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**REPORT ON SUPPLEMENTARY
GEOTECHNICAL INVESTIGATION
PROPOSED SW PARIS PHASE 2 WATERMAIN
COUNTY OF BRANT, ONTARIO**

MTO GEOCRES No. 40P1-106

Prepared for:

AECOM Canada Limited

By:

SPL CONSULTANTS LIMITED

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SPL Consultants Limited
Geotechnical Environmental Materials Hydrogeology

6221 Highway 7, Unit 16
Vaughan, Ontario L4H 0K8
Tel: 905.856.0065 Fax: 905.856.0025

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PART A – FACTUAL DATA

1. INTRODUCTION AND BACKGROUND

SPL Consultants Limited (SPL) was retained by AECOM Canada Ltd. (AECOM) on behalf of the County of Brant to conduct supplementary geotechnical investigation work associated with a proposed watermain. The so-called 'Southwest Paris Phase 2' watermain is proposed to extend from the Bethel Road well located near Bethel Road, west of Rest Acres Road, to a proposed elevated water tank to be sited approximately 300m north of the Highway 403 right of way and about 250m west of Rest Acres Road. The watermain continues northward from the elevated tank to Powerline Road.

This report focuses on the section of this watermain which crosses beneath Hwy 403 (in tunnel) and continues to Powerline Road. This routing is referred to as the 'Alternative 2' alignment in the Class Environmental Assessment. This report supplements previous geotechnical investigation work by Naylor Engineering Associates (Naylor) as reported in a "Preliminary Geotechnical Investigation, Southwest Paris Water and Wastewater Servicing Study, Rest Acres Road, Paris Ontario" prepared for KMK Consultants Limited (now AECOM) dated August 2005, Report Ref. 5703G.R01.

The objectives of SPL's supplementary investigation were to review previous geotechnical work, characterize the subsurface conditions at the proposed Hwy 403 tunnel crossing site within two (2) borings advanced at the edges of the right of way, as well as drilling three (3) additional borings positioned at locations suggested by AECOM between the Hwy 403 right of way and Powerline Road. Geotechnical recommendations are provided for the design and installation of the watermain both in-tunnel beneath the highway and within open cut sections further north.

Part A of this report presents the results of previous geotechnical investigations, describes the factual borehole data from the current investigation, including the method of investigation, the field and laboratory work and test results. Part B discusses and interprets the data and presents recommendations for geotechnical design.

The anticipated construction conditions described in this report are for the benefit of the client in order that their impact on the design can be evaluated and constructibility established. Construction methods described in this report must not be misconstrued as being specifications or as presenting recommendations to the contractor, nor do they purport to be the only suitable methods. Prospective contractors should evaluate all of the factual information, obtain additional subsurface data as they might deem necessary, and select their construction methods, sequencing and equipment based on their own experience in similar ground conditions.

The report is prepared under the assumption that the design will be in accordance with all applicable standards and codes and will be executed with good construction workmanship. The recommendations and opinions provided in this report are applicable only to the proposed project as described herein.

2. REGIONAL PHYSIOGRAPHY / PREVIOUS WORK

2.1 Regional Physiography

Lands both to the north and south of the Highway 403 corridor are gently undulating and are agricultural in nature. The alignment was planted with soy beans and corn at the time of the 2009 field investigation work.

Hwy 403 lies within a relatively deep cut, some 5m to 8m below the table land to the south and north respectively. There is a full highway interchange at Rest Acres Road (formerly Hwy 24A).

The watermain route lies within the physiographic area known as the Norfolk Sand Plain, within the Paris Moraine. The predominant soil deposits consist of outwash sands and silts with discontinuous intervening glacial till, referred to as the Wentworth Till. The more hilly portions of the moraine tend to be quite stony and cobbly in nature.

Properties to the south of Hwy 403 on either side of Rest Acres Road (including parts of the proposed watermain alignment) have been investigated (by others) for their aggregate resource potential. A July 2007 report by Naylor Engineering Associates entitled "Aggregate Resources Investigation, Rest Acres Road Industrial Subdivision, County of Brant" prepared for King & Benton development Group (Naylor report Ref. 4315G3.R01) proved out limited quantities of sand and gravel within a few metres of the existing grade within a rather thin layer (less than 1m thick in areas) and greater tonnages of sand beneath the sand and gravel deposit, extending as deep as 11m in places. There were till layers found both above and below the granular deposits in many areas.

Dolostone of the Salina formation underlies the overburden. MOE water well records suggest that the depth to bedrock is in the range of 20 to 35m in the general vicinity of the site.

2.2 Previous Geotechnical Investigation Work

2.2.1 Rest Acres Road / Hwy 403 Interchange

A geotechnical investigation was conducted by the Department of Transportation and Communications (now MTO) in 1965, reported much later in a 1972 "Foundation investigation Report for Proposed Crossing at Highway 24A, Line J and Highway 403, Line G, County of Brant, WP 160-60 (formerly 65-F-31)" [GeoCres 40P1-54]. The approximate locations of the MTO borings are shown on **Drawing No. 1** and the factual data from that investigation is reproduced in **Appendix A**.

Within a series of five (5) borings which extended between 11m and 12.6m deep (i.e. borehole tip elevations between 254-255m), the MTO found 'generally uniform' conditions consisting primarily of silty sand with traces of clay and gravel in a compact to dense state of packing. MTO reported natural water contents of test samples in the range of 7 to 18%, averaging 12%. The SPT 'N' values ranged from 17 to over 150 blows per 300mm advance and the average SPT 'N' was reported to be in excess of

100 blows per 300mm. The groundwater table was measured in the borings to lie between elevation 264.2 and 264.4m.

2.2.2 Naylor Preliminary Investigation

As referenced previously in Section 1 of this report, Naylor Engineering advanced thirty three (33) borings as part of EA stage investigations for the Southwest Paris servicing study. Included within this investigation were Naylor Boreholes NBH3 through NBH6 (identified in gold colouring on Drawing 1) which were drilled on opposite sides of Highway 403. Boreholes NBH4 and NBH5 were drilled from the north and south edges of the highway pavement respectively, while Boreholes NBH3 and NBH6 were advanced from the higher table land on opposing crests of the right of way.

At the time of the Naylor investigation, details of the watermain Highway 403 crossing were not defined. As such, the tips of Naylor Boreholes NBH4 and NBH5 were not extended three tunnel diameters below what is now established to be the tunnel invert level.

Naylor NBH3 and NBH4 encountered similar soil conditions. Beneath a capping of compact silty sand to silt glacial till (Wentworth Till) extending down to elevation 271-272m, the predominant deposits were compact to very dense brown, fine to medium grained sand in a damp to moist condition. These borings were drilled using solid stem augers and no free water was encountered in the open borings. One (1) grain size distribution analysis provided by Naylor for the NBH4 sample from 3m depth (Appendix A) reveals a rather tightly graded fine to medium sand with approximately 10 percent fines (i.e. percentage finer than 75 microns).

Naylor NBH5 and NBH6, drilled south of Hwy 403, reveal a slightly more complex sequence of granular soil deposits (sand/silt/sand & gravel/ silty sand) with some thin intervening silt glacial till layers which change to very dense silty sand / fine sand, trace silt below elevation 268-269m. SPT 'N' values reported in these borings indicate loose to dense, but generally compact, conditions to the top of the sand unit, becoming very dense within the sand. These borings were again drilled without the benefit of casing, using continuous flight solid stem augers. A standpipe was installed within NBH5 with tip near elevation 268.3m which remained dry. Soil samples taken from NBH6 below elevation 266 were described as being moist, but no free water was reported in the borehole.

2.2.3 Naylor Aggregate Resources Evaluation Study

A July 2007 report by Naylor Engineering Associates entitled "Aggregate Resources Investigation, Rest Acres Road Industrial Subdivision, County of Brant" prepared for King & Benton development Group (Naylor report Ref. 4315G3.R01) included Boreholes 201 and 202 (identified in green colour on Drawing 1) which are near the proposed watermain alignment. These borehole log sheets are provided in **Appendix A** along with grading curves from selected samples. The soils encountered within these two borings are complex and stratified but similar to those described in Section 2.2.2, consisting of a thin silt till capping and thin intervening till sheets embedded within primarily cohesionless deposits of sand, sand & gravel and silt. There are some very thin cohesive layers also reported (clayey silt) which

may be important since they may act to locally 'perch' groundwater. These thin cohesive seams and layers were also reported within Naylor's borings drilled within the proposed industrial subdivision south of Hwy 403, west of Rest Acres Road.

3. INVESTIGATION METHODOLOGY

3.1 Drilling Investigation Work

The field drilling work for this investigation was carried out on September 15 to 17, 2009. A total of five (5) borings (denoted as 09-1 through 09-5) were advanced at the approximate locations indicated on the attached **Drawing 2**.

The borings positioned on either side of Hwy 403 (09-1 and 09-2) were drilled from the private properties just outside of the MTO right of way and these were each taken to depths of 20.3m using a track-mounted drilling rig fitted with hollow stem augers. Boreholes drilled along the watermain alignment north of the highway (09-3 through 09-5) were drilled to 5.8m below grade, also using hollow-stem augering methods.

The approximate borehole coordinates (accurate to about 5m) are provided on the individual borehole log sheets within **Appendix B**.

The ground surface elevations at the borehole locations were surveyed by AECOM.

Soil samples were taken at 0.75m intervals of depth within the upper 6m of overburden and then at 1.5m intervals below. Sampling was effected using two methods. Samples were taken using a conventional 50mm dia. split spoon sampler, driven into the soils using an auto-hammer in accordance with the Standard Penetration Test (SPT) method, ASTM D 1586 and the associated SPT 'N' values were recorded.

In order to provide more detail on the textural variability of the cohesionless deposits at the Hwy 403 crossing and to better assess the presence of larger stones and cobbles, continuous 105mm diameter core samples (PQ cores) were also taken in-between the SPT samples. These samples are denoted as "CC" on the borehole log sheets (i.e. continuous cores) whereas the more conventional split spoon samples are denoted as SS. Auger samples, where taken, are identified as "AS". Photographs of the continuous core samples from BH09-1 and 09-2 are provided in **Appendix C**.

The groundwater levels in the boreholes were measured during and upon completion of drilling. Standpipe piezometers (38mm dia.) were installed in Boreholes 09-1, 09-2 and 09-4 for the longer-term monitoring of groundwater levels. The groundwater levels in the piezometers were measured a few days after completion of installation, on February 18, 2010 and on March 31, 2011 and these data are summarized at the bottom of the borehole log sheets.

3.2 Geotechnical Laboratory Testing

The recovered soil samples were transported to our geotechnical laboratory where they were examined by a senior engineer and selected samples were chosen for geotechnical index property testing.

The testing consisted of determination of the natural water contents of all samples and particle size distribution analyses on nine (9) samples. The results of the laboratory tests are presented in **Appendix D** and are also summarized on the associated borehole log sheets provided in **Appendix B**.

3.3 Environmental Soil Quality Analyses

Environmental soil quality testing was not part of the scope of this assignment.

4. SUBSURFACE CONDITIONS

4.1 Stratigraphy

In general, the boreholes encountered an upper sequence of predominately cohesionless granular soils in a compact to dense state, ranging in texture from silty sand to clean sand, to sand and gravel to silt. Within this sequence, there are layers with glacial till like texture, which have some apparent cohesion and greater percentage clay content. Natural water contents measured in samples of the upper cohesionless soils were typically less than 12%, averaging about 7%, except in the siltier horizons where the average water content was about 10%. SPT 'N' values measured in the upper granular sequence indicates loose to dense, but mostly compact conditions.

Below approximate elevation 271m, this upper granular sequence gives way to dense or very dense fine to medium sand or sand with trace to some silt and variable amounts of gravel sizes. Natural water contents measured in this deposit were in the range of 3 to 7%, then dramatically increasing to more than 20% below approximate elevation 263-262m. SPT 'N' values in the sand/sand some silt unit indicate generally dense to very dense conditions although the 'N' values reported in previous borings by MTO were typically higher than measured by SPL, indicating mostly very dense conditions.

Occasional thin to very thin silty clay layers or seams were encountered within the sands throughout the soil profile explored. Some of these layers are as thin as 40mm and are logged only as seams within the granular soils while others are thicker (e.g. 0.4m within BH09-5) and are identified as distinct soil units on the log sheets.

The presence of stone fragments reported in the log sheets may be indicative of cobbles which were fragmented by the sampler during SPT driving. There a few isolated cobble 'strikes' reported in the right margin of the borehole log sheets, inferred indirectly from auger "grinding". These occurrences were reported in both the upper granular soil sequence as well as in the lower sand/sand some silt.

Photographs of the continuous core samples taken in BH09-1 and 09-2 are provided in Appendix C.

Gradation analyses performed on selected samples of the various strata are provided in Appendix D.

More specific details on the subsurface conditions at the individual boring locations are given in the SPL borehole log sheets of **Appendix B** as well as those of Naylor Engineering which are included in **Appendix A**.

4.2 Groundwater

As previously noted, Naylor was able to complete their boreholes NBH4 through NBH6, 201 and 202 using solid stem continuous flight augers, without the benefit of casing. These borings were open and dry on completion of drilling.

Wet conditions were encountered in SPL borings 09-1 and 09-2 below elevation 262-263m and the short term water levels measured in the installed piezometers in these borings (several hours after installation) were 260.4m and 261.7m respectively. Longer-term groundwater level measurements in the installed piezometers are summarized in Table 4.2 which follows.

Some heaving of sands/silts into the hollow stem augers occurred during drilling of Borehole 09-4. BH09-3 and BH09-4 encountered wet or saturated soil conditions below approximate Elev 277 ±m.

Localized seams or zones of elevated water content in the cohesionless upper deposits as well as in the sands below were also noted. These are believed to be related to perched groundwater impeded from downward flow by the presence of thin to very thin and possibly discontinuous silty clay /clayey silt seams within the cohesionless deposits.

Table 4.2 – Summary of Piezometric Measurements

BH No.	Water Level On completion of drilling Depth/Elev.	W.L Feb 17&18 2010	W.L Mar. 31. 2011
		Depth/Elev.	Depth/Elev.
09-1	15.8/260.4	15.10/261.1	15.20/261.0
09-2	17.35/261.65	16.8/262.2	17.1/261.9
09-4	4.9/274.8	3.0/276.7	n/a

Groundwater levels are expected to fluctuate seasonally and in response to precipitation.

PART B – GEOTECHNICAL INTERPRETATION AND RECOMMENDATIONS

5. PREAMBLE

In **Part B** of this report, the subsurface conditions are interpreted as relevant to the tunnel, shafts and watermain geotechnical design and construction. Comments relating to construction are intended for the guidance of the design engineer (AECOM) to establish constructibility. Such comments relating to the construction conditions may be insufficient for prospective contractors bidding on the project, as they may not fully evaluate all the problems that may be encountered.

The construction methods described in this report must therefore not be misconstrued as being specifications or direct recommendations to the contractors, or as being the only suitable methods. Prospective contractors should evaluate all of the factual information, obtain additional subsurface information as they might deem necessary and should select their construction methods, sequencing and equipment based on their own experience in similar ground conditions. The readers of this report are also reminded that the conditions are known only at the borehole locations and in view of the generally wide spacing of the boreholes, conditions may vary significantly in-between.

6. TUNNEL BENEATH HWY 403

6.1 Design Profile and Anticipated Soil/Groundwater Conditions

We understand that a 400mm diameter watermain is to be constructed in-tunnel beneath Hwy 403. At this time, the shaft locations are slated to be positioned outside the MTO right of way on the table land above the highway.

The design invert of the watermain follows a slightly sloping grade beneath the highway at elevation 266.3m which is approximately 6.7m below Hwy 403 pavement grade (WBL and EBL pavement grade at ~elev. 273m) and approximately 5.2m below the central median highway ditch invert (~elev. 271.5m). We understand that the designers are contemplating that the watermain pipe will be carried within a welded steel liner of 1200mm diameter. The soil cover above the tunnel crown (liner obvert at approximate elevation 267.0m or lower) would thus be between 6.0m and 4.5m below the pavement and median ditch respectively. This allows for some blocking support beneath the pipe. This cover depth is deemed satisfactory. If there are underground utilities within the highway right of way deeper than the median ditch, then SPL must be notified so that we can assess the potential risk.

Based on this watermain invert grade, the shafts will need to be approximately 11 to 13m deep, depending on location.

A stratigraphic profile is provided in **Drawing No. 3**, based on the available SPL and Naylor borings in the vicinity of the tunnel crossing.

Based on these borings, the shafts are expected to penetrate a variety of mostly cohesionless / non-plastic soils ranging (in no particular order) from loose to dense sands, silty sands, sand & gravel and glacial till of silty sand to sandy silt texture. Very dense sands and silty sands will be encountered below Elev. 271m or thereabouts. Some cobbles and the odd boulder will be encountered in all soil types. All of these soils are expected to lie above the groundwater table although some water bearing seams or layers will also be encountered where thin beds of less pervious soil underlie more pervious deposits.

The proposed tunnel horizon, based on the SPL and MTO borings, is expected to lie wholly within dense to very dense sand and/or silty sand, with trace to some gravel, occasional cobbles. Lenses or layers of coarser textured sand or gravel should also be expected. The tunnel horizon, based on the borings and piezometers by MTO and SPL is considered to be above the groundwater table.

6.2 Shaft and Tunnel Construction

The shafts can be constructed as circular shafts supported by bolted steel liner plate, installed in short intervals of depth as the excavation progresses down. The liner plate can be supported by ring beams. Consideration could also be given to the use of drilled in place soldier piles with timber lagging for a rectangular shaft section. Excavation depth intervals between lagging stages would have to be carefully limited so as to prevent sloughing of the cohesionless soils. It might also be necessary to back-line the lagging with geotextile to minimize the potential for loss of fines. Sand should be packed tightly in intimate contact behind the lagging boards. The soldiers would require wales and strut support.

Excavation within the shaft will become more laboured below about Elev. 271m where dense and very dense materials will be encountered.

Unwatering measures by filtered sumps and appropriately sized pumps at the base of the excavation are expected to be required. Advance, active dewatering such as by deep wells / ejectors is not expected to be required. An MOE Permit to Take Water is not considered necessary for the tunnel and shafts construction components of this project.

Under the Tunnelman's Soil Classification, the dense and very dense, damp to moist sands and silty sand expected in the tunnel horizon is expected to behave as "cohesive running ground" when and if maintained moist above the water table. If allowed to dry out, the sand will lose its apparent cohesion and will change to "running ground". If saturated, the performance will be degraded to "flowing" ground.

Under these conditions, it should be possible to excavate the tunnel and install temporary liner support using a partially open face tunnel or micro-tunnel boring machine or possibly a tunnel digger shield. The tunnel digger shield may be better able to accommodate cobbles, depending on the nature and dimensions of the conveyance system but a larger tunnel diameter would be needed. The shield should be fitted with breasting plates or a mechanical shutter gate to mitigate raveling conditions which may be experienced. The tunnel boring machine or tunnel digger shield should be sized such that in the

event that a boulder is encountered, the face can be accessed and the boulder manually split or broken up.

In the following Table 6.2, we have summarized the perceived advantages and drawbacks of a number of trenchless crossing methods in the ground conditions at this site:

Table 6.2 – Summary of Merits/Drawbacks of Various Trenchless Crossing Options

Trenchless Methodology	Merits	Drawbacks
Digger shield TBM with continuous welded steel casing pipe as temporary support*	<p>Good flexibility in dealing with cobbles and obstructions</p> <p>Face conditions are visible, enabling full time assessment of ground losses</p> <p>Face can be bulkheaded if equipped with shuttered front chamber to mitigate raveling and can be reliably closed on stoppages in the work</p> <p>Good ability to control vertical and horizontal alignment by laser</p>	<p>Intermediate to High Cost</p> <p>Not possible for smaller bore diameters</p> <p>Face is unsupported if not equipped with shuttered front chamber or breasting plates which could result in excessive ground loss if a water-bearing pocket or boulder is encountered</p>
Pipe Ramming with continuous welded steel casing pipe as temporary support	<p>Intermediate cost</p> <p>Adaptable to wide range of casing pipe diameters.</p>	<p>Sands at this site are likely too dense to permit this method.</p> <p>Casing Pipe will develop excessive frictional resistance. Would likely require shaft in central median.</p> <p>Ground heave at highway level is a risk.</p> <p>Some difficulty in controlling vertical and horizontal alignment. Casing pipe alignment could deviate in vertical profile and horizontal alignment.</p> <p>Unable to deal with boulders unless</p>

		<p>soil plug is removed from casing pipe which compromises face support conditions.</p> <p>Better suited to weak ground conditions and situations where ground heave is not an issue.</p>
Microtunneling TBM	<p>Good ability to control ground losses, particularly a slurry-shielded machine</p> <p>Good ability to steer in vertical and horizontal alignment</p> <p>Best suited to applications where the regulatory authority does not require a steel liner – i.e. direct jacking of the product pipe</p>	<p>Very high cost</p> <p>Poor availability in the Ontario marketplace</p> <p>May not be able to deal with boulders which could result in having to abandon the tunnel drive if this occurs below the travelled lane of the highway.</p> <p>May or may not require intermediate shaft in centre median</p>
Jack and Bore	<p>Lowest Cost</p> <p>Widely available in the marketplace</p>	<p>Poor ability to control face losses in ravelling ground which could result in excessive settlement</p> <p>Poor ability to deal with boulders which could result in having to abandon the bore and/or excessive ground losses while boulder is being dislodged.</p> <p>May or may not require intermediate shaft in centre median</p> <p>Casing Pipe will develop very high frictional resistance. Bentonite friction reducer injection needed to reduce frictional resistance.</p> <p>Some difficulty in controlling vertical and horizontal alignment. Casing pipe alignment could deviate in vertical profile and horizontal</p>

		<p>alignment.</p> <p>No visual observation of tunnel face is possible so it is not possible to assess face stability.</p> <p>Bulkheading of face using augers is not an effective sealing method in cases where wet pockets of cohesionless material may be encountered.</p>
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*may not be feasible with 1200mm diameter casing pipe contemplated.

On weekends or stoppages in the work overnight, the face must be covered in filter fabric and fully bulkheaded or, if fitted with a shuttered gate, the gates must be fully closed and sealed.

The Owner's Engineer should twice daily inspect the tunnel muck to ensure that it remains consistent with the expectation of damp to slightly moist sand and silty sand. If wet spoils are observed, the geotechnical engineer should be immediately notified and a tunnel face inspection is warranted immediately to assess face stability.

Ground support on MTO tunnel projects often takes the form of a continuous welded steel liner, jacked in place with the assistance of pressurized bentonite injection ports to reduce friction. The annular space between the liner and the ground is grouted. The annular space between the watermain and the temporary tunnel lining must be fully grouted. The heat of hydration of the grout must be taken into consideration and for this reason, concrete pressure pipe may be preferable over PVC. Good success is being achieved currently with the use of foamed cement (cellular concrete) grouts for annular space grouting; however, an experienced contractor is required in this regard given the complexities in mixing, dosing and pumping this product.

6.2.1 Ground Movement Monitoring Program

As with all 400-series highway crossings, we recommend that a settlement monitoring program be instituted to monitor both surface settlements as well as deeper-seated ground movements that might be occurring just above the tunnel crown which take longer to manifest at surface. A suggested monitoring scheme, reading frequency and details of the installations are illustrated in **Drawings 4 and 5**. The settlement rods and surface targets can be remotely read for elevation (to the nearest millimetre) using a one second total station relative to a deep seated benchmark. The existing piezometers should also be monitored (for water level) as part of this work.

Prior to start of shaft construction and tunneling, three (3) sets of repeatable 'zero' readings should be taken on all of the monitoring points to establish an average 'baseline' pre-construction elevation for each monitoring point.

We have recommended various alert and review levels associated with tunneling induced ground movements in the following table:

Table 6.2.1: Settlement 'Alert/Review Levels'

Ground Movement		Notes
<6mm		Proceed with caution. No action required.
6-11mm	REVIEW LEVEL	Immediately notify the MTO and the geotechnical engineer for further assessment. Proceed with caution. Tunnel face inspection by geotechnical engineer and MTO is required. Mining/support/sequencing may require changes.
≥12mm	ALERT LEVEL	Halt mining and stabilize/bulkhead the tunnel face until further assessment is carried out by the MTO and geotechnical engineer; Carry out immediate remedial work to the settlement zone as approved by the MTO.

6.2.2 Theoretical Ground Surface Settlement Induced by Tunneling

We have made a theoretical estimation of the ground surface settlements expected at highway grade level for a 1200mm dia. tunnel with invert grade at elev. 265.7m and highway grade at elev. 273m. We have evaluated the settlements resulting from a range of percentage face volume losses from 0.5% to 0.75% which is possible with good workmanship for tunnelling in dense to very dense fine sand above the groundwater table.

The analysis of ground movement induced by tunnelling was carried out using a semi-theoretical method originally proposed by Peck¹ (1969). In the method, the ground settlement induced by tunnelling is described by a Gaussian distribution curve as follows :

$$S_v = S_{\max} \exp\left(\frac{-x^2}{2i^2}\right)$$

Where,

S_v is the vertical settlement

S_{\max} is the maximum ground settlement on the tunnel centre line

¹ Peck, R.B., 1969. Deep Excavations and Tunneling in Soft Ground, SOA Report, 7th Int. Conf. SM&FE, Mexico City, State of the Art Volume, pp. 225-290,

$$S_{\max} = \frac{0.313V_L D^2}{Kz_o}$$

V_L is the volume loss

D is the diameter of tunnel

K is the trough width parameter and taken as 0.25

z_o is the depth of the tunnel axis = 6.7m

x is the horizontal distance from the tunnel centre line

i is the horizontal distance from the tunnel centre line to the point of inflexion on the settlement trough

$$i = Kz_o$$

Using this method, the theoretical settlement (S_{\max}) directly above the tunnel centreline at highway grade level is estimated to be less than 5mm for face volume losses less than 0.75%. Obviously, greater percentage face losses, such as could occur, for example, when cobbles/boulders are struck, would result in greater settlements.

6.2.3 Earth Pressures

6.2.3.1 Temporary Shaft

The temporary shafts should be designed by contractor's specialist shoring design engineer based on the methods outlined in the 4th Edition of the Canadian Foundation Engineering Manual.

For a multi-level strutted or braced shoring system in primarily cohesionless soils above the water table, the lateral earth pressure p_h at any depth h can be determined as:

$$p_h = 0.65 k \gamma_s H + kq$$

where:

p_h is the lateral earth pressure at any depth h below a horizontal ground surface, kPa

$k = 0.3$ for a flexible shoring system where some ground movements adjacent to the shoring can be tolerated

γ_s = unit weight of soil, assumed at 20.5 kN/cu.m

H = maximum depth of excavation, m

q = construction surcharges in kPa

6.2.3.2 Permanent Chambers

The earth pressure distribution on permanent structures (e.g. chambers) can be taken as hydrostatic, i.e. which is increasing uniformly with depth according to the formula:

$$p_h = K \cdot \gamma_s \cdot h + K \cdot q$$

where

p_h = pressure at depth h , kPa

γ_s = unit weight of soil, assumed at 20.5 kN/cum

h = depth below ground surface (m)

q = surcharge load at ground surface (kPa)

K = coefficient of lateral earth pressure for a horizontal ground surface condition = 0.45 for a rigid structure.

6.2.3.3 Temporary Tunnel Lining

The design of temporary tunnel linings is the responsibility of the tunnelling contractor's specialist tunnel design engineer. The overburden pressure can be estimated using a soil unit weight of 20.5kN/cum.

7. WATERMAIN

7.1 Frost and Structural Soil Cover

We have assumed that the 400mm dia. watermain will be provided with approximately 1.8m or more of earth cover, thus the typical depth of trenching will be about 2.5m for PVC pipe.

7.2 Trenching, Trench Support and Groundwater Control

Based on BH09-3 through 09-5, the soils expected to be encountered in trenches up to about 2.5m deep will consist of mostly silty sand, sand & gravel, and silt glacial till. Some thin layers of cohesive silty clay/clayey silt soil may also be encountered. Cobbles and occasional boulders will be encountered. Based on the piezometer readings taken in BH09-4 and the water content data, we expect that trench base will be above the groundwater table; however, we do expect that pockets or seams of wet material will be encountered due, in part to the presence of the lower permeability till layers and thin layers of cohesive soil.

The Soil Types in this Zone are generally 'Type 3' under the OHSA.

The use of trench boxes to support trench walls will only be appropriate for trenching depths above the groundwater table. The cohesionless soils are prone to sloughing/ravelling.

Unwatering (such as from filtered sumps within the base of the sheeted excavation) will be required to deal with surface water and perched groundwater as indicated above.

An MOE Permit to Take Water is not anticipated to be required based on the data available.

A test dig is recommended at selected locations along the proposed watermain alignment to observe trench wall stability and to demonstrate the ground/ground water conditions to the prospective contractors bidding on the work.

For the design of braced shoring, a rectangular apparent earth pressure envelope can be assumed with uniform pressure p acting at any depth h equal to :

$$p = 0.65 K_a \gamma_s H + K_a q$$

Where $K_a = 0.3$

$$\gamma_s = 20.5 \text{ kN/cu.m}$$

H = maximum trench base depth below a horizontal grade

q = construction/traffic surcharges

Since the soil types prevalent at the trench base level are primarily cohesionless sandy deposits, trench plugs will not be effective in cutting off groundwater flows which may occur preferentially in bedding material. Moreover, the trench base is believed to lie above the groundwater table. As such, the use of trench plugs is not considered necessary or effective.

7.3 Bedding Material

In sections where the trench base is above the water table, Class "B" granular bedding in accordance with the current Ontario Provincial Standards is recommended. Granular fill meeting OPSS Granular 'A' (sand and gravel) grading requirements is the recommended bedding material. Bedding thickness, geometry and cover should meet OPS requirements.

Some areas may have a wet trench base despite unwatering measures. In such cases, if the contractor elects to switch to an open-graded bedding material, such as HL6 clear stone, then the bedding must be fully wrapped (base, sides and top) with a non-woven geotextile filter fabric having an effective opening size (FOS) of 120 microns or less. This separation and filtration is needed in order to prevent soil fines from migrating into the open graded clear stone material.

7.4 Backfill/Backfilling

Some of the excavated native soils will be well suited for reuse as compacted backfill above the bedding zone however, given that much of the soil is quite silty in nature, favourable (dry) weather conditions will be required to facilitate its placement and compaction if a high degree of compaction is required. The insitu water content of some of the till and silty sand material is near to the materials optimum water content and therefore air drying would be required to achieve a degree of compaction greater than 95% of Standard Proctor Maximum Dry Density.

Beneath existing roadways and proposed future roadway areas, the required degree of compaction of backfill material is 95% of SPMDD at a placement water content within 2 percent of the materials optimum, increasing to 98% of SPMDD in the upper 1 metre below basecourse. The more silty soils must be placed at water contents within 2 percent of their optimum moisture or they will “pump and roll” under compactive effort due to pore pressure effects.

Within easements with no proposed future use as roadways or development, the compaction degree can be relaxed to 93% of SPMDD.

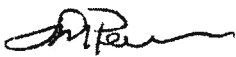
8. STATEMENT OF LIMITATIONS

The Statement of Limitations, as provided in **Appendix E**, forms an integral part of this report.

Thank you for the opportunity to be of service to you. Should you have any questions or require further clarification on any aspect of this report, please do not hesitate to contact this office.

Yours very truly,

SPL CONSULTANTS LIMITED



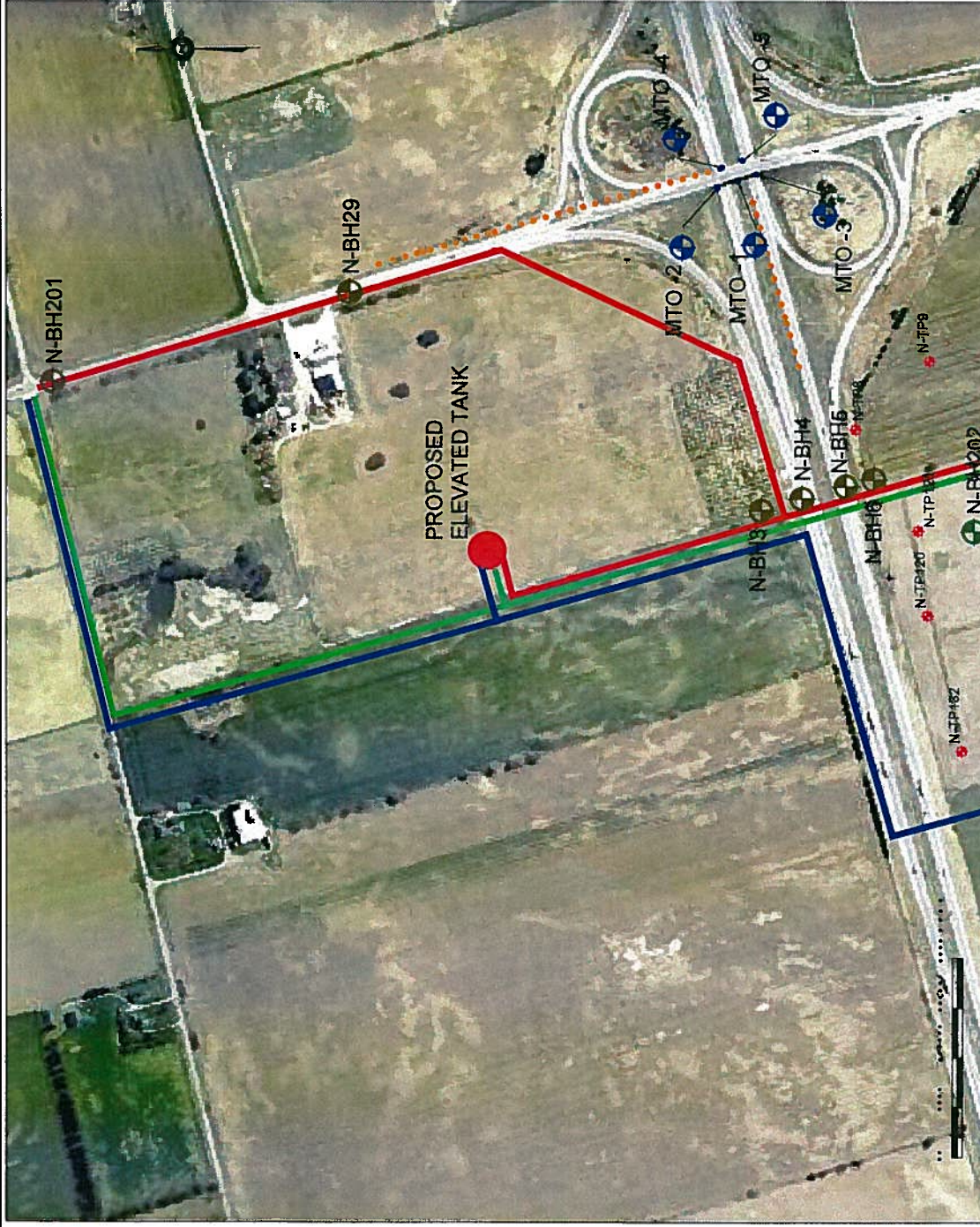
Scott Peaker, M.A.Sc., P.Eng.
Designated MTO Contact - Tunneling



Fanyu Zhu, Ph.D., P.Eng.
Designated MTO Contact - Foundations




Drawings

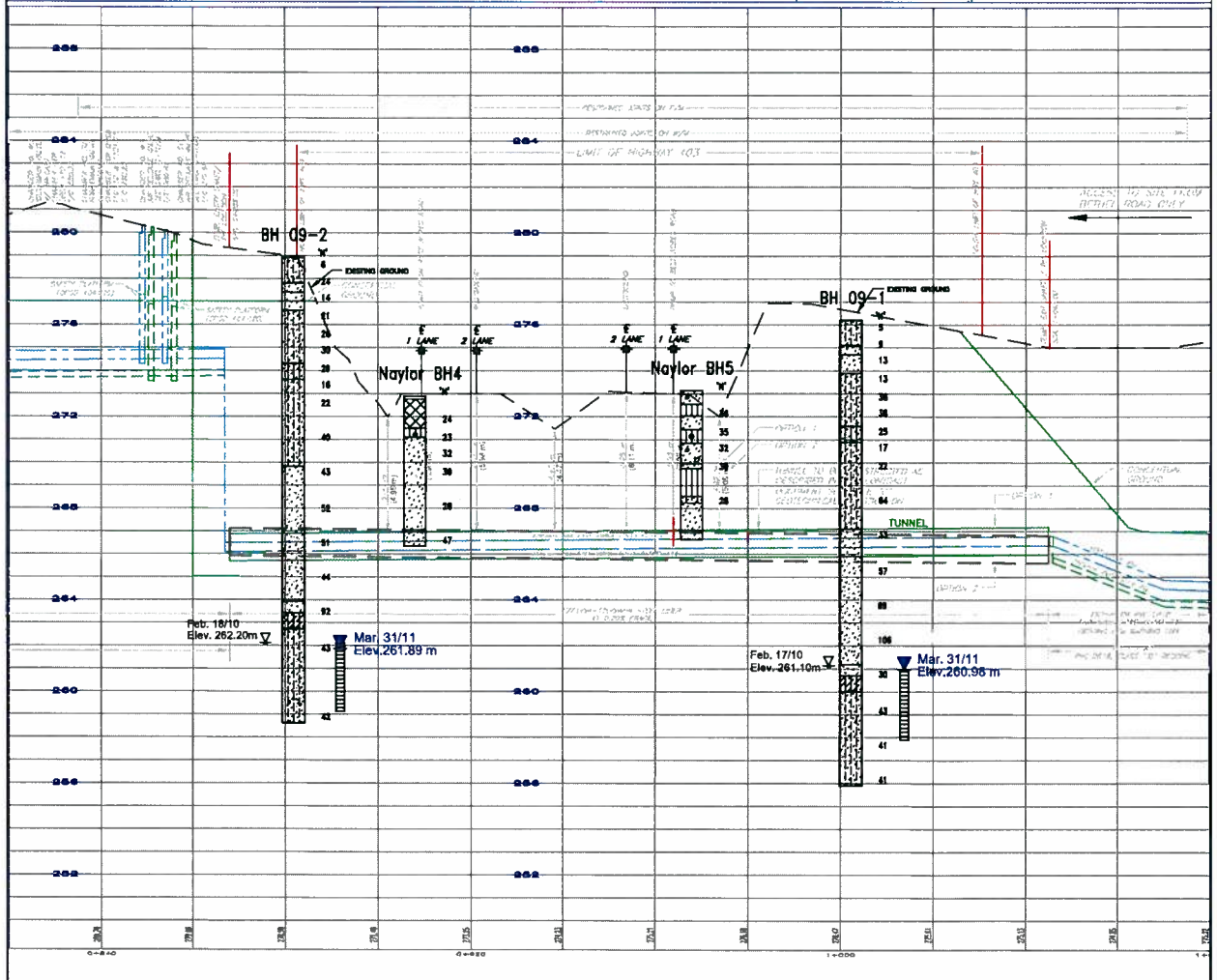
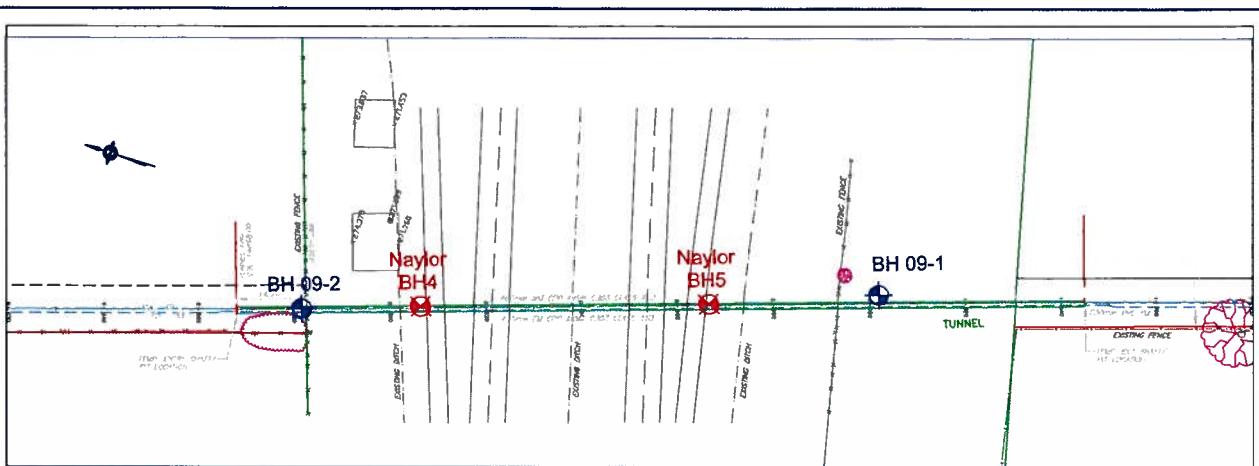


LEGEND

- N-BH6 Naylor Borehole 5703G1
- N-BH2 Naylor Borehole 4351G3
- MTO-1 MTO Borehole 40P1-54
- N-TP121 Naylor Testpit 4315G3
- Alternative 1 Watermain Alignment
- Alternative 2 Watermain Alignment
- Alternative 3 Watermain Alignment

Client:	COUNTY OF BRANT		Project No.	G-09.08.005	Drawing No.	1
Drawn:	MT	Approved:	SMP	BOREHOLE LOCATION PLAN (PREVIOUS INVESTIGATIONS)		
Date:	Feb. 17, 2010	Scale:	see scale bar	SOUTHWEST PARIS PHASE 2 WATERMAIN PARIS, ONTARIO		
Original Size:	Tablet	Rev:		 SPL Consultants Limited Geotechnical - Environmental - Materials - Hydrogeology		

SERVER:\public\Geotechnical\G-09\G-09.06.005 - Rest Acres & 403\0323-2011\Borehole&profile-0401-2011.dwg

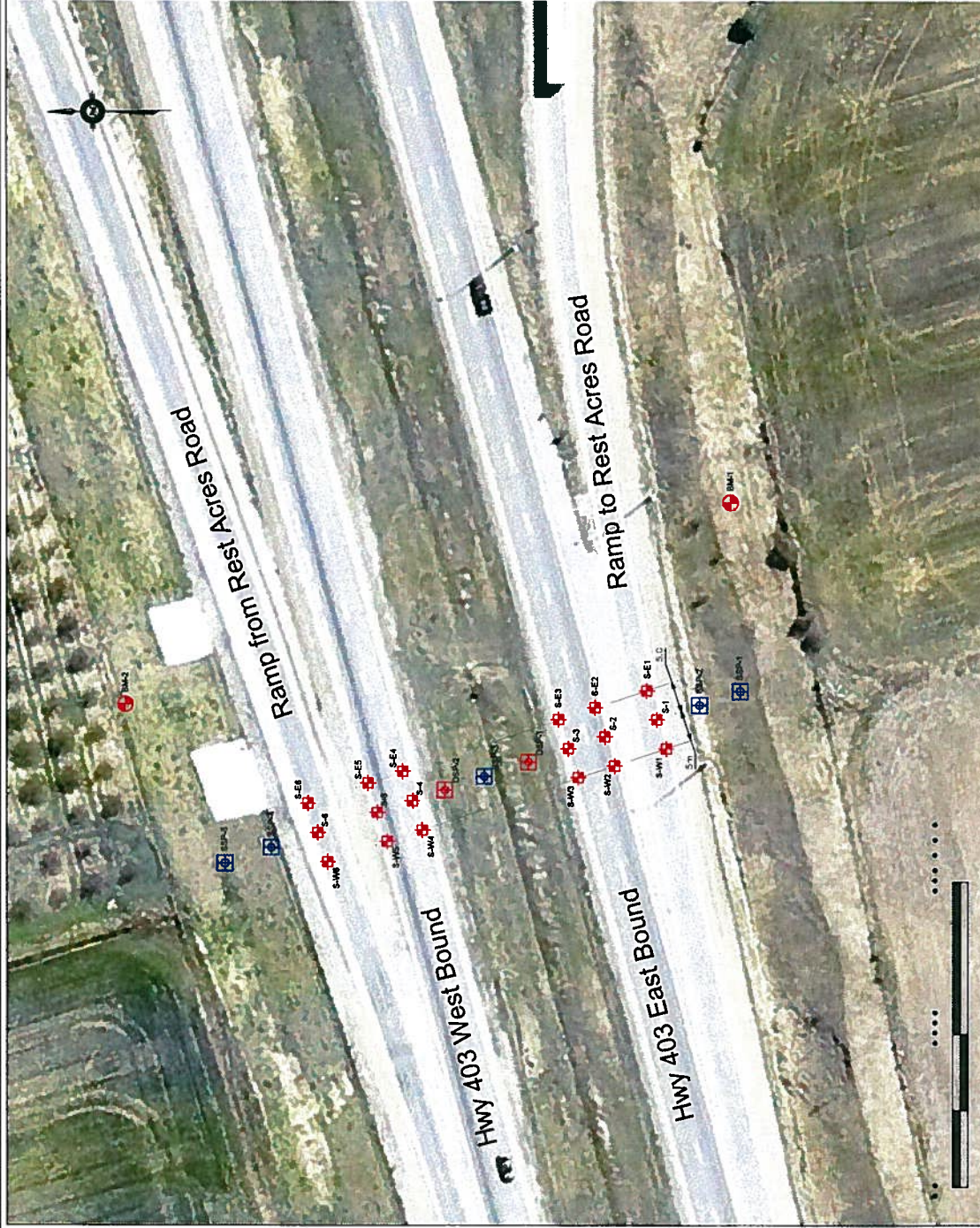


LEGEND

- BH09-1 Borehole without Piezometer
- BH09-2 Borehole with Piezometer
- Naylor BH-4 Naylor Borehole
- Silty Sand
- Sandy Silt
- Silt
- Clay
- Gravel
- Fill
- Silt
- Silt

Note: exact positions of Naylor boreholes are not known

Client:	COUNTY OF BRANT	Project No.:	G-09.06.005	Drawing No.:	3
Drawn:	TJ	Approved:	SP	Title:	BOREHOLE LOCATION AND STRATIGRAPHIC SECTION AT HWY 403
Date:	April 01., 2011	Scale:	As shown	Project:	SOUTHWEST PARIS PHASE2 WATERMAIN PARIS, ONTARIO
Original Size:	Tabloid	Rev:	01	 SPL Consultants Limited Geotechnical • Environmental • Materials • Hydrogeology	



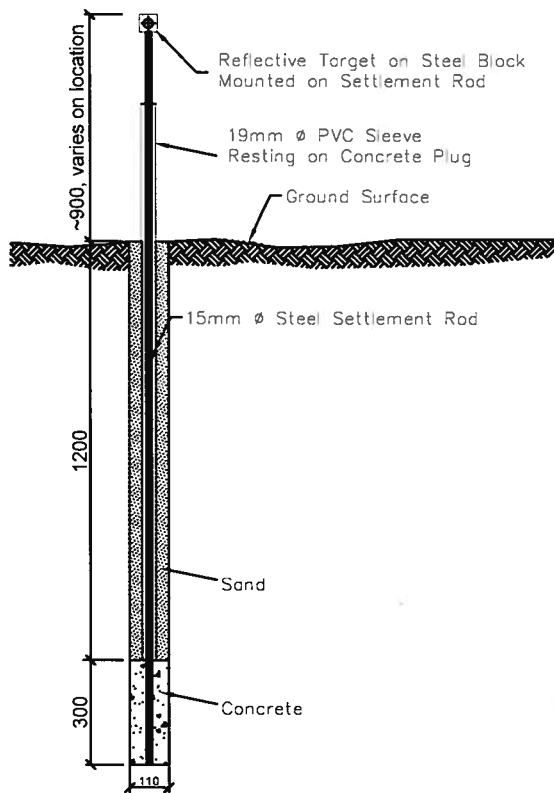
.....

LEGEND

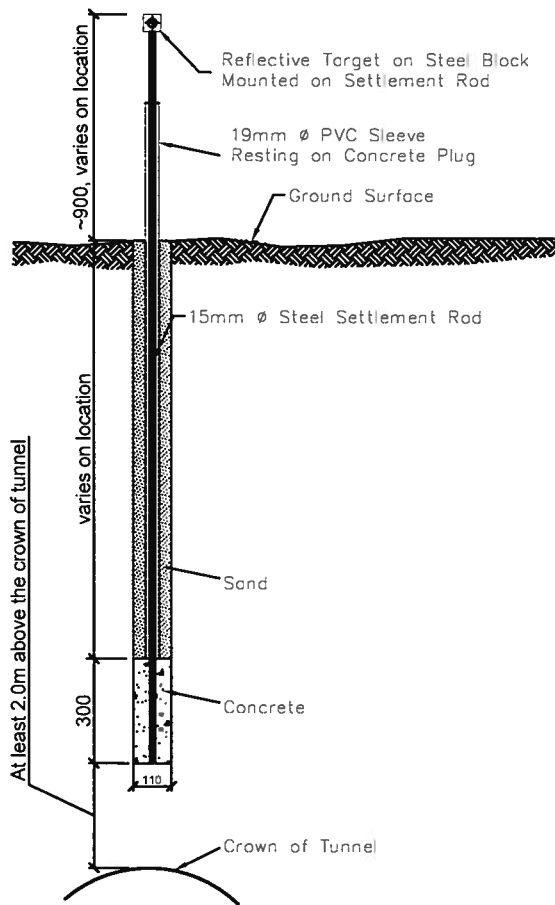
- SSP-1 Shallow Settlement Rod
- DSP-1 Deep Settlement Rod
- BM-1 Benchmark
- S-1 Surface Target
- Center Line of Tunnel

.....


Client:	COUNTY OF BRANT	Project No.:	G-09.06.005	Drawing No.:	4
Drawn:	MT	Approved:	SMP	PROPOSED SETTLEMENT MONITORING ARRAY	
Date:	Feb. 17, 2010	Scale:	see scale bar	LOCATION PLAN	
Original Size:	Tabloid	Rev:	N/A	Project	
				SOUTHWEST PARIS PHASE 2 WATERMAIN	
				PARIS, ONTARIO	
				SPL Consultants Limited	
				Geotechnical - Environmental - Materials - Hydrogeology	



SHALLOW SETTLEMENT POINT (SSP)



DEEP SETTLEMENT POINT (DSP)

Client:	COUNTY OF BRANT	Project No.:	G-09.06.005	Drawing No.:	5
Drawn:	MT	Approved:	SMP	Title:	DETAIL OF SHALLOW/DEEP SETTLEMENT MONITORING ROD (SSP/DSP)
Date:	Feb. 17, 2010	Scale:	N/A	Project:	SOUTHWEST PARIS PHASE 3 WATERMAIN PARIS, ONTARIO
Original Size:	Letter	Rev.:	N/A	 SPL Consultants Limited Geotechnical • Environmental • Materials • Hydrogeology	

Appendix A

Borehole Log Sheets of Previous Investigations

DOCUMENT MICROFILMING IDENTIFICATION

G.I.-30 SEPT. 1976

GEOCRES No. 40P1-54

DIST. 4 REGION

W.P. No. 160-60

CONT. No. 75-132

W. O. No.

STR. SITE No. 1-154

HWY. No. 403

LOCATION Relocated Hwy 24A

No of PAGES -

=====
OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

DEPARTMENT OF TRANSPORTATION AND COMMUNICATIONS

MEMORANDUM

TO: Mr. A. P. Watt, (2)
Regional Bridge Planning Eng.,
Southwestern Region,
London, Ontario.

FROM: Foundations Office,
Design Services Branch,
Central Bldg., Downsview.

ATTENTION:

DATE: February 16, 1972.

OUR FILE REF.

IN REPLY TO FEB 16 1972

SUBJECT:

GEOGRES # 40P1-54

CONT. 75-132
FOUNDATION INVESTIGATION REPORT
For

Proposed Crossing at Hwy. #24A,
Line 'J' and Hwy. #403, Line 'G',
County of Brant, Twp. of Brantford,
Con. 2, Lot 10 and 11, District #24
W.O. 71-11109 -- W.P. 160-60
(Formerly 65-F-31)

Enclosed please find our complete foundation investigation report for the above-mentioned project. The report is a slightly revised version of the original report numbered 65-F-31. We believe that the information contained in the report will prove to be sufficient for your design purposes. If any questions arise, however, you are requested to contact this Office.

Please destroy any copies you may have of the original report 65-F-31.

A. G. Stermac

A. G. Stermac,
PRINCIPAL FOUNDATION ENGINEER.

AGS/ao
Encl.

cc: Messrs. D. W. Farren
A. Rutka
B. R. Davis
B. J. Giroux
C. R. Robertson
J. R. Roy
G. A. Wrong
B. A. Singh

Foundations Office ✓
Documents

FOUNDATION INVESTIGATION REPORT
For
Proposed Crossing at Hwy. #24A,
Line 'J' and Hwy. #403, Line 'G',
County of Brant, Twp. of Brantford,
Con. 2, Lot 10 and 11, District #2.
W.J. 65-F-31 -- W.P. 160-60

1. INTRODUCTION:

A request to carry out a foundation investigation at the proposed crossing of Hwy. #24A, Line 'J' and Hwy. #403, Line 'G' at Paris, Ontario, was received from Bridge Location Engineer, Mr. G. Scott, dated November 3, 1964.

It is proposed to erect a new bridge to carry Hwy. #24A, Line 'J' over Hwy. #403, Line 'G'. The site of the proposed bridge is located approximately 1.5 miles south-west of the City of Paris, County of Brant, Twp. of Brantford, Con. #2, Lot 10 and 11.

In order to determine the soil properties and decide on the type of foundations, an investigation was carried out by this Office. Results and the discussion of the field and laboratory investigations, as well as conclusions and recommendations for the future design work, are contained in the following paragraphs of this report.

2. DESCRIPTION OF SITE:

The site of the proposed bridge is located approximately 1.5 miles south-west of the City of Paris. The surrounding area is generally flat terrain. Physiographically, the site is located in the so-called Norfolk Sand Plain.

3. FIELD AND LABORATORY WORK:

In order to obtain sufficient information on the type and properties of the subsoil, five sampled boreholes and five penetration tests were carried out at this site.

Split-spoon samples were taken at various depth intervals. Samples were used to determine the following physical properties:

1. Natural Moisture Content.
2. Grain-Size Distributions.

Results of these laboratory tests are summarized in the Appendix.

4. SUBSOIL CONDITIONS:

4.1) General:

The stratigraphy of the soil at the site was found to be generally uniform. A detailed description of various soil types encountered during the investigation, is shown in Appendix I of this report and is also given in subsequent paragraphs. The estimated stratigraphical profile, shown on Dwg. No. 65-F-31A, is based upon this information.

4.2) Silty Sand with Traces of Clay and Gravel - Compact to Very Dense:

This stratum, which extends to the depth investigated, was found immediately below the topsoil or highway fill.

The percentage of sand in this stratum is 57%, silt 32%, gravel 6%, and the rest of 5%, is clay. Moisture content determinations for this layer averaged about 12%, ranging from 7% to 18%. The overall stratum was found in a compact to very dense condition, with an average 'N' value in excess of 100 blows/foot. The 'N' value varied from 17 blows/foot to over 150 blows/foot.

5. GROUNDWATER CONDITIONS:

The groundwater level, at the time of the investigation, was found at approximate El. 867.0. It may be assumed that the water level will vary with the seasons of the year. No artesian water conditions were encountered.

APPENDIX I

OFFICE REPORT SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

JOB 65-F-31

W.P. 160-60

DATUM 875.5

RECORD OF BOREHOLE NO. 1

FOUNDATION SECTION

LOCATION Hwy 403 Line "C" & Hwy 24A Line "J" Ch 336+09 30'0" Lt.


BORING DATE March 18, 1965.

BOREHOLE TYPE Washboring - BX Casing.

ORIGINATED BY W.W.K.

COMPILED BY W.W.K.

CHECKED BY K.G.S. *AK*

SOIL PROFILE		SAMPLES		ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE		LIQUID LIMIT PLASTIC LIMIT WATER CONTENT		BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS / FOOT	BLAST. PLAT	BLOWS / FOOT	W.P.	W.L.		
875.5	Groundlevel									
873.5	Sand & gravel - compact.	1	SS	17						26.44 W.L. El 867.3  Observed in casing.
2.0	Hwy Fill	2	SS	51						
	Silty sand with traces of clay and gravel.	3	SS	63						
	Compact to very dense.	4	SS	65						
		5	SS	68						
		6	SS	119						
870										
860										
850										
840										
830										

266.8

254.2

End of borehole.

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 2

FOUNDATION SECTION

JOB 65-F-31

LOCATION Hwy #403 Line "G" & Hwy 24A Line "J" Ch 337+38 30'-0"

ORIGINATED BY W.W.K.

W.P. 160-60

BORING DATE March 19, 1965.

COMPILED BY W.W.K.

DATUM 875.6

BOREHOLE TYPE Washboring - BX Casing.

CHECKED BY K.G.S. *gls*

SOIL PROFILE		SAMPLES		ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE		LIQUID LIMIT		BULK DENSITY P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS / FOOT	BLANKS / FOOT	WATER CONTENT %	PLASTIC LIMIT	WATER CONTENT		
875.6	Groundlevel									
873.6	Sandy gravel compact	1	SS	20						
2.0		2	SS	60						
	Silty sand with traces of clay and gravel.	3	SS	84						
	Compact to very dense.	4	SS	106						
829.1		5	SS	100						
36.5	End of borehole.		for 4"							

264.4
W.L. El 867.3
Observed in casing.

DEPARTMENT OF HIGHWAYS - ONTARIO

RECORD OF BOREHOLE NO. 3

FOUNDATION SECTION

MATERIALS & TESTING DIVISION

JOB 65-T-31

LOCATION Hwy #403 Line "G" & Hwy 24A Line "J" Ch 334/92 30' Lt

ORIGINATED BY W.W.K.

W.P. 160-60

BORING DATE March 23, 1965.

COMPILED BY W.W.K.

DATUM 875.3

BOREHOLE TYPE Washboring - BX Casing.

CHECKED BY K.G.S. *dl*

SOIL PROFILE		SAMPLES		ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE		LIQUID LIMIT PLASTIC LIMIT WATER CONTENT		REMARKS
ELEV. DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS / FOOT	BLows / FOOT	WATER CONTENT %	WATER CONTENT %		
875.3	Ground level								
873.3	Sand & gravel compact Hwy Fill	1	SS	58					
2.0	Silty sand with traces of clay and gravel.	2	SS	51					
	Compact to very dense.	3	SS	69					
		4	SS	60					
			for 3"						
838.5		5	SS	80					
36.5	End of borehole.		for 3"						

264.4
WL El 867.3
Observed in casing.

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

JOB 65-F-31

W.P. 160-60

DATUM 875.0

RECORD OF BOREHOLE NO. 4

FOUNDATION SECTION

LOCATION Hwy 403 Line "G" & Hwy 24A Line "J" Ch 336+91 30' Rt.

BORING DATE March 25-26, 1965.

BOREHOLE TYPE Washboring - BX Casing.

ORIGINATED BY W.H.K.

COMPILED BY W.H.K.

CHECKED BY K.G.S. *dlr*

SOIL PROFILE		SAMPLES		ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE		LIQUID LIMIT PLASTIC LIMIT WATER CONTENT		BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS / FOOT	SHEAR STRENGTH P.S.F.	W.P.	W.L.			
875.0	Groundlevel									
873.0	Black org. topsoil	1	SS	51						
2.0	Silty sand with traces of clay and gravel.	2	SS	51						
	Compact to very dense.	3	SS	51						
		4	SS	57						
		5	SS	81						
838.5	End of borehole.									

266.7 m

255.6 m

m

264.2

EL El 366.9



Observed in casing.

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS & TESTING DIVISION

JOB 65-F-31

W.P. 160-60

DATUM 875.6

RECORD OF BOREHOLE NO. 5

FOUNDATION SECTION

LOCATION Hwy 403 Line "G" & Hwy 24A Line "J" Ch 335/26 301 Rt.

BORING DATE March 24, 1965.

BOREHOLE TYPE Washboring - BX Casing.

ORIGINATED BY W.W.K.

COMPILED BY W.W.K.

CHECKED BY K.G.S. *KL*

SOIL PROFILE		SAMPLES		ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE		LIQUID LIMIT PLASTIC LIMIT WATER CONTENT		BULK DENSITY P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS / FOOT	RESISTANCE	W.P.	W.L.			
375.6	Groundlevel									
873.6	Black org. topsoil	1	SS	29						
2.0	Silty sand with traces of clay and gravel.	2	SS	35						
	Compact to very dense.	3	SS	52						
		4	SS	69						
		5	SS	108						
834.1		6	SS	128						
41.5	End of borehole.									

264.2
EL EL 866.9
Observed in casing.

ABBREVIATIONS USED IN THIS REPORT

PENETRATION RESISTANCE

STANDARD PENETRATION RESISTANCE 'N' - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 12 INCHES INTO THE SUBSOIL, DRIVEN BY MEANS OF A 140 POUND HAMMER FALLING FREELY A DISTANCE OF 30 INCHES.

DYNAMIC PENETRATION RESISTANCE - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A 2 INCH, 60 DEGREE CONE, FITTED TO THE END OF DRILL RODS, 12 INCHES INTO THE SUBSOIL, THE DRIVING ENERGY BEING 350 FOOT POUNDS PER BLOW.

DESCRIPTION OF SOIL

THE CONSISTENCY OF COHESIVE SOILS AND THE RELATIVE DENSITY OR DENSENESS OF COHESIONLESS SOILS ARE DESCRIBED IN THE FOLLOWING TERMS:-

<u>CONSISTENCY</u>	<u>'N' BLOWS / FT.</u>	<u>c LB. / SQ. FT.</u>	<u>DENSENESS</u>	<u>'N' BLOWS / FT.</u>
VERY SOFT	0 - 2	0 - 250	VERY LOOSE	0 - 4
SOFT	2 - 4	250 - 500	LOOSE	4 - 10
FIRM	4 - 8	500 - 1000	COMPACT	10 - 30
STIFF	8 - 15	1000 - 2000	DENSE	30 - 50
VERY STIFF	15 - 30	2000 - 4000	VERY DENSE	> 50
HARD	> 30	> 4000		

TYPE OF SAMPLE

S.S.	SPLIT SPOON	T.W.	THINWALL OPEN
W.S.	WASHED SAMPLE	T.P.	THINWALL PISTON
S.B.	SCRAPER BUCKET SAMPLE	O.S.	OESTERBERG SAMPLE
A.S.	AUGER SAMPLE	F.S.	FOIL SAMPLE
C.S.	CHUNK SAMPLE	R.C.	ROCK CORE
S.T.	SLOTTED TUBE SAMPLE		
	P.H. SAMPLE ADVANCED HYDRAULICALLY		
	P.M. SAMPLE ADVANCED MANUALLY		

SOIL TESTS

Qu	UNCONFINED COMPRESSION	L.V.	LABORATORY VANE
q	UNDRAINED TRIAXIAL	F.V.	FIELD VANE
Qcu	CONSOLIDATED UNDRAINED TRIAXIAL	C	CONSOLIDATION
Qd	DRAINED TRIAXIAL	S	SENSITIVITY

ABBREVIATIONS USED IN THIS REPORT

SOIL PROPERTIES

γ	UNIT WEIGHT OF SOIL (BULK DENSITY)
γ_s	UNIT WEIGHT OF SOLID PARTICLES
γ_w	UNIT WEIGHT OF WATER
γ_d	UNIT DRY WEIGHT OF SOIL (DRY DENSITY)
γ'	UNIT WEIGHT OF SUBMERGED SOIL
G	SPECIFIC GRAVITY OF SOLID PARTICLES $G = \frac{\gamma_s}{\gamma_w}$
e	VOID RATIO
n	POROSITY
w	WATER CONTENT
S_r	DEGREE OF SATURATION
w_L	LIQUID LIMIT
w_p	PLASTIC LIMIT
I_p	PLASTICITY INDEX
s	SHRINKAGE LIMIT
I_L	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$
I_c	CONSISTENCY INDEX = $\frac{w_L - w_p}{I_p}$
e_{max}	VOID RATIO IN LOOSEST STATE
e_{min}	VOID RATIO IN DENSEST STATE
I_D	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
	RELATIVE DENSITY D_r IS ALSO USED
h	HYDRAULIC HEAD OR POTENTIAL
q	RATE OF DISCHARGE
v	VELOCITY OF FLOW
i	HYDRAULIC GRADIENT
k	COEFFICIENT OF PERMEABILITY
j	SEEPAGE FORCE PER UNIT VOLUME
m_v	COEFFICIENT OF VOLUME CHANGE = $\frac{-\Delta e}{(1+e)\Delta\sigma}$
c_v	COEFFICIENT OF CONSOLIDATION
C_c	COMPRESSION INDEX = $\frac{\Delta e}{\Delta \log_{10} \sigma}$
T_v	TIME FACTOR = $\frac{c_v t}{d^2}$ (d, DRAINAGE PATH)
U	DEGREE OF CONSOLIDATION
τ_t	SHEAR STRENGTH
c'	EFFECTIVE COHESION INTERCEPT
ϕ'	EFFECTIVE ANGLE OF SHEARING RESISTANCE, OR FRICTION
c_u	APPARENT COHESION
ϕ_u	APPARENT ANGLE OF SHEARING RESISTANCE, OR FRICTION
μ	COEFFICIENT OF FRICTION
S_t	SENSITIVITY

GENERAL

π	= 3.1416
e	BASE OF NATURAL LOGARITHMS 2.7183
$\log_e \sigma$ OR $\ln \sigma$	NATURAL LOGARITHM OF σ
$\log_{10} \sigma$ OR $\log \sigma$	LOGARITHM OF σ TO BASE 10
t	TIME
g	ACCELERATION DUE TO GRAVITY
V	VOLUME
W	WEIGHT
M	MOMENT
F	FACTOR OF SAFETY

STRESS AND STRAIN

u	PORE PRESSURE
σ	NORMAL STRESS
σ'	NORMAL EFFECTIVE STRESS ($\bar{\sigma}$ IS ALSO USED)
τ	SHEAR STRESS
ϵ	LINEAR STRAIN
γ	SHEAR STRAIN
ν	POISSON'S RATIO (μ IS ALSO USED)
E	MODULUS OF LINEAR DEFORMATION (YOUNG'S MODULUS)
G	MODULUS OF SHEAR DEFORMATION
K	MODULUS OF COMPRESSIBILITY
η	COEFFICIENT OF VISCOSITY

EARTH PRESSURE

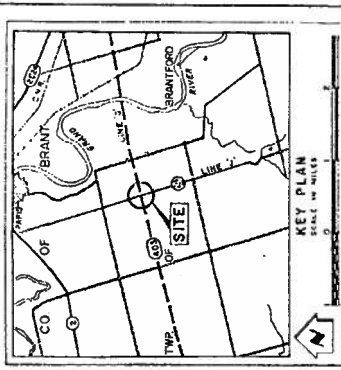
d	DISTANCE FROM TOP OF WALL TO POINT OF APPLICATION OF PRESSURE
δ	ANGLE OF WALL FRICTION
K	DIMENSIONLESS COEFFICIENT TO BE USED WITH VARIOUS SUFFIXES IN EXPRESSIONS REFERRING TO NORMAL STRESS ON WALLS
K_0	COEFFICIENT OF EARTH PRESSURE AT REST

FOUNDATIONS

B	BREADTH OF FOUNDATION
L	LENGTH OF FOUNDATION
D	DEPTH OF FOUNDATION BENEATH GROUND
N	DIMENSIONLESS COEFFICIENT USED WITH A SUFFIX APPLYING TO SPECIFIC GRAVITY, DEPTH AND COHESION ETC. IN THE FORMULA FOR BEARING CAPACITY
k_s	MODULUS OF SUBGRADE REACTION

SLOPES

H	VERTICAL HEIGHT OF SLOPE
D	DEPTH BELOW TOE OF SLOPE TO HARD STRATUM
β	ANGLE OF SLOPE TO HORIZONTAL



LEGEND		
	Bore Hole	
	Core Penetration Hole	
	Bore & Core Penetration Hole	
	Water Level	
Borehole locations established at time of road construction, March 1965		

NO.	ELEVATION	STATION	OFFSET
1	875.5	335+00	30' LT
2	875.4	337+38	50' LT
3	875.3	334+32	30' LT
4	875.0	338+31	30' RT
5	875.6	335+26	33' RT

NOTE
The boundaries between the various areas are indicated only of Bore Hole locations. Between bore holes the boundaries are assumed from geological evidence and may be subject to considerable error.

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION - PRODUCTION SECTION

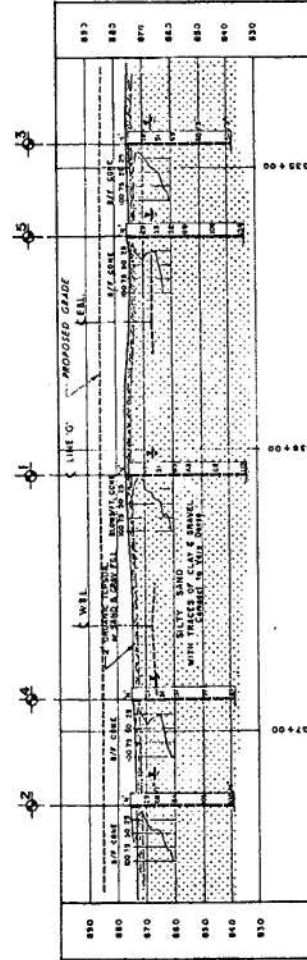
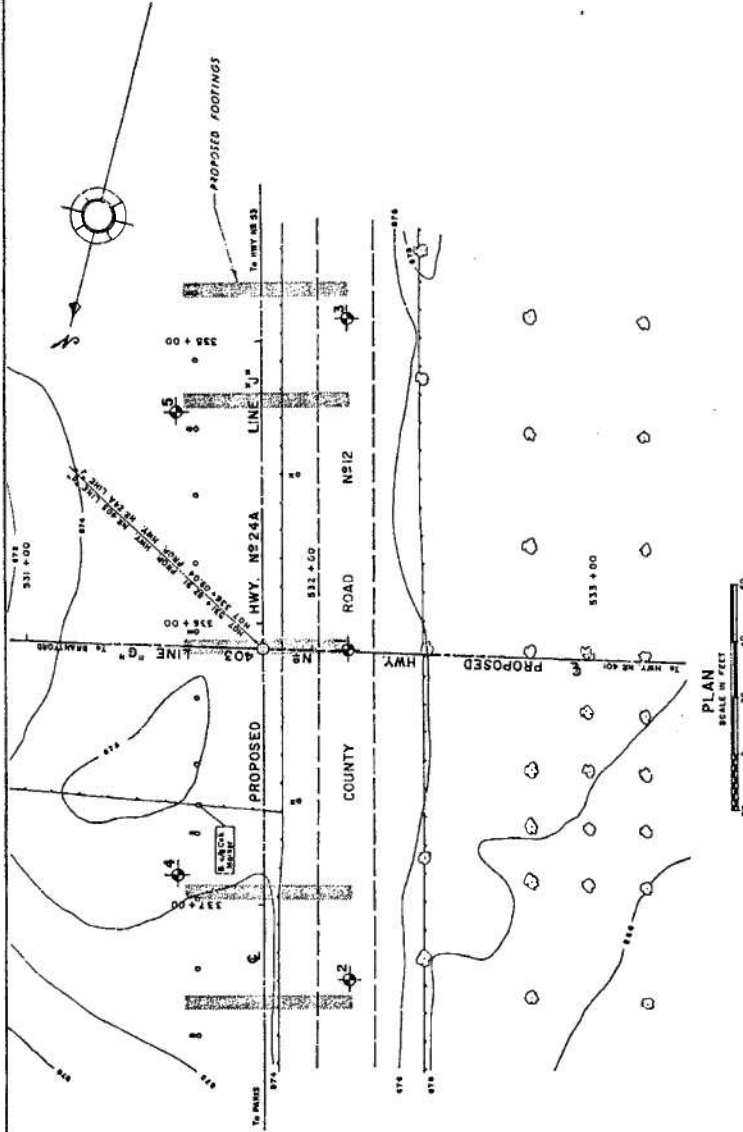
PROPOSED HIGHWAY NO. 24A LINE 'J'

KING'S HIGHWAY NO. 403 LINE 'E' DIST NO. 4

CO. BRANT TWP. BRANTFORD LOT 50 E. 11 CON. 3

BORE HOLE LOCATIONS & SOIL STRATA

START W. E. DECADE 1965	LOT NO.	80-00	W. E. DECADE 1965
PLAN Q24	LEGEND	43-1-31	85-E-31A
DATE 17 MAY 1965	DRAWN BY	W. E. DECADE 1965	W. E. DECADE 1965
APPROVED	DATE	17 MAY 1965	17 MAY 1965



6 PROFILE-LINE 'J'



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Borehole Number: 3

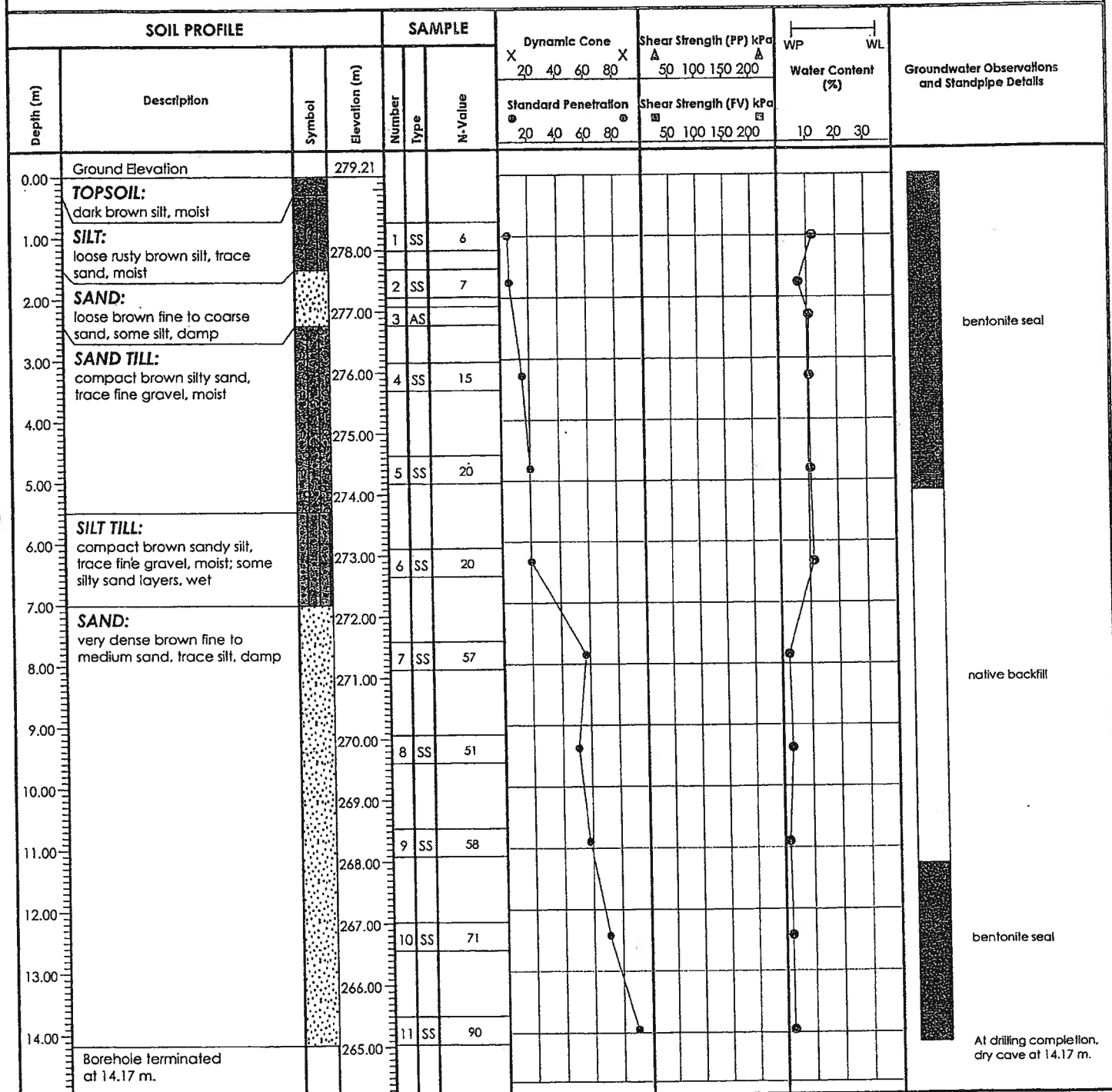
Ground Elevation: 279.21 m

Project: Southwest Paris Water and Wastewater Servicing Study

Job No.: 5703G1

Location: Rest Acres Road, Paris, Ontario

Drill Date: June 27, 2005



Reviewed by: T.S.

Field Tech.: R.M.

Drill Method: Solid Stem Auger

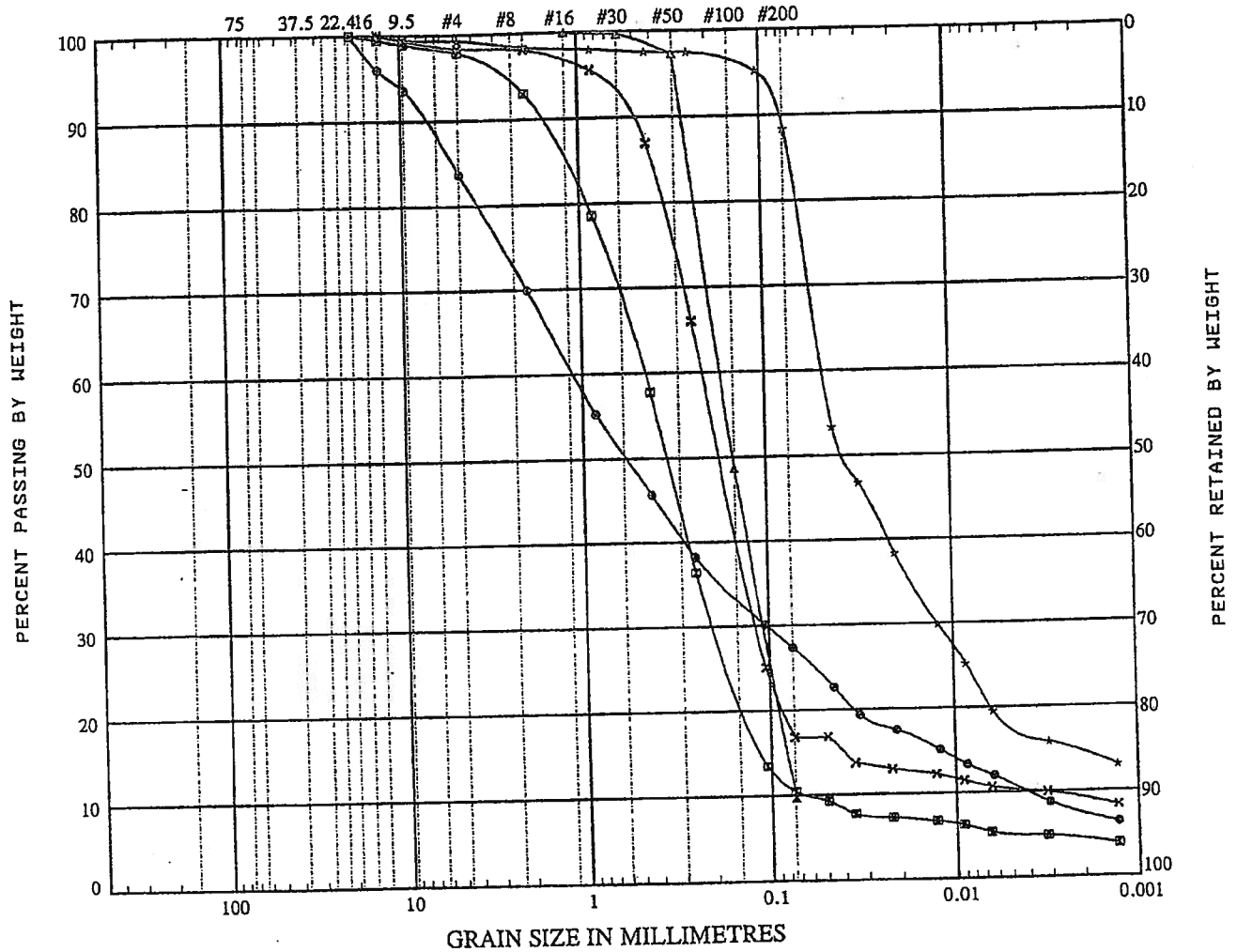
Sheet: 1 of 1

Notes: Bulk sample taken from 3.05 to 4.57 m.

Drafted by: A.G._01a

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN MILLIMETRES			U.S. STANDARD SIEVE No.			HYDROMETER



PROJECT Southwest Paris Water and Wastewater Servicing Study

LOCATION Rest Acres Road, Paris, Ontario

JOB NO. 5703G1

CURVE ID	BOREHOLE/TEST PIT	SAMPLE NO.	DEPTH (ft)	SOIL DESCRIPTION
●	BH1	5	4.57-5.03	Silty SAND AND GRAVEL
◻	BH4	4	3.05-3.51	SAND, trace Silt and Gravel
▲	BH13	4	3.05-3.51	SAND, trace Silt
*	BH18	4	3.05-3.51	SILT, some Sand and Clay
x	BH24	3	2.29-2.74	SAND, trace Silt

REMARKS _____



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Figure No. 1



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Borehole Number: 4

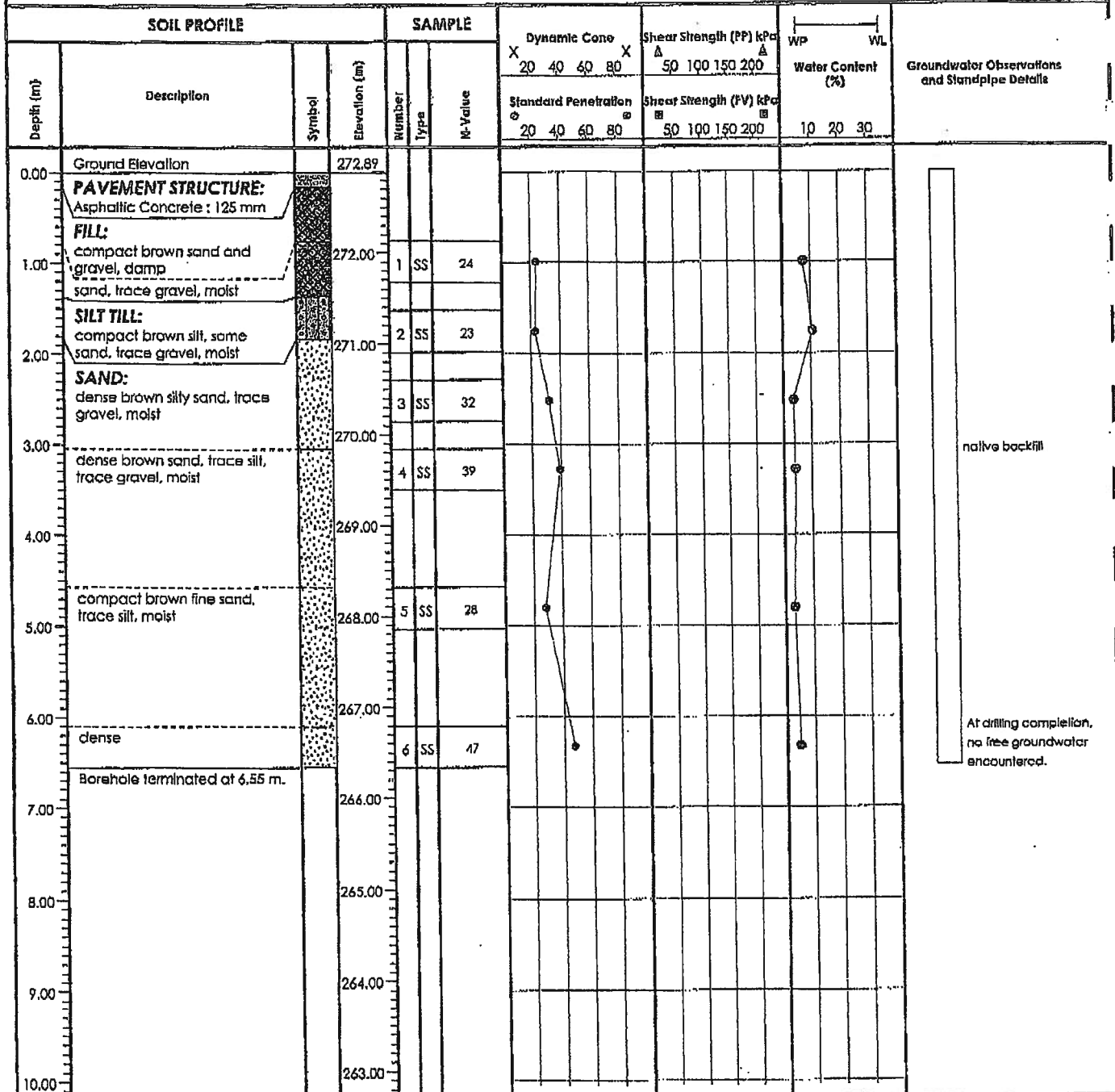
Ground Elevation: 272.89 m

Project: Southwest Paris Water and Wastewater Servicing Study

Job No.: 5703G1

Location: Rest Acres Road, Paris, Ontario

Drill Date: June 16, 2005



Reviewed by: T.S.

Field Tech.: D.B.

Drill Method: Solid Stem Auger

Sheet: 1 of 1

Notes:

Drafted by: A.G._01a



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Borehole Number: 5

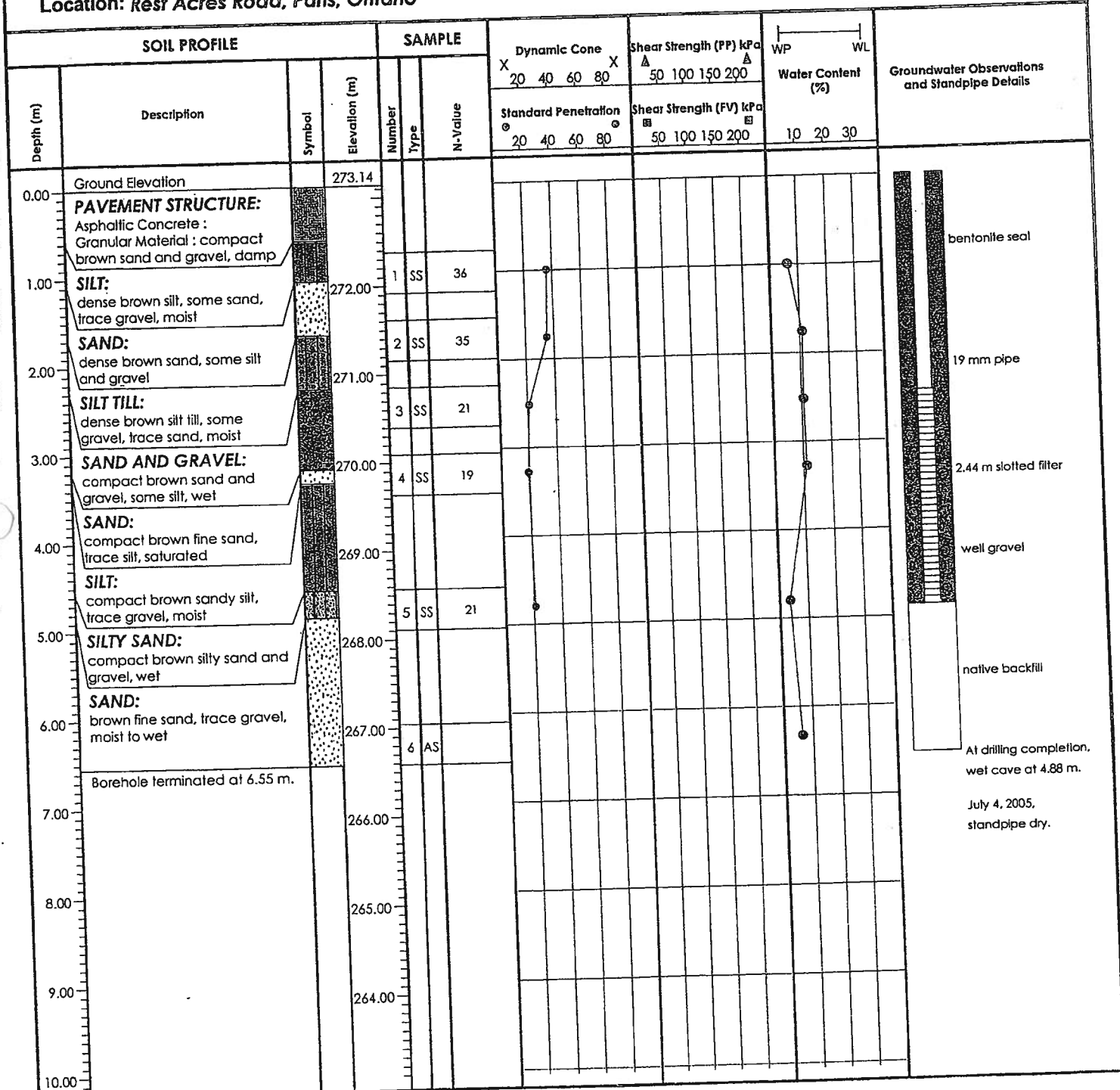
Ground Elevation: 273.14 m

Job No.: 5703G1

Drill Date: June 16, 2005

Project: Southwest Paris Water and Wastewater Servicing Study

Location: Rest Acres Road, Paris, Ontario



Reviewed by: T.S.

Drill Method: Solid Stem Auger

Notes:

Field Tech.: D.B.

Sheet: 1 of 1

Drafted by: A.G._01a



**Naylor
Engineering
Associates Ltd.**
CONSULTING ENGINEERS

Borehole Number: 6

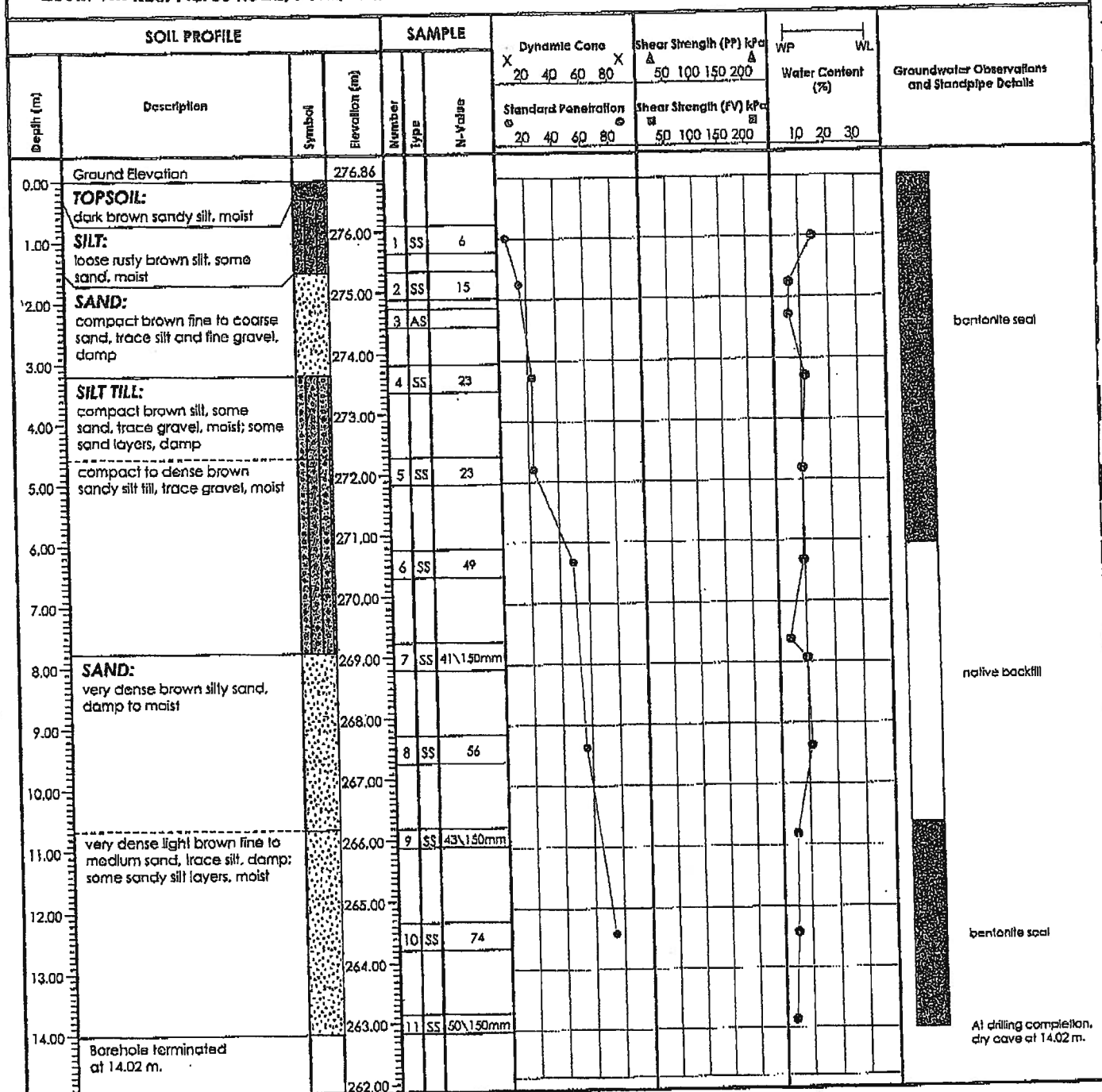
Ground Elevation: 276.86 m

Project: Southwest Paris Water and Wastewater Servicing Study

Job No.: 5703G1

Location: Rest Acres Road, Paris, Ontario

Drill Date: June 27, 2005



Reviewed by: T.S.

Field Tech.: R.M.

Drill Method: Solid Stem Auger

Sheet: 1 of 1

Notes: Bulk sample taken from 3.20 to 4.27 m.

Drafted by: A.G._01a



**Maylor
Engineering
Associates Inc.**
CONSULTING ENGINEERS

Borehole Number: 201

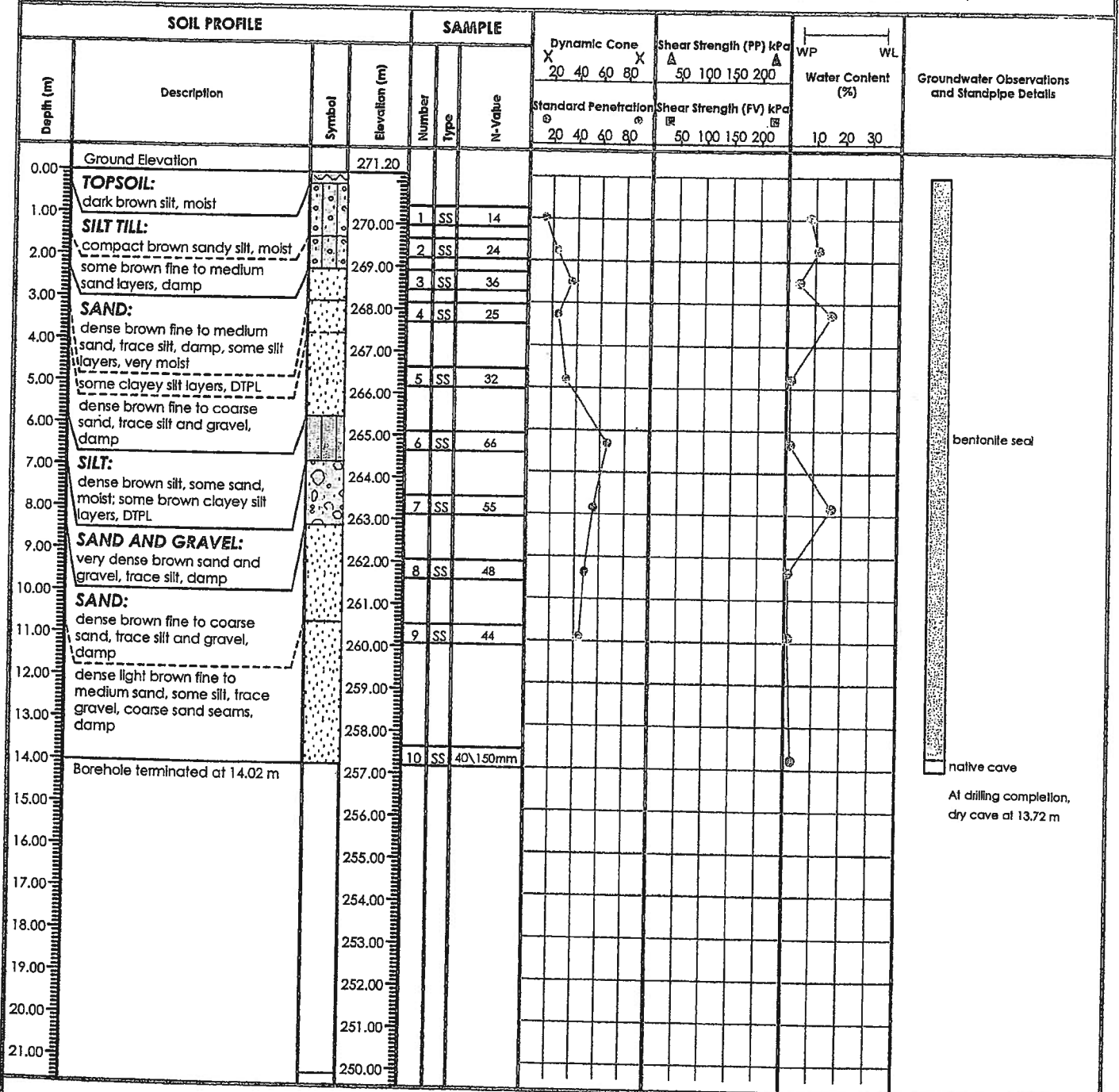
Ground Elevation: 271.20 m

Project: Aggregate Investigation - Rest Acres Road Industrial Subdivision

Job No.: 4315G3

Location: Rest Acres Road, County of Brant, ON

Drill Date: June 14, 2007



Reviewed by: TS

Drill Method: Solid Stem Auger

Notes:

Field Tech.: RM

Sheet: 1 of 1

Drafted by: AE(01a)



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Borehole Number: 202

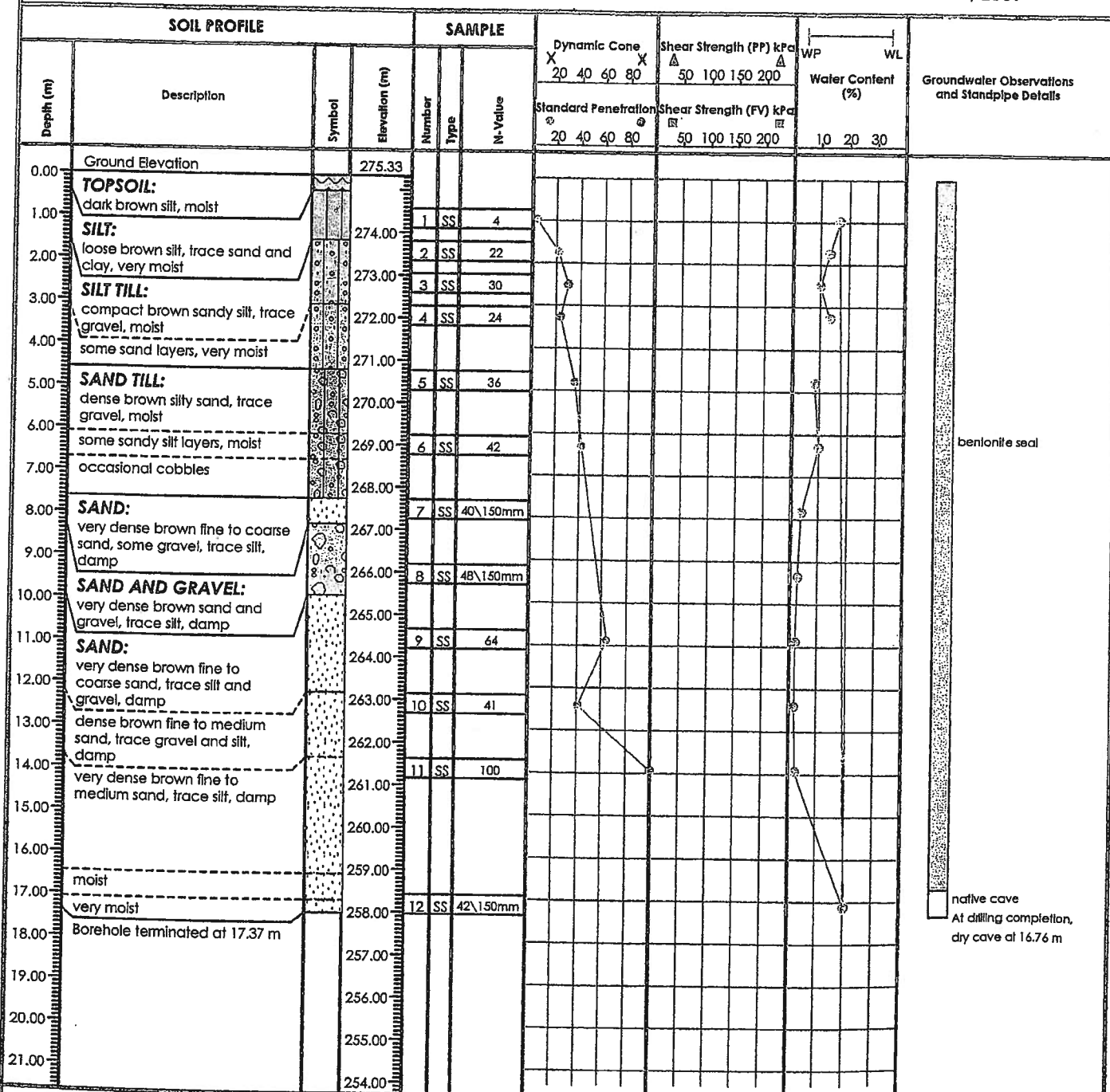
Ground Elevation: 275.33 m

Project: Aggregate Investigation - Rest Acres Road Industrial Subdivision

Job No.: 4315G3

Location: Rest Acres Road, County of Brant, ON

Drill Date: June 14, 2007

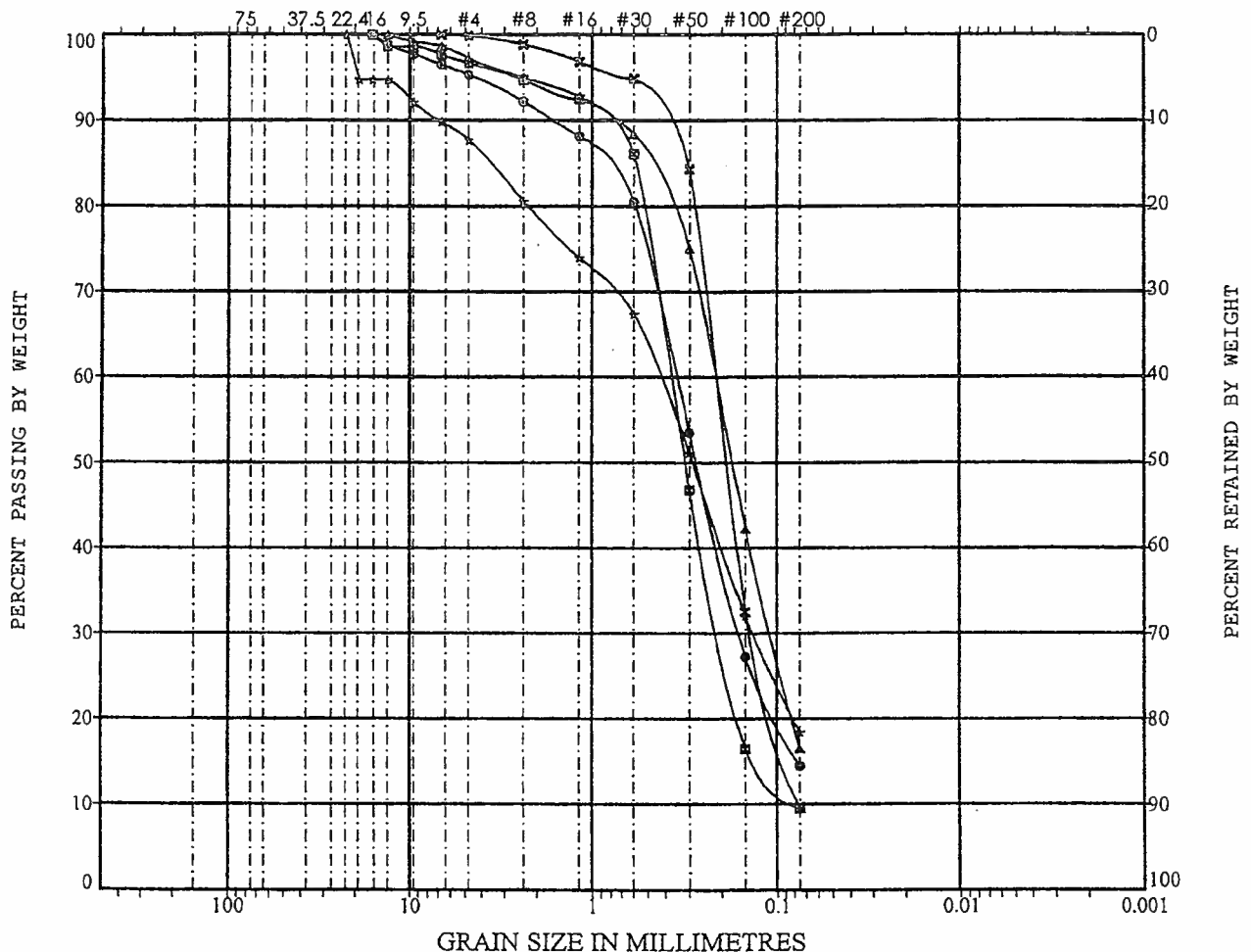


Reviewed by: TS
Drill Method: Solid Stem Auger
Notes:

Field Tech.: RM
Sheet: 1 of 1
Drafted by: AE(01a)

UNIFIED SOIL CLASSIFICATION

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN MILLIMETRES			U.S. STANDARD SIEVE No.			HYDROMETER



PROJECT Aggregate Investigation - Rest Acres Road Industrial Subdivision
 LOCATION Rest Acres Road, County of Brant, ON. JOB NO. 4315G3

CURVE ID	BOREHOLE/TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	BH201	9	10.67-11.12	SAND, some Silt, trace Gravel
⊠	BH202	10	12.19-12.60	SAND, trace Gravel and Silt
▲	BH203	10	10.67-11.12	SAND, some Silt, trace Gravel
★	BH205	7	7.62-8.08	SAND, some Gravel and Silt
✕	BH208	6	6.10-6.55	SAND, trace Silt

REMARKS _____



Naylor Engineering Associates Ltd.
CONSULTING ENGINEERS

Figure No. 1

Appendix B

Borehole Log Sheets, SPL BH09-1 through 09-5

PROJECT: SW Paris Phase 2 Watermain

CLIENT: County of Brant

PROJECT LOCATION: Rest Acres Rd. / Hwy 403, Rest Acres Rd. / Powerline Rd. Diameter: 205 mm

DATUM: Geodetic

BH LOCATION: See BH Location Plan N 4778781 E 550272

DRILLING DATA

Method: Hollow Stem Auger

REF. NO.: G-09.06.005

Date: Sep/15/2009

ENCL NO.: 01

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (C _u) (kPa)	NATURAL UNIT WT (Mg/m ³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%)
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m			SHEAR STRENGTH (kPa)							
276.2								20 40 60 80 100							
0.0	SILTY SAND Silty sand to fine sand, brown, trace rootlets, loose.		1	SS	5		276	○ UNCONFINED	+	FIELD VANE & Sensitivity					7 62 31 Grinding
275.1			2	SS	9		275	● QUICK TRIAXIAL	x	LAB VANE					
1.1	COARSE SAND brown, trace fine gravel, compact.														
274.7															
1.5	SAND trace stone fragments, brown, moist, trace gravel, compact.		3	SS	13		274								
273.9															
2.3	SILTY SAND trace clay, trace gravel, brown, moist, compact. (till like)		4	SS	13		273								
	occ. cobbles, dense.		5	SS	38		272								
			6	SS	38										
271.6	trace stone fragments weathered stone pocket, black.														
4.6	SANDY SILT TO SILT trace clay, brown, very moist to wet, compact.		7	SS	25		271								
270.9															
5.3	SILTY SAND trace clay, trace gravel, brown, moist, compact. (till like)		8	SS	17		270								
			9	SS	22		269								
			10	CC			268								
	very dense.		11	SS	64		267								
	occ. cobbles.		12	CC			266								
267.1															
9.1	FINE SAND trace to some silt, trace gravel, brown, moist, dense to very dense.		13	SS	33		265								
			14	CC			264								
			15	SS	57		263								
			16	CC			262								
			17	SS	69										
			18	CC											
			19	SS	106										
261.2			20	CC											

Continued Next Page

GRAPH
NOTES

+³, x³: Numbers refer to Sensitivity

○ = 3% Strain at Failure

LOG OF BOREHOLE 09-1

PROJECT: SW Paris Phase 2 Watermain

CLIENT: County of Brant

PROJECT LOCATION: Rest Acres Rd. / Hwy 403, Rest Acres Rd. / Powerline Rd. Diameter: 205 mm

DATUM: Geodetic

BH LOCATION: See BH Location Plan N 4778781 E 550272

DRILLING DATA

Method: Hollow Stem Auger

REF. NO.: G-09.06.005

Date: Sep/15/2009

ENCL NO.: 01

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (C _u) (kPa)	NATURAL UNIT WT (Mg/m ³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%)		
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m			SHEAR STRENGTH (kPa)								WATER CONTENT (%)	
								20 40 60 80 100	10 20 30								
15.0	FINE SAND						261								76 24		
260.7	trace to some silt, brown, wet, dense.		21	SS	30		W. L. 261.0 m Mar.31/11										
15.5	CLAYEY SILT/SILT																
260.0	very moist, brown, very stiff.		22	CC			260										
16.2	SILTY FINE SAND																
	brown, saturated, dense.		23	SS	43		259										
			24	CC			258										
		25	SS	41		257											
		26	CC			256											
	occ. sandy silt layers, dilatant, dense.	27	SS	41		255.9											
20.3	END OF BOREHOLE Notes: 1). 40 mm monitorwell installed. Water Level Record Feb. 17/10 Elev. 261.10 m Mar. 31/11 Elev. 260.98 m																

GRAPH
NOTES

+³, ×³: Numbers refer
to Sensitivity

○ = 3% Strain at Failure

LOG OF BOREHOLE 09-2

PROJECT: SW Paris Phase 2 Watermain

CLIENT: County of Brant

PROJECT LOCATION: Rest Acres Rd. / Hwy 403, Rest Acres Rd. / Powerline Rd. Diameter: 205 mm

DATUM: Geodetic

BH LOCATION: See BH Location Plan N 4778892 E 550231

DRILLING DATA

Method: Hollow Stem Auger

REF. NO.: G-09.06.005

ENCL NO.: 02

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	POCKET PEN. (kg)	NATURAL UNIT WT (Mg/m ³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%)
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m			SHEAR STRENGTH (kPa)							
279.0								20 40 60 80 100	50 100 150 200 250						GR SA SI CL
0.0	FILL silty sand, trace topsoil, dark brown, moist, trace rootlets, loose.	XXXX	1	AS	6						10				
278.4											o				
0.6	SILTY SAND trace fine gravel, brown, moist, compact. (till like)		2	SS	24		278				o				
			3	SS	14		277				o				
			4	SS	21		276				o				
	some stone fragments		5	SS	26		275				o				
			6	SS	30		274				o				Grinding
			7	SS	29		273				o				11 58 31
273.8															
5.2	SILTY SAND TO SANDY SILT trace gravel, occ. cobbles, brown, wet, compact. occ. clay layer		8	SS	16		272				o				
			9	SS	22		271				o				4 49 47
			10	CC			270				o				
271.5															
7.5	FINE TO MEDIUM SAND trace silt, trace gravel, occ. cobbles, brown, moist, dense to very dense.		11	SS	40		269				o				Grinding
			12	CC			268				o				
			13	SS	43		267				o				
			14	CC			266				o				
			15	SS	52		265				o				
			16	CC											4 91 5
267.0															
12.0	FINE SAND trace silt, trace gravel, brown, very moist to wet, dense to very dense.		17	SS	51		264				o				
			18	CC			263				o				
			19	SS	44		262				o				
			20	CC			261				o				

Continued Next Page

GRAPH NOTES

+ 3, X 3: Numbers refer to Sensitivity

○ = 3% Strain at Failure

PROJECT: SW Paris Phase 2 Watermain

CLIENT: County of Brant

PROJECT LOCATION: Rest Acres Rd. / Hwy 403, Rest Acres Rd. / Powerline Rd. Diameter: 205 mm

DATUM: Geodetic

DRILLING DATA

Method: Hollow Stem Auger

Date: Sep/16/2009

REF. NO.: G-09.06.005

ENCL NO.: 02

BH LOCATION: See BH Location Plan N 4778892 E 550231

[illegible]

GRAPH
NOTES

+³, ×³: Numbers refer to Sensitivity

○ ●=3% Strain at Failure

PROJECT: SW Paris Phase 2 Watermain

CLIENT: County of Brant

PROJECT LOCATION: Rest Acres Rd. / Hwy 403, Rest Acres Rd. / Powerline Rd. Diameter: 205 mm

DATUM: Geodetic

BH LOCATION: See BH Location Plan

DRILLING DATA

Method: Hollow Stem Auger

Date: Sep/17/2009

REF. NO.: G-09.06.005

ENCL NO.: 03

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT					POCKET PEN. (C _u) (kPa)	NATURAL UNIT WT (Mg/m ³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
(m)	ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE			"N" BLOWS 0.3 m	20	40	60	80				100	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
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282.1	0.0	FILL fine sand to silty sand, trace topsoil, brown, moist, trace small gravel.	XXXX	1	SS	10							○																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		</

GRAPH NOTES

+³, X³: Numbers refer to Sensitivity

○ = 3% Strain at Failure

PROJECT: SW Paris Phase 2 Watermain

CLIENT: County of Brant

PROJECT LOCATION: Rest Acres Rd. / Hwy 403, Rest Acres Rd. / Powerline Rd. Diameter: 205 mm

DATUM: Geodetic

BH LOCATION: See BH Location Plan N 4779451 E 550056




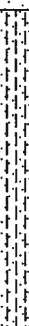

DRILLING DATA

Method: Hollow Stem Auger

Date: Sep/17/2009

REF. NO.: G-09.06.005

ENCL NO.: 04

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (C _u) (kPa)	NATURAL UNIT WT (Mg/m ³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%)			
(m)	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m			SHEAR STRENGTH (kPa)									WATER CONTENT (%)		
ELEV DEPTH								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × LAB VANE	20 40 60 80 100 50 100 150 200 250							10 20 30		
279.7	FILL silty sand, trace to some topsoil, trace rootlets, trace gravel, dark brown to brown, moist, compact. trace topsoil, trace clay, brown, loose.		1	SS	14		279												
			2	SS	4														
278.2	FINE SAND trace silt., brown, moist, compact.		3	SS	10		278										1 85 14		
1.5	SILTY SAND trace to some gravel, occ.cobbles, brown, moist, dense. (till like) wet some coarse to medium sand, saturated, compact below 3.8 m. occ. sand & gravel layers.		4	SS	34		277												
277.3																			
			5	SS	38		276.7 m Feb.18/10												
2.4																			
			6	SS	27	276												5 74 21	
			7	SS	22	275													
			8	SS	17	274													
273.9	END OF BOREHOLE Notes: 1). 40 mm monitorwell installed. 2). sand heaved up into augers during drilling at 4.9 m depth.																		
5.8																			

GRAPH
NOTES

+³, X³: Numbers refer
to Sensitivity

○ = 3% Strain at Failure

LOG OF BOREHOLE 09-5

PROJECT: SW Paris Phase 2 Watermain

CLIENT: County of Brant

PROJECT LOCATION: Rest Acres Rd. / Hwy 403, Rest Acres Rd. / Powerline Rd. Diameter: 205 mm

DATUM: Geodetic

BH LOCATION:

DRILLING DATA

Method: Hollow Stem Auger

Date: Sep/17/2009

REF. NO.: G-09.06.005

ENCL NO.: 05

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	POCKET PEN. (C _u) (kPa)	NATURAL UNIT WT (Mg/m ³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%)		
(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m			20	40	60	80	100							SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	
279.2																				
0.0	FILL silty sand & gravel, organic odour, trace rootlets, brown, moist, loose.		1	SS	7															
278.4																				
0.8	FILL silty sand with gravel, brown, moist, compact.		2	SS	32															
277.7																				
1.5	FILL sand & gravel, brown, moist, compact.		3	SS	44															
276.9																				
2.3	FINE TO MEDIUM SAND		4A	SS	28															
276.5	trace gravel, brown, wet, compact.		4B	SS	28															
2.7	wet silt layer, trace clay.																			
	SANDY SILT TO SILT		5	SS	28															
	trace clay, trace gravel, brown, wet, compact. (till like)																			
275.4																				
3.8	SILTY SAND		6	SS	39															
	trace clay, trace to some gravel, brown, saturated, dense. (till like)																			
274.0			7	SS	31															
5.2	END OF BOREHOLE																			

GRAPH NOTES

+³, ×³: Numbers refer to Sensitivity

○ ■=3% Strain at Failure

Appendix C

Photographs of Continuous Cores, BH09-1, 09-2

G-09.06.005 - Paris

BH09-1, CR 10



BH09-1, CR12



BH09-1, CR14



BH09-1, CR16



BH09-1, CR18



BH09-1, CR20



BH09-1, CR22



BH09-1, CR24



BH09-1, CR26



BH09-2, CR10



BH09-2, CR12



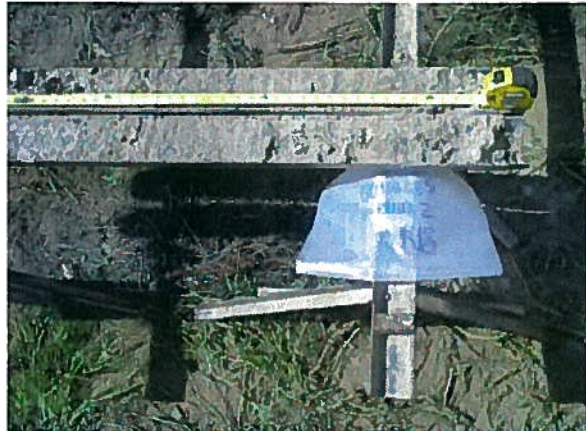
BH09-2, CR14



BH09-2, CR16



BH09-2, CR18



BH09-2, CR20



BH09-2, CR22



BH09-2, CR24



BH09-2, CR26

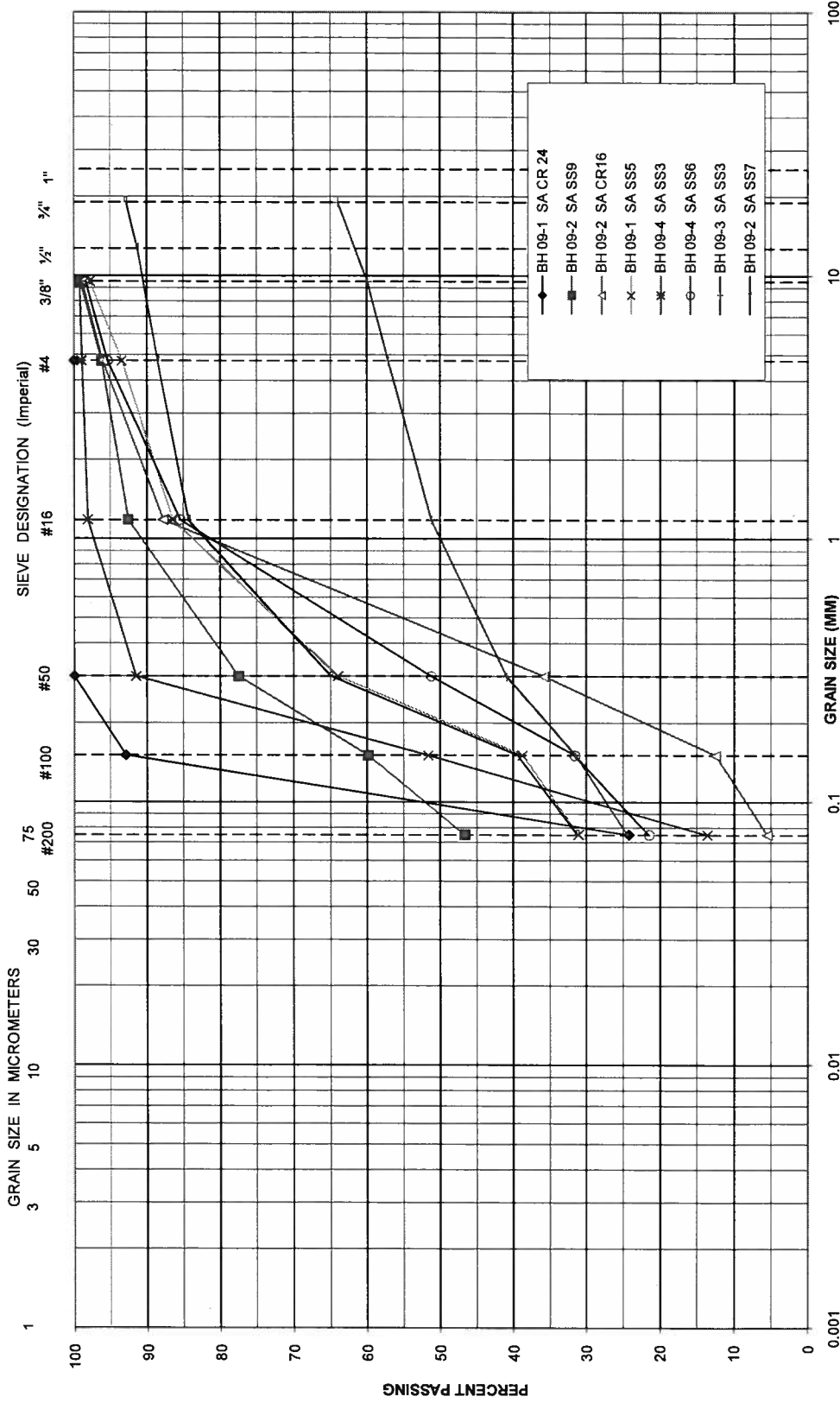


Appendix D

Geotechnical Laboratory Test Results

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT			SAND			GRAVEL		
			Fine	Medium	Coarse	Fine	Coarse	



GRAIN SIZE DISTRIBUTION

Figure No. 1
Project No. G09.06.005
Date: October 14, 2009

Appendix E

Statement of Limitations

LIMITATIONS OF REPORT

This report is intended solely for the Client named. The material in it reflects our best judgment in light of the information available to SPL Consultants Limited at the time of preparation. Unless otherwise agreed in writing by SPL Consultants Limited, it shall not be used to express or imply warranty as to the fitness of the property for a particular purpose. No portion of this report may be used as a separate entity, it is written to be read in its entirety.

The conclusions and recommendations given in this report are based on information determined at the test hole locations. The information contained herein in no way reflects on the environment aspects of the project, unless otherwise stated. Subsurface and groundwater conditions between and beyond the test holes may differ from those encountered at the test hole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the test hole locations and should not be used for other purposes, such as grading, excavating, planning, development, etc.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with the details stated in this report.

The comments made in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of test holes may not be sufficient to determine all the factors that may affect construction methods and costs. For example, the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusions as to how the subsurface conditions may affect their work. This work has been undertaken in accordance with normally accepted geotechnical engineering practices.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. SPL Consultants Limited accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

We accept no responsibility for any decisions made or actions taken as a result of this report unless we are specifically advised of and participate in such action, in which case our responsibility will be as agreed to at that time.