THURBER ENGINEERING LTD.

FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 6 / 21
SLOPE FAILURE INVESTIGATION
OWEN SOUND, ONTARIO

Assignment No.: 2

Agreement No.: 3012-E-007/3012-E-008

Geocres Number: 41A-232

Report to

MTO West Region

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FOUNDATION INVESTIGATION AND DESIGN REPORT

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted for the study of a surficial slope instability near the north crest of the road embankment of Highway 6/21, located west of the Town of Owen Sound, Ontario.

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

Thurber carried out the investigation as a sub-consultant to the Ministry of Transportation Ontario (MTO) West Region under Assignment No. 2, Agreement No. 3012-E-007 and 008

2 SITE DESCRIPTION

The slope instability is located on Highway 6/21, approximately 450 m east of the intersection of Highway 6 and Highway 21 (Grey Road 18) in the Township of Derby. The roadway at this location slopes gently to the east towards Owen Sound and has an exposed bedrock surface along the south edge of the eastbound shoulder. The land to the south contains residential property and the lands to the east and west consists of commercial property. Directly north of the slope instability is Grey Sauble Conservation property consisting of heavily vegetated land and Pottawatomi River which runs near parallel to the toe of the roadway embankment slope.

The site lies within the Bruce Peninsula region, characterized by shallow soils overlying dolostone bedrock of the Amabel Formation.

Photographs are included in Appendix C which show the site of the slope instability on the date of the site visit as well as pavement distress marks/cracking along the west bound shoulder.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out between October 15th and 18th, 2013. A total of twelve boreholes, ranging in depth from 0.4 to 9.9 m, were drilled and sampled during this investigation. Boreholes identified as: BH 13-01 to 03 were advanced along the eastbound curb lane, BH 13-04 to 06 were advanced long the westbound curb lane, BH 13-07 to 09 were advanced along the westbound shoulder and BH 13-10 to 12 were advanced near the toe of the roadway embankment slope.

These boreholes were arranged in arrays, with one centre array along the alignment of the slope instability and one array offset approximately 15 m on either side of the centre array. The approximate locations of the boreholes are shown on the attached Borehole Locations and Soil Strata Drawing included in Appendix D. The coordinates and elevations of the boreholes are given on the drawing and on the individual Record of Borehole sheets included in Appendix A.

Prior to commencement of drilling operations, utility clearances were obtained. An Encroachment Permit from the Ministry of Transportation, West Region was obtained for drilling the nine boreholes on the roadway. In addition, permission was provided by Grey Sauble Conservation to access and drill the three boreholes located at the base of the roadway embankment slope.

Boreholes 13-01 to 09 were drilled using a Diedrich D-90 truck-mounted drill rig using solid-stem auger drilling techniques. Borehole 13-10 was completed by exposing bedrock with a shovel and Boreholes 13-11 and 12 were drilled using NW casing and mobile tripod drilling equipment. Soil samples were obtained at selected intervals using a combination of grab samples and a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Rock coring was not required as part of the scope of this project and was therefore not undertaken.

The drilling and sampling operations were supervised on a full time basis by an experienced member of Thurber's technical staff. The recovered soil samples were logged in the field and processed for transport to Thurber's geotechnical laboratory in Oakville, Ontario for further examination and testing.

Groundwater conditions were observed in the open boreholes during and at the completion of drilling. Standpipe piezometers, consisting of 19mm diameter PVC pipe with a slotted screen, were installed in Boreholes 13-07 to 09, 11 and 12. The installation details of the piezometer are summarized in Table 3-1 along with the borehole completion details for the boreholes with no piezometer installation.

Table 3-1. Borehole Completion and Piezometer Installation Details

Borehole	Piezometer Tip Position		Borehole Completion and Piezometer Installation Details
	Depth (m)	Elev. (m)	
BH13-01	None installed		Borehole backfilled with cuttings and bentonite holeplug to 250 mm and asphalt patch to surface.
BH13-02	None installed		Borehole backfilled with cuttings and bentonite holeplug to 230 mm and asphalt patch to surface.
BH13-03	None installed		Borehole backfilled with bentonite holeplug to 0.4 m, cement to 200 mm and asphalt patch to surface.
BH13-04	None installed		Borehole backfilled with bentonite holeplug to 0.9 m, cuttings to 150 mm and asphalt patch to surface.
BH13-05	None installed		Borehole backfilled with bentonite holeplug to 100 mm and asphalt patch to surface.
BH13-06	None installed		Borehole backfilled with bentonite holeplug to 1.4 m, cuttings to 200 mm and asphalt patch to surface.
BH13-07	4.5	217.5	Sand filter from 4.5 to 2.4 m, bentonite holeplug to 0.3 m, sand to 150 mm and cement to surface.
BH13-08	6.6	214.7	Sand filter from 6.6 to 4.6 m, bentonite holeplug to 0.3 m, sand to 150 mm and cement to surface.
BH13-09	5.7	215.0	Sand filter from 5.7 to 3.7 m, bentonite holeplug to 0.3 m, sand to 200 mm and cement to surface.
BH13-10	None installed		Borehole backfilled with cuttings to surface.
BH13-11	1.8	210.5	Sand filter from 1.8 to 0.4 m and bentonite holeplug to surface.
BH13-12	4.0	207.3	Sand filter from 4.0 to 2.0 m and bentonite holeplug to surface.

4 LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determinations. Selected samples were also subjected to grain size distribution analyses (hydrometer and/or sieve). The results of this testing program are summarized on the Record of Borehole sheets included in Appendix A and are presented on the figures included in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets included in Appendix A and the Borehole Locations and Soil Strata Drawing included in Appendix D. An overall description of the stratigraphy based on the conditions encountered in the boreholes is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions.

The stratigraphy encountered at this site generally consists of a thin, surficial layer of peat/organics or asphalt overlying sand fill and/or native sand. Localized deposits of silty clay to clayey silt were noted at depth in two of the boreholes. More detailed descriptions of the individual strata encountered within the boreholes are presented below.

5.1 Peat

A thin layer of dark brown peat (400 mm thick) with trace sand was encountered at the surface in Borehole 13-10. The peat thickness may vary between and beyond the borehole located at the toe of the highway embankment slope and the data is not intended for the purpose of estimating quantities.

5.2 Asphalt

A 225 to 375 mm layer of asphalt was encountered at the surface of Boreholes 13-01 to 06 drilled within the curb lanes of Highway 6 / 21 and a 40 to 50 mm layer of asphalt was encountered at the surface of Boreholes 13-07 to 09 drilled within the westbound shoulder.

Some asphalt fragments were noted within the granular fill below the surficial asphalt layer within the boreholes drilled along the north side of the roadway.

5.3 Sand Fill

Sand to sand and gravel fill was encountered directly below the asphalt layer in all nine boreholes drilled from the roadway platform. The granular fill was brown in colour and contained some silt to silty and trace clay. The granular fill was noted to vary from 1.8 to 7.8 m in thickness with a lower boundary encountered at a depth of 2.0 to 8.0 m (Elev. 219.5 to 213.4 m).

SPT N-values recorded in the granular fill ranged from 3 to 88 blows for 300 mm of penetration to as high as 50 blows per 50 mm penetration, indicating a very loose to very dense relative density, however, most of the fill is in a dense state.. The higher SPT values may be indicative of coarse gravel or cobbles within the fill. The moisture content of the retained samples of the granular fill ranged from 2 to 19%.

Laboratory grain size distribution analysis was carried out on sixteen samples of the granular fill. The results of this test are presented on the corresponding Record of Borehole sheets included in Appendix A and the grain size distribution curves are presented in Figure B1 through B3 of Appendix B. The results are summarized below:

<table>
<tr><th>Soil Particles</th><th colspan="2">(%)</th></tr>
<tr><td>Gravel</td><td colspan="2">0 to 44</td></tr>
<tr><td>Sand</td><td colspan="2">42 to 70</td></tr>
<tr><td>Silt</td><td rowspan="2">13 to 28</td><td>21 to 29</td></tr>
<tr><td>Clay</td><td>7 to 9</td></tr>
</table>

5.4 Sand

Native sand with some silt to silty, trace gravel and trace clay was encountered below the granular fill in Boreholes 13-01, 03, 06 and 09 and at the surface in Boreholes 13-11 and 12. The sand layer ranged from 0.8 to 3.2 m in thickness with a lower boundary encountered at a depth of 1.8 to 6.9 m (Elev. 218.3 to 208.2 m).

SPT N-values of 1 blow per 300 mm of penetration to 50 blows per 50 mm of penetration were recorded, indicating loose to very dense relative density. The moisture content ranged from 3 to 24%. A moisture content of 41% and 96% was recorded near the surface of Boreholes 13-11 and 12, respectively, where organics/peat was present.

Two laboratory grain size distribution analyses were performed on samples of the sand. The results of these tests are presented on the corresponding Record of Borehole sheet in Appendix A and the grain size distribution curve is plotted on Figure B4 of Appendix B. The results are summarized below:

Soil Particles	(%)
Gravel	1 to 3
Sand	73 to 78
Silt	16 to 21
Clay	3 to 5

5.5 Gravel

Native gravel to sandy gravel with trace fines was encountered below the native sand in Borehole 13-03 and 12. The gravel layer ranged from 0.7 to 2.2 m in thickness with a lower boundary encountered at a depth of 3.9 to 9.1 m (Elev. 211.6 to 207.5 m)

SPT N-values of 22 blows per 300 mm of penetration to 63 blows per 150 mm of penetration were recorded, indicating compact to very dense relative density. The moisture content ranged from 5 to 12%.

One laboratory grain size distribution analysis was performed on a sample of gravel. The results of this test are presented on the corresponding Record of Borehole sheet in Appendix A and the grain size distribution curve is plotted on Figure B5 of Appendix B. The results are summarized below:

Soil Particles	(%)
Gravel	69
Sand	23
Silt and Clay	7

5.6 Silty Clay

A native layer of greenish grey to reddish brown silty clay containing trace sand and occasional bedrock fragments was encountered below the sand fill in Borehole 13-05. The silty clay was 1.9 m thick with a lower boundary encountered at a depth of 9.9 m (Elev. 211.5 m).

A single of SPT N-value of 31 blows for 300 mm of penetration were recorded in the silty clay, indicating a hard consistency. A corresponding moisture content was recorded at 3%.

One laboratory grain size distribution analysis was performed on a sample of the silty clay. The results of this test are presented on the corresponding Record of Borehole sheet in Appendix A and the grain size distribution curve is plotted on Figure B6 of Appendix B. The results are summarized below:

Soil Particles	(%)
Gravel	0
Sand	6
Silt	52
Clay	43

5.7 Clayey Silt Till

A thin layer of hard, native clayey silt till with some sand and trace gravel was encountered below the native gravel in Borehole 13-12. The clayey silt till was 150 mm thick with a lower boundary encountered at a depth of 4.0 m (Elev. 207.3 m).

5.8 Probable Bedrock

Bedrock coring was not required as part of the scope and therefore, bedrock identification by coring was not undertaken. However, all boreholes were terminated upon auger advancement refusal on probable bedrock. The depths and elevations at which probable bedrock was encountered at the borehole locations are summarized in Table 5.1.

Table 5.1 – Depths and Elevations of Probable Bedrock Surface

Location	Borehole	Probable Bedrock Surface	
		Depth (m)	Elevation (m)
Eastbound Curb Lane	BH13-01	4.0	218.3
	BH13-02	2.0	219.5
	BH13-03	9.1	211.6
Westbound Curb Lane	BH13-04	2.9	219.2
	BH13-05	9.9	211.5
	BH13-06	5.8	215.0
Westbound Shoulder	BH13-07	4.5	217.6
	BH13-08	7.3	214.0
	BH13-09	5.7	215.0
North of Roadway Embankment Toe	BH13-10	0.4	211.4
	BH13-11	1.8	210.5
	BH13-12	4.0	207.3

5.9 Groundwater Levels

Water levels were observed in the open boreholes during and at the completion of drilling. Standpipe piezometers were installed in Boreholes 13-07 to 09, 11 and 12. The water levels measured in the open boreholes and piezometers are as follows:

Table 5.3 – Groundwater Depths and Elevations

Borehole	Date of Reading	Water Level		Comment
		Depth (m)	Elevation (m)	
BH13-03	Oct 15, 2013	6.8	214.0	Open Borehole
BH13-07	Oct. 18, 2013	Dry	N/A	Piezometer
	Nov. 28, 2013	4.1	217.9	Piezometer
BH13-08	Oct. 18, 2013	Dry	N/A	Piezometer
	Nov. 28, 2013	4.2	217.1	Piezometer
BH13-09	Oct. 18, 2013	Dry	N/A	Piezometer
	Nov. 28, 2013	4.3	216.4	Piezometer
BH13-11	Oct. 18, 2013	0.4	211.9	Piezometer
		0.2	212.1	Piezometer
BH13-12	Oct. 18, 2013	0.1	211.2	Piezometer
		0.1	211.2	Piezometer

It should be noted that the recorded groundwater levels are short term and are susceptible to seasonal fluctuations. In particular, the groundwater level may be at a higher elevation after the spring snowmelt and after periods of significant and/or prolonged precipitation events.

6 MISCELLANEOUS

Overall planning and supervision of the field program was conducted by Mr. Stephen Peters, P.Eng. and the field investigation was supervised on site by Ms. Eckie Siu of Thurber Engineering Ltd. Routine laboratory testing was carried out in Thurber Engineering Ltd. geotechnical laboratory in Oakville, Ontario.

Borehole locations were selected and established in the field by Thurber Engineering Ltd. Surveyors from MMM Group Limited provided co-ordinates and the ground surface elevations at the boreholes drilled.

Walker Drilling Ltd. of Utopia, Ontario supplied both the truck mounted Diedrich D-90 drill rig and mobile tri-pod drilling equipment and conducted the drilling, standpipe installation, soil sampling and in-situ testing operations.

Interpretation of the data and preparation of this report were carried out by Mr. Stephen Peters, P.Eng. and Mr. Alastair Gorman, P.Eng.. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report provides interpretation of the geotechnical data presented in the factual report and presents recommendations for the immediate repair of the surficial slope instability. Further recommendations are also presented for consideration in relation to the improvement of the long-term stability of the highway embankment. The discussion and recommendations presented in this report are based on the factual data obtained in the course of the investigation and on our understanding and interpretation of the issues involved.

8 ENGINEERING DISCUSSION AND ANALYSIS

The geotechnical analysis in this report includes assessment of the local stability of the north embankment slope. The foundation soils at this site are essentially cohesionless with the stratigraphy of the north embankment slope, along the failure cross section, identified as consisting of a sand fill embankment overlying probable bedrock at depth. Native sand was present surficially beyond the footprint of the embankment. The short term groundwater level measured in the piezometers was at Elev. 216.4 to 217.9 m. The slope of the embankment at the area of failure is approximately 31º to the horizontal (1.64H:1V).

The steepness of the embankment slope combined with the assessed angle of internal friction of 35º immediately indicates that the embankment must exist in a marginally stable condition. Based on visual inspection of the area, Thurber has reached the following conclusions:

- The observed failure is shallow, which is consistent with such a steep slope in cohesionless soils
- The failure scar suggests that the mechanism may have been more a matter of over-saturation of the soil followed by a small soil flow rather than a classical rotational failure

- The absence of any curb or gutter on the highway would allow sheet flow over the embankment crest, which inevitably becomes concentrated in preferred locations due to minor undulations in the pavement.
- Although the surficial erosion and soil deposition downslope has removed the vegetation, the process may have been assisted by an initial loss of vegetation cover.
- Extensive cracking of the asphalt is evident in the paved shoulder and into the driving lane and running parallel to the slope. The pattern of cracking suggests that there is on-going creep in the steep slope.

Site observations also noted similar indications of concentrated surface water runoff at additional locations along the north embankment crest where similar erosion and soil deposition may occur in the future if left untreated.

Following completion of the field investigation and laboratory testing, limit equilibrium slope stability analysis was completed with Slope/W software developed by Geo-Slope International Limited. The analysis was conducted on the slope profile prepared at the failure, Profile S2 of Appendix D, which is considered to be representative of the worst case and a suitable model on which to base recommendations for remediation.

The input parameters and soil model used in the stability analyses, including soil stratigraphy, soil properties, groundwater conditions and embankment geometry are shown in figures included in Appendix E. The analysis indicates that the stability of the embankment slope is near marginal with a computed factor of safety near 1.0 (Figure 1, Appendix E). This is below a factor of safety (FS) of 1.3 which is considered appropriate to achieve both short and long-term stability for the embankment slope.

It should be noted that no seismic acceleration was applied in the analysis. If seismic forces were to be taken into consideration, the factor of safety would be less than 1.0. In that situation, slumping, or outright failure, of the slope would probably occur.

9 OVERVIEW OF SLOPE STABILITY RECOMMENDATIONS

The recommendations provided below are separated into two categories consisting of repair work that should be completed immediately (short term) to maintain the embankment slope stability and rehabilitation work that could be considered for implementation in the future (long term) to increase the embankment slope stability.

9.1 Options to Maintain the Short Term Stability of the Embankment Slope

For short term slope stability and the safety of the highway users, two immediate steps are recommended:

1. Regrading of the slope and reinstatement of the shoulder and guiderail, if the latter has become destabilized
2. Control of the water from highway drainage

The slope should be reinstated with Granular A or Granular B Type II with minimal disturbance to adjacent areas. These materials are recommended for reinstatement due to their physical properties: relatively high angle of internal friction and comparatively high permeability. Construction methods must be selected to minimize disturbance and loss of vegetative cover in the adjacent area. To achieve this, it may be necessary for the regrading be accomplished by placing the material by bucket with a machine sitting on the highway, possibly supplement by manual placement near the toe. The actual methods can be left to the Contractor but the Contract must contain a constraint to protect the adjacent, vegetated slope. Grading should match the adjacent slope. It is recommended that the regraded slope be protected by an erosion control blanket in accordance with OPSS 804.

In conjunction with regrading, it is recommended that control of surface water runoff be initiated to divert the water away from the embankment slope. This might best be accomplished with the installation of a curb and gutter system along the highway alignment to direct the water to a catch basin or to an area with a flatter slope covered with appropriate erosion protection measures. The approximate extent of this treatment would coincide with the length of highway protected by the cable guardrail running parallel to the westbound lane.

The design of a highway drainage system is beyond the scope of this investigation but from a geotechnical point of view it is very important that sheet flow over the crest of the embankment be eliminated.

9.2 Options to Improve the Long Term Stability of the Embankment Slope

Based on the topographic survey completed, it is noted that the existing embankment sideslope is constructed both steeper than the MTO guideline of 2H:1V and also does not have a 2 m wide mid height bench for an embankment height greater than 8 m. This embankment construction may have occurred as a result of the limited right-of-way between the bedrock outcrop to the south and the Pottawatomi River to the north. However, the current configuration is only marginally stable in the long term. Continuing creep of the slope and associated cracking in the pavement must be anticipated.

While the immediate remediation measures described in Section 9.1 will maintain the current degree of stability and should prevent any further localized failures of the type experienced recently, consideration could be given to implementing a more robust long term solution. A long term solution to increase the embankment stability may include one of the following:

1. Flatten the north slope to 2H:1V
2. Flatten the north slope to 2H:1V and include a 2 m wide mid-height berm
3. Locally reinforce the north slope with soil nailing or other mechanical stabilization earth technology.
4. Locally reinforce the upper portion of the north slope with soil nailing or other mechanical stabilization earth technology and flatten the lower portion of the slope to 2H:1V
5. Re-align the highway to the south to allow the north slope to be flattened without moving the existing embankment toe northward

Option 1 and 2, slope flattening, are considered to be the most straightforward and cost effective if the necessary property is available. Drawing 3 (Appendix D) illustrates Option 2 with the minimum extent of a 2H:1V slope with a mid-height berm superimposed on the current survey. Provided that highway drainage is controlled, as described in the immediate repair options (Section 9.1), and the existing slope is benched in accordance with OPSD 208.010, the widening can be carried out using Granular B or SSM.

Slope stability analysis of this profile yielded a factor of safety of 1.3, as shown in Figures 2 and 3 of Appendix E.

Option 3, soil nailing, is seen as a viable option in that it can be installed without first having to excavate the existing slope. The detail design of a soil nail system is beyond the scope of the current assignment. However, in principle, it would consist of an array of short anchors, the “nails”, installed on a grid pattern across the face of the slope. For the sake of evaluating the feasibility, stability analysis was carried out using the following assumptions:

- Nail Grid Spacing: 1 m by 1 m
- Nail Length = 5.0 m
- Nail Diameter: 38 mm
- Skin Friction: 30 kPa
- Bond Factor of Safety = 2

The stability analysis run on the centre profile (S2, Appendix D), using the above assumptions, yielded a factor of safety of 1.2 (Figure 4, Appendix E).

Option 4, slope flattening and soil nailing, includes a combination of Options 2 and 3 and would reduce the property required in Options 1 or 2. The stability analysis run on the centre profile (S2, Appendix D), using the above assumptions, yielded a factor of safety of 1.3 (Figure 5, Appendix E)

Option 5, realigning the highway to the south, would permit the development of a 2H:1V slope on the north side, either with or without the berm. This slope could be assumed to have the same factors of safety against failure as the 2H:1V slopes described above (Option 1 and 2). This however, requires major highway realignment and is not discussed further in this report.

These options are summarized in Table 1 at the end of the text.

It should be noted that the above options may involve significant construction activities, possibly including removing the existing vegetation along the slope, purchasing additional land and/or re-alignment of Pottawatomi River. Since the roadway has been essentially stable previously, though subject to creep, it is recommended that the slope instability be treated as outlined in Section 9.1 and an observational approach be adopted prior to commencing with further treatment as outlined in Section 9.2.

10 CONSTRUCTION CONCERNS

Potential construction concerns include, but are not necessarily limited to:

- Movement of construction equipment may be difficult in areas with vegetation, steep slopes and soft saturated subgrades as noted at the toe of the embankment. Disturbance of the subgrade by construction traffic and activities must be minimized.

- Control of surficial drainage will be required during construction activities and disturbance of existing vegetation must be minimized.

11 CLOSURE

Engineering analyses and preparation of this report was carried out by Mr. Stephen Peters, P.Eng. and Mr. Alastair Gorman, P.Eng.. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

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Alastair Gorman, P.Eng.
Senior Foundations Engineer

Report reviewed by:
P.K. Chatterji, P.Eng.
Review Principal

Table 1. Summary of Stabilization Options

Option	Description	Factor of Safety	Comments	
1	Flatten slope to 2H:1V	1.3	**Advantages** I. The most economical of the long term options II. Achieves a satisfactory factor of safety III. Conventional construction IV. Requires less property than Option 2 **Disadvantages** I. May require taking additional property **II.** Does not meet MTO Policy regarding mid-height berm	**Recommended if property acquisition is difficult**
2	Flatten slope to 2H:1V and incorporate a mid-height berm	1.3	**Advantages** I. More economical than Option 3 II. Achieves a satisfactory factor of safety III. Conventional construction IV. Meets MTO Policy regarding mid-height berm **Disadvantages** I. Requires more property than Option 1. II. More expensive than Option 1	**Recommended if property acquisition is not an issue**
3	Retain existing slope and reinforce using soil nailing	1.2	**Advantages** I. Does not require property acquisition II. Minimal to no excavation required **Disadvantages** I. Most expensive option. II. Not conventional MTO construction method III. Does not achieve a satisfactory factor of safety with the stated assumptions	**Recommended if neither Option 1 or 2 can be implemented**

Option	**Description**	**Factor of Safety**	**Comments**	
4	Flatten lower portion of slope to 2H:1V and retain existing upper portion of slope and reinforce using soil nailing	1.3	**Advantages** I. Requires less property acquisition than Option 2 II. Less excavation required **Disadvantages** I. More expensive than Option 1 or 2. II. Not conventional MTO construction method	**Recommended if neither Option 1 or 2 can be implemented and additional property is available**
5	Realign the highway southward	-	**Out of scope.**	**Out of scope.**

Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT(1) 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

1) Laboratory Triaxial Testing
2) Field Insitu Vane Testing
3) Laboratory Vane Testing
4) SPT value
5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

SS Split Spoon Sample WS Wash Sample AS Auger (Grab) Sample
TW Thin Wall Shelby Tube Sample TP Thin Wall Piston Sample
PH Sampler Advanced by Hydraulic Pressure PM Sampler Advanced by Manual Pressure
WH Sampler Advanced by Self Static Weight RC Rock Core SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

▼ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

(1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.

(2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 13-01

METRIC

W.P. 15-64-26	LOCATION N 4 936 425.2 E 425 247.9	ORIGINATED BY ES
HWY 6/21	BOREHOLE TYPE Solid Stem Augers	COMPILED BY AN
DATUM Geodetic	DATE 2013.10.15 - 2013.10.15	CHECKED BY SP

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
222.3 / 0.0	**ASPHALT:** (225mm)					
0.2	Gravelly **SAND**, some fines Dense to Very Dense Brown Damp (FILL) Occasional cobbles	1	GS		222	28 58 14 (SI+CL)
		1	SS	41	221	
		2	SS	88		44 42 14 (SI+CL)
		3	SS	40	220	
219.5 / 2.8	**SAND**, some to trace silt, trace gravel, trace organics Very Dense Dark Brown to Brown Moist	4	SS	50/ 0.050	219	
		5	SS	50/ 0.025		- no recovery
218.3 / 4.0	END OF BOREHOLE AT 4.0m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH HOLEPLUG AND CUTTINGS TO 0.25m, ASPHALT TO SURFACE.					

Other columns: STRAT PLOT; GROUND WATER CONDITIONS; 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 (%) (20 40 60); UNIT WEIGHT γ kN/m³.

+ ³, × ³ : Numbers refer to Sensitivity   20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 13-02

METRIC

W.P.	15-64-26	LOCATION	N 4 936 421.2 E 425 264.0	ORIGINATED BY	ES
HWY	6/21	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.10.15 - 2013.10.15	CHECKED BY	SP

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
221.5							
0.0	**ASPHALT:** (225mm)						
0.2	Gravelly **SAND**, some fines Very Dense Brown Damp (FILL) Occasional cobbles	1	GS		221	plotted	
		1	SS	51		plotted	24 56 20 (SI+CL)
		2	SS	50/ 0.125	220	plotted	
219.5 2.0	END OF BOREHOLE AT 2.0m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH HOLEPLUG AND CUTTINGS TO 0.23m, ASPHALT TO SURFACE.						

Column headings: SOIL PROFILE; 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 (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

+³, ×³: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 13-03

METRIC

W.P. 15-64-26 LOCATION N 4 936 417.5 E 425 279.8 ORIGINATED BY ES

HWY 6/21 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2013.10.15 - 2013.10.15 CHECKED BY SP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
220.8							
0.0	**ASPHALT:** (225mm)						
0.2	**SAND**, some silt, trace to some gravel, trace clay Compact to Dense Brown Moist (FILL)	1	GS				
		1	SS	34		220	
	25 mm clay	2	SS	15		219	0 70 21 9
	Very Dense	3	SS	85/ 0.250		218	
	Occasional cobbles	4	SS	82/ 0.225		217	
		5	SS	57			13 66 21 (SI+CL)
	Compact	6	SS	19		216	
		7	SS	20		215	
214.7 / 6.1	**SAND**, trace gravel, occasional cobbles Compact Brown Moist	8	SS	15	▽	214	
213.9 / 6.9	Sandy **GRAVEL**, trace fines, occasional cobbles Compact to Very Dense Brown Moist	9	SS	22			69 23 8 (SI+CL)
		10	SS	63/ 0.150		213	
						212	
211.7 / 9.1	END OF BOREHOLE AT 9.1m UPON AUGER REFUSAL ON PROBABLE BEDROCK. WATER LEVEL AT 6.8m UPON COMPLETION. BOREHOLE BACKFILLED WITH						

Natural moisture content (%) plotted (circles) at each sample, approximately: GS1 ~1; SS1 ~3; SS2 ~4; SS3 ~3; SS4 ~2; SS5 ~2; SS6 ~6; SS7 ~3; SS8 ~3; SS9 ~6; SS10 ~4.

Column 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 (%) 20 40 60; UNIT WEIGHT γ kN/m³; STRAT PLOT.

Continued Next Page

+³, ×³: Numbers refer to Sensitivity   20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 13-03

METRIC

W.P.	15-64-26	LOCATION	N 4 936 417.5 E 425 279.8	ORIGINATED BY	ES
HWY	6/21	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.10.15 - 2013.10.15	CHECKED BY	SP

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 (%) 20 40 60	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	HOLEPLUG TO 0.4m, CEMENT TO 0.2m, ASPHALT TO SURFACE.										

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 13-04

METRIC

W.P. 15-64-26 | LOCATION N 4 936 437.2 E 425 251.5 | ORIGINATED BY ES

HWY 6/21 | BOREHOLE TYPE Solid Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2013.10.16 - 2013.10.16 | CHECKED BY SP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT kN/m³	GR	SA	SI	CL
222.1						222						
0.0	**ASPHALT:** (375mm)											
221.7 / 0.4	**SAND** and **GRAVEL**, some fines Dense to Very Dense Brown Damp (FILL) Occasional cobbles	1	GS				○		41	45	14 (SI+CL)	
		1	SS	29		221	○					
	Occasional asphalt fragments	2	SS	32		220	○		39	43	18 (SI+CL)	
		3	SS	54/ 0.150			○					
219.2 / 2.9	END OF BOREHOLE AT 2.9m. UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH HOLEPLUG TO 0.9m, CUTTINGS TO 0.1m, ASPHALT TO SURFACE.											

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 (%) 20 40 60

REMARKS & GRAIN SIZE DISTRIBUTION (%)

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 13-05

METRIC

W.P. 15-64-26 | LOCATION N 4 936 432.9 E 425 267.7 | ORIGINATED BY ES

HWY 6/21 | BOREHOLE TYPE Solid Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2013.10.16 - 2013.10.16 | CHECKED BY SP

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
221.4						
0.0	**ASPHALT:** (225mm)					
0.2	Gravelly **SAND**, some fines Compact to Dense Brown Moist (FILL)	1	GS		221	
		1	SS	33		
	Occasional asphalt fragments	2	SS	40	220	
	Occasional cobbles, trace organics	3	SS	32	219	35 52 13 (SI+CL)
		4	SS	16	218	
		5	SS	50/0.125	217	- difficult augering to 4.6 m 28 46 26 (SI+CL)
		6	SS	41	216, 215	
213.4 / 8.0	Silty **CLAY**, trace sand, occasional bedrock fragments Hard Greenish Grey to Reddish Brown Moist	7	SS	42	214	0 6 52 42
		8	SS	31	213, 212	
211.5						

Plot axes: 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 (%) 20 40 60; UNIT WEIGHT γ kN/m³; GROUND WATER CONDITIONS; STRAT PLOT.

Continued Next Page

+3, ×3: Numbers refer to Sensitivity   20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 13-05

METRIC

W.P.	15-64-26	LOCATION	N 4 936 432.9 E 425 267.7	ORIGINATED BY	ES
HWY	6/21	BOREHOLE TYPE	Solid Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.10.16 - 2013.10.16	CHECKED BY	SP

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 (%) (20 40 60)	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
9.9	END OF BOREHOLE AT 9.9m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH HOLEPLUG TO 0.1m, ASPHALT TO SURFACE.										

ONTMT4S 6426.GPJ 2012TEMPLATE(MTO).GDT 1/20/14

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ◐ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 13-06

METRIC

W.P. 15-64-26 | LOCATION N 4 936 429.6 E 425 282.1 | ORIGINATED BY ES

HWY 6/21 | BOREHOLE TYPE Solid Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2013.10.15 - 2013.10.15 | CHECKED BY SP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	NATURAL MOISTURE CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
220.8							
0.0	**ASPHALT:** (240mm)						
0.2	Gravelly **SAND**, some fines, Compact, Brown, Moist (FILL)	1	GS			○	
		1	SS	25	220	○	27 51 22 (SI+CL)
		2	SS	50/ 0.050		○	
	Occasional asphalt fragments				219		
	Occasional cobbles	3	SS	12		○	
217.7					218		
3.0	Silty **SAND**, trace gravel, trace clay, trace organics, Loose to Compact, Dark Brown to Brown, Moist	4	SS	7		○	1 73 21 5
					217		
		5	SS	18	216	○	
215.0							
5.8	END OF BOREHOLE AT 5.8m UPON AUGER REFUSAL ON PROBABLE BEDROCK. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH HOLEPLUG TO 1.4m, CUTTINGS TO 0.2m, ASPHALT TO SURFACE.						

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; 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 (%) 20 40 60; UNIT WEIGHT γ kN/m^3.

+^{3}, ×^{3}: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 13-07

METRIC

W.P. 15-64-26
LOCATION N 4 936 439.4 E 425 252.2
ORIGINATED BY ES
HWY 6/21
BOREHOLE TYPE Solid Stem Augers
COMPILED BY AN
DATUM Geodetic
DATE 2013.10.16 - 2013.10.16
CHECKED BY SP

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
222.0					222	
0.0	**ASPHALT:** (40mm)					
0.0	**SAND**, some gravel to gravelly, some silt, trace clay, occasional asphalt fragments Compact Brown Moist (FILL)	1	SS	20		32 48 20 (SI+CL)
		2	SS	13	221	
	Occasional cobbles	3	SS	27	220	
	Asphalt layer	4	SS	13		17 54 21 8
	Trace silt, trace gravel	5	SS	21	219	
					218	
217.5 4.5	END OF BOREHOLE AT 4.5m UPON AUGER REFUSAL ON PROBABLE BEDROCK. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.					

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Oct 18/13	Dry	-
Nov 28/13	4.1	217.9

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 (%): 20 40 60
UNIT WEIGHT γ kN/m³

+³, ×³: Numbers refer to Sensitivity
20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 13-08

METRIC

W.P. 15-64-26	LOCATION N 4 936 435.7 E 425 267.5	ORIGINATED BY ES	
HWY 6/21	BOREHOLE TYPE Solid Stem Augers	COMPILED BY AN	
DATUM Geodetic	DATE 2013.10.16 - 2013.10.16	CHECKED BY SP	

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 (%) 20 40 60

UNIT WEIGHT γ kN/m³

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

ELEV / DEPTH	DESCRIPTION
221.3	
0.0	**ASPHALT:** (50mm)
	SAND, trace gravel to gravelly, some silt, trace clay Loose to Compact Brown Moist (FILL)
	Occasional cobbles, occasional wood fibres
	Very Dense
214.0 7.3	END OF BOREHOLE AT 7.3m UPON AUGER REFUSAL ON PROBABLE BEDROCK. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.

SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS / GRAIN SIZE (GR SA SI CL)
1	SS	13	
2	SS	10	22 50 28 (SI+CL)
3	SS	14	
4	SS	8	- SPT refusal at 2.7 m, move borehole 0.6 m to west
5	SS	10	1 70 22 7
6	SS	13	
7	SS	50/ 0.150	

ELEVATION SCALE: 221, 220, 219, 218, 217, 216, 215

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Oct 18/13	Dry	-
Nov 28/13	4.2	217.1

+³, ×³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 13-09

METRIC

W.P. 15-64-26 | LOCATION N 4 936 432.4 E 425 282.6 | ORIGINATED BY ES

HWY 6/21 | BOREHOLE TYPE Solid Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2013.10.16 - 2013.10.16 | CHECKED BY SP

ELEV / DEPTH (m)	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%) (approx.)	GR	SA	SI	CL
220.7 / 0.0	**ASPHALT:** (40mm)								
	SAND, trace gravel to gravelly, trace to some silt, trace clay; Very Loose to Compact; Brown; Damp; (FILL)	1	SS	21		37	49	14 (SI+CL)	
		2	SS	7					
		3	SS	10					
		4	SS	3		6	58	29	7
		5	SS	5					
216.0 / 4.7	**SAND**, some silt, trace gravel, trace clay, trace oxide staining; Loose; Brown; Moist	6	SS	8		3	78	16	3
215.0 / 5.7	END OF BOREHOLE AT 5.7m UPON AUGER REFUSAL ON PROBABLE BEDROCK.								

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

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Oct 18/13	Dry	-
Nov 28/13	4.3	216.4

Elevation scale: 220, 219, 218, 217, 216

Column headings: 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 (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

+³, ×³: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 13-10

METRIC

W.P.	15-64-26	LOCATION	N 4 936 456.4 E 425 258.9	ORIGINATED BY	ES
HWY	6/21	BOREHOLE TYPE	Hand Shovel	COMPILED BY	AN
DATUM	Geodetic	DATE	2013.10.18 - 2013.10.18	CHECKED BY	SP

ELEV / DEPTH	DESCRIPTION (SOIL PROFILE)	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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
211.8											
0.0	**PEAT**, trace sand, trace roots and rootlets Dark Brown Wet		1	GS					116		
211.4 0.4	END OF BOREHOLE AT 0.4m UPON SHOVEL REFUSAL ON PROBABLE BEDROCK. BOREHOLE BACKFILLED WITH CUTTINGS TO SURFACE.										

+ 3, × 3: Numbers refer to Sensitivity

20 / 15 ◐ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 13-11

METRIC

W.P. 15-64-26 | LOCATION N 4 936 452.9 E 425 273.5 | ORIGINATED BY ES

HWY 6/21 | BOREHOLE TYPE Tripod/NW Casing | COMPILED BY AN

DATUM Geodetic | DATE 2013.10.17 - 2013.10.17 | CHECKED BY SP

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%)
212.3							
0.0	**SAND**, some silt to silty, trace gravel, trace organics, trace roots and rootlets, occasional cobble; Very Loose to Dense; Dark Brown to Brown; Moist	1	SS	3	212		
		2	SS	37			
211.0 / 1.3	Silty **SAND**, occasional cobbles; Dense; Grey; Moist	3	SS	41	211		
210.5 / 1.8	END OF BOREHOLE AT 1.8m UPON REFUSAL ON PROBABLE BEDROCK.						

END OF BOREHOLE AT 1.8m UPON REFUSAL ON PROBABLE BEDROCK.
Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.22m slotted screen.

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Oct 18/13	0.4	211.9
Nov 28/13	0.2	212.1

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; 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 (%) 20 40 60; UNIT WEIGHT γ kN/m³; GR SA SI CL

+ 3 , × 3 : Numbers refer to Sensitivity   20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 13-12

METRIC

W.P. 15-64-26	LOCATION N 4 936 447.6 E 425 294.1		ORIGINATED BY ES
HWY 6/21	BOREHOLE TYPE Tripod/NW Casing		COMPILED BY AN
DATUM Geodetic	DATE 2013.10.17 - 2013.10.17		CHECKED BY SP

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 (%) (20, 40, 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL)

Soil Profile

ELEV / DEPTH	DESCRIPTION
211.3	(ground surface)
0.0	Silty **SAND**, trace gravel, trace peat, trace roots and rootlets Very Loose Dark Brown Wet
210.6 / 0.7	Silty **SAND**, occasional wood fibre Compact Grey Moist Trace gravel
208.1 / 3.2	**GRAVEL**, occasional limestone fragments Very Dense Grey Wet
207.4 / 3.9	Clayey **SILT**, some sand, trace gravel, occasional silt stone Hard Reddish Brown (TILL)
207.3 / 4.0	END OF BOREHOLE AT 4.0m UPON REFUSAL ON PROBABLE BEDROCK.

Samples

NUMBER	TYPE	"N" VALUES
1	SS	1
2	SS	14
3	SS	30
4	SS	67
5	SS	18
6	SS	81
7	SS	74/ 0.200

Elevation scale: 211, 210, 209, 208

Water content (sample 1): 96

END OF BOREHOLE AT 4.0m UPON REFUSAL ON PROBABLE BEDROCK.
WATER LEVEL AT 0.2m BELOW SURFACE UPON COMPLETION.
Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Oct 18/13	0.1	211.2
Nov 28/13	0.1	211.2

+³, ×³: Numbers refer to Sensitivity

20 / 15 ◐ 5 / 10 (%) STRAIN AT FAILURE

Appendix B

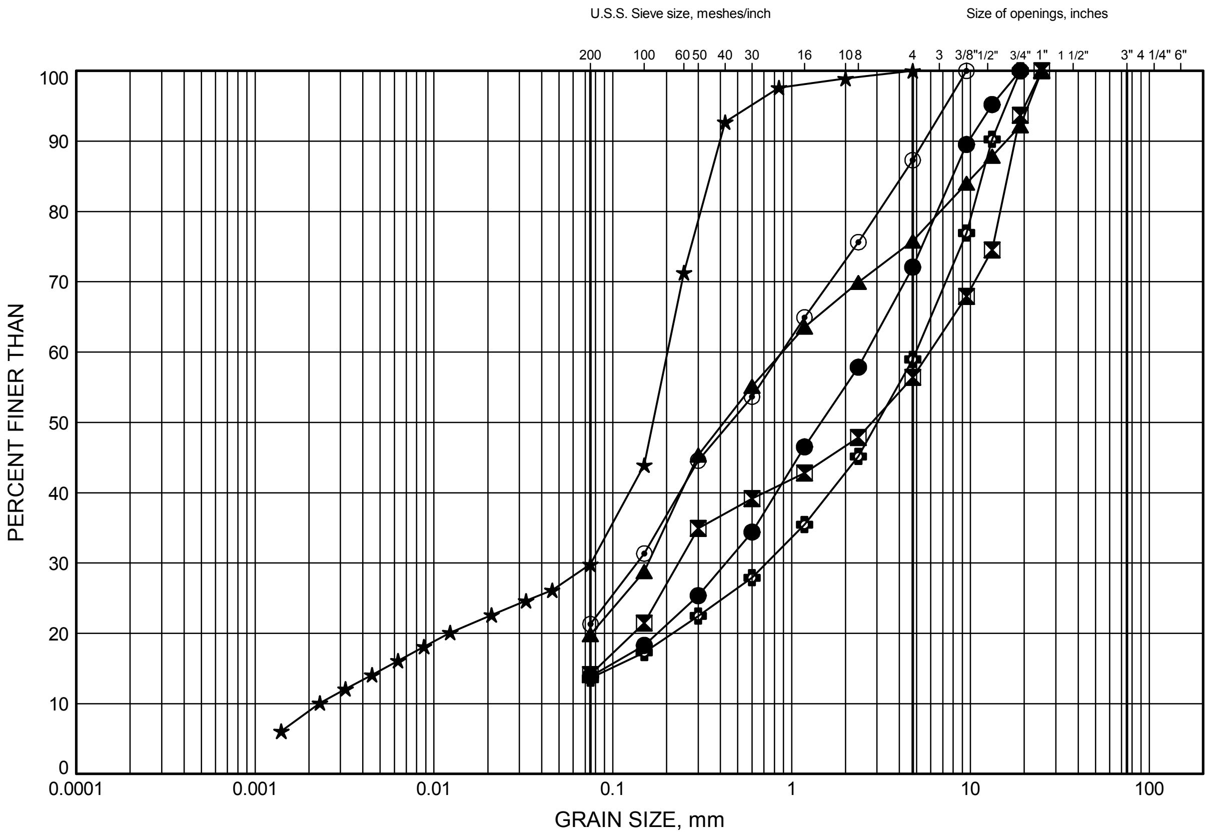
Laboratory Test Results

Hwy 6 - 21 Slope Failure

GRAIN SIZE DISTRIBUTION

FIGURE B1

Granular FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	13-01	0.38	221.90
⧗	13-01	1.83	220.45
▲	13-02	1.03	220.44
★	13-03	1.83	218.93
⊙	13-03	4.11	216.65
✿	13-04	0.41	221.72

Date December 2013

W.P. 15-64-26

THURBER

Prep'd SBP

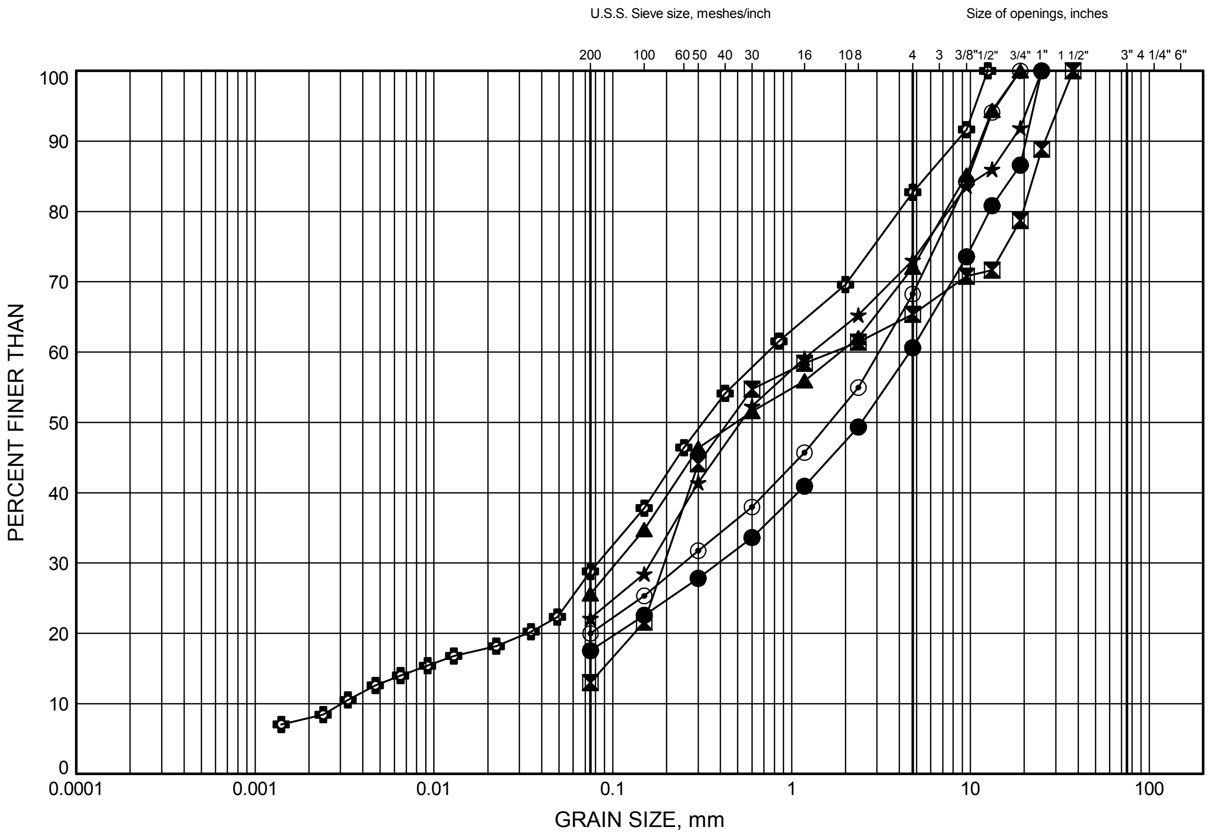
Chkd. SBP

Hwy 6 - 21 Slope Failure

GRAIN SIZE DISTRIBUTION

FIGURE B2

Granular FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	13-04	1.83	220.30
⧗	13-05	2.59	218.78
▲	13-05	4.71	216.66
★	13-06	1.07	219.70
⊙	13-07	0.35	221.68
✿	13-07	2.59	219.44

Date December 2013

W.P. 15-64-26

THURBER

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Chkd. SBP

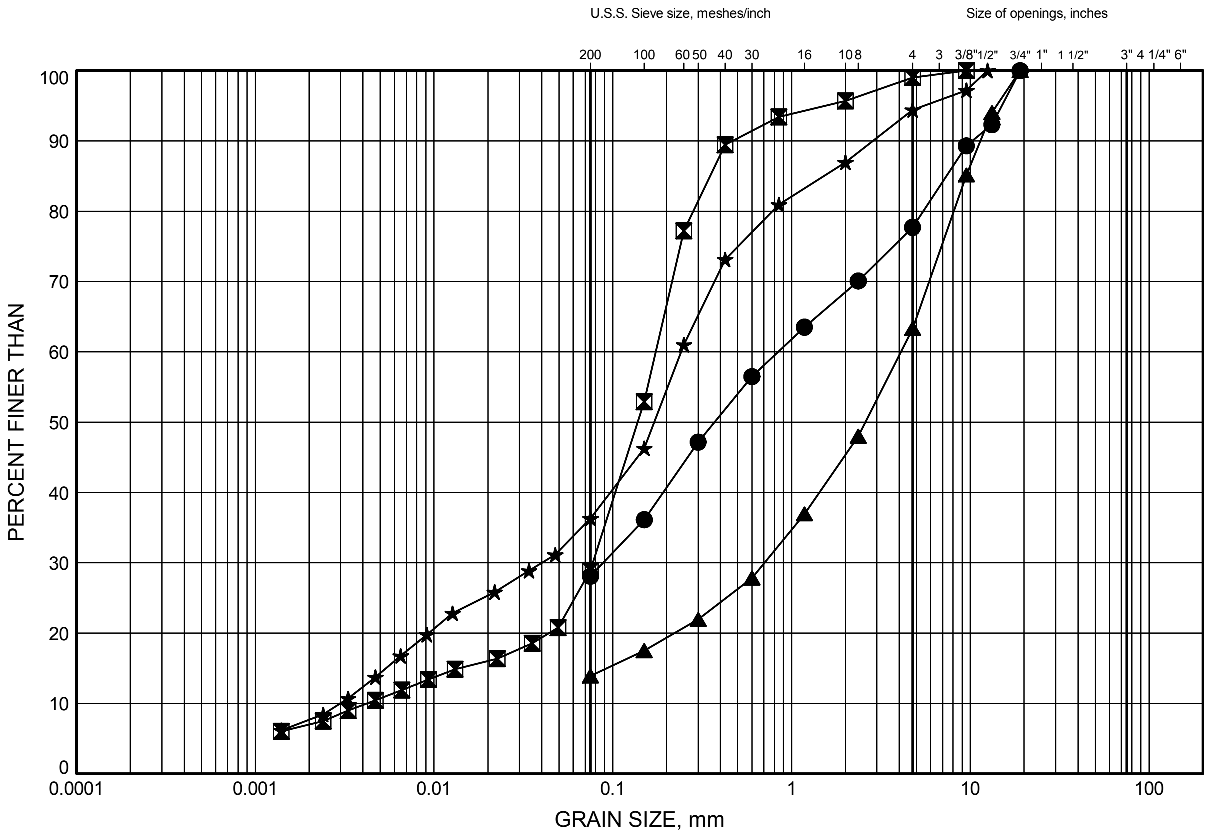
GRAIN SIZE DISTRIBUTION - THURBER 6426.GPJ 4/12/13

Hwy 6 - 21 Slope Failure

GRAIN SIZE DISTRIBUTION

FIGURE B3

Granular FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	13-08	1.07	220.24
⊠	13-08	3.35	217.95
▲	13-09	0.53	220.14
★	13-09	2.59	218.08

Date December 2013

W.P. 15-64-26

THURBER

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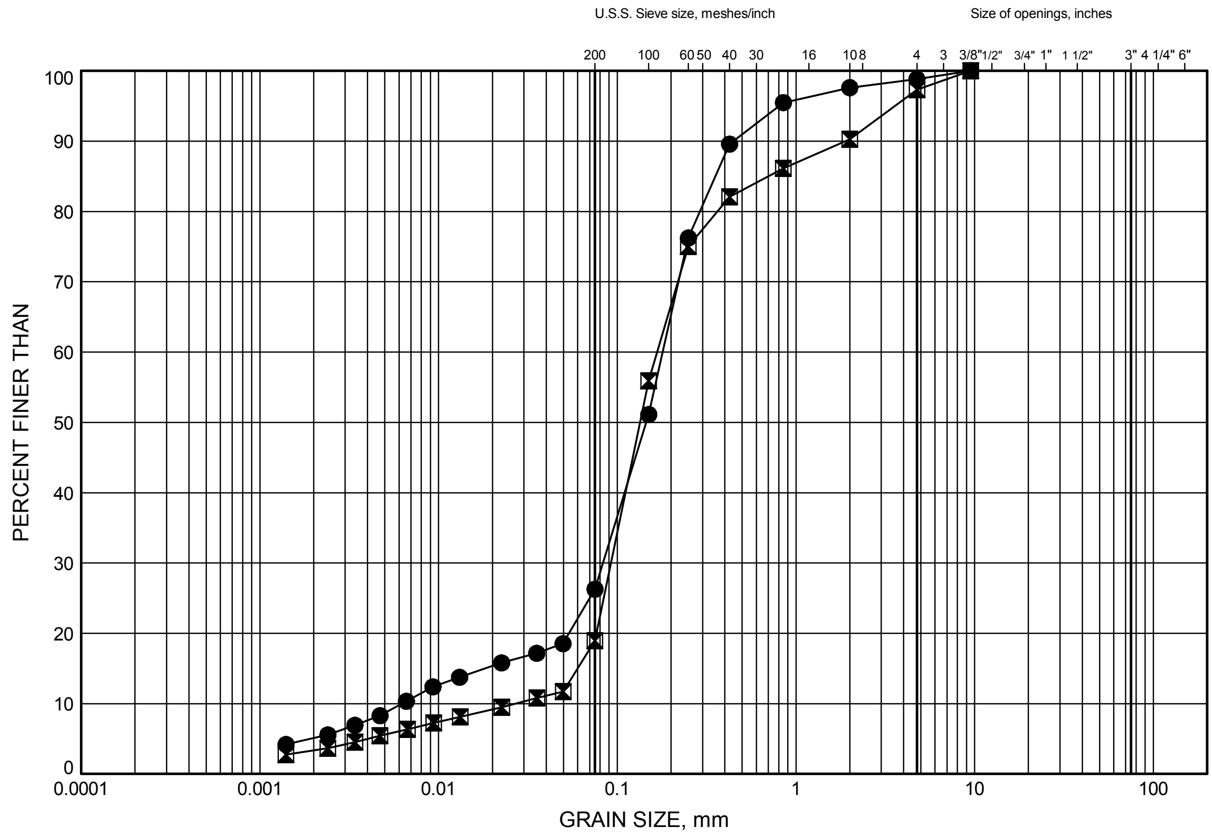
Hwy 6 - 21 Slope Failure

GRAIN SIZE DISTRIBUTION

FIGURE B4

SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	13-06	3.35	217.41
⧗	13-09	4.88	215.79

GRAIN SIZE DISTRIBUTION - THURBER 6426.GPJ 4/12/13

Date December 2013

W.P. 15-64-26

THURBER

Prep'd SBP

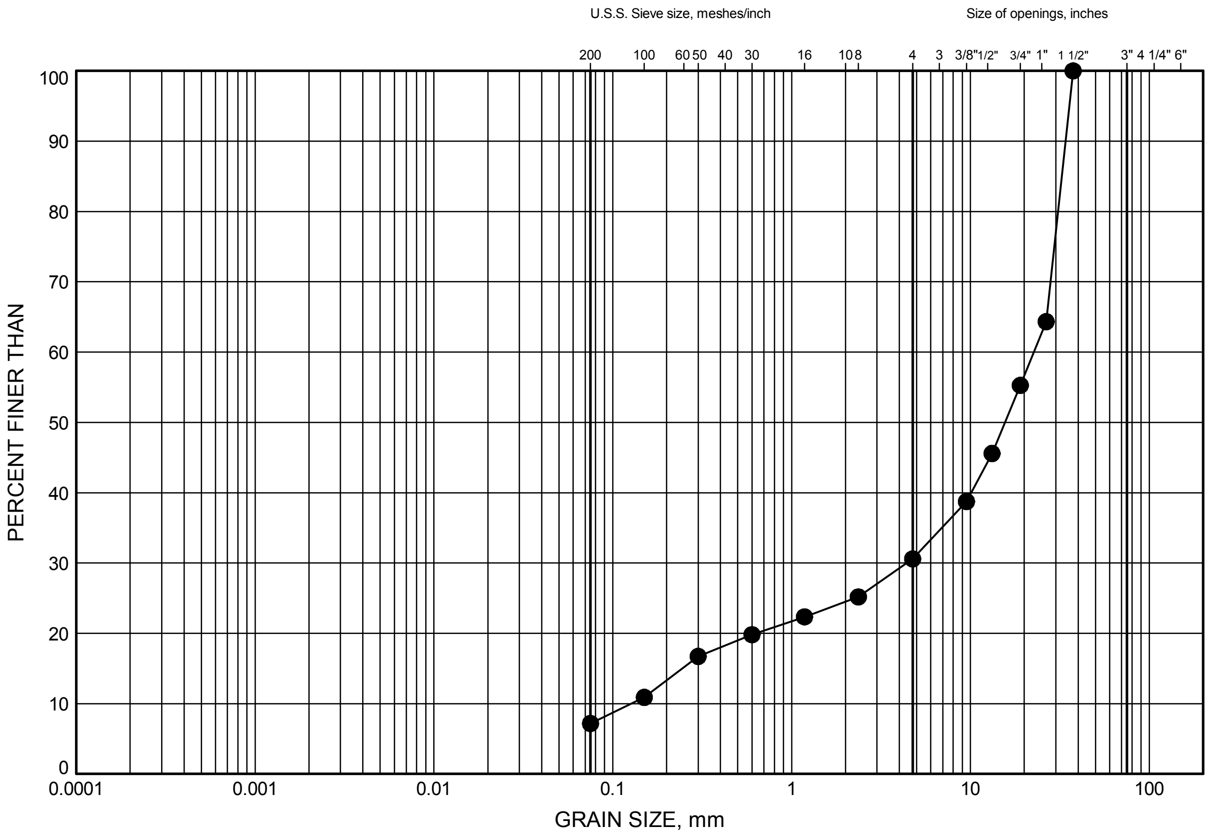
Chkd. SBP

Hwy 6 - 21 Slope Failure

GRAIN SIZE DISTRIBUTION

FIGURE B5

GRAVEL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	13-03	7.16	213.60

Date December 2013

W.P. 15-64-26

THURBER

Prep'd SBP

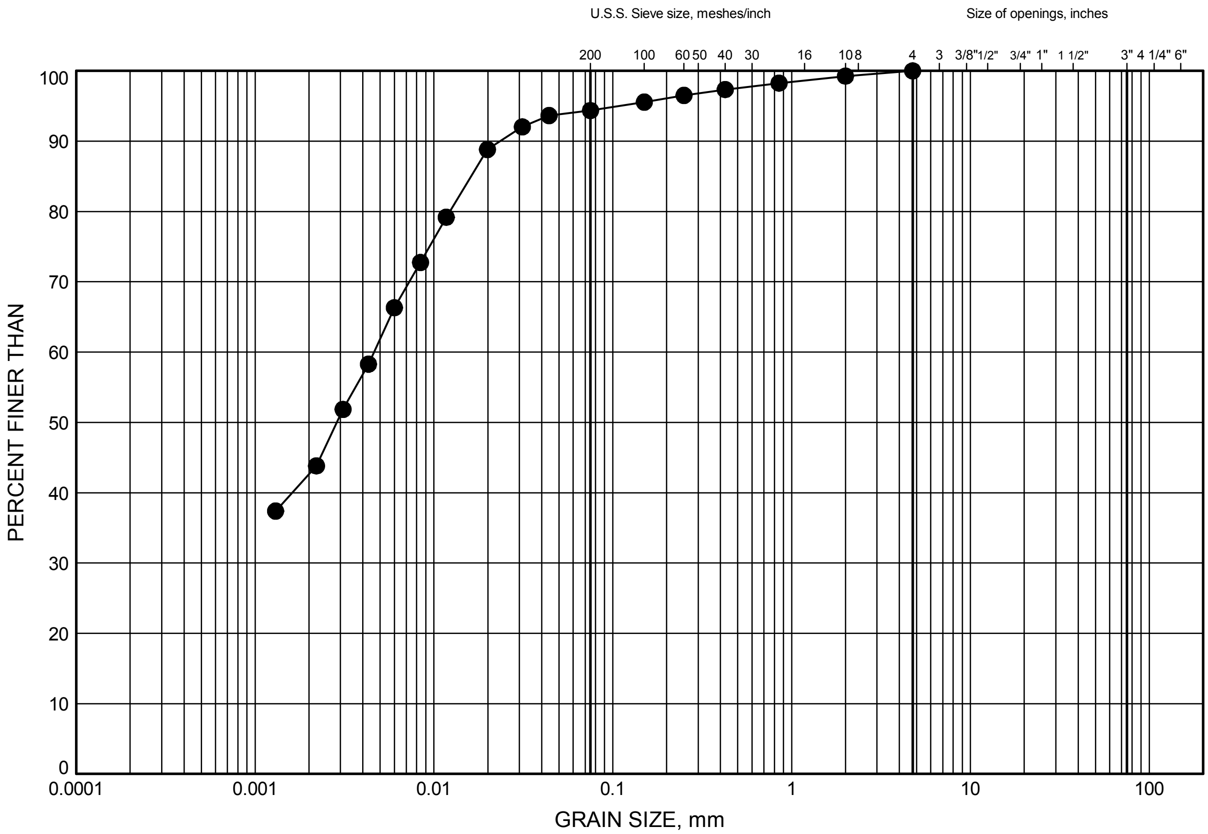
Chkd. SBP

Hwy 6 - 21 Slope Failure

GRAIN SIZE DISTRIBUTION

FIGURE B6

Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	13-05	7.92	213.45

Date December 2013

W.P. 15-64-26

THURBER

Prep'd SBP

Chkd. SBP

Appendix C

Site Photographs

Photo 1: Looking Eastward (toward Owen Sound) from eastbound shoulder showing rock face on south and pylons outlining slope failure on north side of highway

Photo 2: Looking Eastward (toward Owen Sound) from westbound shoulder showing pylons and sandbags outlining slope failure on north side of highway. Also note longitudinal cracking on shoulder parallel to highway.

Photo 3: Looking Northward (perpendicular to Highway) from westbound shoulder showing sandbags and erosion gullies along slope failure on north side of highway

Photo 4: Looking Southward (toward Highway) from north toe of slope showing erosion gullies and soil deposition along slope failure on north side of highway

Appendix D

Borehole Locations and Soil Strata Drawing

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No

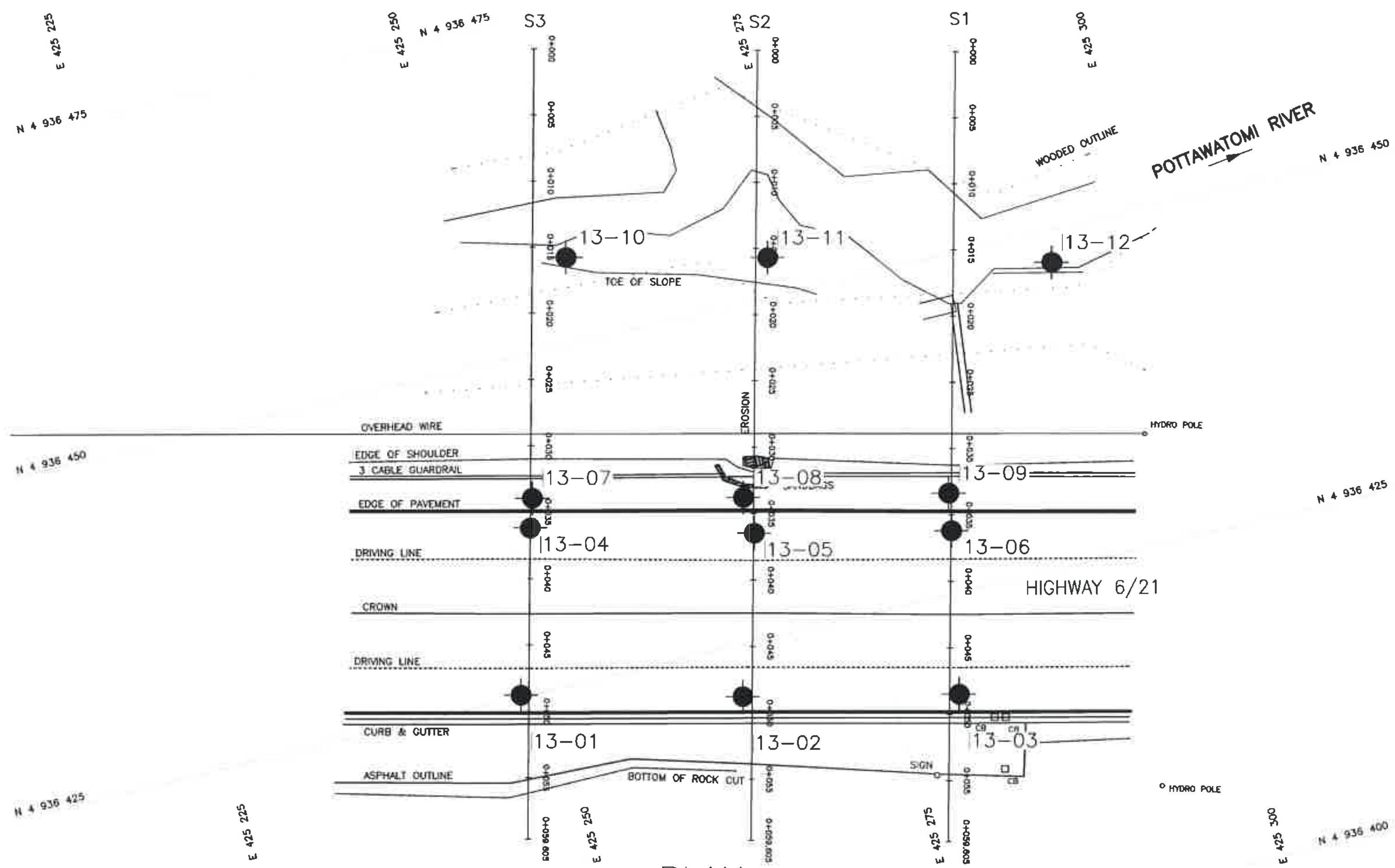
WP No

SHEET

HIGHWAY 6/21
SLOPE FAILURE
OWEN SOUND
BOREHOLE LOCATIONS AND SOIL STRATA

Ontario

THURBER ENGINEERING LTD.



PLAN

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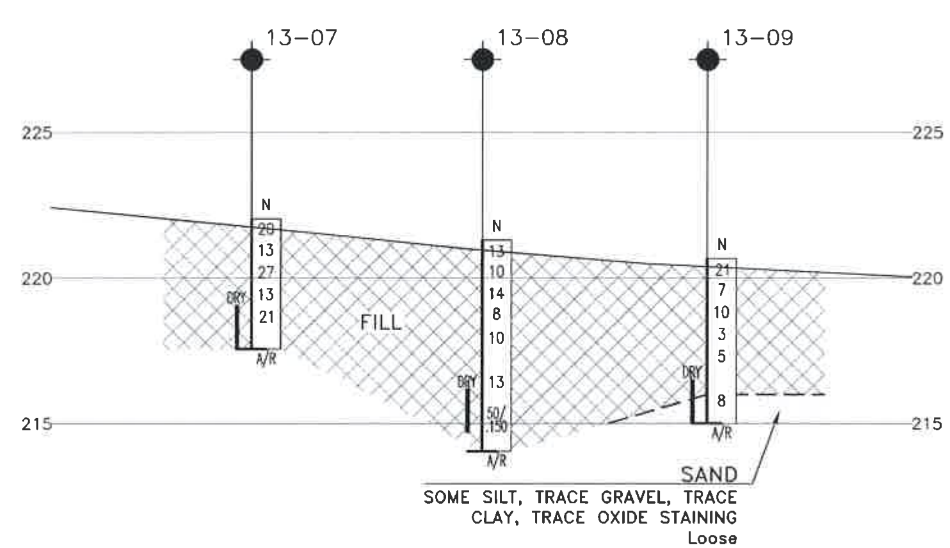


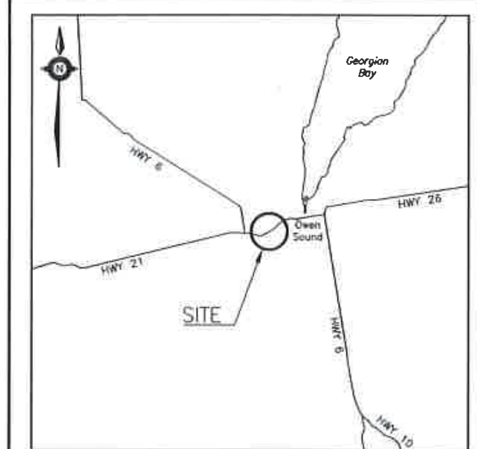
PROFILE ALONG EDGE OF SHOULDER

H 1:500

V 1:250

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Jan 21/14
PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER
A. E. GORMAN
JAN 21/14
PROVINCE OF ONTARIO



KEYPLAN

LEGEND

●	Borehole
⊕	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▼	Water Level
▼	Head Artesian Water
┃	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
13-01	222.3	4 936 425.2	425 247.9
13-02	221.5	4 936 421.2	425 264.0
13-03	220.8	4 936 417.5	425 279.8
13-04	222.1	4 936 437.2	425 251.5
13-05	221.4	4 936 432.9	425 267.7
13-06	220.8	4 936 429.6	425 282.1
13-07	222.0	4 936 439.4	425 252.2
13-08	221.3	4 936 435.7	425 267.5
13-09	220.7	4 936 432.4	425 282.6
13-10	211.8	4 936 456.4	425 258.9
13-11	212.3	4 936 452.9	425 273.5
13-12	211.3	4 936 447.6	425 294.1

-NOTES-

1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

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

GEOCRES No. 41A-232

REVISIONS

DATE	BY	DESCRIPTION

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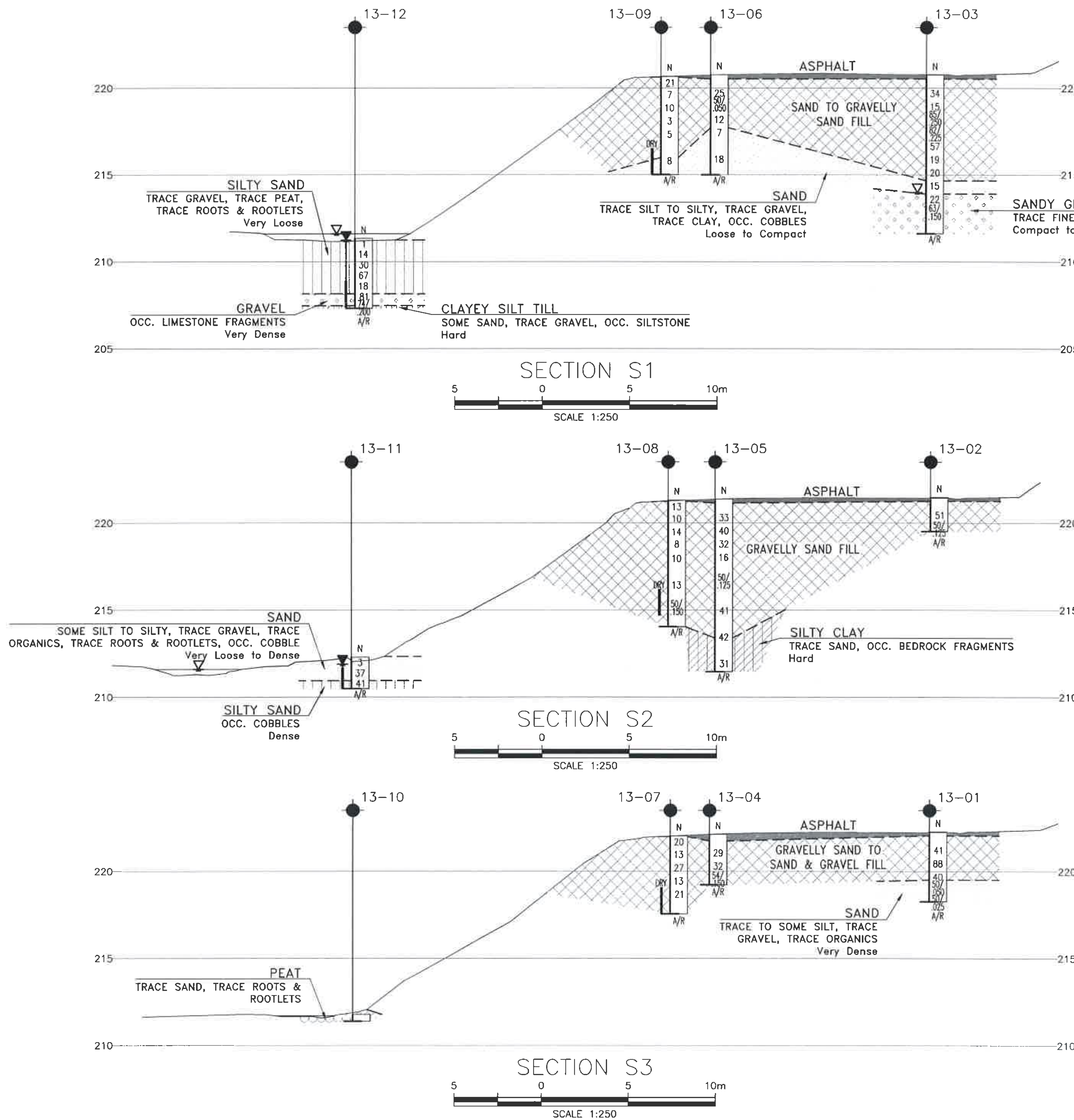


METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Jan 21/14
PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER
A. E. GORMAN
JAN 21/14
PROVINCE OF ONTARIO

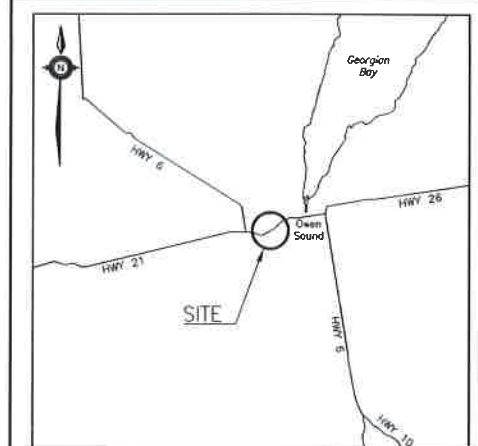
CONT No
WP No

SHEET

HIGHWAY 6/21
SLOPE FAILURE
OWEN SOUND
BOREHOLE LOCATIONS AND SOIL STRATA

Ontario

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

⌖	Borehole
⌖	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
▽	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
13-01	222.3	4 936 425.2	425 247.9
13-02	221.5	4 936 421.2	425 264.0
13-03	220.8	4 936 417.5	425 279.8
13-04	222.1	4 936 437.2	425 251.5
13-05	221.4	4 936 432.9	425 267.7
13-06	220.8	4 936 429.6	425 282.1
13-07	222.0	4 936 439.4	425 252.2
13-08	221.3	4 936 435.7	425 267.5
13-09	220.7	4 936 432.4	425 282.6
13-10	211.8	4 936 456.4	425 258.9
13-11	212.3	4 936 452.9	425 273.5
13-12	211.3	4 936 447.6	425 294.1

-NOTES-

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

GEOCRES No. 41A-232

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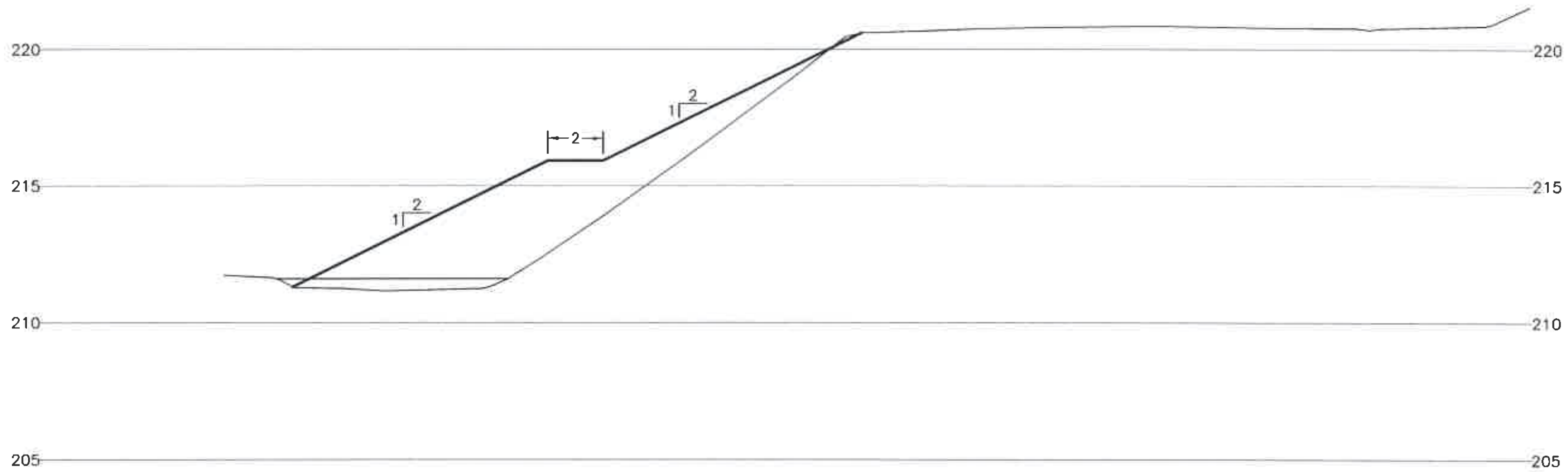

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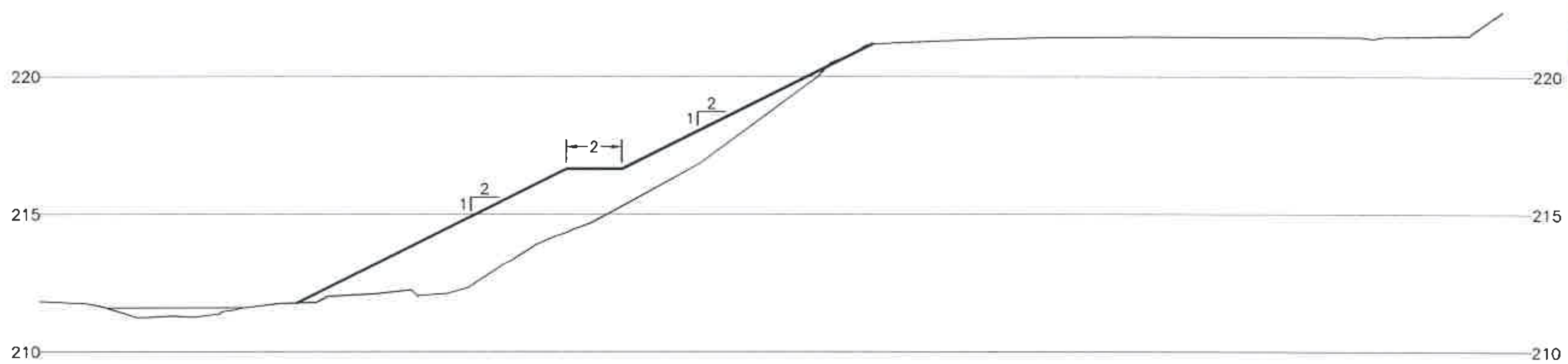

SECTION S2

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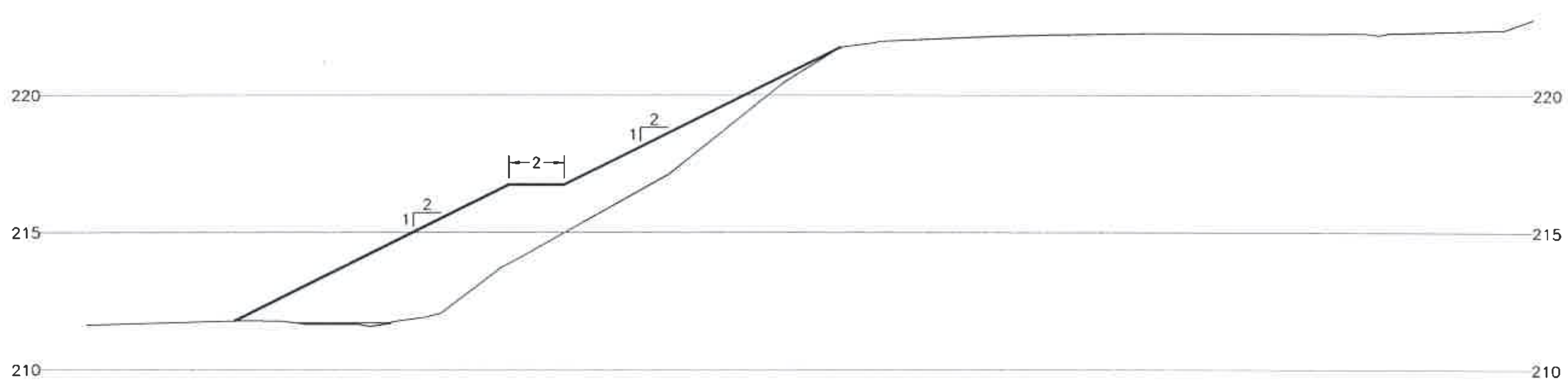

SECTION S3

5 0 5 10m

SCALE 1:250

METRIC

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

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P. K. CHATTERJI
Jan 21/14
PROVINCE OF ONTARIO

REGISTERED PROFESSIONAL ENGINEER
A. E. GORMAN
JAN 21/14
PROVINCE OF ONTARIO

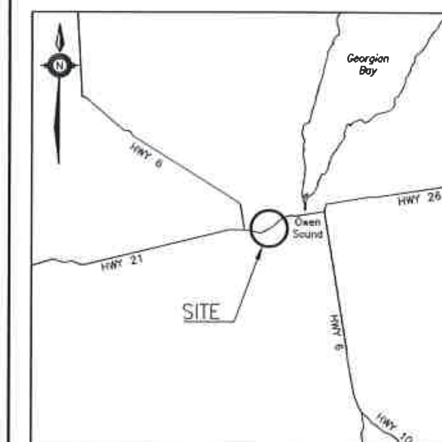
CONT No
WP No

HIGHWAY 6/21
SLOPE FAILURE
OWEN SOUND
NEW SLOPE

SHEET

Ontario

THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

⊕	Borehole
⊕	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
⊥	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING

-NOTES-

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GEOCRES No. 41A-232

REVISIONS	DATE	BY	DESCRIPTION

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Appendix E

Slope Stability Analysis Output

Title: Owen Sound Slope Stability Analysis
Name: Analysis 1
Comments: HWY 6 / 21, West of Owen Sound
Last Solved Date: 12/4/2013, 3:14:53 PM
Last Edited By: Stephen Peters

Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 0.5 m
Horz Seismic Load: 0

FILL: Gravelly SAND some fines to SAND some Silt to Silty, trace Gravel	20 kN/m³	0 kPa	35 °	1
NATIVE: Silty CLAY, trace sand	18 kN/m³	100 kPa	0 °	1
NATIVE: SAND some Silt to Silty, trace Gravel to Silty SAND	19 kN/m³	0 kPa	30 °	1
Probable BEDROCK				

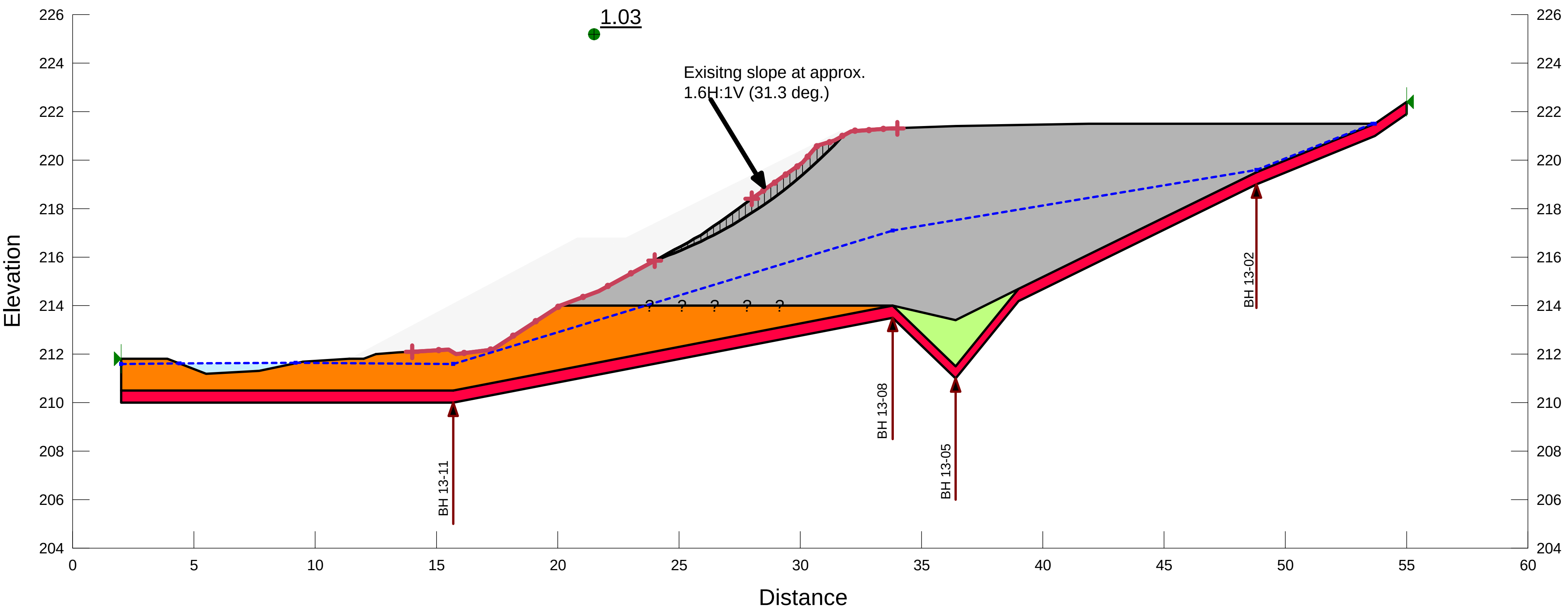
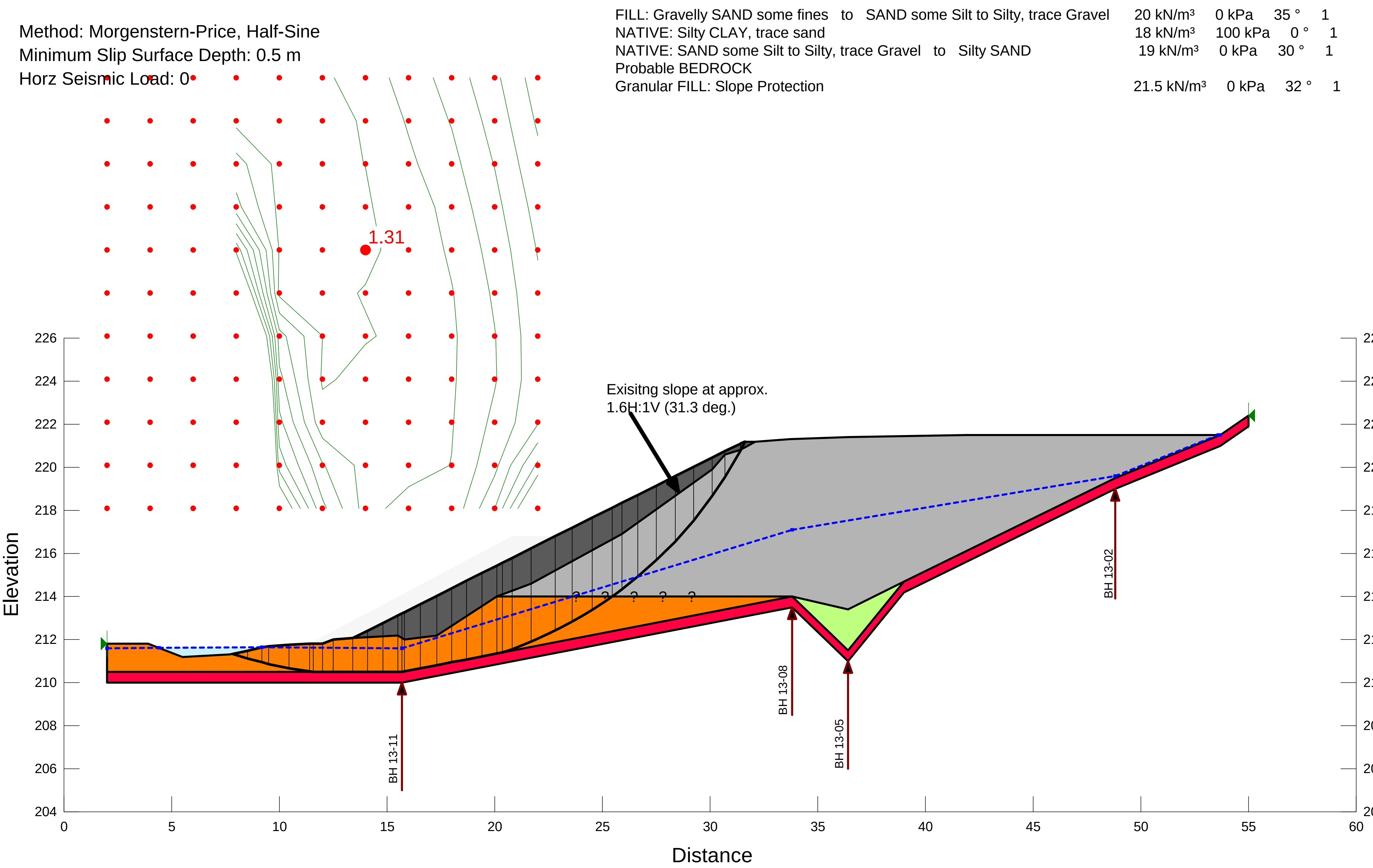


Figure 1.

Directory: H:\15\64\26 Hwy 6-21 Slope Failure\Analysis\Slope Stabilty\File Name: OwenSound_002.gsz

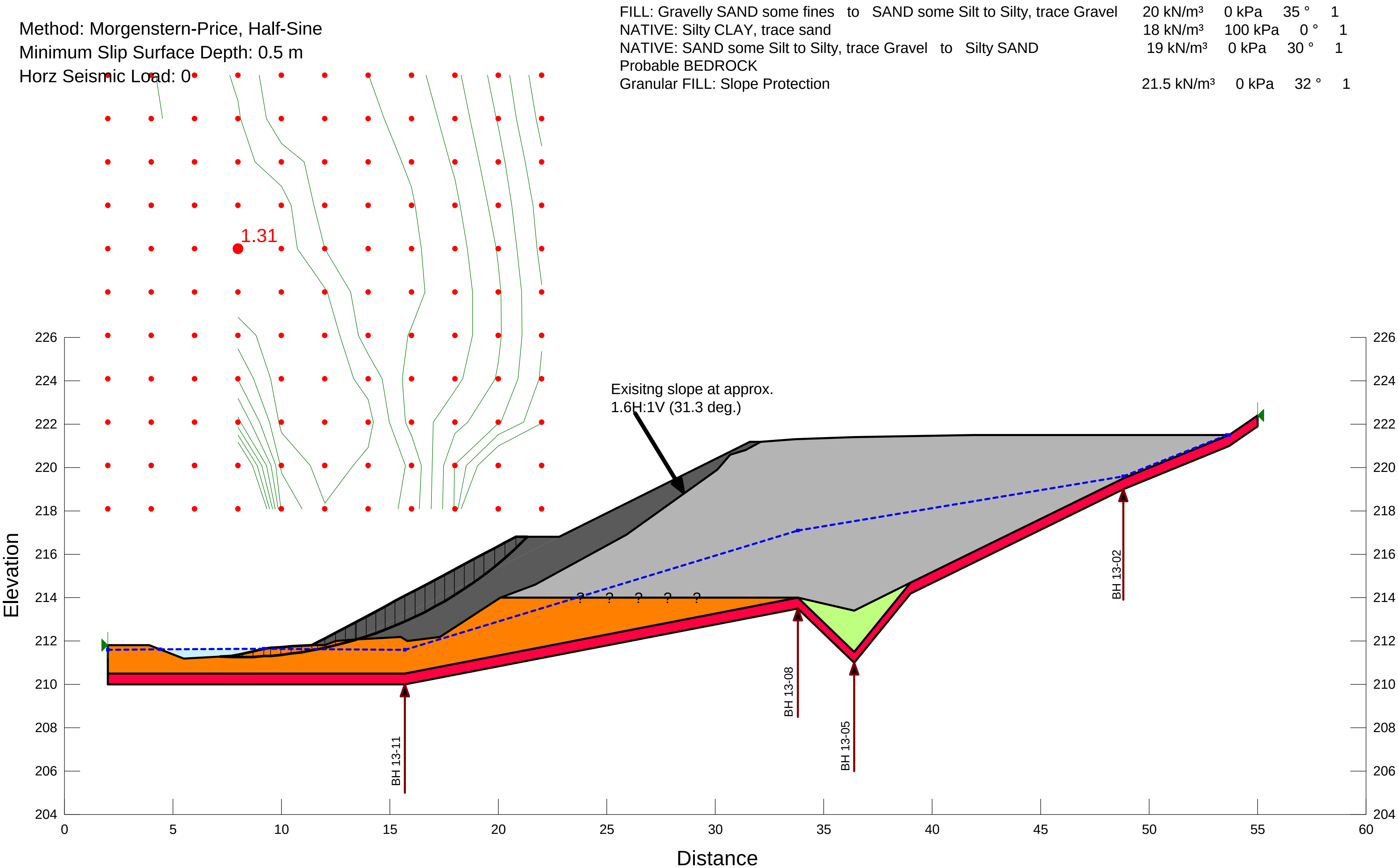
Title: Owen Sound Slope Stability Analysis
Name: Analysis 2
Comments: HWY 6 / 21, West of Owen Sound
Last Solved Date: 12/4/2013, 3:17:22 PM
Last Edited By: Stephen Peters



Directory: H:\15\64\26 Hwy 6-21 Slope Failure\Analysis\Slope Stabilty\File Name: OwenSound_002.gsz

Figure 2.

Title: Owen Sound Slope Stability Analysis
Name: Analysis 3
Comments: HWY 6 / 21, West of Owen Sound
Last Solved Date: 12/4/2013, 3:17:26 PM
Last Edited By: Stephen Peters



Directory: H:\15\64\26 Hwy 6-21 Slope Failure\Analysis\Slope Stabilty\File Name: OwenSound_002.gsz

Figure 3.

Title: Owen Sound Slope Stability Analysis
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Comments: HWY 6 / 21, West of Owen Sound
Last Solved Date: 12/4/2013, 3:17:36 PM
Last Edited By: Stephen Peters

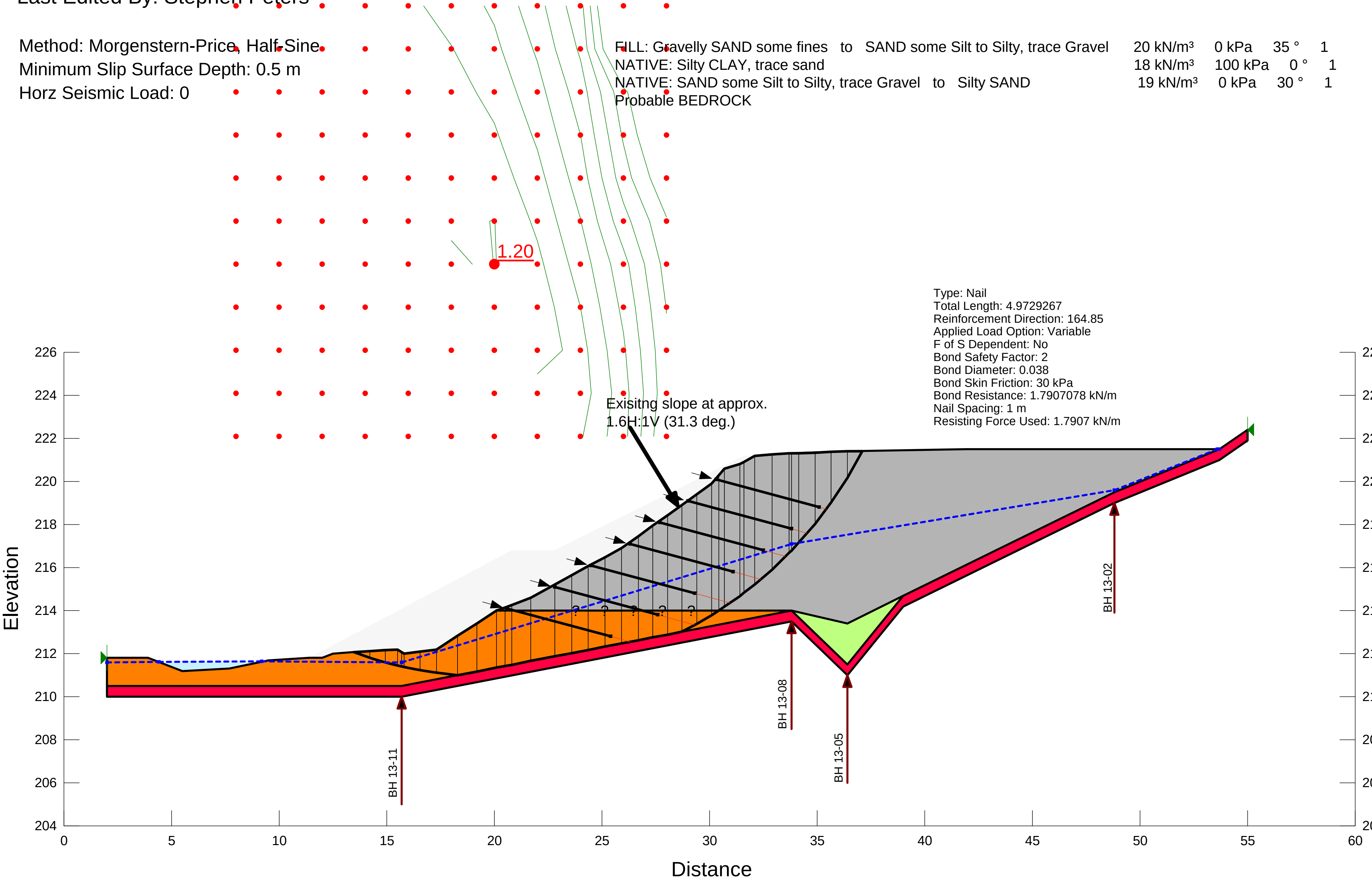

Figure 4.

Directory: H:\15\64\26 Hwy 6-21 Slope Failure\Analysis\Slope Stabilty\File Name: OwenSound_002.gsz

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Last Solved Date: 1/20/2014, 9:25:02 AM
Last Edited By: Stephen Peters

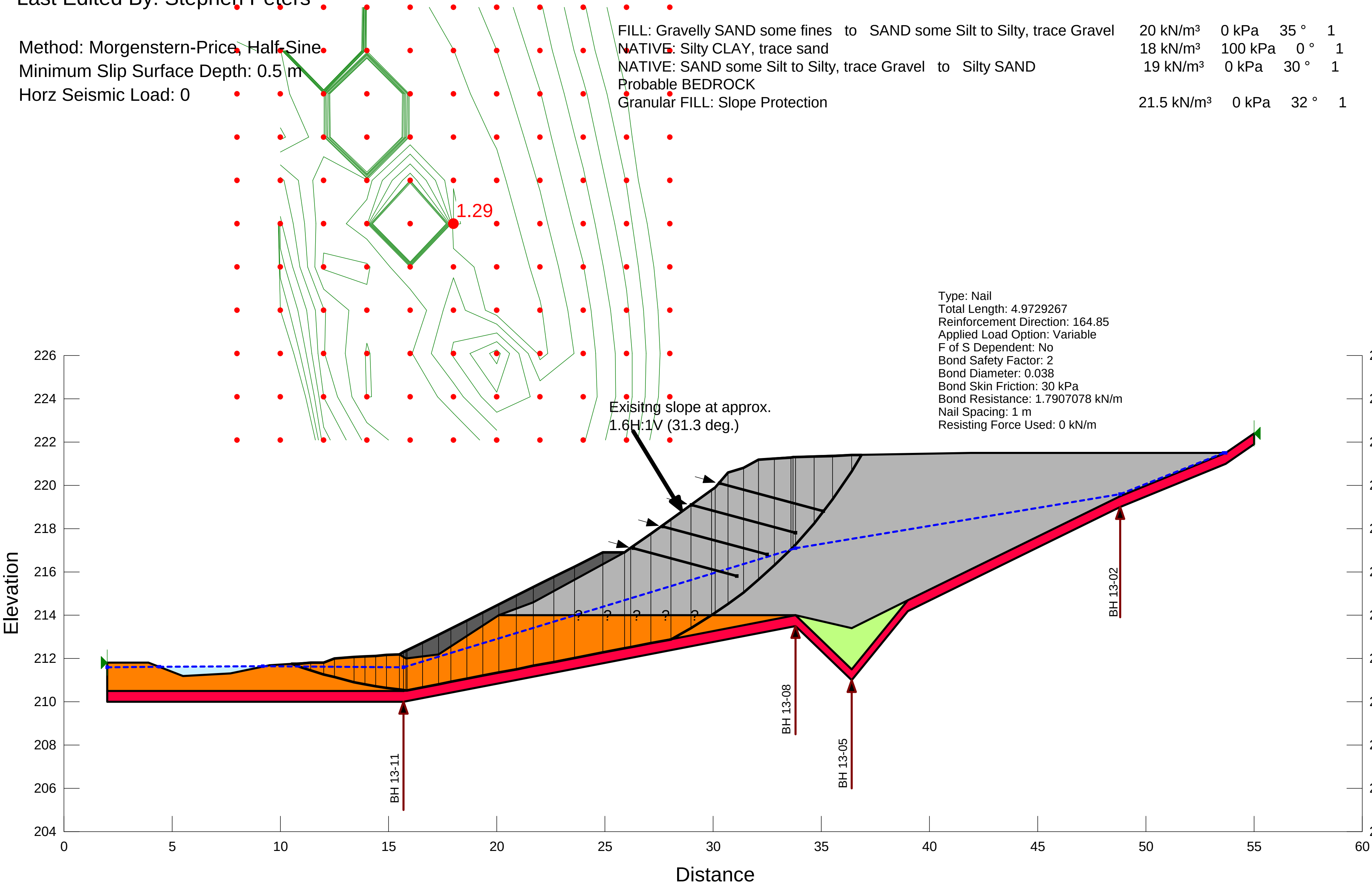

Figure 5.

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