Drilling and completion report

Upland swamp monitoring bore installations

Prepared for Snowy Hydro Limited
July 2019

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Upland swamp monitoring bore installations

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Client

Snowy Hydro Limited

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31 July 2019

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1 Introduction

1.1 Project overview

Snowy Hydro Limited (SHL) proposes to develop Snowy 2.0, a large-scale pumped hydro-electric storage and generation project which would increase hydro-electric capacity within the existing Snowy Mountains Hydro-electric Scheme (Snowy Scheme). This would be achieved by establishing a new underground hydro-electric power station that would increase the generation capacity of the Snowy Scheme by almost 50%, providing an additional 2,000 megawatts (MW) generating capacity, and providing approximately 350 gigawatts hours (GWh) of storage available to the National Electricity Market (NEM) at any one time, which is critical to ensuring system security as Australia transitions to a decarbonised NEM. Snowy 2.0 would link the existing Tantangara and Talbingo reservoirs within the Snowy Scheme through a series of underground tunnels and hydro-electric power station.

Snowy 2.0 has been declared Critical State Significant Infrastructure (CSSI) by the NSW Minister for Planning under the provisions of the *NSW Environmental Planning and Assessment Act 1979* (EP&A Act) and is defined in Clause 9 of Schedule 5 of the State Environmental Planning Policy (State and Regional Development) 2011 (SRD SEPP). Separate applications and environmental impact statements (EIS) for different phases of Snowy 2.0 are being submitted under Part 5, Division 5.2 of the EP&A Act.

1.2 Program objectives

Collection of field data is important for accurate representation of hydrogeological conceptual and numerical groundwater flow models, which will inform the Groundwater Assessment in support of the Snowy 2.0 EIS. This assessment covers all issues relating to site water management, groundwater, and surface water and their related environmental and other uses.

A comprehensive groundwater monitoring network has been progressively installed to provide hydrogeological data which will be used to characterise the groundwater regime in and around the project area.

This report details the drilling and completion of upland swamp monitoring bores installed in ecologically significant upland swamp surface alluvium/colluvium. The shallow piezometers were installed and field tested by EMM Consulting Pty Ltd (EMM) in February 2019.

2 Installation program

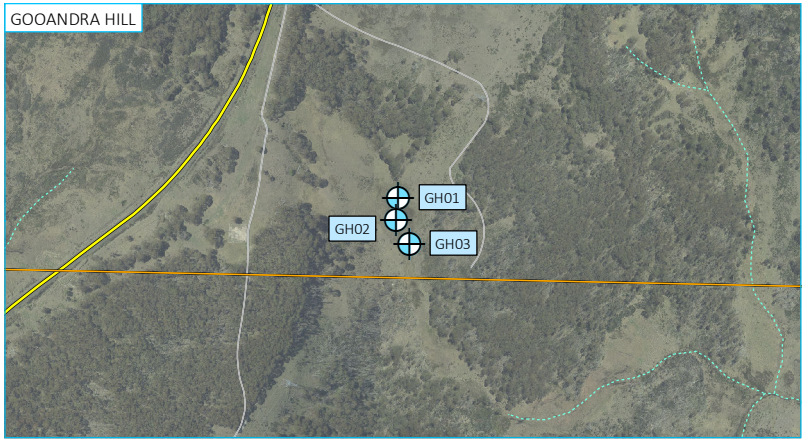
2.1 Upland swamp monitoring bore network

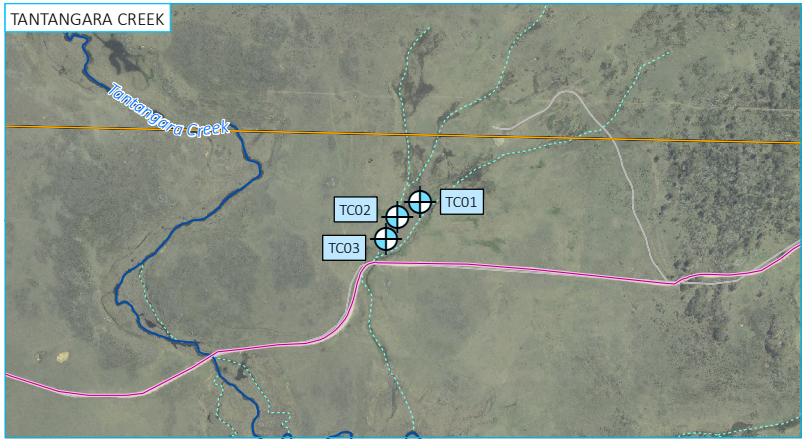
The network is comprised of twelve upland swamp monitoring bores at four locations near Gooandra Hill, Tantangara Creek, Bullocks Hill, and Nungar Creek. Locations of the monitoring bores are illustrated in Figure 2.1 and detailed in Table 2.1. Survey of the monitoring bores was completed by Peter W. Burns Pty Ltd, Cooma.

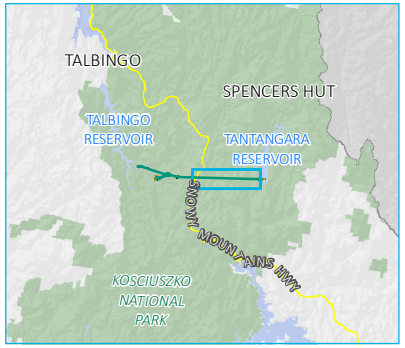
These monitoring bores are located within the vicinity of the Snowy 2.0 project area and are positioned to investigate/monitor ecologically significant upland swamp environments.

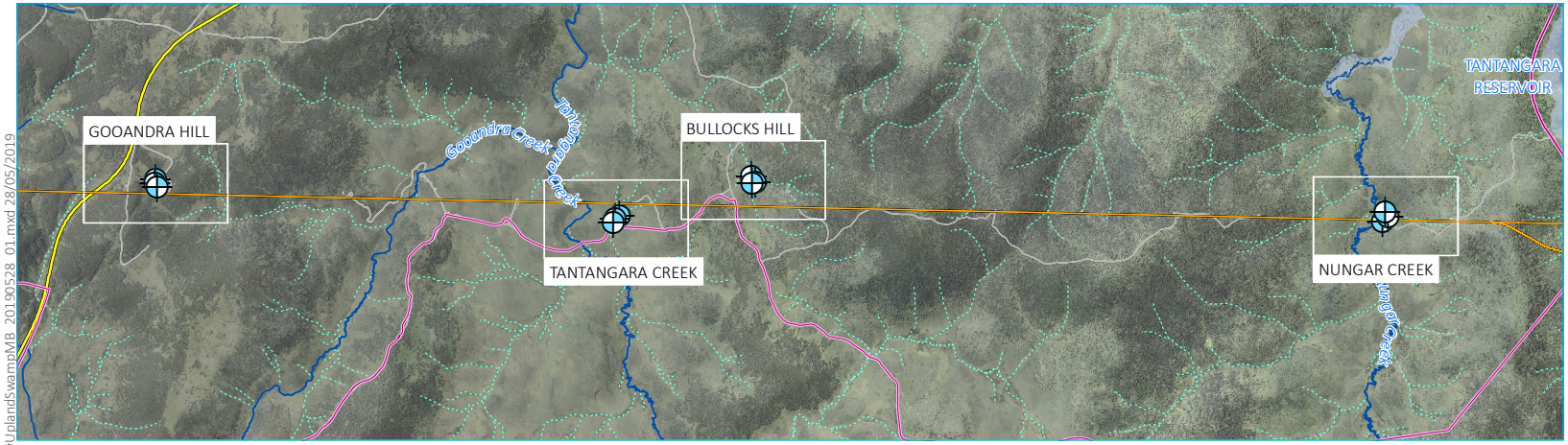
Specifically, the shallow piezometer monitoring network was designed to:

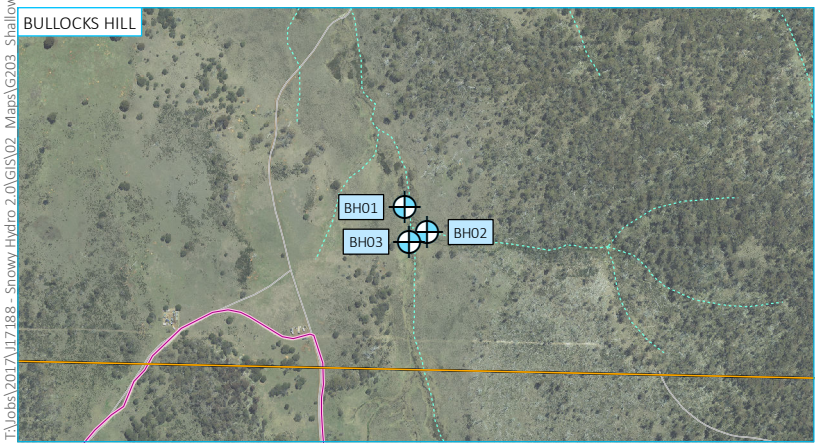
- characterise hydraulic properties in the shallow alluvium/colluvium of upland swamps;
- investigate interaction between surface water in upland swamps and shallow groundwater systems; and
- investigate the extent of perched groundwater in upland swamps.

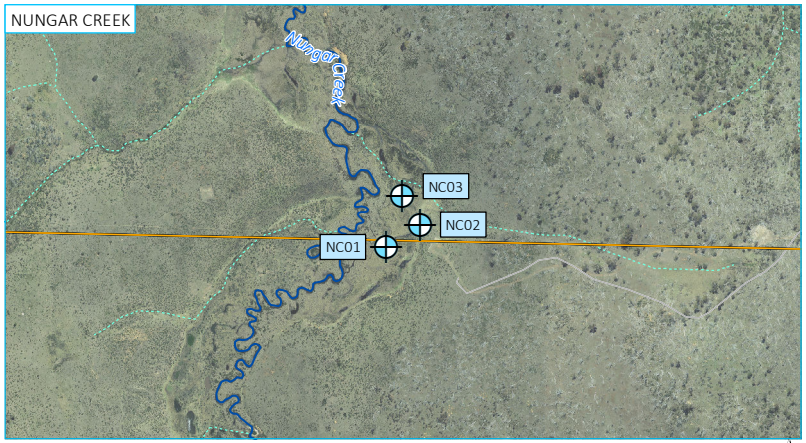












KEY

- Upland swamp monitoring bore

Existing environment

- Main road
- Local road
- No legend
- Drainage line
- Named watercourse
- Scheme storage

Snowy 2.0 operational elements

- Tunnels, portals, intakes, shafts
- Power station
- Utilities

0 1 2 km

GDA 1994 MGA Zone 55

N

Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); DFSI (2017); GA (2015); LPMA (2011)

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Upland swamp monitoring bores

Snowy 2.0
Drilling and completion report
Shallow upland swamp monitoring bores
Figure 2.1

snowy 2.0

EMM creating opportunities

Table 2.1 Shallow piezometer monitoring network summary

Site location	Bore ID	Easting	Northing	Ground level (mAHD)	Groundwater level (mAHD)	Total depth (mBGL)	Screen (mBGL)	Lithology
Bullocks Hill	BH01	641674.6	6038576.2	1351.1	1350.7	0.5	0.3 – 0.5	
	BH02	641711.0	6038536.6	1351.9	1350.6	0.8	0.5 – 0.8	
	BH03	641682.1	6038521.4	1349.9	1349.3	0.7	0.4 – 0.7	
Gooandra Hill	GH01	636471.8	6038556.8	1456.3	1456.2	0.95	0.55 – 0.95	
	GH02	636468.7	6038522.0	1456.1	1456.0	0.95	0.55 – 0.95	
	GH03	636489.1	6038484.4	1455.3	1455.2	0.65	0.35 – 0.65	Alluvium/colluvium
Nungar Creek	NC01	647182.7	6038191.5	1236.6	1235.9	0.8	0.5 – 0.8	
	NC02	647235.8	6038227.3	1236.9	1236.0	1.1	0.8 – 1.1	
	NC03	647208.2	6038273.4	1236.9	1236.0	1.0	0.7 – 1.0	
Tantangara Creek	TC01	640523.2	6038237.8	1323.5	1322.7	1.0	0.6 – 1.0	
	TC02	640487.6	6038213.6	1322.3	1321.5	1.1	0.7 – 1.1	
	TC03	640469.7	6038178.9	1321.1	1320.6	0.8	0.5 – 0.8	

Notes:

1. Coordinates in MGA 94 (Zone 55)
2. mAHD = metres Australian Height Datum (71); and
3. mBGL = metres Below Ground Level.

2.2 Construction and installation specifications

Construction logs for the monitoring bores are presented in Appendix A.

EMM designed and installed the monitoring bores using an 80 millimetre (mm) diameter hand auger. Augering and installation is a minimal impact activity with the final constructed piezometer presenting at the surface as a 0.5 metre (m) high 40 mm diameter PVC monitoring bore. Samples were collected every 0.1 m and stored in chip trays. Augered material was removed from site.

Boreholes were augered to refusal on bedrock and water strikes recorded. The bores were installed with 40 mm diameter PVC casing and screened with machine slotted 40 mm PVC casing. The screened sections were selected based on the depth of the recorded water strikes. The annulus between the borehole and PVC was backfilled with washed and graded (2 to 3 mm) gravel filter pack to approximately 0.1 m above the screened section and a bentonite seal was installed above the gravel pack to surface. Water level dataloggers were installed shortly after installation and were programmed to record groundwater levels every 6 hours.

2.3 Geology encountered during drilling

The predominant lithology of the bores was silt and/or clay that ranged from weak to high plasticity intermixed with alluvial/colluvial gravels. Sandy gravels were also encountered frequently, typically toward the deeper horizons, and were predominately sub-angular to rounded in shape and intermixed with moderate fine to coarse grain sands and clay/silt. The weathered contact was characterised by highly oxidised loose sub-angular to angular gravels, coarse grained sands and a minor clay/silt. Depth of bedrock varied from 0.5 mBGL to 1.1 mBGL.

Table 2.2 provides a comprehensive breakdown of geology encountered during drilling.

Table 2.2 Geological summary

Bore ID	Total depth (mBGL)	Screened formation	Screened lithology
BH01	0.50	Alluvium/colluvium	Clay; medium plasticity
BH02	0.80	Alluvium/colluvium	Sandy gravel; subangular to angular with coarse grained sand
BH03	0.70	Alluvium/colluvium	Sandy gravel; subangular to angular with mod. coarse sand
GH01	0.95	Alluvium/colluvium	Clay; orange mottled grey, weak to medium plasticity
GH02	0.95	Alluvium/colluvium	Clay; medium plasticity with minor gravel
GH03	0.65	Alluvium/colluvium	Silty clay; weak to medium plasticity, minor coarse sand
NC01	0.80	Alluvium/colluvium	Silty clayey sand; fine to coarse grained, weak plasticity clay
NC02	1.10	Alluvium/colluvium	Sandy gravel; sub-angular to rounded, minor weak clay

Table 2.2 Geological summary

Bore ID	Total depth (mBGL)	Screened formation	Screened lithology
NC03	1.00	Alluvium/colluvium	Sandy gravel; sub-angular to rounded, minor weak clay
TC01	1.00	Alluvium/colluvium	Clay; high plasticity
TC02	1.10	Alluvium/colluvium	Gravel; angular
TC03	0.80	Alluvium/colluvium	Gravel; angular

2.4 Groundwater flow

At all locations, a shallow perched water table was observed on the contact between the shallow highly organic soil/peat at surface and underlying silty/sandy clay horizon. A second and more pronounced water strike was observed at the weathered bedrock contact which was, at most locations, comprised of highly weathered clayey/silty sub-angular to angular gravels and medium to coarse grained sand. This weathered bedrock horizon was small, ranging between 0.05 to 0.1 m in thickness before refusal on competent bedrock.

3 Field testing

3.1 Slug tests

3.1.1 Slug test methodology

A series of rising and falling head tests (slug tests) were completed at eight monitoring bores to characterise the hydraulic properties of upland swamps. Slug tests were attempted at the Nungar Creek monitoring bores, but the data was of poor quality and unable to be analysed in Aqtesolv. BH02 was also unable to be analysed because it did not recover within a suitable timeframe.

Falling and rising head tests are completed by introducing a 'slug' to instantly displace water in the monitoring bore causing the static water level to rise (falling head) or fall (rising head). The rate of water level decay is measured over time and the observed curve analysed to provide bulk hydraulic properties of the immediate screened formation (Butler 1998). Only rising head tests can be completed when the water level is between the screened formation.

Multiple rising and falling head tests were performed on the Gooandra Hill piezometers due to their fast rate of recovery. One rising head test was performed on the Bullocks Hill and Tantangara Creek piezometers due to their slow recovery rates. Given their slow responses, these rising head tests were completed by bailing water from the monitoring bores until they were dry and observing the recovery.

For each slug test, an automatic water level datalogger with a measurement frequency of one second was used to record the change in head over time.

3.1.2 Slug test results

Slug test data from each piezometer was analysed using the Hvorslev straight-line solution for unconfined aquifers in AqteSolv. AqteSolv is industry leading software for analysing aquifer tests using a variety of aquifer types and solutions.

A summary of test results is presented in Table 3.1 and a summary report on the analysis of permeability tests is provided in Appendix B. No analysis is provided for BH02 because the piezometer did not recover. Slug tests were attempted at the Nungar Creek monitoring bores but the data was of poor quality and unable to be analysed in Aqtesolv.

Analysis of slug tests at Gooandra Hill demonstrated the highest hydraulic conductivities of the three sites analysed ranging from approximately 0.41 m/day to 1.2 m/day. Conductivities at Bullocks Hill and Tantangara Creek monitoring bores were lower, ranging between 0.10 - 0.13 m/day and 0.013 - 0.035 m/day respectively.

Table 3.1 Summary of slug test analyses

Bore ID	Average K[1] (m/d)*
BH01	0.128
BH02[1]	-
BH03	0.100
GH01	1.217

Table 3.1 Summary of slug test analyses

Bore ID	Average K[1] (m/d)*
GH02	0.407
GH03	0.626
TC01	0.013
TC02	0.015
TC03	0.035
NC01[1]	-
NC02[1]	-
NC03[1]	-

Notes:

1. K = hydraulic conductivity;
2. * = metres per day; and
3. Poor quality data, unable to be analysed.

3.2 Groundwater level monitoring

Water level dataloggers were installed in all monitoring bores with loggers recording every six hours. Data from water level loggers is retrieved monthly during routine monitoring events. Hydrographs for upland swamp monitoring bores are presented in Appendix C.

3.3 Groundwater quality monitoring

3.3.1 Groundwater sampling methodology

Following installation, monitoring bores were sampled for comprehensive water quality using 'skinny' disposable bailers. Water was sampled after purging three bore volumes, or if monitoring bores were bailed 'dry', the monitoring bore was sampled when enough volume had recovered.

During purging, physico-chemical water quality parameters were collected using a calibrated YSI water quality meter. Parameters included temperature, electrical conductivity (EC), pH, dissolved oxygen (DO), total dissolved solids (TDS), and oxidation reduction potential (ORP).

Water quality samples were sent to NATA accredited laboratory ALS for analysis. Samples were tested for the analytes shown in Table 3.2.

Table 3.2 Groundwater sampling analytical suite

Suite	Analytes
Physico-chemical properties	Field parameters (pH, EC, ORP, DO%, temperature), TDS, Total Suspended Solids (TSS)
Major ions	Calcium, magnesium, sodium, potassium, sulphate, chloride, alkalinity
Dissolved metals	Arsenic, cadmium, chromium, copper, fluoride, lead, magnesium, nickel, zinc
Nutrients	Ammonia as N, nitrite as N, nitrate as N, reactive phosphorous, phosphorous, total phosphorous

3.3.2 QA/QC procedures

Quality Assurance and Quality Control (QA/QC) procedures were completed during sampling to ensure field and laboratory procedures are followed accurately and equipment is calibrated. The field sampling procedures conformed to EMM's quality assurance/quality control (QA/QC) protocols to prevent cross contamination and preserve sample integrity. Sampling and reporting were conducted in accordance with *Geoscience Australia's Groundwater Sampling and Analysis – A Field Guide* (Sundaram 2009) and EMM's water sampling Standard Operating Procedure document. The following QA/QC procedures were applied:

- calibration of equipment;
- unstable parameters were analysed in the field (physico-chemical parameters);
- samples were collected in clearly labelled bottles with appropriate preservation solutions;
- samples were delivered to the laboratories within the specified holding times;
- field duplicate samples (QA samples) were collected at a rate of one in ten samples; and
- samples were kept chilled and gloves were worn during sampling.

The laboratories conduct their own internal QA/QC program to assess the repeatability of the analytical procedures and instrument accuracy. These programs include analysis of laboratory sample duplicates, spike samples, certified reference standards, surrogate standards/spikes and laboratory blanks. In addition, a duplicate sample is collected in the field for every ten samples collected to assess sampling and laboratory analysis accuracy.

3.3.3 Groundwater sampling results

Groundwater quality results collected in February 2019 are shown in Table 3.3 and laboratory certificates are presented in Appendix D. BH01 was not sampled because the water was too turbid. Nungar Creek monitoring bores were not sampled because of site access restrictions.

At all sites, pH was weakly to mildly acidic and ranged between 4.2 – 6.5. Acidity is likely due to the formation of weak humic acids from the decomposition of organic matter. Electrical conductivity (EC) is low at most sites ranging between 42.0 - 343.1 µS/cm. EC less than 100 µS/cm would likely indicate direct rainfall recharge.

High concentrations of total nitrogen, total phosphorus and total organic carbon (TOC) were observed at most sites. Again, this is due to the decomposition of organic matter in the swamps.

The dominant cation at most monitoring bores is sodium, which is likely derived from coastal rainfall patterns. The dominant anion is HCO_3 which is likely derived from the weathering of calcite originating from parent geology. Calcium results ranged from 1 mg/L at TC02 and TC03 to 8 mg/L at GH03 with an outlier of 26 mg/L recorded at TC01. Chlorine, Cyanide, and Fluoride recorded similar low results across all sites. Sodium results were in two distinct ranges, five sites ranged between 2 mg/L and 9 mg/L while TC01, BH02, and BH03 ranged between 17 mg/L and 28 mg/L. TC01 recorded the highest level of Magnesium at 6mg/L while all other sites recorded 2 mg/L or less. Potassium results were low at all sites while Sulphate as SO_4 ranged from 1 mg/L at GH01 to 36 mg/L at TC01.

All sites recorded barium, arsenic, cadmium, beryllium, lead, manganese, mercury, nickel, selenium, and silver levels within the acceptable ANZECC 99% guidelines. Aluminium exceeded ANZECC 99% guidelines at six sites which ranged from 0.05 mg/L at GH02 to 8.63 mg/L at BH02. Boron exceeded the guidelines at BH02 recording a level of 0.93 mg/L. Chromium (III+VI) exceeded guidelines at two sites, cobalt exceeded guidelines at three sites, copper exceeded guidelines at two sites, iron exceeded guidelines at five sites, vanadium exceeded guidelines at BH03, and

zinc exceeded guidelines at five sites. High concentrations of iron is likely caused by iron fixing bacteria which can cause orange/brown precipitate and oily sheens.

Table 3.3 Groundwater quality results February 2019

Parameters	Units	ANZECC 2000 99%	BH01	BH02	BH03	GH01	GH02	GH03	TC01	TC02	TC03
Field Parameters											
pH	-	6.5 – 8	4.2	4.85	5.78	5.29	5.81	6.65	5.72	5.84	5.26
EC (field)	µS/cm	30 – 350	158.3	80.6	227.4	42	54.8	168	343.1	102.7	86
Temp (field)	®C		19.6	24.3	19.4	17.1	16.4	17.3	16.7	17.6	20.7
TDS (field)	mg/L		102.7	52.65	147.55	27.3	35.75	109.2	222.95	66.95	55.9
Analytical results											
Alkalinity (total) as CaCO3	mg/L				73	12	11	31	101	20	33
Ammonia as N	mg/L	0.013		0.24	0.14	0.02	0.04	0.07	0.08	0.54	0.4
Nitrite + Nitrate as N	mg/L			0.33	0.17	0.01	<0.01	0.05	0.06	0.01	0.08
Kjeldahl Nitrogen Total	mg/L			4.7	3.9	<0.1	0.5	3.7	1.6	421	8.8
Nitrogen (total)	mg/L	0.25		5	4.1	<0.1	0.5	3.8	1.7	421	8.9
Reactive Phosphorous as P	mg/L	0.015		0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.01
Phosphorous	mg/L	0.02		2.62	0.73	0.09	1.11	2.34	0.3	74.2	3.36
TOC	mg/L			68	11	2	16	14	6	7	5
Inorganics											
Calcium (filtered)	mg/L			2	8	2	2	8	26	1	1
Chloride	mg/L			6	4	<1	<1	2	3	5	5
Cyanide total	mg/L	0.004		<0.16	<0.004	<0.004	<0.004	<0.004	<0.004	<0.4	<0.4
Fluoride	mg/L			<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table 3.3 Groundwater quality results February 2019

Parameters	Units	ANZECC 2000 99%	BH01	BH02	BH03	GH01	GH02	GH03	TC01	TC02	TC03
Sodium (filtered)	mg/L			20	28	3	2	9	17	4	5
Magnesium (filtered)	mg/L			<1	2	<1	<1	2	6	<1	<1
Potassium (filtered)	mg/L			2	<1	<1	<1	<1	<1	<1	<1
Sulphate as SO4 – Turbidimetric (filtered)	mg/L			12	31	1	3	17	36	5	4
Metals											
Aluminium (filtered)	mg/L	0.027		8.63	0.3	0.02	0.05	0.12	<0.01	0.17	5.94
Barium (filtered)	mg/L			1.37	0.016	0.014	0.012	0.017	0.083	0.022	0.015
Arsenic (filtered)	mg/L	0.0008		<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (filtered)	mg/L	0.09		0.93	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cadmium (filtered)	mg/L	0.00006		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Beryllium (filtered)	mg/L			<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium (III+VI) (filtered)	mg/L	0.00001		<0.01	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003
Cobalt (filtered)	mg/L	0.0014		<0.01	<0.001	<0.001	0.002	0.002	0.003	<0.001	<0.001
Copper (filtered)	mg/L	0.001		<0.01	0.002	<0.001	<0.001	<0.001	<0.001	0.001	0.004
Iron (filtered)	mg/L	0.3		1.74	0.33	0.23	2.36	2.41	<0.05	0.29	1.16
Lead (filtered)	mg/L	0.001		<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese (filtered)	mg/L	1.2		0.021	0.034	0.008	0.045	0.084	0.339	0.044	0.013
Mercury (filtered)	mg/L	0.00006		<0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nickel (filtered)	mg/L	0.008		<0.01	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.002

Table 3.3 Groundwater quality results February 2019

Parameters	Units	ANZECC 2000 99%	BH01	BH02	BH03	GH01	GH02	GH03	TC01	TC02	TC03
Selenium (filtered)	mg/L	0.005		<0.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silver (filtered)	mg/L	0.00002		<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium (filtered)	mg/L	0.006		<0.1	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc (filtered)	mg/L	0.0024		0.479	0.008	0.016	0.009	0.016	<0.005	<0.005	<0.005

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Appendix A

Geological and bore construction logs

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WATER MONITORING BORE LOG

Bore ID: BH01

Client: Snowy Hydro Limited **Project:** Snowy 2.0

Date completed:	29/01/2019	**Project number:**	J17188
Drilling contractor:	EMM	**Elevation:**	1351.1 mAHD
Drilling method:	Hand Auger	**Easting:**	641674.6
Hydrogeologist:	Jono Tait	**Northing:**	6038576.2

Static Water Level: 0.4 mBGL **Screened Formation:** Alluvium/Colluvium **Date:** 29/01/2019

Total depth: 0.5 mBGL **Screened depth:** 0.3 - 0.5 mBGL **Casing:** 40 mm U-PVC (PN18)

Depth (mbgl)	Lithology Graphic	Description	Drilling Notes	Bore Completion: Diagram	Bore Completion: Design notes
0		SOIL, black, organic with roots, minor silt lenses.			
		CLAY, black, silty, medium plasticity, high organic matter.	Perched water table		40 mm blank PVC (0 - 0.3 mBGL)
	Alluvium/Colluvium				Bentonite (0 - 0.2 mBGL)
					Gravel pack (0.2 - 0.5 mBGL)
					40 mm slotted PVC screen (0.3 - 0.5 mBGL)
		BEDROCK, yellow orange, weathered.	Refusal and water strike on weathered bedrock		

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WATER MONITORING BORE LOG

Bore ID: BH02

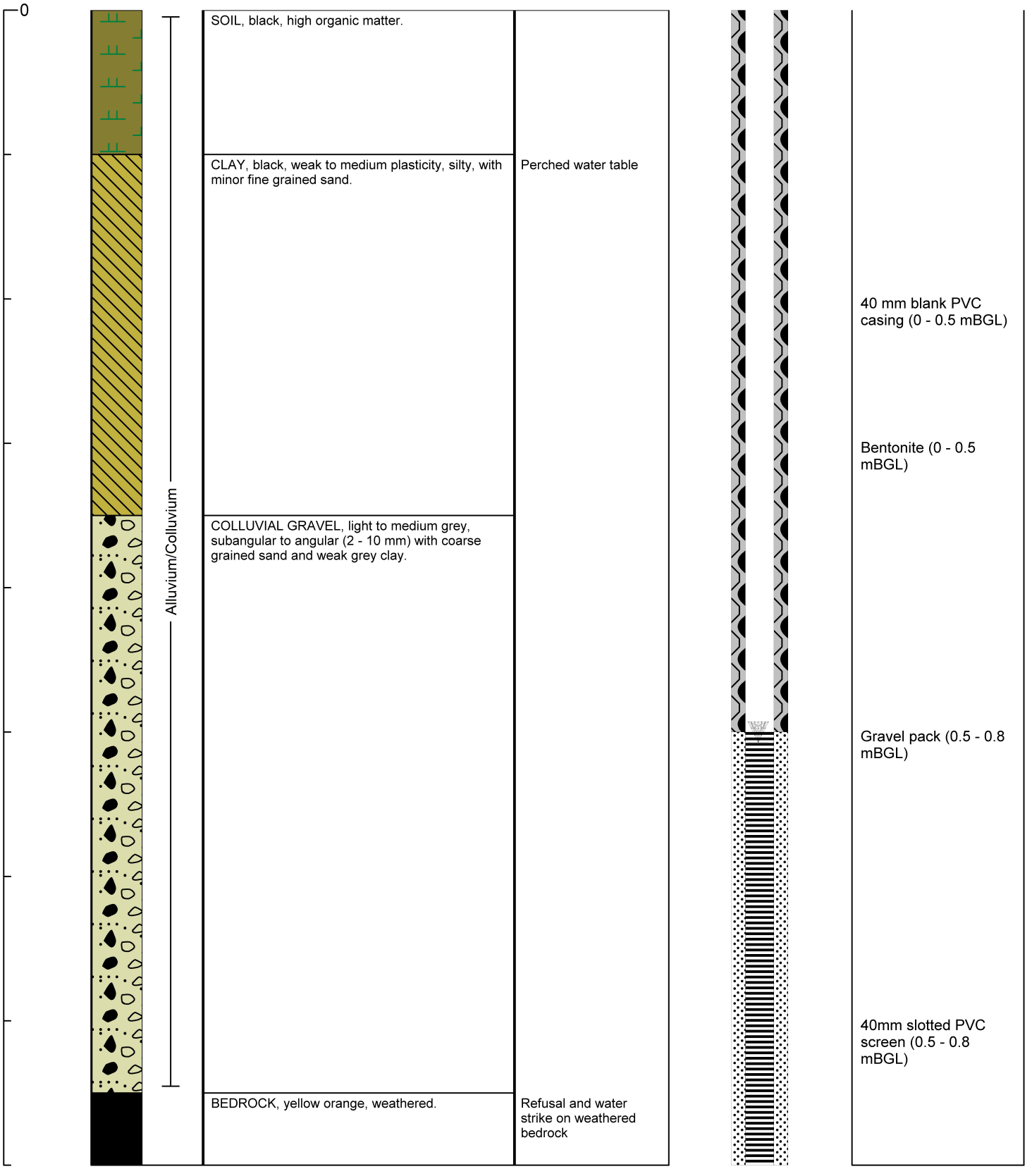
Client: Snowy Hydro Limited **Project:** Snowy 2.0

Date completed:	29/01/2019	**Project number:**	J17188
Drilling contractor:	EMM	**Elevation:**	1351.9 mAHD
Drilling method:	Hand Auger	**Easting:**	641711.0
Hydrogeologist:	Jono Tait	**Northing:**	6038536.6

Static Water Level: 0.5 mBGL **Screened Formation:** Alluvium/Colluvium **Date:** 29/01/2019

Total depth: 0.8 mBGL **Screened depth:** 0.5 - 0.8 mBGL **Casing:** 40 mm U-PVC (PN18)

Depth (mbgl)	Lithology Graphic	Description	Drilling Notes	Bore Completion: Diagram	Bore Completion: Design notes
0		SOIL, black, high organic matter.			40 mm blank PVC casing (0 - 0.5 mBGL)
		CLAY, black, weak to medium plasticity, silty, with minor fine grained sand.	Perched water table		Bentonite (0 - 0.5 mBGL)
	Alluvium/Colluvium	COLLUVIAL GRAVEL, light to medium grey, subangular to angular (2 - 10 mm) with coarse grained sand and weak grey clay.			Gravel pack (0.5 - 0.8 mBGL)
		BEDROCK, yellow orange, weathered.	Refusal and water strike on weathered bedrock		40mm slotted PVC screen (0.5 - 0.8 mBGL)



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WATER MONITORING BORE LOG

Bore ID: BH03

Client: Snowy Hydro Limited **Project:** Snowy 2.0

Date completed:	29/01/2019	**Project number:**	J17188
Drilling contractor:	EMM	**Elevation:**	1349.9 mAHD
Drilling method:	Hand Auger	**Easting:**	641682.1
Hydrogeologist:	Jono Tait	**Northing:**	6038521.4

Static Water Level:	0.65 mBGL	**Screened Formation:**	Alluvium/Colluvium	**Date:**	29/01/2019
Total depth:	0.70 mBGL	**Screened depth:**	0.4 - 0.7 mBGL	**Casing:**	40 mm U-PVC (PN18)

Depth (mbgl)	Lithology Graphic	Description	Drilling Notes	Bore Completion: Diagram	Bore Completion: Design notes
0		SOIL, black, high organic matter, weak to medium plasticity clay, silty.			40 mm blank PVC casing (0 - 0.5 mBGL)
		CLAY, orange mottled white, medium clay, minor subangular gravel (2 - 5 mm)	Perched water table		Bentonite (0 - 0.3 mBGL)
		GRAVEL, black grey, subangular to angular (2 - 10 mm) with moderate coarse grained sand.			Gravel pack (0.3 - 0.7 mBGL)
		BEDROCK, yellow orange, weathered.	Refusal and water strike on weatehred bedrock.		40mm slotted PVC screen (0.4 - 0.7 mBGL)

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WATER MONITORING BORE LOG

Bore ID: GH01

Client: Snowy Hydro Limited **Project:** Snowy 2.0

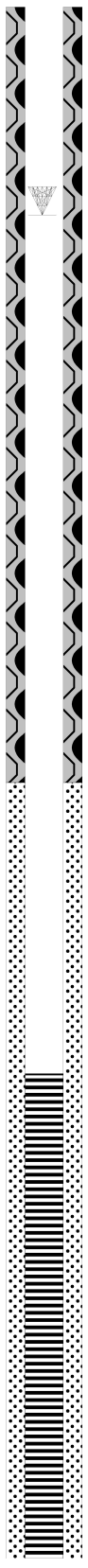
Date completed:	29/01/2019	**Project number:**	J17188
Drilling contractor:	EMM	**Elevation:**	1456.3 mAHD
Drilling method:	Hand Auger	**Easting:**	636471.8
Hydrogeologist:	Jono Tait	**Northing:**	6038556.8

Static Water Level: 0.10 mBGL **Screened Formation:** Alluvium/Colluvium **Date:** 29/01/2019

Total depth: 0.95 mBGL **Screened depth:** 0.55 - 0.95 mBGL **Casing:** 40 mm U-PVC (PN18)

Depth (mbgl)	Lithology Graphic	Description	Drilling Notes	Bore Completion: Diagram	Bore Completion: Design notes
0		SOIL, black, silty, high organic matter.			
		SILTY CLAY, grey, weak plasticity, moderate silt and organic matter.	Perched water table		
		CLAY, grey mottled orange, weak to medium plasticity, minor angular to sub-angular gravel (1 - 5 mm) minor silt.			40 mm blank PVC casing (0 - 0.55 mBGL) Bentonite (0 - 0.4 mBGL)
		CLAY, orange mottled grey, weak to medium plasticity, minor angular to sub-angular gravel (3 - 50 mm) increasing with depth.	Refusal and water strike on weathered bedrock		Gravel pack (0.4 - 0.95 mBGL) 40 mm slotted PVC casing (0.55 - 0.95 mBGL)

Alluvium/Colluvium



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WATER MONITORING BORE LOG

Bore ID: GH02

Client: Snowy Hydro Limited **Project:** Snowy 2.0

Date completed:	29/01/2019	**Project number:**	J17188
Drilling contractor:	EMM	**Elevation:**	1456.1 mAHD
Drilling method:	Hang Auger	**Easting:**	636468.7
Hydrogeologist:	Jono Tait	**Northing:**	6038522.0

Static Water Level: 0.10 mBGL **Screened Formation:** Alluvium/Colluvium **Date:** 29/01/2019

Total depth: 0.95 mBGL **Screened depth:** 0.55 - 0.95 mBGL **Casing:** 40 mm U-PVC (PN18)

Depth (mbgl)	Lithology Graphic	Description	Drilling Notes	Bore Completion: Diagram	Bore Completion: Design notes
0		SOIL, black, high organic matter, silty.			
		SILTY CLAY, black, weak to medium plasticity, organic matter, minor coarse grained sand/gravel.	Perched water table		40 mm blank PVC (0 - 0.55 mBGL)
		CLAY, grey mottled orange, weak to medium plasticity, minor gravel (1 - 5 mm) throughout.			Bentonite (0 - 0.4 mBGL)
		CLAY, orange mottled grey, medium plasticty, minor gravel (1 - 10 mm).			Gravel pack (0.4 - 0.95 mBGL)
		BEDROCK, yellow orange, weathered.	Refusal and water strike on weathered bedrock		40 mm slotted PVC screen (0.55 - 0.95 mBGL)

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WATER MONITORING BORE LOG

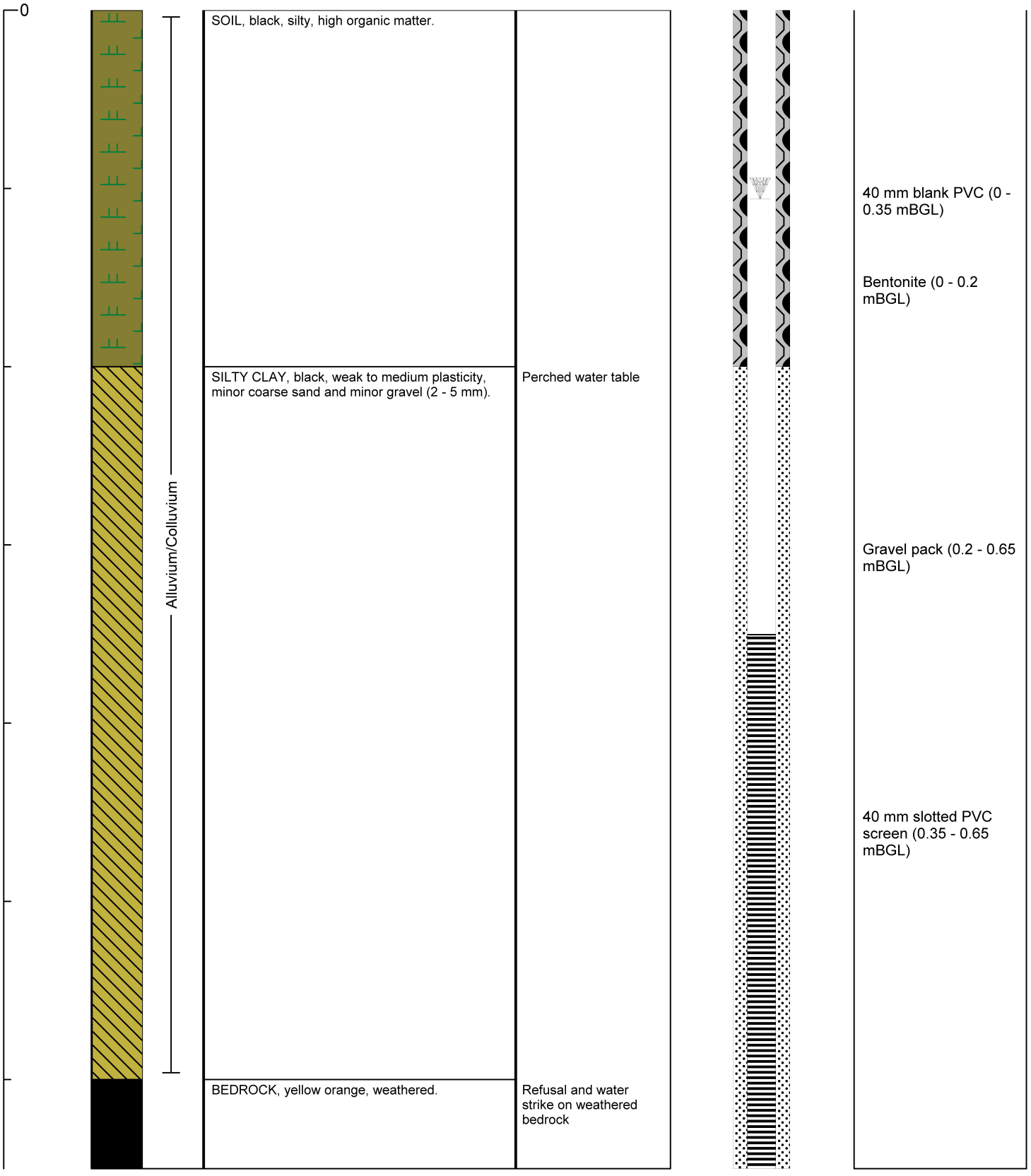
Bore ID: GH03

Client: Snowy Hydro Limited **Project:** Snowy 2.0

Date completed:	29/01/2019	**Project number:**	J17188
Drilling contractor:	EMM	**Elevation:**	1455.3 mAHD
Drilling method:	Hand Auger	**Easting:**	636489.1
Hydrogeologist:	Jono Tait	**Northing:**	6038484.4

Static Water Level:	0.10 mBGL	**Screened Formation:**	Alluvium/Colluvium	**Date:**	29/01/2019
Total depth:	0.65 mBGL	**Screened depth:**	0.35 - 0.65 mBGL	**Casing:**	40 mm U-PVC (PN18)

Depth (mbgl)	Lithology Graphic	Description	Drilling Notes	Bore Completion: Diagram	Bore Completion: Design notes
0		SOIL, black, silty, high organic matter.			40 mm blank PVC (0 - 0.35 mBGL)
		SILTY CLAY, black, weak to medium plasticity, minor coarse sand and minor gravel (2 - 5 mm).	Perched water table		Bentonite (0 - 0.2 mBGL)
	Alluvium/Colluvium				Gravel pack (0.2 - 0.65 mBGL)
		BEDROCK, yellow orange, weathered.	Refusal and water strike on weathered bedrock		40 mm slotted PVC screen (0.35 - 0.65 mBGL)



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WATER MONITORING BORE LOG

Bore ID: NC01

Client: Snowy Hydro Limited **Project:** Snowy 2.0

Date completed:	1/02/2019	**Project number:**	J17188
Drilling contractor:	EMM	**Elevation:**	1236.6 mAHD
Drilling method:	Hand Auger	**Easting:**	647182.7
Hydrogeologist:	Jono Tait	**Northing:**	6038191.5

Static Water Level: 0.70 mBGL **Screened Formation:** Alluvium/Colluvium **Date:** 1/02/2019

Total depth: 0.80 mBGL **Screened depth:** 0.50 - 0.80 mBGL **Casing:** 40 mm U-PVC (PN18)

Depth (mbgl)	Lithology Graphic	Description	Drilling Notes	Bore Completion: Diagram	Bore Completion: Design notes
0		SOIL, black, high organic matter with moderate silt and low to medium plasticity clay.			
		SILTY CLAY, orange mottled brown, low to medium plasticity clay with minor silt.			40 mm blank PVC casing (0 - 0.5 mBGL)
					Bentonite (0 - 0.3 mBGL)
			Perched water strike (0.25 m)		
					Gravel pack (0.3 - 0.8 mBGL)
		SILTY CLAYEY SAND, orange brown, fine to coarse grained, fining upwards, weak plasticity clay.			
					40 mm slotted PVC casing (0.5 - 0.8 mBGL)
		SANDY GRAVEL, yellow brown, sub-angular to rounded (2 - 10 mm) with moderate fine to coarse grained sand (Weathered bedrock).	Refusal and water strike on weathered bedrock		

Alluvium/Colluvium

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WATER MONITORING BORE LOG

Bore ID: NC02

Client: Snowy Hydro Limited **Project:** Snowy 2.0

Date completed:	1/02/2019	**Project number:**	J17188
Drilling contractor:	EMM	**Elevation:**	1236.9 mAHD
Drilling method:	Hand Auger	**Easting:**	647235.8
Hydrogeologist:	Jono Tait	**Northing:**	6038227.3

Static Water Level: 0.90 mBGL **Screened Formation:** Alluvium/Colluvium **Date:** 1/02/2019

Total depth: 1.10 mBGL **Screened depth:** 0.80 - 1.10 mBGL **Casing:** 40 mm U-PVC (PN18)

Depth (mbgl)	Lithology Graphic	Description	Drilling Notes	Bore Completion: Diagram	Bore Completion: Design notes
0		SOIL, black, high organic matter with moderate silt and low to medium plasticity clay.			40 mm blank PVC casing (0 - 0.8 mBGL)
		SILTY CLAY, orange mottled grey, medium plasticity clay with minor silt, stiff clay between 0.3 - 0.4 m.	Perched water strike (0.25 m)		Bentonite (0 - 0.6 mBGL)
		SILTY CLAYEY SAND, orange mottled grey, fine to coarse grained, weak plasticity clay.			Gravel pack (0.6 - 1.10 mBGL)
		SANDY GRAVEL, orange brown, sub-angular to rounded (2 - 10 mm) with moderate fine to coarse grained sand, minor weak clay.			40 mm slotted PVC casing (0.8 - 1.10 mBGL)
1		BEDROCK, yellow orange, weathered.	Refusal and water strike on weathered bedrock		

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WATER MONITORING BORE LOG

Bore ID: NC03

Client: Snowy Hydro Limited **Project:** Snowy 2.0

Date completed:	1/02/2019	**Project number:**	J17188
Drilling contractor:	EMM	**Elevation:**	1236.9 mAHD
Drilling method:	Hand Auger	**Easting:**	647208.2
Hydrogeologist:	Jono Tait	**Northing:**	6038273.4

Static Water Level: 0.90 mBGL **Screened Formation:** Alluvium/Colluvium **Date:** 1/02/2019

Total depth: 1.00 mBGL **Screened depth:** 0.70 - 1.00 mBGL **Casing:** 40 mm U-PVC (PN18)

Depth (mbgl)	Lithology Graphic	Description	Drilling Notes	Bore Completion: Diagram	Bore Completion: Design notes
0		SOIL, black, high organic matter with moderate silt and low to medium plasticity clay.			40 mm blank PVC casing (0 - 0.7 mBGL)
		SILTY CLAY, orange mottled grey, medium plasticity clay with minor silt, stiff clay between 0.3 - 0.4 m.	Perched water table		Bentonite (0 - 0.5 mBGL)
		SILTY CLAYEY SAND, orange mottled grey, fine to coarse grained, weak plasticity clay.			Gravel pack (0.5 - 1.0 mBGL)
		SANDY GRAVEL, yellow brown, sub-angular to rounded (2 - 10 mm) with moderate fine to coarse grained sand, minor weak clay.			40 mm slotted PVC casing (0.7 - 1.0 mBGL)
1		BEDROCK, yellow orange, weathered.	Refusal and water strike on weathered bedrock		

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WATER MONITORING BORE LOG

Bore ID: TC01

Client: Snowy Hydro Limited **Project:** Snowy 2.0

Date completed:	30/01/2019	**Project number:**	J17188
Drilling contractor:	EMM	**Elevation:**	1323.5 mAHD
Drilling method:	Hand Auger	**Easting:**	640523.2
Hydrogeologist:	Jono Tait	**Northing:**	6038237.8

Static Water Level: 0.8 mBGL **Screened Formation:** Alluvium/Colluvium **Date:** 30/01/2019

Total depth: 1.0 mBGL **Screened depth:** 0.6 - 1.0 mBGL **Casing:** 40 mm U-PVC (PN18)

Depth (mbgl)	Lithology Graphic	Description	Drilling Notes	Bore Completion	
				Diagram	Design notes
0		SILT, black, highly organic with roots and peat.			
		CLAY, grey black, medium plasticity with subangular gravel <3mm.	Percehd water table		40 mm blank PVC casing (0 - 0.6 mBGL)
		CLAY and GRAVEL, grey black, medium plasticity with subangular gravel ~3mm.			Bentonite (0 - 0.4 mBGL)
		CLAY and GRAVEL, grey black, high plasticity with subangular gravel (3 - 20 mm).			
		CLAY and SILT, grey black, high plasticity.			Gravel pack (0.4 - 1.0 mBGL)
		CLAY, grey black, high plasticity.			
	Alluvium/Colluvium				40 mm slotted PVC screen (0.6 - 1.0 mBGL)
			Reusal and water strike on weatherd bedrock.		
1		BEDROCK, yellow orange, weathered.			

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WATER MONITORING BORE LOG

Bore ID: TC02

Client: Snowy Hydro Limited **Project:** Snowy 2.0

Date completed:	30/01/2019	**Project number:**	J17188
Drilling contractor:	EMM	**Elevation:**	1322.3 mAHD
Drilling method:	Hand Auger	**Easting:**	640487.6
Hydrogeologist:	Jono Tait	**Northing:**	6038213.6

Static Water Level:	0.8 mBGL	**Screened Formation:**	Alluvium/Colluvium	**Date:**	30/01/2019
Total depth:	1.1 mBGL	**Screened depth:**	0.7 - 1.1 mBGL	**Casing:**	40 mm U-PVC (PN18)

Depth (mbgl)	Lithology Graphic	Description	Drilling Notes	Bore Completion	
				Diagram	Design notes
0		SILT and CLAY, black, highly organic with roots.			
		SILTY CLAY, orange mottled grey, medium plasticity with minor subangular gravel (<3 mm).	Perched water table		40 mm blank PVC casing (0 - 0.7 mBGL)
		SILTY CLAY, grey mottled orange, medium plasticity with subangular gravel (3 - 20 mm).			Bentonite (0 - 0.5 mBGL)
		GRAVEL, yellow orange, angular (10 - 20 mm) becoming larger with depth.			Gravel pack (0.5 - 1.1 mBGL)
1		BEDROCK, yellow orange, weathered.	Refusal and water strike on weathered bedrock		40 mm slotted PVC screen (0.7 - 1.1 mBGL)

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WATER MONITORING BORE LOG

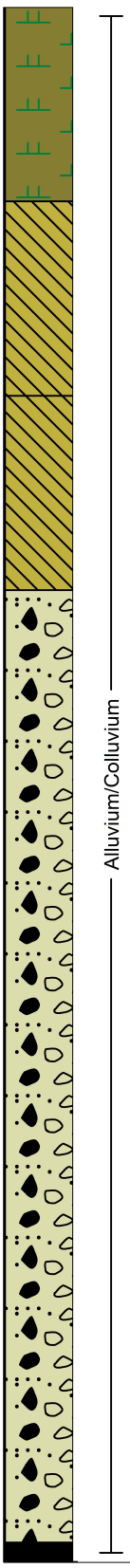
Bore ID: TC03

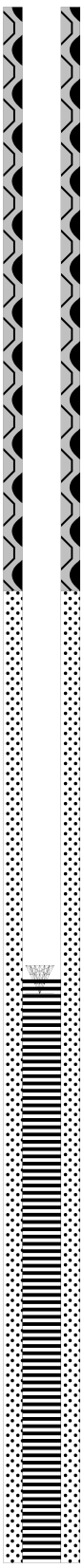
Client: Snowy Hydro Limited **Project:** Snowy 2.0

Date completed:	30/01/2019	**Project number:**	J17188
Drilling contractor:	EMM	**Elevation:**	1321.1 mAHD
Drilling method:	Hand Auger	**Easting:**	640469.7
Hydrogeologist:	Jono Tait	**Northing:**	6038178.9

Static Water Level:	0.5 mBGL	**Screened Formation:**	Alluvium/Colluvium	**Date:**	30/01/2019
Total depth:	0.8 mBGL	**Screened depth:**	0.5 - 0.8 mBGL	**Casing:**	40 mm U-PVC (PN18)

Depth (mbgl)	Lithology Graphic	Description	Drilling Notes	Bore Completion: Diagram	Bore Completion: Design notes
0		SILT and CLAY, black, highly organic with roots.			40 mm blank PVC casing (0 - 0.5 mBGL)
		SILTY CLAY, orange mottled grey black, medium plasticity with some subangular gravel (<3 mm).	Perched water table		Bentonite (0 - 0.3 mBGL)
		SILTY CLAY, yellow orange, medium plasticity with subangular gravel (3 - 20 mm).			Gravel pack (0.3 - 0.8 mBGL)
		GRAVEL, yellow orange, angular (3 - 20 mm) becoming larger with depth.			40 mm slotted PVC screen (0.5 - 0.8 mBGL)
			Refusal and water strike on weathered bedrock.		
		BEDROCK, yellow orange, weathered.			





Appendix B

Slug test analysis report

Memorandum

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16 February 2019

To: Glynn Price
From: EMM Consulting Pty Limited
Subject: Swamp piezometer slug testing analysis report

Dear Glynn,

Please find below a brief technical report, prepared by EMM Consulting Pty Limited, summarising the rising/falling head tests undertaken at three different swamp piezometer sites: Gooandra Hill, Tantangara Creek and Bullocks Hill, in Snowy Mountains, NSW (Figure 1.1).

1 Summary

A series of rising and falling head tests (slug tests) were performed on nine piezometers across three different sites with the purpose of obtaining bulk hydraulic conductivity values of the upper soil layer in the swamp environments.

A falling head test is achieved by introducing a 'slug' device to displace the water column within the monitoring bore causing the water level to instantaneously rise and water to flow from the bore into the aquifer via the well screen (Butler 1998). The water level decay is recorded until the water level has returned to static level.

A rising head test is then conducted where the slug is removed causing a reduction in the bore water level with respect to the screened formation. Water then moves from the formation into the bore via the well screen. The water level recovery is recorded until the water level has returned to static level.

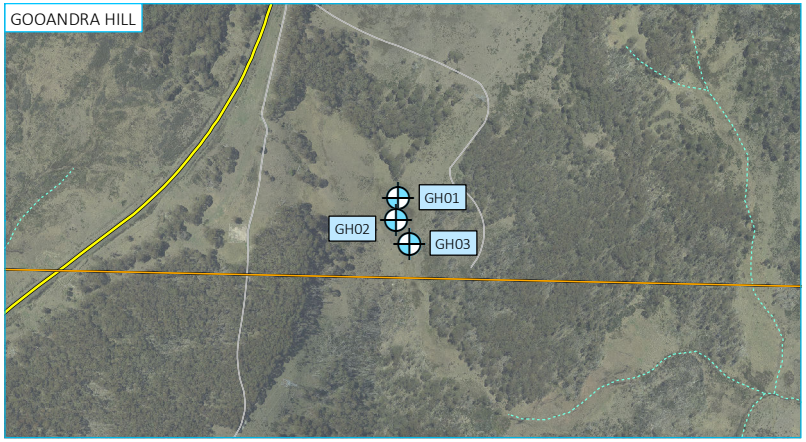
Multiple slug tests were performed on the Gooandra Hill bores due to their fast rate of recovery. Both falling and rising head tests were conducted on these bores by inserting and removing a slug respectively. Conversely, only one rising head test was performed on the Bullocks Hill and Tantangara Creek bores due to their slow recovery rates. These rising head tests were conducted by bailing water from the bores until they were dry.

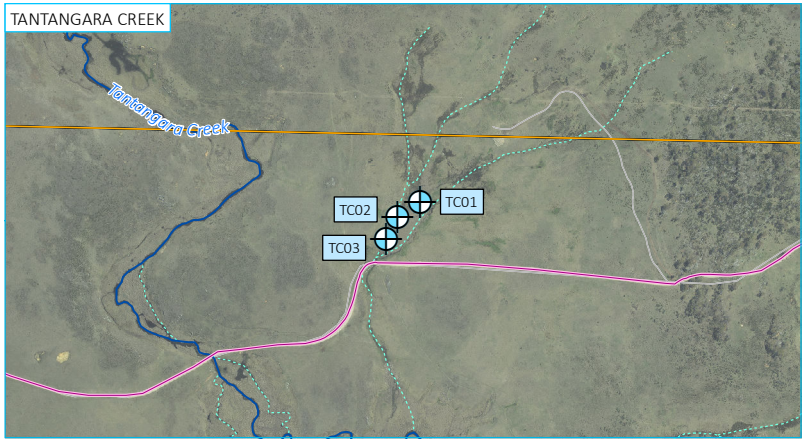
For each slug test, an automatic water level logger with a measurement frequency of one second was used to record the change in head over time.

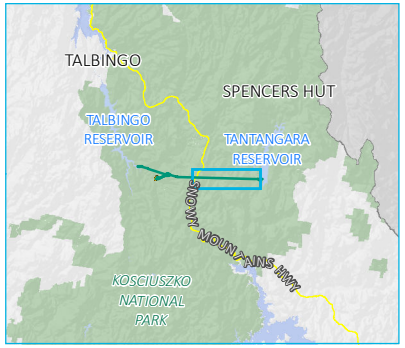
A summary of these tests is provided in Table 1.1.

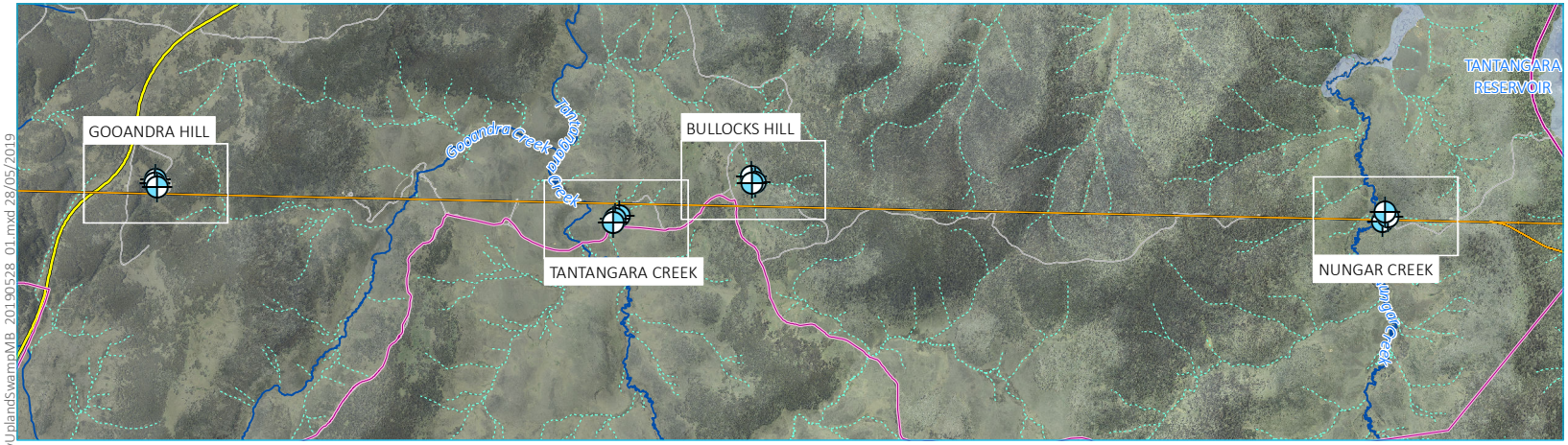
Table 1.1 Swamp piezometer slug testing summary

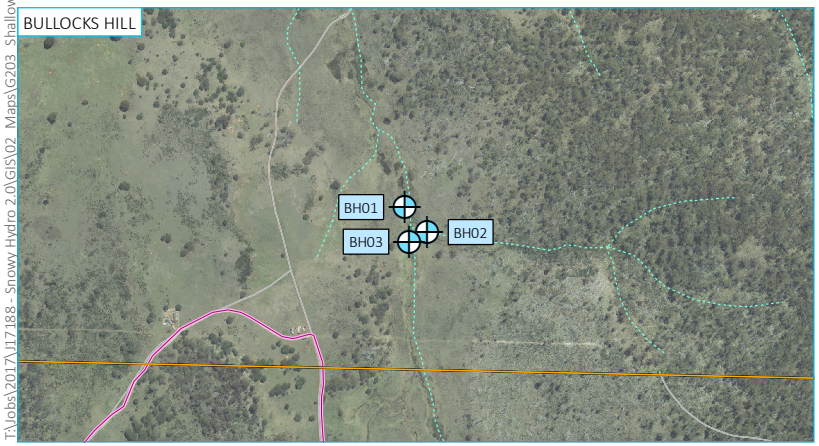
Description	Detail
Test type	Gooandra Hill bores – four rising-head tests, four falling-head tests Tantangara Creek bores – one rising-head test (bailer) Bullocks Hill bores – one rising-head test (bailer)
Date	Gooandra Hill bores – 5 February 2019 Tantangara Creek bores – 6 February 2019 Bullocks Hill bores – 6 February 2019

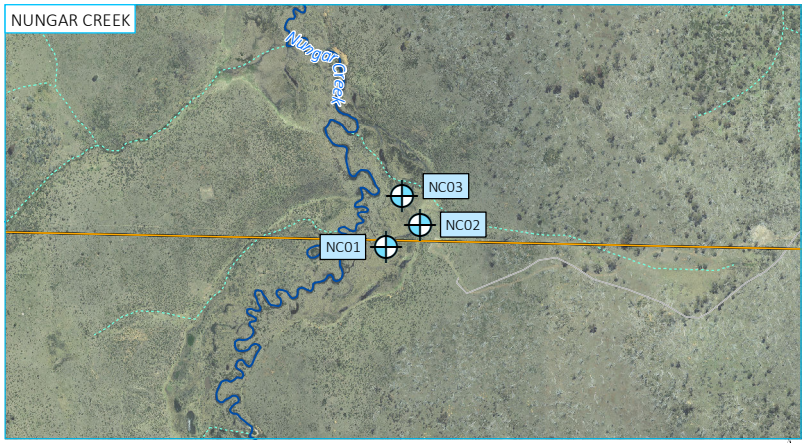












KEY

- Upland swamp monitoring bore

Existing environment

- Main road
- Local road
- No legend
- Drainage line
- Named watercourse
- Scheme storage

Snowy 2.0 operational elements

- Tunnels, portals, intakes, shafts
- Power station
- Utilities

Upland swamp monitoring bores

Source: EMM (2018); Snowy Hydro (2018); NearMap (2018); DFSI (2017); GA (2015); LPMA (2011)

0 1 2 km

GDA 1994 MGA Zone 55

N

Snowy 2.0
Drilling and completion report
Shallow upland swamp monitoring bores
Figure 1.1

snowy 2.0

EMM creating opportunities

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2 Conceptualisation and assumptions

The bore construction details for the piezometers are summarised in Table 2.1. 2-dimensional conceptualised cross-section models for the swamp piezometer sites are shown in Figure 2.1, Figure 2.2 and Figure 2.3.

Table 2.1 Swamp piezometer construction details summary

Site	Bore ID	Total depth (mBGL)	Screened interval (mBGL)
Gooandra Hill	GH01	0.95	0.55–0.95
	GH02	0.95	0.55–0.95
	GH03	0.65	0.35–0.65
Tantangara Creek	TC01	1.0	0.60–1.0
	TC02	1.1	0.70–1.1
	TC03	0.80	0.50–0.80
Bullocks Hill	BH01	0.50	0.30–0.50
	BH02	0.80	0.50–0.80
	BH03	0.70	0.40–0.70

AqteSolv was used to estimate the bulk hydraulic conductivities of the areas surrounding the bores. AqteSolv is industry leading software for analysing aquifer tests using a variety of aquifer types and solutions.

The following additional assumptions were used to facilitate analysis:

- aquifers and aquitards are infinite in extent;
- aquifers are homogeneous and uniform in thickness;
- aquitards have a uniform vertical hydraulic conductivity;
- flow in aquitards are vertical;
- flow to the well is horizontal;
- the aquifer is conceptualised as one thick aquifer only; and
- the aquifer thickness assumed when modelling was equal to the distance between the static water table and the bottom of the screened interval in each bore.

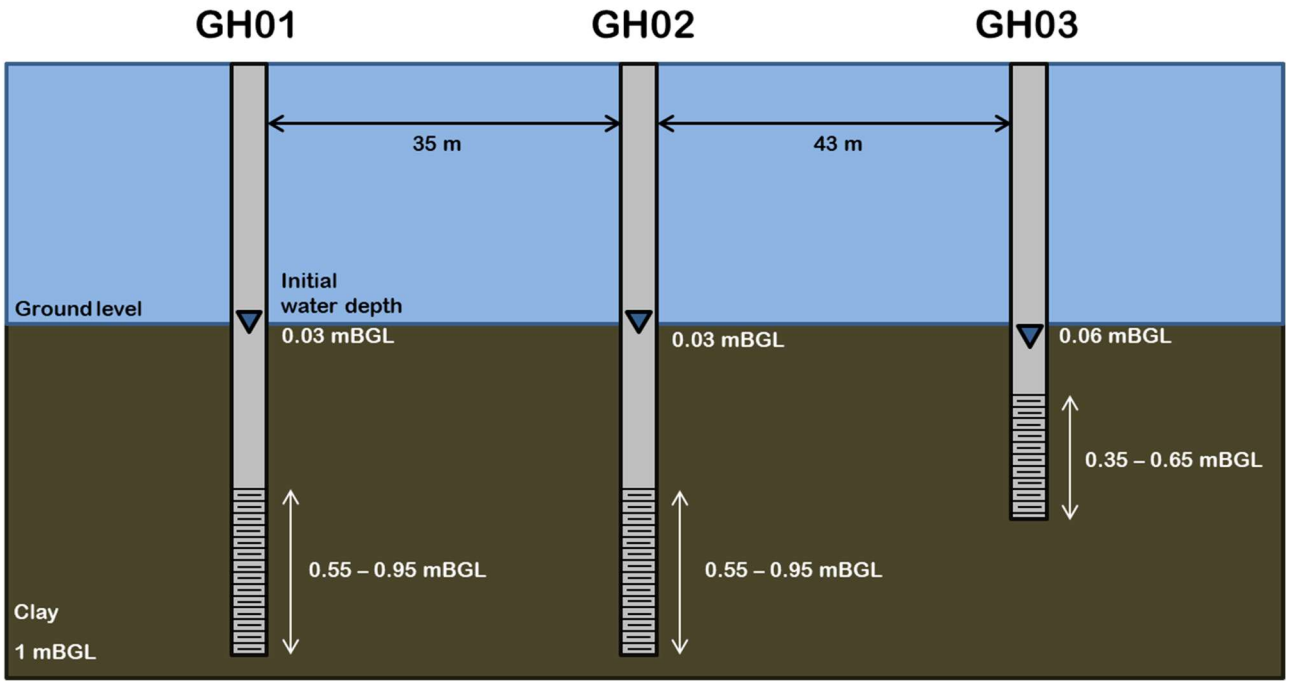

Figure 2.1 Conceptual cross-section of the swamp piezometers at the Gooandra Hill site

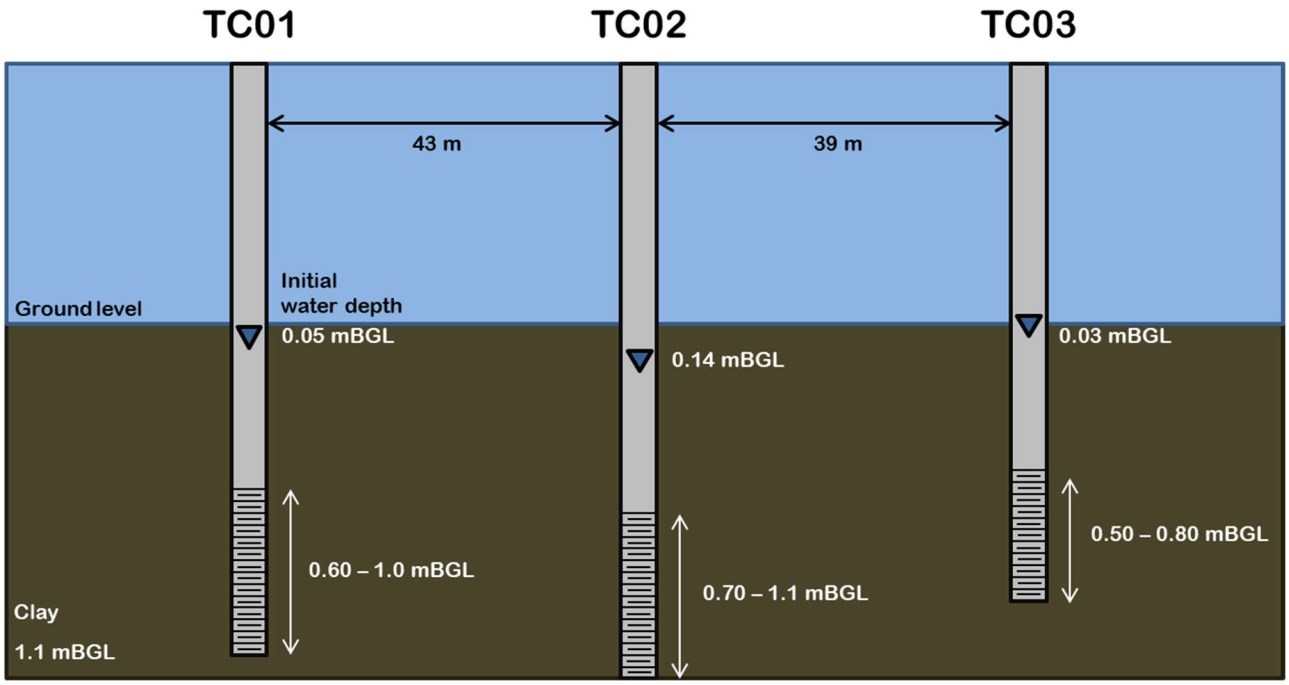

Figure 2.2 Conceptual cross-section of the swamp piezometers at the Tantangara Creek site

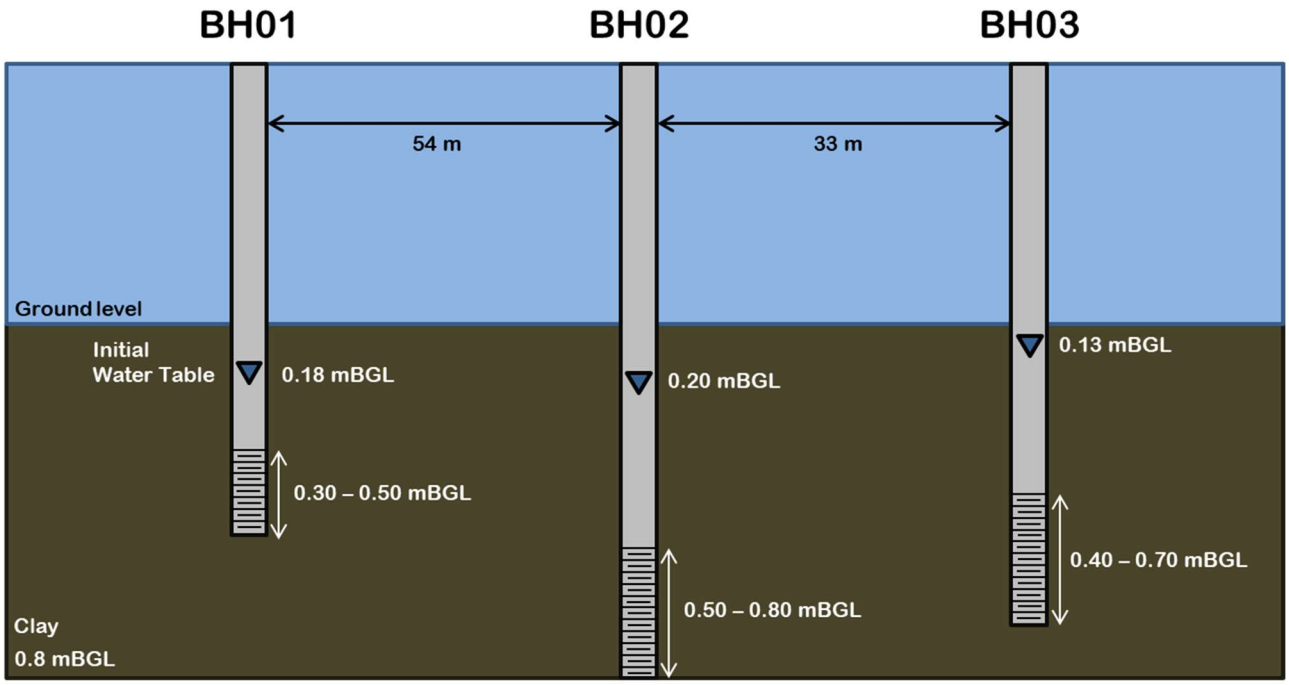

Figure 2.3 Conceptual cross-section of the swamp piezometers at the Bullocks Hill site

3 Analysis

The slug test data from each bore was analysed using the Hvorslev straight-line solution for unconfined aquifers in AqteSolv. A summary of the results derived from the analysis of the slug testing data is presented in Table 3.1, while the complete analyses for each bore are shown in Appendix A. A brief discussion of these results is provided in Section 4. Note that no results or analyses are presented for BH02, as this bore did not show any recovery over the test period.

Note that the displacement values for the falling head tests were converted from negative to positive values to allow the data to be analysed. Additionally, as the slug test data forms a convex curve in some cases, the straight-line Hvorslev test was performed on the data having a normalised head between 0.15 and 0.25, as recommended by Butler (1998). The only exception to this was for the Gooandra Hill falling head tests, where the initial straight-line segment was analysed regardless of normalised head. This section of the curve was analysed as it represents the period of time where the water level was above the slug in the piezometer. During this period, the diameter of the water surface is known, allowing the data to be analysed.

Table 3.1 Summary of slug testing analyses

Bore	GH01	GH02	GH03	TC01	TC02	TC03	BH01	BH02	BH03
Location	Gooandra Hill	Gooandra Hill	Gooandra Hill	Tantangara Creek	Tantangara Creek	Tantangara Creek	Bullocks Hill	Bullocks Hill	Bullocks Hill
K (m/d) Rising head test #1	1.276	0.4789	0.5954	0.01265	0.01452	0.03486	0.1283	–	0.1001
K (m/d) Rising head test #2	1.387	0.2206	0.6383	–	–	–	–	–	–
K (m/d) Falling head test #1	1.22	0.5245	0.6814	–	–	–	–	–	–
K (m/d) Falling head test #2	0.9844	0.4045	0.5876	–	–	–	–	–	–
Average K (m/d)	1.217	0.407	0.626	0.013	0.015	0.035	0.128	–	0.100

4 Discussion

Table 3.1 shows that the hydraulic conductivity values were the highest at the Gooandra Hill site. This result agrees with field observations of fast recovery times in these bores. The large hydraulic conductivity values observed at Gooandra Hill may be due to steady rainfall that occurred prior-to and throughout the testing period. There was no rainfall the next day, when Tantangara Creek and Bullocks Hill bores were slug tested.

Although the results from each bore at the Gooandra Hill site are generally in agreement, GH01 has a noticeably higher average hydraulic conductivity than the other bores, with 1.2 m/d being found compared to the 0.6 m/d in GH03. These bores are both screened in the same material and at the same depth, so this difference may be due to location or other factors.

The hydraulic conductivity values measured at Bullocks Hill are an order of magnitude lower than those at Gooandra Hill, and those from Tantangara Creek are a further order of magnitude below the Bullocks Hill values. This agrees with field observations of slow recovery times at the Bullocks Hill and Tantangara Creek bores. The hydraulic conductivity values measured at these sites are roughly the same in all bores.

Overall, the hydraulic conductivity values observed at these sites are high in comparison to those which have been found at greater depths. This result is expected due to the loose, unconsolidated, sand/gravel nature of the surface alluvium/colluvium.

Yours sincerely,

Bill Bull – Author

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Jonathon Tait – Review

Senior Hydrogeologist

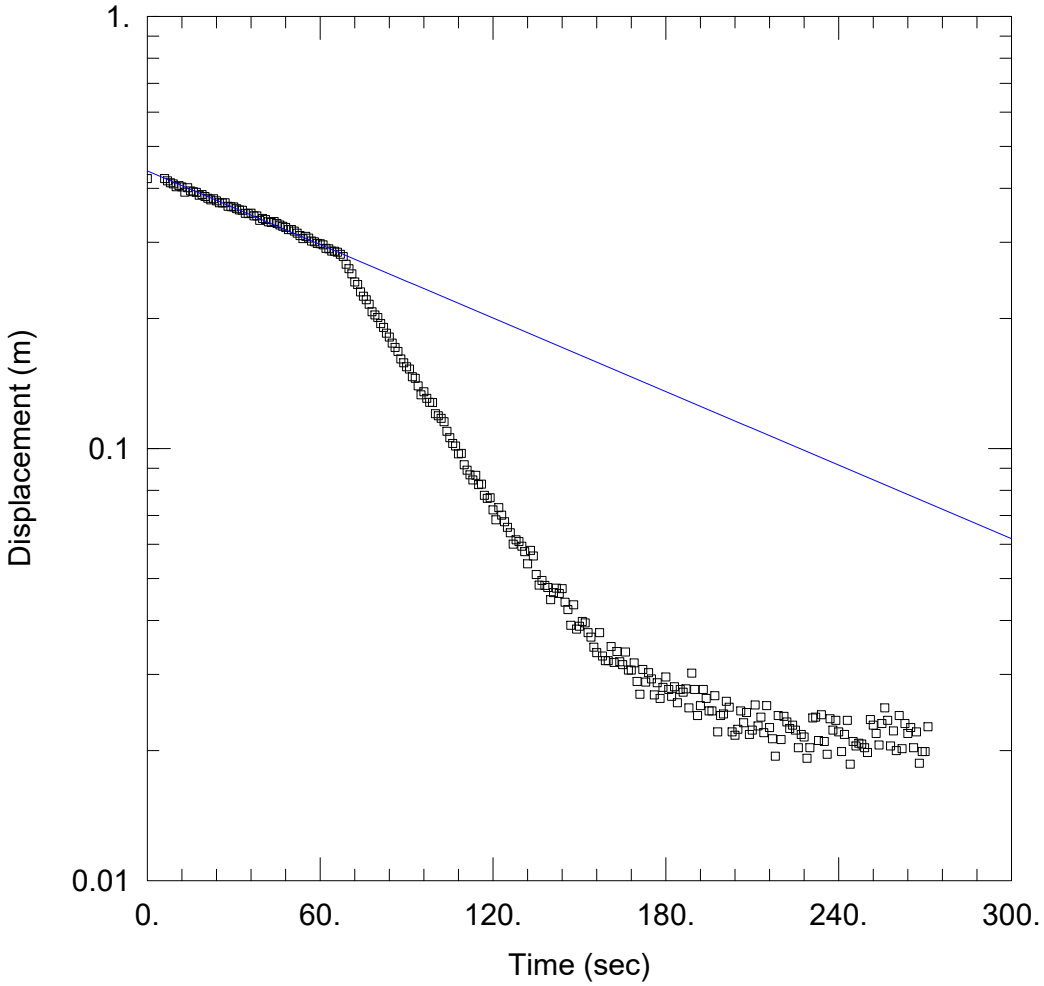
jtait@emmconsulting.com.au

References

Butler, J. J. Jr., 1998, *The Design, Performance, and Analysis of Slug Tests*, Lewis Publishers, New York, 252p.

Appendix A

Slug Test Analysis



GH01 FALLING HEAD TEST #1

Data Set: C:\...\GH01_Falling head_1.aqt
Date: 02/11/19 Time: 12:33:18

PROJECT INFORMATION

Company: EMM Consulting
Project: J17188
Test Well: GH01
Test Date: 5/02/2019

AQUIFER DATA

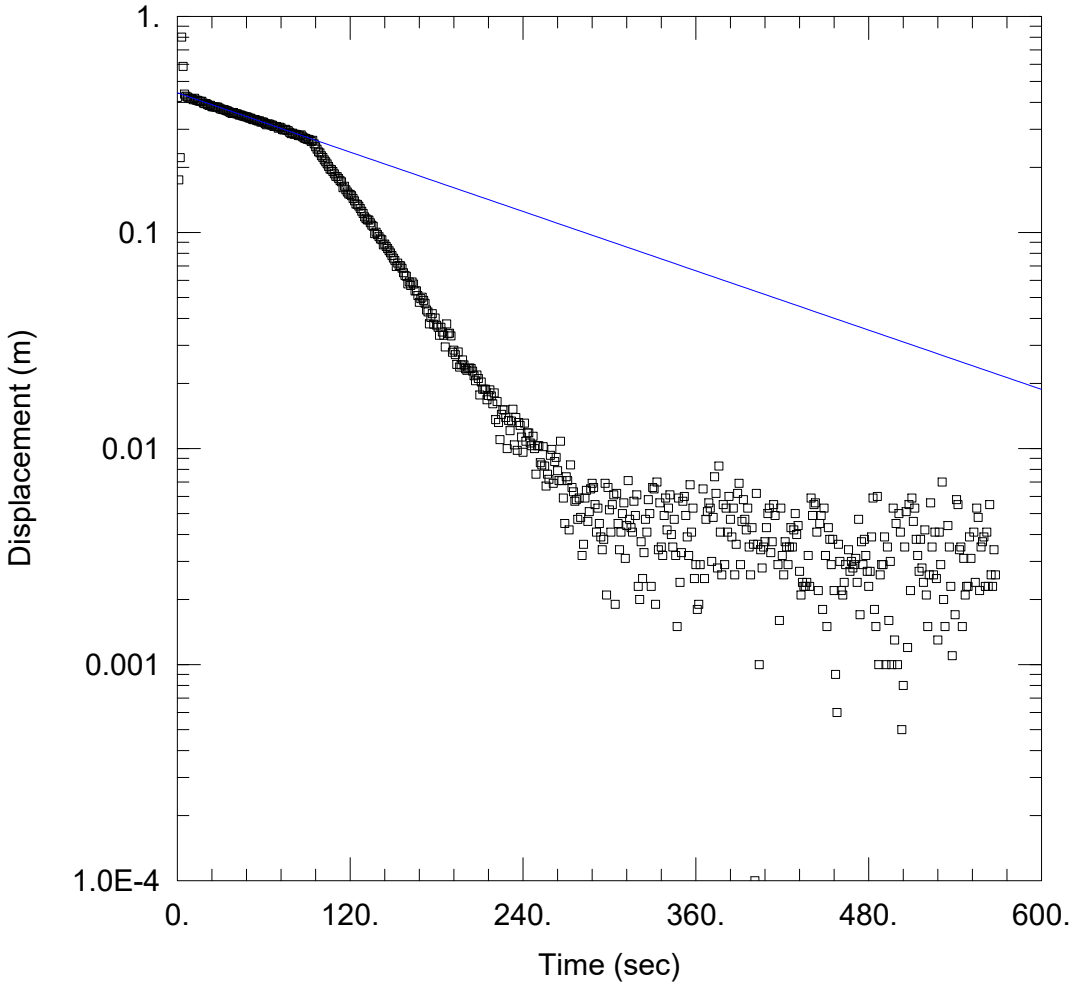
Saturated Thickness: 0.49 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GH01)

Initial Displacement: 0.4212 m
Total Well Penetration Depth: 0.69 m
Casing Radius: 0.02 m
Static Water Column Height: 0.49 m
Screen Length: 0.5 m
Well Radius: 0.04 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev
K = 1.22 m/day
y0 = 0.4388 m



GH01 FALLING HEAD TEST #2

Data Set: C:\...\GH01_Falling head_2.aqt
Date: 02/11/19 Time: 12:32:48

PROJECT INFORMATION

Company: EMM Consulting
Project: J17188
Test Well: GH01
Test Date: 5/02/2019

AQUIFER DATA

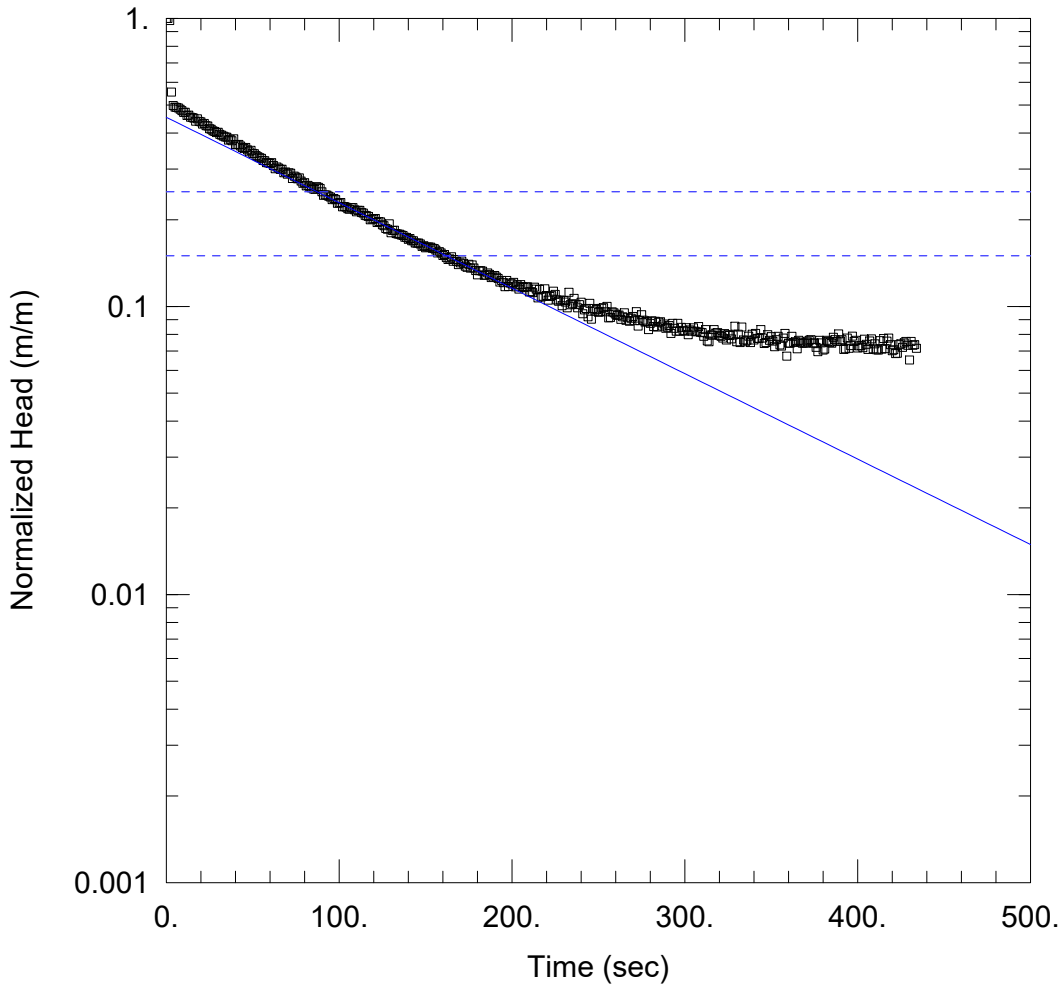
Saturated Thickness: 0.49 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GH01)

Initial Displacement: 0.4212 m
Total Well Penetration Depth: 0.69 m
Casing Radius: 0.02 m
Static Water Column Height: 0.49 m
Screen Length: 0.5 m
Well Radius: 0.04 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev
K = 0.9844 m/day
y0 = 0.4428 m



GH01 RISING HEAD TEST #1

Data Set: C:\...\GH01_Rising head_1.aqt
Date: 02/11/19 Time: 12:34:34

PROJECT INFORMATION

Company: EMM Consulting
Project: J17188
Test Well: GH01
Test Date: 5/02/2019

AQUIFER DATA

Saturated Thickness: 0.49 m Anisotropy Ratio (Kz/Kr): 1.

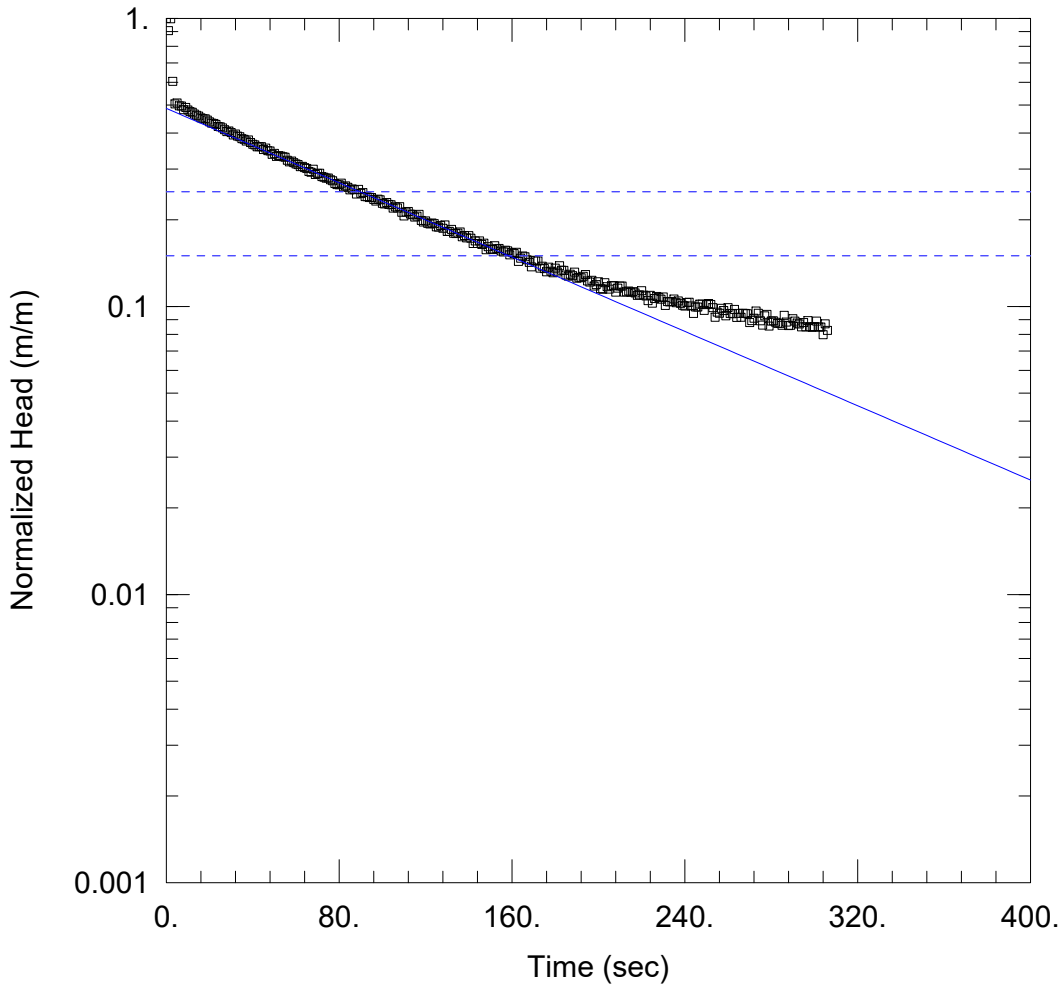
WELL DATA (GH01)

Initial Displacement: 0.5754 m
Total Well Penetration Depth: 0.69 m
Casing Radius: 0.02 m
Static Water Column Height: 0.49 m
Screen Length: 0.5 m
Well Radius: 0.04 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 1.276 m/day y0 = 0.261 m



GH01 RISING HEAD TEST #2

Data Set: C:\...\GH01_Rising head_2.aqt
Date: 02/11/19 Time: 12:34:58

PROJECT INFORMATION

Company: EMM Consulting
Project: J17188
Test Well: GH01
Test Date: 5/02/2019

AQUIFER DATA

Saturated Thickness: 0.49 m Anisotropy Ratio (Kz/Kr): 1.

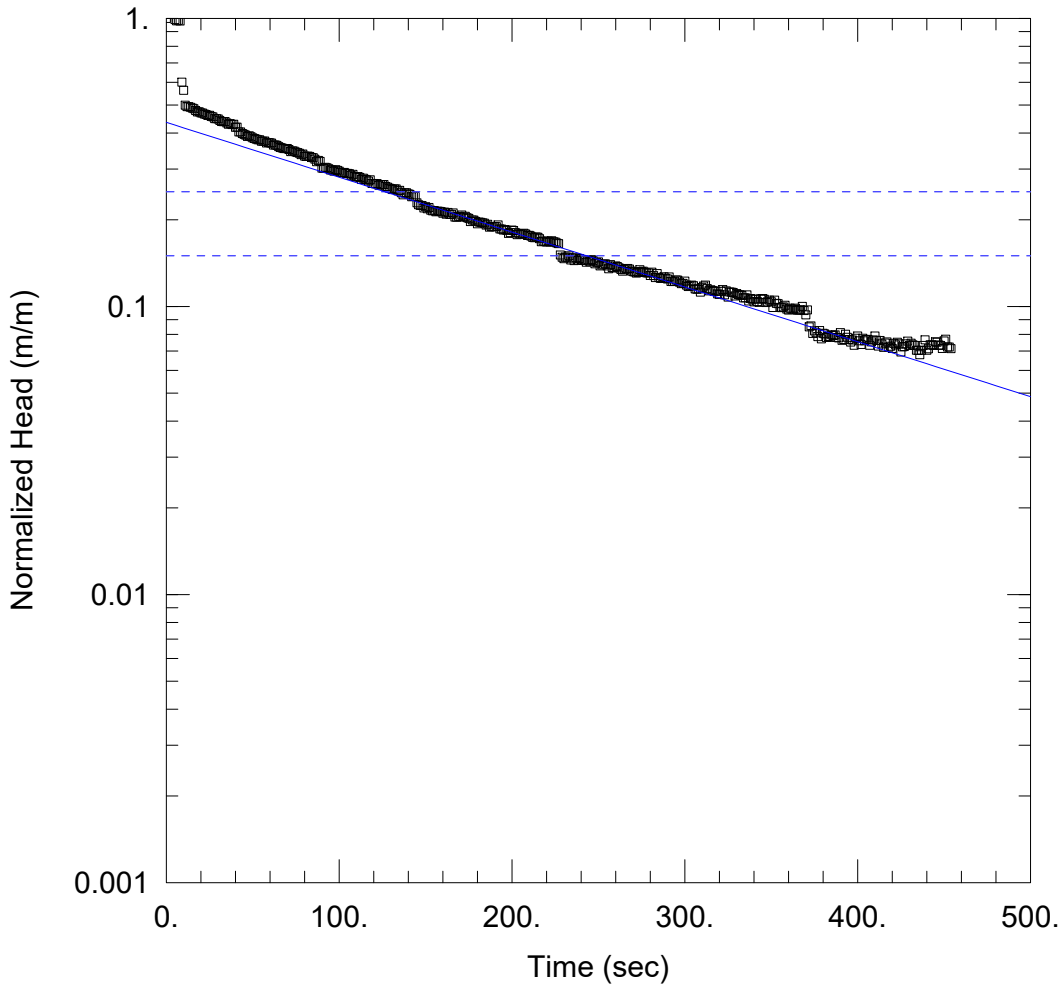
WELL DATA (GH01)

Initial Displacement: 0.5754 m
Total Well Penetration Depth: 0.69 m
Casing Radius: 0.02 m
Static Water Column Height: 0.49 m
Screen Length: 0.5 m
Well Radius: 0.04 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 1.387 m/day y0 = 0.2801 m



GH02 FALLING HEAD TEST #1

Data Set: C:\...\GH02_Falling head_1.aqt
Date: 02/11/19 Time: 12:19:16

PROJECT INFORMATION

Company: EMM Consulting
Project: J17188
Location: Gallandra Hill
Test Well: GH02
Test Date: 5/02/2019

AQUIFER DATA

Saturated Thickness: 0.89 m Anisotropy Ratio (Kz/Kr): 1.

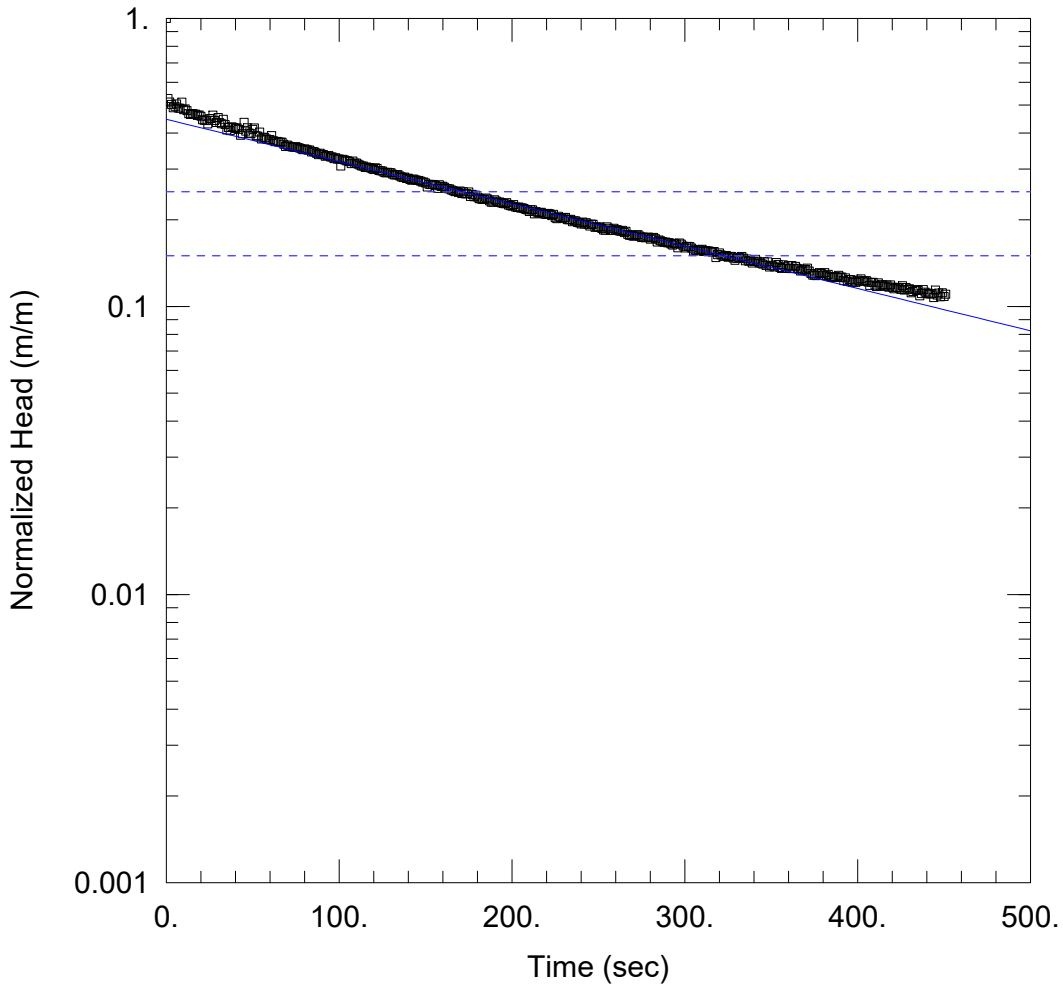
WELL DATA (New Well)

Initial Displacement: 0.86 m
Total Well Penetration Depth: 0.89 m
Casing Radius: 0.02 m
Static Water Column Height: 0.89 m
Screen Length: 0.45 m
Well Radius: 0.04 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 0.5245 m/day y0 = 0.3745 m



GH02 FALLING HEAD TEST #2

Data Set: C:\...\GH02_Falling head_2.aqt
Date: 02/11/19 Time: 12:18:20

PROJECT INFORMATION

Company: EMM Consulting
Project: J17188
Location: Gallandra Hill
Test Well: GH02
Test Date: 5/02/2019

AQUIFER DATA

Saturated Thickness: 0.89 m Anisotropy Ratio (Kz/Kr): 1.

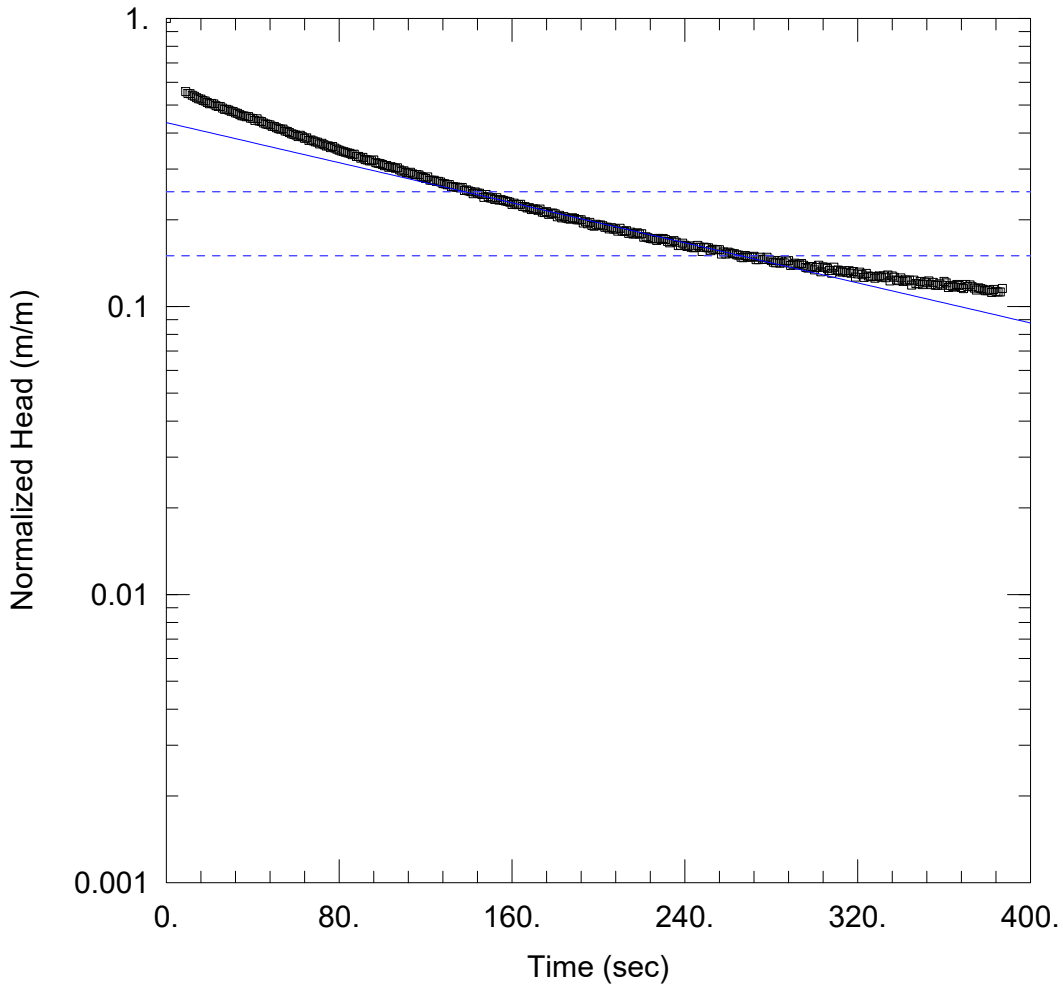
WELL DATA (New Well)

Initial Displacement: 0.86 m
Total Well Penetration Depth: 0.89 m
Casing Radius: 0.02 m
Static Water Column Height: 0.89 m
Screen Length: 0.45 m
Well Radius: 0.04 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 0.4045 m/day y0 = 0.3838 m



GH02 RISING HEAD TEST #1

Data Set: C:\...\GH02_Rising head_1.aqt
Date: 02/11/19 Time: 12:17:06

PROJECT INFORMATION

Company: EMM Consulting
Project: J17188
Location: Gallandra Hill
Test Well: GH02
Test Date: 5/02/2019

AQUIFER DATA

Saturated Thickness: 0.89 m Anisotropy Ratio (Kz/Kr): 1.

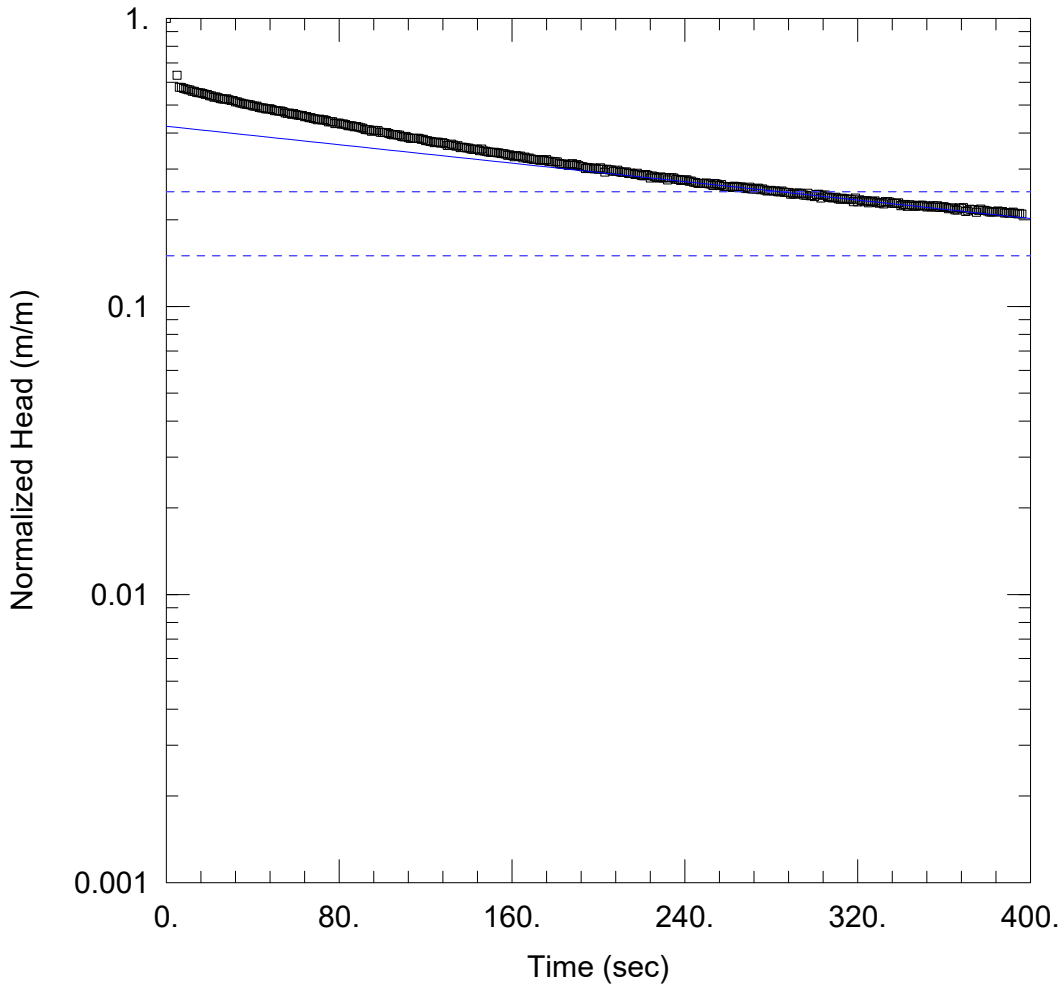
WELL DATA (GH02)

Initial Displacement: 0.86 m
Total Well Penetration Depth: 0.89 m
Casing Radius: 0.02 m
Static Water Column Height: 0.89 m
Screen Length: 0.45 m
Well Radius: 0.04 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 0.4789 m/day
y0 = 0.3738 m



GH02 RISING HEAD TEST #2

Data Set: C:\...\GH02_Rising head_2.aqt
Date: 02/11/19 Time: 12:20:11

PROJECT INFORMATION

Company: EMM Consulting
Project: J17188
Location: Gallandra Hill
Test Well: GH02
Test Date: 5/02/2019

AQUIFER DATA

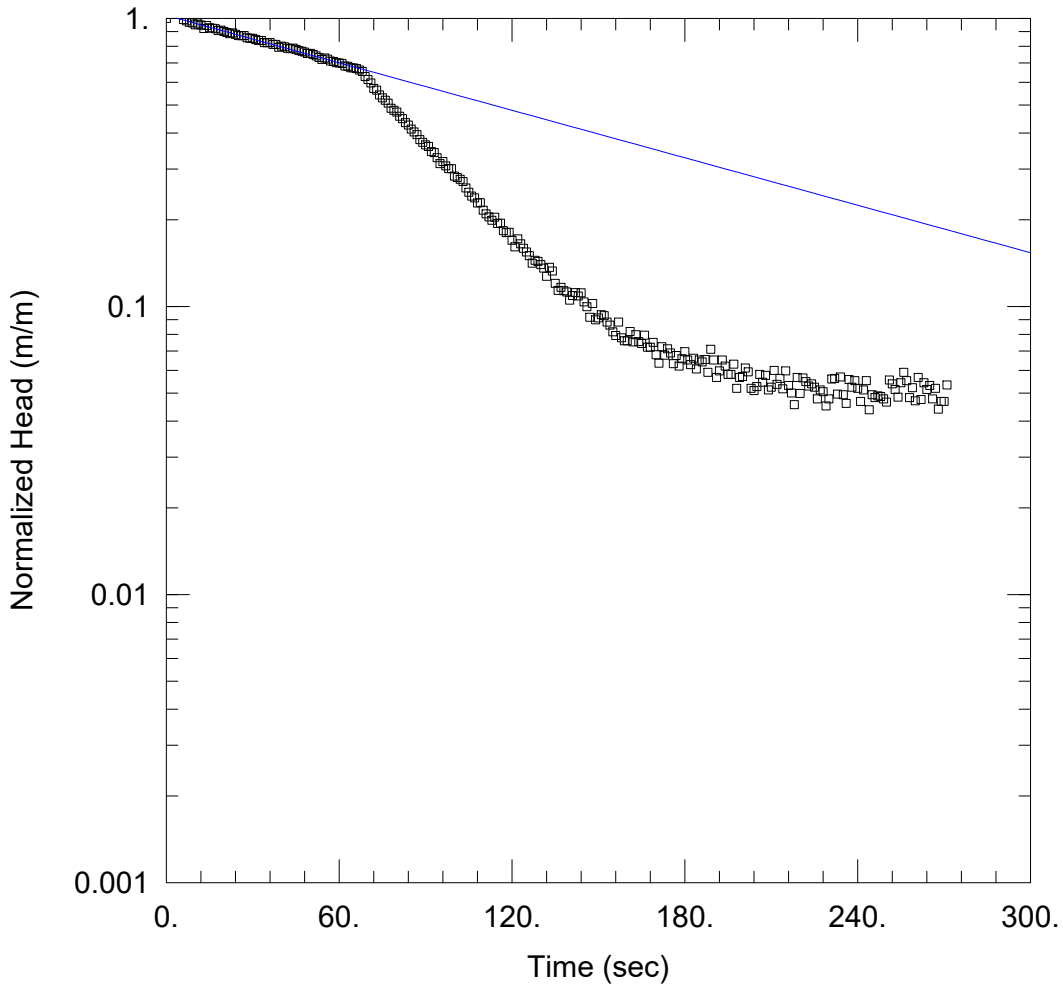
Saturated Thickness: 0.89 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GH02)

Initial Displacement: 0.86 m
Total Well Penetration Depth: 0.89 m
Casing Radius: 0.02 m
Static Water Column Height: 0.89 m
Screen Length: 0.45 m
Well Radius: 0.04 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev
K = 0.2206 m/day
y0 = 0.3631 m



GH03 FALLING HEAD TEST #1

Data Set:
Date: 02/11/19 Time: 11:49:31

PROJECT INFORMATION

Company: EMM Consulting
Project: J17188
Location: Gallandra Hill
Test Well: GH03
Test Date: 5/02/2019

AQUIFER DATA

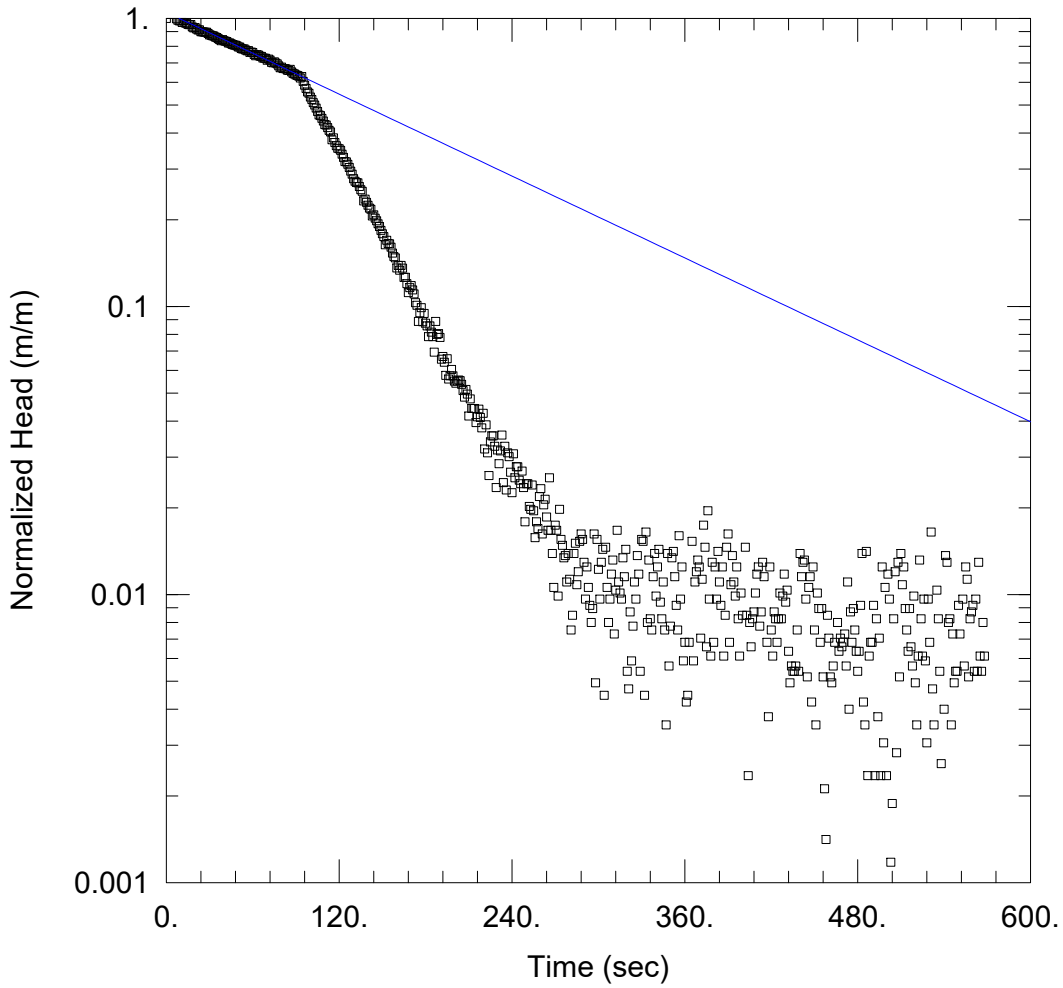
Saturated Thickness: 0.49 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GH03)

Initial Displacement: 0.425 m Static Water Column Height: 0.49 m
Total Well Penetration Depth: 0.45 m Screen Length: 0.35 m
Casing Radius: 0.02 m Well Radius: 0.04 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev
K = 0.6814 m/day y0 = 0.4355 m



GH03 FALLING HEAD TEST #2

Data Set: C:\...\falling head 2.aqt
Date: 02/11/19 Time: 11:51:39

PROJECT INFORMATION

Company: EMM Consulting
Project: J17188
Location: Gallandra Hill
Test Well: GH03
Test Date: 5/02/2019

AQUIFER DATA

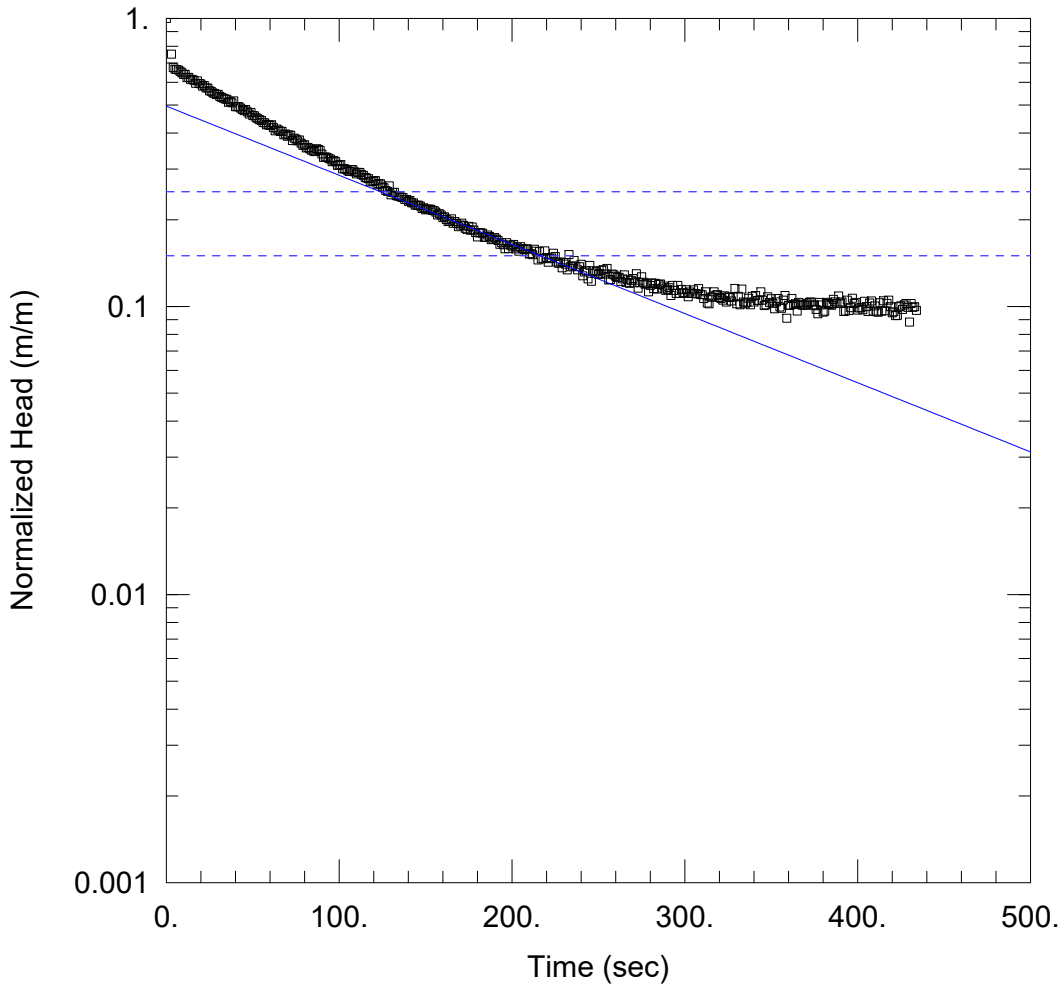
Saturated Thickness: 0.49 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GH03)

Initial Displacement: 0.425 m Static Water Column Height: 0.49 m
Total Well Penetration Depth: 0.45 m Screen Length: 0.35 m
Casing Radius: 0.02 m Well Radius: 0.04 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev
K = 0.5876 m/day y0 = 0.4463 m



GH03 RISING HEAD TEST #1

Data Set: C:\...\Rising head 1.aqt
Date: 02/11/19 Time: 11:54:04

PROJECT INFORMATION

Company: EMM Consulting
Project: J17188
Location: Gallandra Hill
Test Well: GH03
Test Date: 5/02/2019

AQUIFER DATA

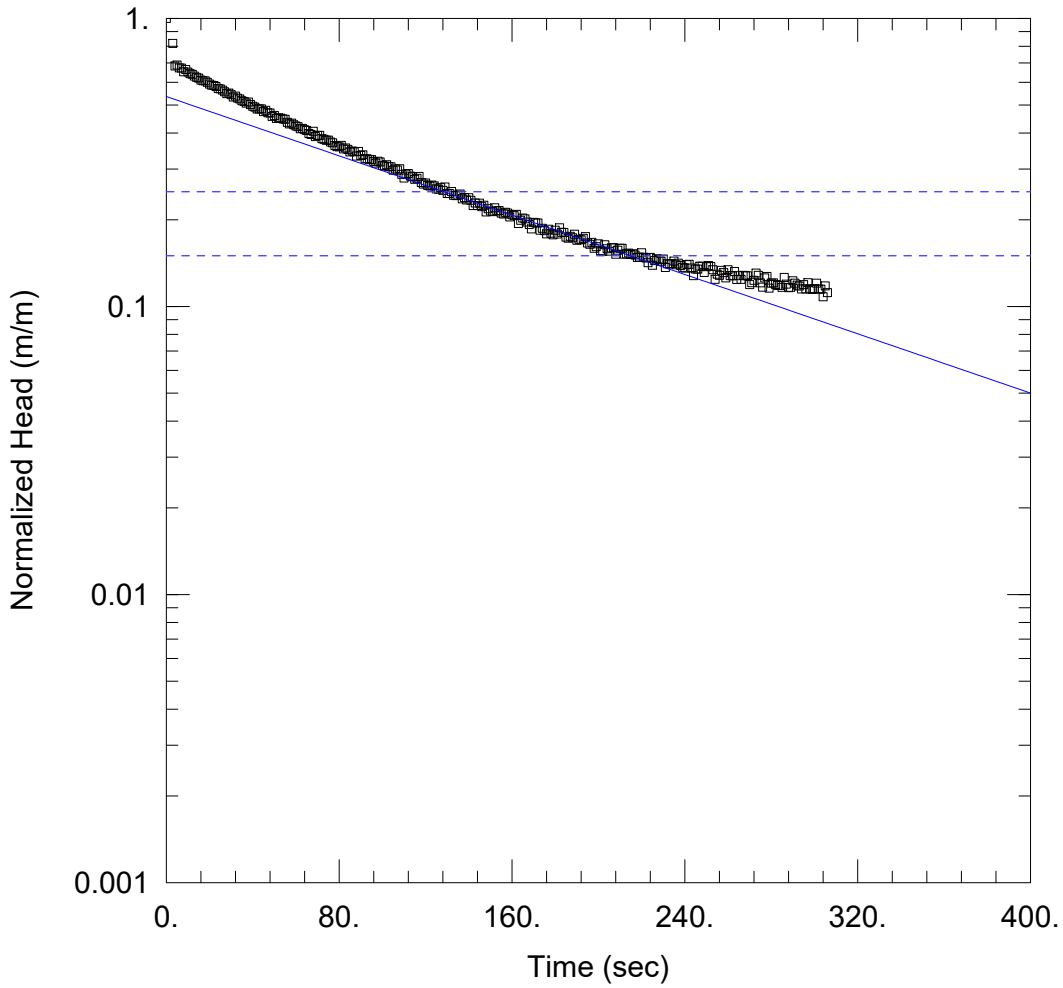
Saturated Thickness: 0.49 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GH03)

Initial Displacement: 0.425 m
Total Well Penetration Depth: 0.45 m
Casing Radius: 0.02 m
Static Water Column Height: 0.49 m
Screen Length: 0.35 m
Well Radius: 0.04 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev
K = 0.5954 m/day
y0 = 0.2107 m



GH03 RISING HEAD TEST #2

Data Set: C:\...\Rising head 2.aqt
Date: 02/11/19 Time: 11:56:08

PROJECT INFORMATION

Company: EMM Consulting
Project: J17188
Location: Gallandra Hill
Test Well: GH03
Test Date: 5/02/2019

AQUIFER DATA

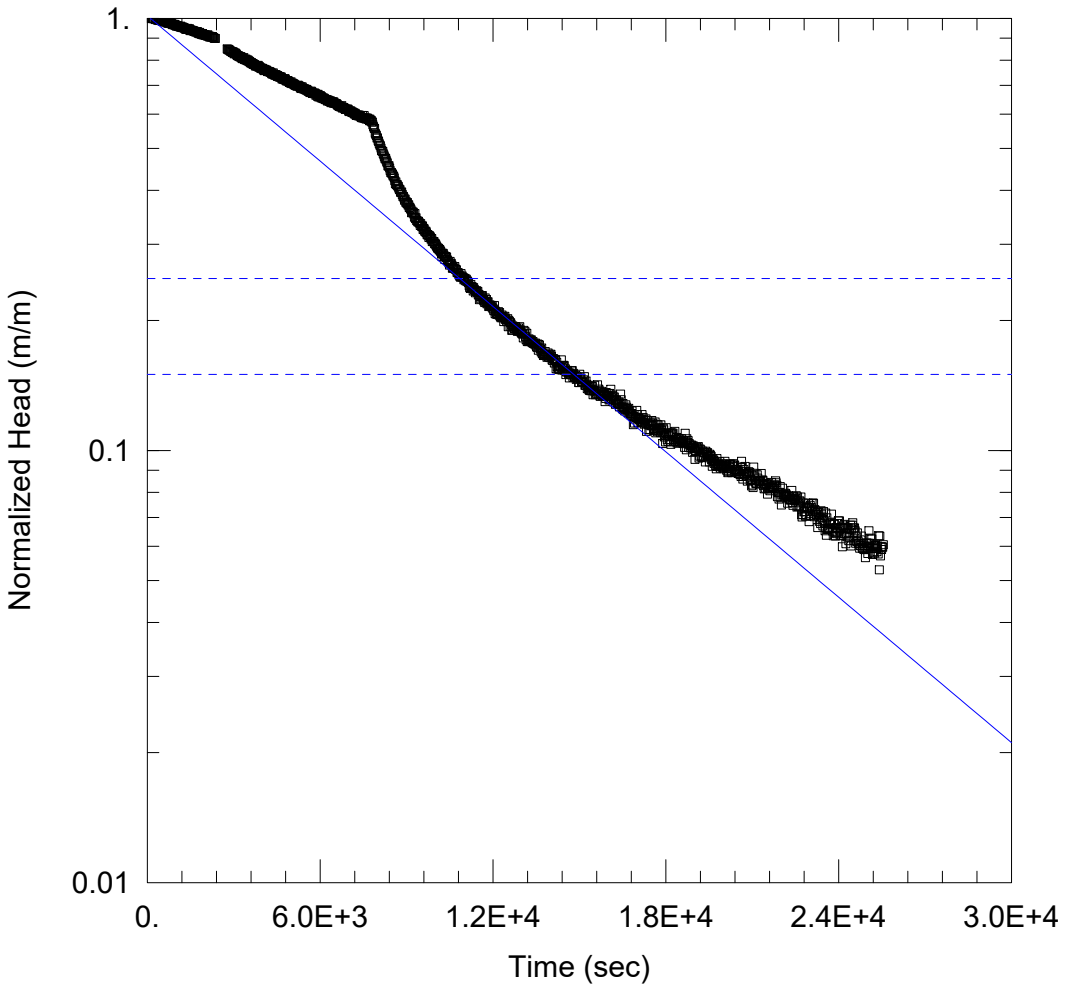
Saturated Thickness: 0.49 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (GH03)

Initial Displacement: 0.425 m
Total Well Penetration Depth: 0.45 m
Casing Radius: 0.02 m
Static Water Column Height: 0.49 m
Screen Length: 0.35 m
Well Radius: 0.04 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev
K = 0.6383 m/day
y0 = 0.2275 m



TC01 RISING HEAD SLUG TEST

Data Set: C:\...\TC01_Rising head.aqt
Date: 02/11/19 Time: 12:39:13

PROJECT INFORMATION

Company: EMM Consulting
Project: J17188
Location: Tantangara Creek
Test Well: TC01
Test Date: 6/02/2019

AQUIFER DATA

Saturated Thickness: 0.82 m Anisotropy Ratio (Kz/Kr): 1.

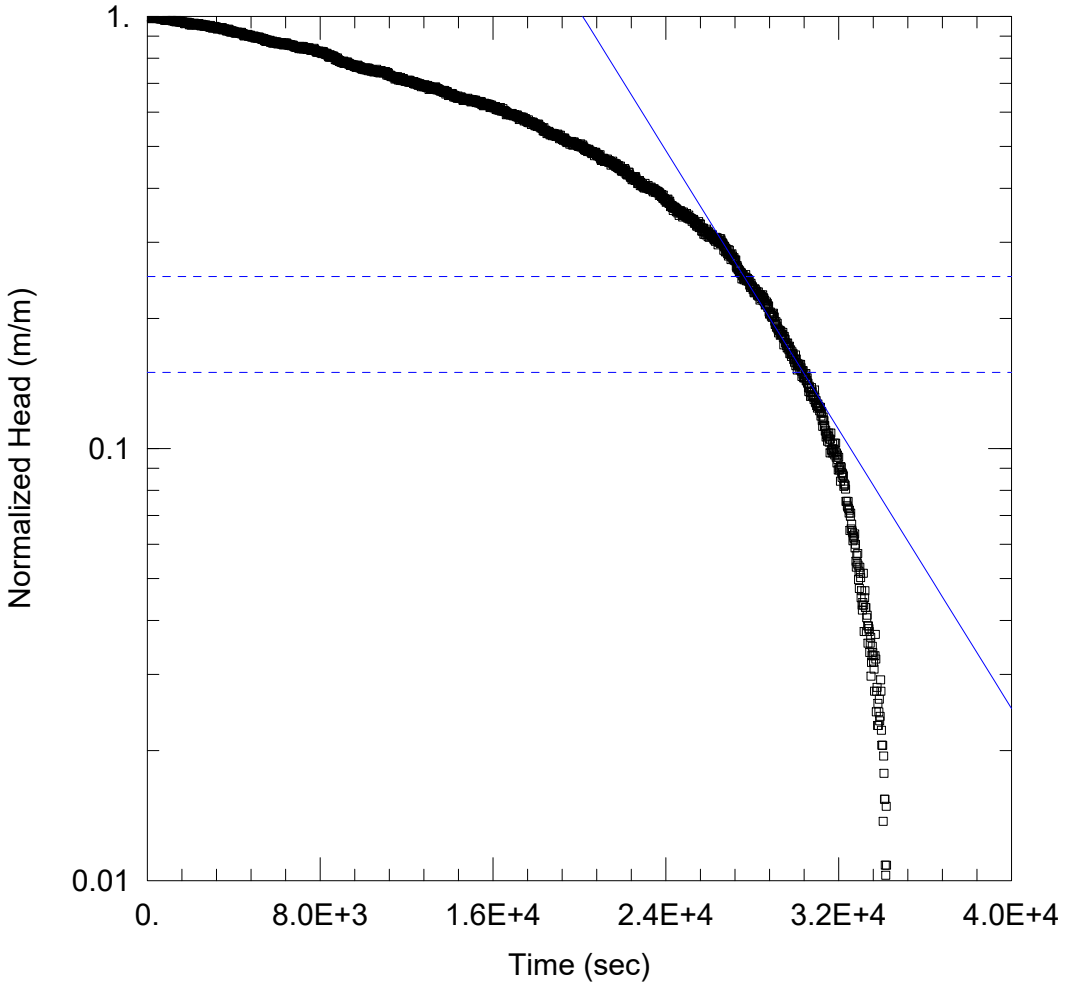
WELL DATA (TC01)

Initial Displacement: 0.71 m
Total Well Penetration Depth: 0.82 m
Casing Radius: 0.02 m
Static Water Column Height: 0.82 m
Screen Length: 0.6 m
Well Radius: 0.04 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 0.01265 m/day y0 = 0.72 m



TC02 RISING HEAD SLUG TEST

Data Set: C:\...\TC02_Rising head.aqt
Date: 02/11/19 Time: 12:40:00

PROJECT INFORMATION

Company: EMM Consulting
Project: J17188
Test Well: TC02
Test Date: 6/02/2019

AQUIFER DATA

Saturated Thickness: 0.93 m Anisotropy Ratio (Kz/Kr): 1.

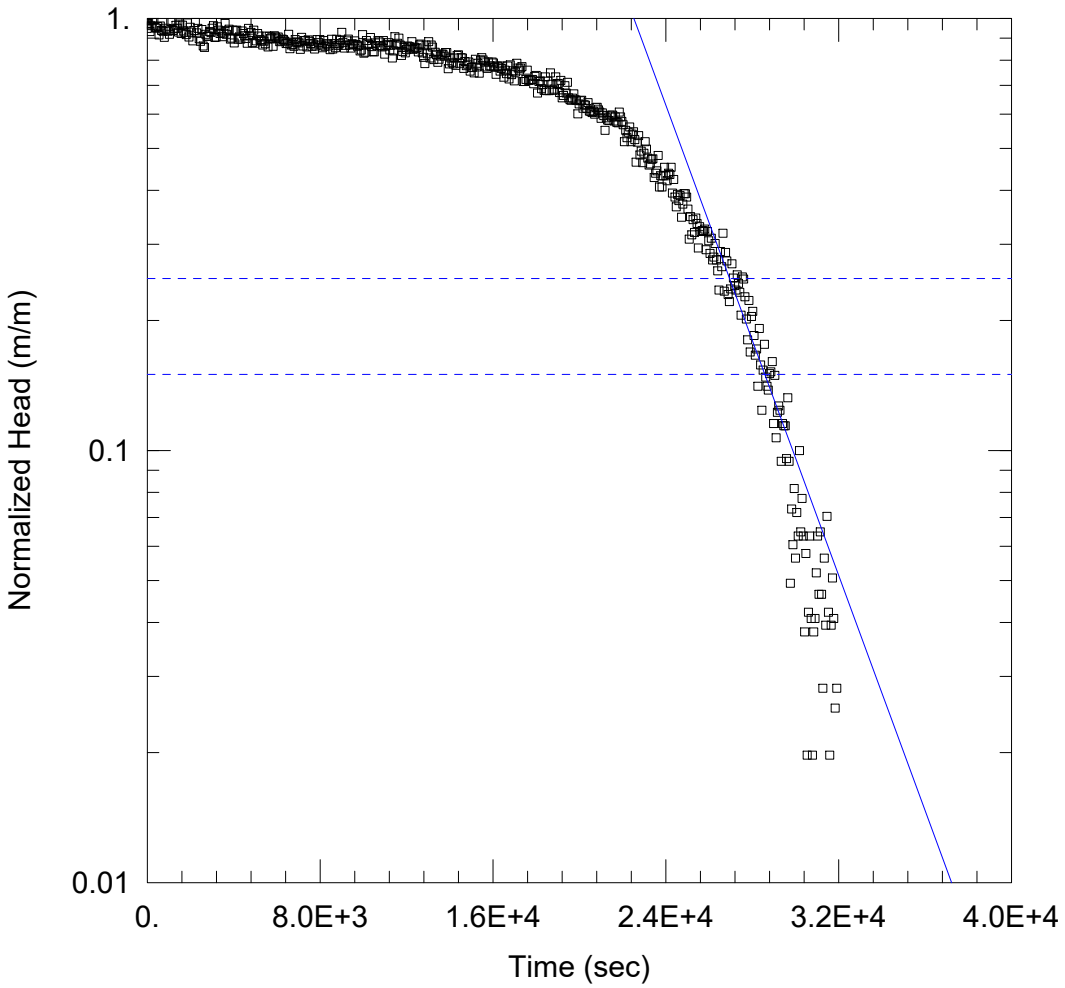
WELL DATA (TC02)

Initial Displacement: 0.175 m
Total Well Penetration Depth: 0.75 m
Casing Radius: 0.02 m
Static Water Column Height: 0.93 m
Screen Length: 0.6 m
Well Radius: 0.04 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 0.01452 m/day y0 = 7.401 m



TC03 RISING HEAD TEST

Data Set: C:\...\TC03_Rising head.aqt
Date: 02/11/19 Time: 12:40:56

PROJECT INFORMATION

Company: EMM Consulting
Project: J17188
Location: Tantangara Creek
Test Well: TC03
Test Date: 6/02/2019

AQUIFER DATA

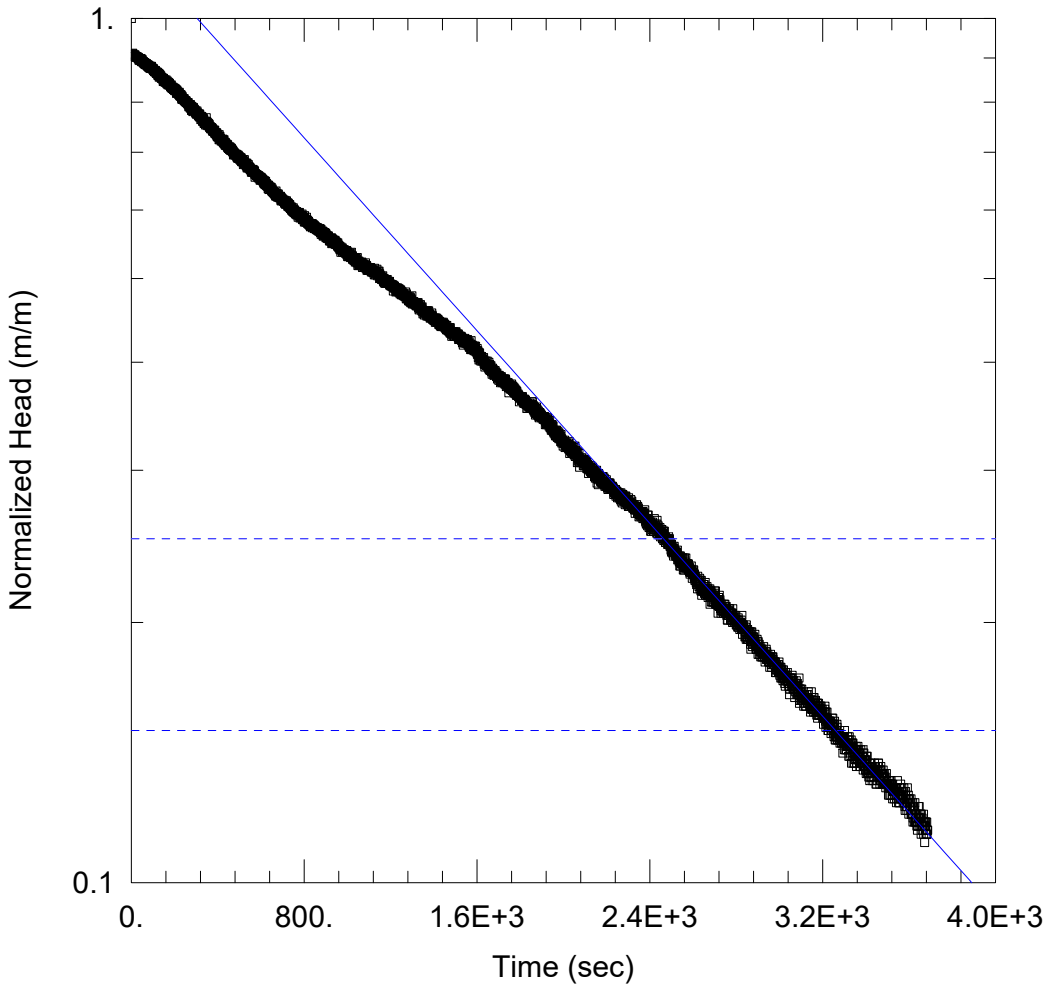
Saturated Thickness: 0.72 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (TC03)

Initial Displacement: 0.071 m Static Water Column Height: 0.72 m
Total Well Penetration Depth: 0.92 m Screen Length: 0.5 m
Casing Radius: 0.02 m Well Radius: 0.04 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev
K = 0.03486 m/day y0 = 82.22 m



BH01 RISING HEAD TEST

Data Set: C:\...\BH01_Rising Head.aqt
Date: 02/11/19 Time: 12:37:18

PROJECT INFORMATION

Company: EMM Consulting
Project: J17188
Location: Bullocks Hill
Test Well: BH01
Test Date: 6/02/2019

AQUIFER DATA

Saturated Thickness: 0.21 m Anisotropy Ratio (Kz/Kr): 1.

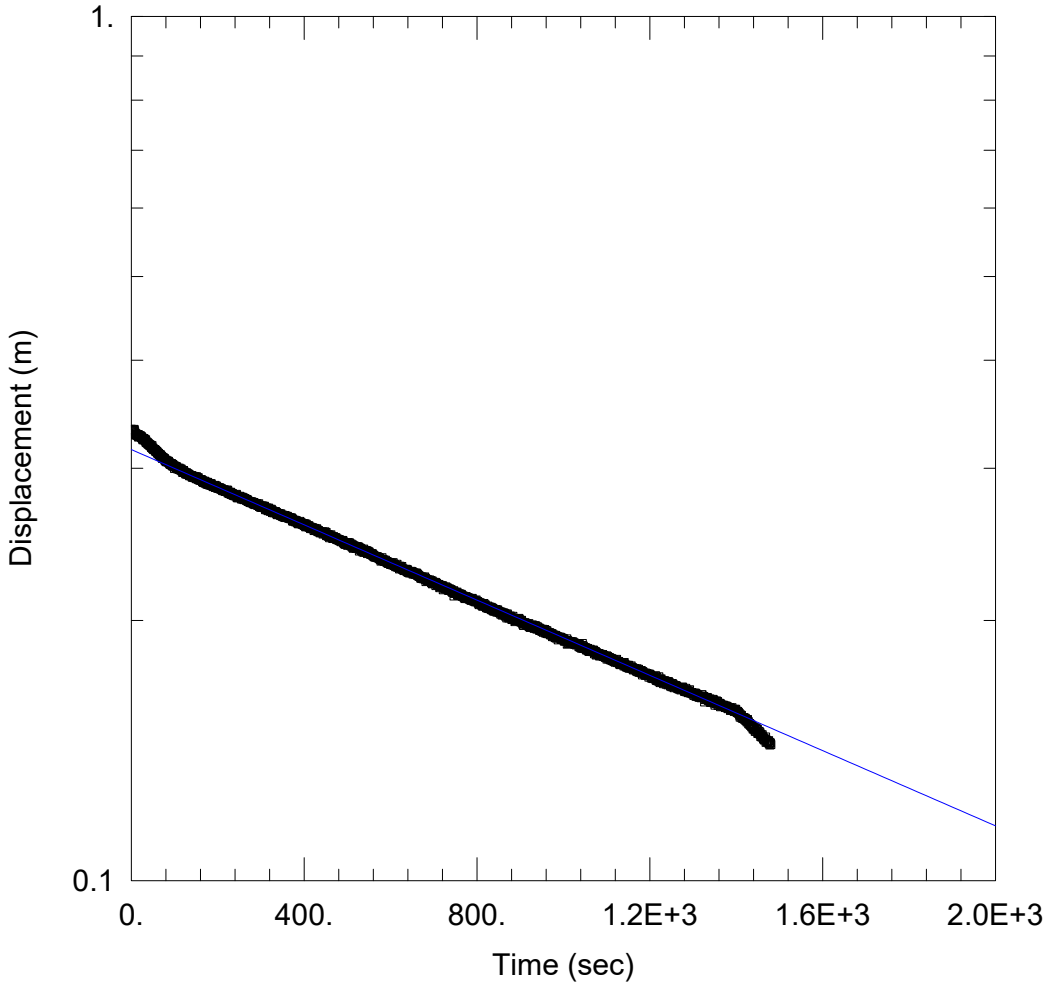
WELL DATA (BH01)

Initial Displacement: 0.08 m
Total Well Penetration Depth: 0.22 m
Casing Radius: 0.02 m
Static Water Column Height: 0.21 m
Screen Length: 0.2 m
Well Radius: 0.04 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev

K = 0.1283 m/day y0 = 0.09728 m



BH03 RISING HEAD TEST

Data Set: C:\...\BH03_Rising Head.aqt
Date: 02/11/19 Time: 12:38:07

PROJECT INFORMATION

Company: EMM Consulting
Project: J17188
Test Well: BH03
Test Date: 6/02/2019

AQUIFER DATA

Saturated Thickness: 0.59 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH03)

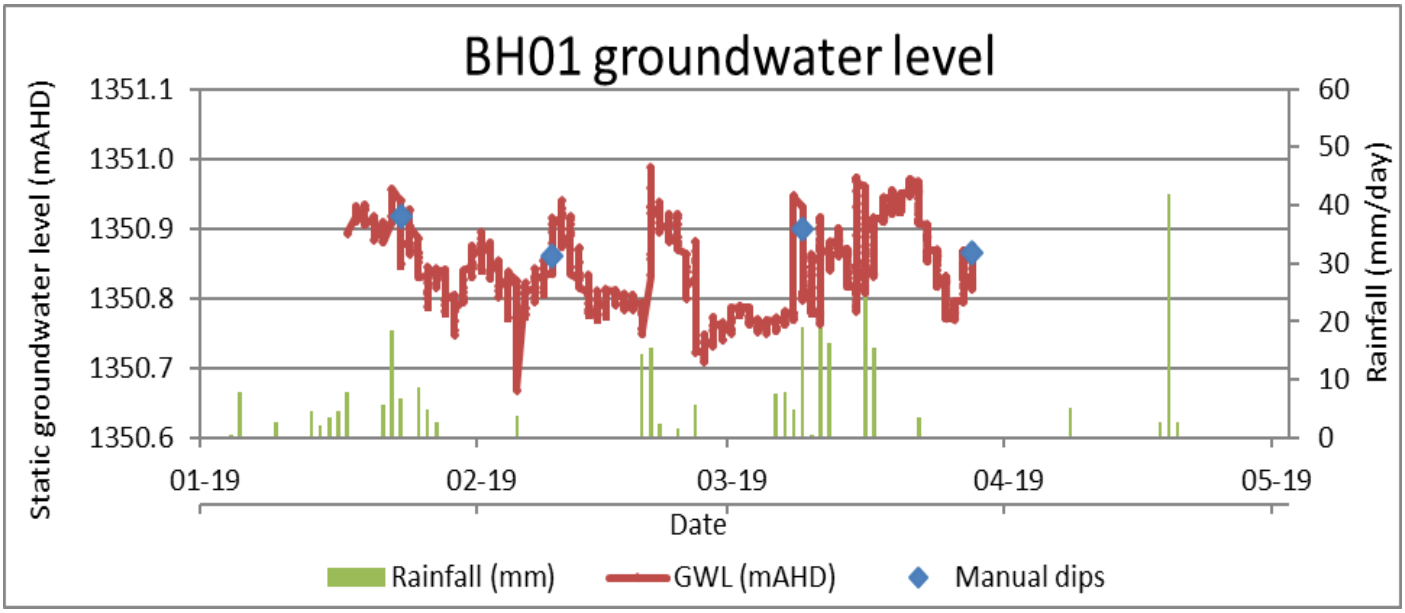
Initial Displacement: 0.33 m Static Water Column Height: 0.59 m
Total Well Penetration Depth: 0.59 m Screen Length: 0.2 m
Casing Radius: 0.02 m Well Radius: 0.04 m

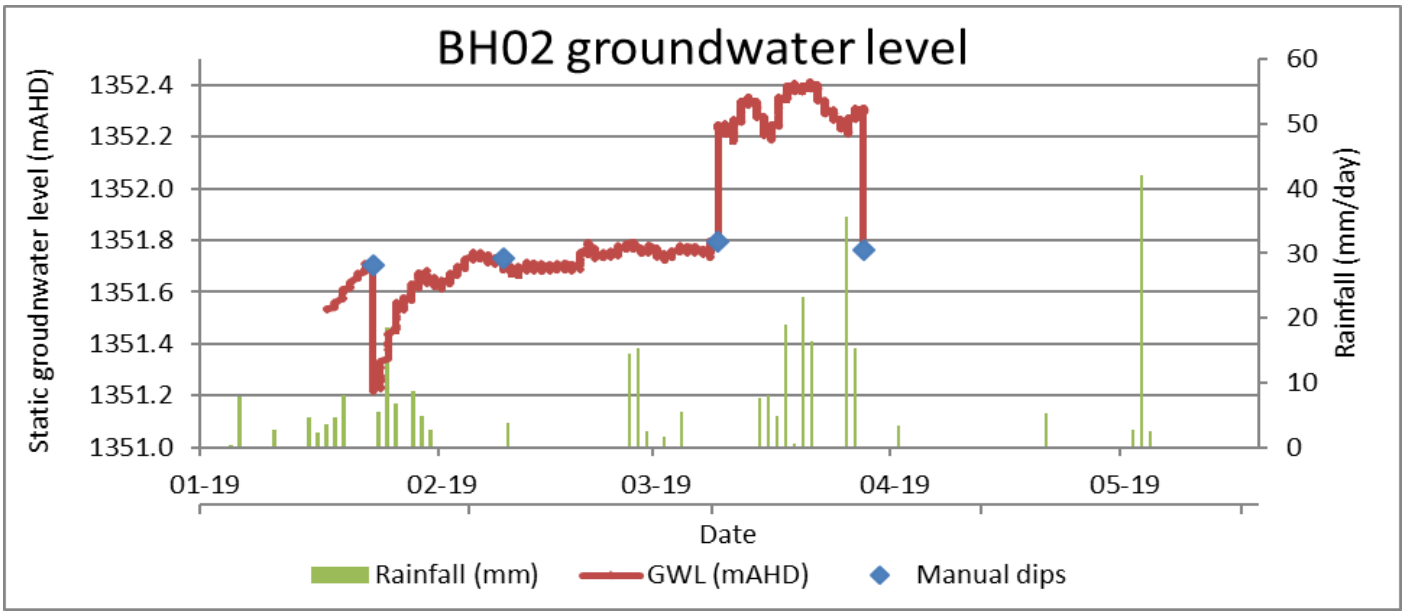
SOLUTION

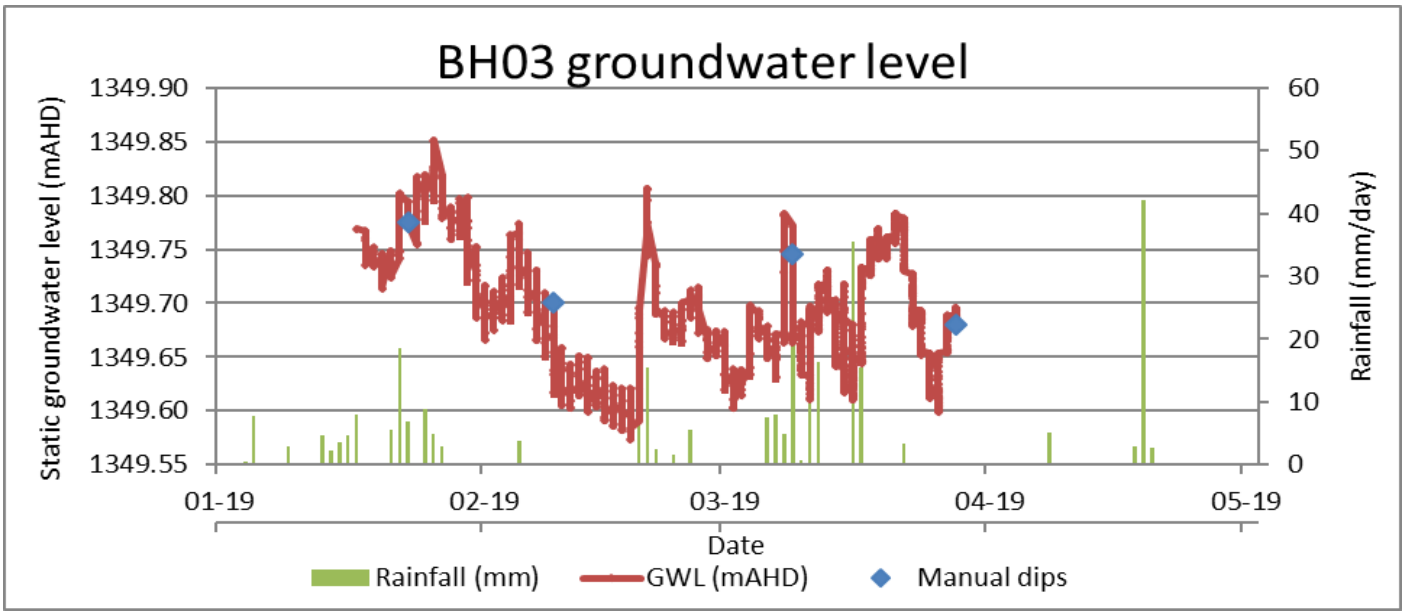
Aquifer Model: Unconfined Solution Method: Hvorslev
K = 0.1001 m/day y0 = 0.3153 m

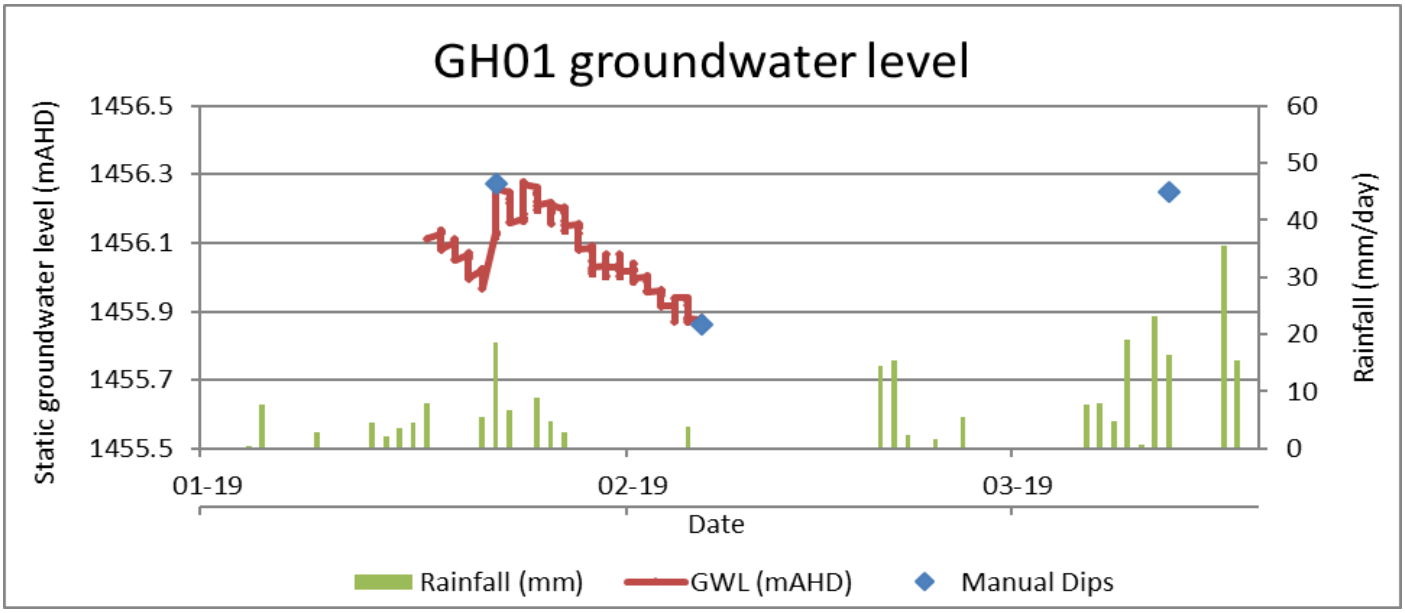
Appendix C

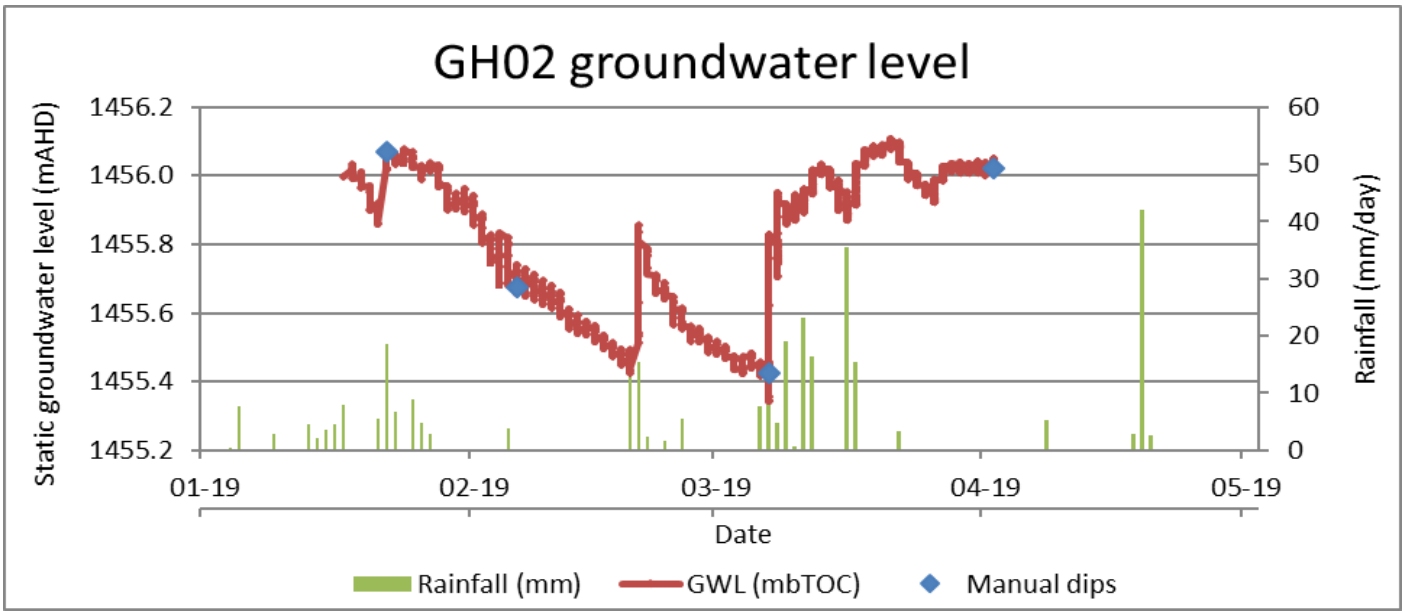
Hydrographs

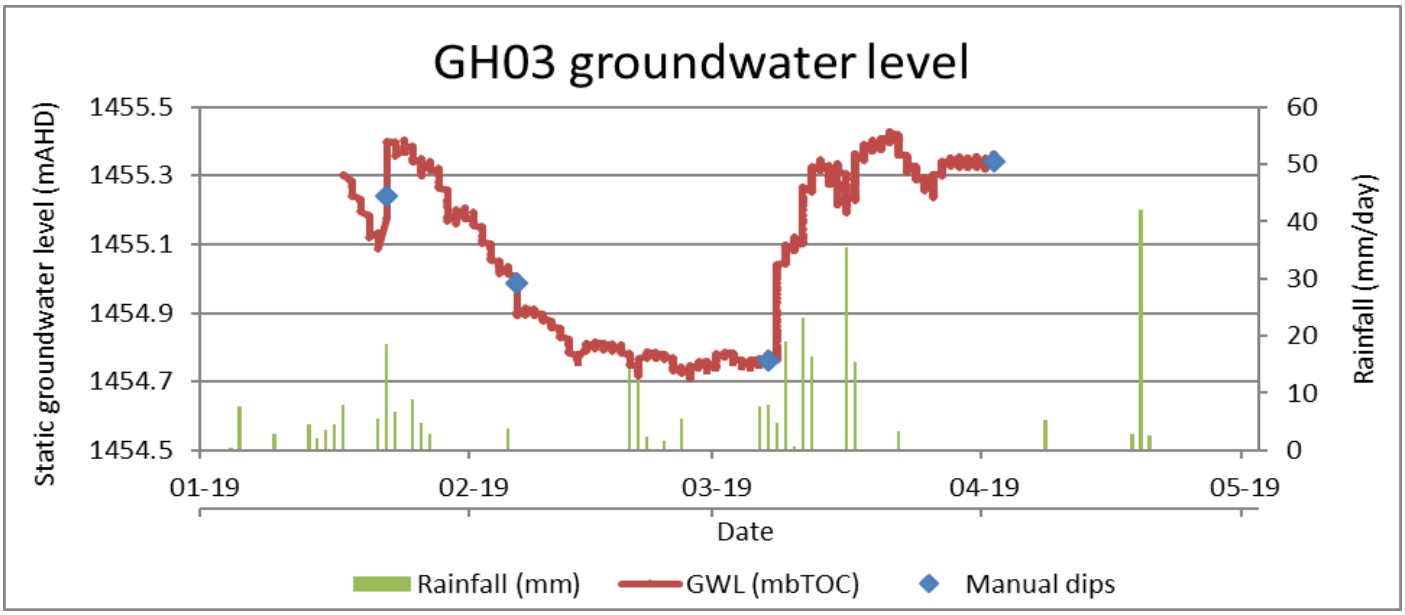

BH01 groundwater level
Static groundwater level (mAHD)
1351.1
1351.0
1350.9
1350.8
1350.7
1350.6
Rainfall (mm/day)
60
50
40
30
20
10
0
01-19
02-19
03-19
04-19
05-19
Date
Rainfall (mm)
GWL (mAHD)
Manual dips

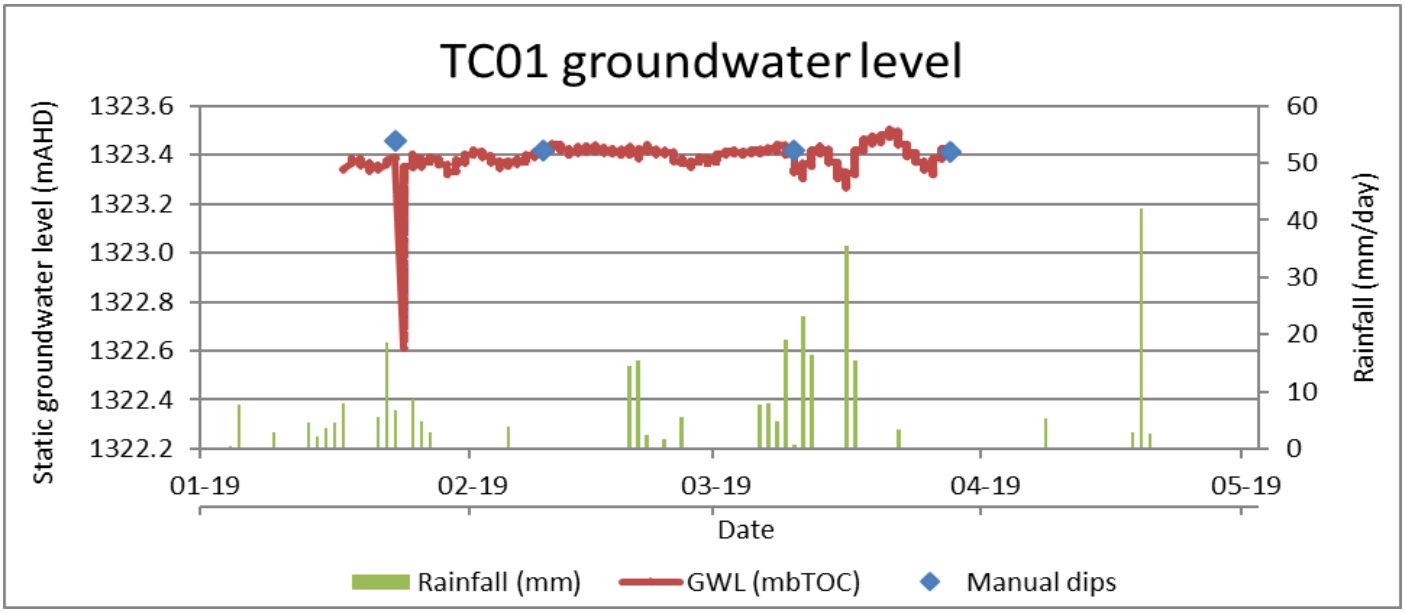

BH02 groundwater level
Static groudnwater level (mAHD)
1352.4
1352.2
1352.0
1351.8
1351.6
1351.4
1351.2
1351.0
Rainfall (mm/day)
60
50
40
30
20
10
0
01-19
02-19
03-19
04-19
05-19
Date
Rainfall (mm)
GWL (mAHD)
Manual dips

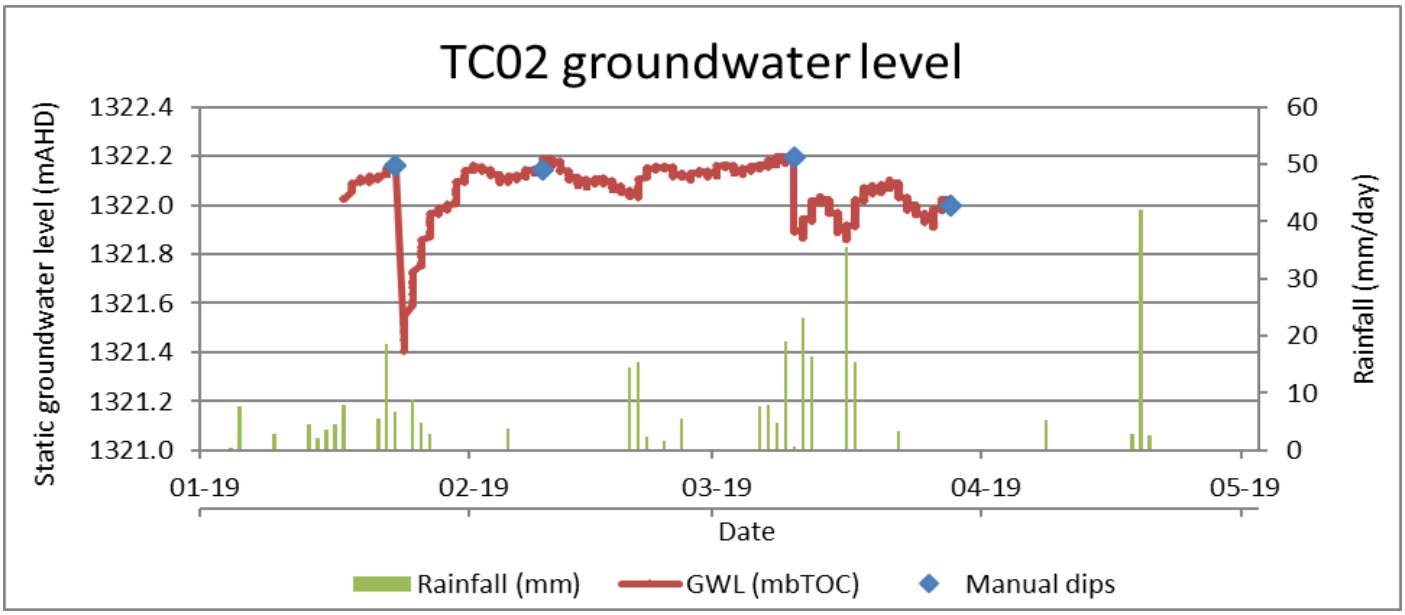

BH03 groundwater level
Static groundwater level (mAHD)
1349.90
1349.85
1349.80
1349.75
1349.70
1349.65
1349.60
1349.55
Rainfall (mm/day)
60
50
40
30
20
10
0
01-19
02-19
03-19
04-19
05-19
Date
Rainfall (mm)
GWL (mAHD)
Manual dips

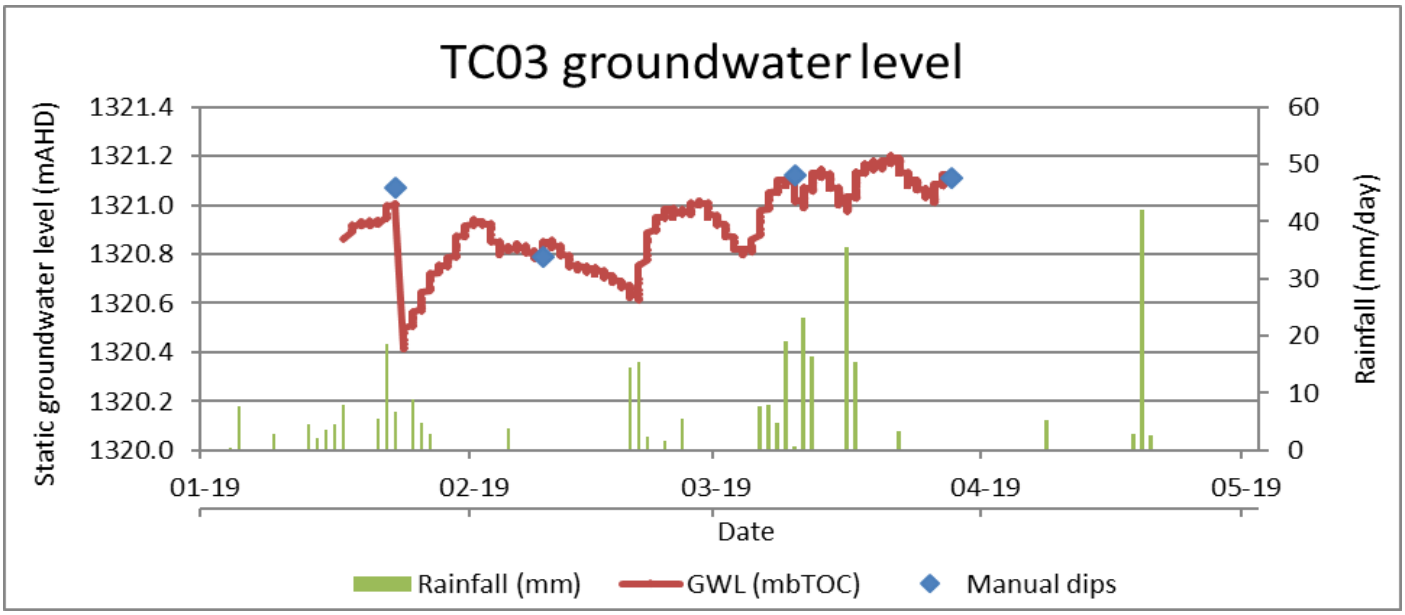

GH01 groundwater level
Static groundwater level (mAHD)
1456.5
1456.3
1456.1
1455.9
1455.7
1455.5
Rainfall (mm/day)
60
50
40
30
20
10
0
01-19
02-19
03-19
Date
Rainfall (mm)
GWL (mAHD)
Manual Dips

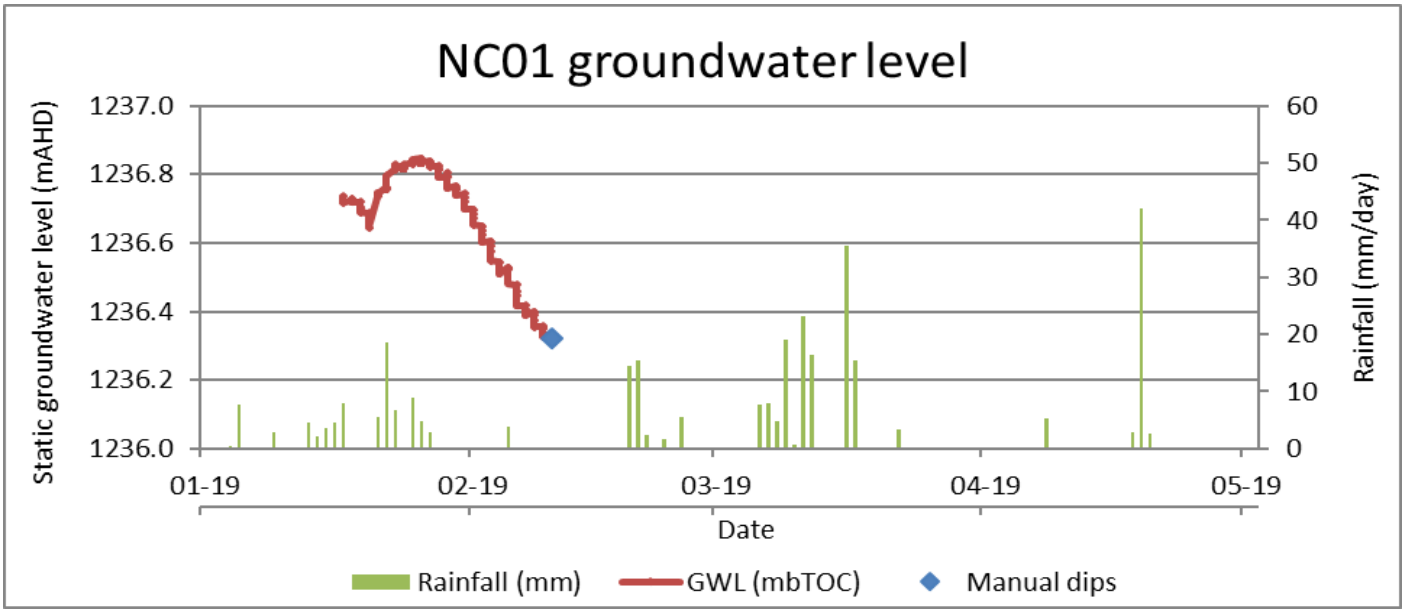

GH02 groundwater level
Static groundwater level (mAHD)
1456.2
1456.0
1455.8
1455.6
1455.4
1455.2
Rainfall (mm/day)
60
50
40
30
20
10
0
01-19
02-19
03-19
04-19
05-19
Date
Rainfall (mm)
GWL (mbTOC)
Manual dips

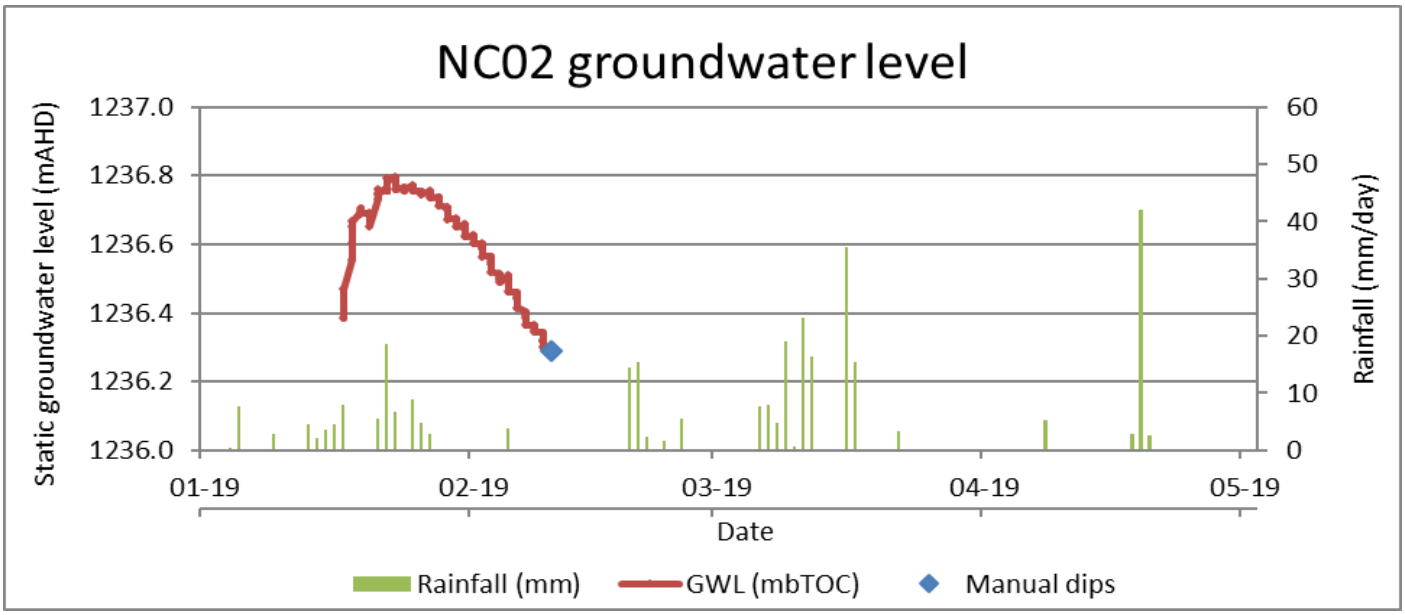

GH03 groundwater level
Static groundwater level (mAHD)
1455.5
1455.3
1455.1
1454.9
1454.7
1454.5
Rainfall (mm/day)
60
50
40
30
20
10
0
01-19
02-19
03-19
04-19
05-19
Date
Rainfall (mm)
GWL (mbTOC)
Manual dips

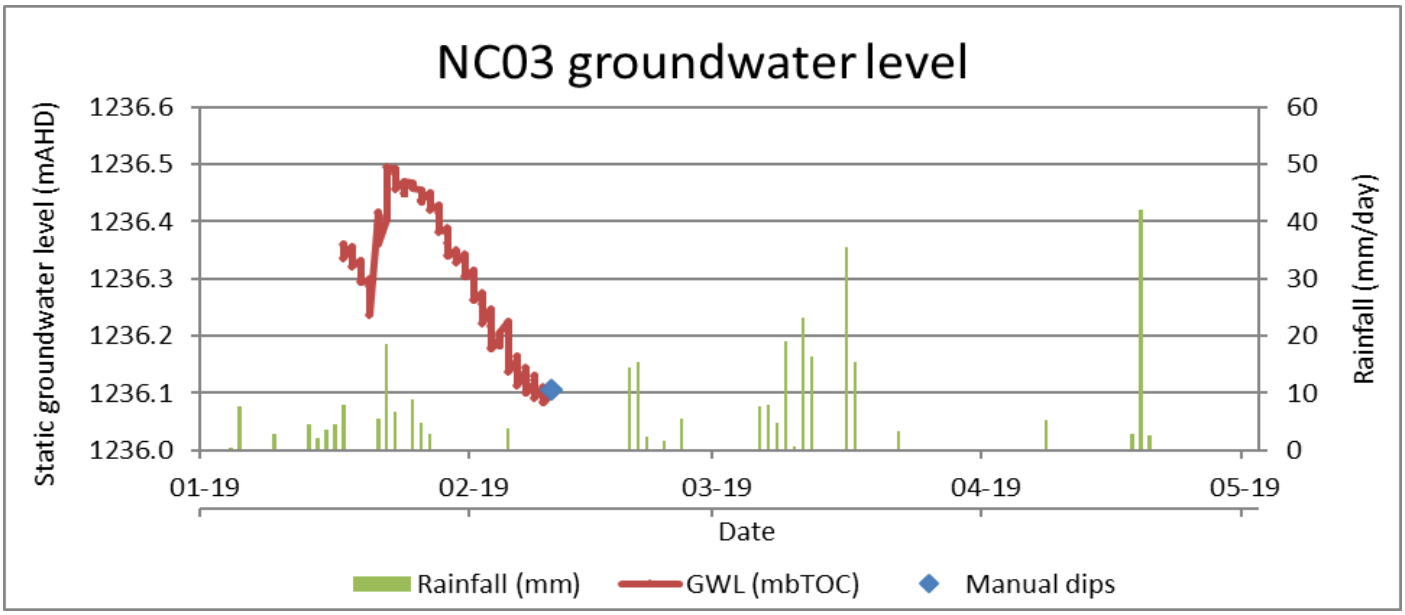

TC01 groundwater level
Static groundwater level (mAHD)
1323.6
1323.4
1323.2
1323.0
1322.8
1322.6
1322.4
1322.2
Rainfall (mm/day)
60
50
40
30
20
10
0
01-19
02-19
03-19
04-19
05-19
Date
Rainfall (mm)
GWL (mbTOC)
Manual dips


TC02 groundwater level
Static groundwater level (mAHD)
1322.4
1322.2
1322.0
1321.8
1321.6
1321.4
1321.2
1321.0
Rainfall (mm/day)
60
50
40
30
20
10
0
01-19
02-19
03-19
04-19
05-19
Date
Rainfall (mm)
GWL (mbTOC)
Manual dips


TC03 groundwater level
Static groundwater level (mAHD)
1321.4
1321.2
1321.0
1320.8
1320.6
1320.4
1320.2
1320.0
Rainfall (mm/day)
60
50
40
30
20
10
0
01-19
02-19
03-19
04-19
05-19
Date
Rainfall (mm)
GWL (mbTOC)
Manual dips


NC01 groundwater level
Static groundwater level (mAHD)
1237.0
1236.8
1236.6
1236.4
1236.2
1236.0
Rainfall (mm/day)
60
50
40
30
20
10
0
01-19
02-19
03-19
04-19
05-19
Date
Rainfall (mm)
GWL (mbTOC)
Manual dips


NC02 groundwater level
Static groundwater level (mAHD)
1237.0
1236.8
1236.6
1236.4
1236.2
1236.0
Rainfall (mm/day)
60
50
40
30
20
10
0
01-19
02-19
03-19
04-19
05-19
Date
Rainfall (mm)
GWL (mbTOC)
Manual dips


NC03 groundwater level
Static groundwater level (mAHD)
1236.6
1236.5
1236.4
1236.3
1236.2
1236.1
1236.0
Rainfall (mm/day)
60
50
40
30
20
10
0
01-19
02-19
03-19
04-19
05-19
Date
Rainfall (mm)
GWL (mbTOC)
Manual dips

Appendix D

Laboratory certificate of analysis

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ES1904009**	Page	: 1 of 6
Client	: **EMM CONSULTING PTY LTD**	Laboratory	: Environmental Division Sydney
Contact	: MR JASON O'BRIEN	Contact	: Customer Services ES
Address	: Ground Floor Suite 1 20 Chandos Street St Leonards NSW NSW 2065	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: J17188	Date Samples Received	: 08-Feb-2019 09:00
Order number	:	Date Analysis Commenced	: 08-Feb-2019
C-O-C number	: ----	Issue Date	: 18-Feb-2019 15:38
Sampler	: Bill Bull, Kaitlyn Brodie		
Site	: ----		
Quote number	: SY/068/18 V2		
No. of samples received	: 10		
No. of samples analysed	: 10		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Celine Conceicao	Senior Spectroscopist	Sydney Inorganics, Smithfield, NSW
Dian Dao		Sydney Inorganics, Smithfield, NSW
Ivan Taylor	Analyst	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EK 040P: LOR raised for Fluoride sample 5 due to sample matrix.
- EK026SF : LOR raised for Total CN samples5,8,9 due to sample matrix.
- EG020/ED093: LOR's have been raised for some samples due to matrix interference (Hard to Filter).
- EG035: ES1904009# 5 and #9 were run (X10) for Hg due to high sediment sample and LOR's have been raised accordingly
- EN055: Ionic balance invalidated for sample 5 due to no valid Alkalinity result.
- TDS by method EA-015 may bias high for various samples due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.
- EN055: It has been noted that DOC is greater than TOC for sample 1, however this difference is within the limits of experimental variation.
- EN055: Ionic Balance out of acceptable limits for various samples due to analytes not quantified in this report.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	CM-D2	GH01	GH02	GH03	BH02
			Client sampling date / time	05-Feb-2019 10:00	05-Feb-2019 14:30	05-Feb-2019 14:00	05-Feb-2019 12:15	06-Feb-2019 14:00
Compound	CAS Number	LOR	Unit	ES1904009-001	ES1904009-002	ES1904009-003	ES1904009-004	ES1904009-005
				Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	**446**	----	----	**382**	----
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	----	5	mg/L	<5	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	----	<1	<1	<1	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	----	<1	<1	<1	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	----	**12**	**11**	**31**	----
Total Alkalinity as CaCO3	----	1	mg/L	----	**12**	**11**	**31**	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	----	**1**	**3**	**17**	**12**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	----	<1	<1	**2**	**6**
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	----	**2**	**2**	**8**	**2**
Magnesium	7439-95-4	1	mg/L	----	<1	<1	**2**	<1
Sodium	7440-23-5	1	mg/L	----	**3**	**2**	**9**	**20**
Potassium	7440-09-7	1	mg/L	----	<1	<1	<1	**2**
ED093F: SAR and Hardness Calculations								
Total Hardness as CaCO3	----	1	mg/L	**59**	**5**	**5**	**28**	<10
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.01**	**0.02**	**0.05**	**0.12**	**8.63**
Arsenic	7440-38-2	0.001	mg/L	**0.002**	<0.001	<0.001	<0.001	<0.010
Boron	7440-42-8	0.05	mg/L	**0.62**	<0.05	<0.05	<0.05	**0.93**
Barium	7440-39-3	0.001	mg/L	**0.149**	**0.014**	**0.012**	**0.017**	**1.37**
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.010
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0010
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	**0.002**	**0.002**	<0.010
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.010
Copper	7440-50-8	0.001	mg/L	**0.009**	<0.001	<0.001	<0.001	<0.010
Manganese	7439-96-5	0.001	mg/L	**0.029**	**0.008**	**0.045**	**0.084**	**0.021**
Nickel	7440-02-0	0.001	mg/L	<0.001	<0.001	<0.001	**0.002**	<0.010
Lead	7439-92-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.010
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.10
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.10

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	CM-D2	GH01	GH02	GH03	BH02
				Client sampling date / time	05-Feb-2019 10:00	05-Feb-2019 14:30	05-Feb-2019 14:00	05-Feb-2019 12:15	06-Feb-2019 14:00
Compound	CAS Number	LOR	Unit		ES1904009-001	ES1904009-002	ES1904009-003	ES1904009-004	ES1904009-005
					Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued									
Zinc	7440-66-6	0.005	mg/L		**0.114**	**0.016**	**0.009**	**0.016**	**0.479**
Silver	7440-22-4	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.010
Iron	7439-89-6	0.05	mg/L		**0.11**	**0.23**	**2.36**	**2.41**	**1.74**
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0010
EK026SF: Total CN by Segmented Flow Analyser									
Total Cyanide	57-12-5	0.004	mg/L		<0.004	<0.004	<0.004	<0.004	<0.160
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**----**	<0.1	<0.1	<0.1	<1.0
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		**0.03**	**0.02**	**0.04**	**0.07**	**0.24**
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N	14797-65-0	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	**0.03**
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N	14797-55-8	0.01	mg/L		**0.08**	**0.01**	<0.01	**0.05**	**0.30**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		**0.08**	**0.01**	<0.01	**0.05**	**0.33**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	**0.5**	**3.7**	**4.7**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		<0.1	<0.1	**0.5**	**3.8**	**5.0**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.06**	**0.09**	**1.11**	**2.34**	**2.62**
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		**0.02**	<0.01	<0.01	<0.01	**0.01**
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**----**	**0.26**	**0.28**	**1.03**	**----**
Total Cations	----	0.01	meq/L		**----**	**0.23**	**0.19**	**0.96**	**----**
EP002: Dissolved Organic Carbon (DOC)									
Dissolved Organic Carbon	----	1	mg/L		**5**	**----**	**----**	**----**	**----**
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		**4**	**2**	**16**	**14**	**68**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	BH03	TC01	TC02	TC03	QA1
				Client sampling date / time	06-Feb-2019 12:30	06-Feb-2019 09:00	06-Feb-2019 09:30	06-Feb-2019 11:00	06-Feb-2019 00:00
Compound	CAS Number	LOR	Unit		ES1904009-006	ES1904009-007	ES1904009-008	ES1904009-009	ES1904009-010
					Result	Result	Result	Result	Result
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		----	186	----	----	406
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		73	101	20	33	36
Total Alkalinity as CaCO3	----	1	mg/L		73	101	20	33	36
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		31	36	5	4	17
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		4	3	5	5	3
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		8	26	1	1	5
Magnesium	7439-95-4	1	mg/L		2	6	<1	<1	2
Sodium	7440-23-5	1	mg/L		28	17	4	5	19
Potassium	7440-09-7	1	mg/L		<1	<1	<1	<1	1
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		28	90	2	2	21
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		0.30	<0.01	0.17	5.94	1.18
Arsenic	7440-38-2	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Boron	7440-42-8	0.05	mg/L		<0.05	<0.05	<0.05	<0.05	<0.05
Barium	7440-39-3	0.001	mg/L		0.016	0.083	0.022	0.015	0.012
Beryllium	7440-41-7	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	7440-48-4	0.001	mg/L		<0.001	0.003	<0.001	<0.001	<0.001
Chromium	7440-47-3	0.001	mg/L		0.001	<0.001	<0.001	0.003	0.002
Copper	7440-50-8	0.001	mg/L		0.002	<0.001	0.001	0.004	0.002
Manganese	7439-96-5	0.001	mg/L		0.034	0.399	0.044	0.013	0.021
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	0.002	0.001
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Selenium	7782-49-2	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	7440-62-2	0.01	mg/L		0.02	<0.01	<0.01	<0.01	0.01
Zinc	7440-66-6	0.005	mg/L		0.008	<0.005	<0.005	<0.005	<0.005
Silver	7440-22-4	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	BH03	TC01	TC02	TC03	QA1
				Client sampling date / time	06-Feb-2019 12:30	06-Feb-2019 09:00	06-Feb-2019 09:30	06-Feb-2019 11:00	06-Feb-2019 00:00
Compound	CAS Number	LOR	Unit		ES1904009-006	ES1904009-007	ES1904009-008	ES1904009-009	ES1904009-010
					Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued									
Iron	7439-89-6	0.05	mg/L		**0.33**	<0.05	**0.29**	**1.16**	**0.27**
EG035F: Dissolved Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0010	<0.0001
EK026SF: Total CN by Segmented Flow Analyser									
Total Cyanide	57-12-5	0.004	mg/L		<0.004	<0.004	<0.400	<0.400	<0.004
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		<0.1	<0.1	<0.1	<0.1	<0.1
EK055G: Ammonia as N by Discrete Analyser									
Ammonia as N	7664-41-7	0.01	mg/L		**0.14**	**0.08**	**0.54**	**0.40**	**0.13**
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N	14797-65-0	0.01	mg/L		**0.01**	**0.03**	<0.01	<0.01	<0.01
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N	14797-55-8	0.01	mg/L		**0.16**	**0.03**	**0.01**	**0.08**	**3.04**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		**0.17**	**0.06**	**0.01**	**0.08**	**3.04**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**3.9**	**1.6**	**421**	**8.8**	**8.4**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		**4.1**	**1.7**	**421**	**8.9**	**11.4**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.73**	**0.30**	**74.2**	**3.36**	**1.35**
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		<0.01	<0.01	**0.02**	**0.01**	<0.01
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**2.22**	**2.85**	**0.64**	**0.88**	**1.16**
Total Cations	----	0.01	meq/L		**1.78**	**2.53**	**0.22**	**0.27**	**1.27**
EP005: Total Organic Carbon (TOC)									
Total Organic Carbon	----	1	mg/L		**11**	**6**	**7**	**5**	**14**