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FINAL
FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 11 NON-STRUCTURAL CULVERT AT STATION 12+650
LEDGER TOWNSHIP, ONTARIO
AGREEMENT NO.: 6022-E-0038
ASSIGNMENT NO.: 1

GEOCRES NO.: 52H01-001

Location: Lat: 49.163634°, Long: -88.233413°

Client Name: Ministry of Transportation
Date: December 5, 2023
File: 40101

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PART 1. FACTUAL INFORMATION

1. INTRODUCTION

This section of the report presents the factual findings obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for a new temporary detour embankment for the replacement of a box culvert that crosses Highway 11 at Sta. 12+650 in Ledger Township approximately 17.8 km north of Nipigon, Ontario. Thurber carried out the foundation investigation for the Ontario Ministry of Transportation (MTO) under Retainer Agreement No. 6022-E-0038, Assignment No. 1.

The purpose of the investigation was to explore the subsurface conditions at the site and based on this data obtained, provide a borehole location plan, record of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions. The stratigraphic profile of the subsurface conditions was developed during the current investigation.

It is a condition of this report that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

2. SITE DESCRIPTION

2.1 General

The culvert site crosses Highway 11 approximately 17.8 km north of the junction between Highway 11 and Highway 17 near Nipigon. For project purposes, Highway 17 is herein described as oriented north-south, and the culvert is described as oriented east-west.

In the area of the culvert, Highway 11 is a two-lane highway and has a posted speed limit of 90 km/h. The road surface near the culvert is at approximate elevation 228 m. The shoulders to the highway are partially paved and steel cable guiderails on wooden posts are present along

both northbound and southbound shoulders of the highway. The 2016 traffic volume for this section of Highway 11 is understood to be approximately 1,500 AADT.

The existing box culvert is reported in drawings provided by MTO to be 1.83 m wide, 1.22 m high and 31.37 m long, with an alignment approximately perpendicular to the highway alignment. The culvert has a relatively flat gradient with the invert of the culvert near elevations 223.40 m and 223.27 m at the inlet and outlet, respectively. The culvert inlet and outlet were both observed to be dry during the field investigation.

The cover above the existing culvert is approximately 4.5 m at the highway centerline. Embankment side slopes, in the vicinity of the culvert, are generally inclined at approximately 1.6H:1V and 2.5H:1V on the west and east sides, respectively. The existing highway embankment side slopes at the culvert site did not show any visible signs of global instability at the time of the investigation.

The site is in a rural setting and the area adjacent to the highway is undeveloped and densely vegetated with mixed forests of coniferous and some deciduous trees and shrubs. Overhead utility lines were not present.

Photographs of the project area are included in Appendix D. These photographs show the existing condition of the highway embankment and the culvert at the time of the field investigation.

2.2 Site Geology

According to Crins et al. 2009[1] the project area is described as Ecoregion 3W (Lake Nipigon Ecoregion) within the Ontario Shield Ecozone. According to Wester et al. 2018[2] the ecoregion is subdivided into Ecodistrict 3W-3 (Black Sturgeon Ecodistrict). The project area is located in the south part of the ecodistrict, which is characterized by Precambrian bedrock overlain with a very shallow to shallow layer of mineral material and morainal deposits. Bedrock Geology Map (M2542)[3] indicates the site is underlain by metasedimentary rocks: paragneisses and migmatites.

2.3 Existing Information

A historical foundation investigation report was not available for this site within the online Geocres Library.

[1] *https://files.ontario.ca/mnrf-ecosystemspart1-accessible-july2018-en-2020-01-16.pdf*
[2] *https://files.ontario.ca/ecosystems-ontario-part2-03262019.pdf*
[3] *https://www.geologyontario.mndm.gov.on.ca/mndmfiles/pub/data/imaging/M2542//M2542.pdf*

Base plan mapping was provided by MTO for the preparation of this report.

3. SITE INVESTIGATION AND FIELD TESTING

The foundation investigation and field-testing program was carried out between September 18 and September 19, 2023, and consisted of one off-road borehole drilled near the toe of the existing highway embankment identified as 23-01 and one on-road borehole identified as 23-02. Both boreholes were advanced with a CME 750 buggy drill rig utilizing hollow stem augers. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

A summary of the borehole coordinates, elevations, and termination depths is provided in the table below. The as-drilled borehole elevations were measured by Thurber following completion of the field program. Horizontal locations were measured by Thurber relative to existing site features. The elevations and borehole coordinates were reviewed and referenced to the survey data provided by MTO. The borehole coordinates and elevations are shown on the Borehole Location and Soil Strata drawing included in Appendix A and on the individual Record of Borehole sheets included in Appendix B. The borehole coordinates are referenced to MTM Zone 14.

Table 3-1 Borehole Summary

Borehole	Northing (m)	Easting (m)	Ground Surface Elevation (m)	Termination Depth Below Ground Surface (m)
23-01	5,448,040.5	214,850.0	225.3	12.8
23-02	5,448,015.6	214,847.0	227.5	17.4

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in general accordance with ASTM D 1586. In-situ vane testing was carried out within the cohesive layers, where possible, using an MTO ‘N’ sized vane in general accordance with ASTM D 2573.

The drilling and sampling operations were supervised on a full-time basis by a member of Thurber’s technical staff. The drilling supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber’s Oakville laboratory for further examination and testing.

Following completion of the field investigation, the boreholes were decommissioned in general in accordance with O. Reg. 903, as amended.

4. LABORATORY TESTING

Laboratory testing was selected in general accordance with the current MTO Guideline for Foundation Engineering Services, Section 5. Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all retained soil samples. Recovered soil samples were selected for grain size distribution and, where appropriate, Atterberg Limit testing in accordance with MTO and ASTM standards. The results of these tests are summarized on the Record of Borehole sheets included in Appendix B.

All laboratory test results from the field investigation are provided in Appendix C.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered subsurface conditions are presented on the Record of Borehole sheets included in Appendix B and on the Borehole Location and Soil Strata Drawing included in Appendix A. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following sections. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description for interpretation of the site conditions. It must be recognized that the soil and groundwater conditions may vary between and beyond borehole locations.

In general, the encountered stratigraphy consists of topsoil or gravelly sand embankment fill underlain by a deposit of clayey silt. A layer of silty clay was encountered within the clayey silt deposit in the off-road borehole (23-01).

5.1 Topsoil

Topsoil was encountered at the ground surface in Borehole 23-01. The topsoil was measured to have a thickness of 50 mm.

5.2 Fill

A fill layer consisting of gravelly sand was encountered at the ground surface in Borehole 23-02. The fill layer was 3.1 m thick (base elev. 224.4 m). SPT N-values in the fill ranged from 9 to 15 blows, indicating a loose to compact relative density.

Moisture contents ranging from 5 to 12% were recorded. The results of a gradation analysis completed on a sample of the gravelly sand fill are illustrated in Figure C1 of Appendix C. The results of the test are summarized in the table below and on the Record of Borehole sheets in Appendix B.

Soil Particle	Percentage (%)
Gravel	37
Sand	50
Silt	13
Clay	

5.3 Clayey Silt

A deposit of clayey silt was encountered below the topsoil in Borehole 23-01 and below the gravelly sand fill in Borehole 23-02. The layer was not fully penetrated in the boreholes but was proven to have a thickness of at least 10.1 to 14.3 m and extend to depths of 12.8 to 17.4 m below the ground surface (base elev. 212.5 to 210.1 m) where the boreholes were terminated. SPT N-values ranged from 5 to 43 blows, indicating a loose to dense relative density.

Moisture contents ranging from 12 to 46% were recorded. The results of gradation analyses completed on seven samples of the clayey silt are illustrated in Figure C2 of Appendix C. The results of the tests are summarized in the table below and on the Record of Borehole sheets in Appendix B.

Soil Particle	Percentage (%)
Gravel	0
Sand	0 – 11
Silt	75 – 94
Clay	6 – 22

Atterberg limits testing was completed on four samples of the clayey silt. The results are illustrated in Figure C3 of Appendix C and summarized below and on the Record of Borehole sheets in Appendix B. The laboratory results indicate that the clayey silt exhibits low plastic behaviour (CL-ML).

Parameter	Value
Liquid Limit	22 – 26
Plastic Limit	18 – 20
Plasticity Index	4 – 7

5.4 Silty Clay

A layer of silty clay was encountered within the clayey silt deposit in Borehole 23-01. The silty clay layer was 2.7 m thick and extended to a depth of 4.9 m (base elev. 220.4 m). SPT N-values of 4 blows were recorded in the silty clay layer. A field vane test was performed within this layer and indicated an undrained shear strength of 63 kPa. The layer is described as firm to stiff based on the SPT N-values and in-situ vane testing.

The recorded moisture contents ranged from 27 to 34%. The results of a gradation analysis completed on a sample of the silty clay are illustrated in Figure C4 of Appendix C. The results of the tests are summarized in the table below and on the Record of Borehole sheets in Appendix B.

Soil Particle	Percentage (%)
Gravel	0
Sand	0
Silt	61
Clay	39

Atterberg limits testing was completed on a sample of the silty clay. The results are illustrated in Figure C5 of Appendix C and summarized below and on the Record of Borehole sheets in Appendix B. The laboratory results indicate that the silty clay exhibits intermediate plastic behaviour (CI).

Parameter	Value
Liquid Limit	38
Plastic Limit	21
Plasticity Index	17

5.5 Groundwater Level

The groundwater levels within the open boreholes were recorded upon completion of drilling and are summarized in the following table.

Table 5-1 Groundwater Level Measurements

Borehole	Groundwater Level		Date of Reading	Note
	Depth (m)	Elevation (m)		
23-01	Dry	-	September 18, 2023	Open Borehole
23-02	7.3	220.2	September 19, 2023	Open Borehole

It should be noted that the values shown above are considered short-term readings and may not reflect groundwater levels at the time of construction. Seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation events.

6. MISCELLANEOUS

The borehole locations reflect existing site features and access constraints. The as-drilled borehole locations and ground surface elevations were measured by Thurber following completion of the field program. RPM Drilling of Thunder Bay, Ontario, supplied and operated the drill rig used to drill, test, sample, and decommission the boreholes. Traffic control was performed in accordance with Ontario Book 7 and was provided by RPM Drilling of Thunder Bay, Ontario. The field investigation was supervised on a full-time basis by Mr. L. Scalena, EIT. Overall supervision of the field investigation program was provided by Mr. M. Eastman, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Oakville.

Interpretation of the factual data and preparation of this report was completed by M. Eastman, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

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PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7. GENERAL

This section of the report provides an interpretation of the factual data from Part 1 of this report and presents foundation design recommendations to assist the project team in the design of the new temporary detour embankment for the replacement of a box culvert that crosses Highway 11 at Sta. 12+650 in Ledger Township approximately 17.8 km north of Nipigon, Ontario. Thurber Engineering Ltd. (Thurber) carried out the foundation investigation for MTO under Retainer Agreement No. 6022-E-0038, Assignment No. 1. The discussion and recommendations presented in this report are based on information provided by MTO and the factual data obtained during the current field investigation.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ontario Ministry of Transportation (MTO) and their designer, Hatch, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. Contractors must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, and scheduling and the like.

It is a condition of this report that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

7.1 Background Information

The culvert site crosses Highway 11 approximately 17.8 km north of the junction between Highway 11 and Highway 17 near Nipigon, Ontario. The road surface near the culvert is at approximate elevation 228 m, and the invert of the culvert is near elevations 223.402 and

223.271 m at the inlet and outlet, respectively. The cover above the existing culvert is approximately 4.5 m at the highway centerline. The ditch drainage flows through the culvert under the highway embankment from east to west. The existing box culvert is reported in drawings provided by MTO to be 1.83 m wide, 1.22 m high and 31.369 m long.

In general, the encountered stratigraphy consists of topsoil or gravelly sand fill underlain by a layer of clayey silt overlying silt. A layer of silty clay was encountered within the silt deposit in the off-road borehole (23-01). Groundwater was recorded at elev. 220.2 m in the open on-road borehole upon completion of drilling (23-02).

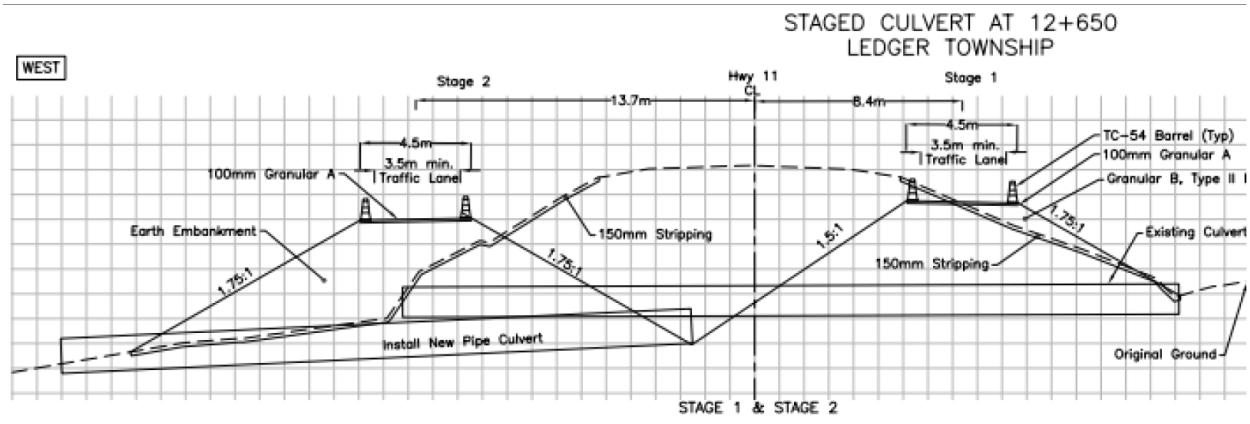
7.2 Proposed Work

The proposed works for this non-structural culvert are indicated in the drawings provided by MTO with the preferred approach to replace the existing culvert with a 1,400 mm diameter pipe culvert with half and half staging along the existing alignment.

8. TEMPORARY DETOUR EMBANKMENT

8.1 Construction Staging

The following culvert construction staging sequence has been provided by MTO in an email dated October 27, 2023.



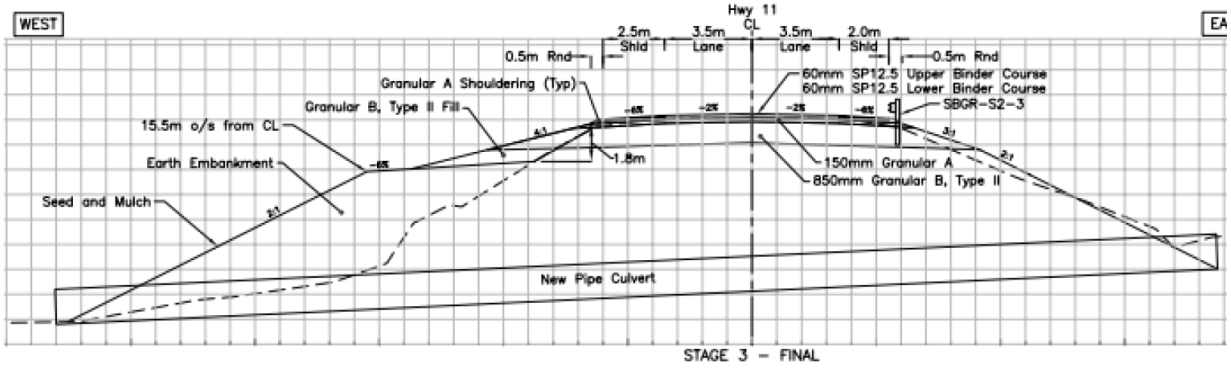


Figure 1: Culvert construction staging sequence (courtesy of MTO).

- Stage 1: Construct temporary embankment widening to the east of the existing highway alignment to facilitate one lane of traffic flow around excavation for the construction of the new culvert west of centreline. The centreline of the widened embankment will be approximately 8.4 m east of the centreline of the existing highway embankment. The temporary embankment will have a 1.75H:1V side slope to the east (outside) and a 1.5H:1V side slope of a cut into the existing highway embankment to the west (inside). The temporary embankment will be widened to the east using OPSS Granular B Type II and the maximum height of new fill is on the order of 1 m. Grade lowering of approximately 1.4 m is indicated.
- Stage 2: Construct temporary embankment to the west of the existing highway alignment to facilitate one lane of traffic flow around excavation for the construction of the new culvert east of centreline. The centreline of the temporary embankment will be approximately 13.7 m west of the centreline of the existing highway embankment. The temporary embankment will have 1.75H:1V side slopes to the west (outside) and east (inside). The temporary embankment will be constructed using earth fill expected to be derived from local excavation of road base granular material (see Section 8.2). The height of the temporary embankment is approximately 6 m. Grade lowering of approximately 2 m is indicated.
- Stage 3 (Final): Reinstate the embankment along the existing highway alignment to match the existing grades and return both crests of slope to that of the original cross-section. The east and west embankment slopes will be reconstructed to 2H:1V or flatter.

8.2 Potential Borrow Material

MTO has indicated that the borrow material for construction of the temporary west detour embankment is anticipated to come from the following sources:

- Distortion areas – excavating approximately 300 mm of primarily Granular A.
- Frost heave at 17+694 UT – pavement structure granulars over mixture of clay, silt and organics. Recommend only using top 1.5 m of excavated material.
- Frost heave at 21+000-015 UT – pavement structure granulars over mixture of clay, sand, silt and organics. Recommend only using top ~1 m of excavated material.

MTO and the Contract Administrator (CA) team will need to ensure that only granular materials free of organics from these excavations are used to build the temporary detour embankment. If the excavated granular materials are too wet of optimum moisture content, they will need to be dried for proper compaction. The granular materials should be placed in lifts and compacted in accordance with OPSS.PROV 501.

8.3 Temporary Embankment Construction

The temporary embankment widening should be carried out in accordance with OPSS.PROV 206. The fill should be placed and compacted in accordance with OPSS.PROV 501. Where fill is placed against existing embankment slopes or on a sloping ground surface steeper than 3H:1V, benching of the existing slope should be carried out in accordance with OPSD 208.010.

All organics, existing fill, timbers, soft or loose deposits, disturbed soils, alluvial deposits and deleterious materials must be stripped from the footprint of the detour embankment.

8.4 Temporary Embankment Stability

Stability analyses were carried out for the temporary detour embankments utilizing the commercially available computer program SLOPE/W of the GeoStudio software package with the option of Morgenstern-Price method of slices for limit equilibrium.

Based on the drawings provided by MTO, the existing culvert and proposed new culvert are understood to be at Sta. 12+650.

The material properties used in the stability analyses are summarized in the table below and were determined by in-situ testing and soil index correlations.

Table 8-1 Summary of Material Properties Used in Slope Stability Analyses

Material	Unit Weight (kN/m^3)	Effective Cohesion (kPa)	Effective Friction Angle (°)
Rock Fill	19	0	42
OPSS Granular B Type II	22	0	35
Earth Fill	21	0	30
Existing Fill	21	0	32
Clayey Silt	19.5	0	29
Silty Clay	19	2	29

The groundwater table assumed in the stability analyses at this site was based on the groundwater level of elevation 220 m recorded in Borehole 23-02 upon completion of drilling.

The stability analysis plots for the conditions analyzed are presented in Appendix E. The results of the stability analyses are summarized in the table below.

Table 8-2 Summary of Slope Stability Analyses

Location	Cut or Fill	Height of New Fill	Embank. Fill	Side	Slope Inclin.	Condition	Factor of Safety	Fig.
Existing Highway Embankment						Long Term (Drained)	1.18	E1
Stage 1 East Detour	Fill on East Side	~ 1.0 m	Gran. B Type II	East	1.75H:1V	Long Term (Drained)	1.39	E2
					1.5H:1V w/ grade lowering by 230 mm	Long Term (Drained)	1.31	E3
			Rock Fill		1.5H:1V	Long Term (Drained)	1.42	E4
	Cut on West Side	-	-	West	1.5H:1V	Long Term (Drained)	1.01	E5
					1.75H:1V w/ grade lowering by 230 mm	Long Term (Drained)	1.15	E6
					1.75H:1V	Long Term (Drained)	1.13	E7
Stage 2 West Detour	Fill	~ 6.0 m	Earth Fill	East	1.75H:1V	Long Term (Drained)	1.21	E8
					1.75H:1V w/ geogrid	Long Term (Drained)	1.42	E9
				West	1.75H:1V	Long Term (Drained)	1.17	E10
					1.75H:1V w/ geogrid	Long Term (Drained)	1.33	E11
				West	2H:1V	Long Term (Drained)	1.29	E12
			Rock Fill	West	1.25H:1V	Long Term (Drained)	1.22	E13
					1.5H:1V	Long Term (Drained)	1.42	E14
					1.75H:1V	Long Term (Drained)	1.53	E15

Stage 1: East Detour

The temporary embankment to the east of the existing highway alignment (Stage 1) with a proposed side slope of 1.75H:1V to the east (outside) results in factor of safety of greater than 1.3 (Figure E2), however, the proposed side slope of 1.5H:1V to the west (inside) results in a marginal factor of safety of 1.0 (Figure E5). It is recommended that the west (inside) slope be flattened to 1.75H:1V while the east (outside) slope be steepened to 1.5H:1V by either lowering the grade by 230 mm or by maintaining the proposed grade and shifting the crest of the

embankment outwards laterally to accommodate the proposed top of embankment width of approximately 4.5 m (Figures E3, E4, E6 and E7).

Stage 2: West Detour

A minimum factor of safety of 1.3 is not achieved for the temporary embankment to the west of the existing highway alignment (Stage 2) with proposed side slopes of 1.75H:1V constructed using earth fill (Figures E8 and E10). It is recommended to place geogrid reinforcement with a minimum unfactored pullout resistance of 30 kN/m halfway up the detour embankment (approx. elev. 223 m) in order to achieve a minimum factor of safety of 1.3 (Figures E9 and E11).

8.5 Temporary Embankment Settlement

An analysis was carried out to estimate the settlement of the foundation soils under the weight of the proposed temporary detour embankment fill of up to 6 m in height. The results of the analysis indicate that approximately 50 mm of settlement is expected to occur.

9. CONSTRUCTION CONCERNS

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

- The side slopes of the detour embankments must be continuously observed during construction and remedial action be taken immediately if the side slopes begin to slough or show any signs of instability.
- Construction of the detour embankments must be carried out during dry periods.
- Moisture changes of the detour embankment fill materials must be prevented.
- Consideration should be given to protecting all temporary excavation and fill slopes with plastic sheeting to minimize erosion and gullying due to precipitation or uncontrolled surface flow running down the slopes.
- Only granular material from the potential borrow sites may be used to construct the temporary detour embankment.

10. CLOSURE

Engineering analysis and preparation of this report were carried out by Mr. M. Eastman, P.Eng. and Mr. K. Shi, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

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THURBER

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

THURBER ENGINEERING LTD.

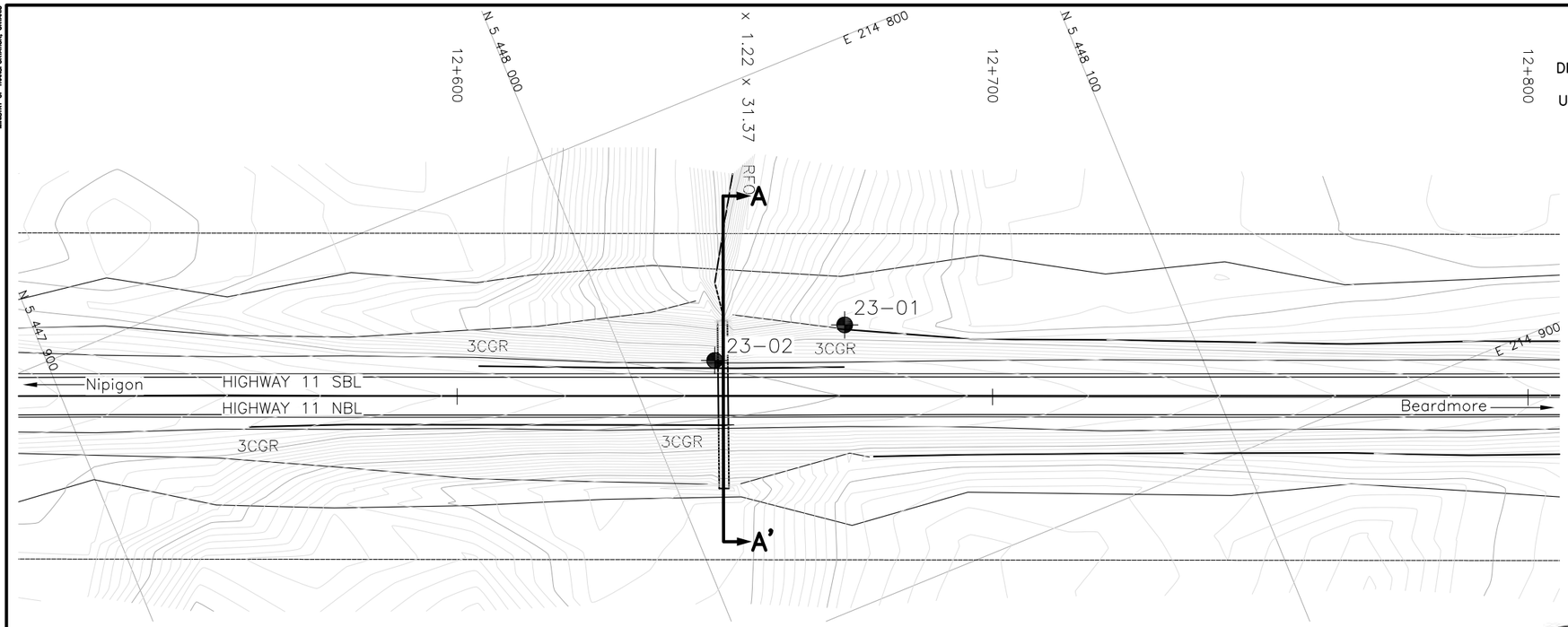
APPENDIX A

Borehole Locations and Strata Drawing

MINISTRY OF TRANSPORTATION, ONTARIO

METRIC

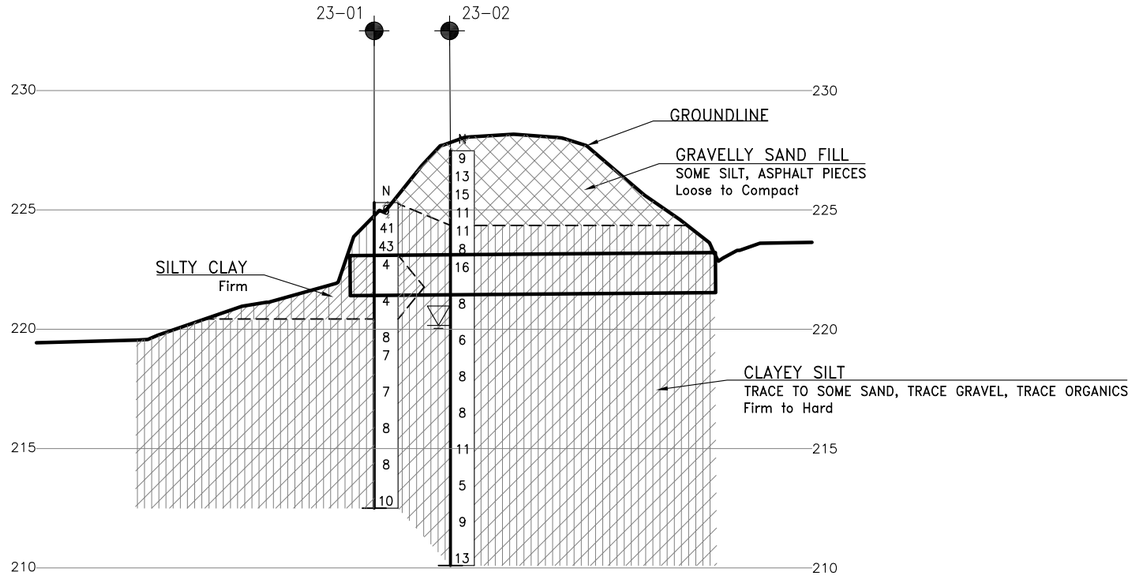
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN



PLAN

20 0 20 40m

SCALE 1:1000



SECTION A–A' ALONG ℄ CULVERT

10 0 10 20m H 1:500

5 0 5 10m V 1:250

LICENSED PROFESSIONAL ENGINEER
M. K. EASTMAN
100209847
2023-12-05
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
2023-12-05
PROVINCE OF ONTARIO

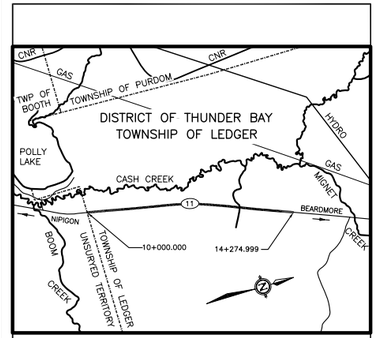
CONT No
WP No

HIGHWAY 11
DEEP FILL CULVERT

BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

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 Upon Completion of Drilling
▼	Water Level in Monitoring Well/Piezometer
	Monitoring Well/Piezometer Screen
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
23–01	225.3	5 448 040.5	214 850.0
23–02	227.5	5 448 015.6	214 846.9

-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.
3) Coordinate system is MTM NAD 83 Zone 14.

GEOCRES No. 52H01-001

REVISIONS		
DATE	BY	DESCRIPTION

DESIGN	MKE	CHK PKC	CODE	LOAD	DATE DEC 2023
DRAWN	JW	CHK	SITE	STRUCT	DWG 1

FILENAME: H:\Drafting\40000\40101\TED-40101-PLPR.dwg
PLOTDATE: 12/4/2023 2:57 PM

THURBER ENGINEERING LTD.

APPENDIX B

Record of Boreholes Sheets

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 23-01 1 OF 2 METRIC

W.P. 6022-E-0038 LOCATION N 5 448 040.5 E 214 850.0 ORIGINATED BY LS

DIST Thunder Bay HWY 11 BOREHOLE TYPE CME 750 Buggy, HSA (150 mm O.D.) COMPILED BY MC

DATUM Geodetic DATE 2023.09.18 - 2023.09.18 LATITUDE 49.163878 LONGITUDE -88.233487 CHECKED BY MKE

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/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
225.3	GROUND SURFACE										
0.0	TOPSOIL: (50 mm)										
0.0	Clayey **SILT**, trace sand, trace gravel Firm to Hard Brown-Grey Moist		1	SS	6		225				
			2	SS	41		224				0 2 85 13
			3	SS	43						
223.1											
2.2	Silty **CLAY** Firm Grey Moist		4	SS	4		223				
			5	SS	4		222				0 0 61 39
220.4							221	2.4 +			
4.9	Clayey **SILT**, trace sand Firm to Stiff Grey Wet		6	SS	8		220				
			7	SS	7		219				
			8	SS	7		218				
			9	SS	8		217				
							216				0 1 87 12

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15}\oplus\frac{5}{10}$ (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 23-01 2 OF 2 METRIC

W.P. 6022-E-0038 LOCATION N 5 448 040.5 E 214 850.0 ORIGINATED BY LS

DIST Thunder Bay HWY 11 BOREHOLE TYPE CME 750 Buggy, HSA (150 mm O.D.) COMPILED BY MC

DATUM Geodetic DATE 2023.09.18 - 2023.09.18 LATITUDE 49.163878 LONGITUDE -88.233487 CHECKED BY MKE

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × 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	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Clayey **SILT**, trace sand Firm to Stiff Grey Wet						215				
			10	SS	8				○		
							214				
212.5			11	SS	10		213		○		0 0 94 6
12.8	END OF BOREHOLE AT 12.8 m. BOREHOLE OPEN TO 12.2 m AND DRY UPON COMPLETION.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

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

ONTMT4S2 2020LIBRARY(MTO) - COPY.GLB MTO-40101.GPJ 11/7/23

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 23-02 1 OF 2 METRIC

W.P. 6022-E-0038 LOCATION N 5 448 015.6 E 214 847.0 ORIGINATED BY LS

DIST Thunder Bay HWY 11 BOREHOLE TYPE CME 750 Buggy, HSA (150 mm O.D.) COMPILED BY MC

DATUM Geodetic DATE 2023.09.19 - 2023.09.19 LATITUDE 49.163653 LONGITUDE -88.233523 CHECKED BY MKE

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "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/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
227.5	GROUND SURFACE										
0.0	Gravelly **SAND**, some silt, asphalt pieces Loose to Compact Brown Moist (FILL)		1	SS	9		227				
			2	SS	13						
			3	SS	15		226				37 50 13 (SI+CL)
			4	SS	11		225				
224.4											
3.1	Clayey **SILT**, trace to some sand, trace organics Firm to Very Stiff Grey Moist		5	SS	11		224				
			6	SS	8		223				
			7	SS	16						0 11 75 14
							222				
			8	SS	8		221				
	Becoming wet		9	SS	6	▽	220				
							219				
			10	SS	8		218				0 1 89 10

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 23-02 2 OF 2 METRIC

W.P. 6022-E-0038 LOCATION N 5 448 015.6 E 214 847.0 ORIGINATED BY LS

DIST Thunder Bay HWY 11 BOREHOLE TYPE CME 750 Buggy, HSA (150 mm O.D.) COMPILED BY MC

DATUM Geodetic DATE 2023.09.19 - 2023.09.19 LATITUDE 49.163653 LONGITUDE -88.233523 CHECKED BY MKE

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100): ○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Clayey **SILT**, trace to some sand Firm to Very Stiff Grey Wet						217				
			11	SS	8				○		
							216				
			12	SS	11		215		○		0 3 84 13
							214				
			13	SS	5				○		
							213	+ 1.4			
			14	SS	9		212		○		0 0 78 22
							211				
210.1			15	SS	13				○		
17.4	END OF BOREHOLE AT 17.4 m. BOREHOLE OPEN TO 11.6 m AND WATER LEVEL AT 7.3 m UPON COMPLETION.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

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

ONTMT4S2 2020LIBRARY(MTO) - COPY.GLB MTO-40101.GPJ 11/7/23

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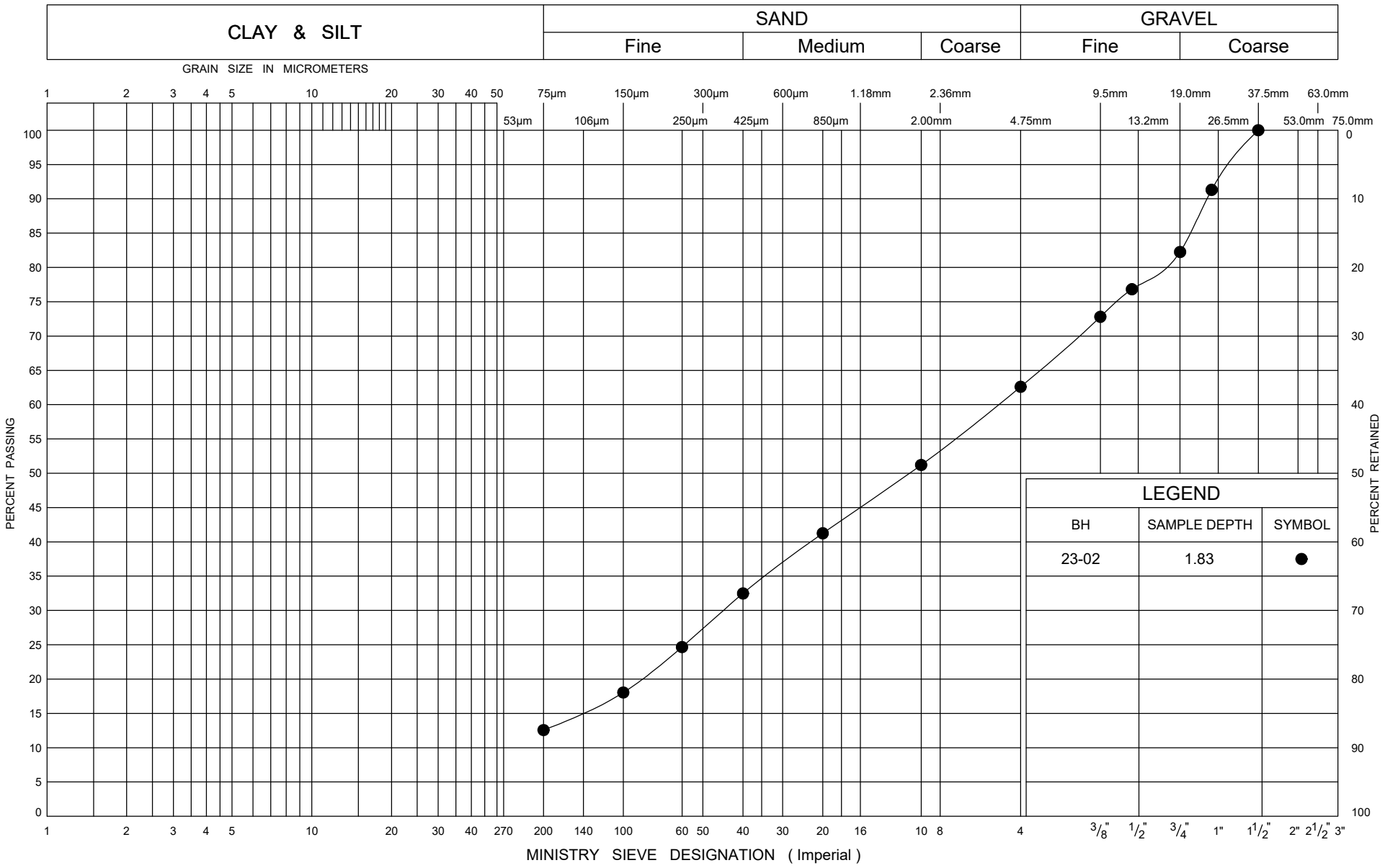
APPENDIX C

Laboratory Test Results



Ministry of Transportation
Ontario

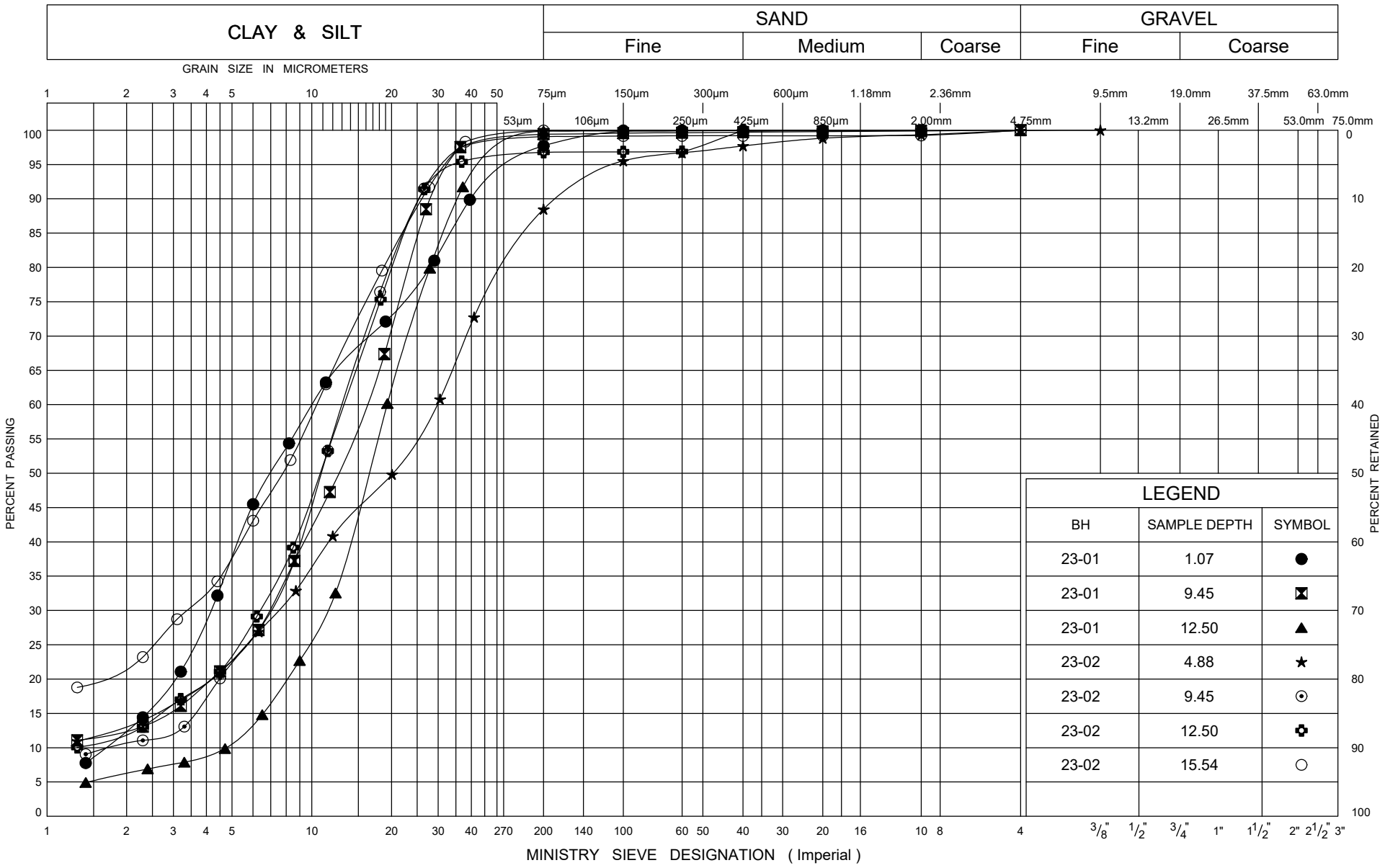
GRAIN SIZE DISTRIBUTION

Gravelly SAND FILL

FIG No C1

W.P. 6022-E-0038

ONTARIO MOT GRAIN SIZE 3 MTO-40101.GPJ ONTARIO MOT.GDT 11/7/23



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GRAIN SIZE DISTRIBUTION

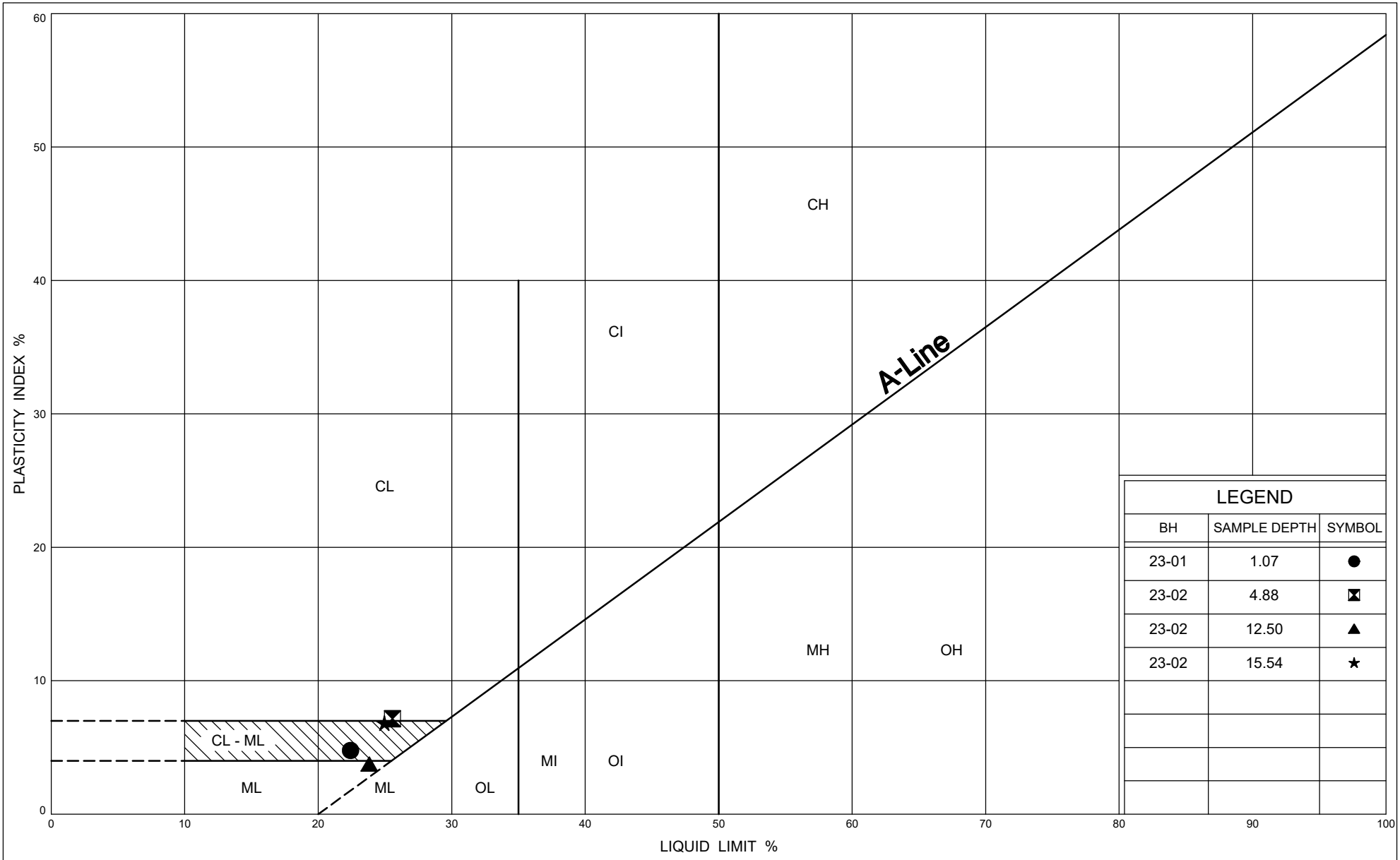
Clayey SILT

FIG No C2

W.P. 6022-E-0038

ONTARIO MOT GRAIN SIZE 3 MTO-40101.GPJ ONTARIO MOT.GDT 11/7/23

Oct 75, FF - S - 21



ONTARIO MOT PLASTICITY CHART 2 MTO-40101.GPJ ONTARIO MOT.GDT 11/7/23

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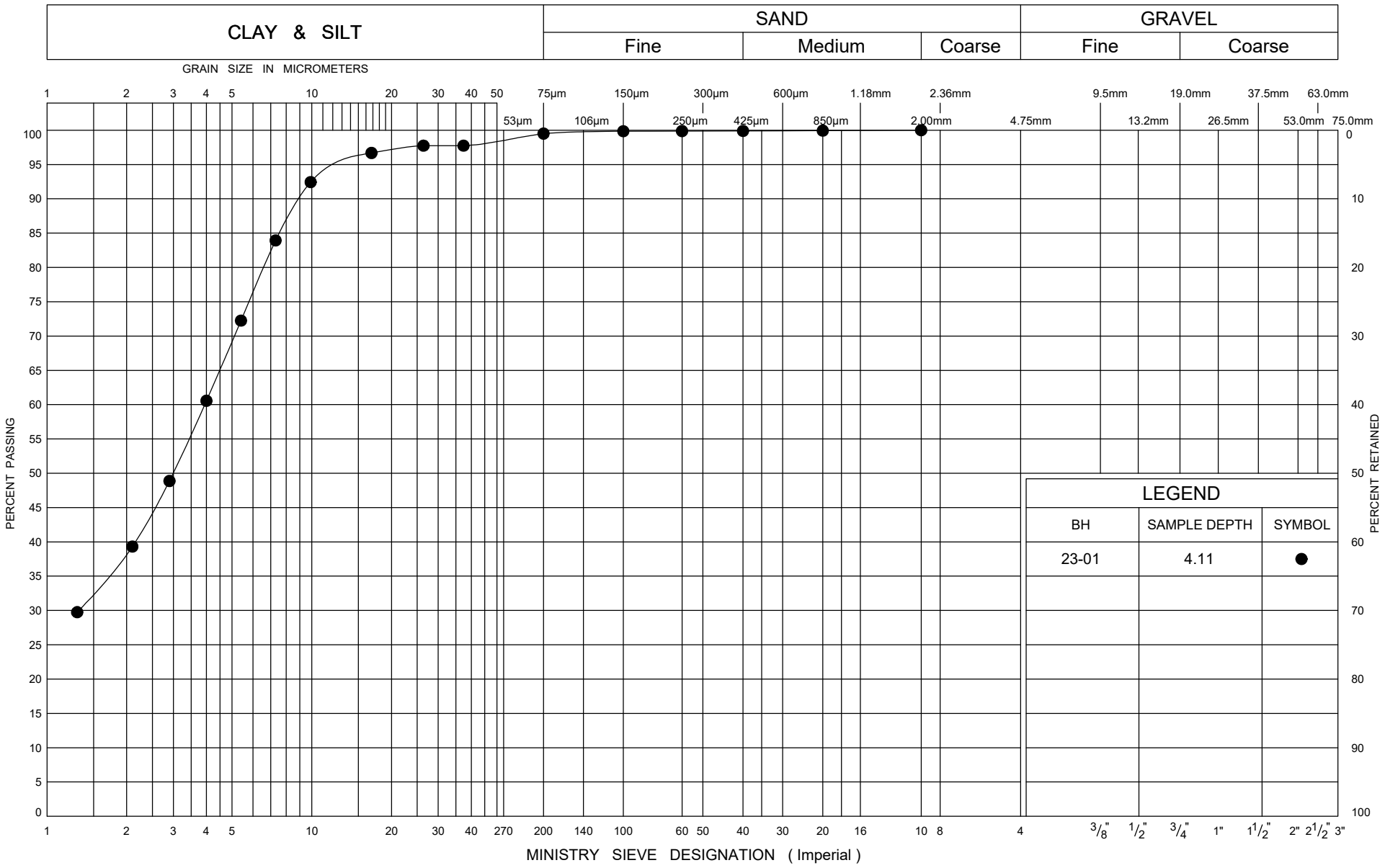
Ontario

PLASTICITY CHART

Clayey SILT

FIG No C3

W.P. 6022-E-0038



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

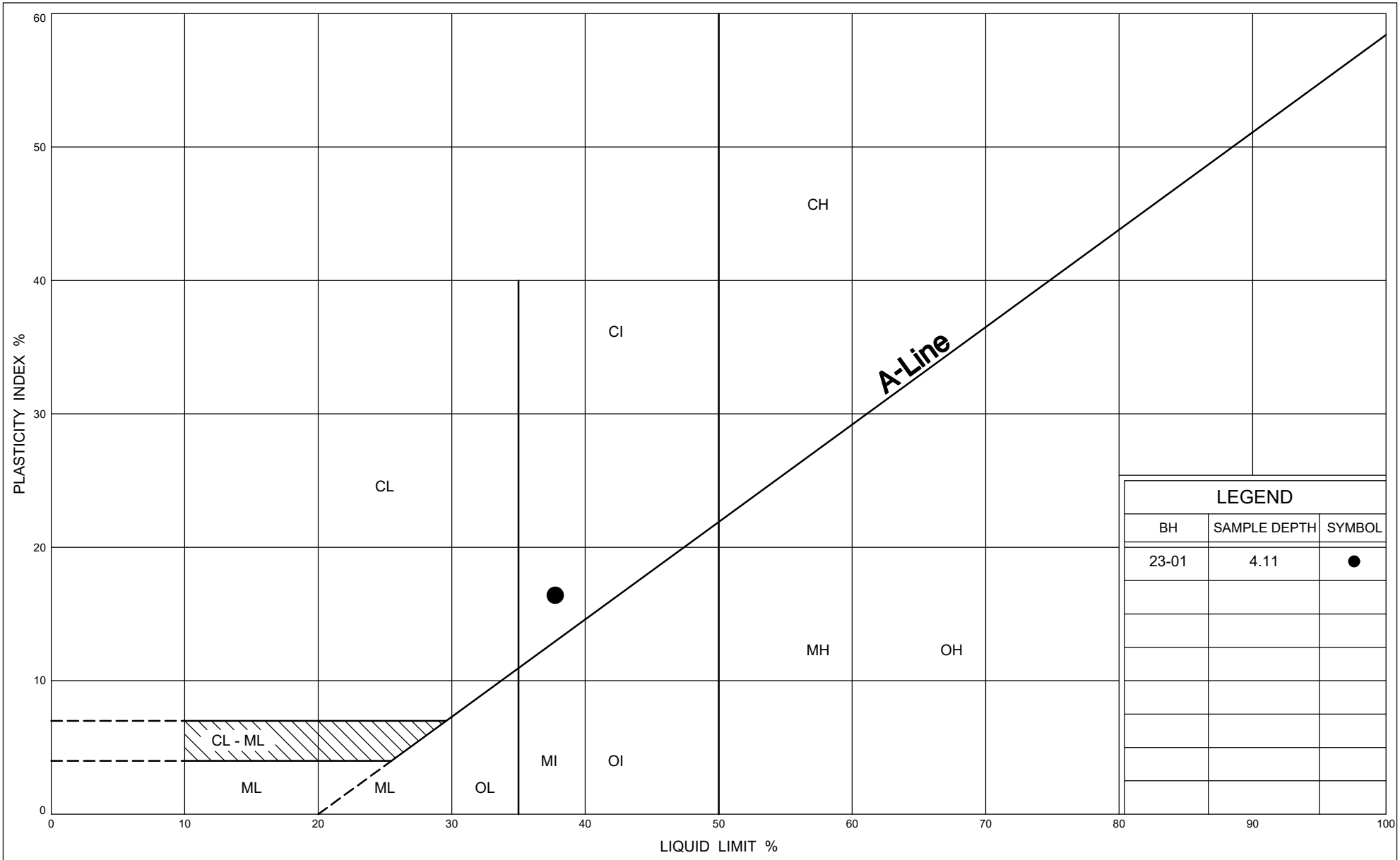
Silty CLAY

FIG No C4

W.P. 6022-E-0038

ONTARIO MOT GRAIN SIZE 3 MTO-40101.GPJ ONTARIO MOT.GDT 11/7/23

Oct 75, FF - S - 21



ONTARIO MOT PLASTICITY CHART 2 MTO-40101.GPJ ONTARIO MOT.GDT 11/7/23

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PLASTICITY CHART

Silty CLAY

FIG No C5

W.P. 6022-E-0038

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APPENDIX D

Site Photographs

Photo 1: Culvert outlet *(taken on September 18, 2023)*

Photo 2: Highway 11 south of the culvert alignment *(taken on September 19, 2023)*

Photo 3: Highway 11 north of the culvert alignment *(taken on September 19, 2023)*

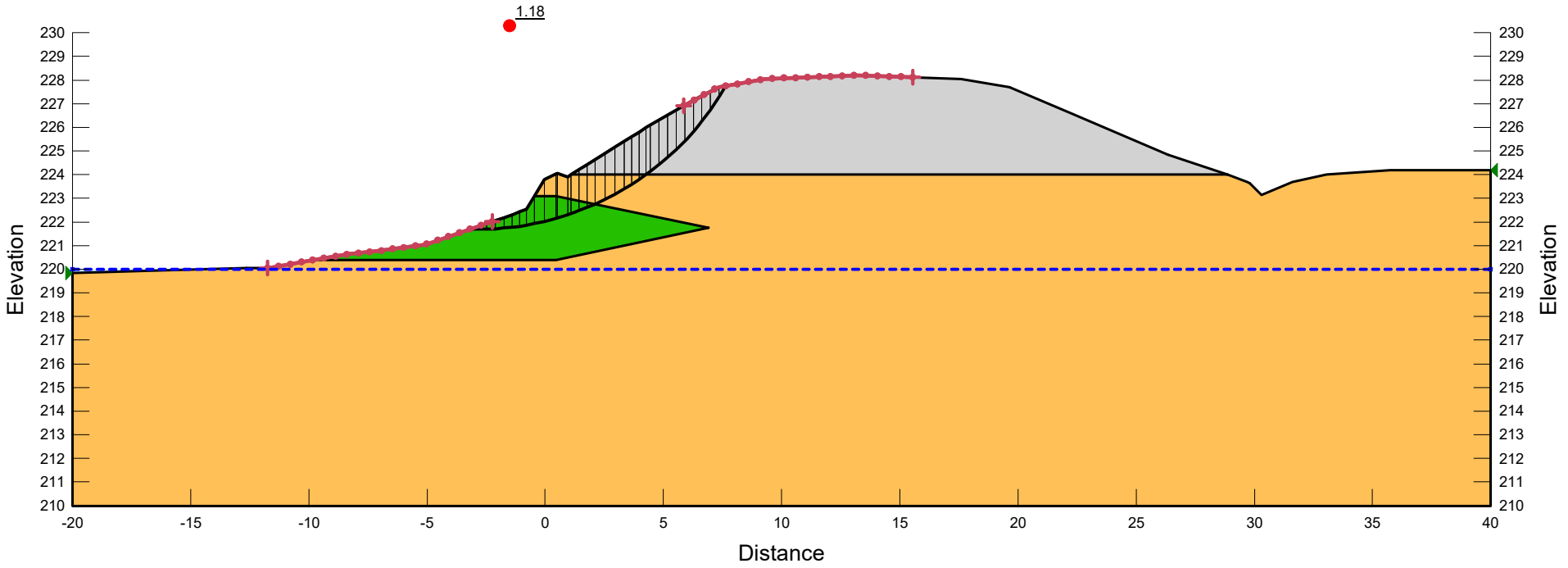
Photo 4: Traffic control set-up *(taken on September 19, 2023)*

THURBER ENGINEERING LTD.

APPENDIX E

Slope Stability Analyses

Color	Name	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Clayey Silt	19.5	0	29
	Existing Fill	21	0	32
	Silty Clay (ESA)	19	2	29



THURBER

Project
Hwy 11 Non-Structural Culvert

Analysis
Existing West Slope (Drained)

Seismic Coefficient
H: 0g, V: 0g

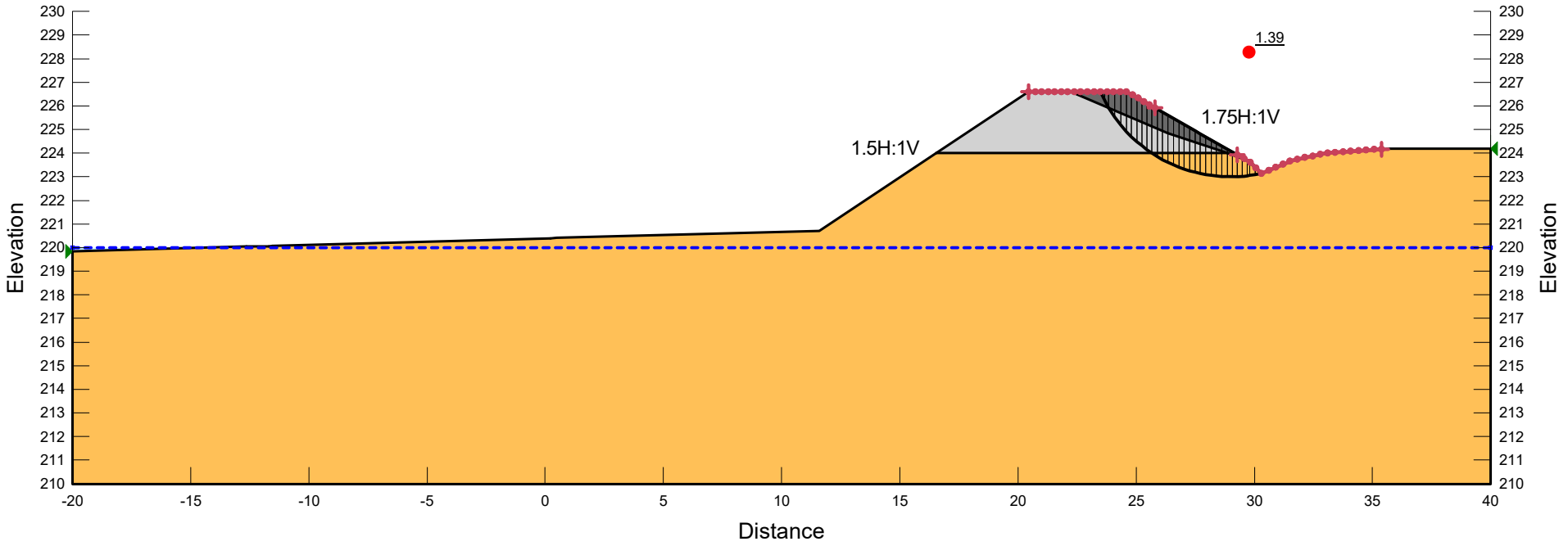
Last Run
2023-11-10, 12:40:09 PM

Scale
1:262

Additional Details
Name: Existing West Slope
Comments: Sta. 12+650
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 2 m
Entry: (-3.1712249, 221.69342) m, Exit: (7.640094, 227.75207) m
Center: (-2.8486719, 233.79326) m, Radius: 12.104138 m

Figure E1

Color	Name	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Clayey Silt	19.5	0	29
	Existing Fill	21	0	32
	OPSS Granular B Type II	22	0	35



THURBER

Project
Hwy 11 Non-Structural Culvert

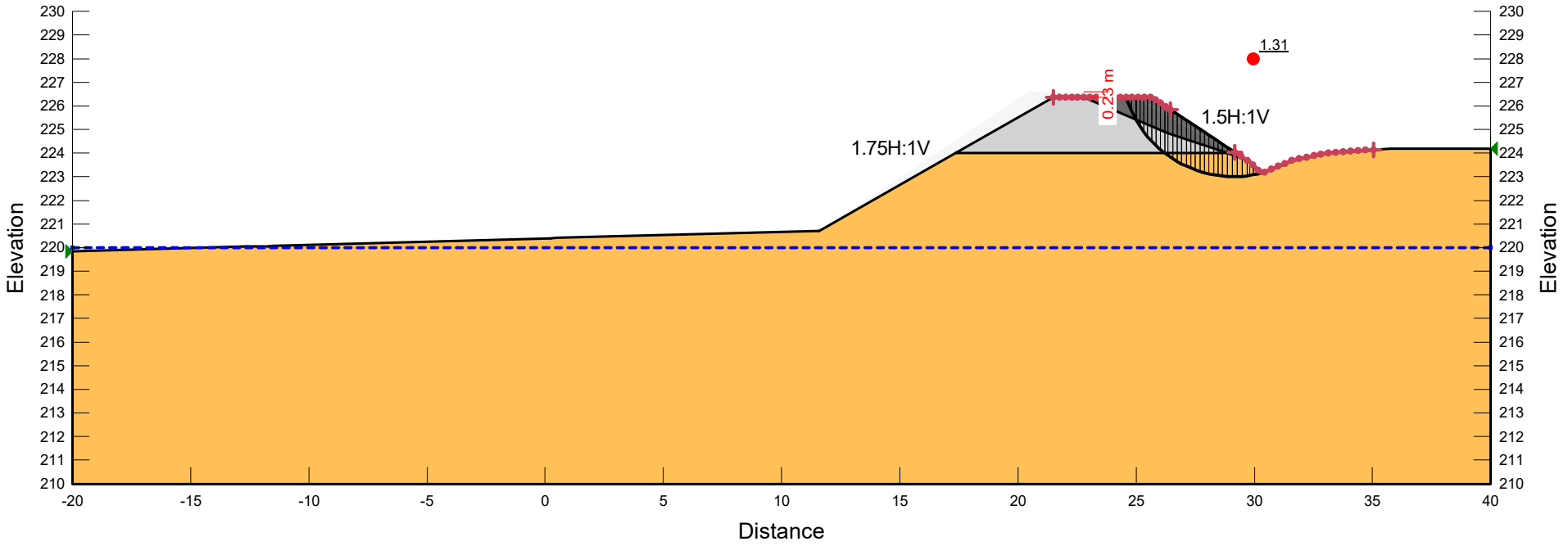
Analysis
Stage 1 East Slope 1.75H:1V with Granular B Type II (Drained)

Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2023-11-10, 12:40:11 PM	1:262

Additional Details
Name: Stage 1 East Slope 1.75H:1V with Granular B Type II
Comments: Sta. 12+650
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 2 m
Entry: (23.492695, 226.6) m, Exit: (30.299833, 223.15017) m
Center: (28.96344, 228.95399) m, Radius: 5.9556973 m

Figure E2

Color	Name	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Clayey Silt	19.5	0	29
	Existing Fill	21	0	32
	OPSS Granular B Type II	22	0	35



THURBER

Project
Hwy 11 Non-Structural Culvert

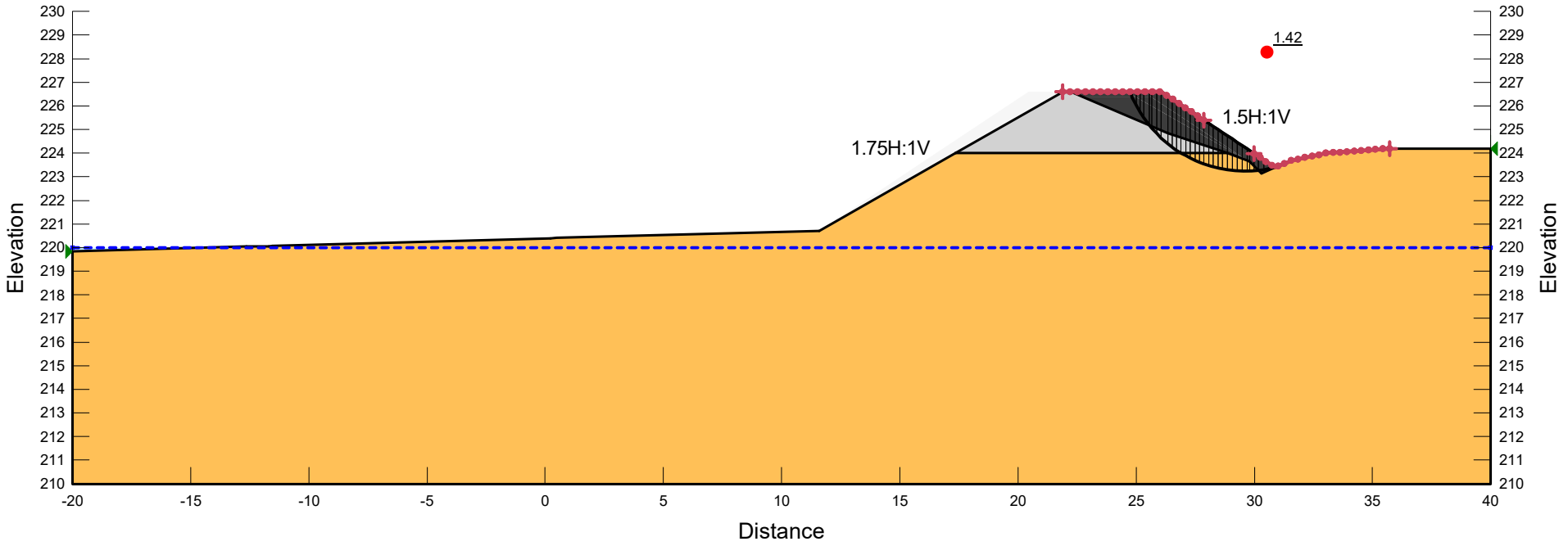
Analysis
Stage 1 East Slope 1.5H:1V with Granular B Type II and Grade Lowering (Drained)

Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2023-11-10, 12:40:37 PM	1:262

Additional Details
Name: Stage 1 East Slope 1.5H:1V with Granular B Type II and Grade Lowering
Comments: Sta. 12+650
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 2 m
Entry: (24.576168, 226.37) m, Exit: (30.296935, 223.15307) m
Center: (29.122418, 227.75956) m, Radius: 4.7538668 m

Figure E3

Color	Name	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Clayey Silt	19.5	0	29
	Existing Fill	21	0	32
	Rock Fill	19	0	42



THURBER

Project
Hwy 11 Non-Structural Culvert

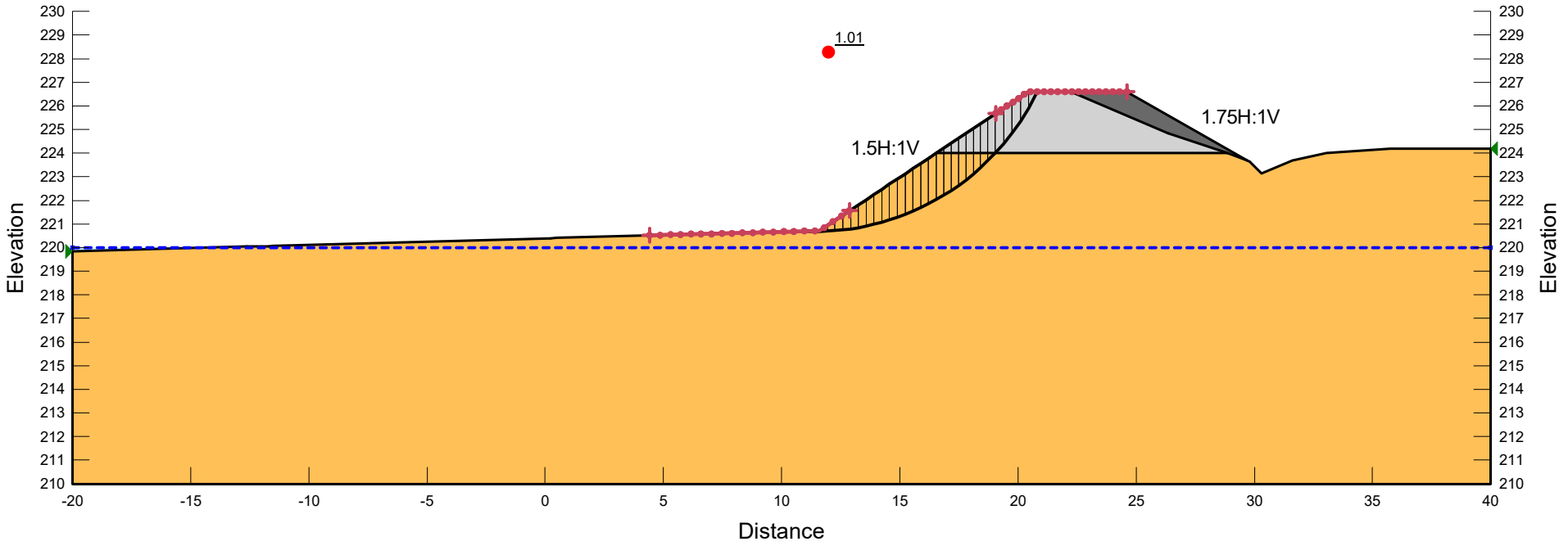
Analysis
Stage 1 East Slope 1.5H:1V with Rock Fill (Drained)

Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2023-11-10, 12:48:52 PM	1:262

Additional Details
Name: Stage 1 East Slope 1.5H:1V with Rock Fill
Comments: Sta. 12+650
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 2 m
Entry: (24.744481, 226.6) m, Exit: (30.865393, 223.3963) m
Center: (29.603578, 228.43459) m, Radius: 5.1938938 m

Figure E4

Color	Name	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Clayey Silt	19.5	0	29
	Existing Fill	21	0	32
	OPSS Granular B Type II	22	0	35



THURBER

Project
Hwy 11 Non-Structural Culvert

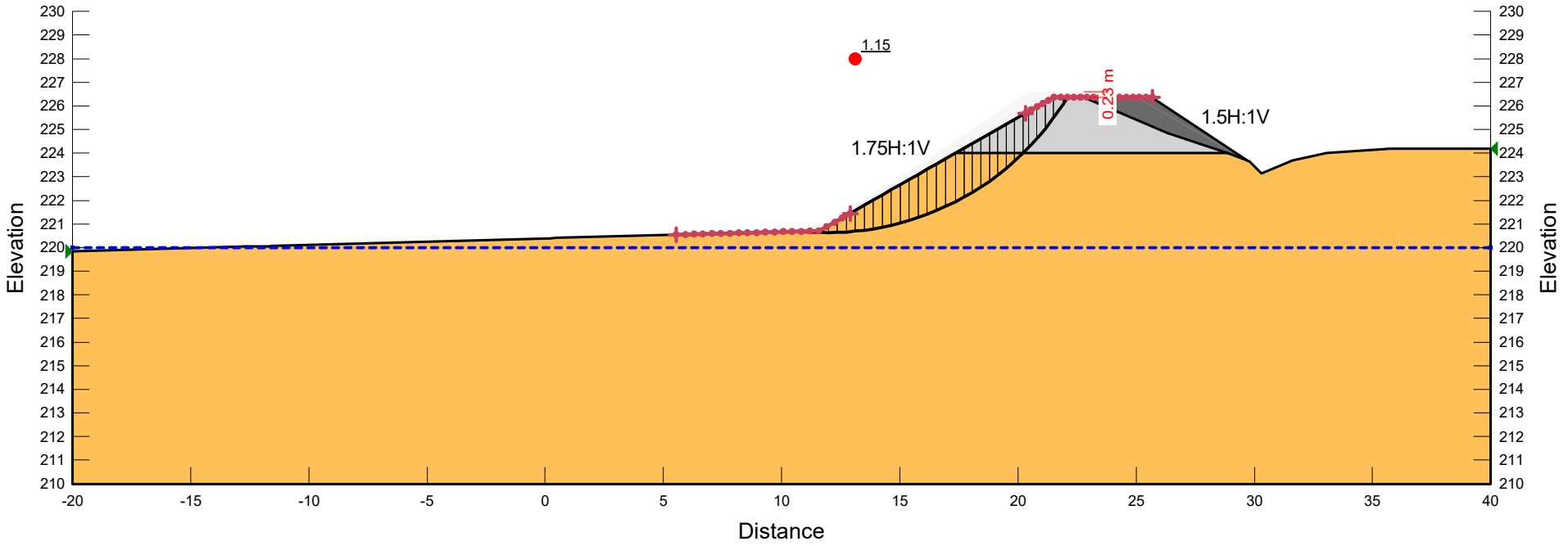
Analysis
Stage 1 West Slope 1.5H:1V (Drained)

Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2023-11-10, 12:48:24 PM	1:262

Additional Details
Name: Stage 1 West Slope 1.5H:1V
Comments: Sta. 12+650
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 2 m
Entry: (10.966995, 220.69271) m, Exit: (20.81896, 226.6) m
Center: (11.416546, 231.11199) m, Radius: 10.42897 m

Figure E5

Color	Name	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Clayey Silt	19.5	0	29
	Existing Fill	21	0	32
	OPSS Granular B Type II	22	0	35



THURBER

Project
Hwy 11 Non-Structural Culvert

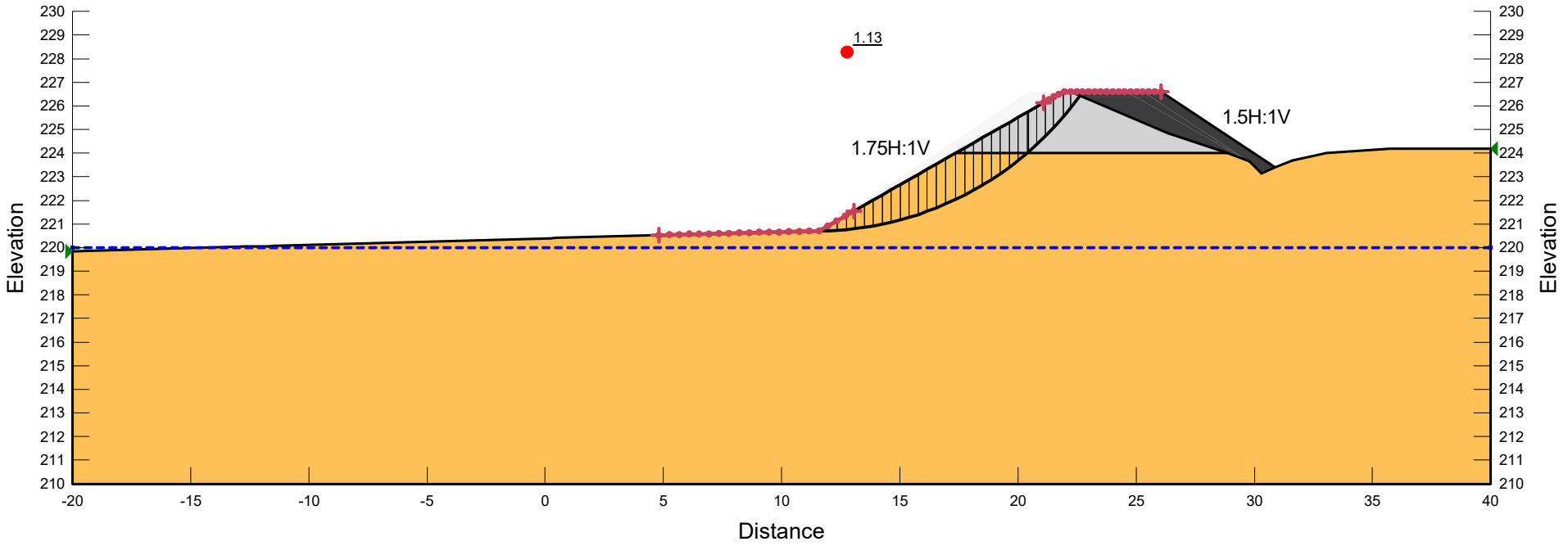
Analysis
Stage 1 West Slope 1.75H:1V with Grade Lowering (Drained)

Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2023-11-10, 12:48:46 PM	1:262

Additional Details
Name: Stage 1 West Slope 1.75H:1V with Grade Lowering
Comments: Sta. 12+650
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 2 m
Entry: (10.82543, 220.68884) m, Exit: (22.088379, 226.37) m
Center: (11.959007, 232.44655) m, Radius: 11.812225 m

Figure E6

Color	Name	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Clayey Silt	19.5	0	29
	Existing Fill	21	0	32
	Rock Fill	19	0	42



THURBER

Project
Hwy 11 Non-Structural Culvert

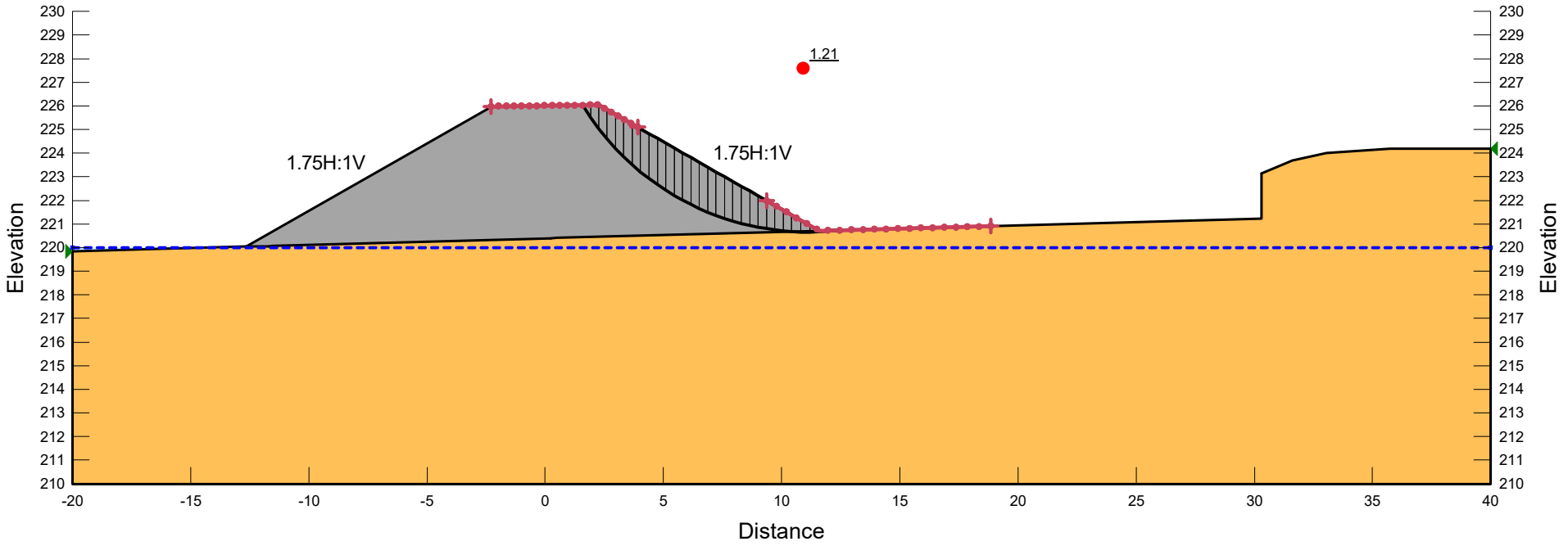
Analysis
Stage 1 West Slope 1.75H:1V (Drained)

Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2023-11-10, 12:48:51 PM	1:262

Additional Details
Name: Stage 1 West Slope 1.75H:1V
Comments: Sta. 12+650
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 2 m
Entry: (11.165496, 220.69813) m, Exit: (22.736296, 226.6) m
Center: (11.446055, 234.44148) m, Radius: 13.746214 m

Figure E7

Color	Name	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Clayey Silt	19.5	0	29
	Earth Fill	21	0	30



THURBER

Project
Hwy 11 Non-Structural Culvert

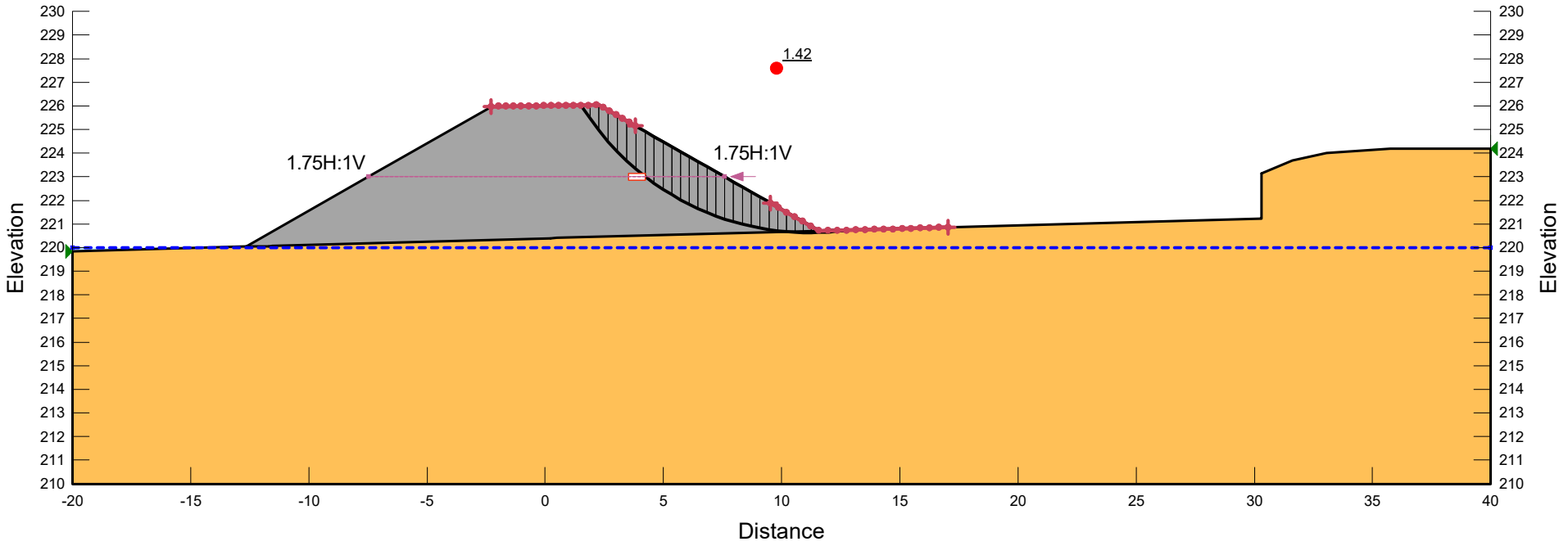
Analysis
Stage 2 East Slope 1.75H:1V with Earth Fill (Drained)

Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2023-11-10, 12:48:40 PM	1:262

Additional Details
Name: Stage 2 East Slope 1.75H:1V with Earth Fill
Comments: Sta. 12+650
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 2 m
Entry: (1.5788372, 226.03098) m, Exit: (12.458077, 220.7334) m
Center: (11.135542, 231.83714) m, Radius: 11.182226 m

Figure E8

Color	Name	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Clayey Silt	19.5	0	29
	Earth Fill	21	0	30



THURBER

Project
Hwy 11 Non-Structural Culvert

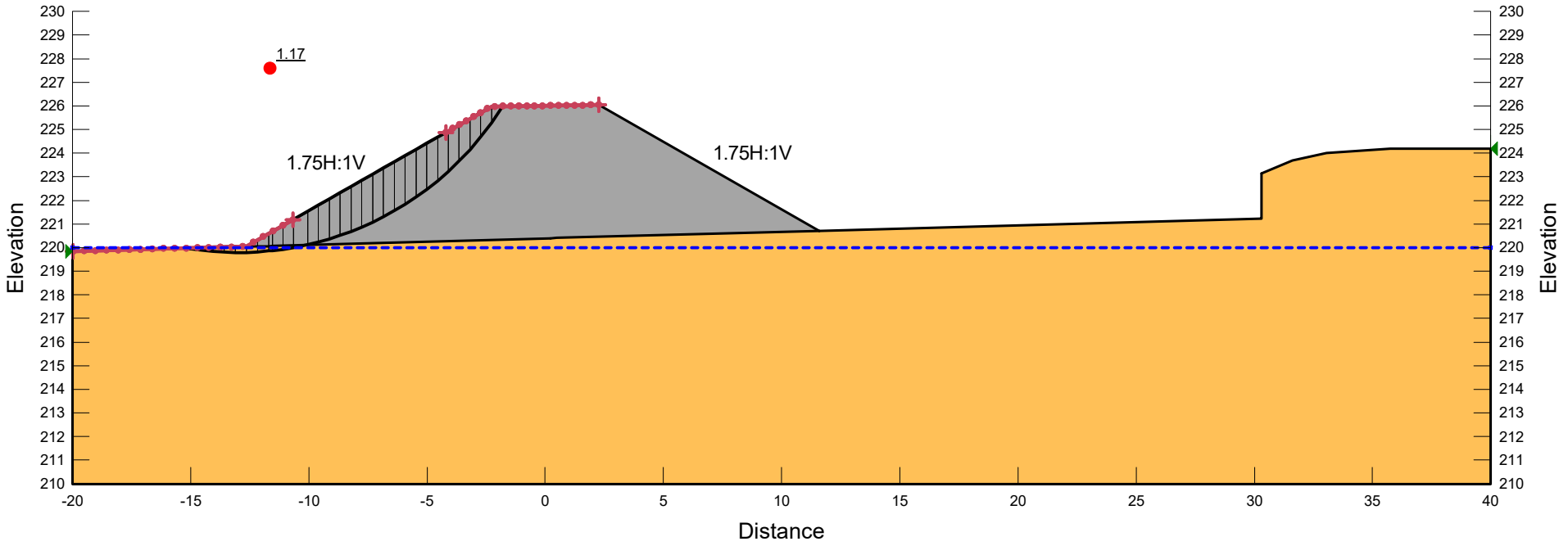
Analysis
Stage 2 East Slope 1.75H:1V with Earth Fill and Geogrid (Drained)

Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2023-11-10, 12:48:43 PM	1:262

Additional Details
Name: Stage 2 East Slope 1.75H:1V with Earth Fill and Geogrid
Comments: Sta. 12+650
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 2 m
Entry: (1.5169837, 226.03016) m, Exit: (12.744263, 220.74121) m
Center: (11.1715, 231.96357) m, Radius: 11.332039 m

Figure E9

Color	Name	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Clayey Silt	19.5	0	29
	Earth Fill	21	0	30



THURBER

Project
Hwy 11 Non-Structural Culvert

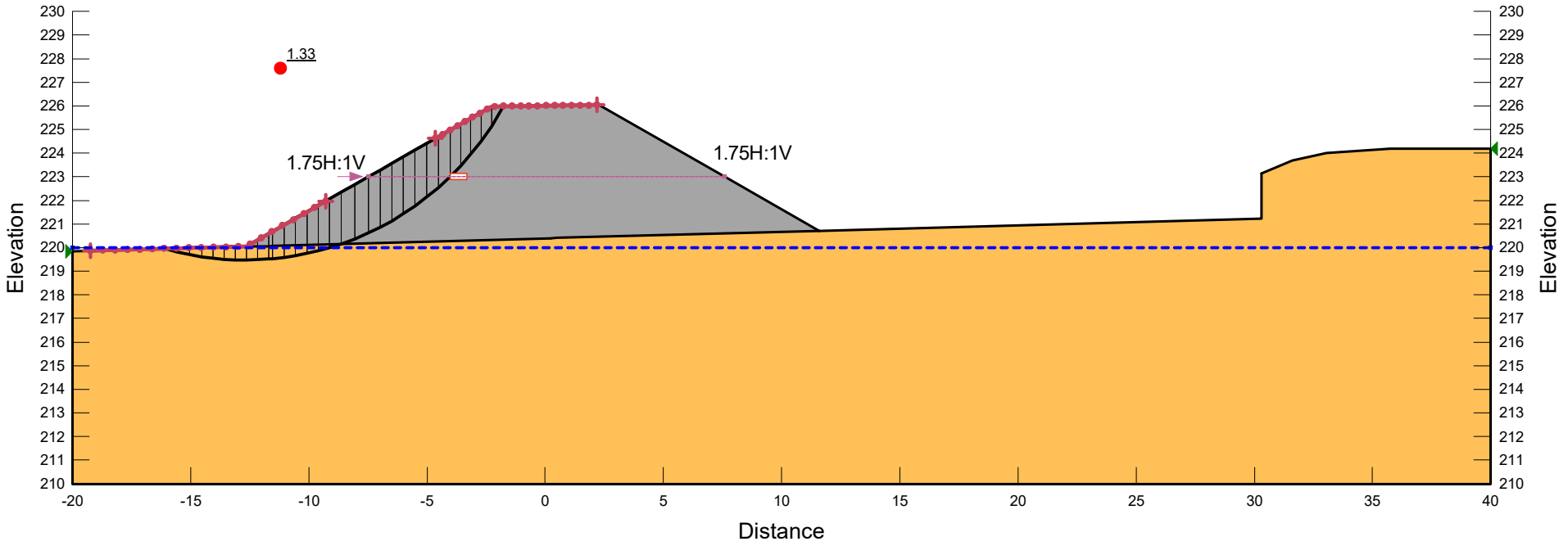
Analysis
Stage 2 West Slope 1.75H:1V with Earth Fill (Drained)

Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2023-11-10, 12:48:26 PM	1:262

Additional Details
Name: Stage 2 West Slope 1.75H:1V with Earth Fill
Comments: Sta. 12+650
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 2 m
Entry: (-15.189389, 219.98228) m, Exit: (-1.7984368, 225.98625) m
Center: (-12.968872, 232.965) m, Radius: 13.171243 m

Figure E10

Color	Name	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Clayey Silt	19.5	0	29
	Earth Fill	21	0	30



THURBER

Project
Hwy 11 Non-Structural Culvert

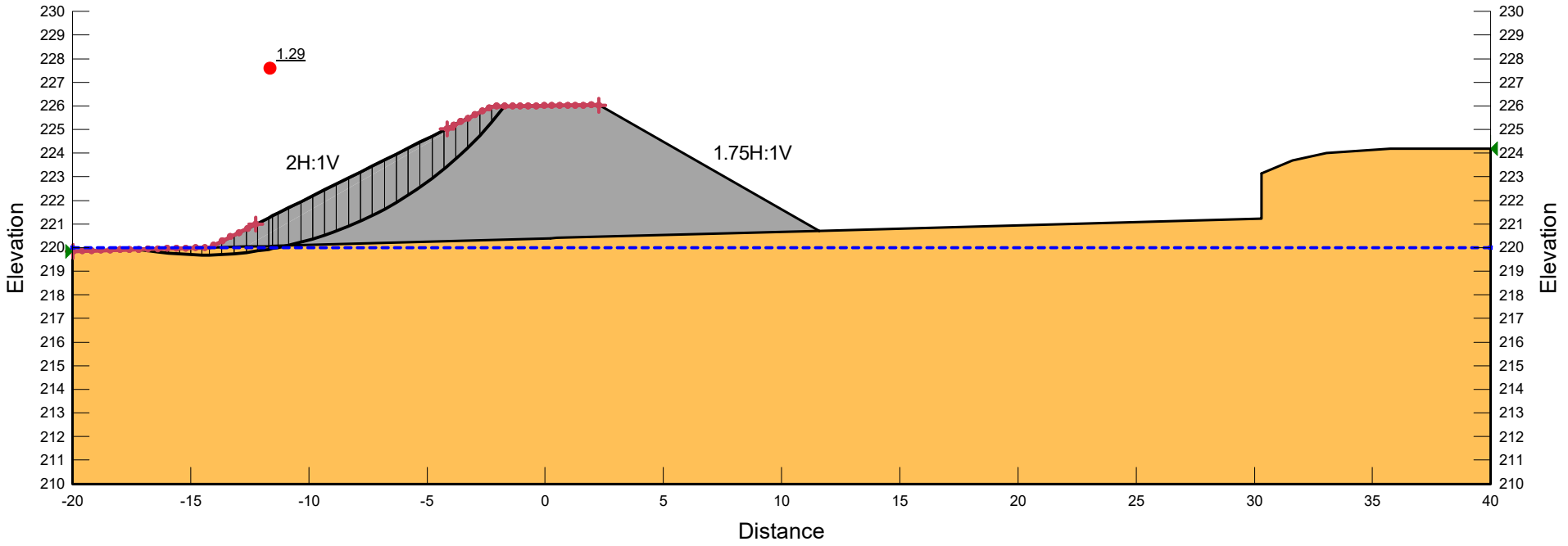
Analysis
Stage 2 West Slope 1.75H:1V with Earth Fill and Geogrid (Drained)

Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2023-11-10, 12:48:38 PM	1:262

Additional Details
Name: Stage 2 West Slope 1.75H:1V with Earth Fill and Geogrid
Comments: Sta. 12+650
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 2 m
Entry: (-16.113033, 219.95765) m, Exit: (-1.7659185, 225.98668) m
Center: (-12.688504, 231.89363) m, Radius: 12.417528 m

Figure E11

Color	Name	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Clayey Silt	19.5	0	29
	Earth Fill	21	0	30



THURBER

Project
Hwy 11 Non-Structural Culvert

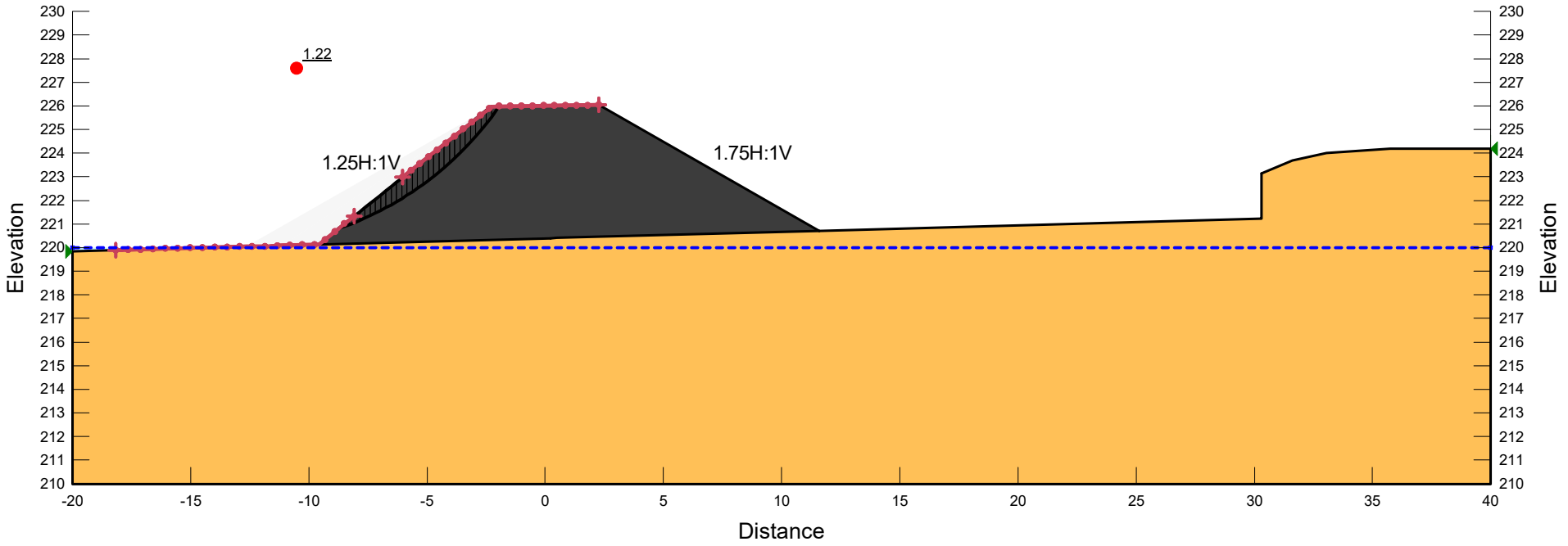
Analysis
Stage 2 West Slope 2H:1V with Earth Fill (Drained)

Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2023-11-10, 12:48:28 PM	1:262

Additional Details
Name: Stage 2 West Slope 2H:1V with Earth Fill
Comments: Sta. 12+650
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 2 m
Entry: (-17.196226, 219.92788) m, Exit: (-1.7178062, 225.98731) m
Center: (-14.447393, 235.70519) m, Radius: 16.014975 m

Figure E12

Color	Name	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Clayey Silt	19.5	0	29
	Rock Fill	19	0	42



THURBER

Project
Hwy 11 Non-Structural Culvert

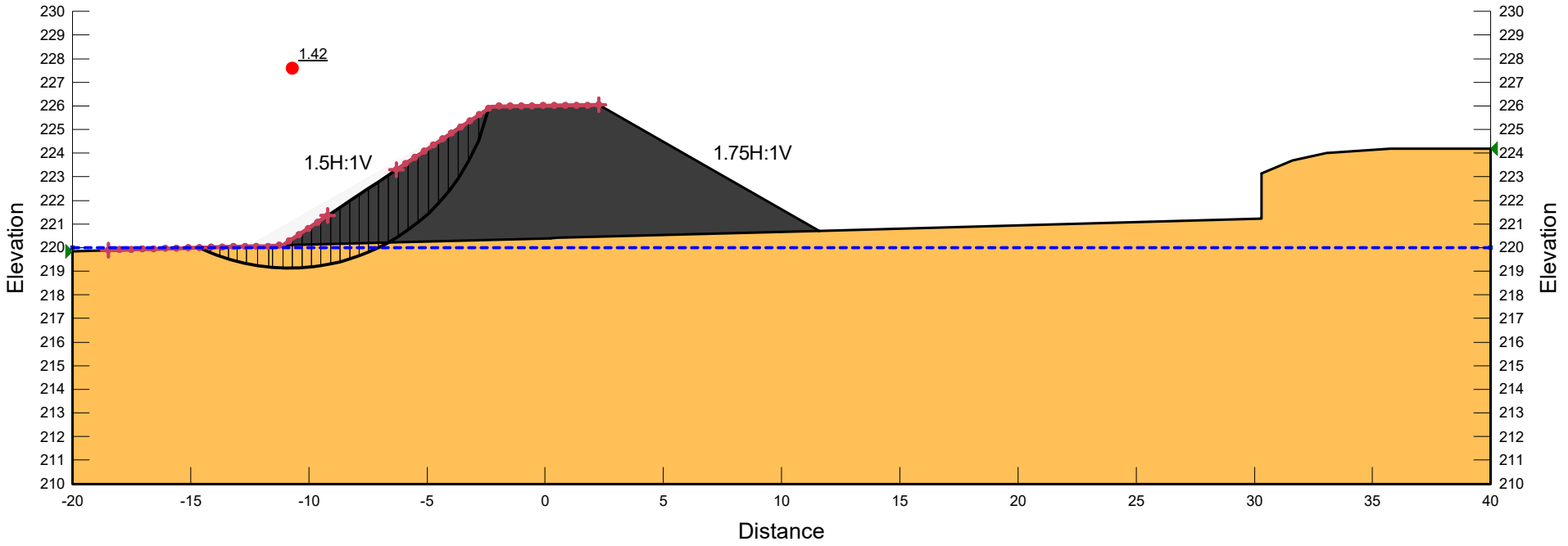
Analysis
Stage 2 West Slope 1.25H:1V with Rock Fill (Drained)

Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2023-11-10, 12:48:35 PM	1:262

Additional Details
Name: Stage 2 West Slope 1.25H:1V with Rock Fill
Comments: Sta. 12+650
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Entry: (-8.7484829, 220.79913) m, Exit: (-1.9468331, 225.98428) m
Center: (-13.295076, 233.81677) m, Radius: 13.788782 m

Figure E13

Color	Name	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Clayey Silt	19.5	0	29
	Rock Fill	19	0	42



THURBER

Project
Hwy 11 Non-Structural Culvert

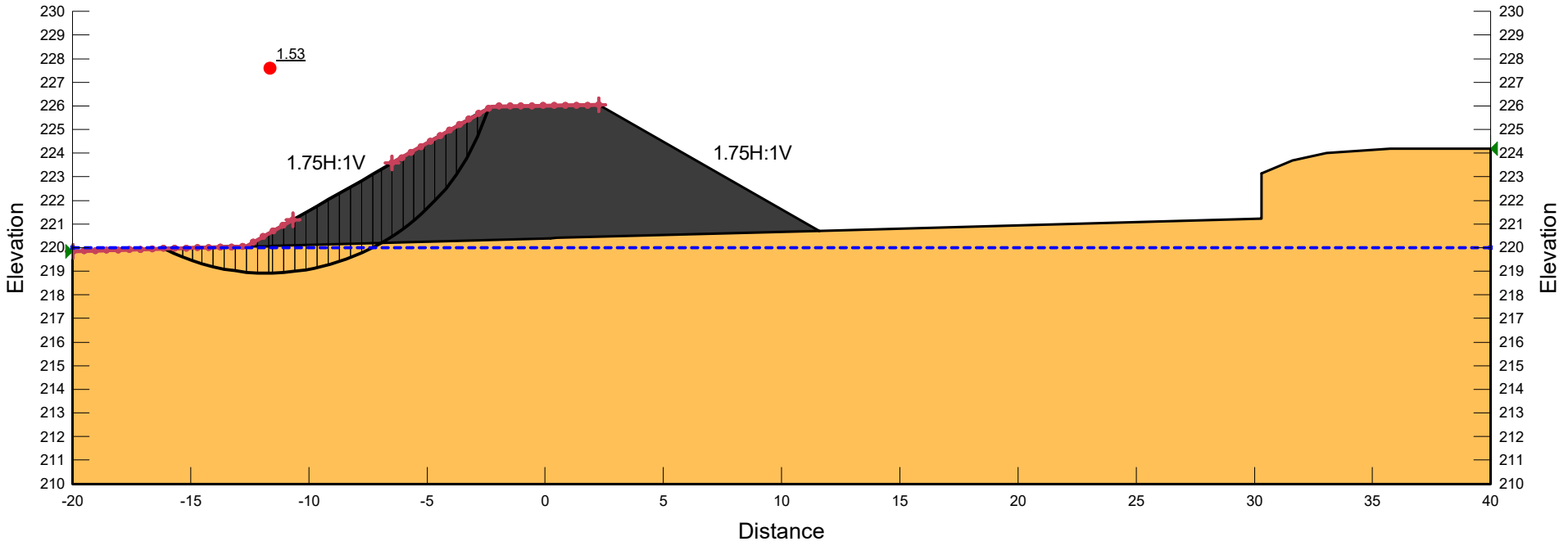
Analysis
Stage 2 West Slope 1.5H:1V with Rock Fill (Drained)

Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2023-11-10, 12:48:33 PM	1:262

Additional Details
Name: Stage 2 West Slope 1.5H:1V with Rock Fill
Comments: Sta. 12+650
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Entry: (-14.629564, 219.99721) m, Exit: (-2.3975679, 225.89495) m
Center: (-10.849639, 227.79113) m, Radius: 8.6621595 m

Figure E14

Color	Name	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)
	Clayey Silt	19.5	0	29
	Rock Fill	19	0	42



THURBER

Project
Hwy 11 Non-Structural Culvert

Analysis
Stage 2 West Slope 1.75H:1V with Rock Fill (Drained)

Seismic Coefficient	Last Run	Scale
H: 0g, V: 0g	2023-11-10, 12:48:30 PM	1:262

Additional Details
Name: Stage 2 West Slope 1.75H:1V with Rock Fill
Comments: Sta. 12+650
Method: Morgenstern-Price, Half-Sine
Minimum Slip Surface Depth: 1 m
Entry: (-16.149533, 219.95668) m, Exit: (-2.4081365, 225.90108) m
Center: (-11.771658, 228.69142) m, Radius: 9.7704406 m

Figure E15