



GEOTECHNICAL INVESTIGATION REPORT

WATERMAIN REPLACEMENT
DIVISION ROAD AT HIGHWAY 3
KINGSVILLE, ONTARIO

THE CORPORATION OF THE TOWN OF
KINGSVILLE

GEOCRES NO: 40J2-148

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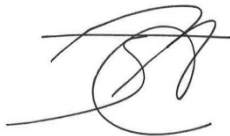
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Part A

GEOTECHNICAL INVESTIGATION REPORT DIVISION ROAD AT HIGHWAY 3 KINGSVILLE, ONTARIO

1 INTRODUCTION

WSP E&I Canada Limited (“WSP”) was retained by the Corporation of the Town of Kingsville (the “Client”) to conduct a geotechnical investigation for the watermain replacement on Road 6 West and Highway 3, just west of Division Road in Kingsville, Ontario. Highway 3 is under the jurisdiction of the Ontario Ministry of Transportation (MTO). The scope for the work for the project was set out in WSP’s proposal POGTW22430, dated August 5, 2022, and subsequent authorization to proceed from the Client. The project area is shown on the Key Plan, Figure 1. The primary intent of the geotechnical investigation was to provide geotechnical recommendations for the installation of the new watermain.

The subsurface exploration and reporting for the section within the Highway 3 right-of-way were conducted in accordance with the Ministry of Transportation Ontario (MTO) tunneling guidelines outlined in their document entitled, “Guidelines for Foundation Engineering – Tunneling Specialty for Corridor Encroachment Permit Application”, dated February 2021. The final scope of the fieldwork for this geotechnical investigation included five (5) boreholes at the site, as shown on Figure 1, with depths ranging from 5.2 metres (m) to 8.2 m below grade.

This report contains the findings of the geotechnical investigation, together with recommendations and comments. The recommendations and comments are based on factual information at the test locations and intended primarily for use by design engineers. Subsurface and groundwater conditions between and beyond the boreholes may differ from those encountered at the borehole locations, and conditions may become apparent during construction that could not be detected or anticipated at the time of the site investigation.

The anticipated construction conditions are also discussed, but only to the extent that they may influence the design decisions. The feasible construction methods, however, express our opinion and are not intended to direct contractors on how they carry out construction. Contractors should also be aware that the data and their interpretation presented in this report may not be sufficient to assess all factors that may have effect upon construction.

This report has been prepared with the assumption that the design will be in accordance with good engineering practices, applicable regulations of jurisdictional authorities, and applicable standards and regulations. Further, the recommendations and opinions in this report are applicable only to the proposed project. Hydrogeological considerations were not included in this scope of work. Environmental considerations are presented under separate cover. The limitations

of this report, as discussed in detail in Appendix A, constitute an integral part of this report.

There should be an ongoing liaison with WSP during both the design and construction phases of this project to ensure that the recommendations in this report have been adequately interpreted and implemented. Also, any further clarification and/or elaboration are needed concerning the geotechnical aspects of this project, WSP should be contacted immediately.

On September 21, 2002, Wood Environmental & Infrastructure Solutions Canada Limited (Wood) was acquired by WSP Global Inc. As a result of the completed acquisition and as of September 23, 2022, Wood has changed its name and is now operated as WSP E&I Canada Limited. WSP E&I Canada Limited is a wholly-owned subsidiary of WSP Canada Inc. ("WSP Canada") and WSP Canada Inc. is a wholly-owned subsidiary of WSP Global Inc.

2 SITE DESCRIPTION & GEOLOGICAL BACKGROUND

2.1 SITE AND PROJECT DESCRIPTION

The site is located west of Division Road in Kingsville Ontario and runs on the shoulder of Road 6 West before crossing Highway 3 and tying into the existing watermain. Highway 3 is a two-lane highway in the County of Essex with a posted speed limit of 80 km/hr with gravel shoulders. The MTO right-of-way extends about 40 m beyond the shoulder of the road. Both Highway 3 and Road 6 West were asphalt covered at the time of the investigation. The area surrounding the site is mainly agricultural or residential.

The scope of work for the project includes installing a new 400 millimetre (mm) diameter watermain on the shoulders of Road 6 West, before crossing into the MTO right-of-way and crossing Highway 3. It will then tie into the existing watermain near South Talbot Road. It is expected that the watermain will be installed using open cut methods along Road 6 West and using trenchless methods to cross Highway 3 and the MTO right-of-way. The length of the proposed trenchless crossing is about 72 m. The watermain will have a depth of no more than 2 m along Road 6 West and will be installed at a depth of about 5 m below grade when crossing Highway 3 and the MTO right-of-way.

2.2 GEOLOGICAL BACKGROUND

The site is located within a geological formation consisting of fine-textured glaciolacustrine deposits, containing sand, gravel, minor silt and clay (Physiography of Southern Ontario; Ontario Geological Survey, Map P. 2715, 1984). The deposit is underlain by limestone, dolostone and shale of the Detroit River group, Onondaga Formation (Geological Highway Map Southern Ontario, Ontario Geological Survey, Map P.2441, 1979) at a depth of about 30 m, based on available drift thickness mapping (Ministry of Northern Development and Mines, Drift Thickness Map P.3254, 1994).

3 INVESTIGATION PROGRAM

3.1 FIELD WORK

The scope of the geotechnical fieldwork included five sampled boreholes designated as BH1 to BH5, inclusive, with the depths ranging from 5.2 m and 8.2 m below grade. The locations of the boreholes are shown on Figure 1.

Prior to the advancement of the boreholes, underground public and private utility locates were requested and completed by Ontario One-Call by WSP.

The borehole drilling program for the investigation was carried out from December 8th to December 12th, 2022. The boreholes were advanced using a self-propelled drilling machine equipped with hollow stem augers and conventional soil sampling tools. Soil samples were taken at frequent intervals of depth following the Standard Penetration Test (ASTM D1586) procedure.

After completion of the boreholes, the augers were extracted, the boreholes were inspected for groundwater and caving, then backfilled using the excavated materials in accordance with O. Reg. 903.

All samples were field logged, placed in airtight containers, and transported to WSP's Tecumseh laboratory for further examination and testing.

The geodetic ground surface elevations at the borehole locations were surveyed using a benchmark provided by the Client described as "*The top of the operating not of the fire hydrant fronting Mun/ No. 51 Road 6 West*" which had an elevation of 196.369 m. The UTM coordinates were measured using a handheld GPS device with a +/- 3 m accuracy. The UTM coordinates are recorded on the Record of Borehole sheets.

Natural moisture content tests were carried out in accordance with ASTM D2216 on all the recovered soil samples. Seven (7) selected native soil samples were tested for grain size distribution and Atterberg limits, in accordance with ASTM D6913, ASTM D7928 and ASTM D4318.

4 SUBSURFACE CONDITONS

4.1 SUBSURFACE SOIL CONDITIONS

The following is a brief summary of the subsurface soil conditions encountered in the boreholes. The results of laboratory testing carried out on select samples are also shown in the table below, on the Record of Borehole Logs in Appendix B, as well as in Appendix C.

Surficial Materials

Four of the boreholes were advanced in the shoulders of the site roads, while one was advanced in the undeveloped portion of the MTO right-of-way. The boreholes in the shoulder of Highway 3, boreholes BH1 and BH2, had granular fill with thicknesses of 430 mm and 460 mm, respectively. Borehole BH3 has had about 150 mm of topsoil at the surface. The boreholes advanced in the shoulder of Road 6 West, boreholes BH4 and BH5 both had granular fill at the surface with a thickness of 205 mm. The moisture content of the granular materials ranged from 6% to 10%.

Silty Clay

Underlying the granular fill or topsoil, the boreholes penetrated an extensive stratum of silty clay. This stratum generally divides into three general zones, the 'weathered' zone, the 'crust' and the grey zone.

The upper zone was generally weathered and soils in the weathered zone are subjected to freeze-thaw cycles, and changes in moisture content caused by seasonal weather variations. This zone is characterized with a mottled brown and grey appearance. The weathered soils extended to depths ranging from 1.5 m to 2.3 m below grade. The measured "N" values from Standard Penetration Tests (SPTs) ranged from 6 blows to 14 blows per 300 mm of penetration, indicating a firm to stiff consistency. The moisture content of the weathered silty clay ranged from 22% to 27%.

Below the weathered zone was the crust. The crust was characterized by a brown colour, fissures and a minor amount of oxidation. The crust extended to a depth ranging from 2.3 m to 3.8 m below grade. The measured "N" values from SPTs ranged from 9 blows to 30 blows, indicating a firm to hard consistency. The moisture content of the crust ranged from 16% to 21%.

Underlying the crust was the grey zone. This zone of the silty clay stratum was generally characterized by increased natural moisture contents, and virtually no fissures. Four of the boreholes terminated in the grey zone at depths ranging from 5.2 m to 8.2 m below grade. The measure "N" values from SPTs ranged from 3 blows

to 16 blows per 300 mm of penetration, and generally decreased with depth. Field vane shear testing was completed in the grey silty clay and had the peak undrained shear strengths ranging from 30 kPa to greater than 40 kPa, indicating a firm consistency. The moisture contents of the grey silty clay ranged from 12% to 25%.

Sandy Silt

Borehole BH2 encountered sandy silt at a depth of 7.3 m to the termination of the borehole at 8.2 m below grade. The sandy silt was grey and had a measured “N” value from SPT of 27 blows per 300 mm of penetration, indicating a compact state of soil. The moisture content of the sandy silt was 10%.

Grain size distribution analyses and Atterberg Limits testing were carried out on seven samples of the silty clay. The results are included in Table 4-1 below and on the Record of Borehole Logs in Appendix B. The results are included in Appendix C.

Table 4-1 Results of Grain Size Analysis and Atterberg Limits Test

BOREHOLE NO. / SAMPLE NO.	SAMPLE DEPTH (m)	GRAIN SIZE DISTRIBUTION				ATTERBERG LIMITS			USCS MODIFIED GROUP SYMBOL
		Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Liquid Limit (W _L)	Plastic Limit (W _P)	Plasticity Index (I _P)	
BH1 / SA6	3.8 to 4.4	1	13	45	41	35	18	17	CI
BH1 / SA7	4.6 to 5.2	1	14	45	40	32	17	15	CI
BH2 / SA5	3.0 to 3.7	0	13	42	45	39	19	20	CI
BH2 / SA6	3.8 to 4.4	1	13	43	43	36	18	18	CI
BH2 / SA8	6.1 to 6.7	2	17	45	36	32	16	16	CI
BH3 / SA4	2.3 to 2.9	1	12	44	43	39	19	21	CI
BH3 / SA5	3.0 to 3.7	1	14	46	39	35	18	17	CI

4.2 GROUNDWATER CONDITIONS

Groundwater level observations and measurements in the boreholes, and in-situ moisture contents of recovered soil samples are presented on the Record of Borehole sheets.

All five boreholes had measured cave in following the removal of the augers, ranging from 3.0 m to 4.9 m. All five boreholes remained dry following the drilling. Due to the low permeability of the clayey soil at the site, insufficient time had passed to allow stabilization of groundwater levels in the open boreholes.

Typically, the grey colour of the soils noted at a depth ranging from 2.3 m to 3.8 m below grade is indicative of a permanent saturated condition, and therefore, fluctuation of the long-term groundwater should be anticipated near this depth level. However, during and after local precipitation events, groundwater that is 'perched' above the long-term level may accumulate in the fills, weathered and fissured clay near the ground surface above the relatively more impervious grey silty clay. In addition, significant amounts of groundwater may be present in any fill materials around existing utilities that may be present.

Perched groundwater may rise to the ground surface following precipitation and snowmelt. In the absence of an active, engineered drainage system, the design should assume possible temporary groundwater levels rising to the ground surface.

5 CLOSURE

This Geotechnical Investigation Report was prepared by Anthony Pusic, P.Eng., Geotechnical Engineer, and reviewed by Ty Garde, M.Eng., P.Eng., Principal Geotechnical Engineer and Designated MTO Contact for WSP E&I Canada (formerly Wood Environment & Infrastructure Canada Limited).

Sincerely,

WSP E&I Canada Limited

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Part B

GEOTECHNICAL DESIGN REPORT DIVISION ROAD AT HIGHWAY 3 KINGSVILLE, ONTARIO

6 DISCUSSION & RECOMMENDATIONS

6.1 GENERAL

This section of the report provides geotechnical comments and recommendations for the proposed watermain installation across Highway 3 just north of Division Road in Kingsville, Ontario. The watermain will have a diameter of 400 mm and will be installed at a depth of about 5.0 m below grade at one location below Highway 3. The watermain will also be installed along the shoulder of Road 6 West.

According to the drawings, the preferred method of installation across Highway 3 is by jack and bore. The total length of the watermain to be installed using trenchless methods is about 72 m.

The recommendations are based on interpretation of the factual geotechnical data obtained from the boreholes advanced during the subsurface investigation at the site. The interpretation and recommendations provided are intended to provide the designers with information to assess and specify the trenchless methodology and equipment. This report does not assess other aspects of the design of trenchless installation methods (e.g. identifying the steel bore pipe type, jacking/ramming force, etc.). Furthermore, the installation of the pipes should be carried out in accordance with all applicable regulations/guidelines. Where comments are made on construction, they are provided to highlight those aspects which could affect the design of the project, and for which special provisions or operational constraints may be required in the Contract Documents. Those planning and undertaking specific aspects of construction should make their own interpretation of the factual information provided, as it may affect equipment selection, proposed construction methods, scheduling, and the like.

The installation of the crossing by trenchless technologies should be undertaken by a qualified specialist contractor, using skilled workers under the direction of an experienced foreman. The geotechnical aspects of the contractor's proposed methodology and schedule should be reviewed by this office prior to commencement of construction.

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 final locations of entry and exit points for the jack and bore method was not known at the time of preparation of this report. Table D.1 in Appendix D, following the text of this report, provides a comparison of the advantages, disadvantages, and risks associated with these installation methods.

6.2 INSTALLATION METHODS

6.2.1 *NON-STANDARD SPECIAL PROVISION*

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

6.2.2 *OPEN CUT EXCAVATIONS*

Open-cut trenching is not the preferred method of installation; however, the recommendations are still provided herein in the event that open-cut is used in some aspect of the watermain installation. Open-cut trenching across the active highway would include pavement structure demolition and restoration; trench excavation including installation of temporary protection systems for support of excavation sides and/or adjacent pipes; pipe installation; and trench backfilling including removal of temporary protection system elements. The open-cut excavation method would offer the best control of gradient and alignment for the pipeline, reduced potential for delays resulting from encountering obstructions, reduced potential for failure in steering in soft clays, and the least risk of unanticipated damage to the active highway. The major disadvantages with open-cut installation of the proposed pipe are the requirement for lane closures resulting in complex traffic staging and disruptions/delays, pavement reconstruction, and the potential for post-construction settlement of the backfill materials (although such post-construction settlement could be minimized by using unshrinkable fill to backfill the trench around and above the pipe).

The open-cut excavation method is feasible at the proposed pipe crossing location, provided that it is acceptable with respect to traffic staging impacts and permitted by MTO. Open-cut excavations can be used along Road 6 West. Further recommendations for open-cut excavations are below in Section 6.4.

6.2.3 JACK AND BORE/HORIZONTAL AUGER BORING

The pipe jacking and boring or horizontal auger boring methods involve drilling a near horizontal borehole from a jacking (sending) pit with a rotating cutter head and jacking a liner/bore pipe to support the borehole walls. The bore pipe is pushed by a jacking system through a thrust block that uniformly distributes the thrust load on the bore pipe cross-section. The soil within the bore pipe is then excavated and spoil from the tunnel excavation is transported to the jacking pit along helical wound auger flights. After the bore pipe is fully installed, the new pipe is welded onto the bore pipe and pulled or pushed into place. In soft or unstable ground conditions, boring and jacking operations are performed simultaneously to minimize ground loss. Lubrication may be provided to reduce the friction between the bore pipe and the borehole walls. The characteristics and stickiness of the surrounding soil should be considered in selecting the appropriate lubricant.

During the jack and bore operations, the bore pipe should be advanced as far ahead of the augers as possible such that the auger is maintained behind the leading edge of the bore pipe creating a plug of soil material at the face. It is recommended that the auger head maintains a distance at least the equivalent of two pipe diameters behind the leading edge of the bore pipe.

It is anticipated that the works will be carried out below the groundwater table. If the bore is carried out in the silty clay soils, significant volumes of water should not be anticipated during the tunneling due to the fine-grained nature of the native cohesive soil. Sand seams may be present within the silty clay which may result in additional water seepage into the tunnel if intersected at the face. Should sand layers be encountered, significant volumes of water may be anticipated. Where sand layers are encountered, dewatering efforts will be required.

The volume of mucked soil should be monitored to provide an indication of the ground loss. Should any sudden loss of ground occur, the contractor should be prepared to properly bulk head the bore pipe immediately and carry out remedial work (such as grouting of the void between the pipe and soil) as soon as possible to minimize future settlements.

Jack and bore installations are typically limited to a maximum of up to about 90 m in length; though in practice are often limited to about 40 to 60 m. The proposed MTO crossing length is 72 m so consideration would need to be given to exceed this limit.

The jack and bore operations should be carried out in general accordance with Ontario Provincial Standard Specification (OPSS) 416, Construction Specification for Pipeline and Utility Installation by Jacking and Boring. The accuracy (line and grade) of a jack and bore installation is highly dependent on the initial set up,

hence the elevation and gradient of the steel liner should be controlled and maintained during the course of the jack and bore. Jacking forces should be continually monitored and the level and alignment of the lead end of the bore pipe checked routinely. It is recommended that on-site inspections be carried out by the geotechnical engineer to monitor the progress of the work and document the soil conditions encountered during the bore.

Ground movements should be monitored during the steel pipe installation to confirm permissible ground surface movement (i.e. settlement/heave) tolerances are not exceeded (see Section 6.7).

6.2.4 PIPE RAMMING

Pipe ramming is a method which basically drives or rams an open-ended bore/liner pipe through the soils and the soil is then removed from within the pipe generally by using an auger. The bore pipe is driven by a ramming tool, powered by an air compressor, hammering on a series of reinforcing cones placed in/on the end of the pipe. Since the bore pipe is installed fully before removal of the soils, there is no mechanism for formation of voids which is the concern with the use of auger boring methods and the risk of loss of ground is therefore minimized. The advantages of pipe ramming method include that it is a relatively simple operation technique as well as the ability to install the liner pipe with minimal displacement of soil in the area of the cutting shoe; hence the anticipated surface settlement is likely to be less compared to open-face jack and bore or HDD operations. During pipe ramming operations, the maximum size of cobbles/boulders that can be ingested by the machine is roughly equivalent to the inner diameter of the bore pipe. The percussive nature of the operation would either displace these obstructions to the outside or inside of the bore pipe or break up the cobbles and boulders. In contrast, the maximum boulder size that can be passed by the equipment in a jack and bore operation is approximately one third of the diameter of the bore pipe. The pipe should be rammed open-ended to reduce the potential for surface heaving and a plug of soil, similar to jack and bore, should be maintained within the bore pipe.

The bore pipe may be lubricated using bentonite slurry or polymers to reduce the frictional forces between bore pipe and the surrounding soil and/or the contractor may utilize a higher energy hammer in this condition; however, the size of pipe and wall thickness requirements should be reviewed further to assess the feasibility of pipe ramming.

The start of the pipe ramming process can be very accurately set for elevation and starting grade; however, the accuracy of the exit elevation is dependent on the workmanship and the experience of the contractor. If cobbles and boulders are encountered, the bore pipe may be cleaned out, allowing access for equipment to

break up the obstructions. It is important that line and grade is carefully monitored during installation of the initial 1.2 m of the drive. The air supply of the pipe-ramming tool must be strictly controlled with slow advance of the pipe during insertion of the pipe. Attempts to correct the initial line and grade by withdrawal and reinsertion of the pipe should be avoided as it creates loose soils at the entry face which complicates achieving line and grade during later stages of the drive.

Pipe ramming is best suited for soft to firm clays and very loose to compact sands above the water table. If the pipe is installed within the upper layer of silty clay encountered in the boreholes, pipe ramming may be suitable for this installation.

Pipe ramming installations are typically limited to a maximum of up to about 90 m in length, though in practice a maximum length of about 40 to 60 m is preferred. The proposed MTO crossing length is 72 m so consideration would need to be given to exceed this limit.

Ground movements should be monitored during the pipe installation to confirm permissible ground surface movement (i.e. settlement/heave) tolerances are not exceeded (see Section 6.9).

6.2.5 HORIZONTAL DIRECTIONAL DRILLING

With the HDD method, a small rotating and steerable drill bit is launched from the surface at a shallow angle and is used to drill a pilot hole supported with drilling fluid. Once the pilot bore is complete, the drill head is replaced with a reamer or expander which enlarges the drill hole. When the desired size is reached, the product pipe is attached to the reaming head and pulled through the bore. The possible length of an HDD installation is much greater than that of pipe ramming or jack and bore. HDD installations of up to 1 km or even greater are possible, depending on available equipment and subsurface conditions.

In general, the HDD will likely pass through the firm silty clay. The silty clay is generally susceptible to hydraulic fracturing with increased fluid pressures. Correlating the soil classification with a modified version of Terzaghi's Tunnelman's Classification, the boring conditions can be described as "squeezing" within the native silty clay for unsupported tunnels. Squeezing soils generally pose a risk of bore collapse and failure in steering against them when the bore path curves horizontally and/or vertically. The boring condition within the silty clay is considered to be "generally suitable" in accordance with Table 1 of ASTM F1962 11.

Therefore, if the HDD installation is to deeper than about elevation 190 m (5 mbgs), consideration should be given to the use of "direct pipe installation" or "drill-with-casing" methods to eliminate the potential of the bore collapse where the hydrostatic pressure of the drilling fluid is not sufficient to support the bore path against collapsing.

As per observations made during the field investigation, groundwater may be encountered within the non-cohesive soils during the installation. The HDD installation procedure should consider that the soil/groundwater conditions between and beyond the borehole locations may be different, that groundwater levels may vary seasonally, and perched groundwater may be present.

As referenced in “Guidelines for Installation of Utilities Beneath Corp of Engineers Levees Using Horizontal Directional Drilling, US Army Corp of Engineers – Engineer Research and Development Center” by Latorre et al (2002), some guidance is provided relating to the recommended minimum depth of cover for various pipe diameters to reduce the potential for drilling fluid release, or “frac-out”, as indicated in the following table.

Table 6-1 Minimum Cover of Various Pipe Diameters (Latorre et al)

DIAMETER OF BORE (mm)	DEPTH OF COVER (m)
50 to 150	1.2
200 to 350	1.8
375 to 600	3.0
625 to 1200	4.5

The values provided in the above table should be considered preliminary. Hydraulic fracture analysis/evaluation should be completed along the bore path in accordance with the Delft Geotechnics Method outlined in Appendix B of the Army Corps of Engineers Report or similar methods. The design bore depth/cover should reflect the results of the hydraulic fracturing analysis.

The above recommendation of minimum depth of soil cover assumes that a clean and engineered HDD bore will be constructed in accordance with good industry practices. Monitoring of drilling fluid pressures, qualities, fluid and solid return rates and advance rates will be carried out during the HDD installation. The HDD contractor should design the drilling fluid, with additives if necessary, and monitor the flow rates during the advance of the pilot bore to confirm drilling fluid flow rates are sufficient to remove cuttings and drilling fluid pressures are within an acceptable range.

The HDD installation should conform to OPSS 450, Construction Specification for Pipeline and Utility Installation in Soil by Horizontal Directional Drilling.

6.2.6 RECOMMENDED INSTALLATION METHOD

From a geotechnical design perspective, the recommended installation method for the proposed watermain installation across Highway 3 is open cut. However, it is recognized that an open cut would result in significant disruption to the traffic on Highway 3 and may not be permitted by MTO Corridor Management. The

second method in order of preference is jack and bore, should the open cut method not be approved for the shoulder installation. The HDD method may be considered as an alternative to jack and bore for the crossing of Highway 3.

The recommended installation method along Road 6 West is open cut.

6.3 LATERAL EARTH PRESSURES

A distinction should be made between short-term earth pressures on temporary excavation support structures, and long-term retaining structures against compacted backfill.

As a preliminary guideline, the temporary shoring structures should be verified for conventional uniform earth pressures of at least $0.35 P_z$, (P_z , in kPa, is the total overburden pressure corresponding to the depth 'z' of excavation below the ground surface). For the in-situ soils a conservative unit weight of 22 kN/m^3 should be used. Surcharges at the ground surface should be added in accordance with applicable soil mechanics methods such as described in the Canadian Foundation Engineering Manual (CFEM).

For permanent retaining structures, unfactored (specified) earth pressure coefficients and associated unit weights are presented in Table 6-2.

Table 6-2 Soil Parameters for Earth Pressure Calculations

BACKFILL TYPE	COEFFICIENT OF EARTH PRESSURE AT ACTIVE CASE	COEFFICIENT OF EARTH PRESSURE AT PASSIVE CASE	COEFFICIENT OF EARTH PRESSURE AT REST CASE	DESIGN BULK UNIT WEIGHT (kN/m^3)	EFFECTIVE FRICTION ANGLE (DEGREES)
Select Crushed Limestone (Granular 'A') ¹	0.29 to 0.27	3.4 to 3.7	0.46 to 0.43	22.0	33 to 35
Well Graded Sand (Granular 'B', Type I) ¹	0.35 to 0.31	2.9 to 3.3	0.52 to 0.47	21.0 to 21.5	29 to 32
Site Generated Mottled Brown and Grey Silty Clay ²	0.38 to 0.33	2.7 to 3.0	0.55 to 0.50	19.5 to 20.5	27 to 30
Site Generated Brown Silty Clay ²	0.36 to 0.31	2.8 to 3.3	0.53 to 0.47	20.0 to 21.0	28 to 32
Site Generated Grey Silty Clay ²	0.39 to 0.33	2.6 to 3.0	0.56 to 0.50	19.5 to 20.5	26 to 30

Notes: 1. All granular compacted to at least 98% Standard Proctor Maximum Dry Density (SPMDD).

2. Compacted to at least 95% SPMDD.

6.4 PIPE BEDDING, COVER AND BACKFILL

6.4.1 STANDARD REQUIREMENTS

The bedding and backfill material for the open cut portion of the watermain should meet the manufacturer's specifications as well as the applicable OPSS standards. This will be applicable to the section of the watermain installed along Road 6 West outside of the MTO right-of-way.

6.4.2 PIPE BEDDING AND COVER

The depth of the pipe bedding should be a minimum of 150 mm; the pipe cover should be completed to at least 300 mm above the pipe crown. All bedding, clearance and cover materials should consist of Granular 'A' (OPSS 1010) compacted to 98% SPMDD in accordance with the OPSS 401 requirements. Granular material meeting the gradation specifications for sewer stone (equivalent to HL4 coarse aggregate per OPSS 1150) may also be used as bedding and cover material, however a non-woven geotextile should be used as a separation fabric between this material and the native soils. It is further recommended that, where used, the geotextile have a minimum overlap of 300 mm and the seams should be stitched to prevent separation of the geotextile at the seams.

Care should be exercised to avoid compaction methods that may damage the pipe. The placement and thickness of the granular bedding should also meet the pipe manufacturer's specifications.

6.4.3 TRENCH BACKFILLING

The project area is located within a deposit of silty clay. Therefore, the backfill material from 300 mm above the top of pipe to the pavement subgrade level can consist of compactable native material or imported Granular 'A' or 'B' Type I and placed in lifts not exceeding 200 mm and compacted to 98% of SPMDD.

Consideration could be given to the reuse of the site generated native mottled or brown silty clay as general trench backfill. However, if this is to be considered, the excavated materials should be carefully sorted and stockpiled by type and any deleterious materials should be separated. Excavated material should meet the requirements of select subgrade material in OPSS 1010. Prior to use of these materials, the geotechnical consultant should inspect the stockpiled soil and take samples for testing. Depending upon the test results, the native soils may be suitable for use as backfill material.

If imported granular soils, such as Granular 'A' or Granular 'B' Type I (OPSS 1010), are used as general trench backfill, the material should be placed in lifts not exceeding 200 mm and compacted to 98% of SPMDD. In the areas where the trench excavation underlies the roadway, it is good practice to backfill the trench with excavated, compactable native inorganic material, at least within the upper frost zone (1.0 m below grade), to provide compatibility with similar native soils. If this technique is not undertaken, in the absence of proper drainage of the pavement, such as subdrains under the shoulders, then problems could arise with yearly differential frost heaving movements between the trench backfill and the adjacent native soils. Considering the depth of the groundwater level, the potential for differential frost heave across the pavement profile is considered low. If the trench backfill within the depth of frost penetration differs from the native soils within the trench sides, and it is desired to eliminate differential frost heave, consideration should be given to the use of frost tapers.

6.5 FROST DEPTH

The upper stratigraphy of the soils is considered highly frost susceptible in the presence of water, and as such, frost effects should be considered for foundations or surface structure sensitive to movement.

In accordance with the Ontario Provisional Standard Drawing (OPSD 3090.101) the design frost depth below the ground surface for the general area is estimated to be 1.0 m. Therefore, a minimum permanent soil cover of 1.0 m or equivalent thermal insulation is required for frost protection of shallow foundations.

Where provision of the minimum depths of soil cover outlined above are not practical, rigid high density extruded polystyrene insulation could be used to reduce the required thickness of soil cover. If engineered pad is considered, and pad is within the frost depth, the rigid insulation will be required. WSP can provide recommended insulation details for specific development conditions upon request.

6.6 OTHER CONSIDERATIONS

Before excavation begins at the proposed crossing location, hand digging or hydro-vacuum methods should be used to expose any underground utilities in the vicinity of the proposed highway crossing, if present, to determine the exact locations and depths.

It is emphasized that the resulting performance of the completed undercrossing of the highway will largely be dependent upon the contractor's construction procedures and techniques. Ground movements (heave or settlement) associated

with the work should be monitored for and, if necessary, the construction method should be changed to control ground movements and minimize disturbance to the highway embankment and pavement. Where adequate provisions are not included to ensure excavation stability, detrimental surface settlement could occur, adversely impacting the highway and any associated existing underground services present.

Should remedial works be required of the highway embankment and pavement for settlement/heave, further monitoring of the situation will be required until all movement has stabilized.

Prior to the 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, such as settlement/heave) for the review and approval from the Contract Administrator and MTO.

6.7 SETTLEMENT

Settlements associated with trenchless installation methods are typically of two types:

- Large settlements: these settlements are results of loss of ground due to over-excavation caused by the inability to control adverse ground condition or operators' errors. Large settlements can lead to the creation of voids and/or sinkholes above the installed pipeline; and
- Systematic settlements: these settlements are primarily caused by the collapse of the annular space between the pipe and the bore annulus or by deformation of the soils ahead of the bore.

The systematic settlements caused by tunneling is the aggregate of two basic types of settlement, which consist of ground loss, or immediate settlement, and consolidation settlement.

The anticipated settlement as a result of the proposed pipe installation is also a function of the selected method, pipe depth, and profile. The anticipated settlements below the Highway 3 embankment due to both the trenchless installation and the shaft construction are anticipated to be less than 15 mm.

An instrumentation and monitoring program is recommended at all of the proposed crossings under Highway 3 to:

- Document the effects of the installation on the overlying highway;
- Obtain prior warning of ground movements that could occur due to the construction methods and equipment or unforeseen ground conditions;

- Verify the Contractor's compliance with the settlement limits imposed in the Contract; and
- Allow adjustments to be made to the installation methods such that the settlement limits are not exceeded.

Good workmanship and site control are the most effective way to reduce immediate settlements to a practical minimum. Factors to consider in the specification and review of tenders include grouting behind the temporary support system as quickly as possible and minimizing the use of over-cutters, if and where applicable.

6.7.1 INSTRUMENTATION AND SETTLEMENT MONITORING

During tunneling, the ground over and in the vicinity of the tunnel alignment may experience settlement. Good workmanship and site control are the most effective way to reduce settlements to a practical minimum. It is recommended that ground movement during tunneling be monitored together with the monitoring of boring activity. This is to confirm that the tunneling process does not cause any significant impact on the existing soil and groundwater conditions and the pipe is properly installed. If any adverse effect of tunneling is identified by the monitoring program, the tunneling process can be modified accordingly.

Additionally, the settlement monitoring of the trenchless crossing should be consistent with the "Appendix – Settlement Monitoring Guidelines-Tunneling" included in MTO's document "Guidelines for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application", dated February 2021 (MTO Guidelines).

The MTO Guidelines detail the requirements for settlement monitoring, including instrumentation, monitoring requirements, and monitoring frequency. As the tunnel is planned to be constructed within MTO's ROW, the MTO Guidelines should be strictly followed.

The instrumentation plan should be designed, as per the MTO Guidelines, when the contractor's proposed construction method is available and prior to beginning the installation of the tunnel, the proposed method should be reviewed by the foundation/tunnel engineer. As per the MTO Guidelines, a qualified geotechnical consultant should supervise the installation of surface settlement points on site and provide directions, technical input and field inspection on this project.

In accordance with MTO Guidelines, a pavement condition survey is required to be carried out prior to the commencement of tunnelling and following the completion of the tunnelling.

7 CLOSURE

This Geotechnical Design Report was prepared by Anthony Pusic, P.Eng., Geotechnical Engineer, and reviewed by Ty Garde, M.Eng., P.Eng., Principal Geotechnical Engineer and Designated MTO Contact for WSP E&I Canada Limited (formerly Wood Environment & Infrastructure Canada Limited).

Sincerely,

WSP E&I Canada Limited

Prepared By:



Anthony Pusic, P.Eng.
Geotechnical Engineer

Reviewed By:

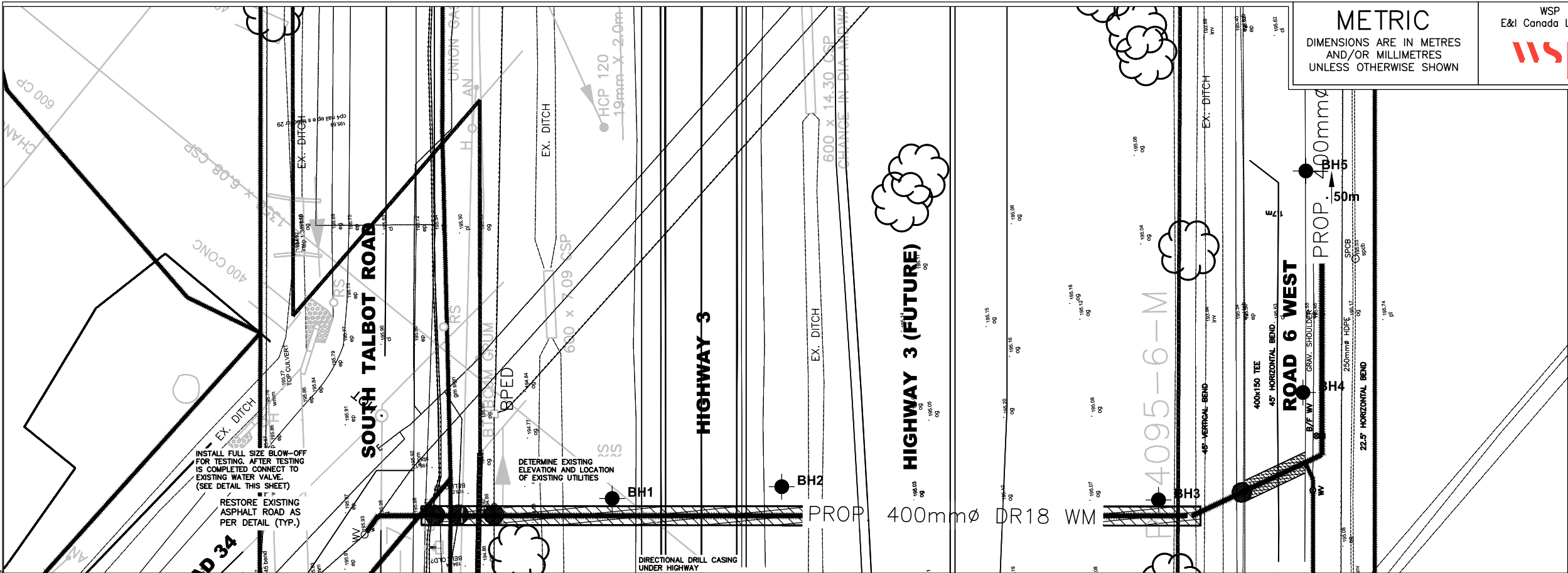


Ty Garde, M.Eng., P.Eng.
Principal Geotechnical Engineer
MTO RAQS Designated Foundations
Contact

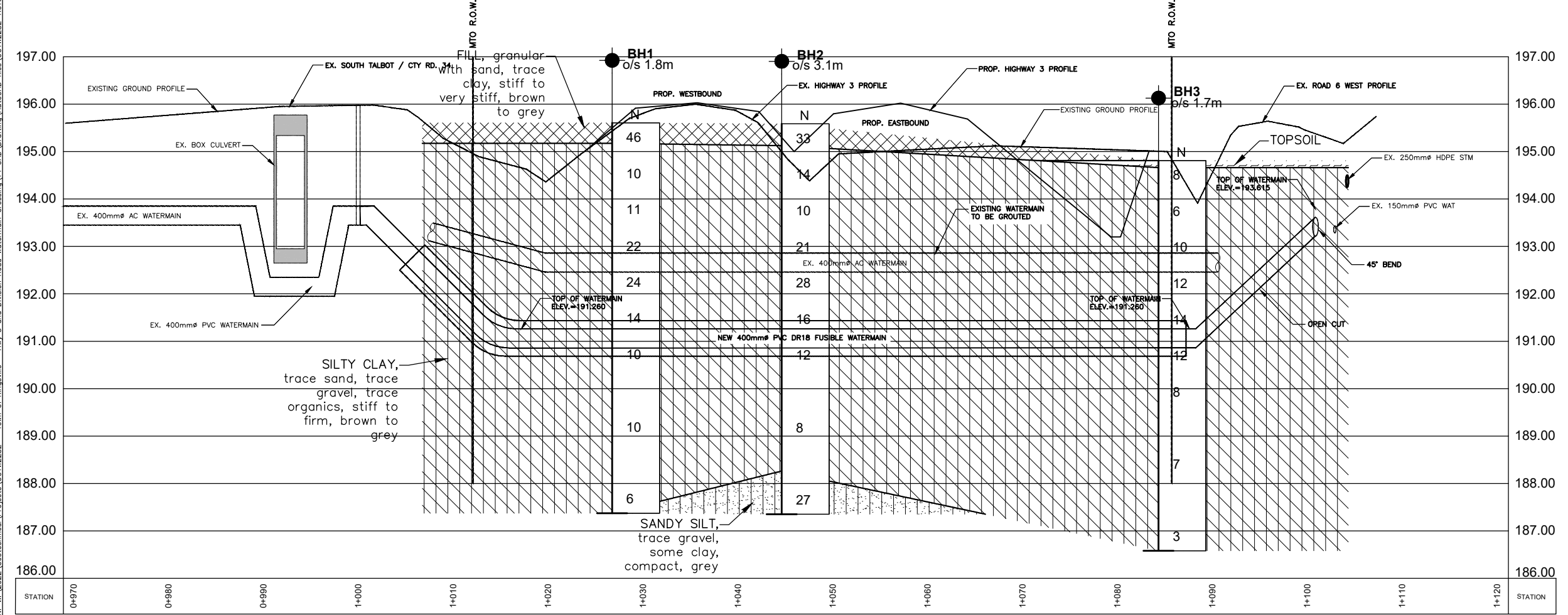
FIGURES



DATE PLOTTED: 5/10/2023 9:44:29 AM
FILE LOCATION: W:\2022\Geotechnical\Projects\OGTW2282 - Hwy 3 and Division Road Watermain Crossing\14 CAD\Drafting\AutoCAD_files\OGTW2282-R01001.dwg



PLAN



PROFILE ALONG PIPELINE

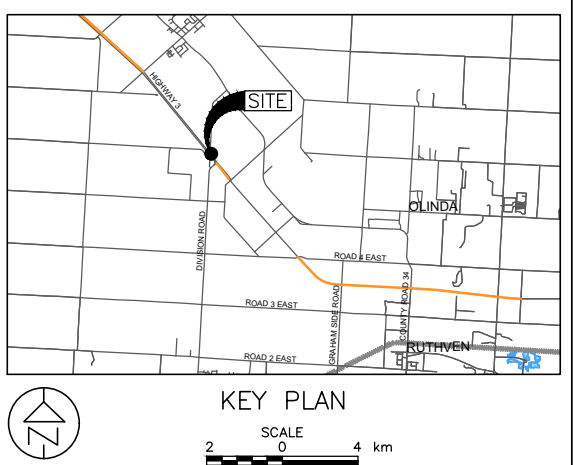
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

WSP
E&I Canada Limited

RC Spencer Associates
Inc. Geotechnical Investigation
Division Road at Highway 3
Kingsville, Ontario

Borehole Location Plan
and Soil Stratigraphy

SHEET
1



LEGEND

BOREHOLE LOCATION

- CURRENT WSP INVESTIGATION REPORT No. OGTW2282

STANDARD PENETRATION TEST VALUE

BLOWS/0.3m UNLESS OTHERWISE STATED (STD. PEN. TEST, 475 J/BLOW)

WATER LEVEL UPON COMPLETION OF DRILLING

- NOTES
1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH THE ACCOMPANYING GEO-ENVIRONMENTAL INVESTIGATION REPORT.

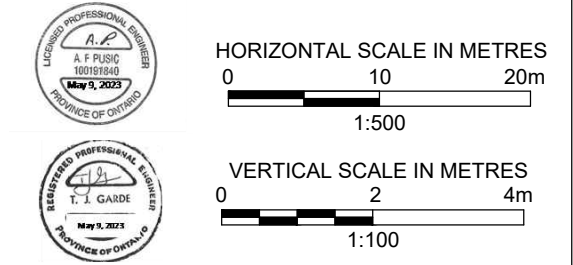
2. THE INTERPRETED STRATIGRAPHY REPRESENTS SIMPLIFIED SUBSURFACE CONDITIONS. THE BOUNDARIES BETWEEN SOIL STRATA HAVE BEEN DEFINED AT BOREHOLE LOCATIONS ONLY. CONDITIONS BETWEEN BOREHOLE LOCATIONS COULD DIFFER FROM ILLUSTRATED CONDITIONS.

3. ELEVATIONS ARE REFERENCED TO GEODETIC DATUM.

REFERENCES

1. DRAWINGS PROVIDED BY CLIENT.

No.	ELEVATION	CO-ORDINATES (MTM, NAD 83 ZONE 11)	
		NORTHING	EASTING
WSP BOREHOLES			
BH1	195.6	4662401.0	285329.6
BH2	195.6	4662388.7	285316.5
BH3	194.8	4662364.8	285284.8
BH4	195.4	4662346.4	285280.1
BH5	195.4	4662289.3	285326.1



Geocres No - 40J2-148

REVISIONS	DATE	REV.	BY	DESCRIPTION
DESIGN	AP	CHK	AP	CODE
DRAWN	LMK	CHK	AP	SITE

LOAD .
DATE 10-MAY-2023
DOC: OGTW2282-R01001

APPENDIX

A

LIMITATIONS TO
GEOTECHNICAL REPORTS



Limitations To Geotechnical Reports

1. The work performed in the preparation of this report and the conclusions presented are subject to the following:
 - 1) The contract between WSP and the Client, including any subsequent written amendment or Change Order duly signed by the parties (hereinafter together referred as the "Contract");
 - 2) Any and all time, budgetary, access and/or site disturbance, risk management preferences, constraints or restrictions as described in the contract, in this report, or in any subsequent communication sent by WSP to the Client in connection to the Contract; and
 - 3) The limitations stated herein.
2. **Standard of care:** WSP has prepared this report in a manner consistent with the level of skill and are ordinarily exercised by reputable members of WSP's profession, practicing in the same or similar locality at the time of performance, and subject to the time limits and physical constraints applicable to the scope of work, and terms and conditions for this assignment. No other warranty, guaranty, or representation, expressed or implied, is made or intended in this report, or in any other communication (oral or written) related to this project. The same are specifically disclaimed, including the implied warranties of merchantability and fitness for a particular purpose.
3. **Limited locations:** The information contained in this report is restricted to the site and structures evaluated by WSP and to the topics specifically discussed in it, and is not applicable to any other aspects, areas or locations.
4. **Information utilized:** The information, conclusions and estimates contained in this report are based exclusively on: i) information available at the time of preparation, ii) the accuracy and completeness of data supplied by the Client or by third parties as instructed by the Client, and iii) the assumptions, conditions and qualifications/limitations set forth in this report.
5. **Accuracy of information:** No attempt has been made to verify the accuracy of any information provided by the Client or third parties, except as specifically stated in this report (hereinafter "Supplied Data"). WSP cannot be held responsible for any loss or damage, of either contractual or extra-contractual nature, resulting from conclusions that are based upon reliance on the Supplied Data.
6. **Report interpretation:** This report must be read and interpreted in its entirety, as some sections could be inaccurately interpreted when taken individually or out-of-context. The contents of this report are based upon the conditions known and information provided as of the date of preparation. The text of the final version of this report supersedes any other previous versions produced by WSP.
7. **No legal representations:** WSP makes no representations whatsoever concerning the legal significance of its findings, or as to other legal matters touched on in this report, including but not limited to, ownership of any

property, or the application of any law to the facts set forth herein. With respect to regulatory compliance issues, regulatory statutes are subject to interpretation and change. Such interpretations and regulatory changes should be reviewed with legal counsel.

8. **Decrease in property value:** WSP shall not be responsible for any decrease, real or perceived, of the property or site's value or failure to complete a transaction, as a consequence of the information contained in this report.

9. **No third party reliance:** This report is for the sole use of the party to whom it is addressed unless expressly stated otherwise in the report or Contract. Any use or reproduction which any third party makes of the report, in whole or in part, or any reliance thereon or decisions made based on any information or conclusions in the report is the sole responsibility of such third party. WSP does not represent or warrant the accuracy, completeness, merchantability, fitness for purpose or usefulness of this document, or any information contained in this document, for use or consideration by any third party. WSP accepts no responsibility whatsoever for damages or loss of any nature or kind suffered by any such third party as a result of actions taken or not taken or decisions made in reliance on this report or anything set out therein. including without limitation, any indirect, special, incidental, punitive or consequential loss, liability or damage of any kind.

10. **Assumptions:** Where design recommendations are given in this report, they apply only if the project contemplated by the Client is constructed substantially in accordance with the details stated in this report. It is the sole responsibility of the Client to provide to WSP changes made in the project, including but not limited to, details in the design, conditions, engineering or construction that could in any manner whatsoever impact the validity of the recommendations made in the report. WSP shall be entitled to additional compensation from Client to review and assess the effect of such changes to the project.

11. **Time dependence:** If the project contemplated by the Client is not undertaken within a period of 18 months following the submission of this report, or within the time frame understood by WSP to be contemplated by the Client at the commencement of WSP's assignment, and/or, if any changes are made, for example, to the elevation, design or nature of any development on the site, its size and configuration, the location of any development on the site and its orientation, the use of the site, performance criteria and the location of any physical infrastructure, the conclusions and recommendations presented herein should not be considered valid unless the impact of the said changes is evaluated by WSP, and the conclusions of the report are amended or are validated in writing accordingly.

Advancements in the practice of geotechnical engineering, engineering geology and hydrogeology and changes in applicable regulations, standards, codes or criteria could impact the contents of the report, in which case, a supplementary report may be required. The requirements for such a review remain the sole responsibility of the Client or their agents.

WSP will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

12. Limitations of visual inspections: Where conclusions and recommendations are given based on a visual inspection conducted by WSP, they relate only to the natural or man-made structures, slopes, etc. inspected at the time the site visit was performed. These conclusions cannot and are not extended to include those portions of the site or structures, which were not reasonably available, in WSP's opinion, for direct observation.

13. Limitations of site investigations: Site exploration identifies specific subsurface conditions only at those points from which samples have been taken and only at the time of the site investigation. Site investigation programs are a professional estimate of the scope of investigation required to provide a general profile of subsurface conditions.

The data derived from the site investigation program and subsequent laboratory testing are interpreted by trained personnel and extrapolated across the site to form an inferred geological representation and an engineering opinion is rendered about overall subsurface conditions and their likely behaviour with regard to the proposed development. Despite this investigation, conditions between and beyond the borehole/test hole locations may differ from those encountered at the borehole/test hole locations and the actual conditions at the site might differ from those inferred to exist, since no subsurface exploration program, no matter how comprehensive, can reveal all subsurface details and anomalies.

Final sub-surface/bore/profile logs are developed by geotechnical engineers based upon their interpretation of field logs and laboratory evaluation of field samples. Customarily, only the final bore/profile logs are included in geotechnical engineering reports.

Bedrock, soil properties and groundwater conditions can be significantly altered by environmental remediation and/or construction activities such as the use of heavy equipment or machinery, excavation, blasting, pile-driving or draining or other activities conducted either directly on site or on adjacent terrain. These properties can also be indirectly affected by exposure to unfavorable natural events or weather conditions, including freezing, drought, precipitation and snowmelt.

During construction, excavation is frequently undertaken which exposes the actual subsurface and groundwater conditions between and beyond the test locations, which may differ from those encountered at the test locations. It is recommended practice that WSP be retained during construction to confirm that the subsurface conditions throughout the site do not deviate materially from those encountered at the test locations, that construction work has no negative impact on the geotechnical aspects of the design, to adjust recommendations in accordance with conditions as additional site information is gained and to deal quickly with geotechnical considerations if they arise.

Interpretations and recommendations presented herein may not be valid if an adequate level of review or inspection by WSP is not provided during construction.

14. Factors that may affect construction methods, costs and scheduling: The performance of rock and soil materials during construction is greatly influenced by the means and methods of construction. Where comments are made relating to possible methods of construction, construction costs, construction techniques, sequencing, equipment or scheduling, they are intended only for the guidance of the project design professionals, and those responsible for construction monitoring. The number of test holes may not be sufficient to determine the local underground conditions between test locations that may affect construction costs, construction techniques, sequencing, equipment, scheduling, operational planning, etc.

Any contractors bidding on or undertaking the works should draw their own conclusions as to how the subsurface and groundwater conditions may affect their work, based on their own investigations and interpretations of the factual soil data, groundwater observations, and other factual information.

15. Groundwater and Dewatering: WSP will accept no responsibility for the effects of drainage and/or dewatering measures if WSP has not been specifically consulted and involved in the design and monitoring of the drainage and/or dewatering system.

16. Environmental and Hazardous Materials Aspects: Unless otherwise stated, the information contained in this report in no way reflects on the environmental aspects of this project, since this aspect is beyond the Scope of Work and the Contract. Unless expressly included in the Scope of Work, this report specifically excludes the identification or interpretation of environmental conditions such as contamination, hazardous materials, wild life conditions, rare plants or archeology conditions that may affect use or design at the site. This report specifically excludes the investigation, detection, prevention or assessment of conditions that can contribute to moisture, mould or other microbial contaminant growth and/or other moisture related deterioration, such as corrosion, decay, rot in buildings or their surroundings. Any statements in this report or on the boring logs regarding odours, colours, and unusual or suspicious items or conditions are strictly for informational purposes

17. Sample Disposal: WSP will dispose of all uncontaminated soil and rock samples after 30 days following the release of the final geotechnical report. Should the Client request that the samples be retained for a longer time, the Client will be billed for such storage at an agreed upon rate. Contaminated samples of soil, rock or groundwater are the property of the Client, and the Client will be responsible for the proper disposal of these samples, unless previously arranged for with WSP or a third party.

APPENDIX

B

EXPLANATION OF RECORD OF
BOREHOLE SHEETS &
RECORD OF BOREHOLE SHEETS
BH1 TO BH5

EXPLANATION OF BOREHOLE LOG

This form describes some of the information provided on the borehole logs, which is based primarily on examination of the recovered samples, and the results of the field and laboratory tests. Additional description of the soil/rock encountered is given in the accompanying geotechnical report.

GENERAL INFORMATION

Project details, borehole number, location coordinates and type of drilling equipment used are given at the top of the borehole log.

SOIL LITHOLOGY

Elevation and Depth

This column gives the elevation and depth of inferred geologic layers. The elevation is referred to the datum shown in the Description column.

Lithology Plot

This column presents a graphic depiction of the soil and rock stratigraphy encountered within the borehole.

Description

This column gives a description of the soil strata, based on visual and tactile examination of the samples augmented with field and laboratory test results. Each stratum is described according to the *Modified Unified Soil Classification System* (modified slightly so that an inorganic clay of "medium plasticity" is recognized).

The compactness condition of cohesionless soils based on standard penetration testing (SPT) and the consistency of cohesive soils (undrained shear strength) are defined as follows (Ref. *Canadian Foundation Engineering Manual, 4th Edition, 2006*):

Compactness of Cohesionless Soils	SPT N-Value
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

Consistency of Cohesive Soils	Undrained Shear Strength	
	kPa	psf
Very Soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1000
Stiff	50 to 100	1000 to 2000
Very Stiff	100 to 200	2000 to 4000

SOIL SAMPLING

Sample types are abbreviated as follows:

SS Split Spoon TW Thin Walled Open (Pushed) RC Rock Core GS Grab Sample
AS Auger Sample TP Thin Walled Piston (Pushed) WS Washed Sample AR Air Return Sample

Additional information provided in this section includes sample numbering, sample recovery (%) and numerical testing results (SPT).

FIELD AND LABORATORY SAMPLING

Results of field testing (e.g., SPT, pocket penetrometer, and vane testing) and laboratory testing (e.g., natural moisture content, and limits) executed on the recovered samples are plotted in this section.

Definitions of Penetration Resistance

Standard penetration resistance 'N' - The number of blows required to advance a standard split spoon sampler 30 cm into the subsoil, driven by means of a 63.5 kg hammer falling freely a distance of 76 cm. WOH = sampler advanced under "weight of hammer"

Dynamic penetration resistance - The number of blows required to advance a 50 mm, 60 degree cone, fitted to the end of drill rods, 30 cm into the subsoil, the driving energy being 474.5 Joules per blow.

INSTRUMENTATION INSTALLATION

Instrumentation installations (monitoring wells, piezometers, inclinometers, etc.) are plotted in this section.

WATER LEVEL

Water levels, if measured during fieldwork, are plotted in the depth/elevation column. These water levels may or may not be representative of the static groundwater level depending on the nature of soil stratum where the piezometer tips are located, the time elapsed from installation to reading and other applicable factors. Other information includes the depth of borehole cave-in, if any. This information is also included in the borehole log footer.

WSP E&I Canada Limited

Geotechnical Discipline

Ontario Region

www.wsp.com



Rev. date: 6-Oct-22

EXPLANATION OF BOREHOLE LOG

GENERAL REPORT NOTE

The soil conditions, profiles, comments, conclusions and recommendations found in this report are based upon the samples recovered during the fieldwork. Soils are heterogeneous materials and, consequently, variations (possibly extreme) may be encountered at site locations away from boreholes. During construction, competent, qualified inspection personnel should verify that no significant variations exist from the conditions described in this report.

MODIFIED* UNIFIED SOIL CLASSIFICATION SYSTEM

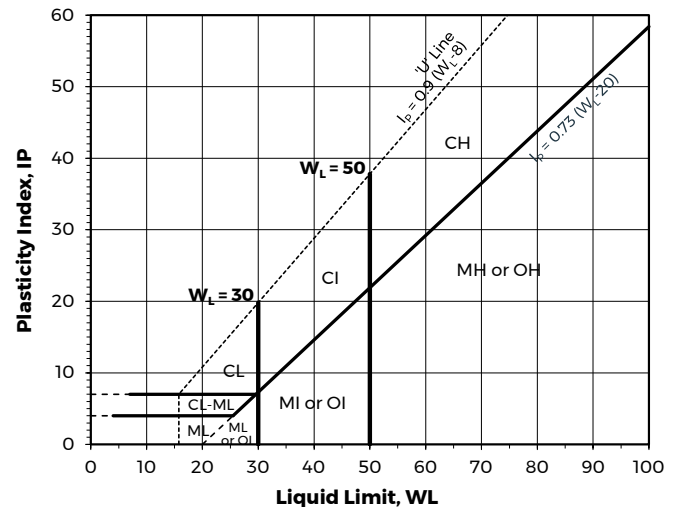
*The soil of each stratum is described using the Unified Soil Classification System (Technical Memorandum 36-357 prepared by Waterways Experiment Station, Vicksburg, Mississippi, Corps of Engineers, U.S Army, Vol. 1, March 1953) modified slightly so that an inorganic clay of "medium plasticity" is recognized.

MAJOR DIVISION			GROUP SYMBOL	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA
COARSE GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 75µm)	GRAVELS MORE THAN HALF THE COARSE FRACTION LARGER THAN 4.75mm	CLEAN GRAVELS (TRACE OR NO FINES)	GW	WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	$C_u = \frac{D_{60}}{D_{10}} > 4$; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1 \text{ to } 3$
			GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS
		DIRTY GRAVELS (WITH SOME OR MORE FINES)	GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	ATTERBERG LIMITS BELOW "A" LINE OR I_p LESS THAN 4
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES	ATTERBERG LIMITS ABOVE "A" LINE OR I_p MORE THAN 7
	SANDS MORE THAN HALF THE COARSE FRACTION SMALLER THAN 4.75mm	CLEAN SANDS (TRACE OR NO FINES)	SW	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	$C_u = \frac{D_{60}}{D_{10}} > 6$; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1 \text{ to } 3$
			SP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS
		DIRTY SANDS (WITH SOME OR MORE FINES)	SM	SILTY SANDS, SAND-SILT MIXTURES	ATTERBERG LIMITS BELOW "A" LINE OR I_p LESS THAN 4
			SC	CLAYEY SANDS, SAND-CLAY MIXTURES	ATTERBERG LIMITS ABOVE "A" LINE OR I_p MORE THAN 7
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75µm)	SILTS BELOW "A" LINE NEGLECTIBLE ORGANIC CONTENT	$W_L < 50\%$	ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	CLASSIFICATION IS BASED UPON PLASTICITY CHART (SEE BELOW)
		$W_L > 50\%$	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS	
	CLAYS ABOVE "A" LINE NEGLECTIBLE ORGANIC CONTENT	$W_L < 30\%$	CL	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY OR SILTY CLAYS, LEAN CLAYS	
		$30\% < W_L < 50\%$	CI	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS	
		$W_L > 50\%$	CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS	
	ORGANIC SILTS & CLAYS BELOW "A" LINE	$W_L < 50\%$	OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	WHENEVER THE NATURE OF THE FINES CONTENT HAS NOT BEEN DETERMINED, IT IS DESIGNATED BY THE LETTER "F", e.g. SF IS A MIXTURE OF SAND WITH SILT OR CLAY
		$W_L > 50\%$	OH	ORGANIC CLAYS OF HIGH PLASTICITY	
	HIGH ORGANIC SOILS			Pt	PEAT AND OTHER HIGHLY ORGANIC SOILS

SOIL COMPONENTS

FRACTION	U.S STANDARD SIEVE SIZE			DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS	
		PASSING	RETAINED	PERCENT	DESCRIPTOR
GRAVEL	COARSE	75 mm	19 mm	35 - 50	AND
	FINE	19 mm	4.75 mm	20 - 35	Y/EY
SAND	COARSE	4.75 mm	2.00 mm	10 - 20	SOME
	MEDIUM	2.00 mm	425 µm	1 - 10	TRACE
	FINE	425 µm	75 µm		
FINES (SILT AND CLAY BASED ON PLASTICITY)		75 µm			
OVERSIZED MATERIAL					
ROUNDED OR SUBROUNDED:			NOT ROUNDED:		
COBBLES 75 mm to 300 mm			ROCK FRAGMENTS > 75 mm		
BOULDERS > 300 mm			ROCKS > 0.76 CUBIC METRE IN VOLUME		

PLASTICITY CHART FOR SOIL PASSING 425 µm SIEVE



MODIFIED USCS

WSP E&I Canada Limited

Geotechnical Discipline
Ontario Region

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Rev. date: 6-Oct-22

Note 1: Soils are classified and described according to their engineering properties and behaviour.

Note 2: The modifying adjectives used to define the actual or estimated percentage range by weight of minor

RECORD OF BOREHOLE No. BH-1

1 OF 2

G.W.P. EC-2022-31L-00000390 V1 LOCATION N4662433, E356503 ORIGINATED BY DS
DIST Ontario HWY 3 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AH
DATUM Geodetic DATE December 8, 2022 CHECKED BY AP
PROJECT Hwy 3 and Division Road Watermain Crossing JOB NO. OGTW2282

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DEPTH m	ELEVATION m	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	SOIL VAPOUR READING COV/ TOV (ppm)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa									WATER CONTENT (%)	
									○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE	20 40 60 80 100	20 40 60							
195.6	0.0	FILL, granular with sand, pieces of asphalt, trace clay, pieces of clay brick	1	SS	46								7	○			0/ 0	Cave-in measured following drilling at 4.9 m	
195.2	0.4	SILTY CLAY, trace sand, trace gravel Stiff Mottled brown and grey						195											
			2	SS	10								24	○			0/ 0		
			3	SS	11			194					24	○			0/ 0		
		Very stiff Brown Fissured Oxidized																	
			4	SS	22			193					18	○			0/ 0		
			5	SS	24								17	○			0/ 0		
								192											
		Stiff Grey											18	○	35		0/ 0	1 13 45 41	
			6	SS	14														
			7	SS	10			191					18	○	32		0/ 0	1 15 44 40	
								190											
		Thin silty sand seam																	
			8	SS	10								22	○			0/ 0		
		Firm						189											

Continued Next Page

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

RECORD OF BOREHOLE No. BH-1

2 OF 2



G.W.P. EC-2022-31L-00000390 V1	LOCATION N4662433, E356503	ORIGINATED BY DS
DIST Ontario HWY 3	BOREHOLE TYPE Hollow Stem Augers	COMPILED BY AH
DATUM Geodetic	DATE December 8, 2022	CHECKED BY AP
PROJECT Hwy 3 and Division Road Watermain Crossing		JOB NO. OGTW2282

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DEPTH m	ELEVATION m	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			SOIL VAPOUR READING	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa					WATER CONTENT (%)					COV/ TOV (ppm)
									20	40	60	80	100	20	40	60			
																		</	

RECORD OF BOREHOLE No. BH-2

1 OF 2

G.W.P. EC-2022-31L-00000390 V1 LOCATION N4662421, E356490 ORIGINATED BY DS
DIST Ontario HWY 3 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AH
DATUM Geodetic DATE December 8, 2022 CHECKED BY AP
PROJECT Hwy 3 and Division Road Watermain Crossing JOB NO. OGTW2282

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DEPTH m	ELEVATION m	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	SOIL VAPOUR READING COV/ TOV (ppm)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa										WATER CONTENT (%)		
									○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE												
195.6									20	40	60	80	100								
0.0	FILL, granular		1	SS	33										6		0/0	Cave-in measured following drilling at 3.0 m			
195.1								195													
0.5	SILTY CLAY, trace sand, trace gravel, trace organics Stiff Mottled brown and grey		2	SS	14		1								27		0/0				
			3	SS	10		2	194							25		0/0				
	Very stiff Brown Oxidized		4	SS	21			193							18		0/0				
			5	SS	28		3								19 16	39	0/0	0 13 42 45			
	Grey		6	SS	16		4	192							18 16	36	0/0	1 13 43 43			
			7	SS	12		5	191							20		5/5				
	Stiff		8	SS	8		6	190							17 16	33	0/0	2 17 45 36			
							7	189													
188.3				VT																	
7.3	SANDY SILT, trace gravel, some																	Intact: 38 kPa Remould: 29 kPa			

Continued Next Page

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

2 OF 2

[illegible]

RECORD OF BOREHOLE No. BH-3

1 OF 2

G.W.P. EC-2022-31L-00000390 V1 LOCATION N4662397, E356458 ORIGINATED BY DS
DIST Ontario HWY 3 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AH
DATUM Geodetic DATE December 8, 2022 CHECKED BY AP
PROJECT Hwy 3 and Division Road Watermain Crossing JOB NO. OGTW2282

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DEPTH m	ELEVATION m	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	SOIL VAPOUR READING COV/ TOV (ppm)	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa									WATER CONTENT (%)			GR	SA	SI	CL
									○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE															
194.8									20	40	60	80	100											
0.0																								
194.7																								
0.2	TOPSOIL																							
	SILTY CLAY, trace sand, trace gravel, rootlets Stiff Mottled brown and grey		1	SS	8										22			0/0	Cave-in measured following drilling at 4.6 m					
			Firm																					
					2	SS	6		1	194							22				0/0			
			Stiff Brown Oxidized																					
					3	SS	10		2	193							18				0/0			
			Grey																					
			4	SS	12										19 17	39		0/0	1 12 44 43					
							3	192																
	Silt seam		5	SS	14										18 12	35		0/0	1 14 46 39					
							4	191																
	Firm																							
							5	190								22		0/0						
				VT																				
							6	189											Intact: 29 kPa Remould: 17 kPa					
	Thin silty sand seam																							
			8	SS	7											25		0/0						
				VT																				
							7	188											Intact: 33 kPa Remould: 29 kPa					

Continued Next Page

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

2 OF 2

[illegible]

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

RECORD OF BOREHOLE No. BH-4

1 OF 1

G.W.P. EC-2022-31L-00000390 V1 LOCATION N4662379, N356453 ORIGINATED BY DS
DIST Ontario HWY 3 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AH
DATUM Geodetic DATE December 12, 2022 CHECKED BY AP
PROJECT Hwy 3 and Division Road Watermain Crossing JOB NO. OGTW2282

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DEPTH m	ELEVATION m	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	SOIL VAPOUR READING COV/ TOV (ppm)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV. DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa										WATER CONTENT (%)		
									20	40	60	80	100						20	40	60
195.4																					
0.0																					
195.2																					
0.2																					

RECORD OF BOREHOLE No. BH-5

1 OF 1

G.W.P. EC-2022-31L-00000390 V1 LOCATION N4662321, N356498 ORIGINATED BY DS
DIST Ontario HWY 3 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AH
DATUM Geodetic DATE December 12, 2022 CHECKED BY AP
PROJECT Hwy 3 and Division Road Watermain Crossing JOB NO. OGTW2282

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	DEPTH m	ELEVATION m	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	SOIL VAPOUR READING COV/ TOV (ppm)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				SHEAR STRENGTH kPa									
									○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE								
195.4									20	40	60	80	100					
0.0									20	40	60	80	100					
195.2																		
0.2																		

APPENDIX

C

GEOTECHNICAL LABORATORY TEST RESULTS

WSP E&I Canada Limited
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ATTERBERG LIMITS ASTM D-4318 or LS-703 / 704

Project Number: OGTW2282.1000
Project Client: RC Spenser
Project Name: Highway 3 Division Watermain
Project Location: Essex

Sampled by: DS
Tested by: JP

Sampled on: 8-Dec-22
Received on: 8-Dec-22
Tested on: 16-Dec-22

Test Results

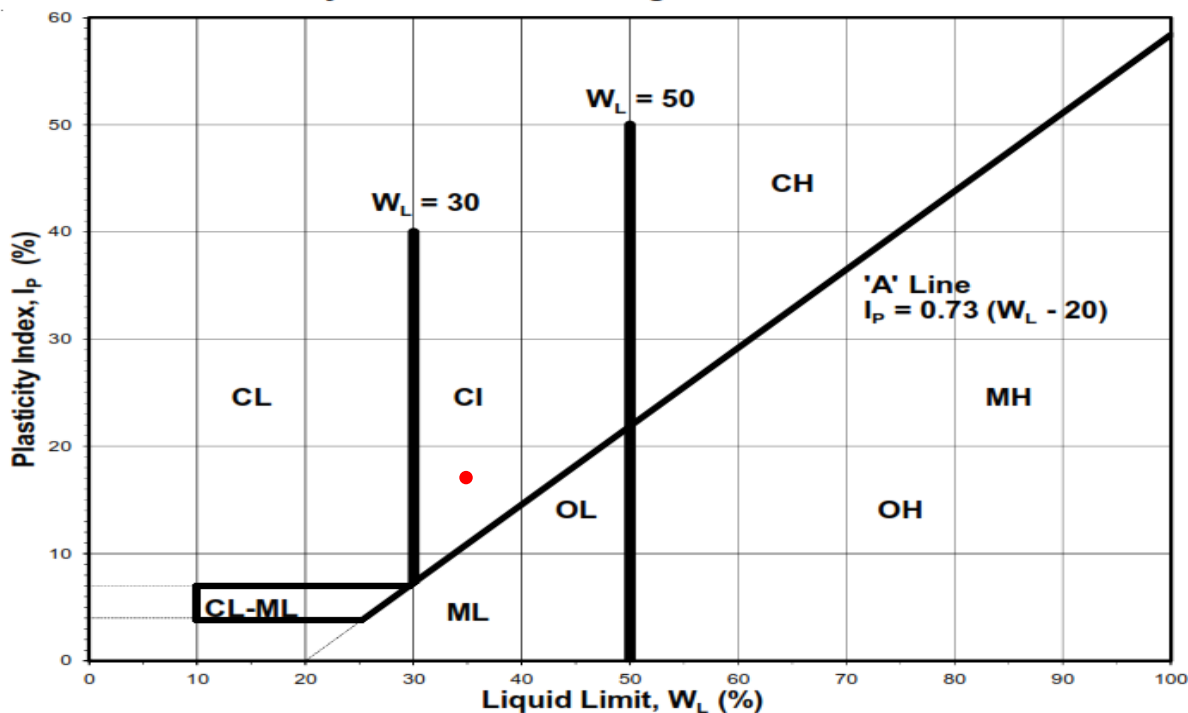
LAB NUMBER
BOREHOLE
SAMPLE
DEPTH (m)

1076
1
6
3.8-4.4

PLASTIC LIMIT
LIQUID LIMIT
PLASTICITY INDEX

17.8
35.3
17.4

Plasticity Chart for Soil Passing 425 Micron Sieve



Signed by: _____

Justin Palmer, C. Tech

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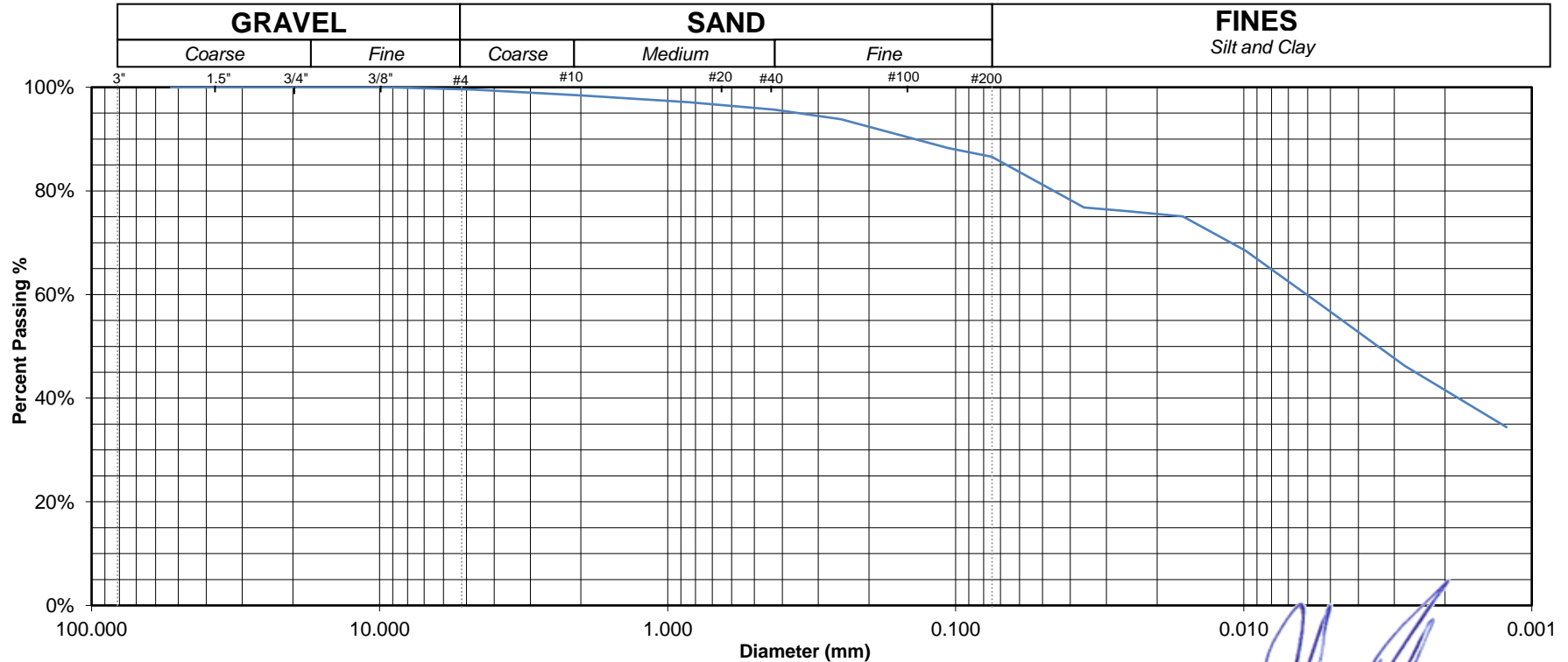
GRAIN SIZE DISTRIBUTION MTO LS 702 / ASTM D7928 / ASTM D6913

Project Number: OGTW2282.1000
Project Client: RC Spenser
Project Name: Highway 3 Division Watermain
Project Location: Essex

Sampled by: DS
Tested by: SS

Sampled on: 8-Dec-2022
Received on: 8-Dec-2022
Tested on: 15-Dec-2022

		Test Results				
Sample Location:	BH 1, Sa.6	Gravel	Sand	Silt	Clay	Moisture content (%)
Sample Identification:	1083	0.5%	13.0%	45.0%	41.5%	18.3%



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ATTERBERG LIMITS ASTM D-4318 or LS-703 / 704

Project Number: OGTW2282.1000
Project Client: RC Spenser
Project Name: Highway 3 Division Watermain
Project Location: Essex

Sampled by: DS
Tested by: JP

Sampled on: 8-Dec-22
Received on: 8-Dec-22
Tested on: 16-Dec-22

Test Results

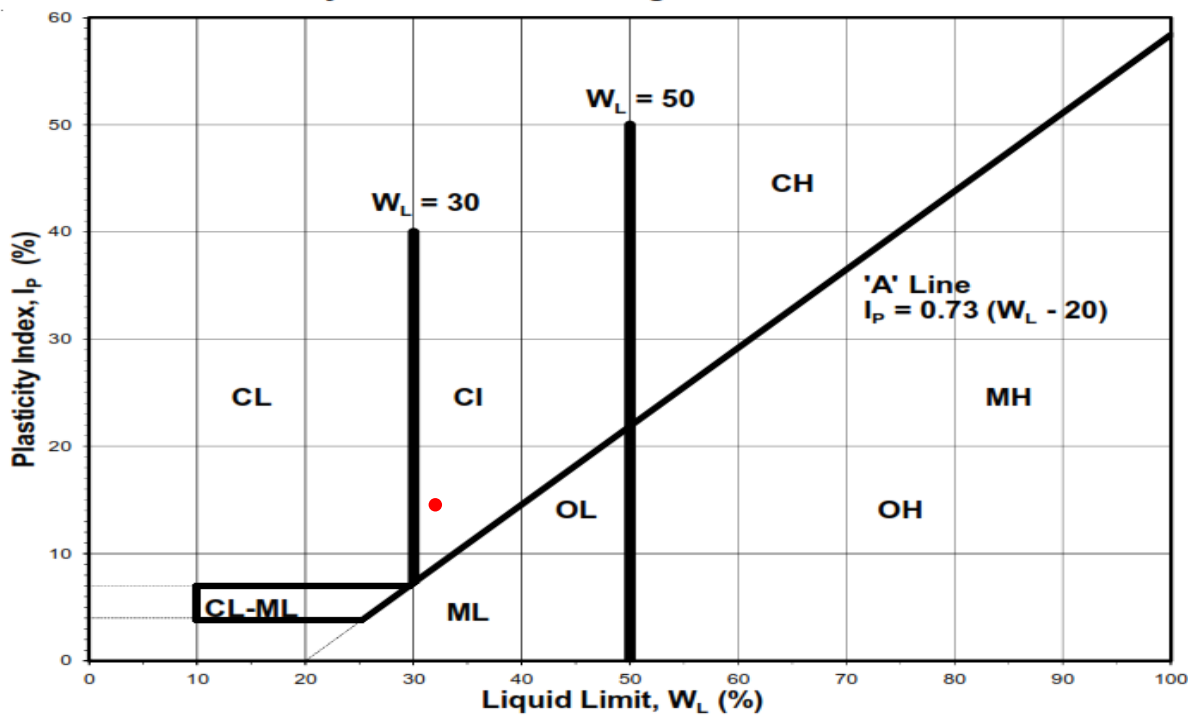
LAB NUMBER
BOREHOLE
SAMPLE
DEPTH (m)

1077
1
7
4.6-5.2

PLASTIC LIMIT
LIQUID LIMIT
PLASTICITY INDEX

17.5
32.4
14.9

Plasticity Chart for Soil Passing 425 Micron Sieve



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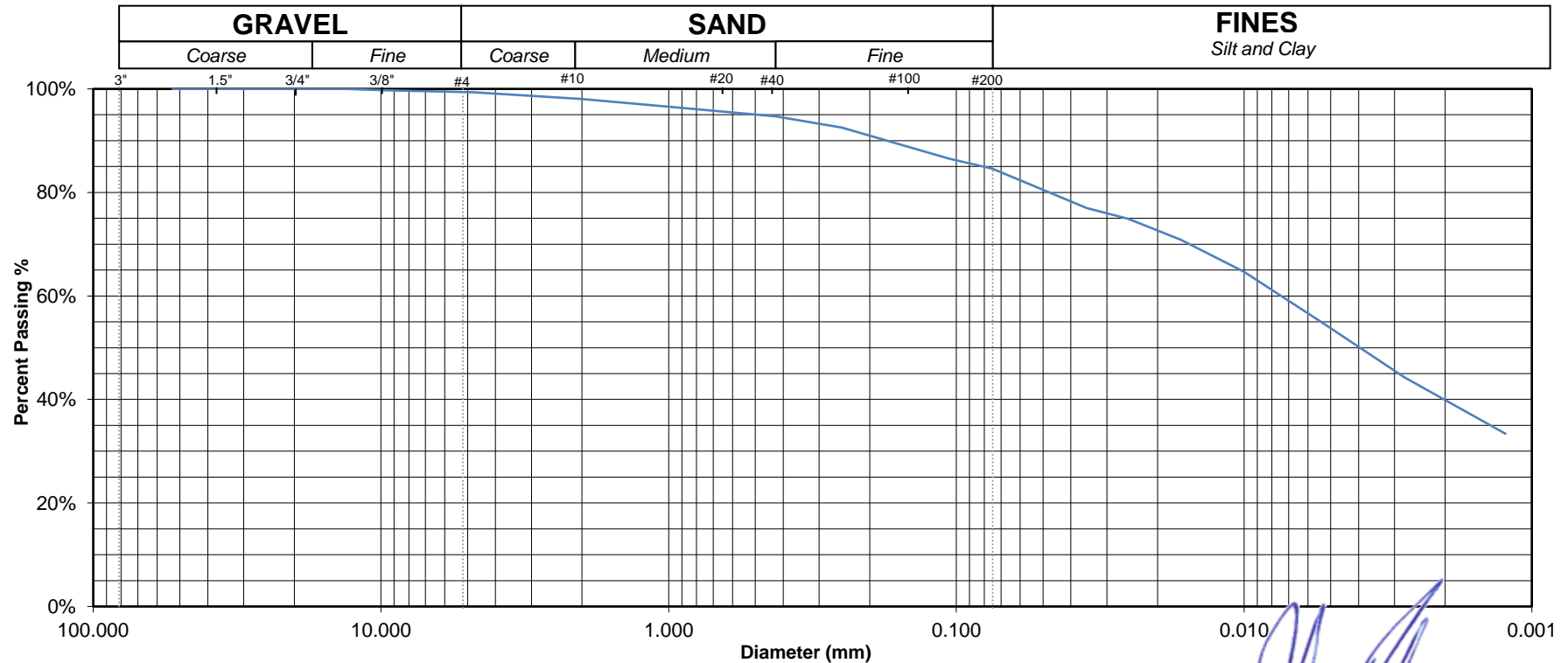
GRAIN SIZE DISTRIBUTION MTO LS 702 / ASTM D7928 / ASTM D6913

Project Number: OGTW2282.1000
Project Client: RC Spenser
Project Name: Highway 3 Division Watermain
Project Location: Essex

Sampled by: DS
Tested by: SS

Sampled on: 8-Dec-2022
Received on: 8-Dec-2022
Tested on: 15-Dec-2022

		Test Results				
Sample Location:	BH 1, Sa.7	Gravel	Sand	Silt	Clay	Moisture content (%)
Sample Identification:	1084	0.7%	14.7%	44.7%	39.9%	20.5%



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Project Number: OGTW2282.1000
Project Client: RC Spenser
Project Name: Highway 3 Division Watermain
Project Location: Essex

Sampled by: DS
Tested by: JP

Sampled on: 8-Dec-22
Received on: 8-Dec-22
Tested on: 16-Dec-22

Test Results

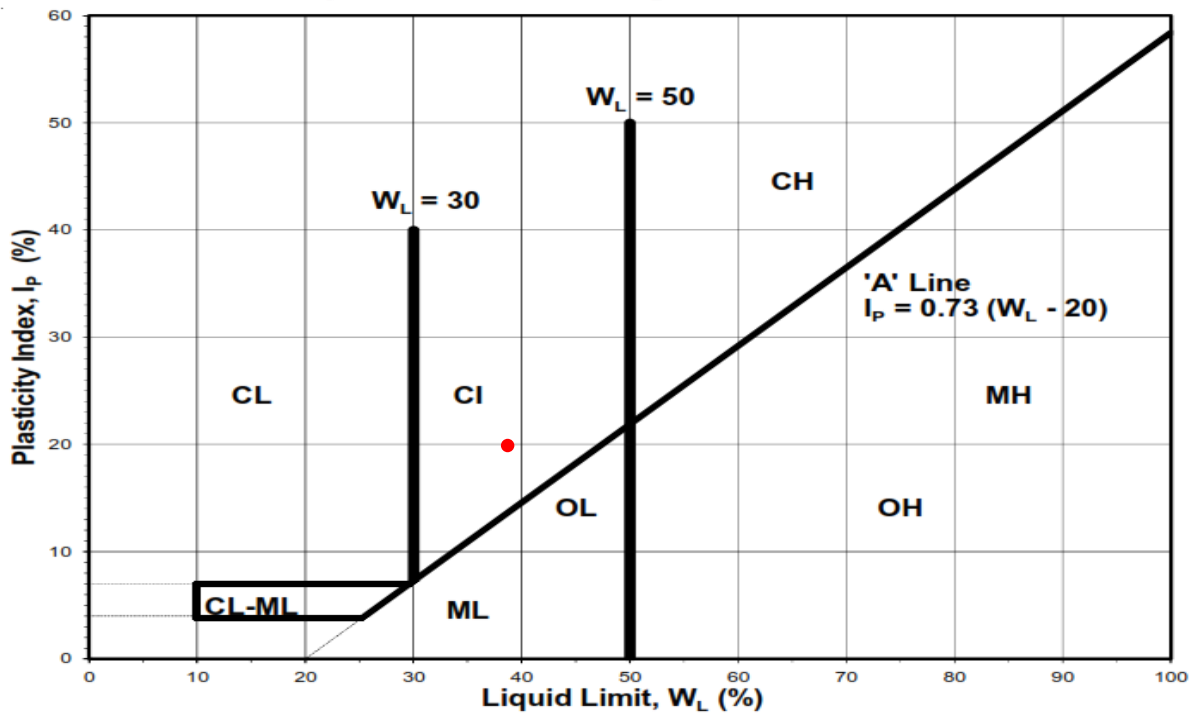
LAB NUMBER
BOREHOLE
SAMPLE
DEPTH (m)

1078
2
5
3-3.7

PLASTIC LIMIT
LIQUID LIMIT
PLASTICITY INDEX

18.9
39.2
20.2

Plasticity Chart for Soil Passing 425 Micron Sieve



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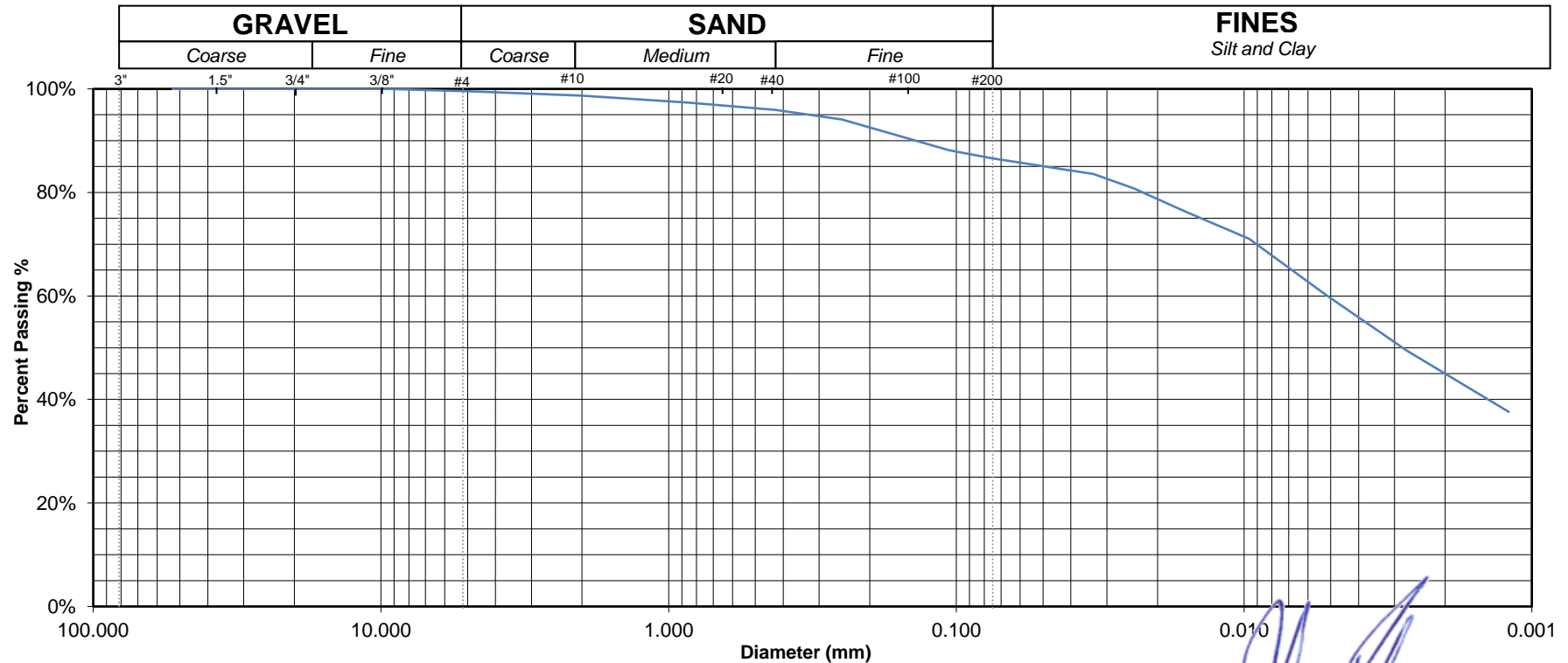
GRAIN SIZE DISTRIBUTION MTO LS 702 / ASTM D7928 / ASTM D6913

Project Number: OGTW2282.1000
Project Client: RC Spenser
Project Name: Highway 3 Division Watermain
Project Location: Essex

Sampled by: DS
Tested by: SS

Sampled on: 8-Dec-2022
Received on: 8-Dec-2022
Tested on: 15-Dec-2022

		Test Results				
Sample Location:	BH 2, Sa.5	Gravel	Sand	Silt	Clay	Moisture content (%)
Sample Identification:	1085	0.5%	12.9%	41.6%	45.0%	17.1%



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Project Number: OGTW2282.1000
Project Client: RC Spenser
Project Name: Highway 3 Division Watermain
Project Location: Essex

Sampled by: DS
Tested by: JP

Sampled on: 8-Dec-22
Received on: 8-Dec-22
Tested on: 16-Dec-22

Test Results

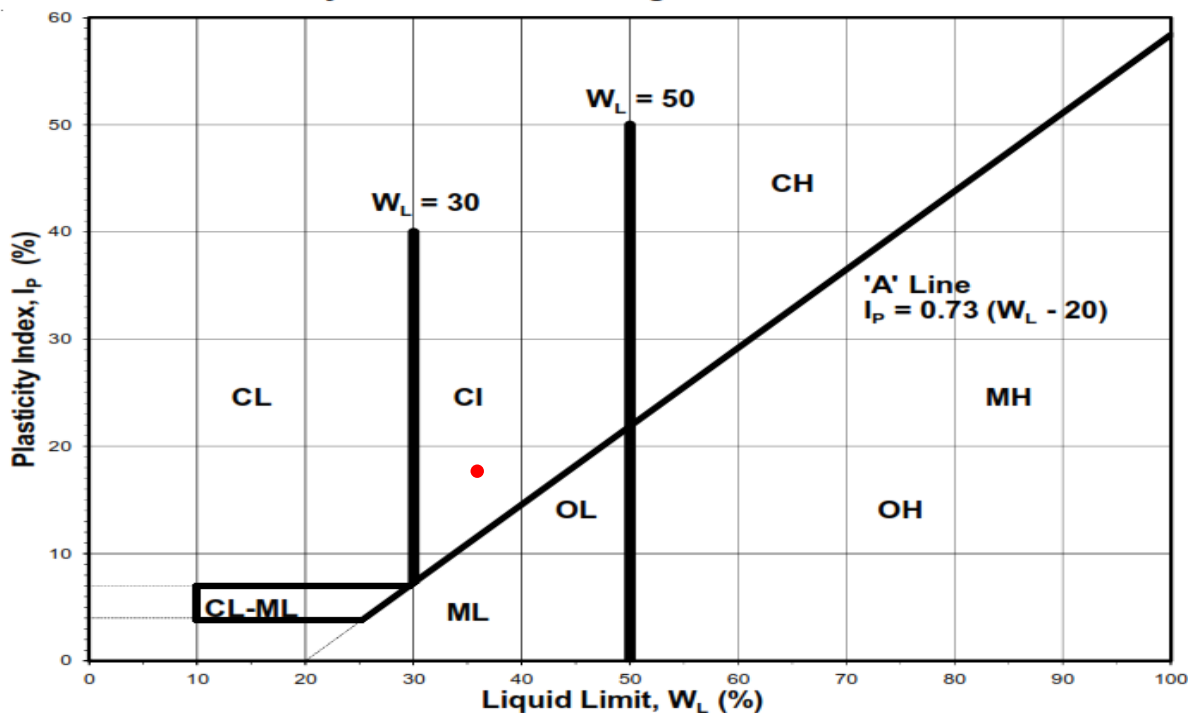
LAB NUMBER
BOREHOLE
SAMPLE
DEPTH (m)

1079
2
6
3.8-4.4

PLASTIC LIMIT
LIQUID LIMIT
PLASTICITY INDEX

18.3
36.3
18.0

Plasticity Chart for Soil Passing 425 Micron Sieve



Signed by:

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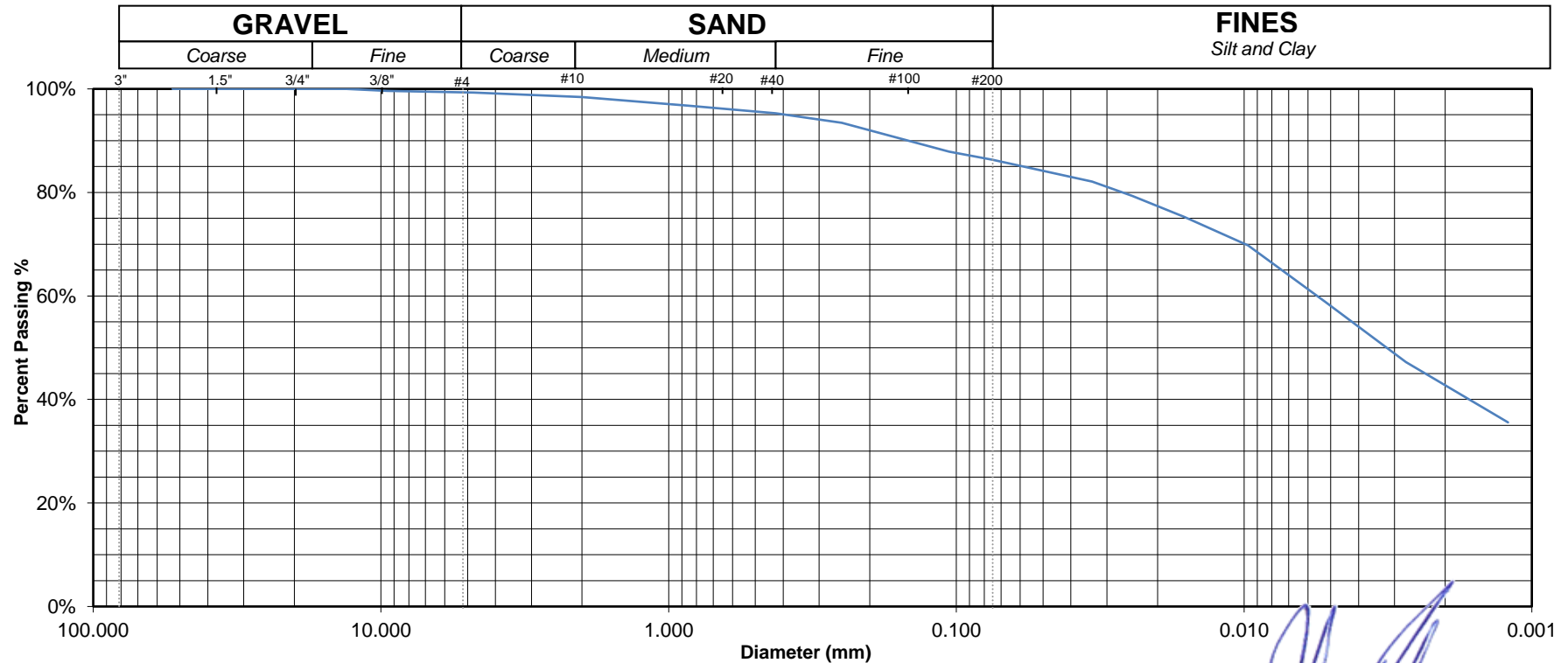
GRAIN SIZE DISTRIBUTION MTO LS 702 / ASTM D7928 / ASTM D6913

Project Number: OGTW2282.1000
Project Client: RC Spenser
Project Name: Highway 3 Division Watermain
Project Location: Essex

Sampled by: DS
Tested by: SS

Sampled on: 8-Dec-2022
Received on: 8-Dec-2022
Tested on: 15-Dec-2022

		Test Results				
Sample Location:	BH 2, Sa.6	Gravel	Sand	Silt	Clay	Moisture content (%)
Sample Identification:	1086	0.7%	13.0%	43.6%	42.7%	18.4%



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ATTERBERG LIMITS ASTM D-4318 or LS-703 / 704

Project Number: OGTW2282.1000
Project Client: RC Spenser
Project Name: Highway 3 Division Watermain
Project Location: Essex

Sampled by: DS
Tested by: JP

Sampled on: 8-Dec-22
Received on: 8-Dec-22
Tested on: 16-Dec-22

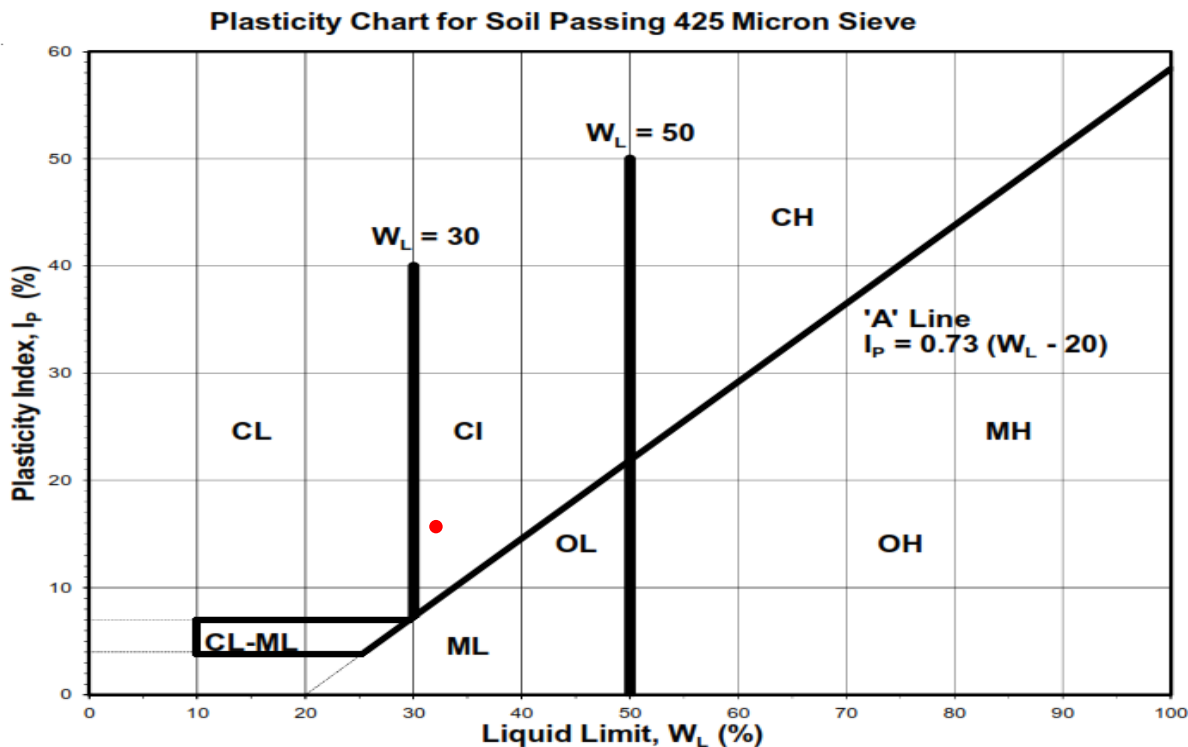
Test Results

LAB NUMBER
BOREHOLE
SAMPLE
DEPTH (m)

1080
2
8
6.1-6.7

PLASTIC LIMIT
LIQUID LIMIT
PLASTICITY INDEX

16.5
32.5
16.0



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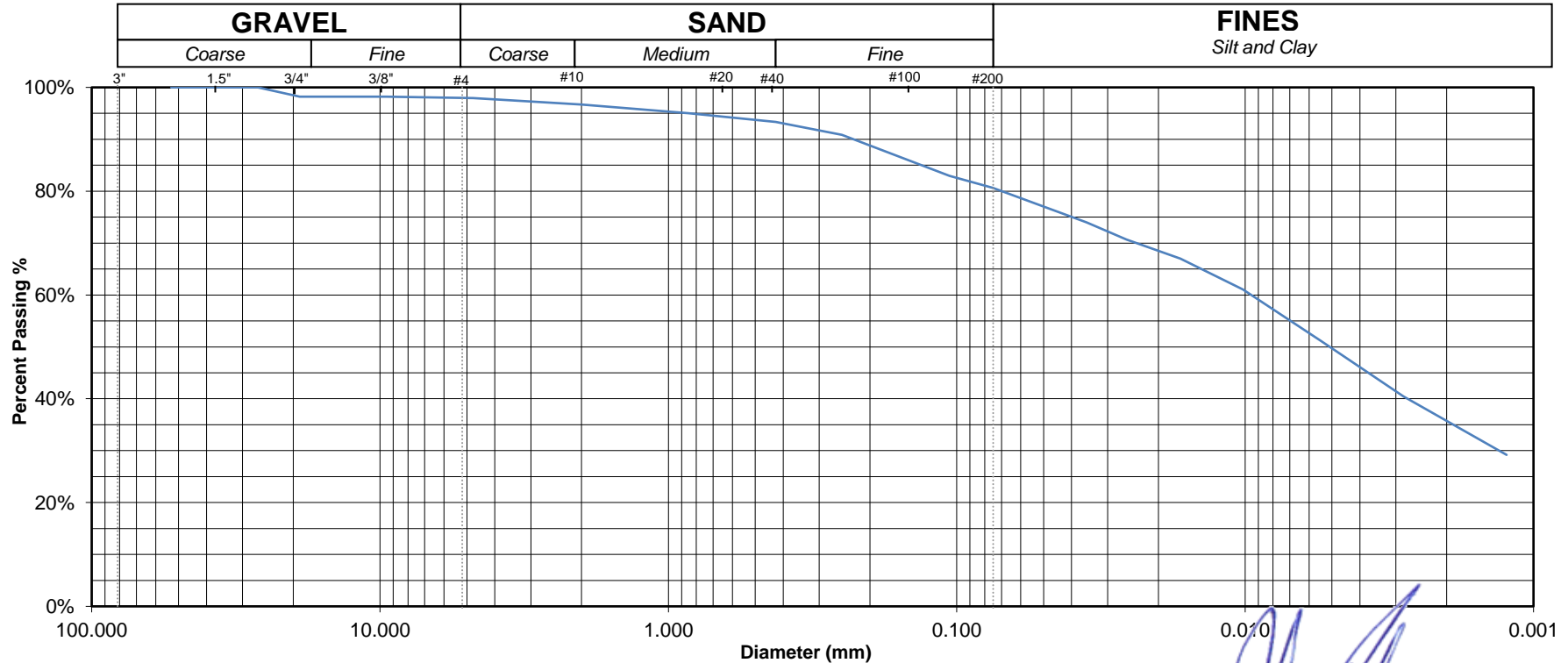
GRAIN SIZE DISTRIBUTION MTO LS 702 / ASTM D7928 / ASTM D6913

Project Number: OGTW2282.1000
Project Client: RC Spenser
Project Name: Highway 3 Division Watermain
Project Location: Essex

Sampled by: DS
Tested by: SS

Sampled on: 8-Dec-2022
Received on: 8-Dec-2022
Tested on: 15-Dec-2022

		Test Results				
Sample Location:	BH 2, Sa.8	Gravel	Sand	Silt	Clay	Moisture content (%)
Sample Identification:	1087	2.1%	17.3%	44.9%	35.7%	20.8%



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ATTERBERG LIMITS ASTM D-4318 or LS-703 / 704

Project Number: OGTW2282.1000
Project Client: RC Spenser
Project Name: Highway 3 Division Watermain
Project Location: Essex

Sampled by: DS
Tested by: JP

Sampled on: 8-Dec-22
Received on: 8-Dec-22
Tested on: 16-Dec-22

Test Results

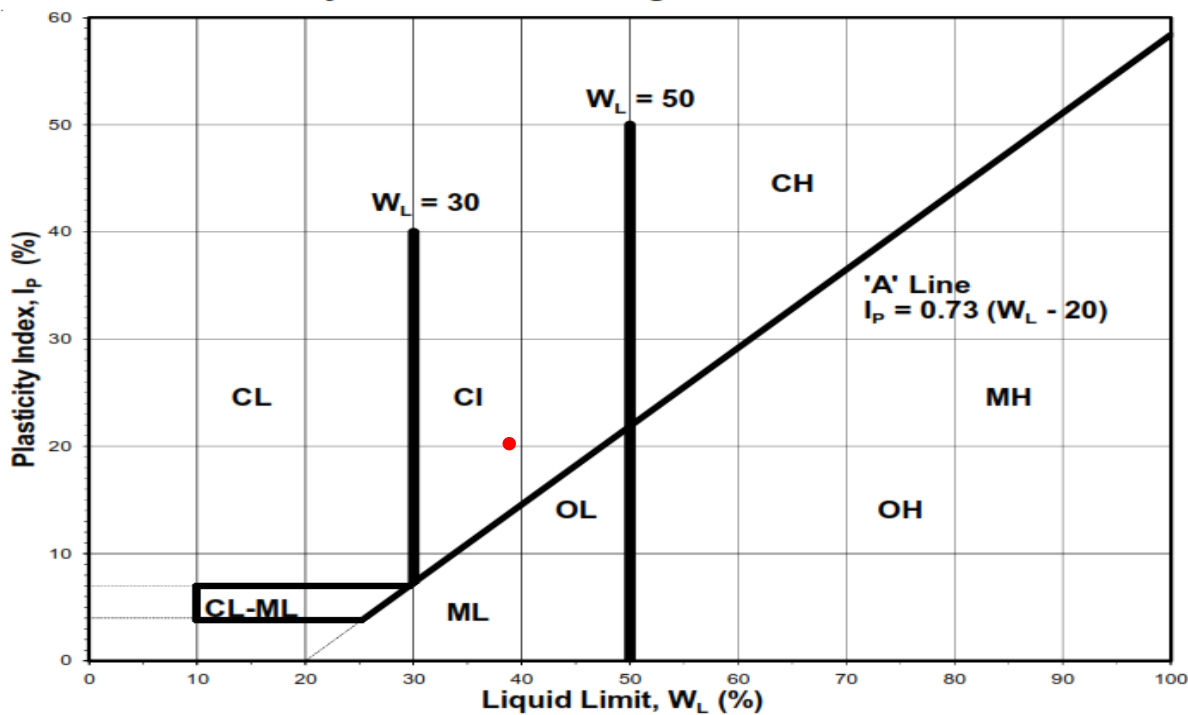
LAB NUMBER
BOREHOLE
SAMPLE
DEPTH (m)

1081
3
4
2.3-2.9

PLASTIC LIMIT
LIQUID LIMIT
PLASTICITY INDEX

18.7
39.3
20.6

Plasticity Chart for Soil Passing 425 Micron Sieve



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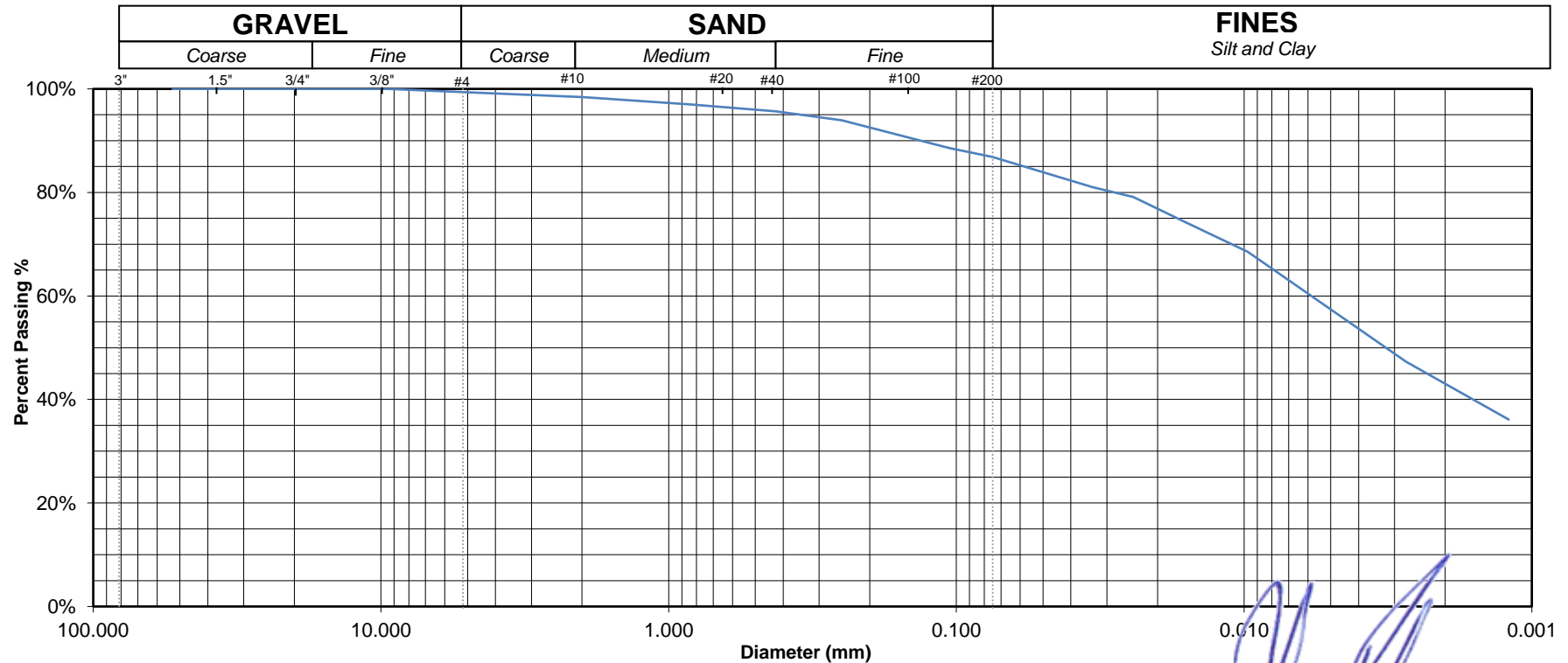
GRAIN SIZE DISTRIBUTION MTO LS 702 / ASTM D7928 / ASTM D6913

Project Number: OGTW2282.1000
Project Client: RC Spenser
Project Name: Highway 3 Division Watermain
Project Location: Essex

Sampled by: DS
Tested by: SS

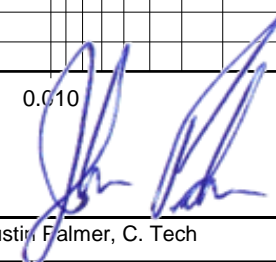
Sampled on: 8-Dec-2022
Received on: 8-Dec-2022
Tested on: 15-Dec-2022

		Test Results				
Sample Location:	BH 3, Sa.4	Gravel	Sand	Silt	Clay	Moisture content (%)
Sample Identification:	1088	0.7%	12.5%	43.8%	43.0%	17.2%



SW-WL-0004

More information available upon request

Signed by: 
Justin Palmer, C. Tech

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ATTERBERG LIMITS ASTM D-4318 or LS-703 / 704

Project Number: OGTW2282.1000
Project Client: RC Spenser
Project Name: Highway 3 Division Watermain
Project Location: Essex

Sampled by: DS
Tested by: JP

Sampled on: 8-Dec-22
Received on: 8-Dec-22
Tested on: 16-Dec-22

Test Results

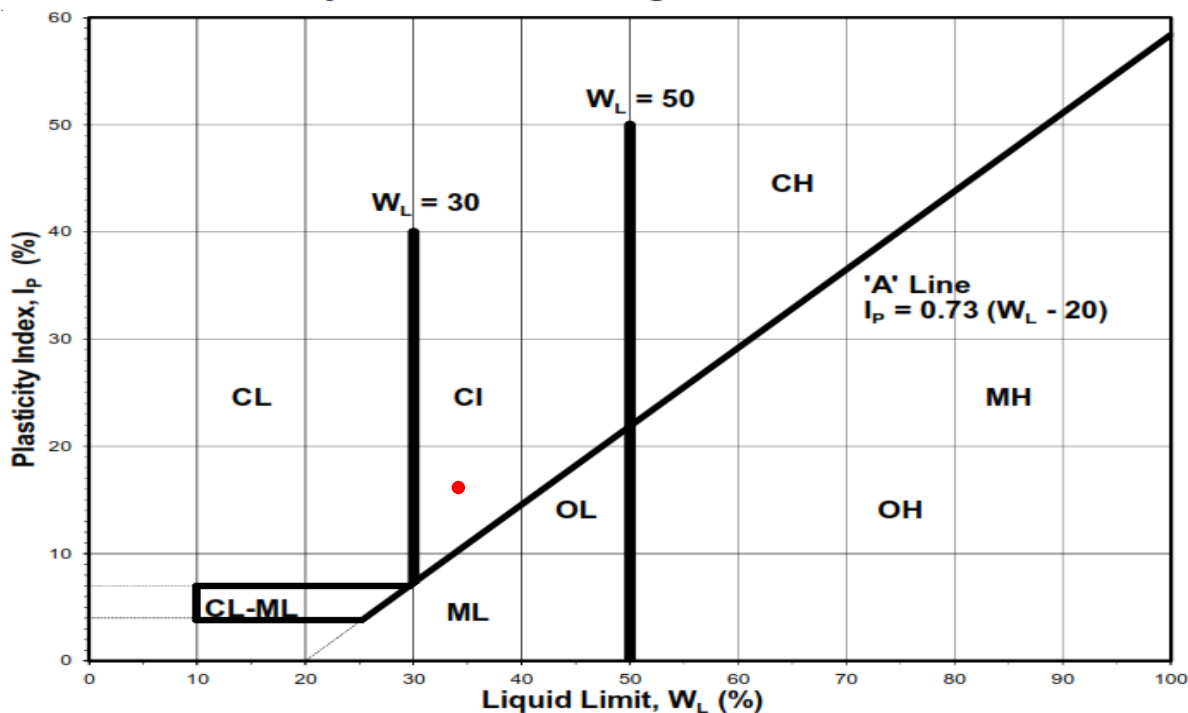
LAB NUMBER
BOREHOLE
SAMPLE
DEPTH (m)

1082
3
5
3-3.7

PLASTIC LIMIT
LIQUID LIMIT
PLASTICITY INDEX

18.1
34.6
16.5

Plasticity Chart for Soil Passing 425 Micron Sieve



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More information available upon request

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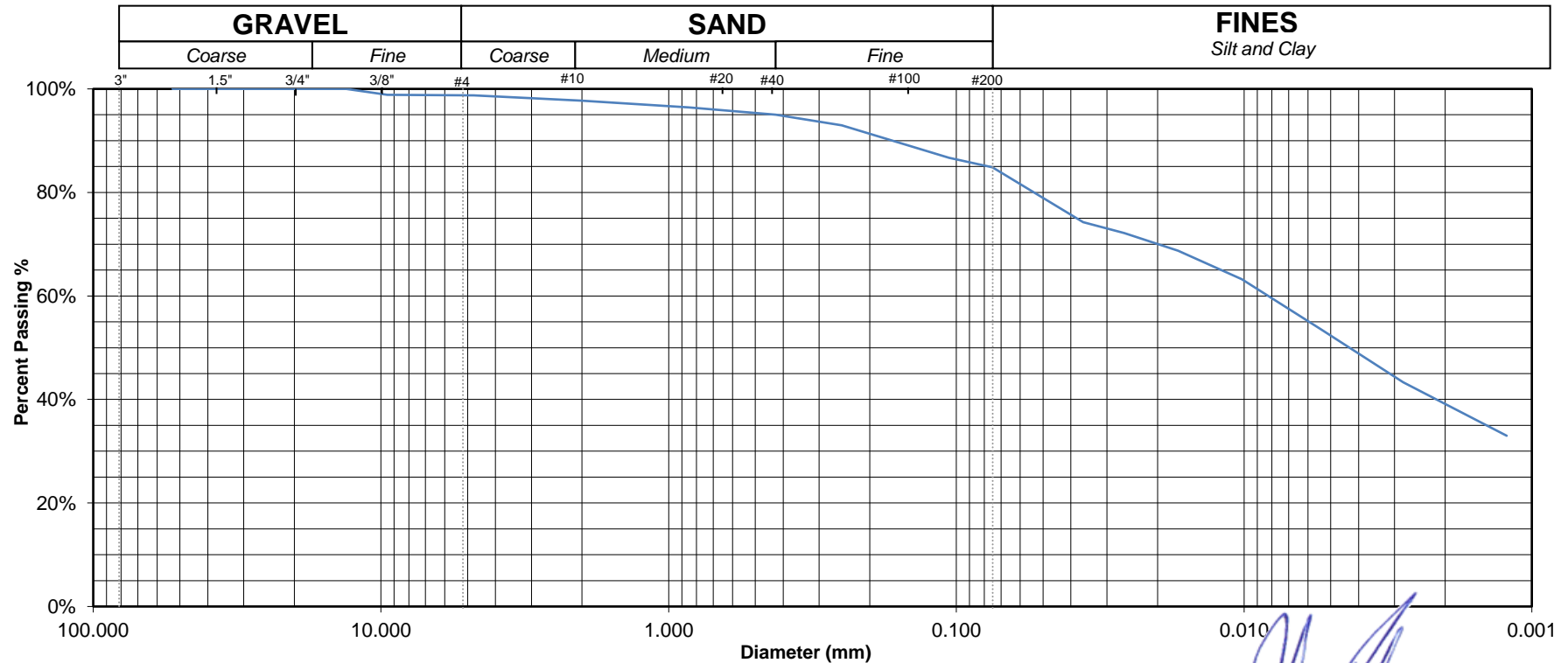
GRAIN SIZE DISTRIBUTION MTO LS 702 / ASTM D7928 / ASTM D6913

Project Number: OGTW2282.1000
Project Client: RC Spenser
Project Name: Highway 3 Division Watermain
Project Location: Essex

Sampled by: DS
Tested by: SS

Sampled on: 8-Dec-2022
Received on: 8-Dec-2022
Tested on: 15-Dec-2022

		Test Results				
Sample Location:	BH 3, Sa.5	Gravel	Sand	Silt	Clay	Moisture content (%)
Sample Identification:	1089	1.3%	13.9%	45.7%	39.1%	19.0%



SW-WL-0004

More information available upon request

Signed by:

Justin Palmer, C. Tech

APPENDIX

D

COMPARATIVE ASSESSMENT OF
INSTALLATION METHODS

TABLE D.1: COMPARATIVE ASSESSMENT OF THE INSTALLATION METHODS

Installation Method	Advantages	Disadvantages
Open-Cut	<ul style="list-style-type: none"> ● Best control of gradient and alignment of sewer ● Reduced potential of difficulties due to obstructions ● Least risk of un-anticipated impact on active highway ● Could permit higher invert elevation than trenchless methods 	<ul style="list-style-type: none"> ● Requires lane closures and pavement reconstruction ● Some groundwater control required to handle perched groundwater condition within silty sand and the highway embankment fill ● Potential post-construction settlement of trench backfill which could be mitigated using unshrinkable fill ● Greater impact on traffic than trenchless technologies
Jack and Bore	<ul style="list-style-type: none"> ● Pipe can be installed without lane closures resulting in minimal traffic disruption 	<ul style="list-style-type: none"> ● Large work area required for jacking pit ● Some groundwater control required to handle perched groundwater condition ● Risk of misalignment of casing/pipe if obstructions are encountered
Pipe Ramming	<ul style="list-style-type: none"> ● Pipe can be installed without lane closures resulting in minimal traffic disruption ● Less risk of subsidence above pipe alignment than jack and bore installation method 	<ul style="list-style-type: none"> ● Some groundwater control required to handle perched groundwater condition ● Potential for heaving at ground surface ● Vibration from pipe ramming may induce settlement of surrounding loose soils ● Lower risk of misalignment of casing/pipe or loss of ground, as compared with jack and bore installation method ● Low risk that vibration from pipe ramming will induce settlement of surrounding loose soils
MTBM	<ul style="list-style-type: none"> ● Machine is able to counterbalance earth and water pressures in a controlled manner, thereby reducing the risk of ground losses during tunnelling ● Machine can also be specified to have the capability to crush boulders and nests of cobbles 	<ul style="list-style-type: none"> ● Lack of availability of machines with a suitable diameter bore ● Relatively expensive, with high mobilization cost relative to this single short crossing
HDD	<ul style="list-style-type: none"> ● Pipe can be installed without lane closures resulting in minimal traffic disruption ● Groundwater control would not be an issue during the installation 	<ul style="list-style-type: none"> ● More risk of subsidence above pipe alignment than other uncased methods ● Large work area required for the temporary work spaces ● Risk of ground surface subsidence increases with decreasing cover alignment deviation and/or halt the bore ● Difficult steering in soft clays

APPENDIX

E

NON-STANDARD SPECIAL PROVISION



**CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY
TRENCHLESS METHOD**

1.0 SCOPE

This Special Provision covers the requirements for the installation of pipes by a selected trenchless method.

2.0 REFERENCES

This Special Provision refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, General

OPSS 180 General Specification for the Management of Excess Materials

Ontario Provincial Standard Specifications, Construction

OPSS 182 Environmental Protection for Construction in Waterbodies and On Waterbody Banks
OPSS 401 Trenching, Backfilling, and Compacting
OPSS 402 Excavating, Backfilling, and Compacting for Maintenance Holes, Catch Basins, Ditch Inlets and Valve Chambers
OPSS 403 Rock Excavation for Pipelines, Utilities, and Associated Structures in Open Cut
OPSS 404 Construction Specification for Support Systems
OPSS 409 Closed-Circuit Television (CCTV) Inspection of Pipelines
OPSS 490 Site Preparation for Pipelines, Utilities, and Associated Structures
OPSS 491 Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492 Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 510 Construction Specification for Removal
OPSS 517 Construction Specification for Dewatering
OPSS 539 Construction Specification for Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

OPSS 1004 Material Specification for Aggregates - Miscellaneous
OPSS 1350 Material Specification for Concrete - Materials and Production
OPSS 1440 Steel Reinforcement for Concrete
OPSS 1802 Material Specification for Smooth Walled Steel Pipe
OPSS 1820 Material Specification for Circular and Elliptical Concrete Pipe
OPSS 1840 Material Specification for Non-Pressure Polyethylene (PE) Plastic Pipe Products
OPSS 1841 Material Specification for Non-Pressure Polyvinyl Chloride (PVC) Plastic Pipe Products

CSA Standards

A3000 Cementitious Materials Compendium
B182.6 Profile polyethylene (PE) sewer pipe and fittings for leak-proof sewer applications

B182.8	Profile Polyethylene (PE) Storm Sewer and Drainage Pipe and Fittings
B182.13	Profile Polypropylene (PP) Sewer Pipe and Fittings for Leak-proof Sewer Applications
C22.1	Canadian Electrical Code
W59	Welded Steel Construction

American Society for Testing and Materials (ASTM) International Standards

A 252M-19	Standard Specification for Welded and Seamless Steel Pipe Piles
C-33	Standard Specification for Concrete Aggregates.
C-39	Standard Test method for Compressive Strength of Cylindrical Concrete
D 2657	Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
D 3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
D6910	Standard Specification for Marsh Funnel Viscosity of Clay Construction Slurries
F 894	Standard Specification for Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

International Organization for Standardization/International Electrotechnical Commission (ISO/IEC)

17025	General Requirements for the Competence of the Testing and Calibration Laboratories
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3.0 DEFINITIONS

For the purpose of this Special Provision, the following definitions apply:

Annular Space means the space between the inside edge of the opening and the outside edge of the penetrating item or inserted pipe.

Auger Jack & Bore means a method of forming a horizontal bore in the subsurface by simultaneously or alternately jacking into the ground a casing pipe and rotating a cutter head at the lead end of an auger flight with removal of material from inside the casing by using continuous-flight augers.

Backreamer or Reamer means a cutting head suitably designed for the subsurface conditions that is attached to drilling equipment and used to enlarge the bore

Bore Path means a drilled path according to the grade and alignment tolerances specified in the Contract Documents.

Boulder Number Ratio (BNR) means the number of individual boulders per m³ of cumulative boulder volume.

Boulder Volume Ratio (BVR) means the ratio between the cumulative volume of boulders and the volume of the material excavated.

Design Engineer means the Engineer retained by the Contractor who produces the design and Working Drawings and other engineering documents required of the Contractor. The Design Engineer shall be licensed to practice in the Province of Ontario.

Design Checking Engineer means the Engineer retained by the Contractor who checks the original design and Working Drawings.

Digger Shield/Hand Mining means a method of forming a horizontal bore in the subsurface by essentially

simultaneously jacking a casing pipe, with or without a protective shield at the lead end, into the ground while tunnelling and removal of earth and rock is completed using manually-operated tools (e.g., pneumatic spades, rams, shovels, breaker bars, etc.) or a “digger” type shield with a hydraulic excavator arm or “road-header” rock cutting machine to remove materials from inside the shield and liner pipe.

Drilling Fluids means a mixture of water and additives, such as bentonite, polymers, surfactants, and soda ash, designed to block the pore space on a bore wall, reduce friction in the bore, and to suspend and carry cuttings to the surface.

Drilling Fluid Hydraulic Fracture or “Frac Out” means a condition where the drilling fluid’s pressure in the bore is sufficient to fracture the soil and/or rock materials and allow the drilling fluids to migrate to the surface at an unplanned location.

Earth Pressure Balance (EPB) means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of mixed earth, rock and any drilling fluids or additives (spoil) as maintained by and in a chamber behind the cutting face of a tunnel boring machine through which spoil can pass only by manner of controlled-load relieving gates or an internal screw-conveyor that is separate from subsequent spoil conveyance systems (e.g., flight augers, belt conveyor, spoil bucket rail cars, etc.). Trenchless systems that apply pressure to the excavated face of the ground only through mechanical and jacking forces on metal parts of the machinery (e.g., steel parts of cutting tools, adjustable gates or doors at cutting face, etc.) will not be considered equivalent to EPB systems.

Excavation means all materials encountered regardless of type and extent and shall include removal of natural soil, boulders, cobbles, wood and fill regardless of means necessary to break consolidated materials for removal.

Environmentally Sensitive Area (ESA) means areas specified in the Contract Documents that are prohibited from entry or use.

Fill means man-made mixture of previously placed or handled materials such as sand, clay, silt, gravel, broken rock, sometimes containing organic and/or deleterious materials, placed in an excavation or other area to raise the surface elevation.

Guidance System means an electronic system capable of indicating the position, depth and orientation of the drill head during the directional drilling process.

Hand Mining means a method of forming a horizontal bore in the subsurface by simultaneously jacking ahead while tunnelling advances using hand-mining (man-entry operation or “Jack and Mine”) or a “digger” type shield with a hydraulic excavator arm to remove materials from inside the liner pipe.

Horizontal Directional Drilling (HDD) means a surface-launched trenchless technology for the installation of pipes, conduits, and cables. HDD creates a pilot bore along the design pathway and reams the pilot bore in one or more passes to a diameter suitable for the product, which is pulled into the prepared bore in the final steps of the process.

Inadvertent Returns means the unexpected flow of fluids, saturated materials (or flowing soil) towards the drilling rig that typically originated from an artesian aquifer encountered during the drilling process.

Loss of Circulation means the discontinuation of the flow of drilling fluid in the bore back to the entry or exit point or other planned recovery points.

Microtunnelling means an underground method of constructing a passage by using a microtunnelling boring machine (MTBM) or hand mining using a shield to support the opening.

MTBM means a microtunnelling boring machine.

Pilot Bore means the initial bore to set directional controlled horizontal and vertical alignment between the connecting points.

Pipe means pipe culverts, pipe storm and sanitary sewers, watermain pipe, conduits, and ducts.

Pipe Jacking means a method for installing steel casing, concrete pipe or other acceptable material in the subsurface utilizing hydraulically operated jacks of adequate number and capacity for the smooth and uniform advancement of the casing or pipe.

Pipe Ramming means a method for installing steel casings utilizing the energy from a percussion hammer to advance a steel casing with a cutting shoe attached at the front end of the casing.

Project Superintendent means an individual representing the Contractor that oversees the trenchless or tunnelling operation qualified to provide the services specified in the Contract Documents.

Pullback means that part of the HDD method in which the drilling equipment is pulled back through the bore path to the entry point.

Reaming means a process for enlarging the bore path.

Rock means natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a volume of 0.5 m³ or greater.

Shaft means an excavation used as entry and/or exit points, alternatively called entry/exit pits, from which the trenchless method is initiated for the installation of the pipe product.

Slurry Pressure Balance (SPB) means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of slurry as maintained by and in a chamber behind the cutting face of a tunnel boring machine (TBM) or microtunnelling boring machine (MTBM), through which spoil can pass only by manner of controlled-pressure and controlled flow slurry pumping systems.

Slurry means a mixture of soil and/or rock cuttings, and drilling fluid.

Soil means all soils except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials.

Spoil means mix of earth cuttings, rock cuttings, water (groundwater or added water), bentonite, polymers and/or other additives that is discharged from the trenchless construction systems.

Strike Alert means a system that is intended to alert and protect the operator in the case of inadvertent drilling into an electrical utility cable. The strike alert system consists of a sensor and an alarm connected to the drill rig and a grounding stake. The alarm may be audio or visual or both.

TBM means a tunnel boring machine.

Trenchless Contractor means the subcontractor retained by the Prime Contractor qualified to provide the services specified in the Contract Documents.

Trenchless Installation means an underground method of constructing a passage open at both ends that involves installing a pipe product by auger jack & boring, pipe ramming, horizontal directional drilling, or tunnelling.

Tunnelling means an underground method of constructing a passage using a tunnel boring machine (TBM) operated by personnel within the tunnel, a microtunnelling boring machine (MTBM) operated by personnel at a remote control station or excavation using a shield to support the opening and protect workers.

Zone of Influence means a zone defined by lines projected outward and upward at 45 degrees from horizontal to the ground surface from the vertical and horizontal alignment of the pipe constructed using trenchless/tunnel methods.

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Design

4.01.01 General

The Contractor shall determine the most appropriate method of trenchless installation for each pipe crossing for each location within the terms of this specification.

The trenchless installation method selected for each pipe crossing shall be designed for the subsurface conditions in accordance with the Contract Documents.

The detailed design of the installation method selected to carry out the Work as specified in the Contract Documents shall be completed.

* Designer Fill-in, See Notes to Designer

4.02 Submission Requirements

4.02.01 Qualifications

At least two weeks prior to construction, the names of the Project Superintendent, and Trenchless Contractor shall be submitted to the Contract Administrator.

4.02.01.01 Project Superintendent

The Project Superintendent shall have a minimum of five (5) years experience on projects with similar scope and complexity.

During construction, the Project Superintendent shall not be changed without written permission from the Contract Administrator. A proposal to change the Project Superintendent shall be submitted at least one week prior to the actual change in Project Superintendent.

** Designer Fill-in, See Notes to Designer

4.02.01.02 Trenchless Contractor

The Trenchless Contractor shall have a minimum of five (5) years experience on projects with similar scope and complexity.

*** Designer Fill-in, See Notes to Designer

4.02.02 Working Drawings

Three (3) sets of Working Drawings for the selected trenchless installation method, and a Request to Proceed shall be submitted to the Contract Administrator two weeks (2) prior to the commencement of the Work or as per the Contract Documents.

The trenchless installation operation shall not proceed until a Notice to Proceed has been received from the Contract Administrator.

All Working Drawings shall bear the seal and signature of the Design Engineer and Design Checking Engineer.

Information and details shown on the Working Drawings shall include, but not limited to the following:

a) Plans and Details:

- i. Plans and profiles defining all horizontal and vertical alignment positions and positions of all utilities and other infrastructure within the zone of influence of the work.
- ii. A work plan outlining the materials, procedures, methods and schedule to be used to execute the Work.
- iii. A list of personnel, including backup personnel, and their qualifications and experience.
- iv. A traffic control plan.
- v. A safety plan including the company safety manual and emergency procedures.
- vi. The Working Area layout.
- vii. An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail.
- viii. A contingency plan with specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner.
- ix. A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan, detailing emergency procedures in the event that the fluid management plan fails.
- x. Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations.
- xi. Excavated materials disposal plan.
- xii. Locations of protection systems.
- xiii. Contingency plans for the following potential conditions:
 - Unforeseen obstructions causing stoppage.

- Deviation from required alignment and grade.
- Extended service disruption.
- Damage to the existing Utilities and methods of repair.
- Soil heaving or settlement.
- Contaminated soil or water.
- Alignment passing through buried structures.

b) Designs:

- i. Primary Liner/Secondary Liner design (e.g. steel liner plates, steel ribs and wood lagging, and steel casing etc.).
- ii. Design assumption and material data when materials other than those specified are proposed for use.
- iii. Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.
- iv. Minimum depth of cover for trenchless installation appropriate for the highway type and pipe diameter, maximum excavation diameter, maximum annulus, alignment and grade tolerance etc.
- v. Detailed subsurface conditions along the proposed path or within the footprint of the trenchless technology equipment or pits/shafts.

c) Materials:

- i. Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application.
- ii. Manufacturer data sheets for all drilling fluids and additives for use in Earth Pressure Balance (EPB), Slurry Pressure Balance (SPB).
- iii. Manufacturer data sheets for drilling systems.
- iv. Mix designs, target rheology criteria (e.g., viscosity, density, shear strength, gel time, pressure-filtration – fluid losses under pressure, etc.) and additive dosage rates for all slurries and Earth Pressure Balance (EPB) tunnel boring machine (TBM) and microtunnelling boring machine (MTBM) operations.
- v. The proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces.
- vi. Compressive strength of concrete pipe products.
- vii. Pipe class for all steel pipe products.
- viii. Steel for Permanent Casings:
 - One copy of a mill test certificate certifying that the steel meets the requirements for the appropriate standards for permanent casings shall be submitted to the Contract Administrator at the time of delivery.
 - Where mill test certificates originate from a mill outside Canada or the United States of America, the information on the mill certificates shall be verified by testing by a Canadian laboratory. The laboratory shall be certified by an organization accredited by the Standards Council of Canada to comply with the requirements of ISO/IEC 17025 for the specific tests or type of tests required by the material standard specified on the mill test certificate.

- The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date (i.e., yyyy-mm-dd), and the signature of an authorized officer of the Canadian testing laboratory.

ix. Slurry, drilling fluids, and tunnelling fluids:

- Type, source, and physical and chemical properties of bentonite, polymer or other additives;
- Source of water;
- Method of mixing;
- Water to solids ratio and the mass and volumes of the constituent parts, including any chemical admixtures or physical treatment employed to achieve required physical properties;
- Details of procedure to be used for monitoring physical properties of slurry, drilling fluids and tunneling fluids or EPB spoils; and
- Method of disposal of the slurry, drilling fluids and associated spoil.

d) Upstream/Downstream Portal Installation Procedure:

- Access shaft or entry/exit pit details, as applicable.
- Face support and other temporary support details, if applicable.

e) Primary Liner/Secondary Liner Installation and Grouting Procedure:

- Excavation and pipe installation procedures, including methods to handle obstructions and prevent soil cave-in.
- Details of tunnelling equipment/methods to be used for the works.

f) Excavation and Dewatering:

- Equipment and methods for control, handling, treatment, and disposal of groundwater and water or fluids introduced by the Contractor;
- Equipment and methods for maintaining control of ground inflow at the excavation face during excavation;
- Equipment and methods for removal of cobbles and boulders;
- Manufacturer data sheets for each TBM, shield, tunnelling system or drilling system noting all intermediate and final cut dimensions, and methods and equipment for controlling and measuring drilling fluid, Slurry Pressure Balance (SPB) and Earth Pressure Balance (EPB) pressures;
- Methods for measuring excavated volumes or weights of earth and rock materials cut from ground on a per meter or per pipe basis up to a maximum of 3 m long intervals per measurement;
- Target operating pressures (minimum and maximum) and range of expected pressure variation for slurry or EPB spoil at excavated face or drilling fluids at lead end of drilling equipment and in annular gap between maximum excavated dimensions and outside dimensions of tunnelling equipment, drilling equipment and primary liner systems;
- Basis for setting target operating conditions (pressures, flow rates, advance rates) and the relationship of target operating conditions to ground conditions;

- viii. Basis for selection of excavation tools (e.g., bits, TBM face tools, MTBM face tools, excavator fittings, etc.) as related to expected ground conditions;
- ix. Jacking forces for installation of pipe, for driving of trenchless equipment forward and, in the case of Auger Jack & Bore, for advancing the lead end of the casing ahead of the lead end of the auger cutting tools.

g) Monitoring Method:

Methods, equipment, frequency and repeatability (accuracy and precision) of data collection to be employed for measuring and monitoring shall be submitted for:

- i. Maintaining the alignment of the installation;
- ii. EPB, SPB and drilling fluid pressures at the leading edge of excavation (face), flow rates and volume or weights of spoil;
- iii. Jacking forces on pipes, linings and cutting tools;
- iv. Torque, total revolutions and revolution rates on rotating equipment such as TBM or MTBM heads, auger flights, drill bits, etc.
- v. Grout injection pressures and volumes;
- vi. Longitudinal position of all casings and excavation cutting tools (auger flight heads, TBM face, drill bit position, etc.); and
- vii. Ground displacements (heave and settlement); and noise and ground vibrations induced by trenchless construction.

4.02.03 As-Built Drawings

As-built drawings shall be submitted to the Contract Administrator in a reproducible format prior to the Contract completion.

The as-built drawings shall be dated and bear the seal and signature of the Design Engineer and Design Checking Engineer.

5.0 MATERIALS

5.01 Pipe

5.01.01 General

The product shall be concrete pipe, steel pipe or high density polyethylene pipe as specified.

All joints shall be suitable for jacking operations as specified in the Working Drawings.

Fittings shall be suitable and compatible with the class and type of pipe with which they will be used.

All fittings shall be designed to be watertight.

5.01.02 Steel Pipe

Steel pipe shall be according to ASTM A252.

All steel casing pipe shall be square cut.

Steel casing pipe shall meet a straightness tolerance of 1.5 mm/m. When placed anywhere on the pipe parallel to the pipe axis, there shall not be a gap more than 1.5 mm between a 1 m long straightedge and the pipe.

5.01.03 High Density Polyethylene Pipe

High density polyethylene (HDPE) pipe according to OPSS 1840 shall be used in accordance with ASTM D3350.

Fittings shall be according to CAN/CSA-B182.6 or ASTM F894 and suitable for the class and type of pipe with which they will be used.

Jointing of HDPE piping shall be completed according to the manufacturer's recommended procedures and ASTM D2657. Where conflicts exist between the manufacturer's instructions and ASTM D2657, the manufacturer's instructions are to be followed.

Jointing of HDPE piping to other piping materials or appurtenances shall be completed using flanged connections.

5.01.04 Concrete Pipe

Concrete pipe shall be according to OPSS 1820.

5.02 Concrete

Concrete shall be according to OPSS 1350. The concrete strength shall be as specified on the Working Drawings.

5.03 Steel Reinforcement

Steel reinforcement for concrete work shall be according to OPSS 1440.

5.04 Wood

Wood shall be according to OPSS 1601.

5.05 Drilling Fluids

Drilling fluid shall be mixed according to the Working Drawings.

Selection of drilling fluid type shall be based on the soils encountered in the subsurface investigation.

The drilling fluids shall be mixed according to the manufacturer's recommendations.

Slurry shall be mixed according to the submitted slurry design and be appropriate for the anticipated

subsurface conditions. The viscosity of slurry used for SPB tunnelling shall be no less than 40 seconds Marsh Funnel viscosity, as defined by ASTM D6910, measured prior to introduction of groundwater and spoil and as required to ensure:

- a) development of appropriate filter cake at excavation face to provide slurry support pressures exceeding ground and groundwater pressures at excavation face;
- b) lubricate installation of primary liners as required;
- c) transport spoil through pipe systems.

5.06 Grout

Purging grout shall conform to the requirements of OPSS 1004 and be wetted with only sufficient water to make the mixture plastic.

6.0 EQUIPMENT

6.01 Auger Jack & Bore

Except in the case of dewatering to at least 1 m below the tunnel/bore invert for the full length of the pipe alignment, Auger Jack & Bore shall not be used and will not be permitted where subsurface conditions indicate that saturated gravel, sand and silt soils may be encountered at pipe level or within one pipe diameter above or below outside pipe dimensions.

Pipe Auger Jack & Bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

Specific details of the equipment with which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner shall be submitted to the Contract Administrator for information purposes prior to proceeding with the Works.

The lead end of the auger shall be maintained at least one pipe diameter inside the lead end of the casing. The auger cutting tools shall not extend to or beyond the lead end of the casing at any time unless specific exception is provided by the Ministry prior to construction. Submittals shall identify anticipated jacking forces for advancing casing ahead of leading edge of auger cutting tools in addition to friction forces that are to be overcome by jacking systems.

6.02 Pipe Ramming

Pipe Ramming equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

The Pipe Ramming hammer(s) shall be capable of driving the pipe casing from the entry pit to the exit pit through the existing subsurface conditions at the site without removal of soil from within the casing until the lead end of the pipe is outside the zone of influence for any overlying infrastructure.

Specific details of the equipment with which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the pipe shall be submitted to the Contract Administrator for information purposes prior to proceeding with the Works.

6.03 Horizontal Directional Drilling

6.03.01 General

The Horizontal Directional Drilling (HDD) equipment shall consist of a directional drilling rig and a drilling fluid mixing and delivery system to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

6.03.02 Drilling Rig

The horizontal directional drilling rig shall:

- a) Consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head.
- b) Have drill rod that is suitable for both the drill and the product pipe installation.
- c) Contain a drill head that is steerable, equipped with the necessary cutting surfaces and fluid jets, and be suitable for the anticipated ground conditions.
- d) Have adequate reamers and down-bore tooling equipped with the necessary cutting surfaces and fluid jets to facilitate the product installation and be suitable for the anticipated ground conditions.
- e) Contain a guidance system to accurately guide boring operations.
- f) Be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation.
- g) Be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

The drill head shall be steerable by changing its rotation, be equipped with the necessary cutting surfaces and drilling fluid jets, and be of the type for the anticipated subsurface conditions,

6.03.04 Guidance System

The guidance system shall be setup, installed, and operated by trained and experienced personnel. The operator shall be aware of any magnetic or electromagnetic anomalies and shall consider such influences in the operation of the guidance system when a magnetic or electromagnetic system is used.

6.03.05 Drilling Fluid Mixing System

The drilling fluid mixing system shall be of sufficient size to thoroughly and uniformly mix the required drilling fluid.

6.03.06 Drilling Fluid Delivery System

The delivery system shall have a means of measuring and controlling fluid pressures and be of sufficient flow capacity to ensure that all slurry volumes are adequate for the length and diameter of the final bore and the anticipated subsurface conditions. Connections between the delivery pump and drill pipe shall be leak-free.

6.04 Tunnelling

Tunnelling equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein. Specific details of the Tunnelling equipment included in the submission shall be provided for:

- a) rock or boulder breaking and removal;
- b) equipment used within shields for spilling, fore-poling, face drainage, breasting boards/plates and for otherwise maintaining support of the tunnel crown and face under all anticipated conditions;
- c) jacking systems;
- d) alignment control systems;

Use of rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use. Use of explosives is prohibited without specific application and acceptance by the Ministry prior to construction.

6.05 Microtunnelling Equipment

The Contractor shall be responsible for selecting Microtunnelling equipment which, based on past experience, has proven to be satisfactory for excavation of the soils that will be encountered.

The Contractor shall employ Microtunnelling equipment that will be capable of handling the various anticipated ground conditions.

The MTBM shall also be capable of controlling loss of soil ahead of and around the machine and shall provide continuous pressurized support of the excavated face.

- a) Remote Control System – The Contractor shall provide a MTBM that includes a remote control system with the following features:
 - i. Allows for operation of the system without the need for personnel to enter the microtunnel.
 - ii. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance and installed length.
 - iii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by product pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.
 - iv. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.
 - v. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
 - vi. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
 - vii. The system shall include a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits required for

successful microtunnelling, can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.

- viii. The type of separation process shall be suited to the size of microtunnel being constructed, the soil type being excavated, and the work space available at each work area.
 - ix. The system shall allow the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.
- b) Active Direction Control – The Contractor shall provide a MTBM that includes an active direction control system with the following features:
- i. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference.
 - ii. Provides active steering information that shall be monitored and transmitted to the operating console and recorded.
 - iii. Provides positioning and operation information to the operator on the control console.

6.05.01 Pipe Jacking Equipment

Provide a pipe jacking system with the following features:

- a) Has the main jacks mounted in a jacking frame located in the launch shaft.
- b) Has a jacking frame that successively pushes towards a receiving shaft, a string of product pipe that follows the microtunnelling excavation equipment.
- c) Has sufficient jacking capacity to push the microtunnelling excavation equipment and the string of pipe through the ground.
- d) The main jack station may be complemented with the use of intermediate jacking stations as required.
- e) Has a capacity at least 20 % greater than the calculated maximum jacking load.
- f) Develops a uniform distribution of jacking forces on the end of the casing pipe.
- g) Provides and maintains a pipe lubrication system at all times to lower the friction developed on the surface of the pipe during jacking.
- h) Jack Thrust Blocking shall adequately support the jacking pressure developed by the main jacking system.
- i) Special care shall be taken when setting the pipe guide rails in the jacking shaft to ensure correctness of the alignment, grade, and stability.

6.05.02 Spoil Separation System

The Contractor shall determine the type of spoil separation equipment needed for each drive based on the geotechnical information available and other project constraints.

6.05.03 Electrical Equipment, Fixtures and Systems

Electrical equipment shall be suitably insulated for noise reduction. Noise produced by electrical equipment must comply with local municipal noise by-laws.

Electrical systems shall conform to requirements of the Canadian Electrical Code – CSA C22.1.

7.0 CONSTRUCTION

7.01 General

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting the work. The proposed method of pipe installation to be used by the Contractor shall be subject to the limitations presented in the following subsections.

The Contractor's Engineer shall supervise the work at all times.

A Request to Proceed shall be submitted to the Contract Administrator upon completion of each of the following operations and prior to commencement of each subsequent operation and no less than 2 weeks prior to the commencement of the trenchless installation.

- a) Site Surveying (see Clause 4.02)
- b) Excavation for pits including dewatering of excavations
- c) Jacking / Ramming / Directional Drilling of Casing / Liner
- d) Installation of the Product
- e) Grouting Operations

Operations a) to e) shall not proceed until the Contract Administrator has issued a Notice to Proceed for each proceeding operation.

7.01.01 Layout, Alignment and Depth Control

The location of the installation shall be established from the lines, elevations and tolerances specified in the Contract Documents. The pipe installation shall be to the horizontal and vertical alignments specified in the Contract Drawings. Deviations from location, alignment, grades and/or invert levels shall be corrected by the Contractor at no cost to the Ministry.

All reference points necessary to construct the pipe installation and appurtenances shall be laid out.

The Contractor shall calibrate tracking and locating equipment at the beginning of each Working Day, and shall monitor and record the alignment and depth readings provided by the tracking system every 2 m.

The Contract Administrator shall be provided with the assistance and access necessary to check the layout of the pipe installation and associated appurtenances.

The Contractor shall submit records of the alignment and depth of the installation to the Contract Administrator at the completion of the installation.

7.01.02 Construction Shafts

Construction shafts shall be specified in the Contractor's submission. The boundaries and protection of these shall be as required to contain all disturbances to areas outside of the ESA limits.

Shafts shall be maintained in a drained condition.

A minimum 2.4 m high secure fence shall be installed around the perimeter of the construction shaft area with gates and truck entrances. The fence shall be removed on completion of the work.

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS 539.

Where the stability, safety, or function of an existing roadway, railway, watercourse, other works, ESA's, or proposed works may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

Any disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the Contractor, at no additional cost to the Ministry.

7.01.05 Stability of Excavation

The construction methods, plant, procedures, and precautions employed shall ensure that excavations are stable, free from disturbance, and maintained in a drained condition.

The construction methods, plant, procedures, and materials employed shall prevent the migration of soil and/or rock material into the excavation from adjacent ground.

7.01.06 Preservation and Protection of Existing Facilities

Preservation and protection of existing facilities shall be according to OPSS 491.

Minimum horizontal and vertical clearances to existing facilities as specified in the Contract Documents shall be maintained. Clearances shall be measured from the nearest edge of the largest cut diameter required to the nearest edge of the facility being paralleled or crossed.

Existing underground facilities shall be exposed to verify its horizontal and vertical locations when the outlet pipe path comes within 1.0 m horizontally or vertically of the existing facility. Existing facilities shall be exposed by non-destructive methods. The number of exposures required to monitor work progress shall be as specified in the Contract Documents.

7.01.07 Transporting, Unloading, Storing and Handling Materials

Manufacturer's recommendations for transporting, unloading, storing, and handling of materials shall be followed.

7.01.08 Trenching, Backfilling and Compacting

Trenching, backfilling, and compacting for entry and exit points or other locations along the pipe path shall be according to OPSS 401.

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

If any open excavation will encroach into the highway embankment, the protection system shall satisfy the requirements for Performance Level 2 as specified in OPSS 539.

7.01.10 Dewatering

The work of this section includes control, handling, treatment, and disposal of groundwater. The Contractor shall review the foundation investigation report for reference to soil and groundwater conditions on the project site and plan a dewatering scheme accordingly.

The Contractor shall control groundwater inflows to excavations to maintain stability of surrounding ground, to prevent erosion of soil, to prevent softening of ground exposed in the excavation, and to avoid interfering with execution of the work.

The Contractor shall maintain excavations free of standing water at all times during excavation, including while concrete is curing.

Should water enter the excavation in amounts that could adversely affect the performance of the work or could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

The Contractor is alerted that seepage zones of perched water within the fill materials should be expected, particularly where granular materials are excavated.

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Cobbles and Boulders

The Contractor is alerted that cobbles and boulders are expected within the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. Removal of cobbles and boulders shall be expected to be routine and will not be considered obstruction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

**** Designer Fill-in, See Notes to Designer

7.01.12 Removal of Obstructions

The Contractor is alerted that obstructions such as, but not limited to wood debris, roots, and construction debris consisting of (broken asphalt, concrete etc.) are expected within the trenchless alignment as identified in the Contract Documents. Accordingly, the Contractor shall address methods for the removal of obstructions in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered and the Contractor's expected method of and schedule for removal.

***** Designer Fill-in, See Notes to Designer

7.01.13 Management of Excess Material

Management of excess material shall be according to OPSS 180.

Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.

7.01.14 Site Restoration

Site restoration shall be according to OPSS 492.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

The installation procedure to be used shall be subject to the following limitations:

- a) Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- b) A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- c) The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- d) Selection of the excavation method and jacking equipment shall take into consideration the conditions at each pipe crossing.

7.02.02 Pipe Installation

Concrete pipe joints shall be watertight and according to OPSS 1820, and must withstand jacking forces, determined by the Contractor.

During the jacking of the liner, the space between the liner and the wall of the excavated volume (e.g., maximum cut diameter) shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavated volume shall be filled with grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

The annular space between the liner and the product shall be fully grouted with a watertight, expandable, and stable grout.

7.03 Pipe Ramming Installation

For Pipe Ramming installation the following requirements apply:

- Only smooth walled steel pipe shall be used. Butt welding of pipe joints shall conform to CSA W59.
- Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement between the shafts/pits without overstressing of the pipe. Delays shall be avoided between ramming operations.
- A Ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.
- Removal of materials from within the pipe shall not be undertaken until the lead end of the pipe has

passed fully through and beyond the zone of influence of any overlying infrastructure.

- Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator.
- Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed.
- The annular space between the liner pipe and the product shall be fully grouted with a watertight, expandable, and stable grout.

7.04 Horizontal Directional Drilling Installation

7.04.01 General

When strike alerts are provided on a drilling rig, they shall be activated during drilling and maintained at all times.

For Horizontal Directional Drilling (HDD), the Contractor shall ensure that during pilot hole drilling the maximum degree of deviation or “dog-leg” shall be 2.5 degrees per 9 m drill pipe length. Any deviation exceeding 2.5 degrees will necessitate a pull-back and straightening of the alignment at the Contractor’s sole expense. The pilot hole exit location shall be within 0.5m of the target location.

7.04.02 Site Preparation

Site preparation shall be according to OPSS 490 and as specified herein.

The work site shall be graded or filled to provide a level working area for the drilling rig. No alterations beyond what is required for HDD operations are to be made. All activities shall be confined to designated Working Areas.

7.04.03 Pilot Bore

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as indicated on the Contractor’s submitted drilling plan to ensure that the product is installed to the line and grade shown on the Contract Drawings. The Contractor’s methods shall take into consideration the conditions at each crossing within the pipe alignment and shall be suitable to advance through such obstructions such as cobbles and boulders and address the potential for deflection off these obstruction and/or soil conditions.

In the event the pilot bore deviates from the submitted path, the Contract Administrator shall be notified. The Contract Administrator may require the Contractor to pullback, fill and abandon the hole and re-drill from the location along the bore path before the deviation.

If a drill hole beneath highways, roads, watercourses or other infrastructure must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence and subsurface water conveyance.

The Contractor shall maintain drilling fluid pressure and circulation throughout the HDD process, including during the initial pilot bore and during the reaming process.

The Contractor shall, at all times and for the entire length of the installation alignment, be able to demonstrate the horizontal and vertical position of the alignment, the fluid volume used, return rates, and pressures.

7.04.04 Drilling Fluid Losses to Surface (“Frac-Out”)

To reduce the potential for hydraulic fracturing of the hole during horizontal directional drilling, a minimum depth of cover of 5 m shall be maintained between the top of pipe and the surface of any pavements or beds of water courses. Sections of the pipe close to the entry and exit pit with less than 5 m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled for the full length of the bore to prevent frac-out for the depth of cover available between the bottom of the pavement structure (bottom of the subbase material) and the top of the bore.

Once a fluid loss or frac-out event is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to collect all fluids discharged to surface, mitigate and prevent additional fluid loss.

7.04.05 Reaming

The bore shall be reamed using the appropriate tools to a diameter at least 50% greater than the outside diameter of the product.

7.04.06 Product Installation

7.04.06.01 General

The product shall be jointed according to manufacturer’s recommendations. The length of the product to be pulled shall be jointed as one length before commencement of the continuous pulling operation.

The product shall be protected from damage during the pullback operation.

The minimum allowable bending radius for the product shall not be contravened.

Product shall be allowed to recover to static conditions from thermal and installation stresses before connections to new or existing facility are made. Product recovery time shall be according to manufacturers recommendations.

7.04.06.02 Pullback and Grouting

After successfully Reaming the bore to the required diameter, the product pipe shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product pipe is completely pulled into bore unless otherwise approved by the Contract Administrator.

A swivel shall be used between the reamer and the product being installed to prevent rotational forces from being transferred to the product. A weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product pipe shall be inspected for damage where visible at excavation pits and where it exits the bore. Any damage noted shall be rectified to the satisfaction of the Contract Administrator.

The pull back and Reaming operations shall not exceed the fluid circulation rate capabilities. Reaming and back pulling operations shall be planned to ensure that, once started, all reaming and back pulling operations are completed without stopping and within the permitted work hours.

The space between the pipe and the walls of the excavated volume shall be filled with grout or slurry with gel

strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

7.05 Tunnelling Installation

7.05.01 General

Excavation of native soil and fill shall be done in a manner to control groundwater inflow to the excavation and to prevent loss of ground into the excavation.

Methods of excavating the tunnel shall be capable of fully supporting the face and shall accommodate the removal of boulders and other oversize objects from the face. Continuous ground support shall be maintained during excavation.

As the excavation progresses, the Contractor shall continuously monitor (every 2 m) indications of support distress, such as cracking, deflection or failure of support system and subsidence of ground near the excavation.

The Contractor shall provide ventilation and lighting in accordance with OSHA requirements for the entire length of the tunnel installed as tunneling progresses.

The tunnel is to be kept sufficiently dry at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times in tunnels.

If excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation and make the excavation face secure. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the Work.

The Contractor shall maintain tunnel excavation line and grade to provide for construction of final lining within specified tolerances.

7.05.02 Tunnelling Method

The Tunnelling method shall be suitable to provide face support in changing ground conditions that may be encountered during the progress of the work. The selection of the Tunnelling method should consider the soil conditions at each pipe crossing and the presence of obstructions, such as cobbles and boulders, with respect to the tunnel alignment.

7.05.03 Primary Liner (Support System)

Primary support systems shall prevent deterioration, loosening, or unravelling of ground surfaces exposed by excavation.

The primary liner support system shall be designed and installed to achieve the intended performance requirements.

Primary liner support system shall maintain the safety of personnel, minimize ground movement into the

excavation, ensure stability and maintain strength of ground surrounding the excavation.

The primary liner shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting and shall ensure that no ground loading or other loading will be placed on the new work until after design strength has been reached.

The primary liner shall be installed so that the exterior is as tight as possible to the excavated surface of the tunnel and allows the placement of the full design thickness of the secondary lining.

Primary support systems shall be compatible with the encountered ground conditions, with the method of excavation, with methods for control of water, and with placement of the permanent lining.

All voids between the primary lining and the wall of the excavated volume shall be filled with cement grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground. If an unexpanded liner is used, the space outside the liner plates shall be filled at least daily.

7.05.04 Secondary Liner

7.05.04.01 Placing of Grout

The void outside the finished secondary liner shall be filled with cement grout according to the Contractor's submission.

Grout shall not be placed until the lining has achieved 85% of its specified strength or 30 MPa. Grouting shall be limited to such sequences and programs as are necessary to avoid damaging any part of the works or any other structure or property. Grout mix design shall be chemically and thermally compatible with all pipe systems.

7.06 Microtunnelling

7.06.01 General

Excavation of soil, rock and fill shall be done in a manner to control and prevent groundwater inflow to the tunnel.

The MTBM shall be capable of fully supporting the face and shall accommodate the removal of boulders and other obstructions from the face. Continuous ground support shall be maintained during excavation.

The tunnel is to be kept well drained at all times to permit work to be performed in a safe and satisfactory manner.

The Contractor shall maintain clean working conditions at all times.

In the event that excavation threatens to endanger personnel, the Work, adjacent property, roadways, railways, waterways, or the public in any way, the Contractor shall cease excavation. The Contractor shall then evaluate the methods of construction and revise as necessary to ensure the safe continuation of the Work.

The Contractor shall maintain the tunnel excavation line and grade to provide for construction of the product within the specified tolerances.

7.06.02 Method of Installation

The installation procedure to be used shall be subject to the following limitations:

- The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- Selection of the excavation method and jacking equipment shall take into consideration the subsurface conditions within the tunnel alignment.
- Perform microtunnelling operations in a manner that will minimize the movement of the ground in front of and surrounding the tunnel in conformance with the limits listed in the Contract Documents.
- Prevent damage to structures and utilities above and in the vicinity of the microtunnelling operations.
- Excavated diameter should be the minimum size required to permit pipe installation by jacking.
- Whenever there is a condition encountered which could endanger the microtunnel excavation or adjacent structures if tunnelling operations cease, continue to operate without intermission including 24-hour Working Days, weekends and holidays, until the condition no longer exists.
- Maintain an envelope of lubricant around the exterior of the pipe during the jacking and excavation operation to reduce the exterior soil/pipe friction and possibility of the pipe seizing in place.
- In the event a section of pipe is damaged during the jacking operation or a joint failure occurs, as evidenced by inspection, visible ground water inflow or other observations, the Contractor shall submit for approval his methods for repair or replacement of the pipe.

7.06.03 Casing Installation

Casing must withstand the jacking forces determined by the Contractor.

The space between the casing and the wall of the excavation shall be kept filled with lubricant during the pipe jacking operation. Upon completion of pipe jacking, the space between the casing and the wall of the excavation shall be filled with grout that is compatible with the casing.

The casing shall act as a support system to maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the casing.

The casing shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting.

7.07 Instrumentation and Monitoring

***** Designer Fill-in, See Notes to Designer

7.07.01 General

The Contractor shall furnish, install and monitor Surface Monitoring Points (SMP) and In-Ground Monitoring Points at the locations shown on the Contract Drawings.

The equipment and procedures used for settlement monitoring during construction must be capable of

surveying the settlement point elevations to within a repeatability (combined accuracy and precision of equipment and methods) ± 2 mm of the actual elevation.

7.07.02 Surface Settlement Monitoring Points

Surface settlement monitoring points shall be installed on the traffic lanes and shoulders to monitor settlement and stability. The surface settlement monitoring points shall be installed centred on the tunnel alignment as arrays of three points at intervals of 5 m or less and off-set a lateral distance of 1.5 m on either side of the tunnel centerline.

Surface settlement monitoring points shall be hardened steel markers treated or coated to resist corrosion, with an exposed convex head having a minimum diameter of 12 mm and similar to surveyor's PK nails. Markers shall be rigidly affixed so as not to move relative to the surface to which it is attached. Traffic shall be managed by the Contractor using short-term lane closures in accordance with the Ontario Traffic Manual (OTM). Surface markers shall be recessed or otherwise designed for safe passage of vehicles at highway speeds and protected from snow removal equipment in the event that work occurs during snow removal seasons.

7.07.03 In-Ground Settlement Monitoring Points

In-ground settlement monitoring points shall be installed beyond the traffic lanes and shoulders to monitor settlement and stability of the ground surface between the surface settlement monitoring points and the entry and exit portals. In-ground settlement monitoring points shall be located at intervals of 5 m or less along the tunnel alignment.

In-ground settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface or below frost penetration depth, whichever is greater. The assembly shall be placed in a drill hole, backfilled with uniform sand and provided with protective covers suitable for high vehicular traffic areas.

7.07.04 Installation, Replacement and Abandonment

The Contractor shall install all settlement monitoring points a minimum of two (2) weeks prior to the start of works to permit baseline surveying to be completed. The settlement monitoring points shall be clearly labelled for easy field identification. The Contractor shall submit to the Contract Administrator a site plan showing the locations of the monitoring points, a geodetic survey of the settlement monitoring points including station, offset and elevation. Instruments damaged by the Contractor's operations or other causes shall be replaced and surveyed at the time of installation within 24 hours at no additional cost. At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work and restore the surface at instrument locations.

7.07.05 Monitoring and Reporting Frequency

The Contractor shall survey and otherwise obtain elevations of all settlement monitoring points at the following time intervals:

- a) Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- b) Once per shift or once daily during tunnelling operations period whichever results in the more frequent reading intervals; and

- c) Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

All readings shall be submitted to the Contract Administrator for information purposes on a weekly basis.

Each report shall include all survey data collected in tabular and graphical format as plots of time versus settlement in comparison to survey data collected prior to commencement of the work.

7.07.06 Benchmarks

Two independent benchmarks shall be used for all settlement monitoring surveying and shall be located sufficiently outside the zone of influence such that the benchmarks are not influenced by any trenchless or other construction activity or weather conditions (e.g., frost heave). All surveying shall be reported using the geodetic datum and coordinate system as defined in the Contract Documents.

7.08 Criteria for Assessment of Roadway Subsidence/Heave

***** Designer Fill-in, See Notes to Designer

Based on the monitoring of the ground movement as specified in Subsections 4.02 and 7.07, the following represents trigger levels that define magnitude of movement and corresponding action:

- a) Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the Contract Administrator and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.
- b) Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:
 - i. The cause of the settlement has been identified.
 - ii. The Contractor submits a corrective/preventive plan complete with a Request to Proceed.
 - iii. Any approved corrective and/or preventive measure deemed necessary by the Contractor is implemented.
 - iv. Operations shall not proceed until the Contract Administrator has issued a Notice to Proceed for each corrective/preventive plan.

7.09 Certificate of Conformance

A Certificate of Conformance shall be submitted to the Contract Administrator upon completion of the installation of the pipe at each location. In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Quality Control Certificate sealed and signed by the Design Engineer and the Design Checking Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, sealed Working Drawings and Contract Documents.

8.0 QUALITY ASSURANCE – Not Used

9.0 MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centreline of the pipes from centre to centre of maintenance holes or chambers (catch basins) or from/to the end of the pipe where no maintenance hole or chamber is installed, of the actual length of pipe installed by trenchless methods.

10.0 BASIS OF PAYMENT

Payment at the Contract price shall be full compensation for all labour, Equipment, and Material required for excavation (regardless of material encountered), dewatering, sheathing and shoring, settlement instrumentation and monitoring, site restoration, and all other work necessary to complete the installation as specified.

If a pipe is installed inside the pipe liner, payment for the pipe shall be paid separately under the appropriate tender items.

Where a protection system is made necessary because of the Contractor's operations (e.g., choice of trenchless installation method), the cost shall be included in this item and shall be full compensation for all labour, Equipment, and Materials required to carry out the work including subsequently removing the temporary protection system and performing any necessary restoration work.

***** Designer Fill-in, See Notes to Designer

NOTES TO DESIGNER:

* Insert the following fill-in: Any method that is not suitable shall be specified.

** Insert the following fill-in: Specify minimum requirements commensurate with complexity.

*** Insert the following fill-in: Specify minimum requirements commensurate with complexity.

**** Insert the following fill-in: Subsurface Condition Baseline Reporting that includes Boulder Volume Ratio (BVR), Boulder Number Ratio (BNR) shall be project specific and included in the Foundation Engineering TOR as selected during the scoping of the project.

***** Insert the following fill-in: Any known obstructions shall be specified.

***** Insert the following fill-in: The Instrumentation and Monitoring program shall be project specific. The work specified in this section includes furnishing and installing instruments for monitoring of settlement (and heave) and ground stability.

***** Insert the following fill-in: Project specific Review and Alert Levels shall be provided if required.

***** Insert the following fill-in: Payment for removal of boulders exceeding Boulder Volume Ratio (BVR) and Boulder Number Ratio (BNR) shall be by Time and Material.

WARRANT: Always with this specification.

