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Geotechnical Reportd

At

0th Killaly Street West,
Port Colborne, ON

PREPARED FOR:

1000046816 ONTARIO LIMITED.

Feb 06, 2024

Table of Contents

1. BACKGROUND

King EPCM (the Engineer) was retained by 1000046816 Ontario Limited (the Client) to carry out geotechnical engineering review for a proposed residential sub-division at 0th Killaly Street West, City of Port Colborne, Regional Municipality of Niagara, Ontario (the Site).

The purpose of this report is to review the existing soil conditions of the proposed residential sub-division. This report details King EPCM's review of historic records, drilling of groundwater monitoring wells, and review of existing soil infiltration rates.

This report was prepared for the Client, 1000046816 Ontario Limited, for the property owners, and any related site-specific engineers, designers, and contractors. This report is considered an intellectual property of King EPCM, and third party use of this report, including reliance, in-part or full, is prohibited without written consent from King EPCM.

2. SITE DESCRIPTION

2.1.SITE LOCATION

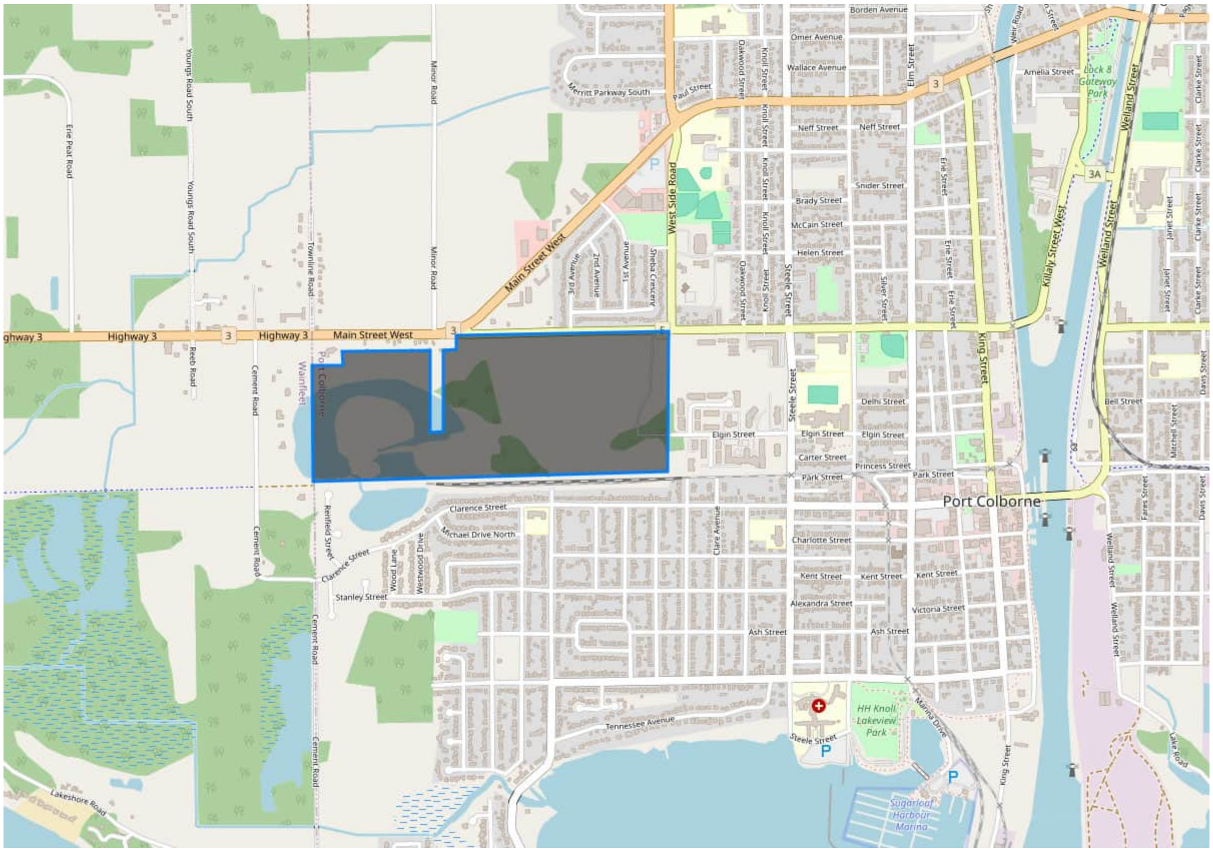


Figure 1 – 0^{th} Killaly St West, Port Colborne, ON

The site is located at the municipal address of 0th Killaly Street West, City of Port Colborne, Regional Municipality of Niagara. Please refer to the legal survey for the exact legal description.

The Site property is considered abandoned brownfield, with the majority of the western portion of the site as an abandoned / vacant quarry pit, while the central area is a scrubby-vegetation vacant property, with exposed high-bedrock and remnants of abandoned demolished concrete structures. The northeast corner of the property is vacant with agricultural hayfields.

The Site is bound by on the north boundary by Killaly Street West, the east boundary by a proposed future extension of West Side Road (but currently vacant), and the south is bound by a commercial railway tracks owned by the City of Port Colborne.

2.2.PROPOSED PROJECT

The purpose of this report is to provide recommendations for the soil capacity, foundation design and construction of an residential sub-division, including driveway pavement recommendations. The project proposes a variety of types of townhouses, mid-rise mixed-use buildings, and single detached dwellings.

3. SURFACE INVESTIGATIONS

Initial surface investigation was conducted through review of various sources:

- Site visits varying from 2022-2023
- Historic well records from O.Reg 903
- Niagara Region Mapping historic aerial photographs
- *A Soil Investigation for Proposed Residential Subdivision Part 3 to 6, Killaly Street West and West Side Road, City of Port Colborne, completed by Soil Engineers Ltd., dated Jan 2011*

From a general desktop review and initial site visits, some small amounts of soil cover are estimated to be available along the northeast corner (an existing hay field) or within the northwest corner (an undeveloped natural heritage complex of forests / wetlands). All other locations, especially in the south and central areas are expected to have minimal soil cover between 0 ~ 0.3m. Based on site visits, significant portions of the site has exposed bedrock.

4. SUB-SURFACE INVESTIGATIONS

Two separate sub-surface investigation program was conducted:

- Feb 2022 – three (3) deep groundwater monitoring wells, through bedrock
- May 2022 – nine (9) shallow boreholes investigating soil depths and construction of shallow-depth groundwater monitoring wells above the bedrock
- All borehole elevations and locations are geodetic using a survey-grade GPS

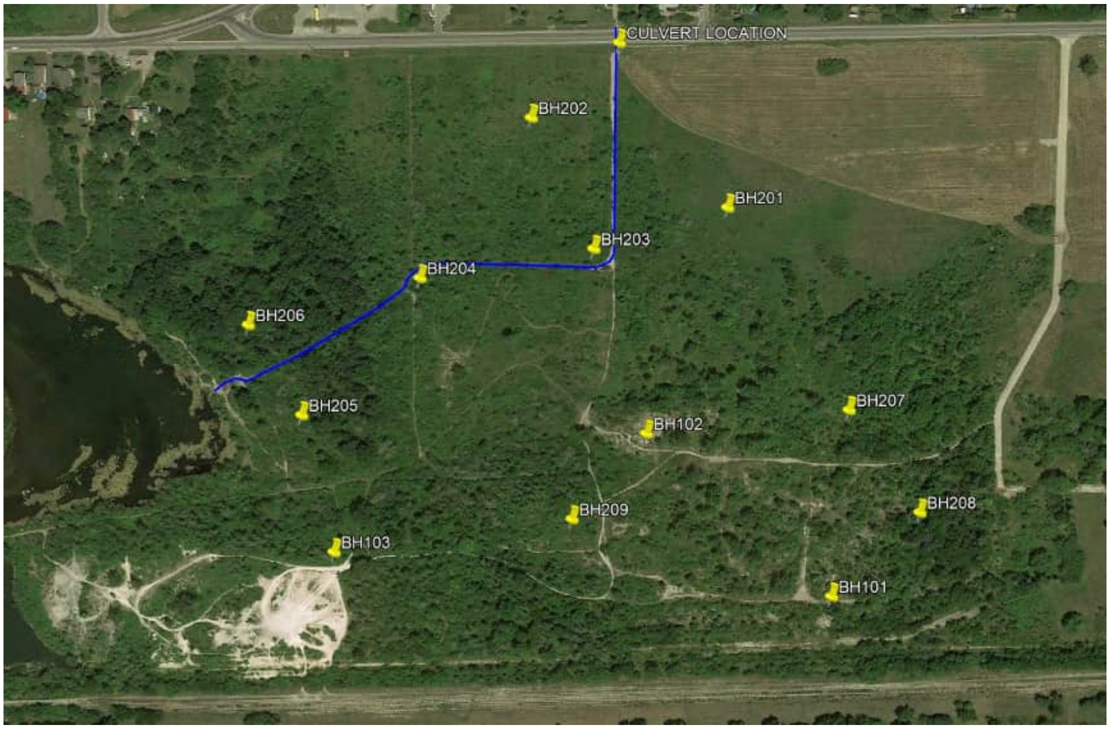


Figure 2 - Location of geotechnical investigation boreholes

4.1.BOREHOLE PROGRAM

Table 1 - BH and Monitoring Well Details

Borehole #	Drilled Date	Northing (UTM)	Easting (UTM)	Surface Elev. (amsl)	Hole Depth (m)	Screen Elevations (m)	Surface Soil type	GW Ecountered
101	2-Mar-22	4,749,772.78	641,413.98	179.69	15.12	164.6-167.7	Bedrock (gravel/stone with sandy clay)	yes
102	28-Feb-22	4,749,890.98	641,263.50	178.54	10.61	167.9-170.9	Bedrock (gravel/stone with sandy clay)	yes
103	2-Mar-22	4,749,799.28	641,016.77	179.3	11.13	168.2-171.2	Bedrock (gravel/stone with sandy clay)	yes
201	10-May-22	4,750,079.70	641,324.17	179.2	0.58	178.54-179.2	Clay with sand	no
202	11-May-22	4,750,147.77	641,166.72	179.1	0.58	178.52-179.1	Clay with sand and pebbles	no
203	11-May-22	4,750,044.10	641,218.90	180.84	1.0	179.84-180.84	Clay with sand	no
204	11-May-22	4,750,018.14	641,080.47	179.19	0.4	178.79-179.19	Clay with sand	no
205	12-May-22	4,749,907.61	640,988.00	178.59	0.58	178.03-178.59	Clay with sand	no
206	12-May-22	4,749,978.35	640,944.37	178.7	0.57	178.13-178.7	Clay with sand	no
207	9-May-22	4,749,920.37	641,424.74	179.96	0.53	179.43-179.96	Sandy clay	no
208	9-May-22	4,749,840.42	641,482.90	178.35	0.43	177.92-178.35	Clay with sand	no
209	9-May-22	4,749,829.82	641,205.52	178.35	1.4	176.95-178.35	Clay with stone chips/backfill	no

In general, all boreholes encountered limestone bedrock at approx 177 ~ 180m elevation. All twelve (12) boreholes were converted into groundwater monitoring wells at the end of the drill program.

4.2.STRATIGRAPHY & SOIL PHYSICAL PROPERTIES

Soil properties at the site, above the limestone bedrock, is generally categorized as moist clay, with significant amounts of backfill, concrete rubble, weathered bedrock sands, gravels, and other materials.

4.3.GROUNDWATER ELEVATIONS

Groundwater was measured on several dates, with only one sample date for the deep bedrock monitoring wells for BH101 – BH103. Out of all of the 200-series shallow groundwater monitoring wells, only BH205 found any groundwater depths.

BH205 had a bottom screening depth of 178.03 (due to auger refusal and start of bedrock), and groundwater was measured at a thickness of around 0.05 ~ 0.17m. This confirms that the area is a local shallow bowl, with groundwater generally flowing horizontally, and does not accumulate significantly.

Table 2 - Groundwater Elevation Review – March – September, 2022

Date		BH 101	BH 102	BH 103	BH 201	BH 202	BH 203	BH 204	BH 205	BH 206	BH 207	BH 208	BH 209	Lake Erie	Quarry pond
11-Mar-22	GW depth (mbgl)	11.45	2.87	1.88											
	GW Level (amsl)	168.237	175.667	177.43											
10-May-22	GW depth (mbgl)				–	–	–	–	–	–	–	–	–		
	GW Level (amsl)				–	–	–	–	–	–	–	–	–	174.46	174.88
8-Jun-22	GW depth (mbgl)				–	–	–	–	–	–	–	–	–		
	GW Level (amsl)				–	–	–	–	–	–	–	–	–	174.57	N/A
6-Jul-22	GW depth (mbgl)				–	–	–	–	0.36	–	–	–	–		
	GW Level (amsl)				–	–	–	–	178.23	–	–	–	–	174.33	174.63
10-Aug-22	GW depth (mbgl)				–	–	–	–	0.51	–	–	–	–		
	GW Level (amsl)				–	–	–	–	178.08	–	–	–	–	174.492	174.471
22-Sep-22	GW depth (mbgl)				–	–	–	–	–	–	–	–	–		
	GW Level (amsl)				–	–	–	–	–	–	–	–	–	174.531	174.464

It is the Engineer's opinion that for the purposes of establishing seasonal high groundwater elevation, that the soils and bedrocks generally do not accumulate groundwater. Any seasonal fluctuations is merely temporary perched groundwater on top of local depressions in natural bedrock.

5. DESIGN RECOMMENDATIONS

5.1. GEOTECHNICAL MODEL

Based on the borehole information, the following geotechnical model are stated:

- Layer #1, 0 – 0.6m, clay soils
  - May contain weathered bedrock, debris, sands and gravel
  - Topsoil may occur in the northeast corner property under agricultural hayfields, or in the northwest natural heritage forested areas
  - Certain locations within site do not have soil and are exposed bedrock

- Layer #2, varying depth, approx 0.6m and below, limestone bedrock
  - Weathered bedrock of approximate thickness of 1.0 ~ 1.5m
  - Full non-weathered bedrock with RQD of 90+ estimated at 1.0m below
  - Certain locations have stripped and bare smooth bedrock; RQD of 100

5.2. FROST PROTECTION

All exterior concrete footings are expected to be exposed to seasonal freezing conditions, with frost penetration down to 1.2 metres, as per OPSD 3090.101, Revision Nov 2010.

Based on OBC 9.12.2.2 Minimum Depth of Foundation requirements, where foundations are constructed on solid rock (non-pervious scraped rock), no minimum foundation depths are required. Where shallow soil cover is clay soils in local spots, it is recommended to excavated down sufficiently to expose bedrock and construct foundation directly on bedrock.

5.3. INITIAL FOUNDATION REVIEW

At the time of preparation of this report, design loading requirements have not been made available as the project is still within a proposed sub-division design stage. Conventional strip foundations with Serviceability Limit State (SLS) of rock bearing capacity of 400kPa may be used on top of clean / scraped weathered bedrock. Ultimate Limit State (ULS) rock bearing capacity of 600kPa may be used.

For the proposed mid-rise mixed-use buildings, an appropriate number of epoxy-grouted rebars should be drilled into bedrock to secure footings onto bedrock. Special attention should be paid to stripping / chipping and removal of all weathered bedrock prior to pouring concrete directly on top of bedrock.

5.4. SETTLEMENT CONSIDERATIONS

In general, soils within the “stress influence zone” beneath all foundation elements of a proposed structure will be consolidated after an extended period of time. This is an important factor to realize, since the SLS is highly impacted by the potential for differential settlement. For a large mid-rise building, differential settlement is mostly controlled by differences of the native soil from one side to the other, and by having sufficient soil-to-concrete contact area.

Excavation within the proposed work area should not be over-excavated, as overworked wet clay does not have good compaction characteristics, and any significant backfills below a proposed foundation to be either undisturbed native soil, or 98% compaction of OPSS 1010 Granular B, Type II, new (non-recycle).

5.5.SEIZEMIC LOADING

Using the information provided by the site investigation, the general soil profile comprises of "Hard rock – Site Class A" as defined by Table 4.1.8.4.A "Site Classification for Seismic Site Response" of the Ontario Building Code, defined by a very high Average Shear Wave Velocity Vs > 1500m/s for the identified limestone below.

5.6.OHSA SOIL TYPE & TRENCH SUPPORT

Using the information provided by the site investigation, the general soil profile (of the shallow clay overburden above bedrock) comprises of "Type 2 Soil" as defined Occupational Health and Safety Act (OHSA) O.Reg 213/91, section 226 "Soil Types".

Type 2 Soil is described as follows:

- Very stiff, dense. You can penetrate it with moderate difficulty by using a smalls harp object but a pick can be driven in easily
- Low to medium natural moisture content, medium degree of internal strength
- Has a damp appearance after it's excavated

Where personnel must enter a trench greater than 1.2m in depth, appropriate temporary shoring solutions must be installed, or, an appropriate 1H:1V benching / side slopes is required.

5.7.BACKFILL

Compaction of fill surrounding the outside of any foundation element or roadway should be compacted to at least 98% of the material's Standard Proctor Maximum Dry Density (SPMDD) within 1.0m of the final subgrade elevation, and then compacted to 100% SPMDD up to final grade. Compaction should be completed in multiple layers, using an appropriately sized steel vibrating roller machine. Smaller vibratory compacting machines must compact 75 – 150mm layers (and thus more total layers), while larger machines allow for thicker layers of compaction, at 150 – 300mm. Small confined locations not suitable for roller machines must be compacted by hand-held compaction equipment, such as jumping-jack style compactor. Small-scale landscaping / asphalt compaction plates are not suitable for compaction.

6. CONSTRUCTION DEWATERING

Construction dewatering is currently not expected to be required, as all of the 200-series boreholes shallow monitoring wells show that minimal groundwater is expected. Where construction dewatering is required, small-scale localized active dewatering with an electric pump and a local sump-pit, combined with an outlet silt filter, is usually sufficient.

7. SOIL INFILTRATION POTENTIAL

Based on a field visit dated August 10, 2022, "field-saturated" hydraulic conductivity, K_{fs}, was achieved using the "Constant Head Well Permeameter" (CHWP) method. K_{fs} was conducted in the southwest, near BH103 using the ETC Standard Pask Permeameter Apparatus, while for the second test located at the northeast, near the entrance, the ETC Slow Soils Pask Permeameter Apparatus was used. The "Constant Head Well Permeameter" (CHWP) method was described in Appendix III in detail.

It is understood that the in-situ infiltration test was not tested at any proposed LID bottom but based on sieve size analysis and borehole soil samples, it is in the Engineer's opinion as a geotechnical engineer that the soils perform similarly in hydrological infiltration potential.

The ETC Pask Permeameter is a convenient and easy-to-use apparatus for ponding a constant head of water in a well, and simultaneously measuring the flow into the soil. The K_{fs} was calculated as:

K_{fs1} = 2.3E-7 m/sec = 2.3E-5 cm/sec
K_{fs2} = 3.4E-5 m/sec = 3.4E-3 cm/sec

It should be noted that the first test has a low permeability in clay soils which confirms the upper thin soil layer (clay mixed with sand, d ~ 0.4 to 1.0m) has a low infiltration rate within this property while the second test shows a high infiltration rate in the lower bedrock layer (i.e., sandy clay). The second value would be used for infiltration calculations in the future development plan.

K_{fs} were then corrected for temperature (for soil temperature=28-29$^{\circ c}$):

K_{a1}=1.3E-7 m/sec = 1.3E-5 cm/sec
K_{a2}=1.9E-5 m/sec = 1.9E-3 cm/sec

Correlations between Perc Time (PT) and field-saturated hydraulic conductivity (K_{fs}) are often used in the development of on-site water recycling and treatment facilities that operate by infiltration into unsaturated soil. Based on OMMAH (1997) interpolation, the measured infiltration rate may be interpolated as:

PT = 5.9 min / cm   (Infiltration Rate = 102 mm/hour)

The engineer's opinion is to trust the values obtained from the OMMAH (1997), with an unfactored surface infiltration rate of 102mm/hour.

For a conservative approach to infiltration speeds, the Wisconsin Department of Natural Resources (2004) method shall be used for the calculation of a factored design infiltration rate and the Engineer's opinion is that the factored engineering design infiltration rate is 41 mm/hour, with a safety factor of 2.5.

8. POTENTIAL ISSUES DURING CONSTRUCTION

The following issues relating to geotechnical and hydrogeology may arise, and should be fully considered by the Client:

- The proposed residential sub-division will require remediation, based on the Environmental Site Assessment, Phase II Report, for the removal of surface-level contamination of metals. This would require scraping of all surface level soil materials (after removal of all organics and vegetation)
- Where excess soil need to be imported from off-site sources, it is mandatory that O.Reg 406/19 Excess Soil Management requirements to be reviewed, and that an efficient work flow to be developed by a Qualified Person (QP)
- Disturbance from small-scale chipping or drilling of bedrock is usually localized within the site, but any active rock blasting will need dedicated noise and vibration review, as well as blast mats / appropriate flyrock management.

9. PAVEMENT

In consideration to the sub-surface investigation, the main subgrade soil is wet / plastic clay. The pavement construction would consist of stripping the existing disturbed agricultural clays, historic concrete debris, stones greater than 150mm, and other wet clay soils, and then raising the existing grade from the prepared native subgrade surface to the underside of the granular base layer using on-site materials with full-time engineering-reviewed compaction.

The granular sub-base is designed using well graded granular fill material (OPSS 1010 Granular B – Type I), with the material being laid and compacted in thin lifts to at least 98% SPMDD. Compaction lift height must be appropriately sized for the weight of the compactor roller machine. Appropriate compaction will not be achieved in full depths if the compaction roller machine is too small, or if the lift height is too thick. Appropriate moisture content is mandatory to achieve the target compaction percentage.

Asphalt compaction must observe the industry standards of asphalt temperature, granular base & ambient temperature, rainfall forecasts, and appropriate compaction effort. A thin layer of asphalt tack coating is also recommended to be sprayed to improve binding between two asphalt layers. A deficit in any of the above factors may cause short-term cracking and delamination, while long-term issues include localized potholes, water infiltration into subgrade soils, and frost-heave expansion.
The below proposed asphalt and road base are based on virgin materials, and if recycled materials are to be used, then thicknesses should be increased appropriately by through re-design.

It is a requirement that appropriate quality assurance and quality control be conducted during all phases of the roadway and pavement construction process. Specific testing requirements include: SPMDD, compaction %, moisture %, material validation, and temperature checks. Note that during construction, test pits may be conducted to evaluate if the existing granular thicknesses achieves the Granular Base / Granular Sub-Base requirements from Table 3.

Table 3 - Pavement Recommendations

Road Layer	Material	Specification	Thickness (mm)
Layer #1 Surface Course Asphalt	Asphaltic Material OPSS 1150/310	HL3 Surface Course	40; tack binder below
Layer #2 Base Course Asphalt	Asphaltic Material OPSS 1150/310	HL8 Base Course	100; 2 layers with tack
Layer #3 Granular Base	Granular Material OPSS 1010	Granular A, new	150
Layer #4 Granular Sub-Base	Granular Material OPSS 1010	Granular B - Type I - new	600
Layer #5 Engineered Fill Soils	Native soils, sandy clay	98% SPMDD	Compact in 150 ~ 300mm layers

10. SUMMARY

The geotechnical aspects of the final design drawings and specifications should be reviewed by King EPCM prior to tendering and construction, and to confirm that the intent of this report has been met. During construction, full-time engineered fill monitoring and sufficient foundation inspections, subgrade inspections, in-situ density tests and materials testing should be carried out. As the proposed residential sub-division needs significant amount of cut and fill, especially around the proposed municipal road, appropriate and consistent tests must be carried out to ensure proper compaction.

King EPCM appreciates the opportunity to be of service for this project, and trusts that this report provides sufficient geotechnical engineering information for a detailed design of the project. King EPCM looks forward to providing continued service during the construction stage. Please do not hesitate to contact King EPCM at any time if there are any questions regarding this project.

Sincerely,

Tony Wang, P. Eng
Principal Engineer

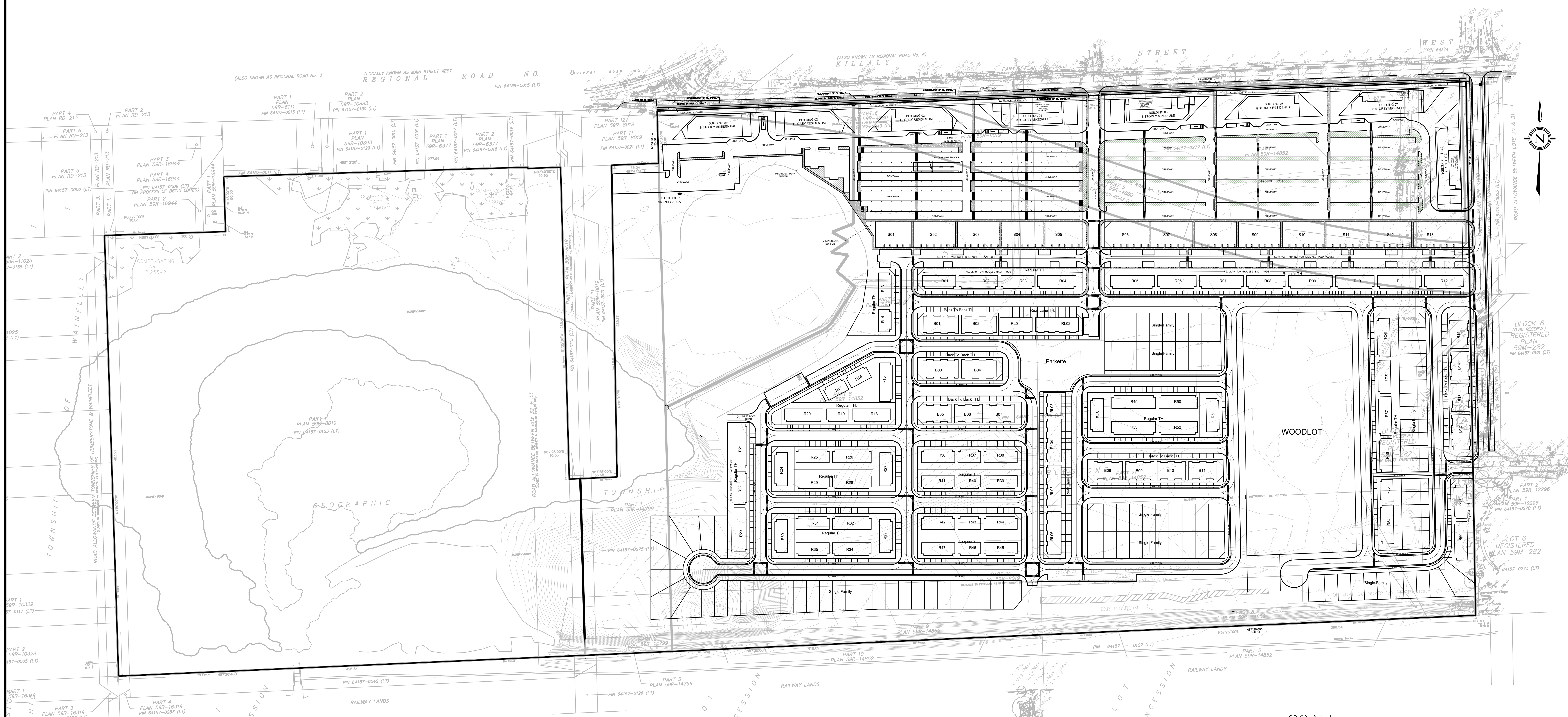
LICENSED PROFESSIONAL ENGINEER
Y. T. WANG
100228476
02/07/2024
PROVINCE OF ONTARIO

APPENDIX I – SITE PLAN

GENERAL NOTES:

1. THIS IS A COMBINED LEGAL SURVEY AND SITE TOPOGRAPHIC SURVEY:
   - LEGAL SURVEY IS BASED ON "BARICH GRENKIE SURVEYING LTD." ON DEC. 22, 2022
   - SPOT ELEVATIONS ABUTTING PROPERTY BOUNDARY AND ROADS ARE BASED ON "BARICH GRENKIE SURVEYING LTD." ON DEC. 20, 2022
   - ELEVATION CONTOUR LINES WITHIN PROPERTY BOUNDARY ARE BASED ON "CHAMBERS AND ASSOCIATES SURVEYING LTD." ON DEC. 20, 2010.
   - NATURAL HERITAGE CONSIDERATIONS AND WATER LEVEL ARE BASED ON "TERRASTORY ENVIRONMENTAL CONSULTING INC." ON OCT. 30, 2022
2. ALL MEASUREMENTS STATED IN METERS

DRAFT – NOT FOR CONSTRUCTION

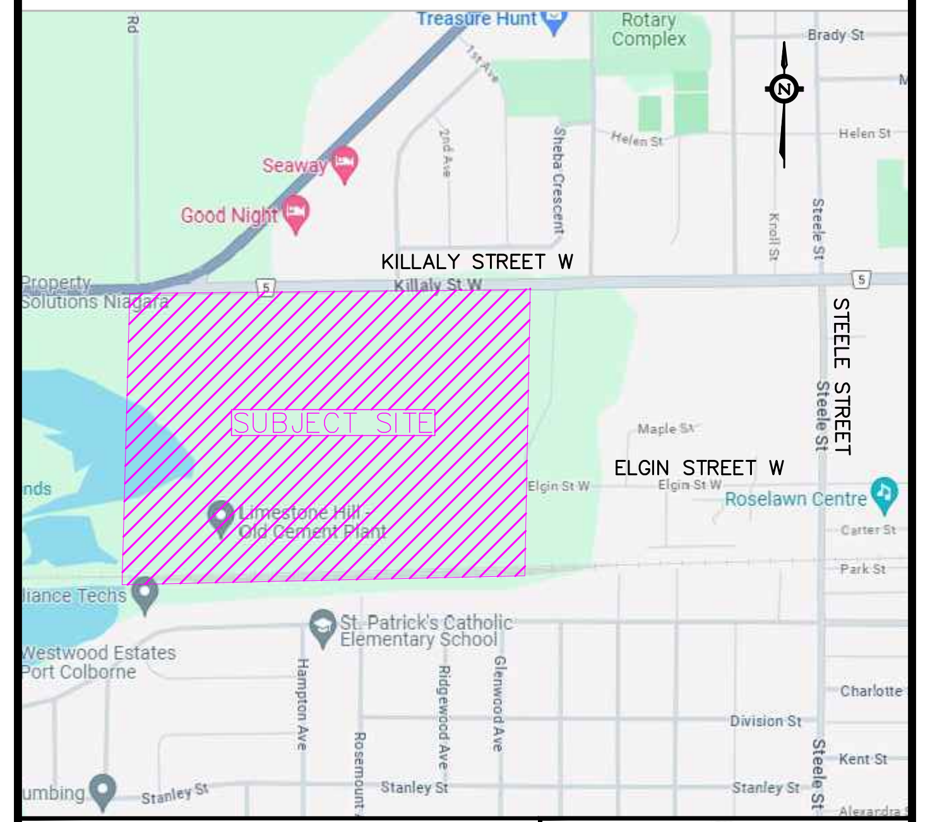


SCALE
1: 2000
1cm = 20m

0m 100m 200m

KEY MAP

N.T.S.



DRAWN

K.L.

DATE

JAN. 19, 2024

STAMP

Y. T. WANG
100228476
FEB 06, 2024

KING EPCM

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CLIENT

1000046816 Ontario Limited

PROJECT NAME

MAPLEVIEW PORT COLBORNE HOMES DEVELOPMENT AREA

PROJECT LOCATION

PARTS OF LOT 31 & 32,
CONCESSION 1,
TOWNSHIP OF HUMBERSTONE,
CITY OF PORT COLBORNE,
KILLALY STREET WEST

PRINT TITLE

DEVELOPABLE AREA (30M OFFSET FROM WATER LEVER) & NATURAL HERITAGE CONSIDERATIONS

FILE No.

SITE PLAN

No.	ISSUED FOR:	DATE	DRAW BY	CHECK
V2	ISSUED TO CLIENT	JAN 19, 2024	K.L.	
V3	FIRST SUBMISSION	FEB 06, 2024	K.L.	

APPENDIX II – BOREHOLE DRILL LOG


CULVERT LOCATION
BH202
BH201
BH203
BH204
BH206
BH205
BH207
BH102
BH208
BH209
BH103
BH101

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BOREHOLE AND GROUNDWATER WELL LOG BH101 MW

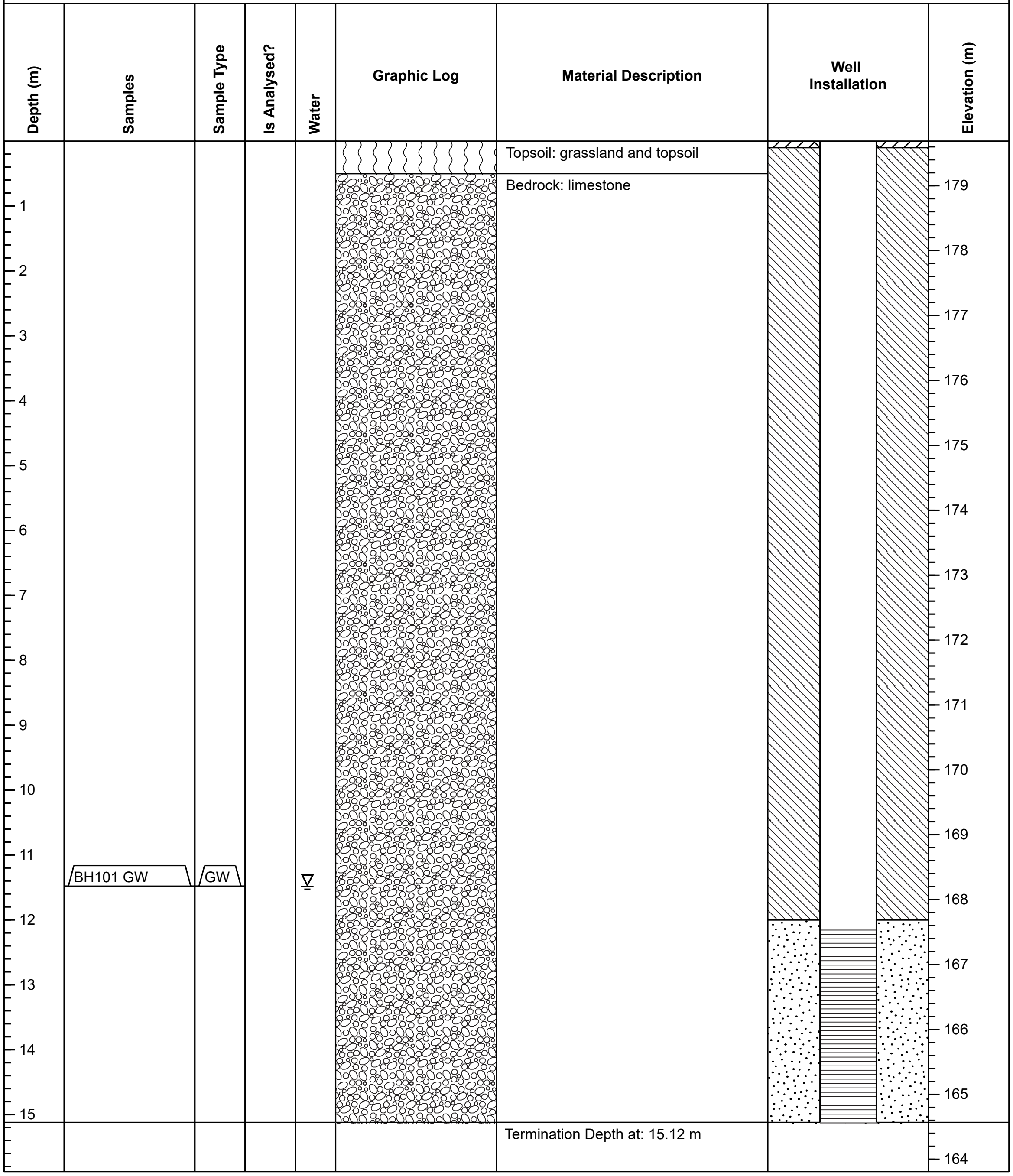
PROJECT NUMBER
PROJECT NAME Phase II ESA
CLIENT 1000046816 Ontario Limited
ADDRESS Mapleview Port Colborne
DRILLING DATE March 2, 2022
LICENCE NO.

DRILLING COMPANY Terra Firma Environmental
DRILLER
DRILL RIG D-50 Drilling Rig
DRILLING METHOD Continuous Flight Auger
TOTAL DEPTH 15.12 m
DIAMETER 2 Inch Well

COORDINATES N:4749772.78m E:641413.98m
COORD SYS UTM17
SURFACE ELEVATION 179.687m
WELL TOC
LOGGED BY CC
CHECKED BY TW

COMPLETION
CASING Casing up type
SCREEN 3 m from the bottom of Well

COMMENTS GW sampled on March 11, 2022



Topsoil: grassland and topsoil

Bedrock: limestone

Termination Depth at: 15.12 m

produced by ESlog.ESdat.net on 28 Mar 2022

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BOREHOLE AND GROUNDWATER WELL LOG BH102 MW

PROJECT NUMBER
PROJECT NAME Phase II ESA
CLIENT 1000046816 Ontario Limited
ADDRESS Mapleview Port Colborne
DRILLING DATE Febuary 28, 2022
LICENCE NO.

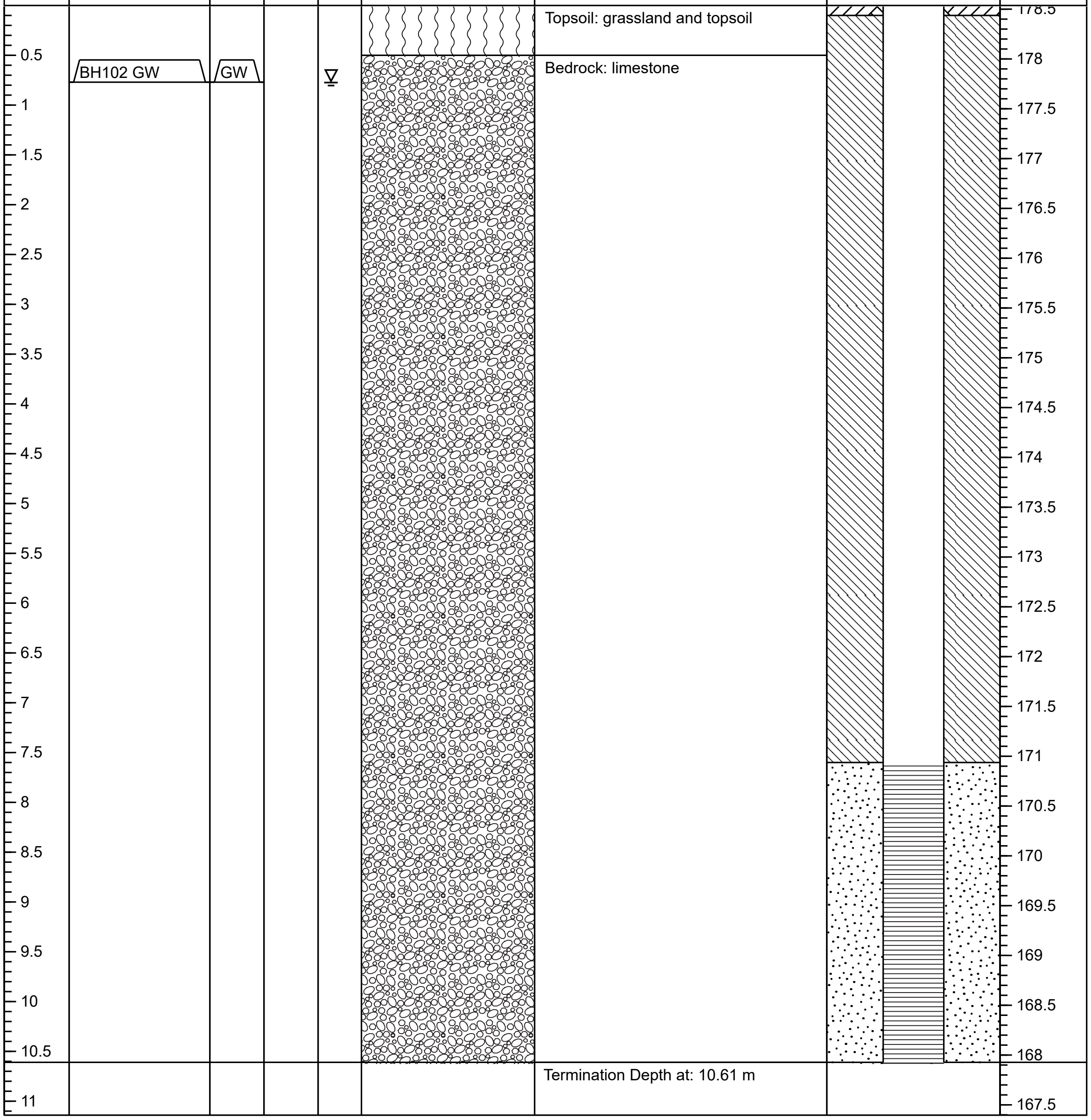
DRILLING COMPANY Terra Firma Environmental
DRILLER
DRILL RIG D-50 Drilling Rig
DRILLING METHOD Continuous Flight Auger
TOTAL DEPTH 10.61 m
DIAMETER 2 Inch Well

COORDINATES N:4749890.98m E:641263.50m
COORD SYS UTM17
SURFACE ELEVATION 178.537m
WELL TOC
LOGGED BY SX
CHECKED BY TW

COMPLETION
CASING Casing up type
SCREEN 3 m from the bottom of Well

COMMENTS GW sampled on March 11, 2022

Depth (m)	Samples	Sample Type	Is Analysed?	Water	Graphic Log	Material Description	Well Installation	Elevation (m)
0						Topsoil: grassland and topsoil		178.5
0.5	BH102 GW	GW		⊻		Bedrock: limestone		178
10.61						Termination Depth at: 10.61 m		167.9



produced by ESlog.ESdat.net on 28 Mar 2022

BOREHOLE AND GROUNDWATER WELL LOG BH103 MW

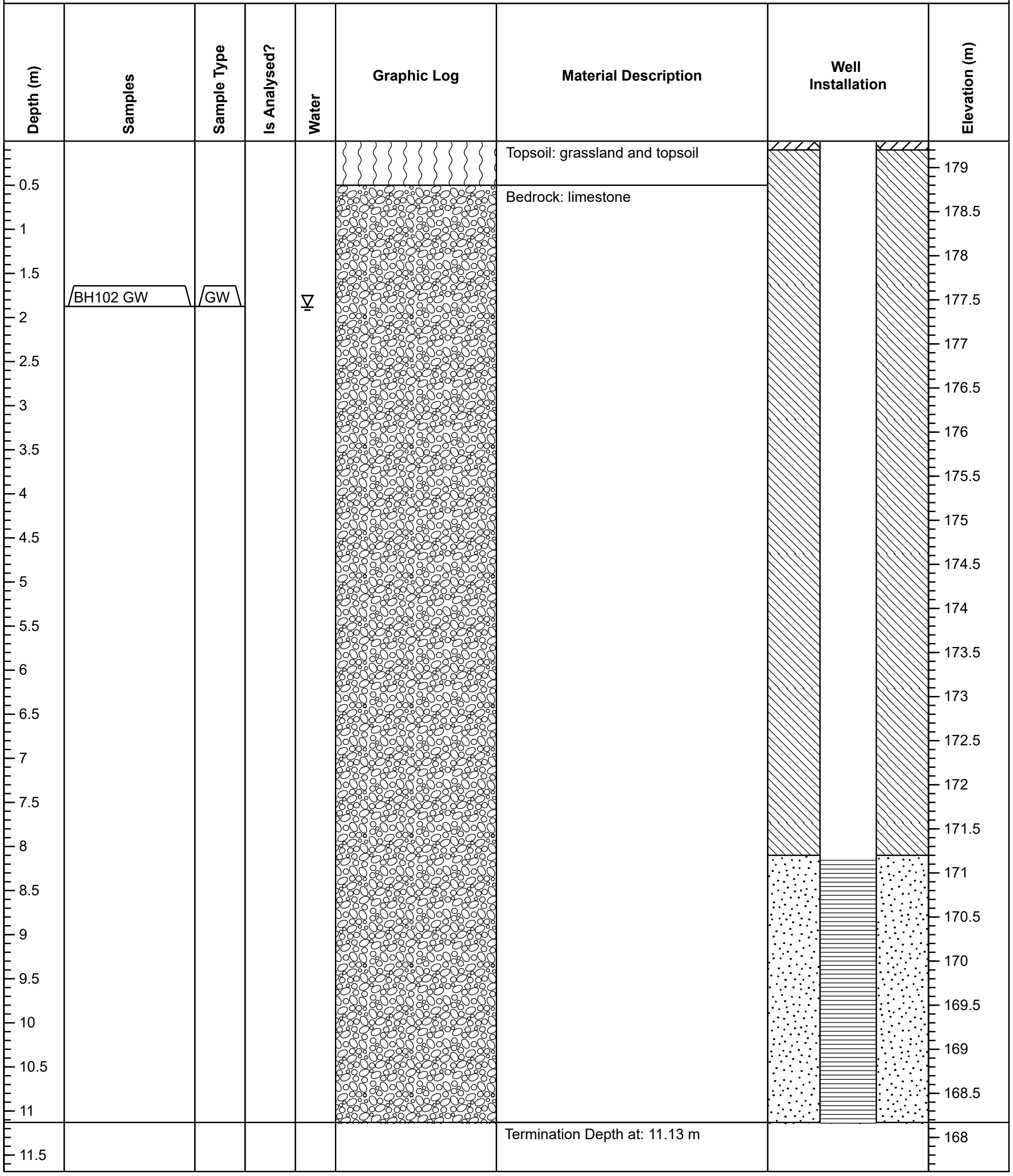
PROJECT NUMBER
PROJECT NAME Phase II ESA
CLIENT 1000046816 Ontario Limited
ADDRESS Mapleview Port Colborne
DRILLING DATE March 2, 2022
LICENCE NO.

DRILLING COMPANY Terra Firma Environmental
DRILLER
DRILL RIG D-50 Drilling Rig
DRILLING METHOD Continuous Flight Auger
TOTAL DEPTH 11.13 m
DIAMETER 2 Inch Well

COORDINATES N:4749799.28m E:641016.77m
COORD SYS UTM17
SURFACE ELEVATION 179.3m
WELL TOC
LOGGED BY CC
CHECKED BY TW

COMPLETION
CASING Casing up type
SCREEN 3 m from the bottom of Well

COMMENTS GW sampled on March 11, 2022



Topsoil: grassland and topsoil

Bedrock: limestone

Termination Depth at: 11.13 m

produced by ESlog.ESdat.net on 25 Mar 2022

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GROUNDWATER MONITORING Well BH201

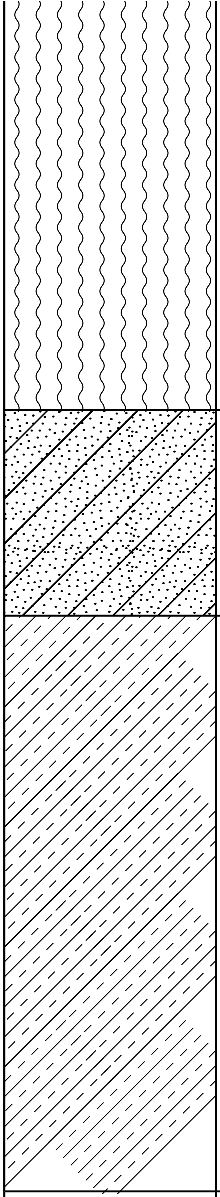
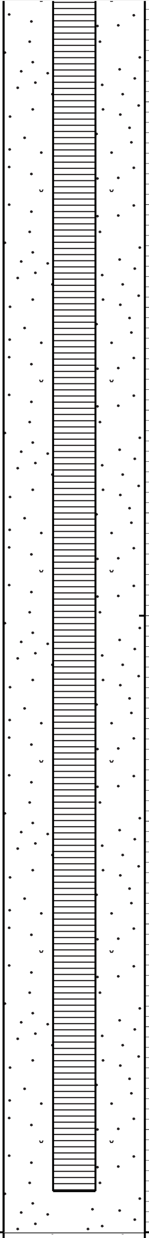
PROJECT NUMBER
PROJECT NAME
CLIENT
ADDRESS Mapleview, PORT COLBORNE
DRILLING DATE 05/10/2022
LICENCE NO. C-7691

DRILLING COMPANY King EPCM
DRILLER Chris Chen
DRILL RIG
DRILLING METHOD Hand Auger
TOTAL DEPTH 0.58
DIAMETER 1.5 inch

COORDINATES 641324.17E, 4750079.70N
COORD SYS UTM-17
SURFACE ELEVATION
WELL TOC None
LOGGED BY Chris Chen
CHECKED BY Tony Wang, P Eng, Principal Engineer

COMPLETION
CASING 1.25 inch
SCREEN 1.25 inch

COMMENTS

Depth (m)	Graphic Log	USCS SAMPLES	Material Description	Additional Observations	Well Installation	Elevation (m)
0.05 0.1 0.15			Topsoil, Black wet			179.1 179.0 179
0.2 0.25		USCS: SC	Brown, moist clay mixed with sand, very plastic			178.9 178.9
0.3 0.35 0.4 0.45 0.5 0.55		USCS: OH	Dark yellow, moist clay, very plastic			178.8 178.8 178.7 178.7 178.6 178.6
0.6						178.5
			Termination Depth at: 0.58 m hit bedrock			

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GROUNDWATER MONITORING Well BH202

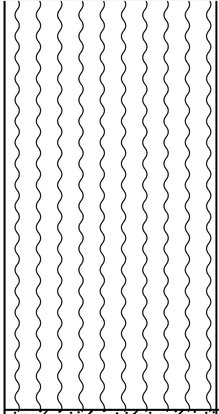
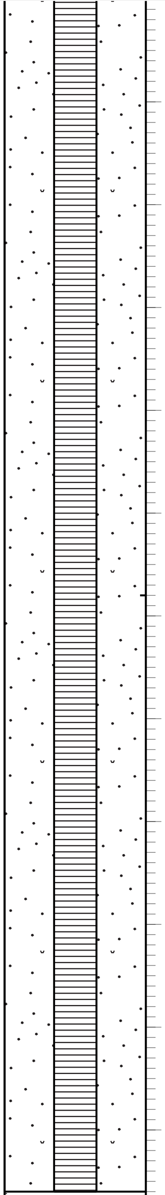
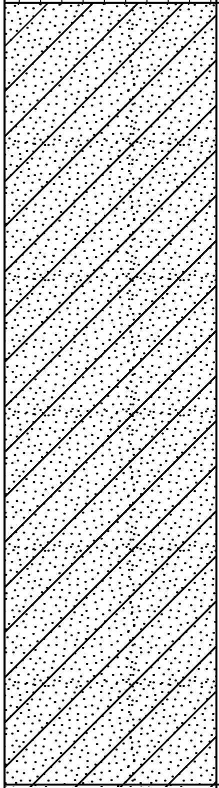
PROJECT NUMBER
PROJECT NAME
CLIENT
ADDRESS Mapleview, PORT COLBORNE
DRILLING DATE 05/11/2022
LICENCE NO. C-7691

DRILLING COMPANY King EPCM
DRILLER Chris Chen
DRILL RIG
DRILLING METHOD Hand Auger
TOTAL DEPTH 0.58 m
DIAMETER 1.5 inch

COORDINATES 641166.72E, 4750147.77N
COORD SYS UTM-17
SURFACE ELEVATION
WELL TOC None
LOGGED BY Chris Chen
CHECKED BY Tony Wang, P Eng, Principal Engineer

COMPLETION
CASING 1.25 inch
SCREEN 1.25 inch

COMMENTS

Depth (m)	Graphic Log	USCS SAMPLES	Material Description	Additional Observations	Well Installation	Elevation (m)
0.05 0.1 0.15			Topsoil, Black, moist			179.0 179 178.9
0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55		USCS: SC	Brown, moist clay mixed with sand and pebbles, very plastic			178.9 178.8 178.8 178.7 178.7 178.6 178.6 178.5
0.6			Termination Depth at: 0.58 m hit bedrock			178.5

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GROUNDWATER MONITORING Well BH203

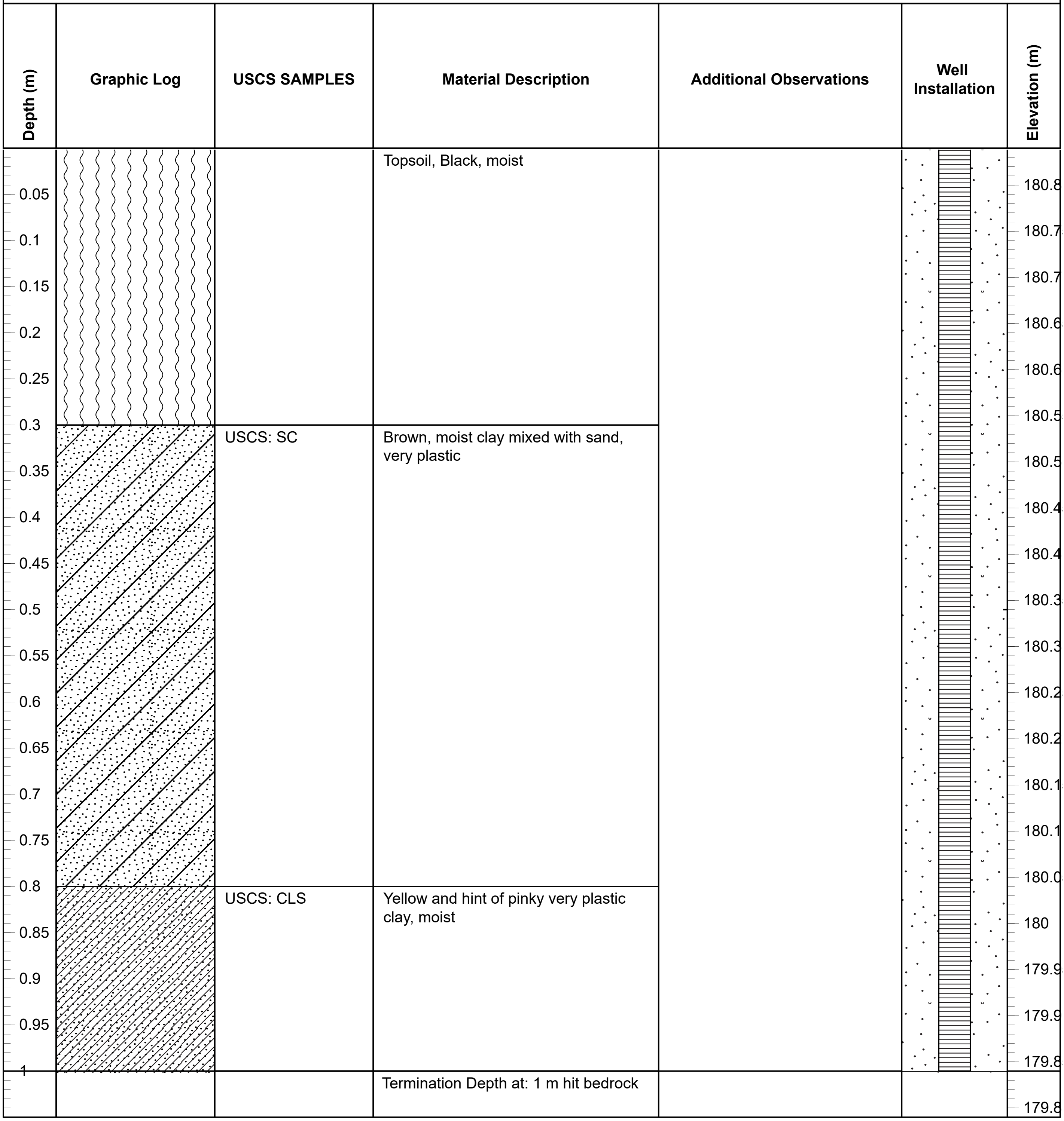
PROJECT NUMBER
PROJECT NAME
CLIENT
ADDRESS Mapleview, PORT COLBORNE
DRILLING DATE 05/11/2022
LICENCE NO. C-7691

DRILLING COMPANY King EPCM
DRILLER Chris Chen
DRILL RIG
DRILLING METHOD Hand Auger
TOTAL DEPTH 1 m
DIAMETER 1.5 inch

COORDINATES 641218.90E, 4750044.10N
COORD SYS UTM-17
SURFACE ELEVATION
WELL TOC None
LOGGED BY Chris Chen
CHECKED BY Tony Wang, P Eng, Principal Engineer

COMPLETION
CASING 1.25 inch
SCREEN 1.25 inch

COMMENTS



Depth (m)	Graphic Log	USCS SAMPLES	Material Description	Additional Observations	Well Installation	Elevation (m)
0			Topsoil, Black, moist			
0.3		USCS: SC	Brown, moist clay mixed with sand, very plastic			
0.8		USCS: CLS	Yellow and hint of pinky very plastic clay, moist			
1			Termination Depth at: 1 m hit bedrock			

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GROUNDWATER MONITORING Well BH204

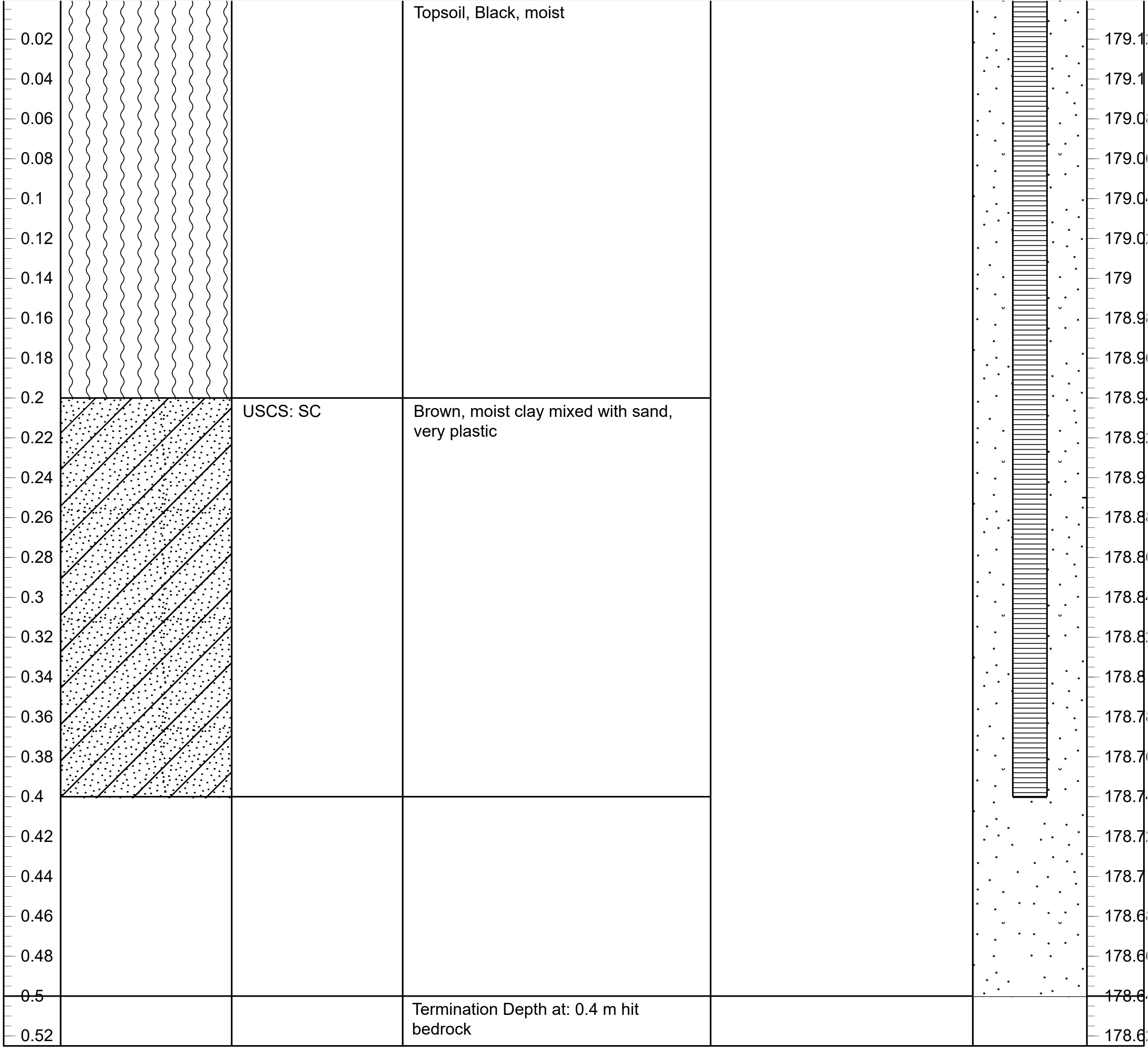
PROJECT NUMBER
PROJECT NAME
CLIENT
ADDRESS Mapleview, PORT COLBORNE
DRILLING DATE 05/11/2022
LICENCE NO. C-7691

DRILLING COMPANY King EPCM
DRILLER Chris Chen
DRILL RIG
DRILLING METHOD Hand Auger
TOTAL DEPTH 0.4 m
DIAMETER 1.5 inch

COORDINATES 641080.47E, 4750018.14N
COORD SYS UTM-17
SURFACE ELEVATION
WELL TOC None
LOGGED BY Chris Chen
CHECKED BY Tony Wang, P Eng, Principal Engineer

COMPLETION
CASING 1.25 inch
SCREEN 1.25 inch

COMMENTS



Depth (m)	Graphic Log	USCS SAMPLES	Material Description	Additional Observations	Well Installation	Elevation (m)
			Topsoil, Black, moist			
		USCS: SC	Brown, moist clay mixed with sand, very plastic			
			Termination Depth at: 0.4 m hit bedrock			

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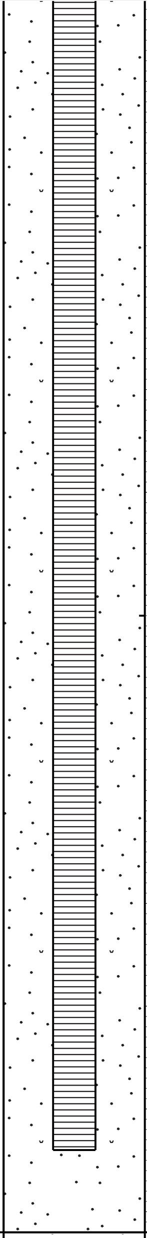
GROUNDWATER MONITORING Well BH205

PROJECT NUMBER	**DRILLING COMPANY** King EPCM	**COORDINATES** 640988.00E, 4749907.61N
PROJECT NAME	**DRILLER** Chris Chen	**COORD SYS** UTM-17
CLIENT	**DRILL RIG**	**SURFACE ELEVATION**
ADDRESS Mapleview, PORT COLBORNE	**DRILLING METHOD** Hand Auger	**WELL TOC** None
DRILLING DATE 05/12/2022	**TOTAL DEPTH** 0.56 m	**LOGGED BY** Chris Chen
LICENCE NO. C-7691	**DIAMETER** 1.5 inch	**CHECKED BY** Tony Wang, P Eng, Principal Engineer
COMPLETION	**CASING** 1.25 inch	**SCREEN** 1.25 inch

COMMENTS

Depth (m)	Graphic Log	USCS SAMPLES	Material Description	Additional Observations	Well Installation	Elevation (m)
0.05 0.1 0.15			Topsoil, Black, very wet			178.5 178.5 178.4 178.4
0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55	▨	USCS: SC	Brown, moist clay mixed with sand, very plastic			178.3 178.3 178.2 178.2 178.1 178.1 178.0
0.6						178
			Termination Depth at: 0.56 m hit bedrock			

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GROUNDWATER MONITORING Well BH206

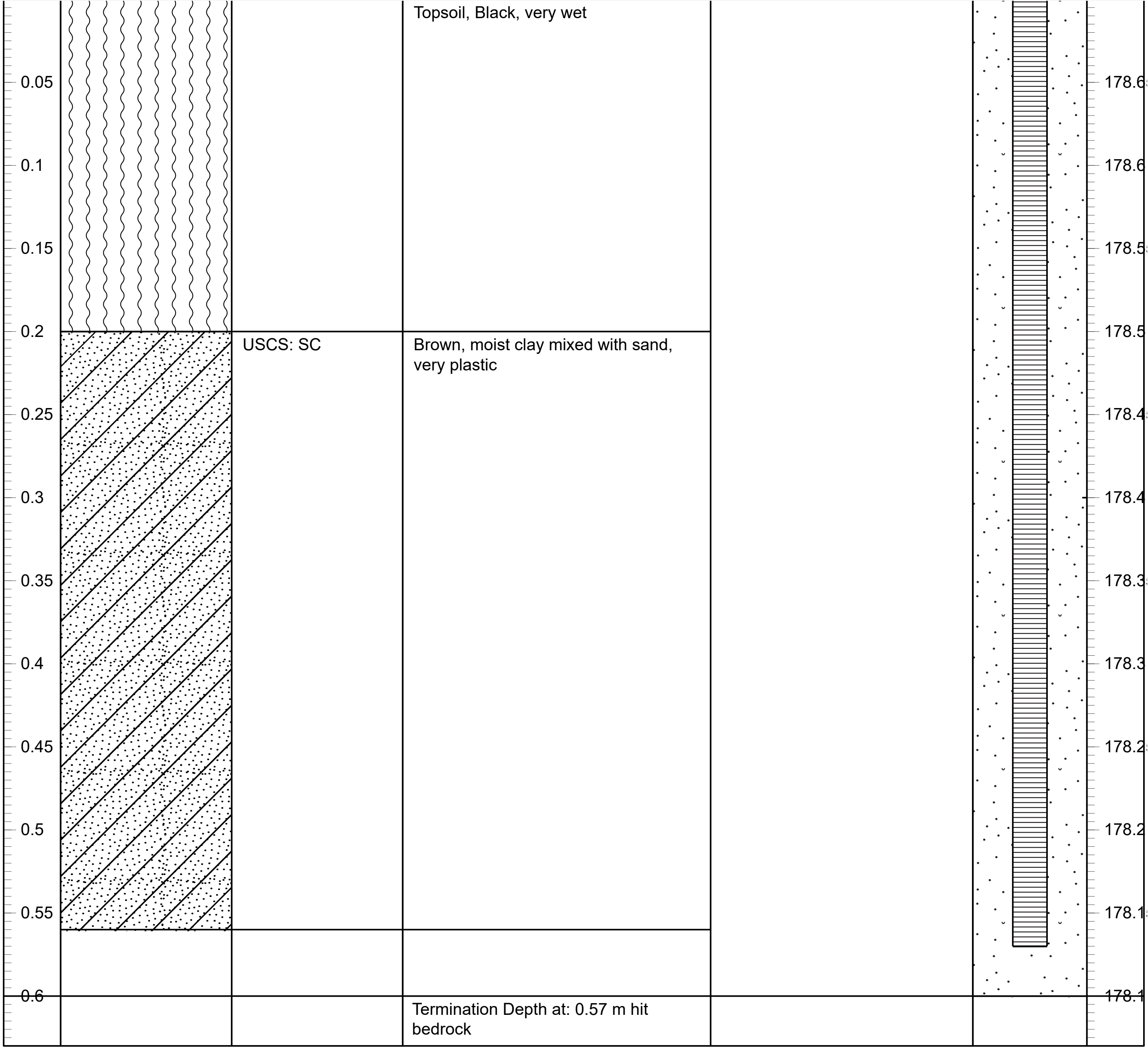
PROJECT NUMBER
PROJECT NAME
CLIENT
ADDRESS Mapleview, PORT COLBORNE
DRILLING DATE 05/12/2022
LICENCE NO. C-7691

DRILLING COMPANY King EPCM
DRILLER Chris Chen
DRILL RIG
DRILLING METHOD Hand Auger
TOTAL DEPTH 0.57 m
DIAMETER 1.5 inch

COORDINATES 640944.37E, 4749978.35N
COORD SYS UTM-17
SURFACE ELEVATION
WELL TOC None
LOGGED BY Chris Chen
CHECKED BY Tony Wang, P Eng, Principal Engineer

COMPLETION
CASING 1.25 inch
SCREEN 1.25 inch

COMMENTS



Depth (m)	Graphic Log	USCS SAMPLES	Material Description	Additional Observations	Well Installation	Elevation (m)
0–0.2			Topsoil, Black, very wet			
0.2–0.56		USCS: SC	Brown, moist clay mixed with sand, very plastic			
			Termination Depth at: 0.57 m hit bedrock			

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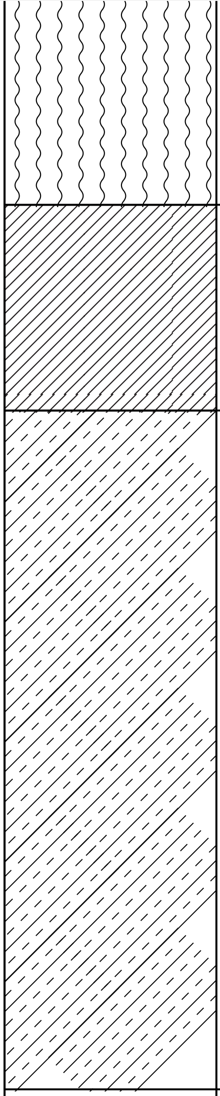
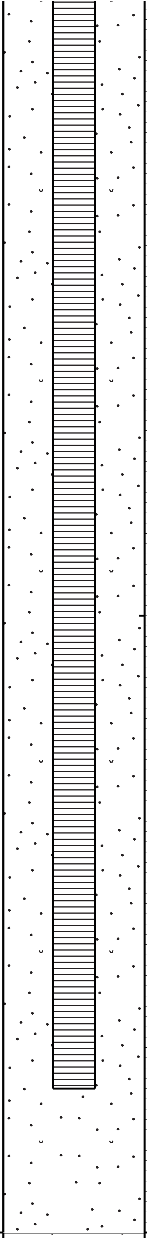
GROUNDWATER MONITORING Well BH207

PROJECT NUMBER	**DRILLING COMPANY** King EPCM	**COORDINATES** 641424.74E, 4749920.37N
PROJECT NAME	**DRILLER** Pincheng Zhao, Chris Chen	**COORD SYS** UTM-17
CLIENT	**DRILL RIG**	**SURFACE ELEVATION**
ADDRESS Mapleview, PORT COLBORNE	**DRILLING METHOD** Hand Auger	**WELL TOC** None
DRILLING DATE 05/09/2022	**TOTAL DEPTH** 0.53	**LOGGED BY** Chris Chen
LICENCE NO. C-7691	**DIAMETER** 1.5 inch	**CHECKED BY** Tony Wang, P Eng, Principal Engineer
COMPLETION	**CASING** 1.25 inch	**SCREEN** 1.25 inch

COMMENTS





Depth (m)	Graphic Log	USCS SAMPLES	Material Description	Additional Observations	Well Installation	Elevation (m)
0.05			Topsoil, Black moist			179.9 179.9
0.1 0.15		USCS: CL	Brown sandy clay, plasticky			179.8 179.8
0.2 0.25 0.3 0.35 0.4 0.45 0.5		USCS: OH	Black moist clay, plasticky			179.7 179.7 179.6 179.6 179.5 179.5 179.4
0.55						179.4
0.6			Termination Depth at: 0.53 m hit bedrock			179.3

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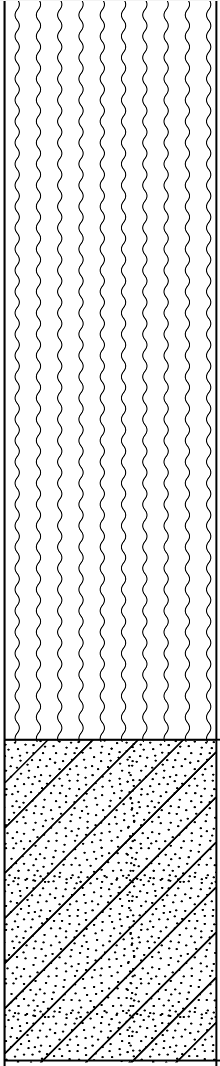
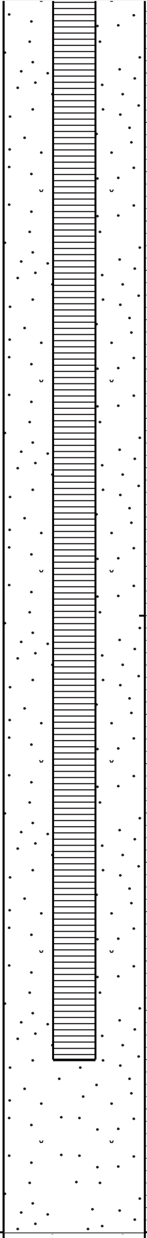
GROUNDWATER MONITORING Well BH208

PROJECT NUMBER	**DRILLING COMPANY** King EPCM	**COORDINATES** 641482.90E, 4749840.42N
PROJECT NAME	**DRILLER** Pincheng Zhao, Chris Chen	**COORD SYS** UTM-17
CLIENT	**DRILL RIG**	**SURFACE ELEVATION**
ADDRESS Mapleview, PORT COLBORNE	**DRILLING METHOD** Hand Auger	**WELL TOC** None
DRILLING DATE 05/09/2022	**TOTAL DEPTH** 0.43	**LOGGED BY** Chris Chen
LICENCE NO. C-7691	**DIAMETER** 1.5 inch	**CHECKED BY** Tony Wang, P Eng, Principal Engineer
COMPLETION	**CASING** 1.25 inch	**SCREEN** 1.25 inch

COMMENTS





Depth (m)	**Graphic Log**	**USCS SAMPLES**	**Material Description**	**Additional Observations**	**Well Installation**	**Elevation (m)**
0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16 0.18 0.2 0.22 0.24 0.26 0.28			Topsoil, Black moist			178.3 178.3 178.3 178.2 178.2 178.2 178.2 178.2 178.1 178.1 178.1 178.1 178.1 178.0 178.0
0.3 0.32 0.34 0.36 0.38 0.4 0.42		USCS: SC	Brown, black moist clay mixed with sand, plastic			178.0 178.0 178 177.9 177.9 177.9
0.44 0.46 0.48						177.9 177.9 177.8 177.8
0.5 0.52			Termination Depth at: 0.43 m hit bedrock			177.8

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GROUNDWATER MONITORING Well BH209

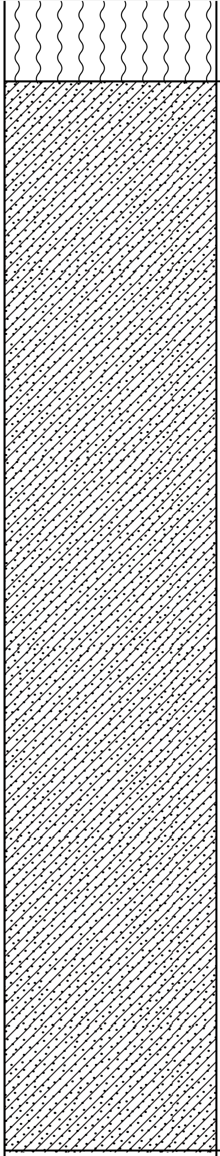
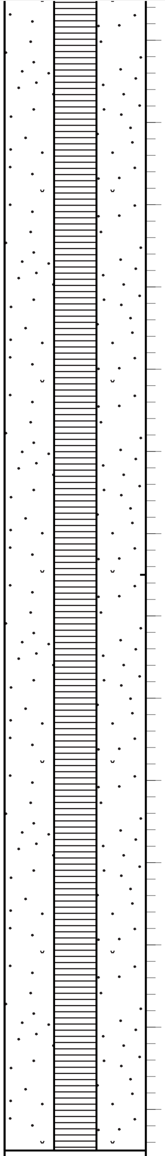
PROJECT NUMBER
PROJECT NAME
CLIENT
ADDRESS Mapleview, PORT COLBORNE
DRILLING DATE 05/09/2022
LICENCE NO. C-7691

DRILLING COMPANY King EPCM
DRILLER Pincheng Zhao, Chris Chen
DRILL RIG
DRILLING METHOD Continuous Flight Auger
TOTAL DEPTH 1.4
DIAMETER 1.5 inch

COORDINATES 641205.52E, 4749829.82N
COORD SYS UTM-17
SURFACE ELEVATION
WELL TOC None
LOGGED BY Chris Chen
CHECKED BY Tony Wang, P Eng, Principal Engineer

COMPLETION
CASING 1.25 inch
SCREEN 1.25 inch

COMMENTS

Depth (m)	Graphic Log	USCS SAMPLES	Material Description	Additional Observations	Well Installation	Elevation (m)
0.1			Topsoil, Black moist			178.3
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4		USCS: CLS	Brown, dark yellow moist clay mixed, plastic, with stone chips/refills			178.2 178.1 178 177.9 177.8 177.7 177.6 177.5 177.4 177.3 177.2 177.1 177
1.5						176.9
			Termination Depth at: 1.4 m			176.8

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APPENDIX III – INFILTRATION TEST DATA

In-situ Measurement of Field Saturated Hydraulic Conductivity

1. Field Permeability Test

The "Constant Head Well Permeameter" (CHWP) method (Reynolds, 1993; Elrick and Reynolds, 1986) is based on the observation that when a constant height or "head" of water is ponded in a borehole or "well" augured into unsaturated soil, a "bulb" of field-saturated soil is gradually established around the base of the well. The K_{fs} value achieved through this method can be less than or equal to half of K_s (Saturated hydraulic conductivity) due to partial blocking of soil pores by air bubbles and it is preferred over Ks in the design of on-site stormwater LID infiltration design, because drainage through the soil should be designed to occur at less than complete soil saturation.

The in-situ measurements were done by the ETC Soils Pask Permeameter, is an extended single-head analysis method and calculations procedure used here are based on the work of W.D. Reynolds and D.E. Elrick formerly of the University of Guelph, Ontario, Canada.

The ETC Pask Permeameter is a convenient and easy to use apparatus for ponding a constant head of water in a well, and simultaneously measuring the flow into the soil. The rate of fall (R) of the water level in the permeameter reservoir and reservoir cross-sectional area (X) allows determination of quasi steady water flow Irate (Q) into the soil (i.e Q = XR). K_{fs} is then calculated using Equation 1 (Reynolds, 1993):

$$K_{fs} = CQ / [2\pi H^2 + C\pi a^2 + (2\pi H/\alpha^*)] \qquad \text{(Eq. 1)}$$

In which:
K_{fs} = the calculated permeability from the field test

Table 1. Parameters used

Parameter	**Description**	**1**	**2**
		NE	**SW**
Soil Texture Factor (**α***) in cm^{-1}	* Porous materials that are both fine textured and massive; including unstructured clayey and silty soils, as well as very fine to fine structureless sandy materials. ** Coarse and gravelly sands; may also include some highly structured soils with large cracks and /or macropores.	0.04	0.36
R in cm/min	Quasi steady state (constant) rate of fall of water in permeameter reservoir (Measured in the site)	0.3	4.9
μ_k/μ_a	Temperature Correction Factor (t= 28-29°c)	0.567	
C	Shape factor	1.35	1.36
X in cm^2	Cross-sectional area of permeameter reservoir	53.46	12.80
H	Height of air inlet hole from bottom of the test hole	15	

in cm		
a in cm	Well hole radius	4.15

Based on data described in the above table and using Pask Permeameter ETC Quick Field Reference Tables for both Standard (BH2) and Slow Soils (BH1), the K_{fs} was calculated as:

K_{fs1} = 2.3E-7 m/sec = 2.3E-5 cm/sec
K_{fs2} = 3.4E-5 m/sec = 3.4E-3 cm/sec

And then the temperature corrected permeability would be calculated using equation 2 as follows:

$$K_a = K_{fs} \text{ x } \mu_k/\mu_a \qquad \text{(Eq. 2)}$$

In which:
K_a = corrected permeability adjusted for design temperature conditions

Then using the temperature correction factor (for t=28-29$^{°c}$) from the manual:
K_{a1}=1.3E-7 m/sec = 1.3E-5 cm/sec
K_{a2}=1.9E-5 m/sec = 1.9E-3 cm/sec

The field permeability data sheet is in the following.

2. Percolation time/infiltration rate for design (Reynolds et al., 2015)

Correlations between Perc Time (PT) and field-saturated hydraulic conductivity (K_{fs}) are often used in development of on-site water recycling and treatment facilities that operate by infiltration into unsaturated soil. The physically based PT versus K_{fs} expression in Reynolds et al. (2015) for cylindrical test holes in unsaturated soil can be simplified to Eq. 3.

$$PT = \frac{\Delta t}{\Delta H} = m\mathrm{K}_{fs}^{-1} \qquad \text{(Eq. 3)}$$

Where:

$$m = \frac{\bar{C}a^2}{\left[2\bar{H}^2+\bar{C}a^2+\frac{2\bar{H}[1-\exp(\alpha\,\psi_\alpha)]}{\alpha}\right]}; 0 < m < 1 \qquad \text{(Eq. 4)}$$

And a is test hole radius, $\bar{H}$ is average water level (ponding depth) in the test hole over time interval, Δt, $\psi\alpha$ is the antecedent or background pore water pressure head in the soil surrounding the test hole, α may be viewed as the “integrally correct” slope of the soil’s unsaturated hydraulic conductivity versus pore water pressure head relationship, K(ψ) and $\bar{C}$ is a “shape function” (Reynolds et al., 2015).

Conversion of CHWP K_{fs}/k_a to equivalent Perc Time, PT for this site using m= 1.05E-06 (Very Strong capillarity category):

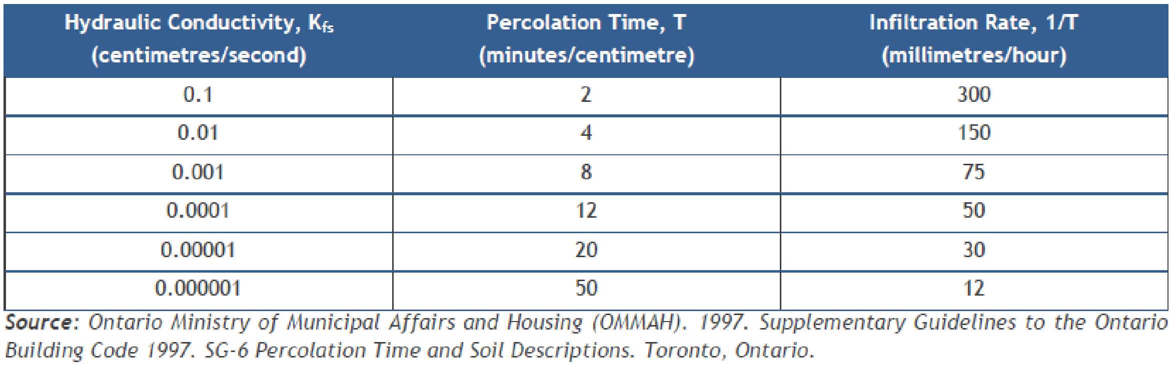
$$PT_1 = \mathrm{mK}_{\mathrm{a1}}^{-1} = \frac{(3.18\mathrm{E}{-6})}{(1.3\mathrm{E}{-7})} = 24.5\ \mathrm{min/cm} \quad \text{(Infiltration Rate =24.5 mm/hour)}$$

$$PT_2 = \mathrm{mK}_{\mathrm{a2}}^{-1} = \frac{(7.0\mathrm{E}{-6})}{(1.9\mathrm{E}{-5})} = 0.37\ \mathrm{min/cm} \quad \text{(Infiltration Rate =1629 mm/hour)}$$

3. Percolation time/infiltration rate for design (OMMAH, 1997)

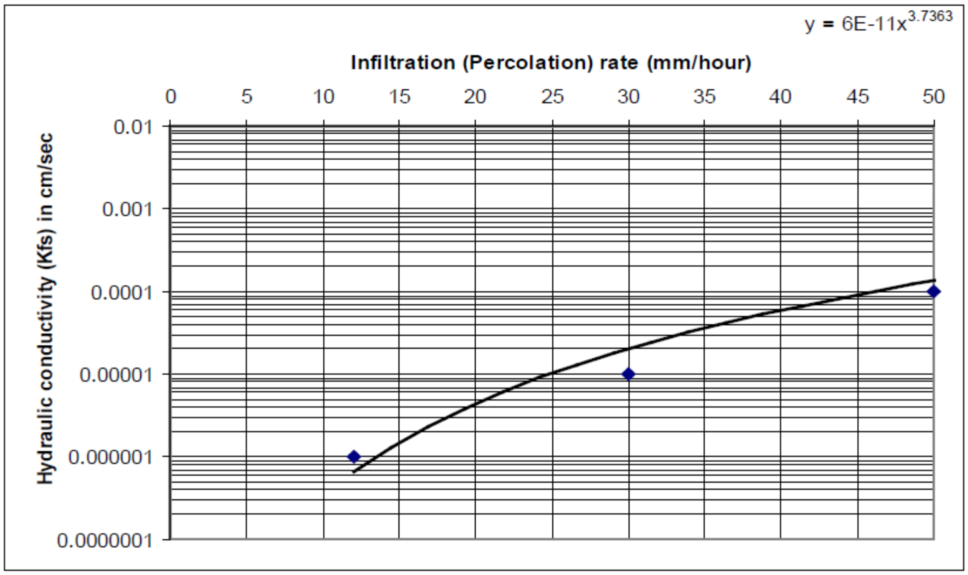
Despite the newer academic papers published by Reynolds et al. (2015), TRCA and other Conservation Authorities often still review design of infiltration basins based on historic trends. Below are two TRCA (2012) design criteria that describe the relationship between K_{fs}, PT, and infiltration rates, based on the 1997 (OMMAH) supplementary guidelines to OBC (1997).

Table 2. Approximate relationships between hydraulic conductivity, percolation time and infiltration rate



Hydraulic Conductivity, K_{fs} (centimetres/second)	Percolation Time, T (minutes/centimetre)	Infiltration Rate, 1/T (millimetres/hour)
0.1	2	300
0.01	4	150
0.001	8	75
0.0001	12	50
0.00001	20	30
0.000001	50	12

Source: *Ontario Ministry of Municipal Affairs and Housing (OMMAH). 1997. Supplementary Guidelines to the Ontario Building Code 1997. SG-6 Percolation Time and Soil Descriptions. Toronto, Ontario.*



Source: *Ontario Ministry of Municipal Affairs and Housing (OMMAH). 1997. Supplementary Guidelines to the Ontario Building Code 1997. SG-6 Percolation Time and Soil Descriptions. Toronto, Ontario.*

Figure 1. Approximate relationship between infiltration rate and hydraulic conductivity

Based on OMMAH interpolation from Table 2 and Figure 1 above, the measured K_{fs} may be interpolated as:

PT_1 = 22.4 min / cm (Infiltration Rate = 27 mm/hour)

PT_2 = 5.9 min / cm (Infiltration Rate = 102 mm/hour)

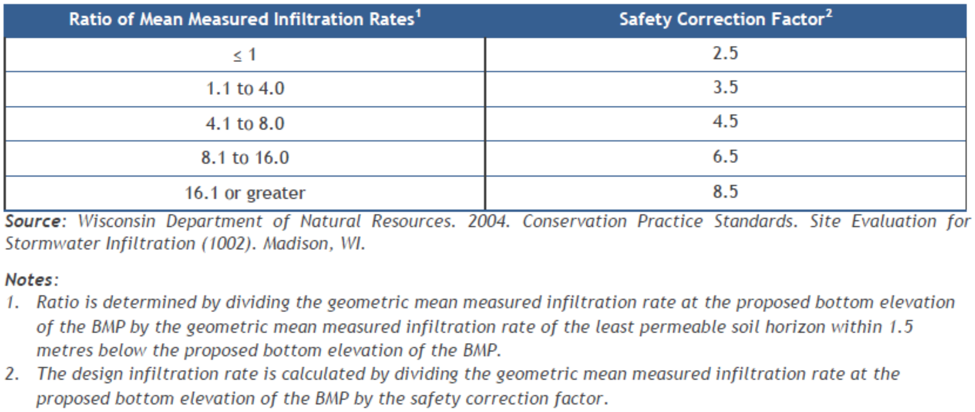
When comparing the OMMAH result with that obtained by Reynolds et al. (2015) formula (PT= 0.37-24.5 min/cm), the two methods of conversion are completely different results, especially for standard soils and it seems that the values of the first method have overestimated the infiltration rate and Perc Time. As per the TRCA Stormwater Management Criteria guideline, the engineer's opinion is to trust to the value obtained from the second method (OMMAH, 1997) which was proposed by TRCA to convert measured hydraulic conductivity to percolation time and/or infiltration rate. Therefore, the engineer's opinion is to trust the values obtained from the second method (OMMAH, 1997), with an unfactored infiltration rate = 27 mm/hour to 102 mm/hour which confirms the upper thin soil layer (clay mixed with sand, d ~ 0.4 to 1.0m) has a low permeability within this property while the lower weathered bedrock layer has high infiltration rate due to some cracks and fissures, in addition to its coarse textured.

4. Factored Engineering Design Infiltration Rate (Wisconsin Department of Natural Resources, 2004)

For a conservative approach to infiltration speeds, the Wisconsin Department of Natural Resources (2004) method shall be used for the calculation of a factored design infiltration rate. The overall upper thin soil formation is clay soils mixed with sand or stone, with an unfactored infiltration rate =27 mm/hour, while the bottom bedrock layer is gravel/stone with sandy clay, with an unfactored infiltration rate =102 mm/hour. Since the infiltration rate used to design an infiltration BMP must incorporate a safety correction factor that compensates for potential reductions in soil permeability due to compaction or smearing during construction, gradual accumulation of fine sediments over the lifespan of the BMP and uncertainty in measured values when less permeable soil horizons exist within 1.5 meters below the proposed bottom elevation of the BMP. As discussed above, the predominant soil material of this site is composed of clay soils to a depth of less than 1 meter and follows with a deep sandy clay layer to a depth of more than 3 meters, which has high permeability rate.

Based on borehole data, the soil layer remains consistent of sandy clay types (similar to BH2), including the soil layers 1.5 meters below the proposed bottom of the BMP. This means that based on the below Table 3, the measured infiltration rate should be divided by a safety correction factor to calculate the design infiltration rate. Thus the mean infiltration rate measured at the proposed bottom elevation of the BMP is 102 mm/hour, and the mean infiltration rate measured in the slowest underlying soil horizon is 41 mm/hour, and the ratio of infiltration rates is 2.5.

Table 3. Safety correction factors for calculating design infiltration rates



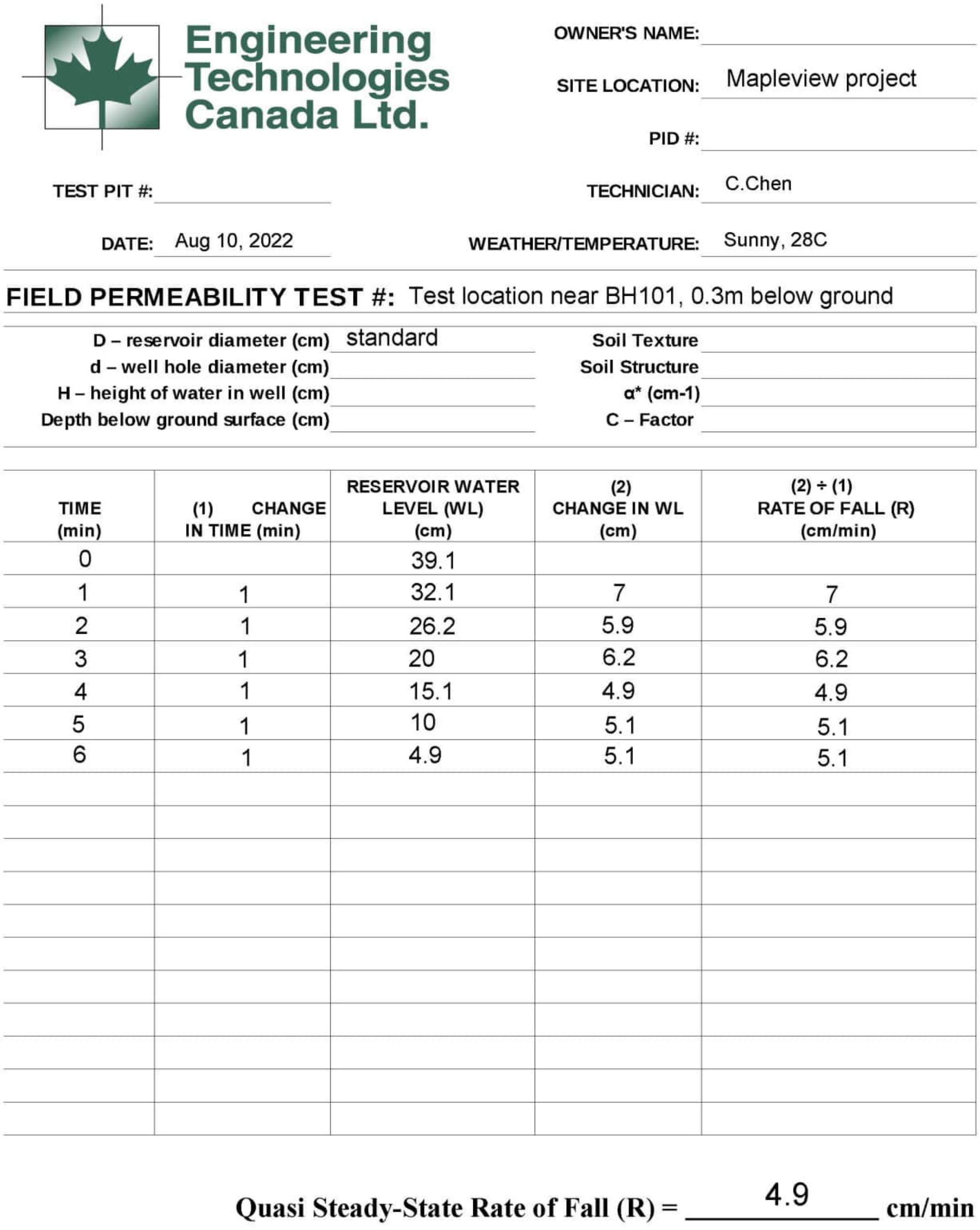
Ratio of Mean Measured Infiltration Rates[1]	Safety Correction Factor[2]
≤ 1	2.5
1.1 to 4.0	3.5
4.1 to 8.0	4.5
8.1 to 16.0	6.5
16.1 or greater	8.5

***Source**: Wisconsin Department of Natural Resources. 2004. Conservation Practice Standards. Site Evaluation for Stormwater Infiltration (1002). Madison, WI.*

***Notes**:*

1. *Ratio is determined by dividing the geometric mean measured infiltration rate at the proposed bottom elevation of the BMP by the geometric mean measured infiltration rate of the least permeable soil horizon within 1.5 metres below the proposed bottom elevation of the BMP.*
2. *The design infiltration rate is calculated by dividing the geometric mean measured infiltration rate at the proposed bottom elevation of the BMP by the safety correction factor.*

Field Permeability Test Sheet



Engineering Technologies Canada Ltd.

OWNER'S NAME:

SITE LOCATION: Mapleview project

PID #:

TEST PIT #:

TECHNICIAN: C.Chen

DATE: Aug 10, 2022

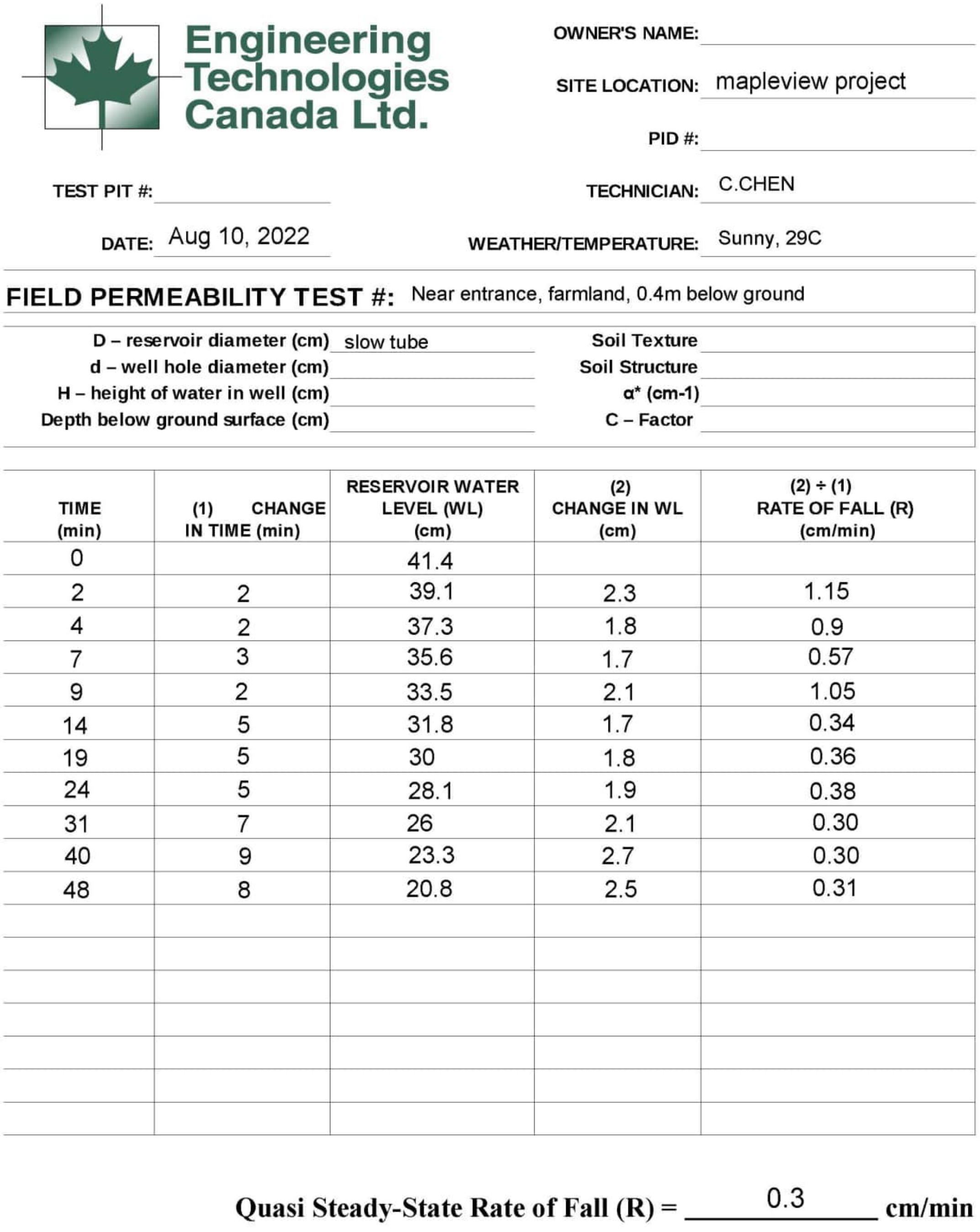
WEATHER/TEMPERATURE: Sunny, 28C

FIELD PERMEABILITY TEST #: Test location near BH101, 0.3m below ground

D – reservoir diameter (cm)	standard	**Soil Texture**	
d – well hole diameter (cm)		**Soil Structure**	
H – height of water in well (cm)		**α* (cm-1)**	
Depth below ground surface (cm)		**C – Factor**	

TIME (min)	(1) CHANGE IN TIME (min)	RESERVOIR WATER LEVEL (WL) (cm)	(2) CHANGE IN WL (cm)	(2) ÷ (1) RATE OF FALL (R) (cm/min)
0		39.1		
1	1	32.1	7	7
2	1	26.2	5.9	5.9
3	1	20	6.2	6.2
4	1	15.1	4.9	4.9
5	1	10	5.1	5.1
6	1	4.9	5.1	5.1

Quasi Steady-State Rate of Fall (R) = 4.9 **cm/min**



Engineering Technologies Canada Ltd.

OWNER'S NAME:

SITE LOCATION: mapleview project

PID #:

TEST PIT #:

TECHNICIAN: C.CHEN

DATE: Aug 10, 2022

WEATHER/TEMPERATURE: Sunny, 29C

FIELD PERMEABILITY TEST #: Near entrance, farmland, 0.4m below ground

D – reservoir diameter (cm)	slow tube	Soil Texture	
d – well hole diameter (cm)		Soil Structure	
H – height of water in well (cm)		α* (cm-1)	
Depth below ground surface (cm)		C – Factor	

TIME (min)	(1) CHANGE IN TIME (min)	RESERVOIR WATER LEVEL (WL) (cm)	(2) CHANGE IN WL (cm)	(2) ÷ (1) RATE OF FALL (R) (cm/min)
0		41.4		
2	2	39.1	2.3	1.15
4	2	37.3	1.8	0.9
7	3	35.6	1.7	0.57
9	2	33.5	2.1	1.05
14	5	31.8	1.7	0.34
19	5	30	1.8	0.36
24	5	28.1	1.9	0.38
31	7	26	2.1	0.30
40	9	23.3	2.7	0.30
48	8	20.8	2.5	0.31

Quasi Steady-State Rate of Fall (R) = 0.3 **cm/min**