Hydrogeological Study

Estimation of Groundwater Inflow to the Proposed 788 March Road Development

Kanata, Ontario

Revision: 0 (Final)

Prepared for:

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February 29, 2024

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1 INTRODUCTION

Geofirma Engineering Ltd. (Geofirma) was retained by SINA to complete a hydrogeological study at 788 March Road, Kanata, Ontario (the site). The study was completed to collect additional hydrogeological data which was used to estimate potential groundwater inflows into a proposed excavation at the site.

1.1 Background

SINA, the current owner of the property, is planning to construct a mid-rise residential tower at the site. The proposed construction will require excavation of material to install the building foundation and an underground parking garage. Based on correspondence with SINA, the excavation is expected to be completed to 69.97 metres above sea level (m ASL) for the footings and 70.97 m ASL for below the floor slab.

A geotechnical study completed by Geofirma for the previous site owner in 2018 (Geofirma 2020) showed that the subsurface of the site consists of approximately 5-6 m of unconsolidated overburden, underlain by fractured bedrock. Available borehole logs (Geofirma 2020) and regional mapping by the Ontario Geological Survey (OGS 2010) indicate that the sediments at the site are composed of fine-grained glaciomarine sediments (clay and silt) and till. Coring completed by Geofirma in 2018 indicates that the shallow bedrock is comprised of fractured dolostone and sandstone (Geofirma 2020) that are interpreted to be part of the March Formation (OGS 2011).

Monitoring wells installed at the site in 2018 showed water levels in the bedrock and overlying sediments that were between 73.2-73.5 metres above sea level (mASL). Slug tests completed by Geofirma (Geofirma, 2020) provide hydraulic conductivity (K_H) estimates of $4x10^{-7}$ m/s for the shallow sediments and $2x10^{-5}$ m/s for the underlying bedrock.

Based on available site information, the excavation is expected to be completed into or near the top of bedrock, with the base of the excavation below the water table. Since the base of the excavation will be below the water table, groundwater inflows are expected. SINA requested that Geofirma provide an estimate of groundwater inflows, however insufficient hydrogeological data was available at the time to accurately estimate inflows. The most notable data gap from the previous study was a rigorous assessment of water levels at the site and the hydraulic conductivity of the bedrock unit which is expected to contribute most of the groundwater inflow to the proposed excavation.

1.2 Study Objectives

The primary objectives of this study were the following:

1. To drill, survey, and test monitoring wells at the site to obtain additional hydrogeological data, including notable static water levels and estimates of hydraulic conductivity of the bedrock.

2. To estimate inflows to the proposed excavation from the bedrock and overlying sediments.

3. To determine the sensitivity of the estimated groundwater inflow rates to uncertainty of key hydrogeological properties (hydraulic conductivity, anisotropy, etc.)

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Figure 1 Site Layout

2 STUDY METHODOLOGY AND RESULTS

Since hydraulic testing and stratigraphic logs from previous work at the site (Geofirma 2020) showed that the sediments were comprised of low permeability material, the focus of data collection for this study was on the bedrock unit, which is expected to be several orders of magnitude more permeable than the overlying sediments and contribute the bulk of the groundwater inflows to the excavation.

Geofirma completed a hydrogeological characterization program between December 20, 2023, to January 19, 2024, which included drilling of six boreholes into the shallow bedrock, installation of a monitoring well at each borehole, and slug testing in each well. Details of the drilling and testing program are summarized in the following sections.

2.1 Monitoring Well Drilling and Installation

The monitoring well drilling and installation was completed on two separate dates because the lower part of the site within the excavation was flooded in late December 2023. Two monitoring wells (MW23-02 and MW23-03) were installed above the excavation on the west side of the site along March Road, on December 20, 2023. The remaining four wells (MW23-01 and MW23-04 through MW23-06) were installed on January 19, 2024, once the water and ground within the excavation was frozen.

The six monitoring wells were drilled and installed by Strata Drilling under supervision of Geofirma staff. Drilling through the sediments was completed using 4’’ (102 mm) diameter augers. Upon reaching the bedrock, drilling was completed by air hammering with a 3.625’’ (92mm) diameter bit and an air compressor. Rock cuttings produced during air hammering were sampled and logged by Geofirma staff. The six wells were drilled between 2.1 m to 2.8 m into bedrock, with final drilled depths between 4.8 m to 9.4 metres below ground surface.

Each well was completed using 2’’ (51mm) PVC riser fitted with a 1.5 m slotted screen set at the bottom of the well. The annulus between the well and the borehole wall was backfilled to just below the top of bedrock using silica sand, then completed to ground surface using bentonite chips. An above ground steel protective casing with a locking lid was used to complete the wells above ground surface.

The monitoring wells were developed immediately after installation by purging with a Waterra Hydrolift inertial pump. Purging was undertaken to clean drill cuttings from the fractured bedrock and well screen, and completed was until the produced water was clear of visible fines. The final purge volume for each well was between 90 to 200 litres.

Borehole drilling and well completion diagrams for the six wells installed as part of this study are provided in Appendix A.

2.2 Slug Testing and Analysis

2.2.1 Testing

Slug testing was completed by Geofirma staff on January 19, 2024. All the wells, excluding MW23-03, were tested using a physical (solid) slug completed as a series of 2-4 rising and falling head tests. Due to ice accumulation within the MW23-03 well riser, a liquid (water) slug was used to complete a series of four falling head tests in the well, instead of the physical slug method.

A Solinst 30 m Levelogger was used to obtain continuous readings during the slug testing at a one-second monitoring frequency. Each rising head and falling head test were completed until the water level recovered to at least 95% of the theoretical displacement. Static water level measurements were also obtained from each well at the start and end of the slug testing using an electronic water level tape.

2.2.2 Analysis

Analysis of the slug test data was completed using AQTESOLV Pro 4.0 to obtain estimates of hydraulic conductivity of the bedrock at each monitoring well. For the AQTESOLV analysis, test data was first filtered to ensure all points fell within the theoretical displacement, calculated based on the slug volume and the well diameter. The data was then visually inspected to identify the best rising or falling head test for analysis. The analysis was completed using the Hvorslev (1951) analytical solution, which assumes that the well is screened within a confined aquifer and flow to the well is radial.

Table 1 shows the estimated hydraulic conductivities for the six wells, which were between 2.3x10^{-5} m/s to 2.5x10^{-3} m/s, with a geometric mean of 1.5x10^{-4} m/s. The estimated values are consistent with hydraulic conductivities typical of heavily fractured bedrock.

Table 1 Bedrock Elevations, Water Levels, and Hydraulic Conductivities

Well ID	Ground Surface Elevation (m ASL)	Top of Bedrock Elevation (m ASL)	Bottom of Screen Elevation (m ASL)	Water Level (m BTOR)	Groundwater Elevation (m ASL)	Hydraulic Conductivity (m/s)
MW23-01	73.41	70.66	67.84	1.99	72.66	2.3E-05
MW23-02	77.63	70.93	68.23	4.91	73.57	2.5E-03
MW23-03	77.45	71.96	69.57	4.96	73.49	7.0E-05
MW23-04	73.56	70.46	67.62	1.51	73.05	6.5E-05
MW23-05	73.54	70.44	68.36	1.28	73.21	2.0E-04
MW23-06	73.52	71.07	68.72	1.01	73.46	2.6E-04

Figures showing the analysis completed in AQTESOLV are provided in Appendix B.

2.3 Survey of Bedrock Surface and Water Levels

All monitoring wells were surveyed to determine well locations and elevations. Surveying was completed using a Trimble Catalyst DA1 system. The datums for the survey data were the North American Datum 1983 (2011) and the Canada Geoid Model HT2_2010V70. The survey data was used to calculate the groundwater elevation and the top of bedrock at each well. Table 1 shows the bedrock and groundwater elevations encountered in the six monitoring wells drilled and completed as part of this study.

Figure 2 shows the bedrock elevation observed in boreholes from this study, which was between 70.44-71.96 m ASL and is consistent with observations from the 2018 study (Geofirma, 2020), where bedrock elevations were between 69.7-71.6 m ASL. The bedrock surface appears to drop in elevation from approximately 71.5 m at the southwest corner of the site to approximately 70 m near the northeast corner of the site.

Figure 3 shows static water levels encountered the bedrock wells, which was between 72.66-73.57 m ASL and is consistent with the water level measured at MW18-06 (at 73.53 m ASL) in 2018 by Geofirma.

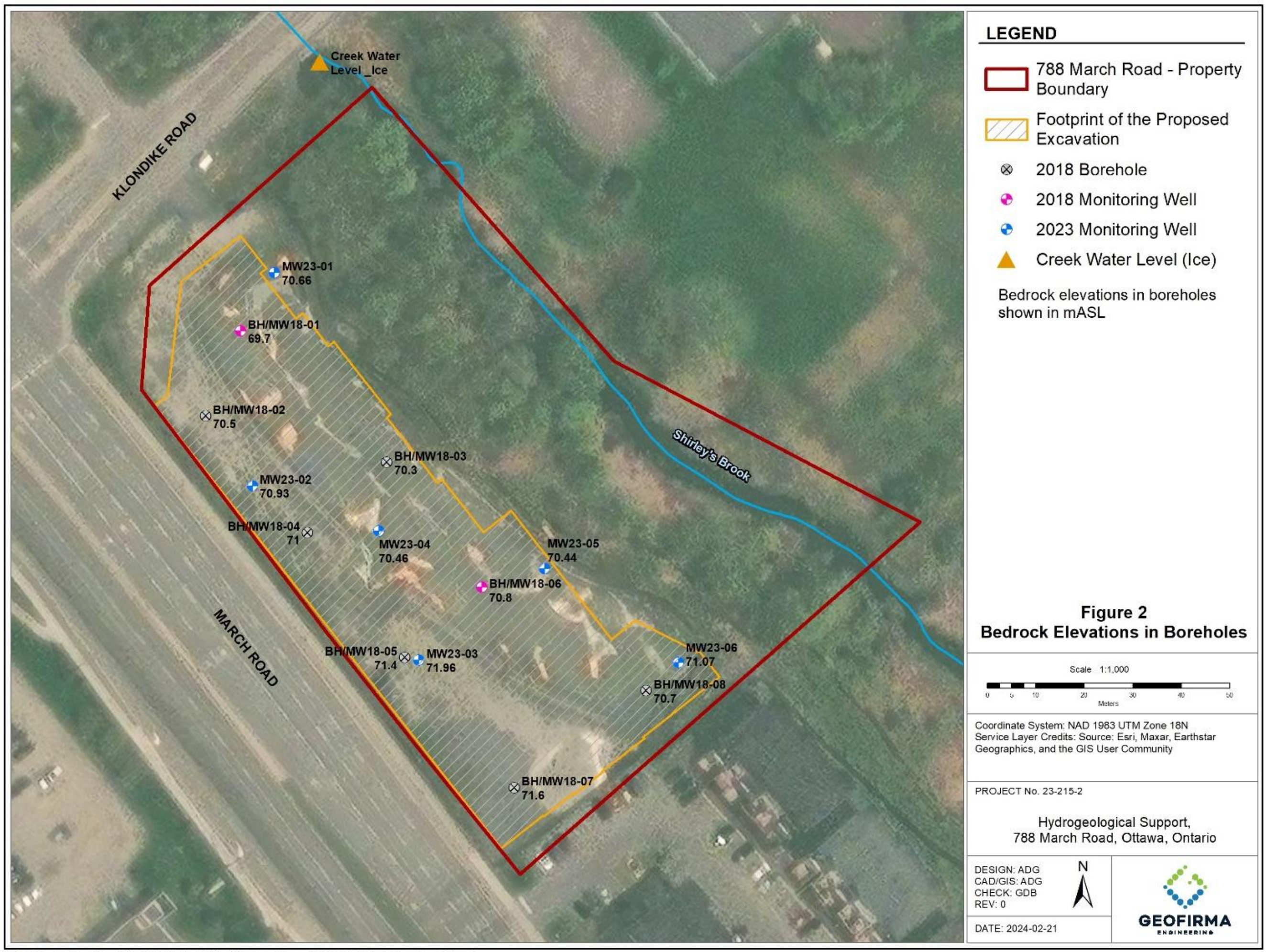

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Figure 2 Bedrock Elevations in Boreholes

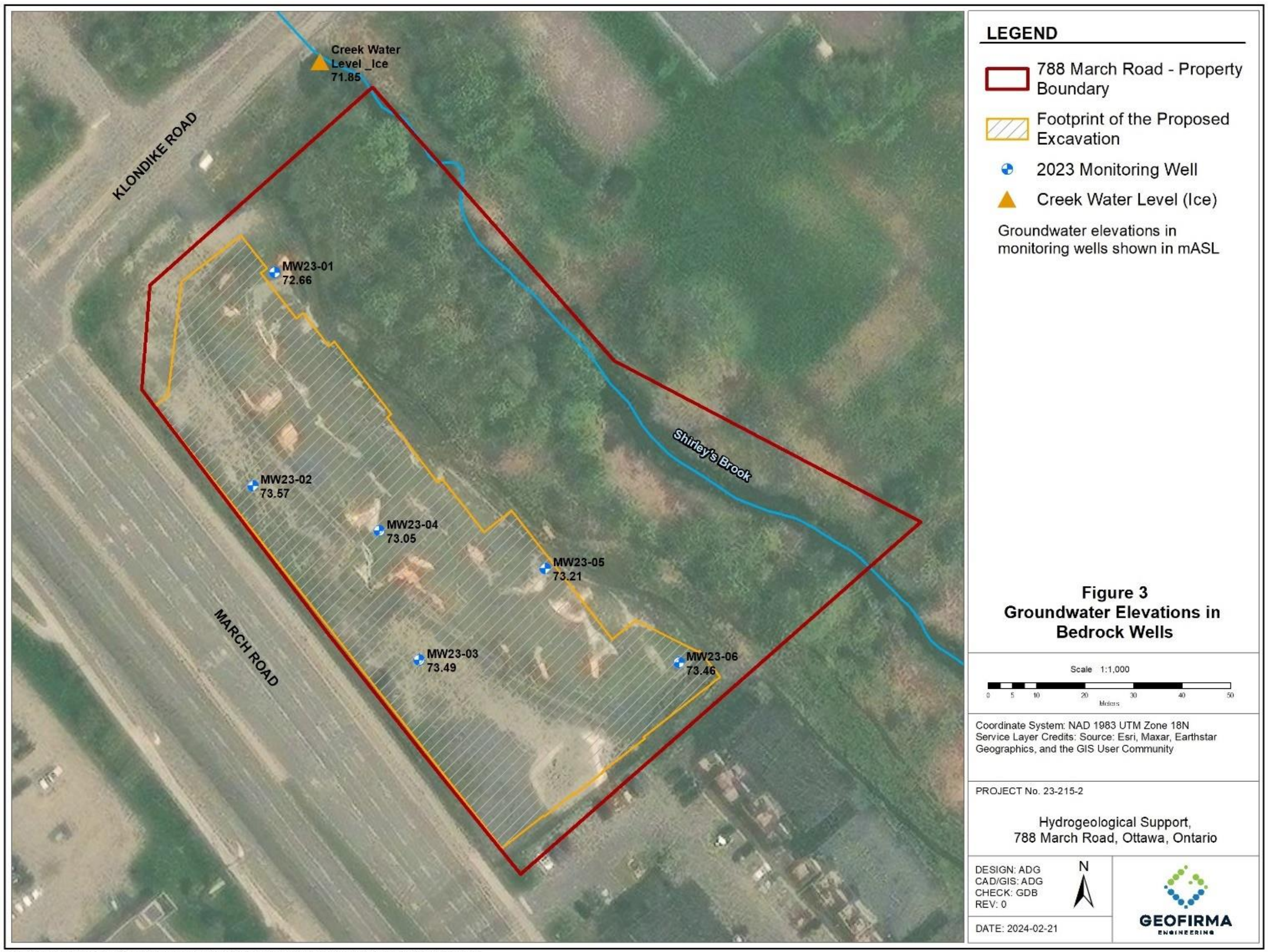

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Figure 3 **Groundwater Elevations in Bedrock Wells**

2.4 Estimation of Groundwater Inflows

2.4.1 Equations for Inflow Estimates

Groundwater inflow to the proposed excavation was calculated by combining several analytical solutions. The Marinelli & Niccoli (2000) solution (Zone 2 equation) for flow to a pit floor was used to calculate inflow to the base of the proposed excavation. Analytical solutions presented by Cashman and Preene (2001) for radial flow to a well were used to calculate inflows to the short walls on either end of the excavation, with the Theim equation used for the bedrock portion (confined) and the Forchheimer-Dupuit equation for the overburden (unconfined). Slot flow equations were used for linear flow to the long walls of the excavation, with separate equations for the confined bedrock and unconfined overlying sediment portions of the walls.

To use the analytical solutions described above, the following key assumptions were made for the initial inflow calculations (base scenario in Table 2):

1. The base of excavation equals the proposed elevation for the footings at 69.97 m ASL (SINA, personal communication)

2. The static water table in the sediments is at 73.6 m ASL, based on the reported level measured from a piezometer at the site in 2018 (Geofirma 2020).

3. The static groundwater elevation in the bedrock is at 73.2 m ASL, which was average water level measured in wells drilled and instrumented as part of this study.

4. Flow to the short walls of the excavation will be radial, with the well radius used for the calculation equal to half the length of the wall.

5. Flow to the long walls of the excavation will be linear.

6. The floor of the excavation is entirely within bedrock. Flow to the walls occurs through 1 m of bedrock plus overlying sediments on west and south walls. Flow to the walls occurs through 0.5m of bedrock plus overlying sediments on east and north walls.

7. The hydraulic conductivity of the sediments is $4x10^{-7}$ m/s, as measured by Geofirma (2020). The sediments are homogeneous and isotropic.

8. The hydraulic conductivity of the bedrock is $1.5x10^{-4}$ m/s, equivalent to the geometric mean calculated from slug testing completed as part of this study. The bedrock is homogeneous and anisotropic ($K_V = 0.1\ K_H$)

2.4.2 Calculated Groundwater Inflows

Estimated groundwater inflow rates shown in Table 2 suggest that inflows of several thousands of litres per minute can be expected into the excavation based on the assumptions listed above. The base case scenario, which is considered to best represent the conceptual model developed for the site, shows an inflow rate of 1,856 litres per minute.

Due to the high hydraulic conductivity of the fractured bedrock at the site, most of the inflow is expected to occur from the floor of the excavation and from portions of the walls where bedrock will be exposed. Contribution of inflows from the shallow sediments are relatively small, even in the High K sediment case, where the hydraulic conductivity of the sediments was increased by an order of magnitude above the value estimated from slug testing completed as part of the geotechnical study (Geofirma 2020).

Additional scenarios presented in Table 2 were used to assess the sensitivity of inflow rates to bedrock parameters that remain uncertain. In the no anisotropy scenario, the horizontal (K_H) and vertical (K_V) components of hydraulic conductivity are set equal for the bedrock resulting in an estimated inflow rate of 5,120 litres per minute. Anisotropy in fractured sedimentary rock is difficult to assess, but K_H 5-10 times the K_V are commonly observed.

Table 2 Estimated Groundwater Inflow Rates

Scenario	Estimated Flow Rate			Key Assumptions
	Floor	Walls	Total	
Base Case	1,509	346	1,856	- Anisotropy: K_V/K_H (bedrock) = 0.1 - base of excavation = footings and French drain elevation - floor entirely within bedrock - wall inflow occurs through 1 m of bedrock plus overlying sediments on west and south walls - wall inflow occurs through 0.5m of bedrock plus overlying sediments on east and north walls - bedrock is confined aquifer overlain by low K sediments
No Bedrock Anisotropy	4,773	346	5,120	Same as base case, except bedrock K_V/K_H = 1
High K Bedrock	7,547	1,476	9,023	Same as base case, except bedrock K increased by half an order of magnitude
	15,095	2,887	17,982	Same as base case, except bedrock K increased by one order of magnitude
High K Sediments	1,509	922	2,431	Same as base case, except sediment K increased by one order of magnitude

The two high K bedrock scenarios show that inflows will increase significantly if the bulk bedrock K at the site is greater than the mean K estimated from slug testing. Given that a K of 2.5x10^{-3} m/s was estimated from testing at MW23-02 as part of this study, and the March Formation is known to be very permeable within the region, especially when heavily fractured, these higher K scenarios may be possible and should be considered when determining the risks from inflows and possible engineered solutions.

A simplified scoping calculation based on Darcy's Law was used to estimate reduction to inflow (from the Base Case scenario) that may be observed if sediments are left covering 50% of the floor area during excavation. The calculation assumes that 0.5 m of sediments are left in place as a confining layer and the head in the underlying bedrock aquifer remains at the static water level at 73.4 m ASL. Based on these assumptions, the scoping calculation indicates that inflows to the excavation may be reduced by approximately 20%, or greater, if 50% of the floor is left covered by fine-grained sediments. The actual reduction to inflow will depend on the retained sediment thickness and the hydraulic conductivity of the sediments.

3 CONCLUSIONS AND RECCOMENDATIONS

Geofirma completed a hydrogeological study at a property owned by SINA at 788 March Road, Kanata, Ontario, between December 20, 2023, and January 19, 2024. The study was conducted to obtain the data required to evaluate potential groundwater inflow rates into a proposed excavation at the site. The study included drilling, well installation, and slug testing of six monitoring wells that were completed into the shallow bedrock.

Results from the drilling program and data from a geotechnical study completed at the site in 2018 (Geofirma 2020) were used to provide input parameters for groundwater inflow calculations. Inflow rates were calculated using a combination of analytical models, with separate equations used for the excavation floor (Marinelli & Niccoli 2000) and the excavation walls (Cashman & Preene 2001).

The calculations show that inflows of several thousands of litres per minute can be expected if the excavation is completed such that bedrock is exposed in the walls and floor of the excavation. The base case scenario shows an estimated inflow rate of 1,856 litres per minute. Much higher inflows may be encountered if the bulk hydraulic conductivity (K) of the bedrock is higher than the geometric mean K calculated from slug testing, or the bedrock anisotropy (K_V/K_H) is higher than the ratio of 0.1 used in the base case. In one of the high K bedrock scenarios, inflow rates of up to 17,982 litres per minute were estimated when the K of the bedrock was increased by an order of magnitude from the mean K from slug testing.

In contrast, inflow from the overlying sediments is expected to be relatively small compared to inflows from the bedrock. Even when the sediment K was increased by an order of magnitude above the value estimated from testing in 2018 (Geofirma 2020), there was only a minor increase in the inflow rate compared to the base case scenario.

Based on findings from this study, Geofirma provides the following recommendations:

- Since the hydraulic conductivity of the bedrock at the site is several orders of magnitude higher than the hydraulic conductivity of the sediments, inflow rates may be reduced by limiting the amount of bedrock exposed during excavation.

- Boreholes drilled at the site show that the elevation of the bedrock surface dips from approximately 72 m ASL in the southwest corner of the site, to approximately 70 m ASL in the northeast corner of the site. Excavation to approximately 70 m ASL for the footings should expect to encounter bedrock and significant inflows across most of the site. The base of the floor slab at approximately 71 m ASL will require excavation into bedrock across much of the southern and western walls and in the floor of the southwest corner of the site.

- Given the sensitivity of the inflow estimates to the hydraulic conductivity of the bedrock, further testing is recommended if the uncertainty in inflow rates between the base case scenario and the high K bedrock scenarios will have a significant impact on building design or dewatering considerations. A pumping test that uses the monitoring wells drilled as part of this study to observe drawdown through the aquifer would provide an improved estimate of bulk hydraulic conductivity of bedrock compared to the slug tests, which have a small radius of investigation.

4 REFERENCES

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Ontario Geological Survey 2010. Surficial geology of Southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 128-REV

5 CLOSURE

This report has been prepared for the exclusive use of SINA using a methodology for conducting a hydrogeological study that is acceptable within the profession. Data obtained from borehole investigations represent the conditions at the time of drilling and testing and are subject to variability with groundwater conditions and local development.

Geofirma Engineering Ltd. (Geofirma) has exercised professional judgment in collecting and analyzing the data as part of this study and in formulating recommendations based on the results. The mandate at Geofirma is to perform the given tasks within guidelines prescribed by the client and with the quality and due diligence expected within the profession. No other warranty or representation expressed or implied, as to the accuracy of the information or recommendations is included or intended in this report.

Geofirma Engineering Ltd. hereby disclaims any liability or responsibility to any person or party, other than the party to whom this report is addressed, for any loss, damage, expense, fines or penalties which may arise or result from the use of any information or recommendations contained in this report by any other party. Any use of this report constitutes acceptance of the limits of Geofirma's liability. Geofirma's liability extends only to its client and only for the total amount of fees received from the client for this specific project and not to other parties who may obtain this report.

Respectfully submitted,

Geofirma Engineering Ltd.

Chris Morgan

Chris Morgan, M.A.Sc., P.Geo.
Geoscientist

Glen Briscoe, P.Eng.
Principal

Appendix A

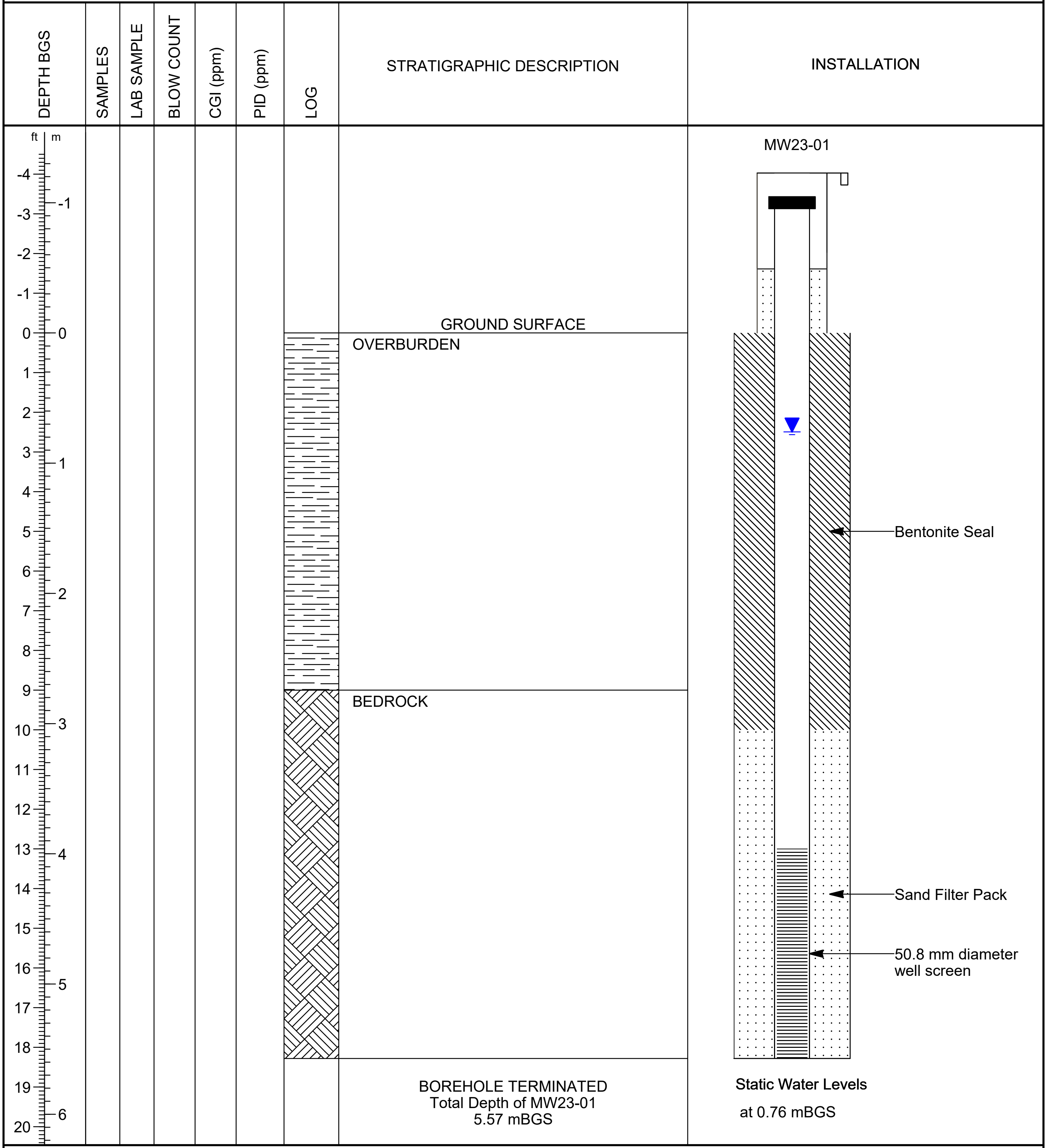
Borehole Drilling and Well Completion Diagrams

BOREHOLE STRATIGRAPHIC AND INSTRUMENTATION LOG

Borehole Number: MW23-01

Project Number: 23-215-2
Client: Sina
Site Location: 788 March Road
Coordinates: 427037.4487E, 5022841.792N (UTM Zone 18)
Drilling Method: Air Hammer
Drilling Rig: Massenza M13

MOE Well ID: A400105
Date Completed: 19-Jan-24
Supervisor: MdK
Logged By: MdK
Ground Surface Elevation: 73.41
Date of Water Level Measurement: 19-Jan-24



GROUND SURFACE

OVERBURDEN

BEDROCK

BOREHOLE TERMINATED
Total Depth of MW23-01
5.57 mBGS

Static Water Levels
at 0.76 mBGS

Prepared By: SMD
Reviewed By: MdK
Doc: 23-215-2_BH LOGS_2024.GPJ
Template: GEOFIRMA_TEMPLATE.GDT

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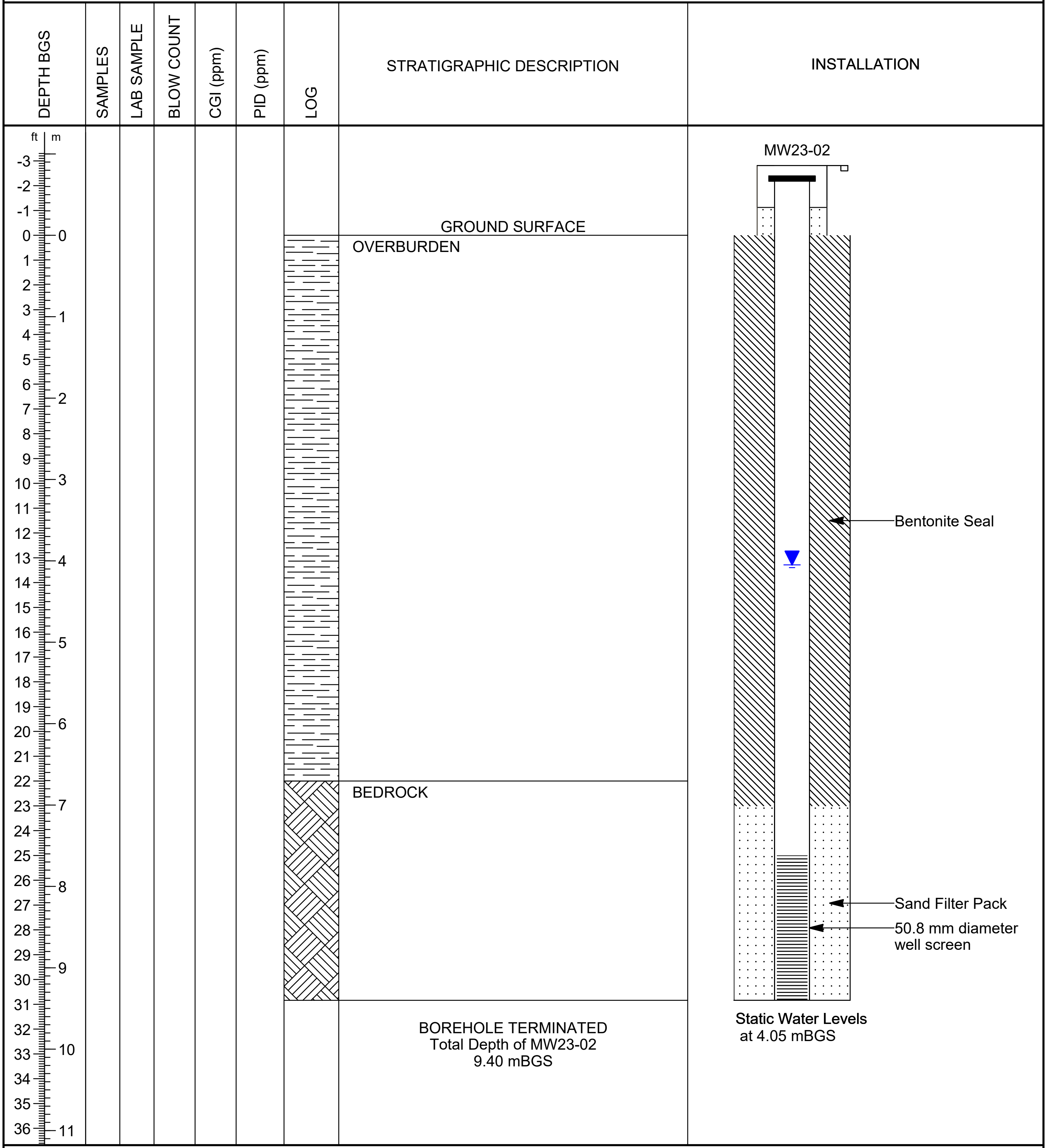
BOREHOLE STRATIGRAPHIC AND INSTRUMENTATION LOG

Borehole Number: MW23-02

Project Number: 23-215-2
Client: Sina
Site Location: 788 March Road
Coordinates: 427032.8881E, 5022797.777N (UTM Zone 18)
Drilling Method: Air Hammer
Drilling Rig: Massenza M13

MOE Well ID: A371053
Date Completed: 20-Dec-23
Supervisor: MdK
Logged By: MdK
Ground Surface Elevation: 77.63
Date of Water Level Measurement: 19-Jan-24



Prepared By: SMD
Reviewed By: MdK
Doc: 23-215-2_BH LOGS_2024.GPJ
Template: GEOFIRMA_TEMPLATE.GDT

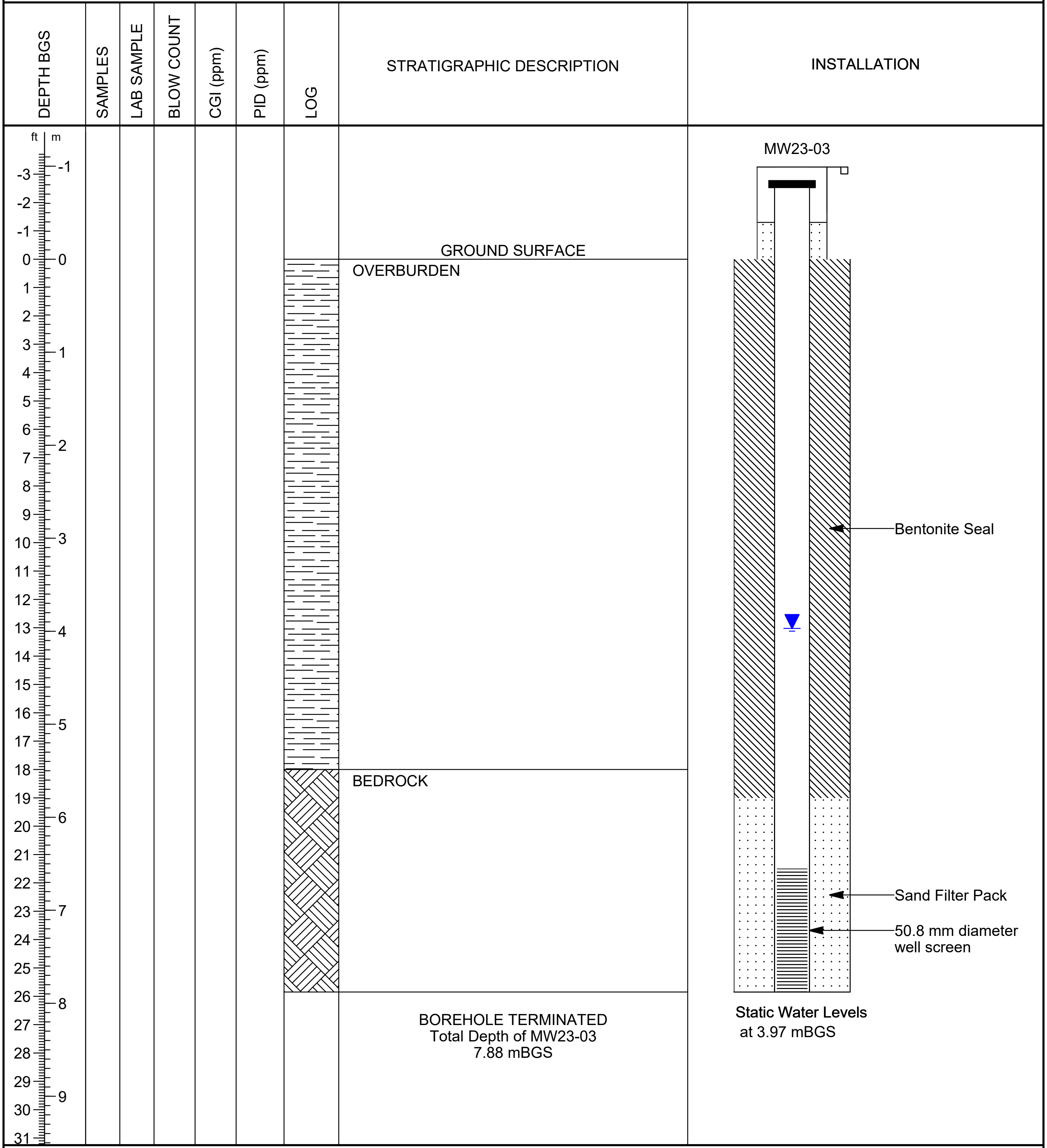
GEOFIRMA ENGINEERING

BOREHOLE STRATIGRAPHIC AND INSTRUMENTATION LOG

Borehole Number: MW23-03

Project Number: 23-215-2
Client: Sina
Site Location: 788 March Road
Coordinates: 427067.2524E, 5022761.807N (UTM Zone 18)
Drilling Method: Air Hammer
Drilling Rig: Massenza M13

MOE Well ID: A379691
Date Completed: 20-Dec-23
Supervisor: MdK
Logged By: MdK
Ground Surface Elevation: 77.45
Date of Water Level Measurement: 19-Jan-24



Prepared By: SMD
Reviewed By: MdK
Doc: 23-215-2_BH LOGS_2024.GPJ
Template: GEOFIRMA_TEMPLATE.GDT

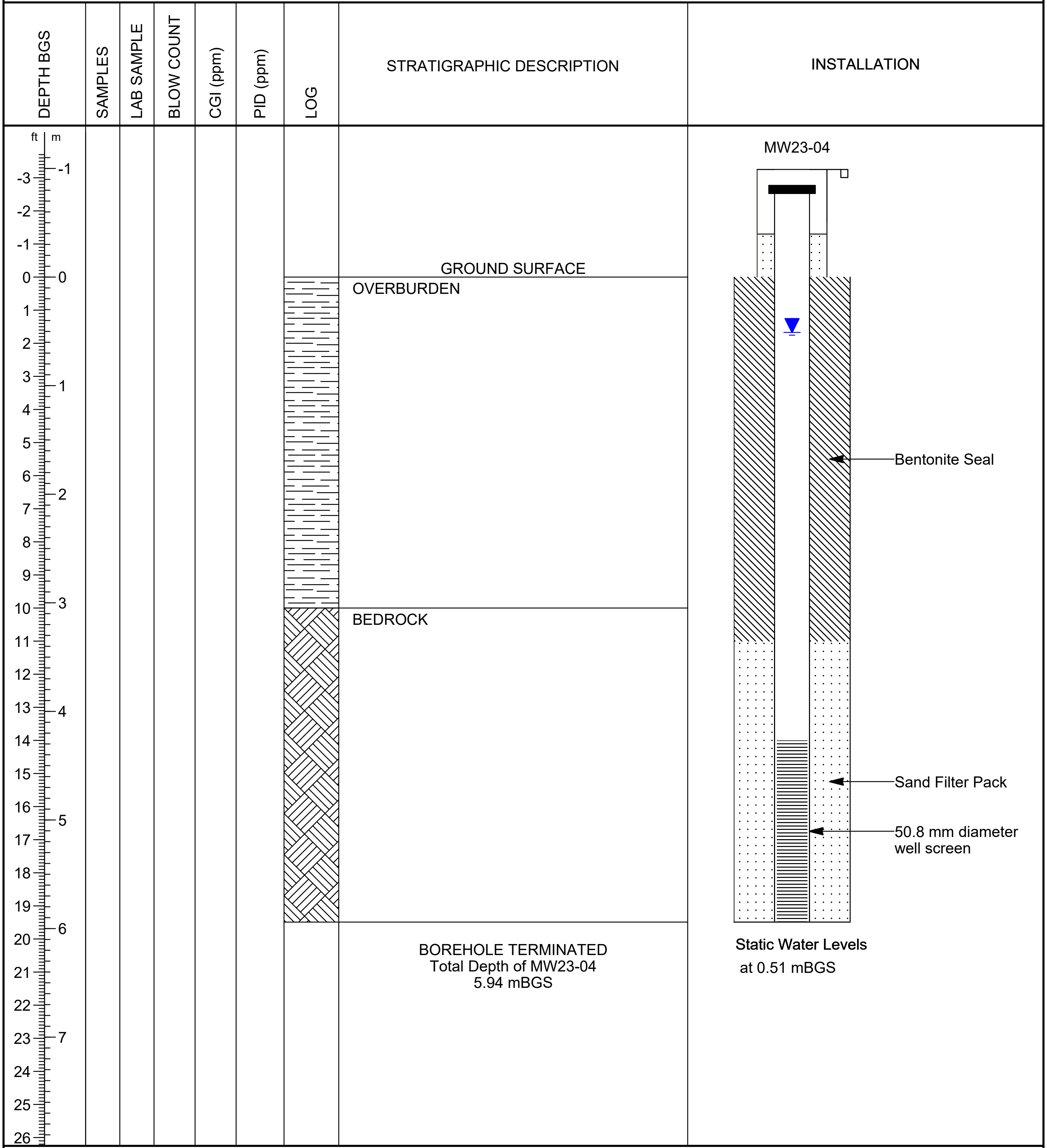
GEOFIRMA ENGINEERING

BOREHOLE STRATIGRAPHIC AND INSTRUMENTATION LOG

Borehole Number: MW23-04

Project Number: 23-215-2
Client: Sina
Site Location: 788 March Road
Coordinates: 427058.9755E, 5022788.431N (UTM Zone 18)
Drilling Method: Air Hammer
Drilling Rig: Massenza M13

MOE Well ID: A400102
Date Completed: 19-Jan-24
Supervisor: MdK
Logged By: MdK
Ground Surface Elevation: 73.56
Date of Water Level Measurement: 19-Jan-24



GROUND SURFACE

OVERBURDEN

BEDROCK

BOREHOLE TERMINATED
Total Depth of MW23-04
5.94 mBGS

Static Water Levels
at 0.51 mBGS

Prepared By: SMD
Reviewed By: MdK
Doc: 23-215-2_BH LOGS_2024.GPJ
Template: GEOFIRMA_TEMPLATE.GDT

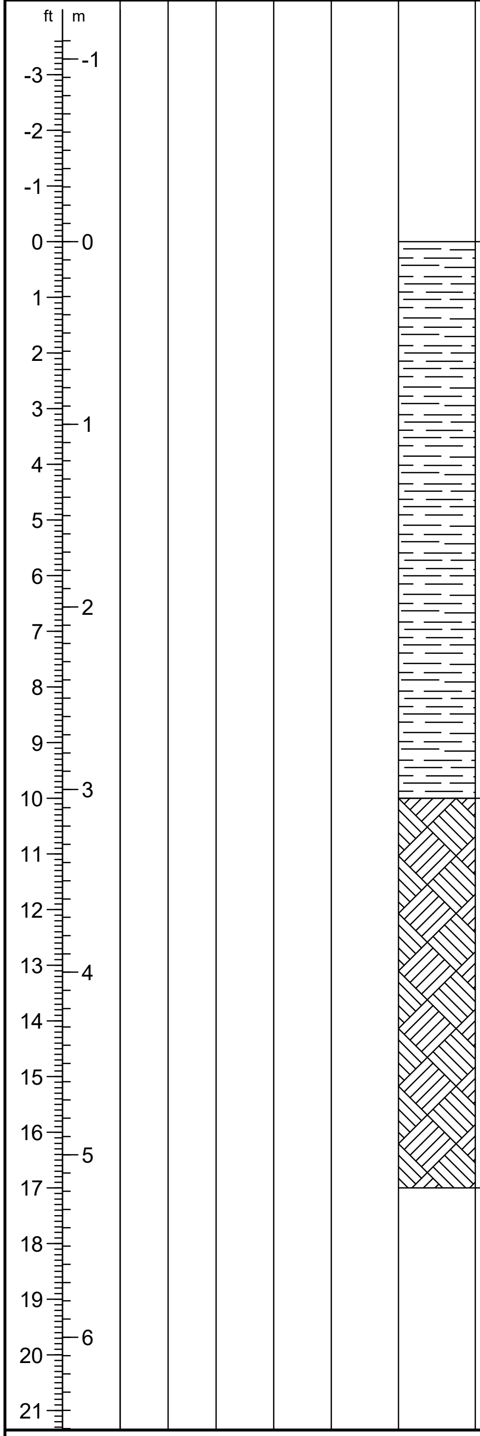
BOREHOLE STRATIGRAPHIC AND INSTRUMENTATION LOG

Borehole Number: MW23-05

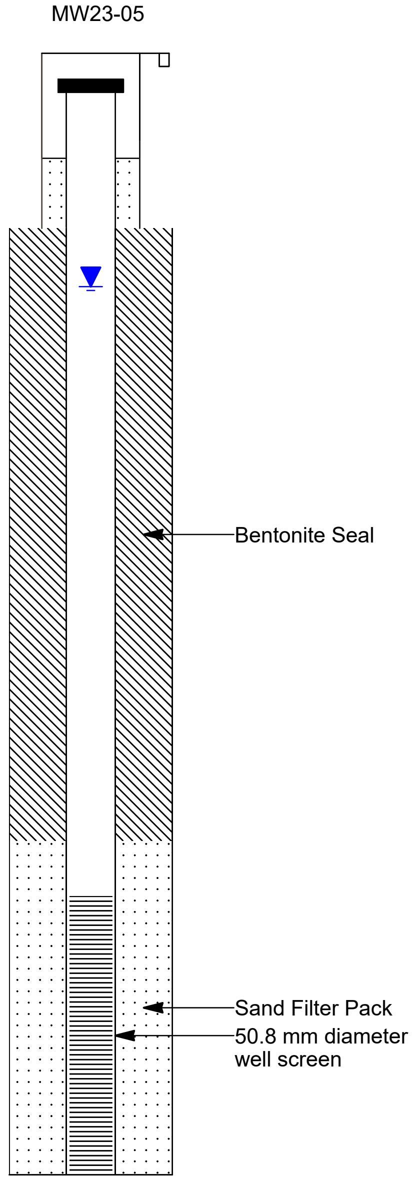
Project Number: 23-215-2
Client: Sina
Site Location: 788 March Road
Coordinates: 427093.2535E, 5022780.678N (UTM Zone 18)
Drilling Method: Air Hammer
Drilling Rig: Massenza M13

MOE Well ID: A400103
Date Completed: 19-Jan-24
Supervisor: MdK
Logged By: MdK
Ground Surface Elevation: 73.54
Date of Water Level Measurement: 19-Jan-24

DEPTH BGS	SAMPLES	LAB SAMPLE	BLOW COUNT	CGI (ppm)	PID (ppm)	LOG	STRATIGRAPHIC DESCRIPTION
							GROUND SURFACE
							OVERBURDEN
							BEDROCK
							BOREHOLE TERMINATED Total Depth of MW23-05 5.18 mBGS



INSTALLATION



Static Water Levels

at 0.32 mBGS

Prepared By: SMD
Reviewed By: MdK
Doc: 23-215-2_BH LOGS_2024.GPJ
Template: GEOFIRMA_TEMPLATE.GDT

GEOFIRMA ENGINEERING

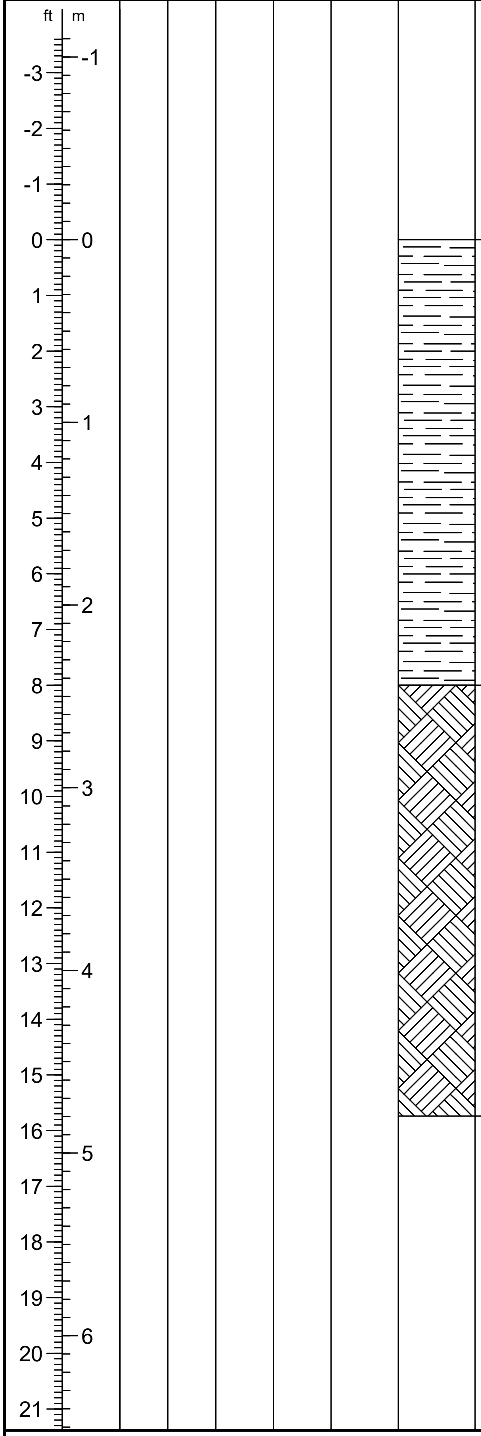
BOREHOLE STRATIGRAPHIC AND INSTRUMENTATION LOG

Borehole Number: MW23-06

Project Number: 23-215-2
Client: Sina
Site Location: 788 March Road
Coordinates: 427120.7849E, 5022761.238N (UTM Zone 18)
Drilling Method: Air Hammer
Drilling Rig: Massenza M13

MOE Well ID: A400101
Date Completed: 19-Jan-24
Supervisor: MdK
Logged By: MdK
Ground Surface Elevation: 73.52
Date of Water Level Measurement: 19-Jan-24

DEPTH BGS	SAMPLES	LAB SAMPLE	BLOW COUNT	CGI (ppm)	PID (ppm)	LOG	STRATIGRAPHIC DESCRIPTION	INSTALLATION

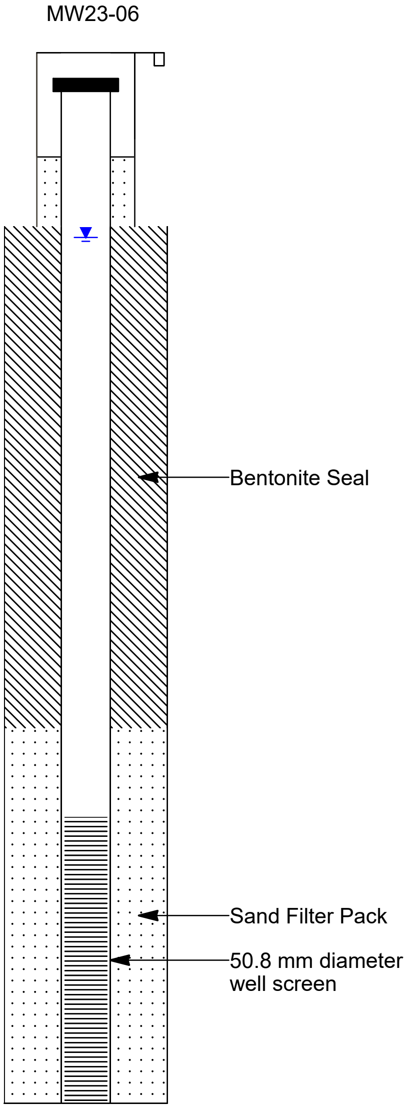


GROUND SURFACE

OVERBURDEN

BEDROCK

BOREHOLE TERMINATED
Total Depth of MW23-06
4.80 mBGS



Static Water Levels

at 0.06 mBGS

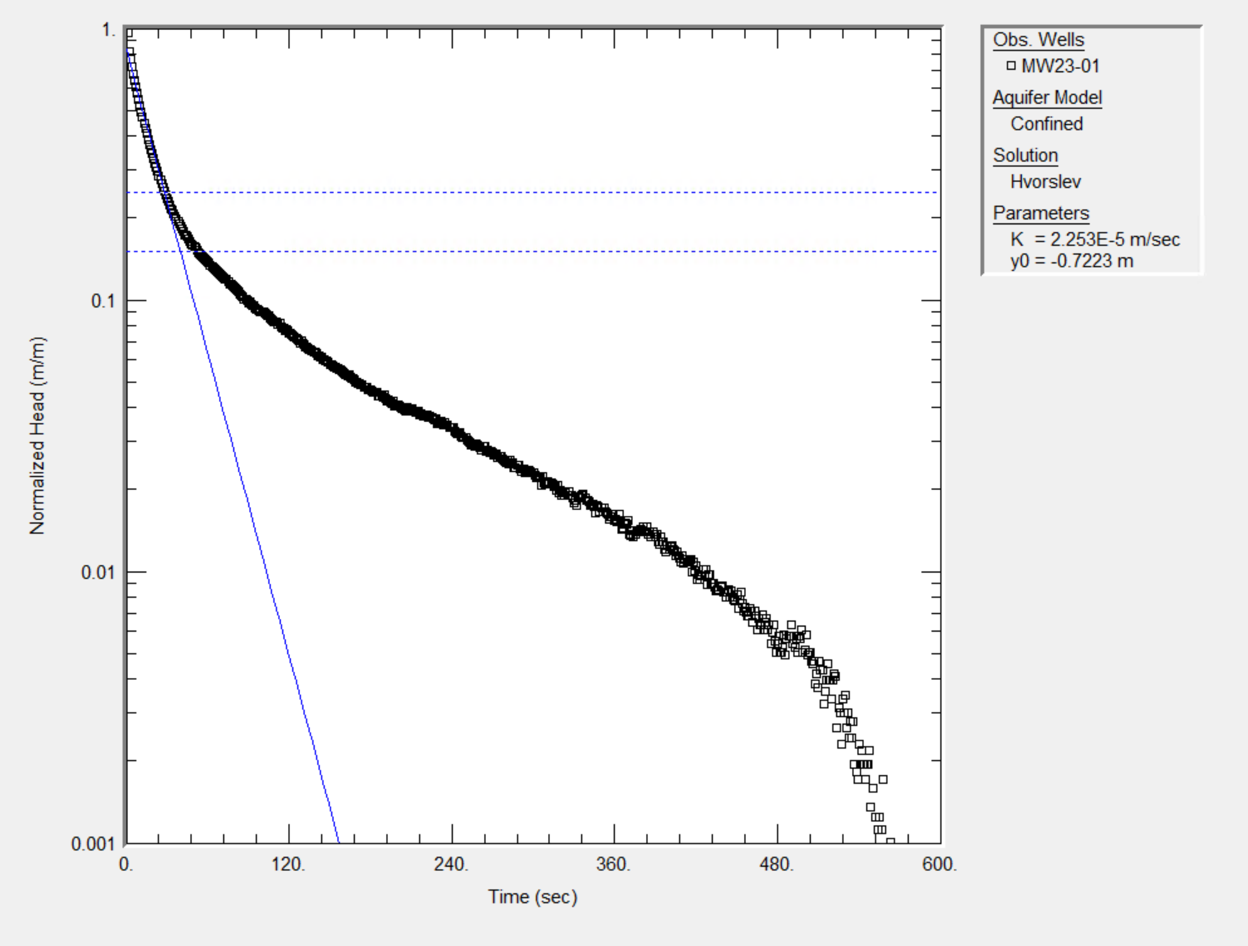
Prepared By: SMD
Reviewed By: MdK
Doc: 23-215-2_BH LOGS_2024.GPJ
Template: GEOFIRMA_TEMPLATE.GDT

GEOFIRMA ENGINEERING

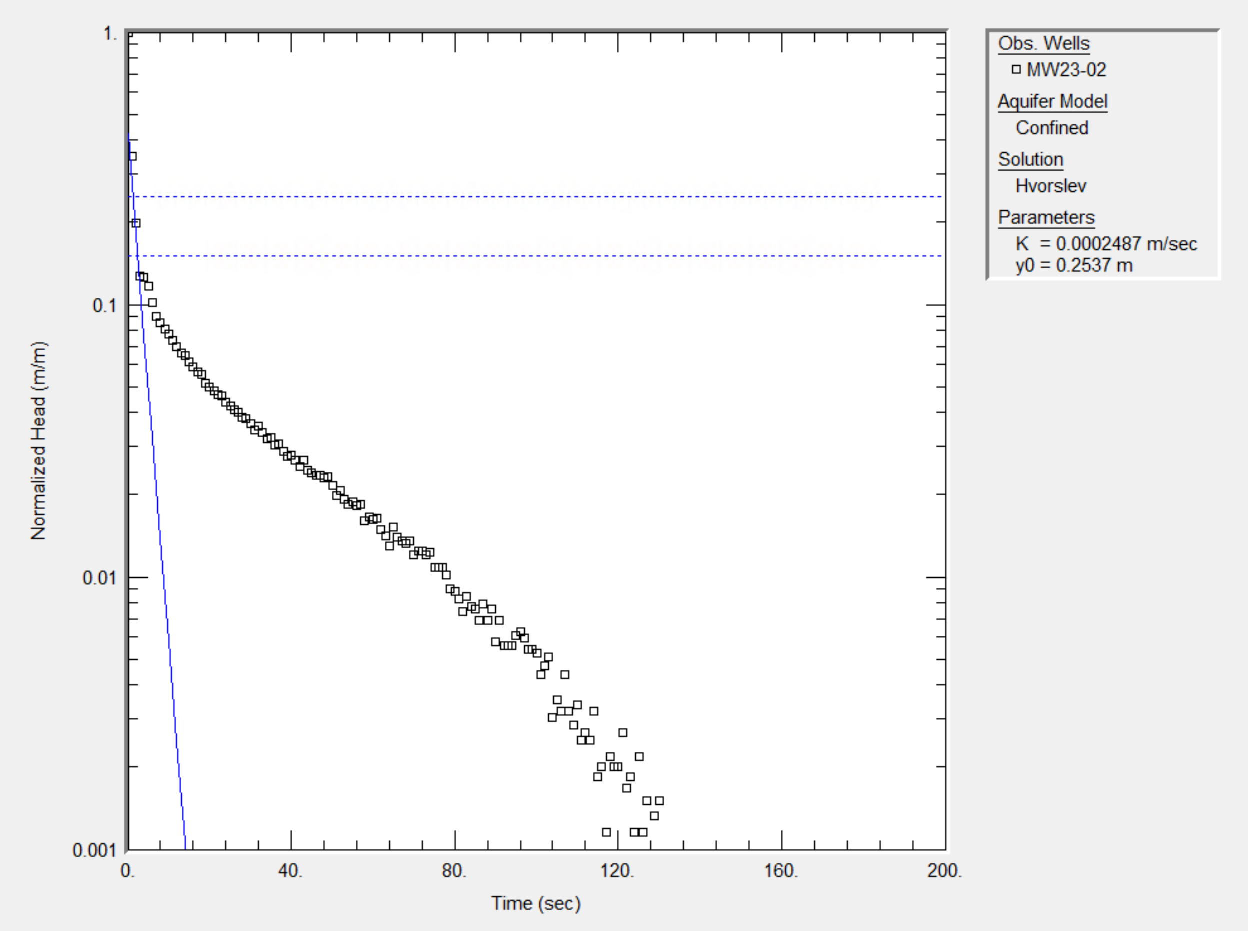
Appendix B

AQTESOLV Slug Test Analyses

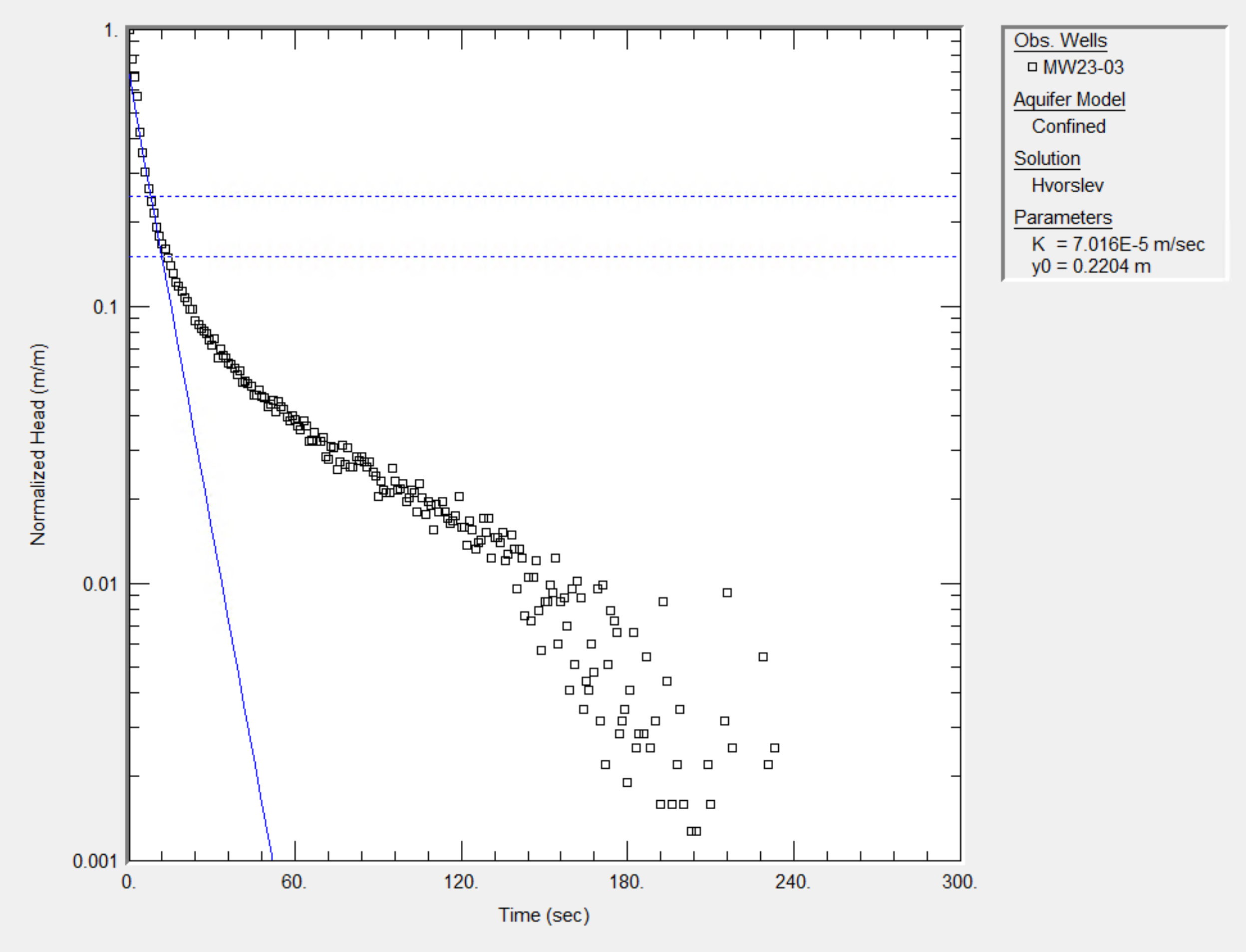
MW23-01


1.
0.1
0.01
0.001
Normalized Head (m/m)
0.
120.
240.
360.
480.
600.
Time (sec)
Obs. Wells
□ MW23-01
Aquifer Model
Confined
Solution
Hvorslev
Parameters
K = 2.253E-5 m/sec
y0 = -0.7223 m

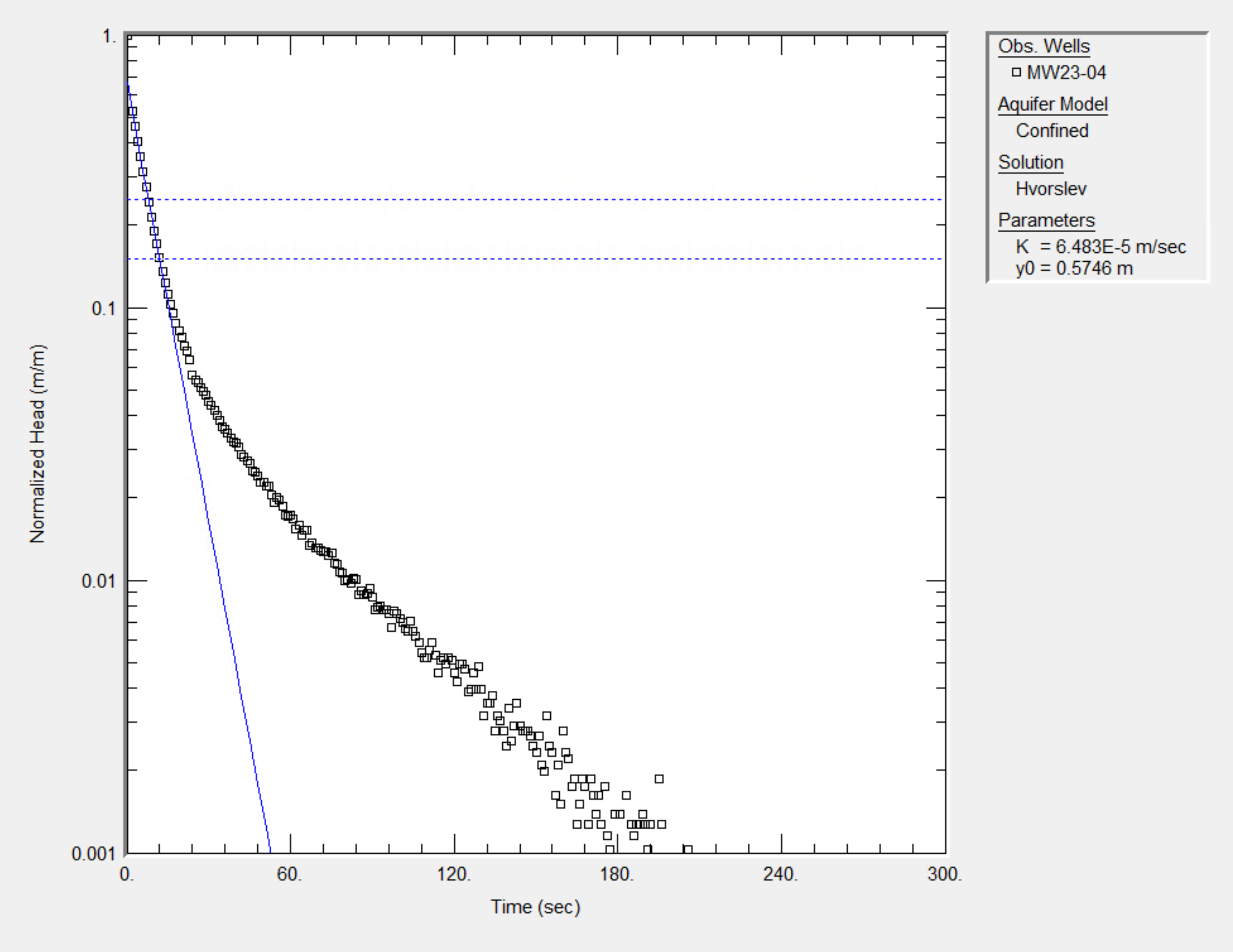
MW23-02


1.
0.1
0.01
0.001
Normalized Head (m/m)
0.
40.
80.
120.
160.
200.
Time (sec)
Obs. Wells
□ MW23-02
Aquifer Model
Confined
Solution
Hvorslev
Parameters
K = 0.0002487 m/sec
y0 = 0.2537 m

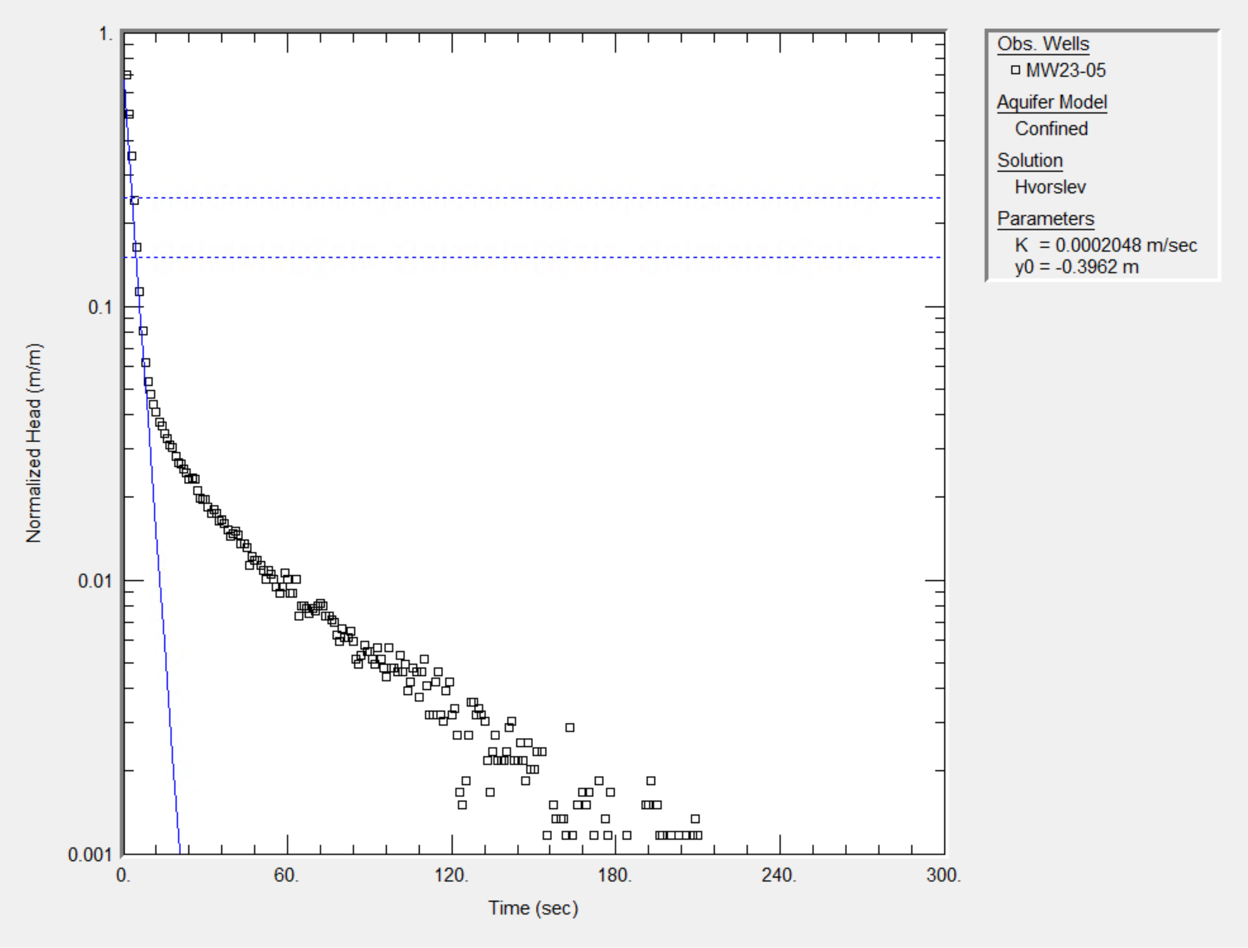
MW23-03


1.
0.1
0.01
0.001
Normalized Head (m/m)
0.
60.
120.
180.
240.
300.
Time (sec)
Obs. Wells
□ MW23-03
Aquifer Model
Confined
Solution
Hvorslev
Parameters
K = 7.016E-5 m/sec
y0 = 0.2204 m

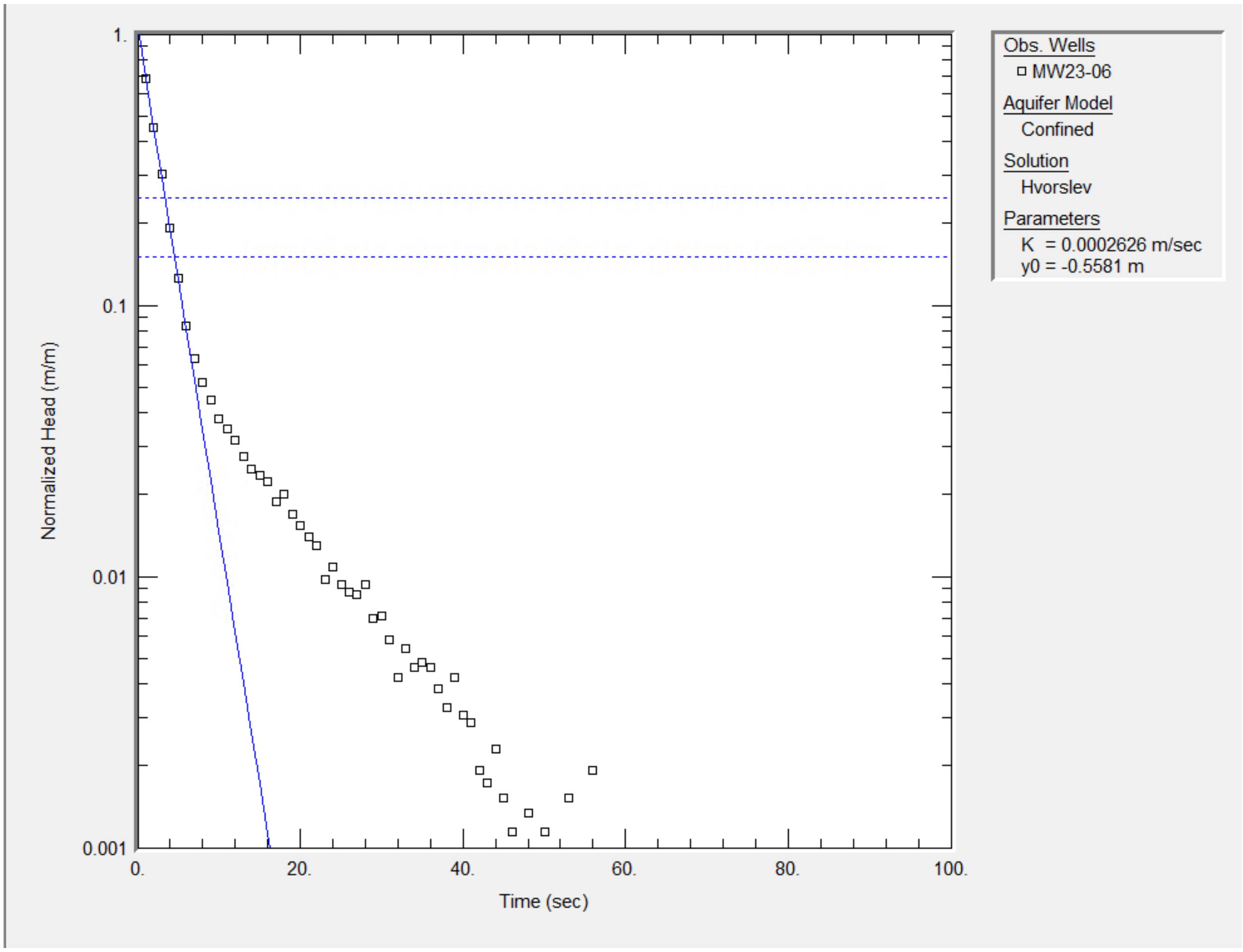
MW23-04


1.
0.1
0.01
0.001
Normalized Head (m/m)
0.
60.
120.
180.
240.
300.
Time (sec)
Obs. Wells
□ MW23-04
Aquifer Model
Confined
Solution
Hvorslev
Parameters
K = 6.483E-5 m/sec
y0 = 0.5746 m

MW23-05


1.
0.1
0.01
0.001
Normalized Head (m/m)
0.
60.
120.
180.
240.
300.
Time (sec)
Obs. Wells
□ MW23-05
Aquifer Model
Confined
Solution
Hvorslev
Parameters
K = 0.0002048 m/sec
y0 = -0.3962 m

MW23-06


1.
0.1
0.01
0.001
Normalized Head (m/m)
0.
20.
40.
60.
80.
100.
Time (sec)
Obs. Wells
□ MW23-06
Aquifer Model
Confined
Solution
Hvorslev
Parameters
K = 0.0002626 m/sec
y0 = -0.5581 m

Appendix C

Groundwater Inflow Calculations

Groundwater Inflow Calculations

Project: 23-215-2 788 March Road - SINA - Hydrogeological Support
Prepared By: Chris Morgan
Date: 07-Feb-24

Table 1: Input Parameters

Parameter	Value	Units	Comments
Pit Length	131.2	m	From CAD Drawing
Pit Width	44.2	m	From CAD Drawing
Pit Surface Area	5294	m2	From client email
Excavation Base	70.97	mASL	Base of Floor Slab
	69.97		Footings and French Drain
Top of Bedrock	70.9	mASL	Average elevation in boreholes drilled January 2024 (this study)
	70.8		Average elevation in boreholes drilled June 2018 (Geofirma 2020)
Static Water Level	73.2	mASL	Average water level in bedrock monitoring wells January 2024 (this study)
	73.4		Water Level in MW18-01, June 2018 (Geofirma 2020)
	73.6		Water Level in MW18-06, June 2018 (Geofirma 2020)
Radius/Length of Influence	50	m	Estimated (see "wall" calculations), conservative 50 m used
Hydraulic Conductivity (Kh)	4.0E-07	m/s	Kh reported for overburden sediments June 2018 (Geofirma 2020)
	1.5E-04		Geometric Mean for Bedrock, Kh from slug testing January 2024 (this study)

Table 1: Inflow Calculations

Scenario	Flow Rate (L/min)						Comments/Key Assumptions
	Floor[1]	South Short Wall[2,3]	North Short Wall[2,3]	East Long Wall[4,5]	West Long Wall[4,5]	Total	
Base Case	1,509	129	77	50	90	1,856	- Anisotropy: Kv/Kh (bedrock) = 0.1 - base of excavation = footings and french drain elevation - floor entirely within bedrock - wall inflow occurs through 1 m of bedrock plus overlying sediments on west and south walls - wall inflow occurs through 0.5m of bedrock plus overlying sediments on east and north walls - bedrock is confined aquifer overlain by low K sediments
No Bedrock Anisotropy	4,773	129	77	50	90	5,120	Same as base case, except bedrock Kv/Kh = 1
High K Bedrock	7,547	577	301	203	395	9,023	Same as base case, except bedrock K increased by half an order of magnitude
	15,095	1,137	580	393	777	17,982	Same as base case, except bedrock K increased by one order of magnitude
High K Sediments	1,509	286	262	157	217	2,431	Same as base case, except sediment K increased by one order of magnitude

1. Marinelli & Niccoli (2001) - Q2 for pit floors
2. Cashman & Preene (2001) Theim Equation for Confined Aquifer (bedrock)
3. Cashman & Preene (2001) Forcheimer-Dupuit Equation for Unconfined Aquifer (sediments)
4. Cashman & Preene (2001) Slot Flow for Confined Aquifer (bedrock)
5. Cashman & Preene (2001) Slot Flow for Unconfined Aquifer (sediments)