

**FOUNDATION INVESTIGATION AND DESIGN REPORT
CULVERT REPLACEMENT
STATION NO. 9+995 HIGHWAY 624
MARTER TOWNSHIP, NEW LISKEARD AREA
AGREEMENT NO.: 5007-E-0065
ASSIGNMENT No. 1
GEOCRES NO.: 31M-77**

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PART 1: FACTUAL INFORMATION

1.0 INTRODUCTION

DST Consulting Engineers Inc. (DST) has been retained by the Ministry of Transportation (MTO), Geotechnical Section, Northeastern Region to conduct a foundation investigation for the proposed culvert replacement at Station 9+995, Highway 624 in the New Liskeard area. This work was carried out under Agreement No.: 5007-E-0065 - Geotechnical Retainer - Assignment No.1.

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 site is located at Station No. 9+995, Highway 624 approximately 11.6 km north of the Junction of Highway 569, in Marter Township, New Liskeard Area, in the MTO Northeastern Region.

It is understood that the existing culvert is a 760 mm diameter corrugated steel pipe that is half plugged at the inlet and that a temporary reduced extension has been placed at the outlet to reduce the side slope steepness and maintain flow. The existing culvert outlet is currently perched 500 mm. The existing culvert appears to have a history of settlement as indicated by its camber below the embankment.

The embankment at the existing culvert location appears to be constructed of sand fill, with a total height of approximately 4 m. The height of cover material above the existing culvert is

approximately 3 m.

The preferred replacement size of culvert is a 760 mm diameter pipe. The new culvert will be located approximately 5 m south of the existing culvert and placed at a higher elevation, approximate invert Elevation 95.8 m. The embankment height at this location is in the order of 3.5 m.

The surrounding area is heavily wooded. Pictures of the site are shown below. The photographs were taken on October 22, 2008.



Looking North, West Slope



Outlet Looking Northeast



Looking South, Toe of the East Slope



Inlet Looking West

3.0 INVESTIGATION PROCEDURES AND LABORATORY TESTING

Site work was carried out between October 21 and 23, 2008 utilizing a CME 750 drill rig equipped for geotechnical drilling and operated by DST. A total of nine boreholes were put down to depths ranging from 3 boreholes to a depth of 11.5 m, and 6 boreholes to a depth of 3.5 m. The minimum number and depth of boreholes was specified by the client.

Borehole locations and a stratigraphic section are shown on the Borehole Location Plan, Drawing 1.

Borehole 1 is located at 0.3 m west of the centre line of Highway 624. Boreholes 2 and 3 are located at the pavement edge of the roadway at 3.5 m from centreline. Boreholes 5 and 7 are located approximately 3.0 m beyond the pavement edge on the embankment side slopes. Boreholes 6 and 8 are located at 9.0 m westerly and 11.0 m easterly at the toe of slope. Boreholes 4 and 9 are located at 11.0 m westerly and 13.5 m easterly of the centreline. The boreholes were located along the proposed new alignment of the replacement culvert. This alignment was identified in the request for quotation by MTO personnel.

Boreholes 1, 2, and 3 were advanced with hollow stem augers to depths of 11.5 m. The remaining boreholes were put down with hand operated equipment to a depth of 3.5 m. Boreholes were backfilled with auger cuttings.

The borehole locations are referenced to the MTO Station numbering system as indicated in the request for quotation by MTO personnel. The ground surface elevations at the borehole locations were surveyed by DST personnel and referenced to a nail in a hydro pole located approximately at Station 9+945 \pm 10.0 m Lt. The benchmark elevation was taken as 100.0 m.

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

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, particle size analyses, liquid limits and plastic limits. Laboratory test results are presented on the Boreholes Logs in Enclosures 1 to 9, and plotted in Enclosures 10 to 13.

4.0 DESCRIPTION OF SUBSURFACE CONDITIONS

4.1 Stratigraphy Overview

The highway embankment at Boreholes 1, 2, and 3 consists of a surface treatment over sand fill with traces of organics and wood pockets, overlying deep clay deposits. Outside the embankment, boreholes indicate topsoil or organics overlying layers of sand which are underlain by the clay. Borehole logs are illustrated on Enclosures 1 to 9.

4.2 Topsoil

Topsoil was noted at surface at Boreholes 6, 7 and 9 up to 200 mm in thickness.

4.3 Surface Treatment

Surface treatment was present at surface at Borehole 1, with a depth of 30 mm in thickness underlain by approximately 170 mm of crushed sand and gravel. A second layer of surface treatment is present with a depth of 30 mm thickness and is underlain by crushed sand and gravel.

4.4 Embankment Fill

The roadway embankment consists of a sand and gravel fill. A trace of organics was noted throughout the sand fill in all boreholes. The borehole logs indicate that at the base of the embankment, the sand fill contains organic and wood pockets.

The fines content (percent passing 0.075 mm) for the fill varies from 8 to 27 percent, with the exception at the base of the fill in Borehole 1 where the fines content was higher at 37 percent. The higher fines content at the base of the fill may be due to migration of fines from the native silty soils into the fill layer caused by piping during fluctuating groundwater levels. Crushed sand and gravel extends to a depth of approximately 1.3 m throughout the fill layer, with the exception at Borehole 2, where the layer extends to a depth of 0.6 m. The fill layer extends to approximately Elevation 95.5

m at Boreholes 1, 2 and 5, and at Boreholes 3 and 7 the layer extends to elevation 94.6 m.

Grainsize distribution for samples of the sand are reported on the Record of Borehole sheets and are plotted on Enclosures 10 to 12. Cobbles were noted on the driller's logs within the first metre only of Boreholes 1, 2 and 3.

Moisture contents throughout the embankment fill layer range from 3 percent up to 29 percent. The upper limit of the moisture range is due to the presence of organic and wood pockets near the base of the fill layer. Moisture contents are plotted on the Borehole Logs.

SPT values are between 1 and 100+ blows per 0.3 m indicating a very loose to very dense state of compactness. The majority of the SPT values are less than 10 blows per 0.3 m indicating a very loose to loose condition.

4.5 Sands and Silts

Beyond the toe of the embankment the surficial soil consists of a thin layer of topsoil over 1 to 3 m of sand and silt layers. These have a variable moisture content ranging from 20 to 29 percent.

4.6 Low Plastic Silty Clay

Beneath the embankment, in all boreholes the soils are silty clays that extend to approximately elevation 91.2 m. The low plastic silty clay is in a very soft to soft condition, based on the N values from the standard penetration tests of 1 to 4 blows per 0.3 m. However a field vane test indicates an undrained shear strength of approximately 52 kPa due to its nature of low plasticity. In general, this deposit is estimated to have a firm to stiff consistency.

Moisture contents for this material range from 20 percent to 54 percent. Moisture contents are

plotted on the Borehole Logs. Atterberg limit test results (Enclosure 13) indicate a low plastic clay.

Gradation analyses conducted on samples from boreholes indicate a gravel content of 0 percent, sand content between 9 and 48 percent, silt content between 25 and 60 percent, and clay content between 19 and 55 percent. Grainsize distributions are reported on the Borehole Logs and are plotted in Enclosures 10 to 12.

At one location (Borehole 6), the low plastic silty clay is underlain by sand. At all other locations, it is underlain by clay with higher plasticity.

4.7 Medium to High Plastic Clay

Beneath the above noted layers, a deep silty clay stratum exists. The clay is of a firm to stiff consistency, as indicated by the in-situ field vane test (FVT) values taken in Boreholes 1, 2 and 3, ranging from 43 to 73 kPa. The plastic and liquid limits completed on samples from the boreholes are shown on Enclosure 13. The clay has a liquid limit between 42 and 52 with a plasticity index between 14 and 31, indicating a medium to high plasticity. Moisture contents for this material range from 24 percent to 58 percent, as indicated on the borehole logs.

4.8 Groundwater Levels

The existing culvert invert at the east inlet was measured at Elevation 95.5 m (above grade) and existing west outlet measured at 94.7 m. The creek level at the culvert inlet was at Elevation 95.5 m. It was at Elevation 94.6 m at the outlet.

The water level in the boreholes at toe of the embankment was between Elevation 95.8 m and 96.0 m. At the east toe of slope at the proposed inlet, 50 mm of standing water was observed, and the

west toe of slope at the proposed outlet, water levels were within 0.1 m of ground surface, near Elevation 95.8 m.

These levels, observed before borehole backfilling and also documented on the record of boreholes and Drawing 1, are not intended to represent accurate information with respect to the water table or groundwater flow. The water table is expected to be close to the creek level. Groundwater levels may fluctuate seasonally and in response to climatic conditions and creek level.

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PART 2: ENGINEERING DISCUSSIONS AND RECOMMENDATIONS

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

5.0 PROJECT DESCRIPTION

MTO has indicated that the preferred option for the replacement culvert is a 760 mm diameter pipe culvert and the preferred method of replacement is utilizing jack and bore techniques. An alternative, open cut construction will also be discussed in this section. It is anticipated that the construction will occur during the 2008/2009 winter season to take advantage of low flow and frozen ground conditions.

Based on the existing culvert levels, it is expected that the invert for the inlet of the new culvert will be at elevation 95.5 m, with the outlet elevation less than 1 m below that.

It is understood that similar culvert replacement projects have been successfully completed by MTO with jack and bore construction.

The generalized make up of the embankment fill in the area of the proposed new alignment for the replacement culvert, based on test results on borehole samples, consists of sand with 8 to 38 percent fines content and up to 42 percent gravel. The fill is classified as a SP-SM to SM (poorly graded sand with silt to silty sand). The general classification of this fill with respect to Table 7.6.1.3 Classification of Placed Soil, Canadian Highway Bridge Design Code is Soil Group II.

The site is in a low lying area with water table near surface. The stratigraphy consists of shallow sands and silts over deep firm to stiff clay deposits. Within the road embankment the fill is sand and gravel over sand. Near the base of the fill, it contains peat zones and, in the case of Borehole 1, small pieces of wood. The latter may indicate 'corderoy' construction or simply that some trees were not cleared before the fill was placed. The latter appears more likely, based on visual examination of the samples.

It should be noted that on the west side of the embankment, there is an exposed cable (possibly a telephone line) directly below the existing temporary outlet, and continues both north and south buried along the toe of slope.

Groundwater levels will fluctuate seasonally and in response to climatic conditions. The water table at the proposed culvert location is expected to be close to the creek level and will also vary with the creek level. Dewatering of any excavations below the water table will be difficult due to the permeable granular nature of the subsoils at the elevation of the new culvert.

There are organic and wood pockets within the fill near the contact between fill and inorganic native soil layers. At the present time, there appears to be a slight depression in the roadway at the existing culvert location. Borehole logs indicate that a 150 mm grade raise and 30 mm surface treatment has been completed in the area. This likely indicates a grade raise occurred in the past, possibly in response to some settlement. Depending on the depth and compressibility of the clays, and the original construction date, the road may still be slowly settling today.

The new culvert will result in a very small net decrease in load on this area of the embankment.

5.1 Jack and Bore Culvert Replacement

5.1.1 Discussion

A jack and bore method is feasible for the replacement of the culvert.

The embankment fill at borehole locations 1, 2 and 3 in the area of the culvert replacement is a sand with 0 to 48 percent gravel and up to 37 percent silt. The condition of the sand is very loose to compact, as indicated by the N values from the standard penetration test of 1, 2, and 3. Beneath the fill pockets of organics and wood exist, at approximately 1 m before the contact between the fill and silt and clay layer above.

It is understood from MTO that jack and bore techniques have been used successfully on other similar projects in this region. Nevertheless, the contractor should make his own conclusion based on the subsurface borehole locations and his own knowledge of the techniques required and/or subsurface investigation.

The contractor should submit to the Contract Administrator for review, plans, specifications and detailed procedures for the jack and bore operation. As a minimum the procedures should be in accordance with Ontario Provincial Standard Specifications (OPSS) 416 "Construction Specifications for Pipeline and Utility Installation by Jacking and Boring", and ensure minimal disturbance of the organics/wood below invert level.

The culvert should be designed to accommodate uneven loading on its walls as a result of surrounding soils with variable stiffness (sand fill, organic/wood pockets, and silt and clay).

5.1.2 Outlet/Inlet Control

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

5.1.3 Frost Depth

In accordance with OPSD 3090.100, "Contours of Frost Depth for Northern Ontario", the frost penetration for this area is in the order of 2.2 m.

5.1.4 Construction Concerns

It should be noted that, on the west side of the embankment, there is an exposed cable directly below the existing temporary outlet, which continues both north and south buried along the toe of the west slope.

The construction methodology must be in accordance with all Ministry of Transportation, Ministry of Environment, Ministry of Natural Resources (MNR) and Department of Fisheries and Oceans (DFO) guidelines, and the Occupational Health and Safety Act of Ontario. The contractor's method and equipment must be suitable for the site conditions and materials used.

The data at the borehole locations indicate no obstructions to a jack and bore procedure such as boulders in the fill material at the proposed elevation of the culvert replacement. There is a possibility that wood from buried trees or branches within the embankment could be encountered, and equipment/methods should be capable of dealing with these.

The contractor's methods must ensure that existing organics and wood pockets below the embankment are not significantly disturbed, thus reducing the potential for future settlement.

The water table is in the vicinity of the base of the embankment and the sand and fill materials at this location are in a very loose to compact saturated condition. The jack and bore procedure will have to take this into account to prevent excess soil loss and potential settlement of the roadway.

Sand exists at a shallow depth beyond the toe of the existing embankment. The materials will not support or provide a suitable jacking reaction to the jack and bore equipment and will have to be excavated and replaced with a suitable engineered granular fill to the required grades. Dewatering of the trenches will be required, although, if the work is completed during the winter months, dewatering requirements will likely be at a minimum.

5.2 Open Cut Construction Option

5.2.1 Discussion

An open cut operation is also feasible but results in more traffic disruption than a jack and bore operation and with a potential for construction difficulties that could prove costly. As a minimum, the procedures should be in accordance with OPSS 421 "Construction Specifications for Pipe Culvert Installation in Open Cut".

For an open cut, the following would have to be completed; construction of detour lanes, extension of existing culvert below detour lanes, and excavation of a greater area of organic and wood pockets to native undisturbed silt and clay to facilitate the construction. The construction methodology must be in accordance with all Ministry of Transportation, Ministry of Environment, Ministry of Natural Resources and Department of Fisheries and Oceans guidelines, and the Occupational Health and Safety Act of Ontario. The contractor's method and equipment must be suitable for the site conditions and materials used.

5.2.2 Earth Excavation

The excavation for the proposed culvert replacement should be in accordance with OPSD 802.010 “Flexible Pipe Embedment and Backfill Earth Excavation”. The sand fill material can be designated as a Type 3 soil.

Organic materials and wood pockets were noted beneath the existing fill. Excavations to remove these organics and wood should be completed in accordance with OPSD 203.040 “Embankments Over Swamp At Pipe Culverts ≤ 1500 mm”.

It is anticipated that the existing groundwater table will be within the excavation dimensions.

Excavation of the organic and wood materials can be undertaken in two ways; the construction can be undertaken in the wet or in the dry with dewatering of the excavation, and backfilling with a suitable granular fill.

If excavation is completed in the wet, the excavated materials can be replaced with clear stone (maximum aggregate size of 25 mm) and surrounded with a non-woven geotextile (OPSS 1860.07.05.01 Class II). The filtration opening size (FOS) should be between 30 and 60 μm .

For open cut construction, specialized dewatering techniques such as well points may be required to satisfactorily dewater the excavation and maintain a stable base. These systems are designed by specialized contractors.

In wet material below the groundwater table, excavated side slopes will need to be flattened (3 horizontal to 1 vertical or flatter) to prevent excessive sloughing of the excavation slopes and will be highly dependent on the contractor’s methodology and ability to effectively dewater the excavation.

Should the method result in disturbed materials at the base of excavation, this will render the soil unsuitable for support of the culvert and headwall.

5.2.3 Frost Depth

In accordance with OPSD 3090.100 "Contours of frost Depth for Northern Ontario" the frost penetration for this area is estimated at 2.2 m.

5.2.4 Outlet/Inlet Control

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

5.2.5 Settlement

With an open cut, as per Section 5.2.2, Earth Excavation, all organics and wood will be removed to competent soils from beneath the culvert. Since there will be no net increase in load being applied due to the construction of the new structure, significant settlement of the culvert from the proposed construction is not expected, assuming the existing embankment is no longer settling and assuming suitable installation methods with adequate groundwater control and without ground disturbance. The effect of lowering the water table by up to 1.8 m will increase the stress within the organic and wood pocket layer and could possibly result in settlement of up to 25 mm in the roadway adjacent to the new culvert.

5.2.6 Roadway Protection

For traffic and road protection, the installation of sheet piles or soldier piles and lagging can be considered. These systems should be designed by an engineer familiar with these types of designs.

Alternatively, the roadway can be temporarily widened in accordance with OPSD 209.010 "Rural Pavement Widening" to provide a detour route.

5.2.7 Construction Concerns

It should be noted that , on the west side of the embankment, there is an exposed cable directly below the existing temporary outlet, and continues both north and south buried along the toe of the west slope.

The two main construction concerns with open cut excavation are providing the requirements for roadway protection and excavation below the water table. These two items could prove costly for the successful installation of the new culvert.

6.0 EMBANKMENT FORESLOPES

At the present time the embankment slopes in the area of the existing and proposed culvert location are 2 horizontal to 1 vertical. This condition complies with MTO standard for foreslopes.

7.0 RECOMMENDATIONS

It is anticipated that open cut construction with detour will be considerably more expensive than jack and bore construction, and without benefits.

Due to the above and that the MTO has successfully completed similar jack and bore construction previously in the area, jack and bore construction is recommended. The main construction concerns of groundwater and possibly buried wood should be addressed using suitable construction equipment and methods. No bedrock or boulder obstructions are anticipated.

The jack and bore method does involve some risks in that potential disturbance of the organic, wood pockets and low plastic clays, and is difficult to monitor during installation. The contractor's methods must therefore ensure that there is no or little disturbance. Furthermore, the method must be able to deal with the variable soil conditions at the jacking face without compromising the design grade. In sandy or unstable soil conditions there is a possibility of void formation in the line of bore, and in this condition grouting of the casing is recommended.

An erosion protection measure such as planting of vegetation along the slope is suggested. In case high flow velocity at the toe of the embankment slope is expected, placing an armour stone to prevent the erosion should be considered. Granular material as specified in OPSS 1004, should be placed on the existing foreslopes to provide a stable, free-draining slope face and prevent surficial erosion.

Monitoring during and after construction may be necessary to evaluate possible settlements, the following monitoring scheme is recommended:

- Monitoring of settlement points during and after construction is recommended. A set of settlement points one at the centre of the embankment and one at each shoulder are recommended to be installed along the proposed culvert alignment. A close interval monitoring is required during construction where as periodic monitoring is required after construction.
- Full time surveillance for signs of instability during construction.
- Daily visual inspection for cracks, deformation and movement during construction, and monthly for the first year after construction.
- Measurement and assessment of settlement along the roadway and shoulders at least weekly during the first month of construction and thereafter monthly during a year after construction.
- Visual inspection of foreslopes for sloughing and erosion.

8.0 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.

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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.

Soil Descriptions

The regional soils investigation crew describes the soil in the field using the abbreviated format. As described in the *Soil Classification Manual*, the principal and secondary components are initially estimated and described, and then the minor components are identified. These minor components are described as follows:

with describes a component having a significant effect on the sample

trace describes a component having only a minor effect on the sample

Further refinements in identifications can be made on the basis of laboratory tests. The descriptive terms, based on percent by mass of the whole sample, are described as follows:

Descriptive Term	Example	Percent by Mass of Sample
and (with two major soil types)	sand and gravel	40-60
adjective (silty)	silty	30-40
with	silt with fine sand	20-30
some	silt, some fine sand	10-20
trace	sand, trace of gravel	0-10

The Ministry Soil Classification System describes four types of organic soils. Three of the fine-grained soil groups are described as organic (O Group). These groups are silt or clay-sized soils having a relatively low plasticity which plots below the A line on the soil plasticity chart. The O Group is differentiated from the Highly Organic Peats (Pt Group). The Pt Group is identified by its dark colour, earthy odour, spongy consistency and frequently by its fibrous texture. Peat may be subdivided into three general classes, as shown on the next page.

The engineering properties of these three types of peat are significantly different and therefore require an accurate identification. Further information on the properties and engineering significance of highly organic soils is provided in Part 7 of the *Construction Manual* [1].

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 51mm 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 (51mm 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 (R Q D), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	50mm	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
r_u	1	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	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
C_v	m ² /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	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_i	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

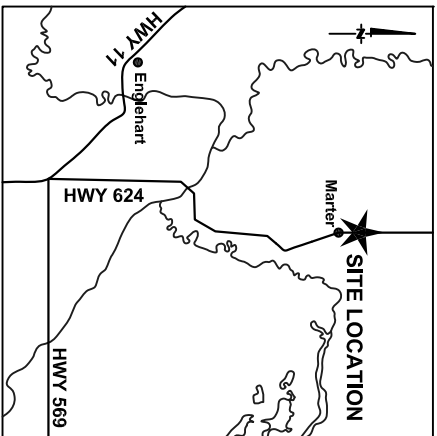
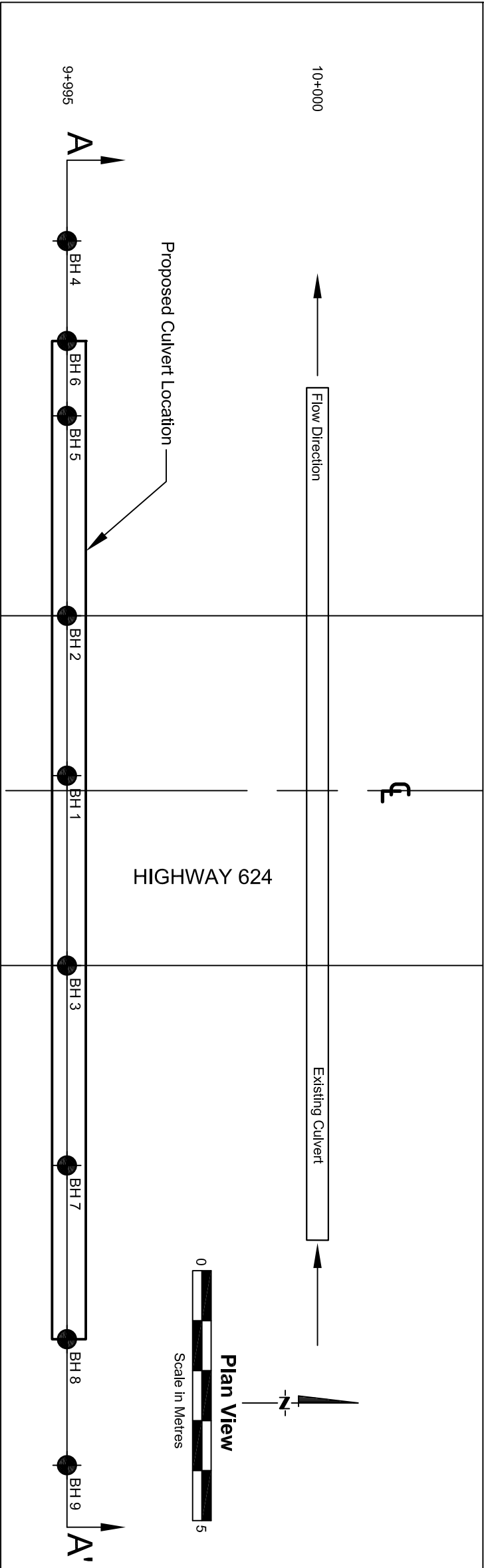
ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	e_{min}	1, %	VOID RATIO IN DENSEST STATE
γ_s	kN/m ³	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m ³	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kN/m ³	UNIT 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	1	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	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kN/m ³	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	e_{max}	1, %	VOID RATIO IN LOOSEST STATE	j	kN/m ³	SEEPAGE FORCE
γ'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL						

DRAWINGS

METRIC

MEASUREMENTS ARE IN METRES
UNLESS OTHERWISE SPECIFIED
DISTANCES BETWEEN STATIONS
IN KILOMETRES + METERS

CULVERT REPLACEMENT
(Jack and Bore)
Foundation Investigation & Design Report
Highway 624 Approximately 11.6 km North of Highway 569 Junction
Station No. 9+995
Agreement No. 5007-E-0065
GWP
GEOCRESS 32D-8
BOREHOLE LOCATIONS & SOIL STRATA



LEGEND

- Borehole
- Borehole with CPT
- Asphalt Core
- Blows/0.3m (Std. Pen Test, 475 J/Blow)
- Water level at time of investigation.

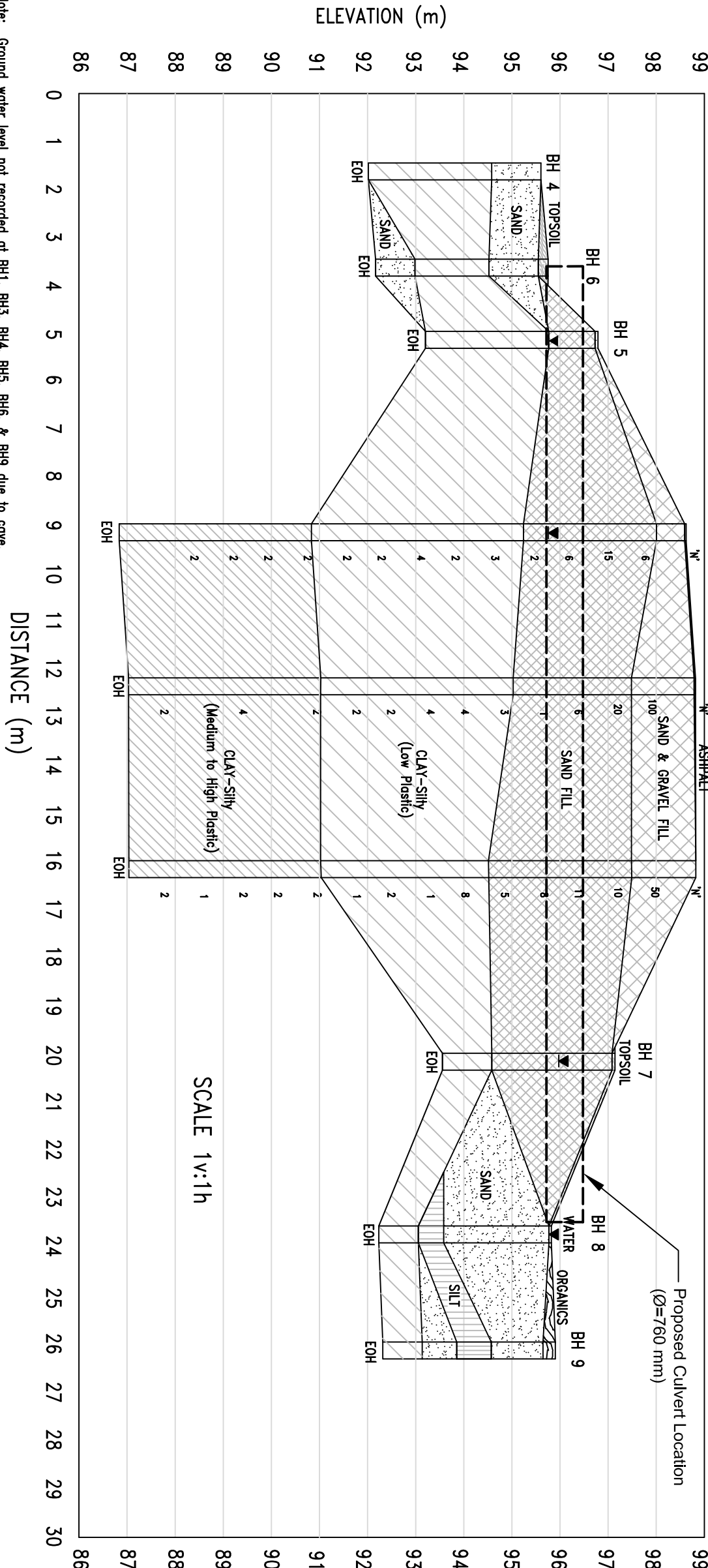
- Fill
- Organics
- Topsoil
- Bedrock
- Sand
- Silt
- Clay
- Sand & Gravel
- Boulders

No.	Elevation	Station	Offset
1	98.800	9+995	0.3 m LT
2	98.570	9+995	3.5 m LT
3	98.760	9+995	3.5 m RT
4	95.635	9+995	11.0 m LT
5	96.840	9+995	7.5 m LT
6	95.710	9+995	9.0 m LT
7	97.175	9+995	7.5 m RT
8	95.765	9+995	11.0 m RT
9	95.875	9+995	13.5 m RT

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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PROFILE ALONG SECTION A-A'



ENCLOSURES

RECORD OF BOREHOLE No 1

1 OF 1

METRIC

W.P. Agreement # 5007-E- 0065 LOCATION 9+995 (0.3 m LT) ORIGINATED BY PR/LM
 DIST HWY 624 BOREHOLE TYPE Jack and Bore COMPILED BY ML
 DATUM NAD83 DATE 2008 10 21 CHECKED BY WS/BV

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		
								20 40 60 80 100						
								20 40 60 80 100						
									○ UNCONFINED × FIELD VANE					
									□ QUICK TRIAXIAL ★ LAB VANE					
98.8														
98.6	SURFACE TREATMENT - 30 mm FILL - SAND & GRAVEL - crushed, occasional cobbles, SURFACE TREATMENT - 30 mm FILL - SAND & GRAVEL - crushed		1	AS			98							42 50 6 2
			2	SS	100+									Wet cave at 6.4 m on completion. Water table not recorded.
97.5														
1.3	FILL - SAND - trace to some silt, brown		3	SS	20		97							
	----- - Organics Layer- 50 mm		4	SS	6									
	----- - Silty, brown/grey		5	SS	1		96							0 63 28 9
	----- - Silty, with organics & wood pockets													
95.1	CLAY - Silty, trace to some sand, grey, low plastic, occasional medium plastic zones, soft to firm		6	SS	3		95							
3.7			7	SS	4		94							0 9 65 26
			8	SS	4									
			9	SS	2		93							
			10	SS	2		92							0 19 38 42 0 26 52 22
91.2														
7.6	CLAY - Silty, grey, medium to high plastic, firm to soft		11	SS	2		91							
			12	SS	4		90							
							89							
			13	SS	2		88							0 1 44 55
87.3														
11.5	End of Borehole at 11.5 m													

ON_MOT_CS-TB-009496 HWY 624 JACK N BORE.GPJ DST_MIN.GDT 28/11/08

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

ENCLOSURE 1

RECORD OF BOREHOLE No 2

1 OF 1

METRIC

W.P. Agreement # 5007-E- 0065 LOCATION 9+995 (3.5 m LT) ORIGINATED BY PR/LM
 DIST HWY 624 BOREHOLE TYPE Jack and Bore COMPILED BY ML
 DATUM NAD83 DATE 2008 10 21 CHECKED BY WS/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			SHEAR STRENGTH kPa						
								20	40	60	80	100		
98.6														
98.5	SURFACE TREATMENT - 30 mm FILL - SAND & GRAVEL - crushed													
98.0			1	AS										Wet cave at 2.7 m on completion. Water table estimated at 2.7 m.
0.6	FILL - SAND - some silt, trace gravel, clay and organics, occasional cobbles, brown		2	SS	6									
	----- - organic pockets		3	SS	15									4 69 18 9
			4	SS	6									
95.3	----- - wood pockets		5	SS	2									
3.3	CLAY - Silty, trace to some sand, grey, low plastic		6	SS	3									
			7	SS	2									
			8	SS	4									
			9	SS	2									0 14 52 34
			10	SS	2									
91.0														
7.6	CLAY - Silty, grey, medium to high plastic, soft		11	SS	2									
			12	SS	2									0 1 30 69
			13	SS	2									
			14	SS	2									
87.1														
11.5	End of Borehole at 11.5 m													

ON_MOT_CS-TB-009496 HWY 624 JACK N BORE.GPJ DST_MIN.GDT 28/11/08

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




ENCLOSURE 2

RECORD OF BOREHOLE No 3

1 OF 1

METRIC

W.P. Agreement # 5007-E-0065 LOCATION 9+995 (3.5 m RT) ORIGINATED BY PR/LM
 DIST HWY 624 BOREHOLE TYPE Jack and Bore COMPILED BY ML
 DATUM NAD83 DATE 2008 10 22 CHECKED BY WS/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			SHEAR STRENGTH kPa							
								20	40	60	80	100			PLASTIC LIMIT W _P
98.8 0.0	FILL - SAND & GRAVEL - crushed, occasional cobbles		1	AS											Water table not recorded.
			2	SS	50										
97.5 1.3	FILL - SAND - Silty, trace organics and clay, grey		3	SS	10										
			4	SS	11										
			5	SS	8										
	----- - wood pockets		6	SS	5										
94.6 4.2	CLAY - Silty, trace to some sand, grey, low plastic, soft to firm		7	SS	8										
			8	SS	1										
	----- - saturated		9	SS	2										
			10	SS	1										
91.2 7.6	CLAY - Silty, grey, medium to high plastic, firm to stiff		11	SS	2										
			12	SS	2										
			13	SS	2										
			14	SS	1										
			15	SS	2										
87.3 11.5	End of Borehole at 11.5 m														

ON_MOT_CS-TB-009496 HWY 624 JACK N BORE.GPJ DST_MIN.GDT 28/11/08

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



ENCLOSURE 3

RECORD OF BOREHOLE No 4

1 OF 1

METRIC

W.P. Agreement # 5007-E-0065 LOCATION 9+995 (11.0 m LT) ORIGINATED BY PR/LM
 DIST HWY 624 BOREHOLE TYPE Jack and Bore COMPILED BY ML
 DATUM NAD83 DATE 2008 10 22 CHECKED BY WS/BV

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 20 40 60 80 100 ○ UNCONFINED × FIELD VANE □ QUICK TRIAXIAL ★ LAB VANE					WATER CONTENT (%) 20 40 60 W _p W W _L				
95.6 0.0	SAND - Silty, brown		1	AS		95										Water table not recorded. 0 54 28 18	
94.6 1.0	CLAY - Silty, trace to some sand, grey, low plastic		2	AS													
			3	AS		94											
			4	AS		93											
92.1 3.5	End of Borehole at 3.5 m																

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

ENCLOSURE 4

RECORD OF BOREHOLE No 5

1 OF 1

METRIC

W.P. Agreement # 5007-E- 0065 LOCATION 9+995 (7.5 m LT) ORIGINATED BY PR/LM
 DIST HWY 624 BOREHOLE TYPE Jack and Bore COMPILED BY ML
 DATUM NAD83 DATE 2008 10 22 CHECKED BY WS/BV

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	20	40	60			
96.8	FILL - SAND & GRAVEL - with rootlets FILL - SAND - Silty, brown		1	AS													
95.8	CLAY - Silty, grey, low plastic		2	AS													
1.0	----- - trace organics		3	AS													
			4	AS													
93.3	End of Borehole at 3.5 m																
3.5																	

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

RECORD OF BOREHOLE No 6

1 OF 1

METRIC

W.P. Agreement # 5007-E- 0065 LOCATION 9+995 (9.0 m LT) ORIGINATED BY PR/LM
 DIST HWY 624 BOREHOLE TYPE Jack and Bore COMPILED BY ML
 DATUM NAD83 DATE 2008 10 22 CHECKED BY WS/BV

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	20	40	60			
95.7	TOPSOIL - 200 mm																
94.8	SAND - Silty, with rootlets, brown		1	AS													
94.5	CLAY - Silty, grey, low plastic		2	AS													
93.0	SAND - Silty, grey		3	AS													
92.2	End of Borehole at 3.5 m		4	AS													

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

RECORD OF BOREHOLE No 7

1 OF 1

METRIC

W.P. Agreement # 5007-E- 0065 LOCATION 9+995 (7.5 m RT) ORIGINATED BY PR/LM
 DIST HWY 624 BOREHOLE TYPE Jack and Bore COMPILED BY ML
 DATUM NAD83 DATE 2008 10 22 CHECKED BY WS/BV

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL LIMIT 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	20	40	60			
97.2																	
97.1	TOPSOIL - 60 mm FILL - SAND - Silty, trace clay and organics, brown/grey		1	AS													
			2	AS													
			3	AS													
94.7	- organics/wood CLAY - Silty, grey, low plastic		4	AS													
2.5																	
93.7	End of Borehole at 3.5 m																
3.5																	

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

RECORD OF BOREHOLE No 8

1 OF 1

METRIC

W.P. Agreement # 5007-E-0065 LOCATION 9+995 (11.0 m RT) ORIGINATED BY PR/LM
 DIST HWY 624 BOREHOLE TYPE Jack and Bore COMPILED BY ML
 DATUM NAD83 DATE 2008 10 22 CHECKED BY WS/BV

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 20 40 60 80 100 ○ UNCONFINED × FIELD VANE □ QUICK TRIAXIAL ★ LAB VANE					WATER CONTENT (%) 20 40 60 W _p W W _L				
95.8																	
95.7	WATER - 50 mm SAND - Silty, trace organics, brown		1	AS												Standing water at surface.	
			2	AS													
93.5																	
2.3	SILT - some sand, grey		3	AS												0 40 42 18	
93.1																	
2.7	CLAY - Silty, grey, low plastic																
92.3																	
3.5	End of Borehole at 3.5 m																

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

RECORD OF BOREHOLE No 9

1 OF 1

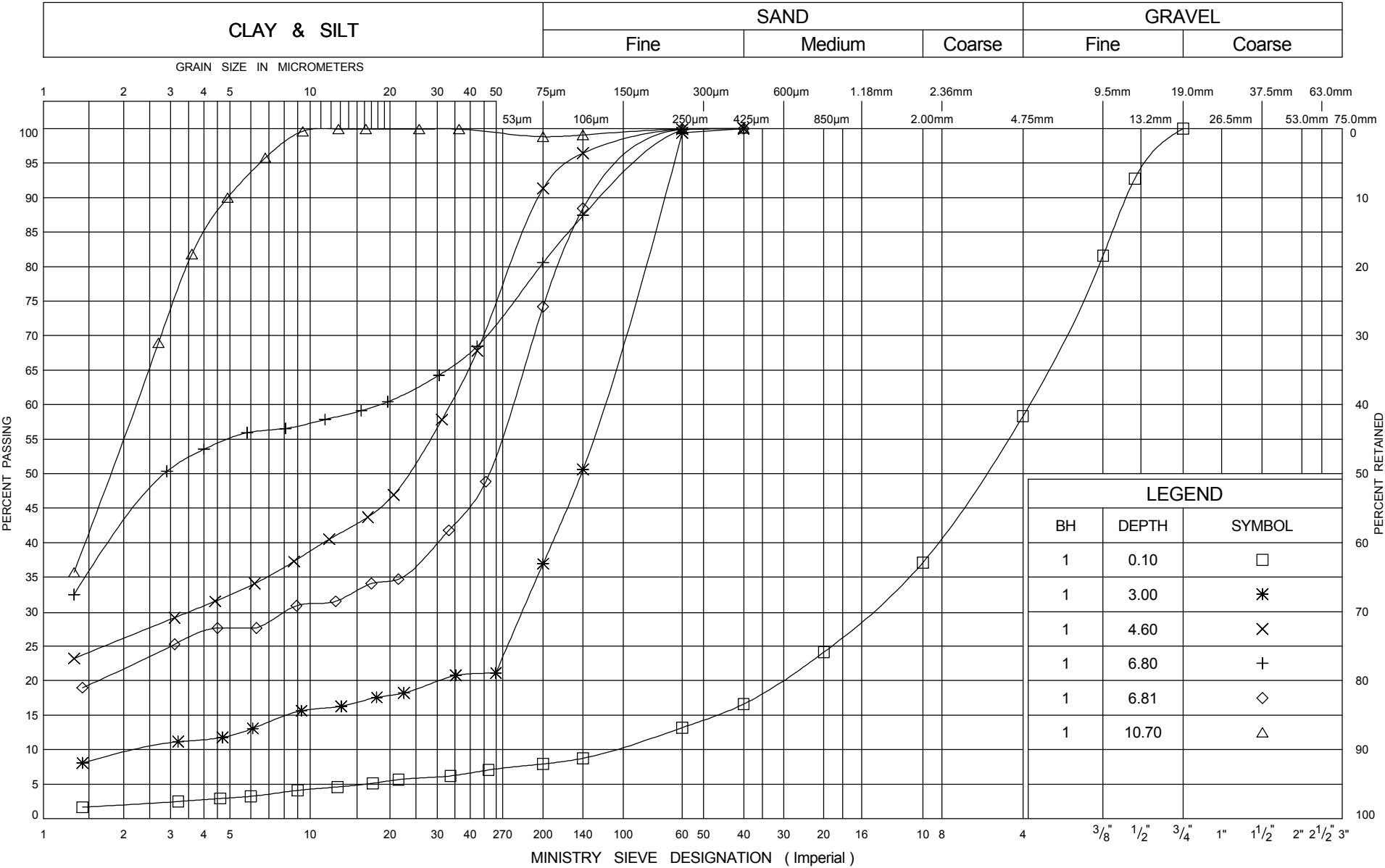
METRIC

W.P. Agreement # 5007-E-0065 LOCATION 9+995 (13.5 m RT) ORIGINATED BY PR/LM
 DIST HWY 624 BOREHOLE TYPE Jack and Bore COMPILED BY ML
 DATUM NAD83 DATE 2008 10 23 CHECKED BY WS/BV

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	20	40	60			
95.9	ORGANICS - grass, roots															Water table not recorded.	
95.6																	
0.3	SAND - Silty, trace organics and rootlets, grey		1	AS													
94.6																	
1.3	SILT - Sandy, trace clay, grey		2	AS												0 19 62 19	
93.9																	
2.0	SAND - Silty, brown		3	AS													
93.2																	
2.7	CLAY - Silty, grey, low plastic		4	AS													
92.4																	
3.5	End of Borehole at 3.5 m																

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

UNIFIED SOIL CLASSIFICATION SYSTEM

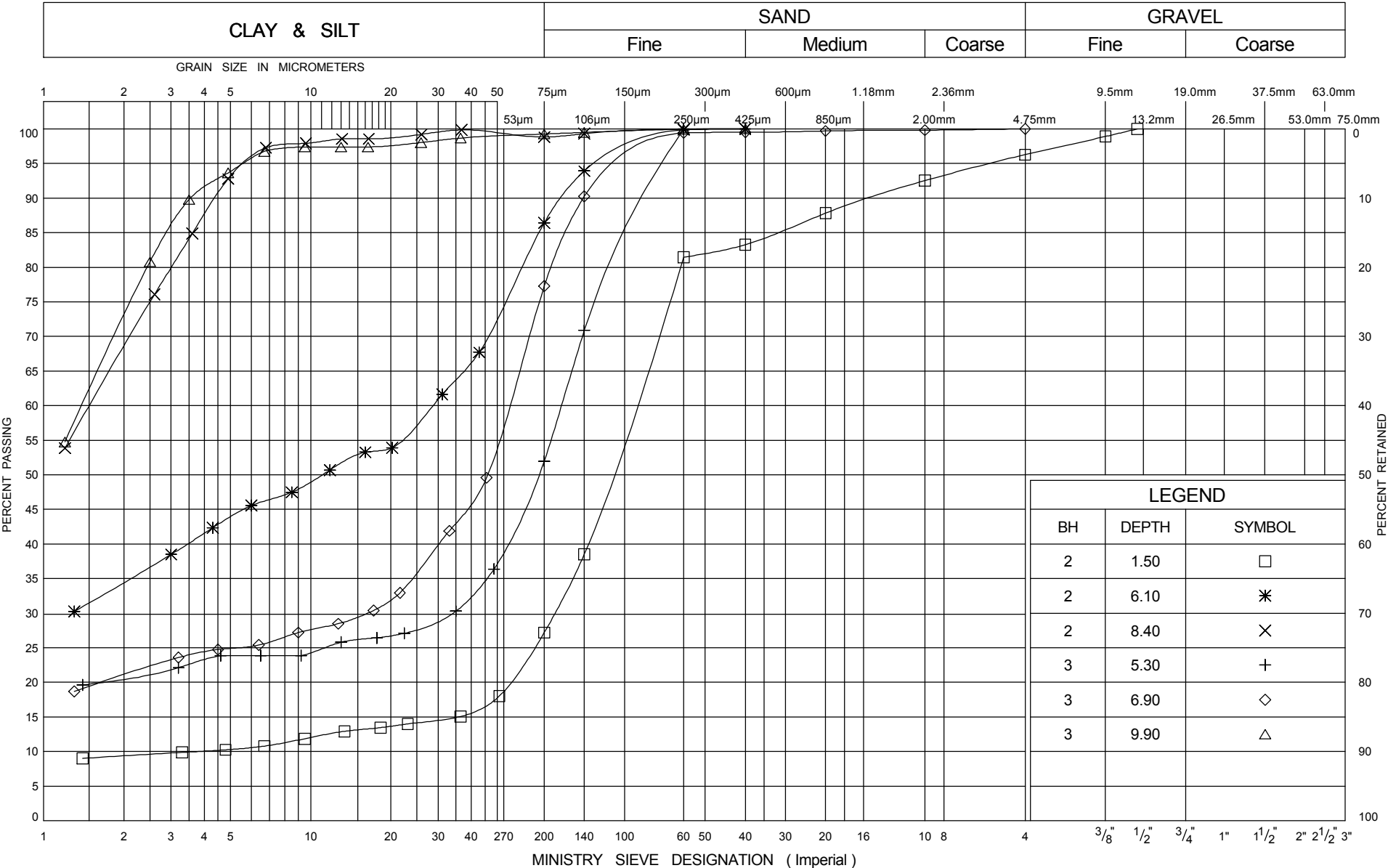


GRAIN SIZE DISTRIBUTION

ENCLOSURE 10
W P # 5007-E- 0065
HIGHWAY 624



UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION

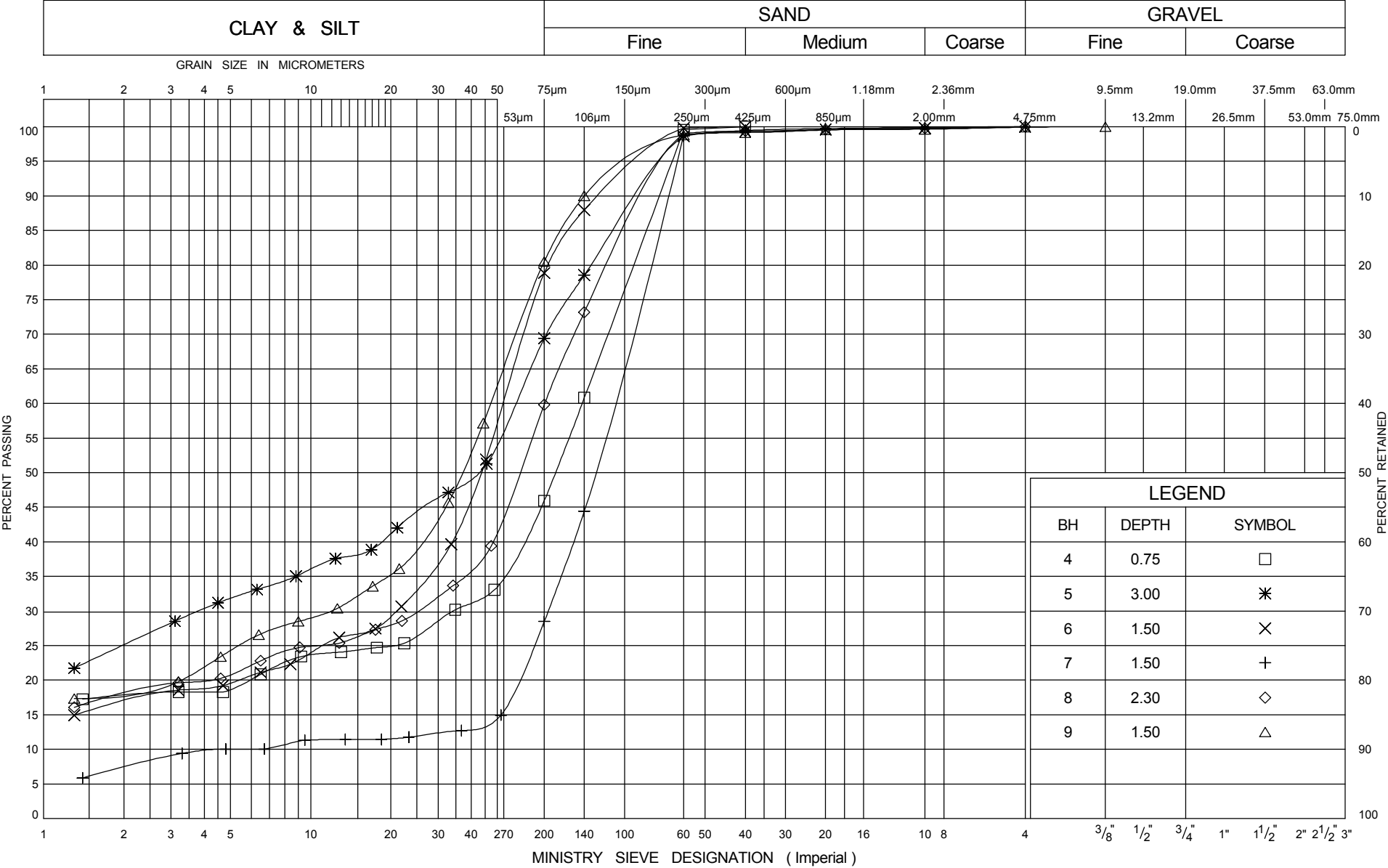
ENCLOSURE 11

W P # 5007-E- 0065

HIGHWAY 624



UNIFIED SOIL CLASSIFICATION SYSTEM



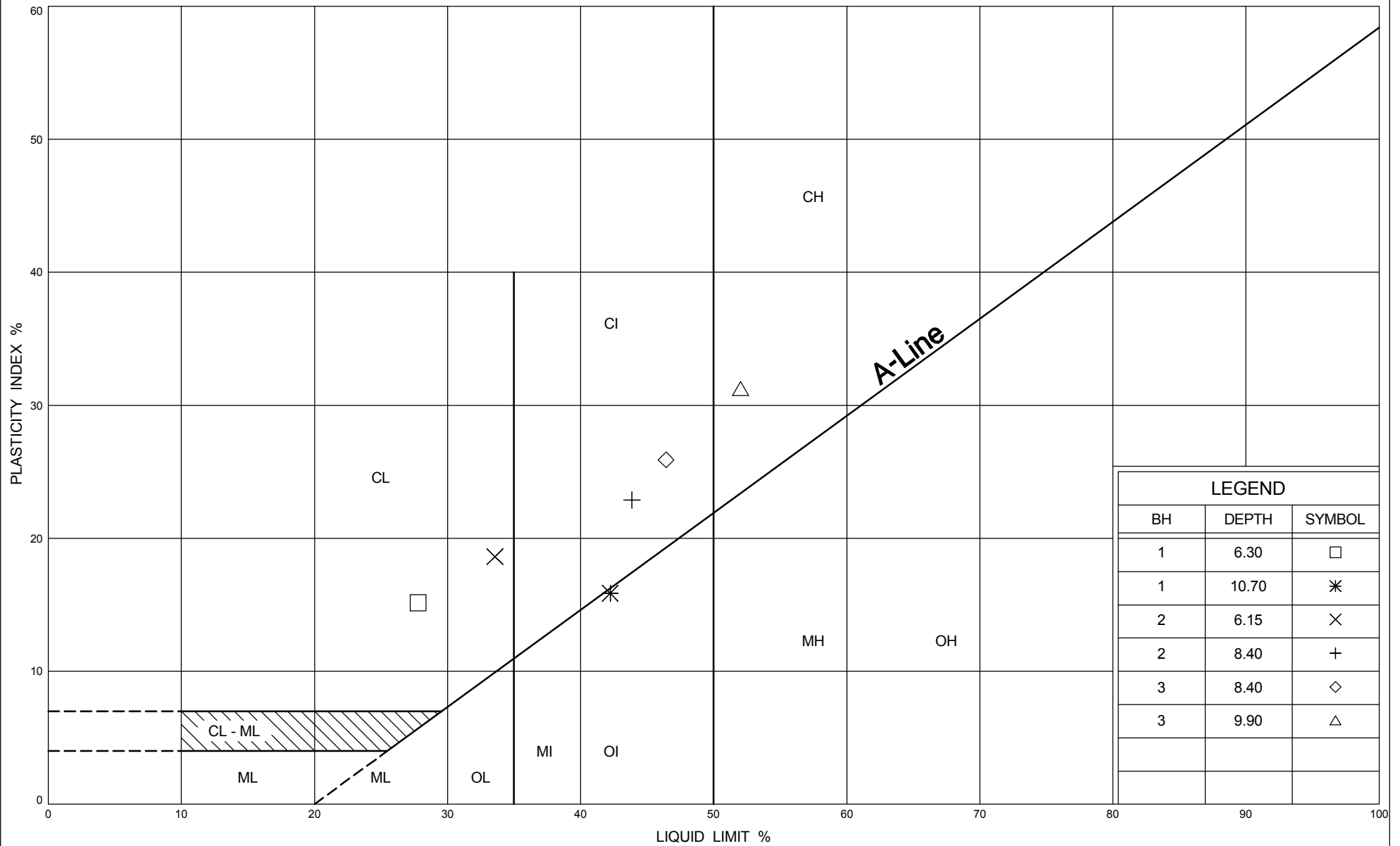
GRAIN SIZE DISTRIBUTION

ENCLOSURE 12

W P# 5007-E- 0065

HIGHWAY 624





PLASTICITY CHART

ENCLOSURE 13

W P # 5007-E- 0065

Highway 624