Structural Geotechnical Report

Existing Culvert Repairs
IL Route 1 near W. Kent Avenue (Culvert 1 & 2)
IL Route 394 near E. Exchange Street (Culvert 3)
Will County, IL

Prepared for:

Illinois Department of Transportation

IDOT PTB 191-002
Contract: 62N27

Project Design Engineer:
Quigg Engineering Inc.

Prepared by:

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May 27, 2021

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Dear Mr. Ahmed:

Attached is a copy of the Structural Geotechnical Report for the above referenced project. The report provides a brief description of the site investigation, site conditions, and geotechnical recommendations for the proposed improvements. The site investigation included advancing two (2) borings to depths of 10 and 50 feet.

Should you have any questions or require additional information, please call us at 630-994-2600.

Sincerely,

Thomas E. Kasang

Thomas E. Kasang, P.E.
Project Engineer

Dawn Edgell.

Dawn Edgell, P.E.
Sr. Project Engineer

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1.0 INTRODUCTION

On behalf of the Illinois Department of Transportation (IDOT), Quigg Engineering Inc. (Quigg) retained GSG Consultants, Inc. (GSG) to complete a geotechnical investigation and to provide recommendations regarding the proposed IL Route 1 and IL Route 394 culvert repairs located near Crete in Will County, Illinois. Two (2) structures (Culvert 1 & 2) are located along IL Route 1 approximately 850 feet south of West Kent Avenue near the Balmoral Hunter Equestrian Center. One (1) structure (Culvert 3) is located approximately 1,050 feet south of East Exchange Street. **Exhibit 1**, Project Location Map, shows the approximate boundaries of the project limits at each culvert location.

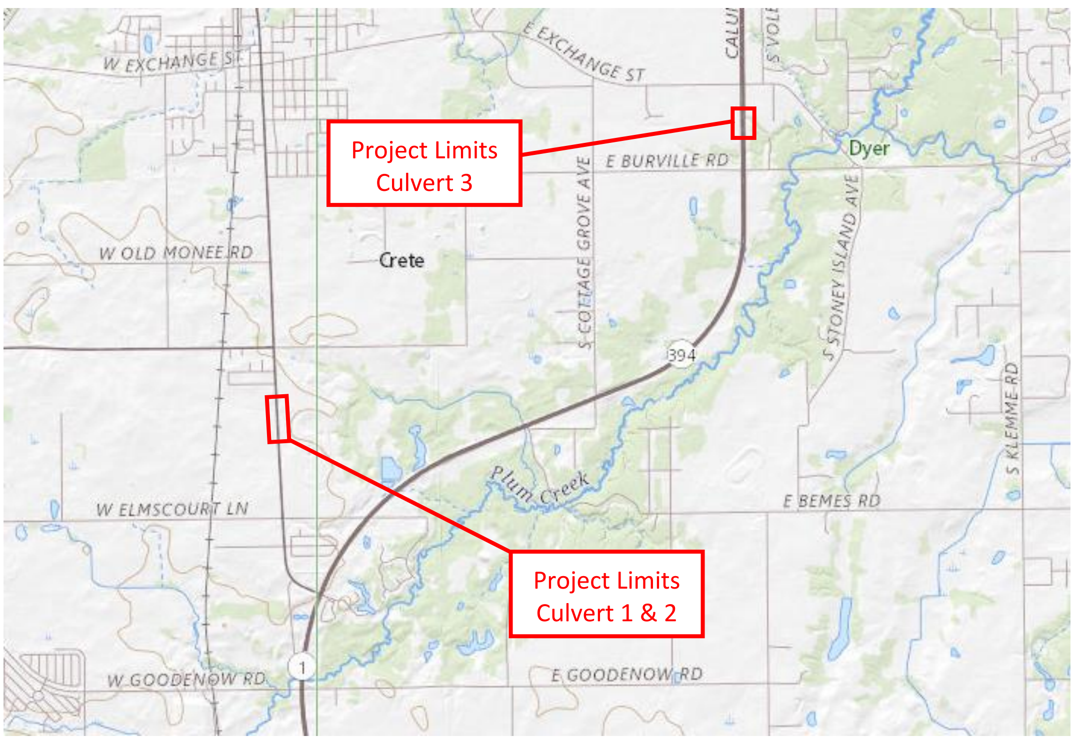


Exhibit 1: Project Location Map

1.1 Existing Site Conditions

The existing culvert structures along IL Route 1 (Culvert 1 & 2) convey an unnamed ditch under IL Route 1. The type, size, and dimensions of these structures are unknown. The existing structure along IL Route 394 (Culvert 3) is a 36-inch reinforced concrete pipe (RCP) storm sewer conveying an unnamed creek southeast under IL Route 394. An existing 15-inch storm sewer bisects the

36-inch RCP storm sewer at the outlet headwall. The areas of the culvert inlets and outlets are heavily vegetated.

At Culvert 3 along IL Route 394, there is evidence of previous slope instability above the headwall of the culvert, however no evidence of failure was observed in the shoulder of the road above the culvert. The exact failure location and size were unknown at the time of this submittal. A photograph of the slope instability was provided by Quigg and is attached in **Appendix F**.

1.2 Proposed Reconstruction

Based on information and drawings provided by Quigg (dated 05/18/2021) (**Appendix A**), the anticipated repair work for Culvert 3 along IL Route 394 will include the following:

- Construction of a sheet pile or solider pile wall offset approximately 18.5 feet from the edge of the east shoulder of IL Route 394 to stabilize the embankment along the edge of IL Route 394. The wall will include a 7 ft-9 inch gap around the existing 36-inch RCP storm sewer.
- Construction of a 12-inch RCP storm sewer connecting to the existing 36-inch RCP storm sewer, reconstruction of a section of the 36-inch RCP storm sewer, and replacement of the culvert outlet headwall.
- Construction of a 7-foot diameter drop manhole near IL Route 394 existing Station 611+05.13, offset approximately 76.5 feet from the centerline of IL Route 394. A retaining wall will be required to install the drop manhole, with a maximum retained height of approximately 18 feet.
- After construction of the drop manhole is completed, new fill will be placed along the eastern side of the proposed retaining wall at a 2H:1V slope and extend to the proposed outlet headwall of the 36-inch RCP storm sewer.

The proposed improvements along IL Route 1 will consist of replacing the culvert headwalls at both Culverts 1 and 2. The type, size, and dimensions of the proposed IL Route 1 improvements were not provided at the time of this submittal.

2.0 SITE SUBSURFACE EXPLORATION PROGRAM

This section describes the subsurface exploration program and laboratory testing program completed as part of this project. The subsurface exploration program was performed in accordance with applicable IDOT geotechnical manuals and procedures.

2.1 Subsurface Exploration Program

The subsurface soil investigation was conducted on January 28, 2021 and included advancing two (2) soil borings near the existing culverts to depths of 10 and 50 feet. Boring B-1 was completed through the pavement on IL Route 1 and approximately 875 feet south of W. Kent Avenue. Boring B-2 was completed off existing IL Route 394 and approximately 1,050 feet south of E. Exchange Street. The soil boring locations were selected by GSG based on the location plans provided by Quigg and completed at locations based on field conditions, utilities, and site accessibility. **Table 1** presents a list of the boring location information.

Table 1 – Summary of Subsurface Exploration Borings

Boring	Location	Northing	Easting	Existing Ground Elevation (ft)	Depth (ft)
B-1	IL Route 1	1730249.690	1177293.910	748.2	10.0
B-2	IL Route 394	1739528.495	1191732.135	705.2	50.0

The existing ground surface elevations for the borings were based on the field survey performed by GSG. The approximate locations of the soil borings are shown on the **Boring Location Plan (Appendix B)**.

The soil borings were drilled using a truck mounted CME-75 drill rig, using 3¼-inch I.D. hollow stem augers and automatic hammers. Soil sampling was performed according to AASHTO T 206, "Penetration Test and Split Barrel Sampling of Soils." Soil samples were obtained at 2.5-foot intervals to soil boring termination in boring B-1 and to a depth of 30 feet below grade in boring B-2. Sampling was then performed at 5-foot intervals to the boring termination depth in boring B-2. GSG's field representative inspected, visually classified and logged the soil samples during the subsurface exploration activities and performed unconfined compressive strength tests on cohesive soil samples using a calibrated hand penetrometer in accordance with IDOT procedures and requirements. Representative soil samples were collected from each sample interval, were placed in jars, and returned to the laboratory for further testing and evaluation.

2.2 Laboratory Testing Program

All samples were inspected in the laboratory to verify the field classifications. A laboratory testing program was undertaken to characterize and determine engineering properties of the subsurface soils encountered in the area of the proposed improvements. The following laboratory tests were performed on representative samples:

- Moisture Contents – ASTM D2216 / AASHTO T-265
- Atterberg Limits – ASTM D4318 / AASHTO T-89 / AASHTO T-90
- Dry Unit Weight – ASTMD7263

The laboratory tests were performed in accordance with test procedures outlined in the IDOT Geotechnical Manual (2020), and per ASTM and AASHTO requirements. Based on the laboratory test results, the soils encountered were classified according to the AASHTO and the Illinois Division of Highways (IDH) classification systems. The results of the laboratory testing program are shown along with the field test results in the Soil Boring Logs **(Appendix C)** and included in the **Laboratory Test Results (Appendix D)**.

2.3 Subsurface Soil Conditions

This section provides a brief description of the soils encountered in the borings performed. Variations in the general subsurface soil profile were noted during the drilling activities. Detailed descriptions of the subsurface soils are provided in the soil boring logs. The soil boring logs provide specific conditions encountered at each boring location. The soil boring logs include soil descriptions, stratifications, penetration resistance, elevations, location of the samples, and laboratory test data. Unless otherwise noted, soil descriptions indicated on boring logs are visual identifications. The stratifications shown on the boring logs represent the conditions only at the actual boring locations and represent the approximate boundary between subsurface materials; however, the actual transition may be gradual.

IL Route 1

Boring B-1 was drilled through the right-lane pavement on the southbound side of IL Route 1. The boring initially noted 4 inches of asphalt over 5 inches of concrete. Beneath the pavement layers, stiff to very stiff dark gray and gray silty clay soils were encountered to a depth of 7 feet below grade. These soils were underlain by stiff to hard brown and gray silty clay to the boring termination depth of 10 feet.

The unconfined compressive strength values of the dark gray and gray silty clay soils ranged between 1.87 tsf and 2.29 tsf. The unconfined compressive strength values of the brown and gray silty clay ranged between 1.25 tsf and 5.0 tsf.

IL Route 394

Boring B-2 was drilled off the IL Route 394 pavement on the north side of the existing culvert. The boring noted 1 foot of sand fill, followed by silty clay fill soils to 8.5 feet below grade. Beneath the existing fill soils, a layer of medium stiff silty clay was encountered to a depth of 11 feet below grade, followed by very stiff silty clay to a depth of 13.5 feet. These soils were underlain by hard brown and gray silty clay to 23.5 feet below grade, followed by stiff to hard gray silty clay to 48.5 feet below grade. Loose gray sand was then encountered to the boring termination depth of 50 feet. A sand seam was noted within the gray silty clay soils at 38.5 feet.

The unconfined compressive strength value of the medium stiff gray silty clay between 8 to 11 feet was 0.62 tsf. Below this layer, the gray silty clay had an unconfined compressive strength of 2.29 tsf. The unconfined compressive strength values of the brown and gray silty clay ranged between 4.58 tsf and 5.41 tsf. The unconfined compressive strength values of the lower gray silty clay soils ranged between 1.67 tsf and 5.21 tsf. The SPT blow count 'N' value of the gray sand was 6 blow per foot (bpf).

2.4 Groundwater Conditions

Water levels were checked in each boring to determine the general groundwater conditions present at the site and were measured while drilling and after each boring was completed. In boring B-2, water was encountered at a depth of 38.5 feet below grade (approx. elevation 666.7 feet). Water was not encountered during drilling in B-1, or after drilling at either of the soil boring locations.

Based on the color change from brown to gray, it is anticipated that the long-term groundwater level for the IL Route 1 culverts is greater than 10 feet below grade. For the IL Route 394 culvert, the long-term groundwater is anticipated to be approximately 23.5 feet below grade (elevation 682 feet). Water level readings were made in the boreholes at times and under conditions shown on the boring logs and stated in the text of this report. However, it should be noted that fluctuations in groundwater level may occur due to variations in rainfall, other climatic conditions, or other factors not evident at the time measurements were made and reported herein.

3.0 GEOTECHNICAL ANALYSIS

This section provides GSG's geotechnical analysis and recommendations for the design of the proposed improvements based the results of the field exploration, laboratory testing, and geotechnical analysis. Subsurface conditions in unexplored locations may vary from those encountered at the boring locations. If the structure location, loadings, or elevations are changed, we request that GSG be contacted so that we may re-evaluate our recommendations.

3.1 Derivation of Soil Parameters for Design

GSG determined the geotechnical parameters to be used for the project design based on the results of the field and laboratory test data on individual boring logs as well as our experience. Unit weights, friction angles and shear strength parameters were estimated using standard penetration test (SPT) results for the fill and cohesionless soils and in-situ and laboratory test results for cohesive soils. The SPT values were corrected for hammer efficiency and overburden weight. The hammer efficiency correction factor considers the use of a safety hammer/rope/cat-head system, generally estimated to be 60% efficient. Thus, correlations should be based upon what is currently termed as N_{60} data. The efficiency of the automatic hammer for the truck mounted CME-75 drill rig was estimated to be approximately 91% based on GSG's most recent calibrations records. The correction for hammer efficiency is a direct ratio of relative efficiencies. The following equation should be used in calculating the corrected blow counts for the purposes of design and analysis:

$$N_{60} = N_{Field}{*}(91/60) \text{ (CME-75)}$$

*Where the N_{Field} value is the field recorded blow counts during drilling activities.

Based on the field investigation data collected, generalized soil parameters for the soils for use in design at the culvert locations are presented in **Tables 2a and 2b.**

Table 2a – Summary of Soil Parameters for IL Route 1 Culverts (B-1)

Depth / Elevation Range (feet)	Soil Description	In situ Unit Weight γ (pcf)	Undrained		Drained	
			Cohesion c (psf)	Friction Angle ϕ (°)	Cohesion c (psf)	Friction Angle ϕ (°)
	New Engineered Clay Fill	125	1,000	0	50	25
	New Engineered Granular Fill	125	0	30	0	30
1-7 (748.2-741.2)	Stiff to Very Stiff Gray and Dark Gray Silty Clay	125	2,000	0	200	25
7-10 (741.2-738.2)	Stiff to Hard Brown and Gray Silty Clay	138	2,500	0	250	28

Table 2b – Summary of Soil Parameters for IL Route 394 Culvert (B-2)

Depth / Elevation Range (feet)	Soil Description	In situ Unit Weight γ (pcf)	Undrained		Drained	
			Cohesion c (psf)	Friction Angle ϕ (°)	Cohesion c (psf)	Friction Angle ϕ (°)
	New Engineered Clay Fill	125	1,000	0	50	25
	New Engineered Granular Fill	125	0	30	0	30
1-8.5 (704.2-696.7)	FILL Brown and Gray Silty Clay	138	2,000	0	50	26
8.5-11 (696.7-694.2)	Medium Stiff Gray Silty Clay	127	600	0	60	28
11-13.5 (694.2-691.7)	Very Stiff Gray Silty Clay	138	2,250	0	200	28
13.5-23.5 (691.7-681.7)	Hard Brown and Gray Silty Clay	138	4,750	0	400	28
23.5-48.5 (681.7-656.7)	Stiff to Hard Gray Silty Clay	138	3,000	0	300	28
48.5-50 (656.7-655.2)	Loose Gray Sand	112	0	29	0	29

3.2 Seismic Parameters

The seismic hazard for the site was analyzed per the IDOT Geotechnical Manual, IDOT Bridge Design Manual, and AASHTO LRFD Bridge Design Specifications.

The Seismic Soil Site Class was determined per the requirements of All Geotechnical Manual Users (AGMU) Memo 9.1, Design Guide for Seismic Site Class Determination, and the "Seismic Site Class Determination" Excel spreadsheet provided by IDOT. A global Site Class Definition was determined for this project, and was found to be Soil Site Class C. The Seismic Performance Zone (SPZ) was determined using Figure 2.3.10-2 in the IDOT Bridge Manual and was found to be Seismic Performance Zone 1.

The AASHTO Seismic Design Parameters program was used to determine the peak ground acceleration coefficient (PGA), and the short (S_{DS}) and long (S_{D1}) period design spectral acceleration coefficients for each of the proposed structures. For this section of the project, the S_{DS} and the S_{D1} were determined using 2017 AASHTO Guide Specifications as shown in **Table 3**. Given the site location and materials encountered, the potential for liquefaction is minimal.

Table 3 – Seismic Parameters

Building Code Reference	PGA	S_{DS}	S_{D1}
2017 AASHTO Guide for LRFD Seismic Bridge Design	0.044g	0.117g	0.067g

4.0 GEOTECHNICAL DESIGN RECOMMENDATIONS

This section provides the results of GSG's geotechnical evaluation of the existing foundation system and design recommendations in accordance with the most current AASHTO LRFD 9th Edition (2020) and IDOT Geotechnical Manual (2020). The foundations for the proposed culvert headwalls must provide sufficient support to resist the dead and live loads.

4.1 Foundation Recommendations - IL Route 1 Culvert Headwalls

GSG evaluated the soils for the proposed headwalls for the IL Route 1 culverts. Design plans were not available at the time of this submittal. GSG's evaluation includes recommending allowable bearing capacities and construction recommendations for the installation of new headwalls. For the design of the foundations, the total live load, impact loads, and dead loads, including the load of the overburden soils, should be considered. Design should be completed in accordance with the IDOT Culvert Manual (2017).

4.2 Shallow Foundation Bearing Capacity and Settlement

GSG evaluated the soils at an assumed bearing grade elevation of 745 feet for the base of the proposed IL Route 1 culvert headwalls. The subsurface investigation noted stiff dark gray and gray silty clay at the preliminary bearing elevation. Bearing resistance shall be evaluated at the strength limit state using load factors and factored bearing resistance. The bearing resistance factor, ϕ_b, for shallow foundations in clay is 0.50 per AASHTO Table 10.5.5.2.2.1. The bearing resistance shall be checked for the extreme limit state with a resistance factor of 1.0. **Table 4** presents the proposed bearing elevation and recommended bearing resistances of suitable materials to support the proposed culvert headwalls.

Table 4 – Recommended Bearing Resistance

Proposed Structure	Approximate Bearing Elevation (feet)	Nominal Bearing Resistance (ksf)	Factored Bearing Resistance (ksf)	Bearing Resistance for 1-inch Settlement Service Limit (ksf)	Bearing Resistance for 2-inch Settlement Service Limit (ksf)	Anticipated Bearing Soil
IL Route 1 Culvert Headwalls	745.0	9.4	4.7	2.5	4.7	Gray & Dark Gray Silty Clay

The subgrade soils at bearing grade should be evaluated per the guidelines provided in Section 8.9 of IDOT Geotechnical Manual (2020) for suitability/workability prior to placing any portion of the proposed culvert structures. According to Section 540, IDOT SSRBC (2016) a minimum of 6-inches of porous granular material should be provided as bedding material, which will serve as a working platform.

Headwalls should be designed based on the information provided in Section 4.1.5 of the IDOT Culvert Manual (IDOT 2017).

Settlement depends on the foundation size and bearing resistance, as well as the strength and compressibility characteristics of the underlying bearing soil. Assuming the foundation subgrades have been prepared as recommended and the service limit bearing resistances for different settlements are used, settlement of the culvert headwalls will be on the order of 1.0 to 2.0 inches.

4.3 Lateral Load Resistance

The lateral earth pressures for the headwalls should be designed per the guidance provided in Section 4 of the IDOT Culvert Manual (2017). Wall sections that are independent of the culvert should be designed using the Rankine active earth pressure coefficient, K_a. Headwalls that are fixed to the culvert to resist movement should be designed using an at-rest earth pressure coefficient. Lateral design parameters provided in **Table 5a** could be used in the design of the proposed IL Route 1 headwalls. Lateral design parameters for the IL Route 394 culvert are provided in **Table 5b**.

Table 5a – Lateral Load Resistance Soil Parameters for IL Route 1 Culverts

Depth / Elevation Range (feet)	Soil Description	Lateral Earth Pressure Coefficient			Lateral Modulus of Subgrade Reaction (pci)	Soil Strain (ε_{50})
		Active Earth Pressure Coefficient (K_a)	Passive Earth Pressure Coefficient (K_p)	At-Rest Earth Pressure Coefficient (K_o)		
	New Engineered Clay Fill	0.41	2.46	0.58	100	0.007
	New Engineered Granular Fill	0.33	3.00	0.50	25	N/A
1-7 (748.2-741.2)	Stiff to Very Stiff Gray and Dark Gray Silty Clay	0.41	2.46	0.58	1,000	0.005
7-10 (741.2-738.2)	Stiff to Hard Brown and Gray Silty Clay	0.36	2.77	0.53	1,000	0.005

Table 5b – Lateral Load Resistance Soil Parameters for IL Route 394 Culvert

Depth / Elevation Range (feet)	Soil Description	Lateral Earth Pressure Coefficient			Lateral Modulus of Subgrade Reaction (pci)	Soil Strain (ε_{50})
		Active Earth Pressure Coefficient (K_a)	Passive Earth Pressure Coefficient (K_p)	At-Rest Earth Pressure Coefficient (K_o)		
	New Engineered Clay Fill	0.41	2.46	0.58	100	0.007
	New Engineered Granular Fill	0.33	3.00	0.50	25	N/A
1-8.5 (704.2-696.7)	FILL Brown and Gray Silty Clay	0.62*	10.27*	0.56	1,000	0.005
8.5-11 (696.7-694.2)	Medium Stiff Gray Silty Clay	0.36	2.77	0.53	100	0.01
11-13.5 (694.2-691.7)	Very Stiff Gray Silty Clay	0.36	2.77	0.53	1,000	0.005
13.5-23.5 (691.7-681.7)	Hard Brown and Gray Silty Clay	0.36	2.77	0.53	2,000	0.004
23.5-48.5 (681.7-656.7)	Stiff to Hard Gray Silty Clay	0.36	2.77	0.53	1,000	0.005
48.5-50 (656.7-655.2)	Loose Gray Sand	0.35	2.88	0.52	20	N/A

* Based on Coulomb equation. Assuming 2.25H:1V slope (or 24 degrees) for sloping backfill and a wall friction of 17 degrees (2/3 of soil friction angle).

4.4 IL Route 394 Slope Evaluation

At Culvert 3 along IL Route 394 there is evidence of previous slope instability above the headwall of the culvert, however no evidence of failure was observed in the shoulder of the road above the culvert. Based on site photos provided by Quigg (**Appendix F**) and a preliminary review of site topography, a 1H:1V was assumed for the analysis of the steepest section of the existing slope parallel with the existing 36-inch RCP storm sewer. According to survey contours provided by Quigg (dated 05/18/21), the ground surface elevation near the toe of the slope at the existing 36-inch RCP storm sewer headwalls is approximately 684 feet.

4.4.1 Global Slope Stability Analysis – Existing Slope

Based on information provided by Quigg, slope stability analysis was performed to evaluate the existing slope above the IL Route 394 culvert. Slide 2018 is a comprehensive slope stability analysis software used to evaluate based on the limit equilibrium method. The existing slope was analyzed based on the assumed grading and the soils encountered while drilling. Circular failure analyses were evaluated using the simplified Bishops analyses methods. The analyses were performed using the soil parameters in **Table 2b**. Based on the existing geometry and the soils encountered, a global stability analysis was performed.

A circular failure analyses was evaluated for the long term (drained) condition based on the assumed existing slope geometry. The results of the analyses are shown in **Table 6**. A copy of the Slope Stability analyses exhibit is included in **Appendix E**.

Table 6 – IL Route 394 Culvert Existing Slope - Global Slope Stability Analyses Result

Analysis Exhibit	Description	Analysis Type	Factor of Safety	Minimum Factor of Safety
Exhibit 1	Existing Slope	Circular – Long Term	0.9	1.5

Based on the evaluation of the existing slope condition, it appear that surficial failures (Factor of Safety less than 1.0) are possible along the assumed slope condition. Based on the initial slope stability analysis, stabilization of the slope is necessary to prevent further failures above the culvert and to prevent any impacts to the roadway above.

4.4.2 Site Improvements – Proposed Sheet Pile Wall

Based on preliminary information provided by Quigg, a sheet pile or solider pile wall is being considered to mitigate the existing slope failure and prevent further movement above the culvert. Additionally, a temporary retaining wall will be required to install the drop manhole at Station 611+05.13. The walls shall be designed to withstand earth and live lateral earth pressures. The lateral earth pressures on retaining walls depend on the type of wall (i.e. restrained or unrestrained), the type of backfill and the method of placement against the wall, and the magnitude of surcharge weight on the ground surface adjacent to the wall. Sheet pile walls are considered flexible and such the earth loads may be calculated using active earth pressure for load above the design grade, and both active and passive earth pressures below the design grade. The active earth pressure coefficient (Ka), and the passive earth pressure coefficient (Kp) are shown in **Table 5b**.

The design should include a structural evaluation of the sheet pile section to meet applied shear and moment, and an evaluation of overturning to determine embedment depth and other design requirements. The simplified earth pressure distributions shown in the AASHTO Standard Specifications for Highway Bridges could be used for the wall design. **Table 5b** also provides recommended lateral soil modulus and soil strain parameters that can be used for laterally loaded pile analysis via the p-y curve method based on the encountered subsurface conditions. The passive resistance in front of the wall should be ignored for the upper 3.5 feet due to excavation activities and frost-heave condition.

Based on the anticipated location of the wall within the slope, surcharge loads should be included in the retaining wall design. Heavy equipment should not be allowed closer than five (5) feet to the retaining wall to prevent inducing high lateral earth pressures and causing wall yielding and/or other damage. Care should be taken to not damage the existing 36-inch RCP storm sewer when installing the retaining system.

4.4.3 Global Slope Stability Analysis – Sheet Pile Wall

The parameters in **Tables 7a and 7b** were used to evaluate the proposed walls for the slope failure mitigation and installation of the proposed drop manhole.

Table 7a – Sheet Pile Wall Description for Slope Failure Mitigation
* Based on preliminary information provided by Quigg

Maximum total exposed height of the retaining wall (H)	15.0 feet
Embedment length of pile within the slope	15.0 feet
Minimum pile tip elevation(s)	675.5 feet
Unit weight of the retained soil	125 pcf

Table 7b – Sheet Pile Wall Description for Installation of Drop Manhole at Sta. 611+05.13
* Based on preliminary information provided by Quigg

Maximum total exposed height of the retaining wall (H)*	18.0 feet
Embedment length of pile within the slope to reach F.S. of 1.5*	2.0 feet
Minimum pile tip elevation(s) to reach F.S of 1.5	680.5 feet

*Additional embedment depth may be required for the lateral pressures and structural design of the wall system

The actual height of the wall should be based on structural analysis performed by a Licensed Structural Engineer in the State of Illinois.

A circular failure analyses was evaluated for the long term (drained) condition for the proposed slope failure mitigation wall location. Circular failure analyses were evaluated for the short term (undrained) and long term (drained) condition for the proposed drop manhole wall location. The results of the analyses are shown in **Table 8**.

Table 8 – IL Route 394 Culvert Sheet Pile Walls - Global Slope Stability Analyses Result

<table>
<tr><th>Analysis Exhibit</th><th>Description</th><th>Analysis Type</th><th>Factor of Safety</th><th>Minimum Factor of Safety</th></tr>
<tr><td>Exhibit 2</td><td>Proposed Sheet Pile Wall for Slope Failure Mitigation</td><td>Circular – Long Term</td><td>2.3</td><td>1.5</td></tr>
<tr><td>Exhibit 3</td><td rowspan="2">Proposed Sheet Pile Wall for Drop Manhole</td><td>Circular – Short Term</td><td>5.3</td><td>1.5</td></tr>
<tr><td>Exhibit 4</td><td>Circular – Long Term</td><td>1.9</td><td>1.5</td></tr>
</table>

Based on the analyses performed, the proposed retaining walls meet the minimum factor of safety of 1.5. A copy of the Slope Stability analyses exhibit are included in **Appendix E**.

4.4.4 Wall and Embankment Settlement

The proposed wall will be installed within the existing slope and may require new fill materials to regrade the slope above the wall to the shoulder of the roadway. If new fill is required along the slope, settlement for both the proposed walls and embankments behind the walls should also be considered. According to AASHTO Section 3.11.8-Downdrag, the sheet piling should be designed to resist downdrag if the anticipated ground settlement is 0.4 inches or greater. GSG should be contacted when final design plans become available to evaluate settlement potential.

4.5 Drainage Recommendations

The retaining walls should be designed to prevent the buildup of hydrostatic forces. This can be done with the construction of a base drain and back drain to collect and remove surface water away from the face of the retaining wall. Geocomposite Wall Drain or open grade stone with a geotextile fabric system should be placed over the entire length of the back face of the wall. If a drain cannot be installed behind the wall, hydrostatic pressures should be accounted for with the lateral design of the sheet pile.

4.6 Tie-Backs/Anchors

Soldier pile/lagging and sheet pile walls over 15 feet in height typically require additional lateral resistance to maintain stability and/or limit wall movements. This lateral resistance can be provided using ground anchors, buried deadmen or soil nails. For highway applications, anchored sheet pile walls are typically less than 33 feet in height due to excessive top of wall deflections, excessive sheet pile bending stresses, and high stresses at the wall-anchor connection. Anchor terminology, minimum anchor length and embedment guidelines are shown in AASHTO Figure 11.9.1-1. Anchor spacing is controlled by many factors including anchor (or deadmen) capacity, temporary (unsupported) cut slope stability, subsurface obstructions in the anchorage zone, and the structural capacity of lagging or facing elements. Performance or proof testing shall be performed on every production anchor in accordance with the requirements in AASHTO Section 11.9.8.1. Excavation shall not proceed more than 3.0 feet below the level of ground anchors until the ground anchors have been accepted by the Engineer. Where backfill is placed behind an anchored wall, either above or around the unbonded length, special designs and construction specifications shall be provided to prevent anchor damage

5.0 CONSTRUCTION CONSIDERATIONS

All work performed for the proposed project should conform to the requirements in the IDOT Standard Specifications for Road and Bridge Construction (SSRBC) (2016) and the IDOT Subgrade Stability Manual (2005). Any deviation from the requirements in the manuals above should be approved by the design engineer.

5.1 Site Preparation

Any topsoil encountered during construction should be stripped and stockpiled as per Section 211.03 of the IDOT Standard Specifications for Road and Bridge Construction (SSRBC). The topsoil should be separated from other materials being stockpiled onsite for reuse or haul off. Stripping of all trees, brush, vegetation and any topsoil will be necessary at the proposed improvements. Although not encountered in the boring logs, it is anticipated that topsoil stripping depths could be on the order of about 12 inches.

5.2 Scour Considerations

For the proposed IL Route 1 improvements, the design scour elevations should be taken as the bottom of the headwalls. To help prevent local erosion, it is recommended to place stone riprap at the end of the culverts. This will help prevent sediments from entering and accumulating in the culvert, reduce long term maintenance, and provide protection to the streambed at the interface.

5.3 Site Excavation

Site excavations are expected to encounter various types of soils as described in the Subsurface Exploration section of this report. The contractor will be responsible to provide a safe excavation during the construction activities of the project. All excavations should be conducted in accordance with applicable federal, state, and local safety regulations, including, but not limited to the Occupational Safety and Health Administration (OSHA) excavation safety standards. In accordance with OSHA Regulation 29 CFR 1926 Subpart P Appendix B, the maximum allowable slopes for excavations less than 20 feet should be completed per the OSHA Excavation Slopes shown in **Table 9**. Excavations made in layered soil systems shall use the maximum allowable slope for each layer as prescribed in the OSHA Regulation. Excavations greater than 20 feet deep should be designed by a registered professional engineer; any shoring or bracing systems should be designed by a licensed structural engineer.

Table 9 – OSHA Excavation Slopes

Soil or Rock Type	Maximum Allowable Slope (H:V) for less than 20 feet
Stable Rock	Vertical (90°)
Type A	¾:1 (53 °)
Type B	1:1 (45 °)
Type C	1 ½:1 (34 °)

Excavation stability and soil pressures on temporary shoring are dependent on soil conditions, depth of excavations, installation procedures, and the magnitude of any surcharge loads on the ground surface adjacent to the excavation. Surcharge loads from the excavated materials, construction equipment, and vehicles should be included in the design of the excavation system. Excavation near existing structures and underground utilities should be performed with extreme care to avoid undermining existing structures.

If water seepage occurs during excavation or where wet conditions are encountered such that the water cannot be removed with conventional sumping, GSG recommends placing open grade stone similar to IDOT CA-7 to stabilize the bottom of the excavation below the water table. The CA-7 stone should be placed to 12 inches above the water table, in 12-inch lifts, and should be compacted with the use of a heavy smooth drum roller or heavy vibratory plate compactor until stable. The remaining portion of the excavation beneath the footings should be backfilled using approved structural fill consisting of granular materials such as IDOT CA-6.

5.4 Borrow Material and Compaction Requirements

If borrow material is to be used for onsite construction, it should conform to Section 204 “Borrow and Furnish Excavations” of the IDOT SSRBC (2016). The fill material should be free of organic matter and debris and should be placed and compacted in accordance with Section 205, Embankment, of the IDOT Construction Manual. Earth-moving operations should be avoided during excessively cold or wet weather to avoid freezing of softening subgrade soils. All backfill materials around the culvert must be pre-approved by the site engineer. Backfill materials for undercut areas beneath the culvert should be placed in 8 inches loose lifts and should be compacted to 95% of the maximum dry density as determined by AASTHO T-180, Modified Proctor Method.

5.5 Groundwater Management

It is anticipated that the long-term groundwater level for the IL Route 1 culverts is greater than 10 feet below grade. For the IL Route 394 culvert, the long-term groundwater is anticipated to be 23.5 feet below grade (approx. elevation 682 feet). GSG does not anticipate significant groundwater related issues during construction, however excavations along the Route 394 Culvert may be impacted by the creek level at time of construction. If rainwater run-off or groundwater is accumulated at the base of excavations, the contractor should remove accumulated water using conventional sump pit and pump procedures and maintain a dry and stable excavation. The location of the sump should be determined by the contractor based on field conditions. During earthmoving activities at the site, grading should be performed to ensure that drainage is maintained throughout the construction period. Water should not be allowed to accumulate in the foundation area either during or after construction. Undercut and excavated areas should be sloped toward one corner to facilitate removal of any collected rainwater or surface run-off. Grades should be sloped away from the excavations to minimize runoff from entering.

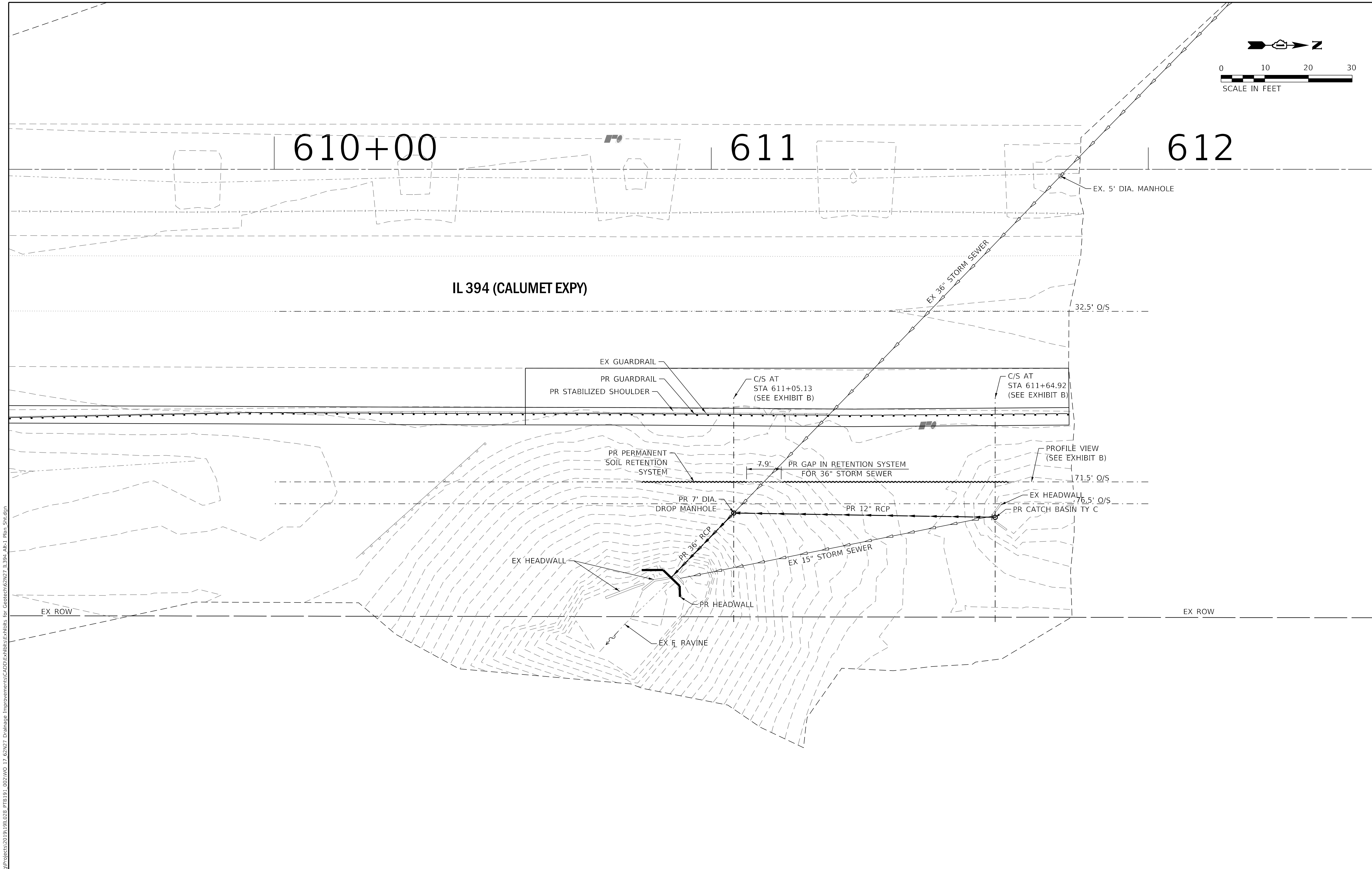
If water seepage occurs during the excavations where wet conditions are encountered such that the water cannot be removed with conventional sumping, we recommend placing open grade stone similar to IDOT CA-7 to stabilize the bottom of the excavation below the water table. The CA-7 stone should be placed to 12 inches above the water table, in 12-inch lifts, and should be compacted with the use of a heavy smooth drum roller or heavy vibratory plate compactor until stable. The remaining portion of the excavation beneath the footings should be backfilled using approved structural fill.

6.0 LIMITATIONS

This report has been prepared for the exclusive use of the Illinois Department of Transportation and its consultant team. The recommendations provided in the report are specific to the project described herein and are based on the information obtained from the soil boring locations within the proposed project limits. The analyses have been performed and the recommendations have been provided in this report are based on subsurface conditions determined at the location of the borings. This report may not reflect all variations that may occur between boring locations or at some other time, the nature and extent of which may not become evident until during the time of construction. If variations in subsurface conditions become evident after submission of this report, it will be necessary to evaluate their nature and review the recommendations presented herein.

APPENDIX A

GENERAL PLANS, ELEVATIONS, AND DETAILS



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QEI QUIGG ENGINEERING INC	USER NAME = wmohammed	DESIGNED -	REVISED -	STATE OF ILLINOIS DEPARTMENT OF TRANSPORTATION	EXHIBIT A – PLAN VIEW IL 394 SLOPE STABILIZATION
		DRAWN -	REVISED -		
	PLOT SCALE = 20.0000 ' / in.	CHECKED -	REVISED -		
	PLOT DATE = 5/18/2021	DATE -	REVISED -		SCALE: SHEET OF SHEETS STA. TO STA.

F.A. RTE.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.
			2	1
		CONTRACT NO. 62N27		
	ILLINOIS	FED. AID PROJECT		

ORIGINAL SURVEY		BY	DATE
	SURVEYED		
	PLOTTED		
NOTE BOOK	TEMPLATE		
	AREAS		
NO.	AREAS CHECKED		

FINAL SURVEY		BY	DATE
	SURVEYED		
	PLOTTED		
NOTE BOOK	TEMPLATE		
	AREAS		
NO.	AREAS CHECKED		

MODEL: Default
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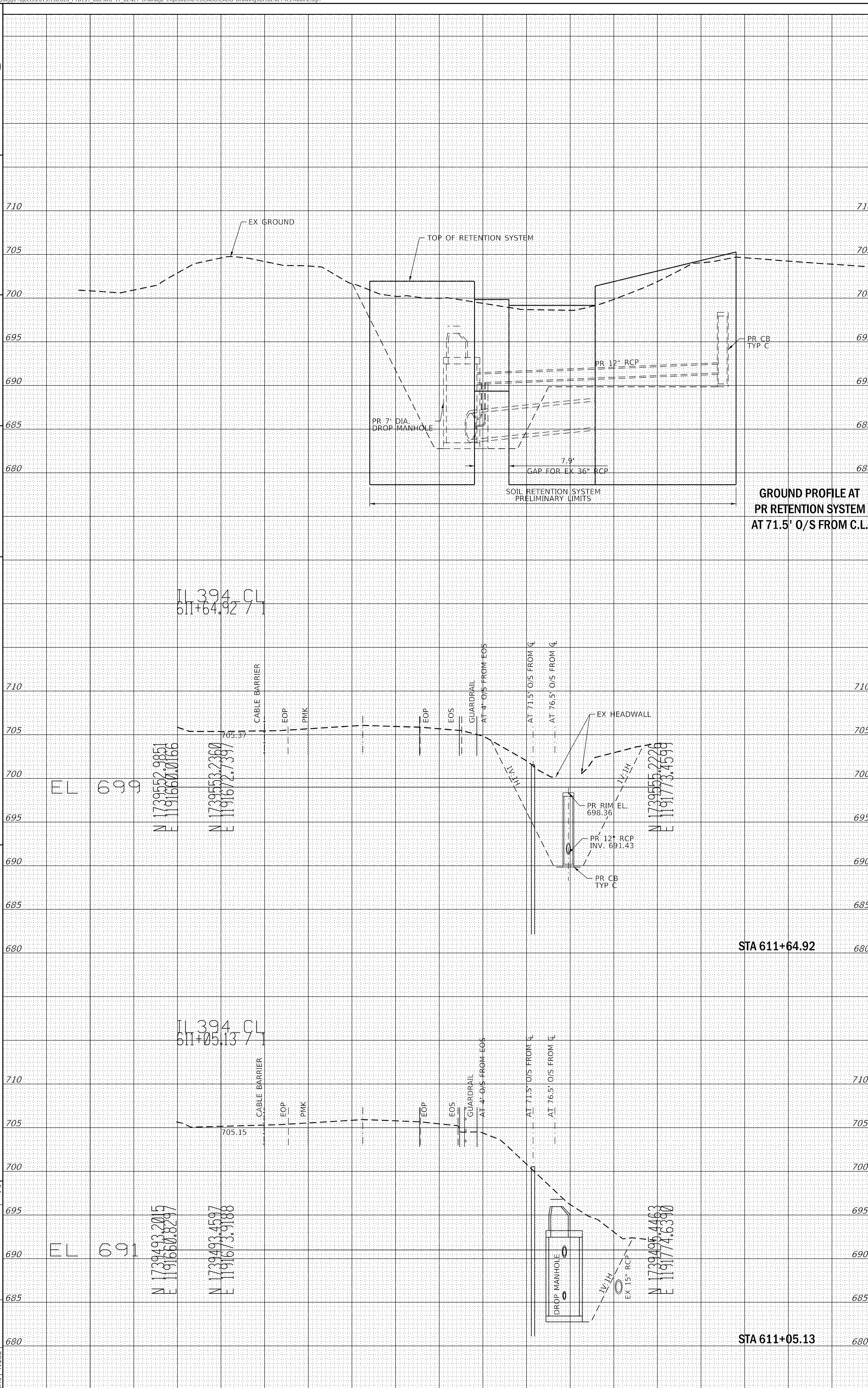


QUIGG ENGINEERING INC

USER NAME = wmohammed
PLOT SCALE = 20.0000 ' / in.
PLOT DATE = 5/18/2021

DESIGNED	-	REVISED	-
DRAWN	-	REVISED	-
CHECKED	-	REVISED	-
DATE	-	REVISED	-

STATE OF ILLINOIS
DEPARTMENT OF TRANSPORTATION

EXHIBIT B – CROSS SECTIONS
IL 394 SLOPE STABILIZATION

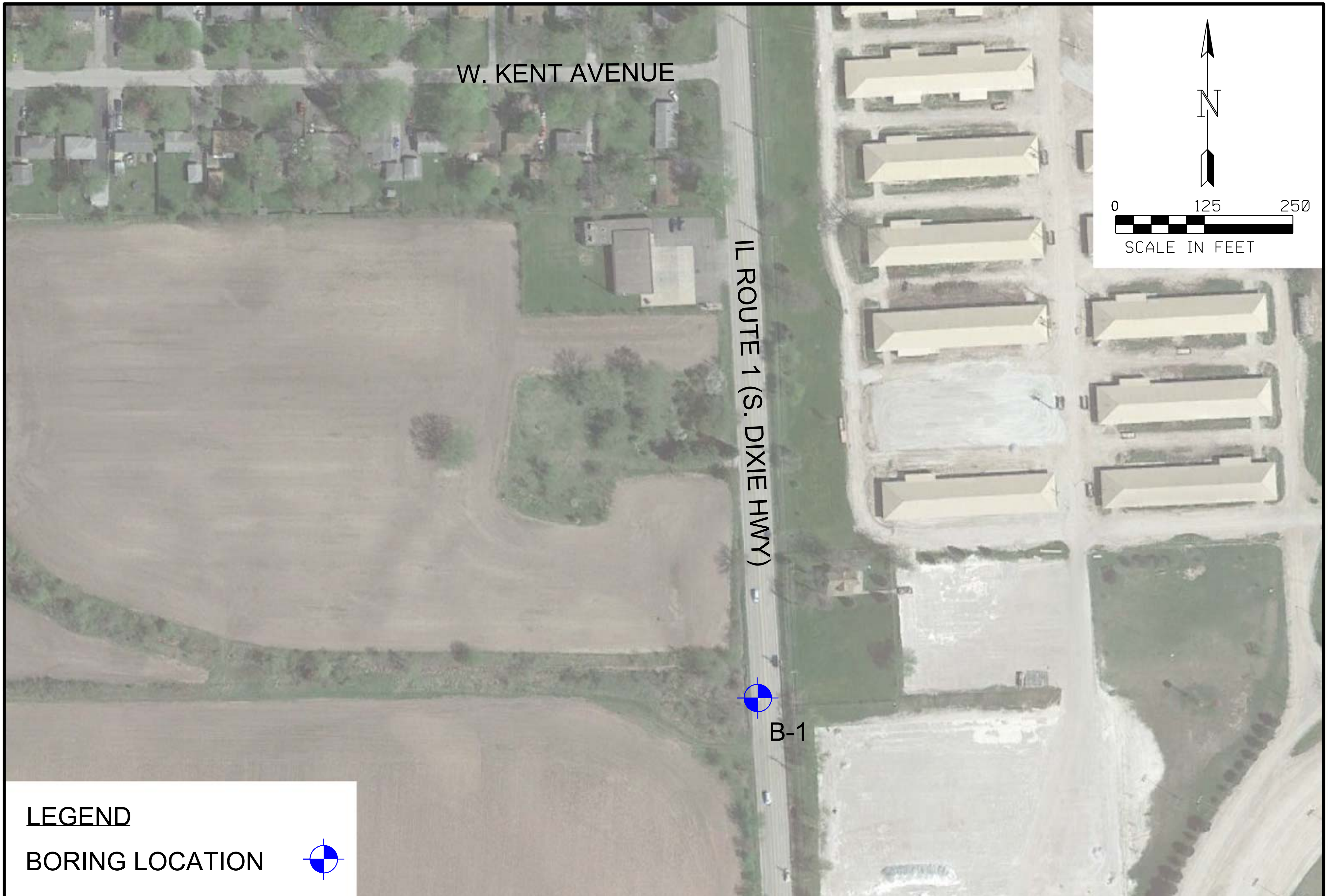
SCALE: SHEET OF SHEETS STA. TO STA.

F.A. RTE.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.
			2	2

ILLINOIS FED. AID PROJECT
CONTRACT NO. 62N27

APPENDIX B

BORING LOCATION PLAN



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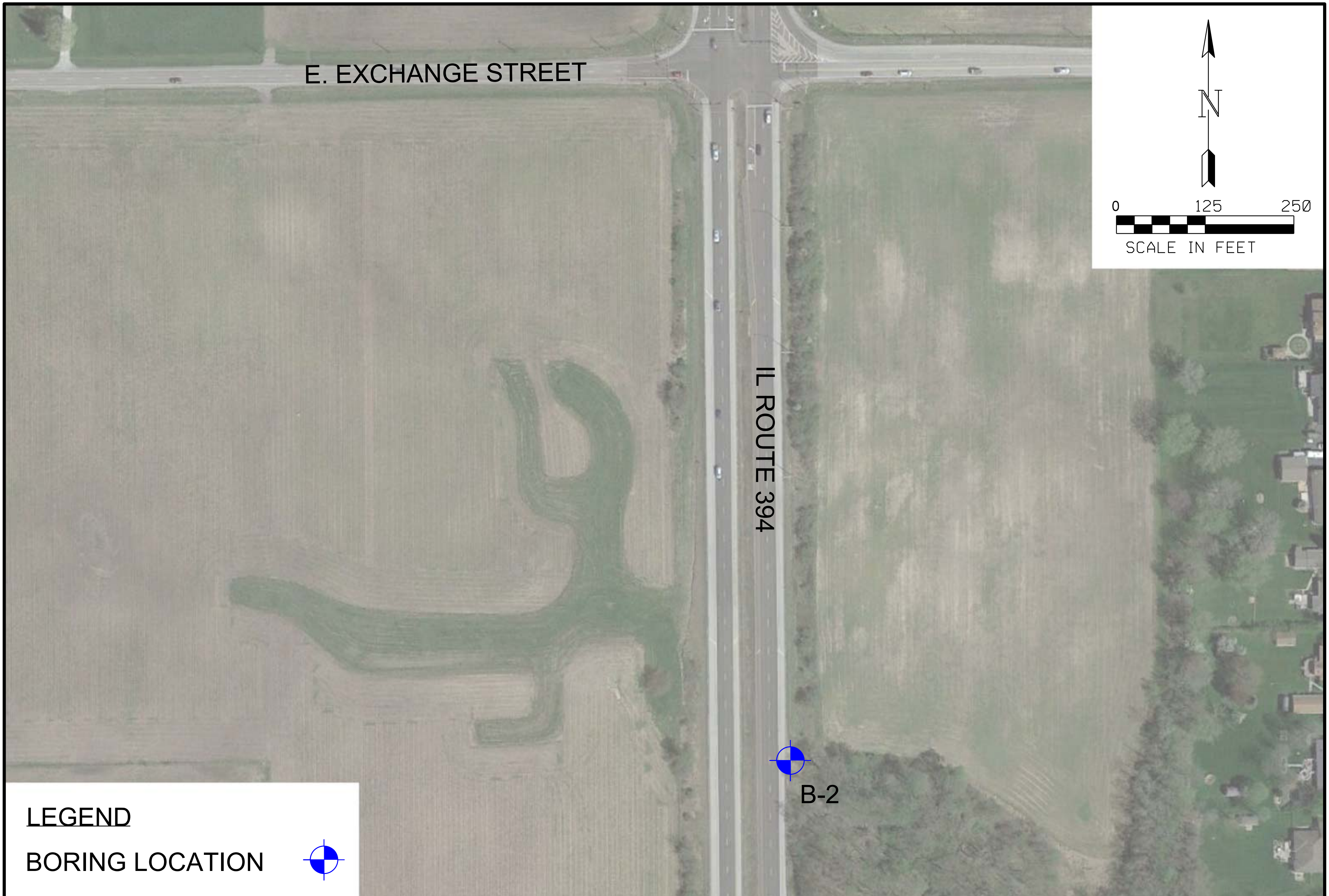
BORING LOCATION PLAN
IL ROUTE 1 CULVERT REPAIR
WILL COUNTY, IL

DRAWN BY:	TK	DATE:	02/05/2021
CHECKED BY:	DE	SCALE:	AS NOTED



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BORING LOCATION PLAN
IL ROUTE 394 CULVERT REPAIR
WILL COUNTY, IL

DRAWN BY:	TK	DATE:	02/05/2021
CHECKED BY:	DE	SCALE:	AS NOTED

APPENDIX C

SOIL BORING LOGS

Illinois Department of Transportation
Division of Highways
GSG Consultants, Inc.

SOIL BORING LOG

Date 1/28/21

ROUTE IL Route 1 **DESCRIPTION** IDOT PTB 191-002 Culvert Repair **LOGGED BY** MH

SECTION **LOCATION** 875 ft. South of W. Kent Ave., **SEC.** , **TWP.** , **RNG.** ,
Latitude 41.440241, **Longitude** -87.5766042

COUNTY WILL **DRILLING METHOD** HSA **HAMMER TYPE** AUTO

STRUCT. NO. Culvert 1 & 2
Station

BORING NO. B-1
Station
Offset
Ground Surface Elev. 748.20 ft

Surface Water Elev. N/A ft
Stream Bed Elev. N/A ft

Groundwater Elev.:
First Encounter None ft
Upon Completion N/A ft
After N/A **Hrs.** N/A ft

Description	Elev.	DEPTH (ft)	BLOWS (/6")	UCS Qu (tsf)	MOIST (%)
4 inches of Asphalt 5 inches of Concrete	747.45				
Stiff to Very Stiff Dark Gray and Gray, Moist to Very Moist SILTY CLAY, with sand, trace gravel (CL)			3 3 5	2.3 B	18
		-5	2 3 4	1.9 B	20
	741.20		2 2 4	1.3 B	28
Stiff to Hard Brown and Gray, Moist SILTY CLAY, trace sand (CL/ML)	738.20	-10	5 7 11	5.0 B	16
End of Boring		-15			
		-20			

The Unconfined Compressive Strength (UCS) Failure Mode is indicated by (B-Bulge, S-Shear, P-Penetrometer)
The SPT (N value) is the sum of the last two blow values in each sampling zone (AASHTO T206)

Illinois Department of Transportation
Division of Highways
GSG Consultants, Inc.

SOIL BORING LOG

Date 1/28/21

ROUTE IL Route 394 **DESCRIPTION** IDOT PTB 191-002 Culvert Repair **LOGGED BY** MH

SECTION **LOCATION** 1050 ft. South of Exchange St., **SEC.** , **TWP.** , **RNG.** ,
Latitude 41.4151118, **Longitude** -87.6295344

COUNTY WILL **DRILLING METHOD** HSA **HAMMER TYPE** AUTO

STRUCT. NO. Culvert 3
Station

BORING NO. B-2
Station
Offset
Ground Surface Elev. 705.22 ft

Surface Water Elev. N/A ft
Stream Bed Elev. N/A ft

Groundwater Elev.:
First Encounter 666.7 ft ▼
Upon Completion N/A ft
After N/A **Hrs.** N/A ft

Description	DEPTH (ft)	BLOWS (/6")	UCS Qu (tsf)	MOIST (%)
Brown and Gray, Wet FILL: SAND, with gravel — 704.22				
Brown and Gray, Moist FILL: SILTY CLAY, trace sand		5 6 6	2.5 P	20
	-5	2 3 3	2.5 P	22
— 696.72		2 3 3	1.5 B	21
Medium Stiff Gray, Moist SILTY CLAY, trace sand (CL) — 694.22	-10	1 2 1	0.6 B	23
Very Stiff Gray, Moist SILTY CLAY, trace sand (CL/ML) — 691.72		1 2 4	2.3 B	23
Hard Brown and Gray, Moist SILTY CLAY (CL/ML)	-15	5 6 10	4.6 B	19
		5 6 10	5.4 B	18
	-20	4 7 11	5.0 B	20

Description	DEPTH (ft)	BLOWS (/6")	UCS Qu (tsf)	MOIST (%)
Hard Brown and Gray, Moist SILTY CLAY (CL/ML) *(continued)*		5 6 11	4.6 B	20
— 681.72 Stiff to Hard Gray, Moist SILTY CLAY, trace sand and gravel (CL/ML)	-25	3 5 7	4.6 B	19
		3 5 7	2.1 B	20
	-30	2 3 5	2.1 B	20
	-35	2 3 4	1.7 B	21
Sand seam at 38.5 feet ▼	-40	5 6 8	4.6 B	14

The Unconfined Compressive Strength (UCS) Failure Mode is indicated by (B-Bulge, S-Shear, P-Penetrometer)
The SPT (N value) is the sum of the last two blow values in each sampling zone (AASHTO T206)

Illinois Department of Transportation
Division of Highways
GSG Consultants, Inc.

SOIL BORING LOG

Date 1/28/21

ROUTE IL Route 394 **DESCRIPTION** IDOT PTB 191-002 Culvert Repair **LOGGED BY** MH

SECTION **LOCATION** 1050 ft. South of Exchange St., **SEC.** , **TWP.** , **RNG.** ,
Latitude 41.4151118, **Longitude** -87.6295344

COUNTY WILL **DRILLING METHOD** HSA **HAMMER TYPE** AUTO

STRUCT. NO. Culvert 3
Station

BORING NO. B-2
Station
Offset
Ground Surface Elev. 705.22 ft

Surface Water Elev. N/A ft
Stream Bed Elev. N/A ft

Groundwater Elev.:
First Encounter 666.7 ft ▼
Upon Completion N/A ft
After N/A **Hrs.** N/A ft

Description	Elev.	DEPTH (ft)	BLOWS (/6")	UCS Qu (tsf)	MOIST (%)
Stiff to Hard Gray, Moist SILTY CLAY, trace sand and gravel (CL/ML) *(continued)*			3		
			7	5.2	17
		-45	12	B	
	656.72				
Loose Gray, Wet SAND, trace gravel (CL/ML)			4		
			1		22
	655.22	-50	5		
End of Boring					
		-55			
		-60			

The Unconfined Compressive Strength (UCS) Failure Mode is indicated by (B-Bulge, S-Shear, P-Penetrometer)
The SPT (N value) is the sum of the last two blow values in each sampling zone (AASHTO T206)

BBS, form 137 (Rev. 8-99)

APPENDIX D

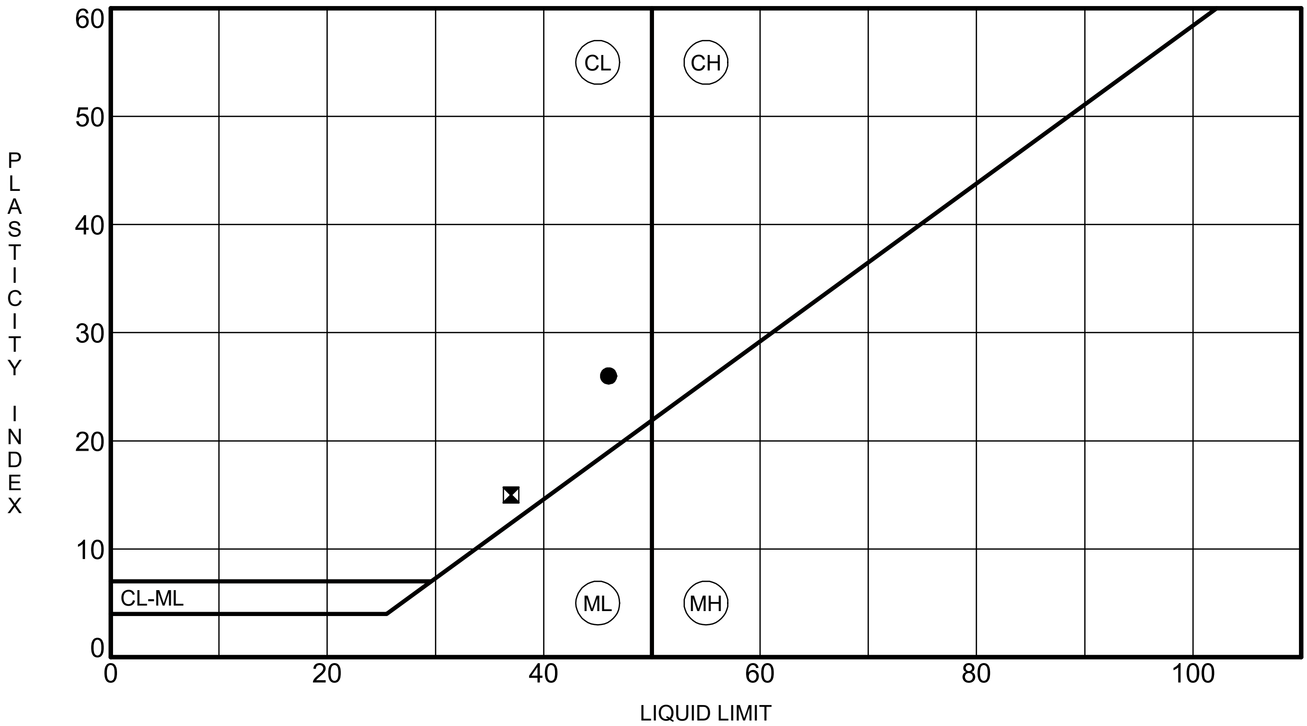
LABORATORY TEST RESULTS

Table C1 – Test Results – Atterberg Limits

Boring ID	Sample Depth (ft)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Soil Classification
B-1	3.5-5	46.0	20.0	26.0	CL/ML
B-2	8.5-10	37.0	22.0	15.0	CL/ML

Table C2 – Test Results – Dry Unit Weight

Boring ID	Sample Depth (ft)	Dry Unit Weight (pcf)	Wet Unit Weight (pcf)	Soil Classification
B-1	3.5-5	99.7	124.6	CL/ML
B-1	6-7.5	95.6	122.6	CL/ML
B-2	8.5-10	103.0	126.9	CL/ML



	Specimen Identification		LL	PL	PI	Fines	Classification
●	**B-1**	**3.50**	**46.0**	**20.0**	**26.0**		
⊠	**B-2**	**8.50**	**37.0**	**22.0**	**15.0**		

Illinois Department of Transportation

Division of Highways
GSG Consultants, Inc.

ATTERBERG LIMITS' RESULTS

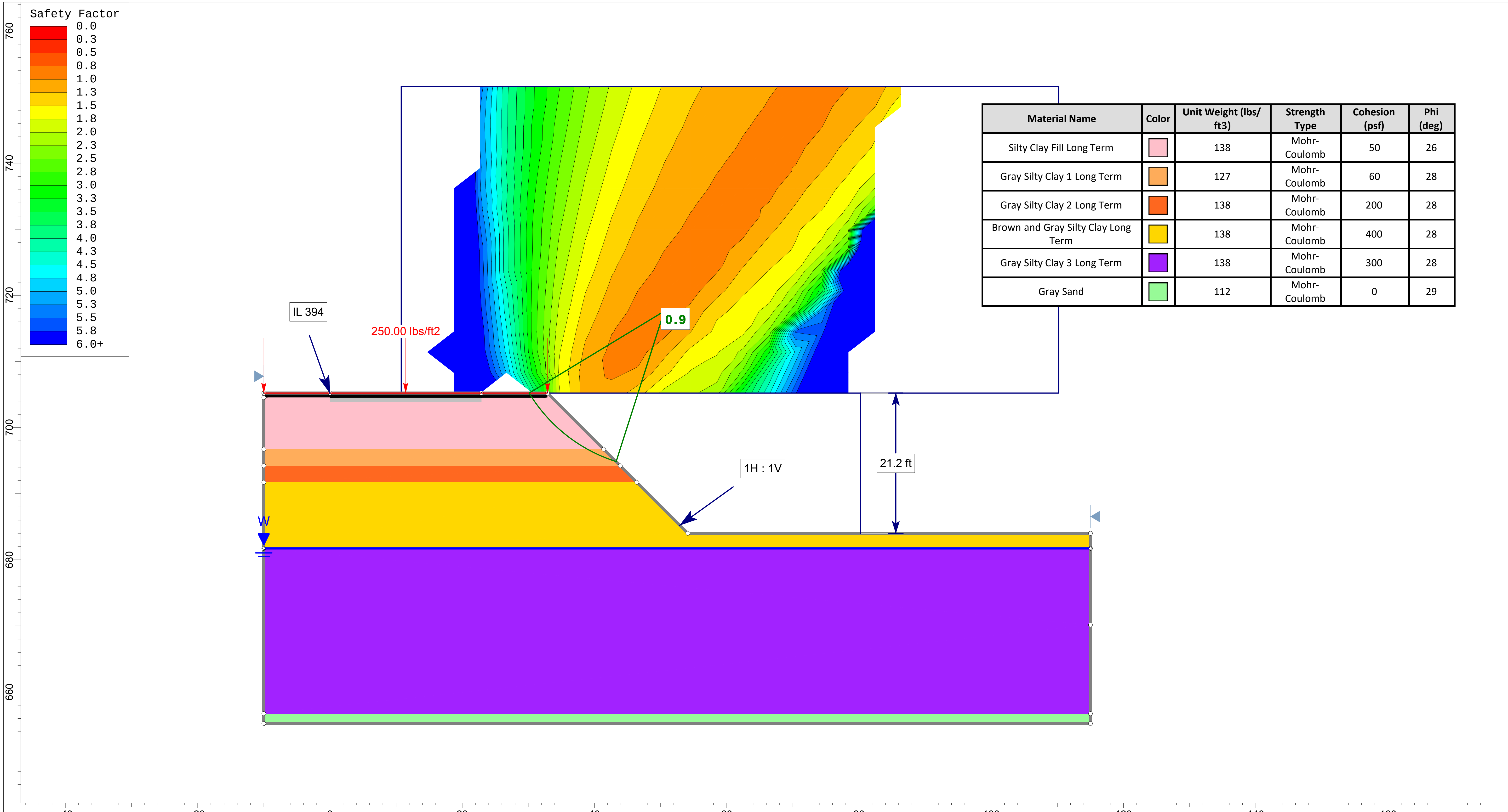
Route: IL 1 and IL 394

Section:

County: WILL

APPENDIX E

SLOPE STABILITY ANALYSES EXHIBITS



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Silty Clay Fill Long Term		138	Mohr-Coulomb	50	26
Gray Silty Clay 1 Long Term		127	Mohr-Coulomb	60	28
Gray Silty Clay 2 Long Term		138	Mohr-Coulomb	200	28
Brown and Gray Silty Clay Long Term		138	Mohr-Coulomb	400	28
Gray Silty Clay 3 Long Term		138	Mohr-Coulomb	300	28
Gray Sand		112	Mohr-Coulomb	0	29

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Project: PTB 191-002 WO 17: IL Route 394

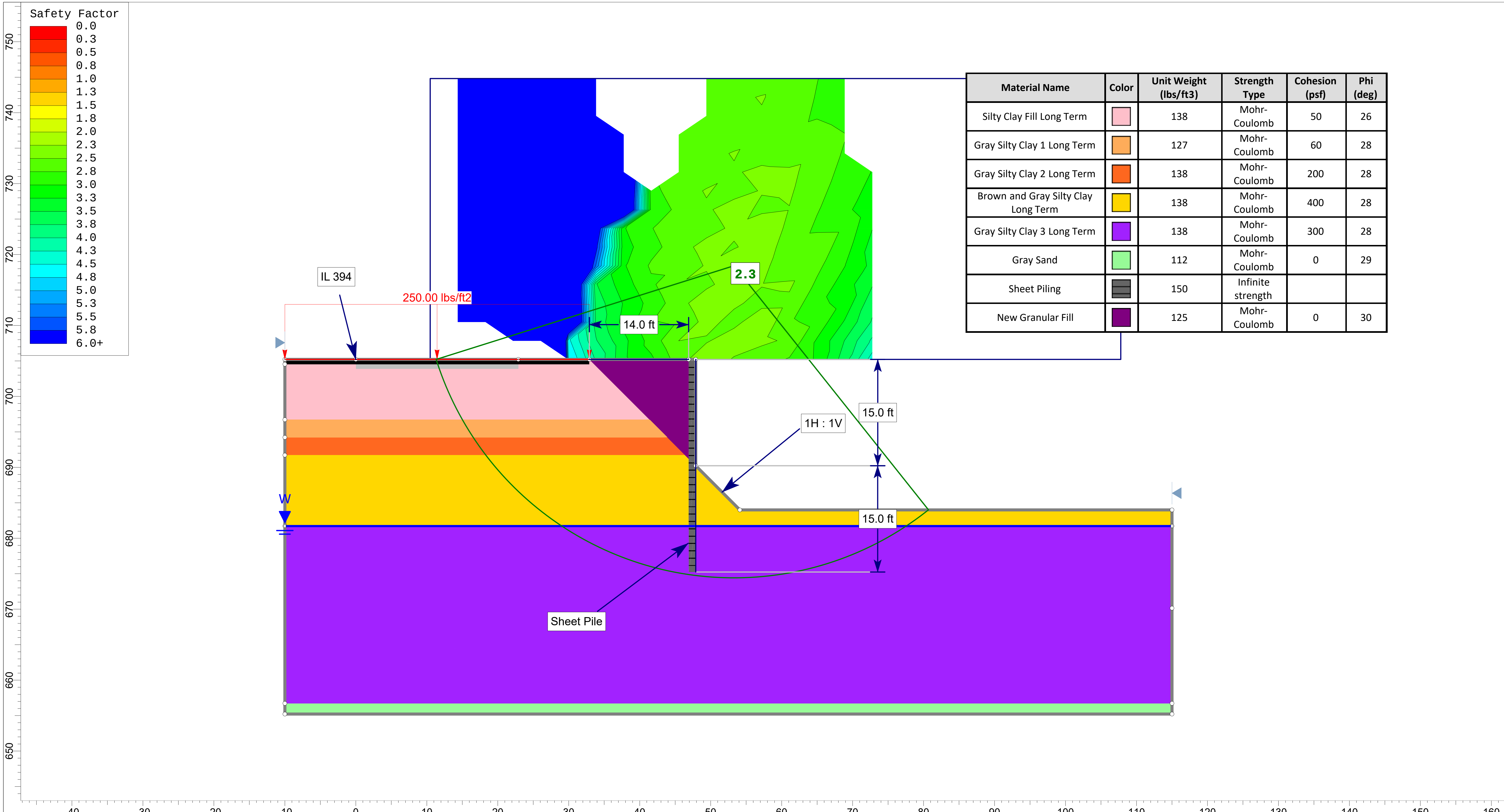
Analysis Description: Exhibit 1 - Existing Slope Circular Failure Long Term

Drawn By: TEK

Company: GSG Consultants, Inc.

Date: 5/24/2021 5:16:07 PM

File Name: IL 394 existing slope - Copy.slmd



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Silty Clay Fill Long Term		138	Mohr-Coulomb	50	26
Gray Silty Clay 1 Long Term		127	Mohr-Coulomb	60	28
Gray Silty Clay 2 Long Term		138	Mohr-Coulomb	200	28
Brown and Gray Silty Clay Long Term		138	Mohr-Coulomb	400	28
Gray Silty Clay 3 Long Term		138	Mohr-Coulomb	300	28
Gray Sand		112	Mohr-Coulomb	0	29
Sheet Piling		150	Infinite strength		
New Granular Fill		125	Mohr-Coulomb	0	30

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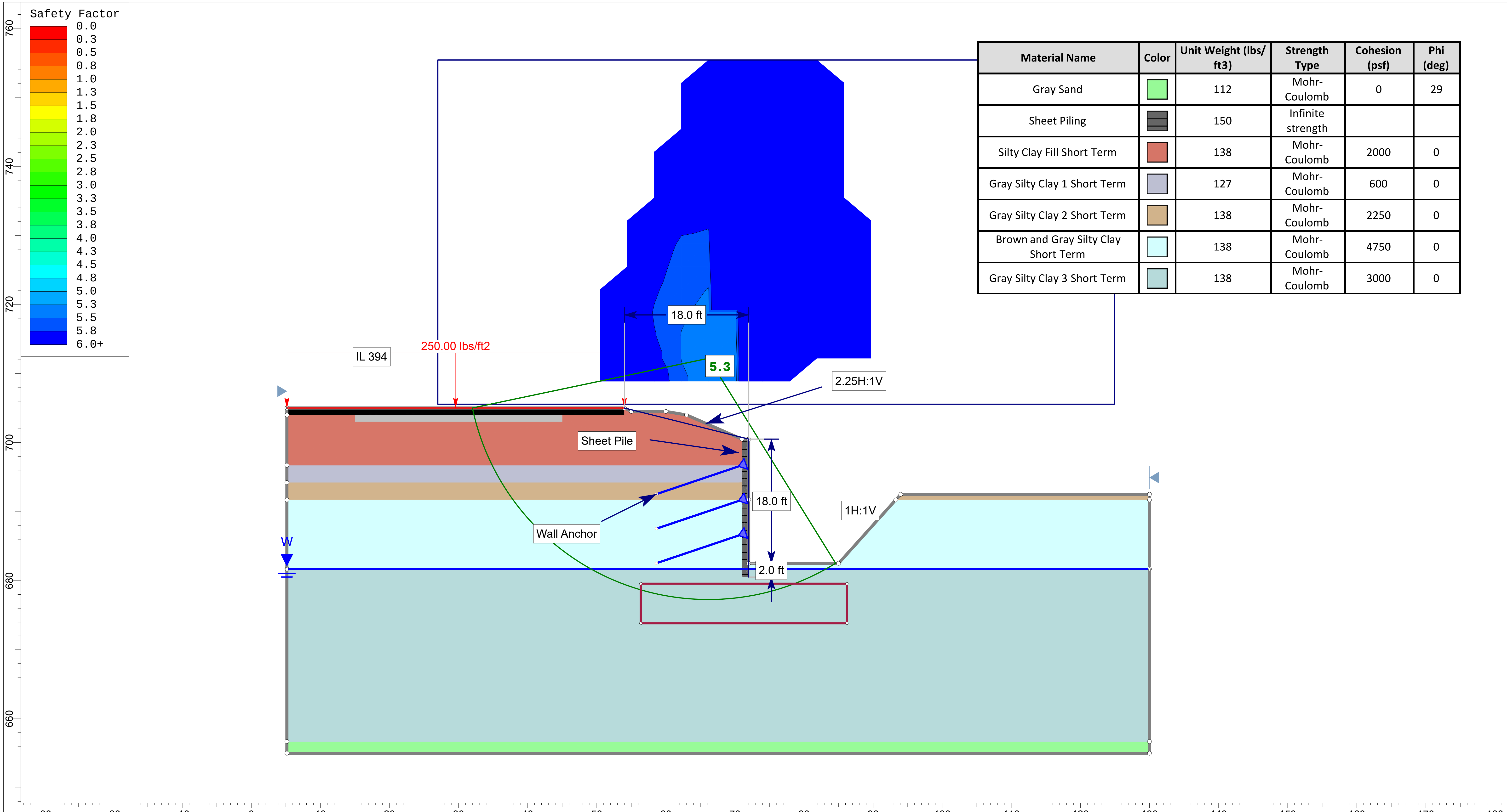
Project	PTB 191-002 WO 17: IL Route 394
Analysis Description	Exhibit 2 - Existing Slope Circular Failure with Sheet Pile Long Term
Drawn By	TEK
Company	GSG Consultants, Inc.
Date	5/24/2021 5:19:03 PM
File Name	IL 394 existing slope - Copy.slmd



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Gray Sand		112	Mohr-Coulomb	0	29
Sheet Piling		150	Infinite strength		
Silty Clay Fill Short Term		138	Mohr-Coulomb	2000	0
Gray Silty Clay 1 Short Term		127	Mohr-Coulomb	600	0
Gray Silty Clay 2 Short Term		138	Mohr-Coulomb	2250	0
Brown and Gray Silty Clay Short Term		138	Mohr-Coulomb	4750	0
Gray Silty Clay 3 Short Term		138	Mohr-Coulomb	3000	0

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Tel: 630.994.2600
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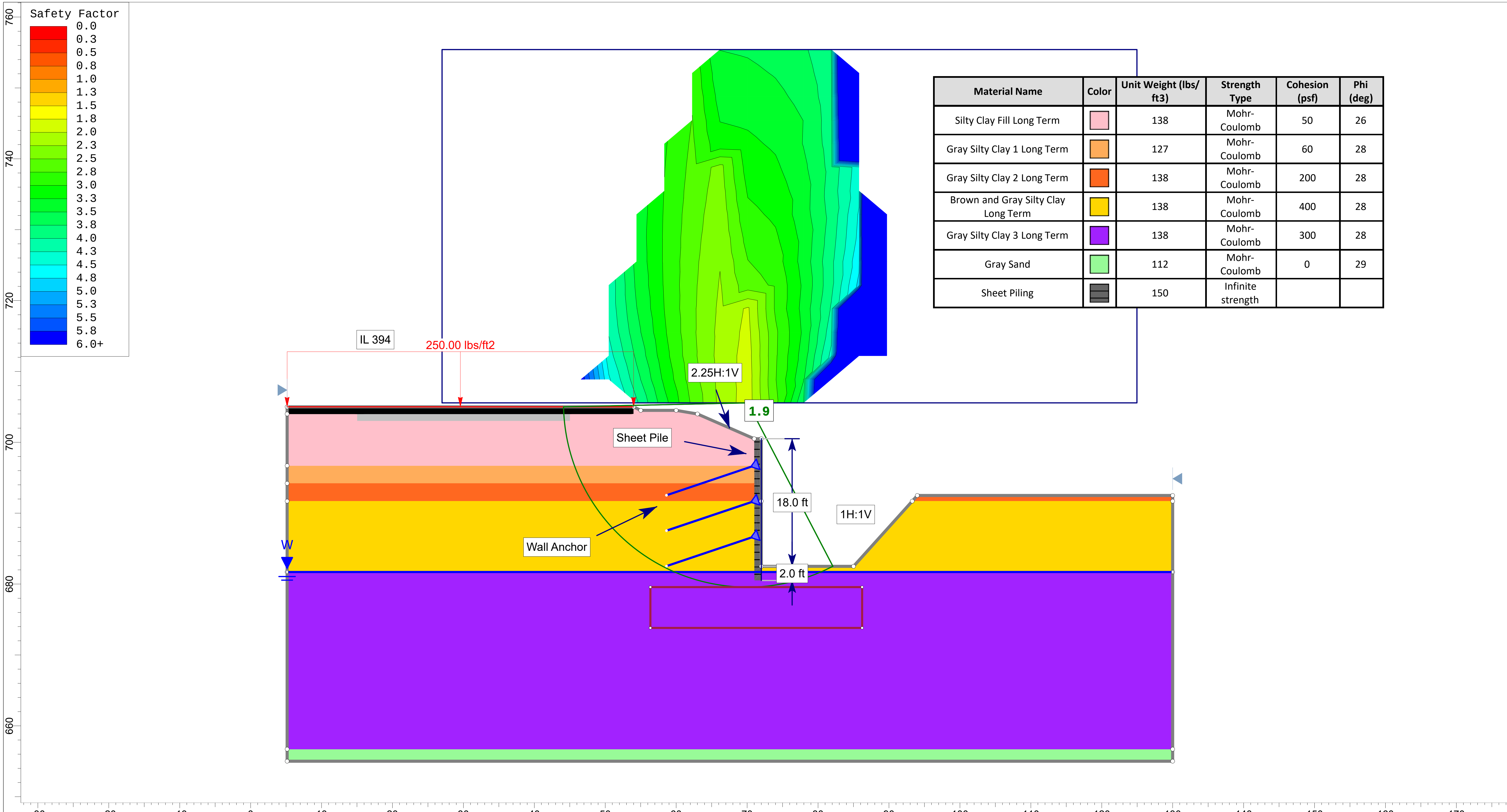
Project	PTB 191-002 WO 17: IL Route 394
Analysis Description	Exhibit 3 - Existing Slope Circular Failure with Sheet Pile Short Term
Drawn By	TEK
Company	GSG Consultants, Inc.
Date	5/24/2021 5:36:38 PM
File Name	IL 394 drop manhole.slmd



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Silty Clay Fill Long Term		138	Mohr-Coulomb	50	26
Gray Silty Clay 1 Long Term		127	Mohr-Coulomb	60	28
Gray Silty Clay 2 Long Term		138	Mohr-Coulomb	200	28
Brown and Gray Silty Clay Long Term		138	Mohr-Coulomb	400	28
Gray Silty Clay 3 Long Term		138	Mohr-Coulomb	300	28
Gray Sand		112	Mohr-Coulomb	0	29
Sheet Piling		150	Infinite strength		

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Project	PTB 191-002 WO 17: IL Route 394
Analysis Description	Exhibit 4 - Existing Slope Circular Failure with Sheet Pile Long Term
Drawn By	TEK
Company	GSG Consultants, Inc.
Date	5/24/2021 5:37:43 PM
File Name	IL 394 drop manhole.slmd

APPENDIX F

SITE PHOTO - IL ROUTE 394 SLOPE