Preliminary Geotechnical Engineering Report

Upper Maple River Watershed
Alt2A Dam Embankment
Barnes County, North Dakota

Prepared for
Moore Engineering, Inc.
West Fargo, North Dakota

November 2019

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Certifications

The document was originally issued and sealed by Kristin N. Alstadt, Registration Number 10208 on November 8, 2019. The original document is stored at Barr Engineering, Minneapolis, Minnesota.

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1.0 Introduction

Barr Engineering Co. (Barr) under authorization and contract with Moore Engineering, Inc., (Moore) completed a geotechnical investigation of a proposed water detention area for the Upper Maple River Watershed. Barr understands that Moore is working in conjunction with the Cass County Joint Water Resource District to evaluate potential flood water detention sites. At the time of this report, several alternative locations have been selected for additional evaluation, including Alt2A site described in this report and shown on **Figure 1**.

Barr performed a preliminary geotechnical investigation analysis of the proposed alternative Alt2A. Field data was used for creating geotechnical models and performing analysis at representative locations across the project area. This report describes the preliminary geotechnical investigations, laboratory testing results, and presents feasibility level geotechnical evaluations, conclusions, and recommendations for the design of Alt2A in Barnes County, North Dakota.

1.1 Site Location and Introduction

The proposed alternative Alt2A is located in Barnes County, North Dakota, northwest of the town of Valley City. The site is currently used as agricultural farmland, with a few farm houses present. Various streams and roads cut across the proposed alignment, and some trees are present near and along the embankment footprint. The proposed alignment is relatively flat, with occasional hills and valleys on the order of 30 feet of relief in a few locations. The proposed alignment at the time of this report is shown on **Figure 2**.

1.2 Geology

The project area is located in Barnes County, North Dakota, northwest of the town of Valley City. The geomorphology of the site generally consists of:

1. Lake and delta deposits from the ancestral Maple River as it flowed into Lake Agassiz; the river eventually cut a channel through the delta as the lake dropped.
2. Lake deposits from Lake Agassiz as it rose again and inundated the delta and old river channel.
3. More recent alluvial deposits on the valley floor from the existing Maple River as the lake again lowered and again cut a deep trench through the deposits.
4. An underlying glacial till formation.
5. Surficial soils consisting of recent alluvium.

Figure 3 provides a summary of the surficial geology near the project area. The primary soil type is mapped as Coleharbor till.

Bedrock is anticipated to consist of shale of the Carlile Formation (**Figure 4**), but is anticipated to be greater than 50 feet below the existing grade and likely will not affect performance of the proposed facility.

No Quaternary faults are mapped at the site (USGS, 2019a).

1.3 Embankment Configuration

Barr was provided preliminary project drawings dated December 30, 2018 for the project, which were reviewed prior to issuance of this report. As understood by Barr, the principal spillway is estimated to consist of a 185-foot long 48-inch diameter reinforced concrete pipe. The proposed flood water detention dam is not intended to provide a permanent pool and is only intended to temporarily retain the water during flood conditions by having a principal spillway and/or conduit through the embankment with limited capacity. It is anticipated that a 24-hour, 100-year storm event would be impounded for 12 days before returning back to existing conditions.

Based on communications with Moore, Barr understands the configuration for Alt2A to consist of a crest elevation of about 1,251.0 feet, side slopes of 3H:1V, and a freeboard height of 5 feet (Moore, 2017). The principal spillway has an invert elevation of approximately 1,217.7 feet. It is possible that the final design elevations and embankment configurations may be different than the criteria used for this report.

Two other small flood protection structures, shown on **Figure 2**, are planned to be constructed at the project site for protection of small farmsteads. The flood protection is currently designed as smaller embankments. These smaller structures were not evaluated in this report.

The ground surface elevation of the proposed alignment was taken from a survey performed by Moore at the completed soil boring locations. It is possible that the final design elevations may be different from the criteria used herein.

1.4 Previous Geotechnical Investigation

Barr was provided a previous geotechnical report performed by Midwest Testing Laboratory, Inc. (MTL) of Fargo, North Dakota. The previous geotechnical work was performed in 2002 and consisted of fourteen hollow stem auger soil borings performed to depths of 16 to 41 feet below the existing grade. The preliminary soil investigation results by MTL was provided to Barr by Moore (MTL, 2002). Barr considered it necessary to obtain additional samples and test results to confirm soil conditions for analysis. Therefore, the results of the MTL geotechnical investigation have been reviewed but not relied upon unless specifically discussed herein.

1.5 Geotechnical Investigation and Analysis

To support the design of Alt2A, a subsurface investigation, laboratory testing, and preliminary geotechnical engineering analysis was performed by Barr. The geotechnical components of the project are detailed below and include the following:

- Evaluation of soil stratigraphy based on field investigations
- Evaluation of soil parameters for seepage and slope stability modeling and analysis
- Modeling of seepage for the proposed embankment
- Underseepage mitigation evaluation
- Preliminary modeling of slope stability for the proposed embankment
- Evaluation of anticipated settlement for the proposed embankment
- Report discussing overall feasibility of Alt2A

2.0 Preliminary Geotechnical Investigation Methods

2.1 Site Exploration

The preliminary site investigation consisted of traditional soil borings, split-spoon sampling, standard penetration testing (SPT), thin-walled tube sampling, and soil laboratory testing. The geotechnical investigation program was design to accurately and efficiently evaluate the strength, compressibility, and density characteristics of the soils at the project site. The investigation was performed in April 2017, and laboratory testing was completed in May 2017. The following sections discuss the site investigation performed for the project.

2.1.1 Soil Borings

A total of 11 soil borings (B-1 through B-11) were completed along the currently proposed alignment for the Alt2A. One boring (B-12) was performed along the alignment of the smaller flood protection structure at a farmstead located north of the project levee alignment. An additional 2 soil borings (B-13 and B-14) were performed offset from the alignment to evaluate the depth and thickness of the existing subgrade soils, which may be considered as a borrow material for construction of the embankment. The final borrow pit location has not been provided to Barr at the time of this report. The soil boring locations are shown on **Figure 5** and boring logs are included in **Appendix A**.

Soil borings along the proposed alignment were completed to depths ranging from 28.0 to 40.0 feet below the existing ground surface. All borings along the alignment terminated at the target depth of 40.0 feet except for B-02 and B-08, which encountered drilling refusal on apparent boulders and cobbles around a depth of 30 feet. These locations were selected by Barr and approved by Moore to provide spatial coverage across the project area. Borings B-13 and B-14, for the potential borrow locations, were performed to a depth of 15.0 and 12.0 feet below the existing grade. **Table 1-1** summarizes the surveyed locations of the soil borings and elevations. Moore surveyed the borehole locations and provided the survey results to Barr.

Table 1-1 Summary of Soil Boring Locations

Boring ID	Geographic Coordinates NAD 83 (Datum)		Ground Surface Elevation [feet]	Total Depth of Boring [feet]
	Latitude	Longitude		
B-01	47.09993	-97.78918	1251.4	40.0
B-02	47.10237	-97.78882	1251.1	28.0
B-03	47.10232	-97.78484	1242.6	40.0
B-04	47.10218	-97.78081	1238.6	40.0
B-05	47.10226	-97.77436	1232.0	39.0
B-06	47.10457	-97.77100	1224.3	40.0
B-07	47.10708	-97.76974	1237.6	40.0
B-08	47.11171	-97.77000	1244.1	30.8
B-09	47.11407	-97.77005	1241.4	40.0

B-10	47.11652	-97.76977	1247.4	40.0
B-11	47.11906	-97.76932	1247.5	40.0
B-12	47.12673	-97.78718	1246.3	40.0
B-13	47.11470	-97.77292	1245.0	15.0
B-14	47.11043	-97.77517	1240.7	12.0

The soil borings were completed by Interstate Drilling Services, LLP, of Grand Forks, North Dakota, with a track-mounted drill rig using hollow stem auger techniques. The augers used for the investigation were 4.25-inches in inner diameter, and the borehole was on the order of 9-inches in outer diameter. The soil borings were performed in general accordance with ASTM D1452, “Standard Practice for Soil Exploration and Sampling by Auger Borings”. SPT and split-spoon sampling was performed in accordance with ASTM D1586, “Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils”. Three-inch diameter Shelby tube samples were also collected at various depths for laboratory testing in accordance with ASTM D1587, “Standard Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes”. Samples were collected continuously in order to determine the entire soil profile and evaluate for the presence of changing stratigraphy, sand or gravel seams, changing moisture content, and organic soils.

Based on the most recent autohammer calibration, which was performed in 2015, the minimum hammer efficiency was 68 percent. This indicates that the corrected *N*-values (N_{60}) are likely to be higher than the raw values if corrected to industry standards of 60 percent hammer efficiency. Hence, the raw *N*-values are reported on the boring logs.

The soil borings were observed and logged by Barr. Soil samples were delivered to Soil Engineering Testing, Inc. (SET) in Bloomington, Minnesota, for laboratory testing. The soil boring logs are provided in **Appendix A**.

2.1.2 Laboratory Testing

The following geotechnical laboratory analyses were completed by SET:

- Moisture content tests were performed in accordance with ASTM D2216, “Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass”
- Dry density tests were performed in accordance with ASTM D7263, “Standard Test Methods for Laboratory Determination of Density (Unit Weight) of Soil Specimens”
- Grain Size and Hydrometer analysis in accordance with ASTM D422, “Standard Test Method for Particle-Size Analysis of Soils”
- Atterberg limit determinations in accordance with ASTM D4318, “Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils”
- Unconfined compressive strength in accordance with ASTM D2166, “Standard Test Method for Unconfined Compressive Strength of Cohesive Soil”

- Unconsolidated-Undrained (UU) Triaxial compressive strength in accordance with ASTM D2850, “Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils”
- Consolidation tests in accordance with ASTM D2435, “Standard Test Methods for One-Dimensional Consolidation Properties Using Incremental Loading”
- Permeability testing in accordance with ASTM D5084, “Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter”

Laboratory test reports and a summary of all the laboratory tests completed are included in **Appendix B**.

3.0 Results

This section presents the data collected as part of the preliminary geotechnical investigations and provides further analysis of these results.

3.1 Subsurface Stratigraphy

Geologic information (**Section 1.2**), soil boring logs (**Appendix A**), and laboratory test results (**Appendix B**) were reviewed to obtain an understanding of the project area stratigraphy.

The results of the soil borings indicated that the soils generally consisted of clayey glacial till soils with frequent sandy outwash deposits. The glacial deposits transitioned from a rusty brown color to gray at depths ranging from 7 to 23 feet below the existing ground surface. Silt was observed in one soil boring (B-08) at a depth of 23.0 to 25.5 feet. In addition, occasional layers of boulders and cobbles caused drilling refusal at two of the borings (B-02 and B-08) performed. The soil types discussed in the following sections are the soil types used in seepage and stability modeling completed for a feasibility level embankment design.

3.1.1 Topsoil

Topsoil at the site consisted primarily of organic clay with lesser amounts of sand. The topsoil was generally dark brown and the thickness ranged from 6 to 18 inches. The topsoil contained roots and other organic material consistent with planted fields.

3.1.2 Lean Clay

The presence of clay soils was noted at all soil borings. The clay was classified in the field as lean clay, indicating that the clay has low to moderate plasticity. The lean clay soils at the site often contained significant concentrations of sand and silt sized particles. The color of the clay soils was observed to be brown to tan towards the surface of the soil borings, and transitioned into gray to dark gray at depths ranging from 7 to 23 feet. The brown clays are likely oxidized over time, with the brown color resulting from higher iron content. It is anticipated that the majority of the lean clay at the site are from glacial deposition.

Occasional lignite coal inclusions and fragments were observed within the lean clay soils, but no zones of intact lignite were not encountered.

Stiff clay (based on blow counts) was observed at borings B-02 (12 to 28 feet), B-05 (29 to 32.5 and 37.5 to 39 feet), B-08 (25.5 to 31 feet), B-09 (27.5 to 40 feet), and B-11 (27.5 to 37 feet), which was noted to be much stiffer than the other clay soils at the site.

Moisture content values for the lean clay ranged from 8.5 to 27.6 percent, with an average of about 21.0 percent.

Dry unit weights of the lean clay ranged from about 100.2 to 120.6 pounds per cubic foot (pcf). Moist unit weights for these soils were computed using the moisture content test results described above from the same samples tested for dry density. The calculated moist unit rates ranged from 123.0 to 137.8 pcf, with an average of approximately 127 pcf.

Atterberg limit testing on samples of the lean clay indicated plastic limit values ranging from 17.2 to 27.7 percent, liquid limit values ranging from 29.4 to 36.7 percent, and plasticity index values ranging from 5.6 to 15.7 percent. According to the Plasticity Chart, these soils plot primarily as CL (lean clay) with occasional CL-ML (silty lean clay) zones.

Mechanical grain size and hydrometer testing indicated that the gravel content of the lean clay ranged from 0.0 to 7.7 percent, the sand content ranged from 13.8 to 46.2 percent, and the fines content ranged from 50.0 to 85.5 percent (dry weight). One hydrometer test was performed and the results indicate a silt content of 75.7 percent and a clay content of 9.8 percent.

Six laboratory unconsolidated-undrained (UU) triaxial compression tests were performed on samples of lean clay. The results of the testing indicated that the maximum deviator stress ranged from 0.71 to 2.60 tons per square foot (tsf), with all but one test exceeding 1.6 tsf. Four laboratory unconfined compressive strength (UCS) tests were performed, and the results indicated that the UCS ranged from 1.61 to 3.25 tsf. Hand penetrometer measurements on lean clay indicated that the unconfined compressive strength ranged from 0.25 to 4.5 tsf, with a typical range of 1.0 to 3.0 tsf.

SPT *N*-values in the lean clay ranged from 1 blow per foot to greater than 50 blows for fewer than 6-inches of sampler penetration. The typical range for SPT *N*-values ranged from 10 to 20 blows per foot, indicating that the lean clay is generally in a stiff to very stiff condition. However, the presence of lower blow counts indicate that there are some zones of lower strength lean clay at the project site.

Two laboratory hydraulic conductivity tests were performed on intact undisturbed samples of the lean clay. The results indicated that the hydraulic conductivity ranged from 2.00×10^{-8} to 1.50×10^{-7} cm/sec (6.56×10^{-10} to 4.92×10^{-9} ft/sec).

3.1.3 Sand

Sand and clayey sand was encountered at ten of the soil borings performed along the proposed alignment. The sand generally existed in thin layers interbedded within the clay soils, but thicker deposits were observed at boring B-12, located near a farmstead north of the proposed levee alignment. The thickness of the sand layers ranged from 1.5 to 14.5 feet. The shallow sand was observed to range in color from tan to orangish-brown and then transitioned to gray at depth similar to the clay soils described previously. Sand soils below the water table were observed to be saturated and water-bearing. The sand was generally classified in the field as a clayey sand, silty sand, or poorly graded sand, and commonly included lesser amounts of gravel. It is anticipated that the majority of the sand present at the site interbedded with the clay till soils are outwash deposits. It is possible that the surficial sands and thicker sand soils are from alluvial deposition.

Moisture content values in the sand ranged from about 14.7 to 30.1 percent, with an average value of about 22.0 percent.

Dry unit weights of intact samples of the sand ranged from about 98.9 to 108.4 pcf. Moist unit weights for these soils were computed using the corresponding moisture content test results described above from the same samples tested for dry density. The calculated moist unit weights ranged from 123.8 to 130.2 pcf, with an average of approximately 126.0 pcf.

Atterberg limit testing on one sample of the fines from a clayey sand sample indicated a plastic limit value of 15.1 percent, a liquid limit value of 22.7 percent, and plasticity index value of 7.6 percent. According to the Plasticity Chart, these soils plot as CL (lean clay).

Mechanical grain size testing was performed on ten samples of granular soils. The results of the testing indicated that the gravel content ranged from 0.4 to 16.2 percent, the sand content ranged from 44.3 to 94.2 percent, and the fines (silt and clay) content ranged from 5.2 to 48.5 percent.

SPT *N*-values for the sand soils ranged from 1 blow per foot to greater than 50 blows for fewer than 6 inches of sampler penetration, with a typical range of 10 to 25 blows per foot. This indicates that the relatively density of the soils was medium dense. Lower blow counts were observed, but tended to be confined to the surficial soils.

One laboratory hydraulic conductivity test was performed on an intact undisturbed sample of clayey sand. The results indicated that the hydraulic conductivity was 8.20×10^{-7} cm/sec (2.69×10^{-8} ft/sec). However, the hydraulic conductivity for clean sands is anticipated to be greater than the measured hydraulic conductivity of the laboratory test result.

3.1.4 Silt

Native silt was observed at one soil boring as confirmed through Atterberg limits testing. Silt was confirmed at boring B-08 from a depth of 23.0 to 25.5 feet below the existing grade. The silt was observed to be dark gray, with trace amounts of sand. It should be noted that the silt was observed over and underlain by seams of sand and that a boulder was encountered within the interval where silt was observed.

The results of this investigation appear to contradict the results from the previous geotechnical report by MTL (2002), which indicated more frequent layers of silt interbedded within the sand and clay soils. Based on the results of this investigation, it appears that the majority of the silt or elastic silt identified in the previous report are likely glacial till, and can generally be classified as lean clay.

One moisture content value on the silt was 21.7 percent.

Atterberg limit testing on one sample of the silt indicated a plastic limit value of 17.7 percent, a liquid limit value of 21.4 percent, and plasticity index value of 3.7 percent. According to the Plasticity Chart, this plots as ML (silt). The silt encountered in the current investigation is not elastic silt.

One SPT *N*-value in the silt resulted in a measured value of 75 blows for 9 inches of penetration, indicating that the silt was in a very dense condition.

3.1.5 Cobbles and Boulders

Layers of boulders and cobbles were observed at a depth of 27.5 feet at soil boring B-02 and 30.5 feet at soil boring B-08. These layers of coarser material caused refusal while drilling, and the borings could not be extended through the boulders. The cobbles and boulders were observed interbedded within lean clay soils.

Laboratory testing was not performed on samples obtained from these layers as the sample recovery was limited.

SPT tests in the boulder and cobble zones resulted in split-spoon refusal; *N*-values were typically 50 blows for fewer than 6 inches of sampler penetration.

3.2 Groundwater Conditions

Groundwater was encountered while drilling or immediately after drilling while augers were still in the ground in all borings at depths ranging from 2.5 to 28.4 feet below ground surface. Upon completion of drilling, after the augers were removed from the borehole, the soils caved in to a depth ranging from 4.5 to 37.5 feet. A summary of groundwater measurements are provided in **Table 3-1**.

Table 3-1 Summary of Groundwater Levels from Soil Borings

Boring ID	Groundwater Measurement Depth [feet]		
	While Drilling	End of Drilling	Cave-in Depth
B-01	3.0	4.7	11.0
B-02	5.0	NE	21.5
B-03	8.0	NE	15.0
B-04	2.5	2.7	26.5
B-05	3.0	2.1	15.0
B-06	2.5	3.7	--
B-07	15.5	NE	20.5
B-08	13.0	12.9	23.5
B-09	7.5	17.1	30.0
B-10	9.0	16.3	30.5
B-11	22.5	28.4	37.5
B-12	4.0	3.6	4.5
B-13	6.0	NE	--
B-14	10.0	NE	--

NE – Not Encountered

Many factors contribute to water level fluctuations, such as heavy rainfall events, dry periods, sand seams, etc. Based upon the observations made during drilling, the groundwater along the proposed alignment is anticipated to be in the upper 5 to 10 feet of soil. This is consistent with the results of the previous investigation by MTL (2002).

3.3 General Laboratory Test Results

The laboratory test results from the soil borings are provided in **Appendix B**. A summary of laboratory testing results is provided in Table B1 of **Appendix B**.

3.3.1 Moisture Content

A total of 64 moisture content tests were performed on samples collected from the soil borings. The soils tested included sands, clays, and silts. The native soil had moisture contents ranging from 8.5 to 30.1 percent, with an overall average of about 21 percent.

3.3.2 Atterberg Limits

Atterberg limits were determined and used to identify soil behavior characteristics and classify the material encountered in the soil borings A total of 10 Atterberg limits tests were conducted on fine-grained soils. Test results indicated that the liquid limit ranged from 21.4 to 36.7 percent, the plastic limit ranged from 15.1 to 27.7percent, and the plasticity index ranged from from 3.7 to 15.7 percent. According to the Plasticity Chart, the soils tested are classified as CL (lean clay), CL-ML (silty lean clay), and ML (silt).

3.3.3 Unit Weight

A total of 15 dry unit weight tests were performed on intact soil samples obtained during the investigation. Dry unit weight test results on all samples ranged from 98.9 to 120.6 pcf. Moist unit weight estimations using moisture contents from samples with dry unit weight results ranged from 123.0 pcf to 137.8 pcf, with an average of about 127 pcf.

3.3.4 Mechanical Grain Size Analysis

Mechanical grain size testing was performed on 14 soil samples collected during the investigation. The results of the testing indicated that the gravel content ranged from none to 16.2 percent, the sand content ranged from 13.8 to 94.2 percent, and the fines (silt and clay) content ranged from 5.2 to 85.5 percent (dry weight). One hydrometer test on a sample of lean clay resulted in a silt content of 75.7 percent and a clay content of 9.8 percent.

3.4 Soil Shear Strength

The shear strength of the soils was determined from field and laboratory testing. The results of laboratory testing is provided in **Appendix B**. The following sections of this report discuss the soil strengths in terms of friction angle (for the drained condition) and undrained shear strength (for the undrained condition).

3.4.1 Drained Shear Strength

The native sand is considered to be a free-draining granular material and its strength can be described using a drained friction angle. Laboratory direct shear testing was not performed on the samples obtained during the field investigation due to the limited amount of granular materials encountered.

Therefore, the friction angle for the native sand soils was determined based on correlations to the SPT value using the equation below (Das, 2006):

$$\phi^{'}=27.1+0.3(N_1)_{60} -0.00054(N_1)_{60}{}^2$$

The SPT values measured in the native sand at the proposed alignment ranged from 1 blow per foot to greater than 50 blows for fewer than 6 inches of sampler penetration, with a typical range of 10 to 25 blows per foot. Using the correlation provided by Das (2006), and assuming that the raw SPT values were equivalent to the corrected SPT $(N_1)_{60}$ values, this corresponds to a typical friction angle exceeding 30 degrees.

The drained friction angle of the fine-grained soils was estimated from correlations to the plasticity index (Terzaghi, 1996). The measured plasticity index of the lean clay and silt ranged from 3.7 to 15.7 percent based on the results of laboratory testing. This correlates to a drained friction angle ranging from 30 to 35 degrees.

3.4.2 Undrained Shear Strength

The undrained shear strength values for cohesive soils were derived from laboratory UCS testing and UU triaxial strength tests on undisturbed samples collected from the borings. Hand penetrometer measurements were also considered for this analysis. Undrained shear strength values are considered to be half of the UCS or maximum deviator stress of the soil at failure.

The results from UCS testing, UU triaxial compressive strength testing, and hand penetrometer testing indicated that the undrained shear strength ranged from 250 to greater than 4,500 psf, with a typical range of 1,500 to 3,000 psf.

The cohesive soils were subdivided into three separate categories based on the apparent shear strength, since there was a pronounced difference between the shallow and deeper clays. The categories were hardpan clay, typical clay, and soft clay. Hardpan clay was observed at borings B-02 (12 to 28 feet), B-05 (29 to 32.5 and 37.5 to 39 feet), B-08 (23 to 31 feet), B-09 (27.5 to 40 feet), and B-11 (27.5 to 40 feet). The results of the testing performed indicated that the following ranges of undrained shear strength were typical for each soil layer:

- Hardpan clay: 4,000+ psf
- Typical clay observed at the site: 1,500 to 3,000 psf
- Softer clays near the surface: 250 to 750 psf

The soil layers identified as soft are described in the following section.

3.4.3 Lower Strength Soil Layers

There were occasional looser sand layers observed through SPT testing, but those were limited and do not exhibit the typical properties of the sand at the project site. Additionally, occasional layers of lower strength lean clay were observed through SPT and laboratory testing, but these were relatively isolated. The lower strength soils will need to be accounted for in final design. A summary of the thicker zones of lower strength soils (for the purposes of this report, this corresponds to soils with an undrained shear strength less than 1,500 psf and a friction angle below 31 degrees) is provided in **Table 3-2**.

Table 3-2 Summary of Lower Strength Soil Layers

Boring ID	Depth of Lower Strength Soils [feet]
B-01	0 to 8.5 feet
B-02	0 to 5 feet
B-03	None Observed
B-04	None Observed
B-05	0 to 8 feet, 13.5-22 feet
B-06	0 to 12 feet, 17.3-20 feet
B-07	None Observed
B-08	None Observed
B-09	0 to 5 feet
B-10	0 to 10 feet
B-11	None Observed
B-12	None Observed

Based on an inspection of the table, the majority of the lower strength soils are present at the surface, which may be due to variations in moisture and the seasonal frost effects experienced by shallow soils.

3.5 Compressibility

Fine-grained soils (clay and silt) experience long term consolidation if saturated and exposed to external loading. The fine grained soils observed along the proposed alignment are anticipated to be saturated below the water table, and are anticipated to experience long term settlement as the increased stress squeezes out the water from the pore spaces.

Compressibility of the existing soils was evaluated using laboratory one-dimensional consolidation testing. Two samples of lean clay and one sample of clayey sand were selected for laboratory testing. The results of the consolidation testing are provided in **Table 3-3**.

Table 3-3 Summary of Laboratory Consolidation Test Results

Boring ID	Depth [feet]	Soil Type	OCR	C_c	C_r	e_0
B-5	12.5-14	SC	1.5	0.08	0.01	0.561
B-10	7.5-9.5	CL	5.8	0.13	0.02	0.542
B-11	10-12	CL	8.2	0.16	0.02	0.641

Based on the results of the testing, the clay soils appear to be overconsolidated (i.e. the current existing stress on the soil is less than the maximum stress that the soil has encountered throughout its history). Overconsolidated soils generally have a lower potential for settlement than normally consolidated soils. Glacial till soils are typically observed to be overconsolidated because the glaciers have previously compressed the material. The results of the testing indicate that the clay soils have a relatively low to moderate compressibility.

3.6 Hydraulic Conductivity from Laboratory Testing

Hydraulic conductivity tests were performed on selected samples to determine the permeability of the material for seepage analysis. The hydraulic conductivity tests on samples were performed with the flexible-wall permeameter method according to ASTM D5084. Two lean clay samples and one clayey sand sample were tested. The results of the testing indicated that the hydraulic conductivity of the soils ranged from $8.20\text{x}10^{-7}$ to $2.00\text{x}10^{-8}$ cm/sec ($6.56\text{x}10^{-10}$ to $2.69\text{x}10^{-8}$ ft/sec), with the lean clay soils exhibiting the lower permeability values.

The hydraulic conductivity results from laboratory testing are considered a measure of vertical permeability as the water is forced to flow through the sample from the bottom face to the top face of the cylindrical specimen.

4.0 Preliminary Geotechnical Analysis

Geotechnical models were created for representative cross sections across the project area where varying conditions of subsurface stratigraphy were encountered. The primary goal of the preliminary analysis was to evaluate the slope and seepage stability across the project alignment for typical and worst case conditions and, if necessary, provide a preliminary design to alleviate slope stability concerns.

4.1 Geometry and Design Considerations

The geometry of the cross-sections is discussed in the following sections. For the preliminary analysis, four cross sections were evaluated. These cross-sections were selected to evaluate the varying conditions beneath the proposed embankment. The location of the modeled cross-sections is shown on **Figure 6**. **Figure 6** also provides the approximate stationing along the proposed alignment. Note that the alignment was created to be used by Barr to create plots, provide a visual representation, and compute distances. It is not a recommendation or a representation of the preliminary alignment.

The crest elevation was provided to Barr in an email from Moore, which indicated that the final height of the levee should be 1,251.0 feet above mean sea level (Moore, 2017). The embankment is not planned to have an upstream pool in normal conditions. A freeboard height of 5 feet was assumed, corresponding to an elevation of 1,246.0 feet above mean sea level. For the purposes of this report, the hydraulic loading condition of water at the freeboard height is referred to as “normal flood conditions”, and the hydraulic loading condition of water at the crest is referred to as “maximum flood conditions”.

The embankment fill was assumed to consist of compacted clay from an on-site borrow pit. The location of the borrow pit has not been identified at the time of this report.

The ground surface geometry used in the models were constructed based on available data from public sources and from measured elevations by Moore at the completed soil boring locations. As such, there is likely some variability between the modeled cross-sections and the actual ground surface elevations. If this location is selected for further development, Barr recommends collecting additional survey information via traditional methods or light detecting and range (LiDAR) for a more precise representation of the existing conditions for use in final analysis and construction.

4.1.1 Soil Profile Alignment

To assist in visualizing the soil stratigraphy along the proposed embankment, Barr prepared a profile drawing of the proposed alignment which took into account the stratigraphy of the recent soil borings. Previous borings were generally not included in the stratigraphic analysis, but the previous soil borings were taken into account when creating the sections for slope stability and seepage analysis. The apparent soil profile alignment is provided in **Appendix C**. The main types of soil considered for analysis were clean sand, clayey sand, silt, soft clay, clay, and hard clay. SPT *N*-values are indicated on the alignment. Because the seasonal water levels have not been studied (or provided to Barr), the assumed groundwater level is not provided on the profile alignment.

4.1.2 Model Cross Sections

Soil stratigraphy was based on the results of the historical and recent geotechnical investigations and represents Barr's interpretation of the existing soil conditions near the selected cross section. To evaluate the slope stability and embankment seepage of the cross section, a clay dam embankment with a crest width of 8 feet and side slopes of 3H:1V was used with the crest elevation of 1,251.0 feet. Barr examined no flood conditions, normal flood conditions, maximum flood conditions and rapid drawdown scenarios.

4.1.2.1 Cross Section 1

This cross section is labeled *CS1* as shown on **Figure 6** and stratigraphy was estimated primarily from soil borings B-04, boring 6, and boring 14 (performed by MTL). The elevation of the existing ground surface is approximately 1,239.0 feet. This location was selected for analysis because of the thick, shallow deposit of sand.

4.1.2.2 Cross Section 2

This cross section is labeled *CS2* as shown on **Figure 6** and stratigraphy was estimated primarily from soil borings B-06, boring 2, boring 3, and boring 13 (performed by MTL). The elevation of the existing ground surface is approximately 1,224.0 feet. This location was selected for analysis because of the thick, shallow deposits of sand and because this may be one of the taller areas of the proposed embankment.

4.1.2.3 Cross Section 3

This cross section is labeled *CS3* as shown on **Figure 6** and stratigraphy was estimated primarily from soil borings B-07 and boring 13 (performed by MTL). The elevation of the existing ground surface is approximately 1,238.0 feet. This location was selected for analysis because the soil conditions are mainly clay.

4.1.2.4 Cross Section 4

This cross section is labeled *CS4* as shown on **Figure 6** and stratigraphy was estimated primarily from soil boring B-09. The elevation of the existing ground surface is approximately 1241.0 feet. This location was selected for analysis because the soil conditions consist of deeper deposits of sand.

4.2 Seepage Analysis

The main objective of the seepage analysis was to develop an understanding of the seepage flow through and under the embankment and its relationship to stability of the embankment slopes. Seepage through an embankment plays a major role in the stability and construction sequence of the embankment. Simulations were made to estimate seepage flow conditions for the assumed embankment.

The seepage simulations presented in this report modeled seepage flow through and under the dam under steady-state conditions and rapid drawdown conditions. The seepage analyses for the hydraulic loading conditions were performed at each of the design sections identified in **Section 4.1.2**. In the analyses, each was evaluated for the final construction configuration (assuming no flood events during the construction process).

4.2.1 Seepage Analysis Background

The seepage analysis used for the embankment was conducted using SEEP/W, a computer modeling program developed by GEO-SLOPE International, Ltd. SEEP/W uses the finite-element analysis technique to model the water movement and pore water pressure distribution within porous materials such as soils. This method was chosen because comprehensive formulation allows evaluation of highly complex seepage problems. SEEP/W can formulate saturated and unsaturated flow, steady-state and transient conditions, and a variety of boundary conditions. Model integration allows the use of seepage files in limit-equilibrium slope-stability analysis. SEEP/W generates an output file containing the heads at the nodes of the finite-element mesh. The integration of Geo Slope products allows the use of the SEEP/W head file in the slope stability program (SLOPE/W) to compute the effective stress. Therefore, it allows evaluation of the seepage impact on stability. SLOPE/W also has an imbedded analysis method to conduct rapid drawdown evaluations.

4.2.2 SEEP/W Parameters

The following sections summarizes the hydraulic conductivity parameters selected for seepage modeling. The main parameter associated with soils relevant to the seepage analysis is hydraulic conductivity, which is also referred to as permeability. The laboratory testing provided estimates of the vertical permeability, which was assumed for the horizontal permeability as well, generally appropriate for well-graded soils.

4.2.2.1 Lean Clay

The parameters for the clay and silt soils were evaluated through laboratory testing performed during the geotechnical investigation. The maximum value of 4.92×10^{-9} ft/sec (1.50×10^{-7} cm/s) was selected.

4.2.2.2 Embankment Fill

For the purposes of this preliminary analysis, it was assumed that the material used to construct the embankment would be on-site clay taken from a borrow pit, and the hydraulic conductivity was taken as equal to the in place hydraulic conductivity. A value of 4.92×10^{-9} ft/sec (1.50×10^{-7} cm/s) was used for the embankment fill.

4.2.2.3 Silt

For the purposes of this preliminary analysis, it was assumed that the permeability of the silt material was similar to the clay soil. This should be further evaluated during the final design. A value of 4.92×10^{-9} ft/sec (1.50×10^{-7} cm/s) was used for silt.

4.2.2.4 Clayey Sand

The clayey sand permeability was taken from the results of laboratory testing. A recommended value of 2.69×10^{-8} ft/sec (8.20×10^{-7} cm/s) was selected for clayey sand soils. This value was also used for materials identified as silty sand.

4.2.2.5 Clean Sand

There were some zones of cleaner sand, or sand with fewer fine-grained (silt and clay) material, observed at the project site. The permeability of the clean sand was estimated using the equation provided below (Cedergren, 1989) as shown below:

$$k\left(\frac{cm}{s}\right)=D_{10}D_{60}$$

Where D_{10} *and* D_{60} are in millimeters.

The range of the D_{10} parameter was 0.09 to 0.2 millimeters based on the results of laboratory testing, and the D_{60} parameter ranged from 0.5 to 1.3 millimeters, which indicate that the hydraulic conductivity ranged from $1.48\text{x}10^{-3}$ to $8.53\text{x}10^{-3}$ ft/sec ($4.50\text{x}10^{-2}$ to $2.60\text{x}10^{-1}$ cm/s). The minimum value of $1.48\text{x}10^{-3}$ ft/sec ($4.50\text{x}10^{-2}$ cm/s) was selected for the clean sands.

4.2.2.6 Summary of Seepage Parameters

All soils were modeled using the "Saturated Only" model type, which assumes all soils in the model are saturated. A summary of inputs used for seepage modeling is provided in **Table 4-1**.

Table 4-1 Recommended Seepage Parameters

Material Type	Model Type	Saturated Hydraulic Conductivity	Saturated Hydraulic Conductivity
		ft/s	cm/s
Hardpan clay	Saturated Only	4.92E-09	1.50E-07
Clay	Saturated Only	4.92E-09	1.50E-07
Silt	Saturated Only	4.92E-09	1.50E-07
Soft Clay	Saturated Only	4.92E-09	1.50E-07
Clean Sand	Saturated Only	1.48E-03	4.50E-02
Clayey Sand	Saturated Only	2.69E-08	8.20E-07
Embankment Fill	Saturated Only	4.92E-09	1.50E-07

*The anisotropy (Ky'/Kx' ratio) was assumed to be 1.0 for all materials.

4.2.3 Boundary Conditions and Assumptions

Boundary conditions and assumptions for the seepage simulations are as follows:

- Under normal flood conditions, the entire upstream portion of the embankment was modeled as constant total head of 1246.0 feet (corresponding to the freeboard height, which is 5 feet below the required embankment height).

- Under maximum flood conditions, the upstream portion of the embankment was modeled as having groundwater up to the crest elevation of 1251.0 feet.

- The new embankment will consist of recompacted on-site lean clay.

- The top crest width of the embankment was 8 feet across, and the side slopes were 3H:1V.

4.2.4 Evaluation of Seepage, Heave, and Erosion Potenial

The USACE provides specific guidance in regard to design of seepage control measures for levees in EM 1110-2-569 (2005), "Design Guidance for Levee Underseepage". The cross sections were modeled and analyzed for seepage (**Section 4.2.4.1**), heave/uplift (**Section 4.2.4.2**), and vertical erosion potential (**Section 4.2.4.2**).

4.2.4.1 Estimated Seepage Flow

The calculated seepage flow through the proposed embankment was assessed to evaluate if additional seepage measures were required, such as underdrains or filters. The estimated total seepage for the entire embankment was estimated based on the results of the modeling. Seepage rates from the individual cross sections are provided in **Table 4-2**. The seepage analyses are included in **Appendix D**.

Table 4-2 Summary of Seepage Rates

Cross Section ID	Hydraulic Condition	Estimated Water Flux Rate Under Embankment [ft^3/sec/ft of embankment]	Estimated Water Flux Rate Under Embankment [gallons/day]	Estimated Water Flux Rate Under Embankment [gallons/minute]
CS1	Normal Flood	1.28E-03	828	0.57
	Maximum Flood	2.11E-03	1364	0.95
CS2	Normal Flood	9.68E-04	626	0.43
	Maximum Flood	1.19E-03	769	0.53
CS3	Normal Flood	2.65E-08	~0	0.00
	Maximum Flood	4.92E-08	~0	0.00
CS4	Normal Flood	1.38E-07	~0	0.00
	Maximum Flood	2.79E-07	~0	0.00

The results of the analysis indicate that the total seepage through the dam is estimated to be on the order of 1,800 gallons per day under normal hydraulic conditions, and is on the order of 2,700 gallons per day under maximum hydraulic conditions (when the water level is equal with the crest height of the embankment) without the use of a spillway. No seepage control measures appear to be needed at this time based on the anticipated seepage flow rates.

4.2.4.2 Potential for Uncontrolled Seepage at the Embankment Downstream Toe

The recommended minimum required seepage factors of safety against vertical erosion and heave/uplift at the downstream toe of the levee are 1.6 for the normal flood water elevation (equal to the freeboard elevation of 1246.0 feet) and 1.3 for the maximum flood water elevation (assumed to be the top of the embankment) (USACE, 2005).

The factor of safety (FOS) for vertical erosion was estimated by dividing the critical gradient (buoyant soil unit weight divided by unit weight of water) by the exit gradient (change in total head divided by distance between measured total heads). The exit gradient was calculated between the toe of the embankment and vertically 2 feet below the toe when the embankment is founded on homogeneous materials. Alternatively, if the embankment is founded on low-permeability materials that are underlain by higher permeability materials, calculations were performed across the entire thickness of the uppermost low permeability layer. The FOS for vertical erosion was only applied at cross-sections where groundwater was passing through the ground surface at or near the downstream toe of the levee. When groundwater was not passing through the ground surface at or near the downstream toe of the levee, only the FOS for heave was calculated.

The FOS for heave or uplift at the toe was determined by dividing total vertical stress by pore water pressure at the interface between a high-permeability material overlain by a low-permeability material. Water above the ground surface was accounted in the heave calculation by subtracting the pore water pressure at the ground surface from the total vertical stress and pore water pressure at the interface between the high and low permeability material.

The results from the analysis for vertical erosion and heave without seepage mitigation are provided in **Table 4-3**. The results of the vertical erosion and heave factors of safety indicate that the embankment and foundation is above the minimum recommended FOS.

Table 4-3 Summary of Factors of Safety for Heave and Erosion at Embankment Toe

Cross Section ID	Hydraulic Condition	Erosion FOS	Heave FOS	Minimum Recommended FOS
CS1	Normal Flood	8.7	2.2	1.6
	Maximum Flood	5.0	2.2	1.3
CS2	Normal Flood	8.6	1.6	1.6
	Maximum Flood	6.9	1.5	1.3
CS3	Normal Flood	3.9	2.1	1.6
	Maximum Flood	2.8	1.9	1.3
CS4	Normal Flood	3.5	2.0	1.6
	Maximum Flood	2.1	1.7	1.3

4.3 Slope Stability Analysis

Two types of stability analyses are typically performed for slopes: the Undrained Strength Stability Analysis (USSA) and the Effective Stress Stability Analysis (ESSA). The USSA case is performed to analyze the case in which loading or unloading is applied rapidly, and excess pore water pressures do not have sufficient time to dissipate during shearing. This scenario typically applies to loading from, for example, embankment construction where the loading takes place quickly relative to the permeability of the soils. Loading from floodwaters qualifies for USSA scenarios.

The ESSA case is performed to account for much slower loading or unloading, no external loading, or the case where excess pore pressures developed during rapid loading or unloading are fully dissipated, in which the drained shear strength of the materials is mobilized and no excess shear-induced pore pressures are present. Final design cases of embankments and excavated slopes also fall into this case. For this reason, the ESSA is often referred to as the "long term" case.

Both USSA and ESSA analyses were performed as part of the slope stability analysis for each of the hydraulic loadings on each cross-section. This is because the initial construction case and flood water levels will cause excess pore water pressures to develop and undrained shear strengths could be mobilized. Long-term design cases based on very slow or no fluctuation of water levels will generally allow for the possibility of drained shear strengths to be mobilized.

In addition to the USSA and ESSA analyses, Barr analyzed the embankment assuming that the water level dropped rapidly from the normal loading condition. This is considered a rapid drawdown condition, which occurs when the stabilizing pressure of the water on the upstream is lost, but the pore water pressures within the dam do not have time to dissipate. This leads to potential instability of embankments. It was considered unlikely that the embankment at the site will ever undergo a rapid drawdown from the maximum (crest height) hydraulic conditions to a water level which provides no support.

The stability of a slope is reported using a FOS value. The FOSis the ratio of the summation of forces and moments that are resisting slope movement to the summation of forces and moments that cause slope movement. These forces and moments could result from increased loading or decreased resistance, which may be caused by variation in pore water pressure and the buttressing effect induced by changes in river levels. The point of "stability" is defined as a FOS equal to 1.0, where the driving forces equal the resisting forces, indicating theoretical failure.

4.3.1 SLOPE/W Parameters

Field and laboratory testing was conducted on materials from the site to evaluate shear strength parameters under drained and undrained conditions. The following sections summarize the reasoning for the selected parameters.

4.3.1.1 Lean Clay

The undrained shear strength of the lean clay was estimated from laboratory testing and SPT testing. Based on the results of the testing, the lean clay soils were subdivided into three groups: hardpan clay, clay, and soft clay. Each category has a different recommended shear strength.

The drained shear strength of the lean clay was estimated based on correlations to the soil's plasticity index, provided by Terzaghi (1996). The hardpan clay is estimated to have the highest drained shear strength, and the weakest clay is likely to have a lower drained shear strength.

The hardpan clay was observed to have high SPT values and high hand penetrometer values, and an undrained shear strength of 4,000 psf was selected. A drained friction angle of 32 degrees is recommended.

The typical strength clay soils at the site have moderate SPT values and hand penetrometer values. Laboratory testing generally indicated that the undrained shear strength ranged from 1,600 to about 3,000 psf. An undrained shear strength of 1,600 psf is recommended for the typical clay soils at the site. A drained friction angle of 31 degrees is recommended for the typical strength clay soils at the project site.

The lower strength clays are generally present near the surface, and have undrained shear strengths ranging from 250 to 750 psf based on hand penetrometer test results and laboratory test results. An undrained shear strength of 500 psf is recommended for the weaker clays. A drained friction angle of 30 degrees is recommended.

Based on the results of laboratory testing, a moist unit weight of 127 pcf is recommended for the clay soil, and a saturated unit weight of 130 pcf was used.

Under rapid drawdown scenarios, the pore pressure is anticipated to remain elevated, while the buoyant force from the slope is removed. No testing was performed in the lean clay, but the values below were assumed based on Barr's experience with lean clay. The effective stress parameters used for the lean clay were a friction angle of 31 degrees, and the total stress parameters were a cohesion of 1,600 psf.

For soft clay, a reduced effective stress friction angle of 30 degrees and total stress cohesion of 500 psf was used under rapid drawdown conditions.

4.3.1.2 Sand Soils

The granular soils are considered free-draining, and the drained parameters were used in both ESSA and USSA analyses. The drained shear strength of the sand soils was estimated from correlations to the measured SPT value (NAVFAC, 1982). A friction angle of 32 degrees is recommended for the clayey sand and clean sand along the proposed alignment.

A moist unit weight of 126 pcf was used for the sand, and the saturated unit weight was taken as 130 pcf.

The drained parameters were considered representative of rapid drawdown scenarios, and an effective friction angle of 32 degrees was used for preliminary analysis.

4.3.1.3 Silt

Silt was not modeled because it is not anticipated to be widespread at the project site.

4.3.1.4 Embankment Fill

The drained shear strength of the recompacted embankment fill was based on correlations to the plasticity index. It was assumed that the drained shear strength of the recompacted clay would be similar to the in-situ clay which would likely be used for fill, provided that it is prepared and compacted properly. A friction angle of 30 degrees was used for the embankment fill.

The undrained shear strength was taken from a previous report prepared by Barr for Moore regarding analysis of the Upper Maple River Dam near Hope, North Dakota (Barr, 2010). The undrained shear strength was determined to be 1,300 psf for that project, and the soils and sites are near each other geographically, so the parameters were assumed to be similar for the preliminary analysis. The saturated unit weight was assumed to be 128 pcf, and the moist unit weight was taken as 119 pcf.

Under rapid drawdown scenarios, the pore pressure is anticipated to remain elevated, while the buoyant force from the slope is removed. No testing was performed in the potential backfill material, but the values below were assumed based on Barr's experience with glacial till lean clay. The effective stress parameters used for the lean clay were a friction angle of 30 degrees, and the total stress parameters were a cohesion of 1,300 psf.

As part of the final design, additional laboratory testing should be performed to develop a more accurate determination of the shear strength of the re-compacted clay used for the embankment fill material.

4.3.1.5 Summary of Shear Strength Parameters

The soils were treated as Mohr-Coulomb materials in the modeling program using the parameters in **Table 4-4** below.

Table 4-4 Recommended Shear Strength Parameters

Material Type	Moist Unit Weight [pcf]	Saturated Unit Weight [pcf]	Drained Condition (ESSA)		Undrained Condition (USSA)		Rapid Drawdown	
			Friction Angle [deg]	Undrained Shear Strength [psf]	Friction Angle [deg]	Undrained Shear Strength [psf]	Effective Stress Friction Angle [deg]	Total Stress Cohesion [psf]
Hardpan Clay	127	130	32	0	0	4000	32	4000
Clay	127	130	31	0	0	1600	31	1600
Soft Clay	127	130	30	0	0	500	30	500
Clean Sand	126	130	30	0	32	0	32	0
Clayey Sand	126	130	30	0	32	0	32	0
Embankment Fill	119	128	30	0	0	1300	30	1300

4.3.2 Stability Analysis

The slope stability analyses were conducted using SLOPE/W, a computer modeling program developed by GEO-Slope International. SLOPE/W uses limit equilibrium theory to compute the FOS of earth and rock slopes. It is capable of using a variety of methods to compute the FOS of a slope while analyzing complex geometry, stratigraphy, and loading conditions. The pore water pressure head file produced by SEEP/W during seepage analysis was imported into SLOPE/W to compute effective stress. As a result, this approach incorporates the calculation of seepage forces when computing the FOS.

Pore water pressures for the slope stability calculations are computed from the flow net during the SEEP/W analyses. Therefore, the integration of SEEP/W seepage pore-water pressures in a SLOPE/W analysis results in a more accurate calculation of FOS than traditional limit equilibrium software, which uses a phreatic line to simulate groundwater.

4.3.2.1 Factor of Safety Calculation and Requirements

Spencer’s method was used to calculate the FOS of the slopes in this stability analysis. This method is typically used because it satisfies both the force and moment equilibrium in determining the FOS. For typical long-term conditions (ESSA) under steady seepage without seismic forces, Barr used the minimum recommended FOS of 1.5 based on requirements from the NRCS (NRCS, 2005; NRCS, 2012). Barr used the minimum recommended end-of-construction (or short term case, USSA) FOS of 1.3 (NRCS, 2005; NRCS, 2012), where pore pressure within the soil has not dissipated when subjected to a shear force. This is recommended for both upstream and downstream slopes. For the hydraulic loading conditions where the water will reach the height of the embankment crest, a long-term FOS of 1.4 was used, since this is considered to be a less-likely loading condition (EM 1110-2-1902, 2003; EM 1110-2-1913, 2000). For the rapid drawdown case, where the water drains out quickly but the pore water pressure remains in the slope, a FOS of 1.2 is recommended (NRCS, 2005; NRCS, 2012), assuming that the water is drawn down from the freeboard height, which was considered more likely to occur than a significant draw down from the embankment crest height. Rapid drawdown conditions from the full embankment height were assumed to not be considered routine for this site and proposed embankment.

Primarily circular potential failure surfaces were used in the analysis. Potential failure surfaces were defined using the entry and exit method. This allows the location of the trial slip surfaces to be chosen manually, or where it is anticipated to enter and exit the ground surface, with a selected number of entry and exit points.

4.4 Results of Slope Stability Modeling

The results of the limit equilibrium stability modeling are provided in this section. For these modeling scenarios, a minimum slip surface thickness of 2 feet was used, therefore small-scale surface sloughing was not considered in the analysis as surficial failures should not affect overall slope stability (commonly assumed to be the maintenance condition). This global stability case is identified in the summary tables.

The assumptions made for the four cross sections analyzed were provided at the beginning of this section.

4.4.1 Slope Stability Results at Cross Section 1

The results of the analysis for Cross Section 1 indicated that the preliminary embankment configuration using side slopes of 3H:1V, a crest width of 8 feet, and a crest height of 1251.0 feet would meet the recommended FOS for all analyzed hydraulic loading scenarios. **Table 4-5** summarizes the various analyses performed and corresponding FOS. The model outputs for Cross Section 1 are included in **Appendix E**.

Table 4-5 Slope Stability Results for Cross Section 1

Scenario	Upstream Water Elevation [feet]	Embankment Height [feet]	Downstream FOS	Upstream FOS	Recommended Minimum FOS
ESSA; No Flood	--	12.7	1.73	1.76	1.50
USSA; No Flood	--		3.28	3.31	1.30
ESSA; Normal Loading	1246.0		1.68	1.86	1.50
USSA; Normal Loading	1246.0		2.74	3.94	1.30
ESSA; Max Loading	1251.0		1.43	2.77	1.40
USSA; Max Loading	1251.0		2.58	5.39	1.30
Rapid Drawdown	1246.0 drawn down to ground water elevation		--	1.76	1.20

4.4.2 Slope Stability Results at Cross Section 2

The results of the analysis for Cross Section 2 indicated that using side slopes of 3H:1V, a crest width of 8 feet, and a crest height of 1251.0 feet would meet recommended FOS for all hydraulic loading scenarios, except undrained conditions during a maximum flood event. **Table 4-6** summarizes the various analyses performed and corresponding factors of safety. The model outputs for Cross Section 2 are included in **Appendix E**.

Table 4-6 Slope Stability Results for Cross Section 2

Scenario	Upstream Water Elevation [feet]	Embankment Height [feet]	Downstream FOS	Upstream FOS	Recommended Minimum FOS
ESSA; No Flood	--	26.7	1.75	1.75	1.50
USSA; No Flood	--		1.44	1.42	1.30
ESSA; Normal Flood	1246.0		1.66	1.95	1.50
USSA; Normal Flood	1246.0		1.33	2.31	1.30
ESSA; Maximum Flood	1251.0		1.54	2.73	1.40
USSA; Maximum Flood	1251.0		1.25	2.74	1.30
Rapid Drawdown	1246.0 drawn down to ground water elevation		--	1.43	1.20

During final design, laboratory testing should be performed to verify the undrained shear strength of the compacted embankment fill. If it is determined that the embankment fill meets the preliminary modeling parameters reported, other alternatives may be necessary to meet the required FOS. Alternative options could consist of a granular filter at the toe of the dam, sand blankets, shallower downstream slopes, or a buttress.

4.4.3 Slope Stability Results at Cross Section 3

The results of the analysis for Cross Section 3 indicated that using side slopes of 3H:1V, a crest width of 8 feet, and a crest height of 1251.0 feet would not meet the required FOS for the long term hydraulic loading scenarios. All other analyses resulted in adequate factors of safety. The drained analyses that did not meet the required safety factors indicated that the slip surface associated with the minimum FOS was very small and largely surficial, and did not propagate through the embankment signifying global failure.

Based on these results, Barr reconsidered the input soil parameters. Assuming that the recompacted clay embankment fill materials will behave fully drained (i.e. there is zero cohesion) is a conservative assumption. In addition, assuming that steady-state conditions are reached is also conservative, as the water is not anticipated to remain at the crest height for a long enough period to induce steady-state conditions (although the exact inundation and detention time has not been provided to Barr). However, steady-state is the currently recommended analysis assumption for dams and levees. Therefore, Barr re-analyzed the slope assuming that the embankment fill and the native clay soils exhibited a modest cohesion of 100 psf using the same embankment configuration. This increase in cohesion increased the FOS to meet the target factors of safety. Based on sensitivity analyses, a reduced value of 50 psf was required for normal flood conditions, and only 90 psf was required for maximum flood conditions.

During final design, laboratory testing should be performed to verify that the soils will exhibit a cohesion of at least 90 psf. If it is determined that the soils will not exhibit this minimum cohesion, other alternatives may be necessary to meet the required FOS. Alternative options could consist of a granular filter at the toe of the dam, sand blankets, shallower downstream slopes, or a buttress. Based on Barr’s experience with lean clay soils, it is anticipated that further laboratory testing will indicate that the soils exhibit cohesion of 90 psf or more under drained conditions.

The factors of safety meet the minimum requirements for the assumed dam geometry with at least 90 psf cohesion for the clay embankment fill. **Table 4-7** summarizes the various analyses performed and corresponding factors of safety. The model outputs for Cross Section 3 are included in **Appendix E**.

Table 4-7 Slope Stability Results for Cross Section 3

Scenario	Upstream Water Elevation [feet]	Embankment Height [feet]	Downstream FOS	Upstream FOS	Recommended Minimum FOS
ESSA; No Flood	--	13.4	1.76	1.75	1.50
USSA; No Flood	--		5.73	5.88	1.30

ESSA; Normal Flood	1246.0		1.20 (1.56 with 50 psf cohesion)	1.69	1.50
USSA; Normal Flood	1246.0		5.53	8.56	1.30
ESSA; Maximum Flood	1251.0		0.91 (1.40 with 90 psf cohesion)	1.99	1.40
USSA; Maximum Flood	1251.0		5.45	11.90	1.30
Rapid Drawdown	1246.0 drawn down to ground water elevation		--	1.75	1.20

4.4.4 Slope Stability Results at Cross Section 4

The results of the analysis for Cross Section 4 indicated that using side slopes of 3H:1V, a crest width of 8 feet, and a crest height of 1251.0 feet would not meet the required FOS for the long term hydraulic loading scenarios. All other analyses resulted in adequate factors of safety. Since this is similar to what was described in **Section 4.4.3** for Cross Section 3, Barr performed a similar analysis, and determined that a modest cohesion of 100 psf for the clay embankment fill would increase the factors of safety to acceptable levels. Based on sensitivity analyses, a reduced value of 50 psf was required for normal flood conditions.

The factors of safety meet the minimum requirements for the assumed dam geometry assuming at least 100 psf cohesion for the clay embankment fill. **Table 4-8** summarizes the various analyses performed and corresponding factors of safety. The model outputs for Cross Section 4 are included in **Appendix E**.

Table 4-8 Slope Stability Results for Cross Section 4

Scenario	Upstream Water Elevation [feet]	Embankment Height [feet]	Downstream FOS	Upstream FOS	Required FOS
ESSA; No Flood	--	10	1.81	1.81	1.50
USSA; No Flood	--		3.36	3.29	1.30
ESSA; Normal Flood	1246.0		1.33 (1.70 with 50 psf cohesion)	1.74	1.50
USSA; Normal Flood	1246.0		3.16	4.06	1.30
ESSA; Maximum Flood	1251.0		0.92 (1.40 with 100 psf cohesion)	2.23	1.40
USSA; Maximum Flood	1251.0		2.81	6.34	1.30
Rapid Drawdown	1246.0 drawn down to ground water elevation		--	1.81	1.20

4.5 Settlement of Existing Soils Due to New Embankment

The construction of an embankment on native soil will increase stress on the soils. The clay soils are likely saturated at shallow depths due to the relatively shallow water table. As such, the clay soils are anticipated to experience long term consolidation settlement, as well as immediate, elastic settlement due to the weight of the fill used to construct the embankment. Settlement was estimated at the center of the embankment, where the impact of the increased load is greatest. The total settlement of the embankment is not necessarily limited by existing codes, but it should be noted that the total settlement of the embankment should be considered during final design to ensure that the required height of the embankment does not fall to below the anticipated hydraulic conditions (i.e. maximum groundwater height and required freeboard).

4.5.1 Primary Settlement from Consolidation Test Results

The subsurface conditions encountered during the field work indicated that the material encountered below the proposed embankment generally consists of clay or sand. The groundwater, as observed during the soil borings, was as shallow as 2.5 feet below the existing grade.

The long-term settlement of clay soils supporting the embankment were computed using consolidation characteristics from laboratory testing and the following equation:

$$S = \frac{C_r}{1+e_o} \cdot L \cdot \log\left(\frac{\sigma'_p}{\sigma'_{vo}}\right) + \frac{C_c}{1+e_o} \cdot L \cdot \log\left(\frac{\sigma'_f}{\sigma'_p}\right) \qquad \text{(Das, 2007)}$$

where:

C_r = recompression index

C_c = compression index

e_o = initial void ratio

L = height of soil layer

σ'_p = past effective stress where soil transitions from overconsolidated to normally consolidated

σ'_{vo} = original effective stress at the midpoint of the clay layer below foundation (normal operating load conditions)

σ'_f = final effective stress equal to $\sigma'_{vo} + \Delta\sigma'$, where $\Delta\sigma'$ = average pressure increase to the clay layer caused by the added load

Using this formula, the primary consoldiation settlement of the embankment can be calculated. To calculate the consolidation settlement, the soil was split into multiple layers, with the effective stress recalculated at the midpoint of each layer. The stress dissipates at greater depth in the ground according to the Poulos and Davis method (FHWA, 1974). The total depth of calculation was taken as twice the approximate width of the embankment footprint. For final design, borings or CPT soundings should be extended until auger or tip refusal are encountered which would provide the appropriate depth at which the settlement calculations would terminate.

Based on the results of the laboratory consolidation tests as discussed in **Section 3.5** and an assumed loading consistent with the embankment design assumed for this report, settlement was estimated for the four cross sections evaluated. Therefore, the analysis consisted of layers of soils with variable compressibility, which closely estimates the in-situ conditions. For the purposes of this report, sand soils and unsaturated cohesive soils were not considered in the consolidation analysis, as the soil structure of granular soils typically exhibits elastic settlement because the excess pore pressure dissipates quickly, and the load is carried by the soil skeleton soon after loading (i.e. during construction). The consolidation parameters discussed in **Section 3.5** represent the anticipated properties of the clay soils at the site based on a review of all available laboratory consolidation data.

The results of the consolidation analysis indicate that the estimated primary consolidation settlement ranged from 1.2 to 2.3 inches, as summarized in **Table 4-9**.

Table 4-9 Summary of Settlement Analysis

Cross Section ID	Primary Consolidation Settlement [inches]
CS1	2.0
CS2	3.5
CS3	2.2
CS4	1.4

The actual primary settlement will likely be slightly higher. The immediate, or elastic settlement was not considered for this analysis, but will likely be realized during construction. Therefore, the total elastic and primary settlement is anticipated to be on the order of 3 to 4 inches at the center of the embankment. A minimum 6-inch overbuild would be recommended for settlement concerns (not including freeboard, superiority, etc.).

4.6 Additional Geotechnical Considerations

The following sections describe some additional consideration for further design of the embankment.

4.6.1 Slope Protection

It is recommended that slope protection be utilized for the constructed embankment. The slope protection should be selected to avoid erosion of the newly constructed embankment, particularly along any slope that will be exposed to moving water during flood events. Slope protection could consist of vegetation, rip-rap, or turf reinforcement. Barr recommends use of a more resilient method (i.e. rip-rap or turf reinforcement) on the upstream slope due to the rural location, potential for erosion due to contact with flood waters, and limited inspection anticipated for the projects once constructed.

4.6.2 Seismic Site Requirements for Foundation Design

The following seismic design criteria are recommended for the design of structures at this site. Seismic design parameters according to the 2012/15 International Building Code (IBC) provided as follows (USGS, 2019b). The seismic values below are specific to boring location B-07 at the site, although the values do not deviate within the extents of the project site.

S_s = 0.047g (Site Class B)
S_1 = 0.020g (Site Class B)
Preliminary Recommended Site Classification: Site Class D

A site Class D is recommended for preliminary design at the site. The above seismic values need to be adjusted accordingly for site class D for structural design (if required). However, seismicity in this area is generally low and likely will not control the design.

4.6.3 In-Situ Shrink/Swell Potential

The shrink/swell potential of a soil is related to its liquid limit and plasticity index. Soils with liquid limit values less than 50 and plasticity index values less than 25 are considered to have low shrink-swell potential. Soils with Liquid Limit values of 50 to 60 and plasticity index values of 25 to 35 are considered to have moderate shrink-swell potential. Soils with liquid limit values greater than 60 and plasticity index values greater than 35 are considered to have high shrink-swell potential (Das, 2006).

Based on the results of the laboratory testing, the measured range of liquid limit values was 21.4 to 36.7 percent, and the measured range of plasticity index values was 3.7 to 15.7 percent. Therefore, the soils at the site are considered to have a low shrink-swell index, and the proposed design should not need to account for potentially swelling soils.

4.6.4 Earthwork Shrink-Swell Factor

The soils will have an earthwork shrink-swell factor and this should be considered during final design. A typical preliminary estimate of 15 percent shrinkage can be used for the feasibility analysis.

4.6.5 Frost depth

The extreme frost penetration depth for the proposed alignment is a depth of 72 inches (NAVFAC, 1982). The frost depth is not anticipated to affect the proposed embankment. However, the infrastructure associated with the proposed embankment should be protected to at least 6 feet for protection from frost.

If site grading and construction is anticipated during cold weather, all snow and ice should be removed from cut and fill areas prior to additional grading. No fill should be placed on frozen subgrades. No frozen soils should be used as fill.

4.6.6 Dispersion Potential

Dispersive soils have their parcels disassociate with some amount of particles going into suspension when immersed in relatively still water. Silt and clay particles exhibit dispersion when the repulsive forces between the particles exceed the attractive forces when saturated. These particles then are carried away with flowing water, weakening the soils and creating seepage paths. For embankments and other water retention structures, the dispersion potential of the foundation and embankment soils should be addressed, as saturation of the soils may lead to dispersion and internal erosion (Maharaj, 2013). Silt and clay soils were observed in the soil borings at the project site. Silt soils often have a lower fraction of clay particles and lack the capillary forces within the soil structure, and are at greater risk for dispersion. In general, the dispersion potential of glacial till is considered to be low due to the higher clay content.

In general, the hydraulic loading conditions on the proposed embankment are anticipated to be relatively short, and steady state conditions may not develop during the short loading periods, which is not considered likely to lead to an internal erosion failure. In addition, the silt layers were observed at depths of 23 to 25 feet below the existing grade and not near the surface. Therefore, the velocity gradient of groundwater at those depths are likely to be very low. Accounting for the available information, the risk of dispersion of the silt is considered low for the project site for the perceived function with no normal upstream pool. Using a properly filtered drainage blanket on the lower portion of the downstream slope would further reduce the potential for piping and internal erosion.

As part of the final design, dispersion potential of the proposed embankment material should be performed.

4.6.7 Selection of Embankment Fill Material

It is recommended to construct the embankment out of homogeneous material to avoid differences in soil behavior and performance. Additional borings or test pits should be performed to evaluate the potential borrow source and material volume. Laboratory testing on remolded samples, including Standard proctors, grain size analysis, dispersion testing, Atterberg limits, and permeability should be performed to better establish the parameters and design performance of the embankment.

Onsite materials free of organic soil and debris can be considered for reuse as embankment fill and backfill associated with the levee construction. The liquid limit of this material should range from 20 to 70 and the plasticity index of these materials should range from 10 to 50. The gradation of the embankment fill that should be met during construction is provided in **Table 4-10**.

Table 4-10 Embankment Fill Material Gradation Specifications

Sieve Size	Range [%]	Test Method
Material Passing the 3/8-inch	100	ASTM D422
Material Passing No. 4	97 - 100	ASTM D422
Material Passing No. 200	55 - 95	ASTM D422

The embankment fill should be placed in loose lifts with a maximum thickness of 9 inches, provided large self-propelled compaction equipment is used, and in loose lifts not exceeding 4 inches if hand-held compaction equipment is used.

4.6.8 Differential Settlement of the Primary Spillway

At the time of this report, the preliminary location of the spillway has been identified and is near Cross Section 2. The spillway consists of a 48-inch diameter reinforced concrete pipe with an invert elevation of 1217.7 feet and located under the embankment. The differential settlement between the center of the pipe (under the heaviest load and tallest part of the embankment) and the edge of the pipe is estimated to be on the order of 2.3 inches. Therefore, the final foundation design should account for this differential settlement. If the estimated settlement is too great for the proposed RCP, an HDPE pipe with greater tolerance for deflection could be considered.

5.0 Summary

5.1 Summary

Barr was retained by Moore to complete a preliminary geotechnical investigation and feasibility level geotechnical evaluation of the alternative Alt2A for the Upper Maple River watershed which consists of an earthen embankment. Upon the completion of the investigation and subsequent laboratory testing, Barr performed geotechnical seepage and stability modeling and performed a primary settlement evaluation of four representative cross sections.

Seepage and slope stability modeling results indicate that the preliminary design for the proposed embankment (clay embankment fill with a crest width of 8 feet, a crest elevation of 1251.0 feet, and side slopes of 3H:1V) is generally suitable. The computed factors of safety for all cross sections indicate that the seepage through and under the embankment meet recommended factors of safety values for erosion and heave. In addition, the slope stability analyses indicate that the proposed embankment will meet the recommended factors of safety based on the assumptions and embankment configurations, with the exception of the long term drained (ESSA) analyses for Cross Sections 3 and 4 under the normal and maximum hydraulic condition. Barr determined through additional analysis that if the clay used for the embankment and the native clay soils are determined to exhibit a cohesion of 100 psf or greater, then the computed FOS should meet the required value. This will need to be verified during final design through further laboratory testing. Alternatively, stability could be achieved by using shallower downstream slopes, granular filters, sand blankets, or buttresses.

The results of the primary settlement analysis indicate that consolidation of saturated fine-grained soils is estimated to range between 1.2 to 2.3 inches. Actual total settlement will likely be on the order of 3 to 4 inches taking into account immediate elastic settlement. A minimum 6-inch overbuild is recommended for design.

5.2 Future Geotechnical Investigation and Analysis

As part of the design phase geotechnical investigation, Barr recommends the following program to further evaluate the proposed embankment.

- CPT soundings in between the previously investigated soil borings along the final alignment to a depth of 40 feet and two soundings advanced until refusal.
    - Flat plate dilatometer testing (DMT) soundings at locations along the proposed final alignment to a depth of 40 feet to determine settlement estimations.
    - Pore pressure dissipation (PPD) testing at various depths and locations along the proposed final alignment to a depth of 40 feet to estimate in-situ horizontal permeability.
- Soil borings coinciding with half of the CPT soundings to verify lithology and to collect additional samples for laboratory testing. Conversely the CPT soundings could be performed near the location of the soil borings completed for this investigation.

- Soil borings or test pits within the proposed borrow area to characterize the proposed embankment fill material. As part of the final design, additional laboratory testing should be performed to develop a more accurate determination of the shear strength of the re-compacted clay used for the embankment fill material.

- Installation of standpipe or vibrating wire piezometers along the alignment to determine the long term groundwater level and seasonal fluctuations.

- Updated or additional seepage and slope stability modeling based on the new investigations and laboratory testing to verify that the assumptions in this report were correct and to evaluate additional critical cross sections, if necessary.

- Evaluation of groundwater control during construction via test pits.

- Review of the proposed spillway design against criteria described in NRCS Technical Release Number 60, Earth Dams and Reservoirs, NRCS (2005).

- Dispersion testing on foundation and proposed borrow area soils to identify the potential risk for piping.

- Chemical testing on soil and groundwater samples for compatibility with concrete design.

- Evaluation of the smaller farm and farm ring levees for protection of homesteads.
    - Soil borings near the property on Section 17 (to the northwest of the alignment) to determine soil lithology for recommendation of embankment configuration.

- Barr recommends collecting additional survey information via traditional methods or light detecting and range (LiDAR) for a more precise representation of the existing conditions for use in final analysis and construction.

- During final design, laboratory testing should be performed to verify that the soils will exhibit a cohesion of at least 100 psf for drained conditions. If it is determined that the soils will not exhibit this minimum cohesion, other alternatives may be necessary to meet the required FOS at Cross Sections 3 and 4.

6.0 Limitations of Analysis

This report is for the exclusive use of Moore Engineering, Inc. Without written approval by Barr, no responsibility to other parties regarding this report is assumed. Barr's evaluation, analysis and recommendations may not be appropriate for other parties or projects. The proposed designs and analysis provided herein should be considered for preliminary use only, and will need to be verified prior to implementation.

No established national standards exist for data retrieval and geotechnical evaluations. Barr has used the methods and procedures described in this report, which generally comply with NRCS recommendations (NRCS, 2005; NRCS, 2012). In performing its services, Barr used the degree of care, skill, and generally accepted engineering methods and practices ordinarily exercised under similar circumstances and under similar budget and time restraints by reputable members of its profession currently practicing in the same locality. Reasonable effort was made to characterize the project site based on the site-specific field work, however, the analyses represent a large area, and variations in stratigraphy, strength, and groundwater conditions from any of the locations at which testing was performed may occur. It is important that engineering and operations personnel regularly observe the embankment slopes and note any changes in strata or water conditions as these may require modification, maintenance, and possible repair to maintain slope stability. No warranty of the investigation, analysis, or design presented herein, expressed or implied, is made.

7.0 References

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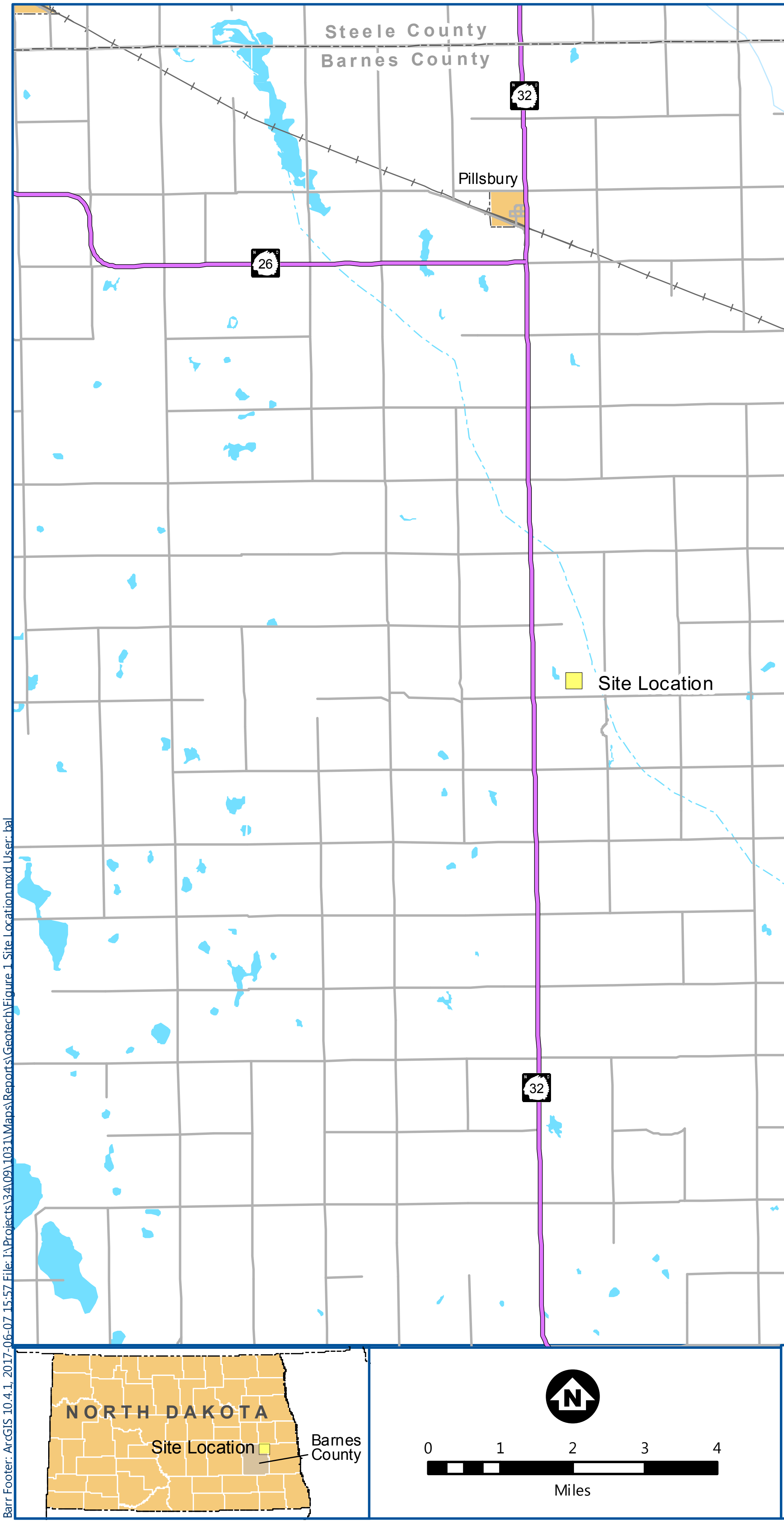
Figures



SITE LOCATION
Proposed Upper Maple River Dam
Barnes County, North Dakota

FIGURE 1

Aerial Imagery: FSA 2016

▬ Proposed Levee Alignment

0 600 1,200 1,800 2,400

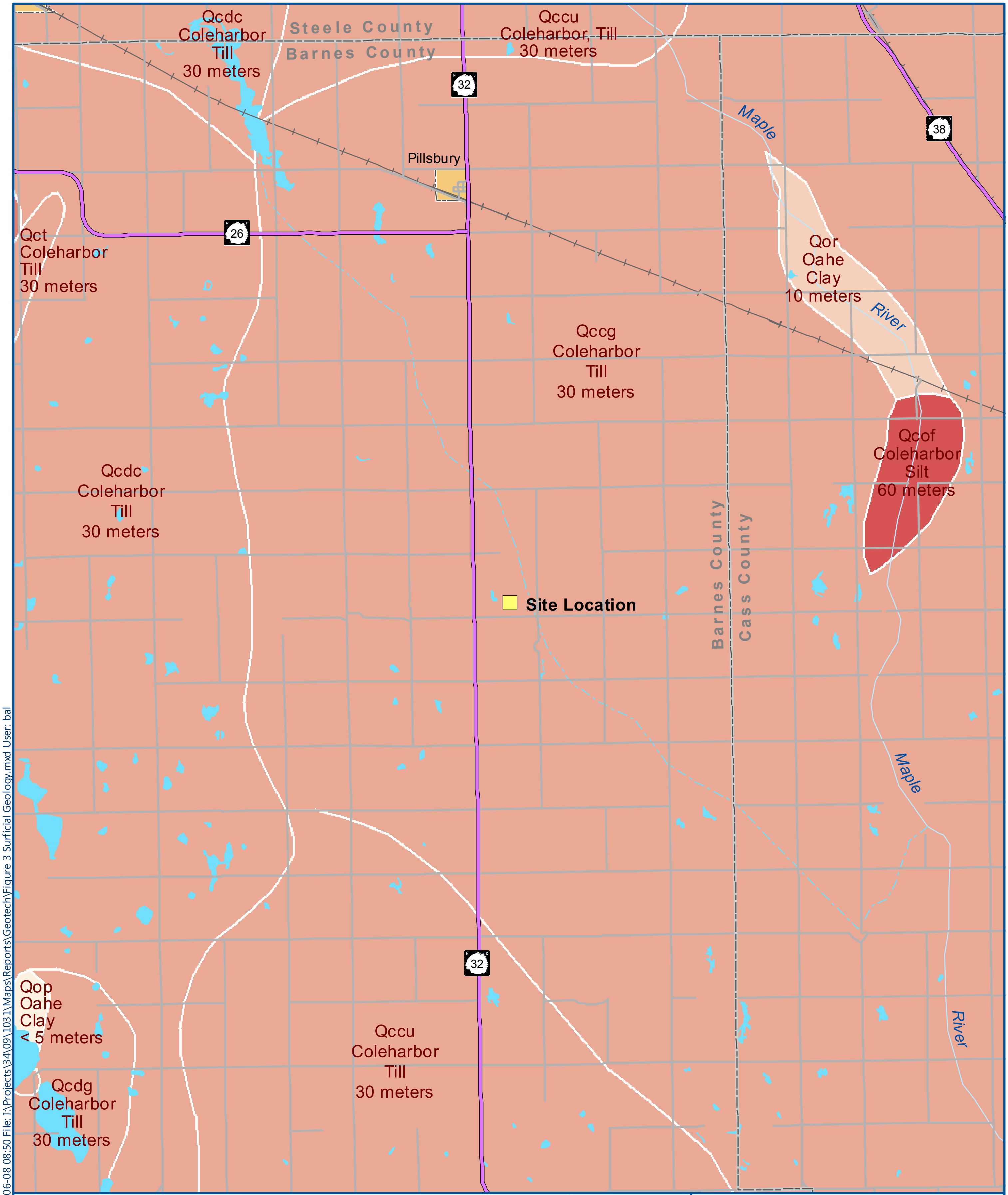
Feet

SITE LAYOUT

Proposed Upper Maple River Dam

Barnes County, North Dakota

FIGURE 2

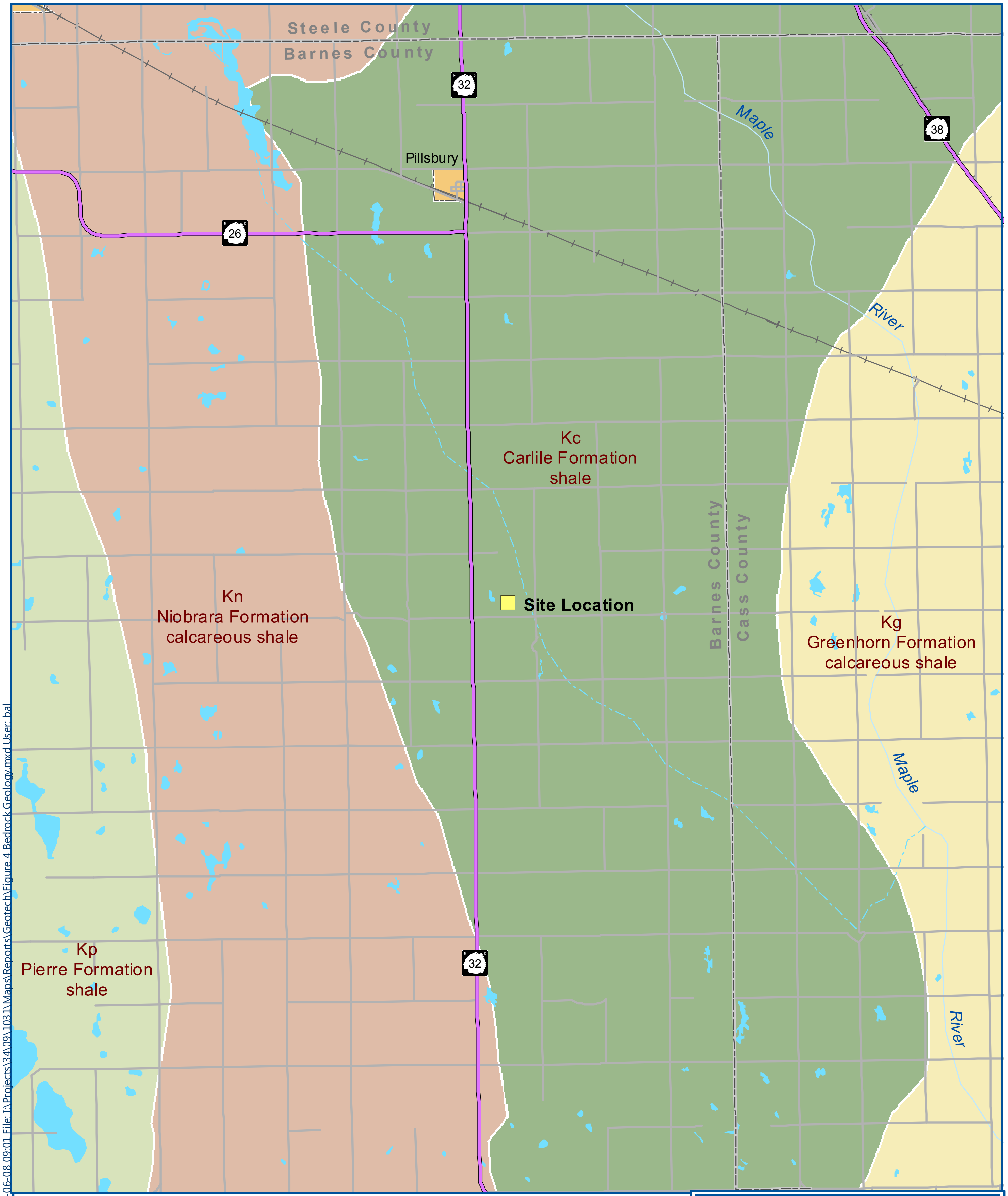


BARR

SURFICIAL GEOLOGY

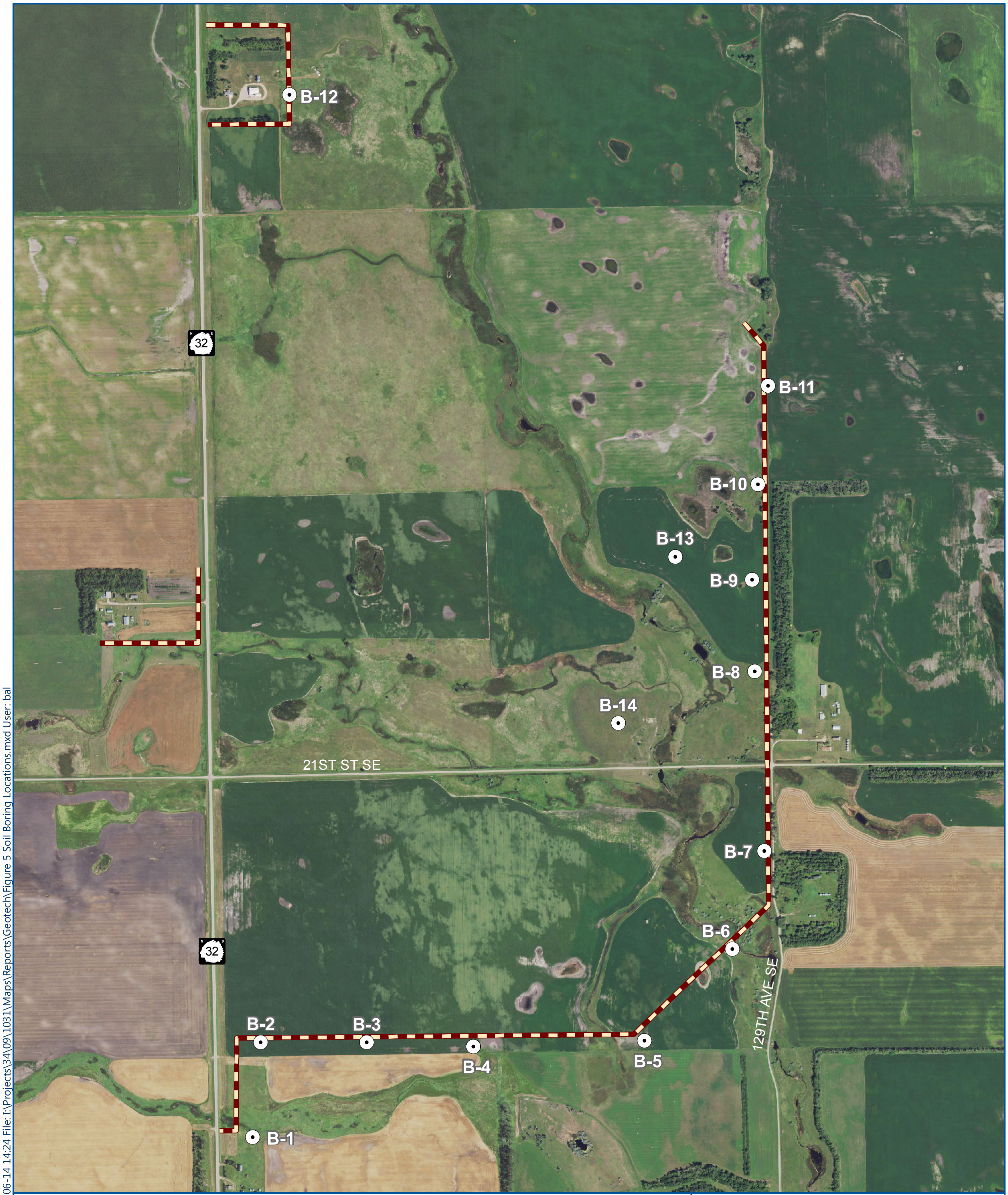
Proposed Upper Maple River Dam
Barnes County, North Dakota

FIGURE 3



BEDROCK GEOLOGY
Proposed Upper Maple River Dam
Barnes County, North Dakota

FIGURE 4



Aerial Imagery: FSA 2016

BARR

⊙ Soil Boring Location

▬ Proposed Levee Alignment

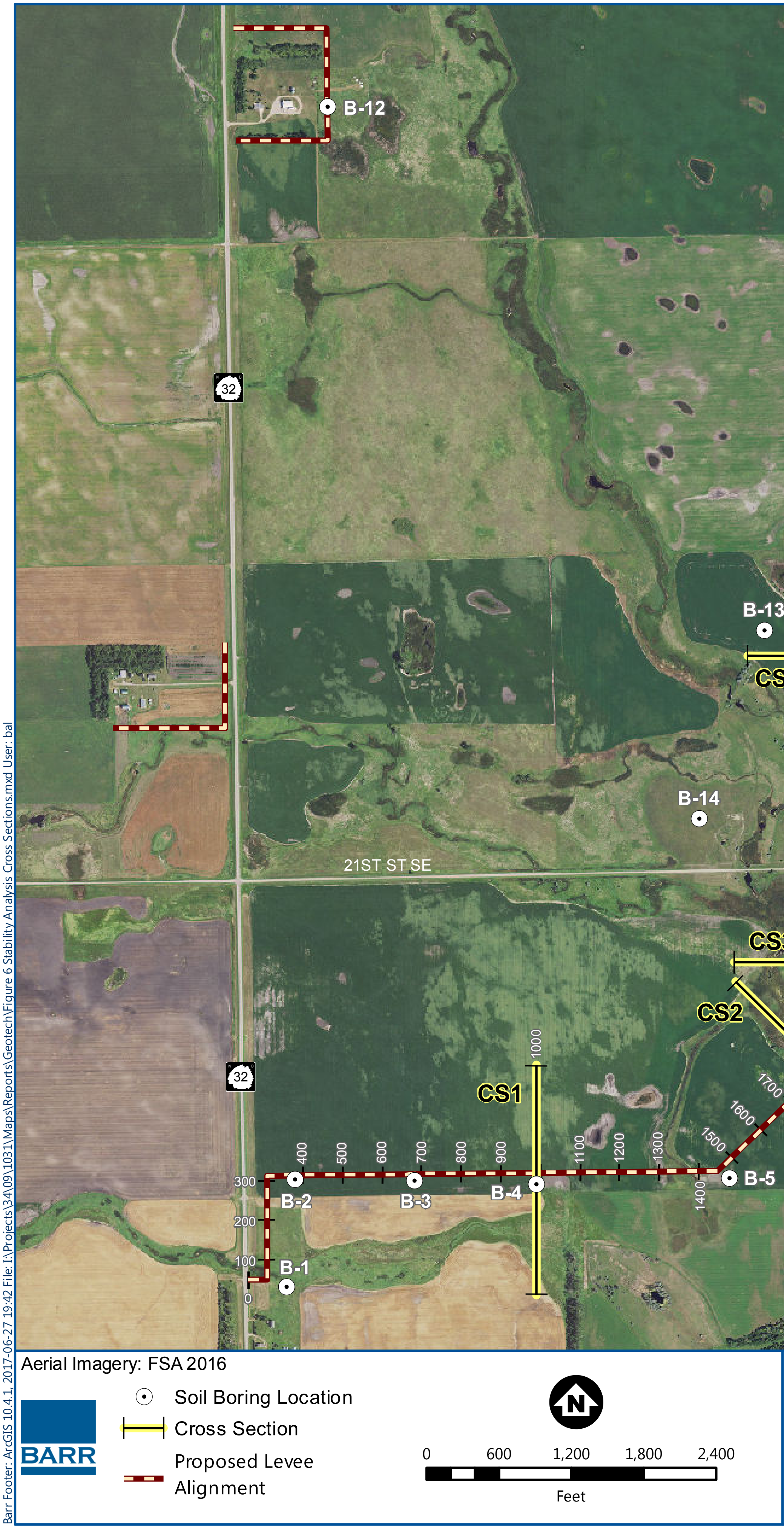
N

0 600 1,200 1,800 2,400

Feet

SOIL BORING LOCATIONS
Proposed Upper Maple River Dam
Barnes County, North Dakota

FIGURE 5



STABILITY ANALYSIS
CROSS SECTIONS
Proposed Upper Maple River Dam
Barnes County, North Dakota

FIGURE 6

Appendix A

Soil Boring Logs

BARR

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4300 MarketPointe Drive Suite 200
Minneapolis, MN 55435
Telephone: 952-832-2600

LOG OF BORING B-01

Sheet 1 of 1

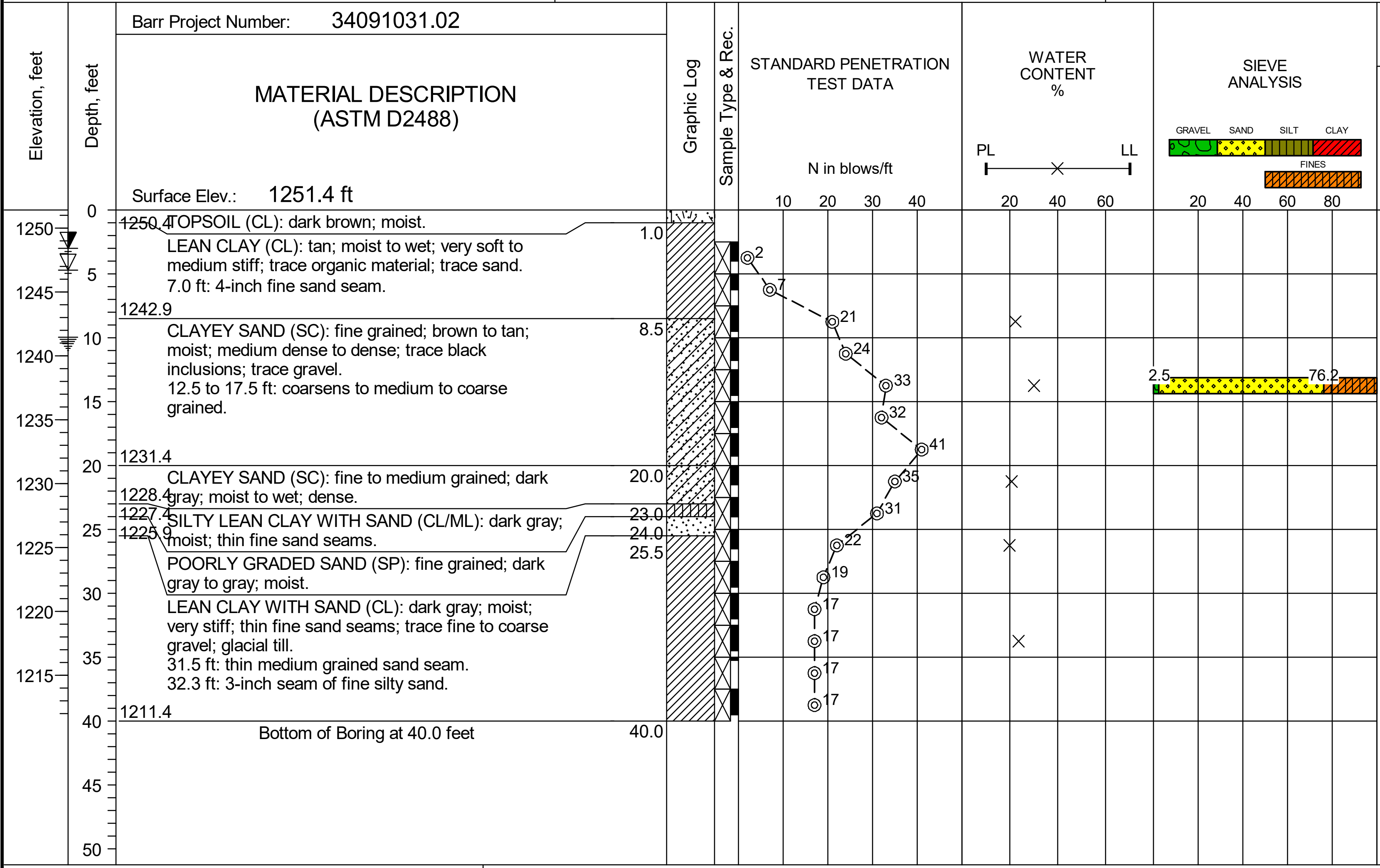
Project:	Upper Maple River Watershed Detention Plan_Site Alt2A	Location:	Barnes Couty, North Dakota	Client:	Moore Engineering, Inc.

Barr Project Number: 34091031.02

MATERIAL DESCRIPTION (ASTM D2488)

Surface Elev.: 1251.4 ft

Elevation, feet	Material Description	Depth, feet
1250.4	TOPSOIL (CL): dark brown; moist.	1.0
1242.9	LEAN CLAY (CL): tan; moist to wet; very soft to medium stiff; trace organic material; trace sand. 7.0 ft: 4-inch fine sand seam.	8.5
1231.4	CLAYEY SAND (SC): fine grained; brown to tan; moist; medium dense to dense; trace black inclusions; trace gravel. 12.5 to 17.5 ft: coarsens to medium to coarse grained.	20.0
1228.4	CLAYEY SAND (SC): fine to medium grained; dark gray; moist to wet; dense.	23.0
1227.4	SILTY LEAN CLAY WITH SAND (CL/ML): dark gray; moist; thin fine sand seams.	24.0
1225.9	POORLY GRADED SAND (SP): fine grained; dark gray to gray; moist.	25.5
1211.4	LEAN CLAY WITH SAND (CL): dark gray; moist; very stiff; thin fine sand seams; trace fine to coarse gravel; glacial till. 31.5 ft: thin medium grained sand seam. 32.3 ft: 3-inch seam of fine silty sand.	40.0
	Bottom of Boring at 40.0 feet	40.0



Physical Properties

WC %	γ_d pcf	ϕ °	Q_u tsf	Q_p tsf	Gs	RQD %
				0.25		
				0.5		
22.4	100.9		3.25	3.75		
30.1						
20.7						
20	103.5		1.61	4.5		
				4		
				3		
23.7				2.75		
				2.75		

Completion Depth:	40.0
Date Boring Started:	4/13/17
Date Boring Completed:	4/13/17
Logged By:	AJL
Drilling Contractor:	Interstate Drilling Services
Drilling Method:	HSA
Ground Surface Elevation:	1251.43
Coordinates:	Lat: 47.09993° Long: -97.78918°
Datum:	NAD83

Remarks:

SAMPLE TYPES

☒ SPLIT SPOON

WATER LEVELS (ft)

≣	Wet Cave-in Depth	11.0
▽	After Drilling	4.7
▼	At Time of Drilling Based on soil moisture. Sampler wet at 10'.	3.0

LEGEND

MC	Moisture Content	Q_u	Unconfined Compression
γ	Dry Unit Weight	Q_p	Hand Penetrometer UC
ϕ	Friction Angle	Gs	Specific Gravity
		RQD	Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

M:\GINTPROJECTS\34091031.02 UPPER MAPLE RIVE ALT2A.GPJ BARRLIBRARY.GLB HORIZONTAL LOG REPORT BARR GEOTECH TEMPLATE.GDT

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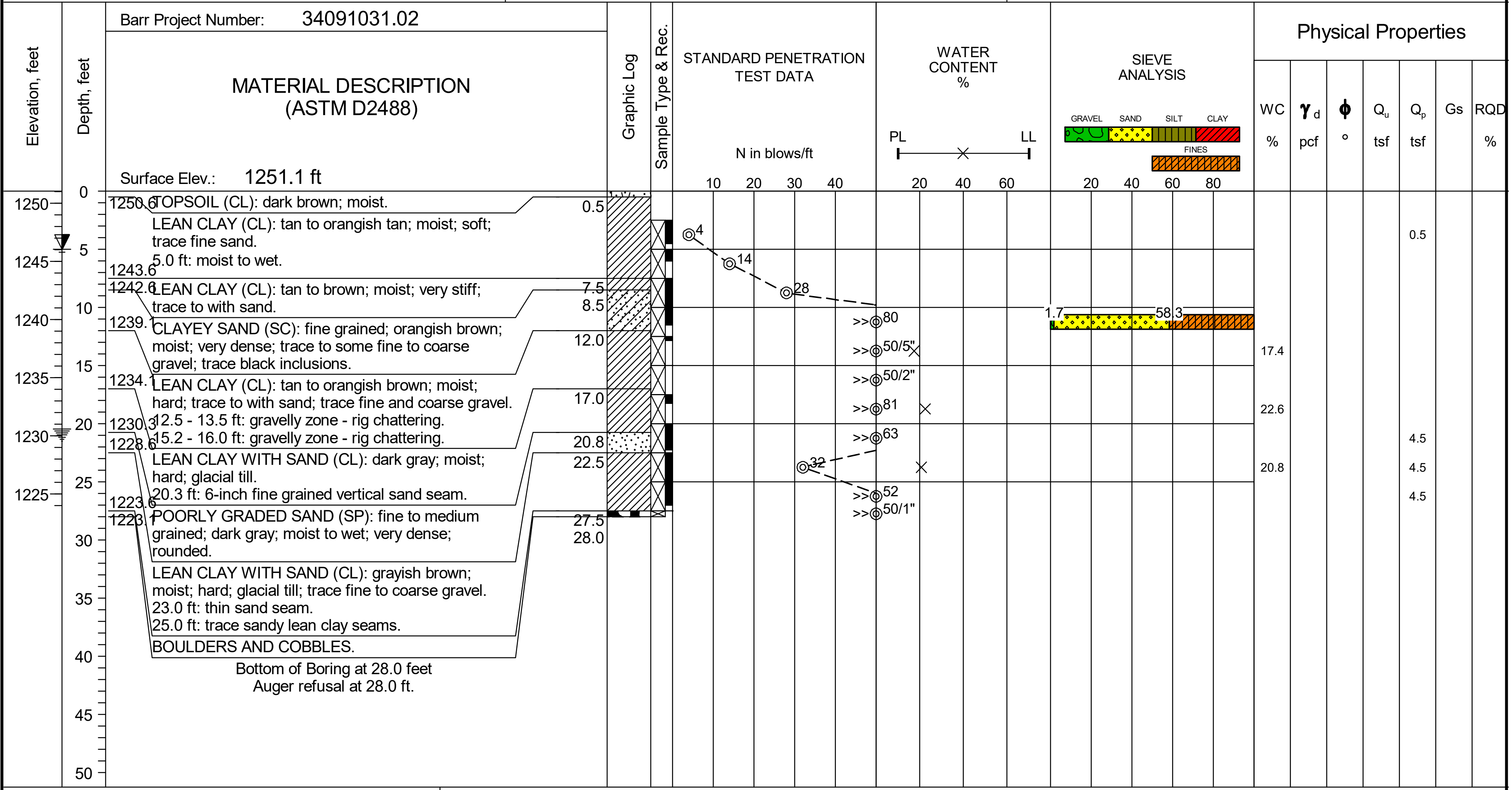
LOG OF BORING B-02

Sheet 1 of 1

Project:	Upper Maple River Watershed Detention Plan_Site Alt2A	Location:	Barnes Couty, North Dakota	Client:	Moore Engineering, Inc.

Barr Project Number: 34091031.02

Surface Elev.: 1251.1 ft



Elevation, feet	Depth, feet	MATERIAL DESCRIPTION (ASTM D2488)
1250.6	0.5	TOPSOIL (CL): dark brown; moist.
1243.6	7.5	LEAN CLAY (CL): tan to orangish tan; moist; soft; trace fine sand. 5.0 ft: moist to wet.
1242.6	8.5	LEAN CLAY (CL): tan to brown; moist; very stiff; trace to with sand.
1239.1	12.0	CLAYEY SAND (SC): fine grained; orangish brown; moist; very dense; trace to some fine to coarse gravel; trace black inclusions.
1234.1	17.0	LEAN CLAY (CL): tan to orangish brown; moist; hard; trace to with sand; trace fine and coarse gravel. 12.5 - 13.5 ft: gravelly zone - rig chattering. 15.2 - 16.0 ft: gravelly zone - rig chattering.
1230.3	20.8	LEAN CLAY WITH SAND (CL): dark gray; moist; hard; glacial till. 20.3 ft: 6-inch fine grained vertical sand seam.
1228.6	22.5	POORLY GRADED SAND (SP): fine to medium grained; dark gray; moist to wet; very dense; rounded.
1223.6	27.5	LEAN CLAY WITH SAND (CL): grayish brown; moist; glacial till; trace fine to coarse gravel. 23.0 ft: thin sand seam. 25.0 ft: trace sandy lean clay seams.
1223.1	28.0	BOULDERS AND COBBLES.

Bottom of Boring at 28.0 feet
Auger refusal at 28.0 ft.

Completion Depth:	28.0
Date Boring Started:	4/12/17
Date Boring Completed:	4/12/17
Logged By:	AJL
Drilling Contractor:	Interstate Drilling Services
Drilling Method:	HSA
Ground Surface Elevation:	1251.06
Coordinates:	Lat: 47.10237° Long: -97.78882°
Datum:	NAD83

Remarks:

SAMPLE TYPES

☒ SPLIT SPOON

WATER LEVELS (ft)

Wet Cave-in Depth	21.5
After Drilling	Dry
At Time of Drilling Based on soil moisture	5.0

LEGEND

MC	Moisture Content	Q_u	Unconfined Compression
γ	Dry Unit Weight	Q_p	Hand Penetrometer UC
ϕ	Friction Angle	Gs	Specific Gravity
		RQD	Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

BARR
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LOG OF BORING B-03

Sheet 1 of 1

Project: Upper Maple River Watershed Detention Plan_Site Alt2A

Location: Barnes Couty, North Dakota

Client: Moore Engineering, Inc.

Barr Project Number: 34091031.02

Elevation, feet | Depth, feet

MATERIAL DESCRIPTION
(ASTM D2488)

Surface Elev.: 1242.6 ft

1242.1 TOPSOIL (CL): dark brown; moist. 0.5

1237.8 POORLY GRADED SAND (SP): fine to coarse grained; orangish tan; moist; medium dense. 4.8

1234.6 LEAN CLAY (CL): oranigsh tan to brown; moist; very stiff; trace fine to coarse gravel; trace sand.
6.25 ft: thin gravelly sand seam. 8.0

1233.1 CLAYEY SAND (SC): fine grained; brown; moist to wet; medium dense. 9.5

1228.1 LEAN CLAY (CL): dark gray; moist; very stiff; trace sand.
12.25 - 12.5 ft: coarse gravel. 14.5

1226.6 CLAYEY SAND (SC): fine grained; dark gray; wet; medium dense; trace fine to coarse gravel. 16.1

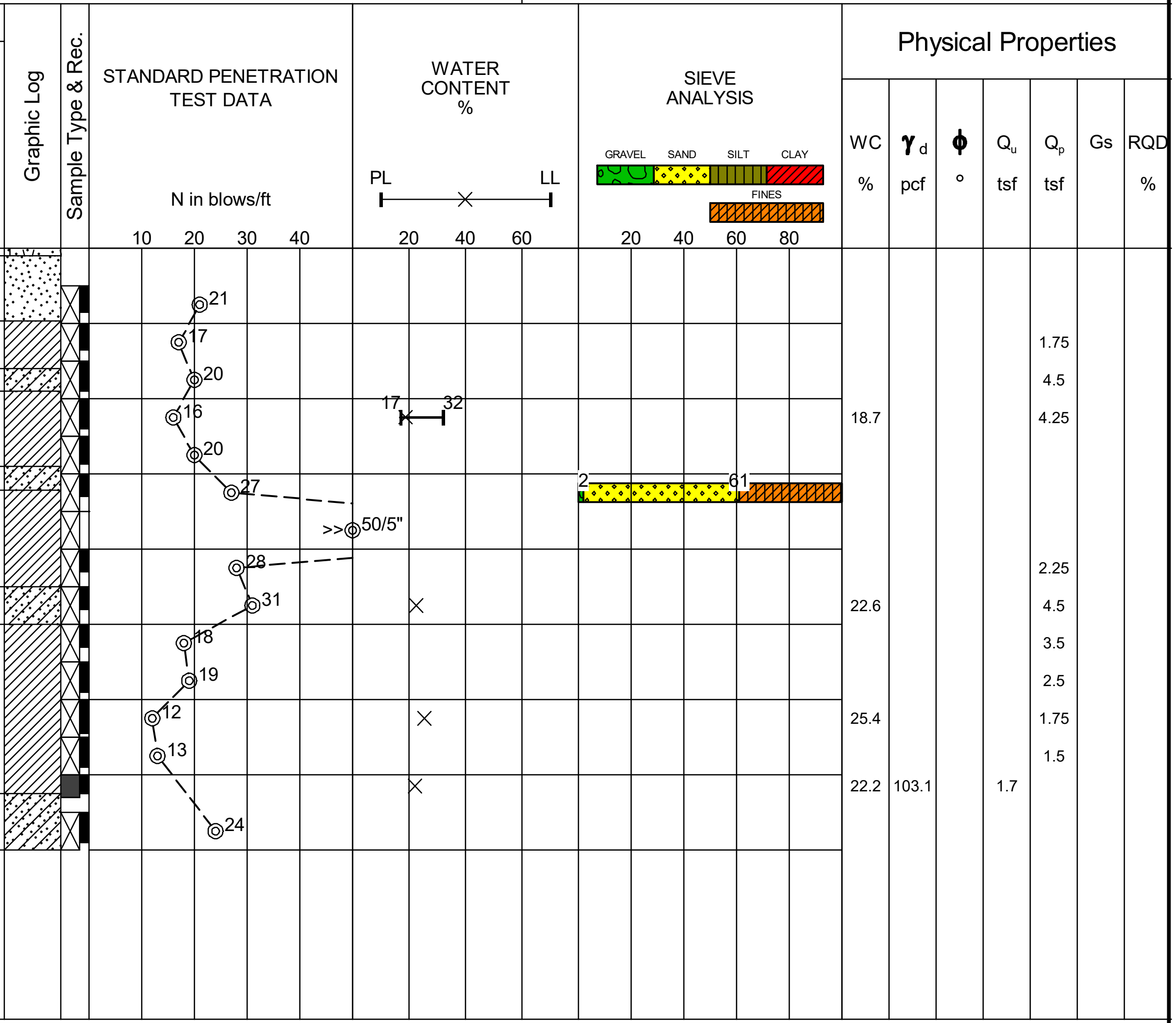
1220.1 LEAN CLAY (CL): dark gray; moist to wet; very stiff to hard; trace medium grained sand.
17.0 - 18.0 ft: encountered boulder. 22.5

1217.6 CLAYEY SAND (SC): fine grained; dark gray; wet; dense; trace fine to coarse gravel. 25.0

1206.4 LEAN CLAY WITH SAND (CL): dark gray; moist to wet; stiff to very stiff.
27.25 ft: fine to coarse gravel seam.
28.5 ft: 3-inch silty sand seam.
32.5 ft: occasional thin sand seams. 36.3

1202.6 CLAYEY SAND (SC): fine grained; dark gray; wet; medium dense; increasing silt with depth. 40.0

Bottom of Boring at 40.0 feet



Completion Depth:	40.0
Date Boring Started:	4/12/17
Date Boring Completed:	4/12/17
Logged By:	AJL
Drilling Contractor:	Interstate Drilling Services
Drilling Method:	HSA
Ground Surface Elevation:	1242.64
Coordinates:	Lat: 47.10232° Long: -97.78484°
Datum:	NAD83

Remarks: Qu value at 35 ft is from UU test.

SAMPLE TYPES

☒ SPLIT SPOON
■ 3-inch Shelby Tube

WATER LEVELS (ft)

≣	Wet Cave-in Depth	15.0
▽	After Drilling	Dry
▼	At Time of Drilling Based on soil moisture	8.0

LEGEND

MC	Moisture Content	Q_u	Unconfined Compression
γ	Dry Unit Weight	Q_p	Hand Penetrometer UC
ϕ	Friction Angle	Gs	Specific Gravity
		RQD	Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

BARR

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4300 MarketPointe Drive Suite 200
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Telephone: 952-832-2600

LOG OF BORING B-04

Sheet 1 of 1

Project: Upper Maple River Watershed Detention Plan_Site Alt2A

Location: Barnes Couty, North Dakota

Client: Moore Engineering, Inc.

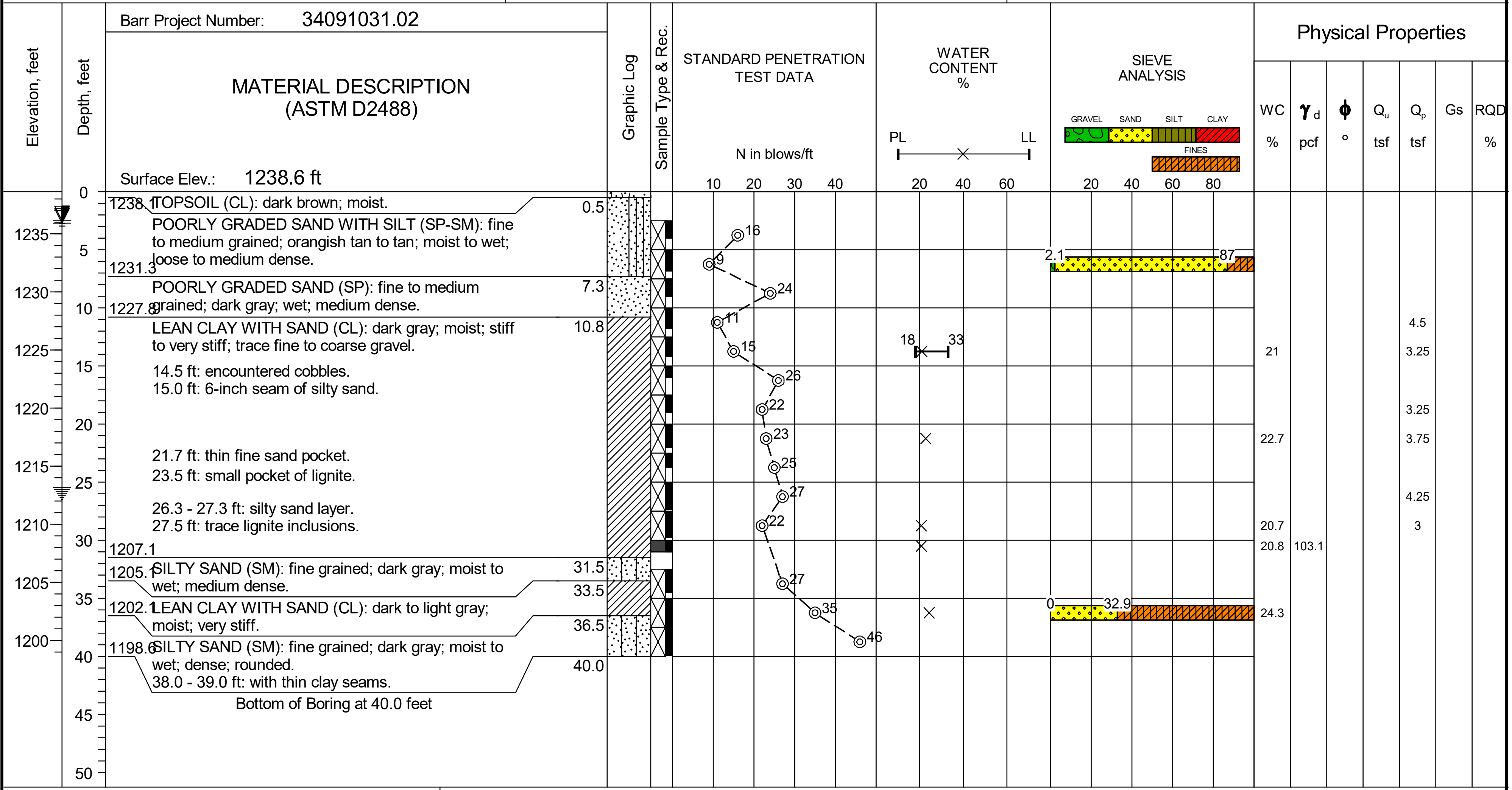
Barr Project Number: 34091031.02

Surface Elev.: 1238.6 ft

MATERIAL DESCRIPTION (ASTM D2488)

Elevation, feet	Material Description	Depth, feet
1238.1	TOPSOIL (CL): dark brown; moist.	0.5
1231.3	POORLY GRADED SAND WITH SILT (SP-SM): fine to medium grained; orangish tan to tan; moist to wet; loose to medium dense.	7.3
1227.8	POORLY GRADED SAND (SP): fine to medium grained; dark gray; wet; medium dense.	10.8
1207.1	LEAN CLAY WITH SAND (CL): dark gray; moist; stiff to very stiff; trace fine to coarse gravel. 14.5 ft: encountered cobbles. 15.0 ft: 6-inch seam of silty sand. 21.7 ft: thin fine sand pocket. 23.5 ft: small pocket of lignite. 26.3 - 27.3 ft: silty sand layer. 27.5 ft: trace lignite inclusions.	31.5
1205.1	SILTY SAND (SM): fine grained; dark gray; moist to wet; medium dense.	33.5
1202.1	LEAN CLAY WITH SAND (CL): dark to light gray; moist; very stiff.	36.5
1198.6	SILTY SAND (SM): fine grained; dark gray; moist to wet; dense; rounded. 38.0 - 39.0 ft: with thin clay seams.	40.0

Bottom of Boring at 40.0 feet



Completion Depth:	40.0		
Date Boring Started:	4/12/17		
Date Boring Completed:	4/12/17		
Logged By:	AJL		
Drilling Contractor:	Interstate Drilling Services		
Drilling Method:	HSA		
Ground Surface Elevation:	1238.63		
Coordinates:	Lat: 47.10218° Long: -97.78081°		
Datum:	NAD83		

Remarks: Large area of ponded water about 50 ft east of staked location. Observed wetland area to southeast.

SAMPLE TYPES

☒ SPLIT SPOON

■ 3-inch Shelby Tube

WATER LEVELS (ft)

≡	Wet Cave-in Depth	26.5
▽	After Drilling	2.7
▼	At Time of Drilling	2.5

LEGEND

MC	Moisture Content	Q_u	Unconfined Compression
γ	Dry Unit Weight	Q_p	Hand Penetrometer UC
ϕ	Friction Angle	Gs	Specific Gravity
		RQD	Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

M:\GINT\PROJECTS\34091031.02 UPPER MAPLE RIVE ALT2A.GPJ BARRLIBRARY.GLB HORIZONTAL LOG REPORT BARR GEOTECH TEMPLATE.GDT

BARR

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LOG OF BORING B-05

Sheet 1 of 1

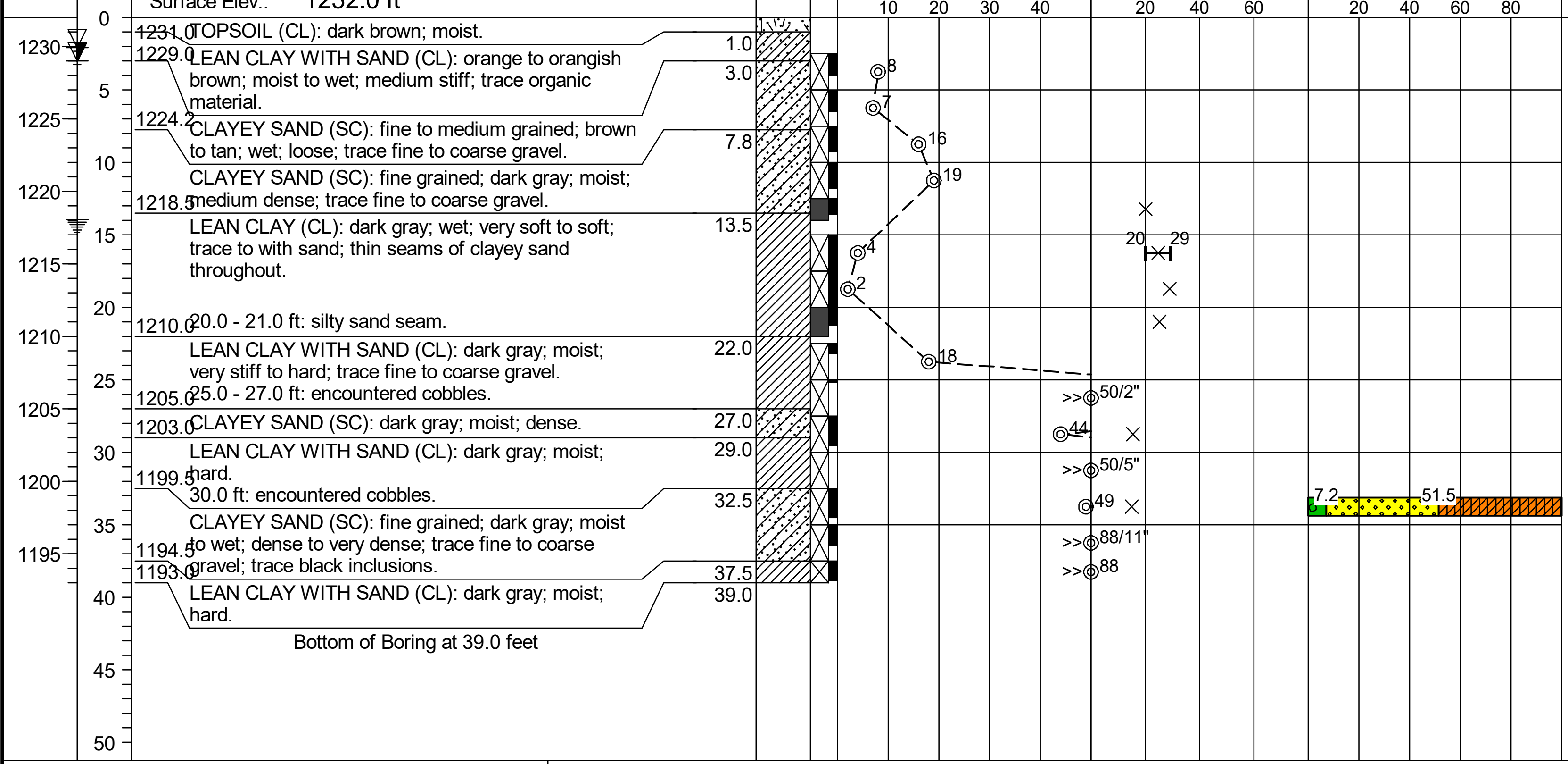
Project:	Upper Maple River Watershed Detention Plan_Site Alt2A	Location:	Barnes Couty, North Dakota	Client:	Moore Engineering, Inc.

Barr Project Number: 34091031.02

Surface Elev.: 1232.0 ft

Elevation, feet	MATERIAL DESCRIPTION (ASTM D2488)	Depth, feet
1231.0	TOPSOIL (CL): dark brown; moist.	1.0
1229.0	LEAN CLAY WITH SAND (CL): orange to orangish brown; moist to wet; medium stiff; trace organic material.	3.0
1224.2	CLAYEY SAND (SC): fine to medium grained; brown to tan; wet; loose; trace fine to coarse gravel.	7.8
1218.5	CLAYEY SAND (SC): fine grained; dark gray; moist; medium dense; trace fine to coarse gravel.	13.5
1210.0	LEAN CLAY (CL): dark gray; wet; very soft to soft; trace to with sand; thin seams of clayey sand throughout. 20.0 - 21.0 ft: silty sand seam.	22.0
1205.0	LEAN CLAY WITH SAND (CL): dark gray; moist; very stiff to hard; trace fine to coarse gravel. 25.0 - 27.0 ft: encountered cobbles.	27.0
1203.0	CLAYEY SAND (SC): dark gray; moist; dense.	29.0
1199.5	LEAN CLAY WITH SAND (CL): dark gray; moist; hard. 30.0 ft: encountered cobbles.	32.5
1194.5	CLAYEY SAND (SC): fine grained; dark gray; moist to wet; dense to very dense; trace fine to coarse gravel; trace black inclusions.	37.5
1193.0	LEAN CLAY WITH SAND (CL): dark gray; moist; hard.	39.0

Bottom of Boring at 39.0 feet



Physical Properties

WC %	γ_d pcf	φ °	Q_u tsf	Q_p tsf	Gs	RQD %
20.1	108.4					
24.8				0.25		
29.1						
25.2	98.9		0.56			
				0.75		
15.4						
14.9						

Completion Depth:	39.0
Date Boring Started:	4/12/17
Date Boring Completed:	4/12/17
Logged By:	AJL
Drilling Contractor:	Interstate Drilling Services
Drilling Method:	HSA
Ground Surface Elevation:	1231.98
Coordinates:	Lat: 47.10226° Long: -97.77436°
Datum:	NAD83

Remarks: Wet area about 100 ft west of staked location. Qu value at 20 ft is from UU test.

SAMPLE TYPES

☒ SPLIT SPOON

■ 3-inch Shelby Tube

WATER LEVELS (ft)

Wet Cave-in Depth		15.0
▽	After Drilling	2.1
▼	At Time of Drilling Based on soil moisture. Rod wet at 10 ft	3.0

LEGEND

MC	Moisture Content	Q_u	Unconfined Compression
γ	Dry Unit Weight	Q_p	Hand Penetrometer UC
ϕ	Friction Angle	Gs	Specific Gravity
		RQD	Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

BARR

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LOG OF BORING B-06

Sheet 1 of 1

Project:	Upper Maple River Watershed Detention Plan_Site Alt2A	Location:	Barnes Couty, North Dakota	Client:	Moore Engineering, Inc.

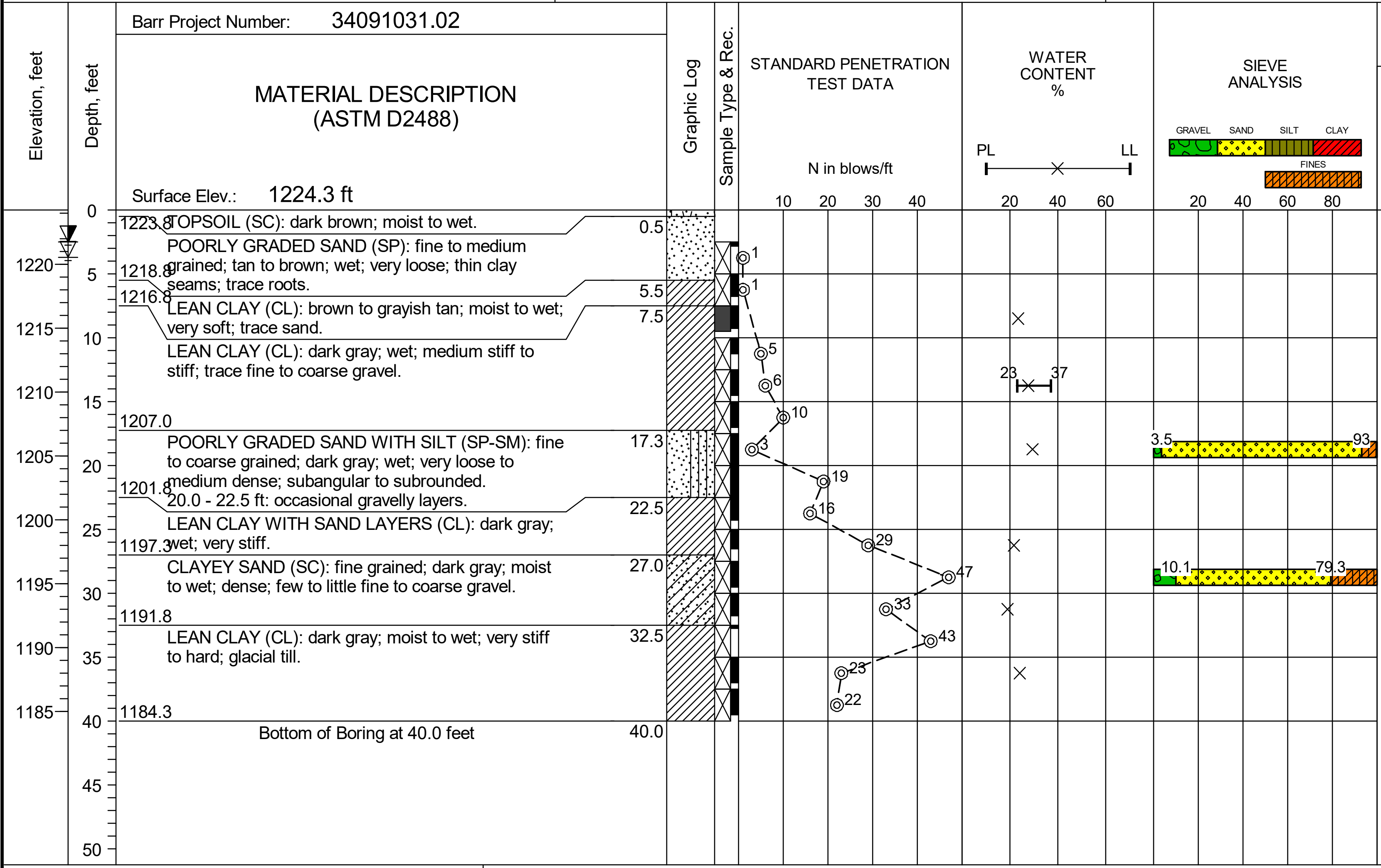
Barr Project Number: 34091031.02

MATERIAL DESCRIPTION (ASTM D2488)

Surface Elev.: 1224.3 ft

Elevation, feet	Material Description	Depth, feet
1223.8	TOPSOIL (SC): dark brown; moist to wet.	0.5
1218.8	POORLY GRADED SAND (SP): fine to medium grained; tan to brown; wet; very loose; thin clay seams; trace roots.	5.5
1216.8	LEAN CLAY (CL): brown to grayish tan; moist to wet; very soft; trace sand.	7.5
1207.0	LEAN CLAY (CL): dark gray; wet; medium stiff to stiff; trace fine to coarse gravel.	17.3
1201.8	POORLY GRADED SAND WITH SILT (SP-SM): fine to coarse grained; dark gray; wet; very loose to medium dense; subangular to subrounded. 20.0 - 22.5 ft: occasional gravelly layers.	22.5
1197.3	LEAN CLAY WITH SAND LAYERS (CL): dark gray; wet; very stiff.	27.0
1191.8	CLAYEY SAND (SC): fine grained; dark gray; moist to wet; dense; few to little fine to coarse gravel.	32.5
1184.3	LEAN CLAY (CL): dark gray; moist to wet; very stiff to hard; glacial till.	40.0

Bottom of Boring at 40.0 feet



Physical Properties

WC %	γd pcf	ϕ °	Qu tsf	Qp tsf	Gs	RQD %
				0.25		
23.5	104.1		0.71			
				0.25		
27.6				1.5		
				3.25		
29.5						
21.7				4.5		
18.9						
24.1				1.75		
				2		

Completion Depth:	40.0
Date Boring Started:	4/11/17
Date Boring Completed:	4/11/17
Logged By:	AJL
Drilling Contractor:	Interstate Drilling Services
Drilling Method:	HSA
Ground Surface Elevation:	1224.27
Coordinates:	Lat: 47.10457° Long: -97.77100°
Datum:	NAD83

Remarks: Offset about 130 ft southwest of staked location due to slough and river/creek. Boring was moved to west side of creek. Qu value at 7.5 ft is from UU test.

SAMPLE TYPES

☒ SPLIT SPOON

■ 3-inch Shelby Tube

WATER LEVELS (ft)

▽ After Drilling 3.7
Cave depth: Unknown. Tape measure sticking to sides at 13.6'.

▼ At Time of Drilling 2.5
Based on soil moisture. Rod wet at 5 ft

LEGEND

MC	Moisture Content	Q_u	Unconfined Compression
γ	Dry Unit Weight	Q_p	Hand Penetrometer UC
ϕ	Friction Angle	Gs	Specific Gravity
		RQD	Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

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LOG OF BORING B-07

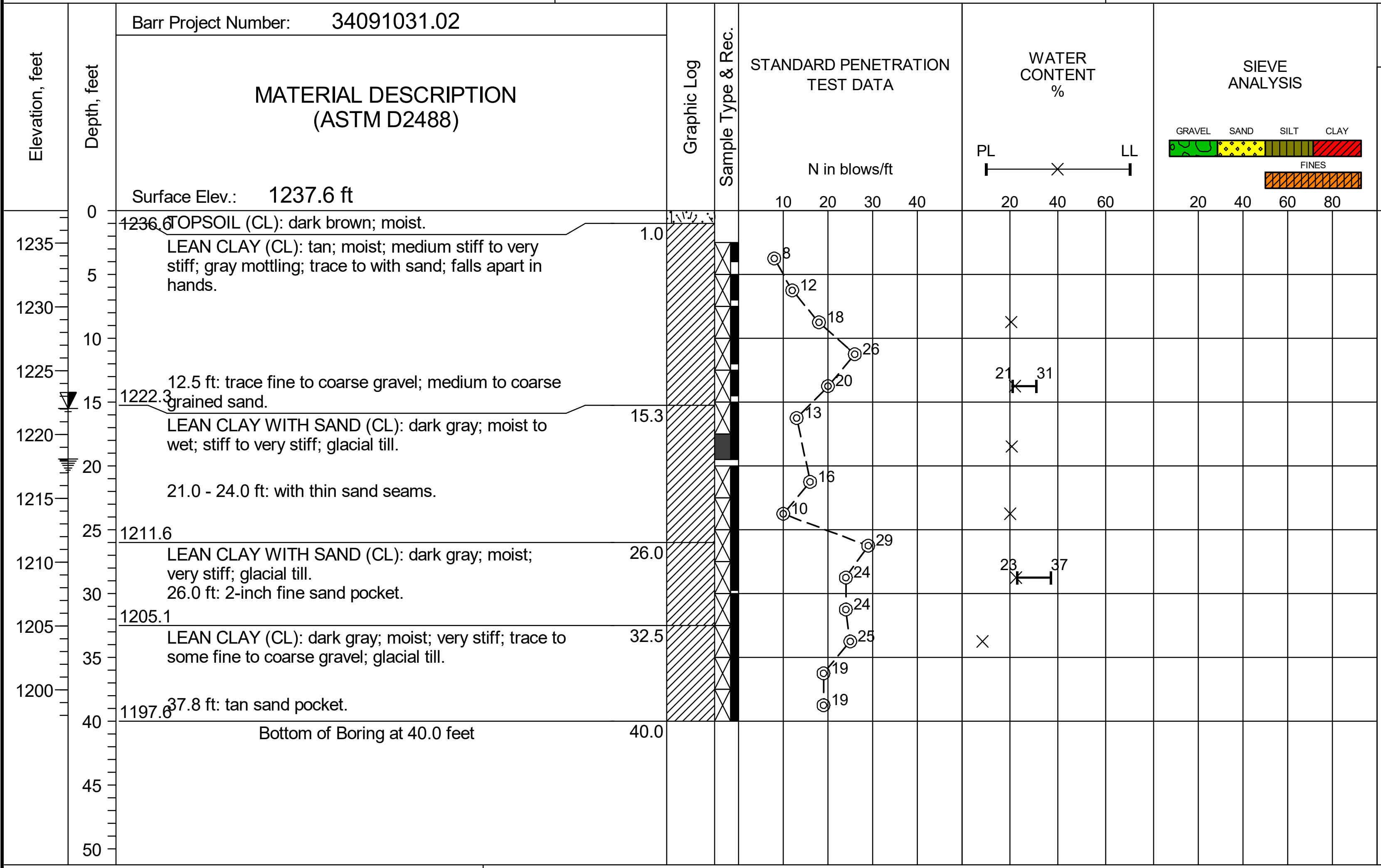
Sheet 1 of 1

Project:	Upper Maple River Watershed Detention Plan_Site Alt2A	Location:	Barnes Couty, North Dakota	Client:	Moore Engineering, Inc.

Barr Project Number: 34091031.02

Surface Elev.: 1237.6 ft

Elevation, feet	MATERIAL DESCRIPTION (ASTM D2488)	Depth, feet
1236.6	TOPSOIL (CL): dark brown; moist.	1.0
	LEAN CLAY (CL): tan; moist; medium stiff to very stiff; gray mottling; trace to with sand; falls apart in hands.	
	12.5 ft: trace fine to coarse gravel; medium to coarse grained sand.	
1222.3		15.3
	LEAN CLAY WITH SAND (CL): dark gray; moist to wet; stiff to very stiff; glacial till.	
	21.0 - 24.0 ft: with thin sand seams.	
1211.6		26.0
	LEAN CLAY WITH SAND (CL): dark gray; moist; very stiff; glacial till. 26.0 ft: 2-inch fine sand pocket.	
1205.1		32.5
	LEAN CLAY (CL): dark gray; moist; very stiff; trace to some fine to coarse gravel; glacial till.	
	37.8 ft: tan sand pocket.	
1197.6		40.0
	Bottom of Boring at 40.0 feet	



Physical Properties

WC %	γ d pcf	ϕ °	Q_u tsf	Q_p tsf	Gs	RQD %
				2.5		
				1.5		
20.5						
22.1				3		
				1.5		
20.8	106.9		1.58			
				1		
20.2				2.75		
22.6						
8.5				4.5		

Completion Depth:	40.0
Date Boring Started:	4/11/17
Date Boring Completed:	4/11/17
Logged By:	AJL
Drilling Contractor:	Interstate Drilling Services
Drilling Method:	HSA
Ground Surface Elevation:	1237.56
Coordinates:	Lat: 47.10708° Long: -97.76974°
Datum:	NAD83

Remarks: Offset 10 ft west of staked location due to overhead powerlines. Qu value at 17.5 ft is from UU test.

SAMPLE TYPES

☒ SPLIT SPOON

■ 3-inch Shelby Tube

WATER LEVELS (ft)

≡	Wet Cave-in Depth	20.5
▽	After Drilling Dry	
▼	At Time of Drilling Based on soil moisture.	15.5

LEGEND

MC	Moisture Content	Q_u	Unconfined Compression
γ	Dry Unit Weight	Q_p	Hand Penetrometer UC
ϕ	Friction Angle	Gs	Specific Gravity
		RQD	Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

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LOG OF BORING B-08

Sheet 1 of 1

Project:	Upper Maple River Watershed Detention Plan_Site Alt2A	Location:	Barnes Couty, North Dakota	Client:	Moore Engineering, Inc.

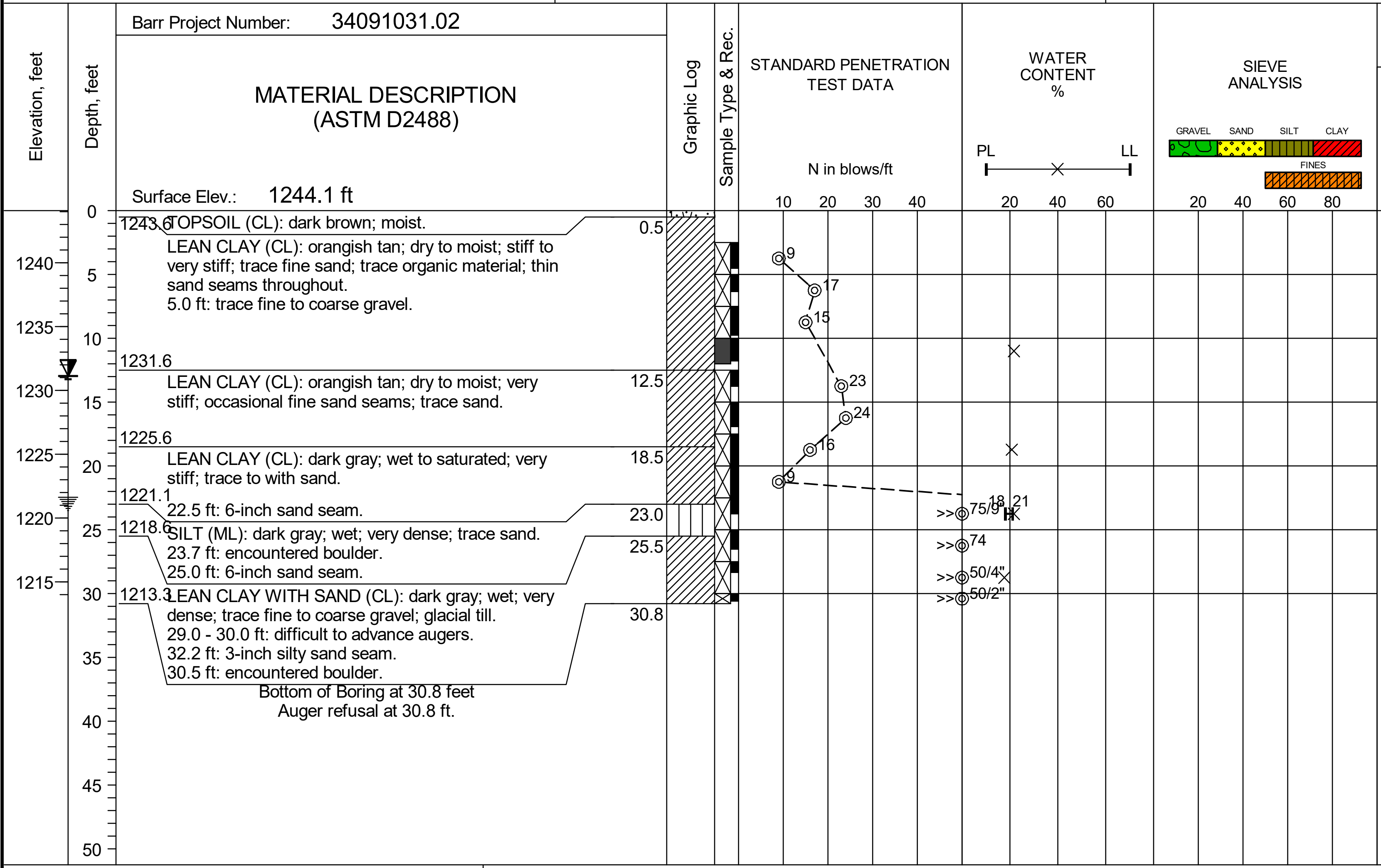
Barr Project Number: 34091031.02

MATERIAL DESCRIPTION
(ASTM D2488)

Surface Elev.: 1244.1 ft

Elevation, feet	MATERIAL DESCRIPTION	Depth, feet
1243.6	TOPSOIL (CL): dark brown; moist.	0.5
1231.6	LEAN CLAY (CL): orangish tan; dry to moist; stiff to very stiff; trace fine sand; trace organic material; thin sand seams throughout. 5.0 ft: trace fine to coarse gravel.	12.5
1225.6	LEAN CLAY (CL): orangish tan; dry to moist; very stiff; occasional fine sand seams; trace sand.	18.5
1221.1	LEAN CLAY (CL): dark gray; wet to saturated; very stiff; trace to with sand. 22.5 ft: 6-inch sand seam.	23.0
1218.6	SILT (ML): dark gray; wet; very dense; trace sand. 23.7 ft: encountered boulder. 25.0 ft: 6-inch sand seam.	25.5
1213.3	LEAN CLAY WITH SAND (CL): dark gray; wet; very dense; trace fine to coarse gravel; glacial till. 29.0 - 30.0 ft: difficult to advance augers. 32.2 ft: 3-inch silty sand seam. 30.5 ft: encountered boulder.	30.8

Bottom of Boring at 30.8 feet
Auger refusal at 30.8 ft.



Physical Properties

WC %	γ d pcf	ϕ °	Qu tsf	Qp tsf	Gs	RQD %
				3		
				1.5		
21.6	102.1		1.73			
				1.5		
20.7				1		
				1.75		
21.7				4.5		
17.7				4.5		

Completion Depth:	30.8
Date Boring Started:	4/11/17
Date Boring Completed:	4/11/17
Logged By:	AJL
Drilling Contractor:	Interstate Drilling Services
Drilling Method:	HSA
Ground Surface Elevation:	1244.08
Coordinates:	Lat: 47.11171° Long: -97.77000°
Datum:	NAD83

Remarks: Offset 20 ft west of staked location due to overhead powerlines. Creek and lower elevation spot southwest of staked location about 200 to 300 ft. Qu value at 10 ft is from UU test.

SAMPLE TYPES

☒ SPLIT SPOON
■ 3-inch Shelby Tube

WATER LEVELS (ft)

≡	Wet Cave-in Depth	23.5
▽	After Drilling	12.9
▼	At Time of Drilling	13.0

LEGEND

MC	Moisture Content	Q_u	Unconfined Compression
γ	Dry Unit Weight	Q_p	Hand Penetrometer UC
ϕ	Friction Angle	Gs	Specific Gravity
		RQD	Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

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BARR

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LOG OF BORING B-09

Sheet 1 of 1

Project: Upper Maple River Watershed Detention Plan_Site Alt2A

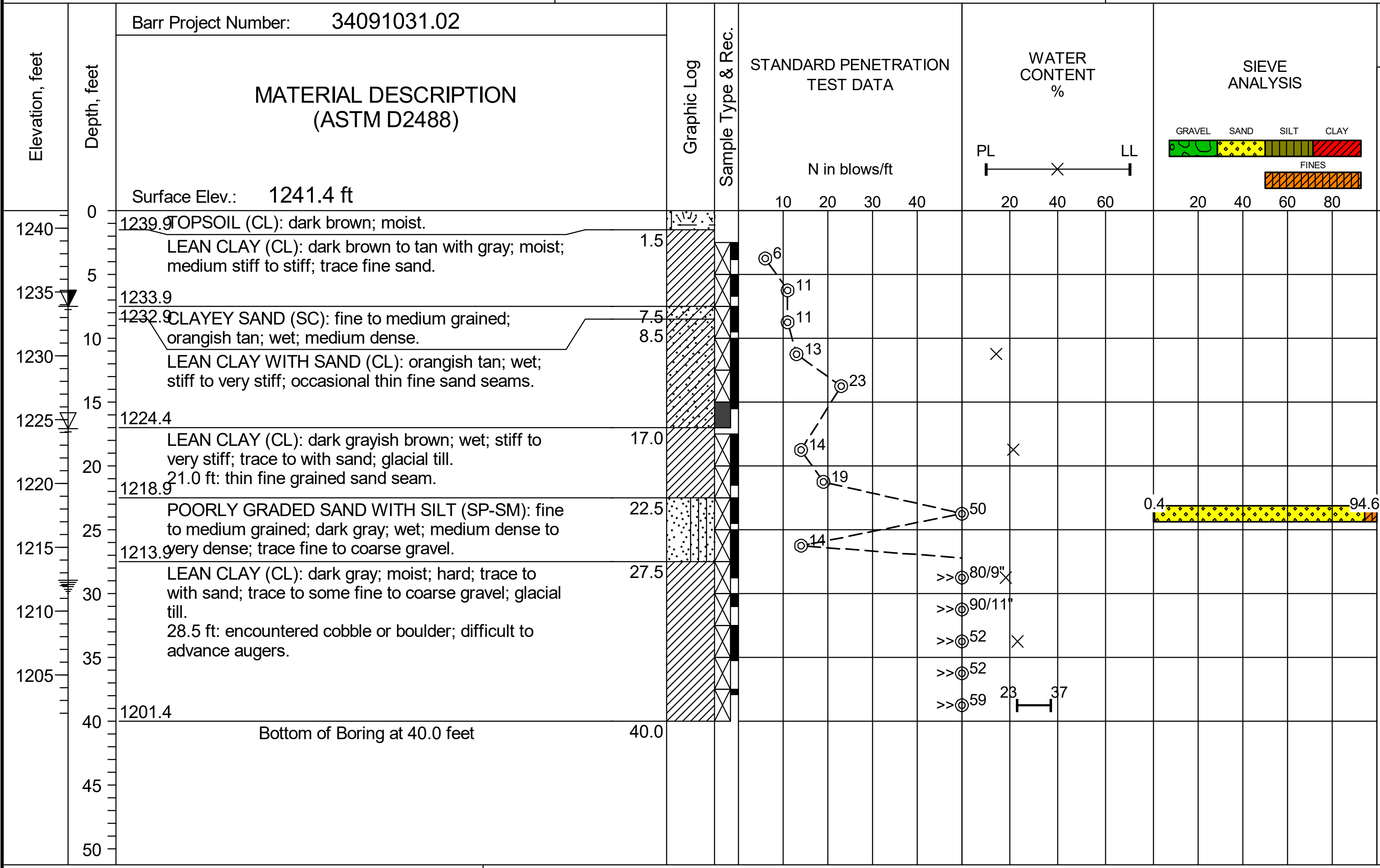
Location: Barnes Couty, North Dakota

Client: Moore Engineering, Inc.

Barr Project Number: 34091031.02

Surface Elev.: 1241.4 ft

Elevation, feet	MATERIAL DESCRIPTION (ASTM D2488)	Depth, feet
1239.9	TOPSOIL (CL): dark brown; moist.	1.5
1233.9	LEAN CLAY (CL): dark brown to tan with gray; moist; medium stiff to stiff; trace fine sand.	7.5
1232.9	CLAYEY SAND (SC): fine to medium grained; orangish tan; wet; medium dense.	8.5
1224.4	LEAN CLAY WITH SAND (CL): orangish tan; wet; stiff to very stiff; occasional thin fine sand seams.	17.0
1218.9	LEAN CLAY (CL): dark grayish brown; wet; stiff to very stiff; trace to with sand; glacial till. 21.0 ft: thin fine grained sand seam.	22.5
1213.9	POORLY GRADED SAND WITH SILT (SP-SM): fine to medium grained; dark gray; wet; medium dense to very dense; trace fine to coarse gravel.	27.5
1201.4	LEAN CLAY (CL): dark gray; moist; hard; trace to with sand; trace to some fine to coarse gravel; glacial till. 28.5 ft: encountered cobble or boulder; difficult to advance augers.	40.0
	Bottom of Boring at 40.0 feet	



Physical Properties

WC %	γ_d pcf	ϕ °	Q_u tsf	Q_p tsf	Gs	RQD %
				0.5		
				2		
				0.75		
14.3	120.6		3.24	1.25		
				1.5		
21.4				1.75		
				4		
				4.5		
18.4						
23.2						

Completion Depth:	40.0
Date Boring Started:	4/11/17
Date Boring Completed:	4/11/17
Logged By:	AJL
Drilling Contractor:	Interstate Drilling Services
Drilling Method:	HSA
Ground Surface Elevation:	1241.39
Coordinates:	Lat: 47.11407° Long: -97.77005°
Datum:	NAD83

Remarks: Offset 40 ft west of staked location due to overhead powerlines. Lower elevation spots to northwest, west, and southwest.

SAMPLE TYPES

☒ SPLIT SPOON
■ 3-inch Shelby Tube

WATER LEVELS (ft)

Wet Cave-in Depth	30.0
▽ After Drilling	17.1
▼ At Time of Drilling	7.5

LEGEND

MC	Moisture Content	Q_u	Unconfined Compression
γ	Dry Unit Weight	Q_p	Hand Penetrometer UC
ϕ	Friction Angle	Gs	Specific Gravity
		RQD	Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

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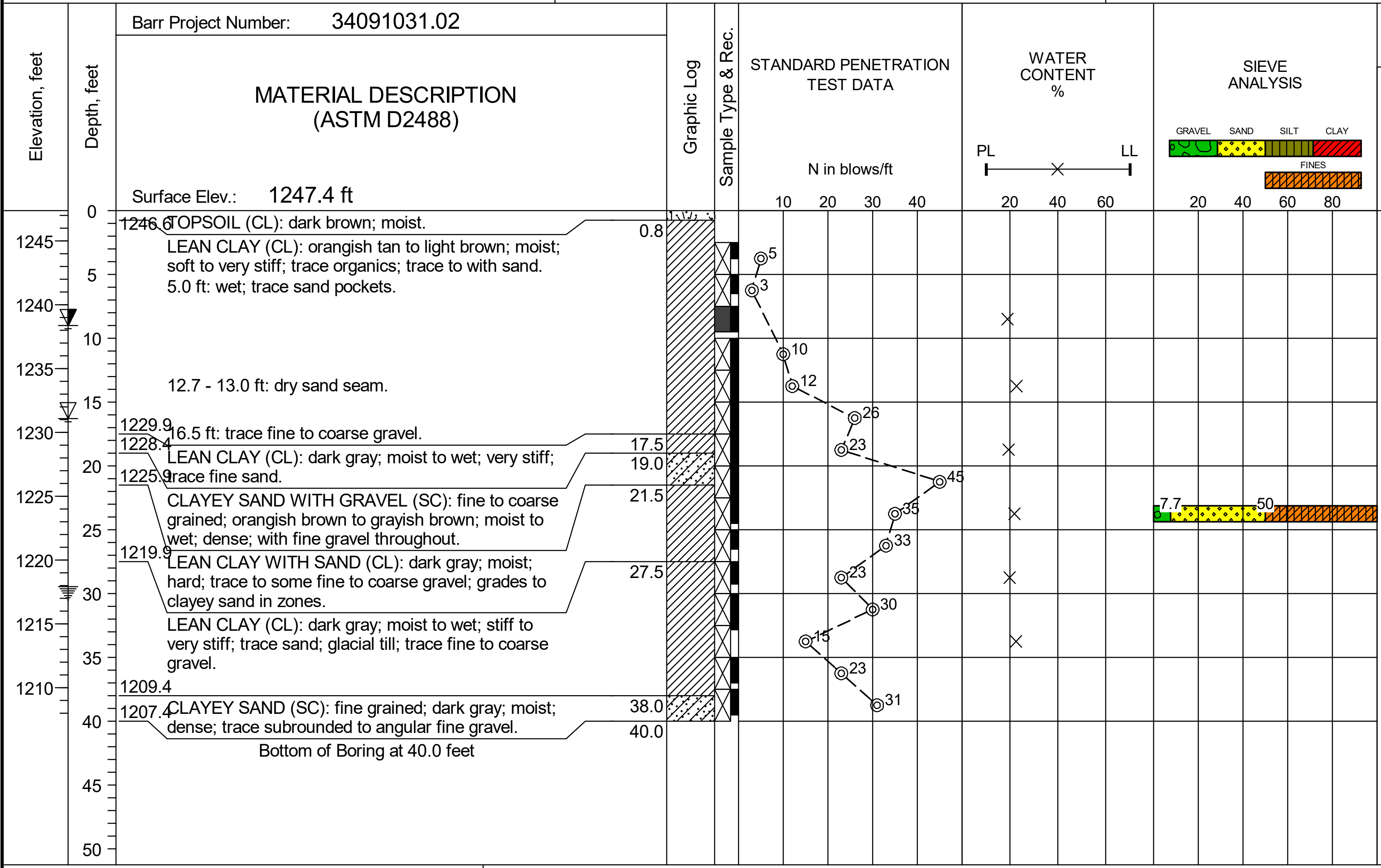
LOG OF BORING B-10

Sheet 1 of 1

Project:	Upper Maple River Watershed Detention Plan_Site Alt2A	Location:	Barnes Couty, North Dakota	Client:	Moore Engineering, Inc.

Barr Project Number: 34091031.02

Surface Elev.: 1247.4 ft



1246.6 — 0.8
TOPSOIL (CL): dark brown; moist.

LEAN CLAY (CL): orangish tan to light brown; moist; soft to very stiff; trace organics; trace to with sand.
5.0 ft: wet; trace sand pockets.

12.7 - 13.0 ft: dry sand seam.

16.5 ft: trace fine to coarse gravel.

1229.9 — 17.5
LEAN CLAY (CL): dark gray; moist to wet; very stiff; trace fine sand.

1228.4 — 19.0
CLAYEY SAND WITH GRAVEL (SC): fine to coarse grained; orangish brown to grayish brown; moist to wet; dense; with fine gravel throughout.

1225.9 — 21.5
LEAN CLAY WITH SAND (CL): dark gray; moist; hard; trace to some fine to coarse gravel; grades to clayey sand in zones.

1219.9 — 27.5
LEAN CLAY (CL): dark gray; moist to wet; stiff to very stiff; trace sand; glacial till; trace fine to coarse gravel.

1209.4 — 38.0
CLAYEY SAND (SC): fine grained; dark gray; moist; dense; trace subrounded to angular fine gravel.

1207.4 — 40.0
Bottom of Boring at 40.0 feet

Physical Properties

WC %	γd pcf	ϕ °	Qu tsf	Qp tsf	Gs	RQD %
				0.25		
19.1	108.7					
				1.5		
22.7				0.5		
				3		
19.5				0.75		
21.8						
19.8	103.6		2.04	1.75		
				3.5		
22.6				1.25		
				1.75		

Completion Depth:	40.0
Date Boring Started:	4/10/17
Date Boring Completed:	4/10/17
Logged By:	AJL
Drilling Contractor:	Interstate Drilling Services
Drilling Method:	HSA
Ground Surface Elevation:	1247.38
Coordinates:	Lat: 47.11652° Long: -97.76977°
Datum:	NAD83

Remarks: Offset 30 ft east of staked location due to overhead powerlines.

SAMPLE TYPES

☒ SPLIT SPOON

■ 3-inch Shelby Tube

WATER LEVELS (ft)

Wet Cave-in Depth	30.5
After Drilling	16.3
At Time of Drilling	9.0

LEGEND

MC	Moisture Content	Q_u	Unconfined Compression
γ	Dry Unit Weight	Q_p	Hand Penetrometer UC
ϕ	Friction Angle	Gs	Specific Gravity
		RQD	Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

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Telephone: 952-832-2600

LOG OF BORING B-11

Sheet 1 of 1

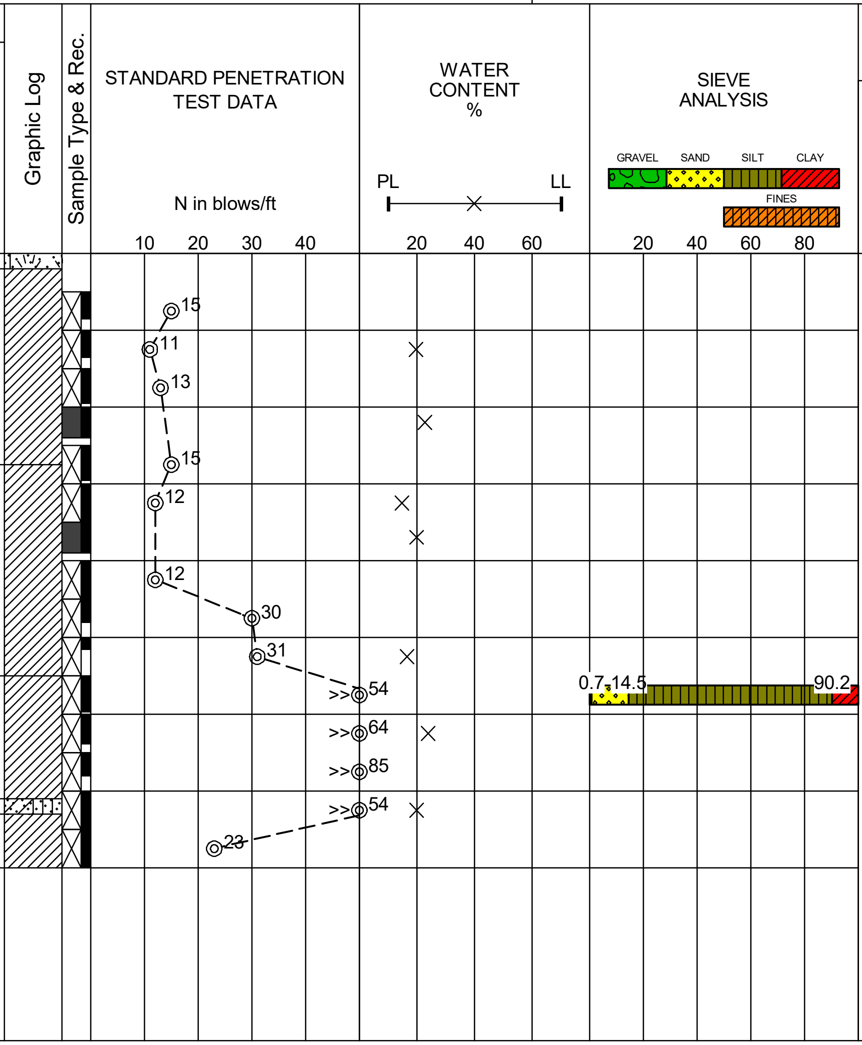
Project:	Upper Maple River Watershed Detention Plan_Site Alt2A
Location:	Barnes Couty, North Dakota
Client:	Moore Engineering, Inc.
Barr Project Number:	34091031.02

MATERIAL DESCRIPTION (ASTM D2488)

Surface Elev.: 1247.5 ft

Elevation, feet	Material Description	Depth, feet
1246.5	TOPSOIL (CL): dark brown; moist.	1.0
	LEAN CLAY WITH SAND (CL): orangish tan; moist; stiff; with pockets and thin seams of sand to 12.5 ft.	
1233.7		13.8
	LEAN CLAY (CL): dark gray; moist to wet; stiff to hard; trace sand; glacial till.	
1220.0		27.5
	LEAN CLAY (CL): dark gray; dry to moist; hard; trace sand; vertical fine grained sand seam to 28.5 ft. 30.0 - 32.5 ft: light and dark gray striations within clay.	
1212.0		35.5
1211.0	CLAYEY TO SILTY SAND (SC-SM): fine grained; dark gray; moist.	36.5
1207.5	LEAN CLAY (CL): dark grayish brown; moist; very stiff; with sand; glacial till.	40.0

Bottom of Boring at 40.0 feet



Physical Properties

WC %	γd pcf	ϕ °	Qu tsf	Qp tsf	Gs	RQD %
				3.5		
19.6				2.5		
				2		
22.8	100.2		2.04			
				3		
14.7				2		
20	108.4		1.86			
				3		
				3.75		
16.5				4		
23.8						
19.9				2.5		
				3.75		

Completion Depth:	40.0
Date Boring Started:	4/10/17
Date Boring Completed:	4/10/17
Logged By:	AJL
Drilling Contractor:	Interstate Drilling Services
Drilling Method:	HSA
Ground Surface Elevation:	1247.49
Coordinates:	Lat: 47.11906° Long: -97.76932°
Datum:	NAD83

Remarks: Ponded water at 100 ft and 300 ft east of staked location. Qu values at 10 and 17.5 ft are from UU tests.

SAMPLE TYPES

☒ SPLIT SPOON
■ 3-inch Shelby Tube

WATER LEVELS (ft)

Wet Cave-in Depth	37.5
After Drilling	28.4
At Time of Drilling	22.5

LEGEND

MC	Moisture Content	Q_u	Unconfined Compression
γ	Dry Unit Weight	Q_p	Hand Penetrometer UC
ϕ	Friction Angle	Gs	Specific Gravity
		RQD	Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

BARR

Barr Engineering Company
4300 MarketPointe Drive Suite 200
Minneapolis, MN 55435
Telephone: 952-832-2600

LOG OF BORING B-12

Sheet 1 of 1

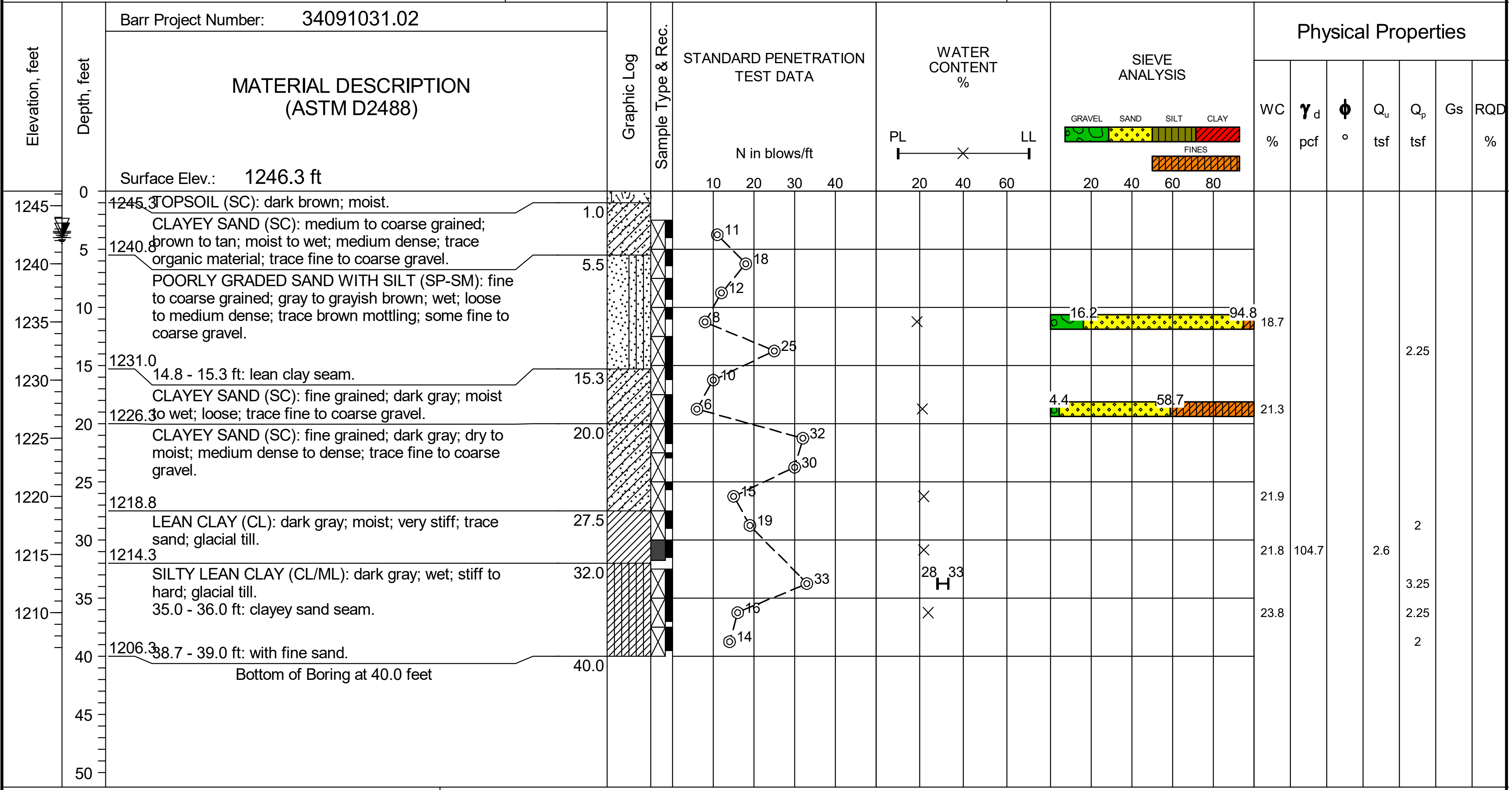
Project:	Upper Maple River Watershed Detention Plan_Site Alt2A	Location:	Barnes Couty, North Dakota	Client:	Moore Engineering, Inc.

Barr Project Number: 34091031.02

Surface Elev.: 1246.3 ft

Elevation, feet	Depth, feet	MATERIAL DESCRIPTION (ASTM D2488)
1245.3	1.0	TOPSOIL (SC): dark brown; moist.
1240.8	5.5	CLAYEY SAND (SC): medium to coarse grained; brown to tan; moist to wet; medium dense; trace organic material; trace fine to coarse gravel.
1231.0	15.3	POORLY GRADED SAND WITH SILT (SP-SM): fine to coarse grained; gray to grayish brown; wet; loose to medium dense; trace brown mottling; some fine to coarse gravel. 14.8 - 15.3 ft: lean clay seam.
1226.3	20.0	CLAYEY SAND (SC): fine grained; dark gray; moist to wet; loose; trace fine to coarse gravel.
1218.8	27.5	CLAYEY SAND (SC): fine grained; dark gray; dry to moist; medium dense to dense; trace fine to coarse gravel.
1214.3	32.0	LEAN CLAY (CL): dark gray; moist; very stiff; trace sand; glacial till.
1206.3	40.0	SILTY LEAN CLAY (CL/ML): dark gray; wet; stiff to hard; glacial till. 35.0 - 36.0 ft: clayey sand seam. 38.7 - 39.0 ft: with fine sand.

Bottom of Boring at 40.0 feet



Completion Depth:	40.0
Date Boring Started:	4/10/17
Date Boring Completed:	4/10/17
Logged By:	AJL
Drilling Contractor:	Interstate Drilling Services
Drilling Method:	HSA
Ground Surface Elevation:	1246.26
Coordinates:	Lat: 47.12673° Long: -97.78718°
Datum:	NAD83

Remarks: Qu value at 30 ft is from UU test.

SAMPLE TYPES

☒ SPLIT SPOON
■ 3-inch Shelby Tube

WATER LEVELS (ft)

≡	Wet Cave-in Depth	4.5
▽	After Drilling	3.6
▼	At Time of Drilling	4.0

LEGEND

MC	Moisture Content	Q_u	Unconfined Compression
γ	Dry Unit Weight	Q_p	Hand Penetrometer UC
ϕ	Friction Angle	Gs	Specific Gravity
		RQD	Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

M:\GINT\PROJECTS\34091031.02 UPPER MAPLE RIVE ALT2A.GPJ BARRLIBRARY.GLB HORIZONTAL LOG REPORT BARR GEOTECH TEMPLATE.GDT

Barr Engineering Company
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LOG OF BORING B-13

Sheet 1 of 1

Project: Upper Maple River Watershed Detention Plan_Site Alt2A

Location: Barnes Couty, North Dakota

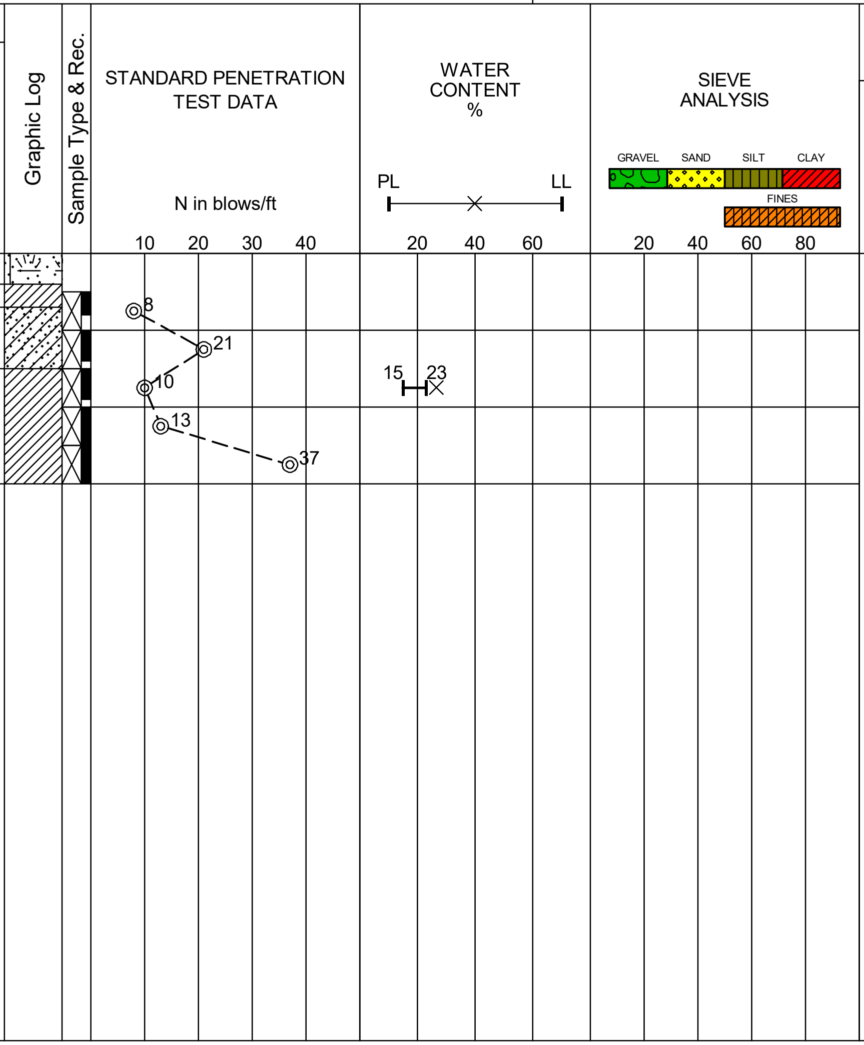
Client: Moore Engineering, Inc.

Barr Project Number: 34091031.02

Surface Elev.: 1245.0 ft

Elevation, feet	MATERIAL DESCRIPTION (ASTM D2488)	Depth, feet
1243.0	TOPSOIL (CL): dark brown; moist.	2.0
1241.5	LEAN CLAY WITH SAND (CL): tan to brown; moist; medium stiff.	3.5
1237.5	CLAYEY SAND (SC): fine grained; tan to brown; moist; medium dense.	7.5
1230.0	LEAN CLAY WITH SAND (CL): tan to brown; moist; stiff to hard; alternating layers of sandy lean clay and clayey sand. 8.5 ft: 6-inch sand seam. 11.0 ft: 4-inch sand seam. 13.5 ft: 4-inch sand seam. 14.5 ft: trace fine gravel.	15.0

Bottom of Boring at 15.0 feet



Physical Properties

WC %	γd pcf	ϕ °	Qu tsf	Qp tsf	Gs	RQD %
26.5				0.5		
				1.25		
				4.5		

Completion Depth:	15.0
Date Boring Started:	4/13/17
Date Boring Completed:	4/13/17
Logged By:	AJL
Drilling Contractor:	Interstate Drilling Services
Drilling Method:	HSA
Ground Surface Elevation:	1245.0
Coordinates:	Lat: 47.11470° Long: -97.77292°
Datum:	NAD83

Remarks: Wetland area observed to north and northwest.

SAMPLE TYPES

☒ SPLIT SPOON

WATER LEVELS (ft)

▼ At Time of Drilling 6.0
Based on soil moisture. Rod wet at 10 ft

LEGEND

MC	Moisture Content	Qu	Unconfined Compression
γ	Dry Unit Weight	Qp	Hand Penetrometer UC
ϕ	Friction Angle	Gs	Specific Gravity
		RQD	Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

BARR

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LOG OF BORING B-14

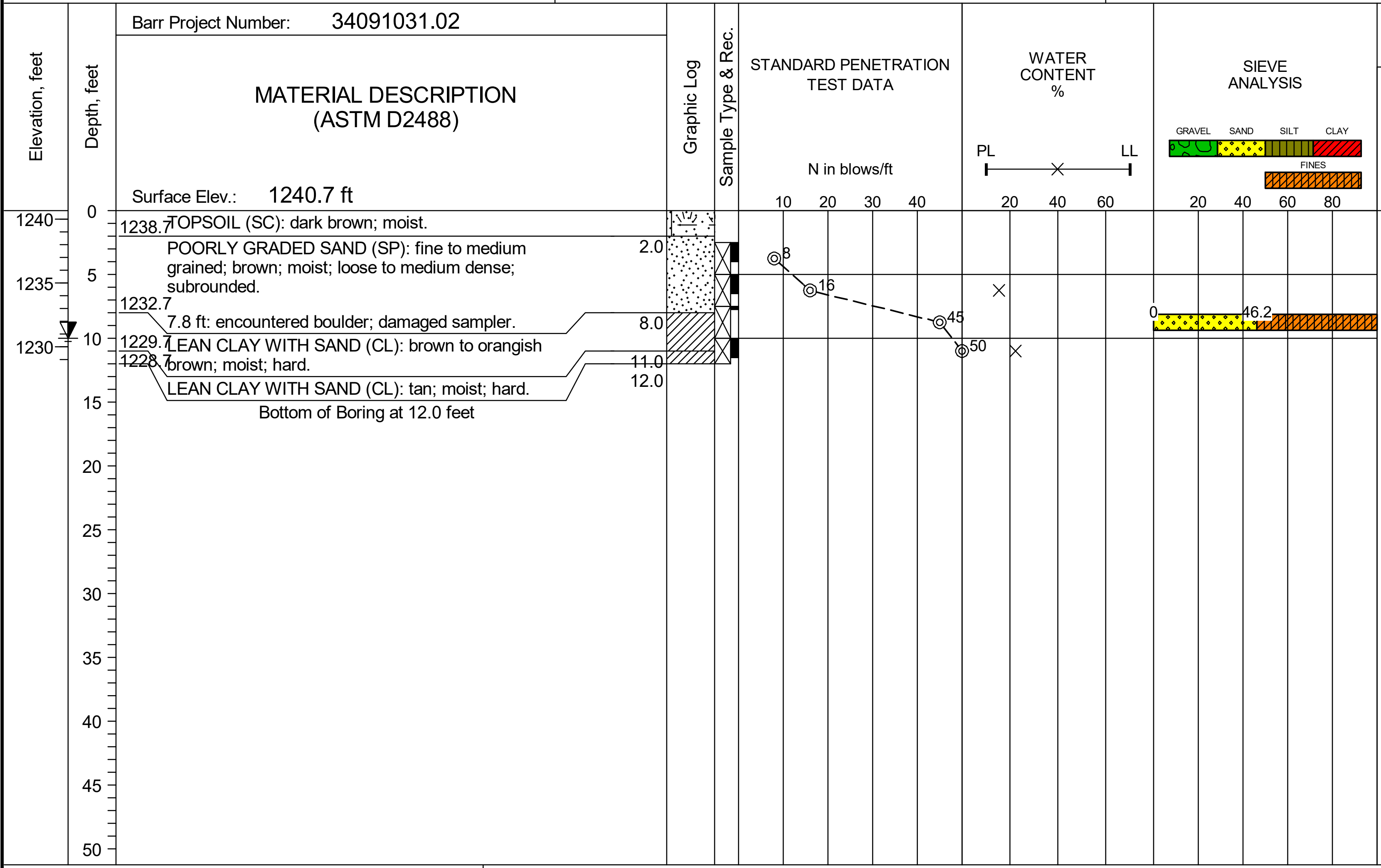
Sheet 1 of 1

Project: Upper Maple River Watershed Detention Plan_Site Alt2A
Location: Barnes Couty, North Dakota
Client: Moore Engineering, Inc.

Barr Project Number: 34091031.02

Surface Elev.: 1240.7 ft

Elevation, feet	Depth, feet	MATERIAL DESCRIPTION (ASTM D2488)	WC %
1238.7	2.0	TOPSOIL (SC): dark brown; moist.	
1232.7	8.0	POORLY GRADED SAND (SP): fine to medium grained; brown; moist; loose to medium dense; subrounded.	15.4
		7.8 ft: encountered boulder; damaged sampler.	
1229.7	11.0	LEAN CLAY WITH SAND (CL): brown to orangish brown; moist; hard.	22.3
1228.7	12.0	LEAN CLAY WITH SAND (CL): tan; moist; hard.	
		Bottom of Boring at 12.0 feet	



Physical Properties

WC %	γd pcf	ϕ °	Q_u tsf	Q_p tsf	Gs	RQD %
15.4						
22.3						

Completion Depth: 12.0
Date Boring Started: 4/13/17
Date Boring Completed: 4/13/17
Logged By: AJL
Drilling Contractor: Interstate Drilling Services
Drilling Method: HSA
Ground Surface Elevation: 1240.65
Coordinates: Lat: 47.11043° Long: -97.77517°
Datum: NAD83

Remarks: Location at a higher elevation than surrounding area. Hit a rock at 7.5 ft that eventually bent the split spoon and ceased drilling at 12 ft because auger began to shift diagonally.

SAMPLE TYPES	WATER LEVELS (ft)	LEGEND	
☒ SPLIT SPOON	▽ At Time of Drilling 10.0 Based on soil moisture.	MC Moisture Content	Q_u Unconfined Compression
		γ Dry Unit Weight	Q_p Hand Penetrometer UC
		ϕ Friction Angle	Gs Specific Gravity
			RQD Rock Quality Designation

The stratification lines represent approximate boundaries. The transition may be gradual.

Appendix B

Laboratory Testing Results

Table B1
Laboratory Testing Summary

Boring ID	Depth of Sample [ft]	Soil Type	Moisture Content [%]	Dry Density [pcf]	Moist Density [pcf]	Liquid Limit [%]	Plastic Limit [%]	Plasticity Index [%]	Hydraulic Conductivity, *k* [cm/sec]	Unconfined Compressive Strength [tsf]	UU Triaxial Compressive Strength [tsf]	Gravel [%]	Sand [%]	Silt [%]	Clay [%]	Fines [%]
B-01	7.5-10	CL	22.4	100.9	123.5					3.25						
	12.5-15	SC	30.1									2.5	73.7			23.8
	20-22.5	SC	20.7													
	25-27.5	CL	20	103.5	124.2					1.61						
	32.5-35	CL	23.7													
B-02	10-12	SC										1.7	56.6			41.7
	12.5-12.9	CL	17.4													
	17.5-20	CL	22.6													
	22.5-25	CL	20.8													
B-03	10-12.5	CL	18.7			32.1	17.2	14.9								
	15-17.5	SC										2.0	59.0			39.0
	22.5-25	SC/CL	22.6													
	30-32.5	CL	25.4													
	35-36.5	CL	22.2	103.1	126.0						1.70					
B-04	5-7.5	SM/SP-SM										2.1	84.9			13.0
	12.5-14.8	CL	21.0			33.3	17.6	15.7								
	20-22.5	CL	22.7													
	27.5-30	CL	20.7													
	30-31	CL/CH	20.8	103.1	124.5											
	35-37.5	CL	24.3									0.0	32.9			67.1
B-05	12.5-14	SC	20.1	108.4	130.2						0.56					
	15-17.5	CL	24.8			29.4	19.7	9.7								
	17.5-20	SC/CL	29.1													
	20-22	SC/CL-ML	25.2	98.9	123.8						0.56					
	27.5-30	SC/CL	15.4													
	32.5-35	SC	14.9									7.2	44.3			48.5
B-06	7.5-9.5	CL	23.5	104.1	128.6				2.00E-08		0.71					
	12.5-15	CL	27.6			36.7	22.9	13.8								
	17.5-20	SP-SM	29.5									3.5	89.5			7.0
	25-27.5	SC/CL	21.7													
	27.5-30	SC										10.1	69.2			20.7
	30-32.5	SC/CL	18.9													
	35-37.5	CL	24.1													
B-07	7.5-10	SC/CL	20.5													
	12.5-15	CL	22.1			30.8	21.4	9.4								
	17.5-19.5	CL	20.8	106.9	129.1						1.58					
	22.5-25	CL	20.2													
	27.5-30	CL	22.6			36.5	23.0	13.5								
	32.5-35	CL	8.5													
B-08	10-12	SC	21.6	102.1	124.2				8.20E-07		1.73					
	17.5-20	CL	20.7													
	22.5-23.8	ML/CL-ML	21.7			21.4	17.7	3.7								
	27.5-28.3	CL	17.7													
B-09	10-12.5	CL	14.3	120.6	137.8					3.24						
	17.5-20	CL	21.4													
	22.5-24	SP-SM/SP										0.4	94.2			5.4
	27.5-28.8	CL	18.4													
	32.5-34.9	CL	23.2													
	37.5-40	CL				36.7	23.4	13.3								
B-10	7.5-9.5	CL	19.1	108.7	129.5				1.50E-07							
	12.5-15	CL	22.7													
	17.5-19.9	CL	19.5													
	22.5-25	CL	21.8									7.7	42.3			50.0
	27.5-30	CL	19.8	103.6	124.1					2.04						
	32.5-35	CL	22.6													
B-11	5-7.5	CL	19.6													
	10-12	CL	22.8	100.2	123.0						2.04					
	15-17.5	SC/CL	14.7													
	17.5-19.5	CL	20.0	108.4	130.1						1.86					
	25-27.5	CL	16.5													
	27.5-30	CL										0.7	13.8	75.7	9.8	85.5
	30-32.5	CL	23.8													
	35-37.5	SC-SM	19.9													
B-12	10-12.5	SP-SM	18.7									16.2	78.6			5.2
	17.5-20	SC	21.3									4.4	54.3			41.3
	25-27.5	SC	21.9													
	30-31.5	CL	21.8	104.7	127.5						2.60					
	32.5-35	CL-ML				33.3	27.7	5.6								
	35-37.5	SC-SM	23.8													
B-13	7.5-10	SC	26.5			22.7	15.1	7.6								
B-14	5-7.5	SP/SP-SM	15.4													
	7.5-10	CL										0.0	46.2			53.8
	10-12.5	CL	22.3													

Number of Tests	64	15	15	10	10	10	3	4	9	14	14	1	1	14
Minimum	8.5	98.9	123.0	21.4	15.1	3.7	2.00E-08	1.6	0.6	0.0	13.8	75.7	9.8	5.2
Maximum	30.1	120.6	137.8	36.7	27.7	15.7	8.20E-07	3.25	2.6	16.2	94.2	75.7	9.8	85.5
Average	21.2	105.1	127.1	31.3	20.6	10.7	3.30E-07	2.5	1.5	4.2	60.0	75.7	9.8	35.9
Standard Deviation	3.7	5.2	4.0	5.5	3.8	4.1	4.29E-07	0.8	0.7	4.6	23.1	--	--	24.5

Water Content Test Summary (ASTM:D2216)

Project: Upper Maple River Job: 10826

Client Barr Engineering Company Date: 4/28/2017

Sample Information & Classification

Boring #	B-01	B-01	B-01	B-02	B-02	B-02	B-03	B-03
Sample #								
Depth (ft)	12.5-15	20-22.5	32.5-35	12.5-12.9	17.5-20	22.5-25	10-12.5	22.5-25
Type	Bag	Bag	Bag	Bag	Bag	Bag	Bag	Bag
Material Classification	Clayey Sand w/a trace of gravel (SC)	Clayey Sand (SC)	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Clayey Sand (SC/CL)
Water Content (%)	30.1	20.7	23.7	17.4	22.6	20.8	18.7	22.6

Sample Information & Classification

Boring #	B-03	B-04	B-04	B-04	B-04	B-05	B-05	B-05
Sample #								
Depth (ft)	30-32.5	12.5-14.8	20-22.5	27.5-30	35-37.5	15-17.5	17.5-20	27.5-30
Type	Bag	Bag	Bag	Bag	Bag	Bag	Bag	Bag
Material Classification	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Clayey Sand (SC/CL)	Clayey Sand (SC/CL)
Water Content (%)	25.4	21.0	22.7	20.7	24.3	24.8	29.1	15.4

Sample Information & Classification

Boring #	B-05	B-06	B-06	B-06	B-06	B-06	B-07	B-07
Sample #								
Depth (ft)	32.5-35	12.5-15	17.5-20	25-27.5	30-32.5	35-37.5	7.5-10	12.5-15
Type	Bag	Bag	Bag	Bag	Bag	Bag	Bag	Bag
Material Classification	Clayey Sand w/a little gravel (SC)	Lean Clay w/sand (CL)	Sand w/silt and a trace of gravel, fine to medium grained (SP-SM)	Clayey Sand (SC/CL)	Clayey Sand (SC/CL)	Sandy Lean Clay (CL)	Clayey Sand (SC/CL)	Sandy Lean Clay (CL)
Water Content (%)	14.9	27.6	29.7	21.7	18.9	24.1	20.5	22.1

Sample Information & Classification

Boring #	B-07	B-07	B-07	B-08	B-08	B-08	B-09	B-09
Sample #								
Depth (ft)	22.5-25	27.5-30	32.5-35	17.5-20	22.5-23.8	27.5-28.3	17.5-20	27.5-28.8
Type	Bag	Bag	Bag	Bag	Bag	Bag	Bag	Bag
Material Classification	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Lean Clay (CL)	Sandy Lean Clay (CL)	Sandy Silt (ML/CL-ML)	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)
Water Content (%)	20.2	22.6	8.5	20.7	21.7	17.7	21.4	18.4

Water Content Test Summary (ASTM:D2216)

Project: Upper Maple River Job: 10826

Client Barr Engineering Company Date: 4/28/2017

Sample Information & Classification

Boring #	B-09	B-10	B-10	B-10	B-10	B-11	B-11	B-11
Sample #								
Depth (ft)	32.5-34.9	12.5-15	17.5-19.9	22.5-25	32.5-35	5-7.5	15-17.5	25-27.5
Type	Bag	Bag	Bag	Bag	Bag	Bag	Bag	Bag
Material Classification	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Sandy Lean Clay (CL/SC)	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Clayey Sand (SC/CL)	Sandy Lean Clay (CL)
Water Content (%)	23.2	22.7	19.5	21.8	22.6	19.6	14.7	16.5

Sample Information & Classification

Boring #	B-11	B-11	B-12	B-12	B-12	B-12	B-13	B-14
Sample #								
Depth (ft)	30-32.5	35-37.5	10-12.5	17.5-20	25-27.5	35-37.5	7.5-10	5-7.5
Type	Bag	Bag	Bag	Bag	Bag	Bag	Bag	Bag
Material Classification	Lean Clay (CL)	Silty Clayey Sand (SC-SM)	Sand w/silt and gravel, medium to coarse grained (SP-SM/SP)	Clayey Sand w/a little gravel (SC)	Clayey Sand (SC)	Silty Clayey Sand (SC-SM)	Clayey Sand (SC/SC-SM)	Sand w/a trace of gravel (SP/SP-SM)
Water Content (%)	23.8	19.9	18.7	21.3	21.9	23.8	26.2	15.4

Sample Information & Classification

Boring #	B-14							
Sample #								
Depth (ft)	10-12.5							
Type	Bag							
Material Classification	Sandy Lean Clay (CL)							
Water Content (%)	22.3							

Sample Information & Classification

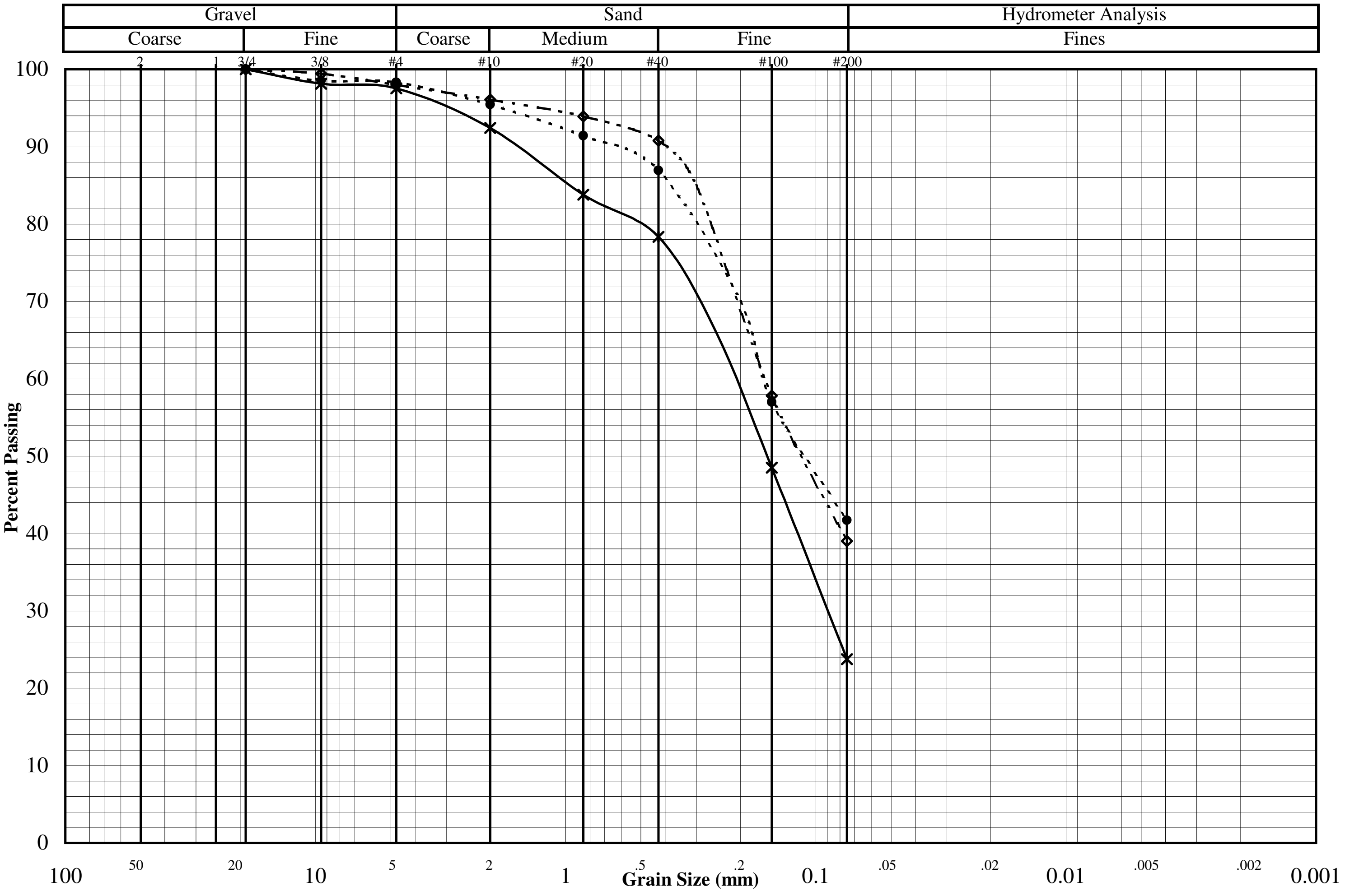
Boring #								
Sample #								
Depth (ft)								
Type								
Material Classification								
Water Content (%)								

Grain Size Distribution ASTM D422

Job No. : **10826**

Project:	Upper Maple River	Test Date:	4/20/17
Reported To:	Barr Engineering Company	Report Date:	4/24/17

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	B-01		12.5-15	Bag	Clayey Sand w/a trace of gravel (SC)
●	B-02		10-12	Bag	Clayey Sand (SC)
◇	B-03		15-17.5	Bag	Clayey Sand w/a trace of gravel (SC)



Other Tests

	*	●	◇
Liquid Limit			
Plastic Limit			
Plasticity Index			
Water Content	30.1		
Dry Density (pcf)			
Specific Gravity			
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	401.2	509.5	514.2
2"			
1.5"			
1"			
3/4"	100.0	100.0	100.0
3/8"	98.1	98.5	99.5
#4	97.5	98.3	98.0
#10	92.4	95.4	96.1
#20	83.8	91.4	93.9
#40	78.3	86.9	90.8
#100	48.5	57.0	57.8
#200	23.8	41.7	39.0

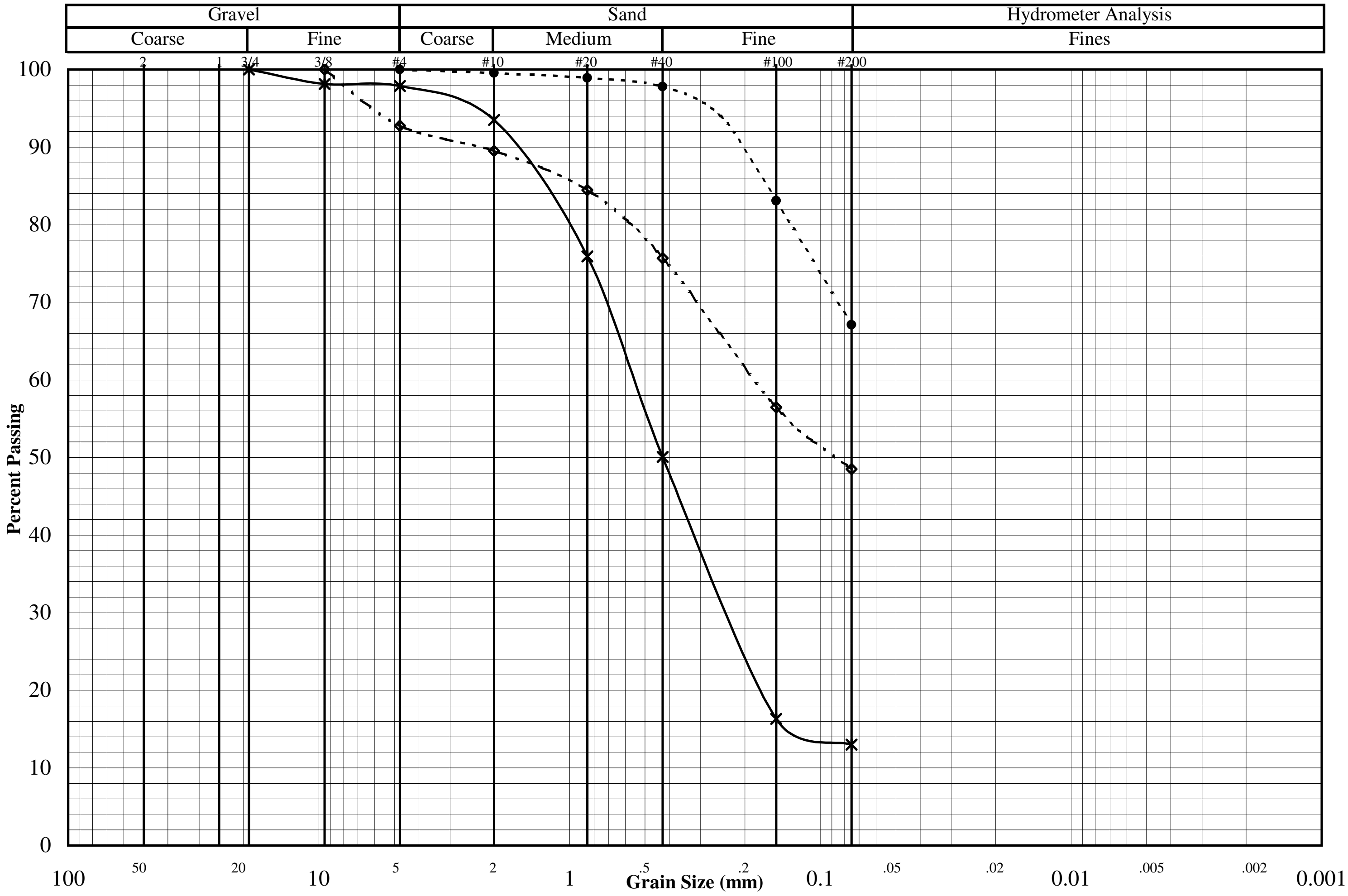
	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Grain Size Distribution ASTM D422

Project:	Upper Maple River	Job No. :	**10826**
		Test Date:	4/20/17
Reported To:	Barr Engineering Company	Report Date:	4/24/17

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
✱	B-04		5-7.5	Bag	Silty Sand w/a trace of gravel (SM/SP-SM)
●	B-04		35-37.5	Bag	Sandy Lean Clay (CL)
◇	B-05		32.5-35	Bag	Clayey Sand w/a little gravel (SC)



Other Tests

	✱	●	◇
Liquid Limit			
Plastic Limit			
Plasticity Index			
Water Content		24.3	14.9
Dry Density (pcf)			
Specific Gravity			
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	✱	●	◇
Mass (g)	539.3	174.3	511.1
2"			
1.5"			
1"			
3/4"	100.0		
3/8"	98.1		100.0
#4	97.9	100.0	92.8
#10	93.5	99.6	89.5
#20	75.9	98.9	84.5
#40	50.1	97.8	75.7
#100	16.3	83.1	56.4
#200	13.0	67.1	48.5

	✱	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

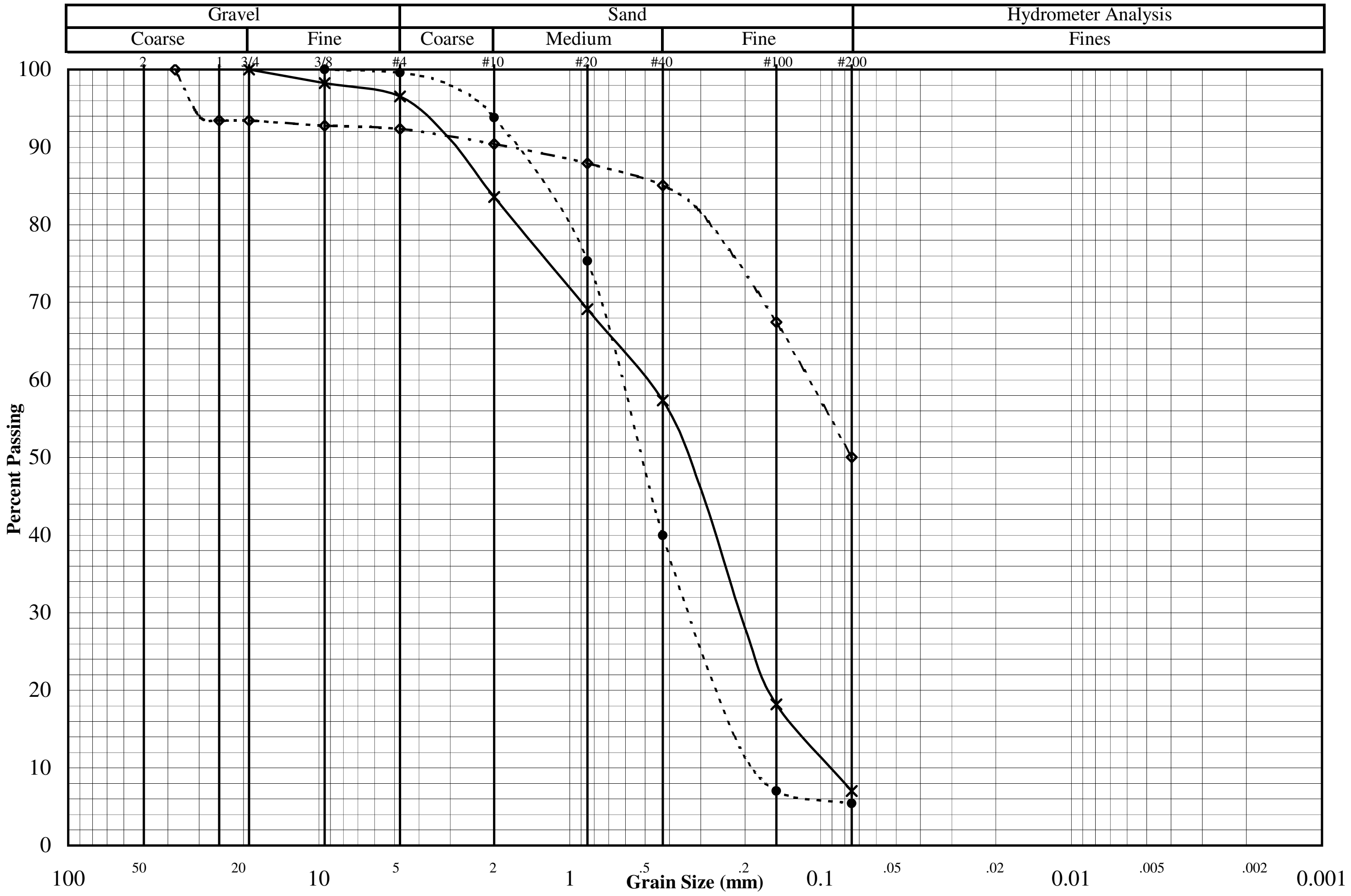
Remarks:

Grain Size Distribution ASTM D422

Job No. : **10826**

Project:	Upper Maple River	Test Date:	4/20/17
Reported To:	Barr Engineering Company	Report Date:	4/24/17

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
∗	B-06		17.5-20	Bag	Sand w/silt and a trace of gravel, fine to medium grained (SP-SM)
●	B-09		22.5-24	Bag	Sand w/silt, medium to fine grained (SP-SM/SP)
◇	B-10		22.5-25	Bag	Sandy Lean Clay (CL/SC)



Other Tests

	∗	●	◇
Liquid Limit			
Plastic Limit			
Plasticity Index			
Water Content	29.7		21.8
Dry Density (pcf)			
Specific Gravity			
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	∗	●	◇
Mass (g)	644.1	208.5	678.5
2"			
1.5"			100.0
1"			93.4
3/4"	100.0		93.4
3/8"	98.2	100.0	92.8
#4	96.5	99.6	92.3
#10	83.6	93.8	90.4
#20	69.1	75.3	87.9
#40	57.4	39.9	85.1
#100	18.2	7.0	67.4
#200	7.0	5.4	50.0

	∗	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

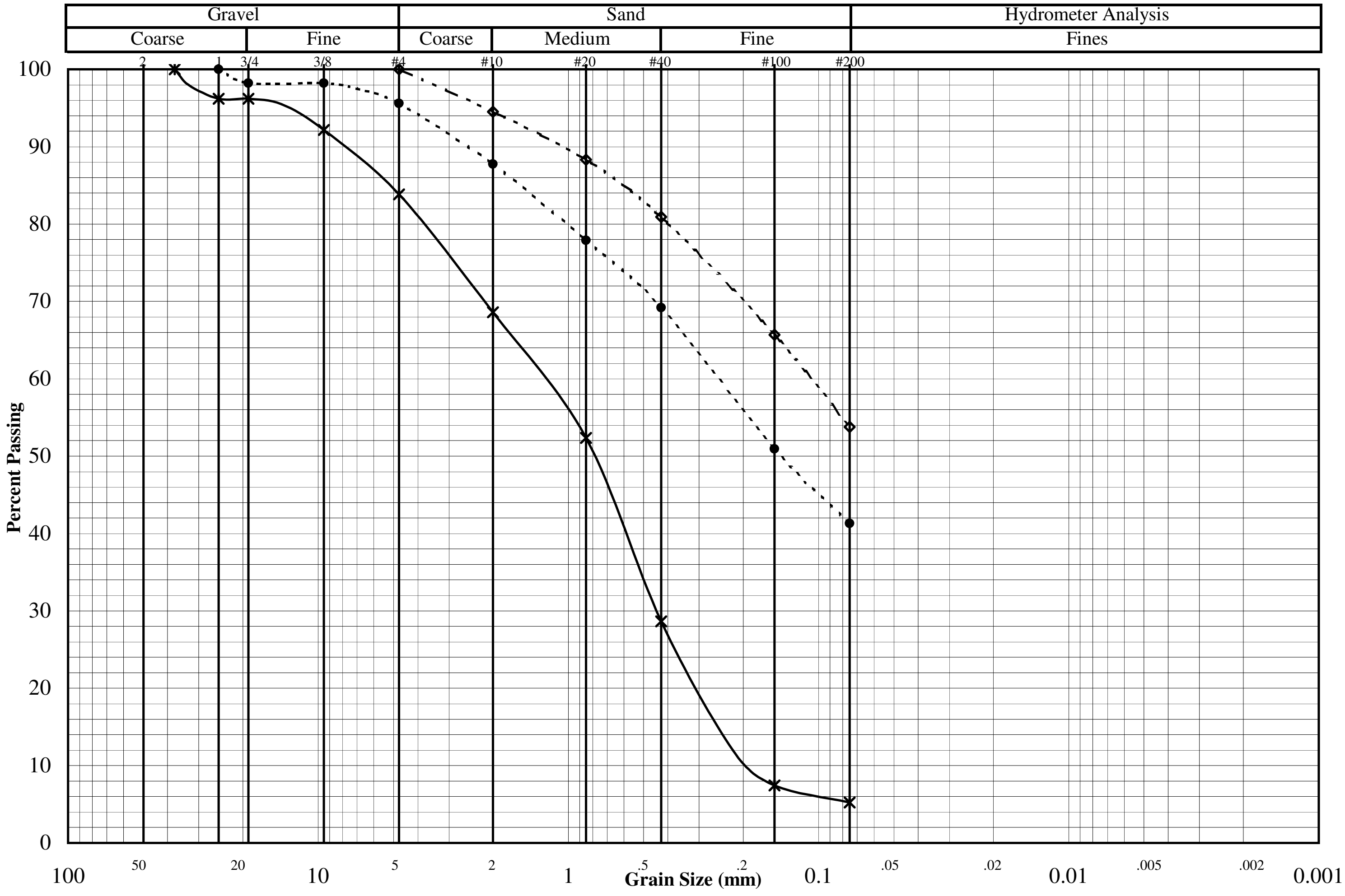
Remarks:

Grain Size Distribution ASTM D422

Job No. : **10826**

Project:	Upper Maple River	Test Date:	4/20/17
Reported To:	Barr Engineering Company	Report Date:	4/27/17

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	B-12		10-12.5	Bag	Sand w/silt and gravel, medium to coarse grained (SP-SM/SP)
●	B-12		17.5-20	Bag	Clayey Sand w/a little gravel (SC)
◇	B-14		7.5-10	Bag	Sandy Lean Clay (CL)



Other Tests

	*	●	◇
Liquid Limit			
Plastic Limit			
Plasticity Index			
Water Content	18.7	21.3	
Dry Density (pcf)			
Specific Gravity			
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	595.8	797.2	45.9
2"			
1.5"	100.0		
1"	96.2	100.0	
3/4"	96.2	98.2	
3/8"	92.2	98.2	
#4	83.8	95.6	100.0
#10	68.6	87.7	94.5
#20	52.3	77.9	88.3
#40	28.7	69.2	80.9
#100	7.4	50.9	65.7
#200	5.2	41.3	53.8

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

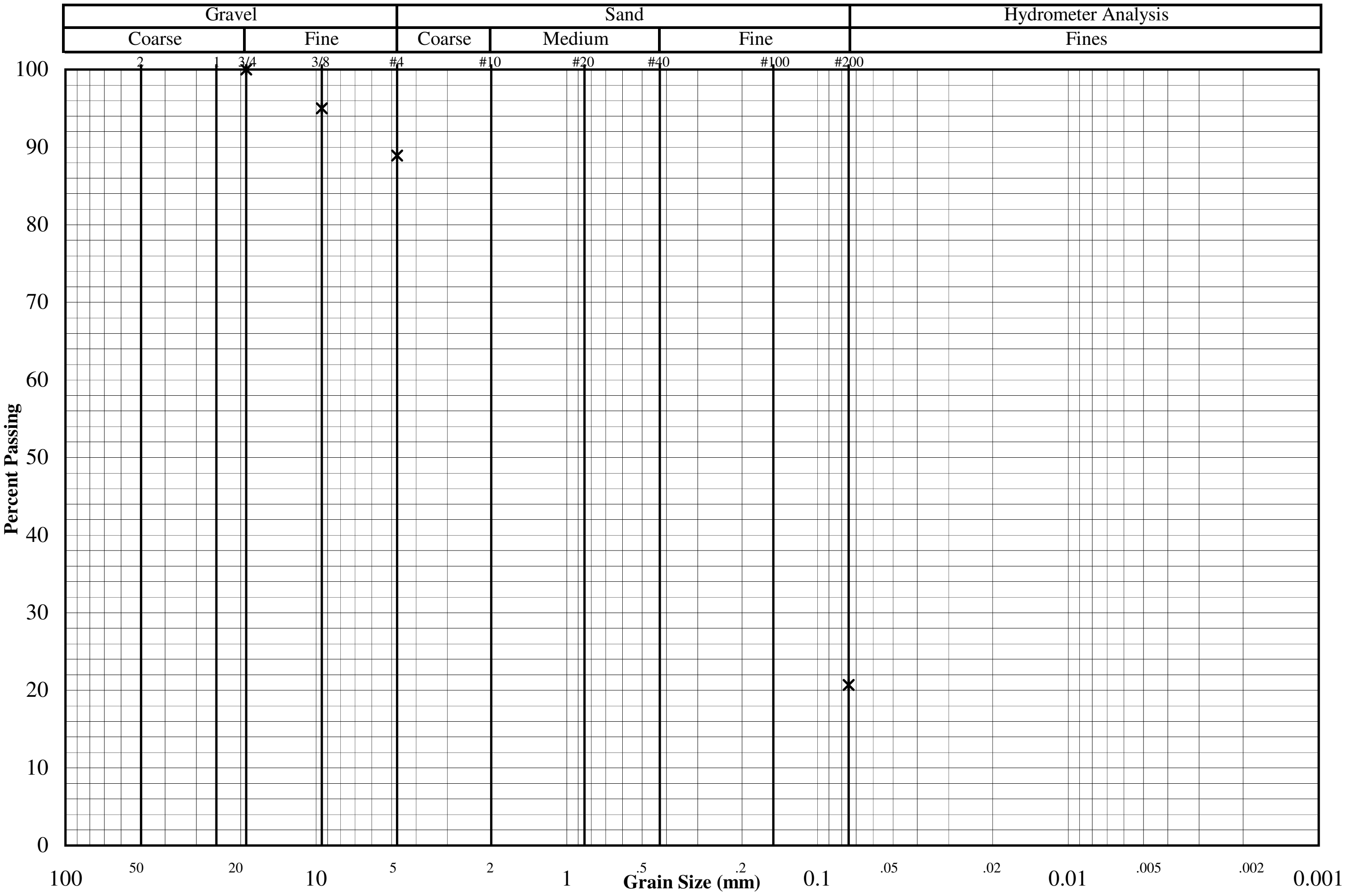
Remarks:

Grain Size Distribution ASTM D1140

Job No. : **10826**

Project:	Upper Maple River	Test Date:	4/20/17
Reported To:	Barr Engineering Company	Report Date:	4/24/17

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
∗	B-06		27.5-30	Bag	Clayey Sand w/a little gravel (SC)
●					
◇					



Other Tests

	∗	●	◇
Liquid Limit			
Plastic Limit			
Plasticity Index			
Water Content			
Dry Density (pcf)			
Specific Gravity			
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	∗	●	◇
Mass (g)	455.9		
2"			
1.5"			
1"			
3/4"	100.0		
3/8"	95.0		
#4	88.9		
#10			
#20			
#40			
#100			
#200	20.7		

	∗	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

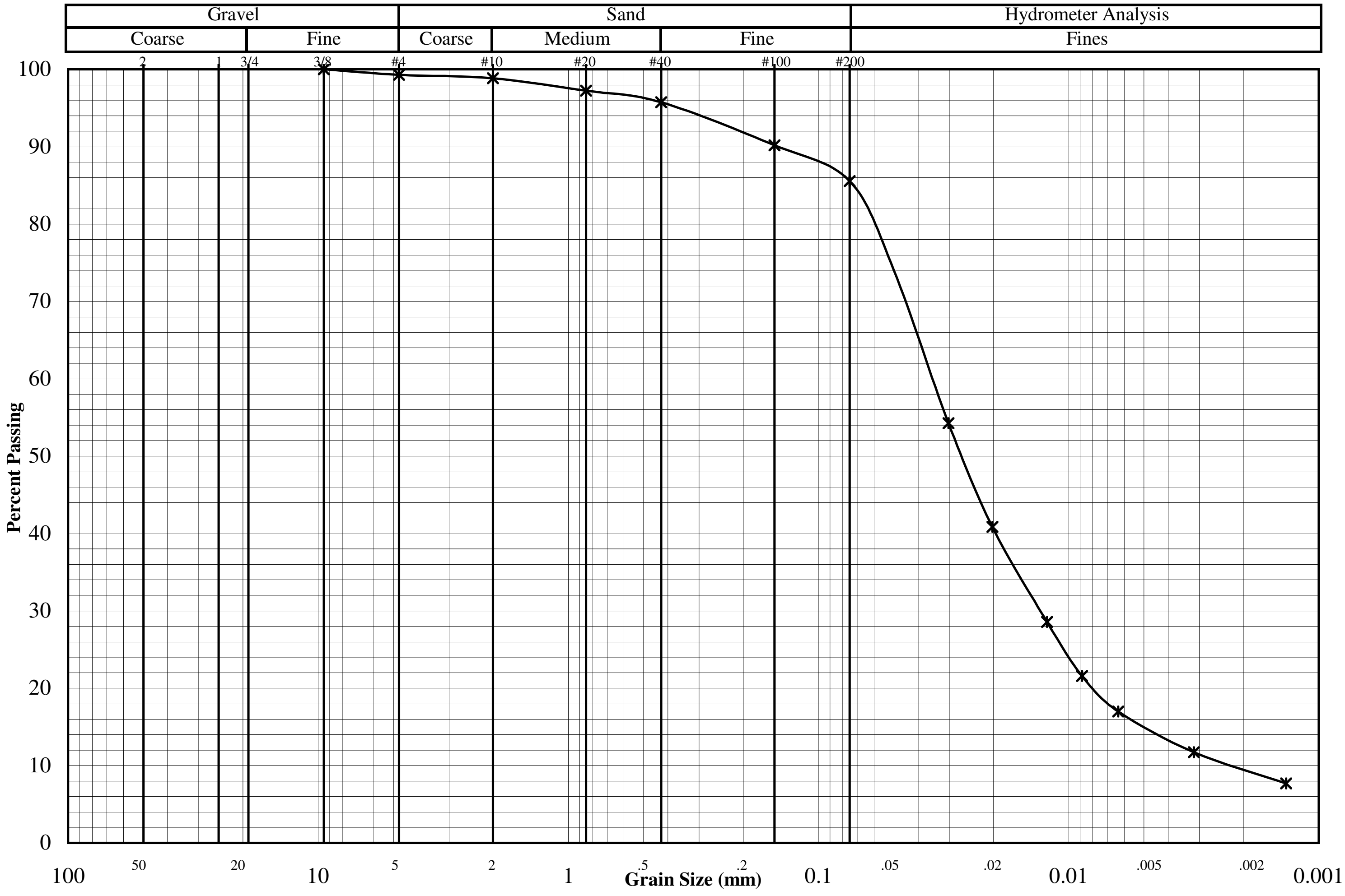
Remarks:

Grain Size Distribution ASTM D422

Job No. : **10826**

Project:	Upper Maple River	Test Date:	4/24/17
Reported To:	Barr Engineering Company	Report Date:	4/27/17

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
*	B-11		27.5-30	Bag	Lean Clay (CL)
●					
◇					



Other Tests

	*	●	◇
Liquid Limit			
Plastic Limit			
Plasticity Index			
Water Content			
Dry Density (pcf)			
Specific Gravity	2.68*		
Porosity			
Organic Content			
pH			
Shrinkage Limit			
Penetrometer			
Qu (psf)			

(* = assumed)

Percent Passing

	*	●	◇
Mass (g)	205.4		
2"			
1.5"			
1"			
3/4"			
3/8"	100.0		
#4	99.3		
#10	98.8		
#20	97.2		
#40	95.7		
#100	90.2		
#200	85.5		

	*	●	◇
D_{60}			
D_{30}			
D_{10}			
C_U			
C_C			

Remarks:

Grain Size Distribution ASTM D422

Job No. : **10826**

Project:	Upper Maple River	Test Date:	4/24/17
Reported To:	Barr Engineering Company	Report Date:	4/27/17

	Location / Boring No.	Sample No.	Depth (ft)	Sample Type	Soil Classification
Spec 1	B-11		27.5-30	Bag	Lean Clay (CL)
Spec 2					
Spec 3					

Sieve Data

Specimen 1		Specimen 2		Specimen 3	
Sieve	% Passing	Sieve	% Passing	Sieve	% Passing
2"		2"		2"	
1.5"		1.5"		1.5"	
1"		1"		1"	
3/4"		3/4"		3/4"	
3/8"	100.0	3/8"		3/8"	
#4	99.3	#4		#4	
#10	98.8	#10		#10	
#20	97.2	#20		#20	
#40	95.7	#40		#40	
#100	90.2	#100		#100	
#200	85.5	#200		#200	

Hydrometer Data

Specimen 1		Specimen 2		Specimen 3	
Diameter (mm)	% Passing	Diameter	% Passing	Diameter	% Passing
0.030	54.3				
0.020	40.9				
0.012	28.6				
0.009	21.6				
0.006	17.0				
0.003	11.7				
0.001	7.7				

Remarks

Specimen 1	Specimen 2	Specimen 3

9530 James Ave South

SOIL
ENGINEERING
TESTING, INC.

Bloomington, MN 55431

Laboratory Test Summary

Project: Upper Maple River Job: 10826

Client: Barr Engineering Company Date: 5/1/2017

Sample Information & Classification

Boring #	B-03	B-04	B-05	B-06	B-07	B-07	B-08	B-09
Sample #								
Depth (ft)	10-12.5	12.5-14.8	15-17.5	12.5-15	12.5-15	27.5-30	22.5-23.8	37.5-40
Sample Type	Bag	Bag	Bag	Bag	Bag	Bag	Bag	Bag
Material Classification	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Lean Clay w/sand (CL)	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Sandy Silt (ML/CL-ML)	Lean Clay w/sand (CL)

Atterberg Limits (ASTM:D4318)

Liquid Limit	32.1	33.3	29.4	36.7	30.8	36.5	21.4	36.7
Plastic Limit	17.2	17.6	19.7	22.9	21.4	23.0	17.7	23.4
Plasticity Index	14.9	15.7	9.7	13.8	9.4	13.5	3.7	13.3

Sample Information & Classification

Boring #	B-12	B-13						
Sample #								
Depth (ft)	32.5-35	7.5-10						
Sample Type	Bag	Bag						
Material Classification	Silty Clay w/sand (CL-ML)	Clayey Sand (SC/SC-SM)						

Atterberg Limits (ASTM:D4318)

Liquid Limit	33.3	22.7						
Plastic Limit	27.7	15.1						
Plasticity Index	5.6	7.6						

Laboratory Test Summary

Project: Upper Maple River **Job:** 10826

Client: Barr Engineering Company **Date:** 5/3/17

Sample Information & Classification

Boring #	B-04						
Sample #							
Depth (ft)	30-31						
Type or BPF	Bag						
Classification	Sandy Lean Clay w/a trace of gravel (CL/CH)						

Water Content, Dry Density (ASTM:D7263)

Water Content (%)	20.8						
Dry Density (pcf)	103.1						

Sample Information & Classification

Boring #							
Sample #							
Depth (ft)							
Type or BPF							
Classification							

Water Content, Dry Density (ASTM:D7263)

Water Content (%)							
Dry Density (pcf)							

Sample Information & Classification

Boring #							
Sample #							
Depth (ft)							
Type or BPF							
Classification							

Water Content, Dry Density (ASTM:D7263)

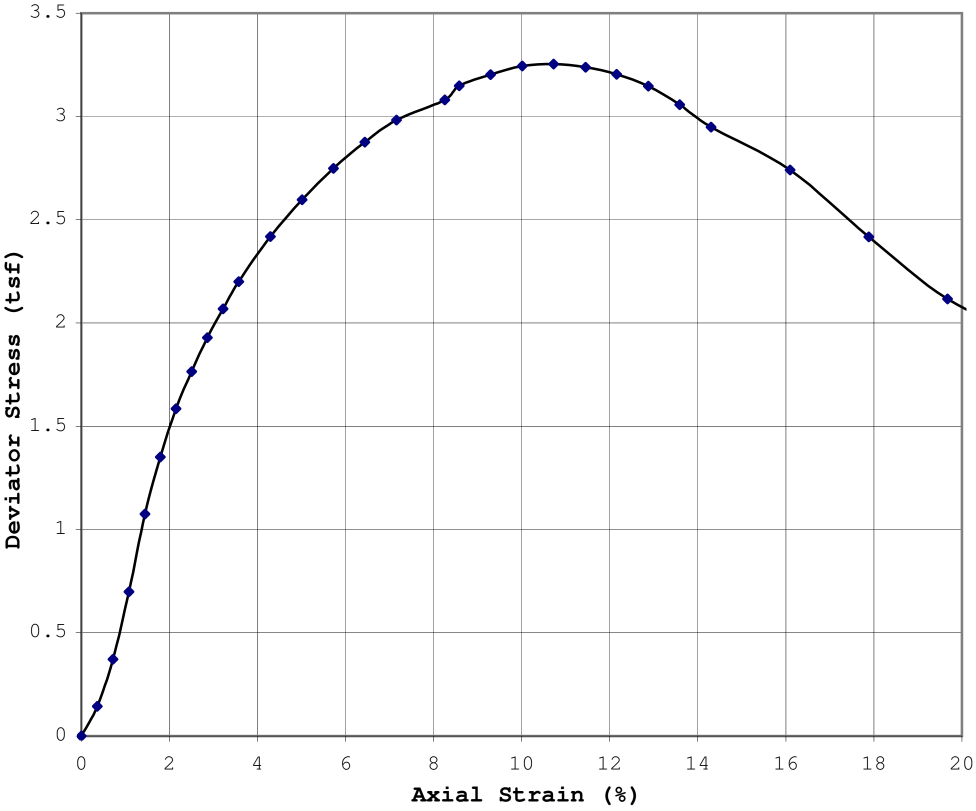
Water Content (%)							
Dry Density (pcf)							

Unconfined Stress/Strain Curves

ASTM: D2166

Project: Upper Maple River
Client: Barr Engineering Company
Remarks:

Job: 10826
Date: 4/27/17



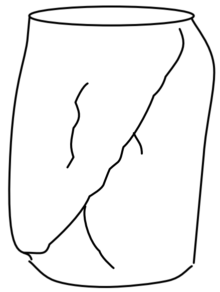
Boring: B-01 Depth: 7.5-10
Sample #:
Soil Type: Sandy Lean Clay w/laminations of silty sand (CL)

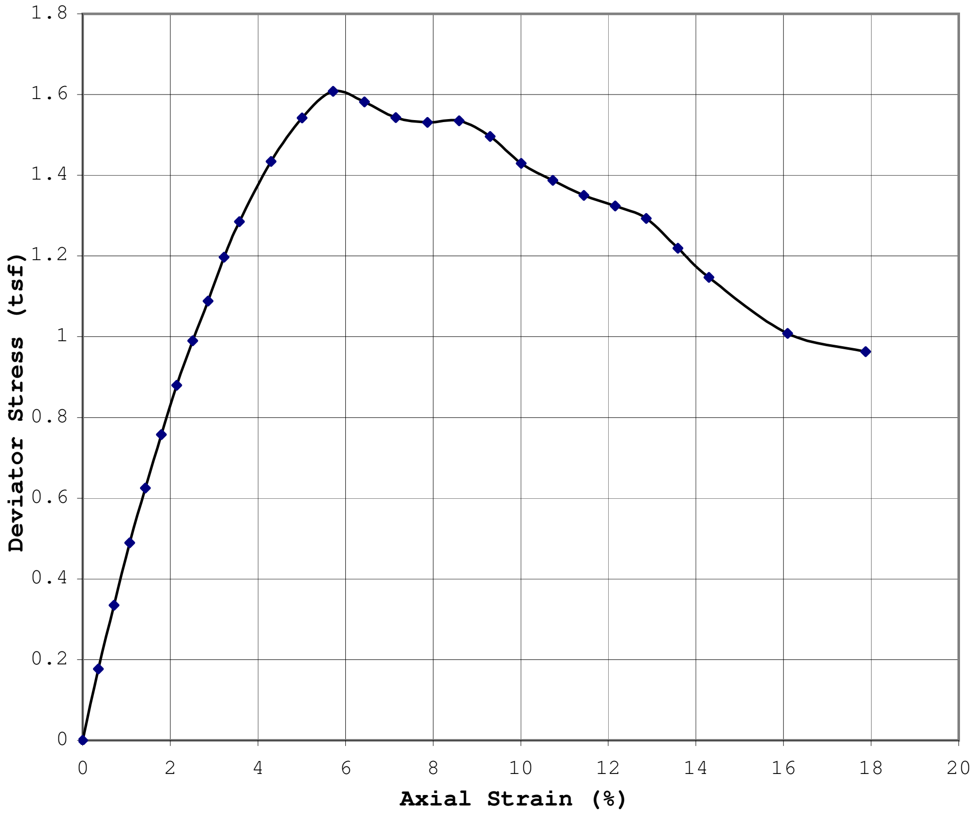
Strain Rate (in/min): 0.030
Sample Type: SB
Dia. (in) 1.38 Ht. (in) 2.80
Height to Diameter Ratio: 2.0

Unconfined Comp. Strength: **3.25** **tsf**
Strain at Failure (%): **10.7**

W.C. (%): 22.4
Yd (pcf): 100.9

Sketch of Specimen After Failure





Boring: B-01 Depth: 25-27.5
Sample #:
Soil Type: Sandy Lean Clay w/laminations of silty sand (CL)

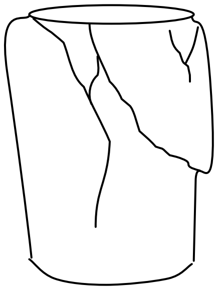
Strain Rate (in/min): 0.030
Sample Type: SB

Dia. (in): 1.46 Ht. (in): 2.80
Height to Diameter Ratio: 1.9

Unconfined Comp. Strength: **1.61** **tsf**
Strain at Failure (%): **5.7**

W.C. (%): 20.0
Yd (pcf): 103.5

Sketch of Specimen After Failure

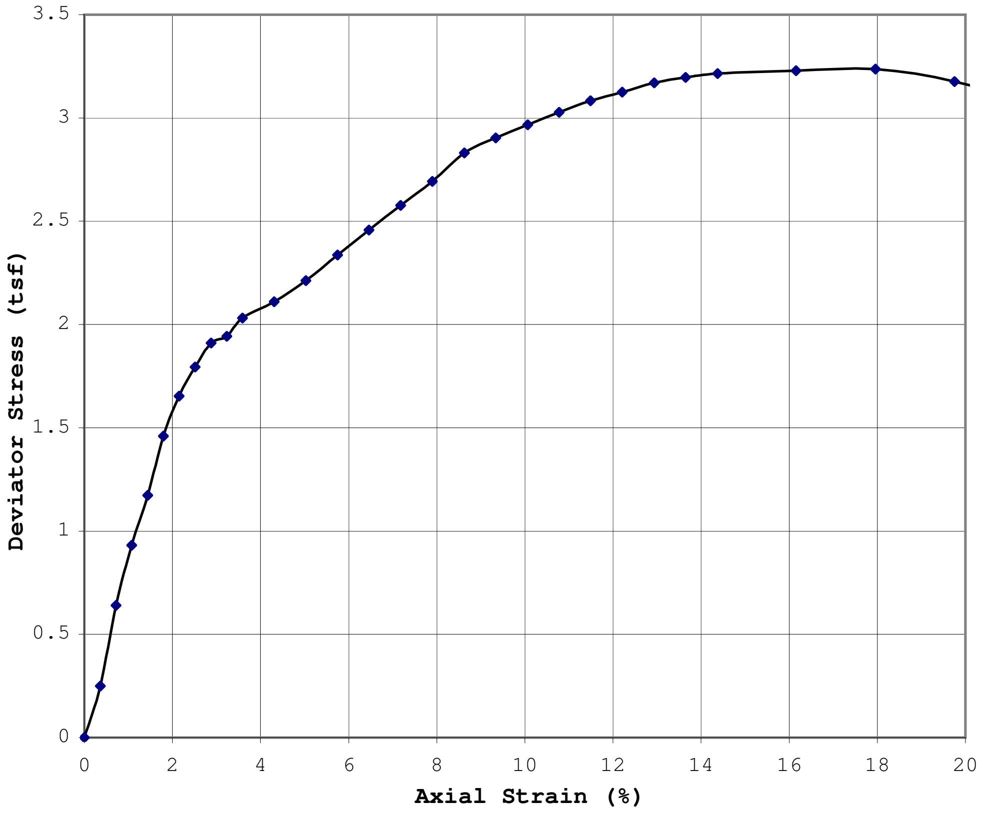


Unconfined Stress/Strain Curves

ASTM: D2166

Project: Upper Maple River
Client: Barr Engineering Company
Remarks:

Job: 10826
Date: 4/27/17



Boring: B-09 Depth: 10-12.5
Sample #:

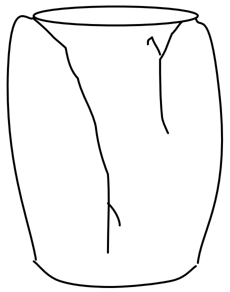
Soil Type: Sandy Lean Clay w/a little gravel (CL)

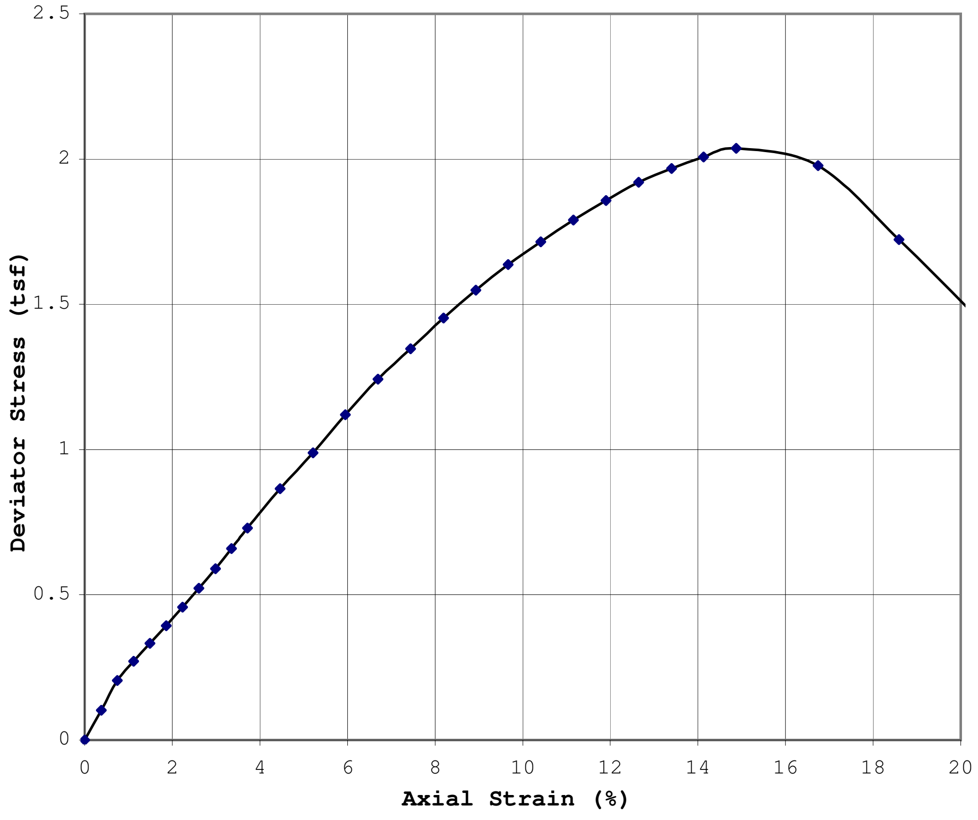
Strain Rate (in/min): 0.030
Sample Type: SB
Dia. (in) 1.36 Ht. (in) 2.79
Height to Diameter Ratio: 2.0

Unconfined Comp. Strength: **3.24** **tsf**
Strain at Failure (%): **18.0**

W.C. (%): 14.3
Yd (pcf): 120.6

Sketch of Specimen After Failure





Boring: B-10 Depth: 27.5-30
Sample #:

Soil Type: Sandy Lean Clay (CL)

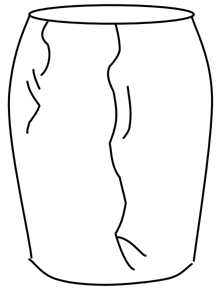
Strain Rate (in/min): 0.030
Sample Type: SB

Dia. (in): 1.53 Ht. (in): 2.69
Height to Diameter Ratio: 1.8

Unconfined Comp. Strength: **2.04** **tsf**
Strain at Failure (%): **14.9**

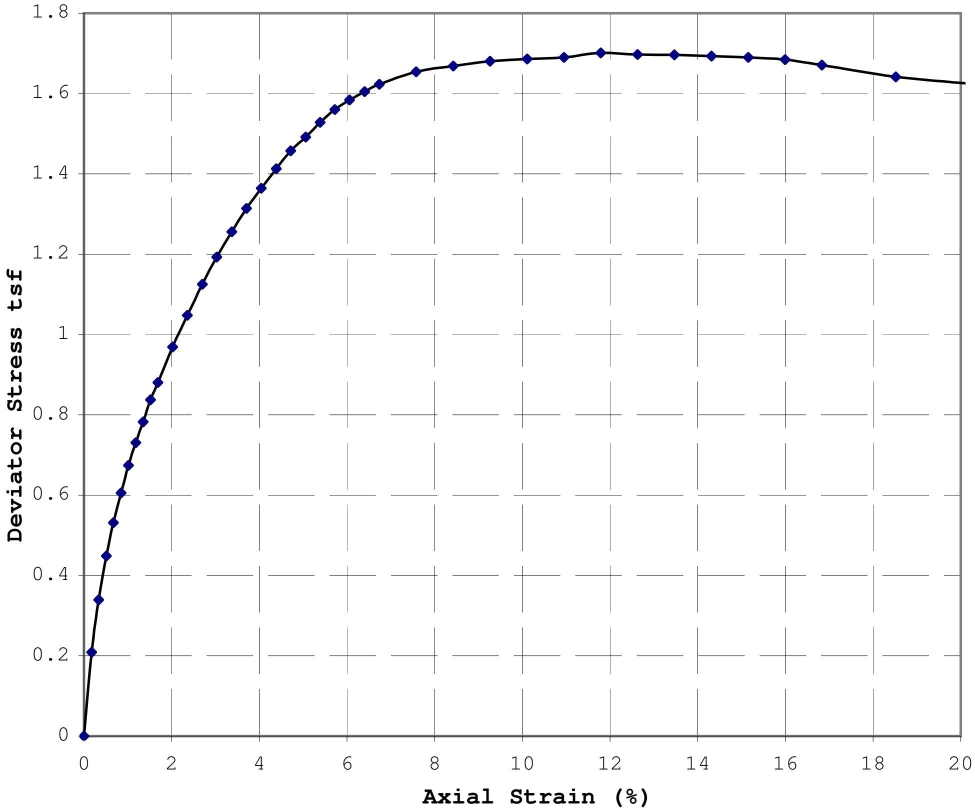
W.C. (%): 19.8
Yd (pcf): 103.6

Sketch of Specimen After Failure



Triaxial U-U Stress/Strain Curves (ASTM:D2850)

Project: Upper Maple River
Job: 10826
Client: Barr Engineering Company
Date: 5/5/17
Remarks: Specimens trimmed to given sizes; Allowed to adjust under applied confining pressures for about 10 minutes.

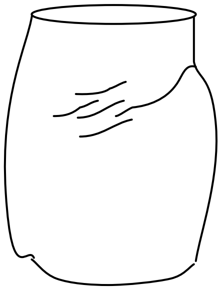


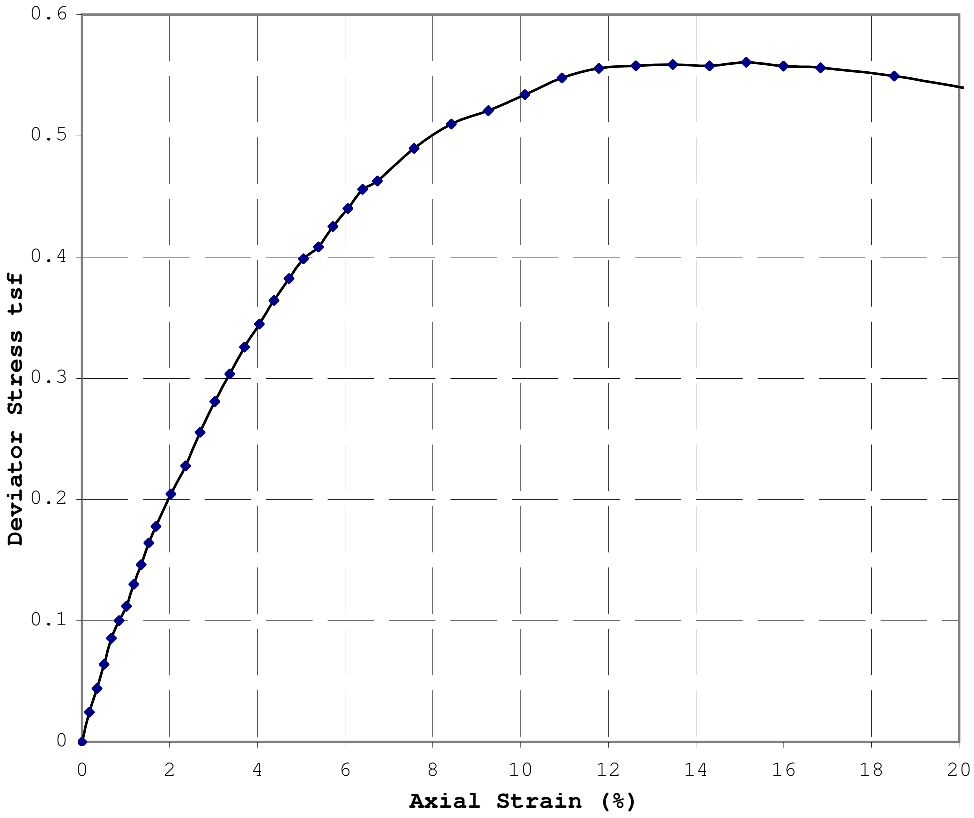
Boring: B-03
Depth: 35-36.5
Sample #: 147
Soil Type: Sandy Lean Clay w/a little gravel and some pockets of silty sand (CL)

Strain Rate (in/min): 0.060
Sample Type: 3T
Dia. (in) 2.89
Ht. (in) 5.94
Height to Diameter Ratio: 2.05

Max Deviator Stress: 1.70 tsf
Strain at Failure (%): 11.8
Confining Pressure: 0.75 tsf
W.C. (%) 22.2
Yd (pcf): 103.1

Sketch of Specimen After Failure





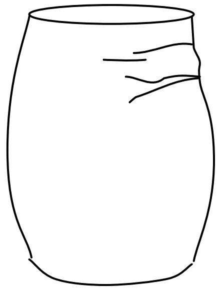
Boring: B-05
Depth: 12.5-14
Sample #: 108
Soil Type: Clayey Sand w/a little gravel (SC)

Strain Rate (in/min): 0.060
Sample Type: 3T

Dia. (in): 2.88
Ht. (in): 5.94
Height to Diameter Ratio: 2.07

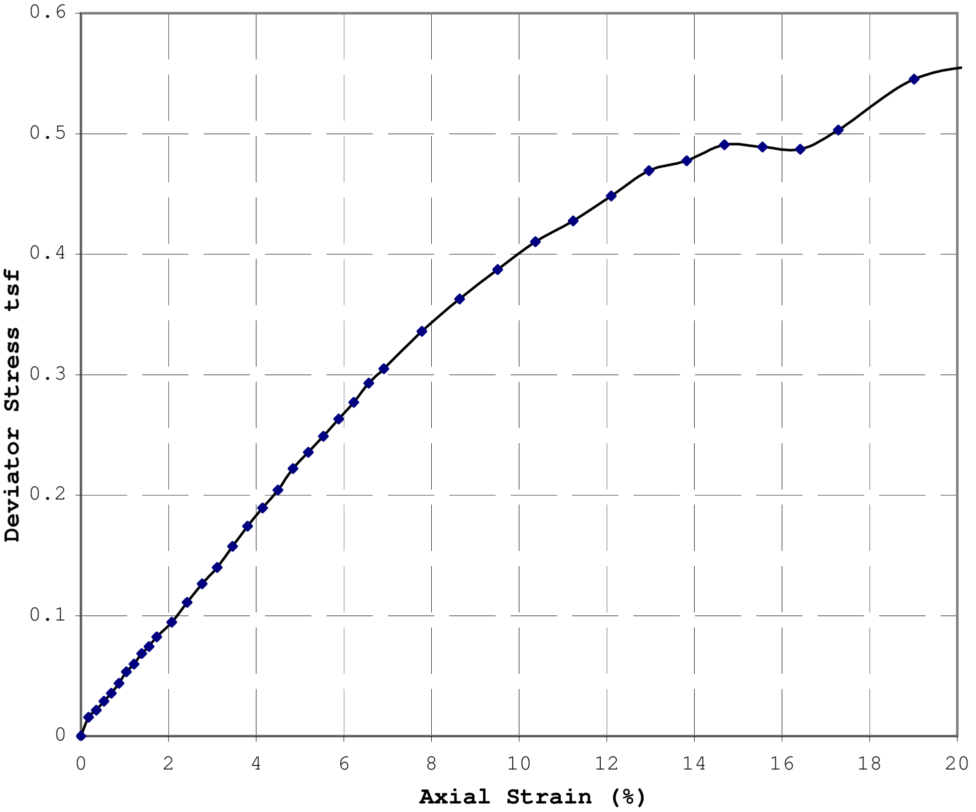
Max Deviator Stress: 0.56 tsf
Strain at Failure (%): 15.2
Confining Pressure: 0.25 tsf
W.C. (%): 20.1
Yd (pcf): 108.4

Sketch of Specimen After Failure



Triaxial U-U Stress/Strain Curves (ASTM:D2850)

Project: Upper Maple River
Job: 10826
Client: Barr Engineering Company
Date: 5/5/17
Remarks: Specimens trimmed to given sizes; Allowed to adjust under applied confining pressures for about 10 minutes.

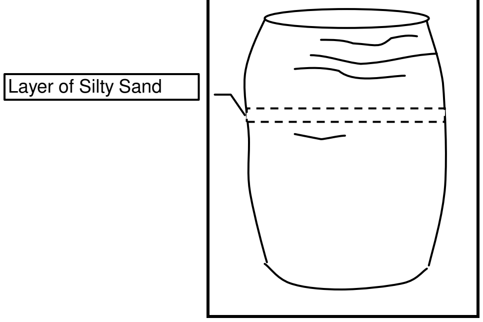


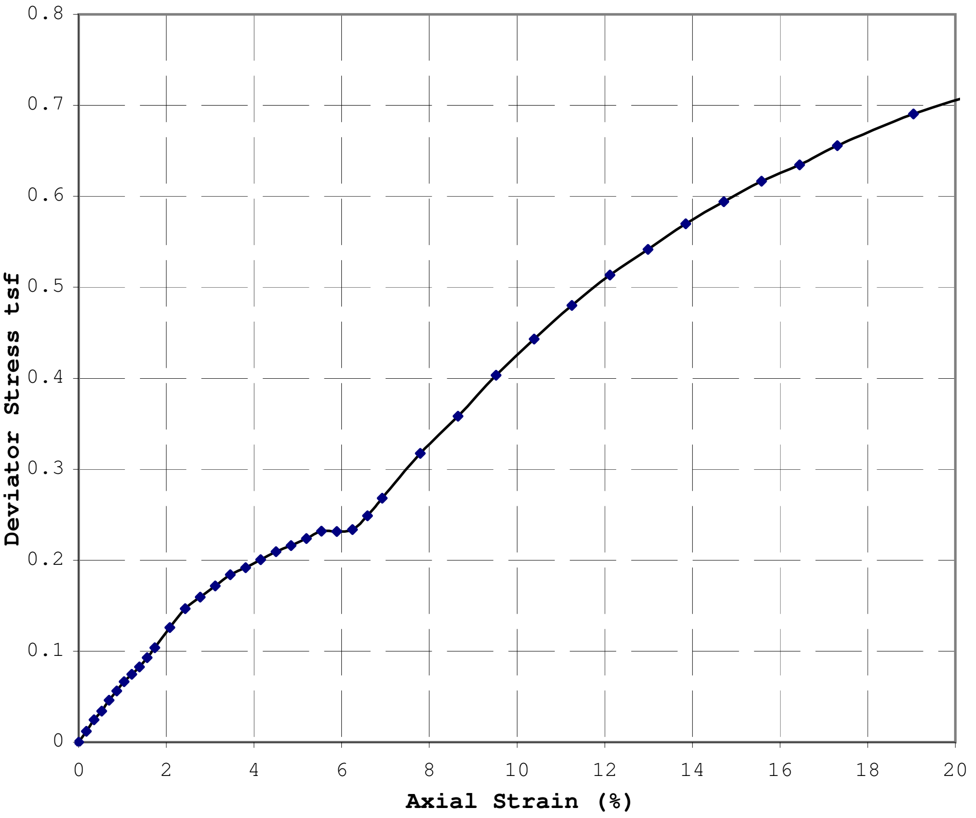
Boring: B-05
Depth: 20-22
Sample #: 111
Soil Type: Mixture of Clayey Sand (SC) and Silty Clay (CL-ML) w/a layer of silty sand

Strain Rate (in/min): 0.060
Sample Type: 3T
Dia. (in) 2.88
Ht. (in) 5.79
Height to Diameter Ratio: 2.01

Max Deviator Stress: **0.56** **tsf**
Strain at Failure (%): **20.0**
Confining Pressure: 0.5 tsf
W.C. (%) 25.2
Yd (pcf): 98.9

Sketch of Specimen After Failure





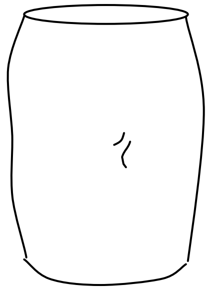
Boring: B-06
Depth: 7.5-9.5
Sample #: 91
Soil Type: Lean Clay w/sand (CL)

Strain Rate (in/min): 0.060
Sample Type: 3T

Dia. (in): 2.88
Ht. (in): 5.78
Height to Diameter Ratio: 2.01

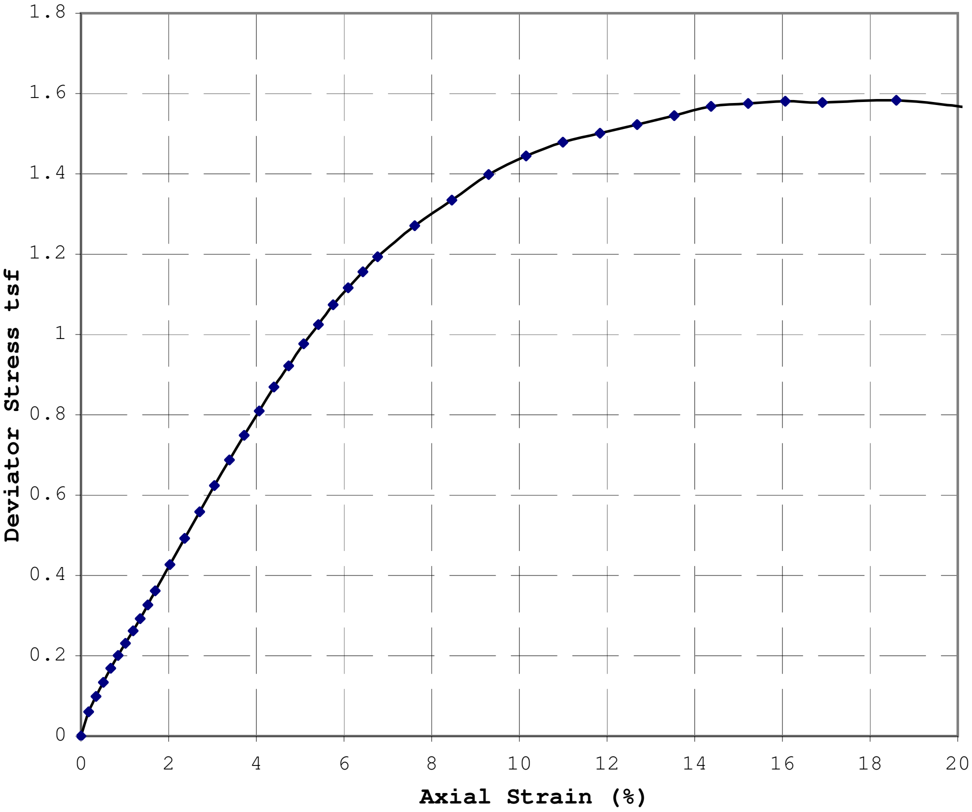
Max Deviator Stress: **0.71** **tsf**
Strain at Failure (%): **20.0**
Confining Pressure: 0.25 tsf
W.C. (%): 23.5
Yd (pcf): 104.1

Sketch of Specimen After Failure



Triaxial U-U Stress/Strain Curves (ASTM:D2850)

Project: Upper Maple River
Job: 10826
Client: Barr Engineering Company
Date: 5/5/17
Remarks: Specimens trimmed to given sizes; Allowed to adjust under applied confining pressures for about 10 minutes.

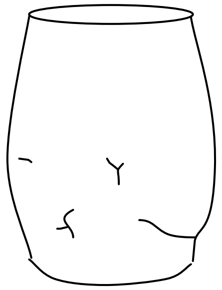


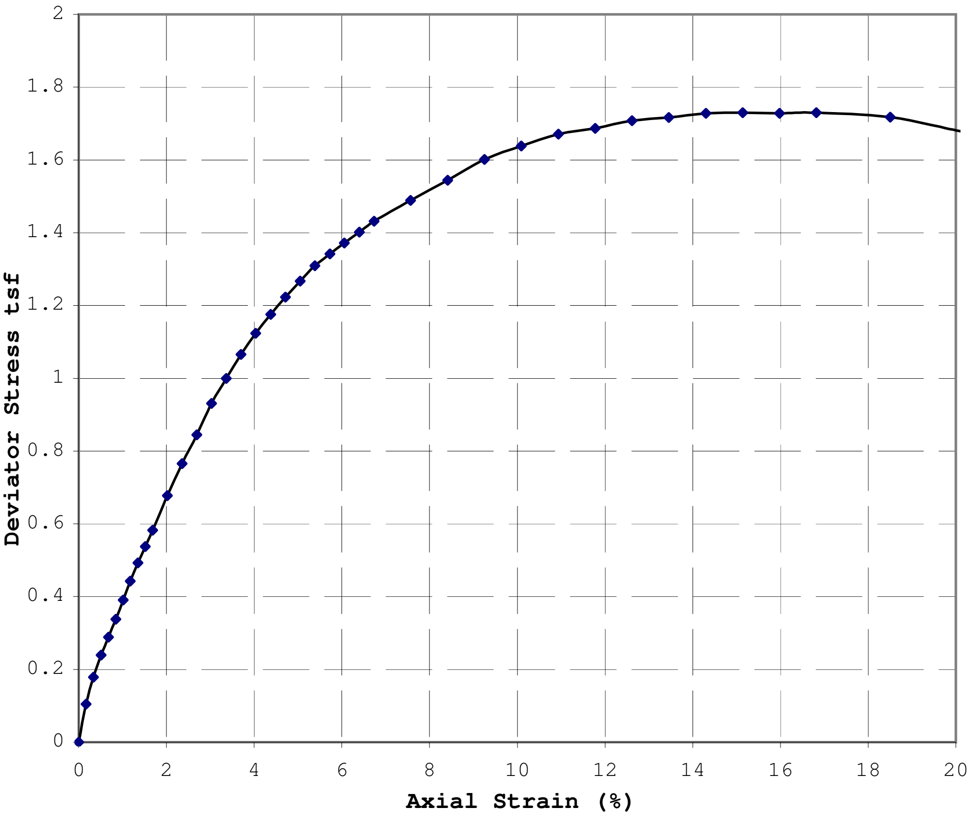
Boring: B-07
Depth: 17.5-19.5
Sample #: 80
Soil Type: Sandy Lean Clay w/a trace of gravel (CL)

Strain Rate (in/min): 0.060
Sample Type: 3T
Dia. (in) 2.88
Ht. (in) 5.91
Height to Diameter Ratio: 2.05

Max Deviator Stress: 1.58 tsf
Strain at Failure (%): 18.6
Confining Pressure: 0.5 tsf
W.C. (%) 20.8
Yd (pcf): 106.9

Sketch of Specimen After Failure





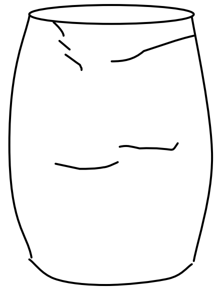
Boring: B-08
Depth: 10-12
Sample #: 65
Soil Type: Clayey Sand w/a trace of gravel (SC/CL)

Strain Rate (in/min): 0.060
Sample Type: 3T

Dia. (in): 2.88
Ht. (in): 5.95
Height to Diameter Ratio: 2.06

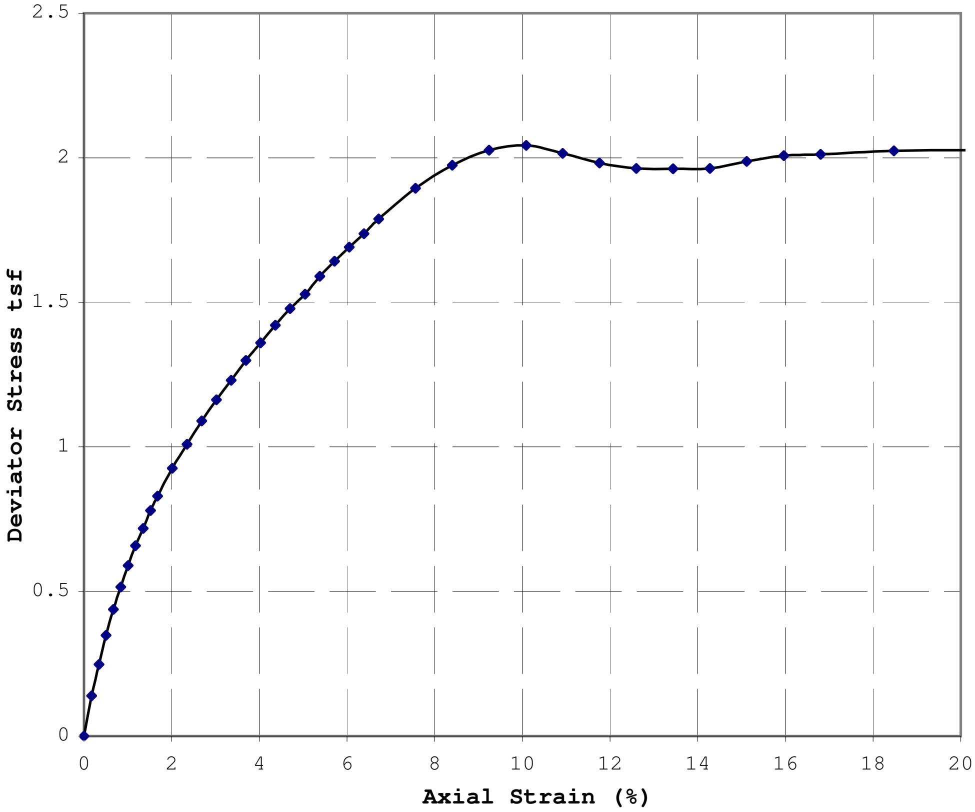
Max Deviator Stress: 1.73 tsf
Strain at Failure (%): 15.1
Confining Pressure: 0.25 tsf
W.C. (%): 21.6
Yd (pcf): 102.1

Sketch of Specimen After Failure



Triaxial U-U Stress/Strain Curves (ASTM:D2850)

Project: Upper Maple River
Job: 10826
Client: Barr Engineering Company
Date: 5/5/17
Remarks: Specimens trimmed to given sizes; Allowed to adjust under applied confining pressures for about 10 minutes.

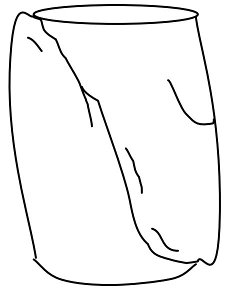


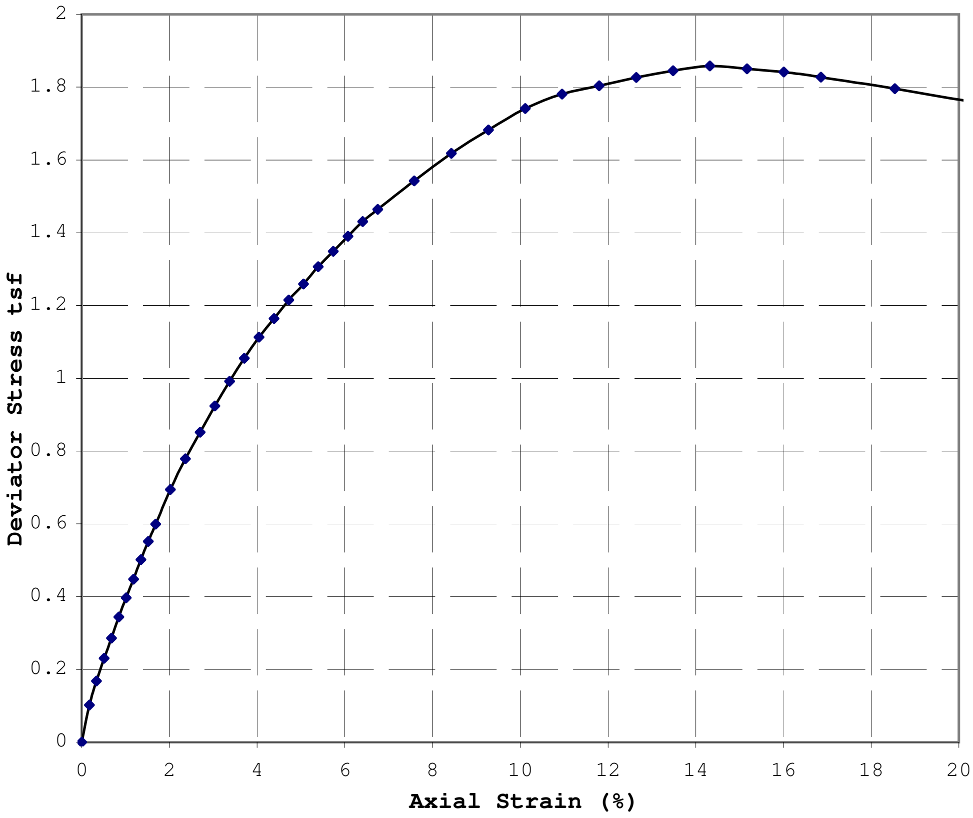
Boring: B-11
Depth: 10-12
Sample #: 19
Soil Type: Sandy Lean Clay w/a little gravel (CL)

Strain Rate (in/min): 0.060
Sample Type: 3T
Dia. (in) 2.89
Ht. (in) 5.95
Height to Diameter Ratio: 2.06

Max Deviator Stress: 2.04 tsf
Strain at Failure (%): 10.1
Confining Pressure: 0.25 tsf
W.C. (%) 22.8
Yd (pcf): 100.2

Sketch of Specimen After Failure





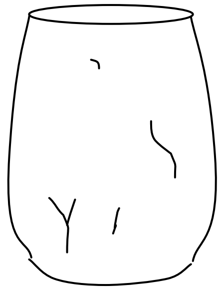
Boring: B-11
Depth: 17.5-19.5
Sample #: 22
Soil Type: Sandy Lean Clay w/a trace of gravel (CL)

Strain Rate (in/min): 0.060
Sample Type: 3T

Dia. (in): 2.88
Ht. (in): 5.93
Height to Diameter Ratio: 2.06

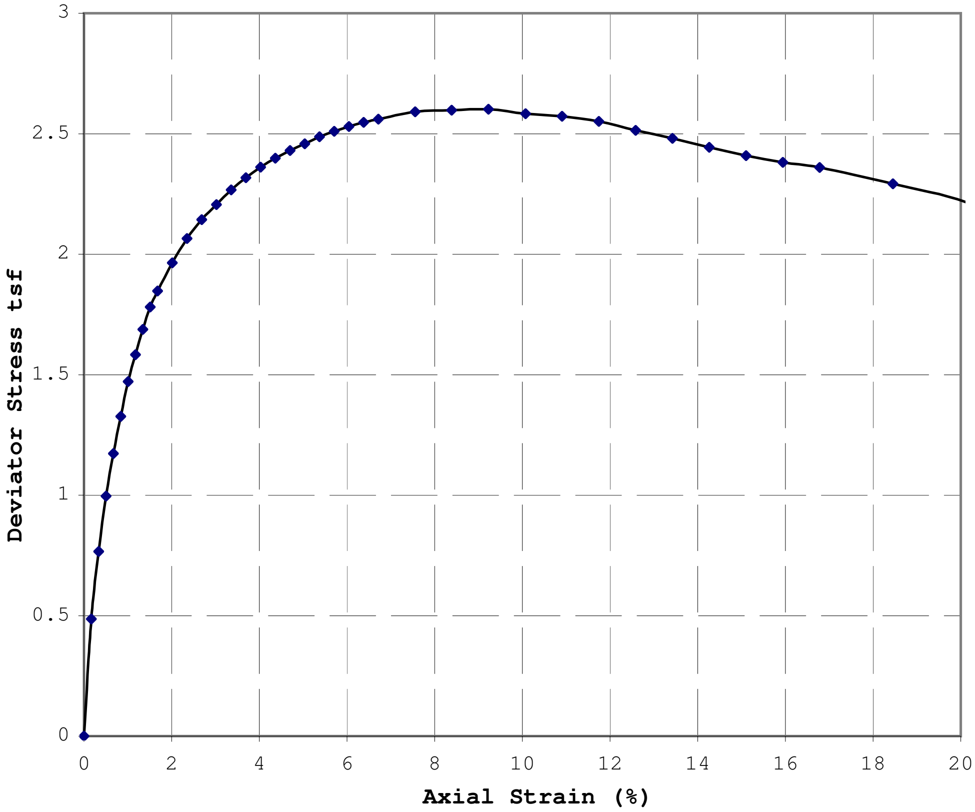
Max Deviator Stress: 1.86 tsf
Strain at Failure (%): 14.3
Confining Pressure: 0.5 tsf
W.C. (%): 20.0
Yd (pcf): 108.4

Sketch of Specimen After Failure



Triaxial U-U Stress/Strain Curves (ASTM:D2850)

Project: Upper Maple River
Job: 10826
Client: Barr Engineering Company
Date: 5/5/17
Remarks: Specimens trimmed to given sizes; Allowed to adjust under applied confining pressures for about 10 minutes.

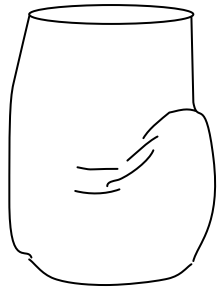


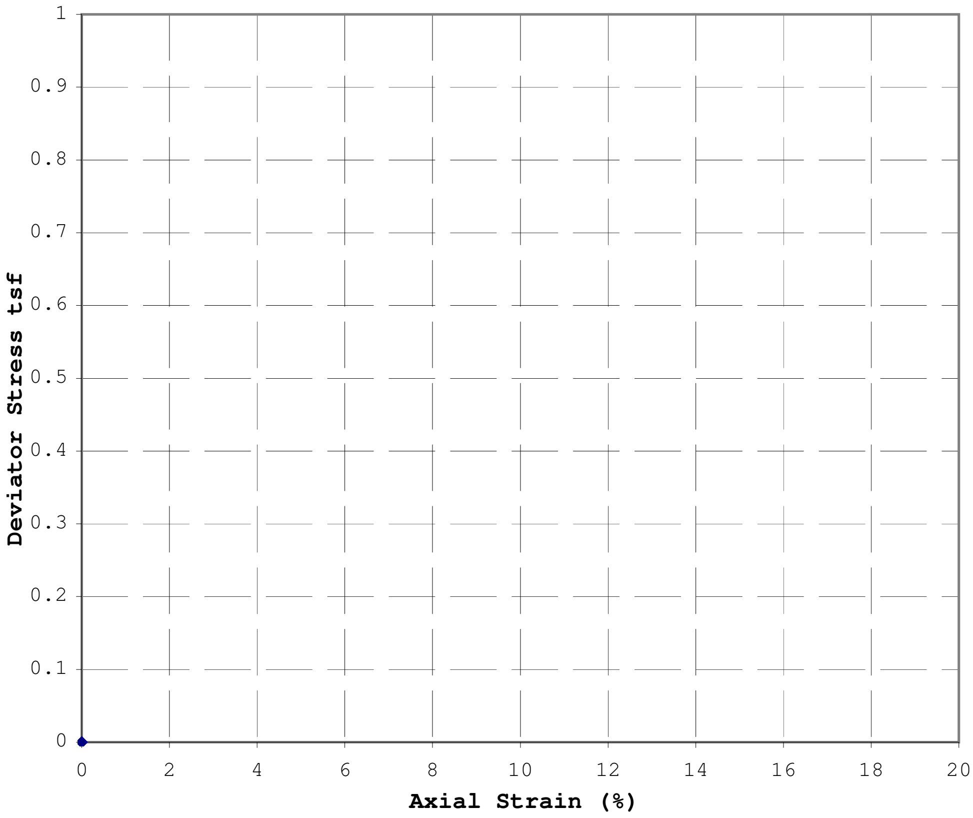
Boring: B-12
Depth: 30-31.5
Sample #: 12
Soil Type: Sandy Lean Clay w/a trace of gravel (CL)

Strain Rate (in/min): 0.060
Sample Type: 3T
Dia. (in) 2.88
Ht. (in) 5.96
Height to Diameter Ratio: 2.07

Max Deviator Stress: **2.60** **tsf**
Strain at Failure (%): **9.2**
Confining Pressure: 0.75 tsf
W.C. (%) 21.8
Yd (pcf): 104.7

Sketch of Specimen After Failure





Boring:
Depth:
Sample #:
Soil Type:

Strain Rate (in/min):
Sample Type:

Dia. (in):
Ht. (in):
Height to Diameter Ratio:

Max Deviator Stress: **tsf**
Strain at Failure (%):
Confining Pressure: tsf
W.C. (%):
Yd (pcf):

Sketch of Specimen After Failure

Hydraulic Conductivity Test Data ASTM D5084

Project: Upper Maple River

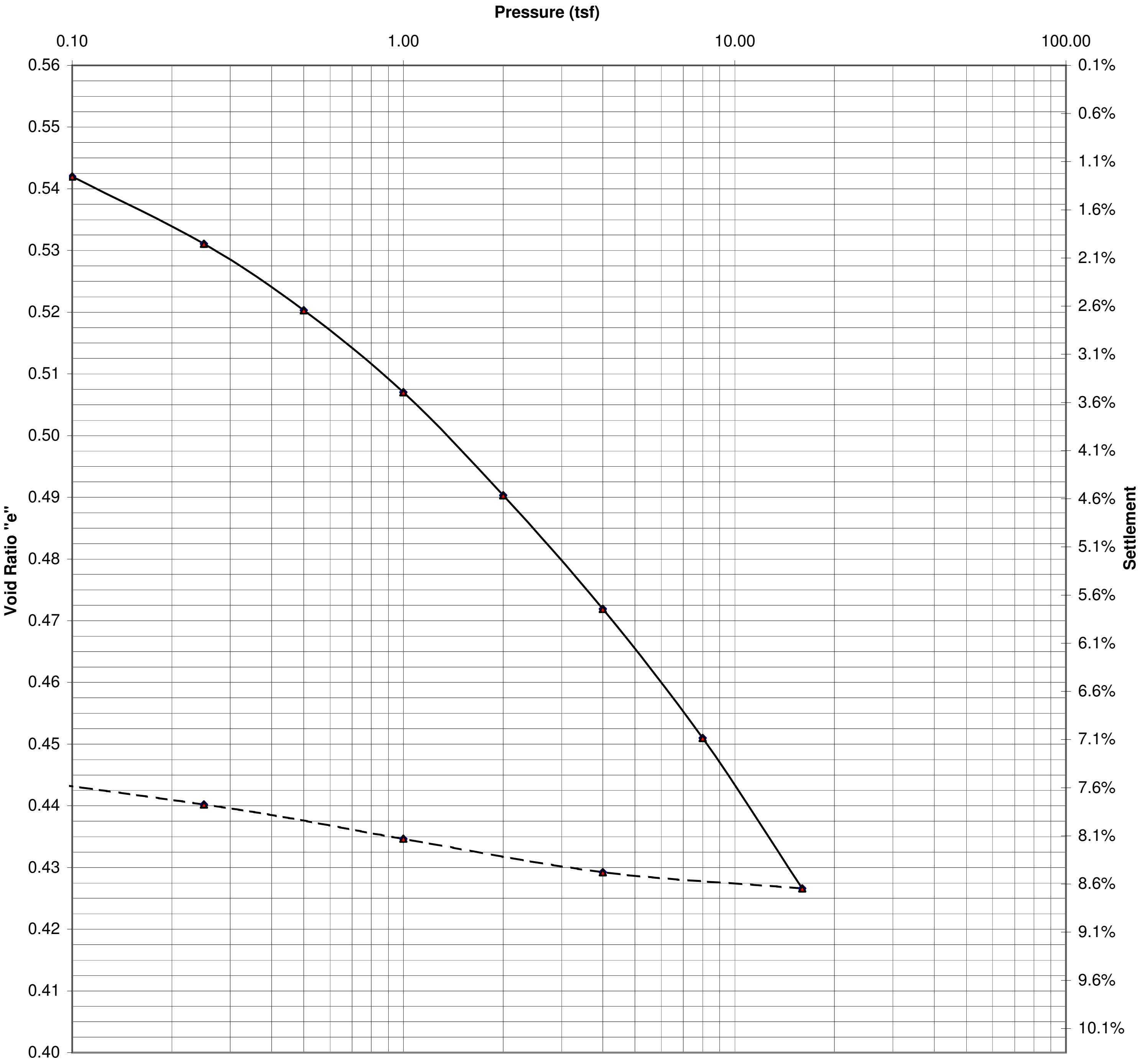
Date: 5/1/2017

Client: Barr Engineering Company

Job No.: 10826

	Boring No.:	B-06	B-08	B-10				
	Sample No.:							
	Depth (ft):	7.5-9.5	10-12	7.5-9.5				
	Location:							
	Sample Type:	TWT	TWT	TWT				
	Soil Type:	Sandy Lean Clay w/a trace of gravel (CL)	Clayey Sand w/a little gravel (SC)	Sandy Lean Clay w/a trace of gravel (CL)				
	Atterberg Limits							
	LL							
	PL							
	PI							
	Permeability Test	Intact	Intact	Intact				
Before Test Conditions:	Saturation %:							
	Porosity:							
	Ht. (in):	2.73	2.74	2.89				
	Dia. (in):	2.77	2.89	2.87				
	Dry Density (pcf):	109.3	100.8	108.7				
	Water Content:	23.2%	22.7%	19.1%				
	Test Type:	Falling Head	Falling Head	Falling Head				
	Max Head (ft.):	5.0	5.0	5.0				
	Confining press. (Effective-psi):	2.0	2.0	2.0				
	Trial No.:	6-10	8-12	7-11				
	Water Temp °C:	22.0	22.0	22.0				
	% Compaction							
	% Saturation (After Test)	95.1%	95.4%	98.7%				
	Coefficient of Permeability							
	K @ 20 °C (cm/sec)	**2.0 x 10^{-8}**	**8.2 x 10^{-7}**	**1.5 x 10^{-7}**				
	K @ 20 °C (ft/min)	**3.9 x 10^{-8}**	**1.6 x 10^{-6}**	**3.0 x 10^{-7}**				
	Notes:							

Void Ratio and % Settlement vs. Log of Pressure



Project: Upper Maple River / Barr Engineering Company

Date: 5/5/17

Sample #:

Boring #: B-05

Depth ft: 12.5-14

Job #: 10826

Soil Type: Clayey Sand w/a little gravel (SC)

Initial W/C (%): 20.0

Dry Density (pcf): 107.6

LL:

PL:

PI:

Gs: 2.69 (Assumed)

Organic Content (%):

Initial Height (in.): 0.746

Diameter (in.): 2.506

e_o= 0.561

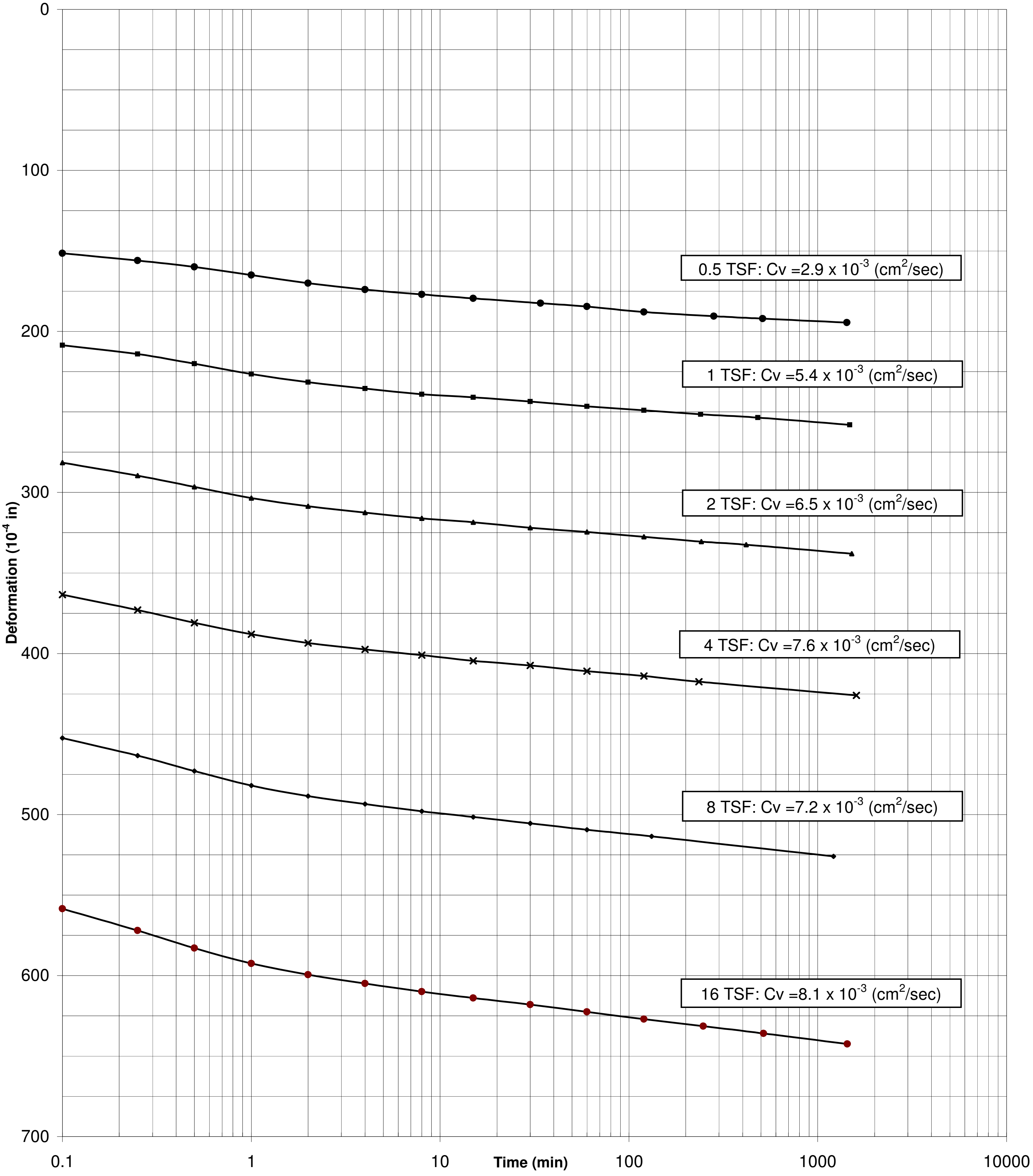
Preconsolidation Pressure (Pc): 1.2 tsf

Compression Index (Cc): 0.08

Recompression Index (Cr): ≅ 0.01

Remarks: Testing performed in general accordance with ASTM:D2435

Consolidation Log of Time Curves



Project: Upper Maple River / Barr Engineering Company

Date: 5/5/17

Sample #:

Boring #: B-05

Depth ft: 12.5-14

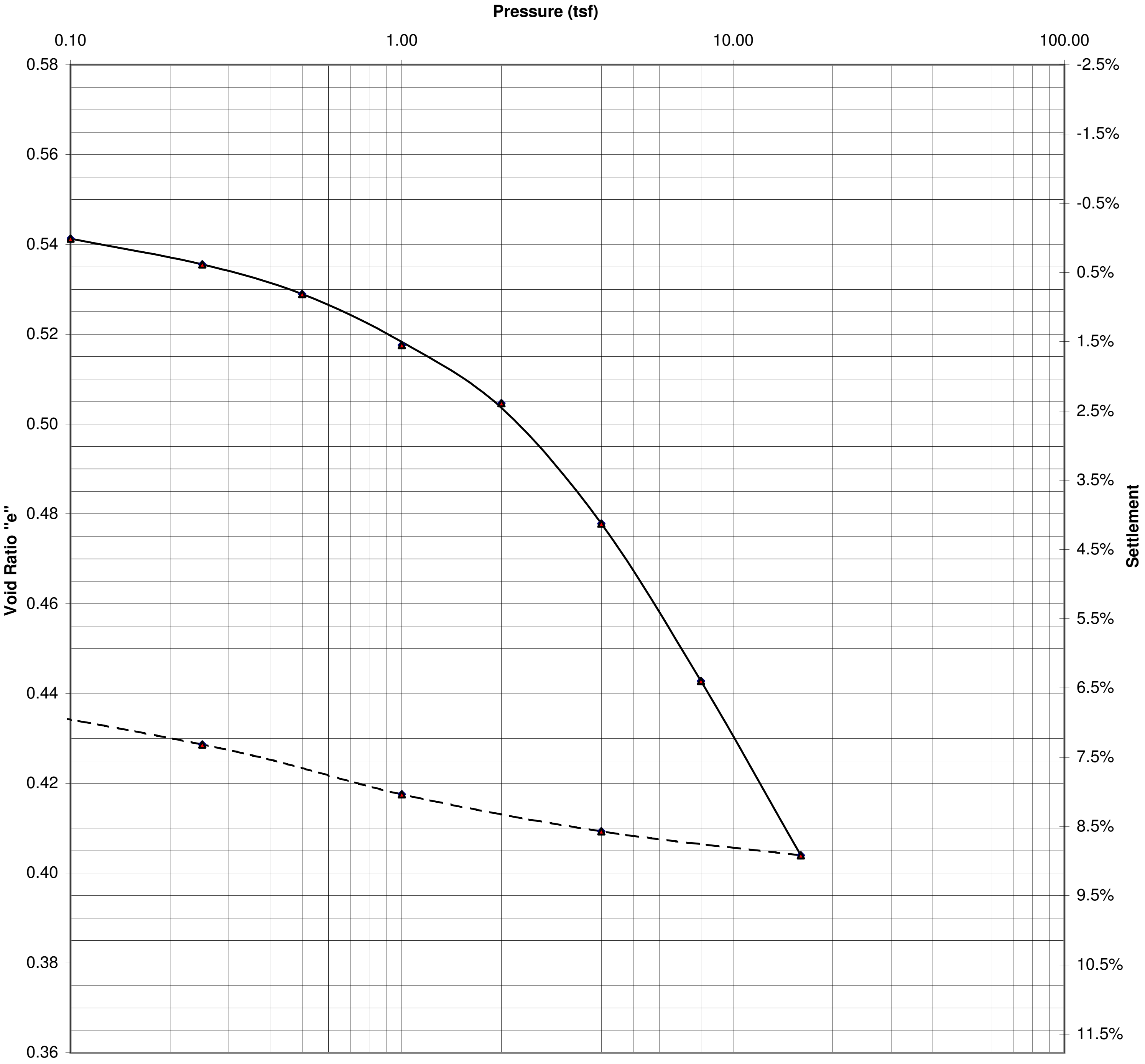
Job #: 10826

9530 James Avenue South

SOIL
ENGINEERING
TESTING, INC.

Bloomington, Minnesota 55431

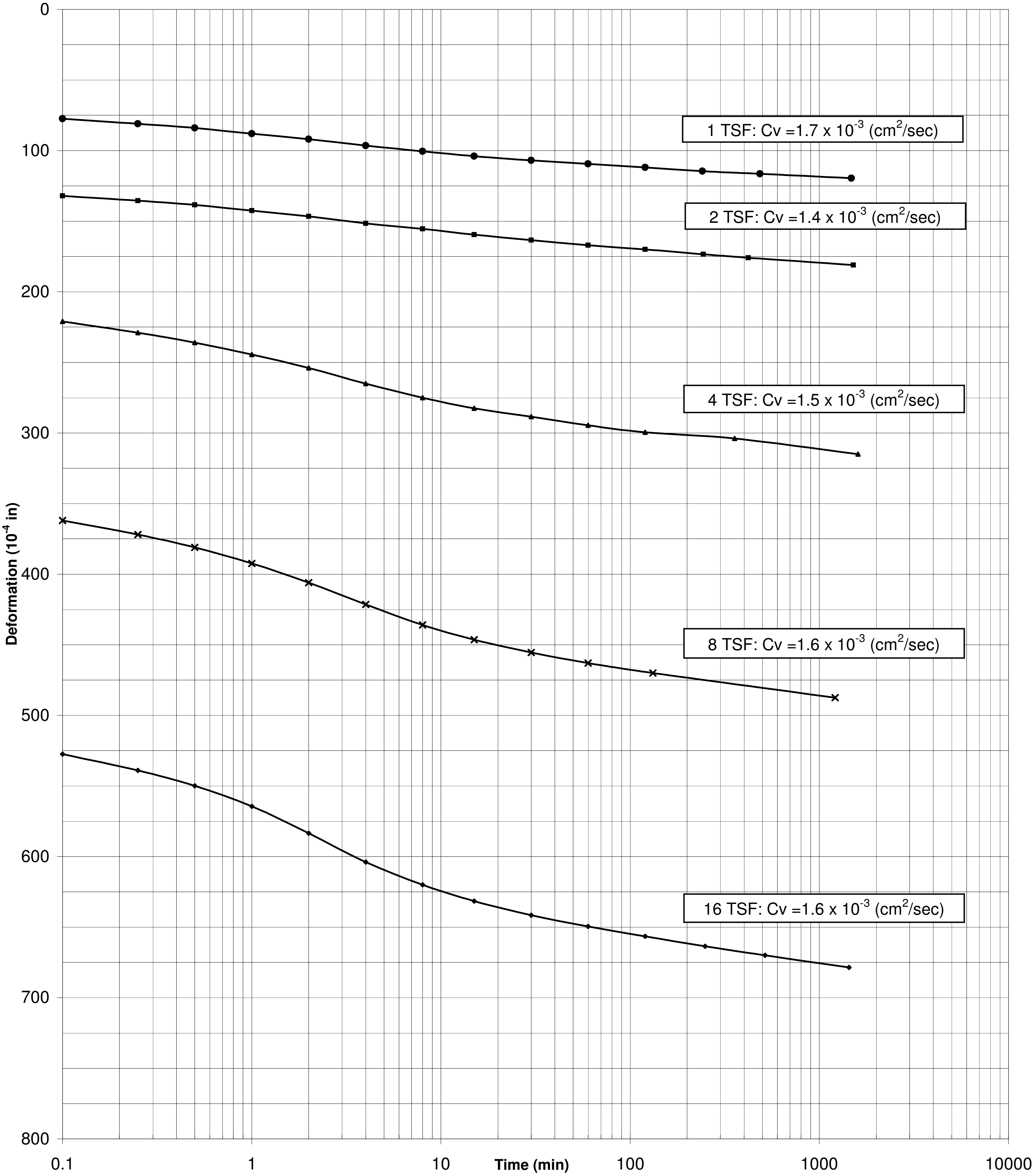
Void Ratio and % Settlement vs. Log of Pressure



Project: Upper Maple River / Barr Engineering Company			Date: 5/5/17
Sample #:	Boring #: B-10	Depth ft: 7.5-9.5	Job #: 10826
Soil Type: Sandy Lean Clay w/a trace of gravel (CL)			
Initial W/C (%): 18.9	Dry Density (pcf): 108.9	LL: PL: PI:	Gs: 2.69 (Assumed)
Organic Content (%):	Initial Height (in.): 0.759	Diameter (in.): 2.505	e_o= 0.542
Preconsolidation Pressure (Pc): 2.8 tsf	Compression Index (Cc): 0.13	Recompression Index (Cr): ≅ 0.02	

Remarks: Testing performed in general accordance with ASTM:D2435

Consolidation Log of Time Curves



Project: Upper Maple River / Barr Engineering Company			Date: 5/5/17
Sample #:	Boring #: B-10	Depth ft: 7.5-9.5	Job #: 10826

9530 James Avenue South

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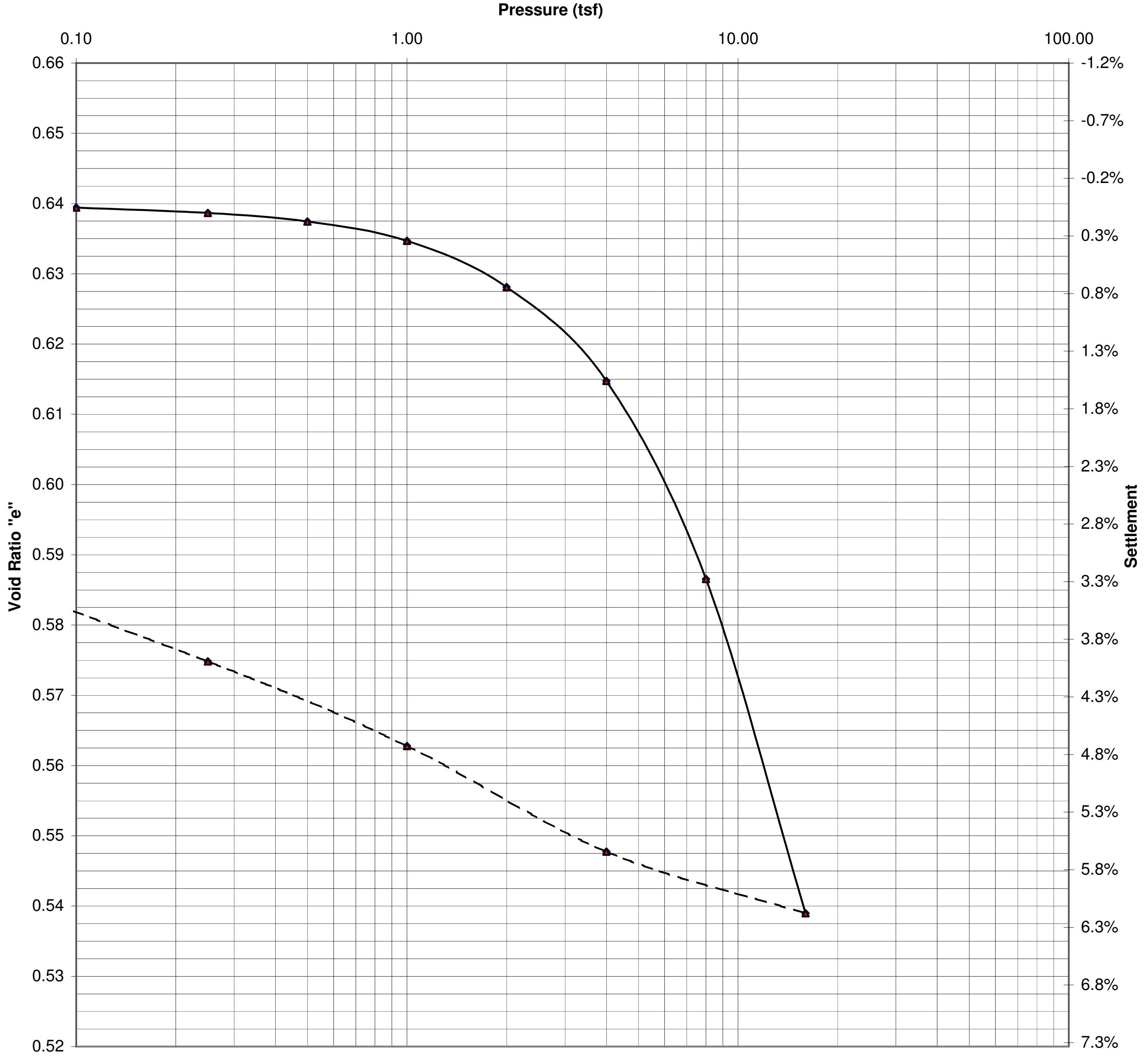
ENGINEERING
TESTING, INC.

Bloomington, Minnesota 55431

Void Ratio and % Settlement vs. Log of Pressure



Project: Upper Maple River / Barr Engineering Company

Date: 5/4/17

Sample #:

Boring #: B-11

Depth ft: 10-12

Job #: 10826

Soil Type: Sandy Lean Clay with a little gravel (CL)

Initial W/C (%): 22.0

Dry Density (pcf): 102.0

LL:

PL:

PI:

Gs: 2.68 (Assumed)

Organic Content (%):

Initial Height (in.): 0.748

Diameter (in.): 2.503

e_o= 0.641

Preconsolidation Pressure (Pc): 5.1 tsf

Compression Index (Cc): 0.16

Recompression Index (Cr): ≅ 0.02

Remarks: Testing performed in general accordance with ASTM:D2435

9530 James Avenue South

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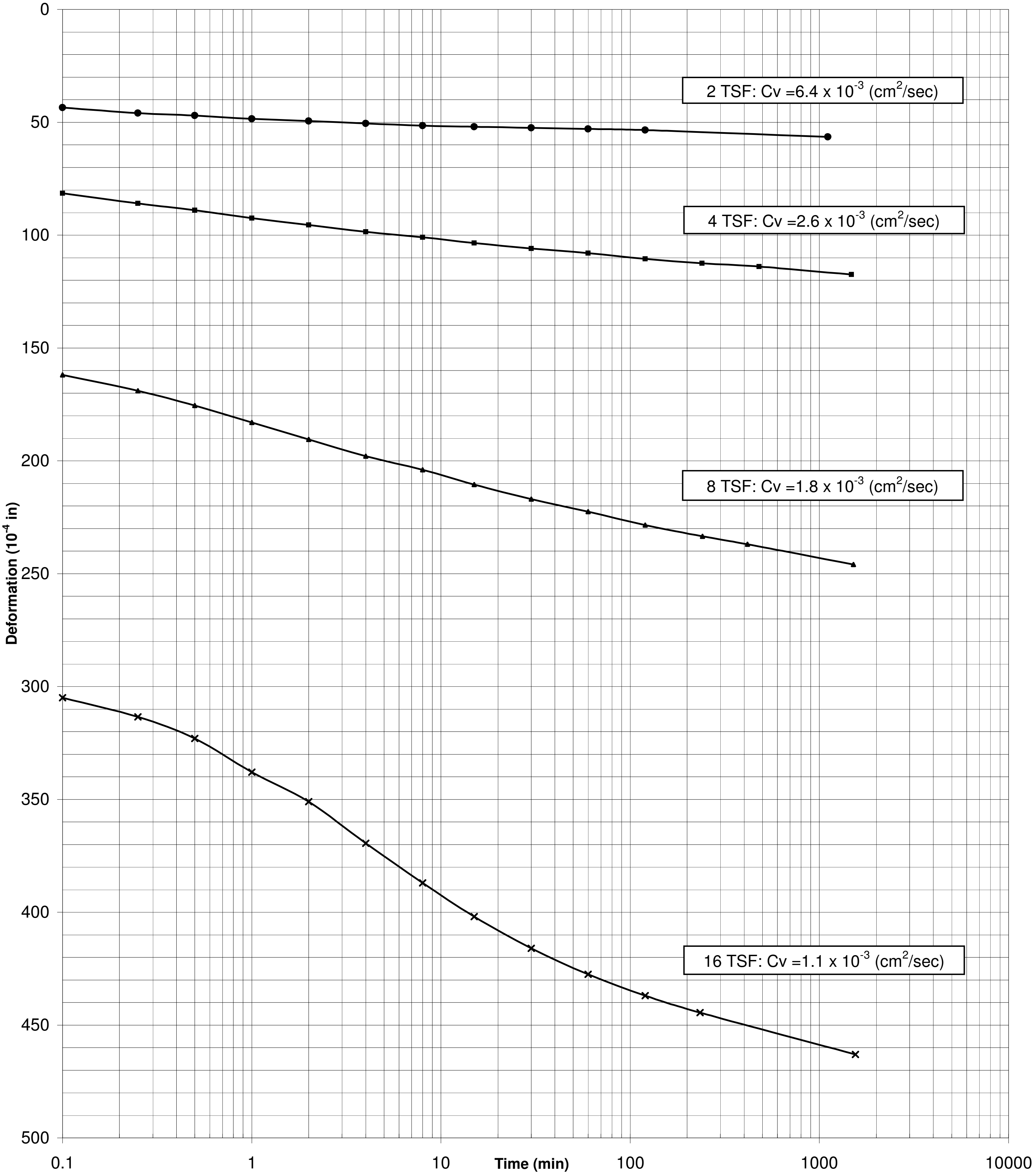
TESTING, INC.

Bloomington, Minnesota 55431

Consolidation Log of Time Curves



Project: Upper Maple River / Barr Engineering Company			Date: 5/4/17
Sample #:	Boring #: B-11	Depth ft: 10-12	Job #: 10826

9530 James Avenue South

SOIL ENGINEERING TESTING, INC.

Bloomington, Minnesota 55431

Appendix C

Soil Lithology Along Alignment Profile

CADD USER: John M. Warner FILE: P:\MPLS\34 ND\09\34091031 SWAN CREEK WATERSHED PLAN\WORKFILES\UPPER MAPLE SPECIFIC\ALTERNATIVES SELECTED\ALT2A\GEOTECH\FIELD\FOR PROFILE CREATION\PLAN-PROFILE_WELLS.DWG PLOT SCALE: 1:2 PLOT DATE: 3/12/2019 2:29 PM

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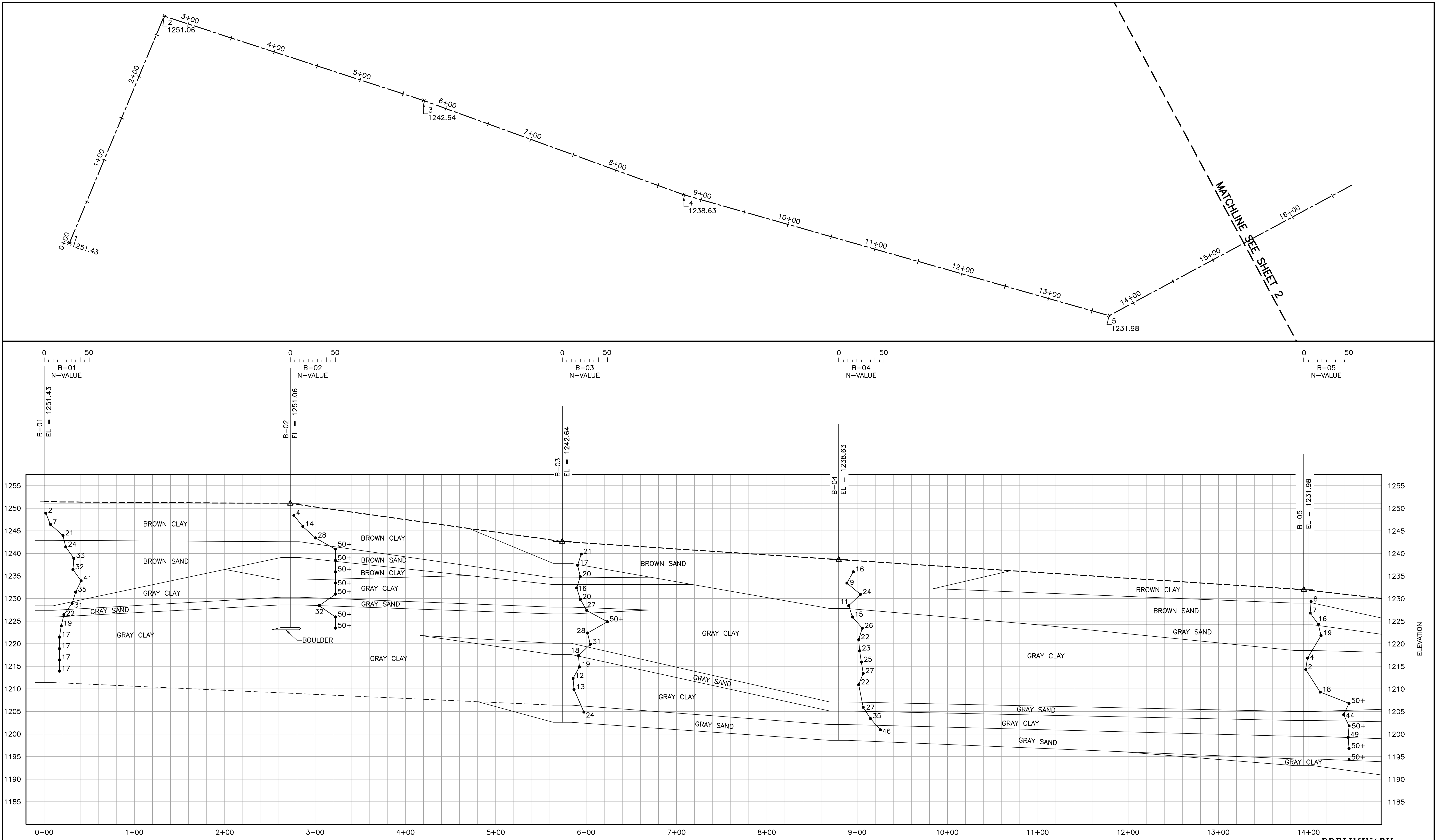

NOTES:
1. ELEVATION BETWEEN BORINGS IS ASSUMED.
2. ALIGNMENT SHOWN PROVIDED FOR VISUALIZATION PURPOSES AND DOES NOT NECESSARILY REPRESENT THE FINAL ALIGNMENT.

PRELIMINARY DRAFT

NO.	BY	CHK.	APP.	DATE	REVISION DESCRIPTION
A	JMW	RJR		2/25/19	PRELIMINARY REVIEW

RELEASED TO/FOR	A	B	C	0	1	2	3
CLIENT	—	—	—	—	—	—	—
BID	—	—	—	—	—	—	—
CONSTRUCTION	—	—	—	—	—	—	—

DATE RELEASED

BARR
Corporate Headquarters:
Minneapolis, Minnesota
Ph: 1-800-632-2277

Project Office:
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
Suite 200
MINNEAPOLIS, MN 55435
Ph: 1-800-632-2277
Fax: (952) 832-2601
www.barr.com

Scale	AS SHOWN
Date	6/19/2017
Drawn	JMW
Checked	RJR
Designed	RJR
Approved	

MOORE ENGINEERING, INC.
WEST FARGO, NORTH DAKOTA

UPPER MAPLE ALTERNATIVE 2A
BARNES COUNTY, NORTH DAKOTA

PLAN AND PROFILE
SHEET 1 OF 3

BARR PROJECT No. 34091031.02
CLIENT PROJECT No.
DWG. No. PP-01
REV. No. A

CADD USER: John M. Warner FILE: P:\MPLS\34 ND\09\34091031 SWAN CREEK WATERSHED PLAN\WORKFILES\UPPER MAPLE SPECIFIC\ALTERNATIVES SELECTED\ALT2A\GEOTECH\FIELD\FOR PROFILE CREATION\PLAN-PROFILE_WELLS.DWG PLOT SCALE: 1:2 PLOT DATE: 3/12/2019 2:30 PM

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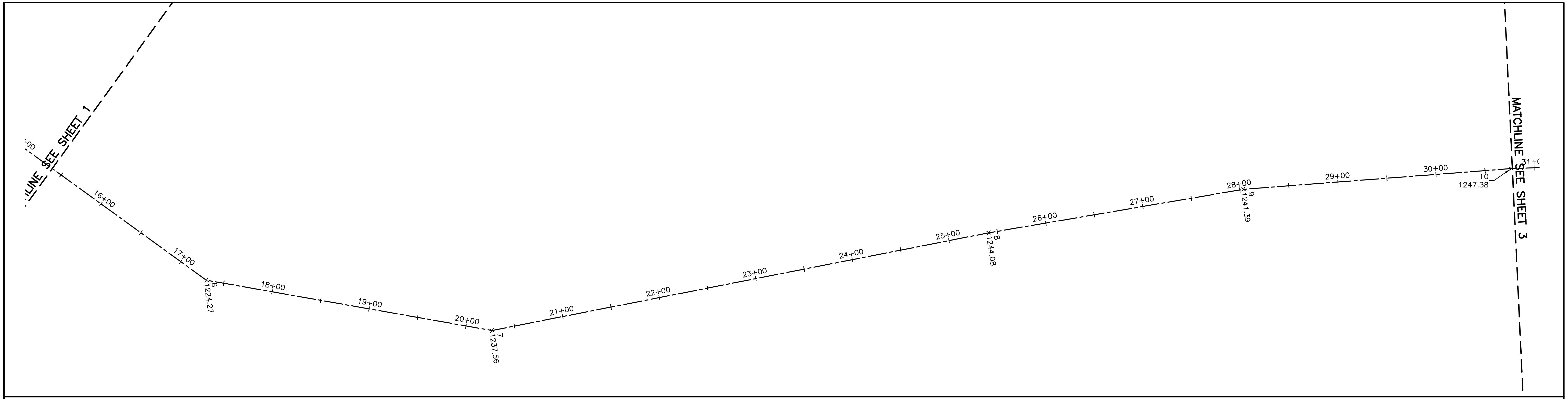

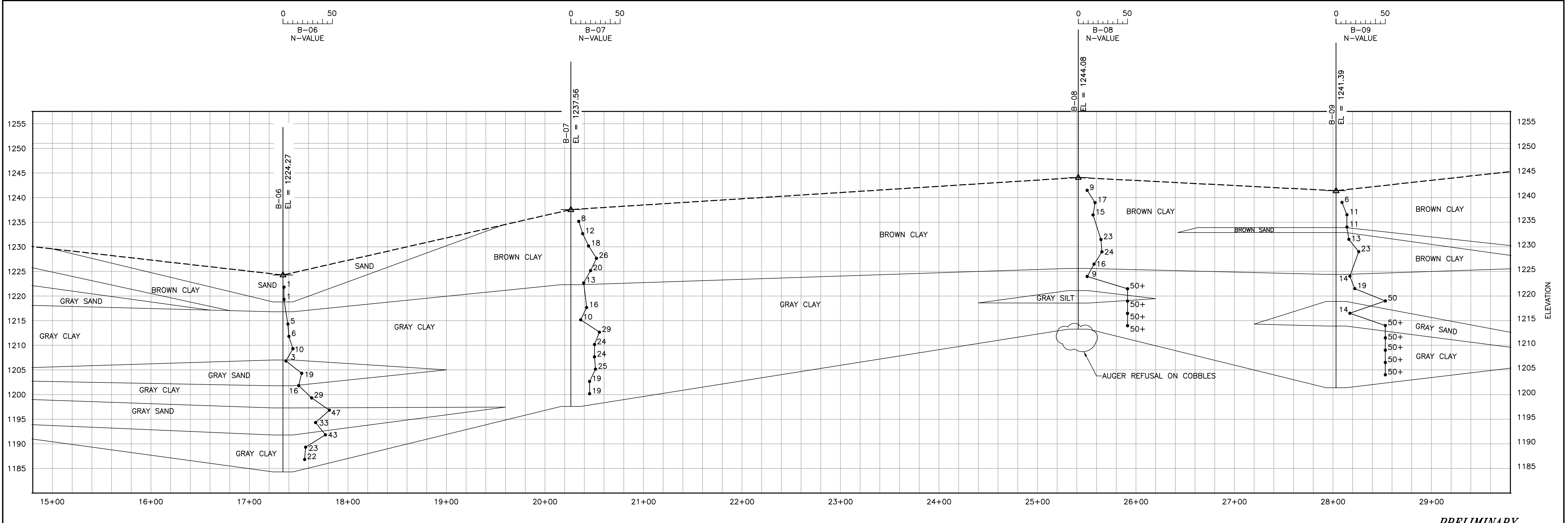

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PRELIMINARY DRAFT

NO.	BY	CHK.	APP.	DATE	REVISION DESCRIPTION
A	JMW	RJR		2/25/19	PRELIMINARY REVIEW

RELEASED TO/FOR	A	B	C	0	1	2	3
CLIENT	—	—	—	—	—	—	—
BID	—	—	—	—	—	—	—
CONSTRUCTION	—	—	—	—	—	—	—
	—	—	—	—	—	—	—
	—	—	—	—	—	—	—
DATE RELEASED							

BARR
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BARR ENGINEERING CO.
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MINNEAPOLIS, MN 55435
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www.barr.com

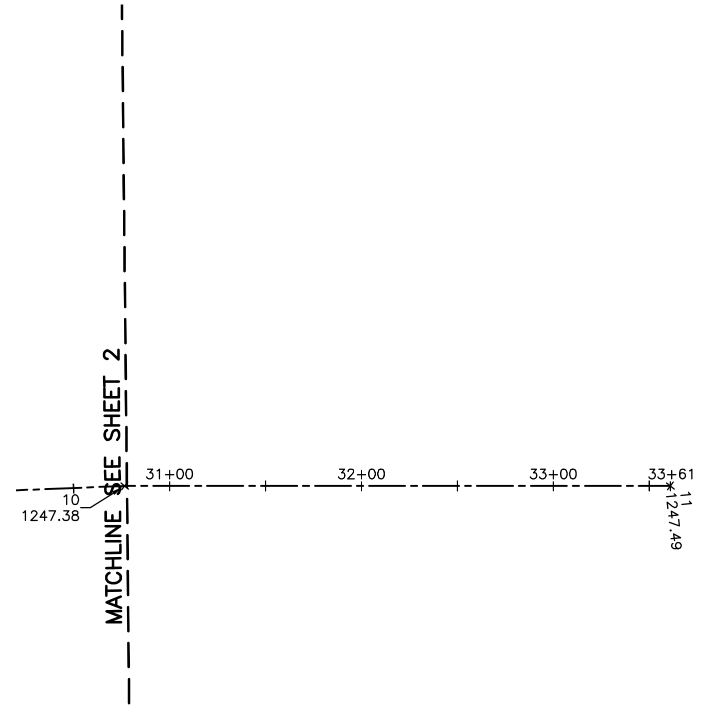
Scale	AS SHOWN
Date	6/19/2017
Drawn	JMW
Checked	RJR
Designed	RJR
Approved	

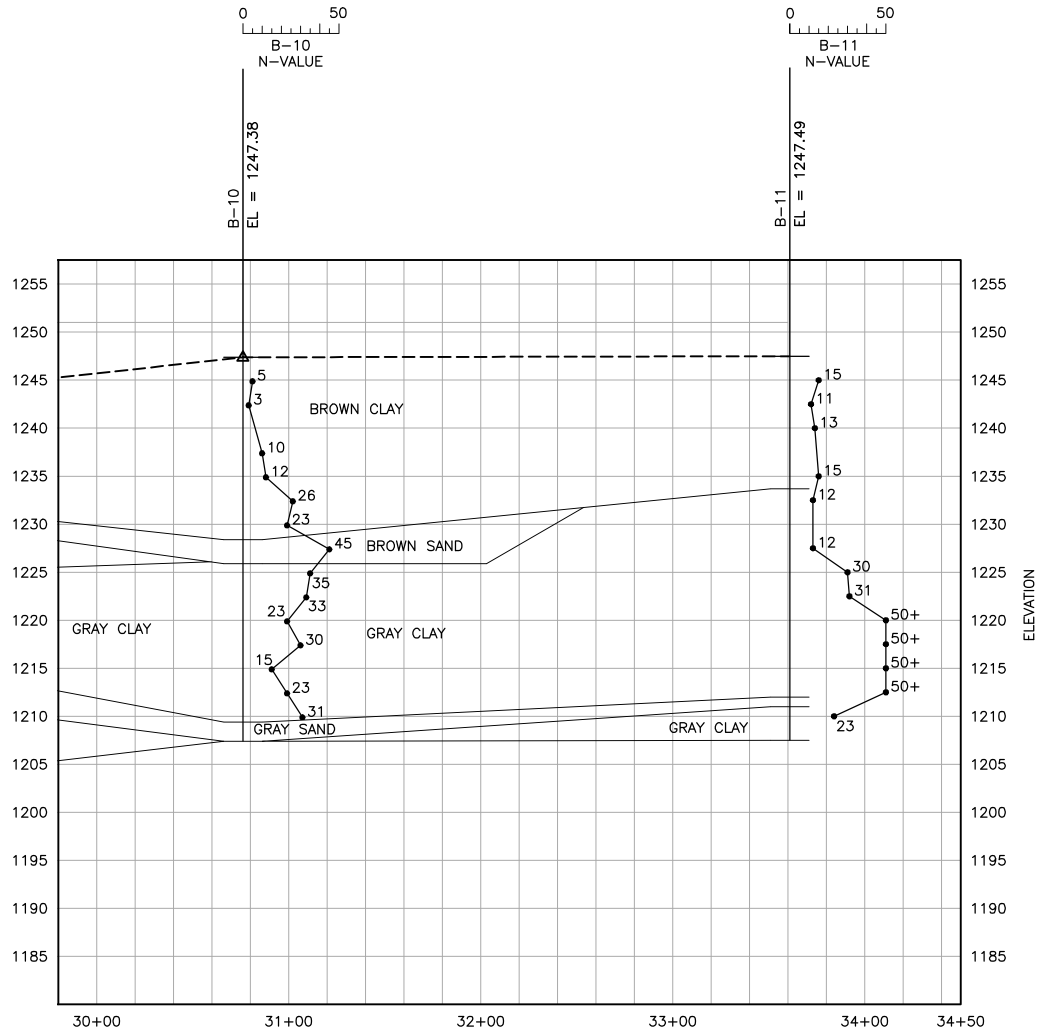
MOORE ENGINEERING, INC.
WEST FARGO, NORTH DAKOTA

UPPER MAPLE ALTERNAATIVE 2A
BARNES COUNTY, NORTH DAKOTA

PLAN AND PROFILE
SHEET 2 OF 3

BARR PROJECT No. 34091031.02
CLIENT PROJECT No.
DWG. No. PP-02
REV. No. A





NOTES:
1. ELEVATION BETWEEN BORINGS IS ASSUMED.
2. ALIGNMENT SHOWN PROVIDED FOR VISUALIZATION PURPOSES AND DOES NOT NECESSARILY REPRESENT THE FINAL ALIGNMENT.

PRELIMINARY DRAFT

NO.	BY	CHK.	APP.	DATE	REVISION DESCRIPTION
A	JMW	RJR		2/25/19	PRELIMINARY REVIEW

RELEASED TO/FOR	A	B	C	0	1	2	3
CLIENT	—	—	—	—	—	—	—
BID	—	—	—	—	—	—	—
CONSTRUCTION	—	—	—	—	—	—	—
	DATE RELEASED						

BARR
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Fax: (952) 832-2601
www.barr.com

Scale	AS SHOWN
Date	6/19/2017
Drawn	JMW
Checked	RJR
Designed	RJR
Approved	

MOORE ENGINEERING, INC.
WEST FARGO, NORTH DAKOTA

UPPER MAPLE ALTERNATIVE 2A
BARNES COUNTY, NORTH DAKOTA

PLAN AND PROFILE
SHEET 3 OF 3

BARR PROJECT No. 34091031.02
CLIENT PROJECT No.
DWG. No. PP-03
REV. No. A

CADD USER: John M. Warner FILE: P:\MPLS\34 ND\09\34091031 SWAN CREEK WATERSHED PLAN\WORKFILES\UPPER MAPLE SPECIFIC\ALTERNATIVES SELECTED\ALT2A\GEOTECH\FIELD\FOR PROFILE CREATION\PLAN-PROFILE_WELLS.DWG PLOT SCALE: 1:2 PLOT DATE: 3/12/2019 2:31 PM
. . BAR M:\AutoCAD 2011\AutoCAD 2011 Support\enu\Template\Barr_2011_Template.dwt Plot at 1 10/05/2010 14:03:50

Appendix D

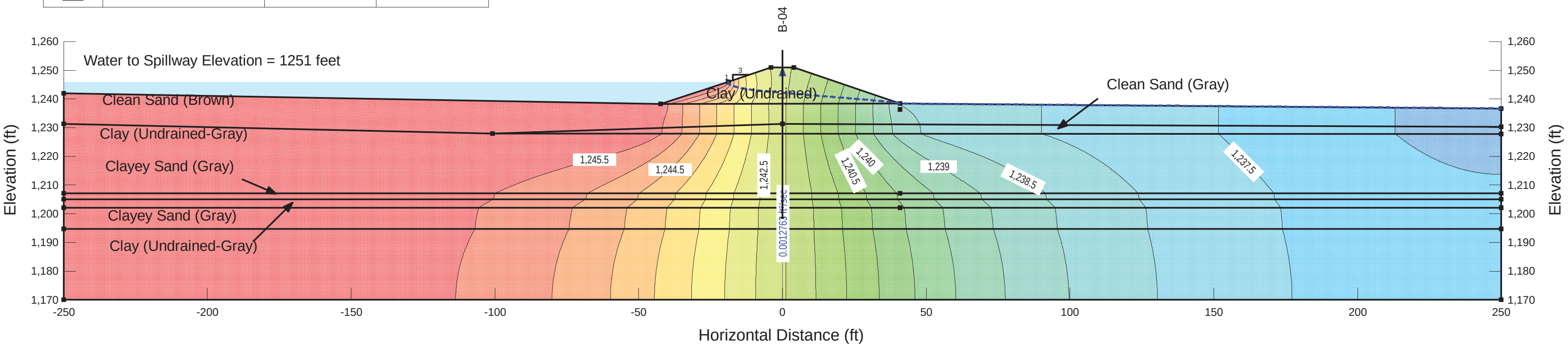
Seepage Model Outputs

Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 1
Upper Maple River Watershed Detention Plan
2.0_CS1_Steady State Seepage_Normal Loading
Last Saved Date: 7/7/2017

Color	Name	Model	Sat Kx (ft/sec)
🟧	Clay (Undrained)	Saturated Only	4.92e-009
⬛	Clay (Undrained-Gray)	Saturated Only	4.92e-009
⬜	Clayey Sand (Gray)	Saturated Only	2.96e-008
🟫	Clean Sand (Brown)	Saturated Only	0.00148
⬜	Clean Sand (Gray)	Saturated Only	0.00148

Contours are Total Head in feet

Water Flux: 0.0012762536 ft³/sec



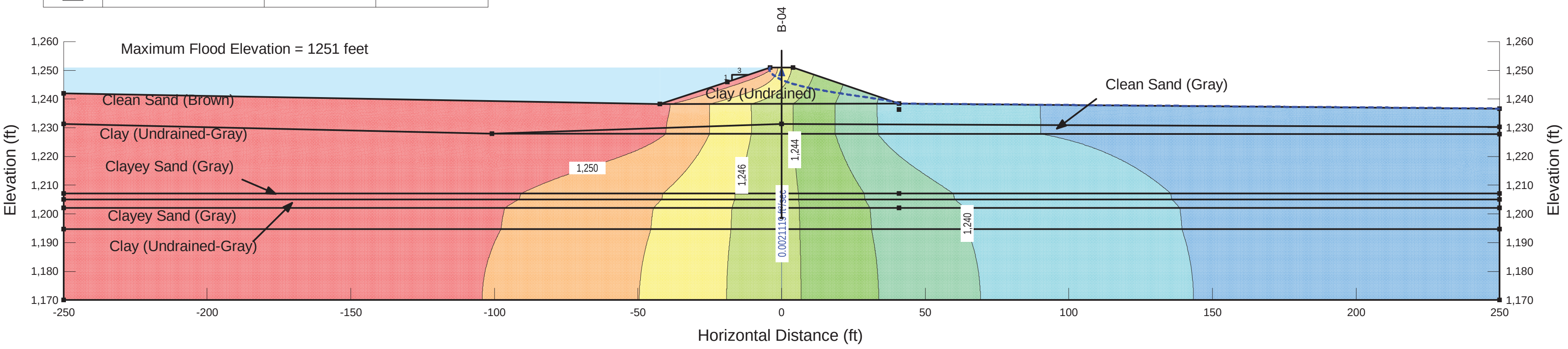
P:\Mpls\34 ND\09\34091031 Swan Creek Watershed Plan\WorkFiles\Upper Maple specific\Alternatives selected\Geostudio Modeling\

Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 1
Upper Maple River Watershed Detention Plan
3.0_CS1_Steady State Seepage_Max Pool
Last Saved Date: 7/7/2017

Color	Name	Model	Sat Kx (ft/sec)
🟧	Clay (Undrained)	Saturated Only	4.92e-009
⬛	Clay (Undrained-Gray)	Saturated Only	4.92e-009
⬜	Clayey Sand (Gray)	Saturated Only	2.96e-008
🟫	Clean Sand (Brown)	Saturated Only	0.00148
⬜	Clean Sand (Gray)	Saturated Only	0.00148

Contours are Total Head in feet

Water Flux: 0.0021119174 ft³/sec



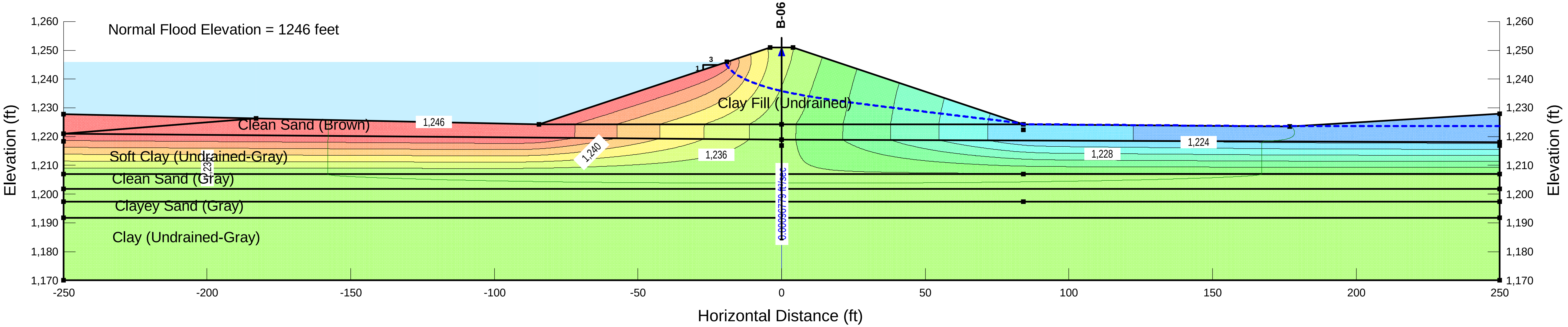
P:\Mpls\34 ND\09\34091031 Swan Creek Watershed Plan\WorkFiles\Upper Maple specific\Alternatives selected\Geostudio Modeling\

Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 2
Upper Maple River Watershed Detention Plan
2.0_CS2_Steady State Seepage_Normal Loading
Last Saved Date: 7/7/2017

Color	Name	Model	Sat Kx (ft/sec)
■	Clay (Undrained-Gray)	Saturated Only	4.92e-009
🟧	Clay Fill (Undrained)	Saturated / Unsaturated	4.92e-009
■	Clayey Sand (Gray)	Saturated Only	2.96e-008
🟫	Clean Sand (Brown)	Saturated Only	0.00148
■	Clean Sand (Gray)	Saturated Only	0.00148
■	Soft Clay (Undrained-Gray)	Saturated Only	4.92e-009

Contours are Total Head in feet

Water Flux: 0.00096778711 ft³/sec



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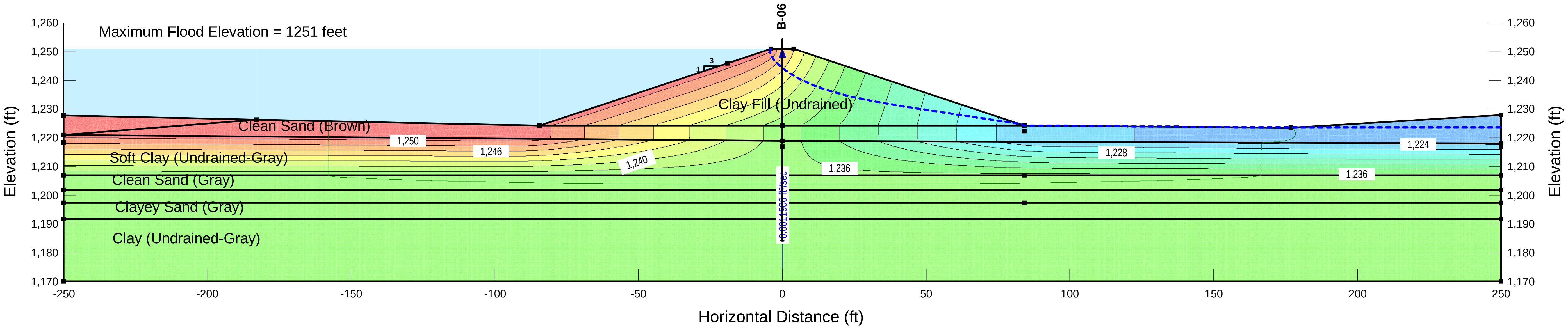
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 2
Upper Maple River Watershed Detention Plan
3.0_CS2_Steady State Seepage_Max Pool
Last Saved Date: 7/7/2017

Color	Name	Model	Sat Kx (ft/sec)
■	Clay (Undrained-Gray)	Saturated Only	4.92e-009
🟧	Clay Fill (Undrained)	Saturated / Unsaturated	4.92e-009
■	Clayey Sand (Gray)	Saturated Only	2.96e-008
🟫	Clean Sand (Brown)	Saturated Only	0.00148
■	Clean Sand (Gray)	Saturated Only	0.00148
■	Soft Clay (Undrained-Gray)	Saturated Only	4.92e-009

Contours are Total Head in feet

Water Flux: 0.0011906137 ft³/sec



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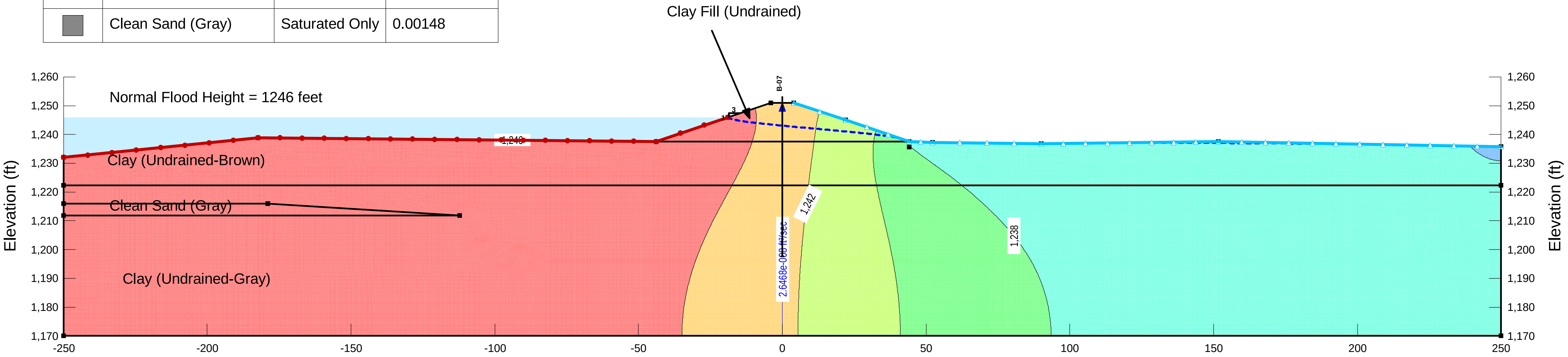
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 3
Upper Maple River Watershed Detention Plan
2.0_CS3_Steady State Seepage_Normal Loading
Last Saved Date: 7/7/2017

Contours are Total Head in feet

Color	Name	Model	Sat Kx (ft/sec)
🟫	Clay (Undrained-Brown)	Saturated Only	4.92e-009
⬛	Clay (Undrained-Gray)	Saturated Only	4.92e-009
🟧	Clay Fill (Undrained)	Saturated / Unsaturated	4.92e-009
▨	Clean Sand (Gray)	Saturated Only	0.00148

Water Flux: 2.6468153e-008 ft³/sec



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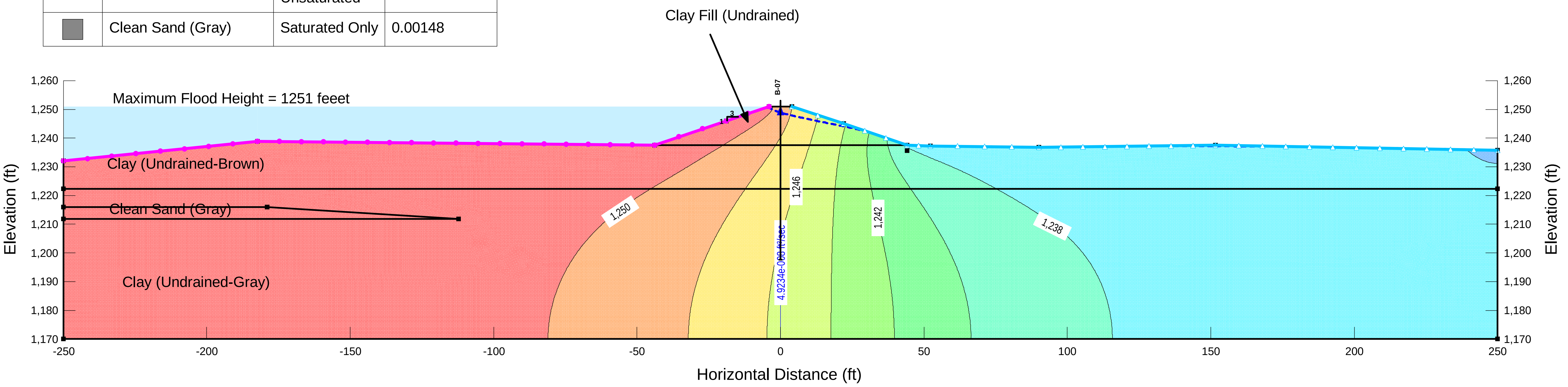
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 3
Upper Maple River Watershed Detention Plan
3.0_CS3_Steady State Seepage_Max Pool
Last Saved Date: 7/7/2017

Contours are Total Head in feet

Color	Name	Model	Sat Kx (ft/sec)
🟫	Clay (Undrained-Brown)	Saturated Only	4.92e-009
⬛	Clay (Undrained-Gray)	Saturated Only	4.92e-009
🟧	Clay Fill (Undrained)	Saturated / Unsaturated	4.92e-009
⬛	Clean Sand (Gray)	Saturated Only	0.00148

Water Flux: 4.9233832e-008 ft³/sec



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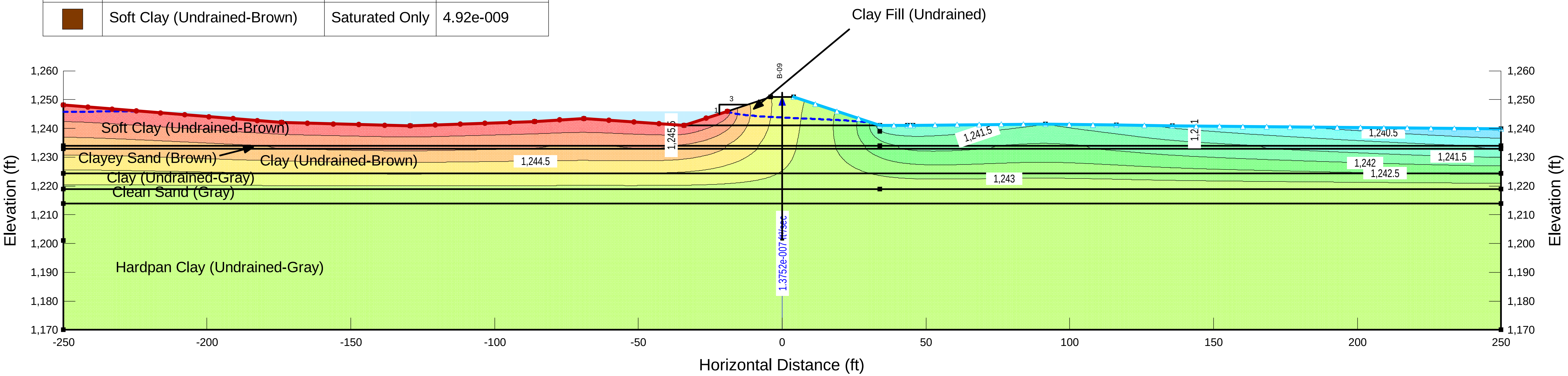
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 4
Upper Maple River Watershed Detention Plan
2.0_CS4_Steady State Seepage_Normal Loading
Last Saved Date: 7/7/2017

Color	Name	Model	Sat Kx (ft/sec)
🟫	Clay (Undrained-Brown)	Saturated Only	4.92e-009
⬛	Clay (Undrained-Gray)	Saturated Only	4.92e-009
🟧	Clay Fill (Undrained)	Saturated / Unsaturated	4.92e-009
🟧	Clayey Sand (Brown)	Saturated Only	2.96e-008
⬜	Clean Sand (Gray)	Saturated Only	0.00148
⬛	Hardpan Clay (Undrained-Gray)	Saturated Only	4.92e-009
🟫	Soft Clay (Undrained-Brown)	Saturated Only	4.92e-009

Contours are Total Head in feet

Water Flux: 1.3752134e-007 ft³/sec



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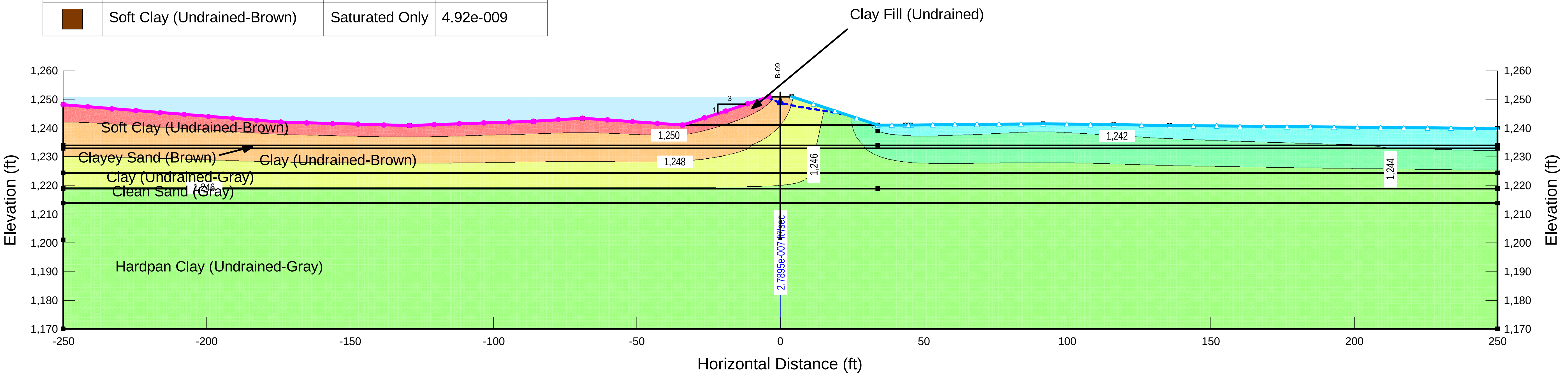
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 4
Upper Maple River Watershed Detention Plan
3.0_CS4_Steady State Seepage_Max Pool
Last Saved Date: 7/7/2017

Color	Name	Model	Sat Kx (ft/sec)
🟫	Clay (Undrained-Brown)	Saturated Only	4.92e-009
⬛	Clay (Undrained-Gray)	Saturated Only	4.92e-009
🟧	Clay Fill (Undrained)	Saturated / Unsaturated	4.92e-009
🟫	Clayey Sand (Brown)	Saturated Only	2.96e-008
⬜	Clean Sand (Gray)	Saturated Only	0.00148
⬛	Hardpan Clay (Undrained-Gray)	Saturated Only	4.92e-009
🟫	Soft Clay (Undrained-Brown)	Saturated Only	4.92e-009

Contours are Total Head in feet

Water Flux: 2.7895352e-007 ft³/sec



P:\Mpls\34 ND\09\34091031 Swan Creek Watershed Plan\WorkFiles\Upper Maple specific\Alternatives selected\Geostudio Modeling\

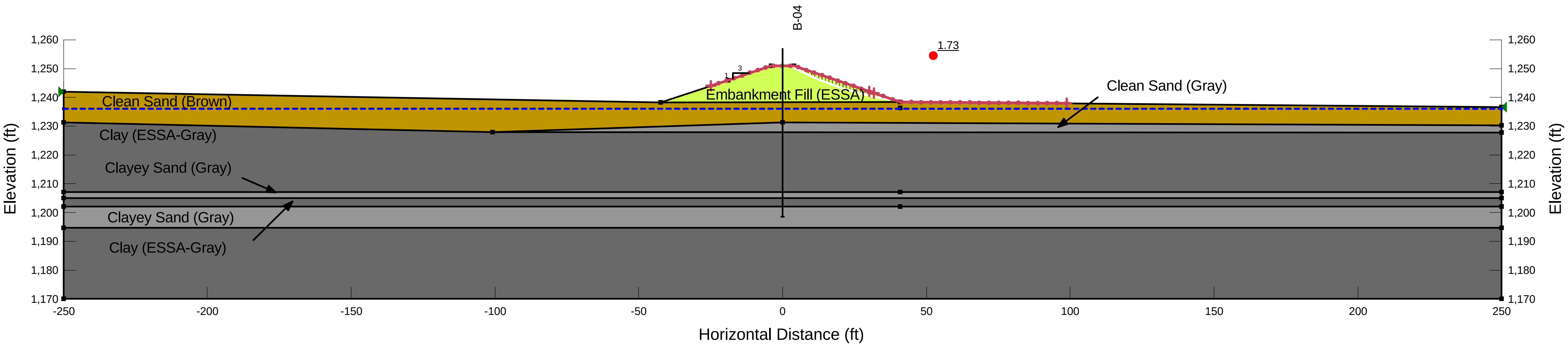
Appendix E

Stability Model Outputs

Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Upper Maple Alt 2A - Cross Section 1
Upper Maple River Watershed Detention Plan _ Alt2A
1.1_CS1_No Loading_ESSA_DS
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
▨	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
▨	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟩	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30

Factor of Safety: 1.73



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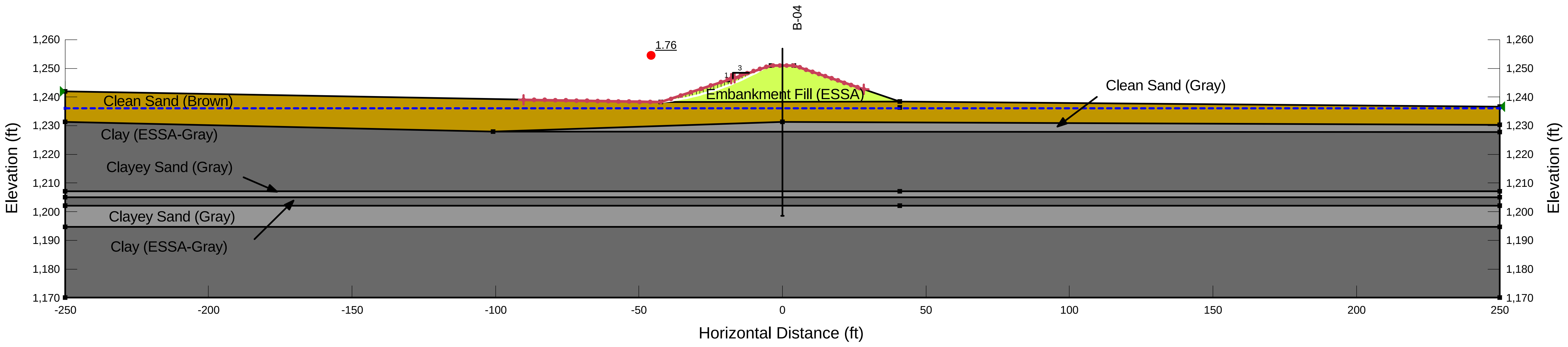
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Upper Maple Alt 2A - Cross Section 1
Upper Maple River Watershed Detention Plan _ Alt2A
1.2_CS1_No Loading_ESSA_US
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
◼	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
◼	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟩	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30

Factor of Safety: 1.76



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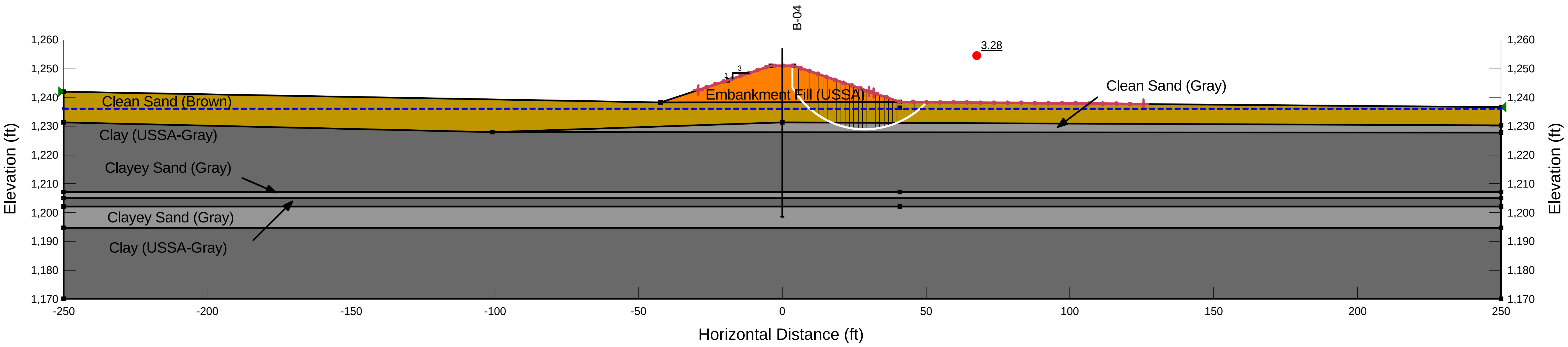
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Upper Maple Alt 2A - Cross Section 1
Upper Maple River Watershed Detention Plan _ Alt2A
1.3_CS1_No Loading_USSA_DS (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
■	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
■	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
■	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0

Factor of Safety: 3.28



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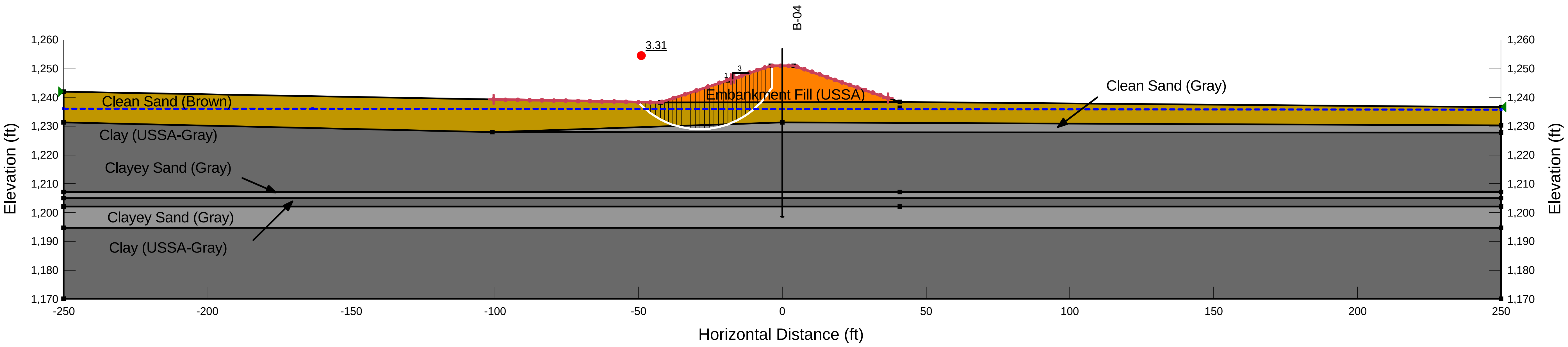
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Upper Maple Alt 2A - Cross Section 1
Upper Maple River Watershed Detention Plan _ Alt2A
1.4_CS1_No Loading_USSA_US (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
⬛	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
▨	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
▨	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0

Factor of Safety: 3.31



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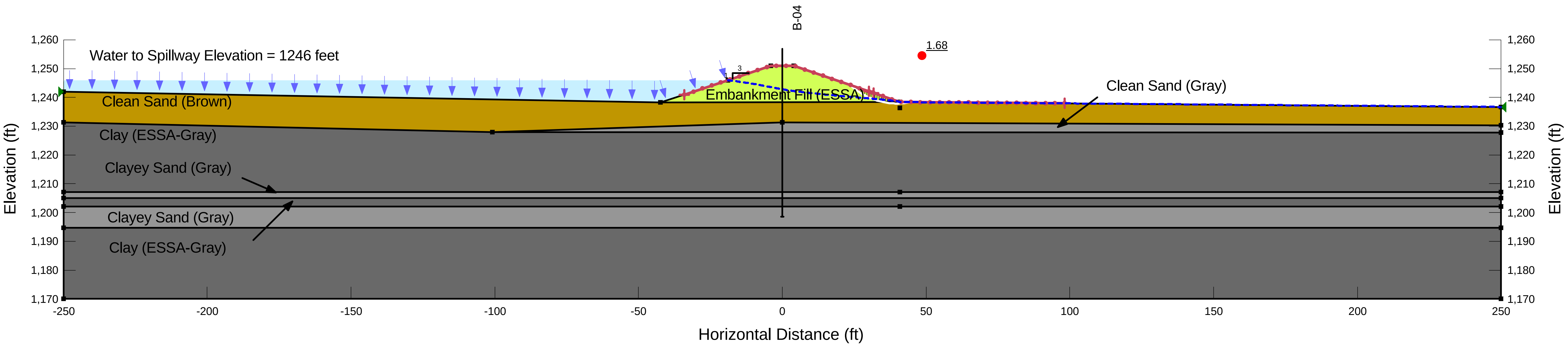
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Upper Maple Alt 2A - Cross Section 1
Upper Maple River Watershed Detention Plan _ Alt2A
2.1_CS1_ESSA_DS_Normal Loading
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
■	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
■	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
■	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟩	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30

Factor of Safety: 1.68



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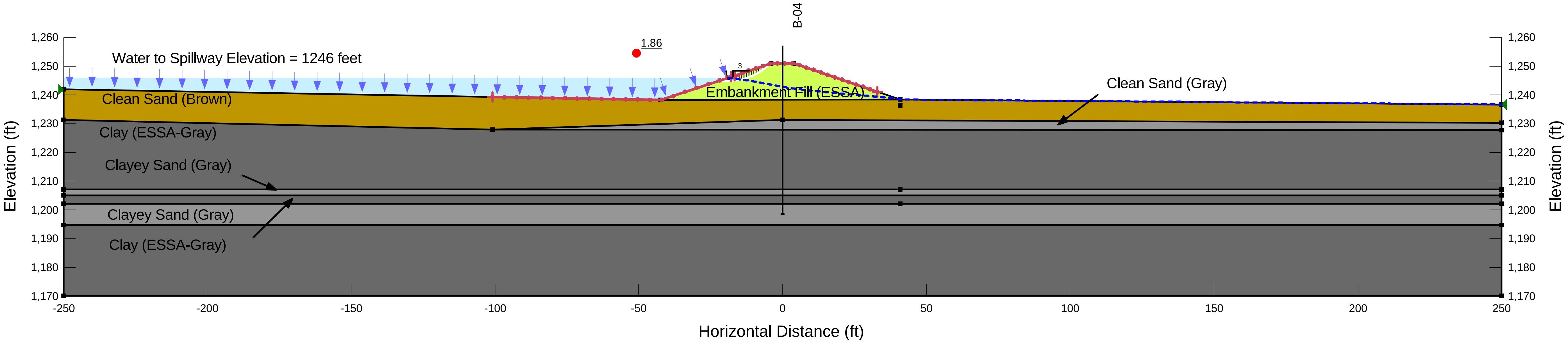
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Upper Maple Alt 2A - Cross Section 1
Upper Maple River Watershed Detention Plan _ Alt2A
2.2_CS1_ESSA_US_Normal Loading
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
▒	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
▒	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟩	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30

Factor of Safety: 1.86



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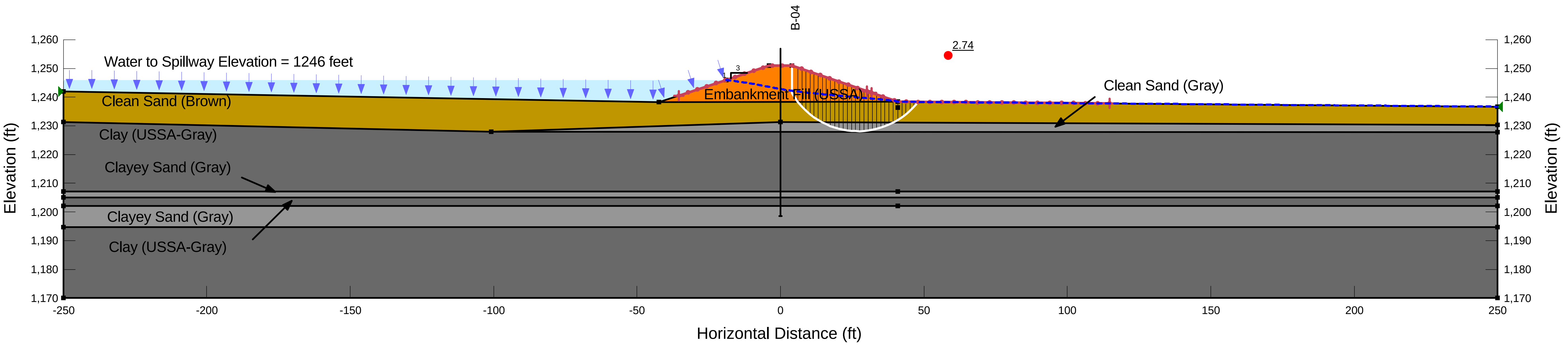
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Upper Maple Alt 2A - Cross Section 1
Upper Maple River Watershed Detention Plan _ Alt2A
2.3_CS1_USSA_DS_Normal Loading (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
⬛	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
◼	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
◼	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0

Factor of Safety: 2.74



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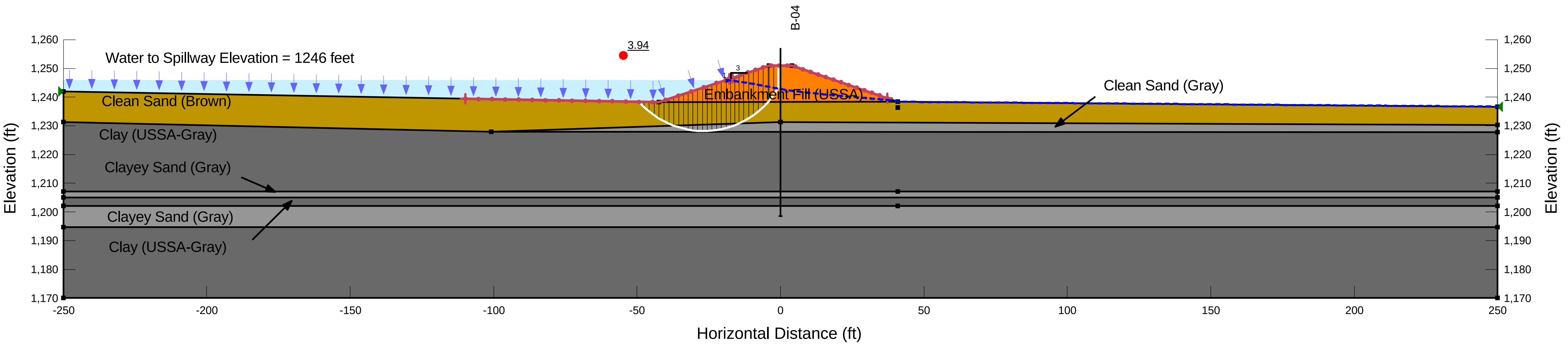
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Upper Maple Alt 2A - Cross Section 1
Upper Maple River Watershed Detention Plan _ Alt2A
2.4_CS1_USSA_US_Normal Loading (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
⬛	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
▩	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
▩	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0

Factor of Safety: 3.94



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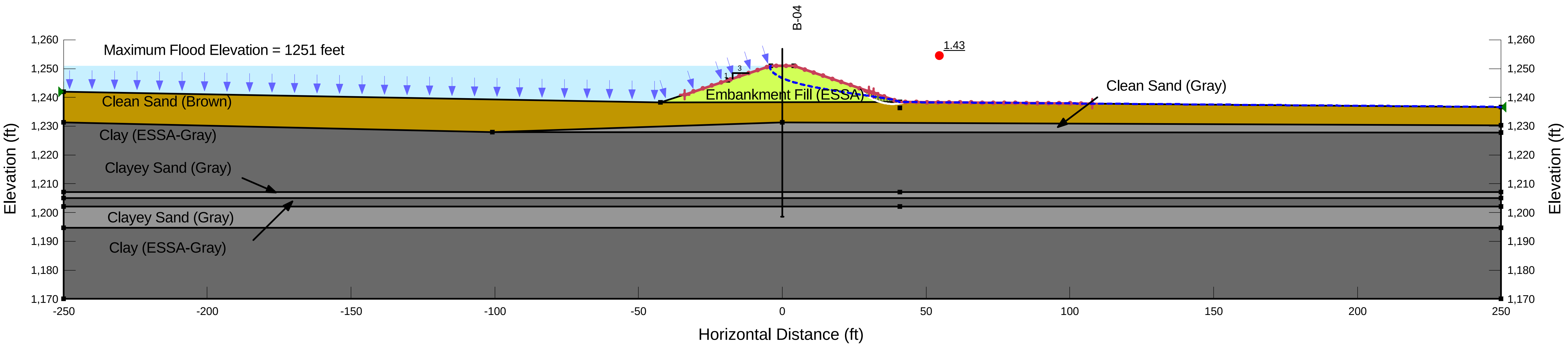
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Upper Maple Alt 2A - Cross Section 1
Upper Maple River Watershed Detention Plan _ Alt2A
3.1_CS1_ESSA_DS_Max Loading
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
▩	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
▩	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟩	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30

Factor of Safety: 1.43



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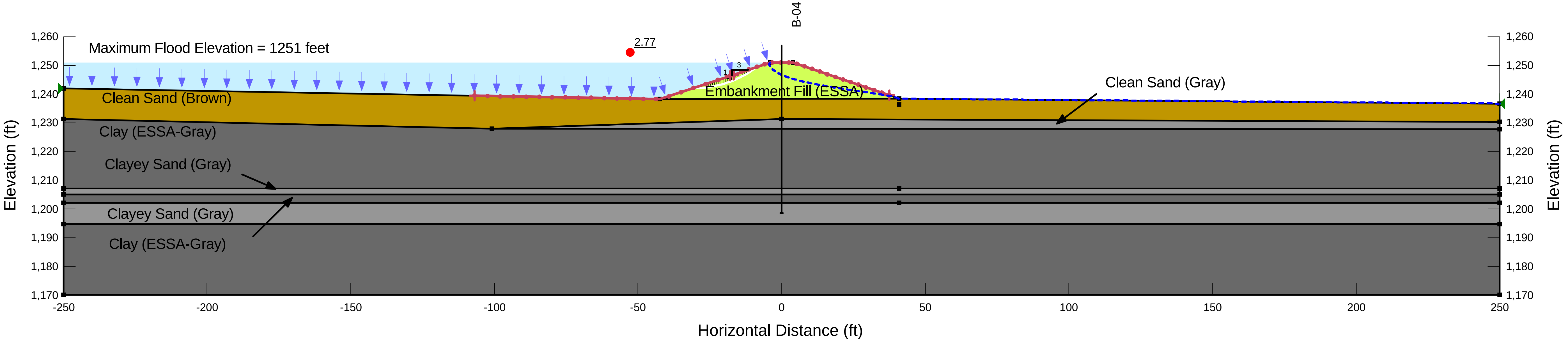
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Upper Maple Alt 2A - Cross Section 1
Upper Maple River Watershed Detention Plan _ Alt2A
3.2_CS1_ESSA_US_Max Loading
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
⬜	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
⬜	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟩	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30

Factor of Safety: 2.77



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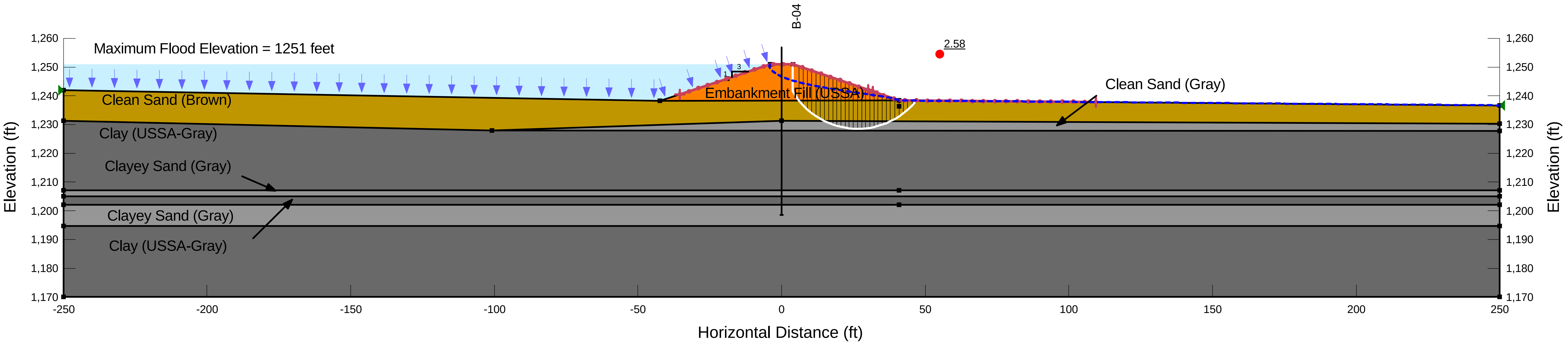
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Upper Maple Alt 2A - Cross Section 1
Upper Maple River Watershed Detention Plan _ Alt2A
3.3_CS1_USSA_DS_Max Loading (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
■	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
■	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
■	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0

Factor of Safety: 2.58



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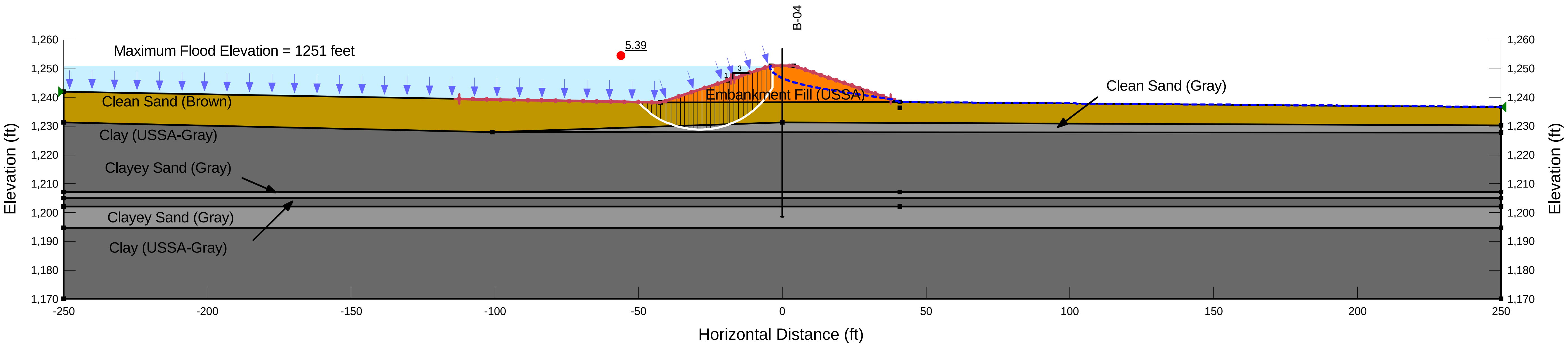
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Upper Maple Alt 2A - Cross Section 1
Upper Maple River Watershed Detention Plan _ Alt2A
3.4_CS1_USSA_US_Max Loading (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
⬛	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
▩	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
▩	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0

Factor of Safety: 5.39



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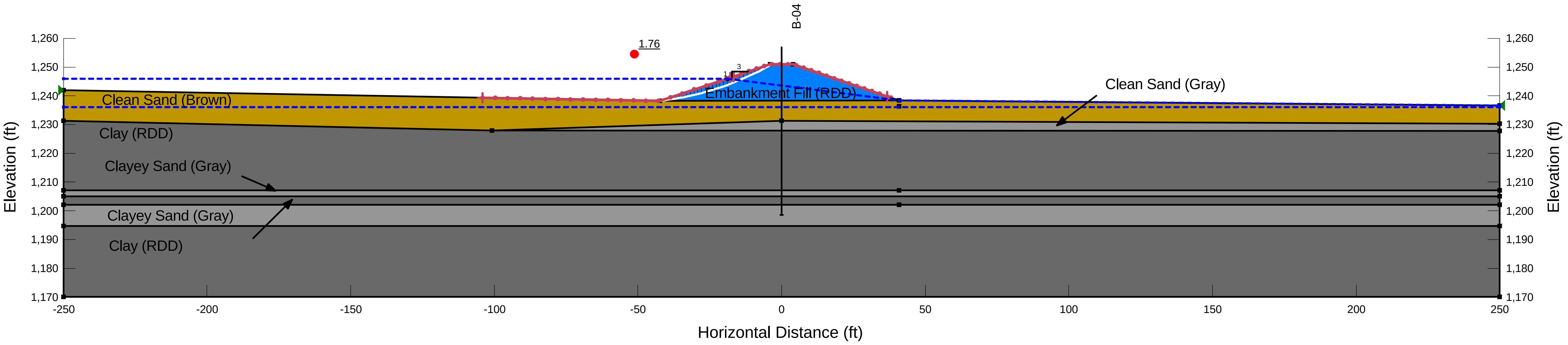
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Upper Maple Alt 2A - Cross Section 1
Upper Maple River Watershed Detention Plan _ Alt2A
4.1_CS1_Rapid Draw Down
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Cohesion R (psf)	Phi R (°)
⬛	Clay (RDD)	Mohr-Coulomb	130	0	31	1,600	0
▨	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32	0	32
▨	Clean Sand (Gray)	Mohr-Coulomb	130	0	32	0	32
🟦	Embankment Fill (RDD)	Mohr-Coulomb	128	0	30	1,300	0

Factor of Safety: 1.76



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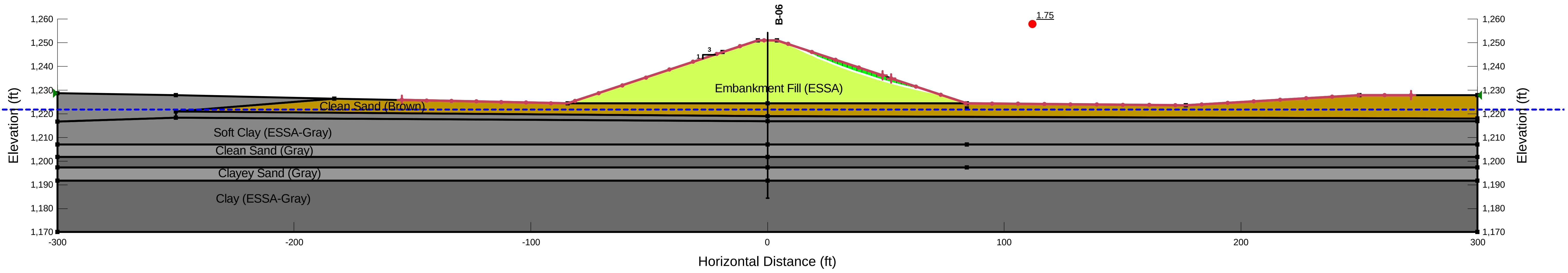
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 2
Upper Maple River Watershed Detention Plan - Alt2A
1.1_CS2_No Loading_ESSA_DS
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
■	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
■	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
■	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟩	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30
■	Soft Clay (ESSA-Gray)	Mohr-Coulomb	130	0	30

Factor of Safety: 1.75



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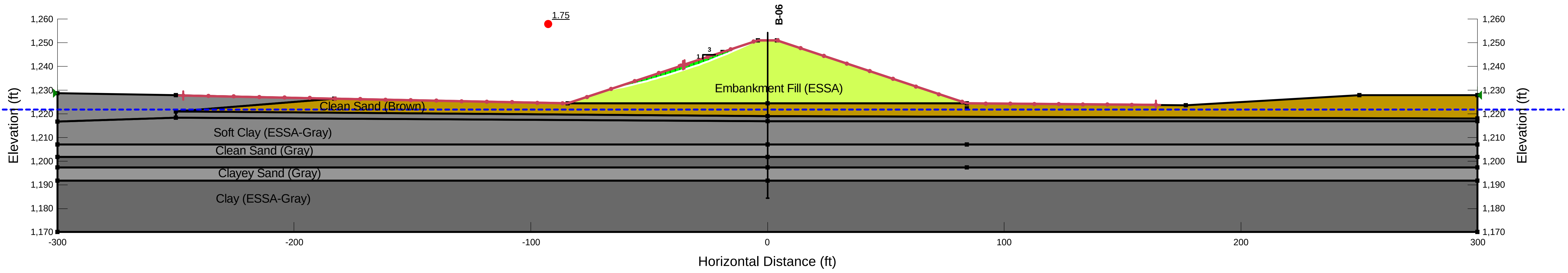
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 2
Upper Maple River Watershed Detention Plan - Alt2A
1.2_CS2_No Loading_ESSA_US
Last Saved Date: 11/08/2019

Color	**Name**	**Model**	**Unit Weight (pcf)**	**Cohesion' (psf)**	**Phi' (°)**
■	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
■	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
■	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟩	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30
■	Soft Clay (ESSA-Gray)	Mohr-Coulomb	130	0	30

Factor of Safety: 1.75



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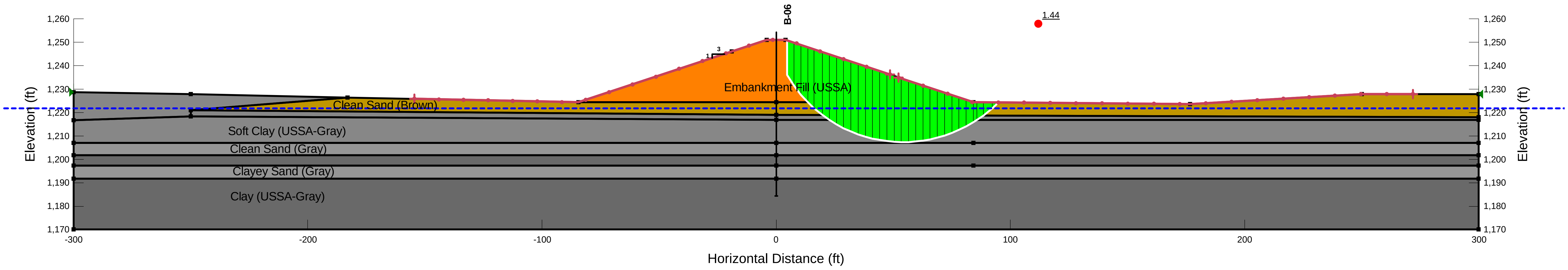
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 2
Upper Maple River Watershed Detention Plan - Alt2A
1.3_CS2_No Loading_USSA_DS (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
■	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
■	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
■	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0
■	Soft Clay (USSA-Gray)	Mohr-Coulomb	130	500	0

Factor of Safety: 1.44



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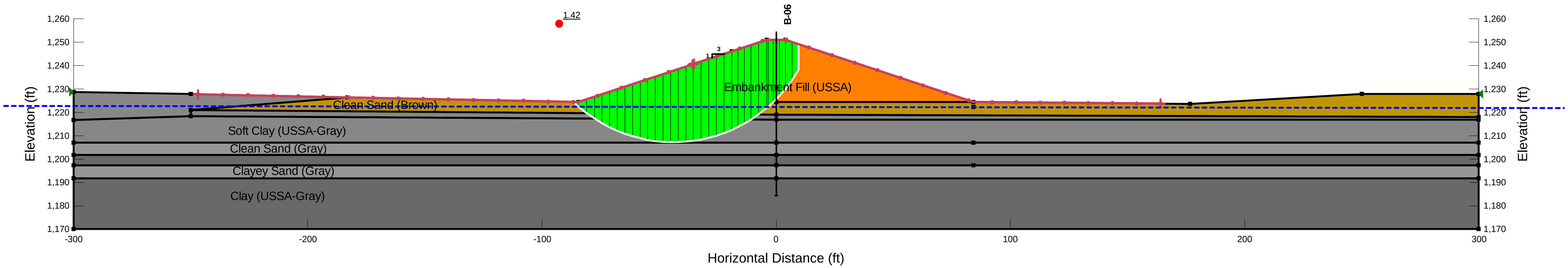
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 2
Upper Maple River Watershed Detention Plan - Alt2A
1.4_CS2_No Loading_USSA_US (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
■	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
■	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
■	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0
■	Soft Clay (USSA-Gray)	Mohr-Coulomb	130	500	0

Factor of Safety: 1.42



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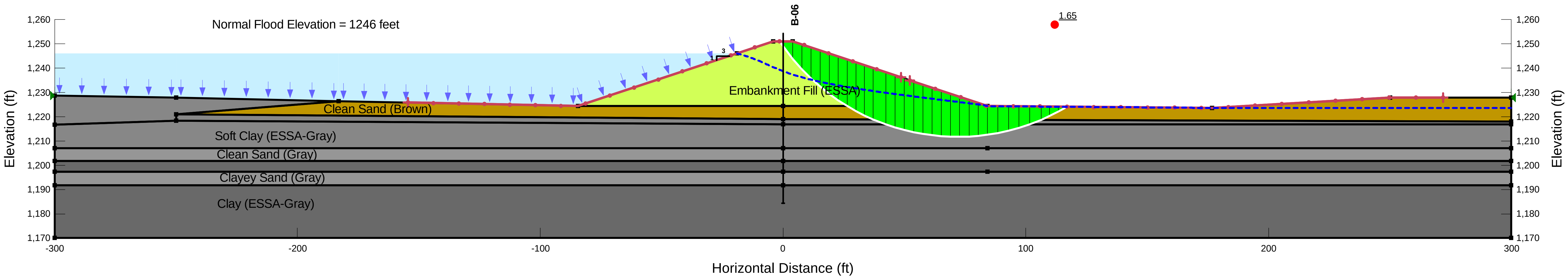
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 2
Upper Maple River Watershed Detention Plan - Alt2A
2.1_CS2_ESSA_DS_Normal Loading
Last Saved Date: 11/08/2019

Color	**Name**	**Model**	**Unit Weight (pcf)**	**Cohesion' (psf)**	**Phi' (°)**
■	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
■	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
■	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟩	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30
■	Soft Clay (ESSA-Gray)	Mohr-Coulomb	130	0	30

Factor of Safety: 1.65



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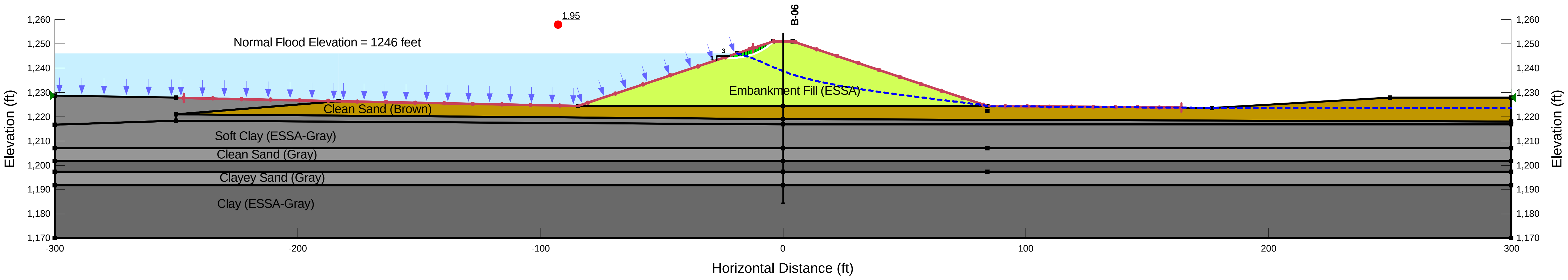
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 2
Upper Maple River Watershed Detention Plan - Alt2A
2.2_CS2_ESSA_US_Normal Loading
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
■	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
■	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
■	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟩	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30
■	Soft Clay (ESSA-Gray)	Mohr-Coulomb	130	0	30

Factor of Safety: 1.95



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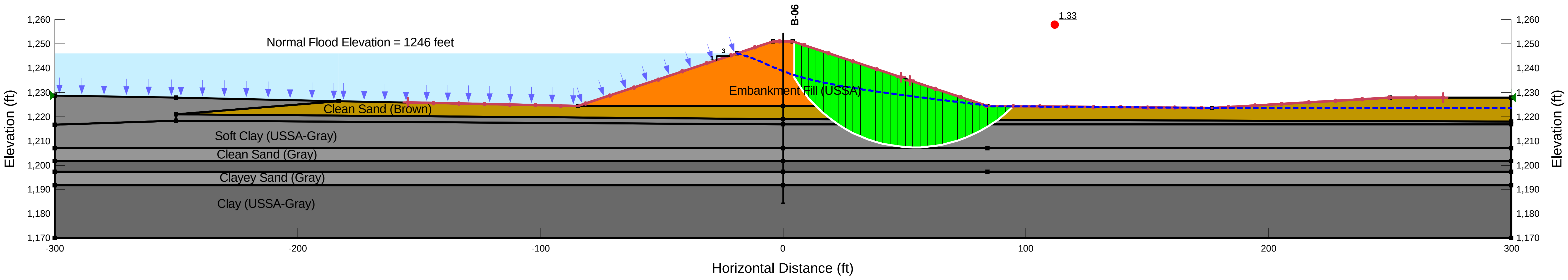
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 2
Upper Maple River Watershed Detention Plan - Alt2A
2.3_CS2_USSA_DS_Normal Loading (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
■	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
■	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
■	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0
■	Soft Clay (USSA-Gray)	Mohr-Coulomb	130	500	0

Factor of Safety: 1.33



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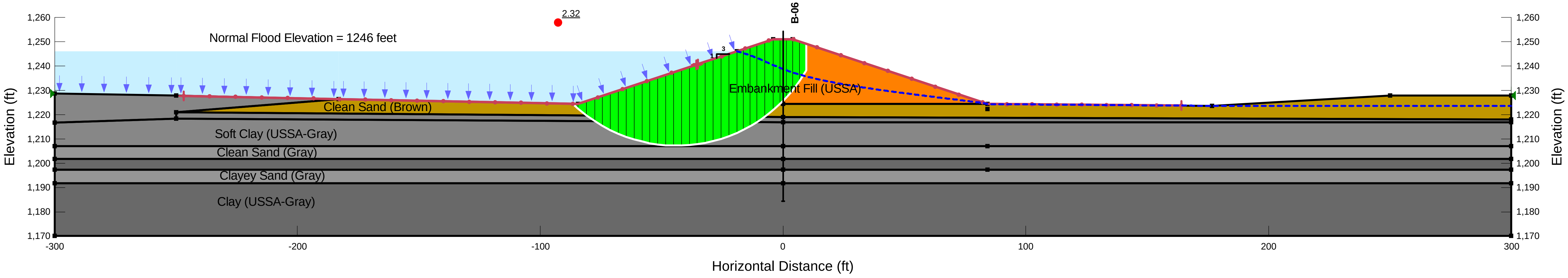
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 2
Upper Maple River Watershed Detention Plan - Alt2A
2.4_CS2_USSA_US_Normal Loading (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
⬛	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
⬜	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
⬜	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0
⬛	Soft Clay (USSA-Gray)	Mohr-Coulomb	130	500	0

Factor of Safety: 2.32



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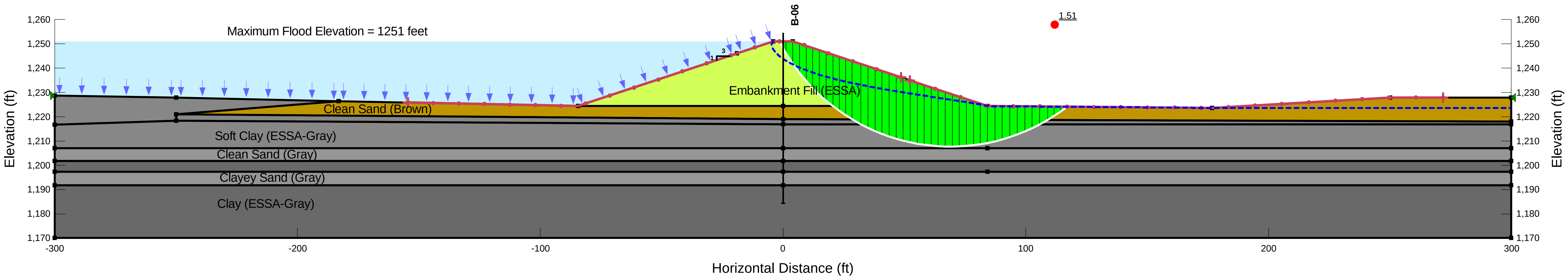
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 2
Upper Maple River Watershed Detention Plan - Alt2A
3.1_CS2_ESSA_DS_Max Loading
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
■	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
■	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
■	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟩	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30
■	Soft Clay (ESSA-Gray)	Mohr-Coulomb	130	0	30

Factor of Safety: 1.51



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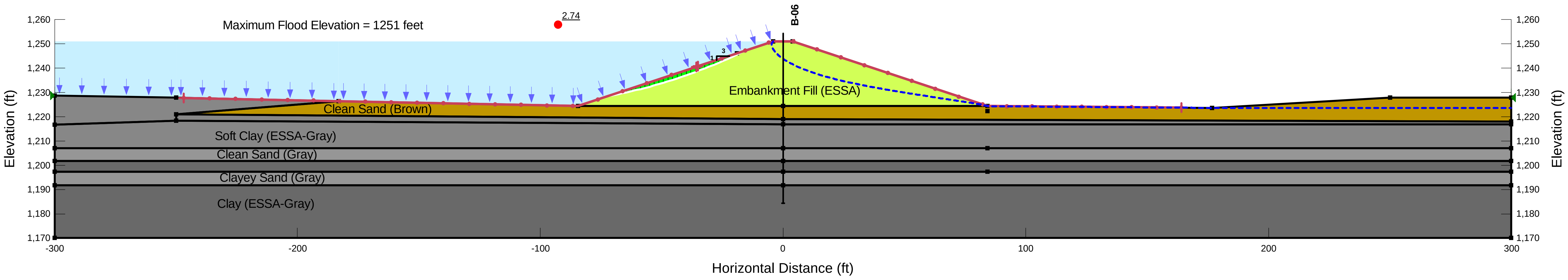
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 2
Upper Maple River Watershed Detention Plan - Alt2A
3.2_CS2_ESSA_US_Max Loading
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
⬛	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
⬛	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟩	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30
⬛	Soft Clay (ESSA-Gray)	Mohr-Coulomb	130	0	30

Factor of Safety: 2.74



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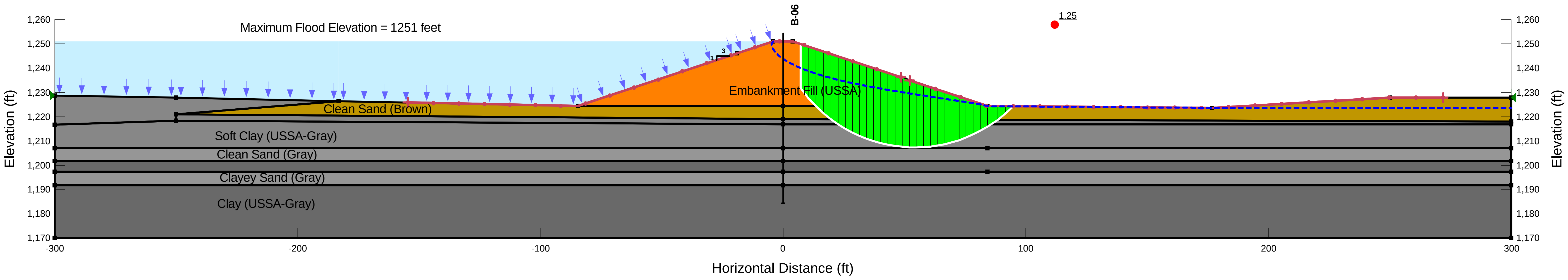
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 2
Upper Maple River Watershed Detention Plan - Alt2A
3.3_CS2_USSA_DS_Max Loading (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
■	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
■	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
■	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0
■	Soft Clay (USSA-Gray)	Mohr-Coulomb	130	500	0

Factor of Safety: 1.25



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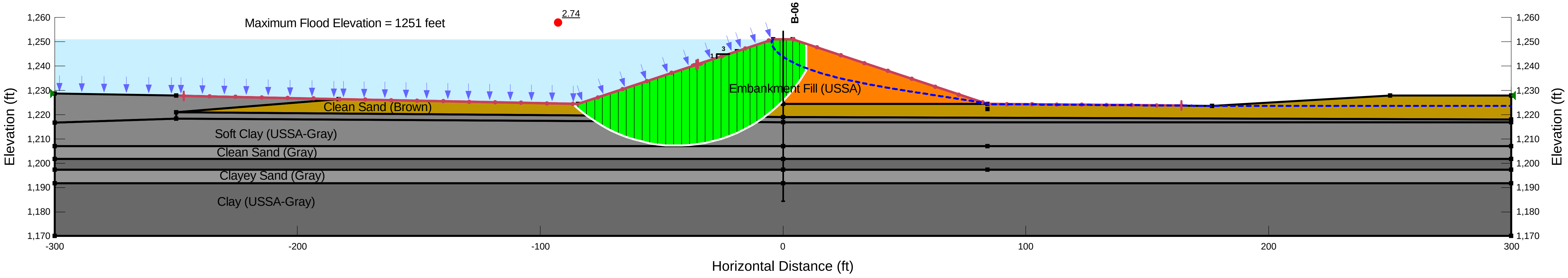
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 2
Upper Maple River Watershed Detention Plan - Alt2A
3.4_CS2_USSA_US_Max Loading (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
⬛	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
⬛	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32
⬛	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0
⬛	Soft Clay (USSA-Gray)	Mohr-Coulomb	130	500	0

Factor of Safety: 2.74



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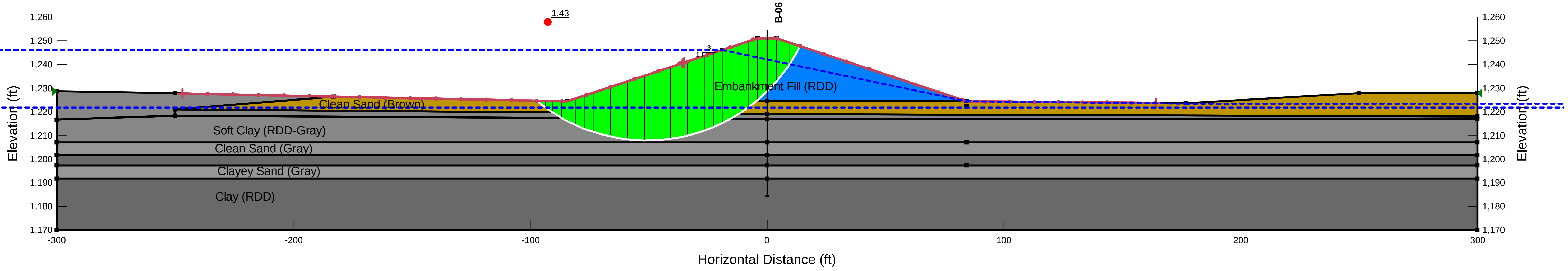
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 2
Upper Maple River Watershed Detention Plan - Alt2A
4.1_CS2_Rapid Draw Down
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Cohesion R (psf)	Phi R (°)
⬛	Clay (RDD)	Mohr-Coulomb	130	0	31	1,600	0
◼	Clayey Sand (Gray)	Mohr-Coulomb	130	0	32	0	32
🟫	Clean Sand (Brown)	Mohr-Coulomb	130	0	32	0	32
◼	Clean Sand (Gray)	Mohr-Coulomb	130	0	32	0	32
🟦	Embankment Fill (RDD)	Mohr-Coulomb	128	0	30	1,300	0
◼	Soft Clay (RDD-Gray)	Mohr-Coulomb	130	0	30	500	0

Factor of Safety: 1.43



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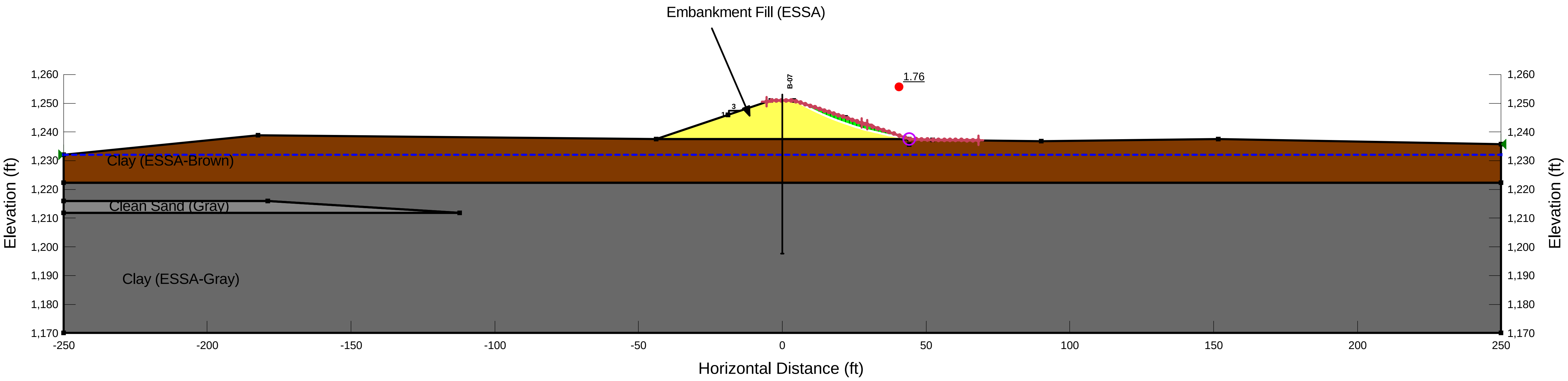
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 3
Upper Maple River Watershed Detention Plan - Alt2A
1.1_CS3_No Loading_ESSA_DS
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (ESSA-Brown)	Mohr-Coulomb	130	0	31
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
◼	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟨	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30



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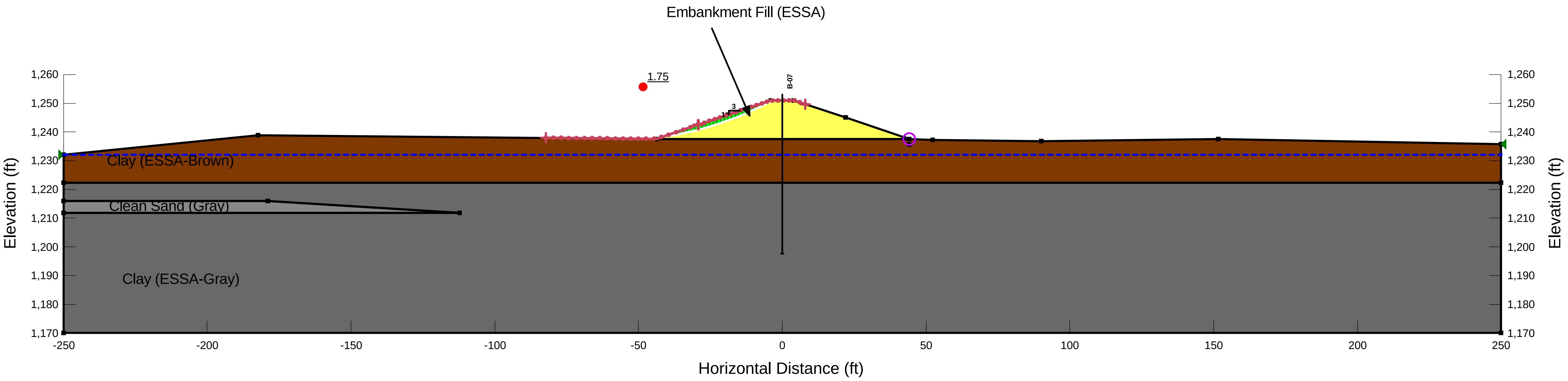
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 3
Upper Maple River Watershed Detention Plan - Alt2A
1.2_CS3_No Loading_ESSA_US
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (ESSA-Brown)	Mohr-Coulomb	130	0	31
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
◼	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟨	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30



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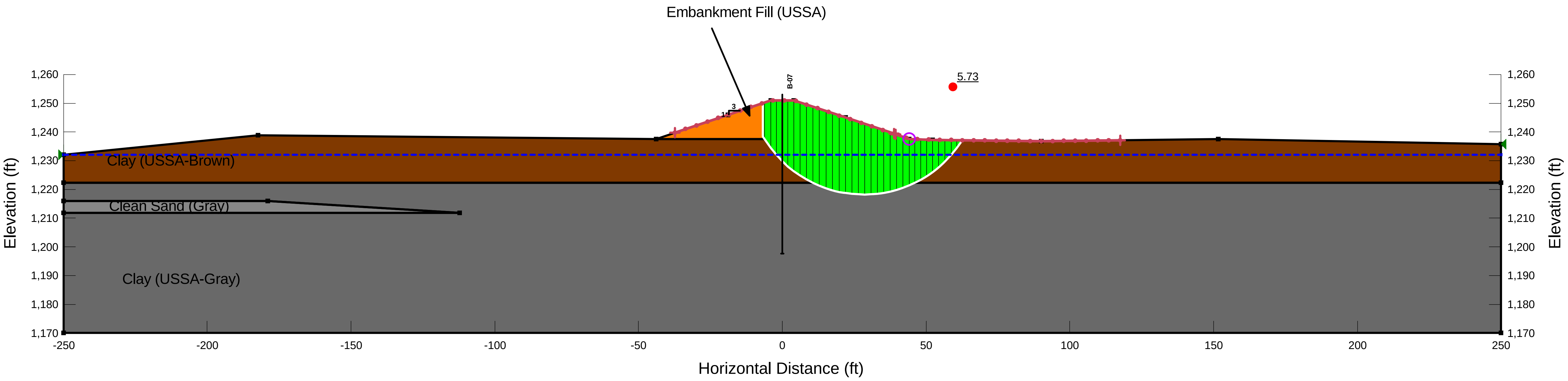
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 3
Upper Maple River Watershed Detention Plan - Alt2A
1.3_CS3_No Loading_USSA-DS (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (USSA-Brown)	Mohr-Coulomb	130	1,600	0
⬛	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
◼	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0



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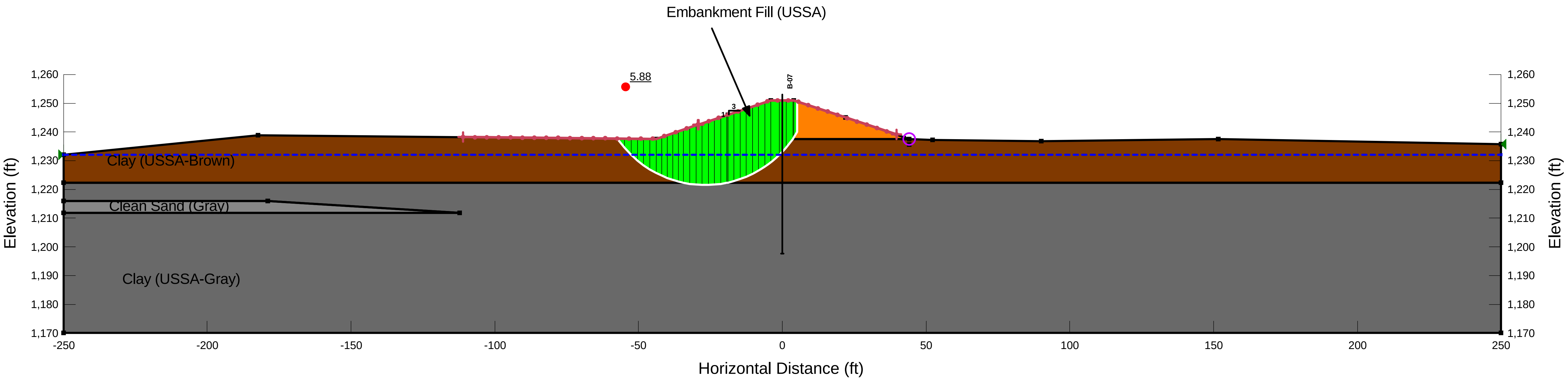
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 3
Upper Maple River Watershed Detention Plan - Alt2A
1.4_CS3_No Loading_USSA-US (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (USSA-Brown)	Mohr-Coulomb	130	1,600	0
⬛	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
◼	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0



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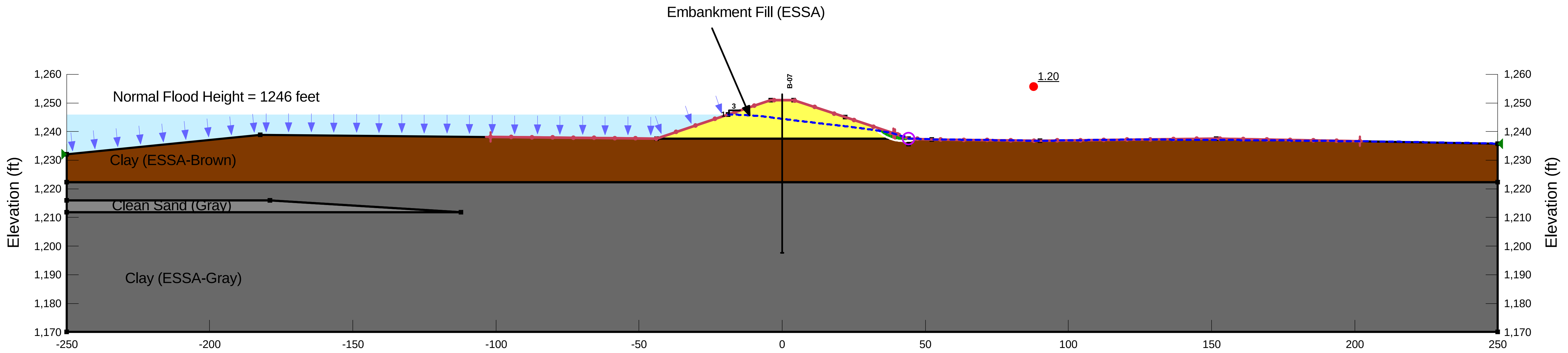
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 3
Upper Maple River Watershed Detention Plan - Alt2A
2.1_CS3_ESSA_DS_Normal Loading
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (ESSA-Brown)	Mohr-Coulomb	130	0	31
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
◼	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟨	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30



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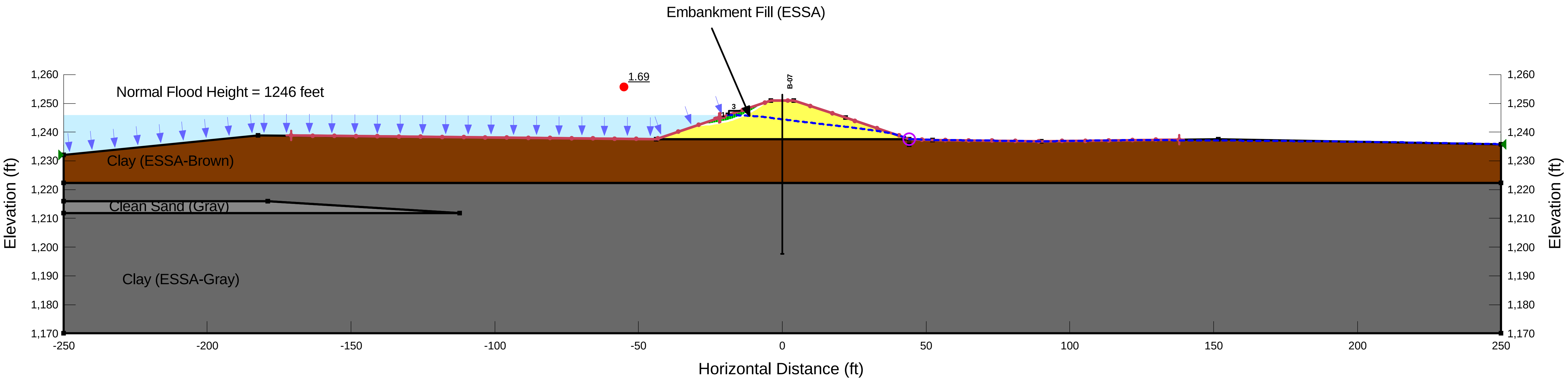
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 3
Upper Maple River Watershed Detention Plan - Alt2A
2.2_CS3_ESSA_US_Normal Loading
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (ESSA-Brown)	Mohr-Coulomb	130	0	31
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
◼	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟨	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30



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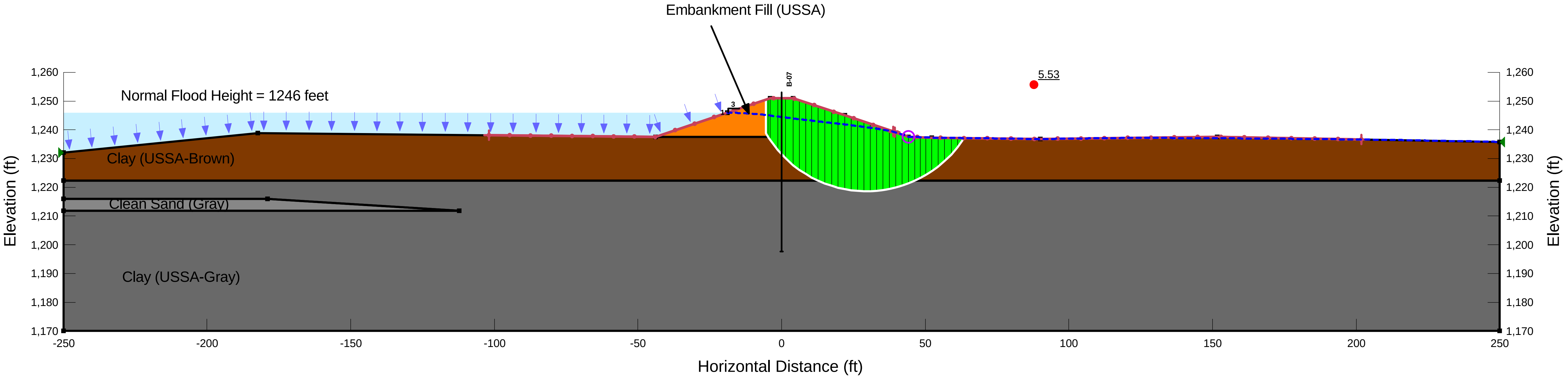
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 3
Upper Maple River Watershed Detention Plan - Alt2A
2.3_CS3_USSA_DS_Normal Loading (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (USSA-Brown)	Mohr-Coulomb	130	1,600	0
⬛	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
◼	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0



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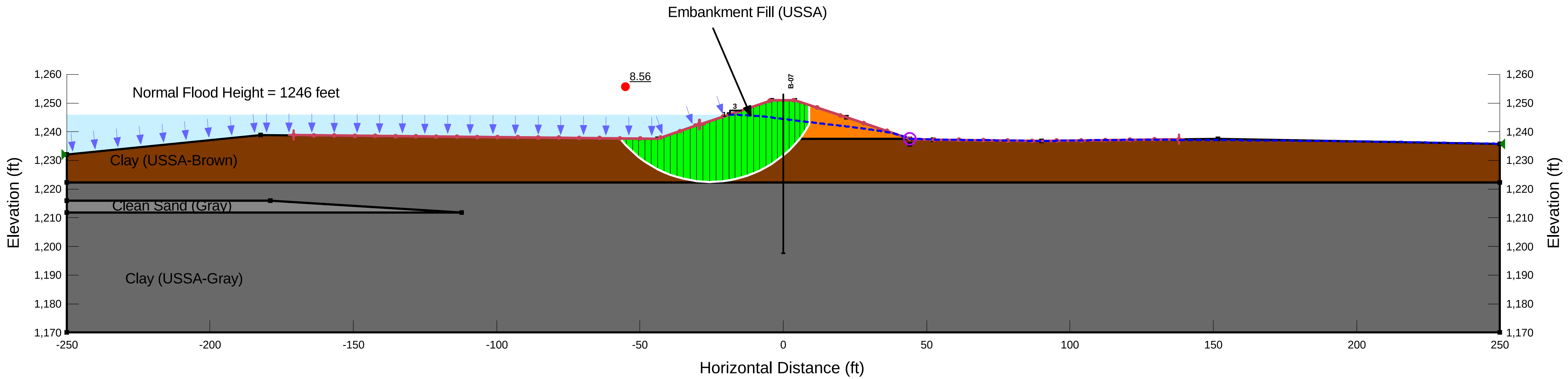
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 3
Upper Maple River Watershed Detention Plan - Alt2A
2.4_CS3_USSA_US_Normal Loading (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (USSA-Brown)	Mohr-Coulomb	130	1,600	0
⬛	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
◼	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0



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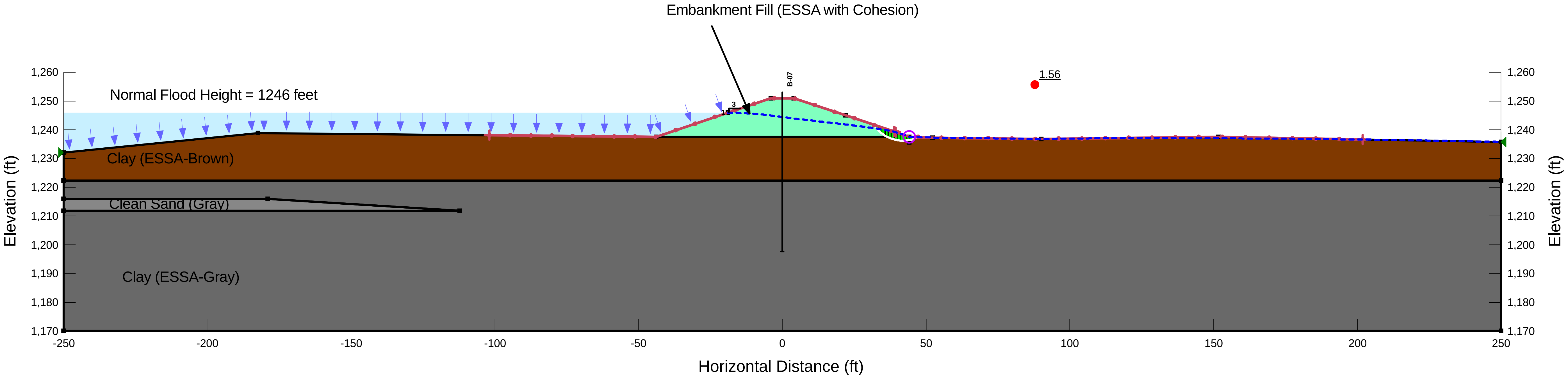
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 3
Upper Maple River Watershed Detention Plan - Alt2A
2.6_CS3_ESSA_DS_Normal Loading (with 50 psf cohesio
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (ESSA-Brown)	Mohr-Coulomb	130	0	31
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
◼	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟩	Embankment Fill (ESSA with Cohesion)	Mohr-Coulomb	128	50	30



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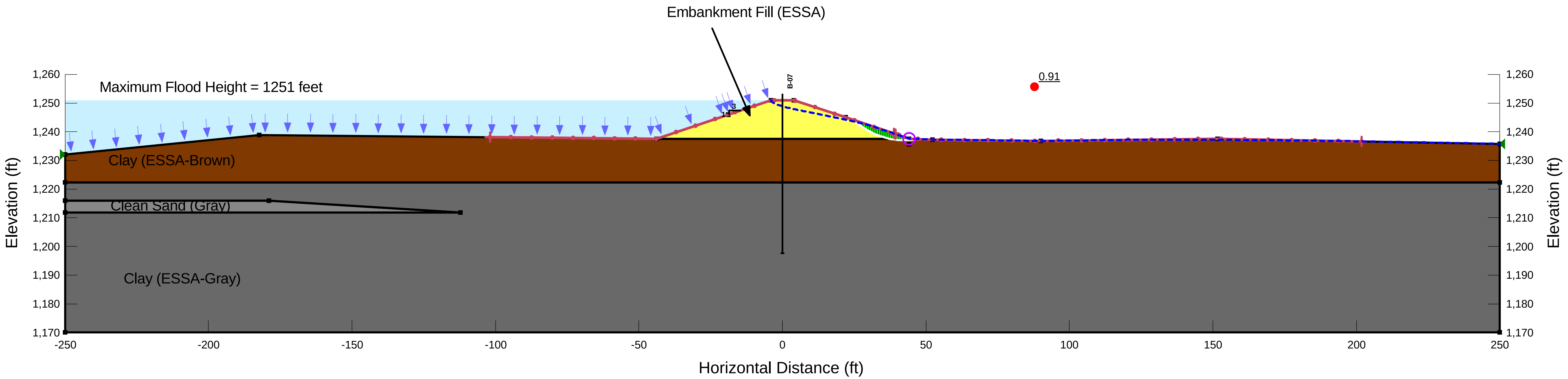
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 3
Upper Maple River Watershed Detention Plan - Alt2A
3.1_CS3_ESSA-DS_Max Loading
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (ESSA-Brown)	Mohr-Coulomb	130	0	31
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
◼	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟨	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30



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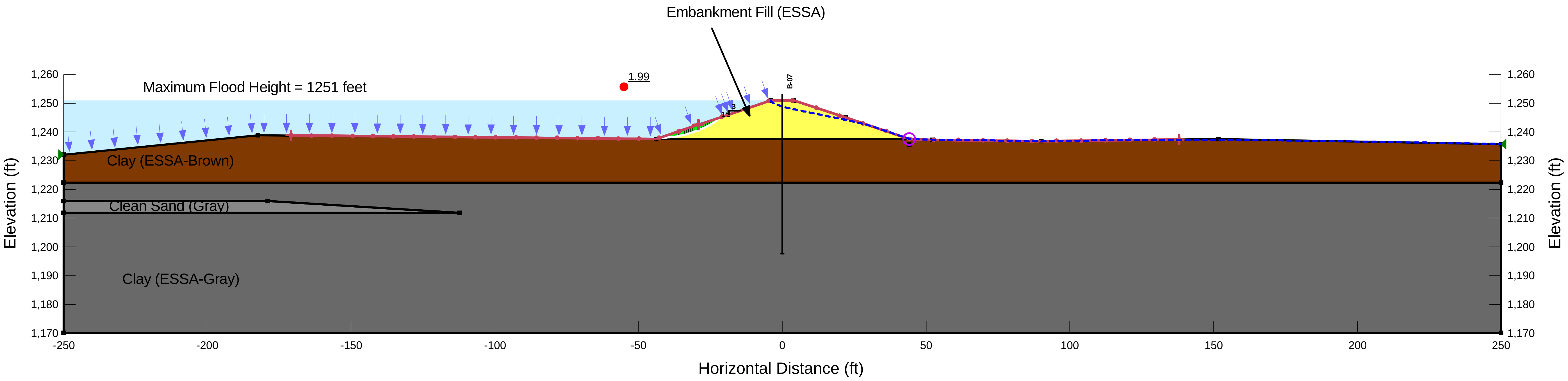
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 3
Upper Maple River Watershed Detention Plan - Alt2A
3.2_CS3_ESSA_US_Max Loading
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (ESSA-Brown)	Mohr-Coulomb	130	0	31
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
▩	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟨	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30



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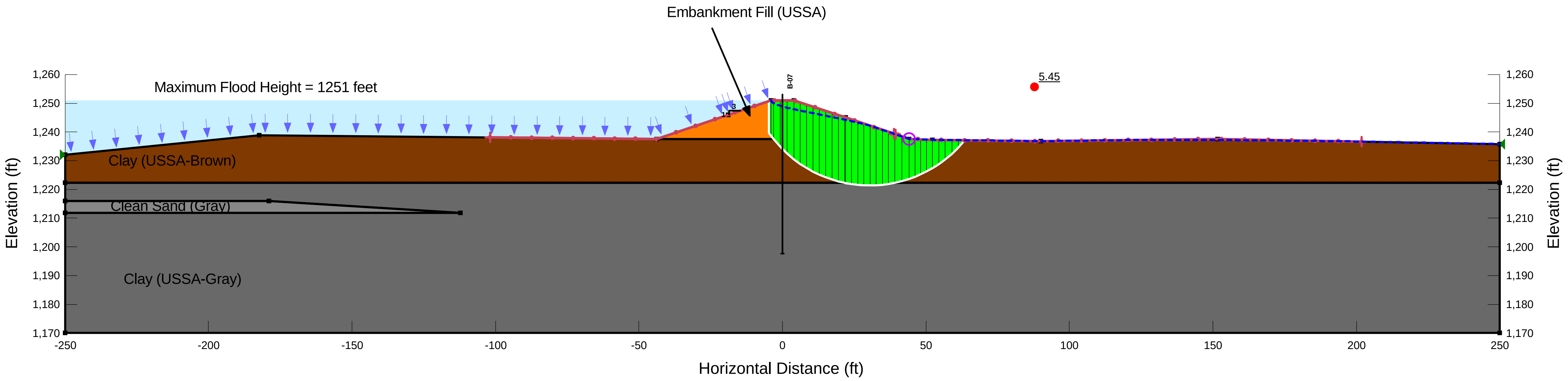
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 3
Upper Maple River Watershed Detention Plan - Alt2A
3.3_CS3_USSA-DS_Max Loading (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (USSA-Brown)	Mohr-Coulomb	130	1,600	0
⬛	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
◼	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0



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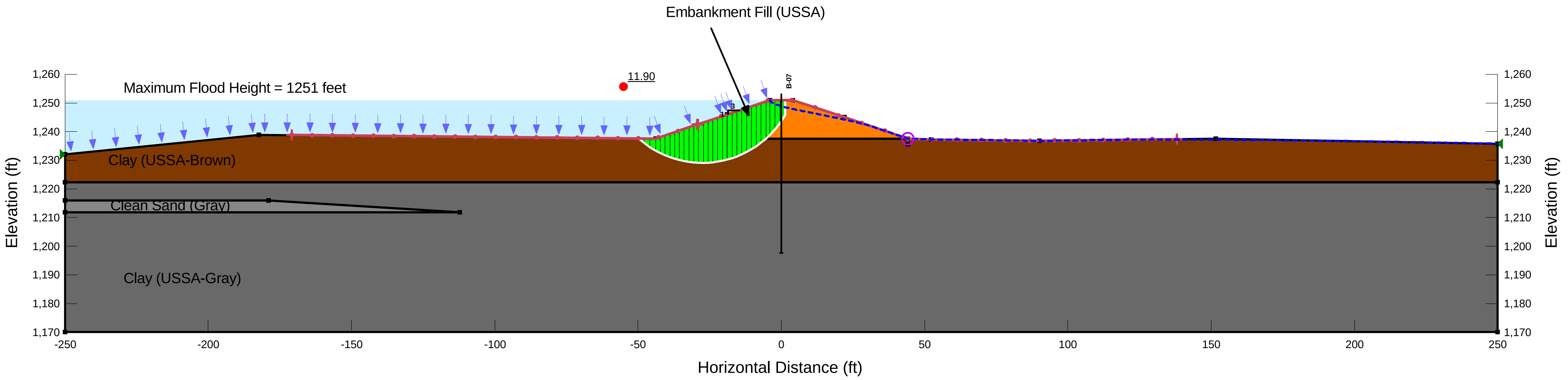
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 3
Upper Maple River Watershed Detention Plan - Alt2A
3.4_CS3_USSA_US_Max Loading (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (USSA-Brown)	Mohr-Coulomb	130	1,600	0
⬛	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
◼	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0



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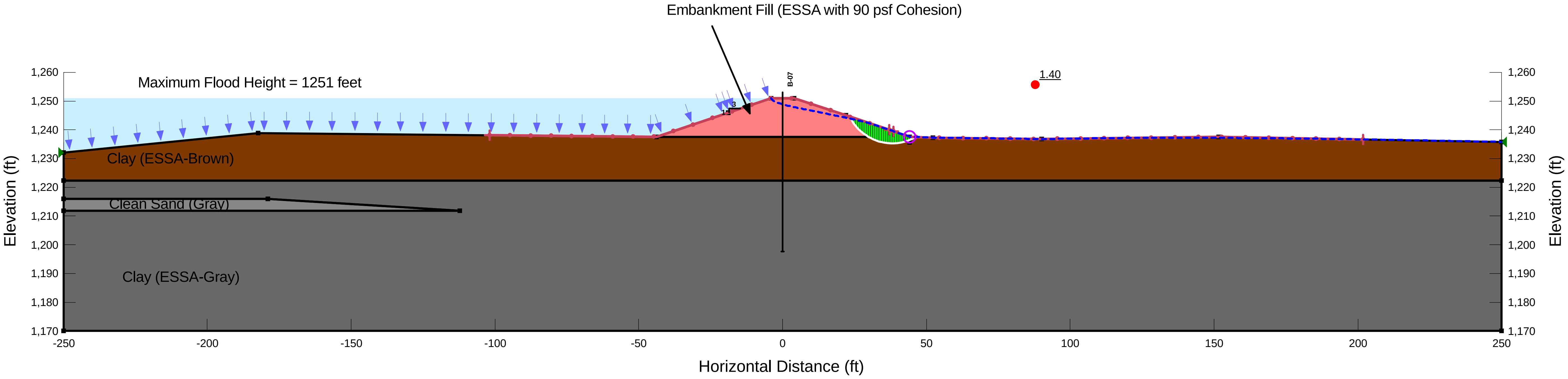
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 3
Upper Maple River Watershed Detention Plan - Alt2A
3.6_CS3_ESSA-DS_Max Loading_Cohesion
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (ESSA-Brown)	Mohr-Coulomb	130	0	31
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
◼	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟥	Embankment Fill (ESSA with 90 psf Cohesion)	Mohr-Coulomb	128	90	30



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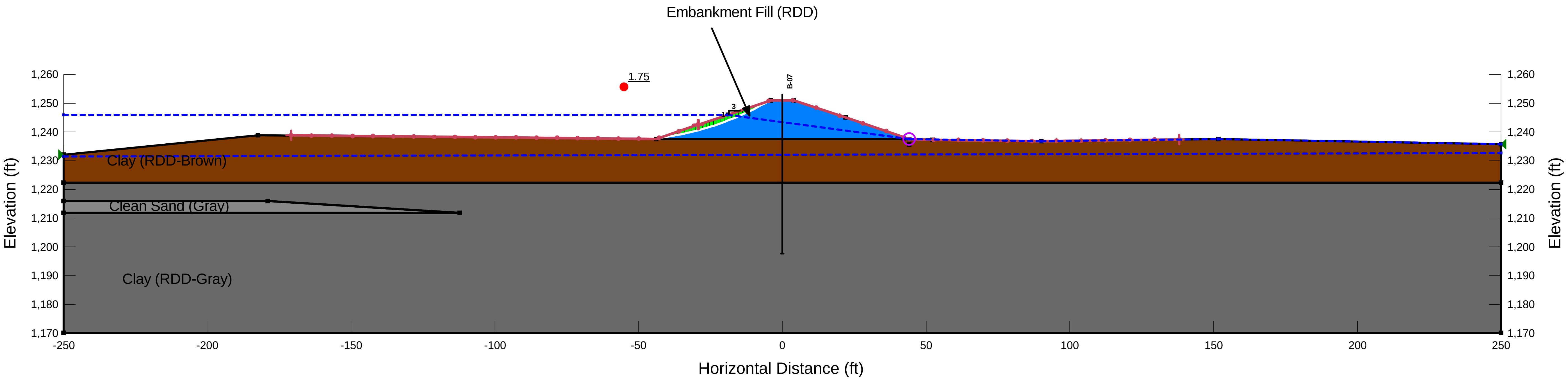
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 3
Upper Maple River Watershed Detention Plan - Alt2A
4.1_CS3_Rapid draw down
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Cohesion R (psf)	Phi R (°)
🟫	Clay (RDD-Brown)	Mohr-Coulomb	130	0	31	1,600	0
⬛	Clay (RDD-Gray)	Mohr-Coulomb	130	0	31	1,600	0
▩	Clean Sand (Gray)	Mohr-Coulomb	130	0	32	0	0
🟦	Embankment Fill (RDD)	Mohr-Coulomb	128	0	30	1,300	0



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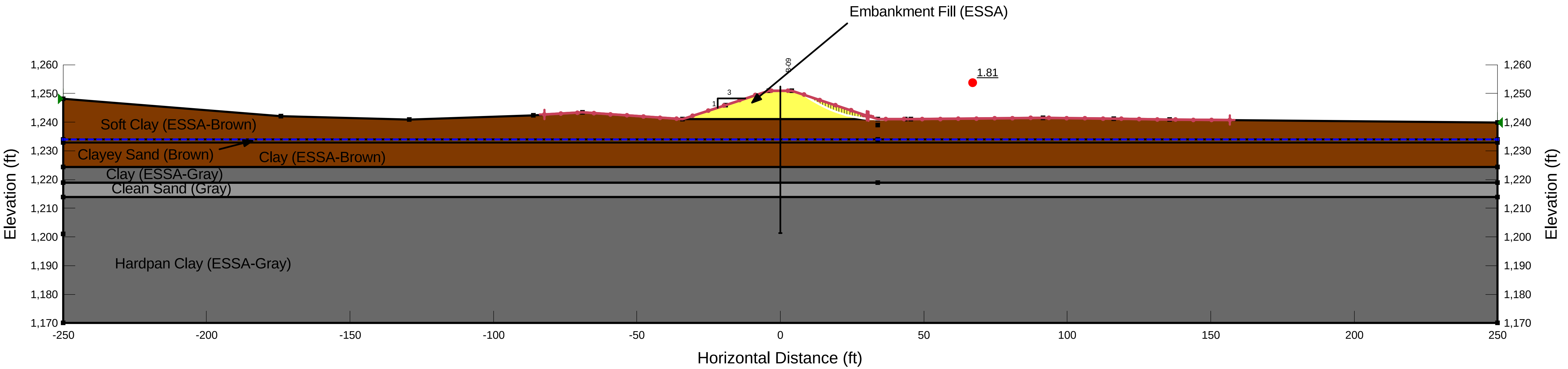
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 4
Upper Maple River Watershed Detention Plan
1.1_CS4_No Loading_ESSA_DS
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (ESSA-Brown)	Mohr-Coulomb	130	0	31
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
🟧	Clayey Sand (Brown)	Mohr-Coulomb	130	0	32
⬜	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟨	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30
⬛	Hardpan Clay (ESSA-Gray)	Mohr-Coulomb	130	0	32
🟫	Soft Clay (ESSA-Brown)	Mohr-Coulomb	130	0	30

Factor of Safety: 1.81



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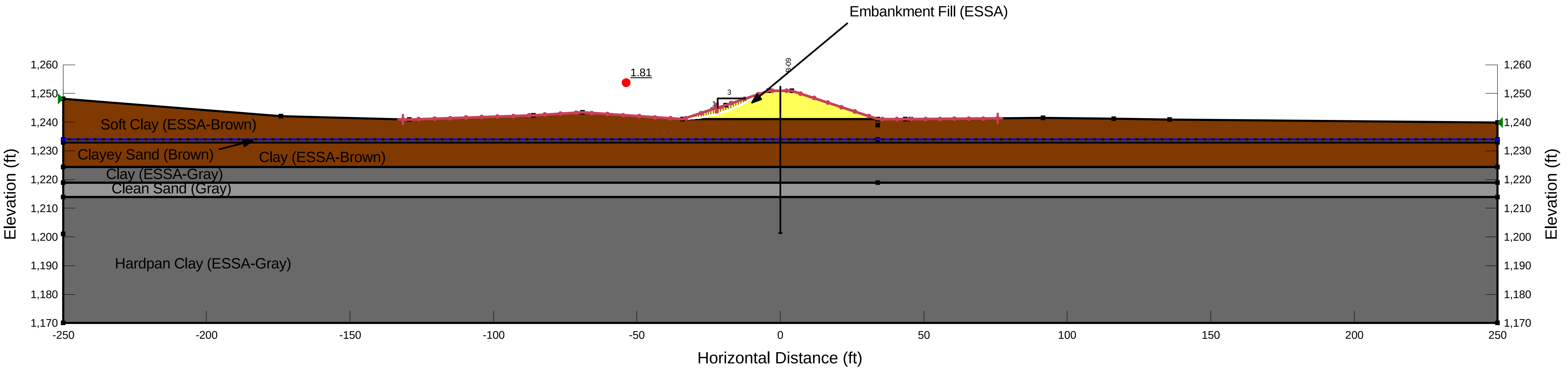
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 4
Upper Maple River Watershed Detention Plan
1.2_CS4_No Loading_ESSA_US
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (ESSA-Brown)	Mohr-Coulomb	130	0	31
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
🟧	Clayey Sand (Brown)	Mohr-Coulomb	130	0	32
⬜	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟨	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30
⬛	Hardpan Clay (ESSA-Gray)	Mohr-Coulomb	130	0	32
🟫	Soft Clay (ESSA-Brown)	Mohr-Coulomb	130	0	30

Factor of Safety: 1.81



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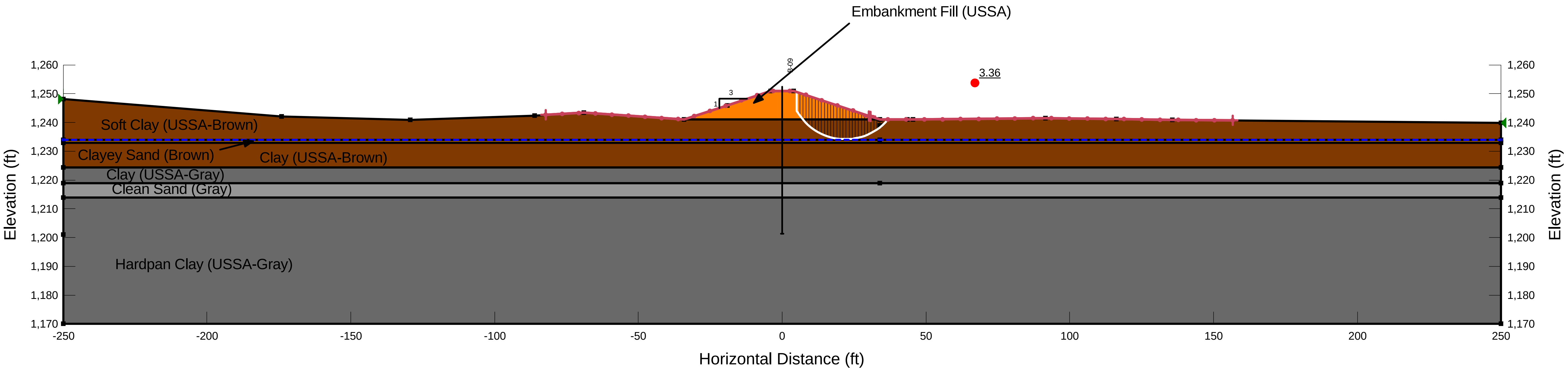
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 4
Upper Maple River Watershed Detention Plan
1.3_CS4_No Loading_USSA_DS (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (USSA-Brown)	Mohr-Coulomb	130	1,600	0
■	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
🟫	Clayey Sand (Brown)	Mohr-Coulomb	130	0	32
■	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0
■	Hardpan Clay (USSA-Gray)	Mohr-Coulomb	130	4,000	0
🟫	Soft Clay (USSA-Brown)	Mohr-Coulomb	130	500	0

Factor of Safety: 3.36



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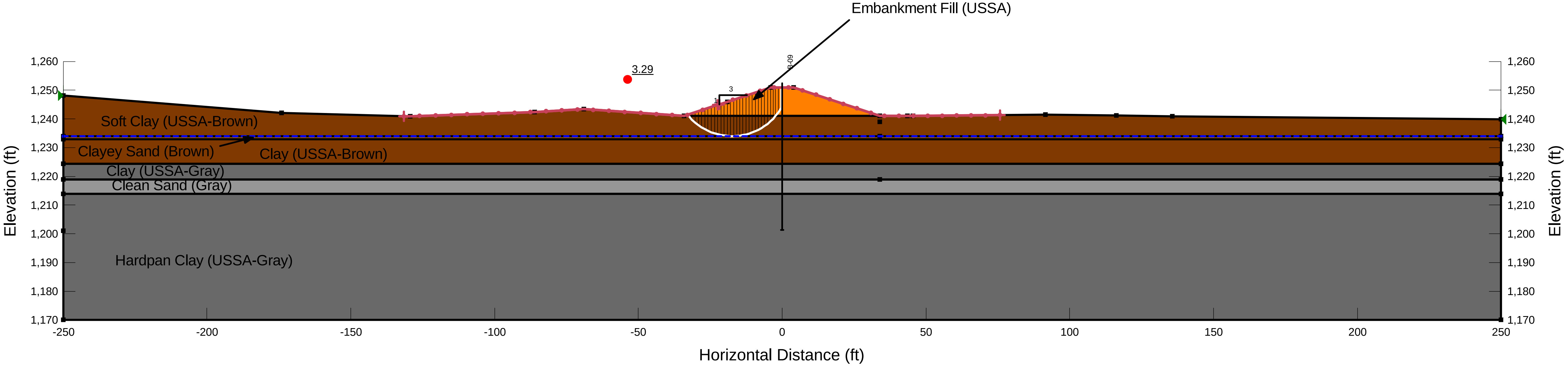
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 4
Upper Maple River Watershed Detention Plan
1.4_CS4_No Loading_USSA_US (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (USSA-Brown)	Mohr-Coulomb	130	1,600	0
⬛	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
🟧	Clayey Sand (Brown)	Mohr-Coulomb	130	0	32
⬜	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0
⬛	Hardpan Clay (USSA-Gray)	Mohr-Coulomb	130	4,000	0
🟫	Soft Clay (USSA-Brown)	Mohr-Coulomb	130	500	0

Factor of Safety: 3.29



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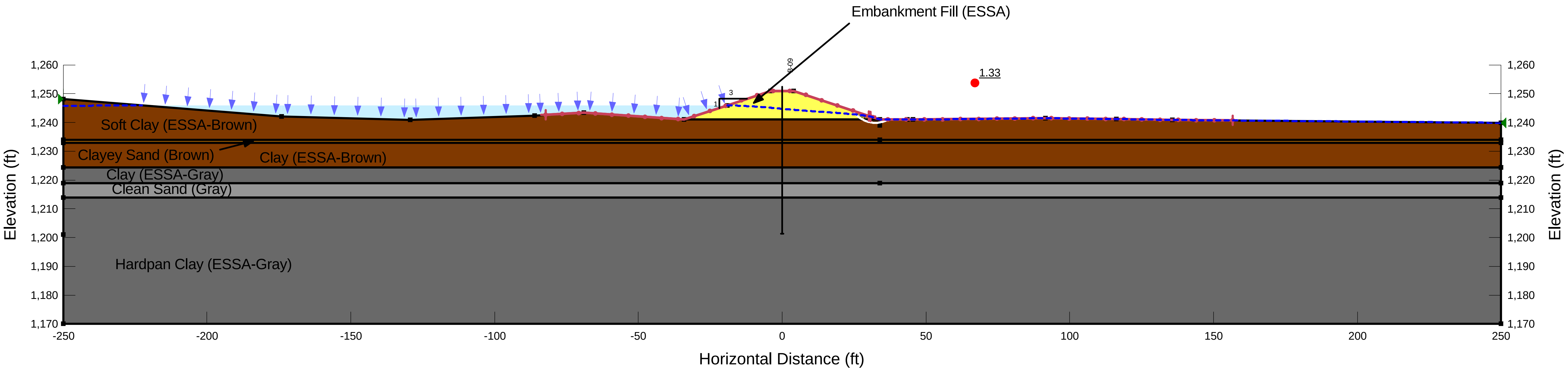
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 4
Upper Maple River Watershed Detention Plan
2.1_CS4_ESSA_DS_Normal Loading
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (ESSA-Brown)	Mohr-Coulomb	130	0	31
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
🟧	Clayey Sand (Brown)	Mohr-Coulomb	130	0	32
⬜	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟨	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30
⬛	Hardpan Clay (ESSA-Gray)	Mohr-Coulomb	130	0	32
🟫	Soft Clay (ESSA-Brown)	Mohr-Coulomb	130	0	30

Factor of Safety: 1.33



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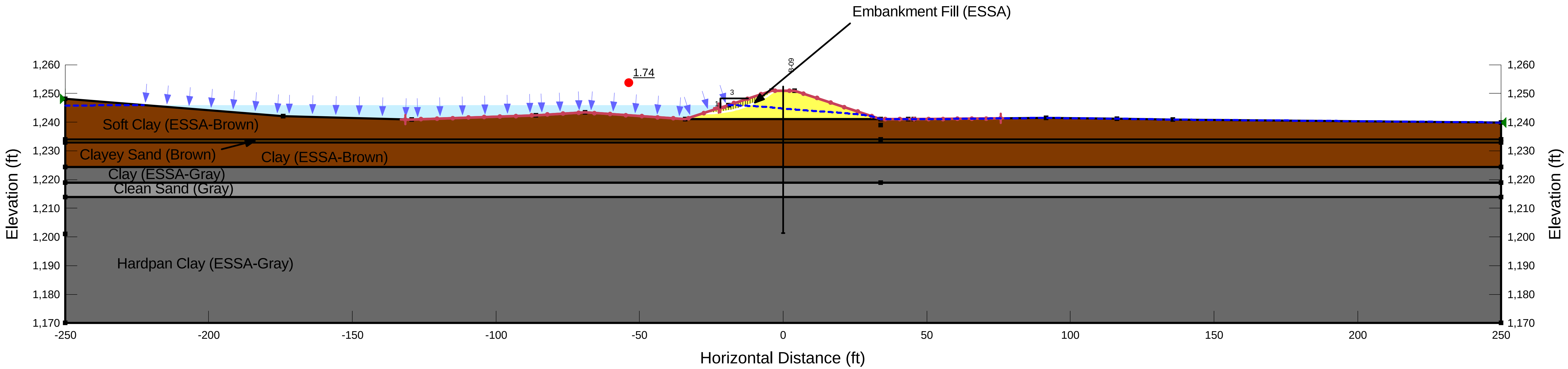
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 4
Upper Maple River Watershed Detention Plan
2.2_CS4_ESSA_US_Normal Loading
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (ESSA-Brown)	Mohr-Coulomb	130	0	31
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
🟧	Clayey Sand (Brown)	Mohr-Coulomb	130	0	32
▩	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟨	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30
⬛	Hardpan Clay (ESSA-Gray)	Mohr-Coulomb	130	0	32
🟫	Soft Clay (ESSA-Brown)	Mohr-Coulomb	130	0	30

Factor of Safety: 1.74



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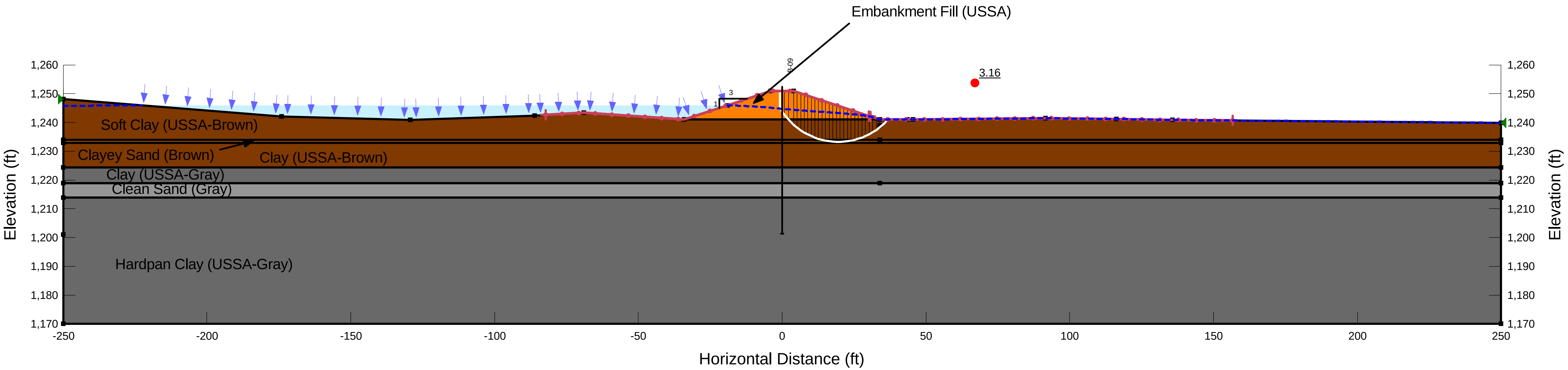
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 4
Upper Maple River Watershed Detention Plan
2.3_CS4_USSA_DS_Normal Loading (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (USSA-Brown)	Mohr-Coulomb	130	1,600	0
⬛	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
🟧	Clayey Sand (Brown)	Mohr-Coulomb	130	0	32
⬜	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0
⬛	Hardpan Clay (USSA-Gray)	Mohr-Coulomb	130	4,000	0
🟫	Soft Clay (USSA-Brown)	Mohr-Coulomb	130	500	0

Factor of Safety: 3.16



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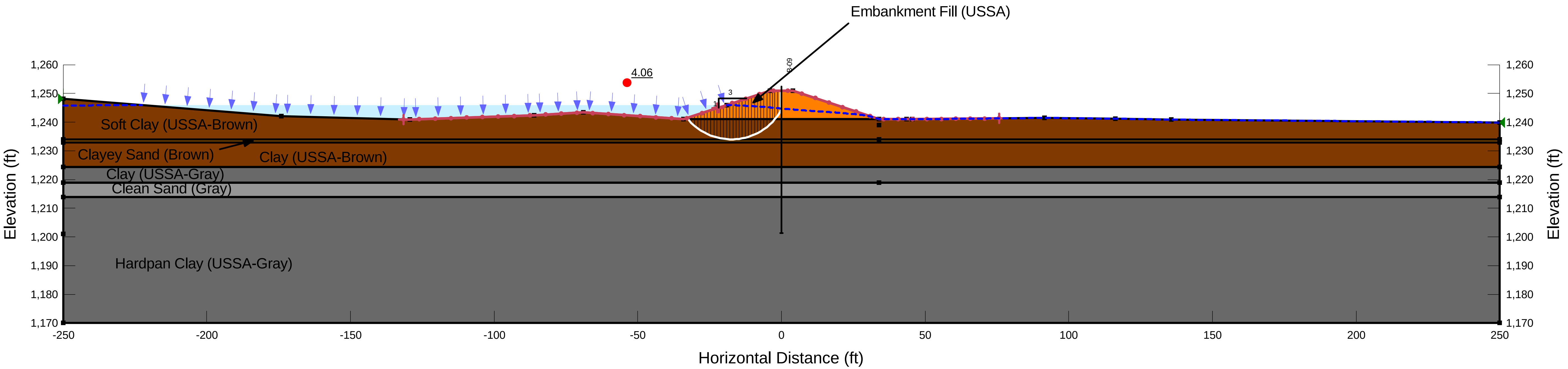
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 4
Upper Maple River Watershed Detention Plan
2.4_CS4_USSA_US_Normal Loading (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (USSA-Brown)	Mohr-Coulomb	130	1,600	0
⬛	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
🟧	Clayey Sand (Brown)	Mohr-Coulomb	130	0	32
⬜	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0
⬛	Hardpan Clay (USSA-Gray)	Mohr-Coulomb	130	4,000	0
🟫	Soft Clay (USSA-Brown)	Mohr-Coulomb	130	500	0

Factor of Safety: 4.06



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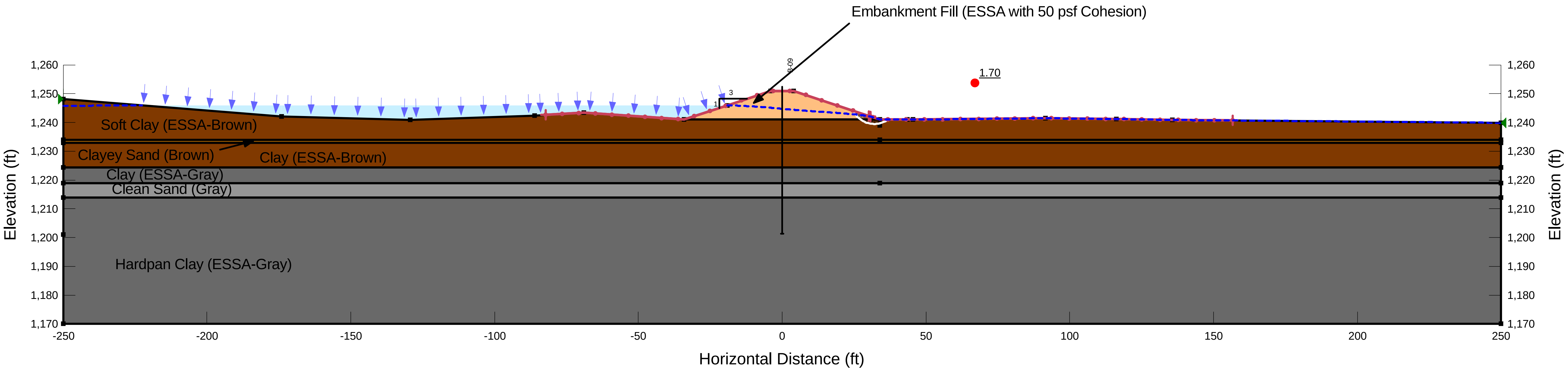
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 4
Upper Maple River Watershed Detention Plan
2.6_CS4_ESSA_DS_Normal Loading (with cohesion)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (ESSA-Brown)	Mohr-Coulomb	130	0	31
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
🟧	Clayey Sand (Brown)	Mohr-Coulomb	130	0	32
⬜	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟨	Embankment Fill (ESSA with 50 psf Cohesion)	Mohr-Coulomb	128	50	30
⬛	Hardpan Clay (ESSA-Gray)	Mohr-Coulomb	130	0	32
🟫	Soft Clay (ESSA-Brown)	Mohr-Coulomb	130	0	30

Factor of Safety: 1.70



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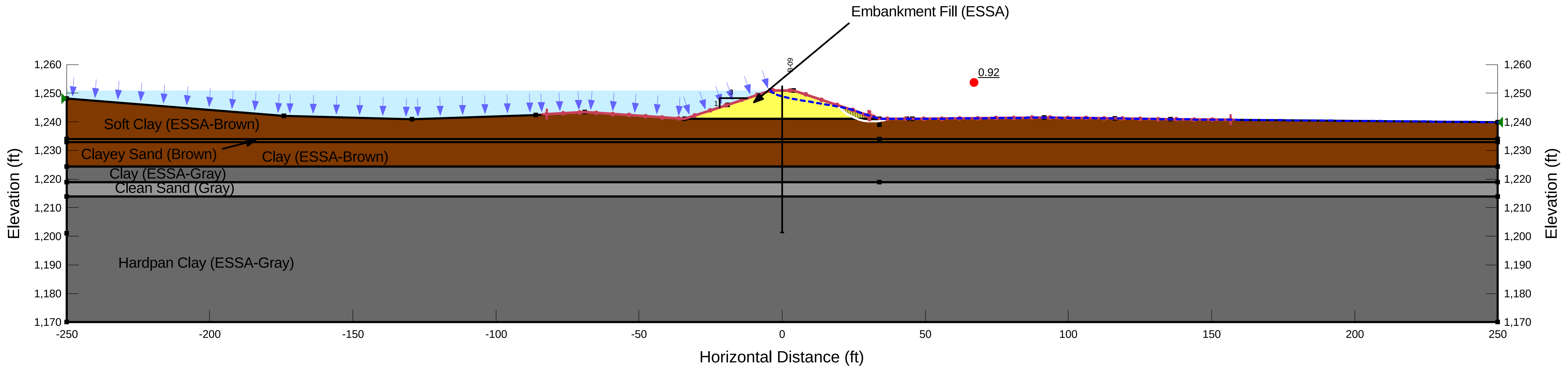
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 4
Upper Maple River Watershed Detention Plan
3.1_CS4_ESSA_DS_Max Loading
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (ESSA-Brown)	Mohr-Coulomb	130	0	31
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
🟧	Clayey Sand (Brown)	Mohr-Coulomb	130	0	32
⬜	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟨	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30
⬛	Hardpan Clay (ESSA-Gray)	Mohr-Coulomb	130	0	32
🟫	Soft Clay (ESSA-Brown)	Mohr-Coulomb	130	0	30

Factor of Safety: 0.92



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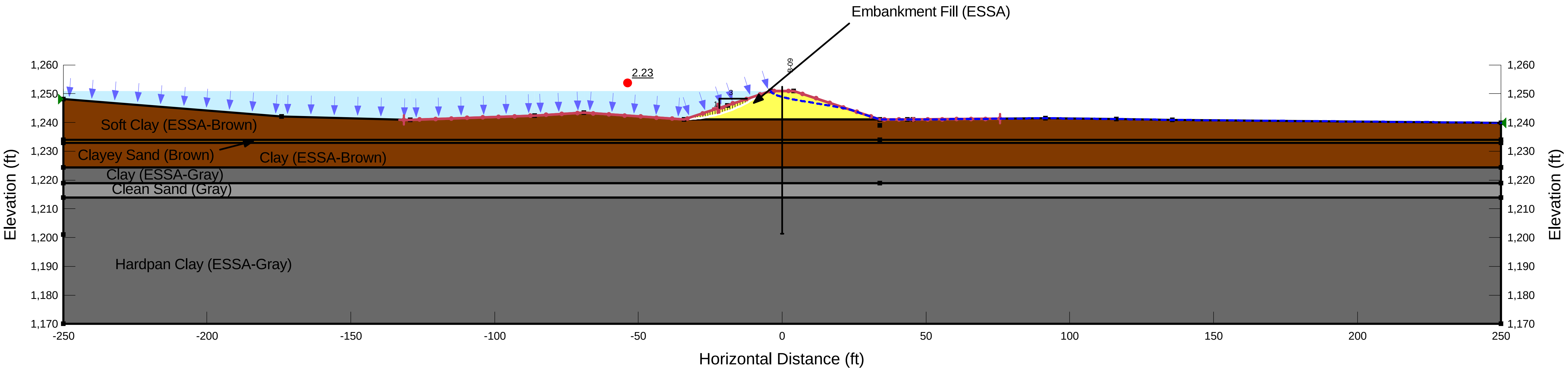
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 4
Upper Maple River Watershed Detention Plan
3.2_CS4_ESSA_US_Max Loading
Last Saved Date: 11/08/2019

Color	**Name**	**Model**	**Unit Weight (pcf)**	**Cohesion' (psf)**	**Phi' (°)**
🟫	Clay (ESSA-Brown)	Mohr-Coulomb	130	0	31
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
🟧	Clayey Sand (Brown)	Mohr-Coulomb	130	0	32
⬜	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟨	Embankment Fill (ESSA)	Mohr-Coulomb	128	0	30
⬛	Hardpan Clay (ESSA-Gray)	Mohr-Coulomb	130	0	32
🟫	Soft Clay (ESSA-Brown)	Mohr-Coulomb	130	0	30

Factor of Safety: 2.23



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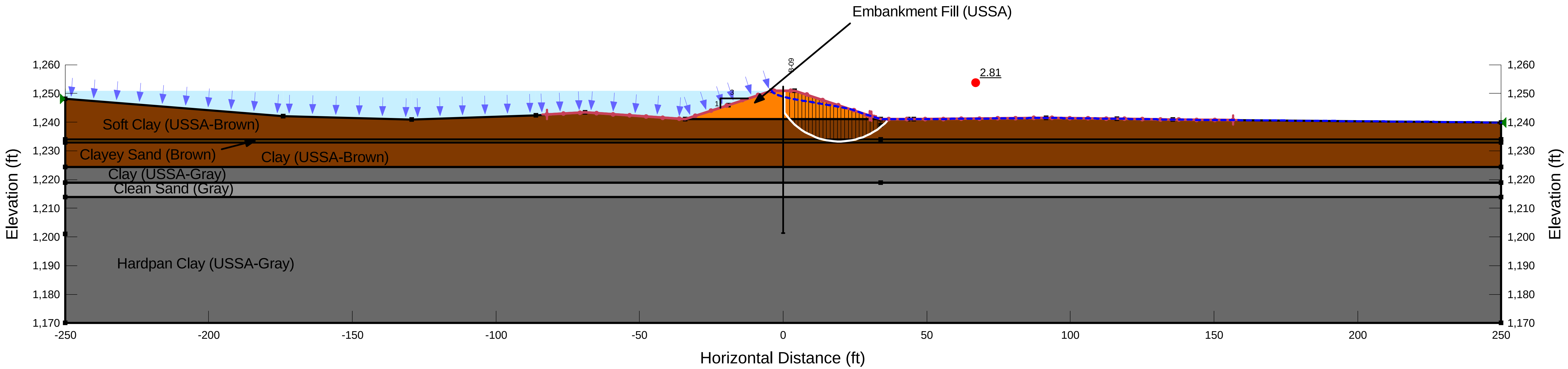
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 4
Upper Maple River Watershed Detention Plan
3.3_CS4_USSA_DS_Max Loading (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (USSA-Brown)	Mohr-Coulomb	130	1,600	0
⬛	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
🟫	Clayey Sand (Brown)	Mohr-Coulomb	130	0	32
⬛	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0
⬛	Hardpan Clay (USSA-Gray)	Mohr-Coulomb	130	4,000	0
🟫	Soft Clay (USSA-Brown)	Mohr-Coulomb	130	500	0

Factor of Safety: 2.81



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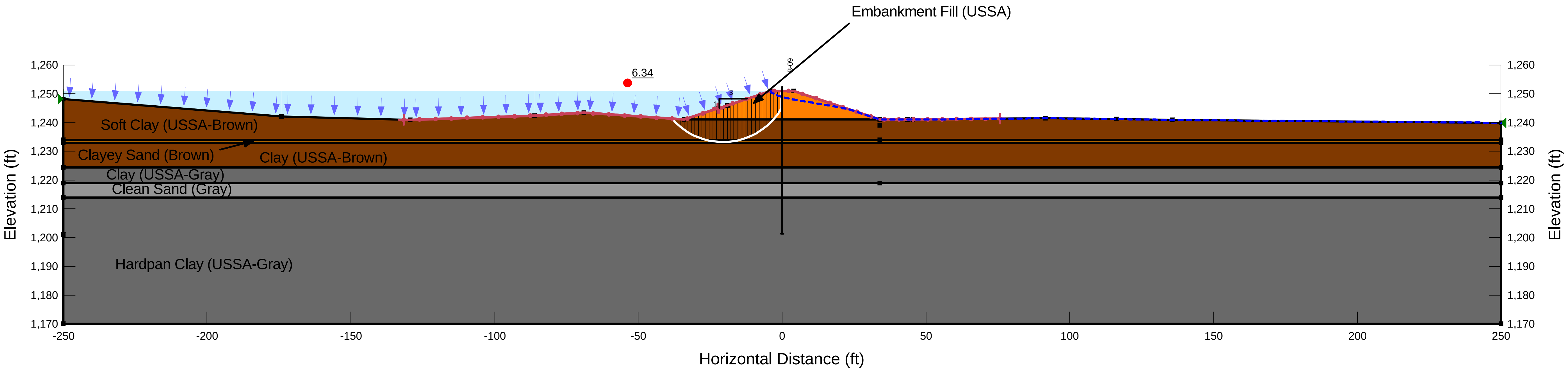
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 4
Upper Maple River Watershed Detention Plan
3.4_CS4_USSA_US_Max Loading (2)
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (USSA-Brown)	Mohr-Coulomb	130	1,600	0
⬛	Clay (USSA-Gray)	Mohr-Coulomb	130	1,600	0
🟫	Clayey Sand (Brown)	Mohr-Coulomb	130	0	32
⬜	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟧	Embankment Fill (USSA)	Mohr-Coulomb	128	1,300	0
⬛	Hardpan Clay (USSA-Gray)	Mohr-Coulomb	130	4,000	0
🟫	Soft Clay (USSA-Brown)	Mohr-Coulomb	130	500	0

Factor of Safety: 6.34



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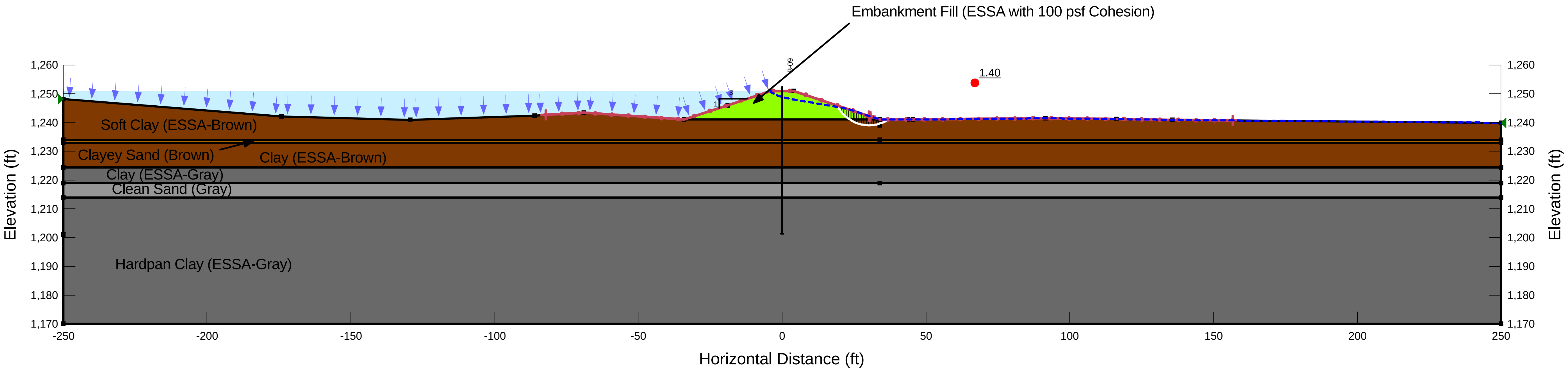
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 4
Upper Maple River Watershed Detention Plan
3.6_CS4_ESSA_DS_Max Loading_With Cohesion
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
🟫	Clay (ESSA-Brown)	Mohr-Coulomb	130	0	31
⬛	Clay (ESSA-Gray)	Mohr-Coulomb	130	0	31
🟧	Clayey Sand (Brown)	Mohr-Coulomb	130	0	32
⬜	Clean Sand (Gray)	Mohr-Coulomb	130	0	32
🟩	Embankment Fill (ESSA with 100 psf Cohesion)	Mohr-Coulomb	128	100	30
⬛	Hardpan Clay (ESSA-Gray)	Mohr-Coulomb	130	0	32
🟫	Soft Clay (ESSA-Brown)	Mohr-Coulomb	130	0	30

Factor of Safety: 1.40



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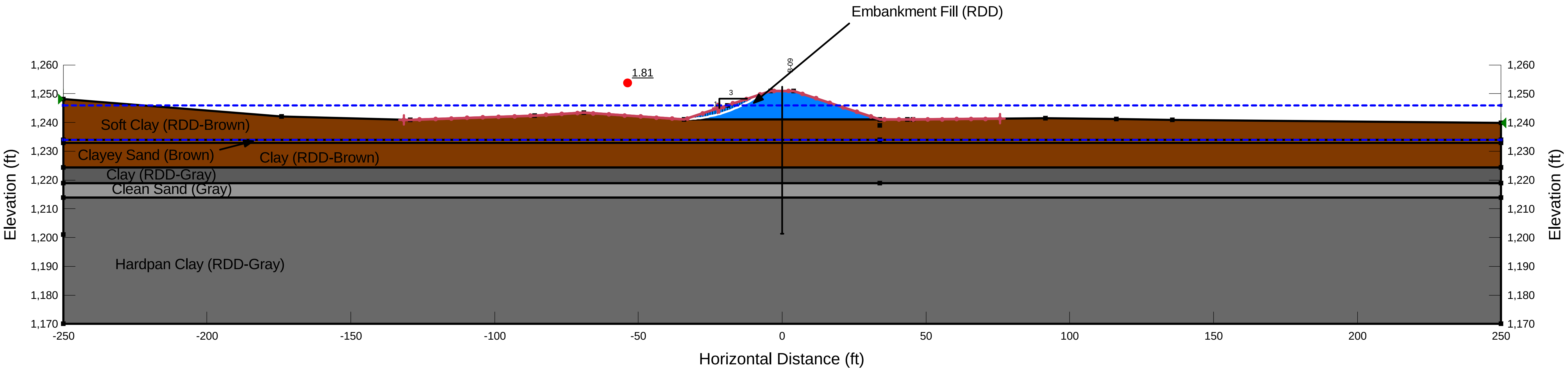
Moore Engineering, Inc.
Seepage and Slope Stability Analysis
Cross Section 4
Upper Maple River Watershed Detention Plan
4.1_CS4_Rapid draw Down
Last Saved Date: 11/08/2019

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Cohesion R (psf)	Phi R (°)
🟫	Clay (RDD-Brown)	Mohr-Coulomb	130	0	31	1,600	0
⬛	Clay (RDD-Gray)	Mohr-Coulomb	130	0	31	1,600	0
🟧	Clayey Sand (Brown)	Mohr-Coulomb	130	0	32	0	0
⬜	Clean Sand (Gray)	Mohr-Coulomb	130	0	32	0	0
🟦	Embankment Fill (RDD)	Mohr-Coulomb	128	0	30	1,300	0
⬛	Hardpan Clay (RDD-Gray)	Mohr-Coulomb	130	0	32	4,000	0
🟫	Soft Clay (RDD-Brown)	Mohr-Coulomb	130	0	30	500	0

Factor of Safety: 1.81



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