Terraprobe

Consulting Geotechnical & Environmental Engineering
Construction Materials Inspection & Testing

FOUNDATION INVESTIGATION AND DESIGN REPORT
PROPOSED FUTURE SERVICE CROSSING
CASING INSTALLATION
HIGHWAY 26 BYPASS IMPROVEMENTS
SOUTH OF RAMBLEWOOD DRIVE
TOWN OF WASAGA BEACH, ONTARIO

Prepared for: Town of Wasaga Beach
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Project Engineer

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Distribution:

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FOUNDATION INVESTIGATION AND DESIGN REPORT PROPOSED FUTURE SERVICE CROSSING CASING INSTALLATION HIGHWAY 26 BYPASS IMPROVEMENTS SOUTH OF RAMBLEWOOD DRIVE TOWN OF WASAGA BEACH, ONTARIO

PART 1: **FACTUAL INFORMATION**

1. INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted along a proposed 450mm diameter steel casing for a future watermain and a proposed 300mm diameter steel casing for a future forcemain alignment crossing beneath the existing Highway 26 in the west end of Wasaga Beach, Ontario (see Figure(s) in Appendix C).

This report addresses the Location 3 (south of Ramblewood Drive) casing installations. A total of three (3) distinct crossings were investigated concurrently. Locations 1 and 2 are addressed under separate cover.

The purpose of this investigation was to explore the subsurface conditions along the alignment and, based on the data obtained, to provide a borehole location plan, records of boreholes, laboratory test results and a written description of the subsurface conditions.

Terraprobe conducted the investigation as a sub-consultant to the Ainley Group on behalf of the Town of Wasaga Beach.

It is proposed to install a pair of 87.0m long steel casings with approximately 2.75m horizontal separation on centre. This will include a 450mm diameter steel casing for a future watermain and a 300mm diameter steel casing for future forcemain crossing beneath the east and west bound lanes of Highway 26 (the lanes travel nearly north-south along this section of Highway 26). The crossing will be installed between stations 28 + 780 and 28+ 825 approximately. The crossing depth will be 5.0m minimum from existing road grade to obvert.

The following documents are referenced in the preparation of this report:

- Ainley Group - Preliminary Plan and Profile Drawings for Location 3
- MTO Guidelines for Foundation Engineering - Tunnelling Speciality

2. SITE DESCRIPTION AND PHYSIOGRAPHY

The site is located approximately 140m south of the intersection of the existing Highway 26 and Ramblewood Drive in the west end of Wasaga Beach, Ontario (see Appendix C). The proposed future watermain and forcemain casings will be 5.0m minimum depth typically. Within the construction limits, Highway 26 is a two-lane highway with gravel shoulders carrying both east and west bound traffic. It is proposed to install these casings in consideration of future development to the west of Highway 26.

The area lies within the Nottawasaga Basin of the Simcoe Lowlands Physiographic Region (Chapman and Putnam).

Quaternary Geology mapping (MNR P2556) indicates the area is underlain by till and glaciolacustrine deposits; undifferentiated predominantly sandy silt to silt matrix but with lacustrine sand to gravelly sand deposits. The depth to bedrock of the Verulam and/or Lindsay formation (limestone) is anticipated to be about 40 m. The crossing alignment is roughly 1630m south of the shoreline of Georgian Bay (Nottawasaga Basin) at this location. Grades fall gently via terraces northward to the shoreline.

3. SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this location were carried out on September 22, 2010 and consisted of drilling and sampling four (4) boreholes (301 to 304) to depths of 7.0 to 7.9m below ground surface. The approximate borehole locations are shown on the attached Borehole Location Plan and Cross Section drawings in Appendix C.

It is our understanding that the proposed borehole locations, depths and number were reviewed by MTO and Town of Wasaga Beach representatives prior to commencement of the field investigation.

The borehole locations were marked in the field by Terraprobe adjacent to the alignment of the proposed crossings. Utility clearances were obtained by Terraprobe prior to drilling and an MTO Encroachment Permit (EC-2010-20T-236) was applied for and obtained by the Ainley Group.

The drilling, sampling and in-situ testing operations were conducted with a crawler-mounted CME45 drill rig owned and operated by a specialist soil drilling contractor. Solid stem auger drilling techniques were utilized to advance the boreholes. Samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in the overburden soils, as specified in ASTM Method D1586.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Standpipe piezometers consisting of 19mm diameter PVC pipe with a slotted screen enclosed in sand were installed in select boreholes to permit longer term static ground water level monitoring. The remaining boreholes were abandoned in accordance with MOE Regulation 903 by sealing with a bentonite mixture after drilling was complete.

The location and completion details of the piezometers are shown in Table 3.1.

Table 3.1 - Piezometer Installation Details

Piezometer Location	Piezometer Details	
	Tip Depth/Elev. (m)	Completion Details
302	7.6/185.6	Piezometer with 3.0m slotted screen installed with filter sand to 4.3m, bentonite seal from 4.3m to 3.0m and drill cuttings from 3.0m to ground surface.
304	7.4/185.5	Piezometer with 3.0m slotted screen installed with filter sand to 4.3m, bentonite seal from 4.3m to 3.0m and drill cuttings from 3.0m to ground surface.

The drilling and sampling operations were observed on a full time basis by members of Terraprobe's technical staff who logged the boreholes and processed the recovered soil samples for transport to Terraprobe's Barrie laboratory for further examination and testing.

4. LABORATORY TESTING

The recovered soil samples were subjected to visual identification and natural moisture content determination. Selected samples were also subjected to gradation analysis and Attenberg Limits tests. The results of this testing program are shown on the Record of Borehole sheets in Appendix A. The grain size distribution curves are illustrated in Appendix B.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to Record of Borehole sheets in Appendix A . Details of the encountered soil stratigraphy are presented in this appendix and on the Borehole Location Plan and Cross Section drawing in Appendix C . An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.

In general, the site is underlain by localized gravelly sand fill to sandy silt fill and overburden soils consisting of clayey silt, silt and silty sand to silt and sand glacial till.

5.1 Topsoil

No defined topsoil layer was encountered at the ground surface in Boreholes 301 to 304 along this proposed alignment. Localized areas of surficial topsoil should be anticipated in landscaped lawn and field areas.

5.2 Fill

At Borehole 301 and 304, gravelly sand road shoulder material was encountered to about 0.15 and 1.3m depth respectively. SPT ‘N’ values in the gravelly sand fill material ranged from 8 to 26 blows for 0.3m penetration indicating a loose to compact consistency. The moisture content of samples of the gravelly sand fill soil varies from about 4% to 5% by weight.

5.3 Fill

Boreholes 303 to 304 encountered an earth fill varying from sandy silt to silt fill with trace clay, organics and gravel, that extended to depths of 1.4m to 2.1m. Standard Penetration tests in this deposit gave ‘N’ values ranging from 6 to 18 blows per 0.3 m penetration. Based on these results the deposit is considered to have loose to compact consistency. The moisture content of samples from this stratum ranged from 16% to 29% by weight. Trace organics were noted in the sandy silt to silt fill soils.

5.4 Silty Sand to Silt and Sand Till

Underlying the surficial granulars and fills at this location, associated with previous earthworks and grading, is silty sand to silt and sand glacial till as shown on the attached borehole logs. A surficial layer of native silty clay with some sand and trace gravel was encountered above the till within Boreholes 301 and 302, extending down to depths of about 3.3 to 1.3m below existing grade. The composition of the silty sand to silt and sand till varied with zones of clayey silt, silt and sand, sandy silt and silty sand. Trace to some gravel was noted as well as occasional cobbles.

Standard Penetration Values through the inter-layered till deposits vary from 16 to greater than 50 blows per 0.1 m of penetration indicating compact to very dense conditions. More typically the ‘N’ values were greater than 40 in the till soils. SPT values of 9 to 27 blows per 0.3m of penetration were recorded in the stiff to very stiff silt and clayey silt deposit.

It is possible that the high ‘N’ values represent gravel and cobbles within the till. Auger grinding on gravel and cobbles was noted during the drilling.

Generally, wet conditions are noted in the open Boreholes 303 and 304 at a depth of approximately 3 to 6m in the underlying silty sand to silt and sand till soils containing trace gravel. Boreholes 301 and 302 remained open and dry upon completion of drilling.

Moisture contents in the silty sand to silt and sand till deposits vary from 6 to 13%. The upper clayey silts of Boreholes 301 and 302 indicated moisture contents of 12 to 32% by weight.

5.5 Water Levels

Standpipe piezometers were installed in selected boreholes and water level readings were taken during a return visit to the site made after the completion of drilling. The water level records are presented in Table 5.5.

Table 5.5 - Water Level Measurements

Borehole	Ground Surface Elevation (m)	Date	Water Levels	
			Depth (m)	Elevation (m)
302	193.2	September 23, 2010	Dry to 7.6	Below 185.6
304	192.9	September 23, 2010	5.8	187.1

The ground water table was estimated based on the recorded water levels in the standpipe piezometers and our review of moisture contents of the retrieved samples. This interpretation indicates a ground water table that is estimated to range between Elev± 187.0m and Elev± 191.0m.

All groundwater observations at this site are short term and the levels are expected to fluctuate seasonally and after significant weather events.

5.6 Miscellaneous

The borehole locations were laid out in the field with the assistance of surveyors from Ainley Group who also provided Terraprobe with their coordinates and geodetic elevations following drilling. The borehole locations and appended drawings are referenced to MTM Zone 10 coordinate system. Terraprobe obtained utility clearances and permits prior to drilling.

The drilling, sampling and in-situ testing operations were conducted with a track-mounted drill rig owned and operated by KC Drilling Limited of Belle Ewart, Ontario.

The boreholes were advanced using solid-stem augers.

Mr. Bo Sung Hwang, EIT, observed and recorded the field work. The laboratory testing was performed at Terraprobe's Barrie laboratory. The report was written by Mr. Blair E. Goss, P. Eng. and reviewed by Mr. Michael Tanos, P. Eng. (Review Principal).

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FOUNDATION INVESTIGATION AND DESIGN REPORT PROPOSED FUTURE SERVICE CROSSING CASING INSTALLATION HIGHWAY 26 BYPASS IMPROVEMENTS SOUTH OF RAMBLEWOOD DRIVE TOWN OF WASAGA BEACH, ONTARIO

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

6. GENERAL

The Town of Wasaga Beach is planning for future development at its western limits, to the southwest of Highway 26.

Associated with this is the necessity to provide for future service crossings of Highway 26 in the west end of Wasaga Beach.

This report presents interpretation of the geotechnical data in the factual report (Part 1) and provides geotechnical design recommendations for the proposed future watermain and forcemain casing installations below Highway 26. The watermain and forcemain casings are to be installed (by tunnelling) under the current two lanes of Highway 26 and the unnamed gravel access road.

The future watermain and forcemain alignment crosses Highway 26 from west to east at about Sta 28 + 780 to 28+825, just south of the Ramblewood Drive/Highway 26 at-grade intersection. The watermain and forcemain casings are proposed to be installed below Highway 26 as 87.0m long, 450mm and 300mm diameter steel casings respectively along an alignment that extends between about Sta. 28 + 780 to Sta.28 + 825. The approximate invert elevation of the steel casing is Elev. 190.2m and the depth below existing grade is about ±5.0m. The minimum overburden cover measured from the lowest ground elevation to the crown of the tunnel exceeds three tunnel excavation diameters or 1.35m, in accordance with MTO Tunnelling Guidelines. The attached Appendix C shows a cross section along the proposed tunnel in addition to the borehole soil stratigraphy.

At the time of preparation of this report the designers are considering use of a jack and bore technology with steel liners to install the casings at this location.

Open cut is technically feasible but would impact traffic flow on Highway 26.

The discussion and recommendations presented in this report are based on our understanding of the project and on the factual data obtained in the course of this investigation.

7. WATERMAIN AND FORCEMAIN CASING CROSSINGS - HIGHWAY 26

7.1 General

This report presents the discussion and recommendations for the proposed trenchless installations (tunnelling) of the watermain and forcemain casings below Highway 26 only. This report does not address servicing installations beyond the limits identified in this report.

A 450mm diameter steel casing for future watermain and a 300mm diameter steel casing for future forcemain are proposed to be installed below Highway 26 at an invert elevation of about 190.2m. The length of the crossing is approximately 87.0m extending from Sta.28 + 780 to Sta. 28 + 825. The casings will be installed in native silty sand to silt and sand glacial till material at or near the ground water level.

7.2 Installation Methods

The diameter, length and anticipated subsurface conditions limit the range of trenchless installation techniques that would be economically viable at this site. Each method considered has advantages; disadvantages or limitations and these are discussed. The methods that were considered are:

1. Pipe Jacking and Horizontal Auger Boring
2. Microtunnelling
3. Horizontal Directional Drilling
4. Pipe Ramming
5. Open Cut Trenching

Tunnelling shall be undertaken in accordance with OPSS 415, 416 and 450 as appropriate. The choice of equipment and the method of tunnelling is the Contractor's responsibility.

For small diameter tunnels (0.3 to 0.45m), the gravel and cobbles within the native till presents an unpredictable risk of obstructions which could result in aborted tunnelling attempts and/or significant delays and increases in cost.

Due to the presence of gravel and cobbles, the tunnel diameter may need to be larger than proposed in order to permit the use of cutting equipment and tools to remove obstacles such as cobbles. If the tunnel diameter were increased, the work could also be completed by hand mining.

Based on the current invert of the proposed crossing at this location, the top of proposed tunnel has the potential to intercept fill soils in the area of Borehole 304. This could cause difficulties in maintaining stability and alignment of the tunnel section.

It is recommended that the tunnel alignment be lowered such that top of the tunnel is at least 1.5 times the tunnel diameter below the fill/native soil interface, entirely within the native soil. Alternatively, the casing could be installed by open cut trenching and lowering of the crossing would not be required.

7.2.1 Pipe Jacking and Horizontal Auger Boring

A pipe jacking operation involves pushing an oversized liner pipe horizontally into the ground by jacking. A range of excavation methods are available for removing the soil from inside the pipe as it is advanced. Augering is one common excavation method. Precision is normally ±1% of the driven length.

Horizontal auger boring requires an auger boring machine that is used to bore horizontally through soil or rock with a cutting head and auger. The cutting head can be located either inside or outside of the casing pipe that is being jacked forward. The auger boring machine can accept many types of cutting attachments ranging from backhoe teeth cutters for excavating soil to small boring units equipped with mini disc cutters for excavating rock. Small boring units can be steered to maintain line and grade.

The borehole data indicates that if the watermain and forcemain casing design inverts are maintained (approximate elevation 190.2m) the tunnelling operation will be made in native silty sand to silt and sand till material. The native silty sand to silt and sand till is dense to very dense and is expected to have a stand-up time of a few hours. More sandy zones found within the till could be fast ravelling and there could be potential loss of ground when tunnelling through this material. Cobbles and boulders should also be anticipated along this alignment. The tunnelling contractor must ensure that the tunnelling equipment is suitably designed to deal with these soil conditions.

The casing should closely follow the advancing cutting head in order to minimize settlements.

When excavation is halted, the casing should be in close contact with the cutting head in order to maintain stability. Ground closure around the liner is expected to be minimal. The application of a bentonite slurry under pressure may be required to reduce frictional resistance.

Settlement at the ground surface on this alignment is estimated to be negligible when tunnelling within the overburden soils. This estimate is based on the assumption that the work will be carried out by experienced tunnellers with great care and good workmanship. Under "normal" tunnelling operations, ground loss can be limited to acceptable levels. However, excessive ground loss, and settlement can occur when unusual conditions (such as boulder removal and water-bearing sand lenses) are encountered. A great deal of care is required under these conditions.

The silty sand to silt and sand till soils have relatively low permeabilities and ground water seepage is expected to be in small quantities at a slow rate. This seepage can be handled by gravity drainage into the entry shaft from where it could be removed by pumping and from filtered sumps.

7.2.2 Microtunnelling

This technique is similar to horizontal auger boring where a liner pipe is jacked horizontally into the ground. The liner follows closely behind a remote controlled cutting head that can be designed to excavate soil and rock.

Microtunnelling is a very precise method of tunnelling and with the suitable choice of cutting tools a wide soil spectrum as well as rock can be excavated. Additionally, there is relatively little settlement with this method if handled properly.

This method is feasible for consideration at this site. However, due to the specialized type of machinery required it might be prohibitvely expensive for this relatively short run.

7.2.3 Horizontal Directional Drilling

Horizontal directional drilling is a trenchless construction method that involves drilling a small pilot hole, using technology that allows the drill to be steered and tracked from the surface. The pilot hole is enlarged (usually approximately 1.5 times the largest outside diameter of the new pipe) by pulling back increasingly larger reamers, or reaming heads, from the insertion point to the rig side.

To achieve the appropriate bore path size it may be necessary to perform several reaming operations. Generally, all reaming procedures prior to the actual product installation are referred to as pre-reams, and the final ream to which the product pipe is attached is referred to as the back ream.

After the pre-reams, the pulling head and connecting product pipe are attached to the reamer using a swivel, a device that isolates the product pipe from the rotation of the drill pipe. The product pipe is then pulled behind the final reamer back through the horizontal directional drill path to the exit pit on the rig side.

This method is feasible and the equipment is readily available in Ontario. However, proper care must be taken at all phases of construction to ensure that proper grade and line is achieved even after a successful pilot bore is completed. Boulder obstructions may cause problems with this method.

7.2.4 Pipe Ramming

Pipe ramming is a trenchless method for installing steel pipes or casings in which a pneumatic tool is used to hammer the pipe or the casing into the ground. The soils inside the pipe can be removed either during or after the installation by augering, compressed air or water jetting.

Pipe ramming is not-steerable, meaning that subsurface obstructions or improperly aligned pipes may result in significant deviations from the desired line and grade.

Although pipe ramming can be applied in a wide variety of soils, some soils are better suited for this method than others.

One drawback is the possibility of significant soil disturbance if a blockage is created at the end of the installed pipe, especially if this occurs below the existing Highway 26. Other issues that require careful consideration include the length of the installation and the high noise levels.

Based on the foregoing, pipe ramming is not recommended.

7.2.5 Open Cut Trenching

The open cut method is a relatively simple method and would be a continuation of other service installations around the site. However, the main disadvantage is that provisions will have to be made for maintaining traffic flow. For this reason, open cut trenching is not considered a preferred option by the Town.

Open cut trenching may need to be reconsidered as a reasonable and viable option for this crossing. Excavations by open cut methods more easily deal with inclusions or obstructions such as cobbles and/or boulders which may otherwise significantly hinder the progress of the trenchless tunnelling methods noted above.

8. TUNNEL SUPPORT

In the completed tunnel the maximum residual stress would be expressed in the spring-line of the tunnel diameter where the unbalanced horizontal stress is a maximum. The horizontal and tangential pressure on the steel casing is a function of the vertical in situ pressure, which is given by:

$P_h = \gamma\ (h - h_w) + \gamma' h_w + h_w\ \gamma_w$

γ = bulk unit weight of soil

γ_w = unit weight of water (9.81 kN/m^3)

h = depth below surface (m)

h_w = depth below the groundwater level (m)

For design purposes assume a unit weight of 21 kN/m^3 for the soil overlying the springline of the tunnel. An allowance should be made for additional surcharge loads.

9. LATERAL EARTH PRESSURE

The entry and exit shafts will have to be supported by a vertical shoring system. The shape of the soil pressure distribution diagram behind the shoring system depends upon the type of soil to be encountered and the amount of movement that can be permitted. The sequence of work may also alter the shape of the pressure diagram during the various construction phases.

Decisions regarding shoring methods and sequencing are the responsibility of the Contractor. Temporary shoring should be designed by a licensed Professional Engineer experienced in shoring design.

Earth pressure computations must also take into account the ground water level. Above the ground water level, earth pressure is computed using the bulk unit weight of the retained soil. Below the ground water level, the earth pressures are computed using the submerged unit weight of the soil. A hydrostatic pressure is also applied if the retained soil is not fully drained.

The appropriate values of the parameters for use in the design of structures subject to unbalanced earth pressures are given in Table 9.1.

Table 9.1 - Earth Pressure Coefficients

Stratum	ϕ	γ	K_a	K_o	K_p
Earth Fill	28	19	0.36	0.53	2.77
Silty Sand to Silt and Sand Till	35	21	0.27	0.43	3.70

The factors in the table above are "ultimate" values and require certain movements for the active and passive conditions to be mobilized. The values to use in design can be estimated from Figure C6.9.1 (a) in the Commentary to the CHBDC, 2006.

Flexible shoring should be designed on the basis of the active earth pressure coefficient (K_a). In this case, the performance level should be Level 1 - Angular Distortion 1:200 but shall not be more than 25mm. Where limited shoring movement (less than performance Level 1) is required the design should be based on the at rest earth pressure coefficient (K_o). For "kick out" design the lateral resistance should be computed on the basis of the passive earth pressure coefficient (K_p).

10. BASAL STABILITY

Tunnelling will require the construction of entry and exit shafts on both alignments. The borehole data shows that the excavation bases will be made in compact to very dense silty sand to silt and sand till. The base of the excavations will be stable with respect to bottom heave when property dewatered.

11. OHSA SOIL CLASSIFICATION

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the fill and native layered soils may be classified as Type 3 soils above the ground water table and Type 4 soils below the groundwater table.

Open cut excavations above the water table may be sloped at 1.5H:1V. Below the ground water table the sandy soils may be excavated at 5H:1V or dewatered prior to excavation. The allowable side slope for excavations made in submerged silts should be at least 2H:1V or flatter. Excavations at steeper inclinations will require shoring and/or dewatering.

12. GROUND WATER CONTROL

The ground water table at this site is estimated to range between Elev. ±187.0m and Elev. ±191.0m. Ground water will be encountered in the excavations.

The Contractor must implement suitable ground water control and ground support systems as required to install the watermain and forcemain casings in a safe, stable, unwatered excavation. The design of the unwatering system should be the responsibility of the Contractor.

Ground water seepage into excavations made through the silt to sand & silt till layers, should be minimal due to the relatively low permeability of these soils. It is believed that this seepage can be controlled by gravity drainage and pumping from strategically located filtered sumps as and where required. Where sand to silty sand seams/layers are to be intercepted below the encountered water level, then dewatering prior to excavation may be warranted.

At shaft locations it is recommended that an allowance be made to pour a 150mm thick layer of lean concrete (mud mat) on the foundation bearing surfaces as soon as possible after excavation. This construction strategy will assist in controlling water infiltration at the base of the excavation and will also provide a stable working platform for construction equipment.

The estimated range of hydraulic conductivities of the silty sand to silt and sand till soils are provided below:

- Silty Sand to Silt and Sand 10^{-3} to 10^{-6} cm/s

13. MONITORING

The contract documents should require the contractor to monitor the roadway surface before, during and after the trenchless installation. A precondition survey is also required prior to tunnelling. A recommended settlement monitoring guideline is included in Appendix D.

It is also necessary to check the amount of spoil removal to determine if there is over excavation and if there are any possible voids outside of the casing. Voids must be grouted with approved grouting materials using approved methods.

14. CONSTRUCTION CONCERNS

During construction, the Contract Administrator should employ experienced geotechnical staff to observe construction activities related to the watermain and forcemain casing installations.

Potential construction concerns include, but are not necessarily limited to:

- maintaining accurate line and grade if the casings are installed by horizontal directional drilling.
- the potential for ground water levels to be higher at the time of construction than those recorded in this report.
- the possibility of encountering boulders or other obstructions during trenchless installation.
- the impact of the ground water level on the stability of excavation in the absence of effective groundwater control.

Prepared by:

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Associate

LICENSED PROFESSIONAL ENGINEER
Nov.16/10
B. E. GOSS
PROVINCE OF ONTARIO

Report Reviewed by:

Michael Tanos, P. Eng.

Review Principal

REGISTERED PROFESSIONAL ENGINEER
M. TANOS
10-11-2010
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APPENDIX A

Record of Borehole Sheets

Terraprobe Inc.

ABBREVIATIONS, TERMINOLOGY, GENERAL INFORMATION

BOREHOLE LOGS

SAMPLING METHOD

SS	split spoon
ST	Shelby tube
AS	auger sample
WS	wash sample
RC	rock core
WH	weight of hammer
PH	pressure, hydraulic

PENETRATION RESISTANCE

Standard Penetration Test (SPT) resistance ('N' values) is defined as the number of blows by a hammer weighing 63.6 kg (140 lb.) falling freely for a distance of 0.76 m (30 in.) required to advance a standard 50 mm (2 in.) diameter split spoon sampler for a distance of 0.3 m (12 in.).

Dynamic Cone Test (DCT) resistance is defined as the number of blows by a hammer weighing 63.6 kg (140 lb.) falling freely for a distance of 0.76 m (30 in.) required to advance a conical steel point of 50 mm (2 in.) diameter and with 60° sides on 'A' size drill rods for a distance of 0.3 m (12 in.).

SOIL DESCRIPTION - COHESIONLESS SOILS

Relative Density	'N' value
very loose	< 4
loose	4 - 10
compact	10 - 30
dense	30 - 50
very dense	> 50

SOIL DESCRIPTION - COHESIVE SOILS

Consistency	Undrained Shear Strength, kPa	'N' value
very soft	< 12	< 2
soft	12 - 25	2 - 4
firm	25 - 50	4 - 8
stiff	50 - 100	8 - 16
very stiff	100 - 200	16 - 32
hard	> 200	> 32

SOIL COMPOSITION

	% by weight
'trace' (e.g. trace silt)	< 10
'some' (e.g. some gravel)	10 - 20
adjective (e.g. sandy)	20 - 35
'and' (e.g. sand and gravel)	35 - 50

TESTS, SYMBOLS

MH	mechanical sieve and hydrometer analysis
w, w_c	water content
w_l	liquid limit
w_p	plastic limit
I_p	plasticity index
k	coefficient of permeability
γ	soil unit weight, bulk
ϕ'	angle of internal friction
c'	cohesion shear strength
C_c	compression index

GENERAL INFORMATION, LIMITATIONS

The conclusions and recommendations provided in this report are based on the factual information obtained from the boreholes and/or test pits. Subsurface conditions between the test holes may vary.

The engineering interpretation and report recommendations are given only for the specific project detailed within, and only for the original client. Any third party decision, reliance, or use of this report is the sole and exclusive responsibility of such third party. The number and siting of boreholes and/or test pits may not be sufficient to determine all factors required for different purposes.

It is recommended Terraprobe be retained to review the project final design and to provide construction inspection and testing.

RECORD OF BOREHOLE No 301

METRIC

W.P. ______ LOCATION Coords: N:4924223 E:256667.9 ORIGINATED BY BH

DIST ______ HWY 26 BOREHOLE TYPE Solid Stem Augers COMPILED BY SS

DATUM Geodetic DATE 9.22.10 CHECKED BY BG

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
193.1	Ground Surface
193.0 / 0.2	150mm FILL - Gravelly Sand to Sand and Gravel, some silt, compact, grey, wet
	SILTY CLAY some sand, trace gravel, stiff to very stiff, brown, moist
189.9 / 3.2	SILT AND SAND some gravel, some clay, frequent cobbles, dense to very dense, grey, moist to wet (GLACIAL TILL)
186.1 / 7.0	End of Borehole

Resistance to augering at 4.6m, from 5.0m to 5.3m, at 6.4m and at 7.0m. Auger refusal at 7.0m on probable boulders.

Borehole was dry (not stabilized) and open to full depth on completion.

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	11	
2	SS	27	
3	SS	12	
4	SS	12	1 18 47 34
5	SS	49	
6	SS	87	14 37 38 11
7	SS	50/ 15cm	
8	SS	50/ 13cm	

GROUND WATER CONDITIONS

ELEVATION SCALE: 193, 192, 191, 190, 189, 188, 187

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE: 20 40 60 80 100

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%): 10 20 30

UNIT WEIGHT γ kN/m³

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

RECORD OF BOREHOLE No 302

METRIC

W.P. ______ LOCATION Coords: N:4924225 E:256683.3 ORIGINATED BY BH

DIST ______ HWY 26 BOREHOLE TYPE Solid Stem Augers COMPILED BY SS

DATUM Geodetic DATE 9.22.10 CHECKED BY BG

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
193.2	Ground Surface				
0.0	SILTY CLAY sandy, trace gravel, stiff to very stiff, brown, moist	1	SS	9	
		2	SS	19	3 32 32 33
191.9 1.3	SAND AND SILT trace to some gravel, trace clay, occasional cobbles, dense to very dense, grey, moist (GLACIAL TILL)	3	SS	48	
		4	SS	45	
	---- compact	5	SS	27	
	----	6	SS	50/ 13cm	
		7	SS	50/ 15cm	10 44 38 8
		8	SS	50/ 15cm	
185.5 7.7	End of Borehole	9	SS	50/ 10cm	

Column headings: SOIL PROFILE (ELEV / DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (193, 192, 191, 190, 189, 188, 187, 186); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) (10 20 30), 49; UNIT WEIGHT γ kN/m^3; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL.

Resistance to augering at 5.8m and 6.4m.

Borehole was dry (not stabilized) and hole open to full depth on completion.

Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 3.0m slotted screen.

Water Level Readings:

Date	Depth(m)	Elevation(m)
Sept.23.10	Dry	-

$+^3, \times^3$: Numbers refer to Sensitivity $\circ^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No 303

METRIC

W.P. ______ LOCATION Coords: N:4924224 E:256704.6 ORIGINATED BY BH

DIST ______ HWY 26 BOREHOLE TYPE Solid Stem Augers COMPILED BY SS

DATUM Geodetic DATE 9.22.10 CHECKED BY BG

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
192.7	Ground Surface										
0.0	FILL - Silt, some sand, trace clay, trace gravel, trace organics, loose, brown, wet	1	SS	6			~20				
		2	SS	10		192	~29				
191.3 / 1.4	clayey silt seams, very stiff ---- SILT AND SAND TO SILTY SAND trace to some gravel, trace to some clay, occasional cobbles, compact to very dense, brown to grey, moist to wet (GLACIAL TILL)	3	SS	16		191	~10	12	38	38	12
		4	SS	41		190	~8				
		5	SS	50/13cm	▽		~10				
		6	SS	50/15cm		189	~6				
		7	SS	57		188	~9	5	53	34	8
		8	SS	50/13cm		187 / 186	~8				
185.0 / 7.7	End of Borehole	9	SS	50/13cm		185	~7				

Resistance to augering at 3.4m.

Water level at 3.2m (not stabilized) and hole open to full depth on completion.

Legend: Dynamic Cone Penetration Resistance Plot (20, 40, 60, 80, 100); Shear Strength kPa: ○ Unconfined, + Field Vane, ● Quick Triaxial, × Lab Vane; Plastic Limit W_P, Natural Moisture Content W, Liquid Limit W_L; Unit Weight γ kN/m³; Remarks & Grain Size Distribution (%).

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

Ministry of Transportation Ontario

Foundation Design

RECORD OF BOREHOLE No 304

METRIC

W.P. ______ LOCATION Coords: N:4924225 E:256723.3 ORIGINATED BY BH

DIST ______ HWY 26 BOREHOLE TYPE Solid Stem Augers COMPILED BY SS

DATUM Geodetic DATE 9.22.10 CHECKED BY BG

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
192.9	Ground Surface				
0.0	FILL - Gravelly Sand, some silt, loose to compact, brown, moist	1	SS	26	26 61 (13)
		2	SS	8	
191.6 / 1.3	FILL - Sandy Silt, trace clay, trace gravel, trace organics, compact, brown, moist	3	SS	18	
190.8 / 2.1	clayey	4	SS	24	19 36 24 21

	SILTY SAND some gravel, trace clay, occasional cobbles, compact to very dense, brown to grey, moist to wet (GLACIAL TILL)	5	SS	47	
		6	SS	50/15cm	
		7	SS	78	
		8	SS	50/15cm	
185.2 / 7.7	End of Borehole	9	SS	50/10cm	13 45 34 8

Elevation scale: 192, 191, 190, 189, 188, 187, 186

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

Resistance to augering from 5.2m.

Water level at 5.9m (not stabilized) and hole open to 6.7m on completion.

Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 3.0m slotted screen.

Water Level Readings:

Date	Depth(m)	Elevation(m)
Sept.23.10	5.8	187.1

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

APPENDIX B
Laboratory Test Results

Terraprobe Inc.

Terraprobe

SIEVE GRADATION ANALYSIS
TEST RESULTS

PROJECT : **Hwy 26 Bypass Tunnels**
LOCATION: **Wasaga Beach, ON**
CLIENT : **Town of Wasaga Beach c/o Ainley Group**

FILE NO. **3-10-6084**
LAB NO: **9645**

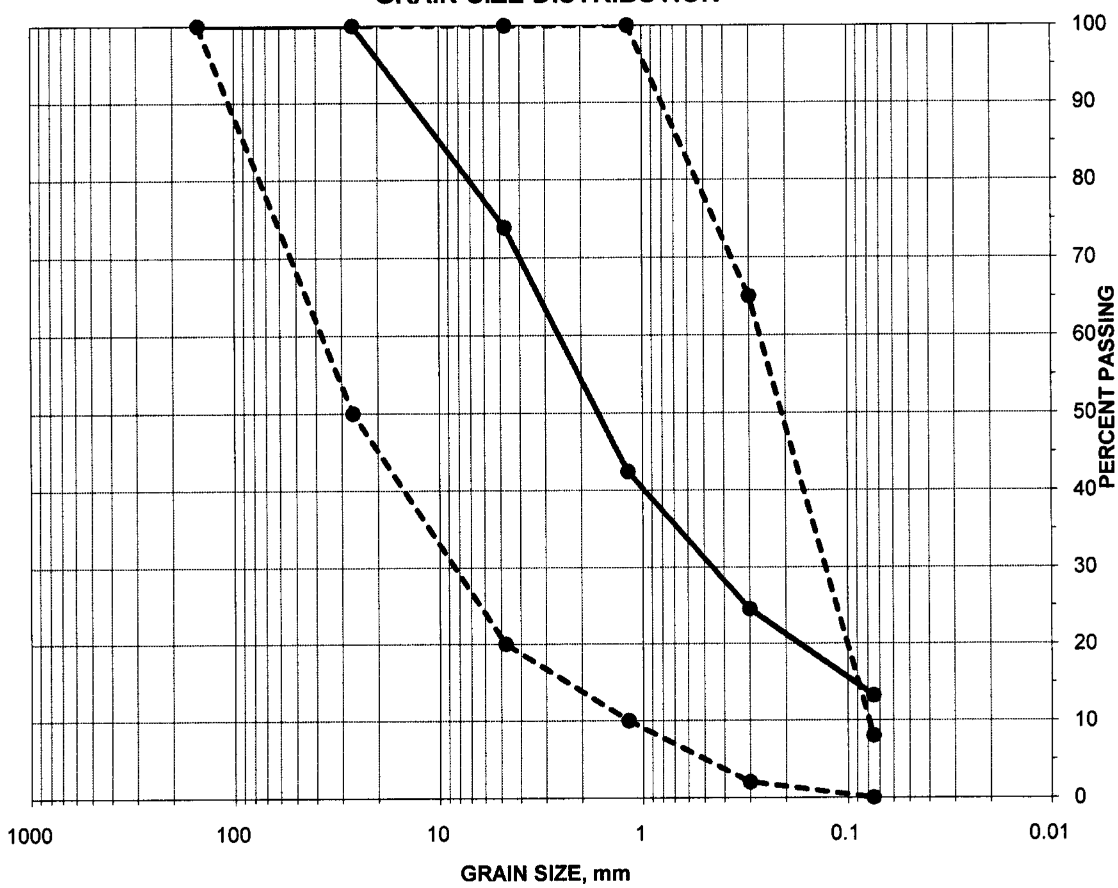
SAMPLE DATE: **Sept-23-10**

SAMPLE MATERIAL: **Fill - Gravelly sand, some silt**

SAMPLED BY: **B.H.**

SAMPLE SOURCE: **BH 304, sample 1**

GRAIN SIZE DISTRIBUTION



SIEVE SIZE mm	PERCENT PASSING			NOTES: GRANULAR 'B' (Type 1) OPSS FORM 1010
	SPECIFIED		SAMPLE	
	MIN.	MAX.		
150.0	100	100	100	
26.5	50	100	100.0	Sample tested does not conform to
4.75	20	100	73.9	OPSS 1010 for gradation
1.18	10	100	42.4	
0.300	2	65	24.5	
0.075	0	8	**13.2**	Note: Boldface denotes not meeting specifications

TTBarrie MAR 2007

Reviewed By:__________

Terraprobe

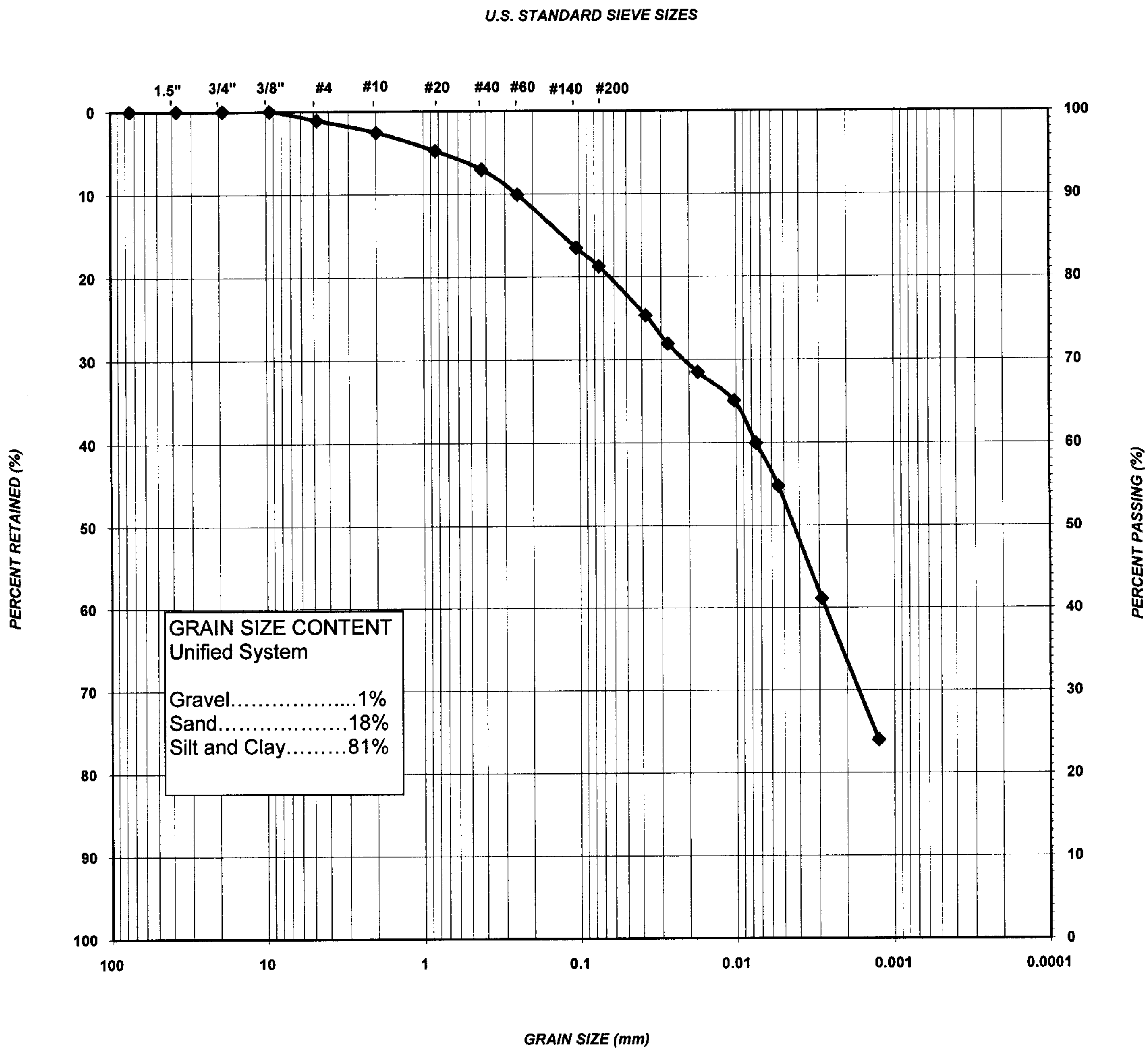
SIEVE AND HYDROMETER ANALYSIS TEST REPORT

PROJECT: **Highway 26, Bypass Tunnels**
LOCATION: **Wasaga Beach, ON**
CLIENT: **Town of Wasaga Beach c/o Ainley Group**

FILE NO.: **3-10-6084**
LAB NO.: **9646a**
SAMPLE DATE: **Sept-23-10**
SAMPLED BY: **B.H.**

BOREHOLE NUMBER: **301** SAMPLE DEPTH: **7.5 to 9'**
SAMPLE NUMBER: **4**
SAMPLE LOCATION: **as above**
SAMPLE DESCRIPTION: **Silty clay, some sand, trace gravel**

GRAIN SIZE DISTRIBUTION



MIT SYSTEM	GRAVEL	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT	CLAY

UNIFIED SYSTEM	GRAVEL: COARSE	GRAVEL: FINE	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT AND CLAY

Terraprobe

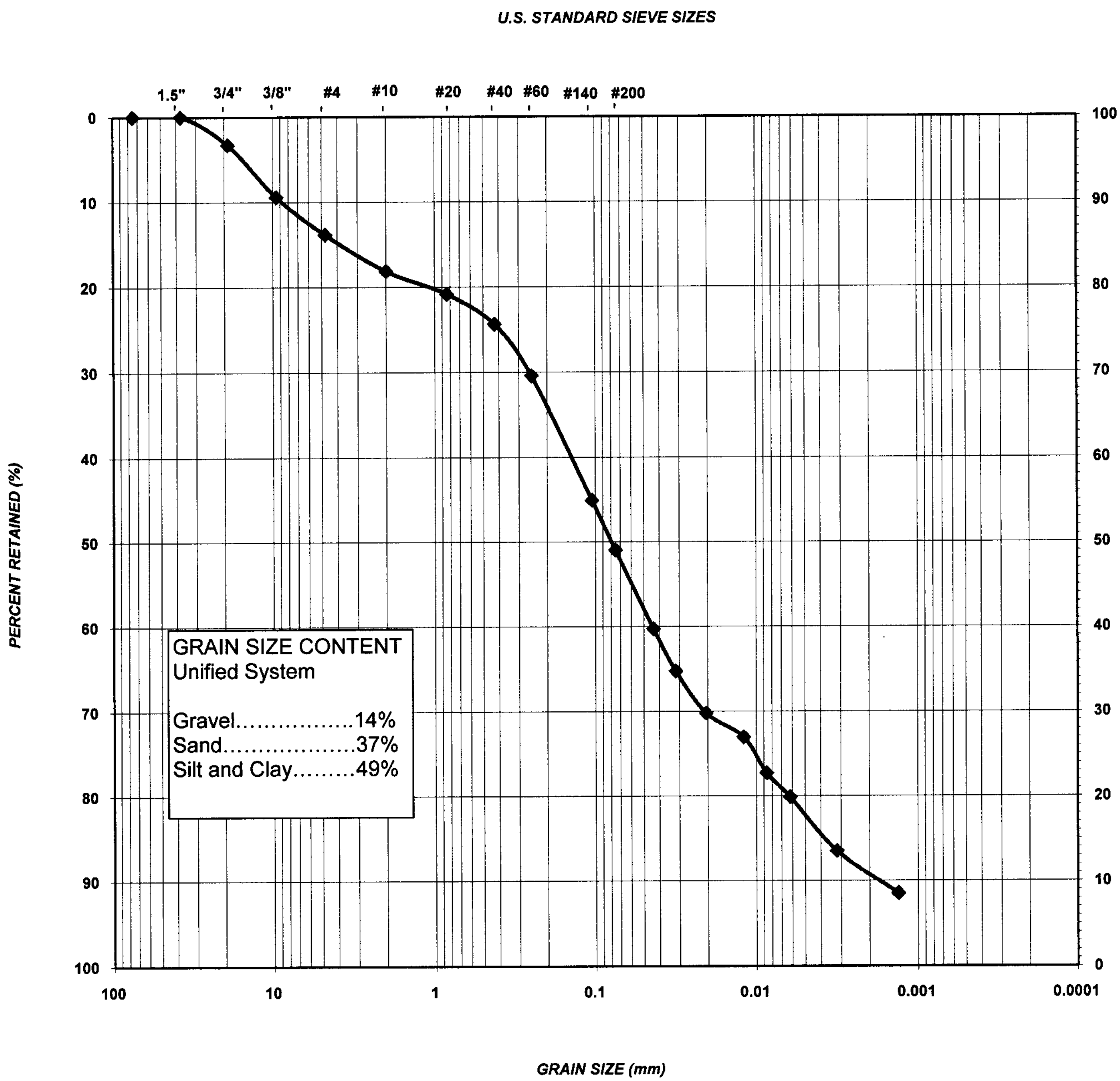
SIEVE AND HYDROMETER ANALYSIS TEST REPORT

PROJECT: **Highway 26, Bypass Tunnels**
LOCATION: **Wasaga Beach, ON**
CLIENT: **Town of Wasaga Beach c/o Ainley Group**

FILE NO.: **3-10-6084**
LAB NO.: **9646b**
SAMPLE DATE: **Sept-23-10**
SAMPLED BY: **B.H.**

BOREHOLE NUMBER: **301** SAMPLE DEPTH: **12.5 to 14'**
SAMPLE NUMBER: **6**
SAMPLE LOCATION: **as above**
SAMPLE DESCRIPTION: **Silt and sand till, some gravel, some clay**

GRAIN SIZE DISTRIBUTION



MIT SYSTEM	GRAVEL	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT	CLAY

UNIFIED SYSTEM	GRAVEL: COARSE	GRAVEL: FINE	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT AND CLAY

Terraprobe

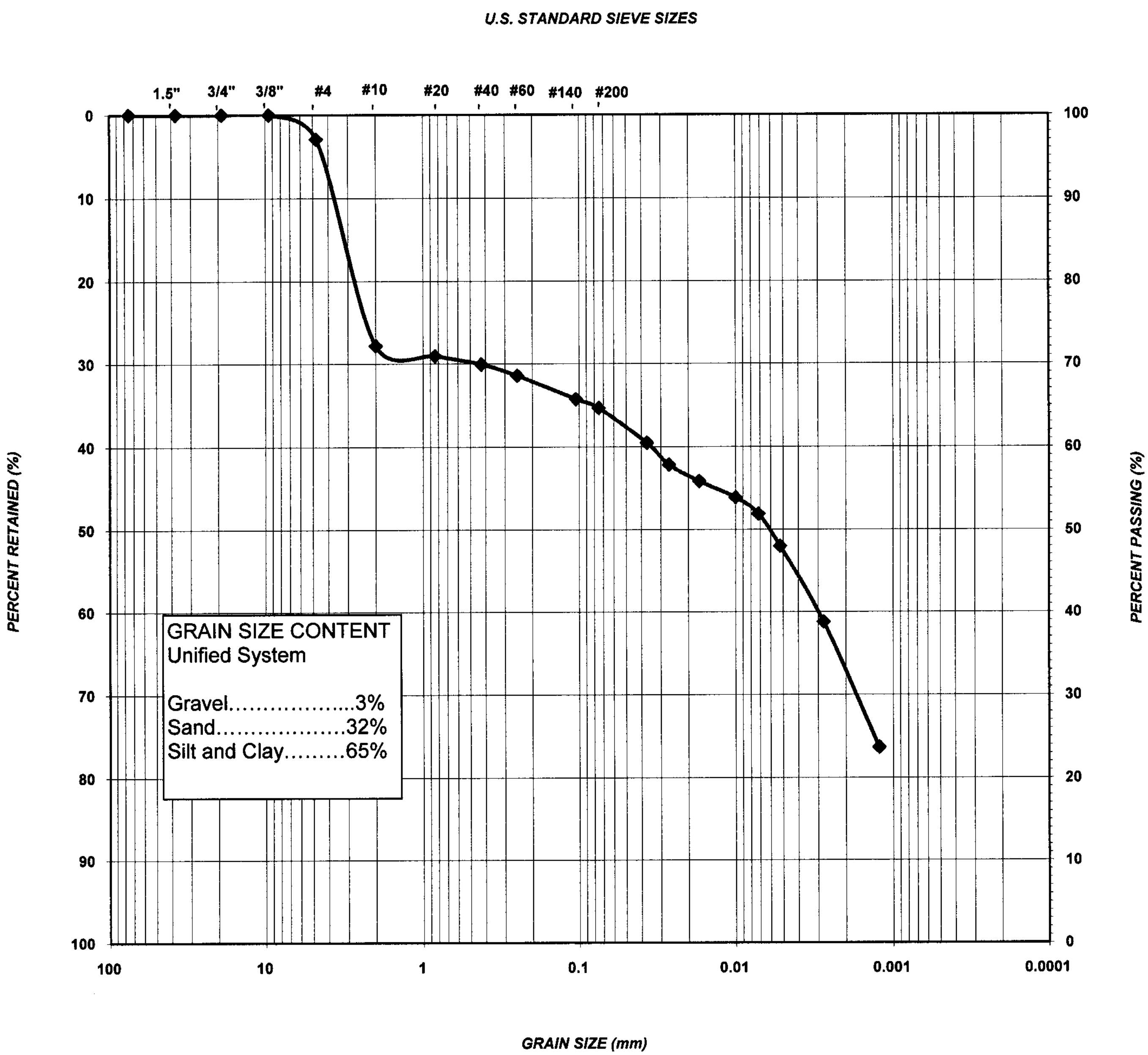
SIEVE AND HYDROMETER ANALYSIS TEST REPORT

PROJECT: **Highway 26, Bypass Tunnels**
LOCATION: **Wasaga Beach, ON**
CLIENT: **Town of Wasaga Beach c/o Ainley Group**

FILE NO.: **3-10-6084**
LAB NO.: **9646c**
SAMPLE DATE: **Sept-23-10**
SAMPLED BY: **B.H.**

BOREHOLE NUMBER: **302** SAMPLE DEPTH: **2.5' to 4'**
SAMPLE NUMBER: **2**
SAMPLE LOCATION: **as above**
SAMPLE DESCRIPTION: **Silty clay, sandy, trace gravel**

GRAIN SIZE DISTRIBUTION



MIT SYSTEM	GRAVEL	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT	CLAY

UNIFIED SYSTEM	GRAVEL: COARSE	GRAVEL: FINE	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT AND CLAY

Terraprobe

SIEVE AND HYDROMETER ANALYSIS TEST REPORT

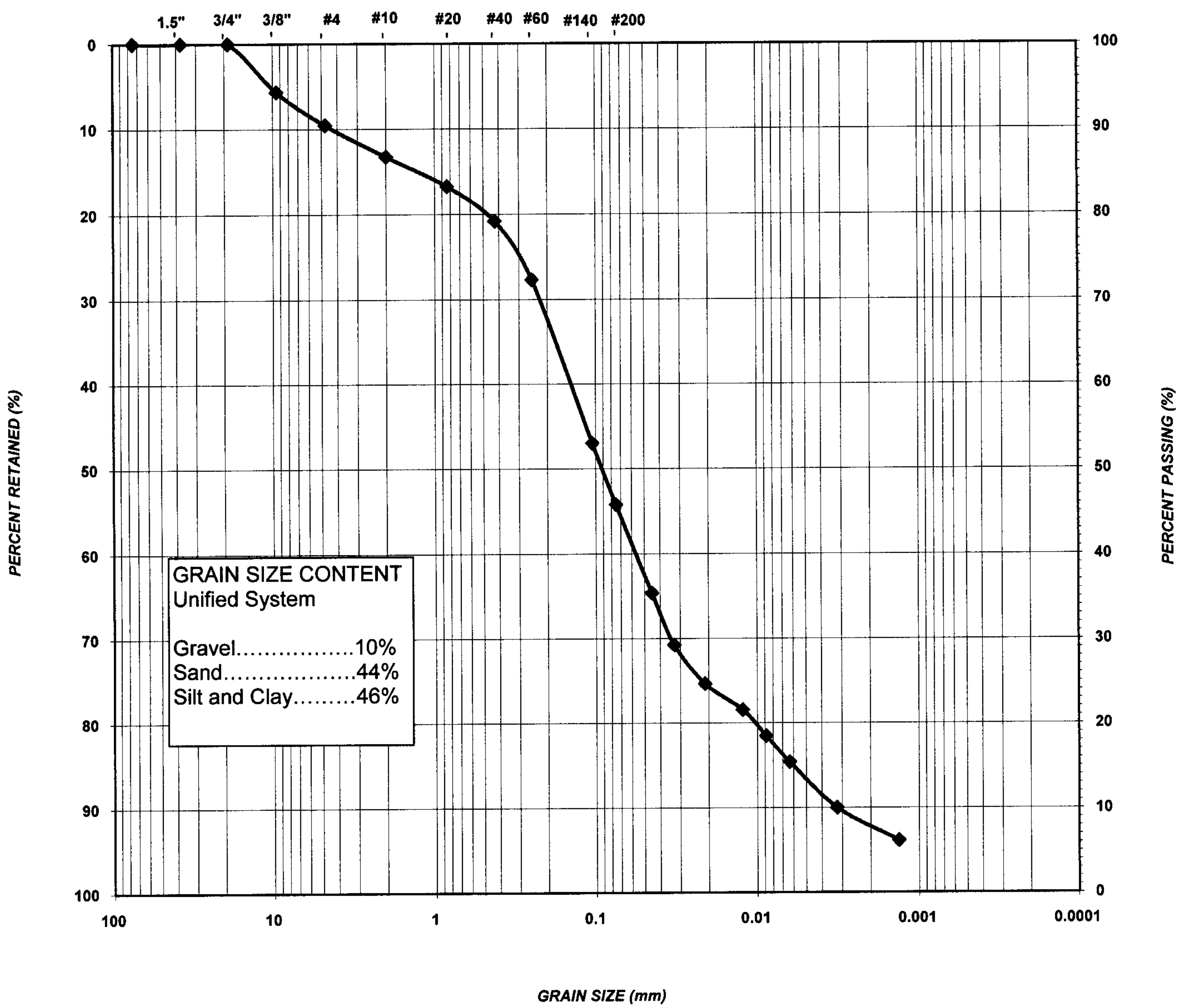
PROJECT: **Highway 26, Bypass Tunnels**
LOCATION: **Wasaga Beach, ON**
CLIENT: **Town of Wasaga Beach c/o Ainley Group**

FILE NO.: **3-10-6084**
LAB NO.: **9646d**
SAMPLE DATE: **Sept-23-10**
SAMPLED BY: **B.H.**

BOREHOLE NUMBER: **302**
SAMPLE DEPTH: **15 to 16.5'**
SAMPLE NUMBER: **7**
SAMPLE LOCATION: **as above**
SAMPLE DESCRIPTION: **Sand and silt till, trace gravel, trace clay**

GRAIN SIZE DISTRIBUTION

U.S. STANDARD SIEVE SIZES



MIT SYSTEM	GRAVEL	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT	CLAY

UNIFIED SYSTEM	GRAVEL: COARSE	GRAVEL: FINE	SAND: ARSE	SAND: MEDIUM	SAND: FINE	SILT AND CLAY

Terraprobe

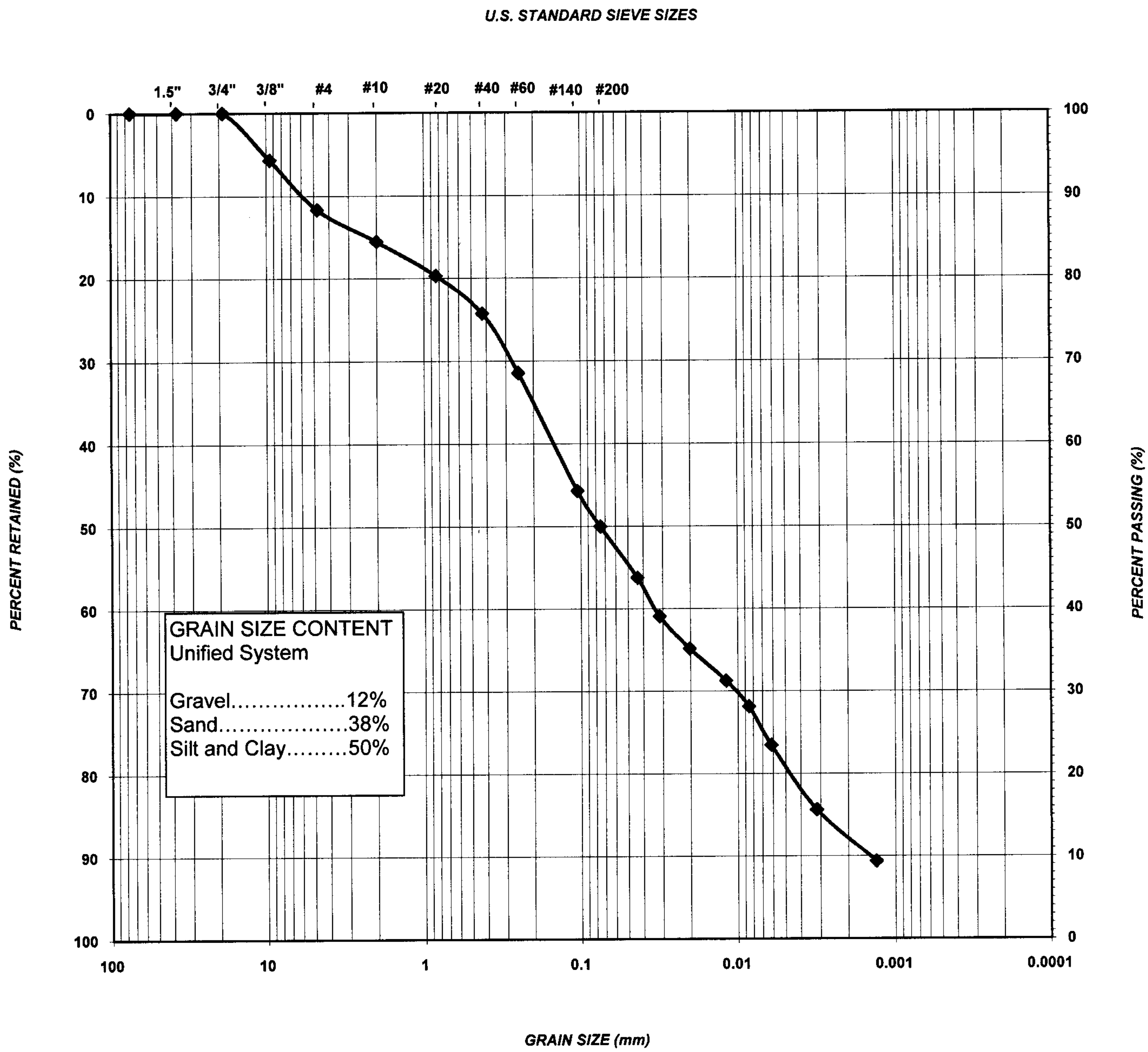
SIEVE AND HYDROMETER ANALYSIS
TEST REPORT

PROJECT: **Highway 26, Bypass Tunnels**
LOCATION: **Wasaga Beach, ON**
CLIENT: **Town of Wasaga Beach c/o Ainley Group**

FILE NO.: **3-10-6084**
LAB NO.: **9646e**
SAMPLE DATE: **Sept-23-10**
SAMPLED BY: **B.H.**

BOREHOLE NUMBER: **303** SAMPLE DEPTH: **5 to 6.5'**
SAMPLE NUMBER: **3**
SAMPLE LOCATION: **as above**
SAMPLE DESCRIPTION: **Silt and sand to silty sand till, some gravel, trace clay**

GRAIN SIZE DISTRIBUTION



MIT SYSTEM	GRAVEL	SAND			SILT	CLAY
		COARSE	MEDIUM	FINE		

UNIFIED SYSTEM	GRAVEL		SAND			SILT AND CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

Terraprobe

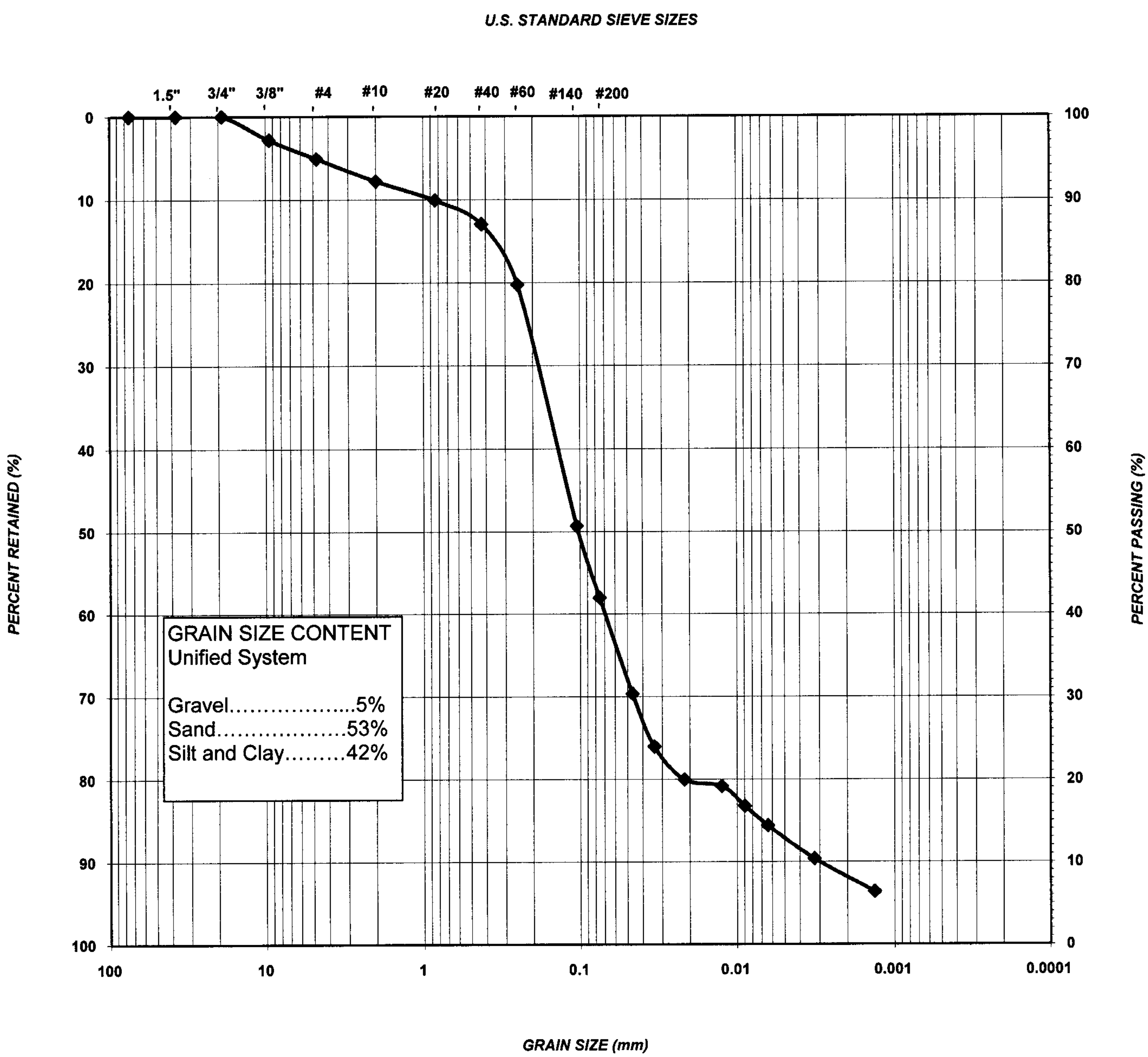
SIEVE AND HYDROMETER ANALYSIS TEST REPORT

PROJECT: **Highway 26, Bypass Tunnels**
LOCATION: **Wasaga Beach, ON**
CLIENT: **Town of Wasaga Beach c/o Ainley Group**

FILE NO.: **3-10-6084**
LAB NO.: **9646f**
SAMPLE DATE: **Sept-23-10**
SAMPLED BY: **B.H.**

BOREHOLE NUMBER: **303** SAMPLE DEPTH: **15 to 16.5'**
SAMPLE NUMBER: **7**
SAMPLE LOCATION: **as above**
SAMPLE DESCRIPTION: **Silt and sand to silty sand till, trace gravel, trace clay**

GRAIN SIZE DISTRIBUTION



MIT SYSTEM	GRAVEL	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT	CLAY

UNIFIED SYSTEM	GRAVEL: COARSE	GRAVEL: FINE	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT AND CLAY

Terraprobe

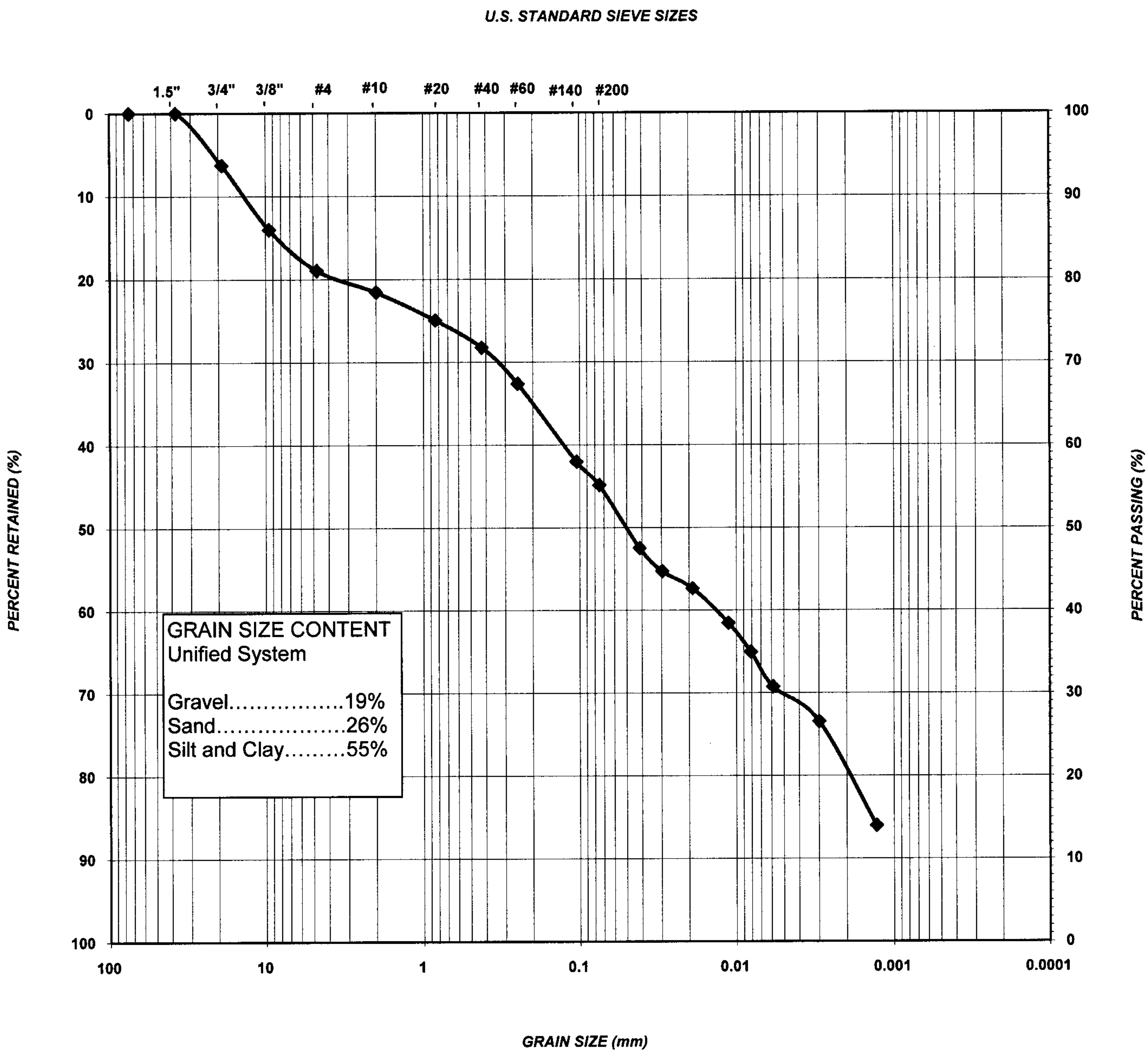
SIEVE AND HYDROMETER ANALYSIS TEST REPORT

PROJECT: **Highway 26, Bypass Tunnels**
LOCATION: **Wasaga Beach, ON**
CLIENT: **Town of Wasaga Beach c/o Ainley Group**

FILE NO.: **3-10-6084**
LAB NO.: **9646g**
SAMPLE DATE: **Sept-23-10**
SAMPLED BY: **B.H.**

BOREHOLE NUMBER: **304** SAMPLE DEPTH: **7.5 to 9'**
SAMPLE NUMBER: **4**
SAMPLE LOCATION: **as above**
SAMPLE DESCRIPTION: **Silty sand till, some gravel, clayey seam**

GRAIN SIZE DISTRIBUTION



MIT SYSTEM	GRAVEL	SAND (COARSE)	SAND (MEDIUM)	SAND (FINE)	SILT	CLAY

UNIFIED SYSTEM	GRAVEL (COARSE)	GRAVEL (FINE)	SAND (COARSE)	SAND (MEDIUM)	SAND (FINE)	SILT AND CLAY

Terraprobe

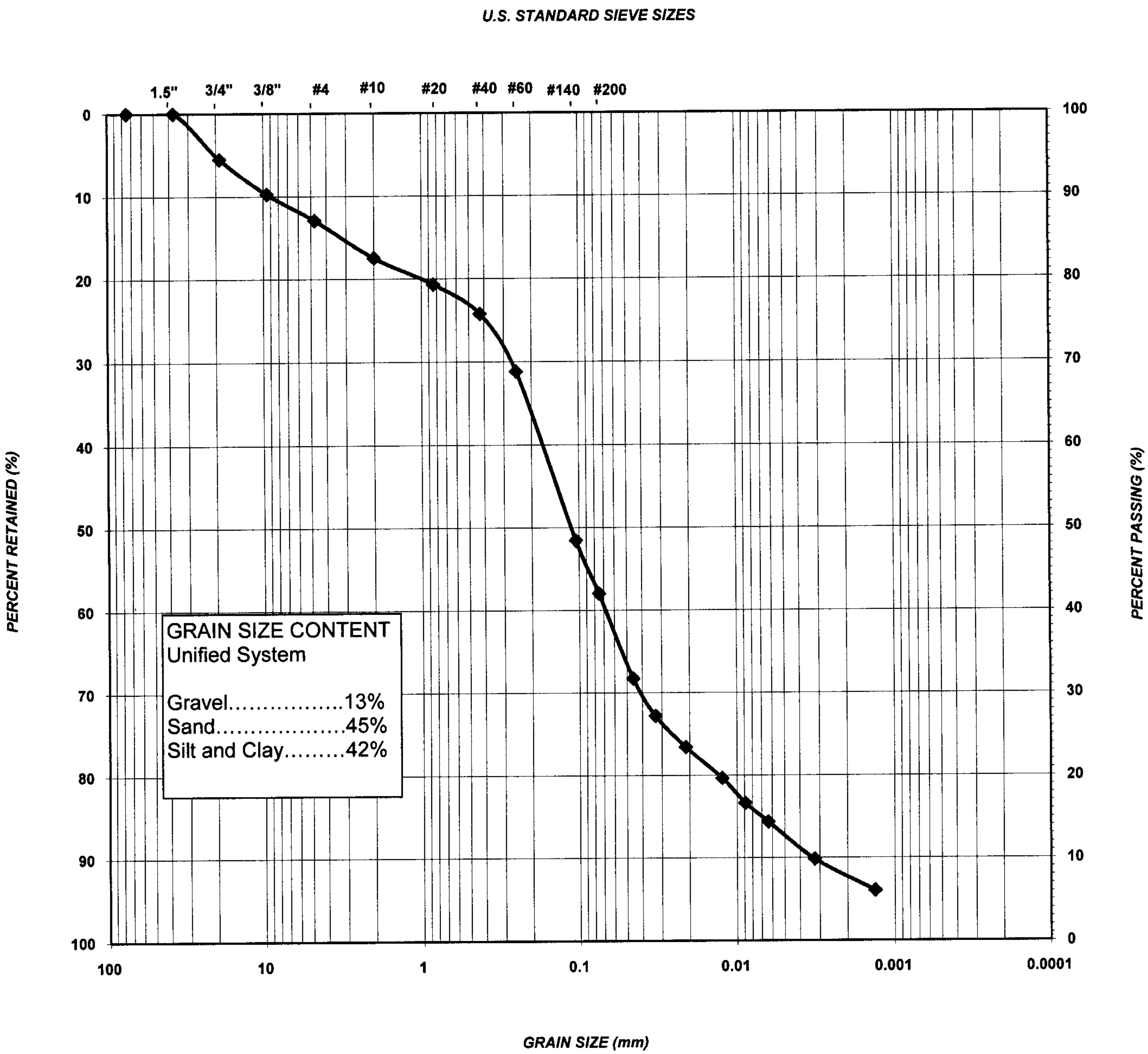
SIEVE AND HYDROMETER ANALYSIS TEST REPORT

PROJECT: **Highway 26, Bypass Tunnels**
LOCATION: **Wasaga Beach, ON**
CLIENT: **Town of Wasaga Beach c/o Ainley Group**

FILE NO.: **3-10-6084**
LAB NO.: **9646h**
SAMPLE DATE: **Sept-23-10**
SAMPLED BY: **B.H.**

BOREHOLE NUMBER: **304** SAMPLE DEPTH: **15 to 16.5'**
SAMPLE NUMBER: **9**
SAMPLE LOCATION: **as above**
SAMPLE DESCRIPTION: **Silty sand till, some gravel, trace clay**

GRAIN SIZE DISTRIBUTION

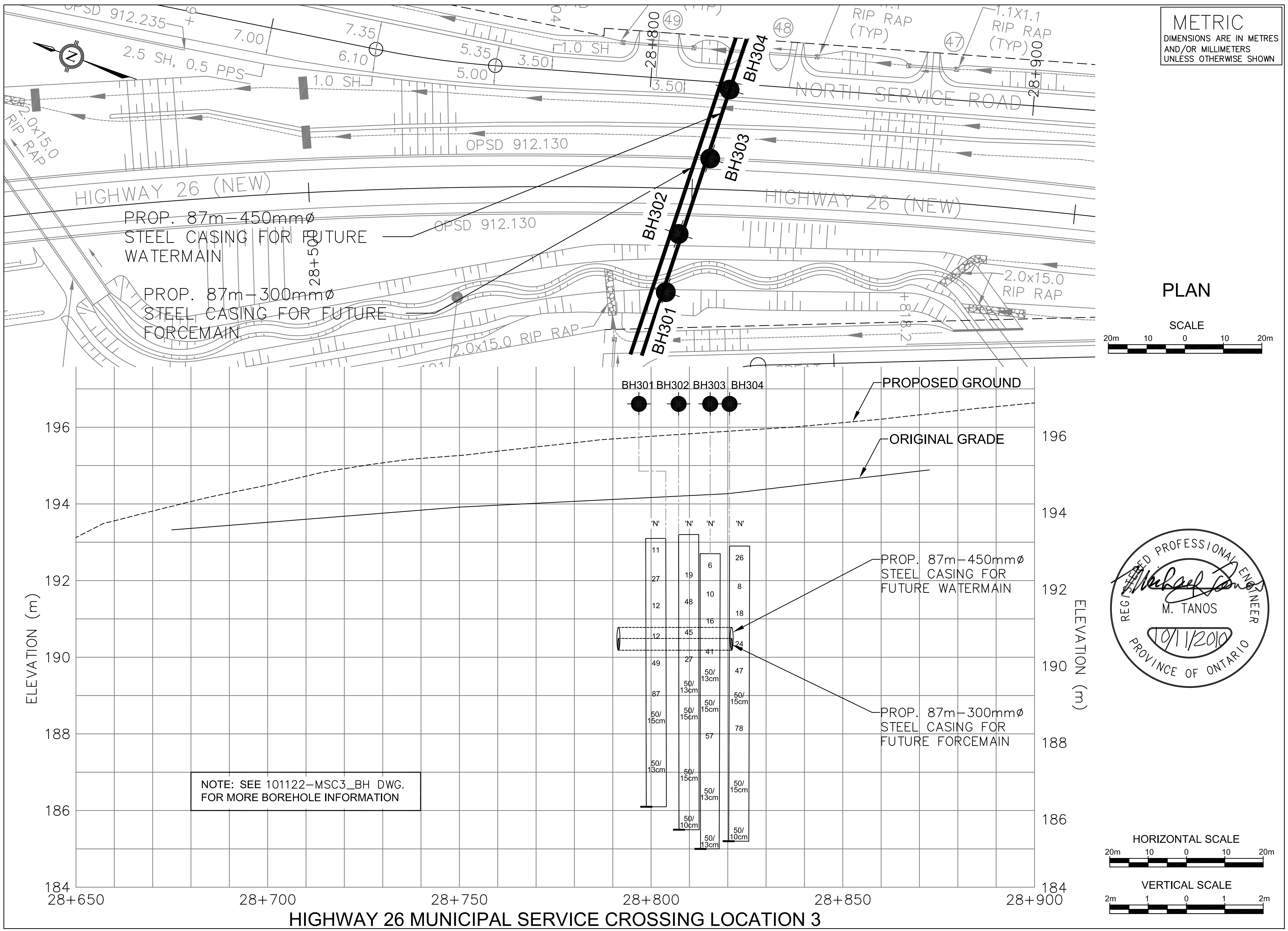


MIT SYSTEM	GRAVEL	SAND (COARSE)	SAND (MEDIUM)	SAND (FINE)	SILT	CLAY

UNIFIED SYSTEM	GRAVEL (COARSE)	GRAVEL (FINE)	SAND (COARSE)	SAND (MEDIUM)	SAND (FINE)	SILT AND CLAY

APPENDIX C
Figures

Terraprobe Inc.



TOWN OF WASAGA BEACH

HIGHWAY 26
PROPOSED STEEL CASING FOR FUTURE WATERMAIN AND FORCEMAIN

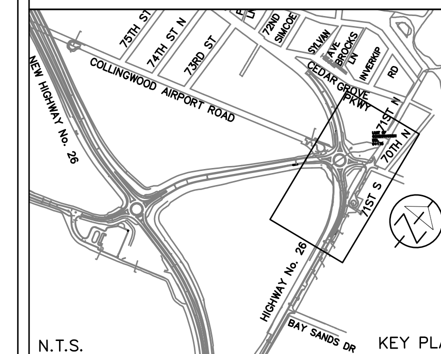
HIGHWAY 26
MUNICIPAL SERVICE CROSSING
LOCATION 3

SHEET 1 OF

REFERENCE DWG. 101122–MSC3

Ainley Group — CONSULTING ENGINEERS PLANNERS

Terraprobe Inc.
Consulting Geotechnical & Environmental Engineering
Construction Materials Engineering, Inspection & Testing
10 Bram Court - Brampton Ontario L6W 3R6 (905) 796-2650



N.T.S. KEY PLAN

LEGEND

(symbol)	Bore Hole
(symbol)	Dynamic Cone Penetration Test
(symbol)	Bore Hole And Cone
'N'	Blows/0.3m (Std Pen Test, 475 J/blow)
CONE	Blows/0.3m (60° Cone, 475 J/blow)
(symbol)	WL at Time of Investigation
(symbol)	WL in Piezometer (AUG. 2010)
(symbol)	Piezometer
90%	Rock Quality Designation
A/R	Auger Refusal

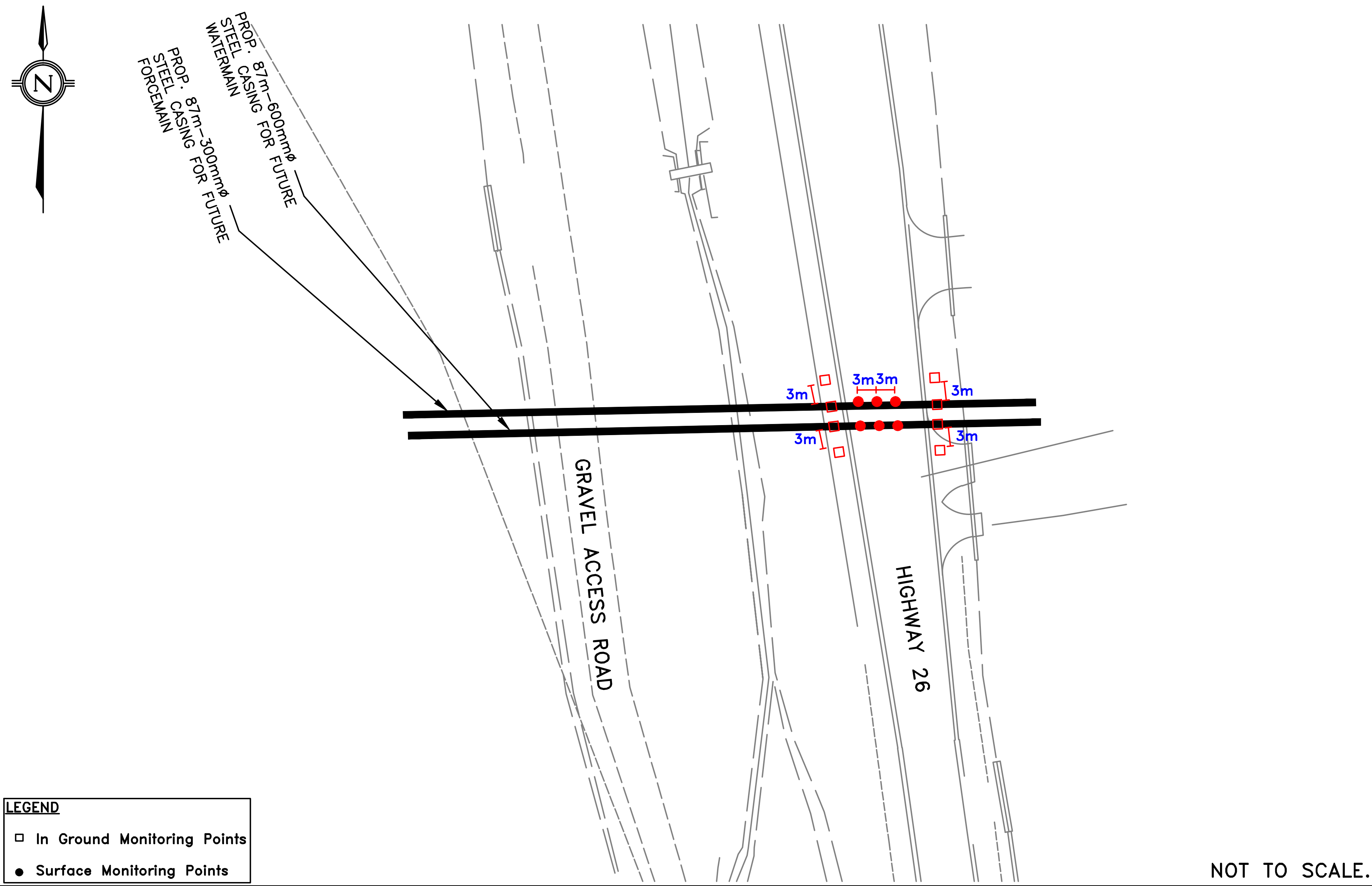
No	ELEV.	COORDINATES	
		NORTHING	EASTING
BH301	193.1	4 924 223	256 667.9
BH302	193.2	4 924 225	256 683.3
BH303	192.7	4 924 224	256 704.6
BH304	192.9	4 924 225	256 723.3

NOTE
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

REVISIONS		
DATE	BY	DESCRIPTION

DESIGN –	CODE	LOAD	DATE NOV. 2010
DRAWN –	CHK –	STRUCT	TERRAPROBE NO. 3–10–6084



LEGEND

- □ In Ground Monitoring Points
- ● Surface Monitoring Points

NOT TO SCALE.

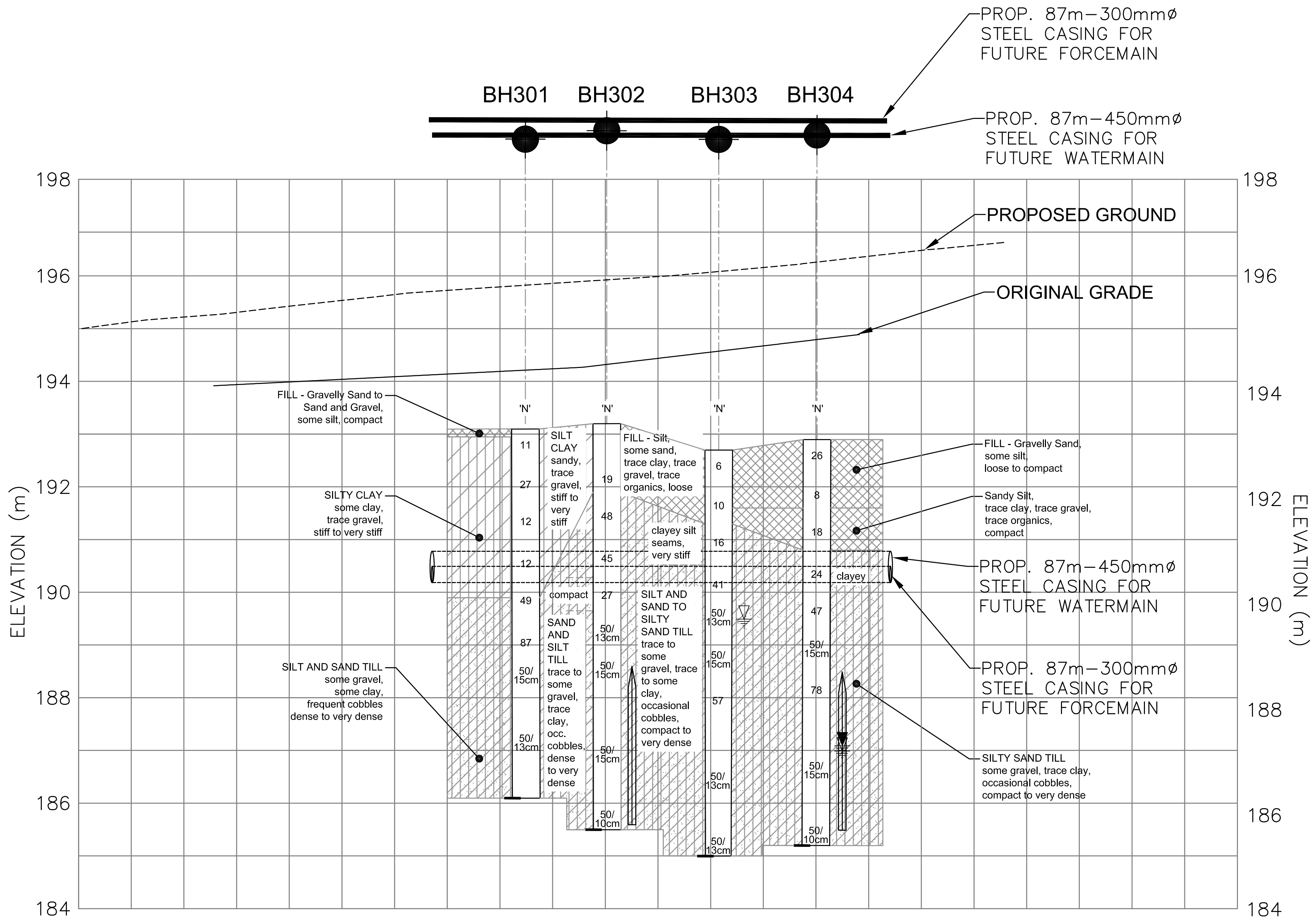
OCTOBER 2010

INSTRUMENT ARRAY PLAN

3–10–6084 (3)

Terraprobe

FIGURE D1



N.T.S.

HIGHWAY 26 MUNICIPAL SERVICE CROSSING LOCATION 3
BOREHOLE INFORMATION ONLY

101122-MSC3_BH DWG.

APPENDIX D

Settlement Monitoring Guideline & Plan

Terraprobe Inc.

SETTLEMENT MONITORING GUIDELINE

Instruments

Two types of settlement monitoring points are required:

- Surface points are placed within the asphalt portion of the highway
- In-ground points, approximately 2 m deep, are proposed next to the outer shoulders of Highway 26 EBL and WBL of the alignment. The in-ground points are important for detecting settlements before they are transferred to the surface.

Instrumentation Arrays

In-Ground Monitoring Points

The lateral extent of the monitoring array shall cover a distance on both sides of the tunnel alignment as defined by a 45 degree line extending from one radius of the centerline at the invert level to the ground surface.

As a minimum, two (2) instrument arrays shall be utilized along this alignment. An array is to be installed next to the east bound and west bound shoulders perpendicular to the proposed watermain casing alignments. At each location, the array of in-ground monitoring points should consist of a minimum of three in-ground monitors, with one point directly over the centerline of the tunnel, and one point each at approximately 3 m on either side of the tunnel.

Surface Monitoring Points

Surface monitoring points will be installed on the pavements.

Surface monitoring points will be located on each travelled lane of Highway 26 EBL and WBL. The surface monitoring points will be identified using paint marks on the pavement.

The instrumentation plan should be finalized when the Contractor's proposed construction method is available.

Condition Survey

A condition survey of the pavement will be carried out prior to commencement of construction and documented for the purpose of requiring restoration, if necessary. The condition survey will be carried out using the surface monitoring points installed on each travelled lane. This surface survey will be completed when the in-ground monitors and settlement points are installed and again when the tunnel has been completed. Interim surveys will be require should movement be detected in the in-ground monitoring points.

Reading Frequency

In-ground and surface monitoring points shall be read and the data recorded continually by the Contractor during the construction period. Readings shall continue to be made after construction to a time at which all parties agree that there is no further movement.

It is recommended that at least three (3) sets of readings be taken during each shift, provided that movements are within anticipated limits. Otherwise, the frequencies should increase according to a pre-planned interval.

Monitoring of movements is required during work stoppages, such as during a non-operation period (off-shifts) or weekends. At least three (3) sets of readings should be taken daily.

Data Collection and Data Transfer

A procedure is required to be established in consultation with MTO so that the monitoring data and the interpreted data will reach all parties as soon as necessary. The responsible prime Consultant and the Contractor should interpret monitoring data as needed for the purpose of on-going construction. The Geotechnical Engineer should be contacted for technical support to the prime Consultant in the interpretation of ground movements and review of the Contractor's response when Review and Alert Levels are reached.

Criteria for Assessment

The suggested acceptable surface settlement (or heave) is 10 mm, or at criteria specified by MTO. The baseline reading, alert level and review level should be established with input from MTO.

Baseline Reading – A baseline reading of the instrumentation shall be taken prior to commencement of the work. All parties should recognize and accept the baseline level in writing.

Review Level – A maximum value of 6 mm relative to the baseline readings is suggested for this project. If this level is reached, the method, rate or sequence of construction, or ground stabilization measures should be reviewed or modified to mitigate further ground displacements.

Alert Level – A maximum value of 15 mm relative to the baseline readings is suggested for this project. If this level is reached, the Contractor shall cease construction operations and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of the public and maintain uninterrupted traffic flow.

Review of Contractor's Proposed Method

The Contractor's proposed method of construction should be reviewed by MTO, the Proponent's prime consultant and Geotechnical Engineer. The proposed method should include a description of the potential loss of ground, calculation of the maximum settlement in relation to the Contractor's procedure and equipment, alternative/remedial measures if the review level of measurement is reached; and contingency/remedial measures if the alert level of measurement is reached.

Contractor's Responsibility For Restoration and Warranty Provision

Notwithstanding the monitoring program to assess the adequacy of the tunnelling construction method to control potential ground movements and ground water, the Contractor is responsible for reinstatement (such as surface paving) should movements or other surface distresses occur. The Contract is also required to provide a reasonable warranty period for the works acceptable to MTO.

Construction Monitoring

The Proponent shall retain a qualified Geotechnical Consultant to supervise the installation of surface and subsurface settlement points on site and to provide direction, technical input and field inspection on this project.

APPENDIX E
Comparison of Installation Methods

Terraprobe Inc.

COMPARISON OF TRENCHLESS INSTALLATION METHODS

Pipe Jacking/Horizontal Auger Boring	Microtunnelling	Horizontal Directional Drilling	Pipe Ramming
Advantages: i. Avoids open cut excavation, highway closure and traffic diversion. ii. Readily available equipment/technology. iii. More economical than microtunnelling. iv. Accuracy/Tolerance ±25mm. v. Relatively good control of potential settlement. **Disadvantages:** i. More expensive than open cut excavation. ii. Requires constructing special jacking and receiving pits. iii. Requires good care and workmanship by experienced tunnellers in order to reduce ground settlement above the existing roadway. iv. Contact with cohesionless water bearing soils can cause ground loss during tunnelling which can result in excessive ground settlement.	**Advantages:** i. Avoids open cut excavation, highway closure and traffic diversion. ii. Well tested technology. iii. Smaller sending and receiving pits compared to Pipe Jacking and Horizontal Auger Boring. iv. Accuracy/Tolerance ±25mm. v. Relatively good control of potential settlement. **Disadvantages:** i. More expensive than open cut excavation. ii. Requires constructing special jacking and receiving pits. iii. Requires good care and workmanship by experienced tunnellers in order to reduce ground settlement above the existing roadway. iv. Equipment may not be readily available. v. More expensive than Pipe Jacking.	**Advantages:** i. Avoids open cut excavation, highway closure and traffic diversion. ii. Readily available equipment/technology. iii. More economical than microtunnelling. iv. Does not require constructing jacking and receiving pits adjacent to the highway. v. Relatively good control of potential settlement. **Disadvantages:** i. More expensive than open cut excavation. ii. Casings not typically used in directional drilling because they require an additional step in the construction process and thus increase cost. iii. Requires good care and workmanship by experienced tunnellers in order to reduce ground settlement above the existing roadway. iv. Accuracy/Tolerance ±100 mm. v. Requires careful control in order to maintain the line and grade tolerances for the casing alignment. vi. Relatively large area required to accommodate bore pit and to lay out pipe.	**Advantages:** i. Avoids open cut excavation, highway closure and traffic diversion. ii. More economical than microtunnelling. iii. Perhaps best control over potential settlement. **Disadvantages:** i. Potential for significant soil disturbance if a blockage is created at the end of the pipe during installation. ii. Accuracy/Tolerance >25 mm. iii. Relatively large area required to accommodate bore pit and to lay out pipe.