Hydrogeological Study Report

Heritage Line Residential Development

Lot 14, Concession 6, Otonabee-South Monaghan

D.M. Wills Project Number 21-10985

D.M. Wills Associates Limited
Partners in Engineering, Planning and Environmental Services
Peterborough

June 2022

Prepared for:
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WILLS

Submissions Summary

Submission No.	Submission Title	Date of Release	Submissions Summary
0	Draft Hydrogeological Study Report	September 3, 2021	Draft Submission to Client
1	Final Hydrogeological Study Report	September 8, 2021	Final Submission to Client
2	Final Hydrogeological Study Report	June 29, 2022	Agency Comments

This report has been formatted considering the requirements of the Accessibility for Ontarians with Disabilities Act.

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1.0 Introduction

D.M. Wills Associates Limited (Wills) was retained by Alina Stewart and Shawn Elmhirst (Client) to complete a Hydrogeological Study (Study) for the property located on Lot 14, Concession 6 in the municipality of Otonabee-South Monaghan, and east of Heritage Line in Keene, Ontario (Subject Property). A Subject Property Plan showing the approximate property boundary is included as **Figure 1**.

Wills understands the Subject Property is approximately 5.6 hectares (ha) and the Client wishes to sever 16 residential lots that are expected to range in size from approximately 0.16 to 0.29 ha. Each residential lot is proposed to be serviced with a private on-site sewage disposal system and potable water supply will be provided via the Keene Heights Municipal Drinking Water System. The Municipal Wellheads and associated Wellhead Protection Areas for the Keene Heights Municipal Drinking Water System are located west and southwest of the Subject Property limits. The Study was requested in order to evaluate the suitability of the Subject Property to accommodate private on-site sewage disposal systems, and to determine the infiltration capacity of the subsurface soils as input to the design of the proposed Low Impact Development (LID) features.

Wills' field investigation was conducted concurrently under a shared scope with a Geotechnical Investigation (Geotechnical Report prepared by PRI Engineering Corp.) to ensure cost efficiencies and to provide additional data to inform both the Hydrogeological Study Report and the Geotechnical Investigation Report.

Legend

Subject Property

Subject Property Plan

Hydrogeological Study

Heritage Line Residential Development

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Project No.	21-10985	Drawing File No.	Figure 1

2.0 Scope of Work

Wills' approved Scope of Work to complete the Study included the following:

- Prior to initiating field investigations, public and private utility service locates were obtained and reviewed by Wills staff. Additionally, a Site-Specific Health and Safety Plan (HASP), and Fieldwork Plan were prepared to ensure a safe and efficient field work program.
- 21 boreholes were advanced on the Subject Property, four of which were completed as monitor wells to facilitate groundwater level monitoring and sample collection.
- Eight test pits were excavated proximal to the proposed sewage disposal system leaching bed. Test pits were originally located to investigate tentative locations for a communal sewage disposal system, however, private individual systems were ultimately chosen for the Proposed Development in view of site specific and regulatory constraints.
- Soil samples were collected and submitted to an accredited laboratory for analysis of Natural Moisture Content and Particle Size Distribution.
- Three single ring infiltrometers were installed in the separate boreholes to determine representative infiltration rates of the shallow subsurface soils for LID design.
- Three groundwater samples were collected from the monitor wells and submitted to an accredited laboratory for analysis of nitrate concentrations to support the Development Impact Assessment.
- A Development Impact Assessment was conducted to determine the carrying capacity of the Subject Property with respect to the Proposed Development.
- The results of Wills' field investigation and modelling were summarized in this Hydrogeological Study Report.

3.0 Subsurface Investigation

Wills retained Canadian Environmental Drilling & Contractors Inc. to advance 21 boreholes at locations selected by Wills staff on the Subject Property from May 3 to May 5, 2021. A Client provided excavator was made available to Wills staff on April 28, 2021, and eight test pits were excavated across the Subject Property. **Table 1** provides a summary of the boreholes, monitor wells and test pits completed for the subsurface investigation. Borehole, monitor well, test pit, and infiltration test locations are shown on **Figure 2.** The Preliminary Servicing and Grading plan, showing Wills' borehole and test pit locations is included in **Appendix A.**

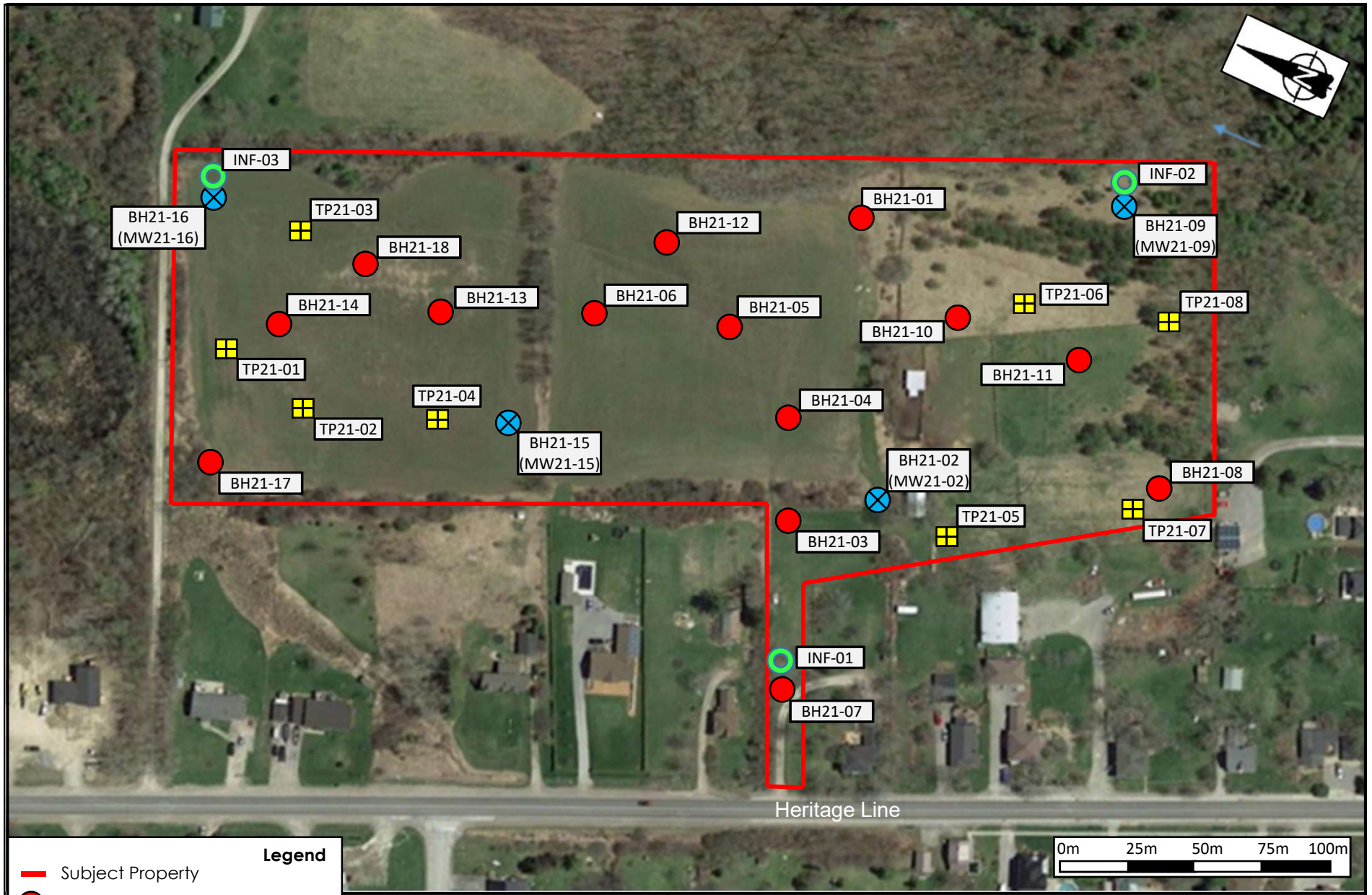
Table 1 – Borehole Summary

Borehole ID	Depth (mbg)	UTM Coordinates (Zone, Easting Northing)	Borehole Application
BH21-01	6.55	17T 0726565 4903233	Stratigraphic logging and soil sampling
BH21-02 (MW21-02)	6.55	17T 0726472 4903186	Stratigraphic logging and soil sampling, monitor well installation
BH21-03	2.00	17T 0726456 4903212	Stratigraphic logging and soil sampling
BH21-04	2.00	17T 0726491 4903229	Stratigraphic logging and soil sampling
BH21-05	2.00	17T 0726511 4903260	Stratigraphic logging and soil sampling
BH21-06	2.00	17T 0726496 4903309	Stratigraphic logging and soil sampling
BH21-07	2.00	17T 0726403 4903191	Stratigraphic logging and soil sampling
INF-01	1.45	Proximal to BH21-07	In-situ infiltration testing
BH21-08	6.55	17T 0726523 4903086	Stratigraphic logging and soil sampling
BH21-09 (MW21-09)	6.55	17T 0726615 4903148	Stratigraphic logging and soil sampling, monitor well installation
INF- 02	1.50	Proximal to BH21-09	In-situ infiltration testing
BH21-10	2.00	17T 0726552 4903179	Stratigraphic logging and soil sampling
BH21-11	5.05	17T 0726548 4903141	Stratigraphic logging and soil sampling
BH21-12	6.55	17T 0726526 4903296	Stratigraphic logging and soil sampling
BH21-13	2.00	17T 0726477 4903356	Stratigraphic logging and soil sampling
BH21-14	2.00	17T 0726452 4903413	Stratigraphic logging and soil sampling
BH21-15 (MW21-15)	6.55	17T 0726456 4903318	Stratigraphic logging and soil sampling, monitor well installation

Borehole ID	Depth (mbg)	UTM Coordinates (Zone, Easting Northing)	Borehole Application
BH21-16 (MW21-16)	6.55	17T 0726499 4903461	Stratigraphic logging and soil sampling, monitor well installation
INF-03	1.20	Proximal to BH21-16	In-situ infiltration testing
BH21-17	6.55	17T 0726401 4903421	Stratigraphic logging and soil sampling
BH21-18	6.55	17T 0726487 4903388	Stratigraphic logging and soil sampling
TP21-01	3.00	17T 0726438 4903429	Stratigraphic logging and soil sampling
TP21-02	3.30	17T 0726449 4903348	Stratigraphic logging and soil sampling
TP21-03	3.30	17T 0726497 4903410	Stratigraphic logging and soil sampling
TP21-04	3.30	17T 0726449 4903348	Stratigraphic logging and soil sampling
TP21-05	3.00	17T 0726474 4903154	Stratigraphic logging and soil sampling
TP21-06	3.00	17T 0726563 4903164	Stratigraphic logging and soil sampling
TP21-07	3.30	17T 0726517 4903086	Stratigraphic logging and soil sampling
TP21-08	3.30	17T 0726574 4903116	Stratigraphic logging and soil sampling

Subsurface soil samples collected by Wills staff during the field program were classified based on grain size, stratigraphy, and relative soil compactness. Representative soil samples were submitted to a Canadian Certified Independent Laboratory (CCIL) [PRI Engineering Corp.] for analysis of Natural Moisture Content and Particle Size Distribution, including sieve and hydrometer analysis. Laboratory testing results were compared to the Ministry of Municipal Affairs and Housing, Building and Development Branch (MMAH) Supplementary Standard SB-6 – Percolation Time and Soil Descriptions Table 2 and Table 3 values (Ontario Building Code [OBC], 2012) (OBC Table 2/3).

Borehole and test pit logs detailing the encountered subsurface conditions and monitor well construction details are included in **Appendix B**. The boreholes used to facilitate the installation of infiltrometers were advanced adjacent to existing boreholes and were not logged. In addition, soil samples were not collected from these boreholes due to the close proximity to the adjacent boreholes.



Subsurface Investigation Plan

Hydrogeological Study
Heritage Line Residential Development

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Project No.: 21-10985	Drawing File No.: Figure 2

3.1 Soil Profile Summary

The Subject Property is located in the Physiographic Region of the Peterborough Drumlin Field (*The Physiography of Southern Ontario, Chapman and Putnam, 1984*), which is characterized by drumlinized till plains. Ontario Geological Survey (OGS) mapping suggests that surficial geology on the Subject Property consists of primarily coarse textured glaciolacustrine deposits. The western boundary borders a bedrock-drift complex in Paleozoic terrain, while the northwestern corner of the Subject Property includes fine textured glaciolacustrine deposits. Glaciolacustrine deposits were not encountered on the Subject Property, and the shallow subsurface soils were more closely aligned with silty sand till deposits that are suggested to be present directly northwest and southeast of the Subject Property. OGS classifies the underlying bedrock geology to be from the upper Ordovician period, and may be comprised of limestone, dolostone, shale, arkose, or sandstone. Geological mapping of the Subject Property has been included in **Appendix C**.

The results of the drilling program indicate the overburden is generally consistent across the Subject Property, with slight variations in gravel, sand, silt, and clay content. Generally, the subsurface profile consists of a surficial layer of silty sand topsoil variably underlain by silty sand, gravelly sand, and sandy silt, and a basal layer of gravelly to silty sand till material.

3.1.1 Top Soil

Top soil material was encountered at all of the borehole and test pit locations, and extended to depths ranging from approximately 0.30 to 0.75 meters below grade (mbg). The top soil material was generally described as silty sand, with trace amounts of clay and gravel. At the time of the field investigation, the top soil material was described as being moist to wet. The natural moisture content as determined by laboratory tests ranged from 17% to 33%. Based on Standard Penetration Test (SPT) N values between 1 to 4 blows per 305 mm of penetration, the topsoil material has a very loose relative compactness.

3.1.2 Silty Sand to Gravelly Sand

Silty sand to gravelly sand material was encountered beneath the topsoil layer at all boreholes with the exception of BH21-09 (MW21-09) and BH21-17, and extended to depths ranging from approximately 2.30 to 3.05 meters below grade (mbg). BH21-03 through BH21-14 were all terminated in the silty sand to gravelly sand material at an approximate depth of 2.0 mbg. This layer was described as sand with some gravel and some silt in BH21-11, and extended to a depth of approximately 2.3 mbg.

The silty sand to gravelly sand material generally contained some clay and occasional cobble material. At the time of the field investigation, this material was described as being moist to saturated. The natural moisture content as determined by laboratory tests for select boreholes ranged from 8% to 16%. Based on SPT N values between 3 to 65 blows per 305 mm of penetration, the silty sand to gravelly sand material has a very loose to very dense relative compactness. This material was predominantly loose to

compact, and it is likely that cobble material in select boreholes may have resulted in higher relative compactness values where encountered.

Three laboratory particle size distribution analyses were completed on samples of the silty sand to gravelly sand. The results are summarized in **Table 2**, on the basis of the Unified Soil Classification System (USCS). Certificates of Analysis for the physical soil testing results are included in **Appendix D**.

The silty sand to gravelly sand material was visually and compositionally similar to the underlying glacial till material, and is interpreted to represent a naturally reworked deposit (i.e. secondary till deposit). A distinction between the primary and secondary deposits is shown on the borehole logs based on the contrasting SPT N values (lower SPT N Values for the shallower materials).

3.1.3 Sandy Silt

Sandy silt material was encountered beneath the topsoil layer at BH21-09 (MW21-09) and BH21-17, and extended to depths ranging from approximately 2.30 to 3.05 mbg, respectively.

The sandy silt material generally contained some clay, trace to some gravel, and occasional cobble material. At the time of the field investigation, this material was described as moist to wet. The natural moisture content as determined by laboratory tests ranged from 9% to 14%. Based on SPT N values between 8 to 15 blows per 305 mm of penetration, the sandy silt material has a loose to compact relative compactness.

Two laboratory particle size distribution analyses were completed on samples of the sandy silt material. The results are summarized in **Table 2**, on the basis of the USCS. Certificates of Analysis for the physical soil testing results are included in **Appendix D**.

The sandy silt material is interpreted to represent a naturally reworked deposit (i.e. secondary till deposit). A distinction between the primary and secondary deposits is shown on the borehole logs based on the contrasting SPT N values.

3.1.4 Silty Sand to Gravelly Sand Till

Silty sand to gravelly sand till material was encountered beneath the inferred secondary till deposits in BH21-01, BH21-08, BH21-09, BH21-11, BH21-12, and BH21-15 through BH21-18. The till material was generally encountered below a depth of approximately 2.3 mbg, and was distinguished from the overlying secondary till deposits by SPT N Values that were generally greater than 20 blows per 305 mm of penetration. The till material contained trace to some clay, and occasional cobbles and/or boulders throughout the investigated depth.

At the time of the field investigation, the till material was described as moist to saturated. The natural moisture content as determined by laboratory tests ranged from 5% to 16%. Based on SPT N values between 19 to greater than 50 blows per 305 mm of penetration, the silty sand till material has a compact to very dense relative compactness.

Six (6) laboratory particle size distribution analyses were completed on samples of the till material. The results are summarized in **Table 2**, on the basis of the USCS. Certificates of Analysis for the physical soil testing results are included in **Appendix D**.

Table 2 – Summary of Particle Size Distribution

Borehole ID	Sample No.	Soil Unit	Gravel (3 in. to No. 4 Sieve) (%)	Sand (No. 4 to No. 200 Sieve) (%)	Silt and Clay (Passing No. 200 Sieve) (%)
BH21-01	SS6	Till	21	41	38
BH21-07	SS2	Silty Sand	6	47	47
BH21-08	SS4	Gravelly Sand	28	43	29
BH21-09	SS3	Sandy Silt	2	25	73
BH21-11	SS6	Till	19	48	33
BH21-12	SS6	Till	14	50	36
BH21-16	SS3	Silty Sand	5	46	49
BH21-17	SS5	Sandy Silt	10	35	55
TP21-02	GS2	Till	24	41	35
TP21-04	GS2	Till	7	57	36
TP21-05	GS2	Till	6	51	43

3.1.5 Bedrock

Bedrock was not encountered at any of the borehole locations. Although bedrock classification was beyond the scope of the Study, OGS Mapping (2007) indicates the local underlying bedrock geology includes limestone, dolostone, shale, arkose, or sandstone from the upper Ordovician period.

3.1.6 Groundwater

Four boreholes were completed as monitor wells to facilitate groundwater level monitoring and sampling. **Table 3** summarizes the construction details and static groundwater levels and elevations measured during the Study. Additionally, **Table 3** provides a summary of groundwater level measurements recorded (where encountered) in the open boreholes prior to backfilling. Groundwater elevations were inferred from a topographic survey completed by Elliot and Parr (Peterborough) Ltd. On March 26, 2021 (Reference No.: 21-19-079-00). Ground surface elevations are shown on the borehole logs in **Appendix B.**

Table 3 – Monitor Well Construction and Groundwater Level Summary

Borehole ID	Construction Date	Borehole Depth/Screened Interval	Screened Material	Stick-Up	Groundwater Level Measurement Date	Groundwater Level/Elevation
BH21-02 (MW21-02*)	May 3, 2021	6.55 mbg/ 3.05 - 6.10 mbg	Till	0.09 mbg	May 11, 2021	0.70 mbg 224.78 masl
BH21-09 (MW21-09)	May 4, 2021	6.55 mbg/ 3.05 - 6.1mbg	Till	1.07 mag	May 11, 2021	3.99 mbg 209.24 masl
BH21-15 (MW21-15)	May 5, 2021	6.55 mbg/ 3.05 – 6.1 mbg	Till	0.98 mag	May 11, 2021	0.91 mbg 224.43 masl
BH21-16 (MW21-16)	May 5, 2021	6.55 mbg/ 3.05 – 6.1 mbg	Till	0.92 mag	May 11, 2021	1.74 mbg 221.07 masl
BH21-03	May 3, 2021	2.00 mbg	-	-	May 5, 2021	1.32 mbg 223.79 masl
BH21-05	May 3, 2021	2.00 mbg	-	-	May 3, 2021	1.20 mbg 223.58 masl
BH21-08	May 4, 2021	6.55 mbg	-	-	May 4, 2021	2.80 mbg 219.79
BH21-11	May 4, 2021	5.05 mbg	-	-	May 4, 2021	4.60 mbg 219.10 masl
BH21-12	May 4, 2021	6.55 mbg	-	-	May 4, 2021	2.10 mbg 223.21 masl
BH21-13	May 4, 2021	2.00 mbg	-	-	May 4, 2021	1.22 mbg 222.83 masl
BH21-17	May 5, 2021	6.55 mbg	-	-	May 5, 2021	4.00 mbg 216.53 masl
BH21-18	May 5, 2021	6.55 mbg	-	-	May 5, 2021	4.60 mbg 219.09 masl

Notes: Monitor wells installed with monument casing unless otherwise noted.

*Monitor wells installed with flush mount casing.

Mbg – meters below grade, mag – meters above grade, masl – meters above sea level

3.1.7 Construction Dewatering

In view of the shallow groundwater conditions encountered during Wills' field investigation, construction dewatering requirements were evaluated with respect to the Proposed Development; including basement excavations and utility trenches.

Static groundwater levels measured in the monitor wells, and observations of groundwater seepage/pooling in the open boreholes and test pits were compared against the proposed site grading (Preliminary Grading and Servicing Plan) and anticipated excavation depths.

Wills understands that the deepest utility trench excavation is required for the proposed watermain, at a depth of 1.8 mbg within the proposed roadway alignment. Natural gas and communication utility trenches are shallower, and are expected to range from 0.6 – 0.9 mbg. Based on Wills review of the proposed site grading, it is expected that the bottom of watermain trench will be at an elevation of approximately 224.2 masl along the majority of the roadway, including the southern cul-de-sac and adjoining road. The bottom of this trench in the northern cul-de-sac will be at a slightly lower elevation of approximately 223.5 masl. Static groundwater elevations beneath the roadway alignment are expected to range from approximately 219 to slightly under 224 masl, and Wills does not expect the utility trenches to intercept the groundwater table or require dewatering efforts.

To evaluate dewatering requirements for the basement excavations, Wills assumed a maximum excavation depth of 3 mbg. It should be noted that at the time of writing this report, it is unknown whether the proposed dwellings will include basements, or will be constructed with slab-on-grade foundations (or both). Following a review of the proposed site grades proximal to the dwellings, and the inferred static groundwater level contours between the subsurface testing locations, Wills determined that only two locations, Lot 7 and Lot 9, may require dewatering activities if the proposed dwellings include basement excavations.

Table 4 summarizes the parameters that were used in the Dupuit-Thiem equation to estimate a dewatering rate (Q) that could be expected in the basement excavations for Lot 7 and Lot 9.

Table 4 – Dewatering Parameters (Dupuit-Thiem)

Parameter	Lot 7	Lot 9
Ground surface elevation (masl)	226.5	226.5
Groundwater elevation (masl)	224.4	224.4
Lowest excavation elevation (masl)	223.5	223.5
Base of aquifer (masl)	206.7	206.7
Hydraulic Conductivity (m/s)	$1x10^{-7}$	$1x10^{-7}$
Excavation dimensions (a x b)	11 x 20	11 x 20
Water level above aquifer bottom before dewatering, H (m)	17.7	17.7
Water level at excavation wall, h (m)	0.9	0.9
Target pumping water level (masl)	223	223
Effective radius of rectangular excavation, R_e (m)	8.4	8.4
Radius of influence, R_0 (m)	24.3	24.3

Based on these estimates, it is expected that the typical day dewatering rate for Lot 7 and Lot 9 is approximately 7,963 L/day. A conservative Factor of Safety (FoS) of 2.0 results in a dewatering rate of 15,927 L/day, which may be encountered at the early stages of dewatering if the excavations are opened rapidly. Dewatering calculations are provided in **Appendix E.** It is expected that groundwater flow into the excavations can be controlled using conventional sumps and pumps located around the excavation perimeter.

It should be noted that during Wills test pit investigation, minor groundwater seepage above a depth of 3 mbg was observed from discrete sand lenses (generally < 0.05 m thick), and very little to no pooling of water was observed in the base of the test pits prior to backfilling (following approximately 0.5 – 0.75 hours of the test pits being open). It is likely that these sand lenses are discontinuous, and may preferentially store infiltrating water as it migrates downwards through the relatively low K-value glacial till. It should also be noted that Wills' subsurface investigation was conducted following a sustained period of precipitation in the spring, and the static groundwater level measurements likely represent perched groundwater that is expected to lower in the drier seasons. Dewatering volumes are expected to decrease as the perched groundwater is removed, and the time to achieve drainage of this water depends on the subsurface connectivity and extent of the water-bearing layers.

In view of these observations, Wills' recommends that updated static groundwater levels be measured, and confirmatory test pits be completed at Lot 7 and Lot 9 prior to construction, to confirm the dewatering requirements.

3.1.8 Groundwater Laboratory Analysis

Three groundwater water samples were collected from monitor well MW21-02, MW21-09, and MW21-16 on May 11, 2021, and submitted to SGS Canada Inc. (SGS) for total nitrogen analysis. The total nitrogen analysis results were used to support Wills Development Impact Assessment discussed in **Section 5.0**. Certificates of Analysis are included in **Appendix F**.

3.2 In-Situ Infiltration Testing

In-situ infiltration testing was completed in boreholes INF-01, INF-02, and INF-03. Infiltrometer construction details are summarized in **Table** 5**5** and infiltration testing locations are shown on **Figure 2**. Infiltration tests were completed adjacent to deeper boreholes as a means of verifying the underlying stratigraphy below the infiltration testing depth. INF-01, INF-02, and INF-03 were positioned in select locations across the Subject Property at the discretion of Wills' engineering design team, as a means of confirming the infiltration capacity of the underlying soils for LID design. Wills understands that the proposed LID features will be situated within the roadside ditches, as well as along the northern property boundary, and adjacent to the on-site slope located to the southeast. The Preliminary Servicing and Grading Plan showing the location of the proposed infiltration features is included in **Appendix A.**

Table 5 – Infiltrometer Construction Summary

Infiltrometer ID	Construction Date	Construction Details	Stick-Up
INF-01	May 10, 2021	51 mm diameter open-end single ring infiltrometer	0.02 mbg
INF-02	May 10, 2021	51 mm diameter open-end single ring infiltrometer	0.01 mag
INF-03	May 10, 2021	51 mm diameter open-end single ring infiltrometer	0.30 mag

The infiltrometers were seated into the undisturbed material at the base of each borehole prior to initiating the infiltration tests. Hydrated bentonite pellets were used as an annular seal above the infiltrometer opening, to ensure that water used during the test could only migrate into the underlying soils.

Water levels within the infiltrometer casings were manually monitored using a Solinst water level tape at each location. The infiltration tests were conducted for a maximum of 24.6-hours, with water levels measured at 30-second intervals for the first 5-minutes, and increasing intervals as the test progressed.

An additional infiltration test was proposed to be completed proximal to BH21-08; however, following completion of the infiltration test borehole, shallow groundwater was observed in above the proposed infiltration testing depth of 1.7 mbg.

Based on input from Wills engineering design team, the infiltration test proximal to BH21-08 was determined to be unnecessary, as the shallow groundwater conditions (saturated soils) would preclude an effective design for LID features in the proposed location.

3.3 In-situ Infiltration Testing Results

The infiltration testing results at each location are summarized in **Table 6, Table 7** and **Table 8.** Detailed calculations and supporting infiltration graphs are provided in **Appendix G.**

Table 6 – In-situ Infiltration Testing Results (INF-01)

	Test INF-01
Test Duration (seconds)	88,560
Total Drop Distance (mm)	1395
Total Number of Measured Intervals	39
Infiltration Rate (mm/sec) - Test Average	1.01
Infiltration Rate (mm/hour)	**3.65×10^3**
Calculated Percolation Time (T) based on Field Infiltration (min/cm)	**0.16**

Notes: 1. Observed infiltration rate was determined using manual measurements of falling head in periodic intervals.

Table 7 – In-situ Infiltration Testing Results (INF-02)

	Test INF-02
Test Duration (seconds)	5,880
Total Drop Distance (mm)	621
Total Number of Measured Intervals	36
Infiltration Rate (mm/sec) - Test Average	0.148
Infiltration Rate (mm/hour)	**532**
Calculated Percolation Time (T) based on Field Infiltration (min/cm)	**1.13**

Notes: 1. Observed infiltration rate was determined using manual measurements of falling head in periodic intervals.

Table 8 – In-situ Infiltration Testing Results (INF-03)

	Test INF-03
Test Duration (seconds)	70,860
Total Drop Distance (mm)	250
Total Number of Measured Intervals	23
Infiltration Rate (mm/sec) - Test Average	3.25×10^{-3}
Infiltration Rate (mm/hour)	**11.7**
Calculated Percolation Time (T) based on Field Infiltration (min/cm)	**51.30**

Notes: 1. Observed infiltration rate was determined using manual measurements of falling head in periodic intervals.

4.0 Permeability and Percolation Time

Percolation rates were estimated on the basis of physical soil characteristics determined through laboratory testing, and were compared against the in-situ infiltration testing results.

From the field observations and the physical soil testing results, the encountered soils within the investigation area were classified based on the USCS. **Table 9** summarizes the permeability and percolation times of the encountered soils on the basis of OBC Table 2.

Table 9 – Permeability and Percolation Time Summary

Borehole ID	Sample ID	Physical Soil Testing Results	Percolation Range	Laboratory Estimated Percolation (T)	Permeability
BH21-09 (MW21-09) *Proxy for INF-02*	SS-3	SM envelope	T = 8 – 20 min/cm or 30 – 75 mm/hr	T = 30 min/cm	Medium to low
		ML envelope	T = 20 – 50 min/cm or 12 – 30 mm/hr		Medium to low
BH21-16 (MW21-16) *Proxy for INF-03*	SS-3	SM envelope	T = 8 – 20 min/cm or 30 – 75 mm/hr	T = 20 min/cm	Medium to low
		ML envelope	T = 20 – 50 min/cm or 12 – 30 mm/hr		Medium to low
TP21-02	GS-2	SM envelope	T = 8 – 20 min/cm or 30 – 75 mm/hr	T = 15 min/cm	Medium to low
		ML envelope	T = 20 – 50 min/cm or 12 – 30 mm/hr		Medium to low
TP21-04	GS-2	SM envelope	T = 8 – 20 min/cm or 30 – 75 mm/hr	T = 13 min/cm	Medium to low
		ML envelope	T = 20 – 50 min/cm or 12 – 30 mm/hr		Medium to low
TP21-05	GS-2	SM envelope	T = 8 – 20 min/cm or 30 – 75 mm/hr	T = 20 min/cm	Medium to low
		ML envelope	T = 20 – 50 min/cm or 12 – 30 mm/hr		Medium to low

Notes: 1. SM envelope –silty sands, sand-silt mixtures
ML envelope – inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity

In-situ infiltration tests INF-01 and INF-02 were conducted in the gravelly sand to silty sand material, and INF-03 were conducted the sandy silt material. The gravelly sand to silty sand material is expected to generally fall within the SM soil envelope due to its coarse-grained nature. The sandy silt material is expected to generally fall within the ML envelope due to it fine-grained nature.

In-situ infiltration testing completed at INF-01and INF-02 suggests the shallow subsurface soils have a much lower T-Time (higher infiltration rate) than that provided in OBC Table 2 for the SM and ML soil envelopes. It should be noted that it was difficult to properly seat the infiltrometer in the coarse soils (which included coarse gravel and cobble components), and thus, the in-situ T-times may have been impacted as a result.

In-situ infiltration testing completed at INF-03 suggests the shallow subsurface soils have a T-Time that approximates the upper limit for that which is provided in OBC Table 3 for the ML soil envelope.

T-Time for the tested soils as derived from the infiltration tests were as follows:

- INF-01: T-Time = 0.16 min/cm
- INF-02: T-Time = 1.13 min/cm
- INF-03: T-Time = 51.30 min/cm

T-Times for INF-01 and INF-02 more closely approximate that for the gravels and gravel sand mixtures on the basis of OBC Table 2. In view of the relative compactness, and well graded nature of the tested soils (including notable clay and silt fractions that are expected to reduce the infiltration capacity) the observed infiltration rates are more likely a result of the testing deficiencies noted above.

It should be noted that sandy silt material (INF-03) was only encountered in two boreholes that were located on the periphery of the Subject Property, and this material is not likely to be encountered beneath the proposed LID features. Wills anticipates that the proposed LID features will be situated over the gravelly sand to silty sand soils that are expected to generally fall with the SM soil envelope.

In view of the in-situ infiltration results, physical soils testing results, and locations of the proposed LID features in context of the encountered subsurface soils, Wills recommends that a T-time of 20 min/cm be used as input into the design of proposed LID features of the subject property. This T-time reflects the upper limit provided for the SM soil envelope in OBC Table 2, and is considered conservative. Furthermore, in view of the consistent subsurface profile encountered across the Subject Property, Wills recommends that the T-time of 20 min/cm should also be used an input into the design of the proposed on-site sewage disposal systems.

5.0 Development Impact Assessment

Wills understands that the Proposed Development will include private on-site sewage disposal systems for the 16 residential lots, and a Development Impact Assessment is required to determine the feasibility and potential for impacts to down-gradient water resources arising from the sewage disposal systems. The Preliminary Servicing and Grading Plan showing the location of the proposed sewage disposal systems is included in **Appendix A.**

Wills' Development Impact Assessment was conducted on the basis the Ministry of the Environment, Conservation and Parks (MECP) *Procedure D-5-4 (D-5-4) Technical Guideline for Individual On-Site Sewage Systems: Water Quality Risk Assessment*, and considered anticipated daily flows to the sewage disposal systems of 1,000 L/day per dwelling, on the basis of *D-5-*4. At the time of preparing this report, actual dwelling sizes and anticipated sewage flows were not available, however, 1,000 L/day is considered to be an acceptable sewage effluent loading rate.

Nitrate, a conservative parameter, was used to assess the impact of sewage effluent on the groundwater environment. D-5-4 requires that the effluent plume at the boundary of the Subject Property cannot exceed the Ontario Drinking Water Quality Standards (ODWQS) limit of 10 mg/L for nitrate to prevent off-site contamination. Although natural

processes and soil interaction can result in nitrate being attenuated in the receiving aquifer system, D-5-4 states that dilution is to be used as the principal attenuation mechanism. As such, a mass balance calculation is required to determine the impact of development on the Subject Property.

Groundwater samples were collected from monitor wells located on the Subject Property, and analyzed for nitrogen (all species) as discussed in **Section 3.1.8**. The lowest total nitrogen value (0.063 mg/L) was used as the background nitrate concentration, as the other two values were significantly higher, and were collected from monitor wells located directly adjacent to a horse-barn, grazing area, and known agricultural uses.

To determine the adequate lot density for the Subject Property, a mass balance calculation was used to determine the sewage loading for nitrate at the property boundary.

$$\mathbf{Q_tC_t = Q_eC_e + Q_iC_i}$$

Where Q_t = Total Volume (Q_e + Q_i)

Note: As per the requirements of D-5-4, the maximum volume of effluent allowed to be used as dilution water is 1000L/day/lot.

C_t = Total Concetration of nitrate at property boundary

Q_e = volume of septic effluent

C_e = Concentration of nitrate in effluent (40 mg/L per *D-5-4*)

Q_i = Volume of available dilution water

C_i = Concentration of nitrate in dilution water (0.063 mg/L)

In order to determine the concertation of the nitrate at the property boundary (C_t), the mass balance equation is rearranged to the following:

$$\boldsymbol{Ct = \frac{QeCe + QiCi}{Qt}}$$

Available post-development dilution/recharge water (Q_i) for the Subject Property was determined from the Water Balance Assessment provided in Wills' Stormwater Management Report. A summary of the water balance calculations, including the Development Impact Assessment is included in **Appendix H**.

The Development Impact Assessment parameters and results are summarized below.

Table 10 – Development Impacts Assessment

Parameter	Value
Number of Lots	16
Volume of Effluent (Q_e)	16 lots x 1,00 L/day = 16,000 L/day
C_e	40 mg/L
Q_i	47,966 L/day
C_i	0.063 mg/L
Q_t	63,966 L/day
C_t	**10.0 mg/L**

In view of the results presented in **Table 10,** Wills concludes that sewage effluent leaving the proposed systems with a nitrate loading of 40 mg/lot/day would result in a groundwater nitrate concentration of 10 mg/L at the property boundary, which satisfies the requirements of *D-5-4*.

6.0 Conclusions and Recommendations

D.M. Wills Associates Limited (Wills) was retained to complete a Hydrogeological Study (Study) for the property located on Lot 14, Concession 6 in the municipality of Otonabee-South Monaghan, east of Heritage Line in Keene, Ontario. The Study was conducted to inform the suitability and design of proposed on-site sewage disposal systems, and to determine the infiltration capacity of the subsurface soils and shallow groundwater conditions as input to the design proposed LID features. The following conclusions with respect to Wills' Study are provided.

- The Subject Property is located outside (west to northwest) of the Municipal Wellhead Protection Areas associated with the Keene Heights Subdivision, and thus, the applicable Trent Source Protection Plan policies for these areas do not apply to the Proposed Development.
- 21 boreholes were advanced on the Subject Property between May 3 to May 5, 2021, and eight test pits were excavated on the Subject Property on April 28, 2021.
- Shallow subsurface soils were generally consistent across the Subject Property, and included a thin layer of silty sand topsoil underlain by silty to gravelly sand with minor sandy silt (secondary till deposit), and a basal layer silty to gravelly sand till (primary till deposit), with varying amounts of clay, cobble, and boulder material.
- Four monitor wells were installed and static groundwater level measurements were recorded on May 11, 2021.
- Static groundwater levels ranged from 0.70 mbg (224.78 masl) to 3.99 mbg (209.24 masl) in the four monitor wells.
- Groundwater level measurements recorded in open boreholes prior to backfilling ranged from 1.20 mbg (223.79 masl) to 4.6 mbg (219.10 masl).
- All eight test pits were free of groundwater accumulation prior to backfilling, however, minor and isolated groundwater seepage was noted from discontinuous centimeter to decimeter-scale coarse-grained lenses.
- Based on the proposed site grading, requirements for construction dewatering is not anticipated for the proposed utility trenches, which are expected to range in depth from 0.6 to 1.8 mbg.
- If basement excavations are required for the proposed dwellings, Wills anticipates that dewatering activities may be required for Lot 7 and Lot 9.
- Dewatering rates were calculated using the Dupuit-Thiem equation, and determined that the typical day dewatering rate for Lot 7 and Lot 9 is approximately 7,963 L/day. An FoS of 2.0 was applied (15,926 L/day) to account for any rapid draining of the perched groundwater, which may be encountered over a short duration if the excavations are opened quickly.
- Based on Wills test pit observations, groundwater seepage was observed to be isolated to thin and possibly discontinuous sand layers that are expected to represent perched groundwater. Additionally, very little seepage/ponding of water was observed in the test pits (3.0 m depths), which remained open for 0.5 – 0.75 hours prior to backfilling.

- Dewatering volumes are expected to decrease as the perched groundwater is removed, and the time to achieve drainage of this water depends on the subsurface connectivity and extent of the water-bearing layers.
- Wills expects that the dewatering can be controlled using conventional sumps and pumps located around the excavation perimeter.
- Wills recommends measuring static groundwater levels in the monitor wells, and completing confirmatory test pits within the footprint of Lot 7 and Lot 9 prior to construction, to confirm the dewatering requirements if basements are proposed.
- Three groundwater samples were submitted for total nitrogen analysis to support the Development Impact Assessment.
- 11 laboratory particle size distribution analyses and laboratory percolation estimates were completed on representative samples of the till material.
- Three in-situ infiltration tests INF-01, INF-02, and INF-03 were conducted on May 10, 2021. T-Times were calculated to be 0.16, 1.13, and 51.3 min/cm, respectively.
- The relatively low T-times (high infiltration rate) determined for INF-01 and INF-02 were attributed to infiltration test deficiencies. The T-time for INF-03 approximates the high end of the range provided for the M.L. soil envelope, however, these soils were only encountered on the margins of the Subject Property and are not anticipated to underlie the proposed LID features or sewage disposal systems.
- A review of the physical soil characteristics and comparison against OBC Table 2 and Table 3 suggests a percolation time (T-Time) between 8 to 50 min/cm for the native till material. Laboratory percolation estimates suggest the T-time ranges from 13 min/cm to 30 min/cm.
- In view of the in-situ infiltration testing and physical soil testing results, and the location of the proposed LIDs features and sewage disposal systems in context of the encountered subsurface soils, Wills recommends that a T-time of 20 min/cm be used for design purposes. This T-time reflects the upper limit provided for the SM soil envelope in OBC Table 2, and is considered conservative.
- Any proposed LID and sewage disposal system design should consider the shallow groundwater depths encountered on the Subject Property, which are expected to impact the respective designs in the areas investigated by Wills. Wills expects that raised sewage disposal system leaching beds will be required to ensure sufficient separation from the seasonally high groundwater table.
- Infiltration rates and percolation times may vary across the Subject Property, as topography, moisture content, soil gradation and relative compactness will affect in-situ infiltration rates.
- A Development Impact Assessment was conducted by Wills to determine the suitability of the Subject Property to accommodate private on-site sewage disposal systems.
- The Development Impact Assessment considered 16 residential lots, and anticipated flows to the sewage disposal systems of 1,000 L/day with a nitrate loading of 40 mg/lot/day on the basis of *D-5-4*.

- The Development Impact Assessment concludes that a groundwater nitrate concentration of 10 mg/L will be achieved at the property boundary, which satisfies the requirements of *D-5-4*.

We trust that the information contained in and attached to this report meets your needs at this time. The following Statement of Limitations should be read carefully and is an integral part of this report. Do not hesitate to contact the undersigned if you have any questions or concerns.

Respectfully submitted,

Prepared by: _____

Ian Ames, M.Sc., P.Geo.
Environmental Monitoring and
Management Lead

Approved by: _____

Michael J. Lord, B.A., Dipl. ET
Manager, Environmental Services

SK/IA/avg

Statement of Limitations

This report is intended solely for Alina Stewart and Shawn Elmhirst (Client) for the Proposed Development located on Lot 14, Concession 6 in the municipality of Otonabee-South Monaghan, east of Heritage Line in Keene, Ontario, and is prohibited for use by others without D.M. Wills Associates Limited's (Wills) prior written consent. This report is considered Wills' professional work product and shall remain the sole property of Wills. Any unauthorized reuse, redistribution of or reliance on this report shall be at the Client and recipient's sole risk, without liability to Wills. The Client shall defend, indemnify and hold Wills harmless from any liability arising from or related to the Client's unauthorized distribution of the report. No portion of this report may be used as a separate entity; it is to be read in its entirety and shall include supporting drawings and appendices.

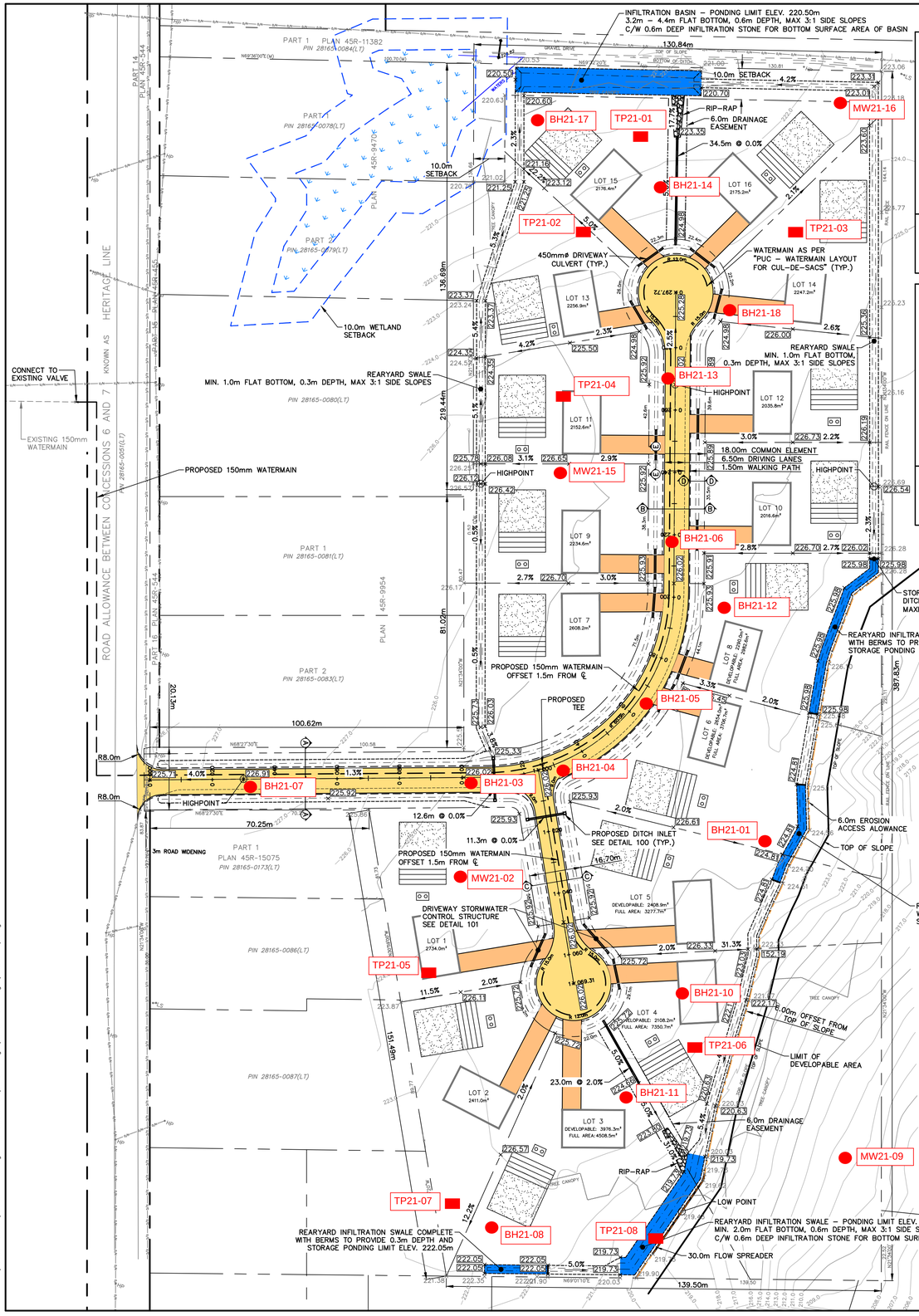
The recommendations made in this report are based on Wills' present understanding of the Project, the current and proposed site use, ground and subsurface conditions, and are based on the work scope approved by the Client and described in the report. The services were performed in a manner consistent with the level of care and skill ordinarily exercised by members of geoscience or engineering professions currently practicing under similar conditions in the same locality. No other representations, and no warranties or representations of any kind, either expressed or implied, are made. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the sole responsibility of such third parties.

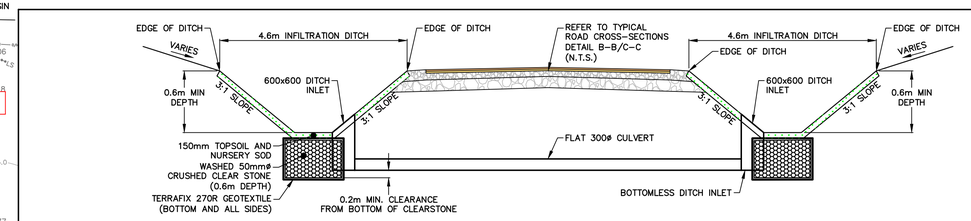
The recommendations and comments made in this report are based on Wills' investigations and resulting understanding of the Project, as defined at the time of the assignment. Wills should be retained to review our recommendations when the final or any modified design drawings and specifications are complete. Without this review, Wills shall not be liable for any misunderstanding of our recommendations or their application and adaptation.

Soil, bedrock, and groundwater conditions between and beyond the test locations may differ both horizontally and vertically from those encountered at the test locations. Should any conditions at the Subject Property be encountered which differ from those found at the test locations, Wills must be notified immediately in order to permit a reassessment of our recommendations. If different conditions are identified, no matter how minor, the recommendations in this report shall be considered invalid until sufficient review and written assessment of said conditions by Wills is completed.

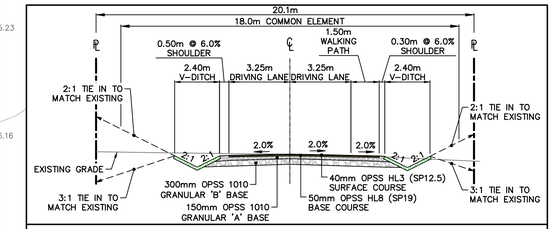
Appendix A

Preliminary Servicing and Grading Plan

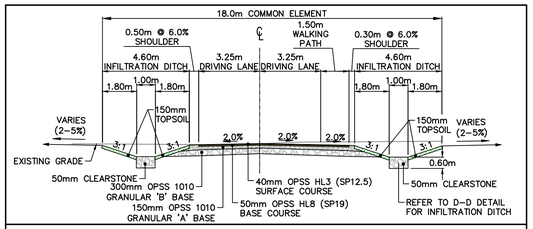




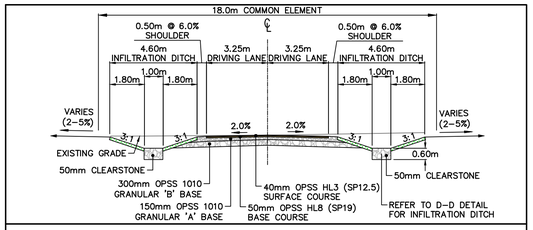
100 DETAIL – TYPICAL DITCH INLET – CROSS CULVERT
SCALE = 1:75



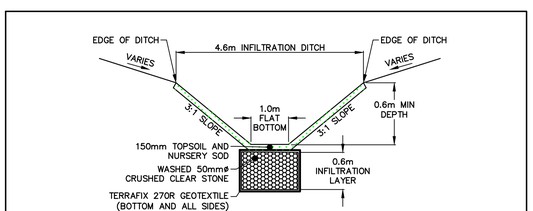
A–A DETAIL – TYPICAL CROSS SECTION
SCALE = 1:150 STA. 0+000 – 0+100



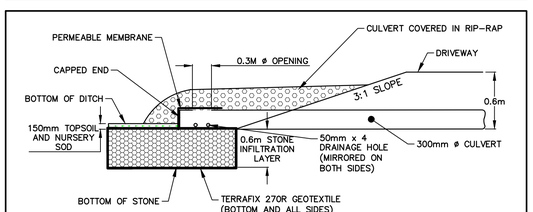
B–B DETAIL – TYPICAL CROSS SECTION
SCALE = 1:150 STA. 0+100 – 0+300



C–C DETAIL – TYPICAL CROSS SECTION
SCALE = 1:150 STA. 1+000 – 1+040



D–D DETAIL – TYPICAL CROSS SECTION
SCALE = N.T.S INFILTRATION DITCH

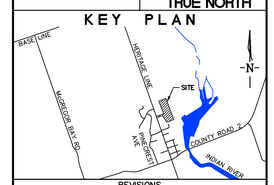


101 DETAIL – TYPICAL CROSS SECTION
SCALE = N.T.S INFILTRATION DITCH & CULVERT

BM1 – 206.93m
N: 4902490.35m
E: 726461.29m
KEENE PUBLIC SCHOOL, TABLET IN NORTHEAST FACE OF CONCRETE FOUNDATION WALL

TRUE NORTH

KEY PLAN



REVISIONS

No.	Description	Date
1	ZBA – 2ND SUBMISSION	22/06/29
1	ZBA – 1ST SUBMISSION	21/09/02

METRIC Dimensions are in METRES and/or MILLIMETRES unless otherwise shown

LEGEND TO BE READ IN CONJUNCTION WITH OPSD 100 SERIES

- PROPOSED HEAVY DUTY ASPHALT
- PROPOSED MEDIUM DUTY ASPHALT
- PROPOSED DRAINAGE STORAGE AREA
- PROPOSED GRASS/LANDSCAPED
- UNEVALUATED WETLAND
- EX. BUILDING
- EX./PR. EDGE OF PAVEMENT
- EX./PR. ROAD CENTERLINE
- EX./PR. EDGE OF SHOULDER/GRAVEL
- EX./PR. WATER VALVE
- EXISTING HYDRO POLE
- EX. OVERHEAD HYDRO
- EX. UNDERGROUND HYDRO
- EX./PR. DITCH
- PR. SWALE
- PR. CULVERT
- PR. CATCH BASIN
- EX./PR. WATERMAIN
- R.O.W
- PROPERTY LINE
- EXISTING VEGETATION
- TEE
- PROPOSED HOUSE WITH 2 CAR GARAGE
- SEPTIC TANK
- TILE FIELD AND MANTLE
- x 214.00 EX./PR. ELEVATION

D.M. Wills Associates Limited
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E. wills@dmwills.com

Project Name/Location

HERITAGE LINE RESIDENTIAL

KEENE, ONTARIO

Drawing Title

PRELIMINARY SERVICING AND GRADING PLAN

Drawn By: M.B.	SCALE: Horz. 1:750 Vert. –		
Designed By: M.B.	Issue Date: JUNE 27, 2022		
Checked By: J.D.F.	Project No.: 21–10985	Sht. No.:	
Engineer: A.M.	Dwg File No.: 10985–SP	500	

NOT FOR CONSTRUCTION

Printed By: mbell Printed On: June 27, 2022
z:\10900-10999\10985 – heritage line residential\02 drawings\current drawings\10985-mp.dwg

Appendix B

Borehole and Test Pit Logs

BORING NUMBER BH21-01

D.M. Wills Associates Limited
150 Jameson Drive
Peterborough, ON K9J 0B9

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/3/21 **COMPLETED** 5/3/21
GROUND ELEVATION 225.24 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING ---
EASTING 726565 **NORTHING** 4903233
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	REMARKS	GRAPHIC LOG	MATERIAL DESCRIPTION	
	SS 1	69	2-2-2-3 (4)			Topsoil: Dark brown silty sand topsoil, trace gravel, moist, very loose	
						0.75	224.49
1	SS 2	93	6-9-5 (14)			Silty Gravelly Sand: Light brown silty gravelly sand, some clay, occasional cobble, moist, compact	
	SS 3	85	3-4-6 (10)				
2						2.30	222.94
	SS 4	96	4-5-14 (19)			Till: Light brown silty gravelly sand till, some clay, occasional cobble, moist to wet, compact	
3							
	SS 5	89	8-18-27 (45)			-Grey, dense to very dense	
	SS 6	59	18-35-50 (85)	GSA SS-6: Gravel: 21% Sand: 41% Silt: 25% Clay: 13%			
4							
	SS 7	100	18-35-38 (73)				
5							
6							
	SS 8	22	50			-Light brown	
						6.55	218.69
						Borehole terminated at 6.55 meters below grade in silty gravelly sand till. Borehole open, no ponded water prior to backfill.	

D.M. Wills Associates Limited
150 Jameson Drive
Peterborough, ON K9J 0B9

BORING NUMBER BH21-03

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/3/21 **COMPLETED** 5/3/21
GROUND ELEVATION 225.11 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING 1.32 m / Elev 223.79 m
EASTING 726456 **NORTHING** 4903212
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION	
	SS 1	79	1-1-1-2 (2)		Topsoil: Dark brown silty sand topsoil, moist, very loose	
					0.75	224.36
1	SS 2	91	6-12-12 (24)		Gravelly Sand: Light brown gravelly sand, some silt, some clay, occasional cobble, wet to saturated, compact	
	SS 3	92	1-5-6 (11)			
2					2.00	223.11

Borehole terminated at 2.0 meters below grade in gravelly sand till. Borehole open, groundwater at 1.3 meters below grade following completion.

D.M. Wills Associates Limited
150 Jameson Drive
Peterborough, ON K9J 0B9

BORING NUMBER BH21-04

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/3/21 **COMPLETED** 5/3/21
GROUND ELEVATION 224.39 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING ---
EASTING 726491 **NORTHING** 4903229
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION	
	SS 1	69	1-1-1-2 (2)		Topsoil: Dark brown silty sand topsoil, moist, very loose	
					0.75	223.64
1	SS 2	93	5-4-7 (11)		Gravelly Sand: Light brown/grey gravelly sand, some silt, some clay, orange-brown mottles, moist to wet, compact	
	SS 3	75	7-6-5 (11)			
2					2.00	222.39
					Borehole terminated at 2.0 meters below grade in gravelly sand till. Borehole open, no ponded water prior to backfill.	

D.M. Wills Associates Limited
150 Jameson Drive
Peterborough, ON K9J 0B9

BORING NUMBER BH21-05

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/3/21 **COMPLETED** 5/3/21
GROUND ELEVATION 224.78 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING 1.20 m / Elev 223.58 m
EASTING 726511 **NORTHING** 4903260
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION	
	SS 1	75	0-0-2-3 (2)		Topsoil: Dark brown silty sand topsoil, moist, very loose	
					0.40	224.38
					Gravelly Sand: Light brown gravelly sand, some silt, some clay, moist, loose	
1	SS 2	74	5-5-2 (7)		-Wet to saturated	
					-Grey, silty, some gravel, compact	
2	SS 3	90	4-5-7 (12)		2.00	222.78

Borehole terminated at 2.0 meters below grade in gravelly sand till. Borehole open, groundwater at 1.2 meters below grade following completion.

D.M. Wills Associates Limited
150 Jameson Drive
Peterborough, ON K9J 0B9

BORING NUMBER BH21-06

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/3/21 **COMPLETED** 5/3/21
GROUND ELEVATION 224.77 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING ---
EASTING 726496 **NORTHING** 4903309
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION	
	SS 1	70	0-0-2-3 (2)		Topsoil: Dark brown silty sand topsoil, moist, very loose	
					0.75	224.02
1	SS 2	93	5-7-10 (17)		Gravelly Sand: Light brown gravelly sand, some silt, some clay, moist, compact	
	SS 3	52	3-7-10 (17)			
2					2.00	222.77
					Borehole terminated at 2.0 meters below grade in gravelly sand till. Borehole open, no ponded water prior to backfill.	

D.M. Wills Associates Limited
150 Jameson Drive
Peterborough, ON K9J 0B9

BORING NUMBER BH21-07

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/3/21 **COMPLETED** 5/3/21
GROUND ELEVATION 227.56 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING ---
EASTING 726403 **NORTHING** 4903191
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	REMARKS	GRAPHIC LOG	MATERIAL DESCRIPTION	
	SS 1	44	1-2-1-2 (3)			Topsoil: Dark brown silty sand topsoil, trace gravel, moist, very loose	
						0.75	226.81
1	SS 2	80	4-6-25 (31)	GSA SS-2: Gravel: 6% Sand: 47% Silt: 30% Clay: 17%		Silty Sand: Light brown silty sand, some clay, trace gravel, moist, dense	
	SS 3	71	4-4-7 (11)			-Light brown/grey, gravely, occasional cobble, compact	
2						2.00	225.56

Borehole terminated at 2.0 meters below grade in silty sand till. Borehole open, no ponded water prior to backfill.

D.M. Wills Associates Limited
150 Jameson Drive
Peterborough, ON K9J 0B9

BORING NUMBER BH21-08

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/4/21 **COMPLETED** 5/4/21
GROUND ELEVATION 222.49 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING 2.70 m / Elev 219.79 m
EASTING 726523 **NORTHING** 4903086
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	REMARKS	GRAPHIC LOG	MATERIAL DESCRIPTION
	SS 1	52	0-1-0-1 (1)	MC = 20%		Topsoil: Dark brown silty sand topsoil, moist, very loose
				GSA SS-2: Gravel: 28% Sand: 43% Silt: 17% Clay: 12%		0.75 221.74 Gravelly Sand: Light brown gravelly sand, some silt, some clay, moist, compact
1	SS 2	59	7-4-7 (11)	MC = 10%		
	SS 3	33	3-3-3 (6)	MC = 12%		-Light brown/grey, wet to saturated, loose
2						
	SS 4	89	4-5-10 (15)	MC = 8%		-Compact ▼
3						3.05 219.44
	SS 5	100	7-15-27 (42)	MC = 10%		Till: Light brown/grey gravelly sand till, some silt, some clay, wet to saturated, dense
4	SS 6	54	23-50	MC = 10%		-Very dense
	SS 7	33	50	MC = 10%		-Occasional cobble
5						
6						
	SS 8	43	20-50	MC = 7%		6.55 215.94
						Borehole terminated at 6.55 meters below grade in gravelly silty sand till. Borehole caved to 3.7 meters below grade, groundwater at 2.7 meters below grade.

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Peterborough, ON K9J 0B9

BORING NUMBER BH21-10

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/4/21 **COMPLETED** 5/4/21
GROUND ELEVATION 224.3 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING ---
EASTING 726552 **NORTHING** 4903179
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION	
	SS 1	61	1-1-1-3 (2)		Topsoil: Dark brown silty sand topsoil, moist, very loose	
					0.75	223.55
1	SS 2	100	8-11-10 (21)		Gravelly Sand: Light brown gravelly sand, some silt, some clay, moist, compact	
	SS 3	75	2-2-5 (7)		-Loose	
2					2.00	222.30
					Borehole terminated at 2.0 meters below grade in gravelly sand till. Borehole open, no ponded water prior to backfill.	

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BORING NUMBER BH21-11

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/4/21 **COMPLETED** 5/4/21
GROUND ELEVATION 223.7 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING 4.60 m / Elev 219.10 m
EASTING 726548 **NORTHING** 4903141
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	REMARKS	GRAPHIC LOG	MATERIAL DESCRIPTION
	SS 1	41	1-1-1-6 (2)			Topsoil: Dark brown silty sand topsoil, trace gravel, moist, very loose
						0.75 222.95
1	SS 2	78	6-23-7 (30)			Sand: Light brown sand, some gravel, some silt, some clay, occasional cobble, moist, compact
	SS 3	100	1-5-5 (10)			-Wet
2						2.30 221.40
	SS 4	100	4-10-13 (23)			Till: Light brown sand till, some gravel, some silt, some clay, occasional cobble, moist to wet, compact
3						
	SS 5	89	10-23-18 (41)			-Dense
4	SS 6	83	13-20-37 (57)	GSA SS-6: Gravel: 19% Sand: 48% Silt: 19% Clay: 14%		-Very dense
	SS 7	69	9-22-50 (72)			-Light brown/grey
5						5.05 218.65
						Borehole terminated at 5.05 meters below grade on assumed boulder material. Borehole open, groundwater at 4.6 meters below grade following completion.

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BORING NUMBER BH21-12

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/4/21 **COMPLETED** 5/4/21
GROUND ELEVATION 225.31 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING 2.10 m / Elev 223.21 m
EASTING 726526 **NORTHING** 4903296
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	REMARKS	GRAPHIC LOG	MATERIAL DESCRIPTION
	SS 1	67	1-1-1-3 (2)	MC = 17%		Topsoil: Dark brown silty sand topsoil, moist, very loose
						0.75 224.56
1	SS 2	72	4-5-2 (7)	MC = 10%		Silty Sand: Light brown silty sand, some clay, trace gravel, occasioanl cobble, wet, loose
2	SS 3	61	2-2-7 (9)	MC = 9%		▼
						2.30 223.01
3	SS 4	93	3-10-15 (25)	MC = 8%		Till: Light brown silty sand till, some clay, trace gravel, occasional cobble, wet, compact
	SS 5	28	50	MC = 9%		-Very dense
4	SS 6	93	17-31-50 (81)	GSA SS-6: Gravel: 14% Sand: 50% Silt: 21% Clay: 15% MC = 7%		-Some gravel, moist
5	SS 7	83	23-20-50 (70)	MC = 8%		-Moist to wet
6	SS 8	89	3-8-50 (58)	MC = 10%		-Light brown/grey, wet
						6.55 218.76
						Borehole terminated at 6.55 meters below grade in silty sand till. Borehole caved to 2.1 meters below grade, groundwater at 2.1 meters below grade following completion.

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150 Jameson Drive
Peterborough, ON K9J 0B9

BORING NUMBER BH21-13

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/4/21 **COMPLETED** 5/4/21
GROUND ELEVATION 224.05 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING 1.22 m / Elev 222.83 m
EASTING 726477 **NORTHING** 4903356
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION	
	SS 1	87	0-1-1-1 (2)		Topsoil: Dark brown silty sand topsoil, moist, very loose	
					0.30	223.75
					Gravelly Sand: Light brown gravelly sand, some silt, some clay, moist, loose	
1	SS 2	104	1-2-3 (5)		-Moist to wet	
					▼	
	SS 3	88	3-8-10 (18)		-Compact	
2					2.00	222.05

Borehole terminated at 2.0 meters below grade in gravelly sand till. Borehole open, groundwater at 1.2 meters below grade following completion.

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BORING NUMBER BH21-14

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/4/21 **COMPLETED** 5/4/21
GROUND ELEVATION 222.71 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING ---
EASTING 726452 **NORTHING** 4903413
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION	
	SS 1	59	0-1-3-2 (4)		Topsoil: Dark brown silty sand topsoil, moist, very loose	
					0.75	221.96
1	SS 2	80	7-7-7 (14)		Silty Sand: Light brown silty sand, some clay, trace gravel, occasional cobbles, moist, compact	
	SS 3	92	2-3-7 (10)			
2					2.00	220.71
					Borehole terminated at 2.0 meters below grade in silty sand till. Borehole open, no ponded water prior to backfill.	

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BORING NUMBER BH21-17

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/5/21 **COMPLETED** 5/5/21
GROUND ELEVATION 220.53 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING 4.00 m / Elev 216.53 m
EASTING 726401 **NORTHING** 4903421
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	REMARKS	GRAPHIC LOG	MATERIAL DESCRIPTION
	SS 1	48	0-0-1-2 (1)	MC = 20%		Topsoil: Dark brown silty sand topsoil, trace clay, moist to wet, very loose
						0.75 219.78
1	SS 2	85	6-6-2 (8)	MC = 12%		Sandy Silt: Light brown sandy silt, some clay, trace gravel, occasional cobble, wet, loose
	SS 3	89	3-5-6 (11)	MC = 11%		-Compact
2						
	SS 4	41	7-7-8 (15)	MC = 9%		
3	SS 5	85	5-5-4 (9)	GSA SS-5: Gravel: 10% Sand: 35% Silt: 38% Clay: 17% MC = 10%		-Light grey, moist to wet, loose
						3.80 216.73
4	SS 6	65	18-27-50 (77)	MC = 7%		Till: Light grey sandy silt till, some clay, trace gravel, occasional cobble, moist, very dense
	SS 7	54	23-22-50 (72)	MC = 6%		-Wet
5						
6						
	SS 8	83	15-29-50 (79)	MC = 15%		-Very dense
						6.55 213.98
						Borehole terminated at 6.55 meters below grade in silty sand till. Borehole caved to 4.0 meters below grade, groundwater at 4.0 meters below grade.

BORING NUMBER BH21-18

D.M. Wills Associates Limited
150 Jameson Drive
Peterborough, ON K9J 0B9

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/5/21 **COMPLETED** 5/5/21
GROUND ELEVATION 223.69 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING 4.60 m / Elev 219.09 m
EASTING 726487 **NORTHING** 4903388
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION	
	SS 1	77	0-1-2-3 (3)		Topsoil: Dark brown silty sand topsoil, trace gravel, moist, very loose	
					0.75	222.94
1	SS 2	20	5-6-6 (12)		Silty Sand: Light brown silty sand, trace clay, trace gravel, occasional cobble, moist, compact	
2	SS 3	100	5-9-11 (20)			
	SS 4	100	12-12-9 (21)			
3					3.05	220.64
	SS 5	54	5-50		Till: Light brown silty sand till, trace clay, trace gravel, occasional cobble, moist, very dense	
4	SS 6	59	8-33-50 (83)		-Moist to wet	
5	SS 7	33	50		-Some gravel	
6						
	SS 8	78	10-32-50 (82)		-Wet	
					6.55	217.14
					Borehole terminated at 6.55 meters below grade in silty sand till. Borehole caved to 4.6 meters below grade, groundwater at 4.6 meters.	

D.M. Wills Associates Limited
150 Jameson Drive
Peterborough, ON K9J 0B9

WELL NUMBER MW21-02

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/3/21 **COMPLETED** 5/3/21
GROUND ELEVATION 225.48 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING ---
EASTING 726472 **NORTHING** 4903186
AFTER DRILLING 0.70 m / Elev 224.78 m

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	REMARKS	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
	SS 1	62	0-1-3-4 (4)	MC = 33%		Topsoil: Dark brown silty sand topsoil, trace clay, moist, very loose	
						0.75 ▼ 224.73	
1	SS 2	72	10-13-24 (37)	MC = 8%		Silty Sand: Light brown silty sand, some clay, trace to some gravel, occasional cobble, moist, dense	Bentonite
	SS 3	100	1-1-2 (3)	MC = 10%		-Wet to saturated, very loose	Riser
2						2.30 223.18	
	SS 4	78	5-7-13 (20)	MC = 8%		Till: Light brown silty sand till, some clay, trace gravel, occasional cobble, saturated, compact to very dense	
3							
	SS 5	100	8-11-24 (35)	MC = 7%			
4	SS 6	65	14-50	MC = 15%			Sand
							Screen
5	SS 7	65	14-50	MC = 10%			
6				Split spoon refusal at 5.33 m. Augered to 6.55 m approximately 1 m west.			
	SS 8	52	11-50	MC = 5%		-Grey	
						6.55 218.93	
						Borehole terminated at 6.55 meters below grade in silty sand till. Static groundwater in monitoring well at 0.70 meters below grade on May 11, 2021.	

WELL NUMBER MW21-09

D.M. Wills Associates Limited
150 Jameson Drive
Peterborough, ON K9J 0B9

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/4/21 **COMPLETED** 5/4/21
GROUND ELEVATION 213.23 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING ---
EASTING 726615 **NORTHING** 4903148
AFTER DRILLING 3.99 m / Elev 209.25 m

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	REMARKS	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
	SS 1	54	0-1-1-2 (2)	MC = 19%		Topsoil: Dark brown silty sand topsoil, trace gravel, moist, very loose	Casing Top Elev: 214.23 (m) Casing Type: Monument
						0.76 / 212.47	
1	SS 2	80	4-6-4 (10)	MC = 14%		Sandy Silt: Light brown sandy silt, some clay, trace to some gravel, moist to wet, compact	Riser
				GSA SS-3: Gravel: 2% Sand: 25% Silt: 57% Clay: 16%			Bentonite
2	SS 3	100	3-5-6 (11)	MC = 14%			
						2.29 / 210.94	
	SS 4	100	4-7-15 (22)	MC = 15%		Till: Light brown sandy silt till, some clay, trace to some gravel, moist to wet, compact	
3							
	SS 5	100	10-14-15 (29)	MC = 10%			
4	SS 6	100	13-17-21 (38)	MC = 13%		-Dense	Sand
							Screen
5	SS 7	100	23-26-26 (52)	MC = 15%		-Very dense	
6							
	SS 8	100	45-37-50 (87)	MC = 12%		-Grey, saturated	
						6.55 / 206.68	

Borehole terminated at 6.55 meters below grade in sandy silt till. Static groundwater level in monitoring well at 4.0 meters below grade on May 11, 2021.

WELL NUMBER MW21-15

D.M. Wills Associates Limited
150 Jameson Drive
Peterborough, ON K9J 0B9

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/5/21 **COMPLETED** 5/5/21
GROUND ELEVATION 225.34 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING ---
EASTING 726456 **NORTHING** 4903318
AFTER DRILLING 0.91 m / Elev 224.44 m

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
	SS 1	64	0-2-2-4 (4)		Topsoil: Dark brown silty sand topsoil, moist, very loose	Casing Top Elev: 226.28 (m) Casing Type: Monument
					0.76 / 224.58	
1	SS 2	74	12-15-50 (65)		Silty Sand: Light brown silty sand, some gravel, occasional cobbles, moist, very dense	Riser
						Bentonite
2	SS 3	96	2-2-3 (5)		-Trace gravel, wet, loose	
					2.29 / 223.05	
3	SS 4	83	6-9-16 (25)		Till: Light brown silty sand till, some gravel, trace clay, occasional cobbles, wet, compact	
	SS 5	91	11-14-20 (34)		-Dense	
4	SS 6	100	12-21-25 (46)		-Light brown/grey, trace to some gravel, moist to wet	Sand
						Screen
5	SS 7	74	12-26-50 (76)		-Some gravel, very dense	
6						
	SS 8	63	20-28-50 (78)		-Light grey	
					6.55 / 218.79	
					Borehole terminated at 6.55 meters below grade in silty sand till. Static groundwater level in monitoring well at 0.9 meters below grade on May 11, 2021.	

D.M. Wills Associates Limited
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Peterborough, ON K9J 0B9

WELL NUMBER MW21-16

CLIENT Alina Stewart and Shawn Elmhirst
PROJECT NAME Heritage Line
PROJECT NUMBER 21-10985
PROJECT LOCATION 1197 Heritage Line, Keene ON
DATE STARTED 5/5/21 **COMPLETED** 5/5/21
GROUND ELEVATION 222.81 m **HOLE SIZE** 6'
DRILLING CONTRACTOR Canadian Environmental Drilling
GROUND WATER LEVELS:
DRILLING METHOD 6" O.D. Solid stem augers and split spoon samplers
AT TIME OF DRILLING ---
LOGGED BY IM **CHECKED BY** IA
AT END OF DRILLING ---
EASTING 726499 **NORTHING** 4903461
AFTER DRILLING 1.74 m / Elev 221.07 m

DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	BLOW COUNTS (N VALUE)	REMARKS	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
	SS 1	87	0-1-1-1 (2)	MC = 18%		Topsoil: Dark brown silty sand topsoil, moist, very loose	Casing Top Elev: 223.69 (m) Casing Type: Monument
						0.76 / 222.05	
1	SS 2	100	4-3-5 (8)	MC = 10%		Silty Sand: Light brown silty sand, some clay, trace gravel, occasional cobble, moist, loose	Riser
				GSA SS-3: Gravel: 5% Sand: 46% Silt: 35% Clay: 14% MC = 16%			Bentonite
2	SS 3	63	1-0-0 (0)			-Moist to wet, very loose	
				Split spoon refusal at 2.29m. Augered to 2.29 m approximately 1 m west.		2.29 / 220.52	
	SS 4	61	9-23-50 (73)	MC = 11%		Till: Brown silty sand till, some gravel, some clay, occasional cobble, wet, very dense	
3							
	SS 5	91	12-17-50 (67)	MC = 6%		-Trace gravel	
4	SS 6	80	25-25-50 (75)	MC = 9%		-Moist to wet	Sand
							Screen
5	SS 7	65	15-31-50 (81)	MC = 7%		-Light brown, some gravel, wet	
6							
	SS 8	93	7-24-50 (74)	MC = 7%		-Trace gravel, moist	
						6.55 / 216.26	

Borehole terminated at 6.55 meters below grade in silty sand till. Static groundwater level in monitoring well at 1.75 meters below grade on May 11, 2021.

WILLS

Test Pit Log – TP21-01

Depth (mbg)	Soil Description
0.0 – 0.4	Brown silty sand topsoil, rootlets, moist.
0.4 - 0.6	Light brown silty sand, trace to some clay, moist.
0.6 – 3.0	Grey silty sand till, some gravel, trace clay, occasional cobble, wet to saturated.

Grab Sample Summary

- GS-01 collected at approximately 0.4 mbg.
- CGS-02 collected between 0.6 mbg – 3.0 mbg.

Groundwater

- Minor and isolated groundwater seepage between 1.0 and 1.6 mbg.

Additional Notes

- Caving below 0.6 mbg.
- Test pit terminated at 3.0 mbg in till.
- Test pit backfilled and compacted using excavator following completion of stratigraphic logging and sampling.

Test Pit Photos

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WILLS

Test Pit Log – TP21-02

Depth (mbg)	Soil Description
0.0 – 0.3	Brown silty sand topsoil, rootlets, moist.
0.3 - 0.5	Light brown silty sand, moist.
0.5 – 3.3	Grey gravelly silty sand till, trace clay, occasional cobble.

Grab Sample Summary

- GS-01 collected at approximately 0.3 mbg.
- CGS-02 collected between 0.6 mbg – 3.3 mbg.

Groundwater

- Groundwater not encountered.

Additional Notes

- Minor caving between 0.6 mbg and 1.6 mbg.
- Test pit terminated at 3.3 mbg in till.
- Test pit backfilled and compacted using excavator following completion of stratigraphic logging and sampling.

Test Pit Photos

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WILLS

Test Pit Log – TP21-03

Depth (mbg)	Soil Description
0.0 – 0.3	Brown silty sand topsoil, rootlets, moist.
0.3 - 0.5	Light brown silty sand, moist.
0.5 – 3.3	Grey silty sand till, some gravel, trace clay, occasional cobble and boulder, moist.

Grab Sample Summary

- GS-01 collected at approximately 0.4 mbg.
- CGS-02 collected between 0.5 mbg – 3.3 mbg.

Groundwater

- Groundwater not encountered

Additional Notes

- Test pit terminated at 3.3 mbg in till.
- Test pit backfilled and compacted using excavator following completion of stratigraphic logging and sampling.

Test Pit Photos

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WILLS

Test Pit Log – TP21-04

Depth (mbg)	Soil Description
0.0 – 0.3	Brown silty sand topsoil, rootlets, moist.
0.3 - 0.4	Light brown silty sand, moist.
0.4 – 3.3	Grey silty sand till, some clay, trace gravel, occasional cobble and boulder.

Grab Sample Summary

- GS-01 collected at approximately 0.3 mbg.
- CGS-02 collected between 0.4 mbg – 3.3 mbg.

Groundwater

- Minor and isolated groundwater seepage at 1.8 mbg.

Additional Notes

- Caving below 1.8 mbg.
- Test pit terminated at 3.3 mbg in till.
- Test pit backfilled and compacted using excavator following completion of stratigraphic logging and sampling.

Test Pit Photos

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Test Pit Log – TP21-05

Depth (mbg)	Soil Description
0.0 – 0.4	Brown silty sand topsoil, rootlets, moist
0.4 - 0.5	Light brown silty sand, moist
0.5 – 3.0	Grey silty sand till, some clay, trace gravel, occasional cobble and boulder, moist to wet.

Grab Sample Summary

- GS-01 collected at approximately 0.5 mbg.
- GS-02 collected at approximately 2.0 mbg.

Groundwater

- Minor and isolated groundwater seepage at 1.3 mbg.

Additional Notes

- Caving below 0.5 mbg.
- Test pit terminated at 3.0 mbg in till.
- Test pit backfilled and compacted using excavator following completion of stratigraphic logging and sampling.

Test Pit Photos

D.M. Wills Associates Limited
150 Jameson Drive, Peterborough, Ontario, Canada K9J 0B9
P. 705.742.2297 **F**. 705.748.9944 **E**. wills@dmwills.com

WILLS

Test Pit Log – TP21-06

Depth (mbg)	Soil Description
0.0 – 0.2	Brown silty sand topsoil, rootlets, moist.
0.2 - 0.4	Light brown silty sand, moist.
0.4 – 3.0	Grey silty sand till, some gravel, trace clay, occasional cobble and boulder, moist.

Grab Sample Summary

- GS-01 collected at approximately 0.3 mbg.
- GS-02 collected at approximately 1.5 mbg.
- GS-03 collected at approximately 2.5 mbg.

Groundwater

- Groundwater not encountered.

Additional Notes

- Test pit terminated at 3.0 mbg in till.
- Test pit backfilled and compacted using excavator following completion of stratigraphic logging and sampling.

Test Pit Photos

D.M. Wills Associates Limited
150 Jameson Drive, Peterborough, Ontario, Canada K9J 0B9
P. 705.742.2297 **F**. 705.748.9944 **E**. wills@dmwills.com

WILLS

Test Pit Log – TP21-07

Depth (mbg)	Soil Description
0.0 – 0.3	Brown silty sand topsoil, rootlets, moist.
0.3 - 0.5	Light brown silty sand, moist.
0.5 – 3.3	Grey silty sand till, some gravel, trace to some clay, occasional cobble and boulder, moist to wet.

Grab Sample Summary

- GS-01 collected at approximately 0.4 mbg.
- CGS-02 collected at approximately 1.0 – 2.0 mbg.

Groundwater

- Minor and isolated groundwater seepage at 2.0 mbg.

Additional Notes

- Caving below 0.5 mbg.
- Test pit terminated at 3.3 mbg in till.
- Test pit backfilled and compacted using excavator following completion of stratigraphic logging and sampling.

Test Pit Photos

D.M. Wills Associates Limited
150 Jameson Drive, Peterborough, Ontario, Canada K9J 0B9
P. 705.742.2297 **F**. 705.748.9944 **E**. wills@dmwills.com

WILLS

Test Pit Log – TP21-08

Depth (mbg)	Soil Description
0.0 – 0.3	Brown silty sand topsoil, rootlets, moist.
0.3 - 0.4	Light brown silty sand, moist.
0.4 – 3.3	Grey silty sand till, some gravel, trace clay, occasional cobble and boulder.

Grab Sample Summary

- GS-01 collected at approximately 0.3 mbg.
- CGS-02 collected between 0.4 mbg – 3.3 mbg.

Groundwater

- Minor and isolated groundwater seepage throughout till.

Additional Notes

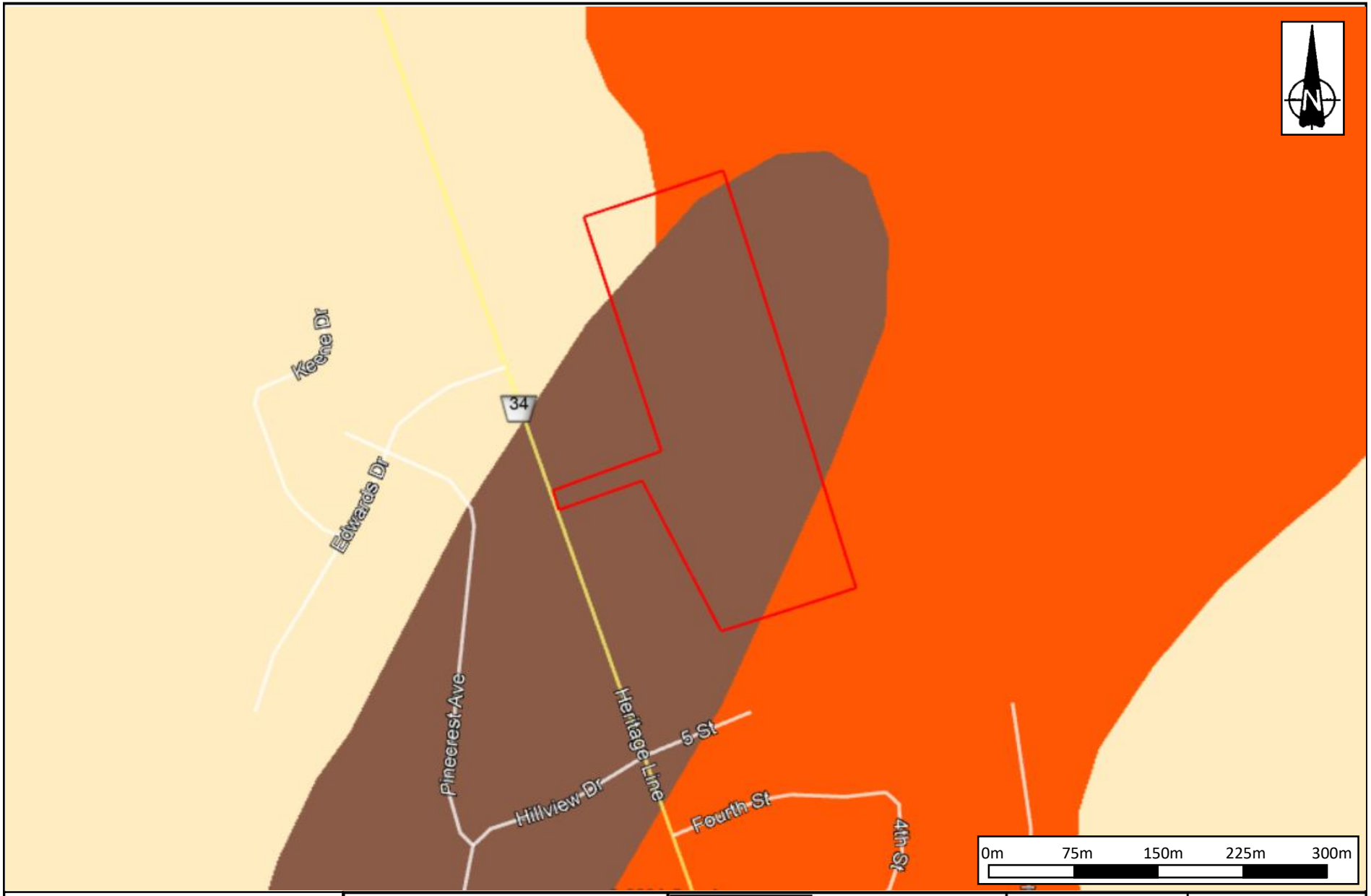
- Caving below 2.0 mbg.
- Test pit terminated at 3.3 mbg in till.
- Test pit backfilled and compacted using excavator following completion of stratigraphic logging and sampling.

Test Pit Photos

D.M. Wills Associates Limited
150 Jameson Drive, Peterborough, Ontario, Canada K9J 0B9
P. 705.742.2297 **F**. 705.748.9944 **E**. wills@dmwills.com

Appendix C

Geological Maps



Legend

- Subject Property
- Till Plains (Drumlinized)
- Drumlins
- Spillways

Physiography

Hydrogeological Study

Heritage Line Residential Development

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Peterborough, Ontario
Canada K9J 0B9

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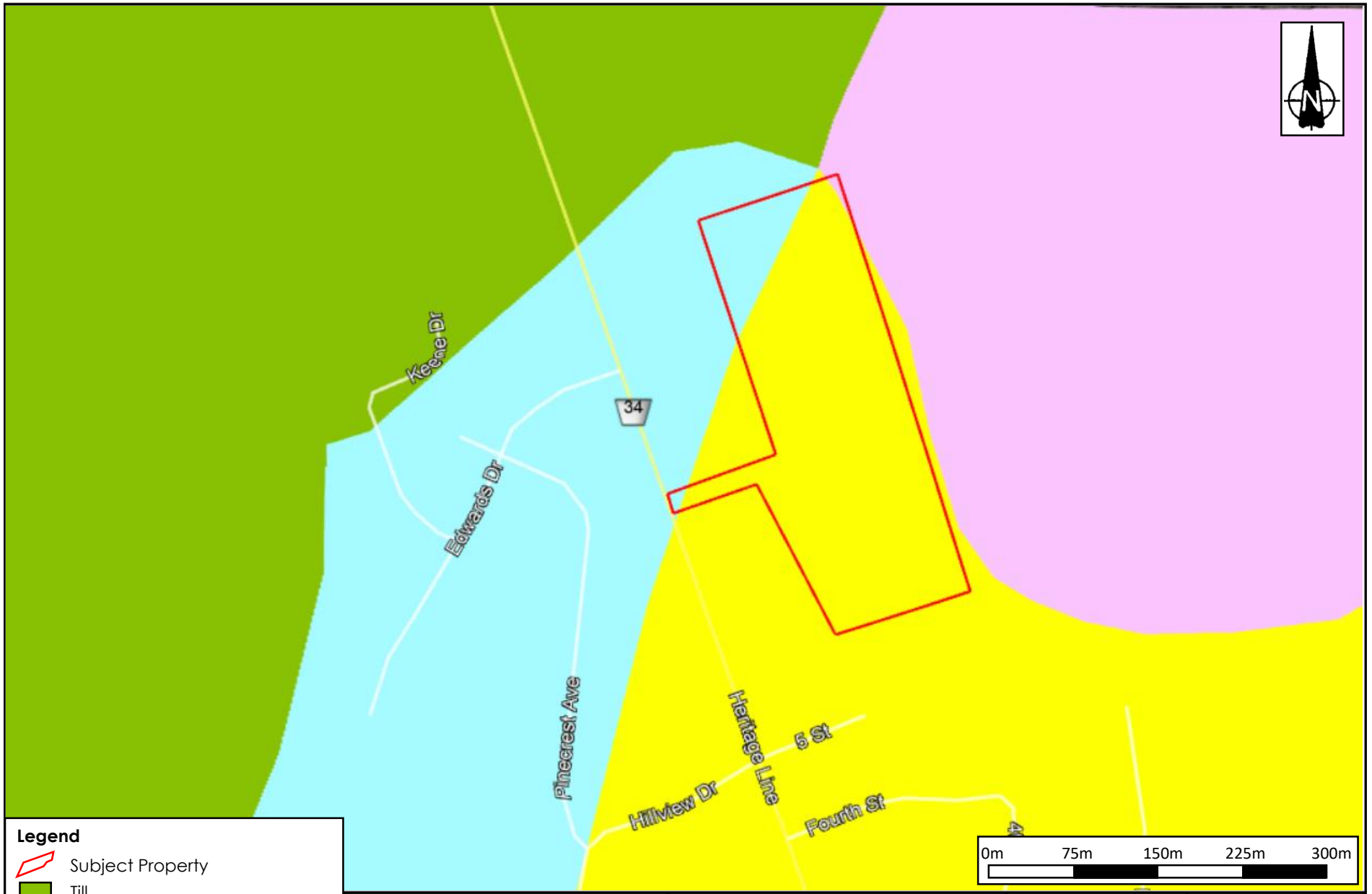
F. 705.748.9944
E. wills@dmwills.com

Drawn By: AT	Scale: See scale bar
Checked: IA	Date: March, 2021
Project No.: 21-10985	Drawing File No.: APP-C1



Surficial Geology

Hydrogeological Study

Heritage Line Residential Development

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150 Jameson Drive
Peterborough, Ontario
Canada K9J 0B9

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F. 705.748.9944
E. wills@dmwills.com

Drawn By: AT	Scale: See scale bar
Checked: IA	Date: March, 2021
Project No.: 21-10985	Drawing File No.: APP-C2

Legend

Subject Property

Limestone, dolostone, shale, arkose, sandstone

Bedrock Geology

Hydrogeological Study

Heritage Line Residential Development

WILLS

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150 Jameson Drive
Peterborough, Ontario
Canada K9J 0B9

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F. 705.748.9944
E. wills@dmwills.com

Drawn By: AT	Scale: See scale bar
Checked: IA	Date: March, 2021
Project No.: 21-10985	Drawing File No.: APP-C3

Appendix D

Certificates of Analysis – Physical Soil Testing

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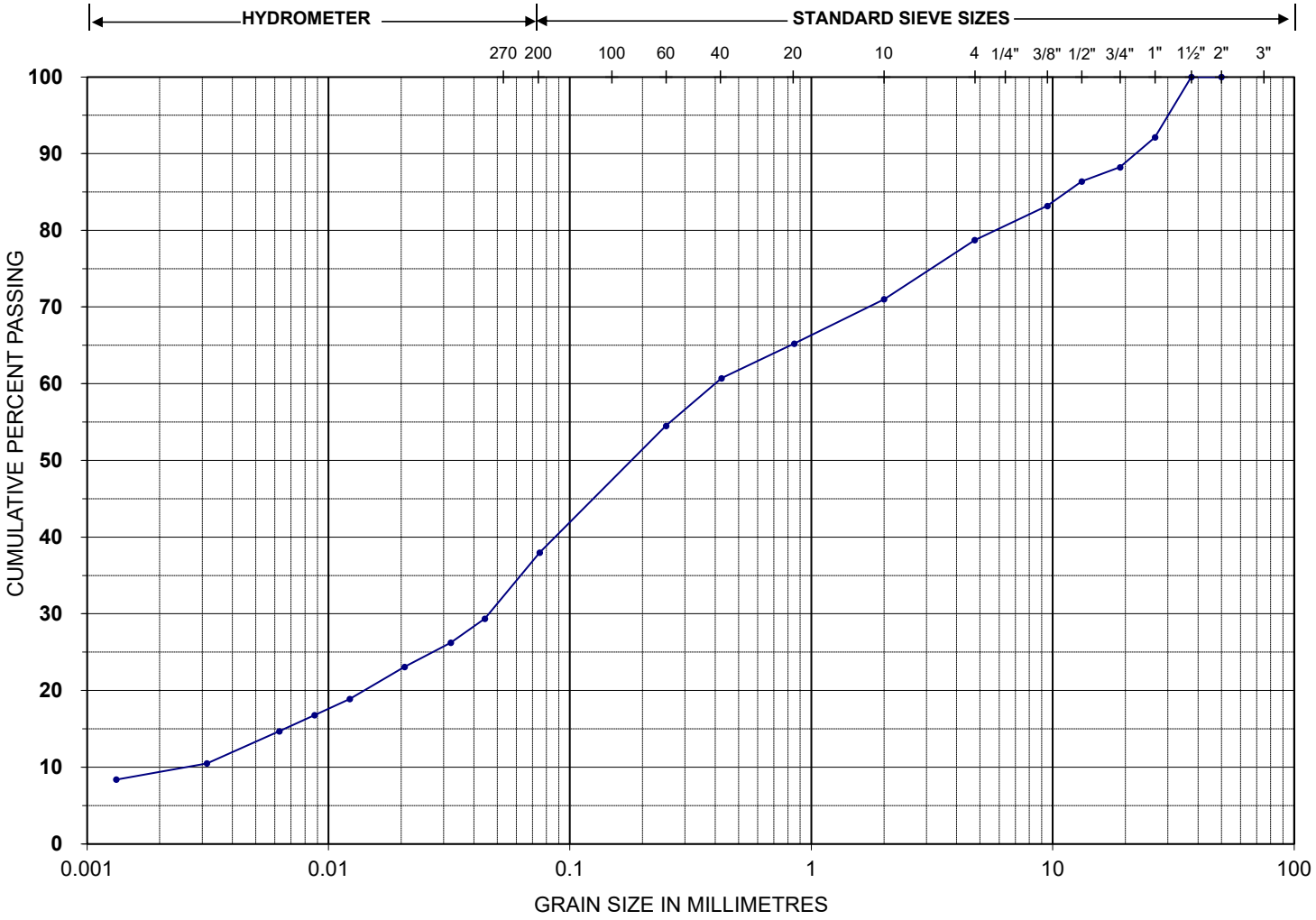
PARTICLE SIZE DISTRIBUTION
LS - 702

Project Name: Heritage Line **Project No.:** 21-049 **Sample Date:** 3-May-21

Borehole/Test Pit ID.: BH21-01 **Sample No./Depth:** SS6 @ 3.80m to 4.26m **Test Date:** 25-May-21



Silt or Clay	Sand	Gravel

Sieve Size (mm)	% Passing
37.5	100.0
26.5	92.1
19.0	88.2
13.2	86.4
9.5	83.2
4.750	78.7
2.000	71.0
0.850	65.2
0.425	60.7
0.250	54.5
0.075	38.0

Hydrometer (mm)	% Passing
0.044	29.4
0.032	26.2
0.021	23.1
0.012	18.9
0.009	16.8
0.006	14.7
0.003	10.5
0.001	8.4

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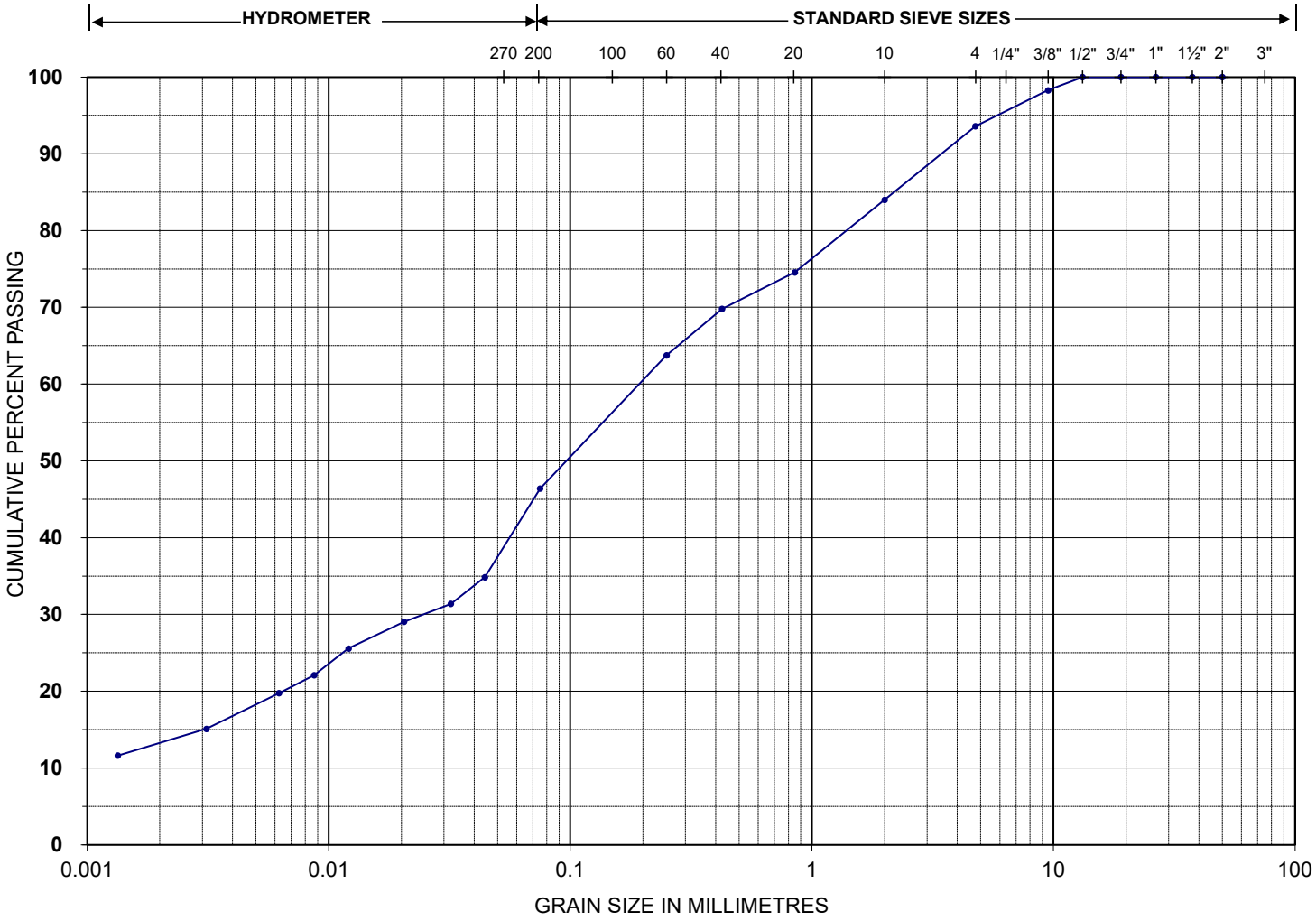
Project Name: Heritage Line **Project No.:** 21-049 **Sample Date:** 3-May-21

Borehole/Test Pit ID.: BH21-07 **Sample No./Depth:** SS2 @ 0.8 - 1.2 m **Test Date:** 25-May-21



Silt or Clay	Sand	Gravel

Sieve Size (mm)	% Passing
37.5	100.0
26.5	100.0
19.0	100.0
13.2	100.0
9.5	98.3
4.750	93.6
2.000	84.0
0.850	74.6
0.425	69.8
0.250	63.7
0.075	46.4

Hydrometer (mm)	% Passing
0.044	34.9
0.032	31.4
0.021	29.1
0.012	25.6
0.009	22.1
0.006	19.8
0.003	15.1
0.001	11.6

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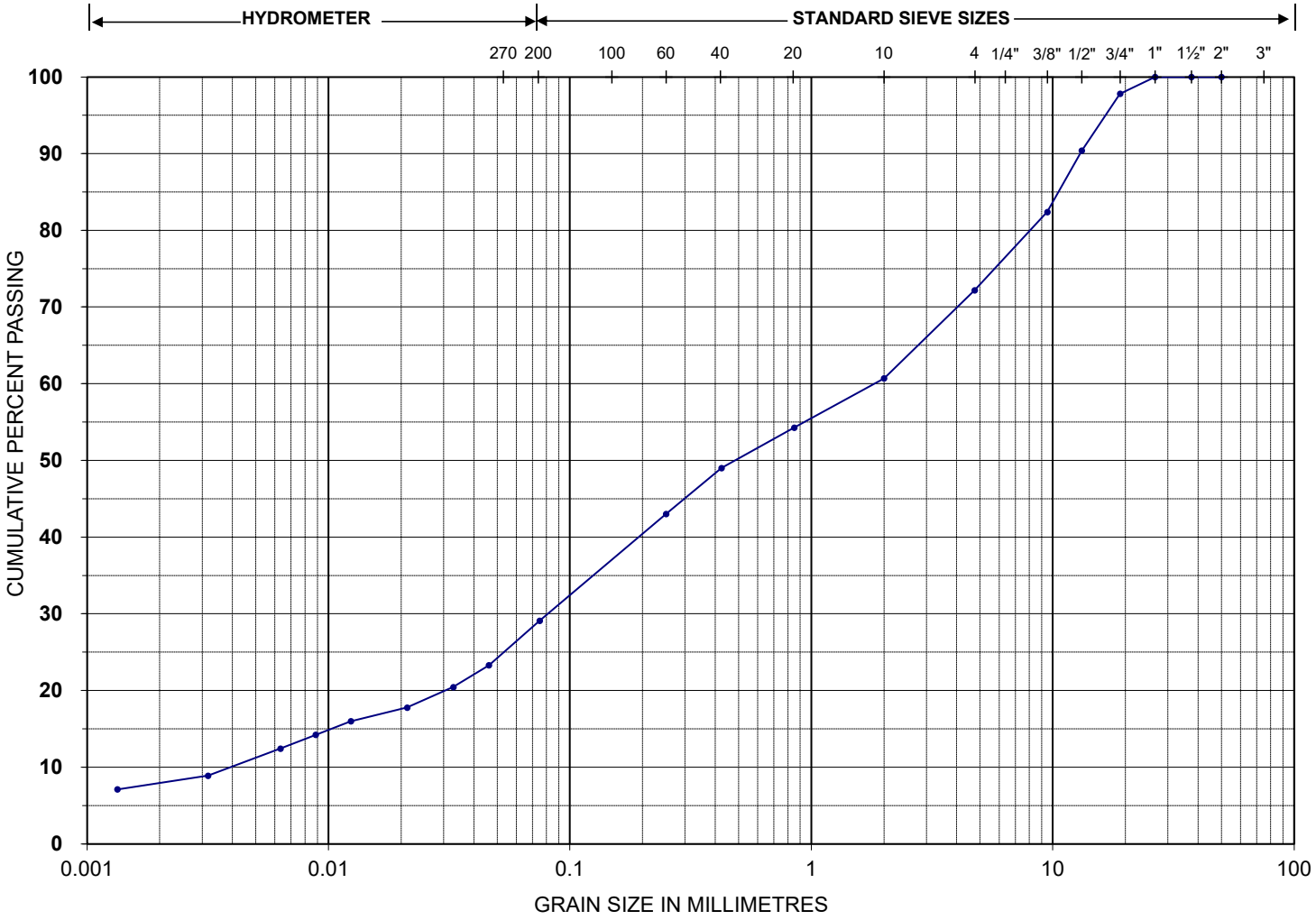
Project Name: Heritage Line **Project No.:** 21-049 **Sample Date:** 3-May-21

Borehole/Test Pit ID.: BH21-08 **Sample No./Depth:** SS2 @ 2.3 - 2.7 m **Test Date:** 25-May-21



Silt or Clay	Sand	Gravel

Sieve Size (mm)	% Passing
37.5	100.0
26.5	100.0
19.0	97.8
13.2	90.4
9.5	82.4
4.750	72.2
2.000	60.7
0.850	54.3
0.425	49.0
0.250	43.0
0.075	29.1

Hydrometer (mm)	% Passing
0.046	23.3
0.033	20.4
0.021	17.8
0.012	16.0
0.009	14.2
0.006	12.4
0.003	8.9
0.001	7.1

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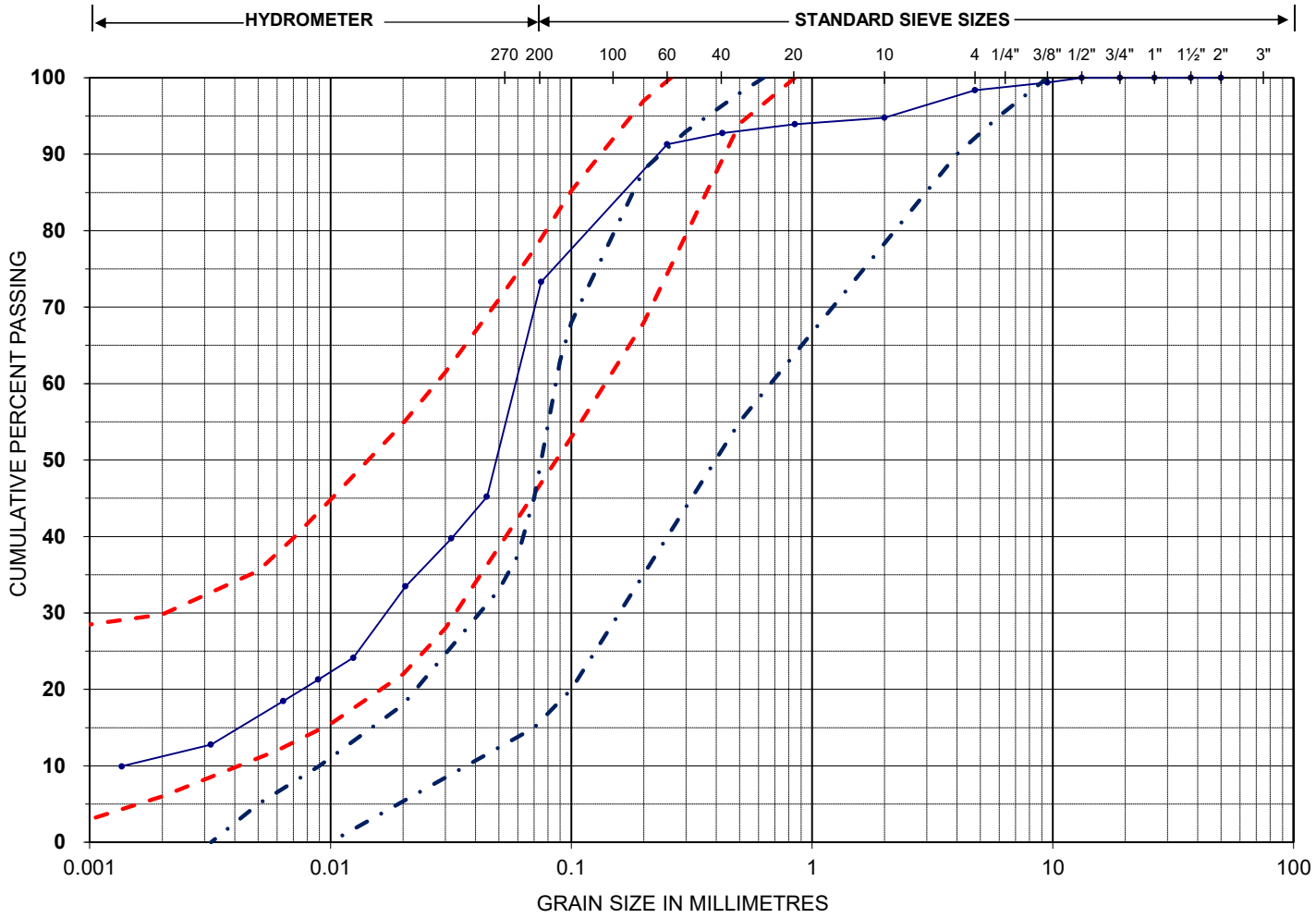
Project Name: Heritage Line **Project No.:** 21-049 **Date:** May 25 2021

Borehole/Test Pit ID.: BH21-09 **Sample No./Depth:** SS3 @ 1.5 - 1.9 m



Silt or Clay	Sand	Gravel

sm envelope T = 8 - 20 min/cm
ml envelope T = 20 - 50 min/cm

Estimated T = 30 min/cm

Sieve Size (mm)	% Passing
37.5	100.0
26.5	100.0
19.0	100.0
13.2	100.0
9.5	99.4
4.750	98.4
2.000	94.8
0.850	93.9
0.425	92.7
0.250	91.3
0.075	73.3

Hydrometer (mm)	% Passing
0.045	45.2
0.032	39.8
0.021	33.5
0.012	24.1
0.009	21.3
0.006	18.5
0.003	12.8
0.001	9.9

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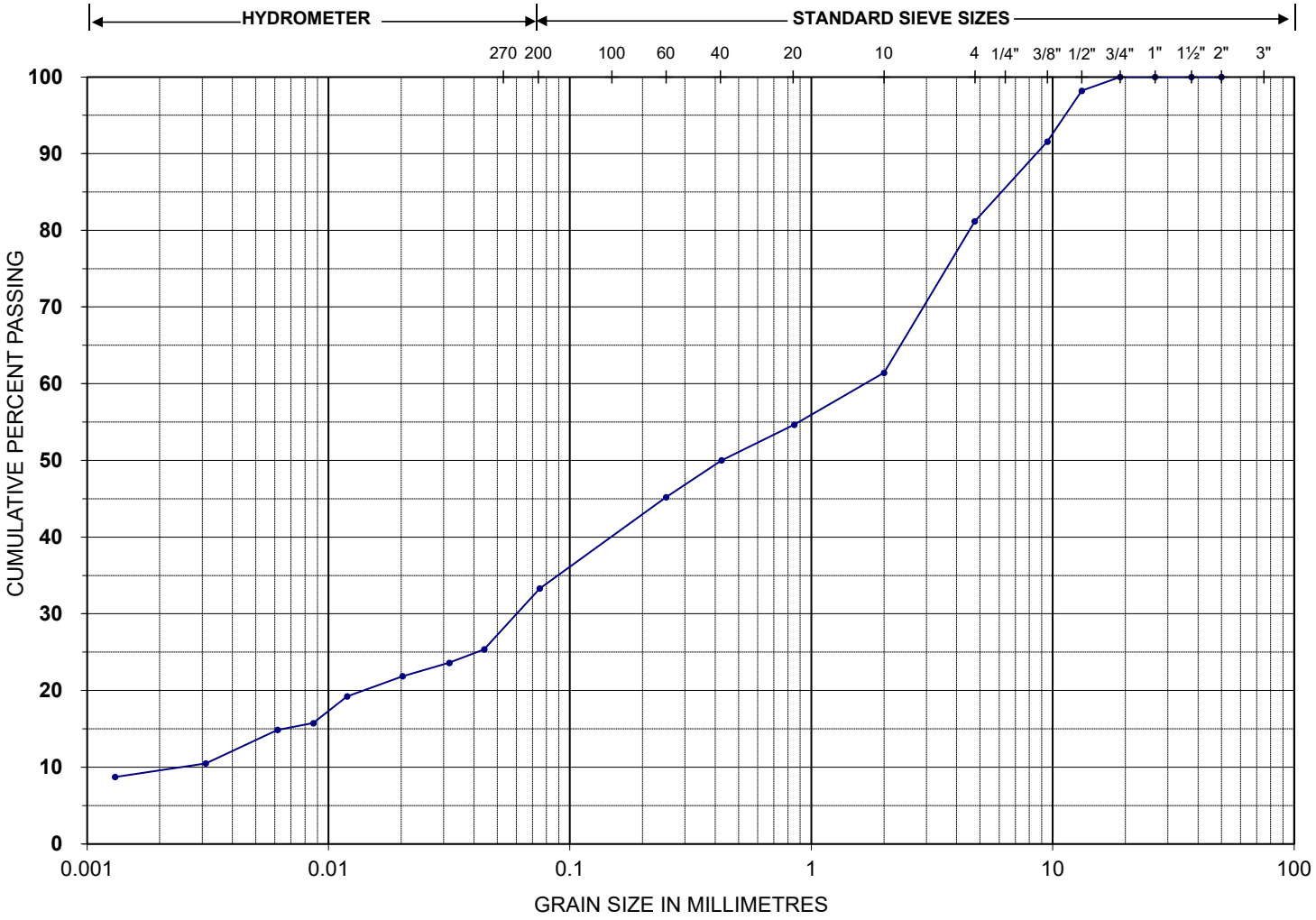
Project Name: Heritiage Line **Project No.:** 21-049 **Sample Date:** 4-May-21

Borehole/Test Pit ID.: BH21-11 **Sample No./Depth:** SS6 @ 3.8m to 4.3m **Test Date:** 25-May-21



Silt or Clay	Sand	Gravel

Sieve Size (mm)	% Passing
37.5	100.0
26.5	100.0
19.0	100.0
13.2	98.2
9.5	91.6
4.750	81.2
2.000	61.4
0.850	54.7
0.425	50.0
0.250	45.2
0.075	33.3

Hydrometer (mm)	% Passing
0.044	25.4
0.032	23.6
0.020	21.9
0.012	19.2
0.009	15.7
0.006	14.9
0.003	10.5
0.001	8.7

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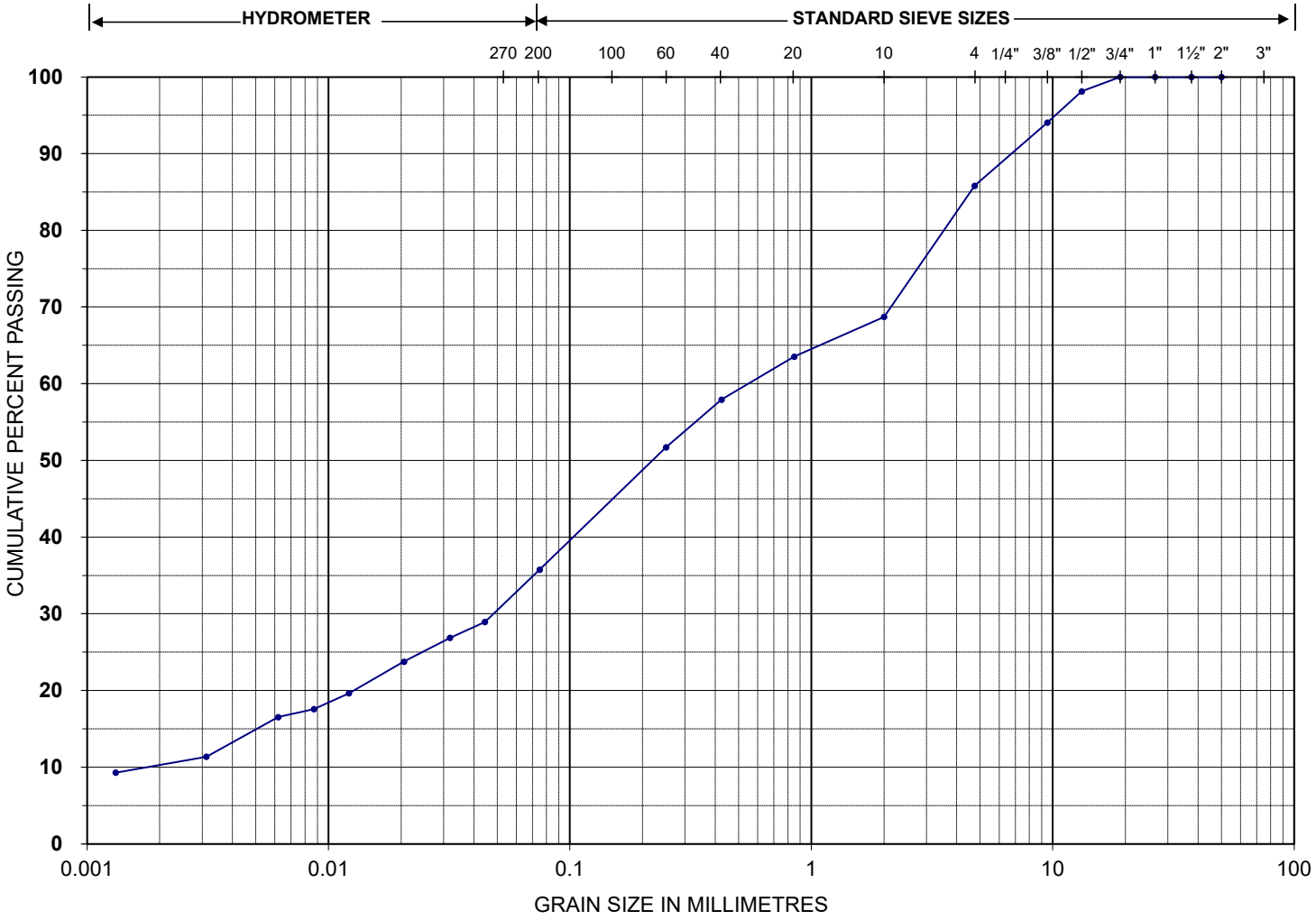
Project Name: Heritiage Line **Project No.:** 21-049 **Sample Date:** 4-May-21

Borehole/Test Pit ID.: BH21-12 **Sample No./Depth:** SS6 @ 3.8 - 4.3 m **Test Date:** 25-May-21



Silt or Clay	Sand	Gravel

Sieve Size (mm)	% Passing
37.5	100.0
26.5	100.0
19.0	100.0
13.2	98.1
9.5	94.0
4.750	85.8
2.000	68.7
0.850	63.5
0.425	57.9
0.250	51.7
0.075	35.8

Hydrometer (mm)	% Passing
0.044	28.9
0.032	26.9
0.021	23.8
0.012	19.6
0.009	17.6
0.006	16.5
0.003	11.4
0.001	9.3

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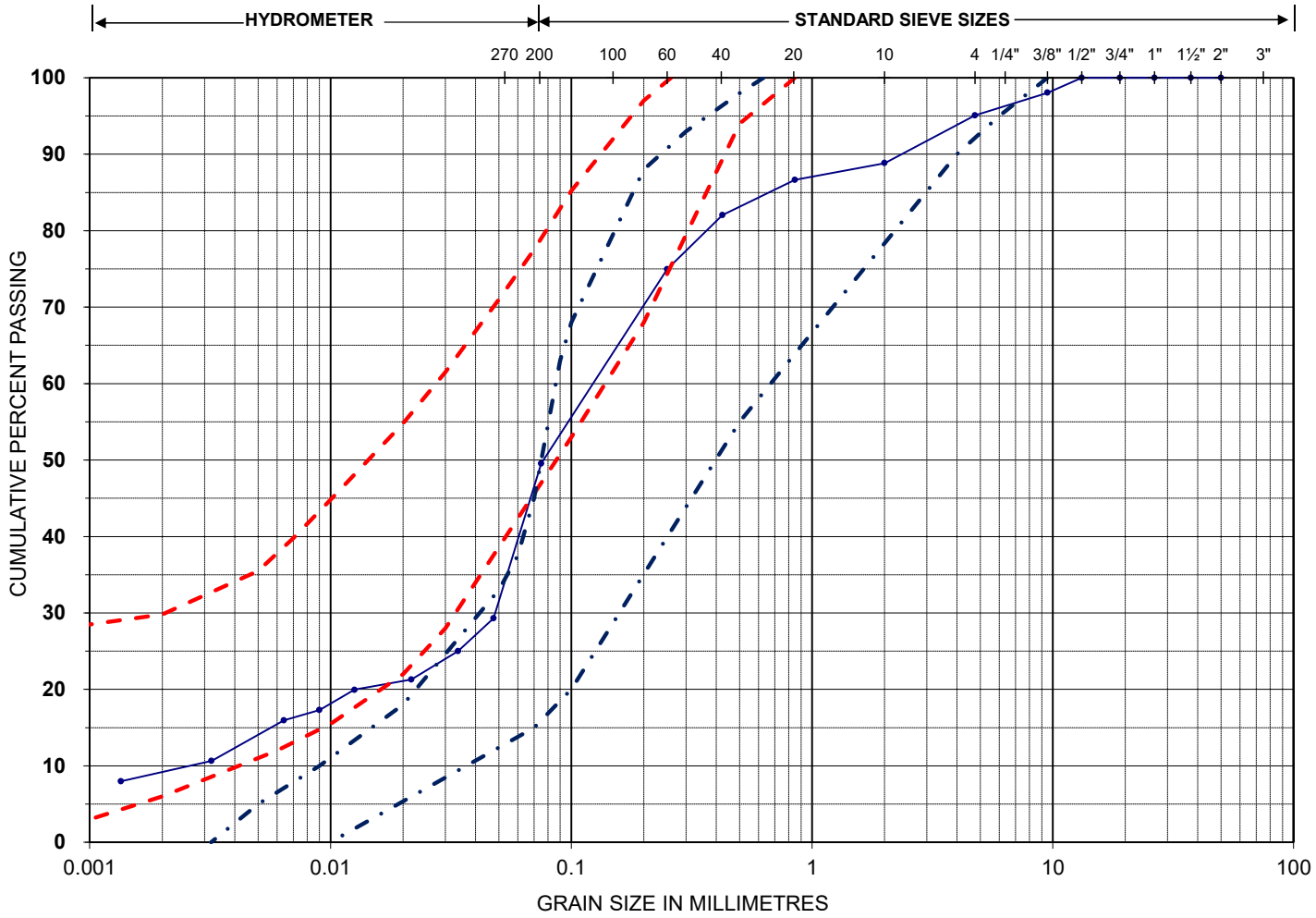
Project Name: Heritiage Line **Project No.:** 21-049 **Date:** 5-May-21

Borehole/Test Pit ID.: BH21-16 **Sample No./Depth:** SS3 @ 1.5 - 2.0 m



Silt or Clay	Sand	Gravel

sm envelope T = 8 - 20 min/cm
ml envelope T = 20 - 50 min/cm

Estimated T = 20 min/cm

Sieve Size (mm)	% Passing
37.5	100.0
26.5	100.0
19.0	100.0
13.2	100.0
9.5	98.0
4.750	95.1
2.000	88.8
0.850	86.7
0.425	82.0
0.250	75.0
0.075	49.5

Hydrometer (mm)	% Passing
0.048	29.3
0.034	25.0
0.022	21.3
0.013	20.0
0.009	17.3
0.006	16.0
0.003	10.6
0.001	8.0

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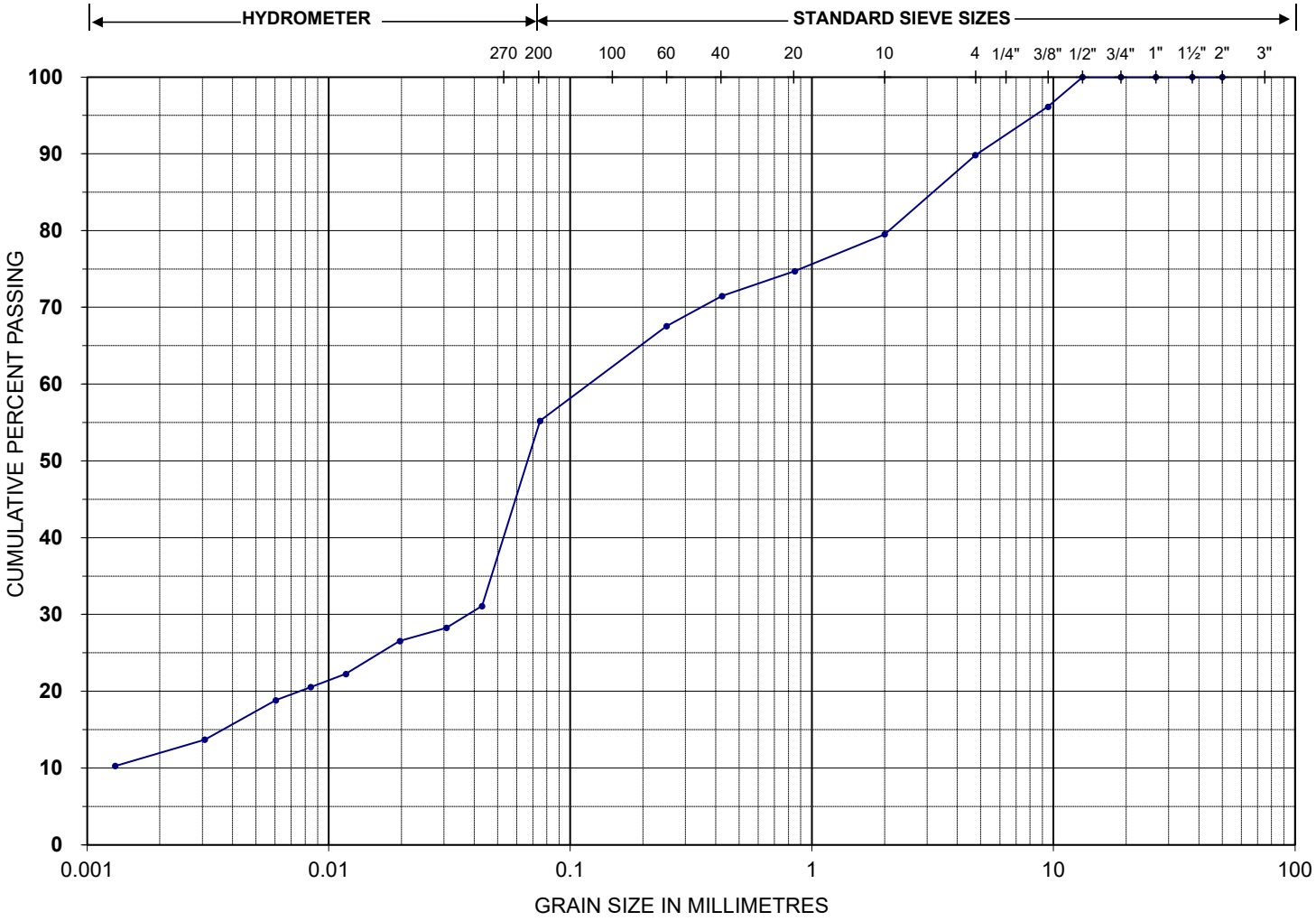
Project Name: Heritage Line **Project No.:** 21-049 **Sample Date:** 3-May-21

Borehole/Test Pit ID.: BH21-17 **Sample No./Depth:** SS5 @ 3.0 - 3.5 m **Test Date:** 25-May-21



Silt or Clay	Sand	Gravel

Sieve Size (mm)	% Passing
37.5	100.0
26.5	100.0
19.0	100.0
13.2	100.0
9.5	96.1
4.750	89.8
2.000	79.5
0.850	74.7
0.425	71.5
0.250	67.5
0.075	55.2

Hydrometer (mm)	% Passing
0.043	31.1
0.031	28.3
0.020	26.5
0.012	22.3
0.008	20.6
0.006	18.8
0.003	13.7
0.001	10.3

ATTERBERG LIMITS

ASTM D4318

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Project Name:	Heritage Line	**Project Number:**	21-049
Sample ID:	BH21-17 SS5	**Technician:**	KV
Sample Date:	5-May-21	**Test Date:**	June 8 2021

Liquid Limit Test

Number of Shocks	33	24	18
Tin No.	RAP	100	RJ2
Tin + Wet soil	21.1	24.0	23.4
Tin + Dry soil	20.1	22.4	22.0
Wt. of Water	1.0	1.6	1.4
Wt. of Tin	13.7	13.5	13.6
Wt. of Dry Soil	6.4	8.9	8.4
Water Content	16	18	17

Plastic Limit Test

Tin No.	V97	DMX
Tin + Wet soil	18.9	18.0
Tin + Dry soil	18.3	17.6
Wt. of Water	0.6	0.4
Wt. of Tin	13.5	13.5
Wt. of Dry Soil	4.8	4.1
Water Content	13	10

Natural Water Content

PR68
872.4
810.5
61.9
185.4
625.1
9.9

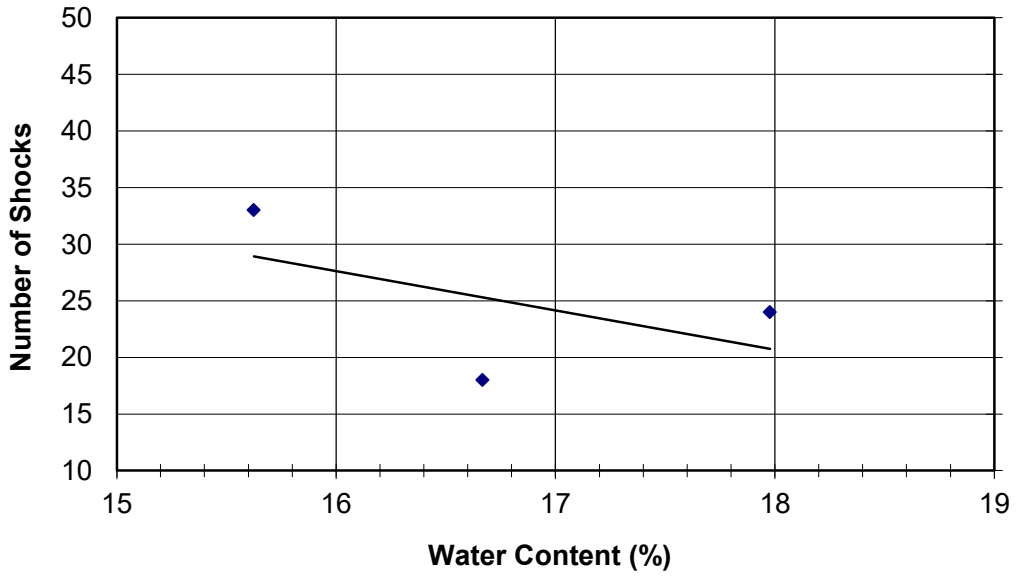
Sample Results

Liquid Limit, (W_L)	17
Plastic Limit, (WP)	11
Plasticity Index ($I_P=W_L-W_P$)	6
Natural Water Content, W	10
Liquidity Index ($I_L=W-W_P/W_L-W_P$)	0

Control Results

Liquid Limit, (W_L)	30.4
Plastic Limit, (WP)	19.3
Plasticity Index ($I_P=W_L-W_P$)	11.1

Liquid Limit



More information available upon request

Approver: VG
Issue Date: 2020-12-08
Issue/Revision Number: Issue 1, Revision 1

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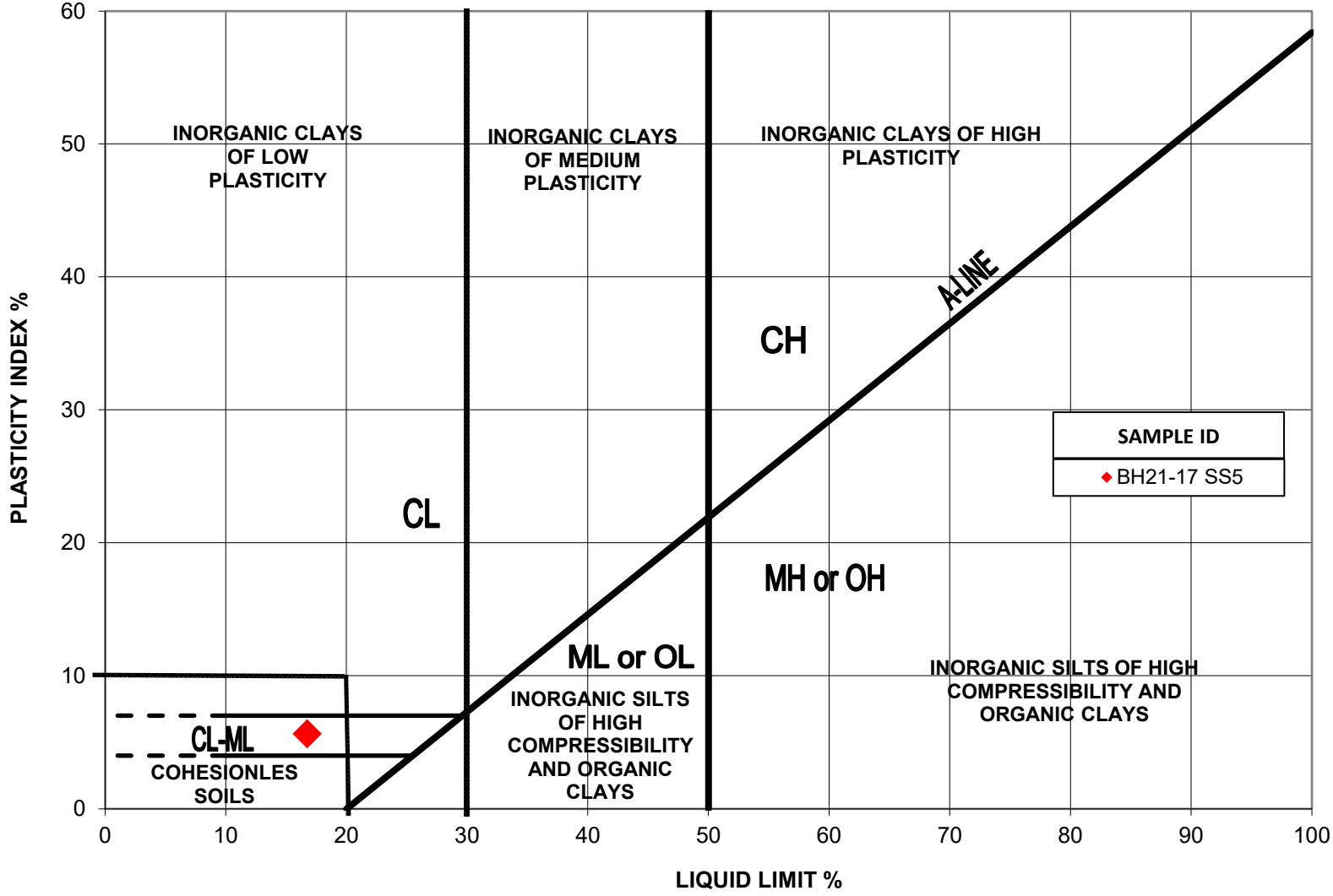
Atterberg Limits Plasticity Chart



https://oyaventures.sharepoint.com/sites/Labratory/Shared Documents/General/Test Results/21-049/21-049_BH21-17 SS5_Atterberg_Re-do

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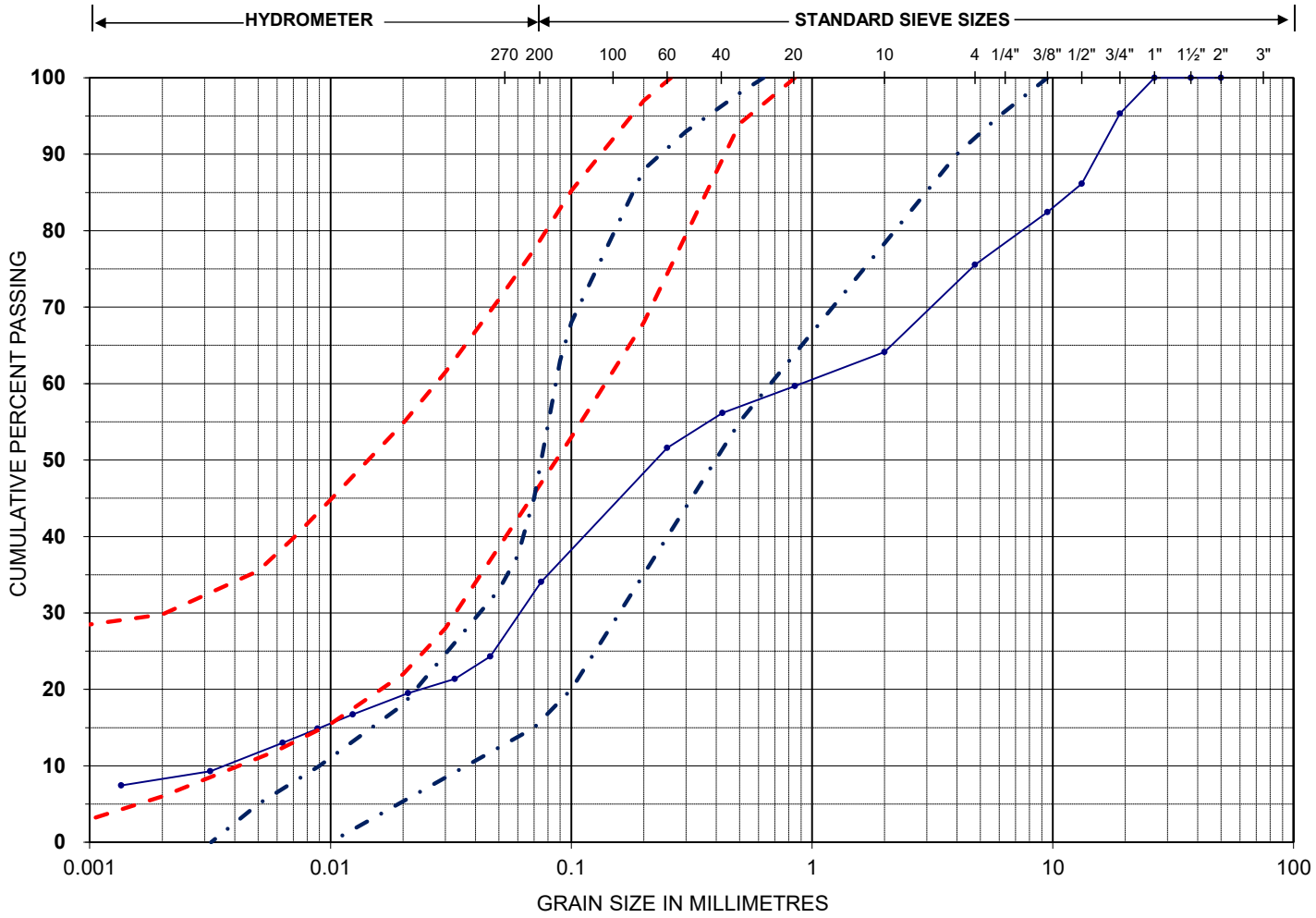
Project Name: Heritage Line **Project No.:** 21-049 **Date:** 25-May-21

Borehole/Test Pit ID.: TP21-02 **Sample No./Depth:** GS-02 @ 0.6 - 3.3 m



Silt or Clay	Sand	Gravel

sm envelope T = 8 - 20 min/cm
ml envelope T = 20 - 50 min/cm

Estimated T = 15 min/cm

Sieve Size (mm)	% Passing
37.5	100.0
26.5	100.0
19.0	95.3
13.2	86.1
9.5	82.4
4.750	75.5
2.000	64.1
0.850	59.7
0.425	56.2
0.250	51.6
0.075	34.1

Hydrometer (mm)	% Passing
0.046	24.3
0.033	21.4
0.021	19.5
0.012	16.7
0.009	14.9
0.006	13.0
0.003	9.3
0.001	7.4

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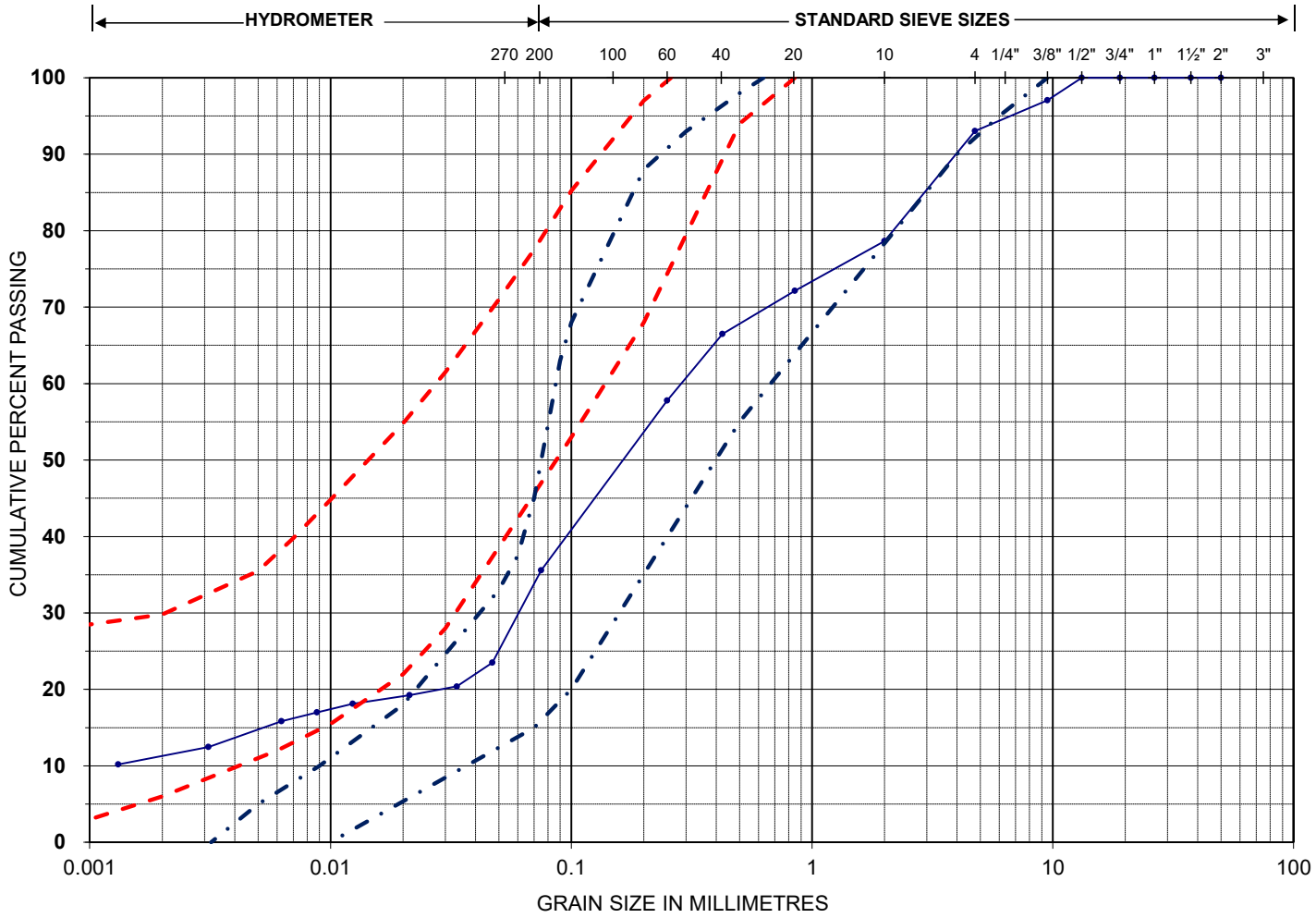
Project Name: Heritiage Line **Project No.:** 21-049 **Date:** 28-Apr-21

Borehole/Test Pit ID.: TP21-04 **Sample No./Depth:** GS2@ 0.4 - 3.3m



Silt or Clay	Sand	Gravel

sm envelope T = 8 - 20 min/cm
ml envelope T = 20 - 50 min/cm

Estimated T = 13 min/cm

Sieve Size (mm)	% Passing
37.5	100.0
26.5	100.0
19.0	100.0
13.2	100.0
9.5	97.0
4.750	93.0
2.000	78.6
0.850	72.1
0.425	66.5
0.250	57.8
0.075	35.6

Hydrometer (mm)	% Passing
0.047	23.5
0.033	20.4
0.021	19.3
0.012	18.1
0.009	17.0
0.006	15.9
0.003	12.5
0.001	10.2

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PARTICLE SIZE DISTRIBUTION
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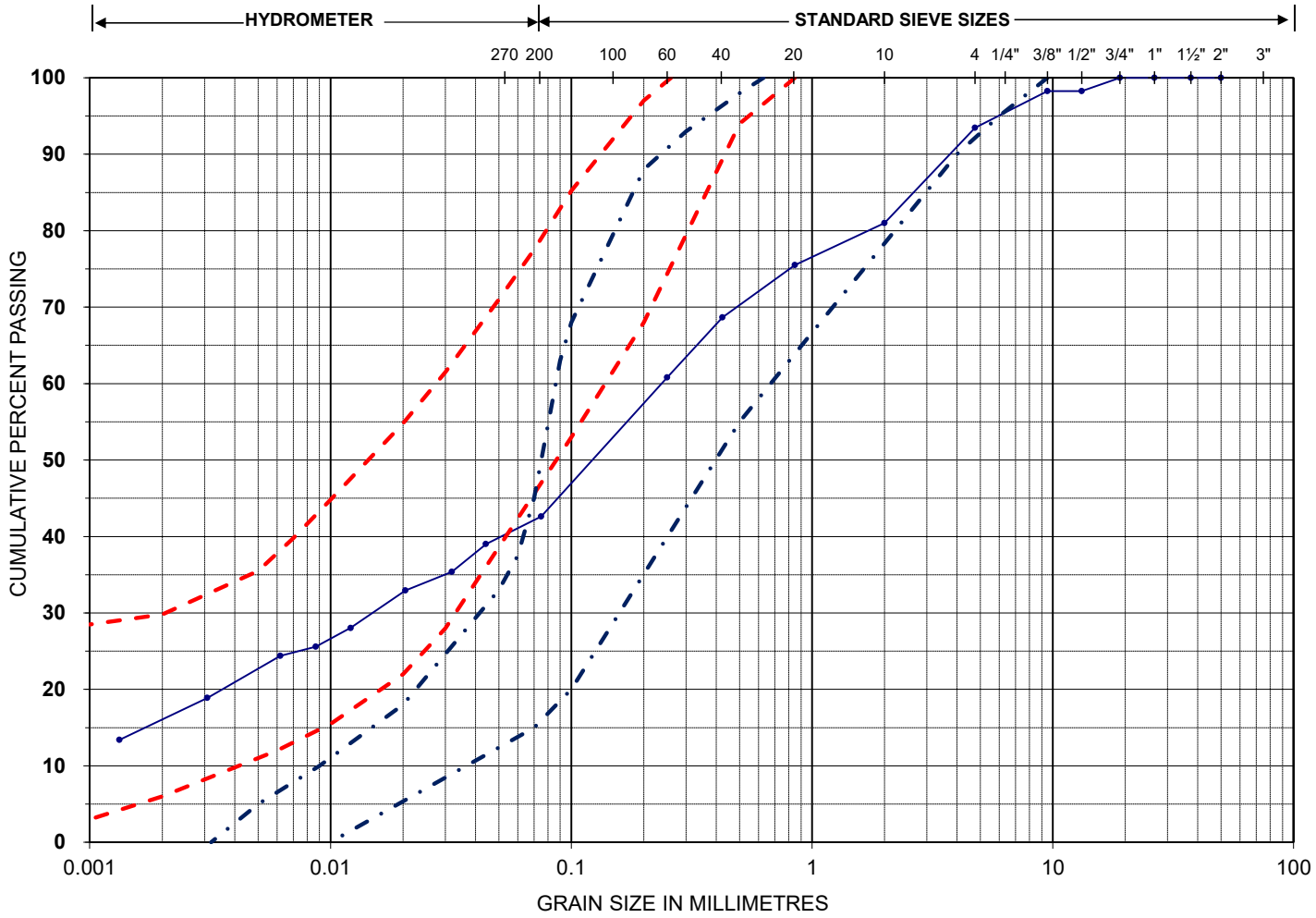
Project Name: Heritage Line **Project No.:** 21-049 **Date:** 25-May-21

Borehole/Test Pit ID.: TP21-05 **Sample No./Depth:** GS-2 @ 2m



Silt or Clay	Sand	Gravel

sm envelope T = 8 - 20 min/cm
ml envelope T = 20 - 50 min/cm

Estimated T = 20 min/cm

Sieve Size (mm)	% Passing
37.5	100.0
26.5	100.0
19.0	100.0
13.2	98.3
9.5	98.3
4.750	93.5
2.000	81.0
0.850	75.5
0.425	68.6
0.250	60.8
0.075	42.6

Hydrometer (mm)	% Passing
0.044	39.0
0.032	35.4
0.020	32.9
0.012	28.0
0.009	25.6
0.006	24.4
0.003	18.9
0.001	13.4

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MOISTURE CONTENTS

Project Name: Heritage Line
Project Number: 21-049
Technician: AYJr
Test Date: 25-May-21

TIN NO.	72	DM8	E5	H5	G3
BOREHOLE NO.	BH21-17	BH21-17	BH21-17	BH21-17	BH21-17
SAMPLE & DEPTH					
WT of TIN & WET SOIL (g)	143.7	112.1	134.1	136.5	126.1
WT of TIN & DRY SOIL (g)	131.5	106.0	118.3	124.0	106.7
WT of WATER (g)	12.2	6.1	15.8	12.5	19.4
TARE WT (g)	9.8	9.9	9.7	9.7	9.7
WT of DRY SOIL (g)	121.7	96.1	108.6	114.3	97.0
MOISTURE CONTENT	10.0%	6.3%	14.5%	10.9%	20.0%
TIN NO.	RN2	C5	WTF	J2	C7
BOREHOLE NO.	BH21-17	BH21-17	BH21-17	BH21-08	BH21-08
SAMPLE & DEPTH					
WT of TIN & WET SOIL (g)	116.8	124.7	108.1	107.0	103.7
WT of TIN & DRY SOIL (g)	109.7	112.5	100.0	98.2	93.5
WT of WATER (g)	3.2	2.5	2.2	8.8	10.2
TARE WT (g)	10.3	9.7	10.3	9.9	9.7
WT of DRY SOIL (g)	99.4	102.8	89.7	88.3	83.8
MOISTURE CONTENT	7.1%	11.9%	9.0%	10.0%	12.2%
TIN NO.	I8	E7	KR29	X9	D7
BOREHOLE NO.	BH21-08	BH21-08	BH21-08	BH21-08	BH21-08
SAMPLE & DEPTH					
WT of TIN & WET SOIL (g)	124.8	124.4	128.7	62.6	110.6
WT of TIN & DRY SOIL (g)	114.3	114.2	117.6	53.8	103.6
WT of WATER (g)	0.8	0.4	0.5	8.8	7.0
TARE WT (g)	9.7	9.8	10.6	10.4	9.7
WT of DRY SOIL (g)	104.6	104.4	107.0	43.4	93.9
MOISTURE CONTENT	10.0%	9.8%	10.4%	20.3%	7.5%
TIN NO.	I4	KR24	GI	Y4	H3
BOREHOLE NO.	BH21-08	BH21-12	BH21-12	BH21-12	BH21-12
SAMPLE & DEPTH					
WT of TIN & WET SOIL (g)	76.4	99	68.8	127.5	120.4
WT of TIN & DRY SOIL (g)	71.9	92.4	63.8	117.0	112.1
WT of WATER (g)	5.2	3.7	4.7	10.5	8.3
TARE WT (g)	9.7	10.3	9.7	10.3	9.7
WT of DRY SOIL (g)	62.2	82.1	54.1	106.7	102.4
MOISTURE CONTENT	7.2%	8.0%	9.2%	9.8%	8.1%
TIN NO.	GH1	B8	F7	A4	
BOREHOLE NO.	BH21-12	BH21-12	BH21-12	BH21-12	
SAMPLE & DEPTH					
WT of TIN & WET SOIL (g)	119.6	90.0	138.5	107.8	
WT of TIN & DRY SOIL (g)	110.4	78.2	126.5	101.8	
WT of WATER (g)	1.2	2.0	2.3	6.0	
TARE WT (g)	10.4	9.8	9.7	9.7	
WT of DRY SOIL (g)	100.0	68.4	116.8	92.1	
MOISTURE CONTENT	9.2%	17.3%	10.3%	6.5%	

PRI ENGINEERING

MOISTURE CONTENTS

Project Name: Heritage Line
Project Number: 21-049
Technician: AYJr
Test Date: 25-May-21

TIN NO.	Q3	B4	G6	G9	X1
BOREHOLE NO.	BH21-16	BH21-16	BH21-16	BH21-16	BH21-16
SAMPLE & DEPTH					
WT of TIN & WET SOIL (g)	112.0	93.8	115.2	81.6	86.6
WT of TIN & DRY SOIL (g)	104.1	81.3	107.9	77.4	78.8
WT of WATER (g)	7.9	12.5	7.3	4.2	7.8
TARE WT (g)	10.7	9.7	9.6	9.6	10.3
WT of DRY SOIL (g)	93.4	71.6	98.3	67.8	68.5
MOISTURE CONTENT	8.5%	17.5%	7.4%	6.2%	11.4%

TIN NO.	C1	I3	DP37	A9	E4
BOREHOLE NO.	BH21-16	BH21-16	BH21-16	BH21-02	BH21-02
SAMPLE & DEPTH					
WT of TIN & WET SOIL (g)	109.1	103.0	94.1	103.9	100.7
WT of TIN & DRY SOIL (g)	100.0	90.1	88.5	95.3	88.9
WT of WATER (g)	0.7	3.2	4.6	8.6	11.8
TARE WT (g)	9.8	9.7	10.2	9.9	10.0
WT of DRY SOIL (g)	90.2	80.4	78.3	85.4	78.9
MOISTURE CONTENT	10.1%	16.0%	7.2%	10.1%	15.0%

TIN NO.	J7	C3	QE15	F5	G5
BOREHOLE NO.	BH21-02	BH21-02	BH21-02	BH21-02	BH21-02
SAMPLE & DEPTH					
WT of TIN & WET SOIL (g)	74.9	103.0	77.2	86.8	93.1
WT of TIN & DRY SOIL (g)	69.1	96.7	60.9	81.1	87.3
WT of WATER (g)	4.0	3.4	5.6	5.7	5.8
TARE WT (g)	9.8	9.7	10.7	9.7	9.7
WT of DRY SOIL (g)	59.3	87.0	50.2	71.4	77.6
MOISTURE CONTENT	9.8%	7.2%	32.5%	8.0%	7.5%

TIN NO.	C9	RR7	6N	L23	7D
BOREHOLE NO.	BH21-02	BH21-09	BH21-09	BH21-09	BH21-09
SAMPLE & DEPTH					
WT of TIN & WET SOIL (g)	94.4	91.6	98.1	136.3	113.6
WT of TIN & DRY SOIL (g)	90.3	78.7	87.4	122.3	100.5
WT of WATER (g)	5.5	2.7	1.3	14.0	13.1
TARE WT (g)	9.6	10.2	12.0	10.3	11.7
WT of DRY SOIL (g)	80.7	68.5	75.4	112.0	88.8
MOISTURE CONTENT	5.1%	18.8%	14.2%	12.5%	14.8%

TIN NO.	F6	H6	I9	F2	
BOREHOLE NO.	BH21-09	BH21-09	BH21-09	BH21-09	
SAMPLE & DEPTH					
WT of TIN & WET SOIL (g)	111.3	118.8	111.3	112.7	
WT of TIN & DRY SOIL (g)	101.7	107.2	97.8	100.1	
WT of WATER (g)	0.0	1.9	3.8	12.6	
TARE WT (g)	9.6	9.7	9.7	9.7	
WT of DRY SOIL (g)	92.1	97.5	88.1	90.4	
MOISTURE CONTENT	10.4%	11.9%	15.3%	13.9%	

Appendix E

Dewatering Calculations

Construction Dewatering Calculations				
Project Name: Heritage Line Development **Project Number: 21-10985**		**Lot 7**		
Description	**Symbol**	**Value**	**Unit**	**Explanation**
Input				
Ground Surface Elevation	-	226.5	masl	Proposed grade
Groundwater Elevation	-	224.4	masl	MW21-15
Lowest Excavated Depth	-	223.5	masl	Assumed 3 m excavation
Base of Aquifer	-	206.7	masl	Terminus of lowest well on property
Hydraulic Conductivity	K	1.0E-07	m/s	Mid range K value for SM envelope
		8.6E-03	m/day	Convert to m/day
Dimensions of Excavation	a	11	m	Approximated from engineering drawings
	b	20	m	Approximated from engineering drawings
Output				
Static Water Level	-	224.4	masl	MW21-05
Target Pumping Water Level	-	223	masl	1 m below base of excavation
Water Level Above Aquifer Bottom Before Dewatering	H	17.7	m	
Water Level at Excavation Wall	h	0.9	m	
Effective Radius	r_e	8.4	m	Effective radius of rectangular excavation
Sichardt Estimate for Radius of Influence	R_{sich}	15.9	m	where c = 3000 for well approximation
Radius of Influence	R_0	24.3	m	Manipulated vaule, when $R_{sich} < r_e$ otherwise $R_0 = R_{sich}$
Construction Dewatering Flow Rate	Q	8.0	m^3/day	Construction flow rate - Dupuit-Thiem Equation
Safety Factor	S.F.	200	%	Enter desired safety factor
Maximum Construction Flow Rate (with applied factor of safety)	Q_{max}	15.9	m^3/day	during the initial period
Estimated Construction Dewatering Flow Rate	-	**7963**	L/day	
Estimated Maximum Construction Flow Rate with Safety Factor	-	**15927**	L/day	

Construction Dewatering Calculations				
Project Name: Heritage Line Development **Project Number: 21-10985**		**Lot 9**		
Description	**Symbol**	**Value**	**Unit**	**Explanation**
Input				
Ground Surface Elevation	-	226.5	masl	Proposed grade
Groundwater Elevation	-	224.4	masl	MW21-15
Lowest Excavated Depth	-	223.5	masl	Assumed 3 m excavation
Base of Aquifer	-	206.7	masl	Terminus of lowest well on property
Hydraulic Conductivity	K	1.0E-07	m/s	Mid range K value for SM envelope
		8.6E-03	m/day	Convert to m/day
Dimensions of Excavation	a	11	m	Approximated from engineering drawings
	b	20	m	Approximated from engineering drawings
Output				
Static Water Level	-	224.4	masl	MW21-05
Target Pumping Water Level	-	223	masl	1 m below base of excavation
Water Level Above Aquifer Bottom Before Dewatering	H	17.7	m	
Water Level at Excavation Wall	h	0.9	m	
Effective Radius	r_e	8.4	m	Effective radius of rectangular excavation
Sichardt Estimate for Radius of Influence	R_{sich}	15.9	m	where c = 3000 for well approximation
Radius of Influence	R_0	24.3	m	Manipulated vaule, when $R_{sich} < r_e$ otherwise $R_0 = R_{sich}$
Construction Dewatering Flow Rate	Q	8.0	m^3/day	Construction flow rate - Dupuit-Thiem Equation
Safety Factor	S.F.	200	%	Enter desired safety factor
Maximum Construction Flow Rate (with applied factor of safety)	Q_{max}	15.9	m^3/day	during the initial period
Estimated Construction Dewatering Flow Rate	-	**7963**	L/day	
Estimated Maximum Construction Flow Rate with Safety Factor	-	**15927**	L/day	

Appendix F

Certificates of Analysis - Groundwater

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Project : 21-10985

17-May-2021

D.M. Wills -Peterborough
Attn : Amanda Tse

150 Jameson Drive
Peterborough, ON
K9J 0B9, Canada

Phone: 289-385-3286
Fax:705-741-3568

Date Rec. : 11 May 2021
LR Report: **CA12346-MAY21**
Reference: 21-10985, Amanda Tse

CERTIFICATE OF ANALYSIS

Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: MAC	6: AO/OG	7: MDL	8: GW-10985-MW21-16-2021-05-11	9: GW-10985-MW21-09-2021-05-11	10: GW-10985-MW21-02-2021-05-11
Sample Date & Time								11-May-21 14:30	11-May-21 14:45	11-May-21 14:55
Temp Upon Receipt [°C]	---	---	---	---	---	---	---	8.0	8.0	8.0
NO2 [as N mg/L]	12-May-21	20:44	17-May-21	15:23	1	---	0.003	0.007	0.004	0.010
NO3 [as N mg/L]	12-May-21	20:44	17-May-21	15:23	10	---	0.006	3.10	0.059	0.681
NO2+NO3 [as N mg/L]	12-May-21	20:44	17-May-21	15:23	---	---	0.006	3.10	0.063	0.691

MAC - Maximum Acceptable Concentration
AO/OG - Aesthetic Objective / Operational Guideline
MDL - SGS Method Detection Limit

Temperature of Sample upon Receipt: 8 degrees C
Cooling Agent Present:Yes
Custody Seal Present:Yes

Chain of Custody Number:021737

SGS Canada Inc.
P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - KOL 2HO
Phone: 705-652-2000 FAX: 705-652-6365

Project : 21-10985
LR Report : **CA12346-MAY21**

Jill Campbell, B.Sc.,GISAS
Project Specialist,
Environment, Health & Safety

OnLine LIMS

0002498032

Appendix G

Infiltration Test Summaries

IN-SITU INFILTRATION TEST

Appendix G

Project:	Heritage Line Residential	**PROJECT NO.:**	10985
Site Location:	1197 Heritage Line, Keene ON	**Date:**	10-May-21
BOREHOLE ID:	INF-01	**Start Time:**	1:37 PM
		Test No.	1

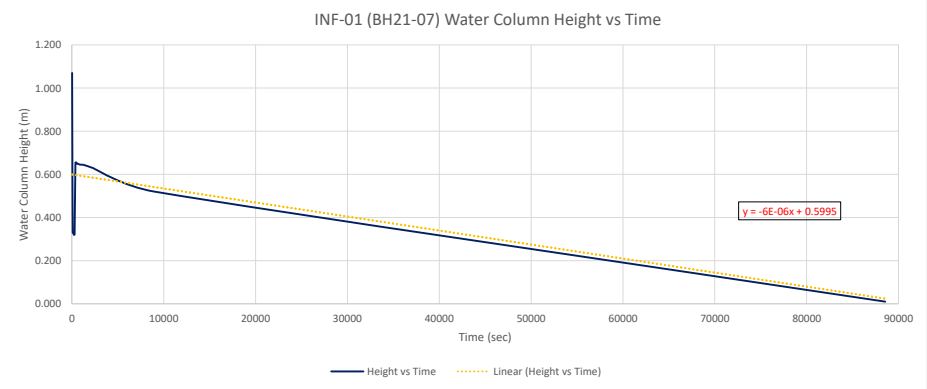
Depth of Borehole (mbeg):	1.45	Pipe Stickup (maeg):	-0.019	Infiltrometer Depth (mbTP):	1.47	

Time* (Seconds)	Measurement Interval (sec)	Depth** (mbTP)	Water Column Height (m)	Distance dropped per interval (m)	Infilitration Rate per Interval (m/sec)	Cumulative Infiltration Rate (m/sec)
30	-	0.400	1.070	-	--	--
90	60	1.140	0.330	0.740	1.233E-02	1.233E-02
150	60	1.140	0.330	0.000	0.000E+00	6.167E-03
180	30	1.140	0.330	0.000	0.000E+00	4.933E-03
210	30	1.150	0.320	0.010	3.333E-04	4.167E-03
240	30	1.150	0.320	0.000	0.000E+00	3.571E-03
270	30	1.150	0.320	0.000	0.000E+00	3.125E-03
300	30	1.150	0.320	0.000	0.000E+00	2.778E-03
390	90	0.815	0.655	--	--	--
450	60	0.815	0.655	0.000	0.000E+00	0.000E+00
480	30	0.815	0.655	0.000	0.000E+00	0.000E+00
510	30	0.818	0.653	0.003	8.333E-05	2.083E-05
540	30	0.820	0.650	0.002	8.333E-05	3.333E-05
570	30	0.820	0.650	0.000	0.000E+00	2.778E-05
600	30	0.820	0.650	0.000	0.000E+00	2.381E-05
630	30	0.821	0.649	0.001	3.333E-05	2.500E-05
660	30	0.822	0.648	0.001	3.333E-05	2.593E-05
690	30	0.822	0.648	0.000	0.000E+00	2.333E-05
720	30	0.822	0.648	0.000	0.000E+00	2.121E-05
810	90	0.824	0.646	0.002	2.222E-05	2.143E-05
900	90	0.825	0.645	0.001	1.111E-05	1.961E-05
1020	120	0.825	0.645	0.000	0.000E+00	1.587E-05
1290	270	0.826	0.644	0.001	3.704E-06	1.222E-05
1350	60	0.827	0.643	0.001	1.667E-05	1.250E-05
1440	90	0.828	0.642	0.001	1.111E-05	1.238E-05
1500	60	0.829	0.641	0.001	1.667E-05	1.261E-05
1560	60	0.830	0.640	0.001	1.667E-05	1.282E-05
1635	75	0.831	0.639	0.001	1.333E-05	1.285E-05
1800	165	0.833	0.637	0.002	1.212E-05	1.277E-05
1860	60	0.834	0.636	0.001	1.667E-05	1.293E-05
1890	30	0.835	0.635	0.001	3.333E-05	1.333E-05
1980	90	0.836	0.634	0.001	1.111E-05	1.321E-05
2040	60	0.837	0.633	0.001	1.667E-05	1.333E-05
2190	150	0.839	0.631	0.002	1.333E-05	1.333E-05
2370	180	0.842	0.628	0.003	1.667E-05	1.364E-05
2490	120	0.845	0.625	0.003	2.500E-05	1.429E-05
2580	90	0.847	0.623	0.002	2.222E-05	1.461E-05
9000	6420	0.950	0.520	0.103	1.604E-05	1.568E-05
88560	79560	1.460	0.010	0.510	6.410E-06	7.315E-06

* Time at 0 indicates end of pour time into unit. Start of Test.
** Depth at time 0 indicates measurement below top of measuring pipe at the start of the test.
More water was added to the infiltrometer at time = 390s
Not used for statistical analysis

	(m/sec)	(mm/sec)	(mm/hour)
Maximum Infiltration Rate Between Sampling Intervals -	1.23E-02	1.23E+01	44400
Minimum Infiltration Rate Between Sampling Intervals -	0.00E+00	0.00E+00	0
Median Infiltration Rate Between Sampling Intervals -	1.33E-05	1.33E-02	48
Average Infiltration Rate Between Sampling Intervals -	**3.57E-04**	**3.57E-01**	**1284**
Average Cumulative Infiltration Rate for Entire Data Set -	**1.01E-03**	**1.01E+00**	**3654**

In-situ Infiltration Rate Measured in the Field (mm/sec):	**1.01**
In-situ Infiltration Rate Measured in the Field (mm/hour):	**3.65E+03**
Calculated Percolation Time (T) based on field infiltration (min/cm):	**0.164**



		Test 1 - Observed
Test Duration (seconds)		**88,560**
Total Drop Distance (mm)		**1395**
Total Number of Measured Intervals		**39**
Infiltration Rate (mm/sec) - Test Average		**1.01**
Infiltration Rate (mm/hour) - Test Average		**3.65E+03**
Calculated Percolation Time (T) based on Field Infiltration (min/cm)		**0.164**

IN-SITU INFILTRATION TEST

Project:	Heritage Line Residential	**PROJECT NO.:**	10985
Site Location:	1197 Heritage Line, Keene ON	**Date:**	10-May-21
BOREHOLE ID:	INF-02	**Start Time:**	2:43 PM
		Test No.	1

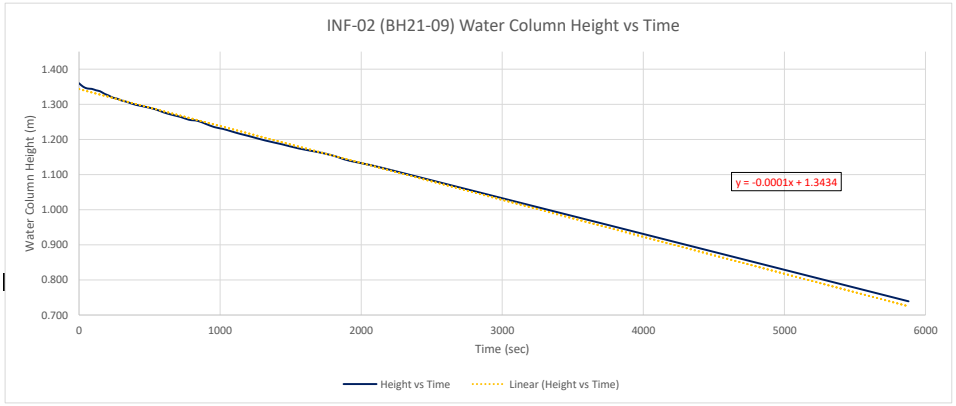
Depth of Borehole (mbeg):	1.47	Pipe Stickup (maeg):	0.006	Infiltrometer Depth (mbTP):	1.51	

Time* (Seconds)	Measurement Interval (sec)	Depth** (mbTP)	Water Column Height (m)	Distance dropped per interval (m)	Infilitration Rate per Interval (m/sec)	Cumulative Infiltration Rate (m/sec)	
0	-	0.150	1.360	-	--	--	
30	30	0.160	1.350	0.010	3.333E-04	3.333E-04	
60	30	0.165	1.345	0.005	1.667E-04	2.500E-04	
90	30	0.166	1.344	0.001	3.333E-05	1.778E-04	
120	30	0.170	1.340	0.004	1.333E-04	1.667E-04	
150	30	0.173	1.337	0.003	1.000E-04	1.533E-04	
180	30	0.180	1.330	0.007	2.333E-04	1.667E-04	
210	30	0.185	1.325	0.005	1.667E-04	1.667E-04	
240	30	0.191	1.319	0.006	2.000E-04	1.708E-04	
270	30	0.194	1.316	0.003	1.000E-04	1.630E-04	
300	30	0.199	1.311	0.005	1.667E-04	1.633E-04	
330	30	0.202	1.308	0.003	1.000E-04	1.576E-04	
360	30	0.206	1.304	0.004	1.333E-04	1.556E-04	
390	30	0.210	1.300	0.004	1.333E-04	1.538E-04	
420	30	0.213	1.297	0.003	1.000E-04	1.500E-04	
480	60	0.218	1.292	0.005	8.333E-05	1.417E-04	
540	60	0.224	1.286	0.006	1.000E-04	1.370E-04	
600	60	0.233	1.277	0.009	1.500E-04	1.383E-04	
660	60	0.240	1.270	0.007	1.167E-04	1.364E-04	
720	60	0.246	1.264	0.006	1.000E-04	1.333E-04	
780	60	0.254	1.256	0.008	1.333E-04	1.333E-04	
840	60	0.257	1.253	0.003	5.000E-05	1.274E-04	
900	60	0.266	1.244	0.009	1.500E-04	1.289E-04	
960	60	0.275	1.235	0.009	1.500E-04	1.302E-04	
1020	60	0.280	1.230	0.005	8.333E-05	1.275E-04	
1080	60	0.287	1.223	0.007	1.167E-04	1.269E-04	
1140	60	0.294	1.216	0.007	1.167E-04	1.263E-04	
1200	60	0.300	1.210	0.006	1.000E-04	1.250E-04	
1320	120	0.313	1.197	0.013	1.083E-04	1.235E-04	
1440	120	0.324	1.186	0.011	9.167E-05	1.208E-04	
1560	120	0.336	1.174	0.012	1.000E-04	1.192E-04	
1680	120	0.345	1.165	0.009	7.500E-05	1.161E-04	
1800	120	0.356	1.154	0.011	9.167E-05	1.144E-04	
1920	120	0.371	1.139	0.015	1.250E-04	1.151E-04	
2160	240	0.392	1.118	0.021	8.750E-05	1.120E-04	
5880	3720	0.771	0.739	0.379	1.019E-04	1.056E-04	
74520	68640	1.510	0.000	0.739	1.077E-05	1.825E-05	DRY

* Time at 0 indicates end of pour time into unit. Start of Test.
** Depth at time 0 indicates measurement below top of measuring pipe at the start of the test.
Not used for statistical analysis

	(m/sec)	(mm/sec)	(mm/hour)
Maximum Infiltration Rate Between Sampling Intervals -	3.33E-04	3.33E-01	1200
Minimum Infiltration Rate Between Sampling Intervals -	3.33E-05	3.33E-02	120
Median Infiltration Rate Between Sampling Intervals -	1.08E-04	1.08E-01	390
Average Infiltration Rate Between Sampling Intervals -	**1.24E-04**	**1.24E-01**	**445**
Average Cumulative Infiltration Rate for Entire Data Set -	**1.48E-04**	**1.48E-01**	**532**

In-situ Infiltration Rate Measured in the Field (mm/sec):	**0.148**
In-situ Infiltration Rate Measured in the Field (mm/hour):	**532**
Calculated Percolation Time (T) based on field infiltration (min/cm):	**1.13**



		Test 1 - Observed
Test Duration (seconds)		**5,880**
Total Drop Distance (mm)		**621**
Total Number of Measured Intervals		**36**
Infiltration Rate (mm/sec) - Test Average		**0.148**
Infiltration Rate (mm/hour) - Test Average		**532**
Calculated Percolation Time (T) based on Field Infiltration (min/cm)		**1.13**

IN-SITU INFILTRATION TEST

Appendix G

Project:	Heritage Line Residential	**PROJECT NO.:**	10985
Site Location:	1197 Heritage Line, Keene ON	**Date:**	10-May-21
BOREHOLE ID:	INF-03	**Start Time:**	3:29 PM
		Test No.	1

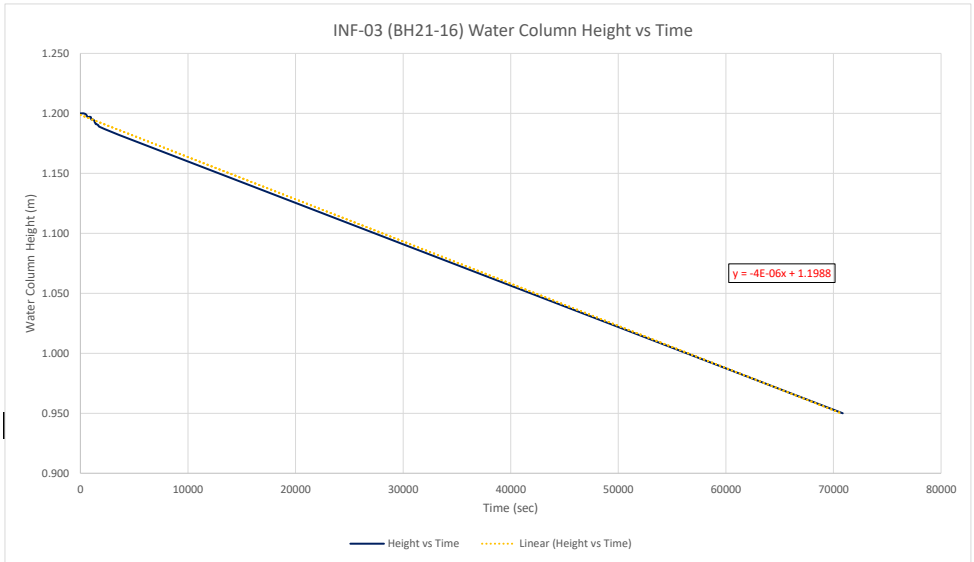
Depth of Borehole (mbeg):	1.19	Pipe Stickup (maeg):	0.29	Infiltrometer Depth (mbTP):	1.50	

Time* (Seconds)	Measurement Interval (sec)	Depth** (mbTP)	Water Column Height (m)	Distance dropped per interval (m)	Infiltration Rate per Interval (m/sec)	Cumulative Infiltration Rate (m/sec)
0	-	0.300	1.200	-	--	--
30	30	0.300	1.200	0.000	0.000E+00	0.000E+00
60	30	0.300	1.200	0.000	0.000E+00	0.000E+00
90	30	0.300	1.200	0.000	0.000E+00	0.000E+00
120	30	0.300	1.200	0.000	0.000E+00	0.000E+00
150	30	0.300	1.200	0.000	0.000E+00	0.000E+00
180	30	0.300	1.200	0.000	0.000E+00	0.000E+00
300	120	0.300	1.200	0.000	0.000E+00	0.000E+00
540	240	0.301	1.199	0.001	4.167E-06	1.852E-06
660	120	0.303	1.197	0.002	1.667E-05	4.545E-06
780	120	0.303	1.197	0.000	0.000E+00	3.846E-06
960	180	0.303	1.197	0.000	0.000E+00	3.125E-06
1,020	60	0.305	1.195	0.002	3.333E-05	4.902E-06
1,140	120	0.305	1.195	0.000	0.000E+00	4.386E-06
1,290	150	0.306	1.194	0.001	6.667E-06	4.651E-06
1,320	30	0.307	1.193	0.001	3.333E-05	5.303E-06
1,380	60	0.308	1.192	0.001	1.667E-05	5.797E-06
1,440	60	0.309	1.191	0.001	1.667E-05	6.250E-06
1,500	60	0.309	1.191	0.000	0.000E+00	6.000E-06
1,680	180	0.310	1.190	0.001	5.556E-06	5.952E-06
1,740	60	0.311	1.189	0.001	1.667E-05	6.322E-06
3,600	1860	0.318	1.182	0.007	3.763E-06	5.000E-06
70,860	67260	0.550	0.950	0.232	3.449E-06	3.528E-06

* Time at 0 indicates end of pour time into unit. Start of Test.
** Depth at time 0 indicates measurement below top of measuring pipe at the start of the test.
Not used for statistical analysis

	(m/sec)	(mm/sec)	(mm/hour)
Maximum Infiltration Rate Between Sampling Intervals -	3.33E-05	3.33E-02	120
Minimum Infiltration Rate Between Sampling Intervals -	0.00E+00	0.00E+00	0
Median Infiltration Rate Between Sampling Intervals -	1.72E-06	1.72E-03	6
Average Infiltration Rate Between Sampling Intervals -	**7.13E-06**	**7.13E-03**	**26**
Average Cumulative Infiltration Rate for Entire Data Set -	**3.25E-06**	**3.25E-03**	**12**

In-situ Infiltration Rate Measured in the Field (mm/sec):	**3.25E-03**
In-situ Infiltration Rate Measured in the Field (mm/hour):	**11.7**
Calculated Percolation Time (T) based on field infiltration (min/cm):	**51.3**



		Test 1 - Observed
Test Duration (seconds)		**70,860**
Total Drop Distance (mm)		**250**
Total Number of Measured Intervals		**23**
Infiltration Rate (mm/sec) - Test Average		**3.25E-03**
Infiltration Rate (mm/hour) - Test Average		**11.7**
Calculated Percolation Time (T) based on Field Infiltration (min/cm)		**51.3**

Appendix H

Water Balance and Development Impact Assessment

Monthly Water Budget Calculations

WILLS

Project No: 21-10985
Project Name: Heritage Line Preliminary SWM
Designed/Checked By: SO/KS
Date: 10-May-22

CANADIAN CLIMATE NORMALS FOR 'PETERBOROUGH A (5186)' (1980-2010)

Climate ID = 6166418
Latitude = 44.23
Longitude = 78.37

Thornthwaite (1948) Inputs				Monthly Water Budget Analysis				
Month	Mean Temperature (°C)[1]	Total Precipitation (mm)[1]	Heat Index	PET (mm)	Daylight Correction Factor	Adjusted PET (mm)	Surplus (mm)	Deficit (mm)
January	-8.9	58.5	0.00	0.0	0.77	0.0	58.5	0.0
February	-7.7	50.6	0.00	0.0	0.87	0.0	50.6	0.0
March	-2.0	65.0	0.00	0.0	0.99	0.0	65.0	0.0
April	5.7	68.8	1.22	28.2	1.12	31.6	40.6	0.0
May	12.4	73.2	3.96	64.3	1.23	79.2	8.9	6.0
June	16.8	76.7	6.26	84.8	1.29	109.2	0.0	32.5
July	19.4	66.7	7.79	101.5	1.26	128.0	0.0	61.3
August	18.2	83.2	7.07	95.1	1.17	110.9	0.0	27.7
September	13.5	78.4	4.50	67.9	1.04	70.8	10.5	0.0
October	7.3	70.0	1.77	37.4	0.92	34.3	32.6	0.0
November	1.7	79.0	0.20	8.2	0.80	6.6	70.8	0.0
December	-5.3	70.3	0.00	0.0	0.74	0.0	70.3	0.0
Totals		**840.4**	32.77			**570.5**	**407.8**	**127.5**
	Thornthwaite Coefficient (α)		**1.021**			Total Water Surplus (mm)		**269.9**

Notes:

1. Temperature and Precipitation are taken from Canadian Climate Normals 1981-2010
2. Water budget adjusted for latitude and length of daylight
3. Potential Evapotranspiration (PET) is calculated based on the Thornthwaite 1948 equation
4. Total Water Surplus (Thornthwaite, 1948) is calculated as total precipitation minus adjusted evapotranspiration

Water Balance Calculations for Existing Conditions

WILLS

Project No: 21-10985
Project Name: Heritage Line Preliminary SWM
Designed/Checked By: SO/KS
Date: 10-May-22

Catchment Parameters	EX-100	EX-200	EX-300								**Total**
Drainage Area (m^2)	21800	17600	17000								**56400**
Pervious Area (m^2)	21800	17600	16800								**56200**
Impervious Area (m^2)	0	0	200								**200**
Evapotranspiration Factors											
Pervious PET Ratio	0.68	0.68	0.68								**0.68**
Impervious Evapotranspiration[3]	0.20	0.20	0.20								**0.20**
Infiltration Factors											
Topography Infiltration Factor	0.15	0.10	0.15								**0.13**
Soil Infiltration Factor	0.30	0.30	0.30								**0.30**
Land Cover Infiltration Factor	0.11	0.14	0.10								**0.12**
MOE Infiltration Factor	0.56	0.54	0.55								**0.55**
Actual Infiltration Factor	0.56	0.54	0.55								**0.55**
Run-Off Coefficient	0.44	0.46	0.45								**0.45**
Runoff from Impervious Surfaces	0.80	0.80	0.80								**0.80**
Inputs (mm/yr)											
Precipitation	840.4	840.4	840.4								**840.4**
Run-On	0.0	0.0	0.0								**0.0**
Other Inputs	0.0	0.0	0.0								**0.0**
Total Inputs	840.4	840.4	840.4								**840.4**
Outputs (mm/yr)											
Precipitation Surplus	269.9	269.9	274.6								**271.3**
Net Surplus	269.9	269.9	274.6								**271.3**
Evapotranspiration	570.5	570.5	565.8								**569.1**
Infiltration	150.8	146.7	147.5								**148.5**
Infiltration Features[4]	0.0	0.0	0.0								**0.0**
Total Infiltration	**150.8**	**146.7**	**147.5**								**148.5**
Runoff Pervious Areas	119.1	123.1	120.6								**120.8**
Runoff Impervious Areas	0.0	0.0	672.3								**672.3**
Total Unadjusted Runoff	119.1	123.1	127.1								**122.8**
Total Adjusted Runoff[5]	**119.1**	**123.1**	**127.1**								**122.8**
Total Outputs	**840.4**	**840.4**	**840.4**								**840.4**
Inputs (m^3/yr)											
Precipitation	18321	14791	14287								**47399**
Run-On	0	0	0								**0**
Other Inputs	0	0	0								**0**
Total Inputs	**18321**	**14791**	**14287**								**47399**
Outputs (m^3/yr)											
Precipitation Surplus	5883	4749	4668								**15300**
Net Surplus	5883	4749	4668								**15300**
Evapotranspiration	12438	10042	9619								**32098**
Infiltration	3287	2582	2507								**8376**
Infiltration Features[4]	0	0	0								**0**
Total Infiltration	3287	2582	2507								**8376**
Runoff Pervious Areas	2596	2167	2027								**6790**
Runoff Impervious Areas	0	0	134								**134**
Total Unadjusted Runoff	2596	2167	2161								**6924**
Total Adjusted Runoff[5]	2596	2167	2161								**6924**
Total Outputs	**18321**	**14791**	**14287**								**47399**

Notes:

1. Water Balance Calculations area in based on methodology described in the Conservation Authority Guidelines for Hydrogeological Assessments (June 2013)
2. Annual Precipitation and Evapotranspiration values were determined using the Thornthwaite (1948) method for monthly water budget calculations
3. Evaporation from impervious areas was assumed to be 20% of Precipitation
4. Infiltration Features are calculated using daily Precipitation data and averaged over the number of years of available data. The entire Catchment is assumed to contribute with no infiltration occuring during months with a negative average temperature.
5. Total Adjusted Runoff is calculated as (Pervious Runoff + Impervious Runoff) - (Infiltration Features)

Water Balance Calculations for Proposed Conditions

WILLS

Project No: 21-10985
Project Name: Heritage Line Preliminary SWM
Designed/Checked By: SO/KS
Date: 10-May-22

Catchment Parameters	PR-100	PR-101	PR-200	PR-201	PR-202	PR-300					**Total**
Drainage Area (m^2)	2400	12800	21400	7400	9300	2300					**55600**
Pervious Area (m^2)	900	11500	12500	6800	9300	2000					**43000**
Impervious Area (m^2)	1500	1300.0	8900	600	0	300					**12600**
Evapotranspiration Factors											
Pervious PET Ratio	0.68	0.68	0.68	0.68	0.68	0.68					**0.68**
Impervious Evapotranspiration[3]	0.20	0.20	0.20	0.20	0.20	0.20					**0.20**
Infiltration Factors											
Topography Infiltration Factor	0.10	0.15	0.20	0.10	0.10	0.15					**0.14**
Soil Infiltration Factor	0.30	0.30	0.30	0.30	0.30	0.30					**0.30**
Land Cover Infiltration Factor	0.10	0.10	0.10	0.10	0.20	0.10					**0.12**
MOE Infiltration Factor	0.50	0.55	0.60	0.50	0.60	0.55					**0.57**
Actual Infiltration Factor	0.50	0.55	0.60	0.50	0.60	0.55					**0.57**
Run-Off Coefficient	0.50	0.45	0.40	0.50	0.40	0.45					**0.43**
Runoff from Impervious Surfaces	0.80	0.80	0.80	0.80	0.80	0.80					**0.80**
Inputs (mm/yr)											
Precipitation	840.4	840.4	840.4	840.4	840.4	840.4					**840.4**
Run-On	0.0	0.0	0.0	0.0	0.0	0.0					**0.0**
Other Inputs	0.0	0.0	0.0	0.0	0.0	0.0					**0.0**
Total Inputs	840.4	840.4	840.4	840.4	840.4	840.4					**840.4**
Outputs (mm/yr)											
Precipitation Surplus	521.4	310.7	437.2	302.5	269.9	322.3					**361.1**
Net Surplus	521.4	310.7	437.2	302.5	269.9	322.3					**361.1**
Evapotranspiration	319.0	529.7	403.2	537.9	570.5	518.1					**479.3**
Infiltration	50.6	133.3	94.6	124.0	161.9	129.1					**118.2**
Infiltration Features[4]	334.4	235.0	246.5	250.0	0.0	0.0					**196.7**
Total Infiltration	**385.0**	**368.3**	**341.1**	**374.0**	**161.9**	**129.1**					**314.9**
Runoff Pervious Areas	134.9	121.4	107.9	134.9	107.9	121.4					**117.0**
Runoff Impervious Areas	672.3	672.3	672.3	672.3	0.0	672.3					**672.3**
Total Unadjusted Runoff	470.8	177.4	342.7	178.5	107.9	193.3					**242.9**
Total Adjusted Runoff[5]	136.4	-57.6	96.2	-71.5	107.9	193.3					**46.2**
Total Outputs	**840.4**	**840.4**	**840.4**	**840.4**	**840.4**	**840.4**					**840.4**
Inputs (m^3/yr)											
Precipitation	2017	10757	17985	6219	7816	1933					**46726**
Run-On	0	0	0	0	0	0					**0**
Other Inputs	0	0	0	0	0	0					**0**
Total Inputs	**2017**	**10757**	**17985**	**6219**	**7816**	**1933**					**46726**
Outputs (m^3/yr)											
Precipitation Surplus	1251	3977	9357	2238	2510	741					**20075**
Net Surplus	1251	3977	9357	2238	2510	741					**20075**
Evapotranspiration	766	6780	8628	3981	5306	1192					**26651**
Infiltration	121	1707	2024	918	1506	297					**6572**
Infiltration Features[4]	803	3008	5275	1850	0	0					**10935**
Total Infiltration	924	4715	7299	2767	1506	297					**17508**
Runoff Pervious Areas	121	1396	1349	918	1004	243					**5031**
Runoff Impervious Areas	1008	874	5984	403	0	202					**8471**
Total Unadjusted Runoff	1130	2271	7333	1321	1004	445					**13503**
Total Adjusted Runoff[5]	327	-737	2058	-529	1004	445					**2567**
Total Outputs	**2017**	**10757**	**17985**	**6219**	**7816**	**1933**					**46726**

Notes:

1. Water Balance Calculations area in based on methodology described in the Conservation Authority Guidelines for Hydrogeological Assessments (June 2013)
2. Annual Precipitation and Evapotranspiration values were determined using the Thornthwaite (1948) method for monthly water budget calculations
3. Evaporation from impervious areas was assumed to be 20% of Precipitation
4. Infiltration Features are calculated using daily Precipitation data and averaged over the number of years of available data. The entire Catchment is assumed to contribute with no infiltration occuring during months with a negative average temperature.
5. Total Adjusted Runoff is calculated as (Pervious Runoff + Impervious Runoff) - (Infiltration Features)

Water Balance Assessment

Sheet 4 of 4

WILLS

Project No: 21-10985
Project Name: Heritage Line Preliminary SWM
Designed/Checked By: SO/KS
Date: 10-May-22

Characteristic	Existing	Proposed No Mitigation	Change	Proposed With Mitigation	Change
Inputs (m^3/yr)					
Precipitation	47399	46726	-1.4%	46726	-1.4%
Run-On	0	0	0.0%	0	0.0%
Other Inputs	0	0	0.0%	0	0.0%
Total Inputs	47399	46726	-1.4%	46726	-1.4%
Outputs (m^3/yr)					
Precipitation Surplus	15300	20075	31.2%	20075	31.2%
Net Surplus	15300	20075	31.2%	20075	31.2%
Evapotranspiration	32098	26651	-17.0%	26651	-17.0%
Infiltration	8376	6572	-21.5%	6572	-21.5%
Infiltration Features	0	0	0.0%	10935	0.0%
Total Infiltration	**8376**	**6572**	**-21.5%**	**17508**	**109.0%**
Runoff Pervious Areas	6790	5031	-25.9%	5031	-25.9%
Runoff Impervious Areas	134	8471	6200.0%	8471	6200.0%
Total Runoff	**6924**	**13503**	**95.0%**	**2567**	**-62.9%**
Total Outputs	47399	46726	-1.4%	46726	-1.4%

Nitrate Dilution Calculations

Total Dilution Area	5.56	ha
No. of Lots	16	
Sewage Flow per Lot	1000	L/day
Total Daily Sewage Loading	16,000	L/day
Nitrate in Septic Effluent	40	mg/L
Background Nitrates	0.063	mg/L
Stormwater Effluent Nitrates	0	mg/L
Infiltration Rates		
Infiltration Rate (Clean Water)	133.3	mm/year
Infiltration Rate (Clean Water)	18,006	L/day
Infiltration Rate (Stormwater)	196.7	mm/year
Infiltration Rate (Stormwater)	29,960	L/day
Nitrate Concentrations		
Nitrate Loading - Development	640,000	mg/day
Nitrate Loading - Rainfall	1,134	mg/day
Nitrate Loading - Runoff	0	mg/day
Total Nitrate Loading	641,134	mg/day
Dilution - Development	16,000	L/day
Dilution - Groundwater Recharge	47,966	L/day
Total Dilution	63,966	L/day
Boundary Nitrate Concentration	**10.0**	**mg/L**