

GEOTECHNICAL INVESTIGATION AND DESIGN REPORT

HIGHWAY 634, CULVERT REPLACEMENT

W.O. 2010-11008

GEOCRES NO.: 42H-39

SMOOTH ROCK FALLS, COCHRANE AREA

AGREEMENT NO.: 5007-E-0064

ASSIGNMENT NO.: 8

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**PREPARED FOR:
MINISTRY OF TRANSPORTATION
447 MCKEOWN AVENUE, SUITE 301
NORTH BAY, ONTARIO, P1B 9S9**

3 Copies	- Ministry of Transportation, North Bay, ON
1 Copy	- Ministry of Transportation, Downsview, ON
1 Copy	- DST Consulting Engineers Inc., Thunder Bay

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GEOTECHNICAL INVESTIGATION AND DESIGN REPORT HIGHWAY 634, CULVERT REPLACEMENT

PART 1: FACTUAL INFORMATION

1.0 INTRODUCTION

DST Consulting Engineers Inc. (DST) has been retained by the Ministry of Transportation, Geotechnical Section, Northeastern Region to conduct a geotechnical investigation for the proposed culvert replacement on Highway 634. This work was carried out under Agreement No. 5007-E-0064; Geotechnical Retainer, Assignment No. 8.

This report addresses the field investigation, laboratory test program, factual report on conditions (Part 1) and recommendations for the design and construction for the proposed culvert replacement (Part 2).

2.0 SITE DESCRIPTION

The existing twin 1800 mm diameter corrugated steel pipe (CSP) centerline culverts are located along Highway 634, approximately 35 km north of the Junction of Highway 11, in Smooth Rock Falls, in the MTO Northeastern Region. The culverts are located south of the Red Sucker River boat launch; approximately 650 m north of the km 34 marker at UTM coordinates N 5488315, and E 461313.

The existing twin centerline culverts are in poor condition due to corrosion as shown below in Photographs 1 and 5. The surface of the highway has distorted and settled due to deformation of the existing culverts, and the guiderail directly over the culvert on the outlet side (east) has shifted as shown in Photograph 3. The culverts are on skew to the highway.

The laboratory sample results obtained during the field investigation indicate that the embankment at the existing twin culvert location is constructed of a silty sand fill, overlying a silty clay, with a total height of approximately 5.5 m. The thickness of fill material above the existing culverts is approximately 3.7 m. The side slope steepness at the inlet is approximately 3 horizontal to 1 vertical, and the outlet is approximately 2.2 horizontal to 1 vertical.

The preferred method of construction is by staged open cut excavation and the existing culverts replaced by a single 2.4 m (width) by 1.8 m (height) precast concrete culvert. The new precast concrete culvert will be located approximately along the same alignment and grade as the existing South CSP.

The surrounding area is moderately treed. Pictures of the site are shown below. Photographs 1, 2, and 3, provided by the Ministry were taken in the fall / winter of 2009. Photographs 4 and 5 were taken on December 14th and 15th, 2009 by DST during the field investigations.



Photo 1: Looking East at the East Side (Where the outlet flows into the Red Sucker River)



Photo 2: Looking South from West Side at the CSP Inlets



Photo 3: Looking Northerly (Culverts are located under the Patch)



Photo 4: Looking East at Inlets and Left Embankment Slope



Photo 5: Looking Easterly at the North CSP Inlet

3.0 INVESTIGATION PROCEDURES AND LABORATORY TESTING

Site work was carried out on December 14th and 15th, 2009 utilizing a CME 55 drill rig equipped for geotechnical drilling and operated by DST. A total of four boreholes were advanced to depths ranging from 2.8 m to 12.8 m. The number, depth, and methods for advancement of the boreholes were specified by the Ministry in the terms of reference provided with this assignment.

The field work was supervised on a full-time basis by DST personnel, who located the boreholes in the field, supervised the drilling, borehole logging, sampling and in-situ testing.

The borehole locations are referenced to the MTO Station numbering system as indicated in the terms of reference. Station 10+000 was assigned to the mid point between the two existing culverts at the centerline. The water levels and ground surface elevations at the borehole locations were surveyed by DST personnel and referenced to a local bench mark located on a nail in the root of a spruce tree at Station 10+008, 18.0 m right of centerline. The benchmark elevation was taken as 100.0 m.

Borehole locations and striagraphic sections are shown on Drawings 1, 2, and 3 of the Enclosures. Borehole 1 is located 2.9 m left of centerline (edge of pavement) at Station 10+005. Borehole 2 is located at 1.7 m right of centerline (midlane) at Station 9+995. Borehole 3 is located at 17.0 m left of centerline at Station 10+004, approximately 1.0 m from the end of the South CPS at the inlet. Borehole 4 is located at 15.0 m right of centerline at Station 9+996, approximately 1.0 m from the end of the South CSP at the outlet. Boreholes 1 and 2 were

advanced with hollow stem augers to a maximum depth of 12.8 m. Boreholes 3 and 4 were advanced with hand operated equipment to a maximum depth of 2.9 m.

All boreholes were abandoned in accordance with O. Reg. 903 and its Amendments under the OWRA. Boreholes were backfilled and compacted in layers with auger cuttings.

Soil samples were obtained from the auger flights and from the split spoon sampler used for the Standard Penetration Tests (SPT). The SPT involves driving a 51 mm diameter thick-walled sampler into the soil under the energy of a 63.5 kg weight falling through 760 mm. The number of blows required to drive the sampler 0.3 m is known as the standard penetration blow count (N) which provides an indication of the condition or consistency of the soil. Field vane shear tests were performed in Boreholes 1 and 2 to estimate the undrained shear strength of the cohesive soils encountered. Auger refusal was not encountered in any boreholes.

The soil samples were identified in the field, placed in labeled containers and transported to DST's laboratory in Thunder Bay for further analysis.

Classification and index tests were subsequently performed in the laboratory on selected samples collected from the boreholes to aid in the selection of engineering properties. Laboratory tests included natural moisture contents, particle size analyses, liquid limits, and plastic limits. Laboratory test results are presented on the Borehole Logs in Enclosures 1 and 2, and are plotted in Enclosures 5 to 7.

4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 Published Geology

Geotechnical information is available from published *Ontario Geological Survey Map # 5033* by the *Ontario Ministry of Natural Resources* for the Island Falls area, District of Cochrane. The map indicates that the local area landform is identified as a clayey glaciolacustrine plain covered by organic terrain. The topography in the area is mainly low local relief; plains and channels contribute to the mixed wet and dry drainage conditions in the area.

4.2 Stratigraphy Overview

The generalized stratigraphy of the existing embankment, shown in Drawings 2 and 3, is based on the conditions encountered in Boreholes 1 and 2. Borehole information indicates that the highway embankment consists of a surface treatment over silty sand fill containing traces of gravel and clay, underlain by silty clay fill with traces of sand, gravel, and organics, which is underlain by a native stratum of very stiff to hard, low plastic silty clay. Boreholes 3 and 4 indicate silty clay is present beyond the toes of the existing embankment.

4.3 Surface Treatment

Surface treatment was present in Boreholes 1 and 2 approximately 30 mm in thickness.

4.4 Embankment Fill

A silty sand fill exists in the embankment boreholes (Boreholes 1 and 2). At Borehole 1 a silty clay fill material with loose organic layers exists beneath the silty sand fill from depths 2.5 m to 6.2 m, which underlain by a thick layer of silty clay encountered to the borehole termination depth of 12.7 m. At Borehole 2 a silty clay fill material exists beneath the silty sand fill from

depths 4.2 m to 5.5 m, and is underlain by a thick layer of silty clay encountered to the borehole termination depth of 12.8 m.

The upper portion of the fill contains sands with varying amounts of silt, gravel, and clay. Gradation analyses conducted on subbase soils in Borehole 2 at 1.6 m indicate 37 percent passing the 75 μm . Due to the fines content, materials at this depth do not meet Ontario Provincial Standards (OPSS) for Select Subgrade Material (SSM). Moisture contents of the upper fill materials range from 2.5 to 10.2 percent. This type of fill, mainly local pit run materials may contain occasional cobbles and boulders. During the field investigations, cobbles and boulders were not encountered in Boreholes 1 and 2. Generally, the materials within the 1.0 m are reusable as a subbase material for temporary widening fills, as well as slope flattening area fills, provided; at the time of construction, they are within the optimum moisture content for placement.

During the investigation, the condition of the upper fill layer was compact to dense with N values recorded ranging from 14 to 31. The higher N values near the surface could be a result of frost penetration within the pavement structure.

The lower portion of the fill encountered in Borehole 1 is silty clay with varying amounts of sand and traces of gravel from depths 2.5 m to 6.2 m. Organic layers up to 50 mm in thickness were recorded within depths of 4.3 m to 5.9 m below the surface in Borehole 1. In Borehole 2, silty clay with varying amounts of sand and traces of gravel was encountered from depths 4.2 m to 5.5 m. Gradation analyses conducted on the soils in Boreholes 1 and 2 indicate up to 2 percent

gravel, 13 to 31 percent sand content, and 45 to 58 percent silt content. The natural moisture contents the silty clay fill ranges from 16.8 to 26.6 percent.

The clay fill material in Borehole 1 is in a loose condition within the organic layers, N values as low as 6 were recorded. At the base of the clay fill in Borehole 1, the materials were dense to very dense with N values as high + 50. In Borehole 2, the clay fill materials were in a compact condition with N values of 10 and 20 recorded.

In Borehole 3, at the inlet ditch, soft silty clay material was encountered to a depth of 2.9 m (borehole termination depth) below the surface. In Borehole 3, at the outlet, silty clay material was encountered to a depth of 1.1 m below the surface.

It is very likely that the lower clay fill materials are natural soils that were cut and fill subgrade materials during the original construction of the roadway.

4.4 Silty Clay

Native silty clay was encountered beneath the fill materials in Boreholes 1 and 2. In Borehole 1 the clay layer extends from 6.2 m to 12.7 m in depth below the surface. In Borehole 2 the clay layer extends from 5.5 m to 12.8 m in depth below the surface. Beyond these depths, the extent of the clay layer is unknown. In Borehole 4, native silty clay was encountered from 1.1 m to 2.8 m below the surface at the borehole termination depth. The silty clay has low plasticity with liquid limits ranging from 22 to 24, plastic indexes ranging from 6 to 8, and natural moisture contents ranging from 12.0 to 17.1 percent. The consistency of the silty clay is very stiff to hard

with N values ranging from 14 to + 50 and in-situ shear vane test results of +120 kPa, indicating the silty clay is overconsolidated.

4.5 Groundwater

Boreholes 1 and 2 were dry on completion of drilling, although, wet soil conditions were encountered at 5.0 m in Borehole 1, and at 8.0 m to 9.0 m in Borehole 2. At the time of the investigation, Borehole 3 (Elevation 97.5) at the inlet had 100 mm of standing water/ice, and Borehole 4 (Elevation 97.1) at the outlet had 150 mm of standing water/ice.

The water levels indicated on the Borehole Logs and Drawings 2 and 3 are not intended to represent the groundwater table or groundwater flow.

The water levels at the centerline culvert location will fluctuate seasonally and in response to climatic conditions.

GEOTECHNICAL INVESTIGATION AND DESIGN REPORT

HIGHWAY 634, CULVERT REPLACEMENT

PART 2: ENGINEERING DISCUSSIONS AND RECOMMENDATIONS

5.0 DISCUSSION

This section presents interpretation of the geotechnical data presented in the factual report and provides geotechnical design recommendations and construction concerns.

The terms of reference indicate the preferred option for the twin culverts replacement is a single precast concrete box culvert 2.4 m (width) by 1.8 m (high) (Canadian Highway Bridge Design Code, Type B Installation).

The new culvert will be located approximately along the same elevation as the existing South CSP. The new alignment may be shifted southerly to maintain a minimum distance of 1.0 m from the edge of the North CSP haunch zone. Unless, a non standard special provision is issued to allow the contractor to crush the existing North CSP on its south side to provide room for construction equipment while maintaining inlet water to flow through.

The preferred method of replacement is open cut excavation as per OPSS 422, staging (half and half) with temporary grade lowering and road widening to provide a single 5.0 m lane of traffic without a detour.

It is anticipated that the final platform grades and dimensions will remain the same upon completion. Side slope steepness can be reduced at the outlet (east) by extending the new concrete box culvert beyond the existing outlet by approximately 1.5 m.

Given that the cross sectional area of the concrete box culvert is larger than the cross sectional area of the South CSP, the overall effect of the culvert foundation soils will be a small increase in the stress in the order of 16 kPa at the base of the culvert and 52 kPa at the base of the fill in the area of the North CSP upon removal. The added load is 124 kN/m run over a width of 2.4 m at the base of the fill.

The design of the new structure must be in accordance with the Canadian Highway Bridge Design Code CAN/CSA-S6-06 and all relevant Ministry of Transportation specification and guidelines.

The generalized make up of the embankment the upper fill layer consists of silty sands with varying amounts of gravel as well as clay. The majority of the N values from the Standard Penetration Test vary between 17 and 31 indicating the silty sand upper fill layer is in a compact condition. The silty sand fill materials in the upper layer extend from surface Elevation 102.5 m to approximately Elevation 100.0 m in Borehole 1 and to approximately Elevation 98.4 m in Borehole 2. The generalized classification of this fill material with respect to the Canadian Highway Bridge Design Code, Clause 7.8.3.1, Table 7.9 Classification of Placed Soils, is a Soil Group II, SM (sandy silt).

The lower fill layer consists of silty clay with varying amounts of sand and gravel. The silty clay fill materials in the lower layer are present from approximately Elevation 100.0 m to 96.3 m in Borehole 1 and from approximately Elevation 98.4 m to 97.1 m in Borehole 2. The majority of the N values from the Standard Penetration Test on the silty clay layer vary between 10 to 12 indicating a loose to compact condition, with the exception being in Borehole 1; at approximately

Elevation 98.2 m the N value was 6 indicating a loose condition. This low N value is due to the presence of organic layers encountered within the fill between Elevation 98.2 m and 96.6 m. At the base of the silty clay fill, the N values are between 20 and + 50, indicating a compact to very dense condition, these higher values could be due to the presence of gravel, cobbles and boulders, although no boulders and cobbles were encountered during the filed investigations. The higher values could also be the result of minimal disturbance of the subgrade soils during the original construction process. The generalized classification of this fill material with respect to the Canadian Highway Bridge Design Code, Clause 7.8.3.1, Table 7.9 Classification of Placed Soils, is a Soil Group III, SC (silty clay).

Silty clays were encountered beyond the toes of the embankment in Borehole 3, from the surface Elevation 97.5 m to 94.6 m, and in Borehole 4, from the surface Elevation 97.1 m to 93.0 m.

The surface water present in Boreholes 3 (inlet) and Borehole 4 (outlet), recorded at the time of the investigation were at Elevations 97.5m and 97.1 m respectively. In Borehole 1, soil conditions were noted as wet at Elevation 97.5, and in Borehole 2 at Elevation 95.1 m. The groundwater table near the culverts is expected to be slightly higher than the water level in the culvert.

Groundwater and surface water levels will fluctuate seasonally and in response to climatic conditions.

5.1 Subgrade Preparation

The new concrete box culvert base will be located approximately at Elevation 96.9 m along the same elevation of the existing South CSP, while maintaining an alignment with a minimum of 1.0 m distance from the North CSP.

The geotechnical bearing resistance of the foundation soils (Granular 'A', over stiff silty clay) at ULS for design purposes may be taken as 250 kPa, for a uniformly distributed reaction pressure on the bottom of the box. This is conservatively based on the area of least resistance at the culvert ends, where there is minimal overburden pressure adjacent the concrete box structure. The resistance is based on a bearing resistance factor of 0.5 and the minimum average shear strength of 100 kPa. The geotechnical reaction for vertical and uniformly distributed loads on the bottom of the box culvert not exceeding 250 kPa is estimated to be less than 25 mm.

Where unsuitable or unstable soils are encountered, the foundation soils must be removed to firm or hard in-situ soils and replaced to the foundation grade with Granular 'A' material meeting OPSS 1010 specifications. The foundation soils for a minimum of one half of the conduit inside width on each side of the conduit should be at least as stiff as the foundation soil below the conduit.

Excavation shall be according to OPSS 902. Excavation of temporary side slopes that do not support traffic should not be steeper than 1 horizontal to 1 vertical, although, flatter slopes may be required depending on construction methods. Temporary slopes supporting traffic during the construction stages should not be steeper than 2 horizontal to 1 vertical.

The trench width shall be sufficient enough to permit proper use of compaction equipment suited for the material to be compacted, the degree of compaction required, and the space available as per Special Provision No. 105S10, Construction Specification for Compaction.

5.3 Bedding and Backfill

For the conditions at this site, it is likely that the proposed construction is to be undertaken in dry conditions, with minimal disturbance of the very stiff to hard in-situ soils. Any foundation soils that could be disturbed shall be protected. Bedding materials should be placed immediately after excavation to avoid exposure and deterioration of the silty clay foundation soils.

The bedding material should be placed as uniformly as possible, and consist Granular 'A' as per Soil Group I in accordance with Table 7.4 of the Canadian Highway Bridge Design Code. The Granular 'A' shall be in accordance to OPSS 1010. The Granular 'A' should be placed in layers not exceeding 200 mm in thickness, loose measurement, and each layer compaction to a minimum of 95 % of Standard Proctor Maximum Dry Density, but, shall be loosely placed and uncompacted under the middle third of the box culvert. A 0.5 m thick layer of Granular 'A' shall be placed and should be separated from the adjacent soil and backfill with a non-woven Class II geotextile as per OPSS 1860. A minimum of 75 mm leveling course of uncompacted Granular 'A' or fine aggregates (as per OPSS 1002) shall be applied as per OPSD 803.010.

A minimum of 300 mm of earth cover is required for concrete culverts and shall consist of Soil Group I or II, and shall be free of boulders (diameter less than 75 mm), debris, organic matter, or frozen materials, as per OPSD 803.010, OPSS 422.05.15, and SP422S01.

Backfilling shall be in accordance with OPSS 902, and shall be placed in layers not exceeding 200 mm in thickness, loose measurement and compacted in accordance with OPSS 501.

5.4 Side Fill and Overfill Zones

The side full and overfill zones for a Type B installation should consist of Soil Group I or II and compacted to 95 % or 98 % respectively. Refer to figure 7.11 Standard Installation for Concrete Box Section in Trenches (CHBDC) for the required dimensions of the fill area. The soil in the outer bedding and side fill zones should be compacted to at least the same degree as the soils the overfill zone.

5.5 Lateral and Sliding Resistances

The earth pressures on each box section should be designed in accordance with Section 7.8.5.3.2 Earth Load of the CHBDC. Granular 'A' or 'B' Type I backfill should be in accordance with OPSS 1010. The ultimate friction factor ($\tan\delta$) for formed concrete against Granular 'A' can be taken as 0.6. The following parameters are recommended when calculating earth pressures.

Table 1:

	* Granular 'A'	* Granular 'B', Type I	Soil Group II
Unit Weight (kN/m^3)	$\gamma = 22$	$\gamma = 21$	$\gamma = 18$
Angle of Internal Friction	$\Phi' = 35^\circ$	$\Phi' = 30^\circ$	$\Phi' = 28^\circ$
Active (K_a)	0.27	0.33	0.36
Passive (K_p)	3.69	3.00	2.76
At Rest (K_o)	0.42	0.50	0.53

5.5 Embankment Design

The existing embankment slopes at the culverts vary from approximately 3 horizontal to 1 vertical and 2.2 horizontal to 1 vertical from the existing shoulder to the top of the culverts. Slope stability analyses were carried out with limit equilibrium method using Geoslope version 2004 software applying Morgenstern and Price methods, and applying a pseudo-static analysis. The results indicated that stability will meet or exceed suitable design factors of safety under both short and long term conditions. A factor of safety that exceeds 1.3 has been achieved under both undrained and drained conditions with a slope configuration of 2.5 horizontal to 1 vertical. This analysis applied a friction angle of 30 degrees for the embankment fill material (well compacted sand and silt), and 28 degrees for underlying silty clay, and a high phreatic surface in the fill (saturated conditions in the fill at the obvert level) as a result of slow drainage immediately after flood conditions.

The results indicate that the existing slopes of 2.2 horizontal to 1 vertical (outlet) should be reinstated with an extension at the outlet to reduce the side slope to 2.5 horizontal to 1 vertical, and the existing 3 horizontal to 1 vertical (inlet) may be reinstated and will have adequate stability.

Gravel sheeting should be placed on the new slopes to provide a stable, free-draining, slope face. Gravel sheeting shall meet the OPSS 1004 specifications.

Temporary slopes of 2 horizontal to 1 vertical will be adequate support traffic during the staged construction process.

The Factor of Safety (FOS) of the slope stability analysis for drained and undrained conditions is provided in the table below:

Table 2:

	Drained Condition	Undrained Condition	Drained Condition	Undrained Condition
Slope	H: V = 2:1	H: V = 2:1	H: V = 2.5:1	H: V = 2.5:1
Factor of Safety (Upstream)	1.2	1.2	1.4	1.4
Factor of Safety (Downstream)	1.3	1.3	1.5	1.5

5.6 Frost Protection

In accordance with OPSD 3090.100, Foundation Frost Depths for Northern Ontario, the frost penetration for the Highway 634 area is 2.6 m. Frost treatment areas for the roadway should be constructed in accordance with OPSD 803.010.

Section 7.8.3.4 of the Canadian Highway Bridge Code indicates “frost susceptible soils shall not be used adjacent to the conduit wall within the depth of frost penetration”. The soils under the culvert are highly frost susceptible (capable of forming thick ice lenses with the associated pressures and heave). Given the temperatures during the winter inside the culvert (and particularly given the large size of the culvert), ice is expected to form inside the culvert. At low flows, it is possible that ice may extend to the culvert invert. Frost could therefore extend into the soils below the culverts, possibly as deep as 2.6 m (less if there is continuous flow). The result, particularly near the ends where there is little earth cover available for restraining heaving, may be ice lensing with the associated high upward pressures on the culverts. Two

design approaches are feasible: either design the culvert with enough strength and rigidity to tolerate these pressures (recognizing that the maximum differential pressures and movements as a result of frost lensing cannot be accurately quantified), or remove the frost susceptible soils within the frost zone. The latter requires complete removal of materials within the zone of influence, which extends to 2.6 m below invert, and laterally 50% of that distance beyond the sides of the culverts (although a 2 dimensional advanced thermal analysis may indicate somewhat less). If this excavation is carried out in the dry (with adequate dewatering controls) then the material can be replaced with Granular B Type 1 material compacted to 95% of standard Proctor maximum dry density. If the excavation is in the wet (water is maintained at or above adjacent groundwater table) then the material should be rockfill or clear stone surrounded by geotextile, without the need for compaction. Depending on the structural design of the culvert, partial subexcavation (less than 2.6 m) may also be considered to reduce differential stresses associated with frost; however the exact pressures and movements cannot be accurately quantified.

The soils at the site are frost susceptible and may loosen/soften with freezing and thawing cycles.

5.7 Channel Diversion

The North CSP may be used a temporary diversion channel for the highway's longitudinal drainage water during the construction. This will require additional staging once the concrete box culvert has been installed, with cover in place, and water can flow; the North CSP shall be removed as per OPSS 510 and backfilled with granular materials as per OPSS 1010.

Alternatively, a sump and pump scheme may be utilized to divert the water over the embankment to the outlet side.

5.8 Outlet/Inlet Control

To prevent erosion of the surrounding soils, at the inlet a clay seal shall be applied in accordance with OPSS 1205 and OPSD 802.095 Clay Seal for Pipe Trenches. As an alternative, Rip-Rap Treatment may be applied as per OPSD 810.020, in accordance with OPSS 511 and SP511S01.

The outlet shall be rip-rapped to prevent erosion of the surrounding soils, as per OPSD 810.010 Rip-Rap treatment for Sewer and Culvert Outlets in accordance with OPSS 511 and SP511S01.

Alternatively, a cut off wall may be installed at the inlet and outlet and should extend to approximately 1.0 m as the soil underlying the existing inlet location is low permeability clay.

5.9 Road Protection

For traffic and roadway protection, due to the depth of excavation, installation of a cantilevered sheet pile system may be considered to ensure the stability of the bank and is a feasible option. This type of system will, however, be expensive and therefore, impractical. There is a sufficient cross sectional area for lowering the road, and minor widening, with a staged construction sequence allowing a single traffic lane of 5.0 m in width. The temporary slopes in the existing materials should not exceed 2 horizontal to 1 vertical.

5.10 Construction Concerns

The construction methodology must be in accordance with all Ministry of Transportation, Ministry of Environment, Ministry of Natural Resources, as well as the Occupational Health and Safety Act of Ontario. The contractor's method and equipment must be suitable for the site conditions and materials used.

An on-site Engineer shall be required to inspect the condition of the foundation and surrounding soils before installation of bedding, ensure the width of the trench and trench slope walls are suitable, and ensure compliance with materials placed and compaction methods.

6.0 LIMITATIONS OF REPORT

A description of limitation which are inherent in carrying out site investigation studies is provided in Appendix 'A', and this forms an integral part of this report.

For DST Consulting Engineers Inc.,

Prepared by:



For
Mohammad Aktar, P. Eng (APPEGA)
Geotechnical/Pavement Specialist

Reviewed by:



Dr.M.W.Bo, PhD., P. Eng., P. Geo., Int PE.,
C. Geol, C. Eng., Eur Geol., Eur Eng.,
Principal / Director of Geo-Services

Revised by:



Diana McKay, A. Sc. T.
Geotechnical Technologist



Mike Fabius, P. Eng.
Principal

APPENDIX A

LIMITATIONS OF REPORT

LIMITATIONS OF REPORT

GEOTECHNICAL STUDIES

The data, conclusions and recommendations which are presented in this report, and the quality thereof, are based on a scope of work authorized by the Client. Note that no scope of work, no matter how exhaustive, can identify all conditions below ground. Subsurface and groundwater conditions between and beyond the testholes may differ from those encountered at the specific locations tested, and conditions may become apparent during construction which were not detected and could not be anticipated at the time of the site investigation. Conditions can also change with time. It is recommended practice that DST Consulting Engineers be retained during construction to confirm that the subsurface conditions throughout the site do not deviate materially from those encountered in the testholes. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the testhole locations and should not be used for other purposes, such as grading, excavation, 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 details stated in this report. Since all details of the design may not be known, we recommend that we be retained during the final stage to verify that the design is consistent with our recommendations, and that assumptions made in our analysis are valid.

Unless otherwise noted, the information contained herein in no way reflects on environmental aspects of either the site or the subsurface conditions.

The comments given in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of testholes may not be sufficient to determine all the factors that may affect construction methods and costs, e.g. 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 conclusion as to how the subsurface conditions may affect their work.

Any results from an analytical laboratory or other subcontractor reported herein have been carried out by others, and DST Consulting Engineers Inc. cannot warranty their accuracy. Similarly, DST cannot warranty the accuracy of information supplied by the client.

EXPLANATION OF TERMS USED IN THIS REPORT

Soil Classification (Based on Amounts by Weight)

Noun	Gravel, sand, silt, clay	>35% and main fraction
“and”	And gravel, and silt, etc.	>35%
Adjective	Gravely, sandy, silty, clayey, etc.	20% - 35%
“some”	Some sand, some silt, etc.	10% - 20%
“trace”	Trace sand, trace silt, etc.	1% - 10%

Consistency and Shear Strength of Cohesive Soils

CONSISTENCY	UNDRAINED SHEAR STRENGTH (kPa)
Very Soft	<12
Soft	12 - 25
Firm	25 - 50
Stiff	50 - 100
Very stiff	100 - 200
Hard	>200

Compactness Condition of Sands from Standard Penetration Tests

COMPACTNESS CONDITION	SPT N-INDEX (blows per 0.3 m)
Very loose	0 - 4
Loose	4 - 10
Compact	10 - 30
Dense	30 - 50
Very dense	Over 50

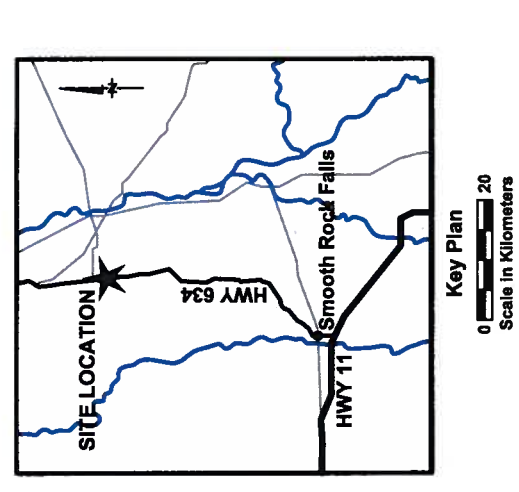
DRAWINGS

METRIC
DIMENSIONS ARE IN METRES
UNLESS OTHERWISE SPECIFIED
IN PARAGRAPHS & NOTES

CONT No. 5007-E-0064
GEORES No. 42H-39
ASSIGNMENT No. 8

HIGHWAY 634
Culvert Replacement
BOREHOLE LOCATIONS & SOIL STRATA

SHEET
1



LEGEND

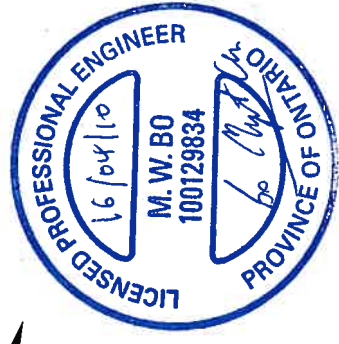
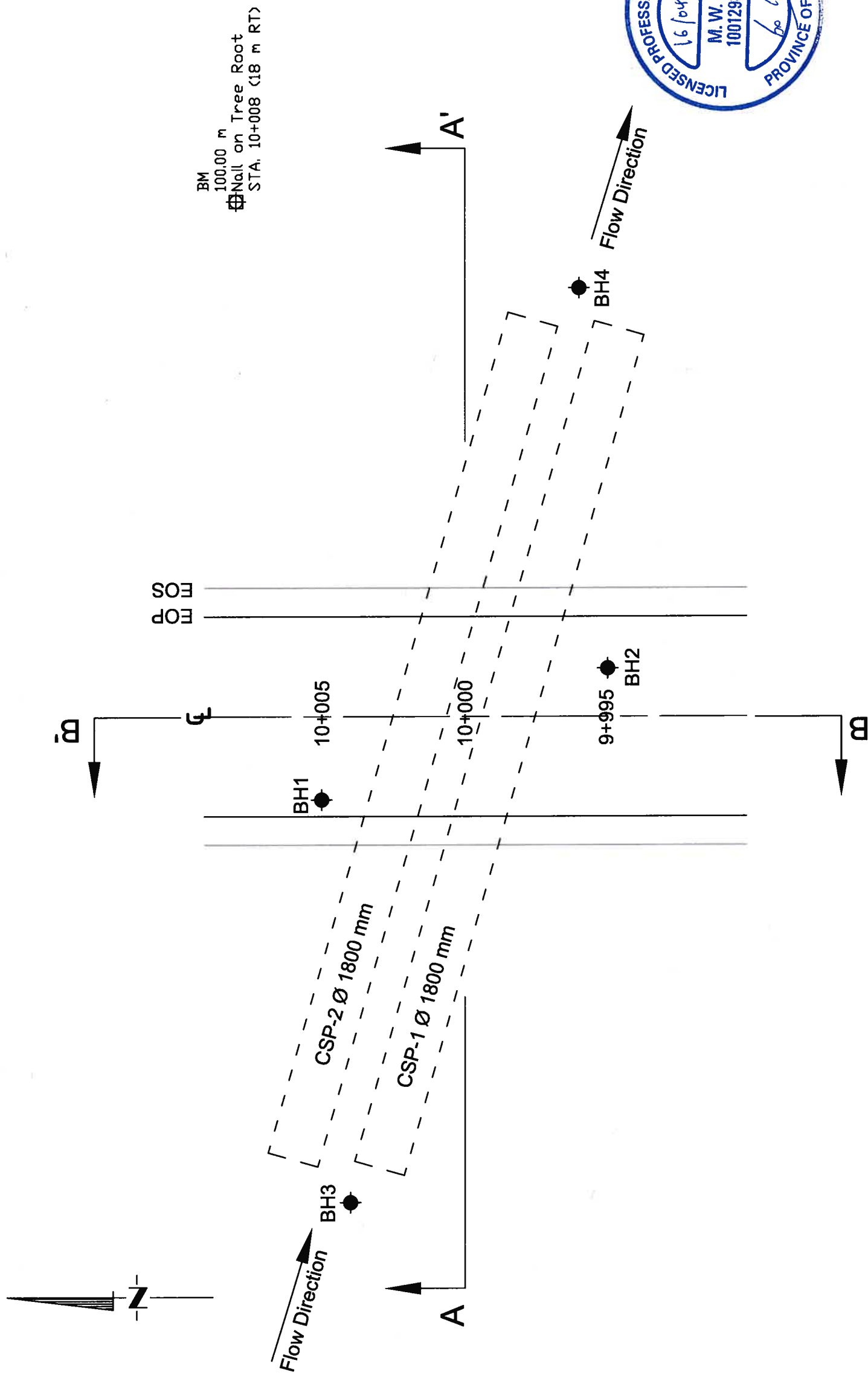
- Borehole
- Dynamic Cone Penetration Test (DCPT)
- Borehole with DCPT
- 'N'
- Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation.

No.	Elevation	Station	Offset
1	102.51	10+005	2.9 m LT
2	102.58	9+995	1.7 m RT
3	98.02	10+004	17.0 m LT
4	97.11	9+996	15.0 m RT

Soil Strata
Fill
Organics
Topsoil
Till
Bedrock
Sand
Silt
Clay
Sand & Gravel
Boulders

NOTE:
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.

DST
DST Consulting Engineers Inc.
605 Hewitson Street
Thunder Bay, ON P7B 5V5
Ph: (807) 623-2929
Fx: (807) 623-1792
Email: thunderbay@dstgroup.com

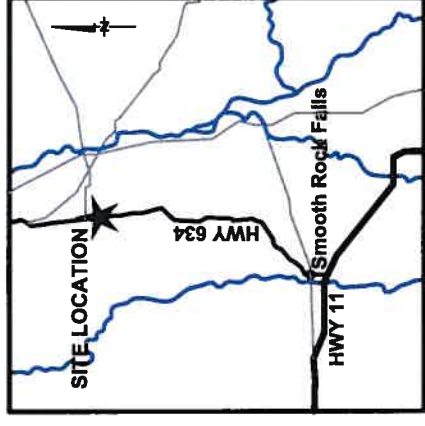


PLAN
Scale in Metres
0 10



**HIGHWAY 634
Culvert Replacement**






SHEET
2 of 3



Key Plan



LEGEND

-  Borehole
 Dynamic Cone Penetration Test (DCPT)
 Borehole with DCPT
 Blows/0.3m (Std. Pen Test, 475 J/Blow)
 Water level at time of investigation.



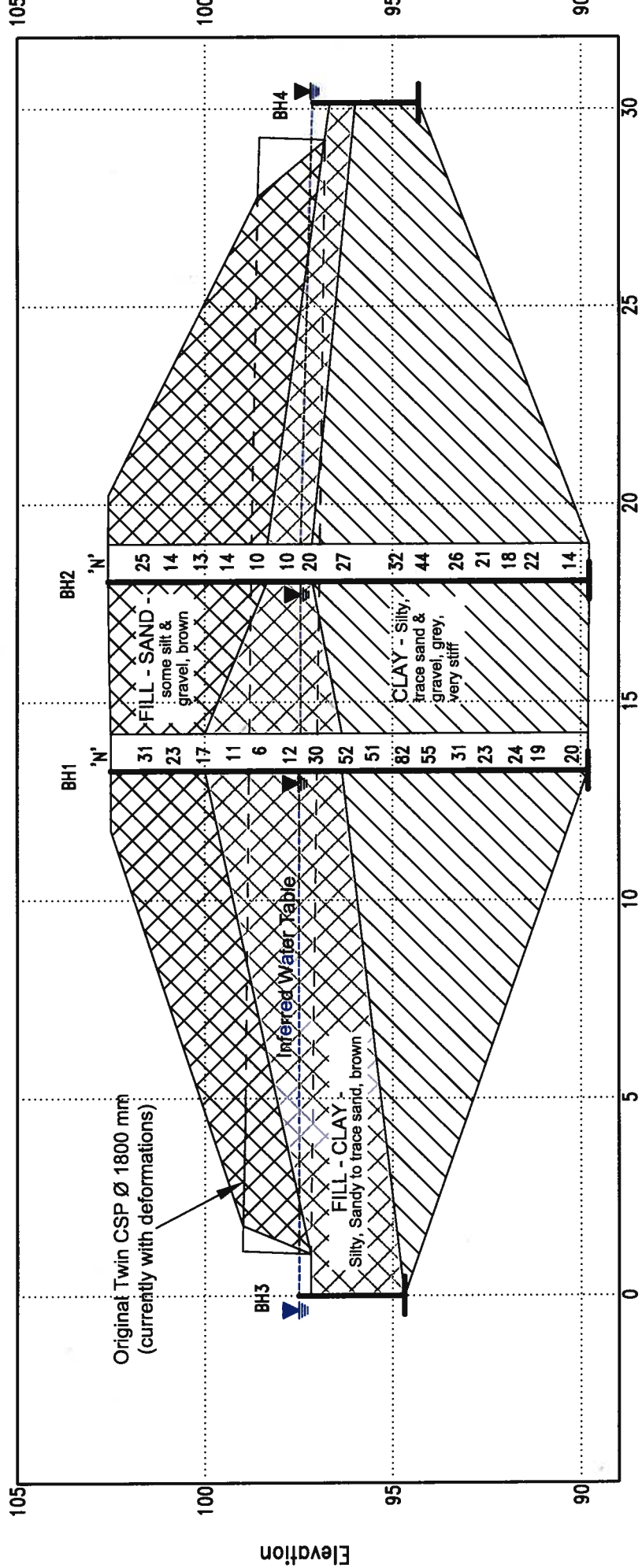
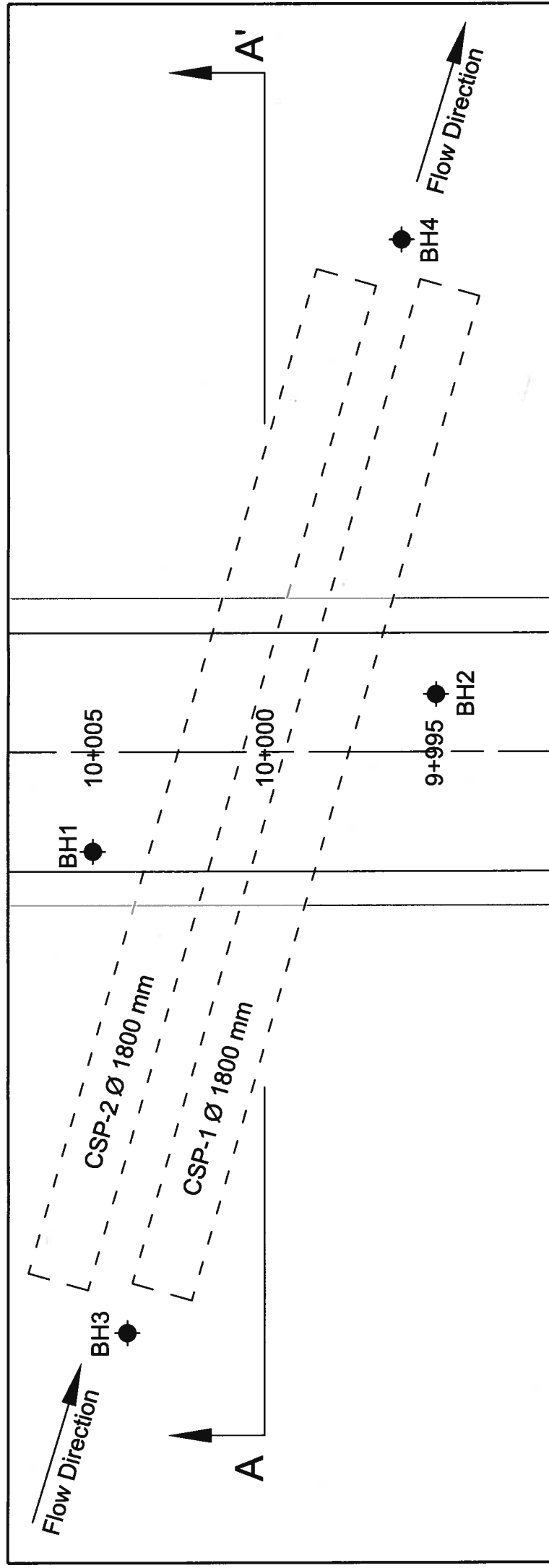
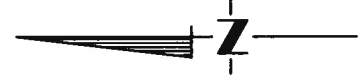
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NOTE: The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.



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METRIC



SHEET
3 of 3



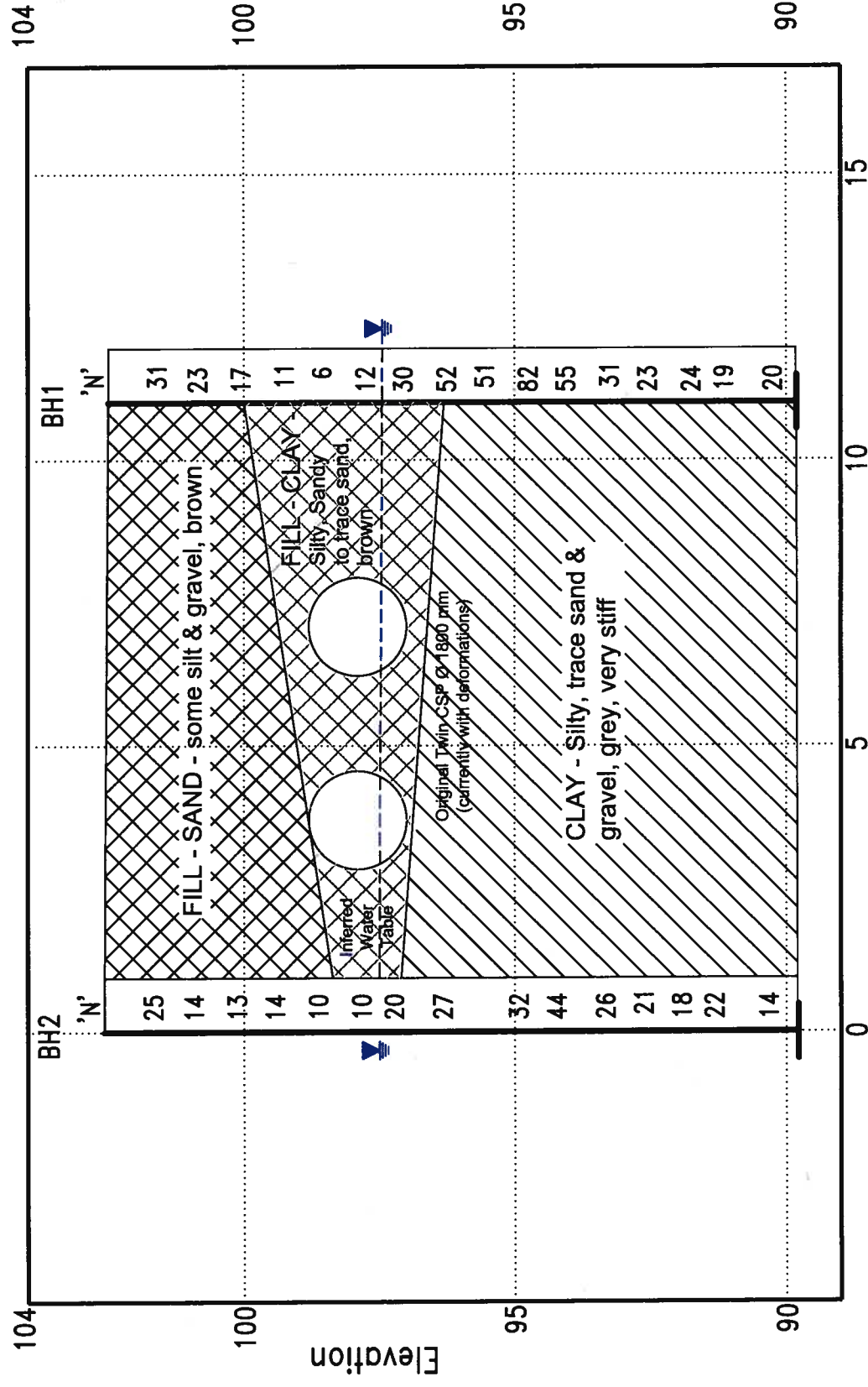
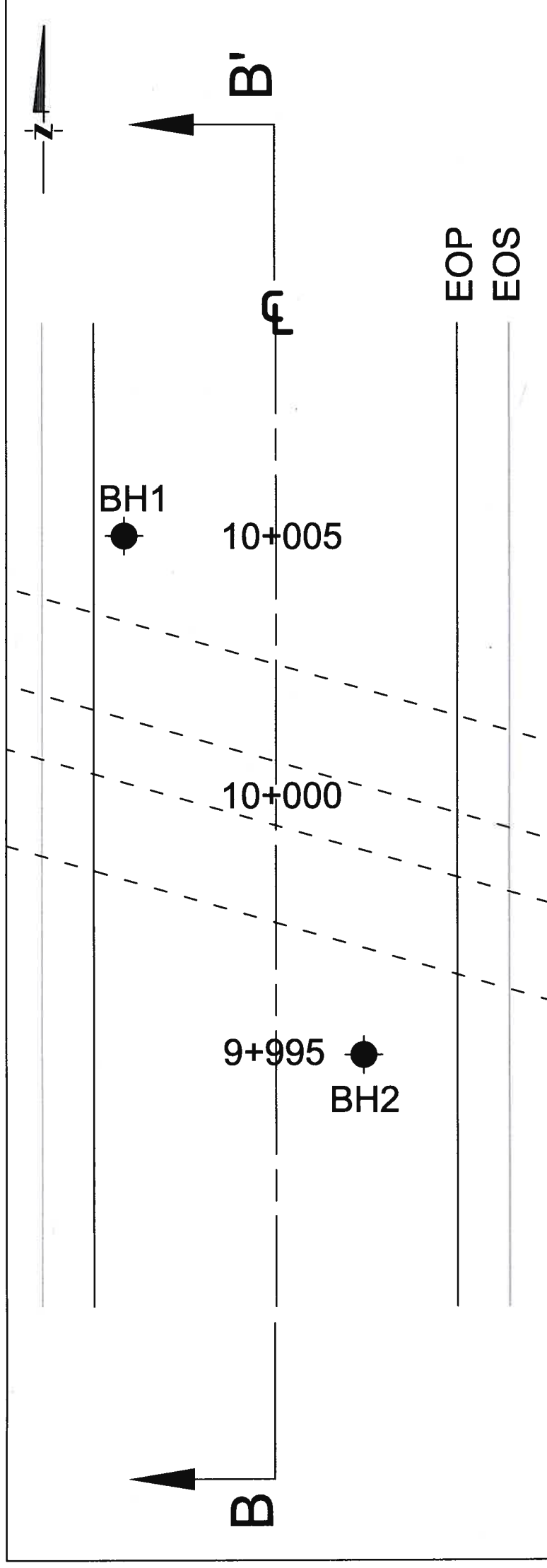
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DESIGNERS ARE IN NEED OF
AND/OR MILLIMETERS UNDER
OFFENSE BROWL. STATION
IN MILLIMETERS + MILLERS



ENCLOSURES

RECORD OF BOREHOLE No 1

1 OF 1

METRIC

W.P. 5007-E-0064 (Assignment #8) LOCATION 10+005 (2.9 m LT) - Local BM 10+800 (18 m LT) ORIGINATED BY DS
 DIST 10 m HWY 634 BOREHOLE TYPE Hollow Stem Auger COMPILED BY ML
 DATUM 100.0 m DATE 2009 12 15 CHECKED BY MF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
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102.5	SURFACE TREATMENT - 30 mm FILL - GRAVEL - Sandy, some silt - 160 mm FILL - SAND - some silt, trace gravel, brown, compact to dense		1	AS			102									GR SA SI CL																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									

\times^3, \star^3 : Numbers refer to Sensitivity \bigcirc 3% STRAIN AT FAILURE

ENCLOSURE 1

ONL MOT CS-TB-011246 MTO - COCHRANE ASS#8 - HWY 634.GPJ DST_MIN.GDT 13/4/10

RECORD OF BOREHOLE No 2

1 OF 1

METRIC

W.P. 5007-E-0064 (Assignment #8) LOCATION 9+995 (1.7 m RT) - Local BM 10+800 (18 m LT) ORIGINATED BY DS
 DIST 10 m HWY 634 BOREHOLE TYPE Hollow Stem Auger COMPILED BY ML
 DATUM 100.0 m DATE 2009 12 14 CHECKED BY MF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W _P	W	W _L		
								○ UNCONFINED □ QUICK TRIAXIAL	✕ FIELD VANE ★ LAB VANE					
102.6								20 40 60 80 100						
100.0	SURFACE TREATMENT - 30 mm FILL - SAND - some gravel, trace to some silt, brown, compact		1	AS			102							Water Level at 7.5 m
				2	SS	25								
101.0							101							1 63 32 5
1.6	FILL - SAND - Silty, trace clay and gravel, compact		3	SS	14									
	----- - trace organics			4	SS	13		100						
				5	SS	14								
							99							
98.4			6	SS	10		98							2 13 58 27
4.2	FILL - CLAY - Silty, some sand, trace gravel, brown, stiff to very stiff		7	SS	10									
				8	SS	20		97						120+
97.1							96							120+
5.5	CLAY - Silty, trace sand and gravel, grey, very stiff, low plastic		9	SS	27		95							
	----- - hard		10	SS	32		94							0 9 67 24
			11	SS	44		93							
			12	SS	26		92							
			13	SS	21		91							120+
	----- - trace gravel, very stiff		14	SS	18		90							4 10 50 36
			15	SS	22									
			16	SS	14									120+
89.8														
12.8	End of Borehole at 12.8 m													

✕³, ★³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ENCLOSURE 2

ON_MOT_CS-TB-011246 MTO - COCHRANE ASS#8 - HWY 634.GPJ DST_MIN.GDT 13/4/10

RECORD OF BOREHOLE No 3

1 OF 1

METRIC

W.P. 5007-E-0064 (Assignment #8) LOCATION 10+004 (17.0 m LT) - Local BM 10+800 (18 m LT) ORIGINATED BY DS
 DIST 10 m HWY 634 BOREHOLE TYPE Hand Auger COMPILED BY ML
 DATUM 100.0 m DATE 2009 12 15 CHECKED BY MF

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)			
						20	40	60	80	100	W _p	W	W _L			
97.5																
97.4	WATER/ICE FILL - CLAY - Silty, Sandy, brown, soft															Water Level at surface.
97.1																
96																
95																
94.6	End of Borehole at 2.9 m															
2.9																

\times^3, \star^3 : Numbers refer to Sensitivity \bigcirc 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 4

1 OF 1

METRIC

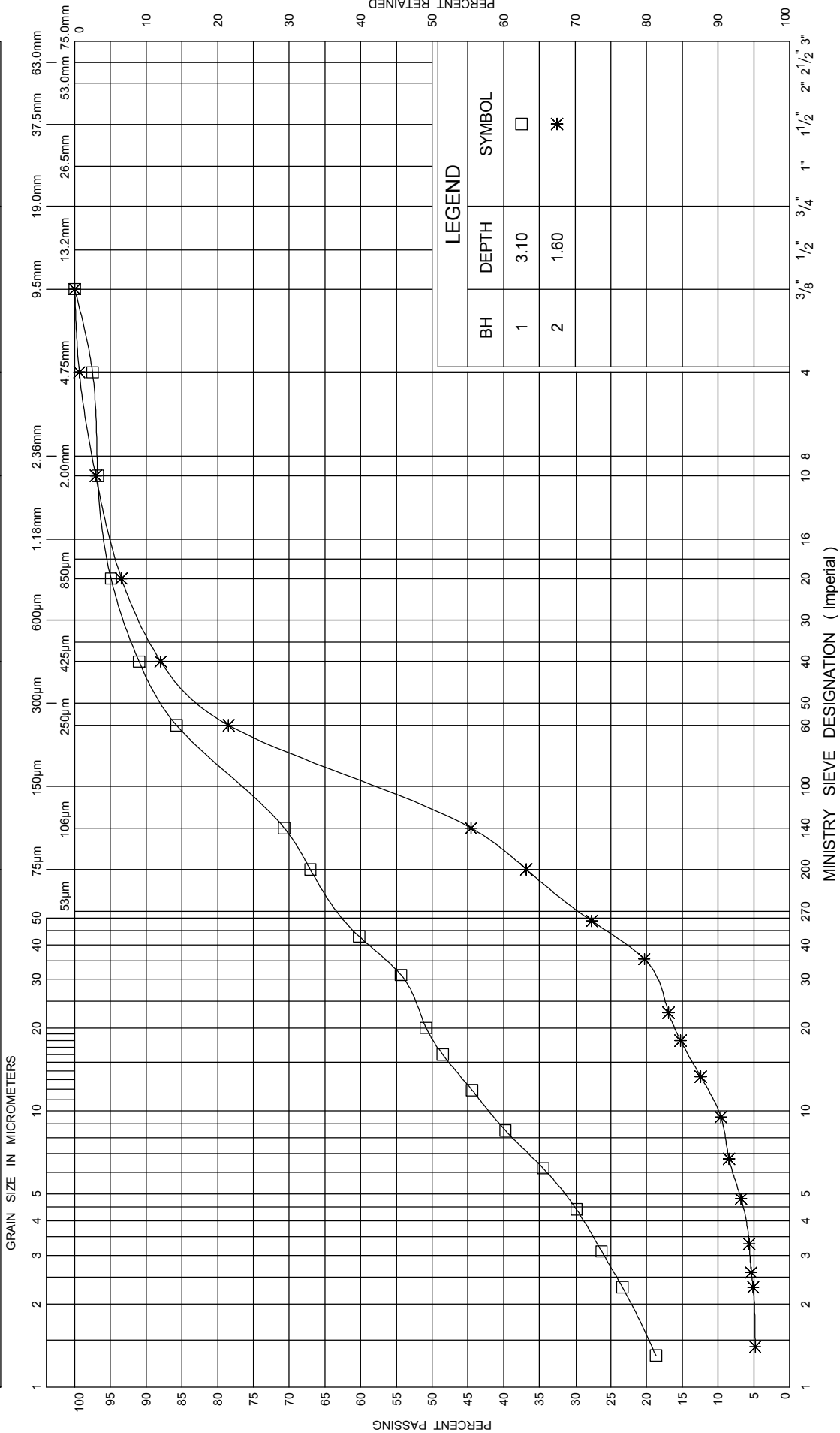
W.P. 5007-E-0064 (Assignment #8) LOCATION 9+996 (15.0 m RT) - Local BM 10+800 (18 m LT) ORIGINATED BY DS
 DIST 10 m HWY 634 BOREHOLE TYPE Hand Auger COMPILED BY ML
 DATUM 100.0 m DATE 2009 12 15 CHECKED BY MF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
97.1														
97.0	WATER/ICE						97							Water Level at surface.
0.2	FILL - CLAY - Silty, trace sand and organics, occasional gravel and cobbles, brown													
96.0							96							
1.1	CLAY - Silty, trace sand and organics, occasional gravel and cobbles, grey, stiff													
94.3							95							
2.8	End of Borehole at 2.8 m													

\times^3, \star^3 : Numbers refer to Sensitivity \bigcirc 3% STRAIN AT FAILURE

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL		
		Fine		Medium	Coarse	Fine	Coarse



GRAIN SIZE DISTRIBUTION
FILL MATERIAL

ENCLOSURE 5

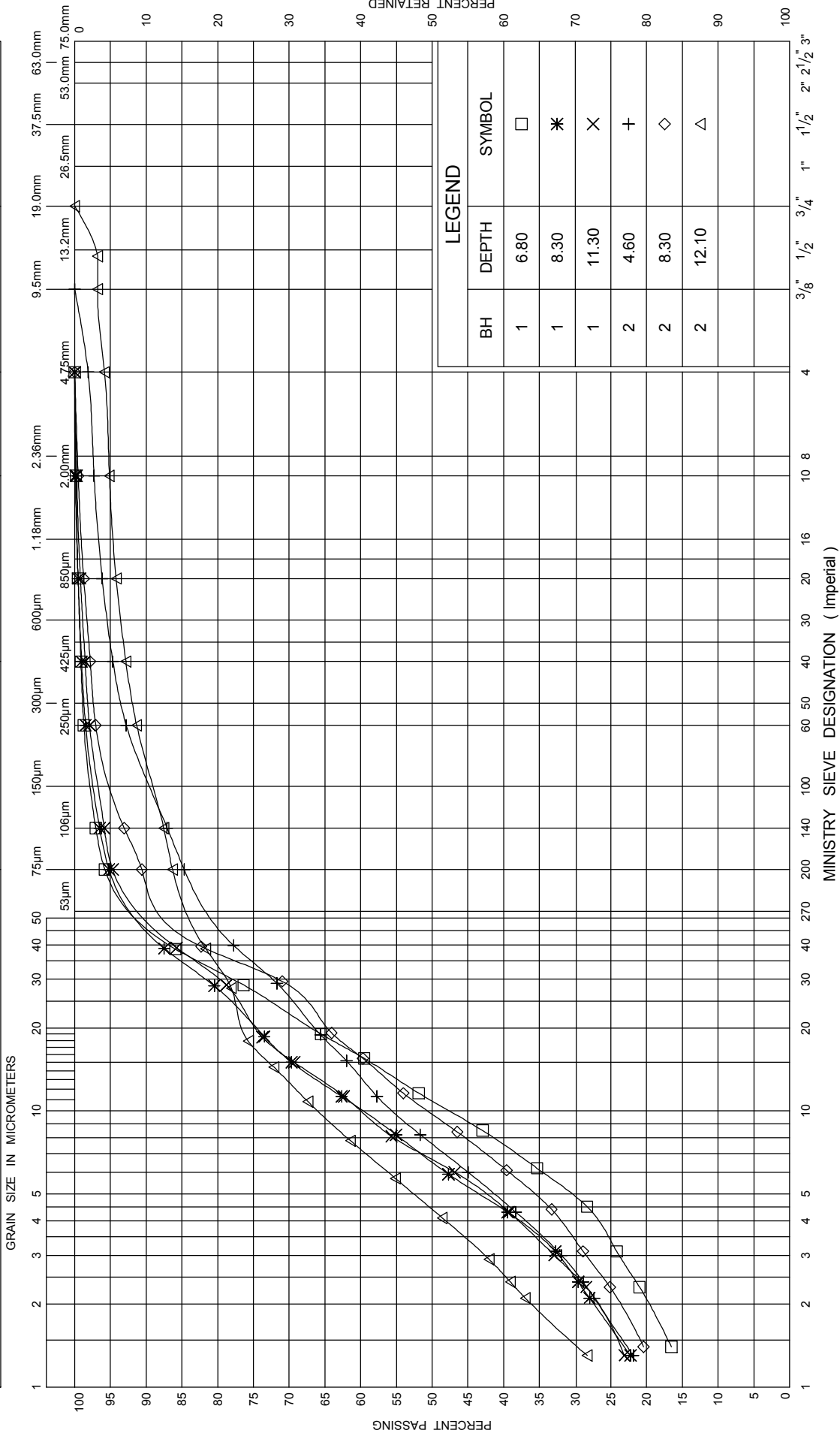
5007-E-0064 (Assignment #8)

HIGHWAY 634



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL	
		Fine	Medium	Coarse	Fine	Coarse

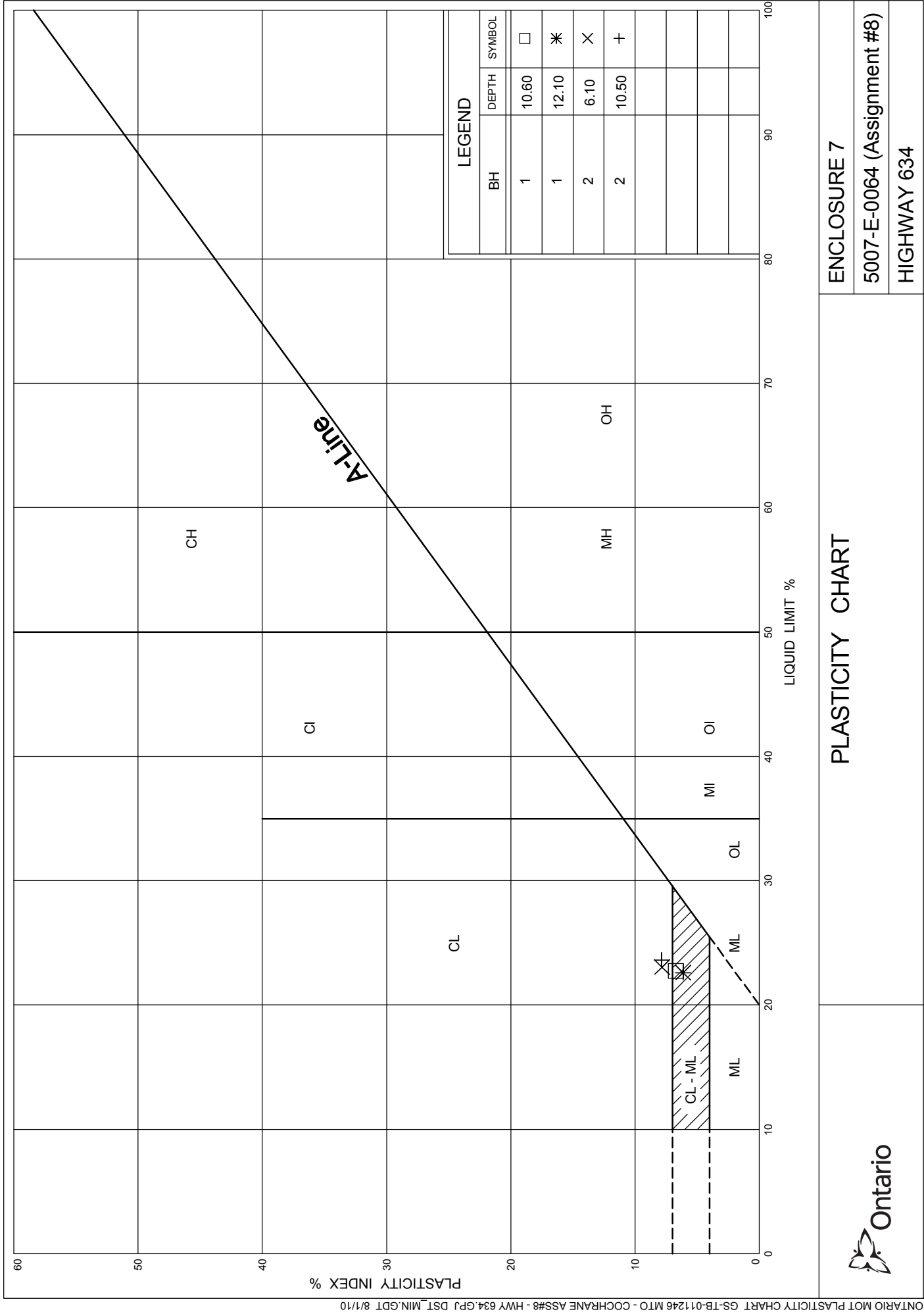


GRAIN SIZE DISTRIBUTION

ENCLOSURE 6

5007-E-0064 (Assignment #8)

HIGHWAY 634



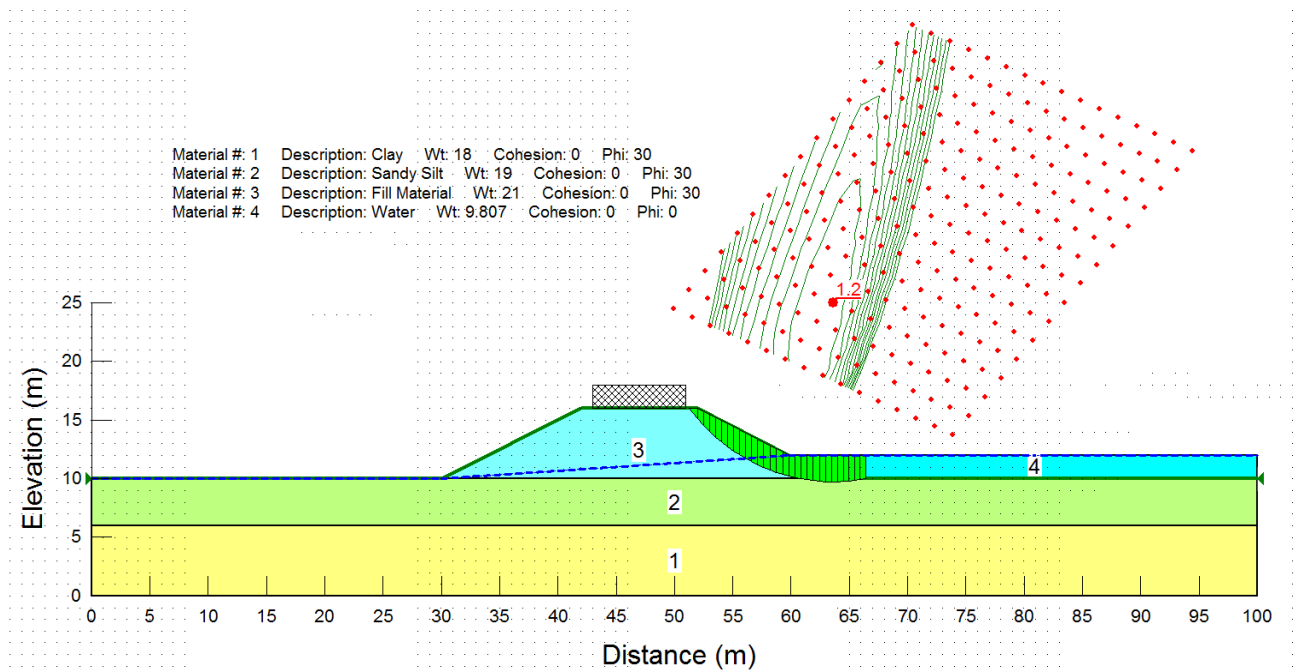
PLASTICITY CHART

ENCLOSURE 7

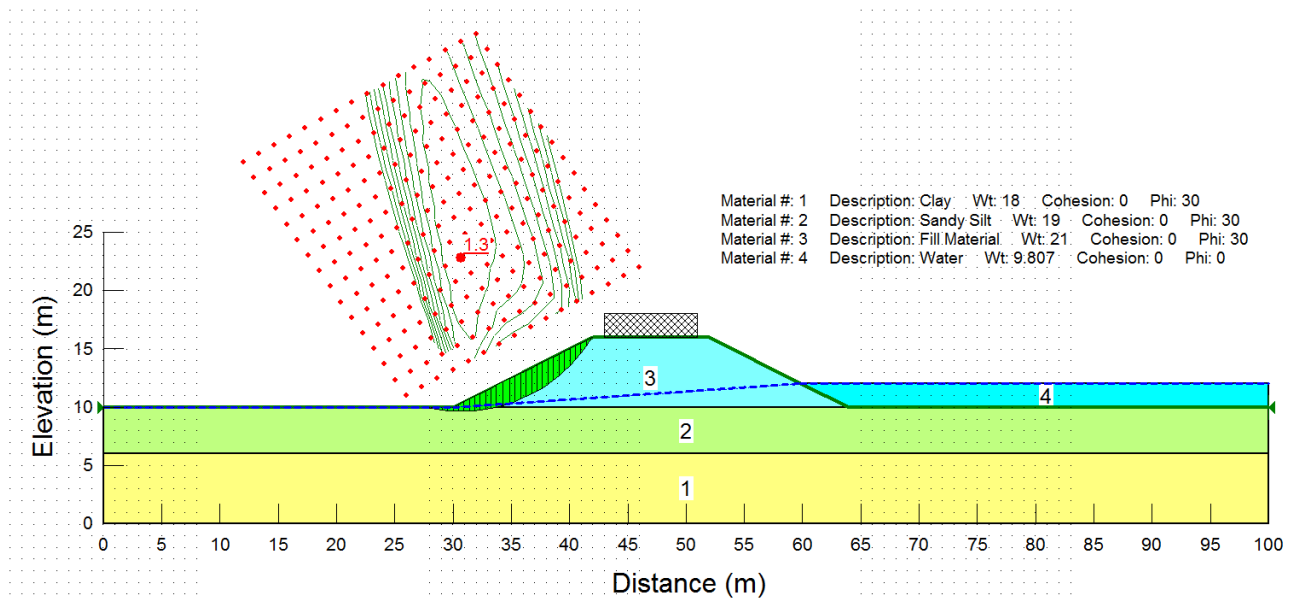
5007-E-0064 (Assignment #8)

HIGHWAY 634

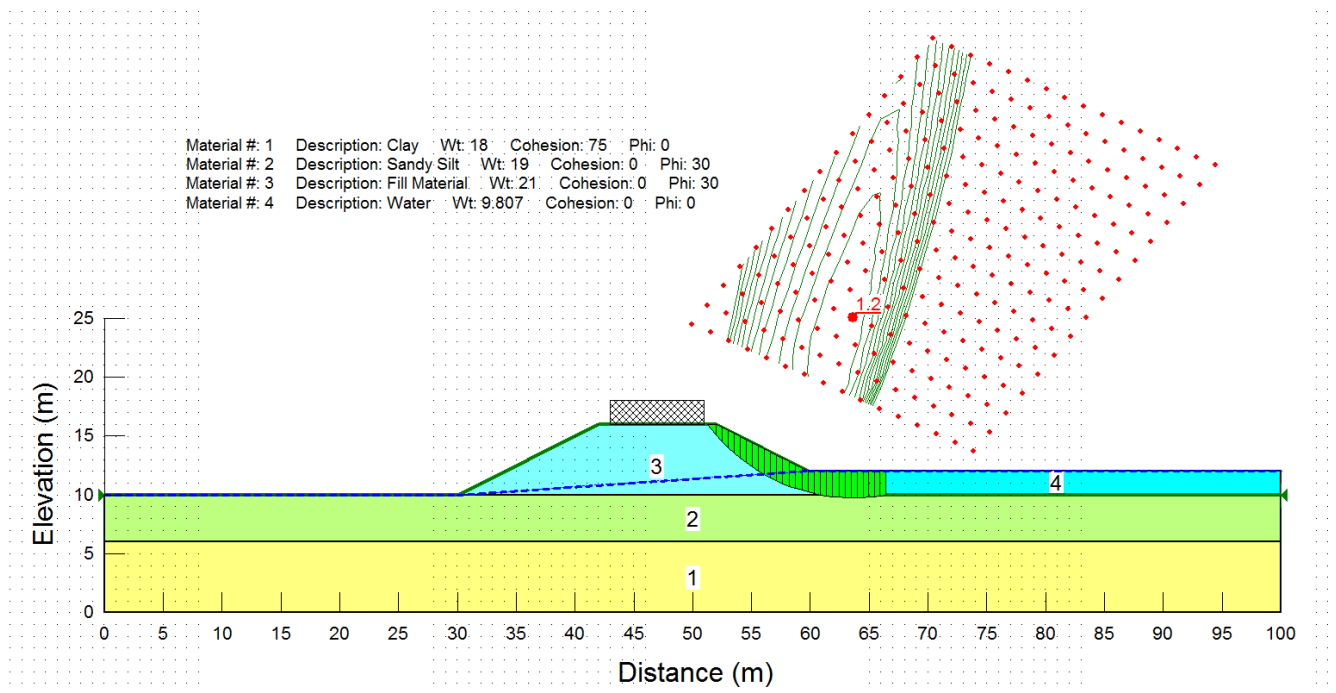




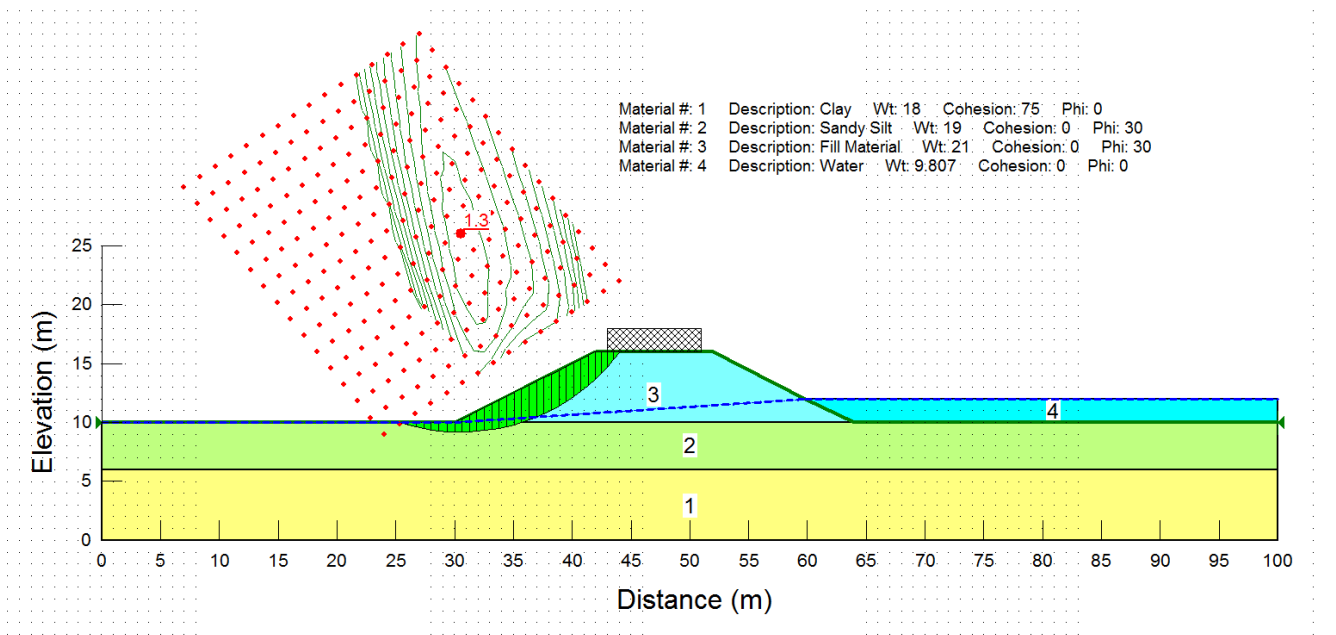
Slope 2h:1v, Drained Condition, Upstream



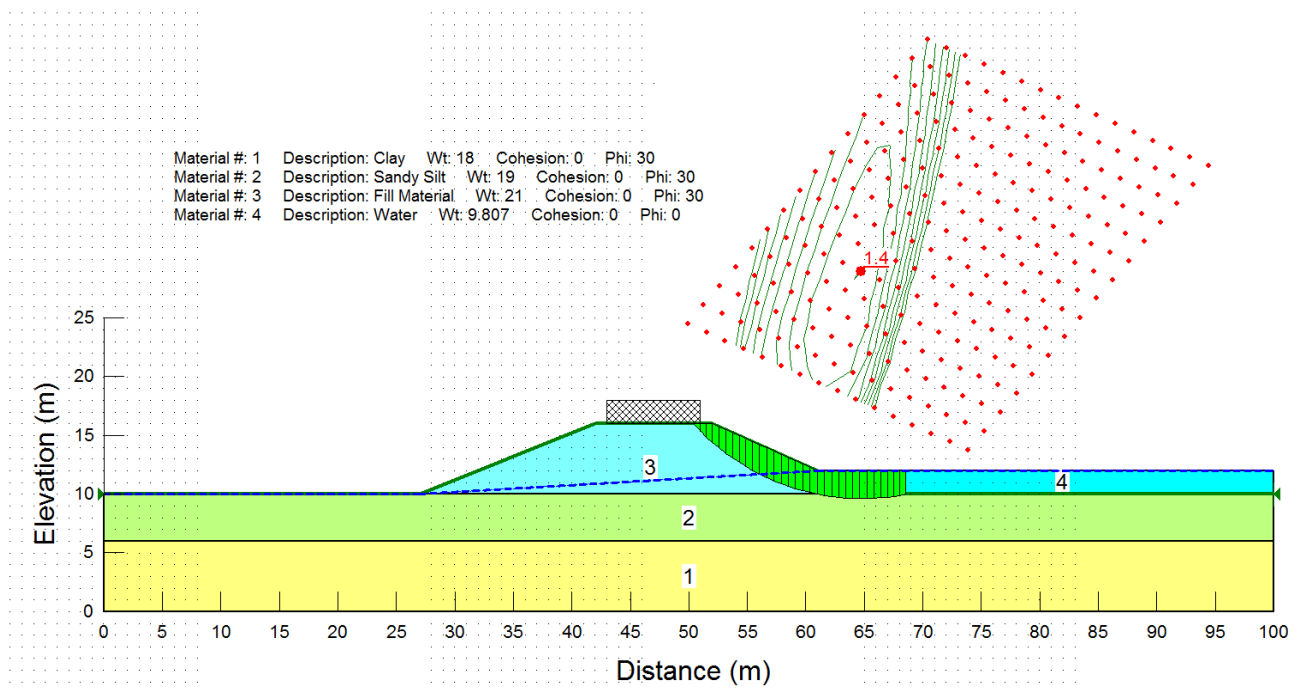
Slope 2h:1v, Drained Condition, Downstream



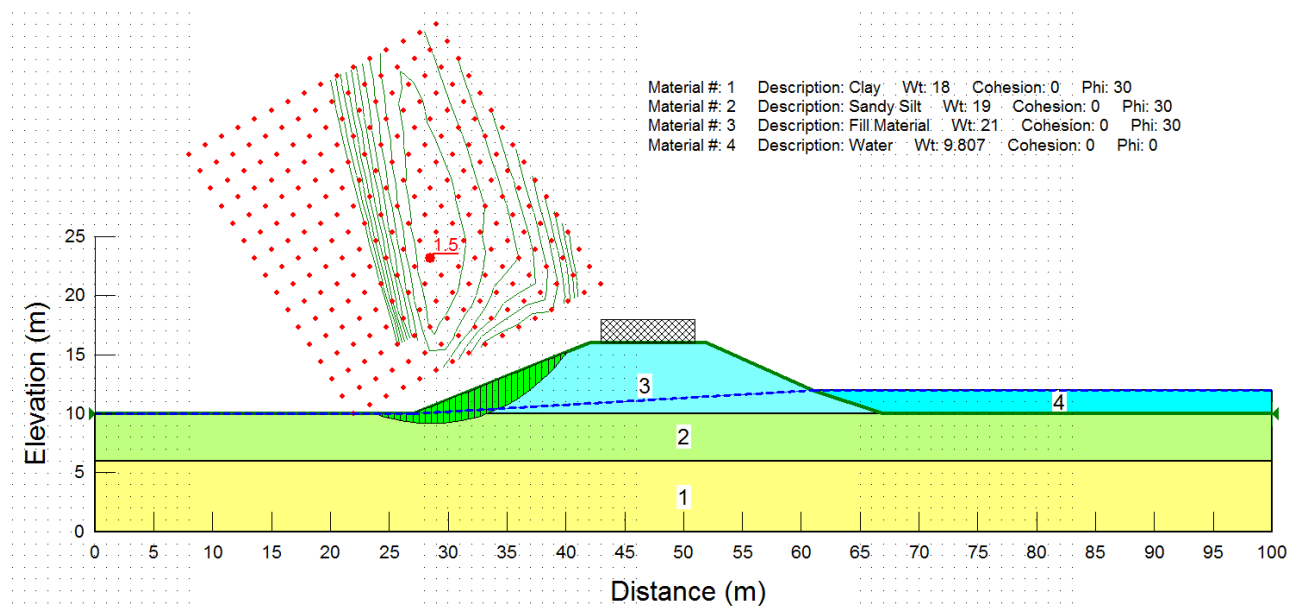
Slope 2h:1v, Undrained Condition, Upstream



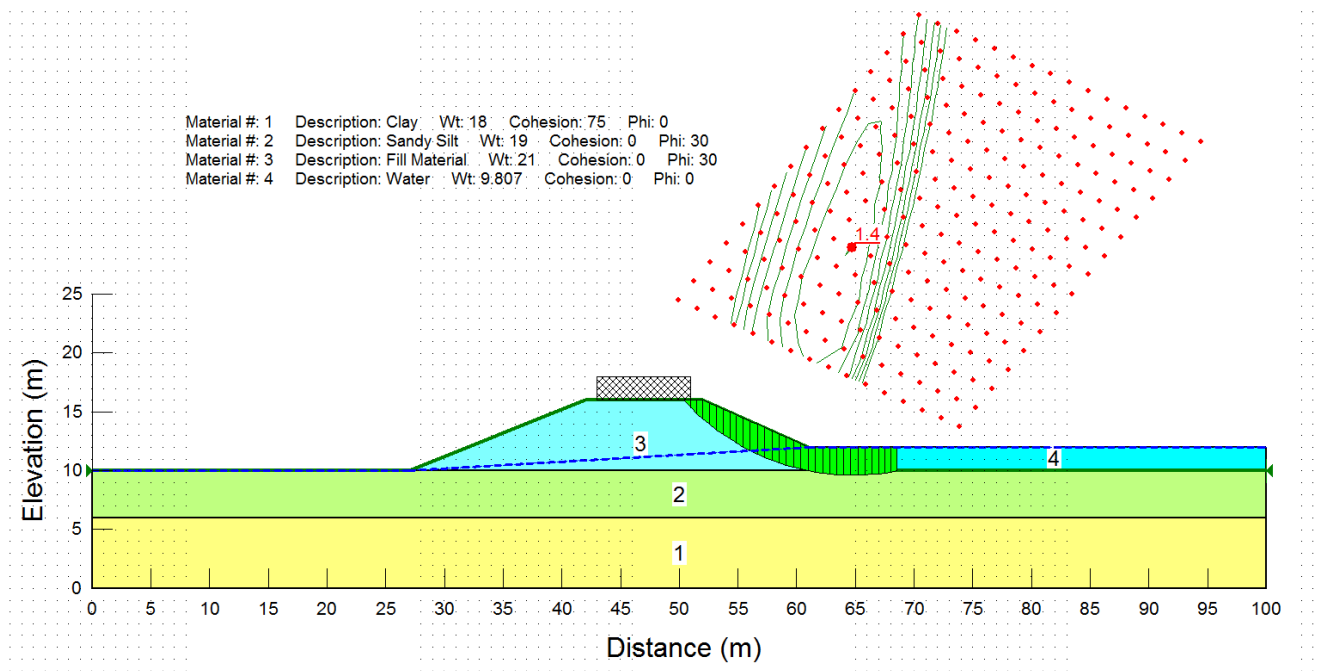
Slope 2h:1v, Undrained Condition, Downstream



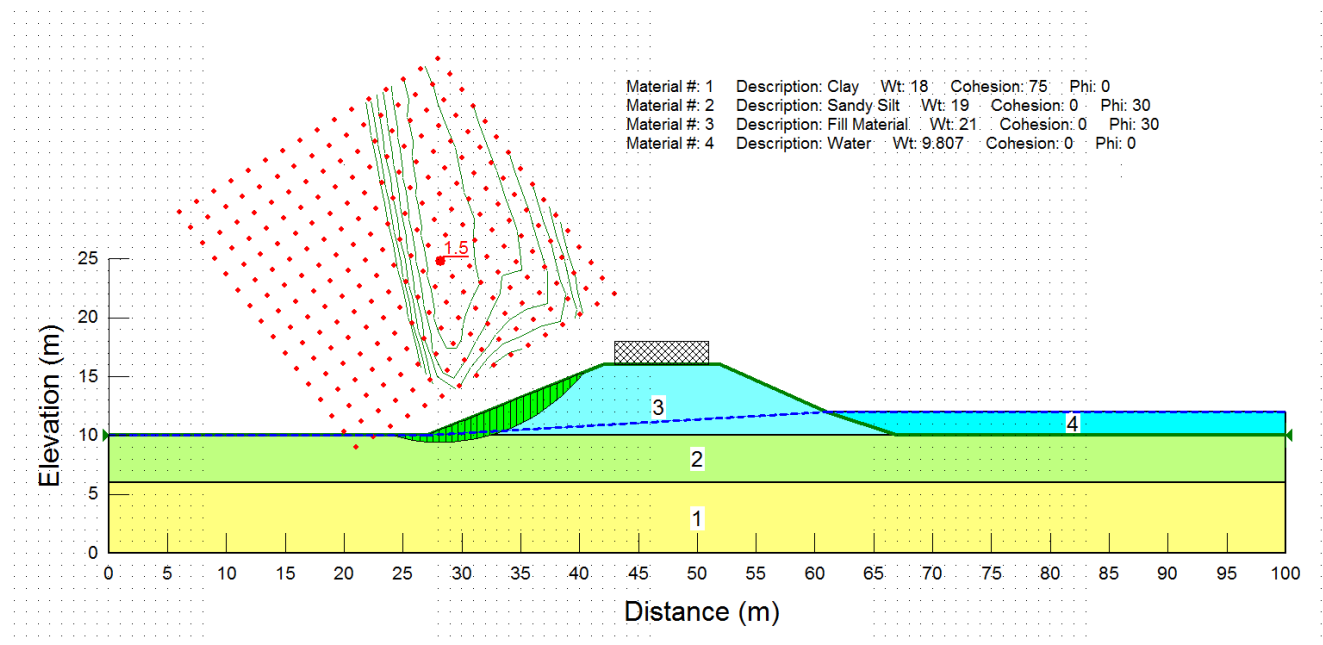
Slope 2.5h:1v, Drained Condition, Upstream



Slope 2.5h:1v, Drained Condition, Downstream



Slope 2.5h:1v, Undrained Condition, Upstream



Slope 2.5h:1v, Undrained Condition, Downstream