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FOUNDATION INVESTIGATION AND DESIGN REPORT

Highway 400 - Culvert 99 Replacement Mapleview Drive E/W-S Ramp Barrie, Ontario G.W.P. 2184-10-00

Agreement No.: 4014-E-0012
Assignment No. 10

Submitted to:

Ministry of Transportation, Ontario
Foundations Section
145 Sir William Hearst Avenue
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REPORT





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PART A

**FOUNDATION INVESTIGATION REPORT
HIGHWAY 400 – CULVERT 99 REPLACEMENT
MAPLEVIEW DRIVE E/W-S RAMP
BARRIE, ONTARIO
G.W.P. 2184-10-00**

AGREEMENT NO. 4014-E-0012 – ASSIGNMENT NO. 10



1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by the Ministry of Transportation, Ontario (MTO) under MTO's Eastern Region Foundation Engineering Retainer (Agreement No. 4014-E-0012) to provide foundation engineering services for temporary protection systems associated with the proposed replacement of a section of Culvert 99 under the Highway 400-Mapleview Drive E/W-S Ramp and installation of a new precast maintenance hole. Culvert 99 is located approximately 200 m south of Mapleview Drive in Barrie, Ontario.

The Terms of Reference and Scope of Work for the foundation investigation are outlined in MTO's Work Item Order Form No. 10 of Agreement No. 4014-E-0012, which was sent to Golder via email on August 2, 2016. The detailed scope of work is presented in Golder's Understanding of Scope document dated August 6, 2016. Authorization to proceed was received from MTO via the executed Work Item Quote Form No. 10 on August 12, 2016.

2.0 SITE AND PROJECT DESCRIPTION

Culvert 99 is located approximately 200 m south of Mapleview Drive in Barrie, Ontario, crossing under Highway 400 at approximately Station 25+075, and under the Mapleview Drive E/W-S Ramp at approximately Station 10+190. The location of the Culvert 99 site is shown on the Key Plan on Drawing 1.

The existing culvert is oriented approximately east-west, with the inlet on the west side of Highway 400 and the outlet on the east side. Culvert 99 is composed of three sections: one section associated with the Mapleview Drive E/W-S Ramp; one section under the southbound and northbound lanes of Highway 400; and one section associated with the Mapleview Drive S-E/W Ramp. The western section, extending under the E/W-S Ramp and the western slope of the Highway 400 embankment, is to be replaced. This existing culvert section consists of a 1200 mm diameter corrugated steel pipe (CSP), approximately 33 m long. The existing invert of the culvert section to be replaced is at approximately Elevation 296 m to 295 m, declining eastward.

The natural ground surface at the culvert site is at approximately Elevation 295 m to 296 m. The road surface along the E/W-S Ramp is between approximately Elevation 298 m and 298.5 m, sloping downward from east to west, and the ramp embankment is approximately 3 m to 3.5 m high relative to the ground surface at the toe, adjacent to the culvert. The grade of the Highway 400 southbound lanes over the culvert is at approximately Elevation 300.5 m, with the Highway 400 embankment approximately 4.5 m high relative to the natural ground surface.

3.0 INVESTIGATION PROCEDURES

The field work was carried out on October 30, 2016, during which time two boreholes (Boreholes 99-1 and 99-2) were advanced: Borehole 99-1 is located at the crest of the Highway 400 embankment and was drilled through the west shoulder of the southbound lanes, and Borehole 99-2 is located on the east shoulder of the Mapleview Drive E/W-S Ramp. Boreholes 99-1 and 99-2 were advanced to depths of 11.3 m and 6.6 m below ground surface, respectively. The borehole locations are shown on Drawing 1.



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The borehole investigation was carried out using a D-25 truck-mounted drill rig supplied and operated by Walker Drilling Ltd. of Utopia, Ontario. The boreholes were advanced through the overburden using 210 mm outside diameter continuous flight hollow-stem augers. Soil samples were obtained at 0.75 m and 1.5 m intervals of depth, using a 50 mm outside diameter split-spoon sampler driven by a manual hammer in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586 – Standard Test Method for Standard Penetration Test).

The groundwater conditions were noted in the open boreholes during and upon completion of drilling. Both boreholes were backfilled to the ground surface upon completion of the drilling operations using bentonite pellets mixed with soil cuttings, in accordance with Ontario Regulation 903 (as amended). The borehole located on the paved shoulder of the Highway 400 southbound lanes was patched at the surface with cold mix asphalt.

The field work for this investigation was observed by a member of Golder's engineering staff who arranged for underground service locates, observed the drilling and sampling operations, and logged the boreholes. The soil samples were identified in the field, placed in appropriate containers, labelled and transported to Golder's geotechnical laboratory in Mississauga, Ontario, where the samples underwent further visual examination and laboratory testing including natural water contents, grain size distributions and Atterberg limits.

A selected sample of native silt and sand soil was submitted to AGAT Laboratories of Mississauga, Ontario for analysis of pH, resistivity/conductivity, chlorides, sulphides and sulphates. Details of the analytical testing are provided on the *Certificates of Analysis* in Appendix C.

The as-drilled boreholes were located in the field by Golder relative to existing site features on the site plan and profile drawings titled "New Construction, Station 25+000 to Station 25+350", dated July 13, 2016, provided by MTO on August 2, 2016. The ground surface elevations and coordinates of the boreholes were obtained by Golder from a Global Positioning System (GPS). The borehole locations in MTM NAD83 Zone 17 northing and easting coordinates, the ground surface elevations referenced to Geodetic datum and the borehole drilled depths are summarized below.

Borehole Number	Location (MTM NAD 83)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m)	Easting (m)		
99-1	4910414.4	290085.0	300.4	11.3
99-2	4910414.4	290057.9	298.4	6.6

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

As delineated in *The Physiography of Southern Ontario*¹, this section of Highway 400 lies within the Peterborough Drumlin Field physiographic region, which consists primarily of sandy till and sand to sand and gravel deposits. Deposits of silt, clay or peat may also be found in the low-lying areas between drumlins and eskers.

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. Ontario Ministry of Natural Resources.



4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes advanced as part of the investigation, together with the results of in situ and geotechnical laboratory testing are presented on the borehole records and laboratory test summary figures provided in Appendices A and B, respectively. The results of the in situ field tests (i.e. SPT 'N'-values) as presented on the borehole records and in Section 4.2 are uncorrected, and are based on sampling with a manual hammer.

The stratigraphic boundaries shown on the borehole records are inferred from observations of drilling progress and non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In general, the subsurface conditions at the Culvert 99 site consist of asphalt or surficial sand and gravel fill, underlain by sand to silt and sand fill. The fill layers are underlain by a non-cohesive deposit consisting predominantly of silt and sand, containing interlayers of silt, silty sand, and sand. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Asphalt

A 180 mm thick layer of asphalt was encountered at ground surface in Borehole 99-1. This surface layer is underlain by an 80 mm thick layer of granular material, which is underlain by another 100 mm thick layer of asphalt.

4.2.2 Sand and Gravel to Sand Fill

A 1.1 m thick layer of granular fill was encountered below the asphalt in Borehole 99-1 at a depth of 0.4 m below ground surface (Elevation 300.0 m) and a 0.6 m thick surficial (Elevation 298.4 m) layer of granular fill was encountered in Borehole 99-2. This fill is interpreted to be associated with the pavement granular structure, and consists of sand containing some gravel, to sand and gravel.

One Standard Penetration Test (SPT) 'N'-value of 35 blows per 0.3 m of penetration was measured within the sand and gravel to sand fill layer, indicating a dense relative density.

4.2.3 Silt and Sand Fill

A 3.0 m and 2.7 m thick layer of silt and sand fill was encountered below the pavement structure in Borehole 99-1 and 99-2 at depths of 1.5 m and 0.6 m (Elevation 298.9 m and 297.8 m), respectively.

The silt and sand fill contains trace gravel. The result of grain size distribution tests completed on two samples of the silt and sand fill are shown on Figure B1 in Appendix B. The water content measured on four samples of the silt and sand fill material ranges from 7 per cent to 17 per cent.

The measured SPT "N"-values within the silt and sand fill range from 12 blows to 67 blows per 0.3 m of penetration indicating a compact to very dense relative density.

4.2.4 Silt to Sand

An interlayered non-cohesive deposit was encountered below the silt and sand fill at a depth of 4.5 m and 3.3 m (Elevations 295.9 m and 295.1 m) in Boreholes 99-1 and 99-2, respectively. Both Boreholes 99-1 and 99-2 were terminated within the silt and sand deposit, at depths of 11.3 m and 6.6 m (Elevation 289.1 m and 291.8 m), respectively.



Based on the borehole results, the deposit is comprised predominantly of silt and sand containing trace clay; however, interlayers of sand containing trace silt, silty sand containing trace clay, and silt containing trace to some sand and clay were encountered within the deposit. The results of grain size distribution tests completed on two samples of the silt and sand deposit are shown on Figure B2, and the result of a grain size distribution test completed on one sample of the silt is shown on Figure B3 in Appendix B. Atterberg limits testing was carried out on one sample of the silt, and measured a liquid limit of 16 per cent, a plastic limit of 15 per cent, and a plasticity index of 2 per cent. This test result, which is plotted on a plasticity chart on Figure B4 in Appendix B, confirms that the tested material is silt of low plasticity. The water content measured on five samples of the silt and sand deposit ranges from 10 per cent to 25 per cent.

The SPT 'N' values measured within the silt to sand deposit range from 12 to 83 blows per 0.3 m of penetration, with one 'N'-value of 55 blows per 0.13 m of penetration, indicating a compact to very dense relative density.

4.3 Groundwater Conditions

Boreholes 99-1 and 99-2 were observed to be dry upon completion of drilling. However, wet soil samples were recovered below depths of 6.7 m and 3.1 m in Boreholes 99-1 and 99-2, respectively. These depths correspond to approximately Elevation 295.3 m (near the natural ground surface) in Borehole 99-2 at the E/W-S Ramp, declining toward the east consistent with the surface topography to about Elevation 293.7 m at Borehole 99-1 (about 2 m below the natural ground surface) under the Highway 400 southbound lanes.

The depths/elevations at which the wet soil samples were observed may not represent the stabilized water level at the site. Furthermore, the groundwater level at the site is expected to fluctuate seasonally in response to changes in precipitation and snow melt, and is expected to be higher during the spring and following periods of precipitation.

4.4 Analytical Testing of Soil

The results of chemical analyses for pH, sulphate, chloride, resistivity and electrical conductivity of one sample of the silt and sand deposit from this site are included in Appendix C and summarized below:

Analytical Testing Results (Borehole 99-2 SA6)	
Parameter	Result
Chloride	776 µg/g
Sulphate	25 µg/g
pH	8.97 pH Units
Electrical Conductivity	1.22 mS/cm
Resistivity	820 ohm.cm



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5.0 CLOSURE

This Foundation Investigation Report was prepared by Alex Szot, EIT, and reviewed by Lisa Coyne, P.Eng., a geotechnical engineer and Principal of Golder. Jorge M. A. Costa, P.Eng., a Designated MTO Foundations Contact for Golder, conducted an independent quality review of the report.

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PART B

**FOUNDATION DESIGN REPORT
HIGHWAY 400 – CULVERT 99 REPLACEMENT
MAPLEVIEW DRIVE E/W-S RAMP
BARRIE, ONTARIO
G.W.P. 2184-10-00**

AGREEMENT NO. 4014-E-0012 – ASSIGNMENT NO. 10



6.0 DISCUSSION AND FOUNDATION ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provides a discussion and foundation engineering recommendations related to temporary works requirements for the replacement of the west segment of Culvert 99 on the west side of Highway 400 southbound lanes (SBL) at approximately Station 25+075, and extending under the Mapleview E/W-S Ramp. These recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the investigation. The discussion and recommendations contained in this Foundation Design Report (Part B) are intended for the use of the MTO and its designer, and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in the Foundation Investigation Report (Part A). Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

Culvert 99 is located approximately 200 m south of Mapleview Drive in Barrie, Ontario, crossing under Highway 400 at approximately Station 25+075, and under the Mapleview Drive E/W-S Ramp at approximately Station 10+190. Culvert 99 is composed of three sections: one section associated with the Mapleview Drive E/W-S Ramp; one section under the mainline Highway 400; and one section associated with the Mapleview Drive S-E/W Ramp.

Based on the plan, profile and details for the proposed new construction provided to Golder by MTO ("Mapleview Drive E/W-S, Culvert 99 Replacement Details", Sheet 97, dated November 16, 2016), it is understood that the section of Culvert 99 under the Mapleview Drive E/W-S Ramp will be replaced, and a new precast maintenance hole will be installed near the west side of the southbound lanes of Highway 400. The invert elevation for the replacement culvert will be slightly higher than the existing culvert, at approximately Elevation 295.59 m to 295.11 m, declining eastward; the invert for the new 2,400 mm diameter maintenance hole will be at approximately Elevation 295.0 m. The excavation for the replacement of this culvert segment and the new maintenance hole will be up to 5.5 m deep relative to the Highway 400 embankment grade, and will require protection systems along the west edge of Highway 400 and along the E/W-S Ramp to maintain traffic flow during construction.

6.2 Excavation and Dewatering

The proposed works will require removal of the asphalt surface on the Mapleview Drive E/W-S Ramp, and excavation of the existing embankment fill and native materials. All excavations should be carried out in accordance with the latest edition of the Ontario Occupational Health and Safety Act and Regulations for Construction Projects. The existing embankment fill is classified as Type 3 soil, and the native silt to sand soils are classified as Type 2 soil above the groundwater level and Type 3 soil below the groundwater level.

Where sufficient space is available, open-cut excavation side slopes in the existing embankment fill and native silt to sand soils are expected to remain stable during construction provided that the temporary side slopes are oriented no steeper than 1 horizontal:1 vertical (1H:1V), and that appropriate groundwater control is in place to lower the groundwater table to at least 0.5 m below the base of the excavation. Some sloughing of excavated slopes due to perched water or surface water runoff may occur and flatter side slopes may become necessary.



Based on the subsurface conditions encountered during the foundation investigation, wet soils were encountered in Boreholes 99-1 and 99-2, at a depth of 6.7 m and 3.1 m (Elevations 293.7 m and 295.3 m), respectively. This inferred water level is near the original ground surface under the E/W-S Ramp, and about 2 m below the original ground surface under the west shoulder of Highway 400. However, this may not represent the stabilized groundwater level, and the groundwater level at the site may be higher during wetter periods of the year (e.g. following periods of increased precipitation or snow melt). The excavations for removal and replacement of this segment of Culvert 99 and the new maintenance hole will extend to near or below the groundwater level. Groundwater control will be required to lower the water level to a least 0.5 m below the required base of the excavation, requiring a drawdown on the order of 1 m, or potentially more during wetter periods of the year. It is anticipated that pumping from filtered sumps will not be sufficient to achieve this groundwater lowering to create a stable subgrade, and that a system of well points will be required to provide this lowering of the groundwater table. It is recommended that a Non-Standard Special Provision (NSSP) be included in the Contract Documents to alert the contractor to the requirement for dewatering for the culvert replacement and maintenance hole construction; an NSSP has been provided in Appendix D for this purposes.

6.3 Temporary Protection Systems

It is understood that temporary protection systems will be required along the western edge of the Highway 400 southbound lanes, adjacent to the new maintenance hole, as well as along the E/W-S ramp, to minimize impacts on traffic flow on both Highway 400 southbound and the on-ramp. The temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (*Temporary Protection Systems*) to meet Performance Level 2.

Temporary protection systems typically consist of either driven steel sheet piling, or soldier piles and lagging where the H-piles would be installed and concreted into a pre-augered hole to a suitable depth and horizontal lagging installed as the excavation proceeds. Lateral support to the system could be in the form of struts and wales (if the protection systems are sufficiently close to one another), rakers or anchors. For this site, the presence of very dense soils (having Standard Penetration Test "N" values of greater than 50 blows per 0.3 m of penetration) may make the installation of driven steel sheetpiles difficult, and therefore soldier pile and lagging systems may be more likely to be adopted. Soldier pile and lagging systems do not provide a cut-off to groundwater, and groundwater control and/or other mitigative measures (e.g., geotextile filter fabric behind the lagging boards) will be required in conjunction with this type of protection system.

The design of the temporary protection system will be completed by the Contractor and their shoring designer. However, for planning and estimating purposes for the design team, the temporary protection system may be designed using the following parameters:



Soil Type	Unit Weight	Internal Angle of Friction	Coefficient of Earth Pressure		
	(γ , kN/m ³)	(ϕ , degrees)	Active K_a	At Rest K_o	Passive, K_p
New Granular A or Granular B Type II fill	22	35	0.27	0.43	3.69
Existing compact to dense sand and gravel to sand fill	20	32	0.31	0.47	3.3
Existing compact to very dense silt and sand fill	20	30	0.33	0.5	3.0
Compact to very dense silt to sand	20	34	0.28	0.44	3.5

The earth pressure coefficients noted above are based on a horizontal surface adjacent to the top of the excavation. If sloped surfaces are present, the coefficient of earth pressure should be adjusted accordingly.

For design purposes, the water table should be assumed to be at Elevation 296 m. Design of the temporary support system by the Contractor and their shoring designer should include an evaluation of base stability, soil squeezing stability and hydraulic uplift stability as defined in the Canadian Foundation Engineering Manual (CFEM, 2006).

The protection system should be removed or cut off (at a minimum of 1.5 m below the lowest surrounding grade) following completion of the culvert replacement and manhole installation. Where possible, full removal of the temporary protection system should be considered to mitigate potential impediments to future rehabilitation/reconstruction work at the culvert site.

6.4 Analytical Testing for Construction Materials

The results of an analytical test on one sample of native silt and sand soil (BH99-2 SA#6) are presented in Appendix C. The analytical test results were compared to CSA A23.1 Table 3 (*"Additional requirements for concrete subjected to sulphate attack"*) for potential sulphate attack on concrete. The sulphate concentration measured in the native silt and sand sample is 0.0025 per cent, which is below the exposure class of S-3 (Moderate). Therefore, based on the single sample of native silt and sand tested, when the designer is selecting the exposure class for the structure, the effects of sulphates from within the native silt and sand deposit around the culvert and maintenance hole may not need to be considered.

The analytical test results of the native soil sample were also compared to Table 2 of the U.S. Criteria for Assessing Ground Corrosion Potential (as derived from Federal Highways Administration (FHWA) 2003) for the potential attack on buried steel. The resistivity and chloride concentrations measured (820 ohm-cm and 0.0776 per cent, respectively) in the native silt and sand sample indicates "strong corrosion potential". Based on the results of the sample tested, and given that the culvert and maintenance hole are located on/under the roadway shoulder and will be exposed to de-icing salt, consideration should be given by the designer to designing for a "C" type exposure class as defined by CSA A23.1 Table 1.

It is ultimately up to the designer to determine the appropriate exposure class and to ensure that all aspects of CSA A23.1 Section 4.1.1 "Durability Requirements" are followed.



6.5 Bedding and Backfill

6.5.1 Bedding and Backfill Above Base of the Pipe Culvert

The bedding, cover material and backfill requirements for the 1200 mm diameter concrete pipe culvert section should be in accordance with OPSP 802.031 (Rigid Pipe Bedding, Cover and Backfill, Type 3 Soil – Earth Excavation) and culvert construction should be in accordance with OPSS.PROV 421 (Pipe Culvert Installation in Open Cut). It is important that the backfill at the haunches be well compacted. The circular culvert should be constructed on a minimum 150 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular A or Granular B Type II material for bedding and up to 300 mm above the pipe for cover purposes. A non-woven Class II geotextile (OPSS 1860 Geotextiles) with a fabric opening size (FOS) not greater than 212 μm should be placed between the bottom of the bedding/engineered fill and native soils is recommended. The bedding should be placed and compacted in accordance with OPSS 421 in lifts not exceeding 200 mm in loose thickness.

6.5.2 Bedding and Backfill Around the Maintenance Hole

The bedding and backfill requirements for the proposed Maintenance hole should be in accordance with OPSS 402 (Excavating, Backfilling, and Compacting – Maintenance Holes, Catch Basins, Ditch Inlets, and Valve Chambers). The maintenance hole should be provided with at least 150 mm of OPSS.PROV 1010 (Aggregates) Granular A for bedding purposes and partial frost protection. The bedding should be placed and compacted in accordance with OPSS 402.

6.6 Embankment Stability and Settlement

6.6.1 Global Stability

Based on the culvert design drawings provided by MTO, the embankment side slope will be reconstructed using granular fill oriented at approximately 2.5H:1V and extended to the bottom of the ditch. A global slope stability analysis was performed for this reconstructed slope configuration using the commercially available program *Slide* (Version 6.0), developed by Rocscience Inc.

The following soil parameters have been used for slope stability analysis for drained (effective stress) conditions. These parameters were estimated from empirical correlations with the Standard Penetration Test data obtained from the field investigation, tempered with experience working with similar materials:

Idealized Soil Deposit	Bulk Unit Weight (kN/m^3)	Drained Conditions	
		Effective Cohesion (kPa)	Effective Friction Angle (Degrees)
Existing Embankment Fill	20	0	30
Silt to Sand	20	0	34
New Fill*	21	0	32

*The parameters for new embankment fill are considered conservative. Higher effective friction angles would apply for OPSS.PROV 1010 granular fill materials.

The groundwater level was assumed to be at Elevation 296.0 m near the bottom of the fill at Borehole 99-1 which yielded “wet” soil samples below approximately Elevation 295.3. The result of the slope stability analysis is shown



on Figure 1, indicating that a Factor of Safety greater than 1.5 against global instability is obtained for the above noted conditions.

6.6.2 Settlement

Given that there is no grade raise or widening of the final embankment associated with this segment of culvert replacement, the subsoils below the existing culvert invert level will not experience increased loading; as a result, the settlement of the foundation soils below the replaced section of culvert is estimated to be less than 25 mm. This settlement is considered to occur relatively quickly (i.e. during construction) in response to the embankment construction.

The above estimate does not include compression of the new fill itself, which would occur during and after the construction of the embankment depending on the type of materials used. The magnitude of fill compression may range from 0.5 per cent to 1 per cent of the height of the embankment, assuming that approximately 98 per cent compaction of the embankment fill is achieved, relative to the material's standard Proctor maximum dry density. In the case where granular fill is used for the embankment construction, settlement of the fill itself is expected to occur essentially during the embankment construction, whereas non-granular earth fill materials are expected to exhibit some additional settlement overtime.

6.7 Erosion Protection

Provision should be made for scour and erosion protection (suitable non-woven geotextiles and/or rip-rap) at the culvert location. To prevent surface water from flowing either beneath the culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill, and potentially causing erosion and loss of fine soil particles), a clay seal or concrete cut-off wall should be provided at the upstream end of the culvert. If a clay seal is adopted, the clay material should meet the requirements of OPSS.PROV 1205 (Clay Seal), and the seal should be a minimum 1 m thick if constructed of natural clay or soil-bentonite mix and extend from a depth of 1 m below the scour level to a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and a minimum vertical height equivalent to the high water level including along the embankment slope. Alternatively, a 0.6 m thick clay blanket (if constructed of natural clay or a soil-bentonite mix) may be constructed, extending upstream three times the culvert diameter, along the adjacent slopes on both sides of the culvert for a length of two times the culvert diameter and the slope face to the high water level.

The requirements for and design of erosion protection measures for the inlet of the culvert should be assessed by the hydraulic design engineer. Erosion protection for the inlet of the culvert should generally follow the standard presented in OPSD 810.010 (Rip-Rap Layout), with the rip-rap placed up to the toe of slope level, in combination with the cut-off measures noted above. Similarly, rip-rap should be provided over the full extent of the clay blanket, if adopted, including the creek side slopes and fill slope over the culvert.



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7.0 CLOSURE

This Foundation Design Report was prepared by Alex Szot, EIT, and reviewed by Lisa Coyne, P.Eng., a geotechnical engineer and Principal of Golder. Jorge M. A. Costa, P.Eng. a Designated MTO Foundation Contact for Golder, conducted an independent quality review of the report.

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Canadian Standards Association (CSA)

A23.1-14 Concrete Materials and Methods of Concrete Construction

Ontario Provincial Standard Specifications (OPSS)

OPSS 402	Construction Specification for Excavating, Backfilling, and Compacting – Maintenance Holes, Catch Basins, Ditch Inlets, and Valve Chambers
OPSS.PROV 421	Construction Specification for Pipe Culvert Installation in Open Cut
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 1010	Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material
OPSS.PROV 1205	Material Specification for Clay Seal
OPSS 1860	Material Specification for Geotextiles

Ontario Provincial Standard Drawings (OPSD)

OPSD 802.031	Rigid Pipe Bedding, Cover and Backfill, Type 3 Soil – Earth Excavation)
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets

ASTM International

ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split Barrel Sampling of Soils

Ontario Water Resources Act

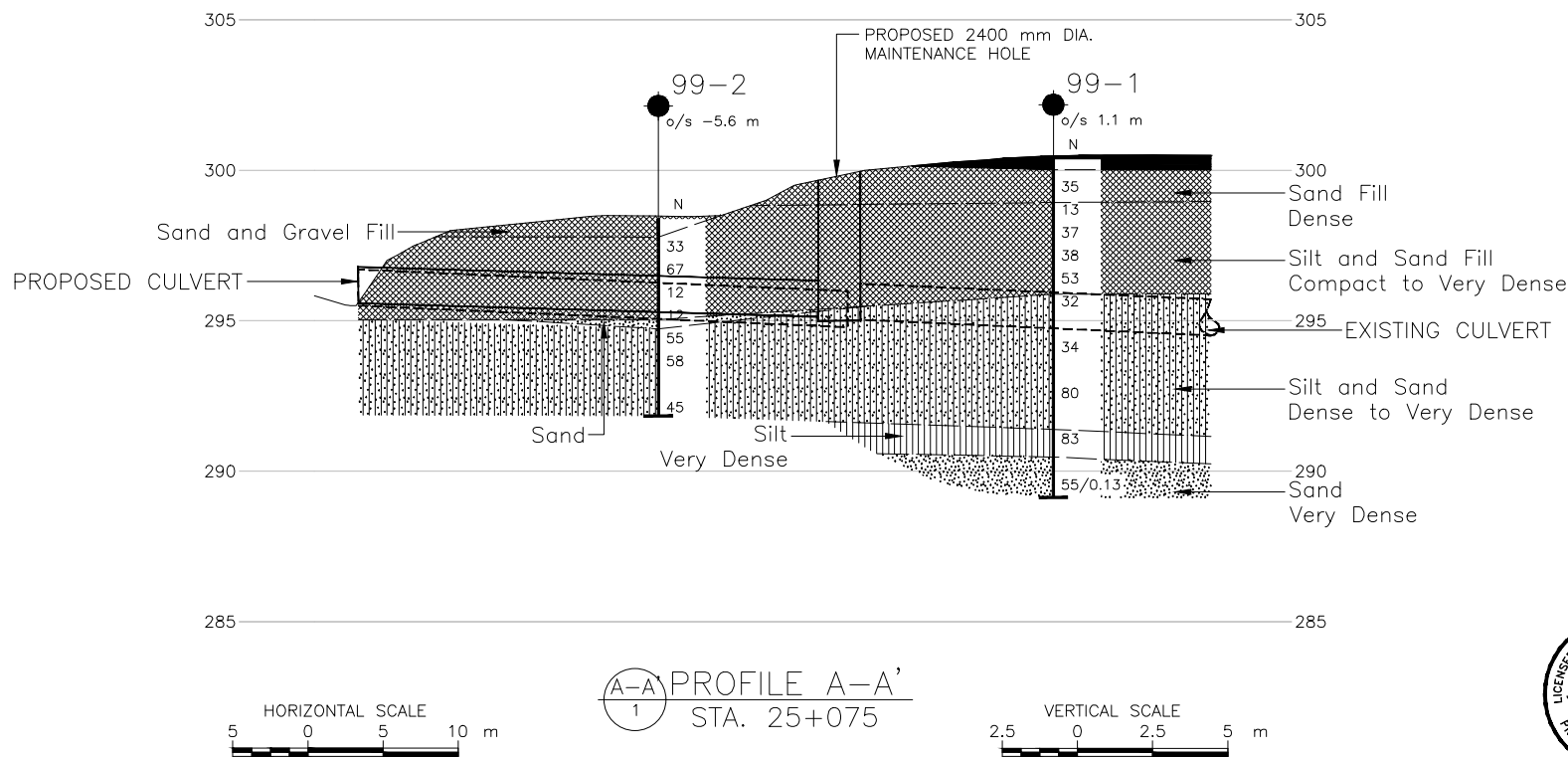
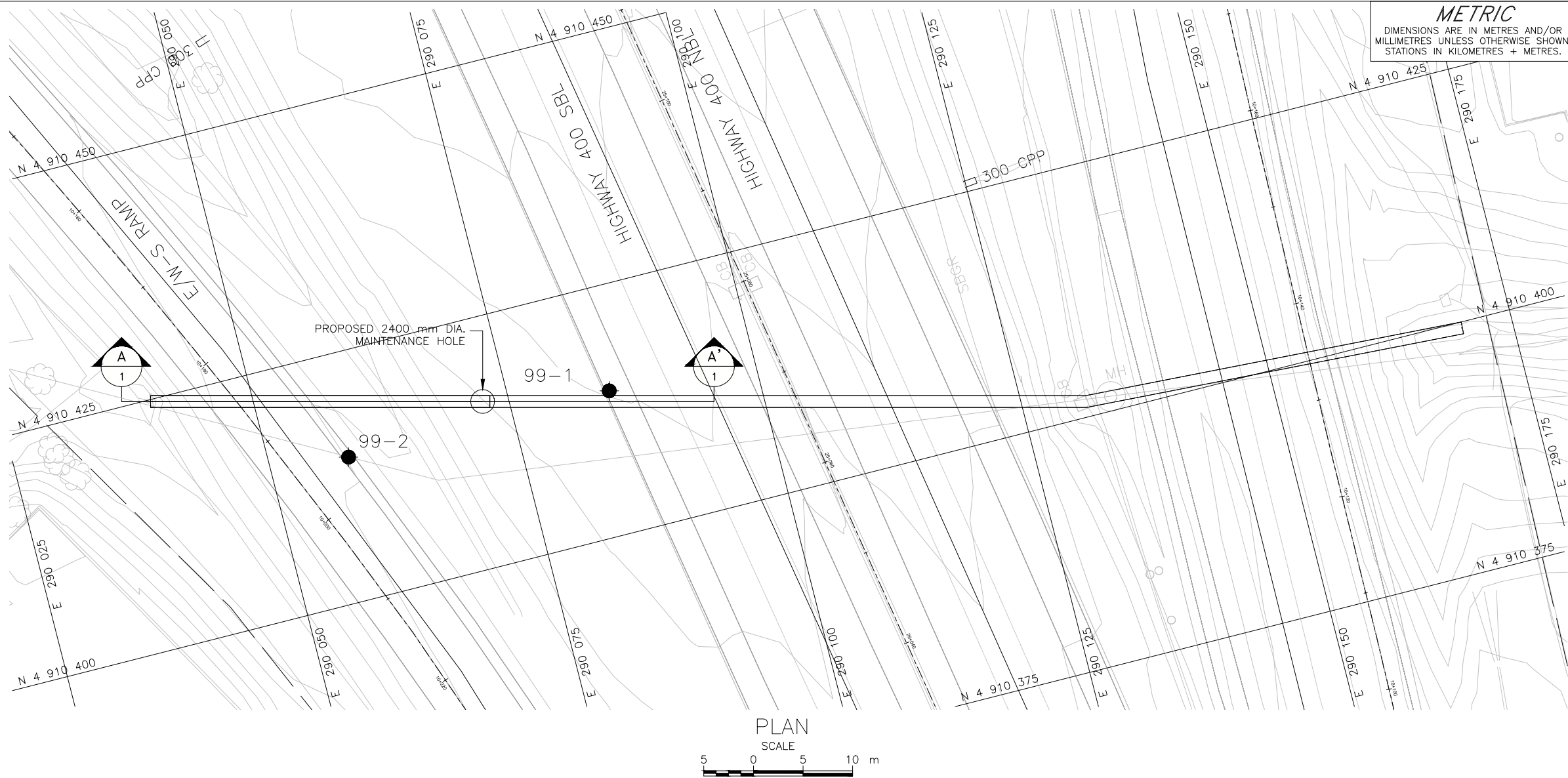
Ontario Regulation 903 Wells (as amended)

Ontario Occupational Health and Safety Act

Ontario Regulation 213 Construction Projects (as amended)

Commercial Software

Settle3D (Version 2.0) by Rocscience Inc.

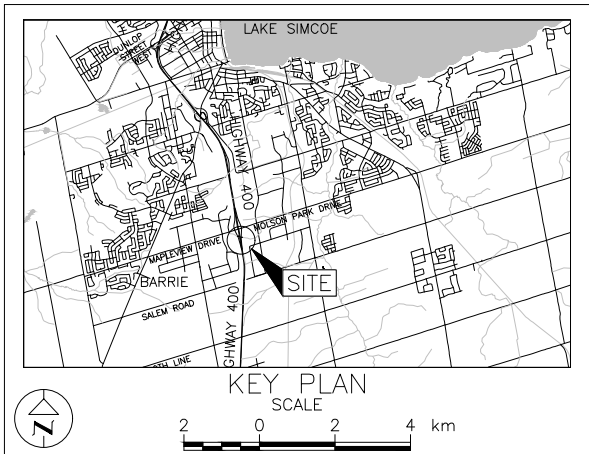


METRIC
DIMENSIONS ARE IN METRES AND/OR
MILLIMETRES UNLESS OTHERWISE SHOWN.
STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 2184-10-00

CULVERT 99 STA. 25+075
HIGHWAY 400
BOREHOLE LOCATIONS
AND SOIL STRATA

SHEET



LEGEND

Borehole - Golder (2016)
N Standard Penetration Test Value
16 Blows/0.3m unless otherwise stated
(Std. Pen. Test, 475 j/blow)

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
99-1	300.4	4910414.4	290085.0
99-2	298.4	4910414.4	290057.9

NOTES

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

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

The complete Foundation Investigation and Design Report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with Section GC 2.01 of OPS General Conditions.

REFERENCE

Base plans, culvert plan and profile, and surface data provided in digital format by URS, drawing file nos. Culvert 97 & 99 Plan View.dwg and HWY 400-BASE PLAN SURFACE.dwg, received Oct. 17, 2016. Vertical culvert alignment provided in digital format by MTO, file no. WP 2184-10-00 - Culvert 99 Design Drawings.pdf, received November 16, 2016.

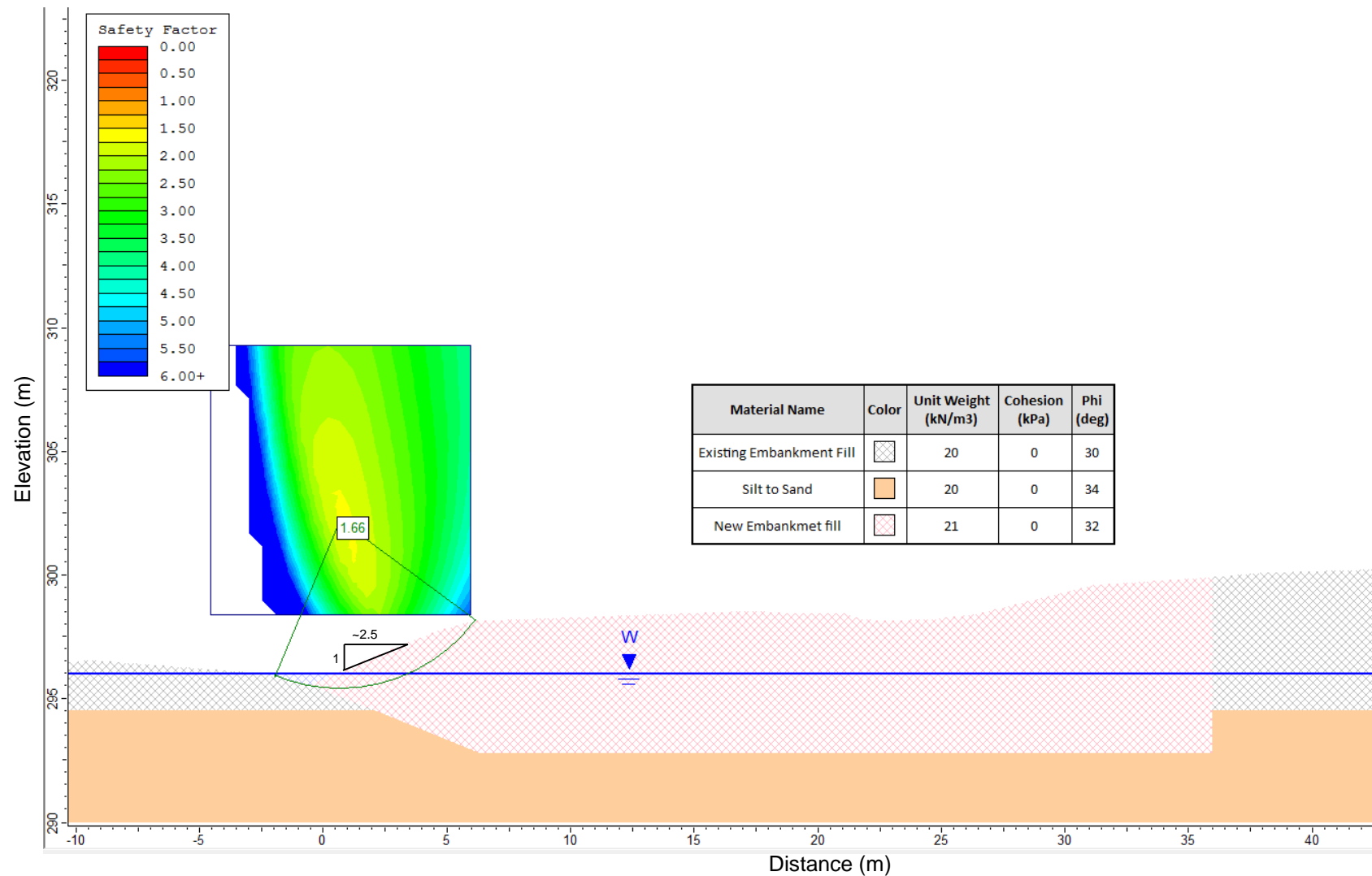


NO.	DATE	BY	REVISION
Geocres No. 31D-668			
HWY. 400	PROJECT NO. 1413191		DIST. .
SUBM'D. AJS	CHKD. AJS	DATE: 12/15/2016	SITE: .
DRAWN: DD	CHKD. LCC	APPD. JMAC	DWG. 1



Static Global Stability - Culvert 99 Embankment Long-Term (Drained) Conditions

Figure 1





APPENDIX A

Borehole Records



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
FoS	factor of safety

II. STRESS AND STRAIN

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

III. SOIL PROPERTIES

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

(a) Index Properties (continued)

w	water content
w_l or LL	liquid limit
w_p or PL	plastic limit
I_p or PI	plasticity index = $(w_l - w_p)$
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

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



LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

II. 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.) drive open sampler for a distance of 300 mm (12 in.)

Dynamic Cone Penetration Resistance; 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

Piezo-Cone Penetration Test (CPT)

A 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 (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III. SOIL DESCRIPTION

(a) Non-Cohesive (Cohesionless) Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

(b) Cohesive Soils Consistency

	c_u, s_u	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV. SOIL TESTS

w	water content
w _p	plastic limit
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
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	field vane (LV-laboratory vane test)
γ	unit weight

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

V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand

PROJECT 1413191 (1100)		RECORD OF BOREHOLE No 99-1		SHEET 1 OF 1		METRIC	
G.W.P. 2184-10-00		LOCATION N 4910414.4 ; E 290085.0		ORIGINATED BY AJ			
DIST Central HWY 400		BOREHOLE TYPE D-25 Truck Mount, 210 mm Outer Diameter Hollow Stem Augers		COMPILED BY PKS/AJS			
DATUM Geodetic		DATE October 30, 2016		CHECKED BY LCC			

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				GR	SA	SI	CL
								20	40	60	80	100	W _p	W	W _L					
300.4	GROUND SURFACE																			
0.0	ASPHALT																			
	GRANULAR FILL																			
0.4	ASPHALT																			
	Sand, some gravel (FILL)																			
	Dense																			
	Brown																			
	Moist																			
299.0			1	SS	35															
1.5	Silt and sand, trace gravel, trace clay (FILL)																			
	Compact to very dense																			
	Brown																			
	Moist																			
			2	SS	13															
			3	SS	37															
			4	SS	38															
			5	SS	53															
295.9																				
4.5	SILT and SAND, trace clay																			
	Dense to very dense																			
	Brown																			
	Moist becoming wet below a depth of about 6.7 m																			
			6	SS	32															
			7	SS	34															
			8	SS	80															
291.4																				
9.0	SILT, trace to some sand, trace to some clay																			
	Very dense																			
	Grey																			
	Wet																			
			9	SS	83															
290.5																				
9.9	Silty SAND, trace clay																			
	Very dense																			
	Grey																			
	Wet																			
			10	SS	55/0.13															
289.2																				
11.3	END OF BOREHOLE																			
	NOTE:																			
	1. Borehole dry upon completion of drilling.																			
	2. A manual hammer was used to obtain SPT 'N' values.																			

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



APPENDIX B

Geotechnical Laboratory Test Results

Silt and Sand (Fill)

U.S.S Sieve size, meshes/inch

Size of openings, inches

PERCENT FINER THAN

GRAIN SIZE, mm

Grain Size (mm)	Percent Finer Than (%) - Soil 1 (Circles)	Percent Finer Than (%) - Soil 2 (Squares)
0.002	8	5
0.004	10	6
0.007	12	7
0.01	15	8
0.015	20	9
0.02	22	10
0.03	25	12
0.04	30	15
0.05	35	18
0.07	45	25
0.1	60	35
0.2	85	55
0.3	92	70
0.5	95	80
1.0	98	90
2.0	99	95
4.0	100	98
10.0	100	100

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

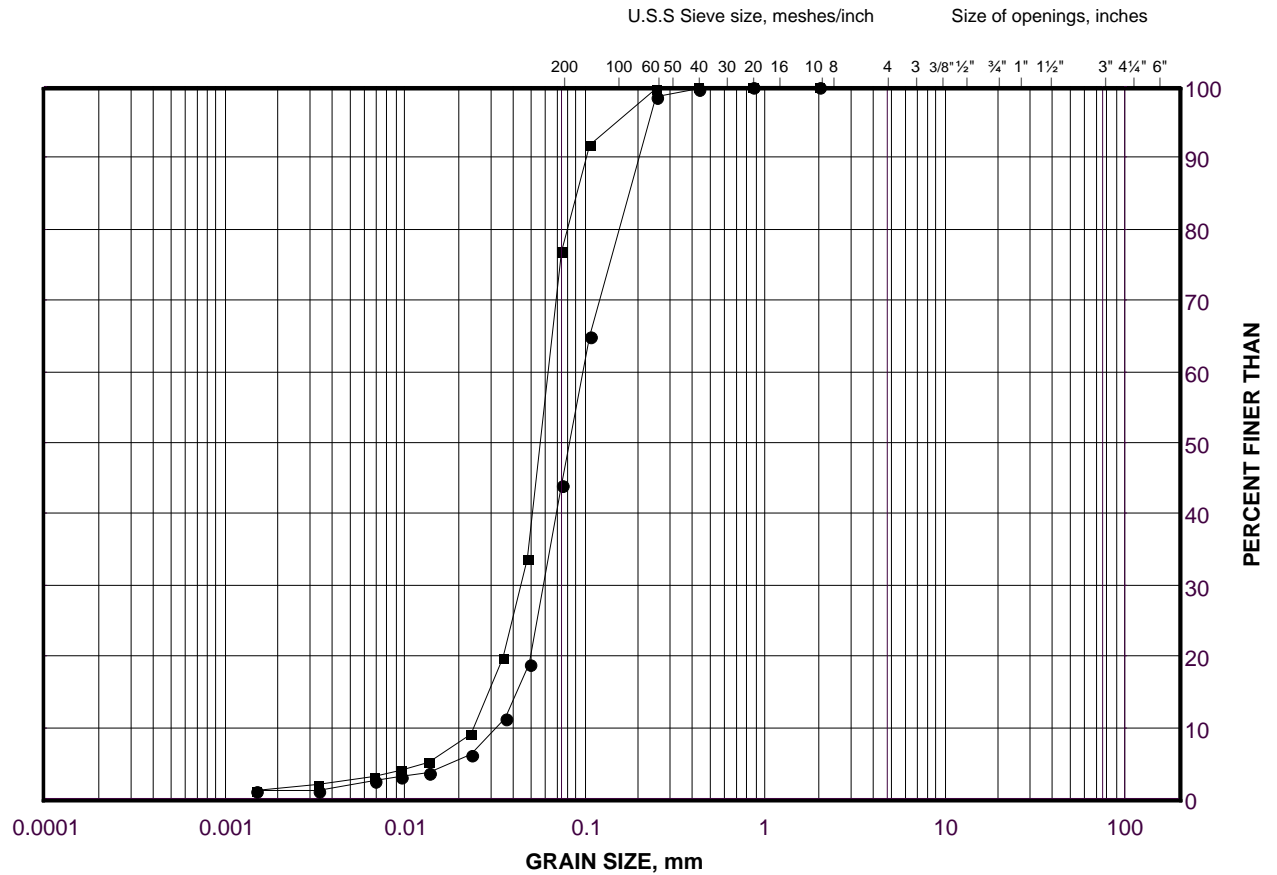
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	99-2	3	295.9
■	99-1	5	296.3

Date: 21-Nov-16

GRAIN SIZE DISTRIBUTION

Silt and Sand

FIGURE B2



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
●	99-2	5	294.4
■	99-1	7	294.0

Project Number: 1413191

Checked By: AJS

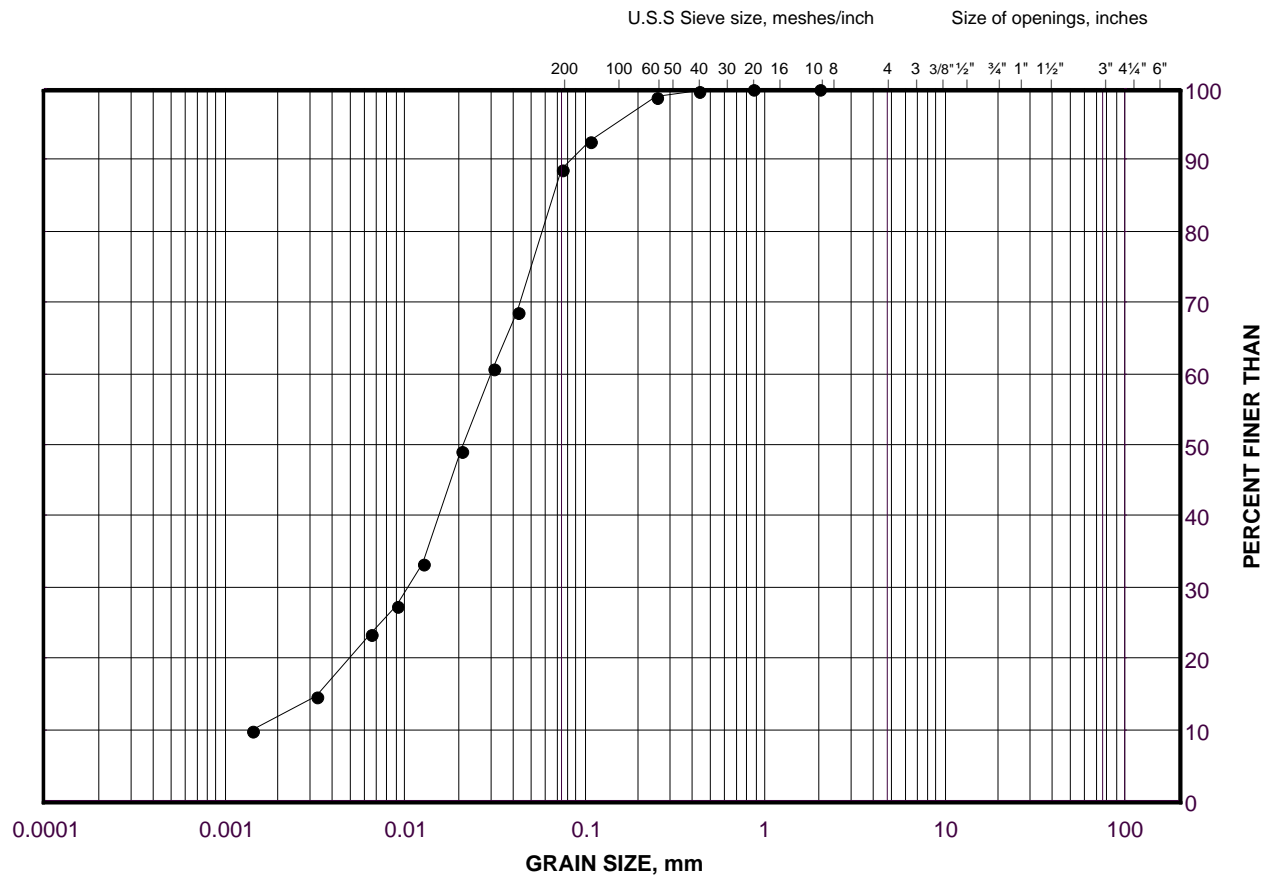
Golder Associates

Date: 21-Nov-16

GRAIN SIZE DISTRIBUTION

Silt

FIGURE B3



LEGEND

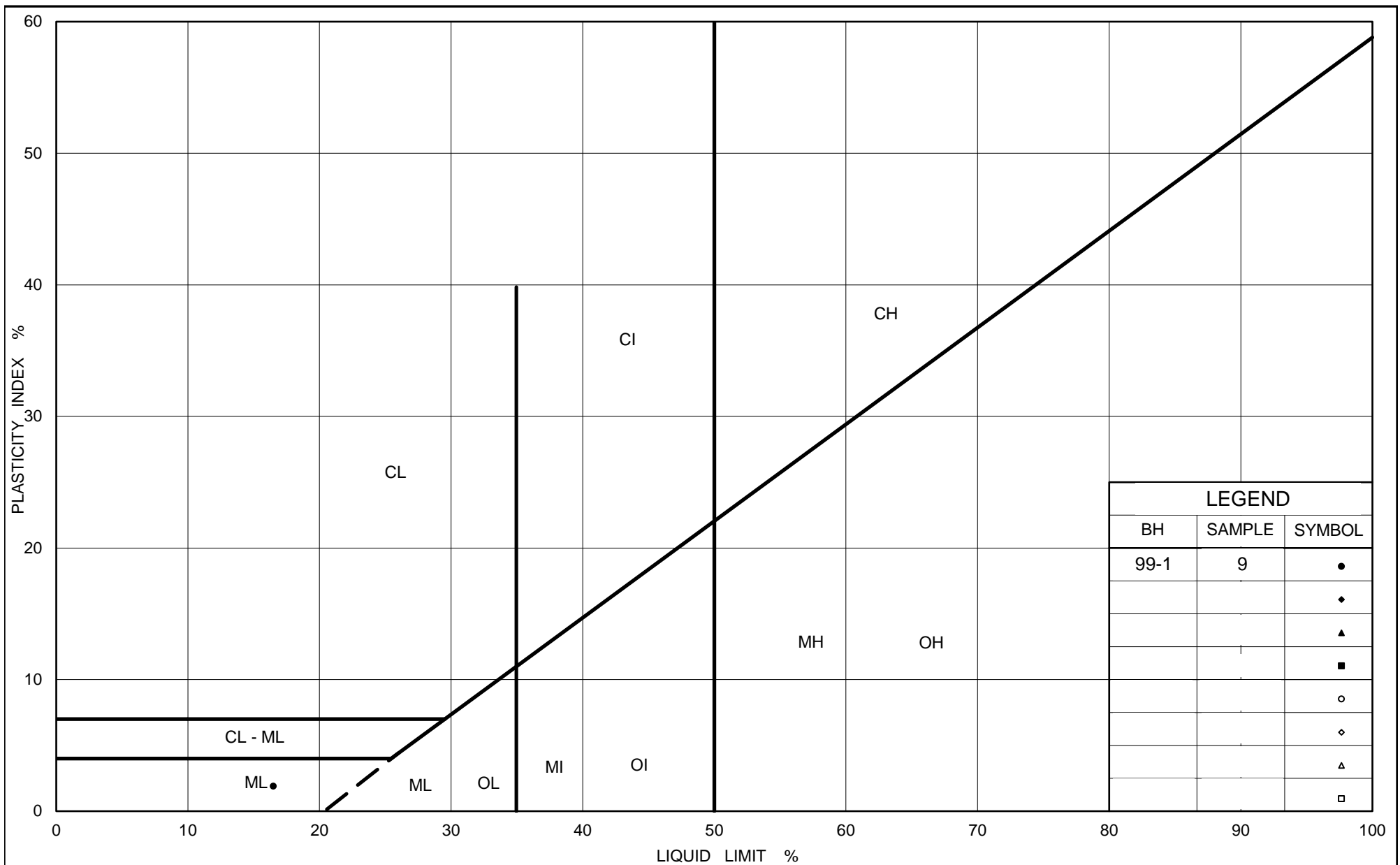
SYMBOL	BOREHOLE	SAMPLE	ELEVATION(m)
•	99-1	9	291.0

Project Number: 1413191

Checked By: AJS

Golder Associates

Date: 21-Nov-16



PLASTICITY CHART Silt

Figure No. B4

Project No. 1413191 (1100)

Checked By:

AJS



APPENDIX C

Analytical Test Results

**CLIENT NAME: GOLDER ASSOCIATES LTD.
6925 CENTURY AVE, SUITE#100
MISSISSAUGA, ON L5N7K2
(905) 567-4444**

ATTENTION TO: Ted Beadle

PROJECT: 1413191(1100)

AGAT WORK ORDER: 16T156184

SOIL ANALYSIS REVIEWED BY: Amanjot Bhela, Inorganic Coordinator

DATE REPORTED: Nov 14, 2016

PAGES (INCLUDING COVER): 5

VERSION*: 1

Should you require any information regarding this analysis please contact your client services representative at (905) 712-5100

***NOTES**

All samples will be disposed of within 30 days following analysis. Please contact the lab if you require additional sample storage time.



AGAT Laboratories

Certificate of Analysis

AGAT WORK ORDER: 16T156184

PROJECT: 1413191(1100)

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
<http://www.agatlabs.com>

CLIENT NAME: GOLDER ASSOCIATES LTD.

SAMPLING SITE:

ATTENTION TO: Ted Beadle

SAMPLED BY:

Corrosivity Package

DATE RECEIVED: 2016-11-03

DATE REPORTED: 2016-11-14

		SAMPLE DESCRIPTION: BH97-2 SA#3				BH99-2 SA#6	
		SAMPLE TYPE: Soil				Soil	
		DATE SAMPLED: 2016-10-27				2016-10-30	
Parameter	Unit	G / S	RDL	7983109	RDL	7983118	
Sulphide*	%		0.05	<0.05	0.05	<0.05	
Chloride (2:1)	µg/g		2	162	4	776	
Sulphate (2:1)	µg/g		2	99	4	25	
pH (2:1)	pH Units		NA	8.02	NA	8.97	
Electrical Conductivity (2:1)	mS/cm		0.005	0.463	0.005	1.22	
Resistivity (2:1)	ohm.cm		1	2160	1	820	
Redox Potential (2:1)	mV		5	274	5	253	

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard

7983109 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).

7983118 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).

Elevated RDL indicates the degree of sample dilution prior to the analysis for Anions in order to keep analytes within the calibration range of the instrument and to reduce matrix interference.

Certified By:

Amanjot Bhela

Quality Assurance

CLIENT NAME: GOLDER ASSOCIATES LTD.

PROJECT: 1413191(1100)

SAMPLING SITE:

AGAT WORK ORDER: 16T156184

ATTENTION TO: Ted Beadle

SAMPLED BY:

Soil Analysis

RPT Date: Nov 14, 2016			DUPLICATE				REFERENCE MATERIAL			METHOD BLANK SPIKE			MATRIX SPIKE		
PARAMETER	Batch	Sample Id	Dup #1	Dup #2	RPD	Method Blank	Measured Value	Acceptable Limits		Recovery	Acceptable Limits		Recovery	Acceptable Limits	
								Lower	Upper		Lower	Upper		Lower	Upper

Corrosivity Package

Sulphide*	7983109	7983109	< 0.05	< 0.09	NA	< 0.05	98%	80%	120%	NA			NA		
Chloride (2:1)	7983109	7983109	162	155	4.4%	< 2	101%	80%	120%	104%	80%	120%	100%	70%	130%
Sulphate (2:1)	7983109	7983109	99	99	0.0%	< 2	94%	80%	120%	98%	80%	120%	105%	70%	130%
pH (2:1)	7983109	7983109	8.02	8.08	0.7%	NA	101%	90%	110%	NA			NA		
Electrical Conductivity (2:1)	7983109	7983109	0.463	0.463	0.0%	< 0.005	99%	90%	110%	NA			NA		
Redox Potential (2:1)	7983109	7983109	274	272	0.7%	< 5	101%	70%	130%	NA			NA		

Comments: NA signifies Not Applicable.

Duplicate Qualifier: As the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

Certified By:



Method Summary

CLIENT NAME: GOLDER ASSOCIATES LTD.

AGAT WORK ORDER: 16T156184

PROJECT: 1413191(1100)

ATTENTION TO: Ted Beadle

SAMPLING SITE:

SAMPLED BY:

PARAMETER	AGAT S.O.P	LITERATURE REFERENCE	ANALYTICAL TECHNIQUE
Soil Analysis			
Sulphide*	MIN-200-12025	ASTM E1915-09	GRAVIMETRIC
Chloride (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
Sulphate (2:1)	INOR-93-6004	McKeague 4.12 & SM 4110 B	ION CHROMATOGRAPH
pH (2:1)	INOR 93-6031	MSA part 3 & SM 4500-H+ B	PH METER
Electrical Conductivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B	EC METER
Resistivity (2:1)	INOR-93-6036	McKeague 4.12, SM 2510 B, SSA #5 Part 3	CALCULATION
Redox Potential (2:1)		McKeague 4.12 & SM 2510 B	REDOX POTENTIAL ELECTRODE



APPENDIX D

Non-Standard Special Provisions

DEWATERING – Item No.

Special Provision

Amendment to OPSS 902

902.04 DESIGN AND SUBMISSION REQUIREMENTS

902.04.02 Submission Requirements

Section 902.04.02 is amended by the addition of the following Subsection:

902.4.02.03 Dewatering

At least two weeks prior to commencing dewatering operations, the Contractor shall submit to the Contract Administrator, for information purposes only, three (3) sets of the working drawings.

902.07 CONSTRUCTION

902.07.04 Dewatering Structure Excavation

Section 902.07.04 is amended by the addition of the following:

The Contractor is advised that excavation and construction for the culvert removal/replacement and new maintenance hole will require excavation to near or below the groundwater level in the silt to sand deposit. Cohesionless soils below the groundwater table will be subjected to conditions of unbalanced hydrostatic head and can slough, boil and/or cave in during temporary excavation work.

The dewatering system shall be adequate to lower the groundwater level to at least 0.5 m below the invert elevation for the replacement culvert and maintenance hole, to allow excavation, subgrade preparation and construction in dry conditions.

The Contractor shall reference borehole records as shown elsewhere in the Contract Documents as a guide in determining dewatering requirements.

A continuous dewatering operation shall be provided to facilitate the excavation and construction operations at all times. All components of the dewatering system shall be maintained in an effective, functioning and stable condition during the construction.

The work for dewatering shall be completed in accordance with the environmental and operational constraints specified elsewhere in the Contract Documents.

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