



FOUNDATION INVESTIGATION AND DESIGN REPORT

PROPOSED WESTBOUND TRUCK CLIMBING LANE AND EXTENSION OF CULVERTS HIGHWAY 17, PAYS PLAT HILL ONTARIO

Culvert at Sta.14+638 (N 48.897623, E 87.631666)
Culvert at Sta. 15+575 (N 48.891876, E 87.623492)
Culvert at Sta. 10+655 ((N 48.885342, E 87.602397)
Culvert at Sta. 12+248 (N 48.880904, E 87.584072)

GWP NO. 6279-13-00
GEOCRES NO. 42D-49

WSP PROJECT NO.: 171-03034-00.
DATE: 10, MAY 2018

WSP CANADA INC.
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TABLE OF CONTENTS

1	INTRODUCTION	1
2	BACKGROUND INFORMATION	2
2.1	GEOLOGICAL SETTING	2
2.2	PREVIOUS GROUND INVESTIGATIONS	2
2.3	PROJECT OUTLINE.....	2
2.4	SITE DESCRIPTION	4
2.4.1	HIGH FILL SECTION 1 (STA. 14+000 TO 14+100), YESNO TWP. - HF1	5
2.4.2	HIGH FILL SECTION 2 (STA.14+230 TO 14+390), YESNO TWP. - HF2.....	5
2.4.3	HIGH FILL SECTION 3 (STA. 14+580 TO 14+700)/CULVERT AT STA.14+638, YESNO TWP. - HF3.....	5
2.4.4	HIGH FILL SECTION 4 (STA. 15+120 TO STA. 15+160), YESNO TWP. - HF4.....	6
2.4.5	HIGH FILL SECTION 5 (STA. 15+210 TO STA. 15+310), YESNO TWP. - HF5.....	6
2.4.6	HIGH FILL SECTION 6 (STA. 15+420 TO STA. 15+620)/ CULVERT AT STA. 15+575, YESNO TWP. - HF6.....	6
2.4.7	HIGH FILL SECTION 7 (STA. 10+460 TO STA.11+110)/CULVERT AT STA. 10+655, LAHONTAN TWP. - HF7	6
2.4.8	HIGH FILL SECTION 8 (STA. 12+170 TO STA.12+270)/ CULVERT AT 12+248, LAHONTAN TWP. - HF8.....	7
2.4.9	HIGH FILL SECTION 9 (STA. 12+810 TO STA. 12+860), LAHONTAN TWP. - HF9	7
3	FIELD AND LABORATORY INVESTIGATIONS	8
3.1	FIELD INVESTIGATION	8
3.2	LABORATORY INVESTIGATIONS.....	12
3.3	GROUNDWATER INVESTIGATION	13
4	SUBSURFACE CONDITIONS	14
4.1	GENERAL	14
4.2	OVERVIEW	14
4.3	SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 1	15
4.3.1	GENERAL.....	15

4.3.2	TOPSOIL	15
4.3.3	EMBANKMENT FILL (SAND AND GRAVEL)	15
4.3.4	EXPLORATORY HOLE STABILITY UPON COMPLETION	16
4.4	SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 2 ...	16
4.4.1	GENERAL.....	16
4.4.2	TOPSOIL	16
4.4.3	PEAT	16
4.4.4	SILTY SAND TO SANDY SILT (FILL)	16
4.4.5	SILTY SAND	16
4.4.6	EXPLORATORY HOLE STABILITY UPON COMPLETION	17
4.5	SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 3 AND CULVERT AT STA. 14+638	17
4.5.1	GENERAL.....	17
4.5.2	TOPSOIL	17
4.5.3	SILTY SAND	17
4.5.4	SAND / COBBLES / BOULDERS	18
4.5.5	GROUNDWATER OBSERVATIONS.....	18
4.5.6	SUBSURFACE CONDITIONS FOR CULVERT AT STA. 14+638	18
4.6	SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 4 ...	18
4.6.1	GENERAL.....	18
4.6.2	TOPSOIL	18
4.6.3	SILTY SAND	18
4.6.4	BEDROCK (GRANITE / GRANITIC GNEISS).....	19
4.6.5	EXPLORATORY HOLE STABILITY UPON COMPLETION	19
4.7	SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 5 ...	19
4.7.1	GENERAL.....	19
4.7.2	TOPSOIL	20
4.7.3	GRAVELLY SAND	20
4.7.4	GROUNDWATER OBSERVATIONS.....	20
4.8	SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 6 AND CULVERT AT STA. 15+575	20
4.8.1	GENERAL.....	20
4.8.2	TOPSOIL	21

4.8.3	PEAT	21
4.8.4	SILTY SAND.....	21
4.8.5	GRAVELLY SAND TO SILTY SAND	21
4.8.6	EXPLORATORY HOLE STABILITY UPON COMPLETION	22
4.8.7	SUBSURFACE CONDITIONS FOR CULVERT AT STA. 15+575.....	22
4.9	SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 7 AND CULVERT AT STA. 10+655	23
4.9.1	GENERAL.....	23
4.9.2	TOPSOIL	23
4.9.3	SILTY SAND/SAND TO GRAVELLY SAND	24
4.9.4	BOULDERS/PRESUMED BEDROCK.....	24
4.9.5	EXPLORATORY HOLE STABILITY UPON COMPLETION	25
4.9.6	SUBSURFACE CONDITIONS FOR CULVERT AT STA. 10+655.....	25
4.10	SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 8 & CULVERT AT STA. 12+248	25
4.10.1	GENERAL.....	25
4.10.2	TOPSOIL	25
4.10.3	ORGANIC CLAYEY SILT	25
4.10.4	UPPER SILTY CLAY TO CLAYEY SILT.....	26
4.10.5	SILT SAND / SANDY SILT (TILL) TO SAND AND SILT (TILL)	27
4.10.6	LOWER SILTY CLAY	28
4.10.7	BASAL SILTY SAND / SANDY SILT TO SAND AND SILT	30
4.10.8	BEDROCK (GRANITE / GRANITIC GNEISS).....	31
4.10.9	GROUNDWATER CONDITIONS	31
4.10.10	SUBSURFACE CONDITIONS FOR THE CULVERT AT STA. 12+248.....	31
4.11	SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 9 ..	32
4.11.1	GENERAL.....	32
4.11.2	PEAT	32
4.11.3	SAND AND GRAVEL.....	32
4.11.4	SILTY CLAY TO CLAYEY SILT	33
4.11.5	SAND AND SILT (TILL)	34
4.11.6	GRAVELLY SAND	34
4.11.7	GROUNDWATER CONDITIONS	35

TABLES

TABLE 2-1: DETAILS OF THE EXISTING HIGH FILL SECTIONS WITHIN THE WBTCL.....	2
TABLE 2-2: DETAILS OF THE EXISTING CULVERT STRUCTURES WITHIN THE HIGH FILLS OF THE WBTCL.....	3
TABLE 3-1: SUMMARY OF EXPLORATORY HOLE DETAILS:	8
TABLE 3-2: PIEZOMETER INSTALLATION DETAILS	13
TABLE 4-1 GRAIN SIZE DISTRIBUTION SUMMARY – SAND AND GRAVEL (FILL)	15
TABLE 4-2 GRAIN SIZE DISTRIBUTION SUMMARY – SILTY SAND.....	17
TABLE 4-3: GRAIN SIZE DISTRIBUTION SUMMARY – SILTY SAND.....	19
TABLE 4-4 GRAIN SIZE DISTRIBUTION SUMMARY – GRAVELLY SAND	20
TABLE 4-5 GRAIN SIZE DISTRIBUTION SUMMARY – GRAVELLY SAND	21
TABLE 4-6 GRAIN SIZE DISTRIBUTION SUMMARY – SILTY SAND.....	22
TABLE 4-7 GRAIN SIZE DISTRIBUTION SUMMARY – SILTY SAND / SAND.....	24
TABLE 4-8 GRAIN SIZE DISTRIBUTION SUMMARY – SILTY CLAY.....	26
TABLE 4-9 ATTERBERG LIMITS TEST RESULTS – SILTY CLAY	26
TABLE 4-10 GRAIN SIZE DISTRIBUTION SUMMARY – CLAYEY SILT	27
TABLE 4-11 GRAIN SIZE DISTRIBUTION SUMMARY – SILTY SAND/SANDY SILT (TILL) TO SAND AND SILT (TILL).....	27
TABLE 4-12 GRAIN SIZE DISTRIBUTION SUMMARY – SILTY CLAY (TILL).....	28
TABLE 4-13 GRAIN SIZE DISTRIBUTION SUMMARY – LOWER SILTY CLAY.....	29
TABLE 4-14 ATTERBERG LIMITS TEST RESULTS – LOWER SILTY CLAY	29
TABLE 4-15 PRE-CONSOLIDATION PRESSURE, σ'_p (KPA) – LOWER SILTY CLAY.....	30
TABLE 4-16 GRAIN SIZE DISTRIBUTION SUMMARY – BASAL SANDY SILT.....	30
TABLE 4-17: SUMMARY OF GROUNDWATER OBSERVATIONS	31
TABLE 4-18 GRAIN SIZE DISTRIBUTION SUMMARY – SILTY CLAY.....	33

TABLE 4-19 ATTERBERG LIMITS TEST RESULTS – SILTY CLAY	33
TABLE 4-20 GRAIN SIZE DISTRIBUTION SUMMARY – SAND AND SILT (TILL)	34
TABLE 4-21: SUMMARY OF GROUNDWATER OBSERVATIONS	35

DRAWING

:DRAWINGS 1 TO 9 –BOREHOLE LOCATIONS AND SOIL STRATA.....	
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APPENDICES

A	RECORD OF BOREHOLE SHEETS
B & B1	LABORATORY TEST RESULTS
C	SITE PHOTOGRAPHS

1 INTRODUCTION

WSP (Environment) Toronto ("Foundations") was retained by WSP Thunder Bay Office ("TPM") to carry out foundation investigations to provide necessary geotechnical information and make recommendations for the proposed widening of the west bound lane to accommodate a truck climbing lane (WBTCL) along Highway 17, Pays Plat, ON for the North-West Region of the Ministry of Transportation (MTO). The section of the alignment of Hwy 17 for the proposed WBTCL lies within the Townships of Lahontan to the east and Yesno to the west. The foundation engineering scope was limited to providing the geotechnical recommendations within the high fill sections only, as identified in MTO Assignment No. 6016-E-0032/ GWP 6279-13-00. The scope of work also includes the addressing of four non-structural CSP culvert extensions with respect to foundation requirements. No sources for previous geotechnical or construction information pertaining to the existing Highway or culverts were referenced in the RFQ.

The purpose of the Geotechnical Investigation was to determine the sub-surface conditions and groundwater observations at the site by means of boreholes, field and laboratory tests. Based on the information obtained, the engineering characteristics of the subsurface soils were assessed and site conditions described to develop geotechnical recommendations to address the above foundation scope.

Part A of this report presents factual information concerning the subsurface conditions based on all of the subsurface information at hand and is followed by Part B wherein engineering discussion and recommendations are made for the design and construction of the proposed WBTCL and widening of four existing CSP culverts. All foundation field investigations were carried out outside the existing embankment generally within the proposed footprint for embankment widening, as per the RFQ.

General Arrangement Drawings (GA) and culvert details were provided to Foundations by the TPM.

2 BACKGROUND INFORMATION

2.1 GEOLOGICAL SETTING

According to surficial geology of the Thunder Bay area Map S265 (Scale: 1:506,880), regionally, the project site lies within lacustrine deposits / ground Moraine/ bare bedrock which includes sand, silty to sandy till and bedrock outcrops.

Ontario Map MNDM-2542 (Scale: 1:1 000 000) describes the regional bedrock geology as comprising intrusive rocks which include Granodiorite to Granite.

2.2 PREVIOUS GROUND INVESTIGATIONS

No previous ground investigation information was available for this site through MTO Geocres Foundation Library and MOE water well records.

2.3 PROJECT OUTLINE

The proposed westbound truck climbing lane (WBTCCL) and four (4) culvert extensions along Highway 17, Pays Plat, ON covered by this report are situated along the existing Highway 17 within the section of the alignment traversing through the Yesno and Lahontan Townships. The investigated foundation footprint (approximate) of the WBTCCL comprises nine (9) high fill embankment sections of varying length (between 40 m to 650 m length sections). The width of the embankment widening between the shoulder of the existing westbound and the crest of the proposed widening is generally about 6 m. Between the eastern limit of the high fill sections, Section 9, and the western limit of the high fill sections, Section 1, the total distance along the highway is 5.5 km. The road elevation difference between the eastern limit of the high fill sections and the western limit of the high fill sections is approximately 210 m. Along this section of the alignment of the WBTCCL, the highway traverses through valleys alignment in significant fill sections and hills alignment in cut.

As per the RFQ, the widening of Hwy 17 cut sections to accommodate the WBTCCL is outside the scope of foundation engineering. The key plan of high fill site locations is shown on **Drawings 1 to 9**.

Table 2-1 gives the township/station details of the nine (9) high fill sections onto the north, i.e. westbound, along with the embankment height variation in each section. This information is based on the preliminary cross sections provided by TPM on May 18, 2017.

Table 2-1: Details of the Existing High Fill Sections within the WBTCCL

High Fill Section No.	Township/ Location	Embankment Height Range, m	Existing Embankment North Slope; H:V	Side Slope at Highest Embankment	Remarks See Appendix C
1	Yesno/ Sta.14+000 to 14+100	3.2 to 3.5	4.3:1 to 11: 1	11: 1	Photos 1 -1 to1- 5
2	Yesno/ Sta.14+230 to 14+390	7.8 to 9.3	1.5:1 to 3.3:1	2.6:1	Photos 2-1 to2- 4

High Fill Section No.	Township/ Location	Embankment Height Range, m	Existing Embankment North Slope; H:V	Side Slope at Highest Embankment	Remarks See Appendix C
3	Yesno/ Sta.14+580 to 14+700	4.0 to 15.5	1.2:1 to 2.8:1	1.3:1	Photos 3-1 to 3-4
4	Yesno/ Sta.15+120 to 15+160	4.0 to 5.6	2.5:1 to 2.8:1	2.8:1	Photos 4-1 to 4-4
5	Yesno/ Sta.15+210 to 15+310	4.8 to 6.2	1.6:1 to 2.7:1	1.6:1	Photos 5-1 to 5-4
6	Yesno/ Sta.15+420 to 15+620	4.5 to 7.0	1:1 to 3.5:1	1.6:1	Photos 6-1 to 6-8
7	Lahontan/ Sta.10+460 to 11+110	4.0 to 14.0	1.3:1 to 2.2:1	1.3:1	Photos 7-1 to 7-15
8	Lahontan/ Sta.12+170 to 12+270	4.5 to 6.0	1.6:1 to 2.8:1	1.6:1	Photos 8-1 to 8-4
9	Lahontan/ Sta.12+810 to 12+860	4.5 to 5.8	2.0:1 to 3.0:1	2.5:1	Photos 9-1 to 9-2

During the site reconnaissance, within the WBTCCL high fill sections, six (6) culvert structures were identified but only three (3) culverts were originally proposed to be extended under the proposed WBTCCL to the north, to be addressed by Foundations under the RFQ. Subsequently, another culvert (in high fill section 6) was included to be extended and to be addressed by Foundations. The addition to scope was made after the foundation field investigations were completed. However, a borehole had been positioned near this culvert during the field investigations and therefore was able to use ground information to address the culvert extension requirements without having to undertake additional field investigations. These latter four (4) culverts only are addressed in the rest of this report. **Table 2-2** gives some details associated with all culvert structures identified within the high fill sections including those not identified to be addressed by Foundations.

Table 2-2: Details of the Existing Culvert Structures within the High Fills of the WBTCCL

High Fill Section No.	Existing Culvert Station / Type / Size	Embankment Height (above Culvert Obvert) at road centerline, m	Proposed Culvert Extension Details	Remarks See Appendix C
2	Sta.14+230/Yesno/ CSP	7.8*	-	Not Identified in the RFQ; Photo 2-3; Included in the pavement discipline
3	Sta.14+638/Yesno/ CSP /1524 mm	9.7	CSP Same diameter Extension = 11 m Outlet Invert EI = 389.8 m	Identified in the RFQ: Photo 3-3
6	Sta.15+575/Yesno/ CSP /1830 mm	3.8	CSP Same diameter Extension = 6.5 m Inlet Invert EI = 378.7 m	Not Identified in the RFQ, but included in the scope after the field

High Fill Section No.	Existing Culvert Station / Type / Size	Embankment Height (above Culvert Obvert) at road centerline, m	Proposed Culvert Extension Details	Remarks See Appendix C
				investigations: Photo 6-2
7	Sta. 10+655/Lahontan/ CSP /1524 mm	13.3	CSP Same diameter Extension = 18.0 m Inlet Invert EI = 275.2 m	Identified in the RFQ: Photo 7-9
8	Sta. 12+248/Lahontan/ CSP /1830 mm	5.0	CSP Same diameter Extension = 7.0 m Inlet Invert EI = 207.4 m	Identified in the RFQ: Photo 8-1

* Embankment height at the culvert location

2.4 SITE DESCRIPTION

WSP Foundations field reconnaissance was undertaken prior to the drilling program, on 24 and 25, April, 2017 with the participation of the authors of this report and some members of the WSP TPM team in Thunder Bay. The observations of this field reconnaissance including the staked borehole locations were documented in a WSP Report and forwarded to the MTO Northwest Region for information, through the TPM on the project.

The reconnaissance site visit was also aimed at making a general assessment of the suitability/appropriateness of drilling techniques along different high fill sections, based on the access to drilling equipment from the roadway and tractability over the varied topographic features.

All site descriptions reported are generally confined to the north of the existing embankment along the general footprint of the proposed widening. The initial reconnaissance site observations have been complemented by site observations made during the field investigation phase in July 2017.

Generally, the landscape to the north within these sections of the WBTCL high fill sites consists of undulating terrain with numerous bedrock outcrop exposures, mostly with thin overburden soils. Slightly to heavily treed native landscape was evident during the July investigation. Isolated areas with stagnant water were also observed. As expected, a general decline of ground slope is observed from the west to the east, i.e. from the summit of the WBTCL to the commencement of the climb at the eastern end of the high fill sections.

The following paragraphs describe the site conditions of each high fill embankment section and four culvert extension locations based on WSP field investigation observations and supplemented by preliminary cross sections provided by the TPM. Boreholes generally meeting the RFQ spacing requirements were staked out during this field trip, subject to possible minor shift after clearance by locates.

Photographs referred to in each high fill section that follows are a combination of those taken during the site reconnaissance in April 2017 (withered vegetation) and those taken during the field investigations in June 2017 (greener vegetation) and are accordingly annotated on the photo titles.

2.4.1 HIGH FILL SECTION 1 (STA. 14+000 TO 14+100), YESNO TWP. -HF1

The embankment heights generally vary from 3.2 m to 3.5 m within this section. Rockfill was noted on the embankment slope face and in the vicinity of this section (Photos 1-1 & 1-2). In Photo 1-1, rock cuts are exposed on the opposite side of the Hwy, i.e. on the southern side. It is then most likely that the road section is in cut/fill. It is also likely that the excavated rock was used in the fill portion of the road cross section, the northern cross-section.

Based on the road cross-section drawings, the ground topography along the footprint of the proposed embankment gently undulates with a topographic elevational change less than 0.7 m, between approximate elevations of El. 407.9 m and El. 407.2 m, pertaining to the highest and the lowest drawing cross-sections within this high fill section. A road leading to a recreational site (Photos 1-3 and 1-4) was observed to the north of the existing alignment towards the east end of the high fill section. The ground surface along this high fill section was mostly covered with low vegetation.

2.4.2 HIGH FILL SECTION 2 (STA.14+230 TO 14+390), YESNO TWP. - HF2

The embankment heights generally vary from 7.8 m to 9.3 m within this section. Massive rock outcrops were observed as shown in Photo 2-1, in the immediate vicinity of the toe of the existing embankment. Rockfill/boulders (Photo 2-1) were noted on the embankment slope face and at the toe of the embankment.

Based on the road cross-section drawings, the ground topography along the footprint of the proposed embankment gently undulates with a topographic elevational change broadly less than 1.7 m, between approximate elevations of El. 402.0 m and El. 400.2 m, pertaining to the highest and the lowest drawing cross-sections within this high fill section. A road leading to a recreational site (Photo 2-2) is located to the north of the existing alignment towards the west end of the section. The ground surface along this high fill section is mostly covered with a mixture of low vegetation and trees.

A 1200 mm dia. CSP culvert (this culvert is to be extended and the foundation requirements to be addressed by the Pavements discipline) was observed at Sta. 14+230 at the beginning of this section (Photo 2-3). Flowing water was noted at culvert location during the WSP investigation (June 2017).

2.4.3 HIGH FILL SECTION 3 (STA. 14+580 TO 14+700)/CULVERT AT STA.14+638, YESNO TWP. - HF3

The embankment heights generally vary from 4.0 m to 15.5 m within this section. Rock outcrops (Photo 3-1)/possible thin drift overlying the shallow bedrock were frequently visible along the section. Rockfill (Photo 3-2) was commonly noted on the embankment slope face.

Based on the road cross-section drawings, the ground topography along the footprint of the proposed embankment steeply undulates with a significant topographic elevational change generally less than 12 m, between approximate elevations of El. 398.8 m and El. 386.7 m, pertaining to the highest and the lowest drawing cross-sections within this high fill section. The ground surface along this high fill section is covered with a mixture of low vegetation and trees.

A 1524 mm dia. CSP culvert (Photo 3-3) was noted at Sta. 14+638. The highway above the obvert of the culvert is approximately 9.7 m high (at centerline of Hwy 17) with an approximately 1.5H:1V side slope to the north. No flowing water was observed during our initial site reconnaissance in April 2017. The outlet of the culvert was surrounded by low vegetation. The water depth of the outlet end was 0.3 m in June 2017 at the time of the field investigation.

2.4.4 HIGH FILL SECTION 4 (STA. 15+120 TO STA. 15+160), YESNO TWP. – HF4

The embankment heights generally vary from 4.0 m to 5.6 m within this section. Rock outcrops were noted along this section (Photos 4-1 & 4-2). Rockfill (Photo 4-3) was commonly noted on the embankment slope face.

Based on the road cross-section drawings, the ground topography along the footprint of the proposed embankment gently undulates with a topographic elevational change generally less than 2.2 m, between approximate elevations of El. 398.0 m and El. 395.4 m, pertaining to the highest and the lowest drawing cross-sections within this high fill section. The ground surface along this high fill section is mostly covered with a mixture of low vegetation and trees.

2.4.5 HIGH FILL SECTION 5 (STA. 15+210 TO STA. 15+310), YESNO TWP. – HF5

The embankment heights generally vary from 4.8 m to 6.2 m within this section. Rock outcrops were noted along this section (Photo 5-1). Rockfill (Photo 5-2) was noted on the embankment slope face.

Based on the road cross-section drawings, the ground topography along the footprint of the proposed embankment gently undulates with a topographic elevational change generally less than 2.1 m, between approximate elevations of El. 392.2 m and El. 389.1 m, pertaining to the highest and the lowest drawing cross-sections within this high fill section. The ground surface along this high fill section is mostly covered with a mixture of low vegetation and trees. A standing water condition (Photo 5-3) was also observed toward the east end of this section in the month of June 2017.

2.4.6 HIGH FILL SECTION 6 (STA. 15+420 TO STA. 15+620)/ CULVERT AT STA. 15+575, YESNO TWP. – HF6

The embankment heights generally vary from 4.5 m to 7.0 m within this section. Rockfill (Photo 6-1) was mostly noted on the embankment slope face. Water ponding (Photo 6-2) was observed toward the east side of this section. Marshy ground conditions were noted in some isolated water logged patches.

Based on the road cross-section drawings, the ground topography along the footprint of the proposed embankment undulates with a topographic elevational change generally less than 4.4 m, between approximate elevations of El. 386.4 m and El. 378.9 m, pertaining to the highest and the lowest drawing cross-sections within this high fill section. The ground surface along this high fill section was covered with low vegetation.

An 1830 mm dia. CSP culvert (Photo 6-2 & 6-3) that was not mentioned under Foundations in the RFQ was noted at Sta. 15+575 toward the east of this section. The highway above the obvert of the culvert is approximately 3.8 m high (at centerline of Hwy 17) with an approximately 1.6H:1.0V side slope to the north.

2.4.7 HIGH FILL SECTION 7 (STA. 10+460 TO STA. 11+110)/CULVERT AT STA. 10+655, LAHONTAN TWP. – HF7

The embankment heights generally vary from 4.0 to 14.0 m within this section. Rock outcrops (Photos 7-1 to 7-7)/ possible thin drift overlying the shallow bedrock were observed extensively along the section. Rockfill (Photo 7-8) was primarily noted on the embankment slope face.

The ground surface in the vicinity of the existing embankment toe was generally undulating bedrock outcrops. Based on the road cross-section drawings, the ground topography along the footprint of the proposed embankment undulates with a topographic

elevational change generally less than 6.8 m, between approximate elevations of El. 298.0 m and El. 251.8 m, pertaining to the highest and the lowest drawing cross-sections within this high fill section. The ground surface along this high fill section was mostly covered with low vegetation to medium high vegetation.

A 1524 mm dia. CSP culvert (Photo 7-9) was noted at Sta. 10+655. The height of the embankment above the obvert of the culvert is approximately 13.3 m (at centerline of Hwy 17) with an approximately 2H:1V side slope to the north. No flowing water was observed during our initial site reconnaissance in April 2017. The inlet of the culvert was surrounded by low vegetation. The water depth of the inlet end was 0.4 m in June 2017 during the field investigation.

2.4.8 HIGH FILL SECTION 8 (STA. 12+170 TO STA.12+270)/ CULVERT AT 12+248, LAHONTAN TWP. - HF8

The embankment heights generally vary from 4.5 m to 6.0 m within this section.

Based on the road cross-section drawings, the ground topography along the footprint of the proposed embankment gently undulates with a topographic elevational change generally less than 1.6 m, between approximate elevations of El. 198.4 m and El. 195.6 m, pertaining to the highest and the lowest drawing cross-sections within this high fill section. The ground surface along this section was covered with a mixture of low vegetation and trees.

An 1830 mm dia. CSP culvert (Photo 8-1) was noted at Sta. 12+248. The height of the embankment above the obvert of the culvert is approximately 5.0 m (at centerline of Hwy 17) with an approximately 1.75H:1V side slope. No flowing water condition was observed during our initial site reconnaissance in April 2017. The inlet/outlet of the culvert was surrounded by low vegetation. The water depth of the inlet end was 0.3 m in June 2017 during the field investigation.

2.4.9 HIGH FILL SECTION 9 (STA. 12+810 TO STA. 12+860), LAHONTAN TWP. - HF9

The embankment heights generally vary from 4.5 m to 5.8 m within this section. Based on the road cross-section drawings, the ground topography along the footprint of the proposed embankment gently undulates with a topographic elevational change generally less than 0.8 m, between approximate elevations of El.208.6 m and El.207.6 m, pertaining to the highest and the lowest drawing cross-sections within this high fill section. The ground surface is covered with a mixture of low vegetation and trees.

3 FIELD AND LABORATORY INVESTIGATIONS

3.1 FIELD INVESTIGATION

Site reconnaissance observations about the nature of terrain and access constraints for conventional drilling equipment were carefully considered in planning the field investigation programme. These deliberations led to the understanding that with the exception of high fill Section 1, the rest of the high fill sections would not be able to accommodate a conventional drilling approach, e.g. use of a track mounted CME 55 type of machine. High fill Section 1 has modest embankment heights, less than 3.5 m and visual observations revealed the likely absence of soft ground conditions being in a cut/fill transition as discussed in Section 2.3.1 of this report. Based on all these considerations, after discussions with the drillers, i.e. Marathon Drilling, led to the adoption of portable tripod drilling to circumvent the difficult ground conditions described.

This particular portable drilling gear can carry out standard SPT penetration testing with a 63.5 kg hammer and uses rotary wash boring powered by an electric generator. It was comparable to a conventional drilling machine, in that, rock coring could be undertaken but at the expense of significant production impacts even for conventional earth drilling. However, during the field investigations, it became clear that in high fill sections 8 and 9, some limited access was possible for a track-mounted rig. A track-mounted drilling rig was mobilised for the limited access areas. Since, all the boreholes were in the off-road areas, no major traffic protection (lane closure) was involved except for setting up cones and signs in the unpaved shoulder area to place a portable water tank (for wash boring) and a generator.

The fieldwork undertaken by WSP during June 2017 consisted of carrying out twenty-two (22) boreholes (including for three culverts investigations), five (5) test pits (including for two culvert investigations) and six (6) Dynamic Cone Penetration Tests (DCPTs) to investigate subsurface conditions of nine (9) high fill sections and four (4) culverts within the WBTCL.

Table 3-1 presents the exploratory hole details of the WSP foundation investigation program. The exploratory hole locations are shown on **Drawings 1 to 9** following the text of the report.

Table 3-1: Summary of Exploratory Hole Details:

BH No:	*Co-ordinates (m)	Station/Offset (m)	Ground El. (m)	Explored Depth (m)	Remarks*/ Drilling Methodology
Section 1 – Sta. 14+000 to Sta. 14+100 (Yesno Twp.)					
BH HF1-6	E257952 N5418212	14+018 /14.0 (Lt.)	407.4	0.7	Tripod with wash boring; terminated within embankment fill material; split spoon sampling; spoon refusal at shallow depth.
BH HF1-6A	E258029 N5418178	14+103 / 13.0 (Lt.)	407.2	2.4	Tripod with wash boring; terminated within road embankment fill material; split spoon sampling; DCPT testing.
Section 2 – Sta. 14+230 to Sta. 14+390 (Yesno Twp.)					

BH No:	*Co-ordinates (m)	Station/Offset (m)	Ground El. (m)	Explored Depth (m)	Remarks*/ Drilling Methodology
BH HF2-7	E258147 N5418136	14+227 / 19.3 (Lt.)	404.6	1.8	Tripod with wash boring; terminated within native silty sand deposit; split spoon sampling; coring in cobbles; dynamic cone penetration test (DCPT).
BH HF2-7B	E258230 N5418102	14+317 / 19.3 (Lt.)	401.5	1.2	Tripod with wash boring; terminated within native silty sand deposit; split spoon sampling; spoon refusal at shallow depth.
Section 3 – Sta. 14+580 to Sta.14+700 / Culvert at Sta.14+638 (Yesno Twp.)					
TP HF3-8	E258490 N5417893	14+642 / 24.7 (Lt.)	389.8	0.9	Hand dug test pit; terminated in presumed bedrock / Cobbles ; Includes investigation for culvert extension at Sta. 14+638
TP HF3-9	E258504 N5417874	14+664 / 26.2 (Lt.)	390.0	0.7	Hand dug test pit; terminated in presumed bedrock / boulder
TP HF3-10	E258512 N5417852	14+687 / 21.5 (Lt.)	395.2	0.7	Hand dug test pit; terminated in presumed bedrock / boulder
Section 4 – Sta. 15+120 to Sta. 15+160 (Yesno Twp.)					
BH HF4-11	E258713 N5417455	15+140 / 16.6 (Lt.)	395.8	3.0	Tripod with wash boring / Rock coring; terminated within bedrock; split spoon sampling / rock core sampling
BH HF4-11A	E258709 N5417468	15+128 / 22.8 (Lt.)	394.4	1.9	Tripod with wash boring; terminated within native silty sand deposit; split spoon sampling
Section 5 – Sta. 15+210 to Sta. 15+310 (Yesno Twp.)					
TP HF5-12	E258773 N5417407	15+219 / 21.2	392.1	0.2	Hand dug test pit; terminated in presumed bedrock / boulder
BH HF5-14	E258821 N5417379	15+277 / 25.4 (Lt.)	389.1	1.0	A surficial split spoon sample without drilling; continued with DCPT. until DCPT cone refusal; An adjacent hand dug test pit advanced.
Section 6 – Sta. 15+420 to Sta. 15+620 (Yesno Twp.) / Culvert at Sta.15+575 (Yesno Twp.)					
BH HF6-15A	E259055 N5417264	15+542 / 16.8 (Lt.)	379.5	5.5	Tripod with wash boring; terminated within native gravelly sand deposit; split spoon sampling, DCPT testing.
BH HF6-15	E259084 N5417249	15+574 / 14.2 (Lt.)	379.2	7.8	A surficial split spoon sample without drilling; continued with the DCPT.until DCPT cone refusal; Includes investigation for culvert extension at Sta. 15+575

BH No:	*Co-ordinates (m)	Station/Offset (m)	Ground El. (m)	Explored Depth (m)	Remarks*/ Drilling Methodology
BH HF6-16	E259099 N5417244	15+590 / 15.5 (Lt.)	379.2	11.4	Tripod with wash boring; terminated within native silty sand deposit; split spoon sampling, DCPT testing; Includes investigation for culvert extension at Sta. 15+575
BH HF6-17	E259118 N5417237	15+611 / 16.1 (Lt.)	379.1	12.2	Tripod with wash boring; terminated within native gravelly sand deposit; split spoon sampling; DCPT testing.
BH HF-18	E259162 N5417218	15+658 / 16.0 (Lt.)	379.0	2.8	Tripod with wash boring; terminated within native gravelly sand deposit; split spoon sampling; DCPT testing.
BH HF6-19	E259180 N5417215	16+676 / 20.1 (Lt.)	378.9	3.2	Tripod with wash boring; terminated within native gravelly sand deposit; split spoon sampling; DCPT testing.
Section 7 – Sta.10+460 to Sta.11+110 / Culvert at Sta.10+655 (Lahontan Twp.)					
BH HF7-20	E260518 N5416593	10.490 / 22.4 (Lt.)	291.6	0.5	Tripod with wash boring; terminated within native silty sand deposit; split spoon sampling; spoon refusal at shallow depth.
BH HF7-21	E260556 N5416565	10+536 / 23.9 (Lt.)	289.0	2.1	Tripod with wash boring; terminated within native sand deposit; split spoon sampling
BH HF7-22	E260607 N5416524	10+601 / 26.0 (Lt.)	283.3	1.2	Tripod with wash boring; terminated within native sand deposit; split spoon sampling; spoon refusal at shallow depth.
TP HF7-23	E260625 N5416510	10+623 / 27.9 (Lt.)	278.6	0.3	Hand dug test pit; terminated in presumed bedrock / boulder
BH HF7-24	E260661 N5416476	10+671 / 27.7 (Lt.)	279.4	2.3	Tripod with wash boring; terminated within native sand deposit; split spoon sampling; Includes investigations for culvert at sta. 10+655
BH HF7-25	E260697 N5416439	10+723 / 26.7 (Lt.)	275.5	0.8	DCPT testing. Terminated at DCPT cone refusal
BH HF7-26	E260734 N5416408	10+770 / 32.0 (Lt.)	271.5	2.5	DCPT testing. Terminated at DCPT cone refusal
BH HF7-27	E260836 N5416275	10+935 / 24.2 (Lt.)	260.2	2.3	DCPT testing. Terminated at DCPT cone refusal
BH HF7-28	E260920 N5416164	11+074 / 20.1 (Lt.)	253.1	0.7	DCPT testing. Terminated at DCPT cone refusal
BH HF7-29	E260953 N5416127	11+124 / 23.1 (Lt.)	251.6	1.7	Tripod with wash boring / Rock coring; terminated within presumed

BH No:	*Co-ordinates (m)	Station/Offset (m)	Ground El. (m)	Explored Depth (m)	Remarks*/ Drilling Methodology
					bedrock/boulder; split spoon sampling / rock core sampling
BH HF7-30	E261083 N5415984	11+323 / 16.0 (Lt.)	237.4	2.4	DCPT testing. Terminated at DCPT cone refusal
Section 8 – Sta. 12+170 to Sta.12+270 / Culvert at Sta.12+248 (Lahontan Twp.)					
BH HF8-33	E261875 N5415984	12+167 / 24.4 (Lt.)	208.5	11.9	Tripod with wash boring; terminated within native silty clay deposit; split spoon sampling; DCPT testing.
BH HF8-33A	E261876 N5415986	12+167 / 26.4 (Lt.)	208.5	13.7	Track mounted rig; casing with wash boring; rock coring; terminated within bedrock; split spoon sampling / shelby sampling/rock core sampling
BH HF8-34	E261896 N5415989	12+189 / 23.4 (Lt.)	208.4	14.5	Track mounted rig; casing with wash boring; terminated within sandy silt deposit; split spoon sampling / Shelby sampling
BH HF8-35	E261965 N5416006	12+260 / 22.9 (Lt.)	208.0	7.3	Track mounted rig; casing with wash boring; terminated within native silty sand deposit; split spoon sampling; piezometer installed; Includes investigations for culvert at sta. 12+248
Section 9– Sta. 12+810 to Sta. 12+860 (Lahontan Twp.)					
BH HF9-36	E262512 N5416074	12+808 / 23.4 (Lt.)	197.5	6.7	Track mounted rig; hollow stem auger; terminated within native sand and silt (Till) deposit; split spoon sampling
BH HF9-37	E262541 N5416078	12+864 / 25.1 (Lt.)	195.5	6.4	Track mounted rig; hollow stem auger; terminated within native gravelly sand deposit; split spoon sampling / shelby sampling

Notes*:

1. The spacing and quantity of boreholes generally conform to RFQ requirements; Rock coring was not stipulated in the RFQ.
2. Type of Drilling rig/Test pit method Used: Tripod with portable drilling system (Hilti-DD 250) with manually lifted SPT hammer (assisted by electric motor) and Track mounted - CME 55 rig; Test pit by hand-dug (manually)
3. Co-ordinates: based on MTM NAD 83 Zone 14 coordinates; Terminology of directions, e.g., North is project defined and do not relate to geographic directions
- 4.. Name of Drilling Company: Marathon Drilling, Ottawa, Ontario
5. Drilling Supervision: by WSP staff from Timmins office

6. Borehole Survey: by WSP, Thunder Bay office

The soil stratigraphy was recorded by observing the quality and changes of augered materials, which were withdrawn from the boreholes, and by sampling the soils at regular intervals of depth using a 50mm O.D. split spoon sampler, in accordance with the Standard Penetration Test (ASTM D 1586) method. This sampling method recovers samples from the soil strata, and the number of blows required to drive the sampler 300 mm depth into the undisturbed soil (SPT 'N'-values) gives an indication of the compactness condition or consistency of the sampled soil material. The SPT 'N' values are indicated on the Record of Borehole Sheets (Refer to **Appendix A**). In-situ Field Shear Vane (FSV) tests (with a MTO 'N' vane) were carried out within the cohesive soils when the consistency of such soils allowed to obtain an indication of the shear strength of the soil. Samples of the cohesive soils were retrieved using 76 mm O.D. Shelby tubes for undisturbed samples. Significant difficulties were experienced retrieving undisturbed samples from some of the cohesive deposits in high fill section 8 and 9 without much success.

Hand dug test pits were carried out at the five (5) locations (TP HF3-8, TP HF3-9, TP HF3-10, TP HF5-12, and TP HF-23) to visually confirm the nature of shallow refusal strata.

Dynamic cone penetration test (DCPT) was carried out under three field conditions:

- (a) where the ground conditions were not suitable to set-up the tripod as in very rough terrain, DCPT was carried out entirely manually with half-weight hammer (31.75 kg), e.g. BH HF7-27, BH HF7-28;
- (b) where the tripod could be assembled but the ground conditions such as frequent outcrop exposures were evident as in locations in high fill Section 7; (BH HF7-25, BH HF7-26). The objective was just to prove shallow refusal which is more expedient with the DCPT than sinking a borehole;
- (c) At some exploratory locations, boreholes/test pits were combined with DCPTs to establish the refusal stratum to hole advancement.

At non-tripod setup locations, the penetration tests (SPT/DCPT) were carried out manually using a half-weight hammer but only SPT 'N' values have been corrected for the reduced hammer weight.

Rock coring was carried out using NQ core barrels to depths of 1.7 and 0.7 m below auger/casing refusal depths and occasional rock coring was carried out through rockfill/cobble material to overcome drilling obstructions.

Generally, boreholes/DCPT/test pits were terminated on refusal to further augering/excavation, driving of casing and/or spoon/DCPT Cone advancement, probably on or in presumed bedrock surface/boulders.

The WSP fieldwork was carried out under full-time supervision of WSP technical staff who directed the exploration and sampling operation, logged borehole/test pit data in accordance with MTO Soils Classification System and took custody of soil/rock samples retrieved for subsequent laboratory testing and identification. Soil/rock samples were visually classified in the field and later re-evaluated by an engineer. The recovered soil/rock samples were placed in labeled moisture-proof bags/rock core boxes and returned to WSP's laboratory for further assessment.

3.2 LABORATORY INVESTIGATIONS

Visual examination and classification were undertaken on the soil/rock samples returned to the WSP laboratory. A routine laboratory

testing program consisting of natural water content tests, grain size analyses, including hydrometer testing, Atterberg limits and Organic content test was carried out on selected representative soil samples. Two unconsolidated-undrained tri-axial tests (UU tests) and one consolidation test (by Terraprobe laboratory) were carried out on selected undisturbed Shelby tube soil samples. The results of the laboratory tests are summarized on the appropriate Record of Borehole Sheets in **Appendix A**, and the details presented in **Appendix B & B1**.

3.3 GROUNDWATER INVESTIGATION

Groundwater conditions in the boreholes were observed during and on completion of drilling in the open boreholes. Groundwater observations on completion of drilling will not be reliable wherever wash boring technique was followed and are not reported. A standpipe piezometer was installed only in Borehole BH HF8-35 upon its completion to enable long-term groundwater level monitoring. The rest of the boreholes were grouted (decommissioned) using a cement/bentonite mixture as per MTO procedures. As part of construction, the piezometer needs to be decommissioned in accordance with Ontario Regulation 903 (amended to Ontario Regulation 372/07).

Table 3.2 below provides information about the piezometer installed for this investigation, including ground surface elevations, depths, and the approximate elevations of the screened interval.

Table 3-2: Piezometer Installation Details

BH ID	Ground Surface Elevation (m)	Borehole Bottom		Well Screen Interval Depth, m		Well Screen Interval Elevation, m	
		Depth (m)	Elevation (m)	From	To	From	To
BH HF8-35	208.0	7.3	200.7	4.3	7.3	203.7	200.7

4 SUBSURFACE CONDITIONS

4.1 GENERAL

The subsurface conditions encountered at each investigated high fill section are described in the following sections. For purposes of soil description, the MTO soil classification manual was generally followed.

Drawings 1 to 9 each shows a borehole/test pit/DCPT location plan with a subsurface profile (projected parallel to the existing Hwy 17 centreline) and a cross-section (projected perpendicular to the existing Hwy 17 centreline) for each high fill section and a profile along the culvert alignment (when appropriate) respectively. The inferred stratigraphic profile at each section is based on the borehole data. The soil descriptions are based on visual and tactile observations and complemented by the results of field and laboratory soil test results.

As stated in Section 3.3, groundwater observations on completion of drilling will not be reliable wherever wash boring technique was followed and hence not reported. However, observed borehole stability conditions upon completion of boreholes are described.

It should be noted that the subsurface conditions and the topsoil thicknesses encountered might vary in between and beyond the borehole locations, the topsoil thicknesses could vary especially in depressed areas and near watercourses. The strata boundaries shown on the subsurface profile must not be interpreted as exact planes of geological change but rather as inferred transitions from one soil type to another. All topsoil thicknesses reported should not be relied upon for quantity estimation. All groundwater levels observed in the exploratory holes are subject to seasonal fluctuations and variations due to precipitation events.

For ease of reading, subsoil information has been summarized for each culvert foundation in the relevant high fill sections at the expense of some minor repetition.

An overview of subsurface conditions is described below. All depths quoted are below the existing ground surface. It is to be noted that based on the borehole data, the elevations (El.) reported for strata boundaries are from the shallowest occurrence to the deepest occurrence.

4.2 OVERVIEW

In general, the sub-soil conditions intercepted in WBTCCL High Fill Sections 1, 2, 3, 4, 5, 6 and 7 were predominantly cohesionless deposits. Access constraints to these high fills sections by conventional drilling gear compelled the use of portable tripod based drilling. Exploratory advancement in boreholes, DCPT soundings and test pitting were prematurely met with refusal either due to cobbles/boulders and/or shallow bedrock. Bedrock exposures were a distinct feature of the landscape within most of the above high fill sections and most notably in high fill Section 7. The above sections constitute 90% of the entire high fill sections in terms of the cumulative length of the high fill sections.

High Fill Sections 8 and 9 at the eastern end of the high fill sections, intercepted compressible cohesive deposits of soft/firm consistency but were of limited thickness. Glacial deposits were also intercepted in these latter high fill sections. Based on the drawings, the maximum embankment height within these compressible deposit laden high fill sections under the proposed widening to accommodate the WBTCCL, will not be in excess of 6 m.

Mildly artesian ground water levels were observed either on completion or in the long-term in high fill sections 8 and 9.

Limited bedrock coring of the very high strength granitic gneisses was also undertaken.

As indicated in the geology maps for this region, the project site revealed lacustrine deposits / ground moraine/ bare bedrock, which includes glacial till and bedrock outcrops.

The following sections give detailed descriptions of sub-soil profiles and groundwater observations as intercepted within the respective high fill sections.

4.3 SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 1

4.3.1 GENERAL

The subsoil characterization for High Fill Section 1 is based on the findings from boreholes BH HF1-6 and BH HF1-6A and the inferred sub-soil profile is shown on **Drawing No.1**.

4.3.2 TOPSOIL

A veneer of topsoil (35 mm thick) was contacted at ground surface in BH HF1-6.

4.3.3 EMBANKMENT FILL (SAND AND GRAVEL)

Brown sand and gravel fill was encountered in boreholes BH HF1-6 and BH HF1-6A. The fill contained traces of silt and cobbles.

The explored thicknesses of the layer were 0.7 m and 2.4 m and the elevations of the base of the unit explored were El.406.7 m and El. 404.8 m at the above borehole locations respectively. The bottom of this layer was characterized by refusal to further penetration of the split-spoon at BH HF1-6.

The grain size distributions of two (2) samples from this embankment fill were determined in the laboratory and gave the grain size distribution shown in **Table 4-1**.

Table 4-1 Grain Size Distribution Summary – Sand and Gravel (Fill)

Samples Tested	Size Fraction	% Passing by Weight	Remarks
BH HF1-6/SS1	Gravel	47 - 52%	Shown in Figure B-1, Appendix B Summarized on the relevant Record of Borehole Sheets
BH HF1-6A/SS2	Sand	43 - 46%	
	Fines (Silt and Clay)	5 - 7%	

The grading results shown above indicate the embankment fill can be classified as cohesionless (SW).

The moisture content based on seven (7) samples recovered from the material ranged from 2% to 25% indicative of a moist to wet condition.

SPT testing carried out in the boreholes, gave SPT 'N' values that ranged from 6 blows/300 mm and 60 blows/300 mm (based on 5 SPT results) which indicate a loose to very dense relative density, typically of loose to compact. In addition, DCPT testing was carried out within this fill material. The DCPT blow counts generally varied from 2 blows/ 300 mm to >100 blows/300 mm.

4.3.4 EXPLORATORY HOLE STABILITY UPON COMPLETION

BH HF1-6 was dry and open whilst BH HF1-6A experienced continuous caving.

4.4 SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 2

4.4.1 GENERAL

The subsoil characterization for High Fill Section 2 is based on the findings from boreholes BH HF2-7 and BH HF2-7B and the inferred sub-soil profile is shown on **Drawing No.2**.

4.4.2 TOPSOIL

A veneer of topsoil (300 mm thick) was contacted at ground surface in BH HF2-7.

4.4.3 PEAT

A 700 mm thick, dark brown peat was encountered at ground surface in BH HF2-7B. It also contained decayed wood and rootlets. A measured moisture content value from this peat material was 76%.

SPT testing carried out in the borehole, gave a SPT 'N' value of 1 blow/300 mm which indicates a very soft consistency.

4.4.4 SILTY SAND TO SANDY SILT (FILL)

Beneath the topsoil, a 300 mm thick silty sand to sandy silt fill material was encountered only in BH HF2-7. It also contained traces of rootlets and organics.

The moisture content based on two (2) samples recovered from the layer were 24% to 27% indicative of a moist to wet condition.

SPT testing carried out in this material, gave a SPT 'N' value of 7 blows/300 mm, which indicates a loose relative density.

4.4.5 SILTY SAND

A native deposit of brown silty sand was contacted in both boreholes (BH HF2-7 and BH HF2-7B). The deposit contained some gravel. Cobbles and boulders were also encountered at the bottom of this layer.

The explored thickness of this deposit was 0.5 m and 1.2 m in BH HF2-7B and BH HF2-7 respectively. The corresponding elevations of the base of the unit explored were El. 400.3 m (BH HF2-7B) and El. 402.8 m (BH HF2-7). The bottom of this layer was characterized by refusal to further penetration of split-spoon/DCPT cone.

The grain size distribution of one (1) sample from this deposit was determined in the laboratory and gave the grain size distribution shown in **Table 4-2**.

Table 4-2 Grain Size Distribution Summary – Silty Sand

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH HF2-7/SS2	Gravel	19%	Shown as Figure B-2, Appendix B ; Summarized on the relevant Record of Borehole Sheet
	Sand	55%	
	Fines	26%	

Based on the grain size distribution results shown above and visual and tactile observations the deposit can be classified as a silty sand (SM).

The moisture content based on three (3) samples recovered from this layer varied from 13% to 37% indicative of a moist to wet condition.

SPT testing carried out in the boreholes gave SPT 'N' values ranging between 2 blows/300 mm to greater than 100 blows/300 mm (based on 3 SPT results) which indicate a loose to very dense relative density. Coring was undertaken in BH HF2-7 from 1.5 m to 1.8 m depth and revealed cobble/boulder pieces. SPT spoon refusal was encountered in BH HF2-7B at a depth of 1.2 m (El. 400.3 m).

In addition, DCPT testing was carried out within this deposit from 1.2 m to 1.8 m depth in a pre-augered hole adjacent to BH HF2-7. The DCPT blow counts generally varied from 10 blows/ 300 mm to greater than 100 blows/300 mm.

These refusal depths may be likely on boulders, or on shallow bedrock as observed in Photo 2-4 at this high fill section.

4.4.6 EXPLORATORY HOLE STABILITY UPON COMPLETION

BH HF2-7 and BH HF2-7B were found to have undergone caving at 1.2 m and 1.1 m depths respectively, upon completion.

4.5 SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 3 AND CULVERT AT STA. 14+638

4.5.1 GENERAL

The subsoil characterization for High Fill Section 3 is based on the findings from test pits TP HF3-8, TP HF3-9 and TP HF3-10 and the inferred sub-soil profile is shown on **Drawing No.3**. Bedrock outcrops were observed within this high fill section (See Photo 3-1). The highest WBTCCL embankment height of 15.5 m is proposed within this high fill section.

4.5.2 TOPSOIL

A veneer of topsoil (200 mm to 330 mm thick) was contacted at ground surface in test pits TP HF3-9 and TP 3-10.

4.5.3 SILTY SAND

Beneath the topsoil, a silty sand deposit (400 mm thick) was encountered only in test pit TP HF3-10. The test pit TP HF3-10 was

terminated within this deposit.

4.5.4 SAND / COBBLES / BOULDERS

A brown sand and cobbles to boulder deposit was contacted in both test pits (TP HF3-8 and TP HF3-9). The deposit contained some silt.

The explored thickness of this deposit was 0.5 m and 0.9 m respectively in the two test pits TP HF3-8 and TP HF3-9. The corresponding elevations of the base of the unit explored were El. 388.9 m (TP HF3-8) and El. 389.3 m (TP HF3-9). The bottom of this layer was characterized by refusal to further excavation of hand-dug test pits.

4.5.5 GROUNDWATER OBSERVATIONS

Test pits TP HF3-8, TP HF8-9 and TP HF3-10 were filled with seeping water upon completion of the excavations.

4.5.6 SUBSURFACE CONDITIONS FOR CULVERT AT STA. 14+638

The existing CSP culvert at the outlet end is to be extended under the proposed WBTCL. Borehole TP HF3-8 was positioned to determine the subsurface conditions for the proposed culvert extension. The borehole location plan and the intercepted subsurface conditions are shown on **Drawing 3A**. The soil and groundwater conditions are described in the following paragraphs.

Sand and Cobbles: A 0.9 m thick, sand and cobble deposit was encountered in test pit TP HF3-8 up to the termination depth. Refusal to hand dug excavation was met at El. 388.9 m presumably on a boulder/bedrock and the test pit was terminated. This deposit contained some silt.

Groundwater Conditions: The test pit was filled with seeping water upon completion of test pit excavation.

4.6 SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 4

4.6.1 GENERAL

The subsoil characterization for High Fill Section 4 is based on the findings from Boreholes BH HF4-11A and BH HF4-11 and the inferred sub-soil profile is shown on **Drawing No.4**. Bedrock outcrops were observed within this high fill section (See Photos 4-1 and 4-2).

4.6.2 TOPSOIL

A veneer of topsoil (75 mm to 110 mm thick) was contacted at ground surface in boreholes BH HF4-11 and BH4-11A.

The moisture content based on one (1) sample recovered from this topsoil was 45% indicative of a wet condition and the organic nature.

4.6.3 SILTY SAND

A brown silty sand native deposit was contacted in both boreholes (BH HF4-11 and BH HF4-11A). The deposit contained some gravel. Cobbles were also encountered within this layer.

The explored thickness of this deposit was 1.2 m and 1.8 m in BH HF4-11 and BH HF4-11A, respectively. The corresponding

elevations of the base of the unit explored were El. 394.5 m (BH HF4-11) and El. 392.5 m (BH HF4-11A). The bottom of this layer was characterized by refusal to further penetration of split-spoon in BH HF4-11A and the borehole was terminated.

The grain size distributions of two (2) samples from the deposit were determined in the laboratory and gave the grain size distribution shown in **Table 4-3**.

Table 4-3: Grain Size Distribution Summary – Silty Sand

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH HF4-11/SS2	Gravel	12 to 18%	Shown as Figure B-3, Appendix B ; Summarized on the relevant Record of Borehole Sheets
BH HF4-11A/SS3	Sand	55 to 61%	
	Fines	21 to 33%	

Based on the grain size distribution results shown above and visual and tactile observations, the deposit can be classified as a silty sand (SM).

The moisture content based on five (5) samples recovered from this layer varied from 10% to 28% indicative of a moist to wet condition.

SPT testing carried out in the boreholes gave SPT 'N' values that ranged between 1 blows/300 mm to 22 blows/300 mm (based on five (5) SPT results) which indicate a very loose to compact relative density. A high SPT 'N' value of >100/300 mm was observed in BH HF4-11A at termination depth (SS4). This spoon refusal depth may be likely on a boulder or on a shallow bedrock surface.

4.6.4 BEDROCK (GRANITE / GRANITIC GNEISS)

Bedrock was cored underlying the silty sand deposit in borehole BH HF4-11 at a depth of 1.3 m below ground surface, corresponding to El. 394.5 m and 1.7 m of bedrock was cored. The bedrock consists of a slightly weathered, red-pink mixed with black granite / granitic gneiss.

The Total Core Recovery (TCR) was 97% for the core sample. Rock Quality Designation (RQD) value measured on the recovered bedrock core sample in the borehole was 19%, indicating the rock is of very poor quality, i.e. intensely fractured, according to Table 3.10 of CFEM (2006).

4.6.5 EXPLORATORY HOLE STABILITY UPON COMPLETION

BH HF4-11 was found to be open whilst BH HF4-11A caved-in at ground level, upon completion.

4.7 SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 5

4.7.1 GENERAL

The subsoil characterization for High Fill Section 5 is based on the findings from borehole/test pit TP HF5-12 and BH HF5-14 and the inferred sub-soil profile is shown on **Drawing No.5**. Bedrock outcrops were observed within this high fill section (See Photo 5-1).

4.7.2 TOPSOIL

A veneer of topsoil (150 mm thick) was contacted at ground surface in test pit TP HF5-12. The bottom of this layer was characterized by refusal to further excavation of hand-dug test pit due to possible bedrock or boulder.

4.7.3 GRAVELLY SAND

A grey / brown gravelly sand deposit was contacted in Borehole BH HF5-14. The deposit contained traces of silt.

The explored thickness of this deposit was 1.0 m. The corresponding elevation of the base of the unit explored was El. 388.1 m. The bottom of this layer was characterized by refusal to further penetration of DCPT cone in BH HF5-14.

The grain size distribution of one (1) sample from the deposit was determined in the laboratory and gave the grain size distribution shown in **Table 4-4**.

Table 4-4 Grain Size Distribution Summary – Gravelly Sand

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH HF5-14/SS1	Gravel	33%	Shown as Figure B-4, Appendix B ; Summarized on the relevant Record of Borehole Sheet
	Sand	58%	
	Fines	9%	

Based on the grain size distribution results shown above and visual and tactile observations, the deposit can be classified as a gravelly sand (SW).

The moisture content based on one (1) sample recovered from this deposit was 17% indicative of a wet condition.

SPT testing carried out in the layer gave a SPT 'N' value of 28 blows/300 mm (based on one (1) SPT result) which indicates a compact relative density.

In addition, DCPT testing was carried out within this borehole. The DCPT blow counts generally varied from 13 blows/ 300 mm to greater than 100 blows/300 mm. Refusal to DCPT cone penetration was encountered in BH HF5-14 at the termination depth. This refusal depth may be likely on a boulder or on presumed bedrock surface.

4.7.4 GROUNDWATER OBSERVATIONS

Water level was at ground surface in BH HF5-14 and the hole caved-in upon completion.

4.8 SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 6 AND CULVERT AT STA. 15+575

4.8.1 GENERAL

The subsoil characterization for High Fill Section 6 is based on the findings from six (6) Boreholes BH HF6-15A, BH HF6-15, BH

HF6-16, BH HF6-17, BH HF6-18 and BH HF6-19. DCPT testing was advanced from the bottom of each borehole up to termination of the hole on reaching DCPT cone refusal. The inferred sub-soil profile is shown on **Drawing No.6**. A general view of the high fill section is shown in Photo 6-1.

4.8.2 TOPSOIL

A veneer of topsoil (60 mm to 100 mm thick) was contacted at ground surface in all boreholes with the exception of BH HF6-15A. The moisture content based on five (5) samples recovered from this layer varied from 35% to 266% likely indicative of high organic content.

4.8.3 PEAT

A 600 mm thick, blackish brown peat was encountered at ground surface in BH HF6-15A. It also contained decayed wood and rootlets. A measured moisture content value from this peat material was 134%.

4.8.4 SILTY SAND

Beneath the peat, a black silty sand deposit was contacted only in borehole BH HF6-15A. The deposit contained some organics and some gravel.

The thickness of this deposit was 0.6 m. The corresponding elevation of the base of the unit was El. 378.3 m.

The moisture content based on one (1) sample recovered from this deposit was 97% indicative of the presence of organics. SPT testing carried out in the layer recorded a SPT 'N' value of 17 blows/300 mm (based on one SPT result) which indicates a compact relative density.

4.8.5 GRAVELLY SAND TO SILTY SAND

A brown gravelly sand to silty sand deposit was contacted in all the boreholes. To circumvent borehole basal stability issues posed by the loose nature of the deposit during wash boring, borehole advancement was further extended by DCPT testing within the boreholes. The deposit contained traces of occasional cobbles and rock pieces.

The explored thickness of this deposit varied from 2.7 m to 12.1 m. The corresponding elevation of the base of the unit explored varied from El. 379.1 m to El. 366.9 m. The bottom of this layer was characterized by refusal to further penetration by DCPT cone in all the boreholes.

The grain size distribution of four (4) samples from the gravelly sand deposit were determined in the laboratory and gave the grain size distribution shown in **Table 4-5**.

Table 4-5 Grain Size Distribution Summary – Gravelly Sand

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH HF6-15A / SS3	Gravel	21 to 34%	Shown as Figure B-5, Appendix B ;
BH HF6-16 / SS3	Sand	59 to 63%	Summarized on the relevant Record of Borehole Sheets

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH HF6-17 / SS2 BH HF6-19 / SS3	Fines	5 to 16%	

Based on the grain size distribution results shown above and visual and tactile observations, the deposit can be classified as a gravelly sand (SW).

The grain size distribution of one (1) sample from the silty sand deposit was determined in the laboratory and gave the grain size distribution shown in **Table 4-6**.

Table 4-6 Grain Size Distribution Summary – Silty Sand

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH HF6-16/ SS6	Gravel	2%	Shown as Figure B-6, Appendix B ; Summarized on the relevant Record of Borehole Sheet
	Sand	58%	
	Fines	40%	

Based on the grain size distribution results shown above and visual and tactile observations, the deposit can be classified as a silty sand (SM).

The moisture content based on ten (10) samples recovered from this deposit varied from 10% to 17% indicative of a moist to wet condition.

SPT testing carried out in the layer gave SPT 'N' values that ranged from 4 blows/300 mm to 28 blows/300 mm (based on 15 SPT results) which indicate a loose to compact relative density. In addition to SPT penetration testing, DCPT testing was carried out within this deposit. The DCPT blow counts generally varied from 2 blows/300 mm to greater than 90 blows/300 mm.

Refusal to DCPT cone penetration was encountered in all the boreholes, and at such occurrence the holes were terminated. These refusal depths may be likely on a boulder or on presumed bedrock surface.

4.8.6 EXPLORATORY HOLE STABILITY UPON COMPLETION

All boreholes with wash boring caved-in at depths ranging from 0.5 m to 3.0 m upon completion.

4.8.7 SUBSURFACE CONDITIONS FOR CULVERT AT STA. 15+575

The extension of this CSP culvert was not part of the original Foundation Assignment but was later added after the foundation fieldwork was completed. However, in anticipation for a possible culvert extension, Borehole BH HF6-16 (about 10 m east of culvert centerline) and DCPT BH HF6-15 (very close to the culvert centerline) were staked during the initial field visit and later advanced to determine the subsurface conditions and followed by DCPT testing, during the field investigation phase. The borehole location plan and the intercepted subsurface conditions are shown on **Drawing 6A**. The soil and groundwater conditions are described in the following paragraphs.

Topsoil: A veneer of topsoil (75 mm thick) was contacted at ground surface in the exploratory locations. The moisture content based on one (1) sample recovered from this layer was 35% indicative of a wet condition.

Gravelly Sand: Beneath the topsoil, a brown to grey gravelly sand deposit was contacted in Borehole BH HF6-16. The deposit contained occasional cobbles and trace of silt. The thickness of this deposit was 3.0 m. The corresponding elevation of the base of the unit was El. 376.2 m.

A grain size analysis on the gravelly sand sample (BH HF6-16/SS3) gave the following: 34% gravel, 59% sand, 7% silt and clay sized particles. The moisture content based on five (5) samples recovered from this deposit varied from 11% to 35% indicative of a moist to wet condition. SPT testing carried out in the layer gave SPT 'N' values that ranged from 8 blows/300 mm to 28 blows/300 mm (based on 5 SPT results) which indicate a loose to compact relative density.

Silty Sand: Beneath the gravelly sand, a grey silty sand deposit was contacted in Borehole BH HF6-16. The deposit contained traces of gravel. The explored thickness of this deposit was 1.2 m. The corresponding elevation of the base of the unit explored was El. 374.9 m. To determine refusal depth, two DCPT soundings were advanced, one below El. 374.9 m and the other at ground surface, in BH HF6-16 and DCPT BH HF6-15 respectively. Refusal to cone penetration was encountered at depths of 7.8 m (DCPT BH HF6-15) and 11.4 m (BH HF6-16) below ground surface, corresponding to El. 371.5 m and El. 367.8 m.

A grain size analysis of a sample from the silty sand deposit (BH HF6-16/SS6) gave the following: 2% gravel, 58% sand, 40% silt and clay sized particles. The moisture content based on one (1) sample recovered from this deposit was 17% indicative of a wet condition. SPT testing carried out in the layer gave SPT 'N' values of 7 blows/300 mm (based on 2 SPT results) which indicate a loose relative density.

Prior to the DCPT refusal, the DCPT blow counts generally varied from 9 blows/300 mm to 73 blows/300 mm (in BH HF6-15) and 8 blows/300 mm to 36 blows/300 mm (in BH HF6-16). The DCPT refusal was identified as greater than 100 blows/300 mm. This depth of DCPT cone refusal, whilst not conclusive of proven bedrock, may be likely on or in close proximity to the bedrock surface.

Standing water condition was noted in the vicinity of Borehole BH HF6-15.

4.9 SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 7 AND CULVERT AT STA. 10+655

4.9.1 GENERAL

The subsoil characterization for High Fill Section 7 is based on the findings from five (5) Boreholes BH HF7-20 to BH HF7-22, BH HF7-24 and BH HF7-29; five (5) DCPT soundings (BH HF7-25 to BH HF7-28, BH HF7-30) and one (1) test pit (TP HF 7-23). This high fill section has the most frequent occurrence of bedrock outcrops as shown in Photos 7-1 to 7-7. This extremely shallow bedrock conditions are clearly reflected in the shallow refusal conditions met in all the exploratory holes. Undulating ground conditions were mostly noted along this section (Photos 7-3, 7-6 and 7-7 and the ground surface shown in Drawing No. 7). The inferred sub-soil profile is shown on **Drawing No.7**. The significant difference in ground elevation at the borehole locations, i.e. El. 291.6 m at BH HF7-20 and El. 237.4 at BH HF7-30 should be noted.

4.9.2 TOPSOIL

A veneer of topsoil (50 mm to 120 mm thick) was contacted at ground surface in all the boreholes.

The moisture content based on two (2) samples recovered from this layer varied from 42% to 222 % indicative of wet and high organic inclusions.

4.9.3 SILTY SAND/SAND TO GRAVELLY SAND

A brown silty sand/sand to gravelly sand deposit was contacted in all the boreholes/test pit. At DCPT soundings, this deposit thickness was indirectly inferred through DCPT refusal.

The explored thickness of this deposit within the SPT boreholes varied from 0.2 m to 2.2 m. The corresponding elevation of the base of the unit explored varied from El. 278.3 m to El. 277.1 m. The bottom of this layer was characterized by refusal to further penetration of the split-spoon.

Refusal to DCPT penetration was encountered in DCPTs (BH HF7-25, BH HF7-26, BH HF7-27, BH HF7-28 and BH HF7-30) at depths between 0.7 m and 2.5 m below ground surface, corresponding to El. 252.4 m to 269.0 m.

The grain size distribution of three (3) samples from the silty sand/sand deposit were determined in the laboratory and gave the grain size distribution shown in **Table 4-7**.

Table 4-7 Grain Size Distribution Summary – Silty Sand / Sand

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH HF7-21 / SS3	Gravel	2 to 15%	Shown as Figure B-7, Appendix B ; Summarized on the relevant Record of Borehole Sheets
BH HF7-22/ SS2	Sand	82 to 96%	
BH HF6-24/ SS3	Fines	1 to 3%	

Based on the grain size distribution results shown above and visual and tactile observations, the deposit can be classified as a silty sand/sand (SP-SW).

The moisture content based on fourteen (14) samples recovered from this deposit varied from 3% to 34% indicative of a moist to wet condition.

SPT testing carried out in the layer gave SPT 'N' values that ranged from 1 blow/300 mm to 16 blows/300 mm (based on 12 SPT results) which indicate a very loose to compact relative density. A high SPT 'N' value of >100/300 mm was observed in BH HF7-21 at termination depth (SS4).

In addition to SPT penetration testing, DCPT testing was carried out within this deposit. The DCPT blow counts generally varied from 2 blows/300 mm to greater than 100 blows/300 mm These depths to refusal, although do not confirm bedrock elevations, may be likely on or in proximity to the bedrock surface.

4.9.4 BOULDERS/PRESUMED BEDROCK

Boulders/Presumed Bedrock was encountered underlying the gravelly sand deposit in Borehole BH HF7-29 at a depth of 1.2 m below ground surface, corresponding to El. 250.4 m and 0.5 m of boulder/presumed bedrock was cored.

4.9.5 EXPLORATORY HOLE STABILITY UPON COMPLETION

All boreholes with wash boring were open and dry upon completion except for BH HF7-21 and BH HF7-29, both of which caved-in at 1.8 m depth.

4.9.6 SUBSURFACE CONDITIONS FOR CULVERT AT STA. 10+655

The existing CSP culvert at the inlet end is to be extended under the proposed WBTCCL. Borehole TP HF7-23 (Test pit by hand-dug) was advanced to determine the subsurface conditions for the proposed CSP culvert extension. A borehole location plan and intercepted subsurface conditions are shown on **Drawing 7A**. The soil and groundwater conditions are described in the following paragraphs.

Topsoil: A veneer of topsoil (120 mm thick) was contacted at ground surface in the test pit.

Silty Sand: Underneath the topsoil, a silty sand deposit was contacted in Test Pit TP HF7-23. The explored thickness of this deposit was 0.2 m. The elevation of the base of the unit explored was El. 278.3 m.

Presumed Bedrock/Boulder: Presumed Bedrock/Boulder was exposed at the bottom of test pit at a depth of 0.3 m below existing ground surface, corresponding to El. 278.3 m.

4.10 SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 8 & CULVERT AT STA. 12+248

4.10.1 GENERAL

The subsoil characterization for High Fill Section 8 is based on the findings from three (3) Boreholes BH HF8-33/33A, BH HF8-34 and BH HF8-35. The inferred sub-soil profile is shown on **Drawing No.8**. Compressible sub-soil conditions were intercepted within this high fill section. The embankment heights for the proposed WBTCCL within this high fill section range from 4.5 m to 6 m.

4.10.2 TOPSOIL

Thin topsoil (600 mm to 610 mm thick) was contacted at ground surface in all three boreholes.

The moisture content based on one (1) sample recovered from this layer was 92% indicative of the organic nature of topsoil.

4.10.3 ORGANIC CLAYEY SILT

Beneath the topsoil, a brown organic clayey silt deposit was contacted only in borehole BH HF8-33. The deposit contained some fibrous matter with sand seams.

The thickness of this deposit was 1.2 m. The corresponding elevation of the base of the unit was El. 206.7 m.

The moisture content based on one (1) sample recovered from this deposit was 37% indicative of a wet condition.

SPT testing carried out in the layer gave SPT 'N' values of 2 blows/300 mm and 3 blows/300 mm (based on 2 SPT results) which indicate a very soft to soft consistency.

4.10.4 UPPER SILTY CLAY TO CLAYEY SILT

Underneath the topsoil/organic clayey silt, a silty clay to clayey silt deposit was contacted in all the boreholes with the exception of BH HF8-35. The deposit contained some to occasional sand seams and traces of gravel. A 0.6 m thick very loose silty sand (Till) lens was only encountered in BH HF8-33 and sandwiched the organic clayey silt from above with the underlying upper silty clay.

The explored thickness of this deposit varied from 2.2 m to 3.9 m. The elevation of the base of the unit explored varied from El. 203.9 m to El. 203.3 m.

The grain size distribution of one (1) sample from the silty clay deposit was determined in the laboratory and gave the grain size distribution shown in **Table 4-8**.

Table 4-8 Grain Size Distribution Summary – Silty Clay

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH HF8-33 / SS5	Gravel	0%	Shown as Figure B-8, Appendix B ; Summarized on the relevant Record of Borehole Sheets
	Sand	1%	
	Silt	30%	
	Clay	69%	

An Atterberg limits test was performed on one (1) sample from this deposit. This test indicated the following index values as shown in **Table 4-9**.

Table 4-9 Atterberg Limits Test Results – Silty Clay

Samples Tested	Atterberg Limits	Index Values	Remarks
BH HF8-33 / SS5	Liquid Limit	49%	Shown as Figure B-9, Appendix B ; Summarized on the relevant Record of Borehole Sheet
	Plastic Limit	18%	
	Plasticity Index	31%	

The above values are characteristic of a silty clay of intermediate plasticity to clayey silt of low plasticity (CI).

The moisture content based on four (4) samples recovered from the silty clay deposit varied from 22% to 69% indicative of a moist to wet condition. The liquidity index of the silty clay was 1.6.

The grain size distribution of one (1) sample from the clayey silt deposit was determined in the laboratory and gave the grain size distribution shown in **Table 4-10**.

Table 4-10 Grain Size Distribution Summary – Clayey Silt

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH HF8-34/ SS5	Gravel	1%	Shown as Figure B-8, Appendix B ; Summarized on the relevant Record of Borehole Sheet
	Sand	13%	
	Silt	71%	
	Clay	15%	

The moisture contents based on two (2) samples recovered from the clayey silt deposit were 24% and 25% indicative of a moist condition.

SPT testing carried out in the upper silty clay to clayey silt layer gave SPT 'N' values that ranged from 0 blows/300 mm to 1 blows/300 mm (based on 7 SPT results) which indicate a very soft consistency. FSV testing carried out with the MTO 'N' vane within this deposit measured undrained shear strengths that varied from 26 kPa to 30 kPa. Based on the FSV, the sensitivity of the upper silty clay to clayey silt varied from 1.9 to 5.8 (an average value of 3.2). Given that the FSV is more reliable for measurement of undrained shear strength of soft cohesive deposits, based on the undrained shear strength measurements with the FSV, the cohesive deposit typically has a soft to firm consistency.

4.10.5 SILT SAND / SANDY SILT (TILL) TO SAND AND SILT (TILL)

Underneath the upper silty clay to clayey silt deposit/topsoil, a silty sand/sandy silt (Till) to sand and silt (Till) deposit was contacted in all the boreholes. A 0.8 m thick silty clay (Till) interlayer was encountered within this deposit in Borehole BH HF8-34 only. The deposit contained traces of gravel and clay.

The explored thickness of this deposit varied from 2.6 m to 4.5 m. The elevation of the base of the unit explored varied from El. 204.3 m to El. 199.4 m.

The grain size distribution of seven (7) samples from this deposit were determined in the laboratory and gave the grain size distribution shown in **Table 4-11**.

Table 4-11 Grain Size Distribution Summary – Silty Sand/Sandy Silt (Till) to Sand and Silt (Till)

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH HF8-33 / SS8	Gravel	0 to 12%	Shown as Figure B-10, Appendix B ; Summarized on the relevant Record of Borehole Sheets
BH HF8-33 / SS9	Sand	25 to 48%	
BH HF8-33A/TW4	Silt	43 to 69%	
BH HF8-33A/TW5	Clay	2 to 6%	

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH HF8-34/SS12			
BH HF8-35/SS5			

Based on the grain size distribution results shown above and visual and tactile observations, the deposit can be classified as a silty sand/sandy silt to sand and silt (SM/ML).

The moisture content based on fifteen (15) samples recovered from the silty sand/sandy silt to sand and silt deposit varied from 11% to 28% indicative of a moist to wet condition.

SPT testing carried out in the non-cohesive till deposit gave SPT 'N' values that ranged from 1 blow/300 mm to 10 blows/300 mm (based on 12 SPT results) which indicate a very loose to loose relative density.

Cohesive Interlayer

The grain size distribution of one (1) sample from the silty clay (Till) interlayer was determined in the laboratory and gave the grain size distribution shown in **Table 4-12**.

Table 4-12 Grain Size Distribution Summary – Silty Clay (Till)

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH HF8-34/ SS9	Gravel	0%	Shown as Figure B-10, Appendix B ; Summarized on the relevant Record of Borehole Sheets
	Sand	32%	
	Silt	45%	
	Clay	23%	

Based on the grain size distribution results shown above and visual and tactile observations, the interlayer can be classified as a silty clay.

The measured moisture content of silty clay interlayer was 23%.which indicates a wet condition.

The SPT 'N' value recorded within the interlayer was 4 blows/300 mm which indicates the cohesive deposit has a soft consistency.

4.10.6 LOWER SILTY CLAY

Underneath the silty sand/sandy silt (Till) to sand and silt (Till) deposit, a silty clay deposit was contacted in all the boreholes. The deposit contained traces of gravel and sand.

The explored thickness of this deposit varied from 2.4 m to 4.7 m. The elevation of the base of the unit explored varied from El. 201.9 m to El. 195.7 m.

The grain size distribution of five (5) samples from the silty clay deposit were determined in the laboratory and gave the grain size distribution shown in **Table 4-13**.

Table 4-13 Grain Size Distribution Summary – Lower Silty Clay

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH HF8-33A /SS6	Gravel	0%	Shown as Figure B-11, Appendix B ; Summarized on the relevant Record of Borehole Sheets
BH HF8-33A /SS8	Sand	1 to 4%	
BH HF8-34 /SS14	Silt	60 to 65%	
BH HF8-34/SS17			
BH HF8-35/SS7	Clay	32 to 36%	

Atterberg limit tests were performed on four (4) samples from this deposit. This test indicated the following index values as shown in Table 4-14.

Table 4-14 Atterberg Limits Test Results – Lower Silty Clay

Samples Tested	Atterberg Limits	Index Values	Remarks
BH HF8-33A /SS6	Liquid Limit	25 to 27%	Shown as Figure B-12, Appendix B ; Summarized on the relevant Record of Borehole Sheets
BH HF8-33A /SS8	Plastic Limit	13 to 16%	
BH HF8-34 /SS14	Plasticity Index	9 to 12%	
BH HF8-34/SS17			

The above values are characteristic of a silty clay of low plasticity (CL).

The moisture content based on twelve (12) samples recovered from this deposit varied from 19% to 34% indicative of a moist to wet condition. The liquidity index of the silty clay varied from 0.8 to 1.6 (an average value of 1.1).

SPT testing carried out in the layer gave SPT 'N' values that ranged from 0 blows/300 mm to 16 blows/300 mm (based on 10 SPT results). FSV testing carried out within this deposit measured undrained shear strengths that varied from 36 kPa to 45 kPa. Based on the FSV, the sensitivity of the lower silty clay varied from 3.0 to 4.6 (an average value of 3.6).

In addition, one laboratory tri-axial (unconsolidated undrained, UU) test was carried out on a specimen of the lower silty clay obtained from Borehole BH HF8-33A/TW-7 and the test results are shown in **Appendix B1**. The measured (average) undrained shear strength was 33 kPa which also indicates that the cohesive deposit has a firm consistency. Based on the collective FSV and triaxial UU test results, the cohesive deposit typically has a firm consistency.

A laboratory consolidation (oedometer) test was carried out on a specimen of the lower silty clay obtained from Borehole BH HF8-33A/TW-7 and the test results are shown in **Appendix B1**.

The pre-consolidation stress was estimated using the following methods:

- Casagrande (1936) method based on void ratio log (pressure) plot of compression results
- Becker et. al. (1987) method based on strain energy considerations of compression results
- Mayne and Mitchell (1988) based on Field Shear Vane based undrained shear strength and Plasticity Index of the clay

The interpreted pre-consolidation pressure test results are summarized below and the graphical plots are shown in **Appendix B1**.

Table 4-15 Pre-Consolidation Pressure, σ'_p (kPa) – Lower Silty Clay

Borehole/ Sample Number	Depth, m	Elevation, m	Effective Overburden Pressure: σ'_{vo} (kPa)	Pre-Consolidation Pressure, σ'_p (kPa)		
				Casagrande (1936)	Becker et. al. (1987)	Mayne and Mitchell (1988)
BH HF33A-TW-7	9.5	199.0	75.7	190	190	240

4.10.7 BASAL SILTY SAND / SANDY SILT TO SAND AND SILT

Underneath the lower silty clay, a basal silty sand/sandy silt, to sand and silt deposit was contacted in all the boreholes with the exception of BH HF8-33. The deposit contained traces of gravel and clay.

The explored thickness of this deposit varied from 0.3 m to 1.8 m. The elevation of the base of the unit explored varied from El. 200.7 m to El. 193.9 m. The boreholes BH HF8-34 and BH HF8-35 were terminated within the deposit.

The grain size distribution of one (1) sample from this deposit was determined in the laboratory and gave the grain size distribution shown in **Table 4-16**.

Table 4-16 Grain Size Distribution Summary – Basal Sandy Silt

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH HF8-34 / SS20	Gravel	1%	Shown as Figure B-13, Appendix B ; Summarized on the relevant Record of Borehole Sheet
	Sand	22%	
	Silt	74%	
	Clay	3%	

Based on the grain size distribution results shown above and visual and tactile observations, the deposit can be classified as a sandy silt (ML).

The moisture content based on five (5) samples recovered from the deposit varied from 9% to 24% indicative of a moist to wet

condition.

SPT testing carried out in the deposit gave SPT 'N' values that ranged from 5 blows/300 mm to 50 blows/300 mm (based on 4 SPT results) which indicate a loose to dense relative density. A high SPT 'N' value of >100/300 mm was recorded within this deposit in BH HF8-35 possibly on cobbles/gravels..

4.10.8 BEDROCK (GRANITE / GRANITIC GNEISS)

Possible bedrock was encountered underlying the basal silty sand/sandy silt to sand and silt deposit in Borehole BH HF8-33A at a depth of 13.0 m below ground surface, corresponding to El. 195.6 m and 0.7 m of bedrock was cored. The cored rock material can be identified as slightly weathered granite/granitic gneiss.

4.10.9 GROUNDWATER CONDITIONS

Groundwater conditions in the open borehole (BH HF8-35) was observed during drilling and at the completion of the borehole. A standpipe piezometer was installed in the borehole for long-term groundwater monitoring. The groundwater observations are shown on the individual Record of Borehole Sheet in **Appendix A**.

The slight artesian condition of 0.8 m (El.208.8 m) above the existing ground surface was encountered in Borehole BH HF8-35.

Table 4-17: Summary of Groundwater Observations

BH No.	Ground Elevation (m)	Top of Screen Depth/Elevation (m)	Water Level Measurements	
			Depth, m	Elevation, m
BH HF8-35	208.0	4.2 / 203.8	0.8 m above ground level (Jun 24-17)	El. 208.8
			0.8 m above ground level (Aug 21-17)	El. 208.8

BH HF8-33A and BH HF8-34 both caved-in upon completion at 2.0 m and 2.4 m depths respectively.

4.10.10 SUBSURFACE CONDITIONS FOR THE CULVERT AT STA. 12+248

Borehole BH HF8-35 was advanced to determine subsurface conditions for the proposed CSP culvert inlet extension. A borehole location plan and the interpreted subsurface conditions are shown on **Drawing 8A**. The soil and groundwater conditions are described in the following paragraphs.

Topsoil: Thin topsoil (610 mm thick) was contacted at ground surface in Borehole BH HF8-35.

Silty Sand to Sandy Silt (Till): Underneath the topsoil, a silty sand (Till) to sandy silt (Till) deposit was contacted in Borehole BH HF8-35. The deposit contained traces of gravel and clay. The explored thickness of this deposit was 3.1 m. The elevation of the base of the unit explored was El. 204.3 m.

A grain size analysis on the sandy silt (Till) sample (BH HF8-35/SS5) gave the following: 1% gravel, 32% sand, 61% silt and 6% clay sized particles. The moisture content based on five (5) samples recovered from this deposit varied from 13% to 28% indicative of a

moist to wet condition. SPT testing carried out in the layer gave SPT 'N' values that ranged from 1 blow/300 mm to 8 blows/300 mm (based on 4 SPT results) which indicate a very loose to loose relative density.

Silty Clay: Underneath the silty sand to sandy silt (Till) deposit, a silty clay deposit was contacted in Borehole BH HF8-35. The deposit contained traces of sand. The explored thickness of this deposit was 2.4 m. The elevation of the base of the explored unit was El. 201.9 m.

A grain size analysis on the silty clay sample (BH HF8-35/SS7) gave the following: 0% gravel, 4% sand, 60% silt and 36% clay sized particles. The moisture content based on three (3) samples recovered from this deposit varied from 19% to 34% indicative of a moist to wet condition. SPT testing carried out in the layer gave SPT 'N' values of 2 blows/300 mm and 16 blows/300 mm which indicate a very soft to very stiff consistency.

Basal Silty Sand: Underneath the silty clay, a basal silty sand deposit was contacted in Borehole BH HF8-35. The explored thickness of this deposit was 1.2 m. The elevation of the base of the unit explored was El. 200.7 m. The Borehole BH HF8-35 was terminated within the deposit. The moisture content based on two (2) samples recovered from this deposit was 22% and 24% indicative of a wet condition. SPT testing carried out in the layer gave SPT 'N' values of 5 blows/300 mm and 100 blows/300 mm which indicate a very loose to very dense relative density.

Groundwater Conditions: Groundwater level was observed in the open borehole while drilling and upon completion of the borehole. A standpipe piezometer was installed in Borehole BH HF8-35 for long term groundwater monitoring. The groundwater levels observed during and after the investigation are summarized in **Table 4-21** and are also presented on the Record of Borehole Sheet in **Appendix A**. Based on water level measurements, the groundwater level at the culvert site was 0.8 m (El. 208.8 m) above the existing ground level (slightly artesian condition). The filter screen was located with the upper silty clay and extended below to the silty sand.

4.11 SUBSURFACE CONDITIONS FOR HIGH FILL SECTION 9

4.11.1 GENERAL

The subsoil characterization for High Fill Section 9 is based on the findings from two (2) Boreholes BH HF9-36 and BH HF9-37 carried out with hollow stem augers. The inferred sub-soil profile is shown on **Drawing No.9**. Compressible sub-soil conditions were intercepted within this high fill section. The embankment height range for the proposed WBTCL within this high fill section is from 4.5 m to 5.8 m.

4.11.2 PEAT

A 1.4 m thick black peat was encountered at ground surface in BH HF9-37. It also contained decayed vegetation and rootlets. A measured moisture content value from this peat material was 163%.

4.11.3 SAND AND GRAVEL

A 0.6 m thick sand and gravel was encountered at ground surface in BH HF9-36. Refusal to spoon penetration was encountered within this deposit.

4.11.4 SILTY CLAY TO CLAYEY SILT

Underneath the peat/sand and gravel, a silty clay to clayey silt deposit was contacted in both Boreholes BH HF9-36 and BH HF9-37. The deposit contained some gravel and traces of sand.

The explored thickness of this deposit was 2.2 m and 2.8 m, in Boreholes BH HF9-36 and BH HF9-37 respectively. The corresponding elevations of the base of the unit explored were El. 194.8 m and El. 191.3 m.

The grain size distribution of one (1) sample from the silty clay deposit was determined in the laboratory and gave the grain size distribution shown in **Table 4-18**.

Table 4-18 Grain Size Distribution Summary – Silty Clay

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH HF9-37 / SS4	Gravel	0%	Shown as Figure B-13, Appendix B ; Summarized on the relevant Record of Borehole Sheets
	Sand	1%	
	Silt	46%	
	Clay	53%	

An Atterberg limits test was performed on one (1) sample from this deposit. This test indicated the following index values as shown in **Table 4-19**.

Table 4-19 Atterberg Limits Test Results – Silty Clay

Samples Tested	Atterberg Limits	Index Values	Remarks
BH HF9-37 / SS4	Liquid Limit	36%	Shown as Figure B-14, Appendix B ; Summarized on the relevant Record of Borehole Sheets
	Plastic Limit	17%	
	Plasticity Index	19%	

The above values are characteristic of a silty clay of intermediate plasticity (CI).

The moisture content based on seven (7) samples recovered from this deposit varied from 6% to 44% indicative of a moist to wet condition. The liquidity index of the silty clay was 1.4.

SPT testing carried out in the layer gave SPT 'N' values that ranged from 0 blows/300 mm to 12 blows/300 mm (based on 4 SPT results) which indicate a very soft to stiff consistency, but typically very soft consistency. Two (2) high SPT 'N' values of greater than 100 blows/300 mm were observed within this layer (BH HF9-36) due to the presence of significant gravel particles at the particular test depths.

In addition, one laboratory tri-axial (unconsolidated, undrained- UU) test was carried out on a specimen of the silty clay deposit

obtained from Borehole BH HF9-37/TW-5 and the test results are shown in **Appendix B1**. The measured (average) undrained shear strength was 27 kPa that indicates that the cohesive deposit has a soft consistency.

4.11.5 SAND AND SILT (TILL)

Underneath the silty clay to clayey silt deposit, a sand and silt (Till) deposit was contacted in both boreholes. The deposit contained trace to some gravel and traces of clay.

The explored thickness of this deposit was 1.9 m and 3.9 m, respectively. The corresponding elevations of the base of the unit explored were El. 189.4 m and El. 190.8 m. The borehole BH HF9-36 was terminated within this deposit due to refusal to spoon penetration.

The grain size distribution of two (2) samples from this deposit were determined in the laboratory and gave the grain size distribution shown in **Table 4-20**.

Table 4-20 Grain Size Distribution Summary – Sand and Silt (Till)

Samples Tested	Size Fraction	% Passing by weight	Remarks
BH HF9-36/SS5	Gravel	9 to 17%	Shown as Figure B-15, Appendix B ; Summarized on the relevant Record of Borehole Sheets
BH HF9-37/SS7	Sand	43 to 48%	
	Silt	38 to 39%	
	Clay	2 to 4%	

Based on the grain size distribution results shown above and visual and tactile observations, the deposit can be classified as a sand and silt (SM/ML).

The moisture content based on seven (7) samples recovered from the sand and silt (Till) deposit varied from 12% to 59% indicative of a moist to wet condition.

SPT testing carried out in the non-cohesive till deposit gave SPT 'N' values that ranged from 8 blows/300 mm to 81 blows/300 mm (based on 5 SPT results) which indicate a loose to very dense relative density. Two (2) high SPT 'N' values of greater than 100 blows/300 mm were observed within this layer (BH HF9-36) and may reflect the presence of significant gravel or larger size particles at that test depth.

4.11.6 GRAVELLY SAND

Underneath the sand and silt (Till) deposit, a gravelly sand deposit was contacted in Borehole BH HF9-37. The deposit contained traces of silt.

The explored thickness of this deposit was 0.3 m. The corresponding elevation of the base of the unit explored was El. 189.1 m. The Borehole BH HF9-37 was terminated within this deposit due to refusal to spoon penetration. A measured moisture content value from this deposit was 14%.

SPT testing carried out in the layer gave a SPT 'N' value of >100 blows/300 mm which indicates a very dense relative density.

4.11.7 GROUNDWATER CONDITIONS

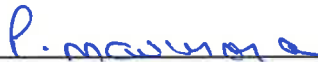
Groundwater conditions in the open boreholes were observed during drilling and at the completion of the boreholes. The groundwater observations are shown on the individual Record of Borehole Sheets in **Appendix A**.

Table 4-21: Summary of Groundwater Observations

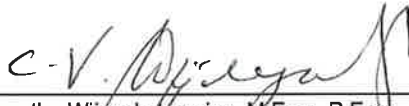
BH No.	Ground Elevation (m)	Water Level Measurements upon completion		Remarks
		Depth below ground surface, m	Elevation, m	
BH HF9-36	197.5	At ground surface	El. 197.5	Caved-in at 2.0 m depth
BH HF9-37	195.5	1.7	El. 193.8	Caved-in at 4.0 m depth

In addition to the possibility that the groundwater levels can be subject to seasonal fluctuations in response to major weather events, the groundwater levels observed at the site can be also influenced by the water level in the Lake Superior.

SIGNATURES



Mani Patchayappan, M.Eng., P.Eng.
Intermediate Geotechnical Engineer



Vasantha Wijeyakulasuriya, M.Eng., P.Eng.
Senior Technical Director, Geotechnical
MTO Designate (Foundations)



DRAWINGS 1 TO 9

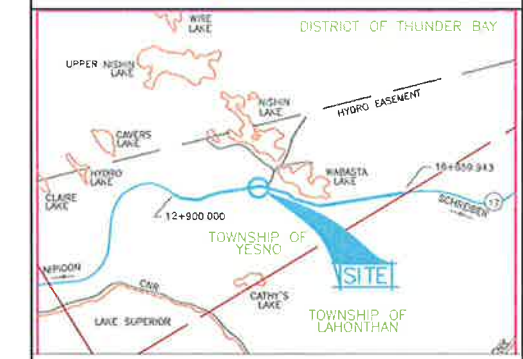
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No: 6016-E-0032
GWP



HWY 17 - WESTBOUND
TRUCK CLIMBING LANE
HIGHFILL SECTION 2
STA. 14+230 to STA. 14+390
TOWNSHIP OF YESNO, ON
BOREHOLE LOCATIONS & SOIL STRATA

wsp 51 Constellation Court
Toronto, Ontario
M9W 1K4



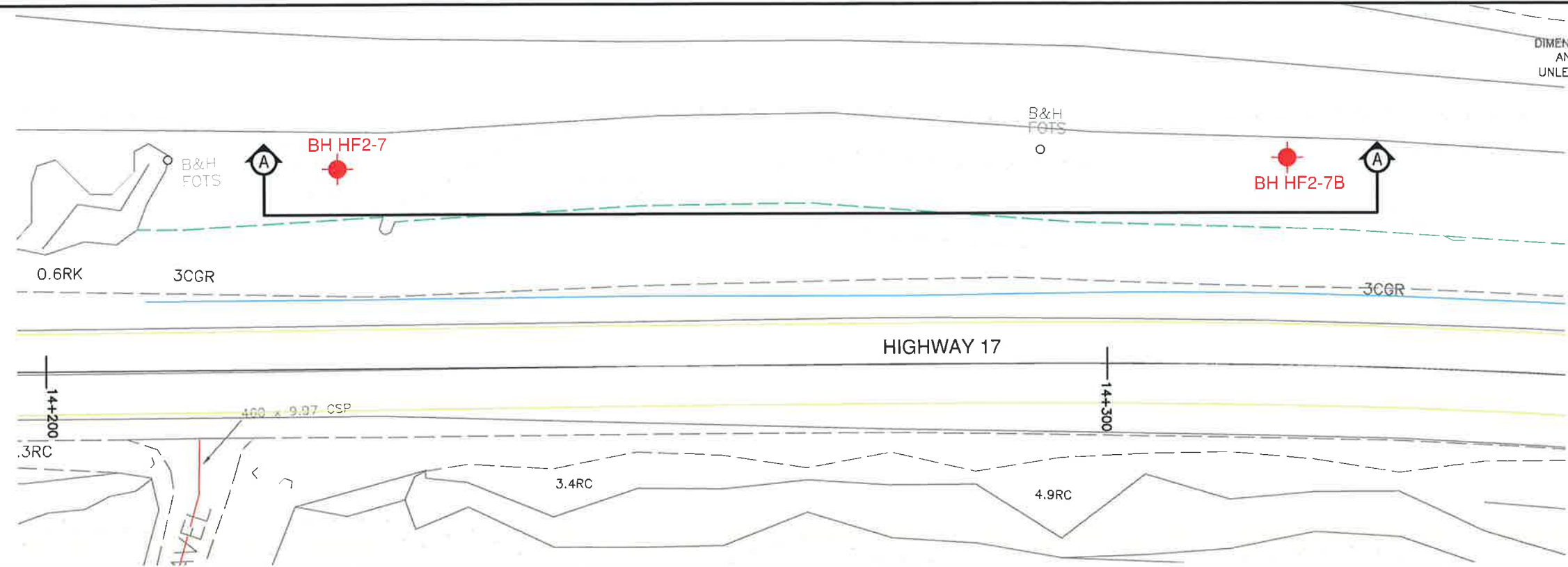
- SOIL STRATA SYMBOLS
- Topsoil/ Peat
 - Silty Sand to Sandy Silt Fill
 - Silty Sand

LEGEND			
	Borehole		
	Blows/0.3m (Std Pen Test, 475 J/blow)		
	Refusal		

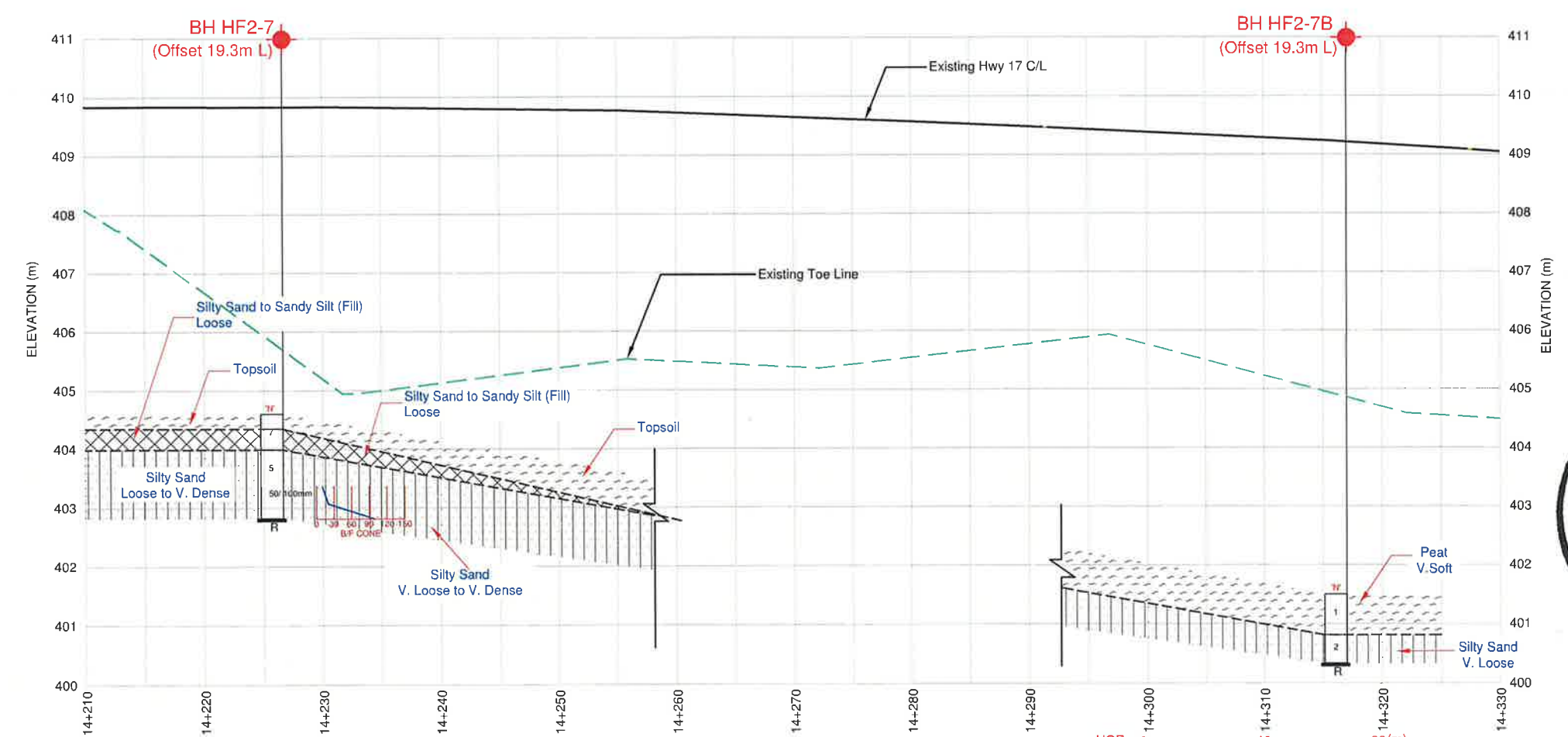
BH No.	APPROX. ELEV. (m)	MTM NAD83 ZONE 14 CO-ORDINATES	
		NORTH (m)	EAST (m)
BH HF2-7	404.6	5418136	258147
BH HF2-7B	401.5	5418102	258230

NOTES

The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence. Borehole Location plan is based on drawing "acad-bc527174 ldd" received on Aug 1, 2017. For Detailed Subsurface Conditions Refer to Record of Borehole Sheets.



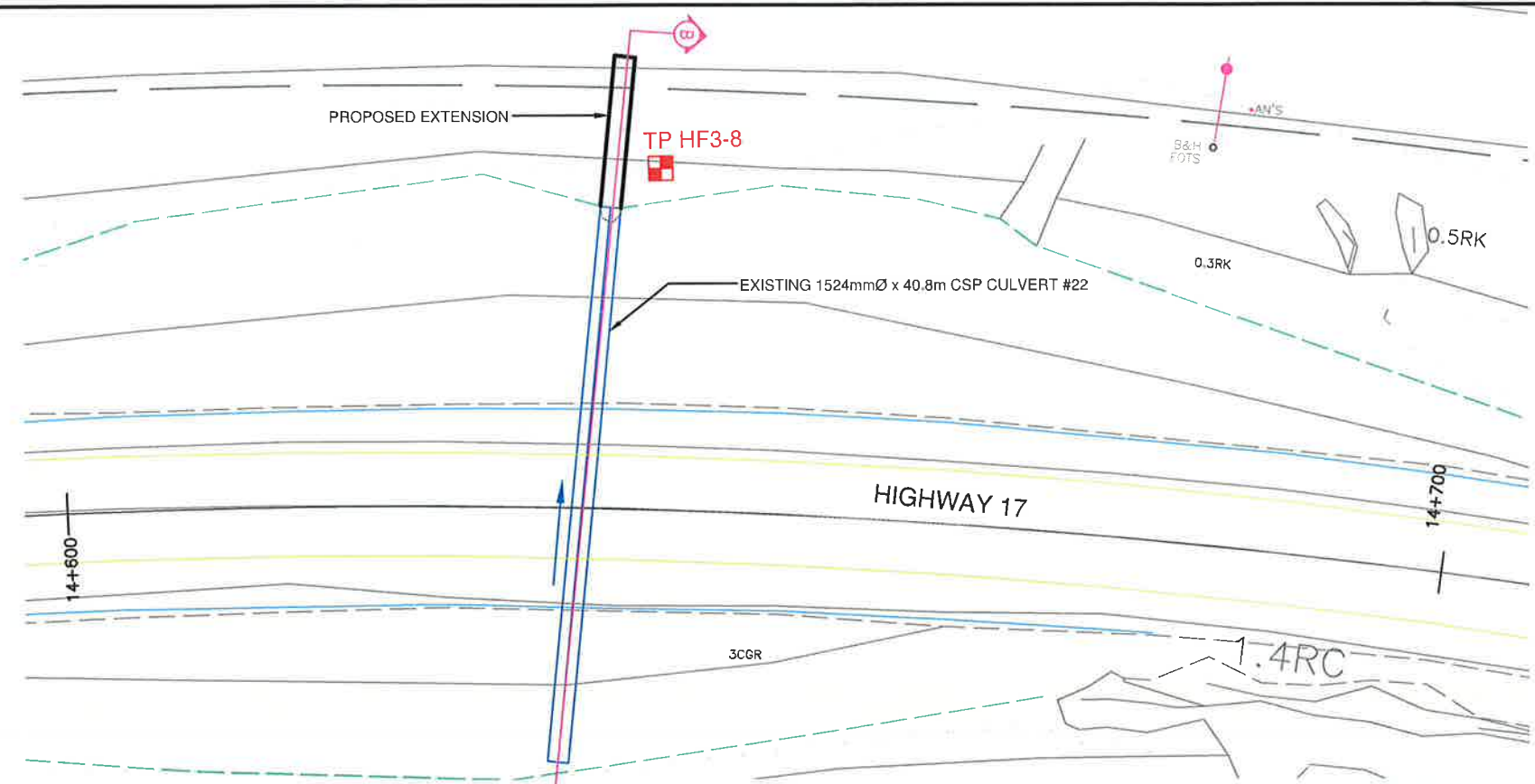
PLAN



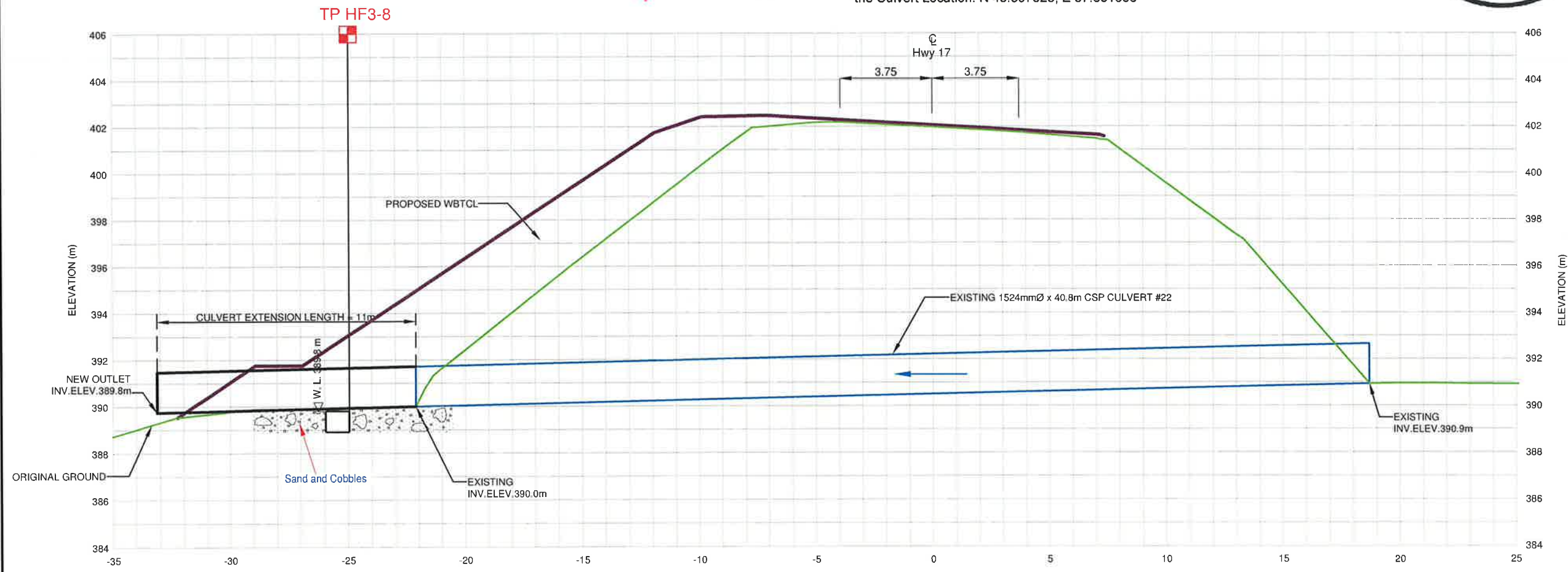
PROFILE A-A

REVISIONS			
DATE	BY	DESCRIPTION	
Sept 28/17	ZMO	Submission for MTO review	

HWY No 17	SUBM'D	CHECKED MP	DATE	Sept 28/17	DIST
DRAWN	ZMO	CHECKED MP	APPROVED	VW	DWG 2



PLAN
Note: Geographic Coordinates of the Culvert Location: N 48.897623, E 87.631666



CROSS SECTION B-B

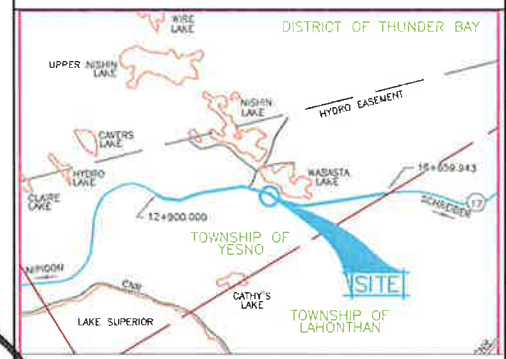
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



CONT No: 6016-E-0032
GWP

HWY 17 - WESTBOUND
PROPOSED CULVERT EXTENSION
CULVERT AT STA. 14+638
STA. 14+580 to STA. 14+700
TOWNSHIP OF YESNO, ON
BOREHOLE LOCATIONS & SOIL STRATA

WSP 51 Constellation Court
Toronto, Ontario
M9W 1K4



KEY PLAN
NOT TO SCALE

SOIL STRATA SYMBOLS

Sand and Cobbles

LEGEND

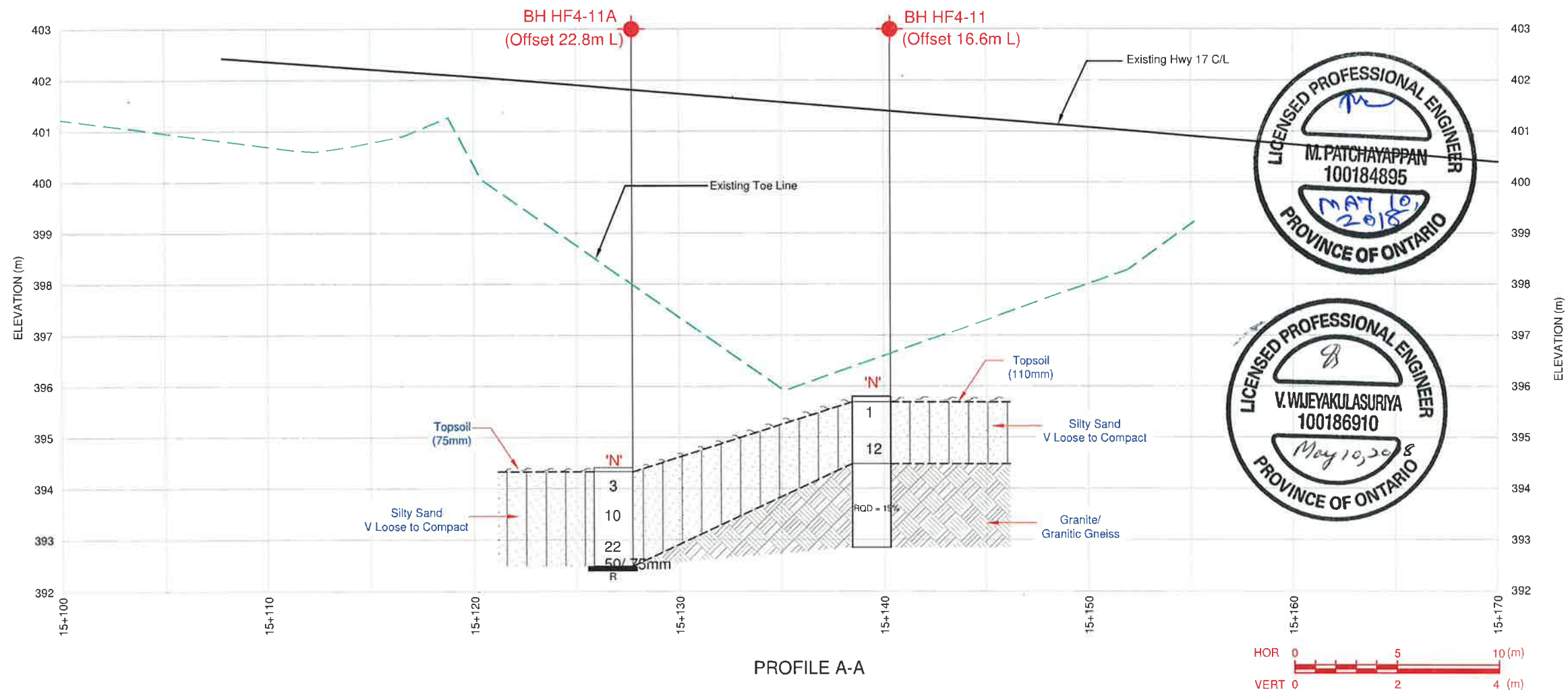
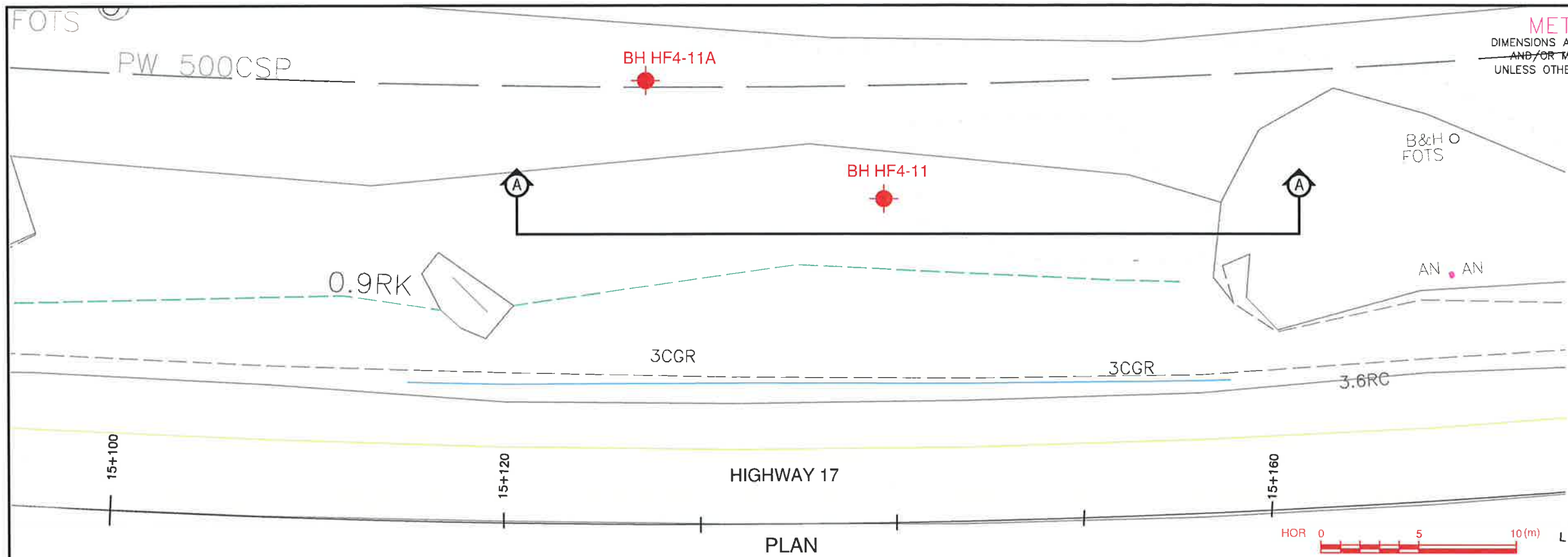
- Hand dug testpit (TP)
- WL upon completion

Testpit No.	APPROX. ELEV. (m)	MTM NAD83 ZONE 14 CO-ORDINATES	
		NORTH (m)	EAST (m)
TP HF3-B	389.8	5417893	258490

NOTES

The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence. Culvert cross-section is based on drawing "171025 Foundations Culv Ext" received on Oct 26, 2017. For Detailed Subsurface Conditions Refer to Record of Borehole Sheets.

REVISIONS		SUBMISSION FOR MTO REVIEW	
DATE	BY	DESCRIPTION	
OCT 27/17	ZMO	Submission for MTO review	
GEOCORES No : 42D-49			
HWY No 17	CHECKED MP	DATE Nov 15/17	DIST
SUBM'D	CHECKED MP	APPROVED VW	SITE
DRAWN ZMO	CHECKED MP	APPROVED VW	DWG 3A

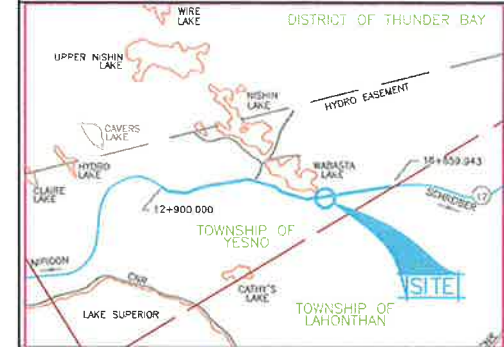


METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No: 6016-E-0032
GWP

HWY 17 - WESTBOUND
TRUCK CLIMBING LANE
HIGHFILL SECTION 4
STA. 15+120 to STA. 15+160
TOWNSHIP OF YESNO, ON
BOREHOLE LOCATIONS & SOIL STRATA

wsp 51 Constellation Court
Toronto, Ontario
M9W 1K4



METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

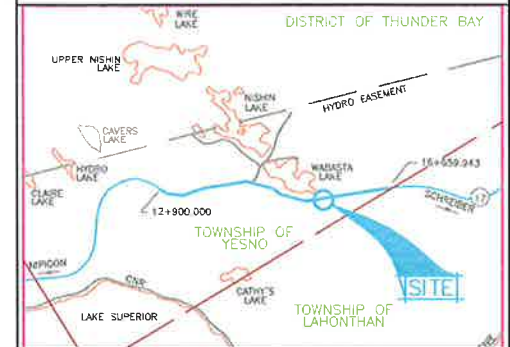
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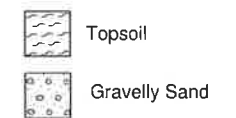
HWY 17 - WESTBOUND
TRUCK CLIMBING LANE
HIGHFILL SECTION 5
STA. 15+210 to STA. 15+310
TOWNSHIP OF YESNO, ON
BOREHOLE LOCATIONS & SOIL STRATA

wsp 51 Constellation Court
Toronto, Ontario
M9W 1K4



KEY PLAN
NOT TO SCALE

SOIL STRATA SYMBOLS



LEGEND

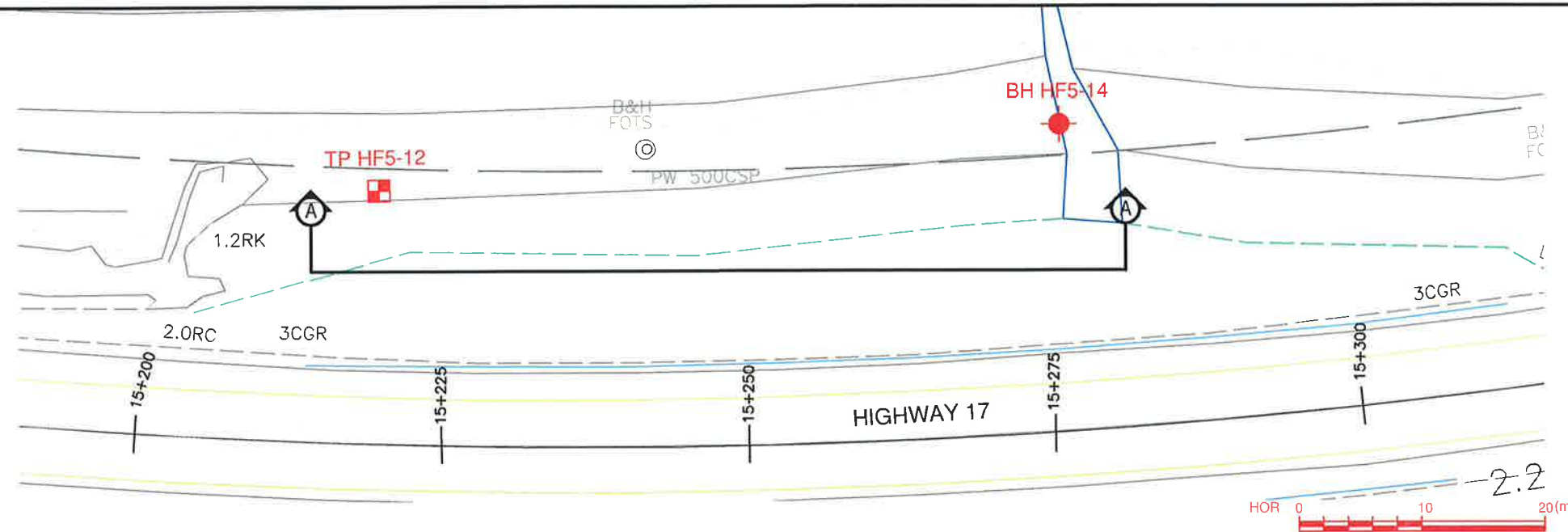
- ◆ Borehole
- Hand dug testpit (TP)
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- R Refusal

BH No.	APPROX. ELEV. (m)	MTM NAD83 ZONE 14 CO-ORDINATES	
		NORTH (m)	EAST (m)
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BH HF5-14	389.1	5417379	258821

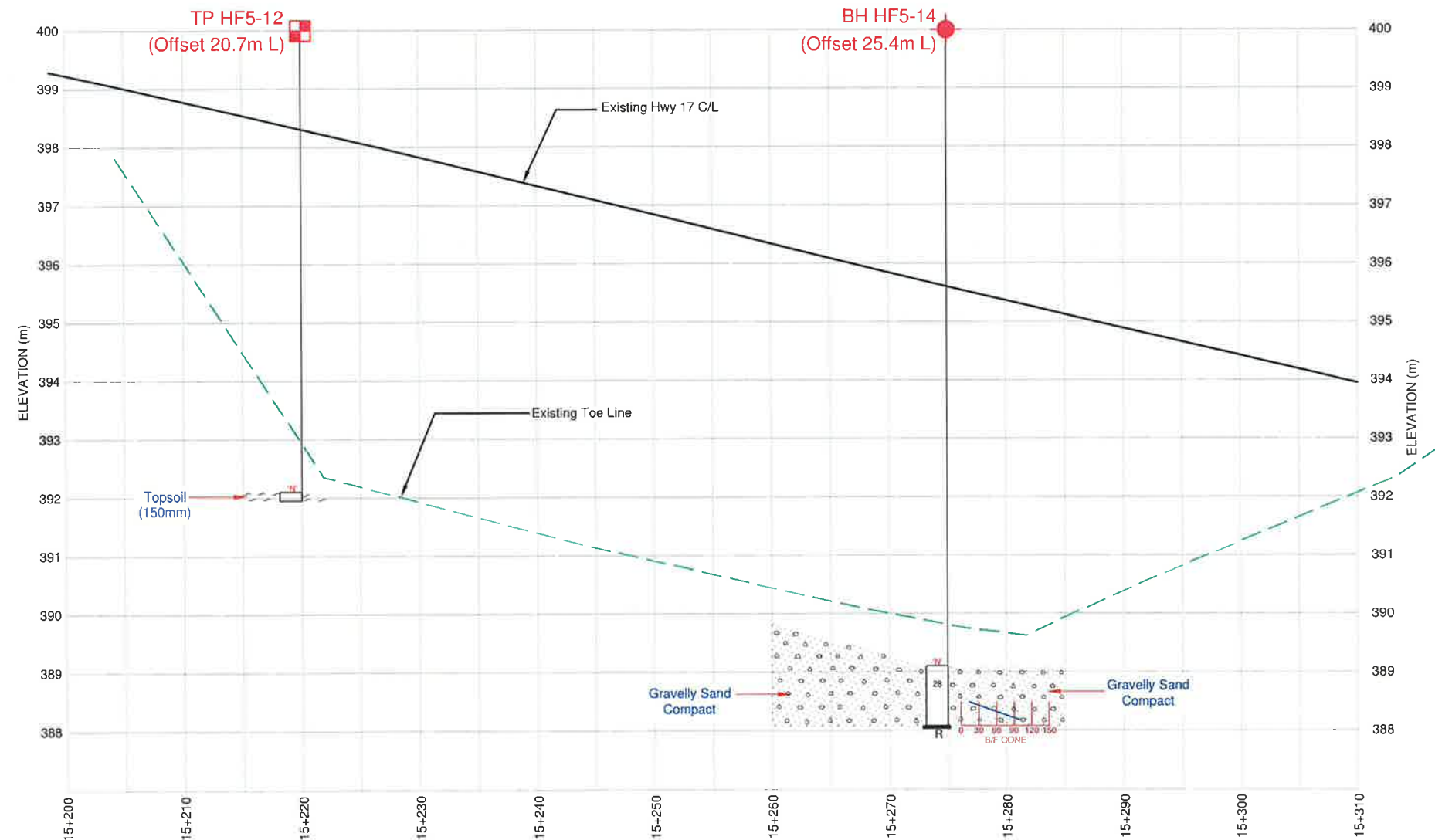
NOTES

The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence. Borehole Location plan is based on drawing "acad-bc527174 ldd" received on Aug 1, 2017. For Detailed Subsurface Conditions Refer to Record of Borehole Sheets.

15							
REVISION	Sept 28/17	ZMO	Submission for MTO review				
	DATE	BY	DESCRIPTION				
GEOCRESS No :			42D-49				
HWY No	17	CHECKED MP	DATE	Sept 28/17	SITE	DIST	
SUBM'D	ZMO	CHECKED MP	APPROVED	VW	DWG	5	



PLAN



PROFILE A-A

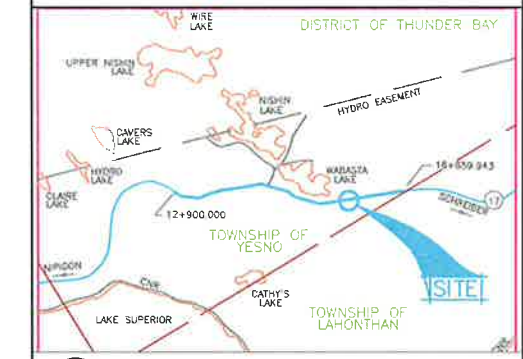


METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No: 6016-E-0032
GWP

HWY 17 - WESTBOUND
PROPOSED CULVERT EXTENSION
CULVERT AT STA. 15+575
STA. 15+530 to STA. 15+680
TOWNSHIP OF YESNO, ON
BOREHOLE LOCATIONS & SOIL STRATA

wsp 51 Constellation Court
Toronto, Ontario
M9W 1K4



KEY PLAN
NOT TO SCALE

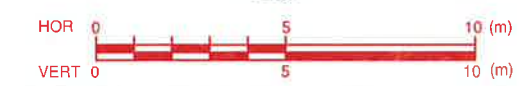
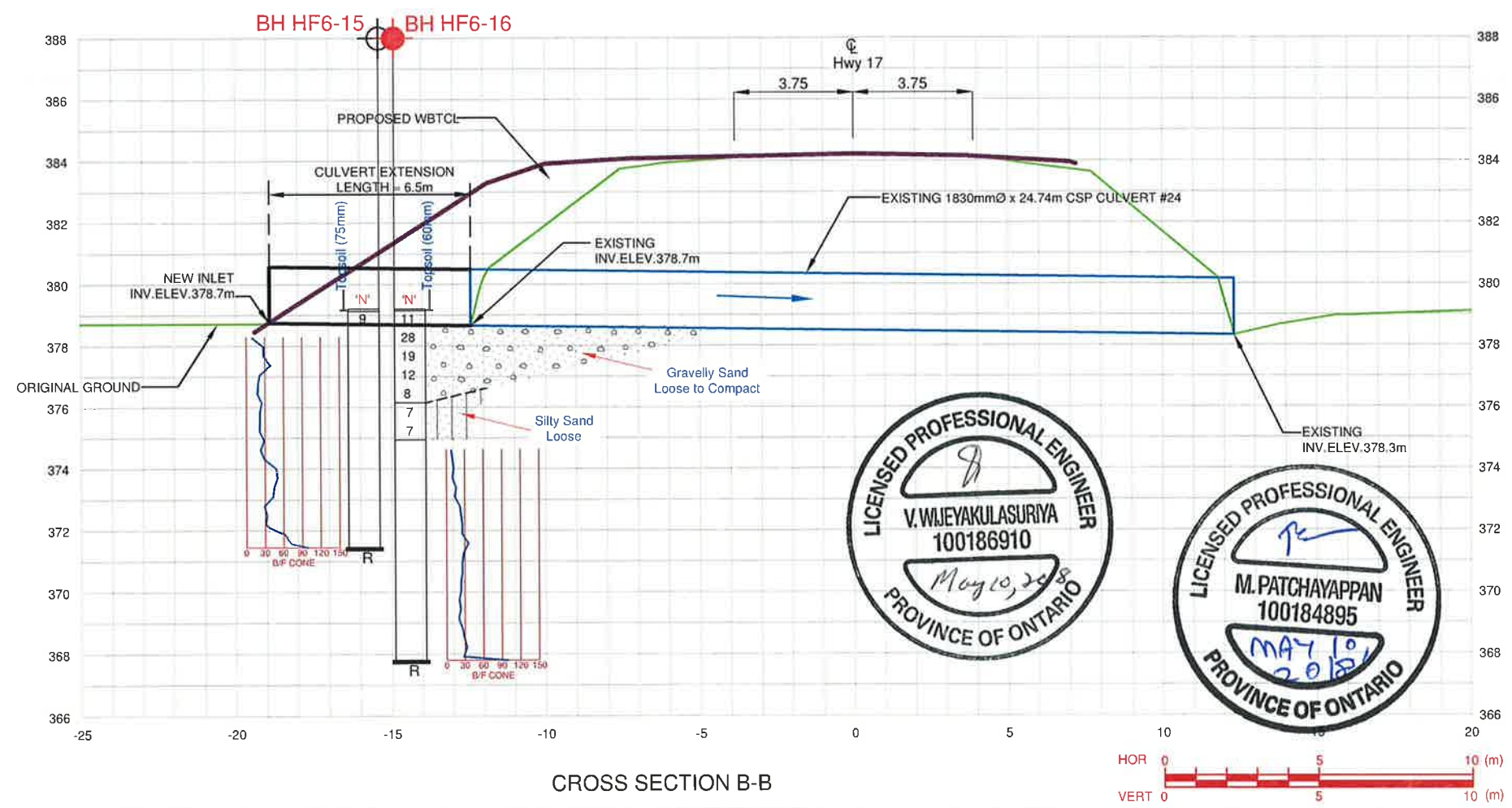
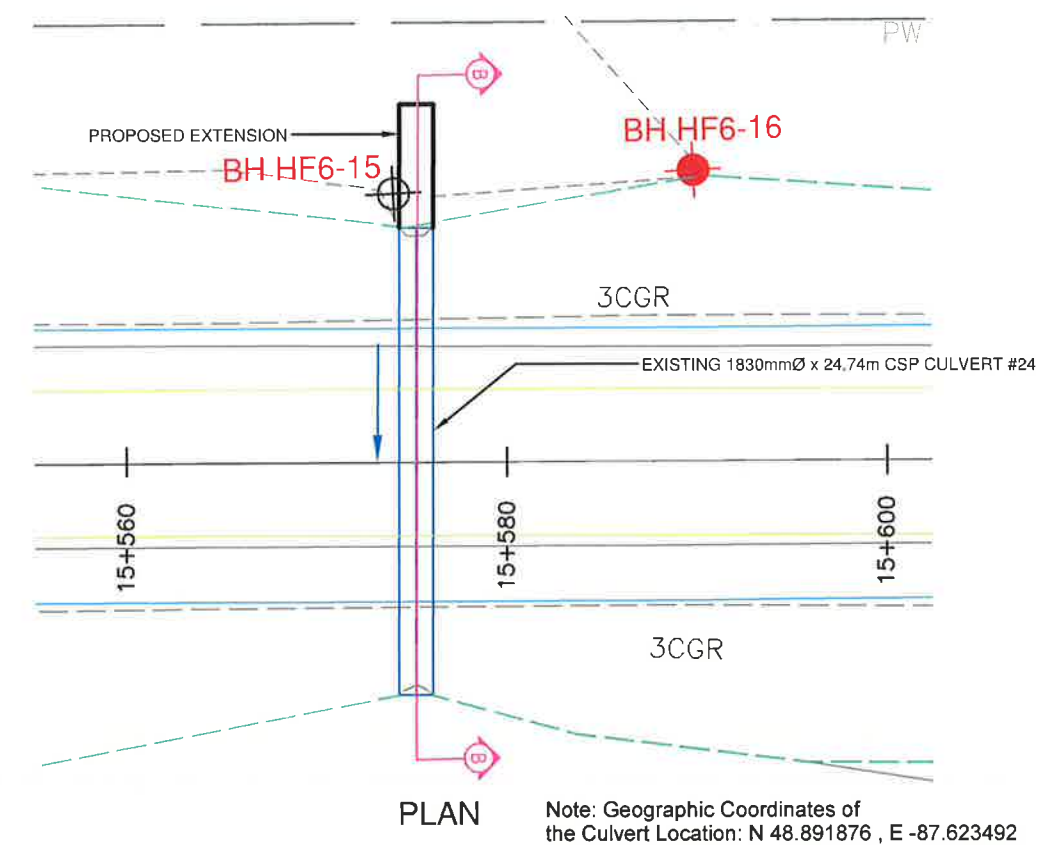
SOIL STRATA SYMBOLS

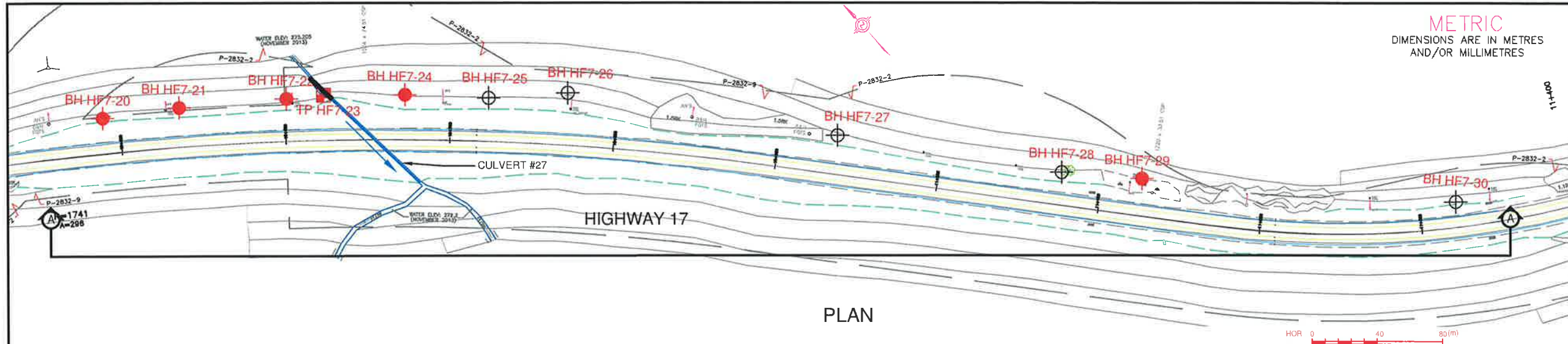
- Gravelly Sand
- Silty Sand

LEGEND			
	Borehole		
	Dynamic Cone Penetration Test (DCPT)		
	Blows/0.3m (Std Pen Test, 475 J/blow)		
	Refusal		
BH No.	APPROX. ELEV. (m)	MTM NAD83 ZONE 14 CO-ORDINATES	
		NORTH (m)	EAST (m)
BH HF6-15	379.2	5417249	259084
BH HF6-16	379.2	5417244	259099

NOTES
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence. Culvert cross-section is based on drawing "171025_Foundations Culv Ext" received on Oct 26, 2017. For Detailed Subsurface Conditions Refer to Record of Borehole Sheets.

REVISIONS		GEOCRE No : 42D-49	
DATE	BY	SUBMISSION FOR MTO REVIEW	
Oct 30/17	ZMD	Description	
HWY No 17		DIST	
SUBM'D		Nov 15/17	
DRAWN ZMD		SITE	
CHECKED MP		APPROVED VW	
DWG		6A	





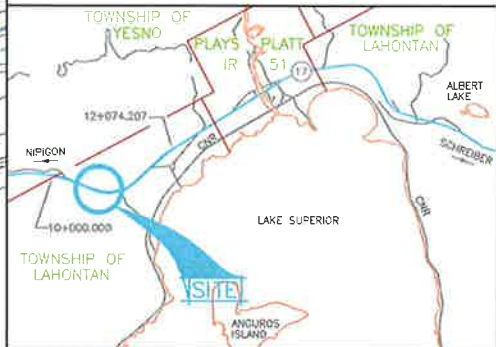
PLAN

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES

CONT No: 6016-E-0032
GWP

HWY 17 - WESTBOUND
TRUCK CLIMBING LANE
HIGHFILL SECTION 7
STA. 10+460 to STA. 11+110
TOWNSHIP OF YESNO, ON
BOREHOLE LOCATIONS & SOIL STRATA

wsp 51 Constellation Court
Toronto, Ontario
M9W 1K4



KEY PLAN
NOT TO SCALE

SOIL STRATA SYMBOLS



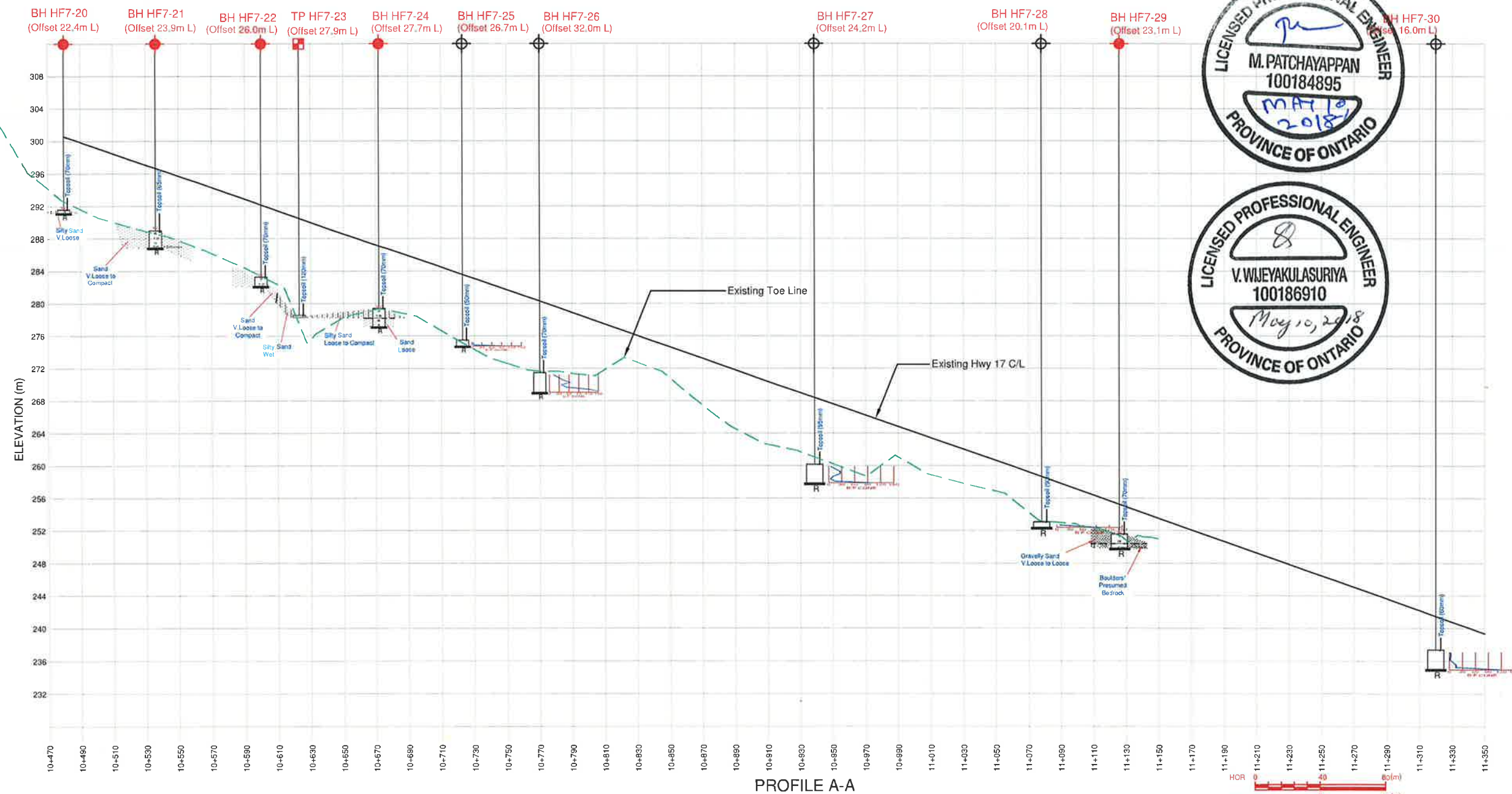
LEGEND

- Borehole
- Dynamic Cone Penetration Test (DCPT)
- Hand dug testpit (TP)
- Blows/0.3m (Std Pen Test, 475 J/blow)
- Refusal

BH No.	APPROX. ELEV. (m)	MTM NAD83 ZONE 14 CO-ORDINATES	
		NORTH (m)	EAST (m)
BH HF7-20	291.6	5416593	260518
BH HF7-21	289.0	5416565	260556
BH HF7-22	283.3	5416524	260807
TP HF7-23	278.6	5416510	260825
BH HF7-24	279.4	5416476	260661
BH HF7-25	275.5	5416439	260697
BH HF7-26	271.5	5416408	260734
BH HF7-27	260.2	5416275	260836
BH HF7-28	253.1	5416164	260920
BH HF7-29	251.6	5416127	260953
BH HF7-30	237.4	5416510	260625

NOTES

The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
Borehole Location plan is based on drawing "acad-bc465171 ldd" received on Aug 1, 2017.
For Detailed Subsurface Conditions Refer to Record of Borehole Sheets.



PROFILE A-A



REVISIONS		Submission for MTO review	
DATE	BY	DESCRIPTION	
Sept. 28/17	ZMO		
GEOCRES No : 42D-49			
HWY No 17			DIST
SUBM'D	CHECKED MP	DATE Nov 15/17	SITE
DRAWN ZMO	CHECKED MP	APPROVED VW	DWG 7

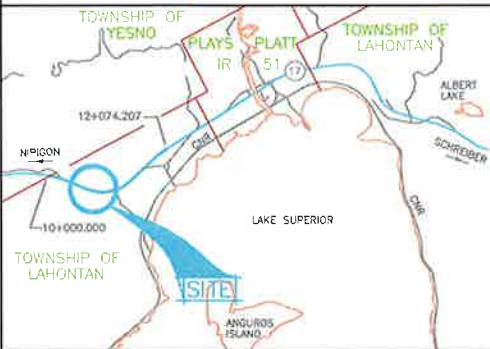
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES

CONT No: 6016-E-0032
GWP



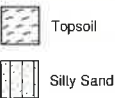
HWY 17 - WESTBOUND
PROPOSED CULVERT EXTENSION
CULVERT AT STA. 10+655
STA. 10+460 to STA. 11+110
TOWNSHIP OF YESNO, ON
BOREHOLE LOCATIONS & SOIL STRATA

wsp 51 Constellation Court
Toronto, Ontario
M9W 1K4



KEY PLAN
NOT TO SCALE

SOIL STRATA SYMBOLS



LEGEND

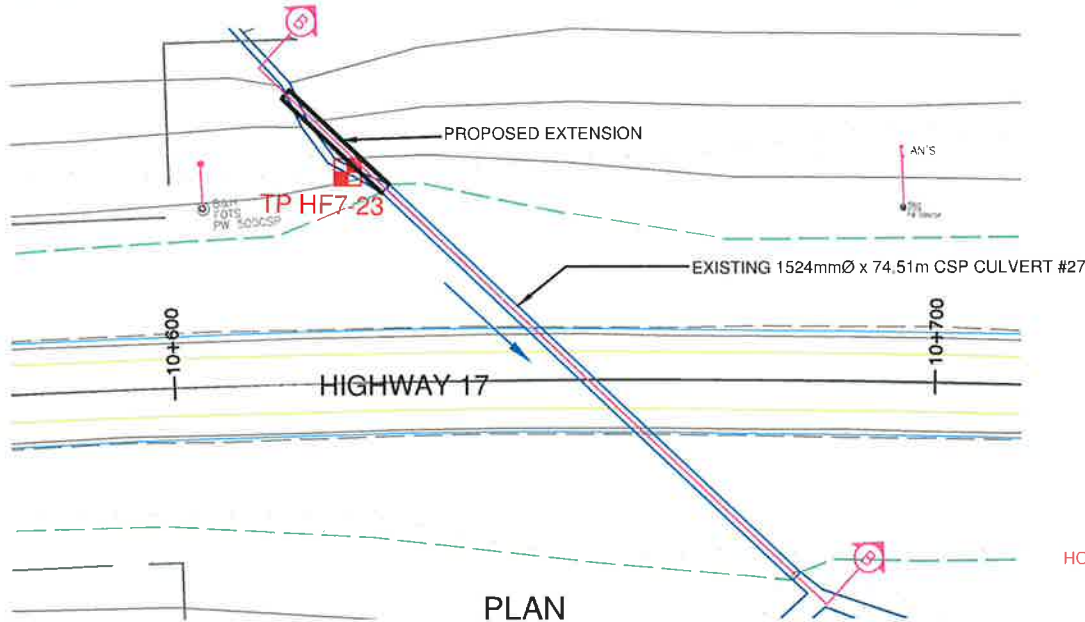
Hand dug test pit (TP)

BH No.	APPROX. ELEV. (m)	MTM NAD83 ZONE 14 CO-ORDINATES	
		NORTH (m)	EAST (m)
TP HF7-23	278.6	5416510	260625

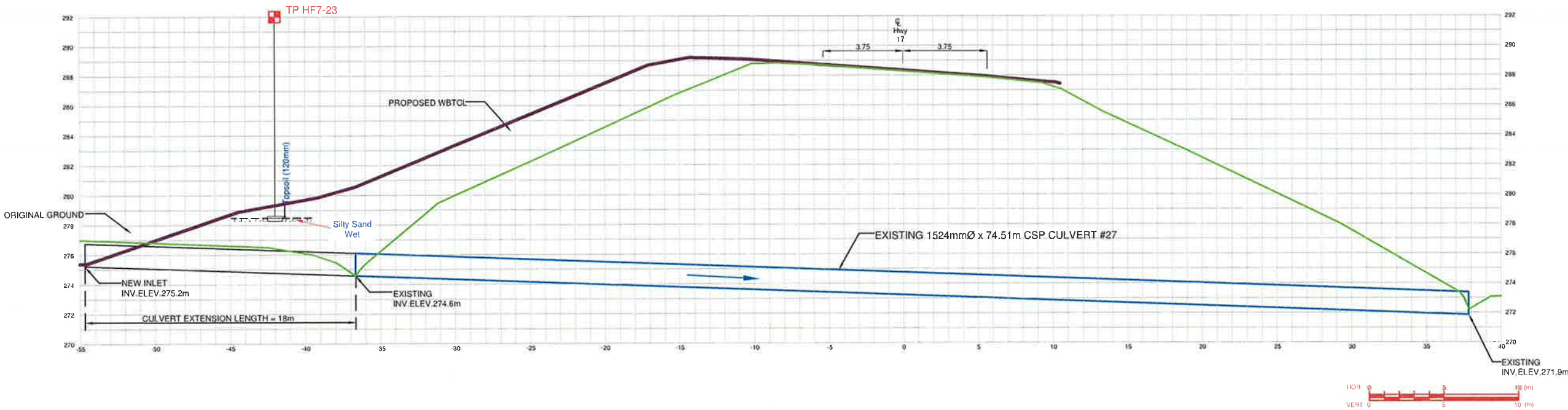
NOTES

The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence. Culvert cross-section is based on drawing "171025_Foundations Culv Ext" received on Oct 26, 2017. For Detailed Subsurface Conditions Refer to Record of Borehole Sheets.

REVISIONS		SUBMISSION FOR MTO REVIEW	
DATE	BY	DATE	DESCRIPTION
Oct 30/17	ZMO		
GEOCRES No : 42D-49			
HWY No 17			DIST
SUBM'D	CHECKED MP	DATE Nov 15/17	SITE
DRAWN ZMO	CHECKED MP	APPROVED VW	DWG 7A

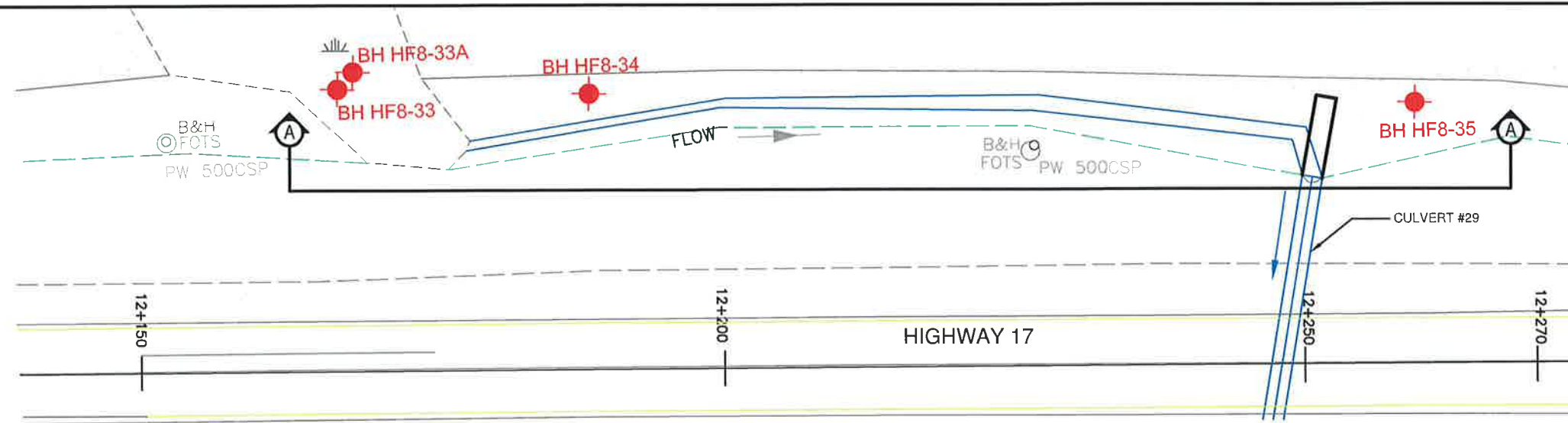


PLAN
Note: Geographic Coordinates of
the Culvert Location: N 48.885342 , E -87.602397



CROSS SECTION B-B





PLAN

HOR 0 10 20 (m)

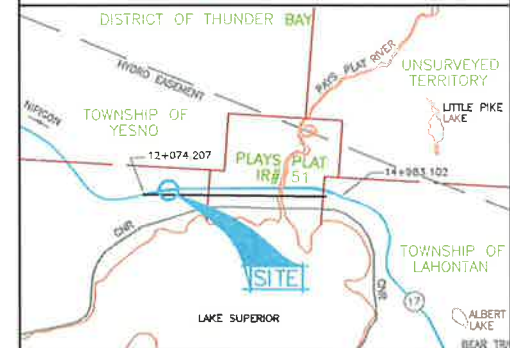
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



CONT No: 6016-E-0032
GWP

HWY 17 - WESTBOUND
TRUCK CLIMBING LANE
HIGHFILL SECTION 8
STA. 12+170 to STA. 12+270
TOWNSHIP OF YESNO, ON
BOREHOLE LOCATIONS & SOIL STRATA

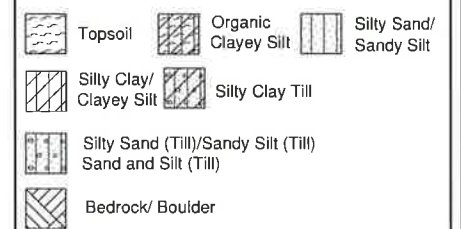
wsp 51 Constellation Court
Toronto, Ontario
M9W 1K4



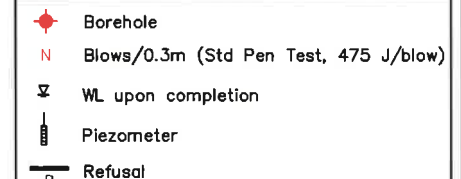
KEY PLAN
NOT TO SCALE



SOIL STRATA SYMBOLS



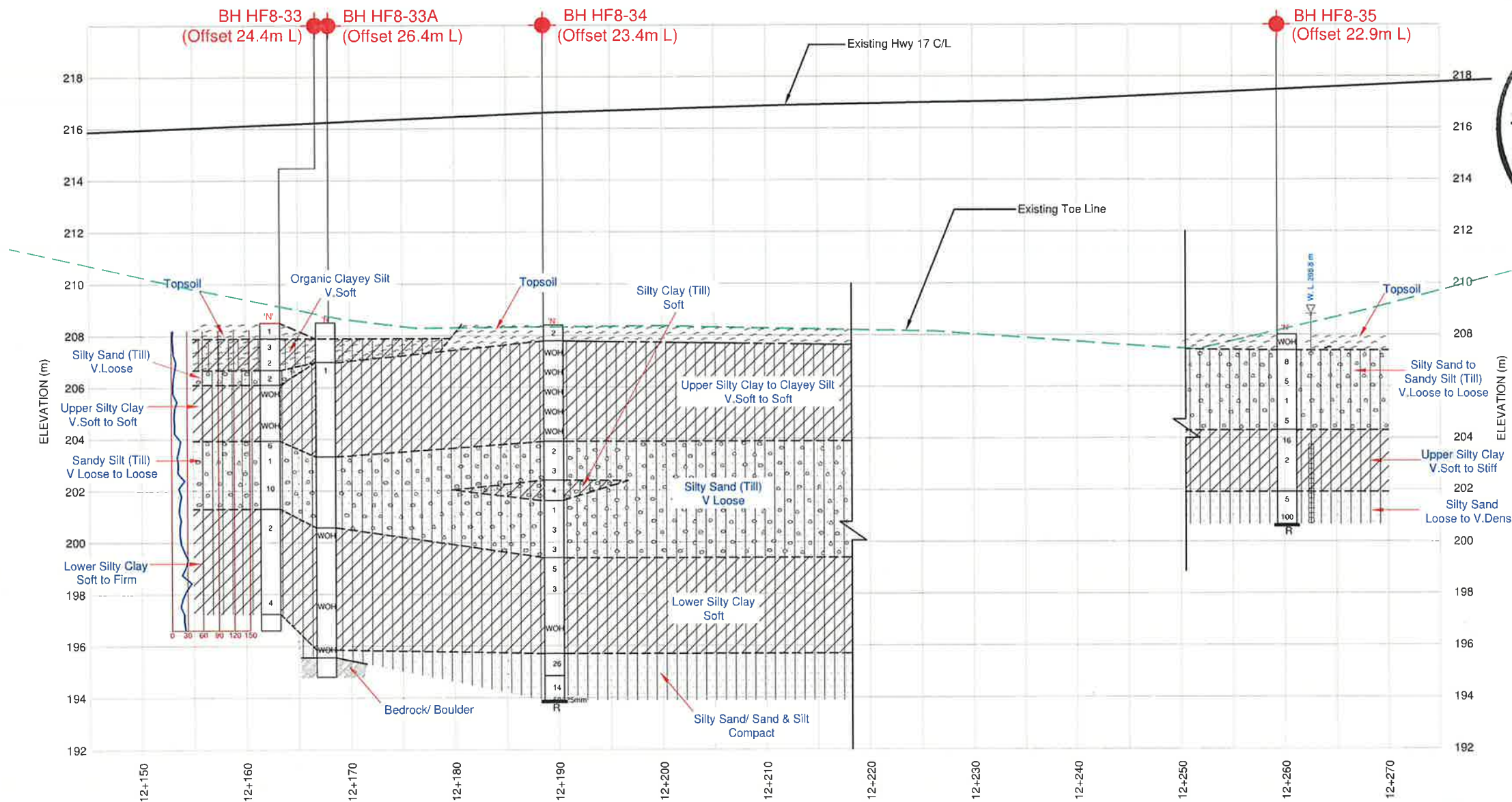
LEGEND



BH No.	APPROX. ELEV. (m)	MTM NAD83 ZONE 14 CO-ORDINATES	
		NORTH (m)	EAST (m)
BH HF8-33	208.5	5415984	261875
BH HF8-33A	208.5	5415986	261876
BH HF8-34	208.4	5415989	261896
BH HF8-35	208.0	5416006	261965

NOTES

The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence. Borehole Location plan is based on drawing "acad-bc465172 ldd" received on Aug 1, 2017. For Detailed Subsurface Conditions Refer to Record of Borehole Sheets.



PROFILE A-A

HOR 0 10 20 (m)
VERT 0 4 8 (m)

REVISIONS	DATE	BY	DESCRIPTION
1	Sept 28, 17	ZMO	Submission for MTO review
2	Sept 28, 17	ZMO	Final

GEOCRES No : 42D-49

HWY No	17	DIST
SUBM'D	CHECKED MP	DATE
DATE	Sept 28, 17	SITE
DRAWN	ZMO	CHECKED MP
APPROVED	VW	DWG
8		

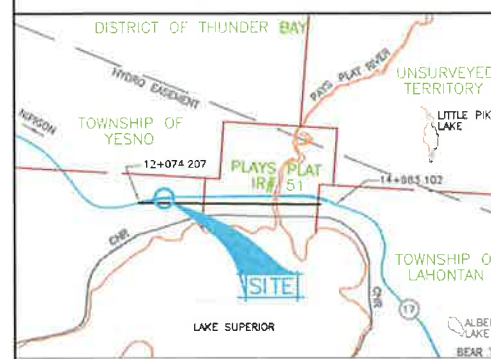
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No: 6016-E-0032
GWP



HWY 17 - WESTBOUND
PROPOSED CULVERT EXTENSION
CULVERT AT STA. 12+248
STA. 12+170 to STA. 12+270
TOWNSHIP OF YESNO, ON
BOREHOLE LOCATIONS & SOIL STRATA

wsp 51 Constellation Court
Toronto, Ontario
M9W 1K4



KEY PLAN
NOT TO SCALE

SOIL STRATA SYMBOLS

- Silty Sand (Till)/Sandy Silt (Till)
- Silty Clay
- Silty Sand

LEGEND

- Borehole
- Blows/0.3m (Std Pen Test, 475 J/blow)
- WL upon completion
- Piezometer
- Refusal

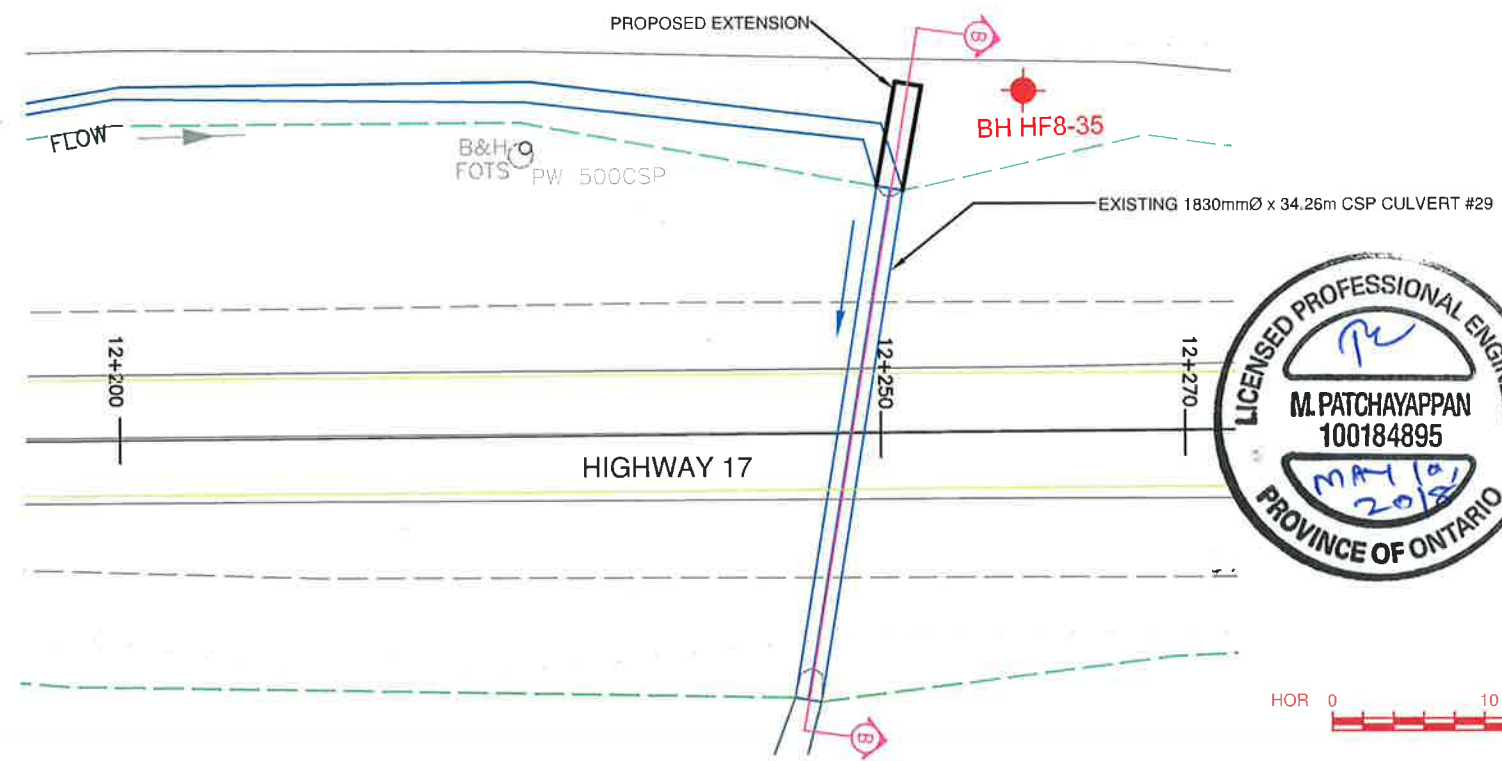
BH No.	APPROX. ELEV. (m)	MTM NAD83 ZONE 14 CO-ORDINATES	
		NORTH (m)	EAST (m)
BH HF8-35	208.0	5416006	261965

NOTES

The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence. Culvert cross-section is based on drawing "171025_Foundations Culv Ext" received on Oct 26, 2017. For Detailed Subsurface Conditions Refer to Record of Borehole Sheets.

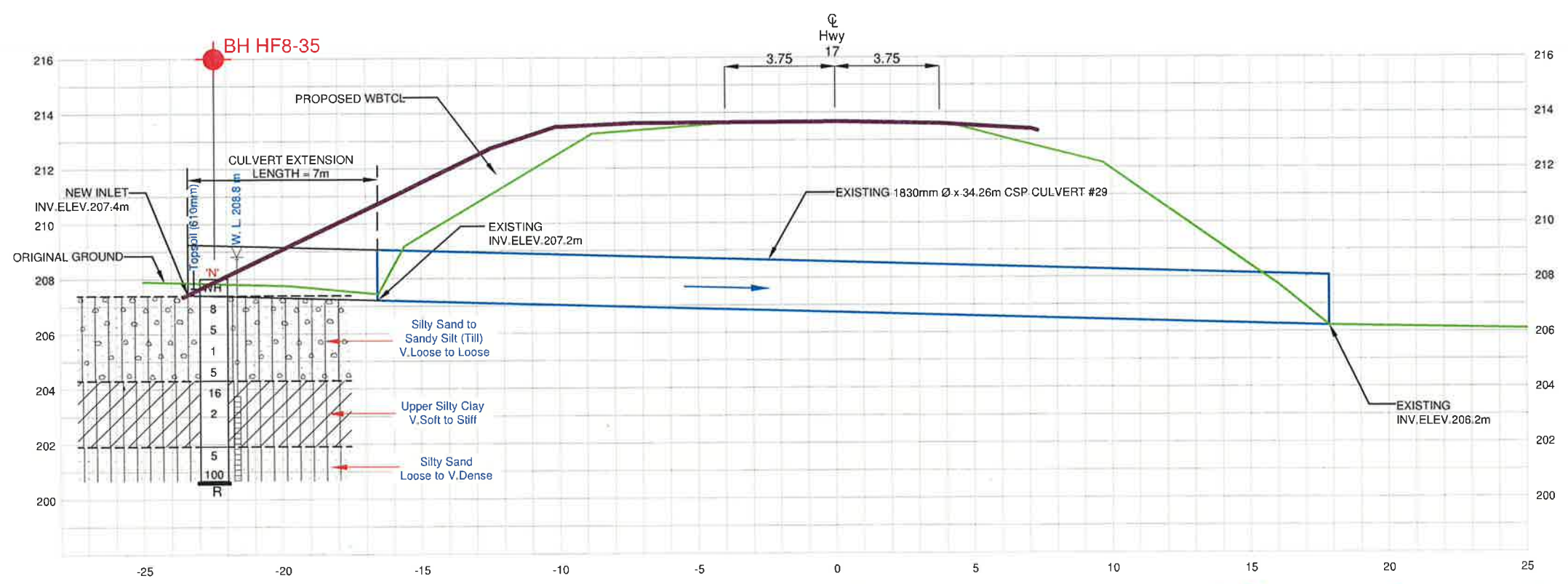
REVISIONS	DATE	BY	DESCRIPTION
1	Oct 30/17	ZMO	Submission for MTO review

HWY No	17	DIST	
SUBM'D	CHECKED MP	DATE	Oct 30/17
DRAWN	ZMO	CHECKED MP	APPROVED VW
			DWG BA

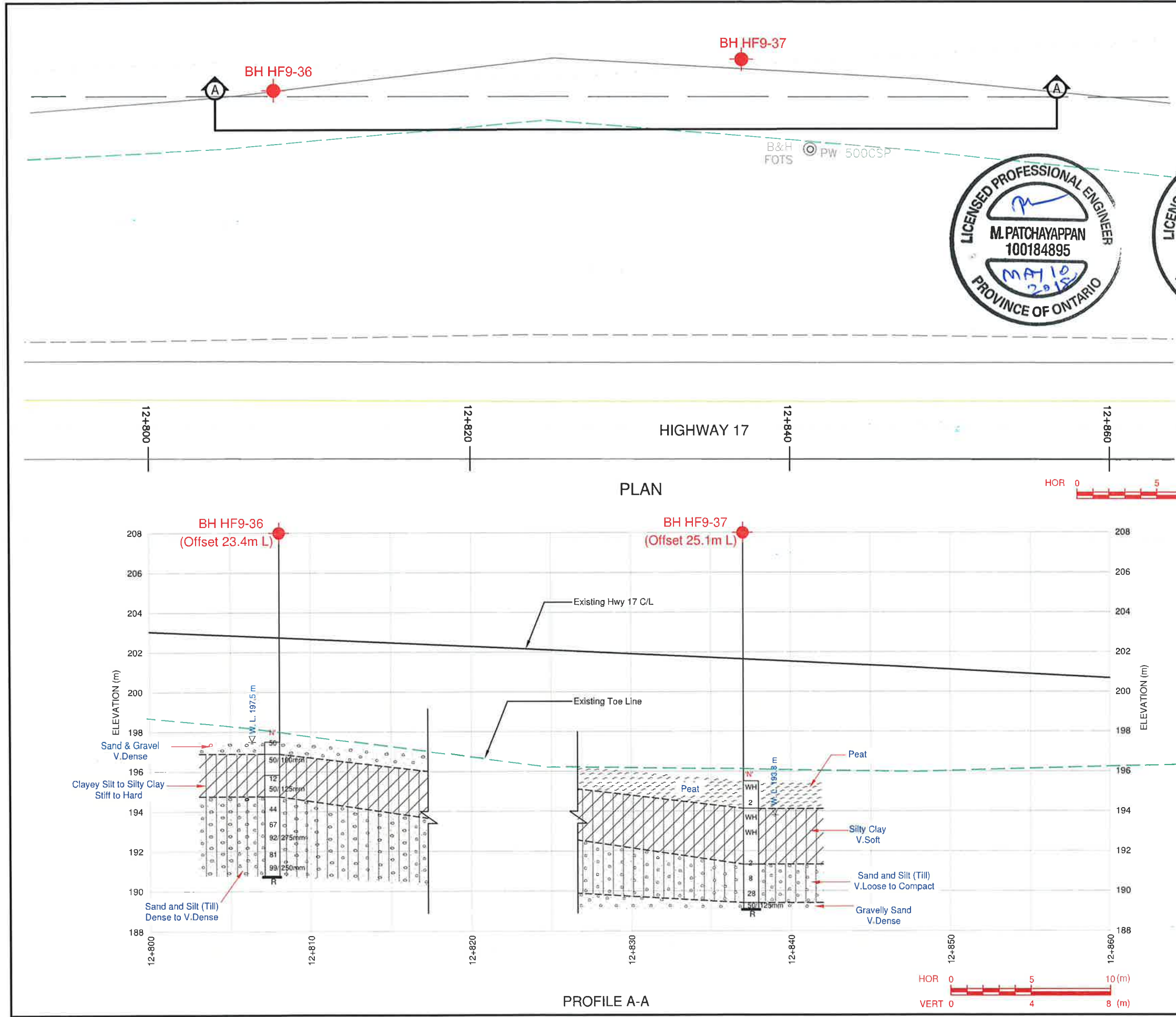


PLAN

Note: Geographic Coordinates of the Culvert Location: N 48.880904, E -87.584072



CROSS SECTION B-B

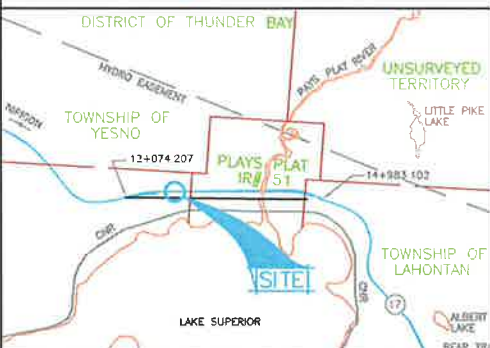


METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No: 6016-E-0032
GWP

HWY 17 - WESTBOUND
TRUCK CLIMBING LANE
HIGHFILL SECTION 9
STA. 12+810 to STA. 12+860
TOWNSHIP OF YESNO, ON
BOREHOLE LOCATIONS & SOIL STRATA

WSP 51 Constellation Court
Toronto, Ontario
M9W 1K4



KEY PLAN
NOT TO SCALE

SOIL STRATA SYMBOLS	
	Peat
	Sand and Gravel/ Gravelly Sand
	Silty Clay/ Clayey Silt
	Sand and Silt (Till)

LEGEND			
	Borehole		
	Blows/0.3m (Std Pen Test, 475 J/blow)		
	WL upon completion		
	Refusal		
	Weight of Hammer		

BH No.	APPROX. ELEV. (m)	MTM NAD83 CO-ORDINATES	
		NORTH (m)	EAST (m)
BH HF9-36	197.5	5416074	262512
BH HF9-37	195.5	5416078	262541

NOTES

The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence. Borehole Location plan is based on drawing "acad-bc465172 ldd" received on Aug 1, 2017. For Detailed Subsurface Conditions Refer to Record of Borehole Sheets.

REVISIONS		SUBMISSION FOR MTO REVIEW	
DATE	BY	DATE	DESCRIPTION
Sept 28/17	ZMO	Sept 28/17	Submission for MTO review
GEOCRE No : 42D-49		DIST	
HWY No 17	CHECKED MP	DATE	SITE
SUBM'D	CHECKED MP	APPROVED	DWG
DRAWN	ZMO	VW	9

APPENDIX

A RECORD OF BOREHOLE SHEETS

METRIC 1 OF 1

[illegible]

171-03034-00

RECORD OF BOREHOLE No HF1-6A

METRIC 1 OF 1

W.P. _____	LOCATION _____	MTM NAD 83 (Zone 14), E 258029, N 5418178	ORIGINATED BY _____	D.W.
DIST _____ HWY <u>17</u>	BOREHOLE TYPE _____	Tripod/Wash Boring/DCPT	COMPILED BY _____	R.J.
DATUM _____	DATE _____	Jun/15/2017 to Jun/15/2017	CHECKED BY _____	MP

[illegible]

171-03034-00

GROUNDWATER ELEVATIONS

+ 3, × 3: Numbers refer to Sensitivity

○ **ε**=3% Strain at Failure

Measurement

1st 2nd 3rd 4th

RECORD OF BOREHOLE No HF2-7

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 258147, N 5418136 ORIGINATED BY D.W.
 DIST _____ HWY 17 BOREHOLE TYPE Tripod/Wash Boring/DCPT/Coring COMPILED BY R.J.
 DATUM _____ DATE Jun/17/2017 to Jun/17/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100			
404.6	Ground Surface														
0.0	TOPSOIL (300 mm)														
404.3															
0.3	SILTY SAND TO SANDY SILT FILL: trace rootlets and organics, brown, wet, loose		1	SS	7										
404.0															
0.6	SILTY SAND: some gravel, brown, moist to wet, loose to very dense		2	SS	5										
1															
	Gravelly		3	SS	50/ 100mm										
402.8															
1.8	End of Borehole														
Notes: 1. Borehole caved-in at 1.2 m upon completion. 2. Cored cobbles / boulders from 1.5 m to 1.8 m. 2. DCPT was performed adjacent to the borehole after augering down to 1.2 m.															

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

METRIC 1 OF 1

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT						POCKET PEN (C _u) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	PLASTIC LIMIT W _P				NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	WATER CONTENT (%)
								SHEAR STRENGTH kPa											
401.5	Ground Surface																		
0.0	PEAT some decayed wood / rootlets, dark brown, wet, very soft		1	SS	1														
400.8	SILTY SAND: some gravel, brown, wet, very loose		2	SS	2														
0.7																			
400.3	End of Borehole Note: Borehole caved-in at 1.1 m upon completion.																Spoon refusal		
1.2																			

171-03034-00

1st 2nd 3rd 4th

RECORD OF TEST PIT No HF3-8

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 258490, N 5417893 ORIGINATED BY T.B.
 DIST _____ HWY 17 BOREHOLE TYPE Test pit / Hand dug COMPILED BY R.J.
 DATUM _____ DATE Jun/23/2017 to Jun/23/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _p	W	W _L			
389.8	Ground Surface																	
0.0	SAND AND COBBLES: some silt, brown, moist						W. L. 389.8 m											
388.9							389											
0.9	End of hand dug test pit Note: Hand dug approximately 1 m x 1 m test pit to a depth of 0.9 m. Unable to advance due to refusal on presumed bedrock / boulders larger than pit size. Test pit submerged under water.																	

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

RECORD OF TEST PIT No HF3-9

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 258504, N 5417874 ORIGINATED BY T.B.
 DIST _____ HWY 17 BOREHOLE TYPE Test pit / Hand dug COMPILED BY R.J.
 DATUM _____ DATE Jun/23/2017 to Jun/23/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
390.0	Ground Surface																	
0.0	TOPSOIL (200 mm)						W. L. 390.0 m											
389.8																		
0.2	COBBLES/BOULDER: wet																	
389.3																		
0.7	End of hand dug test pit																	
Note: Hand dug approximately 1.1 m x 1.2 m test pit to a depth of 0.2 to 0.7 m. Unable to advance due to refusal on cobbles/boulders larger than pit size. Test pit submerged under water.																		

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to
Sensitivity

○ 3% Strain at Failure

171-03034-00

RECORD OF TEST PIT No HF3-10

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 258512, N 5417852 ORIGINATED BY T.B.
 DIST _____ HWY 17 BOREHOLE TYPE Test pit / Hand dug COMPILED BY R.J.
 DATUM _____ DATE Jun/23/2017 to Jun/23/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W _p	W	W _L			
395.2	Ground Surface																	
0.0	TOPSOIL (330 mm)																	
394.9																		
0.3	SILTY SAND: brown, wet																	
394.5																		
0.7	End of hand dug test pit Note: Hand dug approximately 1.1 m x 1.1 m test pit to a depth of 0.7 m. Unable to advance due to refusal on presumed bedrock / boulders larger than pit size.																	

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to
Sensitivity

○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF4-11

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 258713, N 5417455 ORIGINATED BY D.W.
 DIST _____ HWY 17 BOREHOLE TYPE Tripod/ Wash Boring /Coring COMPILED BY R.J.
 DATUM _____ DATE Jun/17/2017 to Jun/19/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100			
395.8	Ground Surface														
0.1	TOPSOIL (110 mm) SILTY SAND: some gravel, brown, moist to wet, very loose to compact		1	SS	1										
			1	RC											
1			2	SS	12										
394.5															
1.3	BEDROCK: GRANITE / GRANITIC GNEISS: slightly weathered, red-pink mixed with black														
2			2	RC											
392.9															
3.0	End of Borehole														
	Notes: 1. Borehole was open upon completion. 2. TCR: Total Core Recovery RQD: Rock Core Recovery														

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF4-11A

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 258709, N 5417468 ORIGINATED BY D.W.
 DIST _____ HWY 17 BOREHOLE TYPE Tripod/Wash Boring COMPILED BY R.J.
 DATUM _____ DATE Jun/17/2017 to Jun/17/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)							
						20 40 60 80 100					10 20 30 40							
394.4	Ground Surface																	
0.75	TOPSOIL (75 mm) SILTY SAND: some gravel, brown, moist, very loose to compact occasional vegetation		1	SS	3													
			2	SS	10													
			3	SS	22													
392.5	End of Borehole		4	SS	50/ 75mm													
1.9	Note: Caved-in at ground level upon completion.																	

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, × 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

RECORD OF TEST PIT No HF5-12

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 258773, N 5417407 ORIGINATED BY T.B.
 DIST _____ HWY 17 BOREHOLE TYPE Test pit / Hand dug COMPILED BY R.J.
 DATUM _____ DATE Jun/23/2017 to Jun/23/2017 CHECKED BY MP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa									
						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											
						20 40 60 80 100											
392.1	Ground Surface																
	TOPSOIL (150 mm)	1/2				392											
0.15	End of hand dug test pit Note: Hand dug approximately 1 m x 1 m test pit. Presumed bedrock / boulder was encountered at a depth of 0.2 m																

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, × 3: Numbers refer to Sensitivity


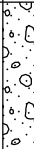
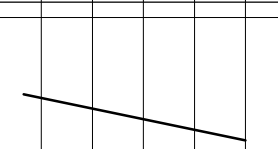
○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF5-14

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 258821, N 5417379 ORIGINATED BY T.B.
 DIST _____ HWY 17 BOREHOLE TYPE Halfweight/DCPT COMPILED BY R.J.
 DATUM _____ DATE Jun/23/2017 to Jun/23/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES									
389.1	Ground Surface													
0.0	GRAVELLY SAND: trace silt, grey/ brown, wet, compact		1	SS	28		389							33 58 (9)
1.0	End of Borehole / DCPT													DCPT refusal
Notes: 1. Caved-in at ground surface upon completion. Water level was at ground surface upon completion. 2. Hand dug approximately 0.3 m x 0.3 m test pit close to the borehole. Presumed bedrock/ boulder encountered at a depth of 0.3 m. 3. The above shown 'N' value is corrected to standard hammer weight (63.5 kg). 4. DCPT values are based on half weight hammer (31.75 kg).														

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF6-15

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 259084, N 5417249 ORIGINATED BY T.B.
 DIST _____ HWY 17 BOREHOLE TYPE Halfweight*/DCPT COMPILED BY R.J.
 DATUM _____ DATE Jun/22/2017 to Jun/23/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40						
379.2	Ground Surface														
0.075	TOPSOIL (75 mm) No Recovery		1	SS	9		379								Caved-in at ground level upon spoon retrieval; no recovery
378.7	End of sampling, DCPT below to 7.8 m below ground surface						378								
0.5							377								
1							376								
2							375								
3							374								
4							373								
5							372								
6															
7															
371.5	End of Borehole / DCPT														DCPT refusal
7.8	Notes: 1. Standing water condition was observed in the vicinity of borehole 2. The above shown 'N' value is corrected to standard hammer weight (63.5 kg). 3. DCPT values are based on half weight hammer (31.75 kg). *SPT Spoon driven without tripod setup.														

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF6-15A

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 259055, N 5417264 ORIGINATED BY T.B.
 DIST _____ HWY 17 BOREHOLE TYPE Tripod/Wash Boring/DCPT COMPILED BY R.J.
 DATUM _____ DATE Jun/23/2017 to Jun/23/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40						
379.5	Ground Surface														
0.0	PEAT: trace decayed wood and rootlets, brownish black, wet, very soft		1	SS	2										
378.9	SILTY SAND: some gravel, some organics, black, wet, compact		2	SS	17										
378.3	GRAVELLY SAND: some silt, brown, moist, compact		3	SS	17										
377.7	End of sampling, DCPT below to 5.5 m below ground surface														
1.8															
374.0	End of Borehole / DCPT Caved-in at 0.5 m depth														
5.5															

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF6-16





METRIC 1 OF 2

W.P. _____	LOCATION _____	MTM NAD 83 (Zone 14), E 259099, N 5417244	ORIGINATED BY _____	D.W.
DIST _____ HWY 17 _____	BOREHOLE TYPE _____	Tripod/Wash Boring/DCPT	COMPILED BY _____	R.J.
DATUM _____	DATE _____	Jun/19/2017 to Jun/19/2017	CHECKED BY _____	MP

[illegible]

Continued Next Page

GROUNDWATER ELEVATIONS

	1st	2nd	3rd	4th
Measurement				

+³, ×³: Numbers refer to Sensitivity ○ **8**=3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF6-16

METRIC 2 OF 2

W.P. _____	LOCATION _____	MTM NAD 83 (Zone 14), E 259099, N 5417244	ORIGINATED BY _____	D.W.
DIST _____ HWY 17	BOREHOLE TYPE _____	Tripod/Wash Boring/DCPT	COMPILED BY _____	R.J.
DATUM _____	DATE _____	Jun/19/2017 to Jun/19/2017	CHECKED BY _____	MP

[illegible]

GROUNDWATER ELEVATIONS

	1st	2nd	3rd	4th
Measurement				

+³, ×³: Numbers refer to Sensitivity ○ **8**=3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF6-17





METRIC 1 OF 2

W.P. _____	LOCATION _____	MTM NAD 83 (Zone 14), E 259118, N 5417237	ORIGINATED BY _____	T.B.
DIST _____ HWY <u>17</u>	BOREHOLE TYPE _____	Tripod/Wash Boring/DCPT	COMPILED BY _____	R.J.
DATUM _____	DATE _____	Jun/20/2017 to Jun/22/2017	CHECKED BY _____	MP

SOIL PROFILE				SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			POCKET PEN (C _u) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	SHEAR STRENGTH kPa			PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L			
379.1	Ground Surface													
0.1	TOPSOIL (90 mm) GRAVELLY SAND: some silt, brown, moist to wet, loose		1A	SS	4									
			1B	SS										
			2	SS										
377.9	End of sampling, DCPT below to 12.2 m below ground surface													
1.2														
376.8														
375.7														
374.6														
373.5														
372.4														
371.3														
370.2														
369.1														
368.0														
366.9														
365.8														
364.7														
363.6														
362.5														
361.4														
360.3														
359.2														
358.1														
357.0														
355.9														
354.8														
353.7														
352.6														
351.5														
350.4														
349.3														
348.2														
347.1														
346.0														
344.9														
343.8														
342.7														
341.6														
340.5														
339.4														
338.3														
337.2														

Continued Next Page

GROUNDWATER ELEVATIONS

	1st	2nd	3rd	4th
Measurement				

+³, ×³: Numbers refer to Sensitivity ○ **8**=3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF6-17

METRIC 2 OF 2

W.P. _____	LOCATION _____	MTM NAD 83 (Zone 14), E 259118, N 5417237	ORIGINATED BY _____	T.B.
DIST _____ HWY <u>17</u>	BOREHOLE TYPE _____	Tripod/Wash Boring/DCPT	COMPILED BY _____	R.J.
DATUM _____	DATE _____	Jun/20/2017 to Jun/22/2017	CHECKED BY _____	MP

[illegible]

GROUNDWATER ELEVATIONS

	1st	2nd	3rd	4th
Measurement				

+³, ×³: Numbers refer to Sensitivity ○ **8**=3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF6-18

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 259162, N 5417218 ORIGINATED BY T.B.
 DIST _____ HWY 17 BOREHOLE TYPE Tripod/Wash Boring/DCPT COMPILED BY R.J.
 DATUM _____ DATE Jun/22/2017 to Jun/22/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES									
379.0	Ground Surface													
0.075	TOPSOIL (75 mm) GRAVELLY SAND: some silt, brown, moist, compact		1	SS	11									
1			2	SS	23									
377.8	End of sampling, DCPT below to 2.8 m below ground surface													
1.2														
376.2	End of Borehole / DCPT													
2.8	Note: Borehole caved-in at 0.9 m upon completion.													

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF6-19

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 259180, N 5417215 ORIGINATED BY T.B.
 DIST _____ HWY 17 BOREHOLE TYPE Tripod/Wash Boring/DCPT COMPILED BY R.J.
 DATUM _____ DATE Jun/22/2017 to Jun/22/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES									
378.9	Ground Surface													
0.1	TOPSOIL (100 mm) GRAVELLY SAND: trace silt, occasional rock pieces, brown, moist to wet, loose to compact		1	SS	6									
1			2	SS	22									Caved-in at 0.7 m
377.1			3	SS	10									34 61 (5)
1.8	End of sampling, DCPT below to 3.2 m below ground surface													
377.7														
376														DCPT refusal
375.7	End of Borehole / DCPT													
3.2	Note: Borehole caved-in at 0.7 m upon completion.													

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to
Sensitivity

○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF7-20

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 260518, N 5416593 ORIGINATED BY D.W.
 DIST _____ HWY 17 BOREHOLE TYPE Tripod/Wash Boring COMPILED BY R.J.
 DATUM _____ DATE Jun/09/2017 to Jun/09/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
291.6	Ground Surface																	
0.07	TOPSOIL (70 mm)																	
	SILTY SAND		1	SS	3													
291.1	some gravel, brown, wet, very loose																Spoon refusal	
0.5	End of borehole																	
	Note: Borehole open and dry upon completion of drilling																	

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF7-21

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 260556, N 5416565 ORIGINATED BY D.W.
 DIST _____ HWY 17 BOREHOLE TYPE Tripod/Wash Boring COMPILED BY R.J.
 DATUM _____ DATE Jun/09/2017 to Jun/09/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
							20	40	60	80	100							
289.0	Ground Surface																	
0.065	TOPSOIL (65 mm)																	
	SAND: trace silt, trace gravel, reddish brown, moist to wet, loose to compact		1	SS	6													
1			2	SS	12													
			3	SS	9												2 96 (2)	
2			4	SS	50/ 150mm												Spoon refusal	
286.9	End of Borehole																	
2.1	Note: Borehole caved-in at 1.8 m upon completion.																	

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to
Sensitivity

○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF7-22

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 260607, N 5416524 ORIGINATED BY D.W.
 DIST _____ HWY 17 BOREHOLE TYPE Tripod/Wash Boring COMPILED BY R.J.
 DATUM _____ DATE Jun/09/2017 to Jun/09/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
283.3	Ground Surface																	
0.07	TOPSOIL (70 mm) SAND: trace silt, trace rootlets, brown, moist, loose		1	SS	7		283											
	some gravel, trace silt, compact		2	SS	12												15 82 (3) Spoon refusal	
282.1	End of Borehole																	
1.2	Note: Borehole was open and dry upon completion.																	

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to
Sensitivity

○ 3% Strain at Failure

171-03034-00

METRIC 1 OF 1

SOIL PROFILE				SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			POCKET PEN. (C _u) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV	DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100			
278.6		Ground Surface														
		TOPSOIL (120 mm)														
0.1		SILTY SAND:														
278.3		brown, wet														
0.3		End of hand dug test pit														
Note: Hand dug approximately 1 m x 1 m test pit. Presumed bedrock/ boulder was encountered at a depth of 0.3 m																

+³, ×³: Numbers refer to Sensitivity ○ **8**=3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF7-24

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 260661, N 5416476 ORIGINATED BY D.W.
 DIST _____ HWY 17 BOREHOLE TYPE Tripod/Wash Boring COMPILED BY R.J.
 DATUM _____ DATE Jun/12/2017 to Jun/12/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100			
279.4	Ground Surface														
0.07	TOPSOIL (70 mm) SILTY SAND: red brown, moist to wet, loose to compact		1	SS	3		279								
	trace rootlets		2	SS	16										
278.2	SAND: trace silt, trace gravel, reddish brown, moist, loose		3	SS	8		278								5 94 (1)
			4	SS	4										Spoon refusal
277.1	End of Borehole														
2.3	Note: Borehole was open and dry upon completion.														

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF7-25

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 260697, N 5416439 ORIGINATED BY D.W.
 DIST _____ HWY 17 BOREHOLE TYPE Tripod/DCPT COMPILED BY R.J.
 DATUM _____ DATE Jun/11/2017 to Jun/11/2017 CHECKED BY MP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE									
275.5	Ground Surface												
0.05	TOPSOIL (50 mm) DCPT below to 0.8 m												
274.7													
0.8	End of Borehole / DCPT												DCPT refusal

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th


+ 3, X 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF7-26

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 260734, N 5416408 ORIGINATED BY D.W.
 DIST _____ HWY 17 BOREHOLE TYPE Tripod/DCPT COMPILED BY R.J.
 DATUM _____ DATE Jun/11/2017 to Jun/11/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100 WATER CONTENT (%) 10 20 30 PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _p W W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES							
271.5	Ground Surface											
0.07	TOPSOIL (70 mm) DCPT below to 2.5 m											
1												
2												
269.0	End of Borehole / DCPT											DCPT refusal
2.5												

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th


+ 3, × 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF7-27

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 260836, N 5416275 ORIGINATED BY D.W.
 DIST _____ HWY 17 BOREHOLE TYPE Halfweight/DCPT COMPILED BY R.J.
 DATUM _____ DATE Jun/11/2017 to Jun/11/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100 WATER CONTENT (%) 10 20 30 PLASTIC LIMIT W _p — W — W _L NATURAL MOISTURE CONTENT LIQUID LIMIT POCKET PEN. (Cu) (kPa) NATURAL UNIT WT (kN/m³)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				
260.2	Ground Surface								
0.1	TOPSOIL (95 mm) DCPT below to 2.3 m						260		
1							259		
2							258		
257.9	End of Borehole / DCPT								DCPT refusal
2.3	Note: The above shown 'DCPT' values are based on half weight hammer (31.75 kg).								

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, × 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

RECORD OF BOREHOLE No HF7-28

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 260920, N 5416164 ORIGINATED BY D.W.
 DIST _____ HWY 17 BOREHOLE TYPE Halfweight/DCPT COMPILED BY R.J.
 DATUM _____ DATE Jun/11/2017 to Jun/11/2017 CHECKED BY MP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa						
253.1	Ground Surface						20 40 60 80 100							
0.1	TOPSOIL (90 mm) DCPT below to 0.7 m					253	20 40 60 80 100							
252.4	End of Borehole													DCPT refusal
0.7	Note: The above shown 'DCPT' values are based on half weight hammer (31.75kg)													

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF7-29

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 260953, N 5416127 ORIGINATED BY D.W.
 DIST _____ HWY 17 BOREHOLE TYPE Tripod/Wash Boring/Coring COMPILED BY R.J.
 DATUM _____ DATE Jun/12/2017 to Jun/12/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)							
						20 40 60 80 100					10 20 30 40							
251.6	Ground Surface																	
0.07	TOPSOIL (70 mm) GRAVELLY SAND: some silt, grey, wet, very loose to loose		1A	SS	1													
			1B	SS														
			1C	SS														
1			2	SS	9													
250.4																		
1.2	BOULDERS/PRESUMED BEDROCK		1	RC														
249.9			3	SS	50/75mm													
1.7	End of Borehole Note: Caved in at 1.8 m upon completion.																	


GROUNDWATER ELEVATIONS
 Measurement 1st 2nd 3rd 4th

+ 3, × 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

RECORD OF BOREHOLE No HF7-30

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 261083, N 5415984 ORIGINATED BY D.W.
 DIST _____ HWY 17 BOREHOLE TYPE Halfweight/DCPT COMPILED BY R.J.
 DATUM _____ DATE Jun/11/2017 to Jun/11/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT  SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100 WATER CONTENT (%) 10 20 30 PLASTIC LIMIT W _p — W — W _L NATURAL MOISTURE CONTENT LIQUID LIMIT POCKET PEN. (Cu) (kPa) NATURAL UNIT WT (kN/m³)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES				
237.4	Ground Surface								
0.06	TOPSOIL (60 mm) DCPT below to 2.4 m								
1									
2									
235.0	End of borehole / DCPT								DCPT refusal
2.4	Note: The above shown 'DCPT' values are based on half weight hammer (31.75kg).								

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

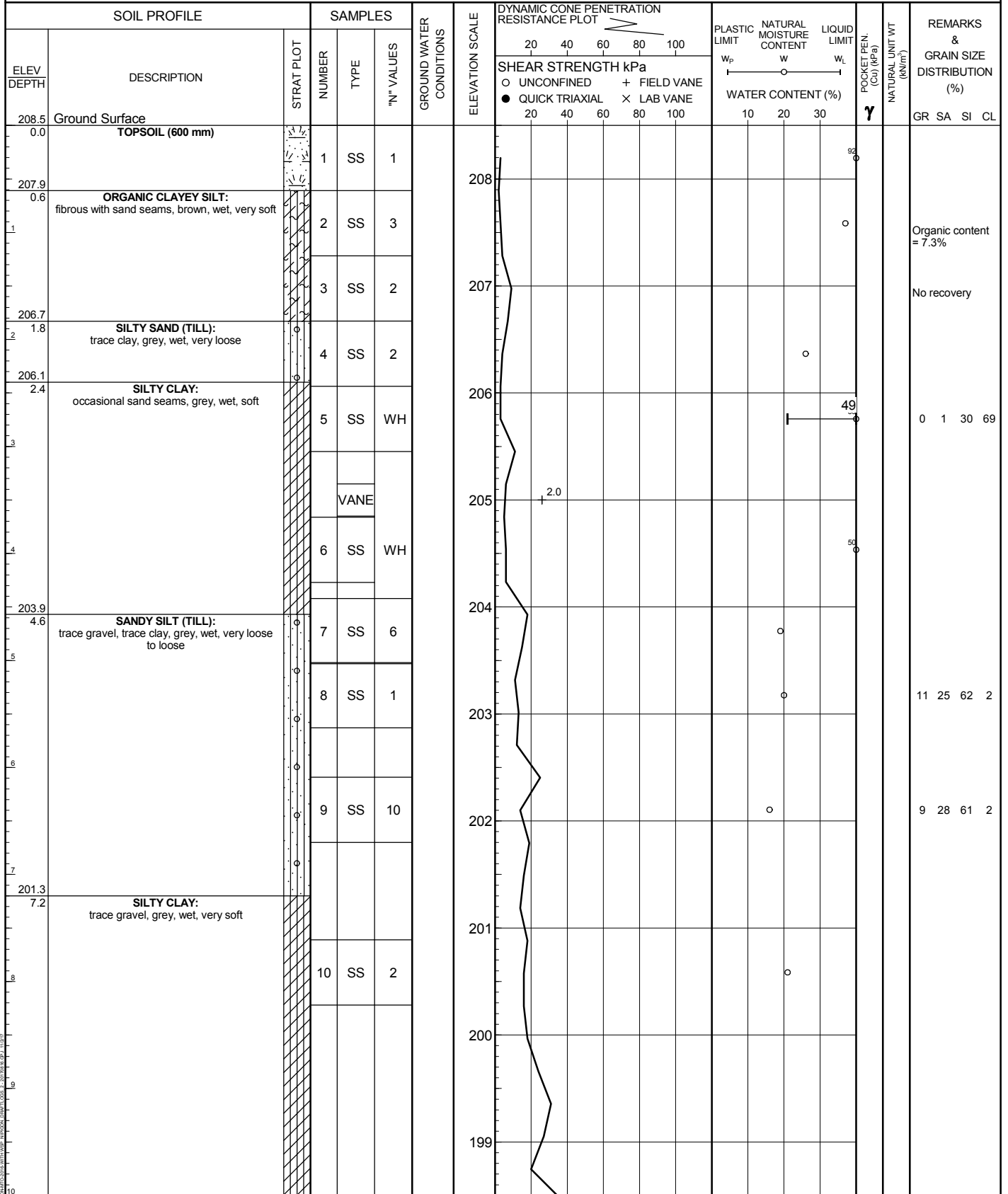
+ 3, × 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF8-33

METRIC 1 OF 2

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 261875, N 5415984 ORIGINATED BY D.W.
 DIST _____ HWY 17 BOREHOLE TYPE Tripod/Wash Boring COMPILED BY R.J.
 DATUM _____ DATE Jun/07/2017 to Jun/07/2017 CHECKED BY MP



GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, × 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF8-33

METRIC 2 OF 2

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 261875, N 5415984 ORIGINATED BY D.W.
 DIST _____ HWY 17 BOREHOLE TYPE Tripod/Wash Boring COMPILED BY R.J.
 DATUM _____ DATE Jun/07/2017 to Jun/07/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES									
	Continued													
	SILTY CLAY: trace gravel, grey, wet, very soft (<i>continued</i>)													
11			11	SS	4									
197.2														
11.3	End of sampling, DCPT continue to 11.9 m													
196.6														
11.9	End of Borehole / DCPT													
	Note: This borehole was terminated (due to limitations of tripod method) prior to competent stratum and re-drilled (by using track-mounted rig) as "HF-33A" adjacent to this borehole location.													

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF8-33A





METRIC 1 OF 2

W.P. _____	LOCATION _____	MTM NAD 83 (Zone 14), E 261876, N 5415986	ORIGINATED BY _____	D.W.
DIST _____ HWY <u>17</u>	BOREHOLE TYPE _____	Track mount CME55 / Wash Boring/Coring	COMPILED BY _____	R.J.
DATUM _____	DATE _____	Jun/22/2017 to Jun/23/2017	CHECKED BY _____	MP

[illegible]

Continued Next Page

GROUNDWATER ELEVATIONS

	1st	2nd	3rd	4th
Measurement				

+³, ×³: Numbers refer to Sensitivity ○ **8**=3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF8-33A

METRIC 2 OF 2

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 261876, N 5415986 ORIGINATED BY D.W.
 DIST _____ HWY 17 BOREHOLE TYPE Track mount CME55 / Wash Boring/Coring COMPILED BY R.J.
 DATUM _____ DATE Jun/22/2017 to Jun/23/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN (C _u) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)
								○ UNCONFINED	+ FIELD VANE	×							
								● QUICK TRIAXIAL	×	LAB VANE							
	Continued						20	40	60	80	100					GR SA SI CL	
	SILTY CLAY: trace sand, grey, wet, firm <i>(continued)</i>			VANE													
11			8	SS	WH											0 1 65 34	
				VANE													
			9A														
195.9																	
12.7	SILTY SAND: some gravel, trace clay, grey, wet		9B	SS	WH												
195.6																	
13	BEDROCK / BOULDER: Granite/Granitic Gneiss		1	RC												Spoon refusal at 12.8 m	
194.8																	
13.7	End of Borehole Note: Caved-in at 2.0 m upon completion.																

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, × 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

RECORD OF BOREHOLE No HF8-34

METRIC 1 OF 2

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 261896, N 5415989 ORIGINATED BY T.B.
DIST _____ HWY 17 BOREHOLE TYPE Track mount CME55 / Casing/Wash Boring COMPILED BY R.J.
DATUM _____ DATE Jun/24/2017 to Jun/24/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			POCKET PEN. (C _u) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				W _P	W	W _L						
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE									
208.4	Ground Surface						20	40	60	80	100						GR	SA	SI	CL
0.0	TOPSOIL (610 mm)		1	SS	2															
207.8	SILTY CLAY TO CLAYEY SILT: some sand, trace gravel, grey, wet, very soft		2	SS	WH															No recovery
0.6																				No recovery
1																				
2				3	SS	WH														
3				4	SS	WH														No recovery
4				5	SS	WH														
203.9	SILTY SAND (TILL): some gravel, trace clay, grey, wet, very loose		6	SS	WH															
4.5																				
5				7	SS	2														
6	trace clay		8	SS	3															
202.4																				
6.0	SILTY CLAY (TILL): sandy, grey, wet, soft		9	SS	4															
201.6	SAND AND SILT (TILL): trace gravel, trace clay, grey, wet, very loose		10	SS	1															
6.8																				
7				11	SS	3														
8				12	SS	3														
199.4	SILTY CLAY: trace sand, grey, wet, soft																			
9.0				13	SS	5														
9																				
10																				

Continued Next Page

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to Sensitivity ○ 6=3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF8-34

METRIC 2 OF 2

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 261896, N 5415989 ORIGINATED BY T.B.
 DIST _____ HWY 17 BOREHOLE TYPE Track mount CME55 / Casing/Wash Boring COMPILED BY R.J.
 DATUM _____ DATE Jun/24/2017 to Jun/24/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN (C _u) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)
								○ UNCONFINED	+ FIELD VANE	×							
								● QUICK TRIAXIAL	×	LAB VANE							
	Continued							20 40 60 80 100		10 20 30					GR SA SI CL		
	SILTY CLAY: trace sand, grey, wet, soft (continued)		14	SS	3		198								0 4 64 32		
11			16	VANE				3.4									
12			17	SS	WH										0 1 65 34		
195.7			18	TW			196								poor recovery		
12.7	SAND AND SILT: some silt, grey, wet, compact		19	SS	26		195										
194.8			20	SS	14										1 22 74 3		
13.6	SANDY SILT: trace gravel, trace clay, grey, wet, compact						194								Spoon refusal		
193.9			21	SS	50/ 25mm												
14.5	End of Borehole Note: Borehole caved-in at 2.4 m upon completion.																

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, × 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF8-35

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 261965, N 5416006 ORIGINATED BY T.B.
 DIST _____ HWY 17 BOREHOLE TYPE Track mount CME55 / Casing/Wash Boring COMPILED BY R.J.
 DATUM _____ DATE Jun/24/2017 to Jun/24/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	W. L.	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
208.0	Ground Surface						208.8 m									GR SA SI CL	
0.0	TOPSOIL (610 mm)		1	SS	WH											No sample recovery	
207.4	SILTY SAND TO SANDY SILT (TILL): trace clay, trace gravel, grey, wet, loose		2	SS	8		207									No sample recovery	
0.6																	
1																	
2				3A	SS	5											
				3B	SS												
		3C	SS														
	grey, wet, very loose to loose		4	SS	1		206										
			5	SS	5		205									1 32 61 6	
204.3	SILTY CLAY: trace sand, grey, moist to wet, very soft to very stiff		6	SS	16		204										
3.7																	
4																	
			7	SS	2		203									0 4 60 36	
			8	TW												No sample recovery in TW; Grab sample from TW tip	
201.9	SILTY SAND: grey / brown / red, wet, loose to very dense		9	SS	5		202										
6.1																	
			10	SS	100		201									Spoon refusal	
200.7	End of borehole																
7.3	<div>Notes: 1. 32 mm monitoring well was installed upon completion. 2. Water level was at 0.8 m above existing ground level upon installation of well and slight flowing condition was observed.</div> <div>WATER LEVEL OBSERVATION: Date Depth(m) Elevation (m) Jun 24-17 0.8(above ground) 208.8 Aug 21-17 0.8(above ground) 208.8</div>																

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, x 3: Numbers refer to Sensitivity ○ 3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF9-36

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 262512, N 5416074 ORIGINATED BY T.B.
 DIST _____ HWY 17 BOREHOLE TYPE Track mount CME55 / Hollow Stem COMPILED BY R.J.
 DATUM _____ DATE Jun/24/2017 to Jun/24/2017 CHECKED BY MP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN (C _u) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE							W _P	W	W _L
197.5	Ground Surface		1	SS	50												GR SA SI CL			
0.0	SAND AND GRAVEL: dry, very dense						W. L. 197.5 m										Spoon refusal No recovery			
196.9	CLAYEY SILT: some gravel, grey, moist, hard		2	SS	50/ 100mm		197													
0.6																				
195.8	SILTY CLAY: light brown, dry to moist, stiff to hard		3	SS	12		196										Poor recovery			
1.7																				
194.8	SAND AND SILT (TILL): trace gravel, trace clay, grey, wet, dense to very dense		4	SS	50/ 125mm		195													
2.8																				
194.8			5	SS	44		194										9 48 39 4			
			6	SS	67		193													
			7	SS	92/ 275mm		192													
			8	SS	81		191													
			9	SS	99/ 250mm												Spoon refusal at 6.7 m			
190.8	End of Borehole																			
6.7	Notes: 1. Borehole caved-in at 2.0 m upon completion. 2. Water level was at ground surface upon completion.																			

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

+ 3, X 3: Numbers refer to Sensitivity ○ 3=3% Strain at Failure

171-03034-00

RECORD OF BOREHOLE No HF9-37

METRIC 1 OF 1

W.P. _____ LOCATION MTM NAD 83 (Zone 14), E 262541, N 5416078 ORIGINATED BY T.B.
 DIST _____ HWY 17 BOREHOLE TYPE Track mount CME55 / Hollow Stem COMPILED BY R.J.
 DATUM _____ DATE Jun/25/2017 to Jun/25/2017 CHECKED BY MP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa						
195.5	Ground Surface													
0.0	PEAT some decayed vegetation and rootlets, black, wet, very soft		1	SS	WH									No recovery
1			2	SS	2									
194.1	SILTY CLAY: trace sand, grey, moist to wet, very soft		3	SS	WH									
1.4			4	SS	WH									
2			5	TW										
3			6A	SS										
4			6B	SS	2									
191.3	SAND AND SILT (TILL): some gravel, trace clay, grey, wet, very loose to compact		7	SS	8									
4.2			8	SS	28									
5			9	SS	50/ 125mm									
6														
189.4	GRAVELLY SAND: trace silt, grey, wet, very dense													
6.1														
189.1	End of Borehole													Spoon refusal
6.4	Notes: 1. Borehole caved-in at 4.0 m upon completion. 2. Water level was at 1.7 m upon completion.													

GROUNDWATER ELEVATIONS

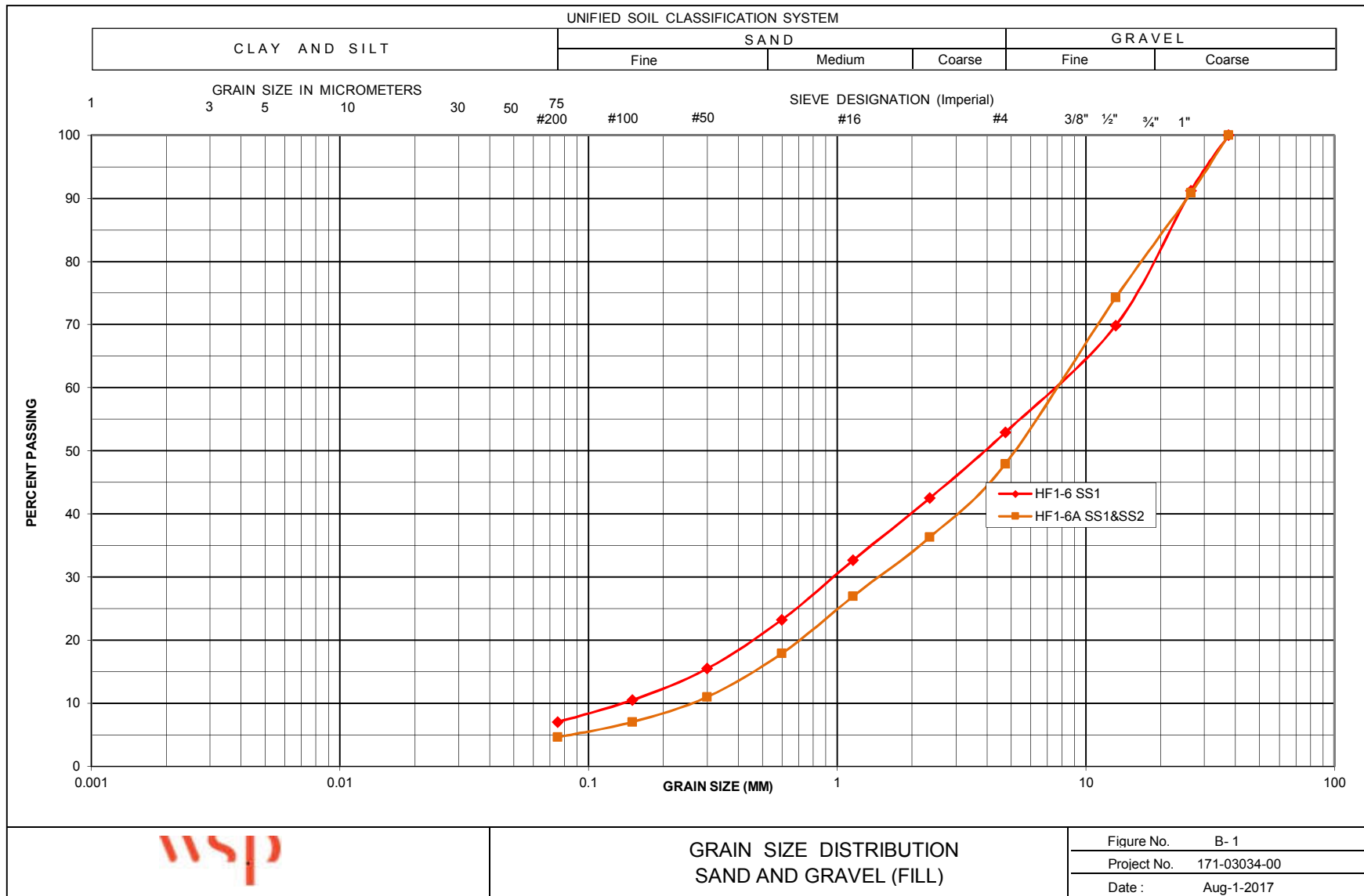
Measurement 1st 2nd 3rd 4th

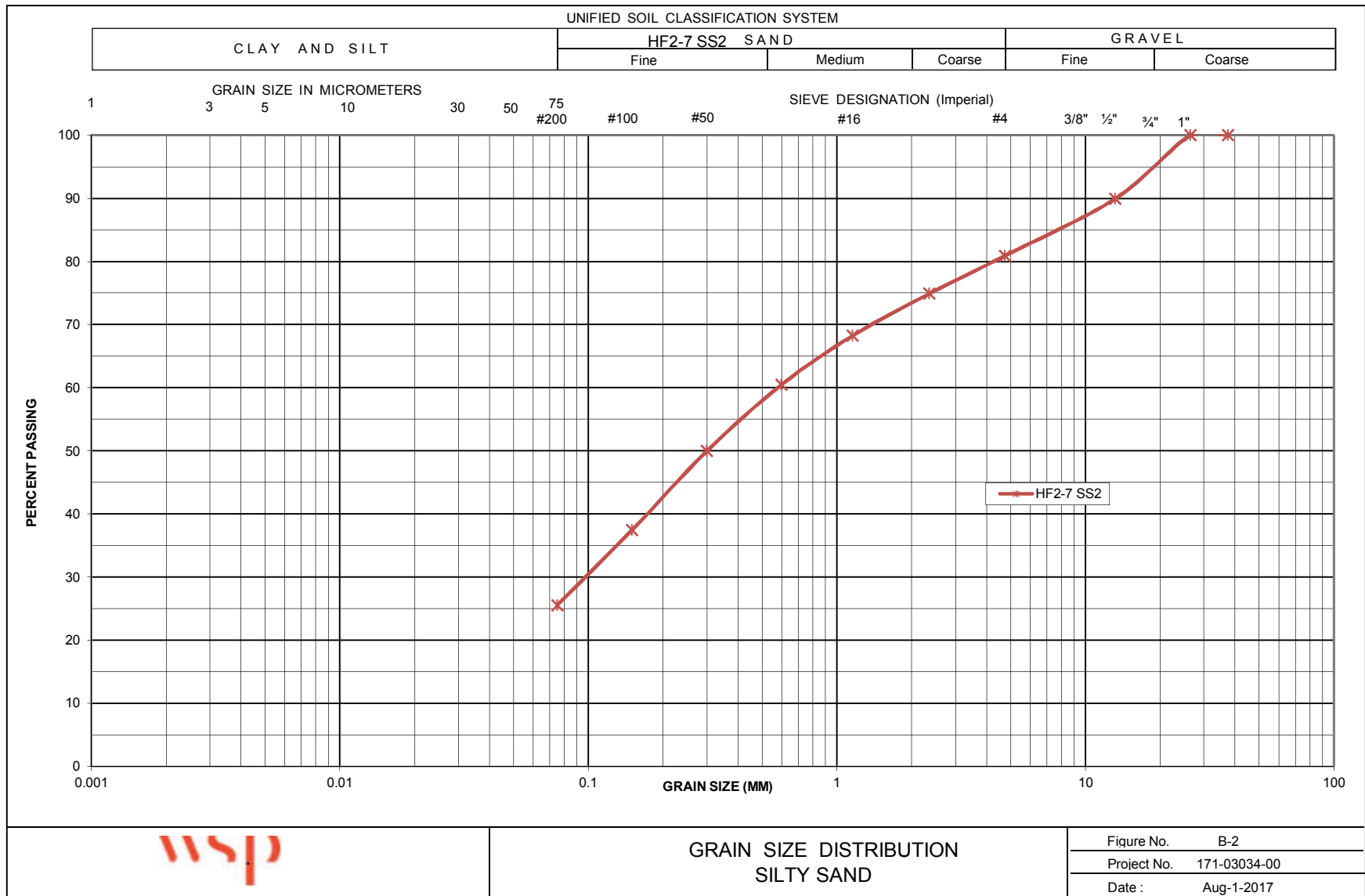
+³, ×³: Numbers refer to Sensitivity ○ s=3% Strain at Failure

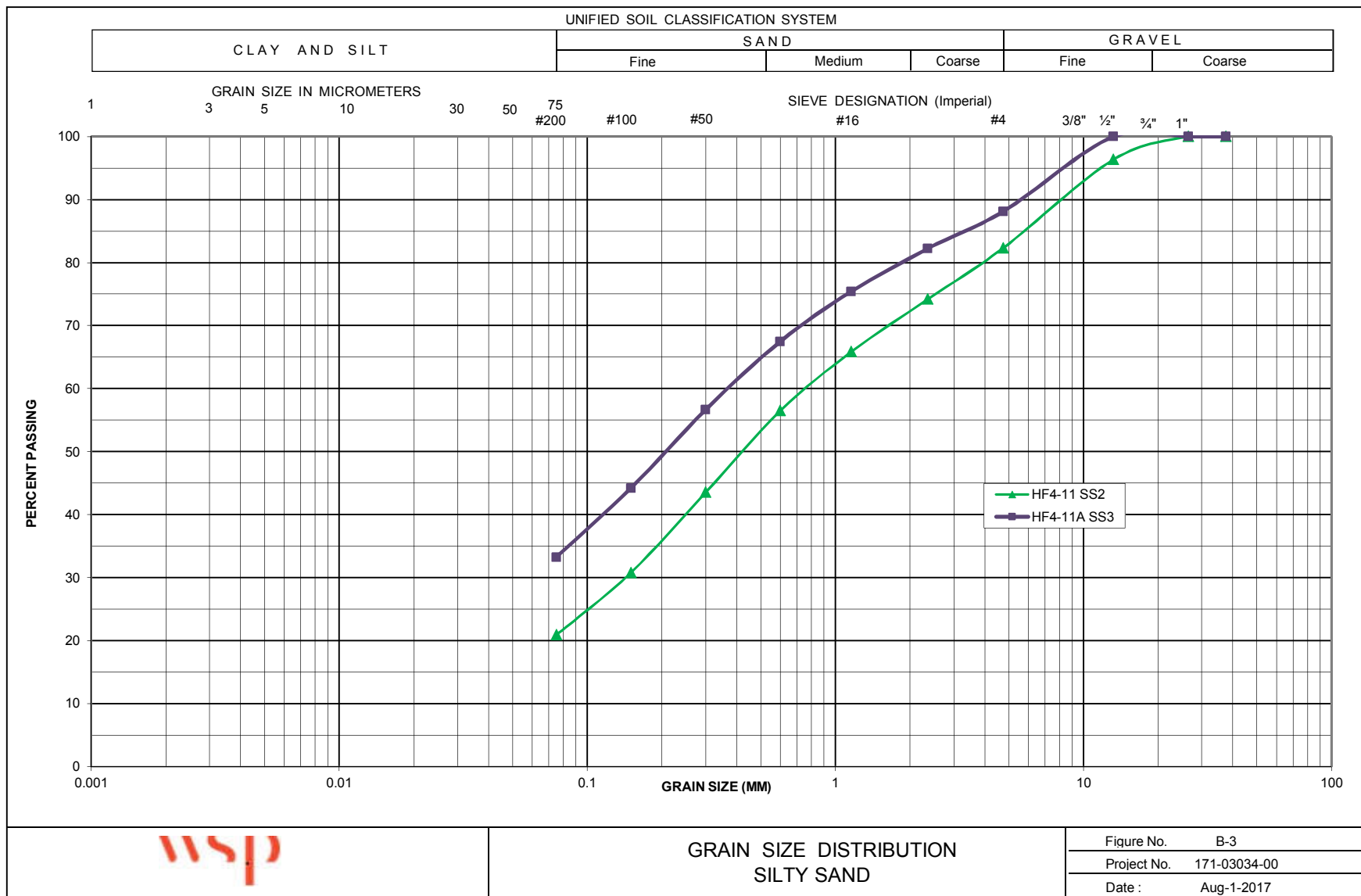
171-03034-00

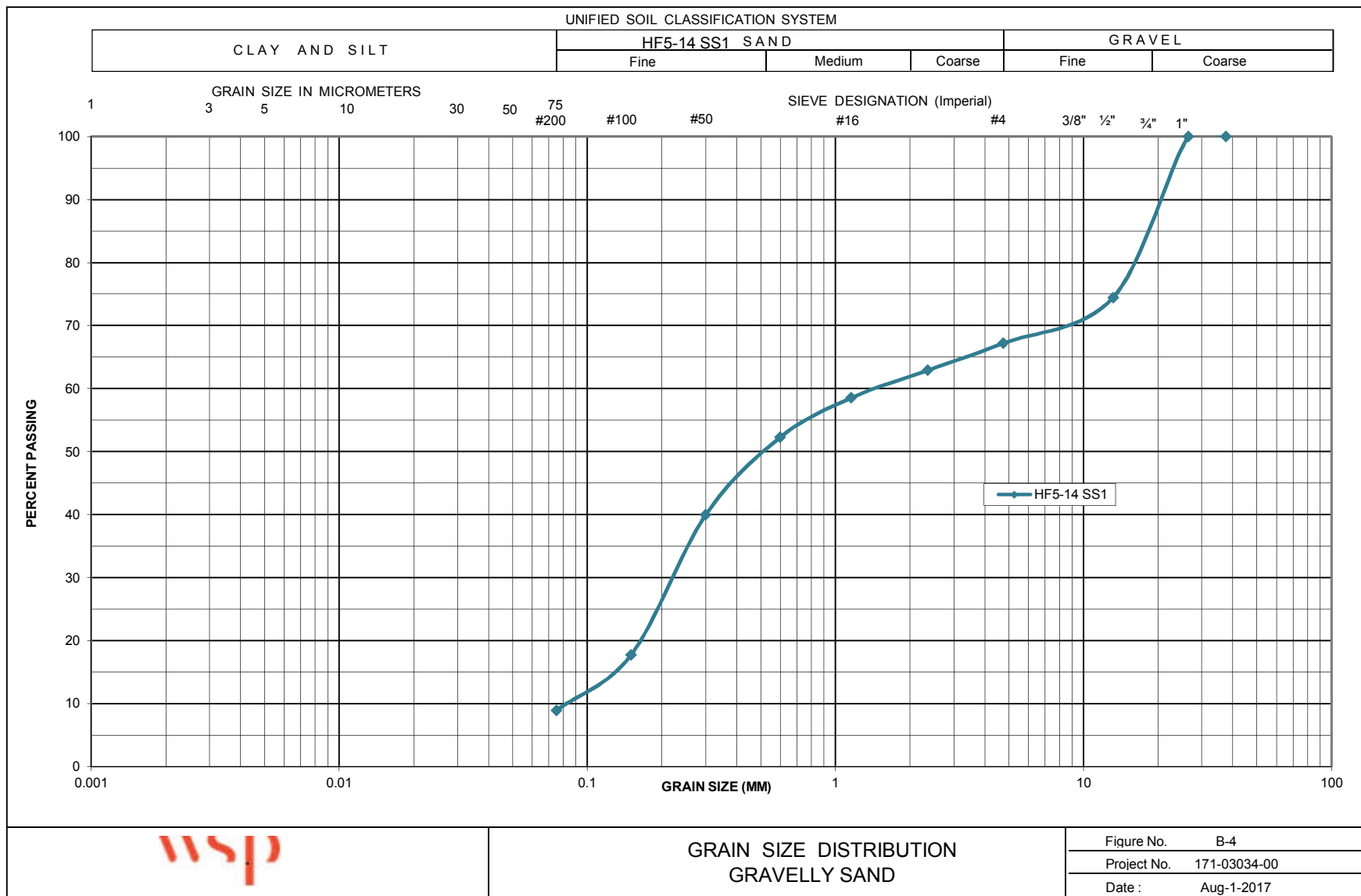
APPENDIX

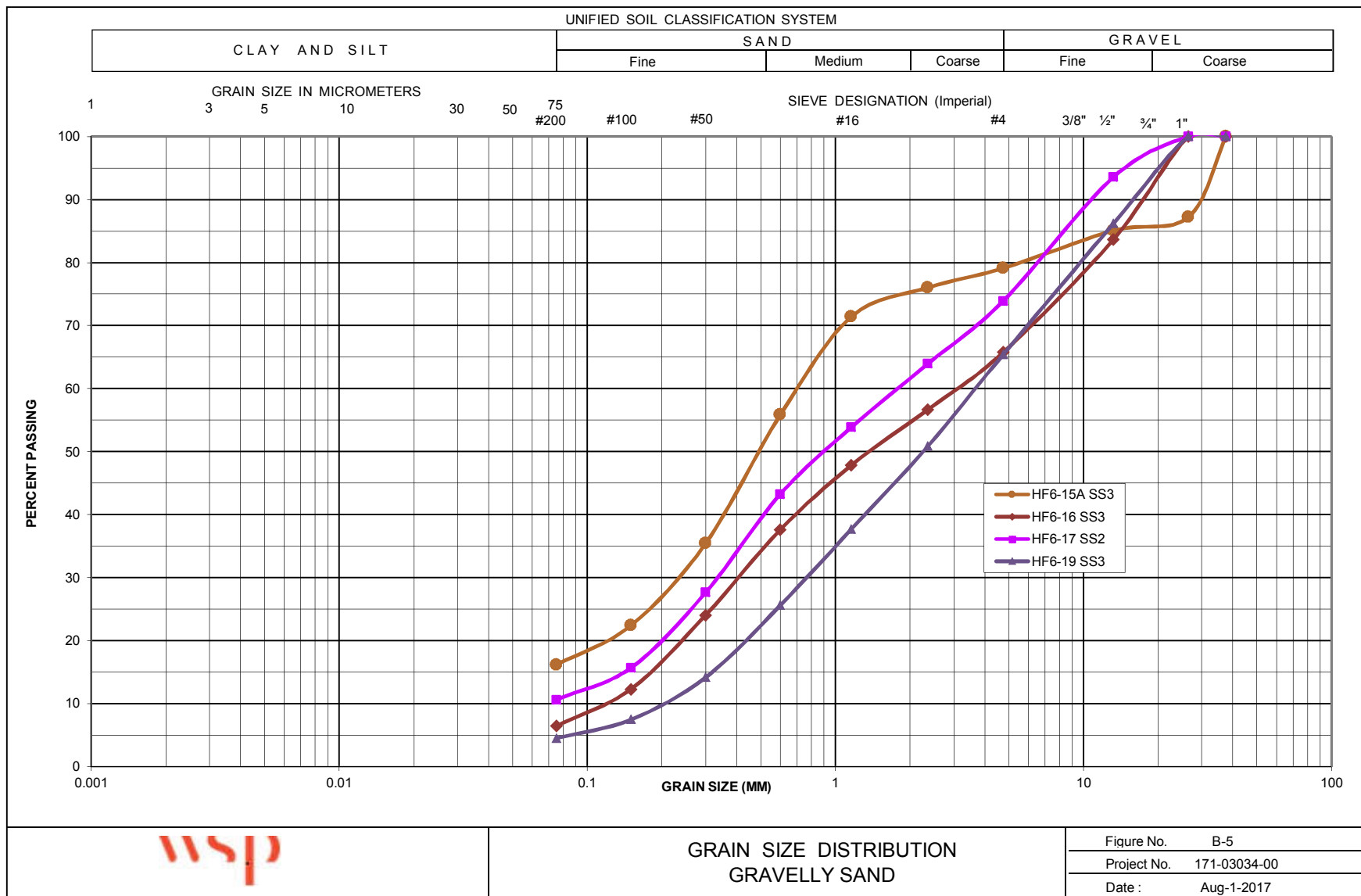
B LABORATORY TEST RESULTS

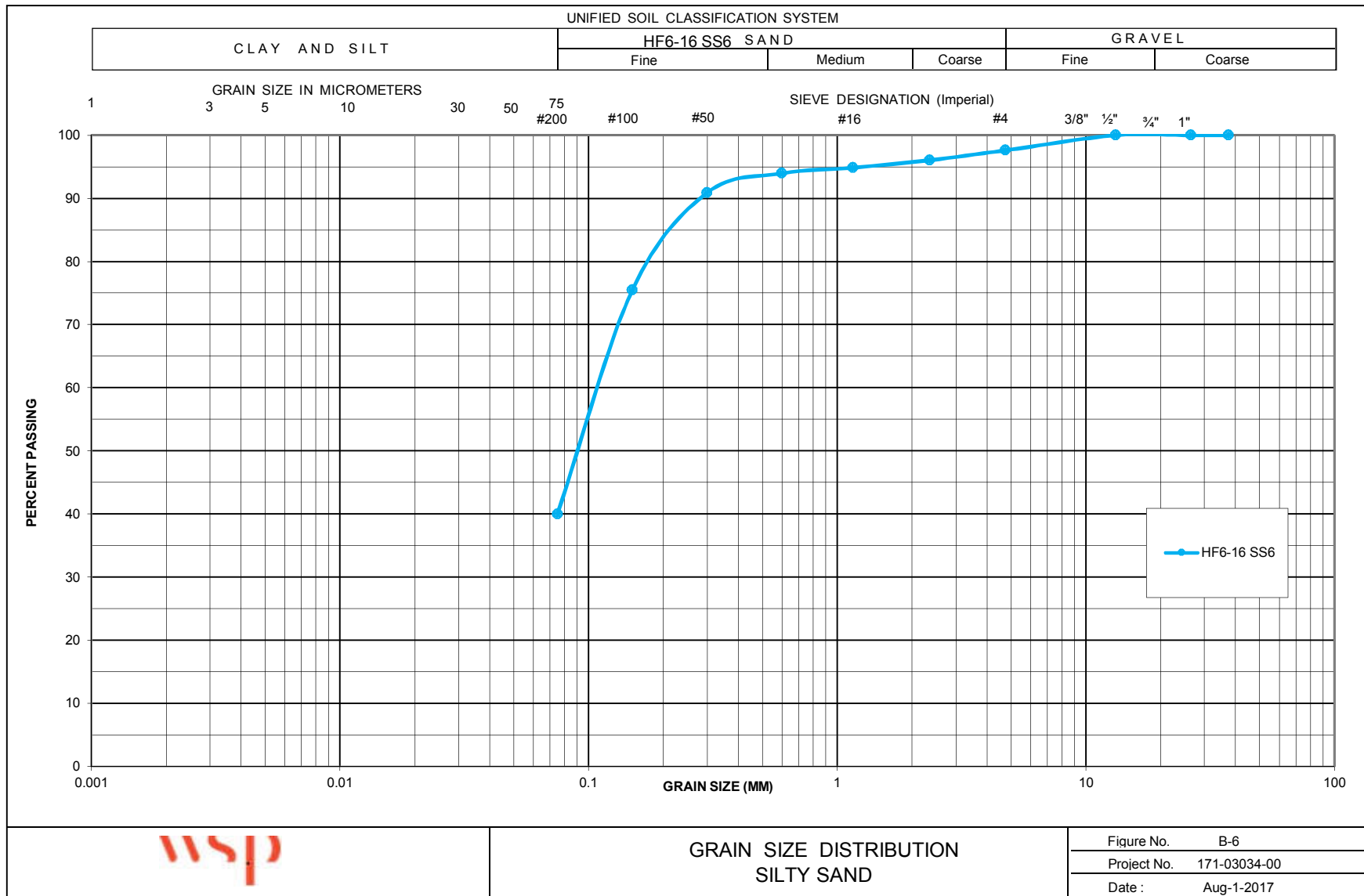


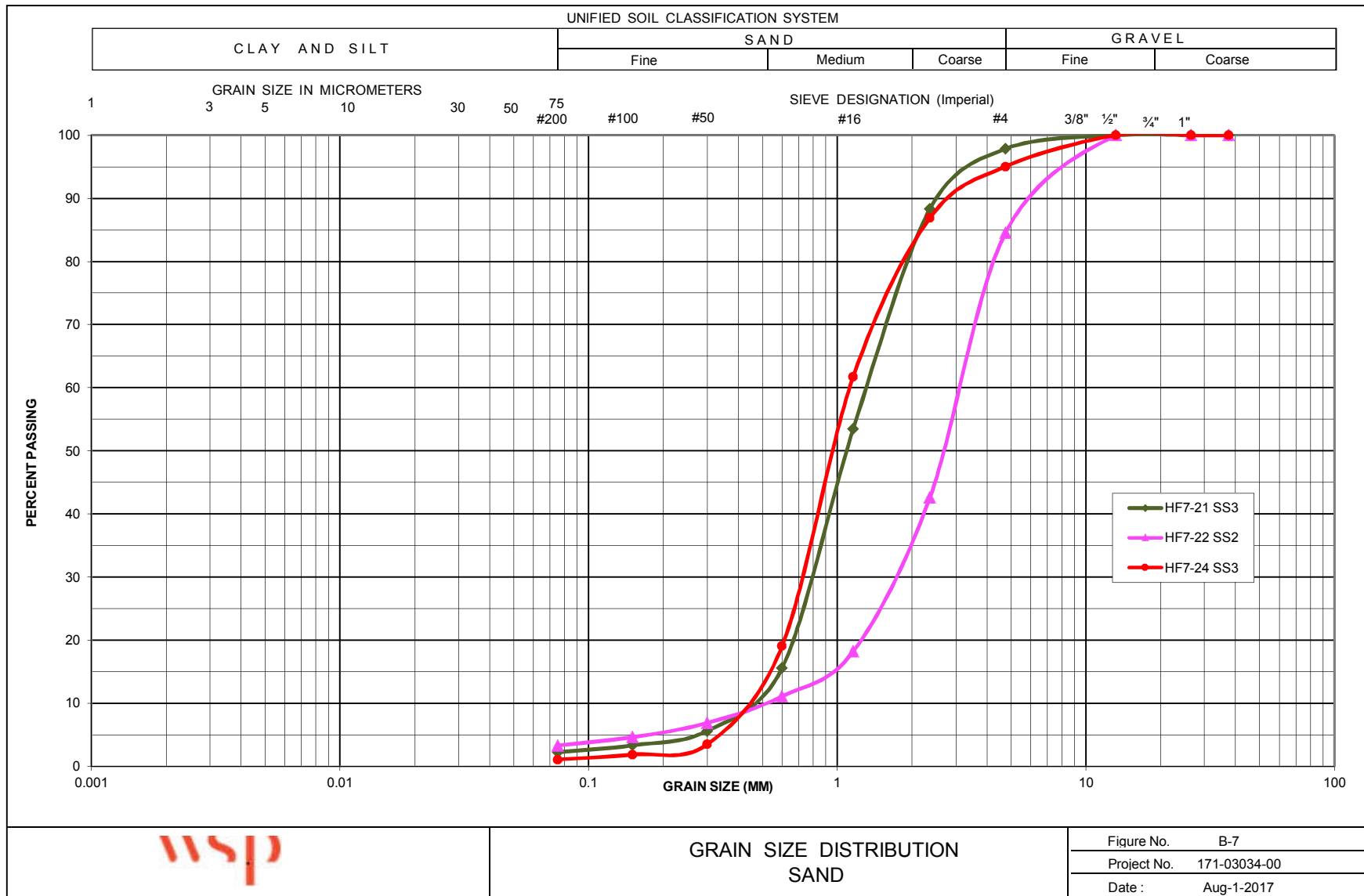


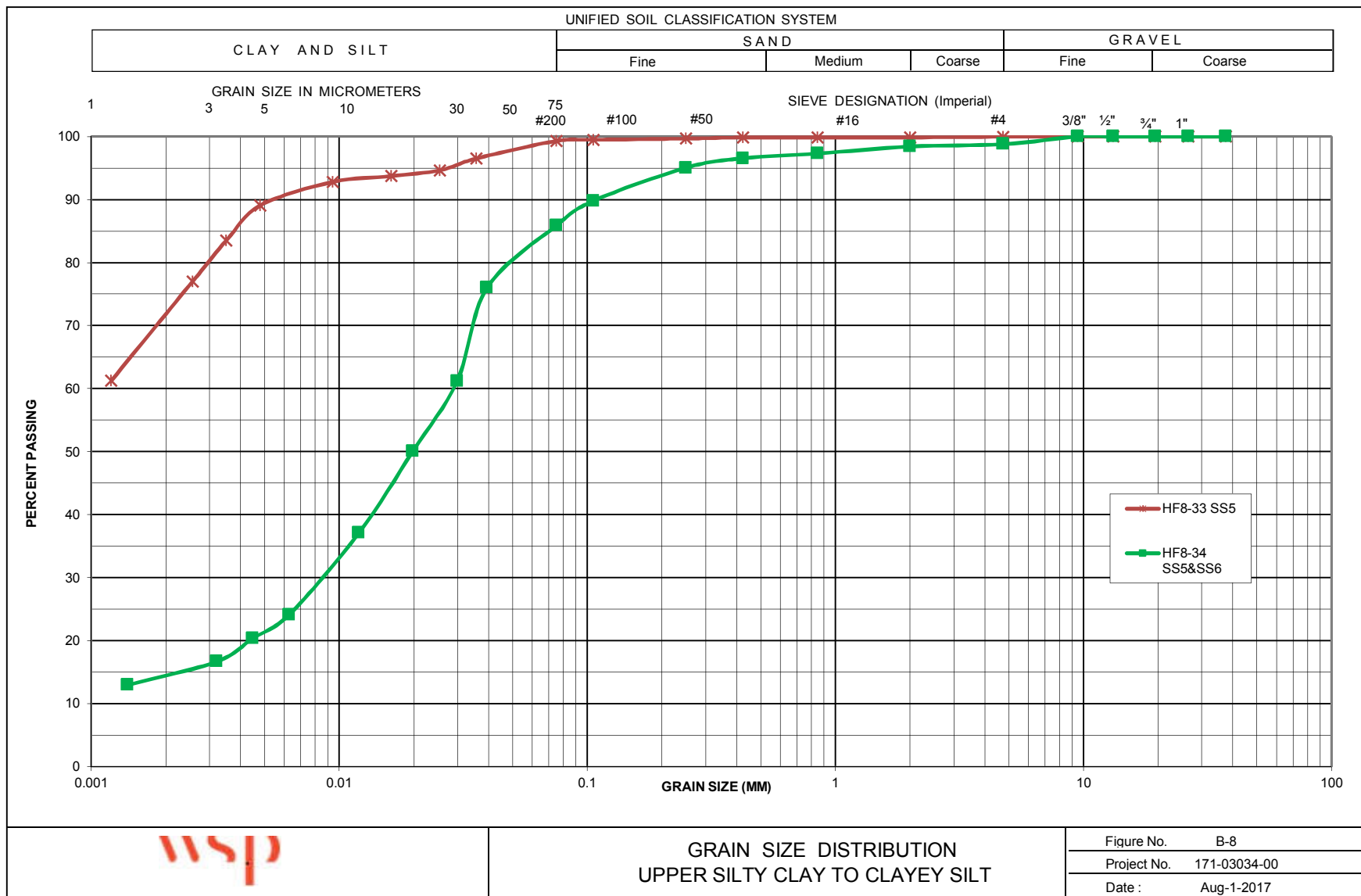


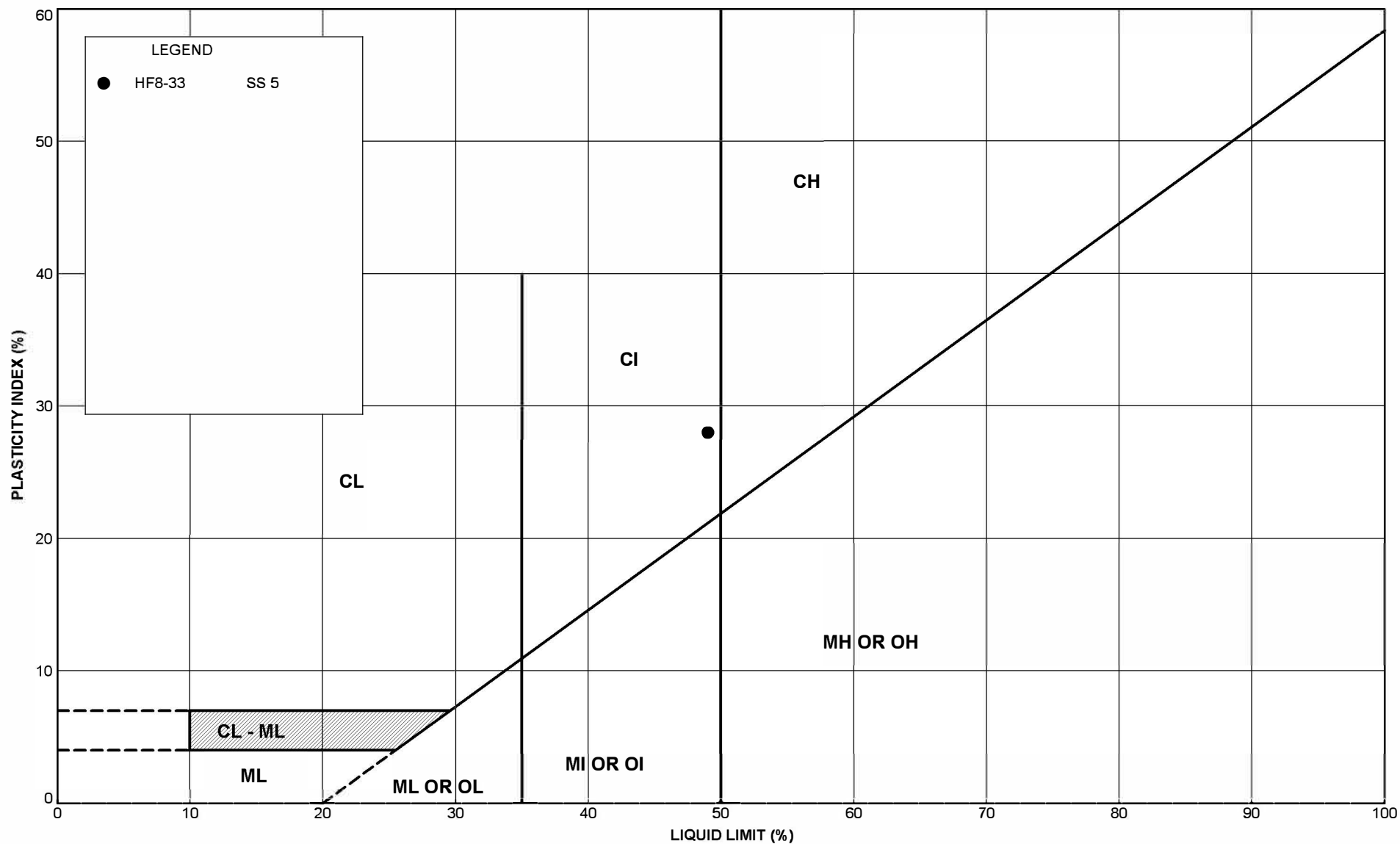






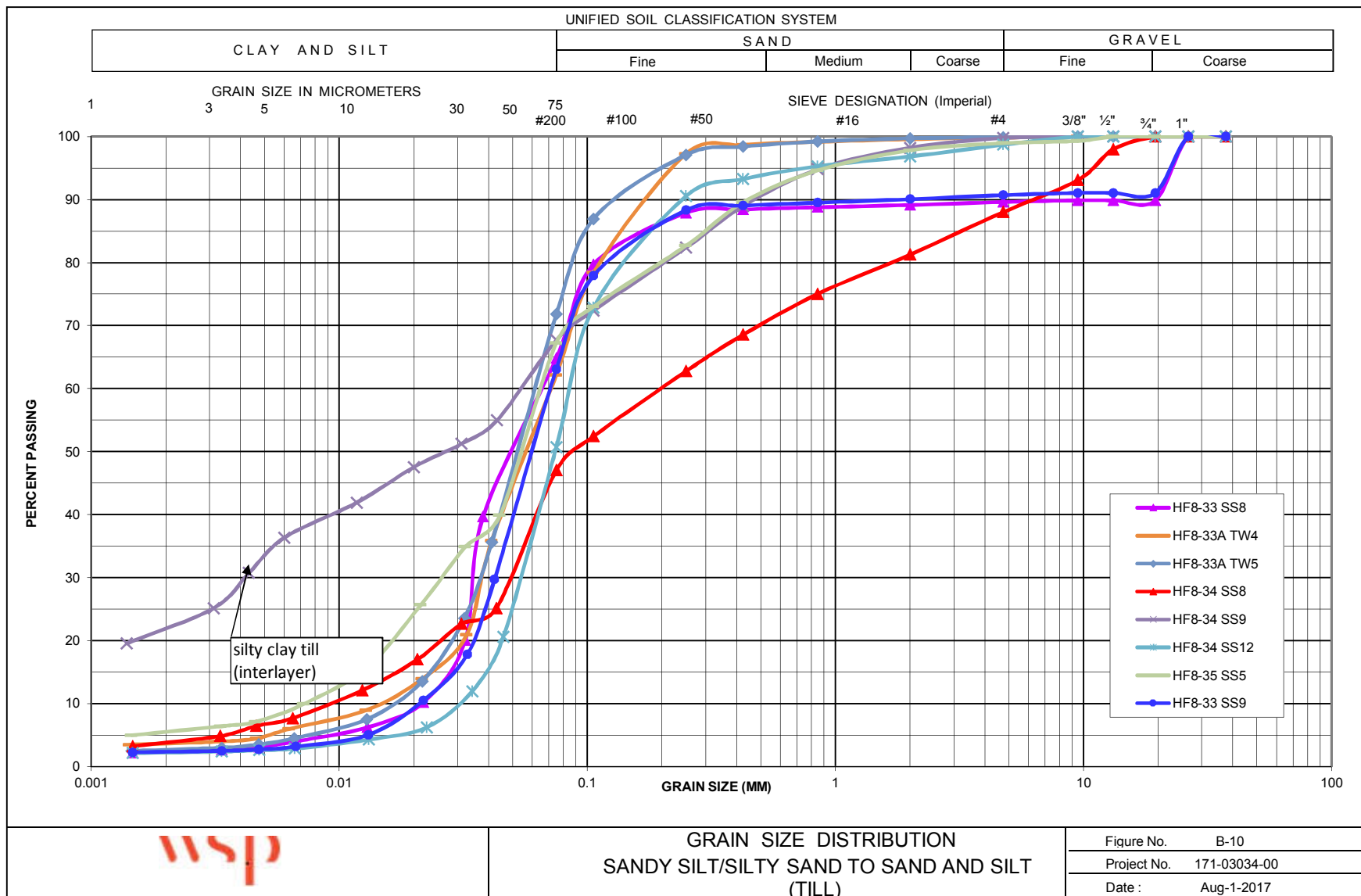


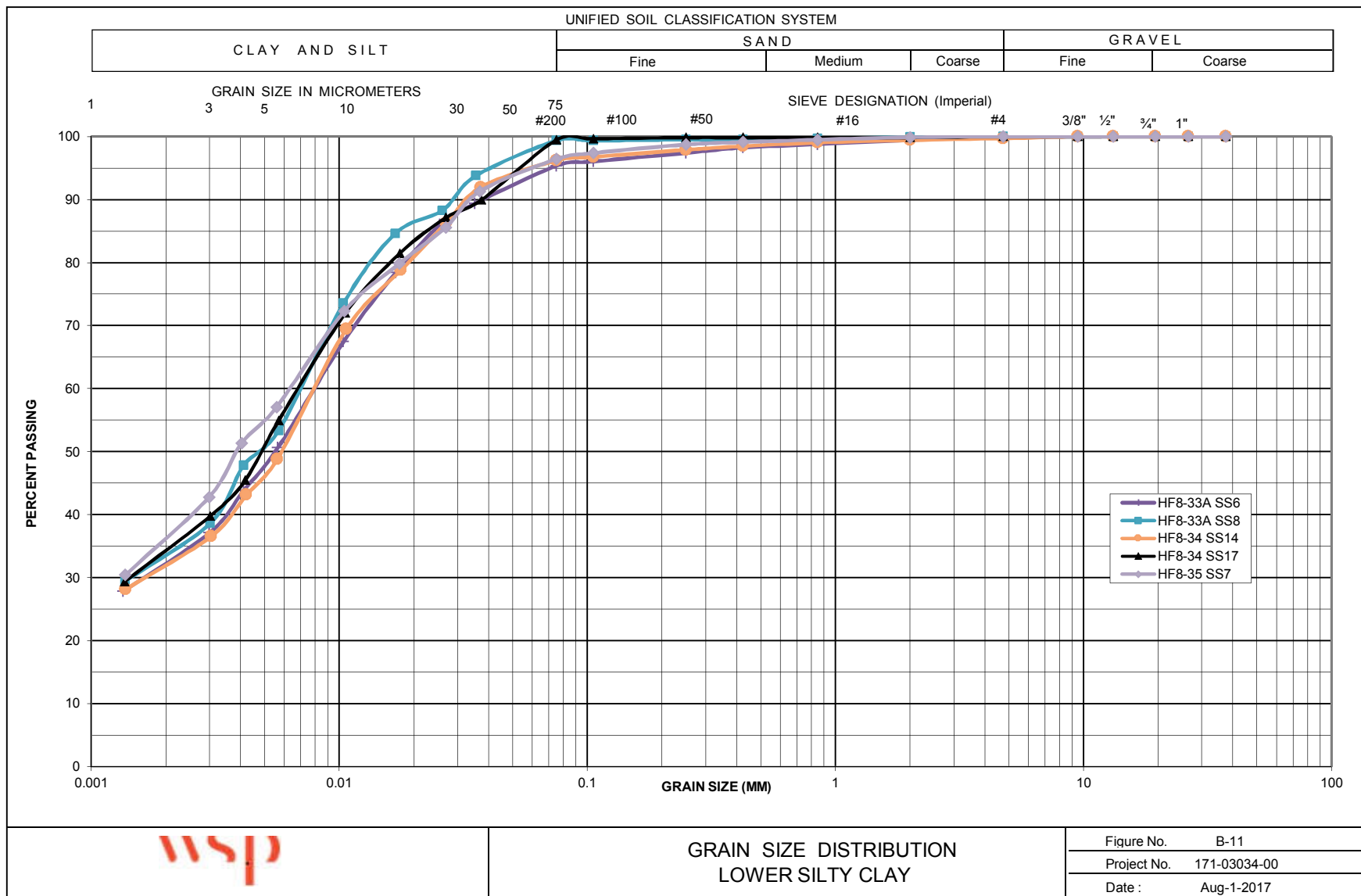


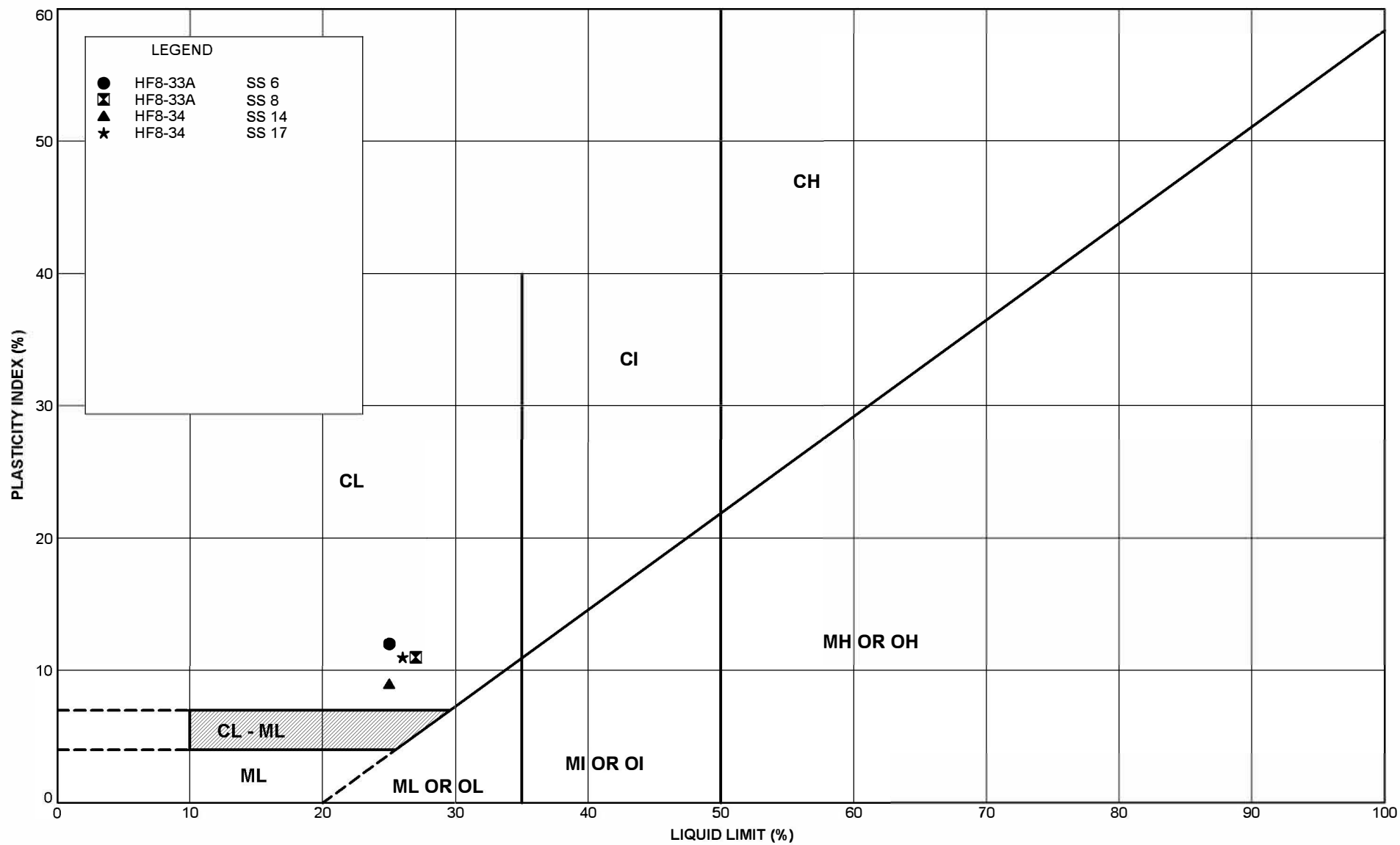


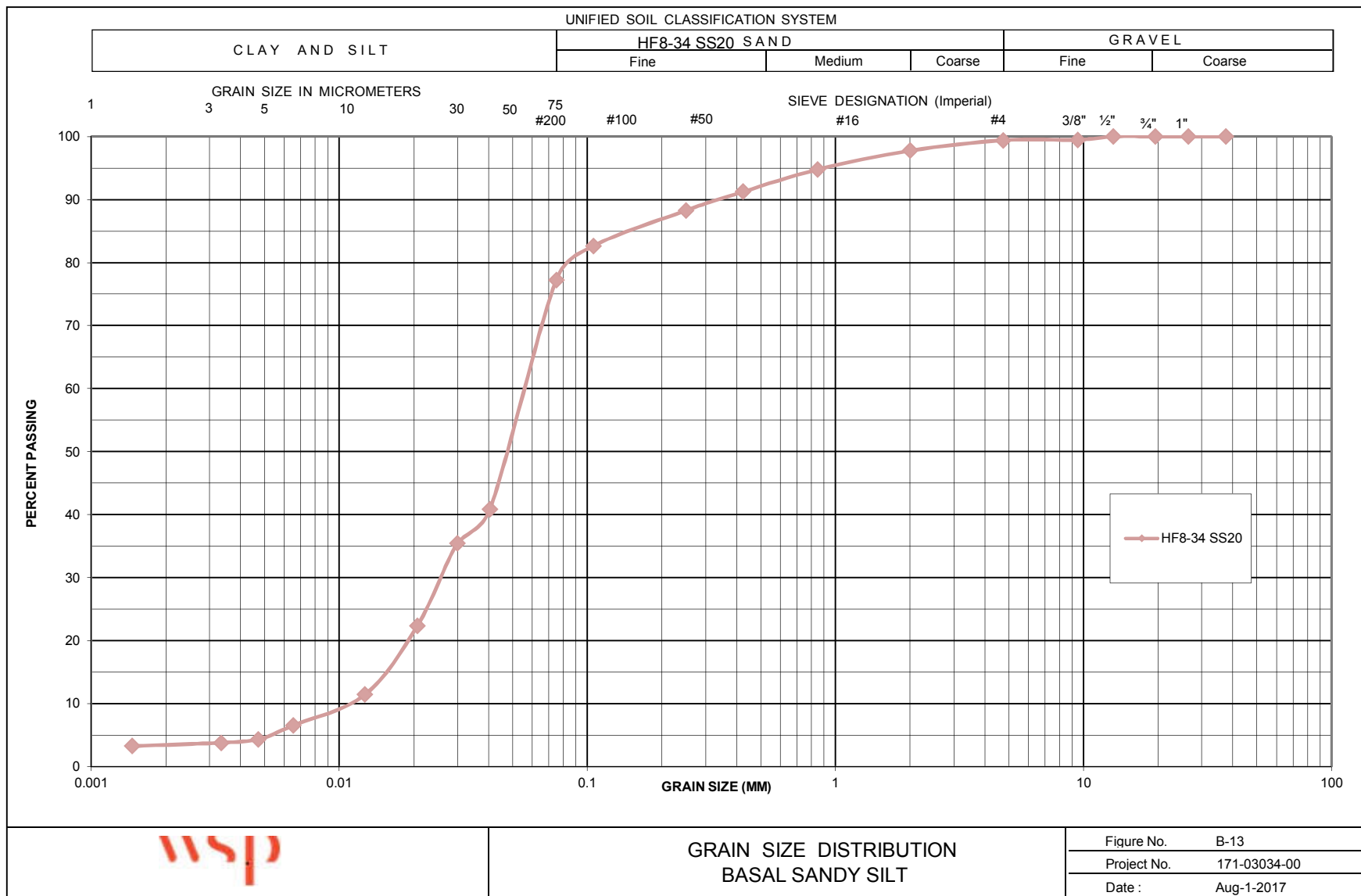
PLASTICITY CHART-UPPER SILTY CLAY

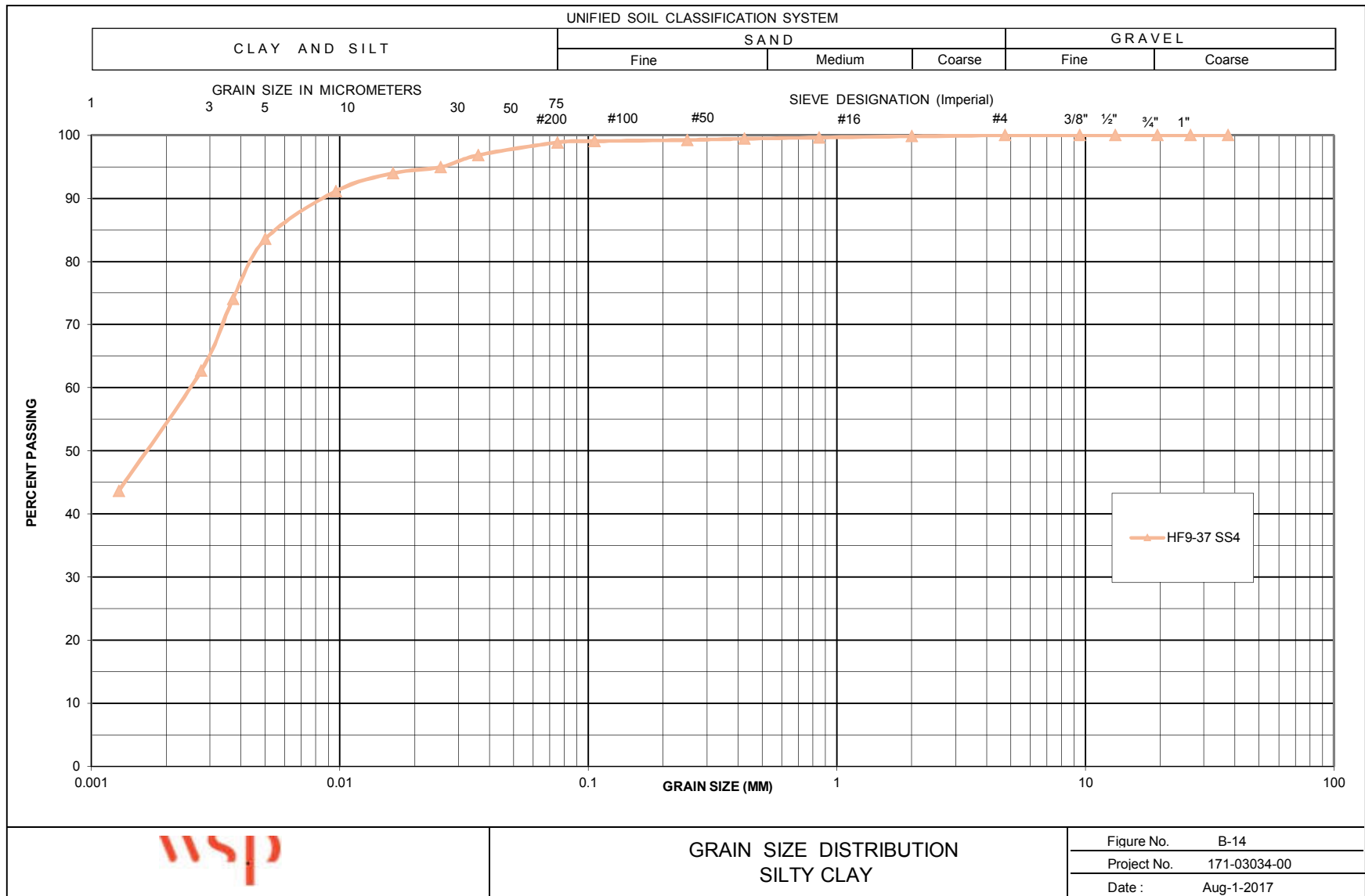
FIGURE NO.	B-9
JOB NO.	171-03034-00
DATE	August 2017

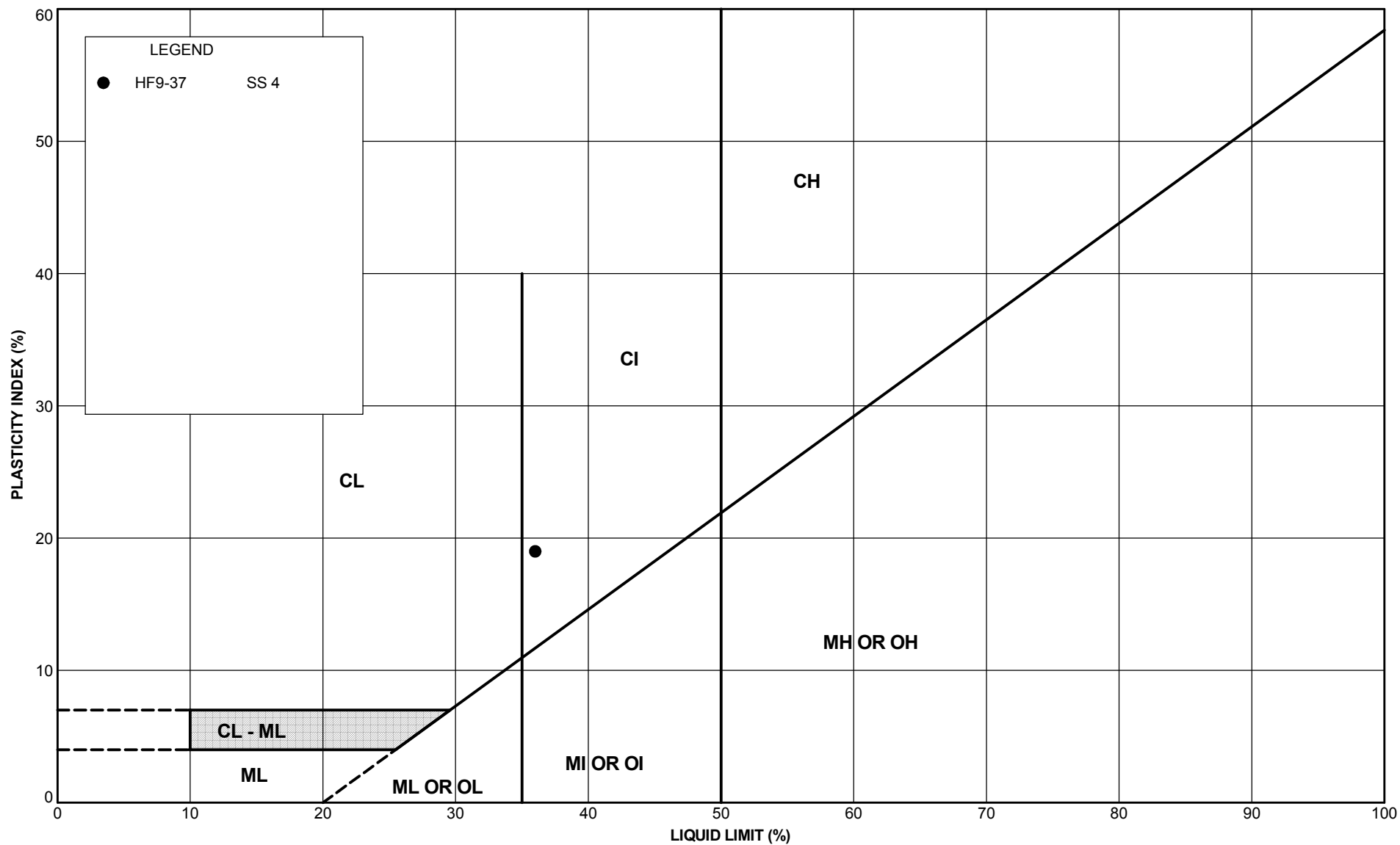












PLASTICITY CHART- SILTY CLAY

FIGURE NO.	B-15
JOB NO.	171-03034-00
DATE	August 2017



APPENDIX

B1-CONSOLIDATION AND TRIAXIAL TEST RESULTS

CONSOLIDATION TEST SUMMARY					FIGURE 1		
SAMPLE IDENTIFICATION							
Borehole No. : 33A				Sample No. :		ST - 7	
				Sample Depth (ft) :		30' - 32'	
TEST CONDITIONS							
Test Type : Laboratory Standard				Date Started :		08-Aug-17	
Load Duration (hr) : 24				Date Completed :		23-Aug-17	
SAMPLE DIMENSIONS AND PROPERTIES _ INITIAL							
Sample Height (mm) :		19.05		Unit Weight (kN/m ³) :		19.44	
Sample Diameter (mm) :		63.50		Dry Unit Weight (kN/m ³) :		15.20	
Area (cm ²) :		31.67		Specific Gravity :		2.715	
Volume (cm ³) :		60.33		Solid Height (mm) :		10.87	
Water Content (%) :		27.9%		Volume of Solids (cm ³) :		34.44	
Wet Mass (g) :		119.57		Volume of Voids (cm ³) :		25.89	
Dry Mass (g) :		93.50		Degree of Saturation (%) :		100.69	
TEST COMPUTATIONS							
Stress (kPa)	Initial Height (mm)	Final Height (mm)	Void Ratio	t ₉₀ (min)	C _v (cm ² /s)	m _v (m ² /kN)	k (cm/s)
1.6	19.05	19.05	0.752				
10.1	19.05	18.53	0.705	77.44	1.58E-04	3.17E-03	4.90E-08
19.8	18.534	18.28	0.681	43.56	2.72E-04	1.42E-03	3.79E-08
40.3	18.28	17.97	0.653	28.62	4.00E-04	8.29E-04	3.25E-08
80.4	17.97	17.62	0.621	16.00	6.88E-04	4.87E-04	3.29E-08
160.2	17.62	17.21	0.583	12.25	8.58E-04	2.92E-04	2.46E-08
130	17.21	17.21	0.583				
100.2	17.21	17.21	0.583				
70.1	17.21	17.21	0.583				
100.2	17.21	17.21	0.583				
130	17.21	17.21	0.583				
160.2	17.21	17.15	0.577	6.25	1.66E-03	1.24E-04	2.02E-08
300.0	17.15	16.75	0.540	7.56	1.32E-03	1.69E-04	2.18E-08
639.9	16.75	16.16	0.486	6.25	1.49E-03	1.04E-04	1.51E-08
1279.6	16.16	15.65	0.439	5.06	1.72E-03	4.92E-05	8.31E-09
321.1	15.65	15.66	0.441				
81.4	15.66	15.76	0.450				
21.5	15.764	15.98	0.470				
SAMPLE DIMENSIONS AND PROPERTIES _ FINAL							
Sample Height (mm) :		15.65		Unit Weight (kN/m ³) :		22.02	
Sample Diameter (mm) :		63.50		Dry Unit Weight (kN/m ³) :		18.27	
Area (cm ²) :		31.67		Specific Gravity :		2.715	
Volume (cm ³) :		49.56		Solid Height (mm) :		10.87	
Water Content (%) :		20.5%		Volume of Solids (cm ³) :		34.01	
Wet Mass (g) :		111.31		Volume of Voids (cm ³) :		15.55	
Dry Mass (g) :		92.34					
					Performed By :		DP
Project No. : 1-17-0607					Prepared By :		SD
Date : August 2017					Checked By :		RA



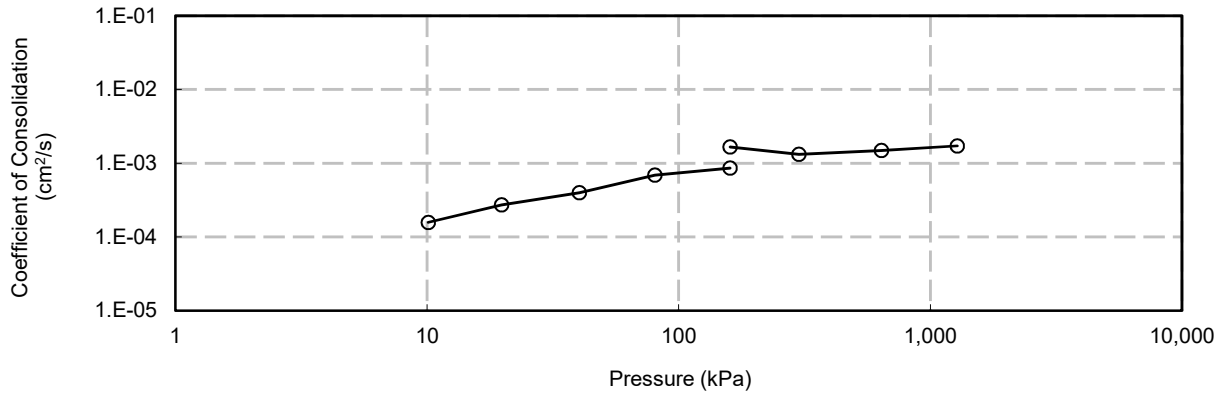
Terraprobe Inc.

CONSOLIDATION TEST

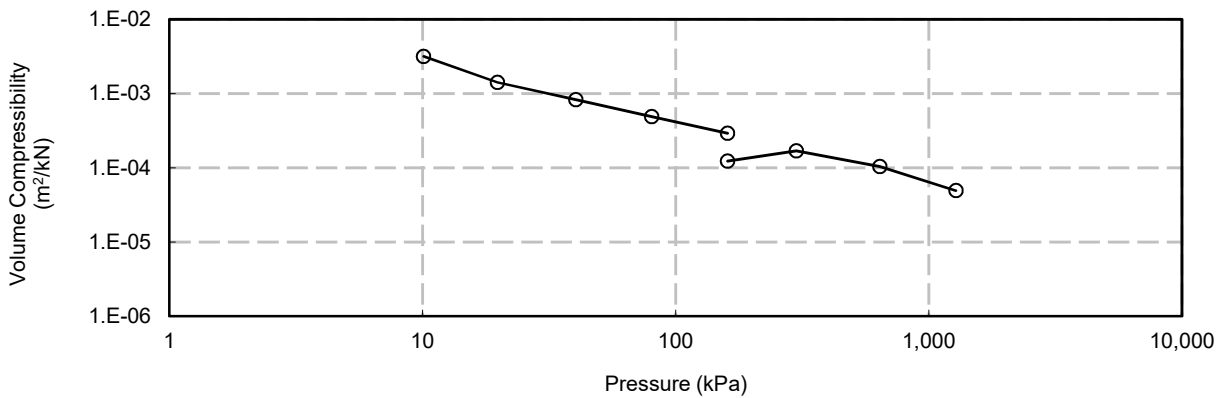
FIGURE 2

Site: Hwy 17-Pays Plat Hill
Sample #: ST - 7

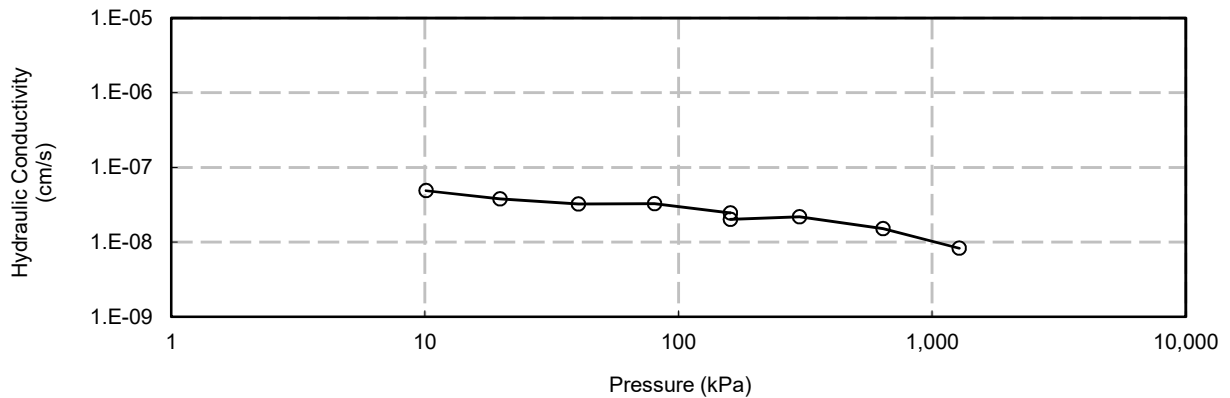
C_v vs Pressure



m_v vs Pressure



k vs Pressure



Project No.: 1-17-0607
Date: August 2017

 **Terraprobe Inc.**

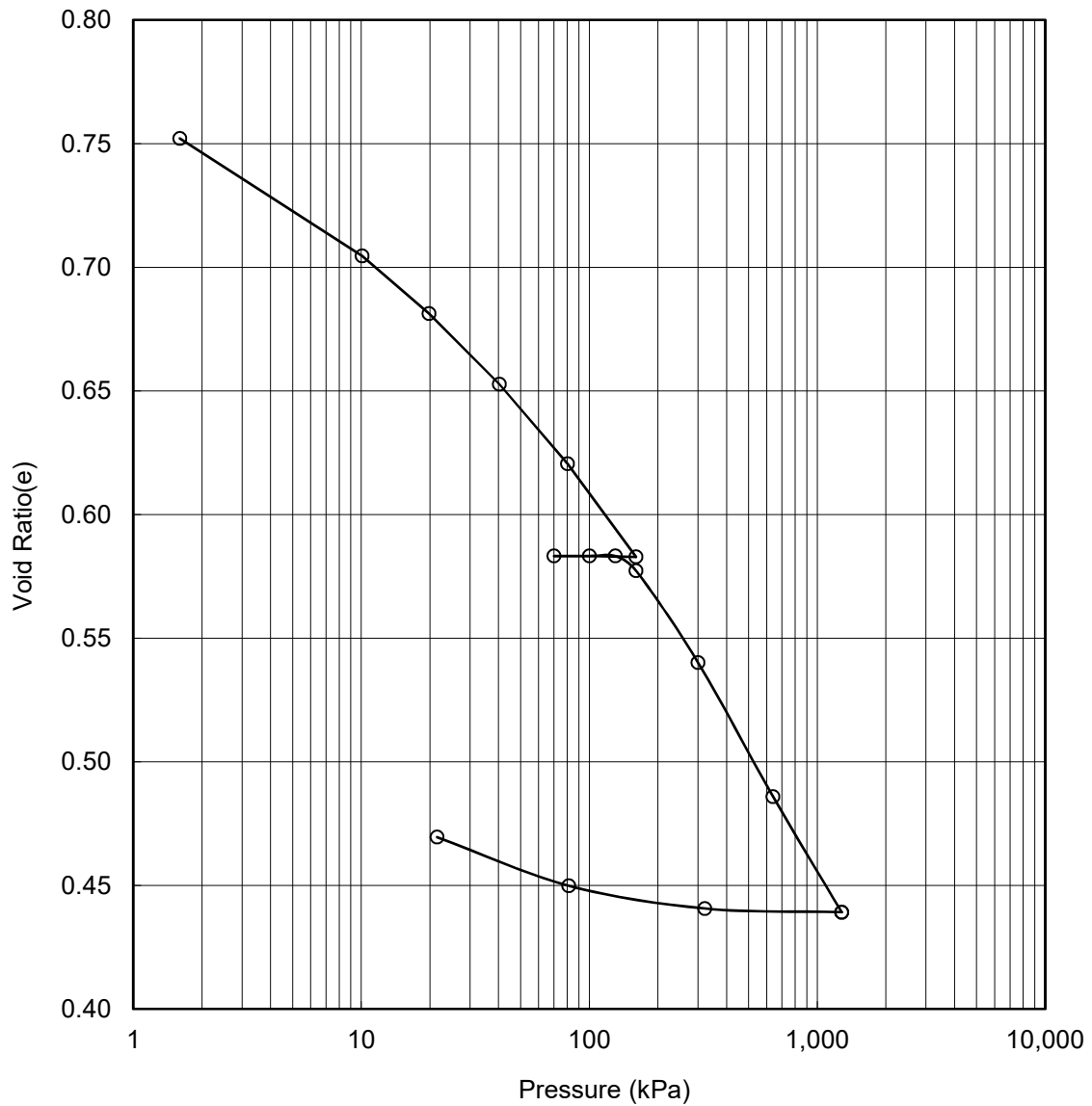
Performed By: DP
Prepared By: SD
Checked By: RA

CONSOLIDATION TEST

FIGURE 3

Site: Hwy 17-Pays Plat Hill
Sample # : ST - 7

Void Ratio vs Pressure



$e_o = 0.752$
 $\omega = 27.9\%$

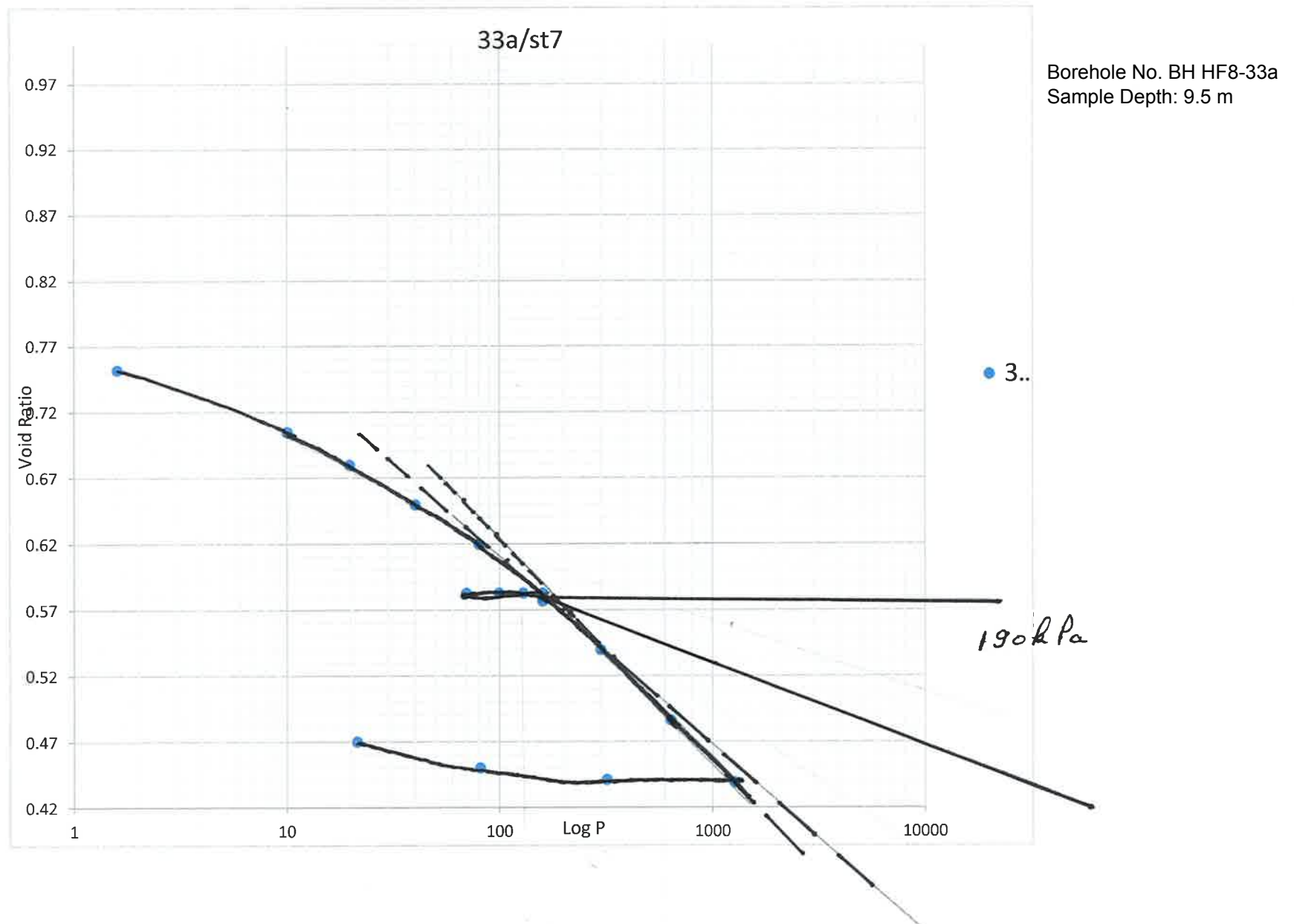
$\gamma = 19.44 \text{ kN/m}^3$
 $G_s = 2.715$

Project No. : 1-17-0607
Date : August 2017



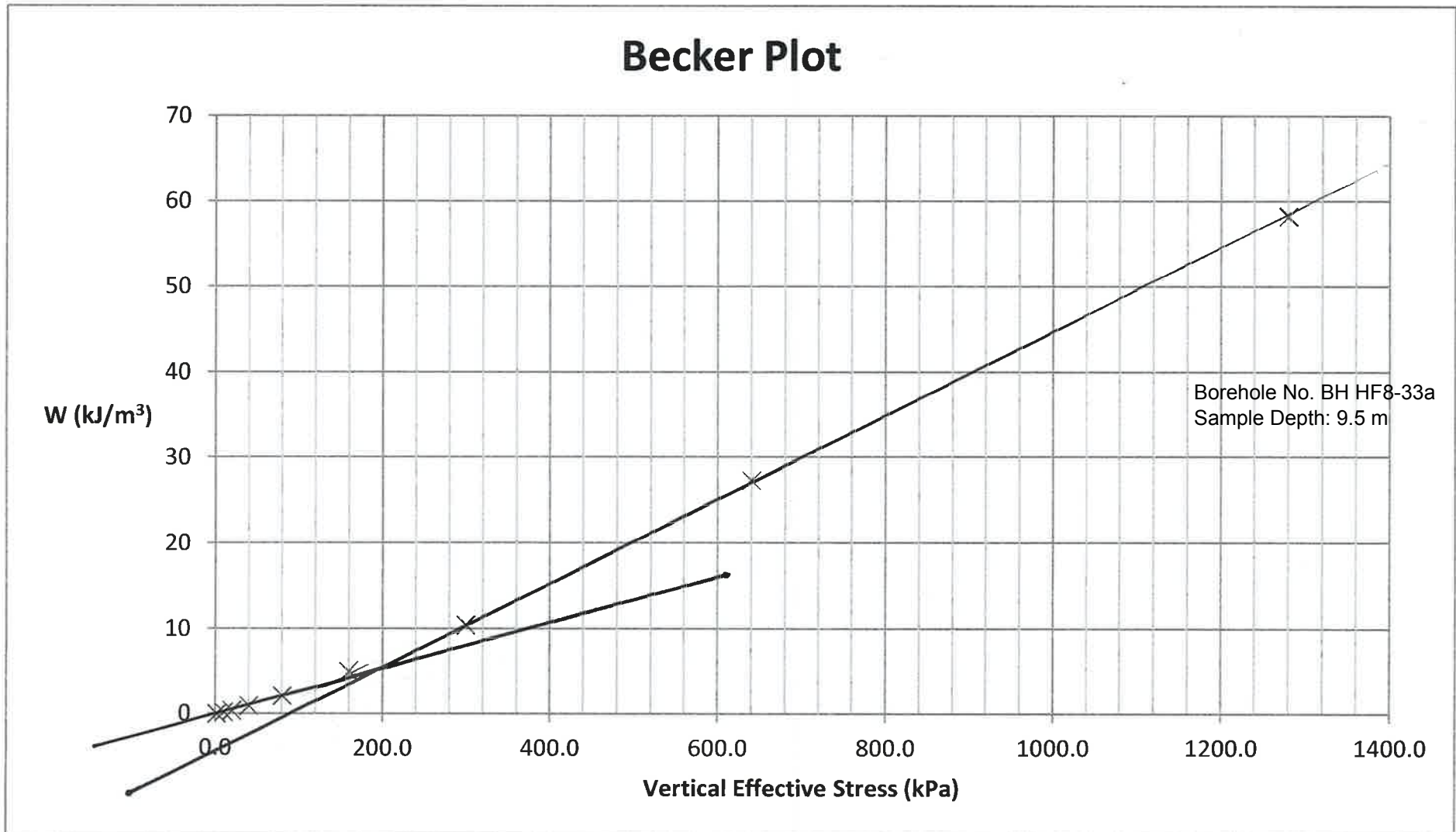
Performed By : DP
Prepared By : SD
Checked By : RA

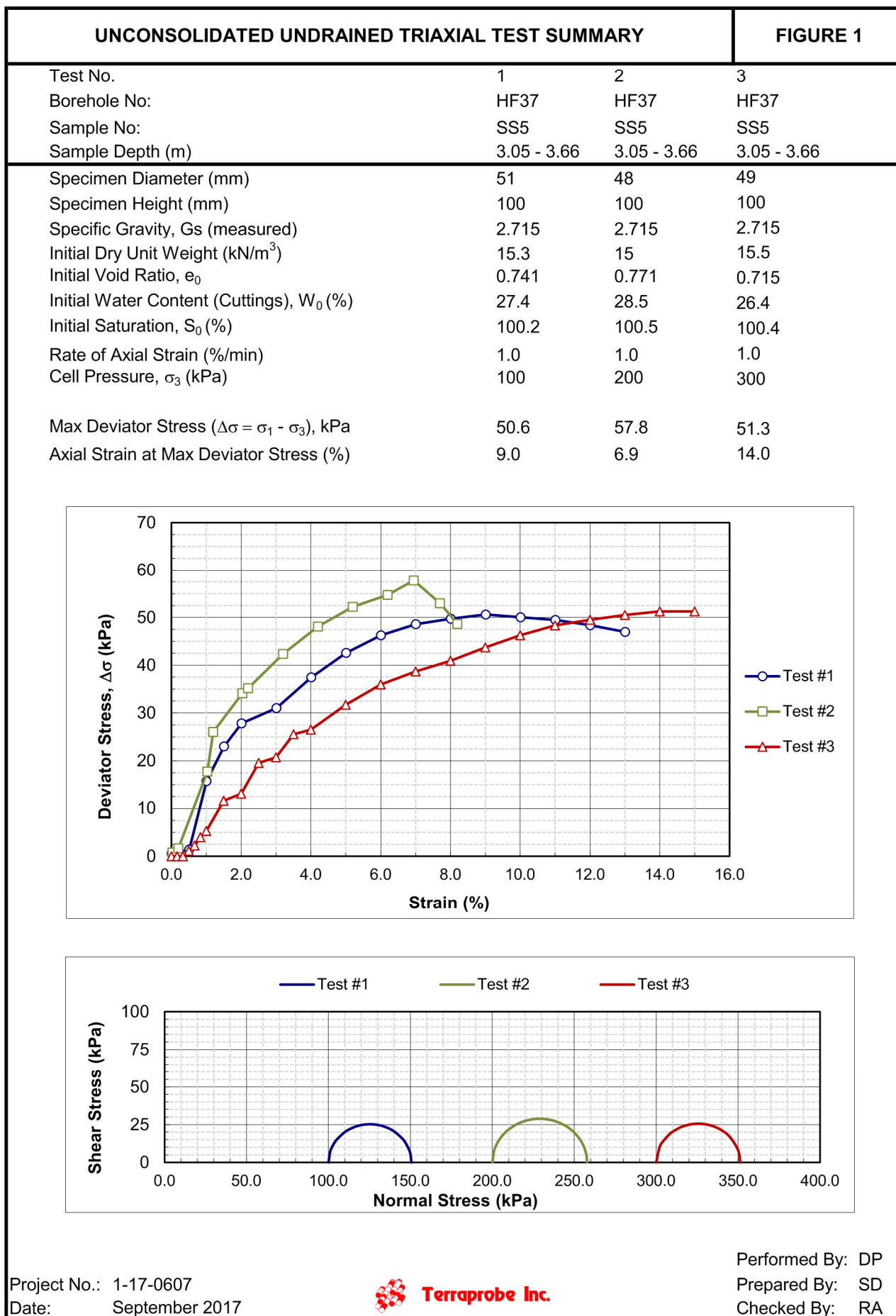
Preconsolidation Pressure by Casagrande Method

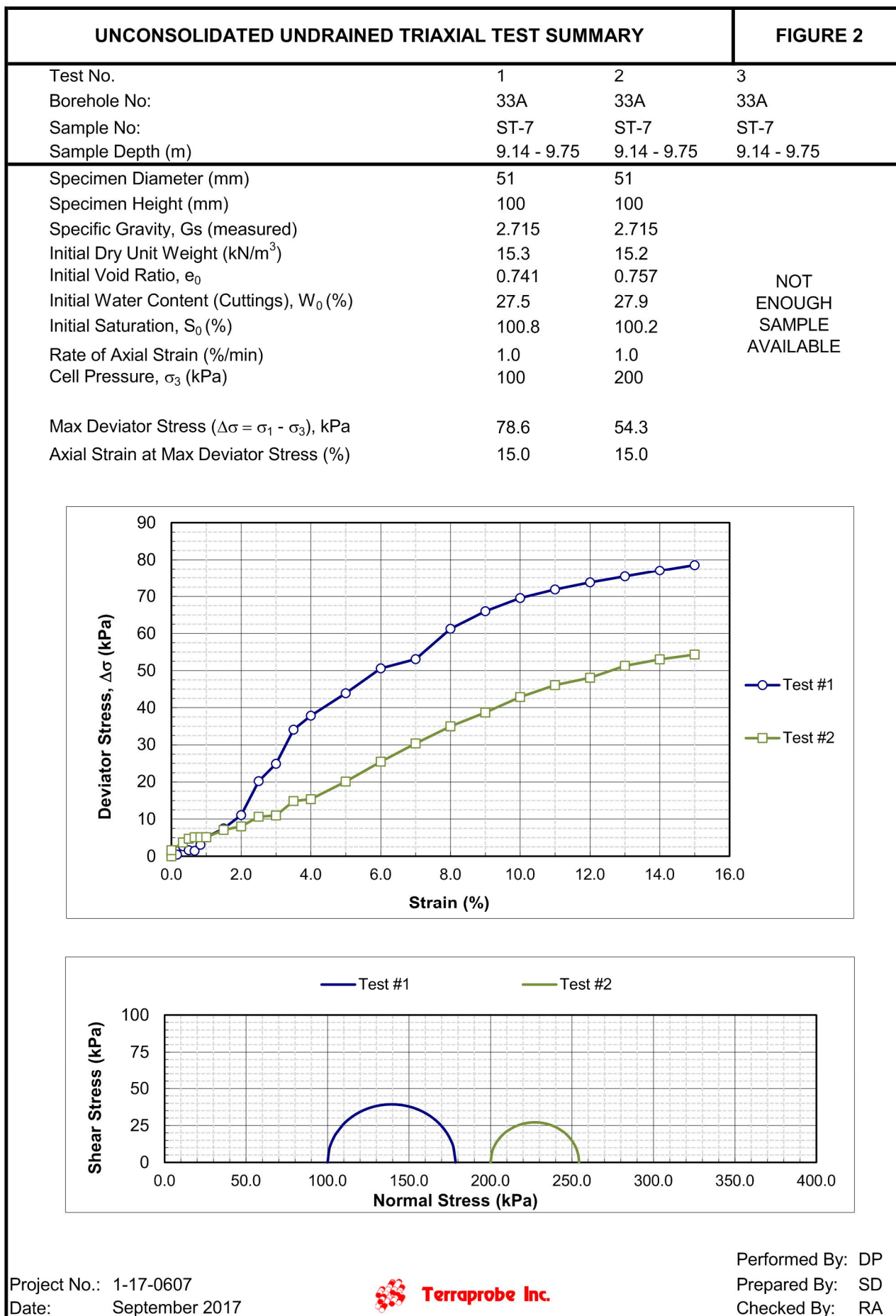


Preconsolidation Pressure by Becker Method

Becker Plot







APPENDIX

C SITE PHOTOGRAPHS

High Fill Section 1- Yesno Twp. (Sta. 14+000 to 14+100)

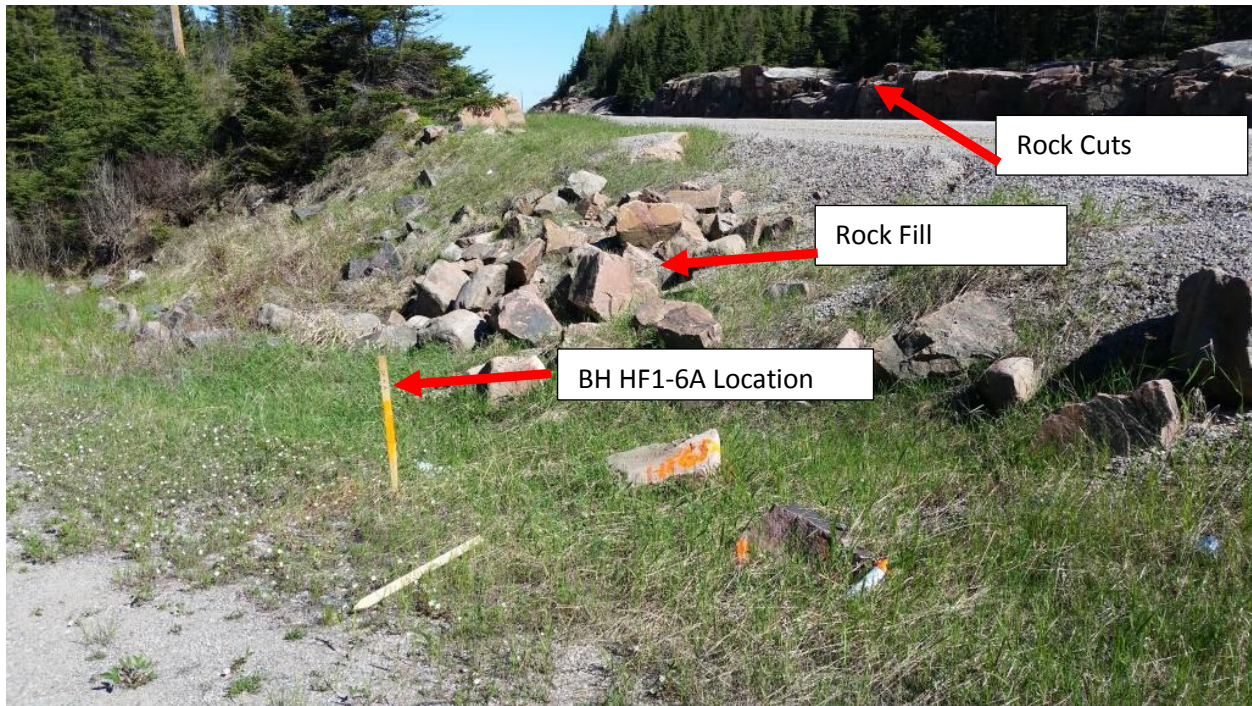


Photo 1-1: Facing towards East - Rock Fill, Rock Cuts and BH HF1-6A (June 2017)



Photo 1- 2: Looking Toward East – Rock Fill (June 2017)



Photo 1-3: Looking toward east- Road leading to a recreational site (June 2017)



Photo 1-4 : Looking toward north –Road leading to a recreational site (April 2017)



Photo 1-5: Looking Toward West -BH HF1-6 (June 2017)

High Fill Section 2- Yesno Twp. (Sta. 14+230 to 14+390)



Photo 2-1: Looking toward east - Rock Fill/Boulders and Rock Outcrops (June 2017)



Photo 2-2: Looking toward east - Side Road Abutting (June 2017)

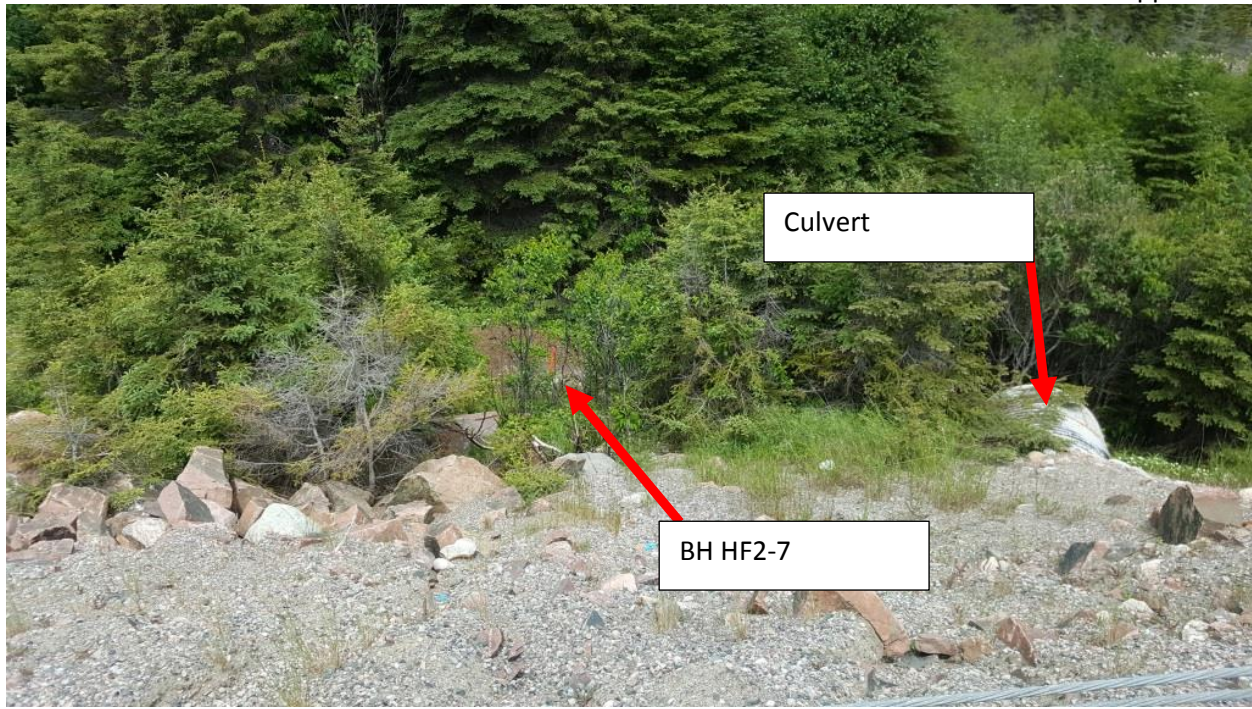


Photo 2-3 : Looking toward north – Culvert at Sta.14+230 and BH HF2-7 (June 2017)



Photo 2-4: Looking toward north– BH HF2-7B (June 2017)

High Fill Section 3- Yesno Twp. (Sta. 14+580 to 14+700) / Culvert at Sta. 14+638



Photo 3-1: Looking toward east - Rock Outcrops (June 2017)



Photo 3-2: Looking toward embankment face- Rock Fill (April 2017)



Photo 3-3: Looking toward west- TP HF3-10 (April 2017)



Photo 3-4: Looking toward west- TP HF3-8 (April 2017)

High Fill Section 4- Yesno Twp. (Sta. 15+120 to 15+160)



Photo 4-1: Looking toward east – Rock Outcrops (June 2017)



Photo 4-2: Looking toward east – BH HF4-11A (June 2017)



Photo 4-3: Looking toward east – Rock Fill (June 2017)



Photo 4-4: Looking toward north – BH HF4-11 (June 2017)

High Fill Section 5- Yesno Twp. (Sta. 15+120 to 15+160)



Photo 5-1: Looking toward west - TP HF5-12 (June 2017)

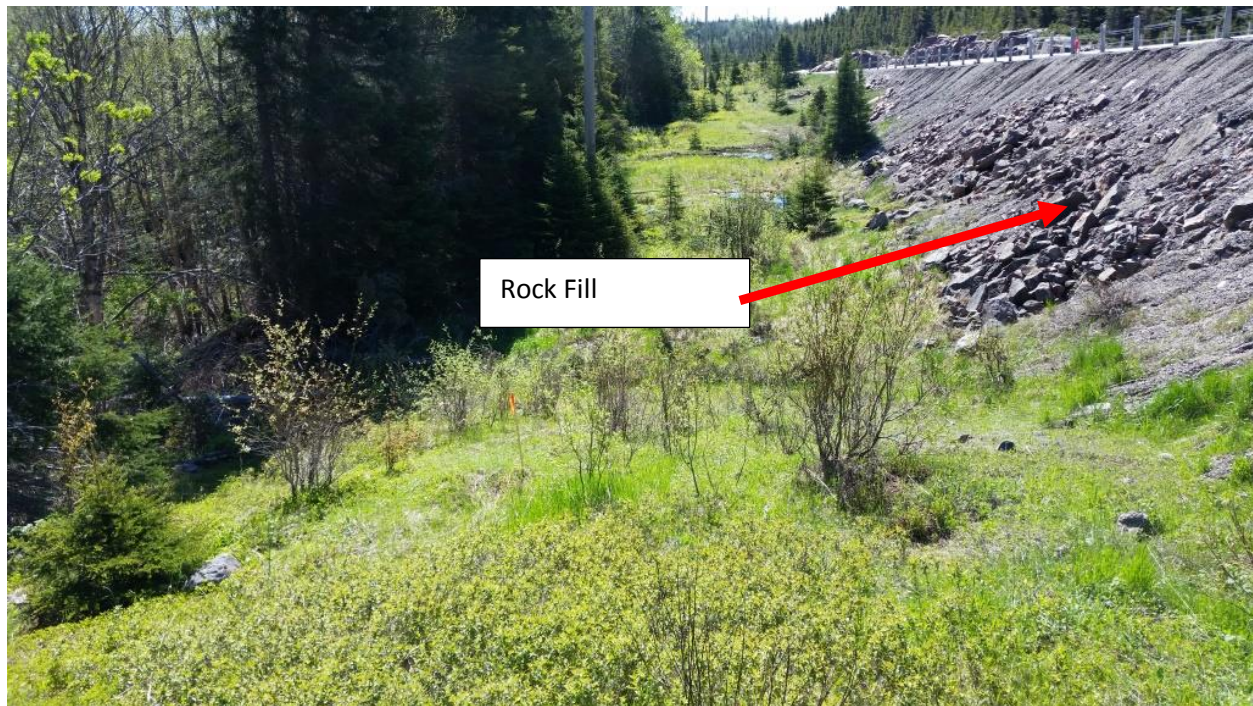


Photo 5-2: Looking toward east – Rock Fill (June 2017)



Photo 5-3: Looking toward east – Standing Water (June 2017)



Photo 5-4: Looking toward west - BH HF5-14 (June 2017)

High Fill Section 6- Yesno Twp. (Sta. 15+420 to 15+620) / Culvert at Sta. 15+575



Photo 6-1: Looking toward west - Rock Fill (April 2017)

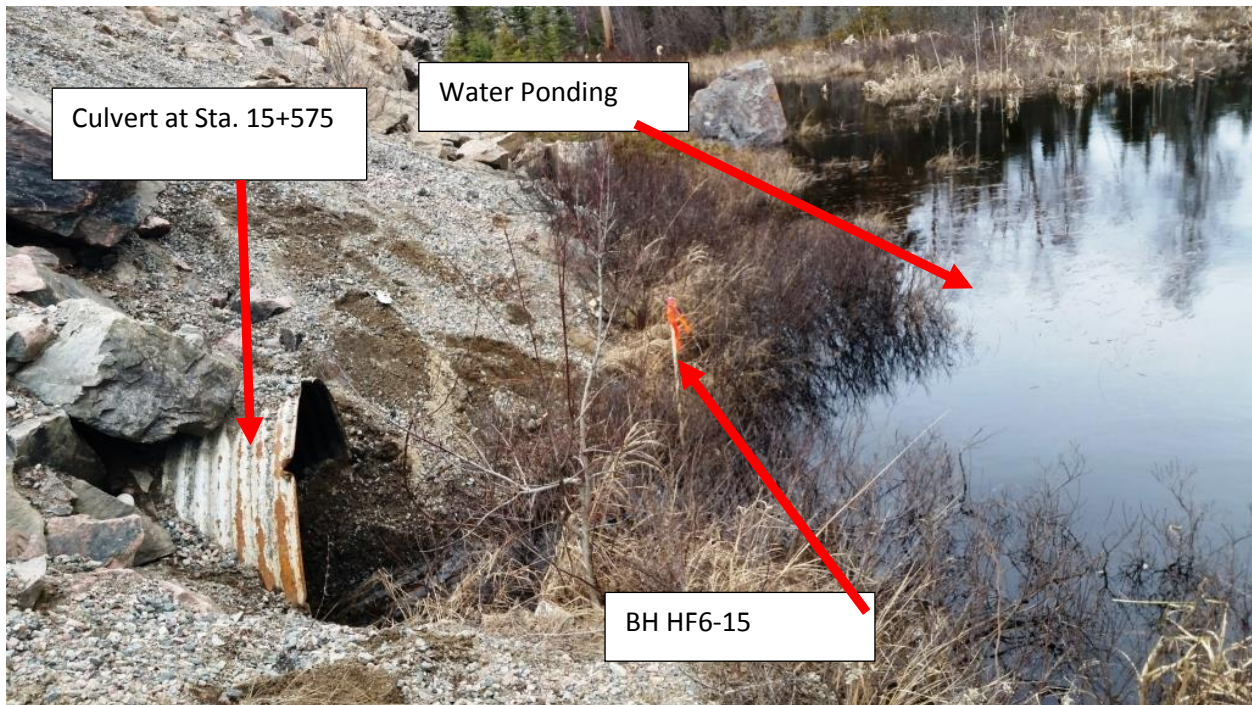


Photo: 6-2: Looking toward west - Culvert and Water ponding (April 2017)



Photo 6-3: Looking toward west – Culvert (June 2017)



Photo 6-4: Looking toward west - BH HF6-15A (June 2017)

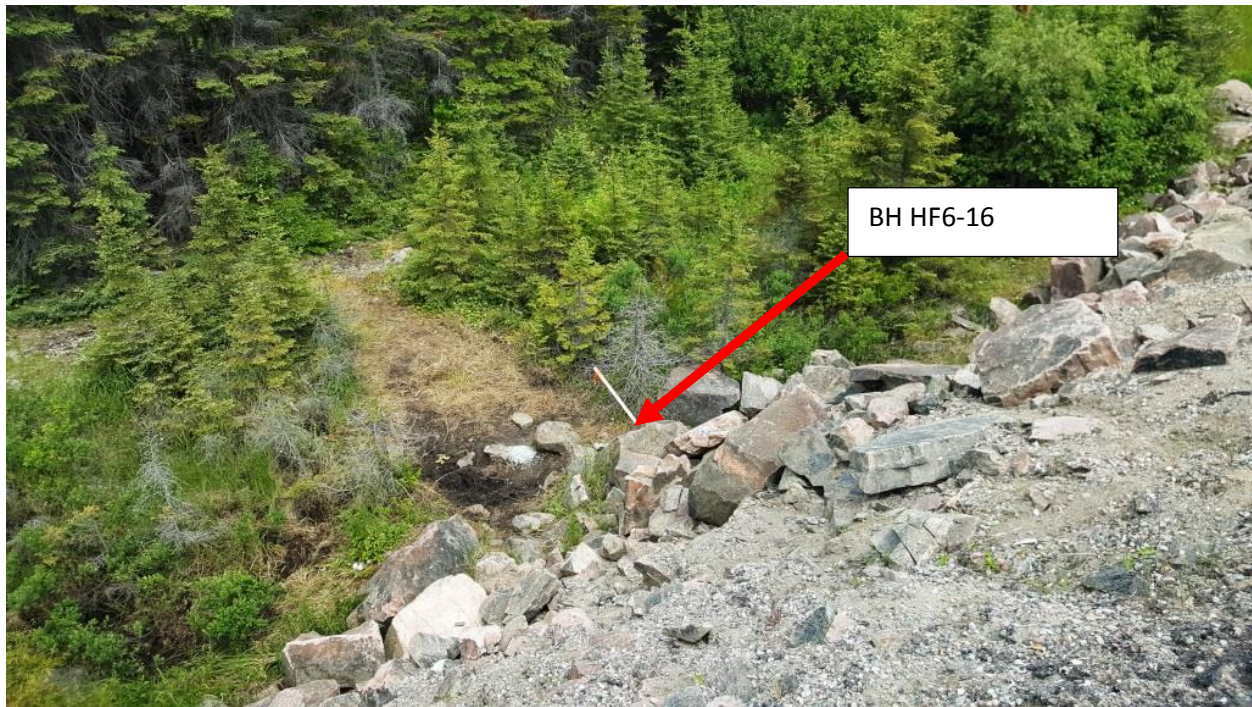


Photo 6-5: Looking toward north - BH HF6-16 (June 2017)



Photo 6-6: Looking toward north - BH HF6-17 (June 2017)



Photo 6-7: Looking toward north - BH HF6-18 (June 2017)



Photo 6-8: Looking toward east - BH HF6-19 (June 2017)

High Fill Section 7- Yesno Twp. (Sta. 10+460 to 11+110) / Culvert at Sta. 10+655



Photo 7-1: Looking toward east - Rock Outcrops (April 2017)



Photo 7-2: Looking toward east - Rock Outcrops (April 2017)



Photo 7-3: Looking toward east - Rock Outcrops and Undulating Ground (April 2017)

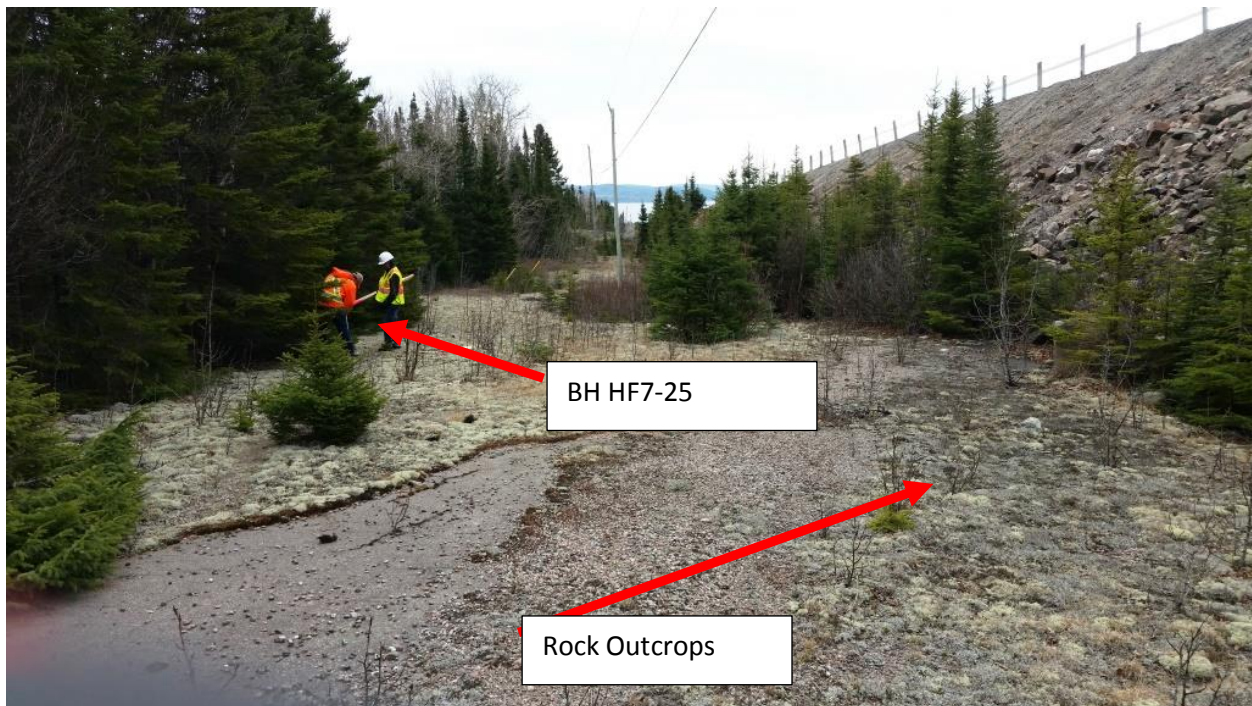


Photo 7-4: Looking toward east - Rock Outcrops and BH HF7-25 (April 2017)



Photo 7-5: Looking toward west - Rock Outcrops and BH HF7-21 (April 2017)

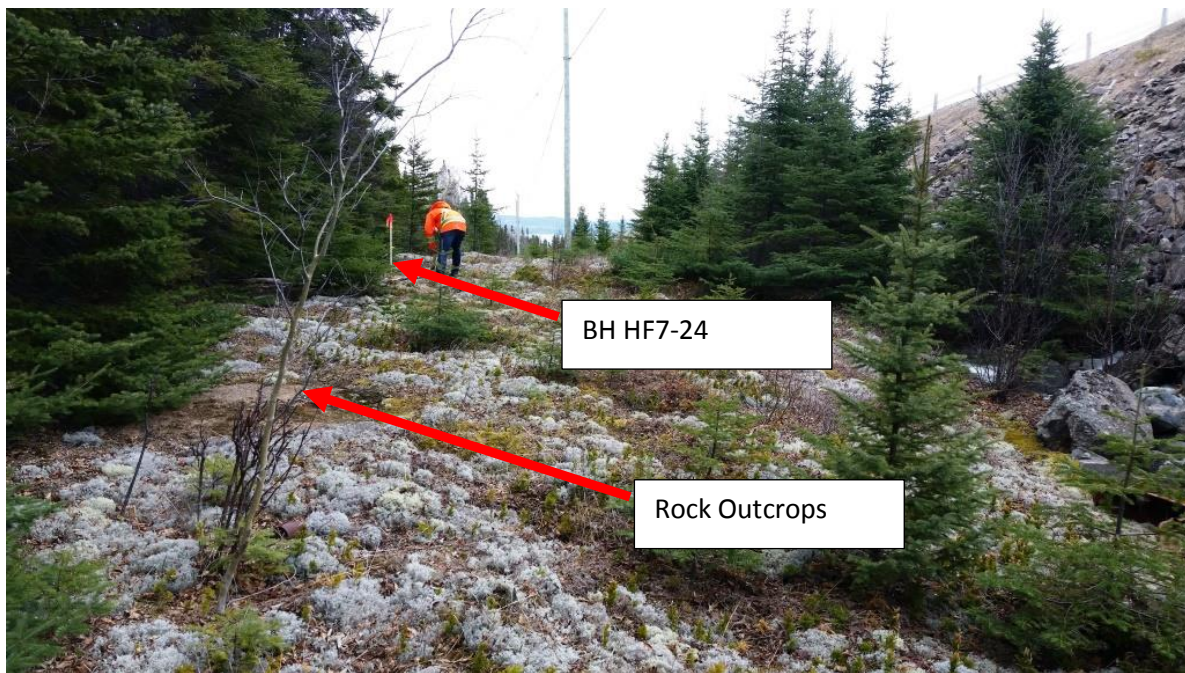


Photo 7-6: Looking toward east - Rock Outcrops and BH HF7-24 (April 2017)



Photo 7-7: Looking toward west - Rock Outcrops (April 2017)

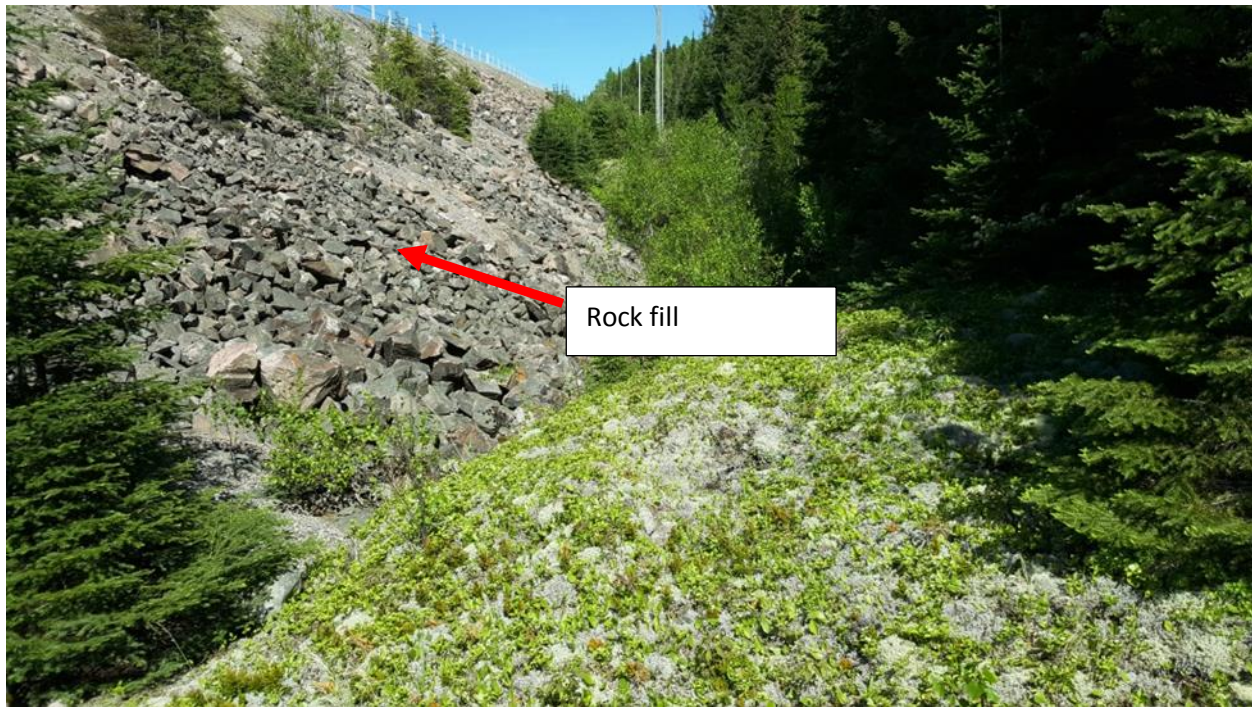


Photo: 7-8: Looking toward west - Rock fill (June 2017)



Photo: 7-9: Culvert at St. 10+655 (June 2017)



Photo: 7-10: Looking toward north – BH HF7-22 (June 2017)



Photo: 7-11: Looking toward west – TP HF7-23 (June 2017)

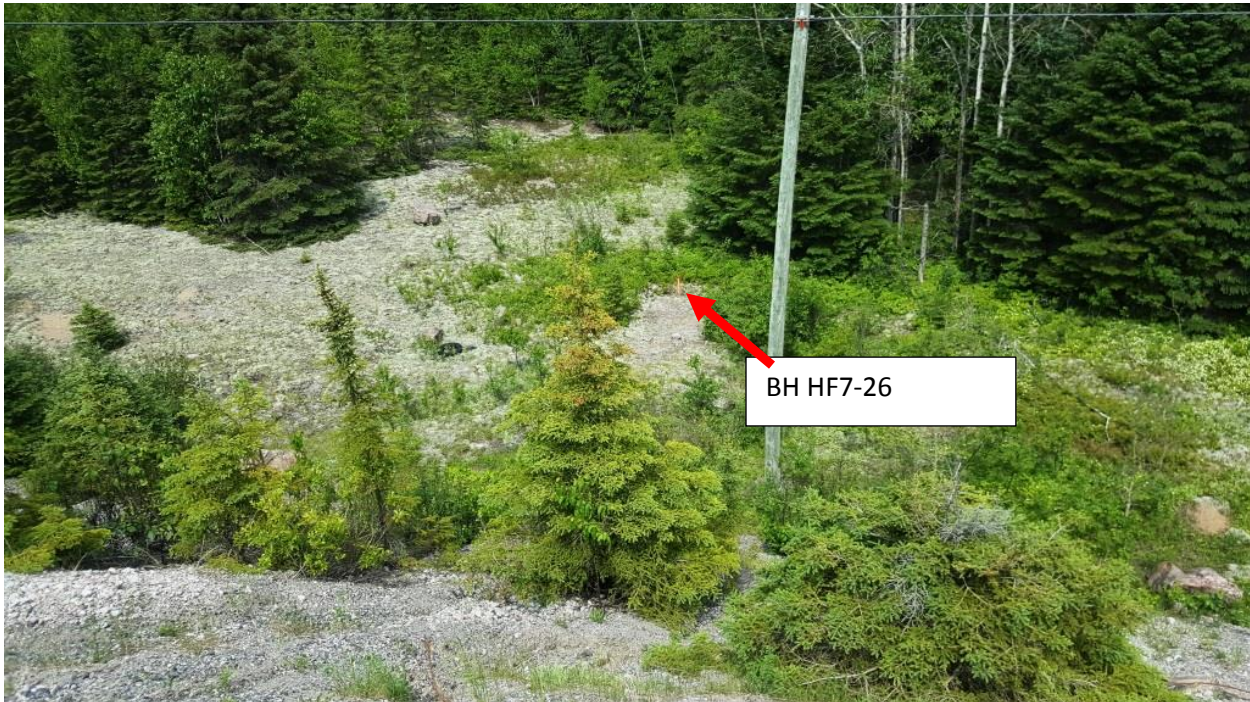


Photo: 7-12: Looking toward north – BH HF7-26 (June 2017)



Photo: 7-13: Looking toward north – BH HF7-27 (June 2017)

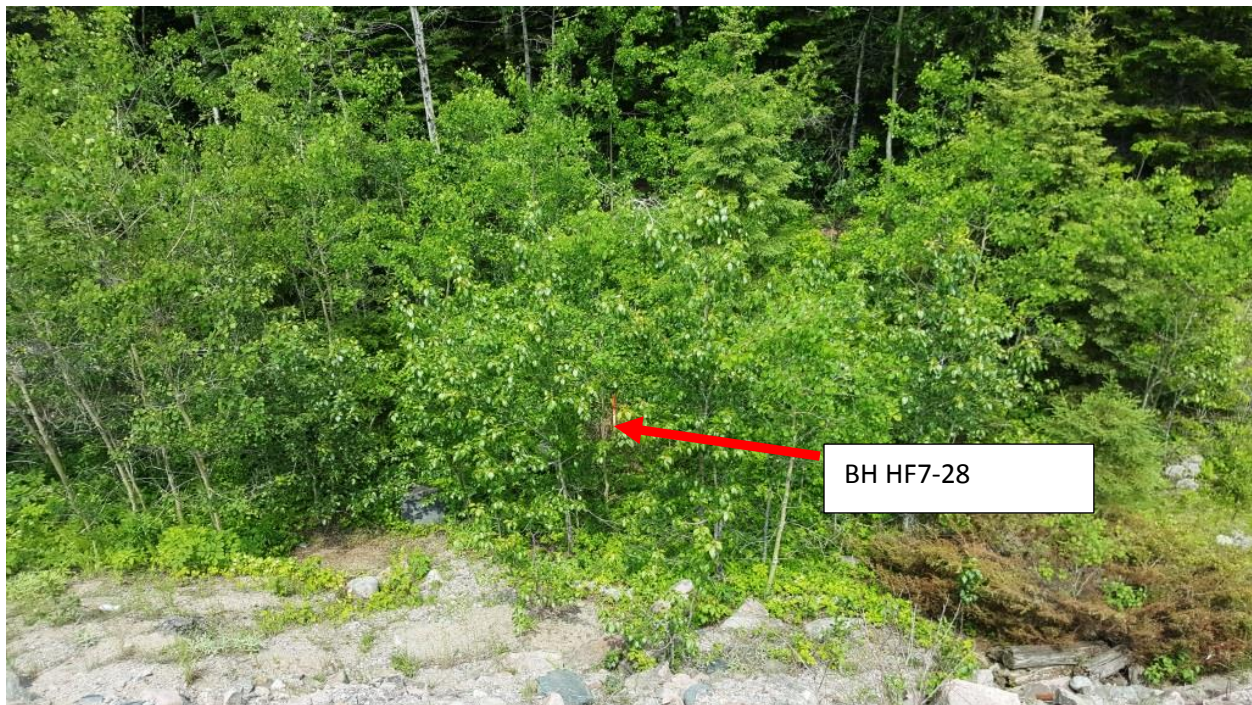


Photo: 7-14: Looking toward north – BH HF7-28 (June 2017)



Photo: 7-15: Looking toward west – BH HF7-30 (June 2017)

High Fill Section 8- Yesno Twp. (Sta. 12+170 to 12+270) / Culvert at Sta. 12+248



Photo: 8-1: Looking toward west - Culvert at Sta. 12+248 (April 2017)



Photo: 8-2: Looking toward east– BH HF8-33A (June 2017)



Photo: 8-3: Looking toward east— BH HF8-34 (June 2017)



Photo: 8-4: Looking toward east— BH HF8-35 (June 2017)

High Fill Section 9- Yesno Twp. (Sta. 12+810 to 12+860)

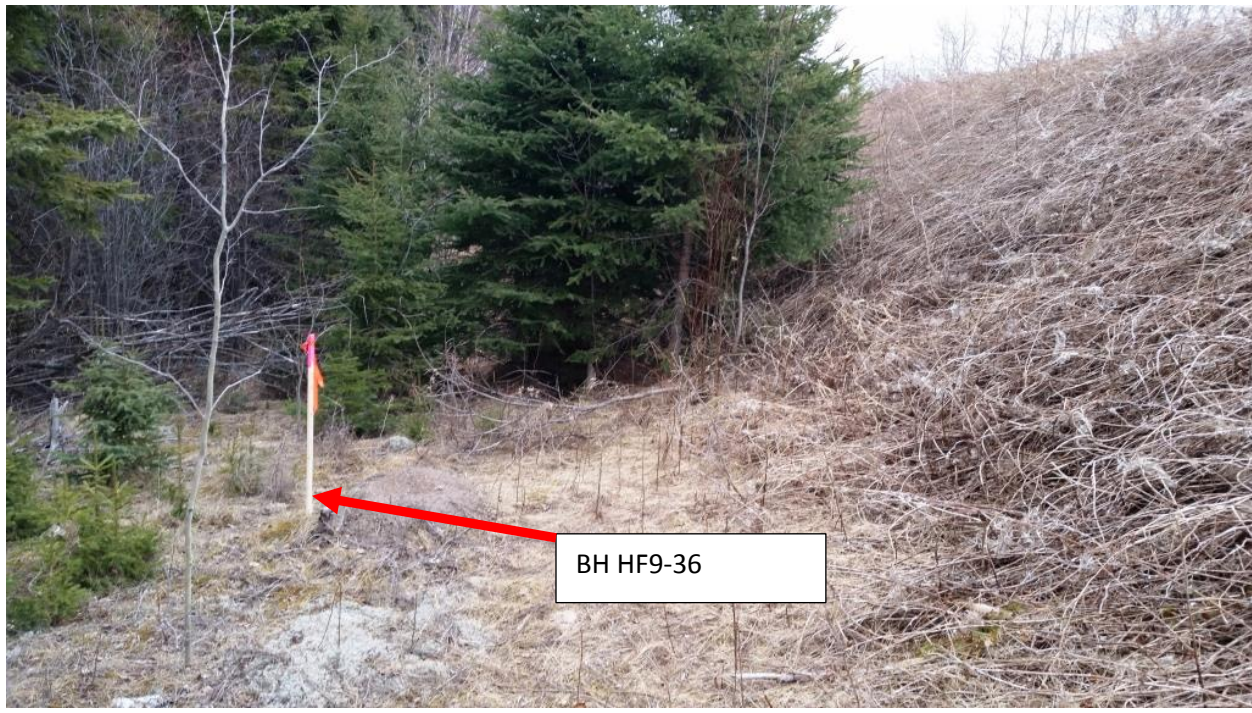


Photo: 9-1: Looking toward east – BH HF9-36 (April 2017)



Photo: 9-2: Looking toward north – BH HF9-37 (April 2017)



FOUNDATION DESIGN REPORT

PROPOSED WESTBOUND TRUCK CLIMBING LANE AND EXTENSION OF CULVERTS HIGHWAY 17, PAYS PLAT HILL ONTARIO

GWP NO. 6279-13-00
GEOCRE NO. 42D-49

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TABLE OF CONTENTS

5	DISCUSSION AND RECOMMENDATIONS	37
5.1	GENERAL.....	37
5.2	GEOTECHNICAL CHARACTERISATION.....	37
5.2.1	OVERVIEW OF SUBSURFACE CONDITIONS.....	37
5.2.2	GEOTECHNICAL MODEL.....	38
5.2.2.1.	<i>Frost depth/susceptibility</i>	<i>38</i>
5.2.2.2.	<i>Earthquake considerations.....</i>	<i>38</i>
5.2.2.3.	<i>Geotechnical ground model</i>	<i>39</i>
	Upper Clay.....	39
	Lower Clay.....	39
	Rockfill.....	40
5.3	GEOTECHNICAL CONSIDERATIONS FOR HIGH FILL EMBANKMENTS.....	41
5.3.1	GENERAL.....	41
5.3.2	SLOPE STABILITY.....	42
5.3.2.1	<i>Static slope stability</i>	<i>42</i>
	END OF CONSTRUCTION (EOC) Foundation STABILITY	42
	LONG TERM foundation STABILITY	43
	RAPID DRAWDOWN STABILITY	43
5.3.2.2	<i>SEISMIC SLOPE STABILITY</i>	<i>43</i>
5.3.2.3	<i>Summary of slope stability findings.....</i>	<i>43</i>
5.3.3	SETTLEMENTS	44
5.3.3.1	<i>general.....</i>	<i>44</i>
5.3.3.2	<i>High Fills on compressible ground.....</i>	<i>44</i>
5.3.3.3	<i>High Fills on non-compressible ground.....</i>	<i>47</i>
5.4	GEOTECHNICAL CONSIDERATIONS FOR CSP CULVERT EXTENSIONS.....	48

5.4.1	GENERAL.....	48
5.4.2	IMPORTANCE OF SOIL-PIPE INTERACTION	48
5.4.3	CULVERT EXTENSION AT HIGH FILL SECTION 3.....	49
5.4.3.1	<i>PROPOSED FOUNDING LEVEL.....</i>	<i>49</i>
5.4.3.2	<i>BEARING RESISTANCE.....</i>	<i>49</i>
5.4.3.3	<i>SLIDING RESISTANCE.....</i>	<i>49</i>
5.4.3.4	<i>SETTLEMENTS.....</i>	<i>49</i>
5.4.3.5	<i>EROSION PROTECTION AT OUTLET</i>	<i>49</i>
5.4.4	CULVERT EXTENSION AT HIGH FILL SECTION 6.....	50
5.4.4.1.	<i>PROPOSED FOUNDING LEVELS.....</i>	<i>50</i>
5.4.4.2.	<i>BEARING RESISTANCE.....</i>	<i>50</i>
5.4.4.3.	<i>SLIDING RESISTANCE.....</i>	<i>50</i>
5.4.4.4.	<i>SETTLEMENTS.....</i>	<i>50</i>
5.4.4.5.	<i>EROSION PROTECTION AT inlet.....</i>	<i>50</i>
5.4.5	CULVERT EXTENSION AT HIGH FILL SECTION 7.....	51
5.4.5.1	<i>PROPOSED FOUNDING LEVELS.....</i>	<i>51</i>
5.4.5.2	<i>BEARING RESISTANCE.....</i>	<i>51</i>
5.4.5.3	<i>SLIDING RESISTANCE.....</i>	<i>51</i>
5.4.5.4	<i>SETTLEMENTS.....</i>	<i>51</i>
5.4.5.5	<i>EROSION PROTECTION AT INLET</i>	<i>52</i>
5.4.6	CULVERT EXTENSION AT HIGH FILL SECTION 8.....	52
5.4.6.1	<i>PROPOSED FOUNDING LEVELS.....</i>	<i>52</i>
5.4.6.2	<i>BEARING RESISTANCE.....</i>	<i>52</i>
5.4.6.3	<i>SLIDING RESISTANCE.....</i>	<i>52</i>
5.4.6.4	<i>SETTLEMENTS.....</i>	<i>53</i>
5.4.6.5	<i>EROSION PROTECTION AT INLET</i>	<i>53</i>
5.4.7	BEDDING, COVER AND BACKFILL FOR ALL HIGH FILL CULVERT EXTENSIONS.....	54
5.4.7.1	<i>Bedding and cover.....</i>	<i>54</i>
5.4.7.2	<i>BACKFILL</i>	<i>54</i>
5.4.8	SUMMARY OF SETTLEMENT ANALYSES.....	54
5.5	CONSTRUCTION CONSIDERATIONS	54
5.5.1	GENERAL.....	54

5.5.2	OPEN CUT EXCAVATIONS FOR CULVERT EXTENSIONS.....	55
5.5.2.1	<i>Open cut excavation stability.....</i>	55
5.5.2.2	<i>excavatability.....</i>	56
5.5.2.3	<i>construction dewatering and creek flows.....</i>	57
5.5.3	CONSTRUCTION ON COMPRESSIBLE SOILS.....	57
5.5.4	CONSTRUCTION OF ROCKFILL HIGHWAY EMBANKMENT WIDENING	57
5.5.5	SETTLEMENT MONITORING.....	58

5 DISCUSSION AND RECOMMENDATIONS

5.1 GENERAL

This section of the report addresses pertinent geotechnical design issues for the construction of the widening of the Hwy 17 at Pays Plat. Widening of the embankment on the westbound side, i.e. to the north, is to provide for a truck climbing lane (WBTCL). As part of the widening, construction of high fill sections is proposed between Sta. 14+000 and Sta. 15+620 within the Yesno Township to the west, and between Sta. 10+460 and Sta. 12+860 within the Lahontan Township to the east. Associated with this widening, foundation investigations for the extension of four (4) existing non-structural CSP culverts are also included in the Foundation Assignment.

As per the General Arrangement (GA) drawings (dated Oct 26, 2017 and forwarded by the TPM) culvert extensions will involve the same size and type of culvert as the existing and will follow the existing culvert gradient. The existing embankment and culvert details within the high fill sections are given in Tables 2-1 and 2-2 respectively. The high fill sections have been grouped into nine (9) sections, with Section 1 towards the west end of the project boundary and Section 9 towards the east end of the project boundary. The individual high fill sections occupying the valleys are separated by extents where the existing alignment traverses through rock cuttings.

The general topography to the north of the existing highway embankment, i.e. in the general area of the footprint to be widened has numerous rock outcrops. The maximum height of the embankment to be widened is approximately 15.5 m. The two high fill sections at the east end (High Fill Sections 8 and 9) of the Foundation Assignment have intercepted compressible sub-soil conditions.

The existing high fill sections are all constructed with rockfill. The side slopes of these sections at the respective highest embankment section vary from 11:1 (High fill Section 1) to 1.3:1 (High fill sections 3 and 7). The highest embankment height was found in High fill section 3 and is 15.5 m. As side slopes consist of rockfill, no erosional features were found. No visible sink holes were observed on top of the embankments including the southern sidewalks.

In the project area, where the local geology is one of thin drift overburden, the most common embankment fill material especially for high fill embankments due to the large quantities required will be rockfill. In addition, the construction of sections of the WBTCL alignment through high strength granitic rock cuttings should also generate significant volumes of rockfill borrow.

As the main thrust of this report, focus will be made on geotechnical aspects associated with the design and construction of the WBTCL with special emphasis on the interaction of the proposed widening with the existing embankment. Measures necessary to mitigate stability and long-term consolidation settlements will form a pivotal part of the report. The impact of project geology and groundwater conditions on the construction of CSP culvert extensions will also be assessed. Based on this assessment, recommendations will be made on foundation support for the CSP culverts.

5.2 GEOTECHNICAL CHARACTERISATION

5.2.1 OVERVIEW OF SUBSURFACE CONDITIONS

As indicated in the geology maps for this region, the project site revealed lacustrine deposits / ground moraine/ bare bedrock, which includes glacial till and bedrock outcrops as is typical of the southern part of the Canadian Shield. In general, the sub-soil conditions

intercepted in WBTCCL High Fill Sections 1, 2, 3, 4, 5, 6 and 7 were predominantly cohesionless deposits (silty sand/sand/gravelly sand). Therefore these deposits are expected to exhibit drained shear behaviour under embankment loading. Bedrock exposures were a distinct feature of the landscape within most of the above high fill sections and most notably in High Fill Section 7. Exploratory advancement by boreholes, by DCPT soundings and test pitting were prematurely met with refusal either due to cobbles/boulders and/or presumed shallow bedrock generally within the above high fill sections.

High Fill Sections 8 and 9 at the eastern end of the WBTCCL, can be broadly described as having intercepted probably two facies of compressible cohesive deposits. These deposits, comprise a more compressible upper cohesive deposit and a less compressible lower cohesive deposit. They are generally separated by glacial deposits largely of cohesionless nature (Dwgs Nos. 8 & 9). However, at some borehole locations either the upper or the lower cohesive deposit only was contacted. The maximum thickness of the more compressible upper clay intercepted was 3.9 m in BH HF8-34. The upper cohesive layer was found to have significant textural variability from silty clay to clayey silt as described in the Record of Borehole Sheets for high fill Sections 8 and 9. This textural variability is further evidenced by the spread of the grain size distribution curves of the upper deposit from both high fill sections as shown in Fig. 5.1. Sandy seams/ some sand have been noted within the upper cohesive layer. In contrast to the upper cohesive deposit, the lower cohesive deposit shows strong homogeneity as shown by the coincident grain size curves in Fig. B-11 of the FIR. These trends are further reflected in the natural moisture contents, with 22% to 69% (mean=39.1%, std. dev.=16.7%;based on 11 tests) for the upper clay and 18% to 34% (mean=25.7%, std. dev.=4.7%;based on 13 tests) for the lower clay. The wider scatter of textural properties in the upper clay is clearly evident in standard deviations of the moisture content of the upper and lower cohesive deposits. In terms of undrained shear strength (S_u), based on FSV and UU triaxial testing, average S_u values of 28 kPa and 39 kPa were measured for the upper clay and lower clay deposits respectively. Based on the FSV, both clay deposits possess average sensitivities between 3 and 4, and accordingly these can be characterised as of medium sensitivity. The maximum embankment height within these sections underlain by compressible ground conditions is about 6 m.

Based on the above geotechnical facts, the critical high fill sections governing the stability and settlement of the WBTCCL are considered to be Sections 8 and 9.

Mildly artesian ground water levels were observed either on completion or in the long-term in these two sections. A basal deposit of cohesionless origin was intercepted in both these high fill sections where further advancement was met with refusal within this deposit. The maximum thickness of overburden contacted was 14.5 m in BH HF8-34. Rock was cored to a length of 0.7 m in BH HF8-33A and was found to be of granitic origin and inferred to be of very high compressive strength. The cored rock can be inferred as possible bedrock given the shallow bedrock profiles visible over the majority of the high fill sections.

Isolated occurrences of surficial peat and organic clayey silt were also intercepted.

5.2.2 GEOTECHNICAL MODEL

5.2.2.1. FROST DEPTH/SUSCEPTIBILITY

The frost depth for the project site area is 2.3 m based on OPSD 3090.100. The soils at the proposed culvert extension ends in high fill sections 3, 6 and 7, based on the subsoil information in proximity to the extended culvert ends, show that within the frost depth below the invert levels to consist of low frost susceptible soils (as per the MTO Frost Classification). However, the sub-soils below the proposed extended culvert end invert in Section 8 show medium/high frost susceptibility (Fig.B-10 shows high silt content).

5.2.2.2. EARTHQUAKE CONSIDERATIONS

Based on the borehole information and our review of the general subsurface conditions in the area, with mostly thin sandy overburden

followed by high strength massive rock (and located in a part of the stable interior of the North American Plate), coupled with the bearing pressures imposed by the proposed high fill sections, the probability of occurrence of earthquake activity is expected to be low. However, in soft soil sections such as High Fill sections 8 and 9, the potential for soil amplification cannot be ruled out. Hence, the subject site for the proposed structures can be classified as 'Class D' for seismic site response according to Table 4.1 of CSA S6-14.

Accordingly, based on NBC 2015 and CHBDC S6-14, for pseudo-static analysis, the following parameter is considered appropriate:
-PGA (Site Adjusted) value of 0.07.

5.2.2.3. GEOTECHNICAL GROUND MODEL

As the critical high fill sections for stability and settlement of the WBTCL are High Fill Sections 8 and 9, the ground conditions within these sections will be the focus of the ground model.

UPPER CLAY

An average S_u value of 28 kPa is adopted based on FSV and UU triaxial testing for the upper clay deposit.

Enquires made by TPM with the Regional MTO Office have indicated that according to the available information, the existing embankment was constructed as far back as 1957. This information would lead to the notion that the compressible subsoils under the existing embankment should have completely consolidated in the intervening 50 years. For high fills in Sections 8 and 9 (where compressible deposits were intercepted), a conservative contribution to gain in S_u was estimated for stability analysis. This resulted in a $S_u = 30.5 \text{ kPa}$ ($S_u = 0.22 * (\sigma_{v0} + \Delta\sigma_v)$, where σ_{v0} is the in-situ vertical effective stress before the existing embankment was built and $\Delta\sigma_v$ is the applied existing embankment vertical stress). However, no strength gain was used within the compressible soils that lie directly below, between the existing embankment crest and the existing embankment toe, as shown in Fig. 5.4.

Given the difficulties experienced in sampling the upper cohesive deposit as stated in Section 3 of the report, compressibility correlations in the literature based on physical properties were used to obtain pessimistic values. The following correlations were used:

-Terzaghi and Peck (1967) – based on LL

-Wroth (1978)- based on PI

-Boone (2010)- based on moisture content

Boone (2010) is based on Ontario Clays, which also gave the most pessimistic stiffness values ($C_c = 0.427$) and hence was used for the analysis. Estimate of the Coefficient of Secondary Compression was based on Mesri and Castro (1987) with a C_α value of 0.01.

Based on the adopted S_u , the pre-consolidation pressure, σ'_p , is estimated as 100 kPa and is adopted for the deposit which gives an approximate effective OCR of 4.0.

LOWER CLAY

An average S_u value of 39 kPa is adopted based on FSV and UU triaxial testing for the lower clay deposit.

The characterisation of compressibility characteristics of the lower cohesive deposit was largely influenced by the results of the consolidation test from that layer. For the lower cohesive deposit, no increase in S_u was included in the analysis. The σ'_p was estimated to range between 190 kPa and 240 kPa (See Table 4-15 of FIR). Adopting a value of 190 kPa for σ'_p , the over-consolidation ratio (OCR) for the deposit is estimated as 2.4.

ROCKFILL

Rockfill is a granular material produced by blasting rock that produces blasted rock of different shapes and sizes. Currently settlement estimates of rock fill embankments in Ontario are based on MTO Guideline (2010) "Rock fill Settlement and Rock fill Quantity Estimates". The construction aspects of these embankments are specified by OPSS.PROV 206. Rock fill is generally modelled as an extreme granular material in the geotechnical literature.

The geotechnical ground model developed based on available subsoil information, our interpretation of the field and laboratory data and engineering judgement, is shown in Table 5-1.

Table 5-1 Geotechnical Strength-Stiffness Model

Material/Deposit	Unit Weight (kN/m ³)	Shear Strength Parameters		Stress History (σ'_p) /Stiffness Parameters(E'/ν')	Saturated Permeability (m/s)
		Total Stress Parameters, S_u (kPa)	Effective Stress Parameters ϕ' (deg) $c' = 0$ (kPa)		
Rockfill (existing / proposed embankment fill)	19	NA	40	$E' = 60$ (MPa); $\nu' = 0.2$	1×10^{-5}
Cohesionless Soil	20 (compact)	NA	32	$E' = 20$ (MPa); $\nu' = 0.3$	1×10^{-6}
	18 (loose)		30	$E' = 15$ (MPa); $\nu' = 0.3$	1×10^{-6}
Cohesionless Till Deposits	19	NA	32	$E' = 15$ (MPa); $\nu' = 0.3$	1×10^{-6}
Upper Cohesive Deposit	17	25	28	$(\sigma'_p) = 100$ kPa/ $E' = 1$ (MPa); $\nu' = 0.4$; $C_c=0.471$; $C_\alpha= 0.01$	1×10^{-9}
Lower Cohesive Deposit	19	39	32	$(\sigma'_p) = 190$ kPa/ $E' = 2$ (MPa); $\nu' = 0.35$; $C_c=0.16$	1×10^{-10}
Upper Cohesive Deposit II (after strength gain)	17.5	30.5	30	$E' = 1.5$ (MPa); $\nu' = 0.35$	1×10^{-9}

Basal Cohesionless Deposit	20	NA	34	$E' = 25 \text{ (MPa)}; \nu' = 0.25$	1×10^{-6}
Bedrock (gneiss)	27.5	UCS= 100 MPa	NA	NA	NA

Notes: NA – Not applicable; Design groundwater table is variable for the different high fill sections and can be assumed at ground surface at each section.

- Partly based on : Schnaid, F., *In-situ Testing in Geomechanics*, Taylor & Francis (2009)

5.3 GEOTECHNICAL CONSIDERATIONS FOR HIGH FILL EMBANKMENTS

5.3.1 GENERAL

It was demonstrated that with the exception of High Fill Sections 6 (comprising cohesionless deposits), 8 and 9 (cohesive deposits), the remaining high fill sections have intercepted shallow refusal depths to exploratory hole advancement, cohesionless subsoils and numerous rock outcrop exposures.

Based on the geotechnical sub-soil properties given in Table 5-1, stability analyses of embankments for the high fill sections were carried out and is discussed in Section 5.3.2. Settlement analyses are reported in Section 5.3.3 and particularly significant for High Fill Sections 8 and 9 in view of the presence of compressible deposits. For the high fill sections, the TPM provided embankment cross-sections incorporating the WBTCL widening geometries were used in the analyses subject to the modifications based on the following reasoning. It is also recognized that the geometry of the widening in addition to meeting stability and settlement criteria will need to have minimum cross-section widths for constructability. These constructability considerations are particularly relevant given the limitations that would be posed by narrow widenings for modern construction equipment manoeuvrability thus having the potential to compromise achieving good compaction. Based on the above considerations, the TPM supplied cross-sections were amended to reflect a minimum 3 m width for the widenings.

In High Fill Sections 8 and 9, the maximum thickness intercepted for the upper clay deposit was 3.9 m. Conventional limit equilibrium analyses were based on this stratum thickness. However, to account for unforeseen thickness variability, all numerical analyses adopted a stratum thickness of 5 m.

Isolated occurrences of surficial peat and organic clayey silt intercepted within some of the high fill sections (predominantly in High Fill Sections 8 and 9) will need to be sub-excavated and a fuller discussion on this issue is in Section 5.5. In the modelling of High Fill Sections 8 and 9, we have assumed that the underlying upper silty clay to clayey silt could occur just below topsoil (topsoil to be stripped away) to cover any unforeseen such occurrence without incorporating the benefit of more competent backfill material that would replace the surficial organic deposits.

Stability and settlement issues at the *culvert* locations are addressed in Section 5.4.

5.3.2 SLOPE STABILITY

5.3.2.1 STATIC SLOPE STABILITY

END OF CONSTRUCTION (EOC) FOUNDATION STABILITY

Conventional limit equilibrium analyses were undertaken (with Rocscience SLIDE Software) for critical embankment cross-sections (the analysed model were based on the maximum adverse sub-soil thicknesses intercepted combined with the highest embankment geometry within the high fill section). All stability figures are given in Appendix D.

For cohesive High Fill Sections 8 & 9, the results are shown in Figures 5.2 and 5.3. This analysis produced factors of safety (FoS) in excess of 1.3 against deep-seated global failure that would impact the operation of the highway. However, when materials widely dissimilar in strength such as rockfill and compressible soft/firm cohesive deposits are involved in a slip mechanism, the slip zones through such contrasting stiffness materials may not necessarily follow a circular slip geometry, as was invoked in the conventional analysis.

To investigate such an adverse potential that is particularly relevant for the cohesive high fill sections, a continuum analysis using FEM (using Rocscience RS² software) was undertaken invoking the Mohr-Coulomb constitutive model in a plane strain analysis using the Shear Strength Reduction Factor Method (SRF; this is akin to the FoS of the limit equilibrium method). The rock fill was modelled as an elasto-plastic Mohr-Coulomb material (Potts & Zdravkovic, 2001). The entire embankment load was applied in a single increment in the analysis making the loading more adverse than the real construction scenario in which the embankment is constructed in lifts.

In the property characterisation, S_u was based on both FSV and Triaxial UU testing, no strength gain was used under the existing embankment and the thickness of the most compressible layer was modelled as 5 m, whereas the maximum intercepted thickness was only 3.9 m. In addition, EOC stability was investigated in a comprehensive continuum analysis. In view of these considerations, a ϕ_{gu} factor of 0.77 is considered reasonable as per Table 6.2 of CSA-S6-14, which is equivalent to a FoS of 1.3.

Without the strength gain effects discussed before, the FEM based FoS for the cohesive high fill sections was 1.3 but when the strength gains were factored in as shown in Fig. 5.4 (geometry), the resulting FoS was 1.32 (See Figs. 5.5 and 5.6). Since the gain in S_u was not considered under the side slopes of the existing embankment, the increased in FoS due to strength gain is marginal. This is to be expected as the slip mechanism has kinematic freedom to move outside the strength gained region towards the toe.

A composite slope model was adopted to investigate the stability of high fill widenings to be founded on predominantly cohesionless deposits (High Fill Sections 1 to 7). The composite slope model had the highest fill height (pertaining to High Fill Section 3) and adopted the thickest subsoil geometry (pertaining to High Fill Section 6) among those sections. The embankment height of this slope model is 15.5 m pertaining to High Fill Section 3. High Fill Section 3 spans from Sta. 14+580 to Sta. 14+700 (120 m) but the highest embankment section is from Sta. 14+625 to Sta. 14+675 (50 m). The total length of the high fill sections on non-compressible ground is about 1370 m based on the TPM drawings. Therefore, the composite model embankment height of 15.5 m represents less than 5% of the subject non-compressible alignment.

The FoS for this composite slope model underlain by cohesionless sub-soils was 1.52 (Fig. 5.7) against deep-seated global failure that would impact the operation of the highway based on the limit equilibrium method. The same FoS applies for long-term stability for High Fill Sections underlain by cohesionless deposits since the foundation soils undergo essentially drained shear straining under the applied embankment loading even during construction under typical field embankment construction loading rates.

LONG TERM FOUNDATION STABILITY

For any embankment constructed on compressible deposits, the induced construction pore water pressures will dissipate with time. Therefore, the stability of such embankments in the long-term is expected to increase. This is reflected in the long-term global stability assessment shown in Fig. 5.8 and 5.9, that was carried out for the cohesive high fill sections, with resulting minimum FoS of 1.5 for long-term stability or achieving a ϕ_{gu} factor of 0.67 as per Table 6.2 of CSA-S6-14.

RAPID DRAWDOWN STABILITY

Rockfill embankments have open networks for drainage by virtue of their particulate nature of assemblage and site specific photographs (see Appendix C) show this is clearly the case with the existing rockfill embankments. Hence, with embankments constructed with rockfill (free draining), the potential for rapid drawdown is not considered an issue because the possibility of unbalanced pore water pressures does not arise within rockfill.

5.3.2.2 SEISMIC SLOPE STABILITY

Based on the ground accelerations reported in Section 5.2.2.2 and the effective stress strength parameters given in Table 5.1, Figs. 5.10 to 5.12 show the limit equilibrium pseudo-static stability analyses for High Fill Sections 8 & 9 and High Fill Section 6, and the resulting FoS exceeding 1.2 are considered acceptable.

5.3.2.3 SUMMARY OF SLOPE STABILITY FINDINGS

Stability analyses discussed in Section 5.3.2 have revealed that the proposed WBTCCL widening can be constructed in a single stage without intervening rest periods. Use of rockfill has been assumed for construction. The stability results reported have not considered practical construction methodology in that it takes place in lifts over a period but in the analyses construction has been simulated as an “instant” embankment load application on the ground. Therefore, in reality, in practical construction the implicit safety against stability would be more than have been reported due to possible strength gain of compressible ground during the construction period. This approach to modelling is conventional practice and provides some safety net against minor unforeseen adverse ground conditions should they arise.

Based on the above stability assessments and with the proviso that the minimum width of widening should be 3 m for all high fill embankment widening of the WBTCCL, the following recommendations are made subject to constructability review addressed in Section 5.5.

In essence, the analysed embankment cross-sections for the widenings are as follows:

- High Fill Sections 1 to 7: The proposed WBTCCL side slope should not be steeper than 1.6H:1V which is same as that of the highest existing northern side slope
- High Fill Section 8: The proposed WBTCCL side slope should not be steeper than 2H:1V which is shallower than the highest existing northern side slope
- High Fill Section 9: The proposed WBTCCL side slope should not be steeper than 2.5H:1V which is same as the highest existing northern side slope.

5.3.3 SETTLEMENTS

5.3.3.1 GENERAL

Regarding the compressibility characteristics of the sub-soils, the cohesive deposits intercepted in High Fill Sections 8 and 9 would be the significant deposits from a long-term extended settlement response perspective as the other deposits are essentially cohesionless and would display a drained/quasi-drained response to embankment loading.

Based on the foregoing discussion, the settlements would be of a larger magnitude and expected to occur over a longer duration for the cohesive high fill sections. Therefore discussion about settlements is grouped into two categories, Section 5.3.3.2, on High Fills on Compressible Ground (High Fills 8 & 9) and Section 5.3.3.3, High Fills on Non- Compressible Ground (High Fills 1 to 7).

Stiffness parameters given in Table 5.1 were used for settlement analyses. It is reasonable to assume that the settlements under the existing highway embankment have practically ceased. It is assumed that the pavement structure for the widening would be similar to that of the existing and will consist of flexible support.

Requirements for sub-excavation and embankment fill lift construction rates are addressed in Section 5.5. The rockfill should be compacted for all high fill embankments. All settlement analyses figures are collated in Appendix D.

Settlement issues at culvert locations are addressed under the respective culvert headings in Section 5.4.

5.3.3.2 HIGH FILLS ON COMPRESSIBLE GROUND

Foundation Settlements

- ALTERNATIVE GROUND IMPROVEMENT OPTIONS

Subject to surficial organic/peat sub-excavation and embankment fill lift construction rates addressed in Section 5.5, stability considerations discussed in Section 5.3.2 have indicated that *single lift* construction is feasible from a foundation stability perspective. In order to mitigate excessive post construction settlements a number of options are available with varying technical and cost implications. They are briefly discussed below and a preferred option recommended.

- Complete sub-excavation of compressible sediments: In an embankment widening context, such sub-excavation can impact on the stability of the existing embankment. As no borehole information is available to confirm if the existing embankment was founded on competent ground, this option is not considered technically safe without further investigation. Further, environmental impacts of disposal of a significant volume of such material is a deterrent.
- Methods that reduce the settlement magnitude by reducing the applied load on the compressible deposits such as the use of light weight fills, although technically feasible, in the absence of critical time constraints and in the absence of bridge abutments within the high fill sections, precludes the use of such interventions from a cost perspective.
- Methods that reduce the magnitude and or the time duration of settlement by positive improvement of the compressible ground by the use of such methods as rammed aggregates/stone columns/wick drains, although technically feasible are not considered cost effective in the present context.
- Preloading/Surcharging: The preload period identified for post-construction settlement mitigation (6 months; this preloading option is discussed below) was the most cost effective since the time frame was within the project schedule as confirmed by the TPM. Surcharging was not feasible in addition to costs associated with haulage and placement of temporary fill, due to stability constraints.

Hence, the preloading option is the preferred option and is recommended.

- CONVENTIONAL SETTLEMENT ANALYSES

Both conventional (Terzaghi type, one-dimensional settlement estimates, understandably approximate under embankment widening situations) and continuum based FEM (plane strain, coupled elasto-plastic type using Rocscience RS² software) analyses were used. Terzaghi settlement analysis approach being one-dimensional would generally tend to overestimate settlements under a widening. Continuum analyses are particularly useful in addressing settlement interaction issues with an existing roadway. Long term-creep settlements are also estimated. In terms of the proposed embankment heights (See Table 2.1) and the nature of compressible deposits (See Dwg Nos: 8 & 9), High Fill Section 8 should pose a greater potential for settlements than High Fill Section 9.

Foundation settlements were computed at two points under the proposed widening.

- Under the mid-point of the proposed widening
- Under the toe of the existing embankment

Elastic stress distributions were used to estimate the induced stress increments with depth due to the proposed embankment widening at the above locations. Based on Terzaghi type of methodology, the predicted consolidation settlements are as follows:

- under the mid-point of the widened base, the estimated consolidation settlement is about 85 mm
- under the toe of the existing embankment, the estimated consolidation settlement is about 100 mm

Based on the above estimates, the bulk of the settlements would be induced in the more compressible upper cohesive deposit. Half the foundation settlements should be complete within 7 months and 90% of the consolidation settlement should occur within about 29 months. However, field settlement rates are faster due macro fabric features inherent in depositional environments such as sand seams resulting in lateral drainage effects.

- NUMERICAL ANALYSIS OF SETTLEMENTS

A plane strain coupled consolidation with an elasto-plastic soil skeleton of the Mohr-Coulomb type was undertaken with pessimistic stiffness values (See Fig. 5.13 for the geotechnical model used for the analysis) to get an upper bound prediction of the settlements. Settlement interaction with the existing highway embankment can be more readily and reliably investigated in a continuum analysis. Settlements were predicted at the crests of the proposed widening and of the existing highway embankment, and close to (just to the north of) the EP (edge of pavement) of the existing westbound. The predicted total settlements are shown at the end of 6, 12, 24, 36, and 48 months in Figs. 5.14 to 5.18, respectively.

The bulk of the settlements are induced in the more compressible upper cohesive deposit. Table 5.2 tabulates the total settlement summaries (excluding creep).

As seen in Table 5.2, the in-service settlements (excluding creep) would be practically complete in 4 years, and assuming a settlement preload period of 6 months, the predicted *in-service* settlements are a maximum of 35 mm.

Table 5-2 Settlement Summary (Based on FEM)

Time Elapsed after EOC (months)	Under the Crest of Proposed Widening	Under the Northern Crest of the Existing Highway Embankment	Under the EP of the Existing Westbound
6	82	53	20

Time Elapsed after EOC (months)	Under the Crest of Proposed Widening	Under the Northern Crest of the Existing Highway Embankment	Under the EP of the Existing Westbound
12	96	66	29
24	108	77	39
36	114	83	44
48 (considered as practical completion)	117 (excess over 6 months = 35 mm)	86 (excess over 6 months = 33 mm)	47 (excess over 6 months = 27 mm)

Rockfill Embankment Settlements

Based on Table 2-1, rockfill embankments are marginally higher for High Fill Section 8 and is of 6 m maximum height. Based on MTO Guideline (2010) on "Rock Fill Settlement and Rock Fill Quality Estimates", for *compacted* rock fill embankment heights more than 5 m and less than 10 m, the expected short-term (1 year) rock fill settlement will be between 0.5%H and 0.75%H (H being embankment height). This will translate to 45 mm for H = 6 m; Further, according to this guide, 90% of this short-term settlement should take place in the first 6 months after construction. Therefore, the post-construction rock fill embankment settlement is estimated at 5 mm. These empirical estimates are useful, in that continuum numerical analysis cannot fully model the clastic nature of high strength blast rock with angular edges that are liable to breakage on compaction (Varshoi et al. 2017).

Settlement Compliance with MTO Settlement Criteria

The total post-construction settlement is estimated at 40 mm (35 mm due to compressible ground (Table 5-2) and 5 mm due to rockfill embankment settlement). Hence, the total post-construction settlement is less than 75 mm (Non-Freeways) and thus comply with the requirements of MTO settlement Guidelines for Compressible Ground (2010) for Flexible Pavement Support. This predicted 40 mm maximum settlement also satisfies the CSA S6-14 Table 6.2 Settlement partial factor of 0.7 (35 mm/0.7 = 50 mm).

The post-construction differential settlement between the westbound EP and the crest of the proposed widening is estimated at 13 mm (35 mm - 27 mm + 5 mm; see Table 5-2 and Section on Rockfill Embankment Settlements under Section 5.3.3.2). The separation distance between these two points is about 6 m. Therefore the angular deflection is 6000:13 or 460:1. This is much less than the maximum permissible MTO tolerance of 100:1.

Subject to the Requirements for sub-excavation of surficial and organic deposits addressed in Section 5.5 and with a construction preload period of 6 months, the predicted settlement issues can be mitigated.

- CREEP SETTLEMENTS

Theoretical prediction of creep settlements are very approximate and the most reliable source would be the maintenance records of asphalt corrections of the existing embankments on the project. However, these records were not available for this study.

Based on a C_{α} value of 0.01, the estimated creep settlement within the first 40 years is about 25 mm.

- SUMMARY OF HIGH FILL SETTLEMENT ON COMPRESSIBLE SOIL

Subject to sub-excavation of surficial peat and organic clayey silt intercepted within the high fill sections on compressible ground, no

significant ground improvement schemes are considered necessary for the proposed WBTCCL construction.

It is recommended that High Fill Sections 8 and 9 be programmed to be constructed first within the construction contract to enable a minimum preload period of six (6) months. Alternatively, this preloading programme may be considered as part of an early works contract such as the winter works program and is recommended. This preload period should ensure compliance with MTO in-service settlement requirements for compressible ground and the class of road, i.e. widening of Hwy 17 in the present context.

This preload period has been acknowledged by the project TPM as being feasible and therefore further expensive settlement mitigation is not considered warranted.

Long-term in-service settlements are best and economically addressed through programmed pavement maintenance.

5.3.3.3 HIGH FILLS ON NON-COMPRESSIBLE GROUND

Foundation Settlements

The same composite slope model that was adopted for stability analysis under Section 5.3.2.1 was used for investigation of foundation settlements. This model incorporates about 12 m thick foundation subsoils of essentially cohesionless nature. Under the highest fill embankment height of 15.5 m, adopted in this model, the estimated foundation settlement is about 225 mm.

Based on 14 grain size distribution results (sieve analyses) carried on these subsoils from the first seven high fill sections, the average percentage fines (silt and clay size) amounts to about 13.5%, and this fine fraction is comprised of essentially silt size particles. Based on this subsurface geology, it is expected that the foundation settlements will be essentially complete during construction.

Rockfill Embankment Settlements

Based on MTO Guideline (2010) on “Rock Fill Settlement and Rock Fill Quality Estimates”, for *compacted* rock fill embankment heights more than 5 m and less than 15 m, the expected short-term (1 year) rock fill settlement will be between 0.5%H and 1.0%H (H being embankment height). This will translate to 150 mm for H = 15 m (this almost covers the high fill embankment height range on this project); Further, according to this guide, 90% of this short-term settlement should take place in the first 6 months after construction. It is assumed that at least 60% of this settlement could occur in three months (Varshoi et al. 2017). Therefore, the post-preload embankment settlement is estimated as 60 mm or less. It is to be noted that five of the seven high fill sections on non-compressible ground have embankment heights less than 10 m which should result in lower post-preload settlements. Embankment heights of 10 m or more represent about 7% of the subject non-compressible high fill alignment.

Theoretical prediction of rockfill creep settlements is very approximate and based on MTO Rockfill Guideline (2010), it is estimated at 0.1%H. As per this document, following one year, the estimated long-term rockfill settlement for a 15 m high rockfill embankment is 15 mm.

Settlement Compliance with MTO Settlement Criteria

The total post-construction settlement is estimated at 60 mm. Hence, the total post-construction settlement is less than 75 mm (Non-Freeways) and thus comply with the requirements of MTO settlement Guidelines for Compressible Ground (2010) for Flexible Pavement Support.

For these high fill sections, a minimum preload period of up to three (3) months is recommended. This minimum period of up to 3 months can be curtailed by undertaking survey monitoring as discussed in Section 5.5.

- SUMMARY OF HIGH FILL SETTLEMENTS ON NON-COMPRESSIBLE SOIL

Subject to sub-excavation of isolated occurrences of surficial peat and organic clayey silt intercepted within some high fill sections on non-compressible ground, no significant ground improvement schemes are considered necessary for the proposed WBTCL construction. A minimum preload period of up to three (3) months is recommended. This minimum period of up to 3 months can be curtailed by undertaking survey monitoring as discussed in Section 5.5.

This preload period has been acknowledged by the project TPM as being feasible and hence further expensive settlement mitigation is not considered warranted.

Long-term in-service settlements are best and economically addressed through programmed pavement maintenance.

5.4 GEOTECHNICAL CONSIDERATIONS FOR CSP CULVERT EXTENSIONS

5.4.1 GENERAL

Culvert type and size are generally dictated by hydraulics, ecology (e.g. fish habitats) and economics. Geotechnical appraisal will include the suitability of in-situ conditions to support the chosen culvert type, any requirements for ground improvement and construction issues specific to the chosen culvert type and in-situ ground conditions.

According to the GA, the existing CSP (flexible) culverts in High Fill Sections 3, 6, 7 and 8 will be extended under the proposed WBTCL. However, flexible pipes, such as CSP conduits, require greater attention to construction detail as they heavily rely on the surrounding soil support to carry the overburden loads. Stiffness and configuration of the soil around the pipe can affect pipe performance limits. In the case of flexible pipes, relative soil stiffness affects in addition to culvert material failure (i.e. yielding/cracking/crushing), deflection and buckling. Whereas for rigid pipes, relative soil stiffness affects only material failure as deflection and buckling are generally not relevant in view of the rigidity of the pipes.

No headwalls or wing walls are proposed for these culvert sites. Each of the above culvert sites are discussed individually except for the bedding/cover/backfill issues that are addressed collectively in Section 5.4.7 as they involve imported select fill and therefore independent of site conditions. All culvert settlement analyses figures are collated in Appendix E.

Construction considerations associated with culvert extensions are discussed in Section 5.5.

5.4.2 IMPORTANCE OF SOIL-PIPE INTERACTION

CSP type culverts being flexible pipes, they derive their soil-load carrying capacity by virtue of the pipe flexibility. When a buried flexible pipe is subject to loads by overburden soils, the pipe and the soil work as a composite system in resisting the load. The pipe tends to deflect outwards under the overburden loads and in turn mobilizes passive soil support/resistance at the sides of the pipe. The ring deflection also induces arching action in the surrounding soil over the pipe and thereby reduces the vertical load acting on the pipe. Hence, soil is a major component of the soil-pipe interaction system and plays an integral role to support the vertical loads. Soil density (direct indicator of soil stiffness) is the most important soil property to ensure that the soil is capable of providing the structural support for the pipe. CSP culverts are very tolerant to movement, carry significant loads but in return require careful attention to detail during installation. In this context, Section 5.4.7 on Bedding, Cover and Backfill discusses the importance of sound compaction of both cover materials and backfill. It is emphasized that faulty compaction has led to more trouble with pipe installations,

for both flexible and rigid pipes, than all other factors combined. The pipe designers should address corrosion issues in relation to site soil/groundwater chemistry. This foundation investigation has not addressed these soil/groundwater chemistry issues.

5.4.3 CULVERT EXTENSION AT HIGH FILL SECTION 3

5.4.3.1 PROPOSED FOUNDING LEVEL

As per Drawing No. 3A, the existing 1.524 m dia. CSP outlet will be extended by 11 m to the north with the new invert elevation shown at El. 389.8 m with the same type and size of pipe. Test pit TP HF3-8 refers to the subsoil conditions close to the culvert location. This test pit contacted sand and cobbles and was advanced to El. 388.9 m, 0.9 m below the invert level of the proposed outlet, meeting refusal. This test pit was filled with seeping water upon completion of excavation. Two other test pit in this high fill section reached resistance to advancement beyond about 1 m.

The sub-soils contacted at the founding level, sand and cobbles, should be sub-excavated to a minimum of 1.0 m below the invert level and replaced with engineered OPSS 1010 Granular 'A' to ensure uniform subgrade support. The sub-excavation should be along the entire pipe extension and be further extended 1 m on either side of the culvert extension footprint and beyond the culvert outlet. The native deposit intercepted is considered to be of low frost susceptibility.

5.4.3.2 BEARING RESISTANCE

The existing culvert has been in-place for years and has undergone full settlement under the existing road embankment. Under the proposed WBTCL, the highest vertical stress on the proposed culvert extension is likely to occur at the pipe connection to the existing. The direct overburden at this pipe connection is estimated to be about 2.5 m as per Dwg No: 3A, with an estimated overburden stress of about 50 kPa. A SLS of 100 kPa and factored ULS of 150 kPa are recommended for the granular subgrade.

5.4.3.3 SLIDING RESISTANCE

Sliding is unlikely to pose a problem as the major horizontal earth pressure thrust on the culvert is along the road axis, which subject to proper backfill placement control as discussed in Section 5.4.7 on Bedding and Cover should not pose an issue. An unfactored friction angle of 32 degrees can be considered for interface sliding resistance between the CSP and the granular subgrade.

5.4.3.4 SETTLEMENTS

Based on the estimated overlying embankment fill stress at the pipe connection discussed in Section 5.4.3.2 on Bearing Resistance and evidence of shallow refusal in test pits in this high fill section, the estimated maximum foundation settlement at the pipe connection is less than 5 mm, subject to sound construction control. Assuming the pipe connection be able to accommodate this movement, no significant ground improvement is required for the CSP extension at this culvert location other than the sub-excavation discussed in Section 5.4.3.1.

5.4.3.5 EROSION PROTECTION AT OUTLET

Rip-rap protection should be provided at the culvert's outlet end and should generally follow OPSD 810.010 and any specific recommendations in the hydrology report. Rip-rap placed up to 1.5H:1V slopes without an underlying geotextile can be stable.

These erosion/scour protection systems can be designed by a specialist River Engineer/Scientist (as erosion and scour largely depend on the hydraulic energy, i.e. velocity of water in the watercourse and its regime and the erodible nature of stream bed material).

5.4.4 CULVERT EXTENSION AT HIGH FILL SECTION 6

5.4.4.1. PROPOSED FOUNDING LEVELS

As per Drawing. No. 6A, the existing 1.830 m dia CSP inlet will be extended by 6.5 m to the north with the new invert elevation shown at El. 378.7 m with the same type and size of pipe. Borehole BH HF6-16 (10 m east of the culvert axis) and DCPT BH HF6-15 collectively refer to the subsoil conditions close to the culvert location. DCPT BH HF6-15 was driven and reached refusal at 7.8 m depth (El. 371.5 m) whilst BH HF6-16 was wash bored to 4.3 m and the DCPT cone was advanced below this depth until refusal at 11.4 m depth (El. 367.8 m).

Based on recovered spoon samples from BH HF6-16, the native deposit intercepted below the proposed pipe invert level is generally compact gravelly sand. This deposit is considered generally suitable as a founding subgrade for the CSP pipe extension, subject to clearing any topsoil/possible organics/peat, if intercepted, and a sub-excavation of 0.5 m to be replaced with compacted OPSS Granular 'A' is recommended to ensure uniform subgrade support for the CSP. The sub-excavation should be along the entire pipe extension and be further extended 1 m on either side of the culvert extension footprint and beyond the culvert inlet. The gravelly sand deposit appears to be fairly uniform texturally within this high fill section based on the grain size distribution results shown in Fig. B-5 in the FIR. Based on the grain size information, this deposit is of low frost susceptibility as per MTO Pavement Design and Rehabilitation Manual.

5.4.4.2. BEARING RESISTANCE

The existing culvert has been in-place for years and has undergone full settlement under the existing road embankment. Under the proposed WBTCL, the highest vertical stress on the proposed culvert extension is likely to occur at the pipe connection to the existing culvert. The direct overburden at this pipe connection is estimated to be about 4.0 m as per Dwg No: 6A, with an estimated overburden stress of about 76 kPa. A SLS of 100 kPa and factored ULS of 150 kPa are recommended for the granular subgrade.

5.4.4.3. SLIDING RESISTANCE

Sliding is unlikely to pose a problem as the major horizontal earth pressure thrust on the culvert is along the road axis, which subject to proper backfill placement control as discussed in Section 5.4.7 on Bedding and Cover should not pose an issue. An unfactored friction angle of 32 degrees can be considered for interface sliding resistance between the CSP and the granular subgrade.

5.4.4.4. SETTLEMENTS

Based on the estimated overlying embankment fill stress at the pipe connection discussed in Section 5.4.4.2 and the borehole information for this high fill section, the estimated maximum foundation settlement at the pipe connection is less than 10 mm, subject to sound construction control. Assuming the pipe connection can accommodate this movement, no special ground improvement is required for the CSP extension at this culvert location other than the sub-excavation discussed in Section 5.4.4.1.

5.4.4.5. EROSION PROTECTION AT INLET

Rip-rap protection should be provided at the culvert's inlet end and should generally follow OPSD 810.010 and any specific recommendations in the hydrology report. Rip-rap placed up to 1.5H:1V slopes without an underlying geotextile can be stable.

Consideration should be also given to a low permeability clay seal/GCL (OPSS 1205/OPSD 802.095) at the inlet especially given the potential erodible nature of the near surface cohesionless soils with a fine sand content up to 30% (See Fig. B-5) found within this high fill section. As the embankment fill will consist of rockfill with voids, it is important to prevent seepage along the outer perimeter

of the CSP. The loss of fines due to seepage can undermine the lateral confinement on the CSP and could lead to local subsidence effects depending on the severity. The installation of an anti-seepage collar surrounding the CSP at the inlet side should be considered, dependent on predicted stream flows based on hydrological advice.

These erosion/scour protection systems can be designed by a specialist River Engineer/Scientist (as erosion and scour largely depend on the hydraulic energy, i.e. velocity of water in the watercourse and its regime and the erodible nature of stream bed material).

5.4.5 CULVERT EXTENSION AT HIGH FILL SECTION 7

5.4.5.1 PROPOSED FOUNDING LEVELS

As per Drawing No. 7A, the existing 1.524 m dia CSP inlet will be extended by 18.0 m to the north with the new invert elevation shown at El. 275.2 m with the same type and size of pipe. Test pit TP HF7-23 refer to the subsoil conditions close to the culvert location. High Fill Section 7 had very shallow overburden based on eleven (11) exploratory holes advanced within this high fill section. All exploratory holes reached refusal between 0.3 m to 2.4 m depth and numerous exposures of rock outcrops (See Appendix C – Site Photographs) were visible. HF7-23 reached refusal at 0.3 m depth (El. 278.3 m), 3.1 m above the inlet invert elevation of the CSP extension. Photo 7-7 shows undulating rock outcrops. Hence, it is uncertain that the entirety of the CSP extension will involve rock excavation or at this location if the CSP extension will be in soil overburden or a combination.

Within the shallow exploratory holes undertaken with wash boring, the intercepted overburden reveal deposits of sand/silty sand and gravelly sand generally of loose to compact relative density. Fig. B-7 shows grain size distribution curves of medium to coarse sand.

Any sub-soils contacted at the invert level along the proposed CSP extension should be sub-excavated to a minimum of 0.5 m below the invert level or to the top of bedrock, if bedrock is shallower, and replaced with engineered OPSS 1010 Granular 'A' to ensure uniform subgrade support. The sub-excavation should be along the entire pipe extension and be further extended 1 m on either side of the culvert extension footprint and beyond the culvert inlet, wherever it is in *soil* overburden. The native deposits intercepted are considered to be of low frost susceptibility based on the grain size information (Fig. B-7 of the FIR).

5.4.5.2 BEARING RESISTANCE

The existing culvert has been in-place for years and has undergone full settlement under the existing road embankment. Under the proposed WBTCL, the highest vertical stress on the proposed culvert extension is likely to occur at the pipe connection to the existing culvert. The direct overburden at this pipe connection is estimated to be about 4.5 m as per Dwg No: 7A, with an estimated overburden stress of about 86 kPa. As discussed in Section 5.4.5.1, the granular 'A' improved overburden soils can be assigned a SLS of 100 kPa and factored ULS of 150 kPa, subject to sound construction control. For any section of the extension in excavated rock no bearing issue is relevant.

5.4.5.3 SLIDING RESISTANCE

Sliding is unlikely to pose a problem as the major horizontal earth pressure thrust on the culvert is along the road axis, which subject to proper backfill placement control as discussed in Section 5.4.7 on Bedding and Cover should not pose an issue. An unfactored friction angle of 32 degrees can be considered for interface sliding resistance between the CSP and the granular subgrade.

5.4.5.4 SETTLEMENTS

Based on the estimated overlying embankment fill stress at the pipe connection discussed in Section 5.4.5.2 and the borehole

information for this high fill section, the estimated maximum foundation settlement at the pipe connection is less than 10 mm, subject to sound construction control. Assuming the pipe connection can accommodate this settlement, no significant ground improvement is required for the CSP extension at this culvert location other than the sub-excavation discussed in Section 5.4.5.1.

5.4.5.5 EROSION PROTECTION AT INLET

If the inlet is in a rock cut, then erosion control measures would not be relevant at the inlet itself. However, transport of sediments into the culvert pipe still needs to be controlled. If the inlet is in the overburden soil, then requirements for erosion control at the inlet takes a greater priority.

Rip-rap protection should be provided at the culvert's inlet end and should generally follow OPSD 810.010 and any specific recommendations in the hydrology report. Rip-rap placed up to 1.5H:1V slopes without an underlying geotextile will be stable. The sandy soils comprise medium to coarse sand (See Fig. B-7) and are not generally prone to piping erosion. As the embankment fill consists of rockfill with voids, it is important to prevent seepage along the outer perimeter of the CSP. The loss of fines due to seepage can undermine the lateral confinement on the CSP and could lead to local subsidence effects depending on the severity. The installation of an anti-seepage collar surrounding the CSP at the inlet side should be considered, dependent on predicted stream flows based on hydrological advice.

These erosion/scour protection systems can be designed by a specialist River Engineer/Scientist (as erosion and scour largely depend on the hydraulic energy, i.e. velocity of water in the watercourse and its regime and the erodible nature of stream bed material).

5.4.6 CULVERT EXTENSION AT HIGH FILL SECTION 8

5.4.6.1 PROPOSED FOUNDING LEVELS

As per Drawing No. 8A, the existing 1.830 m dia CSP inlet will be extended by 7.0 m to the north with the new invert elevation shown at El. 207.4 m with the same type and size of pipe. Borehole BH HF8-35 refers to the subsoil conditions close to the culvert location.

Based on the intercepted soils in BH HF8-35, cohesionless till will likely be contacted along the proposed culvert extension. In view of the very loose/loose nature of the sub-soils contacted in BH HF8-35, sub-soils along the pipe extension below the invert level should be sub-excavated to a minimum of 1.5 m depth and replaced with engineered OPSS 1010 Granular 'A' to ensure uniform subgrade support. The sub-excavation should be along the entire pipe extension and be further extended 1 m on either side of the culvert extension footprint and beyond the culvert inlet. The intercepted native cohesionless deposit based on the grain size distributions shown in Fig. B-10 is considered to be of medium to high frost susceptibility as per the MTO Pavement Design and Rehabilitation Manual.

5.4.6.2 BEARING RESISTANCE

The existing culvert has been in-place for years and has undergone full settlement under the existing road embankment. Under the proposed WBTC, the highest vertical stress on the proposed culvert extension is likely to occur at the pipe connection to the existing culvert. The direct overburden at this pipe connection is estimated to be about 3.5 m as per Dwg No: 8A, with an estimated overburden stress of about 70 kPa. A SLS of 100 kPa and factored ULS of 150 kPa are recommended for the granular subgrade.

5.4.6.3 SLIDING RESISTANCE

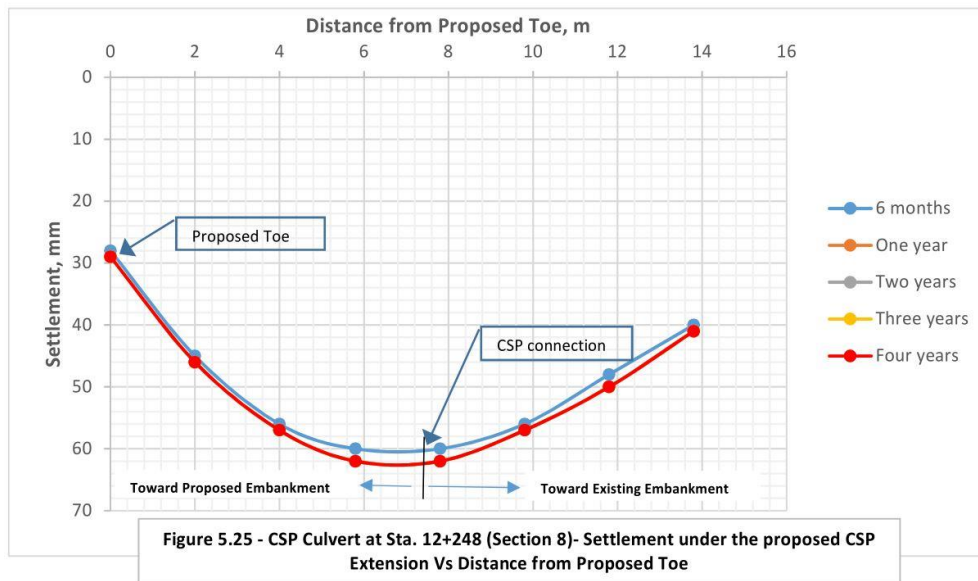
Sliding is unlikely to pose a problem as the major horizontal earth pressure thrust on the culvert is along the road axis, which subject

to proper backfill placement control as discussed in Section 5.4.7 on Bedding and Cover should not pose an issue. An unfactored friction angle of 32 degrees can be considered for interface sliding resistance between the CSP and the granular subgrade.

5.4.6.4 SETTLEMENTS

In order to investigate the likely settlement along the proposed culvert extension, a FEM settlement analysis (elasto-plastic coupled consolidation with a Mohr-Coulomb soil model) was undertaken based on the site specific subsoil information at the existing culvert location. To obtain the worst case scenario, no culvert structure was modelled (no reduction in fill loading in view of the culvert or the reduction of vertical stress under the culvert due to possible arching effects were simulated). The analyzed geometry and the geotechnical model is shown in Fig. 5.19. Settlements were computed at discrete points along the proposed culvert extension axis and settlements beyond the existing inlet into the existing highway embankment (Figs. 5.20 to 5.24 refers).

Fig. 5.25 shown below has summarized the findings from the FEM analysis. The maximum angular distortion anywhere along the pipe invert level is less than 1% (without taking into any account of the pipe stiffness), the limit of 1% is generally used for CSP pipes in practice) and at the CSP pipe joint it is almost negligible. Based on the analysis, no significant ground improvement is required for the CSP extension at this culvert location other than the sub-excavation discussed in Section 5.4.6.1.



5.4.6.5 EROSION PROTECTION AT INLET

Rip-rap protection should be provided at the culvert's inlet end and should generally follow OPSP 810.010 and any specific recommendations in the hydrology report. Rip-rap placed up to 1.5H:1V slopes without an underlying geotextile will be stable. Consideration should be also given to a low permeability clay seal/GCL (OPSS 1205/OPSP 802.095) at the inlet especially given the potential erodible nature of the near surface high silt laden soils (Fig. B.10 in FIR). As the embankment fill will consist of rockfill with voids, it is important to prevent seepage along the outer perimeter of the CSP. The loss of fines due to seepage can undermine the lateral confinement on the CSP and could lead to local subsidence effects depending on the severity. The installation of an anti-seepage collar surrounding the CSP at the inlet side should be considered, dependent on predicted stream flows based on hydrological advice. The minimum sub-excavation of 1.5 m recommended in Section 5.4.6.1 will significantly eliminate the medium to high frost heave potential under the proposed CSP culvert extension.

These erosion/scour protection systems can be designed by a specialist River Engineer/Scientist (as erosion and scour largely

depend on the hydraulic energy, i.e. velocity of water in the watercourse and its regime and the erodible nature of stream bed material).

5.4.7 BEDDING, COVER AND BACKFILL FOR ALL HIGH FILL CULVERT EXTENSIONS

5.4.7.1 BEDDING AND COVER

Uniform bedding conditions should be provided below the pipe invert to prevent localized concentrated foundation support that can lead to possible distress at invert and haunches.

The bedding thickness should be as per OPSD 802.013 and 802.014.

The bedding and cover materials should consist of a well-graded granular material and use of OPSS 1010, Granular 'A' is recommended. The cover should extend to at least one pipe diameter above the obvert of the pipe to promote arching action for these flexible culverts. The bedding material should be placed as soon as practicable after the preparation of the subgrade, its inspection and approval. The placement and compaction should follow OPSS 401 and OPSD 802.010. The level difference between opposite sides, at any time during compaction, must conform to Clause 401.07.10.03.

5.4.7.2 BACKFILL

Rockfill can be considered for backfill subject to complying with OPSS 206.

5.4.8 SUMMARY OF SETTLEMENT ANALYSES

No major ground improvements at the subject culvert locations are considered necessary except for the sub-excavation type ground improvements discussed under each individual culvert site and subject to sub-excavation of isolated occurrences of surficial peat and organic clayey silt, if intercepted. Sound compaction control is required for the construction of culvert bedding, cover and backfill. The predicted settlements under High Fill Section 8 culvert (which is the most critical from a settlement point of view) location meet the angular distortion for flexible CSP pipes used in practice. Erosion protection was highlighted and may require input from specialists in this discipline as well as for the necessity for anti-seep collars at extended culvert inlets.

5.5 CONSTRUCTION CONSIDERATIONS

5.5.1 GENERAL

All loose, soil and rock boulders; topsoil, peat and organic soils should be cleared/sub-excavated from the embankment footprint to be widened. All loose rock/soil on the existing northern highway embankment side slope should be removed carefully without causing dislodgement of rock blocks and resulting ground depressions on the road above.

Due to the wide intervals of the borehole layout (as stipulated in the RFQ), exact depths and extents of sub-excavations of deleterious materials for the high fill widenings cannot be made with any reliability. Based on the limited information at hand, the following approximate limits for sub-excavation (but not limited to) are recommended subject to field verification.

- High Fill Section 2: Stn 14+270 to 14+320; *intercepted thickness* of peat was 700 mm (Bottom El. 400.8 m)

- High Fill Section 6: Stn 15+530 to 15+560; *intercepted thickness* of peat was 600 mm (Bottom El. 378.9 m)
- High Fill Section 8: Stn 12+155 to 12+180; *intercepted thickness* of organic clayey silt was 1200 mm (Bottom El. 206.7 m)
- High Fill Section 9: Stn 12+830 to 12+860; *intercepted thickness* of organic clayey silt was 1400 mm (El. 194.1 m)

Peat and organic soils should be sub-excavated to at least and 5 m beyond (outside) the toe of the proposed widening (to mitigate the influence of such deleterious material on embankment toe stability). In sections of the alignment where slope flattening as per OPSD 202.010 is proposed the lateral extent beyond the flattened toe should be sub-excavated to 2 m. All sub-excavated material should be backfilled with rockfill in view of the high groundwater levels.

It is recommended that actual extents of unsuitable material are identified in the field during construction by the Contract Administrator's geotechnical engineer.

The sub-excavation treatments should be carried out under geotechnical supervision.

5.5.2 OPEN CUT EXCAVATIONS FOR CULVERT EXTENSIONS

5.5.2.1 OPEN CUT EXCAVATION STABILITY

All excavations should be carried out in accordance with the Province's Occupational Health and Safety Act (OHSA), O. Reg. 213/91. It is considered that shored excavations are unlikely to be required in this open project locality and hence not addressed.

In accordance with the Province's Safety Regulation, the following soil classification would be applicable for open cut as shown in Table 5-3. However, based on site specific ground conditions and engineering judgement, OHSA classifications have been qualified and adopted to err on the side of safety. This applies to excavations for culvert extension bases.

Before worker entry, geotechnical assessment of the excavation slopes should be carried out and is recommended, in addition to surveillance requirements discussed below.

Table 5-3 Interpreted OHSA Requirements for Open Cut Excavations

Material/Deposit	Groundwater	OHSA Classification	Remarks
Rockfill	NA	Not steeper than 1H:1V	
		NA	
Cohesionless Soil (sandy gravel/gravelly sand)	Above groundwater	Not steeper than 1.5H:1V	Applicable to culvert extensions in High Fills 3, 6, 7.
	Below groundwater	Not steeper than 2.0H:1V	

Material/Deposit	Groundwater	OHSA Classification	Remarks
Native Cohesionless Deposits(silty sand/sandy silt Till)	Above groundwater	Not steeper than 2.0H:1V	Applicable to culvert extension in High Fill 8.
	Below Groundwater	Not steeper than 3.0H:1V	
Upper Cohesive Deposit)	Above Groundwater	NA	
	Below Groundwater	Not steeper than 2.5H:1V	
Lower Cohesive Deposit	Above Groundwater	NA	
	Below groundwater level	2.5H:1V	
Basal Cohesionless Deposit	Above Groundwater	NA	
	Below Groundwater	Not steeper than 2.0H:1V	
Bedrock		Type 1	

These temporary slopes for the above soil types as per OHSA are only as guidelines for temporary excavation slopes to be used for a short duration. We also recommend that these slopes be visually monitored for any movement especially if workers are present at the toe of the slopes.

All excavations should be undertaken with care to minimize disturbance especially to slopes below the water table and the saturated foundation subgrade.

The above guidelines may be used for sub-excavation under the proposed embankment widening footprint subject to site specific geotechnical assessment.

5.5.2.2 EXCAVATABILITY

Excavations should be possible in the above soil types except bedrock using equipment such as a hydraulic excavator. Although rock exploration was outside the foundation assignment, the contractors should be forewarned about the potential for rock excavation for the proposed culvert extension at High Fill Section 7 and this is “red” flagged. An NSSP is provided to address this.

Based on the intercepted ground conditions, possible obstructions to excavations due to cobbles and boulders are likely and this is

“red” flagged. An NSSP is provided to address this.

These observations apply to excavations in general within the high fill sections.

5.5.2.3 CONSTRUCTION DEWATERING AND CREEK FLOWS

Due to the cohesionless nature of the subsoils in the majority of the high fill sections, the need for strategically placed sumps with ditches and drains will be required for construction of culvert bases. However, given the high groundwater level, permeable lenses and embankment fill (rockfill), the need for positive dewatering measures, e.g. pumping, for maintaining dry excavations cannot be ruled out. Dewatering operations shall conform to OPSS 517, SP517F01 and NSSP FOUND003.

No heavy creek flows were observed during the field investigations. Need for channel diversion should be made on hydrological advice and will depend on time of construction in the year and would be better served if culvert construction is carried out in late summer in dry weather. Some options for creek flow management are sand bagging and hosing the water through the existing culvert or sand bagged creek flows can be pumped along checked swales with silt fence protection, to surrounding lower ground subject to environmental constraints. All temporary erosion and sediment control measures shall conform to OPSS 805.

5.5.3 CONSTRUCTION ON COMPRESSIBLE SOILS

Construction activities shall conform to OPSS.PROV 209. All construction excavations abutting or within 10m from the existing highway embankment northern toe should be staged not more than 5 m in length parallel to the existing highway embankment at any given time and location. This applies to High Fill Sections 8 and 9. It is recommended that High Fill Sections 8 and 9 be programmed to be constructed first within the construction contract to enable a minimum preload period of six (6) months. Alternatively, this preloading programme may be considered as part of an early works contract such as the winter works program and is recommended.

5.5.4 CONSTRUCTION OF ROCKFILL HIGHWAY EMBANKMENT WIDENING

In summary, as discussed in Section 5.3.2, the following embankment northern side slopes for the WBTCCL are recommended:

- High Fill Section 6: The proposed WBTCCL side slope should not be steeper than 1.6H:1V which is same as that of the highest existing northern side slope
- High Fill Section 8: The proposed WBTCCL side slope should not be steeper than 2H:1V which is shallower than the highest existing northern side slope
- High Fill Section 9: The proposed WBTCCL side slope should not be steeper than 2.5H:1V which is same as the highest existing northern side slope
- For all other high fill sections, the northern side slopes should not be steeper than 1.6H:1V.

All construction activities shall conform to OPSS.PROV 206. In High Fill Sections 8 and 9 that comprise compressible subsoils, compacted rockfill placement thickness shall not exceed 1.5 m per week above existing ground surface.

One metre below the elevations of the proposed pavement subgrade for the widening, the existing embankment should be excavated to a width equal to 1.5 m (this will be into the existing embankment shoulder) and the embankment construction should proceed including the overlap. This overlapped construction will help to mitigate any potential influence of a weakness plane that could arise at the interface between the existing side slope and the proposed widening.

In northern Ontario where rock fill embankments are commonly constructed due to widespread availability of near surface rock and rock outcrops as sources, loss of fines into the rockfill from the overlying pavement subgrade continue to cause sink holes during in-service. In order to mitigate such unforeseen maintenance interventions into the future, it is recommended the use of a heavy duty

geotextile over the chinked rockfill embankment top layer before construction of the pavement structure. An NSSP is provided for this geotextile application.

The excavated materials from the construction should be stockpiled and checked for contamination prior to removal/disposal off-site, in order to determine which disposal option is best for the excavated materials (OPSS 180) and site restoration must conform to OPSS 492.

5.5.5 SETTLEMENT MONITORING

Mitigation of post-construction settlement (in-service) is particularly important for high fill embankment widenings in view of the potential settlement interacting effects with the adjoining existing embankments which need to be kept operational. Settlement monitoring gives an extra tool in the management of such risks. It also has the added benefit of early release of sites for continuation of construction, e.g. for construction of the asphalt layers, based on field observed higher settlement rates. In the case of high fill rockfill embankments, settlement monitoring is able to confirm not only the settlements undergone by compressible foundations but also the time dependent settlement of rockfill embankments. Further, there is a significant dearth of available information of highway rockfill embankment settlements for low to medium embankment heights published anywhere. Rockfill highway embankments are almost ubiquitous in the Ontario northern region and further understanding rockfill settlement issues is of interest to these regions. For all these reasons, settlement monitoring is recommended and further discussion of detail follows.

Three settlement plates (SPs) should be installed in every high fill section 1.5 m below the finished grade, except for High Fill Sections 8 and 9 where the SPs should be installed about 1 m above the existing ground surface after any necessary sub-excavation and embankment build-up; one settlement plate should coincide with the highest embankment section for the high fill Section. For High Fill Sections 8 and 9, settlements should be monitored for one year and for other high fill sections settlements should be monitored for three months, or until the settlements have reached practical completion.

The Contractor is responsible for the supply and installation of the instrumentation. The Contract Administrator with a Foundation Engineering Specialist is responsible for the monitoring program. An NSSP is attached giving details of the settlement monitoring programme.

CLOSURE

The "Limitations of Report" as presented in **Appendix G** are an integral part of this report.

SIGNATURES

We trust that the information contained in this foundation investigation report is satisfactory. Should you have any questions, please do not hesitate to contact this office.

WSP Canada Inc.


Mani Patchayappan M.Eng., P.Eng

Intermediate Geotechnical Engineer




Vasantha Wijeyakulasuriya, M.Eng., P.Eng

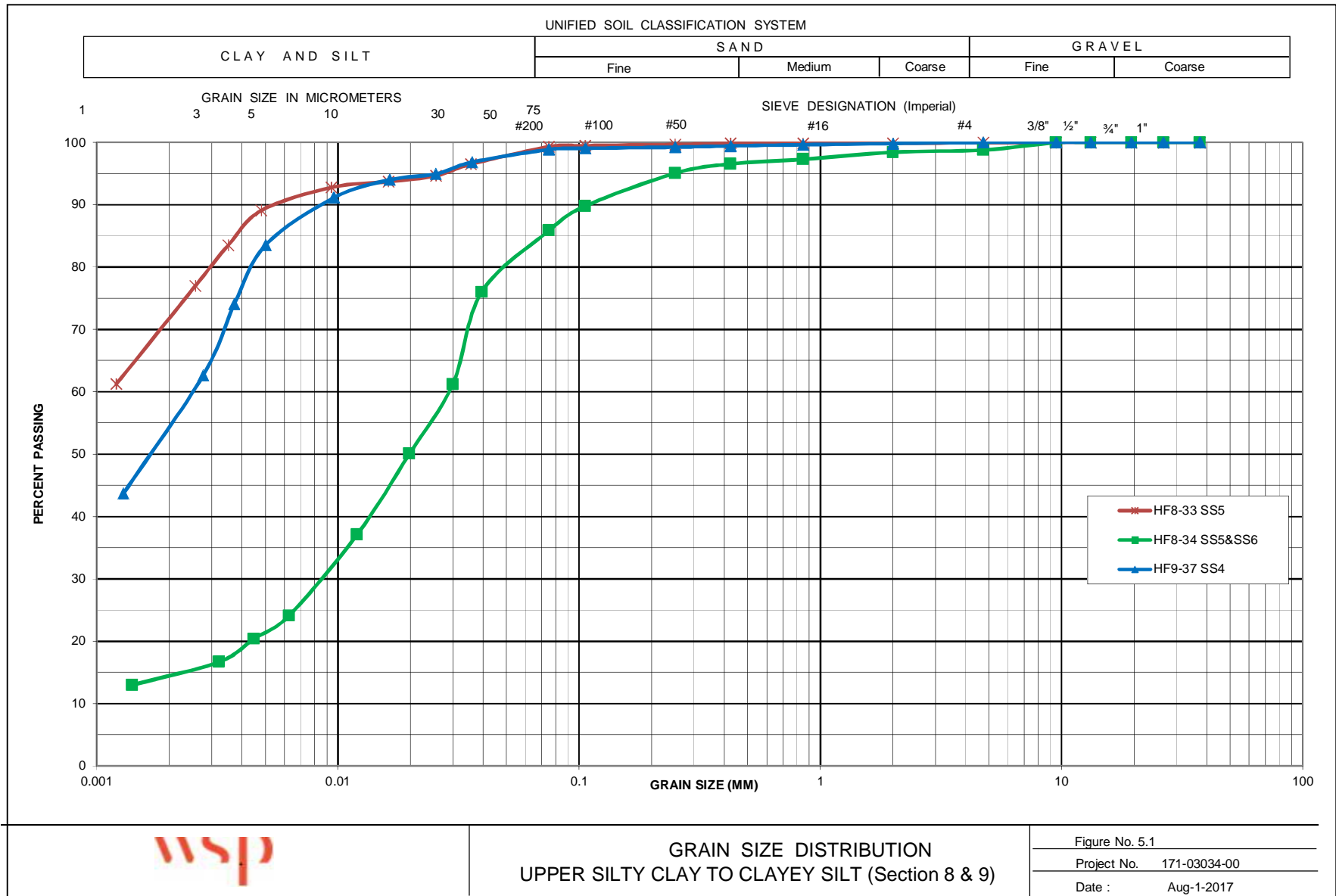
Senior Technical Director, Geotechnical
MTO Designated Contact



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Figure 5.1- Combined Grain Size DistributionCurves of Upper Cohesive Deposit (Section 8and 9)



GRAIN SIZE DISTRIBUTION
UPPER SILTY CLAY TO CLAYEY SILT (Section 8 & 9)

APPENDIX

D STABILITY AND SETTLEMENT ANALYSIS - HIGH FILL SECTIONS

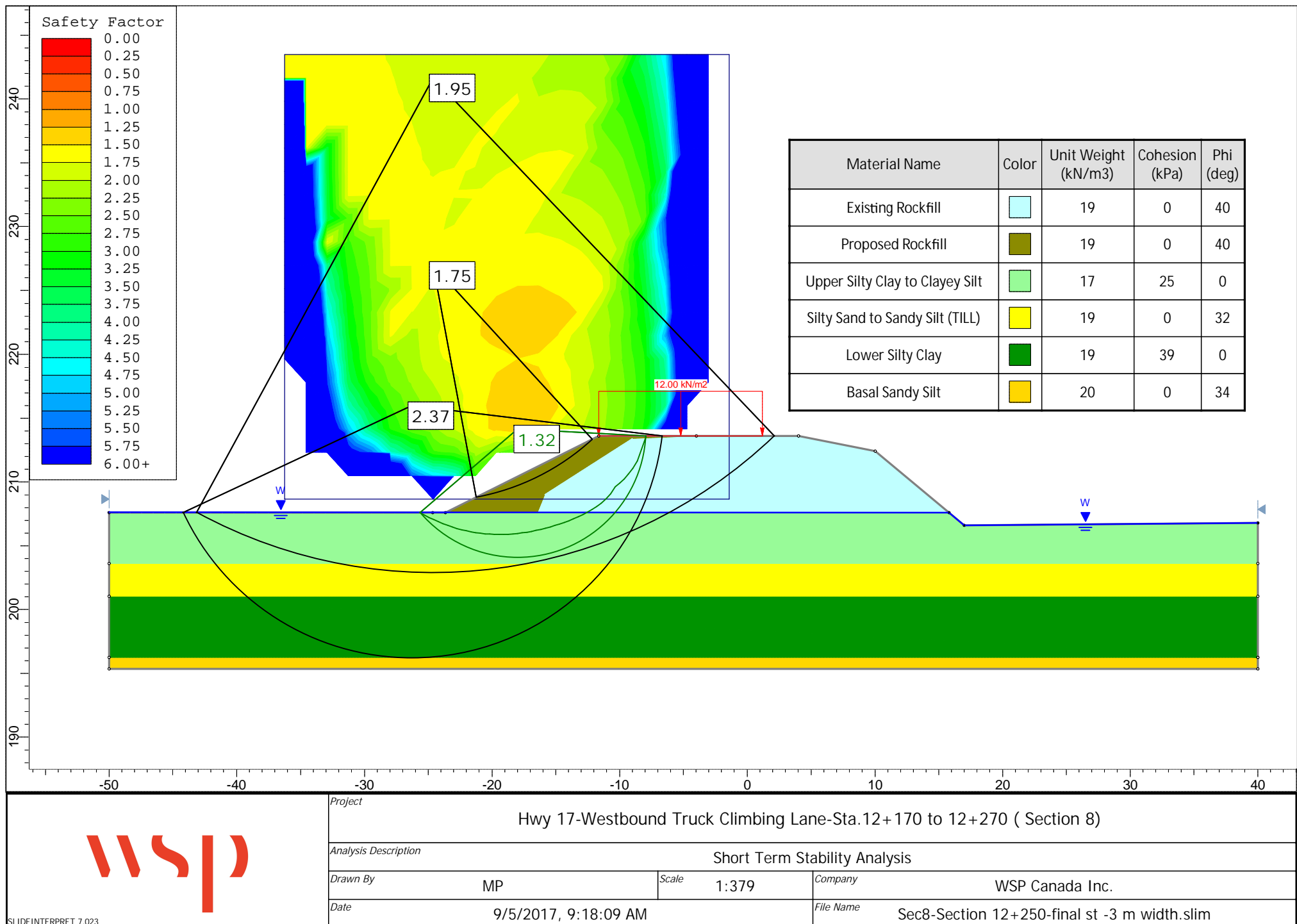


Figure 5.2

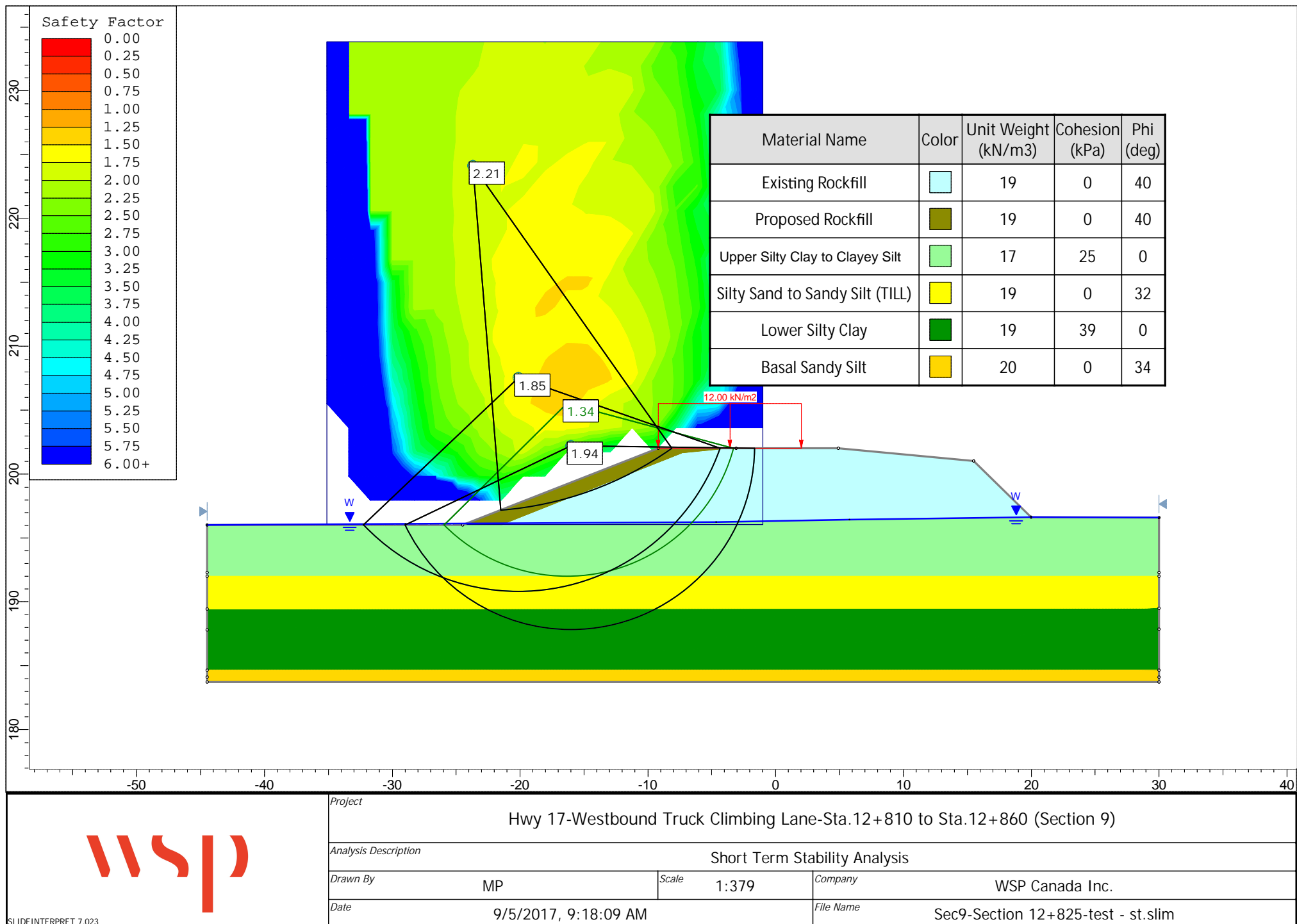


Figure 5.3

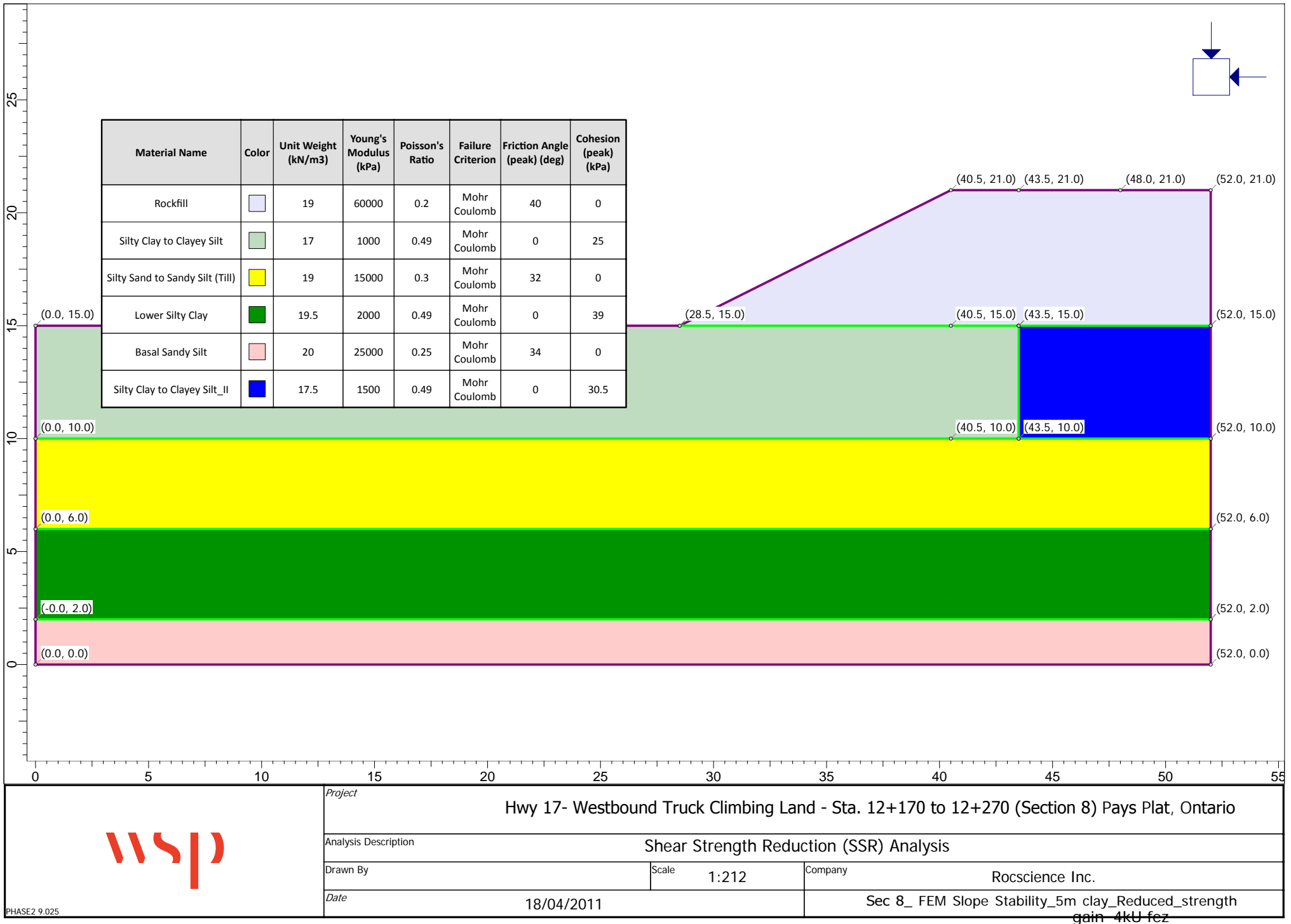


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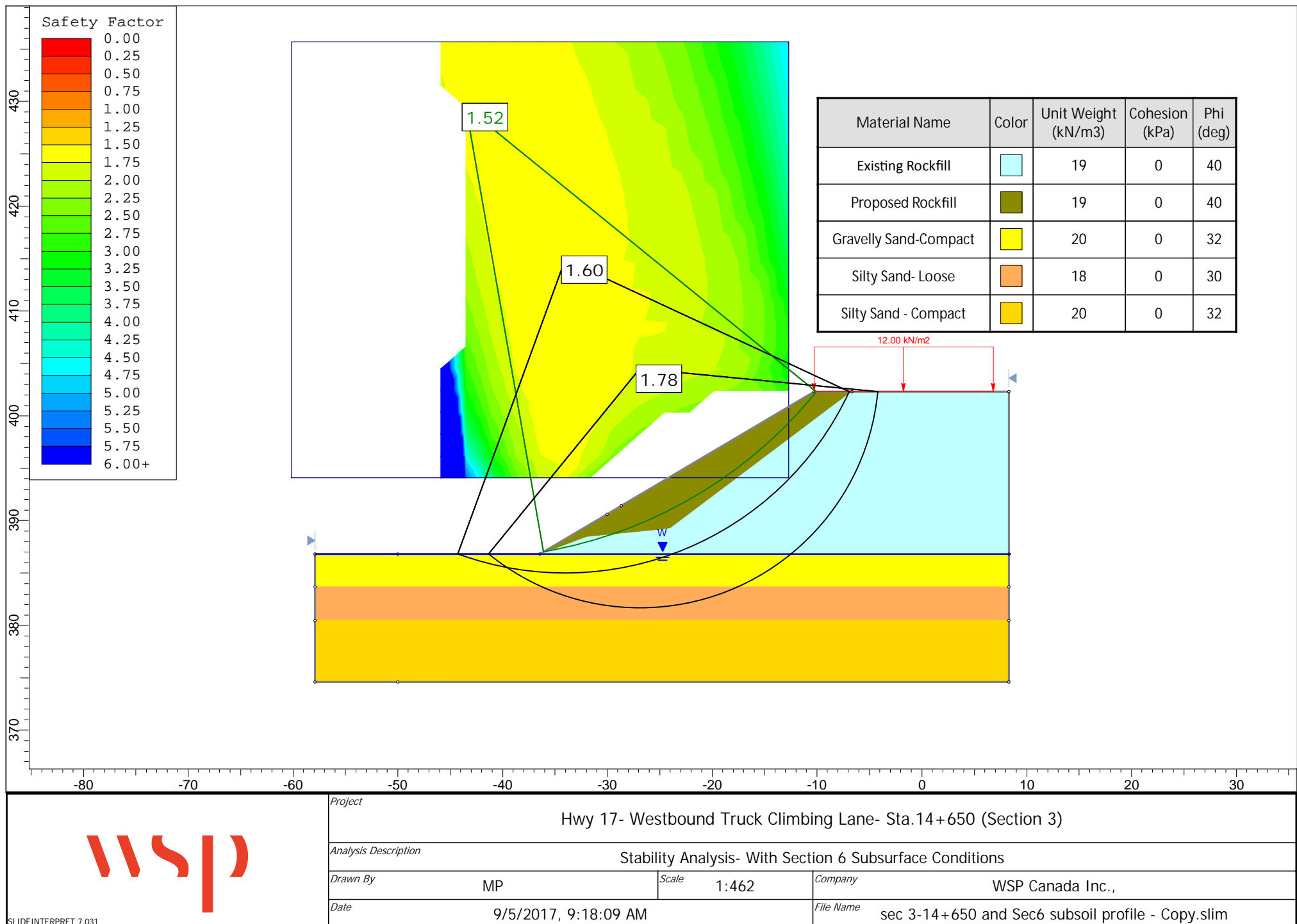


Figure 5.7

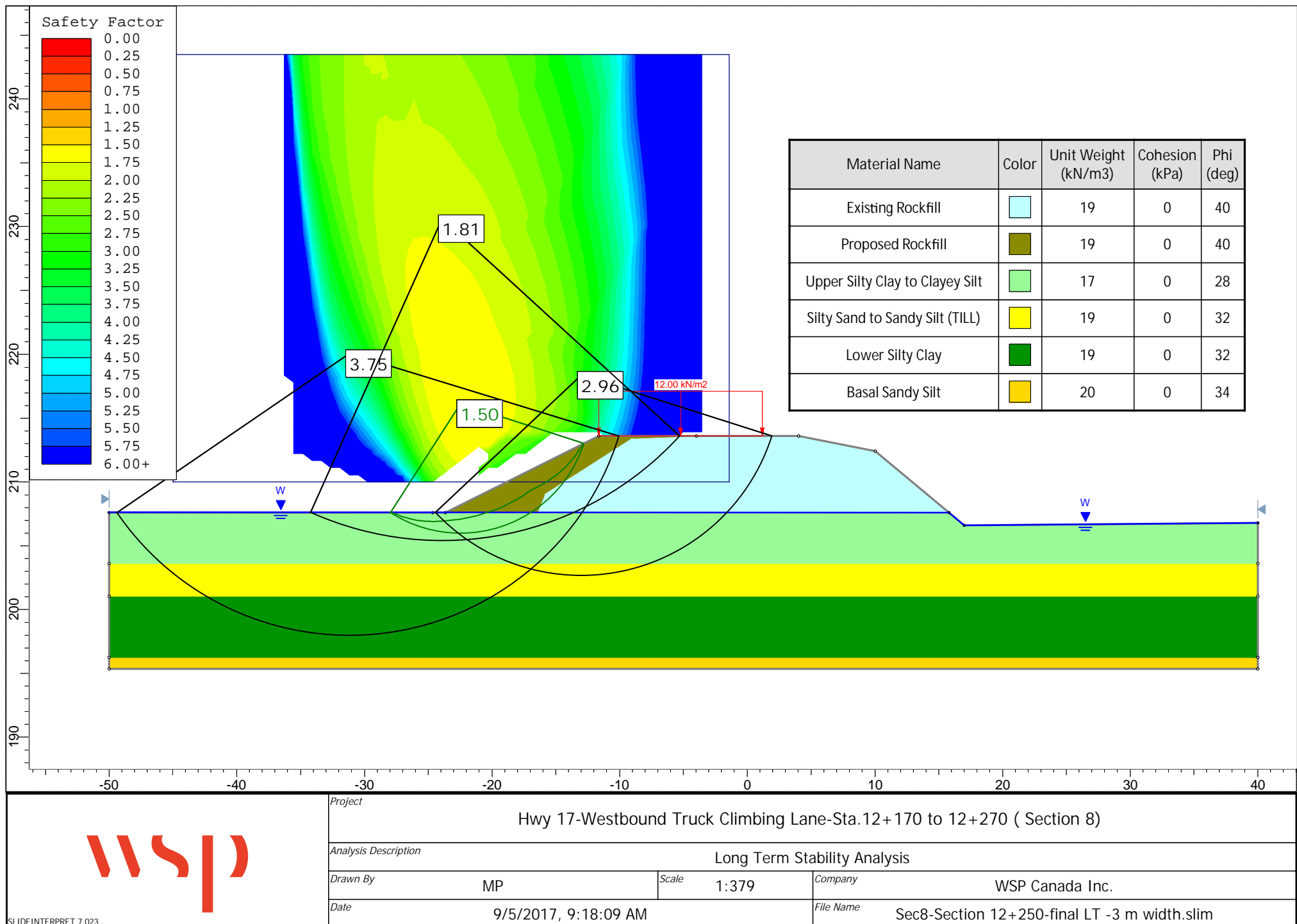


Figure 5.8

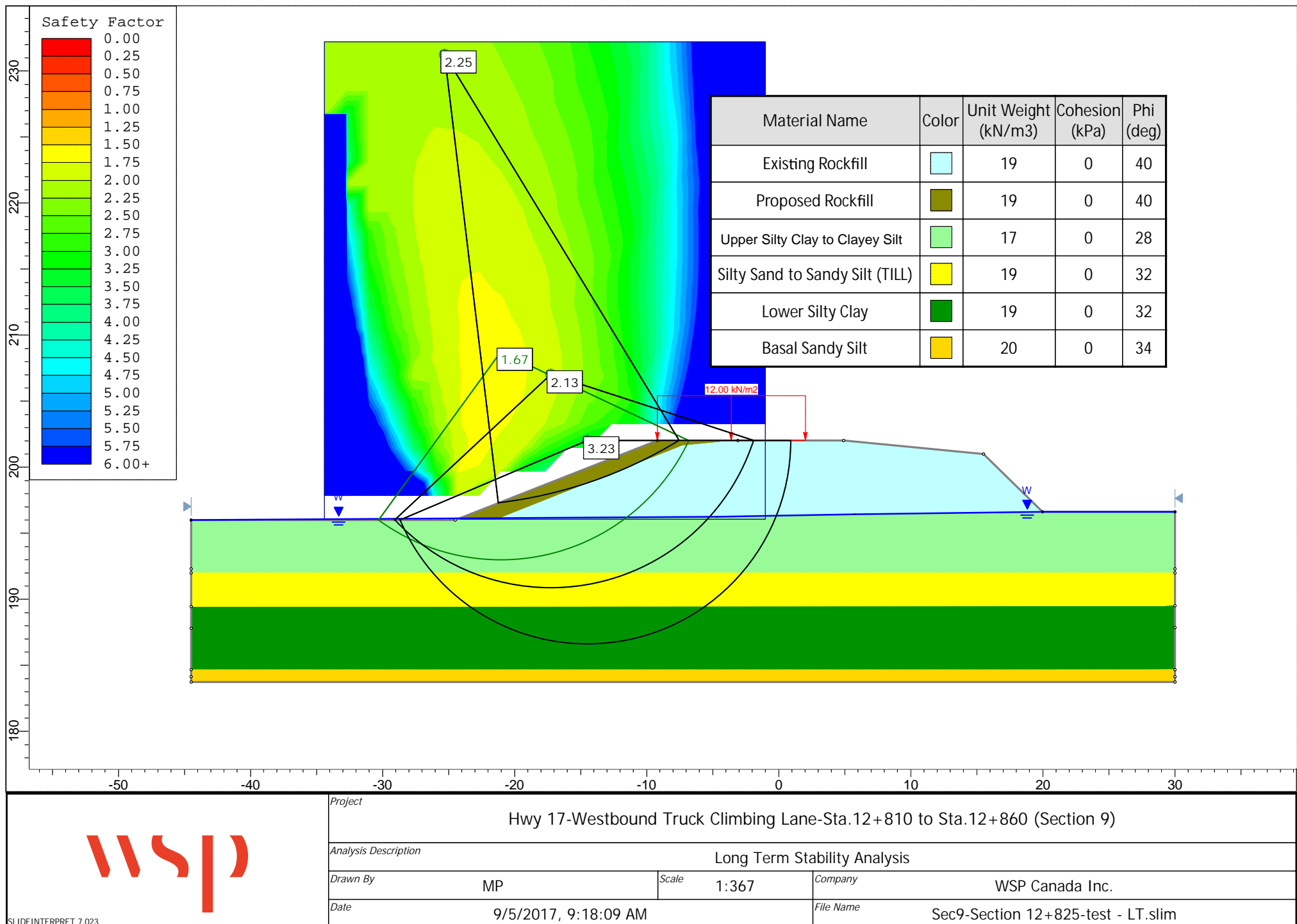


Figure 5.9

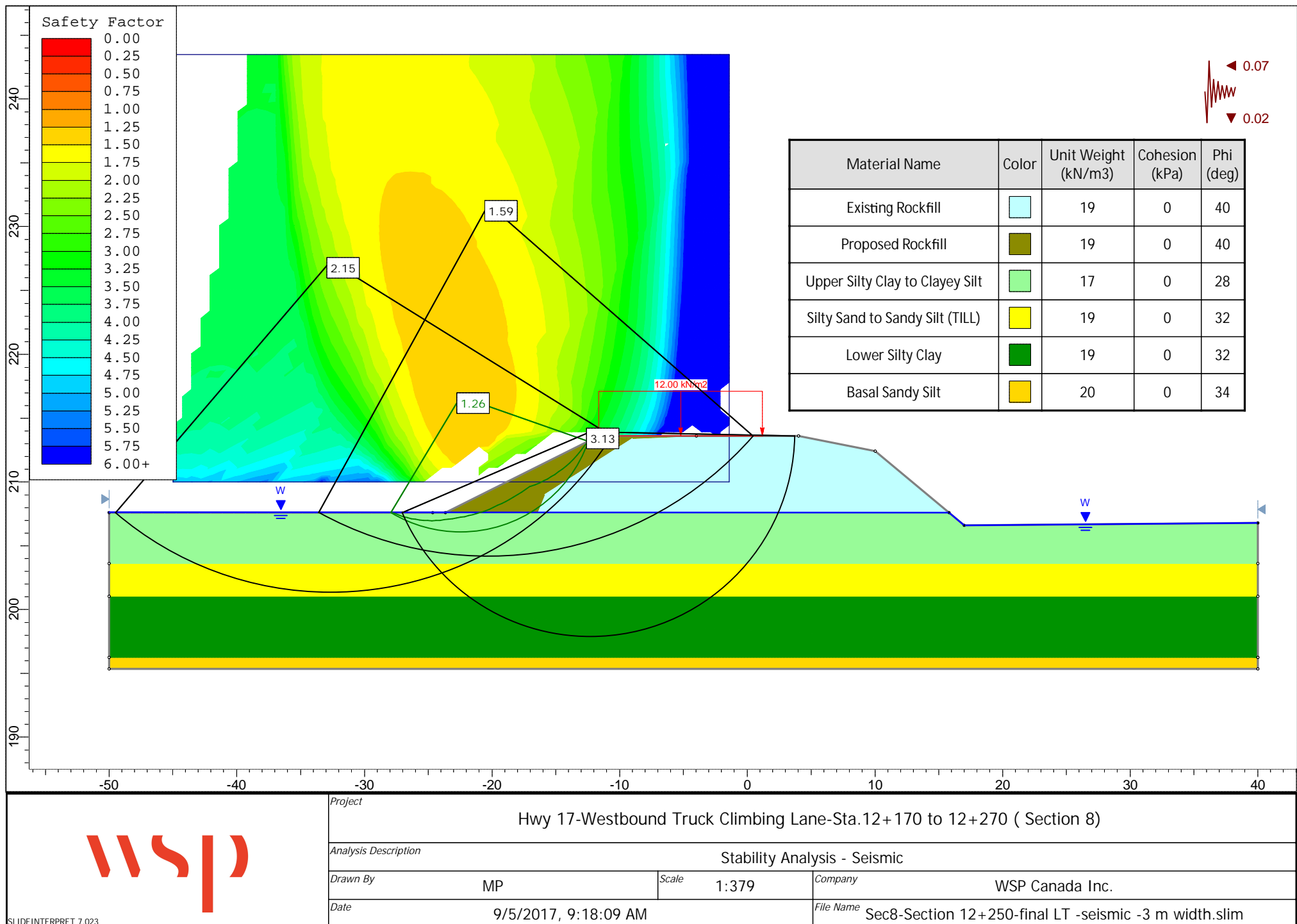


Figure 5.10

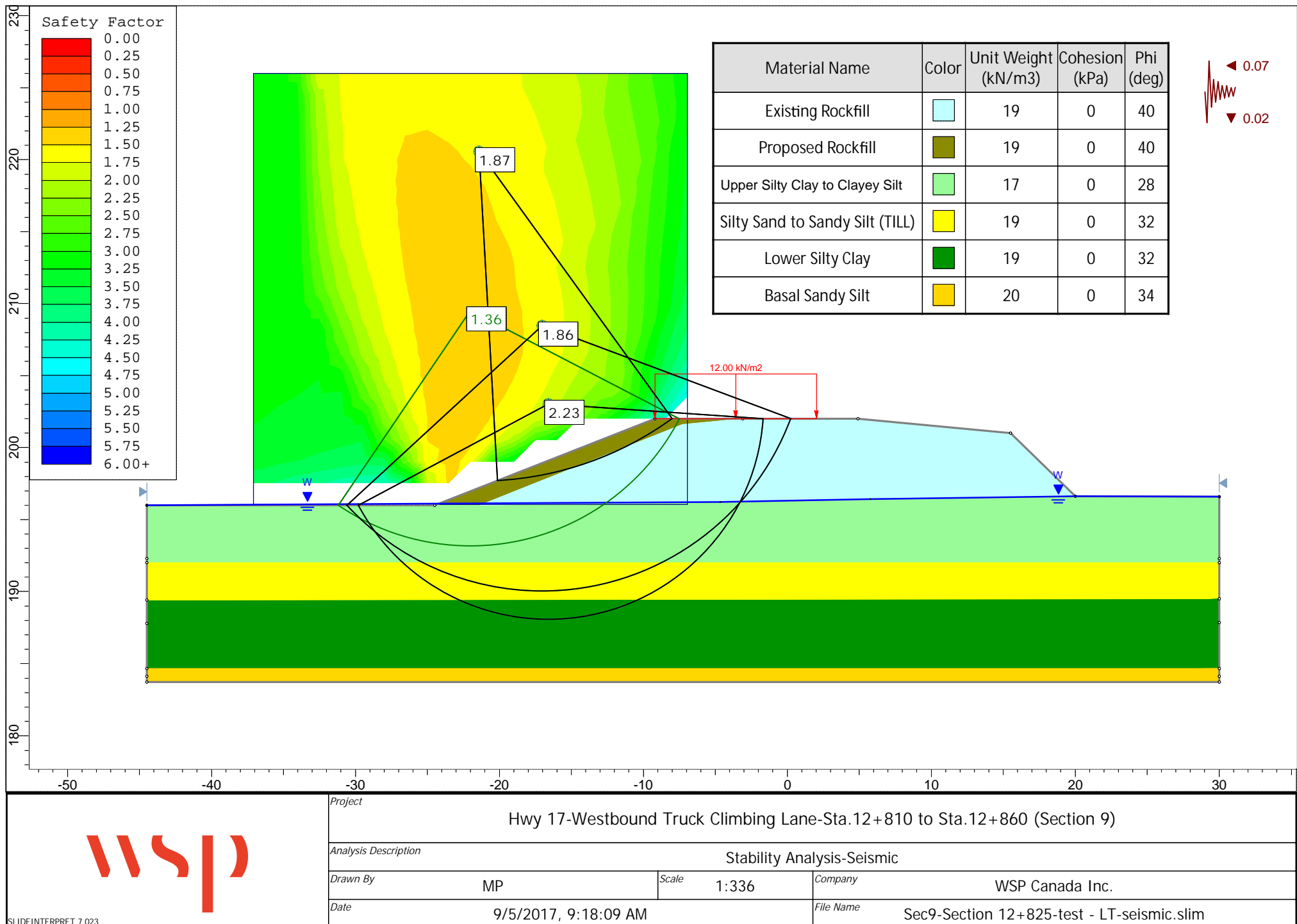


Figure 5.11

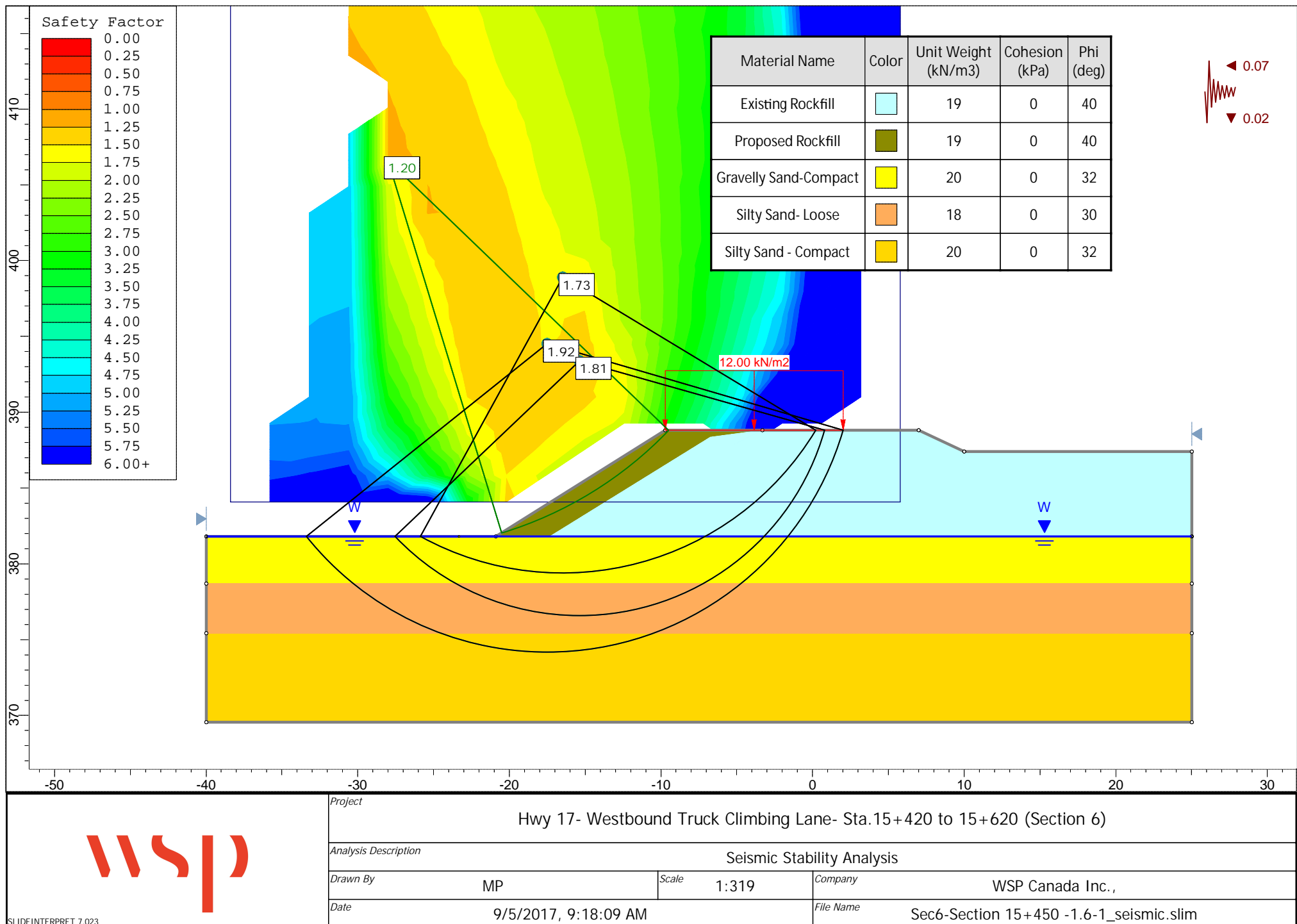


Figure 5.12

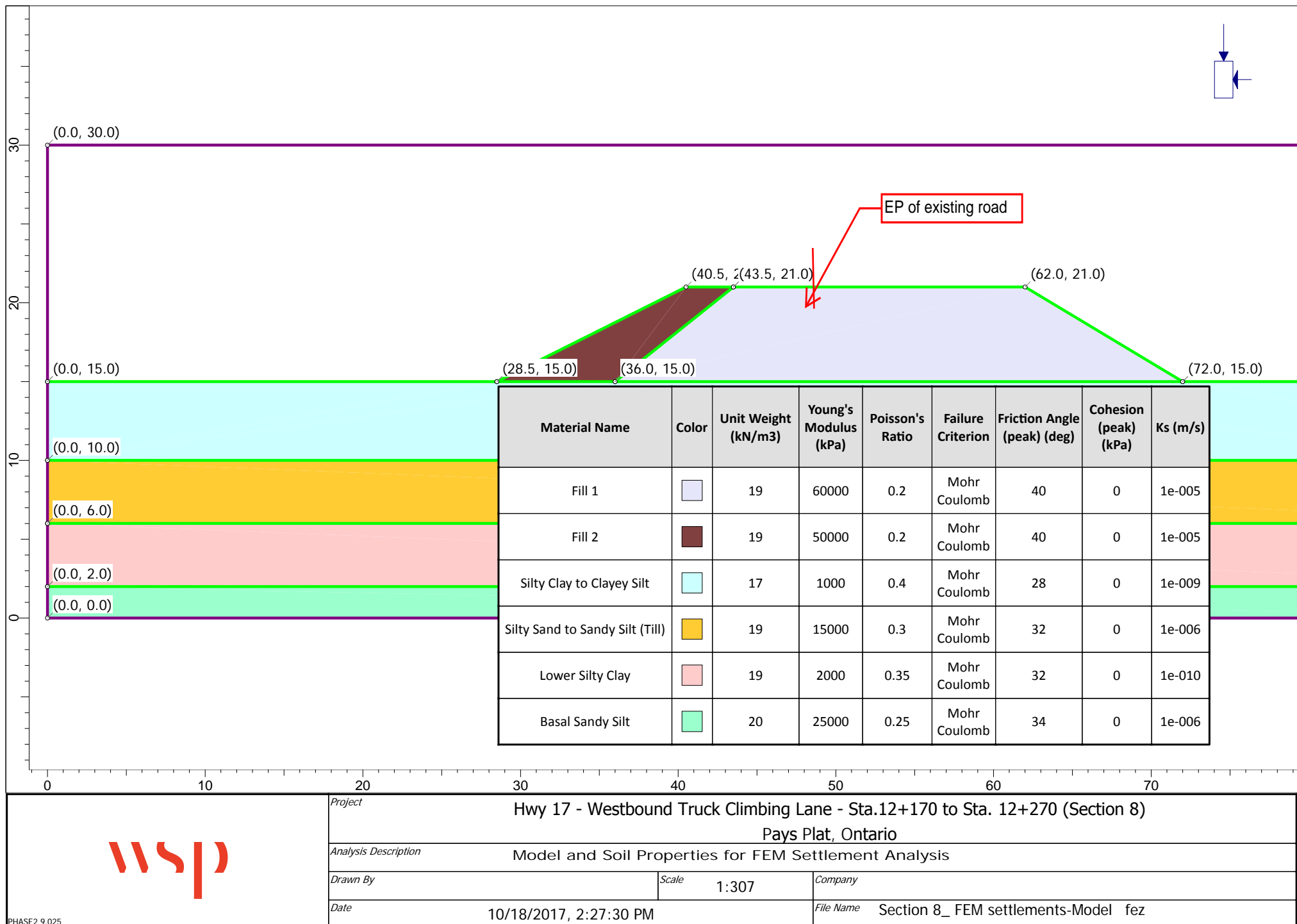


Figure 5.13

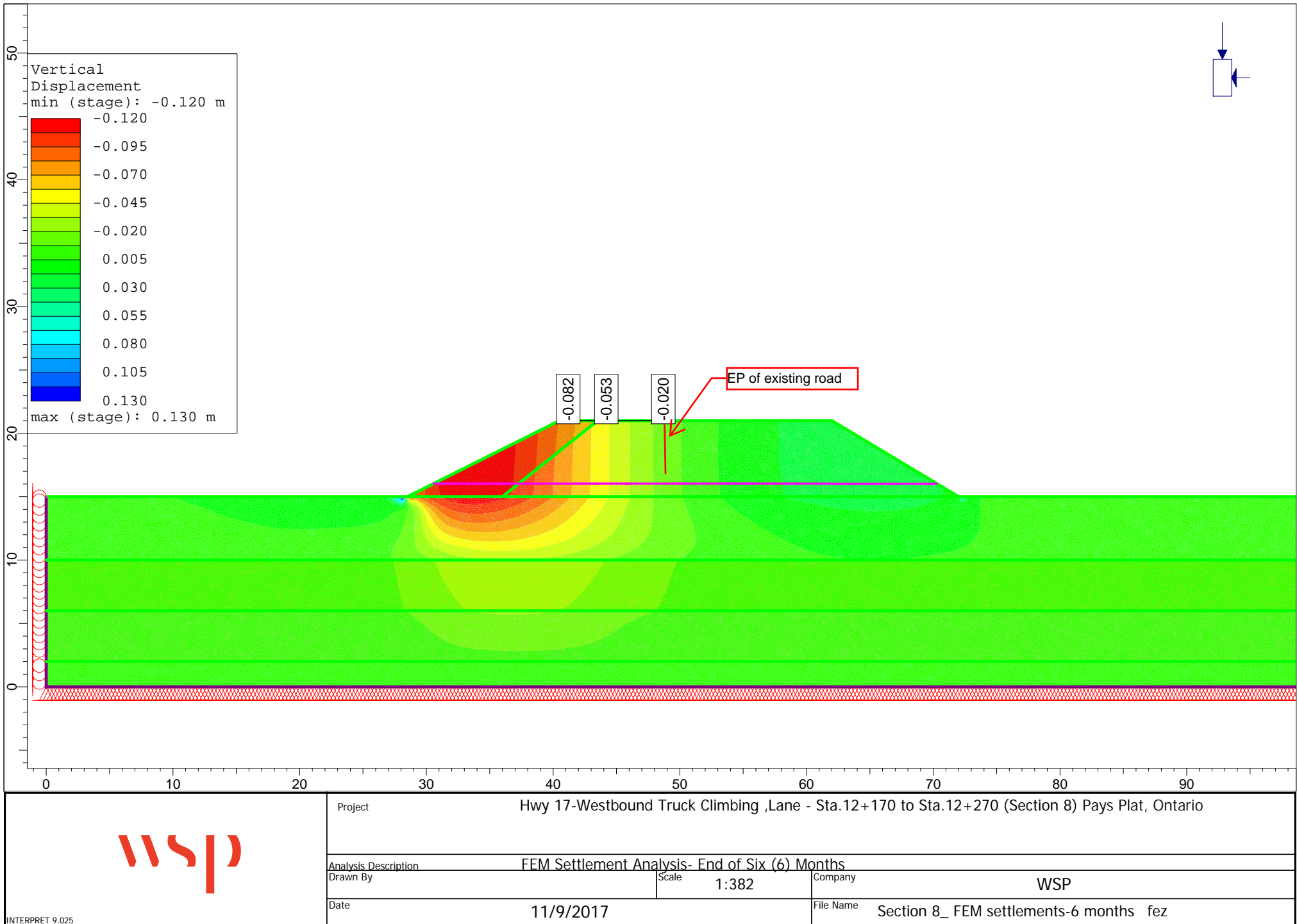


Figure 5.14

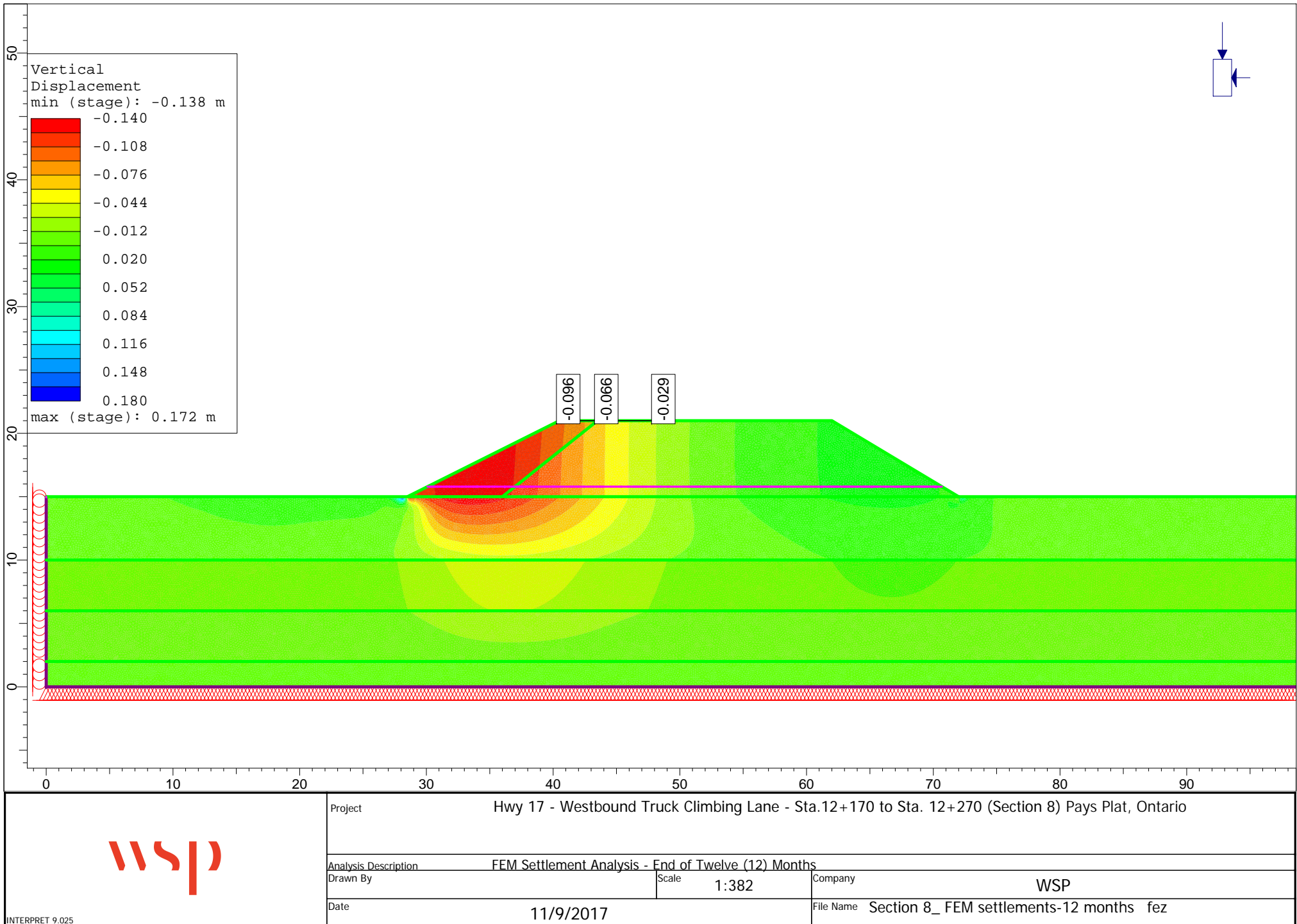


Figure 5.15

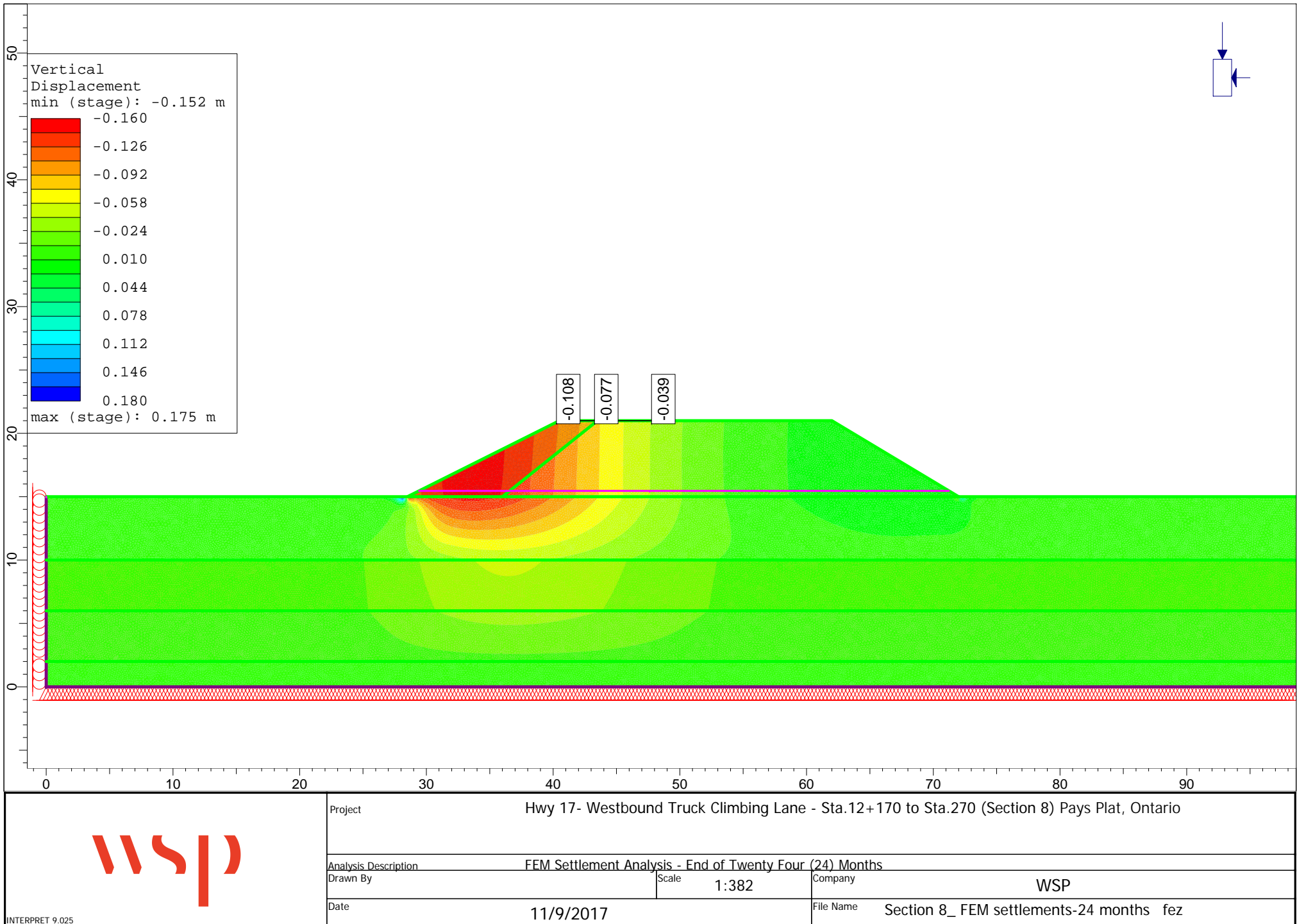
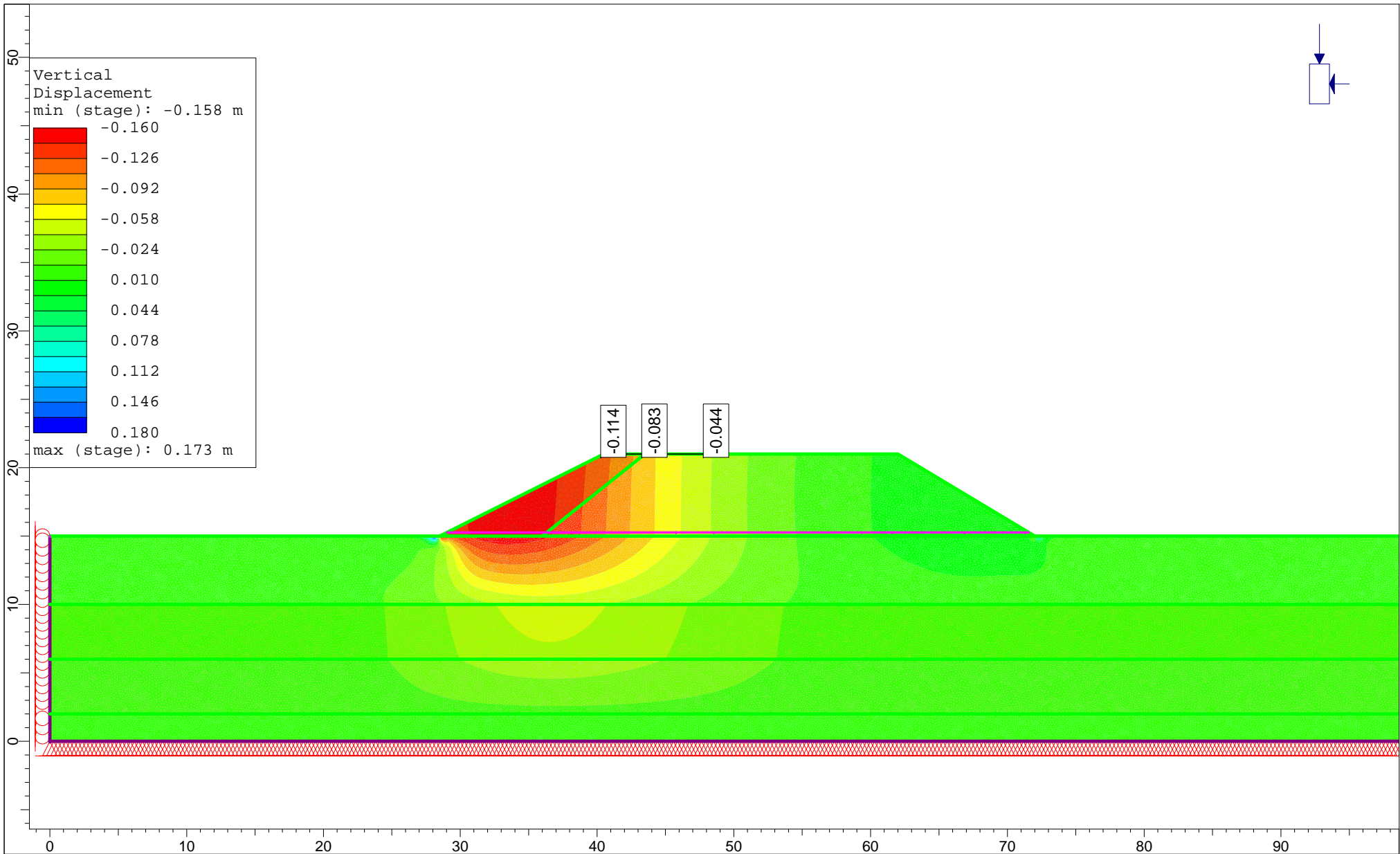



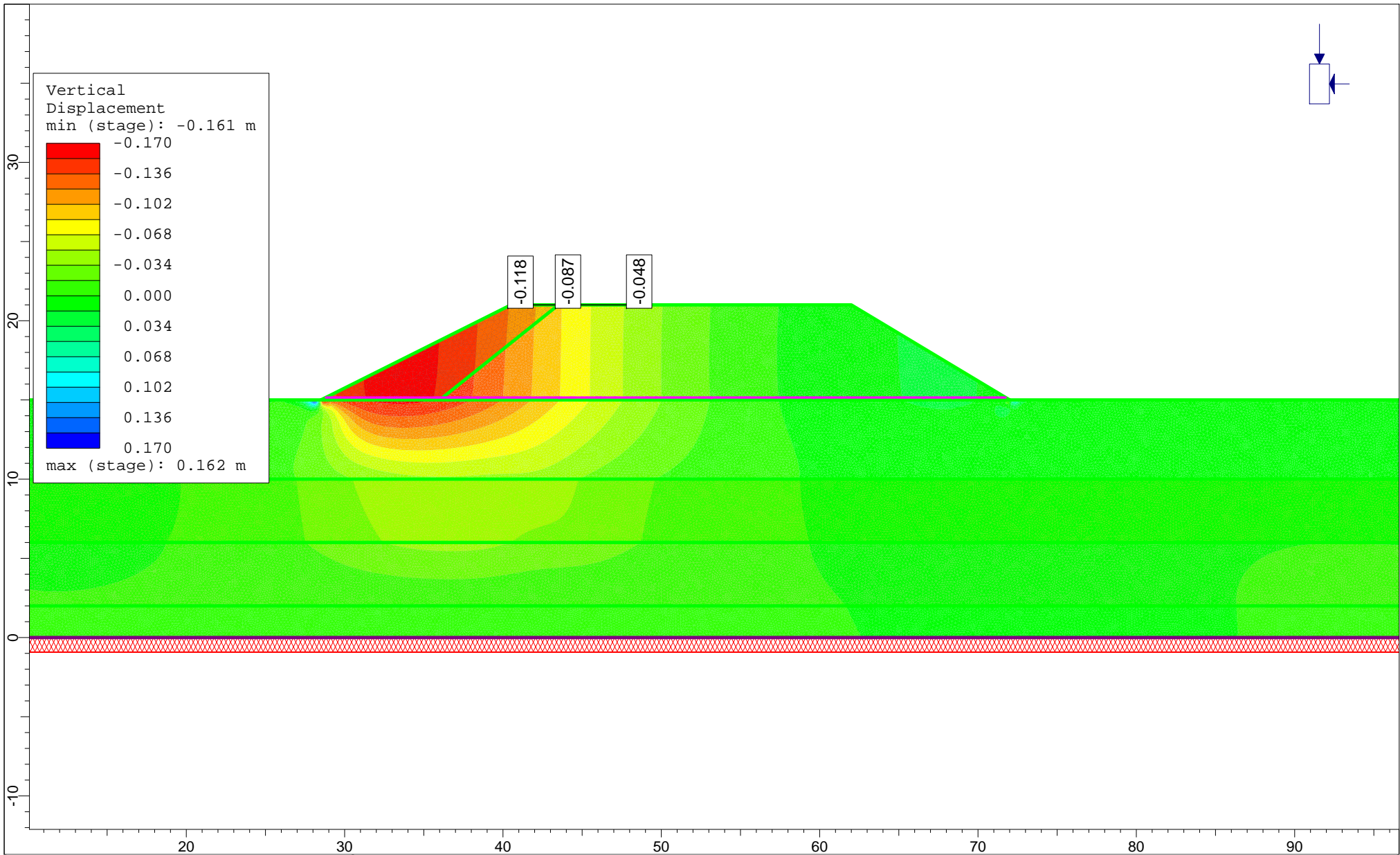
Figure 5.16



	Project Hwy 17 - Westbound Truck Climbing Lane - Sta. 12+170 to Sta. 12+270 (Section 8) Pays Plat, Ontario		
	Analysis Description FEM Settlement Analysis - End of Thirty-Six (36) Months		
	Drawn By	Scale 1:382	Company WSP
	Date 11/9/2017	File Name Section 8_ FEM settlements_5m clay_1&2MPa- 3yr fez	

INTERPRET 9.025

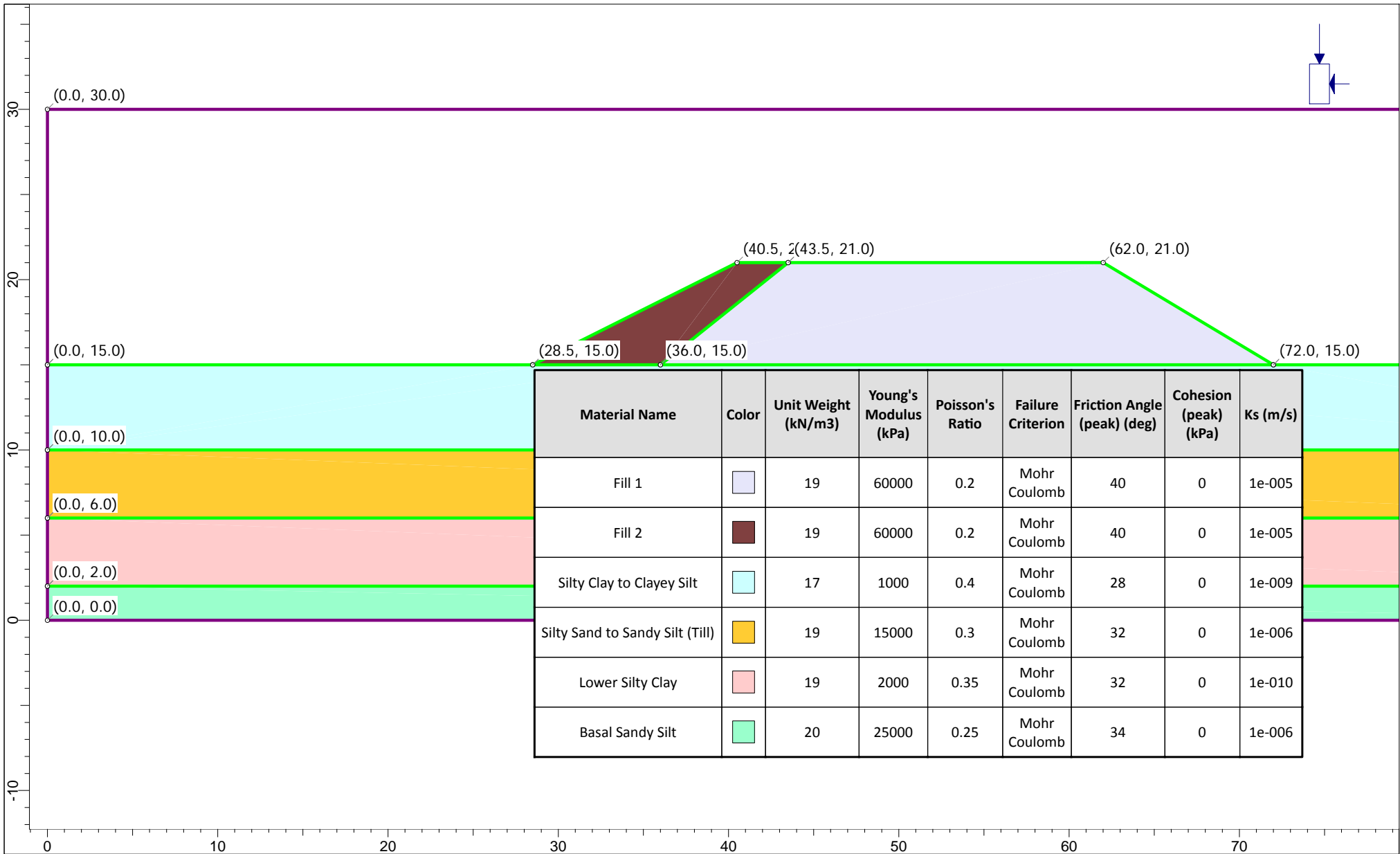
Figure 5.17




Project	Hwy 17 - Westbound Truck Climbing Lane - Sta. 12+170 to Sta. 12+270 (Section 8) Pays Plat, Ontario		
Analysis Description	FEM Settlement Analysis - End of Forty-Eight (48) Months		
Drawn By	Scale	Company	
Date	11/12/2017	WSP	
		File Name	Hwy 17 - Section 8_ FEM settlements_5m clay_1&2MPa_3m top_up to 3yr_fez

APPENDIX

E SETTLEMENT ANALYSIS - CULVERT AT STA. 12+248 (Section 8)



	Project	Hwy 17 - Culvert at Sta. 12+248, Pays Plat, Ontario	
	Analysis Description	FEM Settlement Analysis - Geometry and Soil Properties	
	Drawn By	Scale	Company
	Date	10/18/2017, 2:27:30 PM	Hwy 17 - Section 8_ FEM settlements_5m clay_1&2MPa_3m top_up to 4yr geom. fez

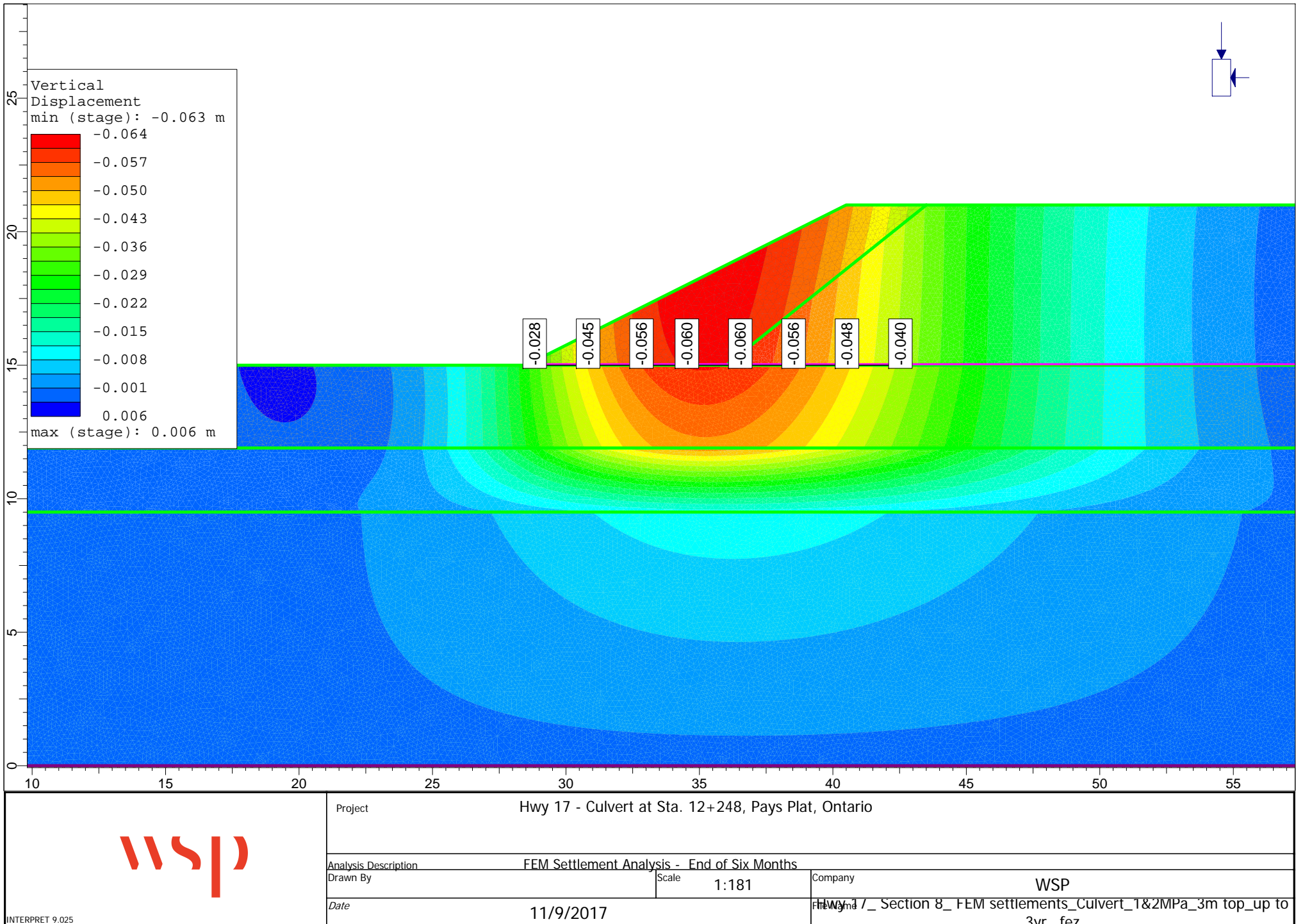


Figure 5.20

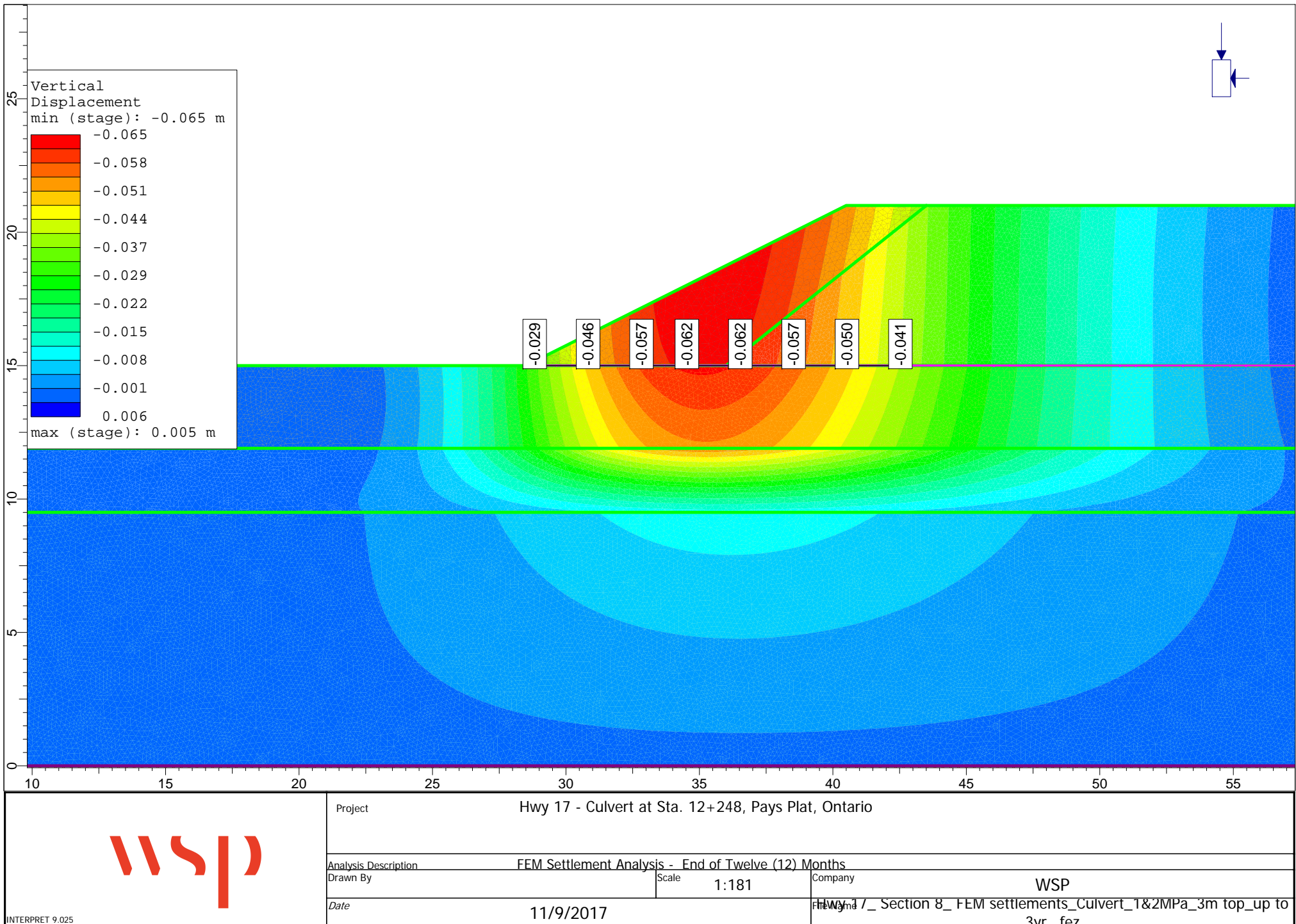


Figure 5.21

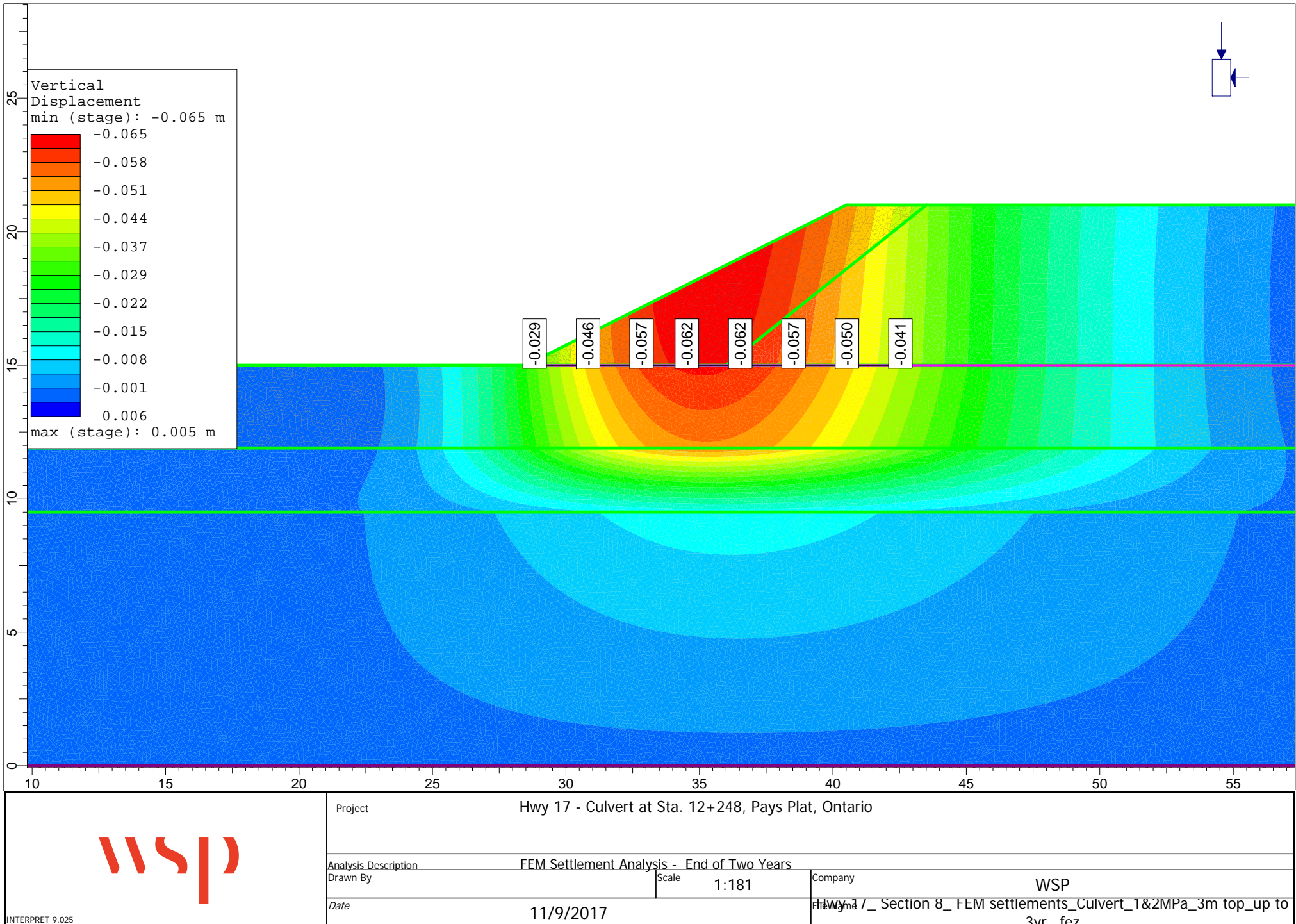
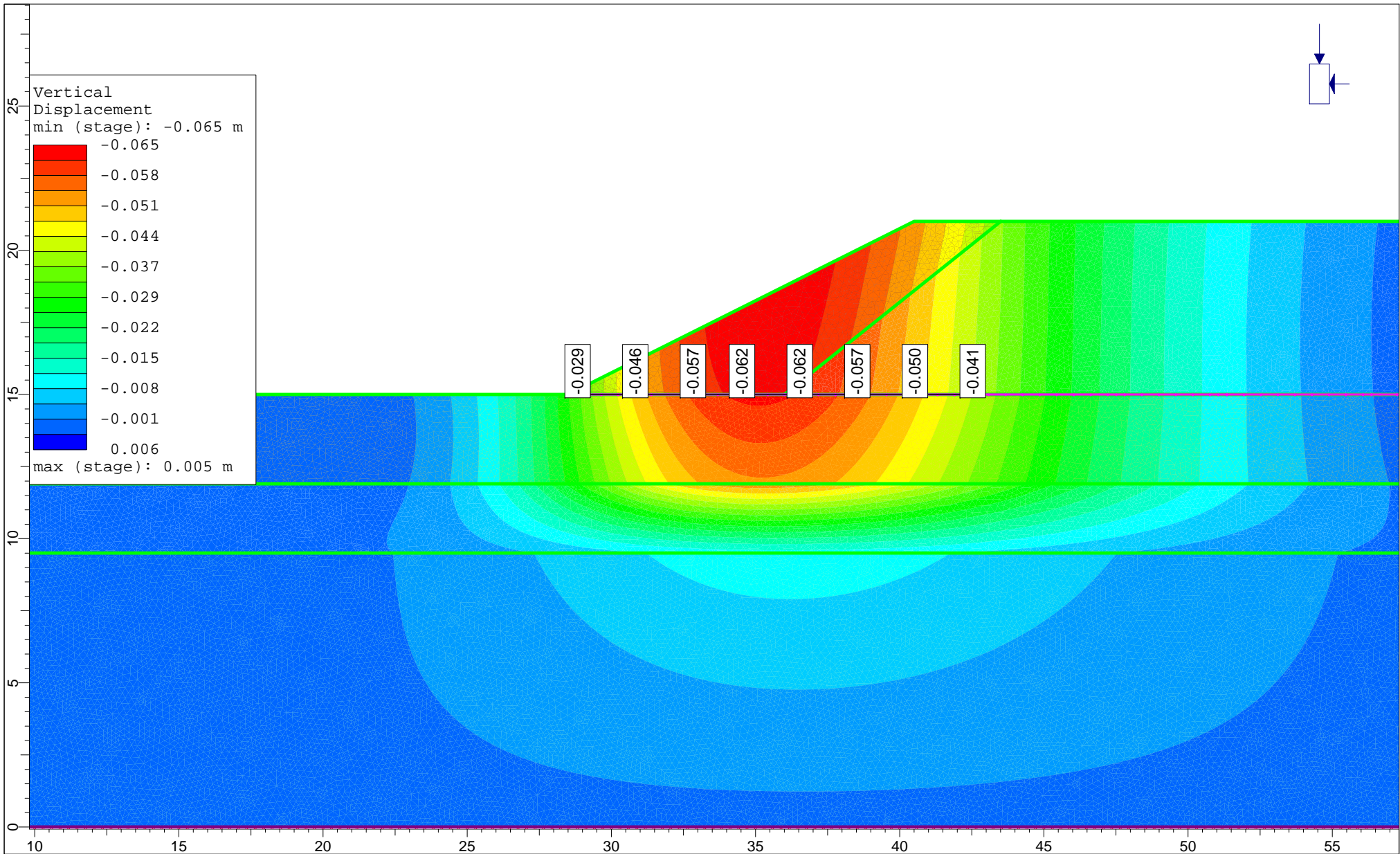


Figure 5.22




	Project Hwy 17 - Culvert at Sta. 12+248, Pays Plat, Ontario		
	Analysis Description FEM Settlement Analysis - End of Three (3) Years		
	Drawn By	Scale 1:181	Company WSP
	Date 11/9/2017	File Name Section 8_ FEM settlements_Culvert__up to 3yr fez	

Figure 5.23

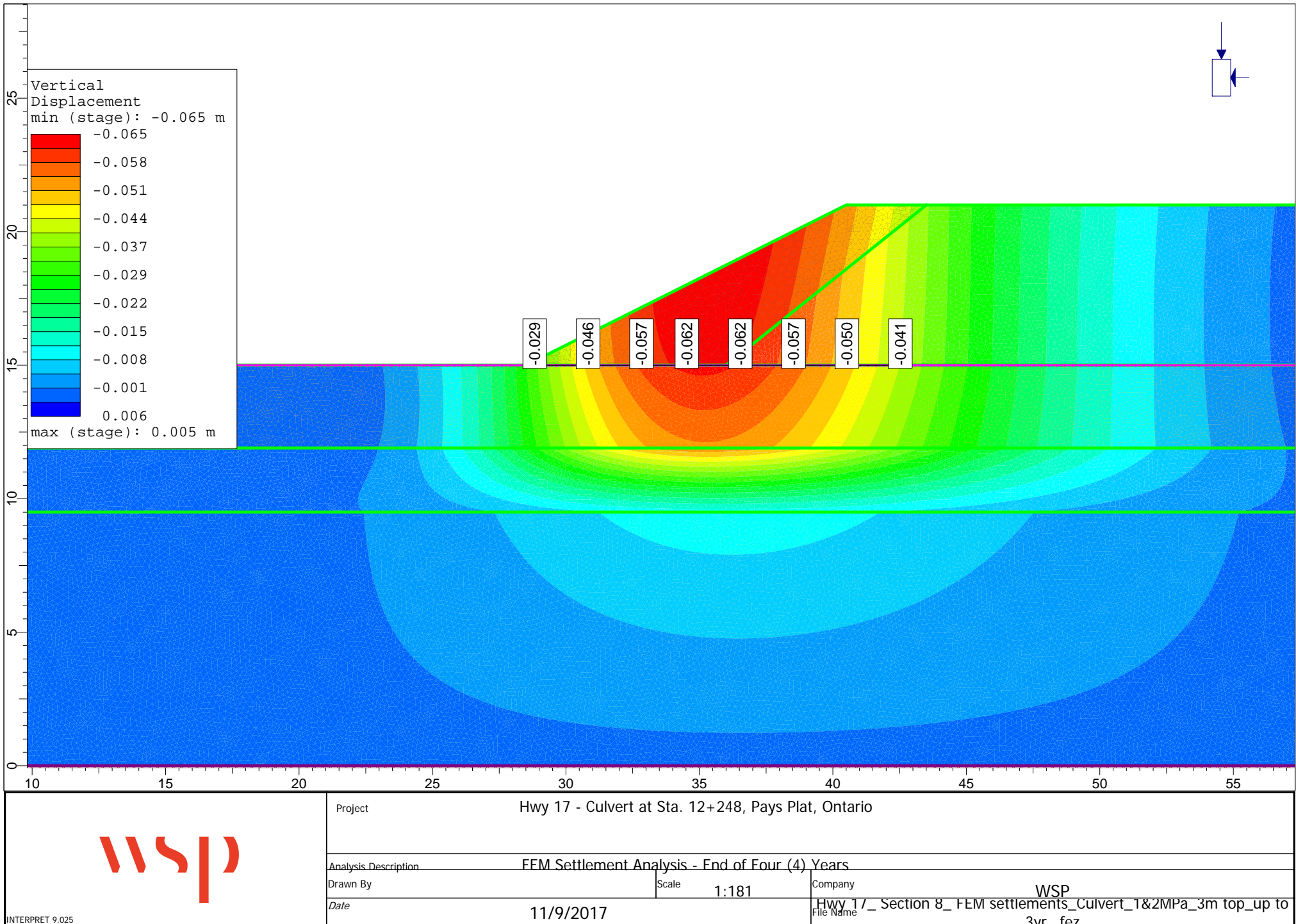


Figure 5.24

APPENDIX

F

List of OPSDs, OPSSs, NSSP and MTO Publication

List of OPSSs, OPSDs, NSSPs and MTO Publication referenced in the Report

NSSP		GEOSYNTHETIC SEPARATOR
NSSP		GROUND SETTLEMENT MONITORING UNDER PRELOAD
NSSP		OBSTRUCTIONS IN EXCAVATION
NSSP		OBSTRUCTIONS –EXCAVATION OF BEDROCK FOR CULVERT EXTENSION IN HIGH FILL SECTIONS
NSSP FOUND003		DEWATERING STRUCTURE EXCAVATIONS
OPSD	802.013	FLEXIBLE PIPE EMBEDMENT AND BACKFILL ROCK EXCAVATION
OPSD	802.014	FLEXIBLE PIPE EMBEDMENT IN EMBANKMENT (ORIGINAL GROUND:EARTH/ROCK)
OPSD	810.01	GENERAL RIP-RAP LAYOUT FOR SEWER AND CULVERT OUTLETS
OPSD	802.095	CLAY SEAL FOR PIPE TRENCHES
OPSS	180	GENERAL SPECIFICATION FOR THE MANAGEMENT OF EXCESS MATERIALS
OPSS	206	CONSTRUCTION SPECIFICATION FOR GRADING
OPSS	209	CONSTRUCTION SPECIFICATION FOR EMBANKMENTS OVER SWAMPS AND COMPRESSIBLE SOILS
OPSS	401	CONSTRUCTION SPECIFICATION FOR TRENCHING, BACKFILLING, AND COMPACTING
OPSS	492	CONSTRUCTION SPECIFICATION FOR SITE RESTORATION FOLLOWING INSTALLATION OF PIPELINES, UTILITIES, AND ASSOCIATED STRUCTURES
OPSS.PROV	517	CONSTRUCTION SPECIFICATION FOR DEWATERING
OPSS.PROV	539	CONSTRUCTION SPECIFICATION FOR TEMPORARY PROTECTION SYSTEMS
OPSS.PROV	805	CONSTRUCTION SPECIFICATION FOR TEMPORARY EROSION AND SEDIMENT CONTROL
OPSS.PROV	1010	MATERIAL SPECIFICATION FOR PAVING AND BACKFILL
OPSS.PROV	1205	MATERIAL SPECIFICATION FOR CLAY SEAL
SP517F01		DEWATERING SYSTEM-TEMPORARY FLOW PASSAGE SYSTEM
MTO Publication		MTO GUIDELINE FOR ROCK FILL SETTLEMENT AND ROCK FILL QUANTITY ESTIMATES (2010)

Geosynthetic Separator

Non-Standard Special Provision

Scope

As part of the work under the above tender item, the Contractor shall supply and install a geosynthetic separator over the chinked rock fill embankment surface to underlie the pavement structure.

References

OPSS 1860 – MATERIAL SPECIFICATION FOR GEOTEXTILES

Materials

Class II Non-Woven Geotextile Separator

Basis of Payment

Payment at the Contract Price for the above tender item shall be full compensation for all labour, equipment and material to do the work.

Non-Standard Special Provision (NSSP)
GROUND SETTLEMENT MONITORING UNDER PRELOAD

Westbound Truck Climbing Lane, Highway 17 between Highway 17 at Pays Plat

1.0 SCOPE

This special provision covers the requirements for the supply, installation and monitoring of square steel settlement plates (SPs) with survey rods (the instruments) to determine the effectiveness of preloading and predicted time rates of settlement.

The purpose of these instruments is to monitor the settlement of the foundation soils/embankment during preloading. Ground movements shall be measured by level surveying with total station equipment at the top of the settlement rods, described in Section 2.0, or as provided for in the alternative option described in Section 7.0.

2.0 INSTRUMENTATION

2.1 Steel Base Plate

The Contractor shall supply minimum Grade 300 steel base plates with a thickness of at least 6.35 mm. The plates shall be square and at least 500 mm by 500 mm in plan dimensions.

2.2 Survey Rod

The Contractor shall supply a Schedule 40 steel pipe with an outside diameter (O.D.) not less than 25.4 mm, supplied in lengths as required to complete the installation as described elsewhere. The lowest rod shall be welded to a settlement monitoring plate. The top end of the topmost length of rod shall be threaded to receive a cap. A rounded cap shall be installed at the top of the rod in such a way that a single survey point can be clearly identified and returned to for repeated observations. Intermediate rods shall be threaded both ends to facilitate extensions commensurate with embankment height increases.

2.3 Friction Reducing Sleeve

The Contractor shall supply a friction-reducing sleeve consisting of Schedule 40 PVC pipe, 50.8 mm O.D., cut perpendicular to the axis of the pipe.

2.4 Protective Surround

The Contractor shall supply a protective surround for the portion of the rod within the embankment. The surround shall consist of 300 mm diameter corrugated steel pipe (CSP, OPSS 1801) with the ends cut perpendicular to the axis of the pipe and free of burrs and sharp edges. The space between the CSP and the Friction Reduction Sleeve (PVC pipe) shall be filled with loose dry medium sand.

3.0 LOCATIONS OF SETTLEMENT PLATES

The locations of the settlement monitoring steel plates shall be as shown in Table 1.

Table 1 – Ground Settlement Monitoring Locations (See Notes)

Settlement Plate No.	High Fill Section No. / Twp.	Station Limits	Settlement Plate Station
SP-1	Section 1 / Yesno	14+000 to 14+100	14+090
SP-2			14+050
SP-3	Section 2 / Yesno	14+230 to 14+390	14+250
SP-4			14+300
SP-5			14+350
SP-6	Section 3 / Yesno	14+580 to 14+700	14+600
SP-7			14+650
SP-8			14+675

Settlement Plate No.	High Fill Section No. / Twp.	Station Limits	Settlement Plate Station
SP-9	Section 4 / Yesno	15+120 to 15+160	15+125
SP-10			15+150
SP-11	Section 5 / Yesno	15+210 to 15+310	15+225
SP-12			15+275
SP-13	Section 6 / Yesno	15+420 to 15+620	15+450
SP-14			15+550
SP-15			15+610
SP-16	Section 7 / Lahontan	10+460 to 11+110	10+500
SP-17			10+625
SP-18			10+900
SP-19	Section 8 / Lahontan	12+170 to 12+270	12+200; El. 209.4
SP-20			12+250; El. 208.4
SP-21	Section 9 / Lahontan	12+810 to 12+860	12+825; El. 197.0
SP-22			12+850; El. 197.0

1. Placement elevation of the SPs for other High Fill Sections: the SPs should be placed at a depth of 1.5 m below the elevation of the underside of the pavement structure at the location.
2. SPs should be placed 1.5 m \pm 100 mm from the slope face of the widened embankment at the elevation of the SP at the relevant Station.

4.0 SURVEY BENCHMARKS

The Contractor shall provide local, stable and non-settling survey benchmarks located a minimum distance of 25 m from any instrument location. The number and locations of benchmarks shall be such that direct sighting is possible from all settlement plate locations to at least one bench mark. Elevations shall be surveyed to an accuracy of \pm 2 mm or better. Prior to the installation of the instruments, the Contractor shall accurately survey and stake the location of each instrument and obtain ground elevations at each instrument location.

5.0 INSTALLATION

The Contractor shall install settlement plates at the approximate elevations shown in Table 1. The actual placement elevation shall be surveyed. The SPs in High Fill Sections 8 and 9 shall be placed on the rockfill embankment when the widened embankment height at the location is 1 m above the existing ground surface (See Table 1). For the other High Fill Sections, the SPs should be placed at a depth of 1.5 m below the elevation of the underside of the pavement structure at the location. As embankment height increases the rods shall be extended above the new top of embankment. Sleeves shall be installed around the rods to reduce friction and allow uninhibited movement of the rod with the plate. The protective surround shall be extended with the rods as embankment and preload construction proceeds.

Settlement plates shall be installed on horizontal ground surface with the SP base placed on locally chinked levelled surface. The elevation of the top of plate shall be surveyed before backfilling and further embankment construction. The rods shall be fixed to the centres of, and perpendicular to, the plates. The coupling of the rods shall be such that all sections have the same axis, with no separation or contraction at the couplings. The friction reducing sleeve shall be placed over the entire length of the rod that is within the embankment, except that the cap on top of the settlement rod shall extend 25 mm above the top of the friction sleeve at all times. The settlement rods shall be extended upwards as fill is placed such that the top of the rod is always at least 0.3 m but not more than 2 m above the surrounding fill. The CSP, Friction Reducing Sleeve and sand protective surround shall be extended with the rods. The settlement rod shall be in the centre of the CSP and friction-reducing sleeve. The annulus between the CSP and the friction-reducing sleeve shall be filled with loose dry medium sand to a level not higher than the top of the sleeve.

The elevation and location coordinates of the centres of the plates and the tops of rods shall be surveyed during the embankment build-up.

6.0 SAFETY AND PROTECTION

The above ground location of settlement monitoring fixtures shall be made clearly visible to avoid accidental damage at all times. Markings shall be of sufficient size to be visible to construction equipment operators and after heavy snowfalls.

Instruments shall be clearly labelled in the field, each instrument having a unique identifier. The labelling shall remain legible for the duration of the monitoring period.

All instruments shall be adequately protected by the Contractor such that they are not damaged during construction. Any instrument damaged by the Contractor's work shall be immediately replaced and resurveyed at the Contractor's cost.

7.0 ALTERNATIVE METHODS OF SETTLEMENT MONITORING

The Contractor may propose alternative methods for measuring the settlement of the ground beneath the approach embankments and preload fill. The proposal shall be signed off by a Professional Engineer and shall be subject to approval prior to implementation.

8.0 SETTLEMENT MONITORING DATA REQUIREMENTS

Settlement monitoring data shall be provided to the Contract Administrator along with copies of all field notes, in accordance with the schedule shown below:

- Immediately after installation, indicating the location of the permanent reliable benchmarks used for ongoing settlement monitoring (Section 4.0).
- When filling commences, or when the ground above the settlement monitoring locations is subjected to continuous daily construction traffic
- Settlements shall be recorded in conformance with the schedule shown in Table 2.

Table 2. Settlement Monitoring Schedule

Location	Frequency	Final
All	<ul style="list-style-type: none"> • After the base reading, weekly for the first three months; bi-weekly for the next three months; and monthly thereafter; or terminated on earlier reaching of practical cessation of settlements <u>after embankment has reached the underside of the pavement structure</u> 	High Fill Sections 8 and 9: 12 months after reaching the bottom elevation of the pavement structure at the SP location or earlier cessation of settlements.
		Other High Fill Sections: 3 months after reaching the bottom elevation of the pavement structure at the SP location or earlier cessation of settlements.

	<u>elevation</u> ; practical cessation is defined as 2 mm or less of settlement increase in a month (accuracy of the instrument).	
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9.0 MEASUREMENT TOLERANCES

The tolerances for settlement monitoring shall be as follows:

- Instrument location: ± 100 mm.
- Error of survey closure from permanent bench mark ± 2 mm.

OBSTRUCTIONS

Non-Standard Special Provision

The interception of cobbles and boulders has been recorded in some Records of Borehole Sheets. Consideration of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for sub-excavation for culvert extensions.

Basis of Payment

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

OBSTRUCTIONS Excavation of Bedrock for Culvert Extension in High Fill Sections

Non-Standard Special Provision

The interception of bedrock and exposure of bedrock outcrops of very high strength have been noted in the FIR in some High Fill Sections. Consideration of the presence of these obstructions must be made in the selection of appropriate equipment and procedures for sub-excavation for culvert extensions.

Basis of Payment

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.

DEWATERING STRUCTURE EXCAVATIONS - Item No.

Special Provision No. FOUN 0003

March 8, 2018

Amendment to OPSS 902, November 2010

902.02 REFERENCES

Section 902.02 of OPSS 902 is amended by the addition of the following:

Ontario Provincial Standard Specifications, Construction

OPSS 517 Dewatering
OPSS 805 Temporary Erosion and Sediment Control Measures

902.03 DEFINITIONS

Section 903.03 of OPSS 902 is amended by the addition of the following:

Automatic Transfer Switch means as defined in OPSS 517.

Cofferdam means as defined in OPSS 539.

Cut-Off Wall means as defined in OPSS 517.

Design Storm Return Period means as defined in OPSS 517.

Dewatering System means as defined in OPSS 517.

Groundwater Control System means as defined in OPSS 517.

Plug means as defined in OPSS 517.

Sediment means as defined in OPSS 517.

Sediment Control Measure means as defined in OPSS 517.

Temporary Flow Passage System means as defined in OPSS 517.

Unwatering means as defined in OPSS 517.

Vegetated Discharge Area means as defined in OPSS 517.

Waterbody means as defined in OPSS 517.

Watercourse means as defined in OPSS 517.

902.04 DESIGN AND SUBMISSION REQUIREMENTS

902.04.01 Design Requirements

902.04.01.01 Dewatering

Clause 902.04.01.01 of OPSS 902 is deleted in its entirety and replaced with the following:

A dewatering system shall be designed to control water and the flow of water into the excavation, prevent disturbance of the foundation, permit the placing of concrete in the dry, and complete the excavating and backfilling for structures work.

When the system includes temporary flow passage system, the system shall be designed, as a minimum, for a [* Designer Fill-In, See Notes to Designer] year design storm return period, and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

The dewatering system shall be according to the design requirements specified in OPSS 517.

902.04.02 Submission Requirements

Subsection 902.04.02 of OPSS 902 is deleted in its entirety and replaced with the following:

902.04.02.01 Working Drawings

Working Drawings for the dewatering system shall be according to OPSS 517.

902.04.02.02 Preconstruction Survey

When a groundwater control system by wells or a well point system will be used, a condition survey of property and structures that may be affected by the work shall be carried out. The condition survey shall include the location and condition of adjacent properties, buildings, underground structures, water wells, Utilities, and structures, within a distance of [** Designer Fill-In, See Notes to Designer] metres from the groundwater control system. In addition, all water wells used as a supply of drinking water and located within this distance shall be tested for compliance with Ontario Drinking Water Quality Standards.

Water wells within the preconstruction survey distance can be located using the website <https://www.ontario.ca/environment-and-energy/map-well-records> or its successor site.

Copies of the condition survey and water quality test results shall be submitted to the Contract Administrator prior to the operation of the groundwater control system.

902.04.02.03 Milestone Inspections

Clause 902.04.02.03 of OPSS 902 is deleted in its entirety.

902.07 CONSTRUCTION

Subsection 902.07.04 of OPSS 902 is deleted in its entirety and replaced with the following:

902.07.04 Dewatering Structure Excavation

902.07.04.01 General

The dewatering systems shall be constructed and operated according to the Working Drawings.

Activation and deactivation of a temporary flow passage system, if applicable, shall be according to OPSS 517.

The dewatering system shall be continuously operational to control buoyancy forces until such forces can be resisted by backfill and structure self-weight, to keep excavations stable, to avoid erosion impacts from the release of accumulated water, and to keep the work area in the condition required to complete the associated work as specified in the Contract Documents.

When a temporary flow passage system is to remain operational through a seasonal shutdown period, the Contractor shall be responsible for any maintenance or repair costs due to the system during the seasonal shutdown period.

Temporary erosion and sediment control measures, including controlling the discharge of water, shall be according to OPSS 805. Measures not specified in OPSS 805 shall be according to the Working Drawings. Temporary erosion and sediment control measures and cover material to protect exposed soils, as required by the Working Drawings, shall be installed as soon as is practical.

Stranded fish shall be managed as specified in the Contract Documents.

Unwatering shall be carried out as necessary.

Water suspected of being contaminated as indicated by visual or olfactory observations shall be reported to the Contract Administrator.

Dewatering and temporary flow passage systems shall be discontinued in a manner that does not disturb any structure, pipeline, or flow channel. Operation of the dewatering system shall be shut down according to the procedures specified in the Working Drawings, where applicable.

902.07.04.02 Discharge of Water

The discharge of water shall be according to OPSS 517.

902.07.04.03 Monitoring

Monitoring shall be according to OPSS 517.

902.07.04.04 System Amendments

Amendments to stop any displacement, damage, soil loss or erosion due to the operation of the dewatering system shall be according to OPSS 517.

902.07.04.05 Removal

Removal of dewatering system and temporary flow passage system components shall be according to OPSS 517.

NOTES TO DESIGNER:

- * Fill in the design storm return period according to MTO Drainage Design Standard TW-1.
- ** Fill in the preconstruction survey distance as recommended by the foundation engineer.

WARRANT: Include with this standard tender item only on the recommendation of a foundation engineer.

CUSTODIAN: Tony Sangiuliano, MERO - Foundation Group.

DEWATERING SYSTEM - Item No.
TEMPORARY FLOW PASSAGE SYSTEM - Item No.

Special Provision No. 517F01

July 2017

Amendment to OPSS 517, November 2016

Design Storm Return Period and Preconstruction Survey Distance

517.01 SCOPE

Section 517.01 of OPSS 517 is deleted in its entirety and replaced with the following:

This specification covers the requirements for the design, operation, and removal of a dewatering or temporary flow passage system or both to control water during construction, and the control of the water prior to discharge to the natural environment and sewer systems.

517.04 DESIGN AND SUBMISSION REQUIREMENTS

517.04.01 Design Requirements

Subsection 517.04.01 of OPSS 517 is amended by deleting the first paragraph in its entirety and replacing it with the following:

A dewatering or temporary flow passage system or both shall be designed to control water at the locations specified in the Contract Documents and at any other location where a system is necessary to complete the work. The design of the system shall be sufficient to permit the work at each location to be carried out as specified in the Contract Documents.

Subsection 517.04.01 of OPSS 517 is further amended by deleting the second last paragraph in its entirety and replacing it with the following:

Temporary flow passage systems shall be designed, as a minimum, for a 2 year design storm return period and groundwater discharge, except for the work specified in Table A. For the work specified in Table A, the temporary flow passage system shall be designed, as a minimum, for the design storm return period specified in Table A and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

Intensity-Duration Factor (IDF) curve location, site specific minimum return period, return period flow estimates, and other information is provided in Table A. The IDF information can be accessed through the MTO IDF Curve Look up Tool on the Drainage and Hydrology page of MTO's website. The return period flow estimates do not include flow volumes from groundwater discharge. The Owner specifically excludes these flow estimates from the warranty in the Reliance on Contract Documents subsection of OPSS 100, MTO General Conditions of Contract.

Table A

IDF Curve Location	Latitude: *		Longitude: *			
Temporary Flow Passage Systems						
Site Name / Station Reference	Minimum Return Period (Years)	Return Period Flow Estimates (m ³ /s)				Design Engineer Requirements (Note 1)
		2 Year	5 Year	10 Year	25 Year	
**	***	****	****	****	****	*****
Dewatering Systems						
Site Name / Station Reference	Preconstruction Survey Distance (Note 2) (m)				Design Engineer Requirements (Note 1)	
**	*****				*****	
<p>Note:</p> <p>1. “Yes” means the design Engineer and design-checking Engineer shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work. “No” means a minimum experience level is not required for the design Engineer and design-checking Engineer.</p> <p>2. “N/A” indicates a preconstruction survey is not required.</p>						

APPENDIX

G LIMITATIONS

LIMITATIONS OF REPORT

This report is intended solely for the Client named. The material in it reflects our best judgment in light of the information available to WSP Canada Inc. at the time of preparation. Unless otherwise agreed in writing by WSP Canada Inc., it shall not be used to express or imply warranty as to the fitness of the property for a particular purpose. No portion of this report may be used as a separate entity, it is written to be read in its entirety.

The conclusions and recommendations given in this report are based on information determined at the test hole locations. The information contained herein in no way reflects on the environment aspects of the project, unless otherwise stated. Subsurface and groundwater conditions between and beyond the test holes may differ from those encountered at the test hole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the test hole locations and should not be used for other purposes, such as grading, excavating, 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 the details stated in this report.

The comments made in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of test holes may not be sufficient to determine all the factors that may affect construction methods and costs. For example, 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 conclusions as to how the subsurface conditions may affect their work. This work has been undertaken in accordance with normally accepted geotechnical engineering practices.

Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. WSP Canada Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

We accept no responsibility for any decisions made or actions taken as a result of this report unless we are specifically advised of and participate in such action, in which case our responsibility will be as agreed to at that time.