



REPORT

Foundation Investigation and Design Report

*Dunlop Street Sanitary Trunk Sewer Relocation Project
City of Barrie, Ontario*

Submitted to:

City of Barrie

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Submitted by:

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PART A

FOUNDATION INVESTIGATION REPORT DUNLOP STREET SANITARY TRUCK SEWER RELOCATION HIGHWAY 400 TRENCHLESS CROSSING CITY OF BARRIE, ONTARIO

1.0 INTRODUCTION

WSP Golder (formerly Golder Associates Ltd., now a member of WSP) has been retained by the City of Barrie to provide foundation engineering services for the proposed sanitary trunk sewer extending from the intersection of Dunlop Street West and Cedar Pointe Drive to Hart Drive, crossing under Highway 400, in Barrie, Ontario. The Key Plan showing the general site location is shown on Drawing 1.

WSP Golder carried out a geotechnical investigation to establish the subsurface conditions along the proposed sewer alignment by borehole drilling and laboratory testing. The scope of services for the geotechnical investigation are outlined in WSP Golder's Work Plan Letter to the City of Barrie, dated August 12, 2022, and addresses both an open-cut section of pipe installation, and a section within the Highway 400 corridor that is to be completed via trenchless installation methods. The subsurface exploration and reporting for the section within the Highway 400 right-of-way were conducted in accordance with the Ministry of Transportation Ontario (MTO) tunneling guidelines outlined in their document entitled, "*Guidelines for Foundation Engineering – Tunneling Specialty for Corridor Encroachment Permit Application*", dated February 2021. In addition to the Highway 400 crossing, a crossing of Dyments Creek is also planned within the MTO right-of-way.

The factual data, interpretations and recommendations contained in this report pertain to a specific project as described in the report and are not applicable to any other project or site location. If the project is modified in concept, location or elevation, or if the project is not initiated within eighteen months of the date of the report, WSP Golder should be given an opportunity to confirm that the preliminary recommendations are still valid. In addition, this report should be read in conjunction with the attached "*Important Information and Limitations of This Report*", included in Appendix A. The reader's attention is specifically drawn to this information, as it is essential for the proper use and interpretation of this report.

2.0 PROJECT AND SITE DESCRIPTION

The existing 750-millimetre (mm) concrete-asbestos trunk sanitary sewer is to be relocated due to the planned widening of Highway 400, which also includes replacement of the Dunlop Street bridge. The bridge is to be replaced by the MTO in 2024 and the City of Barrie (the City) is required to relocate the trunk sanitary sewer prior to this date.

The relocated trunk sanitary sewer will be approximately 1260 metres (m) long and will:

- Connect at an upstream manhole on Edgehill Drive;
- Span along a portion of Edgehill Drive and along Cedar Pointe Drive, crossing under an existing 1500-mm culvert along Cedar Pointe Drive. This trenchless crossing within the City's Right-of-Way will be about 30 m long; and
- Cross under Highway 400 from Cedar Pointe Drive to Hart Drive to connect to a downstream manhole on Hart Drive.

In addition to the above relocated trunk sanitary sewer, the storm sewer located at the intersection of Cedar Pointe Drive and Edgehill Drive will also be relocated to facilitate the trunk sanitary sewer works.

The proposed trenchless crossing for the installation of the 900 mm inner diameter (I.D.) (1,200 mm outer diameter (O.D.)) concrete sanitary sewer is approximately 237 m long extending under Highway 400 from west to east, and will span between existing and proposed MTO culverts and under Dyments Creek. The anticipated soil

cover is approximately 3.7 m below the centreline of the highway and less than 1.0 m below Dyments Creek. The proposed launching and receiving shafts are expected to have depths of approximately 5.0 m and 5.5 m, respectively. The proposed trenchless method for the installation of the sanitary sewer under Highway 400 is micro-tunneling.

It should be noted that the orientation (i.e., north, south, east, west) stated in the text of this report is typically referenced to project north and therefore may differ slightly from magnetic north shown on Drawing 1. For the purpose of this report, it is considered that Highway 400 is oriented in a north-south direction with the proposed sanitary sewer crossing positioned east-west, perpendicular to the highway.

The proposed east and west shaft locations are shown on Drawing 1 and are anticipated to extend about 0.5 m below the trenchless crossing invert depths, at about Elevation 226.5 m and 225.9 m, respectively. An existing 650-mm concrete-asbestos sanitary sewer, with its invert at about Elevation 227.3 m, intersects with the proposed trenchless crossing at about Station 10+225. It is understood that the existing 650-mm sewer will be abandoned and removed.

3.0 INVESTIGATION PROCEDURES

Field work for this investigation was carried out between August 25 and September 13, 2021, during which time nine boreholes (designated as Boreholes MT-1 to MT-8, and AH-1) were advanced near the proposed alignment, at the approximate locations shown on Drawing 1. The borehole locations were laid out based on the proposed sewer alignment to be outside of the tunnel horizon, considering site constraints due to access, traffic control requirements and underground utilities.

The boreholes were advanced using a track-mounted Diedrich D-90 drilling rig and a truck-mounted CME 55 drilling rig, both equipped with 200-mm O.D. Hollow Stem Augers, supplied and operated by Walker Drilling of Utopia, Ontario, and by Pontil Drilling Services of Mount Albert, Ontario, respectively. Where required, traffic control was performed in accordance with MTO's Ontario Traffic Control Manual Book 7 – Temporary Conditions.

Soil samples were obtained in the boreholes at 0.75-m and 1.5-m intervals of depth using 50 mm outer diameter split-spoon samplers driven by a full weight automatic hammer in accordance with the Standard Penetration Test (SPT) procedure (ASTM International D1586-18). The SPT "N"-values indicated on the Record of Borehole sheets and discussed in this report are the values measured directly in the field and are unfactored. The split-spoon samplers used in the investigation limit the maximum particle size that can be sampled and tested to about 35 mm. Therefore, particles or objects that may exist within the soils that are larger than this dimension would not be sampled or represented in the grain size distributions.

Groundwater conditions were noted in the open boreholes during drilling and 50-mm diameter PVC monitoring wells were installed in Boreholes MT-1, MT-6, and MT-8 to allow for monitoring of the groundwater levels at the site. Boreholes MT-2, MT-3, MT-4, MT-4, MT-5 and MT-7 were backfilled to near ground surface with a mixture of Portland cement and bentonite, in accordance with Ontario Regulation 903 (as amended) and topped with sand and/or cold patch asphalt, as required.

The field work was supervised on a full-time basis by members of WSP Golder's technical staff who: located the boreholes in the field; arranged for the clearance of underground services; supervised the drilling and sampling operations; logged the boreholes; and examined the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to WSP Golder's geotechnical laboratory in Mississauga for further examination and laboratory testing. Index and classification testing consisting of water content determinations,

grain size distributions and Atterberg limits was carried out on selected soil samples. The geotechnical laboratory testing was completed according to ASTM International and MTO LS standards, as applicable. In addition, two soil samples were submitted to Bureau Veritas Laboratories, an accredited analytical laboratory, for testing of corrosivity indicator parameters of the soil.

The as-drilled borehole locations and ground surface elevations were measured by WSP Golder using a Trimble Catalyst unit. The UTM NAD83 GRS 1980 Zone 17 northing and easting coordinates, geographical coordinates, ground surface elevations referenced to Geodetic datum, and borehole depths at each borehole location are presented on the borehole records in Appendix B and are summarized below.

Table 1: Borehole Locations and Ground Surface Elevations

Borehole Number	LOCATION				Ground Surface Elevation (m)	Borehole Depth (m)
	UTM NAD 83 Northing (m)	UTM NAD 83 Easting (m)	Latitude (°)	Longitude (°)		
MT-1	4914737.3	602685.6	44.378653	-79.710998	230.5	9.8
MT-2	4914744.5	602664.7	44.378720	-79.711259	230.5	9.6
MT-3	4914732.6	602638.3	44.378608	-79.711589	231.6	9.6
MT-4	4914754.1	602613.1	44.378814	-79.711904	231.5	9.6
MT-5	4914747.3	602579.9	44.378758	-79.712323	229.8	9.8
MT-6	4914757.4	602557.8	44.378851	-79.712598	230.3	9.8
MT-7	4914762.1	602503.7	44.378901	-79.713276	231.9	9.8
MT-8	4914781.0	602445.6	44.379080	-79.714001	231.4	9.8
AH-1	4914749.3	602570.0	44.378777	-79.711447	228.4	1.1

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The project area is located within the Simcoe Lowlands physiographic region, as delineated in *The Physiography of Southern Ontario*¹ (Chapman and Putman, 1984). The Simcoe Lowlands consist of a series of steep sided, flat-floored valleys that were flooded by glacial lake Algonquin. The surficial soils in this area of the Simcoe Lowlands typically comprise glaciolacustrine sediments of very fine to medium-grained sand, silt and minor clay; and fluvial and glaciofluvial ice-contact sediments of fine to very coarse-grained sand, gravelly sand and gravel with minor amounts of silt, clay and flowtill. Modern alluvial deposits of clay, silt, sand gravel that may contain organics are also present. Bedrock in the vicinity of the project area consists of Middle Ordovician limestone, dolostone, shale, arkose and sandstone².

¹ Chapman L.J. and Putman, D.F. 1984. *The Physiography of Southern Ontario*.

² Ontario Geological Survey. 1991b. *Bedrock geology of Ontario, Southern Sheet*. Ontario Geological Survey Map 2544. Scale 1:1,000,000.

4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the summary results of in situ and laboratory testing are presented on the borehole records contained in Appendix B. The detailed results of geotechnical laboratory testing and analytical laboratory testing (i.e., corrosion-related parameters) are contained in Appendix C and D, respectively. The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic profile shown on Drawing 1 are inferred from non-continuous sampling and, therefore, typically represent transitions between soil types rather than exact planes of geological change.

The subsurface conditions will vary between and beyond the borehole locations. A summary description of the soil deposits and groundwater conditions encountered in the boreholes is provided below. It should be noted that the interpreted stratigraphy shown on Drawing 1 is a simplification of the subsurface conditions based on the primary strata encountered.

4.2.1 Asphalt

An approximately 114-mm to 152-mm thick layer of asphalt was encountered at the ground surface in Boreholes MT-1 to MT-4, which were drilled within the pavement area of Highway 400.

4.2.2 Topsoil

An approximately 101-mm to 304-mm thick layer of topsoil was encountered at ground surface in Boreholes MT-5 to MT-8. Materials designated as topsoil in this report were classified based solely on visual and textural observations. Testing for organic content, pH, acidity, alkalinity or other nutrients was not carried out on samples of the topsoil. Accordingly, the materials classified as topsoil herein cannot necessarily be relied upon for the support and growth of landscaping vegetation without supplemental soil fertility analyses.

4.2.3 Gravelly Sand (SP) to Sand (SP) to Silty Sand (SM) / Sandy Silt (ML) (Fill)

An approximately 0.6-m to 2.1-m thick layer of non-cohesive fill was encountered underlying the asphalt in Boreholes MT-1 to MT-4 and underlying the topsoil in Boreholes MT-5 to MT-8. The fill varied in composition from gravelly sand to sand to silty sand to sandy silt. The sand fill encountered in Borehole MT-8 contained organic inclusions.

The SPT “N”-values measured within the non-cohesive fill ranged from 5 blows to 48 blows per 0.3 m of penetration, indicating a loose to dense state of compactness.

The natural moisture content of various samples of the non-cohesive fill ranged from about 1% to 15%.

4.2.4 Organic Silt (OL)

A 0.6-m thick layer of organic silt containing wood fragments and rootlets was encountered underlying the non-cohesive fill in Borehole MT-4 between about Elevations 229.1 m to 228.5 m.

An SPT “N”-value of 5 blows per 0.3 m of penetration was measured within the organic silt layer, indicating a loose state of compactness.

A water content about 36% was measured on one sample of the organic silt. The results of organic content testing carried out of the organic silt gave a result of about 7%.

4.2.5 Sand Some Silt (SM) to Sand and Silt (SP-ML) to Silty Sand (SM) to Sandy Silt (ML) to Silt (ML)

Non-cohesive deposits ranging in composition from sand to sand and silt to silty sand to sandy silt to silt were encountered underlying the fill in Boreholes MT-1 to MT-8, at Elevations 230.2 m and 229.1 m, and at the ground surface in Borehole AH-1. Where fully penetrated, the non-cohesive deposits were about 3.0 m to 7.0 m in total thickness. Boreholes MT-1, MT-2, MT-7, MT-8 and AH-1 were terminated in the non-cohesive strata after exploring them for about 1.0 m to 9.0 m. Various amounts of topsoil, rootlets and wood fragments were encountered within the sand with some silt in Borehole MT-4 between about Elevations 228.5 m to 227.8 m.

The SPT “N”-values measured within the non-cohesive strata ranged from 4 blows to 31 blows per 0.3 m of penetration, indicating a loose to dense state of compactness.

The results of grain size distribution tests carried out on samples of the non-cohesive soil deposit are shown on Figures C1 and C2 in Appendix C. The natural moisture content of various samples of the non-cohesive fill ranged from about 11% to 33%.

4.2.6 Clayey Silt-Silt (CL-ML) to Silt (ML)

A cohesive deposit ranging in composition from clayey silt to silt with some clay and some sand was encountered in Boreholes MT-3 to MT-6 and in MT-8. Where fully penetrated in Borehole MT-8, the cohesive deposit had a thickness of about 1.3 m. Boreholes MT-3 to MT-6 were terminated within the cohesive deposit after exploring it for about 1.0 m to 3.3 m.

The SPT “N”-values measured within the cohesive deposit ranged from 8 blows to 42 blows for 0.3 m of penetration. In situ field vane testing carried out within the cohesive stratum measured an undrained shear strength of about 33 kPa, with a sensitivity of about 2.9 (the peak undrained shear strength divided by the remoulded shear strength). The field vane test results along with the measured SPT “N”-values indicate that the clayey silt to silt deposit has a firm to very stiff consistency.

The results of grain size distribution tests carried out on samples of the clayey silt to silt deposit are shown on Figure C3 in Appendix C. Atterberg limits tests were carried out on five samples of this deposit and measured liquid limits ranging between about 16% and 30%, plastic limits ranging between about 13% and 17%, and plasticity indices ranging between about 2% and 13%. These results, which are plotted on the plasticity chart on Figure C4 in Appendix C, indicate that the material ranges in classification from a clayey silt to silt of low plasticity. The natural water content measured on samples of the cohesive deposit ranged from about 14% to 23% with an average water content of about 18%.

4.3 Groundwater Conditions

The stabilized water levels were measured in the monitoring wells between September 16 and 28, 2022, and are summarized in Table 1. Table 2 below summarizes the observed water levels in the open boreholes during or upon completion of drilling; although such measurements do not necessarily represent the stabilized groundwater level at the borehole location or site, it is noted that these measurements are similar to the groundwater levels measured in the monitoring wells. Groundwater levels in the area will be subject to seasonal fluctuations and variations due to precipitation events and should be expected to be higher during and following wet seasons and snow melt. The measured and observed water levels are also shown on the borehole records in Appendix B.

Table 2: Water Level Measured in Monitoring Wells

Borehole No.	Ground Surface Elevation (m)	Monitoring Well Screen Depth Interval (m)	Depth to Water Level (m)		Groundwater Elevation (m)	
			September 16/2022	September 28/2022	September 16/2022	September 28/2022
MT-1	230.5	223.8 – 220.7	-	2.5	-	228.0
MT-6	230.3	225.3 – 222.2	2.1	2.0	228.2	228.3
MT-8	231.4	226.8 – 223.8	1.5	1.9	229.9	229.5

Table 3: Observed Water Level in Open Boreholes Upon Completion of Drilling

Borehole No.	Ground Surface Elevation (m)	Depth to Water Level (m)	Groundwater Elevation (m)
MT-1	230.5	2.3	228.2
MT-2	230.5	2.3	228.2
MT-3	231.6	3.0	228.6
MT-4	231.5	3.8	227.7
MT-5	229.8	1.5	228.3
MT-6	230.3	1.5	228.8
MT-7	231.9	2.3	229.6
MT-8	231.4	1.5	229.9
AH-1	228.4	0.6	227.7

4.4 Analytical Laboratory Testing Results

4.4.1 Corrosivity Indicator Parameters

Analytical laboratory testing was carried out by Bureau Veritas Laboratories on three soil samples obtained from within the proposed tunnel horizon to assess corrosivity indicator parameters. The soil samples were tested for a suite of parameters associated with potential corrosion to steel and deterioration of concrete. The laboratory certificate of analysis is provided in Appendix D and details of the samples submitted and parameter concentrations/values are summarized below.

Table 4: Summary of Analytical Test Results

Borehole No.	Sample No.	Depth / Elevation (m)	Resistivity (ohm-cm)	Electrical Conductivity (mS/cm)	Soluble Sulphate (SO ₄) Content (%)	Chloride Content (%)	pH
MT-1	6	3.8 – 4.4 / 223.8 – 223.2	5,200	0.193	<0.002	0.003	7.91
MT-2	6	3.8 – 4.4 / 223.9 – 223.3	3,400	0.292	<0.002	0.012	7.87
MT-6	6	3.8 – 4.4 / 224.2 – 223.6	1,200	0.690	0.006	0.033	7.93

5.0 CLOSURE

This Foundation Investigation Report was prepared by Jesús González-Hurtado, Ph.D., P.Eng., Geotechnical Engineer, and reviewed by Mark Swallow, P.E., P.Eng., Senior Principal. Independent reviews were completed by Lisa Coyne, P.Eng., Fellow and MTO Designated Foundations Contact for WSP Golder, and Ty Garde, M.Eng., P.Eng., Senior Principal and MTO Designated Foundations Contact approved in MTO's Registry, Appraisal and Qualifications System (RAQS) for High Complexity Tunnelling Services (with Wood Environment and Infrastructure Solutions Canada Limited, as of September 21, 2022 a WSP-affiliated company).

Signature Page

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PART B

FOUNDATION DESIGN REPORT DUNLOP STREET SANITARY TRUCK SEWER RELOCATION HIGHWAY 400 TRENCHLESS CROSSING CITY OF BARRIE, ONTARIO

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides a discussion and engineering recommendations for the geotechnical design aspects of the proposed sanitary sewer, based on our interpretation of the borehole information and laboratory test data and on our understanding of the project requirements. The information in this section of the report is provided for the guidance of the design team. Where comments are made on construction, they are provided only in order to highlight aspects of construction which could affect the design of the project. Contractors bidding on or undertaking any work at the site should examine the factual results of the investigation, satisfy themselves as to the adequacy of the information for construction, and make their own independent interpretation of the factual data as it affects their proposed construction techniques, schedule, equipment capabilities, costs, sequencing and the like.

Details of the trenchless section of the proposed sanitary sewer are presented in Section 2.0. The following sections of this report provide geotechnical design and construction recommendations for the selection and installation of the sanitary sewer using trenchless installation methods.

6.2 Trenchless Crossing

6.2.1 Description of Trenchless Methods

The trenchless methods considered herein include horizontal directional drilling (HDD), horizontal auger boring (i.e., “Jack and Bore”), pipe ramming, and micro-tunneling by microtunnel boring machine (MTBM). In brief, these construction methods involve the following:

- **Horizontal Directional Drilling (HDD):** HDD involves drilling of a relatively small diameter pilot hole (on the order of 100 mm to 150 mm) using a remotely controlled and steerable drilling bit on a flexible string of drill rods, while the bore is supported using a bentonite slurry. Once the pilot hole is complete, the bore is typically reamed in one or more passes to a larger diameter, and then the final pipe is pulled through the bore (using the drill rods to pull the pipe into place). Pipe materials commonly used with this technique include steel and High-Density Polyethylene (HDPE) pipe. HDD equipment is available for drilling in both bedrock and overburden, but drilling is very challenging in bouldery ground. Deep entrance and exit pits are generally not required; however, larger laydown areas are required to install the final pipe, and the crossing typically needs to be longer to accommodate the shallow entry and exit angles for the drilling equipment (on the order of 10 to 30 degrees from horizontal). Bores are typically limited to less than 1 m in diameter. Control of line and grade to the degree needed for gravity flow at shallow storm or sanitary sewer slopes may be problematic.
- **Horizontal Auger Boring – “Jack and Bore”:** In Ontario, a traditional “jack and bore” operation involves pushing a steel pipe (casing) horizontally into the ground by jacking while simultaneously cutting the ground with an auger head operating near the leading end of the steel pipe. The spoil is generally removed from within the casing using an auger boring machine. The cutting head is driven by, and is positioned at, the leading end of an auger string that is established within the casing pipe. Jacking and receiving pits are required. Typically, there is limited ability to steer the casing during jacking. This method is only applicable to construction in soils and may not be feasible in bouldery soils (e.g., glacial till). In some cases, contractors will run the auger cutting head in front of the lead end of the casing to advance the pipe in difficult ground; however, this approach can lead to high risks for ground losses (settlement, sinkholes). This method is also not feasible in running or flowing ground (dry or saturated sand and silt).

In some cases, traditional “jack and bore” equipment is supplemented with a specialized rotating cutting head, sometimes referred to as a “small boring unit”. These cutting heads are welded to the lead end of steel casings, can sometimes include limited alignment adjustment capabilities, and can be fitted with rock disc cutters. In the right ground conditions (e.g., hard glacial till, weathered rock), the small boring heads can be advantageous. However, these systems are not well suited to, and should not be used in, saturated and potentially flowing ground conditions. Further, these systems should not be confused with micro-tunnelling systems that operate using very different principles of ground support.

- **Pipe Ramming:** Pipe ramming uses a pneumatic tool to hammer a steel pipe or casing into the ground. The pipe is almost always driven “open” to thereby direct the soil into the pipe interior instead of compacting it outside the pipe. The leading edge of the pipe typically has a small overcut to reduce friction/adhesion between the casing pipe and soil and to improve the load conditions on the pipe. Soil/pipe friction/adhesion reduction can also be achieved with lubrication, and different types of bentonite and/or polymers can be used for this purpose. Depending on the length of the installation, the soils inside the pipe can be removed either during or after the installation by augering, compressed air or water jetting. Pipe ramming methods are also better suited for penetrating through/displacing potential obstructions, such as cobbles and boulders in comparison to jack and bore installation method, though this method can still be obstructed by cobbles and boulders depending on their size, number, and their positions relative to the pipe leading edge. Partial or full removal of materials from within the pipe, to facilitate driving, should not be carried out if the ground through which the pipe is being driven consists of running or flowing soils (dry or saturated silt, sand, gravel). As with traditional jack and bore methods, flowing ground conditions and/or operating the cleanout augers beyond, at or near the leading edge of the casing can result in significant ground losses, excessive surface settlement and, in some cases, sinkholes that propagate to the surface.
- **Microtunnel Boring Machine (MTBM):** MTBM is a method of installing pipes in bores ranging from 0.6 m to 3 m in diameter behind a steerable remote-controlled shield that is pressurized with a bentonitic slurry at the cutting face to minimize ground losses. The process is essentially remote-controlled pipe jacking where all operations are controlled from the surface, cuttings are removed by the circulating slurry, and the necessity for personnel to enter the bore is eliminated. Microtunnelling equipment is generally more suited to tunnelling through overburden. Some MTBMs are promoted as being able to “crush” cobbles with internal cone crushing systems. Others have been promoted as capable of passing boulders of as much as 1/3 of the bore diameter. However, both approaches to managing larger stones can be problematic and incapable of completing construction in bouldery ground. Large numbers of cobbles can also “choke” these machines and result in failure of the bore. In bouldery ground, where the boulders can be firmly held in place by the surrounding soil matrix, equipping MTBMs with rock-disc cutters can be successful. In all cases, detailed review of the conditions and equipment configuration are needed prior to construction to achieve a reasonable probability of success. Availability of this equipment in the project area is somewhat limited and a large laydown area may be required for the slurry processing plant typically needed for this technique.

6.2.2 Subsurface Conditions and Tunnelman’s Ground Classification

The soil conditions encountered along the proposed tunnel horizon (between about Elevation 226.4 m and 228.4 m) will consist predominantly of loose to compact non-cohesive soil deposits, ranging in composition from sand and silt to silty sand to sandy silt and low plasticity firm clayey silt to silt. Although not specifically encountered during the field investigation, cobbles and/or boulders could be expected within these glacially derived soils deposits.

The groundwater levels measured at the site between September 16 and 28, 2022 ranged from about Elevation 228.0 m to 229.9 m. Therefore, based on a tunnel obvert ranging from about Elevation 227.5 m to 228.0 m, the groundwater level at the site is expected to be about 0.5 m to 1.0 m above the tunnel obvert.

The anticipated strata that the installation would extend through may be classified based on Terzaghi's Tunnelman's Ground Classification System as reported in Heuer (1974). The System is commonly used to describe the potential behaviour of an unsupported tunnel face during excavation. This System uses qualitative "stand-up time" criteria to classify the ground into six principal categories: firm, slow ravelling, fast ravelling, squeezing, running, flowing and swelling. This System also differentiates the ground behaviour above and below the groundwater table. Therefore, this Ground Classification System has been adopted to provide an objective evaluation of the anticipated ground behaviour during trenchless installations.

Correlating the soil classification with a modified version of Terzaghi's Tunnelman's Classification (as reported in Heuer (1974)), the loose to compact sand and silt to silty sand to sandy silt to silt and firm low plasticity clayey silt to silt within the proposed tunnel horizon may be described as "fast ravelling" and/or "flowing", or "squeezing" below the water table. It is expected that a trenchless excavation made in the soils encountered within the tunnel horizon will be unable to stand unsupported for any given length of time.

Table 5 below summarizes the approximate ranges of geotechnical properties and parameters based on the soil conditions encountered in the boreholes and the geotechnical laboratory test results.

Table 5: Approximate Range of Soil Properties and Parameters

Stratigraphic Unit	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Water Content (%)	D ₁₀ (mm) ¹	Effective Friction Angle (°)	Interface Friction Factor ²	Effective Cohesion (kPa)
Loose to dense gravelly sand to sand to silty sand to sandy silt fill	-	-	-	1 - 15	-	28-32	0.3-0.35	-
Firm to very stiff clayey silt to silt	16 – 30	13 – 17	2 – 13	14 – 25	<0.003	26-28	-	35
Very loose to compact sand to silty sand to sandy silt to silt	-	-	-	10 – 35	0.003 – 0.06	27-30	0.25-0.3	-

Note:

1. D₁₀ is the particle size that corresponds to 10% passing interpreted or inferred from the grain size distribution test results presented in Appendix C.

2. Adhesion between pre-cast concrete pipe and surrounding soils is based on NAVFAC (1986) for non-cohesive soils.

6.2.3 Assessment of Trenchless Methods

It is noted that the contractor should be responsible for choosing the trenchless method and equipment for the installation, unless specific methods are otherwise prohibited. This report provides guidance on the influence of ground behaviour on some possible trenchless installation methods; however, it should not be construed that the contractor is restricted to the particular methods considered herein, and in the event of alternative methods, the contractor must make their own independent interpretation of the anticipated ground behaviour, based on the factual information from the investigation provided in Part A of this report.

Based on the ground conditions at the site, a 1,200 mm O.D pipe, a tunnel length of about 237 m, and in general about 2.5 m to 4.0 m of soil cover above the tunnel (except at Dyments Creek where the soil cover above the

tunnel is about 2.0 m to less than 1.0 m) Jack and Bore, Pipe Ramming, and MTBM could be considered with some options having much higher construction and disturbance risks. Due to the bore size, the soil and groundwater conditions and noting the potential presence of boulders within the glacially derived native soils, HDD is not considered a practical option. A comparison of the advantages, disadvantages, relative costs, and risks/consequences associated with each option are summarized in Table 1 following the text of this report.

The geotechnical issues and risks associated with the above-noted methods at this site include:

- Ground or Road Heave – trenchless installation at shallow depths and with diameters that are relatively large as compared to the depth of burial are particularly susceptible to heaving at the roadway/ground surface – i.e., having a cover to diameter (C/D) ratio of less than about 2, which is the case at this site at Dyments Creek given the 1.2-m diameter pipe and existing soil coverage of about 2.0 m to less than 1.0 m.
- Obstructions – Cobbles and boulders, can obstruct or foul trenchless construction equipment if encountered within the tunnel alignment while boring. Although not specifically encountered during the field investigation and given that the native soils within the tunnel horizon are of glacial origin, there is a moderate to high risk of encountering cobbles and boulders. In such cases, jack and bore and, to a somewhat lesser degree, pipe ramming may require interventions to remove obstructions, with a risk of loss of support at the face and the potential for ground loss. The relatively loose to compact ground may allow the use of an MTBM equipped with appropriate cutters, since boulders would be embedded in a relatively stiff matrix.
- Ground or Road Settlement – Given that the groundwater level at this site is above the tunnel invert, saturated non-cohesive soils (sand to silty sand to sandy silt to silt) and groundwater will flow back through the spoils within the casing/pipe and towards the entry/sending pit. Such flow could cause significant loss of ground at and above the face of excavation. For any method that requires groundwater control for managing risks of ground losses, gravity flow to sumps and pumps or into permeable linings should not be relied upon except as a supplement to a fully designed vacuum well point or eductor system.
- Frac-out – Operating drill fluid pressures must be adequately planned and controlled to mitigate risk for inadvertent slurry returns to surface (i.e., frac-out). The cover above the trenchless installation where the alignment passes below Dyments Creek is approximately 1 m. The contractor must consider the relatively shallow cover at this location when assessing the potential for frac-out. A separate report has been prepared by WSP Golder to address mitigation measures during the tunnel operations in this area.
- Misalignment - Inability to correct for line and grade with jack and bore or pipe ramming methods within the design tolerances. If misalignment occurs, the contractor should be prepared to abandon the casing/pipe in the ground and grout the drill hole excavation.

From a foundations perspective, the lowest risk trenchless installation method is microtunneling. Jack and bore (with dewatering) and pipe ramming are not recommended due to the diameter and length of the bore, the potential requirement for dewatering along the highway, the potential for vibratory densification/settlement (pipe ramming), and the potential risk of encountering cobbles and boulders within the glacially derived soils.

6.2.4 Trenchless Considerations

All trenchless work should be carried out in accordance with MTO's Non-Standard Special Provision (NSSP) for "*Pipe Installation by Trenchless Methods*", dated June 2021, a copy of which is included in Appendix D, or other specification as may be approved by the relevant stakeholders, including WSP Golder, to ensure that the geotechnical risks identified in this report have been addressed. Prior to construction, the contractor should be

required to submit the proposed construction work plan, dewatering plans, machine specifications, slurry management plans and equipment (if applicable), contingency plans for obstructions and other items, and the monitoring program for review and approval from the MTO, and other relevant stakeholders as may be required. It is further recommended that the geotechnical aspects of the contractor's work plan for the trenchless crossing be reviewed by WSP Golder to confirm that the plan is in conformance with the specifications and the geotechnical risks identified in this report. These plans should identify all hazards and the methods proposed to mitigate interference to the highway corridor, such as heave, settlement, obstructions and changes of alignment / profile. The contractor's work plan should also include a provision for compensation grouting around and over the tunnel and for grouting around the outside of any temporary or permanent ground support systems should the need arise.

Performance of the completed trenchless crossing will largely depend on the contractor's construction procedures and techniques. As such, all trenchless works should be carried out by an experienced specialist contractor employing only qualified workers skilled in their trade, under the direction of an experienced foreman. In general, when crossing beneath highways, trenchless operations should be carried out continuously (i.e., 24 hours per day) from the start until the installation is complete. Continuous operations assist with reducing risks of equipment becoming bound in the tunnel by time-dependent increases in friction and/or adhesion, uncontrolled ground losses, and other critical problems that may occur while the work area and equipment are unattended. If forward motion of the casing/pipe is halted at any time other than for pre-planned reasons (e.g., addition of casing/pipe sections, etc.) and prevention of voids under the highway cannot be assured, consideration should be given to stabilising the face (using thick slurry for example or other methods) as soon as possible.

Proper shaft construction is essential for the success of any tunnelling operation. For this reason, it is preferable that construction of shafts be carried out by the trenchless subcontractor. If the shafts are to be constructed by the general contractor on behalf of the trenchless subcontractor, there must be a contractual mechanism to ensure that the shaft design and construction is compatible with the tunnelling equipment and methods. Construction considerations for shaft construction are provided below in Section 6.2.8.

6.2.5 Settlement Monitoring

Settlement monitoring of the trenchless crossing should be consistent with the "*Appendix – Settlement Monitoring Guidelines-Tunneling*" included in MTO's document "*Guidelines for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application*", dated February 2021. Recommendations for a settlement monitoring program have been provided in a separate document entitled "Settlement Monitoring Program Recommendations, Dunlop Street Sanitary Trunk Sewer Relocation, Highway 400 Trenchless Crossing, City of Barrie, Ontario" dated April 6, 2023.

6.2.6 Obstructions

Although not specifically encountered during the current investigation at this site, obstacles such as cobbles and/or boulders may be encountered within the overburden soils retrieved from this site, which are typical of the overburden soils of southern Ontario. The presence of boulders can significantly affect the selection of equipment and progress of construction works, especially in trenchless drilling or boring. The soils at the site are glacially derived, and thus may contain boulders (rock of such a size that it is unable to pass through a 0.3 m square opening); sizes much larger than this should be anticipated at this site. Further, boulders within the soil deposits can originate from the igneous and metamorphic rocks of the Canadian Shield and, these can have unconfined compressive strengths of up to 250 MPa. Therefore, suitable equipment will be required to remove any boulders encountered during drilling or boring.

6.2.7 Grouting

As noted in MTO's "*Pipe Installation by Trenchless Method*" specification (included in Appendix E), the annular space between the 1.2-m concrete sewer pipe and the native ground may need to be sealed or filled/grouted after the sewer pipe is installed.

For any installations at which the settlement monitoring or excavation volume monitoring indicates that pavement settlement or ground loss might have occurred, or where signs of ground loss have been noted, a provision should also be made for a program of grouting the annulus between the pipe and native soil and/or compensation grouting above the pipe and/or repair/padding of the pavement structure, as required.

6.2.8 Shafts

6.2.8.1 Excavations

Proper shaft construction is essential for the success of any tunnelling operation. For this reason, it is preferable that construction of the shafts be carried out by the trenchless subcontractor. If the shafts are to be constructed by the general contractor on behalf of the trenchless subcontractor, there must be a contractual mechanism to ensure that the shaft design and construction is compatible with the tunnelling equipment and methods.

Excavations for construction of the entry/exit shafts are anticipated to extend to about 0.5 m below the tunnel invert, to about Elevations 226.5 m and 225.9 m (or to about 5.0 mbgs and 5.5 mbgs, respectively). The proposed diameters for the entry and exit shafts are 5.0 m and 3.5 m, respectively. The founding soils at these depths are anticipated to consist of loose to compact sand to silty sand to sandy silt to silt at the entry shaft location, and loose to compact sand to silt to firm clayey silt to silt at the exit shaft location. A minimum 150-mm thick concrete mud slab (or working slab) consisting of minimum 28 MPa concrete or granular pad is recommended at the bases of the shafts to maintain the integrity of the base during construction.

All excavations must be carried out in accordance with Ontario Regulation 213 – Ontario Occupational Health and Safety Act for Construction Projects (as amended by Ontario Regulation 443). According to the OHSa, the soils to be excavated can be classified as Type 3 soils above the water table and Type 4 soils below the water table. Temporary excavations should be observed and reviewed during construction to confirm that the soil and groundwater conditions are as anticipated. If unexpected conditions are encountered, a geotechnical engineer should review the excavation plan considering the conditions at that time.

To maintain temporary excavation stability, excavated materials should be placed away from the edge of the excavation a distance equal to the depth of the excavation or greater. Where sufficient space is not available to stockpile the excavated material at the site, off-site disposal of the excavated material intended for reuse would need to be arranged.

6.2.8.2 Temporary Protection Systems

Solider pile and lagging systems braced by anchors or rakers could be considered for construction of the shafts provided that adequate dewatering is carried out. Steel sheet-pile walls may be suitable for this project; however, because of the potential presence of cobbles and boulders difficulties may be encountered during advancement.

"Sunken" caissons are another approach to creating effectively watertight shafts and can also be used as both temporary and permanent structures and are preferred by some contractors. These shafts are constructed by:

- Creating a shallow, circular excavation matching the planned diameter of the shaft;
- Building a concrete or steel cutting edge within the excavation;
- Constructing a circular structural concrete ring, typically on the order of 1.5 to 2.5 m in height on top of the prefabricated cutting edge;
- Progressively excavating within the circular ring and allowing the cutting edge and first ring to move under its own weight to the bottom of the excavation; and
- Sequentially building new rings on top of the first as the excavation progresses downward.

Often, where groundwater conditions require, the excavation is filled with water or a slurry to counteract water pressures, and the final concrete base slab is cast using concrete placed by tremie methods. This system, while it can be more costly than other support systems, has the advantage that dewatering and other groundwater control methods can sometimes be avoided along with the potential for dewatering-related ground settlements. It may be necessary to pre-drill perimeter holes beneath the cutting shoe, and excavation equipment must be selected to cut and remove the glacially derived soils that may contain cobbles and boulders. An eye seal will be required to close the annular space between the wall of the entry/exit shaft and the tunnel to retain soil behind the temporary shoring and stop backflow of slurry or other materials and water into the shafts.

The temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*). The lateral movement of the protection systems should meet Performance Level 2 as specified in OPSS.PROV 539, provided that any utilities, if present, can tolerate this magnitude of deformation.

While the selection and design of the temporary protection system will be the responsibility of the contractor, the information presented in Table 6 is provided to aid in evaluating the design:

Table 6: Estimated Soil Parameters for Temporary Protection System Design

Stratigraphic Unit	Bulk Unit Weight, γ (kN/m ³)	Angle of Internal Friction, ϕ (degrees)	Undrained Shear Strength, s_u (kPa)	Lateral Earth Pressure Coefficients ^{1/2}		
				Active, K_a	At Rest, K_o	Passive, K_p
Loose to dense gravelly sand to sand to silty sand to sandy silt fill	20	29	-	0.35	0.52	2.88
Firm clayey silt to silt	18	26	35	0.39	0.56	2.56
Very loose to compact sand to silty sand to sandy silt to silt	18	27	-	0.38	0.55	2.66

Notes:

1. The design groundwater level should be assumed to be at least Elevation 228 m at the east shaft and 230 m at the west shaft based on the September 2022 water level measurements, with appropriate provision for seasonally higher groundwater levels.
2. The lateral earth pressure coefficients presented above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are expected, the coefficients should be corrected accordingly.

Where protection systems are designed to be water-tight such that dewatering is not required, water pressures must be added to the earth pressures.

As discussed in Section 4.3, the groundwater level was measured at approximately Elevation 228.0 m to 230.0 m in the boreholes near the east and west shafts. For design of the shafts, the temporary works designer should consider seasonal variation in the groundwater level including a higher groundwater level during wet periods of the year. Additionally, base stability for the shafts must be addressed by the tunnelling/temporary works contractor, based on the groundwater elevation relative to the shaft base. The contractor may use a combination of the depth of the shaft/protection system, active dewatering, and/or a plug of concrete at the base of the shaft to counteract any groundwater uplift pressures as applicable.

The loading from construction equipment as well as any material stockpiles within a distance defined by a 1 horizontal to 1 vertical line drawn from the bottom of the excavation to the existing ground surface should be included as a surcharge in the design of the temporary protection system.

Consideration could be given to either partial or full removal of the temporary protection system upon completion of construction (as required). At this site, it is recommended that full removal of the protection system be carried out to mitigate potential impediments to future construction work.

6.2.8.3 Groundwater / Surface Water Control

The groundwater levels at the east and west shaft locations were measured at about Elevations 228.0 m and 230.0 m between September 13 and 28, 2022, respectively. It is anticipated that excavations for the construction of the east and west shafts will extend to about Elevations 225.9 m and 226.5 m, respectively. As such, excavations will extend about 3.0 m below the groundwater level and therefore active dewatering will be required. Alternatively, continuous caissons may be considered as outlined in Section 6.2.8.2.

The shoring design must consider the full groundwater pressure. Further, due to the high groundwater levels and in accordance with good tunnelling practice, an eye seal will be required to close the annular space between the wall of the entry/exit shaft and the tunnel to retain soil behind the temporary shoring and stop backflow of slurry or other materials and water into the shafts.

The hydraulic conductivity of the soil deposits at the site and the assessed dewatering rates have been developed and addressed as part of the Hydrogeological Impact Assessment Report (HIAR) prepared by WSP Golder, dated December 16, 2022, under separate cover; this report addresses the full alignment of the sewer relocation including the cut-and-cover sections. Based on the dewatering estimates, a Permit to Take Water (PTTW) is anticipated for the entirety of the project including the open-cut sections within the City's right-of-way.

As further detailed in the HIAR which addresses the full sewer relocation alignment, assessment of potential dewatering requirements has been completed based on the subsurface conditions in the boreholes near the east and west shafts and hydrogeological testing along the alignment. The following estimations have been made, assuming shaft diameter of 5 m, that the shaft is not water-tight (i.e., full dewatering is required), and a factor of safety of 2 on the assessed rates.

Table 7: Summary of Groundwater Lowering and Dewatering Rate Estimates – Launch and Receiving Shafts

Dewatering Source	Estimated Hydraulic Conductivity (m/s)	Invert Elevation (m)	Min. Lowered Groundwater Elevation (m)	Representative Drawdown (m)	Total Dewatering Capacity (m ³ /day)	Zone of Influence (m)
Launch Shaft (near Borehole MT-1)	1 x 10 ⁻⁶	225.9	224.9	4.1	50	78
Receiving Shaft (near Borehole MT-8)		226.5	225.5	5.4	77	88

The actual rate of groundwater inflow to the excavations will depend on many factors including the contractor's schedule and rate of excavation, the size of the excavation, and the time of year at which the excavation is made. Also, there may be instances where significant volumes of precipitation, surface runoff and/or groundwater may collect in an open excavation and must be pumped out. Although the zone of influence extends up to approximately 80 m to 90 m, the majority of the drawdown would be in close proximity to the shafts, and dewatering-induced settlement is estimated to be up to approximately 10 mm within approximately 10 m of the shafts.

It is understood that water-tight shafts will be specified on the contract to reduce dewatering rates and zone of influence; in this case, the volumes, radius of influence and estimated dewatering-induced settlement will be lower than presented above.

Surface water should be controlled / directed away from all open cut excavations and specifically the entry / exit shaft locations. Dewatering and temporary diversion of surface water should be in accordance with OPSS.PROV 517 and Special Provision SP517F01.

6.3 Material Durability Based on Soil Chemistry

Three soil samples obtained from within the proposed tunnel horizon were submitted for analytical testing of soil corrosivity parameters, and these results are presented above in Section 4.4.1. The potential for sulphate attack and corrosion are discussed in the following paragraphs; however, it is ultimately up to the designer to determine the appropriate construction materials, including the exposure class and ensuring that all aspects of CSA A23.1-14 Section 4.1.1 "*Durability Requirements*" are followed when designing concrete and steel/ductile iron elements.

The analytical test results were compared to CSA A23.1-14 Table 3 ("*Additional requirements for concrete subjected to sulphate attack*") to evaluate the potential for sulphate attack on concrete. The water soluble-sulphate concentration measured in the soil samples tested are less than 0.1%, indicating that the degree of exposure is less than "Moderate", and is considered Negligible according to Table 7.2 in the MTO Gravity Pipe Design Guidelines (2014). Therefore, based on the samples tested, when the designer is selecting the exposure class for pipes or associated structures, the effects of sulphates from within the soil strata tested may not need to be considered. However, given that the location of the sanitary sewer is within the roadway right-of-way, the sewer pipe and/or casing may be exposed to de-icing salts and selection of the exposure class should consider this in the selection of the cement type for use in concrete.

The soil samples had a pH of between 7.87 and 7.94 and according to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to the sewer pipe/casing durability. The resistivity was measured to be between 5,200 ohm-cm and 1,200 ohm-cm, which indicates that the soil corrosiveness is low ($6,000 \text{ ohm-cm} > R > 4,500 \text{ ohm-cm}$) to Severe ($2,000 \text{ ohm-cm} > R$), as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014). The design of the sewer/casing system should take the results of the analytical laboratory testing, the potential for corrosion, and the corrosion susceptibility of pipe materials in Table 7.1 of the MTO Gravity Pipe Design Guidelines (2014) into consideration of the ultimate selection of materials.

6.4 Monitoring Well Decommissioning

One monitoring well was installed within the MTO RoW (in Borehole MT-6) to permit monitoring of the groundwater level at the site, and two monitoring wells were installed outside of MTO RoW. Ontario Regulation (O.Reg.) 903, as amended by O.Reg. 128/03 of the Ontario Water Resources Act, requires that monitoring wells be properly abandoned/decommissioned by qualified personnel. We recommend that the decommissioning of the monitoring well be carried out as part of the construction contract so that water level measurements can be taken immediately prior to trenchless construction. We will prepare a special provision to include in the contract documents to outline the requirement for the contractor to decommission the existing monitoring well(s) in accordance with O.Reg. 903 (as amended).

7.0 CLOSURE

This Foundation Design Report was prepared by Jesús González-Hurtado, Ph.D., P.Eng., Geotechnical Engineer, and reviewed by Mark Swallow, P.E., P.Eng., Senior Principal. Independent reviews were completed by Lisa Coyne, P.Eng., Fellow and MTO Designated Foundations Contact for WSP Golder, and Ty Garde, M.Eng., P.Eng., Senior Principal and MTO Designated Foundations Contact approved in MTO's Registry, Appraisal and Qualifications System (RAQS) for High Complexity Tunnelling Services (with Wood Environment and Infrastructure Solutions Canada Limited, as of September 21, 2022 a WSP-affiliated company).

Signature Page

WSP Golder



Jesús González-Hurtado, Ph.D., P.Eng.
Geotechnical Engineer



Lisa Coyne, P.Eng
Fellow, MTO Designated Foundations Contact

JGH/LCC/MAS/TJG/ljv

[https://golderassociates.sharepoint.com/sites/161475/project files/4 deliverables/5. fir and fidr - mto/5. final/1. rev0/fidr/22521942 fidr rev0 2023'04'06 hwy 400 trenchless crossing.docx](https://golderassociates.sharepoint.com/sites/161475/project%20files/4%20deliverables/5.%20fir%20and%20fidr%20-%20mto/5.%20final/1.%20rev0/fidr/22521942%20fidr%20rev0%202023'04'06%20hwy%20400%20trenchless%20crossing.docx)

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Chapman L.J. and Putman, D.F. 1984. *The Physiography of Southern Ontario*, Map P2715.

Heuer, 1974. Terzaghi's Tunnelman's Ground Classification System.

Ministry of Transportation, Ontario, *MTO Gravity Pipe Design Guidelines*, April 2014

Ministry of Transportation, Ontario, Guidelines for Foundation Engineering – Tunneling Specialty for Corridor Encroachment Permit Application, dated February 2021.

Ontario Regulation 903 (Wells)

Occupational Health and Safety Act and Regulation for Construction Projects (as amended).

ASTM D1586 Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils

Ontario Provincial Standard Drawings (OPSD)

OPSD 3090.101	Foundation Frost Penetration Depths for Southern Ontario
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Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

OPSS.PROV 517	Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation
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OPSS.PROV 539	Construction Specification for Temporary Protection Systems
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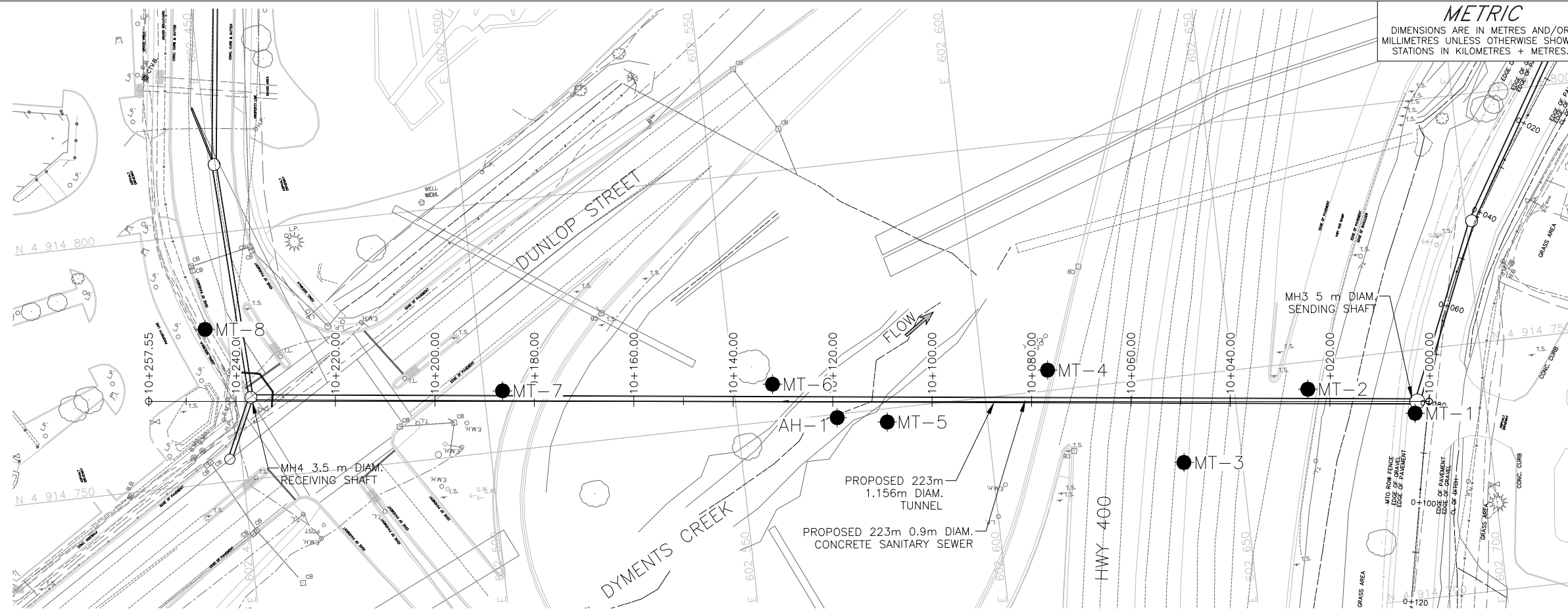
OPSS.PROV 1010	Material Specification for Aggregates
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Special Provisions

SP517F01	Dewatering System / Temporary Flow Passage Systems
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Table 1: Evaluation of Trenchless Pipe Installation Methods

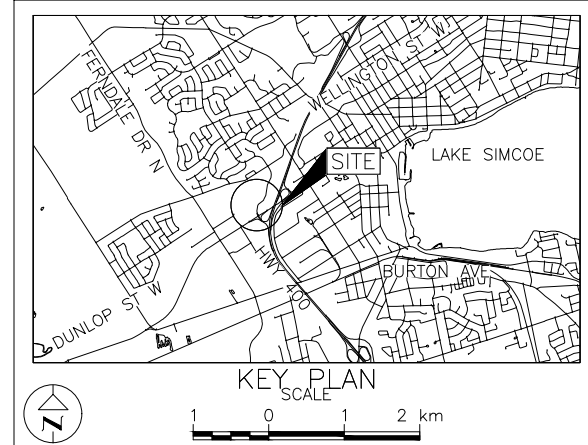
Installation Method	Feasibility of Trenchless Method	Advantages	Disadvantages	Relative Costs	Risk/Consequences
MTBM	Feasible	<ul style="list-style-type: none">■ Less traffic disruption but would still require traffic protection at entry and/or exit shafts, which will be required in any case for installation of the MHs.■ Slurry machines able to counterbalance earth and water pressures in a controlled manner, thereby reducing the risk of ground losses during tunneling.■ Machine can also be specified to have the capability to cut and crush boulders.■ Accurate steering capabilities.■ Tunnel is fully lined as excavation progresses (i.e., sewer pipe is installed behind MTBM during forward advancement).	<ul style="list-style-type: none">■ Availability of equipment may be limited in Ontario and is more specialized.■ Large working / laydown area required to accommodate slurry processing systems and MTBM at shaft/pit locations.■ Susceptible to frac-out and/or migration of slurry into pavement structure depending on slurry viscosity and pressure.	<ul style="list-style-type: none">■ Most expensive method.■ Cost of dewatering and shoring for entre/exit shafts.	<ul style="list-style-type: none">■ Relatively low risk of ground loss during tunnelling when counterbalancing viscous slurry pressure is used.■ Risk of ground surface subsidence increases with decreasing cover (i.e., where the ratio of soil cover to tunnel diameter is less than 2).■ Any slurry exiting onto the pavement or in ditch could be a significant hazard to the travelling public or environmentally.■ If cobbles/obstructions are encountered that cannot be cleared or handled, MTBM could get “stuck” and rescue shaft would be required within highway to retrieve the MTBM.
Jack and Bore	Marginally Feasible	<ul style="list-style-type: none">■ Appropriate for the diameter required at this site.	<ul style="list-style-type: none">■ Not suitable for long bores, as is the case at this site.■ Thrust block design and construction required for jacking pit.■ Limited steering capability■ Obstructions (e.g., cobbles and boulders) may deflect and/or halt bore.■ Saturated non-cohesive soils may “run” if sufficient soil plug behind casing is not maintained.■ Dewatering required along alignment.	<ul style="list-style-type: none">■ Least expensive (Similar cost to pipe ramming), however additional dewatering costs would be required.	<ul style="list-style-type: none">■ Obstructions can result in deflection of the casing resulting in misalignment of pipe.■ High risk for uncontrolled ground loss into casing and/or overexcavation in saturated and/or very loose to loose cohesionless materials (“running” soils) which can lead to ground surface subsidence / settlement / sink holes■ High risk for uncontrolled ground loss if intervention is required to clear obstructions.
Pipe Ramming	Feasible.	<ul style="list-style-type: none">■ Appropriate for the diameter required at this site.■ Less risk of uncontrolled ground loss / subsidence above pipe alignment compared to jack and bore provided soil plug is maintained for entire crossing■ Better suited for penetrating through potential obstructions such as cobbles and boulders compared to jack and bore.	<ul style="list-style-type: none">■ Not suitable for long bores, as is the case at this site.■ Slightly longer entry pit may be required for hammer■ Limited steering capability■ Large obstructions (e.g., cobbles and boulders) can deflect casing.■ Interventions, with loss of face support, may be required to clear obstructions.■ Potential noise complaints in urban areas and bylaws.■ Higher vibration levels than other options	<ul style="list-style-type: none">■ Least expensive (Similar cost to jack and bore)	<ul style="list-style-type: none">■ Obstructions can cause deflection of casing resulting in misalignment of pipe.■ High risk for uncontrolled ground loss if intervention is required to clear obstructions.■ High risk for uncontrolled ground loss into casing and/or overexcavation in saturated and/or very loose to loose cohesionless materials (“running” soils)■ Vibration and noise from pipe ramming activities may be “felt” and “heard” by neighbouring properties and preconstruction surveys recommended
HDD	Not feasible due to the pipe material intended for installation.	<ul style="list-style-type: none">■ N/A	<ul style="list-style-type: none">■ N/A	<ul style="list-style-type: none">■ N/A	<ul style="list-style-type: none">■ N/A



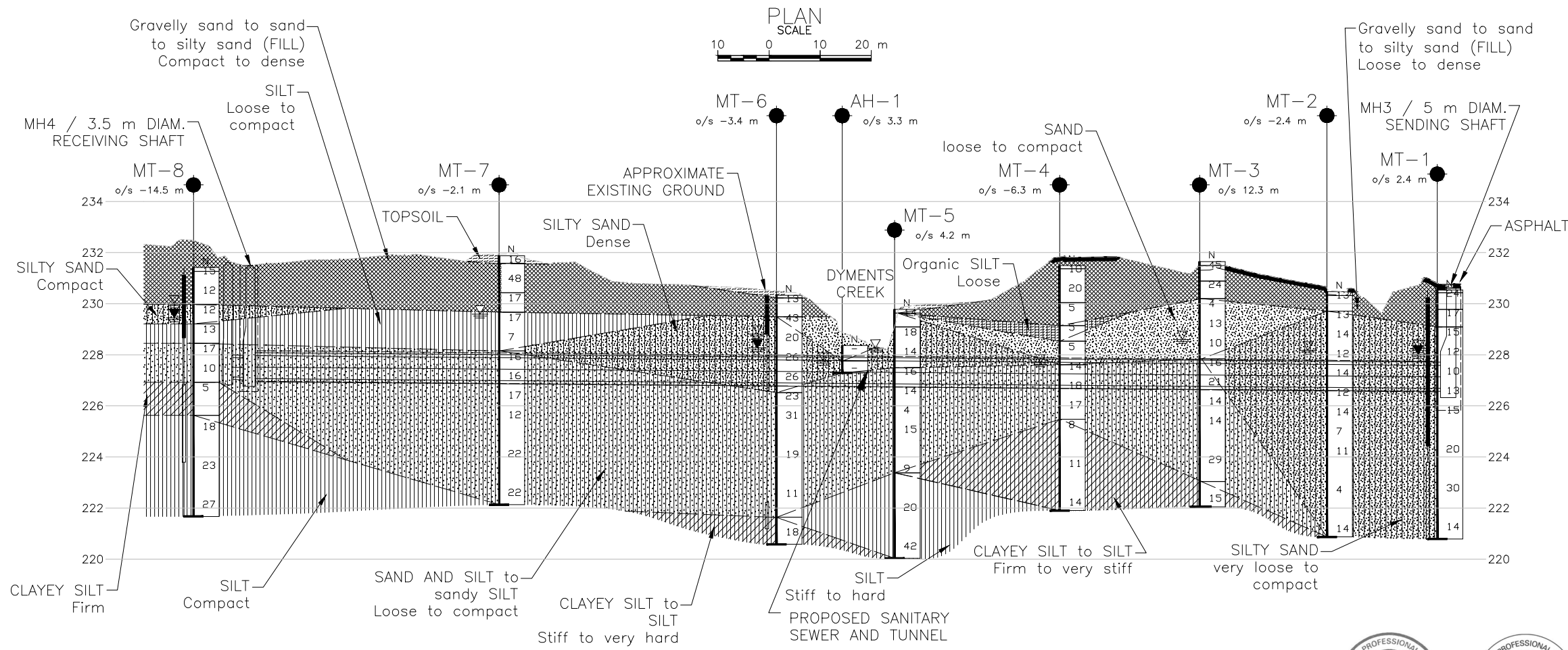
METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

WP No.

GEOTECHNICAL EXPLORATION
HIGHWAY 400 AND DUNLOP STREET
BOREHOLE LOCATIONS AND SOIL STRATA
LAT. 44.37887 LONG. -79.71260



- LEGEND**
- Borehole – Current Investigation
 - Seal
 - Piezometer
 - N Standard Penetration Test Value
 - 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
 - 100% Rock Quality Designation (RQD)
 - WL in piezometer, measured on Sep 28/29, 2022
 - WL upon completion of drilling



BOREHOLE CO-ORDINATES (UTM NAD83 ZONE 17)			
No.	ELEVATION	NORTHING	EASTING
AH-1	228.4	4914749.3	602570.0
MT-1	230.5	4914737.3	602685.6
MT-2	230.5	4914744.5	602664.7
MT-3	231.6	4914732.6	602638.3
MT-4	231.5	4914754.1	602613.1
MT-5	229.8	4914747.3	602579.9
MT-6	230.3	4914757.4	602557.8
MT-7	231.9	4914762.1	602503.7
MT-8	231.4	4914781.0	602445.6

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

REFERENCE

Base plans provided in digital format, drawing file nos. 5615-00-c-me-pnet.dwg, 5615-00-c-mp-pnet.dwg, received Dec. 12, 2022. Base plan provided in digital format, drawing no. 5615-00-c-me-pnet.dwg, received Aug. 19, 2022. Base plan provided in digital format, drawing file no. 5615-00-C-me-pnet.dwg, received on May 30, 2022. Base plan provided in digital format, drawing file no. 5615-00-c-rp-base.dwg, received on March 7, 2023.



NO.	DATE	BY	REVISION
Geocres No.,31D-817			
HWY. 400	PROJECT NO. 22521942		DIST. EASTERN
SUBM'D. JGH	CHKD. JGH	DATE: 4/6/2023	SITE: .
DRAWN: ZS	CHKD. JGH	APPD. LCC	DWG. 1

APPENDIX A

**Important Information and
Limitations of Report**



IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: WSP Canada Inc. (WSP) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to WSP by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. WSP cannot be responsible for use of this report, or portions thereof, unless WSP is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, WSP may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to WSP. The report, all plans, data, drawings and other documents as well as all electronic media prepared by WSP are considered its professional work product and shall remain the copyright property of WSP, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of WSP. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to WSP by the Client, communications between WSP and the Client, and to any other reports prepared by WSP for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. WSP can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Ground Water Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, WSP does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that WSP interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report. The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: WSP will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. WSP should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, WSP should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for WSP to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that WSP be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that WSP be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. WSP takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

APPENDIX B

Borehole Records

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

MINISTRY OF TRANSPORTATION, ONTARIO

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>200	>8
COBBLES	Not Applicable	75 to 200	3 to 8
GRAVEL	Coarse	19 to 75	0.75 to 3
	Fine	4.75 to 19	(4) to 0.75
		2.00 to 4.75	(10) to (4)
SAND	Coarse	0.425 to 2.00	(40) to (10)
	Medium	0.075 to 0.425	(200) to (40)
	Fine		
FINES	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY COMPONENTS^{1,2}

Percentage by Mass	Modifier
> 35	Use 'and' to combine primary and secondary component (<i>i.e.</i> , SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (<i>i.e.</i> , some sand)
≤ 10	trace (<i>i.e.</i> , trace fines)

1. Only applicable to components not described by Primary Group Name.

2. Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (*q_t*), porewater pressure (*u*) and sleeve friction (*f_s*) are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); N_d:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC / SC	Rock core / Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample
OD / ID	Outer Diameter / Inner Diameter
HSA / SSA	Hollow-Stem Augers / Solid-Stem Augers

SOIL TESTS

w	water content
PL, w _p	plastic limit
LL, w _L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D _R	relative density (specific gravity, G _s)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
γ	unit weight

1. Tests anisotropically consolidated prior to shear are shown as CAD, CAU.

COARSE-GRAINED SOILS

Compactness¹

Term	SPT 'N' (blows/0.3m) ²
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

1. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grain size. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.

2. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

FINE-GRAINED SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N' ^{1,2} (blows/0.3m)
Very Soft	< 12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	> 200	> 30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.

2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

LIST OF SYMBOLS

MINISTRY OF TRANSPORTATION, ONTARIO

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
$\ln x$	natural logarithm of x
\log_{10}	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

(a) Index Properties (continued)

w	water content
w_L or LL	liquid limit
w_P or PL	plastic limit
I_P or PI	plasticity index $= (w_L - w_P)$
NP	non-plastic
w_s	shrinkage limit
I_L	liquidity index $= (w - w_P) / I_P$
I_C	consistency index $= (w_L - w) / I_P$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index $= (e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
$C_{a(e)}$	secondary compression index
C_a	rate of secondary compression
$C_{a(e)}$	modified secondary compression index
m_v	coefficient of volume change
C_v	coefficient of consolidation (vertical direction)
C_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
c'	effective cohesion
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction $= \tan \delta$
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q or q'	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

* Density symbol is ρ . Unit weight symbol is γ .
where $\gamma = \rho \cdot g$ (i.e., mass density multiplied by
acceleration due to gravity)

Notes: 1
2

$\tau = c' + \sigma' \tan \phi'$
shear strength = (compressive strength)/2

LITHOLOGICAL AND GEOTECHNICAL ROCK DESCRIPTION TERMINOLOGY

WEATHERING CLASSIFICATION

Fresh (W1): no visible sign of rock material weathering.

Slightly Weathered (W2): discoloration indicates weathering of rock mass material on discontinuity surfaces. **Less than 5%** of rock mass is altered or weathered.

Moderately Weathered (W3): less than 50% of the rock mass is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.

Highly Weathered (W4): more than 50% of the rock mass is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as corestones.

Completely Weathered (W5): 100% of the rock mass is decomposed and/or disintegrated to a soil. The original mass structure is still largely intact.

Residual Soil (W6): all rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.

BEDDING THICKNESS

Description	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 m to 2 m
Medium bedded	0.2 m to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 mm to 60 mm
Laminated	6 mm to 20 mm
Thinly laminated	Less than 6 mm

JOINT OR FOLIATION SPACING

Description	Spacing
Very wide	Greater than 3 m
Wide	1 m to 3 m
Moderately close	0.3 m to 1 m
Close	50 mm to 300 mm
Very close	Less than 50 mm

GRAIN SIZE

Term	Size*
Very Coarse Grained	Greater than 60 mm
Coarse Grained	2 mm to 60 mm
Medium Grained	60 microns to 2 mm
Fine Grained	2 microns to 60 microns
Very Fine Grained	Less than 2 microns

Note: * Grains greater than 60 microns diameter are visible to the naked eye

CORE CONDITION

Total Core Recovery (TCR)

The percentage of solid drill core recovered regardless of quality or length, measured relative to the length of the total core run.

Solid Core Recovery (SCR)

The percentage of solid drill core, regardless of length, recovered at full diameter, measured relative to the length of the total core run.

Rock Quality Designation (RQD)

The percentage of solid drill core, greater than 100 mm length, recovered at full diameter, as measured along the centerline axis of the core, relative to the length of the total core run. RQD varies from 0% for completely broken core to 100% for core in solid segments.

DISCONTINUITY DATA

Fracture Index

A count of the number of discontinuities (physical separations) in the rock core, including both naturally occurring fractures and mechanically induced breaks caused by drilling.

Dip with Respect to Core Axis

The angle of the discontinuity relative to the axis (length) of the core. In a vertical borehole, a discontinuity with a 90° angle is horizontal.

Description and Notes

An abbreviation description of the discontinuities, whether naturally occurring separations such as fractures, bedding planes and foliation planes or mechanically induced features caused by drilling such as ground or shattered core and mechanically separated bedding or foliation surfaces. Additional information concerning the nature of fracture surfaces and infillings are also noted.

Abbreviations

AXJ Axial Joint	KV Karstic Void
BD Bedding	K Slickensided
BC Broken Core	LC Lost Core
CC Continuous Core	MB Mechanical Break
CL Closed	PL Planar
CO Contact	PO Polished
CU Curved	RO Rough
CT Coated	SA Slightly Altered
FLT Fault	SH Shear
FOL Foliation	SM Smooth
FR Fracture	SR Slightly Rough
GO Gouge	SY Stylolite
IN Infilled	UN Undulating
IR Irregular	VN Vein
JN Joint	VR Very Rough

ISRM Intact Rock Material Strength Classification

Grade	Description	Approx. Range of Uniaxial Compressive Strength (MPa)
R0	Extremely weak rock	0.25 – 1.0
R1	Very weak rock	1.0 – 5.0
R2	Weak rock	5.0 – 25
R3	Medium strong rock	25 – 50
R4	Strong rock	50 -100
R5	Very strong rock	100 -250
R6	Extremely strong rock	>250



PROJECT		RECORD OF BOREHOLE				No AH-1		SHEET 1 OF 1		METRIC						
G.W.P.		LOCATION				N 4914749.3; E 602570 UTM NAD 83 ZONE 17		ORIGINATED BY								
DIST		Central		HWY		400		BOREHOLE TYPE		Hand Auger, Open Hole						
DATUM		Geodetic		DATE		September 2, 2022		CHECKED BY		LCC						
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
228.4	GROUND SURFACE															
0.0	(SM) SILTY SAND, trace clay, trace organics Compact to dense Brown to grey Wet		1	AS	-											
227.3			2	AS	-											
1.1	END OF BOREHOLE		3	AS	-											

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PROJECT 22521942			RECORD OF BOREHOLE No MT-1			SHEET 1 OF 1			METRIC															
G.W.P.			LOCATION N 4914737.3; E 602685.6 UTM NAD 83 ZONE 17 (LAT. 44.378653; LONG. -79.710998)			ORIGINATED BY																		
DIST Central HWY 400			BOREHOLE TYPE Power Auger, 200 mm Diam. (Hollow Stem)			COMPILED BY ZS																		
DATUM Geodetic			DATE August 25, 2022			CHECKED BY LCC																		
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS			ELEVATION SCALE			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES																			
230.5	GROUND SURFACE																							
0.0	ASPHALT																							
0.1	(SP) Gravelly sand, trace fines (FILL)		1	SS	24																			
229.7	Compact Brown Moist		2	SS	17																			
0.8	(SM) Silty sand, trace clay (FILL)																							
229.1	Compact Brown Moist		3	SS	15																			
1.5	(SM) SILTY SAND, trace clay																							
	Compact Brown Moist to wet		4	SS	12																			
			5	SS	10																			
			6	SS	13																			
			7	SS	15																			
			8	SS	20																			
			9	SS	30																			
			10	SS	14																			
220.8	END OF BOREHOLE																							
9.8	NOTES: 1. Water level measured in screen at a depth of 2.5 m (Elev. 228.0 m) on September 28, 2022. 2. The following soil sample headspace vapour readings were obtained in the field: Samp. No HEX (ppm) IBL (ppm) 1 0 0 2 0 0 3 0 0 4 0 0 5 5 0 6 5 0 7 10 0 8 0 0																							

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PROJECT		22521942		RECORD OF BOREHOLE		No MT-2		SHEET 1 OF 1		METRIC					
G.W.P.		LOCATION		N 4914744.5; E 602664.7 UTM NAD 83 ZONE 17 (LAT. 44.37872; LONG. -79.711259)		ORIGINATED BY									
DIST		Central		HWY 400		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem)		COMPILED BY ZS					
DATUM		Geodetic		DATE		September 7, 2022		CHECKED BY		LCC					
SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS		ELEVATION SCALE		DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES										
230.5	GROUND SURFACE														
0.0	ASPHALT														
0.2	(SP) Gravelly sand, trace fines (FILL)		1	SS	13										
229.7	Compact Brown Moist		2	SS	13										
0.8	(SM) SILTY SAND, trace clay Very loose to compact Brown Moist to wet		3	SS	14										
			4	SS	12										
			5	SS	14										
			6	SS	12										
			7	SS	14										
			8	SS	7										
			9	SS	11										
			10	SS	4										
			11	SS	14										
220.9	END OF BOREHOLE														
9.6	NOTES: 1. Groundwater encountered at a depth of 2.3 m (Elev. 228.2 m) upon completion of drilling. 2. The following soil sample headspace vapour readings were obtained in the field: Samp. No HEX (ppm) IBL (ppm) 1 0 1 2 0 1 3 0 0 4 0 2 5 0 0 6 0 1 7 0 0 8 0 0 9 0 0														

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PROJECT		22521942		RECORD OF BOREHOLE		No MT-3		SHEET 1 OF 1		METRIC						
G.W.P.		LOCATION		N 4914732.6; E 602638.3 UTM NAD 83 ZONE 17 (LAT. 44.378608; LONG. -79.711589)		ORIGINATED BY										
DIST		Central		HWY		400		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem)						
COMPILED BY		ZS		DATE		September 6, 2022		CHECKED BY		LCC						
SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS		ELEVATION SCALE		DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT		REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES											
231.7	GROUND SURFACE															
0.0	ASPHALT															
0.2	(SP) Gravelly sand, trace fines (FILL)		1	SS	45											
230.9	Dense Brown Dry		2	SS	24											
230.3	(SP) Sand, trace fines, trace gravel (FILL)		3	SS	4											
1.5	Compact Brown Moist		4	SS	13											
	(SM) SAND, some silt, trace clay		5	SS	10											
	Loose to compact Brown Moist to wet		6	SS	16											
227.9	(SP/ML) SAND and SILT, trace clay		7	SS	21											
3.8	Compact Brown to grey Wet		8	SS	14											
	- Turning grey at 4.6 m depth (Elev. 227.1 m)		9	SS	14											
			10	SS	29											
223.1	(CL-ML) CLAYEY SILT to SILT, some sand		11	SS	15											
8.6	Stiff to very stiff Grey Moist															
222.1	END OF BOREHOLE															
9.6	NOTES: 1. Groundwater encountered at a depth of 3.0 m (Elev. 228.6 m) upon completion of drilling. 2. The following soil sample headspace vapour readings were obtained in the field: Samp. No HEX (ppm) IBL (ppm) 1 0 0 2 0 0 3 0 0 4 0 0 5 0 0 6 0 0 7 0 0 8 0 0 9 10 0															

GTA-MTO 011 S:\CLIENTS\CITY_OF_BARRIE\DUNLOP_ST\02_DATA\GINTDUNLOP_STREET.GPJ GAL-GTA.GDT 4/6/23 ZS

+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE

+³, ×³: Numbers refer to Sensitivity ○^{3%} STRAIN AT FAILURE



PROJECT		22521942		RECORD OF BOREHOLE No MT-6		SHEET 1 OF 1		METRIC									
G.W.P.				LOCATION		N 4914757.4; E 602557.8 UTM NAD 83 ZONE 17 (LAT. 44.378851; LONG. -79.712598)		ORIGINATED BY									
DIST		Central HWY 400		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem)		COMPILED BY ZS									
DATUM		Geodetic		DATE		September 1, 2022		CHECKED BY LCC									
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa		WATER CONTENT (%)		γ		GR SA SI CL			
230.3	GROUND SURFACE							20 40 60 80 100	20 40 60 80 100	10 20 30							
0.0	TOPSOIL							○ UNCONFINED + FIELD VANE	○ UNCONFINED + FIELD VANE								
0.1	(SM) Silty sand, trace gravel (FILL)		1	SS	13		230	● QUICK TRIAXIAL × REMOULDED	● QUICK TRIAXIAL × REMOULDED								
229.5	Compact to dense Brown Moist		2	SS	43		229										
0.8	(SM) SILTY SAND, trace gravel Dense Brown to grey Wet		3	SS	20		228										
			4	SS	26		227										
			5	SS	26		226										
226.5	(ML) Sandy SILT, trace clay Compact Grey Wet		6	SS	23		225										
3.8			7	SS	31		224										
			8	SS	19		223										
			9	SS	11		222										
221.6	(CL-ML) CLAYEY SILT to SILT Stiff to very stiff Grey Moist		10	SS	18		221										
8.7																	
220.6	END OF BOREHOLE																
9.8	NOTES:																
	1. Water level measured in screen at a depth of 2.1 m (Elev. 228.2 m) on September 16, 2022																
	2. Water level measured in screen at a depth of 2.0 m (Elev. 228.3 m) on September 28, 2022																
	1. The following soil sample headspace vapour readings were obtained in the field:																
	Samp. No HEX (ppm) IBL (ppm)																
	1 0 0																
	2 0 0																
	3 0 0																
	4 0 0																
	5 0 0																
	6 0 0																

GTA-MTO 011 S:\CLIENTS\CITY_OF_BARRIE\DUNLOP_ST02_DATA\GINTDUNLOP_STREET.GPJ GAL-GTA.GDT 4/6/23 ZS



PROJECT		22521942		RECORD OF BOREHOLE		No MT-7		SHEET 1 OF 1		METRIC			
G.W.P.				LOCATION		N 4914762.1; E 602503.7 UTM NAD 83 ZONE 17 (LAT. 44.378901; LONG. -79.713276)		ORIGINATED BY					
DIST		Central HWY 400		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem)		COMPILED BY		ZS			
DATUM		Geodetic		DATE		August 25, 2022		CHECKED BY		LCC			
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W _p W W _L			
231.9	GROUND SURFACE												
0.0	TOPSOIL		1	SS	16								
231.6													
0.3	(SP) Gravelly sand, trace fines (FILL) Compac to dense Brown Moist		2	SS	48								
230.5													
1.5	(ML) sandy silt, slightly plastic (FILL) Compac Brown Moist		3	SS	17								
229.7													
2.2	(ML) SILT, trace sand, trace clay Loose to compac Brown to grey Wet		4	SS	17								
			5	SS	7								
228.2													
3.7	(ML) sandy SILT, trace clay Compac Grey Wet		6	SS	16								
			7	SS	16								
			8	SS	17								
			9	SS	12								
			10	SS	22								
			11	SS	22								
222.2													
9.8	END OF BOREHOLE												
NOTES:													
1. Groundwater encountered at a depth of 2.3 m (Elev. 229.6 m) upon completion of drilling.													
2. The following soil sample headspace vapour readings were obtained in the field:													
Samp. No HEX (ppm) IBL (ppm)													
1 0 0													
2 0 0													
3 0 0													
4 0 0													
5 0 0													
6 10 0													
7 15 0													
8 5 0													
9 5 0													
10 0 0													
11 0 0													

GTA-MTO011 S:\CLIENTS\CITY_OF_BARRIE\DUNLOP_ST02_DATA\GINTDUNLOP_STREET.GPJ GAL-GTA.GDT 4/6/23 ZS



PROJECT		22521942		RECORD OF BOREHOLE		No MT-8		SHEET 1 OF 1		METRIC										
G.W.P.				LOCATION		N 4914781; E 602445.6 UTM NAD 83 ZONE 17 (LAT. 44.37908; LONG. -79.714001)		ORIGINATED BY												
DIST		Central HWY 400		BOREHOLE TYPE		Power Auger, 200 mm Diam. (Hollow Stem)		COMPILED BY		ZS										
DATUM		Geodetic		DATE		August 22, 2022		CHECKED BY		LCC										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ	GR	SA	SI	CL	
							20	40	60	80	100	W _p	W	W _L						
231.4	GROUND SURFACE																			
0.0	TOPSOIL																			
0.2	(SP) Sand, trace fines, trace gravel, trace organics (FILL) Compact Brown Moist		1	SS	15	231														
			2	SS	12	230														
230.0	(SM) SILTY SAND Compact Brown Wet		3	SS	12	229														
229.2	(ML) SILT, slightly plastic, some sand Compact Grey Wet		4	SS	13	228														
228.4	(ML) sandy SILT, trace clay Loose to compact Grey Wet		5	SS	17	227														
			6	SS	10	226														
226.9	(CL) CLAYEY SILT, some sand Firm Grey Wet		7	SS	5	225														
						224														
225.6	(ML) SILT, some sand, trace clay Compact Grey Wet		8	SS	18	223														
			9	SS	23	222														
			10	SS	27															
221.7	END OF BOREHOLE																			
9.8	NOTES: 1. Water level measured in screen at a depth of 1.5 m (Elev. 229.9 m) on September 16, 2022 2. Water level measured in screen at a depth of 1.9 m (Elev. 229.9 m) on September 28, 2022 3. The following soil sample headspace vapour readings were obtained in the field: Samp. No HEX (ppm) IBL (ppm) 1 0 0 2 0 0 3 0 0 4 0 0 5 0 0 6 0 0 7 0 0 8 0 0																			

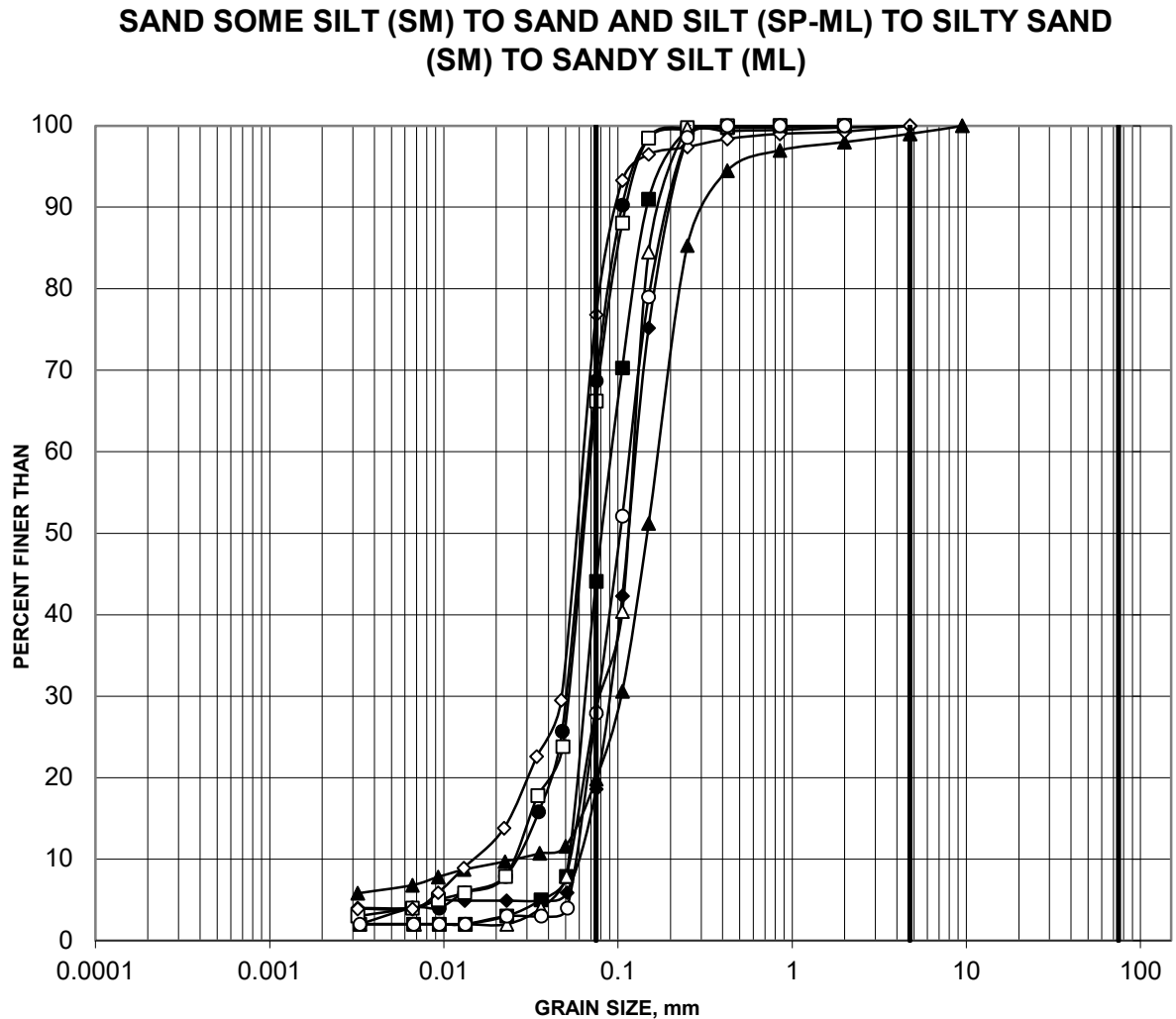
GTA-MTO 011 S:\CLIENTS\CITY_OF_BARRIE\DUNLOP_ST02_DATA\GINTDUNLOP_STREET.GPJ GAL-GTA.GDT 4/6/23 ZS

APPENDIX C

Geotechnical Laboratory Test Results

GRAIN SIZE DISTRIBUTION

FIGURE C1



SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

	Borehole	Sample	Depth (m)	Constituents (%)			
				Gravel	Sand	Silt	Clay
■	MT-3	6	3.81-4.42	0	56	42	2
◆	MT-3	4	2.29-2.90	0	81	15	4
▲	MT-4	5	3.05-3.66	1	79	15	5
●	MT-6	6	3.81-4.42	0	31	67	2
□	MT-7	9	6.10-6.71	0	34	63	3
◇	MT-8	6	3.81-4.42	0	23	73	4
△	MT-1	6	3.81-4.42	0	71	27	2
○	MT-2	6	3.81-4.42	0	72	26	2

Project: 22521942



Created by: JGH

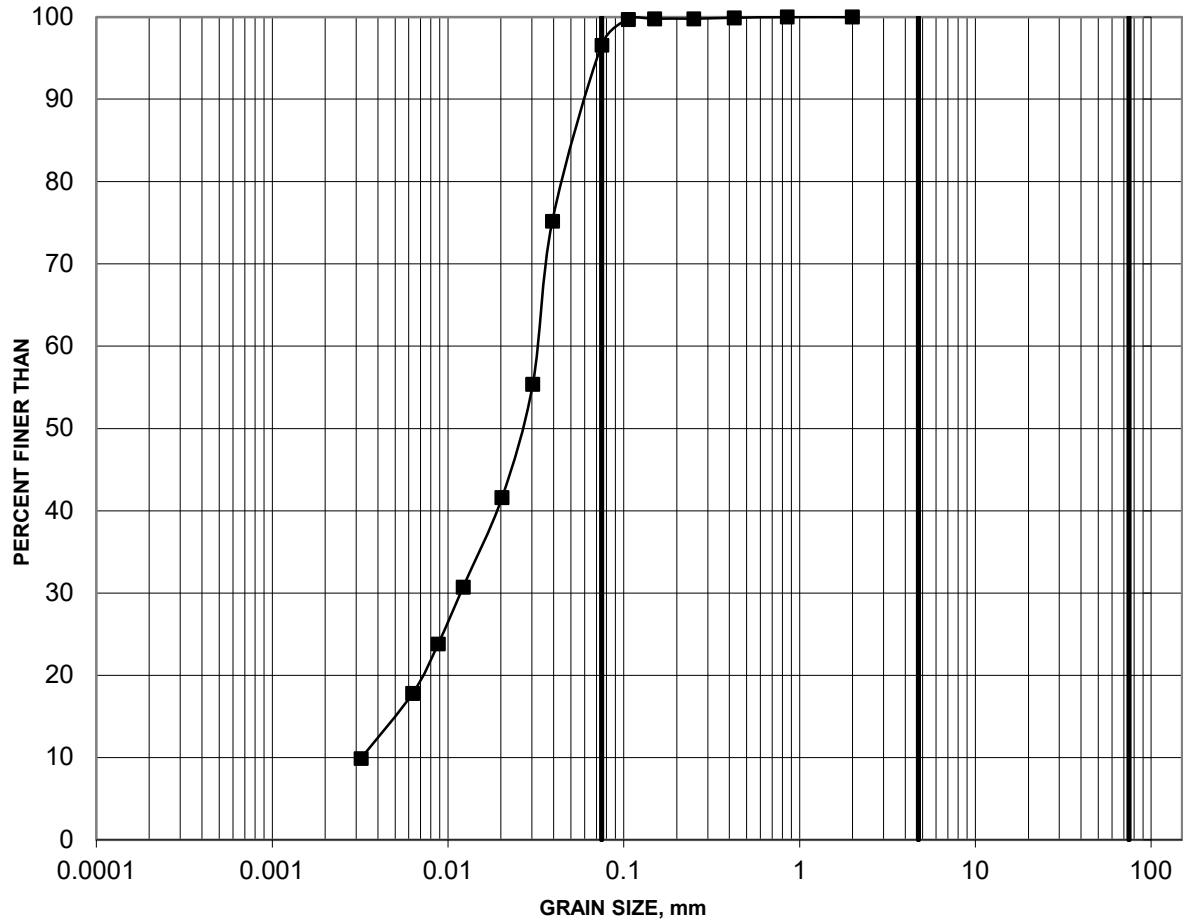
Checked by: MI

[https://goldderassociates.sharepoint.com/sites/161475/Project Files/3 Technical Work/5- Lab Testing/Geotech/2-Geo Lab Tests/2- MTO-ROW/Figures/Spreadsheets/](https://goldderassociates.sharepoint.com/sites/161475/Project%20Files/3%20Technical%20Work/5- Lab Testing/Geotech/2-Geo Lab Tests/2- MTO-ROW/Figures/Spreadsheets/)

GRAIN SIZE DISTRIBUTION

FIGURE C2

SILT TRACE SAND TRACE CLAY (ML)



SILT AND CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
	SAND SIZE			GRAVEL SIZE		

Borehole	Sample	Depth (m)	Constituents (%)			
			Gravel	Sand	Silt	Clay
MT-7	5	3.05-3.66	0	3	88	9

Project: 22521942



Created by: JGH

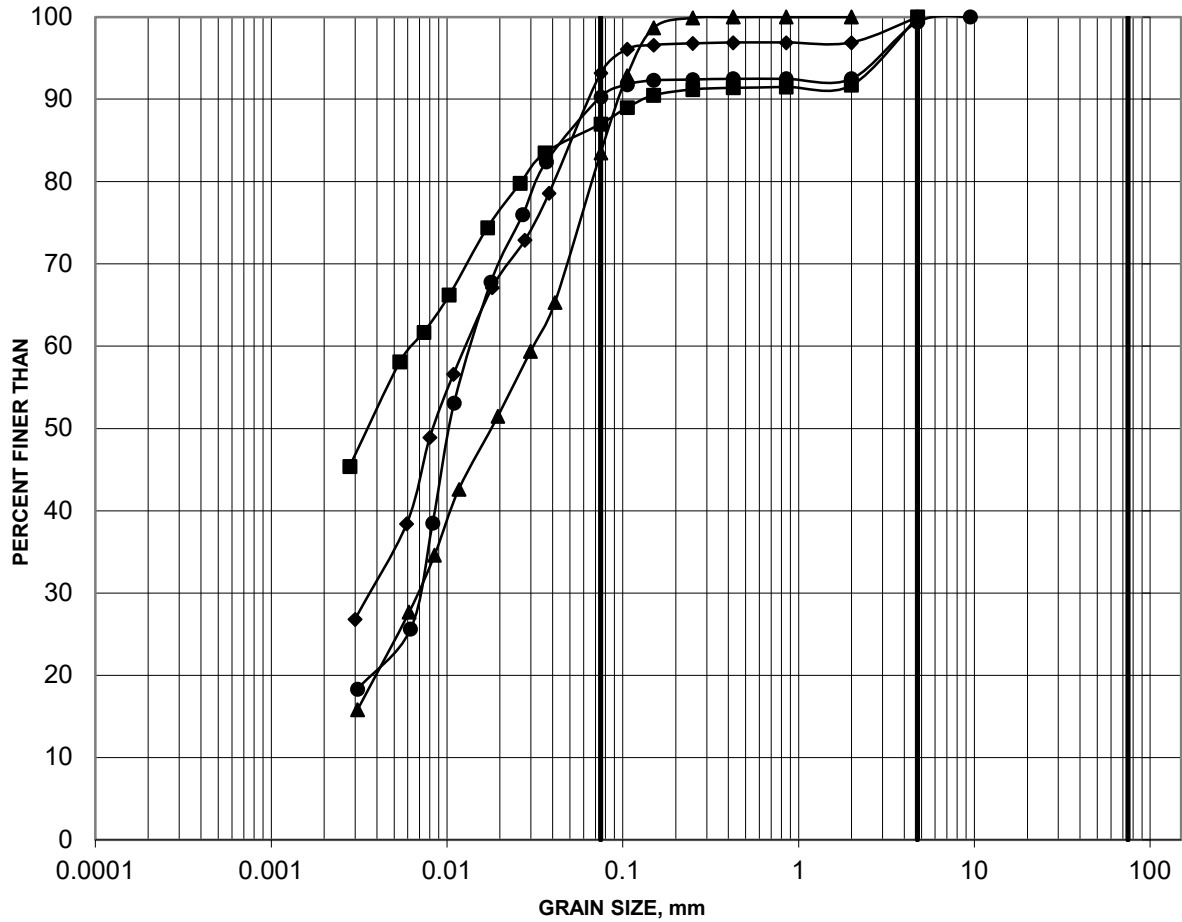
Checked by: MI

[https://golderassociates.sharepoint.com/sites/161475/Project Files/3 Technical Work/5- Lab Testing/Geotech/2-Geo Lab Tests/2- MTO-ROW/Figures/Spreadsheets/](https://golderassociates.sharepoint.com/sites/161475/Project%20Files/3%20Technical%20Work/5- Lab Testing/Geotech/2-Geo Lab Tests/2- MTO-ROW/Figures/Spreadsheets/)

GRAIN SIZE DISTRIBUTION

FIGURE C3

CLAYEY SILT SOME SAND (ML) TO SILT SOME CLAY SOME SAND (ML)



SILT AND CLAY				FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
				SAND SIZE			GRAVEL SIZE		

				Constituents (%)			
Borehole		Sample	Depth (m)	Gravel	Sand	Silt	Clay
■	MT-3	11	9.14-9.60	0	13	48	39
◆	MT-4	9	6.40-6.71	0	7	70	23
▲	MT-5	8B	6.40-6.71	0	16	71	13
●	MT-6	10	9.14-9.75	1	9	74	16

Project: 22521942



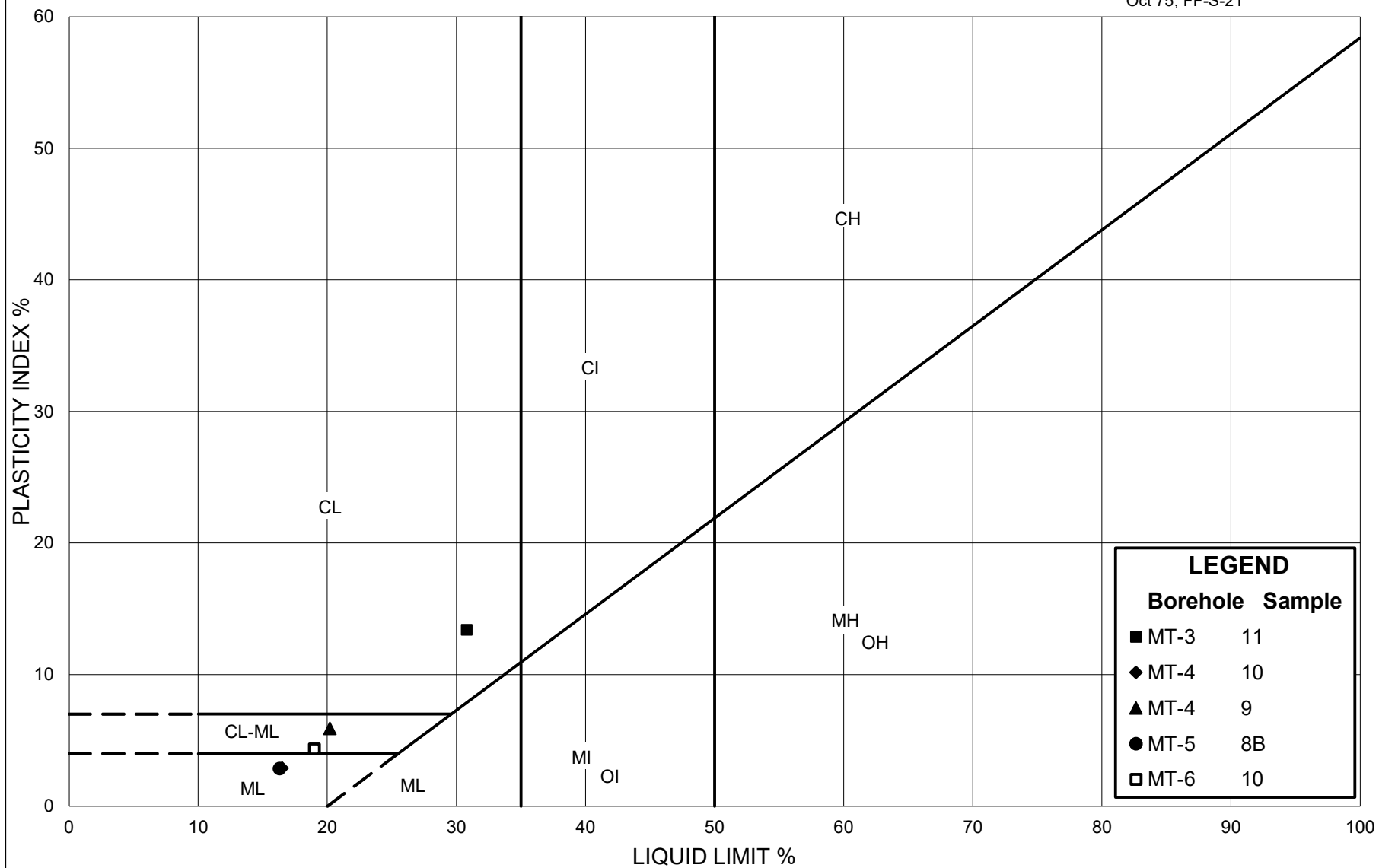
GOLDER
MEMBER OF WSP

Created by: JGH

Checked by: MI

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Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART CLAYEY SILT - SILT

Figure: C4

Project: 22521942

Created By: JGH Checked By: MI

APPENDIX D

Analytical Test Results



Your Project #: 22521942
Your C.O.C. #: 892612-13-01

Attention: Jesus Gonzalez-Hurtado

Golder Associates Ltd
121 Commerce Park Drive
Unit L
Barrie, ON
CANADA L4N 8X1

Report Date: 2022/09/12
Report #: R7292603
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C2O8692

Received: 2022/08/30, 15:18

Sample Matrix: Soil
Samples Received: 6

Analyses	Quantity	Date	Date	Laboratory Method	Analytical Method
		Extracted	Analyzed		
Chloride (20:1 extract)	6	2022/09/06	2022/09/06	CAM SOP-00463	SM 23 4500-Cl E m
Conductivity	6	2022/09/06	2022/09/06	CAM SOP-00414	OMOE E3530 v1 m
Moisture (Subcontracted) (1, 2)	1	N/A	2022/09/08	AB SOP-00002	CCME PHC-CWS m
Moisture (Subcontracted) (1, 2)	5	N/A	2022/09/09	AB SOP-00002	CCME PHC-CWS m
Sulphide in Soil (1)	6	N/A	2022/09/08	AB SOP-00080	EPA9030B/SM4500S2-DF
pH CaCl2 EXTRACT	6	2022/09/02	2022/09/02	CAM SOP-00413	EPA 9045 D m
Redox Potential (3)	6	2022/09/06	2022/09/06	CAM SOP-00421	SM 2580 B
Resistivity of Soil	6	2022/09/01	2022/09/06	CAM SOP-00414	SM 23 2510 m
Sulphate (20:1 Extract)	6	2022/09/06	2022/09/06	CAM SOP-00464	EPA 375.4 m

Remarks:

Bureau Veritas is accredited to ISO/IEC 17025 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Bureau Veritas are based upon recognized Provincial, Federal or US method compendia such as CCME, MELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Bureau Veritas' profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Bureau Veritas in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported; unless indicated otherwise, associated sample data are not blank corrected. Where applicable, unless otherwise noted, Measurement Uncertainty has not been accounted for when stating conformity to the referenced standard.

Bureau Veritas liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Bureau Veritas has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Bureau Veritas, unless otherwise agreed in writing. Bureau Veritas is not responsible for the accuracy or any data impacts, that result from the information provided by the customer or their agent.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.

Results relate to samples tested. When sampling is not conducted by Bureau Veritas, results relate to the supplied samples tested.

This Certificate shall not be reproduced except in full, without the written approval of the laboratory.

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

(1) This test was performed by Bureau Veritas Calgary (19th), 4000 19th Street NE, Calgary, AB, T2E 6P8



Your Project #: 22521942
Your C.O.C. #: 892612-13-01

Attention: Jesus Gonzalez-Hurtado

Golder Associates Ltd
121 Commerce Park Drive
Unit L
Barrie, ON
CANADA L4N 8X1

Report Date: 2022/09/12
Report #: R7292603
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C208692

Received: 2022/08/30, 15:18

- (2) Offsite analysis requires that subcontracted moisture be reported.
(3) Oxidation-Reduction Potential (ORP) values are determined using a Ag/AgCl reference electrode. The test is therefore, not SCC accredited for this matrix.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Ankita Bhalla, Project Manager

Email: Ankita.Bhalla@bureauveritas.com

Phone# (905) 817-5700

=====

This report has been generated and distributed using a secure automated process.

Bureau Veritas has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports.

For Service Group specific validation please refer to the Validation Signature Page.



BUREAU
VERITAS

Bureau Veritas Job #: C2O8692

Report Date: 2022/09/12

Golder Associates Ltd

Client Project #: 22521942

Sampler Initials: KR

SOIL CORROSIVITY PACKAGE (SOIL)

Bureau Veritas ID		TPE438			TPE438			TPE439	TPE440		
Sampling Date		2022/08/25 13:40			2022/08/25 13:40			2022/08/17 13:00	2022/08/16 13:10		
COC Number		892612-13-01			892612-13-01			892612-13-01	892612-13-01		
	UNITS	BHMT-1-6	RDL	QC Batch	BHMT-1-6 Lab-Dup	RDL	QC Batch	BHOC-3-6	BHOC-6-6	RDL	QC Batch
Calculated Parameters											
Resistivity	ohm-cm	5200		8201981				4500	1000		8201981
CONVENTIONALS											
Redox Potential	mV	170	N/A	8207280				180	190	N/A	8207280
Inorganics											
Soluble (20:1) Chloride (Cl-)	ug/g	28	20	8207208				47	610	20	8207208
Conductivity	umho/cm	193	2	8207399				222	997	2	8207399
Available (CaCl2) pH	pH	7.94		8204114				7.74	7.85		8204114
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	8207212	<20	20	8207212	26	<20	20	8207212
Sulphide	mg/kg	1.2 (1)	0.5	8214723				1.2 (1)	0.8 (1)	0.5	8214723
Physical Testing											
Moisture-Subcontracted	%	17	0.30	8219607				15	21	0.30	8219607
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate N/A = Not Applicable (1) Sample contained greater than 10% headspace at time of extraction. Analyzed past method specified hold time											



BUREAU
VERITAS

Bureau Veritas Job #: C2O8692

Report Date: 2022/09/12

Golder Associates Ltd

Client Project #: 22521942

Sampler Initials: KR

SOIL CORROSIVITY PACKAGE (SOIL)

Bureau Veritas ID		TPE441		TPE442			TPE442		
Sampling Date		2022/08/22 11:00		2022/08/22 12:50			2022/08/22 12:50		
COC Number		892612-13-01		892612-13-01			892612-13-01		
	UNITS	BHAB-2-7	QC Batch	BHOC-10-6	RDL	QC Batch	BHOC-10-6 Lab-Dup	RDL	QC Batch
Calculated Parameters									
Resistivity	ohm-cm	4100	8201981	1500		8201981			
CONVENTIONALS									
Redox Potential	mV	200	8207280	260	N/A	8207280			
Inorganics									
Soluble (20:1) Chloride (Cl-)	ug/g	130	8207208	350	20	8207208			
Conductivity	umho/cm	244	8207399	670	2	8207399			
Available (CaCl ₂) pH	pH	7.91	8204114	7.88		8204114			
Soluble (20:1) Sulphate (SO ₄)	ug/g	<20	8207212	<20	20	8207212			
Sulphide	mg/kg	0.7 (1)	8214723	0.6 (1)	0.5	8214723			
Physical Testing									
Moisture-Subcontracted	%	17	8219607	19	0.30	8219608	19	0.30	8219608
RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate N/A = Not Applicable (1) Sample contained greater than 10% headspace at time of extraction. Analyzed past method specified hold time									



SOIL CORROSIVITY PACKAGE (SOIL)

Bureau Veritas ID		TPE443		
Sampling Date		2022/08/24 14:05		
COC Number		892612-13-01		
	UNITS	BHOC-14-4	RDL	QC Batch
Calculated Parameters				
Resistivity	ohm-cm	870		8201981
CONVENTIONALS				
Redox Potential	mV	210	N/A	8207280
Inorganics				
Soluble (20:1) Chloride (Cl-)	ug/g	550	20	8207208
Conductivity	umho/cm	1150	2	8207399
Available (CaCl2) pH	pH	7.80		8204114
Soluble (20:1) Sulphate (SO4)	ug/g	<20	20	8207212
Sulphide	mg/kg	1.7 (1)	0.5	8214723
Physical Testing				
Moisture-Subcontracted	%	15	0.30	8219607
RDL = Reportable Detection Limit QC Batch = Quality Control Batch N/A = Not Applicable (1) Sample contained greater than 10% headspace at time of extraction. Analyzed past method specified hold time				



BUREAU
VERITAS

Bureau Veritas Job #: C2O8692

Report Date: 2022/09/12

Golder Associates Ltd

Client Project #: 22521942

Sampler Initials: KR

TEST SUMMARY

Bureau Veritas ID: TPE438
Sample ID: BHMT-1-6
Matrix: Soil

Collected: 2022/08/25
Shipped:
Received: 2022/08/30

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8207208	2022/09/06	2022/09/06	Alina Dobreanu
Conductivity	AT	8207399	2022/09/06	2022/09/06	Roya Fathitil
Moisture (Subcontracted)	BAL	8219607	N/A	2022/09/09	Ashley Henderson
Sulphide in Soil	SPEC	8214723	N/A	2022/09/08	Marjolen Busslinger
pH CaCl2 EXTRACT	AT	8204114	2022/09/02	2022/09/02	Taslina Aktar
Redox Potential	COND	8207280	2022/09/06	2022/09/06	Surinder Rai
Resistivity of Soil		8201981	2022/09/06	2022/09/06	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8207212	2022/09/06	2022/09/06	Chandra Nandlal

Bureau Veritas ID: TPE438 Dup
Sample ID: BHMT-1-6
Matrix: Soil

Collected: 2022/08/25
Shipped:
Received: 2022/08/30

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Sulphate (20:1 Extract)	KONE/EC	8207212	2022/09/06	2022/09/06	Chandra Nandlal

Bureau Veritas ID: TPE439
Sample ID: BHOC-3-6
Matrix: Soil

Collected: 2022/08/17
Shipped:
Received: 2022/08/30

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8207208	2022/09/06	2022/09/06	Alina Dobreanu
Conductivity	AT	8207399	2022/09/06	2022/09/06	Roya Fathitil
Moisture (Subcontracted)	BAL	8219607	N/A	2022/09/09	Ashley Henderson
Sulphide in Soil	SPEC	8214723	N/A	2022/09/08	Marjolen Busslinger
pH CaCl2 EXTRACT	AT	8204114	2022/09/02	2022/09/02	Taslina Aktar
Redox Potential	COND	8207280	2022/09/06	2022/09/06	Surinder Rai
Resistivity of Soil		8201981	2022/09/06	2022/09/06	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8207212	2022/09/06	2022/09/06	Chandra Nandlal

Bureau Veritas ID: TPE440
Sample ID: BHOC-6-6
Matrix: Soil

Collected: 2022/08/16
Shipped:
Received: 2022/08/30

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8207208	2022/09/06	2022/09/06	Alina Dobreanu
Conductivity	AT	8207399	2022/09/06	2022/09/06	Roya Fathitil
Moisture (Subcontracted)	BAL	8219607	N/A	2022/09/09	Ashley Henderson
Sulphide in Soil	SPEC	8214723	N/A	2022/09/08	Marjolen Busslinger
pH CaCl2 EXTRACT	AT	8204114	2022/09/02	2022/09/02	Taslina Aktar
Redox Potential	COND	8207280	2022/09/06	2022/09/06	Surinder Rai
Resistivity of Soil		8201981	2022/09/06	2022/09/06	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8207212	2022/09/06	2022/09/06	Chandra Nandlal



BUREAU
VERITAS

Bureau Veritas Job #: C2O8692

Report Date: 2022/09/12

Golder Associates Ltd

Client Project #: 22521942

Sampler Initials: KR

TEST SUMMARY

Bureau Veritas ID: TPE441
Sample ID: BHAB-2-7
Matrix: Soil

Collected: 2022/08/22
Shipped:
Received: 2022/08/30

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8207208	2022/09/06	2022/09/06	Alina Dobreanu
Conductivity	AT	8207399	2022/09/06	2022/09/06	Roya Fathitil
Moisture (Subcontracted)	BAL	8219607	N/A	2022/09/09	Ashley Henderson
Sulphide in Soil	SPEC	8214723	N/A	2022/09/08	Marjolen Busslinger
pH CaCl2 EXTRACT	AT	8204114	2022/09/02	2022/09/02	Taslina Aktar
Redox Potential	COND	8207280	2022/09/06	2022/09/06	Surinder Rai
Resistivity of Soil		8201981	2022/09/06	2022/09/06	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8207212	2022/09/06	2022/09/06	Chandra Nandlal

Bureau Veritas ID: TPE442
Sample ID: BHOC-10-6
Matrix: Soil

Collected: 2022/08/22
Shipped:
Received: 2022/08/30

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8207208	2022/09/06	2022/09/06	Alina Dobreanu
Conductivity	AT	8207399	2022/09/06	2022/09/06	Roya Fathitil
Moisture (Subcontracted)	BAL	8219608	N/A	2022/09/08	Maren Glaser
Sulphide in Soil	SPEC	8214723	N/A	2022/09/08	Marjolen Busslinger
pH CaCl2 EXTRACT	AT	8204114	2022/09/02	2022/09/02	Taslina Aktar
Redox Potential	COND	8207280	2022/09/06	2022/09/06	Surinder Rai
Resistivity of Soil		8201981	2022/09/06	2022/09/06	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8207212	2022/09/06	2022/09/06	Chandra Nandlal

Bureau Veritas ID: TPE442 Dup
Sample ID: BHOC-10-6
Matrix: Soil

Collected: 2022/08/22
Shipped:
Received: 2022/08/30

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Moisture (Subcontracted)	BAL	8219608	N/A	2022/09/08	Maren Glaser

Bureau Veritas ID: TPE443
Sample ID: BHOC-14-4
Matrix: Soil

Collected: 2022/08/24
Shipped:
Received: 2022/08/30

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Chloride (20:1 extract)	KONE/EC	8207208	2022/09/06	2022/09/06	Alina Dobreanu
Conductivity	AT	8207399	2022/09/06	2022/09/06	Roya Fathitil
Moisture (Subcontracted)	BAL	8219607	N/A	2022/09/09	Ashley Henderson
Sulphide in Soil	SPEC	8214723	N/A	2022/09/08	Marjolen Busslinger
pH CaCl2 EXTRACT	AT	8204114	2022/09/02	2022/09/02	Taslina Aktar
Redox Potential	COND	8207280	2022/09/06	2022/09/06	Surinder Rai
Resistivity of Soil		8201981	2022/09/06	2022/09/06	Automated Statchk
Sulphate (20:1 Extract)	KONE/EC	8207212	2022/09/06	2022/09/06	Chandra Nandlal



GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	12.3°C
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Results relate only to the items tested.



BUREAU
VERITAS

Bureau Veritas Job #: C2O8692
Report Date: 2022/09/12

Golder Associates Ltd
Client Project #: 22521942
Sampler Initials: KR

QUALITY ASSURANCE REPORT

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
8204114	TAK	Spiked Blank	Available (CaCl ₂) pH	2022/09/02		100	%	97 - 103
8204114	TAK	RPD	Available (CaCl ₂) pH	2022/09/02	0.082		%	N/A
8207208	ADB	Matrix Spike	Soluble (20:1) Chloride (Cl ⁻)	2022/09/06		NC	%	70 - 130
8207208	ADB	Spiked Blank	Soluble (20:1) Chloride (Cl ⁻)	2022/09/06		105	%	70 - 130
8207208	ADB	Method Blank	Soluble (20:1) Chloride (Cl ⁻)	2022/09/06	<20		ug/g	
8207208	ADB	RPD	Soluble (20:1) Chloride (Cl ⁻)	2022/09/06	3.1		%	35
8207212	C_N	Matrix Spike [TPE438-01]	Soluble (20:1) Sulphate (SO ₄)	2022/09/06		103	%	70 - 130
8207212	C_N	Spiked Blank	Soluble (20:1) Sulphate (SO ₄)	2022/09/06		103	%	70 - 130
8207212	C_N	Method Blank	Soluble (20:1) Sulphate (SO ₄)	2022/09/06	<20		ug/g	
8207212	C_N	RPD [TPE438-01]	Soluble (20:1) Sulphate (SO ₄)	2022/09/06	NC		%	35
8207280	SAU	Spiked Blank	Redox Potential	2022/09/06		101	%	95 - 105
8207280	SAU	RPD	Redox Potential	2022/09/06	12		%	N/A
8207399	RFT	Spiked Blank	Conductivity	2022/09/06		99	%	90 - 110
8207399	RFT	Method Blank	Conductivity	2022/09/06	<2		umho/cm	
8207399	RFT	RPD	Conductivity	2022/09/06	1.6		%	10
8214723	éE2	Matrix Spike	Sulphide	2022/09/08		102	%	75 - 125
8214723	éE2	Spiked Blank	Sulphide	2022/09/08		110	%	75 - 125
8214723	éE2	Method Blank	Sulphide	2022/09/08	<0.5		mg/kg	
8214723	éE2	RPD	Sulphide	2022/09/08	17		%	30
8219607	A1H	Method Blank	Moisture-Subcontracted	2022/09/09	<0.30		%	
8219608	MGL	Method Blank	Moisture-Subcontracted	2022/09/08	<0.30		%	
8219608	MGL	RPD [TPE442-02]	Moisture-Subcontracted	2022/09/08	1.1		%	20

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (absolute difference <= 2x RDL).



BUREAU
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Bureau Veritas Job #: C208692

Report Date: 2022/09/12

Golder Associates Ltd

Client Project #: 22521942

Sampler Initials: KR

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by:

Cristina Carriere, Senior Scientific Specialist

Veronica Falk, B.Sc., P.Chem., QP, Scientific Specialist, Organics

Suwan (Sze Yeung) Fock, B.Sc., Scientific Specialist

Bureau Veritas has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation please refer to the Validation Signature Page.



Bureau Veritas
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CHAIN OF CUSTODY RECORD

Page 1 of 1

INVOICE TO:		REPORT TO:		PROJECT INFORMATION:		Laboratory Use Only:	
Company Name: #12323 Golder Associates Ltd		Company Name: Christi Groves Jesus Gonzalez-Hurtado		Quotation #: C20239		Bureau Veritas Job #:	
Attention: Accounts Payable		Attention: Jesus Gonzalez-Hurtado		P.O. #:		Bottle Order #:	
Address: 121 Commerce Park Drive Unit L		Address: Jesus.Gonzalez-hurtado@usp.com		Project: 22521942		COC #:	
Tel: (705) 722-4492 Fax: (705) 722-3786		Tel: (705) 722-4496 Ext: 6020 Fax:		Project Name:		Project Manager:	
Email: CanadaAccountsPayableInvoices@golder.com		Email: Christi-Groves@golder.com		Site #:		Ankita Bhalla	
				Sampled By: Kevin Rupke		C#892612-13-01	

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE BUREAU VERITAS DRINKING WATER CHAIN OF CUSTODY				ANALYSIS REQUESTED (PLEASE BE SPECIFIC)										Turnaround Time (TAT) Required: Please provide advance notice for rush projects																	
Regulation 153 (2011)				Other Regulations				Special Instructions				Regular (Standard) TAT: (will be applied if Rush TAT is not specified)																			
<input checked="" type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Medium/Fine				<input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw								<input checked="" type="checkbox"/>																			
<input checked="" type="checkbox"/> Table 2 <input type="checkbox"/> Ind/Comm <input type="checkbox"/> Coarse				<input type="checkbox"/> Reg 558 <input type="checkbox"/> Storm Sewer Bylaw								Standard TAT = 5-7 Working days for most tests.																			
<input type="checkbox"/> Table 3 <input type="checkbox"/> Agri/Other <input type="checkbox"/> For RSC				<input type="checkbox"/> MISA Municipality								Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.																			
<input checked="" type="checkbox"/> Table 2.1 RPI ESQS				<input type="checkbox"/> PWQO <input type="checkbox"/> Reg 406 Table								Job Specific Rush TAT (if applies to entire submission)																			
Include Criteria on Certificate of Analysis (Y/N)? <input checked="" type="checkbox"/>												Date Required: Time Required:																			
												Rush Confirmation Number: (call lab for #)																			
Sample Barcode Label		Sample (Location) Identification		Date Sampled		Time Sampled		Matrix		Field Filtered (please circle): Metals / Hg / Cr VI		O Reg 153 VOCs by HS & R1-F4		O Reg 153 PAHs		O Reg 153 ICPMMS Metals		Conductivity		SAR		pH CaCl2 EXTRACT		PFAS Standard List 22		Corrosion potential		# of Bottles		Comments	
1		BHMT-1-6		22/08/25		1:40PM		Soil																		4					
2		BH OC-3-6		22/08/17		1:00PM																				4					
3		BH OC-6-6		22/08/16		1:10PM																				4					
4		BH AB-2-7		22/08/22		11:00am																				4					
5		BH OC-10-6		22/08/22		12:50 pm																				4					
6		BH OC-14-4		22/08/24		2:05PM																				5					
7																															
8																															
9																															
10																															

* RELINQUISHED BY: (Signature/Print)		Date: (YY/MM/DD)		Time		RECEIVED BY: (Signature/Print)		Date: (YY/MM/DD)		Time		# jars used and not submitted		Laboratory Use Only	
D. J. / Dan Jennings		22/08/30		8:30am		[Signature]		08/09/25		178				Time Sensitive	
														Temperature (°C) on Reel	
														Custody Seal	
														Present	
														Intact	
														Yes	
														No	

* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO BUREAU VERITAS'S STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS WHICH ARE AVAILABLE FOR VIEWING AT WWW.BVNA.COM/TERMS-AND-CONDITIONS.

* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

** SAMPLE CONTAINER, PRESERVATION, HOLD TIME AND PACKAGE INFORMATION CAN BE VIEWED AT WWW.BVNA.COM/RESOURCES/CHAIN-OF-CUSTODY-FORMS.

SAMPLES MUST BE KEPT COOL (< 10° C) FROM TIME OF SAMPLING UNTIL DELIVERY TO BUREAU VERITAS

White: Bureau Veritas Yellow: Client

APPENDIX E

Non-Standard Special Provisions



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