STRUCTURE GEOTECHNICAL REPORT

US-45 over Stream

Existing S.N. 044-2007
Proposed S.N. 044-2013

F.A.P. RTE. 881 (US 45)
SECTION 35(B-3)
JOHNSON COUNTY, ILLINOIS
JOB NO. D-99-027-19
CONTRACT NO. 78718
PTB 193-032 WO#11
KEG NO. 19-1143.06

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February 9, 2023

Kaskaskia
Engineering Group, LLC

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EXHIBITS

1.0 Project Description and Scope

1.1 Introduction

The geotechnical study summarized in this report was performed by Kaskaskia Engineering Group, LLC (KEG) for the proposed double box culvert at US 45 over Stream, located in Johnson County, Illinois. The purpose of this report is to document subsurface geotechnical conditions, provide analyses of anticipated site conditions as they pertain to the project described herein, and present design and construction recommendations for the proposed structure.

1.2 Project Description

The project consists of the replacement of the existing double barrel reinforced concrete culvert (SN 044-2007) located at US 45 over Stream. The existing structure was built in 1922 and modified in 1937. Each barrel is 10’ by 7’-6”, with an out-to-out headwall length of 41’-4”, with a zero-degree skew, and L-type wingwalls.

The general location of the bridge is shown on the Location Map, Exhibit A. The project is located approximately 1.5 miles south of New Burnside Village. The site lies within the Shawnee Hills Section of the Interior Low Plateaus province.

1.3 Proposed Structure Information

The proposed structure (SN 044-2013) will consist of a double box culvert. The individual boxes will each measure 12’ (Span) x 6’ (Height). The structure will measure 25’-9” wide, and 60’ out-to-out headwalls. The culvert will provide two 12’ traffic lanes with 4’ paved outside shoulders. The centerline of the structure will be located at Station 1038+16 (F.A.P. RTE. 881). Further substructure details will be based on the findings of this SGR. A Type, Size, and Location Plan (TS&L) is included in Exhibit B.

2.0 Field Exploration

2.1 Subsurface Exploration and Testing

The site investigation plan was developed and completed by Illinois Department of Transportation (IDOT) District 9 geotechnical personnel. A representative of Kaskaskia Engineering Group, LLC (KEG) did not conduct a site visit or observe the drilling operations.

Two (2) standard penetration test (SPT) borings, designated 1-S and 2-S, were drilled on April 22, 2019. Table 2.1.1 shows the boring stationing, offsets and surface elevations. The boring locations are shown on the TS&L in Exhibit B. Detailed information regarding the nature and thickness of the soils encountered, and the results of the field sampling and laboratory testing, are shown on the Boring Logs, Exhibit C. The soil profile for the above-mentioned borings can be found in Subsurface Profile, Exhibit D.

Table 2.1.1 - Boring Stations and Offsets

Designation	Stationing	Offset (ft.)	Surface Elevation (ft.)
1-S	1038+34	9 RT	558.1
2-S	1037+94	11 LT	557.7

2.2 Subsurface Conditions

The profiles at the two (2) boring locations exhibited layers of clay, silty loam, and silty clay loam. The pavement structure for Boring 1-S consisted of 16” of concrete and for Boring 2-S, consisted of 7” of asphalt and 10” of concrete. Bedrock was encountered in both borings between 8.8 and 9.7 ft. below Ground Surface Elevation (GSE). The bedrock consisted of hard sandstone.

The N-value in the clay layer was 3 blows per foot (bpf), with a Rimac (Qu) strength value of 0.8 tons per square foot (tsf) and a moisture content of 25 percent. N-values in the silty loam layers ranged from 0 to 6 bpf, with field Rimac (Qu) strength values ranging from 0.3 to 0.8 tsf and moisture contents of 20 to 27 percent. The N-value in the silty clay loam layer was 7 bpf, with a field Rimac (Qu) strength value of 0.3 tsf and a moisture content of 18 percent. The blow counts of the Sandstone bedrock were consistent at 100 blows per 2-inches of penetration in each boring at refusal, respectively. No rock coring was performed on the bedrock.

2.3 Groundwater

Groundwater was not encountered in the borings during or after drilling to the depths explored. It should be noted that the groundwater level is subject to seasonal and climatic variations. In addition, without extended periods of observation, measurement of true groundwater levels may not be possible.

3.0 Geotechnical Evaluations

3.1 Settlement

Due to no anticipated significant grading or changes to the road, and the culvert bearing on competent sandstone, no settlement is anticipated. Therefore, no settlement calculations were performed for the proposed structure.

3.2 Slope Stability

The proposed structure will result in culvert wingwall side-slopes with inclinations of 1 Vertical to 2 Horizontal (1V:2H). Slope stability of the downstream and upstream side-slopes were analyzed using SLOPE-W, the soil properties of 1-S and 2-S, and the side-slope geometrics. Two conditions were modeled: end-of-construction and long-term. A critical factor of safety (FOS) was calculated for each condition. According to the current standard of practice, the target FOS is 1.5 for end-of-construction and long-term slope stability.

In order to model the end-of-construction condition, undrained soil parameters were used and assumed a friction angle of 0 degrees for cohesive soils. The long-term condition used drained soil parameters and assumed friction angles ranging from 26 to 45 degrees to analyze where excess pore water pressure from construction has dissipated. For cohesive materials, a nominal cohesion value between 50 and 100 psf was included in the drained strength parameters. The Modified Bishop Method, which generates circular-arc failure surfaces, was used to calculate the critical failure surfaces and FOS for the analyzed conditions. The FOS obtained in the analysis is shown in Table 3.2.1 Slope Stability Critical FOS. The program output from this analysis can be found in SLOPE-W Stability Analysis, Exhibit E.

Table 3.2.1 - Slope Stability Critical FOS

Location	Reference Boring	End-of-Construction (Undrained)	Long-Term (Drained)
Downstream Slope	1-S	17.5	16.6
Upstream Slope	2-S	20.8	20.0

The results of the analysis, as provided in Table 3.2.1, indicate an acceptable FOS will exist under undrained and drained conditions at all locations.

3.3 Seismic Considerations

Per the 2020 Geotechnical Manual, seismic parameters are not required for buried structures, including box culverts.

4.0 Foundation Evaluations and Design Recommendations

4.1 Bearing Resistance

According to the borings, the culvert will bear on top of sandstone. The assumed bearing elevation at the bottom of the culvert is El. 548+/- ft. The sandstone encountered in both borings at the approximate bearing elevation, was assumed to have a unit weight of 145 pcf, a cohesion of 10,000 psf and a friction angle of 45°. Using Buisman-Terzaghi equations for foundations on rock (Terzaghi 1943), the calculated allowable bearing resistance, using a Factor of Safety of 3, is estimated to be 172 ksf. See Exhibit F for calculations performed.

Table 4.1.1 – Factored Bearing Resistance

Substructure Unit	Factored Bearing Resistance (ksf)
Double Culvert Box	172

If after final design the bearing elevation changes, KEG should be informed to review that the above recommendations still apply.

5.0 Construction Considerations

5.1 Construction Activities

Construction activities should be performed in accordance with the current IDOT Standard Specifications for Road and Bridge Construction and any pertinent Special Provisions or Policies.

Should any design considerations assumed by KEG change, KEG should be contacted to determine if the recommendations stated in this report still apply.

5.2 Temporary Sheeting and Soil Retention

Temporary shoring may be required at various stages of this project, due to the proposed staged-construction layout shown in the TS&L. Temporary shoring methods are not feasible due to the depth to bedrock below the proposed structure.

Therefore, a Temporary Soil Retention System is required to support the structure during construction. An Illinois-licensed Structural Engineer is required to design and seal the design of the Temporary Soil Retention System, if deemed necessary.

5.3 Rock Excavation

An experienced geotechnical engineer, familiar with the site conditions, should observe excavations and the bearing surface for the bedrock, prior to placing concrete. Excessive disturbance in footing slab excavations should be avoided and could potentially complicate construction. The potential for such disturbance will increase during wetter times of the year.

The base of all excavations should be clean, relatively dry, and free of soft/loose soil, uncompacted fill, or fractured weathered rock. Excavations should be protected from extreme temperatures, precipitation, and construction disturbances. To reduce the possibility of desiccation or saturation of the foundation materials, KEG recommends the concrete be placed as soon as possible after excavations are made.

5.4 Site and Soil Conditions

Provisions of the Standard Specifications should adequately address site and soil conditions.

6.0 Computations

Computations and analyses for special circumstances, if any, are included as exhibits. Please refer to each section of the report for reference to the exhibit containing any such calculations or analysis used.

7.0 Geotechnical Data

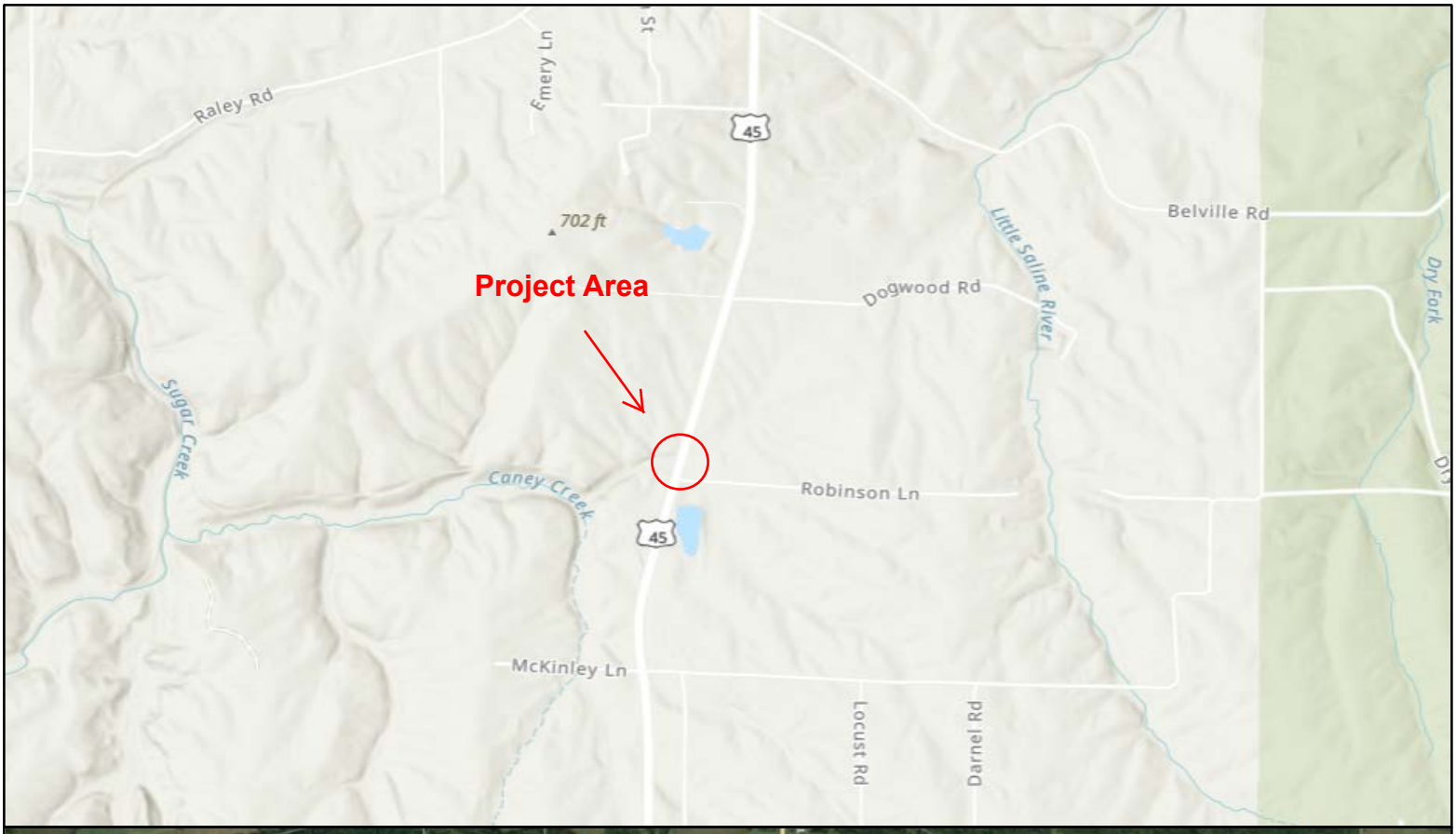
Soil boring logs can be found in Exhibit C. The Subsurface Profile can be found in Exhibit D.

8.0 Limitations

The recommendations provided herein are for the exclusive use of CM&T and the Illinois Department of Transportation (IDOT). They are specific only to the project described and are based on the subsurface information provided to KEG at two boring locations within the structure area, KEG's understanding of the project as described herein, and geotechnical engineering practice consistent with the standard of care. No other warranty is expressed or implied. KEG should be contacted if conditions encountered during construction are not consistent with those described.

EXHIBIT A

LOCATION MAP



Kaskaskia Engineering Group, LLC

LOCATION MAP

REPLACEMENT OF SN 044-2007 ON US 45 OVER STREAM
Section: 13B-3
Johnson County, Illinois

Exhibit No.

A

KEG JOB #19-1143.06

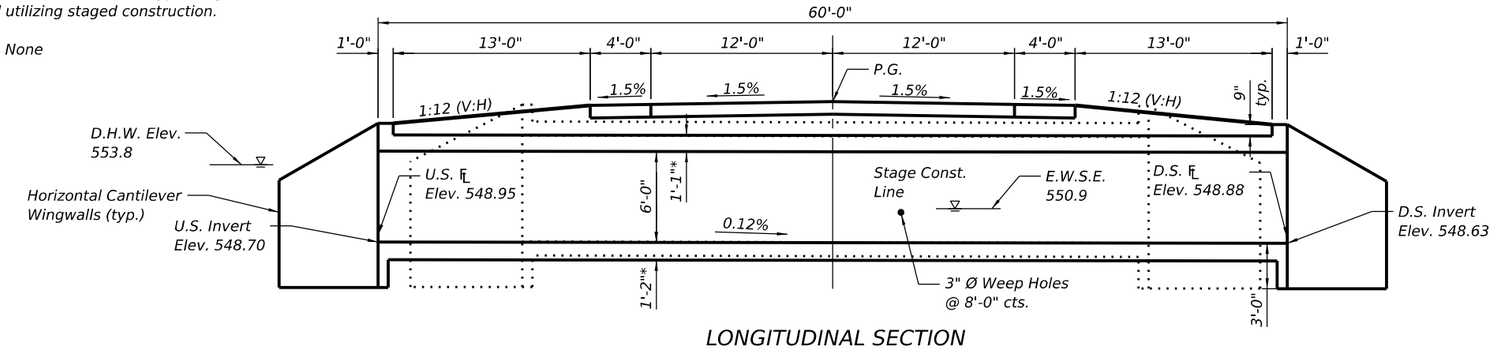
EXHIBIT B

TYPE, SIZE, AND LOCATION PLAN (TS&L)

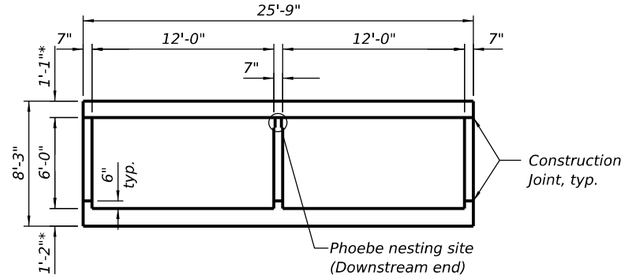
Bench Mark: Stamped "X" in top of exposed rebar on the top of the southeast wingwall. Elev. 556.70

Existing Structure: S.N. 044-2007 was originally constructed in 1922 as a double barrel reinforced 10' x 7'-6" culvert on footings with a zero degree skew. In 1937 the culvert was widened to an out to out headwalls length of 41'-4" with flared L-type wingwalls. The structure will be replaced utilizing staged construction.

Salvage: None

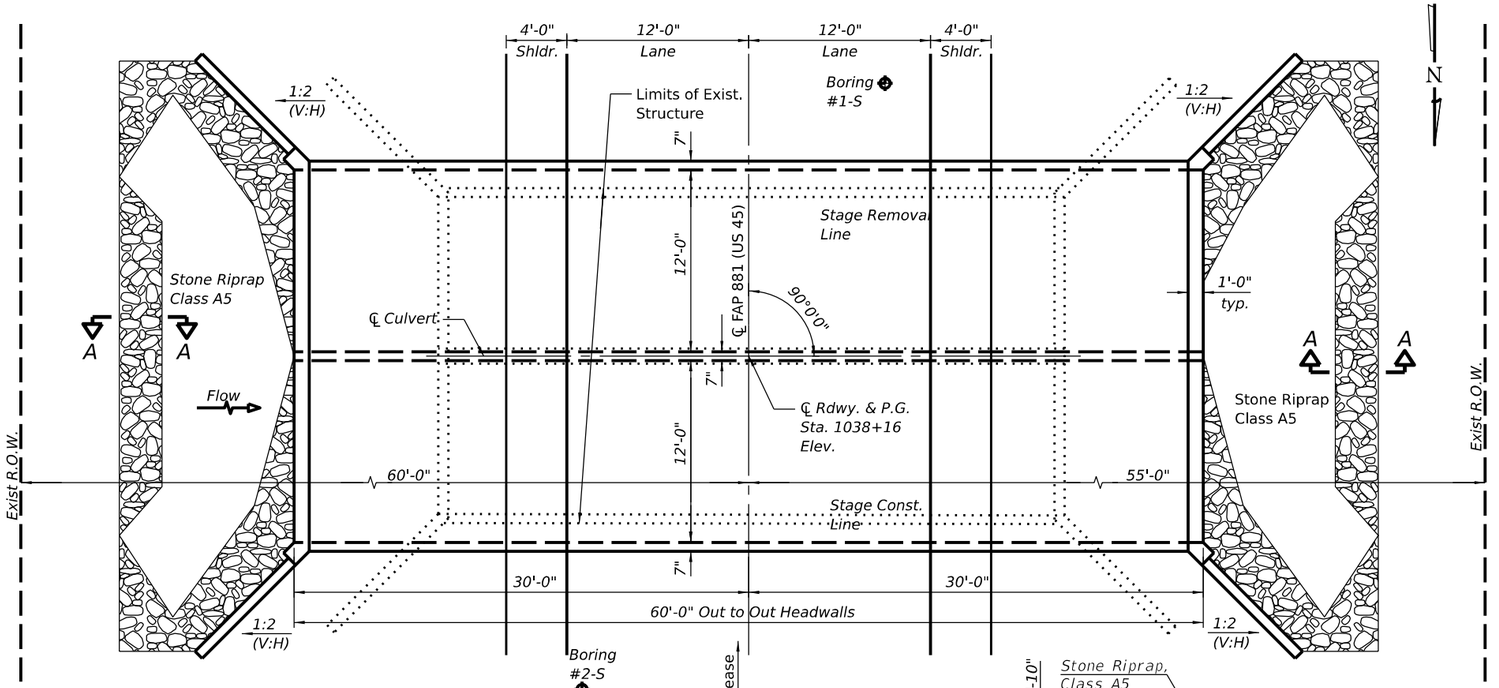


LONGITUDINAL SECTION

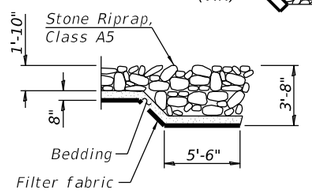


SECTION THRU BARREL

* Slab thickness may be refined in final design



PLAN

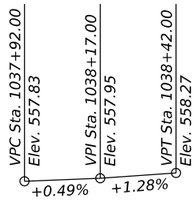


SECTION A-A

WATERWAY INFORMATION

Drainage Area = 0.7 Sq. Mi. Low Grade Elev. = 557.6 @ Sta. 1037+54

Flood	Freq. Yr.	Q C.F.S.	Opening Sq. Ft. Exist.	Opening Sq. Ft. Prop.	Nat. H.W.E.	Head - Ft. Exist.	Head - Ft. Prop.	Headwater El. Exist.	Headwater El. Prop.
	10	644	70	101	552.9	1.3	0.6	554.2	553.5
Design	50	1,110	88	122	553.8	2.6	1.4	556.4	555.2
Base	100	1,330	94	130	554.1	3.2	1.9	557.3	556.0
Max Calc.	500	1,920	106	144	554.7	3.7	3.3	558.4	558.0



PROFILE GRADE

LOADING HL-93

Allow 50#/sq. ft. for future wearing surface

DESIGN STRESSES

FIELD UNITS

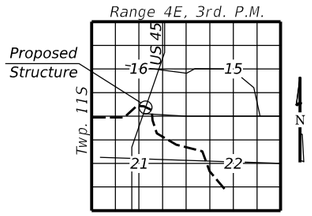
f'c = 3,500 psi
fy = 60,000 psi (Reinf.)

DESIGN SPECIFICATIONS

2020 AASHTO LRFD Bridge Design Specifications, 9th Edition

HIGHWAY CLASSIFICATION

FAP 881 (US 45)
Functional Class: Minor Arterial
ADT: 1900 (2017) / 2490 (2044)
ADTT: 280 (2017) / 365 (2044)
DHV: 170 (2017) / 225 (2044)
Design Speed: 55 mph
Posted Speed: 55 mph
Two-Way Traffic
Directional Distribution: 50/50



LOCATION SKETCH

GENERAL PLAN
FAP 881 (US 45)
OVER STREAM
SECTION 35(B-3)
JOHNSON COUNTY
STATION 1038+16
STRUCTURE NO. 044-

MODEL: $MODELNAME$
FILE NAME: $FILE$

USER NAME = $USER$	DESIGNED - _____	REVISED - _____
	DRAWN - _____	REVISED - _____
PLOT SCALE = $SCALE$	CHECKED - _____	REVISED - _____
PLOT DATE = $DATE$	DATE - _____	REVISED - _____

STATE OF ILLINOIS
DEPARTMENT OF TRANSPORTATION

GENERAL PLAN
STRUCTURE NO. 044-

SCALE: | SHEET 0 OF 1 SHEETS | STA. ___+__.__ | TO STA. ___+__.__

F.A.P. RTE.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.
881	35(B-3)	JOHNSON	1	1
		CONTRACT NO. 78718		
	ILLINOIS FED. AID PROJECT			

EXHBIT C

BORING LOGS

Illinois Department of Transportation
Division of Highways
District 9

SOIL BORING LOG

Date 4/22/19

ROUTE US 45 **DESCRIPTION** Double barrel box culvert carrying US 45 over a stream **LOGGED BY** L. Estel

SECTION 35(B-3) **LOCATION** 1.0 miles south of New Burnside, **SEC.** 16, **TWP.** 11S, **RNG.** 4E, **PM**

COUNTY Johnson **DRILLING METHOD** Hollow stem auger (8" O.D., 3.25" I.D.) **HAMMER TYPE** Auto SPT 140 lbs

STRUCT. NO. 044-2007
Station

BORING NO. 1-S
Station 1038+34
Offset 9.0ft RT
Ground Surface Elev. 558.1 ft

Surface Water Elev. 549.4 ft
Stream Bed Elev. 549.1 ft

Groundwater Elev.:
▽ **First Encounter** ft
▽ **Upon Completion** ft
▼ **After** Hrs. ft

DEPTH (ft)	BLOWS	UCS Qu (tsf)	MOIST (%)	Description
				Cored 16" CONCRETE over broken RIP RAP
556.60				
				(No sample)
554.60				
	WOH			Soft Brown, Moist to Wet SILTY LOAM with PEBBLES
-5	WOH	0.3	25	
552.60	1	B		
	WOH			M. Stiff Brown, Moist CLAY with broken SANDSTONE
	1	0.8	25	
	2	B		
548.40				
-10	100/2"		15	Hard Brown, Dry SANDSTONE
-15				
-20				
-25				
-30				
-35				
-40				

Bottom of hole @ 9 ft. 10 in.

Elevation referenced to BM 442007, 3/4" Rebar with "X" Cut on SW Wingwall of SN 044-2007; EL. 556.70

No free water observed

To convert "N" values to "N60", multiply by 1.5

The Unconfined Compressive Strength (UCS) Failure Mode is indicated by (B-Bulge, S-Shear, P-Penetrometer, E-Estimated)
Abbreviations W.O.H - Sampler Advanced By Weight of Hammer, W.O.P - Advanced by Weight of Pipe, B.S. - Before Seating
The SPT (N value) is the sum of the last two blow values in each sampling zone (AASHTO T206) BBS, from 137 (Rev. 8-99)

Illinois Department of Transportation
Division of Highways
District 9

SOIL BORING LOG

Date 4/22/19

ROUTE US 45 **DESCRIPTION** Double barrel box culvert carrying US 45 over a stream **LOGGED BY** L. Estel

SECTION 35(B-3) **LOCATION** 1.0 miles south of New Burnside, **SEC.** 16, **TWP.** 11S, **RNG.** 4E, **PM**

COUNTY Johnson **DRILLING METHOD** Hollow stem auger (8" O.D., 3.25" I.D.) **HAMMER TYPE** Auto SPT 140 lbs

STRUCT. NO. 044-2007
Station

BORING NO. 2-S
Station 1037+94
Offset 11.0ft LT
Ground Surface Elev. 557.7 ft

Surface Water Elev. 549.4 ft
Stream Bed Elev. 549.1 ft

Groundwater Elev.:
▽ **First Encounter** ft
▽ **Upon Completion** ft
▼ **After** Hrs. ft

DEPTH (ft)	BLOWS	UCS Qu (tsf)	MOIST (%)	Description
				Cored 7" HMA over 10" CONCRETE
556.20				
	2			M. Stiff Brown, Moist SILTY LOAM
	3	0.8	20	
554.70	3	B		
				Soft Brown, Moist SILTY LOAM
	WOH			
-5	WOH	0.3	27	
552.20	WOH	B		
	1			Soft Brown, Moist SILTY CLAY LOAM with broken SANDSTONE
	4	0.3	18	
	3	S		
548.90				
	100/2"		7	Hard Grey, Dry SANDSTONE
-10				
-15				
-20				

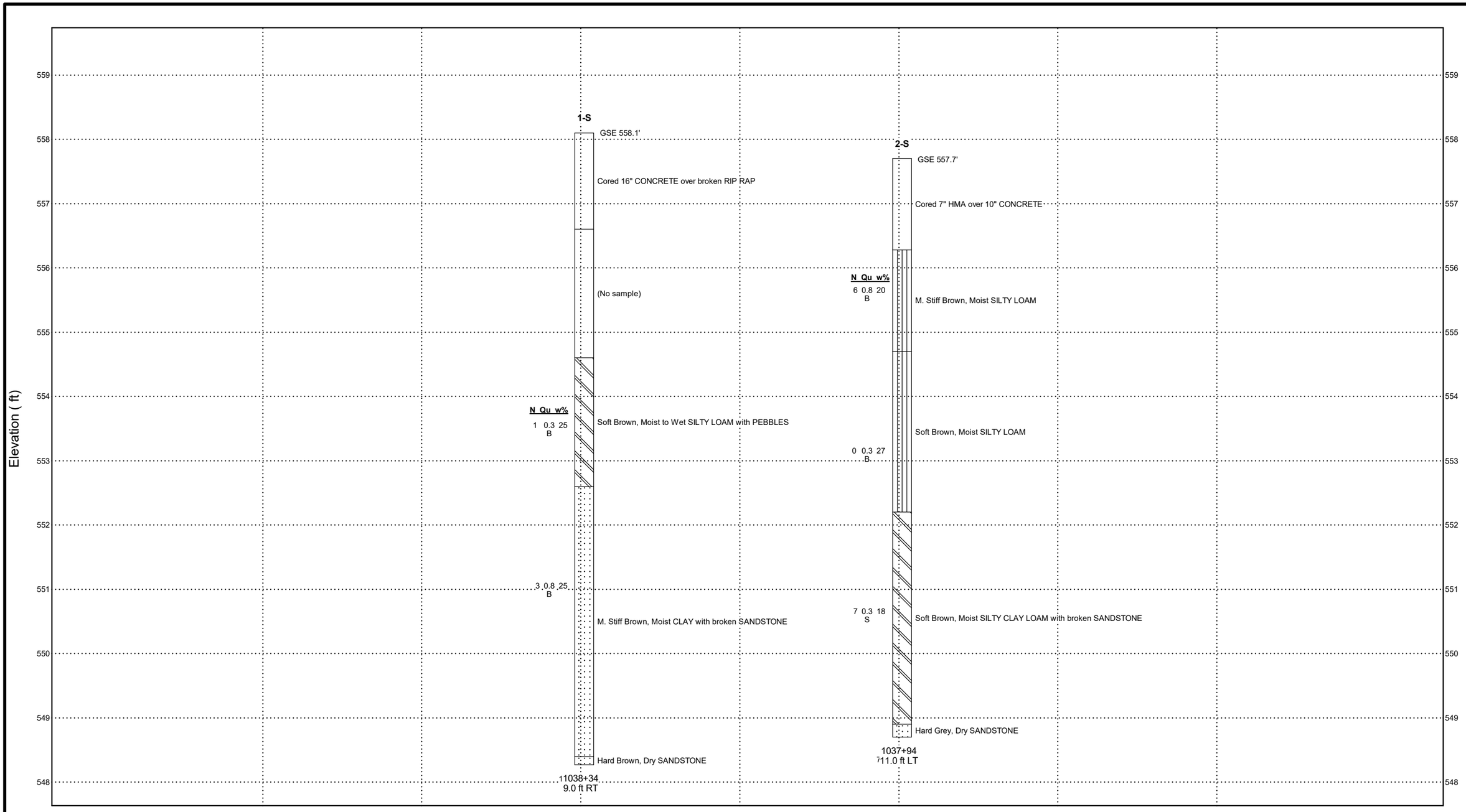
DEPTH (ft)	BLOWS	UCS Qu (tsf)	MOIST (%)	Description
				Bottom of hole @ 9 ft
				Elevation referenced to BM 442007, 3/4" Rebar with "X" Cut on SW Wingwall of SN 044-2007; EL. 556.70
				No free water observed
				To convert "N" values to "N60", multiply by 1.5
-25				
-30				
-35				
-40				

The Unconfined Compressive Strength (UCS) Failure Mode is indicated by (B-Bulge, S-Shear, P-Penetrometer, E-Estimated)
Abbreviations W.O.H - Sampler Advanced By Weight of Hammer, W.O.P - Advanced by Weight of Pipe, B.S. - Before Seating
The SPT (N value) is the sum of the last two blow values in each sampling zone (AASHTO T206) BBS, from 137 (Rev. 8-99)

File Name S:\MATERIALS GEOTECHNICAL UNIT\BORING LOGS USING GINT\STATE STRUCTURES\JOHNSON\044-2007 US 45 OVER STREAM 2019.GPJ Data Template D6TEMPLT.GDT Date Printed 7/15/19
Latitude 37.557242 Longitude -88.771310 Datum NAD83 Job Number

EXHIBIT D

SUBSURFACE PROFILE



NOT TO HORIZONTAL SCALE

Illinois Department of Transportation
Division of Highways

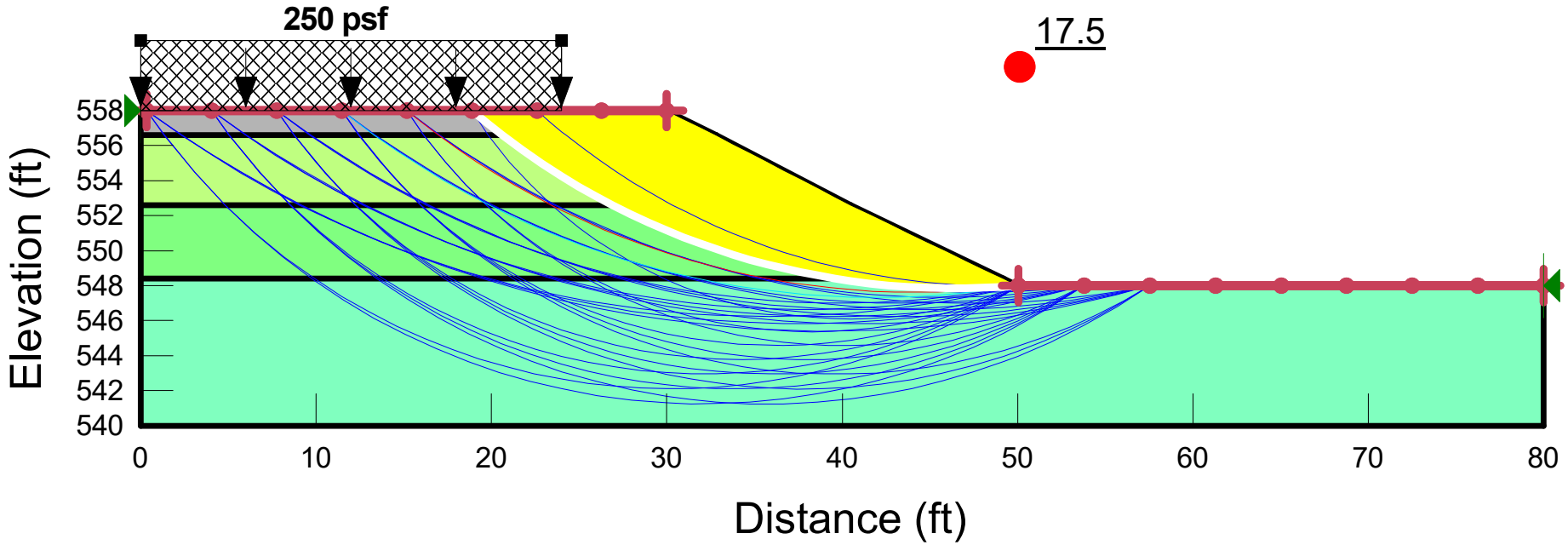
SUBSURFACE PROFILE

Route: FAP 881 (US 45)
Section: 35(B-3)
County: Johnson

EXHIBIT E

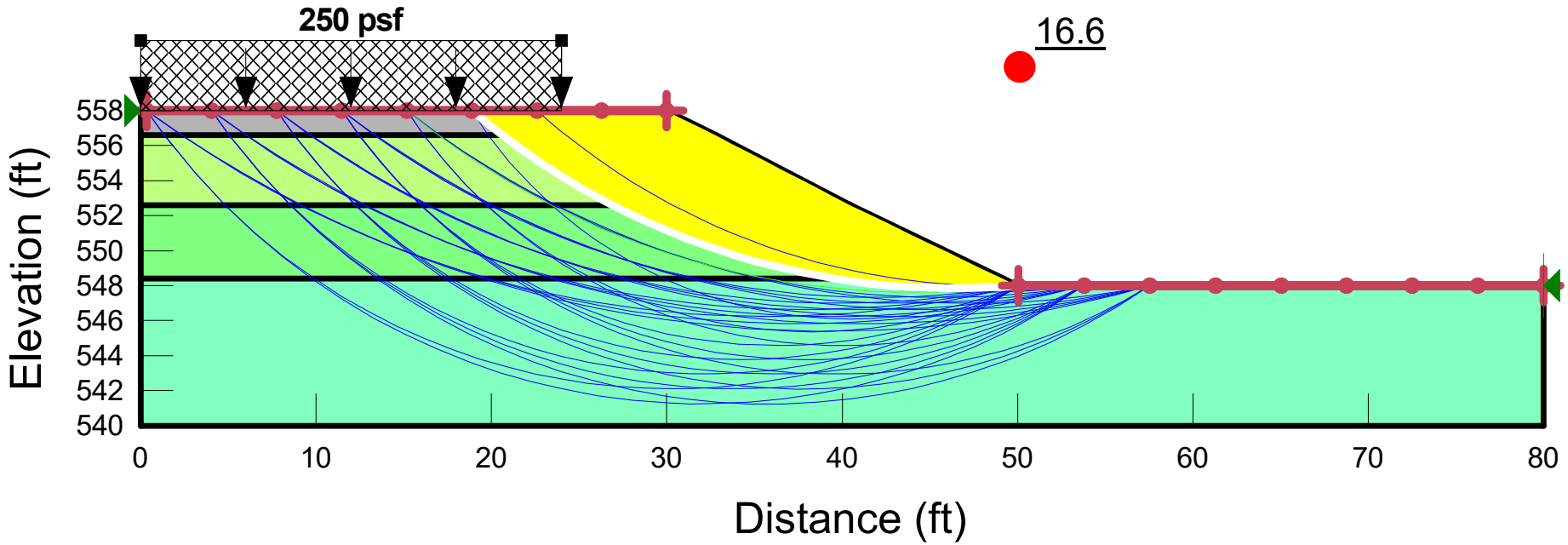
SLOPE STABILITY ANALYSIS

US 45 over Stream
Downstream Slope (Boring 1-S)
End-of-Construction (Undrained Analysis)



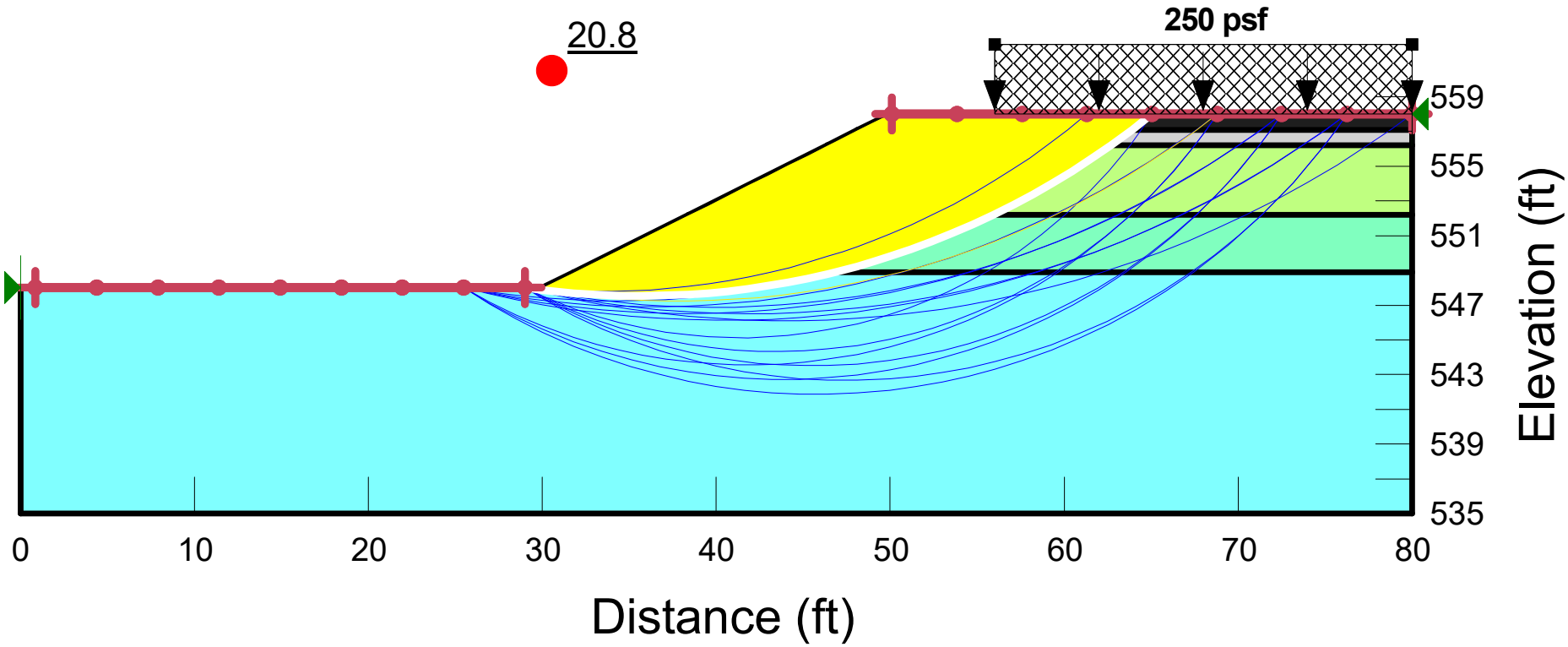
Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	Clay	Mohr-Coulomb	120	800	0
	Concrete Pavement/Rip Rap	Mohr-Coulomb	150	5,000	45
	Sandstone	Mohr-Coulomb	135	10,000	45
	Silty Loam	Mohr-Coulomb	120	300	26

US 45 over Stream
Downstream Slope (Boring 1-S)
Long Term (Undrained Analysis)



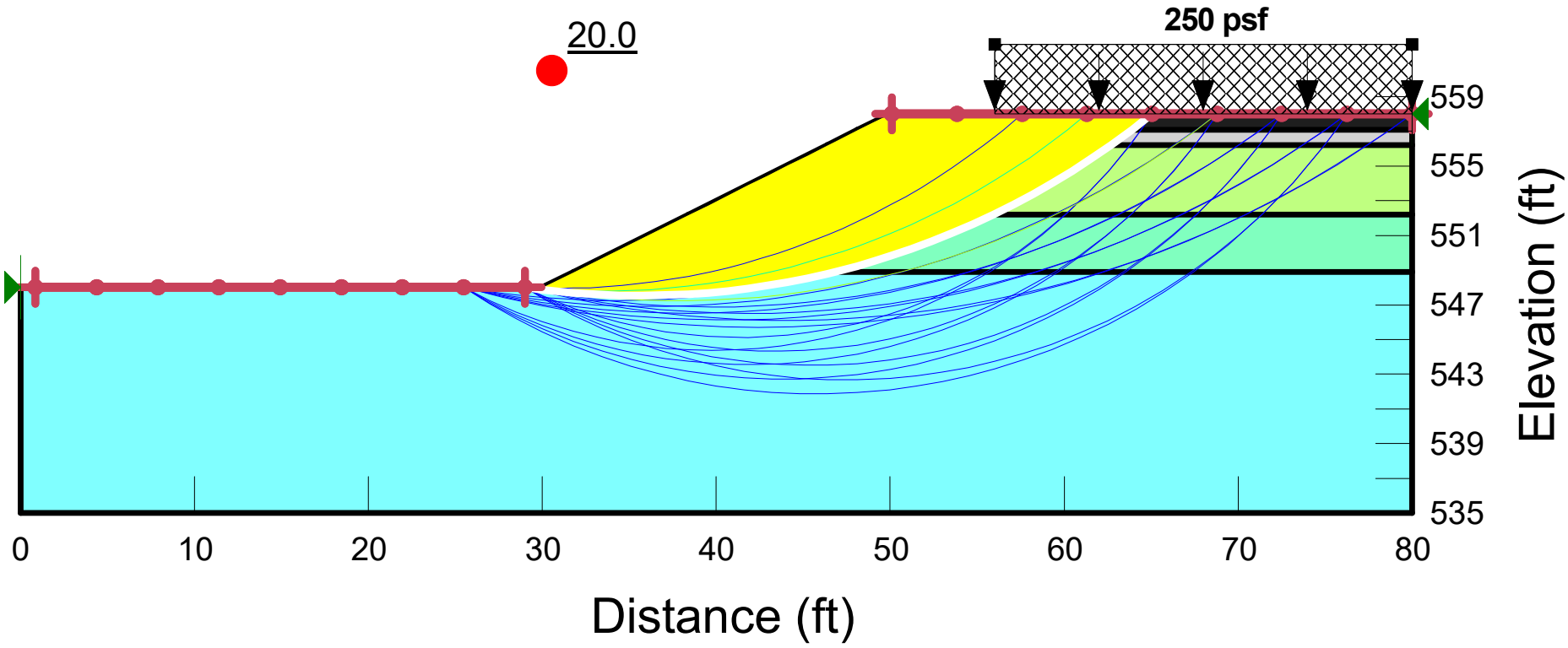
Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	Clay	Mohr-Coulomb	120	50	26
	Concrete Pavement/Rip Rap	Mohr-Coulomb	150	5,000	45
	Sandstone	Mohr-Coulomb	135	10,000	45
	Silty Loam	Mohr-Coulomb	120	50	26

US 45 over Stream
Upstream Slope (Boring 2-S)
End-of-Construction (Undrained Analysis)



Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	Asphalt Pavement	Mohr-Coulomb	130	0	34
	Concrete Pavement	Mohr-Coulomb	150	5,000	45
	Sandstone	Mohr-Coulomb	135	10,000	45
	Silty Clay Loam	Mohr-Coulomb	120	300	28
	Silty Loam	Mohr-Coulomb	120	800	26

US 45 over Stream
Upstream Slope (Boring 2-S)
Long Term (Drained Analysis)



Color	Name	Slope Stability Material Model	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	Asphalt Pavement	Mohr-Coulomb	130	0	34
	Concrete Pavement	Mohr-Coulomb	150	5,000	45
	Sandstone	Mohr-Coulomb	135	10,000	45
	Silty Clay Loam	Mohr-Coulomb	120	100	28
	Silty Loam	Mohr-Coulomb	120	50	26

EXHIBIT F

BEARING RESISTANCE CALCULATIONS

Kaskaskia
Engineering Group, LLC
208 E. Main Street
Suite 100
Belleville, Illinois 62220
618.233.5877 phone
618.233.5977 fax
www.kaskaskiaeng.com

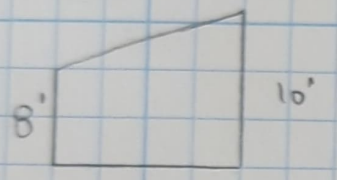
Project Title: US 45 over Sbeam Sheet: 1 of 2
Project Number: 19-1193.06
Calculated By: TG Date: 2/8/23
Checked By: Date:
Comments: Bearing Capacity

Culvert Weight

$V_C = (25+9/12)(1+2/12)(60)(2) + (6)(7/12)(3)(60)$
$= 4235\ ft^3$

$W_C = 4235 \times 150\ pcf$
$= 635250\ lb$

Wingwalls' Weight



$V_C = \left(\frac{8+10}{2}\right)(12)(1)(4)$

$= 432\ ft^3$

$W_W = 432 \times 150$
$= 64800\ lb$

Total Weight → $W_T = W_W + W_C = 700,050.00\ lb$

Bearing Pressure = $\frac{W_T}{A} = \frac{700,050}{60 \times 25'9''} = 453.11\ psf$

Bearing Capacity on Rock (Buisman-Terzaghi)

$q_{ult} = cN_c + 0.5\gamma BN_\gamma + \gamma DN_q$ → assumed values $c = 10,000\ psf$
$\phi = 45°$
$\gamma = 195\ pcf$
$D = 3\ ft$
$B = 25.75$

$N_\phi = \tan^2(15 + \phi/2) = 5.83$

$N_q = N_\phi^2 = 33.97$

$N_c = 2 N_\phi^{1/2} (N_\phi + 1) = 32.98$

$N_\gamma = N_\phi^{1/2} (N_\phi^2 - 1) = 79.65$

Kaskaskia
Engineering Group, LLC
208 E. Main Street
Suite 100
Belleville, Illinois 62220
618.233.5877 *phone*
618.233.5977 *fax*
www.kaskaskiaeng.com

Project Title: US 45 over Sheam Sheet: 2 of 2
Project Number: 19-1143.06
Calculated By: TG Date: 2/8/23
Checked By: _____ Date: _____
Comments: Bearing Capacity

$q_{ult} = 10,000(1.11)(32.98) + 0.5(0.91)(195)(25.75)(79.65) + 145(3)(33.97)$

$= 516,168 \text{ psf}$

Correction Factor for $L/B = 60/25.75 = 2.33$

	Nc correction	Nγ correction
L/B = 2	1.12	0.90
L/B = 5	1.05	0.95
for L/B →	1.11	0.91

$q_{allow} = \frac{q_{ult}}{FS} = \frac{516168}{3} = 172056 \text{ psf} = 172 \text{ ksf}$