*Job No.10494*

MEMORANDUM

To: Nick Geddes - Clark Fortune McDonald & Associates (CFM)

From: Lowe Environmental Impact Ltd

Date: 22nd August 2017

Subject: Homestead Bay – Answers to Commissioner Nugent's Questions

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## 1. Scope

In May 2017, Lowe Environmental Impact Ltd (LEI) prepared an options report for Murphy's Developments Limited (MDL) for the treatment and dispersal of wastewater for the Homestead Bay community. This "Options Report" provided MDL with information on onsite wastewater treatment and effluent land application and assessed the viable methods of wastewater treatment and dispersal. The Homestead Bay development population and design flow rate was based on 130 dwelling equivalents, with Sites A, B and C providing 3.4 ha of usable land for wastewater land treatment.

MDL are seeking a re-zoning which requires a larger land treatment field for wastewater. Clark Fortune McDonald & Associates (CFM) was engaged to assess servicing options for a proposed rezoning of land located at Homestead Bay between Jacks Point and Lake Wakatipu. The change in zone proposes residential activities over the site in separate activity areas. The basis of the preliminary design considers a possible 715 dwelling equivalents (DE) development.

CFM provided evidence that the re-zoning can occur with an adequate system designed on the site. This was based partially on LEI's original options' report. CFM's evidence has been accepted by the QLDC Chief Engineer and the hearings panel, with the exception of questions which were raised by the Chair, Mr Dennis Nugent.

These questions were:
1. If disposal to land could be achieved in accordance with the ORC discharge rule for nutrients, including whether the original report LEI had completed for the 130 lots was based upon the new standards which were to come into effect in relation to the maximum levels of soil nitrogen; and
2. If the disposal to land would be in accordance with the Water Conservation (Kawarau) Order 1997 for the Wakatipu.

The purpose of this memo is to provide the information necessary to address Commissioner Nugent's questions.

## 2. Re-zoning Effect on Nitrogen Loading

The original 130 lots had an approximate nitrogen loading of 390 kg N/ha/yr which was calculated by the hydraulic conductivity (Number of days per year * a daily loading of 65 $m^3$/day based on 2.5 people per dwelling) * a nitrogen concentration of 50 mg/L (Table 2). For 715 lots, the total dispersal area required to have the same inputs as the 130 lots would be 16.55 ha.

Table 2. Land Treatment Design Parameters for Homestead Bay.

| | | |
|---|---|---|
| Residential Lots | 130 | 715 |
| People per lot | 2.5 | 3 |
| Flow (L/person/day) | 200 | 250 |
| Design Flow Rate ($m^3$/day) | 65 | 536 |
| Discharge Area (ha) | 3.4 | |
| Nitrogen Concentration (mg/L) | 50 | 50 |
| Hydraulic Loading ($m^3$/year) | 23,725 | 195,640 |
| Nitrogen Load kg N/yr | 1,186 | 9,782 |
| Required Dispersal Area (ha) | 3.01 | 16.55 |
| Nitrogen Loading (kg/ha/yr) | 390 | 390 |

## 3. Nitrogen Leaching under a Cut and Carry System for the Original 130 lots for Homestead Bay – Overseer Model

An OVERSEER® nutrient budget cut and carry model was produced to indicate the potential leaching from the application of treated wastewater from the original 130 lots from Homestead Bay. The model was separated into two blocks based on soil type. The two soils on the site include Wakatipu Sandy Loam (Site A and C) and Eely Sandy Loam (Site B). The total discharge area is 3.4 ha, with 3.01 ha effective and receiving the wastewater.

Nitrogen loading was calculated as described in Section 2 of this memo. This was applied as a soluble fertiliser and is shown below in Table 3 for each month. The total nitrogen loading from the wastewater for the year has been modelled at 400 kg N/ha/yr.

Table 3: Soluble Nitrogen Fertiliser Application on a per month basis as Modelled in Overseer

| Month | Material | NPKS (kg nutrient/ha) |
|---|---|---|
| January | Soluble fertiliser | 34 - 0 - 0 - 0 |
| February | Soluble fertiliser | 30 - 0 - 0 - 0 |
| March | Soluble fertiliser | 34 - 0 - 0 - 0 |
| April | Soluble fertiliser | 33 - 0 - 0 - 0 |
| May | Soluble fertiliser | 34 - 0 - 0 - 0 |
| June | Soluble fertiliser | 33 - 0 - 0 - 0 |
| July | Soluble fertiliser | 34 - 0 - 0 - 0 |
| August | Soluble fertiliser | 34 - 0 - 0 - 0 |
| September | Soluble fertiliser | 33 - 0 - 0 - 0 |
| October | Soluble fertiliser | 34 - 0 - 0 - 0 |
| November | Soluble fertiliser | 33 - 0 - 0 - 0 |
| December | Soluble fertiliser | 34 - 0 - 0 - 0 |

OVERSEER® modelling applied the wastewater as irrigation in the form of drip irrigation. The total application depth was 790 mm for the year.

A cut and carry system involves removing cut pasture and removing it off the land. This can be modelled as silage, baleage or similar. For the overseer model, a total of 51 t DM of silage was cut and exported off the land to model the effects of a typical cut and carry system which would generally have N loading in the order of 450 – 600 kg N/ha/yr. The nitrogen loading from the silage totalled 468 kg N/ha/yr for each block.

A farm nutrient budget and block nitrogen report was produced (Tables' 4 and 5) and indicates the inputs and outputs on the site, which includes a total leaching value of 81 kg N/ha/yr across the sites.

Table 4: Overseer Nutrient Budget for the Application of Wastewater from 130 lots from Homestead Bay onto Sites A, B and C under a Cut and Carry System.

Farm Nutrient Budget - Whole farm

| | N | P | K | S | Ca | Mg | Na |
|---|---|---|---|---|---|---|---|
| | | | | (kg/ha/yr) | | | |
| **Nutrients added** | | | | | | | |
| Fertiliser, lime & other | 353 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rain/clover N fixation | 42 | 0 | 1 | 1 | 1 | 1 | 2 |
| Irrigation | 18 | 1 | 12 | 18 | 68 | 16 | 69 |
| Supplements imported | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Nutrients removed** | | | | | | | |
| As products | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Exported effluent | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| As supplements | 413 | 42 | 303 | 28 | 83 | 22 | 19 |
| To atmospheric | 19 | 0 | 0 | 0 | 0 | 0 | 0 |
| To water | 81 | 0.3 | 7 | 12 | 104 | 19 | 61 |
| **Change in internal pools** | | | | | | | |
| Plant material | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Organic pool | -99 | 18 | 0 | -20 | 0 | 0 | 0 |
| Inorganic mineral | 0 | 2 | -34 | 0 | -5 | -8 | -9 |
| Inorganic soil pool | 0 | -61 | -263 | 0 | -114 | -16 | 1 |

Table 5: Overseer Nitrogen Report for the Application of Wastewater from 130 lots from Homestead Bay onto Sites A, B and C under a Cut and Carry System.

Block Nitrogen

| Block name | Total N lost (kg N/yr) | N lost to water (kg N/ha/yr) | N in drainage * (ppm) | N surplus (kg N/ha/yr) | Added N ** (kg N/ha/yr) |
|---|---|---|---|---|---|
| Cut and Carry Wakatipu | 172 | 86 | 6.8 | 1 | 400 |
| Cut and Carry Eely | 104 | 104 | 8.3 | 1 | 400 |
| Other farm sources | 0 | | | | |
| Whole farm | 276 | 81 | | | |
| Less N removed in wetlands | 0 | | | | |
| Farm output | 276 | 81 | | | |

Commissioner Nugent has questioned whether LEI's original Options' Report was based upon Otago Water Plan Change 6A, which is in relation to Rule 12.C.1.3 outlined in Table 1, due to concern that any increased loading in nitrogen would eventually enter Lake Wakatipu. Homestead Bay is located within a Nitrogen Sensitive Zone identified in Figure 1, which sets a permitted activity level for nitrogen leaching rate to be 15 kg N/ha/yr or less from 01 April 2020, if this land was used for rural activities.

The total subdivision area for the 715 lots is approximately 200 ha (Hansen C Evidence 2017). This would have a permitted baseline N leaching of 3,000 kg N/yr. The permitted baseline of 3,000 kg is greater that the scaled nitrogen leaching estimate for the proposed 715 lots of 1,340[1] kg N/yr. This is 44% of the Plan permitted leaching.

Table 1: Description of Rule 12.C.1.3

| Rule | Description |
|---|---|
| 12.C.1.3 | The discharge of nitrogen onto or into land in circumstances which may result in nitrogen entering groundwater, is a permitted activity, providing:<br>(a) From 01 April 2020, the nitrogen leaching rate does not exceed:<br>(i) 15 kgN/ha/year for the total area of land managed by a landholder that is located over the relevant Nitrogen Sensitive Zone identified in Maps H5 and H6; and<br>(ii) 20 kgN/ha/year for the total area of land managed by a landholder that is located over the relevant Nitrogen Sensitive Zone identified in Maps H1 to H4; and<br>(iii) 30 kgN/ha/year for the total area of land managed by a landholder that is located outside any Nitrogen Sensitive Zone identified in Maps H1 to H6, as calculated using OVERSEER® version 6 by a Certified Nutrient Management Advisor in accordance with OVERSEER® Best Practice Data Input Standards; and<br>(b) (i) From 1 May 2014 to 31 March 2020, the landholder for outdoor pork, fruit (excluding grapes), berry and rotational vegetable production will keep a record of all inputs into the farm system and evidence that practices complied with the relevant industry good management practices and provide Council upon request with that information. From 1 April 2020, 12.C.1.3(b)(ii) will apply; and<br>(ii) From 1 May 2014, in all other cases, the landholder will:<br>(1) Maintain a record of all necessary data to run OVERSEER® version 6; and<br>(2) Provide Council upon request with:<br>(a) All necessary data to run OVERSEER® version 6; or<br>(b) Any available OVERSEER® version 6 output and input parameter report prepared by a Certified Nutrient Management Advisor in accordance with OVERSEER® Best Practice Data Input Standards. |

[1] 715 lots is 5.5 times greater than 130 Lots assessed by LEI, retaining the same design parameters and loading for N, 715 ha would require 16.55 ha of disposal area. The Overseer estimate for N leached from the disposal field is 81 kg N/ha which for 16.55 ha equated to a total N leaching of 1,340 kg N/yr

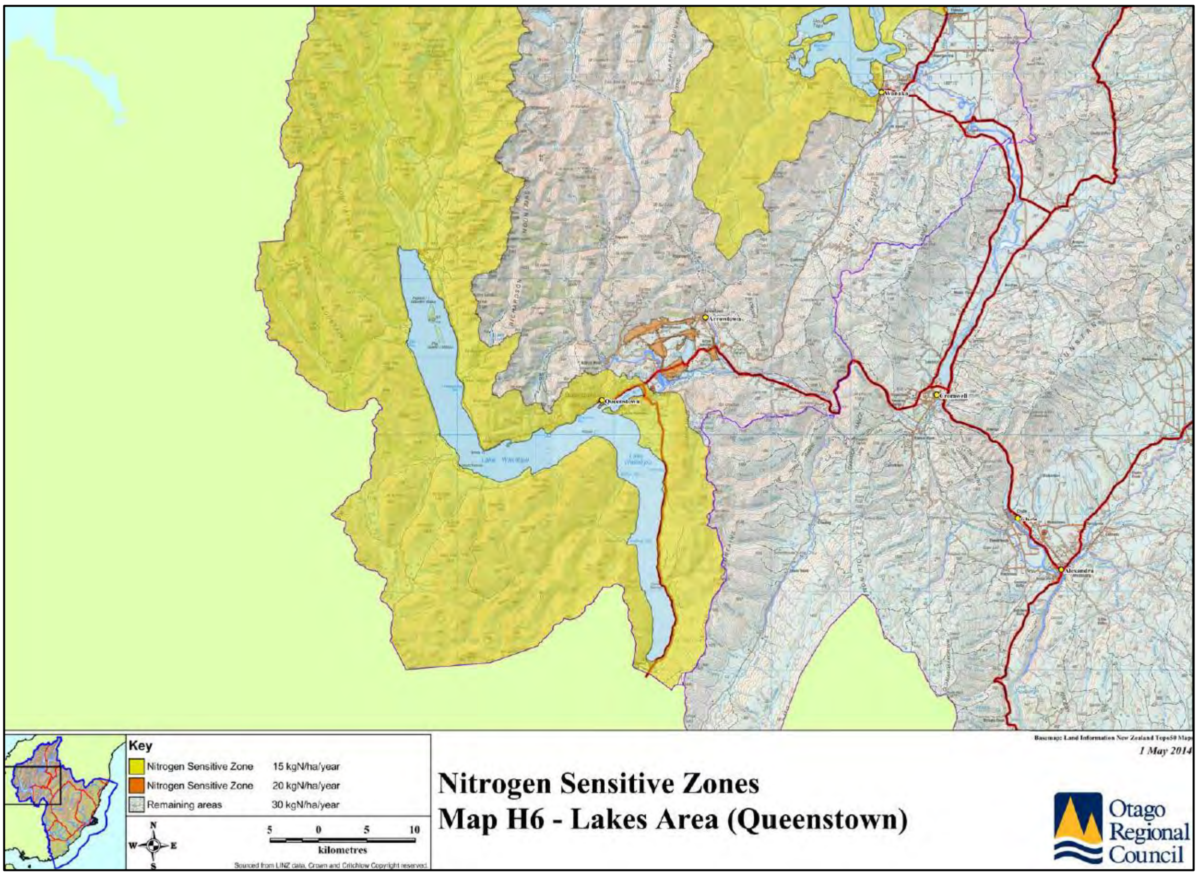


Figure 1: Map H6 from Otago Regional Plan Water Maps. Nitrogen Sensitive Zones for the Lakes Area (Queenstown).

As seen above, scaling up from the original 130 lots to 715 lots would still meet the targets for rural land set in Rule 12.C.1.3 of the Otago Regional Plan for Water which states:
*The discharge of nitrogen onto or into land in circumstances which may result in nitrogen entering groundwater, is a permitted activity, providing:*

*(a) From 01 April 2020, the nitrogen leaching rate does not exceed:*

*(i) 15 kgN/ha/year for the total area of land managed by a landholder that is located over the relevant Nitrogen Sensitive Zone identified in Maps H5 and H6.*

Plan Change 6A 2020 targets were not considered in the original report produced for Murphy's Developments Limited (MDL) as the Proposed Plan Change 6A (Water Quality) seeks to maintain or improve water quality, through control of contaminants discharging from rural land to water, and was therefore not appropriate for the use for land treatment of wastewater.

An alternative analysis to OVERSEER to estimate the leaching from the dispersal field is to consider research undertaken by Beggs, et. al. 2011. Beggs found wastewater applied to land undergoes further biological processes, with research trials indicating that the concentration of nitrogen applied to the soil from wastewater treatment systems via subsurface drip irrigation is not 100% lost via leaching.

In the soil, there are many other processes that utilise the nitrogen that is applied. When compared to other systems of onsite wastewater treatment, secondary treated systems are able to be used with sub-subsurface drip irrigation. Subsurface drip irrigation is more effective at removing nitrogen as they are located between 100 – 150 mm below ground and apply around 3 – 5 mm of treated wastewater per day to the active subsoil layer. The nitrogen in the sub-surface layer can be further broken down by biological processes and also be uptake by plant roots for growth and exported by cut and carry harvesting systems.

Based on the findings of Beggs, et. al. 2011 (see Figure 1), the fate of wastewater nitrogen applied to land via subsurface drip irrigation in a Sandy Loam/ Loam soil is:

- 28 – 35% via root uptake from plants;
- 32 – 62% lost via Denitrification; and
- 7 – 30% lost via leaching

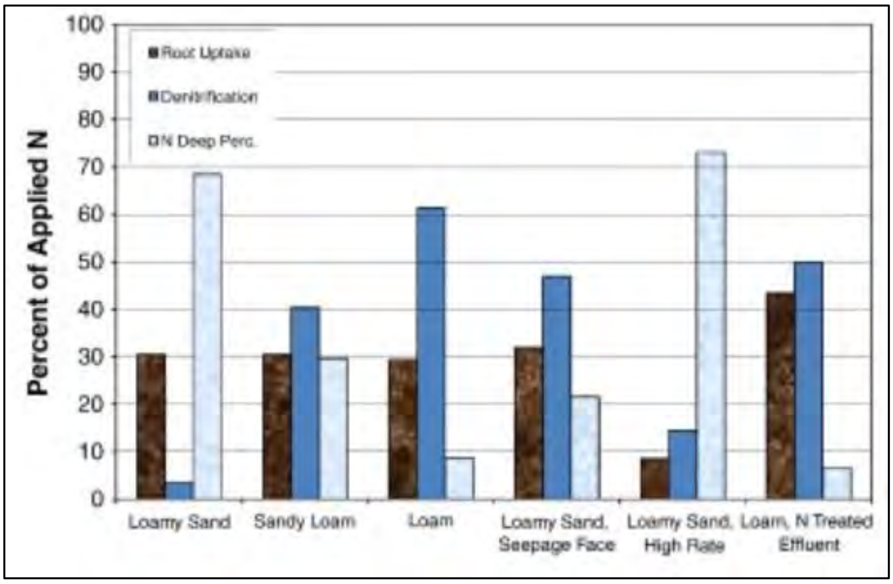


Figure 1. Fate of Nitrogen in Wastewater Effluent Applied to Land (Beggs, et. al., 2011)

From Table 2 on the 130 Lot analysis, 390 kg N/Ha/yr would be applied, using Beggs' 7 to 30% estimation being leached below the root zone, equates to 27.3 to 117 kg N/ha/yr. In comparison to a farming cut and carry Overseer modelled leaching estimation 81 kg N/ha.

Using the upper estimated loss of 117 kg N/ha/yr, the total loss is estimated to be 1,936 kg N which still remains below the site permitted leaching of 3,000 kg N/yr.

## 4. Kawarau Water Conservation Order

Further to the Otago Regional Plan: Water rules, a Water Conservation (Kawarau) Order 1997 is in place for the Wakatipu. Homestead Bay is located on the shores of Lake Wakatipu which comes under Schedule 2 of the Kawarau Water Conservation Order. This schedule has restrictions on the activities that take place under the water conservation order. These have been outlined in Table 7 below.

Table 7: Kawarau Water Conservation Order Outstanding Characteristics and Restrictions and Prohibitions for Lake Wakatipu Control Gates

| Waters | Outstanding characteristics | Restrictions and prohibitions |
|---|---|---|
| Lake Wakatipu (from outlet at control gates (S132:615707) to confluences of Dart River (at or about S122:291916) and Rees River (at or about S123:301915) and including whole lake) | (b) fishery;<br>(c) scenic characteristics;<br>(d) scientific value, in particular water clarity, and bryophyte community;<br>(e) recreational purposes, in particular boating;<br>(g) significance in accordance with tikanga Maori, in particular sites at the head of the lake, and the legend of the lake itself. | (i) fish passage to be maintained;<br>(ii) water quality to be managed to Class AE, Class CR, Class F, and Class FS standards.) |

Schedule 3 of the RMA outlines water quality classes. The water quality of this section of Lake Wakatipu must be managed to Class AE, CR, F and FS standard as outlined in Table 7. These have been assessed in Table 8 below.

Table 8: Assessment of Schedule 3 of the RMA Water Quality Classes that are Relevant to Homestead Bay

| Class | Standards | Complies? Y/N |
|---|---|---|
| Class AE Water (managed for aquatic ecosystem purposes) | (1) The natural temperature of the water shall not be changed by more than 3° Celsius.<br>(2) The following shall not be allowed if they have an adverse effect on aquatic life:<br>(a) any pH change:<br>(b) any increase in the deposition of matter on the bed of the water body or coastal water:<br>(c) any discharge of a contaminant into the water.<br><br>(3) The concentration of dissolved oxygen shall exceed 80% of saturation concentration.<br><br>(4) There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water. | Yes |
| Class CR Water (managed for contact recreation purposes) | (1) The visual clarity of the water shall not be so low as to be unsuitable for bathing. | Yes |

| | | |
|---|---|---|
| | (2) The water shall not be rendered unsuitable for bathing by the presence of contaminants.<br><br>(3) There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water | |
| Class F Water (managed for fishery purposes) | (1) The natural temperature of the water—<br>(a) shall not be changed by more than 3° Celsius; and<br>(b) shall not exceed 25° Celsius.<br><br>(2) The concentration of dissolved oxygen shall exceed 80% of saturation concentration.<br><br>(3) Fish shall not be rendered unsuitable for human consumption by the presence of contaminants. | Yes |
| Class FS Water (managed for fish spawning purposes) | (1) The natural temperature of the water shall not be changed by more than 3° Celsius. The temperature of the water shall not adversely affect the spawning of the specified fish species during the spawning season.<br><br>(2) The concentration of dissolved oxygen shall exceed 80% of saturation concentration.<br><br>(3) There shall be no undesirable biological growths as a result of any discharge of a contaminant into the water. | Yes |

Based on the proposed land treatment of wastewater system, it is assessed that the Homestead Bay re-zoning is consistent with Kawarau Water Conservation Order water quality standards of Class AE, CR, F and FS standards, and does not affect fish passage.

## 5. Summary

The purpose of this memo is to address Commissioner Nugent's questions with regards to Otago Regional Council's discharge rules for nutrients and the Water Conservation (Kawarau) Order 1997 in place for the Wakatipu.

Homestead Bay land is proposed to be used for residential land and for the discharge of treated domestic wastewater to land. The Otago Water Plan Change 6A (Water Quality) seeks to maintain or improve water quality, through control of contaminants discharging from rural land to water, Rule 12.C.1.3 of the Otago Regional Plan, while relating to rural land and not the discharge of human sewage it provides for a permitted activity Nitrogen leaching of 15 kg N/ha/yr. When applied across the proposed site this equals 3,000 kg N/yr. N leaching below the land treatment area is estimated to equal 1,340 (and possibly as high as 1,936 kg N/yr) which is below the Plan Change 6A rural land use permitted baseline.

Furthermore, it is assessed that Homestead Bay re-zoning is consistent with Kawarau Water Conservation Order as it will not cause the water quality in Lake Wakatipu to breach Class AE, CR, F and FS water standards in Schedule 3 of the RMA, and does not affect fish passage.

Yours

Rob Potts

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# ANALYSIS REPORT



| | | | |
|---|---|---|---|
| **Client:** | Stantec New Zealand Limited | **Lab No:** | 1812415 SPv1 |
| **Contact:** | James Dommisse | **Date Received:** | 21-Jul-2017 |
| | C/- Stantec New Zealand Limited | **Date Reported:** | 10-Aug-2017 |
| | PO Box 13249 | **Quote No:** | 86728 |
| | Christchurch 8141 | **Order No:** | |
| | | **Client Reference:** | Groundwater |
| | | **Submitted By:** | James Dommisse |

**Sample Type: Aqueous**

| **Sample Name:** | | Production Bore 20-Jul-2017 11:30 am | Lake Wakatipu 20-Jul-2017 11:30 am | | | |
|---|---|---|---|---|---|---|
| **Lab Number:** | | 1812415.1 | 1812415.2 | | | |
| **Individual Tests** | | | | | | |
| Sum of Anions | meq/L | 1.89 | - | - | - | - |
| Sum of Cations | meq/L | 2.0 | - | - | - | - |
| Turbidity | NTU | 0.06 | - | - | - | - |
| pH | pH Units | 7.9 | 7.9 | - | - | - |
| Acidity (pH 3.7) | $g/m^3$ as $CaCO_3$ | < 1.0 | - | - | - | - |
| Total Alkalinity | $g/m^3$ as $CaCO_3$ | 84 | 74 | - | - | - |
| Bicarbonate | $g/m^3$ at 25°C | 101 | 90 | - | - | - |
| Langelier Saturation Index | | 0.0 | - | - | - | - |
| Electrical Conductivity (EC) | mS/m | 18.5 | - | - | - | - |
| Sample Temperature* | °C | 20.0 | - | - | - | - |
| Dissolved Calcium | $g/m^3$ | - | 29 | - | - | - |
| Dissolved Magnesium | $g/m^3$ | - | 2.5 | - | - | - |
| Dissolved Potassium | $g/m^3$ | - | 0.76 | - | - | - |
| Dissolved Sodium | $g/m^3$ | - | 3.0 | - | - | - |
| Bromide | $g/m^3$ | < 0.05 | - | - | - | - |
| Total Cyanide | $g/m^3$ | < 0.0010 | - | - | - | - |
| Cyanogen Chloride* | mg/L | < 0.005 | - | - | - | - |
| Monochloramine | $g/m^3$ | < 0.05 | - | - | - | - |
| Chloride | $g/m^3$ | 2.0 | 1.8 | - | - | - |
| Chlorite | $g/m^3$ | < 0.005 | - | - | - | - |
| Chlorate | $g/m^3$ | < 0.005 | - | - | - | - |
| Fluoride | $g/m^3$ | 0.10 | - | - | - | - |
| Total Ammoniacal-N | $g/m^3$ | < 0.010 | - | - | - | - |
| Nitrite-N | $g/m^3$ | < 0.002 | < 0.002 | - | - | - |
| Nitrate-N | $g/m^3$ | 1.37 | 1.15 | - | - | - |
| Nitrate-N + Nitrite-N | $g/m^3$ | 1.37 | 1.15 | - | - | - |
| Dissolved Reactive Phosphorus | $g/m^3$ | < 0.004 | - | - | - | - |
| Total Phosphorus | $g/m^3$ | < 0.004 | - | - | - | - |
| Reactive Silica | $g/m^3$ as $SiO_2$ | 10.8 | - | - | - | - |
| Sulphate | $g/m^3$ | 3.0 | 3.2 | - | - | - |
| Total Organic Carbon (TOC) | $g/m^3$ | < 0.5 | - | - | - | - |
| Radon-222* | Bq/L | 1.870 | - | - | - | - |
| **Hazen Colour Profile** | | | | | | |
| Apparent Hazen Colour | Hazen units | < 10 | - | - | - | - |
| pH for Colour Analysis | pH Units | 8.1 | - | - | - | - |

| Sample Type: Aqueous | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Sample Name: | Production Bore 20-Jul-2017 11:30 am | Lake Wakatipu 20-Jul-2017 11:30 am | | | | |
| | Lab Number: | 1812415.1 | 1812415.2 | | | | |
| Drinking water metals suite, dissolved, trace | | | | | | | |
| Total Hardness | g/m³ as $CaCO_3$ | 93 | - | - | - | - | |
| Dissolved Aluminium | g/m³ | 0.003 | - | - | - | - | |
| Dissolved Antimony | g/m³ | < 0.0002 | - | - | - | - | |
| Dissolved Arsenic | g/m³ | 0.0019 | - | - | - | - | |
| Dissolved Barium | g/m³ | 0.00071 | - | - | - | - | |
| Dissolved Beryllium | g/m³ | < 0.00010 | - | - | - | - | |
| Dissolved Boron | g/m³ | 0.006 | - | - | - | - | |
| Dissolved Cadmium | g/m³ | < 0.00005 | - | - | - | - | |
| Dissolved Calcium | g/m³ | 32 | - | - | - | - | |
| Dissolved Chromium | g/m³ | 0.0012 | - | - | - | - | |
| Dissolved Copper | g/m³ | < 0.0005 | - | - | - | - | |
| Dissolved Iron | g/m³ | < 0.02 | - | - | - | - | |
| Dissolved Lead | g/m³ | < 0.00010 | - | - | - | - | |
| Dissolved Lithium | g/m³ | 0.0015 | - | - | - | - | |
| Dissolved Magnesium | g/m³ | 2.8 | - | - | - | - | |
| Dissolved Manganese | g/m³ | < 0.0005 | - | - | - | - | |
| Dissolved Mercury | g/m³ | < 0.00008 | - | - | - | - | |
| Dissolved Molybdenum | g/m³ | < 0.0002 | - | - | - | - | |
| Dissolved Nickel | g/m³ | < 0.0005 | - | - | - | - | |
| Dissolved Potassium | g/m³ | 0.81 | - | - | - | - | |
| Dissolved Selenium | g/m³ | < 0.0010 | - | - | - | - | |
| Dissolved Silver | g/m³ | < 0.00010 | - | - | - | - | |
| Dissolved Sodium | g/m³ | 3.3 | - | - | - | - | |
| Dissolved Tin | g/m³ | < 0.0005 | - | - | - | - | |
| Dissolved Uranium | g/m³ | 0.00022 | - | - | - | - | |
| Dissolved Zinc | g/m³ | 0.0025 | - | - | - | - | |
| Drinking water metals suite, totals, trace | | | | | | | |
| Total Aluminium | g/m³ | < 0.0032 | - | - | - | - | |
| Total Antimony | g/m³ | < 0.00021 | - | - | - | - | |
| Total Arsenic | g/m³ | 0.0022 | - | - | - | - | |
| Total Barium | g/m³ | < 0.0053 | - | - | - | - | |
| Total Beryllium | g/m³ | < 0.00011 | - | - | - | - | |
| Total Boron | g/m³ | 0.0058 | - | - | - | - | |
| Total Cadmium | g/m³ | < 0.000053 | - | - | - | - | |
| Total Calcium | g/m³ | 31 | - | - | - | - | |
| Total Chromium | g/m³ | 0.00122 | - | - | - | - | |
| Total Copper | g/m³ | < 0.00053 | - | - | - | - | |
| Total Iron | g/m³ | < 0.021 | - | - | - | - | |
| Total Lead | g/m³ | < 0.00011 | - | - | - | - | |
| Total Lithium | g/m³ | 0.00143 | - | - | - | - | |
| Total Magnesium | g/m³ | 2.8 | - | - | - | - | |
| Total Manganese | g/m³ | < 0.00053 | - | - | - | - | |
| Total Mercury | g/m³ | < 0.00008 | - | - | - | - | |
| Total Molybdenum | g/m³ | < 0.00021 | - | - | - | - | |
| Total Nickel | g/m³ | < 0.00053 | - | - | - | - | |
| Total Potassium | g/m³ | 0.80 | - | - | - | - | |
| Total Selenium | g/m³ | < 0.0011 | - | - | - | - | |
| Total Silver | g/m³ | < 0.00011 | - | - | - | - | |
| Total Sodium | g/m³ | 3.5 | - | - | - | - | |
| Total Tin | g/m³ | < 0.00053 | - | - | - | - | |
| Total Uranium | g/m³ | 0.00023 | - | - | - | - | |
| Total Zinc | g/m³ | 0.0026 | - | - | - | - | |

| Sample Type: Aqueous | | | | | | |
|---|---|---|---|---|---|---|
| Sample Name: | | Production Bore 20-Jul-2017 11:30 am | Lake Wakatipu 20-Jul-2017 11:30 am | | | |
| Lab Number: | | 1812415.1 | 1812415.2 | | | |
| Radionuclide Activity | | | | | | |
| Total alpha concentration | Bq/L | < 0.033 | - | - | - | - |
| Total beta concentration | Bq/L | < 0.15 | - | - | - | - |

## Analyst's Comments

Appendix No.1 - ESR Subcontract Report

Appendix No.2 - Cyanogen Chloride Report- 1812415

# 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 clean 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.

**Sample Type: Aqueous**

| Test | Method Description | Default Detection Limit | Sample No |
|---|---|---|---|
| Individual Tests | | | |
| Filtration, Unpreserved | Sample filtration through 0.45µm membrane filter. Performed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. | - | 1-2 |
| Total Digestion | Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified). | - | 1 |
| Total acid digest for Silver analysis | Boiling nitric / hydrochloric acid digestion (5:1 ratio). APHA 3030 F (modified) 22nd ed. 2012. | - | 1 |
| Total Phosphorus Digestion | Acid persulphate digestion. | - | 1 |
| Total Cyanide Distillation | Distillation following the addition of sulphuric acid, alkaline trapping solution. APHA 4500-$CN^-$ C (modified) 22nd ed. 2012. | - | 1 |
| Total anions for anion/cation balance check | Calculation: sum of anions as mEquiv/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22nd ed. 2012. | 0.07 meq/L | 1 |
| Total cations for anion/cation balance check | Sum of cations as mEquiv/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH ($H^+$) also included in calculation if available. APHA 1030 E 22nd ed. 2012. | 0.05 meq/L | 1 |
| Turbidity | Analysis using a Hach 2100 Turbidity meter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2130 B 22nd ed. 2012. | 0.05 NTU | 1 |
| pH | pH meter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 4500-$H^+$ B 22nd ed. 2012. 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. | 0.1 pH Units | 1-2 |
| Acidity (pH 3.7) | Titration to pH 3.7 with standard sodium hydroxide solution, bromophenol blue indicator. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2310 B 22nd ed. 2012. | 1.0 g/m³ as $CaCO_3$ | 1 |
| Total Alkalinity | Titration to pH 4.5 (M-alkalinity), autotitrator. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2320 B (Modified for alk <20) 22nd ed. 2012. | 1.0 g/m³ as $CaCO_3$ | 1-2 |
| Bicarbonate | 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 22nd ed. 2012. | 1.0 g/m³ at 25°C | 1-2 |
| Electrical Conductivity (EC) | Conductivity meter, 25°C. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2510 B 22nd ed. 2012. | 0.1 mS/m | 1 |
| Sample Temperature* | Supplied by customer, otherwise 20°C. | 0.1 °C | 1 |
| Filtration for dissolved metals analysis | Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22nd ed. 2012. | - | 1-2 |
| Bromide | Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B 22nd ed. 2012. | 0.05 g/m³ | 1 |
| Total Cyanide | Distillation, colorimetry. APHA 4500-$CN^-$ C (modified) & E (modified) 22nd ed. 2012. | 0.0010 g/m³ | 1 |
| Cyanogen Chloride* | Subcontracted to Watercare Services Ltd., Auckland. APHA (2005) 4500-$CN^-$J. | 0.005 mg/L | 1 |
| Monochloramine | Colorimetric. APHA 4500-Cl G 22nd ed. 2012. | 0.05 g/m³ | 1 |

| Sample Type: Aqueous | | | |
|---|---|---|---|
| **Test** | **Method Description** | **Default Detection Limit** | **Sample No** |
| Chloride | Filtered sample from Christchurch. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 $Cl^-$ E (modified from continuous flow analysis) 22nd ed. 2012. | 0.5 $g/m^3$ | 1-2 |
| Chlorite | Sample analysed as received, filtered if required. Ion Chromatography. US EPA Method 300.1 Part B. | 0.005 $g/m^3$ | 1 |
| Chlorate | Sample analysed as received, filtered if required. Ion Chromatography. US EPA Method 300.1 Part B. | 0.005 $g/m^3$ | 1 |
| Fluoride | Direct measurement, ion selective electrode. APHA 4500-$F^-$ C 22nd ed. 2012. | 0.05 $g/m^3$ | 1 |
| Total Ammoniacal-N | Filtered Sample from Christchurch. Phenol/hypochlorite colourimetry. Flow injection analyser. ($NH_4$-N = $NH_4^+$-N + $NH_3$-N). APHA 4500-$NH_3$ H (modified) 22nd ed. 2012. | 0.010 $g/m^3$ | 1 |
| Nitrite-N | Filtered sample from Christchurch. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-$NO_3^-$ I 22nd ed. 2012 (modified). | 0.002 $g/m^3$ | 1-2 |
| Nitrate-N | Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House. | 0.0010 $g/m^3$ | 1-2 |
| Nitrate-N + Nitrite-N | Filtered sample from Christchurch. Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-$NO_3^-$ I 22nd ed. 2012 (modified). | 0.002 $g/m^3$ | 1-2 |
| Dissolved Reactive Phosphorus | Filtered sample from Christchurch. Molybdenum blue colourimetry. Flow injection analyser. APHA 4500-P G (modified). 22nd ed. 2012. | 0.004 $g/m^3$ | 1 |
| Total Phosphorus | Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis) 22nd ed. 2012. Also modified to include the use of a reductant to eliminate interference from arsenic present in the sample. NWASCA, Water & soil Miscellaneous Publication No. 38, 1982. | 0.004 $g/m^3$ | 1 |
| Reactive Silica | Filtered sample from Christchurch. Heteropoly blue colorimetry. Discrete analyser. APHA 4500-$SiO_2$ F (modified from flow injection analysis) 22nd ed. 2012. | 0.10 $g/m^3$ as $SiO_2$ | 1 |
| Sulphate | Filtered sample from Christchurch. Ion Chromatography. APHA 4110 B 22nd ed. 2012. | 0.5 $g/m^3$ | 1-2 |
| Total Organic Carbon (TOC) | Supercritical persulphate oxidation, IR detection, for Total C. Acidification, purging for Total Inorganic C. TOC = TC -TIC. APHA 5310 C (modified) 22nd ed. 2012. | 0.5 $g/m^3$ | 1 |
| Radon-222* | Liquid scintillation counting. Subcontracted to the National Centre for Radiation Science (previously the National Radiation Laboratory), Christchurch. Health Phys, 33 (1997) 577-581. | 0.010 Bq/L | 1 |
| Langelier Saturation Index (LSI) profile | Calculation: from pH, Electrical Conductivity, Total Alkalinity, Temperature* and Calcium.<br><br>***Note: For accurate calculation of the Langelier Saturation Index (LSI), the sample temperature should be taken using a calibrated thermometer at the time of sampling and recorded on the paperwork submitted with the sample. If a sample temperature is not supplied, a nominal temperature of 20°C will show in the results table above and be used in the calculation. In this case, please interpret the LSI result with caution**.<br><br>APHA 2330 B 21st ed. 2005. | - | 1 |
| Radionuclide Activity | Evaporation, dissolution in a dilute mineral acid with the addition of scintillator solution. Radioactivity level determination by 'liquid scintillation counting' (LSC). Note: This method does not include gaseous radon or its immediate decay products. Subcontracted to National Radiation Laboratory, Christchurch. | 0.033 - 0.15 Bq/L | 1 |
| Hazen Colour Profile | | | |
| Apparent Hazen Colour | Determined on original sample without filtration or centrifugation, determination by Lovibond colorimeter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 2120 B 22nd ed. 2012. | 10 Hazen units | 1 |
| pH for Colour Analysis | pH meter. Analysed at Hill Laboratories - Chemistry; 101c Waterloo Road, Christchurch. APHA 4500-$H^+$ B 22nd ed. 2012. Note: pH measurement performed at the time of Hazen Colour analysis. | 0.1 pH Units | 1 |
| Drinking water metals suite, dissolved, trace | | | |
| Total Hardness | Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012. | 1.0 $g/m^3$ as $CaCO_3$ | 1 |
| Dissolved Aluminium | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.003 $g/m^3$ | 1 |

| Sample Type: Aqueous | | | |
|---|---|---|---|
| **Test** | **Method Description** | **Default Detection Limit** | **Sample No** |
| Dissolved Antimony | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.0002 g/m³ | 1 |
| Dissolved Arsenic | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.0010 g/m³ | 1 |
| Dissolved Barium | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.00010 g/m³ | 1 |
| Dissolved Beryllium | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.00010 g/m³ | 1 |
| Dissolved Boron | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.005 g/m³ | 1 |
| Dissolved Cadmium | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.00005 g/m³ | 1 |
| Dissolved Calcium | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.05 g/m³ | 1-2 |
| Dissolved Chromium | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.0005 g/m³ | 1 |
| Dissolved Copper | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.0005 g/m³ | 1 |
| Dissolved Iron | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.02 g/m³ | 1 |
| Dissolved Lead | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.00010 g/m³ | 1 |
| Dissolved Lithium | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.0002 g/m³ | 1 |
| Dissolved Magnesium | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.02 g/m³ | 1-2 |
| Dissolved Manganese | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.0005 g/m³ | 1 |
| Dissolved Mercury | 0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005. | 0.00008 g/m³ | 1 |
| Dissolved Molybdenum | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.0002 g/m³ | 1 |
| Dissolved Nickel | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.0005 g/m³ | 1 |
| Dissolved Potassium | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.05 g/m³ | 1-2 |
| Dissolved Selenium | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.0010 g/m³ | 1 |
| Dissolved Silver | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.00010 g/m³ | 1 |
| Dissolved Sodium | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.02 g/m³ | 1-2 |
| Dissolved Tin | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.0005 g/m³ | 1 |
| Dissolved Uranium | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.00002 g/m³ | 1 |
| Dissolved Zinc | Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.0010 g/m³ | 1 |
| Drinking water metals suite, totals, trace | | | |
| Total Aluminium | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012 / US EPA 200.8. | 0.0032 g/m³ | 1 |
| Total Antimony | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012 / US EPA 200.8. | 0.00021 g/m³ | 1 |
| Total Arsenic | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012 / US EPA 200.8. | 0.0011 g/m³ | 1 |
| Total Barium | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012 / US EPA 200.8. | 0.0053 g/m³ | 1 |
| Total Beryllium | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012 / US EPA 200.8. | 0.00011 g/m³ | 1 |
| Total Boron | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.0053 g/m³ | 1 |
| Total Cadmium | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012 / US EPA 200.8. | 0.000053 g/m³ | 1 |
| Total Calcium | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012. | 0.053 g/m³ | 1 |
| Total Chromium | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012 / US EPA 200.8. | 0.00053 g/m³ | 1 |

| Sample Type: Aqueous | | | |
|---|---|---|---|
| **Test** | **Method Description** | **Default Detection Limit** | **Sample No** |
| Total Copper | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B $22^{nd}$ ed. 2012 / US EPA 200.8. | 0.00053 $g/m^3$ | 1 |
| Total Iron | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B $22^{nd}$ ed. 2012. | 0.021 $g/m^3$ | 1 |
| Total Lead | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B $22^{nd}$ ed. 2012 / US EPA 200.8. | 0.00011 $g/m^3$ | 1 |
| Total Lithium | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B $22^{nd}$ ed. 2012. | 0.00021 $g/m^3$ | 1 |
| Total Magnesium | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B $22^{nd}$ ed. 2012. | 0.021 $g/m^3$ | 1 |
| Total Manganese | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B $22^{nd}$ ed. 2012 / US EPA 200.8. | 0.00053 $g/m^3$ | 1 |
| Total Mercury | Bromine Oxidation followed by Atomic Fluorescence. US EPA Method 245.7, Feb 2005. | 0.00008 $g/m^3$ | 1 |
| Total Molybdenum | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B $22^{nd}$ ed. 2012 / US EPA 200.8. | 0.00021 $g/m^3$ | 1 |
| Total Nickel | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B $22^{nd}$ ed. 2012 / US EPA 200.8. | 0.00053 $g/m^3$ | 1 |
| Total Potassium | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B $22^{nd}$ ed. 2012. | 0.053 $g/m^3$ | 1 |
| Total Selenium | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B $22^{nd}$ ed. 2012 / US EPA 200.8. | 0.0011 $g/m^3$ | 1 |
| Total Silver | Boiling nitric / hydrochloric acid digestion (5:1 ratio), ICP-MS, trace level. APHA 3125 B $22^{nd}$ ed. 2012. | 0.00011 $g/m^3$ | 1 |
| Total Sodium | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B $22^{nd}$ ed. 2012. | 0.021 $g/m^3$ | 1 |
| Total Tin | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B $22^{nd}$ ed. 2012. | 0.00053 $g/m^3$ | 1 |
| Total Uranium | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B $22^{nd}$ ed. 2012 / US EPA 200.8. | 0.000021 $g/m^3$ | 1 |
| Total Zinc | Nitric acid digestion, ICP-MS, trace level. APHA 3125 B $22^{nd}$ ed. 2012 / US EPA 200.8. | 0.0011 $g/m^3$ | 1 |

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

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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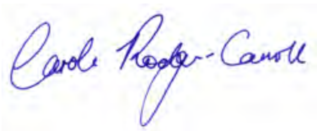

Carole Rodgers-Carroll BA, NZCS
Client Services Manager - Environmental

| | |
|---|---|
| **Report number:** | 2017-860 |
| **Report date:** | 26/07/2017 |
| **Work Order Agreement number:** | N/A |

# TEST REPORT

| | | | |
|---|---|---|---|
| **Client name:** | Hill Laboratories | **Order number:** | 181 2415 |
| **Client's address:** | Private Bag 3205, Hamilton | | |
| **Samples submitted by:** | NA | **Date received:** | 21/07/2017 |
| **Samples analysed by:** | Mary-Jane Okey | **Analyses completed:** | 25/07/2017 |
| **Customer supplied description:** | Water sample 181 2415.1<br>Production Bore 20/07/2017 11:30 | | |
| **Sample received as:** | Liquid | | |
| **Analyses requested:** | Radon-222, Total alpha and total beta concentrations | | |
| **Analytical methods:** | Liquid scintillation counting | | |

**Concentration:** If the measured value is above background at a level of confidence of 95%, then the concentration of the radionuclide is reported. The reported uncertainty is based on the combined standard uncertainty ($u_c$) multiplied by a coverage factor (k) = 2 (providing a level of confidence of 95%) as described by International Organization for Standardization, Guide to the expression of uncertainty in measurement, ISO, Geneva (1995).

**Minimal Detectable Concentration:** Reporting of a 'less than' result means that the measured value was consistent with a background measurement. The minimal detectable concentration with a level of confidence of 95% for both errors of the first and second kind is calculated according to ISO standard 11929 "Determination of the characteristic limits (decision threshold, detection imit and limits of confidence interval) for measurements of ionizing radiation – Fundamentals and application".

**Traceability:** Traceability to appropriate national or international standards is maintained. Details are available on request.

**Scope of accreditation:** All test results in this report are part of the laboratory's scope of accreditation unless marked otherwise.



**INSTITUTE OF ENVIRONMENTAL SCIENCE AND RESEARCH LIMITED**
National Centre for Radiation Science: 27 Creyke Rd, Christchurch 8041
PO Box 29181, Christchurch 8540, New Zealand / **T:** +64 3 351 6019 **F:** +64 3 351 0010
www.esr.cri.nz

## *Results*

| Sample number | Radon-222 (Bq/kg) | Total alpha concentration (Bq/L) | Total beta concentration (Bq/L) |
|---|---|---|---|
| 2017-1486 | 1.87 ± 0.84 | < 0.033 | < 0.15 |

Tests marked with £ are outside of the laboratory's scope of accreditation.

## *Additional Information*

Results relate only to the samples as received.

***This report, or any copy of it, is only valid if it is complete.***

O. Golovko, Environmental Radiochemist

Date: 26/07/2017

Watercare Laboratory Services

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PO Box 2614,
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Queenstown, 9349
(03) 409 0559

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# Certificate of Analysis
# Laboratory Reference:170725-098

| | | | |
|---|---|---|---|
| *Attention:* | Hills Lab Reporting | *Final Report:* | **235580-0** |
| *Client:* | **R J HILLS** | *Report Issue Date:* | **26-Jul-2017** |
| *Address:* | | *Received Date:* | **25-Jul-2017** |
| *Client Reference:* | **Cyanogen Chloride** | | |
| *Purchase Order:* | **148444** | *Quote Reference :* | **3546** |

## Sample Details

| **Sample Details** | | WATERS |
|---|---|---|
| *Lab Sample ID:* | | **170725-098-1** |
| *Client Sample ID:* | | EnvSub WC 13 |
| *Sample Date/Time:* | | 21/07/2017 |
| *Description:* | | 1812415.1 |
| **General Testing** | | |
| Cyanogen Chloride | mg/L | <0.005 |

*Where samples have been supplied by the client they are tested as received. A dash indicates no test performed.*

## Reference Methods

The sample(s) referred to in this report were analysed by the following method(s)

| Analyte | Method Reference | MDL | Samples | Location |
|---|---|---|---|---|
| **General Testing** | | | | |
| Cyanogen Chloride by Spectrophotometry | APHA (online edition) 4500-CN J | 0.005 mg/L | All | Auckland |

*The method detection limit (MDL) listed is the limit attainable in a relatively clean matrix. If dilutions are required for analysis the detection limit may be higher. For more information please contact the Operations Manager.*

Samples, with suitable preservation and stability of analytes, will be held by the laboratory for a period of two weeks after results have been reported, unless otherwise advised by the submitter.

**This report may not be reproduced, except in full, without the written authority of the Operations Manager.**

## Report Signatory 26/07/2017

You-Sing Yong
KTP Signatory

**Watercare Laboratory Services**

| Auckland | Invercargill | Queenstown |
|---|---|---|
| 52 Aintree Ave, | 142 Esk Street, | 74 Glenda Drive, |
| PO Box 107028, | PO Box 747, | PO Box 2614, |
| Auckland Airport, | Invercargill, 9840 | Wakatipu, |
| Tel: (09) 539 7614 | (03) 214 4040 | (03) 409 0559 |
| Fax: (09) 539 7601 | (03) 214 4041 | |

www.watercarelabs.co.nz clientsupport@water.co.nz

# Certificate of Analysis
## Laboratory Reference:170725-143

| | | | |
|---|---|---|---|
| *Attention:* | Chris Hansen | *Final Report:* | **235849-0** |
| *Client:* | **SHOTOVER DESIGN LTD T/A CLARK FORTUNE MCDONALD** | *Report Issue Date:* | **29-Jul-2017** |
| *Address:* | **PO Box 553, Queenstown, 9348** | *Received Date:* | **25-Jul-2017** |
| *Client Reference:* | **Bore Sample** | | |
| *Purchase Order:* | **Not Available** | *Quote Reference :* | **4913** |

## Sample Details

| | | WATERS |
|---|---|---|
| *Lab Sample ID:* | | **170725-143-1** |
| *Client Sample ID:* | | |
| *Sample Date/Time:* | | 26/07/2017 |
| *Description:* | | Bore Sample |
| **Micro Summary View** | | |
| Escherichia coli (Colilert-18) | MPN/100 mL | <1.0 |
| Total Coliforms (Colilert-18) | MPN/100 mL | <1.0 |

*Results marked with * are not accredited to International Accreditation New Zealand*

*Where samples have been supplied by the client they are tested as received. A dash indicates no test performed.*

## Reference Methods

The sample(s) referred to in this report were analysed by the following method(s)

| Analyte | Method Reference | MDL | Samples | Location |
|---|---|---|---|---|
| **Micro Summary View** | | | | |
| Escherichia coli (Colilert-18) | APHA (online edition) 9223 B Colilert Quantitray | 1 MPN/100 mL | All | Queenstown |
| Total Coliforms (Colilert-18) | APHA (online edition) 9223 B Colilert Quantitray | 1 MPN/100 mL | All | Queenstown |

*The method detection limit (MDL) listed is the limit attainable in a relatively clean matrix. If dilutions are required for analysis the detection limit may be higher.*

*For more information please contact the Operations Manager.*

Samples, with suitable preservation and stability of analytes, will be held by the laboratory for a period of two weeks after results have been reported, unless otherwise advised by the submitter.

Watercare Laboratory Services is a division of Watercare Services Limited .



| Report Signatory 29/07/2017 |
|---|
| Tim Richards<br>KTP Signatory |

**SOUTHDRILL** WATER EXPLORATION

# PUMPING TEST DATA SHEET

STEP TEST

PAGE 1

Project: MURPHY DEVELOPMENTS LTD

Name of abstraction well: PUMPING BORE Location: E1264612 N4998187

Name of observation well: ______ Location: ______

Distance from observation to abstraction well: 15.0 METRES (MEASURED)

Depth: Diameter: 300mm Casing: STEEL Screen: 6.0m x 2.5mm

Test date: (Start) 18.7.2017 (Finish) 18.7.2017

Pump details:

Type: GRUNDFOS SP125-2 Pump inlet depth: 26.50m

Initial water level: 0.89m ~~above~~ / below datum

Datum point: 0.31m above / ~~below~~ ground level

Ground level (OD): ______ Datum point (OD): ______

Units of measurement: *t* = MINUTES *Q* = LITRES/SECOND *s* = METRES

Observers Remarks: ROLLY HARREX

| Date | Actual Time | Elapsed time (*t*) (min) | Water level *~~above~~/below datum (m) | Change in water level/s | *Q* L/SEC | Remarks |
|---|---|---|---|---|---|---|
| 18.7.17 | 9.00 | | 0.89 | | 2.9 | PUMP ON |
| | 9.00.5 | 0.5 | 1.54 | 0.65 | " | |
| | 9.01 | 1.0 | 1.76 | 0.22 | " | |
| | 9.01.5 | 1.5 | 1.78 | 0.02 | " | |
| | 9.02 | 2.0 | 1.81 | 0.03 | " | |
| | 9.02.5 | 2.5 | 1.81 | — | " | INCREASE Q |
| | 9.03 | 3.0 | 2.28 | 0.47 | 4.0 | |
| | 9.03.5 | 3.5 | 2.28 | — | " | |
| | 9.04 | 4.0 | 2.29 | 0.01 | " | |
| | 9.04.5 | 4.5 | 2.29 | — | " | |
| | 9.05 | 5 | 2.29 | — | " | |
| | 9.06 | 6 | 2.29 | — | " | |
| | 9.07 | 7 | 2.28 | 0.01 | " | |

| Date | Actual Time | Elapsed time (min) | Water Level *above/below datum (m) | Change in water level/s | Q L/SEC | Remarks |
|---|---|---|---|---|---|---|
| 18.7.17 | 9.08 | 8 | 2.28 | | | |
| | 9.09 | 9 | 2.28 | | | |
| | 9.10 | 10 | 2.28 | | 4.0 | |
| | 9.15 | 15 | 2.28 | | | |
| | 9.20 | 20 | 2.26 | 0.02 | | |
| | 9.25 | 25 | 2.25 | 0.01 | | |
| | 9.30 | 30 | 2.26 | 0.01 | 3.82 | |
| | 9.40 | 40 | 2.25 | 0.01 | | |
| | 9.50 | 50 | 2.27 | 0.02 | | |
| | 10.00 | 60 | 2.27 | | | INCREASE Q |
| | 10.00.5 | 60.00.5 | 3.48 | 1.21 | 8.24 | |
| | 10.01 | 61 | 3.89 | 0.41 | | |
| | 10.01.5 | 61.00.5 | 3.97 | 0.08 | | |
| | 10.02 | 62 | 3.99 | 0.02 | | |
| | 10.02.5 | 62.5 | 4.02 | 0.03 | | |
| | 10.03 | 63 | 4.01 | 0.01 | | |
| | 10.03.5 | 63.5 | 4.01 | | | |
| | 10.04 | 64 | 4.03 | 0.02 | 8.24 | |
| | 10.04.5 | 64.5 | 4.03 | | | |
| | 10.05 | 65 | 4.03 | | | |
| | 10.06 | 66 | 4.04 | 0.01 | | |
| | 10.07 | 67 | 4.04 | | | |
| | 10.08 | 68 | 4.05 | 0.01 | | |
| | 10.09 | 69 | 4.02 | 0.03 | | |
| | 10.10 | 70 | 4.02 | | | |
| | 10.15 | 75 | 4.02 | | | |
| | 10.20 | 80 | 4.03 | 0.01 | | |
| | 10.25 | 85 | 4.04 | 0.01 | 8.24 | |
| | 10.30 | 90 | 4.045 | 0.005 | | |
| | 10.40 | 100 | 4.05 | 0.005 | | |
| | 10.50 | 110 | 4.06 | 0.01 | | |
| | 11.00 | 120 | 4.06 | | | INCREASE Q |
| | 11.00.5 | 120.5 | 7.91 | 3.85 | 25.0 | |
| | 11.01 | 121 | 10.42 | 2.51 | " | DECREASE Q |
| | 11.01.5 | 121.5 | 10.10 | 0.32 | 16.82 | |
| | 11.02 | 122 | 8.83 | 1.27 | | |
| | 11.02.5 | 122.5 | 8.34 | 0.49 | | |
| | 11.03 | 123 | 8.32 | 0.02 | | |
| | 11.03.5 | 123.5 | 8.34 | 0.02 | | |
| | 11.04 | 124 | 8.33 | 0.01 | | |
| | 11.04.5 | 124.5 | 8.35 | 0.02 | | |
| | 11.05 | 125 | 8.35 | | | |
| | 11.06 | 126 | 8.34 | 0.01 | | |
| | 11.07 | 127 | 8.35 | 0.01 | 16.80 | |
| | 11.08 | 128 | 8.35 | | | |
| | 11.09 | 129 | 8.36 | 0.01 | | |
| | 11.10 | 130 | 8.36 | | | |

| Date | Actual Time | Elapsed time (min) | Water Level *~~above~~/below datum (m) | Change in water level/s | Q l/s. | Remarks |
|---|---|---|---|---|---|---|
| 18.7.17 | 11.15 | 135 | 8.36 | | 16.89 | |
| | 11.20 | 140 | 8.36 | | | |
| | 11.25 | 145 | 8.36 | | | |
| | 11.30 | 150 | 8.37 | 0.01 | | |
| | 11.40 | 160 | 8.38 | 0.01 | | |
| | 11.50 | 170 | 8.39 | 0.01 | | |
| | 12.00 | 180 | 8.39 | | | INCREASE Q |
| | 12.005 | 180.5 | 14.26 | 5.87 | | |
| | 12.01 | 181 | 16.70 | 2.44 | 36.36 | |
| | 12.01.5 | 181.5 | 17.25 | 0.55 | | |
| | 12.02 | 182 | 17.55 | 0.30 | | |
| | 12.02.5 | 182.5 | 17.66 | 0.11 | | |
| | 12.03 | 183 | 17.67 | 0.02 | | |
| | 12.03.5 | 183.5 | 17.69 | 0.02 | | |
| | 12.04 | 184 | 17.72 | 0.03 | | |
| | 12.04.5 | 184.5 | 17.74 | 0.02 | | |
| | 12.05 | 185. | 17.75 | 0.01 | | |
| | 12.06 | 186 | 17.76 | 0.01 | 36.89 | |
| | 12.07 | 187 | 17.80 | 0.04 | | |
| | 12.08 | 188 | 17.82 | 0.02 | | |
| | 12.09 | 189 | 17.83 | 0.01 | 36.36 | |
| | 12.10 | 190 | 17.84 | 0.01 | | |
| | 12.15 | 195 | 17.87 | 0.03 | | |
| | 12.20 | 200 | 17.88 | 0.01 | | |
| | 12.25 | 205 | 17.89 | 0.01 | | |
| | 12.30 | 210 | 17.895 | 0.005 | | |
| | 12.40 | 220 | 17.94 | 0.005 | | |
| | 12.50 | 230 | 17.95 | 0.01 | 36.40 | |
| | 1.00 | 240 | 17.96 | 0.01 | | Pump off |
| | | RECOVERY TEST. | | | | |
| | 1.00.5 | 0.5 | 6.09 | | | |
| | 1.01 | 1.0 | 2.49 | | | |
| | 1.01.5 | 1.5 | 2.01 | | | |
| | 1.02 | 2.0 | 1.55 | | | |
| | 1.02.5 | 2.5 | 1.52 | | | |
| | 1.03 | 3.0 | 1.36 | | | |
| | 1.03.5 | 3.5 | 1.38 | | | |
| | 1.04 | 4.0 | 1.38 | | | |
| | 1.04.5 | 4.5 | 1.36 | | | |
| | 1.05 | 5 | 1.35 | | | |
| | 1.06 | 6 | 1.29 | | | |
| | 1.07 | 7 | 1.28 | | | |
| | 1.08 | 8 | 1.27 | | | |
| | 1.09 | 9 | 1.25 | | | |
| | 1.10 | 10 | 1.22 | | | |
| | 1.15 | 15 | 1.14 | | | |
| | 1.20 | 20 | 1.10 | | | |

PAGE 4

| Date | Actual Time | Elapsed time (min) | Water Level *~~above~~/below datum (m) | Change in water level/s | Q L/SEC. | Remarks |
|---|---|---|---|---|---|---|
| 18.7.17 | 1·25 | 25 | 1·07 | | | |
| | 1·30 | 30 | 1·05 | | | |
| | 1·40 | 40 | 1·01 | | | |
| | 1·50 | 50 | 0·98 | | | |
| | 1·60 | 60 | 0·96 | | | |

SOUTHDRILL WATER EXPLORATION

# PUMPING TEST DATA SHEET

STEP TEST. PAGE 5

Project: MURPHY DEVELOPMENT LTD

Name of abstraction well: ______ Location: ______

Name of observation well: MONITORING BORE. Location: E1264607 N4998193.

Distance from observation to abstraction well: 15.0 METRES (MEASURED)

Depth: Diameter: 50mm Casing: PVC Screen: 6.0m SLOTTED

Test date: (Start) 18.7.2017 (Finish) 18.7.2017

Pump details:

Type GRUNDFOS SP125-2 Pump inlet depth: 26.50m.

Initial water level: 0.70m ~~above~~ / below datum

Datum point: 0.25 above / ~~below~~ ground level

Ground level (OD): ______ Datum point (OD): ______

Units of measurement $t$ = MINUTES $Q$ = LITRES/SEC $s$ = METRES.

Observers Remarks: GRACIN MEYER-BUDGE.

| Date | Actual Time | Elapsed time ($t$) (min) | Water level *~~above~~/below datum (m) | Change in water level/s | $Q$ l/s | Remarks |
|---|---|---|---|---|---|---|
| 18.7.17 | 9.00 | | 0.70 | . | 2.9 | Pump on |
| | 9.00.5 | 0.5 | 0.73 | 0.03 | " | |
| | 9.01 | 1.0 | 0.74 | 0.01 | " | |
| | 9.01.5 | 1.5 | 0.74 | | " | |
| | 9.02 | 2.0 | 0.75 | 0.01 | " | |
| | 9.02.5 | 2.5 | 0.75 | | " | INCREASE Q |
| | 9.03 | 3.0 | 0.76 | 0.01 | 4.0 | |
| | 9.03.5 | 3.5 | 0.77 | 0.01 | " | |
| | 9.04 | 4.0 | 0.77 | | " | |
| | 9.04.5 | 4.5 | 0.77 | | " | |
| | 9.05 | 5 | 0.78 | 0.01 | " | |
| | 9.06 | 6 | 0.78 | | " | |
| | 9.07 | 7 | 0.78 | | " | |

| Date | Actual Time | Elapsed time (min) | Water Level *~~above~~/below datum (m) | Change in water level/s | Q l/sec | Remarks |
|---|---|---|---|---|---|---|
| 18.7.17 | 9.08 | 8 | 0.78 | | 4.0. | |
| | 9.09 | 9 | 0.79 | 0.01 | | |
| | 9.10. | 10 | 0.79 | | | |
| | 9.15 | 15 | 0.80 | 0.01 | | |
| | 9.20 | 20 | 0.80 | | | |
| | 9.25 | 25 | 0.80 | | | |
| | 9.30 | 30 | 0.80 | | 3.82 | |
| | 9.40 | 40 | 0.81 | 0.01 | | |
| | 9.50 | 50 | 0.81 | | | |
| | 10.00 | 60 | 0.81 | | | INCREASE Q |
| | 10.00.5 | 60.0.5 | 0.85 | 0.04 | 8.24 | |
| | 10.01 | 61 | 0.87 | 0.03 | | |
| | 10.01.5 | 61.5 | 0.87 | | | |
| | 10.02 | 62 | 0.88 | 0.01 | | |
| | 10.02.5 | 62.5 | 0.89 | 0.01 | | |
| | 10.03 | 63 | 0.89 | | | |
| | 10.03.5 | 63.5 | 0.90 | 0.01 | | |
| | 10.04 | 64 | 0.90 | | 8.24 | |
| | 10.04.5 | 64.5 | 0.90 | | | |
| | 10.05 | 65 | 0.90 | | | |
| | 10.06 | 66 | 0.91 | 0.01 | | |
| | 10.07 | 67 | 0.91 | | | |
| | 10.08 | 68 | 0.91 | | | |
| | 10.09 | 69 | 0.91 | | | |
| | 10.10 | 70 | 0.92 | 0.01 | | |
| | 10.15 | 75 | 0.92 | | | |
| | 10.20 | 80 | 0.93 | 0.01 | | |
| | 10.25 | 85 | 0.94 | 0.01 | 8.24 | |
| | 10.30 | 90 | 0.94 | | | |
| | 10.40 | 100 | 0.94 | | | |
| | 10.50 | 110 | 0.95 | 0.01 | | |
| | 11.00 | 120 | 0.95 | | | INCREASE Q |
| | 11.00.5 | 120.5 | 1.10 | 0.15 | 25 | |
| | 11.01 | 121 | 1.13 | 0.02 | " | DECREASE Q |
| | 11.01.5 | 121.5 | 1.15 | 0.02 | 16.82 | |
| | 11.02 | 122 | 1.13 | | | |
| | 11.02.5 | 122.5 | 1.13 | | | |
| | 11.03 | 123 | 1.14 | 0.01 | | |
| | 11.03.5 | 123.5 | 1.14 | | | |
| | 11.04 | 124 | 1.14 | | | |
| | 11.04.5 | 124.5 | 1.15 | 0.01 | | |
| | 11.05 | 125 | 1.15 | | | |
| | 11.06 | 126 | 1.15 | | | |
| | 11.07 | 127 | 1.16 | 0.01 | 16.80. | |
| | 11.08 | 128 | 1.16 | | | |
| | 11.09 | 129 | 1.17 | 0.01 | | |
| | 11.10 | 130 | 1.17 | | | |

| Date | Actual Time | Elapsed time (min) | Water Level *~~above~~/below datum (m) | Change in water level/s | Q L/SEC | Remarks |
|---|---|---|---|---|---|---|
| 18.7.17 | 11.15 | 135 | 1.19 | 0.02 | | |
| | 11.20 | 140 | 1.20 | 0.01 | | |
| | 11.25 | 145 | 1.21 | 0.01 | | |
| | 11.30 | 150 | 1.22 | 0.01 | | |
| | 11.40 | 160 | 1.23 | 0.01 | | |
| | 11.50 | 170 | 1.24 | 0.01 | | |
| | 12.00 | 180 | 1.24 | | | INCREASE Q |
| | 12.00.5 | 180.5 | 1.43 | 0.19 | 36.36 | |
| | 12.01 | 181 | 1.47 | 0.04 | | |
| | 12.01.5 | 181.5 | 1.52 | 0.05 | | |
| | 12.02 | 182 | 1.54 | 0.02 | | |
| | 12.02.5 | 182.5 | 1.56 | 0.02 | | |
| | 12.03 | 183. | 1.57 | 0.01 | | |
| | 12.035 | 183.5 | 1.58 | 0.01 | | |
| | 12.04 | 184 | 1.59 | 0.01 | | |
| | 12.04.5 | 184.5 | 1.60 | 0.01 | | |
| | 12.05 | 185 | 1.61 | 0.01 | | |
| | 12.06 | 186 | 1.63 | 0.02 | 36.89 | |
| | 12.07 | 187 | 1.64 | 0.01 | | |
| | 12.08 | 188 | 1.65 | 0.01 | | |
| | 12.09 | 189 | 1.66 | 0.01 | 36.36 | |
| | 12.10 | 190 | 1.67 | 0.01 | | |
| | 12.15 | 195 | 1.70 | 0.03 | | |
| | 12.20 | 200 | 1.73 | 0.03 | | |
| | 12.25 | 205 | 1.75 | 0.02 | | |
| | 12.30 | 210 | 1.77 | 0.02 | | |
| | 12.40 | 220 | 1.79 | 0.02 | | |
| | 12.50 | 230 | 1.81 | 0.02 | 36.40 | |
| | 1.00 | 240 | 1.82 | 0.01 | | Pumpoff |
| | RECOVERY TEST. | | | | | |
| | 1.00.5 | 0.5 | 1.50 | 0.32 | | |
| | 1.01 | 1.0 | 1.36 | 0.14 | | |
| | 1.01.5 | 1.5 | 1.30 | 0.06 | | |
| | 1.02 | 2.0 | 1.25 | 0.05 | | |
| | 1.02.5 | 2.5 | 1.22 | 0.03 | | |
| | 1.03 | 3.0 | 1.19 | 0.03 | | |
| | 1.03.5 | 3.5 | 1.17 | 0.02 | | |
| | 1.04 | 4.0 | 1.15 | 0.02 | | |
| | 1.04.5 | 4.5 | 1.13 | 0.02 | | |
| | 1.05 | 5.0 | 1.12 | 0.01 | | |
| | 1.06 | 6 | 1.09 | 0.03 | | |
| | 1.07 | 7 | 1.07 | 0.02 | | |
| | 1.08 | 8 | 1.04 | 0.03 | | |
| | 1.09 | 9 | 1.02 | 0.02 | | |
| | 1.10 | 10 | 1.01 | 0.01 | | |
| | 1.15 | 15 | 0.94 | 0.07 | | |
| | 1.20 | 20 | 0.90 | 0.04 | | |

| Date | Actual Time | Elapsed time (min) | Water Level *~~above~~/below datum (m) | Change in water level/s | Q L/sec. | Remarks |
|---|---|---|---|---|---|---|
| 18.7.17 | 1.25 | 25 | 0.87 | 0.03 | | |
| | 1.30 | 30 | 0.84 | 0.03 | | |
| | 1.40 | 40 | 0.81 | 0.03 | | |
| | 1.50 | 50 | 0.79 | 0.02 | | |
| | 2.00 | 60 | 0.77 | 0.02. | | |

**SOUTHDRILL** WATER EXPLORATION

# PUMPING TEST DATA SHEET

CONSTANT RATE TEST. PAGE 1

Project: MURPHY DEVELOPMENTS LTD

Name of abstraction well: PUMPING BORE Location: E1264612 N4998187

Name of observation well: ______ Location: ______

Distance from observation to abstraction well: 15.0 METRES

Depth: Diameter: 300mm Casing: STEEL Screen: 6.0m x 2.5mm

Test date: (Start) 19.7.2017 (Finish) 22.7.2017

Pump details:

Type: GRUNDFOS SP125-2 Pump inlet depth: 26.50

Initial water level: 0.87 ~~above~~ / below datum

Datum point: 0.31 above / ~~below~~ ground level

Ground level (OD): ______ Datum point (OD): ______

Units of measurement: $t$ = MINUTES $Q$ = LITRES/SECOND $s$ = METRES

Observers Remarks: ROLLY HARREX - GRAVIN MEYER-BUDGE

| Date | Actual Time | Elapsed time ($t$) (min) | Water level *~~above~~/below datum (m) | Change in water level/s | Q l/s | Remarks |
|---|---|---|---|---|---|---|
| 19.7.17 | 8.00 | | 0.87 | | | PUMP ON |
| | | 0.5 | | | 36.0 | |
| | | 1.0 | | | | |
| | | 1.5 | 17.38 | | | |
| | | 2.0 | | | | |
| | | 2.5 | | | | |
| | | 3.0 | 17.68 | | | |
| | | 3.5 | | | | |
| | | 4.0 | | | | |
| | | 4.5 | 17.74 | | | |
| | | 5 | | | | |
| | | 6 | 17.75 | | | |
| | | 7 | 17.78 | | | |

| Date | Actual Time | Elapsed time (min) | Water Level *above/below datum (m) | Change in water level/s | Q | Remarks |
|---|---|---|---|---|---|---|
| | | | | | L/s | |
| 19.7.17 | | 8 | 17.79 | | | |
| | | 9 | 17.81 | | | |
| | | 10 | 17.92 | | | |
| | | 15 | 17.95 | | | |
| | | 20 | 17.95 | | | |
| | | 25 | 17.96 | | | |
| | | 30 | 18.07 | | | |
| | | 40 | 18.10 | | | |
| | | 50 | 18.13 | | | |
| | 9.00 | 60 | 18.16 | | | |
| | 10.00 | | 18.21 | | 36.0 | |
| | 11.00 | | 18.18 | | | |
| | 12.00PM | | 18.18 | | | |
| | 1.00 | | 18.21 | | | |
| | 2.00 | | 18.19 | | | |
| | 3.00 | | 18.17 | | 36.0 | |
| | 4.00 | | 18.26 | | | |
| | 5.00 | | 18.28 | | | |
| | 6.00 | | 18.33 | | | |
| | 7.00 | | 18.32 | | | |
| | 8.00 | | 18.34 | | | |
| | 9.00 | | 18.36 | | | |
| | 10.00 | | 18.39 | | | |
| | 11.00 | | 18.37 | | | |
| | 12.00 | | 18.35 | | | |
| 20.7.17 | 1.00AM | | 18.35 | | | |
| | 2.0 | | 18.38 | | | |
| | 3.0 | | 18.35 | | | |
| | 4.0 | | 18.35 | | | |
| | 5.0 | | 18.35 | | | |
| | 6.0 | | 18.35 | | | |
| | 7.0 | | 18.38 | | | |
| | 8.0 | | 18.38 | | | |
| | 9.0 | | 18.38 | | | |
| | 10.0 | | 18.41 | | | |
| | 11.0 | | 18.40 | | | |
| | 12.0PM | | 18.37 | | 36.0 | |
| | 1.00 | | 18.36 | | | |
| | 2.00 | | 18.37 | | | |
| | 3.00 | | 18.37 | | | |
| | 4.00 | | 18.37 | | | |
| | 5.00 | | 18.38 | | | |
| | 6.00 | | 18.41 | | | |
| | 7.00 | | 18.41 | | | |
| | 8.00 | | 18.41 | | | |
| | 9.00 | | 18.40 | | | |
| | 10.00 | | 18.42 | | | |

| Date | Actual Time | Elapsed time (min) | Water Level *above/below datum (m) | Change in water level/s | Q l/s | Remarks |
|---|---|---|---|---|---|---|
| 20.7.17 | 11.00pm | | 18.41 | | | |
| | 12.00 | | 18.41 | | | |
| 21.7.17 | 1.00AM | | 18.40 | | | |
| | 2.00 | | 18.41 | | | |
| | 3.00 | | 18.41 | | 36.0 | |
| | 4.00 | | 18.42 | | | |
| | 5.00 | | 18.42 | | | |
| | 6.00 | | 18.43 | | | |
| | 7.00 | | 18.43 | | | |
| | 8.00 | | 18.45 | | | |
| | 9.00 | | 18.44 | | | |
| | 10.00 | | 18.44 | | | |
| | 11.00 | | 18.44 | | | |
| | 12.00PM | | 18.46 | | | |
| | 1.00PM | | 18.44 | | | |
| | 2.00 | | 18.44 | | | |
| | 3.00PM | | 18.46 | | | |
| | 4.00 | | 18.48 | | | |
| | 5.00 | | 18.47 | | | |
| | 6.00 | | 18.46 | | | |
| | 7.00PM | | 18.47 | | | |
| | 8.00 | | 18.52 | | | |
| | 9.00 | | 18.50 | | | |
| | 10.00 | | 18.50 | | | |
| | 11.00 | | 18.50 | | | |
| | 12.00AM | | 18.51 | | | |
| 22.7.17 | 1.00AM | | 18.52 | | 36.0 | |
| | 2.00 | | 18.53 | | | |
| | 3.00 | | 18.52 | | | |
| | 4.00 | | 18.51 | | | |
| | 5.00 | | 18.52 | | | |
| | 6.00 | | 18.51 | | | |
| | 7.00 | | 18.51 | | | |
| | 8.00 | | 18.52 | | | PUMP OFF. |
| | RECOVERY | | | | | |
| | | 0.5 | 19.51 | | | |
| | | 1.0 | 3.75 | | | |
| | | 1.5 | 2.25 | | | |
| | | 2.0 | 1.94 | | | |
| | | 2.5 | 1.80 | | | |
| | | 3.0 | 1.74 | | | |
| | | 3.5 | 1.60 | | | |
| | | 4.0 | 1.63 | | | |
| | | 4.5 | 1.62 | | | |
| | | 5.0 | 1.61 | | | |
| | | 6.0 | 1.58 | | | |
| | | 7.0 | 1.55 | | | |

| Date | Actual Time | Elapsed time (min) | Water Level *above/below datum (m) | Change in water level/s | Q | Remarks |
|---|---|---|---|---|---|---|
| 22.7.17 | 8.08pm | 8.0 | 1.53 | | | |
| | | 9.0 | 1.51 | | | |
| | | 10.0 | 1.49 | | | |
| | | 15.0 | 1.42 | | | |
| | | 20.0 | 1.36 | | | |
| | | 25.0 | 1.33 | | | |
| | | 30.0 | 1.30 | | | |
| | | 40.0 | 1.25 | | | |
| | | 50.0 | 1.23 | | | |
| | 9.00 | 60.0 | 1.21 | | | |

**SOUTHDRILL** WATER EXPLORATION

# PUMPING TEST DATA SHEET

CONSTANT RATE TEST



Project: MURPHY DEVELOPMENTS LTD

Name of abstraction well: ______ Location: ______

Name of observation well: MONITORING BORE Location: E1264607 N4998193,

Distance from observation to abstraction well: 15.0m.

Depth: Diameter: 50mm Casing: PVC Screen: 6.0m SLOTTED

Test date: (Start) 19.7.2017 (Finish) 22.7.2017

Pump details:

Type: GRUNDFOS SP125-2 Pump inlet depth: 26.50

Initial water level: 0.86 ~~above~~ / below datum

Datum point: 0.25 above / ~~below~~ ground level

Ground level (OD): ______ Datum point (OD): ______

Units of measurement: t = MINUTES Q = LITRES/SEC s = METRES

Observers Remarks: ROLLY HARREX GRACIN MEYER-BUDGE

| Date | Actual Time | Elapsed time (t) (min) | Water level *above/below datum (m) | Change in water level/s | Q L/S | Remarks |
|---|---|---|---|---|---|---|
| 19.7.17 | 8.00AM | | 0.86 | | | Pump on. |
| | | 1.0 | 1.13 | | 36.0. | |
| | | 2.5 | 1.25 | | | |
| | | 4.0 | 1.32 | | | |
| | | 5.0 | 1.36 | | | |
| | | 6.0 | 1.40 | | | |
| | | 7.0 | 1.43 | | | |
| | | 8.0 | 1.45 | | | |
| | | 9.0 | 1.48 | | | |
| | | 10.0 | 1.50 | | | |
| | | 15.0 | 1.54 | | | |
| | | 20.0 | 1.59 | | | |
| | | 25.0 | 1.61 | | | |

| Date | Actual Time | Elapsed time (min) | Water Level *above/below datum (m) | Change in water level/s | Q | Remarks |
|---|---|---|---|---|---|---|
| | | | | | l/s | |
| 19.7.17 | | 30 | 1.66 | | | |
| | | 40 | 1.70 | | | |
| | | 50 | 1.73 | | | |
| | | 60 | 1.76 | | | |
| | 9.00AM | | 1.82 | | | |
| | 10.00 | | 1.84 | | | |
| | 11.00 | | 1.84 | | | |
| | 12.00 | | 1.85 | | | |
| | 1.00PM | | 1.86 | | | |
| | 2.00 | | 1.86 | | | |
| | 3.00 | | 1.86 | | | |
| | 4.00 | | 1.87 | | | |
| | 5.00 | | 1.87 | | | |
| | 6.00 | | 1.88 | | | |
| | 7.00 | | 1.89 | | | |
| | 8.00 | | 1.90 | | | |
| | 9.00 | | 1.90 | | | |
| | 10.00 | | 1.90 | | | |
| | 11.00 | | 1.90 | | | |
| | 12.00 | | 1.90 | | | |
| 20.7.17 | 1.00AM | | 1.90 | | | |
| | 2.00 | | 1.90 | | | |
| | 3.00 | | 1.90 | | | |
| | 4.00 | | 1.90 | | | |
| | 5.00 | | 1.90 | | | |
| | 6.00 | | 1.90 | | | |
| | 7.00 | | 1.91 | | | |
| | 8.00 | | 1.90 | | 36.0 | |
| | 9.00 | | 1.91 | | | |
| | 10.00 | | 1.92 | | | |
| | 11.00 | | 1.92 | | | |
| | 12.00 | | 1.92 | | | |
| | 1.00PM | | 1.92 | | | |
| | 2.00 | | 1.92 | | | |
| | 3.00 | | 1.93 | | | |
| | 4.00 | | 1.93 | | | |
| | 5.00 | | 1.94 | | | |
| | 6.00 | | 1.94 | | | |
| | 7.00 | | 1.94 | | | |
| | 8.00 | | 1.95 | | | |
| | 9.00 | | 1.95 | | | |
| | 10.00 | | 1.96 | | | |
| | 11.00 | | 1.96 | | | |
| | 12.00 | | 1.96 | | | |
| 21.7.17 | 1.00AM | | 1.95 | | | |
| | 2.00 | | 1.95 | | | |
| | 3.00 | | 1.95 | | 36.0 | |

| Date | Actual Time | Elapsed time (min) | Water Level *~~above~~/below datum (m) | Change in water level/s | Q l/s | Remarks |
|---|---|---|---|---|---|---|
| 21.7.17 | 4.00AM | | 1.96 | | | |
| | 5.00 | | 1.96 | | | |
| | 6.00 | | 1.96 | | | |
| | 7.00 | | 1.97 | | | |
| | 8.00 | | 1.98 | | | |
| | 9.00 | | 1.99 | | | |
| | 10.00 | | 1.99 | | | |
| | 11.00 | | 1.99 | | | |
| | 12.00 | | 1.99 | | | |
| | 1.00PM | | 2.00 | | | |
| | 2.00 | | 2.00 | | | |
| | 3.00 | | 1.99 | | | |
| | 4.00 | | 2.00 | | | |
| | 5.00 | | 2.00 | | | |
| | 6.00 | | 2.00 | | | |
| | 7.00 | | 2.01 | | | |
| | 8.00 | | 2.03 | | | |
| | 9.00 | | 2.03 | | | |
| | 10.00 | | 2.04 | | | |
| | 11.00 | | 2.04 | | | |
| | 12.00 | | 2.06 | | | |
| 22.7.17 | 1.00AM | | 2.06 | | 36.0 | |
| | 2.00 | | 2.06 | | | |
| | 3.00 | | 2.07 | | | |
| | 4.00 | | 2.06 | | | |
| | 5.00 | | 2.07 | | | |
| | 6.00 | | 2.08 | | | |
| | 7.00 | | 2.08 | | | |
| | 8.00 | | 2.08 | | | Pump off |
| | RECOVERY | | | | | |
| | | 0.5 | 1.80 | | | |
| | | 1.0 | 1.65 | | | |
| | | 1.5 | 1.57 | | | |
| | | 2.0 | 1.53 | | | |
| | | 2.5 | 1.48 | | | |
| | | 3.0 | 1.46 | | | |
| | | 3.5 | 1.44 | | | |
| | | 4.0 | 1.42 | | | |
| | | 4.5 | 1.40 | | | |
| | | 5.0 | 1.38 | | | |
| | | 6.0 | 1.35 | | | |
| | | 7 | 1.33 | | | |
| | | 8 | 1.30 | | | |
| | | 9 | 1.29 | | | |
| | | 10 | 1.27 | | | |
| | | 15 | 1.22 | | | |
| | | 20 | 1.17 | | | |

| Date | Actual Time | Elapsed time (min) | Water Level *~~above~~/below datum (m) | Change in water level/s | Q | Remarks |
|---|---|---|---|---|---|---|
| 22-7-17 | | 25 | 1.12 | | | |
| | | 30 | 1.09 | | | |
| | | 40 | 1.04 | | | |
| | | 50 | 1.02 | | | |
| | | 60. | 1.00 | | | |

# Groundwater Take from Homestead Bay, Queenstown

Assessment of Environmental Effects

Prepared for:
Clark Fortune McDonald and Associates

Prepared by:
Stantec New Zealand Limited

August 1, 2017

MWH now part of Stantec

| Revision | Description | Author | | Quality Check | | Independent Review | |
|---|---|---|---|---|---|---|---|
| 1 | Draft for client review | James Dommisse | | | | | |
| | | | | | | | |
| | | | | | | | |

# Sign-off Sheet

Sheryl to add disclaimer comment

Prepared by

James Dommisse

Reviewed by

Frances Lojkine

Approved by

xx

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# 1 Introduction

This report has been prepared on behalf of Clark Fortune McDonald and Associates as part of a resource consent application by Murphy's Developments Ltd to take and use groundwater from a 35.8m deep bore (F42/0150) (referred to hereafter as the Production Bore) at Homestead Bay, 90m from the shore of Lake Wakatipu, near Queenstown. The water will be used for drinking water supply to a proposed community development. The location of the Production Bore, other bores nearby and geographic setting are shown in Figure 1-1 and Figure 1-2.

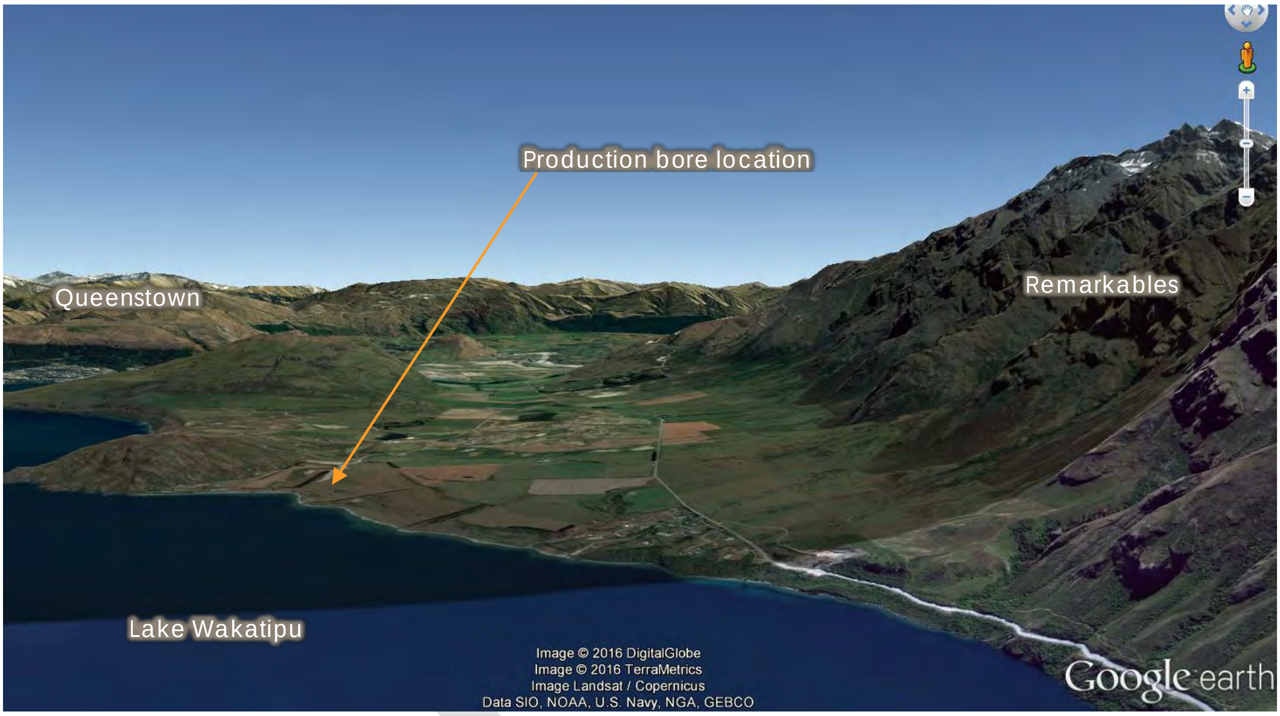



Figure 1-1: Location of the production bore and local geography

This report provides a description of the local hydrogeological setting, groundwater water quality, aquifer testing undertaken on the Production Bore, a summary of the relevant planning legislation and an assessment of environmental effects.


Figure 1-2: Bore locations

# 2 Hydrogology

## 2.1 Geology

The Production Bore is sited within a 3km wide, 8km long valley filled with quaternary sediments. The valley is flanked on either by schist hills and mountain ranges. The surface geology described by Turnbull, 2000[1] is shown in Appendix A.1. At the Production Bore, surface sediments consist of Q1k silt, with some mud and sand. To the east, surface sediments consist of Q2t un-weathered to slightly weathered till consisting of boulders, gravel, sand silt and clay.

Based on available bore logs within 3km of the Production Bore (see Appendix A.2), the thickness of quaternary sediments in the valley is likely to be at least 60m (see Appendix A.3) at some locations. The thickness probably reduces closer to the schist hills and mountain ranges.

At the Production Bore, bore log descriptions (Appendix A.3) generally show a very thin layer of gravel (<1m thick) at the surface, underlain fine grained silts and clays to 2.5m to 3.6m, then silty and sandy gravels down to approximately 37m. The geological descriptions in the nearby Monitoring Bore, BH1 and BH2 are very similar.

## 2.2 Bore Drilling and Construction

Construction details of the Production Bore, Monitoring Bore, and two bores, BH1 and BH2 that have been filled are provided Table 2-1 and Appendix A.3.

Table 2-1: Bore construction details

| Details | Production Bore (F42/0150) | Monitoring Bore | BH1 | BH2 |
|---|---|---|---|---|
| Diameter (mm) | 300 | 50 | 75 | 75 |
| Cased depth (m) | 35.8 | 35.7 | 37 | 36 |
| Screened interval (mBGL) | 29.8 – 35.8 | ? | None | None |
| Static water level (mBGL) | -0.59 | -0.45 | -0.3 | +2.1 (artesian) |
| Easting (NZTM2000) | 1264612 | 1264607 | 1264620 | 1264554 |
| Northing (NZTM2000) | 4998187 | 4998193 | 4998175 | 4998269 |
| Distance to Production Bore (m) | n/a | 15 | 14 | 100 |

BH1 and BH2 were constructed in December 2015 (by McNeil Drilling) as part of an initial investigation to determine the groundwater characterises at the site. The Production Bore and adjacent Monitoring Bore (15m away) were drilled by South Drill between the 6th and 17th of July 2017. Both bores are drilled to a similar depth of approximately 35.8m. The Production Bore is

[1] Turnbull, I.M. (compiler) (2000). Geology of the Wakatipu area: scale 1:250,000. Lower Hutt: Institute of Geological & Nuclear Sciences. Institute of Geological & Nuclear Sciences 1:250,000 geological map 18. 72 p. + 1 folded map.

screened from 29.8m to 35.8m into sandy and silty gravels overlain by silt and a thin layer of coarse gravels.

On completion, the Production Bore and Monitoring Bore had static water levels of 0.59 meters below ground level (mBGL) and 0.45mBGL respectively. The water levels extend approximately 1.5m above the top of the silty and sandy gravel aquifer screened by the Production Bore and into a relatively thin (approximately 3m thick) layer of silts that overlies the aquifer.

At BH1 (37m deep), 100m from the Production Bore, an artesian head of 2.1m above ground level was recorded. This suggests that the aquifer is confined to some degree. During drilling of the Production Bore, Monitoring Bore, BH1 and BH2 (36m deep), Graeme Stewart from South Drill commented that groundwater was only encountered in the silty gravels, suggesting that a shallow aquifer overlying that screened by the Production Bore is unlikely to exist near the site.

On completion, the Production Bore was pumped at a rate of 34L/s for 30min with a maximum drawdown of 17.9m.

## 2.3 Existing Bores

There are 16 bores within an approximately 6km radius of the Production Bore and five bores within a 3.2km radius. Details of the bores are listed in Appendix B.1 and the locations are shown in Appendix B.2. Most of the bores are used for domestic supply (see Appendix B.3). Within 3.2km of the Production Bore, all bores are used for domestic supply apart from one (F41/0324) located 1.7km away that is used for irrigation. The existing bores range from approximately 10m to 62m depth (see Appendix B.4). On completion of drilling, the pumping rates from existing bores varied from 0.7L/s to 10L/s with most bores pumping at a rate no greater than 4L/s (see Appendix B5).

## 2.4 Groundwater Chemistry

Water samples have been taken from the Production Bore and analysed for a comprehensive suite of analytes to determine the suitability of the water for drinking and to characterise the groundwater. The results also provide a means of determining any water treatment that may be required. A water sample was also taken from Lake Wakatipu and analysed for the major ions in order compare with groundwater in the aquifer. A summary of the results and laboratory certificates are provided in Appendix C.

The results show that the groundwater is of high quality and none of the analytes exceed or occur within 50% of the Maximum Acceptable Value (MAV) or aesthetic Guideline Values (GV) for human drinking water.

The pH, hardness and Langlier Saturation Index indicate that corrosion or scale build up are unlikely to occur.

Nitrate-N of 1.2mg/L in the groundwater is well below the MAV but above the natural background concentration for the nearby Wakatipu aquifers of 0.1mg/L indicating some effect of agricultural / pastoral land uses. Concentrations of phosphorus in groundwater, another analyte indicative of agricultural / pastoral land uses are below detection limits indicating potentially low levels of effect.

The major ion chemistry is very similar between Lake Wakatipu and groundwater abstracted from the Production Bore. Both sources can be classified as a Calcium-Bicarbonate type water. The similar chemistry could indicate a high degree of hydraulic connection between the groundwater and lake and or that the surface water feeding the lake has a similar chemistry to groundwater.

## 2.5 Surface Water

The Production Bore is located 90m from shore of Lake Wakatipu and approximately 100m from the lake itself, depending on the level (see Appendix D). The nearest stream or river is located 220m north-east of the Production Bore, the second closest is located 850m to the south-east. Local residents report that streams in the area are ephemeral and flows increase after large rainfall events, and drop significantly or dry-up over summer. This suggests the streams are primarily fed by rainfall run-off and the hydraulic connection to groundwater would be low. In saying this, the streams may act as a recharge source to groundwater if the water table is below the stream bed.

## 2.6 Aquifer Parameters

### 2.6.1 Step Discharge Test

On the 18th of June 2017, South Drill undertook a six step-discharge test on the Production Bore (F42/0150). Manual flow rate readings were taken and groundwater levels were recorded manually and automatically at 2 minute intervals using a non-vented pressure transducer. Groundwater was discharged directly into Lake Wakatipu through a lay-flat hose to avoid any effects on water levels. No rain was recorded during the test.

The static water level in the Production Bore immediately prior to testing was 0.59mBGL. Results from the step-discharge test are summarised in Table 2-2 and manual readings are provided in Appendix E.1.

Table 2-2: Step-discharge test on the production bore

| Step | Duration (min) | Drawdown at end of Step (m) | Flow Rate (L/s) |
|---|---|---|---|
| 1 | 2 | 1.5 | 2.9 |
| 2 | 12 | 1.95 | 4.0 |
| 3 | 44 | 1.93 | 3.8 |
| 4 | 60 | 3.7 | 8.2 |
| 5 | 60 | 8.0 | 16.8 |
| 6 | 60 | 17.6 | 34.5 |
| Recovery | 200 | - | - |

The data was modelled using Eden & Hazel (1973)[2] for confined aquifers to calculate aquifer Transmissivity (T) and bore efficiency. Observed versus modelled data, along with the resultant T value and bore efficiencies are provided in Appendix E.1.

[2] Eden, R.N., and Hazel, C.P. (1973). Computer and graphical analysis of variable discharge pumping tests of wells. Civ. Eng Trans. Inst. of Eng. Vol 15, 5-10.

A close match could be made to the observation data with a resultant T value of 1,500 $m^2$/d and moderately high bore efficiencies of 61% to 84%.

### 2.6.2 Constant-Discharge Test

#### 2.6.2.1 Test Details

A constant-discharge aquifer test was undertaken between the 19th and 22nd of July 2017. The production bore was pumped for three days at an average constant-discharge of 36L/s. Groundwater levels were monitored in the Production Bore (F42/0150), Monitoring Bore (no bore ID) and Jacks Point Bore (F41/0324). Manual readings were taken from the Production Bore and Monitoring Bore (see Appendix E.3) whilst automatic readings were also taken from the Production Bore, Monitoring Bore and Jacks Point Bore at 2 minute intervals using non-vented transducers. Attempts were made to measure water levels in bores F41/0382, F42/0100 and F42/0103, however lack of access to the bores prevented water levels from being taken.

Barometric pressure was measured automatically on site at 2 minute intervals using a barometric pressure transducer. The data was used to compensate the automated groundwater level data into equivalent manual measurements.

The location of the three bores used in testing are shown in Figure 1-2. The test configuration is summarised in Table 2-3.

Table 2-3: Constant-discharge test details

| Details | Production Bore (F42/0150) | Monitoring Bore (No ID) | Jacks Point Bore (F41/0324) |
|---|---|---|---|
| Purpose | Pumping | Observation | Observation |
| Distance to Pump Bore (m) | n/a | 15 | 1,712 |
| Easting (mE) | 1264612 | 1264607 | 1264635 |
| Northing (mN) | 4998187 | 4998193 | 4999899 |
| Depth (m) | 35.8 | - | 46.6 |
| Screened interval | 28.8 – 35.8 | - | 40.2 – 46.6 |
| Static water level | -0.59 | -0.45 | Not measured |

Would be good to have these locations surveyed.

#### 2.6.2.2 Data Analysis and Corrections

Data and Analysis Presentation

| Data / Analysis | Appendix |
|---|---|
| Manual groundwater level measurements | E.3 |
| Plots showing raw data from the pressure transducers un-corrected for barometric efficiency but compensated for barometric pressure and compared to selected manual readings | E.4 |
| Calculations of barometric efficiency | E.5 |

| | |
|---|---|
| Groundwater levels versus rainfall | E.6 |
| Groundwater levels and corrections | E.7 |
| Plots of the drawdown and recovery | E.8 |
| Aquifer parameters (modelled versus observed data) | E.9 |

### Manual Readings

Manual water level readings from the Production Bore and Monitoring Bore (Appendix E.3) were plotted against logger readings (see Appendix E.4). Both readings correlate well and show an accurate data set.

### Pumping Rate

The pumping rate was recorded manually from a flow meter that was fitted to the Production Bore. The manual readings in Appendix E.3 show a stable flow of 36L/s, thus it is considered that the test results are unlikely to have been affected by changes in the pumping rate.

### Discharge of Pumped Water

Groundwater was conveyed from the bore through a lay flat hose before discharging directly into Lake Wakatipu. Thus it is considered that the discharge of the water did not affect water levels.

### Barometric Pressure

Barometric pressure can cause water levels changes in a bore. This effect can be quantified by determining the barometric efficiency of the aquifer which ranges from 0% and 100%. Confined aquifers typically have high barometric efficiencies and unconfined aquifers typically have barometric efficiency values close to zero.

Through a visual assessment (see Appendix E.5), the barometric efficiency for the Production Bore and Monitoring Bore that produces the smoothest data-set are considered to range from 25% to 50%. Values greater than 50% appear to over correct the data. For the Jacks Point Bore, a barometric efficiency of 75% to 100% results in the smoothest data set.

To check this assessment, changes in groundwater levels were plotted against changes in barometric pressure for specific periods of time. The barometric efficiency was determined for each period by the slope of the linear trend line. Corrections were applied to the background trend which was determined by plotting water levels on different dates which corresponded to a fixed barometric pressure. The assessment was undertaken pre-pumping and post recovery in the Production Bore and Monitoring Bore. The Jacks Point Bore was also assessed during pumping as drawdown effects were considered unlikely (1.7cm maximum predicted drawdown based on worst-case parameters from aquifer test relative to an overall water level variation of 17cm during testing). The results presented in Appendix E.5 show a barometric efficiency of 20%, 29% and 77% for the Production Bore, 21%, 29% and 86% for the Monitoring Bore and 62% to 108% for the Jacks Point Bore.

The two high values for the Production Bore and Monitoring Bore are at odds with the visual assessment, possibly as a result of a non-linear background trend. The barometric efficiencies for the Jacks Point Bore are much higher than other bores which confirms the higher barometric efficiency estimated through a visual assessment.

After considering the two assessments, the water level data was corrected using the following barometric efficiency values assigned to each bore:

- Production Bore – 30%
- Monitoring Bore – 35%
- Jacks Point Bore – 90%

#### Rainfall

Daily rainfall from Queenstown Aero Aws (7.5km north of the test site) was plotted against groundwater levels in each of the bores used in testing (see Appendix E.6). A total of 8.6mm of rainfall was recorded in the nine days prior to pumping, 0.8mm fell on the final day of pumping and 9.8mm fell during the four days after pumping ceased. Based on some small water level rises in the Production Bore and Monitoring Bore soon after the rainfall events, and the overall small 17cm water level change and potentially the lack of correlation between water levels changes and rainfall events observed in the Jacks Point Bore, it is considered that rainfall has had only minor effects on the water levels during testing.

### 2.6.2.3 Groundwater Levels and Drawdown

#### Production Bore

The Production Bore is screened from 29.8m to 35.8m. Groundwater levels dropped by approximately 17.5m after pumping for three days at 36L/s. The barometric efficiency of 35% suggest slightly confined or semi-confined aquifer conditions. Though there was no significant effect from rainfall, the groundwater level three days after pumping ceased (likely point in time when water levels had reached full recovery) was approximately 10cm lower than at the start of pumping. This could indicates a slight downward background trend or incomplete recovery as result of depleting groundwater storage. However, the similar trend observed in the Jacks Point Bore which was unlikely to have been affected by pumping suggests that it is more likely a result of a declining background trend.

The recovery data is much smoother than the drawdown data suggesting that there may have been some small changes in the pumping rate though this was not observed from the manual flow meter readings. The semi-log plot shows a flattening of the drawdown between 100min and 300min after pumping started, this is followed by a steepening of the drawdown then another flattening of the drawdown 1,000min prior to the end of pumping. The changes in slope may be a delayed yield response which can be seen in unconfined or semi-confined leaky aquifers or it could also be due to a combination of small effects from rainfall and changes in the pumping rate that were not recorded between the intervals of measurement. The change in slope can also been seen in the recovery data. Based on the geological materials above and adjacent to the bore screen, it is considered that flattening of the drawdown and recovery curves is most likely the result of leakage to the pumped aquifer.

The background trend can be satisfactorily corrected using either a linear antecedent or 70% of the water level change in the Jacks Point Bore which also showed a slight downward background trend.

### Monitoring Bore

The Monitoring Bore is located 15m from the Production Bore and is screened. Approximately 1.4m of drawdown was observed after three days pumping and the water level after being corrected for the barometric efficiency of the aquifer was approximately 11cm lower at the end of recovery than it was at the start of pumping. This downward background trend was also observed in the Production Bore and Jacks Point Bore.

The drawdown shown on a semi-log plot is similar to that which can occur in an unconfined aquifer. However, given that water levels are near ground level and above the confined layer of the aquifer, it is considered that this response is more likely to be delayed yield response from a leaky aquifer as shown in Figure 2-1.

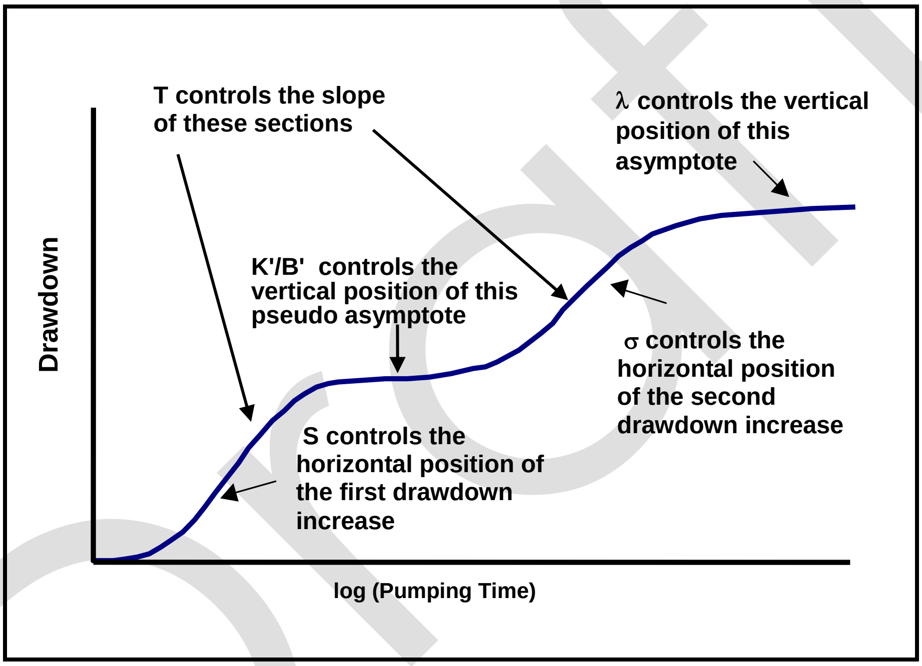



Figure 2-1: Characteristic drawdown curve indicating parameter influence for a well screened in a leaky confined aquifer with stream depletion effects (source Aitchison-Earl and Smith, 2008[3])

The water level response in the monitoring bore is considered to have gone through all of the stages shown in Figure 2-1 apart from the final stage of flattening drawdown which in theory can be the result (in the case of Figure 2-1) of surface water depletion controlled by the stream or lake bed conductance termed lambda (Λ). It is possible that further pumping could show surface water depletion. The most likely source is considered to be Lake Wakatipu given it is the closest water body (90m to 100m) to the bore, its large area, similar water chemistry to the pumped aquifer and the ephemeral nature of nearby streams which make them less likely to be in direct hydraulic connection with the aquifer.

The initial flattening of the drawdown curve controlled by K'/B' and then stepping of the drawdown curve controlled by the specific yield of the aquitard (σ) may have occurred as a result

[3] Aitchison-Earl, P. and Smith, M. (2008). Aquifer test guidelines (2nd edition). Prepared by Environment Canterbury. Report No. R08/25. July 2008.

of dewatering the overlying low permeability material, or from leakage of lower permeability material beneath the pumped aquifer.

Like the Production Bore, the background trend can be satisfactorily corrected using either a linear antecedent or 60% of the water level change in the Jacks Point Bore.

#### Jacks Point Bore

Jacks Point Bore (F41/0324) is an un-used irrigation bore screened from 40.2m to approximately 46.6m and located 1,712m from the Production Bore, further up the valley and away from Lake Wakatipu (see Figure 1-1). Water levels in this bore show a clear effect from changes in barometric pressure. The barometric efficiency was calculated to be 90% which is relatively high and indicative of confined aquifer conditions.

Water levels in the Jacks Point Bore varied by 17cm over the entire period of monitoring. In contrast, the predicted drawdown in this bore at the end of 3 days pumping using the most conservative range of aquifer parameters (discussed later in the report) was 1.7cm. Water levels started to decline from approximately half a day prior to pumping, during pumping and then stabilised just prior to the cessation of pumping. Given the water level decline prior to pumping, stabilisation prior to the cessation of pumping, lack of obvious water level recovery and small amount of drawdown predicted relative to the overall change in water levels, it is considered that the data is largely indicative of the natural background trend in the aquifer. As such, it provided a useful means of correcting for the background trend in the Production Bore and Monitoring Bore.

#### Summary and Conclusions

A summary of the drawdown and data corrections applied to each bore is provided in Table 2-4. The results show that drawdown in the Production Bore and Monitoring Bore is much greater than the data corrections applied, thus providing a high level of confidence to the final drawdown and recovery used to determine the hydraulic properties of the aquifer.

Table 2-4: Maximum corrections applied to each bore

| Details | Production Bore | Monitoring Bore | Jacks Point Bore |
|---|---|---|---|
| Uncorrected drawdown (m) | 17.61 | 1.40 | n/a |
| Barometric corrected drawdown (m) | 17.64 | 1.44 | n/a |
| Barometric correction (m) | 0.1 | 0.11 | 0.29 |
| Background trend correction (m) | 0.1 | 0.11 | n/a |
| Total corrections applied (m) | 0.2 | 0.22 | 0.29 |
| Barometric efficiency (%) | 30 | 35 | 90 |

### 2.6.2.4 Hydraulic Parameters

The drawdown and recovery data were modelled using a range of analytical equations to determine the aquifer hydraulic properties. The drawdown and recovery is considered to show a typical semi-confined leaky aquifer response. Results of modelling also suggest the potential for surface water depletion.

As such, data from the Production Bore and Monitoring Bore were analysed using a range of models including Theis (for confined aquifers), Hantush-Jacob (1955)[4] (for semi-confined aquifers), Functions W_12 from Hunt (2012)[5] for drawdown in a semi-confined aquifer and W_4 from Hunt (2012) for drawdown in a semi-confined aquifer, overlain by an aquitard and adjacent to a surface water body. The results of these analyses are shown in Appendix E.9 and summarised in Table 2-5 for the Monitoring Bore and Table 2-6 for the Production Bore.

Table 2-5: Hydraulic parameters modelled from the Monitoring Bore

| Details | T ($m^2$/d) | S (-) | Sy (-) | Ss (-) | **K'/B' (d)** | $T_o$ ($m^2$/d) | **Λ (m/d)** | q/Q[3] |
|---|---|---|---|---|---|---|---|---|
| **Hunt (W_12)** | | | | | | | | |
| Linear trend[1] | 1,200 | 0.002 | 0.02 | 0.00003 | 0.018 | 1,200 | - | - |
| Jacks Point Bore[2] | 1,450 | 0.0009 | 0.02 | 0.00001 | 0.0055 | 1,500 | - | - |
| **Hunt (W_4)** | | | | | | | | |
| Jacks Point Bore | 1,425 | 0.001 | 0.023 | n/a | 0.008 | n/a | 0.01 | 0.002 |
| Jacks Point Bore | 1,425 | 0.001 | 0.023 | n/a | 0.008 | n/a | 0.1 | 0.02 |
| Jacks Point Bore | 1,425 | 0.001 | 0.01 | n/a | 0.0045 | n/a | 2 | 0.34 |

[1] Data corrected using a linear antecedent trend

[2] Data corrected using the background trend in Jacks Point Bore

[3] q/Q is the ratio of stream depletion (q) divided by the pumping rate (Q) after 3 days continuous pumping

Table 2-6: Hydraulic parameters modelled from the Production Bore

| Details | Match to | T ($m^2$/d) | S (-) | Sy (-) | Ss (-) | **K'/B' (d)** | $T_o$ ($m^2$/d) |
|---|---|---|---|---|---|---|---|
| Hunt (W_12) | Drawdown | 1,400 | - | - | - | 0.02 | - |
| | Recovery | 700 | - | - | - | 0.001 | - |
| Eden-Hazel (1973) | Drawdown and recovery | 1,500[1] | - | - | - | - | - |

[1] Value determined from step-discharge test



[4] Hantush, M.S. and C.E. Jacob, (1955). Non-steady radial flow in an infinite leaky aquifer, Am. Geophys. Union Trans., vol. 36, pp. 95-100.

[5] Hunt (2012). Groundwater analysis using Function .xls. Civil Engineering Department, Canterbury University. January 14, 2012.

Overall, the best matches could be made to both the recovery and drawdown data using W_12, then W_4. The poorest match was made using Theis, followed by Hantush-Jacob. The reason for this is that Theis did not account for leakage and Hantush-Jacob did not account for the aquitard dewatering. Overall, the results from the Monitoring Bore corrected using a linear trend versus background trend in Jacks Point Bore are similar as shown using W_12. This is partly due to the small corrections applied relative to the measured drawdown. W_12 also includes a Transmissivity (T) for an overlying aquifer (To) however, in this case, the model was insensitive to To, and hence suggests that there is no overlying aquifer present as appears to be the case from bore log descriptions and observations made during drilling.

Transmissivity values for the pumped aquifer are similar between all models used and corrections applied, and ranged from 1,200m$^2$/d to 1,500m$^2$/d, apart from the recovery data from the Production Bore which appears to be an anomaly. At these values, the aquifer is considered to be relatively permeable. The T values are also within the range of T values calculated using specific capacity data and the Theis model as shown in Appendix E.9.

Storativity (S) values range from 0.0009 to 0.002 and are indicative of confined to semi-confined aquifer conditions, rather than un-confined aquifers which would be expected to have a much higher storage (or specific yield) value.

Leakage (K'/B') to the pumped aquifer ranges from 0.0045d to 0.18d as determined from the Monitoring Bore data and 0.001d to 0.02d from the Production Bore. These leakage rates are relatively high and indicate a potential connection to hydraulically connected surface water bodies. This was one of the reasons for also using W_4.

The specific yield of the aquitard material overlying and possibly underlying the aquifer ranges from 0.01 to 0.023 and is within the lower range for silts and clays (Fetter, 2001)[6] which matches the description of silts overlying the pumped aquifer as described in the bore logs.

Lambda (Λ) in W_4 is a term used to describe the conductance of material beneath a hydraulically connected surface water body. High rates of Λ mean more water to the pumped aquifer is potentially sourced from surface water and vice versa. Through trial and error, the maximum Λ value whilst still maintaining a good fit to the measured data was 2m/d whilst values down to 0.001m/d or less would also produce a similar fit. At 2m/d, surface water depletion would be high but at values less than 0.01m/d, surface water depletion would be very low or close to zero. The non-uniqueness in matching to the measured data makes it difficult to determine the actual surface water depletion effect (if any), however, the analysis does suggest that the potential for surface water depletion does exist.

## 2.7 Maximum Sustainable Yield

An assessment of the maximum sustainable yield from the Production Bore is provided in Appendix F. An important step in determining the maximum yield is to calculate the maximum available drawdown. In this case, the available drawdown has been calculated as the lowest pumping water level of 22.8mBGL (allowing 6m of water above the top of the screen to account for the pump intake and leader), minus the lowest static water level of 1.5mBGL (this is 1.0m lower than that measured during the constant-discharge testing) which equals 22.3m.

[6] Fetter, C.W. (2001). Applied hydrogeology (4th Ed). New Jersey. Prentice Hall.

An extrapolation of the constant-discharge drawdown curve in the Production Bore shows that pumping at a rate of 36L/s for a continuous period of 27 years results in an increase from 17.5m drawdown after 3 days to between 18.4m and 19.4m (see Appendix F.1). The lesser drawdown is based on extrapolation of the drawdown corrected using the background trend in the Jacks Point Bore. The greater drawdown is based on the data corrected using a linear antecedent trend. Overall the total drawdown would be 18.4m to 19.4m which is within the maximum available drawdown of 22.3m.

The maximum sustainable yield was also assessed from the step-discharge using Eden-Hazel. This equation allows an estimation of the drawdown at different pumping rates based on the laminar and turbulent losses in the aquifer and bore. Based on this analysis (see Appendix F.2) the maximum sustainable yield after 365 days continuous pumping is 40L/s. In reality, the maximum sustainable yield may be higher as Eden-Hazel does not account for leakage and hence the equation will give higher drawdown with time. However, the conservatism of this analysis may account for the likely reduction in yield and increased drawdown over time due to corrosion of the screen, build-up of fine sediment around the outside of the screen and potential increased drawdown if the cone of depression intercepted a barrier to groundwater flow.

# 3 Planning Legislation

Paragraph here on the rule we will apply under once we confirm the annual volume.

Table 3-1: Objectives and policies under Chapters 5, 6 and 9 of the Regional Water Plan

| Objective /Policy | Wording | Comment |
|---|---|---|
| Policy 5.4.2 | *In the management of any activity involving surface water, groundwater or the bed or margin of any lake or river, to give priority to avoiding, in preference to remedying or mitigating:*<br>*(1) Adverse effects on:*<br>*(a) Natural values identified in Schedule 1A;*<br>*(b) Water supply values identified in Schedule 1B;*<br>*(c) Registered historic places identified in Schedule 1C, or archaeological sites in, on, under or over the bed or margin of a lake or river;*<br>*(d) Spiritual and cultural beliefs, values and uses of significance to Kai Tahu identified in Schedule 1D;*<br>*(e) The natural character of any lake or river, or its margins;*<br>*(f) Amenity values supported by any water body; and* | It is considered that the proposed groundwater take will not adversely affect water levels or storage in Lake Wakatipu. If there is a significant hydraulic connection between the lake and pumped aquifer, the volume of surface water depletion will be significantly less than lake storage and lake inflows. |
| Policy 5.4.3 | *In the management of any activity involving surface water, groundwater or the bed or margin of any lake or river, to give priority to avoiding adverse effects on:*<br>*(a) Existing lawful uses; and*<br>*(b) Existing lawful priorities for the use of lakes and rivers and their margins.* | It is considered that the proposed groundwater take will not adversely affect water levels or storage in Lake Wakatipu. If there is a significant hydraulic connection between the lake and pumped aquifer, the volume of surface water depletion will be significantly less than lake storage and lake inflows.<br>An assessment of drawdown in all bores within a 3,256m radius of the Production Bore was undertaken in accordance with Schedule 5B. Of the four bores within this area, the predicted drawdown exceeds the 0.2m cut-off for unconfined aquifers for three of the bores (F41/0382, F41/0100 and F41/0103). For the remaining bore F41/0324 which is considered to be screened into a confined aquifer, the maximum predicted drawdown using aquifer parameter values |

| Objective /Policy | Wording | Comment |
|---|---|---|
| | | determined from the constant-discharge test is less than the 1m cu-off. |
| Issue 6.2.1A | *The taking of water from Otago's aquifers can lead to:*<br>*(a) Long term depletion of groundwater levels and water storage volume; and*<br>*(b) Loss of artesian conditions; and*<br>*(c) Short and long term depletion of surface water; and*<br>*(d) Contamination of groundwater or surface water resources; and*<br>*(e) Aquifer compaction.* | (a) Though the proposed abstraction in addition to existing groundwater takes amounts to approximately 54% of the recharge from rainfall, the constant-discharge test is considered to show that recharge from additional sources is likely. In addition, the long term change in aquifer storage is predicted to be small based on the results of the constant-discharge test.<br>(b) The aquifer is not artesian but the water level is higher than the top of the aquifer. Drawdown as a result of pumping was only 1.4m at a distance of 15m from the Production Bore after 3 days pumping and would be expected to decline up to 1m more by pumping at 40L/s over a long duration. Further from the Production Bore, the change in groundwater level will get smaller. Hence the aquifer water level may drop below the potential confining layer at the Production Bore but at a distance greater than 50m from the Production Bore, the change in water level will be relatively small.<br>(c) Surface water depletion from nearby streams is considered unlikely given there ephemeral nature.<br>Surface water depletion is possible from Lake Wakatipu. The amount of depletion is unclear from the results of the constant-discharge test but could range from zero through to 38L/s when pumping at a rate of 40L/s. Given the storage volume of the lake in comparison to the volume of the take, any effects on the lake will be less than minor.<br>(d) The Production Bore has been constructed to NZ Standards for bore construction. The annulus has been grouted and the bore is capped to ensure that it is secure from surface contamination. In the future, the bore head will be designed in a way that prevents |

| Objective /Policy | Wording | Comment |
|---|---|---|
| | | any surface contamination or backflow of water or contaminants into the aquifer.<br><br>The water itself will be used for community drinking water for residential development. Residential developments can produce contaminants that may enter groundwater but if properly managed it is considered that the risks to groundwater quality will be low.<br><br>Surface water quality is unlikely to be affected as the take is from groundwater and the streams are not likely to be connected to the aquifer.<br><br>(e) Aquifer settlement and compaction is unlikely to be significant given the dominant aquifer material is gravel. |
| Issue<br><br>6.2.4A | *The taking of water from one bore can lower the water level in neighbouring bores.* | Between 0.2m and 0.73m of drawdown has been modelled as potentially occurring in existing neighbouring bores located within the defined groundwater allocation zone as a result of the proposed take.<br><br>An assessment of drawdown in all bores within a 3,256m radius of the Production Bore was undertaken in accordance with Schedule 5B. Of the four bores within this area, the predicted drawdown exceeds the 0.2m cut-off for unconfined aquifers for three of the bores (F41/0382, F41/0100 and F41/0103). For the remaining bore F41/0324 which is considered to be screened into a confined aquifer, the maximum predicted drawdown using aquifer parameter values determined from the constant-discharge test is less than the 1m cu-off. |
| Objective<br><br>6.3.1 | *To retain flows in rivers sufficient to maintain their life-supporting capacity for aquatic ecosystems, and their natural character.* | Surface water depletion from nearby streams is considered unlikely given they are ephemeral. |

| Objective /Policy | Wording | Comment |
|---|---|---|
| Objective 6.3.2 | *To maintain long term groundwater levels and water storage in Otago's aquifers.* | Though the proposed abstraction in addition to existing groundwater takes amounts to approximately 54% of the recharge from rainfall, the constant-discharge test is considered to show that recharge from additional sources is likely. In addition, the long term change in aquifer storage is predicted to be small based on the results of the constant-discharge test.<br><br>It is proposed that groundwater levels and flow be measured on a continuous basis as part of the granting of this consent and that after an initial 6 months of continuous or near continuous pumping that an assessment of the longer term trends in water levels be undertaken to monitor whether or not the take is causing a long-term decline. |
| Policy 6.4.1A | *A groundwater take is allocated as:*<br><br>*(a) Surface water, subject to a minimum flow, if the take is from any aquifer in Schedule 2C; or*<br><br>*(b) Surface water, subject to a minimum flow, if the take is within 100 metres of any connected perennial surface water body; or*<br><br>*(c) Groundwater and part surface water if the take is 100 metres or more from any connected perennial surface water body, and depletes that water body most affected by at least 5 litres per second as determined by Schedule 5A; or*<br><br>*(d) Groundwater if (a), (b) and (c) do not apply.* | (a) The groundwater take does not occur from any aquifer in Schedule 2C.<br><br>(b) The groundwater take is 90m from the shore of Lake Wakatipu and approximately 100m from the water's edge depending on the level of water in the lake. The aquifer is leaky and some water may be sourced from the lake however the amount of surface water depletion is currently unknown.<br><br>(d) As a result of the uncertain nature of any surface water depletion, the groundwater take has also been assessed against the relevant groundwater policies. |
| Policy 6.4.1 | *Surface Water Takes and Connected Groundwater Takes*<br><br>*To enable the taking of surface water, by:*<br><br>*(a) Defined allocation quantities; and*<br><br>*(b) Provision for water body levels and flows,* | While the taking of groundwater may be considered as a surface water take due to its proximity to Lake Wakatipu, Policy 6.4.1 outlines that it will not be subject to compliance with defined allocation limits or restrictions relating to the level of the lake. |

| Objective /Policy | Wording | Comment |
|---|---|---|
| | *except when:*<br>*(i) The taking is from Lakes…Wakatipu…* | |
| Policy 6.4.10A1 | *6.4.10A1 Enable the taking of water allocated as groundwater by Policy 6.4.1A, by:*<br>*(a) Determining the volume available for taking as the maximum allocation limit less the assessed maximum annual take for an aquifer calculated using Method 15.8.3.1; and*<br>*(b) Applying aquifer restrictions where specified in Schedule 4B.* | (a) For the one bore which has a resource consent, the volume of groundwater taken, was based on the annual consented volume as per Method 15.8.3.1.<br>For the remaining bores that do not have a consent to take and use groundwater, it was assumed that each bores takes up to 25,000L/d every day of the year (consistent with the permitted activity rule).<br>The total volume from existing groundwater takes is 237,980m$^3$/yr, from the proposed take is 1,261,440m$^3$/yr (taking at 40L/s, 24hrs per day for 365 days) and combined is 1,499,420m$^3$/yr in comparison to a modelled recharge to the aquifer from rainfall only 2,756,079m$^3$/yr. Thus the total groundwater take would be 54% of the annual rainfall recharge.<br>(b) Schedule 4B does not apply as the proposed take does not occur within the aquifers to which this schedule applies. |
| Policy 6.4.10A2 | *Define the maximum allocation limit for an aquifer as:*<br>*(a) That specified in Schedule 4A; or*<br>*(b) For aquifers not in Schedule 4A, 50% of the mean annual recharge calculated under Schedule 4D.* | (a) The take does not occur in an allocation zone listed in Schedule 4A hence the allocation was estimated for a defined area.<br>(b) The annual allocation based on land surface recharge from rainfall is estimated to be 2,756,079m$^3$. The proposed take in combination with existing takes would amount to a total abstraction of 1,499,420m$^3$ or 54% of this allocation from rainfall recharge when taking at 40L/s, 24hrs per day for 365 days. |
| Policy 6.4.10A5 | *In managing the taking of groundwater, avoid in any aquifer:*<br>*(a) Contamination of groundwater or surface water; and* | (a) Groundwater contamination from sources entering the aquifer through the bore is considered unlikely as the bore and current bore |

| Objective /Policy | Wording | Comment |
|---|---|---|
| | *(b) Permanent aquifer compaction.* | head is secure and the bore has been constructed in accordance with NZS4411:2001.<br>The water will be used for community drinking water supply rather than more irrigation which is often associated with more intensive land use and associated risks for groundwater contamination.<br>(b) The aquifer from is predominantly composed of gravel with some silt. Gravels have a high (modulus) elasticity and the area of high drawdown is limited to that near the bore, thus the potential for settlement and compaction as a result of the abstraction is considered to be less than minor. |
| Policy 6.4.10AC | *To avoid aquifer contamination by:*<br>*(a) Recognising contaminated sites;*<br>*(b) Identifying areas vulnerable to seawater intrusion;*<br>*(c) Setting maximum allocation limits;*<br>*(d) Setting aquifer restriction levels;*<br>*(e) Restricting takes; and*<br>*(f) Requiring monitoring of groundwater quality and levels.* | (a) There are no contaminated sites known within at least 10km radius of the proposed take<br>(b) The proposed take is located at least 100km from the coast. Based on this separation distance, there is considered to be no risk of a landward shift of the freshwater / seawater interface and therefore the effects from seawater intrusion are considered to be less than minor.<br>(c) The proposed take of 40L/s is in addition to all existing groundwater takes is equivalent to 54% of allocation limit based on recharge to the aquifer from rainfall only.<br>(d) No groundwater level restrictions have been set or proposed for this allocation zone.<br>(e) No groundwater level restrictions have been set or proposed for this allocation zone.<br>(f) Regular water quality monitoring will be undertaken. In addition, the flow in the Production Bore will be continuously monitored and groundwater levels will be recorded automatically in the Production |

| Objective /Policy | Wording | Comment |
|---|---|---|
| | | Bore and Monitoring Bore in order to ass the long-term effects on groundwater storage. |
| Policy 6.4.10B | *In managing the taking of groundwater, to have regard to avoiding adverse effects on existing groundwater takes, unless the approval of affected persons has been obtained.* | From the bore interference assessment based on Schedule 5B, it is considered bore F41/0382, F42/0100 and F42/0103 would be adversely affected by the proposed take. |
| Policy 6.4.16 | *In granting resource consents to take water, or in any review of the conditions of a resource consent to take water, to require the volume and rate of take to be measured in a manner satisfactory to the Council unless it is impractical or unnecessary to do so.* | The volume and rate of take will be monitored continuously at 15min intervals from the Production Bore and groundwater levels will be monitored continuously at 15min intervals in the Production Bore and Monitoring Bore. |
| Policy 6.4.19 | *When setting the duration of a resource consent to take and use water, to consider:*<br>*(a) The duration of the purpose of use;*<br>*(b) The presence of a catchment minimum flow or aquifer restriction level;*<br>*(c) Climatic variability and consequent changes in local demand for water;*<br>*(d) The extent to which the risk of potentially significant, adverse effects arising from the activity may be adequately managed through review conditions;*<br>*(e) Conditions that allow for adaptive management of the take and use of water;*<br>*(f) The value of the investment in infrastructure; and*<br>*(g) Use of industry best practice.* | (a) 20 year consent is sought to take and use groundwater for community supply.<br>(b) None exist in this catchment.<br>(c)<br>(d)<br>(e)<br>(f)<br>(g) |
| Policy 6.4.0A | *To ensure that the quantity of water granted to take is no more than that required for the purpose of use taking into account:* | |

| Objective /Policy | Wording | Comment |
|---|---|---|
| | *(a) How local climate, soil, crop or pasture type and water availability affect the quantity of water required; and*<br>*(b) The efficiency of the proposed water transport, storage and application system.* | |
| Policy 6.4.0C | *To promote and give preference, as between alternative sources, to the take and use of water from the nearest practicable source.* | Aquifer is nearest practicable source. |

Table 3-2: Rules under Chapter 12 of the Regional Water Plan

| Rule | Wording | Activity Type | Comment |
|---|---|---|---|
| 12.2.2.0 | - | Permitted | Does not apply as consent is for a new take. |
| 12.2.2.1 | - | Permitted | The proposed daily volume is greater than 25,000L. |
| 12.2.2.2 | - | Permitted | Water is taken from within 90m to 100m from a lake. |
| 12.2.2.3 | - | Permitted | Applies to pump testing. |
| 12.2.2.4 | *Except as provided for by Rule 12.2.1.1, the taking and use of groundwater from within 100 metres of the main stem of the Clutha/Mata-Au or Kawarau Rivers, or from within 100 metres of Lakes Wanaka, Hawea, Wakatipu, Dunstan or Roxburgh, is a permitted activity, providing:*<br>*(a) The take does not exceed 100 litres per second, nor 1,000,000 litres per day; and*<br>*(b) No more than one such take occurs per landholding; and*<br>*(c) No back-flow of any contaminated water occurs to the water body; and* | Permitted | The proposed groundwater take is 90m from the shore of Lake Wakatipu and approximately 100m from the water's edge depending upon the water level in the lake.<br>(a) The take will not exceed 100L/s but the proposed maximum daily volume (of 3,715,200L/d is greater than 1,000,000L/d.<br>(b) The take is to be used for residential development with multiple dwellings.<br>(c) The bore will in the future be installed with back-flow prevention. |

| Rule | Wording | Activity Type | Comment |
|---|---|---|---|
| | *(d) The take is not within 100 metres of any wetland or other lake or river; and*<br><br>*(e) No lawful take of water, and no wetland or other lake or river, is adversely affected as a result of the taking.* | | (d) The take is not within 100 metres of any wetland or other lake or river; and.<br><br>(e) The nearest surface water take within an approximately 2km to 6km radius of the proposed take (shown in Appendix G.3) is from Lake Wakatipu at a location 400m to the north-west at a rate of up to 225L/s.<br><br>Effects on the lake and its existing takes are considered to be less than minor given (even if surface water depletion is high) because the lake storage and inflows are much greater than the proposed take.<br><br>There are no surface water takes from streams within a 2km to 6km radius of the proposed take. In addition, stream depletion is not considered unlikely given there ephemeral nature. |
| 12.2.2.5 | *Except as provided for by Rules 12.2.1.1 to 12.2.2.4, the taking and use of groundwater from:*<br><br>*(i) Any aquifer listed in Schedule 2C; or*<br><br>*(ii) Within 100 metres of any wetland, lake or river,*<br><br>*for no more than 3 days in any one month, is a permitted activity, providing:*<br><br>…. | Permitted | The proposed take will occur for more than 3 days in any one month. |
| 12.2.2A | *Unless covered by Rule 12.2.1A.1, the taking and use of groundwater for community water supply, by any take identified in Schedule 3B, up to any volume or rate listed in Schedule 3B, is a controlled activity.* | Controlled | The proposed take is not identified in Schedule 3B. |

| Rule | Wording | Activity Type | Comment |
|---|---|---|---|
| 12.2.3.1A | *Unless covered by Rule 12.2.1A.1, the taking of groundwater from any Schedule 2C aquifer or from within 100 metres of any connected perennial surface water body, and the use of that groundwater, is a restricted discretionary activity, if all the standards and terms set out under Rules 12.1.4.1 to 12.1.4.7 that apply to the proposed taking and use are met, as if the take is surface water, except that any date should be read as 10 April 2010.*<br><br>*The matters to which the Otago Regional Council has restricted the exercise of its discretion are set out in Rule 12.1.4.8* | Restricted Discretionary | It is not certain whether take is connected to Lake Wakatipu. If it is then the take is covered under this rule. If not, then it is covered by the rule below. |
| 12.2.3.2A | *Except as provided for by 12.0.1.3, 12.2.1A.3 and 12.2.3.1A, the taking and use of groundwater is a restricted discretionary activity, if:*<br><br>*(a) The volume sought is within:*<br><br>*(i) The maximum allocation limit identified in Schedule 4A; or*<br><br>*(ii) 50% of the mean annual recharge calculated under Schedule 4D, for any aquifer not identified in Schedule 4A; or*<br><br>*(iii) That volume specified in an existing resource consent where the assessed maximum annual take of the aquifer exceeds its maximum allocation limit; and*<br><br>*(b) It is subject to any aquifer restriction identified in Schedule 4B; and*<br><br>*(c) Where the rate of surface water depletion is greater than 5 l/s, as calculated using Schedule 5A:*<br><br>*(i) Primary surface water allocation is available; and*<br><br>*(ii) For the Waitaki catchment, allocation to activities set out in Table 12.1.4.2 is available.* | Restricted Discretionary | (a) The annual volume sought is 1,261,440m$^3$ which is equal to 54% (including existing groundwater takes) of the annual recharge from rainfall.<br><br>However, it is considered that the constant-discharge test shows significant leakage which likely means that recharge to the aquifer and annual allocation limit is higher. Based on extrapolation of the drawdown and modelling, the long-term decline in water level is likely to be small 0.4m to 1.2m at the Production Bore itself and less with increasing distance from the bore.<br><br>(c) Based on analysis of the constant-discharge test data, surface water depletion could range from 0L/s to 38L/s over 5 years continuous abstraction. However, significant volumes of primary surface water allocation are available from Lake Wakatipu. |

| Rule | Wording | Activity Type | Comment |
|---|---|---|---|
| 12.2.3.4 | *Restricted discretionary activity considerations*<br><br>*In considering any resource consent for the taking and use of groundwater in terms of Rule 12.2.3.2A, the Otago Regional Council will restrict the exercise of its discretion to the following:*<br><br>*(i) The maximum allocation limit for the aquifer; and*<br><br>*(iA) The assessed maximum annual take for the aquifer; and*<br><br>*(ii) The mean annual recharge of the aquifer; and*<br><br>*(iii) The effect of the take on the hydrodynamic properties of the aquifer and the vulnerability of the aquifer to compaction; and*<br><br>*(iv) Whether any part of the take would constitute allocation from any connected perennial surface water body, and the availability of that allocation; and*<br><br>*(v) The rate, volume, timing and frequency of groundwater to be taken and used; and*<br><br>*(vi) The proposed methods of take, delivery and application of the groundwater taken; and*<br><br>*(vii) The source of groundwater available to be taken; and*<br><br>*(viii) The location of the use of the groundwater, when it will be taken out of a local catchment; and*<br><br>*(ix) In the case of takes from an aquifer identified in Schedule 4B, the restrictions for the aquifer (as identified in that schedule) to be applied to the take of groundwater, if consent is granted; and*<br><br>*(x) The consent being exercised or suspended in accordance with any Council approved rationing regime; and*<br><br>*(xi) Any adverse effect on the existing quality of groundwater in the aquifer; and* | Restricted Discretionary | See discussion in sections 2 and 4 of this report.<br><br>Note that if aquifer is connected to Lake Wakatipu them the matters outlined in rule 12.1.4.8 are discussed in Sections 2 and 4 of report. |

| Rule | Wording | Activity Type | Comment |
|---|---|---|---|
| | *(xii) Any irreversible or long term degradation of soils arising from the use of water for irrigation; and*<br><br>*(xiii) Any actual or potential effects on any surface water body; and*<br><br>*(xiv) Any adverse effect on the habitat of any indigenous freshwater fish species that are listed in Schedule 1AA; and*<br><br>*(xv) Any effect on any Regionally Significant Wetland or on a regionally significant wetland value; and*<br><br>*(xvi) Any financial contribution for regionally significant wetland values or Regionally Significant Wetlands that are adversely affected; and*<br><br>*(xvii)Any adverse effect on any lawful take of water, if consent is granted, including potential bore interference; and*<br><br>*(xviii)Whether the taking of water under a water permit should be restricted to allow the exercise of another water permit; and*<br><br>*(xix) Any arrangement for cooperation with other takers or users; and*<br><br>*(xx) Any water storage facility available for the groundwater taken, and its capacity; and*<br><br>*(xxi) The duration of the resource consent; and*<br><br>*(xxii)The information, monitoring and metering requirements; and*<br><br>*(xxiii)Any bond; and*<br><br>*(xxiv)The review of conditions of the resource consent; and*<br><br>*(xxv) For resource consents in the Waitaki catchment the matters in (i) to (xxi) above, as well as matters in Policies 6.6A.1 to 6.6A.6.* | | |

| Rule | Wording | Activity Type | Comment |
|---|---|---|---|
| 12.2.3.5 | *The suspension of takes* | Restricted Discretionary | |

# 4 Assessment of Environmental Effects

## 4.1 Groundwater Quantity

### 4.1.1 Allocation Limits

The greatest potential effect is considered to be on groundwater storage. If groundwater is taken from the aquifer at a rate which exceeds aquifer inflows then groundwater levels (and storage) will decline over time. This could affect existing groundwater users, groundwater fed streams, any discharge of groundwater to Lake Wakatipu and the ability of the bore itself to deliver the required yield.

Under Rule 12.2.1A.3 (Chapter 12 of the Regional Water Plan), the bore does not occur in any aquifer identified in Schedule 4A or 4B. For any aquifer not included in Schedule 4A, the allocation limit must be calculated as per Schedule 4D.

The following sections assess aquifer recharge, to provide a basis for assessing effects on groundwater storage.

#### 4.1.1.1 Rainfall Recharge

As a conservative initial estimate, an allocation limit has been derived based solely on rainfall recharge, using a soil moisture model and assuming that the areal extent of the aquifer covered the Q1k and Q2 alluvium material shown in Appendix A and delineated in Appendix G.1.

The soil moisture model was based on FAO No. 56 by Allen et al (1998)[7]. Model inputs included daily rainfall, daily Potential Evapotranspiration (PET) and information on the soil Profile Available Water (PAW).

Daily rainfall was sourced from Queenstown Aero Aws (NIWA site 5451) and daily evapotranspiration was sourced from a combination of two sites, Queenstown (NIWA site 5446) and Queenstown Aero Aws (NIWA site 5451). Data was used for the period 1992 to 2016.

The average soil PAW was sourced from Landcare Research's 'Land Resource Information System Spatial Data Layers' or LRIS. PAW is classified as the total available water for the soil profile to a depth of 0.9 m, or to the potential rooting depth (whichever is the lesser). The areal extent of various soil types overlying the assumed aquifer boundary are shown in Appendix G.1.

Results of the soil moisture modelling are shown Table 4-1.

Table 4-1: Results of soil moisture modelling

| Average Soil PAW | Area Covered | Mean Rainfall | Mean PET | Modelled Rainfall Recharge | | | |
|---|---|---|---|---|---|---|---|
| mm | $m^2$ | mm/yr | mm/yr | mm/yr | $m^3$/yr | L/s[1] | % of Rainfall |
| 45 | 78,433 | 722 | 926 | 184 | 14,442 | 0.5 | 26 |

[7] Allen, R., Pereira, L., Raes, D. and Smith, M. (1998). FAO irrigation and drainage paper. No. 56. Crop evapotranspiration. Guidelines for computing crop water requirements.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 75 | 2,785,921 | 722 | 926 | 154 | 430,418 | 14 | 21 |
| 120 | 19,586,593 | 722 | 926 | 118 | 2,311,218 | 73 | 16 |
| Total | 22,450,947 | - | - | - | 2,756,079 | 87 | - |
| Total x 0.5 | - | - | - | - | 1,378,039 | 44 | - |

[1] L/s based on annual volume taken continuously for one year

The modelled rainfall recharge rates are comparable to those determined through soil moisture modelling by Rekker (2014)[8] for the nearby Wakatipu Basin Aquifers.

As of 22/8/2017 there was only one consented groundwater take (RM11.151.01 related to bore F42/0103) within the allocation zone (shown in Appendix G.1). The annual volume for this take is 91,980$m^3$ however local residents have said that the holder of this consent is now taking water directly from Lake Wakatipu. There are another 16 bores within the allocation zone (see Appendix B.2) that do not have a consent to take groundwater and are predominantly used for domestic or stock water purposes. Assuming that each of these bores takes up to 25,000L/d every day of the year (consistent with the permitted activity rule), then the total annual volume from these 16 bores is 146,000$m^3$. The combined existing groundwater take is therefore estimated to be 237,980$m^3$/yr or 7.5L/s if converted to a continuous rate. Based on Table 4-1, the existing groundwater takes account for 9% of the total rainfall recharge.

For the alluvial aquifers in the Wakatipu Basin, Rekker (2014) proposed groundwater allocation limits based on 50% of the mean annual recharge from all defined sources. Applying this same approach, noting that only rainfall recharge was able to be adequately determined, the total groundwater take including the proposed take (40L/s rate taken for 365 days per year at an annual volume of 1,261,440$m^3$) would be 54% of the allocation limit. Hence to be a potentially sustainable long-term take, there may need to be additional sources of recharge to the aquifer.



#### 4.1.1.2 Other Sources of Recharge

Results from the constant-discharge test showed leakage to the pumped aquifer. This suggests additional sources of water to the aquifer, other than rainfall. These sources may include:

- Surface water, which in this case could be Lake Wakatipu, recharge to groundwater from nearby ephemeral streams where they lose flow or potentially the Kawarau River to the north of the allocation zone; and
- Groundwater flow from adjacent aquifers and or other aquitards below or adjacent to the pumped aquifer, which in this case could be the schist hills either side of the valley or the alluvial aquifers north of the Kawarau River if there is a hydraulic connection.

Quantifying the potential for additional recharge from these sources is difficult in the absence of more detailed information on the streams and lake and how they interact with groundwater. It

[8] Rekker, J. (2014). Investigation into the Wakatipu Basin Aquifers. July 2014. Prepared by the Otago Regional Council.

also unknown whether any previous studies have been undertaken to investigate groundwater resources in the schist hills.

#### 4.1.1.3 Groundwater Level Response to Pumping

Extrapolation of groundwater level drawdown in the Production Bore during the constant-discharge test (see Appendix F.1) shows that pumping at a rate of 36L/s for a continuous period of 27 years results in an increase from 17.5m drawdown after 3 days to between 18.4m and 19.4m drawdown. Pumping at a slightly higher rate of 40L/s will result in more drawdown but assuming the slope of the drawdown curve remains largely unchanged, then a similar long-term increase in drawdown would be expected.

In the Monitoring Bore, modelling of drawdown shows the water level dropping by a further 0.8m after 25 years continuous pumping at 40L/s based on matches to the measured data using W_12 (see Figure 4-1 and Figure 4-2). The long-term drawdown will be higher if leakage is less (see Theis curve) or if the drawdown cone intercepts a barrier to groundwater flow. Conversely, the drawdown will be less if higher rates of leakage occur, for example if there develops a significant hydraulic connection to the lake.

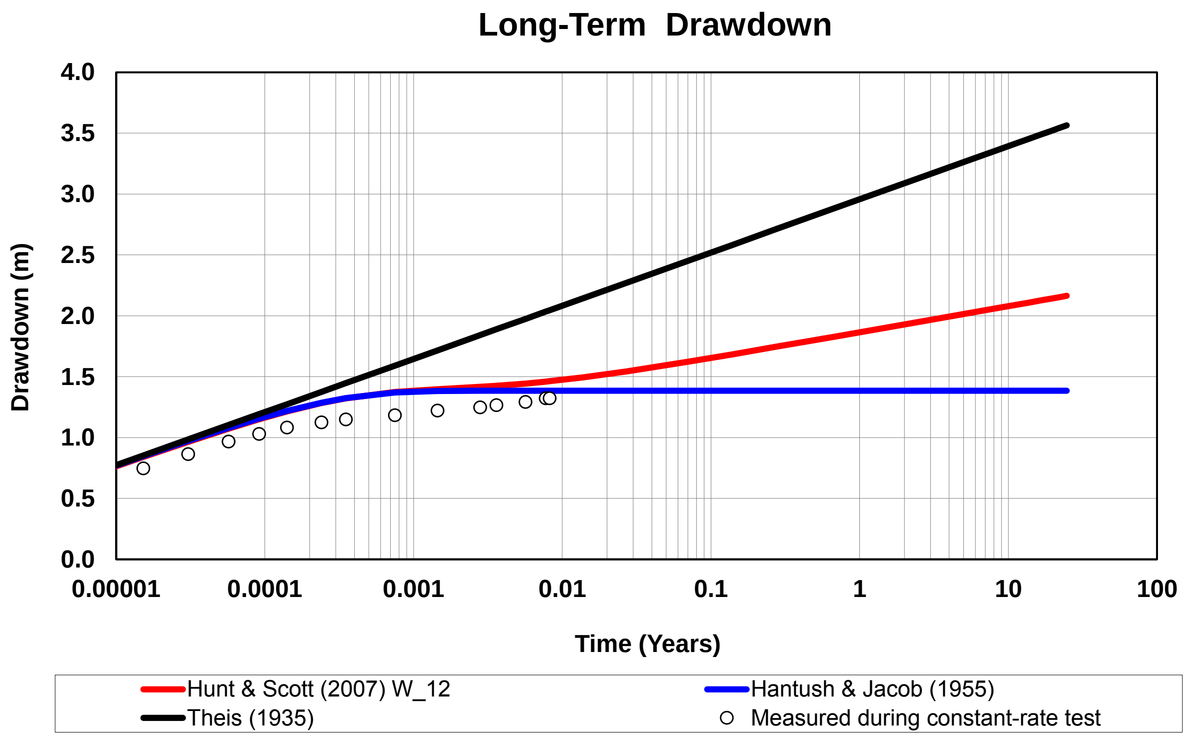



Figure 4-1: Long-term predicted drawdown (to 25 years) in the Monitoring Bore pumping at 40L/s and using the aquifer parameters from W_12 and the Jacks Point Bore (see Table 2-5)

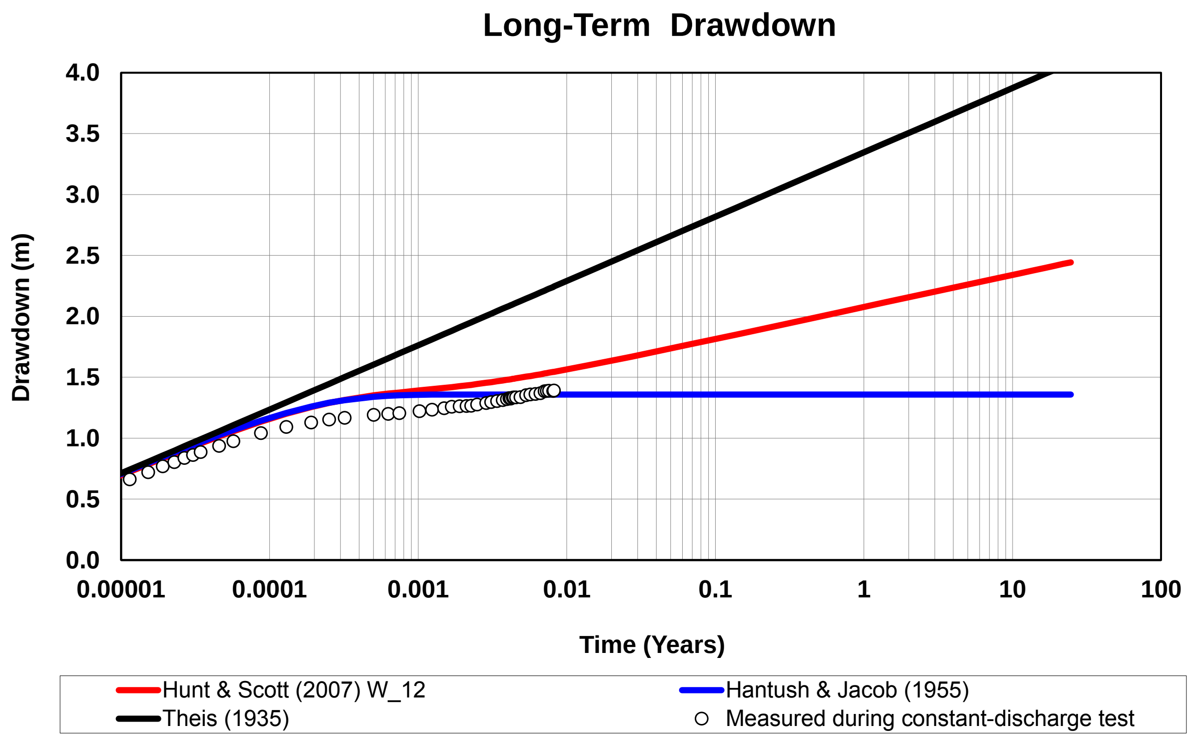



Figure 4-2: Long-term predicted drawdown (to 25 years) in the Monitoring Bore pumping at 40L/s and using the aquifer parameters from W_12 and a linear trend (see Table 2-5)

Overall, the predicted change in aquifer storage based on W_12 which was the best match to the constant-discharge test data is not considered to be significant.

#### 4.1.1.4 Summary and Conclusion

The combined existing and proposed groundwater takes are over half (54%) of the estimated mean annual recharge from rainfall. Despite this, the take is unlikely to result in significant depletion of the aquifer storage because:

- Data from the constant-discharge aquifer test shows leakage which could potentially occur from dewatering of the overlying aquitard, Lake Wakatipu, streams and groundwater flow from within the schist hills; and
- Extrapolation of the constant-discharge test data shows only minor (less than 0.8m to 1.2m) extra drawdown after 27 years continuous pumping.

To account for uncertainty, it is recommended that water levels be monitored in the Production Bore and Monitoring Bore for the duration of the consent and that a review of the groundwater level response to pumping be carried out after 6 months continuous or frequent pumping in order to help confirm the long-term sustainability of the take. After this review, the frequency or need to further reviews should be decided.

### 4.1.2 Bore Interference

An assessment has been undertaken of the drawdown in all neighbouring bores located within the groundwater allocation zone (shown in Appendix G.2) as a result of pumping the Production Bore at 40L/s for 365 days. Drawdown was predicted using a combination of the aquifer parameter values determined from the Monitoring Bore (as these were considered to be more reliable) to predict the worst (most drawdown) and best case (least drawdown) using W_12, Eta_12 from Hunt (2012) and Theis. The results and aquifer parameters values are presented in Appendix G.2.

According to Schedule 5B of the Regional Water Plan, significant interference is defined as greater than 1m for confined aquifers and greater than 0.2m for unconfined aquifers using the Theis equation. For this assessment, drawdown has been modelled using Hunt (2012) as the constant-discharge test showed leakage and using Theis results in two to four times the amount of drawdown predicted.

Using W_12, the worst case drawdown in the pumped aquifer is 0.73m drawdown in the nearest bore F41/0382, 640m away, down to 0.20m for the furthest bore 6,066m away. Using this analytical model, reasonable predictions can be made for bores F41/0382, F41/0324, F42/0100 and F42/0103 that occur within 1,887m of the Production Bore. Predictions from the next closest bore F41/0163 located 3,256m further north and the other bores further north near the Kawarau River are considered less reliable and probably an overestimation of effects given that the model does not account for a sloping water table, changes in aquifer lithology and other potential recharge sources at greater distances. Hence, it has been considered that drawdown effects be limited to an assessment on bores F41/0324, F42/0100 and F42/0103 and F41/0382.

### F41/0324

It is considered that bore F41/0324 (46.6m deep) is screened into a confined aquifer based on the high barometric efficiency value determined from the constant-discharge test. The maximum predicted drawdown is 0.47m using W_12 and 1.36m using Theis. Based on observations of leakage to the pumped aquifer, it is considered that maximum drawdown will be closer to W_12 and thus less than the 1m cut-off for confined aquifers as stated in Schedule 5B.

### F42/0100 and 0103

Bores F42/0100 and F42/0103 (both 55m deep) may be screened into a confined or unconfined aquifer, though it is difficult to determine without further testing. The two bores are located close together, constructed to the same depth, and in bore F42/0100 the static water level has been measured at 36m, suggesting a maximum available drawdown in the order of 14m (calculated as the depth between the static water level and point 2m above the top of the screen) (see Appendix G.2).

The maximum predicted drawdown in these two bores is approximately 0.47m using W_12 and 1.36m using Theis. Based on observations of leakage to the pumped aquifer, it is considered that maximum drawdown will be closer to W_12. Not knowing whether these bores are in a confined or unconfined aquifer the drawdown maybe greater than the 0.2m cut-off for unconfined aquifers as stated in Schedule 5B.

### F42/0382

The nearest bore with the largest predicted drawdown of up to 0.73m using W_12 and 1.81m drawdown using Theis is F41/0382. The bore is 9.6m deep, located 640m away and is likely screened into an un-confined aquifer. Given the bores location adjacent to the lake, the distance from the Production Bore and likely probability that it screens a different aquifer, there may be no drawdown effects. However, given the observations of leakage, drawdown in an overlying aquifer as determined from Hunt (2012) using Eta_12 is theoretically possibly. Given the shallow depth, likely unconfined nature of the aquifer and potentially less available drawdown in comparisons the deeper bores, drawdown exceeds the 0.2m cut-off for unconfined aquifers.

#### 4.1.3 Groundwater Flow Direction

The extent of drawdown to the south of the bore may be limited by the presence of Lake Wakatipu potentially acting as a consent head boundary if the aquifer is hydraulically connected to the lake.

Figure 4-3 shows the drawdown with distance from the Production Bore after 5 years continuous pumping at 40L/s and using the same aquifer parameters adopted for the bore interference assessment. At a distance greater than 500m from the bore, the amount of drawdown is less than 1m. In the top layer aquifer (if one exists further from the Production Bore), the drawdown would be much less at the bore, but similar to that of the pumped aquifer at distances greater than 1,000m away.

Thus it is considered that there will be effects on groundwater pressures and groundwater flow, but these will be largely limited to within 500m of the bore.

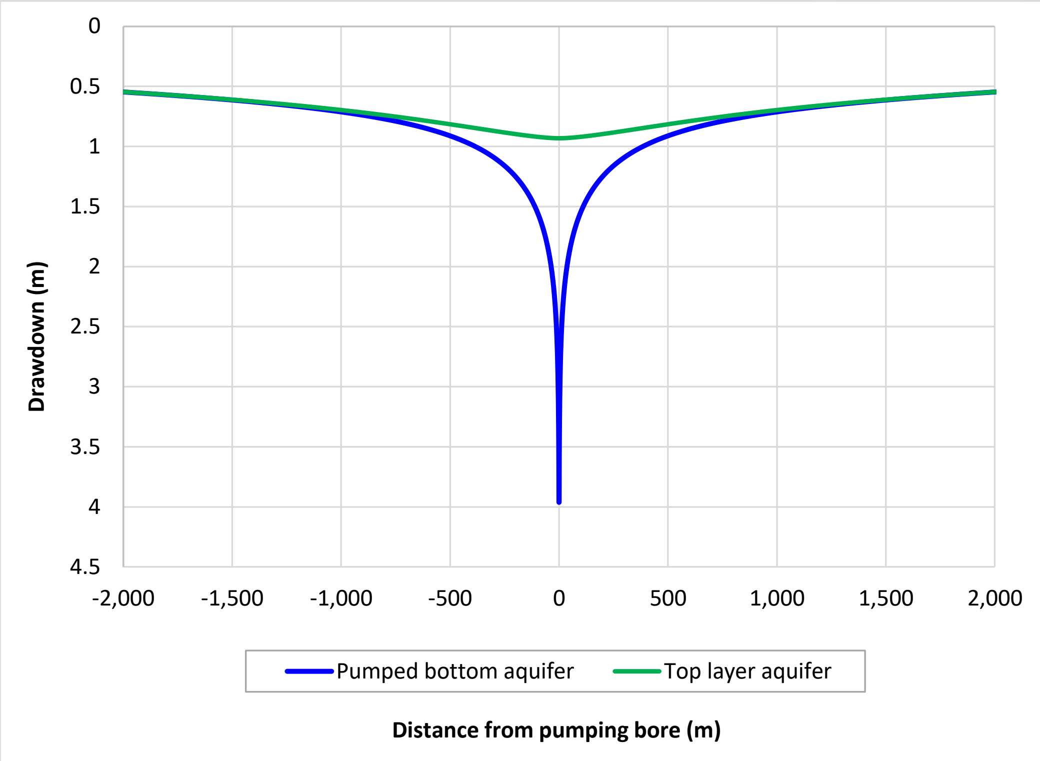



Figure 4-3: Distance drawdown using W_12 and Eta_12 in Hunt (2012) after 5 years continuous pumping at 40L/s

#### 4.1.4 Aquifer Stabilisation

The aquifer from which the Production Bore abstracts groundwater is predominantly composed of gravel with some silt. Gravels have a high (modulus) elasticity and the area of high drawdown is limited to that near the bore, thus the potential for settlement and compaction as a result of the abstraction is considered to be very small and limited to an area close to the bore. Therefore, the effects on aquifer stability are considered to be less than minor.

### 4.2 Surface Water Quantity

### 4.2.1 Lake Wakatipu

The Production Bore is located 90m (see Appendix D.2) from the shoreline of Lake Wakatipu and the lake is the closest surface water body to the bore. Water chemistry in the lake and aquifer screened by the Production Bore is similar, suggesting that a possible hydraulic connection, and some depletion of water from the lake, may occur as result of the groundwater take. Leakage shown in the constant-discharge test also supports the potential for depletion of water from the lake.

Using the three sets of aquifer parameters determined using W_4 in Hunt (2012) as shown in Table 2-5, the lake depletion after 5 years continuous pumping as shown in Appendix G.3 ranges from 2L/s, 12L/s and 38L/s compared to a total take of 40L/s. Similar curve matches could be made to the measured data using all three sets of aquifer parameters and a similar match could also be made setting lambda to zero, which would result in no depletion from the lake.

In conclusion, it is considered that there may be no depletion of the lake or potentially high depletion of the lake, however further testing would be needed to potentially be more certain. High depletion from the lake would result in significant additional recharge to the aquifer which would limit any changes in groundwater storage, whilst low depletion would have the opposite effect.

Given the volume of water and inflows to Lake Wakatipu, the effects on lake storage (regardless of the hydraulic connection) are considered to be less than minor.

### 4.2.2 Stream Flows

The location of streams and rivers near the Production Bore are shown in Appendix D.1. The nearest stream is located 220m north-east of the Production Bore, the second closest is located 850m to the south-east. At these distances, stream depletion is possible based on the results of the constant-discharge aquifer test. However, local residents have observed the streams to be ephemeral and observed that they lose water as they flow across the alluvial valley from their source in the adjacent hills. As such it is considered that the primary source of water for these streams is likely to be rainfall run-off rather than groundwater and that any lowering of the groundwater level beneath or near these streams will not result in any significant additional losses of surface water compared with that which naturally occurs.

### 4.2.3 Spring Flows

There are no known springs within at least a 2km radius of the Production Bore. Thus the effects on springs or spring fed streams are considered to be less than minor.

### 4.2.4 Existing Surface Water Takes

The nearest surface water take within an approximately 2km to 6km radius of the Production Bore (shown in Appendix G.3) is Consent No: 2004.724 (information supplied by Charles Horrell from the ORC, 24/8/2011) to take water from Lake Wakatipu at a location 400m to the north-west at a rate of up to 225L/s. Given that this take is from the lake, there is considered to be no adverse effects resulting from the proposed groundwater abstraction.

## 4.3 Water Quality

### 4.3.1 Groundwater

#### General

Though the water quality of the aquifer could change as a result of drawdown induced seepage from overlying, underlying or adjacent aquifers, aquitards or hydraulically connected surface water it is expected that the changes will not be significant. In addition, the chemical composition of Lake Wakatipu (if leakage from the lake did occur) is similar to that of aquifer (see Section 2.4).

Given that the water is to be used for domestic supply rather than irrigation for farming or other land uses that have potential to cause contamination, it is considered that contamination of the aquifer is highly unlikely.

#### Bore Construction

The bore has been constructed to NZS and the annulus has been sealed to prevent ingress of surface contaminants into the aquifer. The bore head is yet to be completed, but will be designed and constructed in accordance with NZS in order to prevent any contamination of the aquifer.

#### Seawater Intrusion

The Production Bore is located at least 100km from the coast. Based on this separation distance, there is considered to be no risk of a landward shift of the freshwater / seawater interface and therefore the effects from seawater intrusion are considered to be less than minor.

### 4.3.2 Surface Water

Since groundwater will not be discharged to surface water, the only effects on surface water quality could arise from stream depletion lowering stream flows. As discussed in section 4.3.2 above, stream depletion is not considered likely, and adverse effects on surface water quality are therefore not anticipated.

## 4.4 Monitoring

Groundwater levels in the Production Bore and Monitoring Bore along with the flow rate and volume from the Production Bore will be continuously monitored in order to assess effects on aquifer storage, existing groundwater users, aquifer leakage and performance of the bore (drawdown versus yield) over time.

## 4.5 Consent Duration

A resource consent is sought for a duration of 20 years.

# 5 Summary and Recommendations

Murphy's Developments Ltd are seeking a drinking water supply for a proposed residential development at Homestead Bay near Queenstown. In July 2017, a Production Bore and Monitoring Bore were constructed at Homestead Bay to determine how much water could be taken, assess the water quality, environmental effects and effects on existing groundwater users.

The Production Bore is 35.8m deep, and is screened from 29.8m to 35.8m into what is considered to most likely be a semi-confined sandy gravel aquifer. The static water level is approximately 0.6m below ground level. The Production Bore is 90m from the shore of Lake Wakatipu and approximately 100m from the lake itself depending on the water level.

Based on the step-discharge and constant-discharge aquifer testing and assuming that the lowest pumping water level is 2m above the top of the screen, the maximum long-term sustainable yield was determined at approximately 40L/s. Constant-discharge testing also suggests significant leakage to the pumped aquifer which will limit the long-term drawdown and effects on water levels in the aquifer.

The combined existing and proposed groundwater takes would equate to over half (54%) of the estimated mean annual recharge from rainfall. Despite this it is considered that the take is unlikely to result in significant depletion of the aquifer storage due to the likely potential for leakage, and extrapolation of the constant-discharge test data showing only minor (less than 0.8m to 1.2m) extra drawdown after 27 years continuous pumping.

To account for uncertainty, it is recommended that water levels be monitored in the Production Bore and Monitoring Bore for the duration of the consent and that a review of the groundwater level response to pumping be carried out after 6 months continuous or frequent pumping in order to confirm the long-term sustainability of the take. After this review, the frequency or need for further review of effects on groundwater levels should be decided.

Any significant effects on surface water bodies are considered to be unlikely as the streams nearby are ephemeral, Lake Wakatipu has significant storage and there are no springs identified in the area.

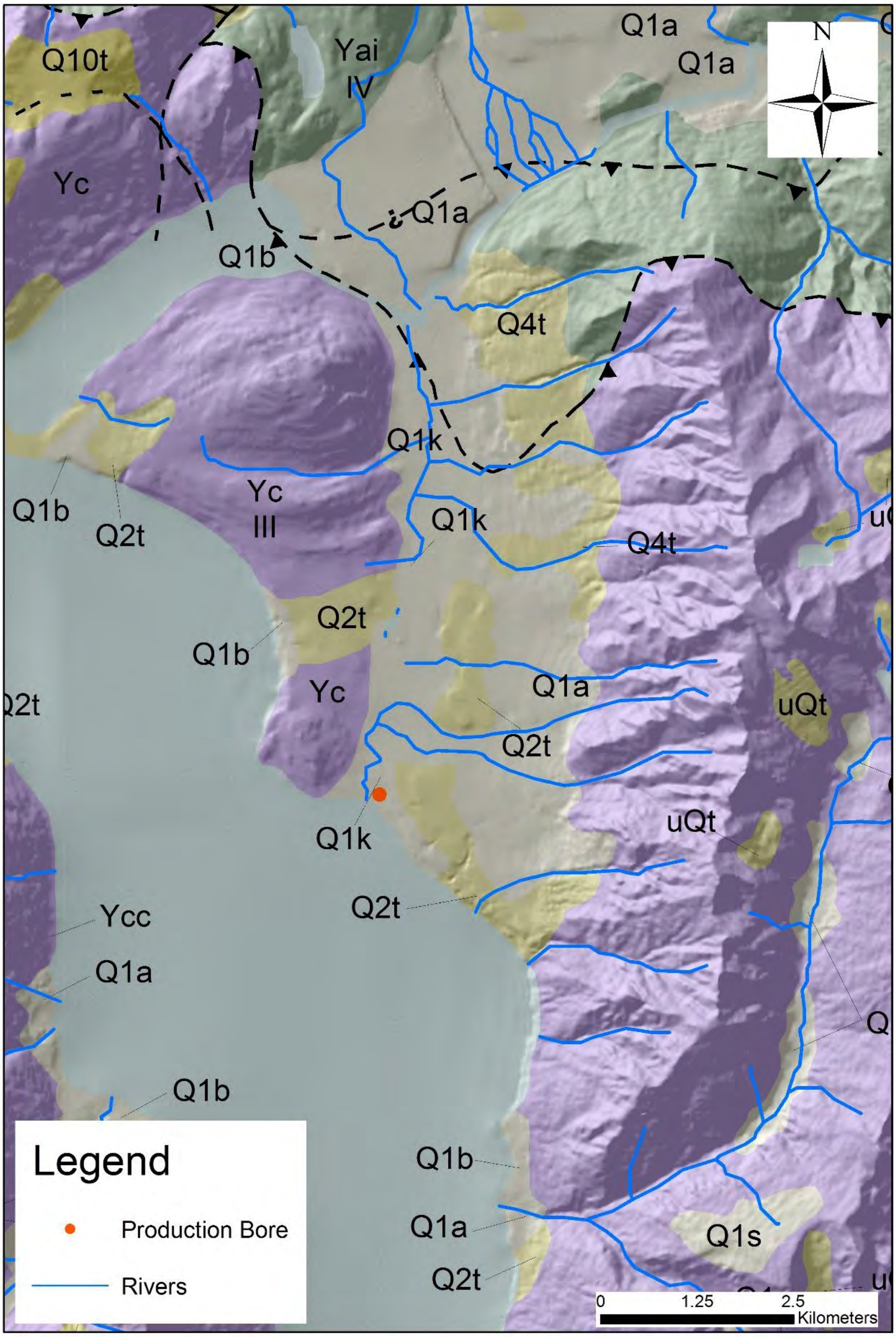
There could be some effect on the water levels in existing bores, with a prediction of 0.73m drawdown in the nearest bore 640m away up 0.20m for the furthest bore 6,066m away.

The water quality of the aquifer is very good. A water quality analysis for the full drinking water suite showed no exeedances of the New Zealand Drinking Water standards. The water chemistry is also very similar to that of Lake Wakatipu.

# APPENDICES

# Appendix A: Geology

## A.1 Surface Geology (from Turnbull, 2000)[9]

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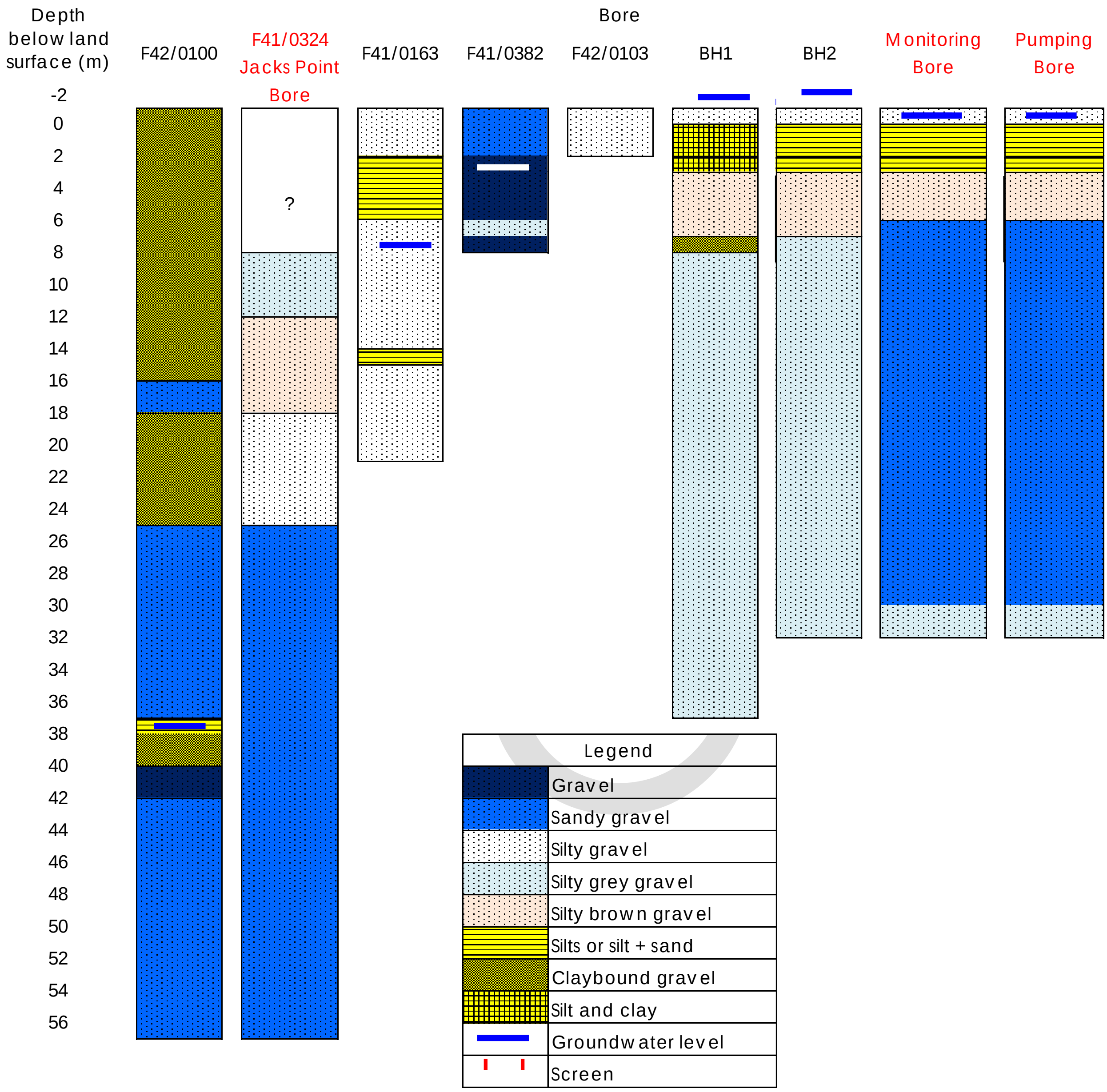
[9] Turnbull, I.M. (compiler) (2000). Geology of the Wakatipu area: scale 1:250,000. Lower Hutt: Institute of Geological & Nuclear Sciences. Institute of Geological & Nuclear Sciences 1:250,000 geological map 18. 72 p. + 1 folded map.

## A.2 Bore log search

## A.3 Jacks Point Bore Logs (for the bores labelled in Appendix A.2)



## Production Bore

SOUTHDRILL WATER EXPLORATION

### BORE LOG DATA SHEET

| | |
|---|---|
| CLIENTS NAMES: | MURPHYS DEVELOPMENTS LTD C/OCRIS HANSEN |
| FULL ADDRESS: | 309 LOWER SHOTOVER R.D RD1 QUEENTOWN 9371 |
| RESOURCE CONSENT NO: | RM17.173 |
| BORE SIZE: | 12"' |
| START DATE: | 6 July 2017 |
| FINISH DATE: | 8 July 2017 |
| MACHINE: | DR24 |
| RAPID NO: | |
| GRID REFERENCE: | N4998187 E1264612 |
| DRILLER: | R HARREX |
| MEASURED FROM: | CASEING .26CM |
| 300mm UPSTAND: | |
| TOTAL DEPTH BORE: | 35.76M |
| TOP LEADER: | 28.77M |
| STATIC WATER LEVEL: | .89CM |
| SCREEN - SLOT: | .250MM |
| SCREEN: | 6M BY 10" |
| LEADER: | 1M BY 10" |
| SUMP: | |
| TOTAL CASING USED: | 29.65M |
| AT TIME OF PUMPING-BORE DID: | 34.1 LTS PER SCD |
| TEST PUMP PERIOD: | 72hr pump test |
| AIR/PUMP INTAKE: | 26.5 |
| BACTERIAL WATER TEST: | |
| CHEMICAL WATER TEST: | |
| IMPERVIOUS SEAL AT GROUND LEVEL AROUND CASING | |
| CASING TOP SEALED TO PREVENT CONTAMINATION | Yes |

COMMENTS:

BORE LOG:

| | |
|---|---|
| 0.0 -.80cm | Loose course gravels |
| 0.80cm - 3.2m | Blue Silts |
| 3.2 - 5.1m | Silty small gravels |
| 5.1 - 31.4m | Sandy small gravels |
| 31.4 - 36m | Coarse silty gravels |

## Monitoring Bore

SOUTHDRILL
WATER EXPLORATION

### BORE LOG DATA SHEET

| | |
|---|---|
| CLIENTS NAMES: | MURPHYS DEVELOPMENTS LTD C/O CRIS HANSEN |
| FULL ADDRESS: | 309 LOWER SHOTOVER R.D RD1 QUEENTOWN 9371 |
| RESOURCE CONSENT NO: | RM17.173 |
| BORE SIZE: | 50MM |
| START DATE: | 16 July 2017 |
| FINISH DATE: | 17 July 2017 |
| MACHINE: | DR24 |
| RAPID NO: | |
| GRID REFERENCE: | N4998193 E1264607 |
| DRILLER: | R HARREX |
| MEASURED FROM: | 6" STEEL COLLER |
| 300mm UPSTAND: | .31CM |
| TOTAL DEPTH BORE: | 35.67M |
| TOP LEADER: | |
| STATIC WATER LEVEL: | .74CM |
| SCREEN - SLOT: | 6M 50MM PVC PLUS 2 50MM CAPS 6M FILTER CLOTH |
| SCREEN: | |
| LEADER: | |
| SUMP: | |
| TOTAL CASING USED: | |
| AT TIME OF PUMPING-BORE DID: | |
| TEST PUMP PERIOD: | |
| AIR/PUMP INTAKE: | |
| BACTERIAL WATER TEST: | |
| CHEMICAL WATER TEST: | |
| IMPERVIOUS SEAL AT GROUND LEVEL AROUND CASING | 1BAG BENTINTE AROUND 6" STEEL 2M LONG |
| CASING TOP SEALED TO PREVENT CONTAMINATION | WELDED STEEL SECEARITY CAP |

COMMENTS:

PESSO 15M AWAY FORM PUMP BORE

BORE LOG:

| | |
|---|---|
| 0.0 - 0.60cm | Loose coarse gravels |
| 0.60cm - 3.60m | Blue silts |
| 3.60 - 5.1m | Silty small gravels |
| 5.1 - 31.70m | Sandy small gravels |
| 31.70 - 36.20m | Silty coarser gravels |

# MCNEILL DRILLING CO LTD
## WATER BORE/WELL
## SUMMARY FORM

| | | | |
|---|---|---|---|
| CLIENTS NAME: Dick Jardine BH1 | PHONE NO. | RESOURCE CONSENT NO: | |
| FULL ADDRESS: | Jacks Point | BORE SIZE: | 75mm |
| RAPID NO: | | START DATE: | 17.12.15 |
| GRID REFERENCE: | E1264620, N4998175 | FINISH DATE: | 17.12.15 |
| DRILLER: | D Aburn | | |
| MEASURED FROM: | Ground level | MACHINE: | Edson |
| TOTAL DEPTH BORE: | 37.00m | DRILL METHOD: | Aircore |
| TOP LEADER: | | | |
| STATIC WATER LEVEL: | 0.30m | | |
| SCREEN :SLOT: | | LENGTH: | |
| TYPE: | | SIZE: | |
| PVC SLOTTED: | TOP: | BASE: | |
| SCREEN/LEADER/SUMP: | | SUMP SIZE: | |
| TOTAL CASING USED: | | | |
| AIRLIFTED/PUMPED AT: | | | |
| TEST PUMP PERIOD: | | | |
| DRAWDOWN FROM SWL: | | | |
| AIR/PUMP INTAKE: | | | |
| BACTERIAL WATER TEST: | | | |
| CHEMICAL WATER TEST: | | | |
| IMPERVIOUS SEAL AT GROUND LEVEL AROUND CASING ☐ | | | |
| CASING TOP SEALED ☐ | | | |
| COMMENTS: | Flow test at 30.00m – 20 seconds for 20 litres | | |

| BORE LOG: | |
|---|---|
| 0.00 – 0.20 | Soil |
| 0.20 – 0.80 | Silty gravel |
| 0.80 – 2.50 | Grey silt / clay |
| 2.50 – 6.50 | Silty brown / grey gravel |
| 6.50 – 7.20 | Claybound gravel |
| 7.20 – 10.00 | Silty grey gravel |
| 10.00 – 10.80 | Silty grey gravel some claybound |
| 10.80 – 11.90 | Silty grey gravel |
| 11.90 – 13.50 | Siltbound grey gravel |
| 13.50 – 37.00 | Grey silty gravel |
| | |
| | |
| | |
| | |

# MCNEILL DRILLING CO LTD
## WATER BORE/WELL
## SUMMARY FORM

| | | | | |
|---|---|---|---|---|
| CLIENTS NAME: | Dick Jardine<br>BH2 | PHONE NO. | RESOURCE CONSENT NO: | |
| FULL ADDRESS: | | | BORE SIZE: | 75mm |
| RAPID NO: | | | START DATE: | 17.12.15 |
| GRID REFERENCE: | E1264554, N4998269 | | FINISH DATE: | 17.12.15 |
| DRILLER: | D Aburn | | | |
| MEASURED FROM: | Ground level | | MACHINE: | Edson |
| TOTAL DEPTH BORE: | 36.00m | | DRILL METHOD: | Aircore |
| TOP LEADER: | | | | |
| STATIC WATER LEVEL: | 2.10m above ground level | | | |
| SCREEN :SLOT: | | | LENGTH: | |
| TYPE: | | | SIZE: | |
| PVC SLOTTED: | | TOP: | BASE: | |
| SCREEN/LEADER/SUMP: | | | SUMP SIZE: | |
| TOTAL CASING USED: | | | | |
| AIRLIFTED/PUMPED AT: | | | | |
| TEST PUMP PERIOD: | | | | |
| DRAWDOWN FROM SWL: | | | | |
| AIR/PUMP INTAKE: | | | | |
| BACTERIAL WATER TEST: | | | | |
| CHEMICAL WATER TEST: | | | | |
| IMPERVIOUS SEAL AT GROUND LEVEL AROUND CASING ☐ | | | | |
| CASING TOP SEALED ☐ | | | | |
| COMMENTS: | Flow test at 36.00m – 40 seconds for 20 litres | | | |
| | Artesian flow in test hole | | | |
| BORE LOG: | | | | |
| 0.00 – 0.10 | Soil | | | |
| 0.10 – 1.00 | Silty gravel coarse | | | |
| 1.00 – 3.30 | Silts | | | |
| 3.30 – 4.50 | Grey silt bound gravel | | | |
| 4.50 – 8.50 | Grey / Brown silty gravel | | | |
| 8.50 – 36.00 | Grey silty gravel | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

## Bore Log Information from the Otago Regional Council (

| Bore ID | Depth From (m) | Depth To (m) | Description | Layer Thickness (m) |
|---|---|---|---|---|
| F41/0163 | 0.0 | 3.2 | Silty Gravels | 3.2 |
| F41/0163 | 3.2 | 6.0 | Silts | 2.8 |
| F41/0163 | 6.0 | 14.2 | Silty Gravels Wet | 8.2 |
| F41/0163 | 14.2 | 15.1 | Silts and Sands | 0.9 |
| F41/0163 | 15.1 | 36.0 | Silty Gravels Dry | 20.9 |
| F41/0324 | 0.0 | 0.2 | Topsoil | 0.2 |
| F41/0324 | 0.0 | 0.3 | Soil | 0.3 |
| F41/0324 | 0.2 | 0.9 | Grey Silt | 0.7 |
| F41/0324 | 0.3 | 3.0 | Grey Clay | 2.7 |
| F41/0324 | 0.9 | 1.4 | Sandy Gravel | 0.5 |
| F41/0324 | 1.4 | 6.1 | Yellow Silty Gravel | 4.7 |
| F41/0324 | 3.0 | 6.1 | Silty grey clay | 3.1 |
| F41/0324 | 6.1 | 14.6 | Silty Coarse Gravel | 8.5 |
| F41/0324 | 6.1 | 8.7 | Sand | 2.6 |
| F41/0324 | 8.7 | 9.1 | Brown sandy gravels | 0.4 |
| F41/0324 | 9.1 | 12.8 | Grey silty quartz gravels | 3.7 |
| F41/0324 | 12.8 | 18.8 | Silty brown gravels | 6.0 |
| F41/0324 | 14.6 | 26.7 | Silty Sandy Gravel | 12.1 |
| F41/0324 | 18.8 | 22.1 | Sandy brown gravels | 3.3 |
| F41/0324 | 22.1 | 23.5 | Very sandy grey/brown gravels | 1.4 |
| F41/0324 | 23.5 | 28.5 | Sandy grey gravels | 5.0 |
| F41/0324 | 26.7 | 30.0 | Grey Small Sandy Gravel | 3.3 |
| F41/0324 | 28.5 | 32.0 | Quite sandy grey gravels | 3.5 |
| F41/0324 | 32.0 | 36.4 | Sandy green/grey gravels | 4.4 |
| F41/0324 | 36.4 | 38.0 | Sandy grey gravels | 1.6 |
| F41/0324 | 38.0 | 39.2 | Very Sandy grey gravels | 1.2 |
| F41/0324 | 39.2 | 47.0 | Sandy grey gravels | 7.8 |
| F41/0382 | 0.0 | 1.3 | Loose gravel | 1.3 |
| F41/0382 | 1.3 | 3.0 | Coarse gravel | 1.7 |
| F41/0382 | 3.0 | 6.4 | Loose sandy gravel | 3.4 |
| F41/0382 | 6.4 | 6.8 | Grey very silty schist gravel | 0.4 |
| F41/0382 | 6.8 | 9.3 | Grey silty schist gravel | 2.5 |
| F41/0382 | 9.3 | 9.6 | Grey schist rock | 0.3 |
| F41/0382 | 0.0 | 1.3 | Loose gravel | 1.3 |
| F41/0382 | 1.3 | 3.0 | Coarse gravel | 1.7 |
| F41/0382 | 3.0 | 6.4 | Loose sandy gravel | 3.4 |
| F41/0382 | 6.4 | 6.8 | Grey very silty schist gravel | 0.4 |
| F41/0382 | 6.8 | 9.3 | Grey silty schist gravel | 2.5 |
| F41/0382 | 9.3 | 9.6 | Grey schist rock | 0.3 |
| F42/0100 | 0.0 | 2.0 | Clay and small gravel | 2.0 |
| F42/0100 | 2.0 | 6.5 | Clay bound gravel and silts | 4.5 |
| F42/0100 | 6.5 | 13.0 | Large Clay Bound Gravels | 6.5 |
| F42/0100 | 13.0 | 16.0 | Clay bound gravels | 3.0 |

| Bore ID | Depth From (m) | Depth To (m) | Description | Layer Thickness (m) |
|---|---|---|---|---|
| F42/0100 | 16.0 | 19.0 | Sandy Gravels | 3.0 |
| F42/0100 | 19.0 | 23.0 | Large Clay Bound Gravels | 4.0 |
| F42/0100 | 23.0 | 24.0 | Loose Gravels | 1.0 |
| F42/0100 | 24.0 | 26.0 | Clay Bound Gravels | 2.0 |
| F42/0100 | 26.0 | 36.0 | Very Loose Sandy Gravels | 10.0 |
| F42/0100 | 36.0 | 37.0 | Sandy Silts | 1.0 |
| F42/0100 | 37.0 | 40.0 | Very hard clay Bound Gravels | 3.0 |
| F42/0100 | 40.0 | 42.0 | Loose Free Running Gravels | 2.0 |
| F42/0100 | 42.0 | 49.0 | Sandy Gravels some Clay | 7.0 |
| F42/0100 | 49.0 | 55.0 | Sandy Gravels | 6.0 |
| F42/0103 | 0.0 | 0.2 | Top Soil | 0.2 |
| F42/0103 | 0.2 | 0.6 | Dark Brown Silt with fine to coarse gravels | 0.4 |
| F42/0103 | 0.6 | 1.6 | Fine to coarse banded gravels | 1.0 |
| F42/0103 | 1.6 | 1.9 | Light Grey Silty sand and gravels | 0.3 |
| F42/0103 | 1.9 | 2.1 | Fine to coarse light grey brown sand | 0.3 |

# Appendix B: Existing Bores

## B.1Bore Details

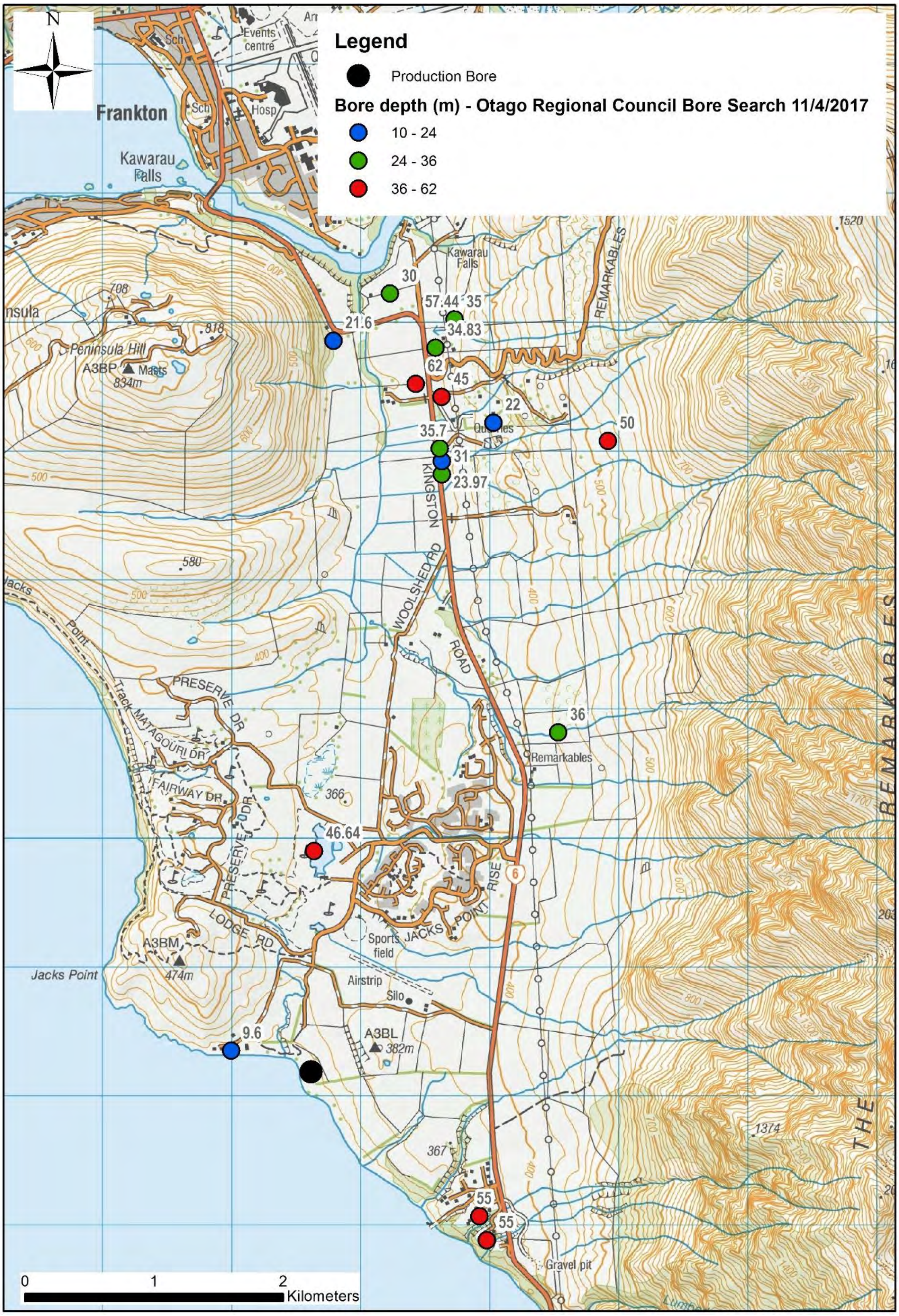
| Bore ID | Easting NZTM2000 | Northing NZTM2000 | Depth (m) | Screen Top (m) | Test | Status | Depth to Water (m) | Aquifer | Drawdown (m) | Pump Rate (L/s) | Transmissivity ($m^2/d$) | Pump Duration (min) | Use1 | Use2 | Bore Log |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F41/0108 | 1265625 | 5002821 | 31 | | | | | UN | | 1.1 | | | DO | | N |
| F41/0119 | 1264787 | 5003857 | 21.6 | 18.6 | | Complete | 1.65 | FR | 1.72 | | | 60 | IR | | Y |
| F41/0127 | 1265625 | 5003422 | 45 | | | | | KG | | 1.1 | | | DO | | N |
| F41/0143 | 1265425 | 5003522 | 62 | 59 | | Complete | | KG | 8 | 1.5 | 36 | | DO | | Y |
| F41/0153 | 1265724 | 5004023 | 57.44 | 56.1 | | Complete | | AR | 13 | 1.5 | 22 | | DO | | Y |
| F41/0156 | 1265724 | 5004023 | 35 | | | | | WG | | 1.4 | | | DO | | N |
| F41/0157 | 1265224 | 5004222 | 30 | | | | | WG | | 1.4 | | | DO | | N |
| F41/0163 | 1266528 | 5000820 | 36 | 12.7 | | Complete | 7.97 | WG | 3.5 | 0.7 | 37 | | DO | | Y |
| F41/0216 | 1265625 | 5002921 | 23.97 | 21.82 | | Complete | 16.2 | WG | 0.45 | 2 | 1,015 | | SC | | Y |
| F41/0304 | 1265609 | 5003020 | 35.7 | 34.6 | | Complete | 1.72 | UN | 1.8 | 2.8 | 313 | 90 | DO | | Y |
| F41/0324 | 1264635 | 4999899 | 46.64 | 40.16 | CT | Complete | | UN | 11.16 | 10 | 196 | 180 | IR | | Y |
| F41/0327 | 1266914 | 5003080 | 50 | | | Complete | | UN | | 1.4 | | | ? | | N |
| F41/0334 | 1266025 | 5003222 | 22 | | | Filled In | | UN | | | | | DO | | N |
| F41/0382 | 1263993 | 4998351 | 9.6 | | CT | Complete | 2.4 | | | | | | DO | ST | Y |
| F41/0482 | 1265578 | 5003802 | 34.83 | | | Complete | 7.56 | Unknown | 0.13 | 3.6 | 6,653 | 105 | DO | | Y |
| F42/0100 | 1265917 | 4997067 | 55 | 52 | CT | Complete | 36 | | 6.7 | 1.2 | 32 | | DO | | Y |
| F42/0103 | 1265975 | 4996882 | 55 | | CT | Complete | | WG | | 2.9 | | | DO | IR | Y |

## B.2Bore Numbers (for all bores listed in Appendix C.1)


Legend
Production Bore
Otago Regional Council Bore Search 11/4/2017
F41/0157
F41/0153
F41/0156
F41/0119
F41/0482
F41/0143
F41/0127
F41/0334
F41/0327
F41/0304
F41/0216
F41/0108
F41/0163
F41/0324
F41/0382
Production Bore
F42/0100
F42/0103
0
750
1,500
Meters
Frankton
Queenstown Airport
Kawarau Falls
Remarkables
THE REMARKABLES
KINGSTON ROAD
WOOLSHED RD
JACKS POINT RISE
Airstrip

## B.3Bore Uses


## B.4 Bore Depths




## B.5Pumping rate after drilling and construction


N
Legend
Production Bore
Pump Rate (L/s) - Otago Regional Coouncil Bore Search 11/4/2017
0.7 - 2
2 - 3.6
3.6 - 10
Frankton
Kawarau Falls
Events centre
Hosp
Peninsula Hill
A3BP
Masts
834m
Kawarau Falls
Quarries
KINGSTON
WOOLSHED RD
ROAD
REMARKABLES
Remarkables
PRESERVE DR
MATAGOURI DR
FAIRWAY DR
PRESERVE DR
LODGE RD
JACKS POINT RISE
Sports field
A3BM
474m
Jacks Point
Airstrip
Silo
A3BL
382m
367
366
580
Gravel pit
THE REMARKABLES
1374
0
1
2
Kilometers

# Appendix C: Water Chemistry

## C.1 Results for the Production Bore and Lake Wakatipu

| Description / Analyte | Units | Production Bore | Lake Wakatipu | Standard | |
|---|---|---|---|---|---|
| | | | | GV | MAV |
| Date Sampled | N/A | 20-Jul-2017 11:30 | 20-Jul-2017 11:30 | N/A | N/A |
| Lab Number: | N/A | 1812415.1 | 1812415.2 | N/A | N/A |
| Sum of Anions | meq/L | 1.89 | | - | - |
| Sum of Cations | meq/L | 2 | | - | - |
| Escherichia coli | MPN/100ml | < 1 | | | |
| Total coliforms | MPN/100ml | < 1 | | | |
| Turbidity | NTU | 0.06 | | 2.5 | - |
| Apparent Hazen Colour | Hazen units | < 10 | | 10 | - |
| pH for Colour Analysis | pH Units | 8.1 | | - | - |
| pH | pH Units | 7.9 | 7.9 | 7.0–8.5 | - |
| Acidity (pH 3.7) | g/m3 as CaCO3 | < 1.0 | | - | - |
| Electrical Conductivity | mS/m | 18.5 | | - | - |
| Total Organic Carbon | g/m3 | < 0.5 | | - | - |
| Sample Temperature | °C | 20 | | - | - |
| Langelier Saturation Index | | 0 | | - | - |
| Total Alkalinity | g/m3 as CaCO3 | 84 | 74 | - | - |
| Bicarbonate | g/m3 at 25°C | 101 | 90 | - | - |
| Bromide | g/m3 | < 0.05 | | - | - |
| Total Cyanide | g/m3 | < 0.0010 | | - | 0.6 |
| Cyanogen Chloride | mg/L | < 0.005 | | - | 0.4 |
| Monochloramine | g/m3 | < 0.05 | | - | 3 |
| Chloride | g/m3 | 2 | 1.8 | 250 | - |
| Chlorite | g/m3 | < 0.005 | | - | 0.8 |
| Chlorate | g/m3 | < 0.005 | | - | 0.8 |
| Fluoride | g/m3 | 0.1 | | - | 1.5 |
| Total Ammoniacal-N | g/m3 | < 0.010 | | 1 | - |
| Nitrite-N | g/m3 | < 0.002 | | - | 0.06 - 0.9 |
| Nitrate-N | g/m3 | 1.37 | 1.15 | - | 11.3 |
| Nitrate-N + Nitrite-N | g/m3 | 1.37 | 1.15 | - | - |
| Dissolved Reactive Phosphorus | g/m3 | < 0.004 | | - | - |
| Total Phosphorus | g/m3 | < 0.004 | | - | - |
| Reactive Silica | g/m3 as SiO2 | 10.8 | | - | - |
| Sulphate | g/m3 | 3 | 3.2 | 250 | - |
| Total Hardness | g/m3 as CaCO3 | 93 | | 200 | - |
| Dissolved metals | | | | | |
| Aluminium | g/m3 | 0.003 | | 0.1 | - |
| Antimony | g/m3 | < 0.0002 | | - | 0.02 |
| Arsenic | g/m3 | 0.0019 | | - | 0.01 |
| Barium | g/m3 | 0.00071 | | - | 0.7 |
| Beryllium | g/m3 | < 0.00010 | | - | 0.012 |
| Boron | g/m3 | 0.006 | | - | 1.4 |
| Cadmium | g/m3 | < 0.00005 | | - | 0.004 |
| Calcium | g/m3 | 32 | 29 | - | - |
| Chromium | g/m3 | 0.0012 | | - | 0.1 |

| Description / Analyte | Units | Production Bore | Lake Wakatipu | Standard | |
|---|---|---|---|---|---|
| | | | | GV | MAV |
| Copper | g/m3 | < 0.0005 | | - | 2 |
| Iron | g/m3 | < 0.02 | | 0.2 | - |
| Lead | g/m3 | < 0.00010 | | - | 0.01 |
| Lithium | g/m3 | 0.0015 | | - | - |
| Magnesium | g/m3 | 2.8 | 2.5 | - | - |
| Manganese | g/m3 | < 0.0005 | | - | 0.4 |
| Mercury | g/m3 | < 0.00008 | | - | 0.01 |
| Molybdenum | g/m3 | < 0.0002 | | - | 0.07 |
| Nickel | g/m3 | < 0.0005 | | - | 0.1 |
| Potassium | g/m3 | 0.81 | 0.76 | - | - |
| Selenium | g/m3 | < 0.0010 | | - | 0.01 |
| Silver | g/m3 | < 0.00010 | | - | 0.1 |
| Sodium | g/m3 | 3.3 | 3 | 200 | - |
| Tin | g/m3 | < 0.0005 | | - | - |
| Uranium | g/m3 | 0.00022 | | - | 0.02 |
| Zinc | g/m3 | 0.0025 | | 1.5 | - |
| Total metals | | | | | |
| Aluminium | g/m3 | < 0.0032 | | 0.1 | - |
| Antimony | g/m3 | < 0.00021 | | - | 0.02 |
| Arsenic | g/m3 | 0.0022 | | - | 0.01 |
| Barium | g/m3 | < 0.0053 | | - | 0.7 |
| Beryllium | g/m3 | < 0.00011 | | - | 0.01 |
| Boron | g/m3 | 0.0058 | | - | 1.4 |
| Cadmium | g/m3 | < 0.000053 | | - | 0.004 |
| Calcium | g/m3 | 31 | | - | - |
| Chromium | g/m3 | 0.00122 | | - | 0.05 |
| Copper | g/m3 | < 0.00053 | | - | 2 |
| Iron | g/m3 | < 0.021 | | 0.2 | - |
| Lead | g/m3 | < 0.00011 | | - | 0.01 |
| Lithium | g/m3 | 0.00143 | | - | - |
| Magnesium | g/m3 | 2.8 | | - | - |
| Manganese | g/m3 | < 0.00053 | | - | 0.4 |
| Mercury | g/m3 | < 0.00008 | | - | 0.007 |
| Molybdenum | g/m3 | < 0.00021 | | - | 0.07 |
| Nickel | g/m3 | < 0.00053 | | - | 0.1 |
| Potassium | g/m3 | 0.8 | | - | - |
| Selenium | g/m3 | < 0.0011 | | - | 0.01 |
| Silver | g/m3 | < 0.00011 | | - | 0.1 |
| Sodium | g/m3 | 3.5 | | 200 | - |
| Tin | g/m3 | < 0.00053 | | - | - |
| Uranium | g/m3 | 0.00023 | | - | 0.02 |
| Zinc | g/m3 | 0.0026 | | 1.5 | - |
| Total alpha concentration | Bq/L | < 0.033 | | - | 0.1 |
| Total beta concentration | Bq/L | < 0.15 | | - | 0.5 |
| Radon-222 | Bq/L | 1.87 | | - | 100 |

Standards sourced from:
Ministry of Health (2008). Drinking-water Standards for New Zealand 2005 (Revised 2008). Wellington: Ministry of Health.
Ministry of Health (2016). Volume 3, datasheets, part 2.3, chemical and physical determinants, pesticides
World Health Organisation (2009). Beryllium in drinking-water. Background document for development of WHO Guidelines for Drinking-water Quality
World Health Organisation (2003). Silver in drinking-water. Background document for development of WHO Guidelines for Drinking-water Quality
World Health Organisation (2004). Inorganic Tin in drinking-water. Background document for development of WHO Guidelines for Drinking-water Quality
Maximum Acceptable Value (MAV) for human health (short-term)
Guideline Value (GV) for human health
Samples taken on 26 July 2017 and analysed by a separate laboratory

## C.2 Laboratory Results

# Appendix D: Surface Water

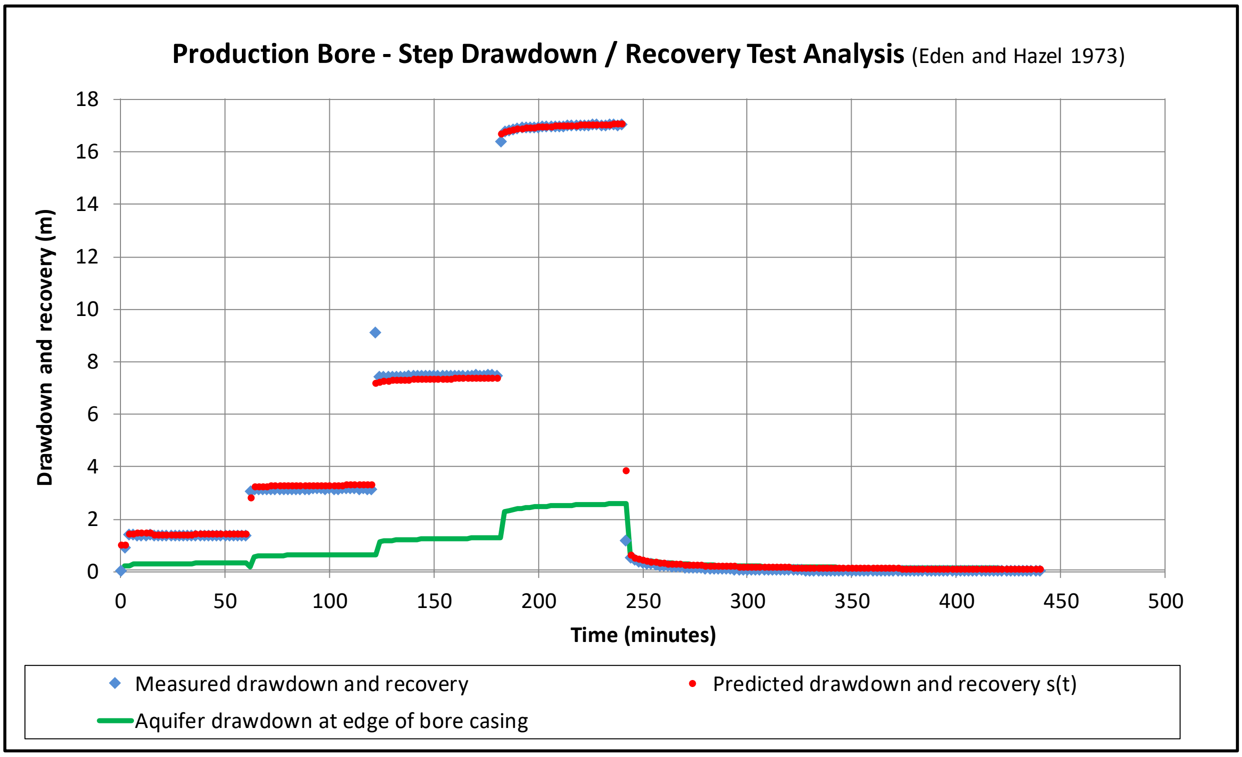
## D.1 Rivers and Streams

## D.2 Lake Wakatipu

# Appendix E: Aquifer Testing

## E.1 Step-Discharge Test – Manual Readings

## E.2 Step-Discharge Test – Data Analysis (using the logger data)



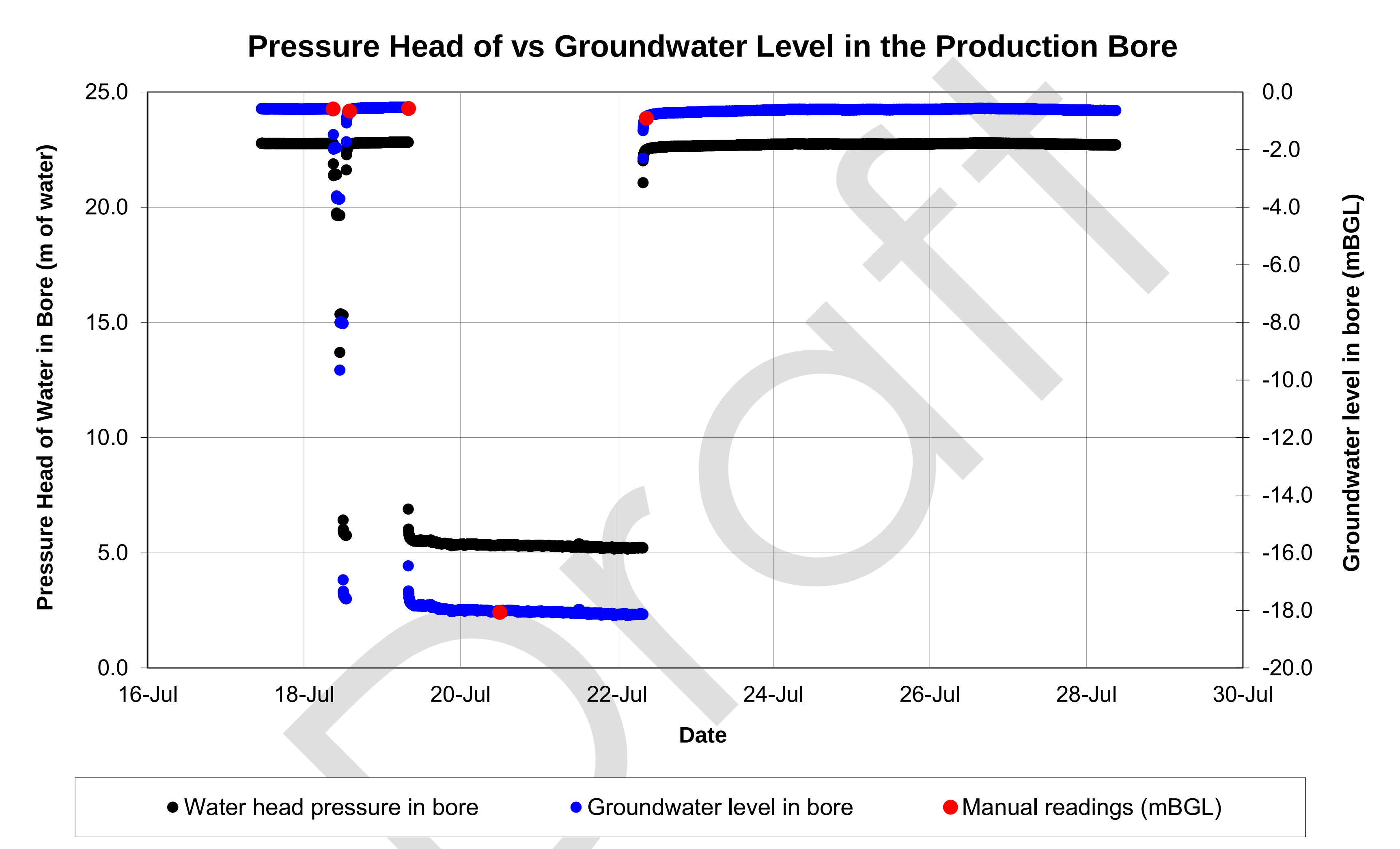

$$\text{Bore efficiency } 1 = \frac{(a + b\log t)Q}{(a + b\log t)Q + CQ^2}$$

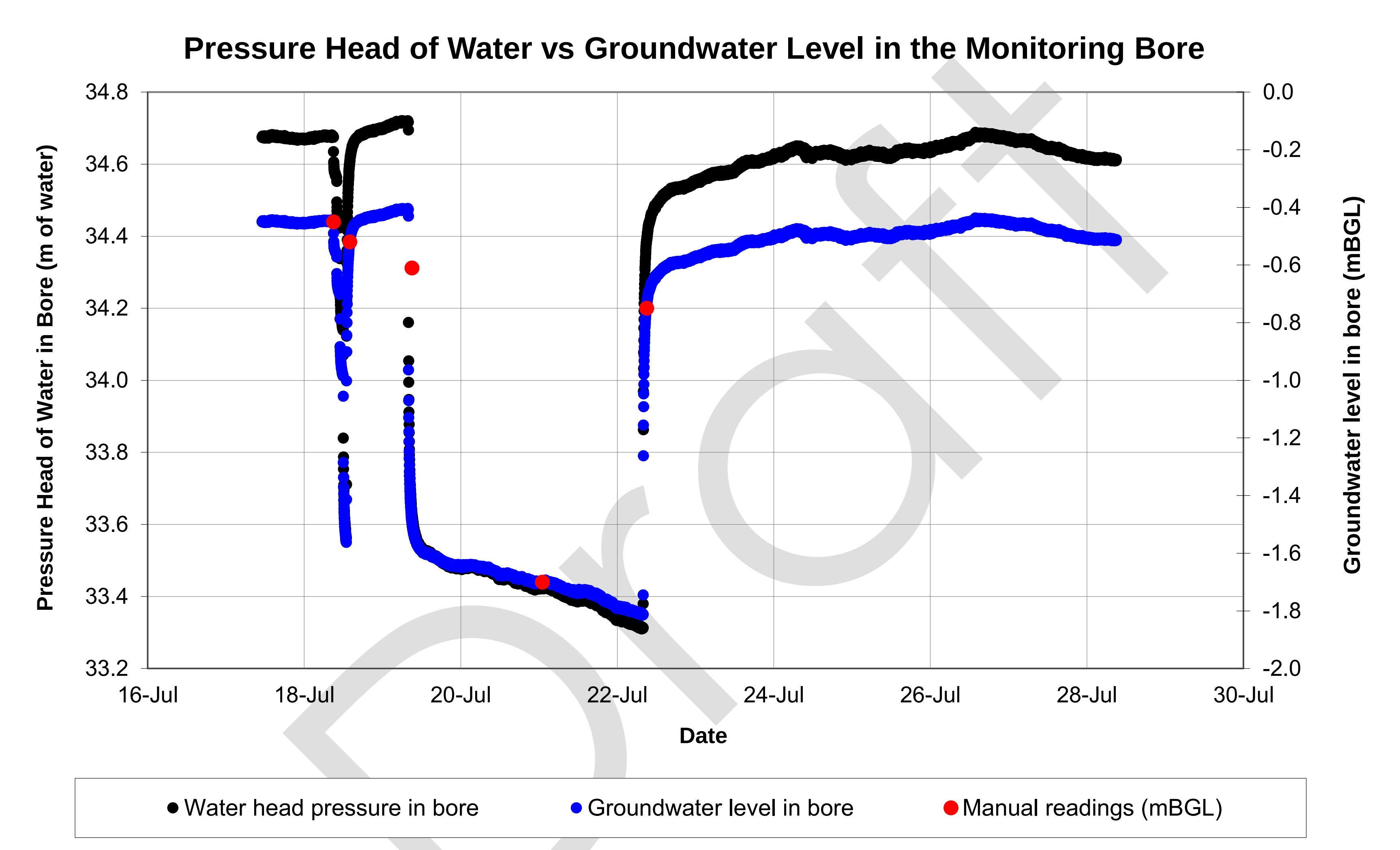
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Laminar drawdown coefficient | a | 4.8 | $min/m^2$ | Transmissivity | T | 1,500 | $m^2/day$ |
| Laminar drawdown coefficent | b | 0.2 | $min/m^2$ | Storativity | S | 0.001 | - |
| Turbulent drawdown coeficient | C | 2.2 | $min^2/m^5$ | Bore radius | $r_w$ | 0.15 | m |
| Exponent between 1.5 and 3.0 | n | 1.5 | | Max bore efficiency 1 | $Ef_{min}$ | 84 | % |
| | | | | Min bore efficiency 1 | $Ef_{max}$ | 61 | % |

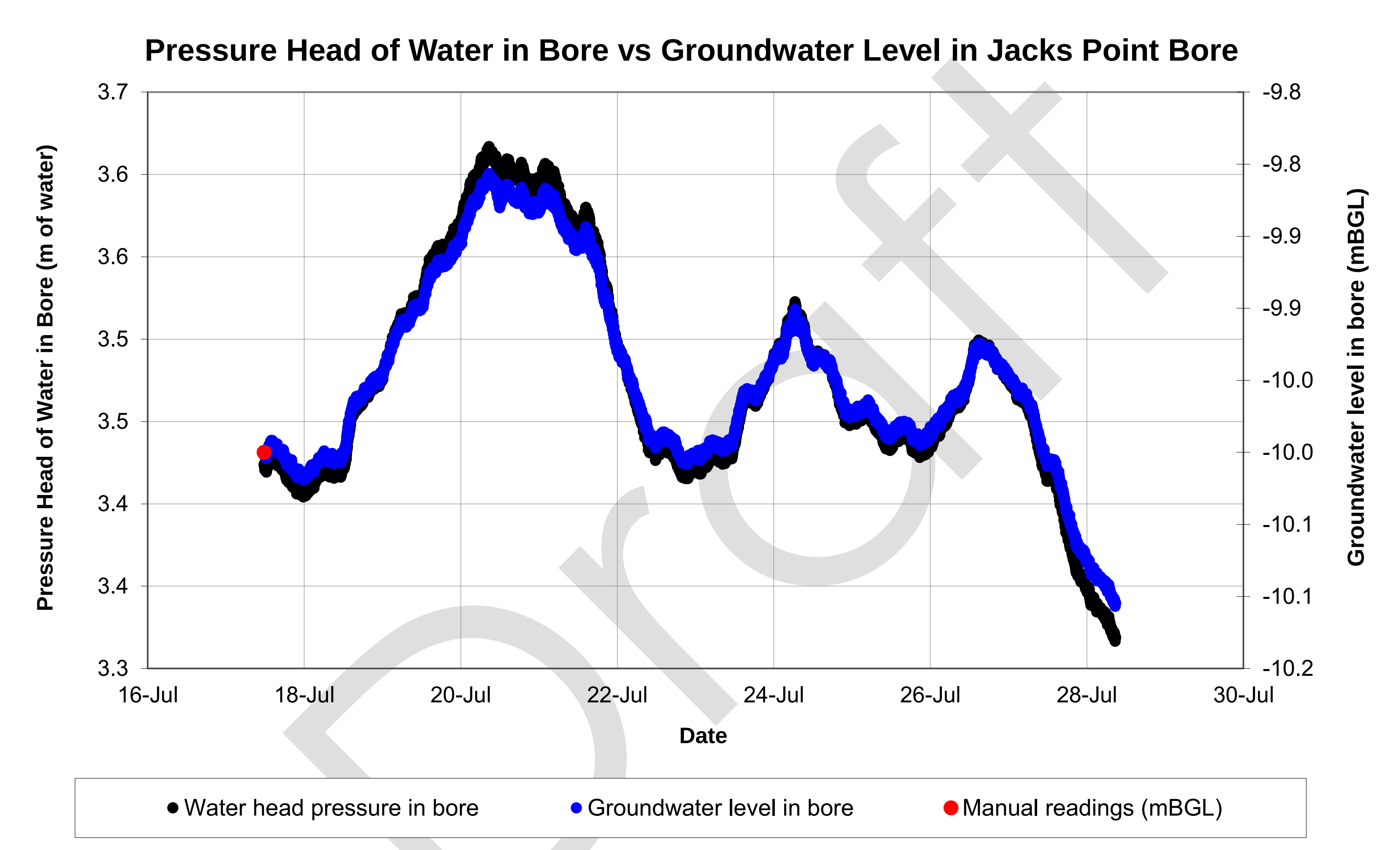
$$s(t) = (aQ + CQ^n) + bLOG_{10}(t)Q \qquad T = \frac{2.3}{4\pi b}$$

## E.3 Constant-Discharge Test - Manual Readings

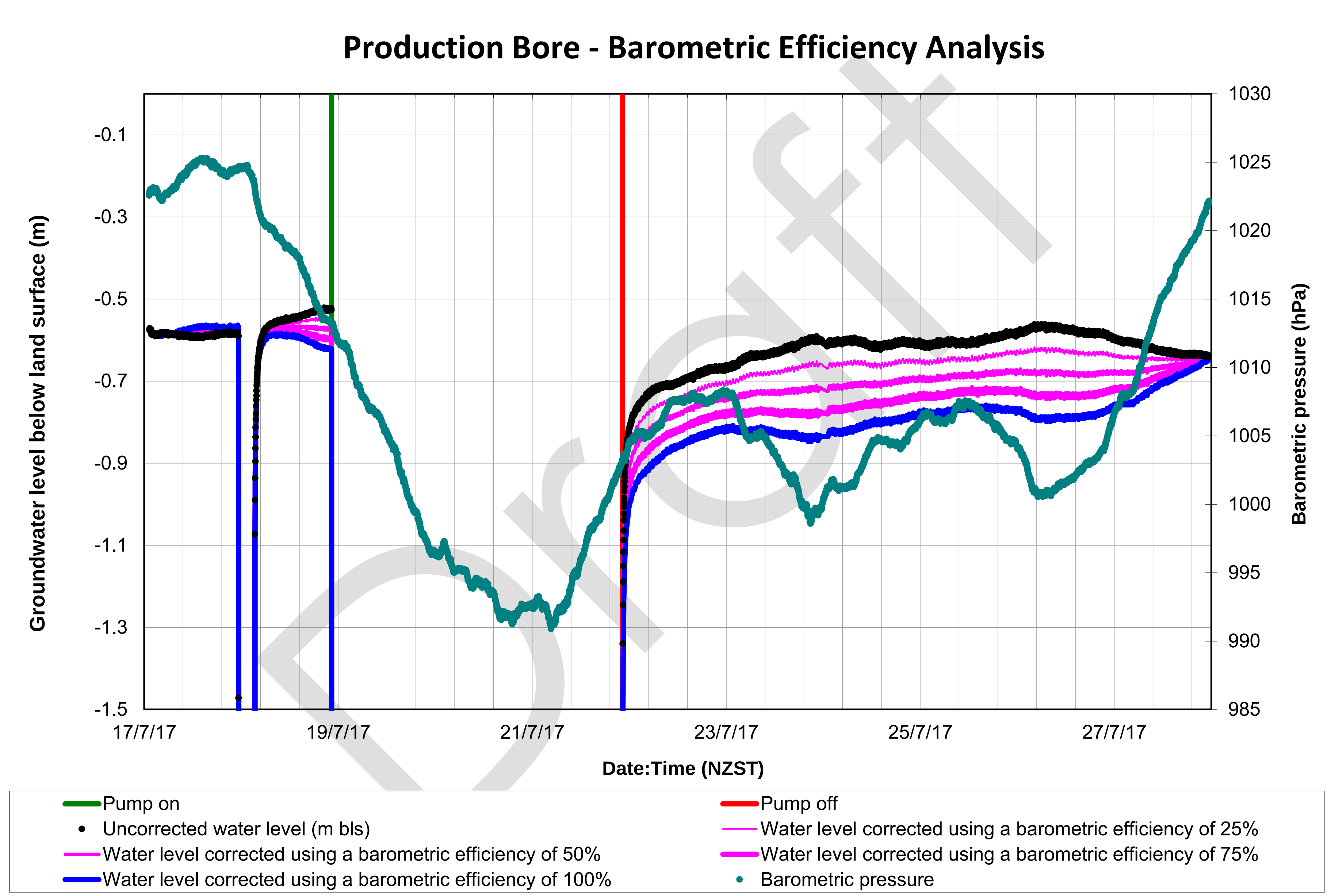
## E.4 Constant-Discharge Test - Raw Logger Data


Pressure Head of vs Groundwater Level in the Production Bore
Pressure Head of Water in Bore (m of water)
25.0
20.0
15.0
10.0
5.0
0.0
Groundwater level in bore (mBGL)
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
-16.0
-18.0
-20.0
16-Jul
18-Jul
20-Jul
22-Jul
24-Jul
26-Jul
28-Jul
30-Jul
Date
Water head pressure in bore
Groundwater level in bore
Manual readings (mBGL)

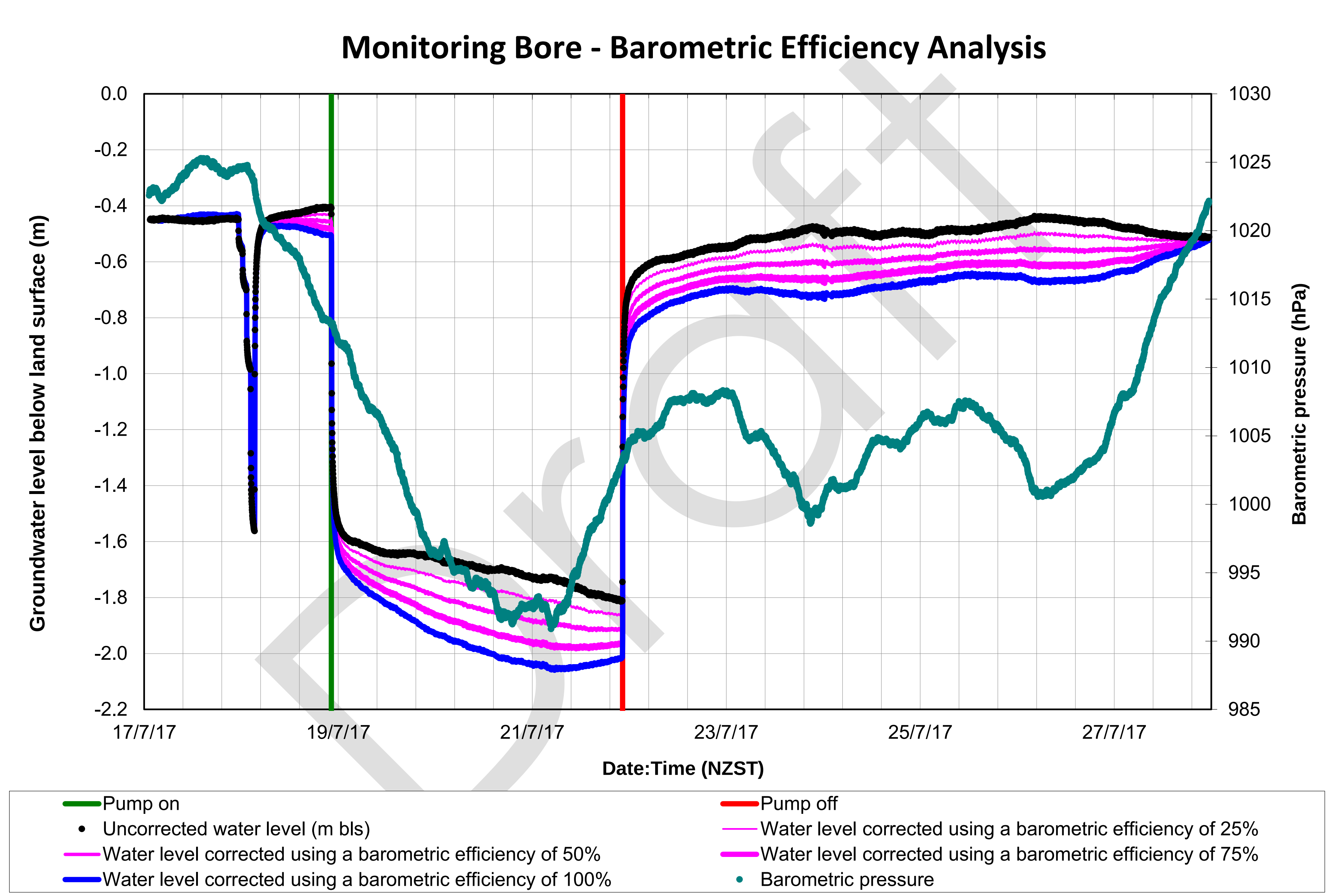

Pressure Head of Water vs Groundwater Level in the Monitoring Bore
Pressure Head of Water in Bore (m of water)
34.8
34.6
34.4
34.2
34.0
33.8
33.6
33.4
33.2
Groundwater level in bore (mBGL)
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
-2.0
16-Jul
18-Jul
20-Jul
22-Jul
24-Jul
26-Jul
28-Jul
30-Jul
Date
Water head pressure in bore
Groundwater level in bore
Manual readings (mBGL)
Draft

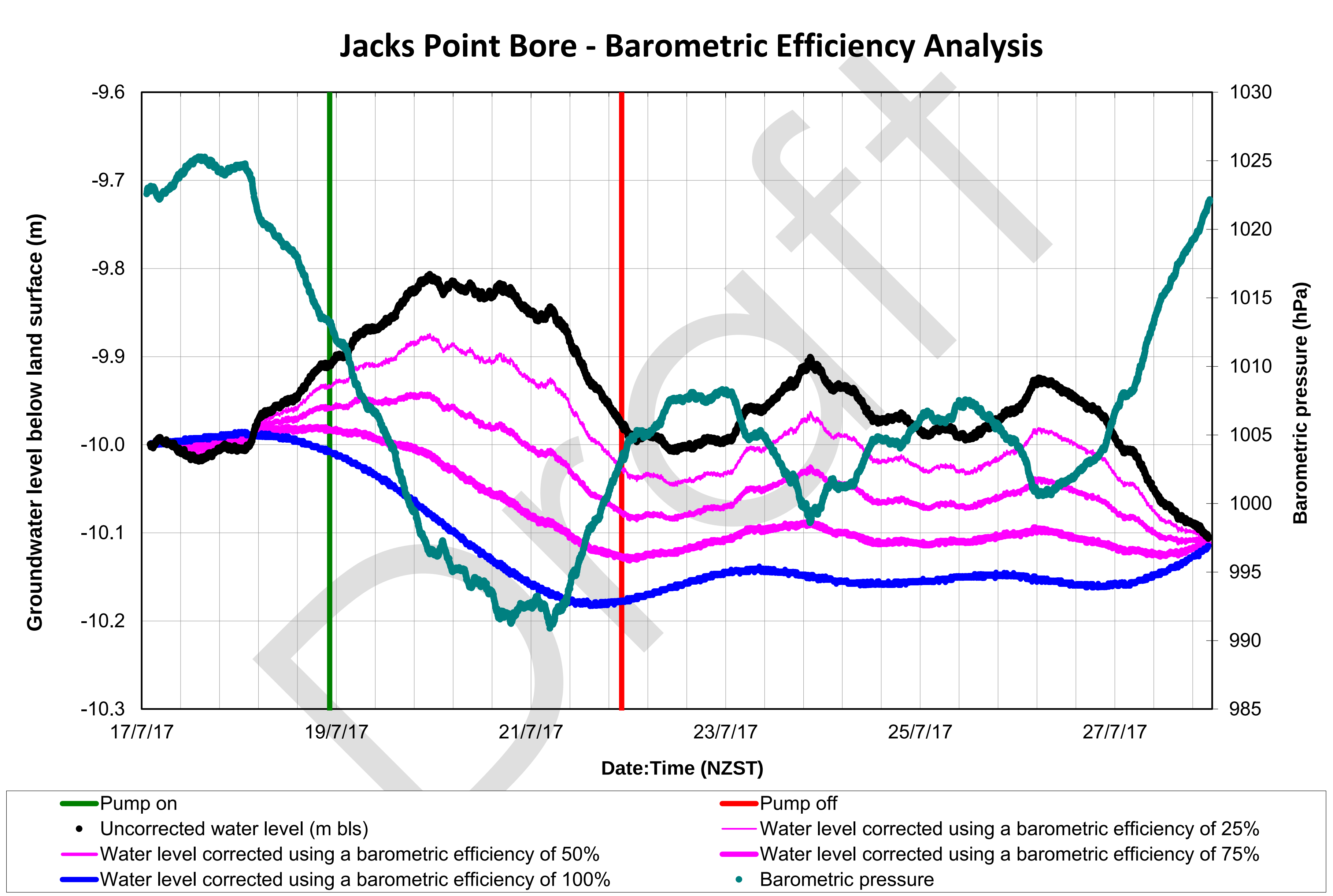

Pressure Head of Water in Bore vs Groundwater Level in Jacks Point Bore
Pressure Head of Water in Bore (m of water)
3.7
3.6
3.6
3.5
3.5
3.4
3.4
3.3
Groundwater level in bore (mBGL)
-9.8
-9.8
-9.9
-9.9
-10.0
-10.0
-10.1
-10.1
-10.2
16-Jul
18-Jul
20-Jul
22-Jul
24-Jul
26-Jul
28-Jul
30-Jul
Date
Water head pressure in bore
Groundwater level in bore
Manual readings (mBGL)

## E.5 Constant-Discharge Test - Barometric Efficiency Estimations



Production Bore - Barometric Efficiency Analysis
Groundwater level below land surface (m)
-0.1
-0.3
-0.5
-0.7
-0.9
-1.1
-1.3
-1.5
Barometric pressure (hPa)
1030
1025
1020
1015
1010
1005
1000
995
990
985
17/7/17
19/7/17
21/7/17
23/7/17
25/7/17
27/7/17
Date:Time (NZST)
Pump on
Pump off
Uncorrected water level (m bls)
Water level corrected using a barometric efficiency of 25%
Water level corrected using a barometric efficiency of 50%
Water level corrected using a barometric efficiency of 75%
Water level corrected using a barometric efficiency of 100%
Barometric pressure
Draft


Monitoring Bore - Barometric Efficiency Analysis
Groundwater level below land surface (m)
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
-2.0
-2.2
Barometric pressure (hPa)
1030
1025
1020
1015
1010
1005
1000
995
990
985
17/7/17
19/7/17
21/7/17
23/7/17
25/7/17
27/7/17
Date:Time (NZST)
Pump on
Pump off
Uncorrected water level (m bls)
Water level corrected using a barometric efficiency of 25%
Water level corrected using a barometric efficiency of 50%
Water level corrected using a barometric efficiency of 75%
Water level corrected using a barometric efficiency of 100%
Barometric pressure
Draft


Jacks Point Bore - Barometric Efficiency Analysis
Groundwater level below land surface (m)
-9.6
-9.7
-9.8
-9.9
-10.0
-10.1
-10.2
-10.3
Barometric pressure (hPa)
1030
1025
1020
1015
1010
1005
1000
995
990
985
17/7/17
19/7/17
21/7/17
23/7/17
25/7/17
27/7/17
Date:Time (NZST)
Pump on
Pump off
Uncorrected water level (m bls)
Water level corrected using a barometric efficiency of 25%
Water level corrected using a barometric efficiency of 50%
Water level corrected using a barometric efficiency of 75%
Water level corrected using a barometric efficiency of 100%
Barometric pressure
Draft

Barometric efficiency calculations calculated by plotting the change in groundwater levels (corrected for an antecedent trend) versus the change in barometric pressure for fixed periods of time

## Production Bore

| Time Period | Start Date | End Date | Barometric Efficiency (%) | $R^2$ |
|---|---|---|---|---|
| A | 17/07/2017 14:22 | 17/07/2017 22:14 | 20 | 0.52 |
| B | 25/07/2017 22:46 | 26/07/2017 13:04 | 77 | 0.89 |
| C | 26/07/2017 19:00 | 28/07/2017 3:40 | 29 | 0.97 |

Antecedent trend corrected for at a fixed barometric pressure of 1,014 hPa

## Monitoring Bore

| Time Period | Start Date | End Date | Barometric Efficiency (%) | $R^2$ |
|---|---|---|---|---|
| A | 17/07/2017 14:22 | 17/07/2017 22:14 | 21 | 0.55 |
| B | 25/07/2017 22:46 | 26/07/2017 13:04 | 86 | 0.92 |
| C | 26/07/2017 19:00 | 28/07/2017 3:40 | 29 | 0.97 |

Antecedent trend corrected for at a fixed barometric pressure of 1,014 hPa

## Jacks Point Bore

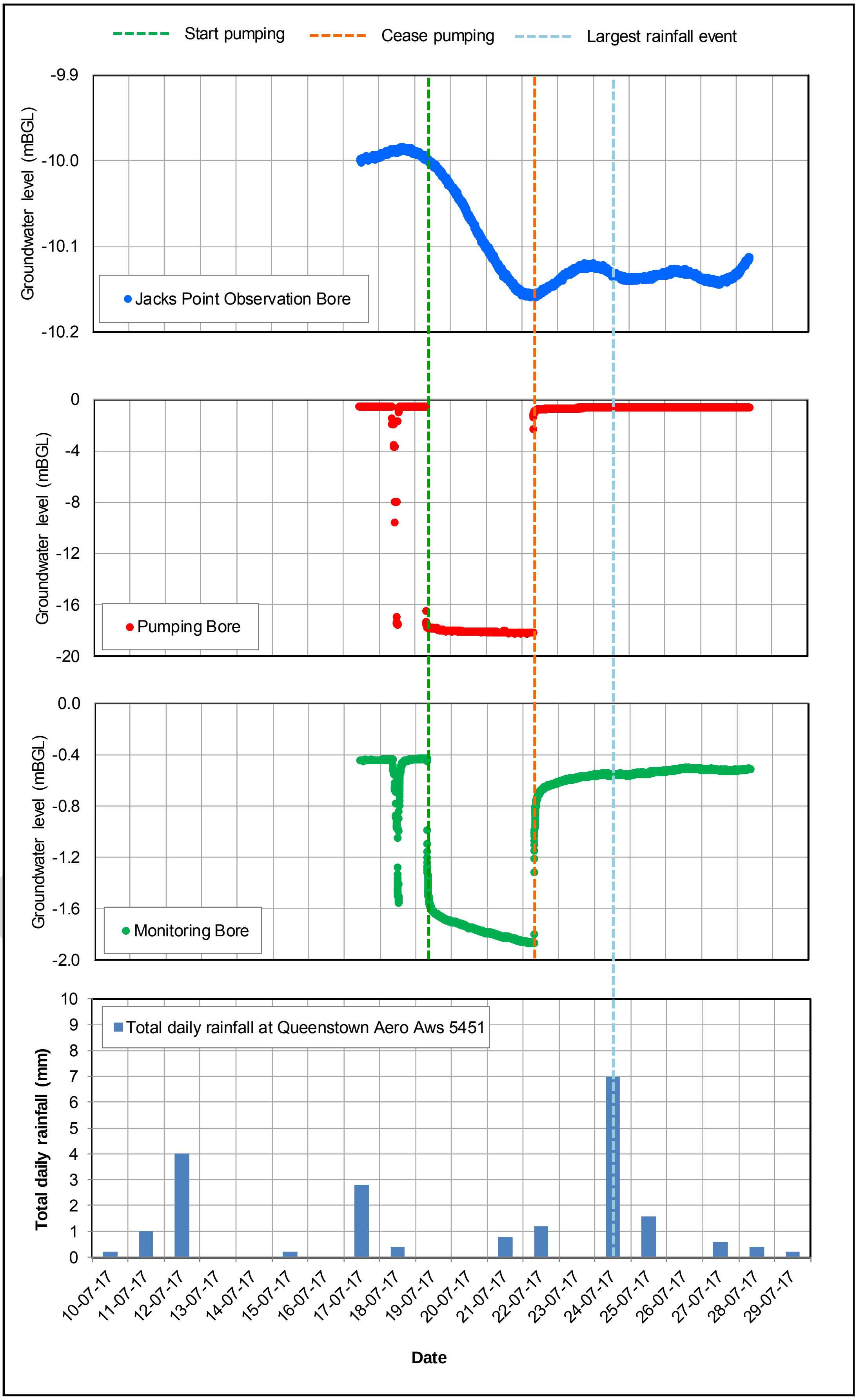
| Time Period | Start Date | End Date | Barometric Efficiency (%) | $R^2$ |
|---|---|---|---|---|
| A | 17/07/2017 14:22 | 17/07/2017 22:14 | 62 | 0.93 |
| B | 25/07/2017 22:46 | 26/07/2017 13:04 | 115 | 0.98 |
| C | 26/07/2017 19:00 | 28/07/2017 3:40 | 76 | 1.00 |

Antecedent trend corrected for at a fixed barometric pressure of 1,014 hPa

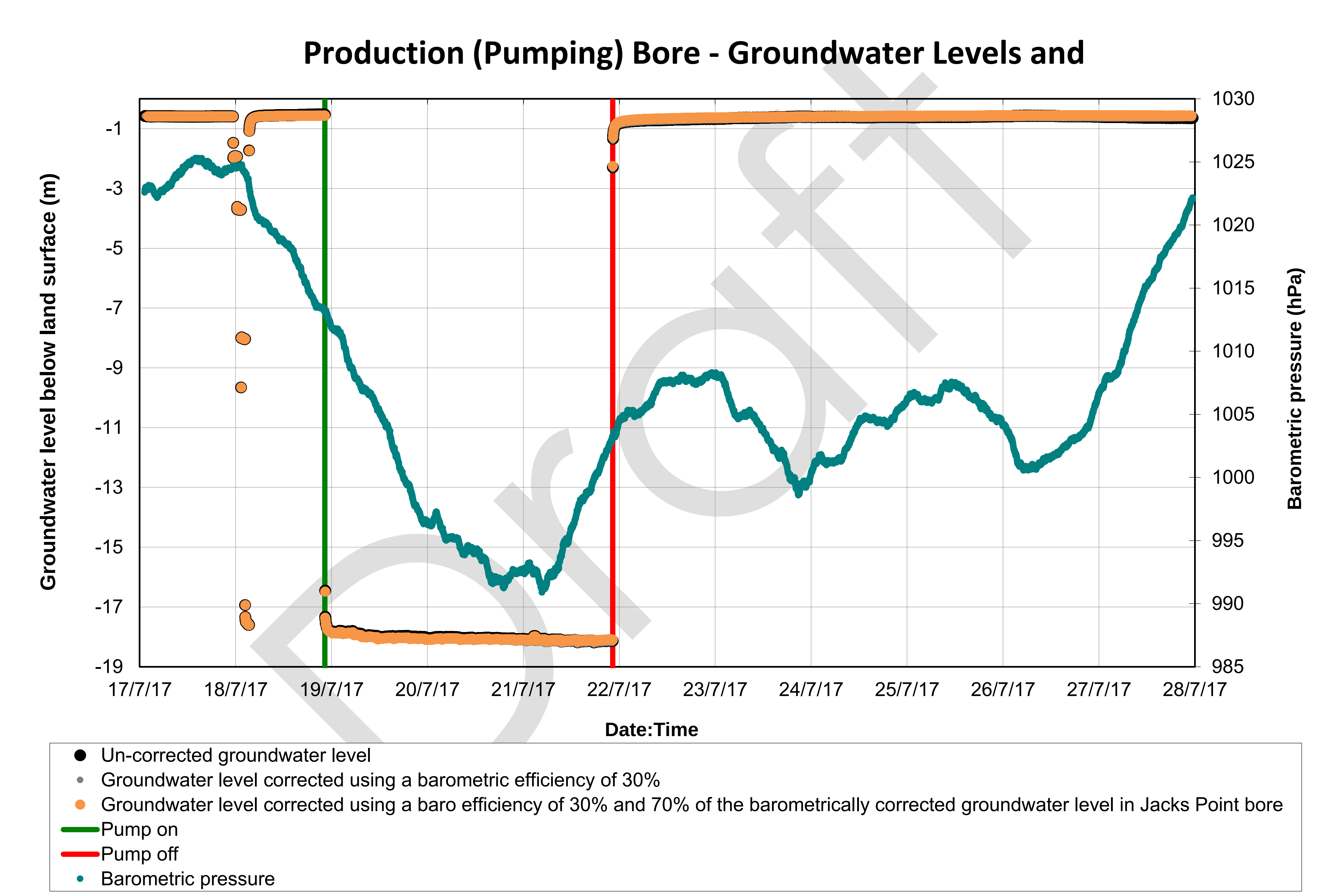
| Time Period | Start Date | End Date | Barometric Efficiency (%) | $R^2$ |
|---|---|---|---|---|
| A | 18/07/2017 12:16 | 19/07/2017 23:10 | 77 | 0.99 |
| B | 25/07/2017 22:46 | 26/07/2017 13:04 | 108 | 0.98 |
| C | 26/07/2017 19:00 | 28/07/2017 3:40 | 80 | 0.99 |
| D | 21/07/2017 18:20 | 22/07/2017 8:58 | 94 | 0.99 |
| E | 23/07/2017 12:08 | 25/07/2017 4:30 | 98 | 0.99 |
| Multiple Periods | 17/07/2017 11:40 | 28/07/2017 9:02 | 60 | 0.80 |

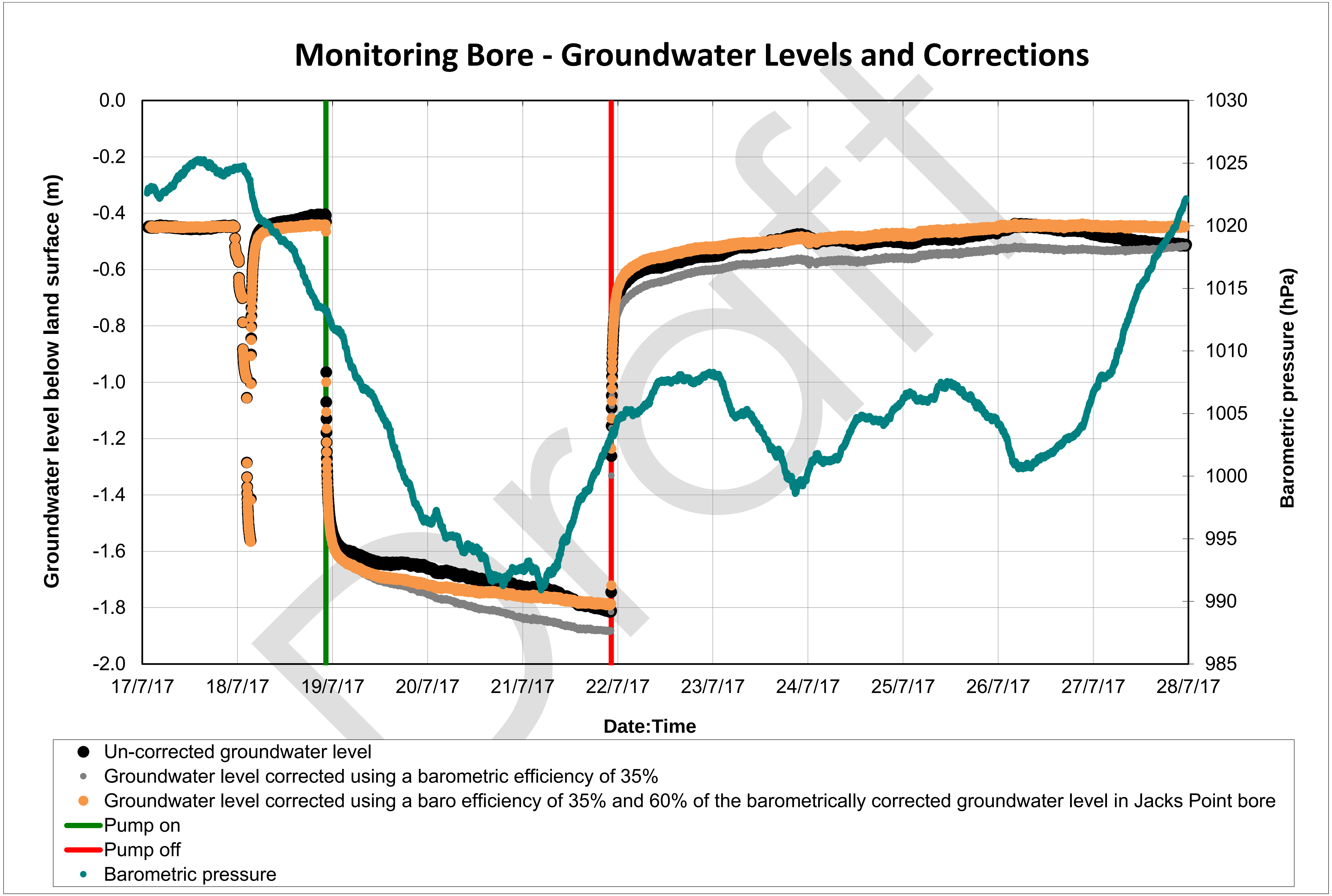
Antecedent trend corrected for at a fixed barometric pressure of 1,006 hPa

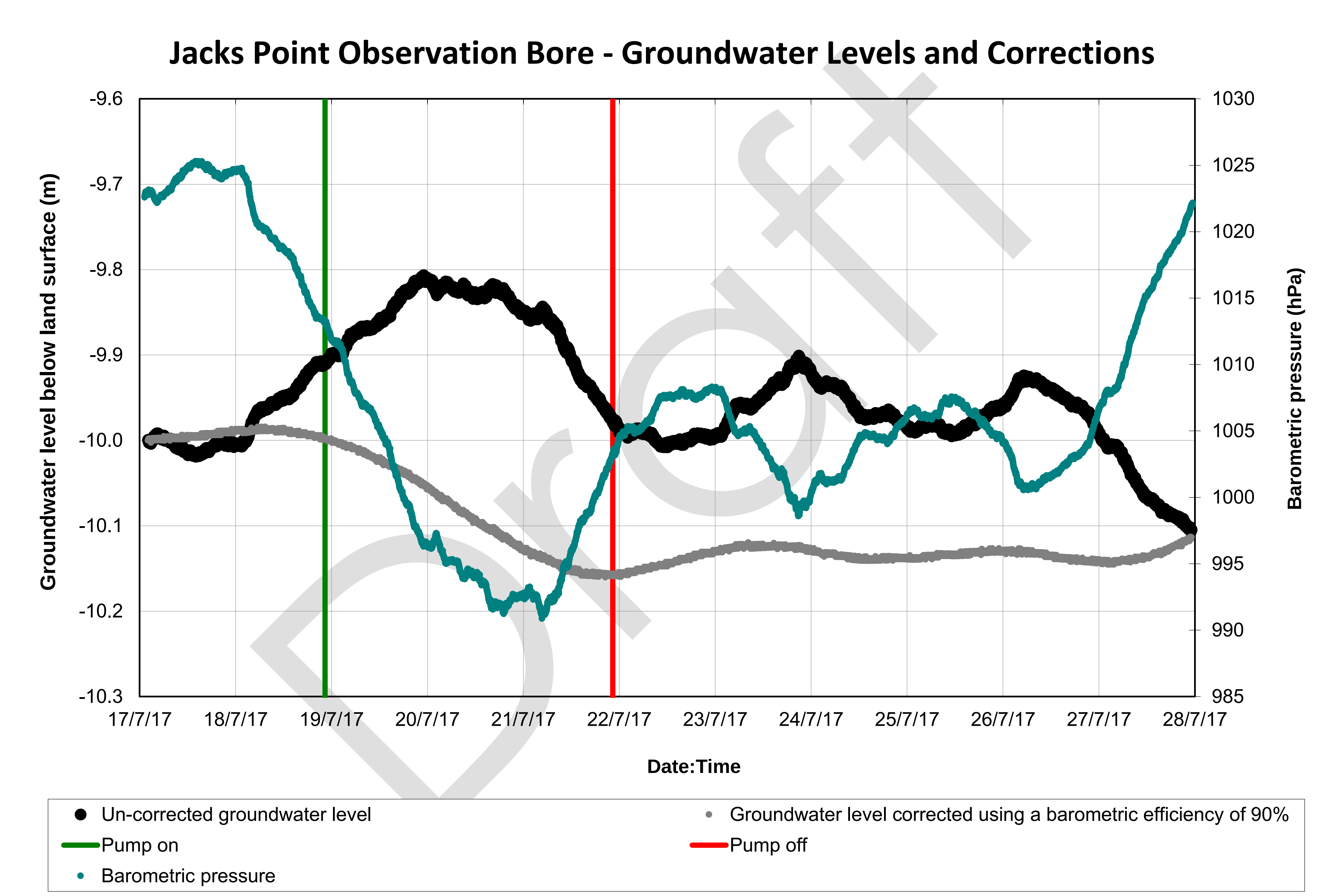
## E.6 Constant-Discharge Test - Groundwater Levels and Rainfall



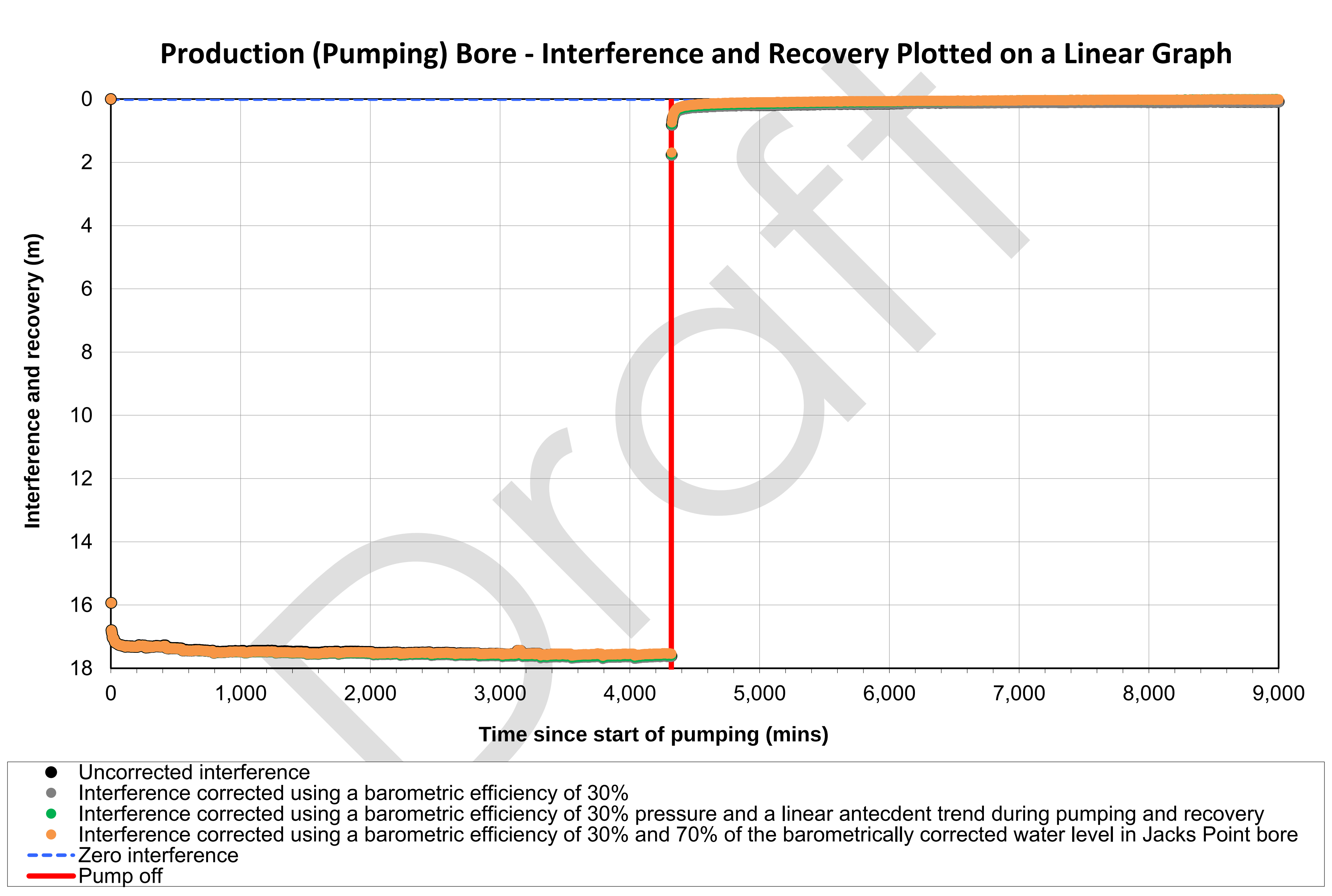
## E.7 Constant-Discharge Test - Groundwater Levels and Corrections

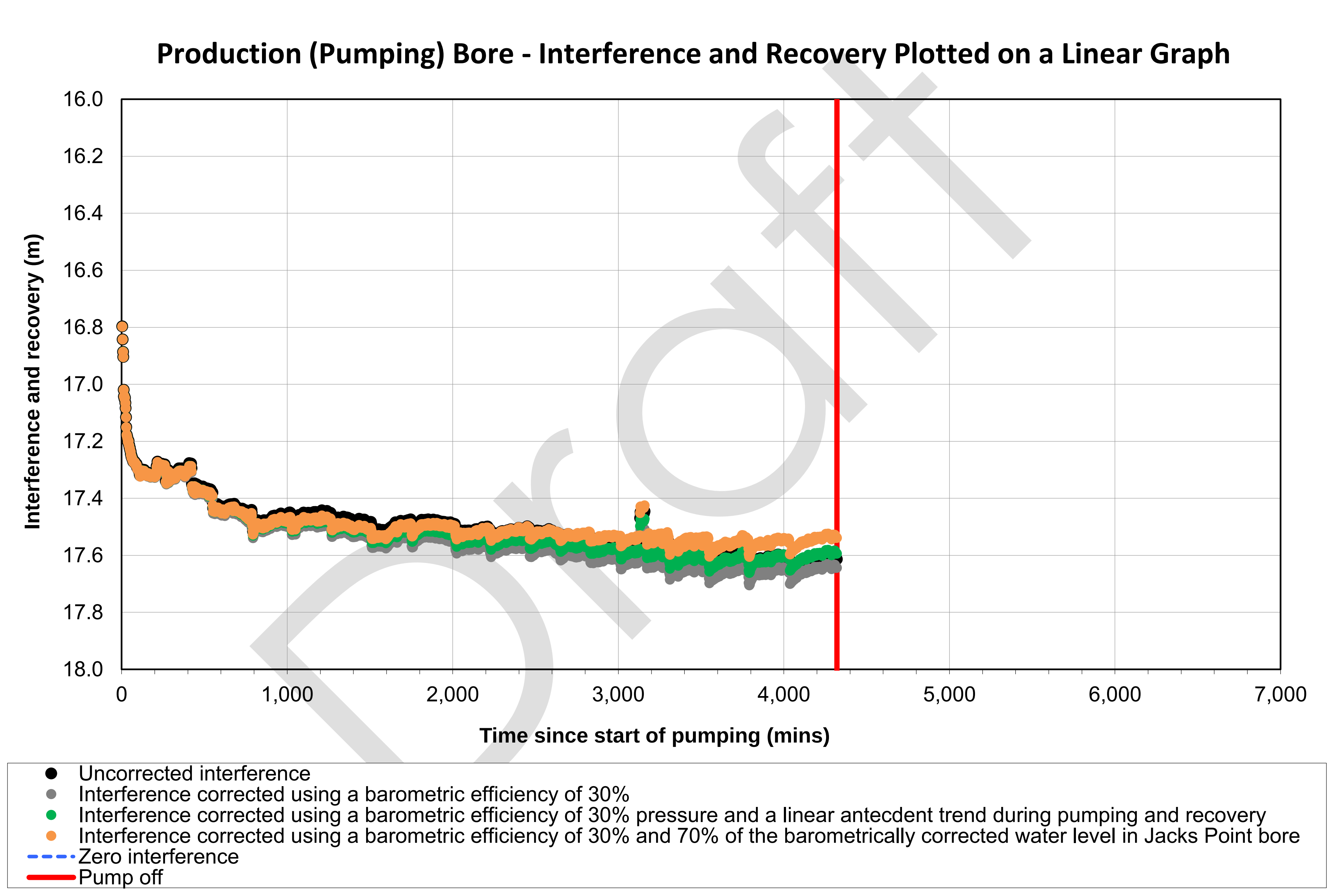

Production (Pumping) Bore - Groundwater Levels and
Groundwater level below land surface (m)
-1
-3
-5
-7
-9
-11
-13
-15
-17
-19
Barometric pressure (hPa)
1030
1025
1020
1015
1010
1005
1000
995
990
985
17/7/17
18/7/17
19/7/17
20/7/17
21/7/17
22/7/17
23/7/17
24/7/17
25/7/17
26/7/17
27/7/17
28/7/17
Date:Time
Un-corrected groundwater level
Groundwater level corrected using a barometric efficiency of 30%
Groundwater level corrected using a baro efficiency of 30% and 70% of the barometrically corrected groundwater level in Jacks Point bore
Pump on
Pump off
Barometric pressure
Draft

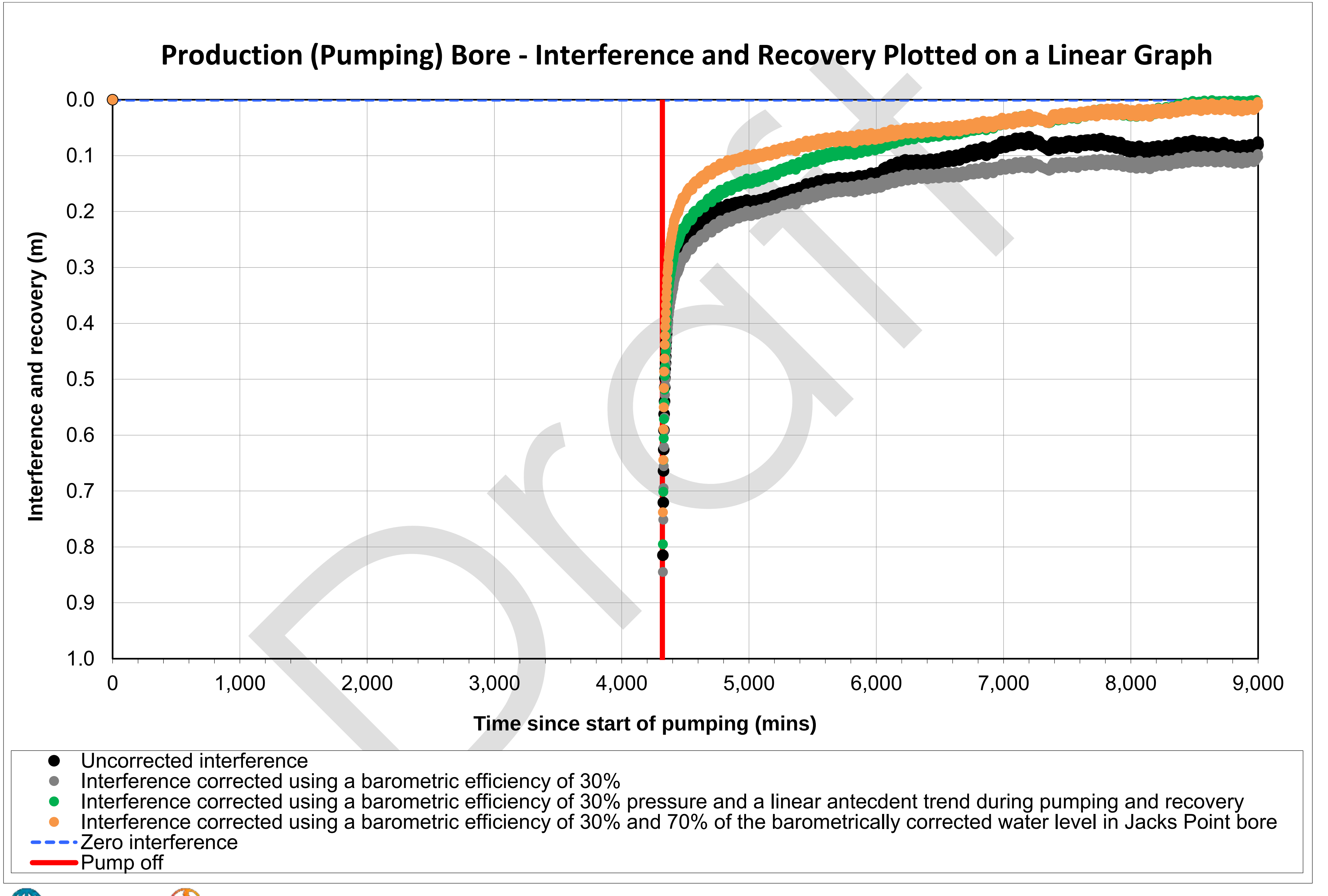

Monitoring Bore - Groundwater Levels and Corrections
Groundwater level below land surface (m)
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
-2.0
Barometric pressure (hPa)
1030
1025
1020
1015
1010
1005
1000
995
990
985
17/7/17
18/7/17
19/7/17
20/7/17
21/7/17
22/7/17
23/7/17
24/7/17
25/7/17
26/7/17
27/7/17
28/7/17
Date:Time
Un-corrected groundwater level
Groundwater level corrected using a barometric efficiency of 35%
Groundwater level corrected using a baro efficiency of 35% and 60% of the barometrically corrected groundwater level in Jacks Point bore
Pump on
Pump off
Barometric pressure

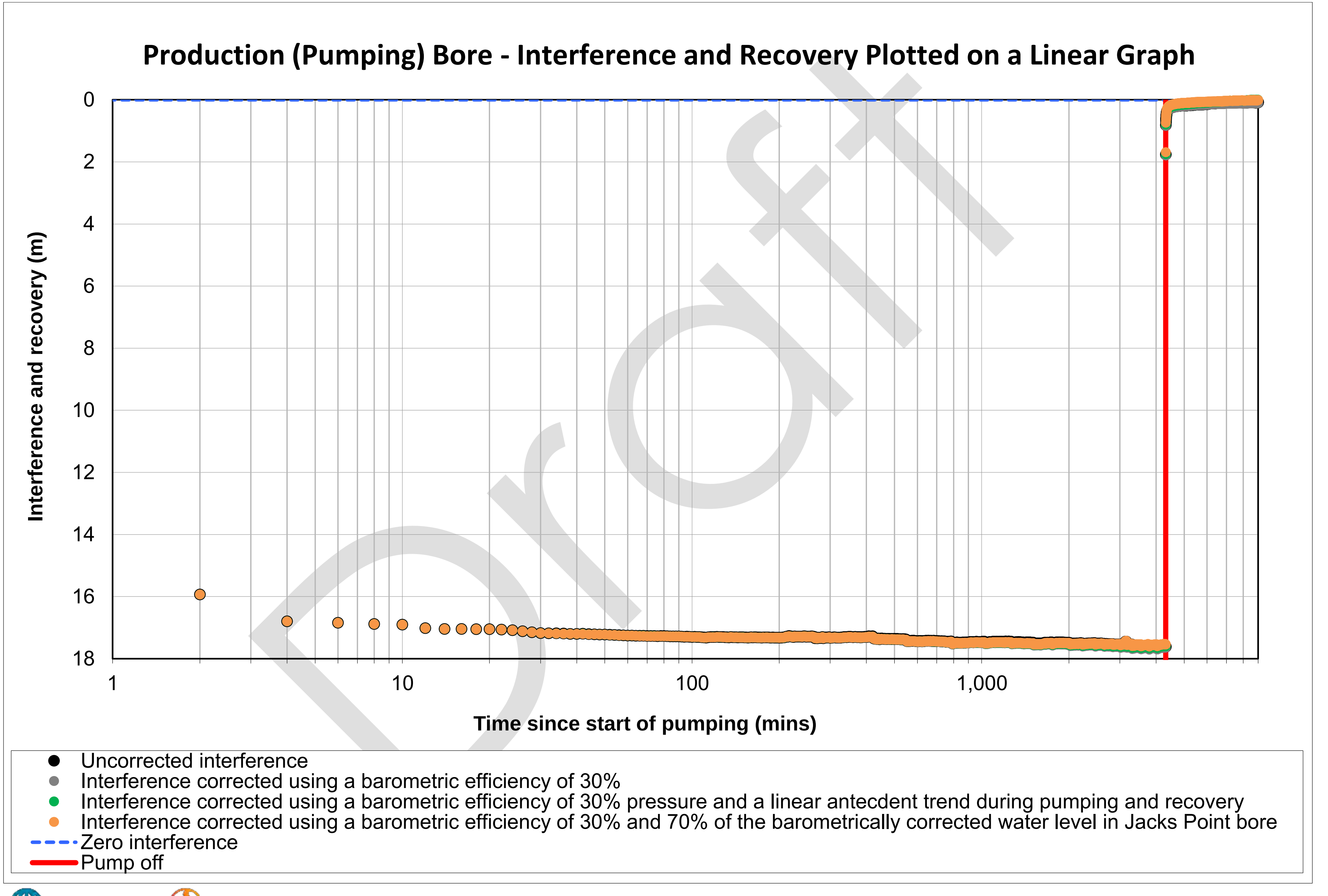

Jacks Point Observation Bore - Groundwater Levels and Corrections
Groundwater level below land surface (m)
-9.6
-9.7
-9.8
-9.9
-10.0
-10.1
-10.2
-10.3
Barometric pressure (hPa)
1030
1025
1020
1015
1010
1005
1000
995
990
985
17/7/17
18/7/17
19/7/17
20/7/17
21/7/17
22/7/17
23/7/17
24/7/17
25/7/17
26/7/17
27/7/17
28/7/17
Date:Time
Un-corrected groundwater level
Groundwater level corrected using a barometric efficiency of 90%
Pump on
Pump off
Barometric pressure

## E.8 Constant-Discharge Test - Drawdown and Recovery

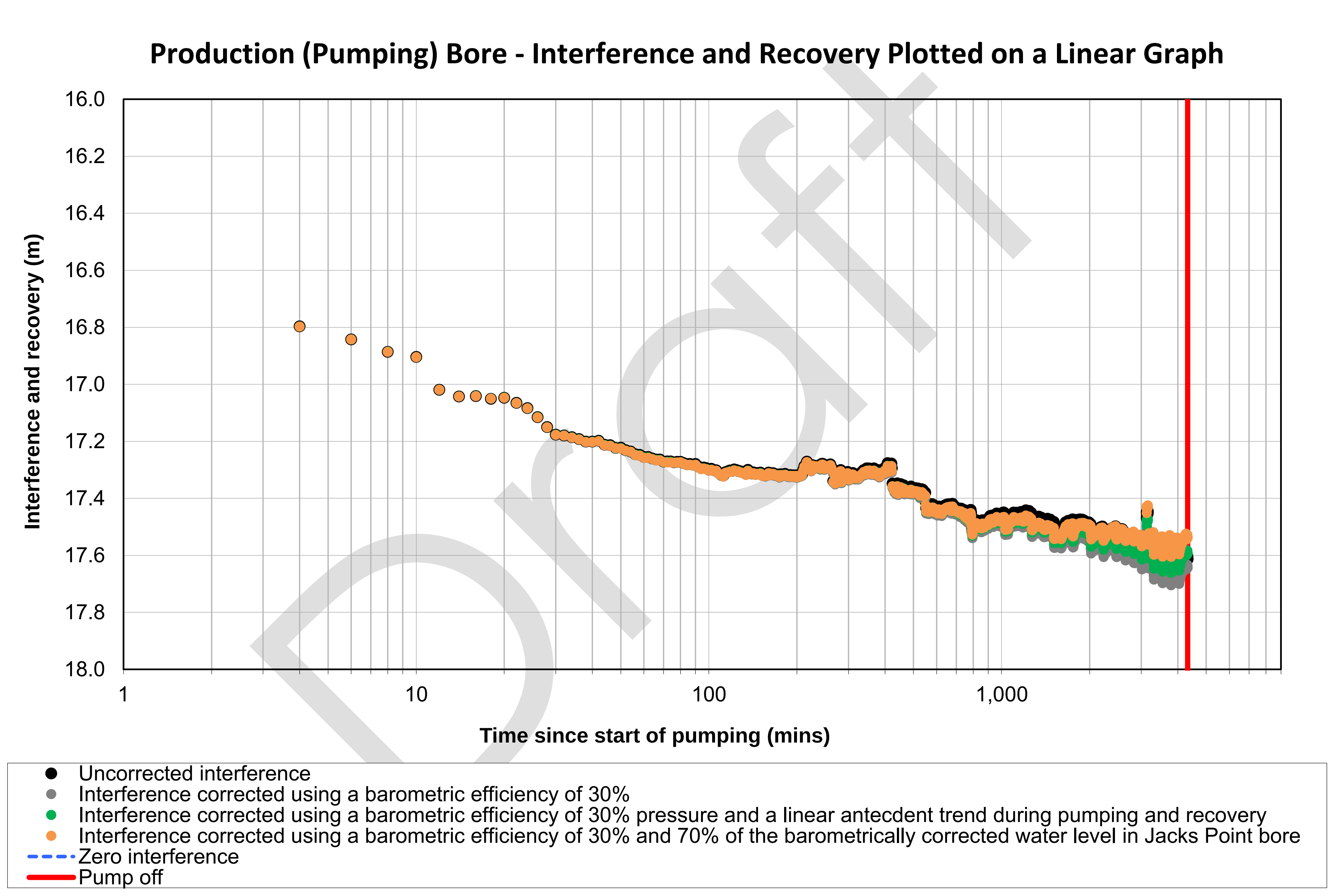

Production (Pumping) Bore - Interference and Recovery Plotted on a Linear Graph
Interference and recovery (m)
0
2
4
6
8
10
12
14
16
18
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
Time since start of pumping (mins)
Uncorrected interference
Interference corrected using a barometric efficiency of 30%
Interference corrected using a barometric efficiency of 30% pressure and a linear antecdent trend during pumping and recovery
Interference corrected using a barometric efficiency of 30% and 70% of the barometrically corrected water level in Jacks Point bore
Zero interference
Pump off


Production (Pumping) Bore - Interference and Recovery Plotted on a Linear Graph
Interference and recovery (m)
16.0
16.2
16.4
16.6
16.8
17.0
17.2
17.4
17.6
17.8
18.0
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Time since start of pumping (mins)
Uncorrected interference
Interference corrected using a barometric efficiency of 30%
Interference corrected using a barometric efficiency of 30% pressure and a linear antecdent trend during pumping and recovery
Interference corrected using a barometric efficiency of 30% and 70% of the barometrically corrected water level in Jacks Point bore
Zero interference
Pump off
Draft

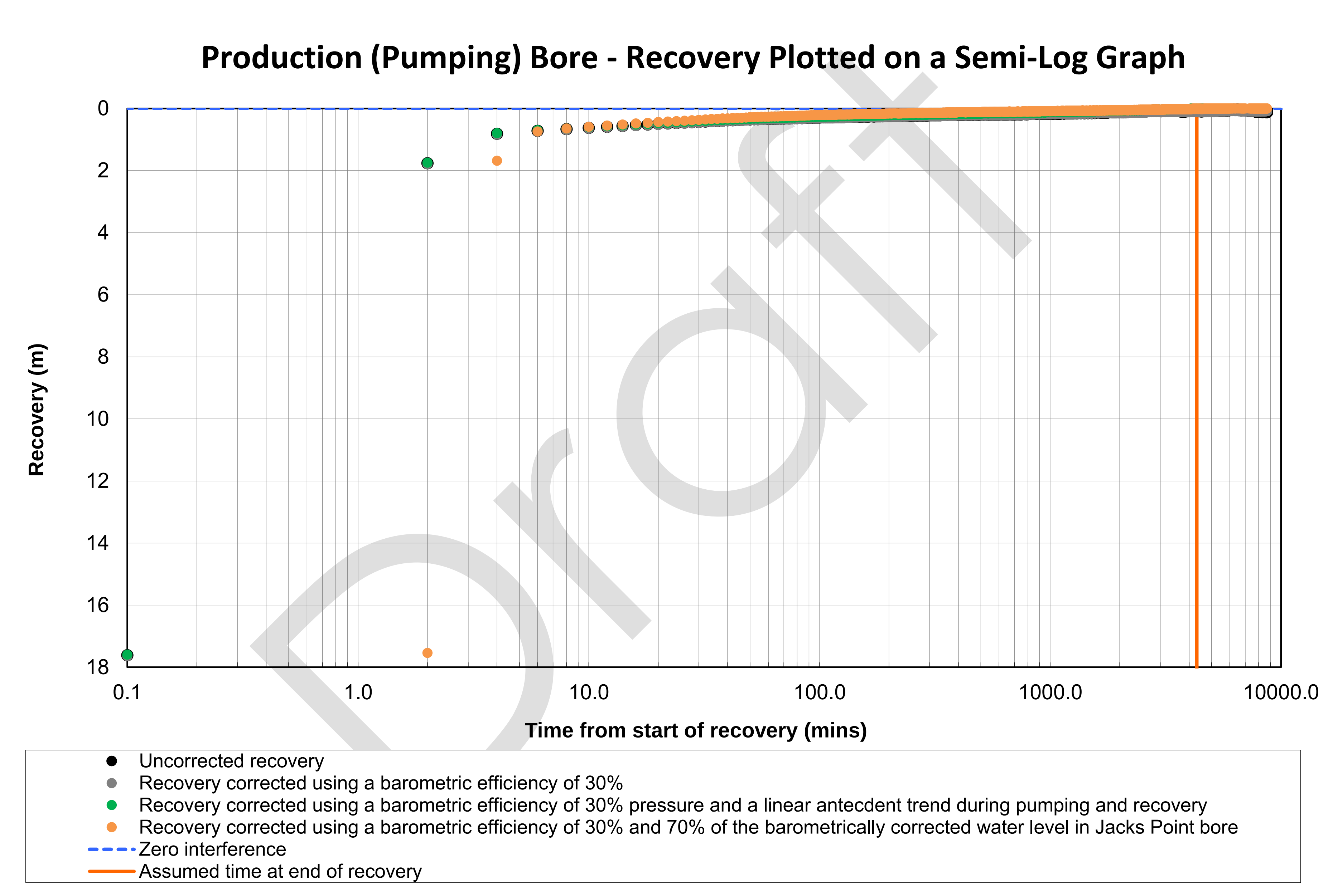

Production (Pumping) Bore - Interference and Recovery Plotted on a Linear Graph
Interference and recovery (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
Time since start of pumping (mins)
Uncorrected interference
Interference corrected using a barometric efficiency of 30%
Interference corrected using a barometric efficiency of 30% pressure and a linear antecdent trend during pumping and recovery
Interference corrected using a barometric efficiency of 30% and 70% of the barometrically corrected water level in Jacks Point bore
Zero interference
Pump off
Draft

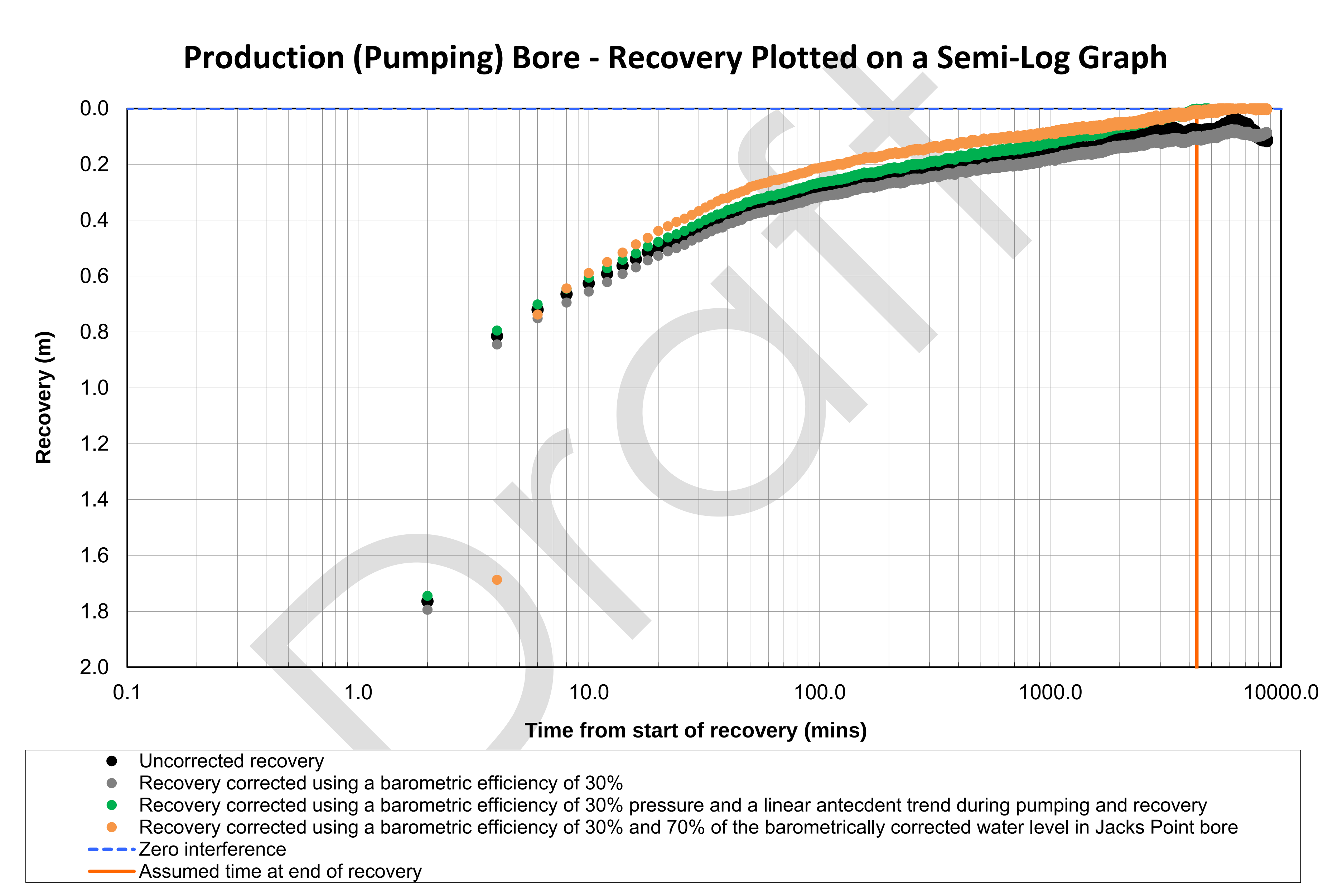


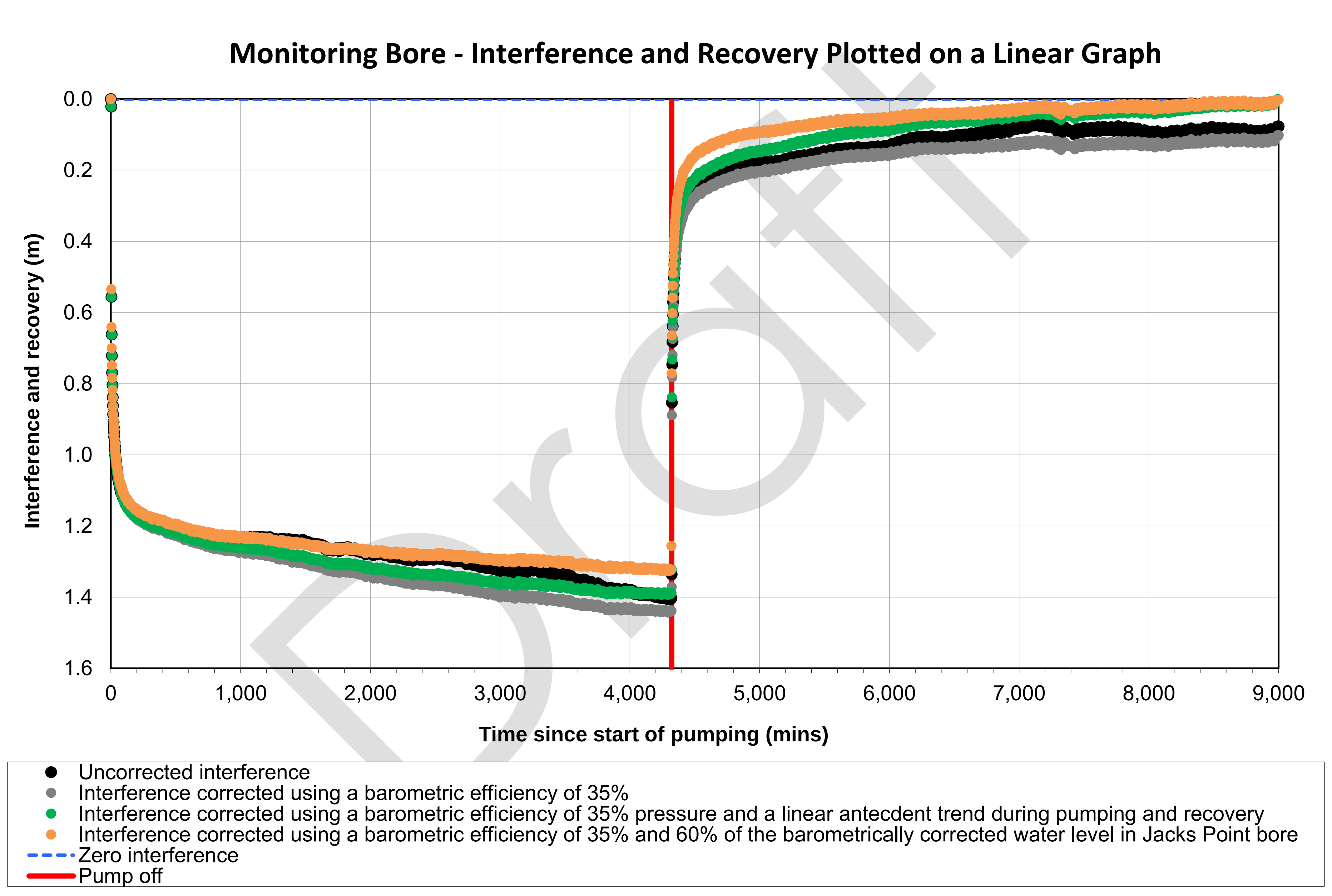
Production (Pumping) Bore - Interference and Recovery Plotted on a Linear Graph
0
2
4
6
8
10
12
14
16
18
Interference and recovery (m)
1
10
100
1,000
Time since start of pumping (mins)
Uncorrected interference
Interference corrected using a barometric efficiency of 30%
Interference corrected using a barometric efficiency of 30% pressure and a linear antecdent trend during pumping and recovery
Interference corrected using a barometric efficiency of 30% and 70% of the barometrically corrected water level in Jacks Point bore
Zero interference
Pump off
Draft

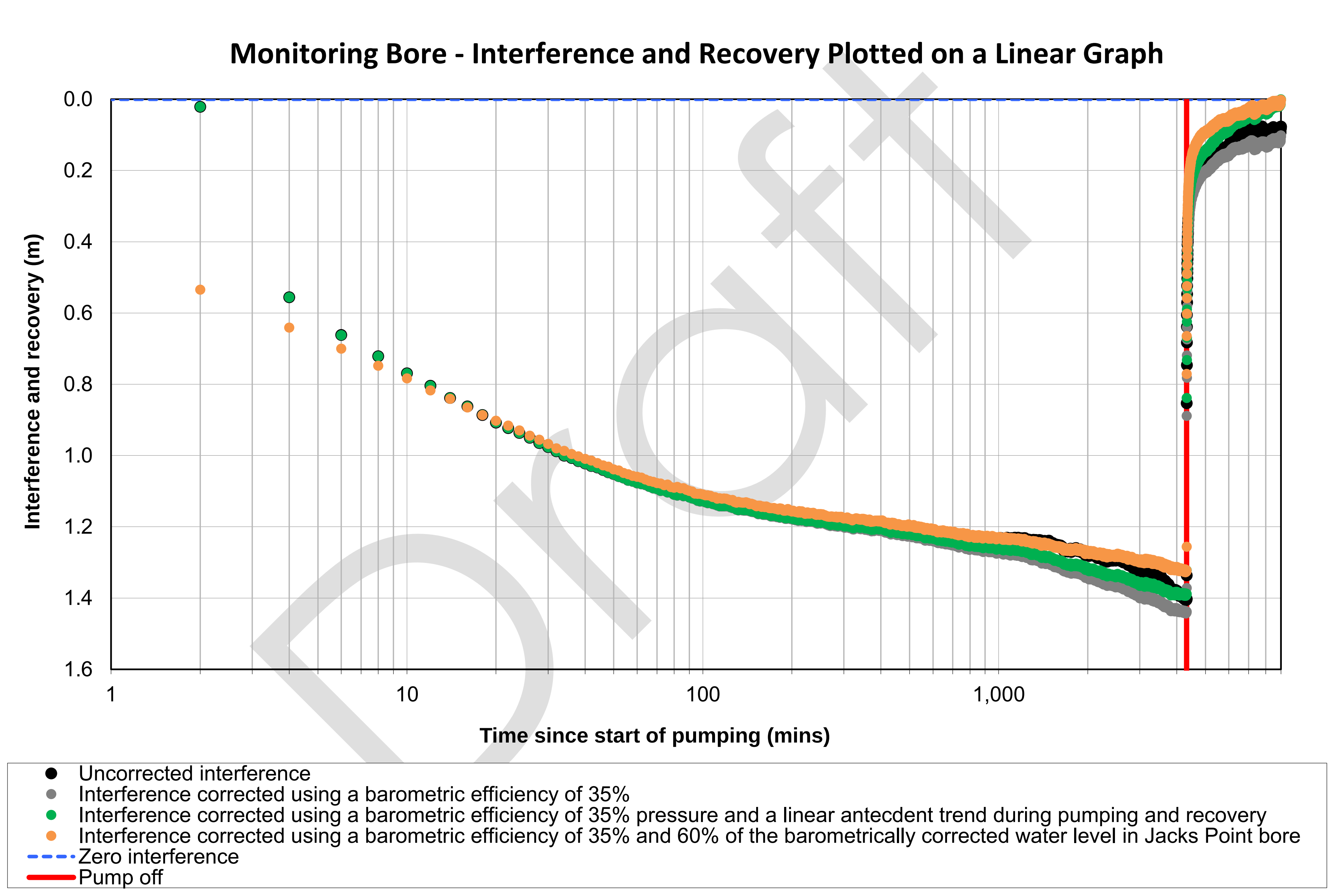


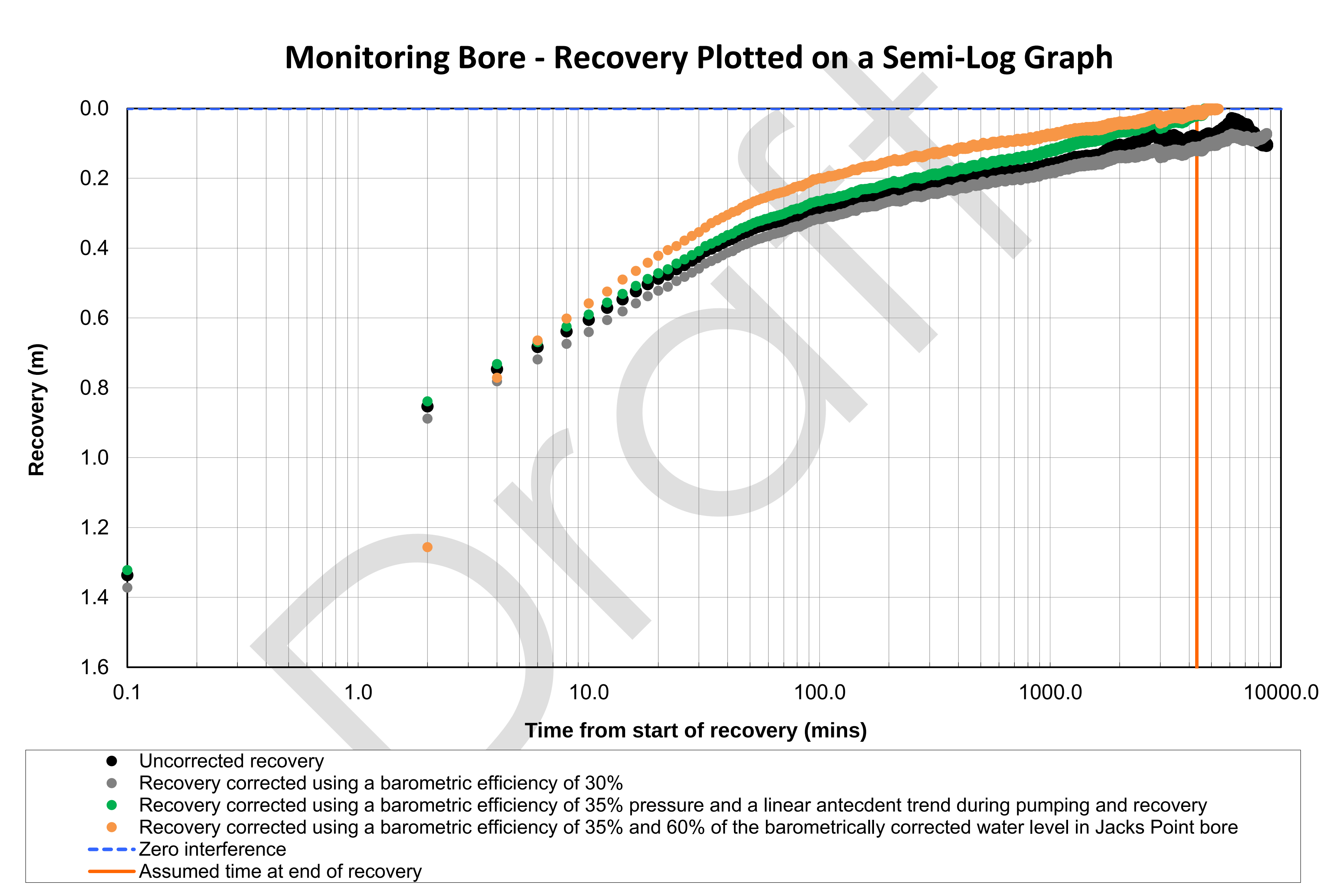

MWH now part of Stantec


Production (Pumping) Bore - Recovery Plotted on a Semi-Log Graph
Recovery (m)
0
2
4
6
8
10
12
14
16
18
0.1
1.0
10.0
100.0
1000.0
10000.0
Time from start of recovery (mins)
Uncorrected recovery
Recovery corrected using a barometric efficiency of 30%
Recovery corrected using a barometric efficiency of 30% pressure and a linear antecdent trend during pumping and recovery
Recovery corrected using a barometric efficiency of 30% and 70% of the barometrically corrected water level in Jacks Point bore
Zero interference
Assumed time at end of recovery
Draft


Production (Pumping) Bore - Recovery Plotted on a Semi-Log Graph
Recovery (m)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
0.1
1.0
10.0
100.0
1000.0
10000.0
Time from start of recovery (mins)
Uncorrected recovery
Recovery corrected using a barometric efficiency of 30%
Recovery corrected using a barometric efficiency of 30% pressure and a linear antecdent trend during pumping and recovery
Recovery corrected using a barometric efficiency of 30% and 70% of the barometrically corrected water level in Jacks Point bore
Zero interference
Assumed time at end of recovery

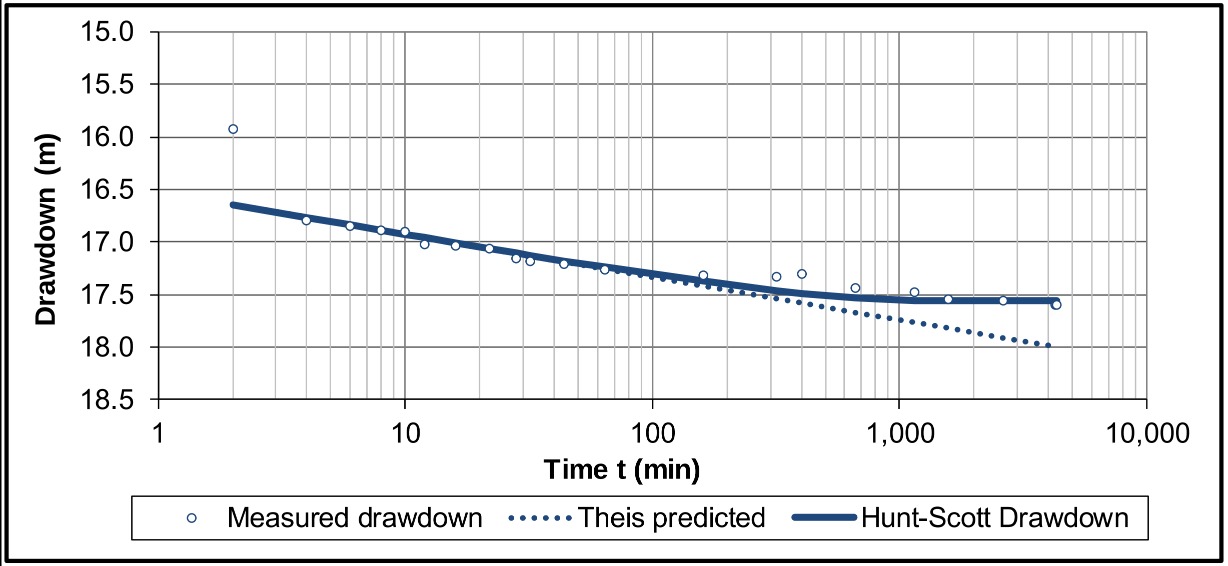

Monitoring Bore - Interference and Recovery Plotted on a Linear Graph
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Interference and recovery (m)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
Time since start of pumping (mins)
Uncorrected interference
Interference corrected using a barometric efficiency of 35%
Interference corrected using a barometric efficiency of 35% pressure and a linear antecdent trend during pumping and recovery
Interference corrected using a barometric efficiency of 35% and 60% of the barometrically corrected water level in Jacks Point bore
Zero interference
Pump off
Draft

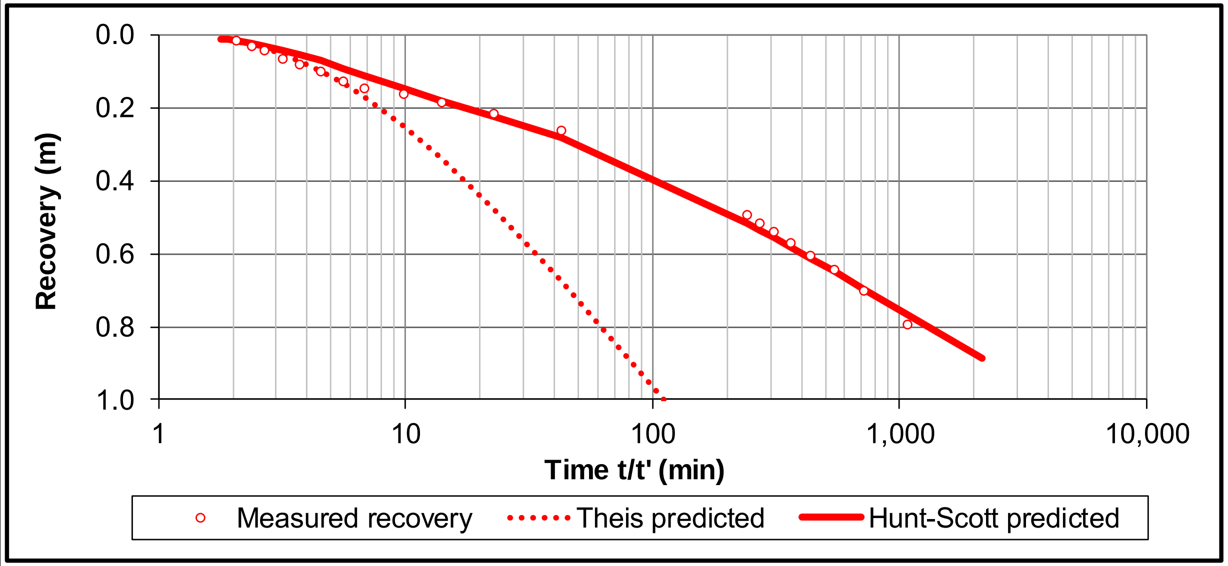

Monitoring Bore - Interference and Recovery Plotted on a Linear Graph
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Interference and recovery (m)
1
10
100
1,000
Time since start of pumping (mins)
Uncorrected interference
Interference corrected using a barometric efficiency of 35%
Interference corrected using a barometric efficiency of 35% pressure and a linear antecdent trend during pumping and recovery
Interference corrected using a barometric efficiency of 35% and 60% of the barometrically corrected water level in Jacks Point bore
Zero interference
Pump off
Draft



Monitoring Bore - Recovery Plotted on a Semi-Log Graph
Recovery (m)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
0.1
1.0
10.0
100.0
1000.0
10000.0
Time from start of recovery (mins)
Uncorrected recovery
Recovery corrected using a barometric efficiency of 30%
Recovery corrected using a barometric efficiency of 35% pressure and a linear antecdent trend during pumping and recovery
Recovery corrected using a barometric efficiency of 35% and 60% of the barometrically corrected water level in Jacks Point bore
Zero interference
Assumed time at end of recovery

## E.9 Constant-Discharge Test - Aquifer Parameters




# Production Bore

Data corrected for background trend using a linear antecedent trend

**Pumping rate** Q 36 L/s

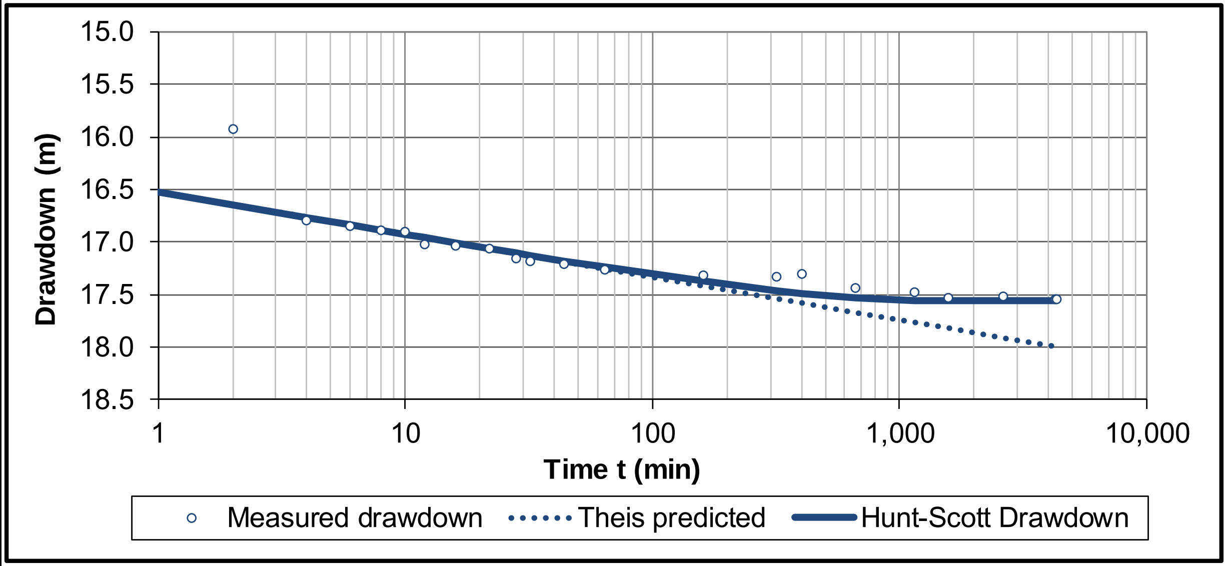
**Drawdown**

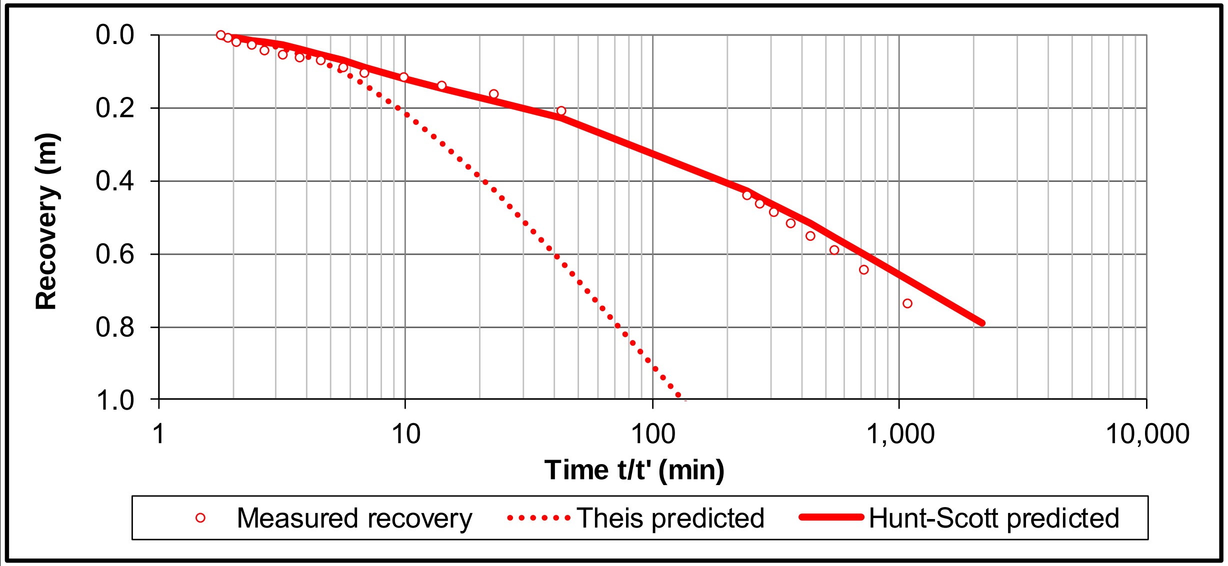
| | | | |
|---|---|---|---|
| Aquifer transmissivity | T | 1,400 | $m^2$/day |
| Aquitard leakage | K'/B' | 0.02 | $day^{-1}$ |
| Aquitard specifc yield | σ | 0.1 | - |
| Transmissivity (overyling aquifer) | $T_0$ | 1,400 | $m^2$/day |
| Aquitard thickness | B' | 10 | m |
| Aquitard specific storage | S's | 1E-06 | - |
| Aquitard storage | S' | 1E-05 | - |

**Recovery**

| | | | |
|---|---|---|---|
| Aquifer transmissivity | T | 700 | $m^2$/day |
| Aquitard leakage | K'/B' | 0.001 | $day^{-1}$ |
| Aquitard specifc yield | σ | 0.04 | - |
| Transmissivity (overyling aquifer) | $T_0$ | 700 | $m^2$/day |
| Aquitard thickness | B' | 10 | m |
| Aquitard specific storage | S's | 1E-06 | - |
| Aquitard storage | S' | 1E-05 | - |

Parameters in-sensitive to value used or can not be accurately assessed from the pumping bore




# Production Bore

Data corrected for background trend using Jacks Point Bore

**Pumping rate** Q 36 L/s

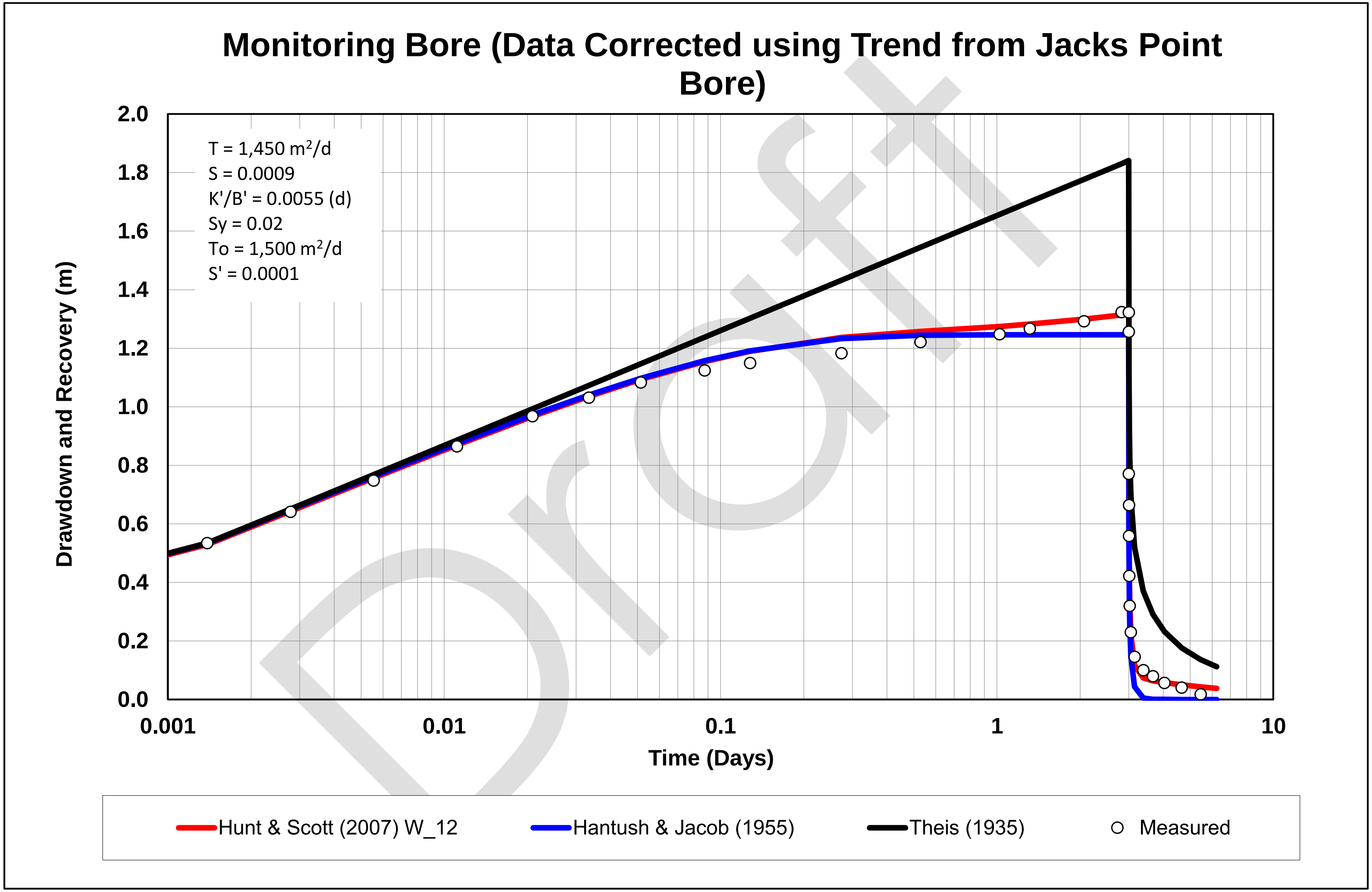
**Drawdown**

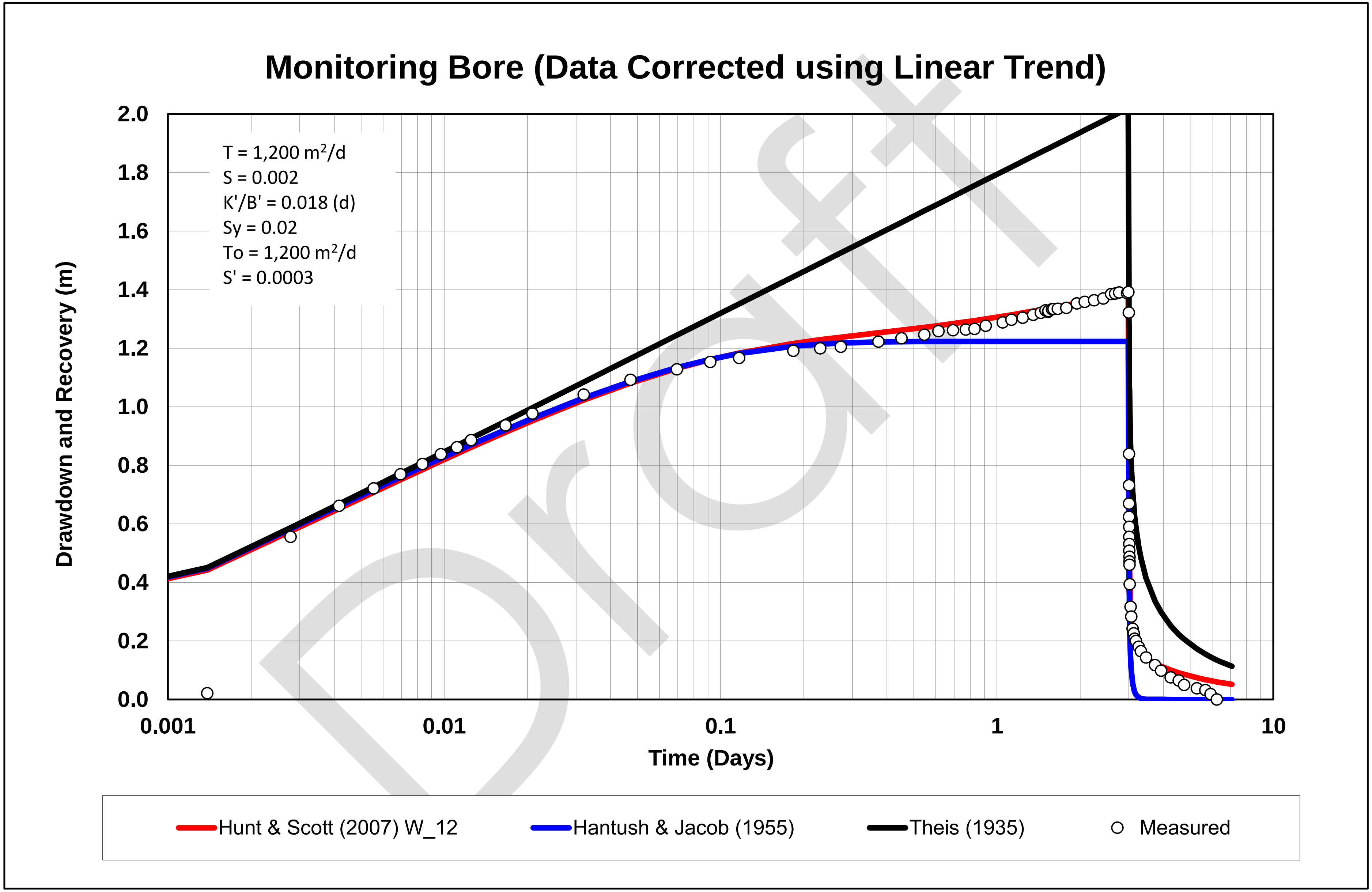
| | | | |
|---|---|---|---|
| Aquifer transmissivity | T | 1,400 | $m^2$/day |
| Aquitard leakage | K'/B' | 0.02 | $day^{-1}$ |
| Aquitard specifc yield | σ | 0.1 | - |
| Transmissivity (overyling aquifer) | $T_0$ | 1,400 | $m^2$/day |
| Aquitard thickness | B' | 10 | m |
| Aquitard specific storage | S's | 1E-06 | - |
| Aquitard storage | S' | 1E-05 | - |

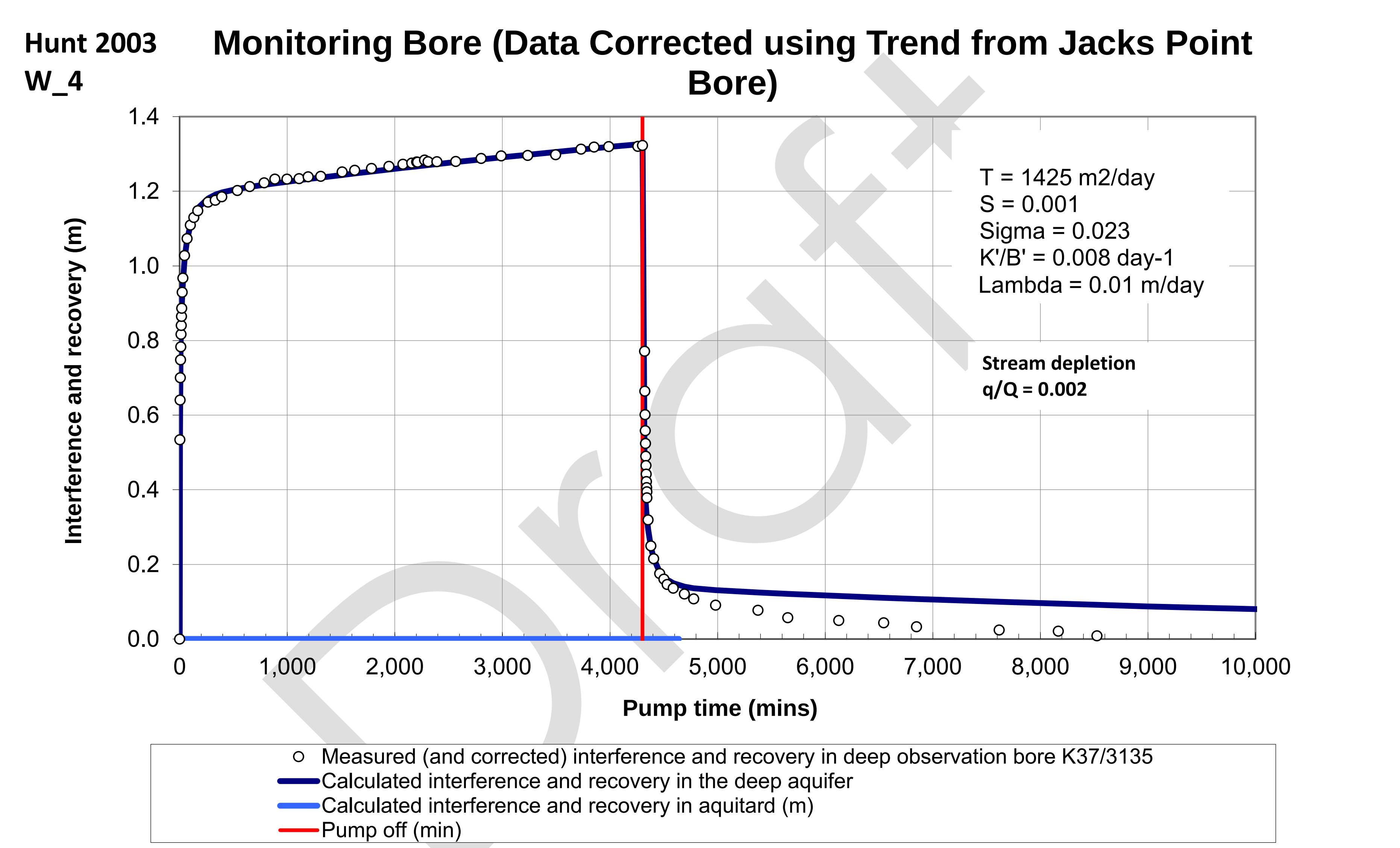
**Recovery**

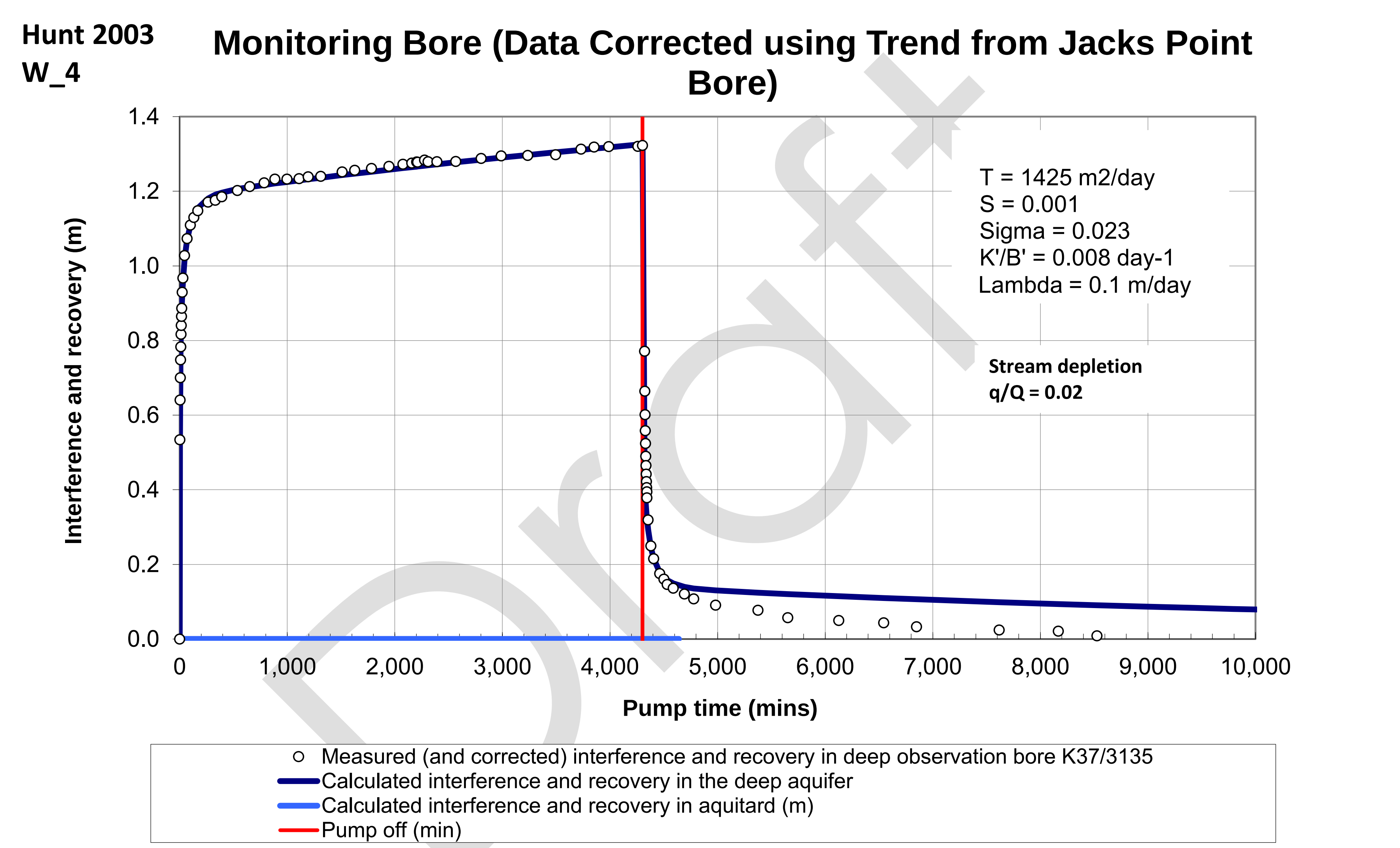
| | | | |
|---|---|---|---|
| Aquifer transmissivity | T | 700 | $m^2$/day |
| Aquitard leakage | K'/B' | 0.001 | $day^{-1}$ |
| Aquitard specifc yield | σ | 0.06 | - |
| Transmissivity (overyling aquifer) | $T_0$ | 700 | $m^2$/day |
| Aquitard thickness | B' | 10 | m |
| Aquitard specific storage | S's | 1E-06 | - |
| Aquitard storage | S' | 1E-05 | - |

Parameters in-sensitive to value used or can not be accurately assessed from the pumping bore


Monitoring Bore (Data Corrected using Trend from Jacks Point Bore)
T = 1,450 m²/d
S = 0.0009
K'/B' = 0.0055 (d)
Sy = 0.02
To = 1,500 m²/d
S' = 0.0001
Drawdown and Recovery (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.001
0.01
0.1
1
10
Time (Days)
Hunt & Scott (2007) W_12
Hantush & Jacob (1955)
Theis (1935)
Measured
Draft


Monitoring Bore (Data Corrected using Linear Trend)
T = 1,200 m²/d
S = 0.002
K'/B' = 0.018 (d)
Sy = 0.02
To = 1,200 m²/d
S' = 0.0003
Drawdown and Recovery (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.001
0.01
0.1
1
10
Time (Days)
Hunt & Scott (2007) W_12
Hantush & Jacob (1955)
Theis (1935)
Measured
Draft

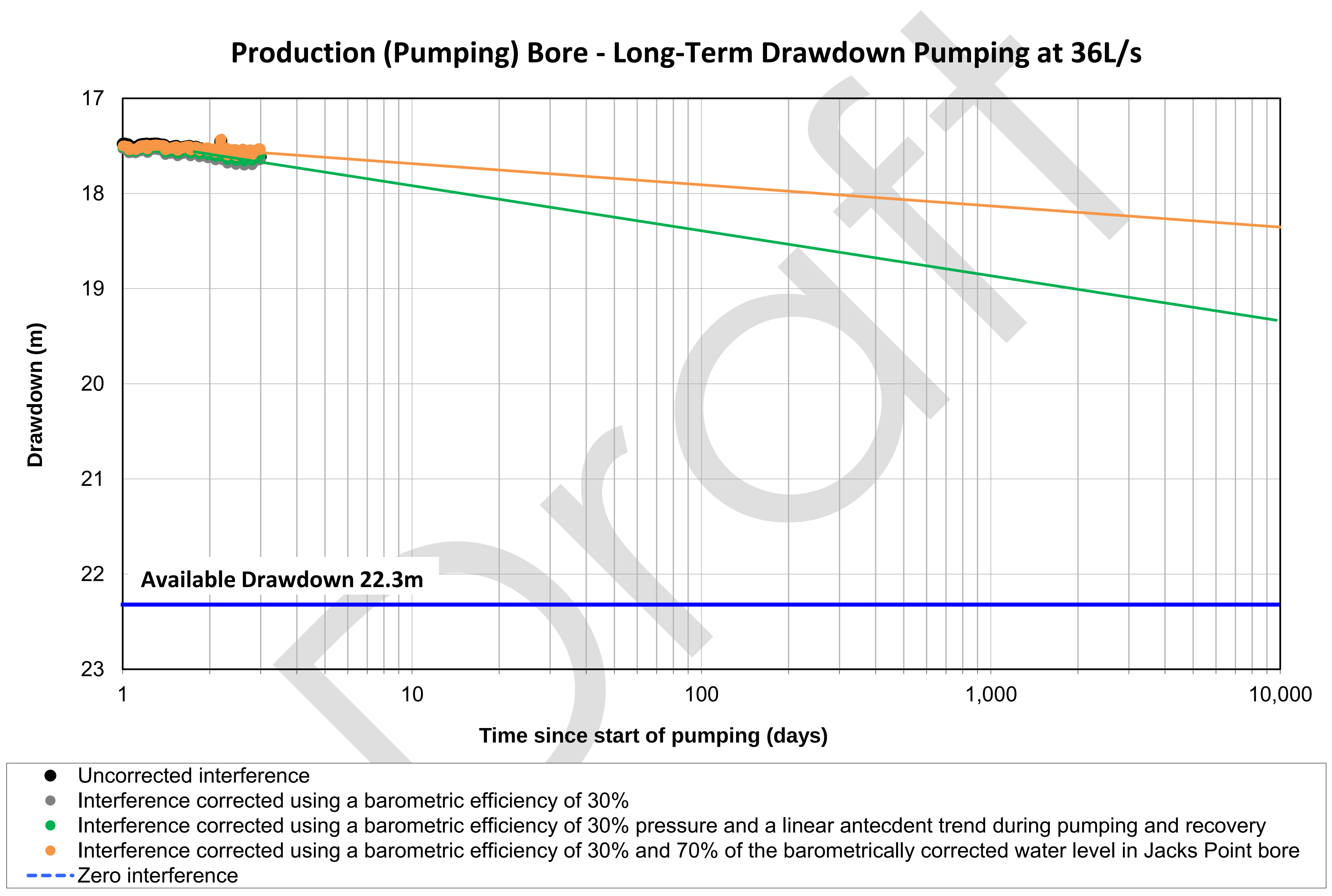

Hunt 2003
W_4
Monitoring Bore (Data Corrected using Trend from Jacks Point Bore)
Interference and recovery (m)
Pump time (mins)
T = 1425 m2/day
S = 0.001
Sigma = 0.023
K'/B' = 0.008 day-1
Lambda = 0.01 m/day
Stream depletion
q/Q = 0.002
Measured (and corrected) interference and recovery in deep observation bore K37/3135
Calculated interference and recovery in the deep aquifer
Calculated interference and recovery in aquitard (m)
Pump off (min)


Hunt 2003
W_4
Monitoring Bore (Data Corrected using Trend from Jacks Point Bore)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Interference and recovery (m)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
Pump time (mins)
T = 1425 m2/day
S = 0.001
Sigma = 0.023
K'/B' = 0.008 day-1
Lambda = 0.1 m/day
Stream depletion
q/Q = 0.02
Measured (and corrected) interference and recovery in deep observation bore K37/3135
Calculated interference and recovery in the deep aquifer
Calculated interference and recovery in aquitard (m)
Pump off (min)


Legend
Production Bore
Transmissivity from Specific Capacity (m2/d)
20 - 300
300 - 1,000
1,000 - 6,700
N
Frankton
Queenstown Airport
Kawarau Falls
Peninsula Hill
Jacks Point
22
6653
36
313
1015
37
196
32
KINGSTON ROAD
WOOLSHED RD
Remarkables
Gravel pit
0
1
2
Kilometers

# Appendix F: Maximum Sustainable Yield

## F.1 Long-Term Predicted Drawdown Pumping at 36L/s



## F.2 Long-Term Predicted Drawdown using Eden-Hazel

**Sustainable Yield** **Bore Production Bore**

| | | |
|---|---|---|
| Continuous pumping duration | 9,000 | days |
| | 24.7 | years |
| Lowest static water level | 1.5 | mBGL |
| Top of screen | 29.8 | mBGL |
| Pump and leader | 6 | mBGL |
| Minimum pumping water level | 23.8 | mBGL |
| Maximum available drawdown | 22.3 | m |
| a | 4.8 | min/m$^2$ |
| b | 0.2 | min/m$^2$ |
| C | 2.2 | min$^2$/m$^5$ |
| n | 1.5 | |

Minimum pumping water level (mBGL)
= top of screen (mBGL) - pump and leader (m)

Pumping water level (mBGL) = Long term drawdown (m) + interference effects (m) + lowest static water level (mBGL)

Long term drawdown = $s(t) = (aQ + CQ^n) + bLOG_{10}(t)Q$

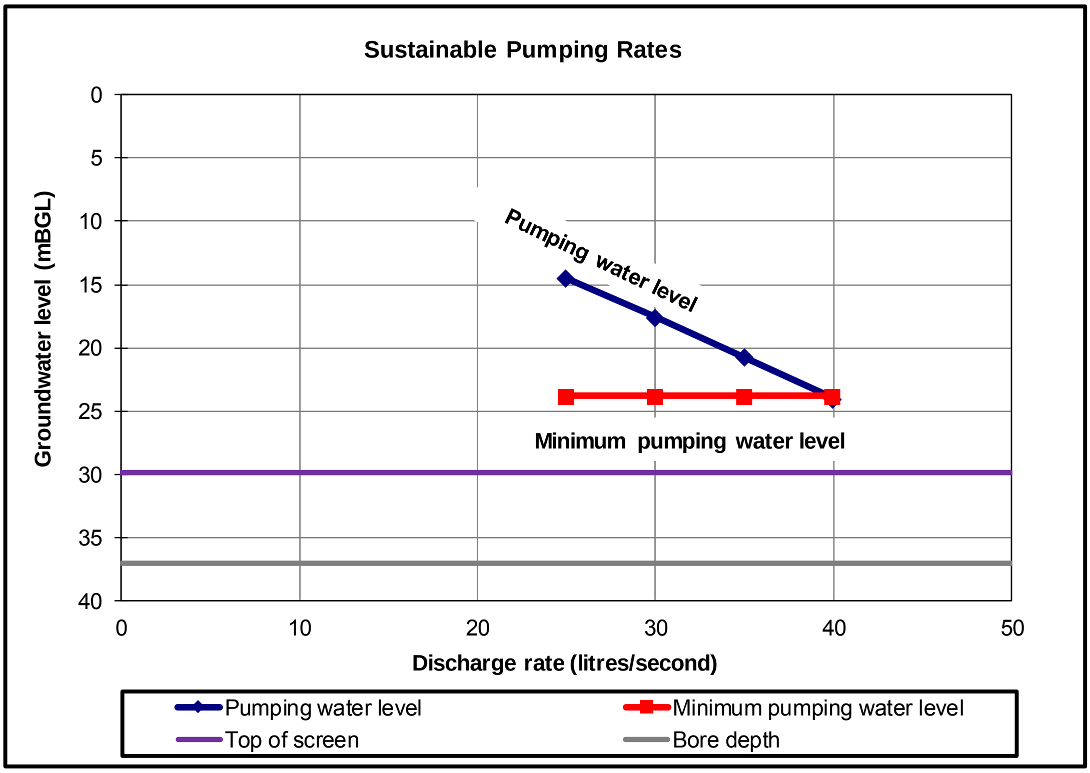
**Interference effects**

| Bore | Pumping Rate (L/s) |
|---|---|

Where:

| | | | |
|---|---|---|---|
| Q | Discharge rate | b | Drawdown coefficient for laminar flow |
| a | Drawdown coefficient for laminar flow | C | Drawdown coefficient for turbulent flow |
| n | Exponent ranging between 1.5 and 3.0 | t | Pump time |

| Discharge rate (Q) L/s | Long term drawdown m | Interference effects m | Total drawdown m | Pumping water level mBGL |
|---|---|---|---|---|
| 25 | 13 | 0 | 13 | 15 |
| 30 | 16 | 0 | 16 | 18 |
| 35 | 19 | 0 | 19 | 21 |
| 40 | 22 | 0 | 22 | 24 |




**References**

Eden, RN and Hazel, CP (1973): Computer and graphical analysis of variable discharge pumping tests of wells. Civ. Eng Trans. Inst. of Eng. Australia: 5-10.

# Appendix G: Assessment of Environmental Effects – Groundwater Quantity

## G.1 Groundwater Allocation – Rainfall Recharge Calculations

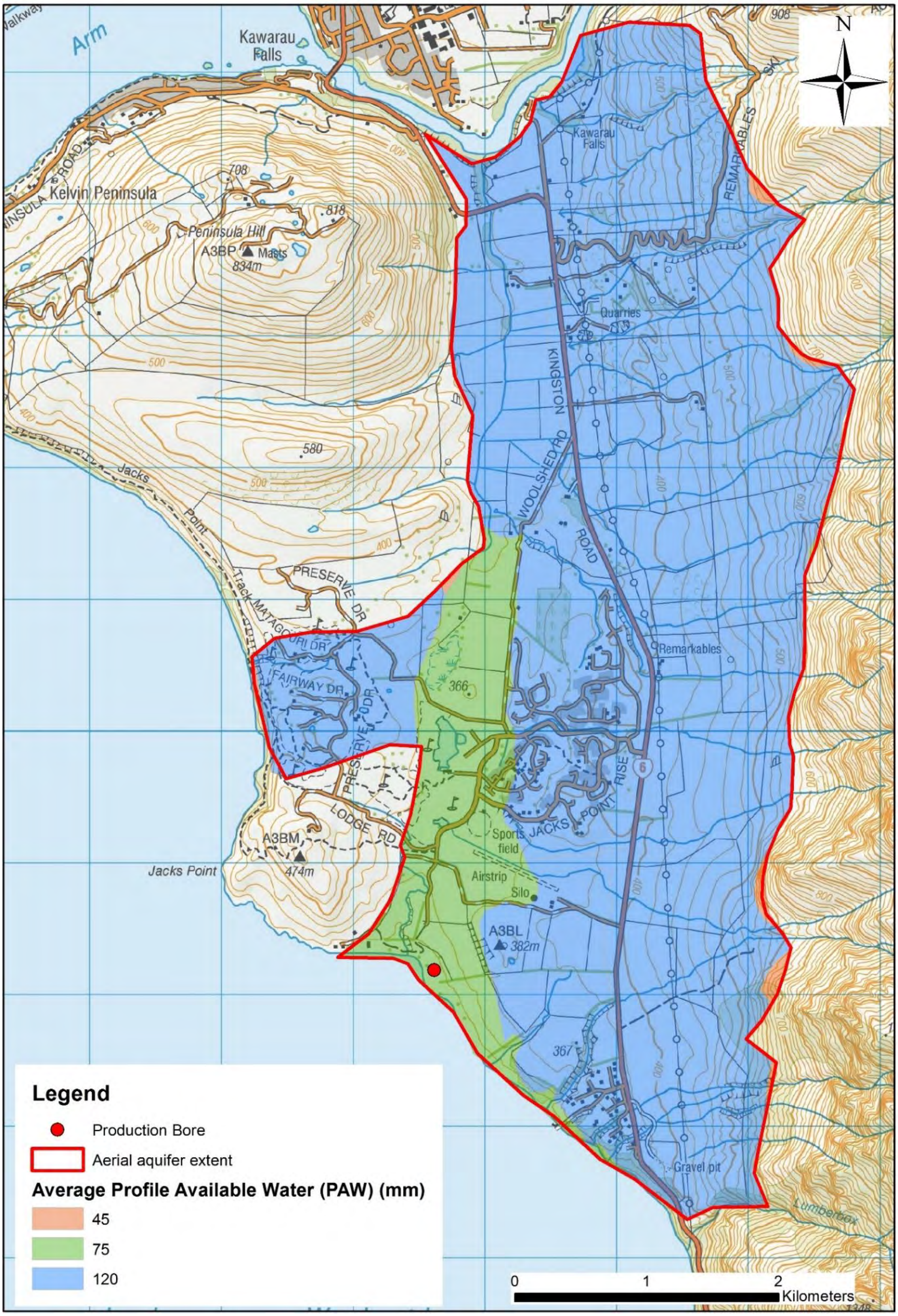


Table summarising the results of calculations of rainfall recharge to the aquifer based on soil moisture modelling

| Average Soil Profile Available Water | Area Covered by Each Soil Type | Mean Rainfall | Mean Potential Evapotranspiration | Modelled Rainfall Recharge | | | |
|---|---|---|---|---|---|---|---|
| mm | $m^2$ | mm/yr | mm/yr | mm/yr | $m^3$/yr | L/s | % of Rainfall |
| 45 | 78,433 | 722 | 926 | 184 | 14,442 | 0.5 | 26 |
| 75 | 2,785,921 | 722 | 926 | 154 | 430,418 | 14 | 21 |
| 120 | 19,586,593 | 722 | 926 | 118 | 2,311,218 | 73 | 16 |
| Total | 22,450,947 | - | - | - | 2,756,079 | 87 | - |
| Total x 0.5 | - | - | - | - | 1,378,039 | 44 | - |

## G.2 Interference Assessment on Neighbouring Bores

## Worst Case Scenario

| *Aquifer Parameters* | | |
|---|---|---|
| Transmissivity of pumped aquifer | 1,200 | $m^2/d$ |
| Storativity of pumped aquifer | 0.0009 | - |
| Aquitard conductance | 0.0045 | $d^{-1}$ |
| Aquitard specific yield | 0.01 | - |
| Top aquifer transmissivity | 1,200 | m/d |
| Aquitard storage | 0.00001 | - |

| *Production Bore Details* | | |
|---|---|---|
| Discharge rate | 40 | L/s |
| | 3,456 | $m^3/d$ |
| Pumping time | 365 | day |
| Easting | 1264612 | mE |
| Northing | 4998187 | mN |

| Well No | Easting (mE) | Northing (mN) | Depth (mBGL) | Top of Screen (mBGL) | Static Water Level (mBGL) | Available Drawdown (m) | Available Drawdown (m) | Aquifer Type | Use | Distance to pumping bore (m) | W_12 (m) | Eta_12 (m) | Theis (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | D | TS | S | A = TS - S | A = (D -1) - S | | | | | | |
| F41/0382 | 1263993 | 4998351 | 9.6 | | 2.4 | - | 6.2 | | Domestic | 640 | 0.73 | 0.66 | 1.81 |
| F41/0324 | 1264635 | 4999899 | 46.64 | 40.16 | | - | | UN | Irrigation | 1,712 | 0.47 | 0.47 | 1.36 |
| F42/0100 | 1265917 | 4997067 | 55 | 52 | 36 | 16.0 | | | Domestic | 1,720 | 0.47 | 0.47 | 1.36 |
| F42/0103 | 1265975 | 4996882 | 55 | | | - | | WG | Domestic | 1,887 | 0.45 | 0.45 | 1.31 |
| F41/0163 | 1266528 | 5000820 | 36 | 12.7 | 7.97 | 4.7 | | WG | Domestic | 3,256 | 0.33 | 0.33 | 1.06 |
| F41/0108 | 1265625 | 5002821 | 31 | | | | | UN | Domestic | 4,744 | 0.25 | 0.25 | 0.89 |
| F41/0216 | 1265625 | 5002921 | 23.97 | 21.82 | 16.2 | 5.6 | | WG | Stockwater | 4,842 | 0.24 | 0.24 | 0.88 |
| F41/0304 | 1265609 | 5003020 | 35.7 | 34.6 | 1.72 | 32.9 | | UN | Domestic | 4,935 | 0.24 | 0.24 | 0.87 |
| F41/0334 | 1266025 | 5003222 | 22 | | | - | | UN | Domestic | 5,230 | 0.23 | 0.23 | 0.85 |
| F41/0127 | 1265625 | 5003422 | 45 | | | - | | KG | Domestic | 5,332 | 0.22 | 0.22 | 0.84 |
| F41/0143 | 1265425 | 5003522 | 62 | 59 | | - | | KG | Domestic | 5,396 | 0.22 | 0.22 | 0.83 |
| F41/0327 | 1266914 | 5003080 | 50 | | | - | | UN | Unknown | 5,407 | 0.22 | 0.22 | 0.83 |
| F41/0119 | 1264787 | 5003857 | 21.6 | 18.6 | 1.65 | 17.0 | | FR | Irrigation | 5,672 | 0.21 | 0.21 | 0.81 |
| F41/0482 | 1265578 | 5003802 | 34.83 | | 7.56 | - | 26.3 | UN | Domestic | 5,697 | 0.21 | 0.21 | 0.81 |
| F41/0153 | 1265724 | 5004023 | 57.44 | 56.1 | | - | | AR | Domestic | 5,941 | 0.20 | 0.20 | 0.79 |
| F41/0156 | 1265724 | 5004023 | 35 | | | - | | WG | Domestic | 5,941 | 0.20 | 0.20 | 0.79 |
| F41/0157 | 1265224 | 5004222 | 30 | | | - | | WG | Domestic | 6,066 | 0.20 | 0.19 | 0.78 |

## Best Case Scenario

| *Aquifer Parameters* | | |
|---|---|---|
| Transmissivity of pumped aquifer | 1,425 | $m^2/d$ |
| Storativity of pumped aquifer | 0.002 | - |
| Aquitard conductance | 0.018 | $d^{-1}$ |
| Aquitard specific yield | 0.02 | - |
| Top aquifer transmissivity | 1,425 | m/d |
| Aquitard storage | 0.00003 | - |

| *Production Bore Details* | | |
|---|---|---|
| Discharge rate | 40 | L/s |
| | 3,456 | $m^3/d$ |
| Pumping time | 365 | day |
| Easting | 1264612 | mE |
| Northing | 4998187 | mN |

| Well No | Easting (mE) | Northing (mN) | Depth (mBGL) | Top of Screen (mBGL) | Static Water Level (mBGL) | Available Drawdown (m) | Available Drawdown (m) | Aquifer Type | Use | Distance to pumping bore (m) | W_12 (m) | Eta_12 (m) | Theis (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | D | TS | S | A = TS - S | A = (D -1) - S | | | | | | |
| F41/0382 | 1263993 | 4998351 | 9.6 | | 2.4 | - | 6.2 | | Domestic | 640 | 0.54 | 0.53 | 1.40 |
| F41/0324 | 1264635 | 4999899 | 46.64 | 40.16 | | - | | UN | Irrigation | 1,712 | 0.35 | 0.35 | 1.02 |
| F42/0100 | 1265917 | 4997067 | 55 | 52 | 36 | 14.0 | | | Domestic | 1,720 | 0.35 | 0.35 | 1.02 |
| F42/0103 | 1265975 | 4996882 | 55 | | | - | | WG | Domestic | 1,887 | 0.33 | 0.33 | 0.99 |
| F41/0163 | 1266528 | 5000820 | 36 | 12.7 | 7.97 | 2.7 | | WG | Domestic | 3,256 | 0.23 | 0.23 | 0.78 |
| F41/0108 | 1265625 | 5002821 | 31 | | | | | UN | Domestic | 4,744 | 0.16 | 0.16 | 0.63 |
| F41/0216 | 1265625 | 5002921 | 23.97 | 21.82 | 16.2 | 3.6 | | WG | Stockwater | 4,842 | 0.16 | 0.16 | 0.62 |
| F41/0304 | 1265609 | 5003020 | 35.7 | 34.6 | 1.72 | 30.9 | | UN | Domestic | 4,935 | 0.15 | 0.15 | 0.62 |
| F41/0334 | 1266025 | 5003222 | 22 | | | - | | UN | Domestic | 5,230 | 0.14 | 0.14 | 0.60 |
| F41/0127 | 1265625 | 5003422 | 45 | | | - | | KG | Domestic | 5,332 | 0.14 | 0.14 | 0.59 |
| F41/0143 | 1265425 | 5003522 | 62 | 59 | | - | | KG | Domestic | 5,396 | 0.14 | 0.14 | 0.58 |
| F41/0327 | 1266914 | 5003080 | 50 | | | - | | UN | Unknown | 5,407 | 0.14 | 0.14 | 0.58 |
| F41/0119 | 1264787 | 5003857 | 21.6 | 18.6 | 1.65 | 15.0 | | FR | Irrigation | 5,672 | 0.13 | 0.13 | 0.57 |
| F41/0482 | 1265578 | 5003802 | 34.83 | | 7.56 | - | 26.3 | UN | Domestic | 5,697 | 0.13 | 0.13 | 0.56 |
| F41/0153 | 1265724 | 5004023 | 57.44 | 56.1 | | - | | AR | Domestic | 5,941 | 0.12 | 0.12 | 0.55 |
| F41/0156 | 1265724 | 5004023 | 35 | | | - | | WG | Domestic | 5,941 | 0.12 | 0.12 | 0.55 |
| F41/0157 | 1265224 | 5004222 | 30 | | | - | | WG | Domestic | 6,066 | 0.12 | 0.12 | 0.54 |

## G.3 Lake and Stream Depletion Assessment

### Stream Depletion in a Infinite Width Semi Confined Aquifer - Hunt (2003)

**Assumptions**
Stream-bed partially penetrates the aquitard which forms the top boundary of the aquifer
Distance between the well and stream is assumed large enough to allow the stream to be modeled with a zero width

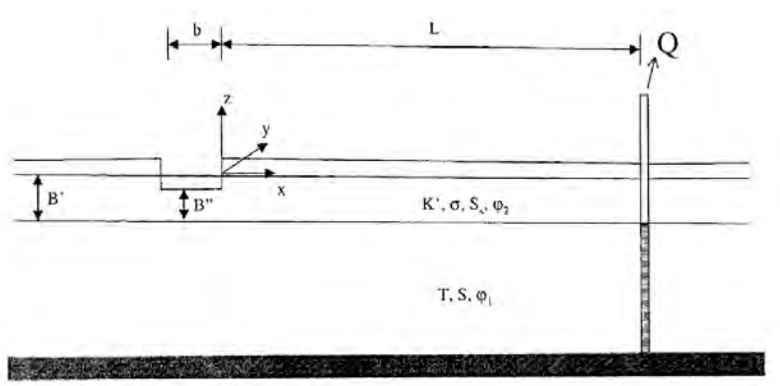



**Fig. 1.** Definition sketch for flow to well in semipermeable aquifer when well is beside stream

| | | | Low | Medium | High | |
|---|---|---|---|---|---|---|
| **Well** | Pumped flow rate | Q | 40 | 40 | 40 | L/s |
| | Duration of pumping | t | 1,825 | 1,825 | 1,825 | d |
| | | | 5 | 5 | 5 | yr |
| | Radial distance from pumped bore to the stream | L | 90 | 90 | 90 | m |
| **Aquifer** | Transmisivity of confined pumped aquifer | T | 1,425 | 1,425 | 1,425 | $m^2/d$ |
| | Storativity of confined aquifer | S | 0.001 | 0.001 | 0.001 | - |
| **Aquitard** | Conductance or effective conductance from top of aquifer | K`/B` | 0.008 | 0.008 | 0.0045 | $d^{-1}$ |
| | Specifc yield of the aquitard | σ | 0.023 | 0.023 | 0.01 | - |
| **Stream bed** | Lambda stream bed conductance | λ | 0.01 | 0.1 | 2 | m/d |
| | Ratio of deletion from the stream to pumped flow | q/Q | **0.04** | **0.31** | **0.94** | ratio |
| | Total stream depletion | q | **2** | **12** | **38** | L/s |

**References**

Hunt, B. (2003). Unsteady stream depletion when pumping from semiconfined aquifer. *Journal of Hydrologic Engineering*. 8(1) 12-19

Hunt, B. (2007). Groundwater analysis using functions.xls. Uni. of Canterbury

## G.4 Consented Surface Water Takes