FOUNDATION INVESTIGATION & DESIGN REPORT
NOISE MITIGATION UPGRADE
HIGHWAY 406 TWINNING
PORT ROBINSION ROAD TO EAST MAIN STREET
AGREEMENT No. 2008-E-0016, W.P. 280-99-00
GEOCRES No. 30M3-267

PREPARED FOR: Giffels Associates Ltd./IBI Group
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File No. 1-09-4135
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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.

A noise berm was aligned parallel to and approximately 70 m west of the present Highway 406. The berm’s geometry was altered in the Advance Contract (Contract 2) to accommodate the proposed 406 NBL and the 406 S - Merritt Road E/W ramp. The adjustments included moving the toe of slope laterally to the east and regrading the berm’s west slope to 3H:1V thereby resulting in a reduction in the berm height.

The main design recommendations to achieve noise attenuation at this site are:

- The existing noise berm can be covered with SSM material at a 2H:1V side slope to fit within the current ROW limits.
- An alternative and economical solution is a noise barrier wall constructed on top of the existing berm.

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.

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at a site where noise attenuation is required for residential properties in the vicinity of the Merritt Road interchange.

The purpose of this investigation was to explore the subsurface conditions at the site and based on the data obtained, to provide borehole and test pit location plans, records of boreholes, test pit logs, a stratigraphic profile, 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 site is located on the east side of Highway 406 between the Merritt Road Interchange and the Old Welland Canal in the City of Thorold, Regional Municipality of Niagara. The alignment is adjacent to the proposed Highway 406 NBL (Sta. 14+175 to 14+434) and Ramp 406N-Merritt E/W (Sta. 10+000 to Sta. 10+125).

A noise berm was aligned parallel to and approximately 70 m west of the present Highway 406. The berm was approximately 395 m long with variable heights ranging from 3 m to 7.5 m. The berm's geometry was altered in the Advance Contract (Contract 2) to accommodate the proposed 406 NBL and the 406 S - Merritt Road E/W ramp. The adjustments included moving the toe of slope laterally to the east and regrading the berm's west slope to 3H:1V thereby resulting in a reduction in the berm height.

The topography in the area is generally flat to undulating with scattered man-made high ground areas. Vegetation at this site consists primarily of deciduous trees and wild bush. The area is a construction site.

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].

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 units within the project limits consist of the Salina Formation and Guelph Formation of Upper Silurian Age[2]. The Salina Formation consists essentially of easily weathered, grey, very finely crystalline, laminated argillaceous dolostone with grey, calcareous shale partings and gypsum veins and lenses of varying thicknesses. The Guelph Formation 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 September 25, 2010 and October 03, 2010 and consisted of drilling and sampling five boreholes to depths ranging from 11.2 m to 15.1 m. Seven test pits were also dug to depths ranging from 4.4 m to 5.7 m on December 16, 2009 prior to the commencement of the Advance Contract (Contract 2). The approximate borehole and test pit locations are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix D. Test pit photographs are provided 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. Test pit locations were established by referring to the staked centre line of Hwy. 406 NBL.

Access to the desired borehole locations was difficult due to the recently cut and relatively steep slopes. The boreholes were therefore relocated to be as close as feasible to the staked location while allowing safe operation of the drill rig. Utility clearances and permits were obtained by Terraprobe prior to drilling.

At the time of the field investigation the site was occupied by Dufferin Construction Company under MTO Contract No. 2010-2022. Therefore, the field work was undertaken on weekends to avoid interference with Dufferin’s work and to ensure compliance with the Ministry of Labour requirements.

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.

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[1] Chapman and Putnam, “The Physiography of South Ontario”, 3rd Edition, 1984.
[2] Ontario Division of Mines, “Quaternary Geology Of The Welland Area”, Preliminary Map P.796, 1972.

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.

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
1	10.7/166.5	Piezometer with 3.0 m slotted screen installed with filter sand to 7.1 m, bentonite seal from 7.1 m to 6.4 m, silty clay cuttings from 6.4 m to 0.6 m and bentonite seal from 0.6 m to ground surface.
3	9.1/168.2	Hole sealed to 9.1 m with bentonite, piezometer with 3.0 m slotted screen installed with filter sand to 5.5 m, bentonite seal from 5.5 m to 4.9 m, silty clay cuttings from 4.9 m to 0.6 m and bentonite seal from 0.6 m to ground surface.
5	12.2/168.4	Hole sealed to 12.2 m with bentonite, piezometer with 3.0 m slotted screen installed with filter sand to 7.9 m, bentonite seal from 7.9 m to 7.3 m, silty clay cuttings from 7.3 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 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, 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 and test pit logs in Appendix A. Details of the encountered soil stratigraphy are presented in this appendix and on the "Borehole Locations and Soil Strata" drawing in Appendix D. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets and test pit logs governs any interpretation of the site conditions.

In general, the site is underlain by topsoil, silty clay fill and native overburden deposits of silty clay and silt.

5.1 Topsoil

An 80 mm thick layer of topsoil was encountered in Boreholes 4 and 5. Topsoil thickness may vary between and beyond the boreholes.

5.2 Fill – Silty Clay

Some of the boreholes encountered silty clay fill material extending to depths ranging from 0.7 m (Elev. 179.9 m) to 1.8 m (Elev. 175.4 m) below ground surface. The test pits encountered fill that extended to depths ranging from 4.1 m to 5.4 m below grade.

Samples of this fill were subjected to grain size analysis and the results are illustrated in Figure B1. These results show a grain size distribution consisting of 0% gravel, 3-14% sand, 40-55% silt and 31-57% clay size particles.

The fill material was also subjected to Atterberg Limits tests and the results are plotted on the plasticity chart, Figure B2. The index values from these tests are summarized below:

Liquid Limit:	32-46%
Plastic Limit:	21-22%
Plasticity Index:	12-24%
Natural Moisture Content:	25-27%

These values are characteristic of clayey soils of low to intermediate plasticity.

Standard Penetration tests in the silty clay fill gave ‘N’ values that ranged from 3 to 14 blows for 0.3 m penetration. Based on these results the fill is considered to have a soft to stiff consistency. The moisture content of samples of this fill ranged from 15% to 27% by weight.

5.3 Silty Clay

A silty clay deposit was encountered at this site in all of the boreholes extending at least to borehole termination depths ranging from 11.2 m (Elev. 166.0 m) to 15.1 m (Elev. 165.0 m). In Boreholes 1 and 4 the silty clay is divided by a layer of silt. The test pits encountered silty clay at depths ranging from 4.1 m to 5.4 m below grade and this silty clay extended at least to the depths of excavation i.e. 4.4 m to 5.7 m below grade.

The grain size distribution curves of tested samples of the silty clay are presented in Figures B3 to B5 inclusive. These results show a grain size distribution consisting of 0-7% gravel, 0-13% sand, 31-81% silt and 18-68% clay size particles.

Samples of the silty clay were also subjected to Atterberg Limits tests and the results are illustrated on the plasticity chart, Figures B6 to B8 inclusive. The index values from these tests are summarized below:

Liquid Limit:	22-52%
Plastic Limit:	15-25%
Plasticity Index:	5-27%
Natural Moisture Content:	16-37%

These values indicate that the silty clay has a generally low to intermediate plasticity with clayey silt inclusions and infrequent zones of high plasticity.

Standard Penetration tests in this stratum gave 'N' values that ranged from 1 to 27 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 22 kPa to 56 kPa. These values indicate that the consistency of the silty clay is generally firm to very stiff with infrequent soft zones. The moisture content of samples of the silty clay ranged from 16% to 37% by weight and the unit weight of selected samples ranged from 18.8 to 22.9 kN/m^3.

5.4 Silt

Boreholes 1 and 4 encountered a silt deposit. This stratum is approximately 1.6 m to 3.1 m thick and extends to depths ranging from 5.6 m (Elev. 171.6 m) to 11.7 m (Elev. 168.4 m) below ground surface.

The grain size distribution plots of tested samples of the silt are presented in Figure B9. These results show a grain size distribution consisting of 0% gravel, 1-2% sand, 92% silt and 6-7% clay size particles.

The deposit is considered to have a loose to dense relative density based on SPT 'N' values that ranged from 7 to 47 blows for 0.3 m penetration. The moisture content of samples from this deposit ranged from 21% to 25% by weight.

5.5 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 5.1.

Table 5.1 – Water Level Measurements

Borehole	Date	Water Levels	
		Depth (m)	Elevation (m)
1	October 03, 2010	6.9	170.3
	October 14, 2010	2.7	174.5
	October 20, 2010	2.6	174.6
3	October 03, 2010	1.9	175.4
	October 14, 2010	1.7	175.6
	October 20, 2010	1.8	175.5
5	September 25, 2010	4.5	176.1
	October 03, 2010	4.1	176.5
	October 14, 2010	4.0	176.6
	October 20, 2010	4.0	176.6

The ground water table was estimated based on the recorded water levels in the standpipe piezometers and our review of moisture contents of the retrieved samples. This interpretation indicates a phreatic surface that generally follows the ground surface topography. The water level exists at Elev. ±174.6 m at BH1 (Sta. 14+175) rising gently to Elev. ±175.5 m at BH3 (Sta. 14+300). The water level continues to rise northwards to BH5 (Sta. 14+475) where the recorded water level is Elev. ±176.6 m.

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

5.6 Miscellaneous

The drilling, sampling and in-situ testing operations were conducted with track-mounted drill rigs owned and operated by DBW Drilling Limited of Ajax, Ontario and Determination Drilling & Soil Investigations of Hamilton, Ontario. The test pits were excavated with a 9010 Case Excavator owned and operated by R & D Construction of Thorold, Ontario. The boreholes were advanced using solid stem auger drilling techniques.

Mr. Marc Paoliello, E.I.T. and Mr. Bob Racher, C.E.T, carried out the field work and the laboratory testing was performed at Terraprobe's Brampton laboratory. The report was written by Rehman Abdul, P.Eng. and reviewed by Michael Tanos, P.Eng.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

6 DISCUSSION AND RECOMMENDATIONS

6.1 General

It is understood that noise attenuation is required on the east side of the proposed Highway 406 NBL (Sta. 14+175 to Sta. 14+434) and Ramp 406S – Merritt Road E/W (Sta. 10+000 to Sta. 10+125). The design elevation of the top of the noise attenuation structure ranges from Elev. 183.0 m to Elev. 185.0 m. It is also noted that the foot print of a noise berm will be limited by the current ROW and any attempts to acquire property will incur delays which cannot be accommodated due to time constraints.

A noise berm existed previously at this site about 70 m east of the present Highway 406. This berm was approximately 395 m long. The geometry of this noise berm was altered as part of the Advance Contract (Contract 2) to accommodate the proposed Hwy. 406 NBL and the Ramp 406 S - Merritt Road E/W. The adjustments included moving the toe of slope laterally to the east and adjusting the berm’s west slope (facing the highway) to 3H:1V. Consequently, the current embankment cross-section and height was reduced.

The design team reviewed reconstructing the current embankment at side slopes of 3H:1V (local earth fill), 2.5H:1V (earth fill core with Granular A facing) and 2H:1V (SSM material covering existing embankment). The review indicated that the current ROW limits will not accommodate embankments constructed at slopes of 3H:1V and 2.5H:1V and these alternatives were excluded from further study.

A reinforced earth embankment was also considered but at a cost of $\$325/m^2$ this option is the most expensive alternative and was therefore excluded from further study.

Embankments constructed by covering the existing earth embankment with SSM material can be accommodated within the current ROW at 2H:1V side slopes and this alternative was carried forward.

The proposed design grade is approximately 2 m to 3 m higher than the existing top of berm elevation. Given the relatively small height, an economical solution would be a post and panel noise wall constructed at the top of the current (reshaped) berm.

6.2 Embankment Stability and Settlement

6.2.1 General

Embankments constructed with local cohesive earth fill at conventional 2H:1V slopes in the Niagara area 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.

As pointed out previously the current ROW limits will not accommodate embankments constructed at slopes of 3H:1V and 2.5H:1V and these alternatives were excluded from further study.

If the existing noise berm is covered with SSM material, the new berm can be constructed at 2H:1V side slopes which can be accommodated within the current ROW. This geometric configuration was selected for further study.

6.2.2 Embankment Stability

For the purpose of embankment stability analyses, the commercially available slope stability program Slide 5.0 developed by Rocscience Inc. was used. The Bishop, Janbu and Spencer methods 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. 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 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 SSM embankment heights equal to or greater than 8 m. Where SSM embankments are higher than 8 m, mid-height berms should be incorporated in the design. Since the site is classified as Seismic Performance Zone 1, seismic stability analysis is not required as per Clause 4.6 of the CHBDC 2006.

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[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.

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.

The soil parameters used for the slope stability analyses are presented in Table 6.3.1.

Table 6.2.2 – 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)
Select Subgrade Material	32	0	20.0	32	0	20.0
Fill – Silty Clay	0	20 - 50	19.0	28	2	19.0
Upper Silty Clay	0	60 - 100	20.5	28	5	20.5
Middle Silty Clay	0	25 - 100	20.5 -21.0	28	5	21.0
Silt	30 - 33	0	18.5 - 19.0	30 - 33	0	18.5 - 19.0
Lower Silty Clay	0	75 - 100	21.0	28	5	22.0

The stability analyses yielded factors of safety ranging from 1.4 to 2.9 for undrained (short term) conditions and 1.4 to 1.7 for drained (long term) conditions. The slope stability models and results are illustrated in Appendix F.

The analysis indicates that embankments consisting of a core of silty clay fill and rebuilt with SSM at a design side slope of 2H:1V, 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.

6.2.3 Embankment Settlement

The deformation parameters used for the analyses were established from predictions/empirical correlations using undrained shear strengths, laboratory index tests and soil moisture contents. These parameters are tabulated below.

Table 6.2.3 – Settlement Parameters

Parameter	Upper Silty Clay	Lower Silty Clay
Preconsolidation Pressure P_c (kPa)	400	300
Coefficient of Compressibility - C_c	0.25	0.19
Recompression Index - C_r	0.045	0.027
Initial Void Ratio - e_o	0.85	0.60

Settlement analyses were conducted for SSM embankments at 2H:1V side slopes. The analyses also took into consideration the loads imparted on the underlying silty clay soils by the previous noise berm. The analyses indicate an estimated total consolidation settlement of 75 mm in the underlying silty clay soils.

Embankments comprised of SSM will also settle during construction (fill compression) and this settlement is expected to be about 1% of the fill height. The settlement of non-cohesive fill should be immediate in nature and essentially be complete shortly after construction is complete.

6.3 NOISE WALLS – DESIGN CONSIDERATIONS

It is anticipated that a noise barrier wall will be supported on conventional augered caissons (i.e. drilled shafts) with typical diameters ranging from 0.6 m to 0.9 m. The depth of the caisson would vary depending on the design of the wall and the subsurface conditions encountered. The design can be carried out in accordance with the following documents and papers.

- Canadian Highway Bridge Design Code and Commentary (2000). CAN/CSA-S6-00 and S6.1-00.
- Ministry of Transportation, Ontario (2007) "Sign Support Manual", Bridge Office, Engineering Standards Branch.
- BROMS, B.B.: Lateral Resistance of Piles in Cohesive Soils, Journal of the Soil Mechanics and Foundation Division, ASCE, Vol. 90 No. SM2, Paper No. 3825, March 1964.
- BROMS, B.B.: Lateral Resistance of Piles in Cohesive Soils, Journal of the Soil Mechanics and Foundation Division, ASCE, Vol. 90 No. SM3, Paper No. 3909, March 1964.
- BROMS, B.B.: Design of Laterally Loaded Piles, Journal of the Soil Mechanics and Foundation Division, ASCE, Vol. 91. Paper No. SM3, May 1965.

The recommended soil parameters for the design of augered caisson foundation units are given in Appendix G.

In order to take into account frost action and surficial disturbance, the ultimate lateral passive resistance in front of a caisson and caisson sidewall adhesion within the upper 1.2 m below final grade, should be neglected in the foundation design. It is also recommended that all surficial weak or variable soils be neglected in determining lateral resistance.

The sloping berm will result in reduced lateral passive resistance that should be taken into account during design. When designing for the portion of a caisson below the groundwater level, the submerged unit weight should be used. The required depth of the drilled shaft will be governed by lateral loads, including wind loads. The length of the caisson should also be sufficient to counteract frost jacking (upward) forces.

An equivalent caisson width equal to 3 times the caisson diameter may be assumed for lateral resistance calculations. Appropriate load and resistance factors should be applied for caisson design.

7 CONSTRUCTION CONSIDERATIONS (EMBANKMENTS)

It is recommended that the topsoil, any deleterious material and soft/loose and other unsuitable soils be removed below the footprint of the proposed noise berm 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 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.

SSM material must meet the requirements of OPSS 1010. SSM 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 should be established 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. Surface water must be directed to armoured outfalls/outlets designed to drain into roadside ditches.

8 CONSTRUCTION CONSIDERATIONS (NOISE WALLS)

The boreholes indicate the presence of silty clay fill and native deposits of silty clay and silt. The history of the on-site fill is unknown but it is likely that this material is un-sorted and could contain obstructions. Obstructions if encountered during excavation can increase the level of construction effort required for caisson installation, such as increasing the time required for drilling etc. Bidders should be advised that obstructions could be encountered and be required to provide adequate equipment to handle the obstructions.

The cohesive silty clay fill material and silty clay are expected to be self-supporting but wet caves can be expected to occur in the more pervious silt layers. The low permeability silty clay soils are not expected to yield significant quantities of water in caisson holes but greater yields can be expected from the wet silt layers. It is therefore recommended that temporary liner(s) be available on site to support the caisson sidewalls and to provide seepage cut-off as and where required.

The concrete should be poured expeditiously on completion of the caisson hole. It is recommended that the concrete be placed by the tremie method in accordance with OPSS PROV 904 as soon as the hole reaches its desired depth. The liner should be withdrawn as concrete is placed. During liner withdrawal, the level of concrete in the caisson hole must always be at least 0.6 m above the bottom of the temporary liner.

We recommend that the following notes be included in the contract documents:

- At the foundation locations the strata may consist of fill material (silty clay), and native deposits of silty clay and wet silt. Groundwater is likely to be encountered above the base of the excavations.
- The contractor shall maintain the stability of the soil along the sides and in the bases of the holes for the concrete footings at all times from the commencement of their construction to the placing of the concrete.
- Dewatering and/or temporary liners may be required to maintain a sufficiently dry condition for proper construction of the caisson hole and the placement of concrete.

Caisson construction should be monitored by qualified geotechnical personnel to verify the soil conditions and to confirm that those conditions are consistent with the design assumptions in this report. Excavations should be undertaken in accordance with OPSS 902 and caissons should be constructed in accordance with OPSS 903.

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TABLES

TERRAPROBE INC.

TABLE 1

DOCUMENT	TITLE
OPSS 206	Construction Specification for Grading.
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.
OPSS 1010	Material Specifications for Aggregates, Select Subgrade, Backfill
OPSS PROV 904	Construction Specification for Concrete Structures
OPSD 208.010	Benching of Earth Slopes.

APPENDICES

TERRAPROBE INC.

APPENDIX A

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

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 1

METRIC

W.P. 280-99-00 | LOCATION Coords: N:4765596.7 E:326997.4 | ORIGINATED BY MP

DIST ____ HWY 406 | BOREHOLE TYPE Solid Stem Augers | COMPILED BY DB

DATUM Geodetic | DATE 10.03.10 | CHECKED BY RA

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT / REMARKS	GR	SA	SI	CL
177.2	Ground Surface								
0.0	FILL - Silty Clay, some sand, trace organics, firm to stiff, brown, moist	1	SS	7					
		2	SS	14		0	14	55	31
175.4 / 1.8	SILTY CLAY trace sand, trace gravel, occasional silt seams and partings, stiff to very stiff, brown, moist	3	SS	17					
		4	SS	20		1	2	58	39
		5	SS	14					
173.2 / 4.0	SILT trace clay, trace sand, dense, brown, wet				>> 1.4				
		6	SS	47		0	1	92	7
171.6 / 5.6	SILTY CLAY trace sand, trace gravel, stiff to very stiff, brown, moist	7	SS	14		7	6	60	27
					>>				
					>>				
		8	SS	17					
		9	SS	22					
		10	SS	27					
166.0 / 11.2	End of Borehole								

Sampler wet at 4.6m.

Resistance to augering at 6.7m.

Water level at 8.5m (not stabilized) and hole open to full depth on completion.

Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 3.0m slotted screen.

Water Level Readings:

Date	Depth(m)	Elevation(m)
Oct.03.10	6.9	170.3
Oct.14.10	2.7	174.5
Oct.20.10	2.6	174.6

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (177–166); 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

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

RECORD OF BOREHOLE No 2

1 OF 1 **METRIC**

W.P. 280-99-00 LOCATION Coords: N:4765647.1 E:326956.5 ORIGINATED BY MP

DIST ___ HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB

DATUM Geodetic DATE 10.02.10 CHECKED BY RA

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	UNIT WEIGHT γ kN/m³
177.4	Ground Surface						
0.0	SILTY CLAY trace to some sand, occasional gravel inclusions, stiff to very stiff, brown, moist	1	SS	17			
		2	SS	22			
		3	SS	16		0 1 31 68	
		4	SS	15			
		5	SS	13			
	--- frequent silt seams and partings ---	6	TW	PH		2 13 61 24	22.9
		7	SS	16		1 2 62 35	
		8	SS	20			
		9	SS	18	∇ (approx. elev. 167.4)		
		10	SS	15		0 1 71 28	
165.4 / 12.0	End of Borehole						

Field vane results: + 1.3 (approx. elev. 173.5); + 1.3 (approx. elev. 173.0); + 1.6 (approx. elev. 165.8); >> 1.6 (at 165.4). Lab vane × at sample 6.

Liquid limit value 52 noted at sample 3.

End of Borehole notes:

Difficulty pushing shelby tube beyond 4.9m.

Sampler wet at 6.1m.

Water level at 10.1m (not stabilized) and hole open to full depth on completion.

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; ELEVATION SCALE 177 to 166.

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 3

METRIC

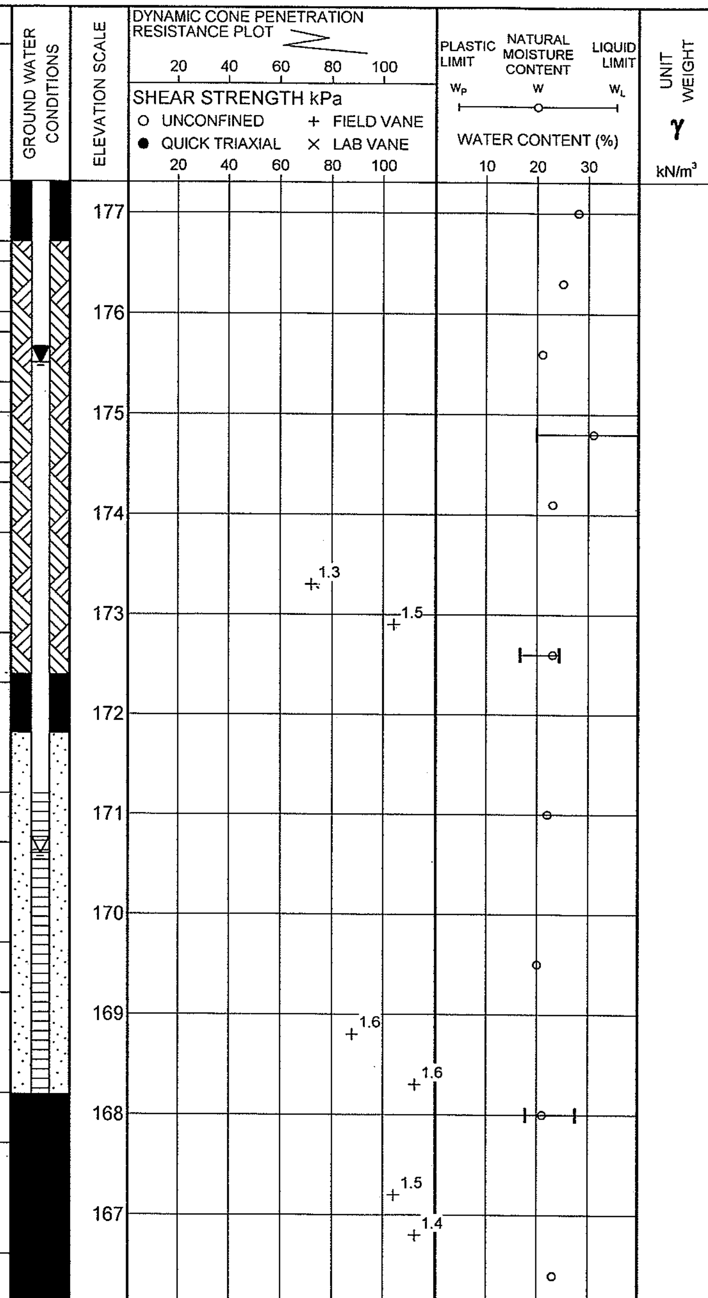
W.P. 280-99-00	LOCATION Coords: N:4765693.3 E:326917.9		ORIGINATED BY MP
DIST	HWY 406	BOREHOLE TYPE Solid Stem Augers	COMPILED BY DB
DATUM Geodetic		DATE 10.02.10	CHECKED BY RA

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
177.3	Ground Surface
0.0	SILTY CLAY trace sand, frequent silt seams and partings from 4.0m to 7.1m, stiff to very stiff, brown, moist ---- firm ----
166.1 11.2	End of Borehole

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	10				
2	SS	14				
3	SS	9				
4	SS	7	0	1	48	51
5	SS	10				
6	SS	20	0	1	81	18
7	SS	12				
8	SS	15				
9	SS	16	0	2	74	24
10	SS	21				



Sampler wet at 2.3m.

Water level at 6.7m (not stabilized) and hole open to full depth on completion.

Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 3.0m slotted screen.

Water Level Readings:

Date	Depth(m)	Elevation(m)
Oct.03.10	1.9	175.4
Oct.14.10	1.7	175.6
Oct.20.10	1.8	175.5

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

RECORD OF BOREHOLE No 4

METRIC

W.P. 280-99-00 LOCATION Coords: N:4765759.7 E:326896.0 ORIGINATED BY MP

DIST ____ HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB

DATUM Geodetic DATE 09.25.10 CHECKED BY RA

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
180.1	Ground Surface								
180.0 / 0.1	80mm TOPSOIL								
	FILL - Silty Clay, trace sand, trace organics, soft, brown, moist	1	SS	3		0	3	40	57
179.4 / 0.7	SILTY CLAY trace sand, firm to very stiff, brown, moist	2	SS	16					
		3	SS	17					
		4	SS	8		0	1	43	56
		5	SS	5					
	very soft	6	SS	1					
		7	TW	PH	18.8	0	1	42	57
		8	SS	2		0	2	59	39
171.5 / 8.6	SILT trace clay, trace sand, loose to compact, brown, wet	9	SS	7		0	2	92	6
		10	SS	10					
168.4 / 11.7	SILTY CLAY trace sand, stiff to very stiff, brown, damp to moist	11	SS	7		0	1	75	24
		12	SS	11					

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (180 to 166); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X 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.

Plot annotations: Liquid limits 46 (sample 1), 42 (sample 4), 46 (sample 7). Field vane sensitivities: 1.2, >>1.5, 3.1, 1.2, 1.3, 1.5, 2.2, 1.3, 2.0, >>, >>1.5.

Continued Next Page

+³, X³: Numbers refer to Sensitivity   O 3% STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 4

METRIC

W.P. 280-99-00	LOCATION Coords: N:4765759.7 E:326896.0		ORIGINATED BY MP
DIST	HWY 406	BOREHOLE TYPE Solid Stem Augers	COMPILED BY DB
DATUM Geodetic		DATE 09.25.10	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: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X 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
165.0 15.1	End of Borehole Sampler wet at 9.1m. Borehole was dry (not stabilized) and hole open to full depth on completion.						165	>>			

+ 3, X 3: Numbers refer to Sensitivity

O 3% STRAIN AT FAILURE

ONTARIO MOT 1-09-4135 SOUND BERM.GPJ ONTARIO MOT.GDT 11/02/10

Ministry of Transportation
Ontario

Foundation Design

RECORD OF BOREHOLE No 5

METRIC

W.P.	280-99-00	LOCATION	Coords: N:4765807.0 E:326859.2	ORIGINATED BY	MP
DIST / HWY	406	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	DB
DATUM	Geodetic	DATE	09.25.10	CHECKED BY	RA

SOIL PROFILE / SAMPLES

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
180.6	Ground Surface				
180.5 / 0.1	80mm TOPSOIL				
179.9 / 0.7	FILL - Silty Clay, some sand, trace organics, stiff, brown, damp to moist	1	SS	9	
	SILTY CLAY trace sand, frequent silt seams and partings from 9.6m to 11.7m, occasional cobbles from 13.1m to 13.7m, firm to stiff, brown, damp to moist	2	SS	7	
		3	SS	14	
		4	SS	10	
		5	SS	7	0 0 50 50
		6	SS	3	
		7	SS	3	0 0 49 51
	---- soft to firm	8	SS	1	
		9	SS	2	0 2 64 34
	----	10	SS	2	0 2 78 20
		11	SS	5	
		12	SS	7	
166.0 / 14.6	End of Borehole				

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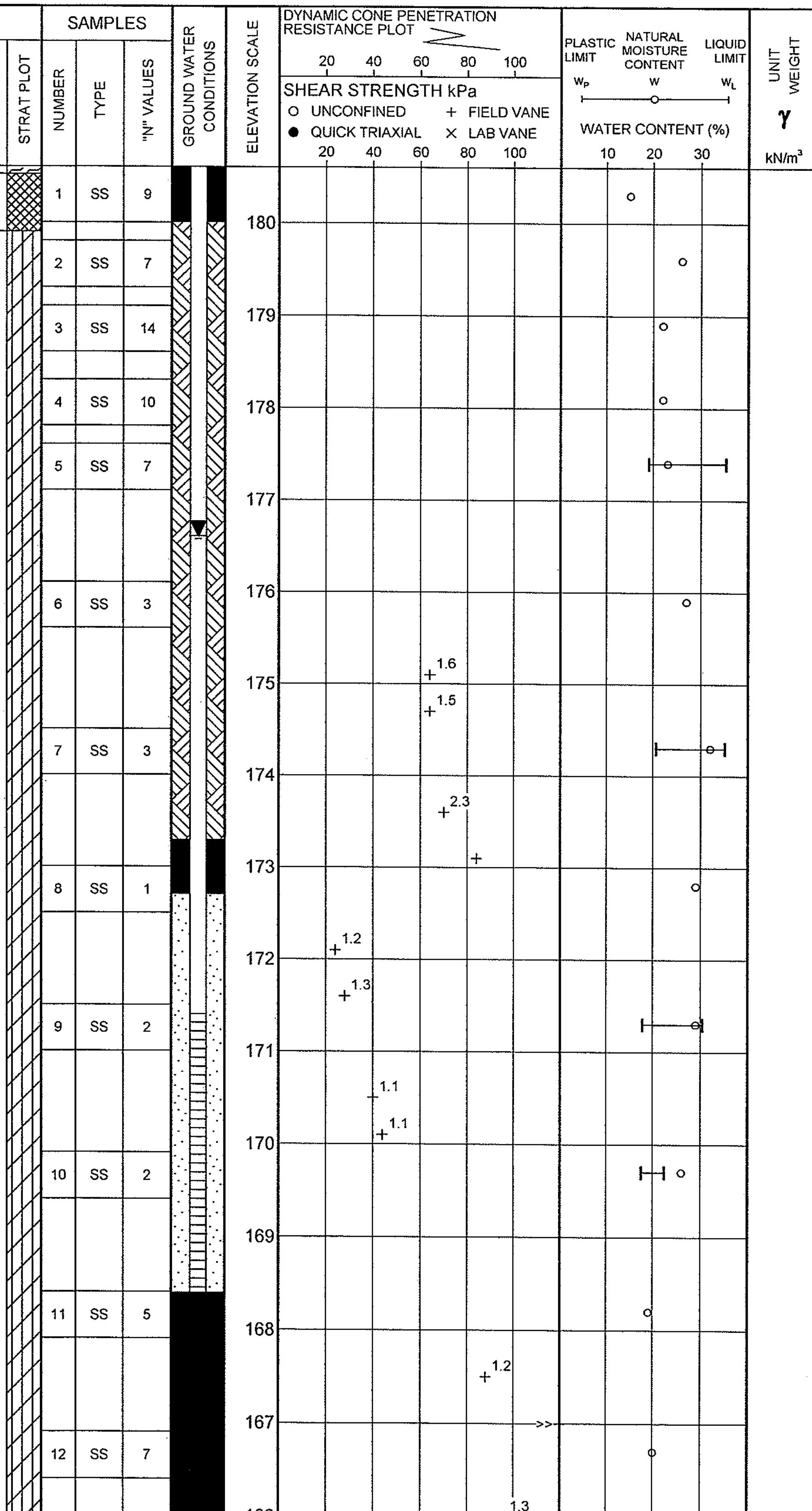


$+^3, \times^3$: Numbers refer to Sensitivity $O^{3\%}$ STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 5

METRIC

W.P. 280-99-00 LOCATION Coords: N:4765807.0 E:326859.2 ORIGINATED BY MP

DIST ____ HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY DB

DATUM Geodetic DATE 09.25.10 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X 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	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Sampler wet at 10.7m. Unable to push vane beyond 11.1m and 14.6m. Resistance to augering from 13.1m to 13.7m. Wet cave at 12.8m on completion. Piezometer installation consists of a 19mm diameter, Schedule 40 PVC pipe with a 3.0m slotted screen. Water Level Readings:										

Date	Depth(m)	Elevation(m)
Sep.25.10	4.5	176.1
Oct.03.10	4.1	176.5
Oct.14.10	4.0	176.6
Oct.20.10	4.0	176.6

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

Test Pit Logs (TP 6A - 6G)
Hwy 406 (Sta. 14+175 to Sta. 14+434)
Ramp 406 S-Merritt Rd E/W (Sta. 10+000 to Sta. 10+125)

Test Pit # TP 6A

0.00	-	2.40	Fill, Br Si(y) Cl, Tr Gr, Tr Cob, Moist to Wet
2.40	-	4.10	Fill, Dk Br Cl(y) Si, Some Org, Blk Stks, Some Wd, Some Roots, Moist to Wet
4.10	-	4.40	Gry/Br Si(y) Cl, Mott, Moist to Wet

Test Pit # TP 6B

0.00	-	1.90	Fill, Br Cl(y) Si, Some Gr, Some Cob, Moist
1.90	-	4.20	Fill, Dk Br Si(y) Cl, Some Org, Blk Stks, Some Wd, Some Roots, Moist to Wet
4.20	-	4.40	Tps
4.40	-	4.90	Br/Gry Si(y) Cl, Moist

Test Pit # TP 6C

0.00	-	2.20	Fill, Br Si(y) Cl, Tr Gr, Cob, Moist to Wet
2.20	-	4.20	Fill, Gry/Br Cl(y) Si, Tr to Some Sa, Tr Sh Rk, Moist to Wet
4.20	-	4.80	Tps, Some Wd (Stumps), Moist to Wet
4.80	-	5.20	Gry/Br Si(y) Cl, Mott, Moist

Test Pit # TP 6D

0.00	-	3.90	Fill, Br Cl(y) Si, Some Gr, Occ Cob, Tr Wd, Moist to Wet, Fr Wat @ 1.2
3.90	-	4.90	Fill, Gry/Br Cl(y) Si to Si Some Cl, Some Roots, Moist to Wet
4.90	-	5.10	Tps, Org M
5.10	-	5.30	Gry/Br Si(y) Sa, Tr Cl, Wet, Fr Wat @ 5.3

Test Pit # TP 6E

0.00	-	1.80	Fill, Br Si, Tr Cl, Tr Sa, Moist
1.80	-	4.40	Fill, Gry/Br Si, Some Cl, Some Org, Moist
4.40	-	4.60	Tps, Org M, Some Wd
4.60	-	4.90	Gry/Br Si(y) Cl, Mott, Moist

Test Pit # TP 6F

0.00	-	3.00	Fill, Br Cl(y) Si, Some Gr, Some Cob, Occ Blds, Moist
3.00	-	5.00	Fill, Gry/Br Sa and Si, Some Cl, Some Roots, Some Wd, Wet
5.00	-	5.30	Br/Gry Si(y) Cl, Moist

Test Pit # TP 6G

0.00	-	3.50	Fill, Br Cl(y) Si, Tr Gr, Occ Cob, Moist
3.50	-	4.60	Fill, Br Cl(y) Si, Tr to Some Org, Blk Stks, Tr Wd, Moist
4.60	-	5.40	Fill, Gry Cl(y) Si, Some Roots, Moist
5.40	-	5.70	Gry/Br Si(y) Cl, Moist

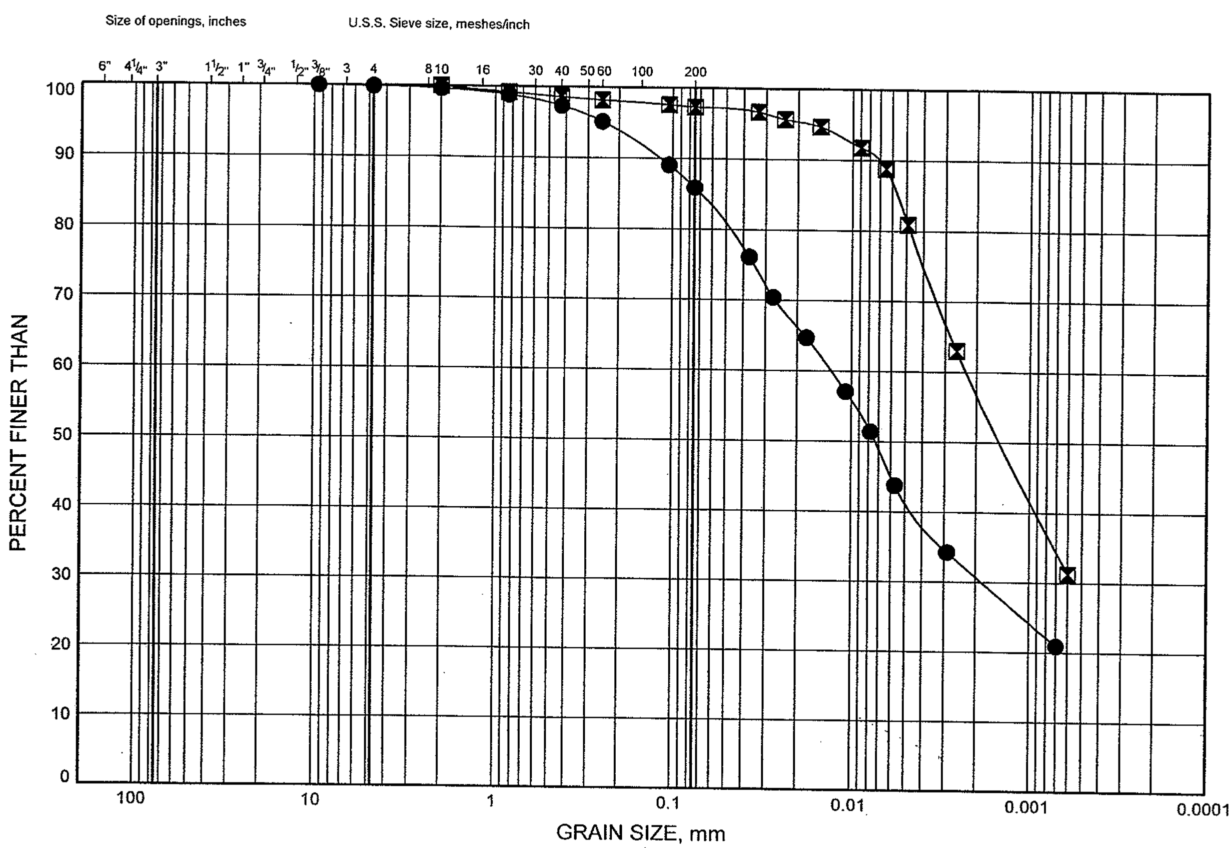
APPENDIX B

TERRAPROBE INC.

GRAIN SIZE DISTRIBUTION

FIGURE B1

FILL - Silty Clay



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	1	1.0	176.2
⊠	4	0.3	179.8

Date November 2010

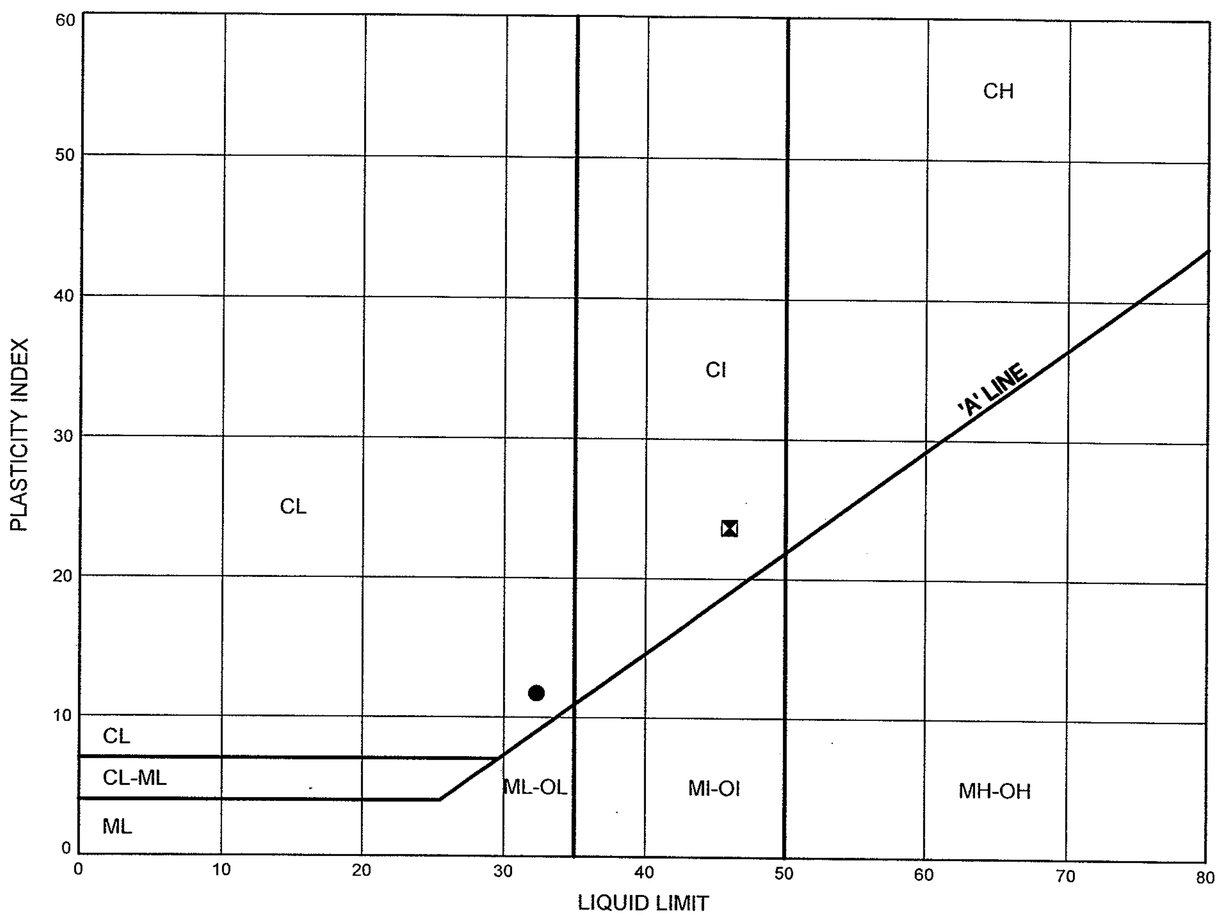
Project 1-09-4135

Prep'd DB

Chkd. HA

ATTERBERG LIMITS TEST RESULTS	FIGURE B2

FILL - Silty Clay



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	1	1.0	176.2
⊠	4	0.3	179.8

Date November 2010
Project 1-09-4135

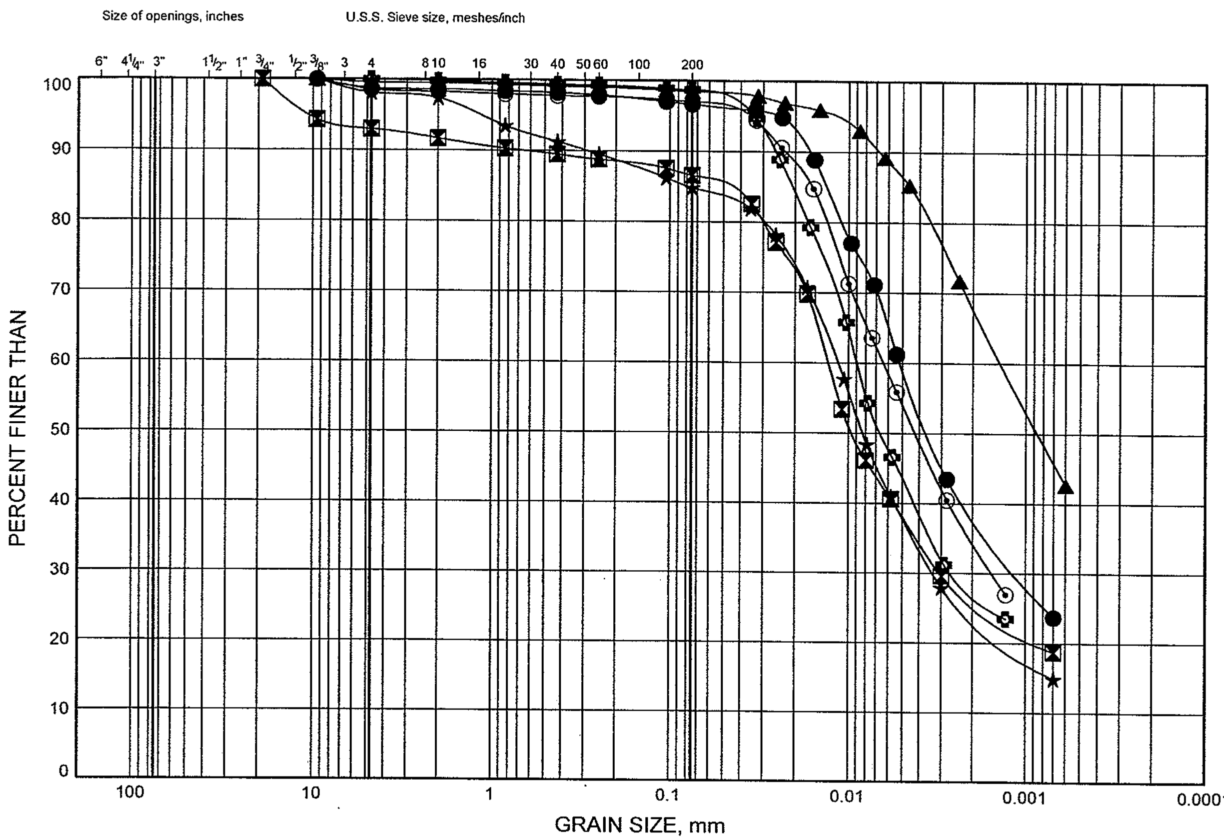
Prep'd DB
Chkd. HA

ALTR 1-09-4135 SOUND BERM.GPJ 11/02/10

GRAIN SIZE DISTRIBUTION

FIGURE B3

SILTY CLAY



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	1	2.5	174.7
⊠	1	6.3	170.9
▲	2	1.7	175.7
★	2	4.7	172.7
⊙	2	6.3	171.1
✿	2	10.9	166.5

Date November 2010

Project 1-09-4135

Prep'd DB

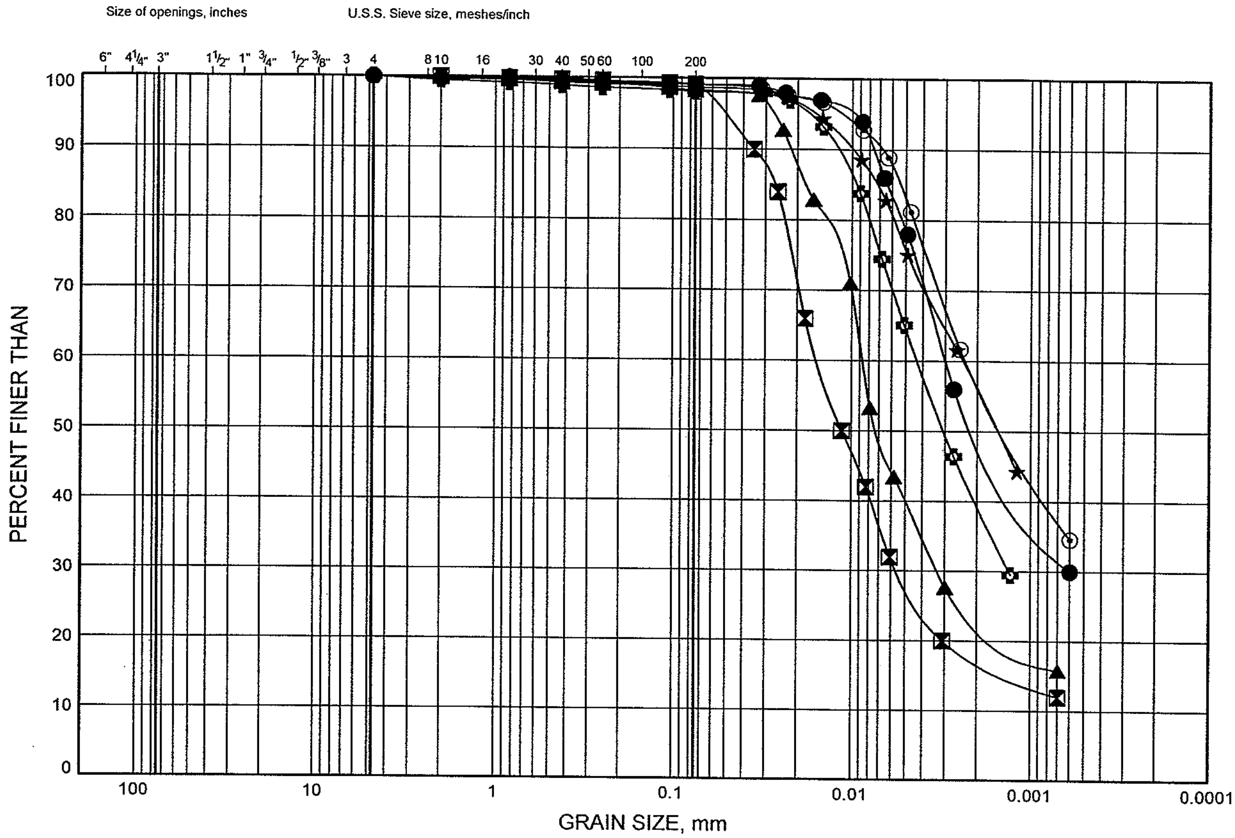
Chkd. HA

GSD 1-09-4135 SOUND BERM.GPJ 11/02/10

GRAIN SIZE DISTRIBUTION

FIGURE B4

SILTY CLAY



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	3	2.5	174.8
⧗	3	4.7	172.6
▲	3	9.3	168.0
★	4	2.5	177.6
⊙	4	6.3	173.8
✿	4	7.8	172.3

Date November 2010

Project 1-09-4135

Prep'd DB

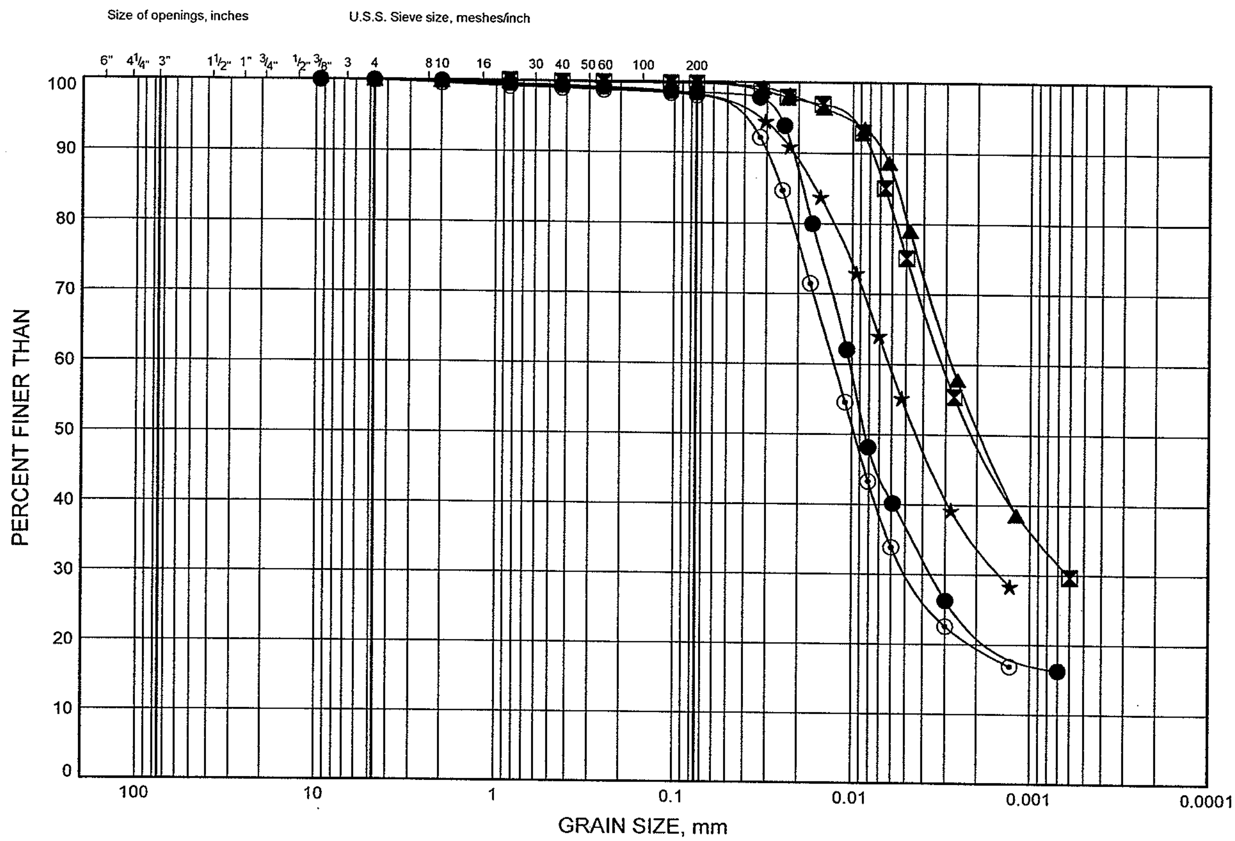
Chkd. HA

GSD 1-09-4135 SOUND BERM.GPJ 11/02/10

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)
●	4	12.4	167.7
⧖	5	3.2	177.4
▲	5	6.3	174.3
★	5	9.3	171.3
⊙	5	10.9	169.7

Date November 2010

Project 1-09-4135

Prep'd DB

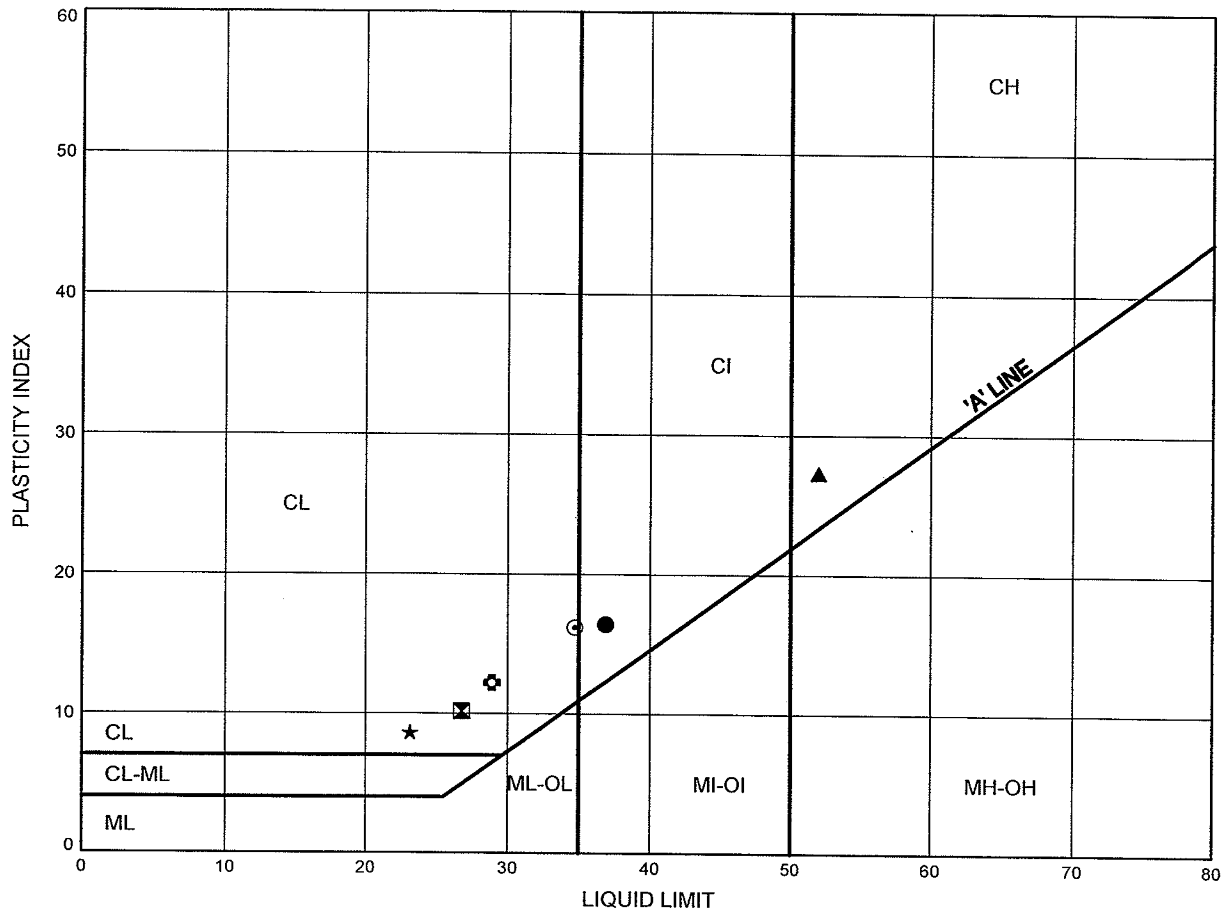
Chkd. HA

GSD 1-09-4135 SOUND BERM.GPJ 11/02/10

ATTERBERG LIMITS TEST RESULTS

FIGURE B6

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	1	2.5	174.7
⊠	1	6.3	170.9
▲	2	1.7	175.7
★	2	4.7	172.7
⊙	2	6.3	171.1
✿	2	10.9	166.5

Date November 2010

Project 1-09-4135

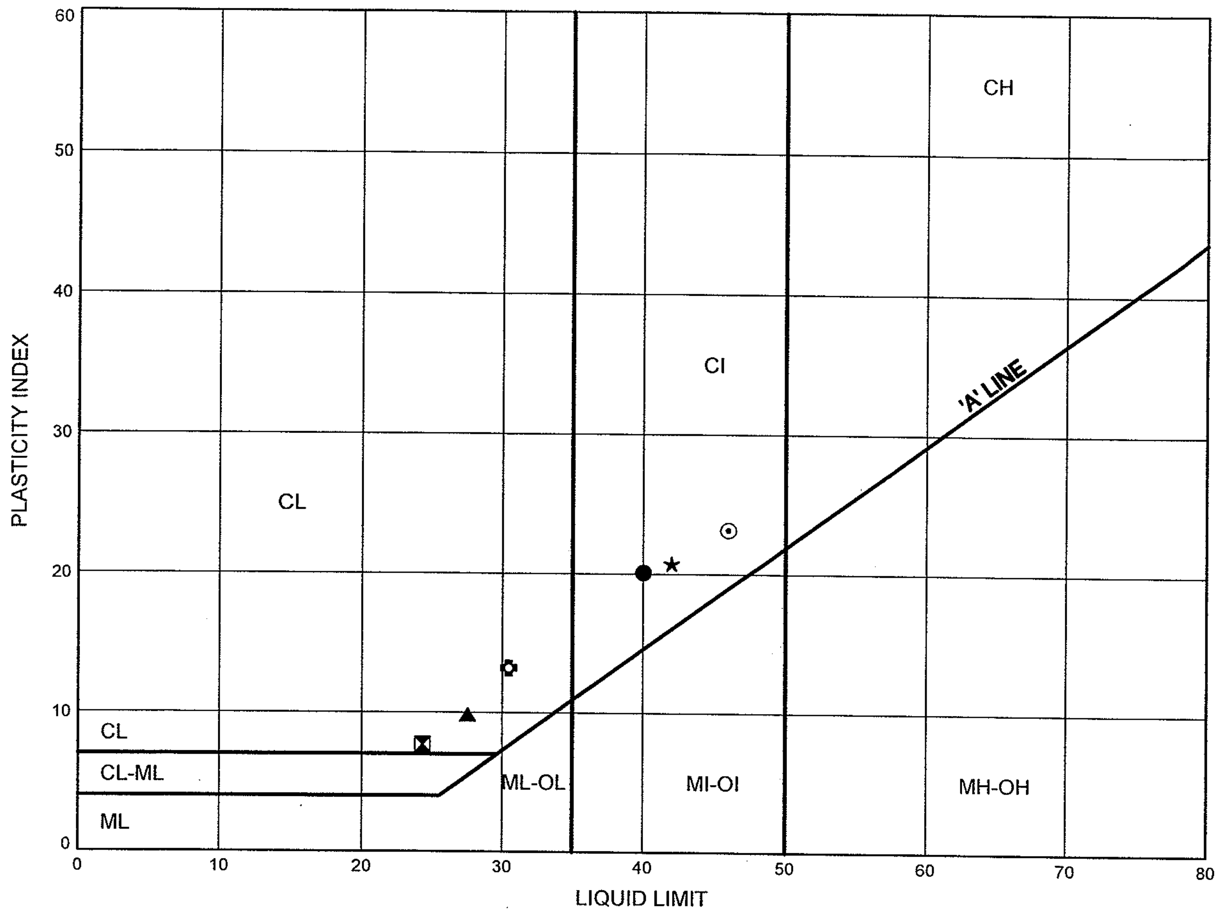
Prep'd DB

Chkd. HA

ATTERBERG LIMITS TEST RESULTS

FIGURE B7

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	3	2.5	174.8
⊠	3	4.7	172.6
▲	3	9.3	168.0
★	4	2.5	177.6
⊙	4	6.3	173.8
✿	4	7.8	172.3

Date November 2010

Project 1-09-4135

Prep'd DB

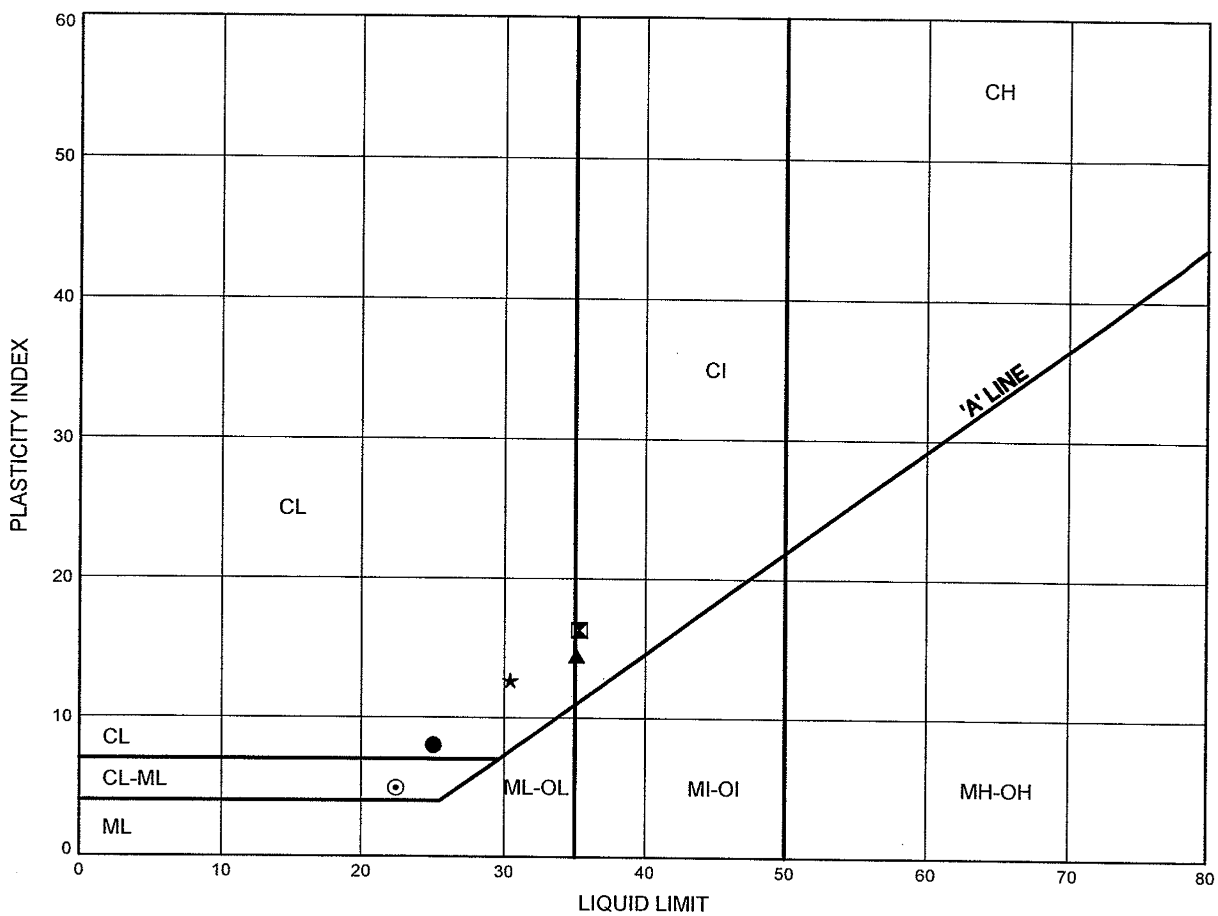
Chkd. HA

ALTR 1-09-4135 SOUND BERM.GPJ 11/02/10

ATTERBERG LIMITS TEST RESULTS

FIGURE B8

SILTY CLAY



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	4	12.4	167.7
⊠	5	3.2	177.4
▲	5	6.3	174.3
★	5	9.3	171.3
⊙	5	10.9	169.7

Date November 2010

Project 1-09-4135

Prep'd DB

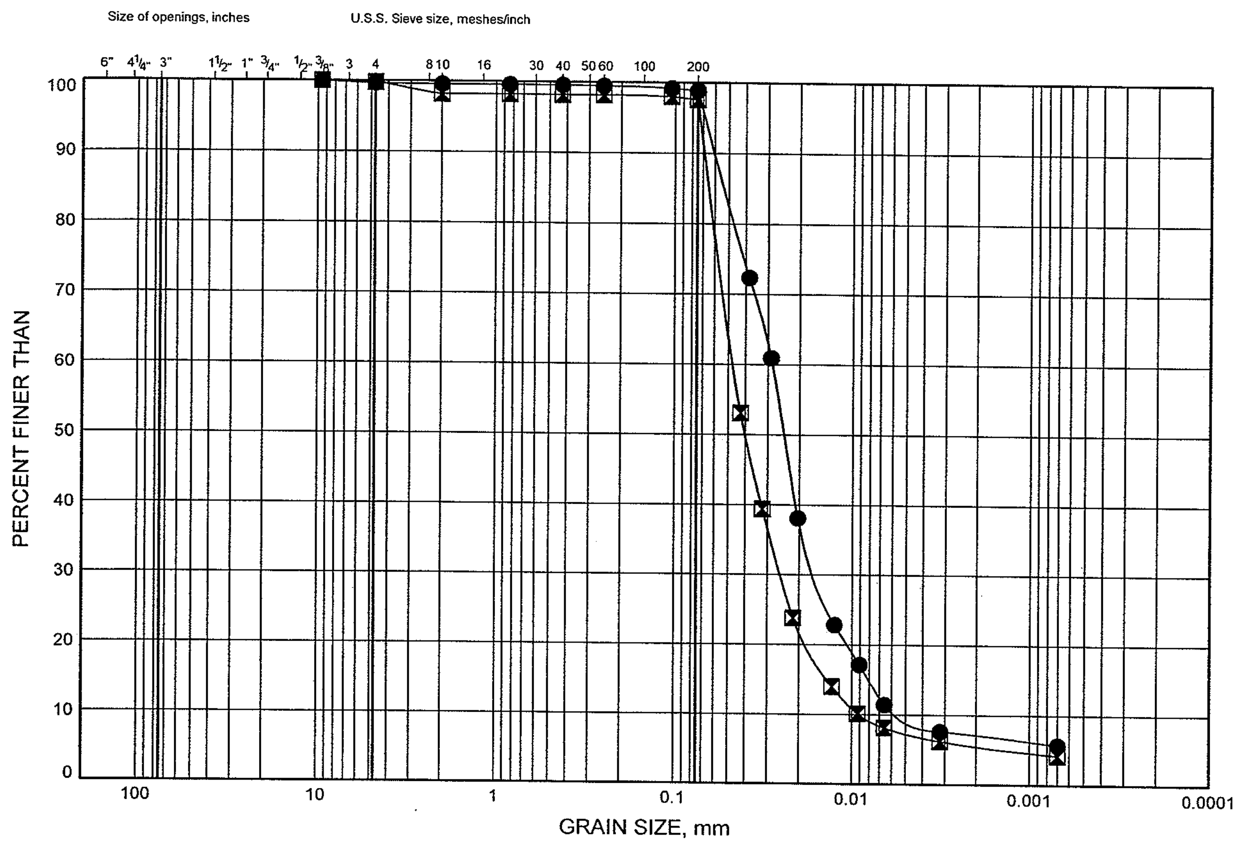
Chkd. HA

ALTR 1-09-4135 SOUND BERM.GPJ 11/02/10

GRAIN SIZE DISTRIBUTION

FIGURE B9

SILT



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	1	4.7	172.5
⊠	4	9.3	170.8

Date November 2010

Project 1-09-4135

Prep'd DB

Chkd. HA

GSD 1-09-4135 SOUND BERM.GPJ 11/02/10

APPENDIX C

TERRAPROBE INC.

Test Pit 6A (Sta. 10+070 406 S-Merritt E/W, 29.0 m Rt C/L)

Test Pit 6A (Sta. 10+070 406 S-Merritt E/W, 29.0 m Rt C/L)

Test Pit 6A (Sta. 10+070 406 S-Merritt E/W, 29.0 m Rt C/L)

Test Pit 6B (Sta. 10+025 406 S-Merritt E/W, 23.0 m Rt C/L)

Test Pit 6B (Sta. 10+025 406 S-Merritt E/W, 23.0 m Rt C/L)

Test Pit 6B (Sta. 10+025 406 S-Merritt E/W, 23.0 m Rt C/L)

Test Pit 6C (Sta. 14+413 Hwy 406, 44.8 m Rt C/L)

Test Pit 6C (Sta. 14+413 Hwy 406, 44.8 m Rt C/L)

Test Pit 6D (Sta. 14+372 Hwy 406, 45.9 m Rt C/L)

Test Pit 6D (Sta. 14+372 Hwy 406, 45.9 m Rt C/L)

Test Pit 6E (Sta. 14+331 Hwy 406, 46.3 m Rt C/L)

Test Pit 6F (Sta. 14+284 Hwy 406, 46.8 m Rt C/L)

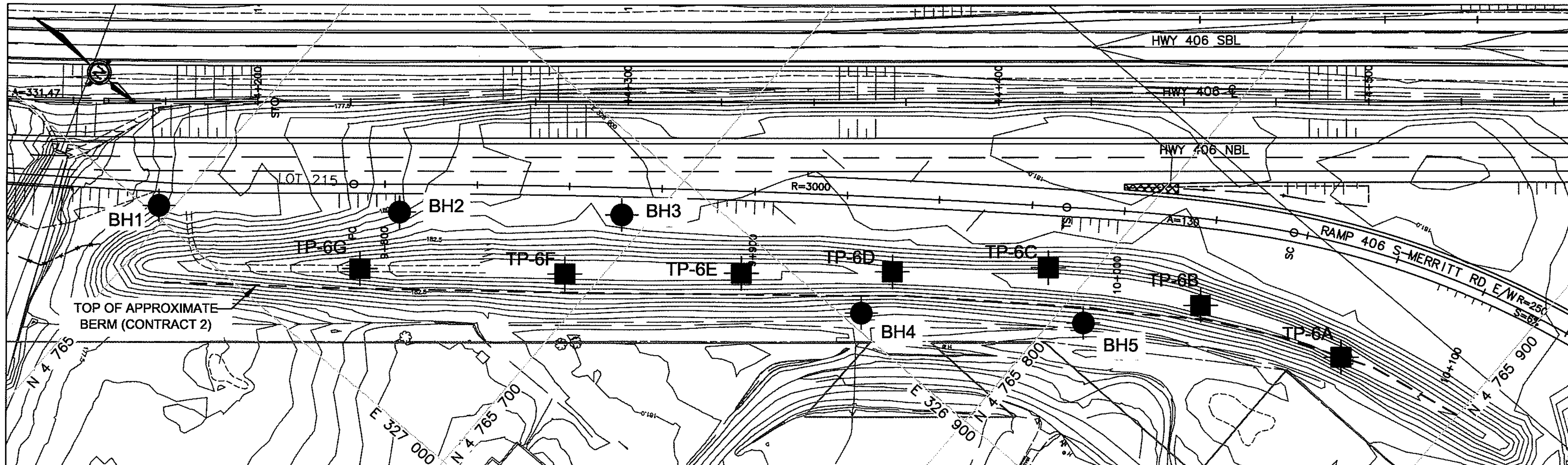
Test Pit 6F (Sta. 14+284 Hwy 406, 46.8 m Rt C/L)

Test Pit 6G (Sta. 14+228 Hwy 406, 45.1 m Rt C/L)

Test Pit 6G (Sta. 14+228 Hwy 406, 45.1 m Rt C/L)

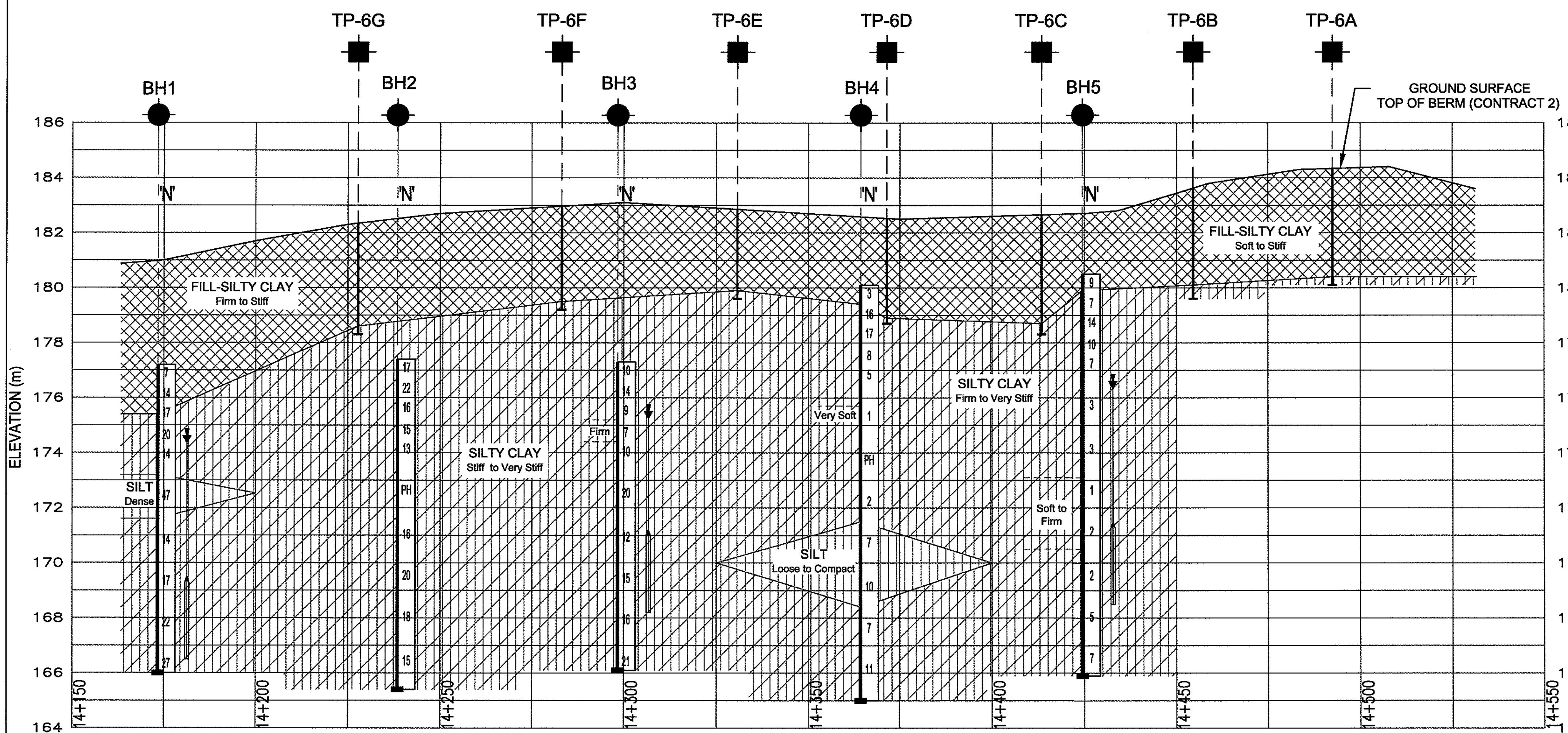
APPENDIX D

TERRAPROBE INC.



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

PLAN
SCALE
0 10 20 30 40m



PROFILE ℄ - TOP OF BERM (CONTRACT 2)

VERTICAL SCALE
0 1 2 3 4 5m

HORIZONTAL SCALE
0 10 20 30 40m

LICENSED PROFESSIONAL ENGINEER
M. TANOS
25'01'2011
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
R.A. ABDUL
Jan 25/2011
PROVINCE OF ONTARIO

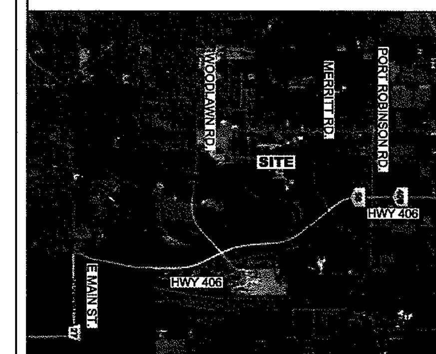
CONT No
WP No 280-99-00

HIGHWAY 406
NOISE MITIGATION UPGRADE
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET
1 OF

Giffels Associates Limited
Consulting Engineers and Architects
An IBI Group Company

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



KEY PLAN

LEGEND

Symbol	Description
●	Bore Hole
⊕	Dynamic Cone Penetration Test
⊕	Bore Hole And Cone
■	Test Pit
'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 (OCT. 2010)
	Piezometer
90%	Rock Quality Designation
A/R	Auger Refusal

No	ELEV.	COORDINATES	
		NORTHING	EASTING
BH1	177.2	4 765 596.7	326 997.4
BH2	177.4	4 765 647.1	326 956.5
BH3	177.3	4 765 693.3	326 917.9
BH4	180.1	4 765 759.7	326 896.0
BH5	180.6	4 765 807.0	326 859.2
TP6A	184.5	4 765 865.9	326 820.9
TP6B	184.5	4 765 828.0	326 835.0
TP6C	183.5	4 765 790.0	326 854.0
TP6D	184.0	4 765 758.8	326 882.1
TP6E	184.5	4 765 728.0	326 909.0
TP6F	184.5	4 765 692.0	326 940.0
TP6G	184.0	4 765 649.0	326 975.0

Ground Surface elevation prior to Contract 2.

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.Existing berm regraded in Contract 2. Base mapping illustrates ground conditions prior to Contract 2.

REVISIONS	DATE	BY	DESCRIPTION

DESIGN R.A	CODE CHBDC2006	LOAD	DATE NOV. 2010
DRAWN K.C	CHK R.A	STRUCT	GEOCRES 30M3-267

C:\Users\wmer\Documents\1-09-4135 HWY 406 (TEST PITS & Sound Berm)\1-09-4135 MERRITT ROAD SOUND BERM.dwg, KAMAL

APPENDIX E

TERRAPROBE INC.

COMPARISON OF NOISE ATTENUATION ALTERNATIVES

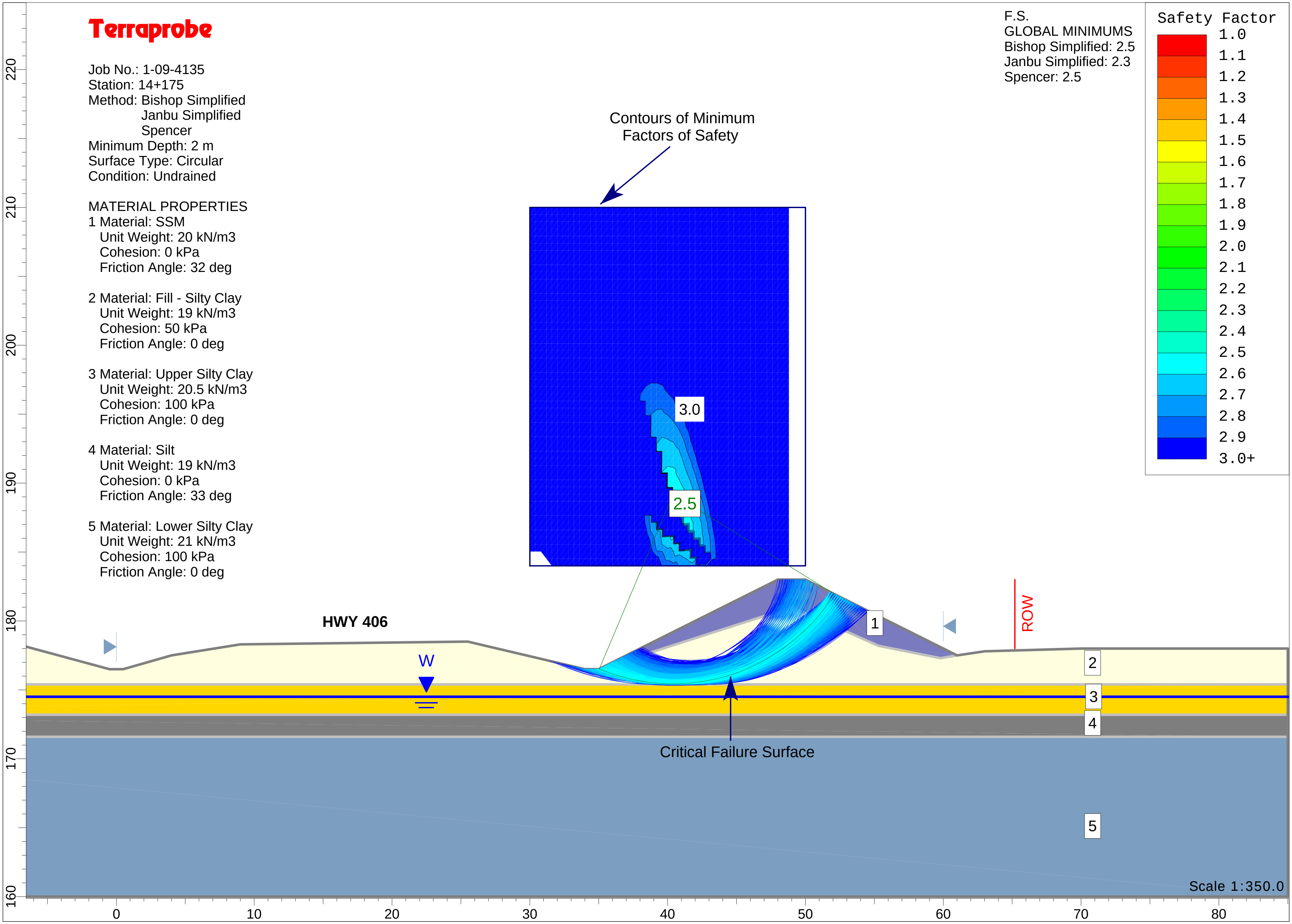
<table>
<tr><th>SSM Embankment Covering Existing Berm</th><th>Noise Walls</th></tr>
<tr><td>Advantages:
i. Can be constructed at conventional 2H:1V slopes.
ii. Conventional embankment footprint that will fit within current ROW limits.
iii. Proven reliable performance on MTO projects.

Disadvantages:
i. Costly to construct.
ii. Requires stringent quality control to ensure that only approved material is selected and used.
iii. Relatively high construction effort required i.e. benching and placement of dissimilar materials.</td><td>Advantages:
i. Can be constructed on existing berm.
ii. Simple to construct
iii. Less construction effort compared to constructing an embankment.
iv. Proven reliable performance on MTO projects.

Disadvantages:
None</td></tr>
<tr><td>Risks/Consequences
i. Very low risk of failure.
ii. Relatively higher material cost.</td><td>Risks/Consequences
i. Very low risk of failure.
ii. Lower cost compared to embankment construction</td></tr>
<tr><th colspan="2">APPROXIMATE COSTS (Source MTO HICO)</th></tr>
<tr><td>$ 23.00 per cubic metre</td><td>2 m High - $596.00 per metre
3 m High - $863.00 per metre</td></tr>
</table>

APPENDIX F

TERRAPROBE INC.


Terraprobe
Job No.: 1-09-4135
Station: 14+175
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Surface Type: Circular
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: 19 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Upper Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Silt
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 33 deg
5 Material: Lower Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
F.S.
GLOBAL MINIMUMS
Bishop Simplified: 2.5
Janbu Simplified: 2.3
Spencer: 2.5
Safety Factor
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0+
Contours of Minimum
Factors of Safety
3.0
2.5
HWY 406
W
ROW
1
2
3
4
5
Critical Failure Surface
Scale 1:350.0
220
210
200
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180
170
160
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10
20
30
40
50
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70
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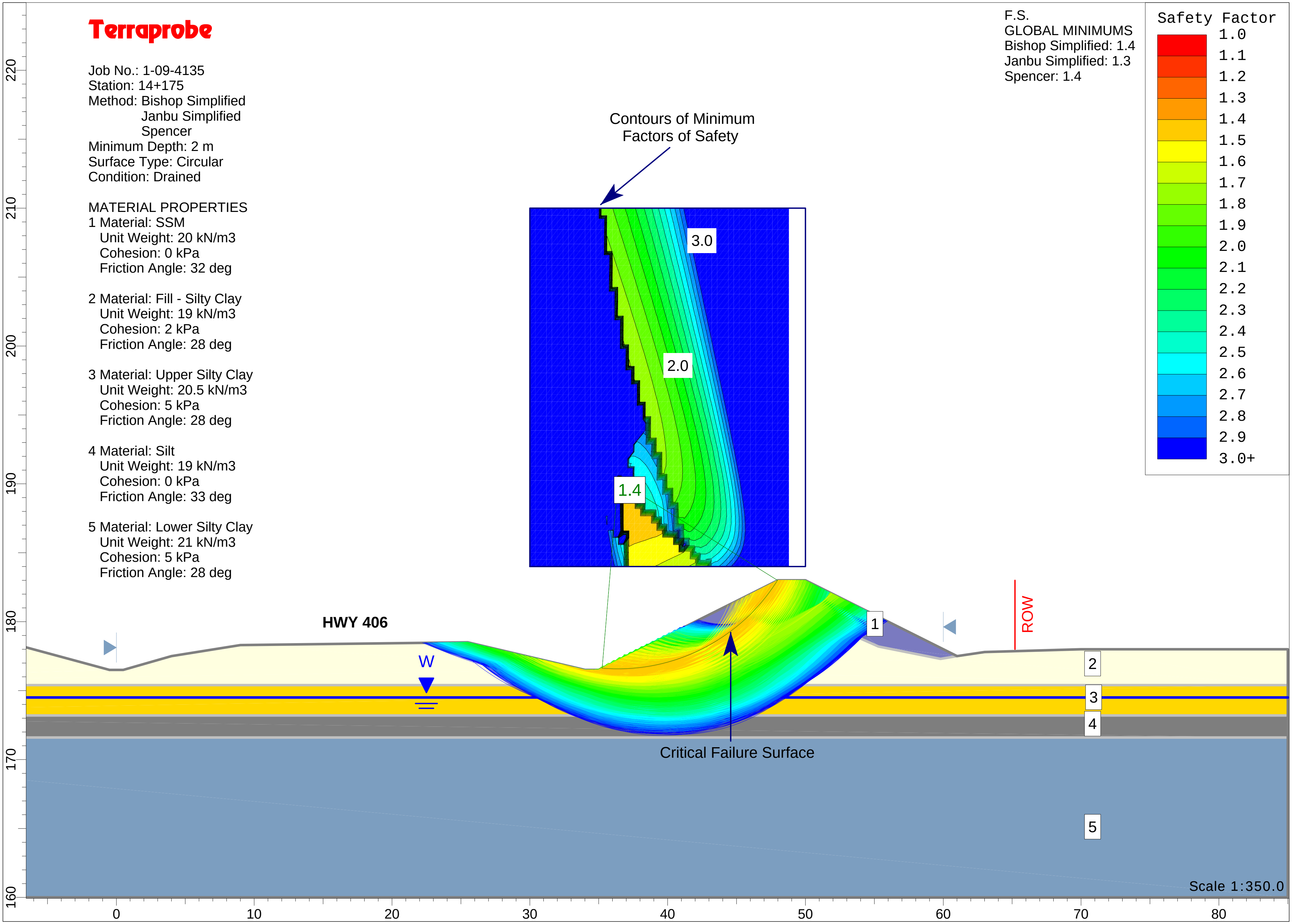

Terraprobe
Job No.: 1-09-4135
Station: 14+175
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Surface Type: Circular
Condition: Drained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill - Silty Clay
Unit Weight: 19 kN/m3
Cohesion: 2 kPa
Friction Angle: 28 deg
3 Material: Upper Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
4 Material: Silt
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 33 deg
5 Material: Lower Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
F.S.
GLOBAL MINIMUMS
Bishop Simplified: 1.4
Janbu Simplified: 1.3
Spencer: 1.4
Safety Factor
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0+
Contours of Minimum
Factors of Safety
3.0
2.0
1.4
HWY 406
W
ROW
1
2
3
4
5
Critical Failure Surface
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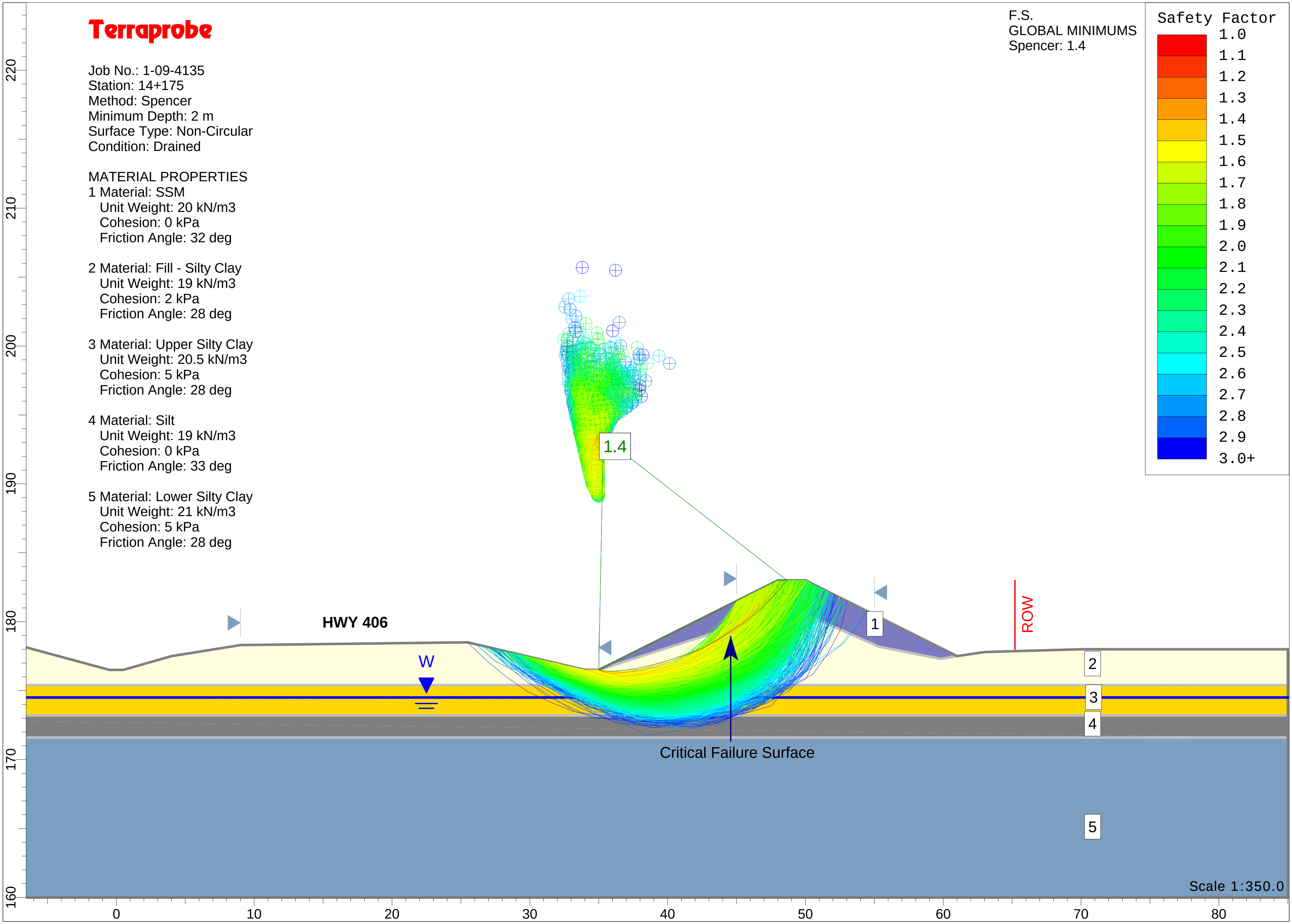

Terraprobe
Job No.: 1-09-4135
Station: 14+175
Method: Spencer
Minimum Depth: 2 m
Surface Type: Non-Circular
Condition: Drained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill - Silty Clay
Unit Weight: 19 kN/m3
Cohesion: 2 kPa
Friction Angle: 28 deg
3 Material: Upper Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
4 Material: Silt
Unit Weight: 19 kN/m3
Cohesion: 0 kPa
Friction Angle: 33 deg
5 Material: Lower Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
F.S.
GLOBAL MINIMUMS
Spencer: 1.4
Safety Factor
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0+
1.4
HWY 406
W
ROW
1
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4
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Critical Failure Surface
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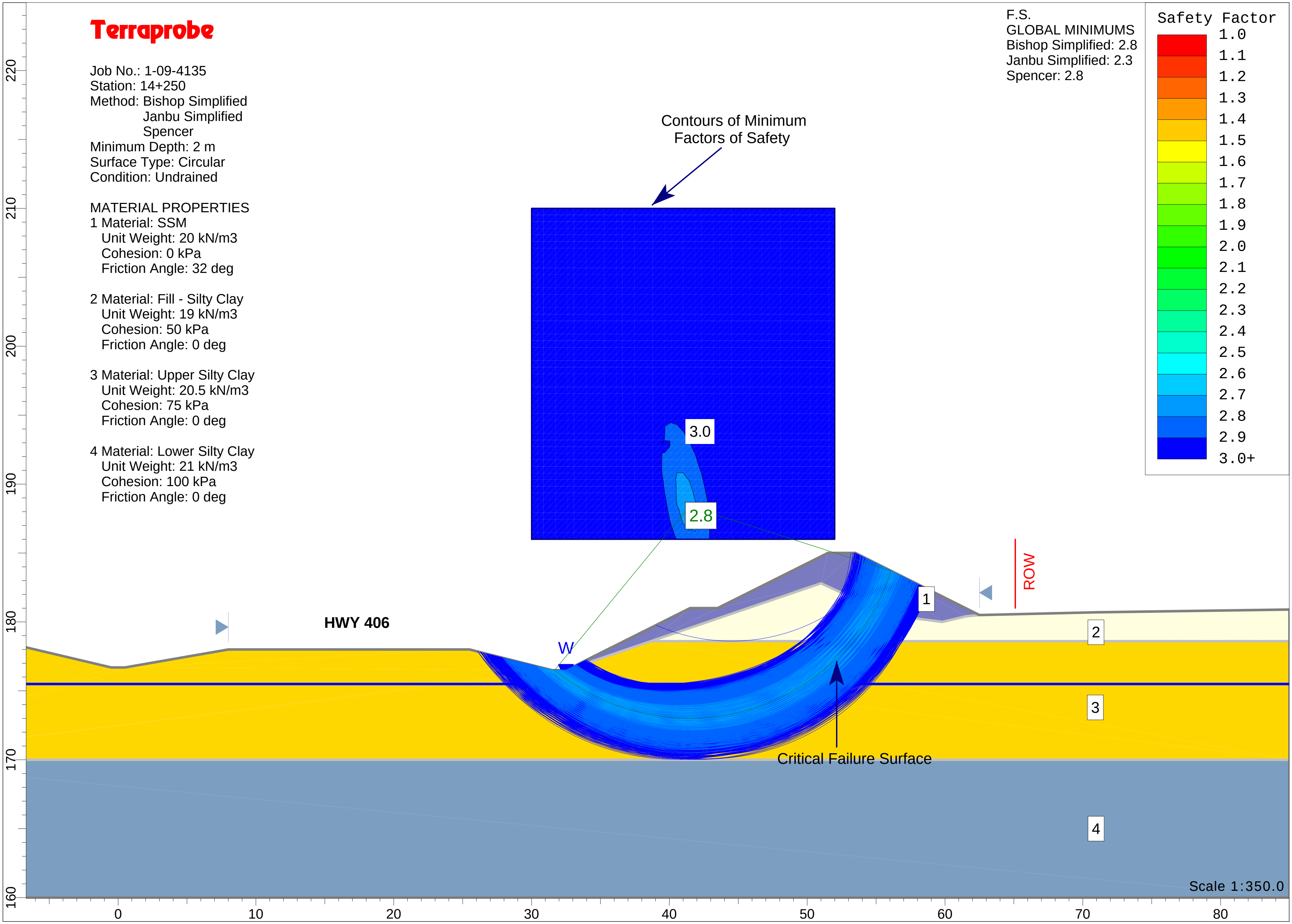
Terraprobe
Job No.: 1-09-4135
Station: 14+250
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Surface Type: Circular
Condition: Undrained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill - Silty Clay
Unit Weight: 19 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Upper Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 75 kPa
Friction Angle: 0 deg
4 Material: Lower Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
F.S.
GLOBAL MINIMUMS
Bishop Simplified: 2.8
Janbu Simplified: 2.3
Spencer: 2.8
Safety Factor
1.0
1.1
1.2
1.3
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1.5
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1.8
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2.1
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2.6
2.7
2.8
2.9
3.0+
Contours of Minimum
Factors of Safety
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2.8
ROW
HWY 406
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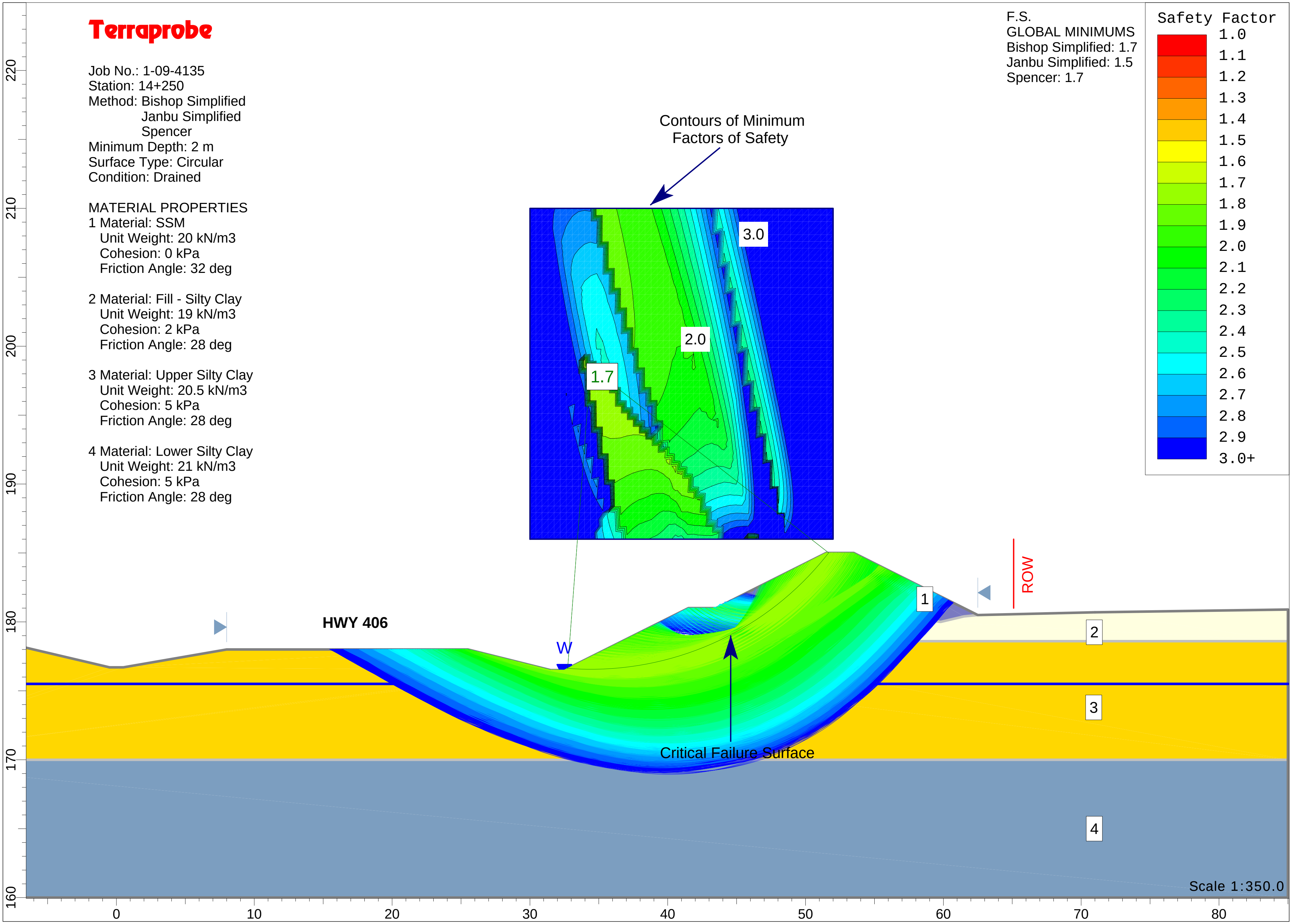

Terraprobe
Job No.: 1-09-4135
Station: 14+250
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Surface Type: Circular
Condition: Drained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill - Silty Clay
Unit Weight: 19 kN/m3
Cohesion: 2 kPa
Friction Angle: 28 deg
3 Material: Upper Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
4 Material: Lower Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
F.S.
GLOBAL MINIMUMS
Bishop Simplified: 1.7
Janbu Simplified: 1.5
Spencer: 1.7
Safety Factor
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1.1
1.2
1.3
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2.9
3.0+
Contours of Minimum
Factors of Safety
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2.0
1.7
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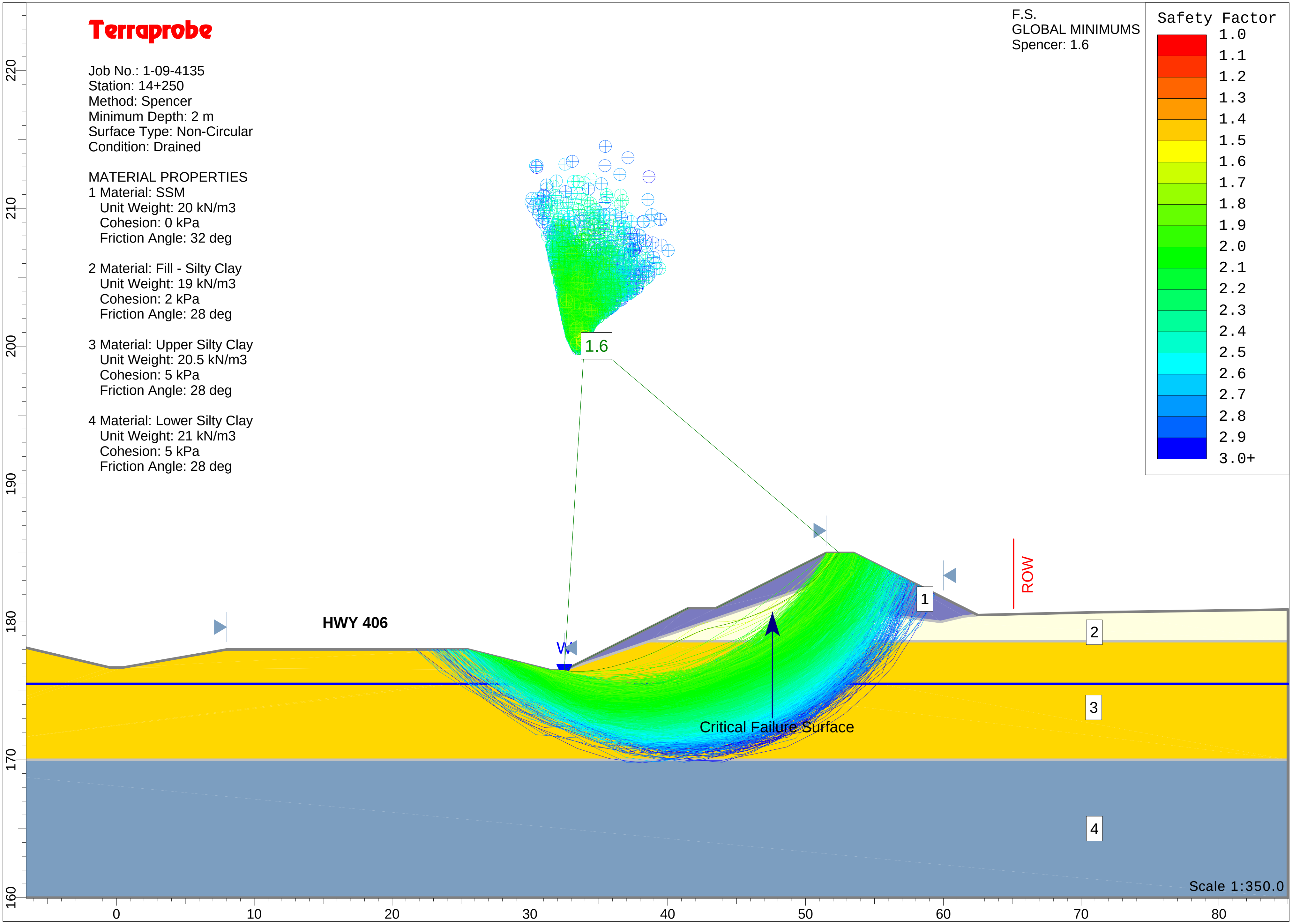
Terraprobe
Job No.: 1-09-4135
Station: 14+250
Method: Spencer
Minimum Depth: 2 m
Surface Type: Non-Circular
Condition: Drained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill - Silty Clay
Unit Weight: 19 kN/m3
Cohesion: 2 kPa
Friction Angle: 28 deg
3 Material: Upper Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
4 Material: Lower Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
F.S.
GLOBAL MINIMUMS
Spencer: 1.6
Safety Factor
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0+
1.6
HWY 406
ROW
W
Critical Failure Surface
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2
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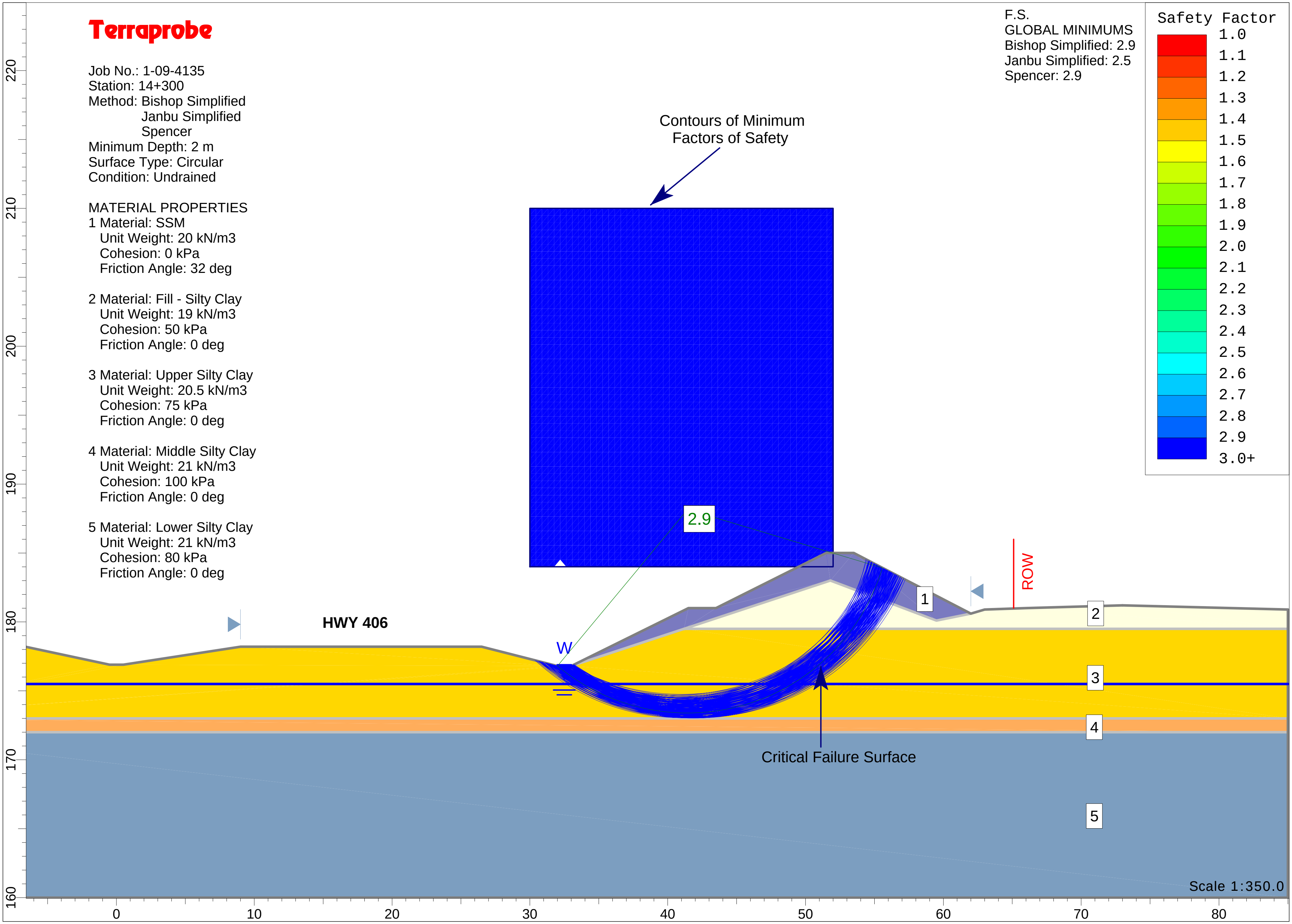
Terraprobe
Job No.: 1-09-4135
Station: 14+300
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Surface Type: Circular
Condition: Undrained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill - Silty Clay
Unit Weight: 19 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Upper Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 75 kPa
Friction Angle: 0 deg
4 Material: Middle Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
5 Material: Lower Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 80 kPa
Friction Angle: 0 deg
F.S.
GLOBAL MINIMUMS
Bishop Simplified: 2.9
Janbu Simplified: 2.5
Spencer: 2.9
Safety Factor
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1.1
1.2
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1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0+
Contours of Minimum Factors of Safety
2.9
HWY 406
W
ROW
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4
5
Critical Failure Surface
Scale 1:350.0
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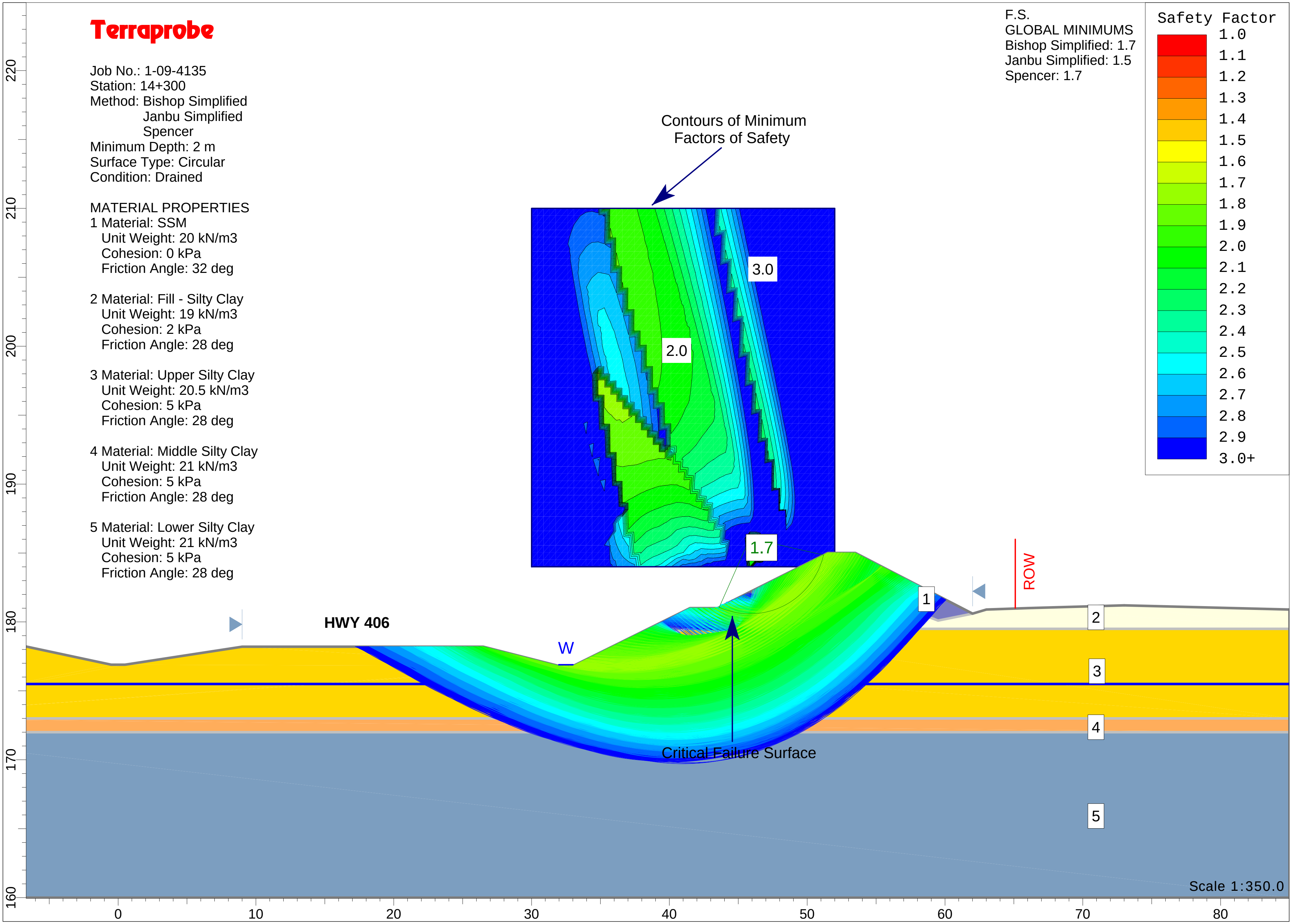
Terraprobe
Job No.: 1-09-4135
Station: 14+300
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Surface Type: Circular
Condition: Drained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill - Silty Clay
Unit Weight: 19 kN/m3
Cohesion: 2 kPa
Friction Angle: 28 deg
3 Material: Upper Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
4 Material: Middle Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
5 Material: Lower Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
Contours of Minimum
Factors of Safety
3.0
2.0
1.7
F.S.
GLOBAL MINIMUMS
Bishop Simplified: 1.7
Janbu Simplified: 1.5
Spencer: 1.7
Safety Factor
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0+
ROW
HWY 406
W
1
2
3
4
5
Critical Failure Surface
Scale 1:350.0
220
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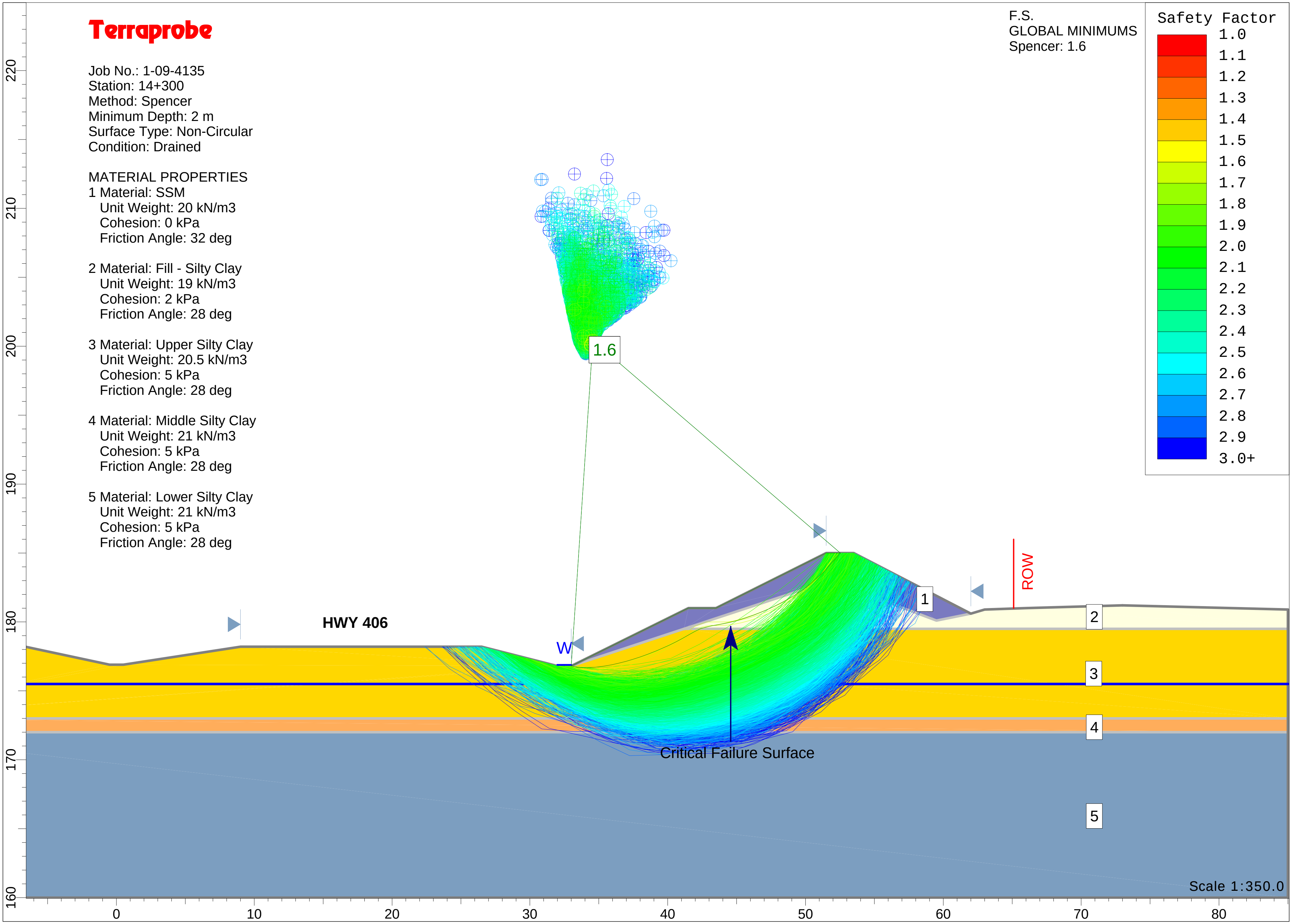
190
180
170
160
0
10
20
30
40
50
60
70
80


Terraprobe
Job No.: 1-09-4135
Station: 14+300
Method: Spencer
Minimum Depth: 2 m
Surface Type: Non-Circular
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: 19 kN/m3
Cohesion: 2 kPa
Friction Angle: 28 deg
3 Material: Upper Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
4 Material: Middle Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
5 Material: Lower Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
F.S.
GLOBAL MINIMUMS
Spencer: 1.6
Safety Factor
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0+
1.6
HWY 406
W
ROW
1
2
3
4
5
Critical Failure Surface
Scale 1:350.0
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190
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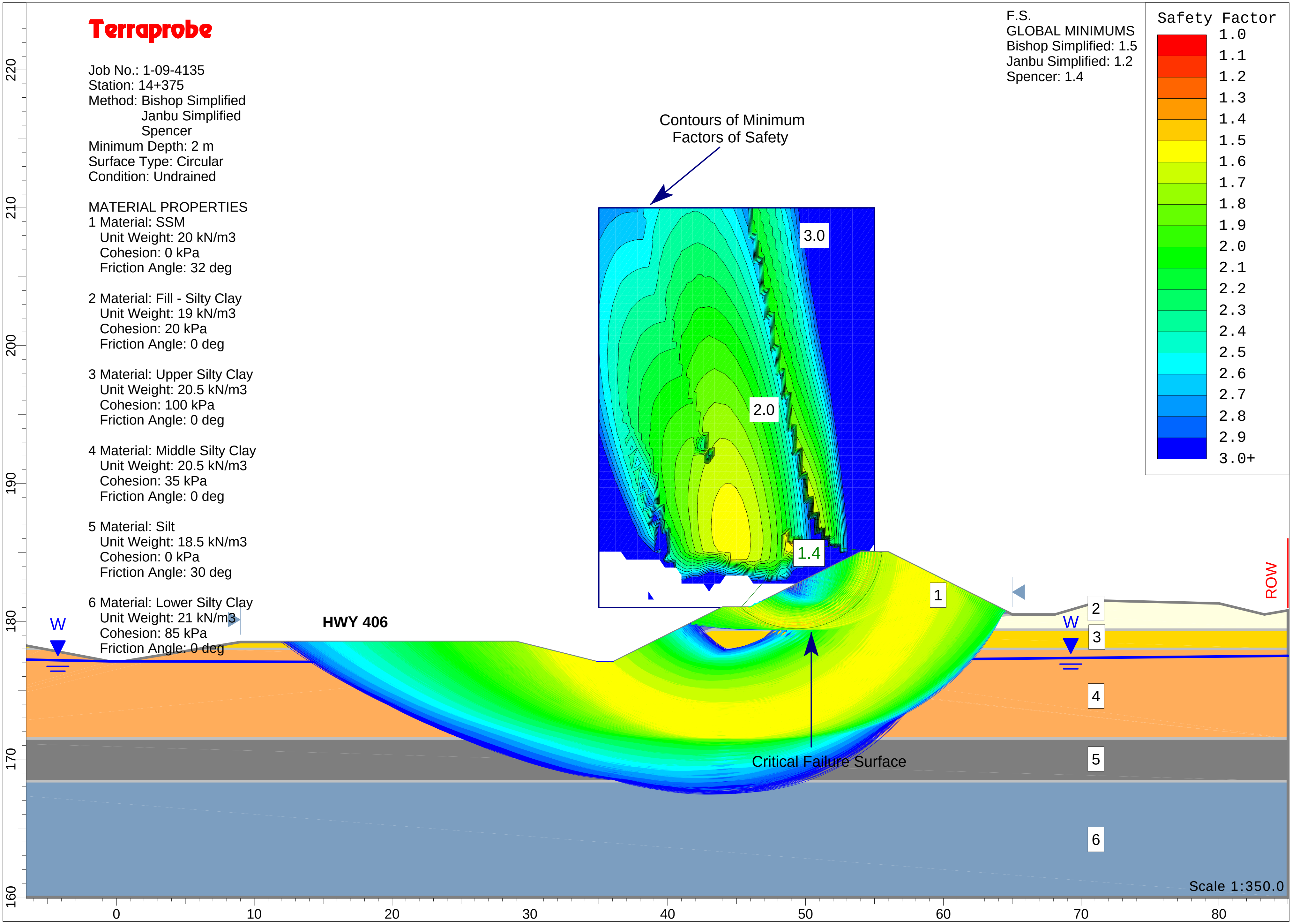
Terraprobe
Job No.: 1-09-4135
Station: 14+375
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Surface Type: Circular
Condition: Undrained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill - Silty Clay
Unit Weight: 19 kN/m3
Cohesion: 20 kPa
Friction Angle: 0 deg
3 Material: Upper Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 100 kPa
Friction Angle: 0 deg
4 Material: Middle Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 35 kPa
Friction Angle: 0 deg
5 Material: Silt
Unit Weight: 18.5 kN/m3
Cohesion: 0 kPa
Friction Angle: 30 deg
6 Material: Lower Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 85 kPa
Friction Angle: 0 deg
F.S.
GLOBAL MINIMUMS
Bishop Simplified: 1.5
Janbu Simplified: 1.2
Spencer: 1.4
Safety Factor
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0+
Contours of Minimum Factors of Safety
3.0
2.0
1.4
HWY 406
W
W
ROW
1
2
3
4
5
6
Critical Failure Surface
Scale 1:350.0
220
210
200
190
180
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0
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60
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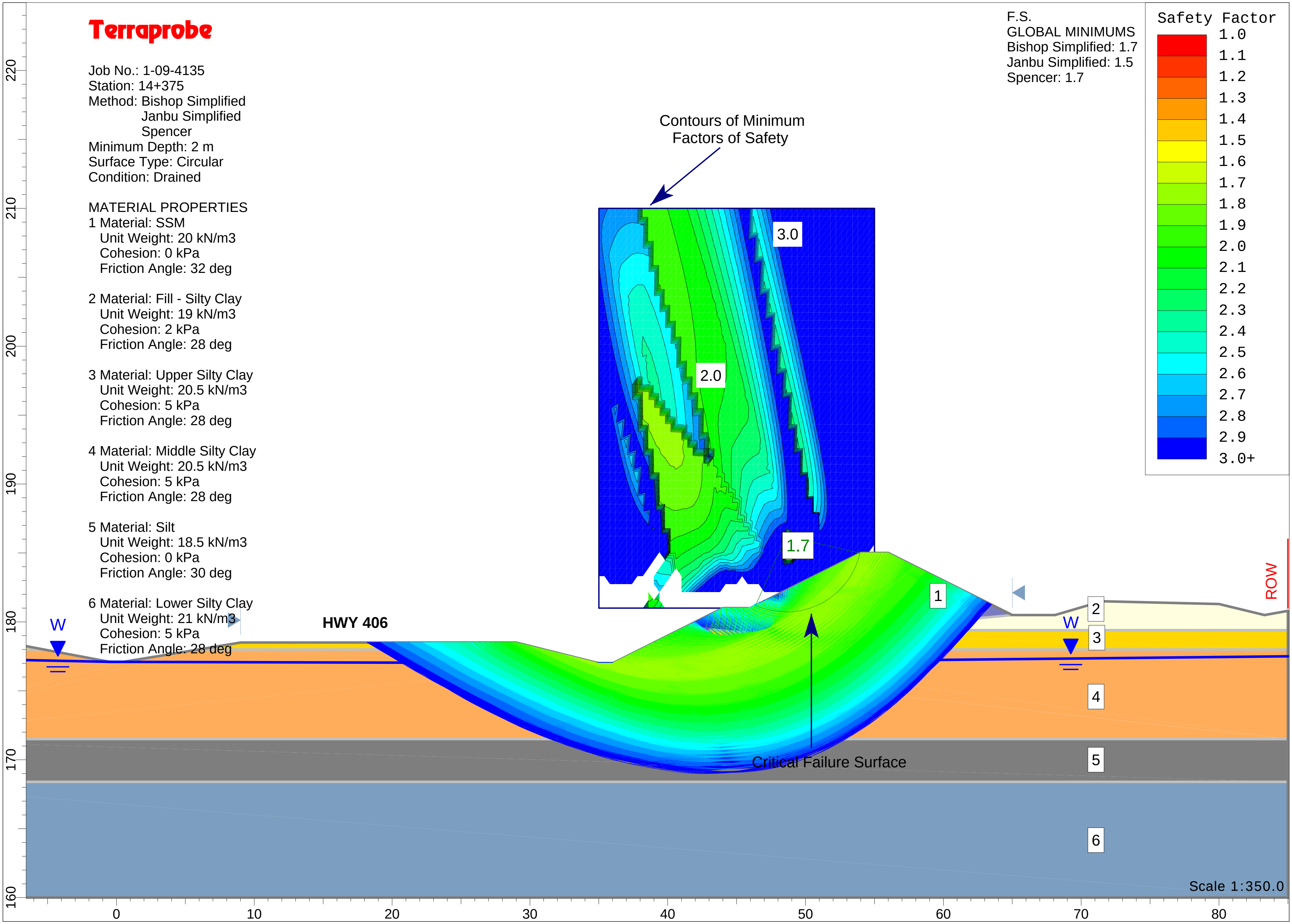
80


Terraprobe
Job No.: 1-09-4135
Station: 14+375
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Surface Type: Circular
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: 19 kN/m3
Cohesion: 2 kPa
Friction Angle: 28 deg
3 Material: Upper Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
4 Material: Middle Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
5 Material: Silt
Unit Weight: 18.5 kN/m3
Cohesion: 0 kPa
Friction Angle: 30 deg
6 Material: Lower Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
F.S.
GLOBAL MINIMUMS
Bishop Simplified: 1.7
Janbu Simplified: 1.5
Spencer: 1.7
Safety Factor
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0+
Contours of Minimum
Factors of Safety
3.0
2.0
1.7
HWY 406
W
W
ROW
1
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5
6
Critical Failure Surface
Scale 1:350.0
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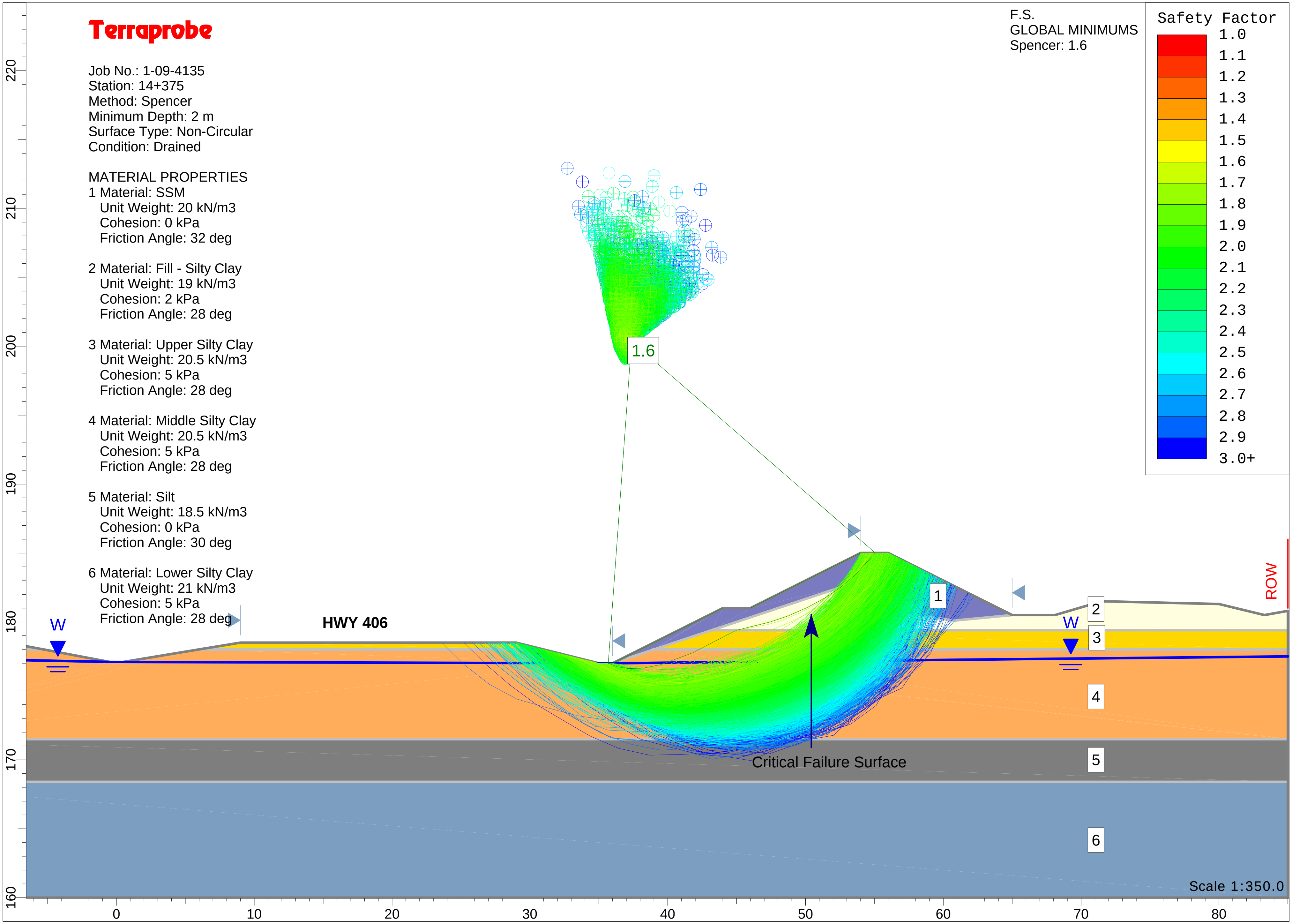
Terraprobe
Job No.: 1-09-4135
Station: 14+375
Method: Spencer
Minimum Depth: 2 m
Surface Type: Non-Circular
Condition: Drained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill - Silty Clay
Unit Weight: 19 kN/m3
Cohesion: 2 kPa
Friction Angle: 28 deg
3 Material: Upper Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
4 Material: Middle Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
5 Material: Silt
Unit Weight: 18.5 kN/m3
Cohesion: 0 kPa
Friction Angle: 30 deg
6 Material: Lower Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
F.S.
GLOBAL MINIMUMS
Spencer: 1.6
Safety Factor
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0+
1.6
HWY 406
W
W
ROW
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6
Critical Failure Surface
Scale 1:350.0
220
210
200
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180
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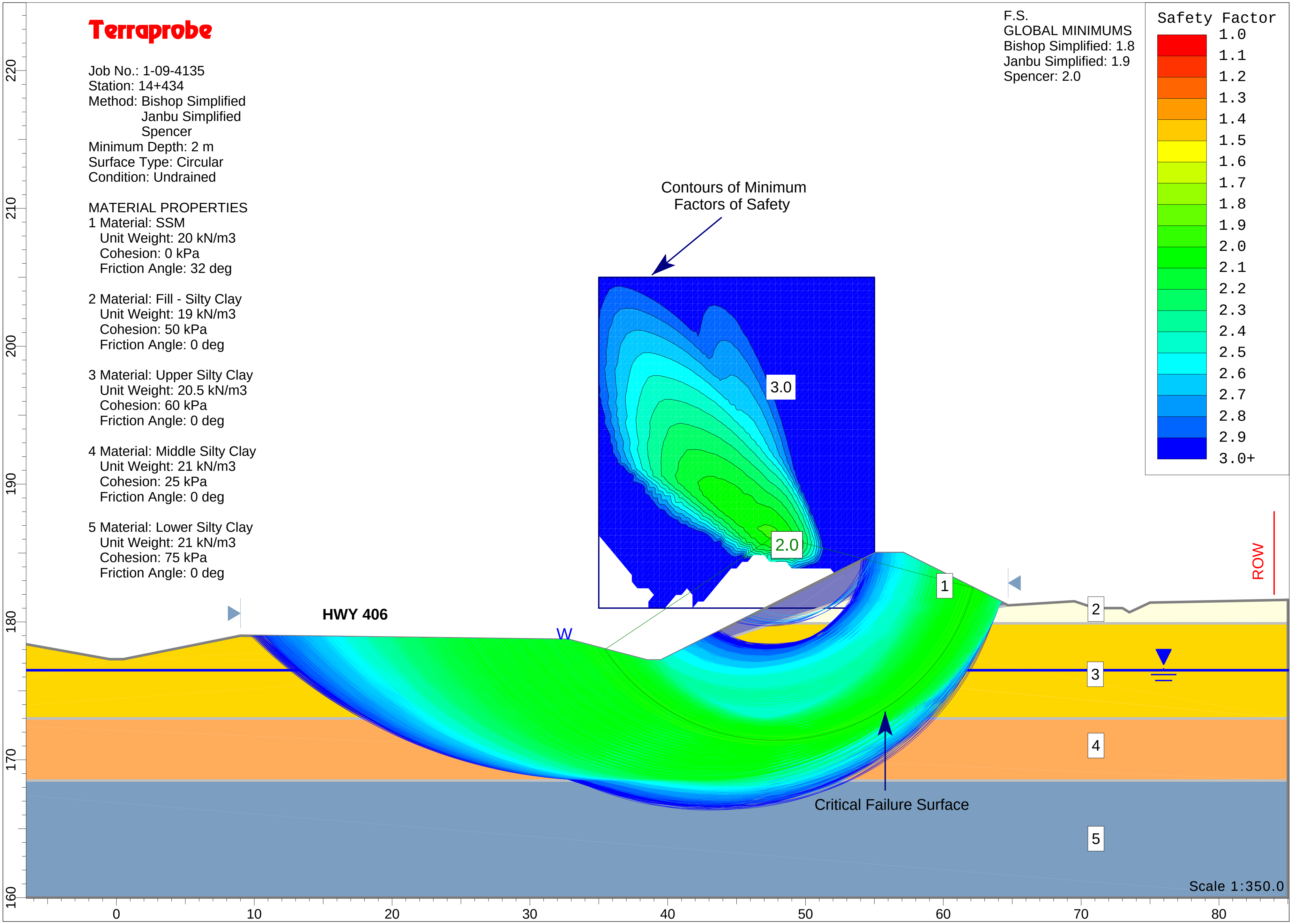
Terraprobe
Job No.: 1-09-4135
Station: 14+434
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Surface Type: Circular
Condition: Undrained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill - Silty Clay
Unit Weight: 19 kN/m3
Cohesion: 50 kPa
Friction Angle: 0 deg
3 Material: Upper Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 60 kPa
Friction Angle: 0 deg
4 Material: Middle Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 25 kPa
Friction Angle: 0 deg
5 Material: Lower Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 75 kPa
Friction Angle: 0 deg
F.S.
GLOBAL MINIMUMS
Bishop Simplified: 1.8
Janbu Simplified: 1.9
Spencer: 2.0
Safety Factor
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0+
Contours of Minimum
Factors of Safety
3.0
2.0
HWY 406
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ROW
1
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4
5
Critical Failure Surface
Scale 1:350.0
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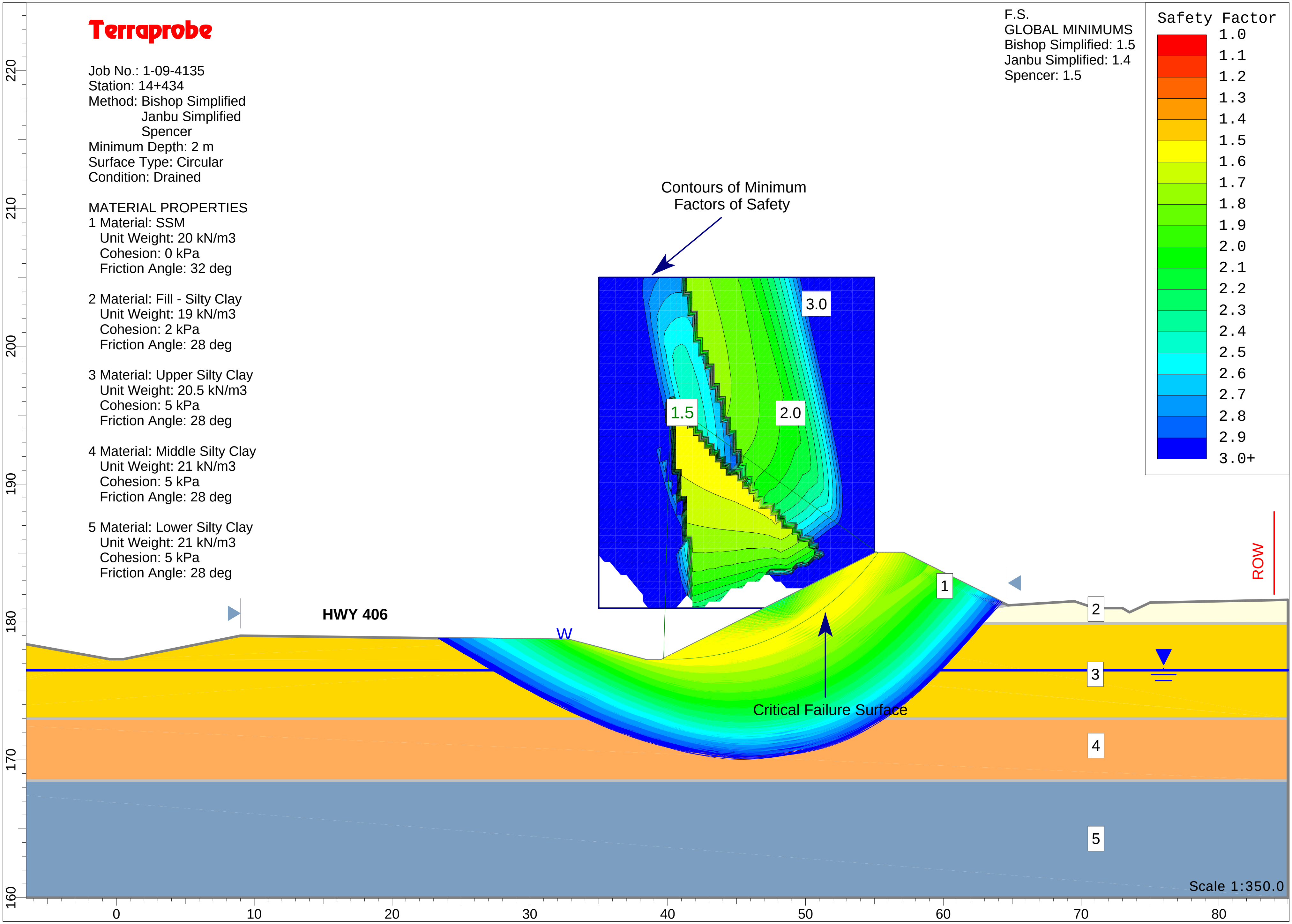

Terraprobe
Job No.: 1-09-4135
Station: 14+434
Method: Bishop Simplified
Janbu Simplified
Spencer
Minimum Depth: 2 m
Surface Type: Circular
Condition: Drained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill - Silty Clay
Unit Weight: 19 kN/m3
Cohesion: 2 kPa
Friction Angle: 28 deg
3 Material: Upper Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
4 Material: Middle Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
5 Material: Lower Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
F.S.
GLOBAL MINIMUMS
Bishop Simplified: 1.5
Janbu Simplified: 1.4
Spencer: 1.5
Safety Factor
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
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2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0+
Contours of Minimum
Factors of Safety
3.0
1.5
2.0
HWY 406
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Critical Failure Surface
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Scale 1:350.0
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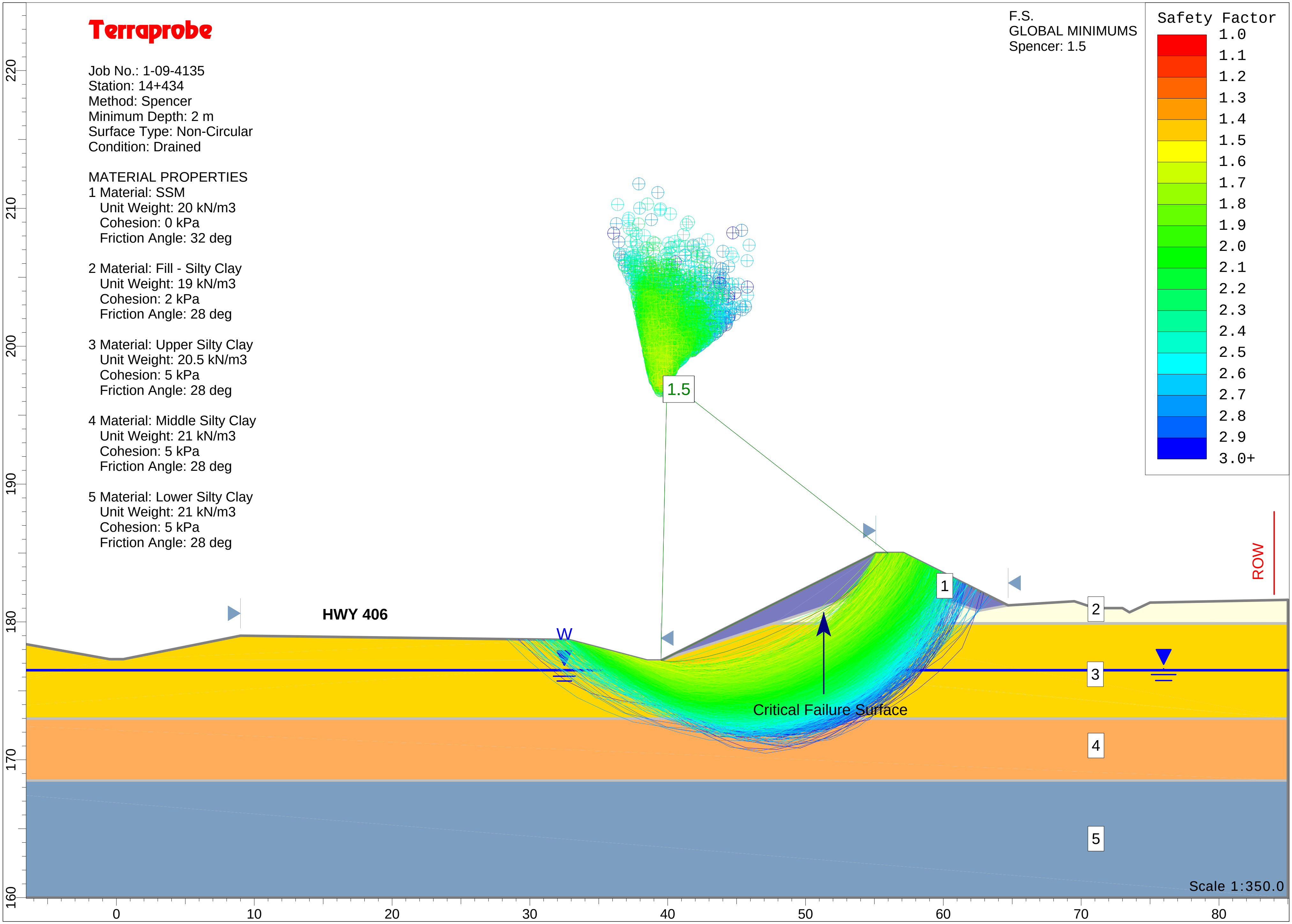

Terraprobe
Job No.: 1-09-4135
Station: 14+434
Method: Spencer
Minimum Depth: 2 m
Surface Type: Non-Circular
Condition: Drained
MATERIAL PROPERTIES
1 Material: SSM
Unit Weight: 20 kN/m3
Cohesion: 0 kPa
Friction Angle: 32 deg
2 Material: Fill - Silty Clay
Unit Weight: 19 kN/m3
Cohesion: 2 kPa
Friction Angle: 28 deg
3 Material: Upper Silty Clay
Unit Weight: 20.5 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
4 Material: Middle Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
5 Material: Lower Silty Clay
Unit Weight: 21 kN/m3
Cohesion: 5 kPa
Friction Angle: 28 deg
F.S.
GLOBAL MINIMUMS
Spencer: 1.5
Safety Factor
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0+
1.5
HWY 406
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ROW
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Critical Failure Surface
Scale 1:350.0
220
210
200
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180
170
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APPENDIX G

TERRAPROBE INC.

Recommended Soil Parameters

Station & BH No.	Elevation (m) From	Elevation (m) To	Type of Soil	Consistency or Compactness Condition	q_u (kPa)	ϕ (degrees)	γ (kN/m^3)	Water Level Depth (Elevation) (m)
South Limit to 14+200 BH1	177.2	175.4	Fill	Firm to Stiff	100	-	19.0	2.6 (174.6)
	175.4	173.2	Cohesive	Stiff to Very Stiff	200	-	20.5	
	173.2	171.6	Cohesionless	Dense	-	33	19.0	
	171.6	168.5	Cohesive	Stiff to Very Stiff	200	-	21.0	
	168.5	166.0	Cohesive	Very Stiff	300	-	21.0	
14+200 to 14+275 BH2	177.4	174.5	Cohesive	Very Stiff	200	-	20.5	1.9♦ (175.5)♦
	174.5	171.5	Cohesive	Stiff	100	-	21.0	
	171.5	165.4	Cohesive	Very Stiff	200	-	21.0	
14+275 to 14+325 BH3	177.3	173.0	Cohesive	Firm to Stiff	120	-	20.5	1.8 (175.5)
	173.0	172.0	Cohesive	Very Stiff	200	-	21.0	
	172.0	166.1	Cohesive	Stiff to Very Stiff	160	-	21.0	
14+325 to 14+400 BH4	180.0	179.4	Fill	Soft	40	-	19.0	4.1♦ (176.0)♦
	179.4	178.0	Cohesive	Very Stiff	200	-	20.5	
	178.0	176.5	Cohesive	Firm	75	-	20.5	
	176.5	171.5	Cohesive	Very Soft to Soft	50	-	20.5	
	171.5	168.4	Cohesionless	Loose to Compact	-	30	19.0	
	168.4	165.0	Cohesive	Firm to Stiff	170	-	21.0	
14+400 to North Limit BH5	180.5	179.9	Fill	Stiff	100	-	19.0	4.0 (176.6)
	179.9	178.0	Cohesive	Stiff	150	-	20.5	
	178.0	173.0	Cohesive	Firm to Stiff	120	-	20.5	
	173.0	168.5	Cohesive	Soft to Firm	50	-	21.0	
	168.5	166.0	Cohesive	Firm to Stiff	150	-	21.0	

♦ = estimated

The notations used are defined below:

ϕ = apparent angle of friction for cohesionless soils in degrees.
q_u = unconfined compressive strength in kPa (q_u=2xC_u) for cohesive soils (estimated based on field and laboratory vane tests as well as correlations with SPT "N" values).
C_u = undrained shear strength in kPa.
γ = bulk unit weight of soil in kN/m^3.