



**FOUNDATION INVESTIGATION  
AND DESIGN REPORT  
FARLEY CREEK CULVERT  
REPLACEMENT  
HIGHWAY 124  
TOWNSHIP OF HAGERMAN  
AGREEMENT NO.: 5010-E-0007  
WP: 5424-06-01  
GWP: 5424-06-00  
GEOCRES NO.: 31E-306**

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**PART 1: FACTUAL INFORMATION**

**1. INTRODUCTION**

DST Consulting Engineers Inc. (DST) has been subcontracted by Genivar which was retained by Ministry of Transportation (MTO), Northeastern Region, to conduct a geotechnical investigation for the replacement a culvert on Highway 124. This work was carried out under Agreement No.: 5010-E-0007, Detailed Design for the Replacement/Rehabilitation of various culverts.

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. SITE DESCRIPTION**

The site is located on Highway 124, approximately 3.36 km west of junction Highway 520, in Hagerman Township, Huntsville Area. The structural site number is 44-288.

The existing culvert is a 3000 mm x 30 m corrugated steel pipe (CSP) culvert with approximately 1.6 m of cover (Figure 2.1). It was determined to be in poor condition with severe corrosion, flaking below the waterline, few perforations and cracks at the bolt locations as well as some deformation of the culvert shape. It is understood that the existing structure will be replaced by a 3.0 x 2.1 x 29.4 m precast box culvert.

The outlet and inlet of the existing culvert are grassed (Figures 2.3 and 2.4). The embankment slopes at this location vary from 2H:1V to 3H:1V and include rockfill (Figure 2.2). Figures 2.1 to 2.4 were taken during DST drilling activities on October 06, 2010.





Figure 2.1 Corrugated Steel Pipe (CSP) culvert (looking south)



Figure 2.2 Rockfill along the embankment (looking north)





Figure 2.3 Outlet of the existing culvert (looking west)



Figure 2.4 Inlet of the existing culvert (looking west)

### **3. INVESTIGATION PROCEDURES AND LABORATORY TESTING**

Site work was carried out in the period of three days (October 06, 2010 to October 08, 2010) utilizing a CME 750 drill rig that was operated by DST personnel. Two (2) hydraulically powered boreholes and two (2) hand auger boreholes were put down for foundation design purpose. The boreholes were put down using hollow stem augers.

According to the given specification in Request For Quotation (RFQ) by MTO, three boreholes (one at the inlet, one at the outlet, one at the embankment), were recommended for the purpose of the foundation design. However, the field investigation plan was slightly altered due to the inaccessibility to the inlet and outlet by the hydraulically powered drill rig.

The two hand auger boreholes were advanced at either side of the existing culvert (inlet and outlet). The two hydraulically powered boreholes that were close to the existing culvert were advanced at either side of the embankment shoulder. Borehole locations and stratigraphic sections are shown on the Borehole Location Plans (Drawings 1 to 4). All boreholes were abandoned using suitable abandonment barrier as described in O. Reg. 903 and its amendments.

The borehole locations are referenced to the MTO Station numbering system as indicated in the RFQ. The ground surface elevations at the borehole locations were surveyed by DST personnel. A nail in a hydro pole was assigned as temporary benchmark with elevation of 259.0 m (Drawing 1). Elevations were subsequently correlated to survey data provided by Genivar. A station on the highway marked as Station 21+000 was chosen as referenced station (Figure 3.1). According to the referenced station, the existing culvert was identified at Station 21+030. Table 3.1 summarizes the detail of borehole locations and depths.

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. In-situ tests included standard penetration test (SPT) and field vane shear test (FVST). The soil samples collected during drilling 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 moisture contents, particle size analyses and Atterberg limits including plastic limit and



liquid limit. A total of thirty (30) moisture contents, five (5) sieve analyses, nine (9) particle analyses, and five (5) Atterberg limits have been carried out for this assignment. Laboratory test results are presented in the Boreholes Logs (Enclosures 1 to 4), and Plots (Enclosures 5 to 8).

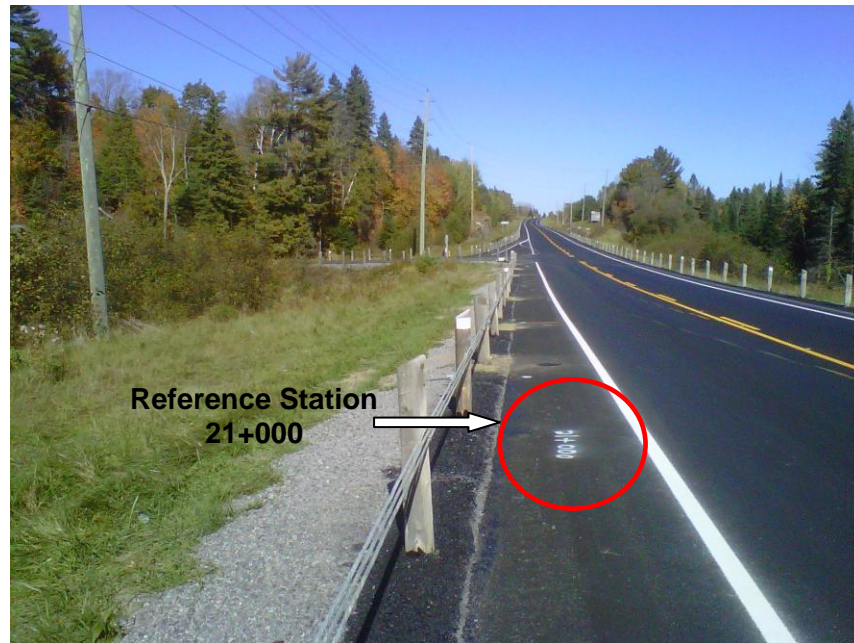


Figure 3.1 Reference station (looking north)

Table 3.1 Detail of borehole locations

Borehole ID	Station	Elevation (m)	Depth (m)	Offset (m)
BH1	21+029	255.3	4.0	15.0 Lt
BH2	21+030	255.4	5.5	10.0 Rt
BH3	21+030	259.1	9.1	5.5 Lt
BH4	21+029	259.1	12.0	4.8 Rt

#### **4. DESCRIPTION OF SUBSURFACE CONDITIONS**

The subsurface conditions are presented based on the information obtained during field and laboratory testing.

The generalized stratigraphy of the existing embankment, based on the conditions encountered in boreholes, consists of asphalt overlying a fill material that is underlain by a silt material overlying a clay material. The fill consists of a sand material underlying sand and crushed gravel. Table 4.1 summarizes the elevations and depths of boreholes, in which auger refusal was encountered during drilling. In Boreholes 1 and 2, auger refusal was not encountered within the capable depth of drilling by the hand auger.

Table 4.1 Depths and elevations of auger refusals

Borehole ID	Depth of auger refusal (m)	Elevation of auger refusal (m)
BH3	9.1	250.0
BH4	12.0	247.1

##### **4.1 Asphalt**

Asphalt was encountered in Borehole 4. The thickness of the asphalt is about 70 mm.

##### **4.2 Embankment Fill**

A fill material was identified in Boreholes 3 and 4 that were drilled on the embankment. The thickness of the fill is about 3.7 m. Occasional cobbles were identified within the fill material. Although boulders were not identified at the advanced borehole locations, site photographs indicate the presence of some rock fill and the potential for boulders to be present. Grain size distributions of the fill material are reported in borehole logs (Enclosures 3 and 4) and plots (Enclosure 5).

A sand and crushed gravel material was identified below the asphalt in Borehole 4 and at upper layer in Borehole 3. The thickness of this material is about 0.1 m.

A sand fill, based on main fraction of the material, was identified below the sand and crushed gravel. The thickness of the sand fill varies from 3.5 to 3.6 m. The fill consists of gravel varying from 7 to 32%, sand varying from 63 to 81% and fines varying from 5 to 14%. SPT values of this fill vary

from 3 to 16 and indicate the compactness varying from very loose to compact. The moisture contents vary from 4 to 16%.

#### **4.3     Silt**

A silt material was identified beneath the fill in Boreholes 3 and 4. The thickness of the silt material varies from 0.8 to 1.5 m. In Borehole 3, some organics were identified within the silt material.

According to the particle size analysis results, the silt material consists of sand varying from 3 to 8%, silt varying from 79 to 81% and clay varying from 13 to 16%. The Atterberg limits test (Enclosure 8) indicates that the silt material has a liquid limit of 30% and plasticity index of 11%, indicating low plasticity. SPT values vary from 1 to 6 and indicate consistency from very soft to firm. The moisture contents of the fill material vary from 28 to 30%.

#### **4.4     Sand**

A sand material was identified below topsoil in Boreholes 1 and 2. The thickness of the sand material is about 0.1 m. Trace amount of organics were identified within the sand material during the geotechnical investigation.

#### **4.5     Clay**

A clay material was identified below the silt material in Boreholes 3 and 4 (Enclosures 3 and 4) and below the sand material in Boreholes 1 and 2 (Enclosures 1 and 2). According to the Boreholes 3 and 4, the thickness of the clay material varies from 3.9 to 5.5 m. The Atterberg limit tests indicate that the clay has a liquid limit varying from 25 to 44% and plasticity index varying from 5 to 24%, indicating low plasticity to intermediate plasticity (Enclosure 8). The moisture contents of the clay vary from 23 to 55%.

According to the field vane shear tests, the clay exhibits intact undrained strength varying from 20 and 130 kPa, indicating consistency from soft to very stiff. The clay material shows sensitivity  $S_t$  varying from 2 to 7 and it indicates medium sensitivity to sensitive.

#### **4.6     Sandy Silt**

A sandy silt material was identified beneath the clay material in Borehole 4. The thickness of the sandy silt material is about 2.0 m.

According to the particle size analysis results, the silt material consists of 21% sand, 75% silt and 4% clay. SPT value of this material is about 4 and indicates compactness as very loose. The moisture content of this material is 21%.

#### 4.7 Groundwater

The groundwater table was identified below the ground surface during the field investigation and visual identification of soil samples. The estimated depth of groundwater level below the ground surface elevation is given in Table 4.2. The water level at the culvert was at an elevation of 255.3 m during the field investigation. The groundwater levels can be expected to vary with season and precipitation events.

Table 4.2 Probable depth of water table at boreholes

Borehole ID	Depth of water table (m) below the ground surface	Water table elevation (m)
BH1	0.0	255.3
BH2	0.0	255.4
BH3	3.2	255.9
BH 4	3.1	256.0

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**PART 2: ENGINEERING DISCUSSIONS AND RECOMMENDATIONS**

**5. PROJECT DESCRIPTION**

DST Consulting Engineers Inc. (DST) has been subcontracted by Genivar which was retained by Ministry of Transportation (MTO), Northeastern Region, to conduct a geotechnical investigation for the replacement a culvert on Highway 124. This proposed culvert is replaced by a pre-cast box structure (3000 x 2100 mm x 29.958 m). The existing culvert invert elevations are approximately 254.20 and 254.24 m. It is understood that a staged method of construction with widening of the embankment is the preferred replacement approach. Roadway protection may be required to facilitate the staged construction.

The generalized stratigraphy of the existing embankment, based on the conditions encountered in boreholes, consists of asphalt overlying a fill that is underlain by a silt material, consistency of very soft to firm, overlying a clay material indicating very soft to very stiff. In addition, the underlying clay material indicates medium sensitivity to sensitive. The fill material consists of sand and crushed gravel underlying sand indicating compactness condition from very loose to compact. Cobbles were encountered within the fill. Auger refusals were encountered at different elevations in each borehole (Table 4.1). Water table was indentified at an elevation of about 255.4 m during the geotechnical investigation.

This section presents interpretation of the geotechnical data presented in the factual report and presents geotechnical design recommendations and construction concerns for the proposed culvert replacement. A reasonable statigraphic profile interpreted from the borehole locations, strategically placed across the embankment, with one borehole, BH 4, penetrating the entire depth of the compressible silty clay layer was utilized. The geotechnical information obtained from the geotechnical investigation is sufficient enough for the necessary recommendations for the required embankments and protection systems.



## **5.1 Precast Concrete Box Culvert**

For this culvert replacement, a four sided precast concrete culvert (3000 x 2100 mm and 29.958 m in length) is to be used. Open cut excavation will be used to replace the structure. There will be no grade change for the highway.

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

### **5.1.1 Earth Excavation**

An open cut operation along the proposed culvert alignment is proposed by MTO for the culvert replacement. This method of construction may result in traffic disturbances and may require temporary surface water ditch diversion and temporary pavement support for traffic. Open cut excavations can accommodate excavation of large boulders if encountered, although the presence of large boulders was not identified at the advanced borehole locations. As a minimum, the procedures should be in accordance with OPSS 902 "Construction Specifications for Excavating and Backfilling-Structures".

If organic materials are encountered during excavation, the sub-excavations to remove any organics and wood should be completed in accordance with OPSD 203.040. It is anticipated that the existing groundwater table will be above the invert level and dewatering will be required.

Since sensitive clay was encountered beneath the embankment, the excavation for culvert replacement should be performed without disturbance to the soil. The disturbance of sensitive clay may induce deformations of the culvert even at no net increase of load, because disturbance may reduce the soil strength and increase the compressibility. During construction, any disturbed and unsuitable soils as determined by the geotechnical engineer should be replaced by compacted "Granular B" Type 1 material to minimize settlement.

### **5.1.2 Staged Construction**

Staged construction has been identified by prime consultant (Genivar) as preferred approach to maintain traffic during the construction of the culvert at this site. The proposed stage construction includes two (2) stages as given in Drawing 5. Slope stability analyses for the proposed slope geometries have been conducted and are presented in Section 5.1.4 Embankment Design.

Stage 1 is a temporary lane diversion which involves widening of the southbound lane to 8.26 m with temporary side slopes of 3H:1V and 1.25H:1V in the granular and rock fill materials respectively as well as the installation of level II roadway protection. Excavation adjacent the roadway protection is anticipated to an elevation of approximately 252.6 m to allow for placement of bedding materials. Use of temporary concrete barriers will be required.

Stage 2 is a temporary land diversion which involves widening of the northbound lane to 8.26 m with temporary side slopes of 3H:1V and 1.25H:1V in the granular and rock fill materials respectively as well as the installation of level II roadway protection. Excavation adjacent the roadway protection is anticipated to an elevation of approximately 252.6 m to allow for placement of bedding materials. Use of temporary concrete barriers will be required.

Embankment foreslopes should be reinstated as presented in Section 5.1.12 Embankment Foreslopes.

### 5.1.3 Foundation Design

The culvert will be located approximately at the same elevation and location as the existing culvert. As the proposed culvert is not expected to be heavily loaded, a shallow foundation is considered suitable for this site. The geotechnical resistance was estimated for the ultimate limit state (ULS) and serviceability limit state (SLS) for a maximum settlement of 25 mm. The resistance at ULS was calculated by applying load resistance factor of 0.5 according to the Canadian Highway Bridge Design Code (CHBDC) CAN/CSA-S6-06 section 6.6.3.6, Table 6.1. The geotechnical resistance was estimated assuming a strip footing consisting of a width equal to the width of the culvert (3.6 m), a minimum depth of 4.0 m below top of pavement and bedding material placed on undisturbed soil below an elevation of 255.2 m.

Table 5.1 Geotechnical resistances and reactions

Footing Size	Ultimate bearing capacity (kPa)	Resistance at ULS (kPa)	Resistance at SLS (kPa)
Width B = 3.6 m	100	50	45

Where unsuitable or unstable soils are encountered, the foundation soils must be removed to suitable soils and replaced to the foundation grade with Granular "A" material meeting OPSS 1010 specifications and compacted to a minimum of 95 % of standard Proctor maximum dry density.

#### 5.1.4 Embankment Design

Slope stability analyses were carried out with limit equilibrium methods using Geoslope version 2004 software applying Morgenstern and Price methods, and applying a pseudo-static analysis. Slope stability analyses were performed under the following slope conditions with an embankment height of up to 3.5 m:

- Reinstated embankment with minimum 2H:1V granular fill foreslopes,
- Reinstated embankment with 1.5H:1V rock fill foreslopes,
- Widened embankment with temporary 1.25H:1V rock fill foreslopes.

Results indicate that stability will meet or exceed suitable design factors of safety under both short and long term conditions for the evaluated slope configurations and are presented in Table 5.2.

Table 5.2 Summary of stability analyses

Slope Condition	Foreslope Gradient	Drained or Undrained Analyses	Factor of Safety
Reinstated Embankment with Granular Fill	2H : 1V	Drained	1.7
		Undrained	1.7
Reinstated Embankment with Rock Fill	1.5H : 1V	Drained	1.3
		Undrained	1.4
Temporary Embankment with Rock Fill	1.25H : 1V	Drained	1.3
		Undrained	1.3

This analyses considered the soil parameters as defined in Table 5.3 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.

Excavation of temporary side slopes above the water table that do not support traffic should not be steeper than 1.0H:1.0V, although, flatter slopes may be required depending on construction methods. Temporary rock fill slopes above the water table supporting traffic during the construction stages should not be steeper than 1.25H:1V. Temporary granular slopes above the water table supporting traffic during the construction stages should not be steeper than 2H:1V. Design of temporary slopes below the water table will depend on the dewatering method. Embankment foreslopes should be reinstated as indicated in Section 5.1.12 Embankment Foreslopes.

The trench width must be sufficient to permit proper use of compaction equipment suited for the material to be compacted, to reach the degree of compaction required, and to accommodate within the space available as per SP105S10, "Construction Specification for Compaction".

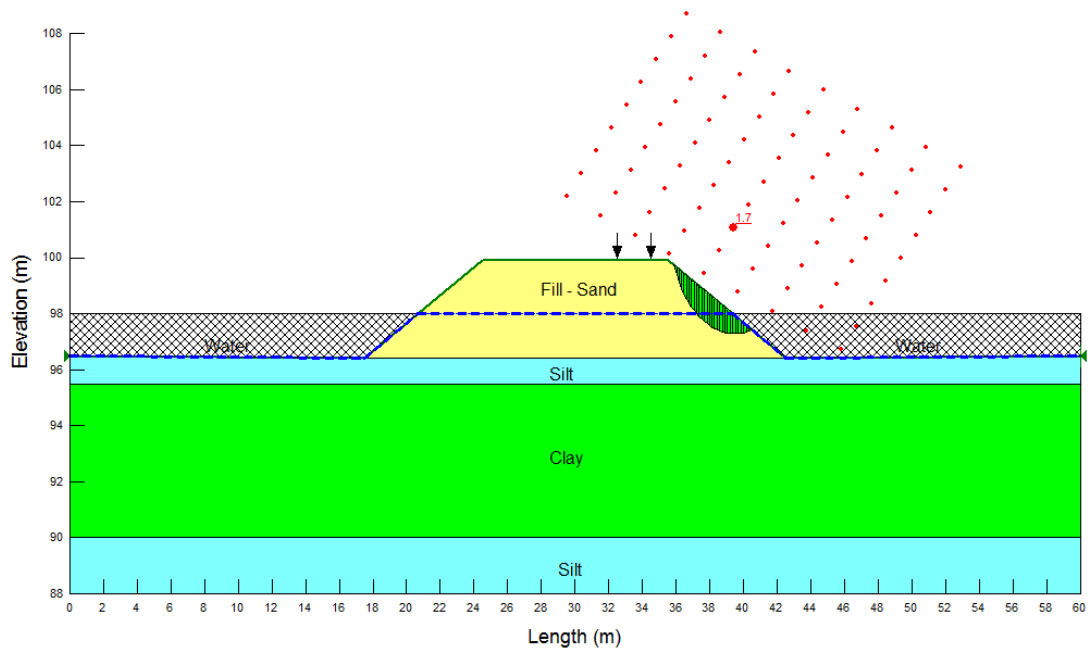


Figure 5.1 Slope stability analysis of reinstated embankment with 2H:1V granular fill foreslopes in an undrained condition

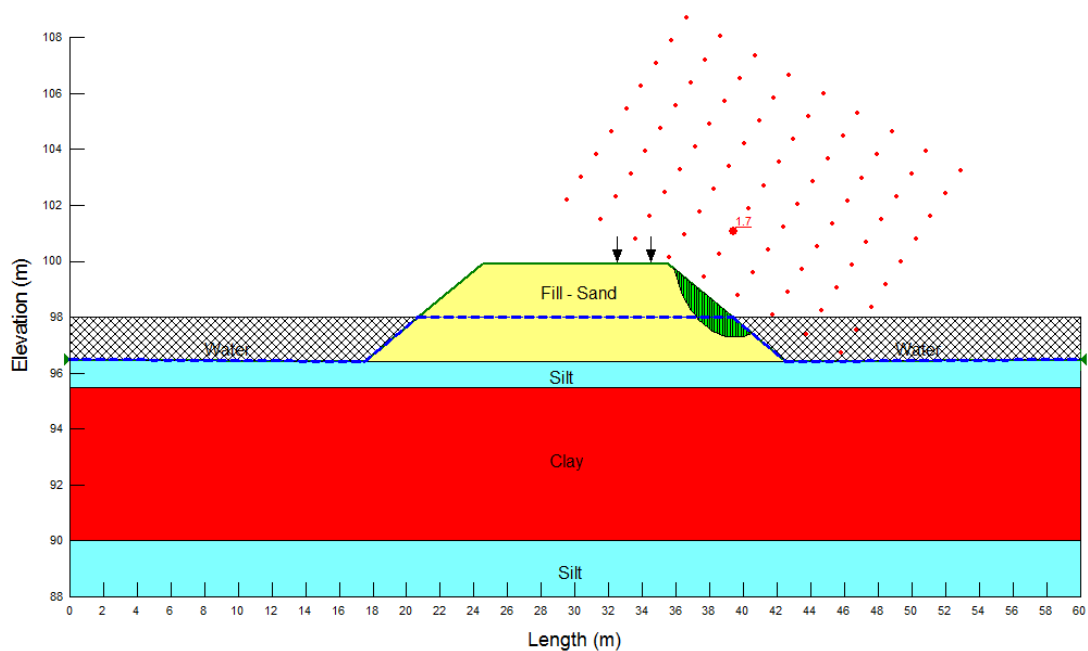


Figure 5.2 Slope stability analysis of reinstated embankment with 2H:1V granular fill foreslopes in a drained condition

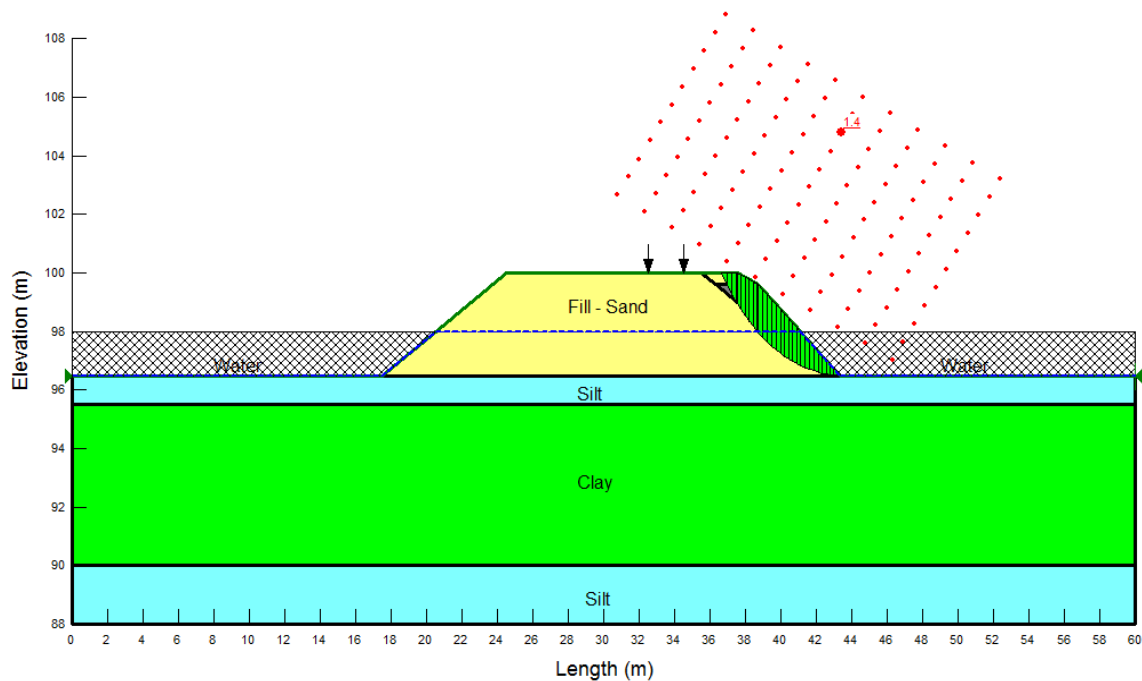


Figure 5.3 Slope stability analysis of reinstated embankment with 1.5H:1V rock fill foreslopes in an undrained condition

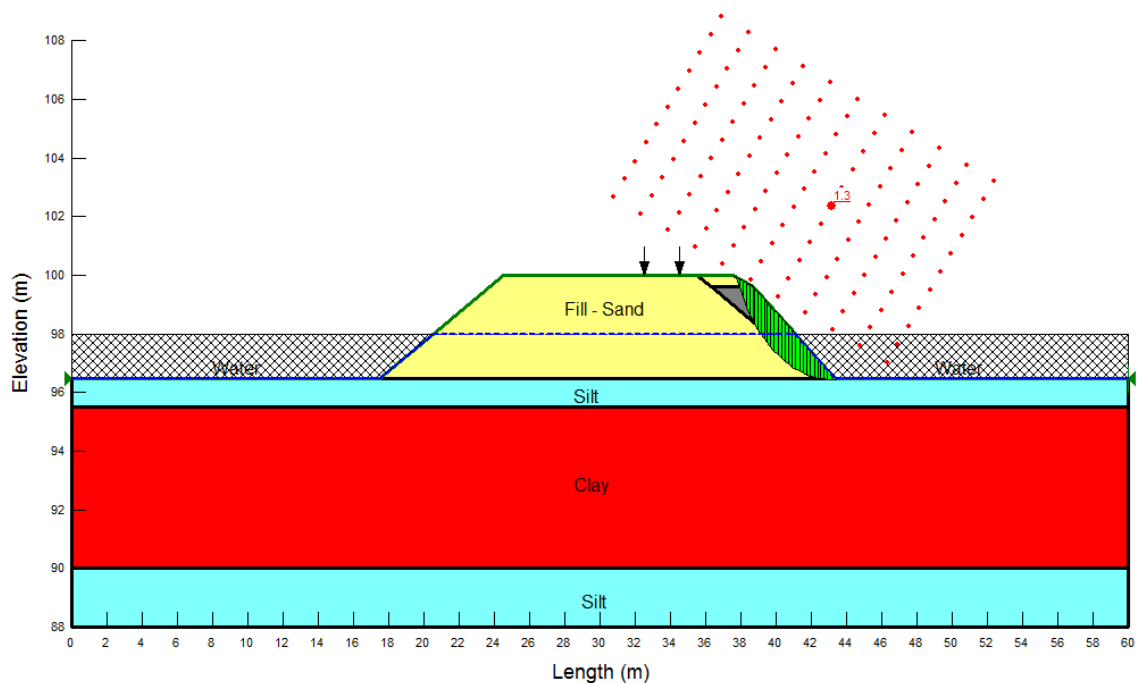


Figure 5.4 Slope stability analysis of reinstated embankment with 1.5H:1V rock fill foreslopes in a drained condition

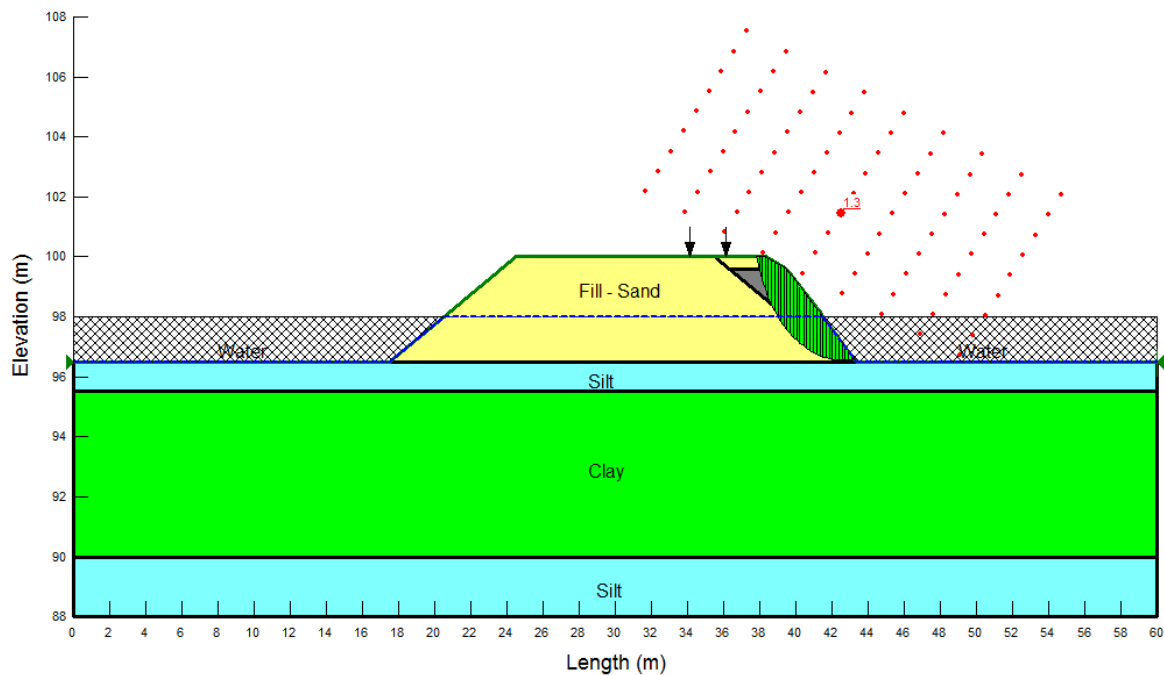


Figure 5.5 Slope stability analysis of temporary embankment with 1.25H:1V rock fill foreslopes in an undrained condition

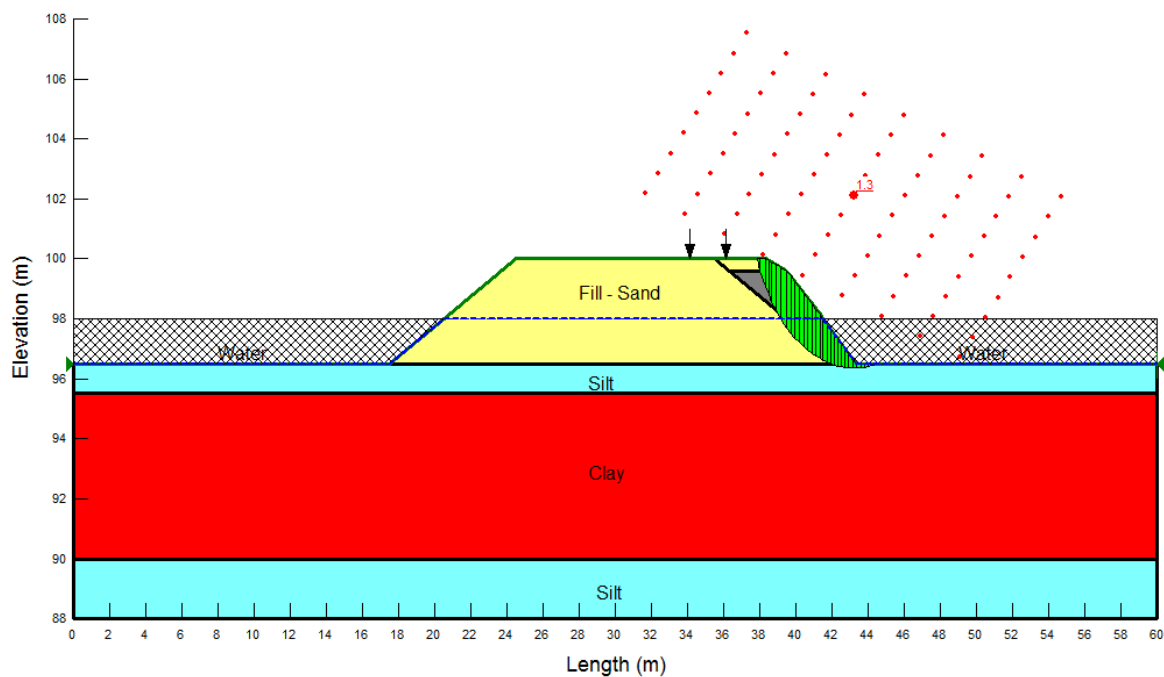


Figure 5.6 Slope stability analysis of temporary embankment with 1.25H:1V rock fill foreslopes in a drained condition

### 5.1.5 Lateral and Sliding Resistances

The analysis of horizontal and vertical effects of earth loads on the culvert can be performed considering soil parameters given in Table 5.1 and assuming linearly variation of stress change with the depth as described in Section 7.8.5.3.2 in Canadian Highway Bridge Design Code. Temporary bracing and shoring may be designed using the typical soil parameters given in Table 5.1, but the designer/contractor should verify the appropriate soil parameters for the designs of specific bracing and shoring system.

It is recommended that all excavations be either adequately sloped or securely shored and braced to prevent earth caving and to provide a safe and stable work area. The design should incorporate the effects of hydrostatic pressure, traffic surcharge and retained sloping earth conditions in the bracing design.

Table 5.3 Typical soil parameters for earth loads

Soil type	Unit weight (kN/m <sup>3</sup> )	Internal friction angle (Deg)	Interface friction angle, $\delta$ (Deg)	Adhesion factor	Intact undrained shear strength (kPa)	Sensitivity
Rock Fill	22	45	-	-	-	-
Granular A	21	35	17	-	-	-
Granular B	21	35	17	-	-	-
Sand	20	32	15	-	-	-
Silt	19	30	14	-	40	-
Clay	19	27	-	0.5	30	3.0

### 5.1.6 Roadway Protection

Roadway protection for this project should be constructed in accordance with the requirements of the Occupational Health and Safety Act of Ontario (OHSA), O.Reg. 213/91. According to O.Reg. 213/91, s.226, the soils in the area of interest classify as Type 3 and Type 4 if located above and below the water table respectively. Type 3 soils generally are stiff to firm and compact to loose or are previously excavated soil, exhibit signs of surface cracking, exhibit signs of seepage, if it is dry, may run easily into a conical pile and have a low degree of internal strength. Type 4 soils generally are soft to very soft and very loose in consistency, very sensitive and upon disturbance are



significantly reduced in natural strength, run easily or flow unless it is completely supported before excavation procedure, have almost no internal strength, are wet or muddy and exerts substantial fluid pressure on its supporting system. In accordance with O. Reg. 213/91, s.227 (3), if an excavation contains more than one type of soil, the soil shall be classified with the highest number as described in section 226. These should be assessed and confirmed in the field as construction progresses.

Since roadway protection is required during the culvert replacement, installation of a cantilevered sheet pile system may be considered to ensure the stability of the bank and is a feasible option. The design of sheet piles may be performed using the typical soil parameters given in Table 5.3, but the designer/contractor should verify the appropriate soil parameters for the designs.

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 also the Occupational Health and Safety Act of Ontario. The contractor's method and equipment must be suitable for the site conditions and materials used.

#### 5.1.7 Bedding

For the conditions at this site, it is likely that the proposed construction will be undertaken with dewatering. The foundation soils, sensitive clay in particular, will be very susceptible to disturbance and weakening as a result of traffic, standing water and frost. Any foundation soils that could be disturbed should be protected. The bottom of the excavation on which the culvert or granular pad is to rest should not be disturbed. In soft conditions, the bedding placement should commence immediately after the final removal of material to the foundation level has been completed.

As sensitive clay is expected below the bedding, an initial thicker granular lift and static compaction is recommended to minimize the disturbance on sensitive clay. The proposed bedding thickness of 1.25 m is acceptable and should extend to a minimum width (half of the width of culvert) beyond all sides of the culvert. The bedding material should consist of "Granular A" as per Soil Group I in accordance with Table 7.4 of the Canadian Highway Bridge Design Code. The "Granular A" should be in accordance to OPSS 1010 and SP110S13. The "Granular A" should be placed in layers not exceeding 200 mm in thickness, loose measurement, and each layer compacted to a minimum of 95 % of standard Proctor maximum dry density. The middle one-third of the culvert width of the top bedding layer, having minimum thickness of 75 mm, shall be loosely placed and

uncompacted.

#### 5.1.8 Sidefill and Overfill

The material used for culvert sidefill should not contain debris, organic matter, frozen materials, or large stones of a diameter greater than one-half the thickness of the compacted layers being placed or 100 mm, whichever is smaller. Soils should be deposited uniformly on each side of the structure in order to prevent lateral displacement. The minimum width of the sidefill should be at least half of the culvert width in each side. The sidefill should consist of Granular A” and compacted to 95% of standard Proctor maximum dry density.

Overfill should consist of “Granular A” and should be compacted not be greater than the compaction or equivalent stiffness of soils in the sidefill zone and bedding. The backfill materials should be separated from the adjacent soil with a non-woven Class II geotextile specified in OPSS 1860.

When the concrete culvert is installed on the undisturbed original ground and fill material is placed around and over the culvert, relative settlements between the fill adjacent to the sides of the culvert and the fill directly over the culvert generates downward frictional forces on the culvert, also effecting a load transfer. This increased load on the culvert can be represented by a column of fill of width  $K \times B$ , where  $K$  is a load transfer coefficient and  $B$  is the width of the culvert. For the design purpose,  $K$  can be assumed as 1.35.

#### 5.1.9 Channel Diversion and Dewatering

The culvert should be replaced by diverting the creek channel temporarily adjacent to the existing culvert. It is important to ensure that a flood in the channel does not cause damage to the partly constructed permanent works, to the temporary works or to plant. Floods have a habit of occurring overnight or at weekends and inadequate temporary works can fail with expensive consequences.

If the creek has comparatively a small amount of flow that may depend on the season, it may be feasible for the creek flow to be directed by staging construction. In order to prevent back up of water from upstream and downstream, a dyke made of sand bags has sometimes been used as a hydraulic barrier. However, a sheet pile vertical cut-off wall will provide better control of both surface and groundwater. A suitable sump and pump system will be required to dewater and stabilize the excavation. It should be noted that depending on the season, depth of excavation and amount of

water flow through the creek may vary. The contractor should be prepared to tackle this situation.

A continuous dewatering operation must be provided to keep the excavation stable and free of water. The excavation must be monitored daily throughout the duration of excavation until the completion of backfilling to confirm this. The dewatering system must be maintained and the surrounding area monitored for impacts to items such as, but not limited to, settlement and groundwater usage. The control of water from the dewatering operation should be accordance with OPSS 518 "Construction Specification for Control of Water from Dewatering Operations".

#### 5.1.10 Erosion Control

Erosion control is essential at inlet and outlet for the successful performance of a culvert. Generally, rip-rap is used to avoid the erosion at inlet and outlet of the culvert. The rip-rap slows down the flow close to the channel bed and prevents culvert failure by undermining.

To prevent erosion of the surrounding soils at the inlet, rip-rap Treatment should be applied accordance with OPSD 810.020 "Rip-Rap Treatment for Ditch Inlets" and OPSS 511 and SP511S01 "Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting".

The outlet should be rip-rapped to prevent erosion of the surrounding soils accordance with OPSD 810.010 "Rip-Rap treatment for Sewer and Culvert Outlets" and OPSS 511 and SP511S01 "Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting".

To prevent undermining the bedding of the culvert, cutoff walls should be installed along the entrance and exit end bottom sides of culvert. Cutoff wall should be designed based on velocity of the water flow and the type of soil underneath.

Considering the replacement of Granular A material underneath and in front of the inlet and replacement of cover material with clear stone or granular material, a clay seal should be considered to minimize underflow. A blanket clay seal should be at minimum 300 mm thick and extend 2 m beyond the fill materials. Clay seals should be constructed in accordance with OPSS 422 and have material properties as specified in OPSS 1205. Alternatively, a geosynthetic clay liner installed to manufacturer's specifications may also be suitable.

The temporary erosion and sedimentation measures during the construction of culvert should be controlled as described in OPSS 577 "Construction Specification for Temporary Erosion and Sedimentation Control Measures".

#### 5.1.11 Frost Protection

In accordance with OPSD 3090.100 “Foundation Frost Depths for Northern Ontario”, the frost penetration at this location is about 1.8 m. The frost susceptible soils should not be used adjacent to the culvert wall within the depth of frost penetration from the road surface. The soils under the culvert are highly frost susceptible (capable of forming thick ice lenses with the associated pressures and heave).

During winter season, ice may form inside the culvert and a low flow rate may assist the ice formation. It is expected that ice may extend to the culvert invert and frost could therefore extend into the soils below the culverts, possibly as deep as 1.8 m. The frost heave may generate additional stresses on the culvert foundation and walls.

Two design approaches are commonly applied, either designing 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 removing the frost susceptible soils within the frost zone. As the frost penetration is extended below the invert level of the culvert, the frost protection should be in accordance with OPSD 803.010 “Backfill and Cover for Concrete Culverts, Frost Penetration Line below Top of Culvert”.

If sub-excavation for frost effects is carried out in the dry (with adequate dewatering controls), the material can be replaced with Granular A 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 sub-excavation (less than 1.8 m) may also be considered to reduce differential stresses associated with frost; however the exact pressures and movements cannot be accurately quantified.

#### 5.1.12 Embankment Foreslopes

Existing culvert foreslopes are approximately 3H:1V and 2H:1V on the west and east embankments respectively. The foreslopes should be reinstated with a slope not steeper than 2H: 1V if being constructed with granular materials. The foreslopes should be reinstated with a slope not steeper than 1.5H: 1V if being constructed with rock fill.

### 5.1.13 Construction Concerns

The main construction issues that need to be addressed for this site are provisions required for roadway protection, diversion of the channel, excavation below the water table, construction on sensitive soils and reinstatement of the embankment fill. These items are important for the successful installation of the culvert.

Sensitive clays exhibit lower strength when it is disturbed. The load producing shear stress that is less than intact shear strength of the clay may produce a failure, when the clay is disturbed. The construction on sensitive clay should be performed with additional care. A static compaction method is recommended to achieve the required compaction during construction this culvert.

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

## 6. REFERENCES

*Canadian Highway Bridge Design Code* (2006), CAN/CSA-S6-06, A National Standard of Canada, Canadian standards Association.

Municipal and Provincial Common, Volume 1 - General & Construction Specifications, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSS 510, 511, 518, 577, 902.

Municipal and Provincial Common, Volume 3 - Drawings for Roads, Barriers, Drainage, Sanitary Sewers, Watermains and Structures, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSD 203.040, 803.010, 810.010, 810.020, 3090.100.

Municipal and Provincial Common, Volume 2 - Material Specifications, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSS 1010, 1860.

Special Provisions, Ontario Provincial Standards, SP110S13, SP105S10, SP511S01.

## 7. 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:



for

Loges Paramaguru, PhD.  
Geotechnical Specialist

Reviewed by:



Dr. M W Bo, PhD., P. Eng, P.Geo, Int PE,  
C.Geol, C. Eng, Eur Geol, Eur Eng  
Principal / Director (GeoServices)

Reviewed by:



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.

**APPENDIX 'B'**

**NONSTANDARD PROVISIONS**

## **DEWATERING STRUCTURE EXCAVATION - Item No.**

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### **Non-Standard Special Provision**

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#### **902.01 SCOPE**

Section OPSS 902.01 of OPSS 902 is amended by the addition of the following:

As part of the work under this item, the Contractor shall:

- Carry out any additional field investigation the Contractor deems necessary in order to engineer the unwatering systems;
- Design and install dewatering systems to construct the work in the dry;
- Carry out works necessary for the dewatering system that may include sheet piling, tremie concrete seal, sand bagging, etc.;

The Contractor is advised that the use of a suitable sump and pump system is required for working under dry conditions and to prevent disturbance of the excavation base through hydraulic heave. It should be noted that depending on the season, depth of excavation and amount of water flow through the creek may vary.

The Contractor shall provide a continuous dewatering operation to keep the excavation stable and free of water. The excavation must be monitored daily throughout the duration of excavation until the completion of backfilling to confirm this. The dewatering system must be maintained and the surrounding area monitored for impacts to items such as, but not limited to, settlement and groundwater usage.

Section OPSS 902.01 of OPSS 902 is amended by the following subsection:

##### **902.01.01 Flow Rates**

The Contractor must satisfy himself with the local conditions and anticipated water flows, levels and flow velocity to be met with during construction. He shall make his own estimate of the facilities required and difficulties to be encountered including the nature of subsurface materials and conditions. For the protection scheme water flows, the average daily flow rate is 5.44 m<sup>3</sup>/s.

#### **902.03 DEFINITIONS**

Section OPSS 902.03 of OPSS 902 is amended by the addition of the following:

<b>Stamped:</b>	Refers to drawings or details that have been reviewed and stamped "Conforms With Contract Documents". The stamp shall include the date and signature of the Quality Verification
-----------------	--

Engineer (QVE).

**Quality Verification Engineer (QVE):** An Engineer licensed to practice in the Province of Ontario who has a minimum of five (5) years of experience in the field of design and/or construction of dewatering systems. The Contractor shall retain the QVE to ensure conformance with the contract document.

**Dewatering System Design Engineer:** An Engineer licensed to practice in the Province of Ontario who has a minimum of five (5) years of experience in the field of design and/or construction of bridges. In addition, the Dewatering System Design Engineer shall have had responsible experience in the design of at least 5 other dewatering systems. The Contractor shall retain the Dewatering System Design Engineer to ensure conformance with the contract documents and issue certificate(s) of conformance for the design.

## **902.04 SUBMISSION AND DESIGN REQUIREMENTS**

Section OPSS 902.04 of OPSS 902 is amended by the addition of the following:

Design of components of the dewatering systems shall be in accordance with CAN/CSA-S6-00 and standard referenced therein.

### **Submission of Shop Drawings**

All shop drawings submissions shall bear the seal and signature of the Dewatering System Design Engineer.

The Contractor shall submit to the Quality Verification Engineer shop drawings for review and stamping.

At least two weeks prior to the commencement of dewatering system construction, the Contractor shall submit to the Contract Administrator, for information purposes only, four (4) sets of stamped drawings/calculations of the dewatering system.

The Contractor shall, at least three (3) weeks prior to the commencement of the dewatering system installation, submit to the QVE for review, four sets of drawings and calculations indicating:

- the dewatering system design, including design criteria and loading;
- the location, type and dimensions of each dewatering system to be used;
- a schematic showing the configuration of all dewatering systems;
- the material and dimensions of dewatering system components to ensure stability of the design excavation and the dewatering system, and the construction sequence and schedule of each component for which the dewatering system is designed.

The QVE shall review all calculations, construction details, shop drawings and procedures.

All submissions shall bear the seal and signature of the Dewatering System Design Engineer and QVE.

### **Certificates of Conformance**

The Dewatering System Design Engineer shall inspect the installation of each component prior to the executing of the next stage in that dewatering system. After the installation/construction of each component, the Contractor shall submit a Certificate of Conformance to the Contract Administrator, sealed and signed by the Dewatering System Design Engineer. The Certificates of Conformance shall state that the dewatering system is in place, and has been installed in conformance with the stamped shop drawings and the Contract Drawings.

The Contractor will note that several Certificates of Conformance may be required, each to coincide with each dewatering system installation.

### **902.07 CONSTRUCTION**

Section OPSS 902.07 of OPSS 902 is amended by the addition of the following:

All concrete work must be carried out in the dry.

Minimum dimensions for the inside face of the dewatering system shall be sufficient for installation of the new culvert.

### **902.10 BASIS OF PAYMENT**

Section OPSS 902.10 of OPSS 902 is amended by the addition of the following:

Payment at the contract price for the dewatering systems shall be full compensation for all labour, equipment and materials to carry out the work.

## **NOTICE TO CONTRACTOR**

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Special Provision

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### **FOUNDATION CONDITIONS**

The Contractor is advised of the following foundation conditions:

Occasional cobbles were identified within the fill material. Although boulders were not identified at the advanced borehole locations, site photographs indicate the presence of some rock fill and the potential for boulders to be present.

The foundation soils, sensitive clay in particular, will be very susceptible to disturbance and weakening as a result of traffic, standing water and frost. Any foundation soils that could be disturbed should be protected. The bottom of the excavation on which the culvert or granular pad is to rest shall not be disturbed. The bedding placement shall commence immediately after the final removal of material to the foundation level has been completed.



# **DRAWINGS**

METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SHOWN. STATIONS  
IN KILOMETRES + METERS

CONT No 5010-E-0007

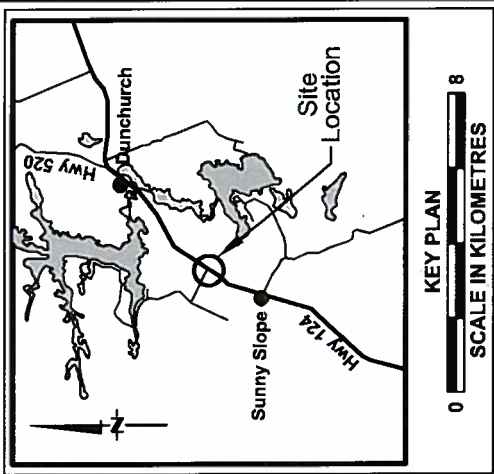
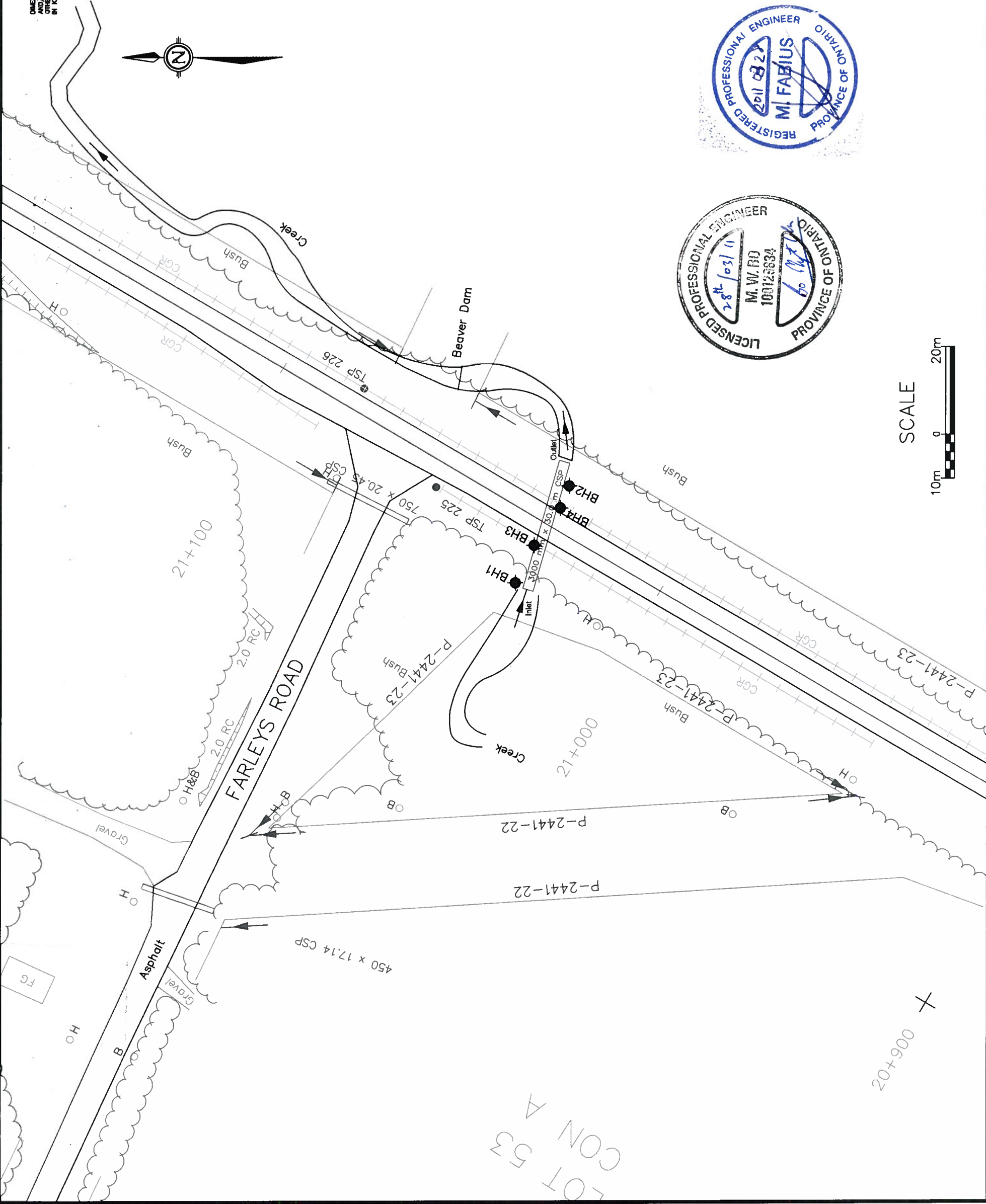
GWP No 5424-06-00

WP No 5424-06-01

Site No 44-288

CULVERT REPLACEMENT  
AT FARLEY CREEK  
Highway 124 - Hagerman Twp.  
Borehole Location Plan

SHEET



LEGEND

Borehole

Borehole with DCPT

Dynamic Cone Penetration Test (DCPT)

Rock Probe

Blows/0.3m (Std. Pen Test, 475 J/Blow)

Water level at time of investigation

Benchmark

Fill

Organics

Topsoil

Till

Bedrock

Sand

Silt

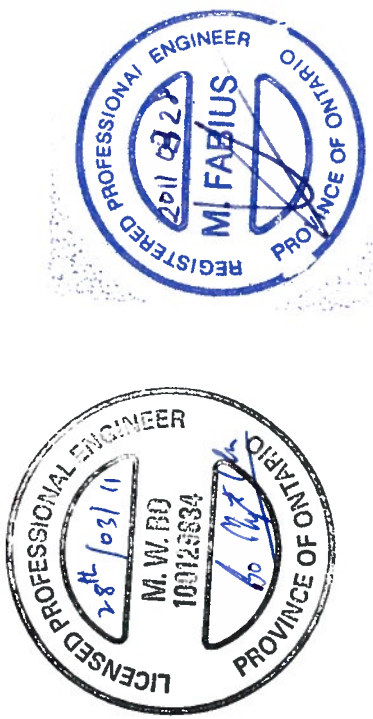
Clay

Sand & Gravel

Boulders

No.	Elevation	Northing	Eastings	Station	Offset
BH1	255.306	5054582	275366	21+029	15.0 LT
BH2	255.388	5054570	275328	21+030	16.0 RT
BH3	256.143	5054578	275315	21+030	5.5 LT
BH4	256.066	5054572	275323	21+029	4.8 RT


NOTE: Coordinates based on MTM Zone 10

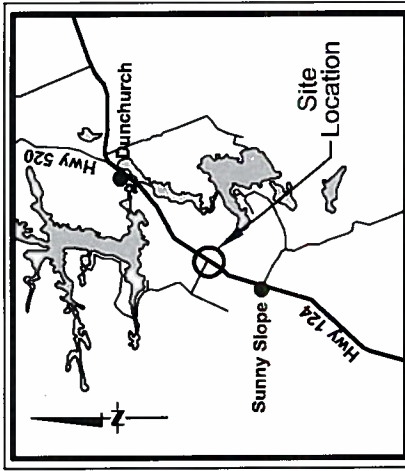



















NOTE:  
The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.

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CONT No 5010-E-0007		SHEET
GWP No 5424-06-00		20
WP No 5424-06-01		
Site No 44-288		
CULVERT REPLACEMENT AT FARLEY CREEK Highway 124 – Hagerman Twp. Borehole Location & Soil Stratigraphy		

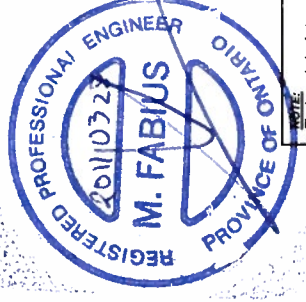
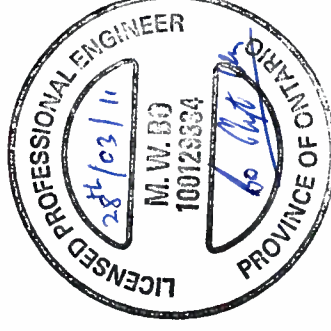


LEGEND					
	Borehole		Fill		Sand
	Borehole with DCPT		Organics		Silt
	Dynamic Cone Penetration Test (DCPT)		Topsoil		Clay
	Rock Probe		Till		Sand & Gravel
	Blows/0.3m (Std. Pen Test, 47.5 J/Blow)		Bedrock		Boulders
	Water level at time of investigation.				
	Benchmark				

No.	Elevation	Northing	Easting	Station	Offset
BH1	255.308	5054582	275506	21+029	15.0 LT
BH2	255.388	5054570	275528	21+030	10.0 RT
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BH4	256.088	5054572	275523	21+029	4.8 RT

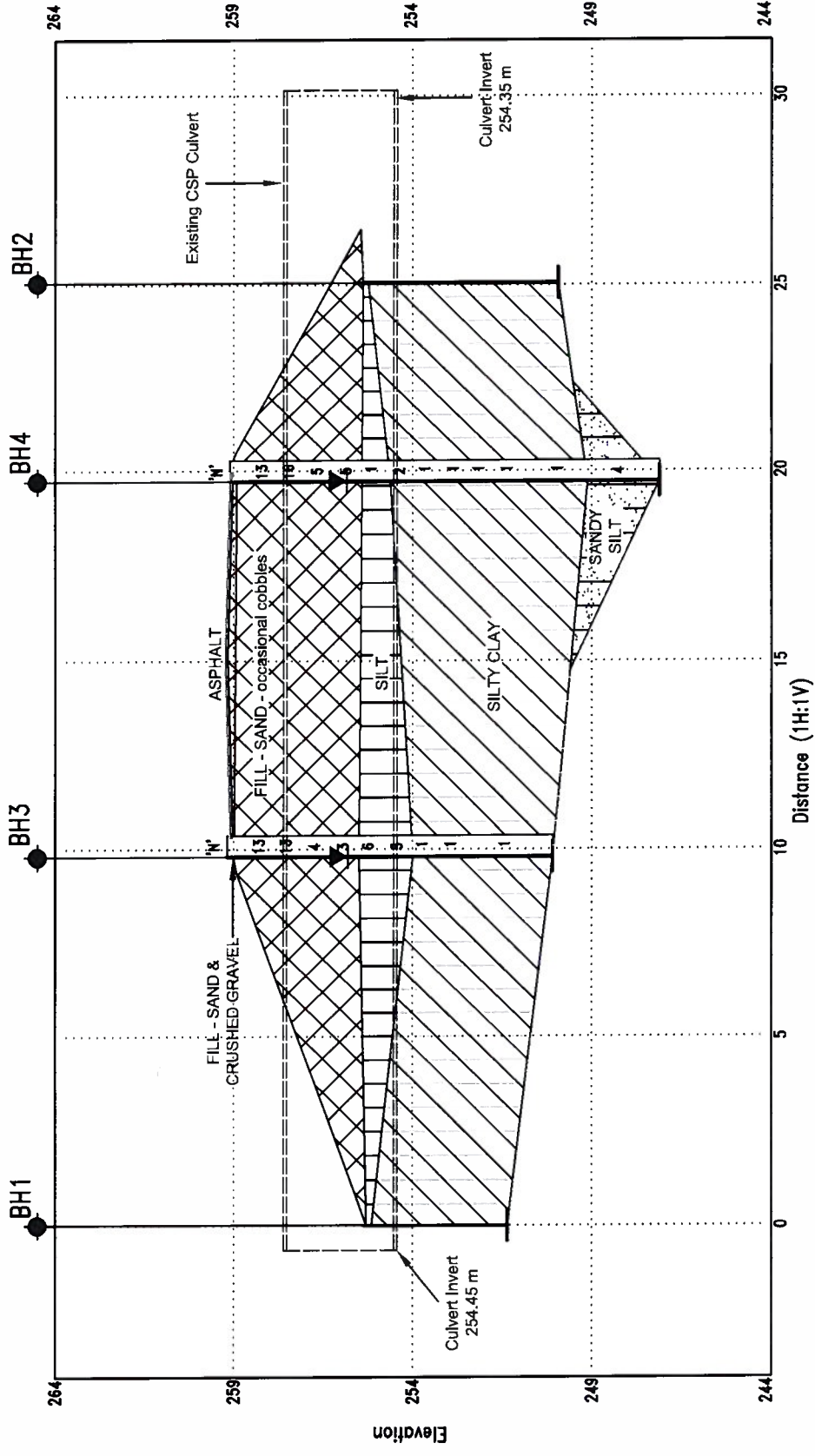
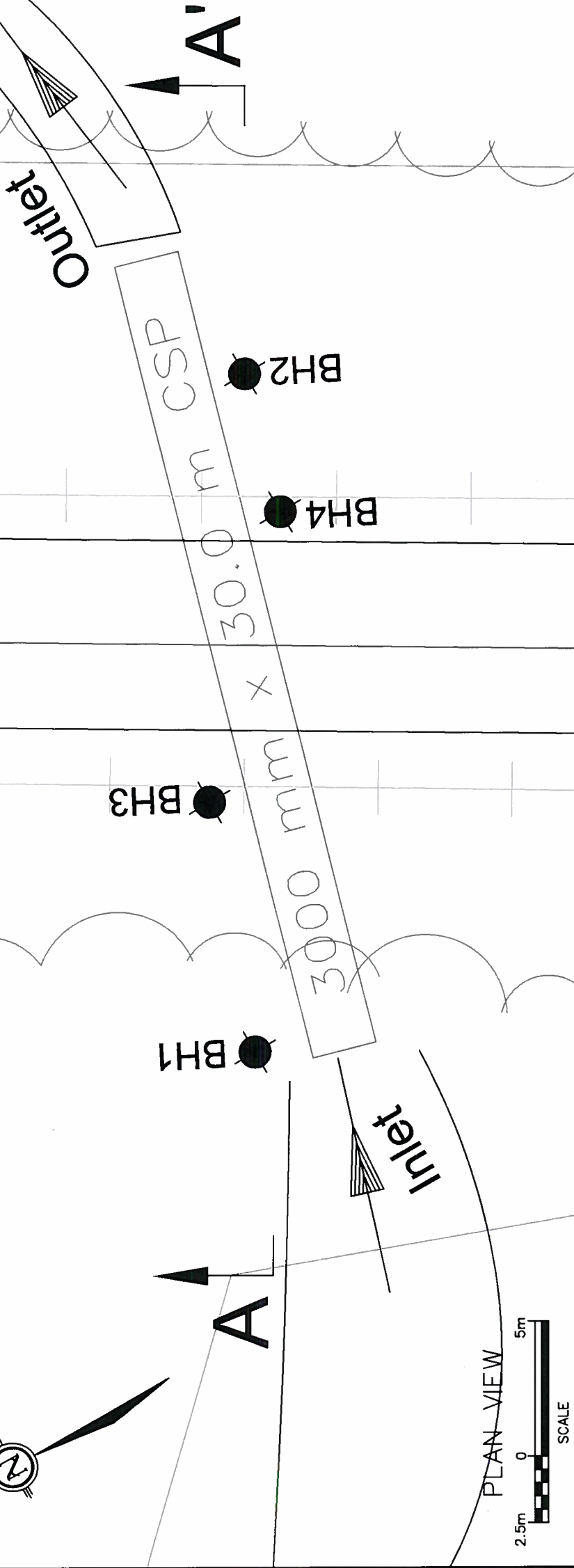
**NOTE: Coordinates based on MTM Zone 10**



**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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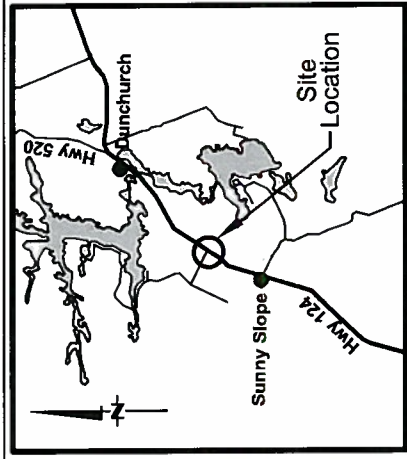
## DRAWING 2





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DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SHOWN. STATIONS  
IN KILOMETERS + METERS

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WP No	5424-06-01	
Site No	44-288	
CULVERT REPLACEMENT AT FARLEY CREEK Highway 124 - Hagerman Twp. Borehole Location & Soil Stratigraphy		SHEET 21

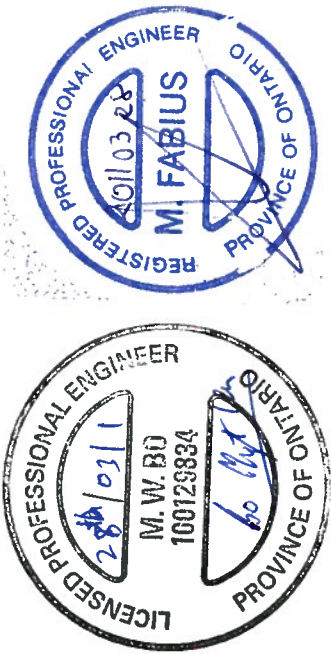
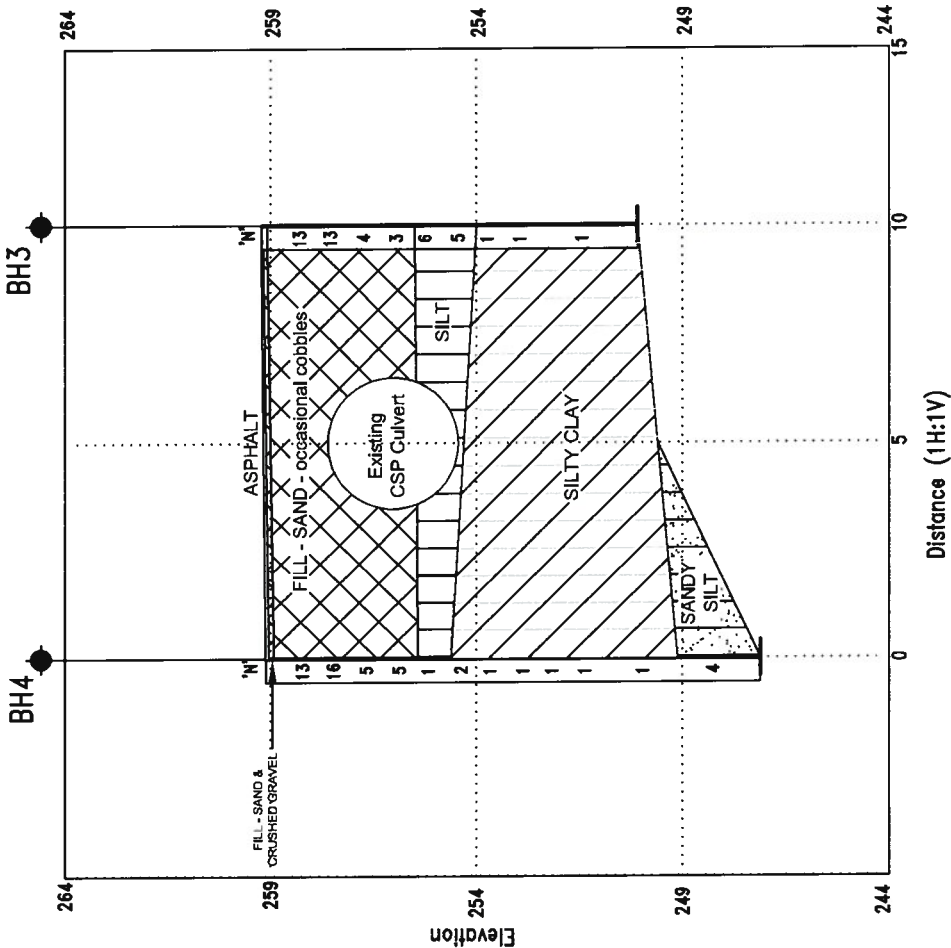
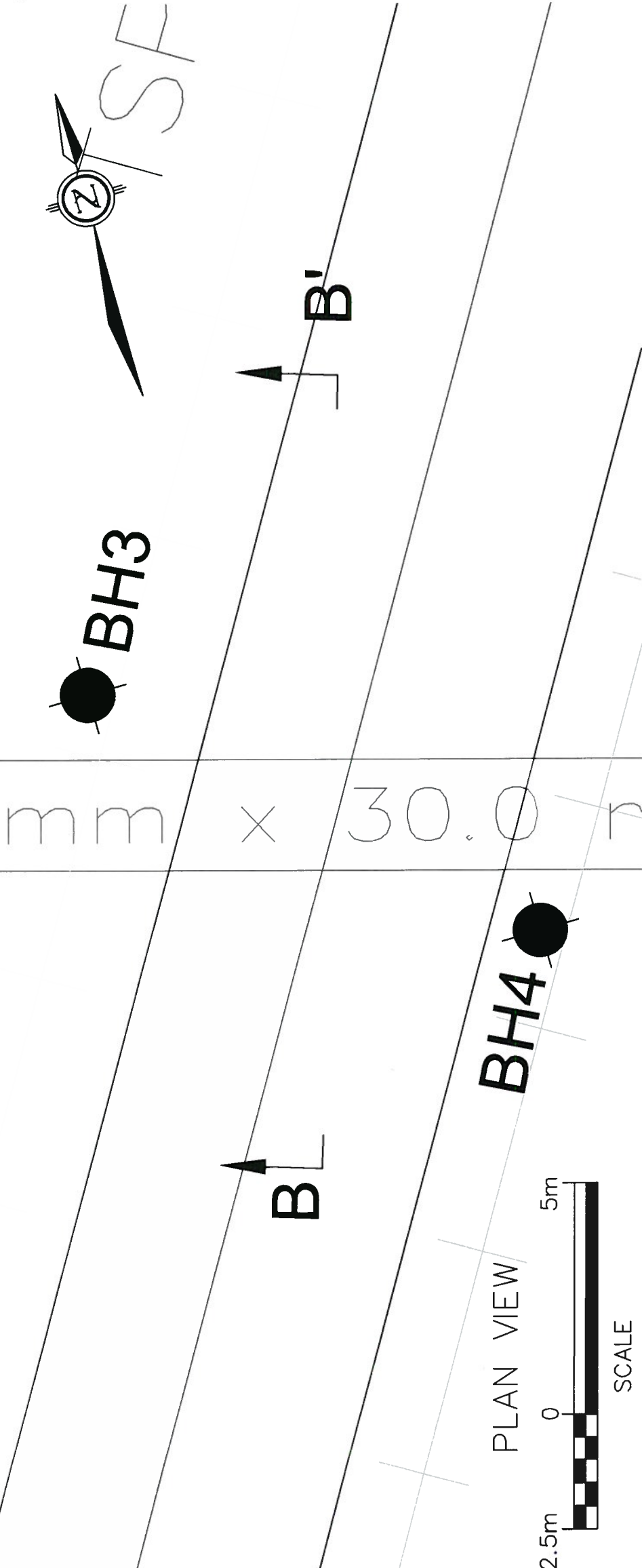


LEGEND			
	Borehole		Dynamic Cone Penetration Test (DCPT)
	Rock Probe		Blows/0.3m (Std. Pen Test, 475 J/Blow)
	Water level at time of investigation.		Benchmark
	Fill		Organics
	Topsoil		Till
	Bedrock		Sand
	Silt		Clay
	Sand & Gravel		Boulders
No.	Elevation	Northing	Easting
BH1	255.306	5054582	275306
BH2	255.386	5054570	275328
BH3	259.143	5054578	275315
BH4	259.068	5054572	275323
			Station
			15.0 LT
			10.0 RT
			5.5 LT
			4.8 RT

NOTE: Coordinates based on NTM Zone 10

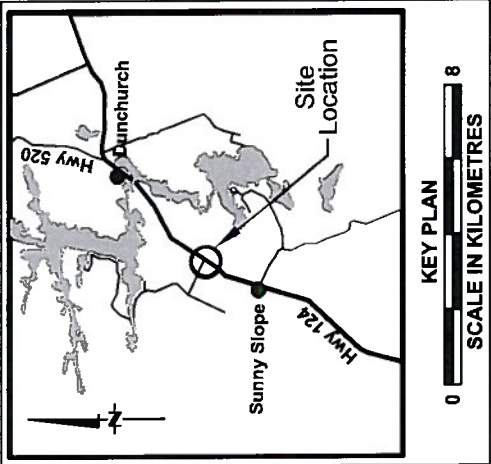
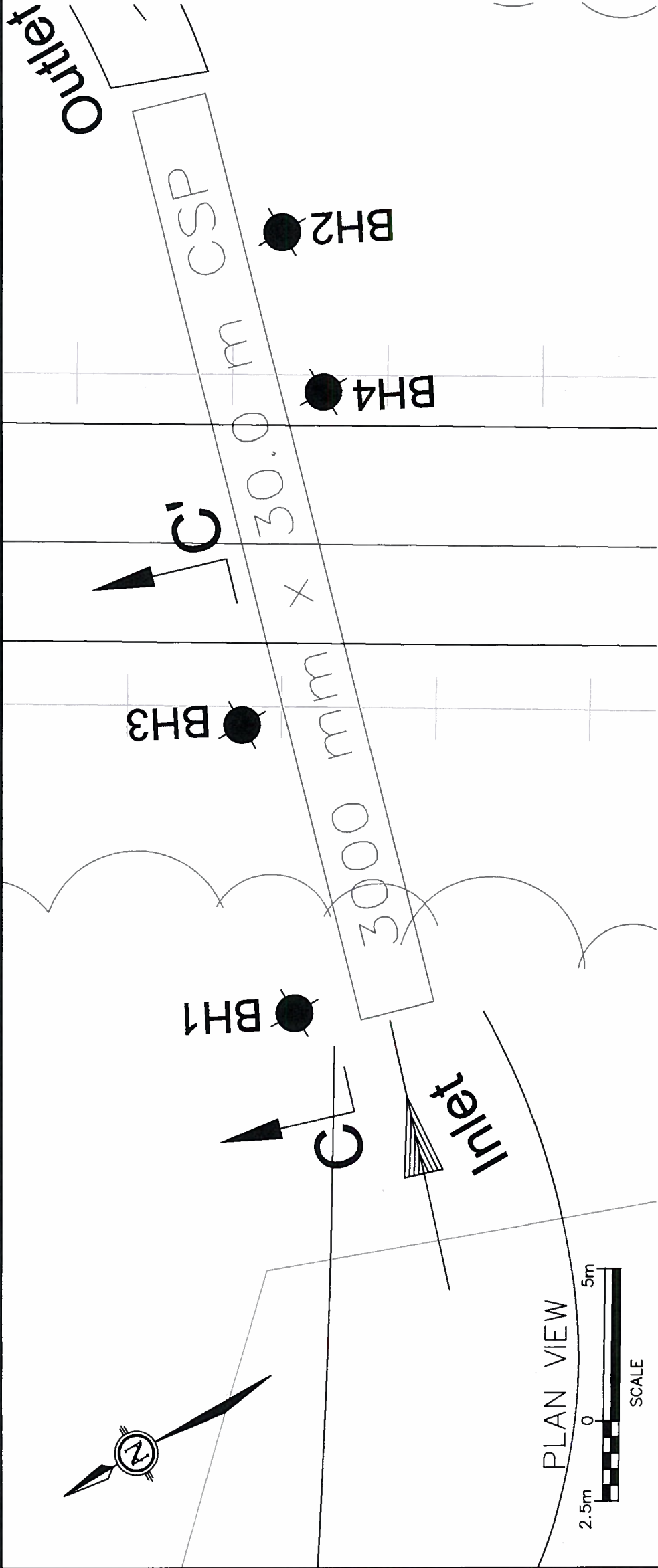
NOTE: The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.

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METRIC  
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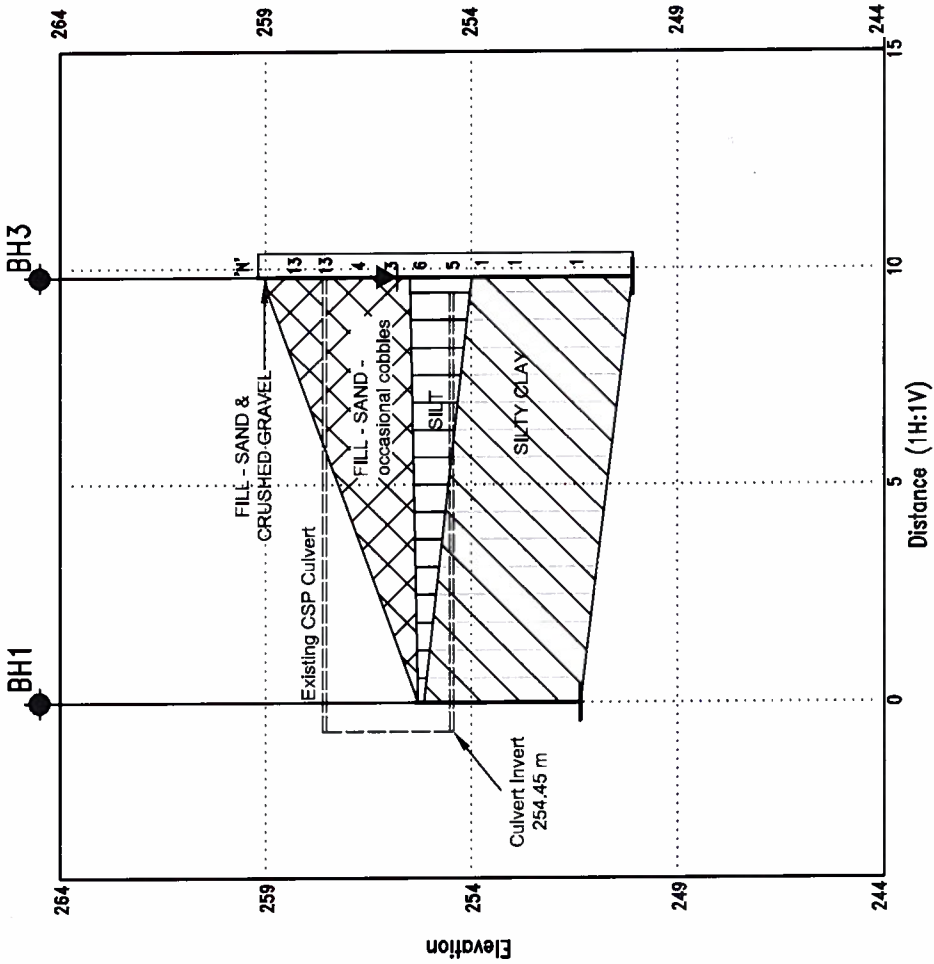
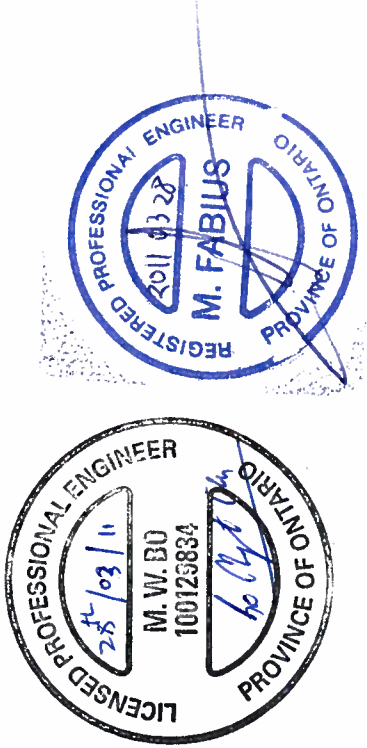
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GWP No	5424-06-00	
WP No	5424-06-01	
Site No	44-288	
CULVERT REPLACEMENT AT FARLEY CREEK Highway 124 - Hagerman Twp. Borehole Location & Soil Stratigraphy		SHEET 22



LEGEND				
	Borehole		DCPT	
	Borehole with DCPT		Rock Probe	
	Blows/0.3m (Std. Pen Test, 475 J/Blow)		Water level at time of Investigation	
	Benchmark		Fill	
	Organics		Topsoil	
	Till		Sand & Gravel	
	Bedrock		Boulders	
	Sand		Silt	
	Clay		Sand & Gravel	
	Boulders		Boulders	

No.	Elevation	Northing	Easting	Station	Offset
BH1	255.308	5054582	275306	21+029	15.0 LT
BH2	255.388	5054570	275338	21+030	10.0 RT
BH3	259.143	5054578	275515	21+030	5.5 LT
BH4	259.088	5054572	275323	21+029	4.8 RT

NOTE: Coordinates based on MTM Zone 10



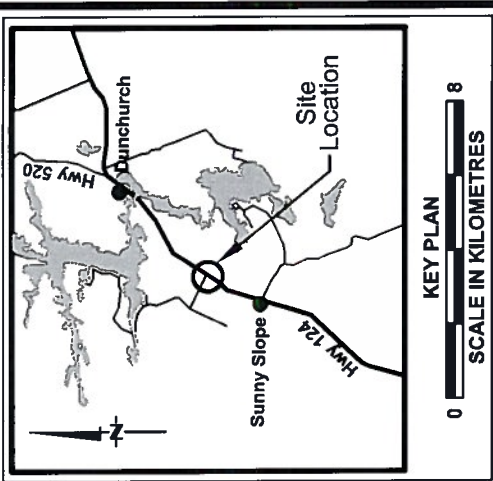
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METRIC  
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OTHERWISE SHOWN. STATIONS  
IN KILOMETERS + METERS

CONT	No	5010-E-0007	
GWP	No	5424-06-00	
WP	No	5424-06-01	
Site	No	44-288	
CULVERT REPLACEMENT AT FARLEY CREEK Highway 124 - Hagerman Twp. STAGE 1			SHEET



LEGEND			
	Borehole		Organics
	Borehole with DCPT		Topsoil
	Dynamic Cone Penetration Test (DCPT)		Bedrock
	Rock Probe		Sand
	Blows/0.3m (Std. Pen Test, 475 J/Blow)		Silt
	Water level at time of investigation.		Clay
	Benchmark		Sand & Gravel
	Fill		Boulders
No.	Elevation	Northling	Station
BH1	255.308	5054582	21+028
BH2	255.388	5054570	21+030
BH3	259.143	5054578	21+030
BH4	259.888	5054572	21+028

NOTE: Coordinates based on MTM Zone 10

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

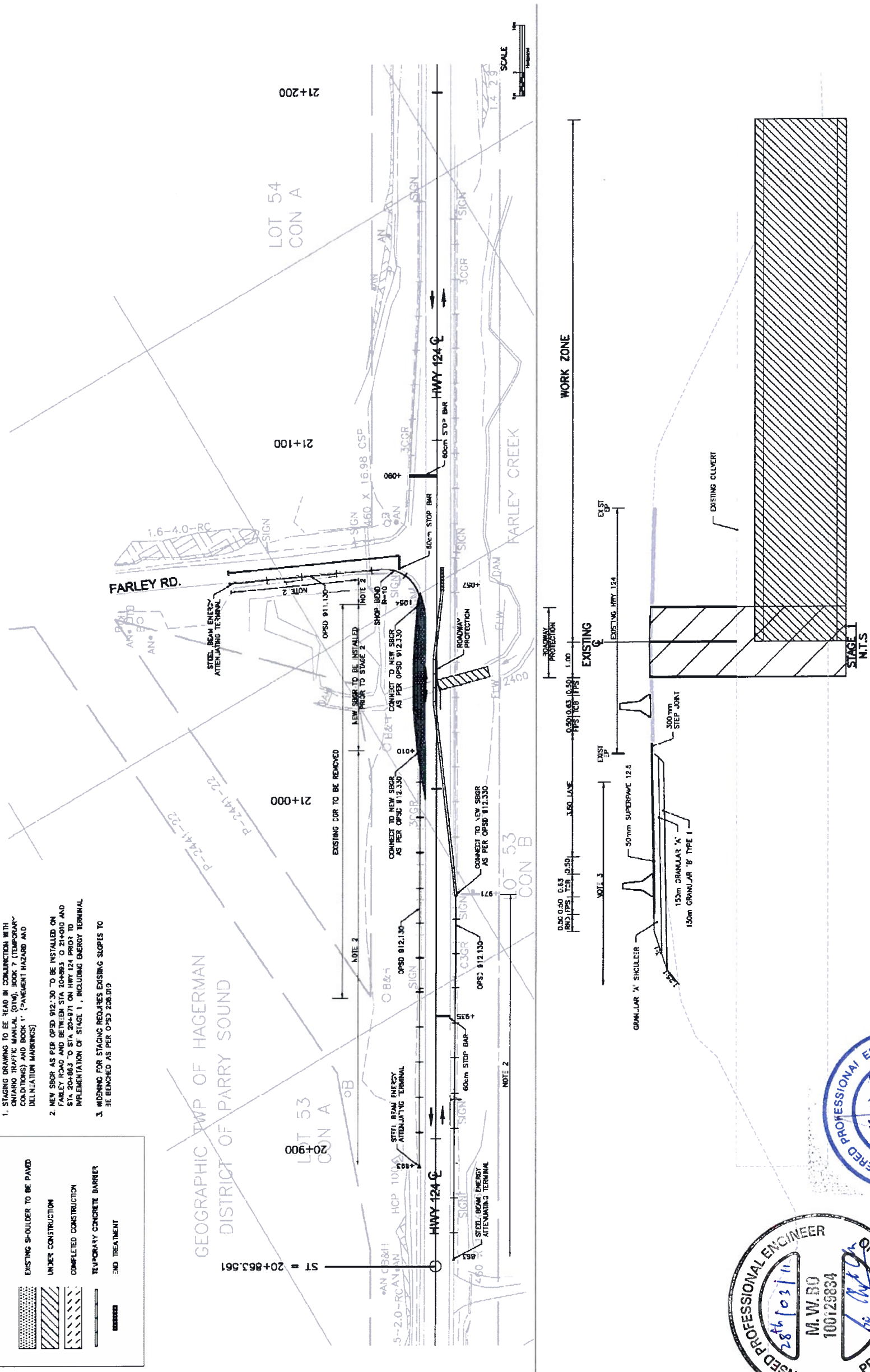
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LEGEND

	EXISTING SHOULDER TO BE PAVED
	UNDER CONSTRUCTION
	COMPLETED CONSTRUCTION
	TEMPORARY CONCRETE BARRIER
	END TREATMENT

NOTES:

- STAGING DRAWING TO BE READ IN CONJUNCTION WITH ONTARIO TRAFFIC MANUAL (OTM), BOOK 2 (TEMPORARY CONDITIONS) AND BOOK 1 (PAVEMENT HAZARD AND DELINEATION WARNINGS)
- NEW SBRG AS PER OPSD 912.130 TO BE INSTALLED ON FARLEY ROAD AND BETWEEN STA 20+863.561 AND STA 20+863 TO STA 20+871 ON HWY 124 PRIOR TO IMPLEMENTATION OF STAGE 1, INCLUDING ENERGY TERMINAL
- WORKING FOR STAGING REQUIRES EXISTING SLOPES TO BE BENCHMARKED AS PER OPSD 238.012



**REGISTERED PROFESSIONAL ENGINEER**  
M. FABIUS  
2016 0328  
PROVINCE OF ONTARIO

**LICENSED PROFESSIONAL ENGINEER**  
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28/10/11  
PROVINCE OF ONTARIO

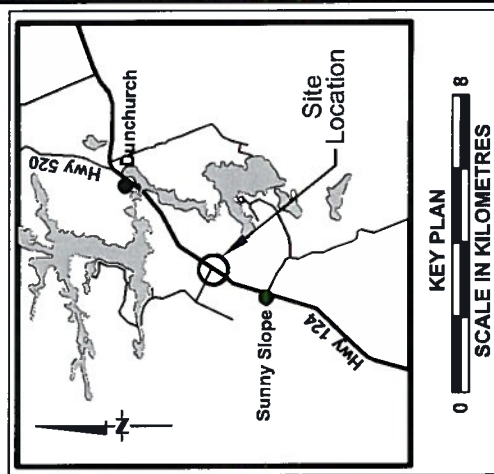












1. STAGING DRAWING TO BE READ IN CONJUNCTION WITH ONTARIO TRAFFIC MANUAL (CTM), BOOK 7 (TEMPORARY CONDITIONS) AND BOOK 8 ("PAVENET" HAZARD AND DEJECTION MARKINGS)
2. NEW SIGR AS PER OPSD #12130 TO BE INSTALLED BETWEEN STA 21+077 AND 21+280 PRIOR TO IMPLEMENTATION OF STAGE 2, INCLUDING ENERGY ATTENUATING TERMINAL.
3. WEIGHING FOR STAGING REQUIRES EXISTING SLOPES TO BE BENCH-MARKED AS PER OPSD 208.030

MINISTRY OF TRANSPORTATION, ONTARIO PR-D-707 88-0

CULVERT REPLACEMENT  
AT FARLEY CREEK  
Highway 124 – Hagerman Twp.  
STAGE 2

SHEET



LEGEND					
◆	Borehole				
⊕	Borehole with DCPT				
⊗	Dynamic Cone Penetration Test (DCPT)				
●	Rock Probe				
⏏	Blows/0.3m (Std. Pen Test, 475 J/Blow)				
≍	Water level at time of investigation.				
⚙	Benchmark				
	Fill		Sand		
	Organics		Silt		
	Topsoil		Clay		
	Fill		Sand & Gravel		
	Bedrock		Boulders		
No.	Elevation	Nothing	Easting	Station	Offset
BH1	295.306	5054582	2753906	21+028	15.0 LT
BH2	295.388	5054570	2753528	21+030	10.0 RT
BH3	296.143	5054578	2753515	21+030	5.5 LT
BH4	296.068	5054572	2753523	21+026	4.8 RT

**NOTE: Coordinates based on MTM Zone 10**

**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**  
consulting engineers

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Email: [thunderbay@distingroup.com](mailto:thunderbay@distingroup.com)

**NOTE: Drawing provided by Genivar**

## DRAWING 6

# **ENCLOSURES**




# RECORD OF BOREHOLE No BH1

1 OF 1

METRIC

W.P. #5010-E-0007 - Farley Creek LOCATION STA. 21+029, 15.0 LT (17T 5053645 m N, 587497 m E) ORIGINATED BY PR/KS  
 DIST HWY 124 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML  
 DATUM Local DATE 2010 10 06 CHECKED BY LP/MWB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT  w <sub>p</sub>	NATURAL MOISTURE CONTENT  w	LIQUID LIMIT  w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      ✕ FIELD VANE □ QUICK TRIAXIAL    ★ LAB VANE							
255.3	GROUND SURFACE														GR SA SI CL Wet at surface.  0 2 (98)
255.2	TOPSOIL - 60 mm														
255.2	SAND - Silty, trace organics, brown		AS1	AS											
255.2	CLAY - Silty, grey/brown, stiff to very stiff		AS2	AS											
253.3															
2.0	CLAY - Silty, trace gravel, grey/red, firm to stiff		AS3	AS											
251.3															
4.0	End of Borehole at 4.0 m														

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

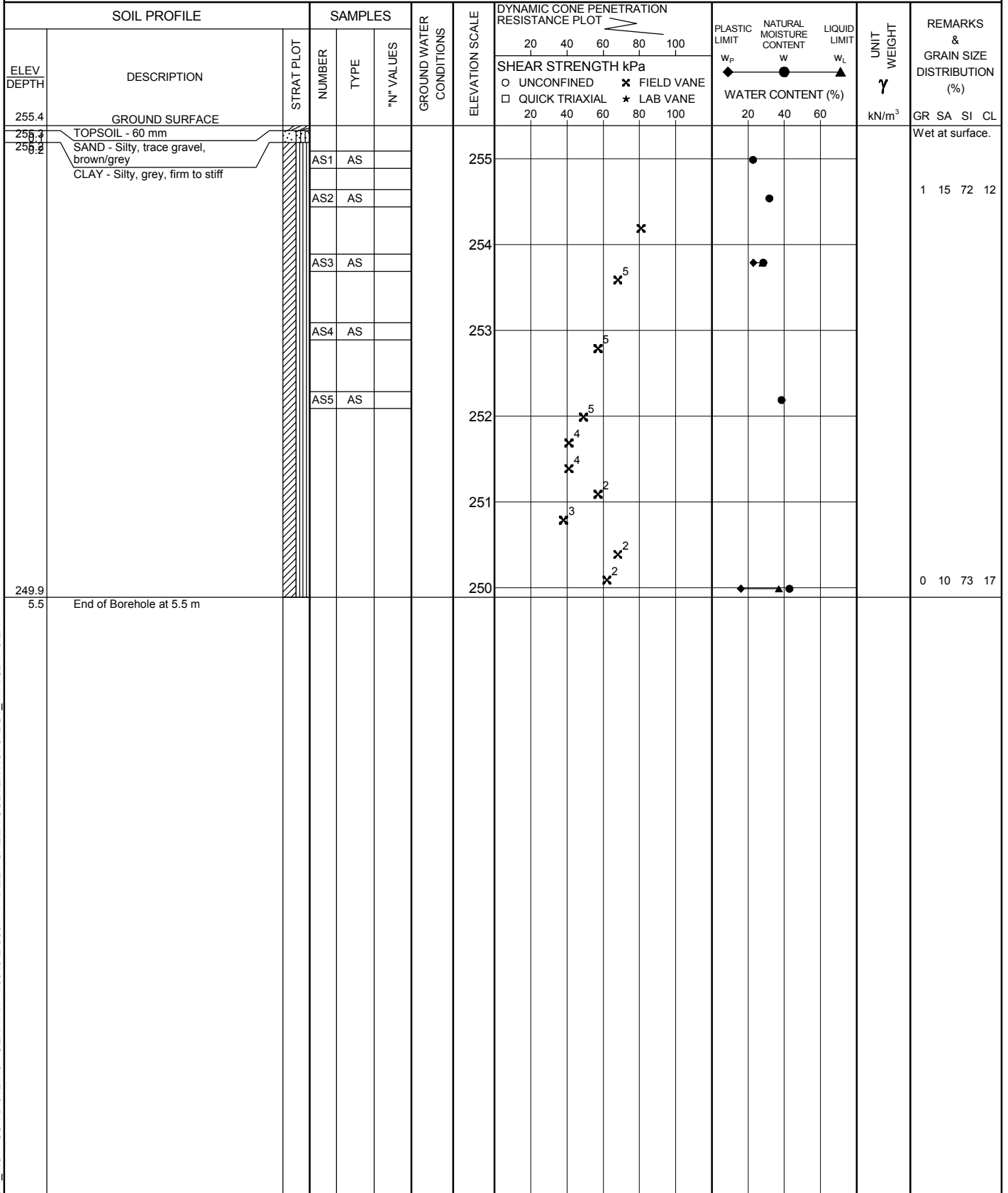
ENCLOSURE 1

# RECORD OF BOREHOLE No BH2

1 OF 1

METRIC

W.P. #5010-E-0007 - Farley Creek LOCATION STA. 21+030, 10.0 RT (17T 5053596 m N, 587465 m E) ORIGINATED BY PR/KS  
 DIST HWY 124 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML  
 DATUM Local DATE 2010 10 06 CHECKED BY LP/MWB



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




ENCLOSURE 2

# RECORD OF BOREHOLE No BH3

1 OF 1

METRIC

W.P. #5010-E-0007 - Farley Creek LOCATION STA. 21+030, 5.5 LT (17T 5053595 m N, 587417 m E) ORIGINATED BY PR/KS  
 DIST HWY 124 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML  
 DATUM Local DATE 2010 10 06 CHECKED BY LP/MWB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>P</sub>	W	W <sub>L</sub>		GR	SA	SI	CL	
								20   40   60   80   100	WATER CONTENT (%)									
259.1	GROUND SURFACE																	
259.0	FILL - SAND & CRUSHED GRAVEL		AS1	AS			259								32   63   (5) Water level at 3.2 m on completion. Cave at 3.2 m.			
0.1	FILL - SAND - Gravelly to some gravel, trace silt, occasional cobbles, brown, very loose to compact																	
			SS2	SS	13													
								258										
			SS3	SS	13													
		SS4	SS	4			257											
		SS5	SS	3			256											
255.4	SILT - some clay, trace sand and organics, grey, firm																	
3.7			SS6	SS	6		255											
			SS7	SS	5													
253.9	CLAY - Silty, grey/red, soft to stiff						254											
5.2			SS8	SS	1													
			SS9	SS	1		253											
							252											
			SS10	SS	1													
							251											
250.0	End of Borehole at 9.1 m Auger Refusal																	
9.1																		

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

ENCLOSURE 3

ON MOT CS-TB-012143 - GENIVAR - #5010-E-0007 - FARLEY CREEK CULVERT.GPJ DST\_MIN.GDT 9/2/11

# RECORD OF BOREHOLE No BH4

1 OF 1

METRIC

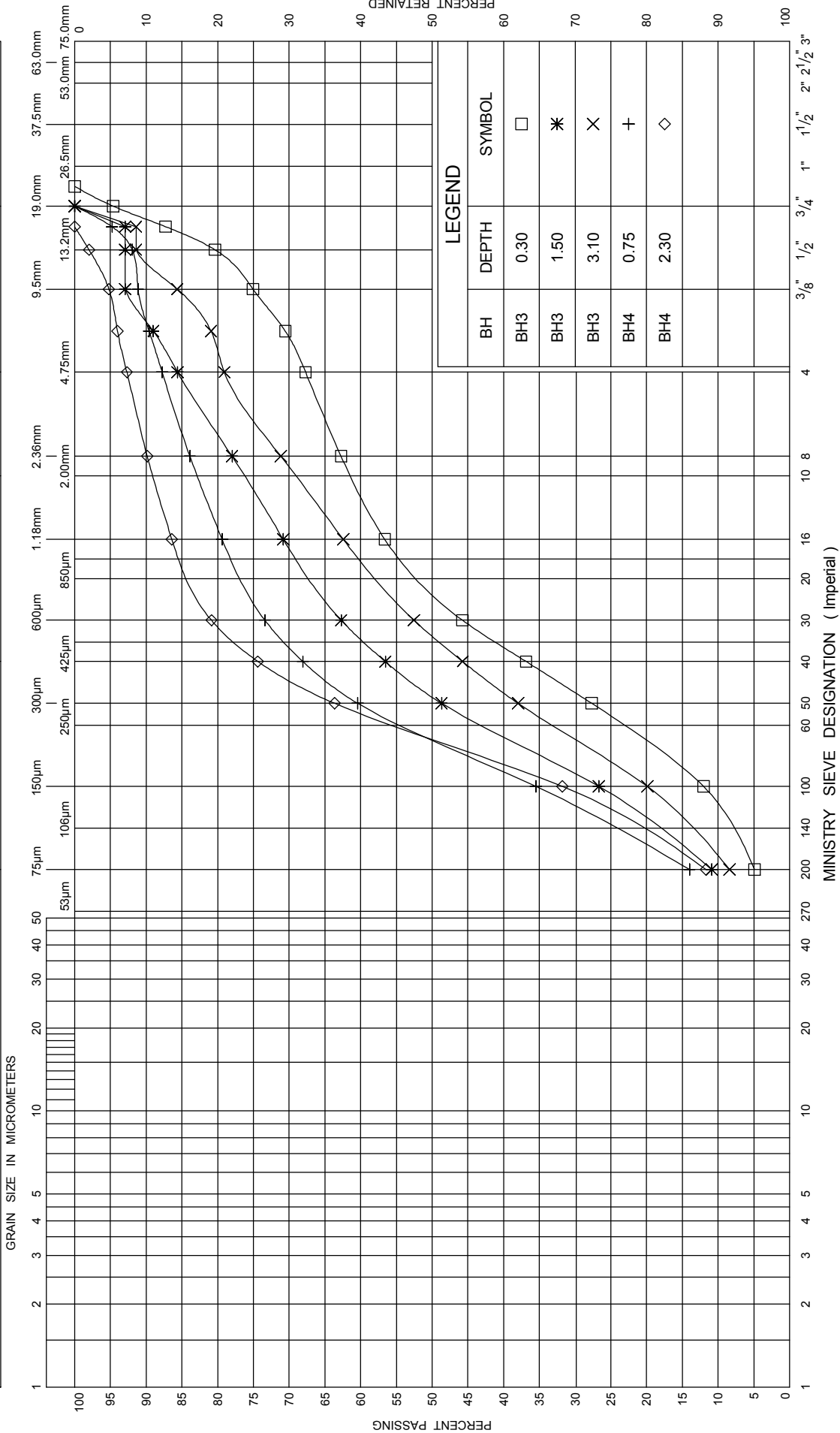
W.P. #5010-E-0007 - Farley Creek LOCATION STA. 21+029, 4.8 RT (17T 5053597 m N, 587456 m E) ORIGINATED BY PR/KS  
DIST HWY 124 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML  
DATUM Local DATE 2010 10 06 CHECKED BY LP/MWB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT   NATURAL MOISTURE CONTENT   LIQUID LIMIT			UNIT WEIGHT  $\gamma$  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>P</sub>	W	W <sub>L</sub>		
								20   40   60   80   100	WATER CONTENT (%)					
259.1	GROUND SURFACE						259							Water level at 3.1 m on completion. Cave at 7.9 m. 12   74   (14)
258.9	ASPHALT - 70 mm		AS1	AS										
258.2	FILL - SAND & CRUSHED GRAVEL													
	FILL - SAND - some silt and gravel, occasional cobbles, brown, loose to compact		SS2	SS	13									
			SS3	SS	16									
	----- - trace gravel		SS4	SS	5									
			SS5	SS	5									
255.4														
3.7	SILT - some clay, trace sand, grey/brown, very soft		SS6	SS	1			255						
254.6														
4.5	CLAY - Silty, trace sand, layered, grey, soft to stiff		SS7	SS	2		254							
			SS8	SS	1									
			SS9	SS	1		253							
			SS10	SS	1		252							
			SS11	SS	1		251						0   5   69   26	
			SS12	SS	1		250							
249.1														
10.0	SILT - Sandy, trace clay, layered, grey, very loose						249							

Numbers refer to Sensitivity  $\phi$  3% STRAIN AT FAILURE

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL		
		Fine		Medium	Coarse	Fine	Coarse

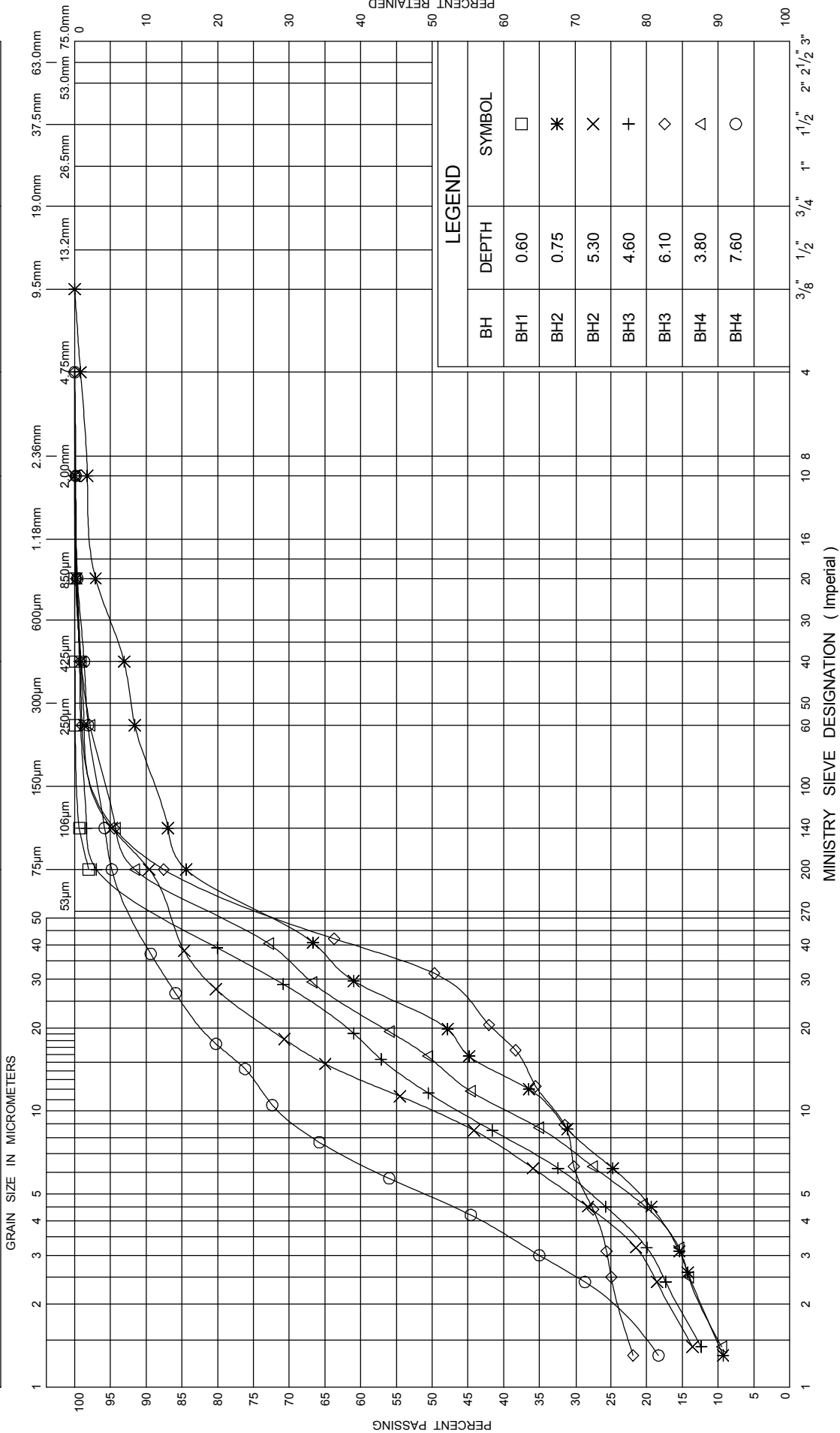


GRAIN SIZE DISTRIBUTION  
SAND

ENCLOSURE 5  
#5010-E-0007 - Farley Creek  
HIGHWAY 124

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL	
		Fine	Medium	Coarse	Fine	Coarse

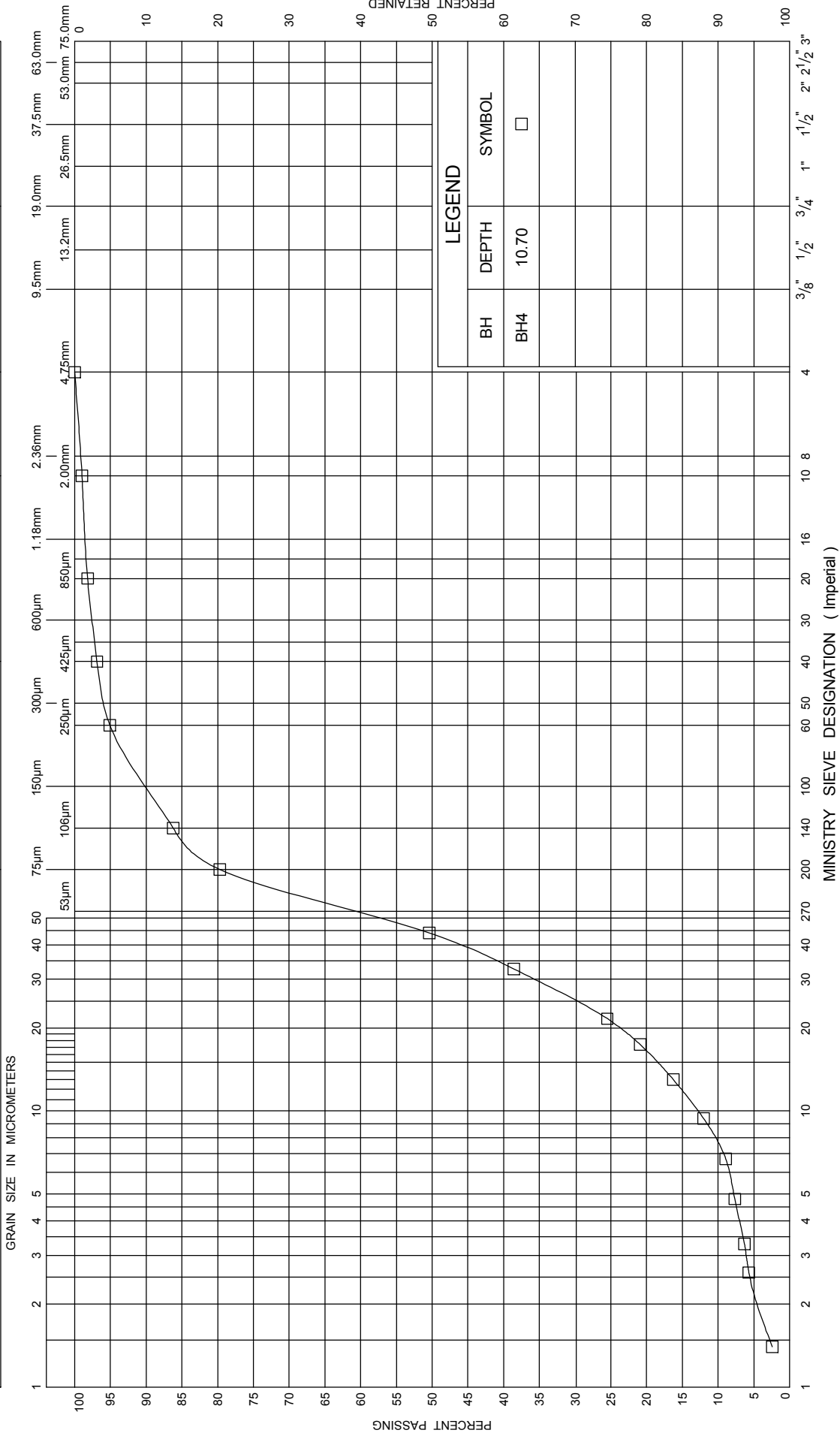


GRAIN SIZE DISTRIBUTION  
SILTY CLAY

ENCLOSURE 6  
#5010-E-0007 - Farley Creek  
HIGHWAY 124

UNIFIED SOIL CLASSIFICATION SYSTEM

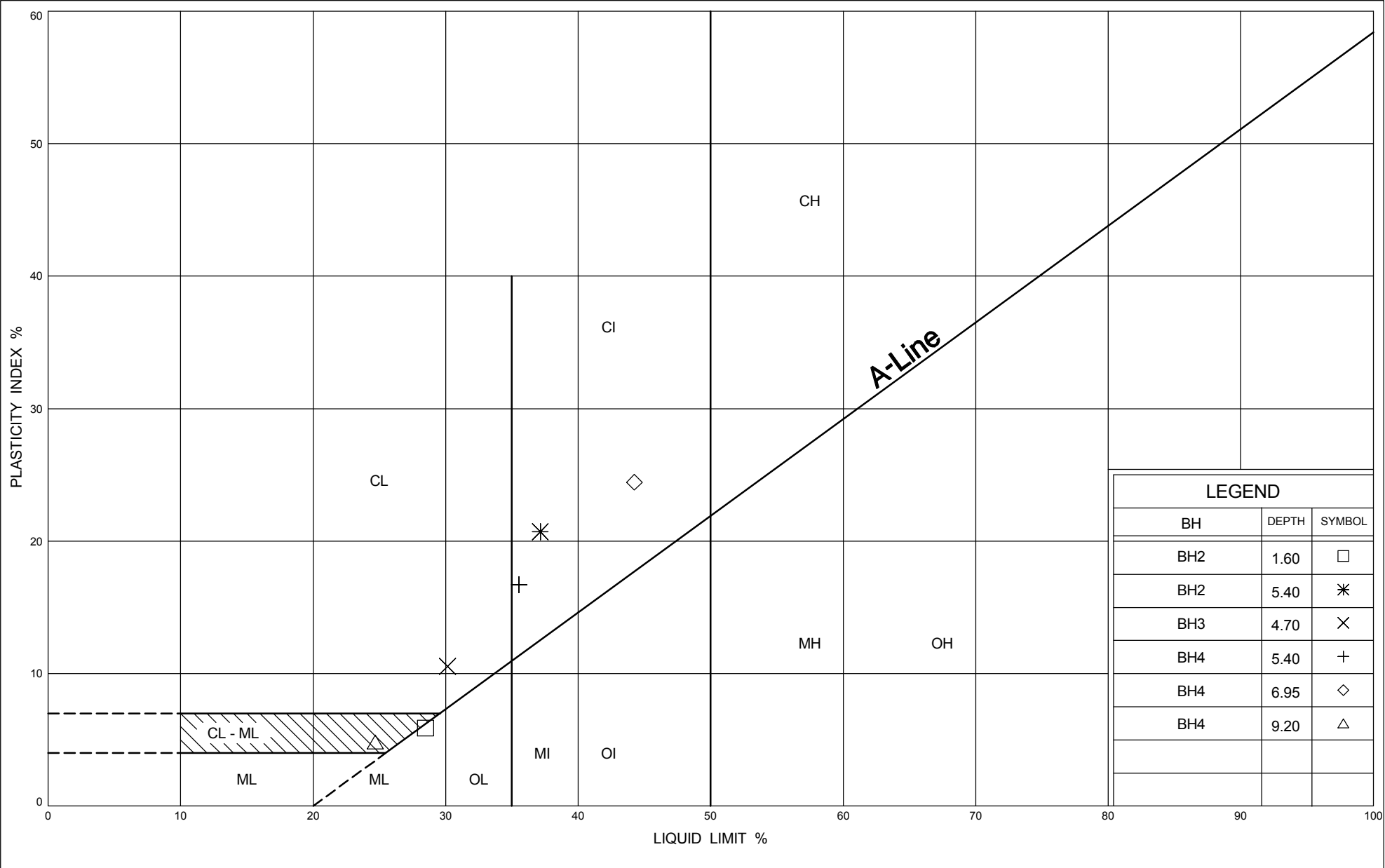
CLAY & SILT		SAND			GRAVEL	
		Fine		Medium	Fine	Coarse



GRAIN SIZE DISTRIBUTION  
SANDY SILT

ENCLOSURE 7  
#5010-E-0007 - Farley Creek  
HIGHWAY 124





PLASTICITY CHART

ENCLOSURE 8  
#5010-E-0007 - Farley Creek  
HIGHWAY 124