Terraprobe

Consulting Geotechnical & Environmental Engineering
Construction Materials Inspection & Testing

FOUNDATION INVESTIGATION & DESIGN REPORT
HIGH FILLS AT PORT ROBINSON ROAD
HIGHWAY 406 TWINNING
PORT ROBINSON ROAD TO EAST MAIN STREET
AGREEMENT No. 2008-E-0016, W.P. 280-99-00
GEOCRES NO. 30M3-264

PREPARED FOR: Giffels Associates Ltd./IBI Group
30 International Blvd.
Toronto, Ontario

Attention: Mr. Stephen Chiu, P.Eng.
Manager,Transportation Engineering

File No. 1-09-4135
September 30, 2010

Terraprobe Inc.
10 Bram Court
Brampton, Ontario
L6W 3R6
Phone: (905) 796 2650
Fax: (905) 796 2250

Distribution:

2 Copies	-	MTO Project Manager (Central Region)
1 Copy	-	MTO Pavements and Foundations Section
1 Copy	-	Giffels Associates Ltd./IBI Group
1 Copy	-	Terraprobe Inc., Brampton

TABLE OF CONTENTS

Table

Appendices

DESIGN SUMMARY

This project (W.P. 280-99-00) is the Ministry of Transportation of Ontario undertaking to twin Highway 406 from 0.2 km north of Port Robinson Road to its current terminus at East Main Street.

Terraprobe carried out the investigation as a sub-consultant to Giffels Associates Limited/IBI Group (Giffels), under the Ministry of Transportation Ontario (MTO) Agreement Number 2008-E-0016.

The project is located in the Regional Municipality of Niagara, City of Thorold and City of Welland, Ontario. Approximately 6.5 km of two lane staged freeway will be twinned from Sta. 10+000 to Sta. 6+400. Within the project limits Highway 406 has signalized intersections at Merritt Road, Woodlawn Road and East Main Street and one un-signalized intersection at Port Robinson Road.

High fills (embankments) are required to carry Port Robinson Road over Highway 406 NBL and SBL.

The main design recommendations are:

- Local earth fill embankments should be constructed at 3H:1V side slopes. Embankment alternatives are provided if steeper side slopes are desired.
- After the first year of embankment construction the remaining post construction settlement will be equal to or less than the acceptable maximum of 25 mm.
- If a 6 months target for paving is preferred we recommend that conventional temporary surcharging be carried out (2 m of additional earth fill height) to accelerate the settlement and ensure full consolidation after embankment construction. Hence, other means/methods (light weight fill, wick drains) of accelerating the settlement are not warranted.

Notwithstanding the foregoing the designer is advised to review this report in its entirety to ensure that the geotechnical recommendations provided herein are adequately addressed in the designs and contract documents.

FOUNDATION INVESTIGATION REPORT
HIGH FILLS AT PORT ROBINSON ROAD
HIGHWAY 406 TWINNING
ONTARIO
AGREEMENT No. 2008-E-0016, W.P. 280-99-00
GEOCRES NO. 30M3-264

PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from foundation investigations conducted at high fill areas along the proposed alignment of Port Robinson Road in the City of Thorold, Regional Municipality of Niagara, Ontario.

The purpose of this investigation was to explore the subsurface conditions at this site and based on the data obtained, to provide borehole location plans, records of boreholes, stratigraphic profiles, laboratory test results and a description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained.

Terraprobe conducted the investigation as a sub-consultant to Giffels Associates Ltd./IBI Group, under the Ministry of Transportation Ontario (MTO) Agreement Number 2008-E-0016.

2 SITE DESCRIPTION & PHYSIOGRAPHY

The alignment is located approximately 25 m south of the existing at grade intersection of Highway 406 and Port Robinson Road. It merges with the existing Port Robinson Road approximately 300 m east and west of the intersection. At this location Highway 406 is a two-lane highway with gravel shoulders carrying both north and south bound traffic.

The topography is flat consisting of farmland and open fields. Vegetation consists primarily of deciduous trees and wild bush and areas of groomed grass can be found at some locations along the existing roadways.

The site is located between the Niagara Escarpment and Lake Erie in the physiographic region of Southern Ontario referred to as the Haldimand Clay Plain. The Haldimand Clay Plain is best described as falling into a series of parallel belts with the highest ground adjacent to the Escarpment. Generally this region is flat and poorly drained although it includes several distinctive landforms such as dunes, cobble, clay and sand beaches, limestone pavements and back-shore wetland basins[1].

[1] Chapman and Putnam, "The Physiography of South Ontario", 3rd Edition, 1984.

The Niagara Region is underlain by a sequence of very gently south-dipping dolostones, limestones, shales and sandstones overlying Precambrian basement rock. The key elements in the bedrock geology of the region are the multiple layers of softer sedimentary limestones, shale, sandstone and dolostone.

The bedrock unit at this site is the Guelph Formation of Upper Silurian Age[2]. This unit consists essentially of unweathered, grey, laminated argillaceous dolostone.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out between December 21, 2009 and July 13, 2010 and consisted of drilling and sampling ten boreholes to depths ranging from 18.8 m to 38.0 m. The boreholes were numbered PR1 to PR10 and their approximate locations are shown on the attached Borehole Locations and Soil Strata Drawings in Appendix C.

The borehole locations were marked in the field by surveyors from Callon Dietz Inc. who also provided Terraprobe with their coordinates and geodetic elevations. Access to Borehole PR3 was difficult due to locally steep slopes and this borehole was relocated to be as close as feasible to the staked out location while allowing safe operation of the drill rig. Terraprobe obtained utility clearances and permits prior to drilling.

Samples of the overburden soils were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT), as specified in ASTM Method D1586. In the cohesive (clayey) deposits the undrained shear strength of the soil was measured in-situ by means of field vane tests using an MTO type field vane. Relatively undisturbed soil samples were also collected with thin-walled Shelby Tube samplers. Boreholes drilled for the proposed bridge were also advanced into bedrock by NQ size diamond coring techniques.

Ground water conditions in the open boreholes were observed throughout the drilling operations and standpipe piezometers consisting of 19 mm diameter PVC pipe with a slotted screen enclosed in sand were installed in selected boreholes to permit longer term ground water level monitoring. The remaining boreholes were abandoned in accordance with MOE Regulation 903 by sealing/grouting with a clay slurry mixture after drilling was complete.

[2] Ontario Division of Mines, "Quaternary Geology Of The Welland Area", Preliminary Map P.796, 1972.

The locations and completion details of the piezometers are shown in Table 3.1.

Table 3.1 – Piezometer Installation Details

Piezometer Location	Piezometer Details	
	Tip Depth/ Elevation (m)	Completion Details
PR1	32.0/149.7	Piezometer with 1.5 m slotted screen installed with filter sand to 29.9 m, bentonite seal from 29.9 m to 29.0 m, silty clay cuttings from 29.0 m to 1.5 m and bentonite seal from 1.5 m to ground surface.
PR3	32.0/149.3	Hole sealed to 32.0 m with bentonite, piezometer with 1.5 m slotted screen installed with filter sand to 29.9 m and bentonite seal from 29.9 m to ground surface.
PR4	14.6/167.6	Hole sealed to 14.8 m with bentonite, piezometer with 1.5 m slotted screen installed with filter sand to 12.8 m and bentonite seal from 12.8 m to ground surface.
PR5	30.5/150.7	Piezometer with 1.5 m slotted screen installed with filter sand to 28.3 m, bentonite seal from 28.3 m to 27.1 m, silty clay cuttings from 27.1 m to 0.6 m and bentonite seal from 0.6 m to ground surface.
PR6	10.7/168.3	Hole sealed to 10.7 m with bentonite, piezometer with 1.5 m slotted screen installed with filter sand to 8.5 m, bentonite seal from 8.5 m to 7.9 m, silty clay cuttings from 7.9 m to 0.6 m and a flush mounted casing installation from 0.6 m to ground surface.
PR8	16.8/163.8	Piezometer with 1.5 m slotted screen installed with filter sand to 14.6 m, bentonite seal from 14.6 m to 14.0 m, silty clay cuttings from 14.0 m to 0.6 m and bentonite seal from 0.6 m to ground surface.
PR9	16.8/164.8	Piezometer with 1.5 m slotted screen installed with filter sand to 14.6 m, bentonite seal from 14.6 m to 14.0 m, silty clay cuttings from 14.0 m to 1.5 m and bentonite seal from 1.5 m to ground surface.
PR10	13.7/167.8	Piezometer with 1.5 m slotted screen installed with filter sand to 11.9 m, bentonite seal from 11.9 m to 11.3 m, silty clay cuttings from 11.3 m to 0.6 m and bentonite seal from 0.6 m to ground surface.

The drilling, sampling and in-situ testing operations were observed on a full time basis by members of Terraprobe's technical staff who logged the boreholes and processed the recovered soil and rock samples for transport to Terraprobe's Brampton laboratory for further examination and testing.

4 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and natural moisture content determination. Select samples were also subjected to a laboratory testing programme consisting of gradation analysis, Atterberg Limits tests, consolidation tests, unit weight and undrained shear strength testing with a laboratory vane. The results of this testing program are shown on the Record of Borehole sheets in Appendix A and the figures in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets in Appendix A. Details of the encountered soil stratigraphy are presented in this appendix and on the "Borehole Locations and Soil Strata" drawings in Appendix C. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.

In general, the site is underlain by topsoil, asphalt, fill material (gravelly sand to sandy gravel, silty sand and silty clay) and native overburden deposits of silty clay, silt, silty clay to clayey silt, and clayey silt till. These soils are underlain by bedrock consisting primarily of dolostone of the Guelph formation.

5.1 Topsoil

Topsoil ranging from 50 mm to 300 mm in thickness was encountered at this site. Topsoil thickness may vary between and beyond the boreholes.

5.2 Asphalt

Borehole PR6 was drilled through the existing pavement on Port Robinson Road. This borehole encountered an approximately 130 mm thick layer of asphalt.

5.3 Fill – Gravelly Sand to Sandy Gravel

Boreholes PR4 and PR6 encountered layers of gravelly sand and sandy gravel fill extending to depths of 0.7 m (Elev. 181.5 m) and 1.4 m (Elev. 177.6 m) respectively.

A sample of the gravelly sand fill was subjected to a grain size analysis and the results are presented in Figure B1. These results show a grain size distribution consisting of 22% gravel, 50% sand, 20% silt and 8% clay size particles.

Standard Penetration tests in the gravelly sand to sandy gravel fill gave 'N' values ranging from 12 to 53 blows for 0.3 m penetration. Based on these results the fill is considered to have a compact to very dense relative density. The moisture content of samples of this fill ranged from 4% to 8% by weight.

5.4 Fill – Silty Sand

An approximately 1.1 m thick layer of silty sand fill was encountered in Borehole PR3 extending to a depth of 1.4 m (Elev. 179.9 m) below ground surface. Based on visual and tactile examinations of the retrieved samples, the fill is essentially a cohesionless material with frequent cohesive silty clay inclusions.

A sample of this fill material was subjected to a grain size analysis and the results are presented in Figure B2. These results show a grain size distribution consisting of 0% gravel, 48% sand, 34% silt and 18% clay size particles.

Standard Penetration tests in the fill gave 'N' values that ranged from 4 to 8 blows for 0.3 m penetration. Based on these results the fill is considered to have a loose relative density. The moisture content of samples of this fill ranged from 15% to 20% by weight.

5.5 Fill – Silty Clay

Silty clay fill material was encountered at this site extending to depths ranging from 0.7 m (Elev. 180.9 m) to 2.9 m (Elev. 176.1 m) below ground surface.

Samples of this fill were subjected to grain size analysis and the results are illustrated in Figure B3. These results show a grain size distribution consisting of 0% gravel, 8-32% sand, 35-45% silt and 30-57% clay size particles.

The fill material was also subjected to Atterberg Limits tests and the results are plotted on the plasticity chart, Figure B4. The index values from these tests are summarized below:

Liquid Limit:	35-40%
Plastic Limit:	19-20%
Plasticity Index:	16-20%
Natural Moisture Content:	18-36%

These values are characteristic of clayey soils of intermediate plasticity.

Standard Penetration tests in the silty clay fill gave 'N' values that ranged from 4 to 22 blows for 0.3 m penetration but generally the recorded 'N' values ranged from 4 to 11 blows for 0.3 m penetration. Based on these results the fill is considered to have a generally firm to stiff consistency with occasional very stiff zones. The moisture content of samples of this fill ranged from 13% to 36% by weight.

5.6 Silty Clay

A silty clay deposit was encountered across the site. This stratum was fully penetrated in all of the boreholes where it was found to extend to depths ranging from 13.9 m to 15.7 m below ground surface or to elevations ranging from 167.7 m to 165.1 m.

The grain size distribution plots of tested samples of the silty clay are presented in Figures B5 to B12 inclusive. These results show a grain size distribution consisting of 0-7% gravel, 0-4% sand, 16-77% silt and 23-83% clay size particles.

Samples of the silty clay were also subjected to Atterberg Limits tests and the results are illustrated on the plasticity charts, Figures B13 to B20 inclusive. The index values from these tests are summarized below:

Liquid Limit:	25-61%
Plastic Limit:	16-27%
Plasticity Index:	8-35%
Natural Moisture Content:	19-47%

These values indicate that the silty clay has a low to high plasticity.

Standard Penetration tests in this stratum gave ‘N’ values ranging from 0 to 44 blows for 0.3 m penetration. Field vane tests gave in-situ undrained shear strengths ranging from 24 kPa to in excess of 100 kPa and laboratory vane tests on relatively undisturbed Shelby tube samples gave undrained shear strengths ranging from 38 kPa to 108 kPa. These values indicate that the consistency of the silty clay is generally firm to very stiff with infrequent soft zones. The moisture contents of samples of the silty clay range from 18% to 47% by weight and the unit weight of selected samples ranged from 17.4 to 20.3 kN/m^3.

The variation of undrained shear strength with elevation is depicted in Figure B29 (Elev. ±181.0 m to Elev. ±166.0 m). This “lower bound” plot generally illustrates a trend of decreasing shear strength with depth. The upper portion of this deposit up to about Elev. 177.5 m is estimated to have a relatively high undrained shear strength i.e. in excess of 100 kPa. Below Elev. 177.5 m the undrained shear strength decreases with depth and is about 30 kPa at about Elev. 170.0 m. Below Elev. 170.0 m the trend indicates increasing undrained shear strength with depth.

The Atterberg Limits tests results are also plotted against elevation, Figure B30 (Elev. ±181.0 m to Elev. ±166.0 m). These results illustrate that the natural moisture contents of this deposit are generally at or below the plastic limit above Elev. 178.0 m. Below Elev. 178.0 m the natural moisture content increases and is between the plastic and liquid limits.

Consolidation tests were also performed on Shelby tube samples retrieved from Boreholes PR1 and PR5 and the results are presented in Figures B31 to B36 inclusive. Preconsolidation pressures were estimated from the e-log p curves. Due to the rounded nature of the curves the preconsolidation pressures were also assessed based on the ‘Work’ – method proposed by Becker et al. (1987). The details of the test results are summarized below.

Borehole/Sample No.	Sample Depth/Elevation (m)	P_c (kPa)	C_c	C_r	e_o
PR1 TW8	6.1/175.6	270 – 360	0.321	0.060	0.79
PR5 TW9	7.6/173.6	200 – 350	0.337	0.049	0.75

Where: P_c = Preconsolidation pressure
C_c = Compression index
C_r = Recompression index
e_o = Initial void ratio

5.7 Silt

A native silt deposit was encountered at this site in all of the boreholes. The stratum is approximately 2.1 m to 5.0 m thick and extends to depths ranging from 16.8 m to 18.9 m below ground surface or to elevations ranging from 164.6 m to 160.1 m. Based on visual and tactile examinations of the retrieved samples, the unit is essentially a cohesionless silt with frequent cohesive silty clay seams and partings.

The grain size distribution plots of tested samples of this silt deposit are presented in Figures B21 and B22. These results show a grain size distribution consisting of 0-1% gravel, 0-6% sand, 75-96% silt and 3-24% clay size particles.

The deposit is considered to have a very loose to compact relative density based on SPT 'N' values that ranged from 0 to 26 blows for 0.3 m penetration. SPT 'N' values of 0 are likely attributed to sample disturbance. The moisture content of samples from this deposit ranged from 16% to 29% by weight.

5.8 Silty Clay to Clayey Silt

A deposit of silty clay to clayey silt was encountered across this site. This stratum was fully penetrated in Boreholes PR1 to PR5 where it extends to depths ranging from 26.9 m (Elev. 154.8 m) to 29.9 m (Elev. 152.3 m) below ground surface. The remaining boreholes were terminated in this deposit at depths ranging from 18.8 m to 21.8 m below ground surface or to elevations ranging from 161.8 m to 158.7 m.

The grain size distribution plots of tested samples from this stratum are depicted in Figures B23 and B24. These results show a grain size distribution consisting of 0-7% gravel, 0-14% sand, 59-81% silt and 16-37% clay size particles.

Samples were also subjected to Atterberg Limits tests and the results are plotted on the plasticity charts, Figures B25 and B26. The index values from these tests are summarized below:

Liquid Limit:	22-39%
Plastic Limit:	14-20%
Plasticity Index:	4-19%
Natural Moisture Content:	16-31%

These values indicate that the silty clay to clayey silt is generally of low plasticity with occasional zones of intermediate plasticity.

Standard Penetration tests in this deposit yielded 'N' values ranging from 6 to 43 blows for 0.3 m penetration. Field vane tests were also performed in this deposit and the results indicate undrained shear strengths ranging from 80 kPa to in excess of 100 kPa. Based on these results the silty clay to clayey silt is considered to have a stiff to hard consistency with occasional firm zones. The moisture content of samples from these deposits varies from 9% to 34% by weight.

The variation of undrained shear strength with elevation is depicted in Figure B29 (Elev. ±163.5 m to Elev. ±153.0 m). This "lower bound" plot illustrates a slight decrease in shear strength with depth. The undrained shear strength decreases from about 95 kPa at Elev. 163.5 m to about 75 kPa at Elev. 157.0 m. Below Elev. 157.0 m the trend indicates increasing undrained shear strength with depth.

The Atterberg Limits tests results are also plotted against elevation, Figure B30 (Elev. ±163.5 m to Elev. ±153.0 m). These results illustrate that the natural moisture content of the upper portion of this deposit is generally at or below the plastic limit above Elev. 158.0 m. Between Elev. 158.0 m and Elev. 154.0 m the natural moisture content increases and is generally between the plastic and liquid limits. Below Elev. 154.0 m the natural moisture content is below the plastic limit.

5.9 Clayey Silt Till

Clayey silt till was encountered across the site extending to depths ranging from 33.5 m to 34.3 m below ground surface or to elevations ranging from 148.2 m to 147.7 m. Boreholes PR1 and PR5 were terminated in this deposit at depths of 32.0 m (Elev. 149.7 m) and 30.5 m (Elev. 150.7 m) respectively. The lower 1.5 m to 1.8 m of this stratum overlying bedrock contains frequent cobbles and in Borehole PR3 a boulder was encountered above the bedrock.

The grain size distribution plot of a tested sample from this till deposit is depicted in Figure B27. These results show a grain size distribution consisting of 3% gravel, 18% sand, 64% silt and 15% clay size particles.

A sample was also subjected to an Atterberg Limits test and the results are plotted on the plasticity chart, Figure B28. The index values from these tests are summarized below:

Liquid Limit:	20%
Plastic Limit:	14%
Plasticity Index:	6%
Natural Moisture Content:	11%

This data is typical of a low plasticity clayey silt soil.

Standard Penetration tests in this stratum yielded 'N' values ranging from 16 to more than 100 blows per 0.3 m penetration but generally the recorded 'N' values ranged from 30 to more than 100 blows for 0.3 m penetration. Based on these results the clayey silt till is considered to have a hard consistency with occasional very stiff zones. The moisture content of samples from this deposit varies from 3% to 23% by weight.

5.10 Bedrock (Guelph Formation)

The overburden soils described above are underlain by the Guelph Formation. Bedrock was proved by coring at the abutment and pier locations of the proposed bridge structure. Table 5.1 summarizes the bedrock depth and the elevations to the top of bedrock.

Table 5.1 – Depth to Bedrock

Location	BH Number	Depth to Bedrock (m)	Top of Bedrock Elevation (m)
West Abutment	PR2	33.5	148.2
Pier	PR3	33.6	147.7
East Abutment	PR4	34.3	147.9

The bedrock is described as unweathered dolostone and its colour is light to medium brownish grey. Total core recovery in the bedrock generally ranged from 52% to 100%. The RQD values ranged widely from 0% to 76%, but generally most of the RQD values were between 24% and

69%. The core data also reveals that there is no trend of improving rock quality with depth. Based on these results the rock quality is considered to be very poor to fair with infrequent zones of good quality rock.

5.11 Water Levels

A standpipe piezometer was installed in selected boreholes. The water level readings measured on separate visits made after the completion of drilling are presented in Table 5.2.

Table 5.2 – Water Level Measurements

Borehole	Date	Water Levels	
		Depth (m)	Elevation (m)
PR1	January 11, 2010	7.0	174.7
	January 19, 2010	7.2	174.5
	January 27, 2010	7.1	174.6
	February 08, 2010	7.2	174.5
	February 19, 2010	7.1	174.6
PR3	January 19, 2010	8.2	173.1
	January 27, 2010	6.6	174.7
	February 08, 2010	0.6	180.7
	February 19, 2010	0.5	180.8
PR4	February 08, 2010	5.0	177.2
	February 19, 2010	4.5	177.7
	April 16, 2010	4.3	177.9
PR5	January 19, 2010	6.4	174.8
	January 27, 2010	6.2	175.0
	February 08, 2010	6.3	174.9
	February 19, 2010	6.2	175.0
PR6	July 21, 2010	1.9	177.1
	July 26, 2010	1.9	177.1
PR8	July 19, 2010	2.9	177.7
	July 26, 2010	2.8	177.8
PR9	July 19, 2010	3.5	178.1
	July 26, 2010	3.3	178.3
PR10	July 19, 2010	2.8	178.7
	July 26, 2010	2.1	179.4

The ground water table was estimated based on the recorded water levels in the standpipe piezometers and our review of the moisture contents of the retrieved samples. Based on these observations and interpretations, the local ground water level is estimated to be about Elev. ±177.0 m in the vicinity of Sta. 9+750 increasing gradually to about Elev. ±179.5 m at the Port Robinson Road/Highway 406 intersection. The ground water elevation east of the Port Robinson Road/Highway 406 intersection varies between Elev. ±179.0 m and Elev. ±178.5 m. At Borehole PR3, perched water exists in the silty sand fill at Elev. ±180.8 m.

All ground water observations at this site are short term and the levels are expected to fluctuate seasonally and after severe weather events.

5.12 Miscellaneous

The drilling, sampling and in-situ testing operations were conducted with track and truck mounted drill rigs owned and operated by DBW Drilling Limited of Ajax, Ontario and Determination Drilling & Soil Investigations of Hamilton, Ontario. The boreholes were extended using both hollow stem and solid stem auger drilling techniques. NQ size rock cores of the bedrock were obtained using diamond drilling techniques.

Messrs. Alexander Winkelmann, E.I.T., Phil Khuu, B.A.T. and Brady Lin, P.Eng. carried out the field work. The laboratory testing was performed at Terraprobe's Brampton laboratory and the Mississauga laboratory of Golder Associates. The report was written by Rehman Abdul, P.Eng. and reviewed by Michael Tanos, P.Eng.

Prepared by:
R. Abdul, P.Eng.,
Senior Geotechnical Engineer

Report Reviewed by:
Michael Tanos, P.Eng.,
Review Principal

FOUNDATION DESIGN REPORT
HIGH FILLS AT PORT ROBINSON ROAD
HIGHWAY 406 TWINNING
ONTARIO
AGREEMENT No. 2008-E-0016, W.P. 280-99-00
GEOCRES NO. 30M3-264

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

6 DISCUSSION AND RECOMMENDATIONS

6.1 General

Port Robinson Road will be realigned south of its current alignment and will cross the twinned Highway 406 via a two span underpass. The drawings indicate that high fills equal to or greater than 4.5 m in height are required on the west side of Hwy. 406 from Sta. 9+750 to Sta. 9+950 and on the east side of the highway from Sta. 10+050 to Sta. 10+160. The bridge and its approach embankments are located between Sta. 9+950 and Sta. 10+050 approximately.

The design grade of Port Robinson Road ranges from Elev. 182.4 m (Sta. 9+750) increasing to Elev. 189.3 m (Sta. 9+950). On the east side of the highway the design grade is at Elev. 189.3 m (Sta. 10+050) decreasing to Elev. 186.0 m (Sta. 10+160). The maximum height of embankment fill measured from existing grade is approximately ±7.5 m on the west side and ±8.5 m on the east side.

The discussion and recommendations presented in this report are based on our understanding of the project and on the factual data obtained in the course of the investigations.

Stability

In the Niagara area embankments constructed with local cohesive earth fill at conventional 2H:1V slopes have historically performed below par. Shallow surficial failures usually occur on the face of these slopes thereby requiring frequent maintenance in order to prevent more significant deep-seated failures.

Recent studies conducted by the Ministry of Transport indicate that these shallow surficial failures occur because of the mineralogy of the local soils and its inherent effect on the effective shear strength of the local clay fill. Poor performance was also attributed to climatic effects including precipitation, wetting and drying cycles, snow melt and freezing and thawing cycles.

The historical performance of existing embankments in the area was considered when selecting embankment alternatives and design side slopes for this project. The selected alternatives are outlined herein and a summary of the advantages, disadvantages, risks/consequences and approximate costs of each alternative is presented in Appendix E.

- Embankments consisting of local earth borrow.
- Composite embankment consisting of a local earth borrow core protected with a Granular A face.
- Embankments consisting of SSM imported from a designated source.
- Embankments consisting of rock fill.

The global, internal and surficial stability of the embankments will depend on their slope geometries and also to a large degree on the material used to construct the embankment. For the purpose of embankment stability analyses, the commercially available slope stability program Slide 5.0 developed by Rocscience Inc. was used. The Janbu, Morgenstern-Price and Bishop's simplified method for stability analysis were employed and a minimum target factor of safety of 1.3 was established. Critical sections were selected where the embankment height was the greatest and also where the subsurface soils were the weakest.

For the undrained (short-term) analyses, the measured field vane results were corrected by applying a vane shear correction factor intended to compensate for pore-pressure and shearing-rate effects during field testing. The correction factor was derived in accordance with Morris and Williams (1994)[3].

In our analysis we incorporated a 2 m wide mid-height berm for earth fill, composite and SSM embankment heights equal to or greater than 8 m. No mid-height berms are required for rock fill embankments since the maximum embankment height is not expected to exceed ±10 m.

The composite embankment was modelled as a core of local earth fill material with a Granular A facing as depicted in Figure G2. Constructing this type of embankment requires benching the earth core/Granular A interface in accordance with OPSD 208.010.

Where earth fill, composite or SSM embankments are higher than 8 m, mid-height berms should be incorporated in the design. The berms should:

- extend for the length through which the embankment height exceeds 8 m
- be at least 2 m wide
- have 2% positive drainage to shed run-off water.

Settlement

To predict the magnitude and time rate of settlement of the underlying silty clay soils the commercially available program Settle 3D developed by Rocscience Inc. was used. The highest embankment sections (next to the bridge approaches) were selected as critical sections.

The deformation parameters used for the analyses were established from data obtained from consolidation tests as well as from predictions based on undrained shear strengths, laboratory index tests and soil moisture contents.

---

[3] Morris, P.M., and Williams, D.T. (1994). "Effective Stress Vane Shear Strength Correction Factor Correlations," Canadian Geotechnical Journal, Vol.31, No.3, pp. 335-342.

Pre-consolidation pressures were estimated from the consolidation test e-log p curves and the Strain-Energy method proposed by Becker (1987). The empirical correlation suggested in the literature by Skempton (1957) was also used to estimate the preconsolidation pressure. Profiles of the preconsolidation pressure range versus elevation are illustrated in Figure F1. The vertical effective overburden stress is also plotted on this figure.

Values of the compression index (C_c) and recompression index (C_r) were estimated from the consolidation tests as well as from laboratory index test data using empirical correlations proposed in literature by Terzaghi and Peck (1967), Osterberg (1972), Nagaraj and Murty (1985), Lav & Ansal (2001), Kulhawy and Mayne (1990) and Das (1993). Profiles of the design lines versus elevation are shown on Figures F2 and F3.

Initial void ratio (e_o) values were estimated from the consolidation tests as well as from empirical correlations proposed in the literature by Cozzolino (1961) and Azzouz et al. (1976). A profile of the design line versus elevation is shown on Figure F4.

Settlement monitoring is a requirement to confirm that most of the settlement is complete prior to commencing paving operations and a special provision for the supply and installation of embankment monitoring equipment will be required. A special provision and drawings of the proposed settlement instrumentation plan is included in Appendix H. This plan includes settlement monitoring of the bridge approach embankments, assumed to be constructed as part of this high fill construction.

6.2 Embankment Stability

The soil parameters used for the slope stability analyses are presented in Table 6.2.1.

Table 6.2.1 – Soil Parameters

Material Type	Short-Term Analysis			Long-Term Analysis		
	ϕ (degrees)	c (kPa)	γ (kN/m^3)	ϕ (degrees)	c (kPa)	γ (kN/m^3)
Local Earth Fill	31	0	19.0	31	0	19.0
Granular A	35	0	22.8	35	0	22.8
Select Subgrade Material	32	0	20.0	32	0	20.0
Rock Fill	42	0	19.0	42	0	19.0
Fill – Silty Clay	0	50	18.0	27	5	18.0
Silty Clay	0	25 – 100	20.0 – 20.5	27 – 29	5 – 7	20.0 – 20.5
Silt	25	0	18.0	25	0	18.0
Silty Clay to Clayey Silt	0	80 – 150	20.5	27	5	20.5

Numerous stability analyses were conducted and the minimum factors of safety obtained for the various embankment options are summarized in Table 6.2.2. The slope stability models and results are also illustrated in Appendix D.

Table 6.2.2 – Minimum Factors of Safety

Embankment Composition	Design Side Slope	Minimum Factor of Safety Short-Term	Minimum Factor of Safety Long-Term
Local Earth Fill Embankment	3H:1V	1.8 – 2.2	1.9 – 2.2
Composite Embankment	2.5H:1V	1.7 – 2.1	1.7 – 2.0
SSM Embankment	2H:1V	1.5 – 1.8	1.5 – 1.8
Rock Fill Embankment	2H:1V	1.3 – 1.6	1.3 – 1.6

The analysis indicates that embankments constructed at the recommended design side slopes will have acceptable factors of safety of 1.3 or greater with respect to both shallow surficial failures and deep seated failures in the underlying soils.

6.3 Embankment Settlement

The parameters used for the settlement calculations are tabulated below. There is a wide scatter in the data and a slight variation of P_c with depth. Therefore the two rows of data represent the range of values for the upper and lower half of the two strata.

Table 6.3.1 – Settlement Parameters

Parameter	Upper Silty Clay	Lower Silty Clay	Lower Silty Clay/Clayey Silt
Preconsolidation Pressure Range P_c (kPa)	600 to 450 500 to 360	450 to 360	450 to 360
Coefficient of Compressibility - C_c	0.30 to 0.35	0.22 to 0.26	0.14 to 0.17
Recompression Index - C_r	0.04 to 0.045	0.030 to 0.040	0.019 to 0.025
Initial Void Ratio - e_o	0.95 to 1.0	0.80 to 0.90	0.55 to 0.65

Settlement analyses were undertaken for various embankment compositions and geometries and the estimated range of total settlements are provided in Table 6.3.2. Where the loads induced by the embankments do not exceed the estimated preconsolidation pressure the recompression index (C_r) was used for settlement calculations. Where the embankment loads exceed the preconsolidation pressure the analysis was based on soil recompression and consolidation and both the recompression index (C_r) and the coefficient of consolidation (C_c) were used.

Table 6.3.2 – Estimated Total Consolidation Settlement

Type of Fill	Unit Weight of Fill (kN/m^3)	Side Slope Geometry	Settlement (mm)
Local Earth Fill	19.0	3H:1V	155 – 200
Composite Embankment	19.5	2.5H:1V	155 – 200
SSM	20.0	2H:1V	155 – 200
Rock Fill	19.0	1.25H:1V	155 – 200

Embankments comprised of local earth fill or select subgrade material will also settle during construction (fill compression) and this settlement is expected to be about 1% of the fill height. This settlement should be immediate in nature and essentially be complete shortly after construction is complete. For rock fill, compression is expected to be 0.5% of fill height for embankments up to 5 m high and 0.75% of fill height for embankments of 5 m to 10 m high.

The length of time required to complete consolidation settlement of the foundation strata is a function of the value of the coefficient of consolidation of the native silty clay strata and the assumed depth of drainage path. Given the very stiff to hard consistency, heavily over-consolidated and likely fractured nature of the desiccated upper crust, it is reasonable to assume that consolidation/recompression will occur quickly in the crust and that the rate of consolidation will be primarily controlled by the coefficient of consolidation and thickness of the underlying firm to stiff silty clay stratum. The coefficient of consolidation was estimated to range between $2.0 \times 10^{-3} cm^2/s$ and $3.5 \times 10^{-3} cm^2/s$.

Tabulated below are the predicted ranges of settlements at various time periods.

Port Robinson Road					
Embankment Type	**Settlement At Various Time Periods (mm)**				**Total Settlement (mm)**
	6 months	**12 months**	**18 months**	**24 months**	
Local Earth Fill	120 – 155	135 – 175	145 – 185	150 – 190	155 – 200
Composite Embankment	120 – 155	135 – 175	145 – 185	150 – 190	155 – 200
SSM	120 – 155	135 – 175	145 – 185	150 – 190	155 – 200
Rock Fill	120 – 155	135 – 175	145 – 185	150 – 190	155 – 200

It is understood that a maximum allowable post construction settlement of about 25 mm would be considered acceptable for this project. The analysis indicates that after embankment construction an approximately 1 year waiting period is required in order to meet this performance criterion. If an accelerated construction schedule is preferred (target of 6 months) then conventional temporary surcharging can be carried out (2 m of additional earth fill height) to accelerate the settlement and ensure full consolidation after embankment construction.

Surcharged embankments were analysed for stability in accordance with the recommended side slopes in Figures G3 to G6 and the analyses yielded factors of safety equal to or greater than a target factor of safety of 1.3.

7 CONSTRUCTION STAGING

Initially it was thought that total consolidation settlements might interfere with construction staging of advance contracts, and might require special treatment (surcharging, light weight fill, wick drains). Detailed analysis was conducted to evaluate the settlement performance requirements.

It is anticipated that the areas where settlement will be critical will be where the embankments are the highest i.e. within 20 m away from the bridge abutments. After paving, a maximum allowable post construction settlement of about 25 mm in these areas would be considered acceptable for this project.

It is understood that the construction staging on this project is critical and it is required that paving operations commence as soon as possible after embankment construction. Our analyses indicates that after the first year of embankment construction the remaining post construction settlement will be less than or equal to the acceptable maximum of 25 mm.

Alternatively, if a target of 6 months after embankment construction is preferred we recommend that conventional temporary surcharging be carried out (2 m of additional earth fill height) to accelerate the settlement and ensure full consolidation. Therefore other means/methods (light weight fill, wick drains) of accelerating the settlement are not warranted. A settlement monitoring program (Appendix H) must be conducted to confirm the anticipated settlement performance. Refer to Figures G3 to G6 for typical surcharge arrangements. The material costs for various surcharge materials are provided in Appendix E.

8 CONSTRUCTION CONSIDERATIONS

It is recommended that the topsoil, any deleterious material and soft/loose and other unsuitable soils be removed within an envelope given by an imaginary slope not steeper than 1H:1V from the toe of the proposed embankment. Refer to Appendix G1 for a schematic figure illustrating the envelope for removal of unsuitable material.

Borrow material must meet the requirements of OPSS 212. Rock fill shall consist of rock as defined in OPSS 206 excluding shale. Grading shall be undertaken in accordance with OPSS 201, and OPSS 206. The recommended stripping depths of the proposed embankments are:

Location	From Station	To Station	Average Stripping Depth (m)
Port Robinson Road	9+610	9+940	±0.0
	9+940	9+950	±0.3
	10+050	10+075	±0.7
	10+075	10+350	±0.0

After stripping, the exposed subgrade should be inspected, approved and properly compacted from the surface in accordance with OPSS 501. If the silty clay soils at this site become wet they will be weakened when subjected to construction traffic. To facilitate construction operations in inclement weather (when stripping to the recommended subgrade elevation) surface water runoff should be controlled by gravity drainage and a system of interceptor trenches. In wet weather an approximately 200 mm thick free draining granular layer would also be required to minimize disturbance and maintain trafficability of construction equipment.

Materials used for embankment construction should be placed in lifts not exceeding 300 mm before compaction and each lift should be uniformly compacted to at least 95 % of the material's Standard Proctor Maximum Dry Density (SPMDD). Embankment construction should be in accordance with OPSS 501 and OPSS 206. Bonding between new and existing embankment fill is required by benching as per OPSD 208.010.

Proper erosion control measures should be implemented both during construction and permanently. Temporary erosion and sediment control must be provided in accordance with OPSS 577. Fill slopes must be provided with permanent erosion protection in accordance with OPSS 571 and/or OPSS 572.

It is also imperative that the designs include provisions for preventing the flow of surface water down the face of slopes. Consideration can be given to using a mountable curb and gutter arrangement to control and divert surface water away from the top of the slope. Surface water must be directed to armoured outfalls/outlets designed to drain into roadside ditches.

9 SEISMIC CONSIDERATIONS

9.1.1 Liquefaction Potential

The potential for liquefaction of the deep silt layer encountered at this site was assessed using the Seed and Idriss (1971) method[4]. The silt is prone to liquefaction at some locations. However, it is noted that this stratum is overlain by a relatively thick non-liquefiable layer of silty clay which will prevent any observable effects of this in-depth liquefaction from reaching ground surface.

Since the embankments will generally bear on stiff to very stiff silty clay soils above the ground water level there is negligible potential for soil liquefaction immediately below the embankments. Some toe failure may occur but is expected to be limited and readily repairable.

Engineering Analysis and Report Preparation by:
R. Abdul, P.Eng.,
Senior Geotechnical Engineer

Report Reviewed by:
Michael Tanos, P.Eng.,
Review Principal

[4] Seed, H.B. and Idriss, I.M. 1971, "Simplified Procedure for Evaluating Soil Liquefaction Potential" Journal of Soil Mechanics and Foundations Division, ASCE, Vol. 101, No. SM9, September, pp. 1249-1273

TABLE

TERRAPROBE INC.

TABLE 1

DOCUMENT	TITLE
OPSS 201	Construction Specification for Clearing, Close Cut Clearing, Grubbing and Removal of Surface and Piled Boulders.
OPSS 206	Construction Specification for Grading.
OPSS 212	Construction Specification of Borrow.
OPSS 501	Construction Specification for Compacting.
OPSS 571	Construction Specification for Sodding.
OPSS 572	Construction Specification for Seed and Cover.
OPSS 577	Construction Specification for Temporary Erosion and Sediment Control Measures.
OPSD 208.010	Benching of Earth Slopes.

APPENDICES

TERRAPROBE INC.

APPENDIX A

Record of Borehole Sheets

Terraprobe Inc.

LIMITATIONS AND RISK

Procedures

The soil conditions were confirmed at the borehole and test pit locations only and conditions may vary between and beyond the boreholes. The boundaries between the various strata as shown on the logs are based on non-continuous sampling. These boundaries represent an inferred transition between the various strata, rather than a precise plane of stratigraphic change.

This investigation has been carried out using investigation techniques and engineering analysis methods consistent with those ordinarily exercised by Terraprobe and other engineering practitioners, working under similar conditions and subject to the time, financial and physical constraints applicable to this project. The discussions and recommendations that have been presented are based on the factual data obtained.

It must be recognized that there are special risks whenever engineering or related disciplines are applied to identify subsurface conditions. Even a comprehensive sampling and testing programme implemented in accordance with the most stringent level of care may fail to detect certain conditions. Terraprobe has assumed for the purposes of providing design parameters and advice, that the conditions that exist between sampling points are similar to those found at the sample locations. The conditions that Terraprobe has interpreted to exist between sampling points can differ from those that actually exist.

It may not be possible to drill a sufficient number of boreholes or sample and report them in a way that would provide all the subsurface information that could affect construction costs, techniques, equipment and scheduling. Contractors bidding on or undertaking work on the project should be directed to draw their own conclusions as to how the subsurface conditions may affect them, based on their own investigations and their own interpretations of the factual investigation results, cognizant of the risks implicit in the subsurface investigation activities.

Changes In Site And Scope

It must be recognized that the passage of time, natural occurrences, and direct or indirect human intervention at or near the site have the potential to alter subsurface conditions. Groundwater levels are particularly susceptible to seasonal fluctuations.

The design advice is based on the factual data obtained from this investigation made at the site by Terraprobe and are intended for use by the owner and its retained designers in the design phase of the project. If there are changes to the project scope and development features, or there is any additional information relevant to the interpretations made of the subsurface information, the geotechnical design parameters and comments relating to constructibility issues and quality control may not be relevant or complete for the revised project. Terraprobe should be retained to review the implications of such changes with respect to the contents of this report

This report was prepared for the express use of the Ministry of Transportation, its retained design consultants and Giffels Associates Ltd./IBI Group. It is not for use by others. This report is copyright of Terraprobe Inc. and no part of this report may be reproduced by any means, in any form, without the prior written permission of Terraprobe Inc. The Ministry of Transportation, its retained design consultants and Giffels Associates Ltd./IBI Group, are authorized users.

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS $\bar{N}$.

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

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

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

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

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

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

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

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

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

JOINTING AND BEDDING:

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

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	FOIL SAMPLE

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ε	%	LINEAR STRAIN
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
C_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = c_u / τ_r

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	1,%	VOID RATIO	e_{min}	1,%	VOID RATIO IN DENSEST STATE
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	1,%	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m^3	DENSITY OF WATER						
γ_w	kN/m^3	UNIT WEIGHT OF WATER	w	1,%	WATER CONTENT	D	mm	GRAIN DIAMETER
ρ	kg/m^3	DENSITY OF SOIL	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
γ	kN/m^3	UNIT WEIGHT OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
ρ_d	kg/m^3	DENSITY OF DRY SOIL	w_P	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL	w_S	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_P	%	PLASTICITY INDEX = $(w_L - w_P)$	v	m/s	DISCHARGE VELOCITY
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $(w - w_P)/I_P$	i	1	HYDRAULIC GRADIENT
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	I_C	1	CONSISTENCY INDEX = $(w_L - w)/I_P$	k	m/s	HYDRAULIC CONDUCTIVITY
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL	e_{max}	1,%	VOID RATIO IN LOOSEST STATE	j	kN/m^3	SEEPAGE FORCE

RECORD OF BOREHOLE No PR1

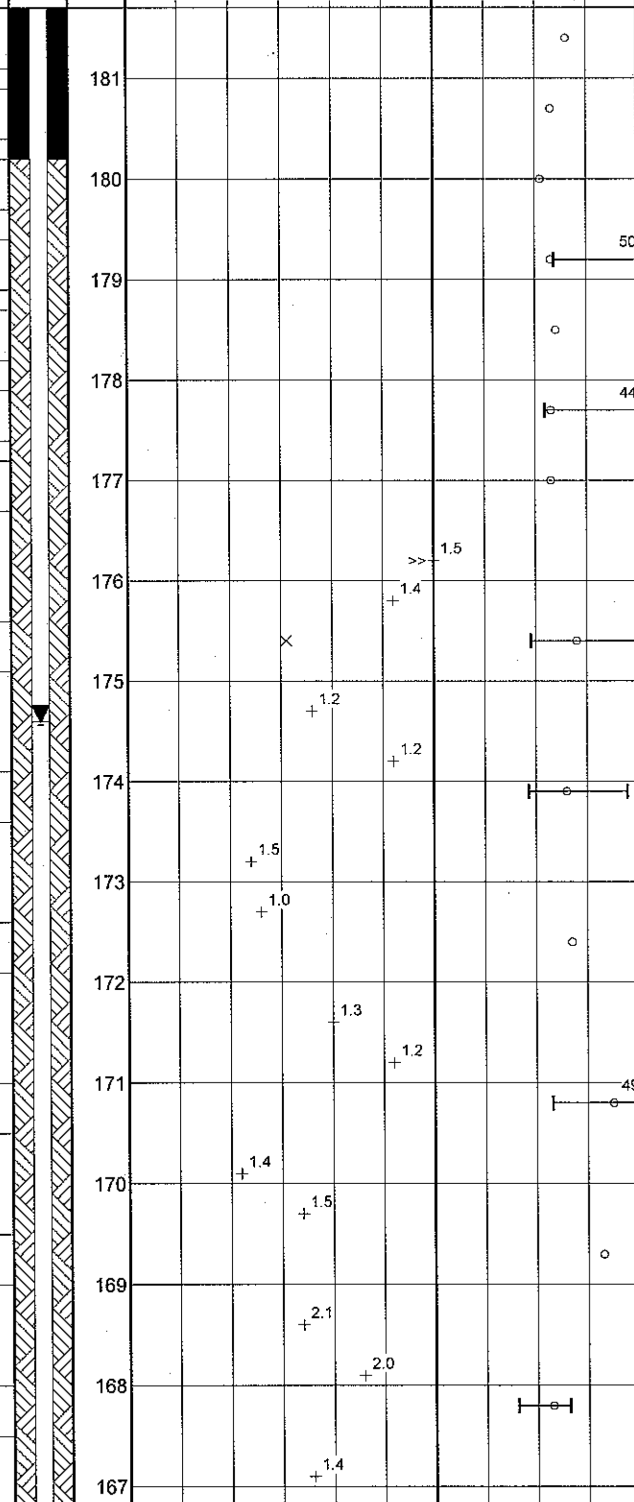
METRIC

W.P. 280-99-00	LOCATION Coords: N:4766747.4 E:326297.5		ORIGINATED BY PK
DIST	HWY 406	BOREHOLE TYPE Hollow Stem Augers	COMPILED BY DB
DATUM Geodetic	DATE 01.04.10 - 01.06.10		CHECKED BY RA

SOIL PROFILE | SAMPLES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100) / SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100) | PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L — WATER CONTENT (%) (10, 20, 30) | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

ELEV / DEPTH	DESCRIPTION
181.7	Ground Surface
0.0	280mm TOPSOIL
181.4 / 0.3	FILL - Silty Clay, trace to some sand, trace gravel, trace organics, firm, brown, moist
180.3 / 1.4	SILTY CLAY trace sand, stiff to very stiff, brown, damp to moist
	---- firm to stiff
167.0 / 14.7	

NUMBER	TYPE	"N" VALUES	Unit Weight (kN/m³)	GR	SA	SI	CL
1	SS	6					
2	SS	6					
3	SS	20					
4	SS	19		0	4	37	59
5	SS	16					
6	SS	10		0	0	53	47
7	SS	9					
8	TW	PH	19.5	0	2	45	53
9	SS	3		0	3	56	41
10	SS	7					
11	SS	3		0	0	39	61
12	SS	4					
13	SS	5		0	0	77	23



Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity   ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No PR1

METRIC

W.P. 280-99-00	LOCATION Coords: N:4766747.4 E:326297.5		ORIGINATED BY PK
DIST	HWY 406	BOREHOLE TYPE Hollow Stem Augers	COMPILED BY DB
DATUM Geodetic		DATE 01.04.10 - 01.06.10	CHECKED BY RA

Soil profile:

ELEV / DEPTH	DESCRIPTION
	SILT trace sand, frequent silty clay seams and partings, loose, brown, wet
163.9 / 17.8	SILTY CLAY TO CLAYEY SILT trace sand, stiff to hard, brown / reddish brown, damp to moist
154.3 / 27.4	CLAYEY SILT trace to some sand, trace gravel, very stiff to hard, brown, moist (GLACIAL TILL)

Samples:

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
14	SS	4	0 0 84 16
15	SS	6	0 1 84 15
16	SS	15	
17	SS	12	
18	SS	29	
19	SS	32	
20	SS	15	
21	SS	10	
22	SS	18	
23	SS	34	

Elevation scale: 166, 165, 164, 163, 162, 161, 160, 159, 158, 157, 156, 155, 154, 153, 152

Dynamic cone penetration resistance plot (20 40 60 80 100): >> at elev. 161

Shear strength kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100): field vane values with sensitivity 1.7 and 1.8 between elev. 155 and 154

Water content (%) (plastic limit w_P, natural moisture content w, liquid limit w_L; 10 20 30); unit weight γ kN/m³

Remarks: Jan.04 / Jan.05 (at elev. approx. 158)

Continued Next Page

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

ONTARIO MOT 1-09-4135 PORT ROBINSON HIGH FILL.GPJ ONTARIO MOT.GDT 07/26/10

RECORD OF BOREHOLE No PR1

METRIC

W.P. 280-99-00	LOCATION Coords: N:4766747.4 E:326297.5		ORIGINATED BY PK
DIST	HWY 406	BOREHOLE TYPE Hollow Stem Augers	COMPILED BY DB
DATUM Geodetic	DATE 01.04.10 - 01.06.10		CHECKED BY RA

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
			24	SS	182/ 28cm		151		○ (~8)		
	frequent cobbles										Jan.05
149.7			25	SS	100/ 2.5cm		150				Jan.06
32.0	End of Borehole										

Resistance to augering at 10.5m, 12.8m, 31.4m, and 31.7m.

Borehole was dry (not stabilized) and hole open to full depth on completion.

Consolidation test performed on TW 8.

Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.

Water Level Readings:

Date	Depth(m)	Elevation(m)
Jan.11.10	7.0	174.7
Jan.19.10	7.2	174.5
Jan.27.10	7.1	174.6
Feb.08.10	7.2	174.5
Feb.19.10	7.1	174.6

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

RECORD OF BOREHOLE No PR2

METRIC

W.P. 280-99-00	LOCATION Coords: N:4766747.3 E:326311.5	ORIGINATED BY PK
DIST ___ HWY 406	BOREHOLE TYPE Hollow Stem Augers / NQ Rock Coring	COMPILED BY DB
DATUM Geodetic	DATE 12.29.09 - 12.30.09	CHECKED BY RA

Soil Profile

ELEV / DEPTH	DESCRIPTION
181.7	Ground Surface
181.4 / 0.0	300mm TOPSOIL
0.3	FILL - Silty Clay, trace sand, firm to stiff, brown, moist
180.3 / 1.4	SILTY CLAY trace sand, occasional gravel inclusions, stiff to very stiff, brown, damp to moist
	— firm to stiff

Samples

NUMBER	TYPE	"N" VALUES	Remarks: Grain Size Distribution (%) GR SA SI CL	Other
1	SS	5		
2	SS	11	0 8 35 57	
3	SS	27	0 1 39 60	W_L 52
4	SS	20		
5	SS	14	0 0 46 54	W_L 44
6	SS	10		
7	SS	7		
8	SS	8	2 3 52 43	
9	SS	6		
10	SS	6	0 3 58 39	
11	TW	PH		Unit weight 17.4 kN/m³
12	SS	1		
13	SS	4	0 1 67 32	

Elevation scale: 181, 180, 179, 178, 177, 176, 175, 174, 173, 172, 171, 170, 169, 168, 167

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

Field vane sensitivity values (top to bottom): 1.0, 1.6, 1.4, 1.8, 1.3, 1.4, 1.7, 1.6, 1.6, 1.1, 2.7, 2.7

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

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

RECORD OF BOREHOLE No PR2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766747.3 E:326311.5 ORIGINATED BY PK

DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers / NQ Rock Coring COMPILED BY DB

DATUM Geodetic DATE 12.29.09 - 12.30.09 CHECKED BY RA

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
		14	SS	3		
166.0 15.7	SILT trace clay, trace sand, very loose, brown, wet				166	
		15	SS	0	165	0 1 95 4
163.9 17.8	SILTY CLAY TO CLAYEY SILT trace sand, stiff to hard, brown / reddish brown, damp to moist				164	
		16	SS	15	163	
		17	SS	12	162	0 5 79 16
		18	SS	23	161, 160	
		19	SS	43	159	0 0 80 20
		20	SS	17	158, 157	
		21	SS	16	156	0 1 79 20
154.8 26.9	CLAYEY SILT trace to some sand, trace gravel, very stiff to hard, brown, moist (GLACIAL TILL)				155	
		22	SS	16	154	Dec.29 / Dec.30
		23	SS	41	153, 152	

Plot annotations: field vane values 3.2 (near elev. 166.5), 1.2 (near elev. 162.5); 1.2 (>> at elev. 162).

Continued Next Page

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

RECORD OF BOREHOLE No PR2

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766747.3 E:326311.5 ORIGINATED BY PK

DIST HWY 406 BOREHOLE TYPE Hollow Stem Augers / NQ Rock Coring COMPILED BY DB

DATUM Geodetic DATE 12.29.09 - 12.30.09 CHECKED BY RA

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS
		24	SS	86	151	
	---- frequent cobbles	25	SS	100/ 10cm	150	
		1	RUN	NQ	149	RUN#1 TCR=32% SCR=19% RQD=0%
148.2 33.5	BEDROCK - DOLOSTONE Unweathered, thinly laminated, light to medium brownish grey, medium strength, argillaceous.	2	RUN	NQ	148	RUN#2 TCR=52% SCR=35% RQD=24%
		3	RUN	NQ	147, 146	RUN#3 TCR=100% SCR=100% RQD=69%
		4	RUN	NQ	145	RUN#4 TCR=100% SCR=100% RQD=56%
144.4 37.3	End of Borehole					

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Resistance to augering at 12.5m.

Sampler wet at 16.8m.

No sample recovery at SS17. Sampler redriven and disturbed sample collected.

Unable to push vane beyond 20.3m.

Borehole filled with drill water on completion.

Borehole sealed with bentonite slurry to ground surface.

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No PR3

METRIC

W.P. 280-99-00 | LOCATION Coords: N:4766747.0 E:326343.5 | ORIGINATED BY PK

DIST | HWY 406 | BOREHOLE TYPE Hollow Stem Augers / NQ Rock Coring | COMPILED BY DB

DATUM Geodetic | DATE 01.07.10 - 01.08.10 | CHECKED BY RA

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
181.3	Ground Surface
181.0 / 0.0	280mm TOPSOIL
0.3	FILL - Silty Sand, frequent clayey inclusions, loose, grey, wet
179.9 / 1.4	SILTY CLAY trace sand, occasional gravel inclusions, firm to stiff, grey / brown, moist
	soft
166.6 / 14.7	

SAMPLES

NUMBER	TYPE	"N" VALUES	Water content / remarks	GR	SA	SI	CL
1	SS	8		0	48	34	18
2	SS	4					
3	SS	6					
4	SS	12	Liquid limit 48	0	1	39	60
5	SS	14					
6	SS	9		1	1	65	33
7	SS	4					
8	SS	4		0	4	55	41
9	SS	7		0	3	54	43
10	SS	4		0	1	57	42
11	TW	PH	Unit weight 18.3 kN/m³				
12	SS	1		0	0	65	35
13	SS	3					

Field vane sensitivities (noted on plot): 2.4, 2.2, 1.7, 1.8, 2.1, 1.4, 2.2, 1.4, 1.5

Continued Next Page

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

RECORD OF BOREHOLE No PR3

METRIC

W.P.	280-99-00	LOCATION	Coords: N:4766747.0 E:326343.5	ORIGINATED BY	PK
DIST	HWY 406	BOREHOLE TYPE	Hollow Stem Augers / NQ Rock Coring	COMPILED BY	DB
DATUM	Geodetic	DATE	01.07.10 - 01.08.10	CHECKED BY	RA

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT / SHEAR STRENGTH (kPa)	GR	SA	SI	CL
	SILT trace clay, trace sand, very loose, brown, wet	14	SS	0	166		0	1	96	3
					165					
164.5 / 16.8	SILTY CLAY TO CLAYEY SILT trace sand, trace gravel, stiff to very stiff, brown / reddish brown, damp to moist	15	SS	15	164					
		16	SS	17	163		1	5	75	19
					162					
		17	SS	19	161					
		18	SS	22	160					
					159					
		19	SS	16	158		0	2	81	17
		20	SS	12	157					
					156	Field vane 1.5				
						Field vane 1.2				
		21	SS	11	155					
						Field vane 1.7				
					154	Field vane 1.4				
153.9 / 27.4	CLAYEY SILT some sand, trace gravel, hard, brown, moist (GLACIAL TILL)	22	SS	30			3	18	64	15
					153					
		23	SS	52	152					

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No PR3

METRIC

W.P. 280-99-00	LOCATION Coords: N:4766747.0 E:326343.5		ORIGINATED BY PK
DIST	HWY 406	BOREHOLE TYPE Hollow Stem Augers / NQ Rock Coring	COMPILED BY DB
DATUM Geodetic		DATE 01.07.10 - 01.08.10	CHECKED BY RA

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS
					151		
		24	SS	172		o	
					150		
		25	SS	33		o	Jan.07 / Jan.08
	---- frequent cobbles	1	RUN	NQ	149		RUN#1 TCR=0% SCR=0% RQD=0%
	---- boulder				148		RUN#2 TCR=71% SCR=69% RQD=29%
147.7 / 33.6	BEDROCK - DOLOSTONE Unweathered, thinly laminated, light to medium brownish grey, medium strength, argillaceous.	2	RUN	NQ	147		
		3	RUN	NQ	146		RUN#3 TCR=100% SCR=100% RQD=76%
		4	RUN	NQ	145		RUN#4 TCR=96% SCR=94% RQD=25%
144.2 / 37.1	End of Borehole						

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L, WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Unable to push vane beyond 5.5m and 14.7m.

Borehole filled with drill water on completion.

Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.

Water Level Readings:

Date	Depth(m)	Elevation(m)
Jan.19.10	8.2	173.1
Jan.27.10	6.6	174.7
Feb.08.10	0.6	180.7
Feb.19.10	0.5	180.8

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No PR4

METRIC

W.P. 280-99-00	LOCATION Coords: N:4766752.2 E:326382.2	ORIGINATED BY PK
DIST	HWY 406	BOREHOLE TYPE Hollow Stem Augers / NQ Rock Coring	COMPILED BY DB
DATUM Geodetic		DATE 01.28.10 - 02.03.10	CHECKED BY RA

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
182.2	Ground Surface
182.0 / 0.2	180mm TOPSOIL
	FILL - Sand, gravelly, some silt, trace clay, trace organics, compact, brown, moist
181.5 / 0.7	FILL - Silty Clay, some sand, trace gravel, stiff to very stiff, brown, moist
180.1 / 2.1	SILTY CLAY trace sand, firm to very stiff, brown, damp to moist
167.5 / 14.7	

SAMPLES

NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ (kN/m³)	GR	SA	SI	CL
1	SS	12		22	50	20	8
2	SS	10					
3	SS	22		0	12	44	44
4	SS	12		0	1	35	64
5	SS	12					
6	SS	13		0	0	47	53
7	SS	4					
8	TW	PH	20.3				
9	SS	7		0	2	59	39
10	SS	8					
11	SS	1		0	1	16	83
12	SS	4					
13	SS	3					

ELEVATION SCALE: 182, 181, 180, 179, 178, 177, 176, 175, 174, 173, 172, 171, 170, 169, 168

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE — 20 40 60 80 100

Field vane sensitivities (top to bottom): 1.2, 2.0, 1.4, 1.8, 1.3, 1.3, 1.1, 2.0, 1.6, 1.4, 1.9

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%): 10 20 30

Liquid limits noted: 56, 44, 61 (47)

REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity   ○ 3% STRAIN AT FAILURE

ONTARIO MOT 1-09-4135 PORT ROBINSON HIGH FILL.GPJ ONTARIO MOT.GDT 07/26/10

RECORD OF BOREHOLE No PR4

METRIC

W.P. 280-99-00	LOCATION Coords: N:4766752.2 E:326382.2		ORIGINATED BY PK
DIST	HWY 406	BOREHOLE TYPE Hollow Stem Augers / NQ Rock Coring	COMPILED BY DB
DATUM Geodetic		DATE 01.28.10 - 02.03.10	CHECKED BY RA

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT / LIMITS	GR SA SI CL
	SILT trace sand, frequent silty clay seams and partings, very loose to compact, brown, wet	14	SS	1	167		0 1 75 24
		15	SS	15	166–165		
164.5 / 17.7	SILTY CLAY TO CLAYEY SILT trace to some sand, trace gravel, stiff to very stiff, brown, damp to moist	16	SS	12	164		
		17	SS	12	163–162		
					162–161	>> 1.8	
		18	SS	19	161		0 2 80 18
		19	SS	21	160–159		
		20	SS	6	158		0 0 63 37
					157–156	>> 1.4	
		21	SS	10	156		
		22	SS	13	155		3 11 63 23
		23	SS	19	154–153		
152.3							

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100. PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30. UNIT WEIGHT γ kN/m³. REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL. STRAT PLOT. GROUND WATER CONDITIONS.

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No PR4

METRIC

W.P. 280-99-00	LOCATION Coords: N:4766752.2 E:326382.2		ORIGINATED BY PK
DIST	HWY 406	BOREHOLE TYPE Hollow Stem Augers / NQ Rock Coring	COMPILED BY DB
DATUM Geodetic		DATE 01.28.10 - 02.03.10	CHECKED BY RA

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
29.9	CLAYEY SILT trace to some sand, trace gravel, hard, brown, moist (GLACIAL TILL)				152		
		24	SS	46		o	
					151		
		25	SS	145	150	o	
	---- frequent cobbles	1	RUN	NQ	149		RUN#1 TCR=23% SCR=18% RQD=0%
147.9 34.3		2	RUN	NQ	148		RUN#2 TCR=54% SCR=40% RQD=0%
	BEDROCK - DOLOSTONE Unweathered, thinly laminated, light to medium brownish grey, medium strength, argillaceous.	3	RUN	NQ			RUN#3 TCR=100% SCR=100% RQD=41%
		4	RUN	NQ	147		RUN#4 TCR=56% SCR=34% RQD=0%
		5	RUN	NQ	146		RUN#5 TCR=100% SCR=100% RQD=62%
144.2 38.0		6	RUN	NQ	145		RUN#6 TCR=100% SCR=100% RQD=14%

End of Borehole

Sampler wet at 10.7m.

Unable to push vane beyond 27.9m.

Borehole filled with drill water on completion.

Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.

Water Level Readings:

Date	Depth(m)	Elevation(m)
Feb.08.10	5.0	177.2
Feb.19.10	4.5	177.7
Apr.16.10	4.3	177.9

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

RECORD OF BOREHOLE No PR5

METRIC

W.P. 280-99-00	LOCATION Coords: N:4766743.3 E:326398.5	ORIGINATED BY PK
DIST HWY 406	BOREHOLE TYPE Hollow Stem Augers	COMPILED BY DB
DATUM Geodetic	DATE 12.21.09 - 12.22.09	CHECKED BY RA

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
181.2	Ground Surface
181.0 / 0.2	300mm TOPSOIL
180.5 / 0.7	FILL - Silty Clay, some sand, trace organics, firm, brown, moist
	SILTY CLAY trace sand, occasional gravel inclusions, stiff to very stiff, brown, moist
	---- firm to stiff
166.5 / 14.7	

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	UNIT WEIGHT γ kN/m³
1	SS	4		
2	SS	8		
3	SS	16		
4	SS	14	0 1 45 54	
5	SS	11		
6	SS	12	0 1 68 31	
7	SS	3		
8	SS	2	0 3 52 45	
9	TW	PH	0 3 57 40	19.7
10	SS	0	7 4 38 51	
11	SS	4		
12	SS	3	0 0 60 40	
13	SS	5	0 0 64 36	

Elevation scale: 181, 180, 179, 178, 177, 176, 175, 174, 173, 172, 171, 170, 169, 168, 167

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100

Field vane sensitivities: 1.3, 1.6, 1.5, 1.6, 1.3, 1.4, 2.4, 1.9, 1.8, 2.4, 1.9, 2.1, 1.8

PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L WATER CONTENT (%) 10 20 30 (Liquid limit 49 at sample 4)

Continued Next Page

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No PR5

METRIC

W.P. 280-99-00	LOCATION Coords: N:4766743.3 E:326398.5		ORIGINATED BY PK
DIST	HWY 406	BOREHOLE TYPE Hollow Stem Augers	COMPILED BY DB
DATUM Geodetic	DATE 12.21.09 - 12.22.09		CHECKED BY RA

Columns: SOIL PROFILE (ELEV / DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Soil Profile

ELEV / DEPTH	DESCRIPTION
	SILT trace clay, loose to compact, brown, wet
163.9 / 17.3	SILTY CLAY TO CLAYEY SILT trace to some sand, trace gravel, stiff to very stiff, brown, damp to moist
153.8 / 27.4	CLAYEY SILT trace to some sand, trace gravel, very stiff to hard, brown, damp (GLACIAL TILL)

Samples

NUMBER	TYPE	"N" VALUES	Remarks / Grain size (GR SA SI CL)
14	SS	6	0 0 93 7
15	SS	26	
16	SS	8	
17	SS	17	
18	SS	16	
19	SS	15	
20	SS	9	
21	SS	9	
22	SS	25	
23	SS	31	

Elevation scale: 166, 165, 164, 163, 162, 161, 160, 159, 158, 157, 156, 155, 154, 153, 152

Shear strength annotations: >> 1.7 (at 162); + 1.3 (at 156); + 1.0; >> 2.4; >> 1.5 (at 154)

Remarks: Dec.21 / Dec.22 (water level, approx. elev. 157.7)

Continued Next Page

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

RECORD OF BOREHOLE No PR5

METRIC

W.P. 280-99-00 | LOCATION Coords: N:4766743.3 E:326398.5 | ORIGINATED BY PK

DIST | HWY 406 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY DB

DATUM Geodetic | DATE 12.21.09 - 12.22.09 | CHECKED BY RA

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
150.7 / 30.5			24	SS	92		151		o		
	End of Borehole										

Shear strength legend: ○ UNCONFINED; + FIELD VANE; ● QUICK TRIAXIAL; × LAB VANE. Plastic limit W_P, natural moisture content W, liquid limit W_L.

Unable to push vane beyond 19.2m.

Resistance to augering at 28.9m.

No sample recovery at SS5 and SS23. Sampler redriven and disturbed sample collected.

Consolidation test performed on TW 9.

Sampler wet at 6.1m.

Borehole was dry (not stabilized) and hole open to full depth on completion.

Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.

Water Level Readings:

Date	Depth(m)	Elevation(m)
Jan.19.10	6.4	174.8
Jan.27.10	6.2	175.0
Feb.08.10	6.3	174.9
Feb.19.10	6.2	175.0

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

RECORD OF BOREHOLE No PR6

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766772.3 E:326098.9 ORIGINATED BY BL

DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB

DATUM Geodetic DATE 07.12.10 CHECKED BY RA

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa (sensitivity)	WATER CONTENT / LIMITS	GR SA SI CL (%)
179.0	Ground Surface							
178.9 / 0.1	130mm ASPHALT							
	FILL - Sandy Gravel, dense to very dense, brown, damp	1	SS	46				
		2	SS	53	178			
177.6 / 1.4	FILL - Silty Clay, sandy, stiff, brown, damp to moist	3	SS	9	177			
		4	SS	11			wp, w, wL	0 25 45 30
176.1 / 2.9	SILTY CLAY trace sand, stiff to very stiff, brown, damp to moist	5	SS	16	176			
		6	SS	26	175			0 4 51 45
		7	SS	9	174			
	firm to stiff	8	SS	3	173			
					172	3.0		
					171	1.3		
		9	SS	WOH	170		wp, w, wL	0 0 48 52
					169	2.0		
					168	2.7		
		10	SS	1	167		wp, w, wL	0 0 61 39
					166	1.8		
165.1 / 13.9					165			

Continued Next Page

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

RECORD OF BOREHOLE No PR6

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766772.3 E:326098.9 ORIGINATED BY BL

DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB

DATUM Geodetic DATE 07.12.10 CHECKED BY RA

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	SILT trace clay, trace sand, very loose to loose, brown, wet		11	SS	2					0	2	90	8
							163						
			12	SS	6		162						
							161						
160.1			13	SS	6								
18.9	SILTY CLAY TO CLAYEY SILT trace sand, hard, brown, damp to moist						160						
158.7			14	SS	32		159						
20.3	End of Borehole												

Borehole was dry (not stabilized) and hole open to full depth on completion.

Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.

Water Level Readings:

Date	Depth(m)	Elevation(m)
Jul.21.10	1.9	177.1
Jul.26.10	1.9	177.1

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30

REMARKS & GRAIN SIZE DISTRIBUTION (%)

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No PR7

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766756.9 E:326163.1 ORIGINATED BY PK

DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB

DATUM Geodetic DATE 07.12.10 CHECKED BY RA

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa (sensitivity)	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
180.1	Ground Surface					180				
180.0 / 0.1	50mm TOPSOIL FILL - Silty Clay, trace sand, trace organics, stiff, brown, damp to moist	1	SS	11				○		
179.4 / 0.7	SILTY CLAY trace sand, stiff to hard, brown, moist	2	SS	28		179		○		
		3	SS	30		178		○		
		4	SS	21				○ (LL 43)		0 1 60 39
		5	SS	16		177		○		
		6	SS	12		176		○		
		7	SS	13				○ (LL 42)		0 2 55 43
	firm to stiff					175	+ 1.7; >> 2.7			
		8	TW	PH		174	×	○	19.8	sampler wet
						173	1.7; + 1.1			
		9	SS	8		172		○		
					∇	171	+ 1.6; 1.3			
		10	SS	9				○ (53, 42)		0 3 29 68
						170	3.0; + 1.4			
						169				
						168				
		11	SS	7				○		
						167	1.5; >> 1.3			
166.2 / 13.9						166				

Continued Next Page

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No PR7

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766756.9 E:326163.1 ORIGINATED BY PK

DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB

DATUM Geodetic DATE 07.12.10 CHECKED BY RA

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	SILT trace sand, trace gravel, frequent clay inclusions, loose, brown, wet		12	SS	8		165							
							164							
							163							
162.4 17.7	SILTY CLAY TO CLAYEY SILT trace sand, trace gravel, very stiff, brown, damp						162							
			13	SS	24						2	4	72	22
161.3 18.8	End of Borehole Water level at 9.1m (not stabilized) and hole open to 15.5m on completion.													

Legend: SHEAR STRENGTH kPa — O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE. PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L.

+³, ×³: Numbers refer to Sensitivity O³% STRAIN AT FAILURE

RECORD OF BOREHOLE No PR8

METRIC

W.P. 280-99-00	LOCATION Coords: N:4766748.9 E:326227.6		ORIGINATED BY PK
DIST	HWY 406	BOREHOLE TYPE Solid Stem Augers	COMPILED BY DB
DATUM Geodetic	DATE 07.13.10		CHECKED BY RA

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
180.6	Ground Surface
180.5 / 0.1	50mm TOPSOIL
	FILL - Silty Clay, some sand, stiff, dark brown, damp to moist
179.9 / 0.7	SILTY CLAY trace sand, trace gravel, very stiff to hard, brown, damp to moist
	firm to stiff
166.7 / 13.9	

SAMPLES

NUMBER	TYPE	"N" VALUES	NATURAL MOISTURE / LIMITS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
1	SS	11						
2	SS	25						
3	SS	35	61		5	2	40	53
4	SS	16						
5	SS	31			0	1	55	44
6	SS	8						
7	SS	9	41		0	3	43	54
8	SS	8						
9	TW	PH		19.6	0	2	53	45
10	SS	6						
11	SS	8						

Field vane sensitivity values (top to bottom): 1.2, >>, 1.4, 1.1, 1.8, 1.1, 2.6, 1.5, 2.0, 1.4

Chart headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL; ELEVATION SCALE 180 to 166; GROUND WATER CONDITIONS; STRAT PLOT

Continued Next Page

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

RECORD OF BOREHOLE No PR8

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766748.9 E:326227.6 ORIGINATED BY PK

DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB

DATUM Geodetic DATE 07.13.10 CHECKED BY RA

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT w (%)	GR	SA	SI	CL
	SILT trace clay, trace sand, trace gravel, very loose to loose, brown, wet	12	SS	4	165	~18	1	6	85	8
					164					
163.6 17.0	SILTY CLAY TO CLAYEY SILT trace sand, trace gravel, very stiff, brown, damp				163					
161.8		13	SS	29	162	~17				
18.8	End of Borehole									

Water level at 14.0m (not stabilized) and hole open to 16.8m on completion.

Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.

Water Level Readings:

Date	Depth(m)	Elevation(m)
Jul.19.10	2.9	177.7
Jul.26.10	2.8	177.8

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No PR9

METRIC

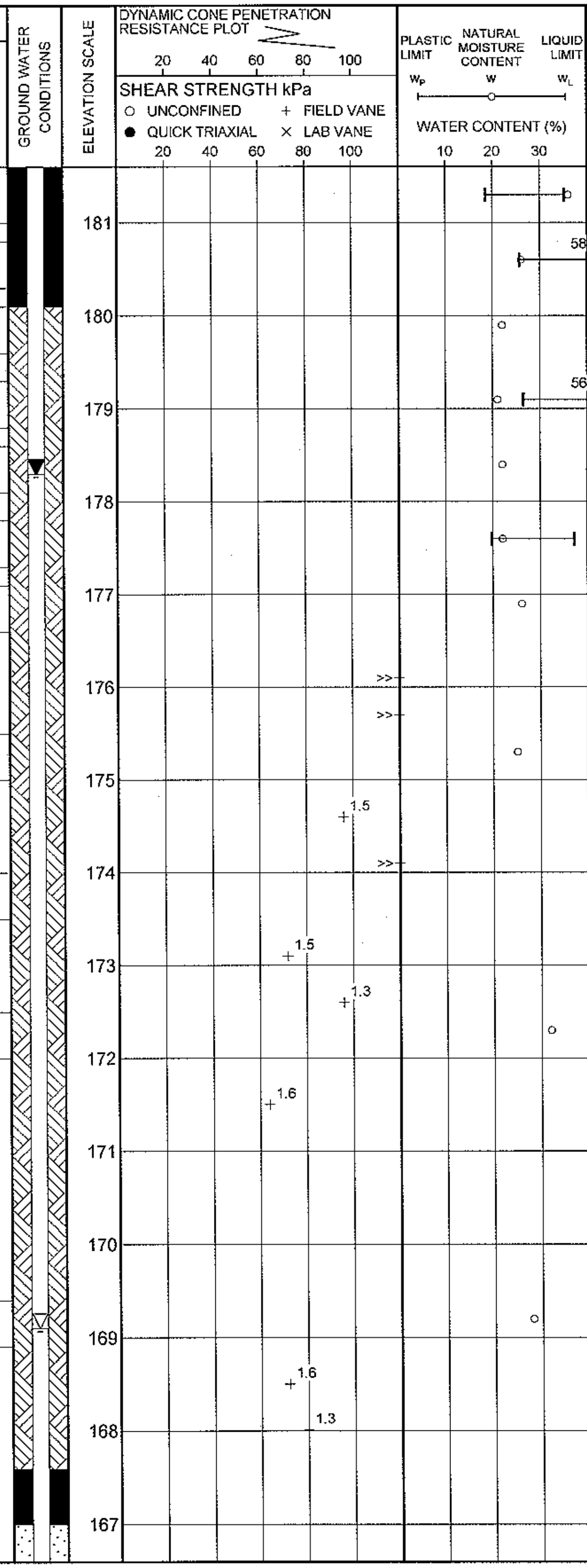
W.P. 280-99-00	LOCATION Coords: N:4766746.6 E:326427.5		ORIGINATED BY PK
DIST	HWY 406	BOREHOLE TYPE Solid Stem Augers	COMPILED BY DB
DATUM Geodetic		DATE 07.06.10	CHECKED BY RA

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
181.6	Ground Surface
181.4 / 0.2	200mm TOPSOIL
	FILL - Silty Clay, sandy, trace organics, stiff, brown, damp to moist
180.9 / 0.7	SILTY CLAY trace sand, very stiff to hard, brown, damp to moist
	---- firm to stiff
167.7 / 13.9	

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	11	0	32	37	31
2	SS	31	0	1	26	73
3	SS	44				
4	SS	29	0	1	44	55
5	SS	24				
6	SS	13	0	1	70	29
7	SS	12				
8	SS	11				
9	TW	PH				
10	SS	9				
11	SS	8				



Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No PR9

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766746.6 E:326427.5 ORIGINATED BY PK

DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB

DATUM Geodetic DATE 07.06.10 CHECKED BY RA

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT	GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILT trace clay, compact, brown, wet	12	SS	20	166	o	0 0 94 6
					165		
164.6 17.0	SILTY CLAY TO CLAYEY SILT trace sand, occasional silt seams and partings, very stiff to hard, brown, damp to moist				164		
		13	SS	21	163	o	
					162		
					161		
		14	SS	40	160	o	
159.8 21.8	End of Borehole						

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%).

Water level at 12.5m (not stabilized) and hole open to 16.8m on completion.

Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.

Water Level Readings:

Date	Depth(m)	Elevation(m)
Jul.19.10	3.5	178.1
Jul.26.10	3.3	178.3

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

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No PR10

METRIC

W.P. 280-99-00		LOCATION	Coords: N:4766748.2 E:326497.5
DIST	HWY 406	BOREHOLE TYPE	Solid Stem Augers
DATUM Geodetic		DATE	07.07.10

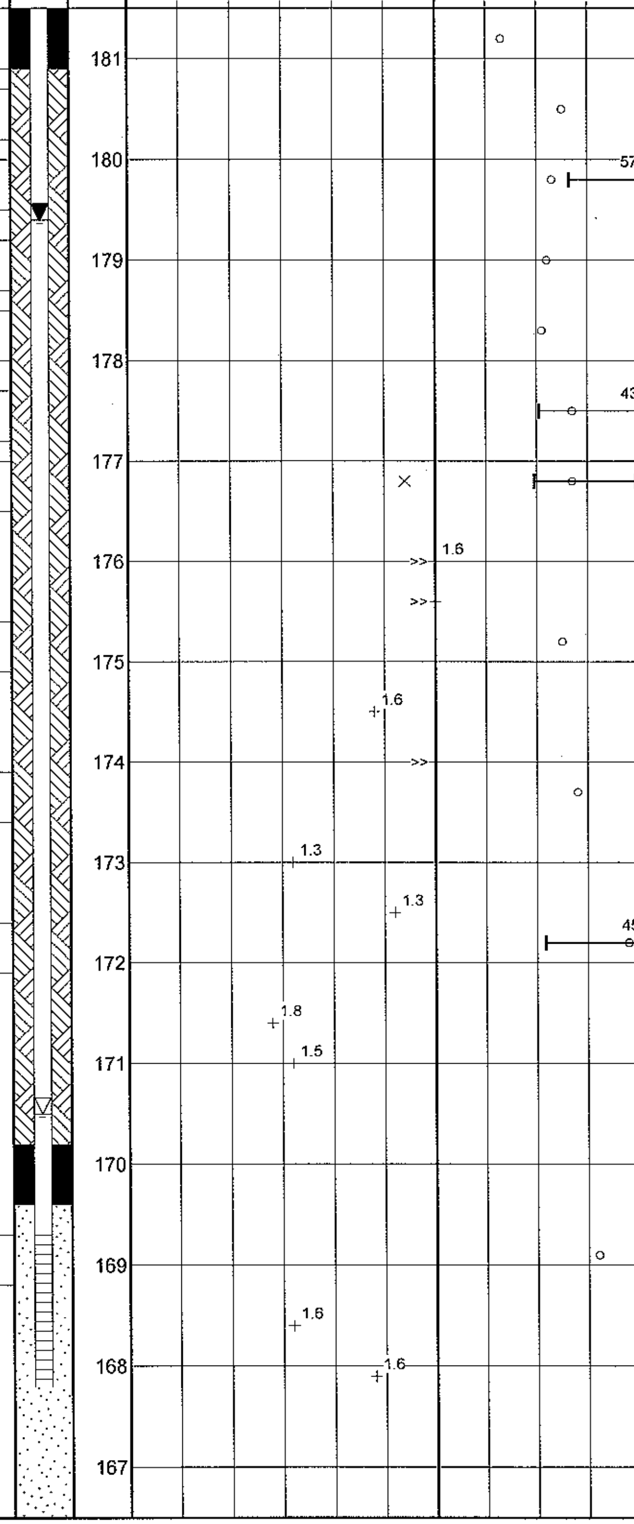
ORIGINATED BY PK
COMPILED BY DB
CHECKED BY RA

SOIL PROFILE / SAMPLES

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
181.5	Ground Surface									
181.4	130mm TOPSOIL									
0.1	FILL - Silty Clay, some sand, trace organics, stiff, dark brown, damp	1	SS	11	181					
180.8 / 0.7	SILTY CLAY trace sand, very stiff to hard, brown, damp to moist	2	SS	24						
		3	SS	32	180		0	3	41	56
		4	SS	38	179					
		5	SS	19	178					
		6	SS	14			0	2	43	55
		7	TW	PH	177	20.0	0	3	44	53
		8	SS	12	175					
	---- firm to stiff									
		9	SS	8	174					
		10	SS	8	172		0	1	35	64
		11	SS	7	169					
167.6 / 13.9										

ELEVATION SCALE: 181, 180, 179, 178, 177, 176, 175, 174, 173, 172, 171, 170, 169, 168, 167

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE: 20 40 60 80 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L
WATER CONTENT (%): 10 20 30



Continued Next Page

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No PR10

METRIC

W.P. 280-99-00 LOCATION Coords: N:4766748.2 E:326497.5 ORIGINATED BY PK

DIST HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB

DATUM Geodetic DATE 07.07.10 CHECKED BY RA

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	NATURAL MOISTURE CONTENT w (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	SILT trace sand, trace gravel, occasional clay inclusions, compact, brown, wet		12	SS	13		166	o					
							165						
164.5 17.0	SILTY CLAY TO CLAYEY SILT trace to some sand, trace gravel, very stiff to hard, brown, damp						164						
			13	SS	17		163	⊢o⊣		7	14	59	20
							162						
			14	SS	33			o		0	2	79	19
161.2 20.3	End of Borehole												

Water level at 11.0m (not stabilized) and hole open to 13.7m on completion.

Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 1.52m slotted screen.

Water Level Readings:

Date	Depth(m)	Elevation(m)
Jul.19.10	2.8	178.7
Jul.26.10	2.1	179.4

Chart headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30; REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

APPENDIX B

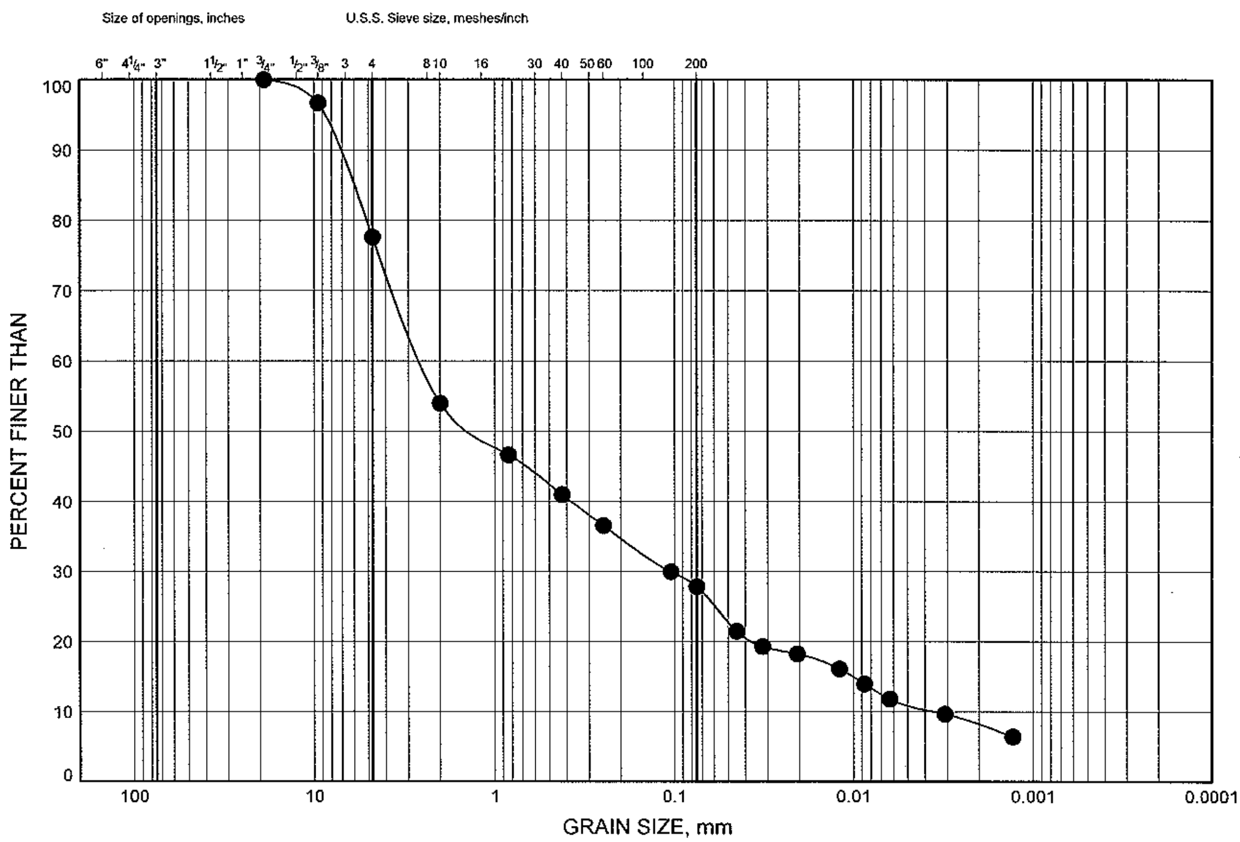
Laboratory Test Results

Terraprobe Inc.

GRAIN SIZE DISTRIBUTION

FIGURE B1

FILL - Gravelly Sand



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR4	0.3	181.9

GSD 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/22/10

Date July 2010

Project 1-09-4135

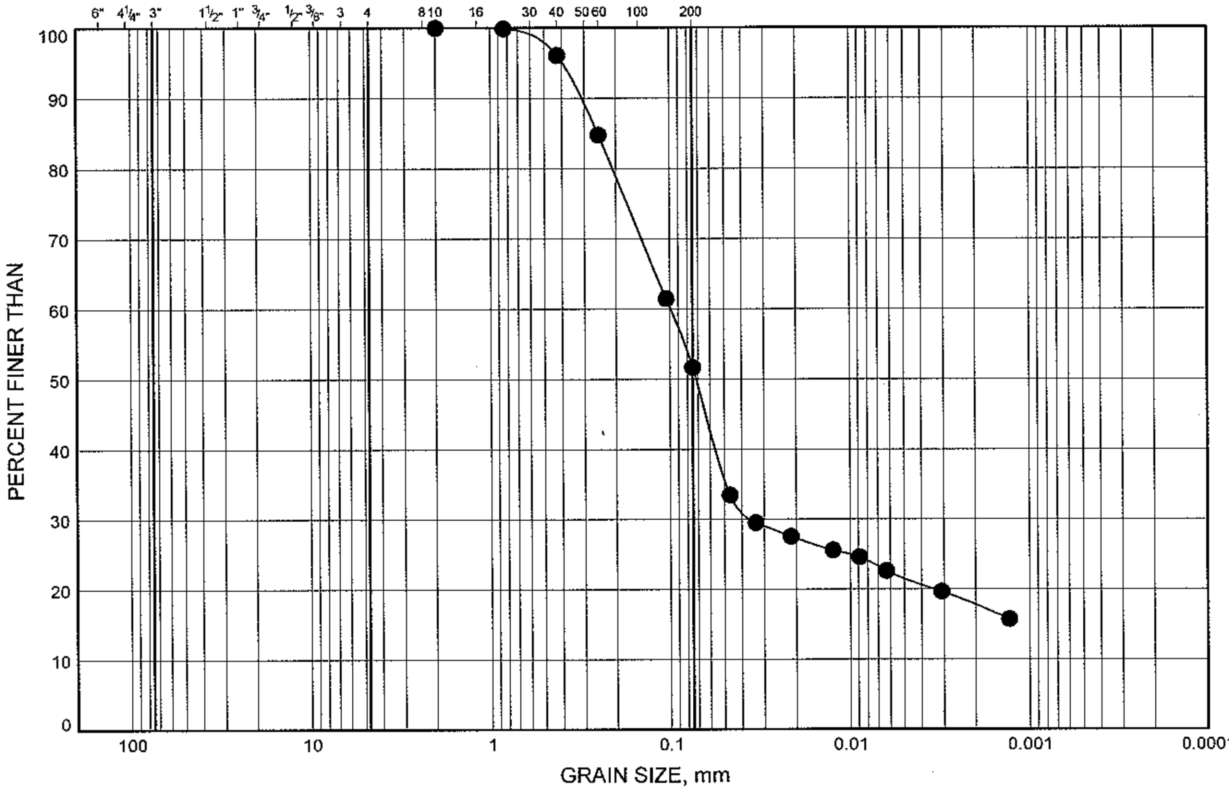
Prep'd DB

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B2

FILL - Silty Sand



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR3	0.3	181.0

GSD 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/22/10

Date July 2010

Project 1-09-4135

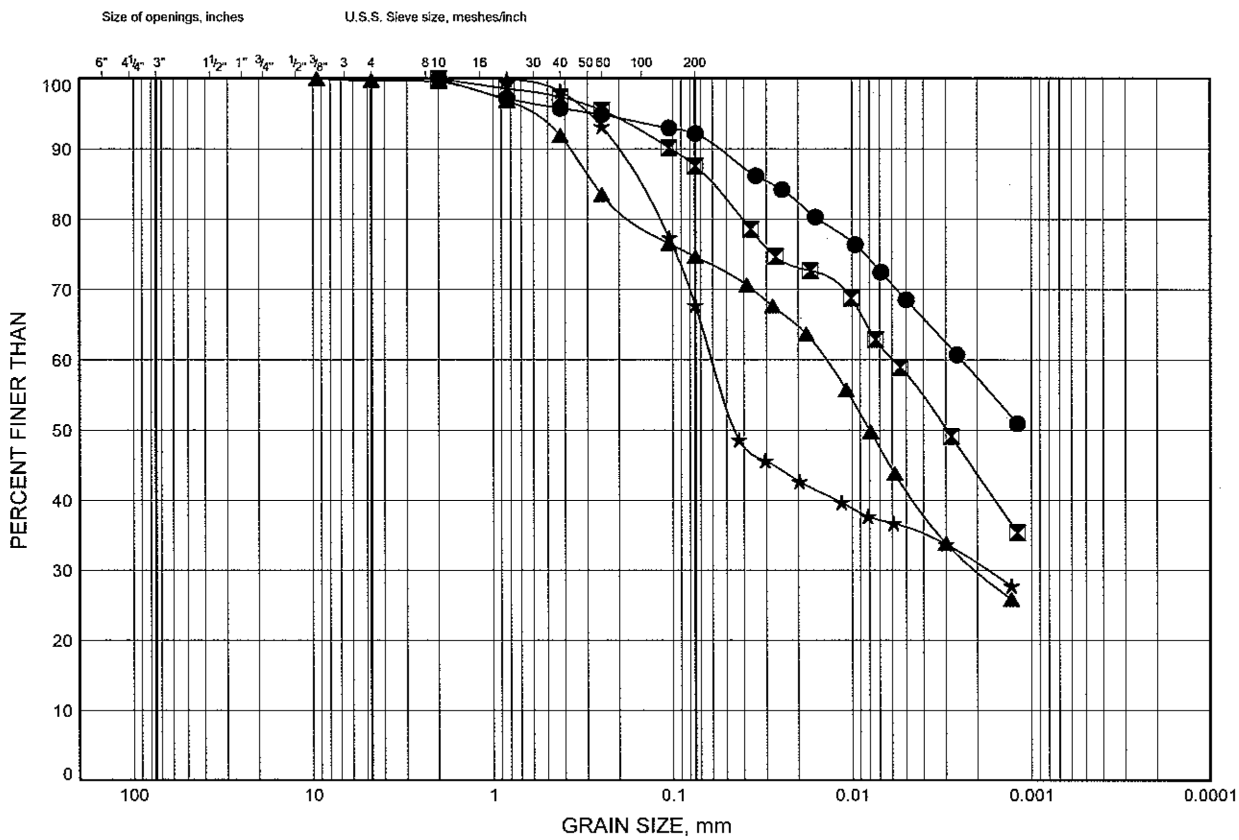
Prep'd DB

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B3

FILL - Silty Clay



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR2	1.0	180.7
⧗	PR4	1.7	180.5
▲	PR6	2.5	176.5
★	PR9	0.3	181.3

Date July 2010

Project 1-09-4135

Prep'd DB

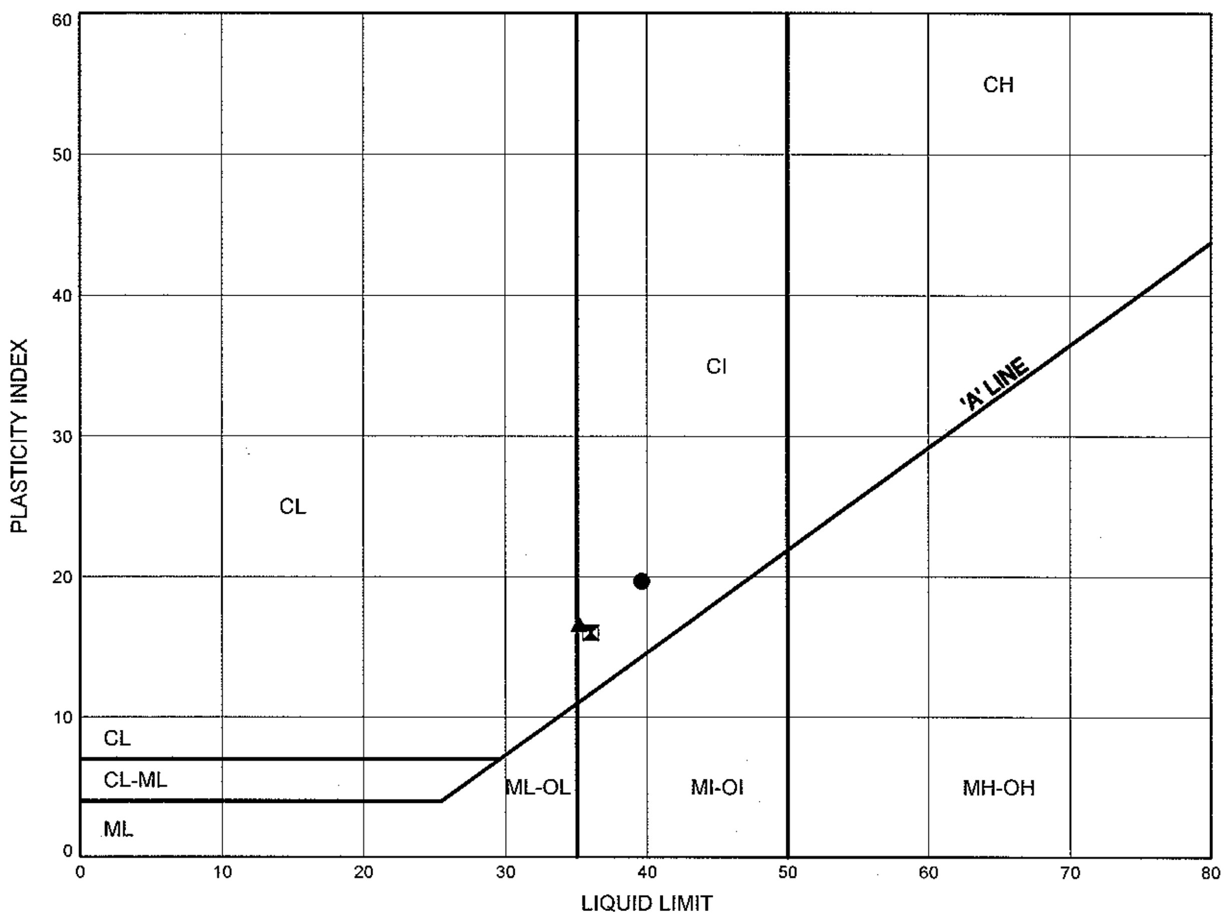
Chkd. MP

GSD 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/22/10

ATTERBERG LIMITS TEST RESULTS

FIGURE B4

FILL - Silty Clay



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR4	1.7	180.5
⧗	PR6	2.5	176.5
▲	PR9	0.3	181.3

Date July 2010
Project 1-09-4135

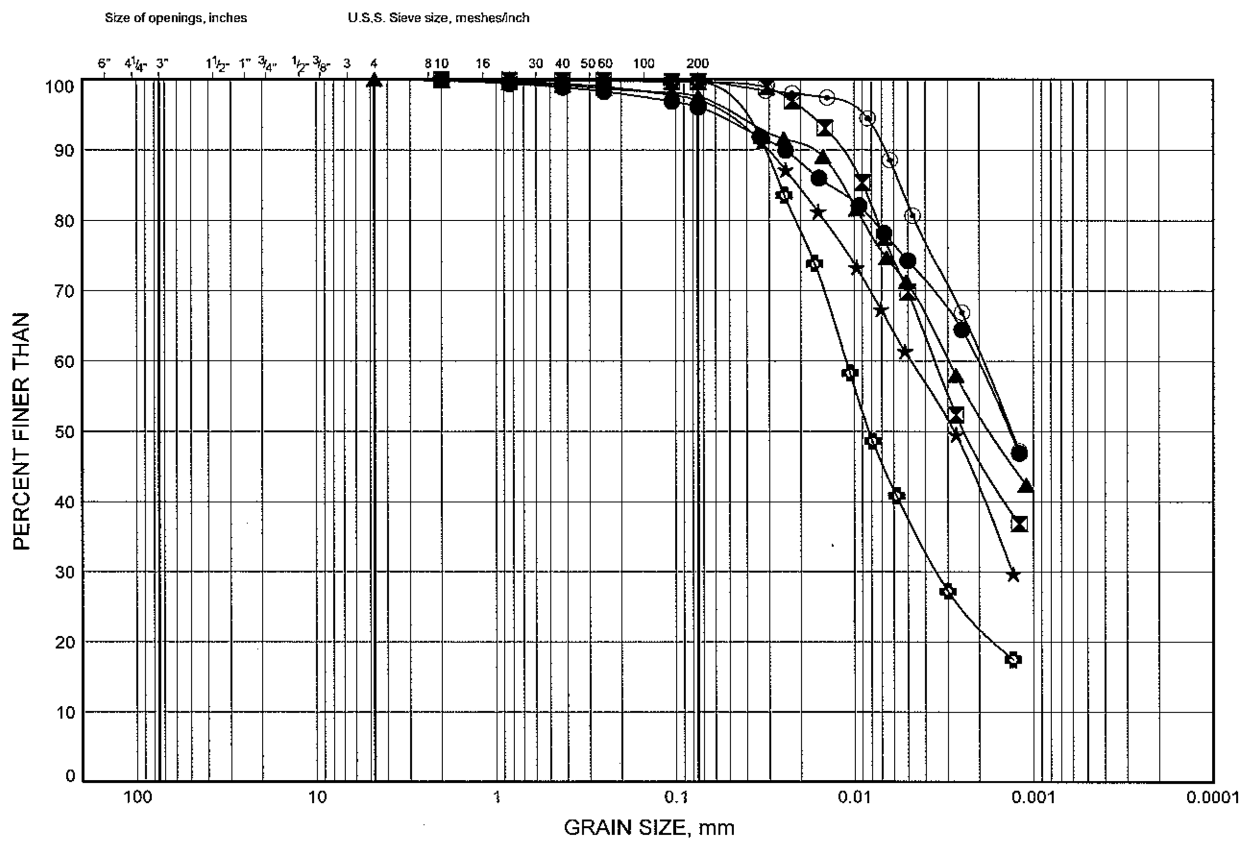
Prep'd DB
Chkd. MP

ALTR 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/22/10

GRAIN SIZE DISTRIBUTION

FIGURE B5

SILTY CLAY



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR1	2.5	179.2
⧗	PR1	4.0	177.7
▲	PR1	6.3	175.4
★	PR1	7.8	173.9
⊙	PR1	10.9	170.8
✪	PR1	13.9	167.8

Date July 2010

Project 1-09-4135

Prep'd DB

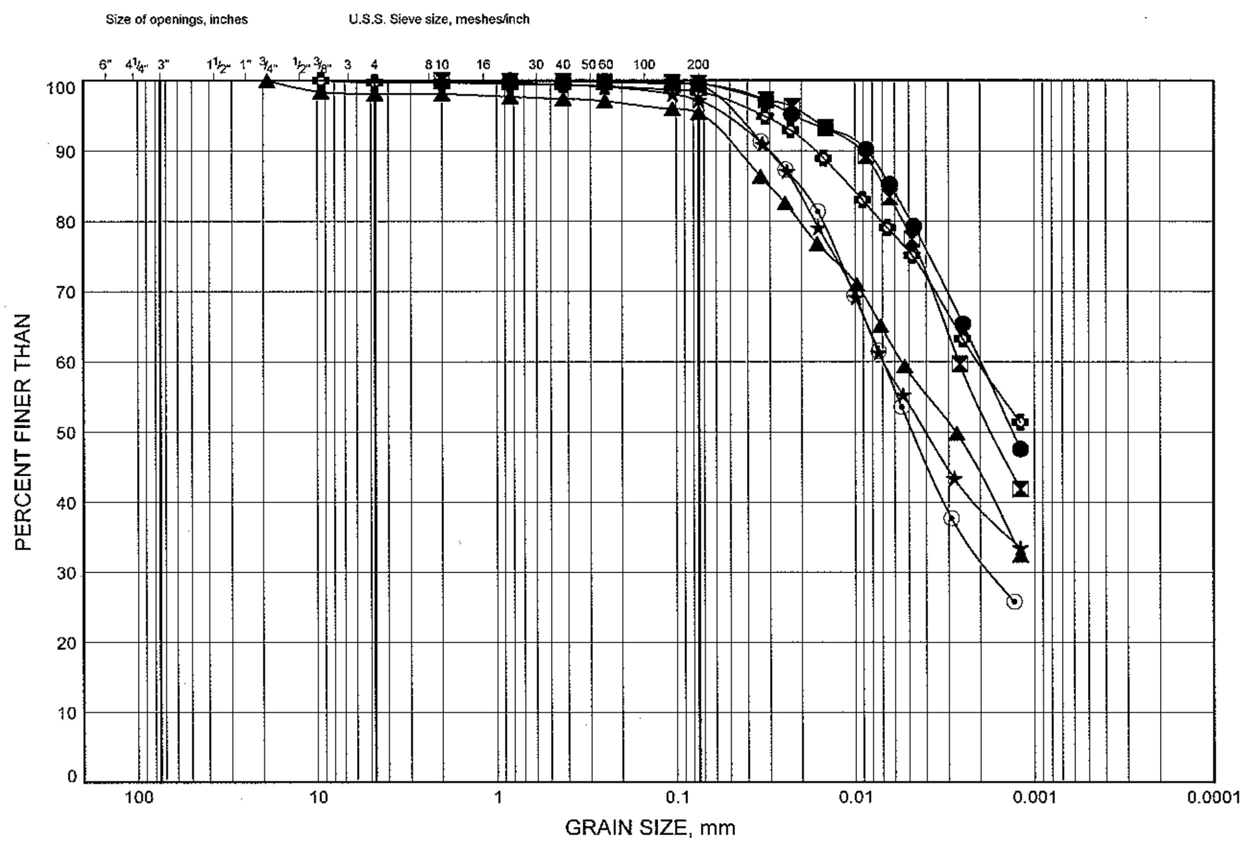
Chkd. MP

GSD 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/22/10

GRAIN SIZE DISTRIBUTION

FIGURE B6

SILTY CLAY



COBBLE SIZE	GRAVEL		SAND			FINE GRAINED
	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR2	1.7	180.0
⧗	PR2	3.2	178.5
▲	PR2	6.3	175.4
★	PR2	9.3	172.4
⊙	PR2	13.9	167.8
✪	PR3	2.5	178.8

Date July 2010

Project 1-09-4135

Prep'd DB

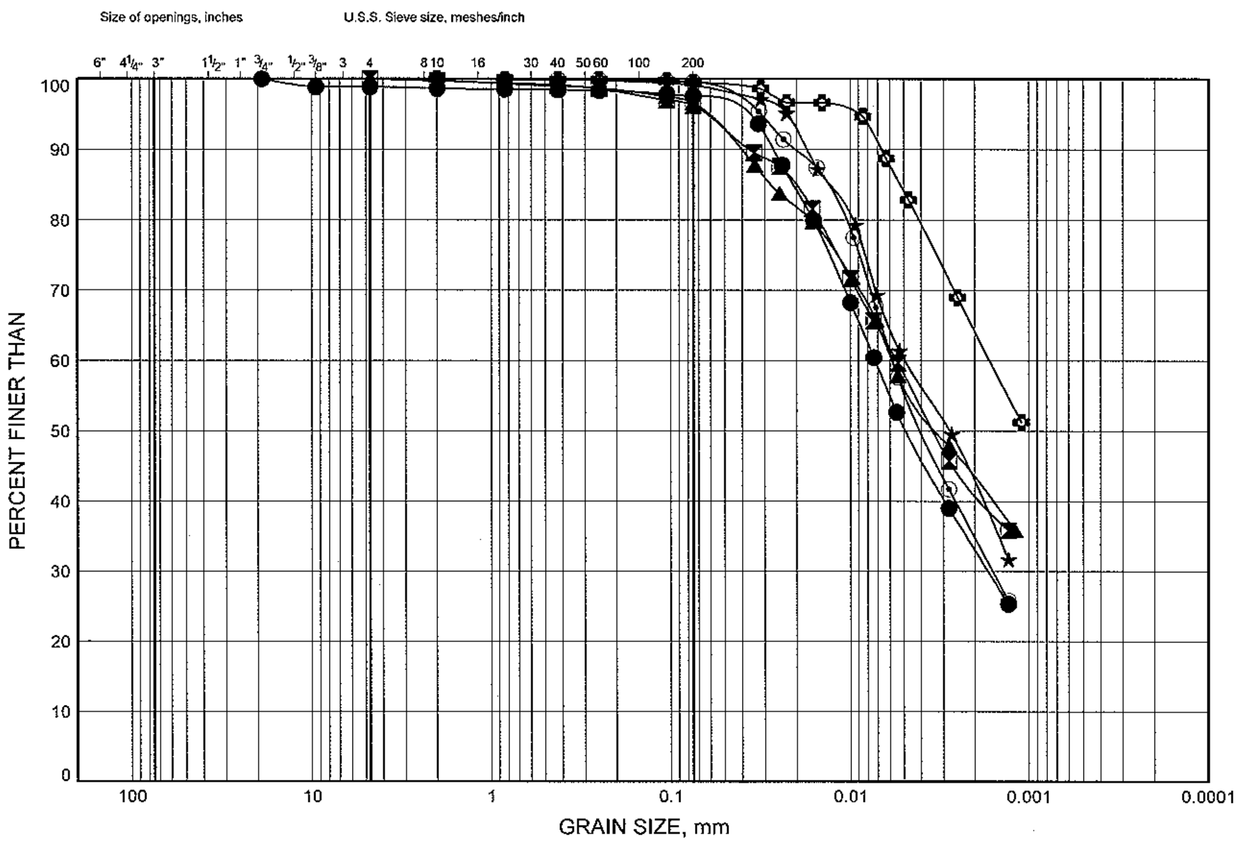
Chkd. MP

GSD 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/22/10

GRAIN SIZE DISTRIBUTION

FIGURE B7

SILTY CLAY



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR3	4.0	177.3
⧗	PR3	6.3	175.0
▲	PR3	7.8	173.5
★	PR3	9.3	172.0
⊙	PR3	12.4	168.9
✿	PR4	2.5	179.7

GSD 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/22/10

Date July 2010

Project 1-09-4135

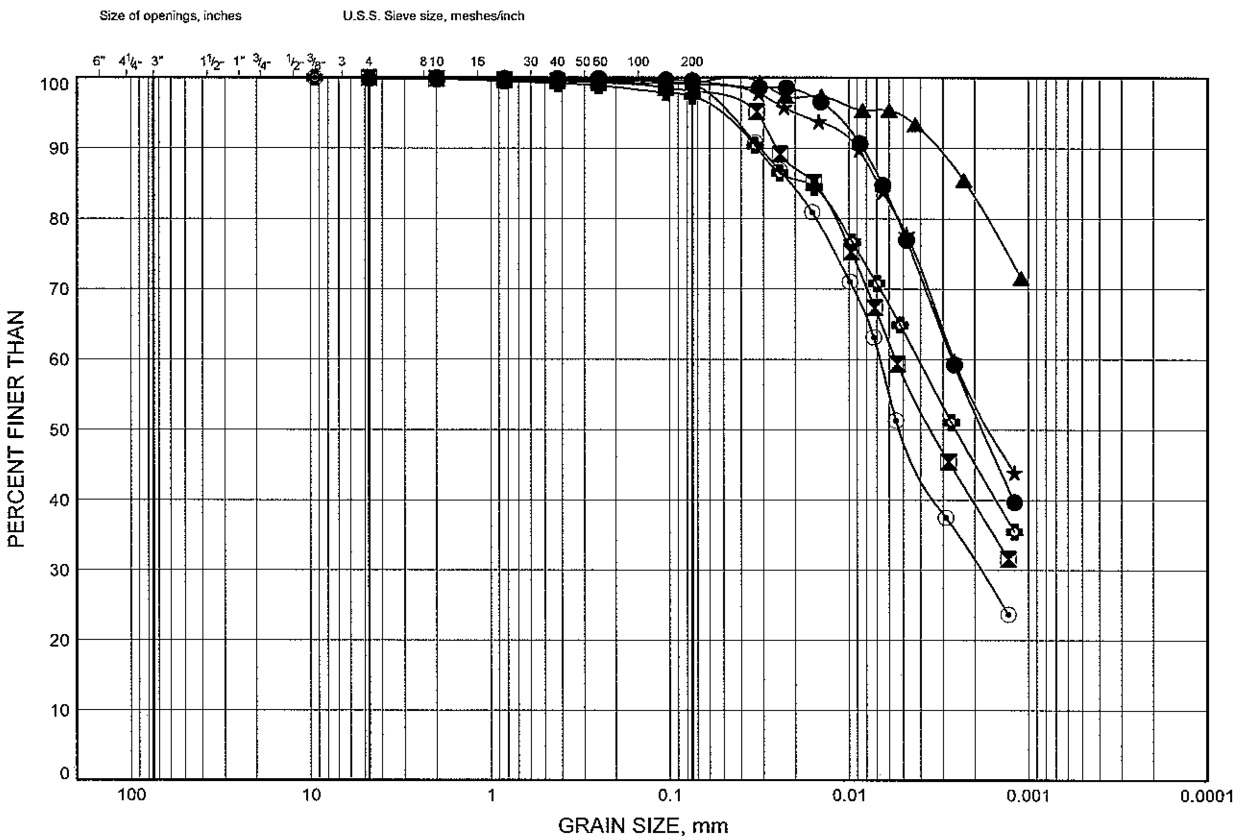
Prep'd DB

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B8

SILTY CLAY



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR4	4.0	178.2
⧗	PR4	7.8	174.4
▲	PR4	10.9	171.3
★	PR5	2.5	178.7
⊙	PR5	4.0	177.2
✪	PR5	6.3	174.9

Date July 2010
Project 1-09-4135

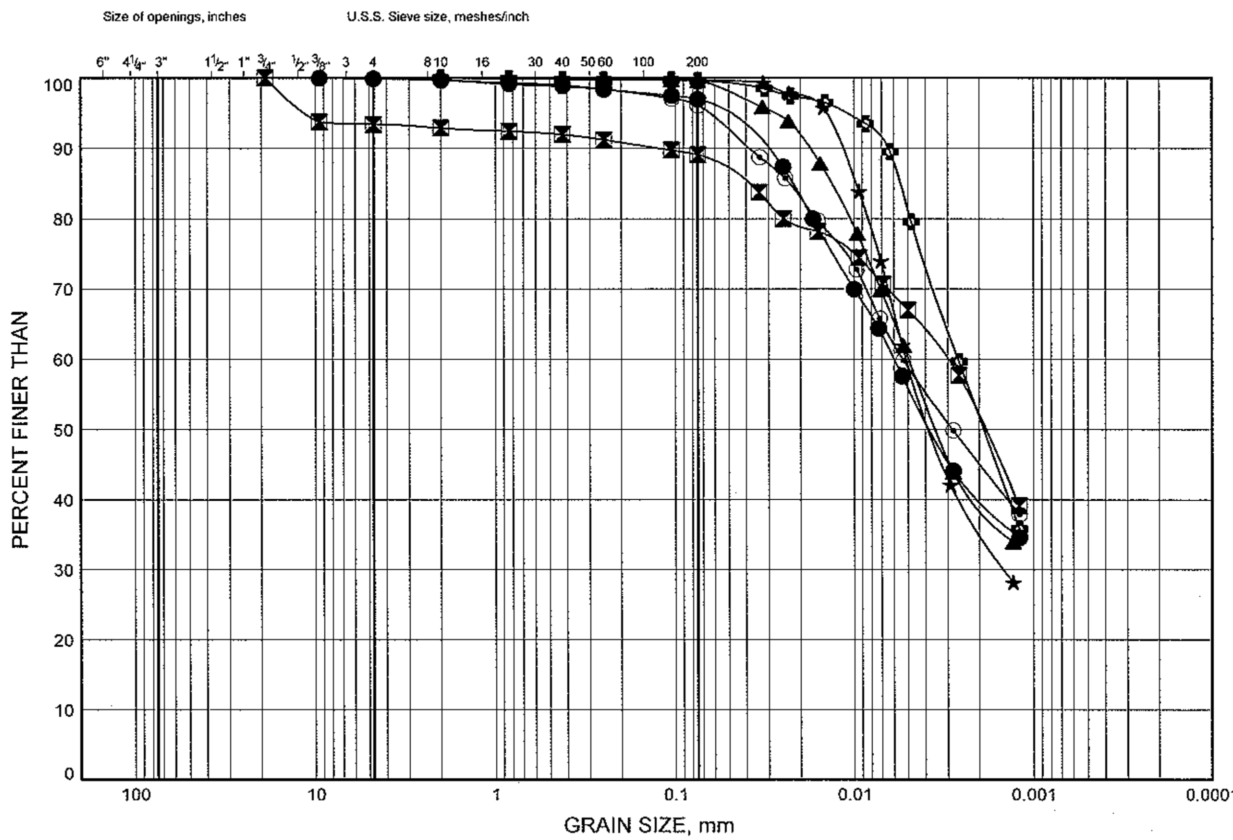
Prep'd DB
Chkd. MP

GSD 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/22/10

GRAIN SIZE DISTRIBUTION

FIGURE B9

SILTY CLAY



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR5	7.8	173.4
⧗	PR5	9.3	171.9
▲	PR5	12.4	168.8
★	PR5	13.9	167.3
⊙	PR6	4.0	175.0
✪	PR6	9.3	169.7

GSD 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/22/10

Date July 2010

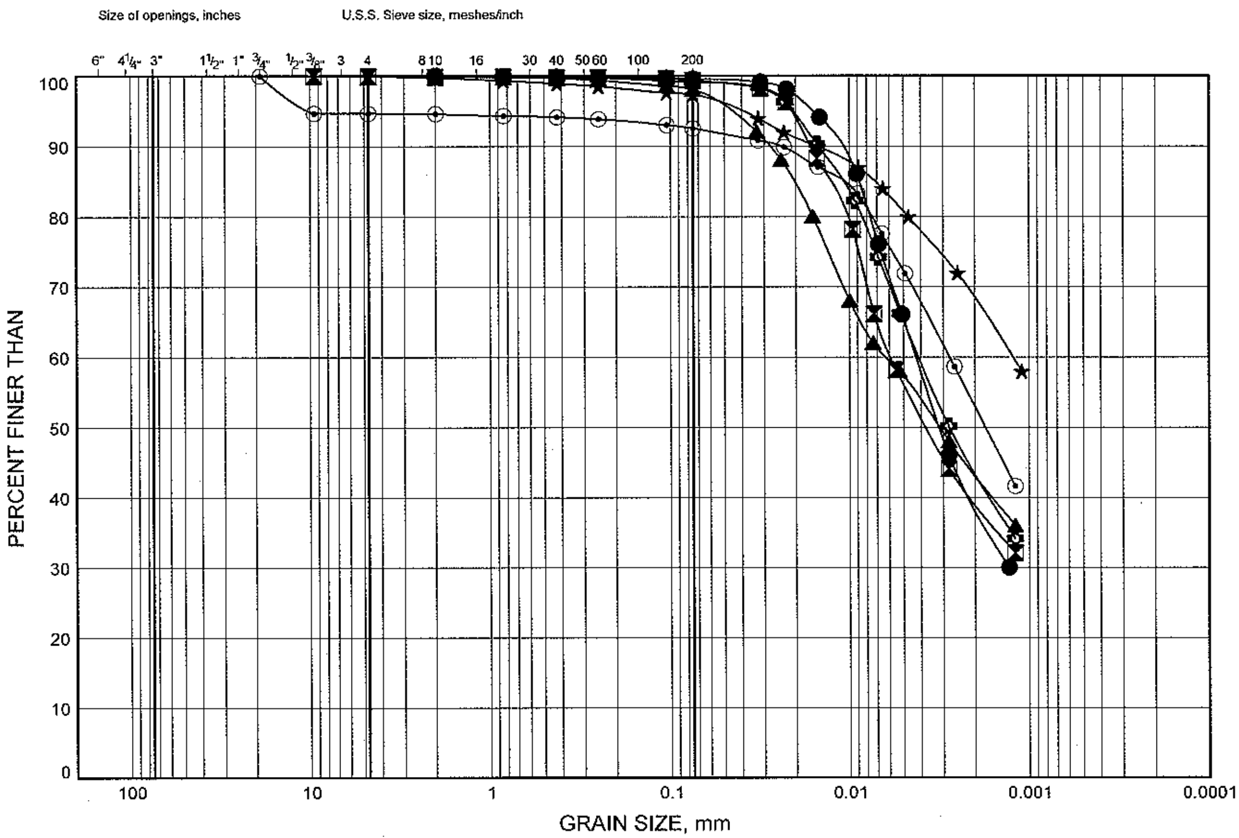
Project 1-09-4135

Prep'd DB

Chkd. MP

GRAIN SIZE DISTRIBUTION	FIGURE B10

SILTY CLAY



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR6	12.4	166.6
⧗	PR7	2.5	177.6
▲	PR7	4.7	175.4
★	PR7	9.3	170.8
⊙	PR8	1.7	178.9
✿	PR8	3.2	177.4

Date July 2010
Project 1-09-4135

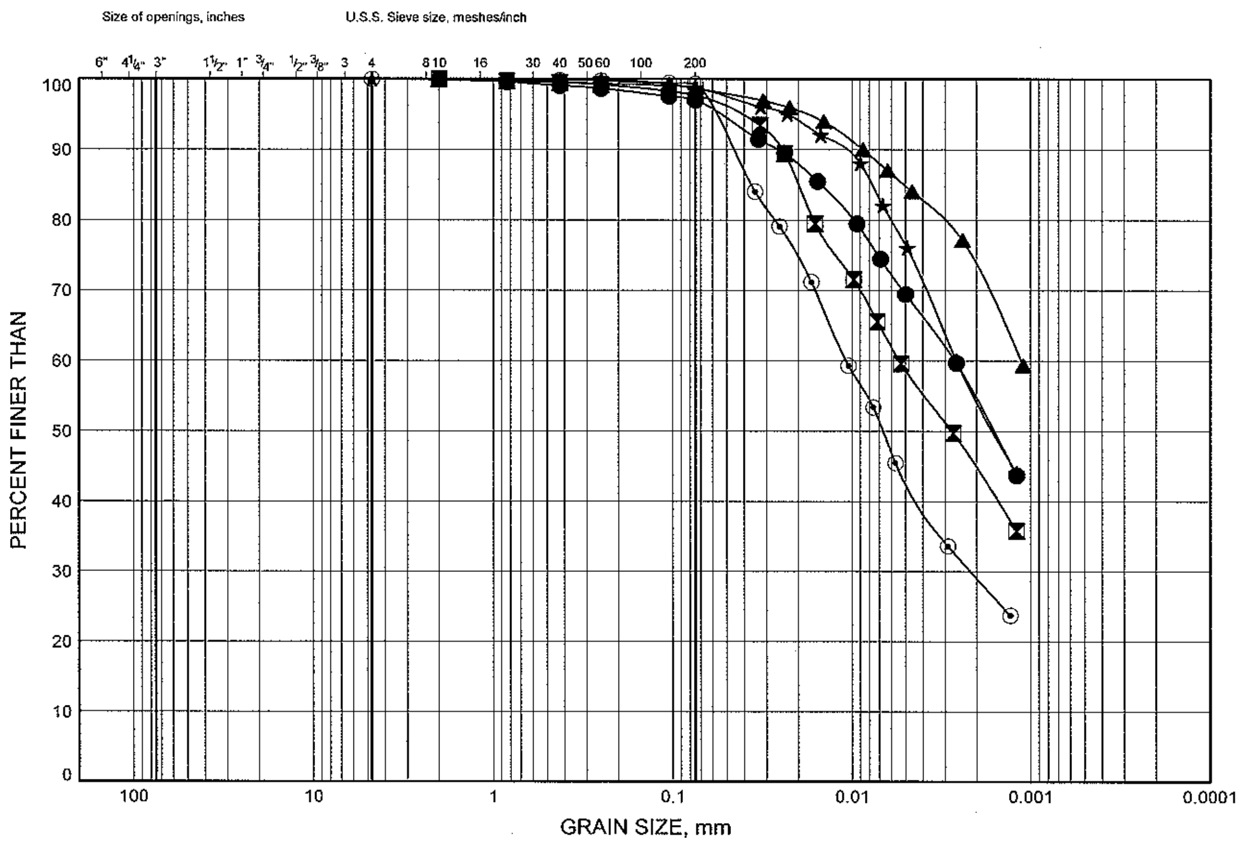
Prep'd DB
Chkd. MP

GSD 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/22/10

GRAIN SIZE DISTRIBUTION

FIGURE B11

SILTY CLAY



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR8	4.7	175.9
⧗	PR8	7.8	172.8
▲	PR9	1.0	180.6
★	PR9	2.5	179.1
⊙	PR9	4.0	177.6

Date July 2010

Project 1-09-4135

Prep'd DB

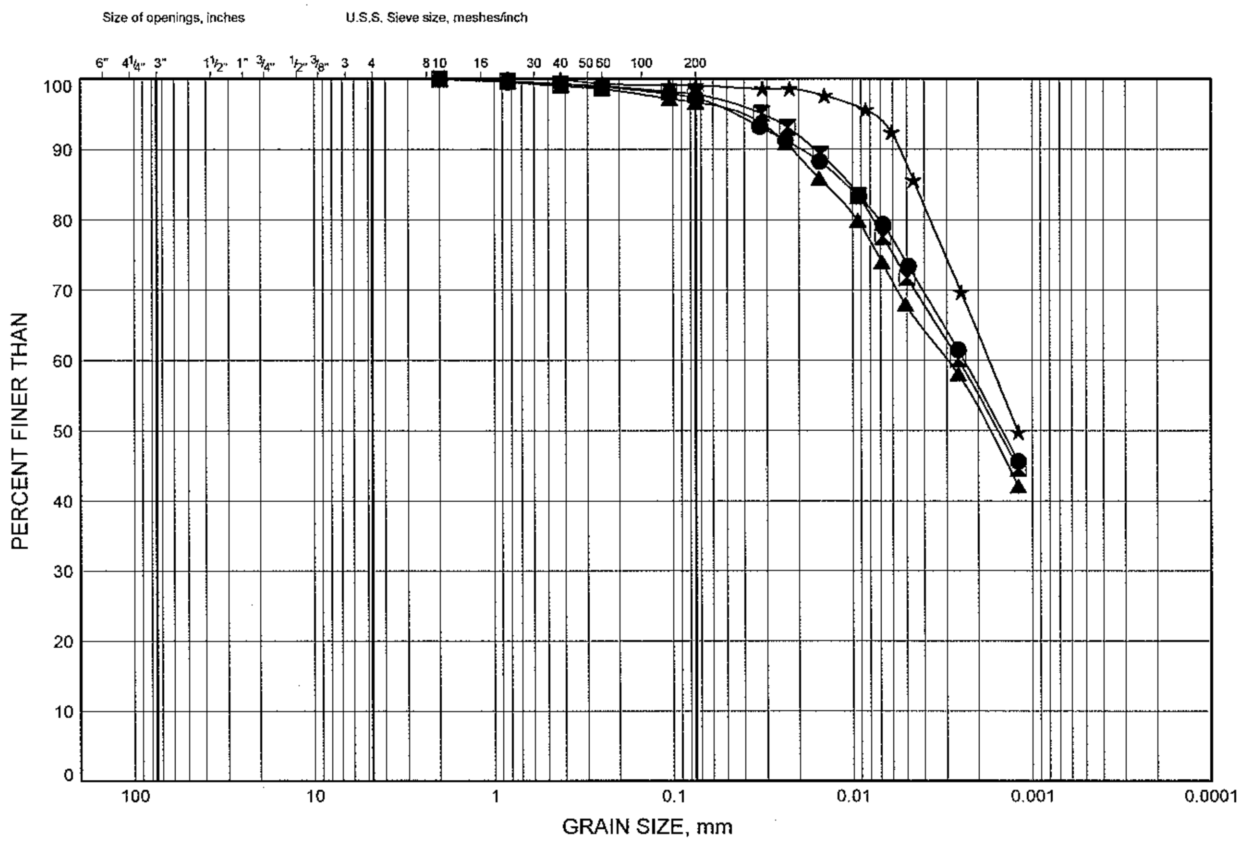
Chkd. MP

GSD 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/22/10

GRAIN SIZE DISTRIBUTION

FIGURE B12

SILTY CLAY



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR10	1.7	179.8
⧗	PR10	4.0	177.5
▲	PR10	4.7	176.8
★	PR10	9.3	172.2

Date July 2010

Project 1-09-4135

Prep'd DB

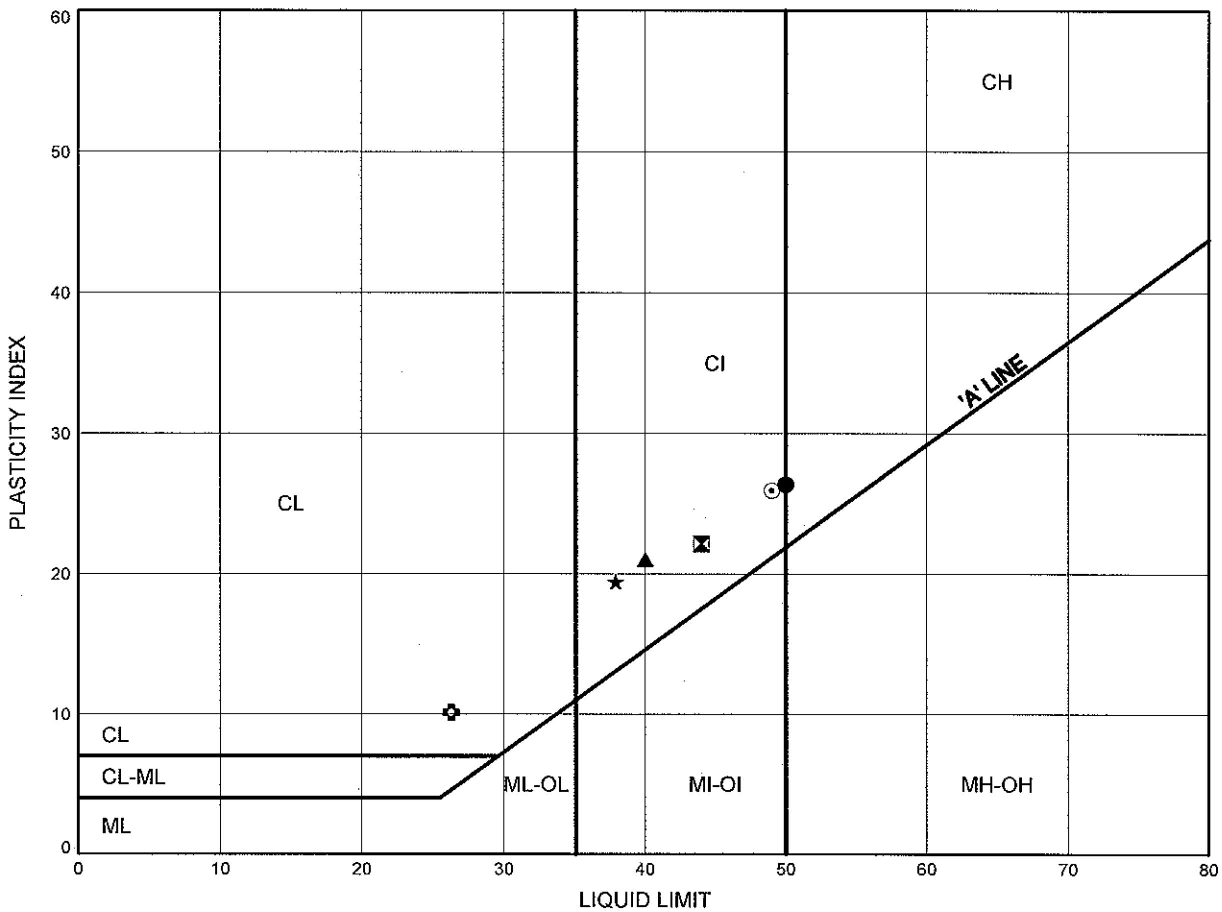
Chkd. MP

GSD 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/22/10

ATTERBERG LIMITS TEST RESULTS

FIGURE B13

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR1	2.5	179.2
⊠	PR1	4.0	177.7
▲	PR1	6.3	175.4
★	PR1	7.8	173.9
⊙	PR1	10.9	170.8
✿	PR1	13.9	167.8

Date July 2010

Project 1-09-4135

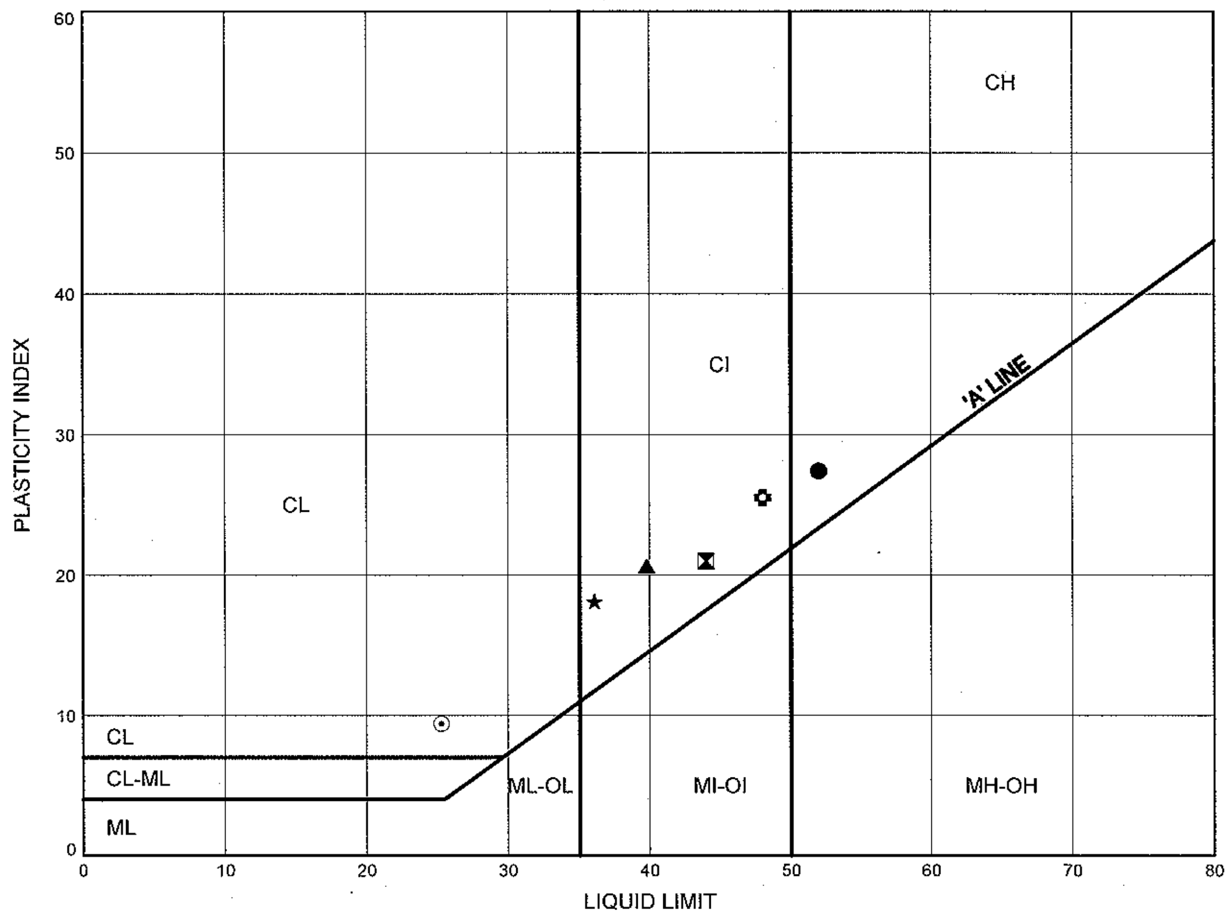
Prep'd DB

Chkd. MP

ATTERBERG LIMITS TEST RESULTS

FIGURE B14

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR2	1.7	180.0
⧗	PR2	3.2	178.5
▲	PR2	6.3	175.4
★	PR2	9.3	172.4
⊙	PR2	13.9	167.8
✿	PR3	2.5	178.8

Date July 2010

Project 1-09-4135

Prep'd DB

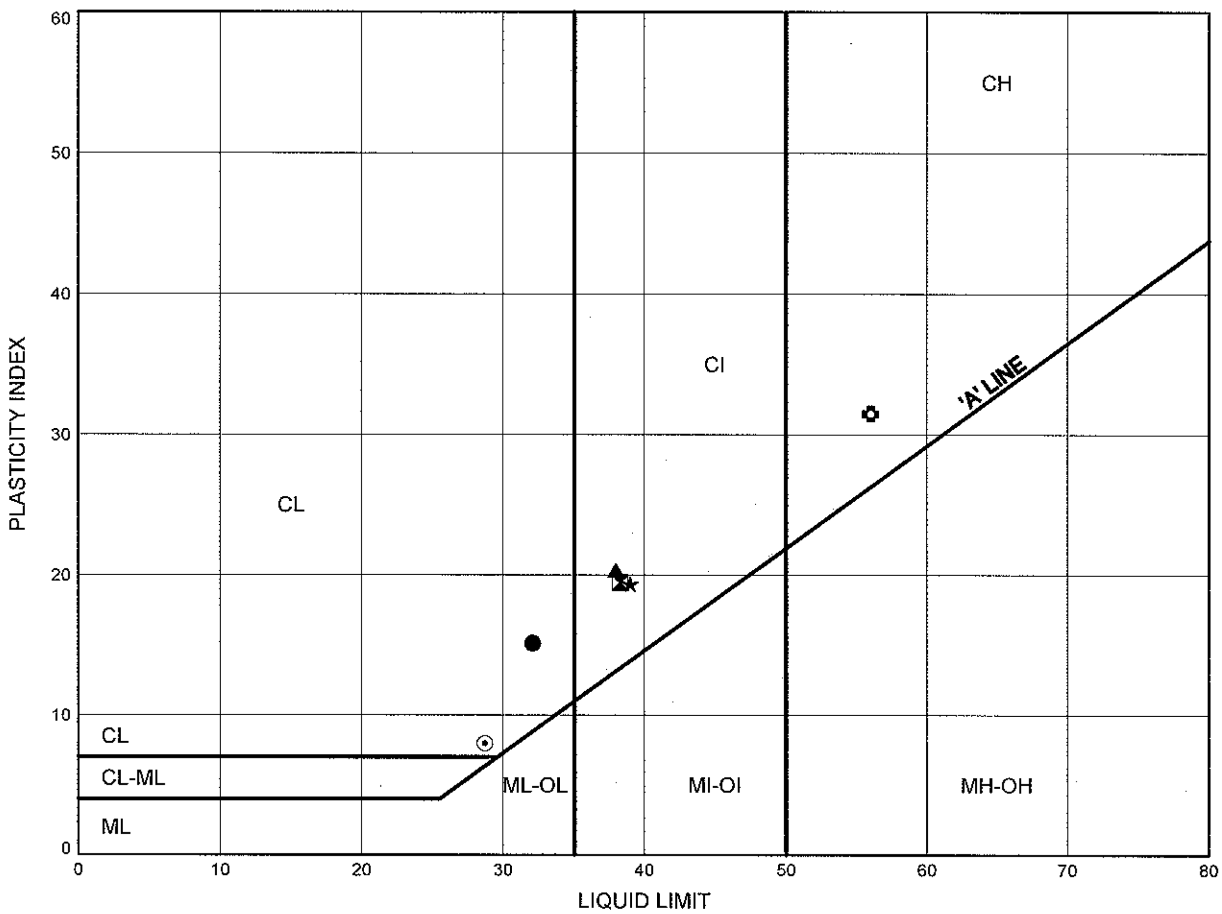
Chkd. MP

ALTR 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/22/10

ATTERBERG LIMITS TEST RESULTS

FIGURE B15

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR3	4.0	177.3
⊠	PR3	6.3	175.0
▲	PR3	7.8	173.5
★	PR3	9.3	172.0
⊙	PR3	12.4	168.9
✿	PR4	2.5	179.7

Date July 2010

Project 1-09-4135

Prep'd DB

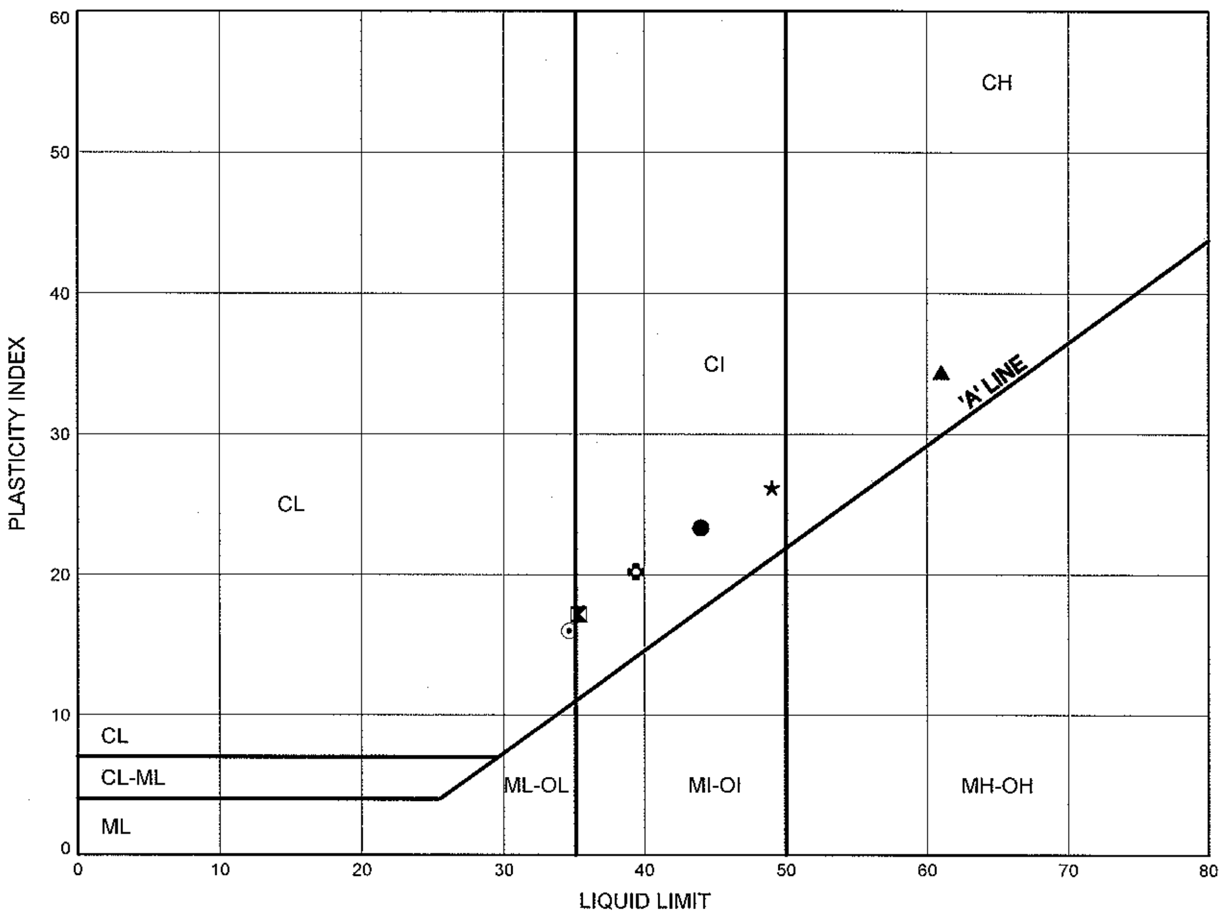
Chkd. MP

ALTR 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/22/10

ATTERBERG LIMITS TEST RESULTS

FIGURE B16

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR4	4.0	178.2
⧗	PR4	7.8	174.4
▲	PR4	10.9	171.3
★	PR5	2.5	178.7
⊙	PR5	4.0	177.2
✿	PR5	6.3	174.9

Date July 2010

Project 1-09-4135

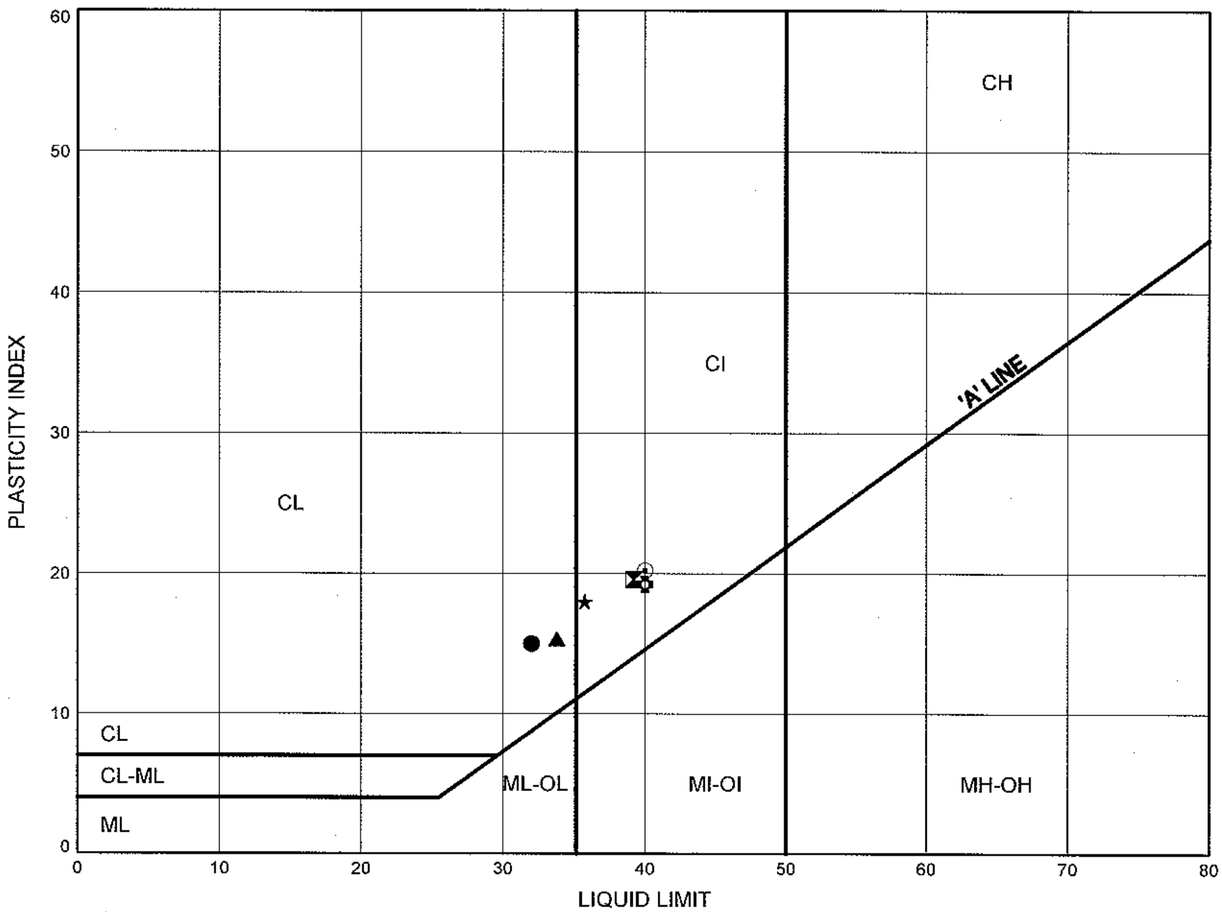
Prep'd DB

Chkd. MP

ATTERBERG LIMITS TEST RESULTS

FIGURE B17

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR5	7.8	173.4
⧗	PR5	9.3	171.9
▲	PR5	12.4	168.8
★	PR5	13.9	167.3
⊙	PR6	4.0	175.0
✿	PR6	9.3	169.7

Date July 2010

Project 1-09-4135

Prep'd DB

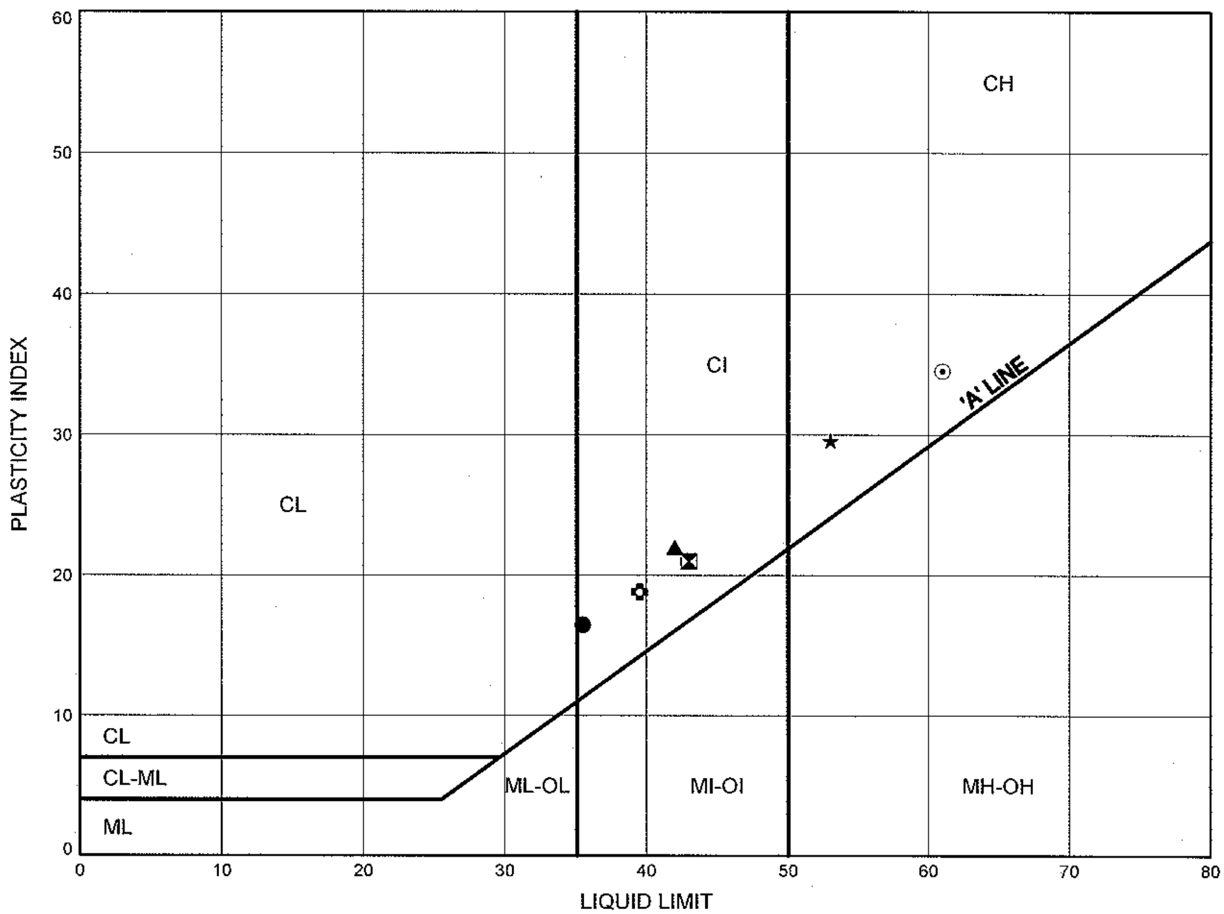
Chkd. MP

ALTR 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/23/10

ATTERBERG LIMITS TEST RESULTS

FIGURE B18

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR6	12.4	166.6
⧗	PR7	2.5	177.6
▲	PR7	4.7	175.4
★	PR7	9.3	170.8
⊙	PR8	1.7	178.9
✿	PR8	3.2	177.4

Date July 2010

Project 1-09-4135

Prep'd DB

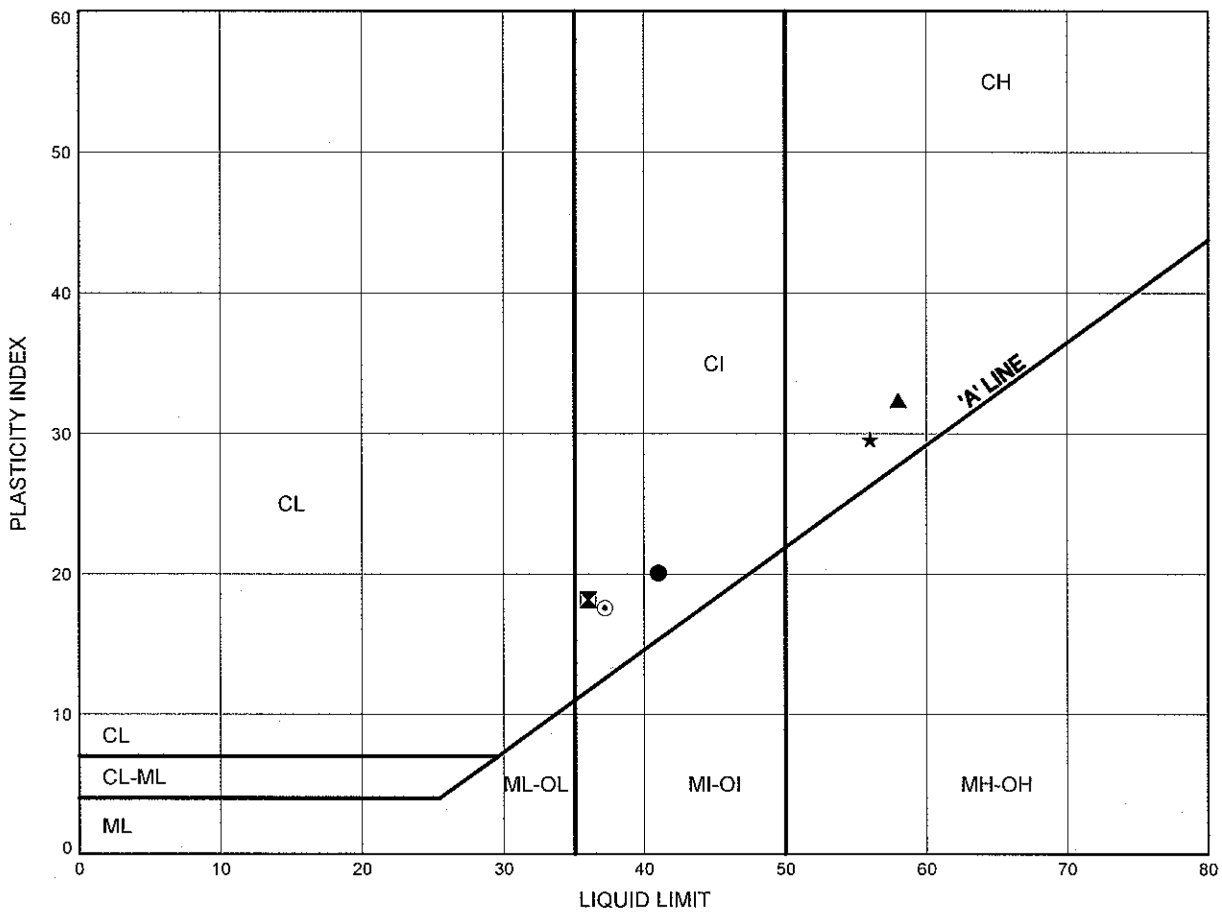
Chkd. MP

ALTR 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/23/10

ATTERBERG LIMITS TEST RESULTS

FIGURE B19

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR8	4.7	175.9
⧗	PR8	7.8	172.8
▲	PR9	1.0	180.6
★	PR9	2.5	179.1
⊙	PR9	4.0	177.6

ALTR 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/23/10

Date July 2010

Project 1-09-4135

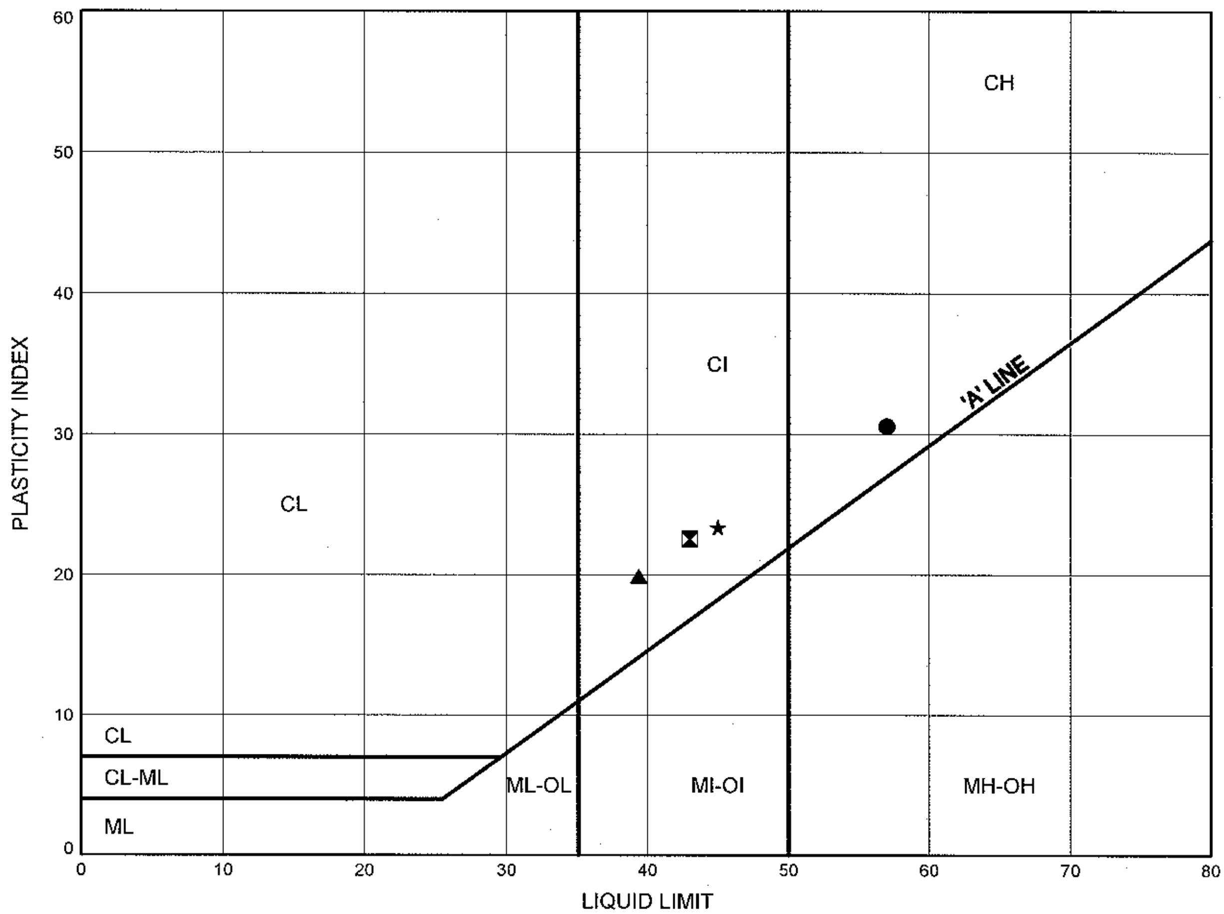
Prep'd DB

Chkd. MP

ATTERBERG LIMITS TEST RESULTS

FIGURE B20

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR10	1.7	179.8
⧗	PR10	4.0	177.5
▲	PR10	4.7	176.8
★	PR10	9.3	172.2

Date July 2010

Project 1-09-4135

Prep'd DB

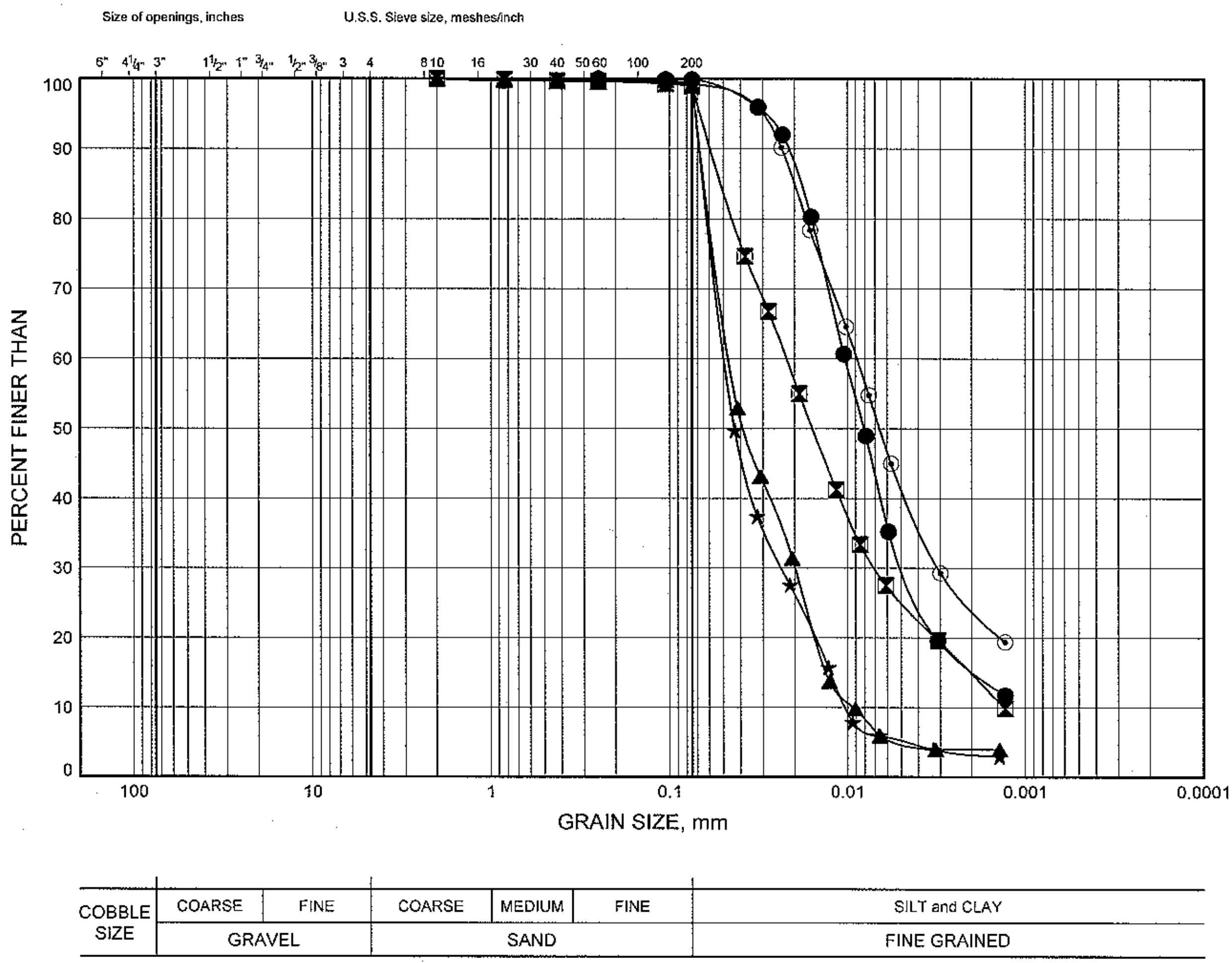
Chkd. MP

ALTR 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/23/10

GRAIN SIZE DISTRIBUTION

FIGURE B21

SILT



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR1	15.4	166.3
⧗	PR1	17.0	164.7
▲	PR2	17.0	164.7
★	PR3	15.4	165.9
⊙	PR4	15.4	166.8

Date July 2010

Project 1-09-4135

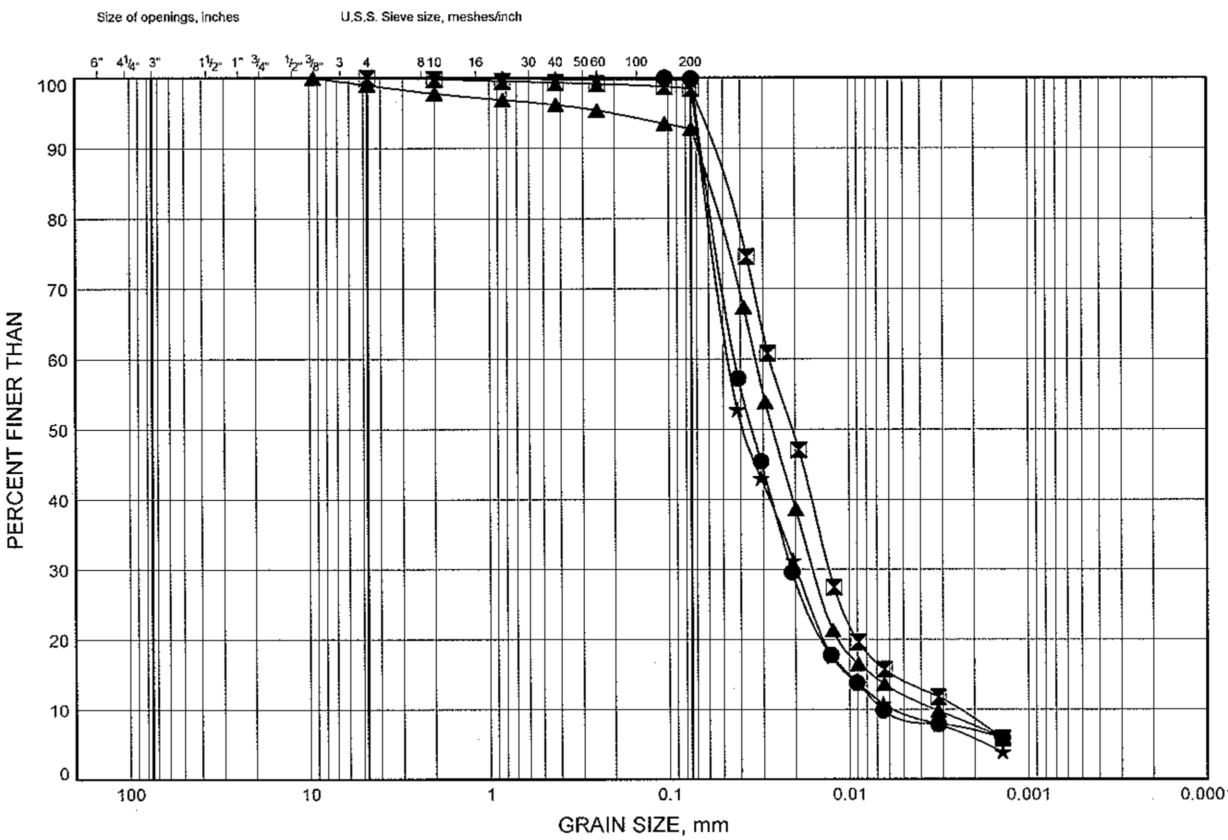
Prep'd DB

Chkd. MP

GSD 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/23/10

GRAIN SIZE DISTRIBUTION

SILT



COBBLE SIZE	GRAVEL		SAND			FINE GRAINED
	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR5	15.4	165.8
⧗	PR6	15.4	163.6
▲	PR8	15.4	165.2
★	PR9	15.4	166.2

Date July 2010

Project 1-09-4135

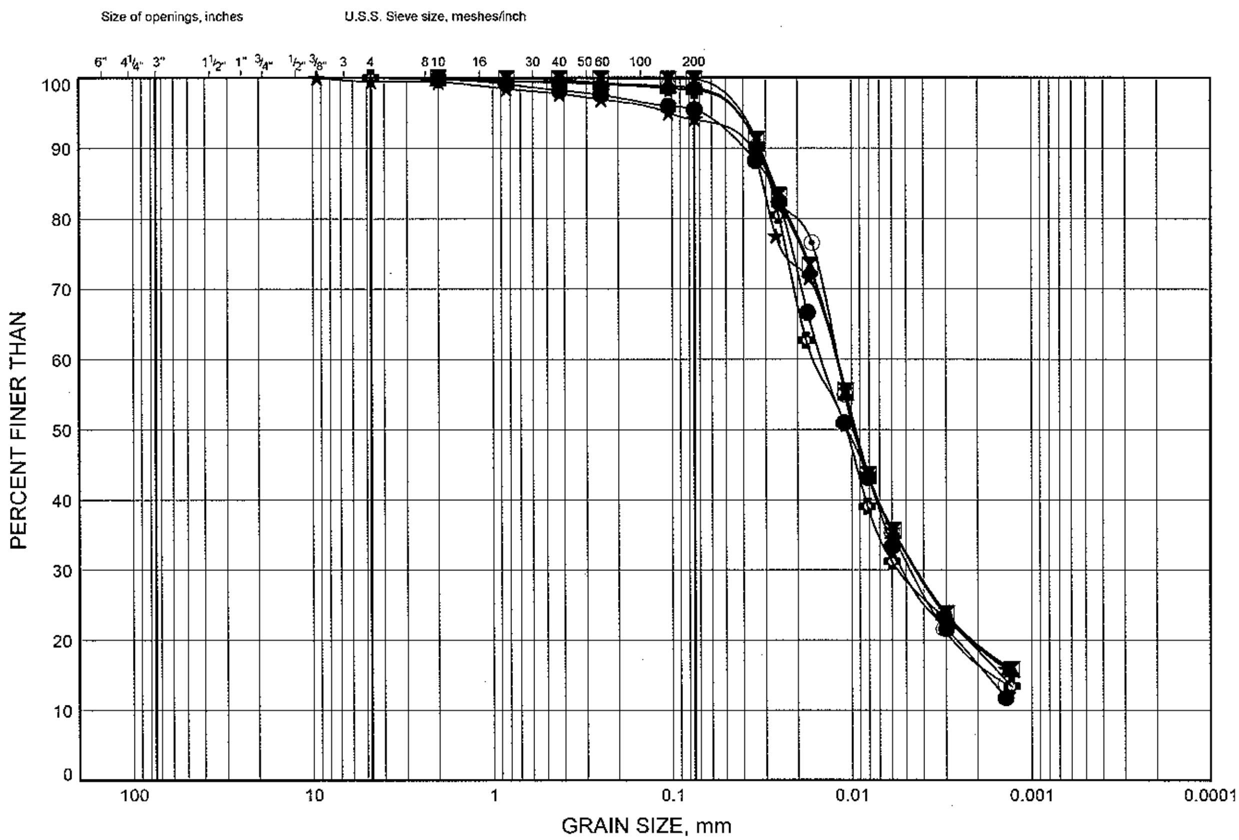
Prep'd DB

Chkd. MP

GSD 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/23/10

GRAIN SIZE DISTRIBUTION	FIGURE B23

SILTY CLAY TO CLAYEY SILT



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR2	20.0	161.7
⧗	PR2	23.1	158.6
▲	PR2	26.1	155.6
★	PR3	18.5	162.8
⊙	PR3	23.1	158.2
✿	PR4	21.5	160.7

Date July 2010

Project 1-09-4135

Prep'd DB

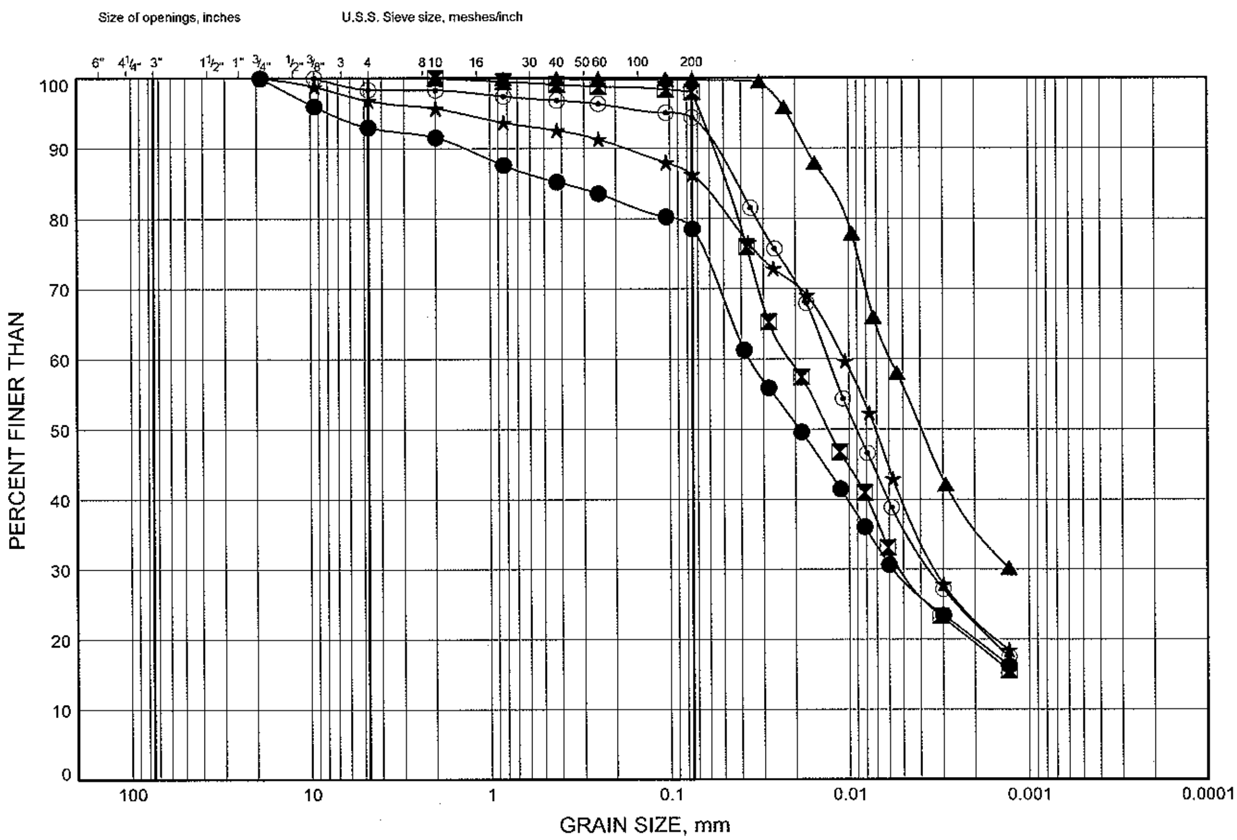
Chkd. MP

GSD 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/23/10

GRAIN SIZE DISTRIBUTION

FIGURE B24

SILTY CLAY TO CLAYEY SILT



COBBLE SIZE	GRAVEL		SAND			FINE GRAINED
	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
▲	PR4	24.6	157.6
★	PR4	27.6	154.6
⊙	PR7	18.5	161.6
●	PR10	18.5	163.0
⧗	PR10	20.0	161.5

Date July 2010

Project 1-09-4135

Prep'd DB

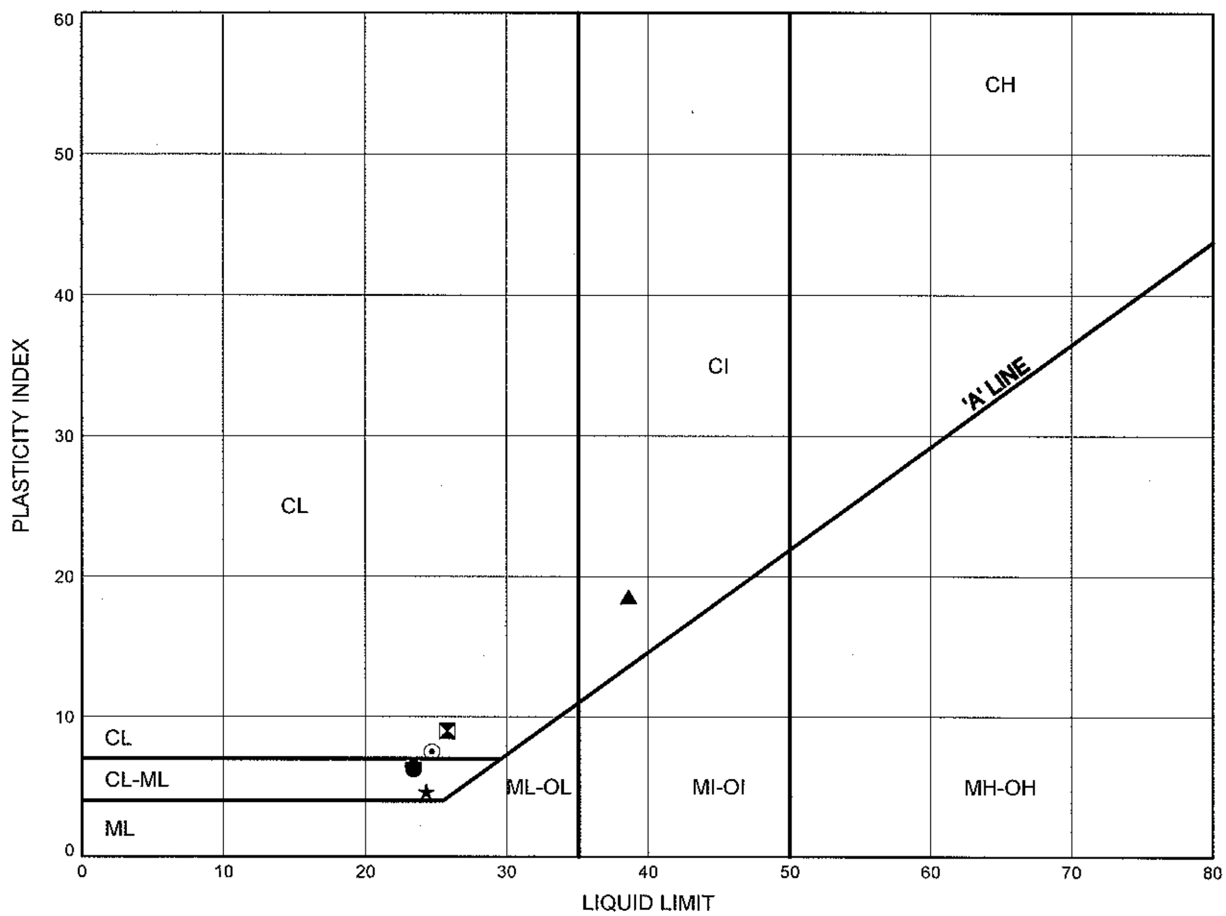
Chkd. MP

GSD 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/23/10

ATTERBERG LIMITS TEST RESULTS

FIGURE B25

SILTY CLAY TO CLAYEY SILT



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR2	20.0	161.7
⧗	PR2	23.1	158.6
▲	PR2	26.1	155.6
★	PR3	18.5	162.8
⊙	PR3	23.1	158.2
✿	PR4	21.5	160.7

Date July 2010

Project 1-09-4135

Prep'd DB

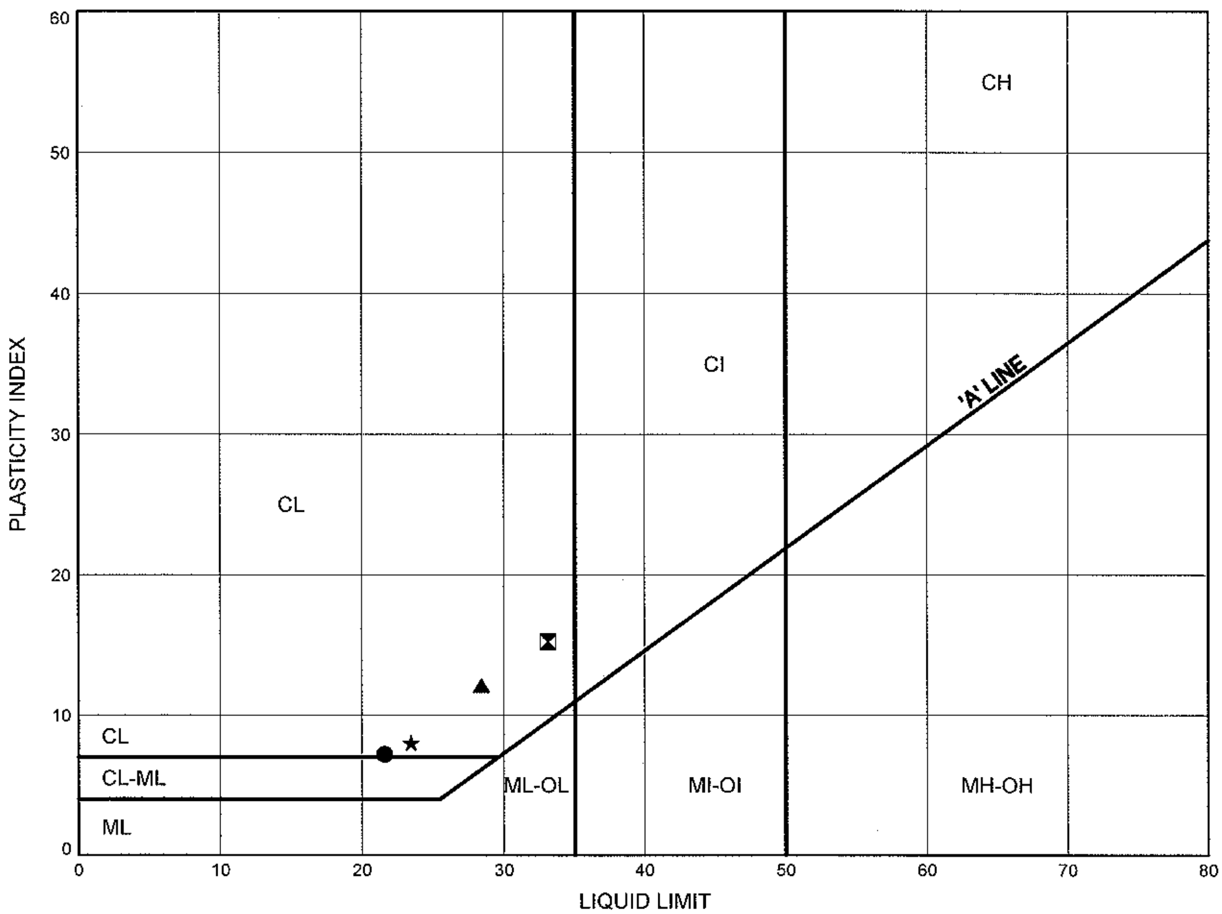
Chkd. MP

ALTR 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/23/10

ATTERBERG LIMITS TEST RESULTS

FIGURE B26

SILTY CLAY TO CLAYEY SILT



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
⧗	PR4	24.6	157.6
▲	PR4	27.6	154.6
★	PR7	18.5	161.6
●	PR10	18.5	163.0

ALTR 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/23/10

Date July 2010

Project 1-09-4135

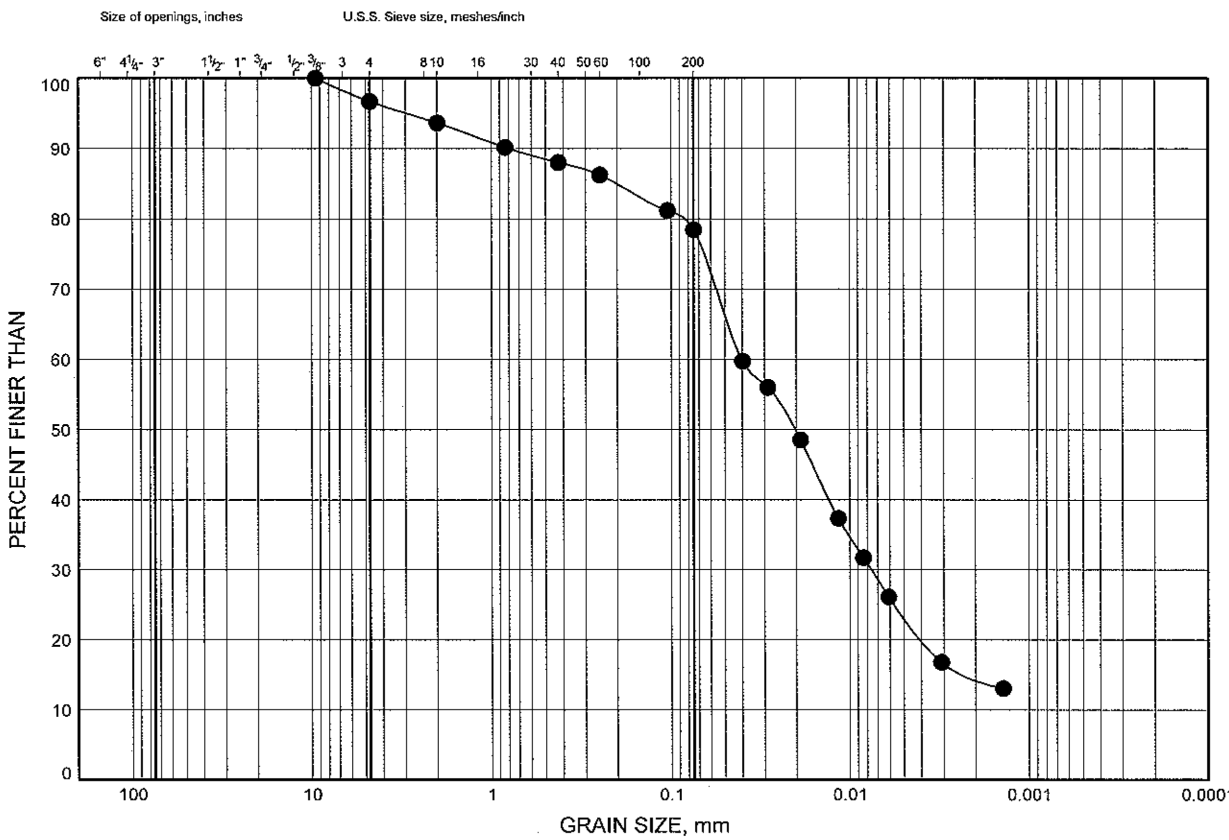
Prep'd DB

Chkd. MP

GRAIN SIZE DISTRIBUTION

FIGURE B27

CLAYEY SILT TILL



COBBLE SIZE	GRAVEL		SAND			FINE GRAINED
	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR3	27.6	153.7

Date July 2010

Project 1-09-4135

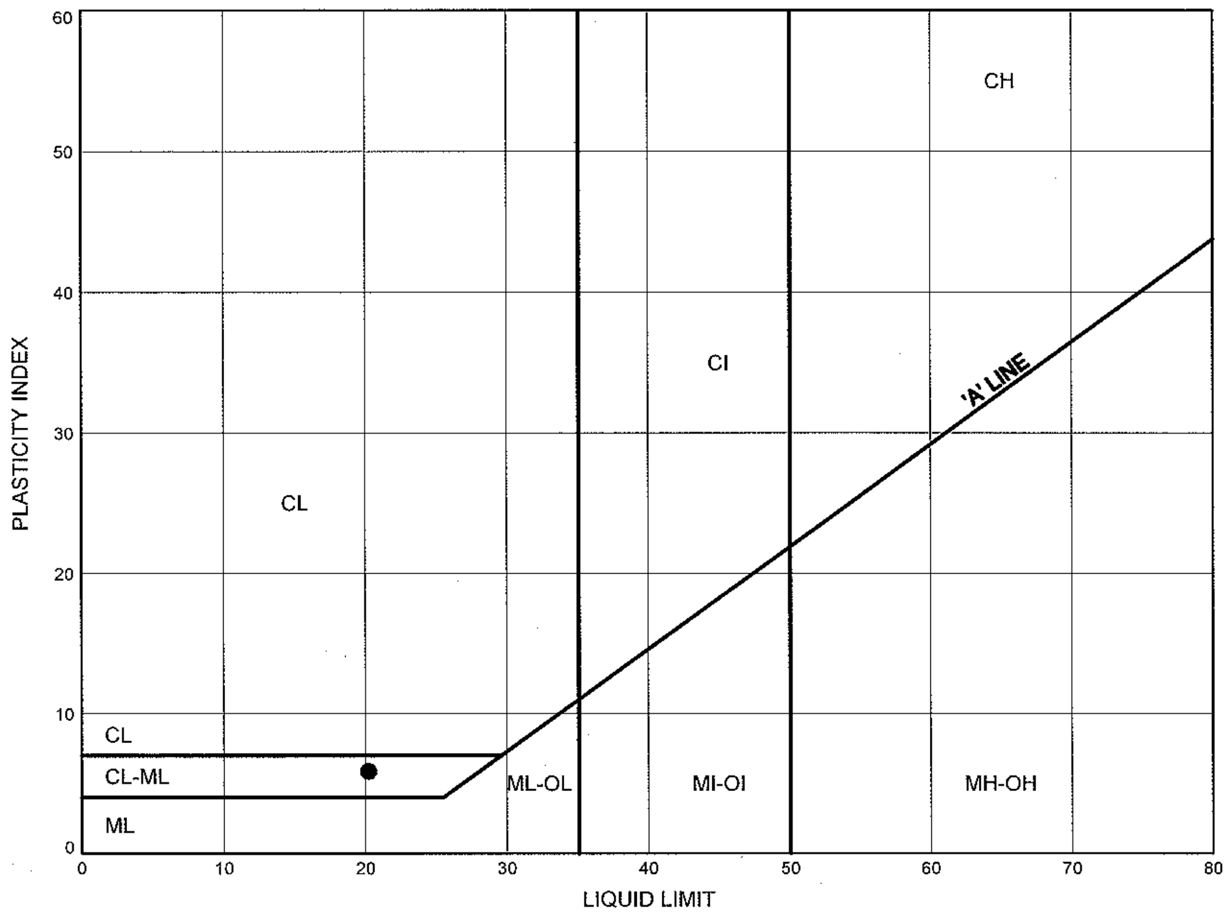
Prep'd DB

Chkd. MP

ATTERBERG LIMITS TEST RESULTS

FIGURE B28

CLAYEY SILT TILL



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	PR3	27.6	153.7

ALTR 1-09-4135 PORT ROBINSON HIGH FILL.GPJ 07/23/10

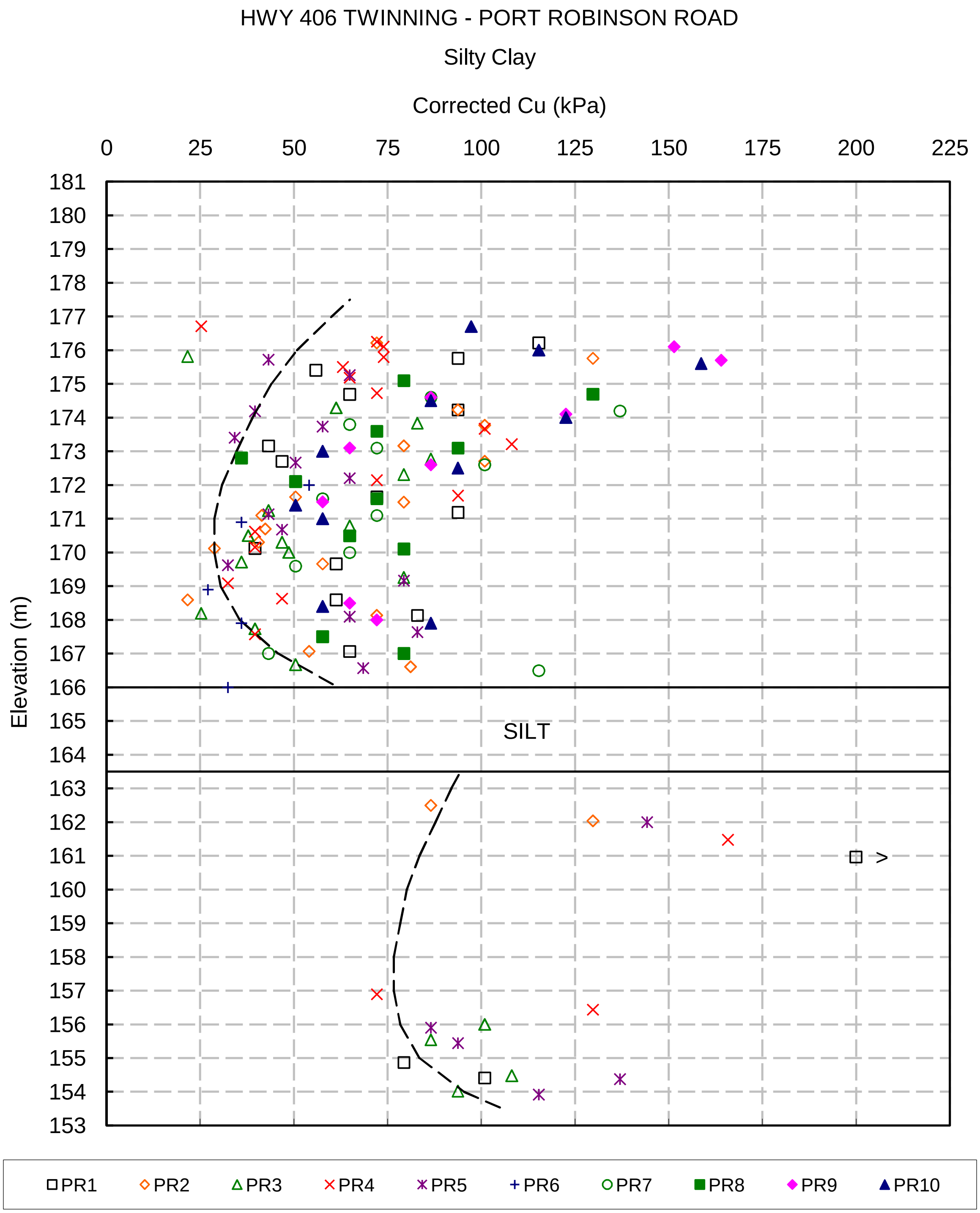
Date July 2010

Project 1-09-4135

Prep'd DB

Chkd. MP

CORRECTED UNDRAINED SHEAR STRENGTH	FIGURE B29



Field Shear Vane Correction	Applied Correction Factors	
Morris & Williams (1994)	0.72 (Elev.>177.5m)	0.90 (Elev.<177.5m)
(μ = 1.18 EXP(-0.08 Ip) + 0.57)		

Project No. : 1-09-4135

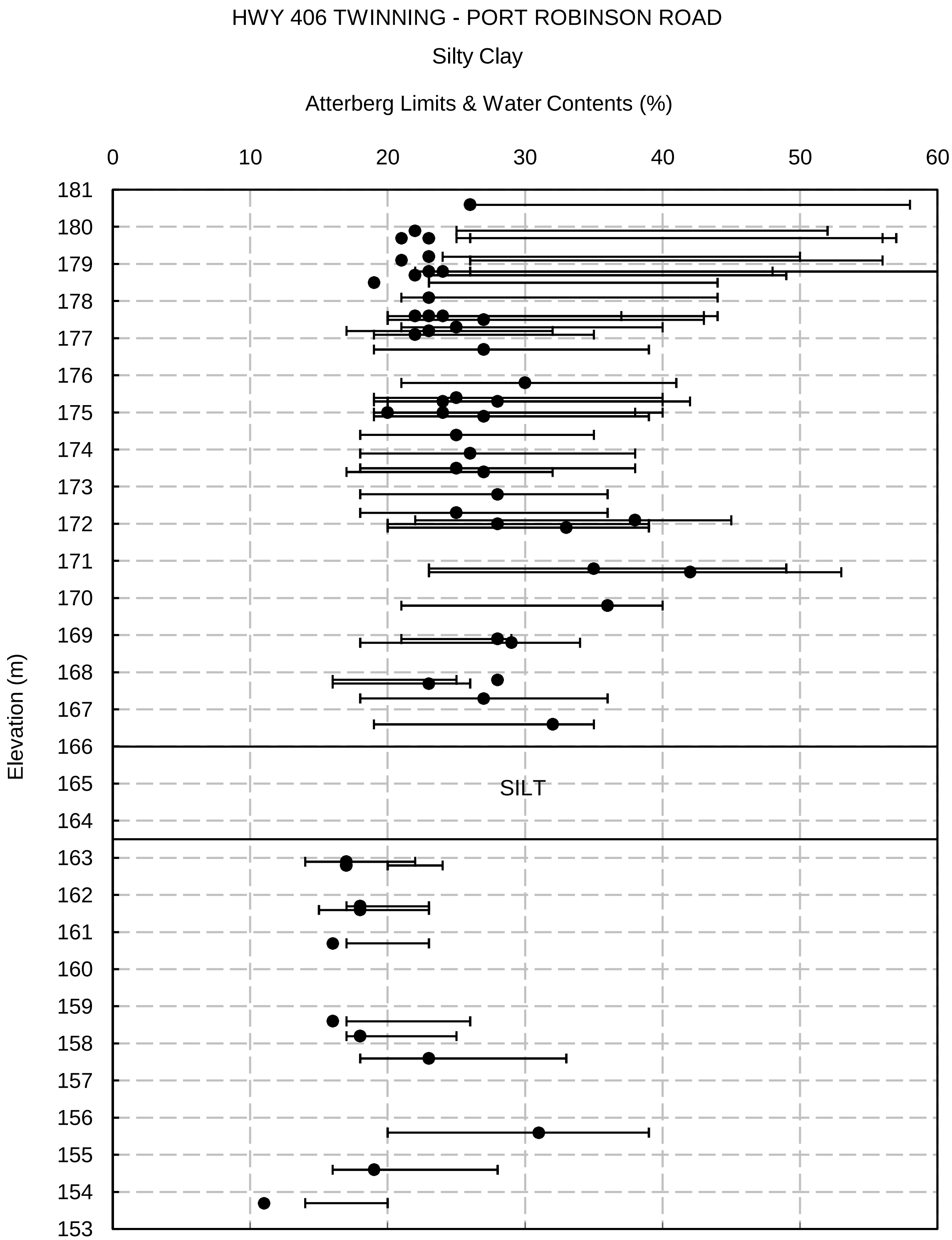
Date : September, 2010

Terraprobe Inc.

Prepared By : HW

Checked By : RA

ATTERBERG LIMITS AND WATER CONTENTS	FIGURE B30

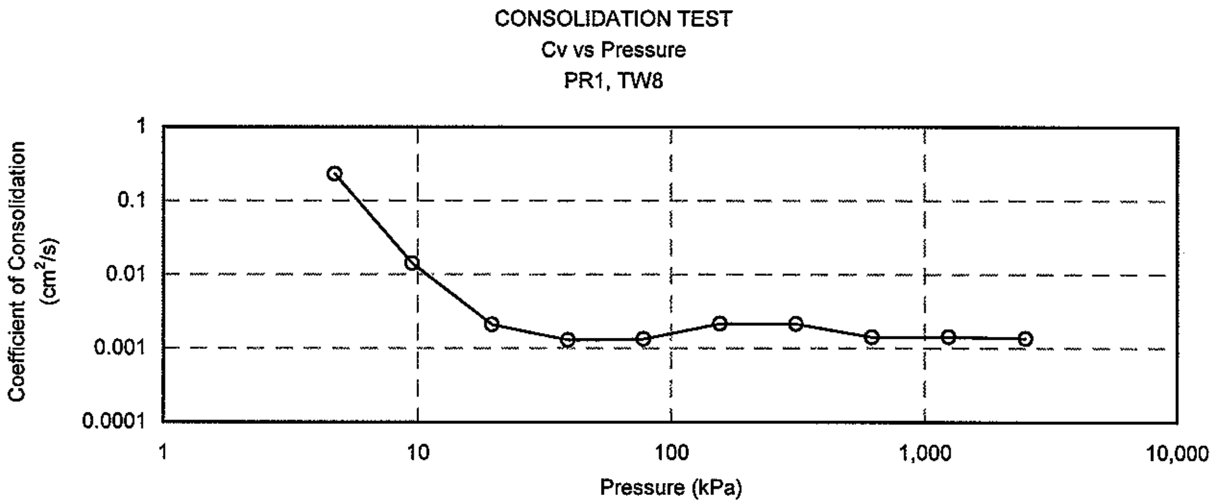


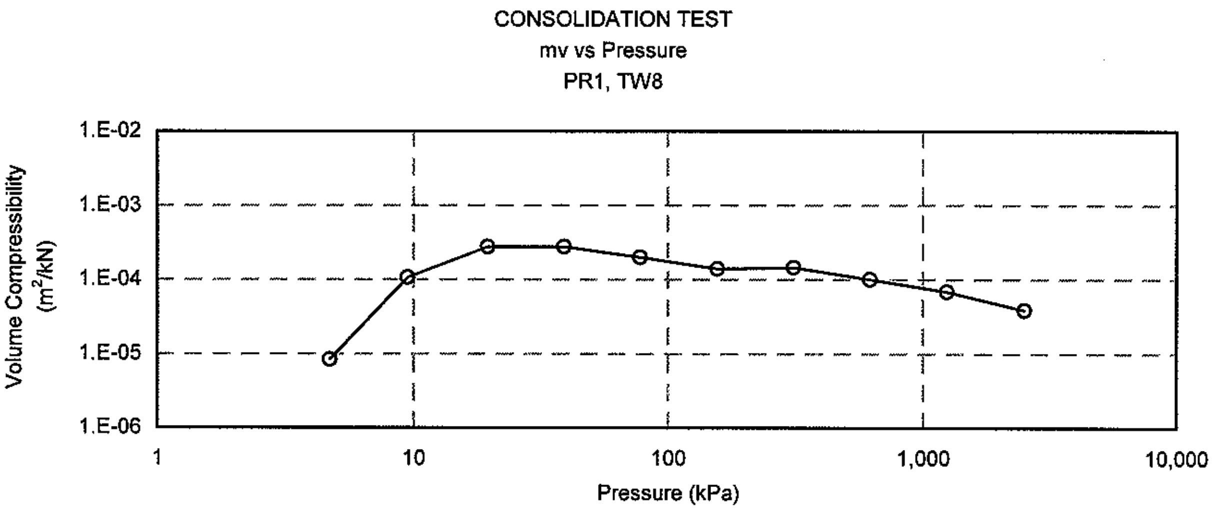
Project No. : 1-09-4135
Date : September, 2010

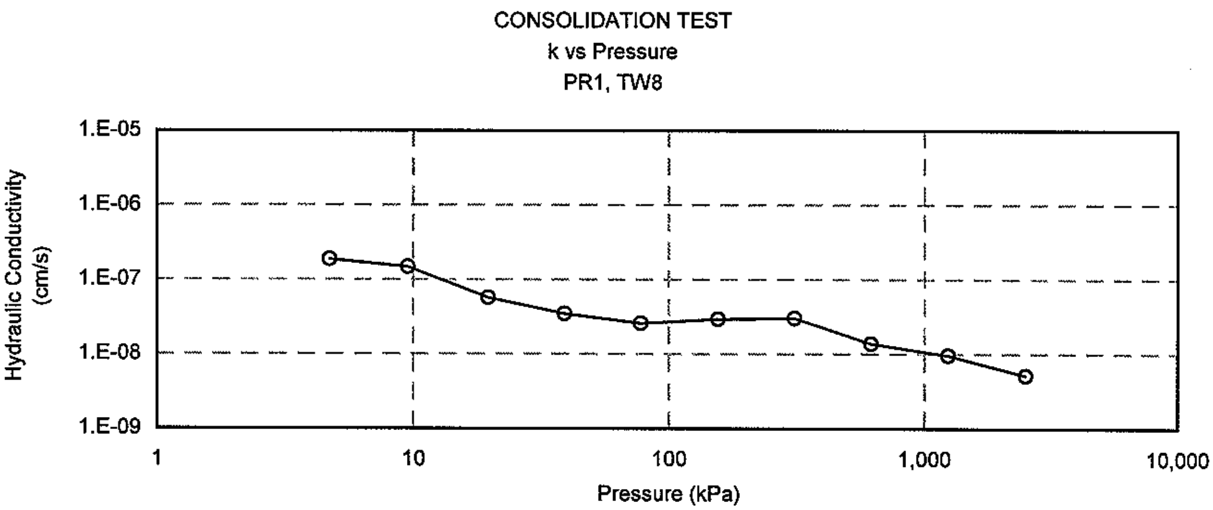
Terraprobe Inc.

Prepared By : HW
Checked By : RA

HWY 406 TWINNING - PORT ROBINSON ROAD	FIGURE B31







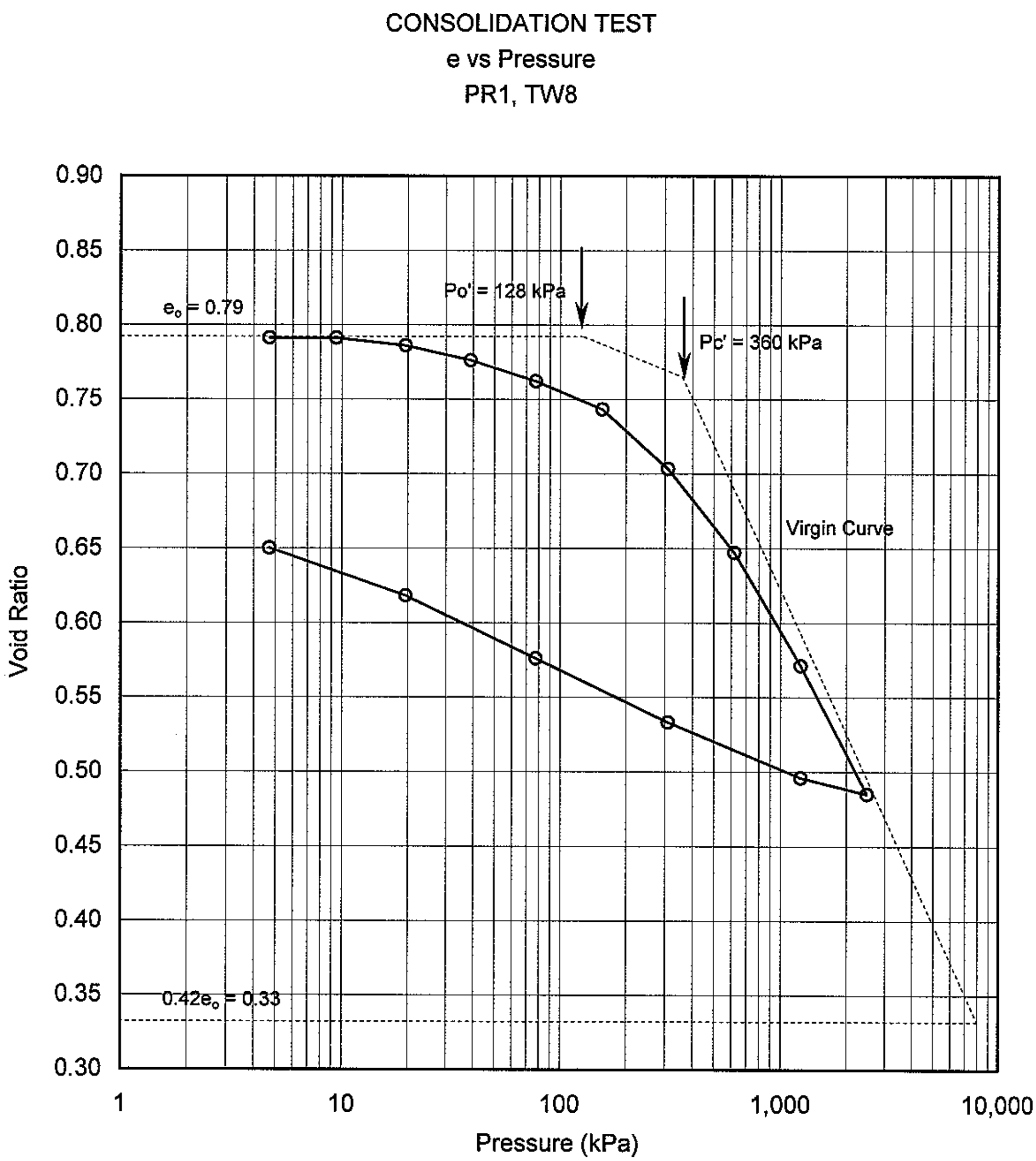
C:\Documents and Settings\Hongliu\My Documents\Project 2009\1-09-4135 - HWY 406 Foundations\Port Robinson Rd\1-09-4135 Consolidation Results-PR.xls

Project No. : 1-09-4135
Date : July 2010

Terraprobe Inc.

Prepared By : HW
Checked By : RA

HWY 406 TWINNING - PORT ROBINSON ROAD	FIGURE B32



Soil Type : Silty Clay

e_o =	0.79	ω_L =	40%	Po' =	128 kPa
ω =	28%	ω_P =	19%	Pc' =	360 kPa
γ =	19.5 kN/m^3	PI =	21%	Cc =	0.321
Gs =	2.78			Cr =	0.060

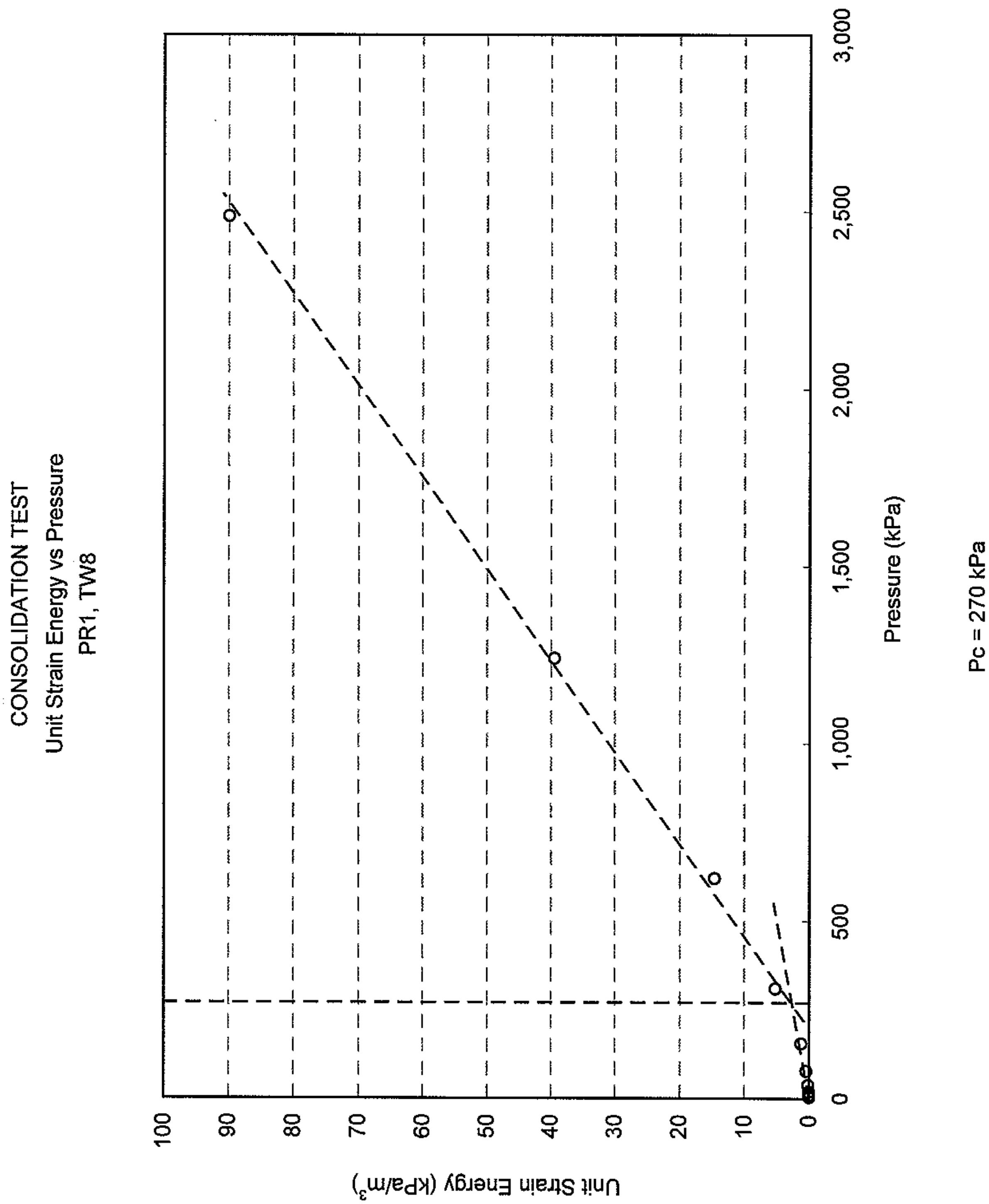
Project No. : 1-09-4135
Date : July 2010

Terraprobe Inc.

Prepared By : HW
Checked By : RA

C:\Documents and Settings\Hongliu\My Documents\Project 2009\1-09-4135 - HWY 406 Foundations\Port Robinson Rd\1-09-4135 Consolidation Results-PR.xls

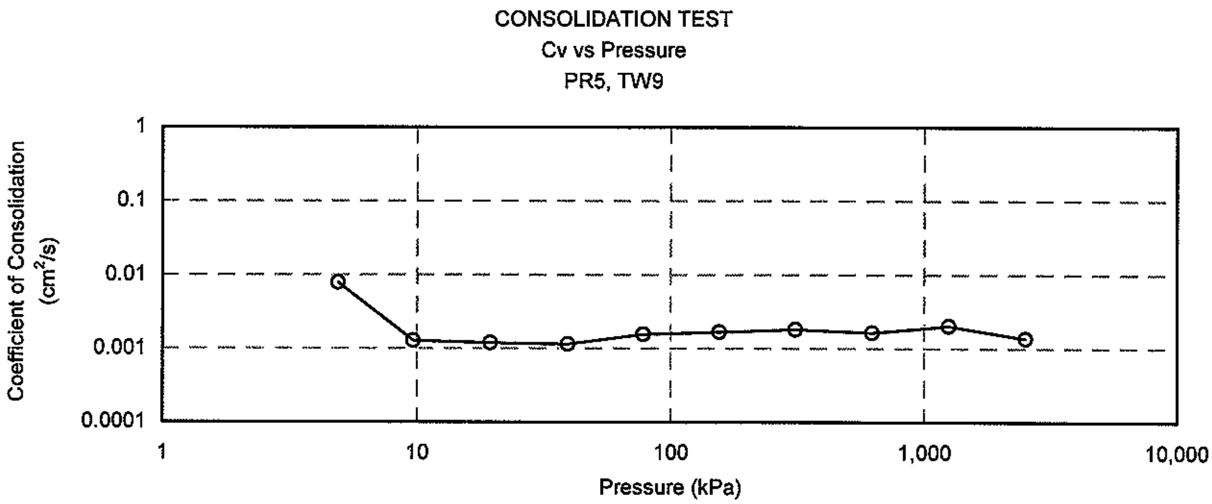
HWY 406 TWINNING - PORT ROBINSON ROAD	FIGURE B33

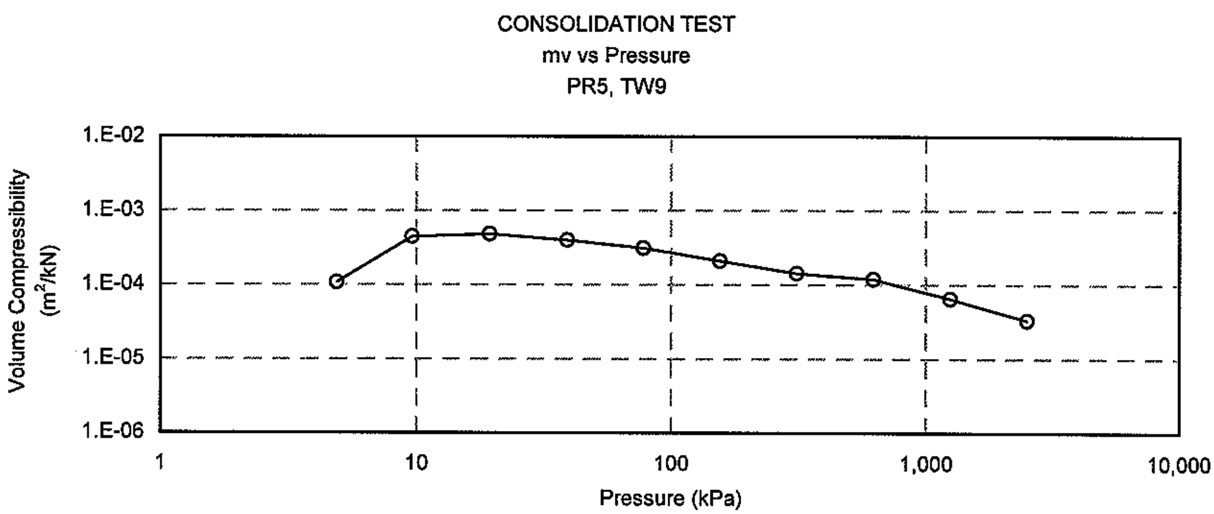


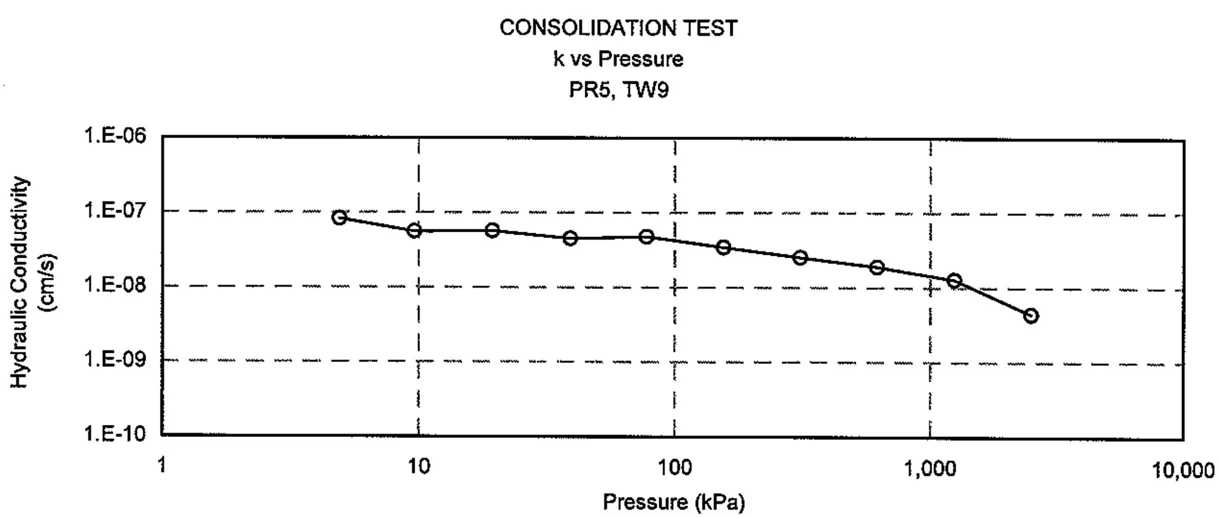
Project No. :	1-09-4135	Terraprobe Inc.	Prepared By :	HW
Date :	July 2010		Checked By :	RA

C:\Documents and Settings\Hongliu\My Documents\Project 2009\1-09-4135 - HWY 406 Foundations\Port Robinson Rd\1-09-4135 Consolidation Results-PR.xls

HWY 406 TWINNING - PORT ROBINSON ROAD	FIGURE B34



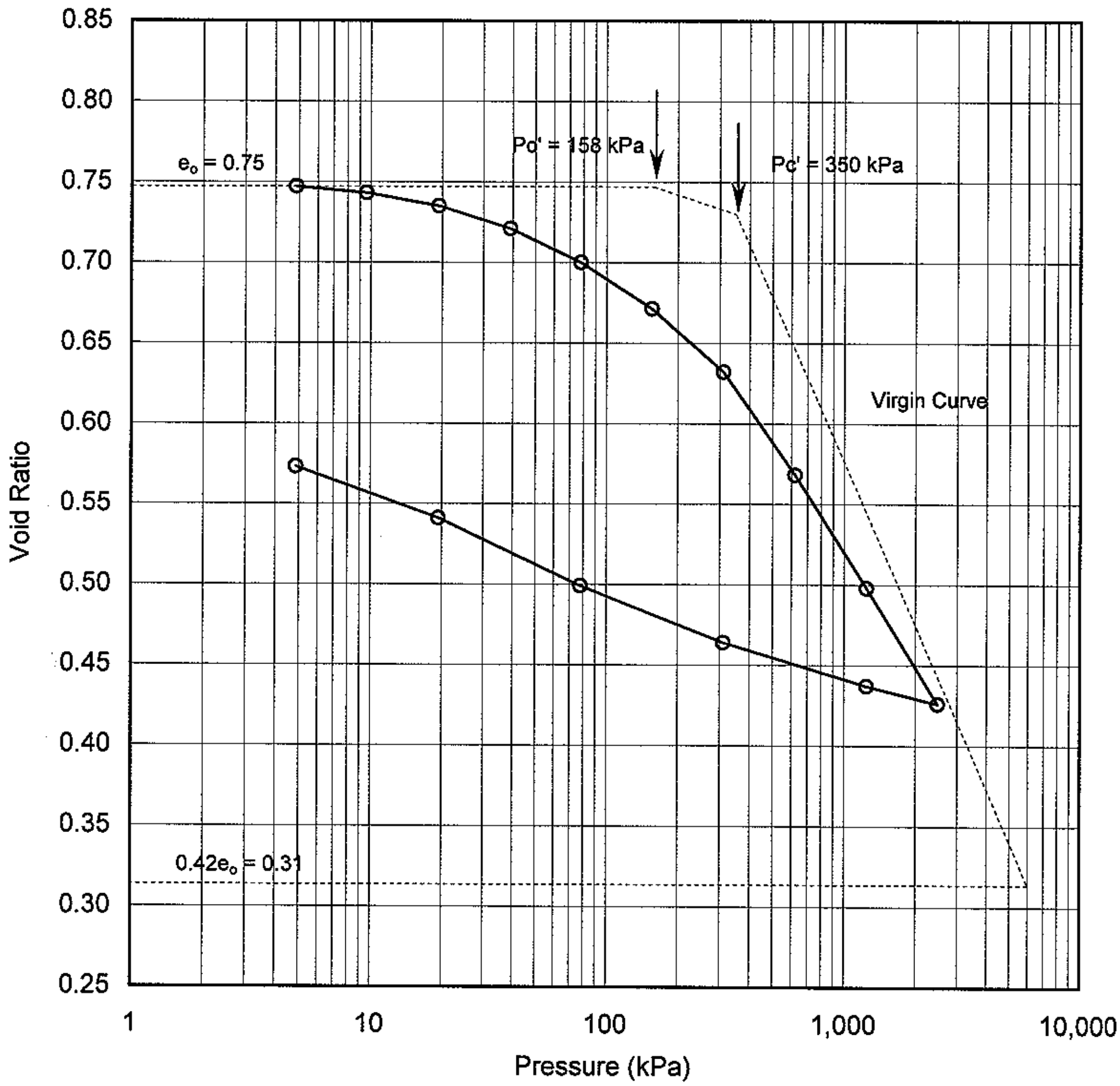




Project No. : 1-09-4135	Terraprobe Inc.	Prepared By :	HW
Date : July 2010		Checked By :	RA

HWY 406 TWINNING - PORT ROBINSON ROAD	FIGURE B35

CONSOLIDATION TEST
e vs Pressure
PR5, TW9



Soil Type : Silty Clay

e_o =	0.75	ω_L =	32%	Po' =	158 kPa
ω =	27%	ω_P =	16%	Pc' =	350 kPa
γ =	19.7 kN/m^3	PI =	15%	Cc =	0.337
Gs =	2.76			Cr =	0.049

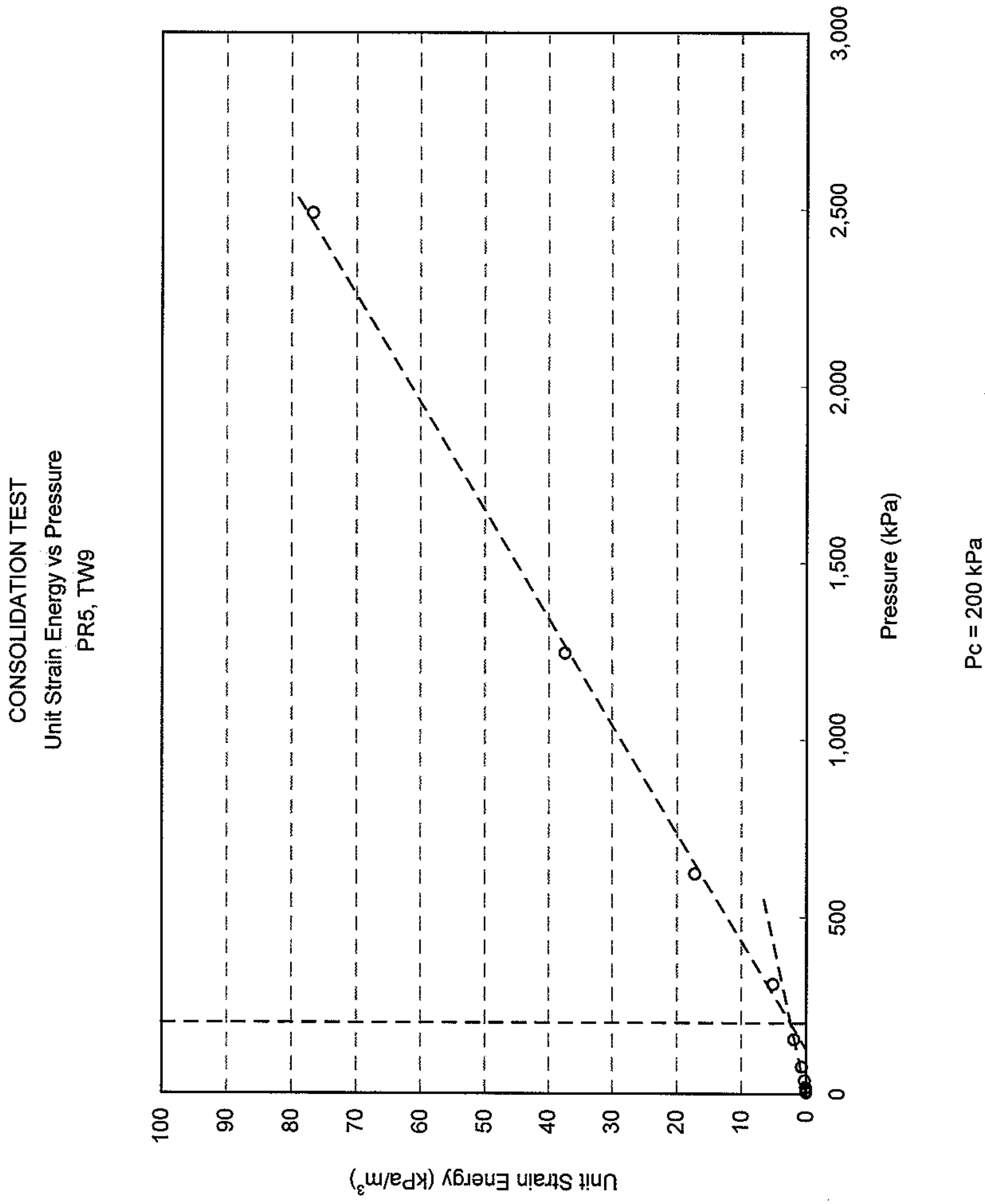
Project No. : 1-09-4135
Date : July 2010

Terraprobe Inc.

Prepared By : HW
Checked By : RA

C:\Documents and Settings\Hongliu\My Documents\Project 2009\1-09-4135 - HWY 406 Foundations\Port Robinson Rd\1-09-4135 Consolidation Results-PR.xls

HWY 406 TWINNING - PORT ROBINSON ROAD	FIGURE B36

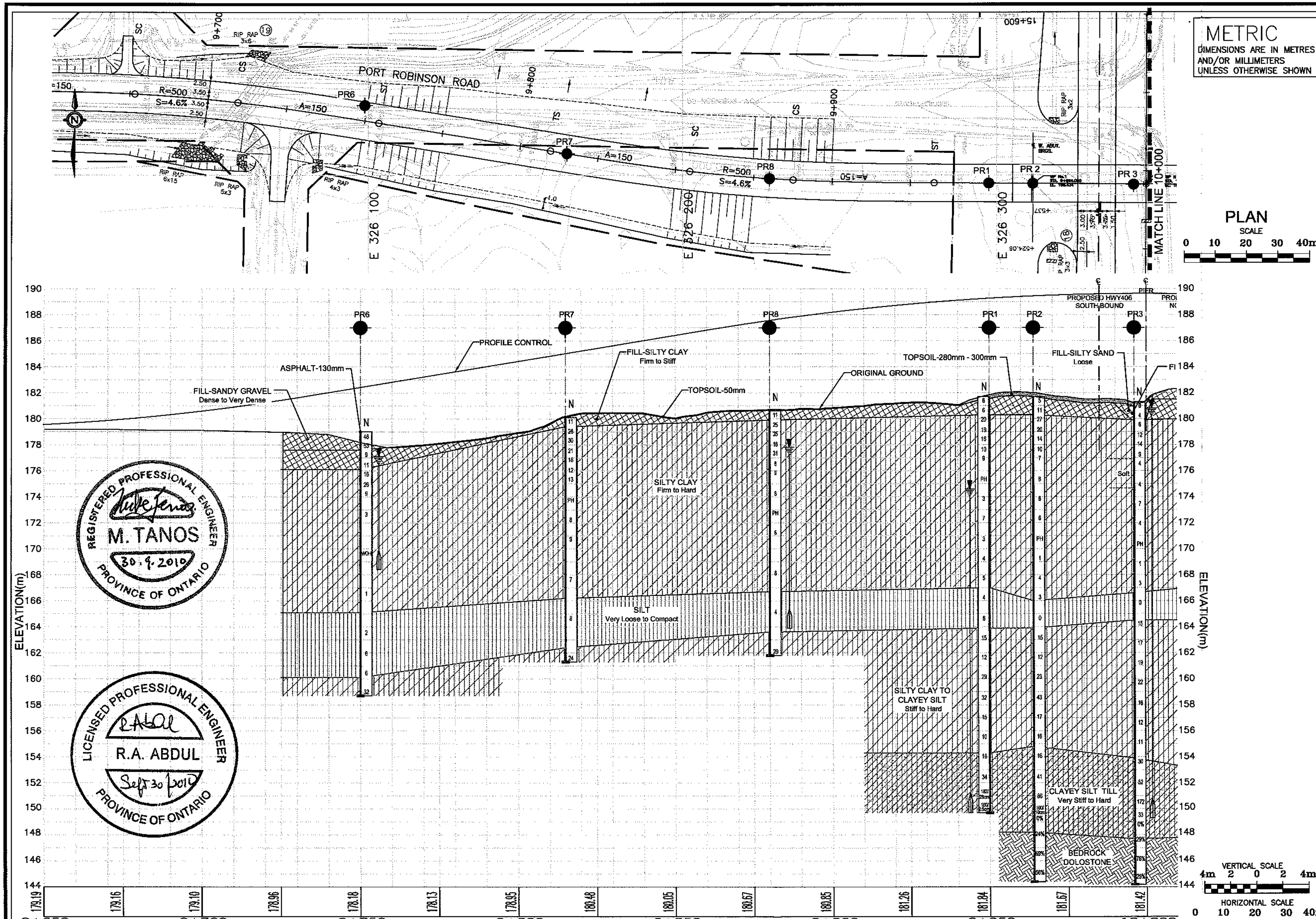


Project No. :	1-09-4135	Terraprobe Inc.	Prepared By :	HW
Date :	July 2010		Checked By :	RA

APPENDIX C

Drawings titled "Borehole Locations and Soil Strata"

Terraprobe Inc.



℄ PROFILE PORT ROBINSON ROAD

CONT No

WP No 280-99-00

HIGHWAY 406

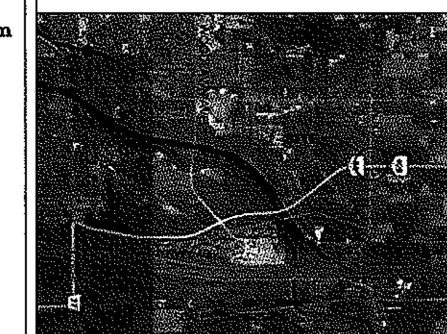
PORT ROBINSON HIGH FILL

BOREHOLE LOCATIONS AND SOIL STRATA

SHEET 1 OF 2

Giffels Associates Limited
Consulting Engineers and Architects
An IBI Group Company

Terraprobe
Consulting Geotechnical & Environmental Engineering
Construction Materials Engineering, Inspection & Testing



KEY PLAN

LEGEND

	Bore Hole
	Dynamic Cone Penetration Test
	Bore Hole And Cone
'N'	Blows/0.3m (Std Pen Test, 475 J/blow)
CONE	Blows/0.3m (60° Cone, 475 J/blow)
	WL at Time of Investigation
	WL in Piezometer (JULY. 2010)
	Piezometer
90%	Rock Quality Designation
A/R	Auger Refusal

No	ELEV.	COORDINATES	
		NORTHING	EASTING
PR1	181.7	4 766 747.4	326 297.5
PR2	181.7	4 766 747.3	326 311.5
PR3	181.3	4 766 747.0	326 343.5
PR4	182.2	4 766 752.2	326 382.2
PR5	181.2	4 766 743.3	326 398.5
PR6	179.0	4 766 772.3	326 098.9
PR7	180.1	4 766 756.9	326 163.1
PR8	180.6	4 766 748.9	326 227.6
PR9	181.6	4 766 746.6	326 427.5
PR10	181.5	4 766 748.2	326 497.5

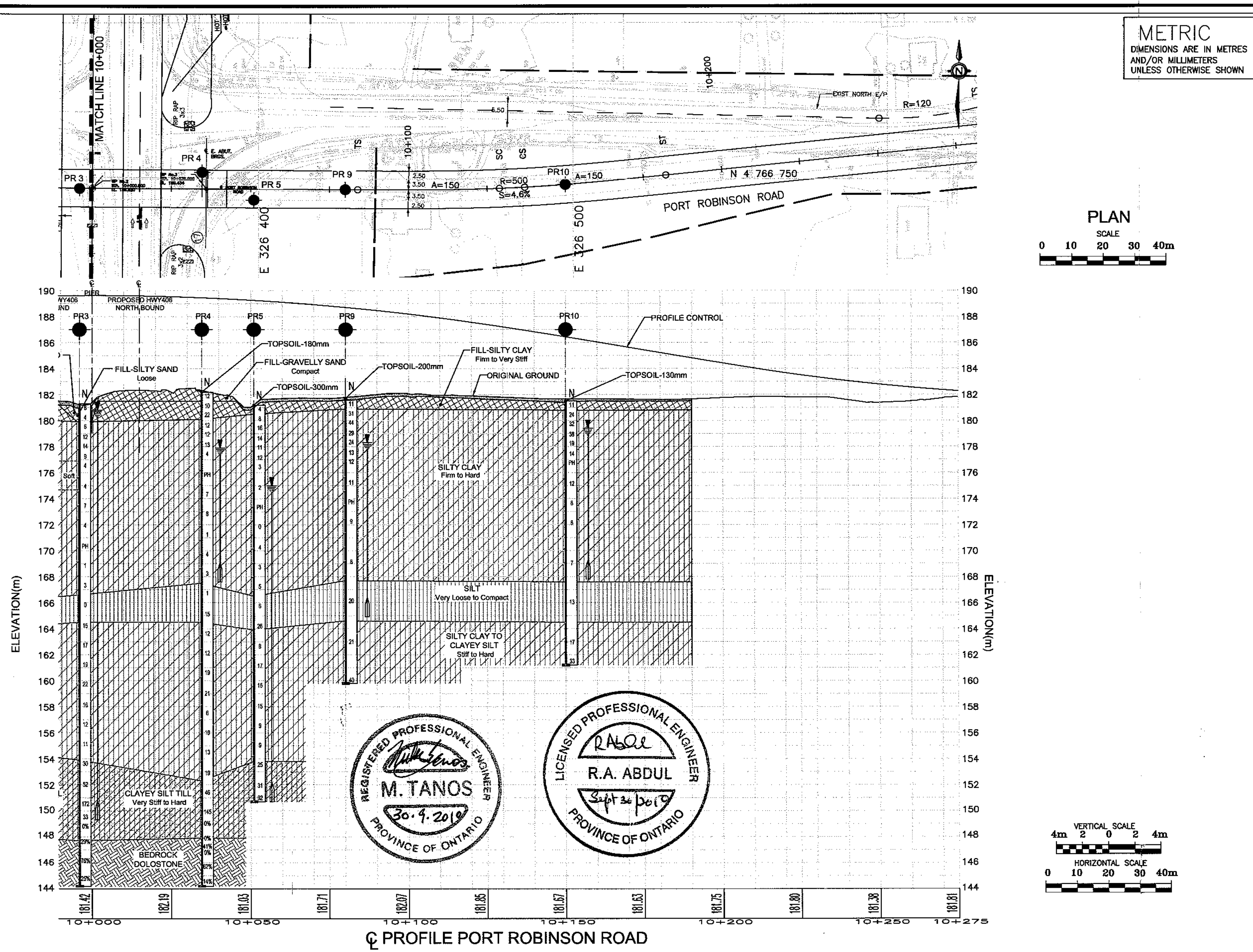
NOTE

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

REVISIONS	DATE	BY	DESCRIPTION

DESIGN R.A	CODE CHBDC2006	LOAD	DATE SEPT. 2010
DRAWN K.C	CHK R.A	STRUCT	



CONT No

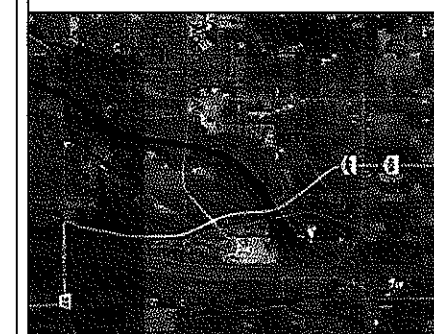
WP No 280-99-00

HIGHWAY 406
PORT ROBINSON HIGH FILLS
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET
2 OF 2

Giffels Associates Limited
Consulting Engineers and Architects
An IBI Group Company

Terraprobe
Consulting Geotechnical & Environmental Engineering
Construction Materials Engineering, Inspection & Testing



KEY PLAN

LEGEND

Symbol	Description
●	Bore Hole
⊕	Dynamic Cone Penetration Test
⊕	Bore Hole And Cone
'N'	Blows/0.3m (Std Pen Test, 475 J/blow)
CONE	Blows/0.3m (60° Cone, 475 J/blow)
≚	WL at Time of Investigation
▼	WL in Piezometer (JULY. 2010)
▮	Piezometer
90%	Rock Quality Designation
A/R	Auger Refusal

No	ELEV.	COORDINATES	
		NORTHING	EASTING
PR1	181.7	4 766 747.4	326 297.5
PR2	181.7	4 766 747.3	326 311.5
PR3	181.3	4 766 747.0	326 343.5
PR4	182.2	4 766 752.2	326 382.2
PR5	181.2	4 766 743.3	326 398.5
PR6	179.0	4 766 772.3	326 098.9
PR7	180.1	4 766 756.9	326 163.1
PR8	180.6	4 766 748.9	326 227.6
PR9	181.6	4 766 746.6	326 427.5
PR10	181.5	4 766 748.2	326 497.5

NOTE

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

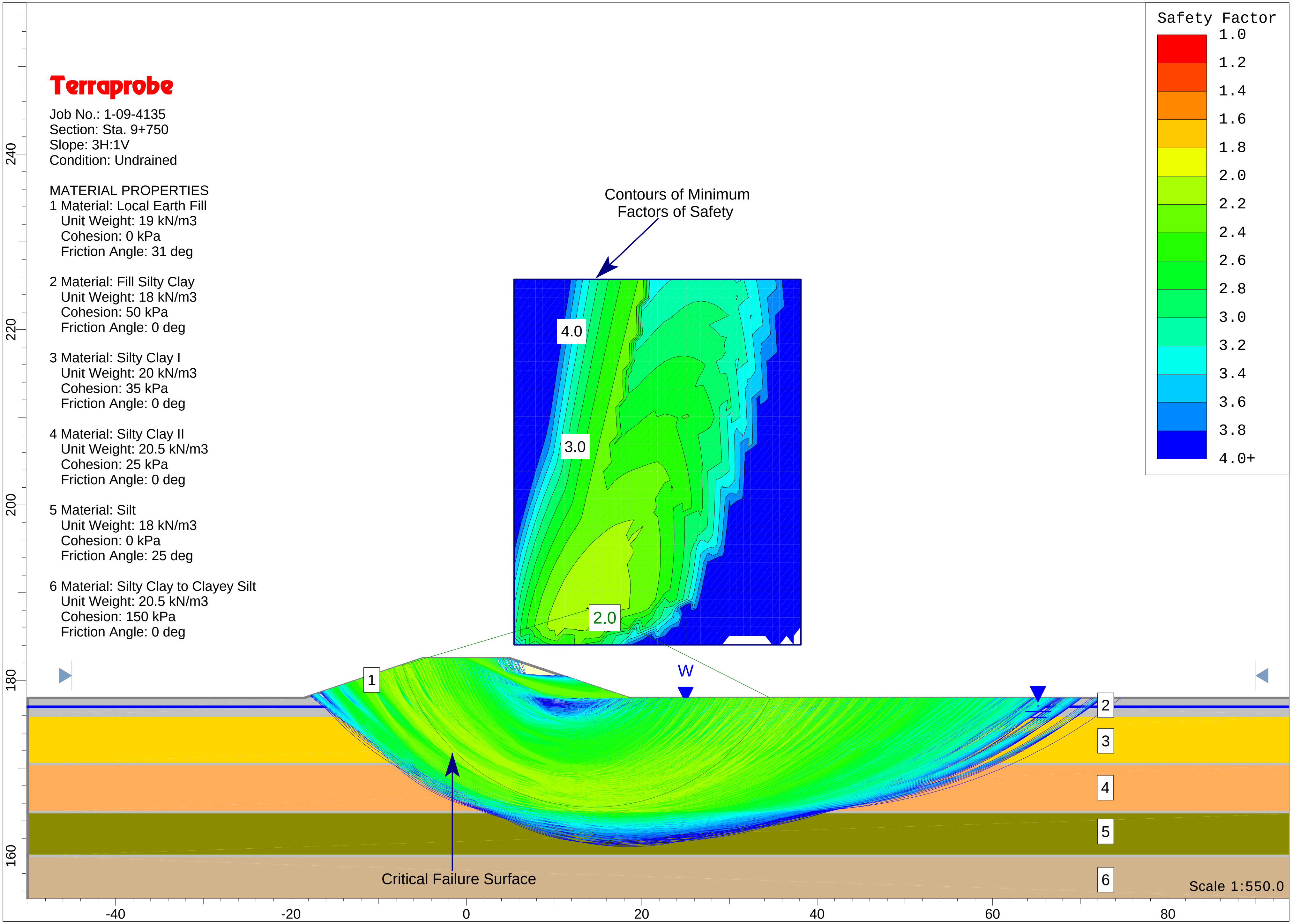
REVISIONS	DATE	BY	DESCRIPTION

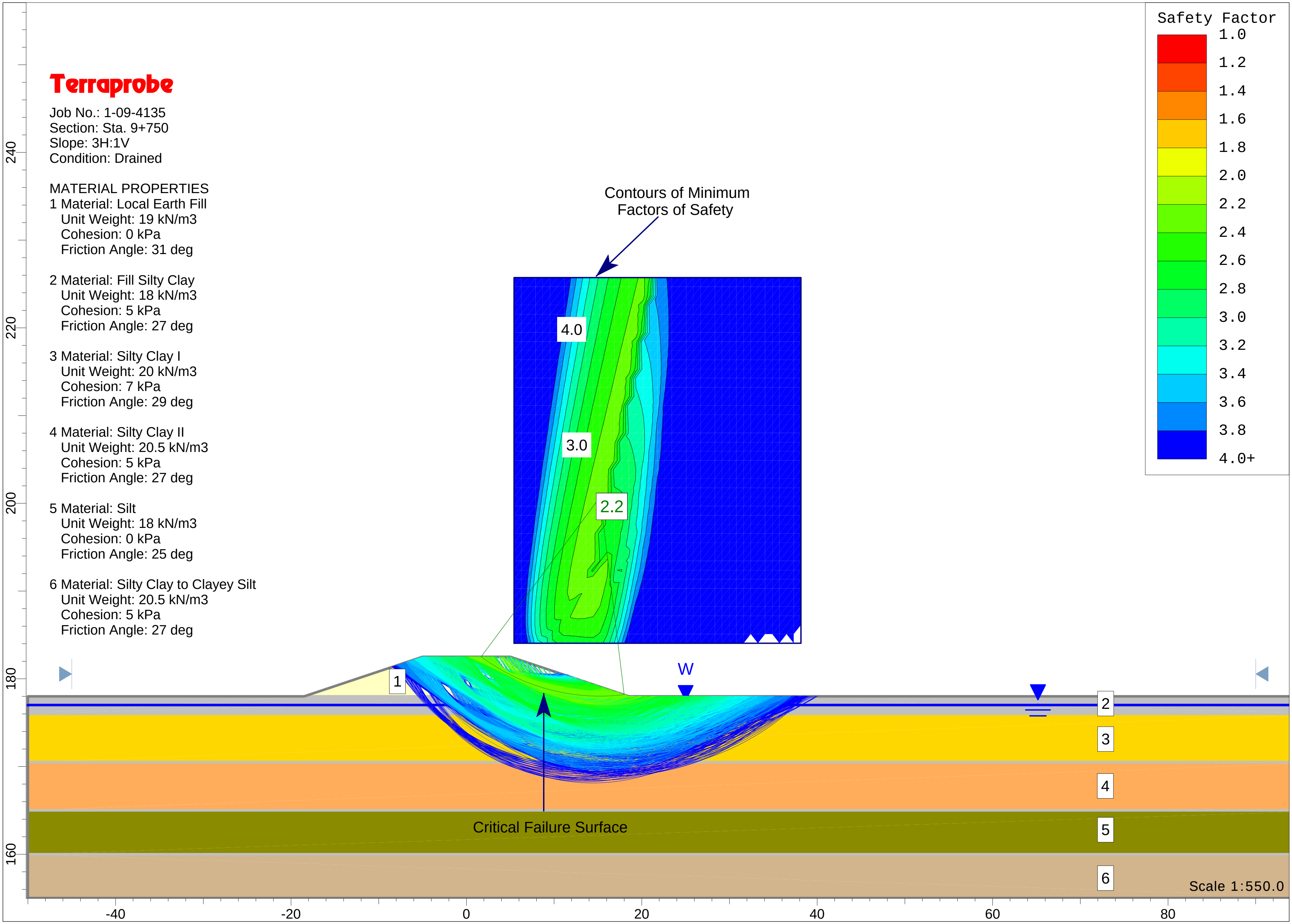
DESIGN R.A	CODE CHBDC2006	LOAD	DATE SEPT. 2010
DRAWN K.C	CHK R.A	STRUCT	

APPENDIX D

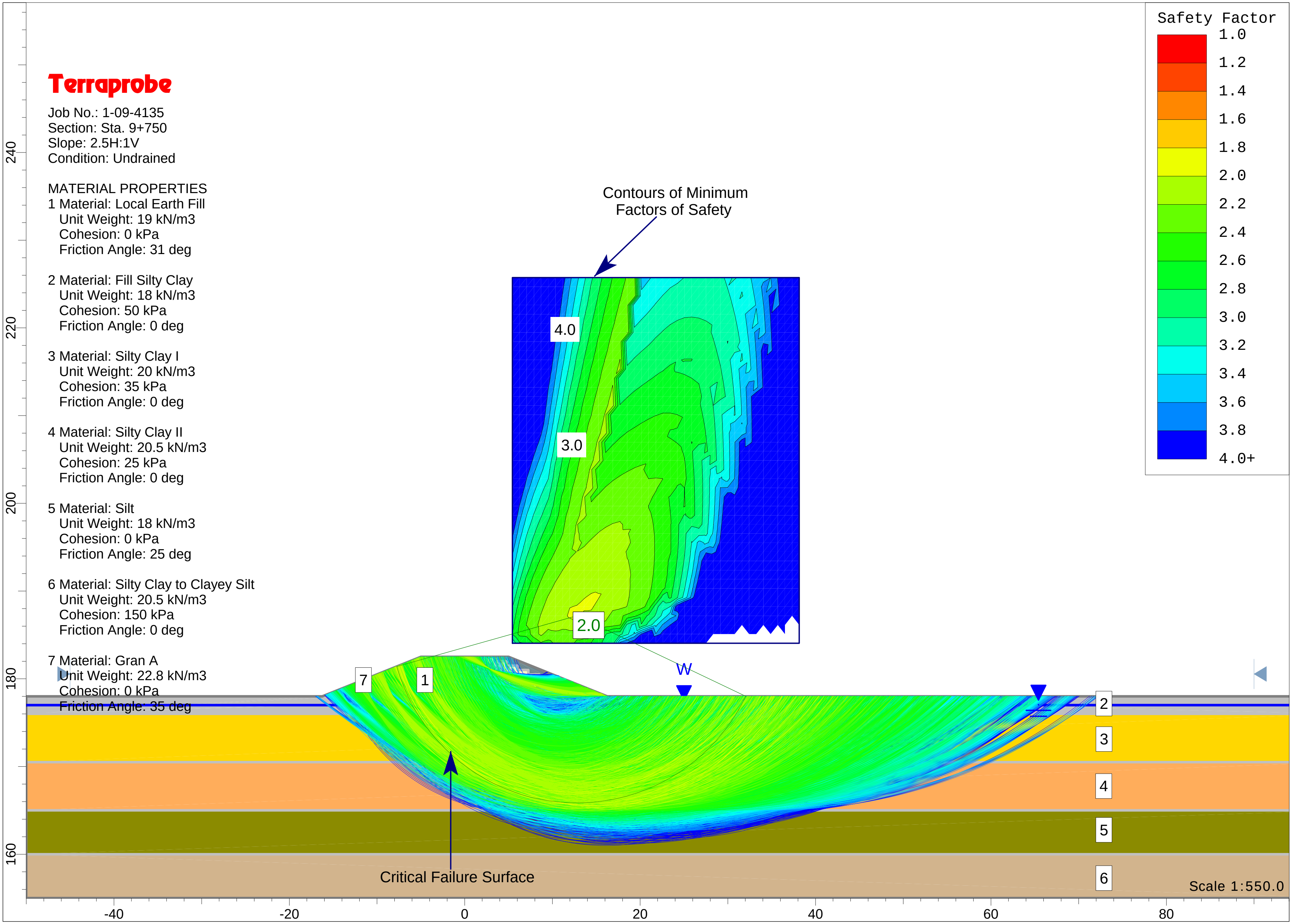
Slope Stability Data and Results

Terraprobe Inc.

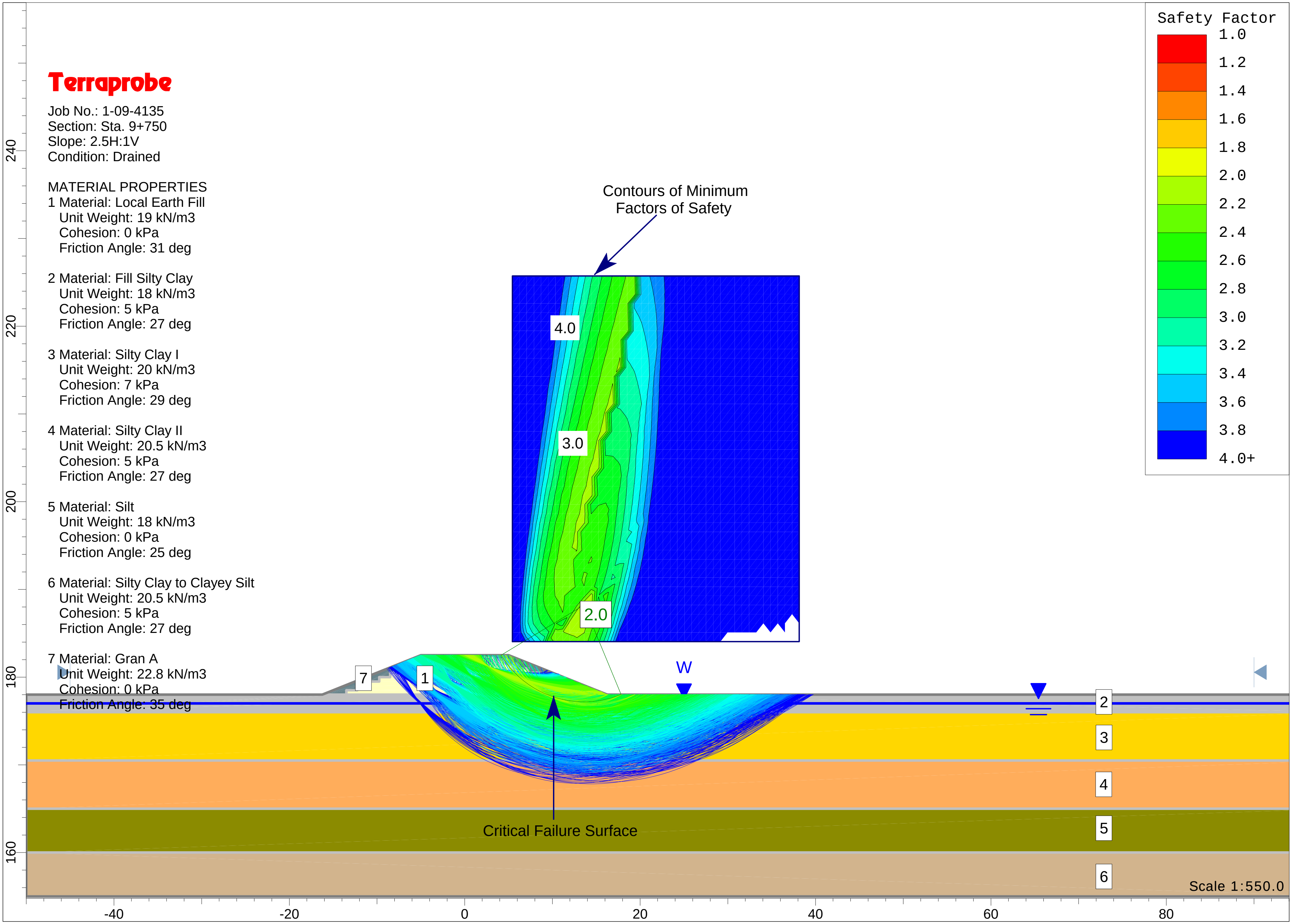

Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+750
Slope: 3H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 25 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
W
1
2
3
4
5
6
Critical Failure Surface
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80



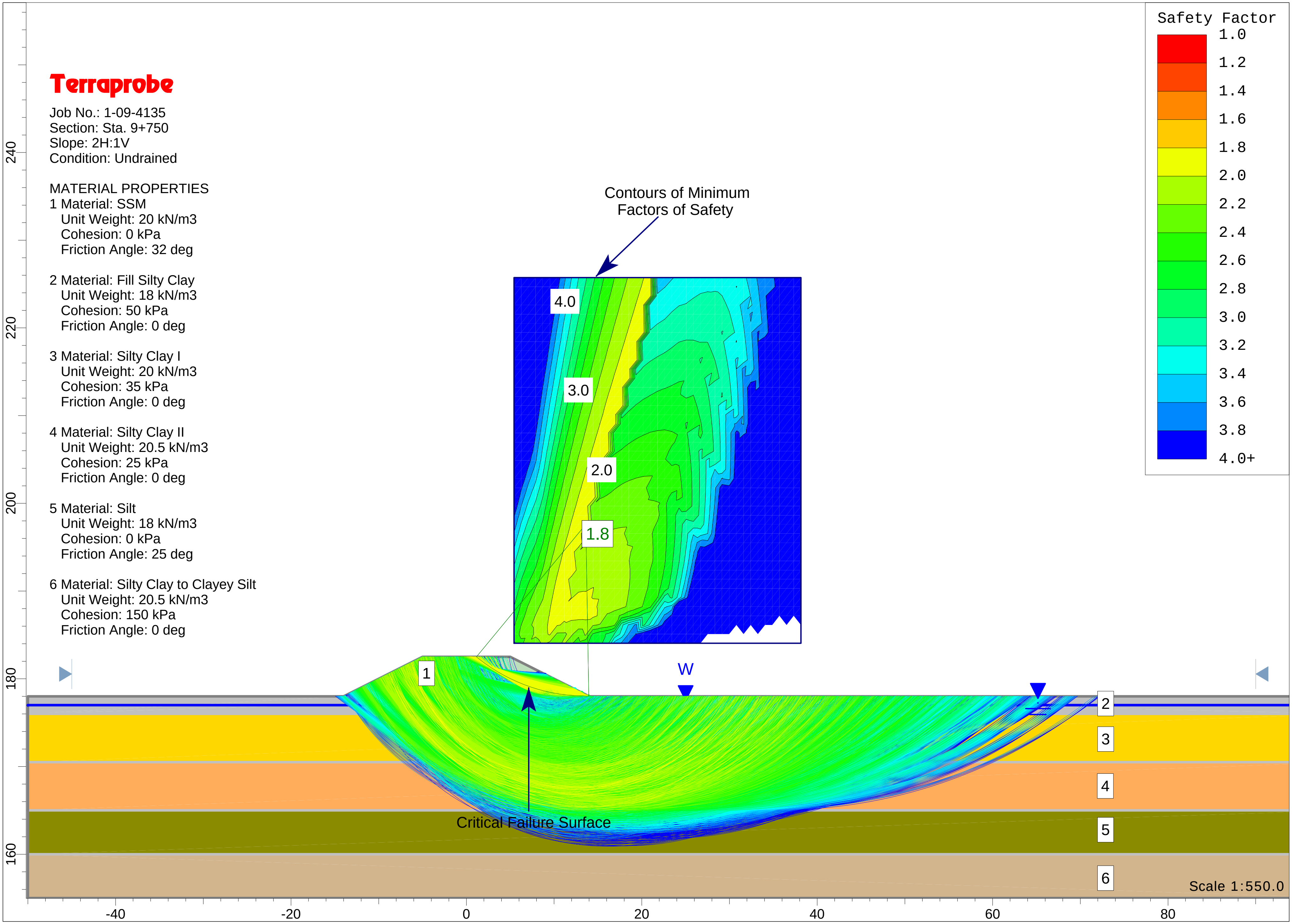
Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+750
Slope: 3H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum Factors of Safety
4.0
3.0
2.2
Critical Failure Surface
W
1
2
3
4
5
6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80



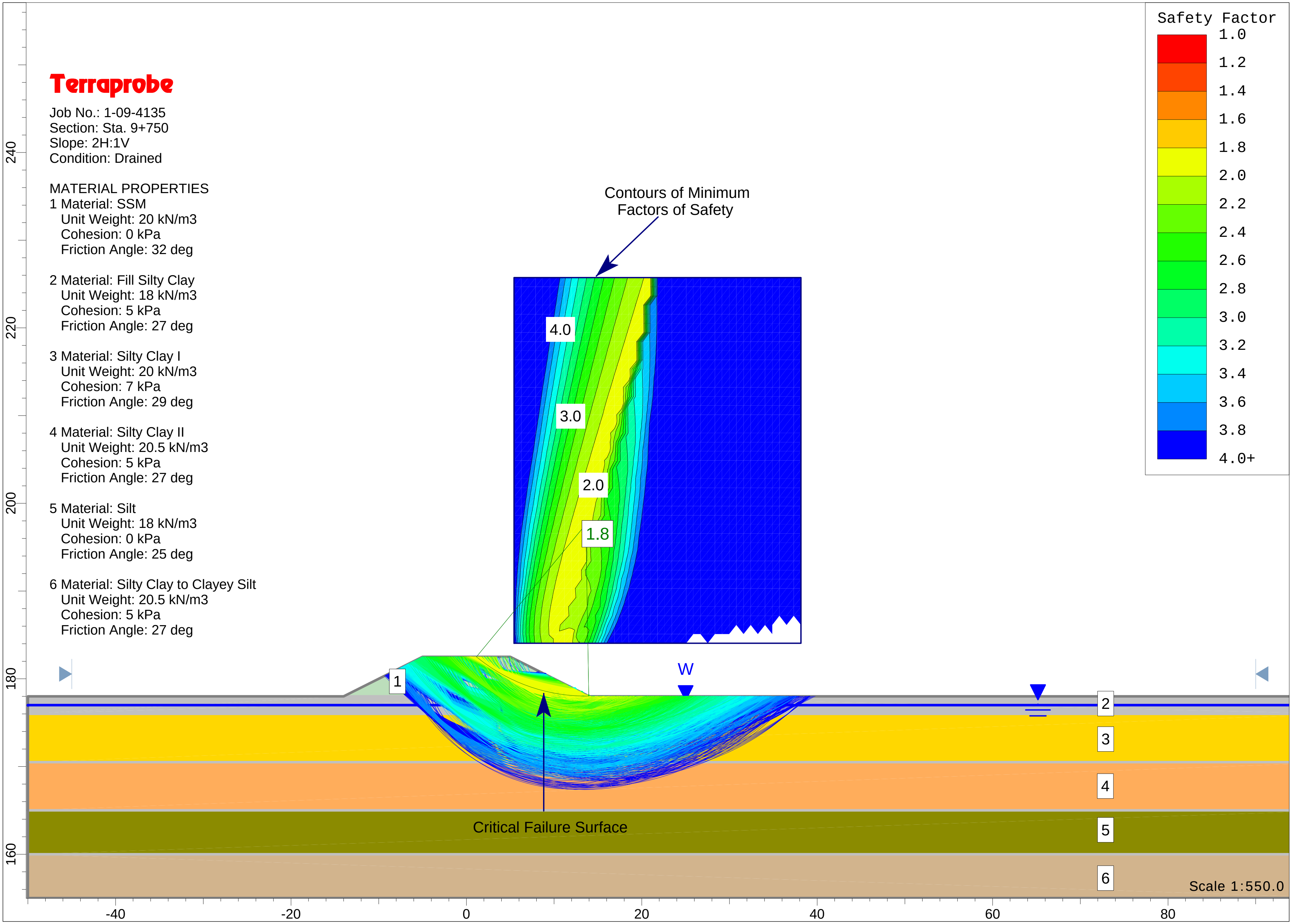
Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+750
Slope: 2.5H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 25 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
7 Material: Gran A
Unit Weight: 22.8 kN/m3
Cohesion: 0 kPa
Friction Angle: 35 deg
Contours of Minimum Factors of Safety
4.0
3.0
2.0
W
Critical Failure Surface
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

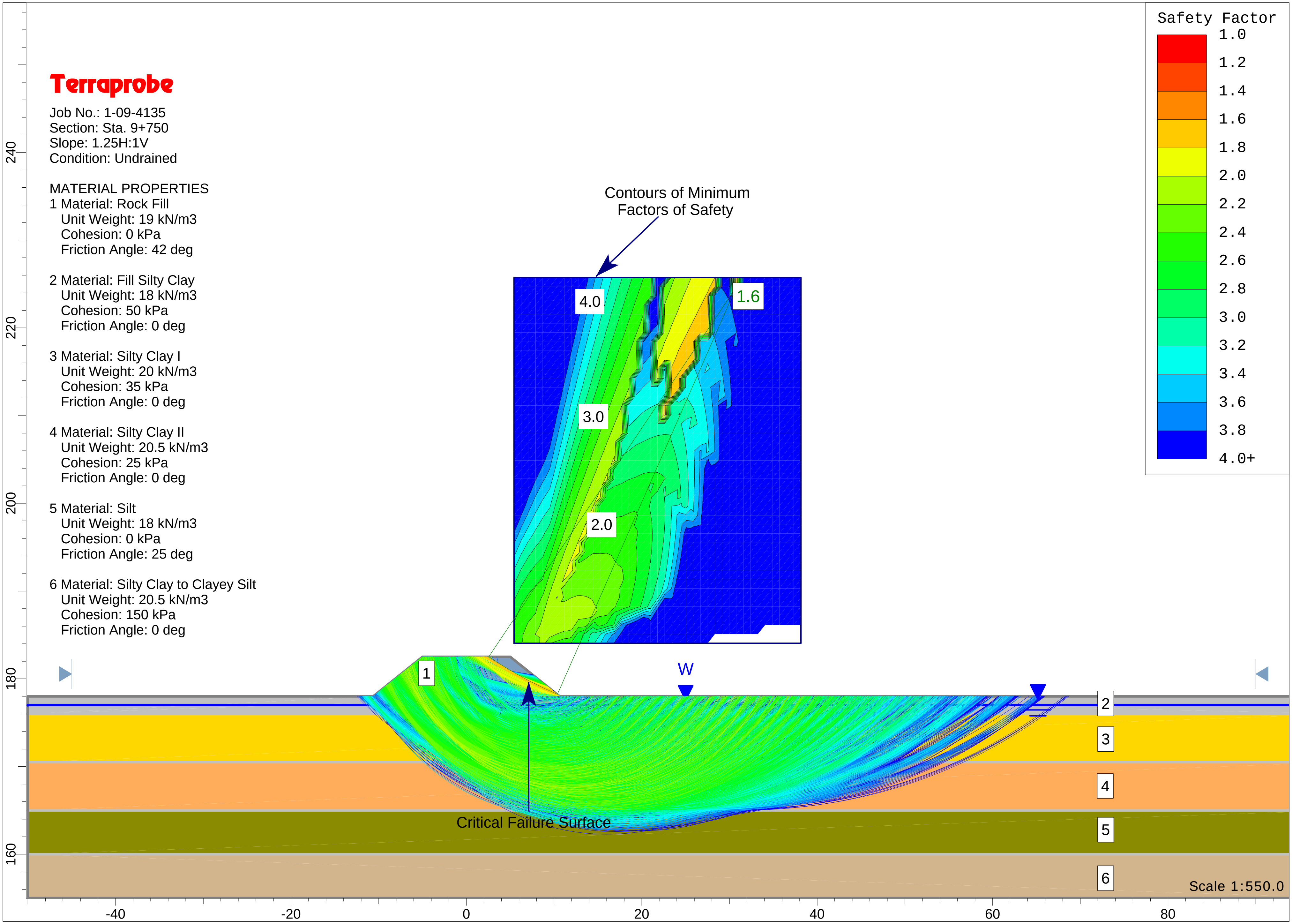


Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+750
Slope: 2.5H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
7 Material: Gran A
Unit Weight: 22.8 kN/m3
Cohesion: 0 kPa
Friction Angle: 35 deg
Contours of Minimum Factors of Safety
4.0
3.0
2.0
Critical Failure Surface
W
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0

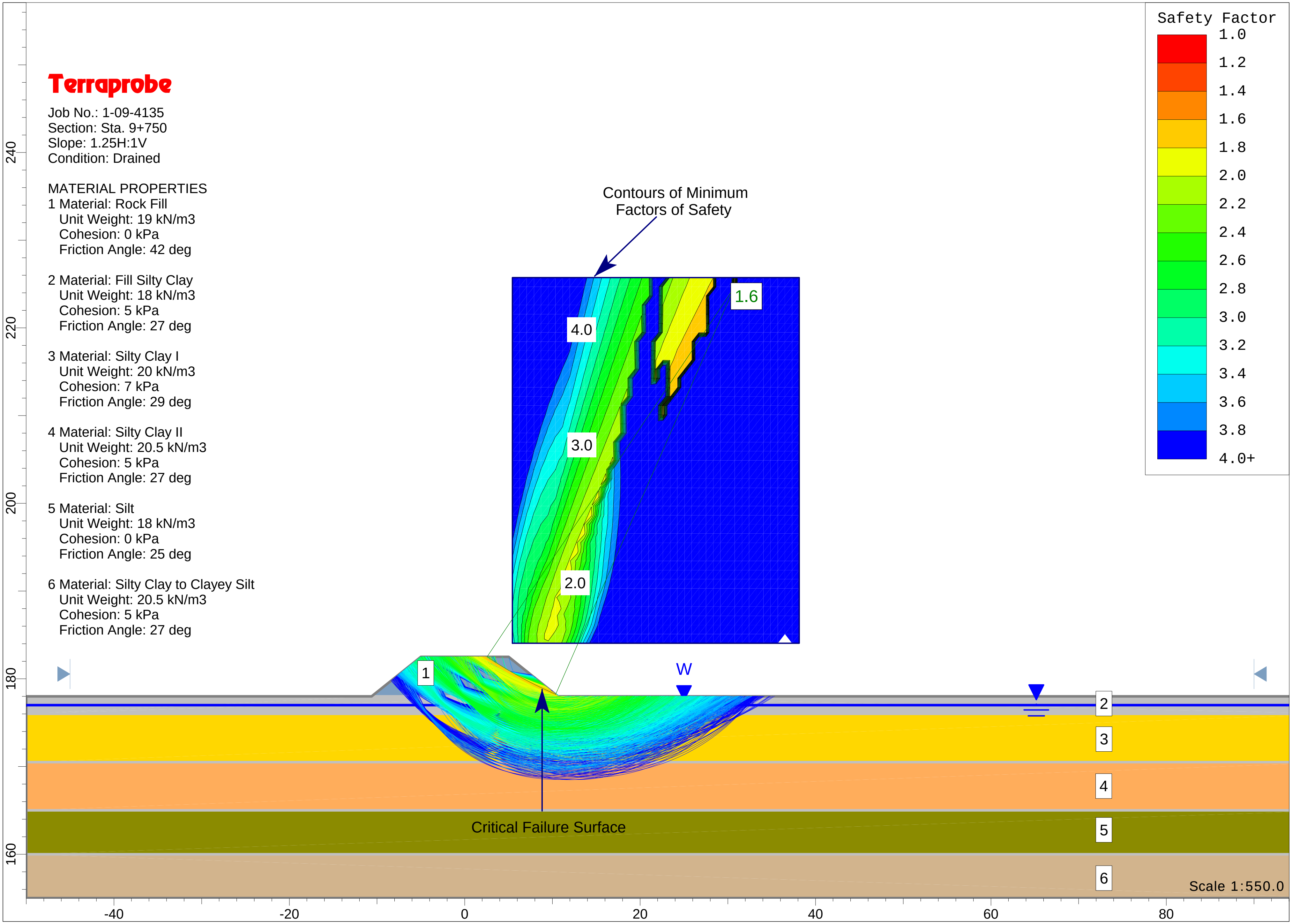


Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+750
Slope: 2H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 25 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
1.8
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
W
1
2
3
4
5
6
Critical Failure Surface
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

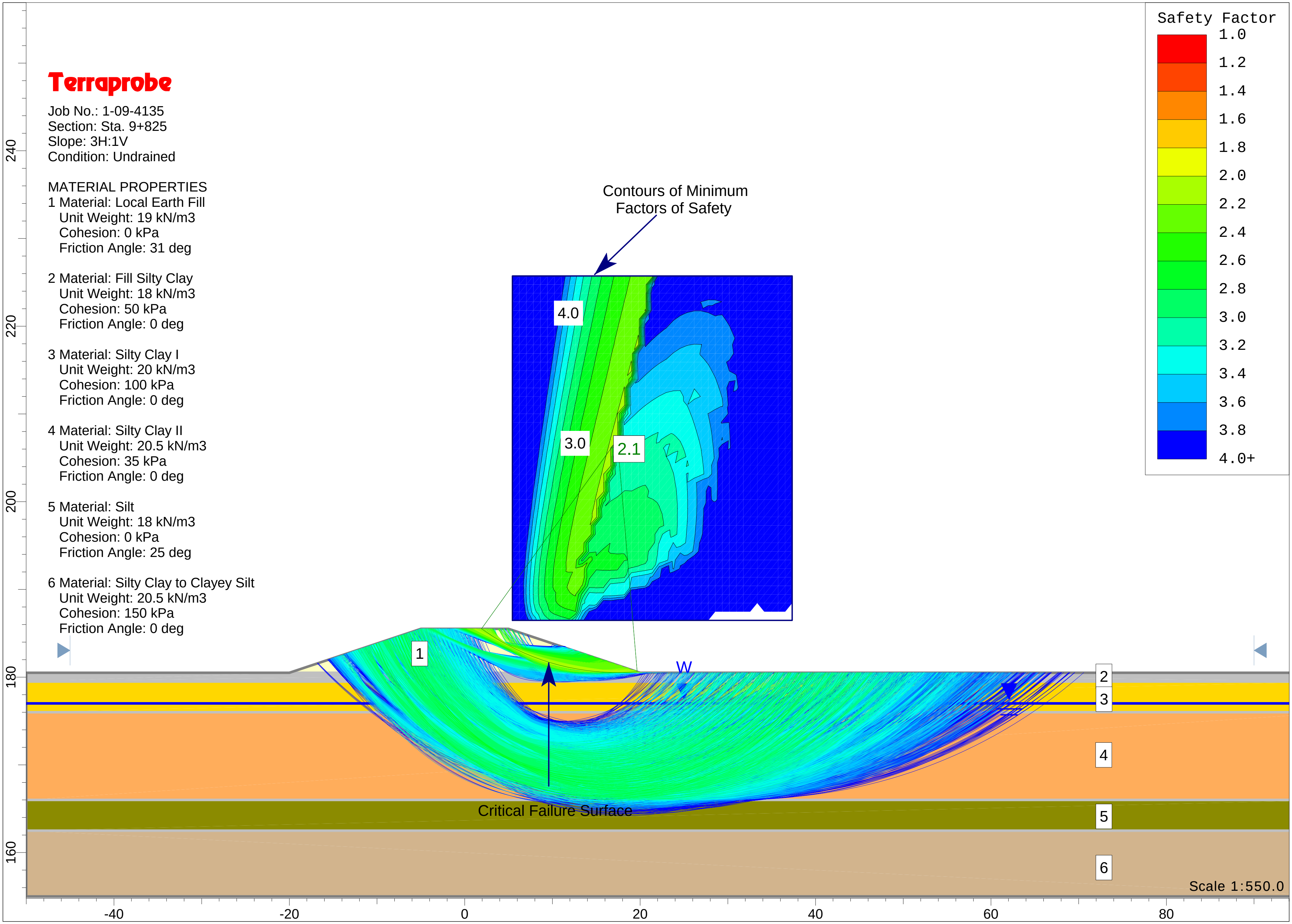

Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+750
Slope: 2H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
1.8
Critical Failure Surface
W
1
2
3
4
5
6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

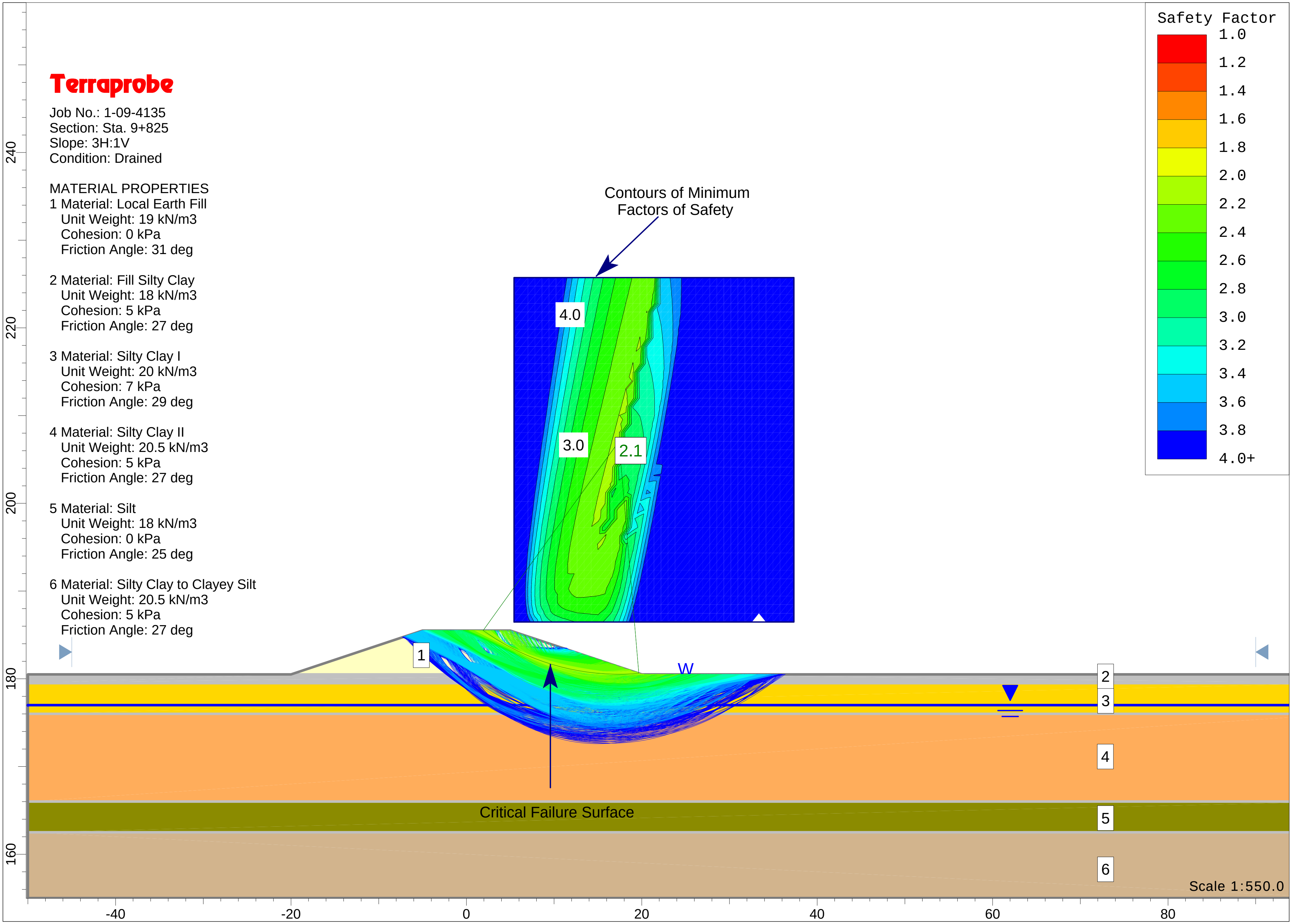


Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+750
Slope: 1.25H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Rock Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 42 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 25 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
Contours of Minimum
Factors of Safety
4.0
1.6
3.0
2.0
Critical Failure Surface
W
1
2
3
4
5
6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
240
220
200
180
160
-40
-20
0
20
40
60
80
Scale 1:550.0

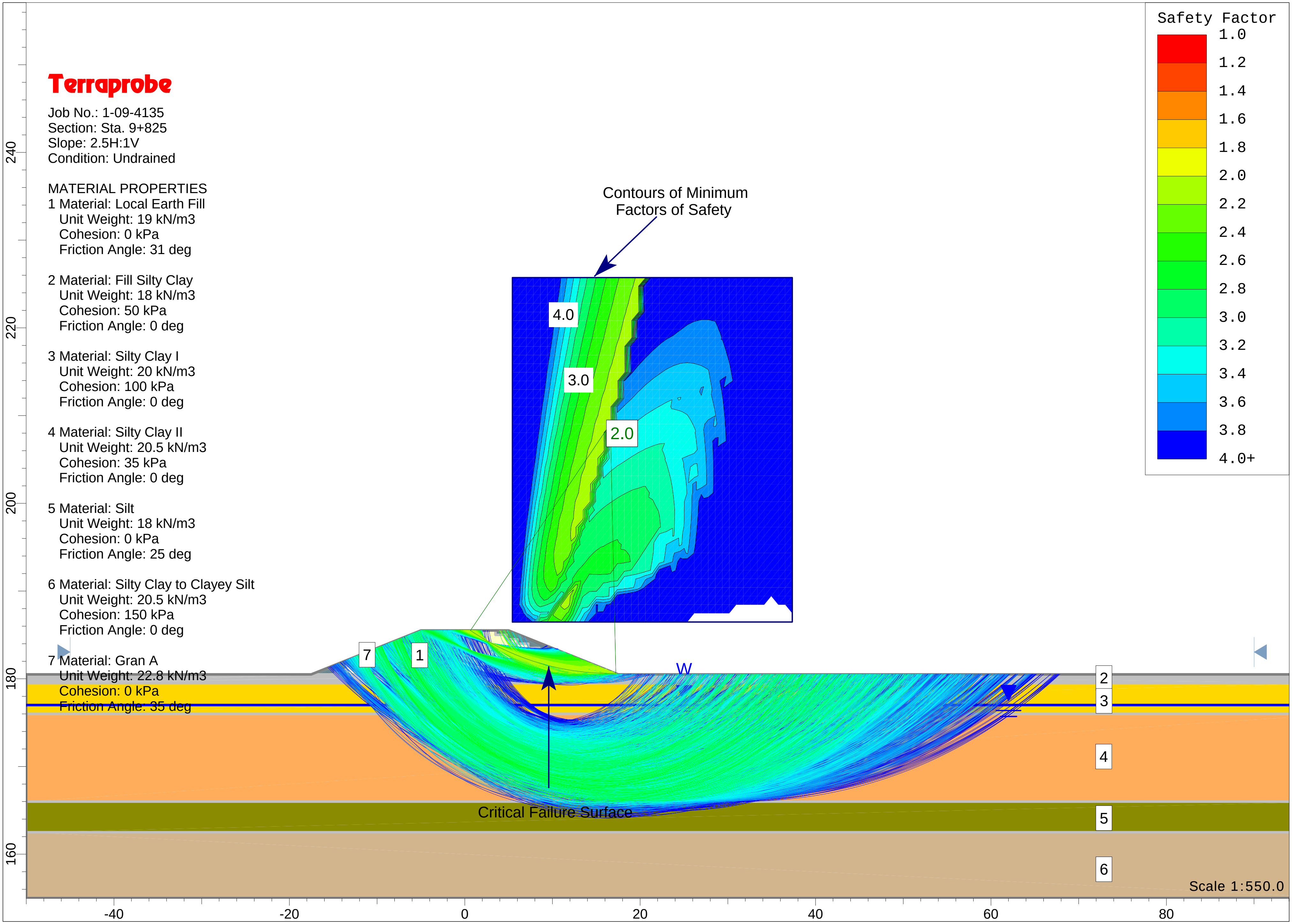


Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+750
Slope: 1.25H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Rock Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 42 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum Factors of Safety
4.0
3.0
2.0
1.6
Critical Failure Surface
W
1
2
3
4
5
6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
240
220
200
180
160
-40
-20
0
20
40
60
80
Scale 1:550.0

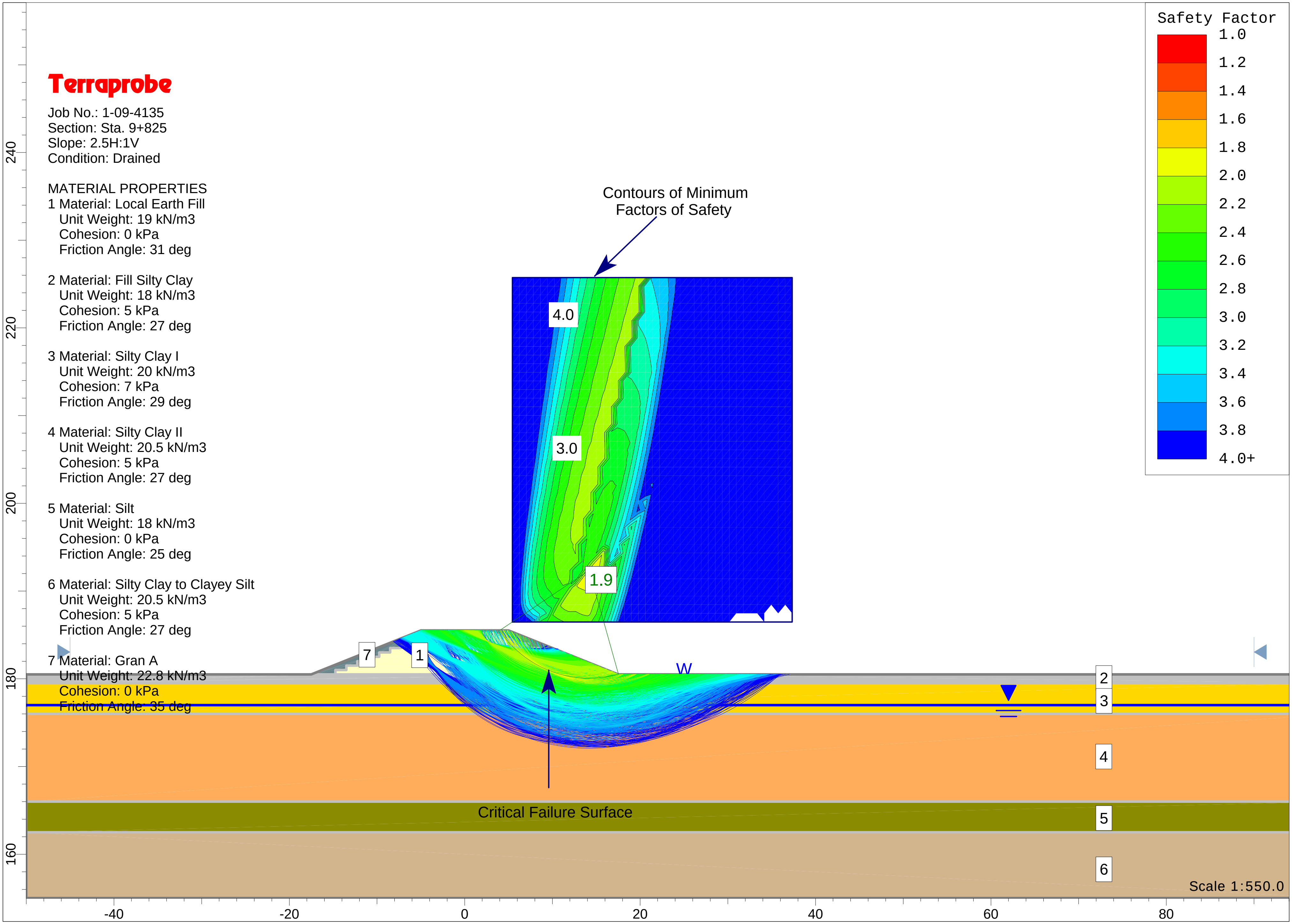

Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+825
Slope: 3H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.1
Critical Failure Surface
W
1
2
3
4
5
6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
240
220
200
180
160
-40
-20
0
20
40
60
80
Scale 1:550.0

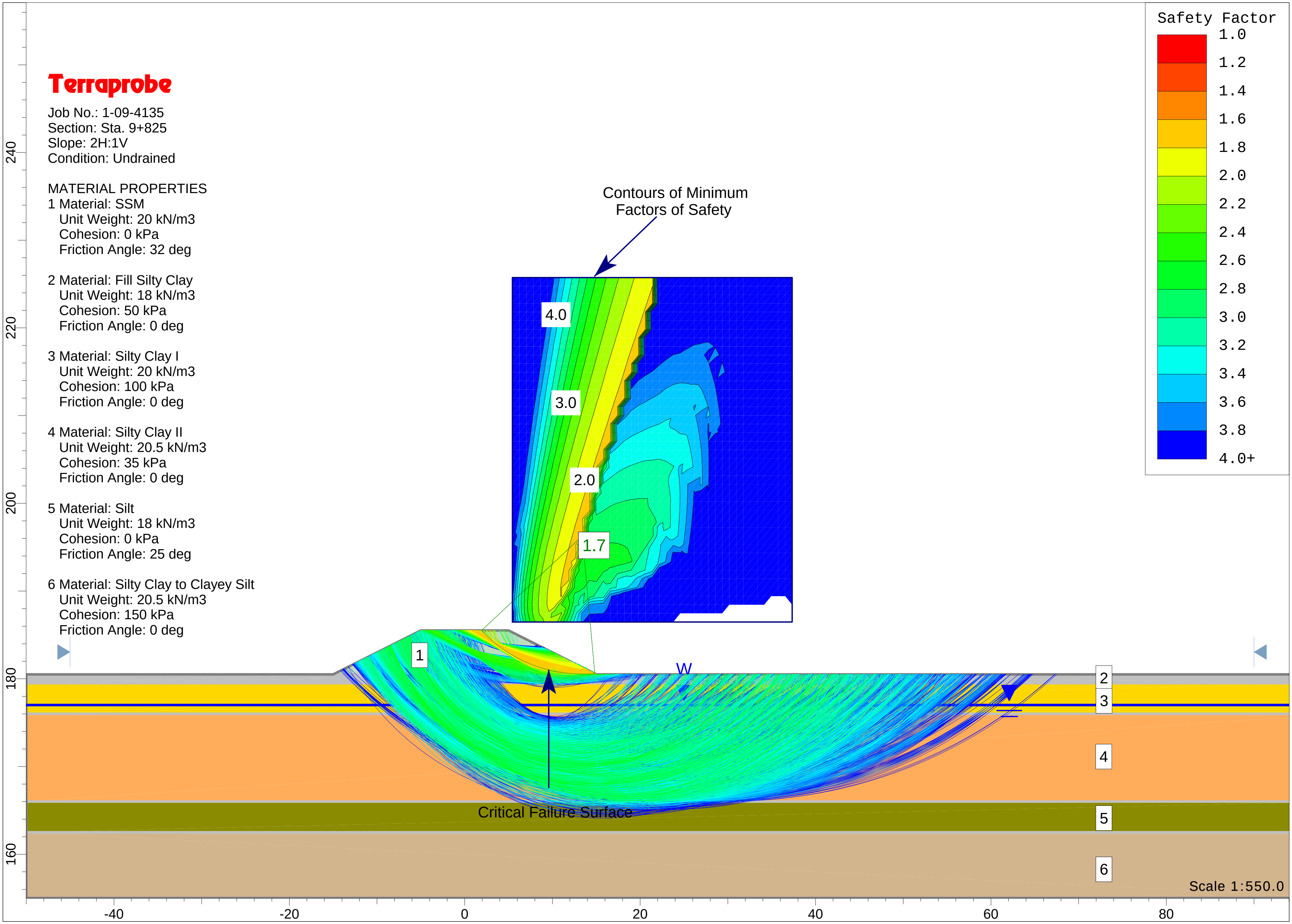


Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+825
Slope: 3H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.1
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
W
1
2
3
4
5
6
Critical Failure Surface
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

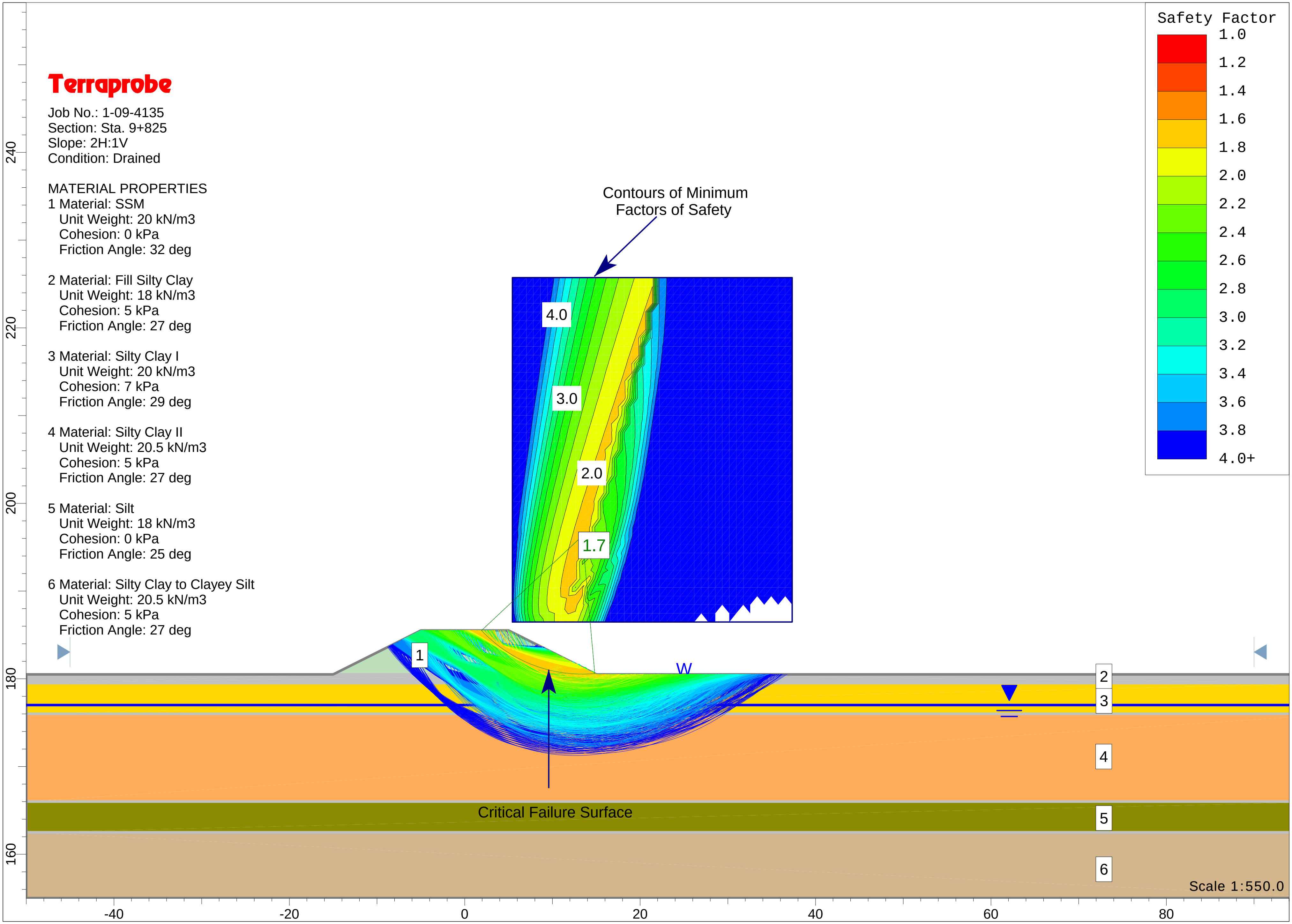


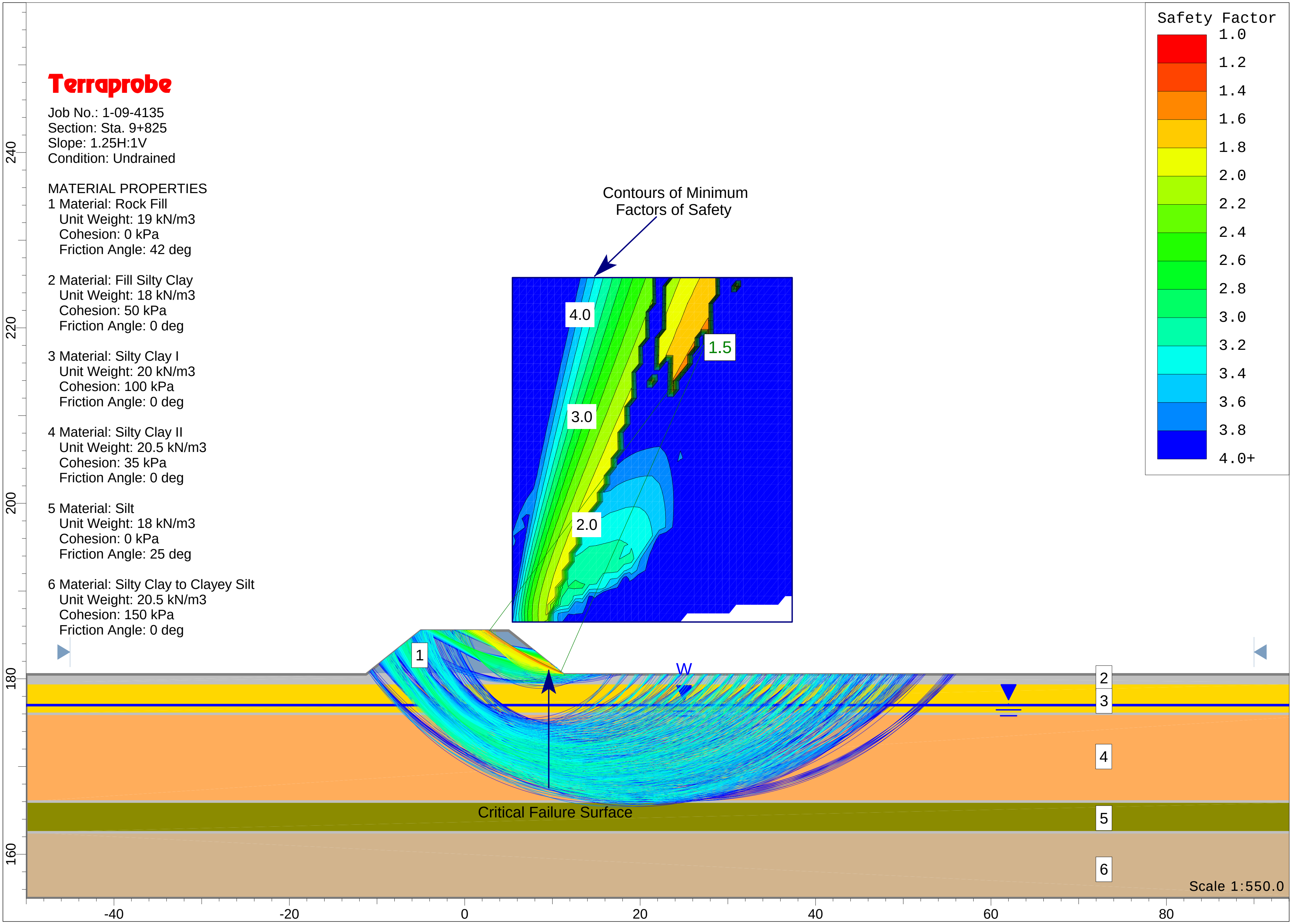
Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+825
Slope: 2.5H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
7 Material: Gran A
Unit Weight: 22.8 kN/m3
Cohesion: 0 kPa
Friction Angle: 35 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
Critical Failure Surface
W
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
7
1
2
3
4
5
6
240
220
200
180
160
-40
-20
0
20
40
60
80


Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+825
Slope: 2.5H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
7 Material: Gran A
Unit Weight: 22.8 kN/m3
Cohesion: 0 kPa
Friction Angle: 35 deg
Contours of Minimum
Factors of Safety
4.0
3.0
1.9
W
Critical Failure Surface
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

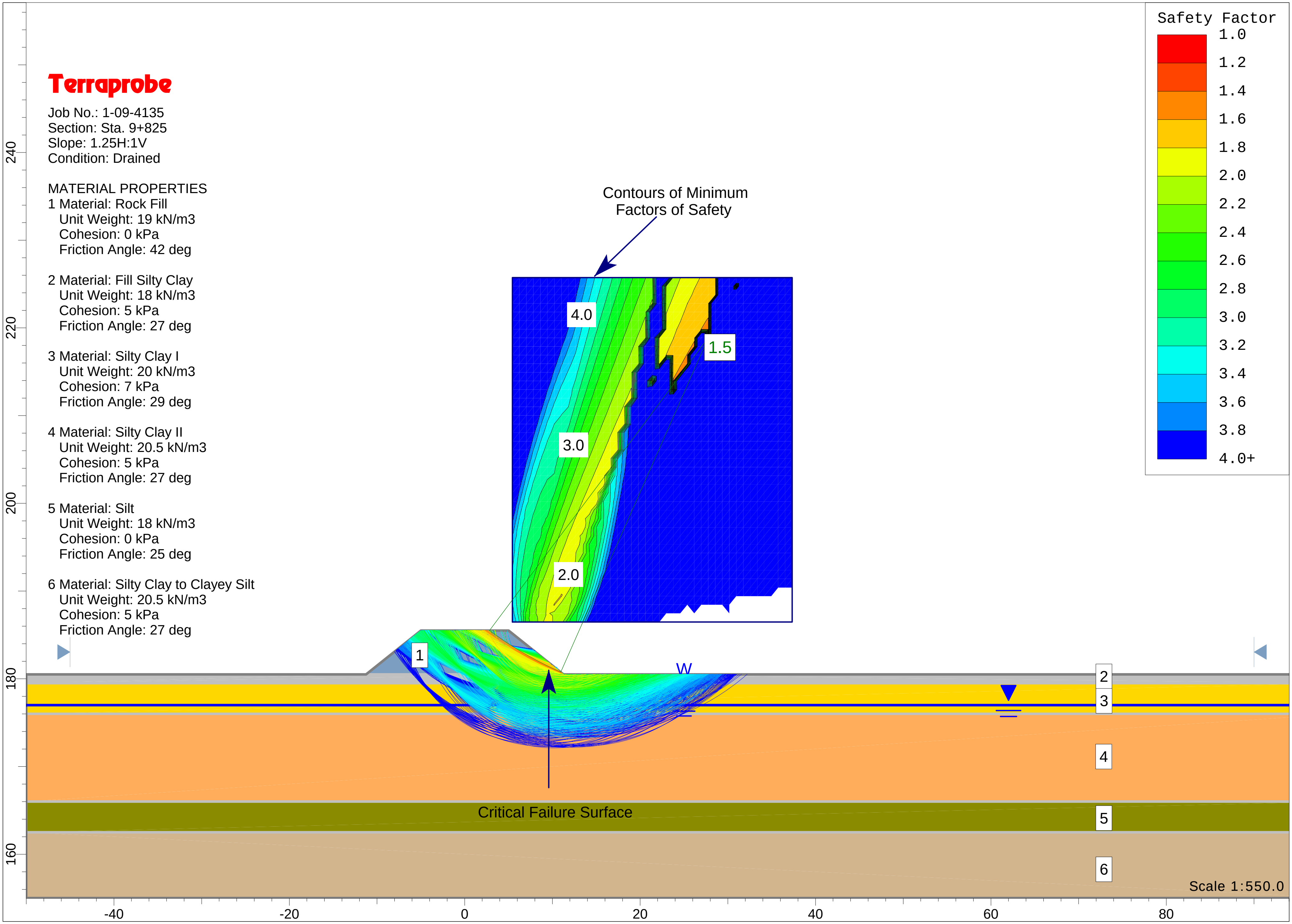


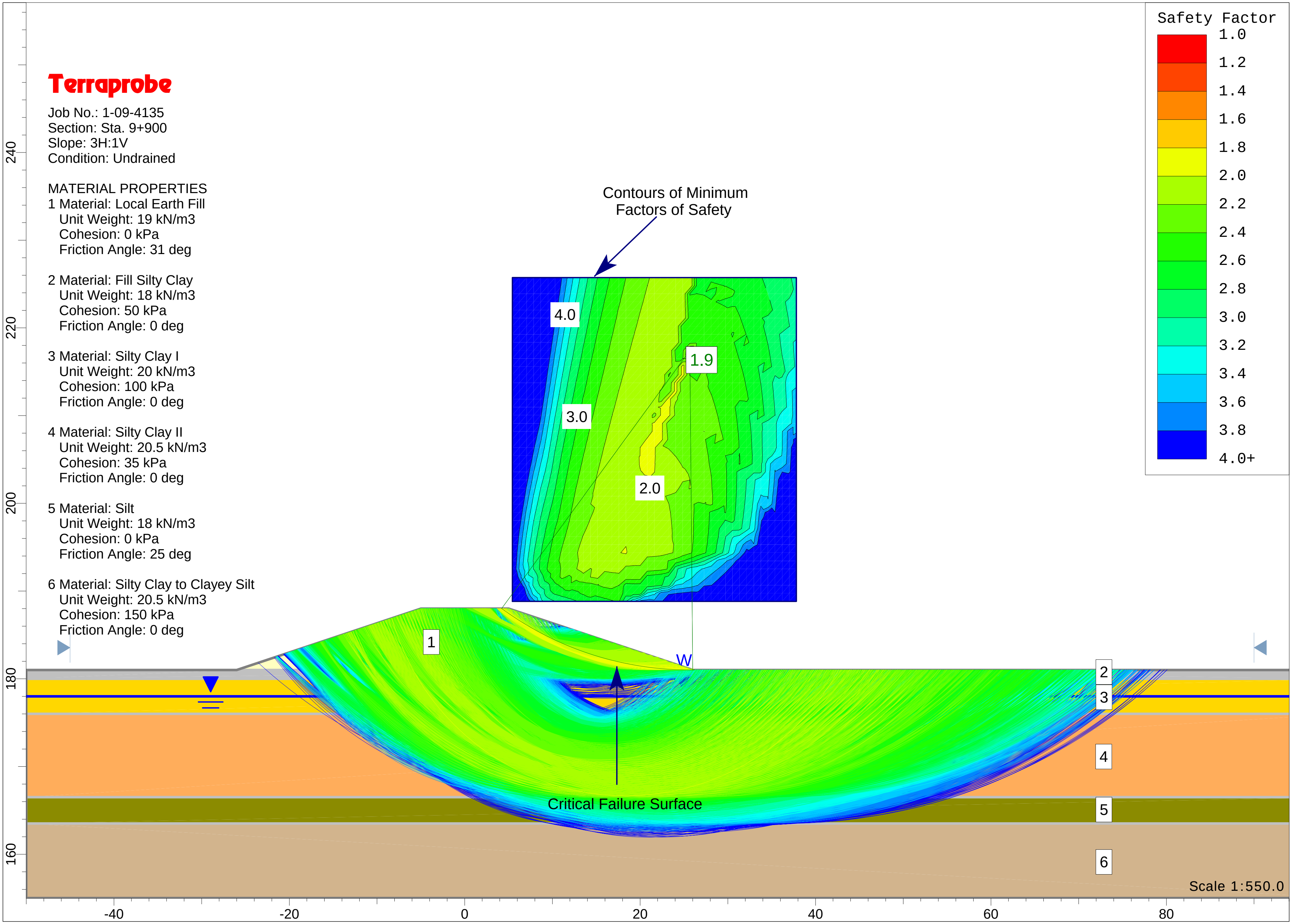
Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+825
Slope: 2H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
Contours of Minimum Factors of Safety
4.0
3.0
2.0
1.7
Critical Failure Surface
W
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
1
2
3
4
5
6
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80


Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+825
Slope: 2H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
1.7
Critical Failure Surface
W
1
2
3
4
5
6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
240
220
200
180
160
-40
-20
0
20
40
60
80
Scale 1:550.0

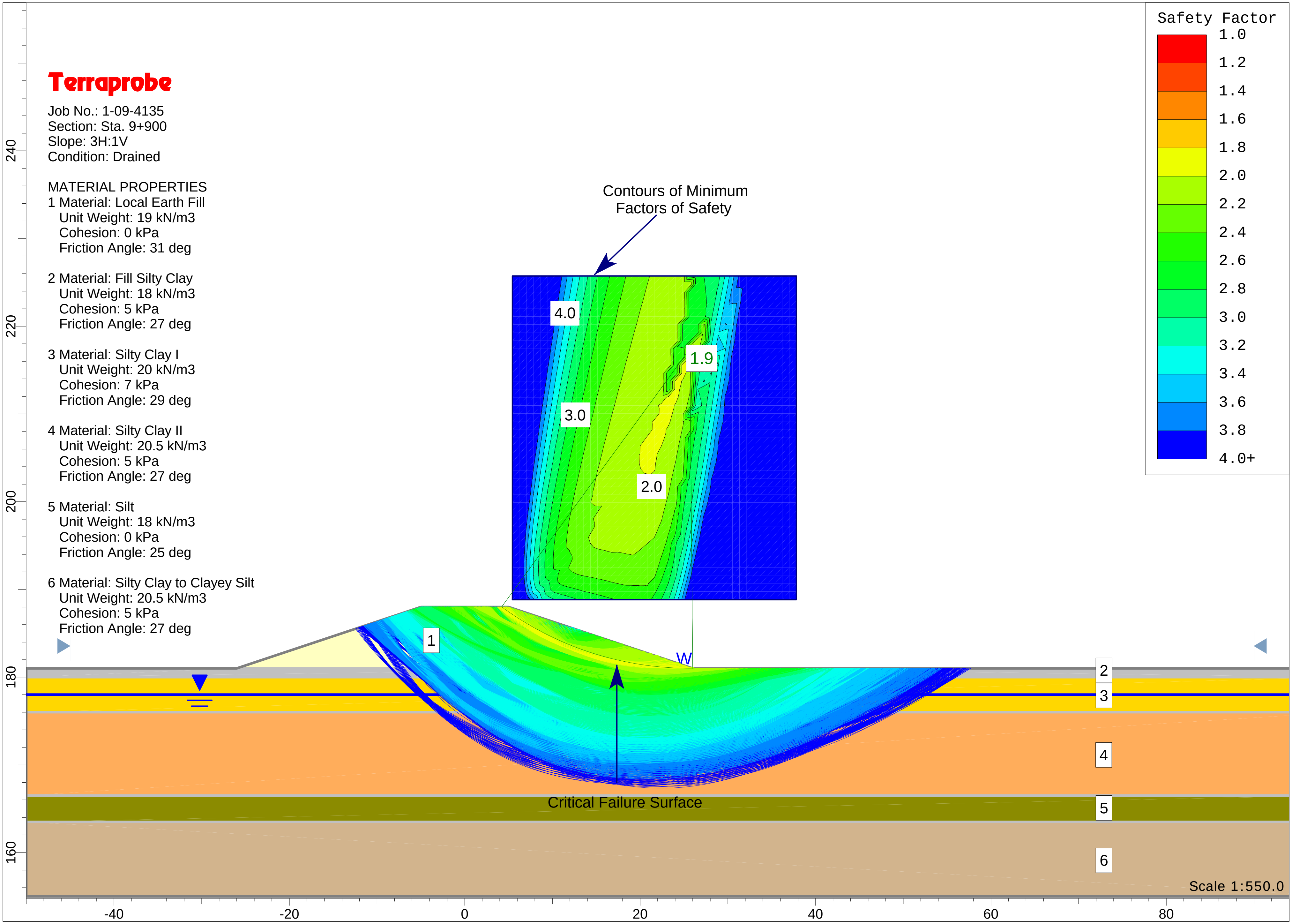


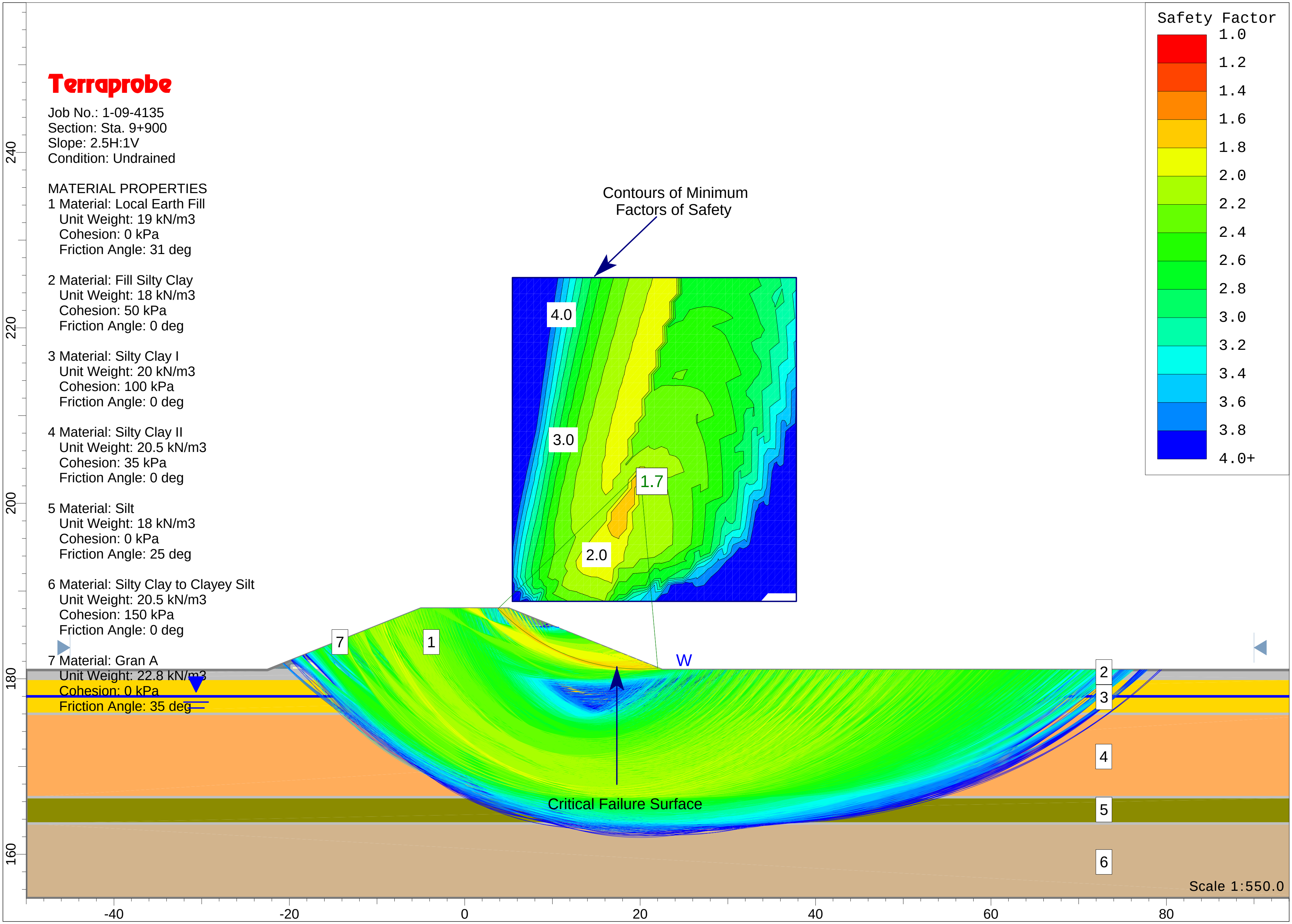
Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+825
Slope: 1.25H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Rock Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 42 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
1.5
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
1
2
3
4
5
6
W
Critical Failure Surface
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80


Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+825
Slope: 1.25H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Rock Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 42 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum
Factors of Safety
4.0
1.5
3.0
2.0
Critical Failure Surface
W
1
2
3
4
5
6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

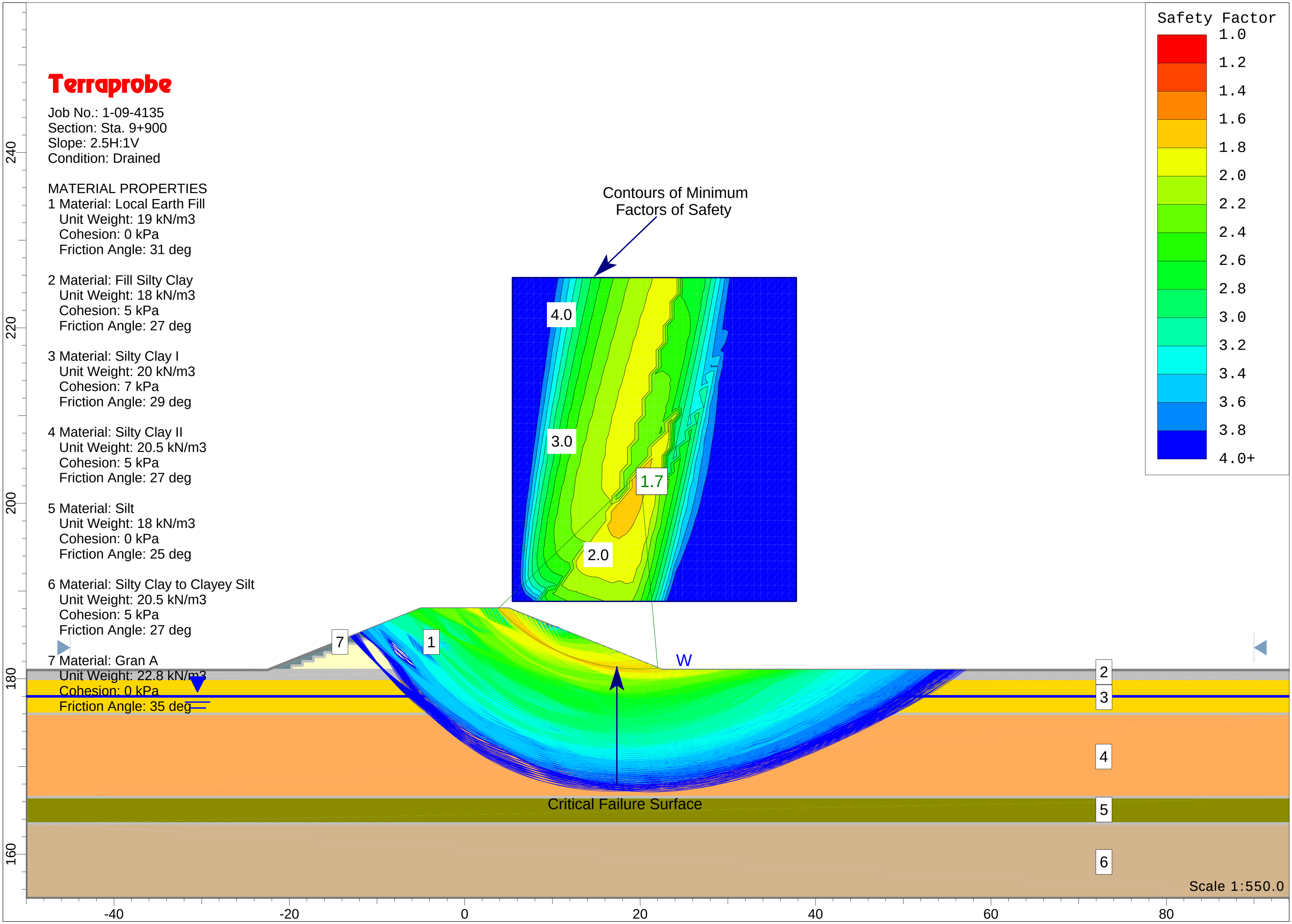


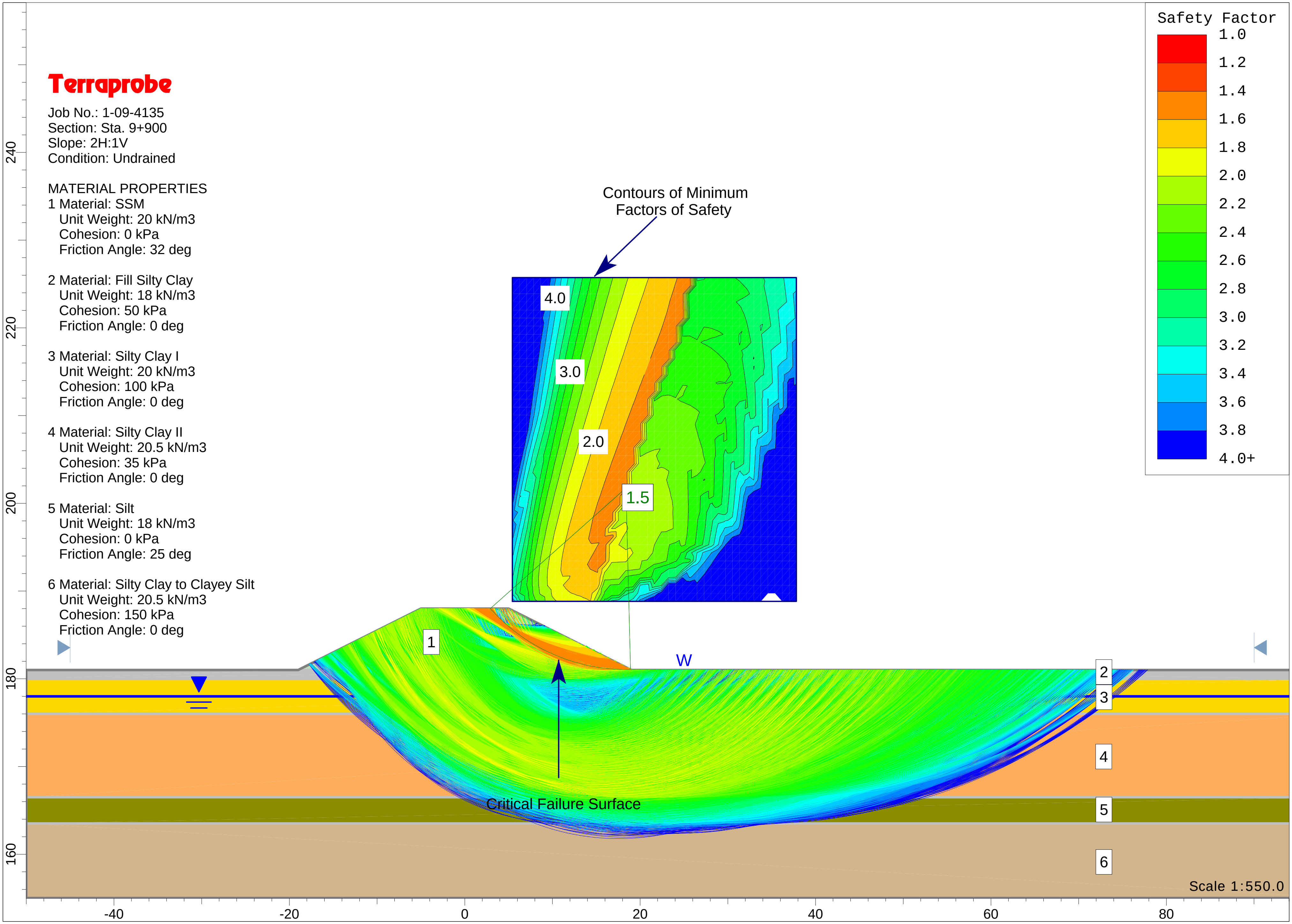
Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+900
Slope: 3H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
Contours of Minimum Factors of Safety
4.0
1.9
3.0
2.0
W
Critical Failure Surface
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80


Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+900
Slope: 3H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum Factors of Safety
4.0
1.9
3.0
2.0
W
Critical Failure Surface
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
1
2
3
4
5
6
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

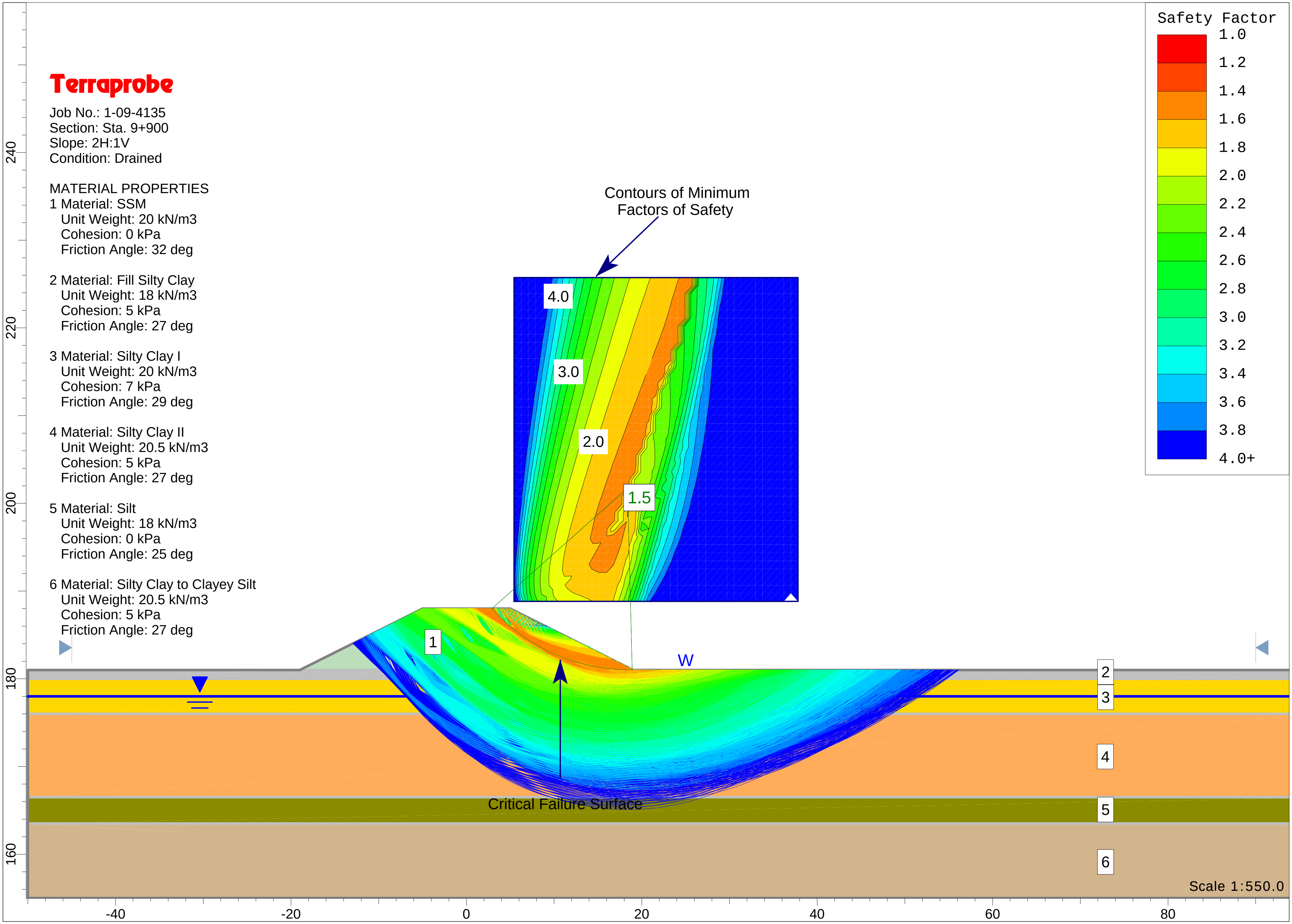


Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+900
Slope: 2.5H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
7 Material: Gran A
Unit Weight: 22.8 kN/m3
Cohesion: 0 kPa
Friction Angle: 35 deg
Contours of Minimum
Factors of Safety
4.0
3.0
1.7
2.0
W
Critical Failure Surface
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
7
1
2
3
4
5
6
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

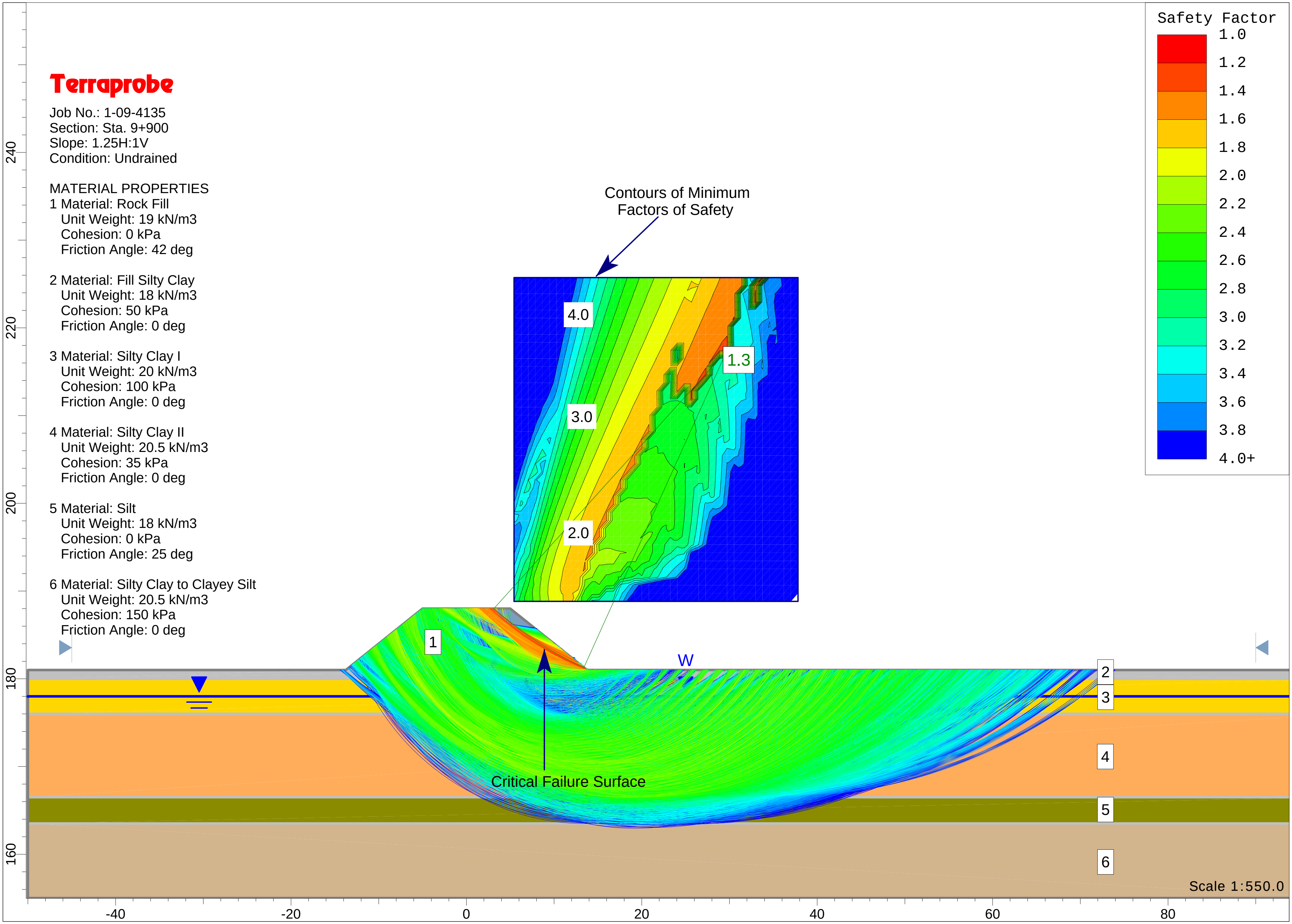

Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+900
Slope: 2.5H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
7 Material: Gran A
Unit Weight: 22.8 kN/m3
Cohesion: 0 kPa
Friction Angle: 35 deg
Contours of Minimum Factors of Safety
4.0
3.0
1.7
2.0
Critical Failure Surface
W
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80



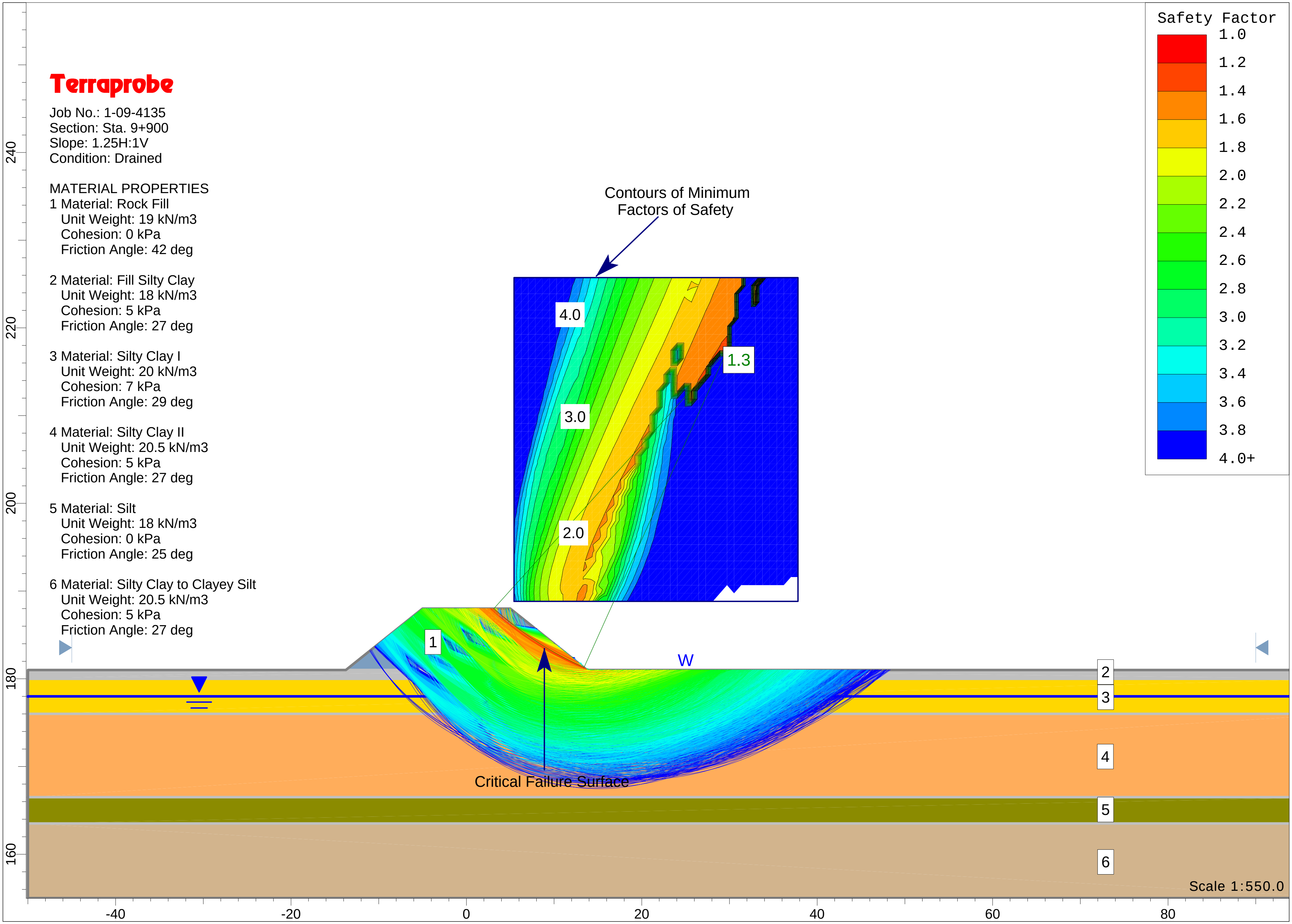
Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+900
Slope: 2H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
1.5
Critical Failure Surface
W
1
2
3
4
5
6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

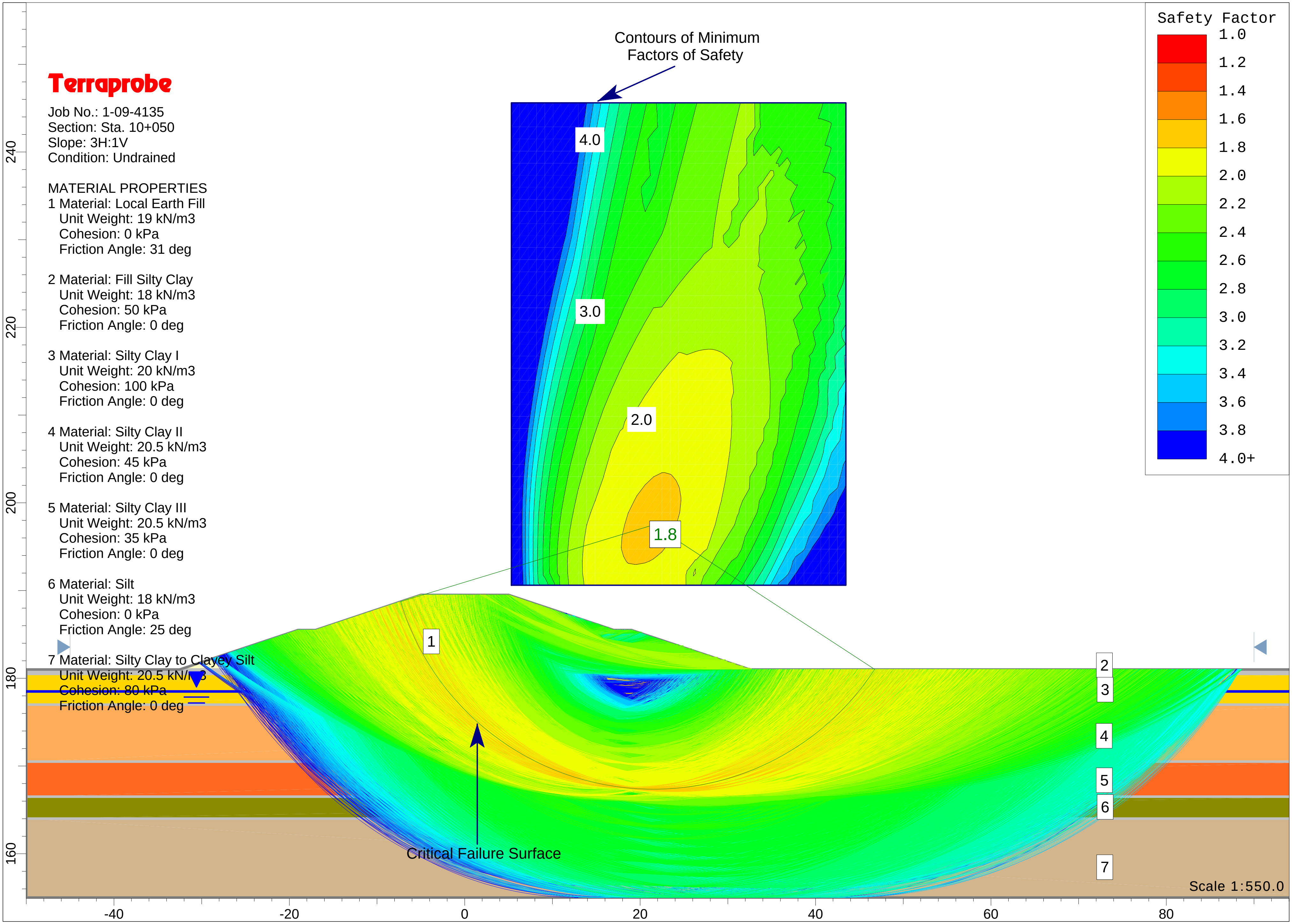


Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+900
Slope: 2H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
1.5
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
W
Critical Failure Surface
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

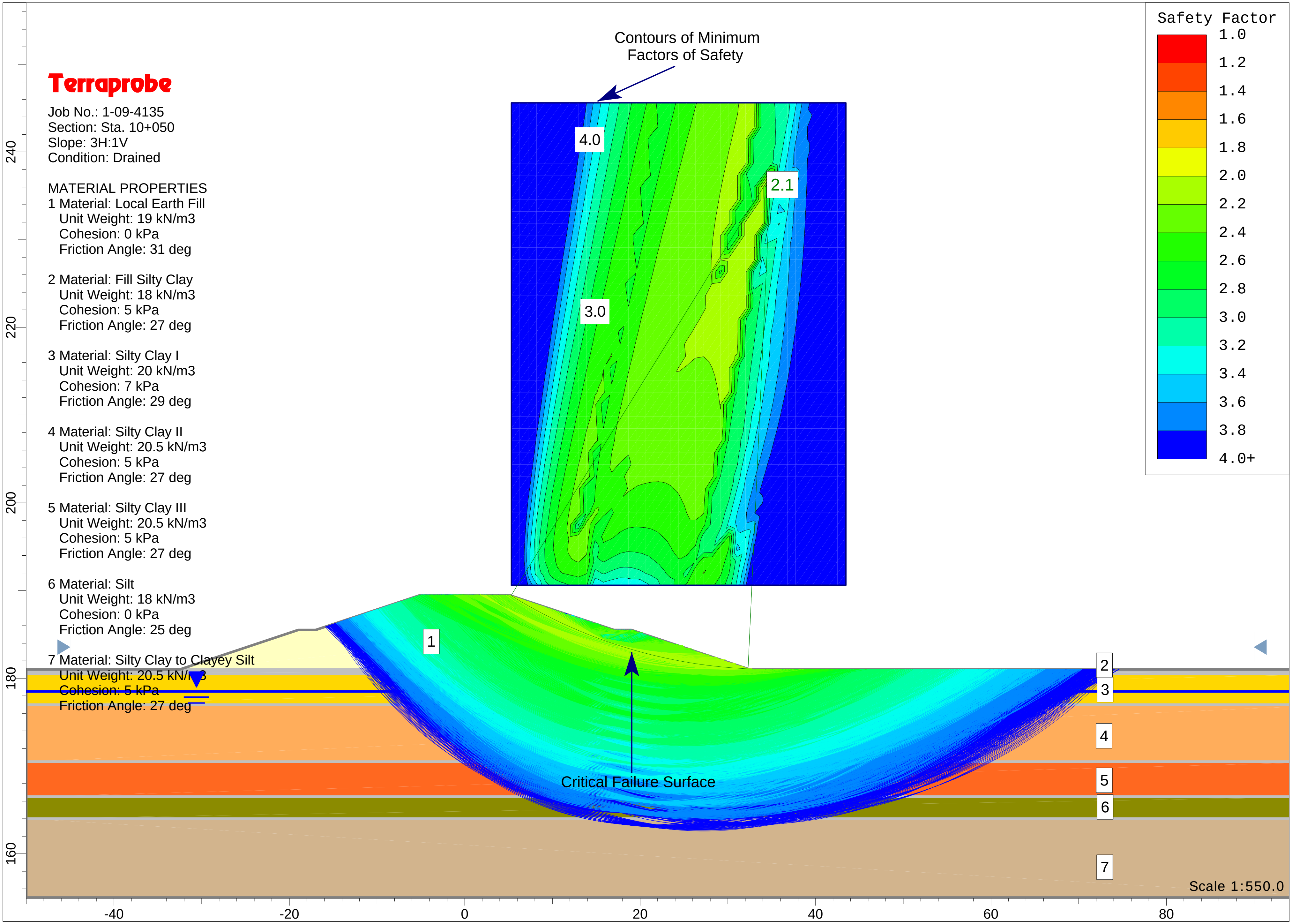


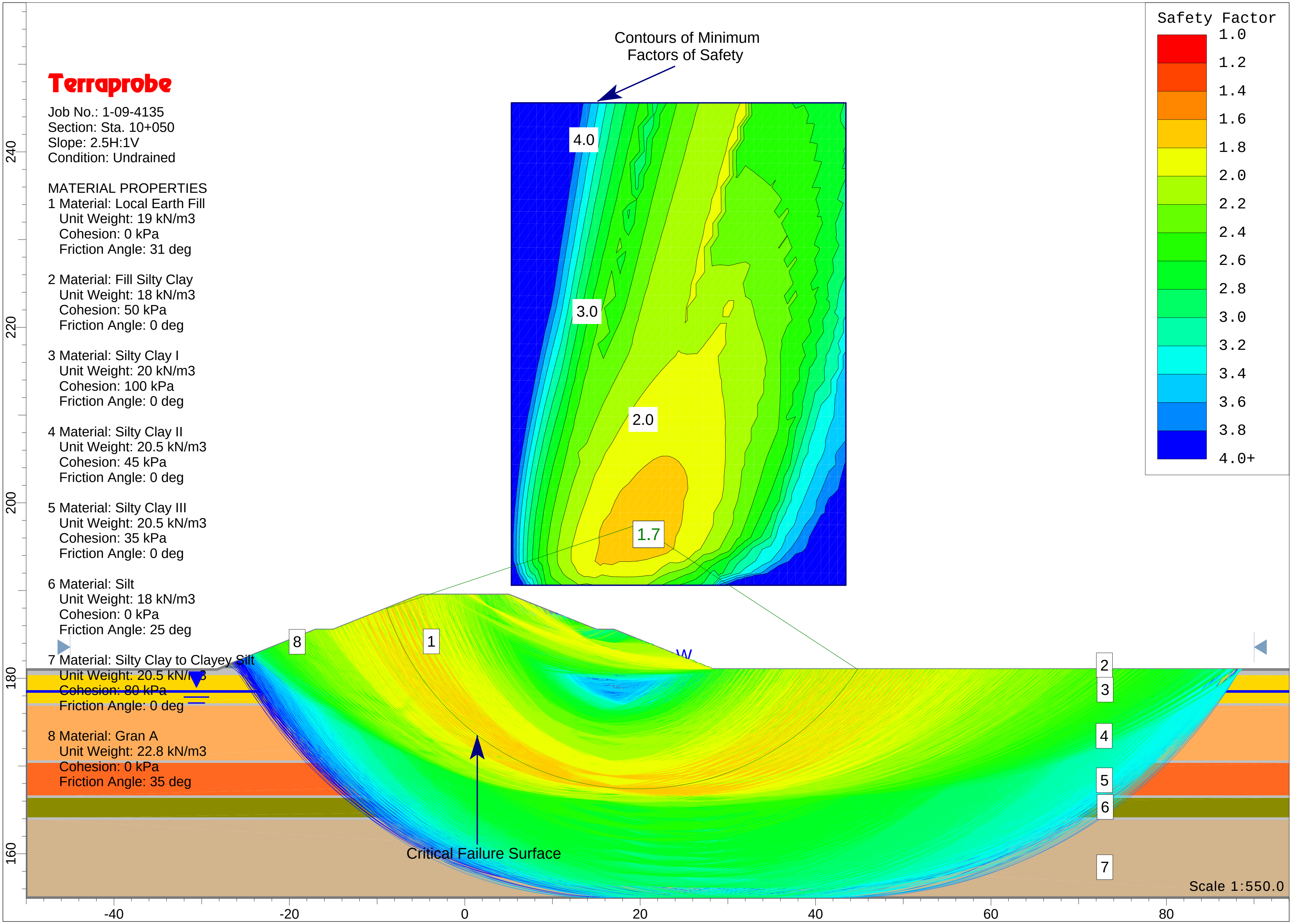
Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+900
Slope: 1.25H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Rock Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 42 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
Contours of Minimum
Factors of Safety
4.0
1.3
3.0
2.0
Critical Failure Surface
W
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

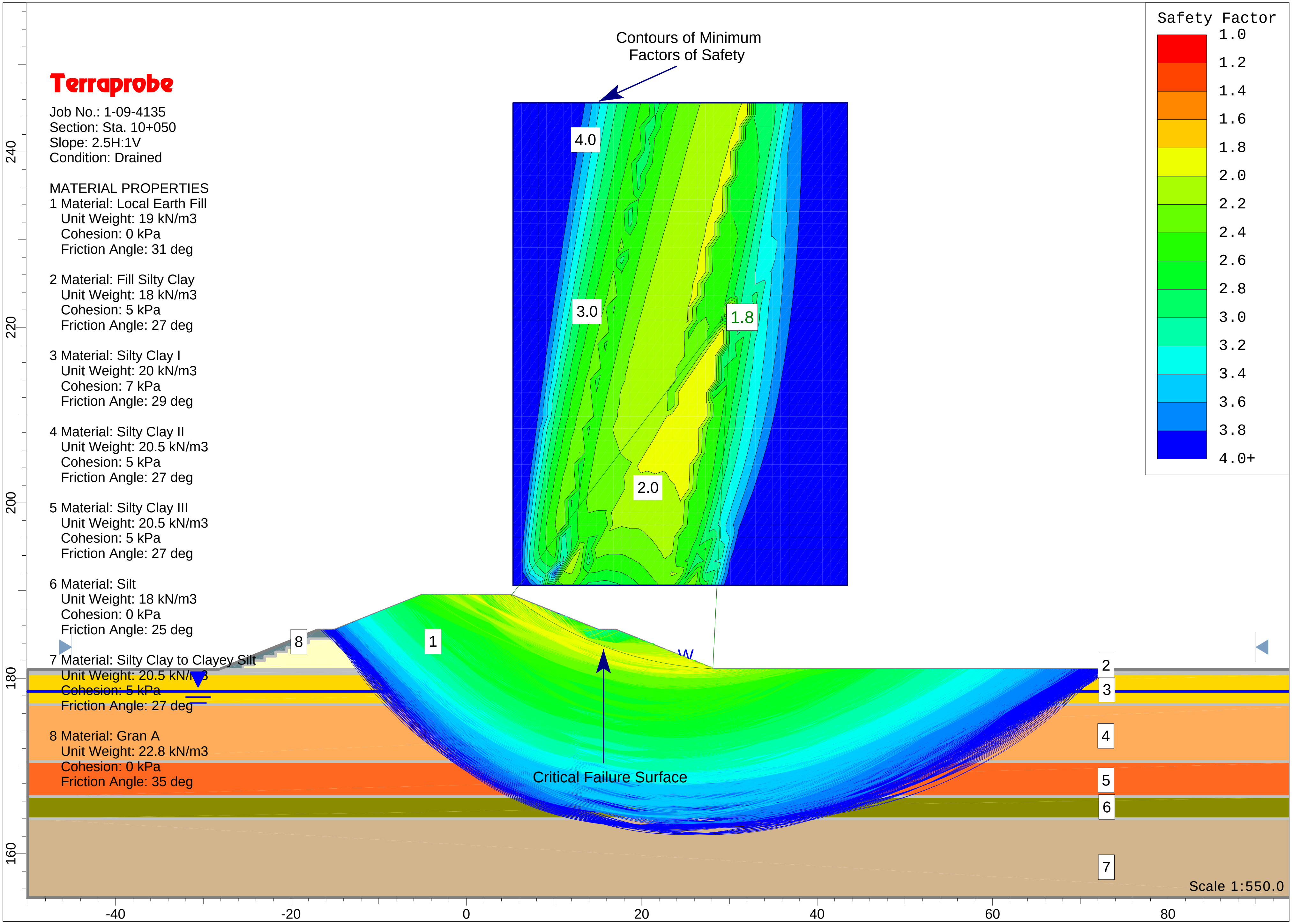

Terraprobe
Job No.: 1-09-4135
Section: Sta. 9+900
Slope: 1.25H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Rock Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 42 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
1.3
1
W
Critical Failure Surface
2
3
4
5
6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

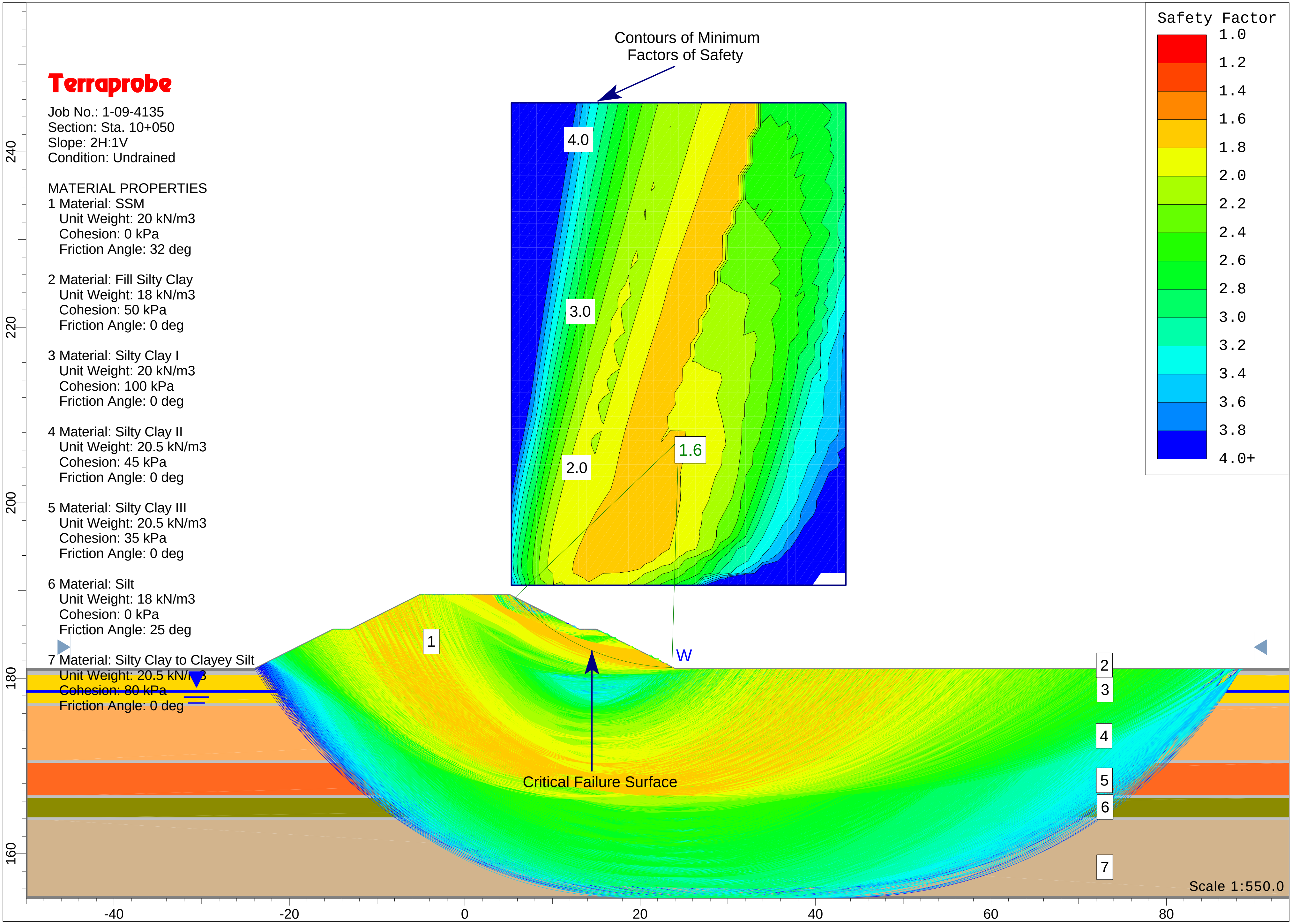


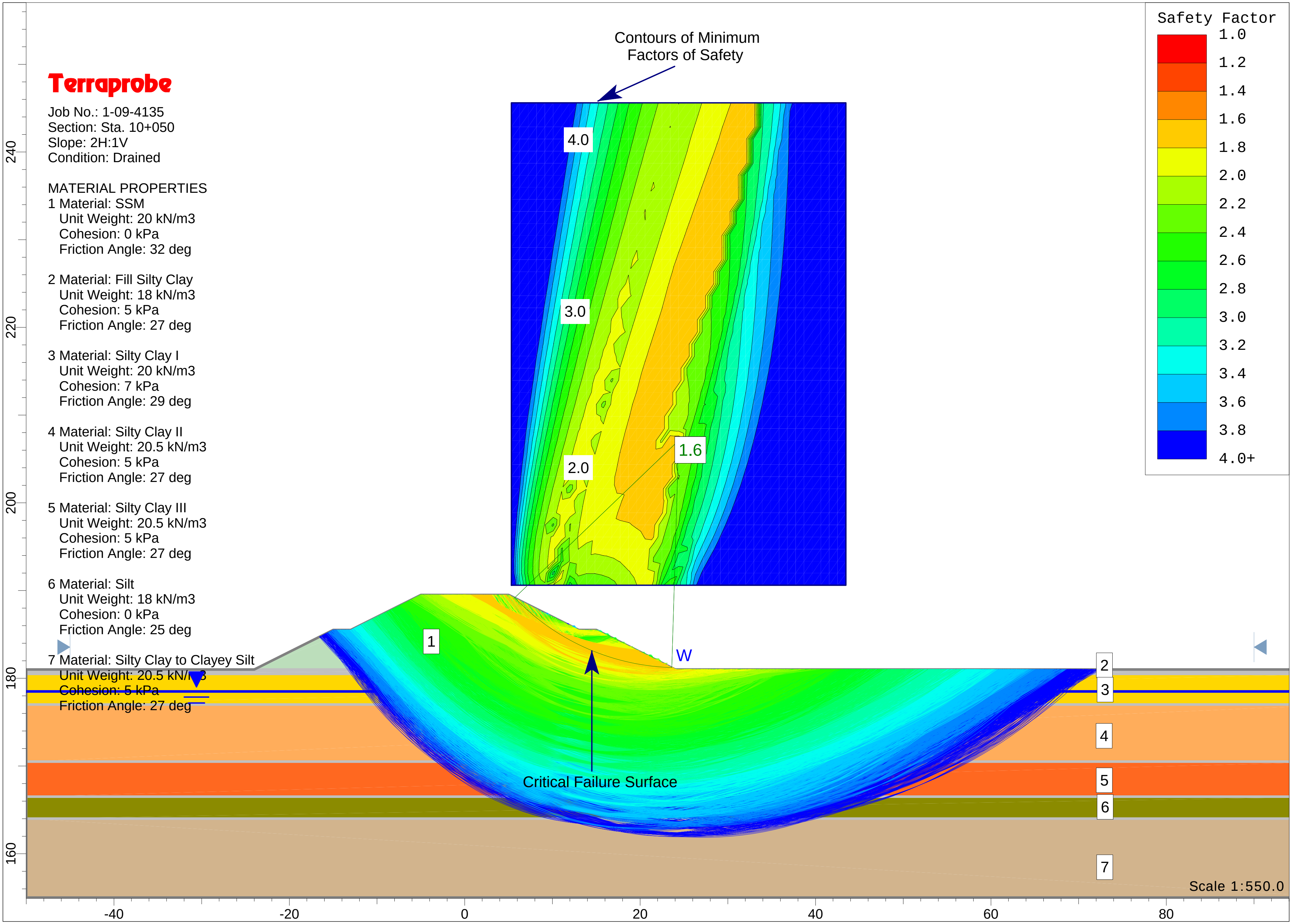
Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+050
Slope: 3H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 45 kPa
Friction Angle: 0 deg
5 Material: Silty Clay III
Unit Weight: 20.5 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
6 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
7 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 80 kPa
Friction Angle: 0 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
1.8
Critical Failure Surface
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
1
2
3
4
5
6
7
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80


Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+050
Slope: 3H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silty Clay III
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
6 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
7 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum
Factors of Safety
4.0
2.1
3.0
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
1
2
3
4
5
6
7
Critical Failure Surface
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

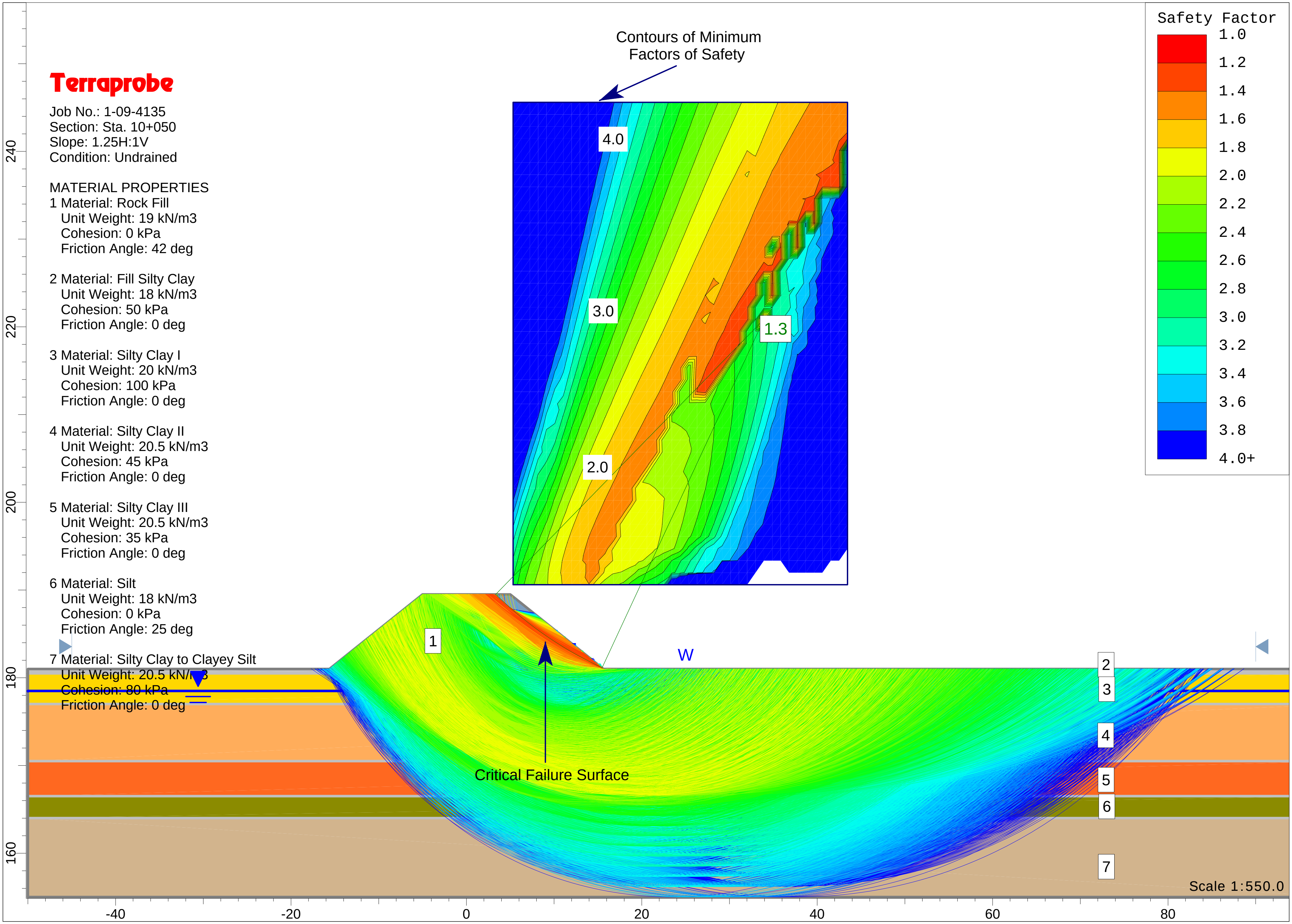

Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+050
Slope: 2.5H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 45 kPa
Friction Angle: 0 deg
5 Material: Silty Clay III
Unit Weight: 20.5 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
6 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
7 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 80 kPa
Friction Angle: 0 deg
8 Material: Gran A
Unit Weight: 22.8 kN/m3
Cohesion: 0 kPa
Friction Angle: 35 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
1.7
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Critical Failure Surface
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80


Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+050
Slope: 2.5H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silty Clay III
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
6 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
7 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
8 Material: Gran A
Unit Weight: 22.8 kN/m3
Cohesion: 0 kPa
Friction Angle: 35 deg
Contours of Minimum
Factors of Safety
4.0
3.0
1.8
2.0
Critical Failure Surface
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

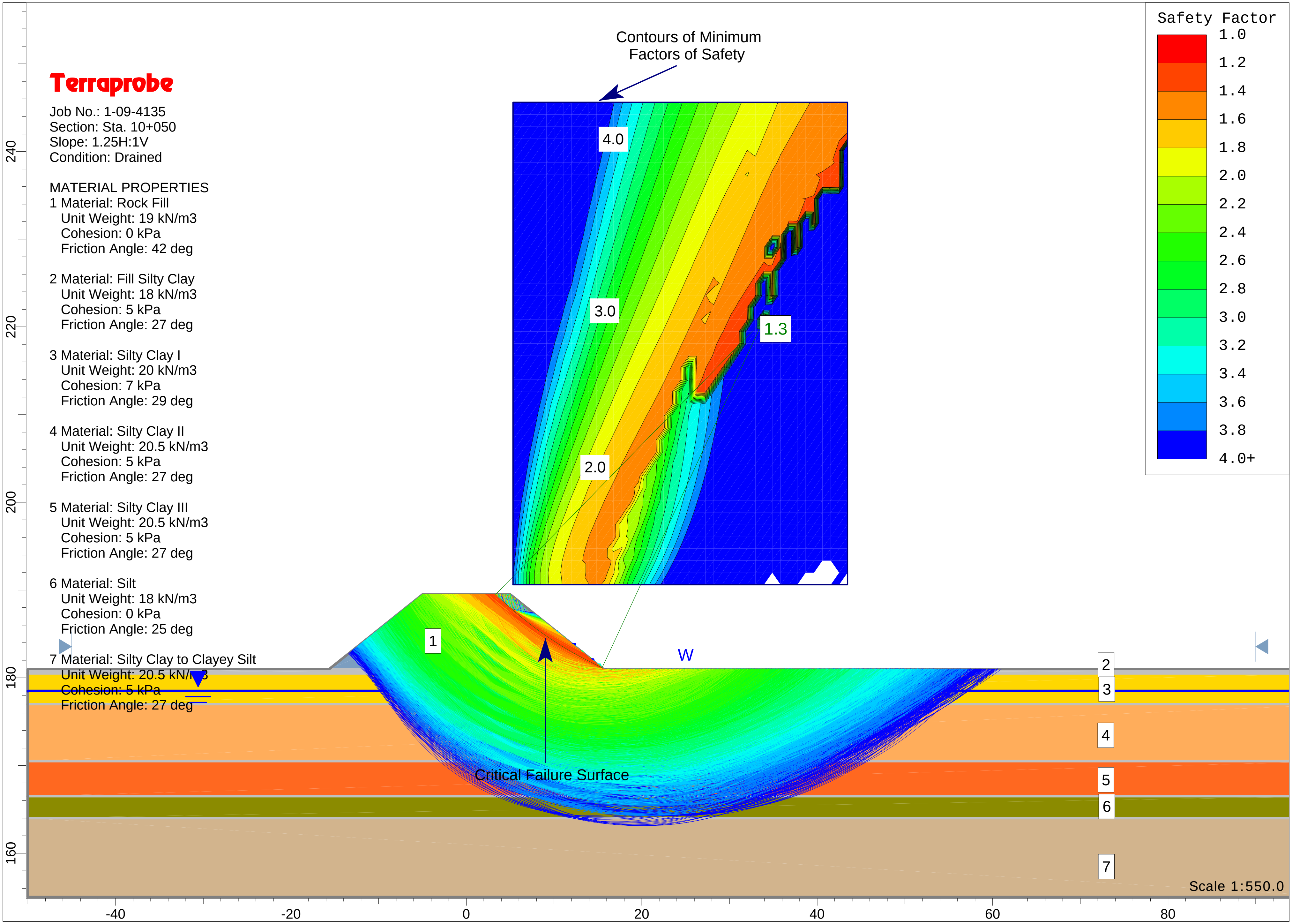

Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+050
Slope: 2H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 45 kPa
Friction Angle: 0 deg
5 Material: Silty Clay III
Unit Weight: 20.5 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
6 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
7 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 80 kPa
Friction Angle: 0 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
1.6
W
Critical Failure Surface
1
2
3
4
5
6
7
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
240
220
200
180
160
-40
-20
0
20
40
60
80
Scale 1:550.0

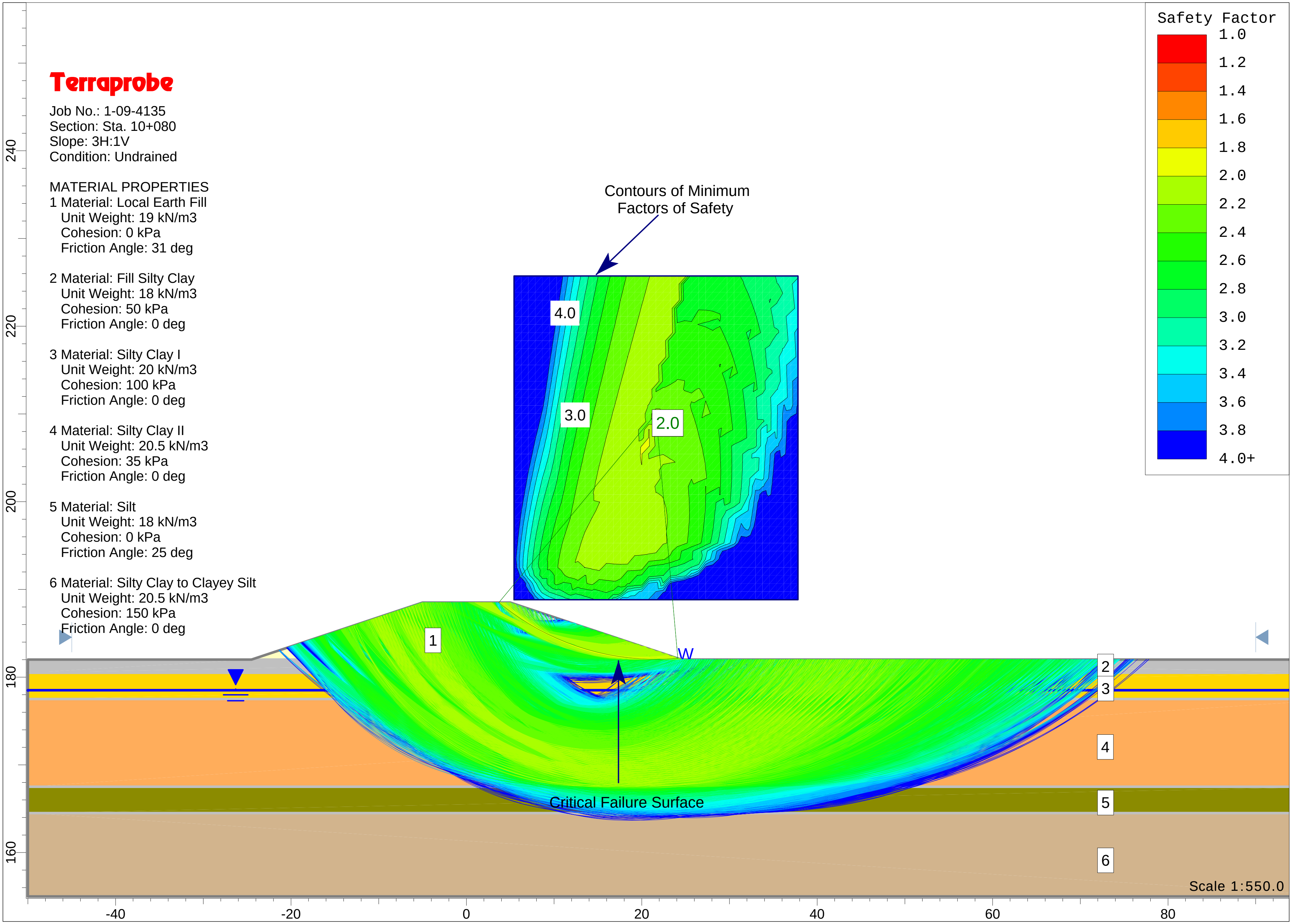


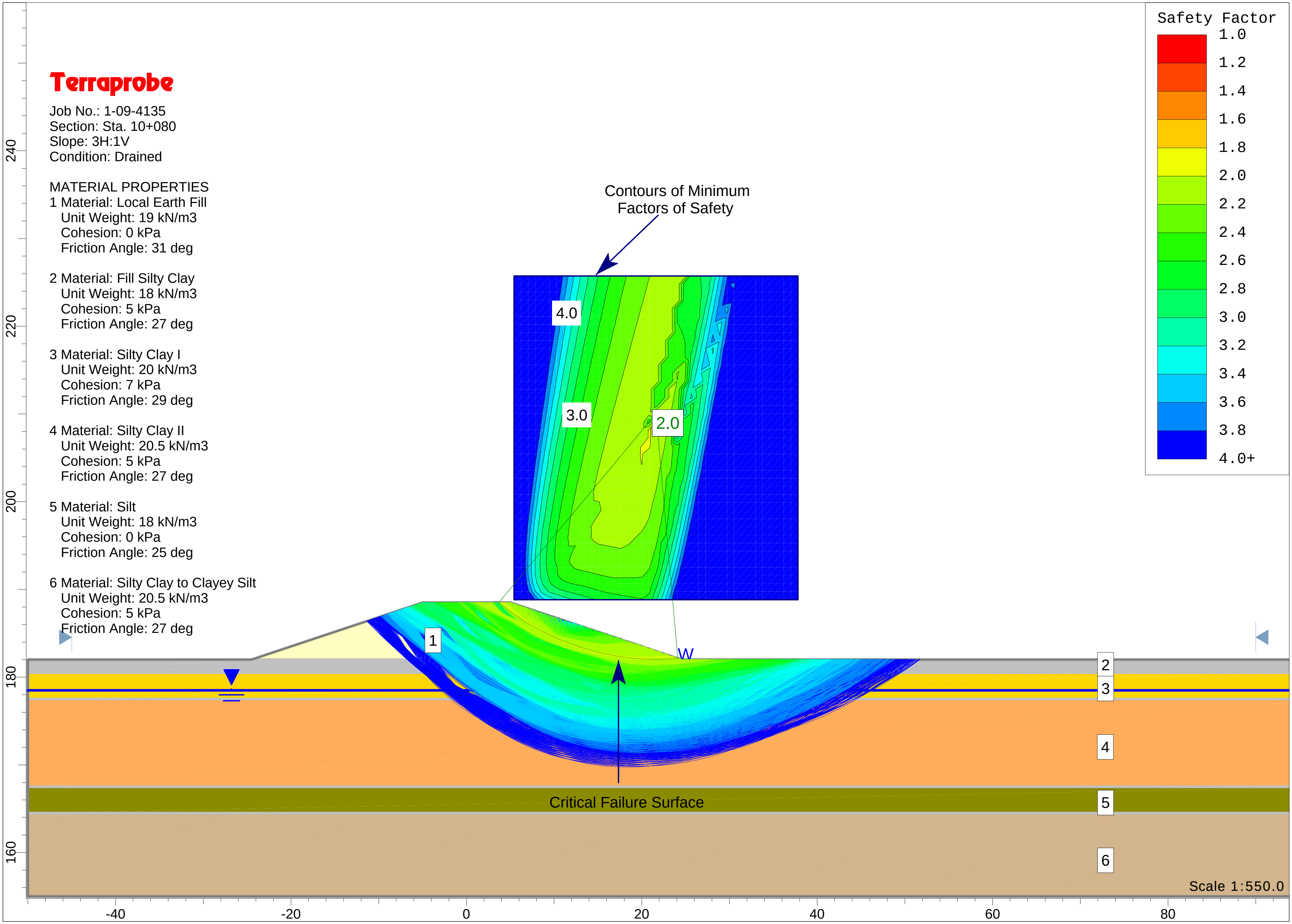
Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+050
Slope: 2H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silty Clay III
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
6 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
7 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
1.6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
W
Critical Failure Surface
Scale 1:550.0



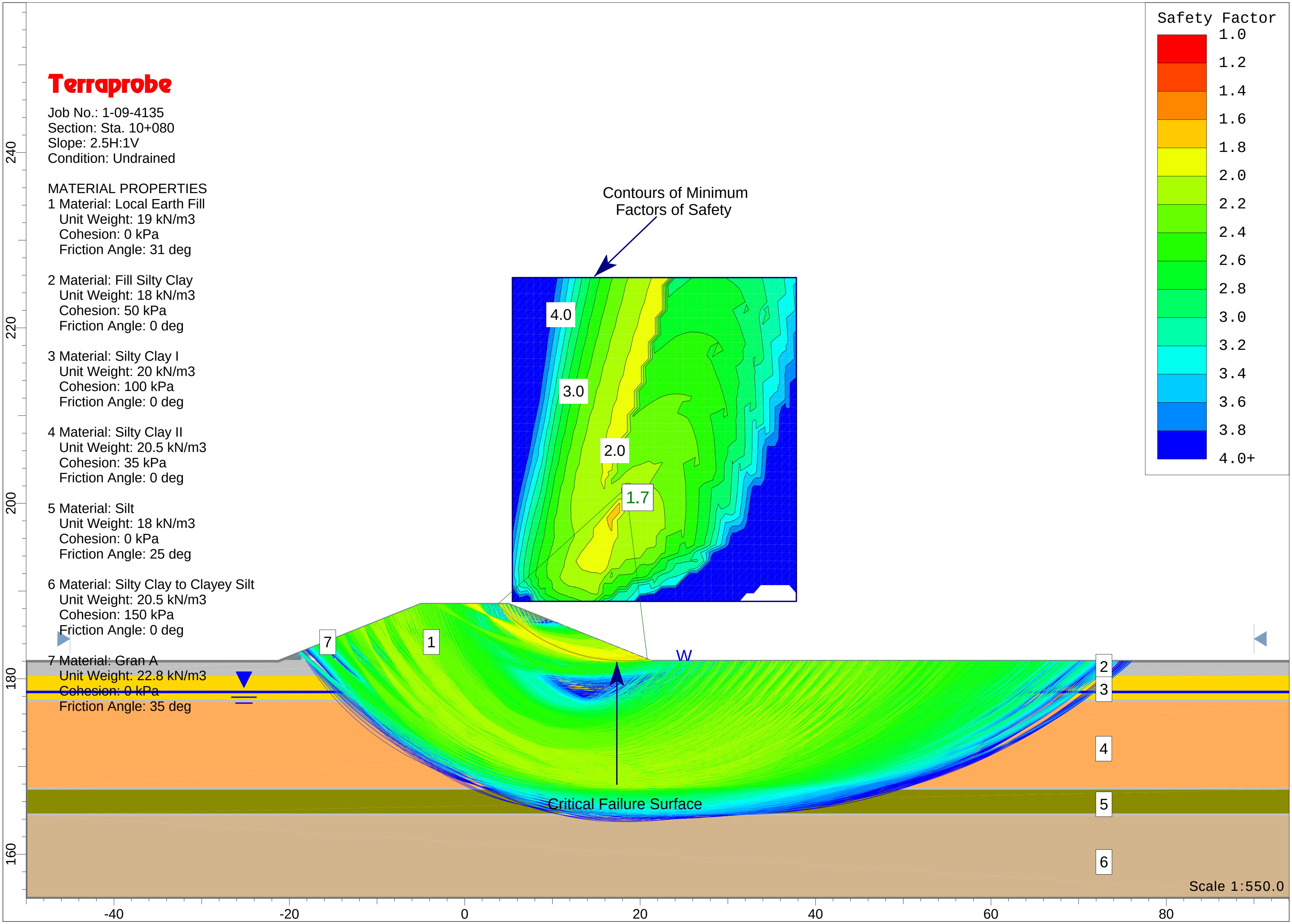
Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+050
Slope: 1.25H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Rock Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 42 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 45 kPa
Friction Angle: 0 deg
5 Material: Silty Clay III
Unit Weight: 20.5 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
6 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
7 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 80 kPa
Friction Angle: 0 deg
Contours of Minimum Factors of Safety
4.0
3.0
2.0
1.3
Critical Failure Surface
W
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80


Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+050
Slope: 1.25H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Rock Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 42 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silty Clay III
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
6 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
7 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
1.3
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
1
2
3
4
5
6
7
W
Critical Failure Surface
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

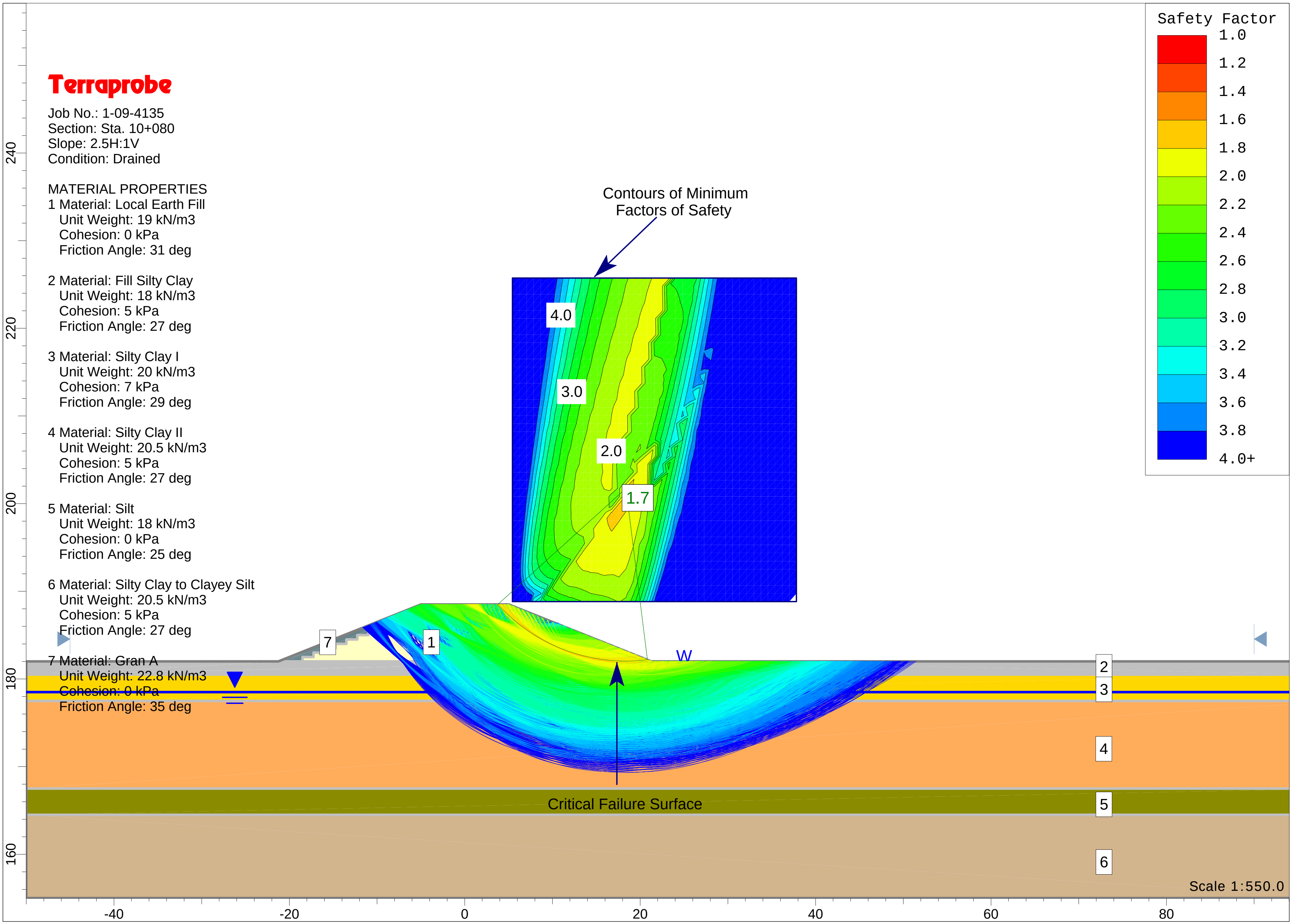

Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+080
Slope: 3H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
Contours of Minimum Factors of Safety
4.0
3.0
2.0
Critical Failure Surface
W
1
2
3
4
5
6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80



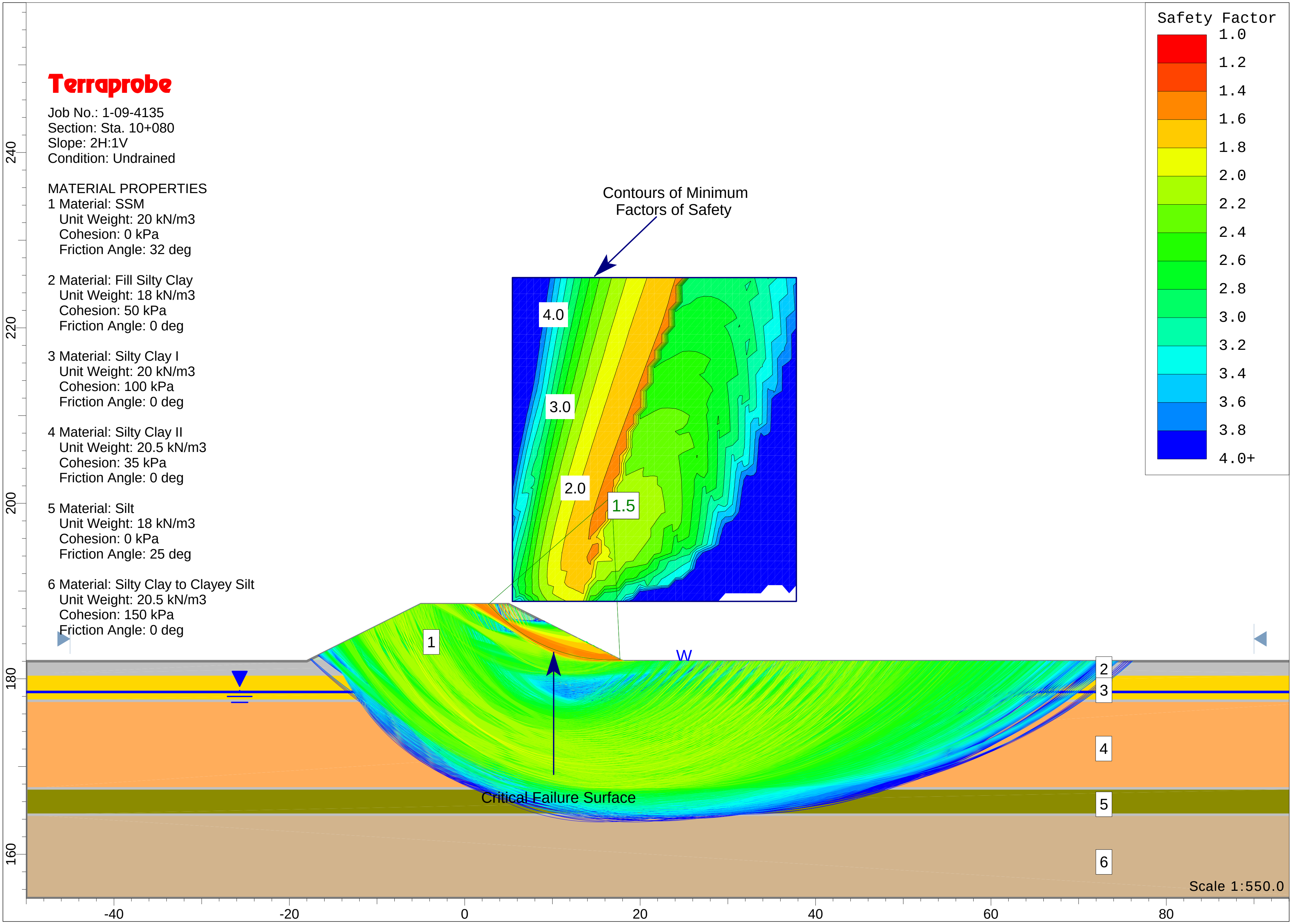
Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+080
Slope: 3H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
W
Critical Failure Surface
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80



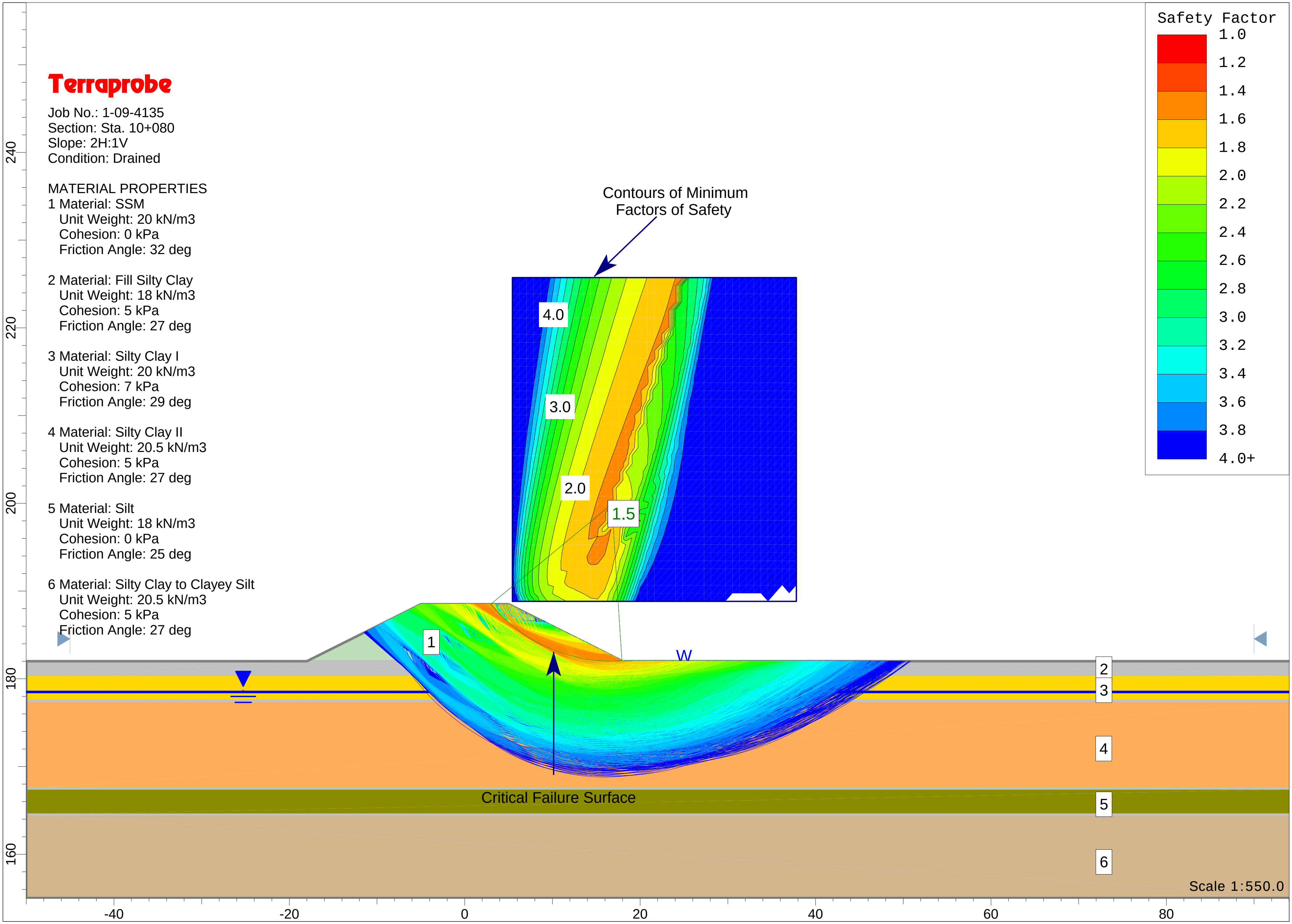
Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+080
Slope: 2.5H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
7 Material: Gran A
Unit Weight: 22.8 kN/m3
Cohesion: 0 kPa
Friction Angle: 35 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
1.7
Critical Failure Surface
W
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

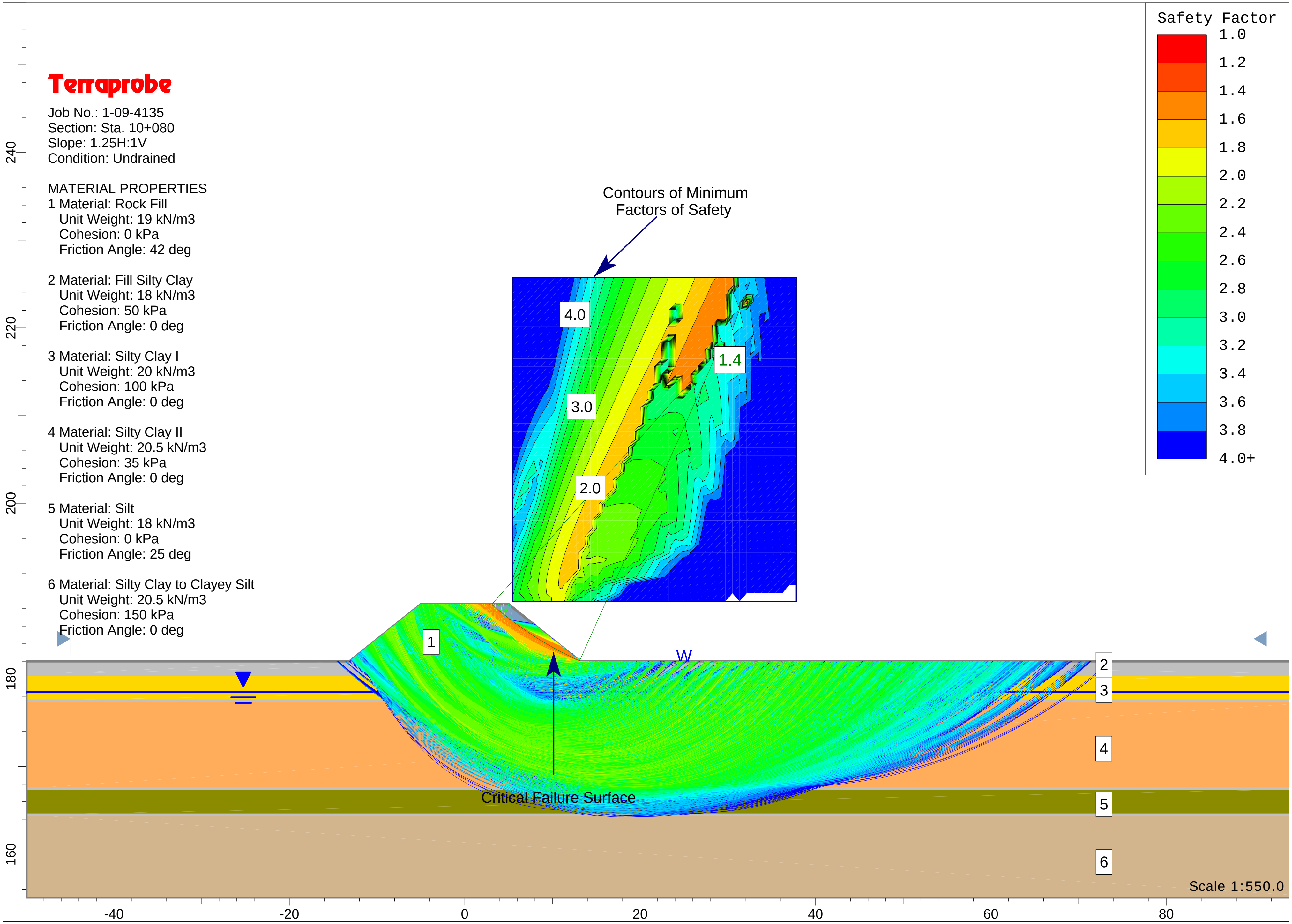


Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+080
Slope: 2.5H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
7 Material: Gran A
Unit Weight: 22.8 kN/m3
Cohesion: 0 kPa
Friction Angle: 35 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
1.7
Critical Failure Surface
W
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

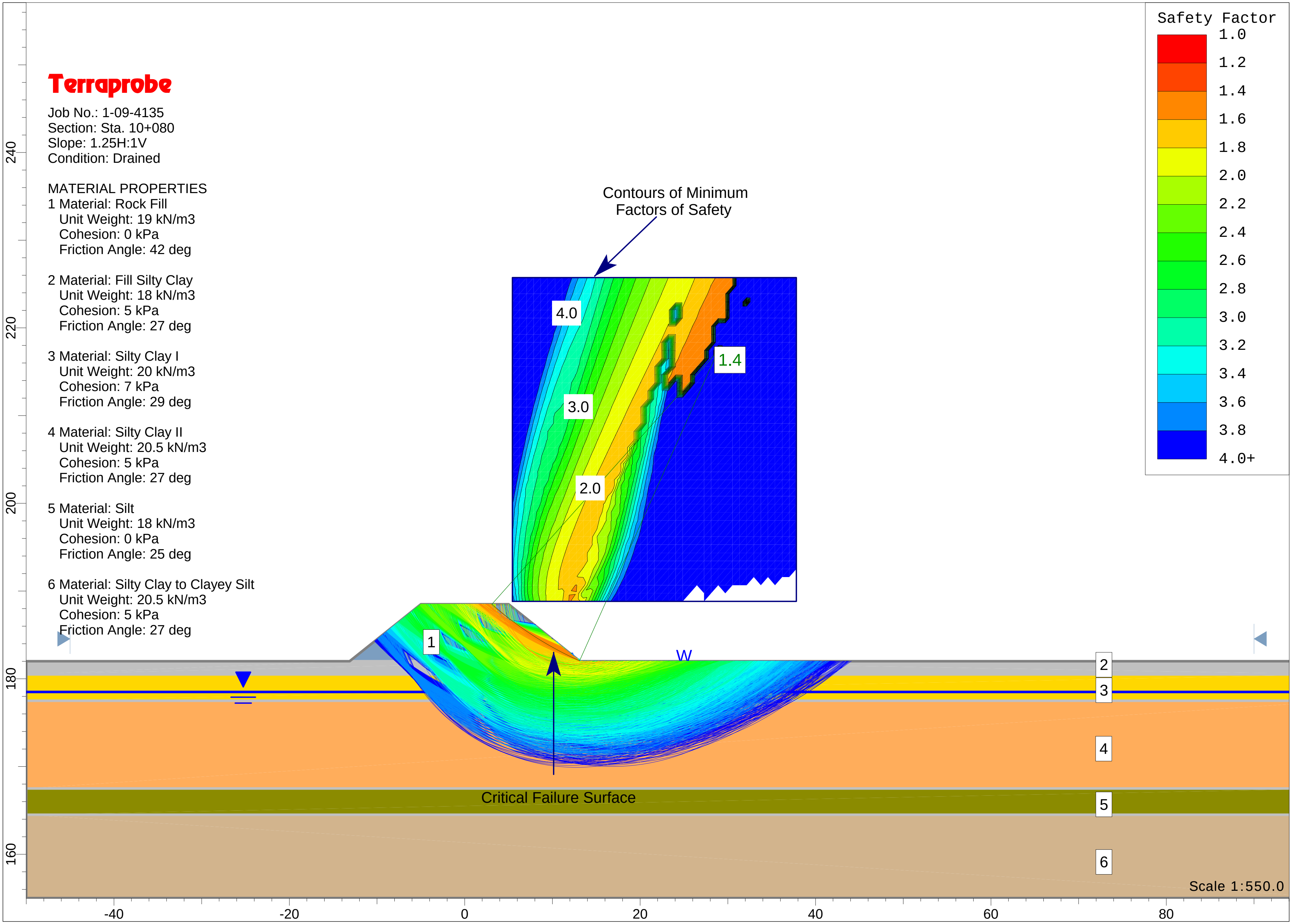


Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+080
Slope: 2H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
1.5
Critical Failure Surface
W
1
2
3
4
5
6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

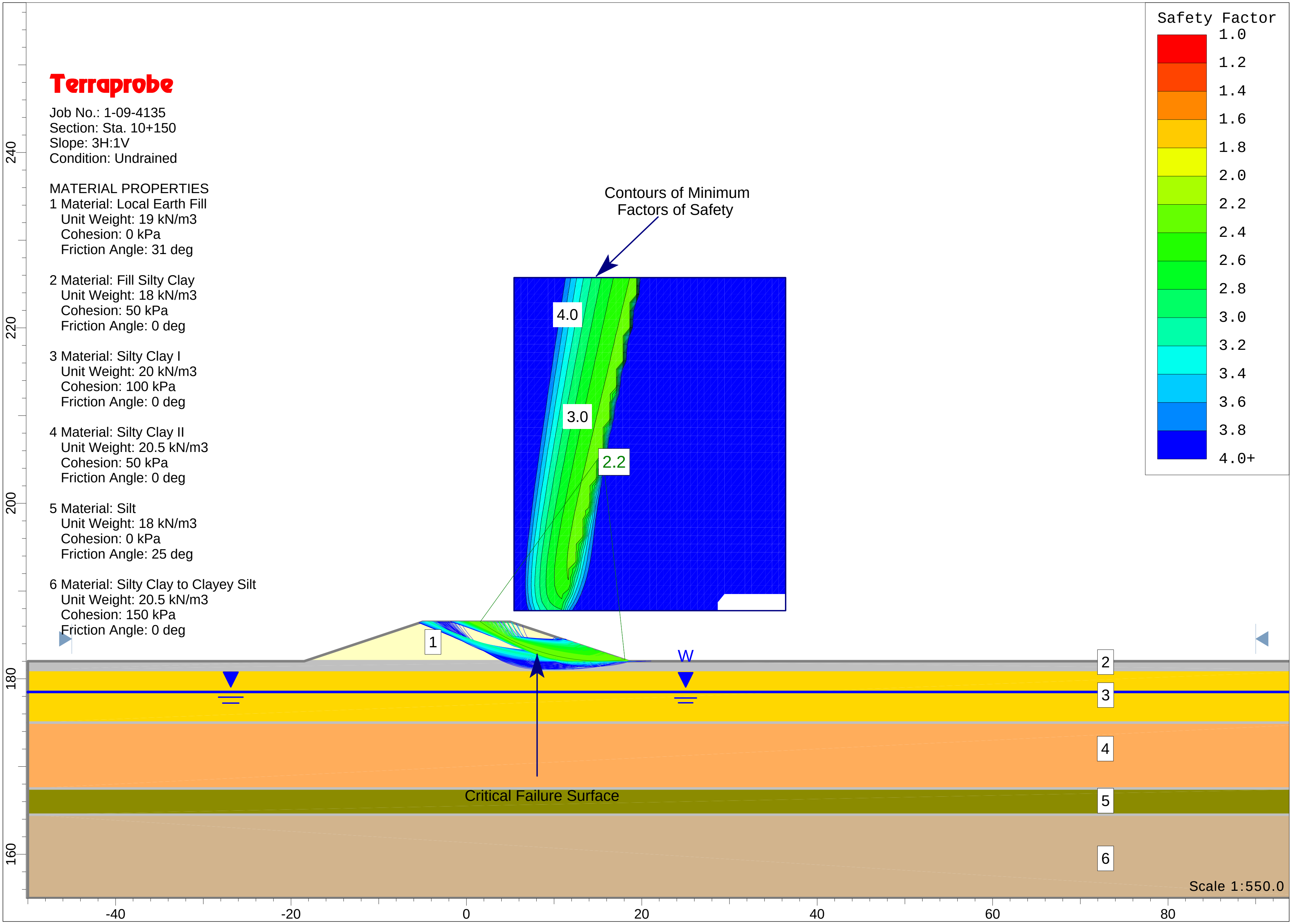

Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+080
Slope: 2H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum Factors of Safety
4.0
3.0
2.0
1.5
Critical Failure Surface
W
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

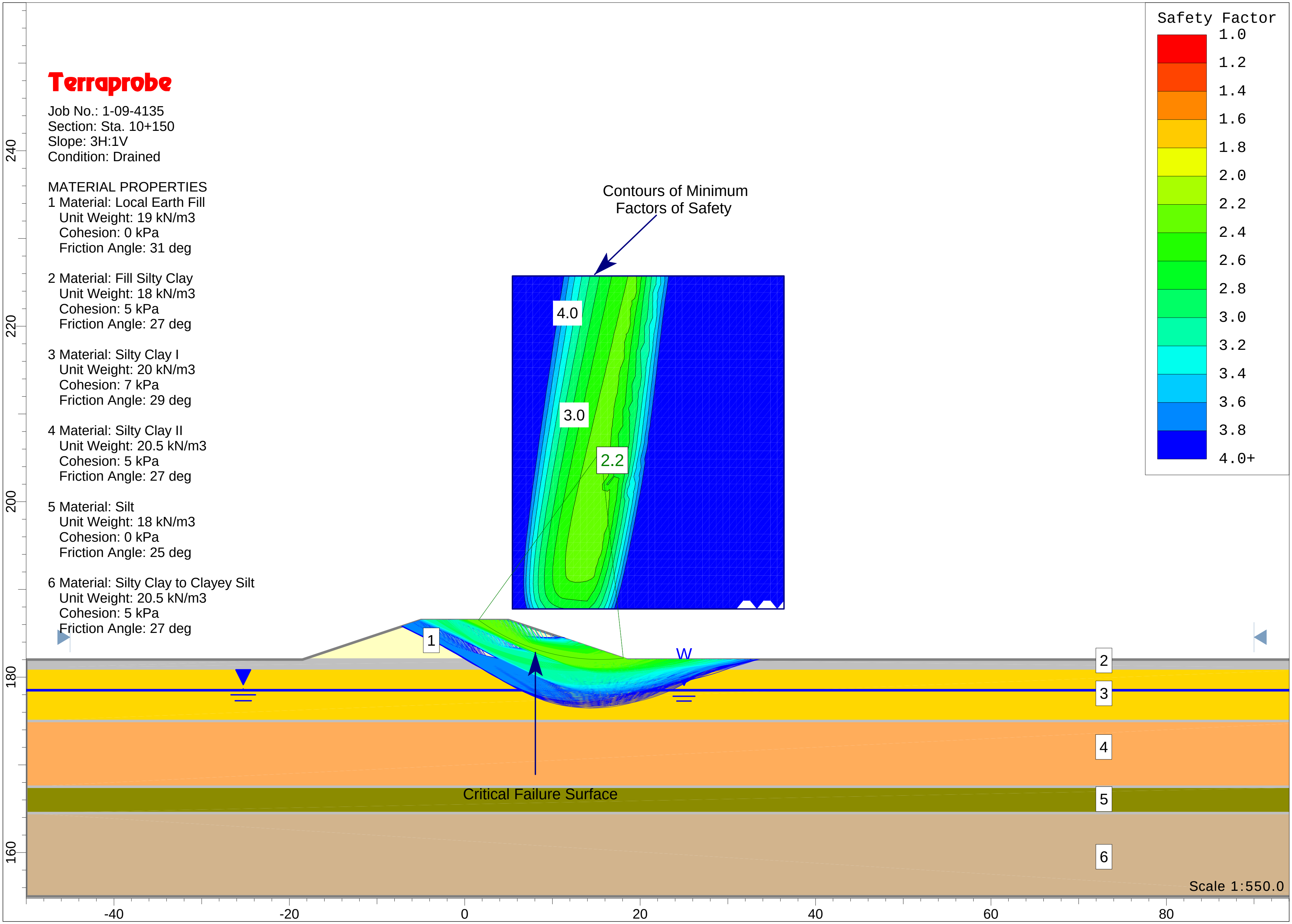


Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+080
Slope: 1.25H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Rock Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 42 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
Contours of Minimum Factors of Safety
4.0
3.0
2.0
1.4
Critical Failure Surface
W
1
2
3
4
5
6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

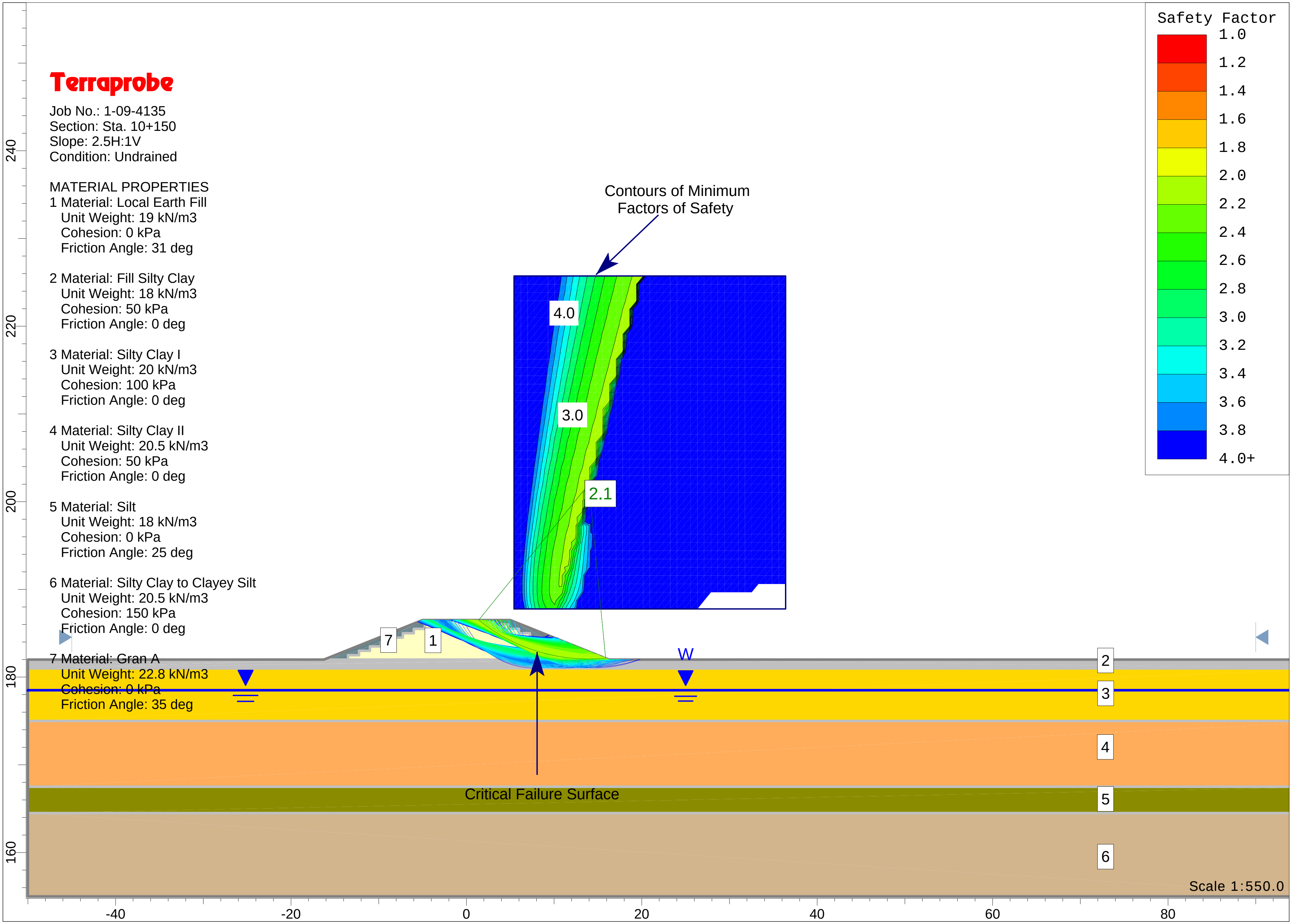


Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+080
Slope: 1.25H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Rock Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 42 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
1.4
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
1
2
3
4
5
6
W
Critical Failure Surface
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

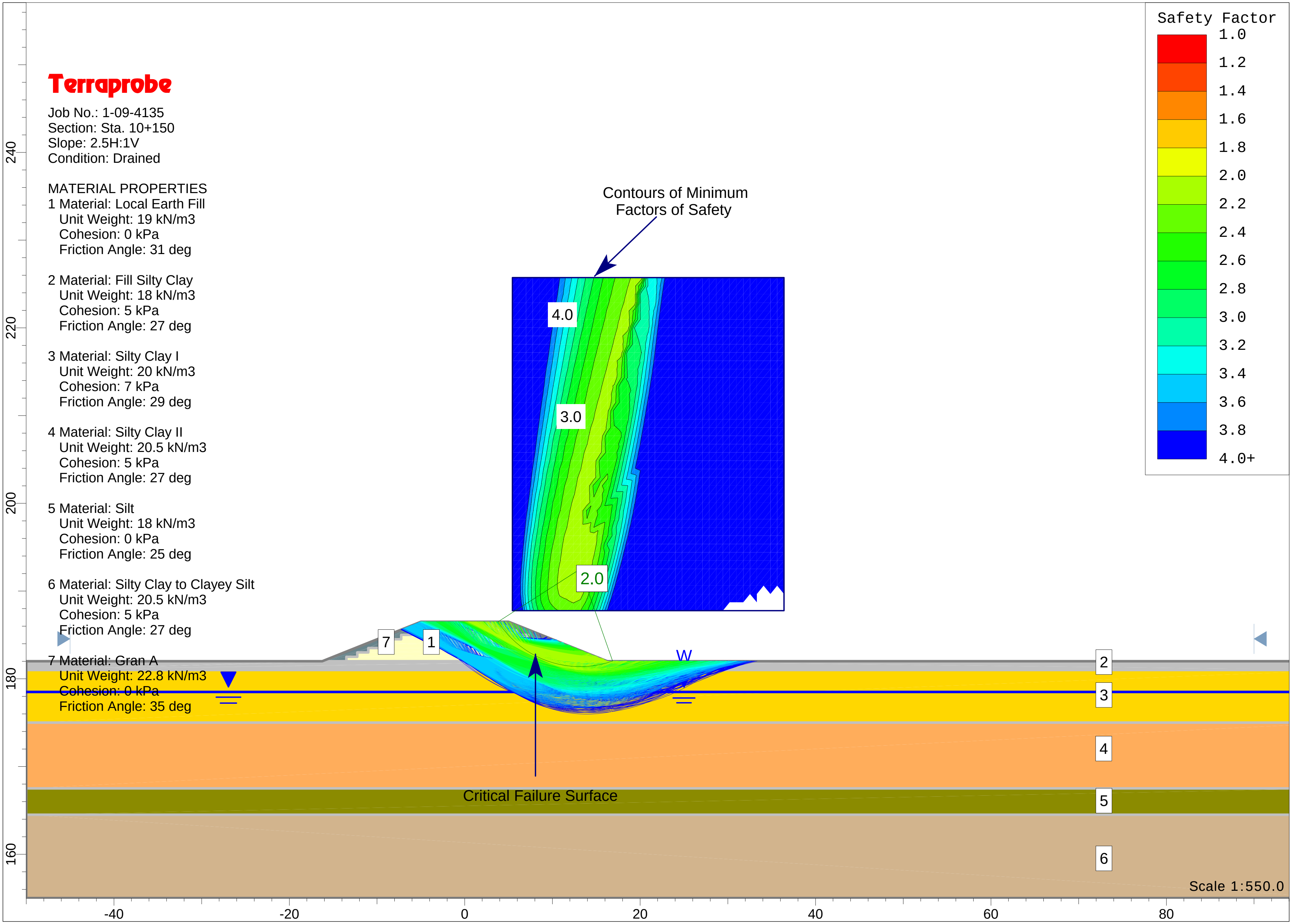

Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+150
Slope: 3H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.2
Critical Failure Surface
W
1
2
3
4
5
6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80



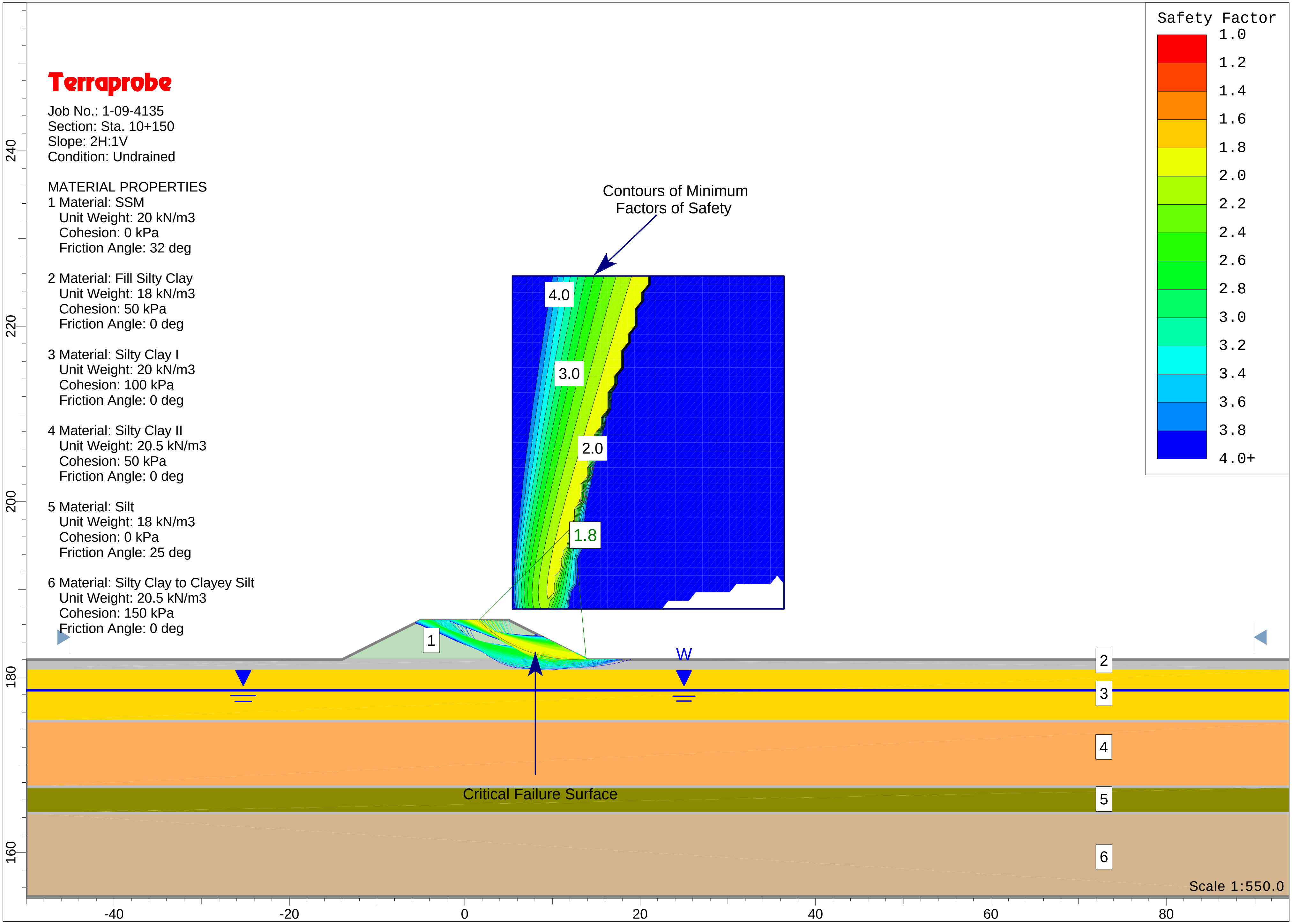
Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+150
Slope: 3H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.2
Critical Failure Surface
W
1
2
3
4
5
6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

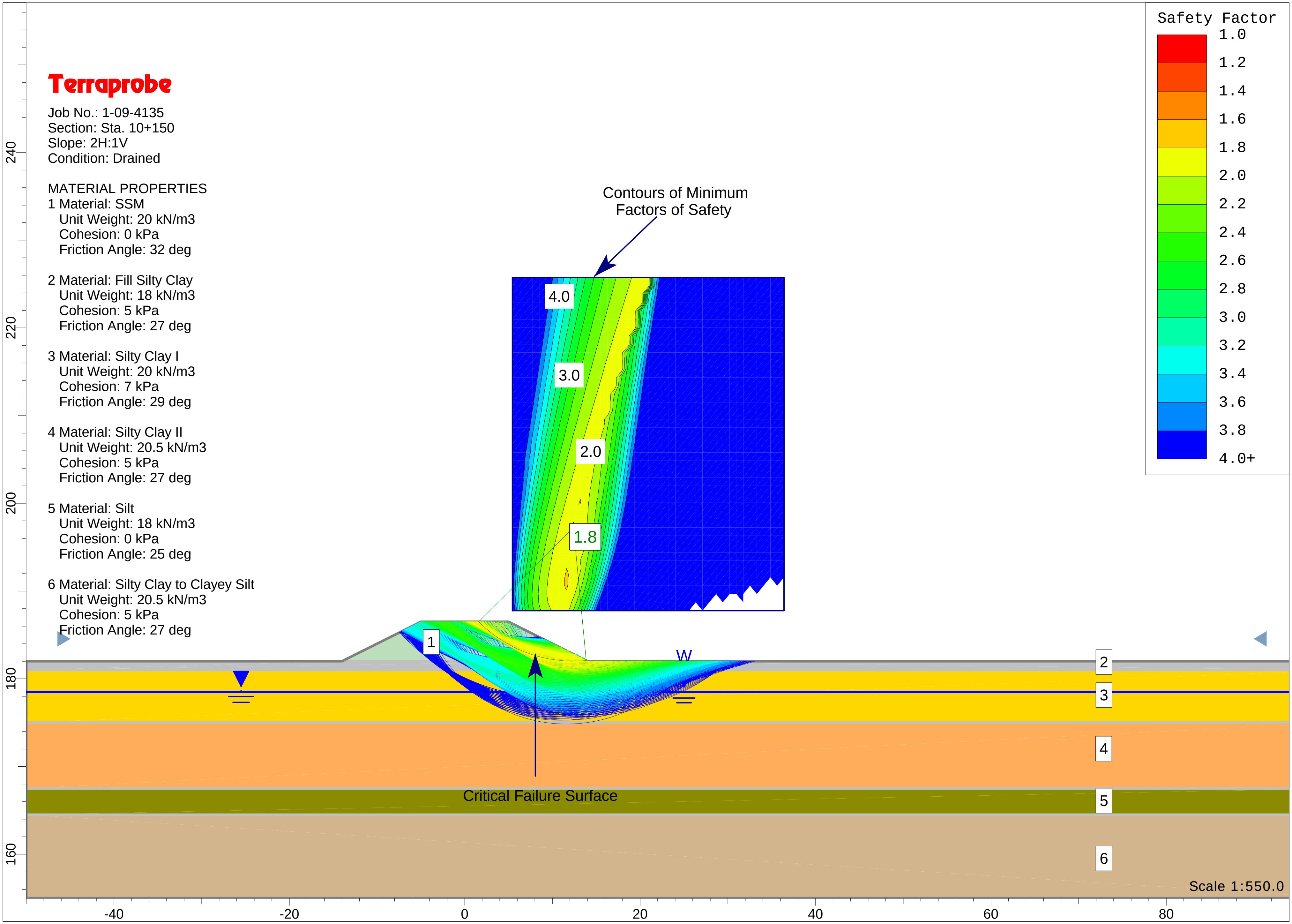


Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+150
Slope: 2.5H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
7 Material: Gran A
Unit Weight: 22.8 kN/m3
Cohesion: 0 kPa
Friction Angle: 35 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.1
Critical Failure Surface
W
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

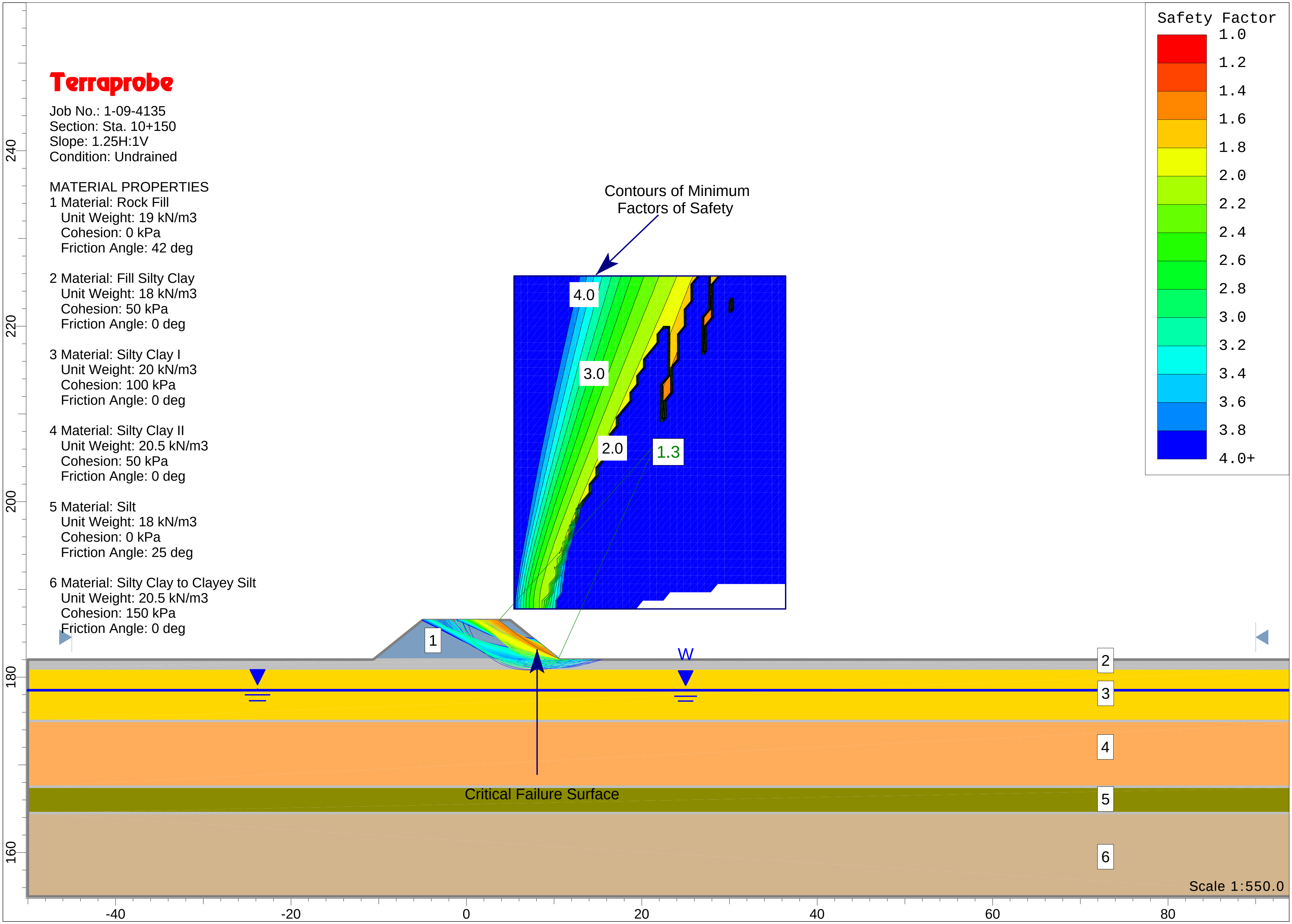


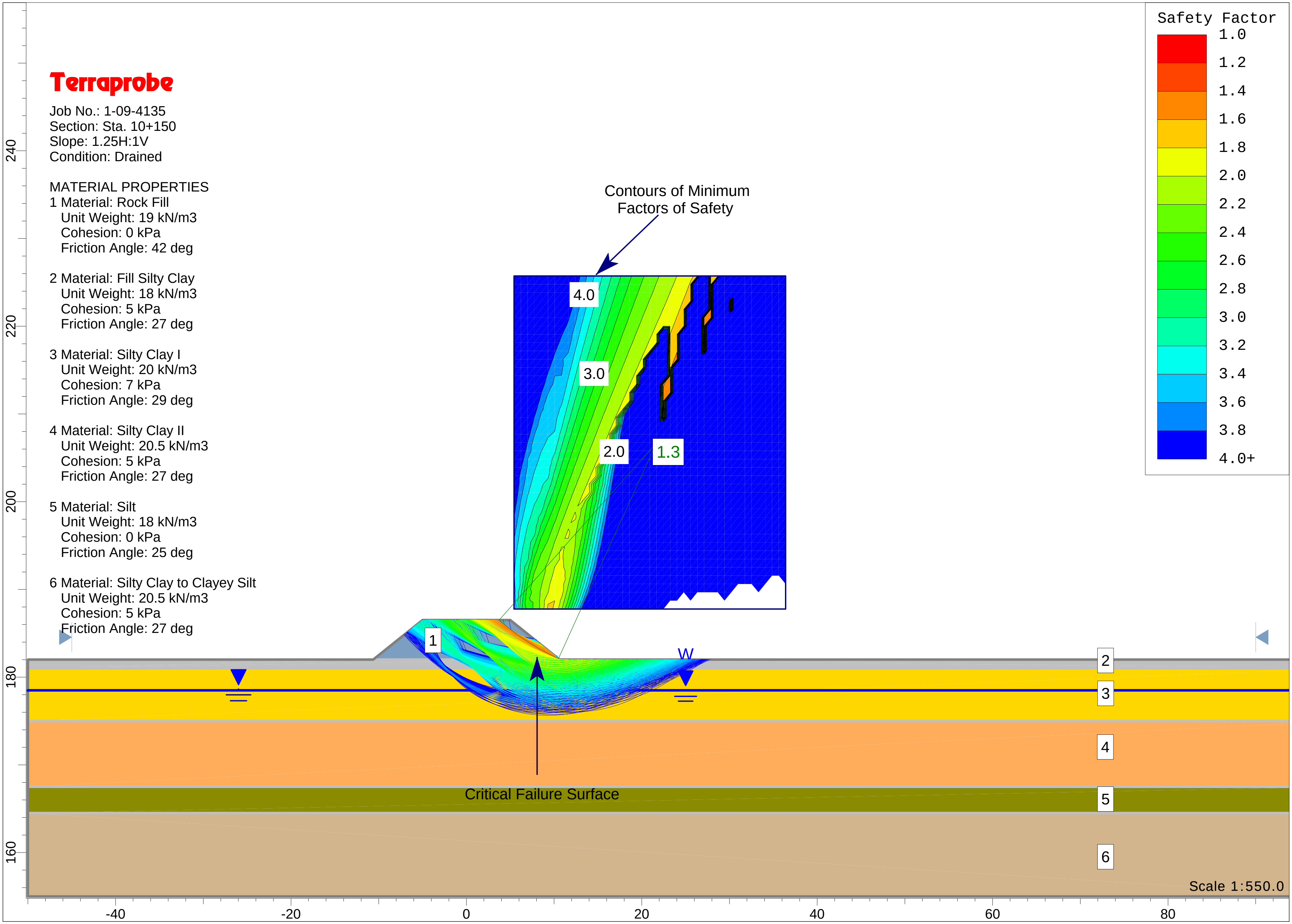
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+150
Slope: 2.5H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Local Earth Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 31 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
7 Material: Gran A
Unit Weight: 22.8 kN/m3
Cohesion: 0 kPa
Friction Angle: 35 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
W
Critical Failure Surface
Scale 1:550.0


Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+150
Slope: 2H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
Contours of Minimum Factors of Safety
4.0
3.0
2.0
1.8
Critical Failure Surface
W
1
2
3
4
5
6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80



Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+150
Slope: 2H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum
Factors of Safety
4.0
3.0
2.0
1.8
Critical Failure Surface
W
1
2
3
4
5
6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80


Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+150
Slope: 1.25H:1V
Condition: Undrained
MATERIAL PROPERTIES
1 Material: Rock Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 42 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 150 kPa
Friction Angle: 0 deg
Contours of Minimum Factors of Safety
4.0
3.0
2.0
1.3
Critical Failure Surface
W
1
2
3
4
5
6
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80



Terraprobe
Job No.: 1-09-4135
Section: Sta. 10+150
Slope: 1.25H:1V
Condition: Drained
MATERIAL PROPERTIES
1 Material: Rock Fill
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 42 deg
2 Material: Fill Silty Clay
Unit Weight: 18 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
3 Material: Silty Clay I
Unit Weight: 20 kN/m3
Cohesion: 7 kPa
Friction Angle: 29 deg
4 Material: Silty Clay II
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
5 Material: Silt
Unit Weight: 18 kN/m3
Cohesion: 0 kPa
Friction Angle: 25 deg
6 Material: Silty Clay to Clayey Silt
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 27 deg
Contours of Minimum Factors of Safety
4.0
3.0
2.0
1.3
Safety Factor
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0+
Critical Failure Surface
W
1
2
3
4
5
6
Scale 1:550.0
240
220
200
180
160
-40
-20
0
20
40
60
80

APPENDIX E

Comparison of Embankment Alternatives

Terraprobe Inc.

COMPARISON OF EMBANKMENT ALTERNATIVES

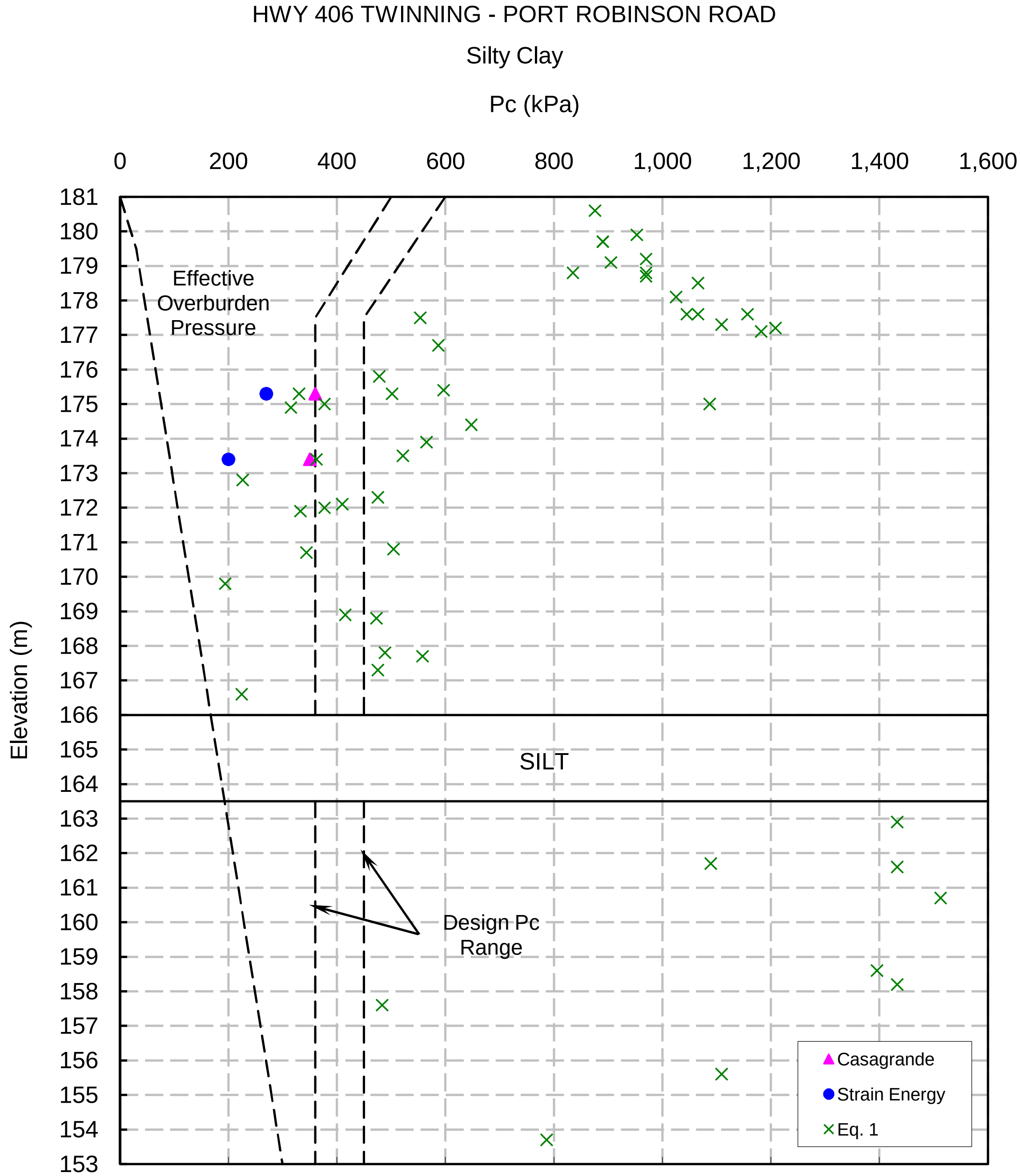
Local Earth Borrow	Composite Embankment	SSM Embankment	Rock Fill Embankment
Advantages: i. Material readily available and less costly to import. ii. Easy to place and compact. ***Disadvantages:*** i. Requires relatively flat 3H:1V side slopes because of known performance related issues with cohesive fill. ii. Requires a larger embankment footprint that may conflict with adjacent highway elements. iii. Must be instrumented and monitored until consolidation settlement is complete.	***Advantages:*** i. Can be constructed at steeper side slopes compared to local earth borrow. ii. Smaller embankment footprint than local earth borrow. ***Disadvantages:*** i. Relatively high construction effort required i.e. benching and placement of dissimilar materials. ii. More costly than using local earth borrow. iii. Little MTO case history on performance. iv. Must be instrumented and monitored until consolidation settlement is complete	***Advantages:*** i. Can be constructed at conventional 2H:1V slopes. ii. Conventional embankment footprint. iii. Proven reliable performance on MTO projects. ***Disadvantages:*** i. More costly than earth borrow. ii. Requires stringent quality control to ensure that only approved material is selected and used. iii. Must be instrumented and monitored until consolidation settlement is complete	***Advantages:*** i. Can be constructed at 1.25H:1V slopes. ii. Small embankment footprint. iii. Proven reliable performance on MTO projects. ***Disadvantages:*** i. Material may not be readily available compared to local earth borrow. ii. Must be instrumented and monitored until consolidation settlement is complete.
Risks/Consequences i. Low risk of future stability issues and less costly preventative maintenance provided 3H:1V slopes are used. ii. Larger footprint area may conflict with adjacent highway elements.	***Risks/Consequences*** i. Low risk of shallow failures. ii. No documented MTO case history on performance. iii. Large footprint area may conflict with adjacent highway elements.	***Risks/Consequences*** i. Very low risk of failure. ii. Relatively higher material cost.	***Risks/Consequences*** i. Very low risk of failure. ii. Higher construction effort required to widen embankment in the future.
APPROXIMATE COSTS			
$ 7.65 per cubic metre	$ 46.00 per cubic metre	$ 23.00 per cubic metre	$29.00 per cubic metre

APPENDIX F

Settlement Parameters and Results

Terraprobe Inc.

PREDICTED AND MEASURED PRECONSOLIDATION STRESS	FIGURE F1



Eq. 1 $Pc = Cu / (0.11 + 0.0037 * I_P)$ Skempton (1957)

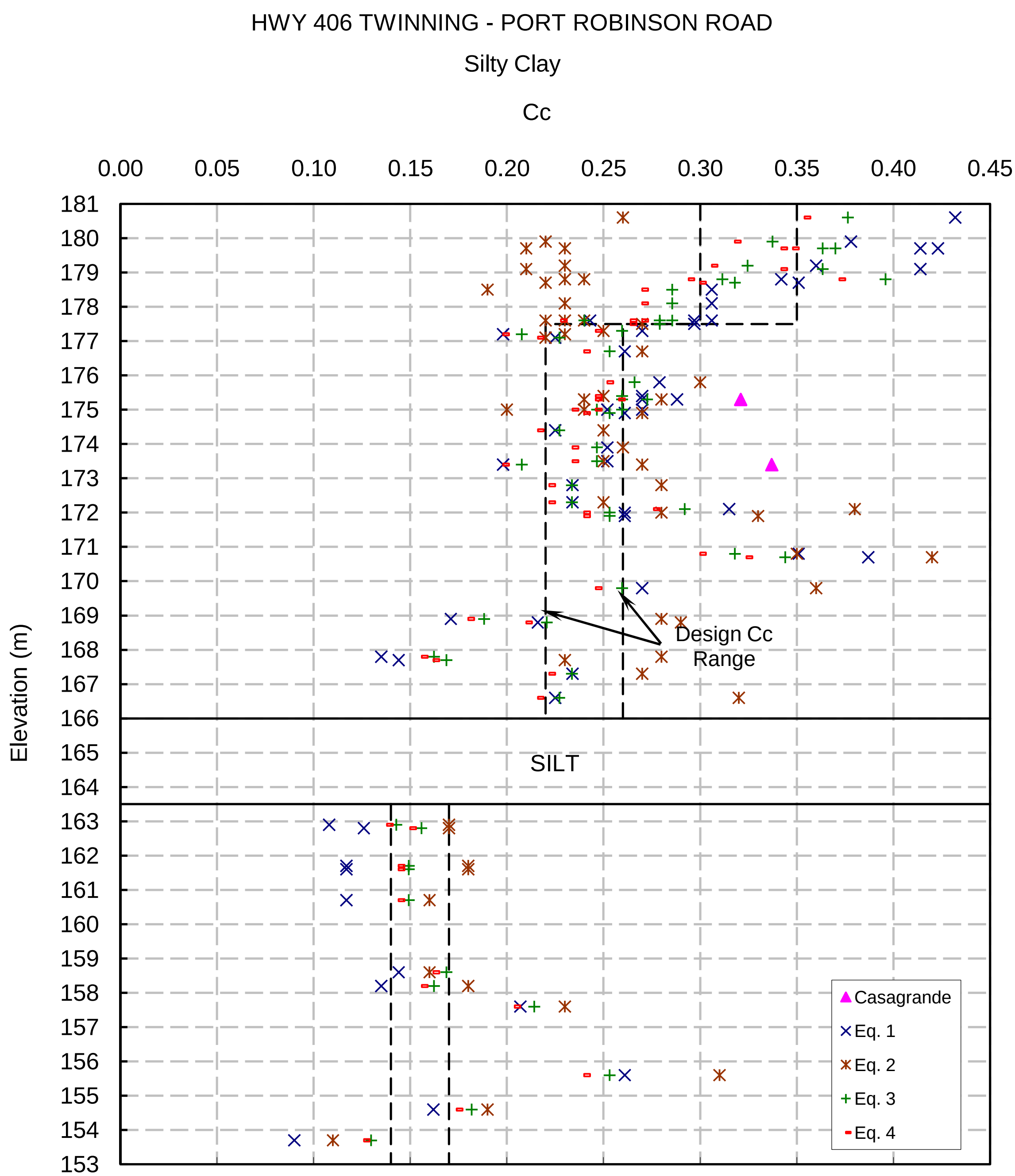
C:\Documents and Settings\Hongliu\My Documents\Project 2009\1-09-4135 - HWY 406 Foundations\Port Robinson Rd\Copy of 1-09-4135 Soil Parameter Estimation-PR.xls

Project No. : 1-09-4135
Date : September, 2010

Terraprobe Inc.

Prepared By : HW
Checked By : RA

PREDICTED AND MEASURED COMPRESSION INDEX	FIGURE F2



Eq. 1	Cc = 0.009 * (LL - 10)	Terzaghi & Peck (1967)
Eq. 2	Cc = 0.01 * ω	Osterberg (1972)
Eq. 3	Cc = 0.002343 * LL * Gs	Nagaraj & Murty (1985)
Eq. 4	Cc = 0.006 * (LL + 1)	Lav & Ansal (2001)

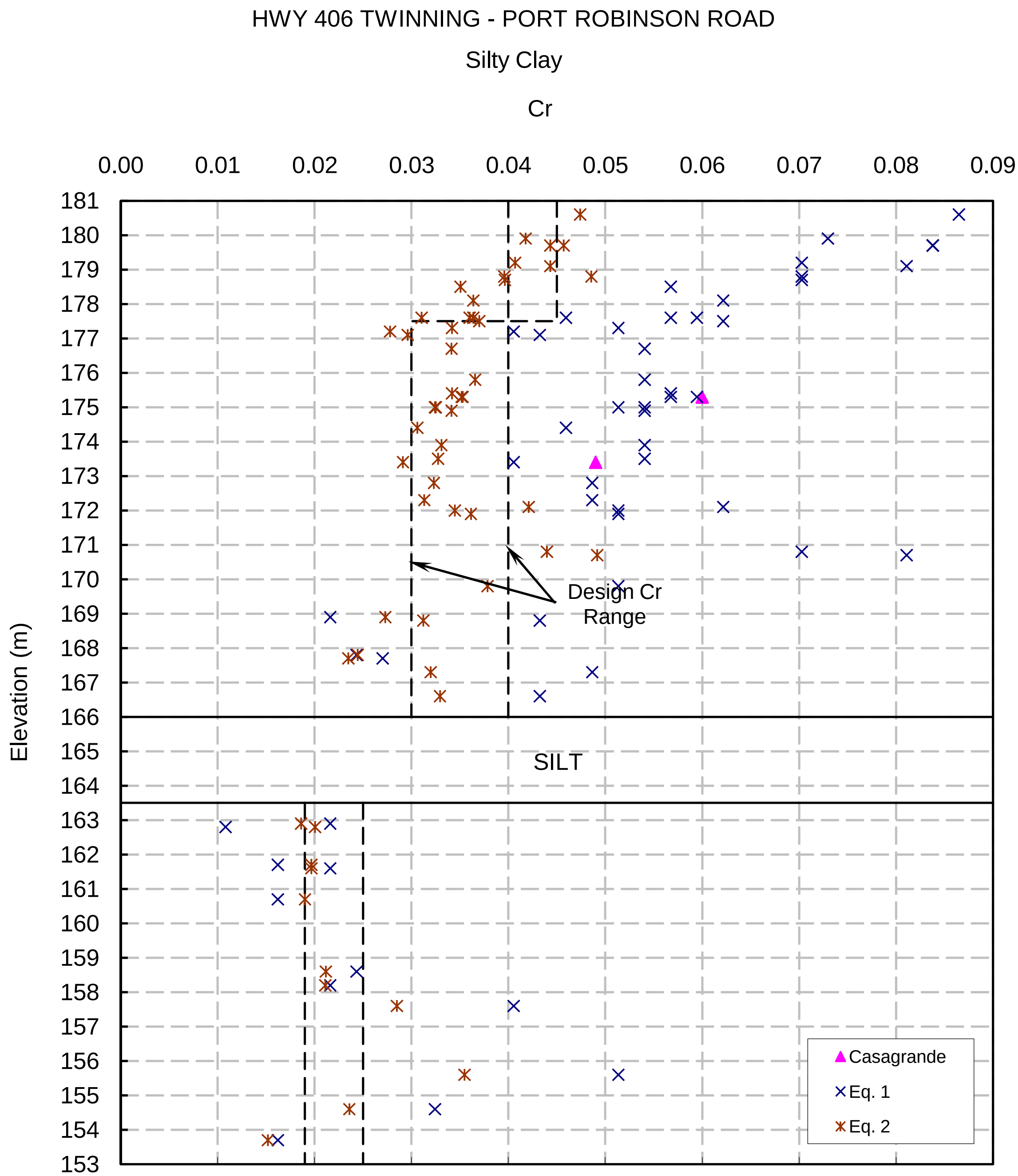
Project No. : 1-09-4135
Date : September, 2010

Terraprobe Inc.

Prepared By : HW
Checked By : RA

C:\Documents and Settings\Hongliu\My Documents\Project 2009\1-09-4135 - HWY 406 Foundations\Port Robinson Rd\Copy of 1-09-4135 Soil Parameter Estimation-PR.xls

PREDICTED AND MEASURED RECOMPRESSION INDEX	FIGURE F3



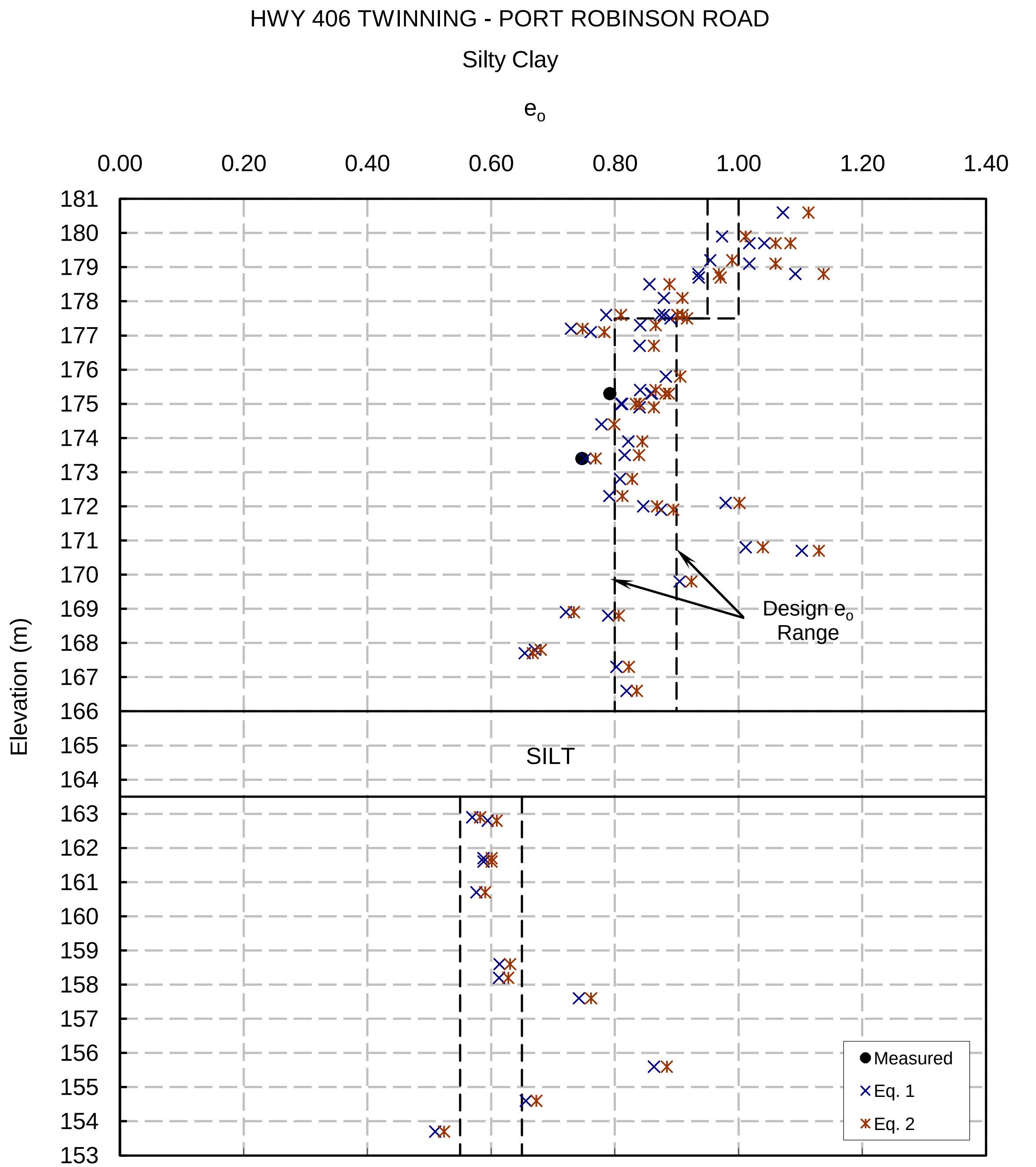
Eq. 1	Cr = Ip / 370	Kulhawy & Mayne (1990)
Eq. 2	Cr = Cc / 5 ~ Cc / 10	Das (1993)

Project No. : 1-09-4135
Date : September, 2010

Terraprobe Inc.

Prepared By : HW
Checked By : RA

PREDICTED AND MEASURED VOID RATIO	FIGURE F4



Eq. 1 $e_o = (Cc - 0.256) / 0.43 + 0.84$ derived from Cozzolino (1961)

Eq. 2 $e_o = Cc / 0.40 - 0.001 * \omega + 0.25$ derived from Azzouz et al. (1976)

C:\Documents and Settings\Hongliu\My Documents\Project 2009\1-09-4135 - HWY 406 Foundations\Port Robinson Rd\Copy of 1-09-4135 Soil Parameter Estimation-PR.xls

Project No. : 1-09-4135

Date : September, 2010

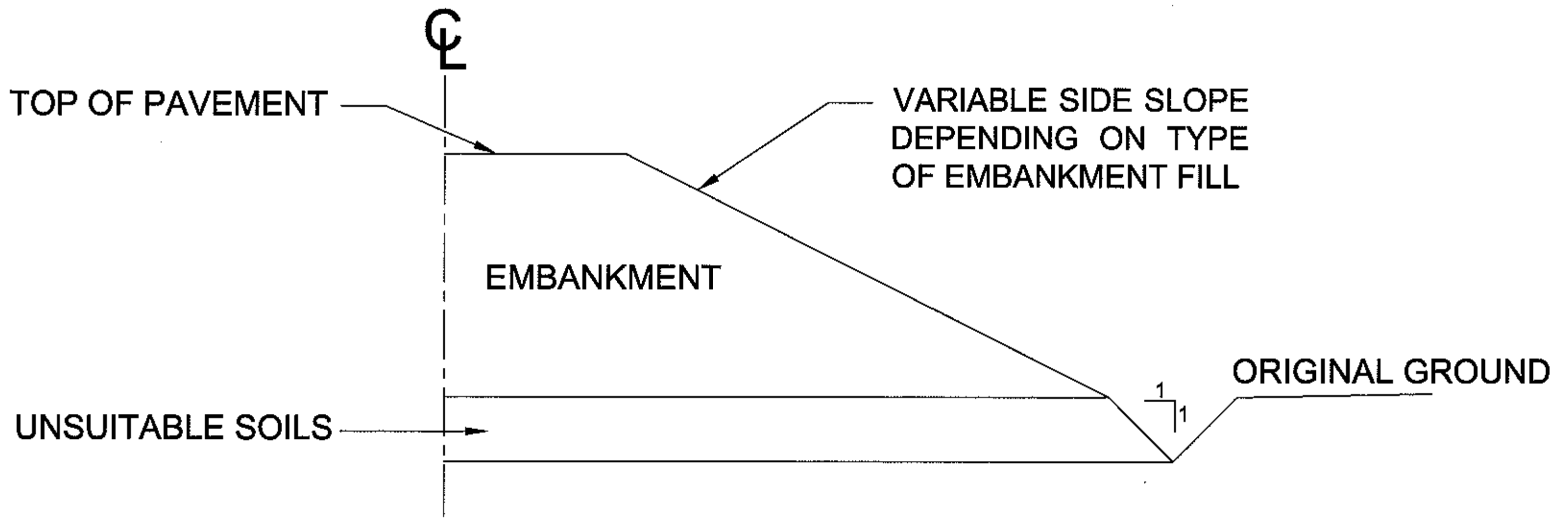
Terraprobe Inc.

Prepared By : HW

Checked By : RA

APPENDIX G
Figures

Terraprobe Inc.



FILL SECTION

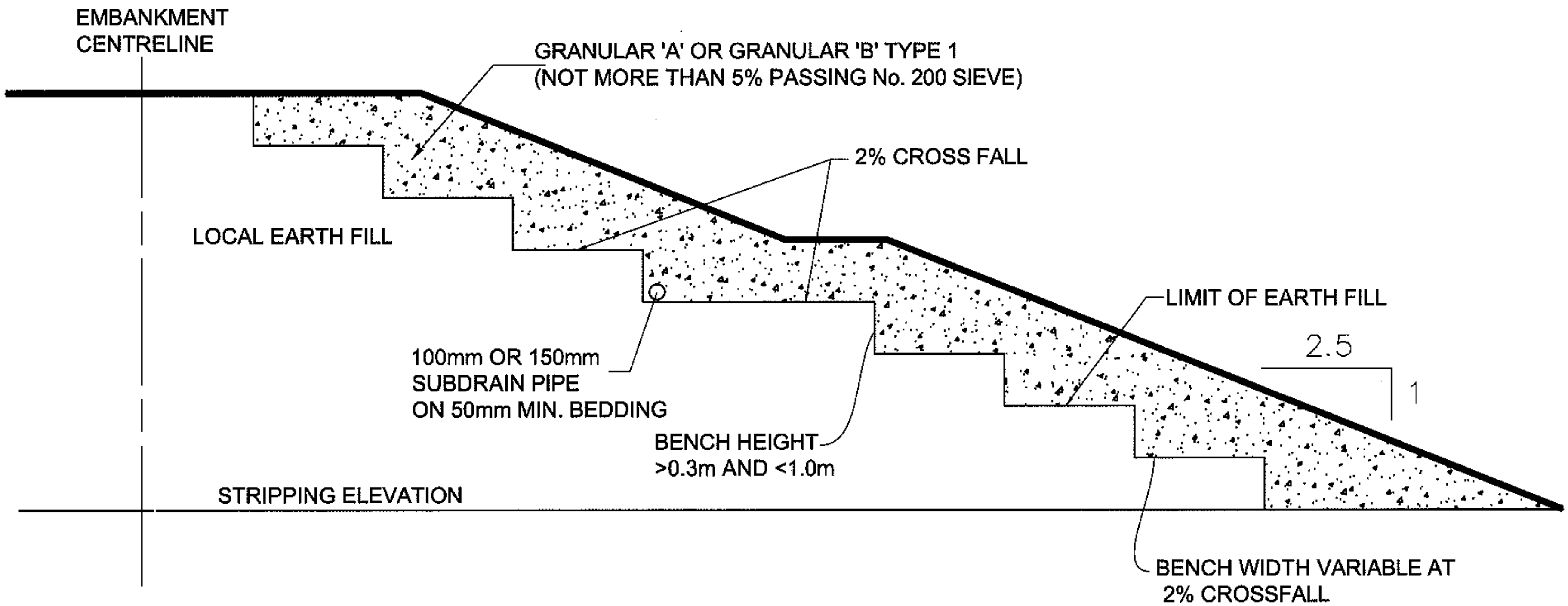
N.T.S

ENVELOPE FOR REMOVAL OF UNSUITABLE MATERIAL

TERRAPROBE

File No. 1-09-4135

FIGURE G1



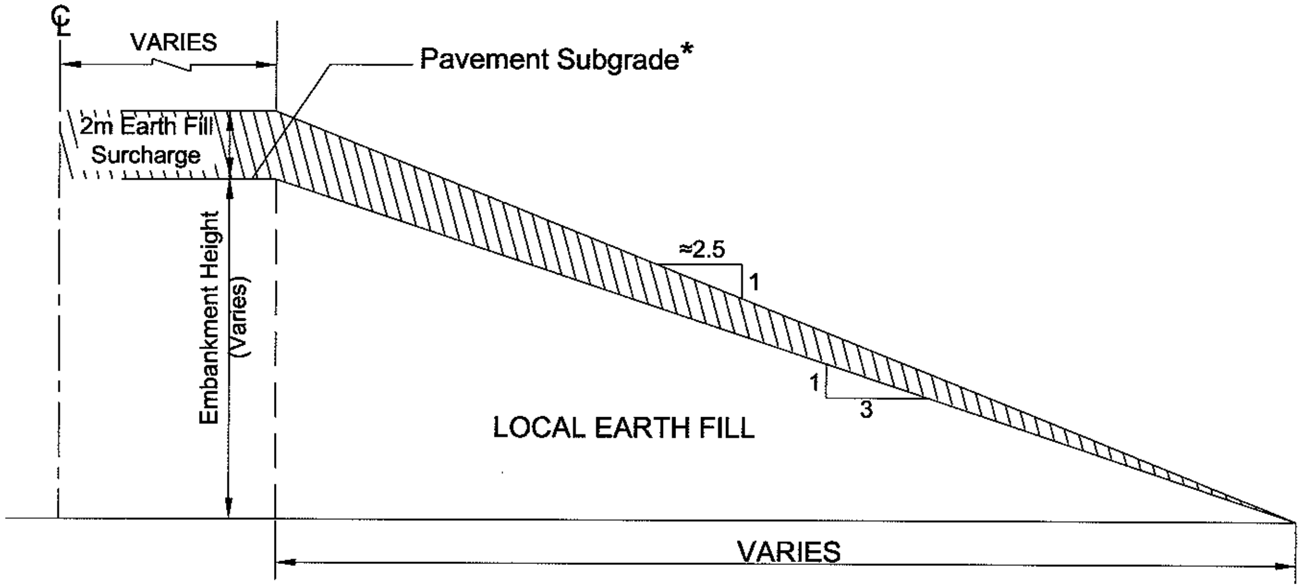
NOTES: FLOW FROM SUBDRAIN PIPE TO OUTLET FREELY AND BE DIRECTED TO ARMOURED OUTFALLS /OUTLETS DESIGNED TO DRAIN INTO ROADSIDE DITCHES.

N.T.S.

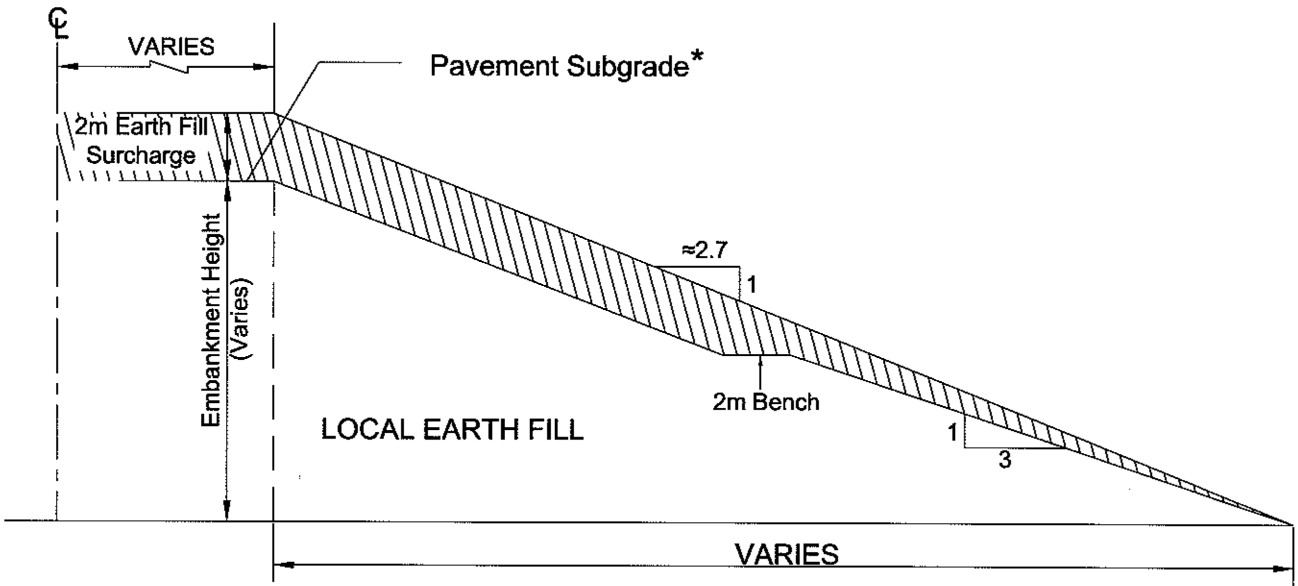
COMPOSITE EMBANKMENT DETAILS

TERRAPROBE

FIGURE G2



Local Earth Fill Embankment < 8m



Local Earth Fill Embankment > 8m

* Notes- Pavement subgrade to be established after removal of surcharge

N.T.S

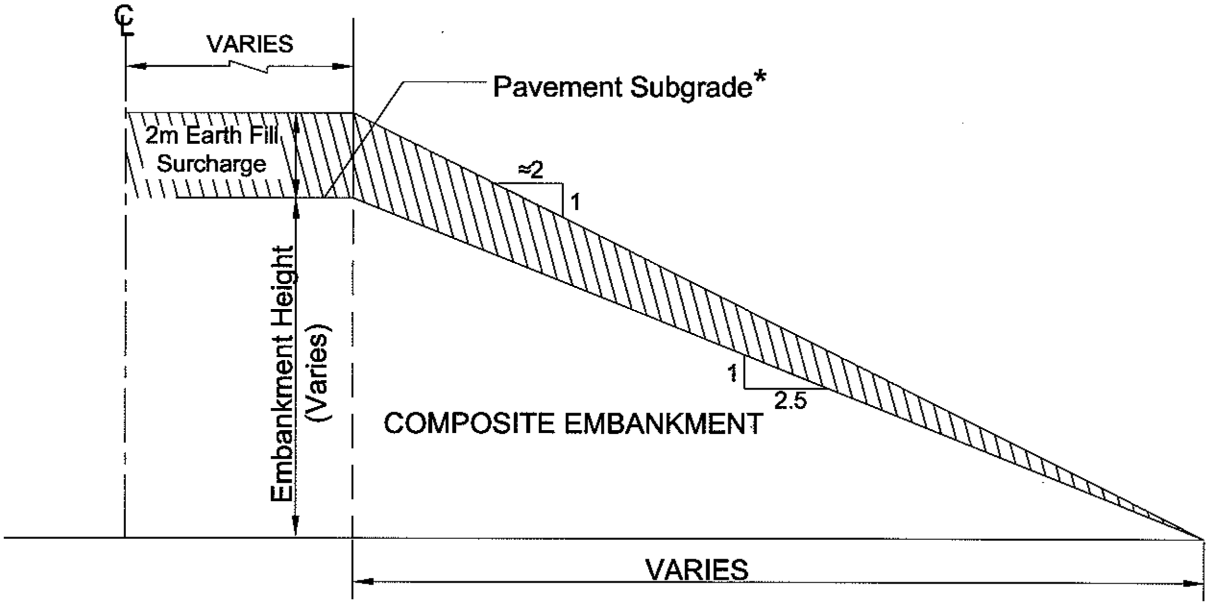
SURCHARGE ARRANGEMENT

TERRAPROBE

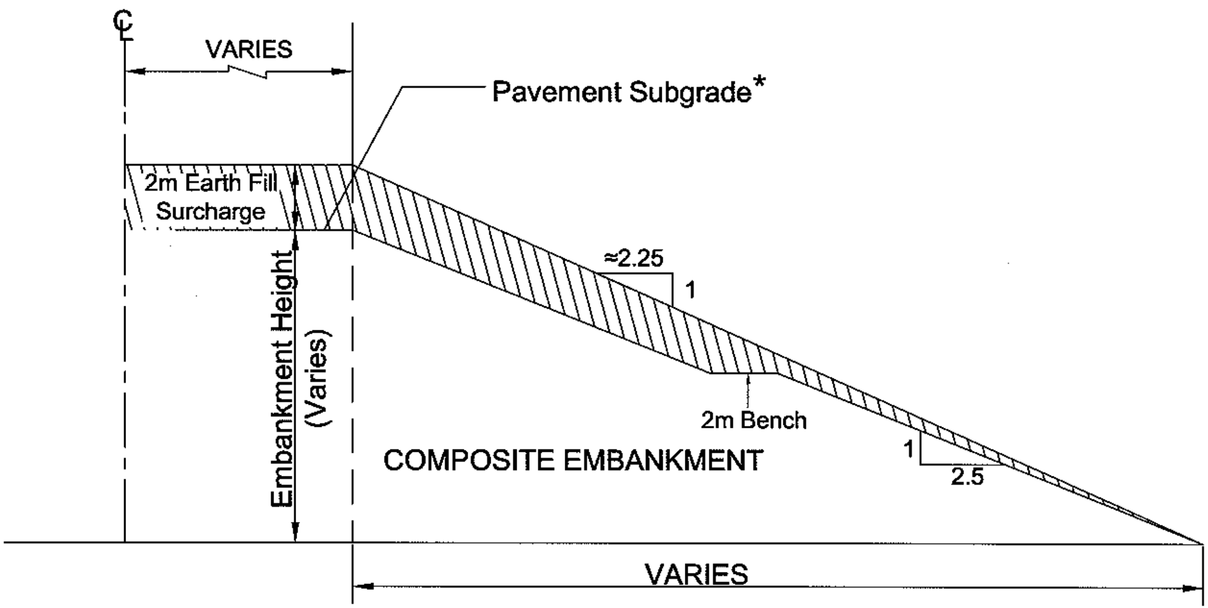
File No. 1-09-4135

FIGURE G3

C:\Users\wner\Documents\1-09-4135 HWY 406 PORT ROBINSON ROAD\COMPOSITE EMBANKMENT DETAILS 406.dwg, KAMAL



Composite Embankment <8m



Composite Embankment > 8m

* Notes- Pavement subgrade to be established after removal of surcharge.
Embankment and surcharge constructed initially with local earth fill and granular face installed after removal of surcharge.

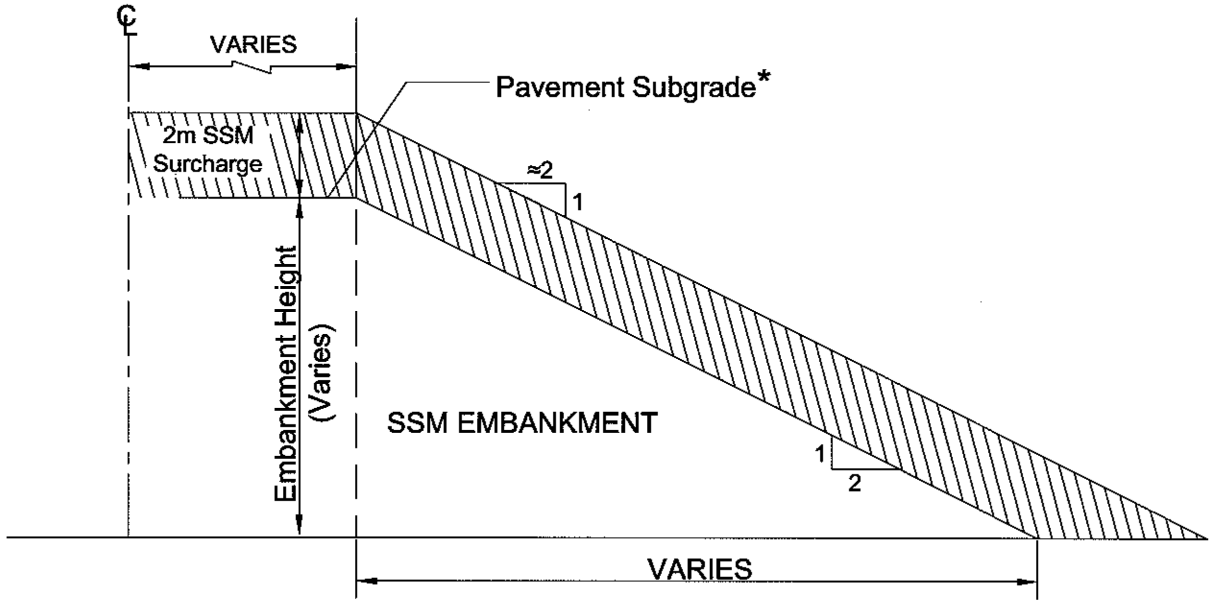
N.T.S

SURCHARGE ARRANGEMENT

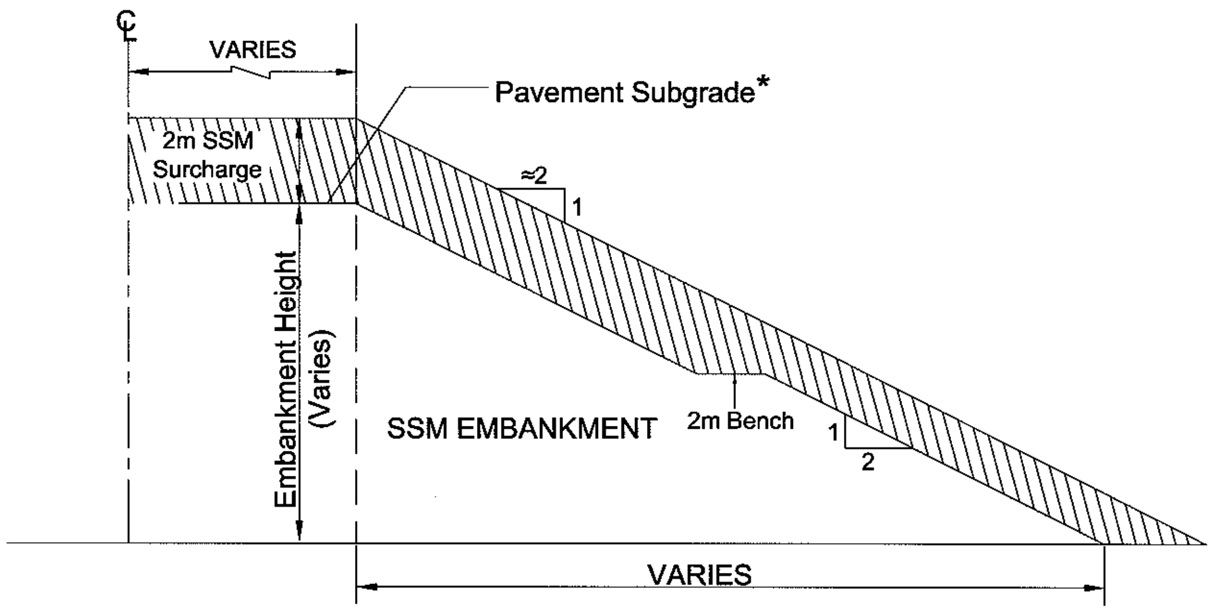
TERRAPROBE

File No. 1-09-4135

FIGURE G4



SSM Embankment <8m



SSM Embankment > 8m

* Notes- Pavement subgrade to be established after removal of surcharge.
Only SSM surcharge recommended in order to minimize handling/sorting and compaction of dissimilar materials.

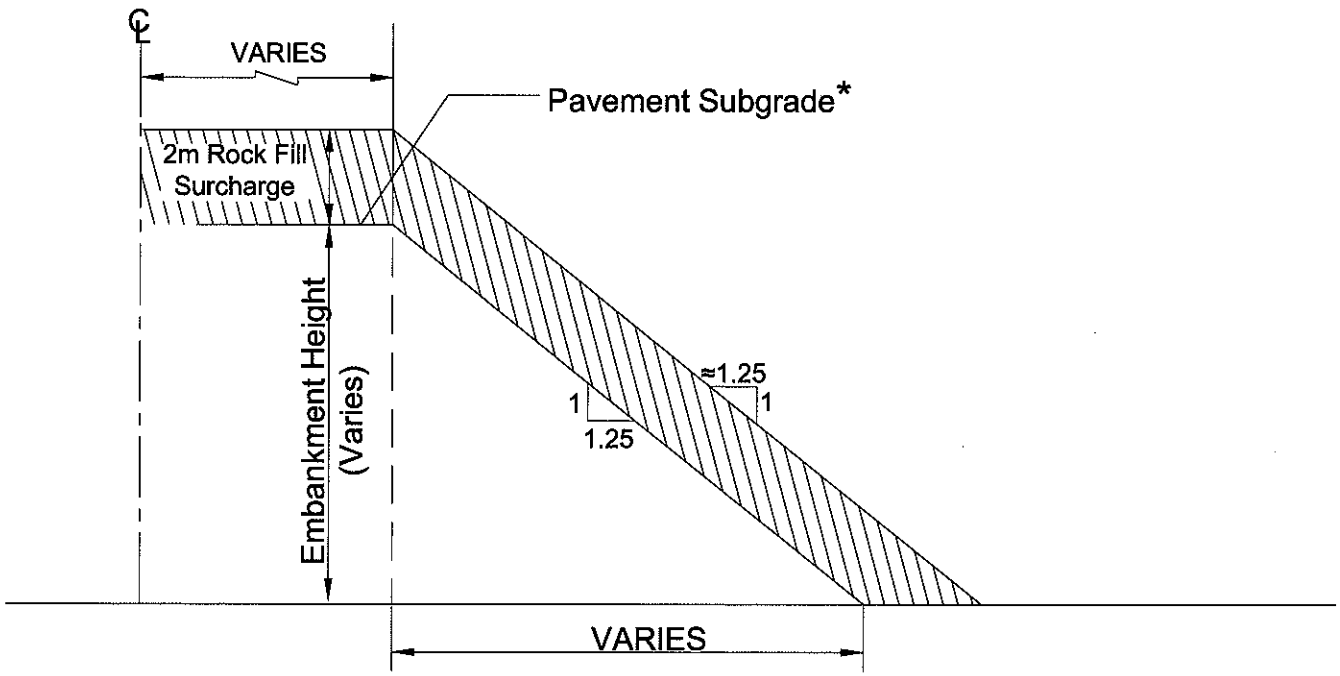
N.T.S

SURCHARGE ARRANGEMENT

TERRAPROBE

File No. 1-09-4135

FIGURE G5



Rock Fill Embankment <10m

* Notes- Pavement subgrade to be established after removal of surcharge.

N.T.S	SURCHARGE ARRANGEMENT	
TERRAPROBE	File No. 1-09-4135	FIGURE G6

APPENDIX H

Settlement Monitoring Programme

Terraprobe Inc.

SUPPLY AND INSTALLATION OF EMBANKMENT MONITORING EQUIPMENT – Item No.

Special Provision

1.0 GENERAL

1.1 Scope

This special provision contains the requirements for the supply and installation of the following geotechnical instruments:

- Settlement Plates (SP)
- Vibrating Wire Piezometers (VWP)
- Standpipe Piezometers (SSP)
- Survey Benchmark/s (BM)

1.2 Purpose

The purpose of these instruments is to monitor settlements and pore water pressures in the foundation soils under the embankments including the approach embankments of the bridge structure. The data will be used for planning the commencement of pile driving operations, construction scheduling, and final paving operations. Settlements will be measured by level surveying of the top of the settlement rods.

The piling at the foundation elements, the fill placement, timing for the removal of the preload, and final paving operations shall be controlled by the instrumentation readings.

1.3 Personnel

The Contractor shall retain a Geotechnical Consultant with MTO classification of "Geotechnical (Structures and Embankments) – High Complexity", to undertake the supply and installation of geotechnical instruments.

The Contractor (as referenced herein) shall be understood to refer to the Contractor and their Geotechnical Consultant.

1.4 Or equal

The term "or equal" shall be understood to indicate that the equal product is the same or better than the specified product in function, performance, reliability, quality and general configuration. Only one supplier shall be selected for the supply of data acquisition system and vibrating wire instruments (piezometers).

1.5 Notification

The Contract Administrator shall be notified a minimum of 15 working days in advance of commencing the installation of instruments.

1.6 Submission Requirements

The Contractor shall submit details of proposed installations including:

- Design and construction drawings, including equipment layout;
- Installation methodology and timing; monitoring shed;
- Equipment and material specifications, data sheets;
- Location and types of survey benchmarks; and
- Installation schedule.

Submissions shall be made to the Contract Administrator a minimum of 15 days before the start of the instrument installation.

1.7 Subsurface Conditions

The subsurface conditions at the site(s) are described in the reports:

- Foundation Investigation Report – High Fills at Port Robinson Road, Highway 406 Twinning, Port Robinson Road to East Main Street, Ontario. Agreement No. 2008-E-0016, W.P. 280-99-00, Geocres. No. 30M3-264, dated September 30, 2010, by Terraprobe Inc.
- Foundation Investigation Report – Port Robinson Road Underpass, Highway 406 Twinning, Port Robinson Road to East Main Street, Ontario. Agreement No. 2008-E-0016, W.P. 280-99-00, Site No. 34-462, Geocres. No. 30M3-262, dated September 24, 2010, by Terraprobe Inc.

The owner warrants that the information provided in the report can be relied upon with the following exceptions.

1. Any interpretations of the data or opinions expressed in the report are not warranted; and
2. Although the raw measured data presented is warranted, the Contractor must satisfy himself as to the sufficiency of the information presented and obtain any updated or additional information, and perform any studies, analysis or investigations the Contractor deems necessary in order to prepare his design, at no additional cost to the Owner.

1.8 Equipment Operation and Weather Conditions

All installations and monitoring equipment and associated materials shall be capable of withstanding the range of temperatures possible for their location within the ground or on the surface. The instruments shall be capable of operating within the manufacturer's stated accuracy throughout the temperature range. Monitoring shall be conducted year round and the Contractor is advised that the equipment should be accessible for monitoring throughout the duration of the Contract.

2.0 INSTALLATION

A summary of instrumentation requirements is given in Table 2.1. Details and specific material requirements are presented elsewhere in this special provision.

Table 2.1 – Instrument & Benchmark Quantities and Locations

INSTRUMENT I.D.	STATION	OFFSET FROM CENTRELINE	NO. OF INSTRUMENTS			
			SP	VWP	SSP	BM
West Approach						
SP1	9+935	5.5 m Lt	1			
SP2	9+935	5.5 m Rt	1			
VWP1	9+945	0		1		
SSP1	9+945	Outside of construction area			1	
SP3	9+950	0	1			
SP4	9+960	5.5 m Lt	1			
SP5	9+960	5.5 m Rt	1			
SP11	9+800	0	1			
SP12	9+850	0	1			
SP13	9+900	0	1			
BM1	N/A	N/A				1
East Approach						
SP6	10+040	5.5 m Lt	1			
SP7	10+040	5.5 m Rt	1			
SP8	10+050	0	1			
VWP2	10+055	0		1		
SSP1	10+055	Outside of construction area			1	
SP9	10+065	5.5 m Lt	1			
SP10	10+065	5.5 m Rt	1			
SP14	10+100	0	1			
SP15	10+150	0	1			
BM2	N/A	N/A				1
Total Instruments			**15**	**2**	**2**	**2**

2.1 Instrument Location

Prior to the installation of instruments, the Contractor shall accurately survey and stake the location of each instrument and obtain a ground surface elevation at each instrument location.

2.2 Survey Benchmarks (BM)

The Contractor shall provide a minimum of one non-yielding deep seated survey benchmark (BM) at the site. Alternatively the contractor may select stable non-settling points on existing structures within the area subject to approval by the contract administrator.

The number and locations(s) of benchmark(s) shall be such that direct sighting is possible from all settlement rods to at least one benchmark.

2.3 Accuracy of Surveying for Elevations

Elevations shall be surveyed referenced to Geodetic datum to an accuracy of ± 2 mm or better.

2.4 Monitoring Instrument Location

All monitoring instruments shall be located in MTM NAD83 northing and easting coordinates.

2.5 Materials and Equipment

The Contractor shall supply all materials and equipment required for the installation of instrumentation unless noted otherwise.

2.6 Underground Utilities

The Contractor shall be responsible for locating and protecting all underground utilities prior to drilling boreholes for installing instruments. Any damage to underground utilities caused by the Contractor's work shall be repaired by the Contractor, at no cost to the Ministry.

2.7 Marking and Labelling

The location of any above ground monitoring fixture shall be made clearly visible to nearby traffic before, during and after embankment construction. Marking shall be of sufficient size to be visible from a reversing vehicle and after heavy snow falls.

Instruments or their data cables shall be clearly labelled in the field, each instrument having a unique identifier. The labelling shall remain legible for at least 1 year.

2.8 Protection of Instruments

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 at no cost to the Ministry.

2.9 Boreholes

The Contractor shall make a basic stratigraphic log of boreholes as they are being drilled. In situ or laboratory testing is not required.

Boreholes shall be advanced using conventional drilling methods and shall be as straight and vertical as practical.

2.10 Installation Program

Instrument installation shall be completed before the start of any piling installation and before any embankment construction. Table 2.2 provides a summary of the installation schedule requirements.

Table 2.2 – Installation Program

TYPE	START INSTALLATION	FINISH INSTALLATION
SP	After excavating to recommended stripping elevation of embankment	On completion of embankment construction
VWP	Before Piling and Embankment Construction	Before Piling and Embankment Construction
SSP	Before Piling and Embankment Construction	Before Piling and Embankment Construction
BM	Before commencement of embankment construction	Before commencement of embankment construction

3.0 BENCHMARK (BM) – SUPPLY & INSTALLATION

3.1 GENERAL

3.1.1 Scope

This Section contains the requirements for the supply and installation of benchmark/s (BM).

The purpose of the benchmark is to provide non-settling references for the surveying of settlement rods.

3.1.2 General Procedure

The benchmark consists of a steel rod anchored to the bottom of a borehole. The benchmark shall be installed prior to embankment construction. The number and locations of benchmarks shall be such that direct sighting is possible from all settlement rods to at least one benchmark. Elevations shall be surveyed to an accuracy of ± 2mm or better.

Prior to the installation of instruments, the Contractor shall accurately survey and stake the locations of each instrument and obtain a ground elevation at each instrument location.

3.1.3 Location

Benchmarks shall be located and installed outside of the area of construction activity. Notwithstanding the installation details provided herein the contractor may select stable non-settling points on existing structures within the area subject to approval by the contract administrator.

Table 3 – Approximate Bench Mark Locations

Station	Offset (m)	No. of BM	Estimated Rod Anchor Elevation (m)
Outside of Construction Area	N/A	BM1	152.0
Outside of Construction Area	N/A	BM2	152.0

3.2 MATERIALS

3.2.1 General

The Contractor shall supply all materials and equipment required for the installation of the benchmark.

3.2.2 Rod

The Contractor shall supply a steel pipe Schedule 40 with an outside diameter not less than 25.4 mm (1”), supplied in lengths as required to complete the installation as described.

The top end of each 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.

3.2.3 Sand

The Contractor shall supply clean washed sand. The sand shall be Sakcrete washed general-purpose sand – or equal.

3.2.4 Grout

The Contractor shall supply cement-bentonite grout. A suitable grout mix design consists of 23 kg of bentonite (OPSS 1205), 143 litres of water and 40 kg of cement (Type G.U. – OPSS 1301).

3.2.5 Rod Anchor Grout

The Contractor shall supply cement-bentonite grout. A suitable grout mix design consists of 14 kg of bentonite (OPSS 1205), 49 litres of water and 40 kg of cement (Type G.U. – OPSS 1301).

3.2.6 Friction Reducing Sleeve

The Contractor shall supply a friction reducing sleeve consisting of Schedule 50 – 50.8 mm (2") O.D. PVC pipe cut perpendicular to the axis of the pipe.

3.3 INSTALLATION

3.3.1 General

The Contractor shall install the benchmark in accordance with the information below.

3.3.2 Borehole Installation

The borehole shall be advanced to the rod anchor elevation provided in Table 3 using suitable drilling techniques. The diameter of the borehole shall be sufficient to fit the rod, friction reducing sleeve and rod anchor. The sides of the borehole shall be stable and the borehole shall be free of drilling mud and debris.

3.3.3 Rod

The coupling of the rods shall be such that all sections have the same axis and no separation or contraction will occur at the couplings.

3.3.4 Rod Anchor

The rod shall be installed vertically in the borehole with its bottom end resting at the bottom of the borehole. The bottom portion of the rod shall be fixed against the surrounding native soil by grouting the bottom 0.5 m of the borehole to form a concrete/soil anchor.

Once grouting is completed and the rod anchor grout has set, the Contractor shall pour 0.5 m of clean sand in the borehole above the concrete/soil anchor to create a base for the end of the friction reducing sleeve to rest on.

The elevation of the bottom of the rod anchor shall be determined by measuring the length of the rod to the ground surface elevation.

3.3.5 Friction Reducing Sleeve

The friction reducing sleeve shall be over the entire length of the rod above the rod anchor and sand.

3.3.6 Installation Details

The elevation, easting and northing of the top of the benchmark rod shall be surveyed.

3.4 COORDINATION WITH MONITORING

3.4.1 Notification

The Contractor shall notify the Contract Administrator no later than 3 days after installing a benchmark. At this time the Contractor shall also supply the following information to the Contract Administrator.

- Location of the rod anchor and elevation top of rod;
- Dates of installation;
- Stratigraphic log of subsurface conditions at the benchmark, including drilling method notes;
- Installation notes/sketches; and
- Description of benchmarks, sleeve and rod anchor.

3.4.2 Monitoring

Monitoring of settlements with reference to the benchmark shall be done by others. Monitoring shall be conducted during and following the embankment construction at the north and south approaches. The Contractor shall provide installation information as specified above and provide access to the benchmark for monitoring including, but not limited to snow clearing in the winter. The Contractor shall provide electric power and general area lighting as needed.

3.5 REPORTING

The Contractor shall record and report relevant installation details to the Contract Administrator. These include, but are not limited to:

- Benchmark easting, northing in MTM NAD83 coordinates;
- Elevation of bottom of rod anchor and top of rod relative to Geodetic datum;
- Dates of installation; and
- Installation notes/sketches.

4.0 SETTLEMENT PLATES (SP) – SUPPLY & INSTALLATION

4.1 GENERAL

4.1.1 Scope

This Section contains the requirements for the supply and installation of settlement plates.

The purpose of the settlement plates is to monitor settlements of the foundation soils below the embankment base. The settlement readings shall help to establish the timing for the removal of preload fill, the commencement of pile driving operations, as well as final paving operations. Settlement is measured by survey of the top of the rod with reference to stable, non-settling benchmarks.

4.1.2 General Procedure

The settlement rods shall be attached to a plate at the existing ground surface. As embankment construction proceeds the rods shall be extended above the new top of embankment.

Sleeves around the rods shall be installed to reduce friction and allow uninhibited movement of the rod with the plate.

A protective surround shall be extended with the rods as embankment construction proceeds.

4.1.3 Location

The locations of the settlement plates are shown on the Contract Drawings and are given in Table 4.

Table 4 – Approximate Settlement Plate Locations

Station	Offset (m)	No. of SP	Estimated Fill Thickness (m)*
West Approach			
9+800	0	1	5.5
9+850	0	1	6.5
9+900	0	1	7.5
9+935	5.5 m Lt	1	8.0
9+935	5.5 m Rt	1	8.0
9+950	0	1	8.0
9+960	5.5 m Lt	1	8.0
9+960	5.5 m Rt	1	8.0
East Approach			
10+040	5.5 m Lt	1	9.0
10+040	5.5 m Rt	1	9.0
10+050	0	1	9.0
10+065	5.5 m Lt	1	9.0
10+065	5.5 m Rt	1	9.0
10+100	0	1	6.5
10+150	0	1	4.5

Notes:* Embankment thickness based on surface elevation of removal levels/stripping depths.

4.2 MATERIALS

4.2.1 General

The Contractor shall supply all materials and equipment required for the installation of the settlement plates.

4.2.2 Plate

The Contractor shall supply a steel plate with thickness of at least 6.35 mm. The plate shall be at least 0.5 m by 0.5 m.

4.2.3 Rod

The Contractor shall supply a steel pipe Schedule 40 with an outside diameter not less than 25.4 mm (1”), supplied in lengths as required to complete the installation as described in Section 4.3.

The top end of each 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.

4.2.4 Friction Reducing Sleeve

The Contractor shall supply a friction reducing sleeve consisting of Schedule 40 – 50.8mm (2”) O.D. PVC pipe cut perpendicular to the axis of the pipe.

4.2.5 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 medium to coarse sand.

4.3 INSTALLATION

4.3.1 General

The Contractor shall install settlement rods as per the Contract Drawings provided in addition to what is stated or emphasized below.

4.3.2 Settlement Plate

The settlement plate shall be installed horizontally after subgrade preparation is completed and prior to fill placement.

The elevation of the base of the plate shall be surveyed before backfilling.

4.3.3 Rod

The rod shall be fixed to the center of the plate and installed perpendicular to the plate.

The coupling of the rods shall be such that all sections have the same axis and no separation or contraction will occur at the couplings.

4.3.4 Friction Reducing Sleeve

The friction reducing sleeve shall be over the entire length of the rod that is below ground and within the embankment fill except that the cap on top of the settlement rod shall extend 25 mm above the top of the friction sleeve at all times.

4.4 EXTENSION OF ROD

The settlement rods shall be extended upwards as the embankment is constructed so that the top of the rod is always at least 0.3 m but not more than 2 m above the surrounding fill.

4.4.1 Protective Surround

The CSP, Friction Reducing Sleeve and sand protective surround shall be extended with the rods.

The settlement rod shall be in the center of the CSP and friction-reducing sleeve.

The annulus between the CSP and the friction-reducing sleeve shall be filled with sand to a level not higher than the top of the sleeve.

4.4.2 Installation Details

The elevation, easting and northing of the center of the base of the plate shall be surveyed.

The elevation, easting and northing of the top of the rod shall be surveyed.

The total distance from the base of the plate to the top of the rod shall be measured to an accuracy of ± 2 mm or better.

4.5 COORDINATION WITH MONITORING

4.5.1 Notification

The Contractor shall notify the Contract Administrator no later than 3 days after installing a settlement rod. At this time the Contractor shall also supply the following information to the Contract Administrator.

- Elevation of plate and rod referenced to Geodetic datum;
- Dates of installation;
- Installation notes/sketches; and
- Description of settlement rods, sleeve and plate.

Adjustments in the length of any settlement rod shall be coordinated with the Contract Administrator to allow surveying by others of the elevation of the top of the rod immediately before and immediately after adjustment. This surveying is necessary to accurately track the settlement data.

4.5.2 Monitoring

Monitoring of the settlement plates shall be done by others. Monitoring shall be conducted during the embankment construction and preload period. A target settlement of 175 mm is specified. A minimum preload period of 6 months is required. The Contractor shall provide installation information as specified above and provide access to the settlement rods for monitoring including, but not limited to a level scaffolding platform and ladder, if required and snow clearing in the winter. The Contractor shall provide electric power and general area lighting as needed for reading the instruments.

4.6 REPORTING

The Contractor shall record and report relevant installation details to the Contract Administrator. These include, but are not limited to:

- Settlement rod easting, northing referenced to MTM NAD83 coordinates;
- Elevation of the plate and the top of the rod referenced to Geodetic datum;
- Distance between base of plate and top of rod;
- Dates of installation; and
- Installation notes/sketches.

5.0 VIBRATING WIRE PIEZOMETER (VWP) – SUPPLY & INSTALLATION

5.1 GENERAL

5.1.1 Scope

This Section contains the requirements for the supply and installation of vibrating wire (VW) piezometers.

The purpose of the piezometers is to monitor piezometric head at depth within the foundation soil below the embankments. The piezometer readings shall help to establish the timing and sequence of the piling at the foundation elements, the removal of embankment preload, and final paving operations.

5.1.2 General Procedure

The piezometers shall be installed in boreholes prior to the start of any embankment construction, any preload fill construction, and any piling. Prior to installation of instruments adjacent to new construction features (including limit of pile cap, edge of unwatering system, extent of sub-excavation and backfilling), the construction features shall be laid out in the field to ensure there are no conflicts with the instruments.

The VW signal cables for the VWPs shall be extended out of the embankment and preload footprint area (where applicable) and away from the piling area through a metal or plastic conduit buried in trenches, as shown in the Contract Drawings.

The conduits for the VW signal cables for the VWPs may be routed so that they may be connected to a single data acquisition system (data-logger).

5.1.3 Locations

The Contractor shall install VW sensors at the locations and depths given in Table 5.

Table 5 – VW Piezometer Locations

Station	Offset (m)*	No. of VWP	Approximate Elevation of Ground Surface (m)	Tip Elevations (m)
West Approach 9+945	0	1	188.5	159.0
East Approach 10+055	0	1	188.5	174.0

Notes: * Offset from centerline of Port Robinson Road.

5.2 MATERIALS

5.2.1 VW Piezometers

The Contractor shall supply VW borehole piezometers by Slope Indicator model 52611020 (-5 to 50 psi), RST model VW2100-0.35 – or equal; compatible with the Slope Indicator CR1000 data-logger, RST model ELGL1200 – or equal. All VW piezometers (and Settlement Cells) shall be of the same make.

All piezometers shall be calibrated prior to installation and the calibration data for each piezometer shall be provided for the Contract Administrator.

5.2.2 Signal Cable

The Contractor shall supply Slope Indicator model 50613524 cable, RST model EL380004 cable – or equal. The length of cable for each piezometer shall be carefully estimated from the construction Contract Drawings to ensure that there is enough signal cable for each piezometer to provide enough slack in the borehole and along the trenches until each cable is out of the construction area where they shall be protected from earthmoving equipment.

5.2.3 Bentonite

The Contractor shall supply bentonite (OPSS 1205) in pellet from in sufficient quantity to form borehole plugs as required.

5.2.4 Filter Sand

The Contractor shall supply clean washed sand for filter around VWP sensors. The sand shall be Sakcrete washed general-purpose sand – or equal.

5.2.5 Grout

The Contractor shall supply cement-bentonite grout. A suitable grout mix design consists of 23 kg of bentonite (OPSS 1205), 143 litres of water and 40 kg of cement (Type G.U. – OPSS 1301).

5.2.6 Trench Burial and Conduit

The signal cable for each piezometer shall be buried in a shallow trench and taken out of the construction area. The Contractor shall supply suitable conduits (e.g. Schedule 40 – 75 mm (3”) – steel pipe or Schedule 80 - 75 mm (3”) – rigid PVC pipe) to protect the signal cables in the trenches and above ground surface. If appropriate, several signal cables may be housed in a single conduit and laid in a common trench.

The signal cables and conduits shall be routed such that future grading works do not interfere with the cables or conduits.

5.2.7 Data Acquisition System (Data-Logger)

The signal cables from the vibrating wire piezometers shall be connected to a data-logger (to be located away from the proposed approach embankment), Slope Indicator model

56701000 (CR1000), RST model ELGL1200 – or equal. The data-logger shall consist of the following:

- ENC 16/18 Water-proof Enclosure model 56705020, model ELF0638 – or equal;
- SC32A Serial Interface (with RS232 transfer cable) model 56704010, model CS-SC32A – or equal;
- VW Interface model 56701510 or 56701500, model CS-AVW200 – or equal;
- AM16/32 Multiplexer model 56702110, model ELGL2042 – or equal;
- A suitable power supply which shall be able to last for 2 years (i.e. large capacity rechargeable battery coupled with solar panel); and
- LoggerNet Software model 56708020, model CS-Loggernet – or equal.

A minimum of one data logger shall be installed. The Contractor shall submit a detailed proposal on the setup of the data-logging system (i.e. number and location of the data-logging unit(s) to the Contract Administrator for review, prior to ordering the data-logger(s). The Contractor shall program the data-logger according to the following:

- Recording Software: VWP data shall be recorded at 5 minutes intervals during piling and four times a day (one reading every 6 hours) when not piling
- Test Software: once this program is transferred to the data-logger, one shall be able to test the system and record data manually on site

The real-time data shall be retrieved on site by direct wire (i.e. RS232 Cable) with a portable laptop computer as specified in the next section.

5.2.8 Portable Laptop Computer

The Contractor shall supply:

- A New Portable Laptop Computer (with a Three year warranty): Intel Pentium M or IV or better (1.6 GHz or above) with Windows 7 Professional Operating System, minimum 1GB memory,
  Network Card: 10/100 Integrated Ethernet LAN, a minimum of 80GB hard drive storage, a DVD/CD-RW ROM and Microsoft Office Standard 2007, to retrieve, read and store the VW piezometer readings.
- Extra battery pack and cigarette lighter charger.

The portable laptop computer will become property of the MTO and shall be handed to the Contract Administrator after the installation of instruments for the Monitoring program.

The calibration factors for all vibrating wire instruments shall be entered in the portable laptop computer by the Contractor for initialization of the instruments.

5.2.8 Wooden Posts

Wooden posts: 100 mm x 100 mm (4”x4”), minimum 3 m (10”) long, if required.

5.3 INSTALLATION

5.3.1 General

Installation of the VW piezometers shall be as per the manufacturer's recommendations in addition to what is stated or emphasized below.

The VWPs shall not be installed closer than 1.5 m to the nearest adjacent edge of shoring or unwatering system.

The exact location of the VWP installations shall be determined in the field after sub-excavation and backfilling to original ground surface.

5.3.2 Protection for Long-term Monitoring (Monitoring Shed)

The Data-logger shall be installed in a walk-in Monitoring Shed to prevent vandalism and prolonged wear-out of the data-loggers against extreme weather. The Monitoring Shed shall be a lockable and weather proof enclosure surrounded by 2 m high chainlink fence and a lockable gate. The Monitoring Shed shall also be seating on a gravel pad and securely tied down to the ground. The location of the Monitoring Shed shall not be susceptible to ground settlement. The Contractor shall submit a detailed proposal of the Monitoring Shed (i.e. materials and location(s) etc.) to the Contract Administrator for review, prior to construction.

The Contractor shall ensure access to the Monitoring Shed at all times, including but not limited to snow clearing in the winter.

5.3.3 Completion of Installation

It is known that the process of installing VW piezometers can temporarily alter the pore water pressure acting on the piezometer tip. The installation of a VW piezometer shall not be considered to be complete until the pore pressure acting on the piezometer has returned to and stabilized at the value prevailing in the surrounding, unaffected soil mass. The Contractor shall take daily reading of the pore pressures until the value has stabilized. Stabilization shall be deemed to have occurred:

a) When no change in the measured value has occurred over a period of 5 days and the measured value is within 10% of the anticipated hydrostatic value.
b) When the daily rate of change is less than four (4) kPa per day for three consecutive days and the measured value is within 5% of the anticipated hydrostatic value.
c) Failing either of the two above conditions, as determined by the Contract Administrator.

The Contractor shall be prepared to wait for a period of 10 to 15 days after completion of installation of instruments for the baseline readings to stabilize prior to the commencement of the construction works.

5.4 COORDINATION WITH MONITORING

5.4.1 Notification

The Contractor shall notify the Contract Administrator no later than 3 days after installing a VW piezometer. At this time, the Contractor shall also supply the following information to the Contract Administrator.

- VW piezometer location, easting, northing referenced to MTM NAD83 coordinates;
- Elevations of VW sensor referenced to Geodetic datum;
- Stratigraphic log of subsurface conditions, including drilling method notes;
- Dates of installation;
- Installation notes/sketches;
- Model, make and serial numbers of VW sensors, readout unit and signal cable; and
- Calibration details of VW sensors.

5.4.2 Monitoring

Monitoring of the VW piezometers shall be done by others. Monitoring shall be conducted during and after piling at the abutments, during embankment fill construction and during the preload period. The Contractor shall provide installation information as specified above and provide access to the data-loggers for monitoring.

The Contractor shall transfer the Portable Laptop Computer to the Contract Administrator, including all the data-logging softwares and hardware, operation instructions and calibration constants. The Contractor shall also transfer the keys for the locks of the Monitoring Shed(s). The Contractor shall be available for one site meeting with the Contract Administrator to transfer and explain about any questions from the Contract Administrator regarding the data-logging system.

6.0 STANDPIPE PIEZOMETER (SSP) – SUPPLY & INSTALLATION

6.1 General

6.1.1 Scope

This Section contains the requirements for the supply and installation of standpipe piezometers.

The purpose of the standpipe piezometer is to provide bench mark data by monitoring the hydrostatic piezometric head at depth outside of the construction area of the approach embankment fill.

6.1.2 General Procedure

The standpipes shall be installed prior to any piling and embankment fill construction.

Standpipes shall be installed in vertical boreholes.

6.1.3 Location

The locations of the standpipes shall be outside of the construction area near the given Station. The depths of the standpipes are given in Table 6

Table 6 – Standpipe Piezometer Locations and Depths

Station	Offset* (m)	No. of SSP	Tip Elevations (m)
West Approach 9+945	30	1	159.0
East Approach 10+055	30	1	174.0

Note: * Approx. offset from centerline of Port Robinson Road

6.2 MATERIALS

6.2.1 General

The Contractor shall supply material and equipment, required for installation of the standpipe piezometers.

6.2.2 Pipe and Couplings

The Contractor shall supply Schedule 40 flush jointed – 19 mm (3/4") PVC pipe (e.g. 75x5R or 75x10R – Canadian Pipe Supply Ltd.).

6.2.3 Perforated Section

The Contractor shall supply one 1.5 m long slotted Schedule 40 flush-jointed – 19 mm (3/4") PVC slotted pipe (e.g. 75x5S Slot 10 Sch 40 – F/J – PVC – Canadian Pipe Supply Ltd.) for each SSP.

6.2.4 Bottom Cap

The Contractor shall supply bottom caps Schedule 40 flush-jointed – 19 mm (3/4”) PVC (e.g. 448–007FJ – Canadian Pipe Supply Ltd.) to fit the perforated section.

6.2.5 Top Caps

The Contractor shall supply vented top caps Schedule 40 – 19 mm (3/4”) PVC (e.g. 448-007FJ-perforated – Canadian Pipe Supply Ltd.) to fit the pipe.

6.2.6 Filter Sand

The Contractor shall supply clean washed sand for backfilling around perforated section. The sand shall be Sakcrete washed general purpose sand – or equal.

6.2.7 Bentonite

The Contractor shall supply bentonite (OPSS 1205) in pellet form for backfilling above the filter sand.

6.2.8 Grout

The Contractor shall supply cement-bentonite grout for general backfilling. A suitable grout mix design consists of 23 kg of bentonite (OPSS 1205), 143 litres of water and 40 kg of cement (Type G.U. – OPSS 1301).

6.2.9 Protective Housing

The Contractor shall supply a protective housing consisting of 100 mm minimum diameter galvanized steel pipe with a locking cap.

6.3 INSTALLATION

6.3.1 General

Installation of the standpipe shall be as per the Contract Drawings provided in addition to what is stated or emphasized below.

The borehole shall be advanced to 300 mm below the tip elevation using suitable drilling techniques. The sides of the borehole shall be stable and the borehole shall be free of debris.

The standpipe piezometers must be of sufficient length above the ground surface to accommodate the piezometric head and to allow for snow accumulation.

The standpipe piezometer location shall be at sections indicated on the Contract Drawings.

6.4 COORDINATING WITH MONITORING

6.4.1 Notification

The Contractor shall notify the Contract Administrator no later than 3 days after installing a standpipe. At this time, the Contractor shall also supply the following information to the Contract Administrator.

- Standpipe piezometer location, easting, northing referenced to MTM NAD83 coordinates;
- Elevation of ground level referenced to Geodetic datum;
- Stratigraphic log of subsurface conditions at the standpipe;
- Dates of installation;
- Depth of pipe, stick-up; and
- Installation notes/backfilling notes.

6.4.2 Monitoring

Monitoring of standpipe piezometers shall be done by others. Monitoring shall be conducted during and after piling at the abutments, embankment fill construction and preload period. The Contractor shall provide installation information as specified above and provide access to the standpipe piezometers for monitoring including, but not necessarily limited to snow clearing in the winter. The Contractor shall provide electric power and general area lighting as needed for reading the instruments.

7.0 DECOMMISSING OF INSTRUMENTS

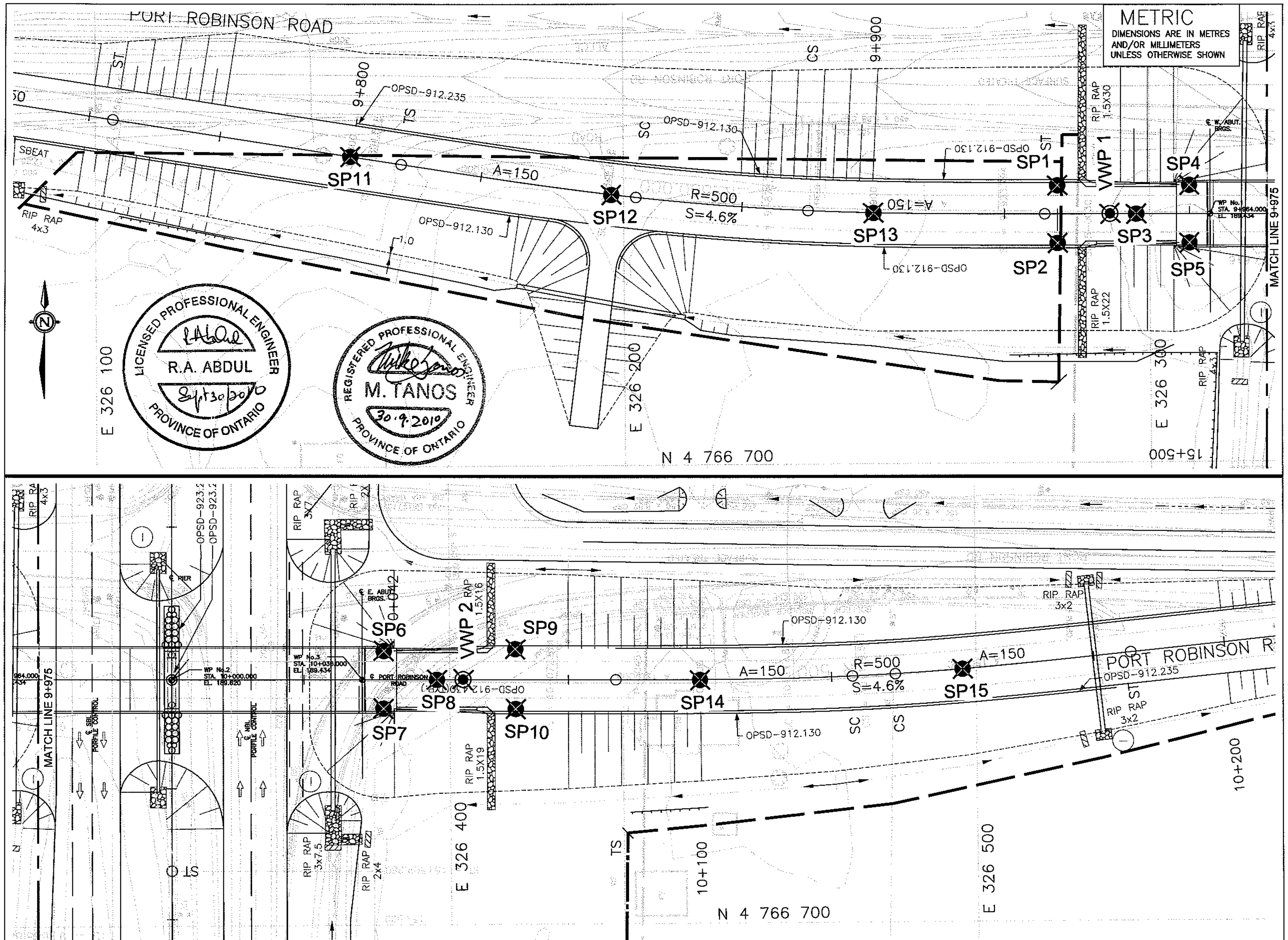
7.1 General

The Contractor shall decommission all the Settlement Plates (SP), VW piezometers (VWP), and Standpipe Piezometers (SSP) at the end of the monitoring program following construction unless advised otherwise by the Contract Administrator. Decommissioning of instrumentation shall be carried out according to the Ontario Water Resources act, R.R.O. 1990, Regulation 903 (as amended by Ontario Reg. 372).

8.0 PAYMENT

8.1 Basis Of Payment

Payment at the Lump Sum price for this tender item shall be full compensation for all labour, monitoring equipment and material to do the work.



CONT No

WP No 280-99-00

HWY 406
PORT ROBINSON HIGH FILLS
SETTLEMENT MONITORING
INSTRUMENT LAYOUT

Terraprobe Inc.

Consulting Geotechnical & Environmental Engineering
Construction Materials, Inspection & Testing
10 Bram Court - Brampton Ontario L6W 3R6 (905) 796-2650

GENERAL NOTES:

1. THIS DRAWING TO BE READ IN CONJUCTION WITH INSTRUMENT DETAILS DRAWING.

LEGEND

(SP1) APPROXIMATE LOCATION OF SETTLEMENT PLATE (SP)

(VWP1) APPROXIMATE LOCATION OF VIBRATING WIRE PIEZOMETER (VWP)

INSTRUMENT LOCATIONS

I.D.	LOCATION	STATION	OFFSET FROM CENTRELINE(m)
PORT ROBINSON ROAD			
SP1	West Approach	9+935	5.5 Lt
SP2	West Approach	9+935	5.5 Rt
SP3	West Approach	9+950	0
SP4	West Approach	9+960	5.5 Lt
SP5	West Approach	9+960	5.5 Rt
SP6	East Approach	10+040	5.5 Lt
SP7	East Approach	10+040	5.5 Rt
SP8	East Approach	10+050	0
SP9	East Approach	10+065	5.5 Lt
SP10	East Approach	10+065	5.5 Rt
SP11	West Approach	9+800	0
SP12	West Approach	9+850	0
SP13	West Approach	9+900	0
SP14	East Approach	10+100	0
SP15	East Approach	10+150	0
VWP1	West Approach	9+945	0
VWP2	East Approach	10+055	0

SCALE
0 10 20 30 40m

REVISIONS	DATE	BY	DESCRIPTION
DESIGN R.A	CODE CHBDC2006	LOAD	DATE SEPT. 2010
DRAWN K.C	CHK R.A	STRUCT	

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

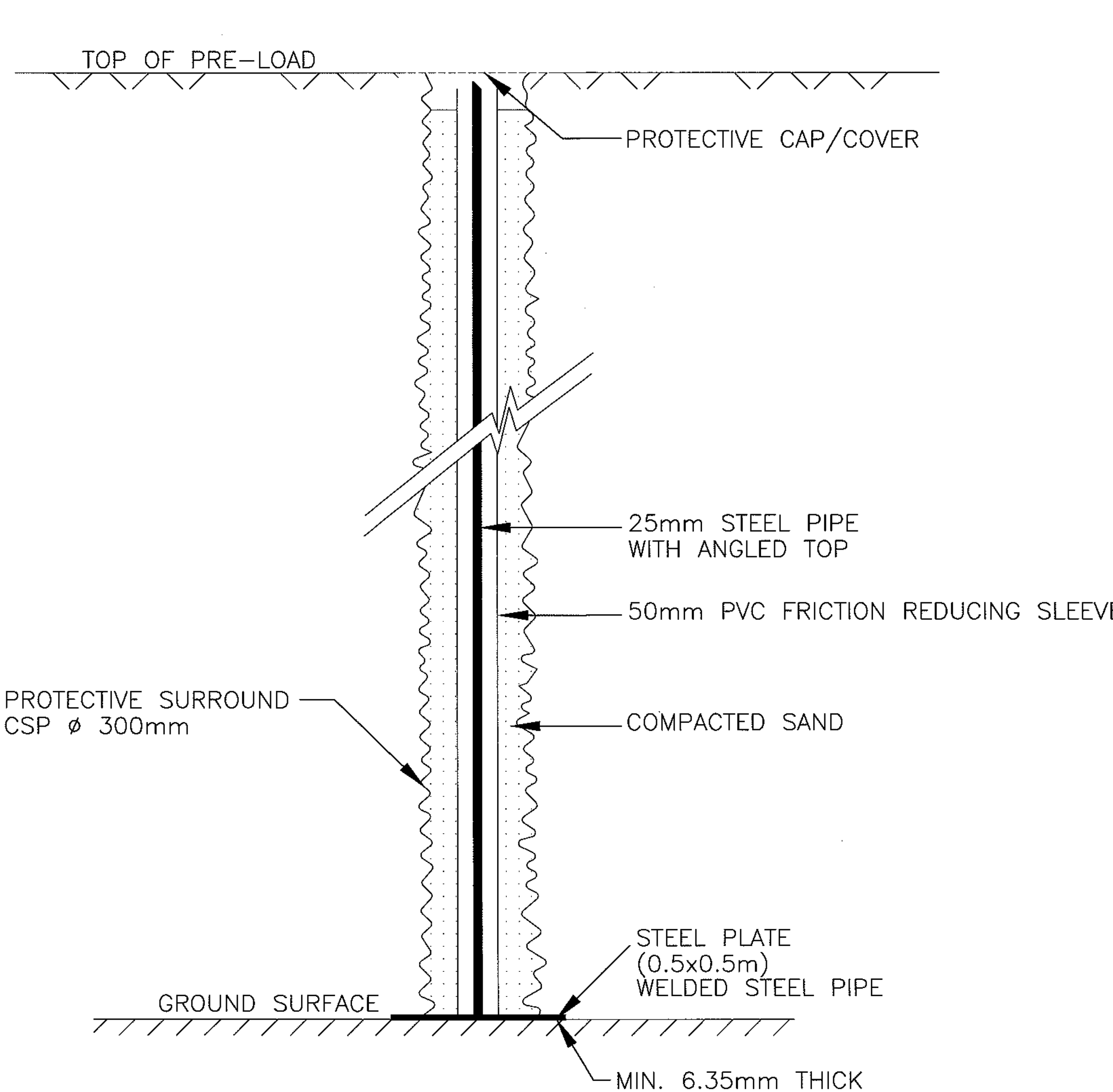
CONT No
WP No 280-99-00

HWY 406
PORT ROBINSON HIGH FILLS
SETTLEMENT MONITORING
INSTRUMENT DETAILS

Terraprobe Inc.
Consulting Geotechnical & Environmental Engineering
Construction Materials, Inspection & Testing
10 Bram Court - Brampton Ontario L6W 3R6 (905) 796-2650

REGISTERED PROFESSIONAL ENGINEER
M. TANOS
30.9.2010
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
R.A. ABDUL
Sept 30/2010
PROVINCE OF ONTARIO



SETTLEMENT PLATE (SP)

N.T.S.

GENERAL NOTES:

1. THIS DRAWING TO BE READ IN CONJUCTION WITH THE SETTLEMENT MONITORING INSTRUMENT LAYOUT DWG.

REVISIONS		
DATE	BY	DESCRIPTION

DESIGN R.A	CODE CHBDC2006	LOAD	DATE SEPT. 2010
DRAWN K.C	CHK R.A	STRUCT	