

FINAL REPORT**Foundation Investigation and Design Report**

*Proposed NPS 20 Enbridge Pipeline Crossing of Highway 5
Hamilton, Ontario*

Submitted to:

Aecon Utility Engineering

4096 Meadowbrook Drive, Unit 128
London, Ontario
N6L 1G4

Submitted by:

Golder Associates Ltd.

1931 Robertson Road,
Ottawa, Ontario, K2H 5B7

Latitude: 43.301826°

Longitude: -79.946538°

GEOCRES No. 30M5-337
20446494

January 2022



Distribution List

1-copy Ministry of Transportation

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Certificate of Analysis – Report#R6571860

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by Aecon Utility Engineering (AUE) to provide foundation engineering services in support of the trenchless installation of a Normal Pipe Size (NPS) 20 pipeline across the Ministry of Transportation, Ontario (MTO) Highway 5 in the City of Hamilton, Ontario. It is understood that the proposed NPS20 pipeline will cross Highway 5 approximately 80 m east of Millgrove Side Rd. The location of the site and the proposed pipeline alignment are shown in plan on Figure 1. Authorization to Proceed with the investigation, in general accordance with our Proposal (CX20446494) dated January 21, 2021, was provided by AUE, a division of Aecon Construction Group Inc. (Aecon) under Purchase Order 4700077089.

The purpose of this geotechnical investigation was to assess the subsurface soil and groundwater conditions and provide site specific geotechnical engineering recommendations for the proposed trenchless crossing. Information provided by AUE, indicates that an approximately 43 m long section of the pipe installation will take place within the Ministry of Transportation, Ontario (MTO) right-of-way.

This report has been prepared in accordance with MTO's Guidelines for Foundations Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application (dated January 2019).

The factual data, interpretations and preliminary 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, 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 "*Important Information and Limitations of This Report*", included following the text of this report. 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 SITE DESCRIPTION AND REGIONAL GEOLOGY

2.1 Site Description

The proposed NPS20 pipeline is located within the City of Hamilton, Ontario and will cross Highway 5, approximately perpendicular to the roadway. The product pipe is understood to be 508 mm in outside diameter. The proposed bore alignment is shown on the plan and profile drawings on Figure 1.

The project area is surrounded by farmer's fields, with a Pioneer gas station located at the north side of the proposed crossing. In general, the existing ground surface on Highway 5 is about Elevation 119 m, with drainage ditches located on the south side of the highway. There is an existing 0.8 m diameter ditchline culvert that passes under the gas station entrance. The existing ditchline culvert is orthogonal to the proposed bore alignment. The location of the ditchline culvert is shown on the Figures 1 and 2.

2.2 Regional Geology

The project area is located within the Norfolk Sand Plain physiographic region, as delineated in *The Physiography of Southern Ontario* (Chapman and Putman, 1984)¹. The Norfolk Sand Plain consists of fine textured sands and silts deposited as a delta in glacial Lakes Whittlesy and Warren. The bedrock is reported to be dolomite belonging to the Guelph Formation of middle Silurian Age (Geological Survey of Canada, Map 1263A entitled “Geology, Toronto-Windsor Area, dated 1969)².

3.0 PROCEDURE

Field work for this subsurface investigation was carried out on March 15, 2021, during which time a total of two boreholes (Boreholes 21-1 and 21-2) were advanced along the proposed alignment, at the approximate locations shown on Figure 1. Boreholes 21-1 and 21-2 were terminated upon auger refusal at depths of 8.6 m and 7.2 m below ground surface (at Elevations 210.1 m and 209.9 m), respectively.

The boreholes were advanced using a CME 55 track-mounted drill rig, equipped with 210 mm outside diameter (O.D.) hollow stem augers, supplied and operated by Landshark Drilling Inc. of Brantford, Ontario. Soil samples were obtained at vertical sampling intervals of about 0.76 m. using a 50 mm O.D. split-spoon sampler driven by automatic hammer in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586³). 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 and water levels in the open boreholes were observed during and immediately following the drilling operations. A standpipe piezometer was installed in Borehole 21-1 to monitor the groundwater level at the site. The installed piezometer consists of a 50 mm diameter PVC pipe with a slotted screen sealed within a selected depth within the borehole. The borehole annulus surrounding the piezometer screen was backfilled with sand and the remainder of the borehole was then backfilled with bentonite to ground surface. Details of the piezometer installation and groundwater level readings are presented on the Record of Boreholes in Appendix A. All other boreholes were backfilled with bentonite upon completion in accordance with Ontario Regulation 903 Wells (as amended), and the ground surface was restored to near original condition as practical.

The field work was observed a full-time basis by members of Golder's engineering and technical staff, who marked the borehole locations, arranged for the clearance of underground services, observed the drilling, sampling and in-situ testing operations, logged the boreholes, and examined and cared for the soil samples. The soil samples were identified in the field, placed in appropriate containers, labelled and transported back to Golder's Mississauga geotechnical laboratory where the samples underwent further visual examination and laboratory testing. All the soil laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Index and classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. The results of the laboratory testing for the current investigation are included in Appendix B.

¹ Chapman, L.J. and Putnam, D.F. 1984. *The Physiography of Southern Ontario*, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P. 2715, Scale 1:600,000.

² Geological Survey of Canada, 1969. *Map 1263A Geology, Toronto Windsor Area*, Scale 1:250,000.

³ ASTM D1586 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of the Soils.

One selected soil sample was submitted to Bureau Veritas Laboratories of Mississauga, Ontario, a Standards Council of Canada (SCC) accredited laboratory for chemical analysis. The selected sample was analyzed for a suite of corrosivity parameters, including conductivity, resistivity, soluble chloride, soluble sulphate and pH. The results of the chemical analysis are presented in Appendix B.

The as-drilled borehole locations and the ground surface elevations were obtained using a GPS Trimble GEO 7X, having an accuracy of approximately 0.1 m in the vertical and 0.1 m in the horizontal directions. The locations given on the Record of Boreholes and shown on Figure 1 are positioned related to NAD 83 Universal Transverse Mercator (UTM) CSRS CGVD28 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole locations, geographic coordinates, ground surface elevations and drilled depths are summarized in Table 1.

Table 1: Borehole Summary

| Borehole | UTM NAD 83 Northing (m) (Latitude) | UTM NAD 83 Easting (m) (Longitude) | Ground Surface Elevation (m) | Borehole Depth (m) |
|----------|---------------------------------------|---------------------------------------|------------------------------------|--------------------------|
| 21-1 | 4,794,870.8 (43.301826) | 585,445.1 (-79.946538) | 218.7 | 8.6 |
| 21-2 | 4,794,830.1 (43.301459) | 585,455.1 (-79.946420) | 217.1 | 7.2 |

4.0 SUMMARY OF SUBSURFACE CONDITIONS

4.1 General

The detailed subsurface soil and groundwater conditions encountered in the boreholes are presented on the Record of Borehole sheets contained in Appendix A. The geotechnical and analytical laboratory test results are presented on the figures in Appendix B. The results of in-situ tests (i.e., SPT) as presented in the borehole records and in Section 4.1 are uncorrected. The boundaries between the soil deposits on the Record of Boreholes provided in Appendix A and illustrated on the profile drawing on Figure 1 have been inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Variation in the stratigraphic boundaries between and beyond boreholes will exist and is to be expected; however, the factual data presented on the borehole records governs any interpretation of the site conditions.

In general, the soil stratigraphy at the boreholes consisted of cohesive and non-cohesive fill underlain by native silty sand and silty clay all underlain by glacial till. A silt deposit was encountered within the glacial till deposit at Borehole 21-1 and 21-2. Both boreholes were terminated upon auger refusal. Descriptions of the observed subsurface conditions within the boreholes are provided in the following sections of the report. The inferred soil stratigraphy based on observations from the boreholes advanced along the alignment is shown in profile on Figure 1.

4.1.1 Fill

A 0.6 m and 1.1 m thick layer of fill was encountered at ground surface (Elevation 218.7 m and 217.1 m) in Boreholes 21-1 and 21-2, respectively. The fill is composed of silty sand, some gravel, trace rootlets in Borehole 21-1, and silty clay, trace sand, trace rootlets in Borehole 21-2.

The SPT 'N'-value measured within the non-cohesive fill layer was 20 blows per 0.3 m of penetration indicating a compact state of compactness. The SPT 'N'-value measured within the cohesive fill layer was 8 blows per 0.3 m of penetration indicating a stiff consistency.

4.1.2 Silty Sand

A 0.3 m thick deposit of native silty sand was encountered below the fill at Borehole 21-2. The deposit was encountered at a depth of 1.1 m below ground surface (Elevation 216.0 m) and extends to a depth of 1.4 m below ground surface (Elevation 215.7 m). The measured water content of one sample of the silty sand deposit was about 25%.

4.1.3 Silty Clay

A 0.8 m and 1.6 m thick deposit of silty clay, trace to some sand, trace gravel, was encountered below the fill at Borehole 21-1, and below the sandy silt deposit at Borehole 21-2. The top of the cohesive deposit was encountered at depths of 0.6 m and 1.4 m below ground surface (Elevations 218.1 m and 215.7 m) and extends to a depth of 2.2 m below ground surface (Elevations 216.5 m and 214.9 m), at both boreholes 21-1 and 21-2.

SPT 'N'-values measured within the deposit ranged from 8 to 29 blows per 0.3 m of penetration indicating that the deposit has a stiff to very stiff consistency.

Water contents measured on two samples of the silty clay were about 18% and 27% at Boreholes 21-1 and 21-2, respectively.

4.1.4 Glacial Till

A glacial till deposit was encountered underlying the silty clay at Boreholes 21-1 and 21-2, respectively. The till deposit consists of silty clay, trace to some sand, trace gravel and silty clay and gravel. A deposit of gravelly silt and silt, some sand, was also encountered within the till deposits are described in detail in Section 4.1.5 below. Although not encountered in these boreholes, cobbles and boulders are commonly present within glacially derived soils and should be expected within this deposit.

The top of the till deposit was encountered at a depth of 2.2 m below ground surface (Elevation 216.5 and 214.9 m) and extends to depths of 8.6 m and 7.2 m below ground surface (Elevation 210.2 m and 210.0 m) in Boreholes 21-1 and 21-2, respectively. Both boreholes were terminated within this deposit upon auger refusal.

SPT "N"-values measured within till ranged from 14 to 66 blows per 0.3 m of penetration, suggesting a stiff to hard consistency.

The water content measured on three samples of the till deposit range from about 12% to 16%.

Atterberg limit testing was carried out on two samples of the cohesive portions of the till deposit, and the results are presented on Figure B1 in Appendix B. The Atterberg limit tests measured liquid limits of about 26%, plastic limits of about 16%, and plasticity indices of about 10%, indicating that the material is a silty clay of low plasticity.

4.1.5 Gravelly Silt to Silt

A 2.3 m and 2.6 m thick deposit of gravelly silt to silt was encountered within the till deposit at both boreholes. The silt deposit contains some gravel, ranging to gravelly, and some sand, ranging to sandy. The top of the silt deposit was encountered at depths of 3.7 m and 4.1 m below ground surface (Elevations 215.0 m and 213.0 m) and extends to depths of 6.0 m and 6.7 m below ground surface (Elevations 212.7 m and 210.4 m), in Boreholes 21-1 and 21-2 respectively.

The SPT 'N'-values measured within the silt deposit ranged from 12 to 34 blows per 0.3 m of penetration indicating a compact to dense state of compactness.

Grain size distribution testing was carried out on a single sample of the silt deposit, and the results are presented on Figure B2 in Appendix B.

Water contents measured on two samples of the silt deposit were about 16% and 18%.

4.2 Auger Refusal

Bedrock was not proven by bedrock core drilling as part of the current investigation. Auger refusal was encountered in both boreholes.

Auger refusal could represent the presence of cobbles and boulders within the till material or the bedrock surface.

Table 2 summarizes the auger refusal depths and elevations as encountered at the borehole locations.

Table 2: Summary of Depths to Auger Refusal

| Borehole | Existing Ground Surface Elevation (m) | Auger Refusal Elevation (m) | Depth to Auger Refusal (m) |
|----------|---------------------------------------|-----------------------------|----------------------------|
| 21-1 | 218.7 | 210.2 | 8.6 |
| 21-2 | 217.1 | 209.9 | 7.2 |

4.3 Groundwater Conditions

A monitoring well was installed at Borehole 21-1 to observe the stabilized groundwater level at the site. Table 3 summarizes the depths and the elevations of the groundwater levels measured in the monitoring well installed at the site.

Table 3: Groundwater Conditions

| Borehole | Screened Stratigraphy | Water Level | | Date of Measurement |
|----------|-----------------------|-------------|---------------|---------------------|
| | | Depth (m) | Elevation (m) | |
| 21-1 | Silty Clay (Till) | 7.0 | 211.7 | March 15, 2021 |
| | | 1.7 | 217.0 | April 16, 2021 |

It is expected that the groundwater levels will be subject to fluctuations both seasonally and as a result of precipitation events.

4.4 Analytical Testing

One soil sample was submitted to Bureau Veritas Laboratories for chemical analysis related to the potential corrosion of exposed buried steel and potential sulphate attack on buried concrete elements (corrosion and sulphate attack). The test results are provided in Appendix B and are summarized in Table 4.

Table 4: Analytical Test Results

| Borehole | Sample | Sample Depth (Elevation) (m) | Parameters | | | | |
|----------|--------|------------------------------------|--------------------|---|------|---------------------------|-------------------------|
| | | | Chloride (µg/g) | Soluble Sulphate (SO ₄) (µg/g) | pH | Conductivity (µmho/cm) | Resistivity (ohm-cm) |
| 21-1 | 5 | 3.0 – 3.7 (215.7 – 215.0) | 32 | <20 | 7.71 | 193 | 5,200 |

5.0 DISCUSSION AND RECOMMENDATIONS

5.1 General

The proposed alignment of the NPSP20 pipeline will cross Highway 5 approximately 80 m east of Millgrove Side Road, at the location shown on Figure 1. This section of the report provides geotechnical engineering information related to the design aspects of the proposed Enbridge crossing, based on our interpretation of the borehole information and laboratory test data and our understanding of the project requirements. It is understood that as part of MTO protocols, open cut techniques are typically not permitted within their right-of-way. Therefore, the feasibility of different trenchless pipeline installation methodologies (Horizontal Directional Drilling (HDD) micro-tunneling, pipe jacking and horizontal auger boring, and pipe ramming) are discussed herein. Based on email correspondence with AUE, it is understood that pipe ramming with a pilot tube, pipe jacking and horizontal auger boring (auger jack and bore) installation methods are being considered for this installation.

Note, the interpretation and recommendations contained herein are intended for the guidance of the project's design engineers. Where comments are made on construction, they are only provided to highlight aspects of construction that could affect the design and planning 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 interpretation of the factual data as it affects their proposed construction techniques, schedule, equipment capabilities, costs, sequencing and the like.

The Contractor should be responsible for choosing the method and equipment for the crossing installation unless specific methods are otherwise prohibited. Ground behaviour will be, in part, dependent on the installation method adopted and this report provides guidance on the influence of ground behaviour on possible installation methods. It should not be construed that the Contractor is restricted to the particular methods considered herein, and in the event that alternative methods are considered, the Contractor must make their own interpretation of the anticipated ground behaviour, based on the factual information from the investigations undertaken at this site.

The following discussion and recommendations should be considered preliminary as the final design details for the proposed works have not been confirmed. It is understood that AUE is considering two crossing options, in which the preferred depth of cover for the trenchless crossing has not been confirmed. The proposed crossing alignment options are shown on Figure 1. The following assumptions have been made with regards to the geometry of the proposed crossing:

- The length of the trenchless crossing will be approximately 43 m (with approximately 33 m crossing within the MTO right-of-way).
- The O.D. of the product pipe will be about 508 mm.

As the design progresses to detailed design, if the assumptions are no longer appropriate or if the horizontal or vertical alignments of the proposed pipeline are revised, Golder can review and update our recommendations at the request of AUE.

5.2 Proposed Pipe Alignment and Profile Considerations

The base plan mapping provided by AUE for this project and the ground surface elevations at the borehole locations surveyed during the field investigation indicate that the top of roadway elevation of Highway 5 in the vicinity of the proposed crossing ranges from 218.7 to 219 m. Based on the design drawings provide by AUE on May 11, 2021 it is understood that two crossing options are currently being considered. The two proposed crossing alignments for the NPS20 crossing is shown on Figure 1 and consist of the following:

- Option 1: The invert ranges from elevation 215.6 m at the north end of the crossing to elevation 214.6 m at the south end of the crossing.
- Option 2: The invert ranges from elevation 216.0 m at the north end of the crossing to elevation 214.6 m at the south end of the crossing.

The depth of installation will also need to consider the presence of other utilities within the Highway 5 right-of-way, allowing for sufficient separation from any existing services.

The minimum cover below the highway surface based on the proposed pipe diameter of 0.5 m would be between 2.3 and 3.2 m for Option 1, and between 2.3 m and 2.6 m for Option 2, providing cover-to-diameter ratios ranging from 5 to 6. If an oversize carrier pipe is installed the cover to diameter ratios would be reduced to about 2 to 3, assuming a 1 m diameter carrier pipe, however it is understood that an oversized carrier pipe will not be used at this site. The cover reduces to the south along the pipe alignment.

Typically, a minimum clearance of 3 times the diameter of the proposed pipe is required when crossing under existing infrastructure. However, in this case, as the bore alignment is orthogonal to the existing ditchline culvert at the north end of the bore alignment and in consistent ground conditions, 1 to 1.5 times the diameter of pipe diameter (or approximately 0.7 m) should be sufficient for an orthogonal crossing like the one at this site. The profile drawing on Figure 1 indicates the clearance between the existing ditchline culvert and the proposed tunnel bore.

For crossings, MTO generally requires that the three tunnel diameters or greater, at any point along the entire length of the tunnel crossing. Based on the profiles provided by AUE, both crossing alignment options meet this requirement and in accordance with the guidelines is considered a low complexity crossing for the purpose of assessing the Foundations specialty requirements.

Typically, it is recommended that the tunnel invert or obvert be a minimum of 0.5 m above or below (respectively) the interface of the fill materials, native materials and/or bedrock so that the tunnel horizon is not through mixed face conditions. It should be noted that based on the results of the borehole investigation the proposed crossing could be through a till and silt interface. For maximum distance between the till and silt interface, it is suggested that crossing Option 2 be implemented in order to reduce risk of ground loss during the tunnelling installations.

Prior to commencing the undercrossing, the contractor will have to carefully expose any utilities that may cross the pipeline alignment and confirm their locations and elevations. The contractor's work plan should include a method of supporting the face of the bore in the case of an emergency, depending on tunnelling method, should the need arise. Additionally, the contractor should have a plan in place to capture and dispose of inadvertent returns.

5.3 Anticipated Ground Behaviour

At the crossing location, the subsurface conditions generally consist of embankment fill, overlying native silty clay overlying till all underlain by bedrock. The groundwater level was measured at the site at a depth of 1.7 m, corresponding to Elevation 217.0 m (approximately 2.5 m above the proposed south tie in elevation). Based on the groundwater levels and the relatively impermeable soils (silty clay and silty clay till) dewatering measures (other than pumping from sumps) will likely not be required for excavations that do not extend below about elevation 216 m on the north side of Highway 5 and below elevation 214 m on the south side (i.e., that do not extend into the silt deposit). Should excavations extend below these elevations, the factor of safety against basal heave will be less than 1.2 and dewatering of the silt deposits will be required to lower the water level in that deposit to the excavation invert level. Excavations that extend into the silt deposit will avoid the risk of basal heave but will require significant dewatering effort to maintain the excavation.

The ground conditions along the pipe alignment within the tunnel vertical limits (i.e., invert and obvert of the pipe) are likely to consist of silty clay and silty clay till for both crossing options, although there is an increased potential that the bore may encounter the gravelly silt along crossing option 1. Based on interpolation between boreholes, this should be expected to be the case for the majority of length of the proposed tunnel bore. However, at the entry and exit pits tunnelling conditions will consist of embankment fill and native silty clay, if shallower pits and HDD methods (as discussed below) are used.

Based on the soil descriptions, the deposits encountered at the borehole locations have been classified according to the Tunnelman's Ground Classification System by Terzaghi as reported in Heuer (1974). This system is commonly used to describe the expected behaviour of an unsupported tunnel face during excavation and uses qualitative "stand-up time" criteria to classify the ground at and above the tunnel face into the following principal categories: hard, firm, slow ravelling, fast ravelling, squeezing, swelling, cohesive-running, running, very soft squeezing, flowing, and bouldery.

The silty sand embankment fill and native silty sand about the groundwater level would be classified as cohesive running and the silty clay embankment fill would be classified as slow ravelling. The native silty clay and silty clay till would be classified as firm ground and the silt deposit, which is below the groundwater level, would be classified as flowing ground under the Tunnelman's Ground Classification System.

5.4 Feasibility of Tunneling Methods

Common trenchless construction methods include horizontal directional drilling, pipe jacking and horizontal auger boring, pipe ramming, micro-tunneling, pilot tube micro-tunneling, tunnel boring machine and tunnel digging machine (i.e., open face shield tunnelling).

Based on the available information for this project and the list of methods discussed below, Horizontal Directional Drilling (HDD), Micro-tunnelling, pipe jacking and horizontal auger boring (Auger Jack and Bore), and pipe ramming, all with or without a pilot tube, are considered suitable for the proposed crossing.

It is understood that pipe ramming with a pilot tube is the preferred methodology for the trenchless installation at this location. Based on the boreholes advanced at the site, the bore will be entirely within the cohesive deposits and is therefore feasible. However, the potential does exist for the bore to encounter the flowing silt at the invert, depending on the lateral extent of that deposit. Option 2, as shown on Figure 1, reduces the potential to encounter the flowing silt and may be considered to reduce risk for this trenchless installation. In addition, there is the potential to encounter cobbles and boulders within the glacial till.

A summary comparison of the advantages, disadvantages, relative costs, and risks associated with the installation methods is presented in Table 6 provided after the text of this report.

The Contractor should be responsible for choosing the method and equipment for the crossing installation unless specific methods are otherwise prohibited. Ground behaviour will be, in part, dependent on the installation method adopted and this report provides guidance on the influence of ground behaviour on possible installation methods. It should not be construed that the Contractor is restricted to the particular methods considered herein, and in the event that alternative methods are considered, the Contractor must make their own interpretation of the anticipated ground behaviour, based on the factual information from the investigations undertaken at this site.

The following sections provide more information on the feasibility of trenchless technologies that may be employed at this site. The discussion contained herein should be considered preliminary in nature as the final alignment/depth of cover over the pipeline has not been determined.

1) Horizontal Directional Drilling (HDD)

HDD methods are being considered for the proposed pipeline installation at this site however the potential difficulties and risks associated with HDD methods need to be considered by the designers.

HDD method involves forward-thrusting a small rotating and steerable bit launched from the ground or shallow surface entry pit, at a shallow angle. Initially, a pilot hole is drilled, with the bore being supported by drilling fluid. Once the pilot bore is complete, the drill head is replaced with a back reamer or expander to enlarge the bore so that the product pipe or casing can be pulled into place. The HDD method is adaptable to a range of drilling conditions by various combinations of compatible drilling fluids, downhole tools and drill equipment. Typically, HDD alignments must start and end at some distance from the desired end points of relatively horizontal pipe sections because of the need for allowable entry and exit angles during the drilling and pullback operations. HDD equipment is available for drilling in both bedrock and overburden but is very challenging in bouldery ground. Deep entrance and exit pits are generally not required, however, larger laydown areas are required to install the product pipe, and the crossing typically needs to be longer to accommodate the shallow entry and exit angles for the drilling equipment. Bores are typically limited to less than 1.2 m in diameter. Sufficient cover is important to minimize the risk of hydraulic fracturing of the ground and loss of drilling fluid to the surface.

ASTM F1962-20 (Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings) indicates that “difficulties may occur” for an HDD installation with the soil conditions encountered at this site (i.e., granular fill and silty sand to silt, including transitions).

The HDD unit must have sufficient thrust over the length of the bore to overcome the soil resistance typical of the stiff to hard silty clay and silty clay till encountered at this site. The HDD contractor must consider dealing with the site-specific soils and whether the equipment is appropriate for the conditions. For the HDD bore advanced through the soils at this site, the selected drilling tools and methods must be compatible with primarily till, containing gravel, cobbles, and boulders. HDD provides some steering ability, with the amount of deviation from the proposed alignment or potential loss of the hole depending on the soils encountered along the bore alignment and contractor experience.

The drilling fluid, materials, pressures, fluid volumes and rate of advancement must also be compatible with the ground conditions. Reaming and pullback rates should be carefully controlled so that the annulus is properly prepared, and cuttings are effectively mixed with the slurry. After completion, the borehole diameter will exceed the diameter of the installed pipe. In some cases, the annular gap is filled with grout injected through small

separate grout tubes that are pulled through along with the final pipeline. In other cases, the drilling fluid is designed with appropriate materials (e.g., bentonite) such that over a period of time after the fluids stop circulating the combined fluids and cuttings develop sufficient gel strength to form a semi-solid that does not “bleed” or otherwise shrink sufficiently to result in an annular gap.

2) Micro-tunneling:

Micro-tunnelling is a method of installing pipes in bores ranging from 0.6 to greater than 3 m in diameter behind a steerable remote-controlled shield that is pressurized with a bentonitic fluid 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. Availability of this equipment locally is limited.

Micro-tunnelling is a very precise method of tunnelling and there is relatively little settlement with this method, if the face pressure and cutting tools are appropriate for the ground and are maintained over the length of the drive.

This method can be applied to a wide range of ground conditions from saturated sands and gravels, through to soft or stiff, dry or saturated clays and mudstones, to solid rock. Specialist advice on machine selection should be sought and recommendations regarding the machine design for the given ground conditions should be supported by the manufacturer. Appropriate machine design refinements may be used to extend the application range of the machine to cover more adverse soil conditions, including mixed face conditions and handling of obstructions such as cobbles and boulders.

3) Pipe Jacking and Horizontal Auger Boring (also referred to as Auger Jack and Bore):

A pipe jacking operation involves pushing a pipe (casing) horizontally into the ground by jacking through reaction against a thrust block (i.e., backstop) located within the jacking pit. 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. The casing may be lubricated to reduce the frictional forces between casing and the surrounding soil. The profile needs to be approximately horizontal and there is limited ability to steer the casing during jacking.

The jack and bore method is generally suitable for penetrating cohesive soils (silt and clay) and wet but unsaturated cohesionless soils that are well-graded (i.e., broadly graded). This method is not feasible in flowing ground which can lead to excessive ground losses, settlement and development of sinkholes extending to the surface when passing through saturated (flowing) sand, silt and/or gravel.

This method is only applicable to installation in the overburden and may not be feasible in bouldery soils (e.g., glacial till) as the presence of boulders and cobbles can obstruct augering operations, damage the equipment and require manual interventions that slow progress. The removal of obstructions may also result in loss of ground at the face and ground settlement at the ground surface, depending on the soil conditions.

However, this method can be adapted for use in mixed-face conditions and ground with boulders, with the addition of a Small Boring Unit (SBU) cutterhead. The SBU is equipped with mini disc cutters on the cutterhead and is welded to the lead casing to facilitate cutting through mixed ground, ground containing cobbles and boulders and/or bedrock. With the addition of the rotating cutterhead, the SBU also allows for some steering capability.

Jacking and receiving pits are required. The size of the jacking pit is controlled by the equipment size, operator access requirements and the length of the casing sections which are being installed. Typically, a work area of

about 10 m long by about 3 m to 5 m wide is required to accommodate the jacking/drive pit for jack and bore operations. The receiving pit is typically about 3 m square. The excavation depth for the pits will depend on the final invert elevation of the crossing alignment.

4) Pipe Ramming:

Pipe ramming is a trenchless method that uses a pneumatic tool to hammer a steel pipe or casing with a cutting shoe attached into the ground. The pipe is almost always driven open-ended to thereby direct the soil into the pipe interior instead of compacting it outside the pipe, reducing the potential for ground loss into the casing during driving. As each casing length is installed, the hammer is removed, the next casing is welded in place and the hammer replaced and restarted. The leading edge of the pipe typically has a small overcut to reduce friction between the carrier pipe and soil and to improve the load conditions on the pipe. Soil/pipe friction reduction can also be achieved with lubrication, and different types of bentonite and/or polymers can be used for this purpose.

Entry and receiving pits are also required for pipe ramming but, as there is no need for a thrust block in the entry pit, a smaller pit size is required than in jack and bore installations (which is an advantage for congested urban highways). The excavation depth for the pits will depend on the final invert elevation of the crossing alignment.

Pipe ramming is best suited for overburden installations in soft to firm clays and very loose to compact sands above the water table. This method is not considered feasible in mixed face conditions. These methods are also better suited for penetrating through/displacing potential obstructions such as cobbles and boulders in comparison to jack and bore installation method, although this method can still be obstructed by cobbles and boulders depending on their size and number. Pipe ramming is not-steerable, so there is no control over the profile and alignment of the bore once the pipe ramming has started, although a pilot tube can be used as a guide to aid in maintaining line and profile of the pipe. Vibrations from the pipe ramming operations may result in settlement of loose materials in the immediate vicinity of the installation. Furthermore, a “plug” of soil may form at the head of the casing inducing surficial heave as the pipe is advanced.

Compared to the jack and bore method, the most important advantage of pipe ramming is that the soil is typically removed from the pipe only after the pipe has fully passed beneath overlying infrastructure. Depending on the length of the installation, the soils inside the pipe can be removed either during or after the installation by auguring, compressed air or water jetting.

5.4.1 General Considerations for Trenchless Installations

Risk of subsidence or heave during the tunnelling installations generally increase as the depth of the overburden cover decreases. The same is true for other extreme events such as sinkholes forming at the ground surface. These risks can be reduced by increasing the depth of overburden cover above the tunnel crown and proper installation techniques. Maintaining minimum depth of cover equivalent to 3 tunnel diameters has been successfully employed in Ontario small-diameter tunnelling practice, depending on the method used.

The contractor must be aware of inherent risks and consequences involved with trenchless installations that could include some or all of the following:

- Existing buried infrastructure, including the existing natural gas, Bell service, and storm culverts, could be obstructions for a trenchless installation through the soils.
- The cobbles and boulders that may be present within the till could pose difficulties and may impact the contractor's choice of equipment.

- The presence of high groundwater levels across the site could lead to instability of the face and/or crown of the tunnel crossing and/or flow of material into the casing with associated potential for ground deformations and settlement.
- There is little ability to correct for line and grade within the design tolerances. If misalignment occurs, the contractor should be prepared to abandon the pipes in the ground and grout the bore.
- There is risk of ground loss and/or disturbance. Minimizing the time that the final bore is required to stay open is an important consideration in reducing potential ground loss in trenchless crossings.

5.5 Excavations and Groundwater Control

Excavations at the entry and exit points will be required to about 1 m below invert depth for all methods with the exception of HDD which require slightly (i.e., 0.7 metre less) shallower excavations.

Excavations should be carried out in accordance with current Ontario Occupational Health and Safety Act and Regulations for Construction Projects (OHSA). Soil types encountered in the boreholes can be classified according to the OHSA soil types summarized in Table 5.

Table 5: OHSA Soil Types for Temporary Excavations

| Soil Description | Fully Dewatered Excavations | Wet or Partially Unwatered Excavations |
|---|-----------------------------|--|
| Existing silty sand and silty clay fill | Type 3 | N/A |
| Loose silty sand | Type 3 | Type 4 |
| Stiff to very stiff silty clay | Type 2 | Type 2 |
| Stiff to hard silty clay till | Type 2 | Type 2 |
| Compact to dense silt | Type 3 | Type 4 |

To comply with OSHA, temporary dewatered excavations within these soils should be consistent with the following:

- Type 2 soils should be sloped at angles not steeper than 1H:1V (Horizontal:Vertical) with the bottom 1.2 m of the excavation depth permitted to be cut vertically.
- Type 3 soils should be sloped at angles not steeper than 1H:1V.
- Type 4 soils should be sloped at angles no steeper than 3H:1V.

Depending upon construction methodology, the groundwater control procedures adopted by the contractor and weather conditions at the time of construction, some local flattening of the slopes may be required. Existing utilities and portions of the roadway which are located in the zone of influence of potential excavations will require adequate support to limit unacceptable movements or deformations. The zone of excavation influence is defined by a line drawn from the base of the excavation upward at an inclination of 1V:1H. If sufficient space is not available to develop the excavations or if such excavations would encroach into the zone of influence of existing services or roadways, properly designed temporary support systems could be used to limit the extent of the excavations and reduce potential effects on adjacent services.

Stockpiling or storage of excavation spoils, construction materials or heavy equipment should not be permitted within 2 m of the crest of temporary excavation slopes to reduce the potential for excavation sidewall instability.

As noted in Section 5.3, dewatering measures (other than pumping from sumps) will likely be required for the excavations since they will likely extend below about elevation 216 m on the north side of Highway 5 and below elevation 214 on the south side. The factors of safety against basal heave will be less than 1.2 at these excavation depths and dewatering of the silt deposits will be required to lower the water level in that deposit to the excavation invert level.

It would be prudent to carry out a "public digging" (i.e. test pitting), extending to the silt deposit, prior to tender closing to allow the prospective contractors to assess the subsurface conditions at the entry/exit pits and determine the type of groundwater control required, consistent with their equipment capabilities and the actual groundwater conditions at that time. The locations of the test pits should be determined in consultation with the geotechnical engineer.

According to O.Reg 63/16 and O.Reg 387/04, if the volume of water to be pumped from excavations for the purpose of construction dewatering is greater than 50,000 L/day and less than 400,000 L/day, the water taking will need to be registered as a prescribed activity in the Environmental Activity and Sector Registry (EASR). Alternatively, a Permit to Take Water (PTTW) is required from the Ministry of the Environment, Conservation and Parks (MECP) if a volume of water greater than 400,000 L/day is to be pumped from the excavations.

5.6 Monitoring Program

Details regarding monitoring programs for the crossing are presented in the following sections. Various monitoring methods are available to assess the success of the drilling operation. Monitoring options during construction include assessing cutting returns, downhole fluid pressures, and surface settlement. Review and Alert Levels should be established for the selected monitoring options. The occurrence of a Review Level indicates the contractor and design team need to re-assess their current course of action and determine if an alternative approach is required, and an exceedance of an Alert Level indicates that construction should be discontinued until a path forward has been determined jointly by the contractor and design team.

5.6.1 Settlement Monitoring

Ground movement associated with trenchless installations generally occur as a result of bore instability and can consist of:

- Heave (i.e., observed upward movement at ground surface), as a result of the zone of plastic failure (i.e., blowout) extending towards the ground surface. The amount of heave is expected to increase as the zone of plastic failure nears ground surface.
- Settlement (i.e., downward movement at ground surface), as a result of loss of ground due to over-excavation (i.e., washout). Washout of the bore can be caused by the inability to control adverse ground conditions or the creation of voids around the installed pipeline. As the voids collapse, settlement may be observed at ground surface.

Provision should be made in the Contract Documents for a settlement monitoring program to be implemented to measure ground settlement at the existing roadways prior to, during and following the proposed installation. Monitoring of settlement instruments on Highway 5 is constrained by the continuous and high traffic volume and the limited periods during which access to the highway can be obtained. By necessity, settlement points on the highway must be read remotely and the use of Electronic Data Management (EDM) equipment reading reflectors installed on the lanes is recommended. A specialist surveying firm should be retained to confirm the set-up and to carry out the settlement monitoring during construction; their equipment and procedures must be capable of surveying the settlement point elevation to within ± 2 mm of the actual elevation. The results of the monitoring

should be made available to the Owner's geotechnical consultant for review on an ongoing basis. The proposed locations of the settlement points and markers and details of the proposed instrumentation are shown on Figure 2.

A monitoring program for the proposed NPS20 natural gas crossing under Highway 5 is required to be consistent with the "Appendix: Settlement Monitoring Guideline – Tunnelling" contained in MTO's document "Guideline for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application (October 2020)". The proposed monitoring program is summarized below:

- According to Table 1 of MTO's document "Guideline for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application (October 2020)", a geotechnical consultant rated with Medium Complexity in the MTO Consultant Acquisition System (RAQS) should be retained to supervise the installation of the surface settlement points on site, and to provide direction, technical input and field inspection during the trenchless drive.
- A condition survey of Highway 5 should be carried out by the retained geotechnical consultant in cooperation with the contractor prior to commencement of the construction and documented for the purpose of requirement of restoration. The highway surface survey should be completed during the installation of the monitoring points, and again once the drive has been completed.
- In-ground monitoring point arrays anchored below the depth of frost penetration, as detailed on Figure 2, should be installed on the north and south shoulders and embankment side slopes within the limits of the highway. Surface monitoring arrays (comprising hexagonal head bolts, as detailed on Figure 2, or reflectors) should be installed directly on the pavement over the alignment along the centreline of the undercrossing where it crosses Highway 5. The maximum spacing between the arrays should not exceed 5 m along the trenchless alignment, where practical.
- All monitoring points should be read at least three times, on separate days, before the start of boring to establish a pre-construction baseline.
- During the trenchless installation, all points should be read three times per day including during shut-down periods and weekends. The effectiveness of this monitoring method could be impacted by weather conditions if the work is undertaken during the winter months. Further, an allowance should be made for more frequent monitoring (up to every 4 hours) should observations dictate the need.
- After installation, the monitoring points within the Highway 5 right-of-way should be read and recorded at least once per day for 10 days, then once every 3 days for 15 days, and then once every 10-day period for the 30 days following completion of the installation or until the monitoring data indicate that movements have ceased (provided the monitoring has occurred for at least two weeks post-construction).
- Measurements of the monitoring points should be reported promptly to the geotechnical consultant for assessment/review and submitted to MTO for information/comment. A procedure is required to be established in consultation with MTO so that the monitoring data and the interpreted data will reach all parties as soon as practical.

The Review and Alert Levels are outlined in the MTO guideline for Highway 5. The following procedure should be followed if settlement levels reach the Review and Alert Levels:

- If the Review Level of 10 mm is reached the Contractor should be required to provide a formal plan that clearly states what measures need to be taken to ensure that the Alert Level is not reached.

- If the Alert Level of 15 mm is reached, the Contractor shall stop installation operations and the MTO, through Enbridge, would have the authority to order that the Contractor alter the installation methods prior to continuing with the installation. The Contractor must have a Protocol in place, pre-approved by the MTO, for instituting a traffic control plan, including a red light/amber light/green light notification system, to ensure the safety of roadway users and to maintain traffic flow on the highway.

5.6.2 Drill Fluid Pressure Monitoring (HDD)

If HDD is selected as the trenchless option, the downhole drill fluid pressure will vary during the advancement of the pilot hole and will be impacted by the depth of cover, distance drilled, etc. In general, changes in the downhole fluid pressures should be gradual, whereas rapid or unexpected changes in fluid pressure may indicate downhole issues. Two techniques available to monitor downhole fluid pressure are downhole pressure monitoring and standpipe pressure monitoring.

Downhole pressure monitoring involves combining a pressure transducer with the downhole survey probe. Pressure measurements from the transducer are transmitted to surface via the same electrical cable used for relaying information from the survey probe. This approach allows the measured downhole pressures to be compared to the predicted pressure diagram for the crossing. In general, higher than predicted downhole pressures may indicate insufficient flushing of the cuttings (i.e., plugging), whereas lower than predicted downhole pressures may indicate loss of drill fluid into the surrounding overburden.

Standpipe pressure monitoring involves measuring the drill fluid pressure in the drill pipe string at surface. This approach is an indirect measurement as it does not include the elevation pressure experienced downhole. As with measuring the drill fluid pressure downhole, higher or lower than predicted pressures may provide indications of downhole issues.

The contractor should provide a pressure monitoring plan along with potential action items if higher or lower than predicted downhole pressures are encountered.

5.6.3 Monitoring Cutting Returns

Measurement of the cutting returns during a jack and bore, HDD or micro-tunnelling bore can provide an indication if washout is occurring along the advancing bore. The rate and quantity of anticipated cuttings return can be estimated using the properties of the proposed drilling fluid. As the drilling fluid is to be selected by the contractor and the methodology for measuring the quantity of cuttings returned will need to be compatible with the contractor's equipment, the contractor will need to estimate the cutting returns beforehand and develop Review and Alert Levels if the cutting returns are higher or lower than predicted.

5.7 Analytical Assessment

One soil sample obtained was submitted for analytical testing of soil corrosivity parameters. 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*") for the potential sulphate attack on concrete. The water soluble-sulphate concentration measured in the soil samples tested are less than 0.01 per cent, indicating 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 sample tested, when the designer is selecting the exposure class for

pipes or associated structures, the effects of sulphates from within the soil stratum tested may not need to be considered. However, given the location of the crossing is within the roadway right-of-way, the pipe and/or casing may be exposed to de-icing salts and selection of the exposure class should consider this in the selection of cement type for use in concrete, if required.

The soil sample has a pH of 7.7 and according to the MTO Gravity Pipe Design Guidelines (2014), the pH is not considered detrimental to the watermain pipe/casing durability. The resistivity was measured to be 5,200 ohm-cm, which indicates that the soil corrosiveness is low ($6,000 \text{ ohm-cm} > R > 4,500 \text{ ohm-cm}$), as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014). The design of the 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.

5.8 Other Considerations

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. Prior to construction, the contractor should be required to submit their proposed construction method and monitoring program (identifying the risks and methods of control for possible problems that could cause interference to the highway, which as heave, settlement, changes of alignment) for review and approval from Enbridge and the relevant stakeholders (i.e., Ministry of Transportation Ontario and City of Hamilton as may be applicable). It is recommended that the geotechnical aspects of the contractor's work plan for the undercrossing be reviewed by the Owner's geotechnical consultant prior to construction.

Before excavation begins at the proposed undercrossing location, hand digging or hydro-vacuum methods are recommended to expose any underground utilities in the vicinity of the proposed crossing, if present such as the existing gas pipelines, to determine the exact locations and depths.

Performance of the completed undercrossing will largely be dependent upon the contractor's construction procedure and techniques. Ground movements (heave or settlement) associated with the work should be monitored as discussed in Section 5.6 and, if necessary, the construction method should be modified to control the ground movements and minimize disturbance of the overlying roadway. Where adequate provisions are not included to ensure stability of the bore and associated excavations, detrimental surface settlement could occur adversely affecting the roadways and any existing underground services in the vicinity of the jack and bore installation which would then require remedial measures to be undertaken. The contractor's work plan should include a provision for compensation grouting should the need arise.

Should remedial works to the roadways be required due to settlement/heave, further monitoring of the condition will be required until all movement has stabilized.

One piezometer has been installed to permit monitoring of the groundwater levels at the site. Ontario Regulation (O.Reg.) 903, as amended, of the Ontario Water Resources Act, requires that the standpipes be properly abandoned/decommissioned by an MOE licensed Water Well Contractor. We recommend that the decommissioning of the piezometers be carried out just prior to construction activities at the site so that water level measurements can be taken immediately prior to construction and to remove the potential for preferential pathway for drill fluid migration. If requested, Golder could provide assistance to AUE in arranging for the decommissioning of the piezometer by a licensed Water Well Contractor.

6.0 GEOTECHNICAL INSPECTION AND TESTING

Due to the variable subsurface conditions, it is recommended that geotechnical input continue throughout the design and construction of the project.

As discussed in Section 5.6, review of the geotechnical aspects of the trenchless installation contractor's work plan and a program of geotechnical inspection and monitoring should be required during construction of the undercrossing to ensure that the intent of the design recommendations provided is being met and that the various project criteria are being achieved.

7.0 CLOSURE

This report was prepared by Ms. Katie Nero, EIT, and Kenton Power, P.Eng. It was reviewed by William Cavers, P.Eng. a Senior Geotechnical Engineer with Golder and the Designated MTO Foundations Contact for this project.

Golder Associates Ltd.



*Kenton Power, P.Eng.
Geotechnical Engineer*



*William (Bill) Cavers, P.Eng.
Designated MTO Contact*



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The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder 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. Golder 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, Golder 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 Golder 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: Golder 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. Golder 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, Golder 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 Golder 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 Golder 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 Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

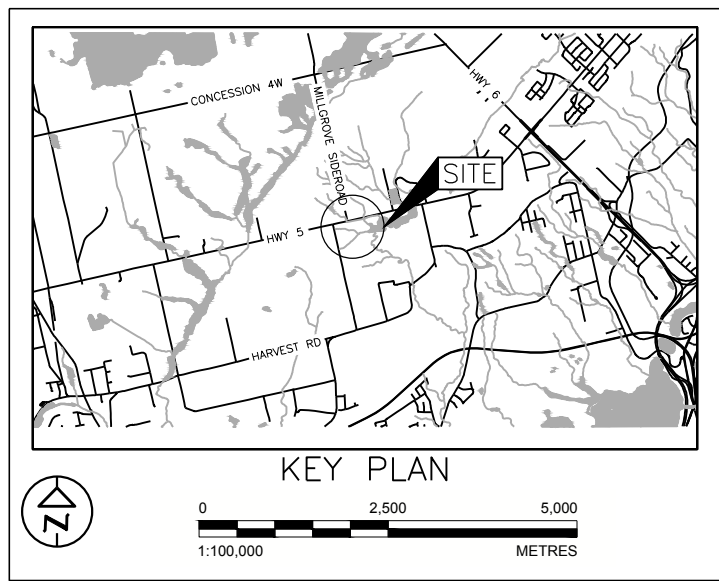
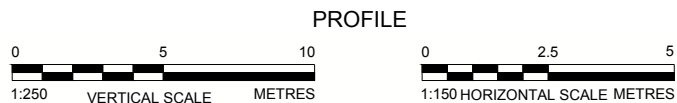
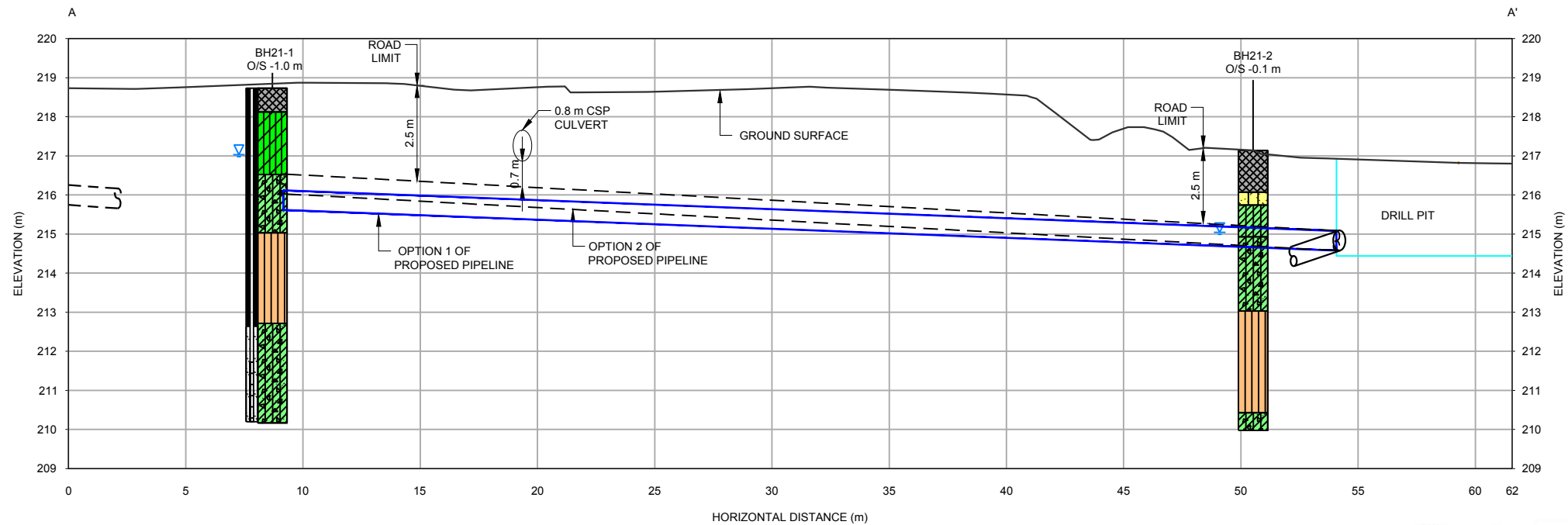
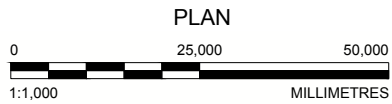
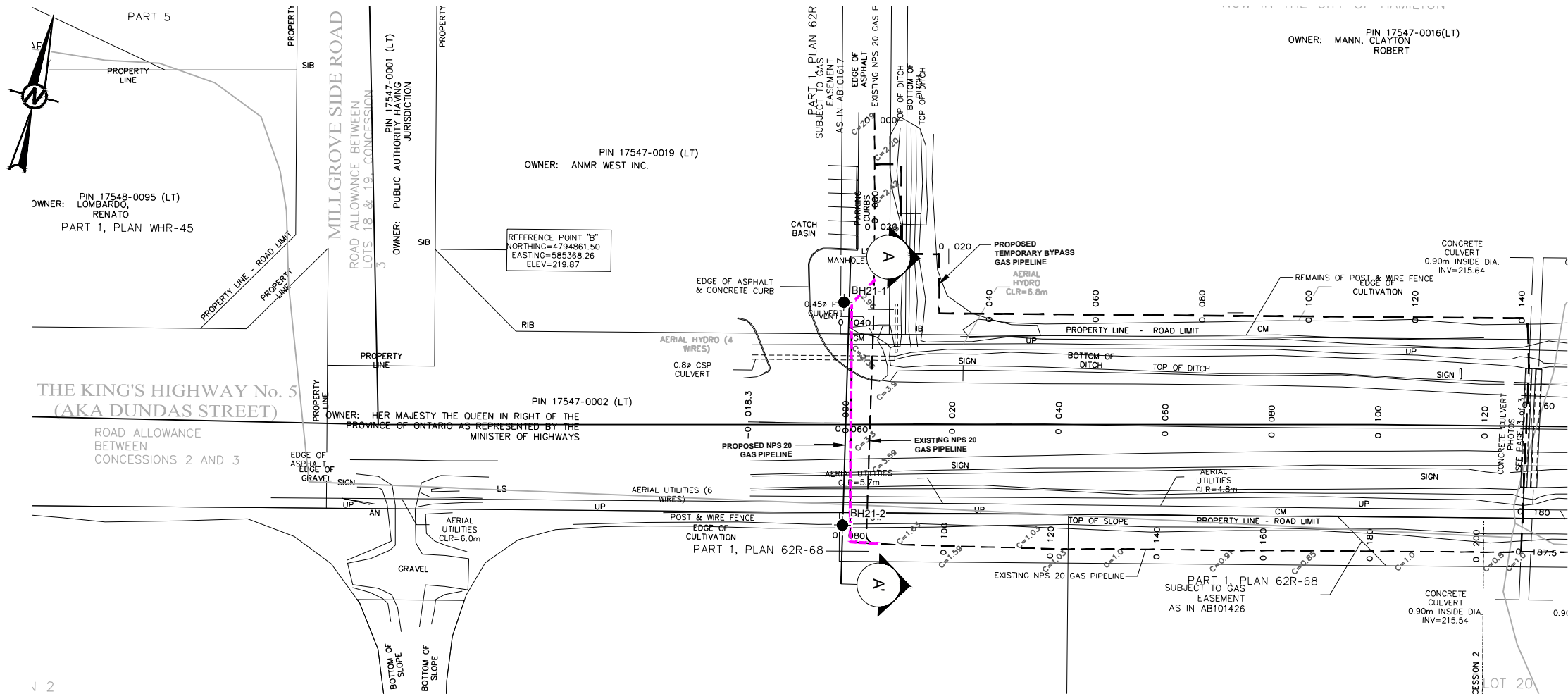
Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed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

Table 6: Evaluation of Tunnel Installation Methods

| Method | Feasibility | Advantages | Disadvantages | Relative Cost | Risk/Consequences |
|---|---|---|--|---------------------------|--|
| Auger Boring (with SBU) | <div>■ Feasible</div> | <div>■ Simple construction method.</div> <div>■ Equipment and skilled construction workforce available.</div> | <div>■ Significant backstop and jacking/receiving pits are required.</div> <div>■ Obstructions (e.g., cobbles and boulders) may deflect and/or halt bore. Higher risk of ground subsidence of highway, particularly if obstructions that slow installation procedures or if granular soils (particularly below the water table) encountered.</div> <div>■ Groundwater lowering is required at both the entry/exit pits.</div> <div>■ Limited ability to steer to correct for line and grade during installation.</div> | <div>■ Moderate</div> | <div>■ Large cobbles and/or boulders can impede the auger boring operations where removal of obstructions is not possible. Use of an SBU is recommended for this method.</div> <div>■ Obstructions can result in deflection of the casing resulting in misalignment of the gravity culvert.</div> <div>■ Potential for loss of ground into casing, particularly if flowing conditions are encountered.</div> <div>■ Risk of ground surface subsidence increases with decreasing cover.</div> |
| Pipe Ramming | <div>■ Feasible</div> | <div>■ Unsupported face condition not created, unless casing needs to be cleaned/emptied to remove obstructions at face. Can be better suited for low-cover situations.</div> <div>■ Better suited for penetrating through potential obstructions such as cobbles and boulders than jack and bore methods without SBU.</div> <div>■ Equipment and skilled construction workforce available.</div> | <div>■ Large work area required for ramming pit.</div> <div>■ Large obstructions can deflect casing.</div> <div>■ Potential for heaving at ground surface.</div> <div>■ Groundwater lowering is required at both the entry/exit pits.</div> <div>■ Unable to correct for line and grade during installation.</div> <div>■ Potential noise objections in urban areas.</div> | <div>■ Moderate</div> | <div>■ Obstructions can cause deflection of casing resulting in misalignment of casing.</div> <div>■ Some risk of installed casing not meeting project tolerance for alignment and profile;</div> <div>■ Nests of cobbles and/or boulders can stop penetration of casing requiring hand mining.</div> |
| Horizontal Directional Drilling | <div>■ Feasible</div> | <div>■ Shallow excavations for both sending/receiving pits required.</div> <div>■ Simple construction method.</div> <div>■ Equipment and skilled construction workforce available.</div> | <div>■ Alignment length could be longer than other methods depending on entry angle of bore</div> <div>■ Deeper excavations for tie ins will be required</div> <div>■ Groundwater lowering only required on north side for Option 1 tie-in.</div> <div>■ Larger laydown areas are required to install the product pipe</div> | <div>■ Least cost</div> | <div>■ Large cobbles and/or boulders can impede or halt the HDD operations.</div> <div>■ Obstructions can result in deflection of the product pipe resulting in misalignment and/or longer alignment</div> <div>■ Risk of ground surface subsidence increases with decreasing cover.</div> |
| Micro-tunnelling (with or without pilot bore) | <div>■ Feasible (provided at least 0.75 m carrier pipe)</div> | <div>■ Fully supported face, with less potential for settlement or loss of ground.</div> | <div>■ Complicated set-up and larger equipment. May require larger shafts.</div> <div>■ Can have difficulty with obstructions, if encountered (not expected).</div> | <div>■ Higher Cost.</div> | <div>■ Low risk of settlement or loss of ground if properly operated.</div> |
| Tunnel Boring Machine | <div>■ Not feasible</div> | <div>■ N/A</div> | <div>■ N/A</div> | <div>■ N/A</div> | <div>■ N/A</div> |
| Tunnel Digging Machine | <div>■ Not feasible</div> | <div>■ N/A</div> | <div>■ N/A</div> | <div>■ N/A</div> | <div>■ N/A</div> |

FIGURES

Path: \\golder\golder\Mississauga\SM\Clients\MT\OHwy_5_Crossing\99_PROJ\2046494\01_NPS_20_Gas_Pipeline.dwg | File Name: 2046494-001_EG-0001.dwg | Last Edited By: zsaave Date: 2022-01-07 Time: 4:21:35 PM
Path: \\golder\golder\Mississauga\SM\Clients\MT\OHwy_5_Crossing\99_PROJ\2046494\01_NPS_20_Gas_Pipeline.dwg | File Name: 2046494-001_EG-0001.dwg | Last Edited By: zsaave Date: 2022-01-07 Time: 4:13:37 PM | Printed By: zsaave Date: 2022-01-07 Time: 4:21:35 PM



LEGEND

● BOREHOLE LOCATION

--- PROPOSED PIPELINE ALIGNMENT

SOIL STRATIGRAPHY

FILL/OVERBURDEN

SILTY CLAY

SILTY CLAY TILL

SILT

SILTY SAND AND GRAVEL

SILTY CLAY

NOT FOR CONSTRUCTION

REFERENCE(S)

BASE PLANS PROVIDED IN DIGITAL FORMAT BY AECON, DRAWING FILE NO. 20-23-250-00 PRE ENGINEERING DRAWING_GAS PIPELINE CROSSING - HWY 5_REV 01.DWG, RECEIVED MARCH 8, 2021.

CLIENT

AECON UTILITY ENGINEERING

PROJECT

NPS 20 TRENCHLESS CROSSING
HIGHWAY 5
HAMILTON, ONTARIO

TITLE

BOREHOLE LOCATION PLAN AND SOIL STRATIGRAPHY
GEOCRES NO. 30M5-337

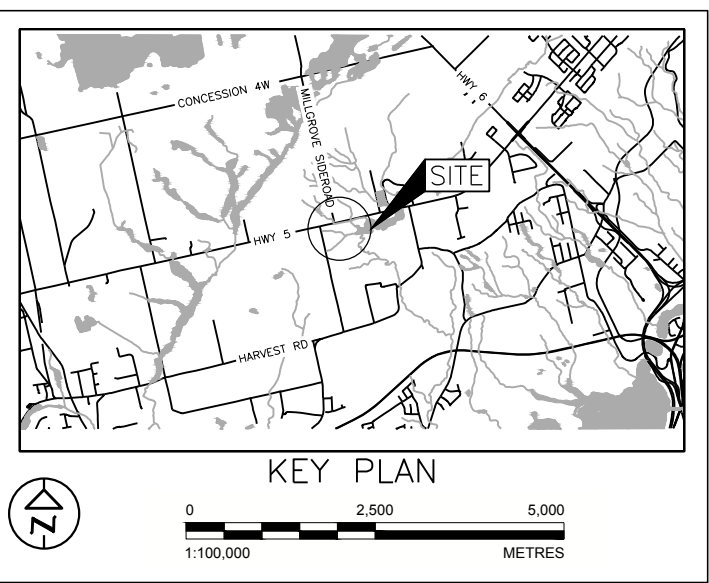
| | | |
|------------|------------|------------|
| CONSULTANT | YYYY-MM-DD | 2021-05-03 |
| DESIGNED | ---- | |
| PREPARED | DD/JL | |
| REVIEWED | KCP | |
| APPROVED | WC | |





| | | | |
|-------------|---------|------|--------|
| PROJECT NO. | CONTROL | REV. | FIGURE |
| 2046494 | 0001 | 0 | 1 |

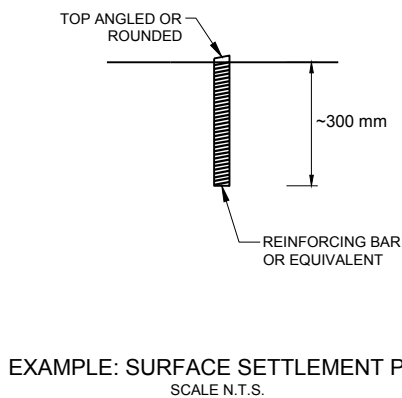
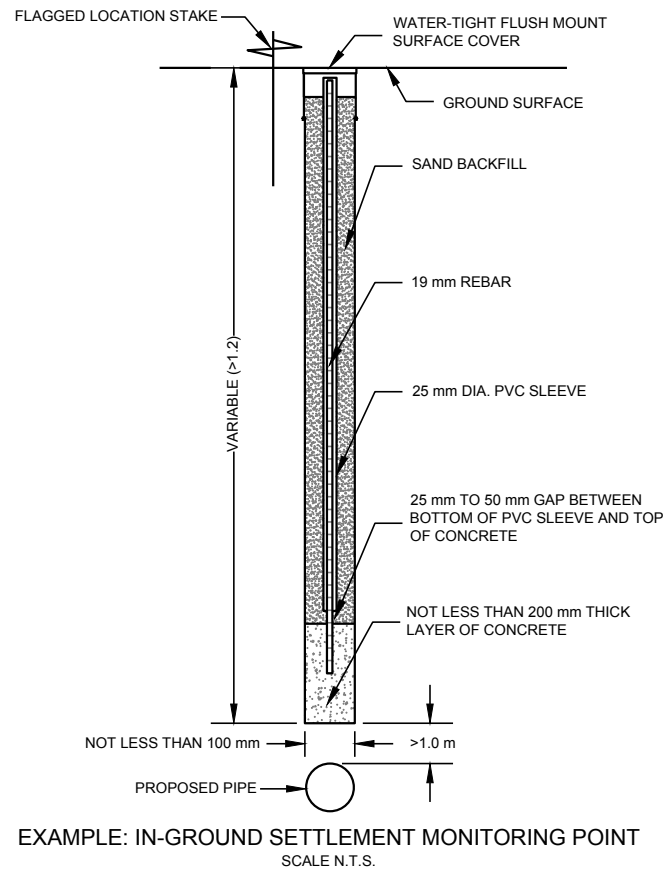


IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM A3S/B



LEGEND

- | | |
|---|---------------------------------------|
|  | IN-GROUND SETTLEMENT MONITORING POINT |
|  | SURFACE SETTLEMENT PIN |
| | PROPOSED PIPELINE ALIGNMENT |



NOT FOR CONSTRUCTION

REFERENCE(S)
BASE PLANS PROVIDED IN DIGITAL FORMAT BY AECON, DRAWING FILE NO. 20-23-250-00 PRE
ENGINEERING DRAWING_GAS PIPELINE CROSSING - HWY 5_REV 01.DWG, RECEIVED MARCH
8, 2021.

CLIENT
AECON UTILITY ENGINEERING

PROJECT
NPS 20 TRENCHLESS CROSSING
HIGHWAY 5
HAMILTON, ONTARIO

TITLE
SETTLEMENT MONITORING PLAN AND INSTRUMENTATION
DETAILS
GEOCRES NO. 30M5-337

| | | |
|--|------------|------------|
| CONSULTANT | YYYY-MM-DD | 2021-04-26 |
|  GOLDER MEMBER OF WSP | DESIGNED | ---- |
| | PREPARED | DD/JL |
| | REVIEWED | KCP |
| | APPROVED | WC |

| | | | |
|-------------|---------|------|--------|
| PROJECT NO. | CONTROL | REV. | FIGURE |
| 20446494 | 0001 | 0 | 2 |

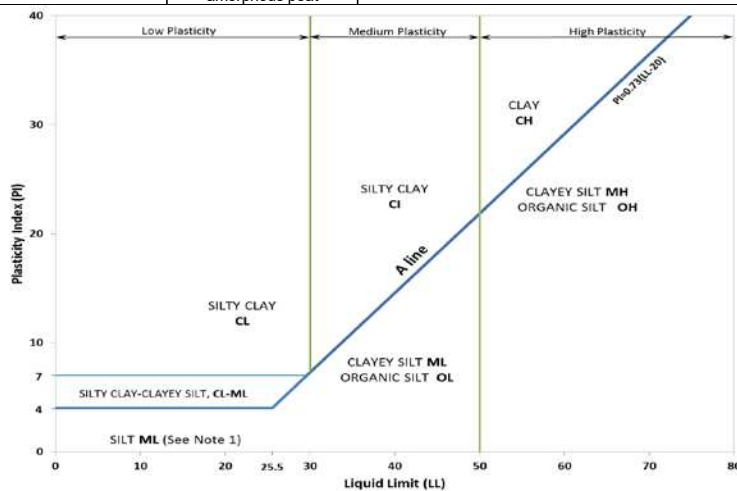
APPENDIX A

Borehole Records

METHOD OF SOIL CLASSIFICATION

The Golder Associates Ltd. Soil Classification System is based on the Unified Soil Classification System (USCS)

| Organic or Inorganic | Soil Group | Type of Soil | | Gradation or Plasticity | $Cu = \frac{D_{60}}{D_{10}}$ | | $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ | | | Organic Content | USCS Group Symbol | Group Name | | |
|--|--|---|---|---|------------------------------|------------------|--|---------------|-------------------------------|-----------------|------------------------------|-------------------|------------------------|------|
| INORGANIC (Organic Content ≤30% by mass) | COARSE-GRAINED SOILS (>50% by mass is larger than 0.075 mm) | GRAVELS (>50% by mass of coarse fraction is larger than 4.75 mm) | Gravels with ≤12% fines (by mass) | Poorly Graded | <4 | | ≤1 or ≥3 | | | ≤30% | GP | GRAVEL | | |
| | | | | Well Graded | ≥4 | | 1 to 3 | | | | GW | GRAVEL | | |
| | | | Gravels with >12% fines (by mass) | Below A Line | n/a | | | | | | GM | SILTY GRAVEL | | |
| | | | | Above A Line | n/a | | | | | | GC | CLAYEY GRAVEL | | |
| | | SANDS (≥50% by mass of coarse fraction is smaller than 4.75 mm) | Sands with ≤12% fines (by mass) | Poorly Graded | <6 | ≤1 or ≥3 | | | SP | | SAND | | | |
| | | | | Well Graded | ≥6 | 1 to 3 | | | SW | | SAND | | | |
| | | | Sands with >12% fines (by mass) | Below A Line | n/a | | | | | | SM | SILTY SAND | | |
| | | | | Above A Line | n/a | | | | | | SC | CLAYEY SAND | | |
| | | Organic or Inorganic | Soil Group | Type of Soil | Laboratory Tests | Field Indicators | | | | | Organic Content | USCS Group Symbol | Primary Name | |
| | | INORGANIC (Organic Content ≤30% by mass) | FINE-GRAINED SOILS (≥50% by mass is smaller than 0.075 mm) | SILTS (Non-Plastic or PI and LL plot below A-Line on Plasticity Chart below) | Liquid Limit <50 | Rapid | None | None | >6 mm | | N/A (can't roll 3 mm thread) | <5% | ML | SILT |
| Slow | None to Low | | | | | Dull | 3mm to 6 mm | None to low | <5% | ML | CLAYEY SILT | | | |
| Slow to very slow | Low to medium | | | | | Dull to slight | 3mm to 6 mm | Low | 5% to 30% | OL | ORGANIC SILT | | | |
| Liquid Limit ≥50 | Slow to very slow | | | | Low to medium | Slight | 3mm to 6 mm | Low to medium | <5% | MH | CLAYEY SILT | | | |
| | None | | | Medium to high | Dull to slight | 1 mm to 3 mm | Medium to high | 5% to 30% | OH | ORGANIC SILT | | | | |
| CLAYS (PI and LL plot above A-Line on Plasticity Chart below) | Liquid Limit <30 | | | None | Low to medium | Slight to shiny | ~ 3 mm | Low to medium | 0% to 30% (see Note 2) | CL | SILTY CLAY | | | |
| | Liquid Limit 30 to 50 | | | None | Medium to high | Slight to shiny | 1 mm to 3 mm | Medium | | CI | SILTY CLAY | | | |
| | Liquid Limit ≥50 | | | None | High | Shiny | <1 mm | High | | CH | CLAY | | | |
| HIGHLY ORGANIC SOILS (Organic Content >30% by mass) | | | | Peat and mineral soil mixtures | | | | | | | 30% to 75% | PT | SILTY PEAT, SANDY PEAT | |
| | | | | Predominantly peat, may contain some mineral soil, fibrous or amorphous peat | | | | | | | 75% to 100% | | PEAT | |



Dual Symbol — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC and CL-ML.

For non-cohesive soils, the dual symbols must be used when the soil has between 5% and 12% fines (i.e. to identify transitional material between “clean” and “dirty” sand or gravel.

For cohesive soils, the dual symbol must be used when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (see Plasticity Chart at left).

Borderline Symbol — A borderline symbol is two symbols separated by a slash, for example, CL/CI, GM/SM, CL/ML.

A borderline symbol should be used to indicate that the soil has been identified as having properties that are on the transition between similar materials. In addition, a borderline symbol may be used to indicate a range of similar soil types within a stratum.

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

PARTICLE SIZES OF CONSTITUENTS

| Soil Constituent | Particle Size Description | Millimetres | Inches (US Std. Sieve Size) |
|------------------|---------------------------|---|--|
| BOULDERS | Not Applicable | >300 | >12 |
| COBBLES | Not Applicable | 75 to 300 | 3 to 12 |
| GRAVEL | Coarse Fine | 19 to 75 4.75 to 19 | 0.75 to 3 (4) to 0.75 |
| SAND | Coarse Medium Fine | 2.00 to 4.75 0.425 to 2.00 0.075 to 0.425 | (10) to (4) (40) to (10) (200) to (40) |
| SILT/CLAY | Classified by plasticity | <0.075 | < (200) |

MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

| Percentage by Mass | Modifier |
|--------------------|--|
| >35 | Use 'and' to combine major constituents (i.e., SAND and GRAVEL) |
| > 12 to 35 | Primary soil name prefixed with "gravelly, sandy, SILTY, CLAYEY" as applicable |
| > 5 to 12 | some |
| ≤ 5 | trace |

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 frictions 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 | Rock core |
| SC | 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 |

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.

NON-COHESIVE (COHESIONLESS) SOILS

Compactness²

| Term | SPT 'N' (blows/0.3m) ¹ |
|------------|-----------------------------------|
| Very Loose | 0 to 4 |
| Loose | 4 to 10 |
| Compact | 10 to 30 |
| Dense | 30 to 50 |
| Very Dense | >50 |

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

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. |

COHESIVE 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 |

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

Water Content

| Term | Description |
|--------|--|
| w < PL | Material is estimated to be drier than the Plastic Limit. |
| w ~ PL | Material is estimated to be close to the Plastic Limit. |
| w > PL | Material is estimated to be wetter than the Plastic Limit. |

LIST OF SYMBOLS

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 |

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_α | 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 = σ'_p / σ'_{vo} |

(d) Shear Strength

| | |
|------------------|--|
| τ_p, τ_r | peak and residual shear strength |
| ϕ' | effective angle of internal friction |
| δ | angle of interface friction |
| μ | coefficient of friction = $\tan \delta$ |
| c' | effective cohesion |
| 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 | $(\sigma_1 - \sigma_3)/2$ 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 $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$

SHEET 1 OF 2

DATUM: Geodetic

BORING DATE: March 15, 2021

[illegible]

CHECKED: KN

PROJECT: 20446494

RECORD OF BOREHOLE: BH21-1

SHEET 2 OF 2

LOCATION: N 585445.1; E 4794870.8

BORING DATE: March 15, 2021

DATUM: Geodetic

NAD83 MTM ZONE 10 (LAT. 43.301826; LONG. -79.946538)

| DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE | | SAMPLES | | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m | | | | HYDRAULIC CONDUCTIVITY, k, cm/s | | | | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION |
|-----------------------|---------------|---|-------------|-----------------------|--------|---|------------|---------------------------|----|------------------------------------|----|-----------------------|------------------|----------------------------|---|
| | | DESCRIPTION | STRATA PLOT | ELEV. DEPTH (m) | NUMBER | TYPE | BLOWS/0.3m | SHEAR STRENGTH Cu, kPa | | nat V. + Q - rem V. U - | | WATER CONTENT PERCENT | | | |
| | | | | | | | | 20 | 40 | 60 | 80 | 10 ⁻⁶ | 10 ⁻⁵ | | |
| | | | | | | | | | | | | | | | |
| 10 | | --- CONTINUED FROM PREVIOUS PAGE --- | | | | | | | | | | | | | |
| | | 3. Groundwater level measurements in piezometer: | | | | | | | | | | | | | |
| | | Date | Depth (m) | Elev. (m) | | | | | | | | | | | |
| | | 15-03-21 | 7.0 | 211.7 | | | | | | | | | | | |
| | | 16-04-21 | 1.7 | 217.0 | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | |
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| 17 | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | |

DEPTH SCALE

1 : 50



LOGGED: LM

CHECKED: KN

GTA-BHS 001 Y:\MISSISSAUGA\CLIENTS\MTM\HWY 5 CROSSINGS\02 DATA\GINT\HWY 5 CROSSINGS.GPJ GAL-MIS.GDT 1/6/22

PROJECT: 20446494

LOCATION: N 585455.1; E 4794830.1

NAD83 MTM ZONE 10 (LAT. 43.301459; LONG. -79.946420)

RECORD OF BOREHOLE: BH21-2

BORING DATE: March 15, 2021

SHEET 1 OF 1

DATUM: Geodetic

| DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE | | SAMPLES | | | DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m | | | | HYDRAULIC CONDUCTIVITY, k, cm/s | | | | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION | |
|-----------------------|---------------|--------------|-------------|-----------------------|--------|------|---|---------------------------|----|----|------------------------------------|-----------------------|--------|------------|----------------------------|---|--------|
| | | DESCRIPTION | STRATA PLOT | ELEV. DEPTH (m) | NUMBER | TYPE | BLOWS/0.3m | | | | | | | | | | |
| | | | | | | | | SHEAR STRENGTH Cu, kPa | | | | WATER CONTENT PERCENT | | | | | |
| | | | | | | | | 20 | 40 | 60 | 80 | nat V. rem V. | + ⊕ | Q - U - | | | ● ○ |
| | | | | | | | | | | | | | | | | | |
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DEPTH SCALE

1 : 50

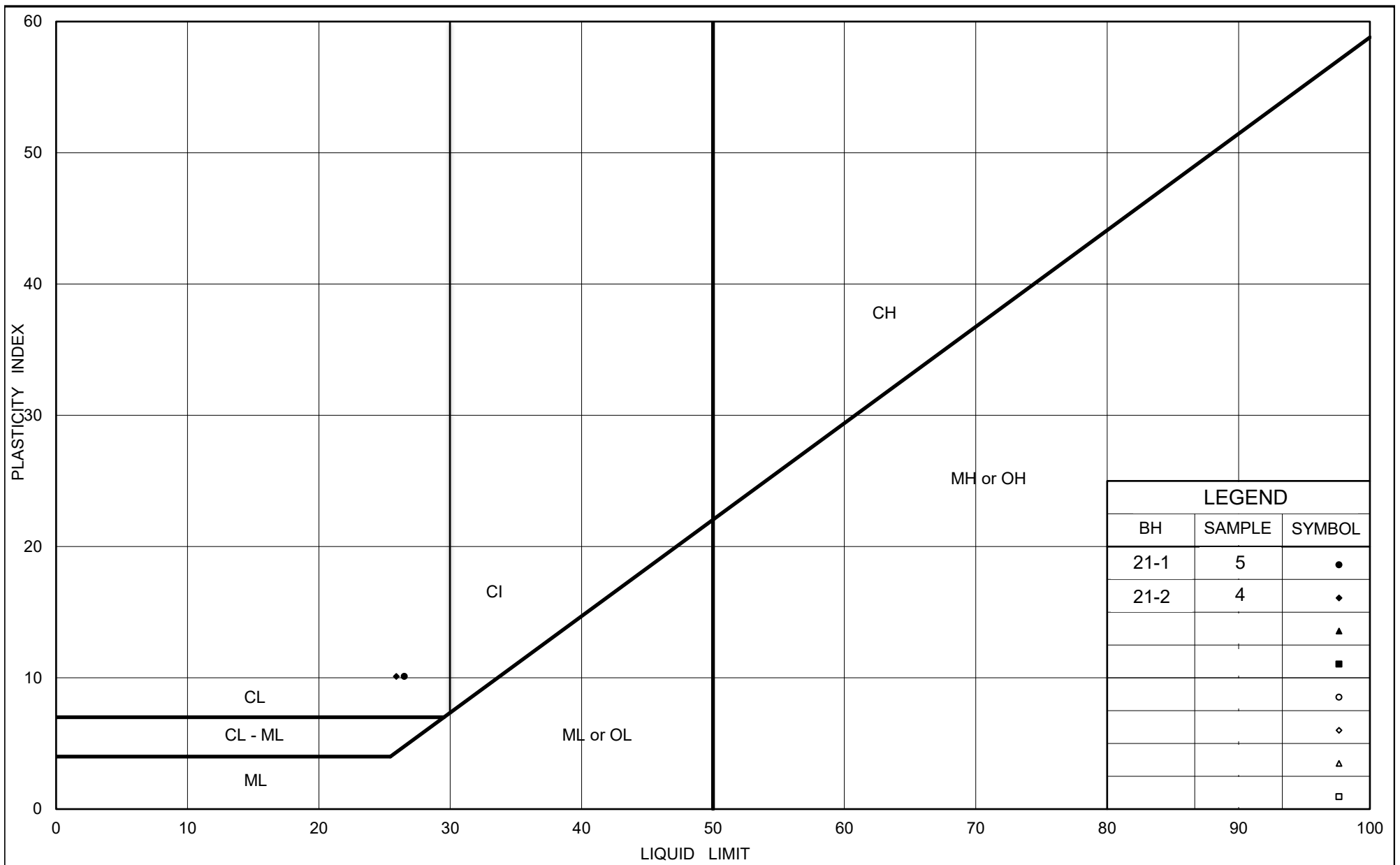
LOGGED: LM

CHECKED: KN

GTA-BHS 001 Y:\MISSISSAUGA\CLIENTS\MTM\HWY 5 CROSSINGS\02 DATA\GINT\HWY 5 CROSSINGS.GPJ GAL-MIS.GDT 1/6/22

APPENDIX B

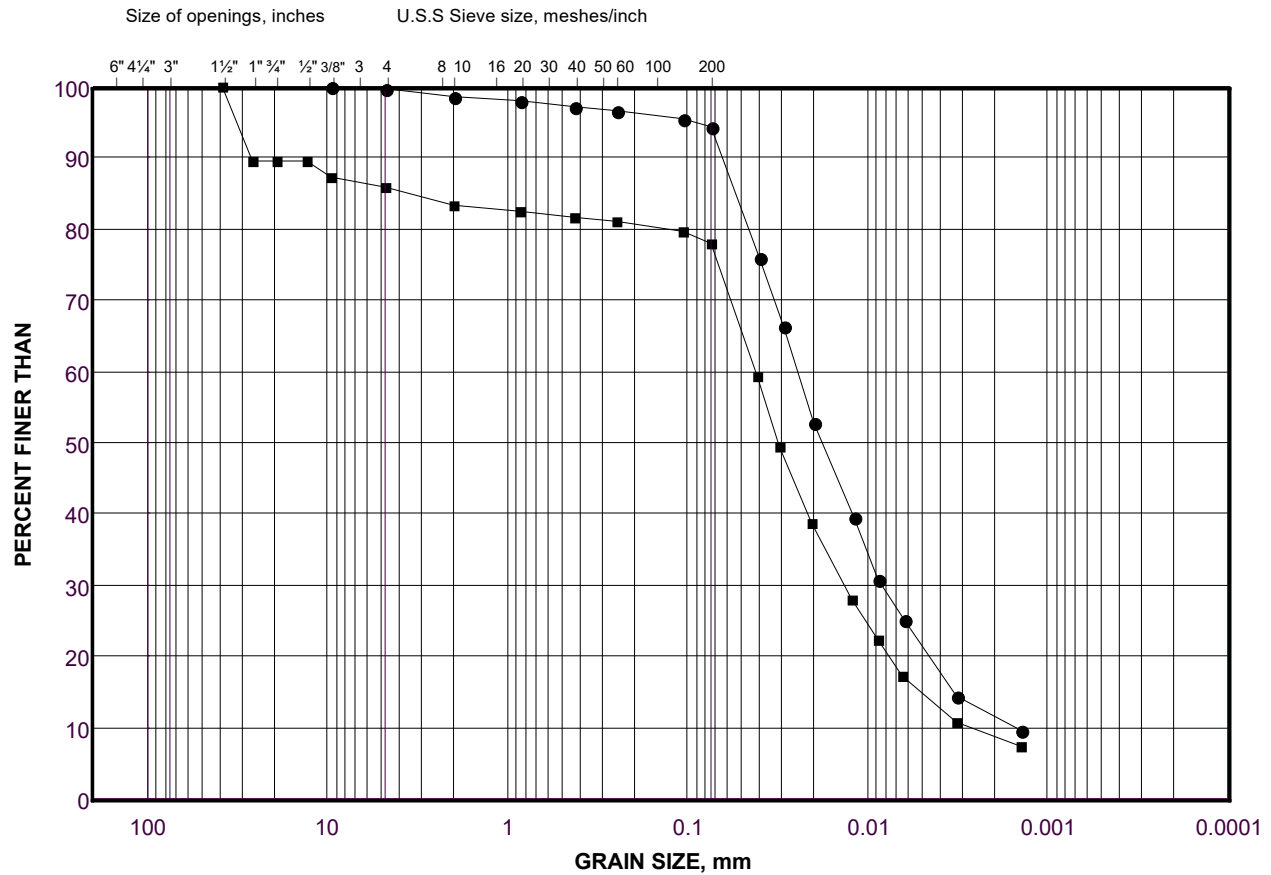
Geotechnical Laboratory and Analytical Test results



GRAIN SIZE DISTRIBUTION

(ML) Gravelly SILT to SILT

FIGURE B2





Your Project #: 20446494
Site Location: HWY 5 AECON
Your C.O.C. #: 808525-03-01

Attention: Katelyn Nero

Golder Associates Ltd
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2021/03/27
Report #: R6571860
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C173826

Received: 2021/03/19, 14:00

Sample Matrix: Soil
Samples Received: 1

| Analyses | Quantity | Date | Date | Laboratory Method | Analytical Method |
|-------------------------|----------|------------|------------|-------------------|-------------------|
| | | Extracted | Analyzed | | |
| Chloride (20:1 extract) | 1 | 2021/03/24 | 2021/03/24 | CAM SOP-00463 | SM 23 4500-Cl E m |
| Conductivity | 1 | 2021/03/24 | 2021/03/24 | CAM SOP-00414 | OMOE E3530 v1 m |
| pH CaCl2 EXTRACT | 1 | 2021/03/24 | 2021/03/24 | CAM SOP-00413 | EPA 9045 D m |
| Resistivity of Soil | 1 | 2021/03/19 | 2021/03/24 | CAM SOP-00414 | SM 23 2510 m |
| Sulphate (20:1 Extract) | 1 | 2021/03/24 | 2021/03/24 | 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.



Your Project #: 20446494
Site Location: HWY 5 AECON
Your C.O.C. #: 808525-03-01

Attention: Katelyn Nero

Golder Associates Ltd
6925 Century Ave
Suite 100
Mississauga, ON
CANADA L5N 7K2

Report Date: 2021/03/27
Report #: R6571860
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C173826

Received: 2021/03/19, 14:00

Encryption Key

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

Ema Gitej, Senior Project Manager

Email: emese.gitej@bureauveritas.com

Phone# (905)817-5829

=====

BV Labs 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

BV Labs Job #: C173826
Report Date: 2021/03/27

Golder Associates Ltd
Client Project #: 20446494
Site Location: HWY 5 AECON
Sampler Initials: LM

SOIL CORROSIVITY PACKAGE (SOIL)

| | | | | | | | |
|--|--------------|--------------------------|------------|-----------------|--------------------------------------|------------|-----------------|
| BV Labs ID | | PCU028 | | | PCU028 | | |
| Sampling Date | | 2021/03/15 | | | 2021/03/15 | | |
| COC Number | | 808525-03-01 | | | 808525-03-01 | | |
| | UNITS | 20446494_21-1_SA5 | RDL | QC Batch | 20446494_21-1_SA5 Lab-Dup | RDL | QC Batch |
| Calculated Parameters | | | | | | | |
| Resistivity | ohm-cm | 5200 | | 7258172 | | | |
| Inorganics | | | | | | | |
| Soluble (20:1) Chloride (Cl ⁻) | ug/g | 32 | 20 | 7264106 | 36 | 20 | 7264106 |
| Conductivity | umho/cm | 193 | 2 | 7264243 | | | |
| Available (CaCl ₂) pH | pH | 7.71 | | 7263843 | | | |
| Soluble (20:1) Sulphate (SO ₄) | ug/g | <20 | 20 | 7264104 | | | |
| RDL = Reportable Detection Limit QC Batch = Quality Control Batch Lab-Dup = Laboratory Initiated Duplicate | | | | | | | |



BUREAU
VERITAS

BV Labs Job #: C173826
Report Date: 2021/03/27

Golder Associates Ltd
Client Project #: 20446494
Site Location: HWY 5 AECON
Sampler Initials: LM

TEST SUMMARY

BV Labs ID: PCU028
Sample ID: 20446494_21-1_SA5
Matrix: Soil

Collected: 2021/03/15
Shipped:
Received: 2021/03/19

| Test Description | Instrumentation | Batch | Extracted | Date Analyzed | Analyst |
|-------------------------|-----------------|---------|------------|---------------|-------------------|
| Chloride (20:1 extract) | KONE/EC | 7264106 | 2021/03/24 | 2021/03/24 | Avneet Kour Sudan |
| Conductivity | AT | 7264243 | 2021/03/24 | 2021/03/24 | Tarunpreet Kaur |
| pH CaCl2 EXTRACT | AT | 7263843 | 2021/03/24 | 2021/03/24 | Neil Dassanayake |
| Resistivity of Soil | | 7258172 | 2021/03/24 | 2021/03/24 | Automated Statchk |
| Sulphate (20:1 Extract) | KONE/EC | 7264104 | 2021/03/24 | 2021/03/24 | Avneet Kour Sudan |

BV Labs ID: PCU028 Dup
Sample ID: 20446494_21-1_SA5
Matrix: Soil

Collected: 2021/03/15
Shipped:
Received: 2021/03/19

| Test Description | Instrumentation | Batch | Extracted | Date Analyzed | Analyst |
|-------------------------|-----------------|---------|------------|---------------|-------------------|
| Chloride (20:1 extract) | KONE/EC | 7264106 | 2021/03/24 | 2021/03/24 | Avneet Kour Sudan |



BUREAU
VERITAS

BV Labs Job #: C173826
Report Date: 2021/03/27

Golder Associates Ltd
Client Project #: 20446494
Site Location: HWY 5 AECON
Sampler Initials: LM

GENERAL COMMENTS

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

| | |
|-----------|-------|
| Package 1 | 3.0°C |
|-----------|-------|

Results relate only to the items tested.



**BUREAU
VERITAS**

BV Labs Job #: C173826

Report Date: 2021/03/27

QUALITY ASSURANCE REPORT

Golder Associates Ltd

Client Project #: 20446494

Site Location: HWY 5 AECON

Sampler Initials: LM

| QC Batch | Parameter | Date | Matrix Spike | | SPIKED BLANK | | Method Blank | | RPD | |
|----------|--|------------|--------------|-----------|--------------|-----------|--------------|---------|-----------|-----------|
| | | | % Recovery | QC Limits | % Recovery | QC Limits | Value | UNITS | Value (%) | QC Limits |
| 7263843 | Available (CaCl ₂) pH | 2021/03/24 | | | 99 | 97 - 103 | | | 0.19 | N/A |
| 7264104 | Soluble (20:1) Sulphate (SO ₄) | 2021/03/24 | 118 | 70 - 130 | 104 | 70 - 130 | <20 | ug/g | NC | 35 |
| 7264106 | Soluble (20:1) Chloride (Cl ⁻) | 2021/03/24 | NC | 70 - 130 | 104 | 70 - 130 | <20 | ug/g | 12 | 35 |
| 7264243 | Conductivity | 2021/03/24 | | | 103 | 90 - 110 | <2 | umho/cm | 4.0 | 10 |

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
VERITAS

BV Labs Job #: C173826
Report Date: 2021/03/27

Golder Associates Ltd
Client Project #: 20446494
Site Location: HWY 5 AECON
Sampler Initials: LM

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Anastassia Hamanov, Scientific Specialist

BV Labs 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 Laboratories
6740 Campbell Road, Mississauga, Ontario Canada L5N 2L8 Tel: (905) 817-5700 Toll-free 800-563-6266 Fax: (905) 817-5777 www.bvlabs.com

CHAIN OF CUSTODY RECORD

Page of

| INVOICE TO: | | REPORT TO: | | PROJECT INFORMATION: | | Laboratory Use Only: | |
|--|---|----------------------------------|-----------------------|--|---|---|-------------|
| Company Name: #1326 Golder Associates Ltd | Company Name: <u>Golder</u> | Quotation #: B80683 | BV Labs Job #: | Attention: <u>Sandra McGeaghan</u> <u>Katie Nero</u> | P.O. #: | Bottle Order #: | |
| Address: 6925 Century Ave Suite 100 | Address: | Project: <u>1800332 20446444</u> | COC #: | Address: <u>Mississauga ON L5N 7K2</u> | Project Name: <u>HW#5 AECON</u> | Project Manager: | |
| Tel: (905) 567-4444 Fax: (905) 567-6561 | Tel: | Site #: <u>LM</u> | Sampled By: <u>LM</u> | Email: <u>CanadaAccountsPayableInvoices@golder.com</u> | Email: <u>smcgeaghan@golder.com</u> <u>kncro@golder.com</u> | Ema Gitej | |
| MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE BV LABS DRINKING WATER CHAIN OF CUSTODY | | | | Turnaround Time (TAT) Required: | | | |
| Regulation 153 (2011) | | Other Regulations | | Special Instructions | | Regular (Standard) TAT: | |
| <input type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Medium/Fine | <input type="checkbox"/> CCME <input type="checkbox"/> Sanitary Sewer Bylaw | | | | | (will be applied if Rush TAT is not specified): | |
| <input 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 <input type="checkbox"/> Municipality | | | | | Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details. | |
| <input type="checkbox"/> Table | <input type="checkbox"/> PWDO <input type="checkbox"/> Reg 406 Table | | | | | Job Specific Rush TAT (if applies to entire submission) | |
| Include Criteria on Certificate of Analysis (Y/N)? | | | | | | Date Required: Time Required: <input type="checkbox"/> | |
| Sample Barcode Label | Sample (Location) Identification | Date Sampled | Time Sampled | Matrix | Field Filtered (please circle): Metals / Hg / Cr VI | # of Bottles | Comments |
| 1 | <u>20446444-21-L-SAS</u> | <u>MAR 15 2021</u> | <u>AM</u> | <u>SOI</u> | <input checked="" type="checkbox"/> | <u>1</u> | |
| 2 | | | | | | | |
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| 9 | | | | | | | |
| 10 | | | | | | | |
| * RELINQUISHED BY: (Signature/Print) | | Date: (YY/MM/DD) | Time | RECEIVED BY: (Signature/Print) | | Date: (YY/MM/DD) | Time |
| <u>Katie Nero/Katie Nero</u> | | <u>21/03/19</u> | | <u>[Signature]</u> | | <u>20/03/19</u> | <u>1900</u> |
| * UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO BV LABS' 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.BVLABS.COM/TERMS-AND-CONDITIONS. | | | | | | Laboratory Use Only | |
| * 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. | | | | | | Time Sensitive | |
| ** SAMPLE CONTAINER, PRESERVATION, HOLD TIME AND PACKAGE INFORMATION CAN BE VIEWED AT WWW.BVLABS.COM/RESOURCES/CHAIN-OF-CUSTODY-FORMS. | | | | | | Temperature (°C) on Reel | |
| | | | | | | <u>5/1/3</u> | |
| | | | | | | Custody Seal | |
| | | | | | | Present | |
| | | | | | | Intact | |
| | | | | | | Yes | |
| | | | | | | No | |
| | | | | | | White: BV Labs Yellow: Client | |
| | | | | | | SAMPLES MUST BE KEPT COOL (< 10°C) FROM TIME OF SAMPLING UNTIL DELIVERY TO BV LABS | |

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