

**FOUNDATION INVESTIGATION AND DESIGN REPORT
BROWNRIGG CREEK CULVERT REPLACEMENT
HIGHWAY 634 (MTO SITE 39E-245/C)
AGREEMENT No.: 5005-E-0063
GWP: 5296-06-00
Geocres No. 42H-33
ASSIGNMENT No. 9**

**May 1, 2007
GS-TB-007061**

**Prepared For:
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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 foundation investigation for the proposed culvert replacement at Brownrigg Creek on Highway 634. This work was carried out under Agreement No. 5005-E-0062 - Geotechnical Retainer, Cochrane, Sault Ste. Marie and Sudbury, Assignment No. 9.

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 Brownrigg Creek culvert is a twin SPCS structure located on Highway 634 approximately 60 km north of Smooth Rock Falls in the Township of Avon.

The existing culverts are 3400 mm diameter and 43 m in length. The structures are structural plate culverts in poor condition due to corrosion (Photos 1 and 2). Inside the south culvert, evidence of corrosion and structural failure can be seen (Photo 3). The culverts are to be replaced with twin precast concrete box culverts 3000 mm in width by 2000 mm high placed at the same elevation and alignment.

The embankment height at the culverts is in the order of 7.5 m. The side slope from the edge of shoulder to the top of culverts at the outlet side is approximately 2.5 horizontal to 1 vertical, and 1.5 horizontal to 1 vertical at the inlet side. At the time of the soil investigation the surface of the side slopes on the area was covered with up to 1 m of snow. There is a beaver dam inside the south culvert close to the culvert inlet. The surrounding local area is moderately treed.

Pictures of the inlet and outlet areas of the culverts and inside the south culvert are shown below.

The photos were taken between March 14 and March 17, 2007.



Photo 1 Looking west at Culvert Outlets



Photo 2 - Looking east at the Culvert Inlets

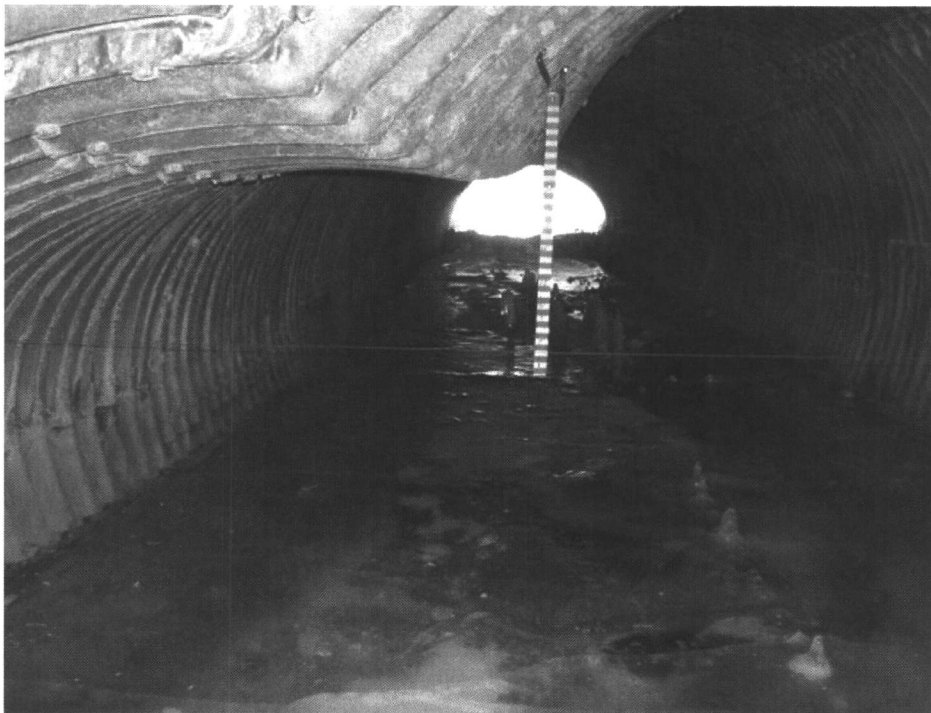


Photo 3 - Looking west at the south Culvert Outlet

3.0 INVESTIGATION PROCEDURES AND LABORATORY TESTING

Site work was carried out between March 14 and March 17, 2007 utilizing a CME 750 drill rig mounted on an all terrain chassis with large floatation tires, equipped for geotechnical drilling and operated by DST. Seven boreholes were put down to depths ranging between 6.1 and 16.5 m.

Borehole locations and a stratigraphic profile and sections are shown on the Borehole Location Plan, Drawing 1. Boreholes 1 is located at pavement edge of the roadway adjacent (southeast side) the existing culverts. Boreholes 7 and 6 are in the area of the inlet and outlet of the culvert, respectively. Due to accessibility to the sloping terrain at the outlet, Borehole 6 could not be advanced at the inlet without disturbing the creek bed and was relocated to the top of the slope at Station 2+018 Lt 18 m which is approximately 18 m north of the outlet.

Note that Boreholes 2, 3, 4 and 5 were advanced near to the embankment toe to depths between 6.1 and 8.1 m for the temporary culvert extensions and embankment widening. Boreholes 1, 6 and 7 were advanced with hollow stem augers to auger refusal. No wells were installed. Boreholes were backfilled with the auger cuttings. A standpipe was installed at Boreholes 1 location for groundwater level measurement; it was removed at the end of the geotechnical investigation.

The borehole locations are related to MTO Station numbering system shown in the Sutcliffe Rody Quesnel Inc. Drawing. The ground surface elevations at the borehole locations were surveyed by DST personnel and referenced to a mark Rib 1 located to the northeast of Highway 634 (close to Station 2+018 Lt 18 m). The elevation of the benchmark was taken as 100.00 m, as indicated on Sutcliffe Rody Quesnel Inc. Drawing provided by the Ministry of Transportation.

The fieldwork was supervised on a full-time basis by DST personnel who located the boreholes in

the field, supervised the drilling, sampling and in-situ testing, and logged the boreholes. The soil samples were identified in the field, placed in labelled containers and transported to DST's laboratory in Thunder Bay for further analysis. Soil descriptions for these samples were determined in the field during drilling.

Classification and index tests were subsequently performed in the laboratory on samples collected from the boreholes to aid in the selection of engineering properties. Laboratory tests included natural moisture contents, gradation analyses and plastic and liquid limits. Laboratory test results are presented on the Boreholes Logs and Enclosures 1 to 11.

4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 Stratigraphy Overview

The highway embankment at Borehole 1, 2 m south of the culverts, consists of asphalt overlying 7.7 m of sandy silt fill that in turn is underlain by a 1.5 m thick layer of sand. Beneath the sand a silt stratum occurs, overlying a sand stratum until auger refusal at the Elevation 83.5 m.

The stratigraphy near the outlet, based on Borehole 6, consists of topsoil overlying fill that in turn is underlain with silt. Beneath the silt a sand stratum occurs that continues until auger refusal.

Auger refusal occurred at Elevation 83.6 m, 16.5 m from existing grade. Note that Borehole 6 is located approximately 18 m west of the outlet and may not be truly representative of the soils below the culvert at the outlet. Therefore, subsurface conditions at the outlet location are unknown for design and construction. Foundation design for the new culvert inlet must be based on interpolation of subsurface conditions. As noted in Appendix A, Limitations of Report, contractors bidding on this project or undertaking the construction must make their own interpretation of the factual information presented and draw their own conclusion as to how the subsurface conditions may affect their work.

The stratigraphy at the inlet based on Borehole 7 consists of topsoil and organics overlying silt fill that turn is underlain with a thin layer of organics. Beneath the organics a sand stratum occurs, overlying silt. Under the silt a sand stratum occurs that continues until auger refusal at Elevation 83.0 m.

Four boreholes were drilled at the toe of the embankment (south and north of the culverts on both sides of the highway). Boreholes 2 and 3, north of the culverts, generally consist of a thin layer of topsoil overlain by a layer of silt that in turn is underlain with clay. Beneath the clay, a layer of silt

occurs. Boreholes 4 and 5, south of the culverts, generally consist of a layer of silt. Borehole 5 shows two embedded layers of clay in a silt matrix.

4.2 Topsoil

A topsoil layer up to 100 mm in thickness was encountered at Boreholes 2, 3,4,5,6 and 7.

4.3 Asphalt

An 80 mm thick asphalt layer was encountered at Borehole 1.

4.4 Fill

A silt fill is present beneath the asphalt and sand and gravel road base noted above at Borehole 1. The upper portion of this layer is most likely a fill in embankment borehole.

Adjacent to the culvert the fill extends to Elevation 93.2 m in Borehole 1, to Elevation 95.1 m in Borehole 6 and to Elevation 91.0 m in Borehole 7, as evident by traces of organics encountered at the base of the layer. The sand noted below Elevation 93.2 m in Borehole 1 could also be fill. Occasional Cobbles were encountered within this deposit.

SPT values between 14 and 32 blows per 0.3 m were measured in the silt at Borehole 1 indicating a compact condition. At Boreholes 6 and 7, the SPT values were less than 12 blows per 0.3 m indicating a very loose to compact condition. Gradation analyses conducted on samples from Boreholes 1, 6 and 7 indicate a gravel content up to 10%, sand content between 13% and 20% and a fines content between 55% and 77%. Grainsize distributions for the sand are reported on the Borehole Logs and are plotted in Enclosures 8, 9 and 10.

4.5 Sand

A sand layer between 1.5 m and 3.3 m in thickness is present in Boreholes 1, 6 and 7.

In Borehole 1 the sand is encountered at two elevations, 92.3 m and 88.8 m. In Borehole 6 sand was encountered at Elevation 86.4 m and extends to auger refusal at elevation 83.6 m. At Borehole 7 the sand was found at two elevations, 91.0 m and 87.2 m. Occasional cobbles were encountered within these deposits.

SPT values between 13 and 48 blows per 0.3 m were measured in the sand at boreholes 1, 6 and 7 indicating a compact to dense condition. Gradation analyses conducted on samples from Boreholes 1, 6 and 7 indicate a gravel content between 3% and 19%, sand content between 33% and 63% and a fines content between 15% and 56%. Grainsize distributions for the sand are reported on the Borehole Logs and are plotted in Enclosures 8, 9 and 10.

4.6 Silt

Silt was encountered in all 7 boreholes. The silt layers vary in thickness from 0.70 m to 6.0 m. The elevation of the top of these strata varies between 102.7 m to 86.4 m.

SPT values between 5 and 45 blows per 0.3 m were measured in the silt at Borehole 1, 6 and 7 indicating a loose to dense condition. At Boreholes 2, 3, 4 and 5 (toe of the embankment), the SPT values were between 5 and 55 blows per 0.3 m indicating also a loose to very dense condition. Gradation analyses conducted on samples from boreholes indicate a gravel content up to 5%, sand content between 0% and 32% and a fines content between 63% and 100%. Grainsize distributions for the sand are reported on the Borehole Logs and are plotted in Enclosures 8, 9 and 10

4.7 Organics

Two organic layers were encountered in Borehole 7, the layers are overlying and underlain the fill, 0.35 m and 0.30 m in thickness respectively,

4.8 Clay

Clay was encountered in 3 of the 7 boreholes (Boreholes 2, 3 and 5). The clay layer varies in thickness from 2.2 m to 3.8 m in Boreholes 2 and 3 respectively. In Borehole 5, two layers of clay were encountered. The elevation of the top of this stratum varies between 102.0 m to 100.5 m. Plastic and liquid limits completed on samples from Borehole 2, 3, 6 and 7 are shown on Enclosure 11. The clay has a liquid limit between 22 and 41 with a plasticity index between 3 and 16, indicating a low to medium plasticity. The natural water content is below the liquid limit indicating. An in-situ field vane tests taken in Borehole 2 and 3 at indicates undrained shear strength between 103 and 162 kPa. These high value could be explained due presence of gravel and occasional cobbles.

4.9 Groundwater

Upon completion of drilling, the following water depths were observed in the boreholes.

Borehole No	Depth Below Grade (m)	Elevation (m)
1	8.5	92.5
2	Dry on Completion	< 94.5
3	Dry on Completion	< 92.8
4	Dry on Completion	< 96.2
5	Dry on Completion	< 96.7
6	9.4	90.7
7	1.5	91.8

These levels, observed before backfilling and also documented on Borehole Logs and Drawing 1, are not intended to represent information with respect to the water table location or groundwater flow.

The creek level elevation at the time of the investigation was at approximately 92.2 m at the outlet.

Groundwater levels may fluctuate seasonally and in response to climatic conditions and creek level.

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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 preferred option for the replacement culvert is a precast concrete box culvert 3400 mm in width and 2000 mm in height (Canadian Highway Bridge Design Code, Type B installation). The new culvert will be placed at the same elevation and alignment as the existing steel culvert. There is no grade increase planned. Given that the cross sectional area of the box culvert will be smaller than the existing culvert, the overall effect on the culvert foundation soils will be a small increase in stress in the order of 20 kPa at the base of the culverts.

In accordance with instructions from MTO, other options for culvert replacement are not discussed in this report.

The generalized make up of the embankment fill in the area of the existing culvert consists of silt with a trace of gravel and sand, and is in a compact to very loose state of denseness. The general classification of this fill with respect to Table 7.8.3.1 Classification of Placed Soil, Canadian Highway Bridge Design Code, is a Soil Group II, SM (sandy silt).

A clay layer was encountered in Borehole 2 from Elevation 100.3 m to 98.1 m (2.2 m thickness) and

in Borehole 3 from Elevation 98.6 m to 97.1 m (1.5 m in thickness). The clay layer is discontinuous.

From the cross section A-A Drawing 1, it appears that there should be no clay within the existing culvert excavation since it would likely have been sub-excavated during the installation of the culvert.

Borehole 6 is 18 m west of the culvert; no upper sand layer was detected beneath the culvert as detected in Borehole 1 and 7, however it is nevertheless possible that sand exists beneath entire length of the culvert.

Auger refusal was encountered in Boreholes 1, 6 and 7 at Elevations 85.5 m, 83.6 m and 85.5 m respectively. The elevation of the new culvert base will be 92.5 m which generally places the auger refusal 7 m to 9.5 m below the base of the culvert.

Groundwater levels will fluctuate seasonally and in response to climatic conditions. The water table at the culvert location is expected to be close to or above the creek level and will also vary with the creek level. Dewatering of the excavation will be difficult due to the granular nature of the subsoil. This is discussed in greater detail below.

5.1 Subgrade Preparation

It is anticipated that with the existing groundwater table, unknown potential flows through the fill and flow through the existing native material, dewatering will be difficult. If the dewatering system is not efficient, then a quick condition of the existing subgrade materials may occur, making it unsuitable for support of the culvert.

For the conditions at this site, it is likely to be most practical for the proposed construction to be

undertaken in the wet (maintaining the water level in the excavation at or above the original water table), with the existing soils excavated 0.50 m below the proposed founding elevation of the culverts. This should be replaced with a clear stone (concrete coarse aggregate with maximum aggregate size of 25mm), surrounded by a non-woven geotextile (OPSS 1860.07.05.01 Class II).

The foundation base for the concrete box culvert should extend one box inside width on each side, corner and end of the box structure. Excavation side slopes should be not steeper than 1:1, although flatter slopes may be required depending on dewatering/construction methods. This applies to temporary slopes not supporting traffic, and does not apply to longitudinal excavation slope for the embankment supporting traffic during the construction work, where a 2h:1v slope is required (see Section 5.7).

Preparation of the subgrade as above will provide competent support for the proposed concrete box culvert.

5.2 Bedding and Backfill

5.2.1 Bedding for Precast Concrete Structure

The bedding for the structure should be designed in accordance with Section 7.8.15.3 of the Canadian Highway Bridge Design Code (CHBDC). The bedding shall consist of Soil Group I in accordance with Table 7.8.3.1 of the CHBDC and placed to a minimum 90% of standard Proctor maximum dry density but shall be loosely placed and uncompacted under the middle third of the box culvert. The 0.5 m thick layer of clear stone (less than 25 mm) placed below the culvert meet these requirements.

5.2.2 Side Fill and Overfill Zones

The side fills and overfill zones for a Type B installation can consist of Soil Group I or II and compacted to 90% or 95% respectively. Refer to Figure 7.8.3.6(a) Standard Installation for Concrete Box Section (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 in the overfill zone.

5.3 Lateral and Sliding Resistances

The earth pressures on each box section should be designed in accordance with Section 7.8.5.3.2 Earth Loads of the CHBDC (Installation Type BI). The ultimate friction factor ($\tan\delta$) for formed concrete against silt and sand can be taken as 0.35.

The following factors are recommended when calculating earth pressures.

	* Granular 'A'	* Granular 'B', Type I	Soil Group II
Angle of Internal Friction	$\Phi' = 35^\circ$	$\Phi' = 30^\circ$	$\Phi' = 28^\circ$
Unit Weight (kN/m^3)	$\gamma = 22$	$\gamma = 21$	$\gamma = 18$

* Granular 'A' and Granular 'B', Type I fill material can be classified as Soil Group I as long as the fines content (material less than 0.075 mm) is restricted to less than 5%.

5.4 Embankment Design

At the present time the embankment slopes at the culverts vary from approximately 2.5 to 1.5 horizontal to 1 vertical from the existing shoulder to the top of the culverts. Slopes stability analyses were performed on the existing condition and the proposed configuration. A factor of safety that exceeds 1.3 has been attained with a slope configuration 3 horizontal to 1 vertical. This analyses applied a friction angle of 35 degrees to the embankment material (well compacted silt), and a high

phreatic surface in the fill (saturated conditions in the fill below the obvert level) as a result of slow drainage immediately after flood conditions. Slopes constructed at this angle will be stable even under such severe conditions.

An alternate is available for increasing the embankment slopes to 2h:1v. In this case, the outer zone of silt fill below obvert level, 2.5 m wide (measured horizontally perpendicular to the highway centreline) on each slope is replaced with Granular B Type 1 when the embankment is reconstructed. This zone will drain very quickly as a flood level recedes, even if the silt inside the embankment stays saturated, maintaining an adequate degree of safety against slope failure.

Total settlement is not expected to exceed 25 mm with differential settlement less than 20mm.

Detour embankments should be constructed with slopes at 2h:1v, which provides adequate stability of the embankment against failure through the embankment fill and the foundation soil. Temporary detour embankments may be constructed of compacted Granular B Type 1 material, constructed in accordance with OPSS requirements.

5.5 Frost Protection

In accordance with OPSD 3090.100, Contours of Frost Depth for Northern Ontario, the frost penetration for this area is in the order of 2.6 m.

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 culverts (and particularly given the

large size of the culverts), ice is expected to form inside the culverts. At low flows, it is also possible that ice may extend to the culvert invert. Frost will therefore extend into the soils below the culverts, possibly as deep as 2.6 m. 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. 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 rock fill or clear stone, without the need for compaction. Depending on the structural design of the culvert, partial subexcavation 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 with freezing and thawing cycles.

Frost treatment areas for the roadway should be constructed in accordance with OPSD 803.031.

5.6 Channel Diversion

To divert Brownrigg Creek during the construction period, two options are possible, and should be reviewed with respect to design flows. For both options, traffic can be maintained by implementing the diversion option over one half of the road at a time, with traffic initially travelling on the opposite

side over the existing culvert and later on the other side over the new culverts.

The first option is to dam the creek and with correctly sized pumps, and pump the water over the road to the opposite creek.

Secondly, an open ditch adjacent the new culvert may be feasible. The ditch will be in granular soils below the water table, therefore the trench will require suitable rip rap to prevent erosion. In addition, it should be located a minimum distance of 1.5 m from the proposed foundation to prevent undermining of the new box culvert. A staged construction sequence is recommended for this project, allowing a single lane (3 - 5 m width) detour at all times during construction.

With, if the clear stone option is utilized for foundation preparation, much of the water will flow through the clear stone and strategically placed sump and pump systems may be sized and installed to maintain the water level below the stone.

All diversion of the stream bed must be completed in compliance with all Ministry of the Environment, Department of Fisheries and Oceans and Ministry of Natural Resources regulations.

5.7 Outlet/Inlet Control

To prevent erosion of the surrounding soils, the outlet should be rip-raped in accordance with OPSD 810.010. A cut-off wall should be installed at the inlet to prevent erosion of the surrounding soils.

5.8 Road Protection

For traffic and road protection, due to the depth to auger refusal and the depth of excavation, installation of a cantilevered sheet pile system is feasible to ensure the stability of the bank. This

type of system will, however, be very expensive and not very practical. Furthermore, there appears to be sufficient cross section for lowering the road with a staged construction sequence and allowing a single lane (3 - 5 m width) detour. Therefore, a staged detour system is recommended for this project. The temporary slopes in the existing materials should not exceed 2 h: 1v.

5.9 Construction Concerns

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

Given the groundwater level (stream flow), advanced dewatering methods are required to construct the proposed project in the dry. Unknown water flow through the fill and granular nature of the subsoils under the creek could prove problematic. A quick condition of the subgrade (with the associated disturbance and weakening of the soil) could occur if the dewatering system is not sufficient. Where construction in the wet is considered, tight quality control will be required to ensure a successful completion of the excavation and placement of clear stone.

6.0 LIMITATIONS OF REPORT

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

For DST CONSULTING ENGINEERS INC.

Prepared by:

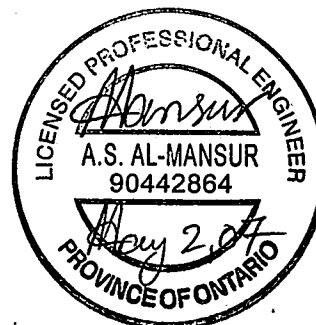
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Geotechnical Specialist



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Principal



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Senior Project Engineer

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.

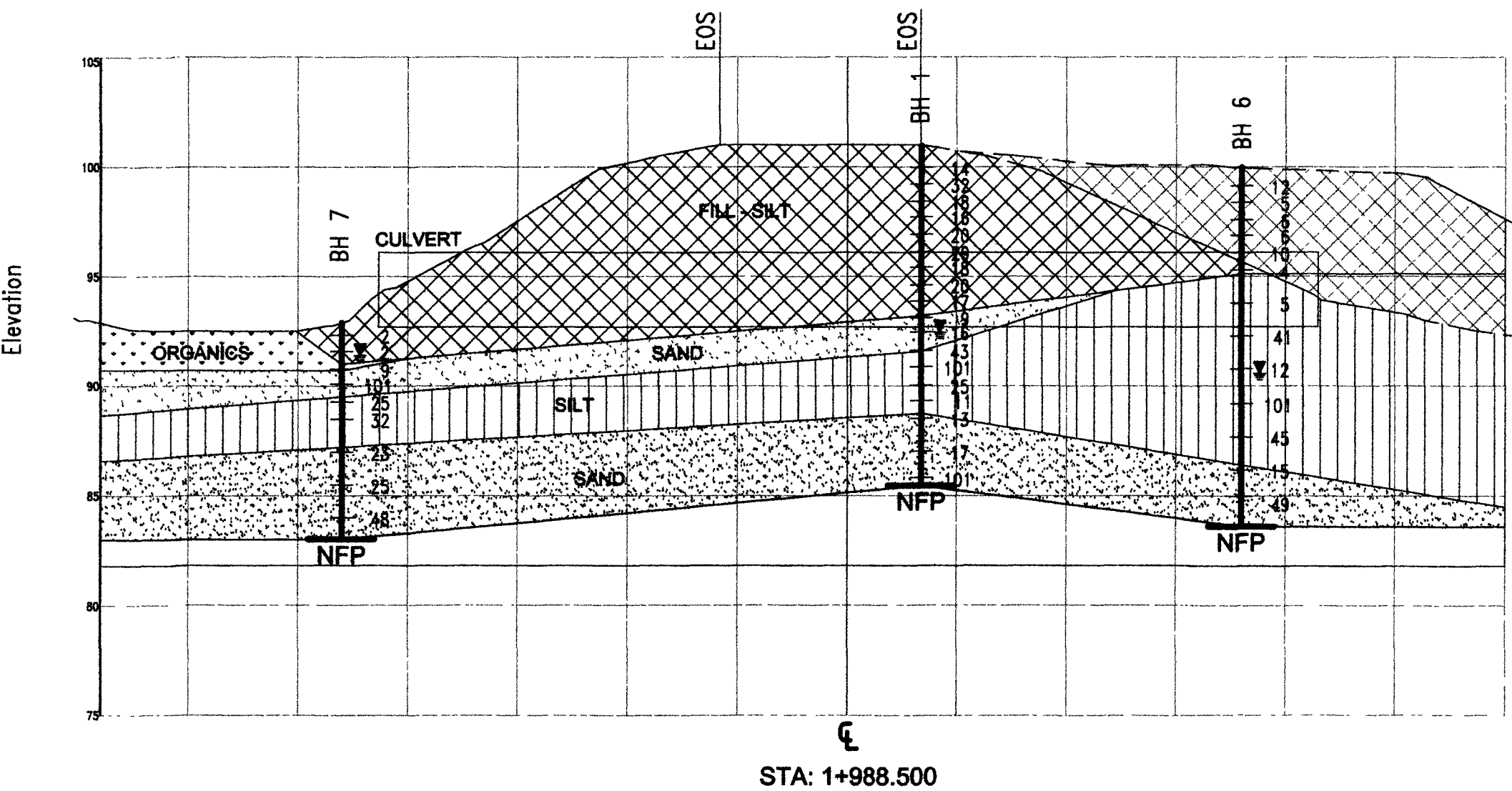
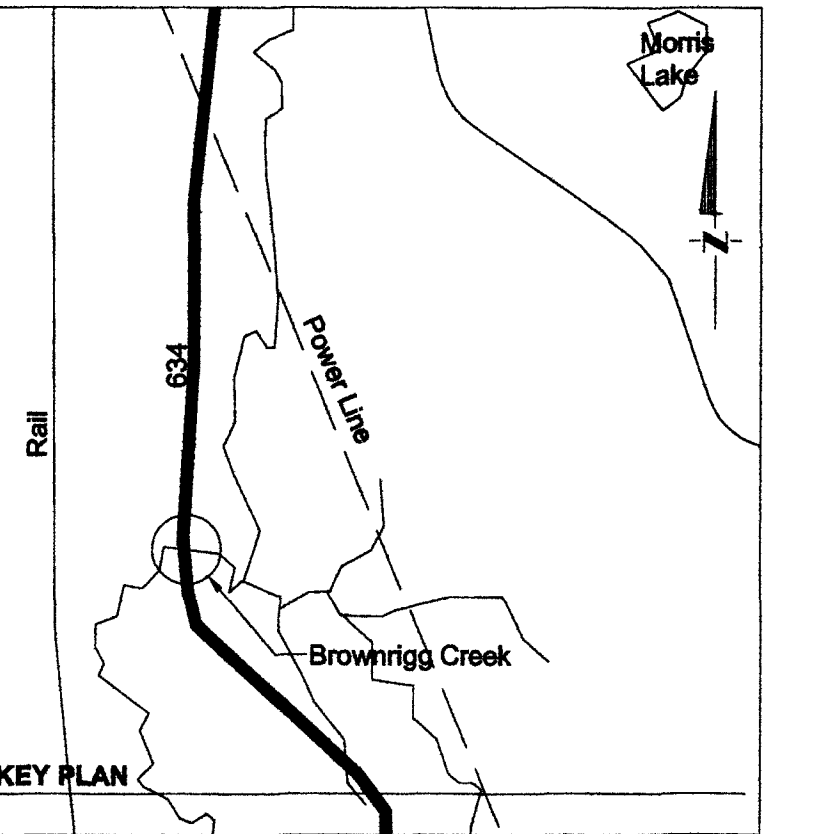
Unless otherwise noted, the information contained herein in no way reflects on environmental aspects of either the site or the subsurface conditions.

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.

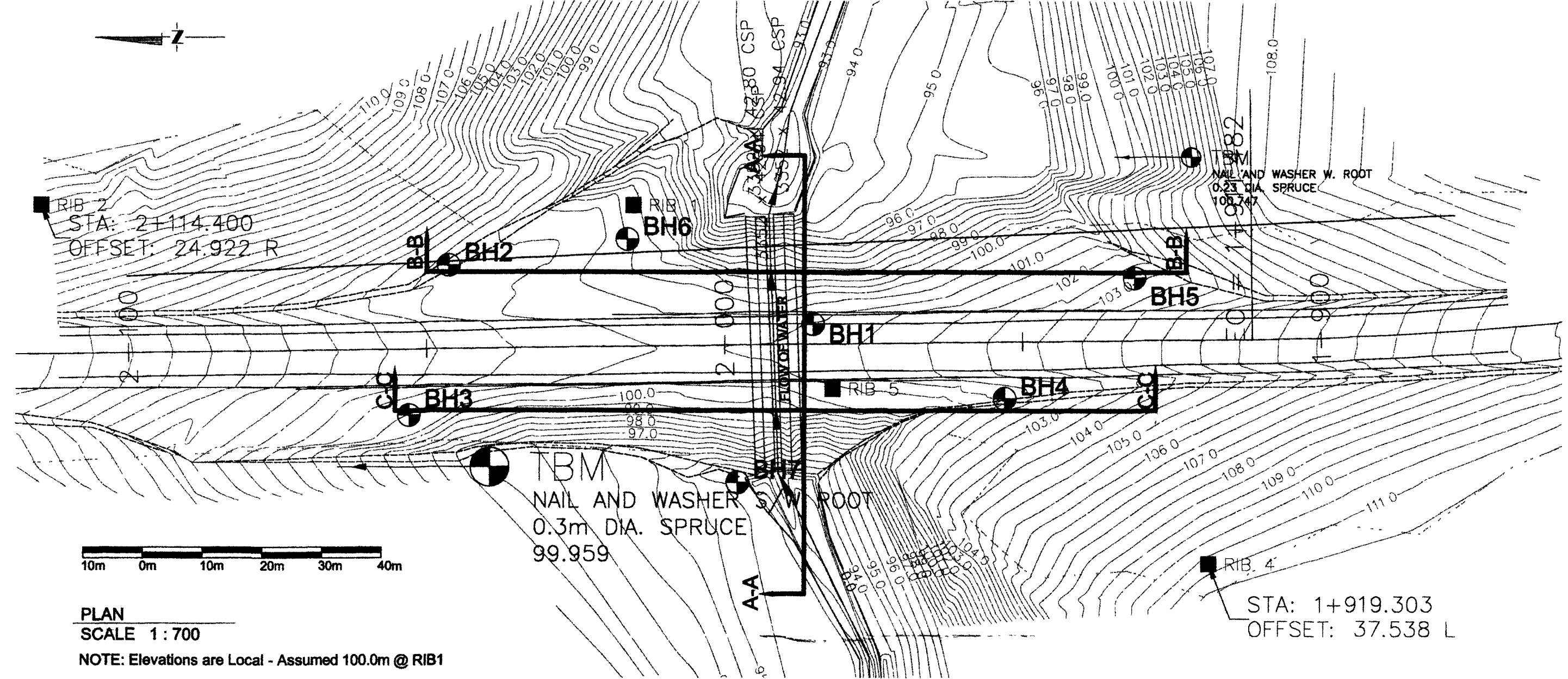
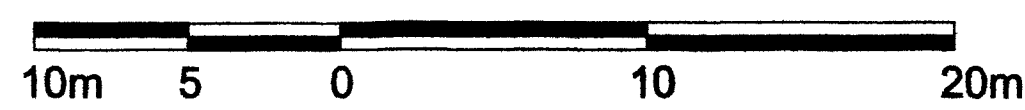
Any results from an analytical laboratory or other subcontractor reported herein have been carried out by others, and DST Consulting Engineers Inc. cannot warranty their accuracy. Similarly, DST cannot warranty the accuracy of information supplied by the client.

DRAWINGS

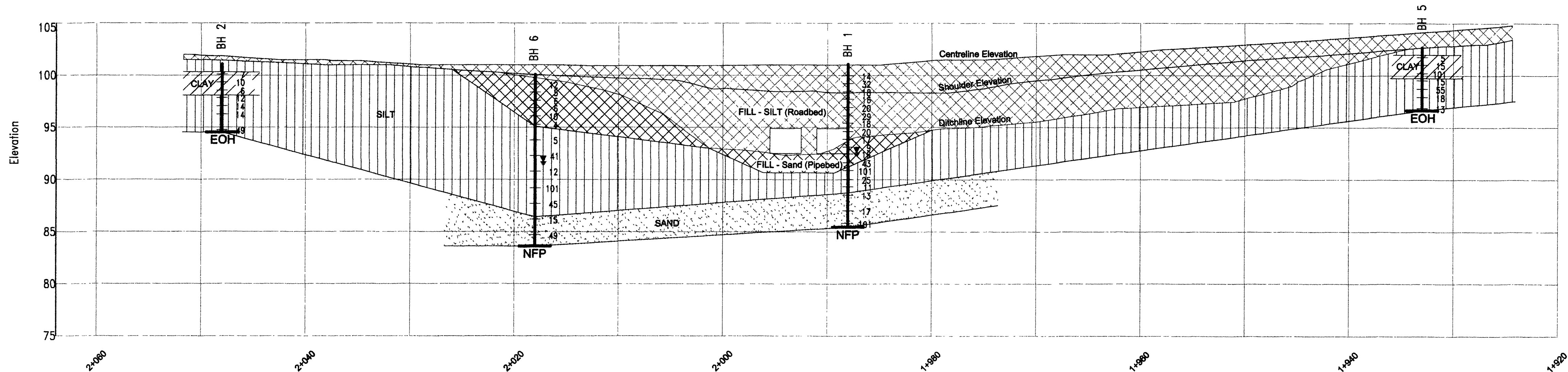
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Township of Avon
WP: 5296-06-00
MTO GEOCRES No. 42H-33
AGREEMENT NO.: 5005-E-0063
BOREHOLE LOCATIONS
& SOIL STRATA**



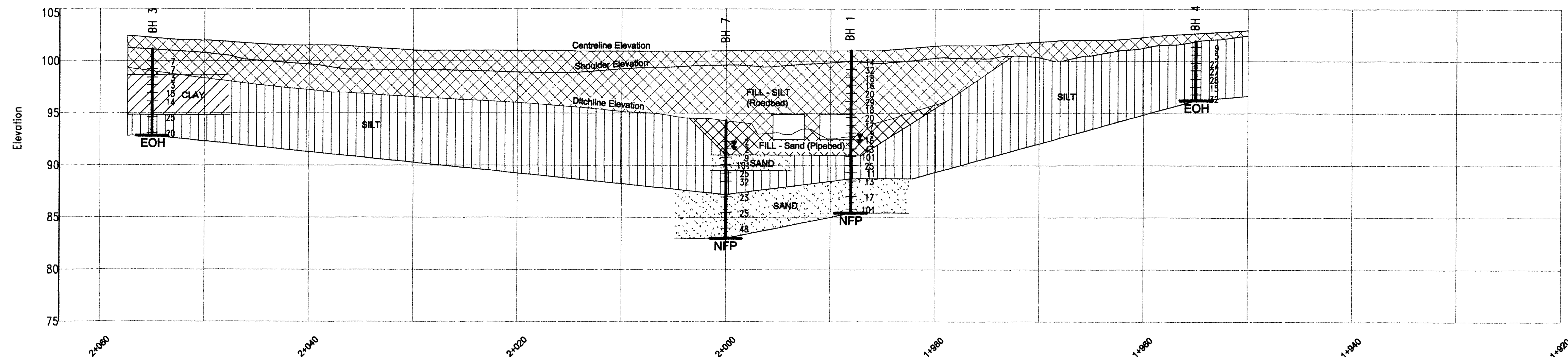
SECTION A-A
SCALE 1:250



PLAN
SCALE 1:700
NOTE: Elevations are Local - Assumed 100.0m @ RIB1



SECTION B-B
SCALE 1:250



SECTION C-C
SCALE 1:250



LEGEND

- Borehole
- Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation.
- NFP No Further Progress
- EOH End of Hole
- EOS Edge of Shoulder
- Fill
- Organics
- Clay
- Silt
- Sand

No.	Elevation	Station	Offset
1	101.0	1+988	3.4m Rt
2	101.08	2+048	14.0m Lt
3	100.93	2+055	11.0m Lt
4	102.33	1+955	9.5m Rt
5	102.76	1+933	10.5m Rt
6	100.105	2+018	18.0m Rt
7	93.305	2+000	23.0m Lt

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.

ENCLOSURES

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 31mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{N} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (31mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON "A" SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND/OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 30	30 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	30mm	50 - 300mm	0.3m - 1m	1m - 3m	> 3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
u	l	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	l	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	l	COMPRESSION INDEX
C_s	l	SWELLING INDEX
α	l	RATE OF SECONDARY CONSOLIDATION
c_v	m ² /s	COEFFICIENT OF CONSOLIDATION
M	m	DRAINAGE PATH
T_v	l	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{v0}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_r	l	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	e	l, %	VOID RATIO	e_{min}	l, %	VOID RATIO IN DENSEST STATE
γ_s	kN/m ³	UNIT WEIGHT OF SOLID PARTICLES	n	l, %	POROSITY	I_D	l	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m ³	DENSITY OF WATER	w	l, %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m ³	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m ³	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	l	UNIFORMITY COEFFICIENT
γ	kN/m ³	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m ³	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m ³ /s	RATE OF DISCHARGE
γ_d	kN/m ³	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m ³	DENSITY OF SATURATED SOIL	I_L	l	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	l	HYDRAULIC GRADIENT
γ_{sat}	kN/m ³	UNIT WEIGHT OF SATURATED SOIL	I_C	l	CONSISTENCY INDEX = $\frac{w - w_p}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	e_{max}	l, %	VOID RATIO IN LOOSEST STATE	j	kN/m ²	SEEPAGE FORCE
γ'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL						

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%

A soil with 45% sand, 30% silt, 15% gravel and 3% clay would be sand, silty, some gravel, trace clay

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

Classification of Placed Soils Canadian Highway Bridge Design Code Table 7.8.3.1

Soil Group	Description	USCS Symbols
I	Sand and Gravel	SW, SP, GW, GP
II	Sandy Silt	GM, SM, ML Also GC and SC with less than 20% passing #200 sieve
III	Silty Clay	GC and SC with more than 20% passing #200 sieve, CL, MH

RECORD OF BOREHOLE No 1

1 OF 1

METRIC

W.P. 5296-06-00 LOCATION 1+988 3.4m Rt ORIGINATED BY PR
 DIST 53 HWY 634 BOREHOLE TYPE HS AUGER COMPILED BY SR
 DATUM LOCAL(RIB1) DATE 2007 03 14 CHECKED BY BV

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI C	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED □ QUICK TRIAXIAL	× FIELD VANE ★ LAB VANE						
101.0							20 40 60 80 100	20 40 60							
100.9	ASPHALT - 80mm		1	AS										26 60 (14)	
	FILL - Silt		2	SS	14									Water Level 8.5m, cave 13.8m on completion.	
	- Sand, some gravel, brown		3	SS	32										
	- Silt, grey, compact		4	SS	18									1 23 (76)	
			5	SS	16										
			6	SS	20										
	- trace sand, occasional cobbles		7	SS	29										
			8	SS	18										
			9	SS	20										
			10	SS	17										
93.2			11	SS	9										
7.8	SAND - Silty, trace rootlets, grey, compact to dense		12	SS	16										
	- some organics, brown														
91.7			13	SS	43										
9.3	- some gravel, trace silt, occasional cobbles		14	SS	101										
	SILT - Sandy, occasional cobbles, grey, compact to dense		15	SS	25									5 32 (63)	
			16	SS	11										
88.8			17	SS	13										
12.2	SAND - Silty, trace gravel, occasional cobbles, grey, compact		18	SS	17									19 33 (48)	
			19	SS	101										
85.5															
15.5	- with gravel End of Borehole @ 15.5m Auger Refusal														

ON MOT LOGS GPJ DST_MIN GDT 05/04/07

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

1 OF 1

METRIC

[illegible]

ENCLOSURE 2

ON MOT LOGS.GPJ DST_MIN.GDT 05/04/07

RECORD OF BOREHOLE No 3

1 OF 1

METRIC

W.P. 5296-06-00 LOCATION 2+055 11.0m Lt ORIGINATED BY PR
DIST 53 HWY 634 BOREHOLE TYPE HS AUGER COMPILED BY SR
DATUM LOCAL(RIB1) DATE 2007 03 16 CHECKED BY BV

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	20 40 60 80 100	20 40 60 80 100		
100.9	TOPSOIL - 60mm		1	AS			100					Dry on completion.
100.9	SILT - trace gravel, trace clay, brown		2	SS	7		100					
	-----		3	SS	7		99					2 16 (82)
	- trace rootlets, brown/grey		4	SS	3		98					
98.6	CLAY - Silty, trace sand, trace gravel, trace rootlets, grey, stiff		5	SS	3		97					
2.3	-----		6	SS	15		96					
	- trace organics, brown		7	SS	14		95					
97.1	-----		8	SS	25		94					
3.8	- Sandy, occasional cobbles, grey		9	SS	20		93					
	-----						92					
	- Silty						91					
							90					
94.8	SILT - trace gravel, compact						89					
6.1	-----						88					
	- some gravel, occasional cobbles						87					
92.8	-----						86					
8.1	End of Borehole @ 8.1m						85					
							84					
							83					
							82					

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

ENCLOSURE 3

ON MOT LOGS.GPJ DST_MIN.GDT 05/04/07

RECORD OF BOREHOLE No 4

1 OF 1

METRIC

W.P. 5296-06-00 LOCATION 1+955 9.5m Lt ORIGINATED BY PR
 DIST 53 HWY 634 BOREHOLE TYPE HS AUGER COMPILED BY SR
 DATUM LOCAL(RIB1) DATE 2007 03 17 CHECKED BY BV

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	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 (%)					
102.3	TOPSOIL - 50mm		1	AS										
102.0	SILT - trace gravel, trace clay, brown		2	SS	9									
			3	SS	5									
			4	SS	22									
			5	SS	27									
			6	SS	28									
			7	SS	15									
96.2	End of Borehole @ 6.1m		8	SS	32									

ON MOT LOGS.GPJ DST_MIN GDT 05/04/07

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

ENCLOSURE 4

RECORD OF BOREHOLE No 5

1 OF 1

METRIC

W.P. 5296-06-00 LOCATION 1+933 10.5m Rt ORIGINATED BY PR
DIST 53 HWY 634 BOREHOLE TYPE HS AUGER COMPILED BY SR
DATUM LOCAL(RIB1) DATE 2007 03 17 CHECKED BY BV

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED □ QUICK TRIAXIAL	× FIELD VANE ★ LAB VANE						
102.8								20 40 60 80 100	20 40 60					GR SA SI CL	
102.7	TOPSOIL - 50mm		1	AS										Cave 5.65m, dry on completion.	
102.0	SILT - trace gravel, brown		2	SS	5									2 21 (77)	
101.3	CLAY - Silty, trace gravel, brown		3	SS	15										
100.5	SILT - trace clay, trace gravel, brown		4	SS	101										
99.8	CLAY - Silty, occasional cobbles, brown		5	SS	15										
96.7	SILT - grey		6	SS	55										
			7	SS	18									0 0 (100)	
			8	SS	13										
6.1	End of Borehole @ 6.1m														

×³ *³ Numbers refer to
Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 6

1 OF 1

METRIC

W.P. 5296-06-00 LOCATION 2+018 18.0m Rt ORIGINATED BY PR
DIST 53 HWY 634 BOREHOLE TYPE HS AUGER COMPILED BY SR
DATUM LOCAL(RIB1) DATE 2007 03 15 CHECKED BY BV

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
100.1							20 40 60 80 100	20 40 60 80 100	20 40 60				kN/m ³	GR SA SI CL
100.0	TOPSOIL - 60mm		1	AS										Water Level 9.4m, cave 9.4m on completion.
	FILL - Silt, trace gravel, brown		2	SS	12									
	----- - trace gravel		3	SS	5									
	----- - some gravel, some wood, brown/grey		4	SS	6									
	----- - trace gravel		5	SS	6									
			6	SS	10									
			7	SS	4									
95.1	SILT - Sandy, trace organics, black/grey, loose to dense		8	SS	5									
5.0			9	SS	41									0 1 (99) 2 28 (70)
	----- - some organics		10	SS	12									
	----- - occasional cobbles		11	SS	101									
			12	SS	45									
	----- - some gravel, occasional cobbles, grey													
86.4	SAND - some gravel, trace silt, grey, compact to dense		13	SS	15									21 63 (15)
13.7			14	SS	49									4 40 (56)
	----- - with silt, with gravel													
83.6	End of Borehole @ 16.5m Auger Refusal													
16.5														

ON MOT LOGS.GPJ_DST_MIN.GDT_05/04/07

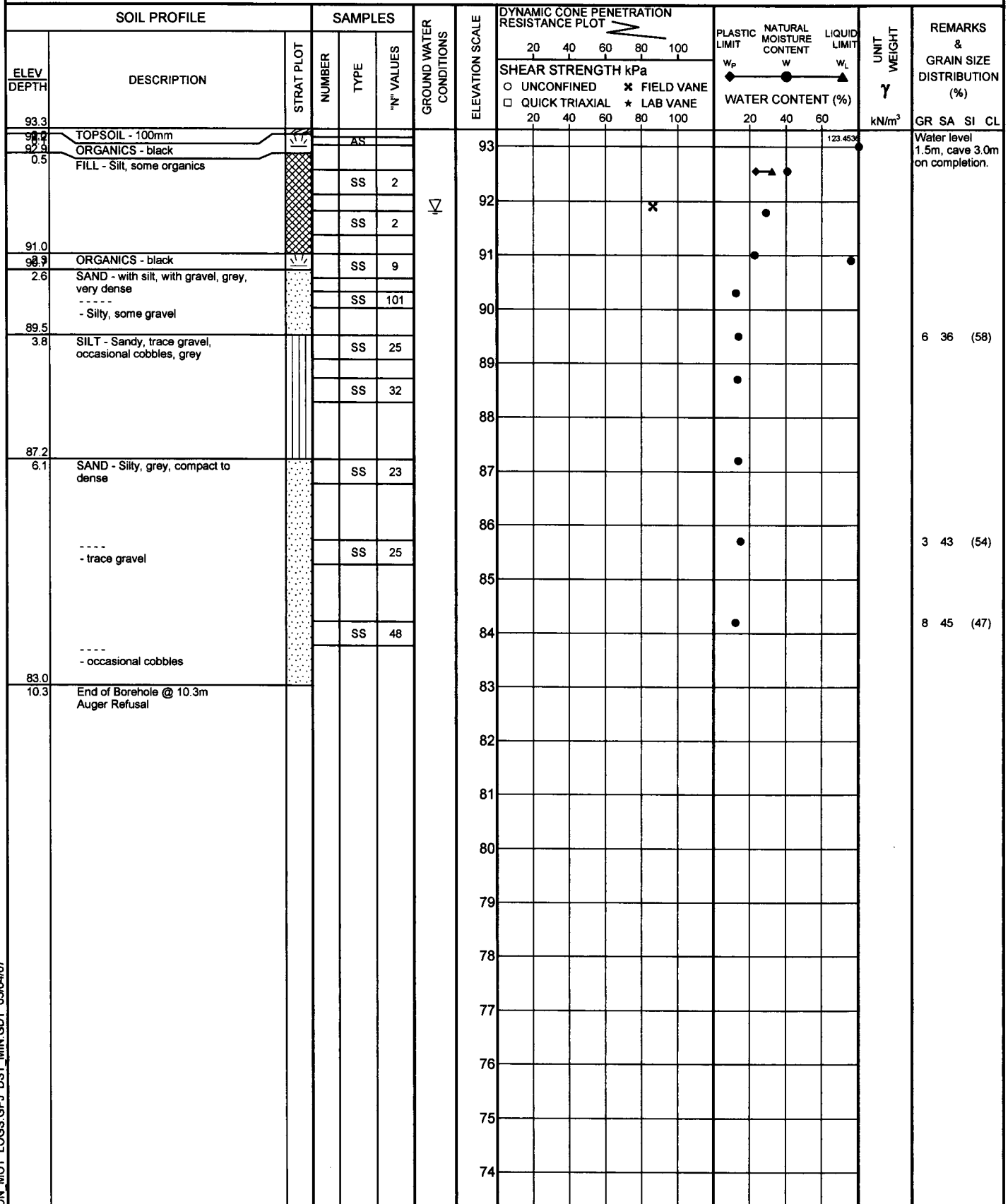
×³, *³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 7

1 OF 1

METRIC

W.P. 5296-06-00 LOCATION 2+000 23.0m Lt ORIGINATED BY PR
 DIST 53 HWY 634 BOREHOLE TYPE HS AUGER COMPILED BY SR
 DATUM LOCAL(RIB1) DATE 2007 03 16 CHECKED BY BV

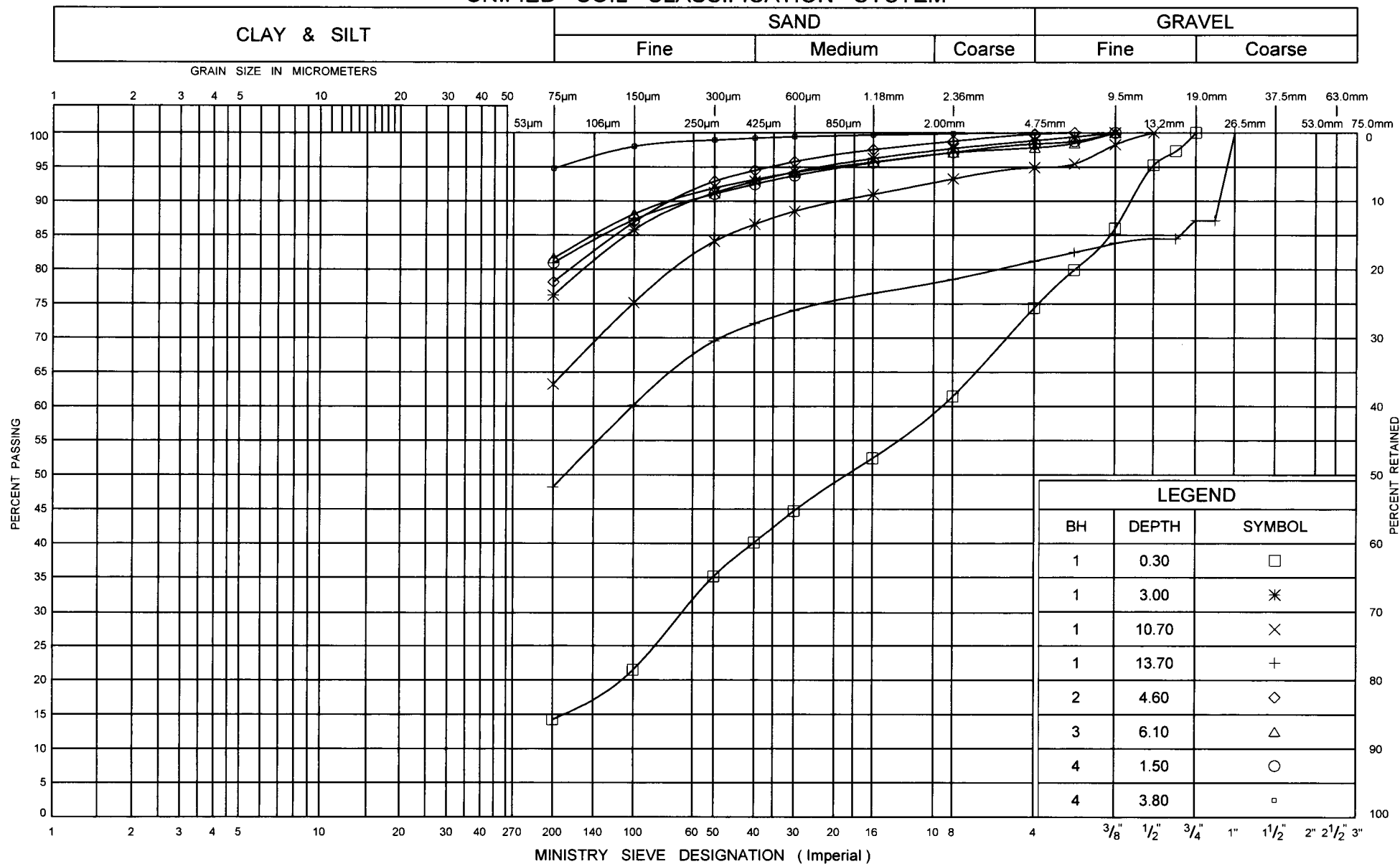


ON MOT LOGS.GPJ DST_MIN.GDT 05/04/07

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

ENCLOSURE 7

UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION

ENCLOSURE 8

W P 5296-06-00

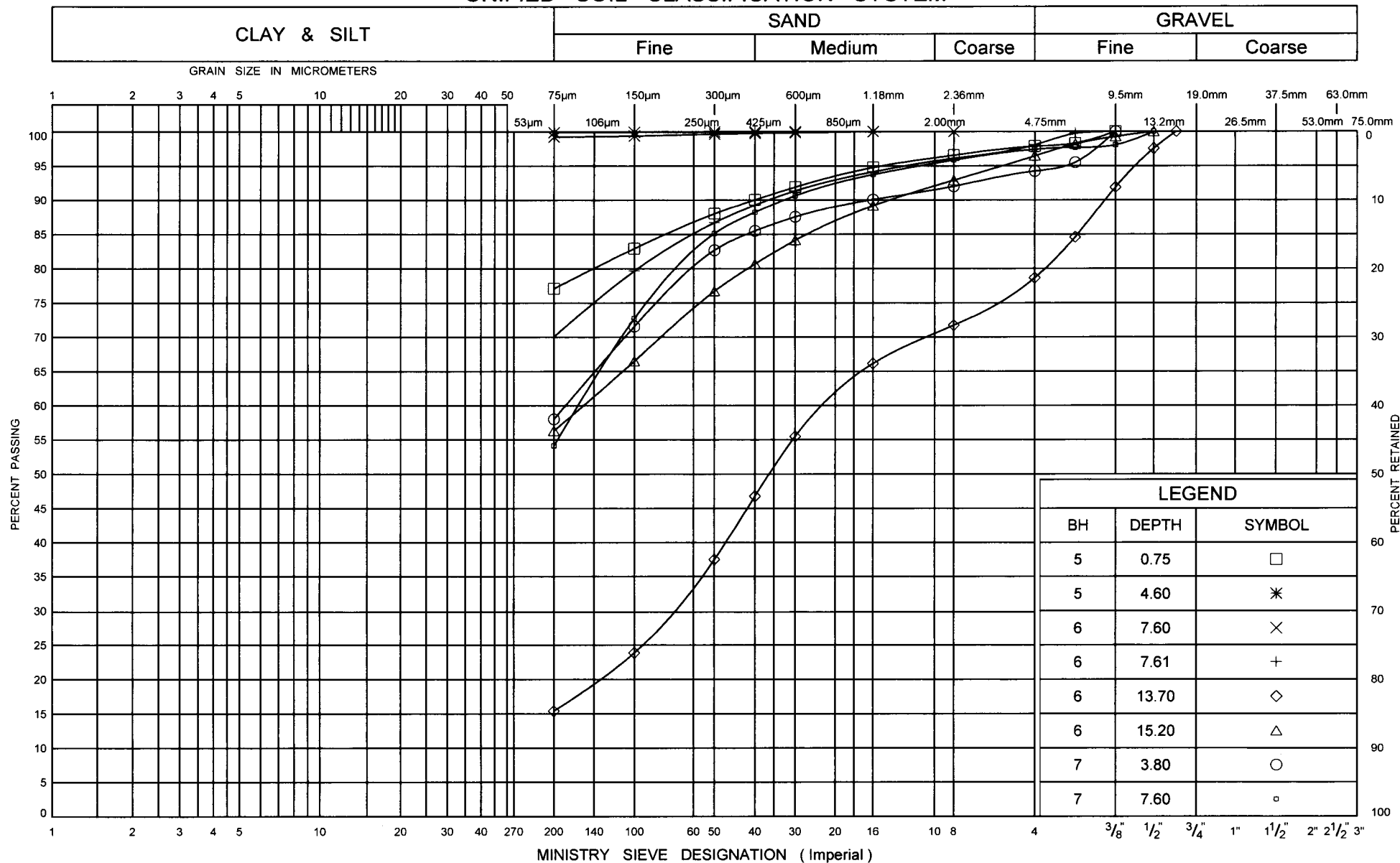
634



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GRAIN SIZE DISTRIBUTION

ENCLOSURE 9

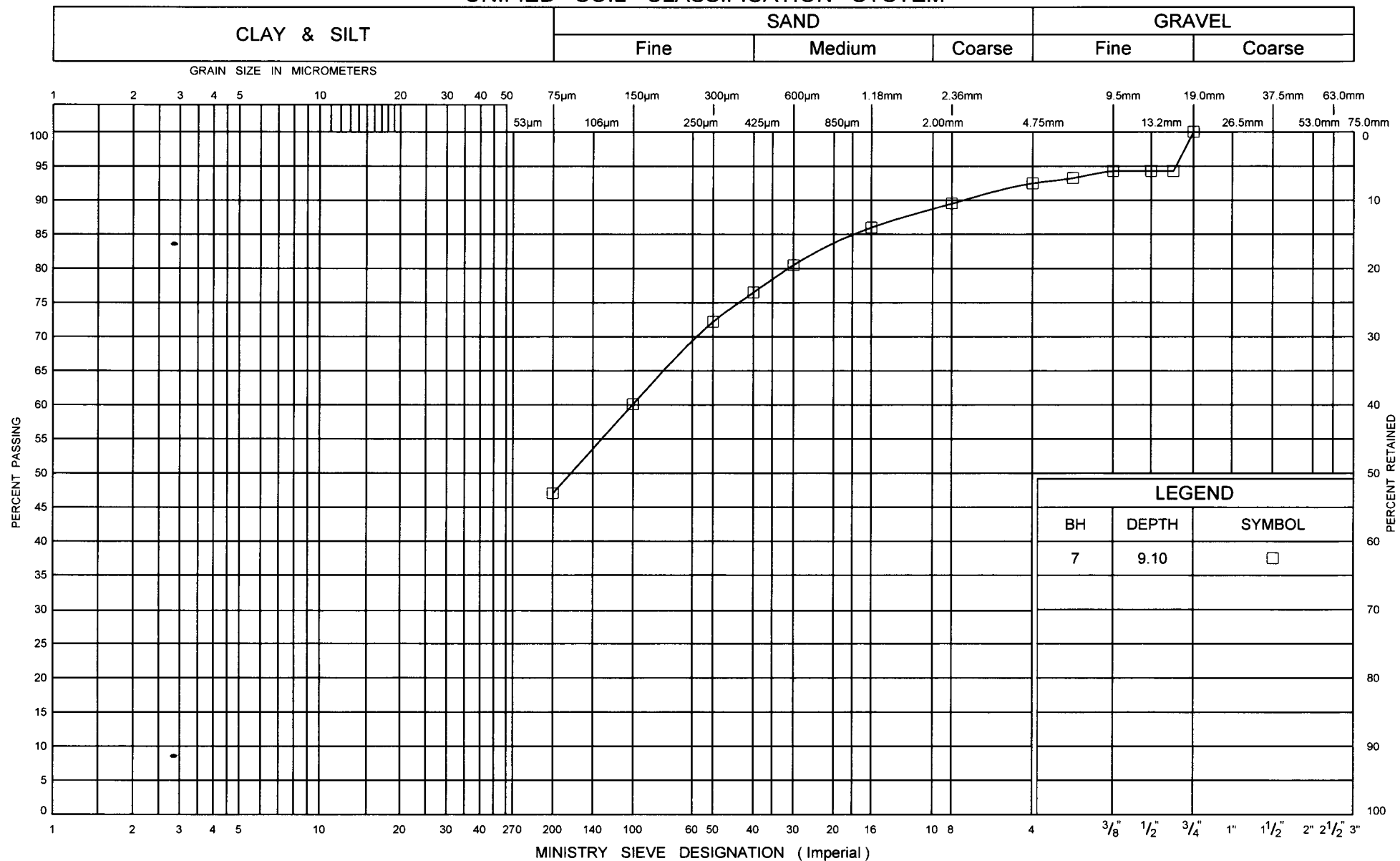
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634

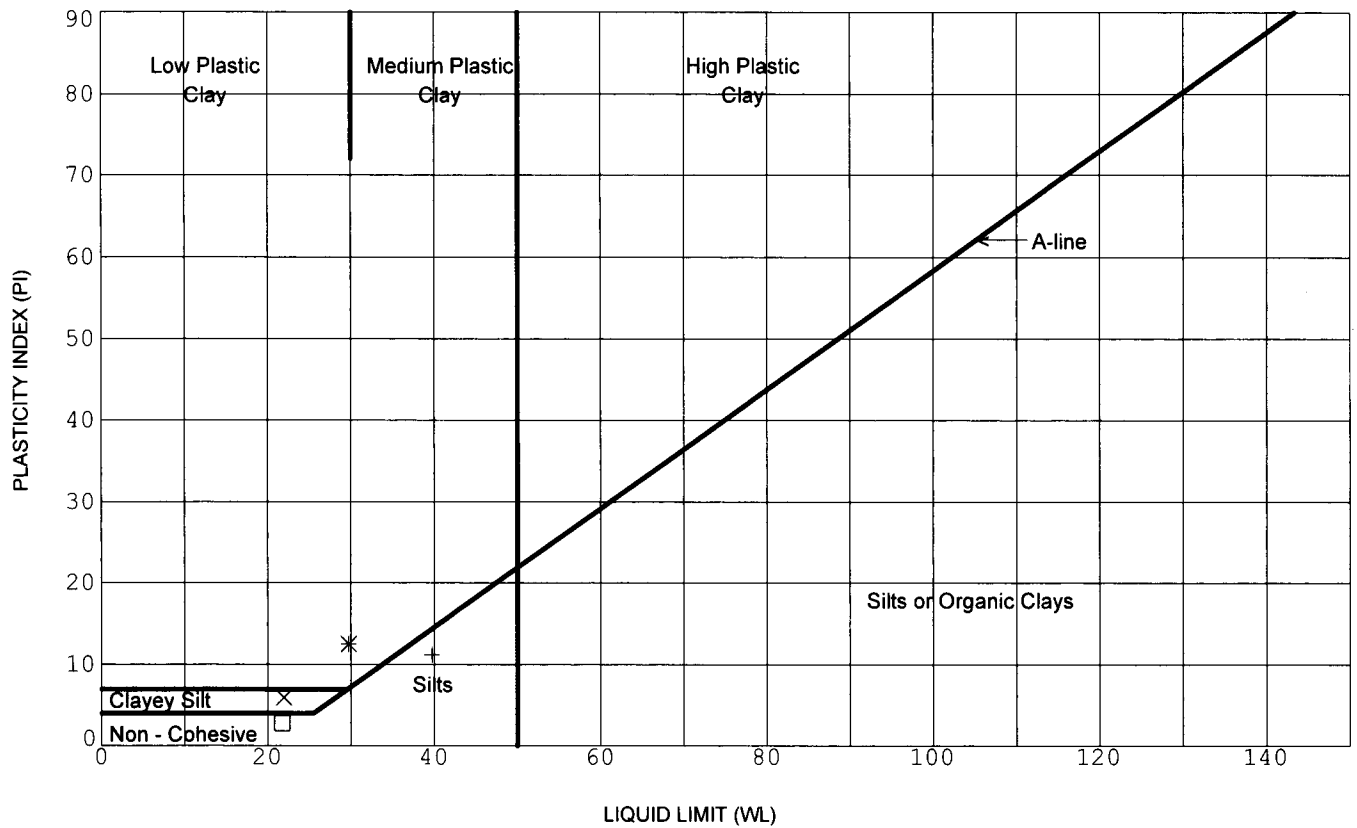
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UNIFIED SOIL CLASSIFICATION SYSTEM



ATTERBERG LIMIT TEST RESULTS



LEGEND:

- BOREHOLE 2 DEPTH 3.00
- * BOREHOLE 3 DEPTH 2.30
- × BOREHOLE 6 DEPTH 3.80
- + BOREHOLE 7 DEPTH 0.75

W _L	W _P	PI	W
22	19	3	21
30	17	13	16
22	16	6	16
40	29	11	41

April 2007

Reference No.: