipe/3 inch oriface)			
7/05/2021	1		could not see due to sun. Still adjusting @ 4min mark
	2		
	3	13.675	
	4	13.930	
	5	13.985	
	6	14.040	
	8	14.110	
	10	14.190	
	15	14.315	
	20	14.405	
	25	14.485	
	30	14.540	
	40	14.625	
	59	14.740	

Date	Time/Minutes	Water Level (m)	Adjustments
Pump Test Rate: 6.94 L/sec (6 inch pipe/3 inch oriface)			
7/05/2021			
	1	16.120	
	2	16.300	
	3	16.310	
	4	16.430	adjusted slightly approx 3-5mins in
	5	16.460	
	6	16.485	
	8	16.535	
	10	16.575	
	12	16.620	
	15	16.670	
	20	16.730	
	25	16.785	
	30	16.830	
	40	16.920	
	59	17.035	

Date	Time/Minutes	Water Level (m)	Adjustments
Pump Test Rate: 9.25 L/sec (6 inch pipe/3 inch oriface)			
7/05/2021			
	1	18.930	
	2	19.045	
	3	19.105	
	4	19.150	
	5	19.195	
	6	19.230	
	8	19.290	
	10	19.340	
	15	19.455	
	20	19.520	
	25	19.580	
	30	19.635	
	59	19.860	

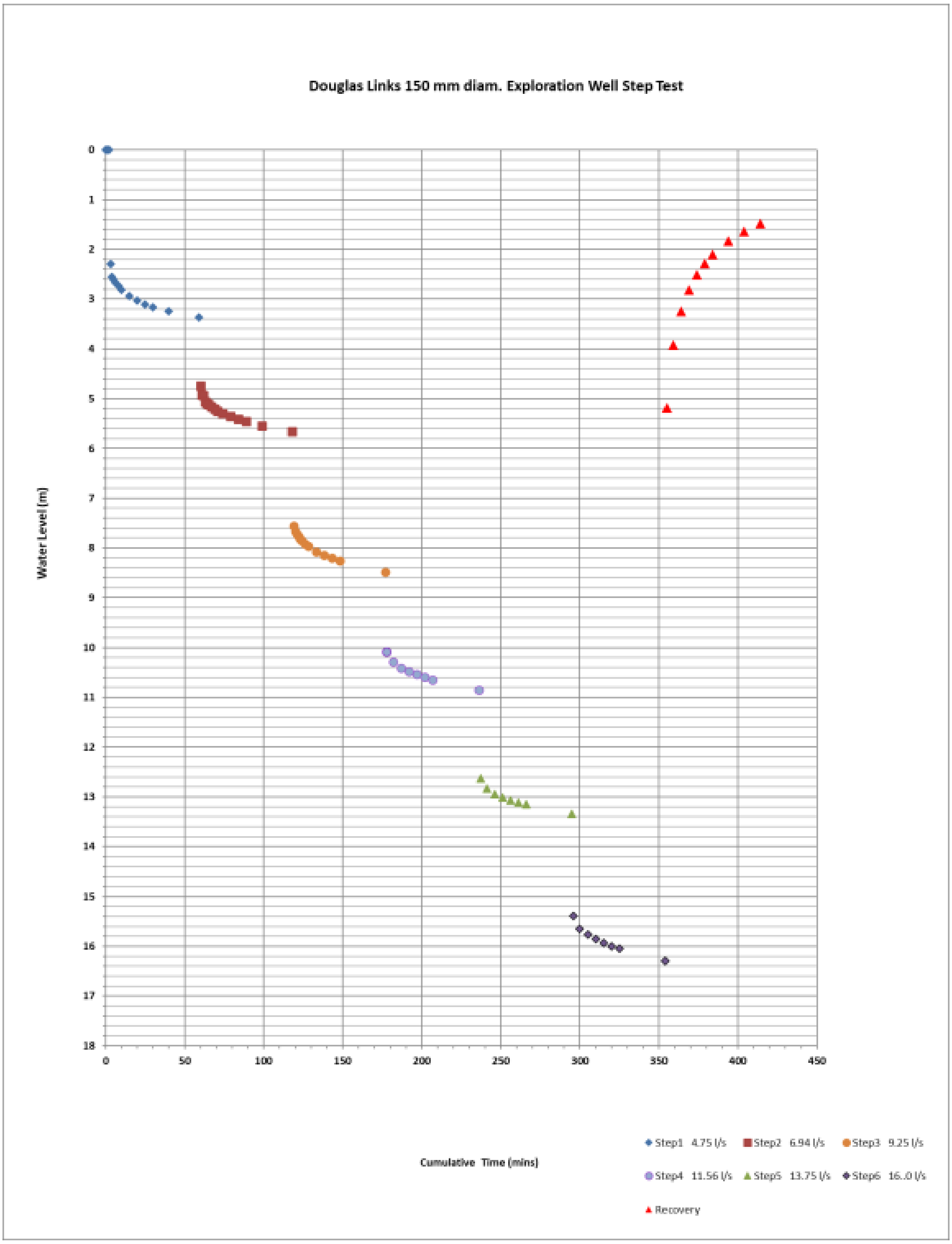
Date	Time/Minutes	Water Level (m)	Adjustments
Pump Test Rate: 11.56 L/sec (6 inch pipe/4 inch oriface)			
7/05/2021			
	1	21.460	
	5	21.655	
	10	21.790	
	15	21.855	
	20	21.910	
	25	21.970	
	30	22.020	
	59	22.230	

Date	Time/Minutes	Water Level (m)	Adjustments
Pump Test Rate: 13.75 L/sec (6 inch pipe/4 inch oriface)			
7/05/2021			
	1	24.005	
	5	24.205	
	10	24.315	
	15	24.385	
	20	24.440	
	25	24.485	
	30	24.520	
	59	24.720	

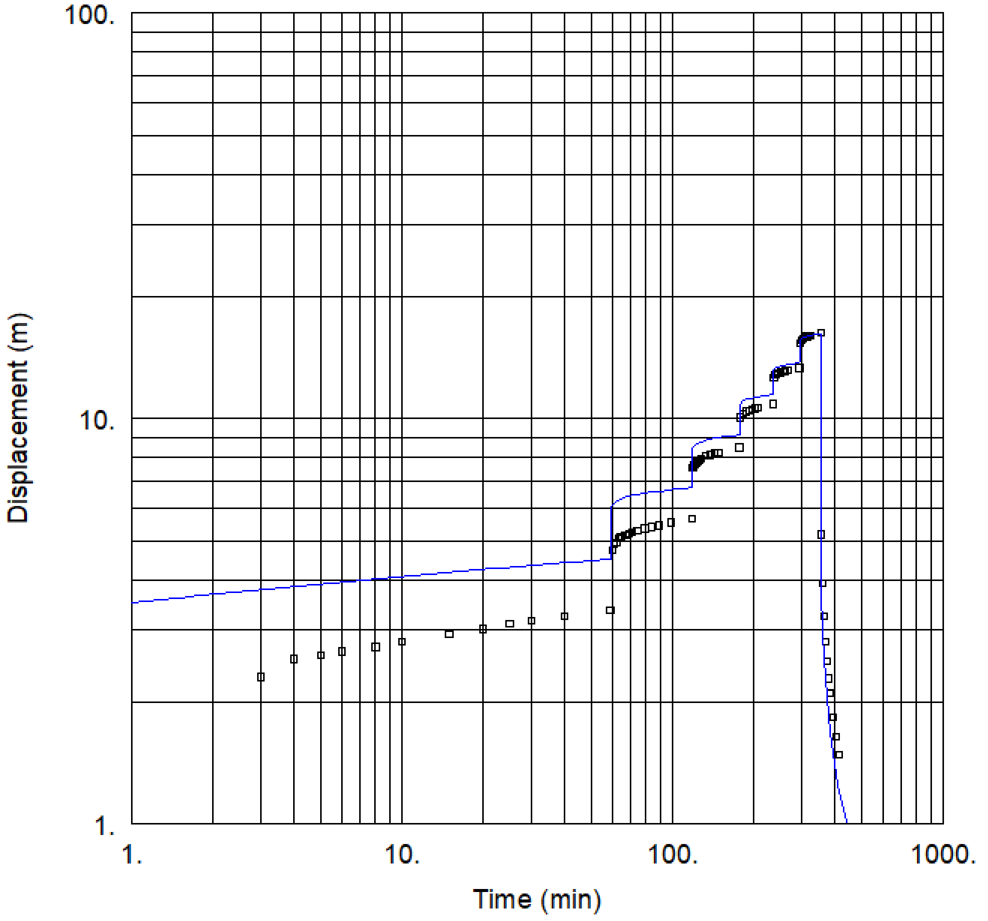
Date	Time/Minutes	Water Level (m)	Adjustments
Pump Test Rate: 16.07 L/sec (6 inch pipe/4 inch oriface)			
7/05/2021			
	1	26.765	
	5	27.025	
	10	27.140	
	15	27.230	
	20	27.310	
	25	27.380	
	30	27.420	
	59	27.665	

Date	Time/Minutes	Water Level (m)	Adjustments
Recovery			
7/05/2021			
	1	16.560	
	5	15.295	
	10	14.620	
	15	14.185	
	20	13.890	
	25	13.660	
	30	13.480	
	40	13.210	
	50	13.015	
	60	12.860	

APPENDIX D2: MS Excel plot of Douglas Links Well Step Test data



APPENDIX D3: Aqtesolv plot of Douglas Links Well Step Test data



DOUGLAS LINKS 150 MM DIAM. WELL, 765 MUHUNOA WEST RD, OHAU

Data Set: C:\...\Douglas Links 150mm Prod Well StepTest, Muhunoa Rd, Ohau.aqt
Date: 06/25/21 Time: 15:13:03

PROJECT INFORMATION

Company: Bay Geological Services Ltd
Client: Grenadier Limited
Project: BGS258
Location: 765 Muhunoa West Road, Ohau
Test Well: Douglas Links 150 mm Prod Well
Test Date: 07 May 2021

AQUIFER DATA

Saturated Thickness: 104.9 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
DouglasLinks 150mm diam	E2693349	6059640

Observation Wells

Well Name	X (m)	Y (m)
▫ DouglasLinks 150mm diam	2693349ll	6059640

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Step Test)

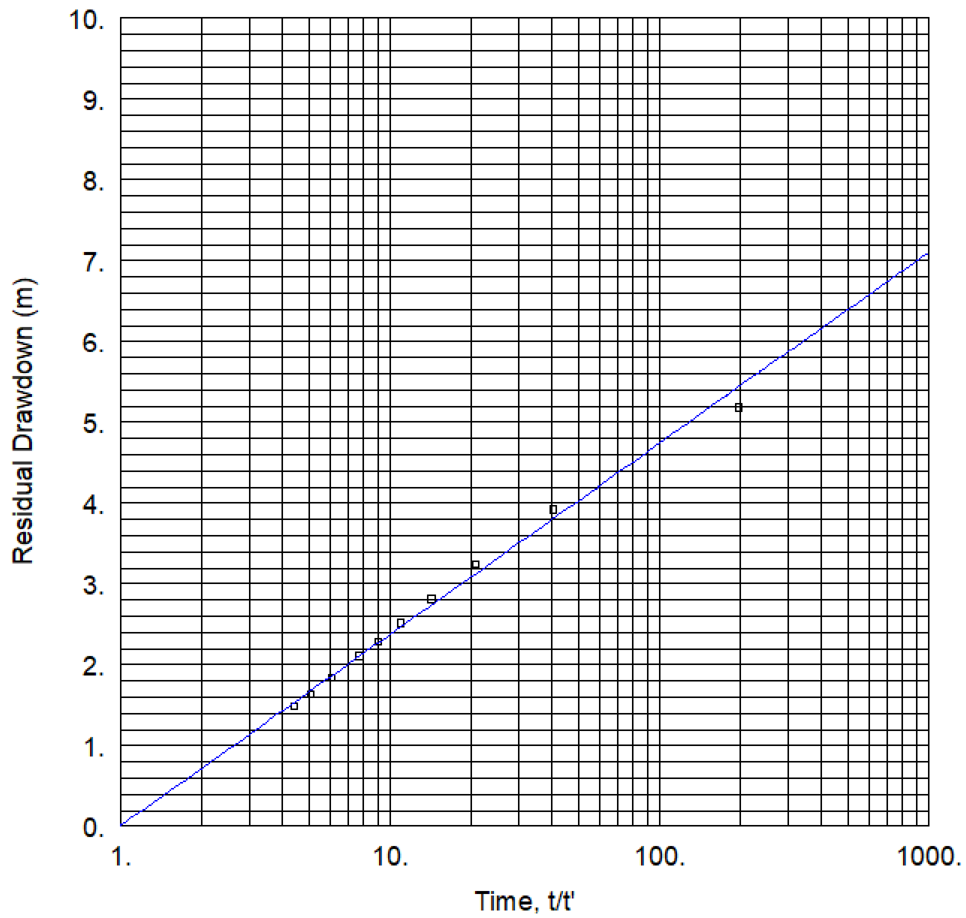
T = 134.3 m^2/day
Sw = 0.
P = 2.

S = 2.09E-5
C = 0. min^2/m^5

Step Test Model: Jacob-Rorabaugh
Time (t) = 1. min Rate (Q) in cu. m/min

s(t) = 12.28Q + 0.Q^2.
W.E. = 100.% (Q from last step)

APPENDIX D4: Douglas Links. Well Step Test Aqtesolv Recovery data



DOUGLAS LINKS 150 MM DIAM. EXPL WELL STEP TEST RECOVERY DATA

Data Set: C:\...\Douglas Links 150mm Prod Well StepTest Recovery data.aqt
Date: 06/25/21 Time: 15:14:37

PROJECT INFORMATION

Company: Bay Geological Services Ltd
Client: Grenadier Limited
Project: BGS258
Location: 765 Muhunoa West Road, Ohau
Test Well: Douglas Links 150 mm Expl Well
Test Date: 07 May 2021

AQUIFER DATA

Saturated Thickness: 104.9 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
DouglasLinks 150mm diam.	2693349	6059640

Observation Wells

Well Name	X (m)	Y (m)
DouglasLinks 150mm diam	2693349	6059640

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 107.6 m^2/day S/S' = 0.9904

APPENDIX E

Surrounding Well Data

(Horizons)

APPENDIX E1: Horizons map displaying bores within a 4 km radius of pumped Well (Lattey, 2020).

Key:

Red: Bores with 2 km radius with a depth range 10 to 45.8 m bgl (Bore Nos. 361021, 361060, 361051, 361041, 361003, 361012)

Purple: Bore located 2390 m radius with a depth of 33.21 m bgl. (Bore No. 361063)

Orange: no data

APPENDIX E2: Selected lithology data from selected nearby bores (Lattey, 2020)

Selected Lithologies

id	Easting	Northing	From	To	Lithology	Driller's Description	stn_type
361021	2694396	6060883	0	2	Sand	Brown fine silty sand, loose	Borehole
361021	2694396	6060883	2	6.5	Sand	Blue medium sand, loose	Borehole
361021	2694396	6060883	6.5	12	Sand	Grey coarse sand && some shells, loose	Borehole
361021	2694396	6060883	12	24	Sand	Grey fine silty sand	Borehole
361060 x							
361051	2694600	6059300	0	0.5	Top Soil	Top soil	Borehole
361051	2694600	6059300	0.5	2.8	Sand	Brown sand medium	Borehole
361051	2694600	6059300	2.8	4.2	Sand	Brown medium sand with peat	Borehole
361051	2694600	6059300	4.2	7	Sand	Blue medium sand water bearing	Borehole
361051	2694600	6059300	7	7.5	Clay	Blue clay	Borehole
361051	2694600	6059300	7.5	12.5	Sand	Blue coarse sand water bearing	Borehole
361051	2694600	6059300	12.5	20.3	Sand	Blue medium sand sand with small amount of gravel	Borehole
361051	2694600	6059300	20.3	23.8	Clay	Blue clay	Borehole
361051	2694600	6059300	23.8	24.5	Gravel	Blue gravel with coarse sand 75-25 wb	Borehole
361051	2694600	6059300	24.5	28.9	Gravel	Blue gravel water bearing	Borehole
361051	2694600	6059300	28.9	29.6	Gravel	Blue gravel with some sand	Borehole
361051	2694600	6059300	29.6	31	Gravel	Blue gravel and coarse sand 50-50 wb	Borehole
361051	2694600	6059300	31	31.8	Sand	Blue medium sand wb	Borehole
361051	2694600	6059300	31.8	32.2	Gravel	Blue gravel and sand	Borehole
361051	2694600	6059300	32.2	39.2	Sand	Blue medium sand wb	Borehole
361051	2694600	6059300	39.2	39.8	Peat	Peat with medium sand 50-50	Borehole
361051	2694600	6059300	39.8	45.8	Sand	Brown coarse to medium sand wb swl -0.6 m fe=0.5ppm mn 0.3ppm	Borehole
361041	2694699	6059345	0	2	Sand	Brown sand	Borehole
361041	2694699	6059345	2	8	Sand	Blue sand	Borehole
361041	2694699	6059345	8	14	Sand	Blue sand && wood, w/b	Borehole
361041	2694699	6059345	14	25	Sand	Blue fine sand, w/b	Borehole
361041	2694699	6059345	25	33	Sand	Dark blue/green semi-cemented sand, w/b	Borehole
361041	2694699	6059345	33	37	Sand	Blue clean sand, w/b	Borehole
361003 x							
361012	2695200	6061300	0	2	Top Soil	Black/brown sandy organic soil	Borehole
361012	2695200	6061300	2	10	Sand	Sands, fine, yellow/brown graded<0.25mm	Borehole
361012	2695200	6061300	10	17	Sand	Sands, fine, well graded<0.25mm, blue/grey, wood fragments throughout	Borehole
361012	2695200	6061300	17	19	Sand	Clayey sands, very fine<0.2mm, dark blue/grey well graded 01m thick	Borehole
361012	2695200	6061300	19	20.5	Sand	Blue/grey sands, fine well graded	Borehole
361012	2695200	6061300	20.5	23	Sand	Sands, med <0.4mm, well graded, blue/grey with small silt band, firm dark blue/grey	Borehole
Deeper wells - more distant - due west							
362131	2696361	6058957	0	6.1	Sand	Brown sand	Borehole
362131	2696361	6058957	6.1	12.2	Sand	Grey sand	Borehole
362131	2696361	6058957	12.2	28.4	Sand	Brown sand	Borehole
362131	2696361	6058957	28.4	29	Peat	Peat, wood, grey sand	Borehole
362131	2696361	6058957	29	45.4	Sand	Grey sand	Borehole
362131	2696361	6058957	45.4	46.7	Sand	Fatty sand	Borehole
362131	2696361	6058957	46.7	54.6	Sand	Grey sand	Borehole
362131	2696361	6058957	54.6	55.2	Sand	Coarse grey sand, fine gravel, shells, w/b	Borehole
362131	2696361	6058957	55.2	55.8	Gravel	Blue clay bound gravel	Borehole
362131	2696361	6058957	55.8	56.4	Gravel	Blue loose gravel, w/b	Borehole
362166 x							
361011	2696002	6059120	0	1.5	Peat	Peat, wood && soil	Borehole
361011	2696002	6059120	1.5	9.5	Sand	Grey sand, small water lenses	Borehole
361011	2696002	6059120	9.5	10.1	Top Soil	Woood && sand, small water lenses	Borehole
361011	2696002	6059120	10.1	22.6	Sand	Grey sand, small water lenses	Borehole
361011	2696002	6059120	22.6	23.2	Sand	Brown clay bound sand	Borehole
361011	2696002	6059120	23.2	24.4	Sand	Coarse brown sand	Borehole
361011	2696002	6059120	24.4	26.5	Sand	Brown fatty sand	Borehole
361011	2696002	6059120	26.5	48.2	Sand	Coarse brown sand	Borehole
361011	2696002	6059120	48.2	58	Sand	Hard grey sand	Borehole
361011	2696002	6059120	58	61	Sand	Grey sand	Borehole
361011	2696002	6059120	61	62	Gravel	Gravel && clay	Borehole
362306 x							
361063	2693650	6057766	0	5.5	Sand	Sand	Borehole
361063	2693650	6057766	5.5	10	Sand	Sand - cemented	Borehole
361063	2693650	6057766	10	22	Silt	Very silty sand (close to clay)	Borehole
361063	2693650	6057766	22	26.7	Peat	Peat/clay	Borehole
361063	2693650	6057766	26.7	28.2	Gravel	Gravel W/B and gravel fines	Borehole
361063	2693650	6057766	28.2	33.86	Gravel	Gravel W/B - Good range of sizes	Borehole
361063	2693650	6057766	33.86	35.11	Sand	Silty sand	Borehole

APPENDIX E3: Bore log for Tahamata Irrigation Monitor Bore No. 361063

NEVILL WEBB & SON LTD

AGRICULTURAL, DOMESTIC & INDUSTRIAL WELL DRILLERS

P.O. Box 1155,
Levin 5510

Telephone: (06) 368 5829
Mobile: 0274 423 591
Fax: (06) 368 5197

Well Log

Property Owner Surname: First Name:	Tahamata Farm	Completion Date:	9 December 2010
Bore Location House No.: Street/Road: Area: Town/City	Kuku Beach Road Kuku Levin	Postal Address Street: RD no: Area: Town/City:	

Map Reference N:	6057766	Map Reference E:	2693650
Drilled Depth (m):	35.110	Diameter (mm):	250
Lgth of Casing (m):	29.426	Static Water Level (m):	2.46 above flange
Lgth of Screen (m):	4.500	Test Pumping Rate:	42.58 L/sec
Screen Position:	28.71m to 33.21m	Draw Down (m):	1.015
Lgth Leader Pipe (m):	0.800		

Iron:		Mag:	

LITHOLOGICAL WELL LOG

Name: *Tahamata Farm*
Address: *Kuku Beach Road, Kuku*

Depth from (m)	Depth to (m)	Description	W/B Code
0.00	5.50	Brown sand	P
5.50	10.00	Blue sand, cemented	P/M
10.00	22.00	Blue very silty sand	D
22.00	26.70	Peat, clay	D
26.70	28.20	Blue gravel & gravel fines W/B	G
28.20	33.86	Blue gravel W/B. Good range of sizes	G
33.86	35.11	Blue silty sand	

Water-bearing Code: V = very good, G = good, M = moderate, P = poor, D = dry

APPENDIX E4: Bore log for Tahamata Farm Monitor Bore No. 361051

NEVILL WEBB & SON LTD

AGRICULTURAL, DOMESTIC & INDUSTRIAL WELL DRILLERS

P.O. Box 1155,
Levin 5510

Telephone: (06) 368 5829
Mobile: 0274 423 591
Fax: (06) 368 5197

Well Log

Property Owner Surname: First Name:	Tahamata Corporation	Completion Date:	16 December 2002
Bore Location House No.: Street/Road: Area: Town/City	Muhunoa West Road Ohau Levin	*Postal Address* Street: RD no: Area: Town/City:	

Map Reference N:		Map Reference E:	
Drilled Depth (m):	45.800	Diameter (mm):	150
Lgth of Casing (m):	40.885	Static Water Level (m):	0.600
Lgth of Screen (m):	6.000	Test Pumping Rate:	1500 G/hr
Screen Position:	6.000	Draw Down (m):	4.670
Lgth Leader Pipe (m):	1.545		

Iron:	0.5	Mag:	0.3

LITHOLOGICAL WELL LOG

Name: *Tahamata Corporation*
Address: *Muhunoa West Rd, Ohau*

Depth from (m)	Depth to (m)	Description	W/B Code
0.00	0.50	Topsoil	
0.50	2.800	Brown sand, medium	
2.80	4.20	Brown medium sand with peat	
4.20	7.00	Blue medium sand W/B	
7.00	7.50	Blue clay	
7.50	12.50	Blue coarse sand W/B	
12.50	20.30	Blue medium sand with small amount of gravel	
20.30	23.80	Blue clay	
23.80	24.50	Blue gravel with coarse sand W/B at 24.1m pump test	
		SWL .7m. Iron 4pts, Mang .5pts	
24.50	28.90	Blue gravel W/B. WL .5m above ground level at 25.7m	
28.90	29.60	Blue gravel with some sand (75/25) W/B	
29.60	31.00	Blue gravel & coarse sand (50/50) W/B	
31.00	31.80	Blue medium sand W/B	
31.80	32.20	Blue gravel & sand	
32.20	39.20	Brown medium sand W/B	
39.20	39.80	Peat with medium sand (50/50) easy drilling	
39.80	45.80	Brown coarse to medium sand W/B. Harder than above.	

Water-bearing Code: V = very good, G = good, M = moderate, P = poor, D = dry

APPENDIX E5: Lithology bore log for the Douglas Links Monitoring Wet Well (Neville Webb Welldrilling)

LITHOLOGICAL WELL LOG

(Page 1/2)

Council use only:
Well Number: □□□-□□□

Lithological log:

From (m)	To (m)	Colour	Lithology	Description	Water Depth (m)*	W B**
0	.050			Top soil		
.050	.600	Brown	fine	sand.		
.600	2.6	Blue	coarse	sand.	1.1	✓

APPENDIX F

Manual Pump Test Data

(Neville Webb Welldrilling)

Douglas Links (Grenadier) CONSTANT RATE TEST			
Bore Name:	Production Well		
Location:	365 Muhunoa West Road, Ohau		
GPS:	E 2693349	N 6059640	Company Mapping System
Data Logger S/N:	1066924		
SWL (m) :	**11.310M**		
SWL Date:	10/05/2021	**SWL Time:**	8.33am

Manual Readings (Datum 1.072m) Constant Rate Test			
Date	**Time/Minutes**	**Water Level (m)**	**Comments**
Pump Test Rate: 16.07 L/sec			
10/05/2021			
	1	22.400	
	2	23.080	
	3	23.480	
	4	23.740	
	5	23.950	
	6	24.110	
	8	24.395	
	10	24.630	
	12	24.835	
	14	25.000	
	16	25.150	
	18	25.275	
	20	25.395	
	25	25.630	
	30	25.830	
	35	26.000	
	40	26.165	
	45	26.320	
	50	26.445	
	55	26.550	
	60	26.650	

Date	Time/Minutes	Water Level (m)	Comments
	70	26.800	
	80	26.920	
	90	27.045	
	100	27.135	
	110	27.215	
	120	27.295	
	150	27.530	
	180	27.655	
5/05/2021	9.34am	11.325	
6/05/2021	11.28am	11.355	
7/05/2021	8.27am	11.360	before start of step draw down
8/05/2021	10.28am	11.440	
9/05/2021	11.30am	11.300	
10/05/2021	8.33am	11.310	before start of constant rate
10/05/2021	4.52pm	28.635	adjusted valve slightly
11/05/2021	11.12am	29.080	
12/05/2021	11.49am	29.490	
13/05/2021	9.29am	29.910	
14/05/2021	8.28am	30.200	

Date	Time/Minutes	Water Level (m)	Adjustments
Recovery			
14/05/2021	1	18.010	
	2	17.490	
	3	17.175	
	4	16.935	
	5	16.735	
	6	16.550	
	8	16.265	
	10	16.025	
	12	15.810	
	14	15.660	
	16	15.505	

Date	Time/Minutes	Water Level (m)	Adjustments
	18	15.360	
	20	15.245	
	25	14.985	
	30	14.780	
	35	14.590	
	40	14.460	
	45	14.325	
	50	14.215	
	55	14.110	
	60	14.020	
	70	13.855	
	80	13.710	
	90	13.590	
	100	13.480	
	110	13.380	
	120	13.290	
	12.11pm	12.810	
	1.31pm	11.525	
	1.45pm	11.455	

Tahamata Irrigation
Manual Readings

Bore Name:	Tahamata Irrigation		
Location:	Kuku Beach Road, Levin		
GPS Reading	E 2693650	N 6057766	Company Mapping System
Data Logger S/N:	10395687		
SWL (M):	**2.0390**		
SWL Date:	7/05/2021	**SWL Time:**	7.45am

Manual Readings (Datum 1.103m above ground)

Date	Time/Minutes	Water Level (M)	Comments
5/05/2021	8.30am	2.018	middle reading, pump not running
6/05/2021	10.39am	1.983	middle reading, pump not running
7/05/2021	7.45am	2.039	staying on reading
	10.29am	2.109	stayed at reading
	1.30pm	2.039	hovered 2.70-3.08, pump on
	4.47pm	2.046	(average)
8/05/2021	9.39am	2.130	average - pump not running
9/05/2021	10.47am	2.137	average - pump not running
10/05/2021	7.49am	2.109	held on number
	12.44pm	2.123	average
	4.02pm	2.053	average
11/05/2021	10.27am	2.151	holding
12/05/2021	10.51am	2.137	average
13/05/2021	8.54am	2.130	average
14/05/2021	7.46am	2.144	average
	11.19am	2.102	average
15/05/2021	12.41pm	2.130	average
16/05/2021	12.50pm	2.155	average

Tahamata Well
Manual Readings

Bore Name:	Tahamata Farm Well		
Location:	589 Muhunoa West Road		
GPS:	E 2694600	N 6059300	Company Mapping System
Data Logger S/N:	10395686		
SWL (m):	**.850m**		
SWL Date:	7/05/2021	**SWL Time:**	8.03am

Manual Readings (Datum 1.116m above ground)

Date	Time/Minutes	Water Level (m)	Adjustments
5/05/2021	9.00am	0.805	
6/05/2021	11am	1.000	
7/05/2021	8.03am	0.850	
	10.47am	0.840	
	2.00pm	1.420	Pump on and off
	4.23pm	1.060	
8/05/2021	10.04am	0.950	
9/05/2021	11.07am	0.870	
10/05/2021	8.05am	0.825	
	1.02pm	0.810	
	4.21pm	0.800	
11/05/2021	12.05pm	0.860	
12/05/2021	11.18am	0.810	
13/05/2021	10.01am	2.480	Pump on and off
14/05/2021	8.05am	1.020	
	11.40am	1.003	Pump on and off
15/05/2021	1.02pm	0.780	
16/05/2021	1.21pm	0.810	Recovery

Donald Bryant
Manual Readings

Bore Name:	Donald Bryant		
Location:	591 Muhunoa West Road, Levin		
GPS:	E 2694014	N 6060368	Company Mapping System
Data Logger S/N:	1184419		
SWL (m):	**2.60M**		
SWL Date:	7/05/2021	**SWL Time:**	8.11am

Manual Readings (Datum 116mm above ground)

Date	Time/Minutes	Water Level (m)	Comments
5/05/2021	9.13am	2.645	
6/05/2021	11.11am	2.610	
7/05/2021	8.11am	2.600	
	10.55am	2.660	pump on
	2.14pm	2.610	pump just off
8/05/2021	10.14am	2.610	
9/05/2021	11.17am	2.600	
10/05/2021	8.15am	2.605	
	12.27pm	2.600	
11/05/2021	10.45am	2.625	
12/05/2021	11.27am	2.610	
13/05/2021	9.46am	2.620	
14/05/2021	8.13am	2.600	
	11.54am	2.625	
15/05/2021	1.14pm	2.625	
16/05/2021	1.32pm	2.600	

Monitoring Well (near River)
Manual Readings

Bore Name:	Monitoring Well (near River)		
Location:	Muhunoa West Road, Levin		
GPS:	E 2693194	N 6059518	Company Mapping System
Data Logger S/N:	1184418		
SWL (m):	**2.040m**		
SWL Date:	7/05/2021	**SWL Time:**	8.21am

Manual Readings (Datum 493mm above ground)

Date	Time/Minutes	Water Level (m)	Comments
5/05/2021	9.28am	2.000	
6/05/2021	11.22am	2.015	
7/05/2021	8.21am	2.040	
	11.07am	2.050	
	2.30pm	2.040	
	4.06pm	2.040	
8/05/2021	10.25am	2.030	
9/05/2021	11.26am	2.020	
10/05/2021	8.26am	1.990	
	12.14pm	1.980	
	4.40pm	1.950	
11/05/2021	10.54am	1.880	
12/05/2021	11.36am	1.720	
13/05/2021	9.37am	1.620	lots of rain last 3 days
14/05/2021	8.23am	1.560	
	12.04pm	1.540	
15/05/2021	1.25pm	1.565	
16/05/2021	1.41pm	1.595	

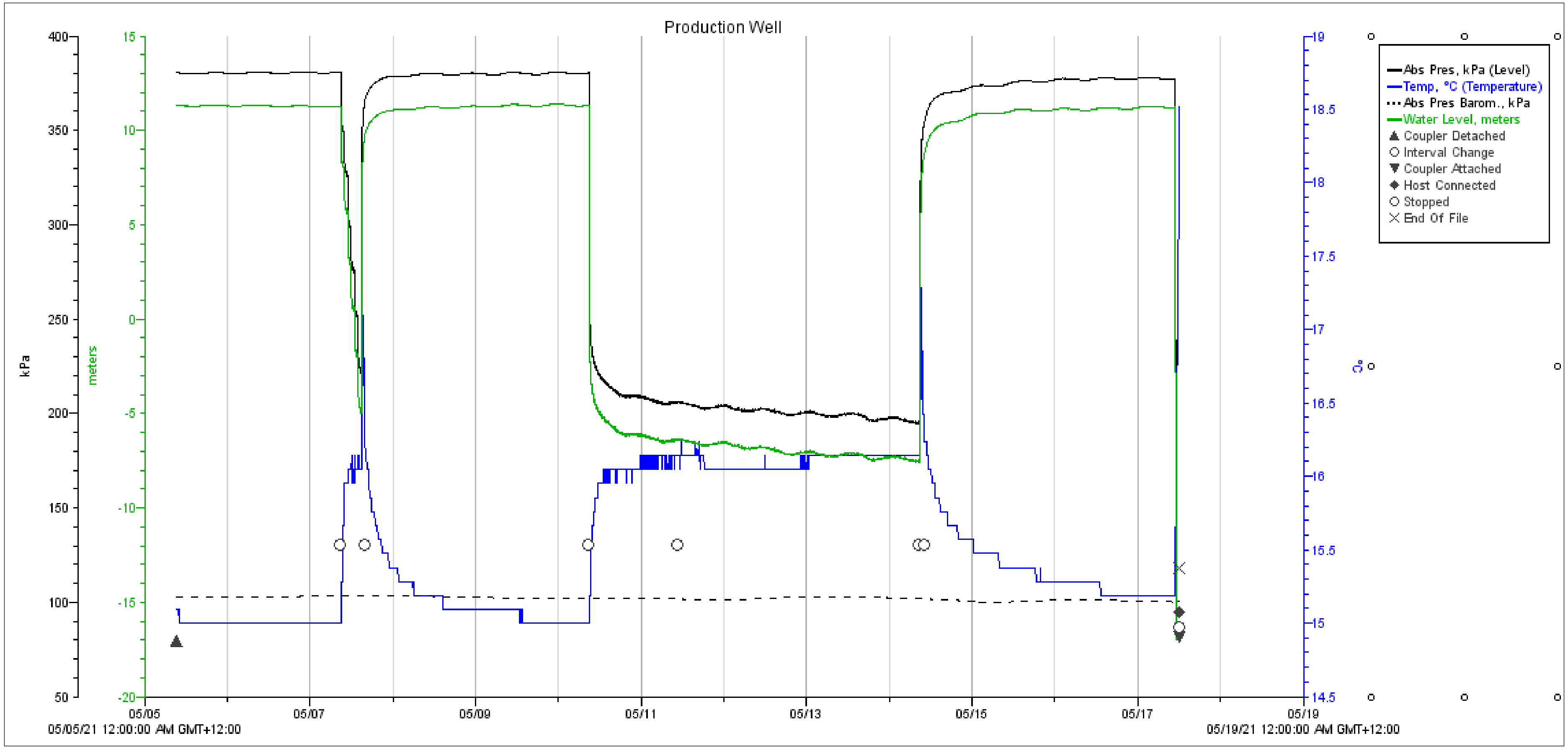
APPENDIX G

Douglas Links Pumped Well

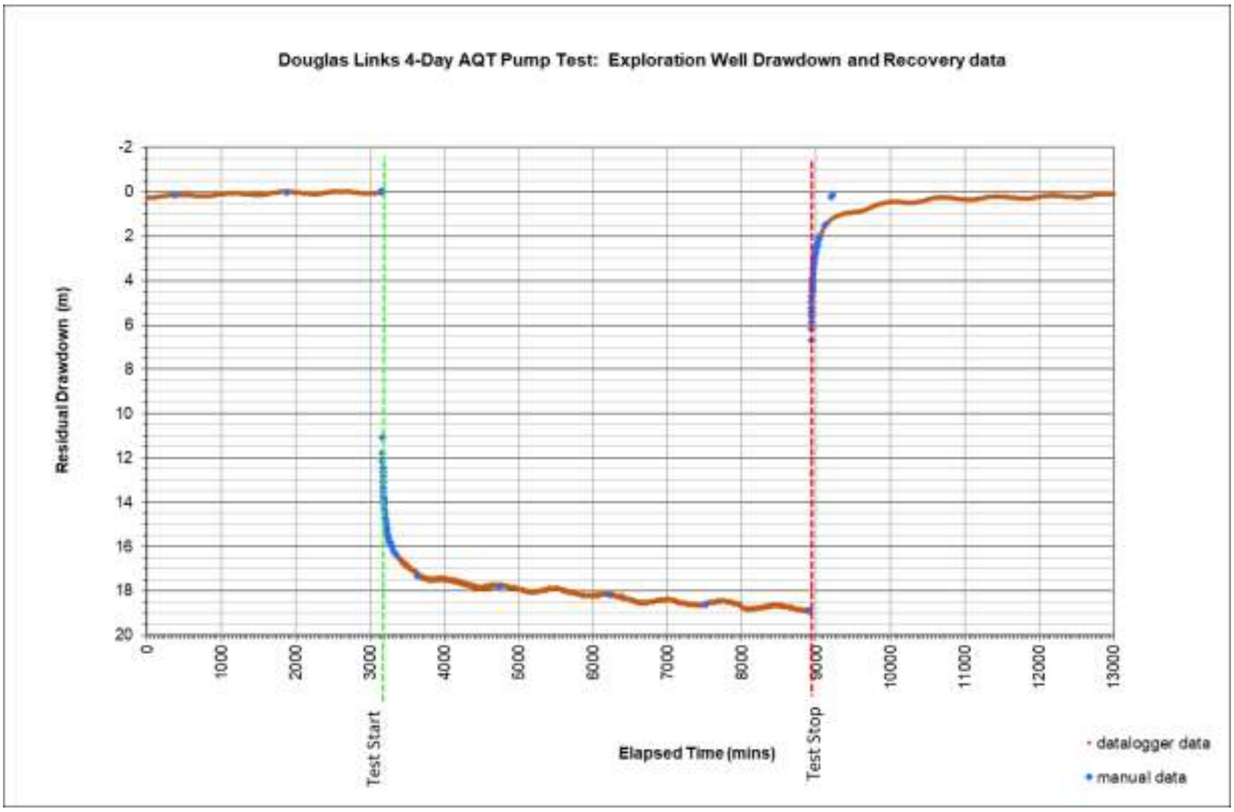
Drawdown and Recovery Graphs

(MS Excel and Aqtesolv (Duffield, 2007))

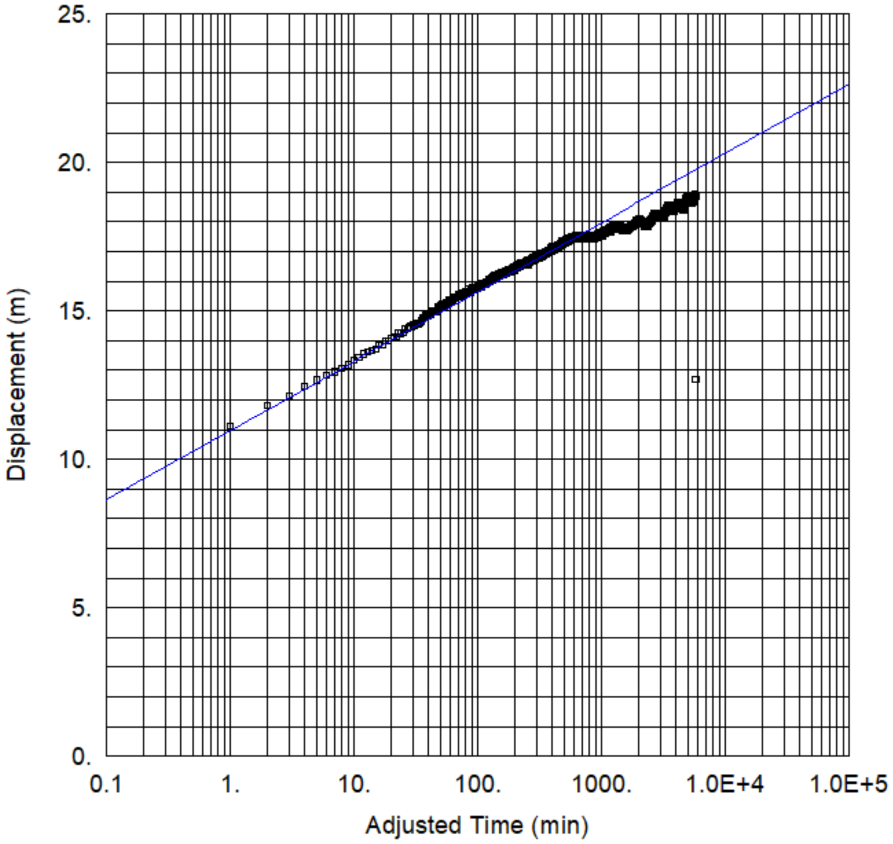
APPENDIX G1: Datalogger plot across Step Test and 4-day Pump Test (Douglas Links Pumped Well). Neville Webb Welldrilling Ltd.



G2. Pumped Well Aquifer Pump Test Time v Drawdown Graph



G3. Pumped Well Displacement (m) v Time (mins) Electronic Data (Aqtesolv, 2007) using Cooper-Jacob (1946) straight line solution for confined aquifers.



DOUGLAS LINKS 4-DAY AQT PUMP TEST,, EXPLORATION WELL, MUHUNOA WEST ROAD, OHAU

Data Set: C:\...\D Links 4-day AQT Expl Well DD & Rec Edata Cooper Jacob.aqt
Date: 07/01/21 Time: 16:30:19

PROJECT INFORMATION

Company: Bay Geological Services Ltd
Client: Grenadier Developments Ltd
Project: BGS258-01
Location: 765 Muhunoa West Road, Ohau
Test Well: 150mm diam Expl Well
Test Date: 10 May 2021

AQUIFER DATA

Saturated Thickness: 10.4 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Douglas Links Expl Well	2693377	6059684

Observation Wells

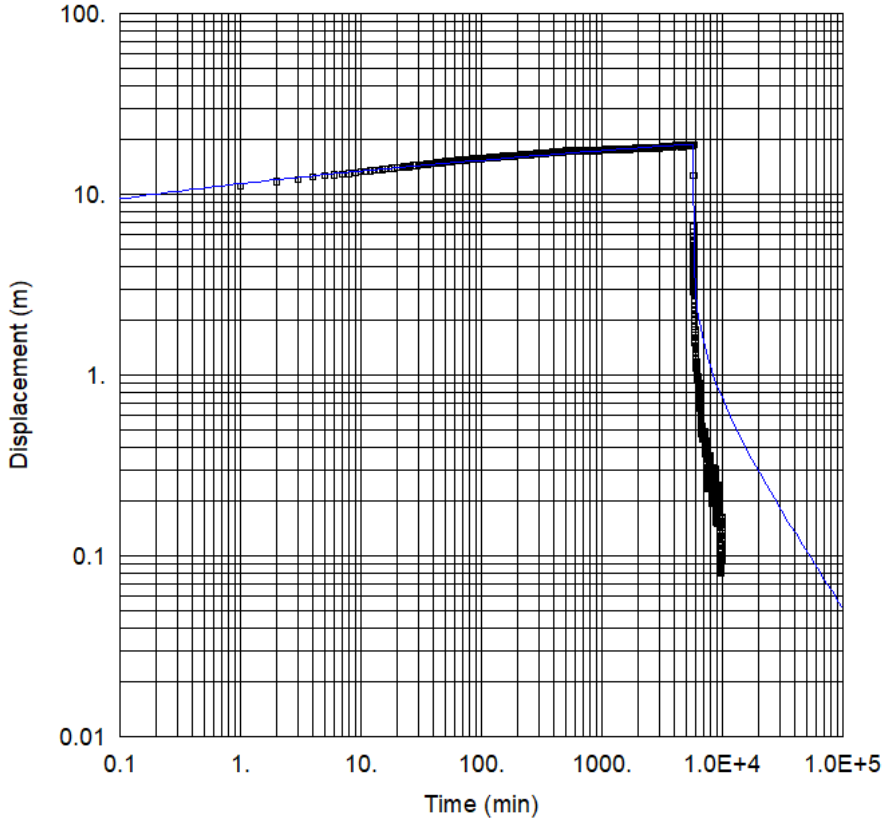
Well Name	X (m)	Y (m)
◦ Douglas Links Expl Well	2693377	6059684

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 108.9 m^2/day S = 0.0006146

G4. Pumped Well Displacement (m) v Time (mins) Electronic Data (Aqtesolv, 2007) using Theis (1935) solution for confined aquifers.



DOUGLAS LINKS 4-DAY AQT PUMP TEST, MUHUNOA WEST ROAD, OHAU

Data Set: C:\...\D Links 4-day AQT Expl Well DD & Rec Edata Theis.aqt
Date: 07/01/21 Time: 16:32:03

PROJECT INFORMATION

Company: Bay Geological Services Ltd
Client: Douglas Links
Project: BGS258-01
Location: 765 Muhunoa West Road, Ohau
Test Well: 150mm diam Test Well
Test Date: 09 Feb 2021

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Douglas Links Test Well	2693377	6059684

Observation Wells

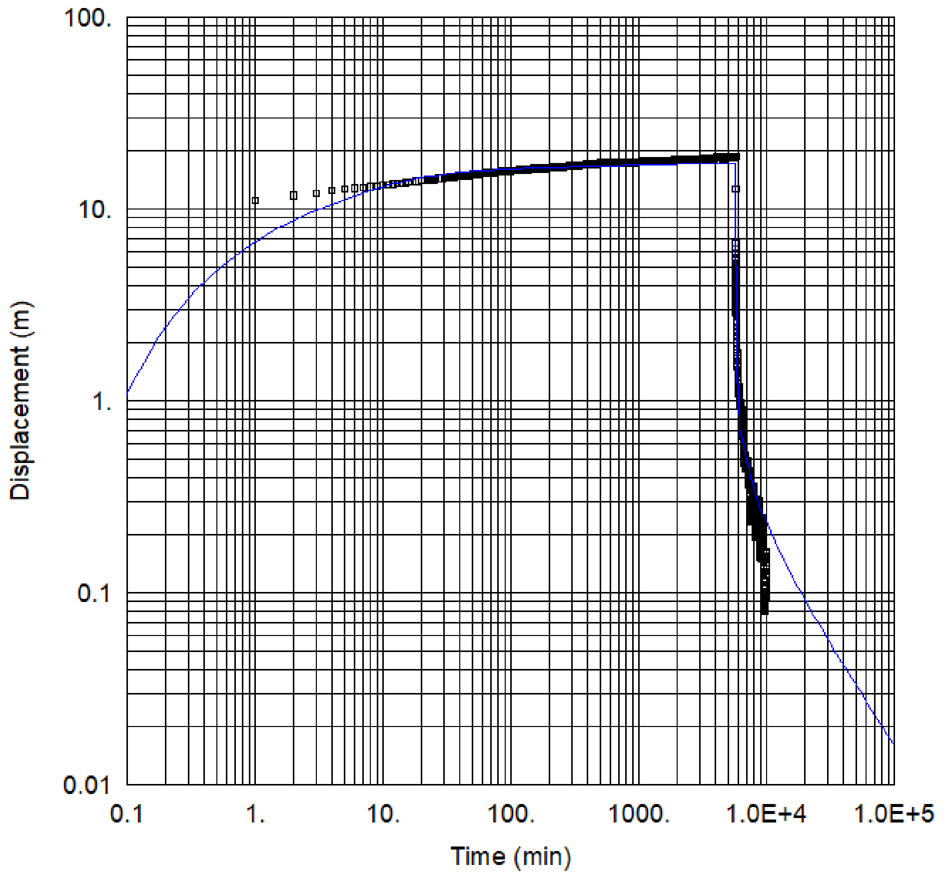
Well Name	X (m)	Y (m)
▫ Douglas Links Test Well	2693377	6059684

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 126.9 m^2/day
S = 6.862E-5
Kz/Kr = 1.
b = 10.4 m

G5. Pumped Well Displacement (m) v Time (mins) Electronic Data (Aqtesolv, 2007) using Neuman-Witherspoon (1946) solution for leaky confined aquifers.



DOUGLAS LINKS 4-DAY AQT PUMP TEST, EXPL WELL, MUHUNOA WEST ROAD, OHAU

Data Set: C:\...\D Links 4-day AQT Expl Well DD & Rec Edata N-W sol.aqt
Date: 07/01/21 Time: 16:33:42

PROJECT INFORMATION

Company: Bay Geological Services Ltd
Client: Grenadier Developments Ltd
Project: BGS258-01
Location: 765 Muhunoa West Road, Ohau
Test Well: 150mm diam Expl Well
Test Date: 10 May, 2021

AQUIFER DATA

Saturated Thickness: 10.4 m
Aquitard Thickness (b'): 14. m
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b"): 1. m

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Douglas Links Expl. Well	2693377	6059684

Observation Wells

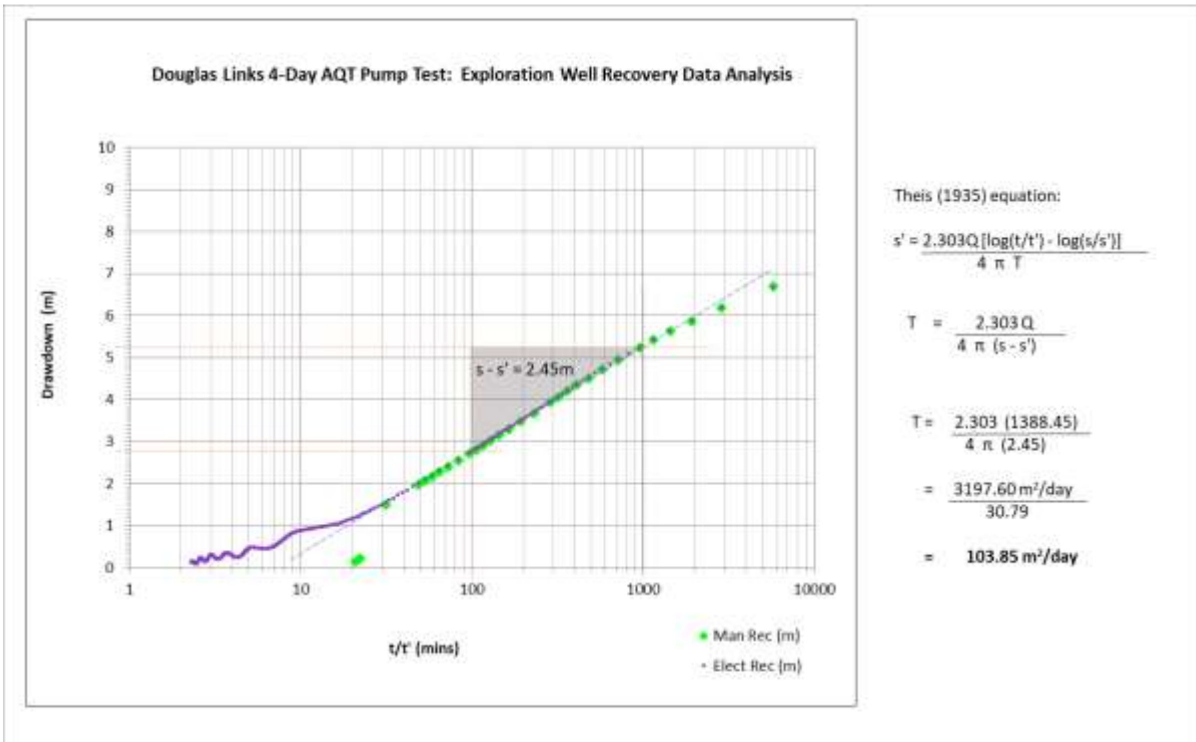
Well Name	X (m)	Y (m)
▫ Douglas Links Expl. Well	2693377	6059684

SOLUTION

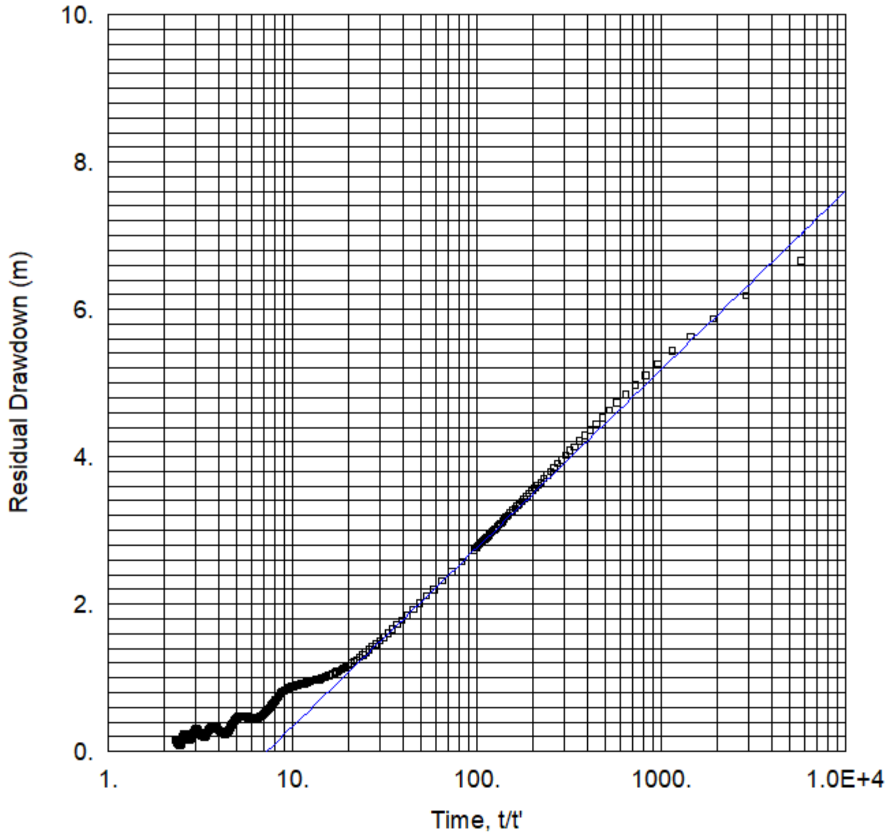
Aquifer Model: Leaky
Solution Method: Neuman-Witherspoon

T = 25.11 m^2/day
r/B = 0.2
T2 = 381.7 m^2/day
S = 1.
ß = 0.1
S2 = 0.0009183

G6. Pumped Well Recovery data MS Excel graph using Theis (1935).



G7. Pumped Well Recovery Elect data Aqtesolv graph using Theis (1935).



DOUGLAS LINKS 4-DAY AQT TEST EXPL WELL RECOVERY EDATA, MUHUNOA WEST RD, OHAU

Data Set: C:\...\4-day AQT Expl Well Recovery Edata.aqt
Date: 07/01/21 Time: 16:27:16

PROJECT INFORMATION

Company: Bay Geological Services Ltd
Client: Grenadier Developments Ltd.
Project: BGS258-01
Location: 765 Muhunoa West Road, Ohau
Test Well: 150 mm diam. Expl Well
Test Date: 10 May 2021

AQUIFER DATA

Saturated Thickness: 10.4 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Pumped Expl Well Recovery	2693377	6059684

Observation Wells

Well Name	X (m)	Y (m)
▫ Pumped Expl Well Recover	2693377	6059684

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 105. m^2/day S/S' = 7.257

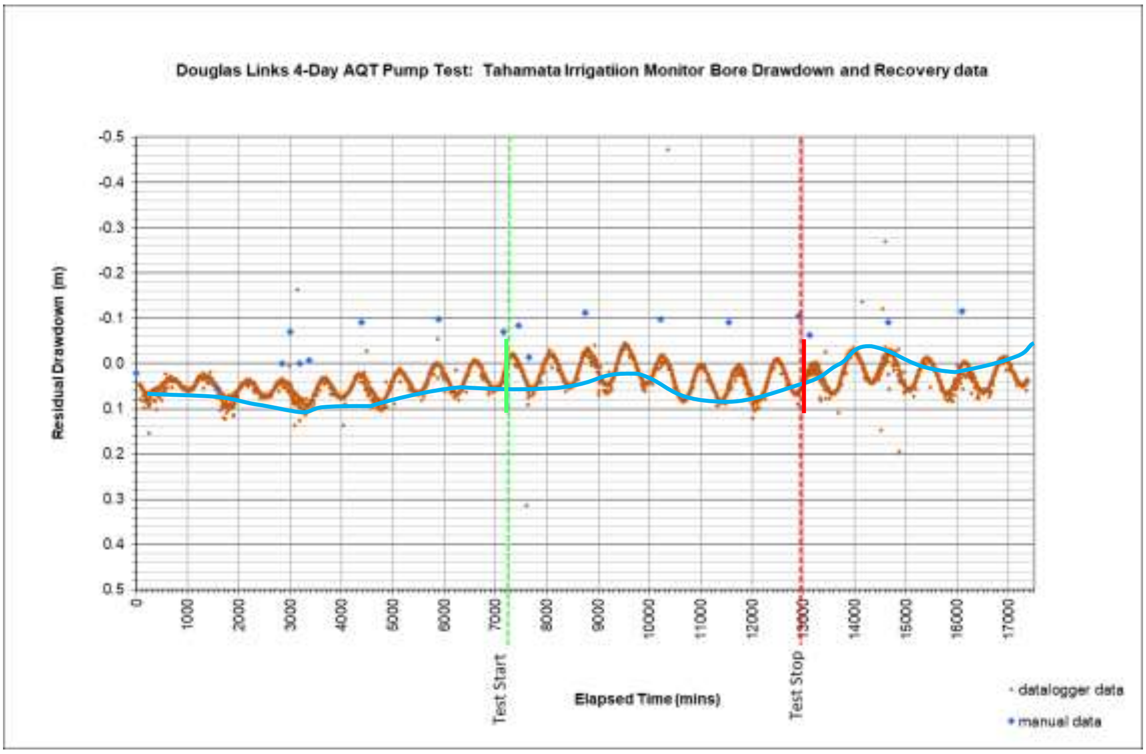
APPENDIX H

Monitor Bores

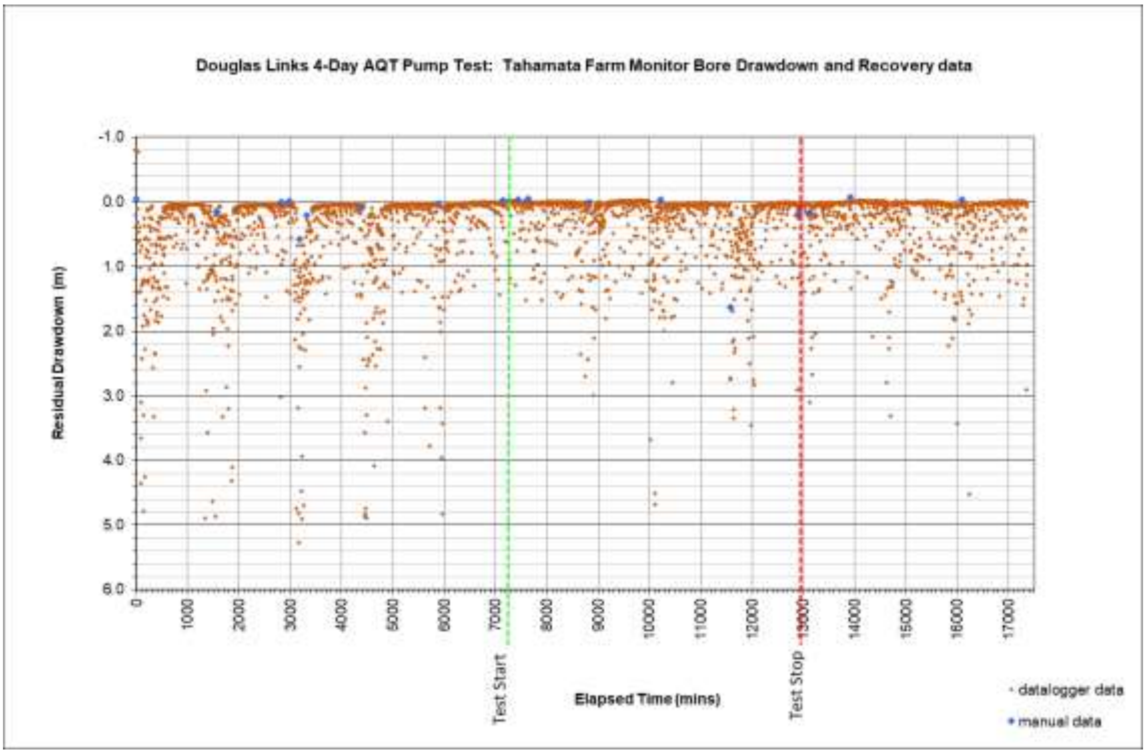
Drawdown Graphs

(MS Excel and Aqtesolv (Duffield, 2007))

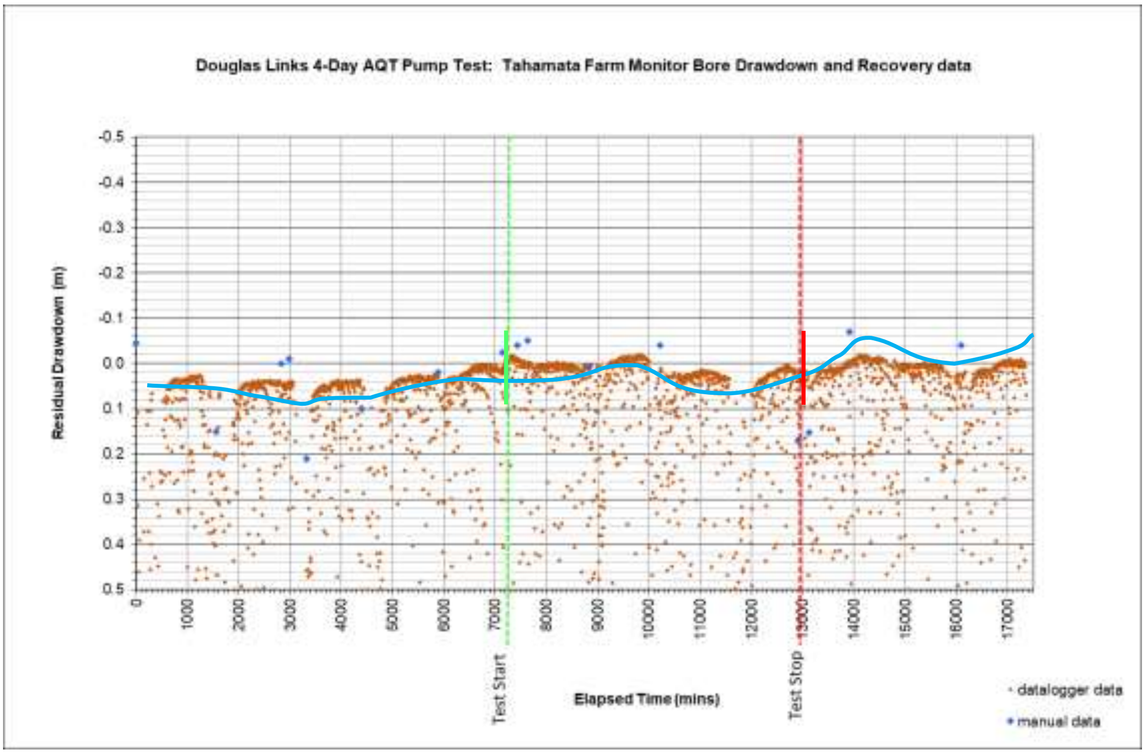
H1. Tahamata Irrigation Monitor Bore No. 361063 pump test data graph with inverse of barometric pressure fluctuations (blue line).



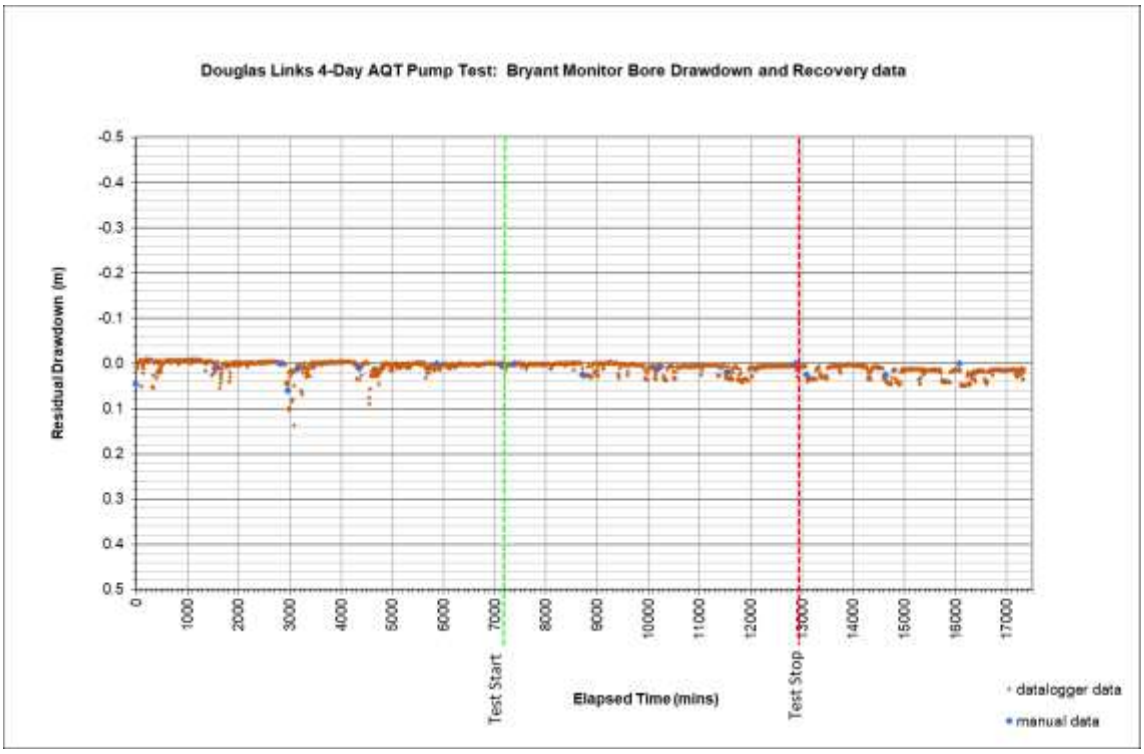
H2. Tahamata Farm Monitor Bore No. 361051 pump test data graph (expanded Y-axis).



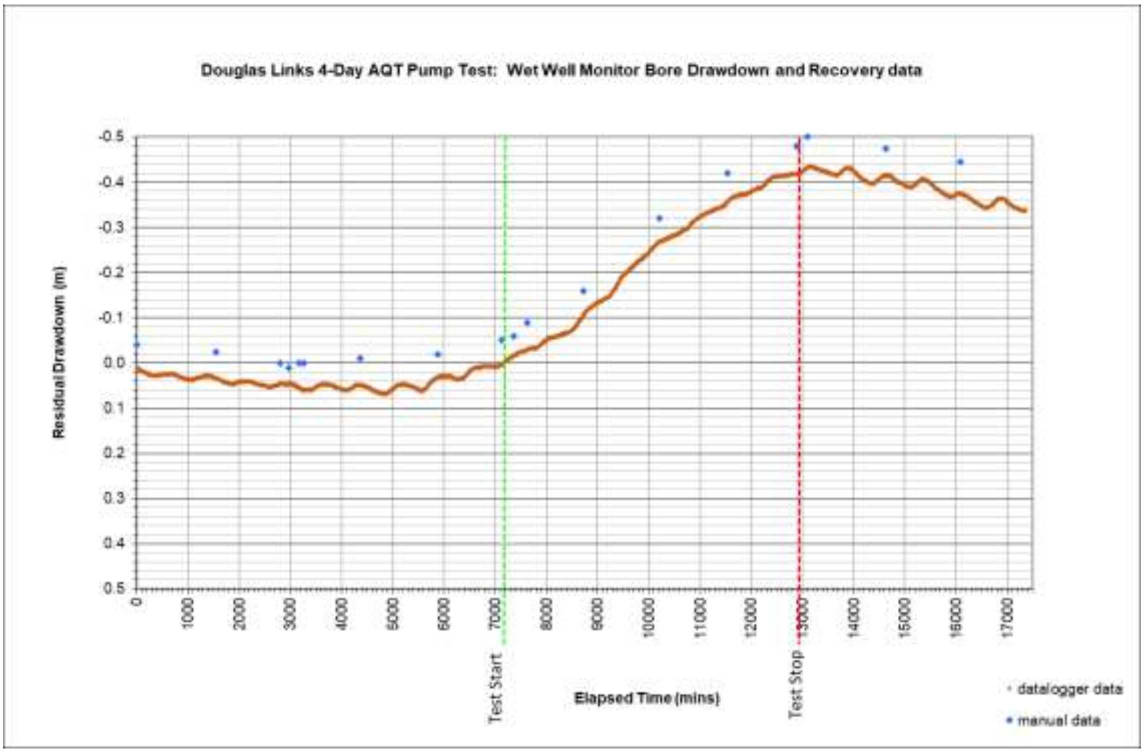
H2b. Tahamata Farm Monitor Bore No. 361051 pump test data graph (reduced Y-axis) with inverse of barometric pressure fluctuations (blue line)



H3. Bryant Monitor Bore pump test data graph.



H4. Douglas Links Monitoring Wet Well Bore pump test data graph.



APPENDIX I

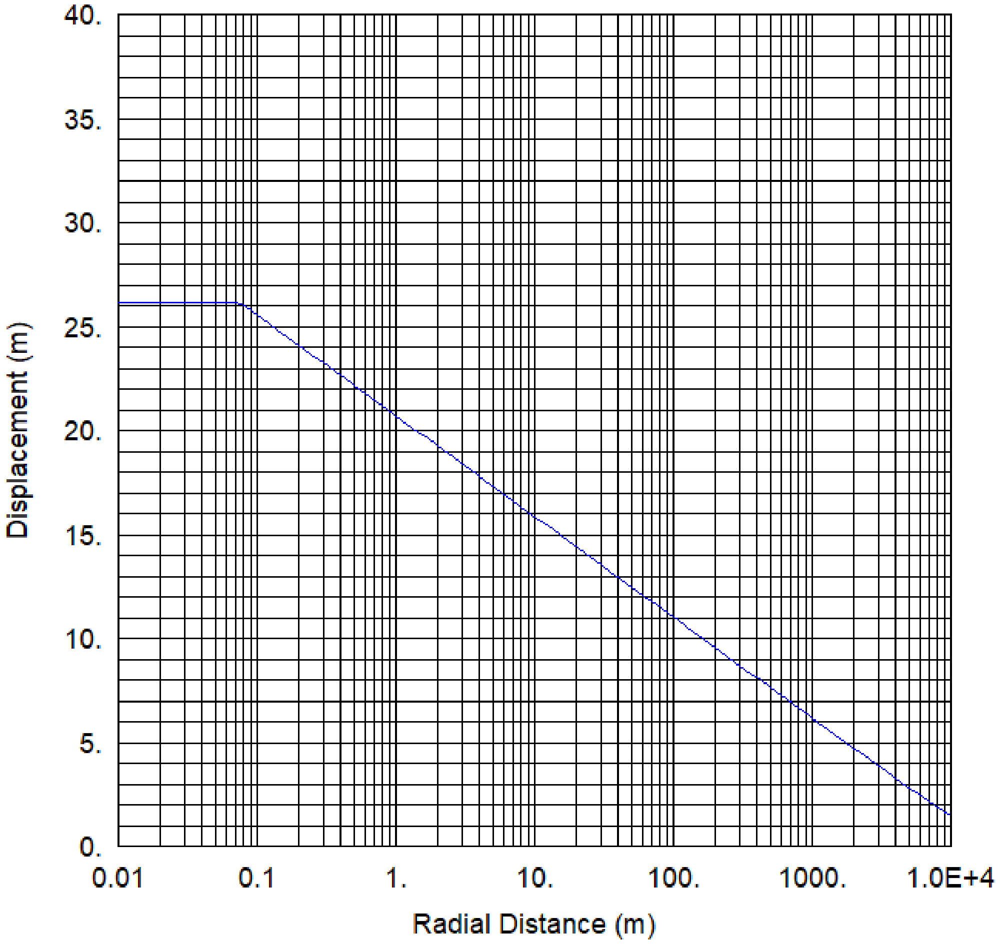
Aqtesolv Forward Solution

(Duffield, 2007)

Long Term Predicted Drawdown

(Scott, 2001)

I1. Pumped Well Aqtesolv Forward Solution using Theis (1935) 150-day, Displacement – Time Graph at 16.07 l/s (T = 105 m²/day)



DOUGLAS LINKS 4-DAY AQT PUMP TEST,, EXPL WELL, FORWARD SOLUTION (16.07 L/S)

Data Set: C:\...\D Links 4-day AQT Expl Well DD & Rec Edata TheisFwd Sol.aqt
Date: 07/01/21 Time: 16:35:30

PROJECT INFORMATION

Company: Bay Geological Services Ltd
Client: Grenadier Developments Ltd
Project: BGS258-01
Location: 765 Muhunoa West Road, Ohau
Test Well: 150mm diam Expl Well
Test Date: 10 May, 2021

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Douglas Links Test Well	2693377	6059684

Observation Wells

Well Name	X (m)	Y (m)
▫ Douglas Links Test Well	2693377	6059684

SOLUTION

Aquifer Model: Confined

Solution Method: Theis

T = 105. m^2/day
Kz/Kr = 1.

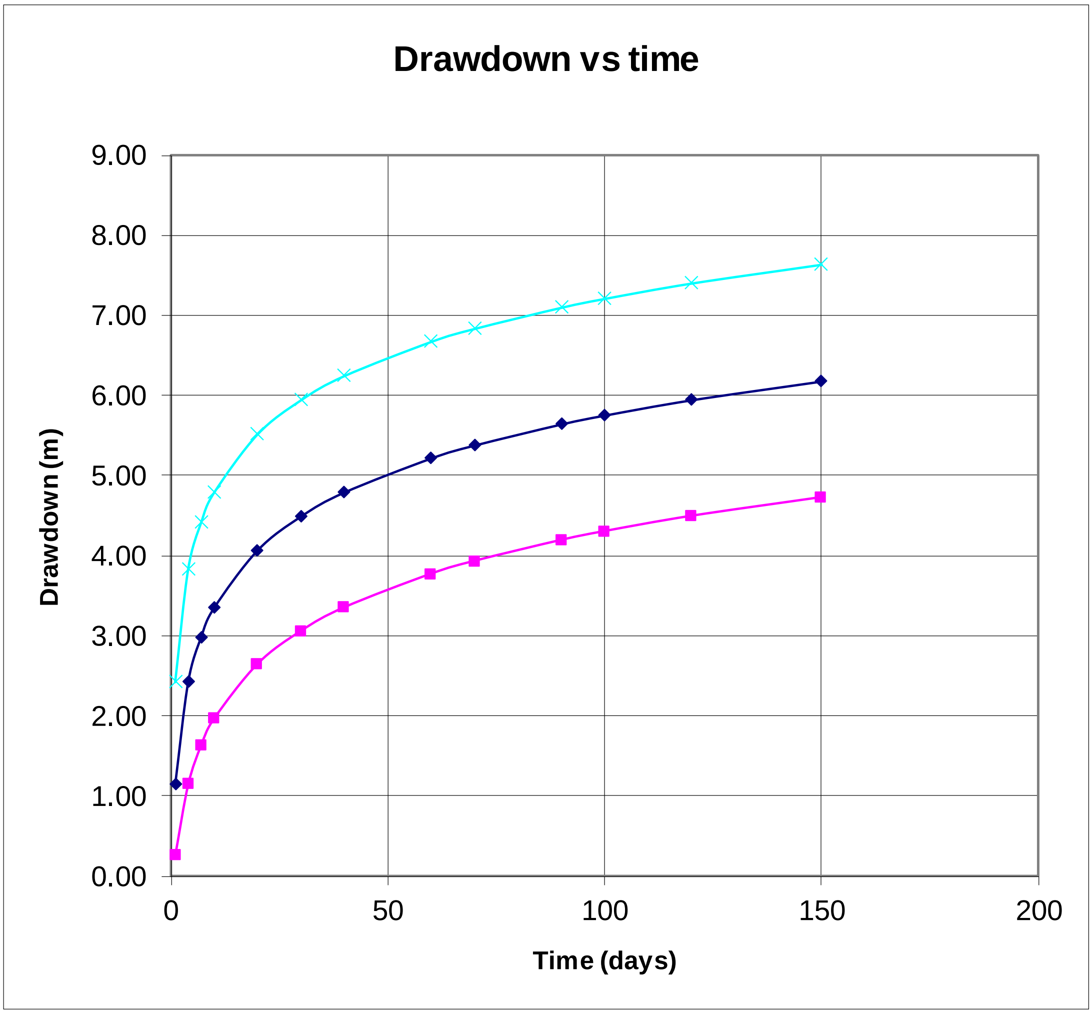
S = 0.0001
b = 10.4 m

I2. Scott (2001) Drawdown v Time Calculations using Theis (1935)

Time-drawdown calculations using Theis equation

Aquifer parameters		
T	105	m2/d
S	0.0001	
B		
Pumping rate		
Q	16.07	l/s

Radius (m)	500	1000	2000
Time (days)	Drawdown (m)	Drawdown (m)	Drawdown (m)
1	2.423	1.139	0.250
4	3.836	2.423	1.139
7	4.418	2.986	1.630
10	4.791	3.351	1.965
20	5.517	4.068	2.646
30	5.943	4.490	3.056
40	6.245	4.791	3.351
60	6.671	5.215	3.769
70	6.833	5.377	3.929
90	7.097	5.641	4.190
100	7.208	5.751	4.300
120	7.400	5.943	4.490
150	7.634	6.177	4.723



I3. Scott (2001) Drawdown v Distance calculations using Theis (1935).

Distance-drawdown calculations using Theis equation

Aquifer parameters		
T	105	m2/d
S	0.0001	
B		
Pumping rate		
Q	16.07	l/s

Time (days)	1	30	150
Radius (m)	Drawdown (m)	Drawdown (m)	Drawdown (m)
1	15.440	19.019	20.713
10	10.595	14.174	15.867
20	9.136	12.715	14.408
50	7.208	10.786	12.480
100	5.751	9.328	11.021
250	3.836	7.400	9.093
500	2.423	5.943	7.634
750	1.645	5.092	6.782
1000	1.139	4.490	6.177
1500	0.546	3.647	5.326
2000	0.250	3.056	4.723
3000	0.042	2.243	3.878
4000	0.005	1.694	3.284