



**FOUNDATION INVESTIGATION  
AND DESIGN REPORT  
JUMBO CREEK ALIGNMENT  
HIGHWAY 537  
TOWNSHIP OF CLELAND,  
SUDBURY AREA  
AGREEMENT NO: 5009-E-0061  
GWP 5279-03-00**

**5<sup>th</sup> July 2012  
GS-TB-014485**

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**FOUNDATION INVESTIGATION AND DESIGN REPORT  
JUMBO CREEK ALIGNMENT  
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TOWNSHIP OF CLELAND, SUDBURY AREA  
AGREEMENT NO.: 5009-E-0061  
GWP 5279-03-00  
PART 1: FACTUAL INFORMATION**

**1. INTRODUCTION**

DST Consulting Engineers Inc. was retained by the Ministry of Transportation (MTO), Northeastern Region, to conduct a foundation investigation report for the 700 m Road Alignment and proposed highway re-alignment on Highway 537 near to Jumbo Creek. This work was carried out under Agreement No.: 5009-E-0061, to design and evaluate two alignment options. Option 1 consists of a 1.0 m grade raise on the existing road alignment and Option 2 consists of a construction a new 750 m re-aligned new highway (proposed highway re-alignment) as shown in Drawing 1.

This report addresses the field investigation, laboratory test program, factual report on field findings (Part 1) and design recommendations for the existing and proposed highway re-alignment (Part 2).

Geological information is available from *Northern Ontario Geology Terrain Study* published by the Ontario Ministry of Natural Resources for the Districts of Nippising, Parry Sound, and Sudbury. This indicates, Organic terrain (OT) commonly occurs, most commonly in poor drained depressions within bedrock terrain. A typical terrain unit letter code is: pOT (RN) / Lp-W

This indicates that the peaty organic terrain has low relief and a planar surface. The water table is at the surface giving rise to wet drainage conditions. Rock knobs are common subordinate landform and can be seen at both south and north part of the area of study.

Bedrock and lacustrine plain are the dominant terrain units in Sudbury map area. Aggregate resources are scarce and organic materials are common in low areas.

## 2. SITE DESCRIPTION

The site is located on Highway 537, approximately 7.0 km south of Trans-Canada Highway, Township of Cleland, Sudbury Area.

Five (5) boreholes were drilled along existing highway alignment and six (6) boreholes were drilled along proposed highway re-alignment to investigate, design and evaluate two alignment options. These eleven (11) boreholes were drilled between stations 18+350 and 18+715.

The following photos show locations on the existing alignment and proposed highway re-alignment.



Figure 2.1 At station 18+350, looking from highway towards proposed centre line



Figure 2.2 At station 18+400, looking north from highway



Figure 2.3 At station point 18+400, looking south from highway





Figure 2.4 At proposed highway re-alignment, station 18+525 looking south



Figure 2.5 At proposed highway re-alignment, station 18+600 looking south



Figure 2.6 At proposed highway re-alignment, station 18+650 looking out towards highway

### 3. INVESTIGATION PROCEDURES AND LABORATORY TESTING

Site work was carried out in a period between February 27<sup>th</sup>, 2012 and March 9<sup>th</sup>, 2012 utilizing a CME 750 drill rig and was operated by DST personnel. A total of eleven (11) drilled boreholes were drilled using hollow stem auger for the purpose of road section foundation design at this site.

Five boreholes were drilled on the existing highway alignment and six boreholes were drilled on the proposed highway re-alignment. Borehole locations are shown on the Borehole Location Plans, (Drawings 1).

The borehole locations are referenced to the MTO Station numbering system as indicated in the Drawing 1 to 6. The ground surface elevations at the borehole locations were surveyed by DST personnel. At approximately Station 18+715, MTC benchmark with an elevation of 225.927 m was used as reference point to measure ground surface and groundwater elevations at the borehole locations. Table 3.1 summarizes the detail of borehole locations, ground surface elevations, offsets and depths.

Table 3.1 Detail of borehole locations

Borehole ID	Station	Elevation (m)	Depth (m)	Offset (m)
BH1*	18+412	221.76	15.5	2.2 Lt
BH2*	18+450	221.84	22.5	0
BH3*	18+500	221.94	22.0	0.9 Rt
BH4*	18+550	221.97	26.0	0
BH5*	18+600	221.89	22.9	2.3 Lt
BH6*	18+650	221.82	21.5	0
BH7	18+715	225.30	4.6	3.0 Lt
BH8	18+675	222.81	9.1	4.0 Rt
BH9	18+575	221.83	21.3	4.0 Lt
BH10	18+475	221.97	21.3	4.8 Rt
BH11	18+350	222.13	18.9	3.0 Lt

\* New proposed alignment



The fieldwork was conducted 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. Standard Penetration Tests (SPT) was performed in each borehole and Filed Vane Shear tests were performed in eight boreholes. The soil samples collected during drilling were identified in the field, placed in labelled bags and transported to DST's laboratory in Thunder Bay for further analyses.

All aspects of implementation of foundation test holes (including planning, licensing, construction, maintenance, abandonment, and reporting), were carried out in accordance with the Ministry of the Environment (MOE) Regulation 903, as amended by Regulation 128/03 (the water well regulation under the Ontario Water Resources Act). Specifically, all boreholes, test holes or wells that are no longer in use, due to location in the right-of-way, or no longer needed for groundwater monitoring were properly decommissioned. Proper abandonment procedures specified and followed are as per MOE Regulation 903. All boreholes, test holes and dewatering wells were effectively sealed at surface and at depth as appropriate.

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 one hundred and eighteen (118) moisture contents, nine (9) particle size analyses and twenty nine (29) Atterberg limit tests have been carried out for this assignment. Five (5) one dimensional consolidation tests were carried out. Laboratory test results are presented in the Boreholes Logs (Enclosures 1 to 11), Plots (Enclosures 12 to 34).

#### **4. DESCRIPTION OF SUBSURFACE CONDITIONS OF THE PROPOSED HIGHWAY RE-ALIGNMENT**

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

The generalized stratigraphy of the proposed highway re-alignment, based on the conditions encountered in boreholes, consists of a layer of organics (fibres, roots etc.) that is underlain by very soft to stiff clay. The subsurface condition of proposed highway re-alignment is described below.

##### **4.1 Top Soil**

Top soil layer of 0.3 m thickness was encountered at Borehole 2 location; this corresponds to top and bottom elevations of 221.8 m and 221.5 m.

##### **4.2 Organics**

Organics were encountered in Boreholes 1 to 6 along the proposed highway re-alignment at depths from 0 to 3.1 m, 0.3 to 5.3 m, 0 to 6.1 m, 0 to 6.1 m, 0 to 6.1 m and 0 to 4.6 m respectively; these correspond to top and bottom elevations of 221.8 to 218.7 m, 221.5 to 216.5 m, 221.9 to 215.8 m, 222.0 to 215.9 m, 221.9 to 215.8 m and 221.8 to 217.2 m respectively. The thickness of this stratum is from 3.1 m to 6.1 m. Von Post tests were carried out on samples from Boreholes 1, 2, 3, 4, and 6 at depths of 2.3 m, 3.1 m, 4.6 m, 0.3 m and 1.5 m respectively indicate decomposition very strong to complete decomposition, water contents ranged from 344% to 1037%, fine fibers were low to moderate contents, nil (0) coarse fibers, wood and shrubs contents were nil to low.

##### **4.3 Clay**

Clay was encountered in Boreholes 1 to 6 at depths from 3.1 to 15.5 m, 5.3 m to 22.5 m, 6.1 to 22.0 m, 6.1 to 26 m, 6.1 to 22.9 m, 4.6 to 21.5 m respectively; these correspond to top and bottom elevations of 218.7 to 206.3 m, 216.5 m to 199.3 m, 215.8 to 199.9 m, 215.9 to 196 m, 215.8 to 199.0 m and 217.2 to 200.3 m respectively. The thickness of this stratum is from 12.4 m to 19.9 m. Sixteen (16) Atterberg limit tests were carried out on samples from Boreholes 1, 2, 3, 5 and 6 indicate medium to high plasticity clay and organic clay with liquid limits and plasticity index of 25% to 56% and 6% to 32% respectively. In-situ field vane tests carried out in the clay indicate soft to stiff consistency with undrained shear strengths between 14 to 60 kPa and sensitivities ranging from 2 to

3, however in a great part of the clay layer field vane test was not carried out due to insufficient resistance, even the drilling rods were sinking with itself weight. This indicates the soil at this depth has shear strength of less than 10 kPa. Moisture contents of samples ranged from 36% to 75%.

Table 4.1 Summary of clay by Atterberg limit Test

Clay	
Property	Water Content
Liquid Limit	25% to 56%
Plasticity Index	6% to 32%

## **5. DESCRIPTION OF SUBSURFACE CONDITIONS OF THE EXISTING ROAD ALIGNMENT**

The generalized stratigraphy of the existing road alignment, based on the conditions encountered in boreholes, consists of wood chips, sand and gravel fill that is underlain by soft to very stiff clay. Organic materials were encountered in the Boreholes 8, 9 and 10 at between 3.0 m and 5.8 m depths. The thickness was approximately between 0.8 m and 1.6 m. Sand layer was encountered in Borehole 8 at 7.6 m and approximately 1.5 m in thickness. Silt was encountered in Boreholes 7 at approximately 3.8 m depth. Silt was found approximately 0.8 m in thickness.

The subsurface condition of existing road alignment is further described below;

### **5.1 Sand and Gravel Fill**

Sand and gravel fill layer was encountered in Borehole 8 and 10 at the depths of 0 to 2.2 m, 0 to 1.5 m below surface respectively; these correspond to top and bottom elevations of 222.8 m to 220.6 m, 222.0 m to 220.5 m respectively. The thickness of this layer was approximately 1.5 to 2.2m. Gradation analyses conducted on the samples from Boreholes 8 and 10 indicate gravel, sand, and fine contents of 43 to 45%, 48 to 49%, and 6 to 9% respectively. Moisture contents of samples ranged from 1 to 27%.

Table 5.1 Summary of sand and gravel layers particle size distribution

Sand and Gravel	
Soil Type	Percentage
Gravel	43 to 45%
Sand	48 to 49%
Silt	6 to 9%
Clay	

### **5.2 Gravel Fill**

Gravel fill material layer with some sand, trace fines was encountered in Borehole 7 at depths 2.9 m to 3.8 m below surface; this corresponds to top and bottom elevations of 222.4 m and 221.5 m. The thickness of this layer was 0.9 m. SPT 'N' value of 13 indicates a compact condition. Gradation analyses conducted on the sample indicate gravel, sand, and fine contents of 71%, 22%, and 7% respectively. A moisture content of sample was found to be 12%.

Table 5.2 Summary of gravel layer particle size distribution

Gravel	
Soil Type	Percentage
Gravel	71%
Sand	22%
Silt	7%
Clay	

### 5.3 Sand Fill

Sand fill layer with some gravel, trace to some fines was encountered in Boreholes 7, 9 and 11 at depths of 0 to 2.9 m, 0 to 1.1 m and 1.5 to 3.8 m, 0 to 3.4 m respectively; these correspond to top and bottom elevations of 225.3 m to 222.4 m, 221.8 m to 220.7 m and 220.3 m and 218.0 m, 222.1 m to 218.7 m respectively. The thickness of this layer was between 1.1 m to 3.4 m. SPT 'N' value of 9 to 55 indicates loose to very dense condition. Gradation analyses conducted on the four (4) samples from boreholes 7, 9 and 11 indicate gravel, sand, and fine contents of 24 to 27%, 62 to 67%, and 6 to 11% respectively. Moisture contents of samples ranged from 1 to 27%.

Table 5.3 Summary of sand layers particle size distribution

Sand	
Soil Type	Percentage
Gravel	24 to 27%
Sand	62 to 67%
Silt	6 to 11%
Clay	

### 5.4 Wood Chips Fill

Wood chips fill layer with sand, trace silt and gravel was encountered in Boreholes 8, 9 and 10 on the existing road alignment at the depths of 2.2 to 3.0 m and 3.8 to 4.5 m, 1.1 to 1.5 m, 1.5 to 4.6 m respectively; this corresponds to top and bottom elevations of 220.6 m to 219.8 m and 219.1 to 218.3 m, 220.7 m to 220.3 m, 220.5 m to 217.4 m respectively. The thickness of this stratum is from 0.4 m to 3.1 m. Von Post tests were carried out on samples from Boreholes 8 at depths of 2.3 m indicates none decomposition, water contents were 499%, fine fibers contents were moderate, coarse fibers contents were high, wood and shrubs contents were high.

## 5.5 Organics

Organics were encountered in Boreholes 8, 9 and 10 on the existing road alignment at the depths of 3 to 3.8 m, 3.8 to 5.4 m and 4.6 to 5.8 m respectively; this corresponds to top and bottom elevations of 219.8 m to 219.1 m, 218.0 m to 216.4 m and 217.4 m to 216.2 m respectively. The thickness of this stratum is from 0.8 m to 1.6 m. Von Post tests were carried out on samples from Boreholes 9 and 10 at depths of 3.8 m and 4.6 m respectively indicate insignificant to moderately strong decomposition, water contents were 154% and 549%, fine fibers were moderate to high contents, coarse fibers were low to high contents, wood and shrubs contents were nil to low.

## 5.6 Sand

A layer of native sand material was encountered in Borehole 8 at depth of 7.6 m to 9.1 m below surface; this corresponds to top and bottom elevations of 215.2 m to 213.7 m. The thickness of this layer was approximately 1.5 m. SPT 'N' value of 8 indicates compact condition.

## 5.7 Silt

Silt layer with some sand, trace clay was encountered in Borehole 7 at depth between 3.8 m to 4.6 m below surface; this corresponds to top and bottom elevation of 221.5 m and 220.7 m respectively. The thickness of the layer was 0.8 m. SPT 'N' value of 5 indicates loose condition. Hydrometer test carried out on sample indicate gravel, sand, silt and clay contents of 0%, 20%, 70% and 9% respectively. Moisture content of sample was found to be 24%.

Table 5.1 Summary of Silt layer particle size distribution

Silt	
Soil Type	Percentage
Gravel	0%
Sand	20%
Silt	70%
Clay	9%

## 5.8 Clay

Clay was encountered in Boreholes 8 to 11 at depths 4.5 to 7.6 m, 5.4 to 21.3 m, 5.8 to 21.3 m, 3.4 to 18.9 m respectively; these correspond to top and bottom elevations of 218.3 m to 215.2 m, 216.3 m to 200.5 m, 216.2 m to 200.7 m, 218.7 m to 203.2 m respectively. The thickness of this layer is

between 3.1 m to 15.9 m. Thirteen (13) Atterberg limit tests carried out on samples from Boreholes 8, 9, 10 and 11 indicate low to high plasticity clay with liquid limits and plasticity index of 32% to 57% and 12% to 32% respectively. In-situ field vane tests taken in Boreholes indicate soft to very stiff consistency with undrained shear strengths between 19 to 118 kPa and sensitivities ranging from 2 to 12. Moisture contents of samples ranged from 26% to 65%.

Table 5.2 Summary of clay by Atterberg limits Test

Clay	
Property	Water Content
Liquid Limit	32% to 57%
Plasticity Index	12% to 32%

## 6. GROUNDWATER

The groundwater levels can be expected to vary with season and precipitation events. Table 6.1 below summarize the groundwater level measured during the Boreholes drilling.

Table 6.1 Groundwater table at boreholes

Date Water Level Recorded	Borehole ID	Borehole elevation (m)	Groundwater elevation (m)	Depth below ground surface (m)
27/02/2012	BH1	221.76	221.76	0.00
28/02/2012	BH2	221.84	221.84	0.00
01/03/2012	BH3	221.94	221.94	0.00
02/03/2012	BH4	221.97	221.97	0.00
05/03/2012	BH5	221.89	221.89	0.00
05/03/2012	BH6	221.82	221.42	0.40
06/03/2012	BH7	225.30	222.45	2.85
06/03/2012	BH8	222.81	221.86	0.95
07/03/2012	BH9	221.83	220.83	1.00
08/03/2012	BH10	221.97	221.57	0.40
08/03/2012	BH11	222.13	221.68	0.45



## **7. MISCELLANEOUS**

Site work was carried out in a period between February 27<sup>th</sup>, 2012 and March 9<sup>th</sup>, 2012 utilizing a CME 750 drill rig and was operated by DST personnel. Fieldwork was conducted on a full time basis by Joe Forgues and Carl Dumas who located the boreholes in the field, performed sampling, in-situ testing and logged the boreholes. 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. Interpretation of the data and preparation of the report was completed by Tanveer Mubarik P.Eng, Bernardo Villegas, and Tun Lwin and reviewed by Prof. Myint Win Bo, P.Eng a designated principal contact for MTO projects.

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TOWNSHIP OF CLELAND, SUDBURY AREA  
AGREEMENT NO.: 5009-E-0061  
GWP 5279-03-00  
PART 2: ENGINEERING DISCUSSIONS AND RECOMMENDATIONS**

**8. PROJECT DESCRIPTION**

DST Consulting Engineers Inc. was retained by the Ministry of Transportation (MTO), North Eastern Region, to conduct a foundation investigation and provide geotechnical recommendation for the 700 m Road Alignment and proposed highway re-alignment on Highway 537 near to Jumbo Creek. This work was carried out under Agreement No.: 5009-E-0061, to design and evaluate two alignment options. Option 1 consists of a 1.0 m grade raise on the existing road alignment and Option 2 consists of a construction a new 750 m re-aligned new highway between stations 18 + 130 and 18 + 880, as shown in Drawing 1.

This section presents interpretation of the geotechnical data presented in the factual report and geotechnical recommendations for options of grade raise for existing road and design of the proposed highway re-alignment construction.

## **9. SUBSURFACE CONDITIONS AT EXISTING ROAD AND PROPOSED HIGHWAY RE-ALIGNMENT**

Field geotechnical investigation was completed along the existing road between sections 18 + 412 and 18 + 650 as well as along the proposed highway re-alignment. The sub-surface profiles along the existing road and the proposed highway re-alignment are shown in Drawing 7 and 8.

### **9.1 Subsurface Condition along Existing Road**

The subsurface condition along the existing road consists of fill (sand and gravel) underlain by wood chips and organic material (Boreholes 8, 9 and 10) which again underlain by soft to firm clay before encountering refusal. The thickness of fill was found approximately between 1.1 m and 3.8 m. The thickness of organic material was found between 1.6 m and 4.3 m. Thickness of clay was found between 3.1 m and > 15.5 m. The possible bedrock depths were estimated by the dynamic cone test at the end of boreholes. Rock coring in the boreholes was not carried out. The possible bedrock depths were 4.6 m (220.7 m elevation at Borehole 7) and > 21.3 m (< 200.5 m elevation at Boreholes 9 & 10).

It appears that the investigated section is formerly swamp area and with clay and organic soil profile. The clay was found to be in very soft condition. Wood chips were found in the Boreholes 8, 9, and 10. Wood chips have been used as a light weight fill material in the embankment. The density of the wood chip can be assumed as  $\sim 12 \text{ kN/m}^3$ .

### **9.2 Subsurface Condition at Proposed Highway Re-alignment**

The subsurface condition along the proposed highway re-alignment consists of organic material overlying very soft to stiff clay which is underlain by possible bedrock. The thicknesses of organic material were found approximately between 3.1 m (Borehole 1) and 6.1 m (Borehole 3 and 4). Thicknesses of clay were found between 12.4 m and > 19.9 m. possible bedrock is estimated to be at an elevation between 196.0 m and 200.3 m. Thick organic materials and clay present at the proposed highway re-alignment location may have significant settlement issue for the proposed highway re-alignment embankment.

A ditch is located at the left side of the road (facing west). The surface water was noticed in the ditch. The groundwater could be found close to ground surface or less than below 1.0 m below

existing grade level (except BH 7 where it is 2.85 m below the existing grade). The groundwater elevation was found between 221.42 m and 222.45 m. It shall be noted that groundwater elevation will vary with season and precipitation event.

### 9.3 Geotechnical Parameters for the Analyses

Typical soil parameters for the analyses are shown in Tables 9.1 and 9.2. Undrained shear strength were obtained from the field vane shear tests directly. Drained internal friction angles for the granular soils were estimated from standard penetration tests applying empirical correlations proposed by Wolff (1989). Drained internal friction angle of cohesive soil was estimated from the plasticity index applying empirical correlations (Bjerrun and Simons, 1960; Kenney, 1959). The oedometer consolidation tests provide consolidation parameter for the clay. Five (5) oedometer consolidation tests were carried out on undisturbed soil sample. The test results are attached in Enclosures 25 to 34. Summary of test results are shown in Table 9.3.

Table 9.1 Soil parameters for slope stability analyses at existing road

Soil Type	Thickness, m	Unit Weight, kN/m <sup>3</sup>	Undrained Vane Shear Strength, kPa	Drained Internal Friction angle, degrees, $\phi$
Fill (Sand and gravel)	1.1 – 3.8	20 – 23 (21)*	-	(32)*
Fill (wood chip)	1.5 – 3.1	(12)*	-	-
Organic	1.6 – 4.3	(12)*	18 – 85 (20)*	(25)*
Clay	3.1 – > 15.9	(17)*	18 – 55 (25)*	27 – 30 (27)*

\*Values in brackets provide typical design values.

Table 9.2 Soil parameters for analyses at the proposed highway re-alignment

Soil Type	Thickness, m	Unit Weight, kN/m <sup>3</sup>	Undrained Vane Shear Strength, kPa	Drained Internal Friction angle, degrees, $\phi$
Fill (Sand and gravel)	1.1 – 3.8	20 – 23 (21)*	-	(32)*
Organic	1.6 – 4.3	(12)*	18 – 21 (18)*	(25)*
Clay	3.1 – > 15.9	(17)*	16 – 60 (20)*	26 – 28 (26)*

\*Values in brackets provide typical design values.

Table 9.3 Consolidation test results

Borehole No.	Sample Depth, m	Sample Elevation, m	e <sub>0</sub>	Preconsolidation Pressure, kPa	C <sub>c</sub>	C <sub>r</sub>	C <sub>v</sub>	C <sub>α</sub>
Borehole 2	6.1	215.7	1.069	29	0.182	0.038	14.0 - 21.1	0.009
Borehole 8	7.9	214.9	1.225	47	0.344	0.062	3.8 - 11.2	0.017
Borehole 9	7.6	214.2	1.236	25	0.277	0.029	1.8 - 11.2	0.014
Borehole 9	10.6	211.2	1.270	38	0.262	0.052	2.4 - 6.2	0.013
Borehole 11	12.1	209.9	1.251	32	0.297	0.045	2.7 - 10.1	0.015

C<sub>c</sub> = Compression Index

C<sub>r</sub> = Recompression Index

C<sub>v</sub> = Coefficient of Consolidation (m<sup>2</sup>/year)

C<sub>α</sub> = Secondary Compression Index

## 10. GRADE RAISE OF EXISTING HIGHWAY

Very thick soft to stiff clay and organic material (Boreholes 8, 9 and 10) were found below the existing road embankment. 1 m grade raise on existing road will have settlement and stability issues. Differential settlements along the road between section 18 + 280 and 18 + 680 are expected due to variation of the compressible soil and organic materials layers.

The 1 m grade raise could be constructed using stages construction or using temporary detour road to minimize traffic disruption during construction. Stages construction may cause differential settlement along the road alignment. Stages construction will add the loads on the existing embankment at different time and will cause differential settlement. Surface settlement shall be monitored and allow sufficient time for the excessive differential settlement to cease before paving the road.

Settlement and stability of embankment for 1 m grade raise on existing road were analysed and further discussed.

### 10.1 Settlement

The settlements due to 1 m grade raise along existing embankment were analysed using soil profile and geotechnical parameters shown in Table 9.1. The assumption of normally consolidated soil condition was made in the analyses. One dimensional consolidation theory applying Terzaghi (1925) is used for the settlement analyses. Consolidation parameters for clay were interpreted from oedometer consolidation tests result. Settlement in organic material was estimated using the method proposed by S. Leroueil and R. K. Rowe (2000). Consolidation settlement at four locations along the existing road was analysed. Settlements of 0.06 to 0.57 m were estimated from the analyses. The estimated settlements are shown in Table 10.1.

Table 10.1 Estimated consolidation settlement by 1 m grade raise, (m)

	Station 18 + 350 (BH 11)	Station 18 + 475 (BH 10)	Station 18 + 575 (BH 9)	Station 18 + 675 (BH 8)
Grade raise of 1 m	0.27	0.29	0.57	0.06

## 10.2 Time Rate of Settlement

Time rate of settlement in the clay was calculated at four sections. The time required to complete the 90% degree of primary consolidation with the proposed 1 m grade raise at one stage for sections at Station 18 +675 (Borehole 8), Station 18+575 (Borehole 9), Station 18+475 (Borehole 10) and Station 18+350 (Borehole 11) are analysed. Coefficient of consolidation ( $C_v$ ) of 5 m<sup>2</sup>/year was used for time rate of settlement calculation. The estimated time to reach 90 % consolidation is summarized in Table 10.2. Time settlement graphs are shown in Figures 10.1 to 10.4.

Table 10.2 Estimated 90 % consolidation time by 1 m grade raise, (years)

	Station 18 + 350 (BH 11)	Station 18 + 475 (BH 10)	Station 18 + 575 (BH 9)	Station 18 + 675 (BH 8)
Grade raise of 1 m	28	9	21	0.8

### Settlement Vs. Time at BH 8

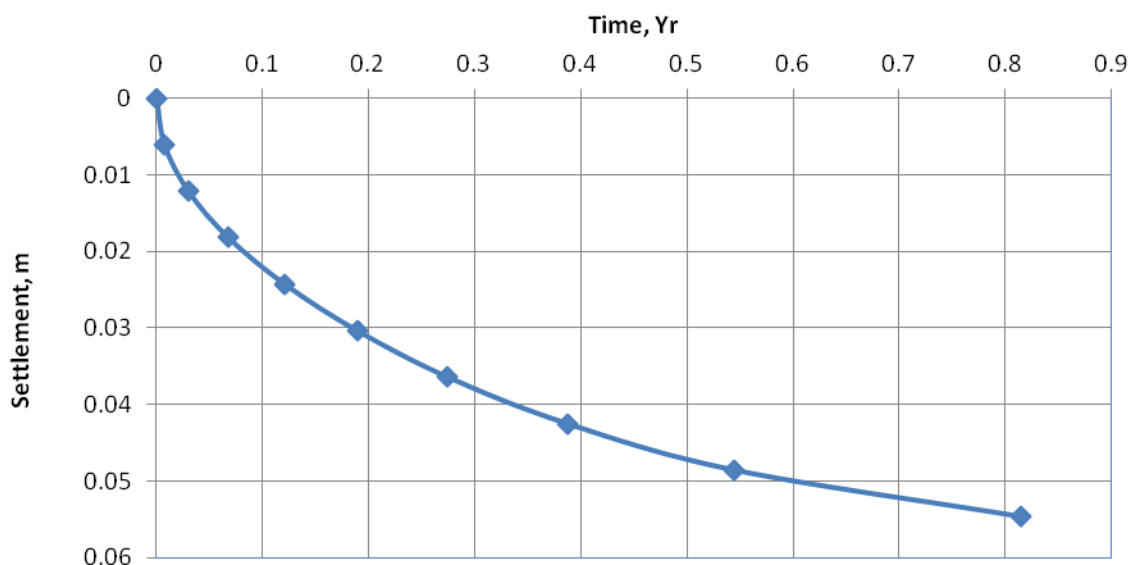


Figure 10.1 Time rate of settlement in clay layer at BH 8

## Settlement Vs. Time at BH 9

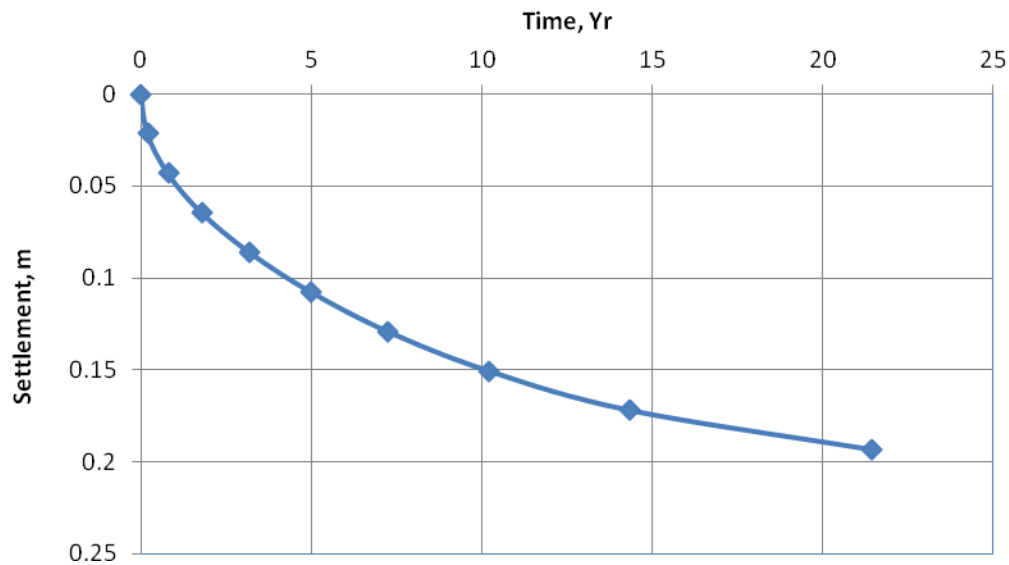


Figure 10.2 Time rate of settlement in clay layer at BH 9

## Settlement Vs. Time at BH 10

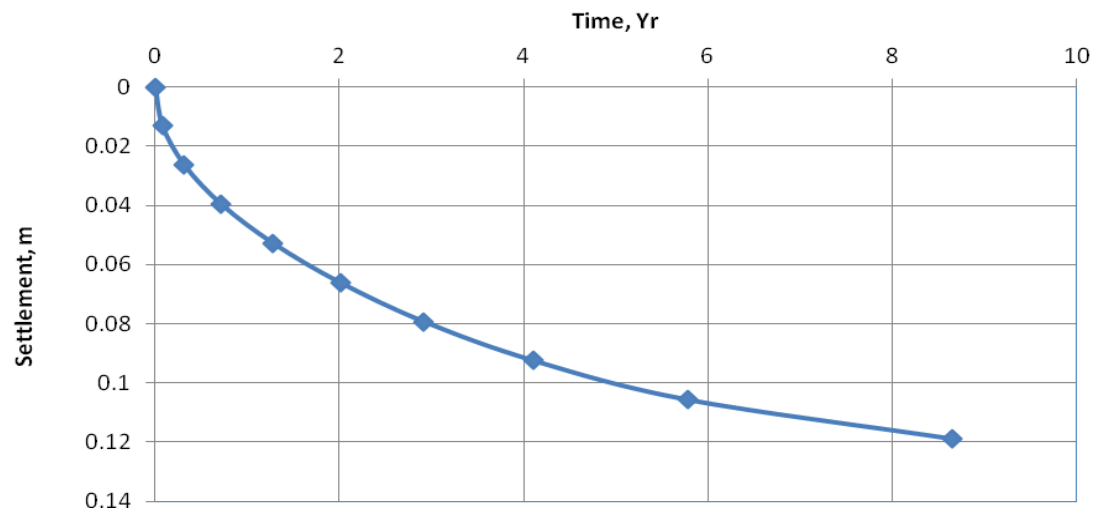


Figure 10.3 Time rate of settlement in clay layer at BH 10



## Settlement Vs. Time at BH 11

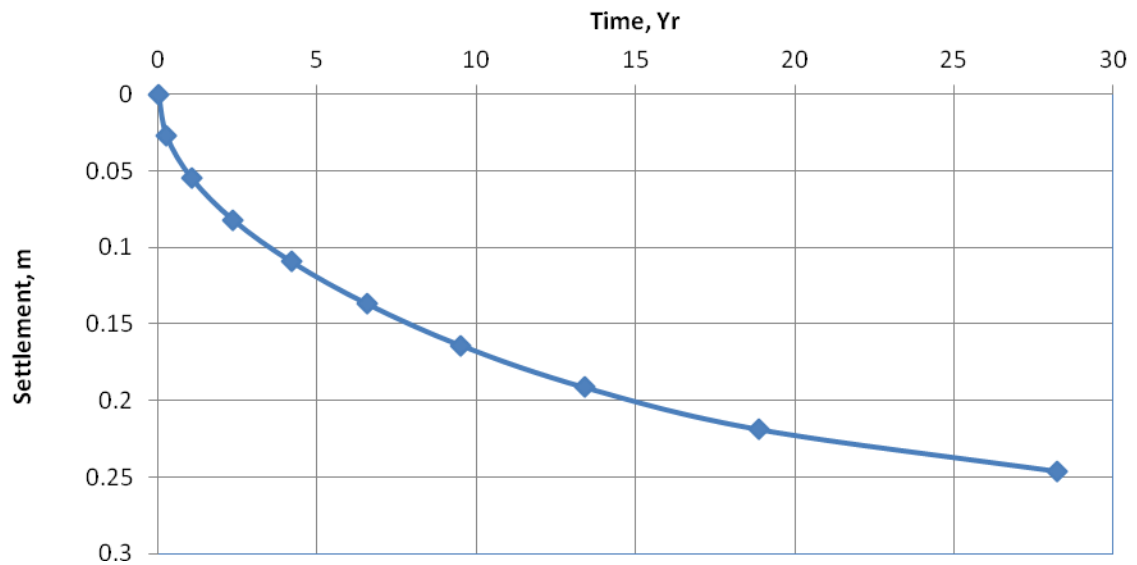


Figure 10.4 Time rate of settlement in clay layer at BH 11

## Settlement Vs. Log Time

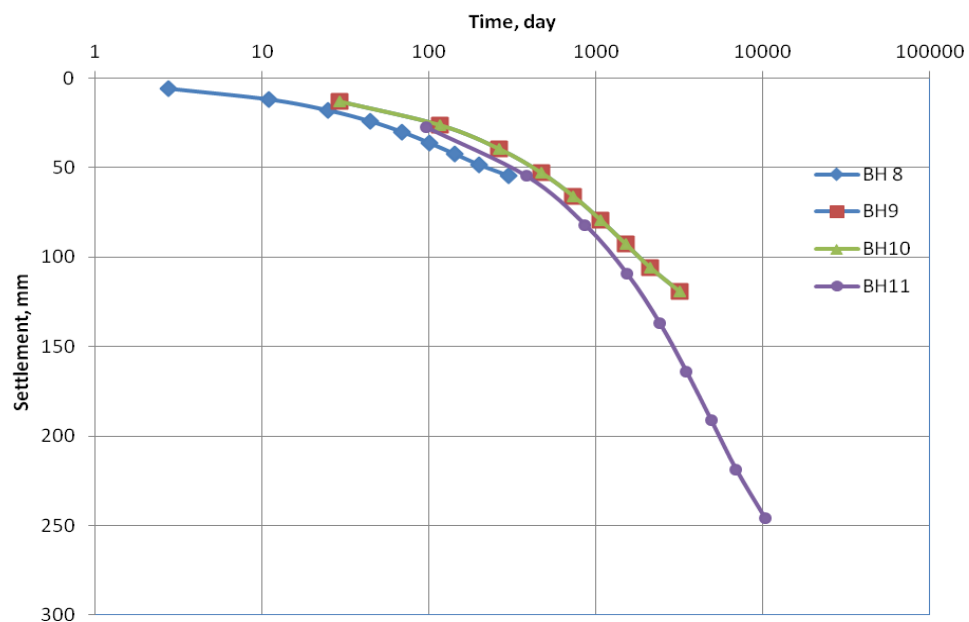


Figure 10.5 Settlement versus log time plot of clay layer for 1 m Grade Raise on Existing Road Alignment

### **10.3 Stability**

The stability of existing embankment with 1 m grade raise was analysed. The side slopes for grade raise is 2.0 H: 1.0 V and used in the analyses. The soil parameters shown in Table 9.1 were used for the stability analyses. The stability of sides embankment after 1 m grade raise were analysed for both deep and shallow slips. These slopes were analyzed for both short and long term conditions using Slope/W software. As Morgenstern & Price's method satisfies force equilibrium, overall moment equilibrium and inter slice moment equilibrium as well as providing consistent results for all groundwater conditions (Bo 2005, Bo & Choa 2004), this method was applied and factors of safety (FOSs) from this method have been reported here. Groundwater level used in the analysis was based on the recent groundwater information.

Subsurface soil profile at Borehole 9 location was used for the stability analyses. Stability analyse results of 1.0 m grade raise are summarized in Table 10.3. The example Slope/W results are shown in Figures 10.6 to 10.11. Total stress parameters were used for the undrained condition stability analysis. Effective stress parameters were used for drained condition stability analysis.

### **10.4 Settlement Mitigation for 1 m Grade Raise**

Surface settlement by 1 m grade raise on existing road alignment is expected. Settlement between 60 mm and 570 mm is expected along the existing road alignment which will vary with thickness of clay and organic material present underneath the road. MTO document of "Embankment Settlement Criteria for Design", July 2, 2010 can be used as a guideline for the grade raise design work.

The settlement problem due to 1 m grade raise can be prevented by using vertical drain and preloading method. The required design preload shall be estimated and used for the preloading work. Vertical drain shall be installed in the clay layer to shorten the drainage path which in turn will accelerate the consolidation process. The consolidation condition under the preload shall be monitored by settlement markers, settlement plates and pore pressure transducers. During the preloading along the existing road alignment, temporary paving shall be carried out to be able allow the traffic use of the road during ground improvement work in progress. Permanent pavement structure could be constructed after reaching 90 % consolidation under the preload. Ground improvement design, instrumentation and monitoring work for vertical drain installation should be

designed by the experienced geotechnical engineer.

1 m grade raise will be on the existing embankment and the option of using light weight fill material is not feasible.

Table 10.3 Slope Stability Analysis Results for 1 m Grade Raise along Existing Road

	Slope	Undrained	Drained
Right side slope	2.0H : 1.0V	1.53	1.37
Left side slope	2.0H : 1.0V	1.32	1.04
Left side slope with 1 m deep fill	2.0H : 1.0V	1.30	1.30

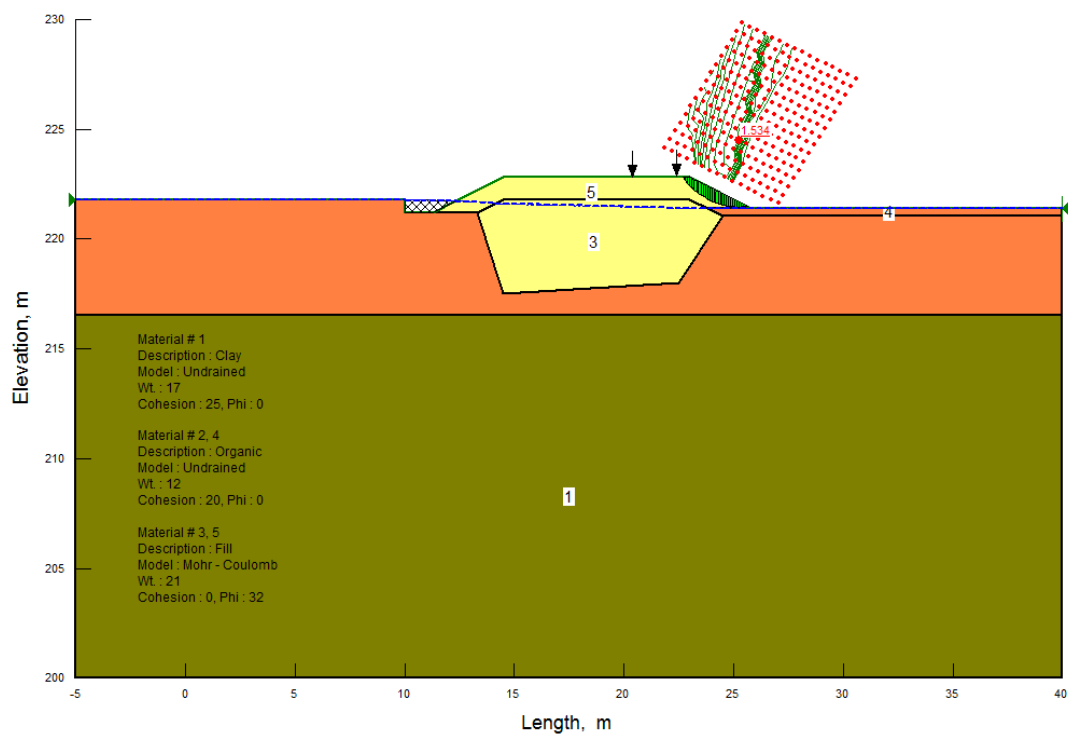


Figure 10.6 Slope stability analysis result, right side slope, undrained condition analysis

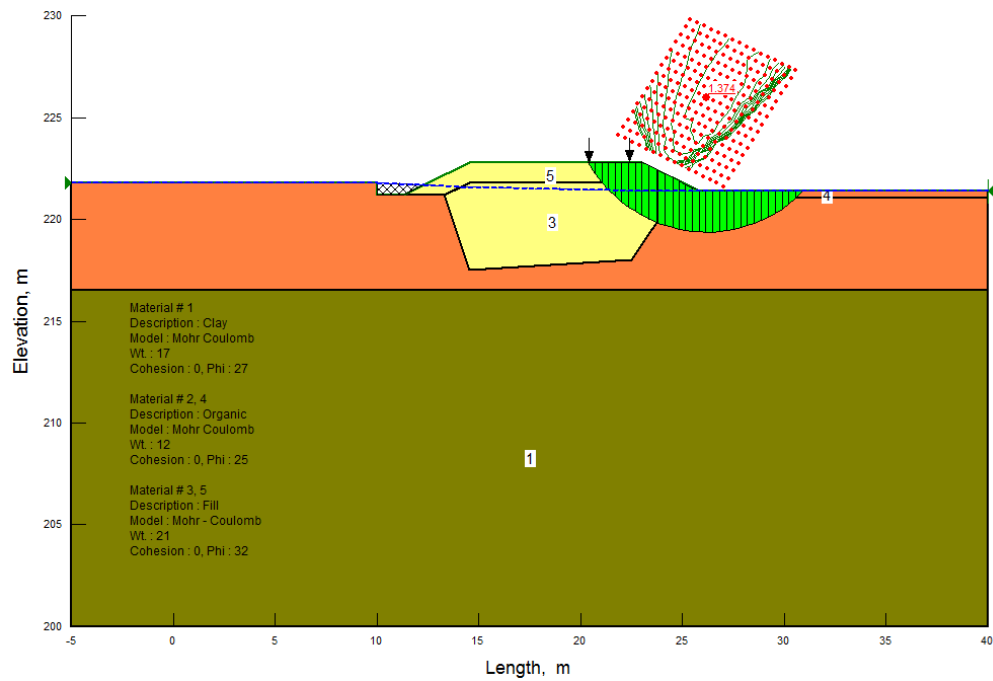


Figure 10.7 Slope stability analysis result, right side slope, drained condition analysis

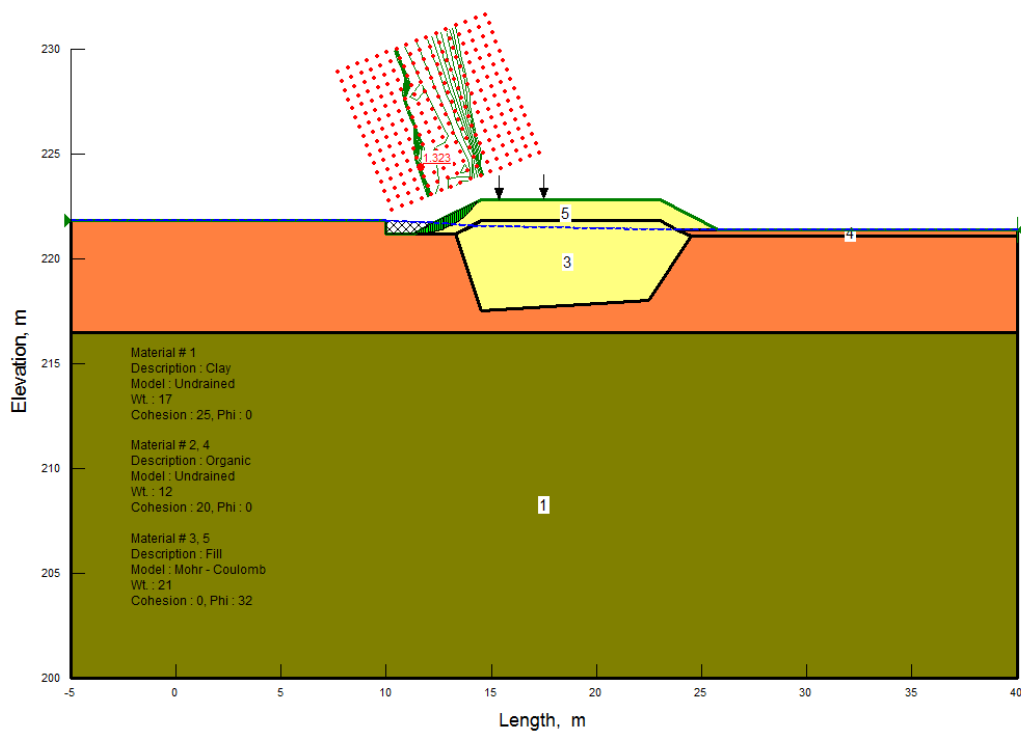


Figure 10.8 Slope stability analysis result, left side slope, undrained condition analysis

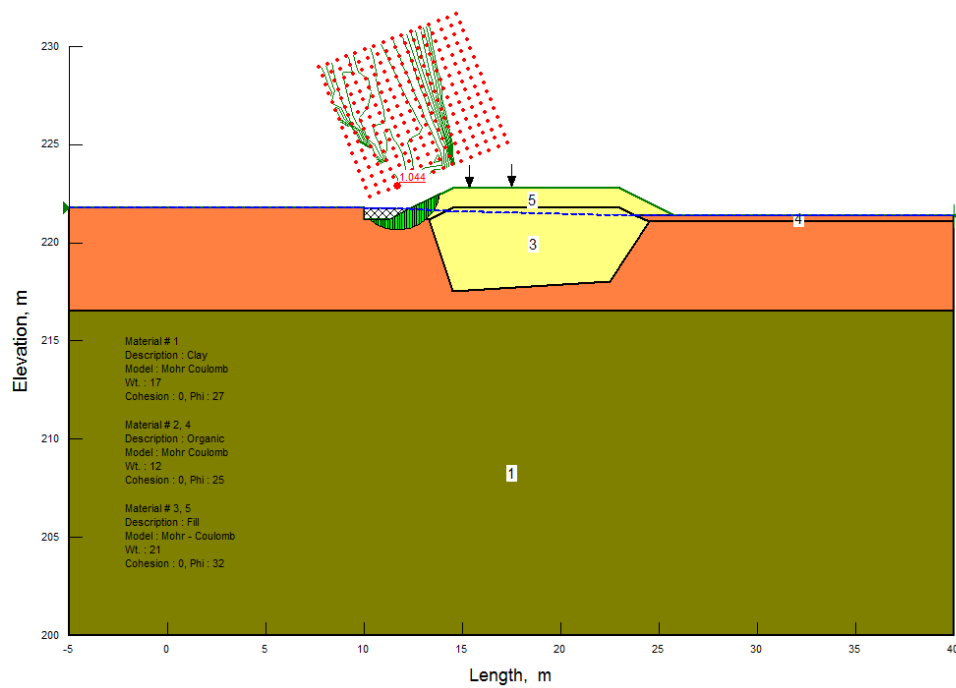


Figure 10.9 Slope stability analysis result, left side slope, drained condition analysis

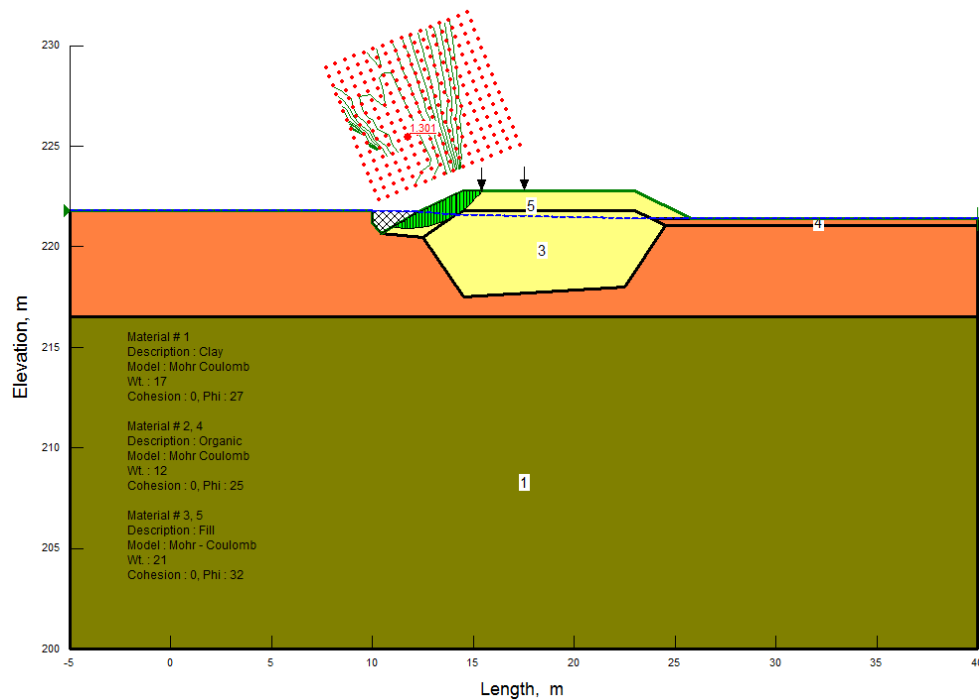


Figure 10.10 Slope stability analysis result, left side slope, drained condition analysis, 1 m extra deep fill in ditch

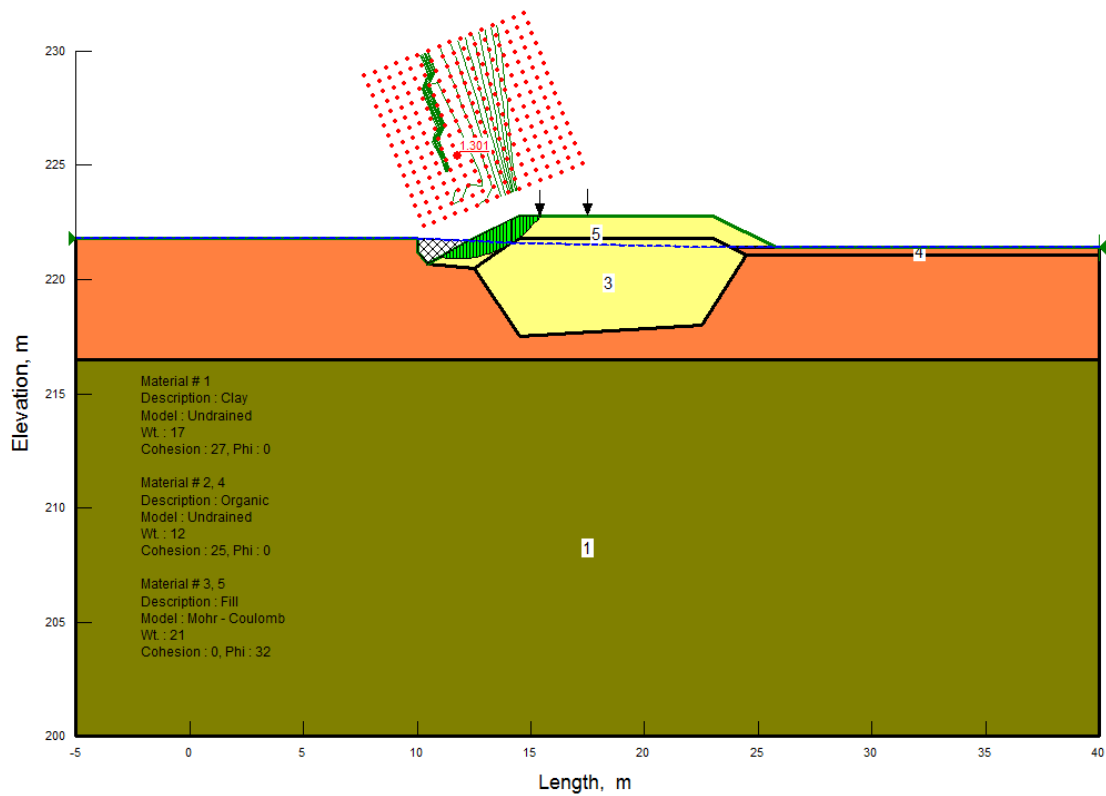


Figure 10. 11 Slope stability analysis result, left side slope, undrained condition analysis, 1 m extra deep fill in ditch

## **11. PROPOSED HIGHWAY RE-ALIGNMENT**

The proposed highway re-alignment subsurface condition consists of thick organic material and clay layers. Therefore, it will have significant settlement issues than 1 m grade raise option along existing road.

The possible options at the proposed highway re-alignment include following;

- 1) Constructing embankment with existing condition (which requires future maintenances of road settlement);
- 2) Total removal of organic material and using light weight fill material (which will reduce settlement in the organic material);
- 3) Ground improvement before constructing the proposed highway re-alignment embankment.

### **11.1 Settlement and Time Rate of Settlement**

The settlement estimation along the proposed highway re-alignment embankment was analysed. The geotechnical parameters used in the analyses are shown in Table 9.2. One dimensional consolidation theory applying Terzaghi (1925) was used for the settlement analyses. Consolidation parameters for clay were interpreted from oedometer consolidation test results. Settlement in organic material was estimated using the method proposed by S. Leroueil and R. K. Rowe (2000). Consolidation settlement at four locations along the proposed highway re-alignment was analysed. The height of the proposed highway re-alignment embankment analysed was with 2 m and slopes of 2.0 H: 1.0V. The settlements for constructing the proposed highway re-alignment embankment were estimated between 2.16 m and 2.23 m. the latter does not include displacement and immediate deformation of very highly compressible peat during the fill placement. Settlements for the proposed highway re-alignment construction with removal of organic material and using light weight fill were estimated between 0.45 m and 0.53 m. The estimated settlements for without removable of organic material and with removable of organic material are shown in Tables 11.1. Settlement time graphs are shown in Figures 11.1 and 11.4.

Table 11.1 Estimated consolidation settlement - 1 m grade raise, (m).

Option No	Option	Station 18 + 450 (BH 2)	Station 18 + 500 (BH 3)	Station 18 + 550 (BH 4)	Station 18 + 600 (BH 5)
1	Constructing with present condition using fill material	2.16	2.16	2.23	2.18
2	Removal of organic material and using light weight fill	0.45	0.45	0.53	0.47
3	Removal of organic material and ground improvement using vertical drain and preload	To be designed for ground improvement work.			

## 11.2 Time Rate of Settlement

Time rate of settlement in the clay was calculated at the four sections. The estimated time required to complete the 90% degree of primary consolidation with the proposed highway re-alignment of two options are analysed. Coefficient of consolidation ( $C_v$ ) of  $15 \text{ m}^2/\text{year}$  was used for time rate of settlement calculation. The estimated time to reach 90 % consolidation for clay is summarized in Table 11.2.

Table 11.2 Estimated 90 % consolidation time - 1 m grade raise, (years)

Option No	Option	Station 18 + 450 (BH 2)	Station 18 + 500 (BH 3)	Station 18 + 550 (BH 4)	Station 18 + 600 (BH 5)
1	Constructing with present subsoil condition without organic removal	15	15	23	17
2	Removal of organic material and using light weight material	15	15	23	17
3	Removal of organic material and ground improvement using vertical drain and preload	To be designed for the ground improvement work.			



Organic material has higher hydraulic conductivity compare to the clay soil. 90% consolidation time for the clay is longer than the 90% consolidation of organic material. Organic material removal option and without organic material removal option will have the same thickness of clay underneath. Therefore, the time for estimated 90% consolidation for organic material removal option and without organic material removal option will have the same.

Organic material removal option will eliminate settlement in the organic material. However, if light weight material is not used in replace of organic material, additional load from the organic material replacement will cause additional settlement to the estimated above and longer time for completion of 90% consolidation will be required.

Settlement versus time graphs for clay layer is presented in Figure 11.1 to Figure 11.6.

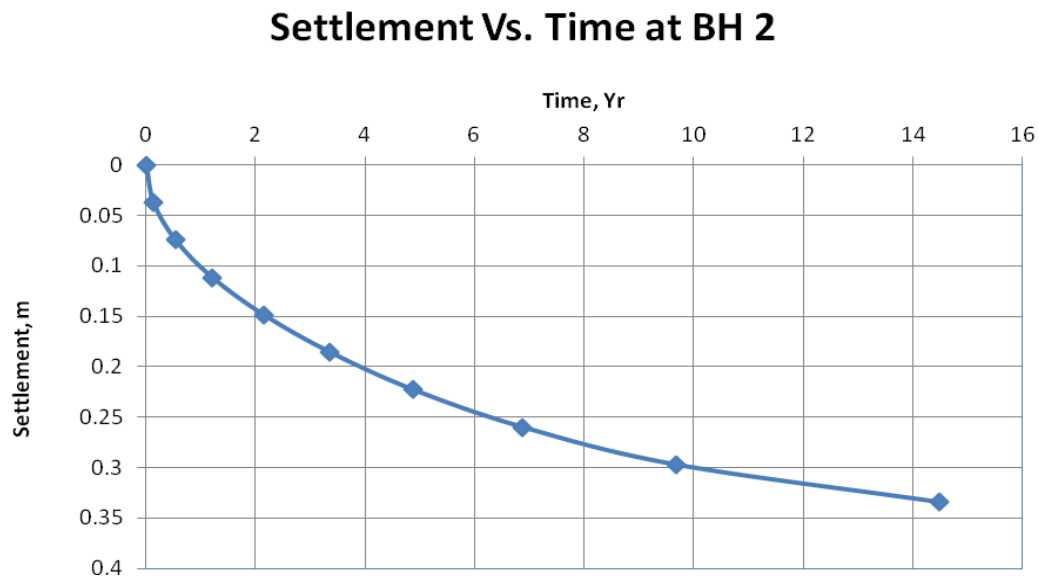


Figure 11.1 Time rate of settlement in clay layer at BH 2

### Settlement Vs. Time at BH 3

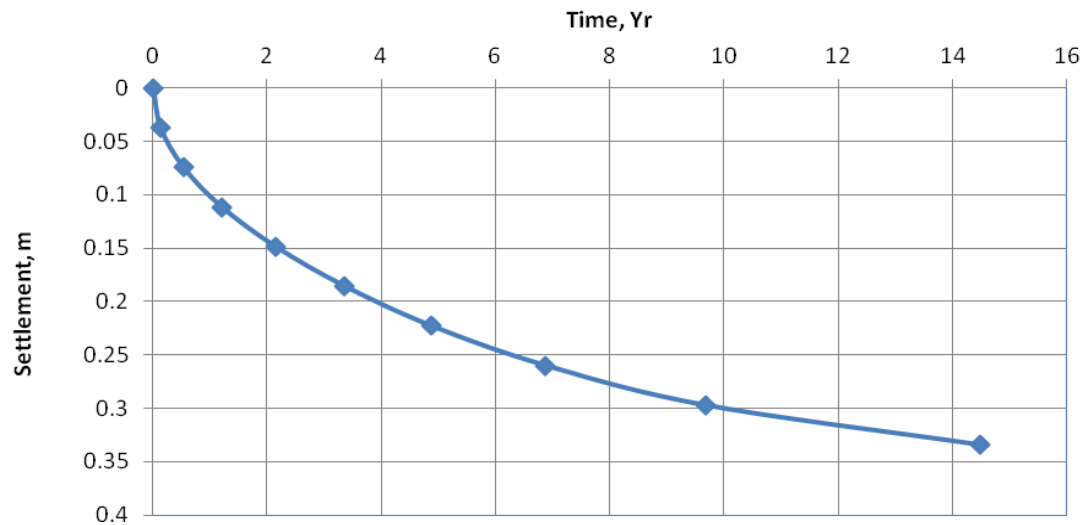


Figure 11.2 Time rate of settlement in clay layer at BH 3

### Settlement Vs. Time at BH 4

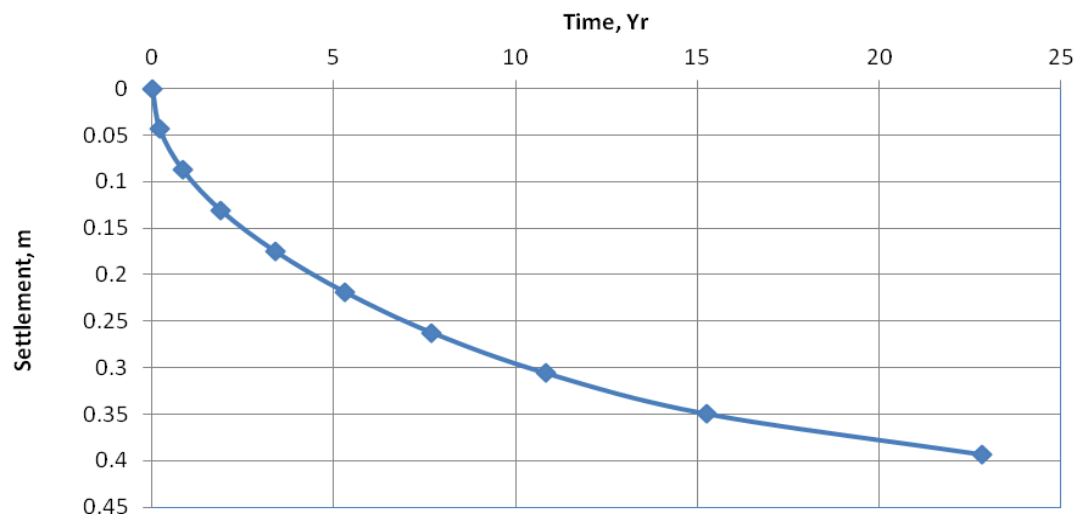


Figure 11.3 Time rate of settlement in clay layer at BH 4

### Settlement Vs. Time at BH 5

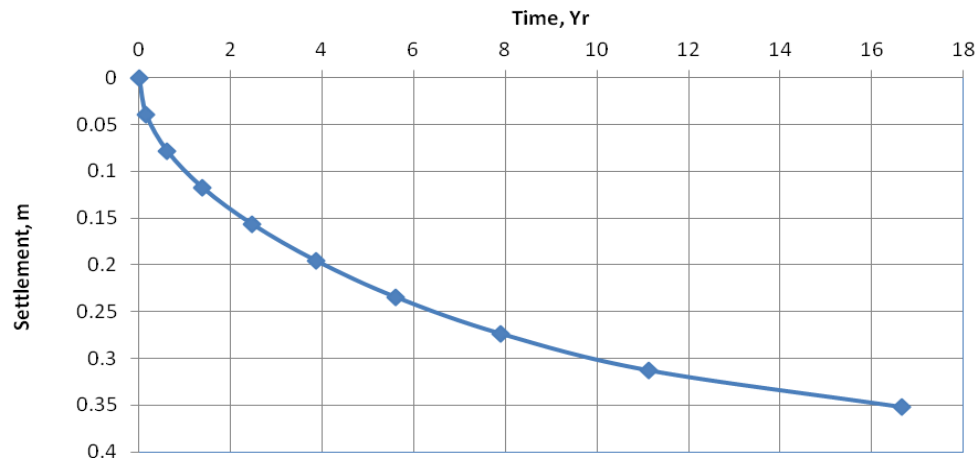


Figure 11.4 Time rate of settlement in clay layer at BH 5

### Settlement Vs. Log Time

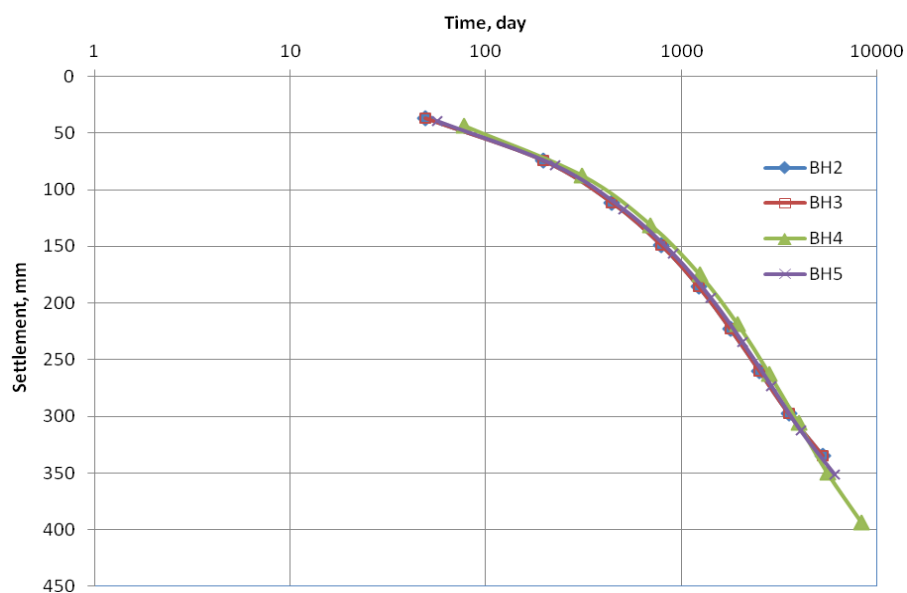


Figure 11.5 Settlement versus log time plot of clay layer for new road alignment (for both organic material removal and without removal)

### 11.3 Stability of New Road Embankment and Settlement Remediation

#### Stability of New Road Embankment

The road can be constructed using 3.5H: 1.0V slope to be stable for construction without removal of organic material. Present of organic material and soft soil layer, gave low factor of safety for the slope with 3.5H: 1.0V slope. In the analysis, 2 m height of embankment was used. The factor of safety of 1.11 and 1.16 was obtained. With new road embankment, soil and organic material will have consolidation and will increase the factor of safety over the time. Figure 11.6 and Figure 11.7 show the factor of safety result for new embankment loading.

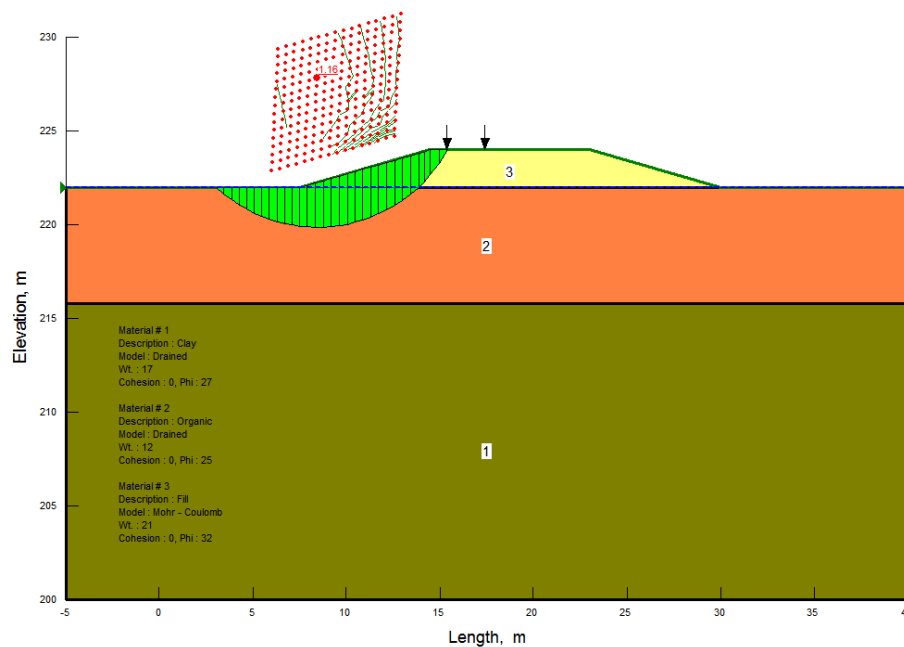


Figure 11. 6 Slope stability analysis result, left side slope, drained condition analysis, new alignment without organic removal

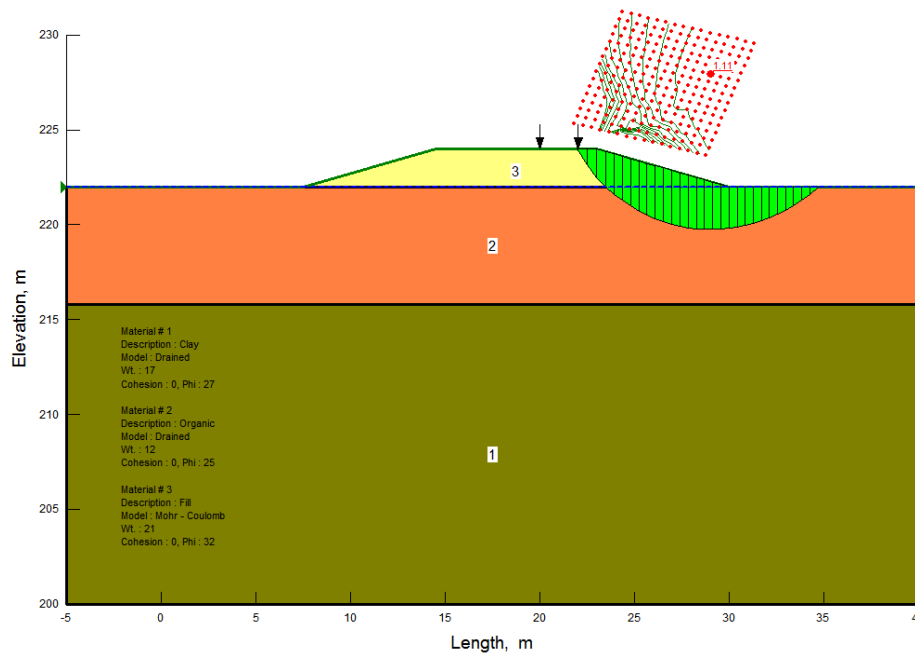


Figure 11.7 Slope stability analysis result, right side slope, drained condition analysis, new alignment without organic removal

With the organic material removal and replacement with light weight fill material, higher factor of safety was resulted for the 2H: 1V slopes. For the option of organic material removal, the embankment can be built with 2H: 1V slope. Factor of safety of 1.48 and 1.63 were resulted from the analyses for the organic material removal option. The slope stability results for organic material removal and replacement option are shown in the Figure 11.8 and Figure 11.9.

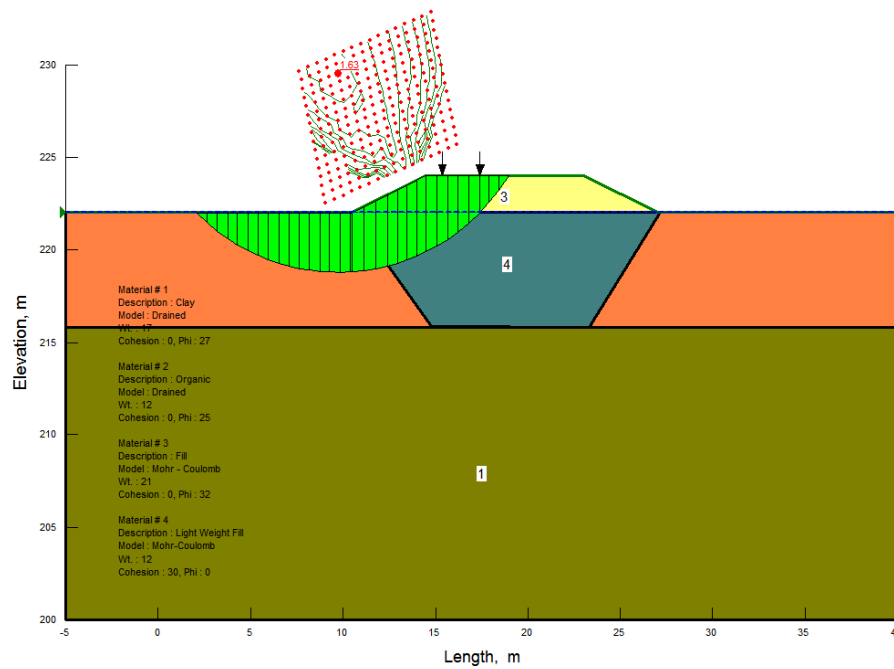


Figure 11. 8 Slope stability analysis result, left side slope, drained condition analysis, new alignment with organic removal and replacement with light weight fill

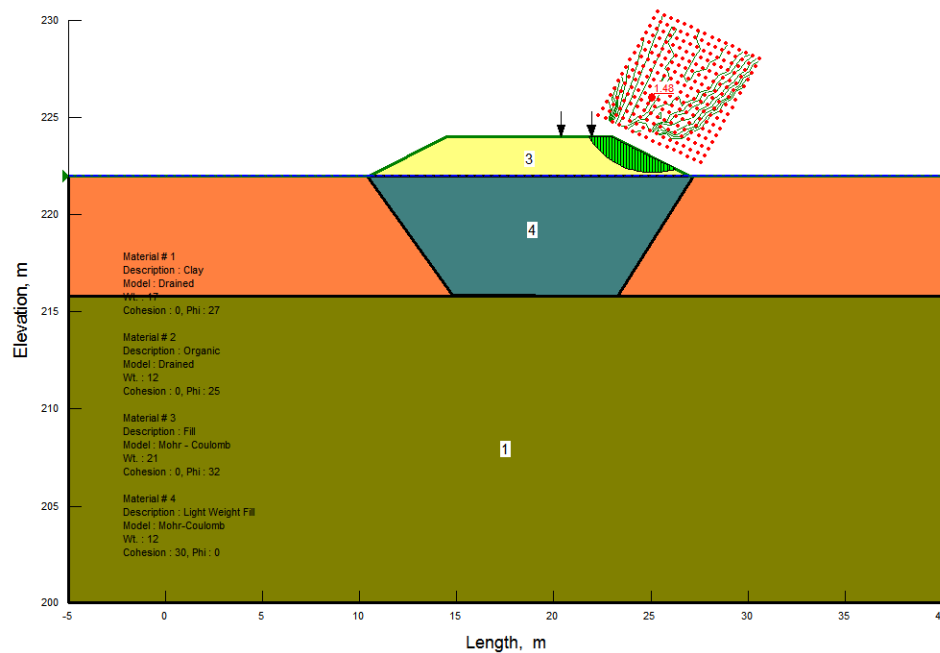


Figure 11. 9 Slope stability analysis result, right side slope, drained condition analysis, new alignment without organic removal and replacement with light weight fill

### Settlement Remediation

The option to mitigate the settlement problem is to use ground improvement at new road alignment. Preload with vertical drain method is recommended for remediating settlement problem at the site. This ground improvement method will accelerate the consolidation of the soft soil and prevent road embankment settlement problem. The vertical drain installation and preload shall be designed by experienced geotechnical engineer familiar with this method. DST has experiences in this type of ground improvement work and can provide consulting services if the ministry requires. Ground improvement work shall be monitored using installation of surface settlement markers, settlement plates and pore pressure transducers. The permanent new road pavement structure shall be constructed only after completion of 90% consolidation under required design preload.

## 12. RECOMMENDATIONS

The grade raise of 1 m on the existing road may cause settlement of between 0.06 m and 0.57 m. The settlement will be contributed mainly from primary and secondary consolidation settlement in the clay layer and organic material. However, the settlement at the proposed highway re-alignment will have much greater magnitude than the grade raise option along existing road alignment. The existing road subsurface condition has lesser organic layer thickness compare to the proposed highway re-alignment location. The soil below the existing road also has consolidated to certain degree of consolidation under the existing load of embankment as well as displacement or removal of organic and soft soil. From the analyses, it appears that 1 m grade raise may have much lesser magnitude of settlement compared to the proposed highway re-alignment options. Therefore, it seems 1 m grade raise to existing road will be a better option.

Constructing the proposed highway re-alignment will have excessive settlement issues due to a thick organic material and soft clay layer. If this option is chosen to construct, the possible options are 2a) constructing without removing organic but provide reinforced layer of geotextile, 2b) removing organic material and place light weight fill materials, and 2c) removing organic material and improvement of ground using wick drain and preload. Option 2a and 2b require road maintenance and repair works for future road settlement.

Advantages and disadvantages for the options grade raise and the proposed highway re-alignment are discussed in the Table 12.1.

Table 12.1 Advantages and disadvantages for various options

Option	Advantages	Disadvantages
1a. Raising the existing grade at exiting alignment	<ul style="list-style-type: none"> <li>• Less magnitude of settlement.</li> <li>• Road can be built directly on existing embankment and site clearance is not necessary.</li> <li>• Cost of construction is less than other options.</li> </ul>	<ul style="list-style-type: none"> <li>• Traffic disruption during 1 m grade raise.</li> <li>• Stages construction or temporary detour road is required during construction if utilization of road is required during construction.</li> <li>• Differential settlement between two stages could experience.</li> <li>• Drainage requires to be relocated.</li> <li>• Future road maintenance and repair work may be required.</li> </ul>



1b. Preload and vertical drain ground improvement before 1 m grade raise	<ul style="list-style-type: none"> <li>Settlement problem is prevented.</li> <li>Road can be built directly on existing embankment and site clearance is not necessary.</li> <li>Long term maintenance cost from the road settlement may not be required.</li> </ul>	<ul style="list-style-type: none"> <li>Traffic disruption during construction work.</li> <li>Require instrumentation and monitoring for assessment of consolidation.</li> <li>Required qualified contractor for ground improvement work.</li> <li>Immediate more cost than option 1a. However, it will save the long term maintenance cost.</li> </ul>
Option	Advantages	Disadvantages
2a. The proposed highway re-alignment (constructing without removal of organic)	<ul style="list-style-type: none"> <li>No traffic disruption during construction.</li> <li>No organic material removal.</li> <li>Less construction cost than organic material removal option.</li> </ul>	<ul style="list-style-type: none"> <li>Excessive road total settlement.</li> <li>Geosynthetics material is required to prevent excessive differential settlement.</li> <li>Future road maintenance and repair work for the road settlement is required.</li> <li>Higher cost and require more volume of fill than option 1.</li> </ul>
2b. The proposed highway re-alignment (replacement of organic material and using light fill material)	<ul style="list-style-type: none"> <li>No traffic disruption during construction.</li> <li>Reduce road settlement compare to no organic removal option.</li> </ul>	<ul style="list-style-type: none"> <li>Organic material removal and disposal is required.</li> <li>Light weight fill material is required.</li> <li>Future road maintenance and repair work is still required.</li> <li>Costly.</li> </ul>
2c. The proposed highway re-alignment (removal of organic material and ground improvement using wick drain and preloading)	<ul style="list-style-type: none"> <li>Settlement problem is eliminated.</li> <li>Long term maintenance may not be required.</li> <li>No traffic disruption.</li> </ul>	<ul style="list-style-type: none"> <li>Construction time is longer.</li> <li>Organic removal and disposal is required.</li> <li>Additional road construction material is required.</li> <li>Ground improvement work is required.</li> <li>Costly.</li> </ul>

The 1 m grade raise could be constructed on existing embankment. The clay layer was found very thick and highly compressible. In addition, total removal of compressible layer is not economical. The side slopes of the embankment could be constructed with 2.0 H: 1.0 V. The water table is expected near the ground surface. However, differential settlement between two stages is expected. By raising 1 m above the present grade, the drainage could be 1 m below the proposed highway re-alignment embankment after the grade raise. However, due to the future road settlement, embankment elevation will become lower by approximately 0.5 m.

The 1 m grade raise could be constructed using stages construction or using temporary detour road to minimize traffic disruption during construction. Stages construction will cause

differential settlement. The settlement of the ground shall be monitored using surface settlement marker. The paving shall be carried out only after stable rate differential settlement. Side slopes erosion could be protected by using vegetation or placing rip rap on the road shoulder. The road will require regular maintenance.

The ground improvement using preload and vertical drain can be used at 1 m grade raise to existing embankment. Vertical drain can be installed in the clay layer and allow the consolidation settlement under the preload condition. The consolidation settlement shall be monitored and analyze the consolidation achievement. After completion of required consolidation, final paving shall be carried out.

Alternate options for the proposed highway re-alignment construction is removal of organic material and ground improvement to the soft clay layer. Settlement problem in the soft clay soil can be reduced by ground improvement using wick drain and preloading. This option requires time for ground improvement work. Design work for the wick drain installation and preloading is required. Monitoring of ground improvement work is also required.

### **13. CONSTRUCTION PRACTICES**

The contractor's methods and equipment must be suitable for the site conditions and materials used. Furthermore, due to the presence of peat, full time surveillance of the construction should be carried out by qualified personnel for any signs of impending movements. If noted, the construction should be immediately halted, the embankment stability reassessed, and the methodology reviewed and modified as required.

The excavation is to be as per OPSD and OPSS. Earth embankment construction should be completed as per OPSS and OPSD 200.

It is recommended that the granular materials required for this project be specified as Granular 'A' and Granular 'B' Type I meeting the specifications of OPSS 1010. Embankment slopes for general compacted earth fill should be 2H to 1V. The granular materials should be compacted to 98 % of standard proctor compaction with suitable lifts (not more than 200 mm thick).

Placement of fill could be carried out with the help of long arm excavator and not by end dumping over the slope (this creates temporarily steep unstable conditions). The method of placement must not adversely affect the stability of existing embankment. Observation of movement of embankment by means of surveying is suggested. Performance of the solution should be monitored using surface monitoring monuments to record vertical and horizontal displacements. If any significant magnitude and rate of movement is registered, the construction process should be halted. The installation of a set piezometer in strategic location along the treated area, this will provided a record of pore pressure in the clay layer.

The recommended seed mixture to be specified is the MTO Standard Roadside Seed Mix. Seed and mulch are to be applied as per OPSS 804 over all newly constructed earth slopes and all newly constructed slope-flattening areas. It is recommended that seed and mulch be applied soon after the slopes are shaped to the final grade.

If the ground improvement by vertical drain and preload method is used, instrumentation and monitoring will be required. Settlement markers, settlement plates and pore pressure transducers shall be used for monitoring of ground improvement work. The vertical drain ground improvement design work, instrumentation and monitoring design shall be carried out by experienced geotechnical engineer. The expected consolidation settlement from preload shall be estimated.

## 14. REFERENCES

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## 15. LIMITATION 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.

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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 a Quality Verification Engineer 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'**  
**DESCRIPTIVE TERMS**  
**FOR SOIL CLASSIFICATION**



## EXPLANATION OF TERMS USED IN REPORT

**SPT 'N' VALUE:** THE STANDARD PENETRATION TEST (SPT) N VALUE OF THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51 mm O.D. SPLIT BARREL SAMPLES TO PENETRATE 0.3 m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5 kg, FALLING FREELY A DISTANCE OF 0.76 m. FOR PENETRATION OF LESS THAN 0.3 m 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 (DCPT):** CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51 mm 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 0.3 m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

### ***SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS***

#### **TEXTURAL CLASSIFICATION OF SOILS**

BOULDERS	COBBLES	GRAVEL	SAND	SILT	CLAY
GREATER THAN 200 mm	75 TO 200 mm	4.75 TO 75 mm	0.075 TO 4.75 mm	0.002 TO 0.075 mm	LESS THAN 0.002 mm

#### **COARSE GRAIN SOIL DESCRIPTION (50% GREATER THAN 0.075 mm)**

TERMINOLOGY	TRACE OR OCCASIONAL	SOME	ADJECTIVE (e.g. SILTY OR SANDY)	AND (e.g. SAND AND SILT)
	LESS THAN 10%	10 TO 20%	20 TO 35%	35 TO 50%

#### **CONSISTENCY\*: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH ( $C_u$ ) AND SPT 'N' VALUES AS FOLLOWS**

$C_u$ (kPa)	0 – 12	12 – 25	25 – 50	50 - 100	100 - 200	> 200
N (BLOWS / 0.3 m)	<2	2 - 4	4 - 8	8 - 15	15 - 30	>30
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

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

N (BLOWS / 0.3 m)	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, 100 mm+ IN LENGTH EXPRESSED AS A PERCENTAGE OF THE LENGTH OF THE CORING RUN.

THE **ROCK QUALITY DESIGNATION (R.Q.D)** FOR MODIFIED RECOVERY IS:

R.Q.D (%)	0 – 25	25 – 50	50 – 75	75 – 90	90 – 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

#### **LEGEND OF RECORDS FOR BOREHOLES: SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE**

SS	SPLIT SPOON SAMPLE	WS	WASH SAMPLE
TW	THIN WALL SHELBY TUBE SAMPLE	AS	AUGER (GRAB) SAMPLE
PH	SAMPLER ADVANCED BY HYDRAULIC PRESSURE	TP	THIN WALL PISTON SAMPLE
WH	SAMPLER ADVANCED BY SELF STATIC WEIGHT	PM	SAMPLER ADVANCED BY MANUAL PRESSURE
SC	SOIL CORE	RC	ROCK CORE
	WATER LEVEL	$SENSITIVITY = \frac{UNDISTURBED\ SHEAR\ STRENGTH}{REMOLDED\ SHEAR\ STRENGTH}$	

\*HIERARCHY OF SOIL STRENGTH PREDICTION: **1)** LABORATORY TRIAXIAL TESTING. **2)** FIELD INSITU VANE TESTING. **3)** LABORATORY VANE TESTING. **4)** SPT VALUES. **5)** POCKET PENETROMETER.

# **A P P E N D I X ‘ C ‘**

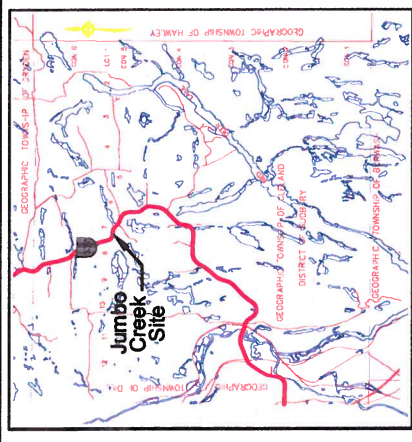
## **D R A W I N G S**

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

CONT No 5279-03-00  
GWP No  
WP No  
Site No  
GeoCres No 421-286

ROAD ALIGNMENT  
AT JUMBO CREEK  
Hwy 537 - Cleland Twp.  
Borehole Locations

SHEET



0 8  
SCALE IN KILOMETRES

- LEGEND**
- Borehole/Hand Auger
  - Borehole with DCPT
  - Dynamic Cone Penetration Test (DCPT)
  - Rock Probe
  - 'N' 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

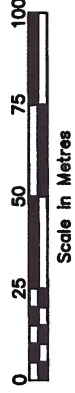
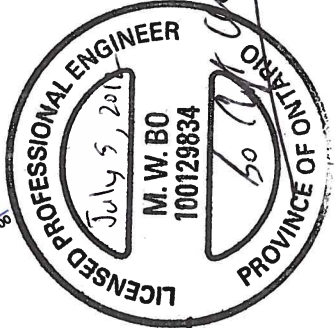
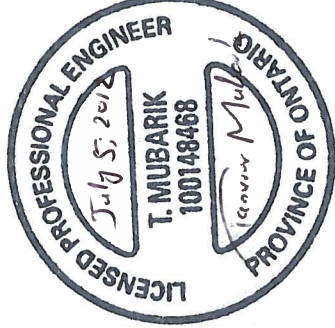
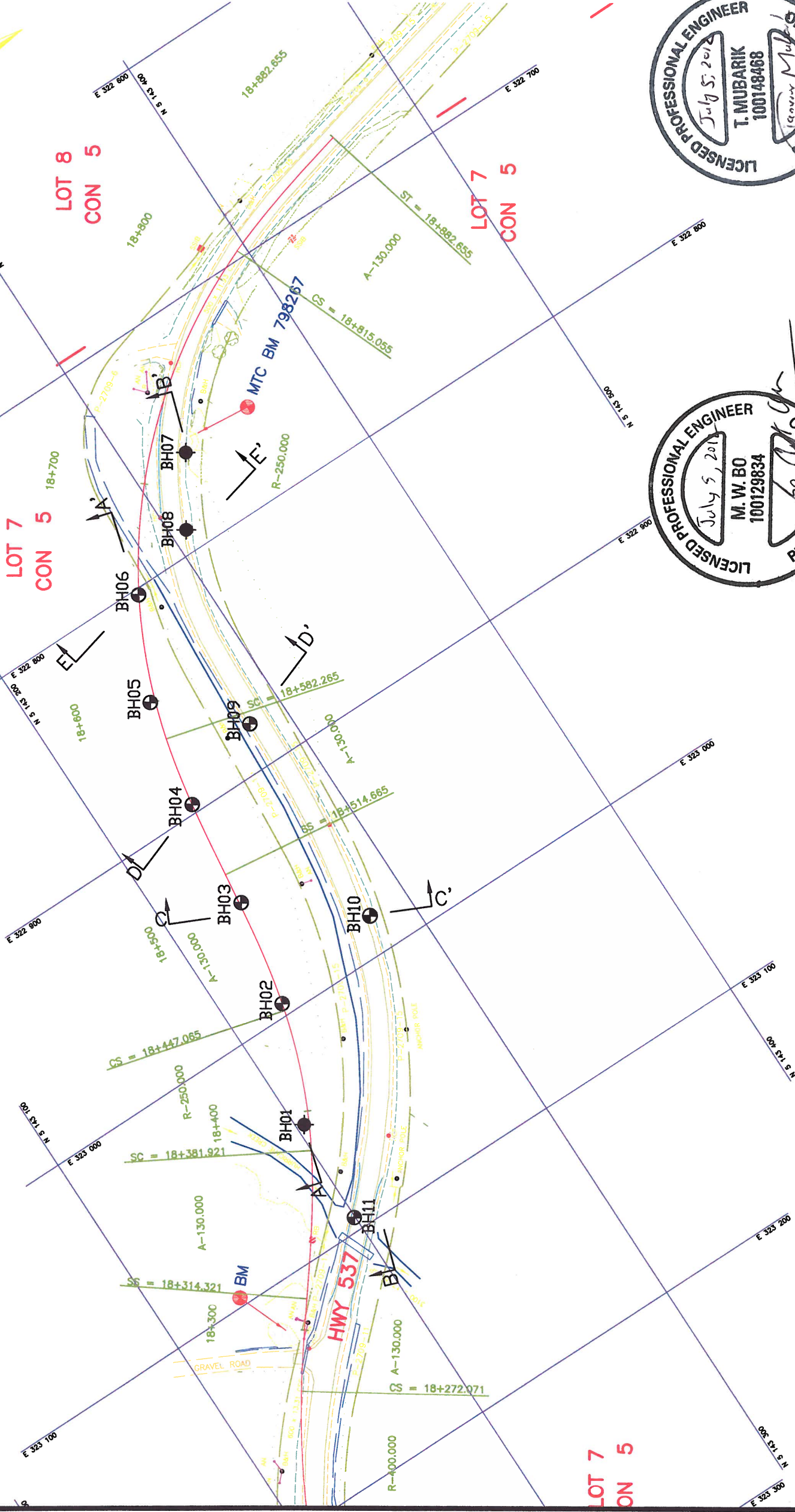
No.	Elevation	Northing	Eastings	Station	Offset
BH1	221.761	5141673	518228	18+412	2.2 m LT
BH2	221.841	5141688	518167	18+450	CL
BH3	221.836	5141684	518133	18+500	0.9 m RT
BH4	221.970	5141689	518090	18+550	CL
BH5	221.888	5141712	518046	18+600	2.3 m LT
BH6	221.815	5141731	517988	18+650	CL
BH7	223.300	5141762	517947	18+715	3.0 m RT
BH8	223.606	5141762	517932	18+875	4.0 m RT
BH9	221.632	5141738	518037	18+975	4.0 m LT
BH10	221.874	5141731	518189	18+475	4.8 m RT
BH11	222.130	5141652	518233	18+350	3.0 m LT

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

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consulting engineers Email: thunderbay@dstgroup.com

DRAWING 1

GEOGRAPHIC TOWNSHIP OF CLELAND  
DISTRICT OF SUDBURY

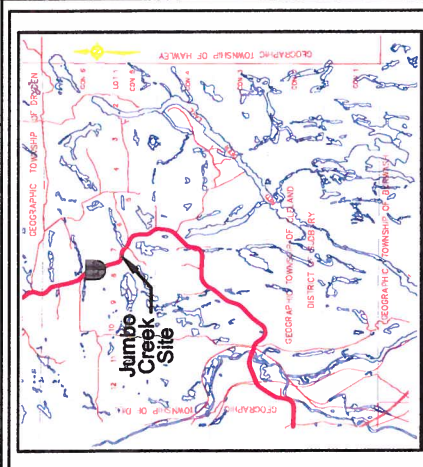




METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SHOWN. STATIONS  
IN KILOMETRES + METERS

CONT	No	No
GWP	No	5279-03-00
WP	No	
Site	No	
GeoCres	No	421-286

PROPOSED ROAD ALIGNMENT AT JUMBO CREEK Hwy 537 - Cleland Twp. Borehole Locations & Soil Strata	SHEET
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0 8  
SCALE IN KILOMETRES

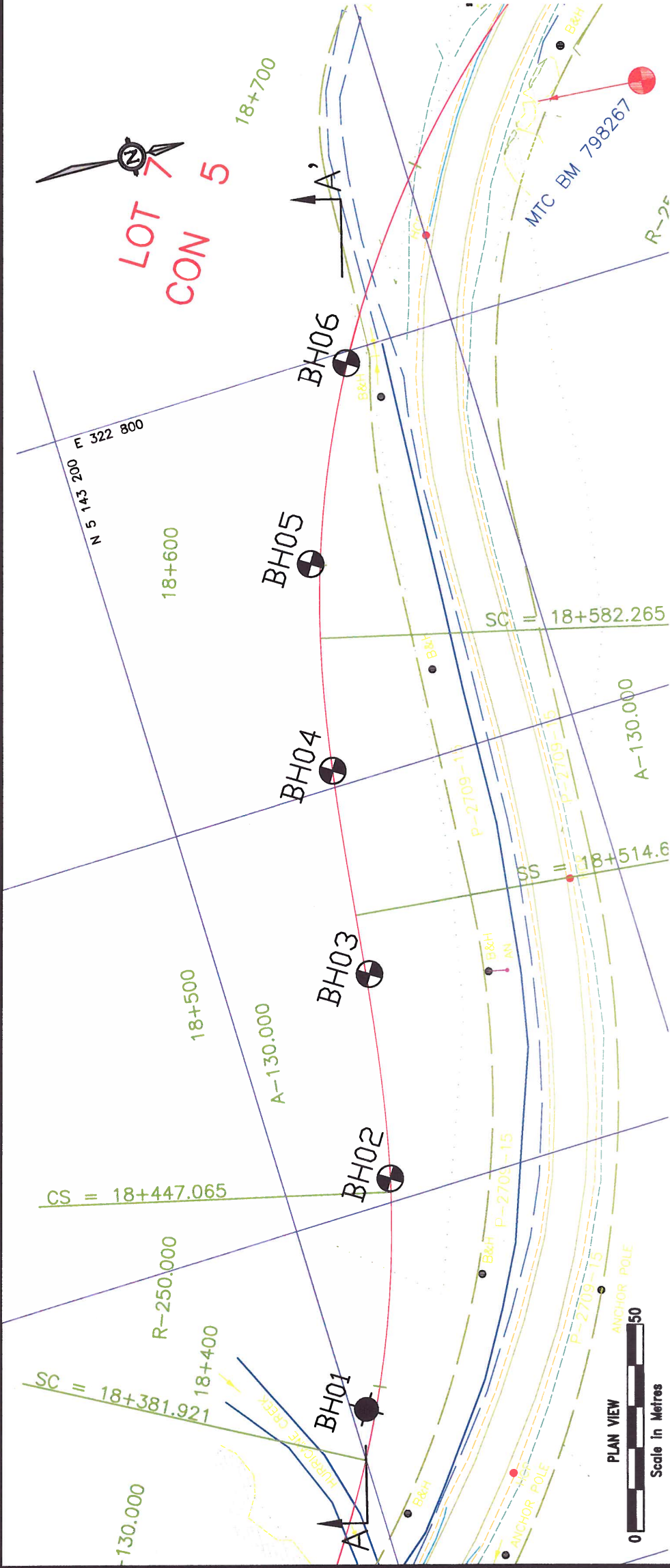
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	Borehole with DCPT
	Dynamic Cone Penetration Test (DCPT)
	Rock Probe
	Blows/0.3m (Std. Pen Test, 475 J/Blow)
	Water level at time of investigation.
	Benchmark
	Fill
	Organics
	Topsoil
	Till
	Bedrock
	Sand
	Silt
	Clay
	Sand & Gravel
	Boulders

No.	Elevation	Northing	Eastings	Station	Offset
BH1	221.761	5141673	514228	18+412	2.2 m LT
BH2	221.041	5141686	514167	18+450	CL
BH3	221.636	5141684	514136	18+500	0.9 m RT
BH4	221.970	5141689	514090	18+550	CL
BH5	221.889	5141712	514046	18+600	2.3 m LT
BH6	221.516	5141762	517698	18+650	CL
BH7	223.300	5141731	517647	18+715	3.0 m RT
BH8	223.506	5141762	517683	18+675	4.0 m RT
BH9	221.832	5141738	518087	18+875	4.0 m LT
BH10	221.974	5141731	518189	18+475	4.8 m RT
BH11	222.130	5141652	518253	18+350	3.0 m LT

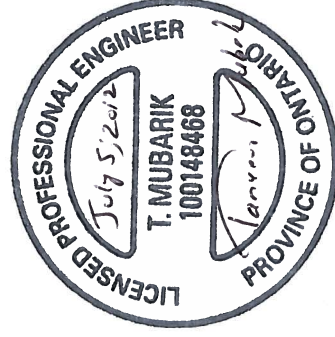
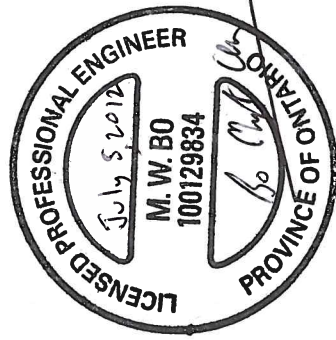
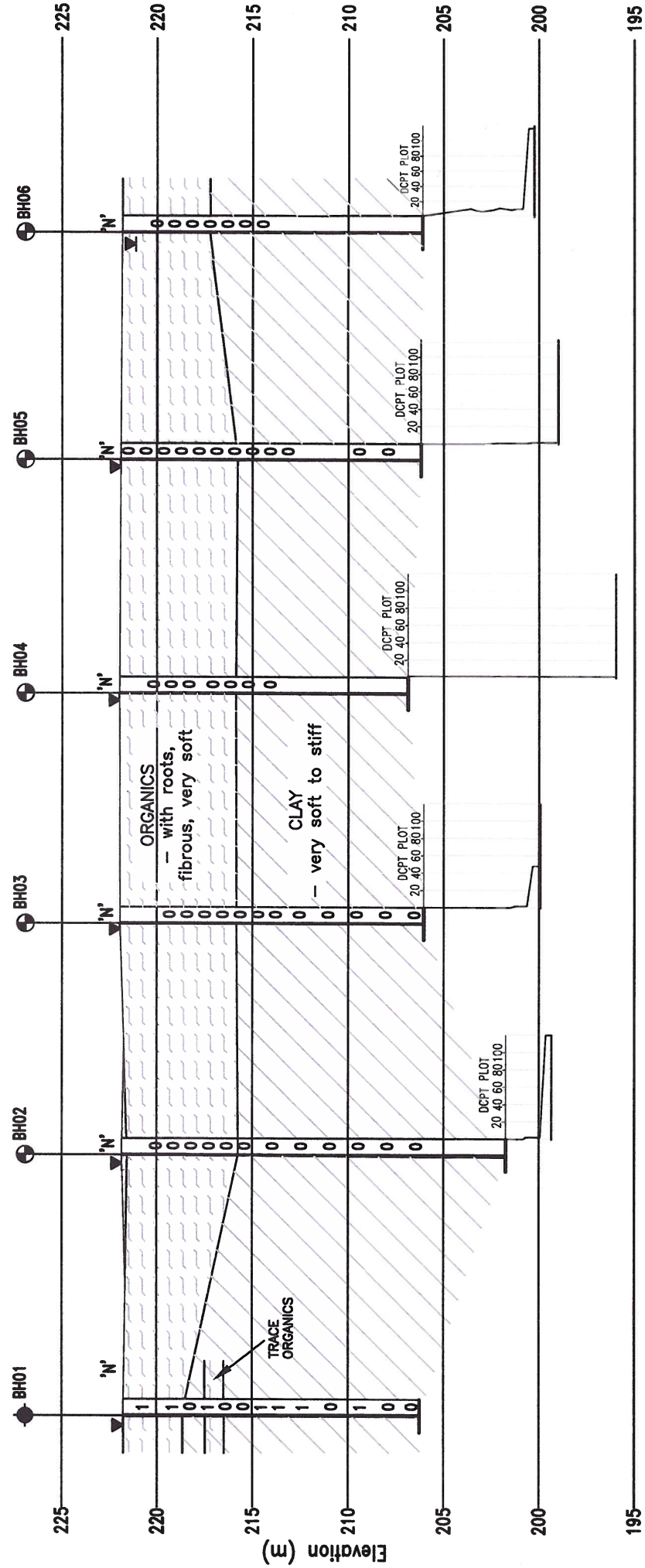
Vertical Scale in Metres  
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Horizontal Scale in Metres  
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NOTE:  
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consulting engineers Email: thunderbay@dstgroup.com



PROFILE ALONG THE PROPOSED ALIGNMENT





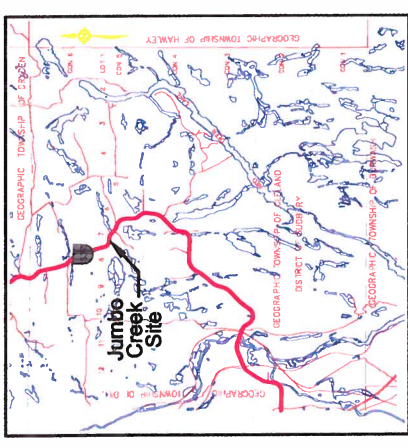




METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SHOWN. STATIONS  
IN KILOMETRES + METERS

CONT No 5279-03-00  
GWP No  
WP No  
Site No  
GeoCres No 421-286

CROSS SECTION  
AT JUMBO CREEK  
Hwy 537 - Cleland Twp.  
Borehole Locations & Soil Strata



KEY PLAN  
0 8  
SCALE IN KILOMETRES

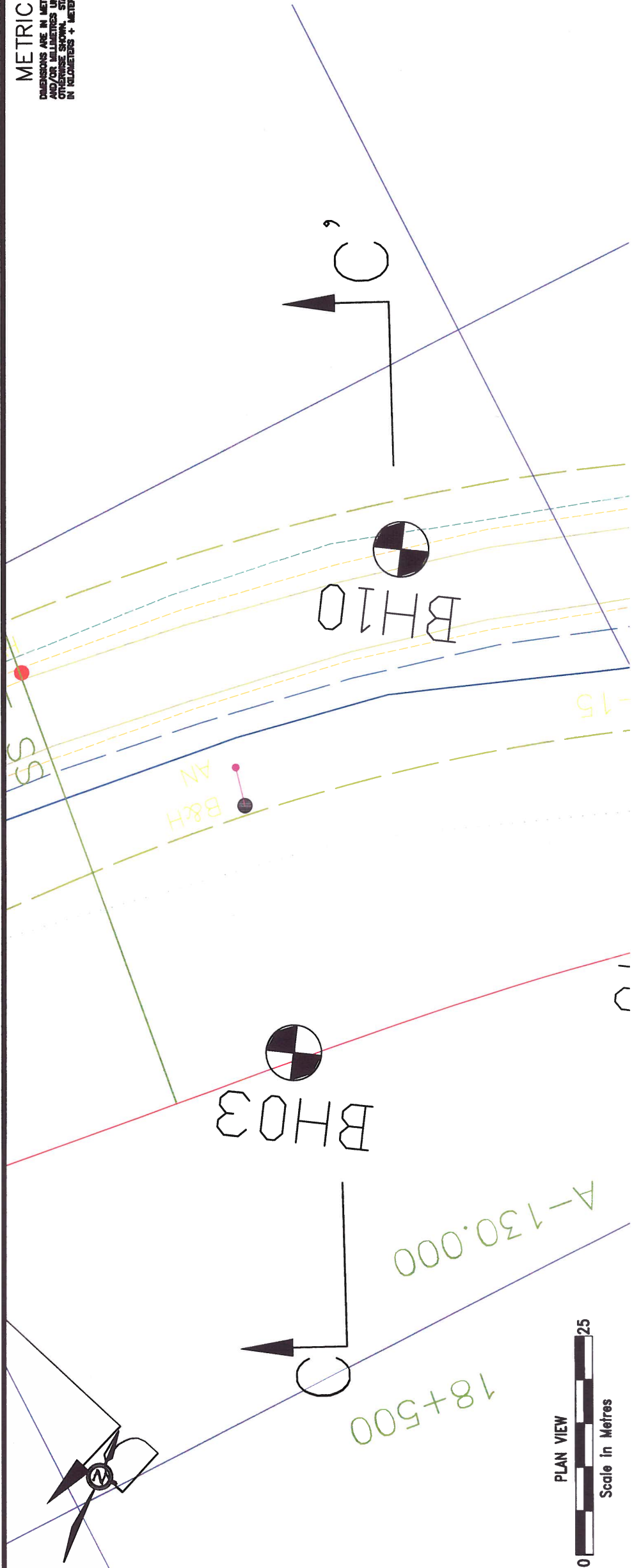
LEGEND	
	Borehole/Hand Auger
	Borehole with DCPT
	Dynamic Cone Penetration Test (DCPT)
	Rock Probe
	Blows/0.3m (Std. Pen Test, 475 J/Blow)
	Water level at time of investigation.
	Benchmark
	Fill
	Organics
	Topsoil
	Till
	Bedrock
	Sand
	Silt
	Clay
	Sand & Gravel
	Boulders

No.	Elevation	Northing	Eastings	Station	Offset
BH1	221.761	5141673	516228	18+412	2.2 m LT
BH2	221.841	5141686	516187	18+450	CL
BH3	221.836	5141684	516138	18+500	0.9 m RT
BH4	221.970	5141689	516090	18+550	CL
BH5	221.889	5141712	516046	18+600	2.3 m LT
BH6	221.816	5141731	517888	18+650	CL
BH7	223.300	5141762	517847	18+715	3.0 m RT
BH8	222.806	5141762	517682	18+715	4.0 m RT
BH9	221.832	5141738	516087	18+875	4.0 m LT
BH10	221.874	5141731	516189	18+875	4.8 m RT
BH11	222.130	5141652	516293	18+350	3.0 m LT

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

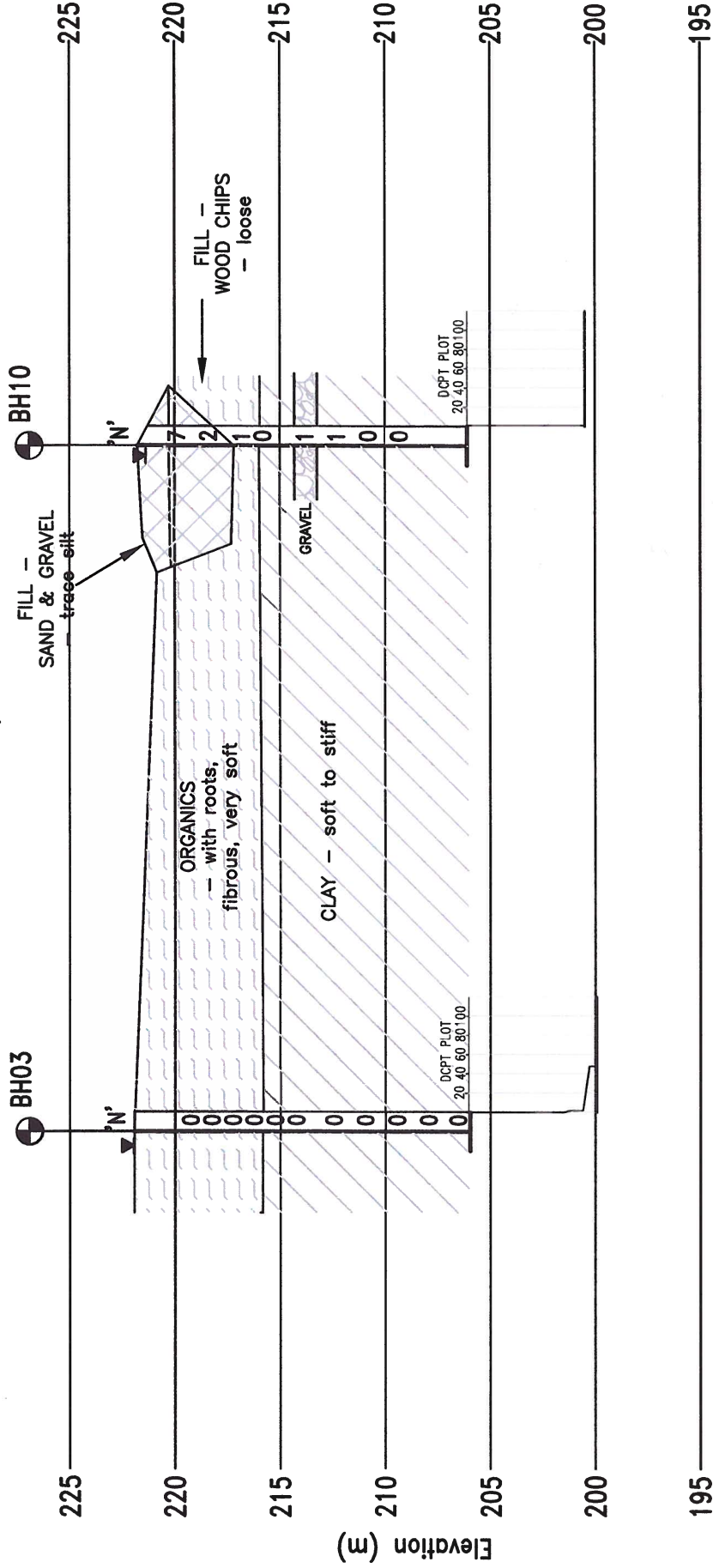
DST Consulting Engineers Inc.  
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Thunder Bay, ON P7B 5V5  
Ph: (807) 623-2929  
Fx: (807) 623-1792  
Email: thunderbay@dstgroup.com

DRAWING 4



PLAN VIEW  
0 25  
Scale in Metres

CROSS SECTION AT THE PROPOSED/EXISTING ALIGNMENT

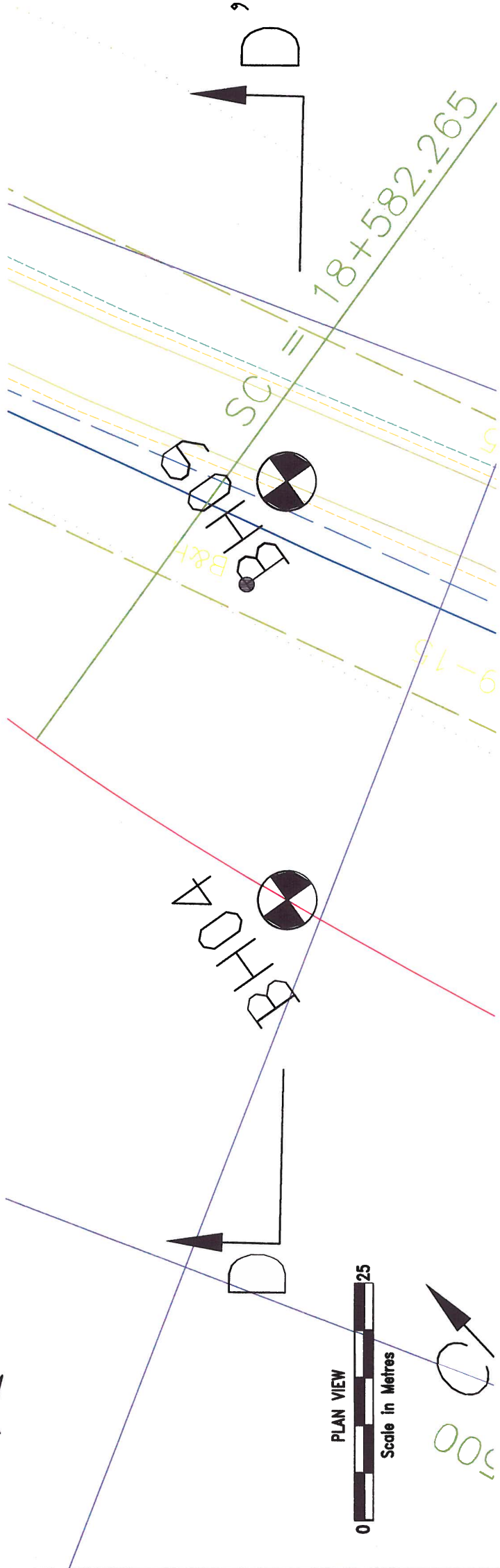


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Horizontal Scale in Metres  
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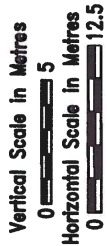
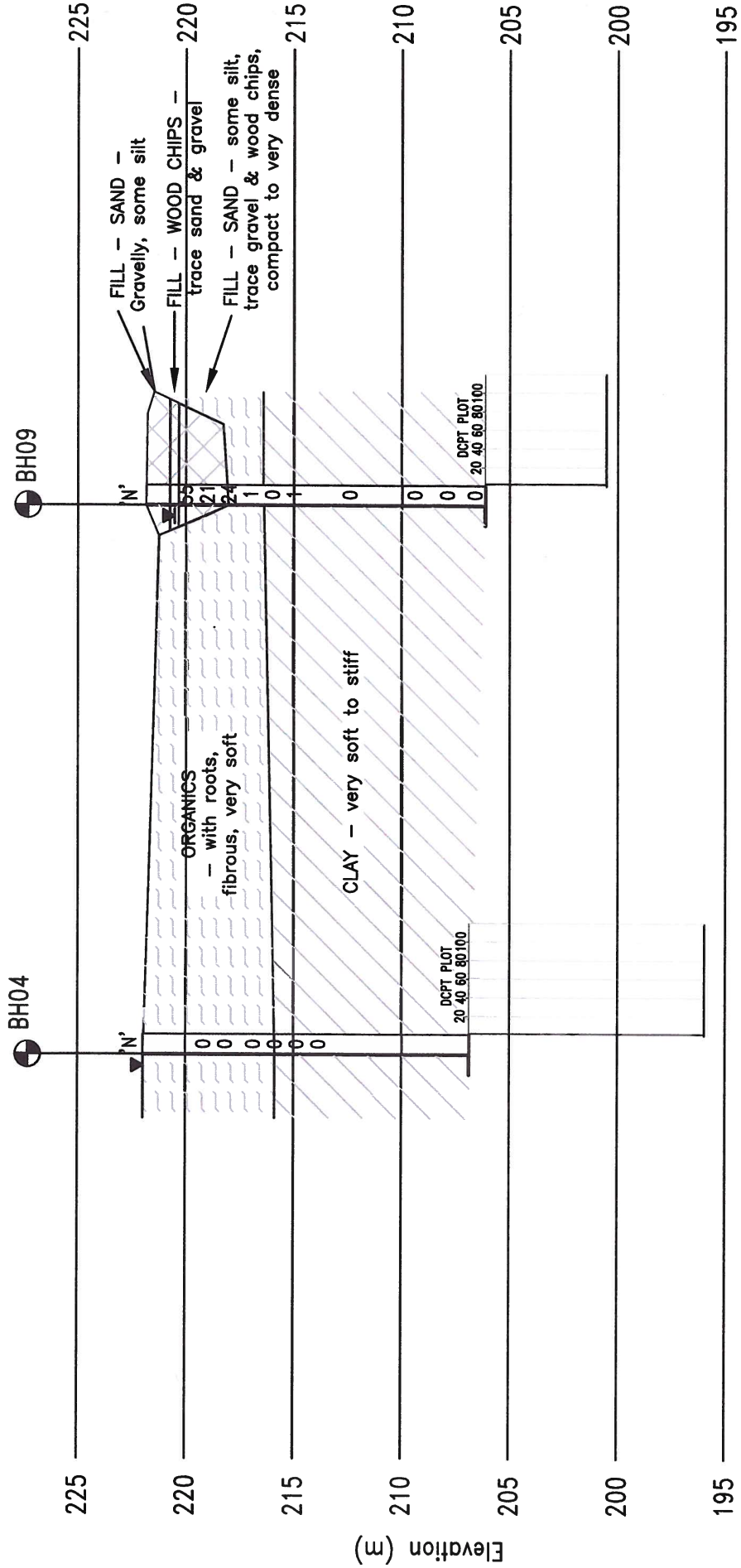
LICENSED PROFESSIONAL ENGINEER  
July 5, 2012  
M. W. BO  
100129834  
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER  
July 5, 2012  
T. MUBARIK  
100148468  
PROVINCE OF ONTARIO





CROSS SECTION AT THE PROPOSED/EXISTING ALIGNMENT



METRIC

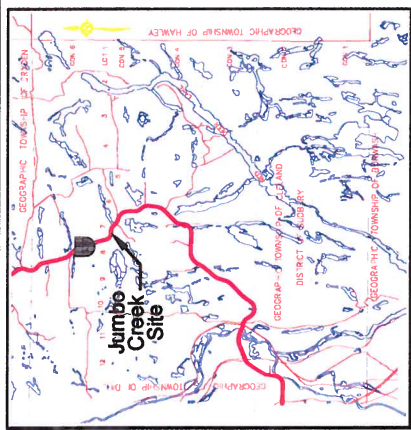
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SHOWN. STATIONS  
IN KILOMETERS + METERS

CONT No 5279-03-00  
GWP No  
WP No  
Site No  
GeoCres No 421-286



CROSS SECTION  
AT JUMBO CREEK  
Hwy 537 - Cleland Twp.  
Borehole Locations & Soil Strata

SHEET



KEY PLAN

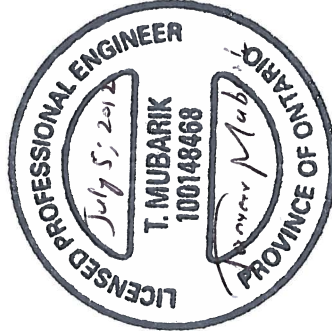
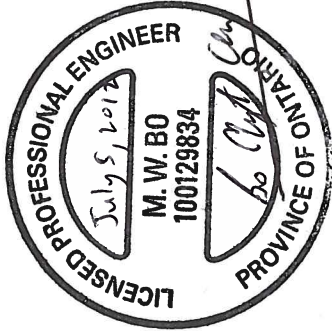


LEGEND

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



No.	Elevation	Northing	Easting	Station	Offset
BH1	221.761	5141673	518228	18+412	2.2 m LT
BH2	221.841	5141686	518187	18+450	CL
BH3	221.336	5141684	518133	18+500	0.9 m RT
BH4	221.970	5141689	518080	18+550	CL
BH5	221.689	5141712	519046	18+600	2.3 m LT
BH6	221.815	5141731	517883	18+650	CL
BH7	223.300	5141762	517947	18+715	3.0 m RT
BH8	222.806	5141762	517982	18+675	4.0 m RT
BH9	221.532	5141738	519087	18+575	4.0 m LT
BH10	221.974	5141731	518189	18+475	4.8 m RT
BH11	222.130	5141682	518293	18+350	3.0 m LT



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

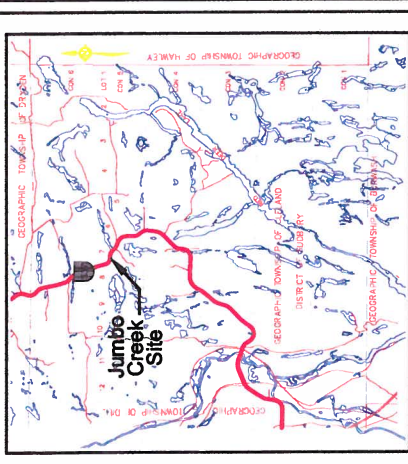
DST Consulting Engineers Inc.  
605 Hewitson Street  
Thunder Bay, ON P7B 5V5  
Ph: (807) 623-2929  
Fx: (807) 623-1782  
Email: thunderbay@dstgroup.com



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

CONT No  
GWP No 5279-03-00  
WP No  
Site No  
GeoCres No 421-286

CROSS SECTION  
AT JUMBO CREEK  
Hwy 537 - Cleland Twp.  
Borehole Locations & Soil Strata



KEY PLAN  
0 8  
SCALE IN KILOMETRES

LEGEND	
	Borehole/Hand Auger
	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

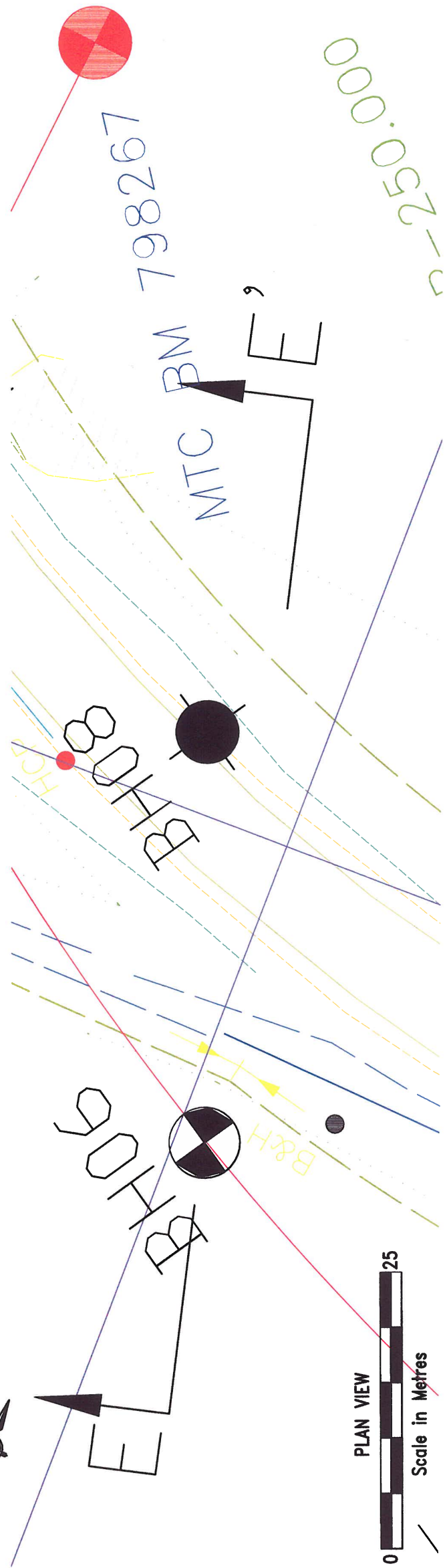
No.	Elevation	Northing	Eastings	Station	Offset
BH1	221.761	5141673	516226	18+412	2.2 m LT
BH2	221.941	5141688	516167	18+450	CL
BH3	221.636	5141684	516138	18+500	0.9 m RT
BH4	221.970	5141689	516090	18+520	CL
BH5	221.686	5141712	516046	18+600	2.3 m LT
BH6	221.815	5141731	517898	18+650	CL
BH7	225.300	5141762	517947	18+715	3.0 m RT
BH8	222.606	5141762	517932	18+875	4.0 m RT
BH9	221.632	5141738	516067	18+975	4.0 m LT
BH10	221.874	5141731	516189	18+475	4.8 m RT
BH11	222.130	5141652	516233	18+350	3.0 m LT

Vertical Scale in Metres  
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Horizontal Scale in Metres  
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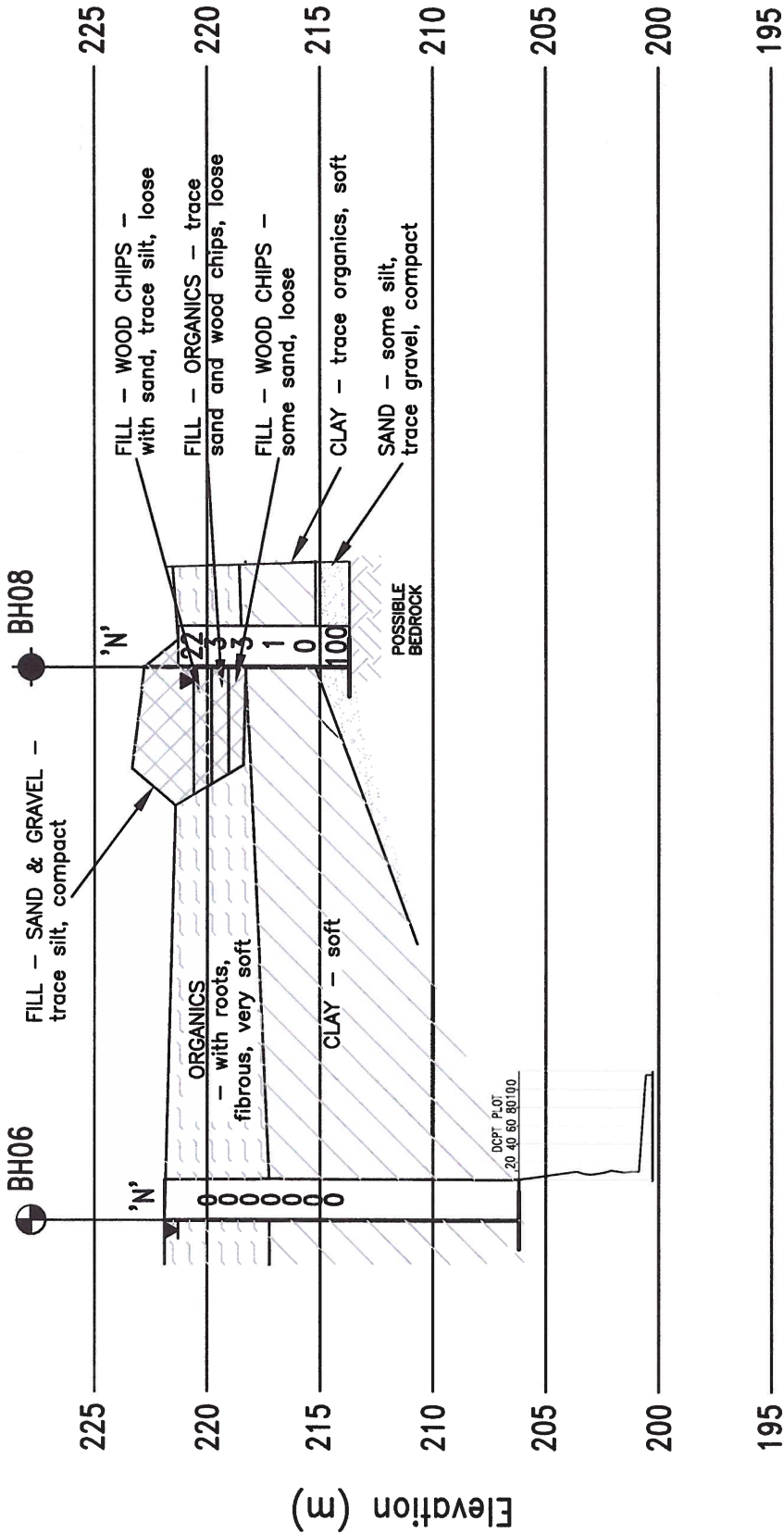
NOTE:  
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consulting engineers Email: thunderbay@dstgroup.com

DRAWING 6



CROSS SECTION AT THE PROPOSED/EXISTING ALIGNMENT



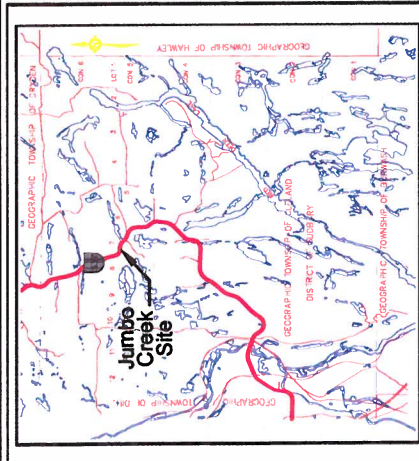


METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SPECIFIED  
CONVERSIONS TO METRES  
IN PARENTHESES

CONT No 5279-03-00  
GWP No 5279-03-00  
WP No 5279-03-00  
Site No 5279-03-00  
GeoCres No 421-286

EXISTING TYPICALS ALONG ROAD  
ALIGNMENT AT JUMBO CREEK  
Hwy 537 - Cleland Twp.  
Existing Section Drawings

SHEET



KEY PLAN  
SCALE IN KILOMETRES  
0 8

LEGEND	
	Borehole/Hand Auger
	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

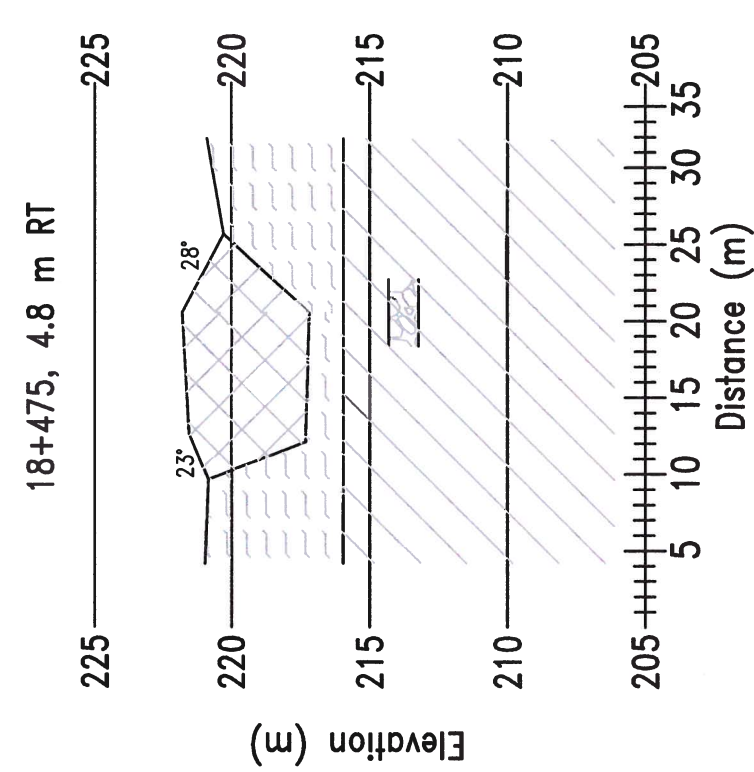
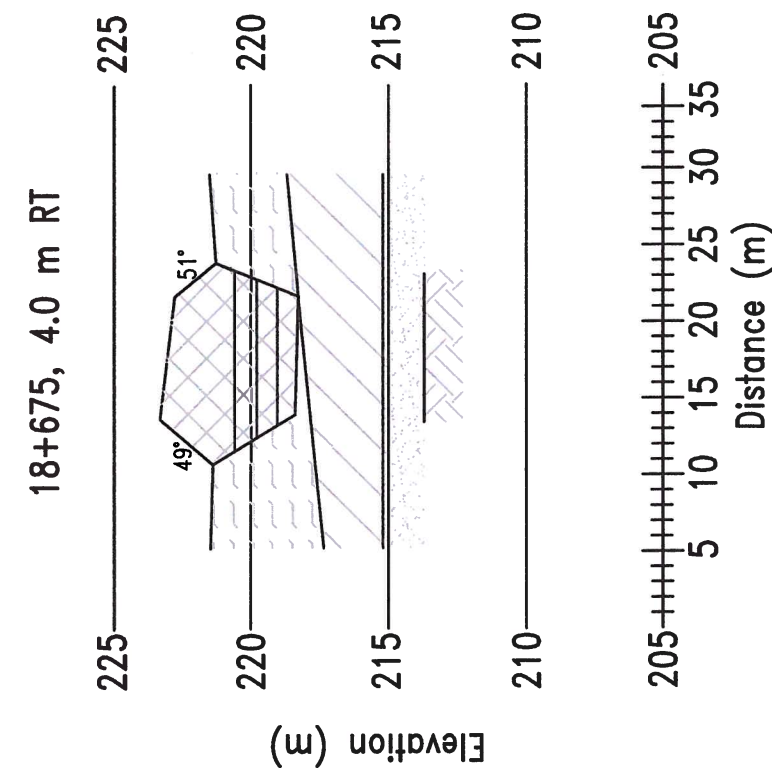
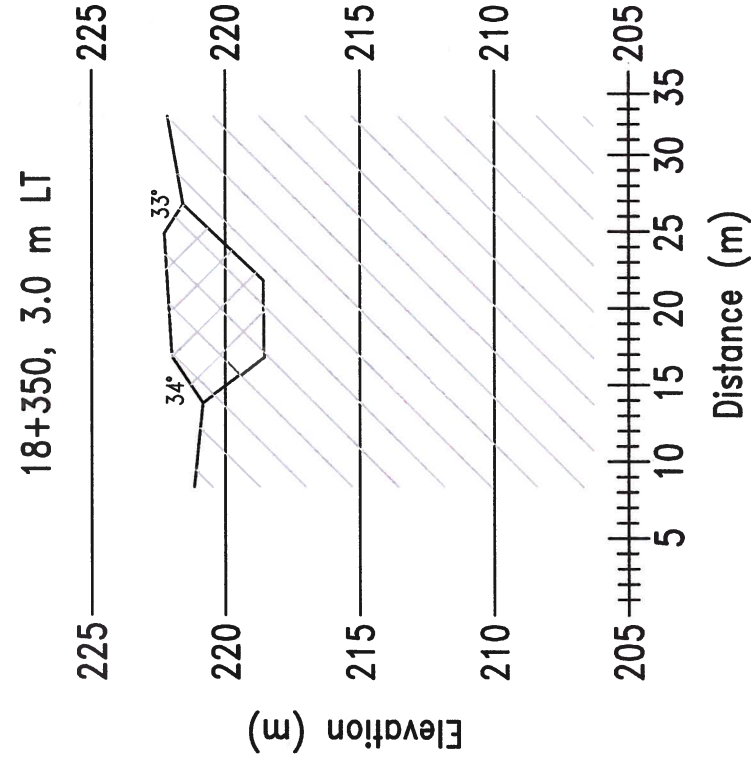
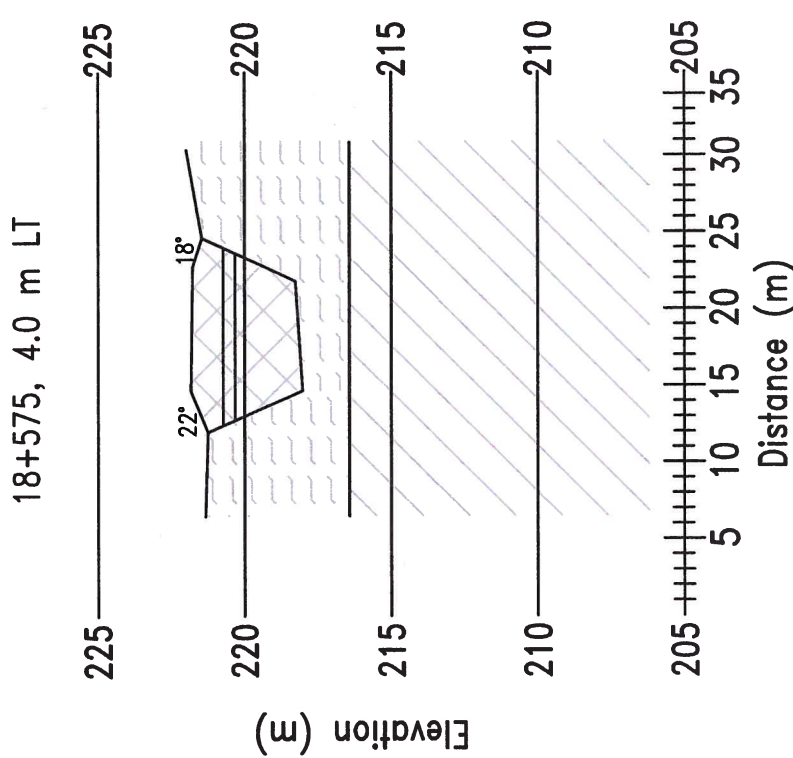
No.	Elevation	Station	Offset
BH1	221.761	5141673	18+412
BH2	221.841	5141686	18+450
BH3	221.536	5141684	18+500
BH4	221.570	5141689	18+550
BH5	221.589	5141712	18+600
BH6	221.515	5141731	18+650
BH7	222.500	5141762	18+715
BH8	222.806	5141762	18+675
BH9	221.532	5141738	18+575
BH10	221.574	5141731	18+475
BH11	222.130	5141652	18+350

Vertical Scale in Metres  
0 5  
Horizontal Scale in Metres  
0 10

NOTE:  
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locations. Intermediate boundaries are assumed by interpolation  
and may not represent actual conditions.

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Ph: (807) 623-2929  
Fax: (807) 623-1792  
Email: thunderbay@dstgroup.com

DRAWING 7





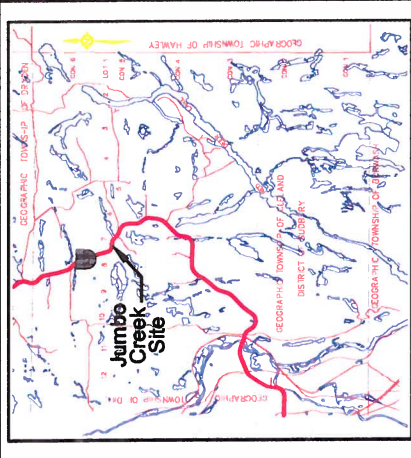
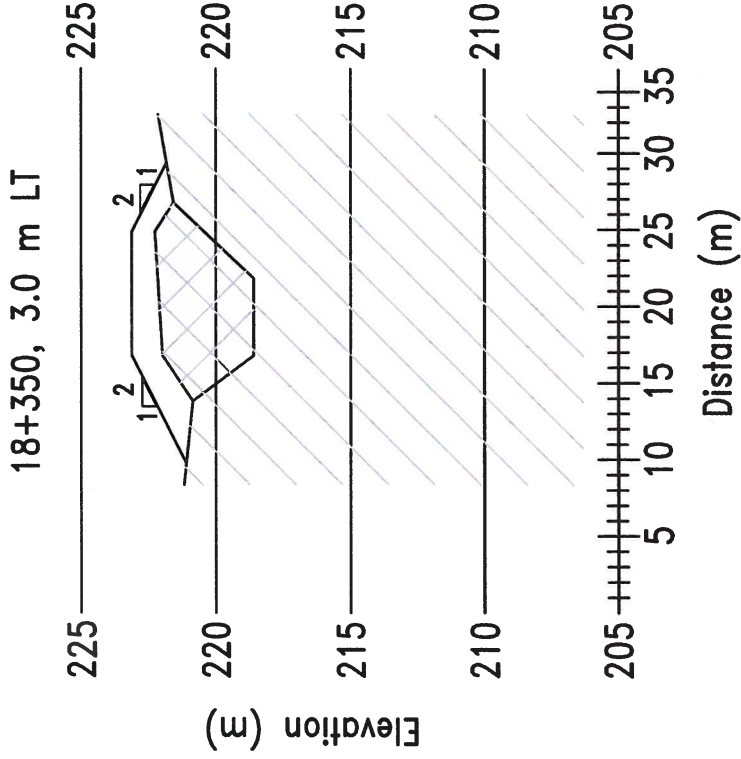
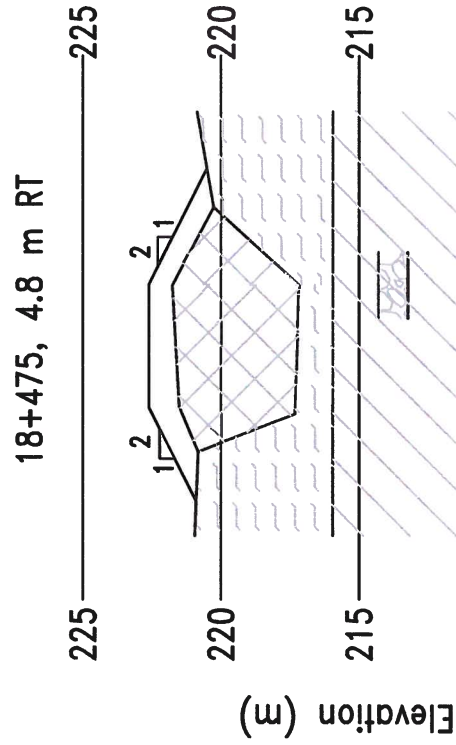
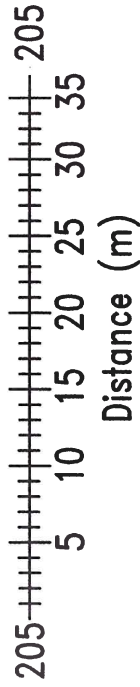
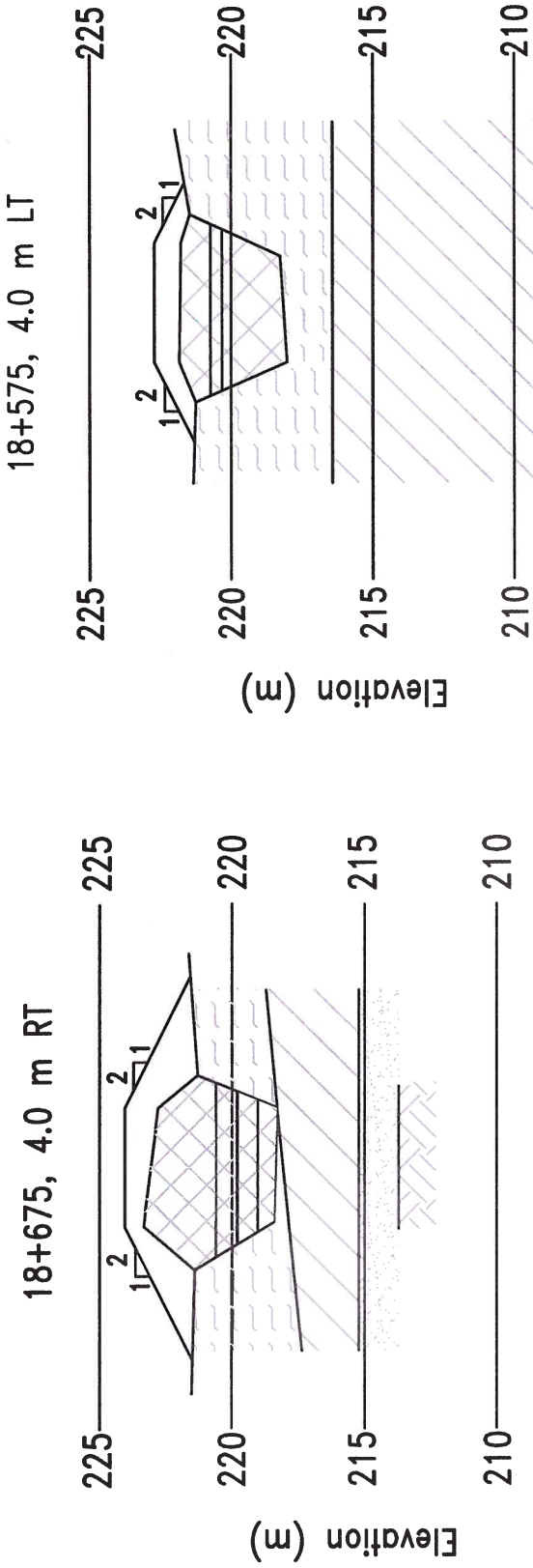
METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SHOWN. STATIONS  
IN KILOMETRES + METERS

CONT No 5279-03-00  
GWP No  
WP No  
Site No  
GeoCres No 421-286



OPTION 1 - TYPICAL PROFILES  
OF GRADE RAISES ON  
EXISTING ROAD ALIGNMENT  
Hwy 537 - Cleland Twp.

SHEET

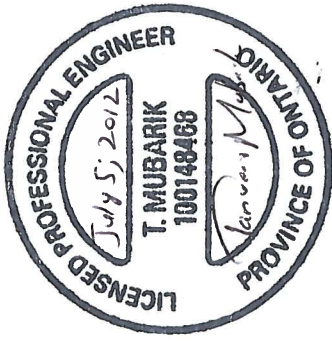
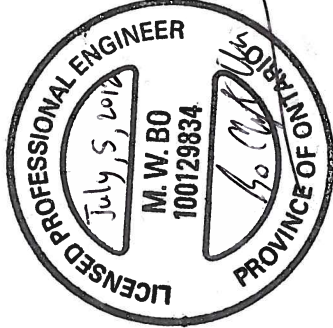


KEY PLAN  
SCALE IN KILOMETRES  
0 8

LEGEND	
	Borehole/Hand Auger
	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	221.761	5141673	516228	18+412	2.2 m LT
BH2	221.841	5141686	516128	18+450	CL
BH3	221.536	5141694	516138	18+500	0.9 m RT
BH4	221.870	5141689	516090	18+550	CL
BH5	221.888	5141712	516048	18+600	2.3 m LT
BH6	221.815	5141731	517688	18+650	CL
BH7	225.300	5141762	517947	18+715	3.0 m RT
BH8	222.806	5141762	517982	18+75	4.0 m RT
BH9	221.832	5141736	516087	18+575	4.0 m LT
BH10	221.574	5141731	516189	18+475	4.8 m RT
BH11	222.130	5141682	516263	18+350	3.0 m LT

Vertical Scale in Metres  
0 5  
Horizontal Scale in Metres  
0 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 Inc.  
605 Hewitson Street  
Thunder Bay, ON P7B 5V5  
Ph: (807) 623-2928  
Fax: (807) 623-1782  
Email: thunderbay@dstgroup.com

DRAWING 8

# **APPENDIX 'D'**

# **ENCLOSURES**

# RECORD OF BOREHOLE No BH01

1 OF 1

METRIC

W.P. 5279-03-00 LOCATION STA. 18+412, 2.2 m LT (5141673 m N, 518228 m E) ORIGINATED BY JF  
 DIST 400 m HWY 537 BOREHOLE TYPE Hollow Stem Auger (100 mm ID) COMPILED BY ML  
 DATUM Geodetic DATE 2012 02 27 CHECKED BY TM

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 <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> WATER CONTENT (%)					
								○ UNCONFINED      + FIELD VANE □ QUICK TRIAXIAL    × LAB VANE							
221.8	GROUND SURFACE							20   40   60   80   100		20   40   60					
218.7 3.1	ORGANICS - with roots, fibrous, humification (H9), very soft, black		AS1	AS			220						587	Sank by rod weight Water at surface	
			NR	SS	1										
	Von Post Test at 2.3 m: H9, B3, F2, R0, W1, N0		SS2	SS	1										840
	CLAY - grey, wet, soft to firm ---- - trace organics ----		SS3	SS	0				218	+ <sup>2</sup>					715
			SS4	SS	1										
			SS5	SS	0										
			SS6	SS	0				216	+ <sup>2</sup>					110
			SS7	SS	1										
			SS8	SS	1				214	+ <sup>2</sup>					
			SS9	SS	1					+ <sup>3</sup>					
206.3 15.5	End of Borehole at 15.5 m		SS10	SS	0		212						Retainer/Screen was used; could not recover sample		
			SS11	SS	1										
			SS12	SS	0		208								
			SS13	SS	0										

NR = NO RECOVERY

+<sup>3</sup>, X<sup>3</sup>: Numbers refer to  
Sensitivity

O 3% STRAIN AT FAILURE

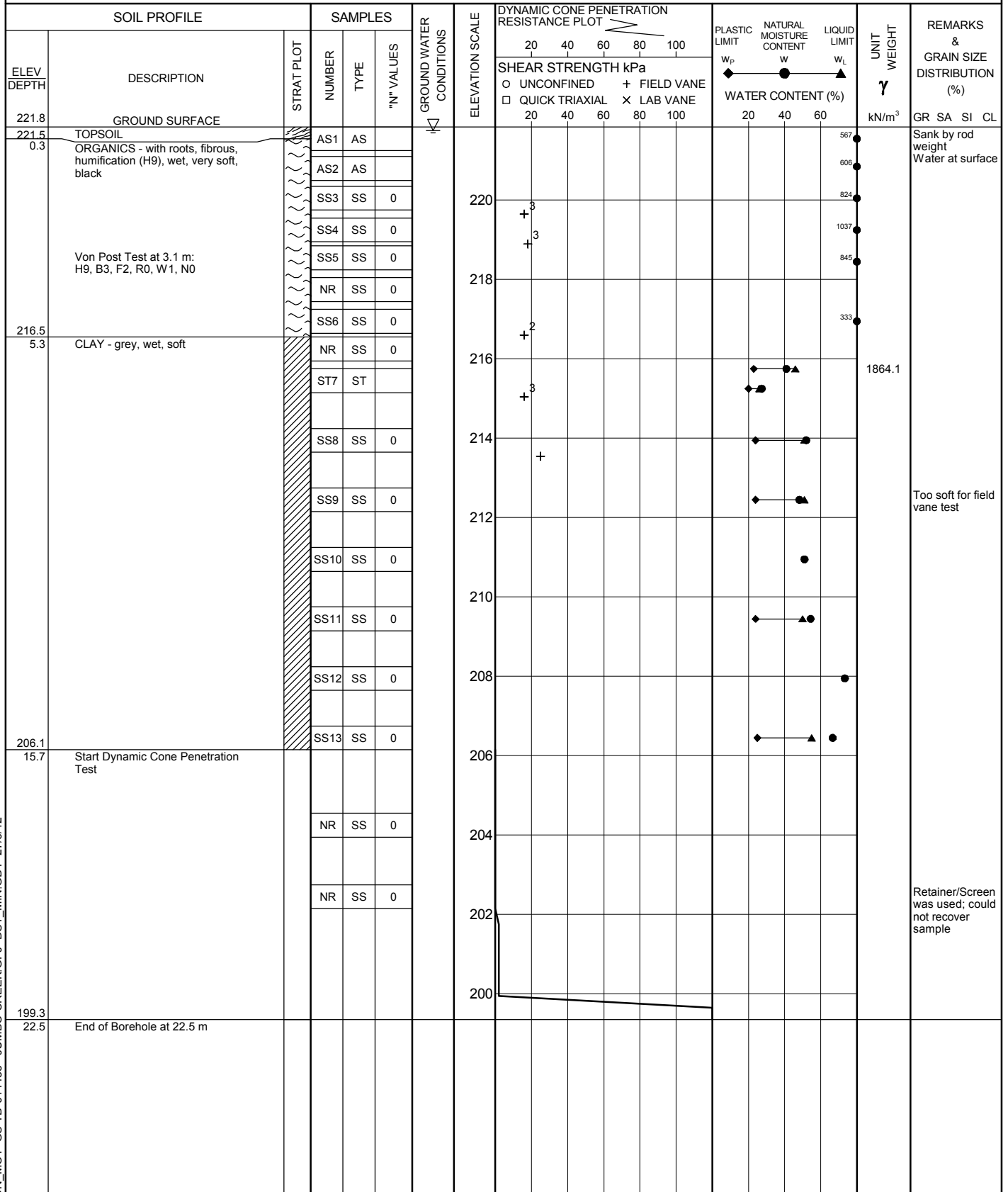
ENCLOSURE 1

# RECORD OF BOREHOLE No BH02

1 OF 1

METRIC

W.P. 5279-03-00 LOCATION STA. 18+450, CL (5141686 m N, 518187 m E) ORIGINATED BY JF  
 DIST 400 m HWY 537 BOREHOLE TYPE Hollow Stem Auger (100 mm ID) COMPILED BY ML  
 DATUM Geodetic DATE 2012 02 29 CHECKED BY TM



NR = NO RECOVERY

+<sup>3</sup>, X<sup>3</sup>: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

ENCLOSURE 2

# RECORD OF BOREHOLE No BH03

1 OF 1

METRIC

W.P. 5279-03-00 LOCATION STA. 18+500, 0.9 m RT (5141694 m N, 518138 m E) ORIGINATED BY JF  
 DIST 400 m HWY 537 BOREHOLE TYPE Hollow Stem Auger (100 mm ID) COMPILED BY ML  
 DATUM Geodetic DATE 2012 03 01 CHECKED BY TM

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			20   40   60   80   100	20   40   60   80   100	W <sub>P</sub> W   W <sub>L</sub>				
221.9	GROUND SURFACE													
215.8	ORGANICS - with roots, fibrous, humification (H10), wet, very soft, black  Von Post Test at 4.6 m: H10, B3, F1, R0, W0, N0		AS1	AS								386	Sank by rod weight Water at surface	
			AS2	AS										449
			SS3	SS	0									629
			SS4	SS	0									774
			SS5	SS	0									952
			SS6	SS	0									785
215.8			SS7	SS	0							714		
6.1	CLAY - grey, wet, stiff		SS8	SS	0								Too soft for field vane test	
NR	ST													
SS9	SS		0											
SS10	SS		0											
SS11	SS		0											
SS12	SS		0											
206.0			SS13	SS	0								Retainer/Screen was used; could not recover sample	
15.9	Start Dynamic Cone Penetration Test													
199.9														
22.0	End of Borehole at 22.0 m													

NR = NO RECOVERY +<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ENCLOSURE 3

ON\_MOT\_CS-TB-014485 - JUMBO CREEK.GPJ DST\_MIN.GDT 27/6/12

## RECORD OF BOREHOLE No BH04

1 OF 1

METRIC

W.P.	5279-03-00	LOCATION	STA. 18+550, CL (5141699 m N, 518090 m E)	ORIGINATED BY	JF
DIST	400 m	HWY	537	BOREHOLE TYPE	Hollow Stem Auger (100 mm ID)
DATUM	Geodetic	DATE	2012 03 02	CHECKED BY	TM

[illegible]

ON\_MOT GS-TB-014485 - JUMBO CREEK.GPJ DST\_MIN.GDT 27/6/12

NR = NO RECOVERY      +<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

**ENCLOSURE 4**





# RECORD OF BOREHOLE No BH06

1 OF 1

METRIC

W.P. 5279-03-00 LOCATION STA. 18+650, CL (5141731 m N, 517998 m E) ORIGINATED BY JF  
 DIST 400 m HWY 537 BOREHOLE TYPE Hollow Stem Auger (100 mm ID) COMPILED BY ML  
 DATUM Geodetic DATE 2012 03 05 CHECKED BY TM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
								20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
221.8	GROUND SURFACE											
	ORGANICS - with roots, fibrous, humification (H8), wet, very soft, black		AS1	AS								
			AS2	AS								
	Von Post Test at 1.5 m: H10, B2, F1, R0, W0, N0		SS3	SS	0		220					
			SS4	SS	0							
			SS5	SS	0							
			SS6	SS	0		218					
217.2	CLAY - grey, wet, soft		NR	SS	0							
4.6			SS7	SS	0		216					
			SS8	SS	0							
			NR	ST			214					
			NR	ST			212					
			NR	ST			210					
			NR	ST			208					
206.1			NR	ST			206					
15.7	Start Dynamic Cone Penetration Test						204					
							202					
200.3												
21.5	End of Borehole at 21.5 m Refusal on possible bedrock											

NR = NO RECOVERY

+<sup>3</sup>, X<sup>3</sup>: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

# RECORD OF BOREHOLE No BH07

1 OF 1

METRIC

W.P. 5279-03-00 LOCATION STA. 18+715, 3.0 m RT (5141762 m N, 517947m E) ORIGINATED BY JF  
 DIST 400 m HWY 537 BOREHOLE TYPE Hollow Stem Auger (100 mm ID) COMPILED BY ML  
 DATUM Geodetic DATE 2012 03 06 CHECKED BY TM

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 (%)  GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
								○ UNCONFINED	+ FIELD VANE	□ QUICK TRIAXIAL	× LAB VANE								
225.3	GROUND SURFACE							20	40	60	80	100							
	FILL - SAND - Gravelly, some silt, brown, dry, loose to dense		AS1	AS			224										Water level at 222.450 m		
			AS2	AS															27 62 (11)
			SS3	SS	47														
222.4			SS4	SS	9														29 61 (11)
2.9	FILL - GRAVEL - Sandy, trace silt, some organics and wood, brown, compact		SS5	SS	13				222										71 22 (7)
221.5		SS6	SS	5															0 20 70 9
3.8	FILL - SILT - some sand, some organics, trace clay, brown/grey, firm	SS7	SS	100+															
220.7																			
4.6	End of Borehole at 4.6 m Refusal on possible bedrock																		

NR = NO RECOVERY + 3, X 3: Numbers refer to Sensitivity O 3% STRAIN AT FAILURE

ENCLOSURE 7

ON\_MOT\_CS-TB-014485 - JUMBO CREEK.GPJ DST\_MIN.GDT 27/6/12

# RECORD OF BOREHOLE No BH08

1 OF 1

METRIC

W.P. 5279-03-00 LOCATION STA. 18+675, 4.0 m RT (5141762 m N, 517982 m E) ORIGINATED BY JF  
DIST 400 m HWY 537 BOREHOLE TYPE Hollow Stem Auger (100 mm ID) COMPILED BY ML  
DATUM Geodetic DATE 2012 03 06 CHECKED BY TM

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 (%)  GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								○ UNCONFINED      + FIELD VANE □ QUICK TRIAXIAL    x LAB VANE								
222.8	GROUND SURFACE						20 40 60 80 100	20 40 60 80 100	20 40 60							
	FILL - SAND & GRAVEL - trace silt, brown, compact		AS1	AS											45 49 (6) Water level at 221.856 m	
			AS2	AS												
			SS3	SS	22											
220.6																
2.2	FILL - WOOD CHIPS - with sand, trace silt, grey, loose wet		SS4	SS	3											499
219.8	Von Post Test at 2.3 m: H1, B2, F3, R3, W3, N3															
3.0			SS5	SS	3											114
219.1	FILL - ORGANICS - trace sand and wood chips, black, loose		SS6	SS	3											96
3.8																
218.3	FILL - WOOD CHIPS - some sand, loose, wet		SS7	SS	1											
4.5	CLAY - trace organics, grey, wet, soft		ST8	ST												
			SS9	SS	0											
215.2																
7.6	SAND - some silt, trace gravel, grey, compact		ST10	ST												
213.7			SS11	SS	100+											
9.1	End of Borehole at 9.1 m Refusal on possible bedrock															

NR = NO RECOVERY

+<sup>3</sup>, X<sup>3</sup>: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

## RECORD OF BOREHOLE No BH09

1 OF 1

METRIC

W.P.	5279-03-00	LOCATION	STA. 18+575, 4.0 m LT (5141738 m N, 518087 m E)	ORIGINATED BY	JF
DIST	400 m	HWY	537	BOREHOLE TYPE	Hollow Stem Auger (100 mm ID)
DATUM	Geodetic	DATE	2012 03 07	CHECKED BY	TM

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	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 (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		SHEAR STRENGTH kPa									WATER CONTENT (%)
							UNCONFINED		FIELD VANE							
							QUICK TRIAXIAL	LAB VANE								
221.8	GROUND SURFACE															
	FILL - SAND - Gravelly, some silt, grey, wet		AS1	AS		▽										
220.7			AS2	AS												
220.4	FILL - WOOD CHIPS - trace sand and gravel		AS3	AS												
1.5	FILL - SAND - some silt, trace gravel and wood chips, grey, wet, compact to very dense		SS4	SS	55											
			SS5	SS	21											
			SS6	SS	24											
218.0	ORGANICS - fibrous, brown Von Post Test at 3.8 m: H2, B2, F2, R3, W1, N1		SS7	SS	1											
			SS8	SS	0											
216.4	CLAY - grey, wet, firm to stiff		SS9	SS	1											
5.4			ST10	ST												
			ST11	ST												
			SS12	SS	0											
			ST13	ST												
			SS14	SS	0											
			SS15	SS	0											
206.1			SS16	SS	0											
15.7	Start Dynamic Cone Penetration Test															
200.5	End of Borehole at 21.3 m															
21.3																

NR = NO RECOVERY      +<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

ON MOT GS-TB-014485 - JUMBO CREEK.GPJ DST MIN.GDT 27/6/12

# RECORD OF BOREHOLE No BH10

1 OF 1

METRIC

W.P. 5279-03-00 LOCATION STA. 18+475, 4.8 m RT (5141731 m N, 518189 m E) ORIGINATED BY JF  
DIST 400 m HWY 537 BOREHOLE TYPE Hollow Stem Auger (100 mm ID) COMPILED BY ML  
DATUM Geodetic DATE 2012 03 07 CHECKED BY TM

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    x LAB VANE							
222.0	GROUND SURFACE							20 40 60 80 100		20 40 60				GR SA SI CL	
	FILL - SAND & GRAVEL - trace silt, brown/grey		AS1	AS										43 48 (9)	
220.5			AS2	AS										Water level at 221.574 m	
1.5	FILL - WOOD CHIPS - wet, loose		SS3	SS	7		220						121		
			NR	SS	1										
			SS4	SS	2								187		
			NR	SS	0		218								
217.4	ORGANICS - fibrous, wet, very soft, black		SS5	SS	1								549		
4.6	Von Post Test at 4.6 m: H6, B3, F3, R1, W0, N0		SS6	SS	0								395		
216.2	CLAY - grey, soft to firm, wet		ST7	ST			216							Sank by rod weight	
5.8															
	- gravel		SS8	SS	1		214								
			SS10	SS	1		212								
			SS11	SS	0		210								
			SS12	SS	0		208								
			NR	ST											
206.3			NR	ST			206							Retainer/Screen was used; could not recover sample	
15.7	Start Dynamic Cone Penetration Test						204							Sank by rod weight	
							202								
200.7															
21.3	End of Borehole at 21.3 m														

NR = NO RECOVERY

+<sup>3</sup>, X<sup>3</sup>: Numbers refer to Sensitivity

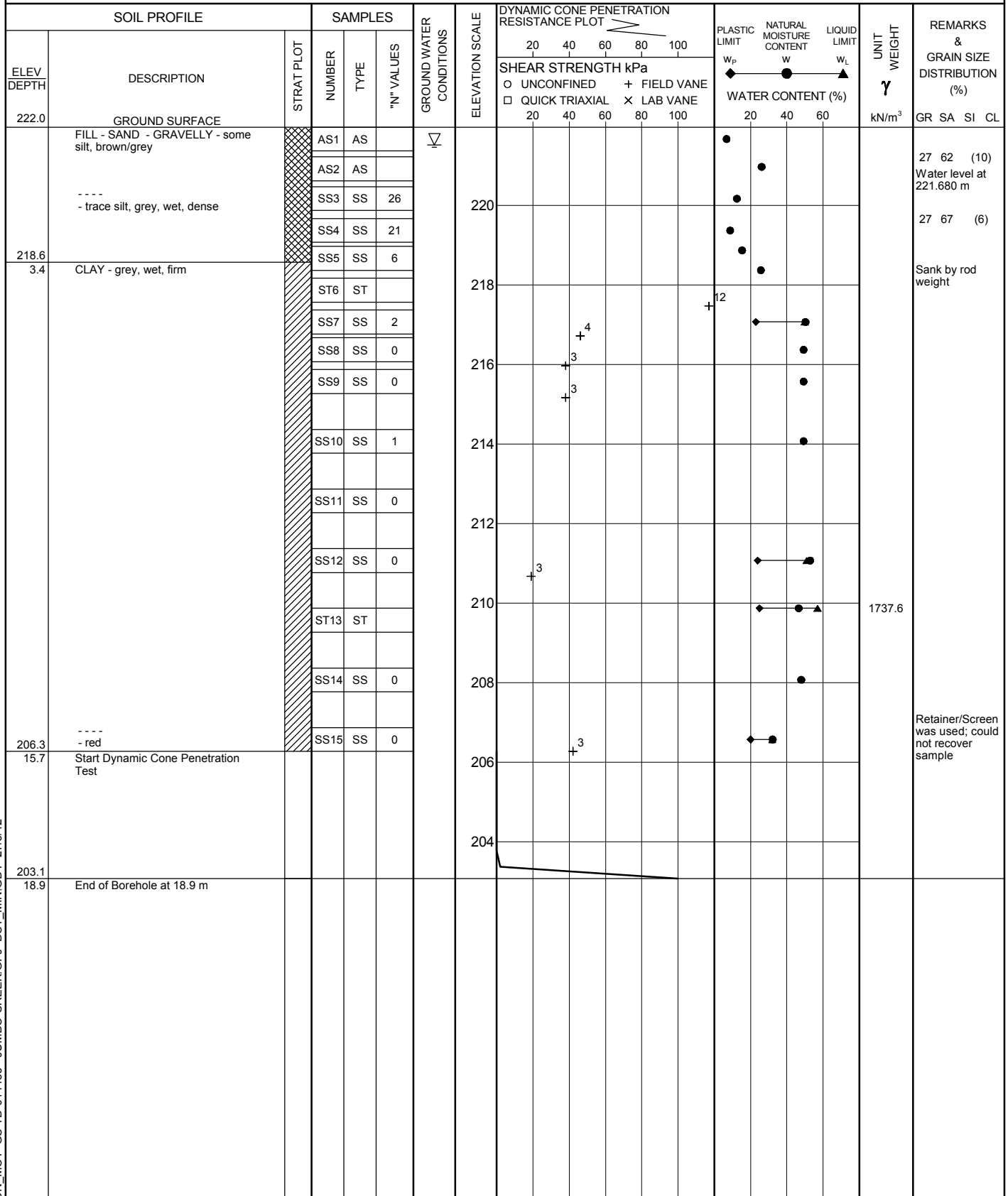
○ 3% STRAIN AT FAILURE

# RECORD OF BOREHOLE No BH11

1 OF 1

METRIC

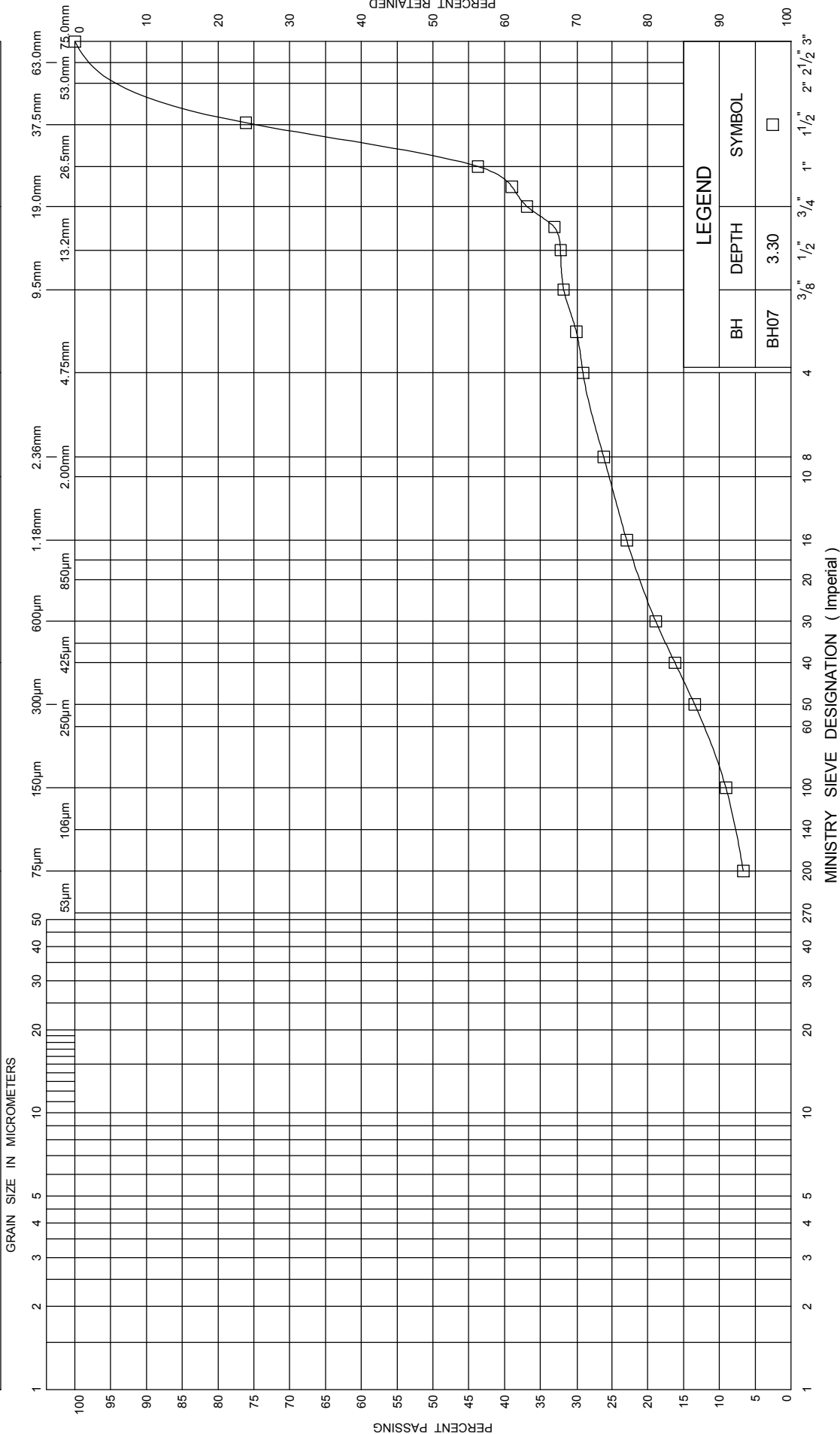
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DIST 400 m HWY 537 BOREHOLE TYPE Hollow Stem Auger (100 mm ID) COMPILED BY ML  
DATUM Geodetic DATE 2012 03 09 CHECKED BY TM



NR = NO RECOVERY +<sup>3</sup>, X<sup>3</sup>: Numbers refer to Sensitivity O 3% STRAIN AT FAILURE

UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND				GRAVEL	
		Fine		Medium	Coarse	Fine	Coarse



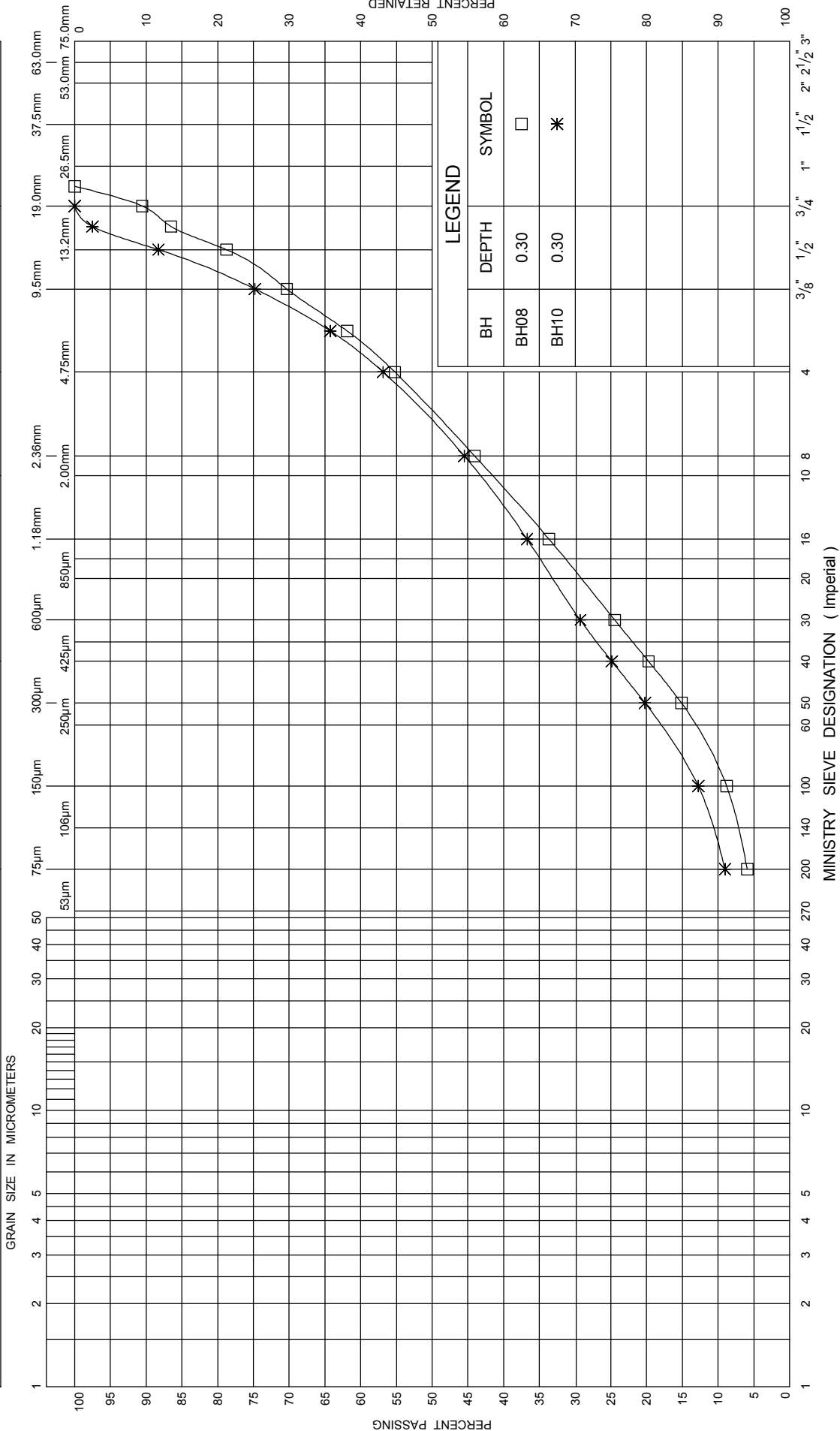
GRAIN SIZE DISTRIBUTION  
SANDY GRAVEL - Existing

ENCLOSURE 12  
W P 5009-E-0061  
HIGHWAY 537



UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND			GRAVEL		
		Fine		Medium	Coarse	Fine	Coarse



ENCLOSURE 13

W P 5009-E-0061

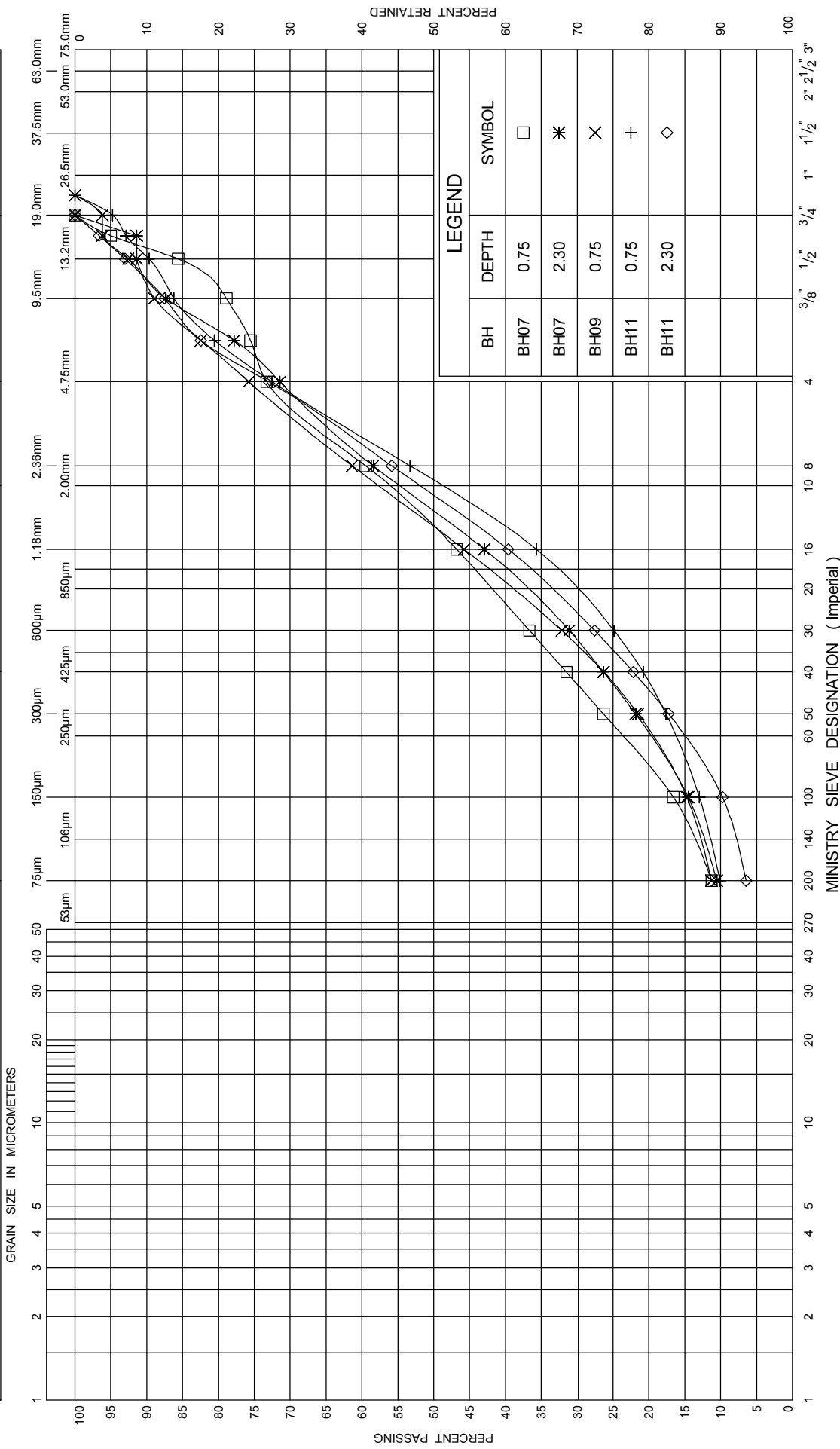
HIGHWAY 537





UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT		SAND				GRAVEL			
		Fine		Medium		Coarse		Fine	

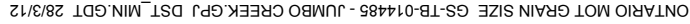


GRAIN SIZE DISTRIBUTION  
GRAVELLY SAND - Existing

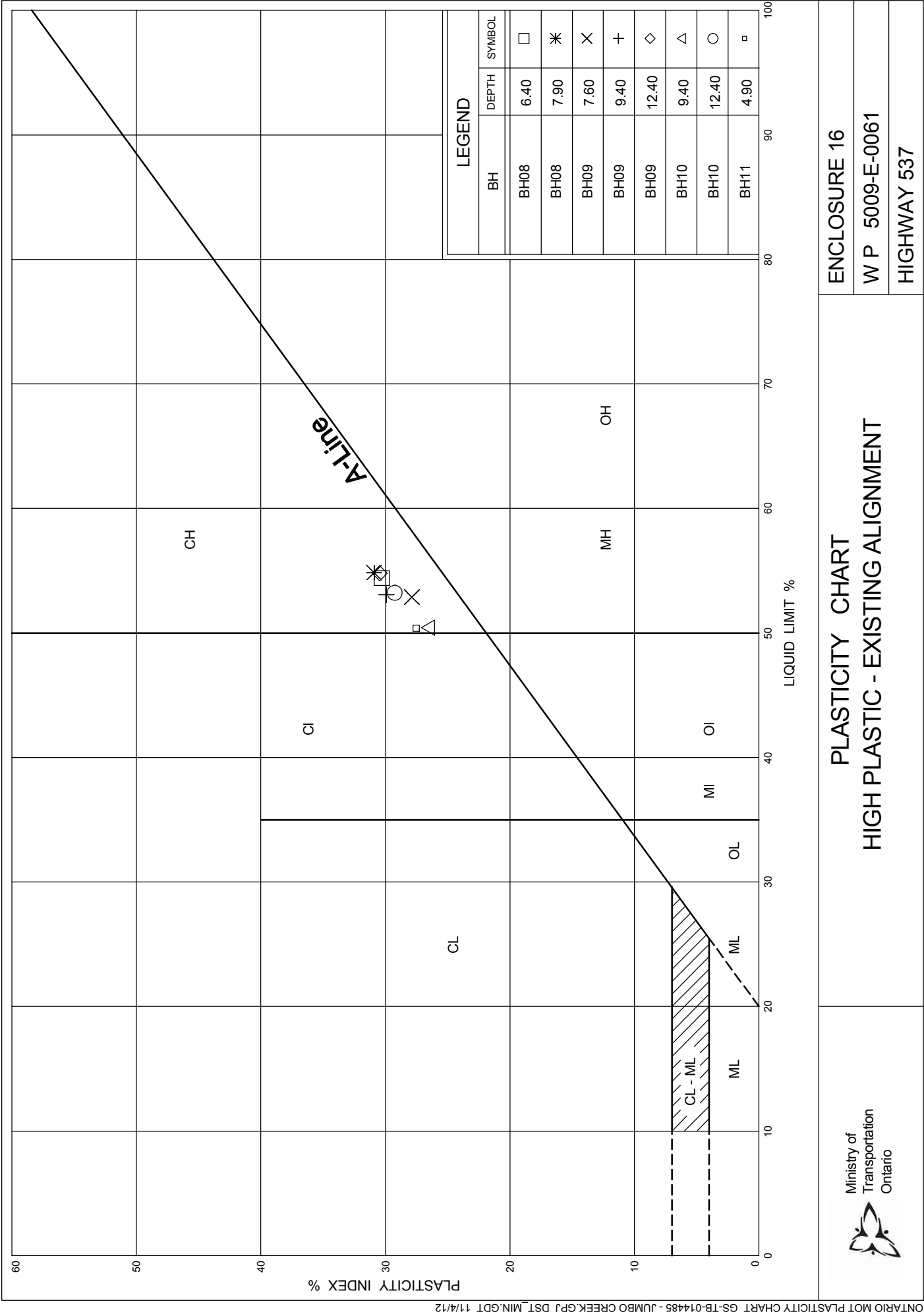
ENCLOSURE 14  
W P 5009-E-0061  
HIGHWAY 537

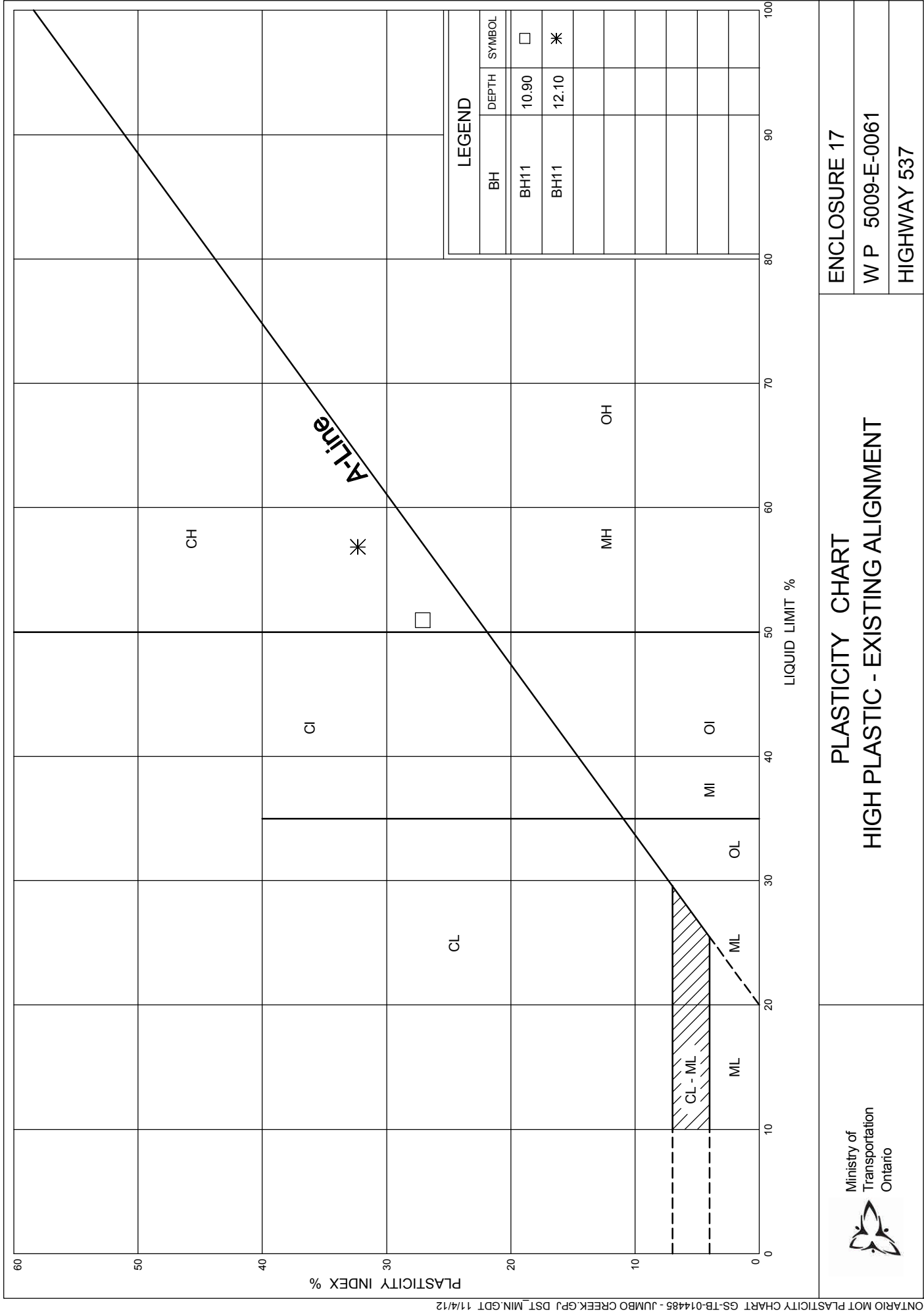


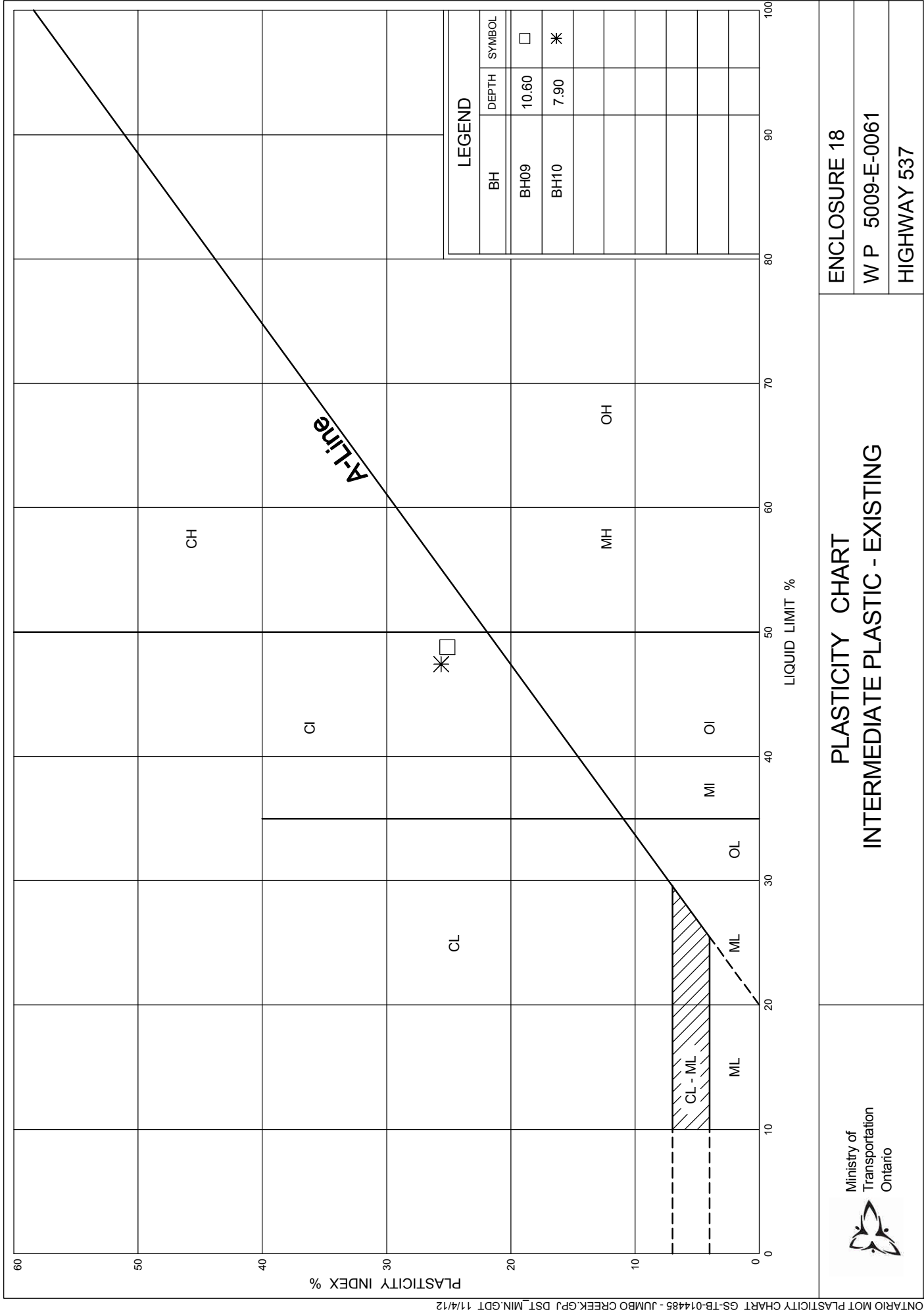
CLAY & SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse

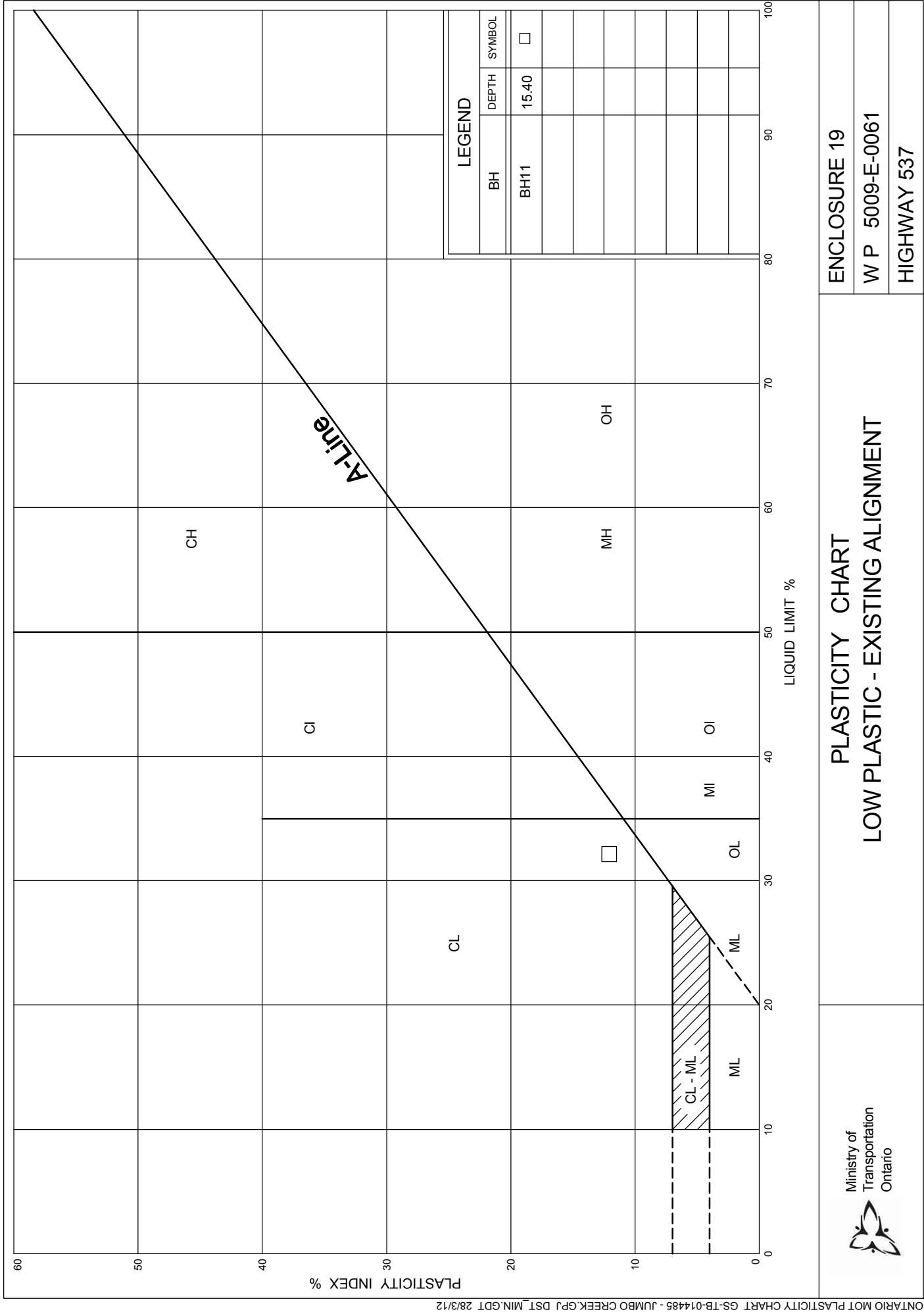


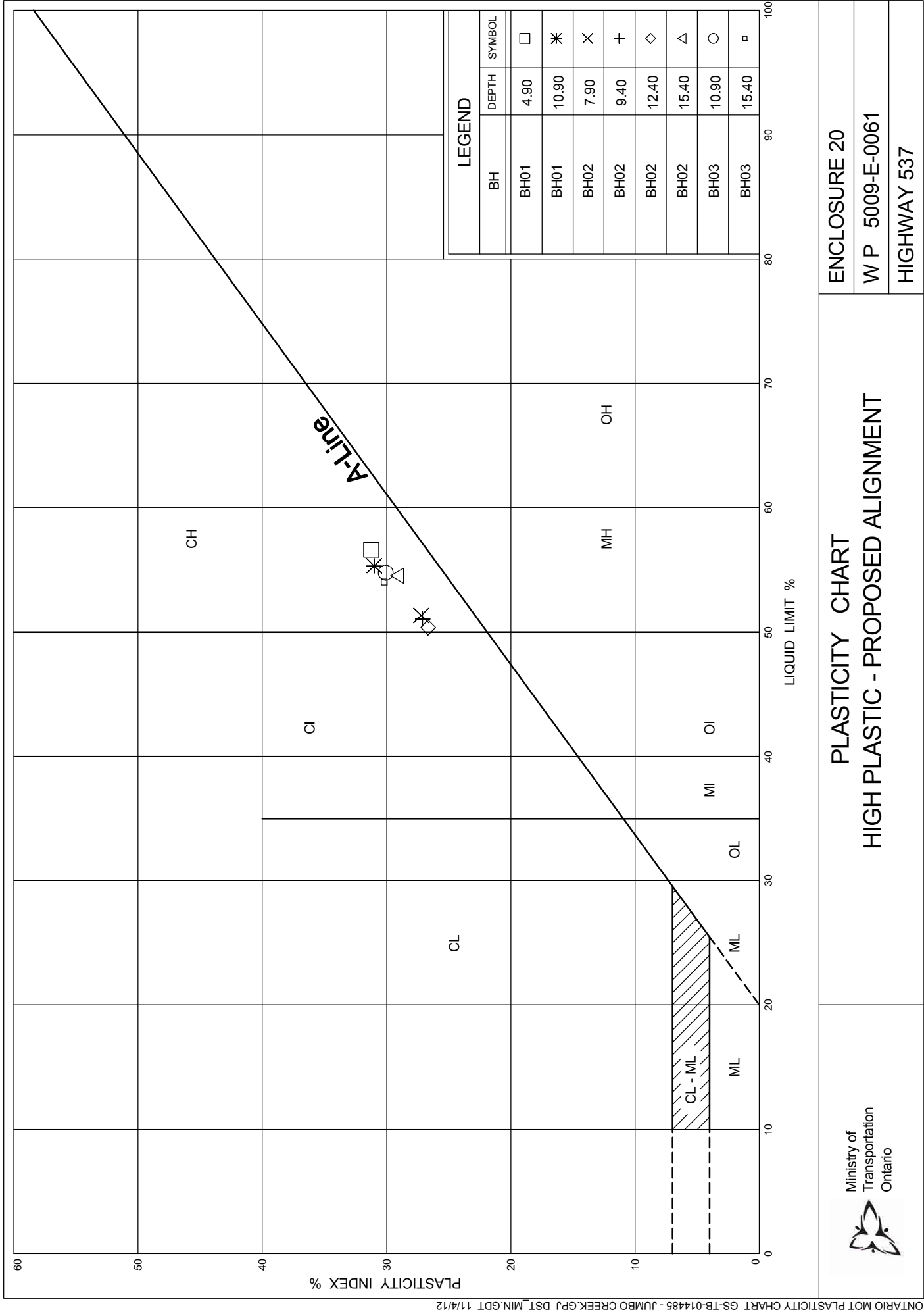
HIGHWAY 537

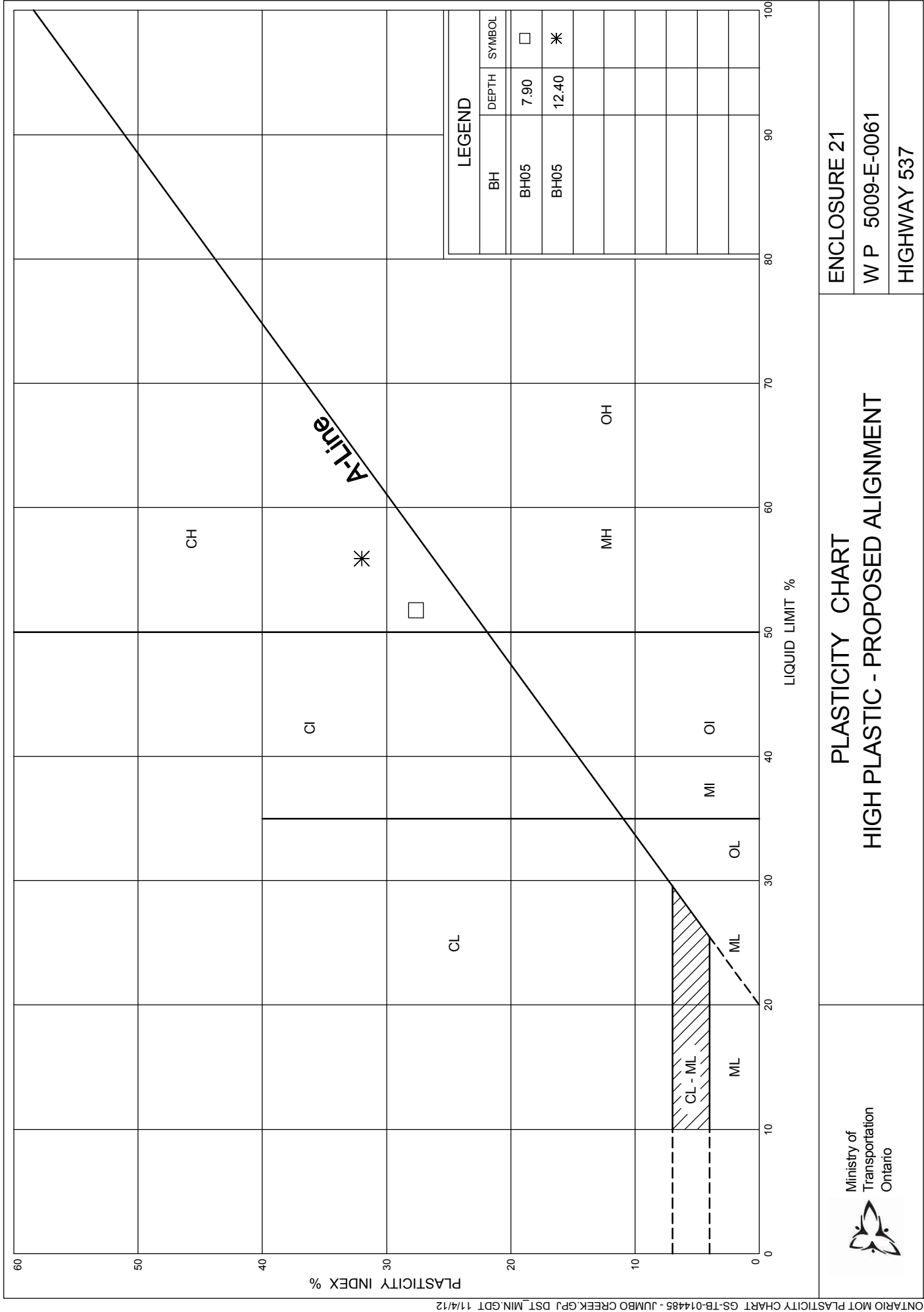




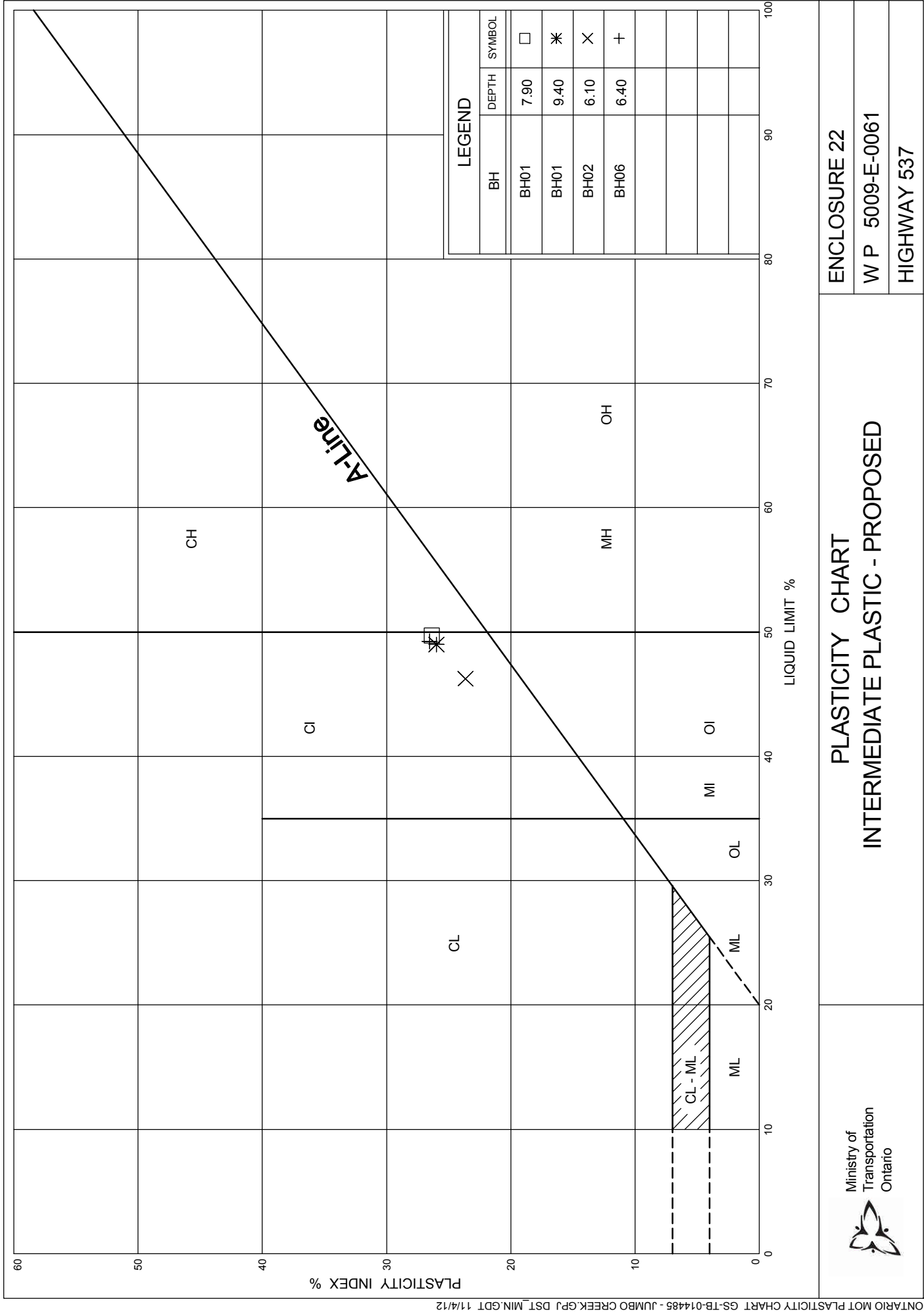


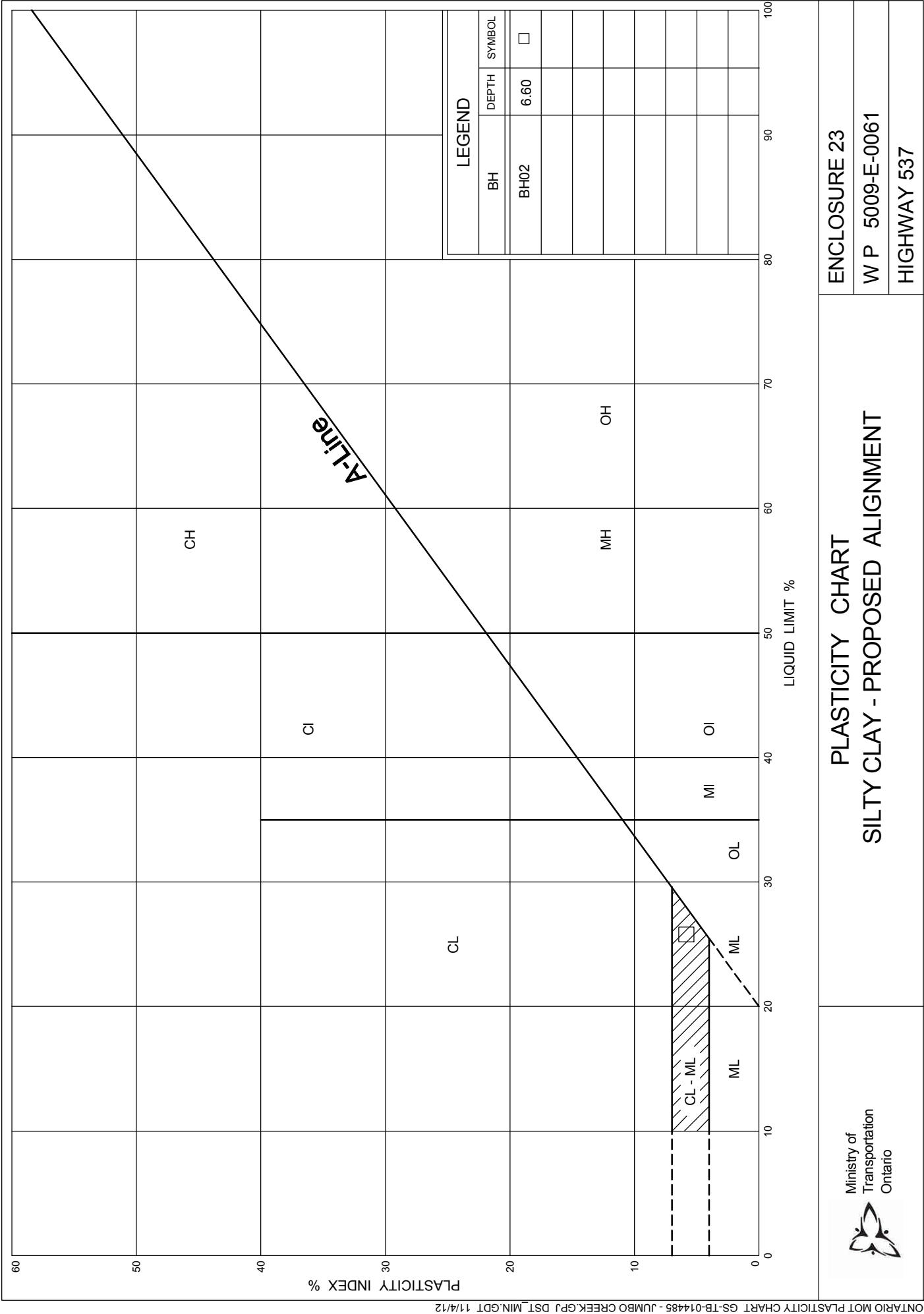


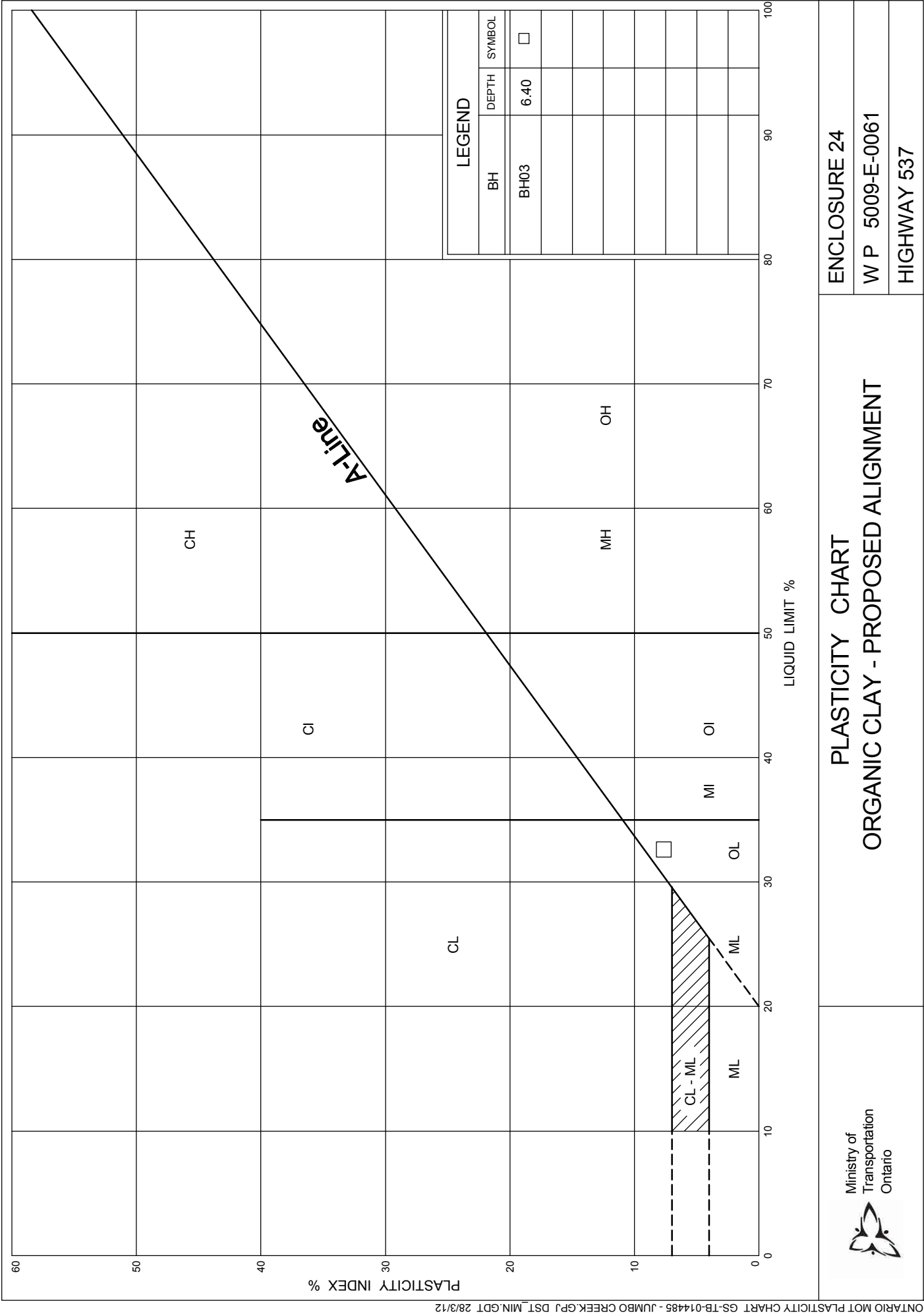












## RESULTS OF ONE-DIMENSIONAL CONSOLIDATION TEST

**Project :** Hwy 537 Jumbo Creek (GS-TB-014485)

Borehole No.	:	BH2
Sample No.	:	ST 7
Sample Depth, m	:	6.1 m
Sample Description	:	Soft Grey Clay

Date of Test : March 28, 2012  
Tested By : abc/jc

Test Method	:	ASTM D 2435-04
Consolidation Type	:	Fixed Ring Oedometer
Condition of Test	:	Vertical trimmed/ horizontal trimmed/ Remoulded/ other

Stage	Initial	Final
Diameter of Sample (mm)	63.56	63.56
Height of Sample (mm)	19.07	15.53
Volume of Sample (cm <sup>3</sup> )	60.51	49.28
Mass of Ring + Wet Soil (g)	185.56	174.66
Mass of Ring + Dry Soil (g)	154.56	154.56
Mass of Ring (g)	75.96	75.96
Mass of Wet Soil (g)	109.61	98.70
Mass of Dry Soil (g)	78.61	78.61
Mass of Moisture (g)	31.00	20.10
Moisture Content (%)	39.44	25.57
Bulk Density (Mg/m <sup>3</sup> )	1.81	2.00
Dry Density (Mg/m <sup>3</sup> )	1.30	1.60
Specific Gravity (tested/ assumed)	2.69	2.69
Voids Ratio	1.069	0.685
Degree of Saturation (%)	99.15	100.33

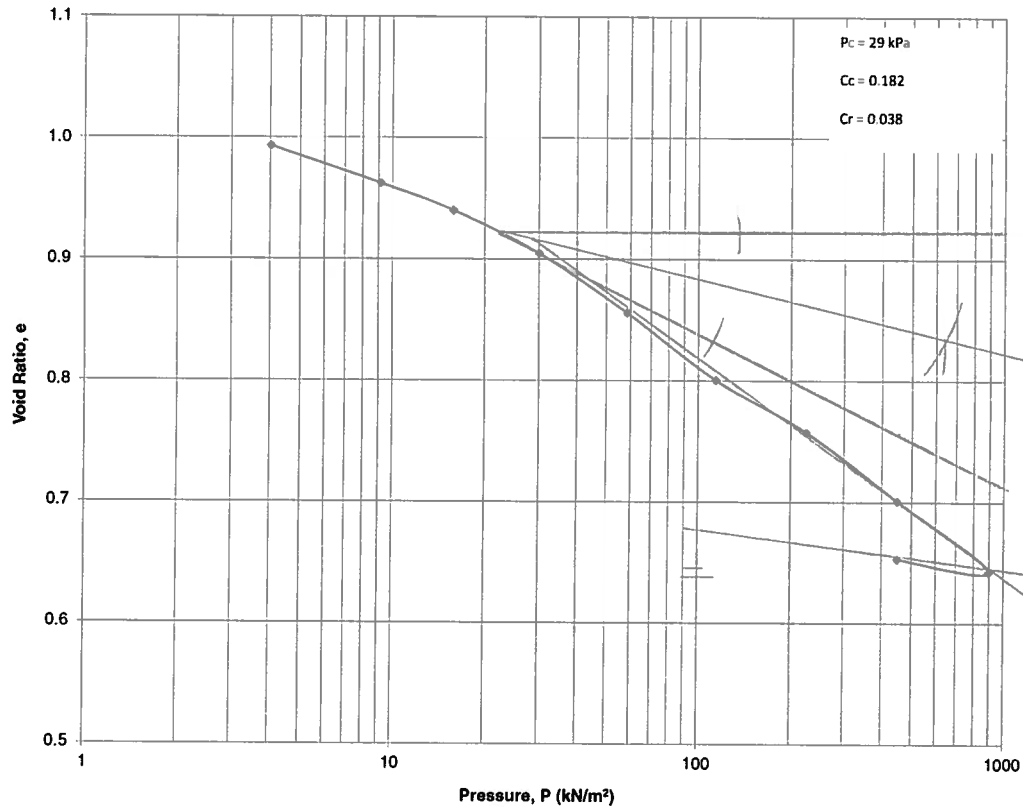
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# ONE-DIMENSIONAL CONSOLIDATION TEST PRESSURE VS. VOID RATIO CURVE

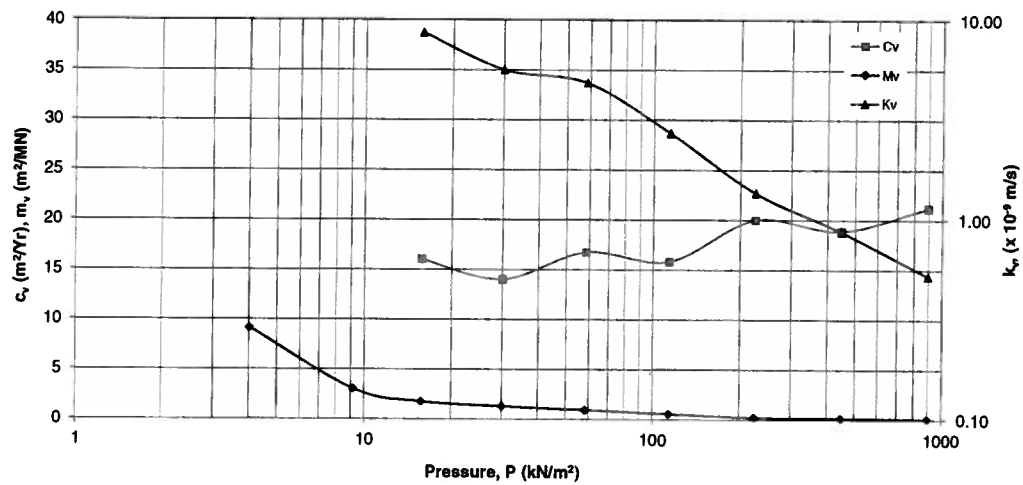
Borehole No.: BH2

Sample No. : ST 7

Depth : 6.1 m



## PRESSURE VS. $C_v$ , $M_v$ & $K_v$ CURVE



## RESULTS OF ONE-DIMENSIONAL CONSOLIDATION TEST

**Project :** GSTB014486

Borehole No. : BH8  
 Sample No. :  
 Sample Depth, m : 7.9 m  
 Sample Description :

Date of Test : April 2 2012  
 Tested By : JM

Test Method : ASTM D 4186-06  
 Consolidation Type : Fixed Ring Oedometer  
 Condition of Test : Vertical trimmed/ horizontal trimmed/ Remoulded/ other

Stage		Initial	Final
Diameter of Sample	(mm)	63.50	63.50
Height of Sample	(mm)	25.40	19.74
Volume of Sample	(cm <sup>3</sup> )	80.44	62.52
Mass of Ring + Wet Soil	(g)	355.53	340.27
Mass of Ring + Dry Soil	(g)	313.64	313.64
Mass of Ring	(g)	216.01	216.01
Mass of Wet Soil	(g)	139.52	124.26
Mass of Dry Soil	(g)	97.63	97.63
Mass of Moisture	(g)	41.89	26.63
Moisture Content	(%)	42.91	27.28
Bulk Density	(Mg/m <sup>3</sup> )	1.73	1.99
Dry Density	(Mg/m <sup>3</sup> )	1.21	1.56
Specific Gravity (tested/ assumed)		2.70	2.70
Voids Ratio		1.225	0.729
Degree of Saturation	(%)	94.60	101.04

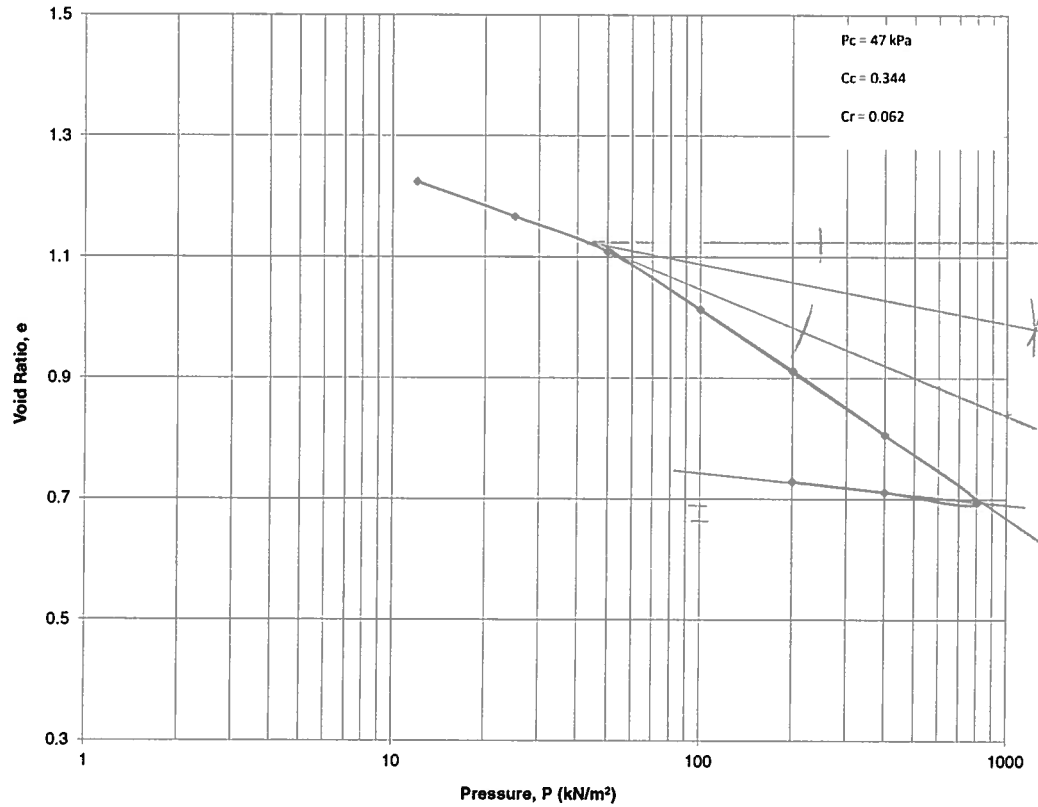
Inc. No	Load (kN/m <sup>2</sup> )	Change in Ht. (mm)	Voids Ratio	t <sub>90</sub> (min)	C <sub>v</sub> (m <sup>2</sup> /yr)	M <sub>v</sub> (m <sup>2</sup> /MN)	K <sub>v</sub> (x 10 <sup>-9</sup> m/s)
1	12	0.004	1.224			0.013	
2	25	0.660	1.167	25.00	11.211	2.040	7.089
3	50	1.318	1.109	29.20	9.102	1.093	3.084
4	100	2.414	1.013	65.60	3.765	0.954	1.113
5	200	3.571	0.912	49.00	4.570	0.530	0.751
6	400	4.778	0.806	33.60	5.980	0.293	0.543
7	800	6.049	0.695	25.00	7.126	0.164	0.363
8	400	5.861	0.711				
9	200	5.661	0.729				
10							
11							
12							

# **ONE-DIMENSIONAL CONSOLIDATION TEST** **PRESSURE VS. VOID RATIO CURVE**

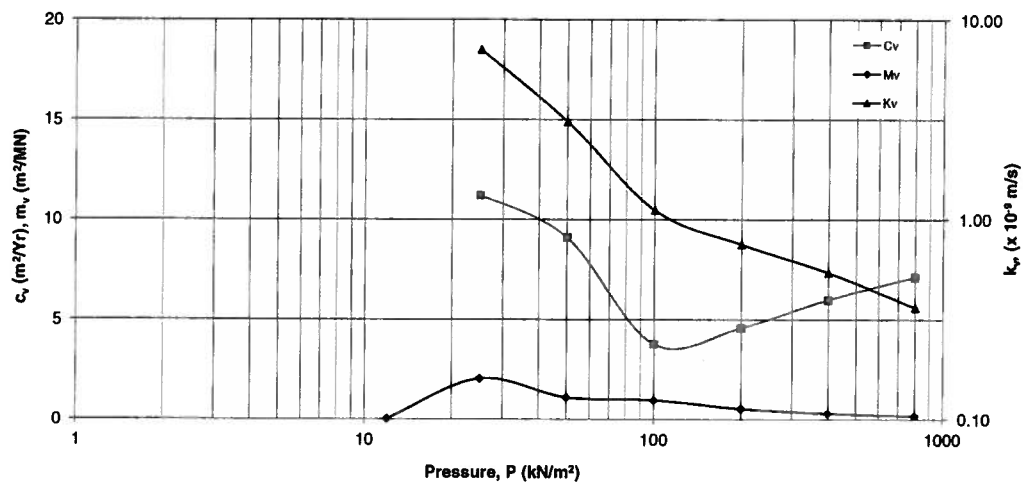
Borehole No.: BH8

Sample No. :           

Depth : 7.9 m



## **PRESSURE VS. $C_v$ , $M_v$ & $K_v$ CURVE**



**Project : GSTB 014485**

Date of Test : April 2, 2012  
Tested By : abc/jc

Test Method	: ASTM D 2435 - 04
Consolidation Type	: Fixed Ring Oedometer
Condition of Test	: Vertical trimmed/ horizontal trimmed/ Remoulded/ other

Stage		Initial	Final
Diameter of Sample	(mm)	63.56	63.56
Height of Sample	(mm)	19.07	14.73
Volume of Sample	(cm <sup>3</sup> )	60.51	46.73
Mass of Ring + Wet Soil	(g)	181.18	166.06
Mass of Ring + Dry Soil (cal from mc)	(g)	145.32	145.32
Mass of Ring	(g)	75.96	75.96
Mass of Wet Soil	(g)	105.22	90.11
Mass of Dry Soil	(g)	69.37	69.37
Mass of Moisture	(g)	35.86	20.74
Moisture Content	(%)	51.69	29.90
Bulk Density	(Mg/m <sup>3</sup> )	1.74	1.93
Dry Density	(Mg/m <sup>3</sup> )	1.15	1.48
Specific Gravity (tested/ assumed)		2.69	2.69
Voids Ratio		1.346	0.812
Degree of Saturation	(%)	103.27	99.04

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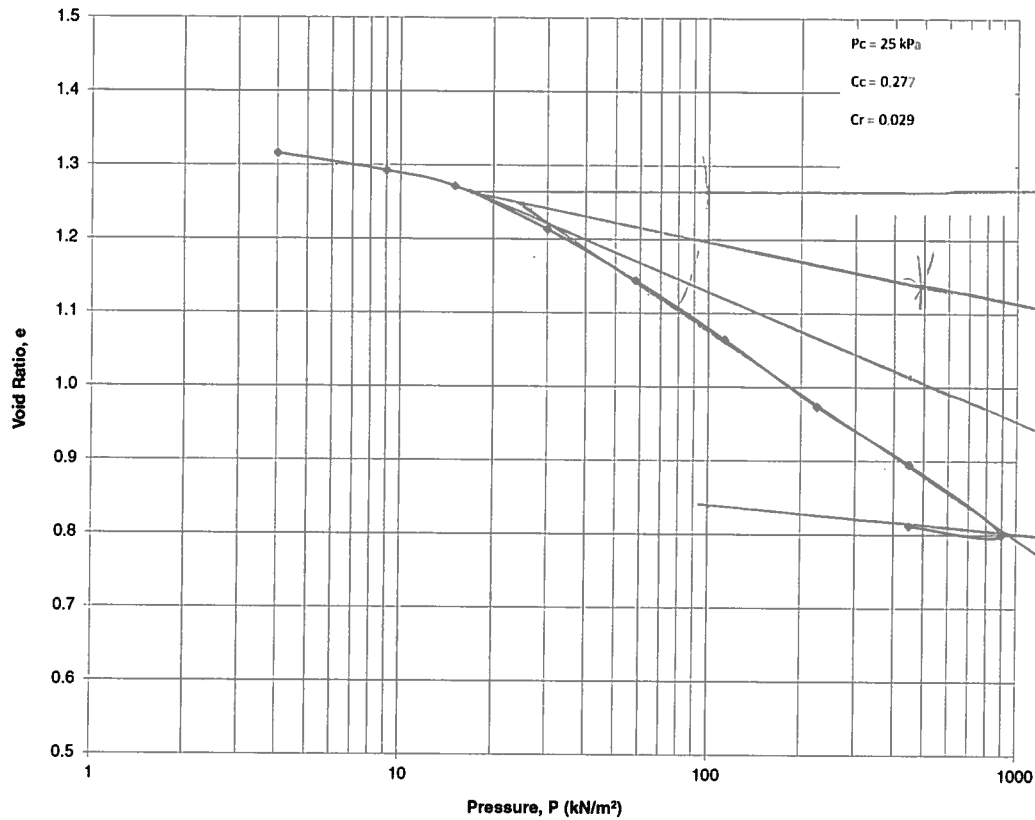


# ONE-DIMENSIONAL CONSOLIDATION TEST PRESSURE VS. VOID RATIO CURVE

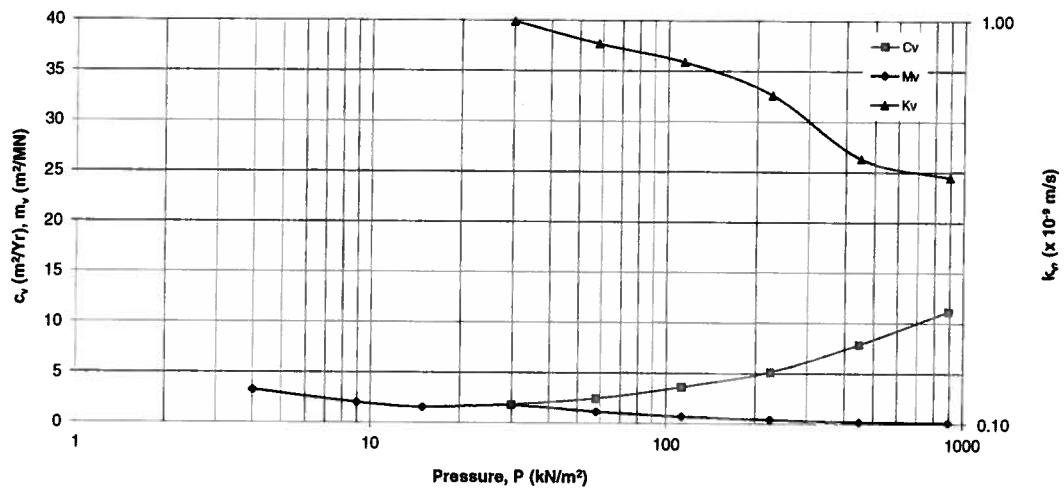
Borehole No.: BH9

Sample No. : ST 13

Depth : 7.6 m



## PRESSURE VS. $C_v$ , $M_v$ & $K_v$ CURVE



## RESULTS OF ONE-DIMENSIONAL CONSOLIDATION TEST

**Project :** GSTB014486

Borehole No. : BH9

Date of Test : April 4 2012

Sample No. :

Tested By : JM

Sample Depth, m : 10.6 m

**Sample Description :**

Test Method : ASTM D 2435-04

Consolidation Type : Fixed Ring Oedometer

Condition of Test : Vertical trimmed/ horizontal trimmed/ Remoulded/ other

Stage	Initial	Final
Diameter of Sample (mm)	63.50	63.50
Height of Sample (mm)	25.40	21.00
Volume of Sample (cm <sup>3</sup> )	80.44	66.51
Mass of Ring + Wet Soil (g)	361.78	348.06
Mass of Ring + Dry Soil (g)	318.30	318.30
Mass of Ring (g)	216.01	216.01
Mass of Wet Soil (g)	145.77	132.05
Mass of Dry Soil (g)	102.29	102.29
Mass of Moisture (g)	43.48	29.76
Moisture Content (%)	42.51	29.09
Bulk Density (Mg/m <sup>3</sup> )	1.81	1.99
Dry Density (Mg/m <sup>3</sup> )	1.27	1.54
Specific Gravity (tested/ assumed)	2.70	2.70
Void Ratio	1.123	0.755
Degree of Saturation (%)	102.18	103.98

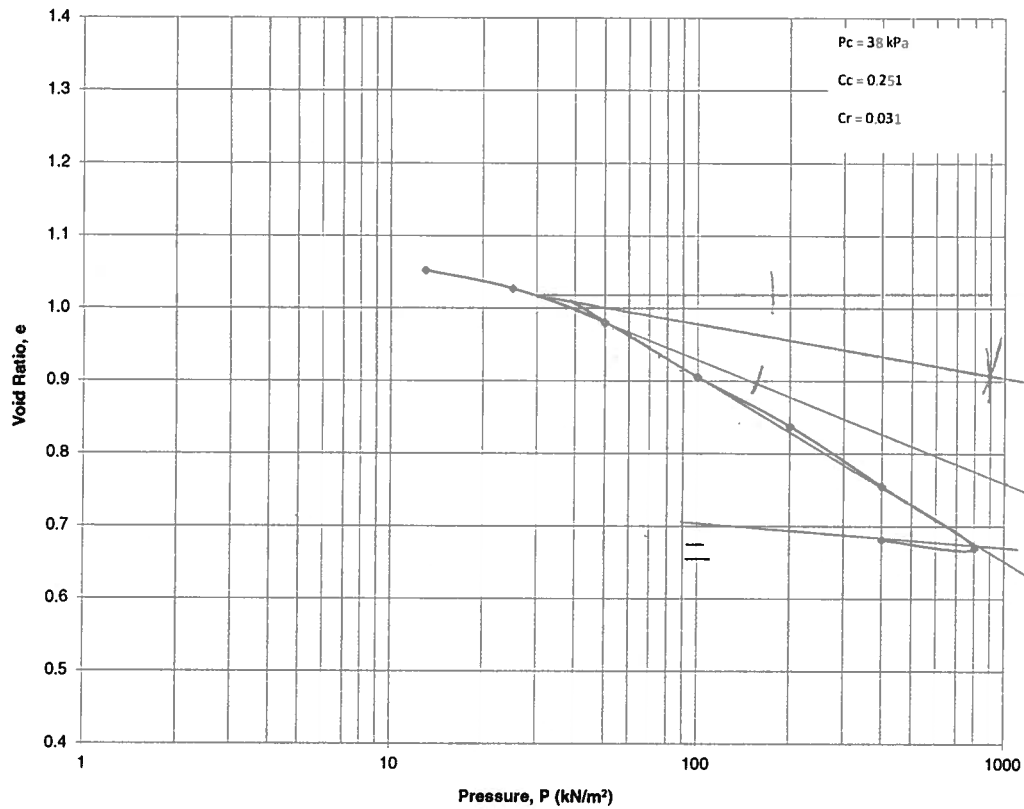
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# ONE-DIMENSIONAL CONSOLIDATION TEST PRESSURE VS. VOID RATIO CURVE

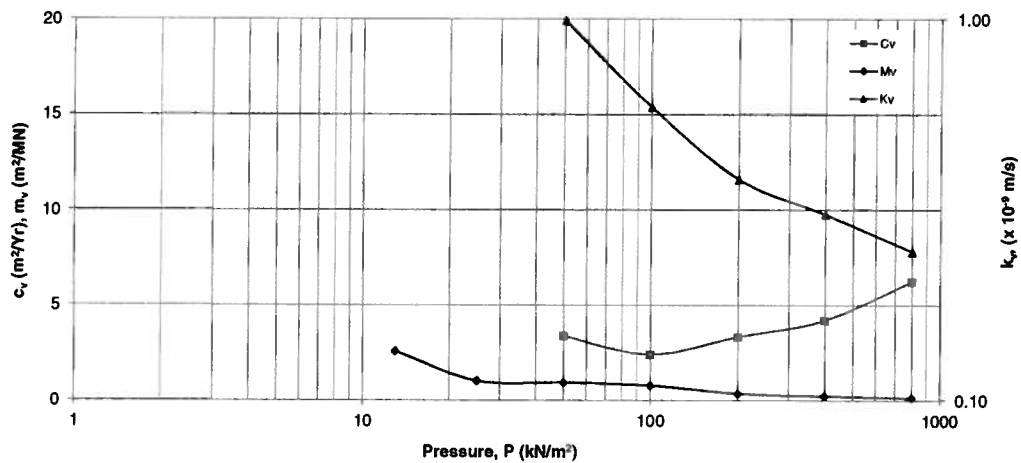
Borehole No.: BH9

Sample No. :

Depth : 10.6 m



## PRESSURE VS. $C_v$ , $M_v$ & $K_v$ CURVE



## RESULTS OF ONE-DIMENSIONAL CONSOLIDATION TEST

**Project :** Hwy 537 Jumbo Creek (GS-TB-014485)

Borehole No. : BH11

Date of Test : March 30, 2012

Sample No. :

Tested By : JM/IC

Sample Depth, m : 12.1 m

**Sample Description** : Soft Grey Clay (P.P=0)

Test Method : ASTM D 2435-04

Consolidation Type : Fixed Ring Oedometer

Condition of Test : Vertical trimmed/ horizontal trimmed/ Remoulded/ other

Stage	Initial	Final
Diameter of Sample (mm)	63.56	63.56
Height of Sample (mm)	19.07	15.23
Volume of Sample (cm <sup>3</sup> )	60.51	48.34
Mass of Ring + Wet Soil (g)	181.09	170.21
Mass of Ring + Dry Soil (g)	148.20	148.20
Mass of Ring (g)	75.96	75.96
Mass of Wet Soil (g)	105.14	94.26
Mass of Dry Soil (g)	72.25	72.25
Mass of Moisture (g)	32.89	22.01
Moisture Content (%)	45.53	30.47
Bulk Density (Mg/m <sup>3</sup> )	1.74	1.95
Dry Density (Mg/m <sup>3</sup> )	1.19	1.49
Specific Gravity (tested/ assumed)	2.69	2.69
Voids Ratio	1.251	0.798
Degree of Saturation (%)	97.80	102.56

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# ONE-DIMENSIONAL CONSOLIDATION TEST PRESSURE VS. VOID RATIO CURVE

Borehole No.: BH11

Sample No. :

Depth : 12.1 m

