Illinois Department of Transportation

Abbreviated Structure Geotechnical Report

Original Report Date:	12/4/2017	**Proposed SN:**	092-2045	**Route:**	FAP 840 (IL 49)
Revised Date:	4/1/19	**Existing SN:**	092-0060	**Section:**	121-BR
Geotechnical Engineer:	Terry McCleary of McCleary Engineering			**County:**	Vermilion
Structural Engineer:	Richard J. Chaput			**Contract:**	70905

Indicate the proposed structure type, substructure types, and foundation locations (attach plan and elevation drawing): The proposed culvert will be a cast in place concrete box culvert, double cell 10’x11’x63’ with a 40-degree left forward skew over a ditch 0.25 miles north of US 136(E) near Armstrong, IL. The structure will carry two 12 ft. lanes of IL 49 with 3 ft. HMA shoulders over a drainage ditch. The proposed out to out dimension is 48’ 1”. The upstream wingwalls will be oriented to help direct water into the barrel of the box culvert. We recommend using porous granular material to replace weak soils that may exist on the west side of the box culvert, and as a 6” working platform to facilitate construction operations. This 6” should be considered an undercut beyond that recommended in the Standard Specifications for Road and Bridge Construction. The District would like to use sheet piling or a soldier pile wall for the wingwalls. See the attached plan & profile sheet for further information.

Discuss the existing boring data, existing plans foundation information, new subsurface exploration and need for any additional exploration to be provided with SGR Technical Memo (attach all data and subsurface profile plot): Two 35 ft. borings taken in May 27, 2017 at the SE & NW corners of the existing structure. Boring SB-1 has 7 feet of a medium stiff to stiff clay loam fill with some sand intermingled. Below the fill is 15.5 ft of stiff to very stiff Silty Clays, Silty Clay Loams and Silty Clay Loam Tills. The water table was found next at the top of a 4 ft. fine Sand layer. Under the sand was a very hard 3.5 ft. layer of Clay Loam Till over another thin layer of sand. Boring SB-2 is somewhat similar to SB-1 except below Elev. 679 exists 5 ft. of loose Sand over a 1.5 ft. band of medium dense silt. The bottom 19 feet of SB-2 are alternating layers of medium dense to dense sand to very stiff to very hard Clay Loam Tills and Sandy Clay Loam.

The district provided two 25 ft. borings from 1969. The soil descriptions of the 2017 borings generally matched the 1969 borings. The borings north of the structure also generally report stronger soils than the south side borings. Of particular note—Boring SB-1 encountered a dense layer of gray fine Silty Sand between approximate Elevations 664 to 660 and boring SB-2 encountered a 1.5 ft. layer of very hard gray Clay Loam Till over the dense sand layer and may prove difficult to drive sheet piling through. Because the hard layer of Till material is only 1.5 ft., the author believes the sheet piling can be driven at this location, but a larger than normal sheet pile section will likely be warranted.

The information provided by the District reports the existing structure (SN 092-0060) is a single span concrete slab bridge built in 1928 and widened and reconstructed in 1969 with spread footings supported by friction piles. Substantial portions of the existing substructure foundation will require removal. It is quite possible that the loose sand and medium dense Silt found in boring SB-2 exists under a substantial portion of the proposed box culvert. No further soil exploration is recommended.

Provide the location and maximum height of any new soil fill or magnitude of footing bearing pressure. Estimate the amount and time of the expected settlement. Indicate if further testing, analysis, and/or ground improvement/treatment is necessary: The proposed structure will remain in the same location as the existing structure. There are no existing settlement issues and future settlement is of minimal concern as there is only a minor increase in loading on the founding soils between the existing abutments. However, the sand and silt found near the proposed flowline elevation in boring SB-2, may become unstable during construction and undercutting this area may become necessary. Based on both borings, undercut depths are anticipated to be less than 1.5 ft. As mentioned above, these soils may be removed during the process of removing the existing structure.

Identify any new cuts or fill slope angles and heights. Estimate the factor of safety against slope failure. Indicate if further testing, analysis or ground improvement/treatment is necessary: The proposed structure will maintain the same grade of the roadway. The new box culvert will have a larger out to out dimension pushing the ditches out away from the road—resulting in proposed side slopes being flatter than the existing side slopes near the structure. The existing slopes are stable and no further testing is required.

Indicate at each substructure, the 100-year and 200-year total scour depths in the Hydraulics report, the non-granular scour depth reduction, the proposed ground surface, and the recommended foundation design

scour elevations: From All Bridge Designer Memorandums 14.2, a Design Scour Table is not required for closed bottom box culverts. The Design Scour elevations would be the bottom of the cut off wall; these elevations are 673.12, upstream, and 672.98, downstream. However, the district has noted scour issues at the existing structure and feel it would be prudent to increase the depth of the cut off wall to match the Q100 and Q200 scour elevations (which are the same elevation). This approach seems appropriate and we see no geotechnical issues which would restrict the construction of deeper cut off walls.

Determining the seismic soil site class, the seismic performance zone, the 0.2 and 1.0 second design spectral accelerations and indicate if that the soils are liquefiable: This structure is a buried structure. Per Section 2.3.10 of the Departments Bridge Manual seismic data is not needed for most walls or buried structures. However, if desired the seismic soil class site = D. The SD1 = 0.126 g. The SDs = 0.211 g. The Seismic Performance Zone (SPZ) for this bridge = 1 and therefore a liquefaction analysis was not performed.

Confirm feasibility of the proposed foundation or wall type and provide design parameters. Attach a pile design table indicating feasible pile types, various nominal required bearings, factored resistances available and corresponding estimated lengths at locations where piles will be used. Provide factored bearing resistance and unit sliding resistance at various elevations and confirm no ground improvement/treatment is necessary where spread footings are proposed. Estimated top of rock elevations as well as preliminary factored unit side and tip resistance values shall be indicated when drilled shafts are proposed: It is understood that wingwalls are to be driven sheet pile or soldier pile walls. For the box culvert itself, both strength and service limit states were used to analyze the spread footing option. As can be seen in boring SB-1 the soils beneath an assumed bottom of footing elevation of 675.98 ft. are cohesive. The strengths in the 20 ft. of soil under the footing are stiff with an average Qu=3.3 tsf. Because of these high Qu values the factored bearing resistance from a strength limit state approach is quite high at 7.2 ksf.

Using an estimated load of 1,020 kip, footprint of 48 ft. by 25 ft., (850 psf) the settlement of the proposed box culvert was calculated using the formulas found in the AASHTO Design Manual. At this load the estimated settlement is 0.35 inches at boring SB-1 and 0.51 at boring SB-2. The service limit state bearing resistance value of 2.0 ksf is based on a 1-inch tolerable settlement. With an estimated 3 ft. of fill above the top of the culvert this bearing resistance should be sufficient. To increase this value, the footing may be lowered or the stiff material may be removed and replaced with a crushed Limestone material. The settlement from the granular soils are not considered to be an issue as it will occur over a relatively short period of time. At this time, a TSL is not available, therefore the exact length of the wingwalls are not known. The soil parameters used for determining a soil pressure diagram are:

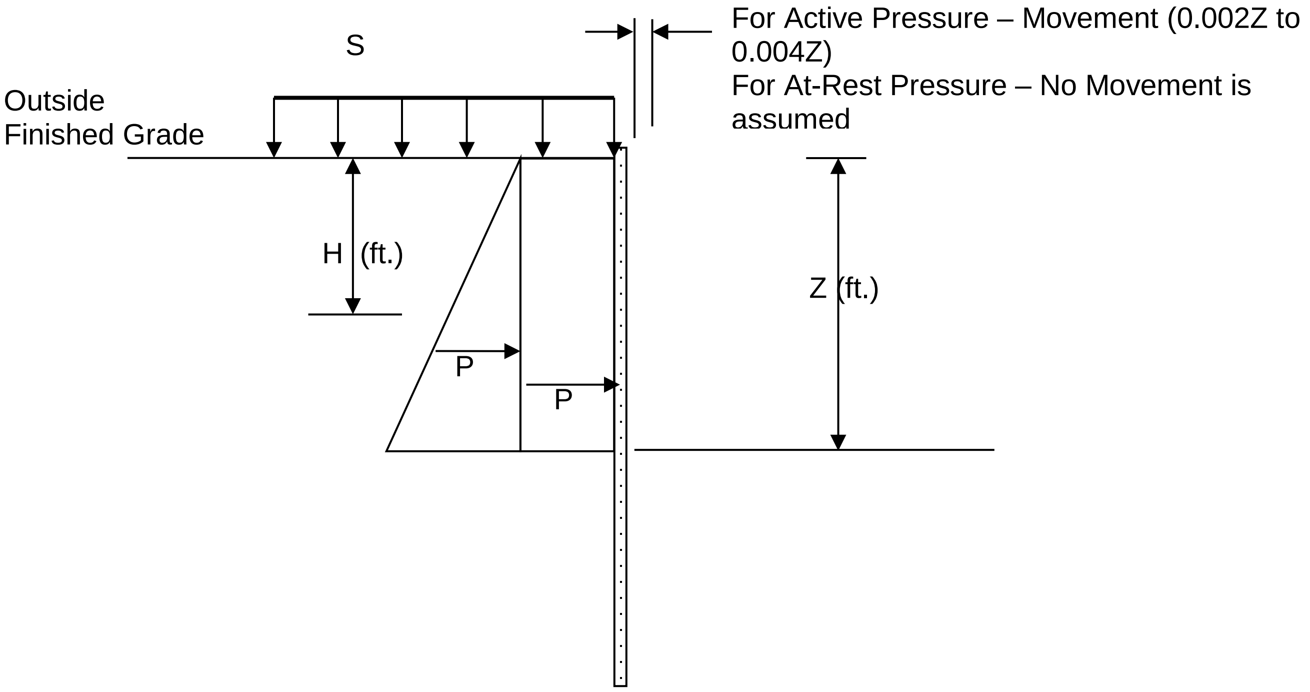

Figure 1, Generic Vertical Cantilever Retaining Wall Schematic

Table 1 - Earth Pressure Coefficients for the use with flexible retaining walls, $H < 20$ ft.

Earth Pressure Conditions	Coefficient for Retained Soil Type	Equivalent Fluid Pressure (psf/lin. ft. of wall)	Surcharge Pressure, P_1 (psf)	Earth Pressure, P_2 (psf)
Active, K_a	Granular – 0.33	40	0.33 x Surcharge	40 x H
	Cohesive - 0.50	60	0.50 x Surcharge	60 x H
At-Rest, K_o	Granular – 0.46	55	0.46 x Surcharge	55 x H
	Cohesive - 0.65	78	0.65 x Surcharge	78 x H
Passive, K_p	Granular – 3.00	360	---	---
	Cohesive - 2.00	240	---	---

Table 1 is applicable for the following conditions:

- For active earth pressure, the wall must rotate about the base with top lateral movements
- For passive earth pressure, the wall must move horizontally back into the soil to mobilize resistance.
- For walls that are not expected to move, at rest earth pressures are recommended for design.
- Grade in front and behind the wall is flat
- Uniform surcharge, where S is the surcharge pressure
- In-situ soil backfill weight is a maximum of 120 pcf
- Loading from heavy compaction equipment is not included
- No groundwater acting on the wall
- Earth pressures do not take into account the effects of frost, swell or forces from compactive efforts while placing backfill.
- Per the IDOT Bridge Manual, Section 3.11.3.1, 2012, ignore the top 36 inches below the dredge line on the passive side.
- No safety factor included

For a more detailed earth pressure diagram

- Ignore cohesion and used a long term friction value for a drained condition.
  - $\phi = 20^\circ$ for soft cohesive soils
  - $\phi = 27.5^\circ$ for stiff cohesive soils
  - $\phi = 30^\circ$ for very stiff cohesive soils
  - $\phi = 32^\circ$ for hard cohesive soils
- For the granular soils
  - $\phi = 28^\circ$ for loose silty sand
  - $\phi = 30^\circ$ for medium dense fine sand
  - $\phi = 34^\circ$ degrees for dense fine sand and granular backfill

Calculate the estimated water surface elevation and determine the need for cofferdams (type 1 or 2), and seal coat: The Estimated Water Surface Elevation is 680.25. For box culvert construction the contractor is responsible for diverting the flow of water from the construction using a method approved by the engineer. This is often handle by a diversion culvert pipe.

Assess the need for sheeting or soil retention or temporary construction slope and provide recommendation for other construction concerns: The road will remain open during construction by use of stage construction. Temporary sheet piling at the stage line will be required. There are no geotechnical considerations which would restrict the use of temporary sheet piling, but hard drive should be expected near the elevation 664.00 ft. Because the width of the new structure is wider than the existing structure this site will be constructed a cut condition, therefore the Temporary MSE wall is not recommended.

This report was prepared by McCleary Engineering
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Office Phone 815-780-8486

LICENSED PROFESSIONAL ENGINEER
TERRENCE L.
McCLEARY
062.050019
OF ILLINOIS

Terrence L. McCleary

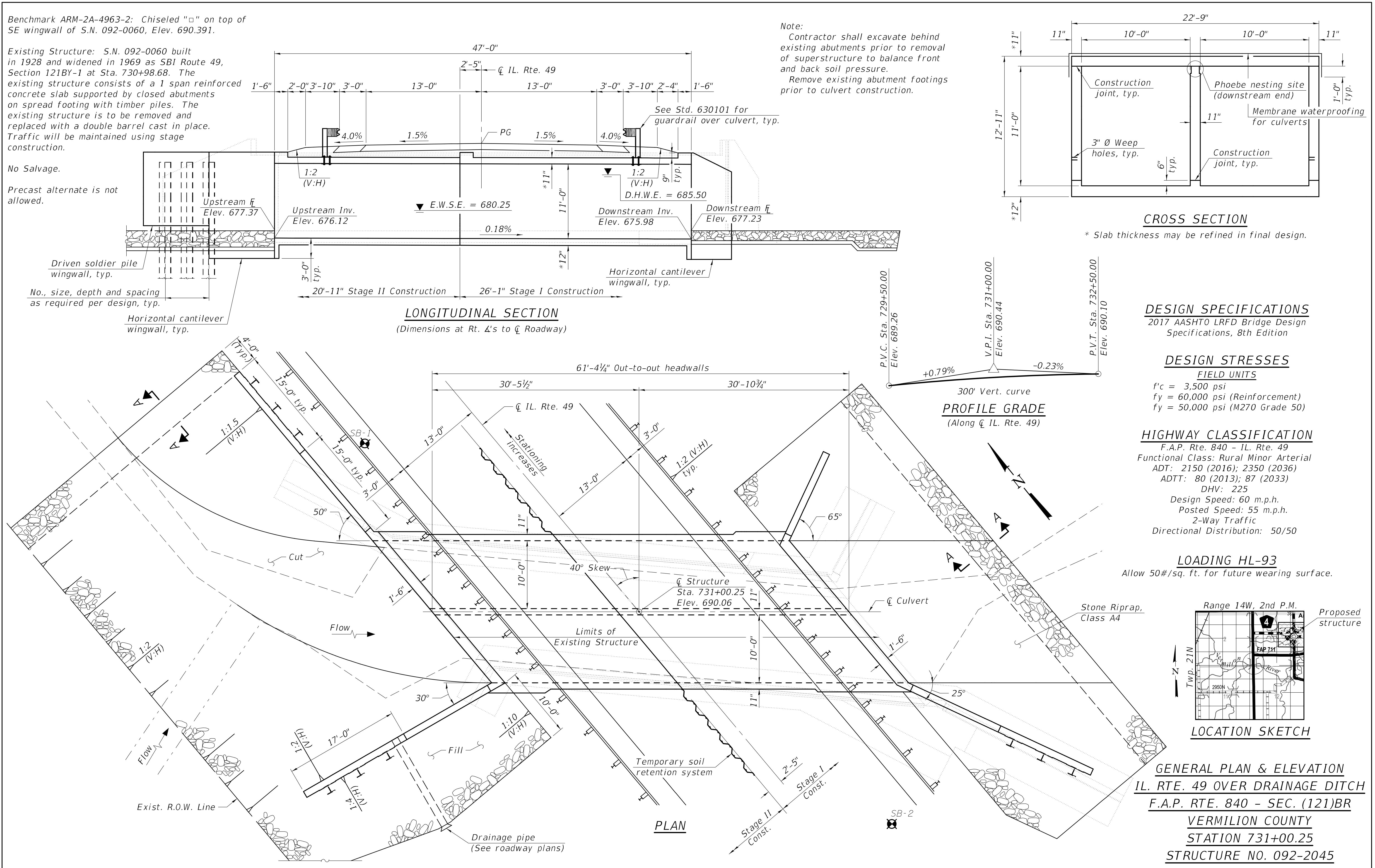
Benchmark ARM-2A-4963-2: Chiseled "□" on top of SE wingwall of S.N. 092-0060, Elev. 690.391.

Existing Structure: S.N. 092-0060 built in 1928 and widened in 1969 as SBI Route 49, Section 121BY-1 at Sta. 730+98.68. The existing structure consists of a 1 span reinforced concrete slab supported by closed abutments on spread footing with timber piles. The existing structure is to be removed and replaced with a double barrel cast in place. Traffic will be maintained using stage construction.

No Salvage.

Precast alternate is not allowed.

Note:
Contractor shall excavate behind existing abutments prior to removal of superstructure to balance front and back soil pressure.
Remove existing abutment footings prior to culvert construction.



DESIGN SPECIFICATIONS

2017 AASHTO LRFD Bridge Design Specifications, 8th Edition

DESIGN STRESSES

FIELD UNITS

f'c = 3,500 psi
fy = 60,000 psi (Reinforcement)
fy = 50,000 psi (M270 Grade 50)

HIGHWAY CLASSIFICATION

F.A.P. Rte. 840 - IL. Rte. 49
Functional Class: Rural Minor Arterial
ADT: 2150 (2016); 2350 (2036)
ADTT: 80 (2013); 87 (2033)
DHV: 225
Design Speed: 60 m.p.h.
Posted Speed: 55 m.p.h.
2-Way Traffic
Directional Distribution: 50/50

LOADING HL-93

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

GENERAL PLAN & ELEVATION
IL. RTE. 49 OVER DRAINAGE DITCH
F.A.P. RTE. 840 - SEC. (121)BR
VERMILION COUNTY
STATION 731+00.25
STRUCTURE NO. 092-2045

MODEL: $MODELNAME$
FILE NAME: pw:\\IL084EBIDINTEG.illinois.gov:PWIDOT\Documents\IDOT Offices\Bureau of Bridges and Structures\Projects\0922045\CADD Plans\0922045-70905.dgn

DESIGNED - ANDREW BAUER
CHECKED - ALLY KELLEY
DRAWN - DENNIS A. POP
CHECKED - RICHARD J. CHAPUT

2/13/2019 - STIMES

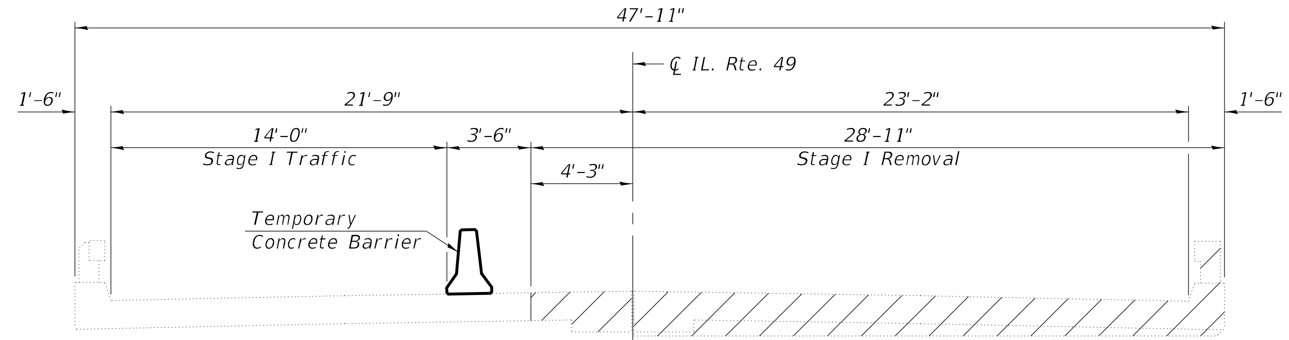
STATE OF ILLINOIS
DEPARTMENT OF TRANSPORTATION

SHEET 1 OF 2 SHEETS

F.A.P. RTE.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.
840	121BR	VERMILION		

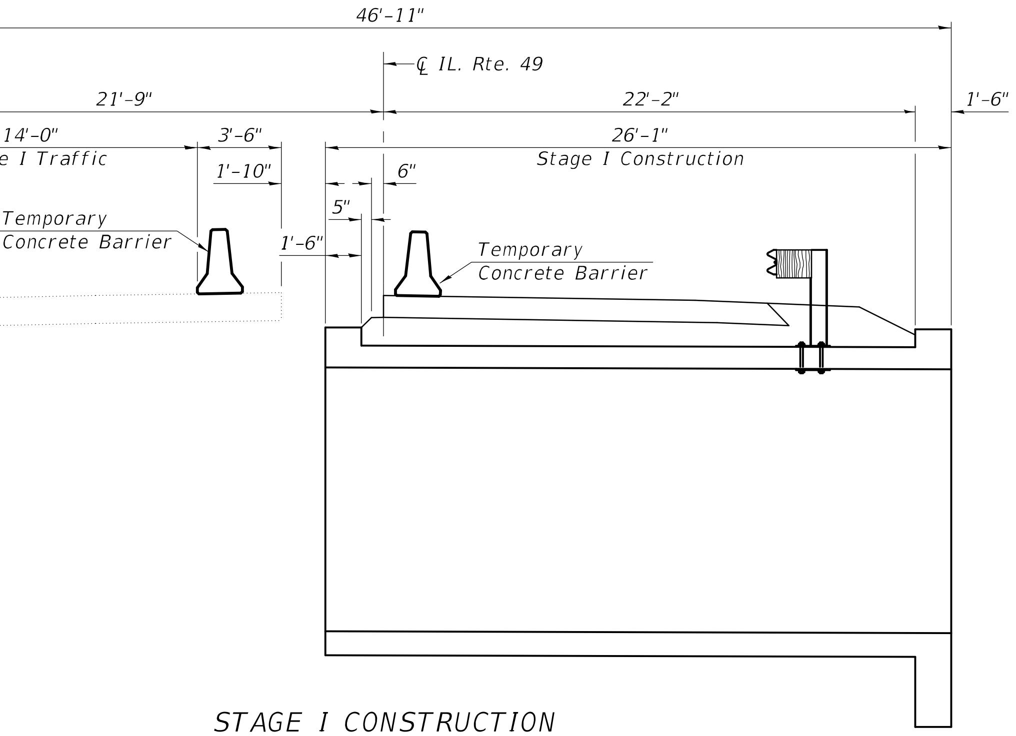
CONTRACT NO. 70905

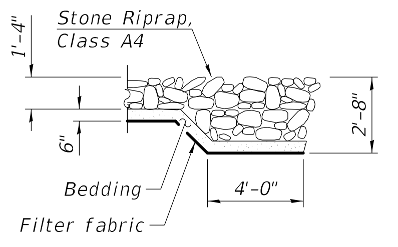
ILLINOIS FED. AID PROJECT



STAGE I REMOVAL

(Dimensions at Rt. ∠'s to ℄ Roadway)

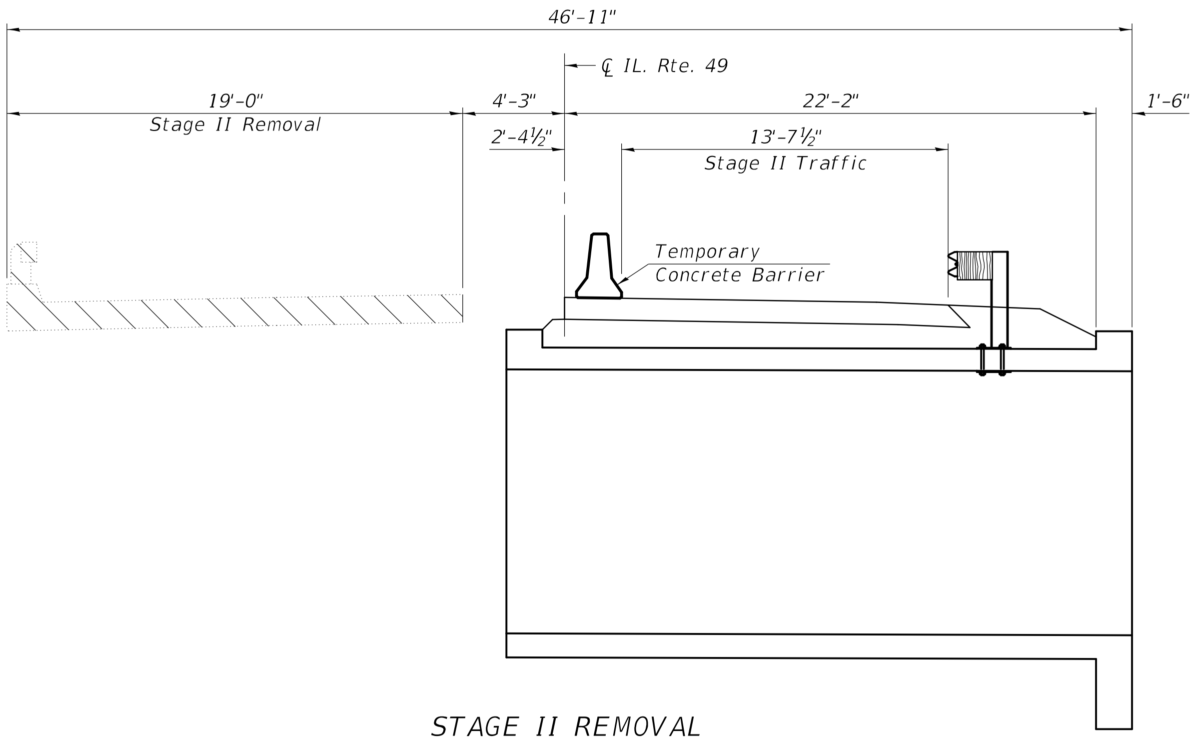




SECTION A-A

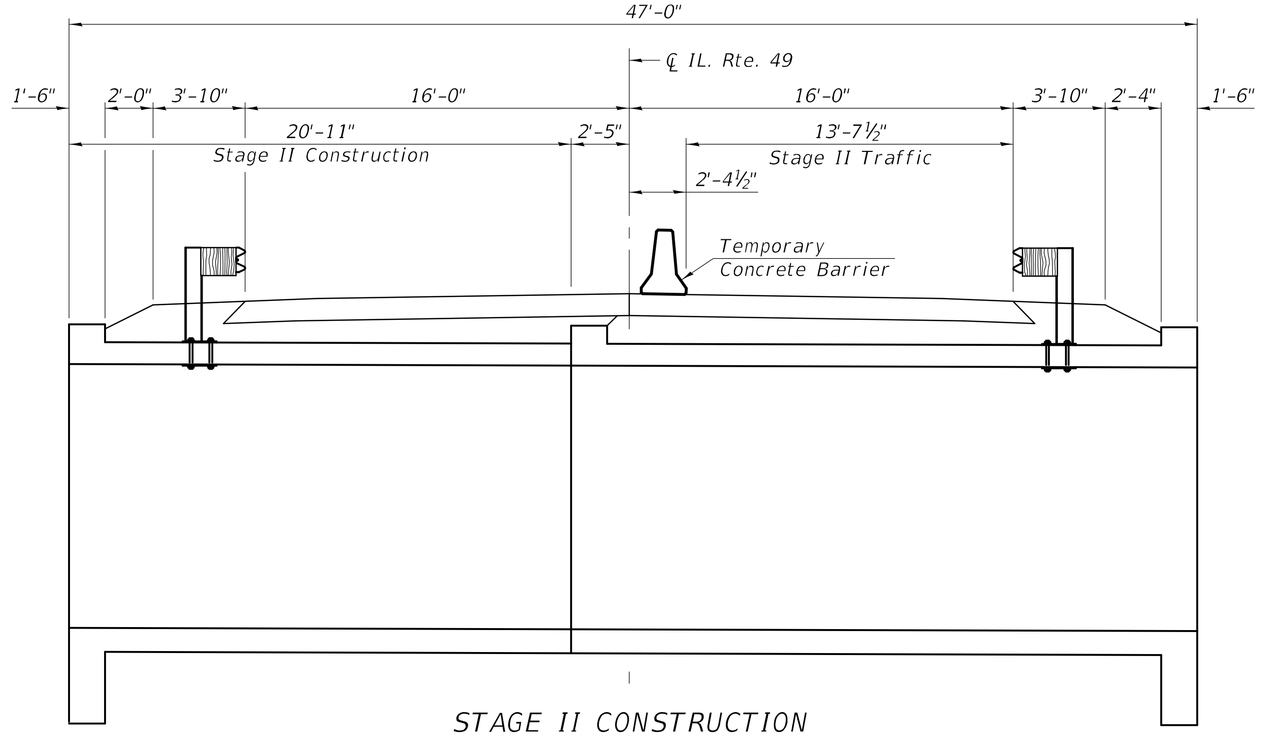
STAGE I CONSTRUCTION

(Dimensions at Rt. ∠'s to ℄ Roadway)



STAGE II REMOVAL

(Dimensions at Rt. ∠'s to ℄ Roadway)



STAGE II CONSTRUCTION

(Dimensions at Rt. ∠'s to ℄ Roadway)

WATERWAY INFORMATION

Drainage Area = 1.36 Sq. Mi.			Low Grade Elev. 688.05 @ Sta. 727+89.80						
Flood	Freq. Yr.	Q C.F.S.	Opening Ft²		Nat. H.W.E.	Head - Ft.		Headwater El.	
			Exist.	Prop.		Exist.	Prop.	Exist.	Prop.
	10	540	84	144	684.3	0.8	0.1	685.1	684.4
Design	50	910	103	168	685.5	1.5	0.5	687.0	686.0
Base	100	1080	111	176	685.9	2.1	0.6	688.0	686.5
Overtopping	100	1080	111	-	685.9	2.1	-	688.0	-
Scour	200	1261	119	186	686.4	1.9	0.8	688.3	687.2
Max. Calc.	500	1500	123	192	686.7	1.7	1.1	688.4	687.8

10-year velocity through existing bridge = 6.43 ft/s
10-year velocity through proposed culvert = 3.75 ft/s

DETAILS
IL. RTE. 49 OVER DRAINAGE DITCH
F.A.P. RTE. 840 - SEC. (121)BR
VERMILION COUNTY
STATION 731+00.25
STRUCTURE NO. 092-2045

MODEL: $MODELNAME$
FILE NAME: $FILEL$

DESIGNED -	ANDREW BAUER
CHECKED -	ALLY KELLEY
DRAWN -	DENNIS A. POP
CHECKED -	RICHARD J. CHAPUT

$DATE$ - $TIME$

STATE OF ILLINOIS
DEPARTMENT OF TRANSPORTATION

SHEET 2 OF 2 SHEETS

F.A.P. RTE.	SECTION	COUNTY	TOTAL SHEETS	SHEET NO.
840	121BR	VERMILION		
		CONTRACT NO.		
	ILLINOIS	FED. AID PROJECT		

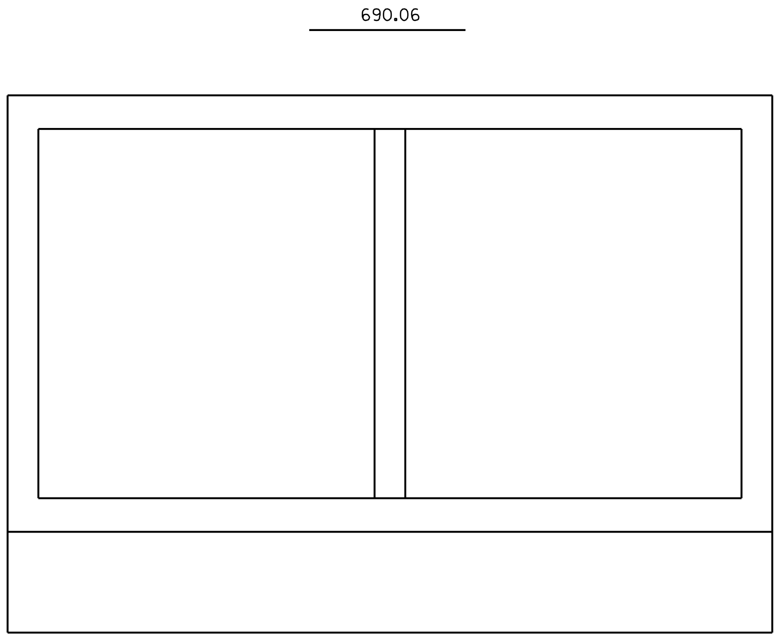
SOIL BORINGS ON ELEVATION VIEW
S.N. 092–2045

2017 BORING DATA

NORTHWEST CORNER EXISTING STR. STA. 731+45.18 Offset 15' Lt. GROUND SURFACE	Elevation 689.69	Standard Penetration (N/6")	Unconfined Compression Strength (TSF)	Moisture (%)
Medium Stiff Brown & Black Clay Loam, Fill (Moist)		2 2 4	0.8 B	13
Stiff Brown Silty Clay Loam W/2" Sand Layer	686.69	2 2 2	2.0 P	16
	-5	2 2 3	0.7 B	21
Stiff Black Topsoil, Silty Clay Loam Original Ground	682.69	2 2 2	0.8 B	17
Medium Stiff Brown/Gray Silty Clay Loam W/ Bits of Rock	680.69 -10			
Very Stiff Brown/Gray Silty Clay Loam W/ Trace of Sand	679.19	2 4 5	2.5 B	19
	-15	2 4 7	3.7 S	21
Very Stiff Gray Silt Clay Loam Till	674.19	4 6 9	2.5 B	13
Very Stiff Gray Silt Clay	671.69	3 5 11	3.3 B	18
Very Stiff Gray (W/Purple) Silty Clay Loam Till W/ Silt & Sand Seams	670.19 -20	6 10 11	2.7 B	12
	-25	5 9 13	3.3 S	10
Dense Gray Silty Fine Sand (Wet)	664.19	14 16 18	-	22
		5 4 8	4.5 P	16
Very Hard Gray Clay Loam Till	660.19 -30			
Medium Dense Gray Fine Sand	656.69	6 7 12	3.0 P	13
Very Stiff Gray Clay Loam Till	655.19 -35			

Bottom Box
Elev. 675.12

Cut Off Wall
Elev. 672.12



UPSTREAM OPENING

2017 BORING DATA

Moisture (%)	Unconfined Compression Strength (TSF)	Standard Penetration (N/6")	Elevation 689.64	SOUTHEAST CORNER EXISTING STR. STA. 730+51.68 Offset 15' Lt. GROUND SURFACE
15	1.5 B	7 4 4		Stiff Black Silty Clay, Fill
10	1.0 P	3 2 2		
			685.64 -5	Loose Gray Sand & Gravel, Fill
20	0.7 B	1 1 1	684.14	Medium Stiff Dark Gray Clay Loam, Some Gravel
21	0.4 B	1 2 2	681.64 -10	Soft Blue-Gray & Brown Silty Clay Loam, Some Gravel
23	-	2 2 2	679.14	Loose Gray Silty Medium Sand, Trace Gravel
25	-	1 2 5	676.64	Loose Brown Silty Medium Sand, Wet
			675.14 -15	Medium Dense Brown/Gray Silt
18	2.9 B	3 7 11	673.64	Very Stiff Gray Clay Loam Till
22	2.7 B	5 8 7		
			670.14 *	
			-20 669.64	Very Still Gray Sandy Clay Loam
11	2.4 B	6 8 6		
22	-	7 12 14	666.64 -25	Medium Dense Gray fine Sand
10	8.2 B	11 15 17	663.14	Very Hard Gray Clay Loam Till
20	-	6 19 12	661.64 -30	Dense Gray Fine Sand W/ Trace Gravel
19	-	7 16 10	656.64 -35	Medium Dense Gray Fine Sand Wet

Bottom Box
Elev. 675.12

Cut Off Wall
Elev. 672.12

* Medium Dense Gray Silty Medium Sand W/ Layers of Silt

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$MODELNAME$

USER NAME = shawleres
PLOT SCALE = 40.0000 ' / in.
PLOT DATE = 7/13/2018

DESIGNED -
DRAWN
CHECKED -
DATE -

REVISED -
REVISED -
REVISED -
REVISED -

STATE OF ILLINOIS
DEPARTMENT OF TRANSPORTATION

SCALE: SHEET OF SHEETS STA. TO STA.

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

CONTRACT NO.

ILLINOIS FED. AID PROJECT

Mc Cleary Engineering
3705 Progress Blvd
Peru, Il 61354
815 780-8486

Solutions You Can Build On

SOIL BORING LOG

Date 5/27/17

ROUTE US 49 over Vermilion Creek **DESCRIPTION** NW Corner of Existing Structure **LOGGED BY** TLM

SECTION 121BR **LOCATION** , **SEC.** , **TWP.** , **RNG.** , **Latitude** , **Longitude**

COUNTY Vermilion **DRILLING METHOD** Hollow Stem Auger **HAMMER TYPE** CME Automatic

STRUCT. NO.
Station

BORING NO. SB-1
Station 731+45.18
Offset 15.0 ft Lt.
Ground Surface Elev. 689.69 ft

Surface Water Elev. ft
Stream Bed Elev. ft

Groundwater Elev.:
First Encounter 664.2 ft ▼
Upon Completion 664.2 ft ▽
After ____ **Hrs.** ft

		DEPTH (ft)	BLOWS (/6")	UCS Qu (tsf)	MOIST (%)
Medium Stiff Brown and Black Clay Loam, Fill moist			2 2 4	0.8 B	13
	686.69				
Stiff Brown Silty Clay Loam w/ 2" sand layers, Fill moist		-5	2 2 2	2.0 P	16
	682.69		2 2 3	0.7 B	21
Stiff Black Topsoil, Silty Clay Loam moist (original ground)	680.69				
Medium Stiff Brown/Gray Silty Clay Loam w/ bits of rock moist	679.19	-10	2 2 2	0.8 B	17
Very Stiff Brown/Gray Silty Clay w/ trace sand moist			2 4 5	2.5 B	19
		-15	2 4 7	3.7 S	21
	674.19				
Very Stiff Gray Silty Clay Loam Till moist			4 6 9	2.5 B	13
	671.69				
Very Stiff Gray Silty Clay moist	670.19	-20	3 5 11	3.3 B	18

		DEPTH (ft)	BLOWS (/6")	UCS Qu (tsf)	MOIST (%)
Very Stiff Gray (w/ purple) Silty Clay Loam Till w/ silt & sand seams moist *(continued)*			6 10 11	2.7 B	12
		-25	5 9 13	3.3 S	10
	664.19 ▽▼				
Dense Gray Silty Fine Sand wet			14 16 18	-	22
	660.19	-30	5 4 8	4.5 P	16
Very Hard Gray Clay Loam Till moist					
	656.69				
Medium Dense Gray Fine Sand moist	655.19		6 7 12	3.0 P	13
Very stiff Gray Clay Loam Till moist	654.69	-35			
End of Boring		-40			

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)

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Page 1 **of** 1

SOIL BORING LOG

Date 5/27/17

ROUTE US 49 over Vermilion Creek **DESCRIPTION** SE Corner of Existing Structure **LOGGED BY** TLM

SECTION 121BR **LOCATION** **, SEC. , TWP. , RNG. ,**
Latitude , Longitude

COUNTY Vermilion **DRILLING METHOD** Hollow Stem Auger **HAMMER TYPE** CME Automatic

STRUCT. NO. ______
Station ______

BORING NO. SB-2
Station 730+51.68
Offset 15.0 ft Rt.
Ground Surface Elev. 689.64 ft

Surface Water Elev. ______ ft
Stream Bed Elev. ______ ft

Groundwater Elev.:
First Encounter 676.6 ft▼
Upon Completion 666.6 ft▽
After ____ **Hrs.** ______ ft

		DEPTH (ft)	BLOWS (/6")	UCS Qu (tsf)	MOIST (%)
9" HMA Shoulder	688.89				
Stiff Black Silty Clay, Fill moist			7		
			4	1.5	15
			4	B	
	685.64		3		
Loose Gray Sand & Gravel, fill moist			2	1.0	10
		-5	2	P	
	684.14				
Medium Stiff Dark Gray Clay Loam, some gravel moist			1		
			1	0.7	20
			1	B	
	681.64				
Soft Blue-Gray and Brown Silty Clay Loam, some gravel moist			1		
			2	0.4	21
		-10	2	B	
	679.14				
Loose Gray Silty Medium Sand, trace gravel moist			2		
			2	-	23
			2		
	676.64▼				
Loose Brown Silty Medium Sand wet			1		
	675.14		2	-	25
Medium Dense Brown/Gray Silt moist		-15	5		
	673.64				
Very Stiff Gray Clay Loam Till			3		
			7	2.9	18
			11	B	
			5		
	670.14		8	2.7	22
Medium Dense Gray Silty Medium	669.64	-20	7	B	

		DEPTH (ft)	BLOWS (/6")	UCS Qu (tsf)	MOIST (%)
Sand w/ layers of silt					
Very Stiff Gray Sandy Clay Loam			6		
			8	2.4	11
			6	B	
	666.64▽				
Medium Dense gray Fine Sand wet			7		
			12	-	22
		-25	14		
	663.14		11		
Very Hard Gray Clay Loam Till moist			15	8.2	10
			17	B	
	661.64				
Dense Gray Fine Sand w/ trace gravel wet			6		
			19	-	20
		-30	12		
	656.64				
Medium Dense Gray Fine Sand wet			7		
			16	-	19
	654.64	-35	10		
End of Boring					
		-40			

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)

SEISMIC SITE CLASS DETERMINATION

I.D.O.T. BBS FOUNDATIONS AND GEOTECHNICAL UNIT

Modified on 12/10/10

PROJECT TITLE=====IL-49 over Drainage Ditch near Armstrong, IL

Substructure 1

Base of Substruct. Elev. (or ground surf for bents)	674	ft.
Pile or Shaft Dia.		inches
Boring Number	SB-1	
Top of Boring Elev.	689.69	ft.

Approximate Fixity Elev. 674 ft.

Individual Site Class Definition:

N (bar):	14	(Blows/ft.)	Soil Site Class E
N_{ch} (bar):	NA	(Blows/ft.)	NA
s_u (bar):	3.83	(ksf)	Soil Site Class C <----Controls

Seismic Soil Column Depth (ft)	Bot. Of Sample Elevation	Sample Thick. (ft.)	N	Qu (tsf)	Layer Description Boundary
	687.2	2.50	6	0.80	B
	684.7	2.50	4	2.00	
	682.2	2.50	5	0.70	B
	679.7	2.50	4	0.80	B
	677.2	2.50	9	2.50	
	674.7	2.50	11	3.70	B
1.8	672.2	2.50	15	2.50	
4.3	669.7	2.50	16	3.30	B
6.8	667.2	2.50	21	2.70	
9.3	664.7	2.50	12	3.30	
11.8	662.2	2.50	34		B
14.3	659.7	2.50	12	4.50	B
16.8	657.2	2.50	12	4.50	B
19.3	654.7	2.50	19	3.00	B
100.0	574.0	80.70	14	4.00	R

Substructure 2

Base of Substruct. Elev. (or ground surf for bents)	674	ft.
Pile or Shaft Dia.	0	inches
Boring Number	SB-2	
Top of Boring Elev.	688.89	ft.

Approximate Fixity Elev. 674 ft.

Individual Site Class Definition:

N (bar):	27	(Blows/ft.)	Soil Site Class D
N_{ch} (bar):	28	(Blows/ft.)	Soil Site Class D <----Controls
s_u (bar):	3.77	(ksf)	Soil Site Class C

Seismic Soil Column Depth (ft)	Bot. Of Sample Elevation	Sample Thick. (ft.)	N	Qu (tsf)	Layer Description Boundary
	688.1	0.75	8	1.50	B
	685.6	2.50	8	1.50	B
	684.1	1.50	4	1.00	B
	681.6	2.50	2	0.70	B
	679.1	2.50	4	0.40	B
	676.6	2.50	4		B
	675.1	1.50	7		B
0.4	673.6	1.50	7		B
2.9	671.1	2.50	18	0.90	
3.9	670.1	1.00	15	2.70	B
4.4	669.6	0.50	15	2.70	B
6.9	667.1	2.50	14	2.40	
7.4	666.6	0.50	26		B
9.9	664.1	2.50	26		
12.4	661.6	2.50	32	8.20	B
14.9	659.1	2.50	31		
17.4	656.6	2.50	31		B
19.9	654.1	2.50	26		B
100.0	574.0	80.10	28	4.00	R

Substructure 3

Base of Substruct. Elev. (or ground surf for bents)		ft.
Pile or Shaft Dia.		inches
Boring Number		
Top of Boring Elev.		ft.

Approximate Fixity Elev. ft.

Individual Site Class Definition:

N (bar):		(Blows/ft.)	NA
N_{ch} (bar):		(Blows/ft.)	NA
s_u (bar):		(ksf)	NA

Seismic Soil Column Depth (ft)	Bot. Of Sample Elevation	Sample Thick. (ft.)	N	Qu (tsf)	Layer Description Boundary

Substructure 4

Base of Substruct. Elev. (or ground surf for bents)		ft.
Pile or Shaft Dia.		inches
Boring Number		
Top of Boring Elev.		ft.

Approximate Fixity Elev. ft.

Individual Site Class Definition:

N (bar):		(Blows/ft.)	NA
N_{ch} (bar):		(Blows/ft.)	NA
s_u (bar):		(ksf)	NA

Seismic Soil Column Depth (ft)	Bot. Of Sample Elevation	Sample Thick. (ft.)	N	Qu (tsf)	Layer Description Boundary

Global Site Class Definition: Substructures 1 through 2

N (bar):	21	(Blows/ft.)	Soil Site Class D <----Controls
N_{ch} (bar):	21	(Blows/ft.)	Soil Site Class D
s_u (bar):	3.8	(ksf)	Soil Site Class C

USGS Design Maps Summary Report

User–Specified Input

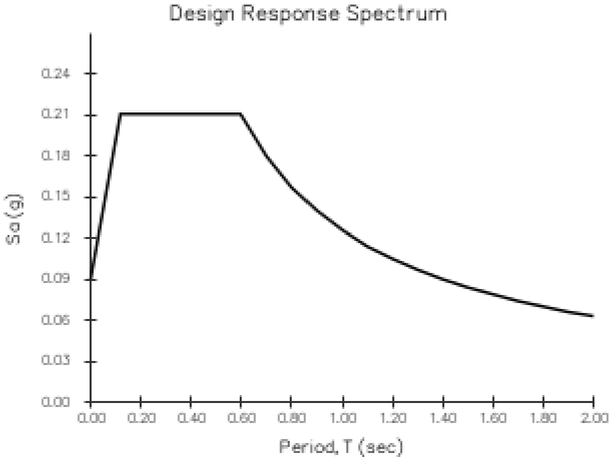
Report Title	SN 092-2045 Box Culvert Tue June 20, 2017 14:38:24 UTC
Building Code Reference Document	2009 AASHTO Guide Specifications for LRFD Seismic Bridge Design (which utilizes USGS hazard data available in 2002)
Site Coordinates	40.30718°N, 87.89178°W
Site Soil Classification	Site Class D – "Stiff Soil"

USGS–Provided Output

PGA = 0.056 g **A_s =** 0.090 g

S_S = 0.132 g **S_{DS} =** 0.211 g

S_1 = 0.052 g **S_{D1} =** 0.126 g



Preliminary Settlement Calculations for Proposed Mill at Boring SB-1

Calculated by Terry McCleary Apri 6/12/17
Revised 12/02/17

For Normally Consolidated Cohesive Soils: **NC**

$$S = \left(\frac{C_c \cdot H}{1+e_o}\right)\log(\frac{P'_o\ +\ \Delta P'}{P'_o})$$

For Overconsolidated Cohesive Soils, CASE I: $\sigma'_{z0} < \sigma'_{zf} \leq \sigma'_c$

$$S = \left(\frac{C_r \cdot H}{1+e_o}\right)\log(\frac{P'_o\ +\ \Delta P'}{P'_o})$$

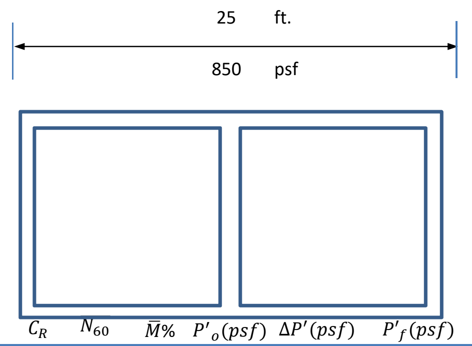
For Overconsolidated Cohesive Soils, CASE II: $\sigma'_{z0} < \sigma'_c \leq \sigma'_{zf}$

$$S = \Sigma\left[\frac{C_r}{1+e_o}\cdot \mathrm{H}\cdot\log\left(\frac{P'_c}{P'_o}\right)+\frac{C_c}{1+e_o}\cdot H\cdot\log\left(\frac{P'_f}{P'_c}\right)\right]$$

For Granular Soils:

$$S = \left(\frac{H}{C'}\right)\log(\frac{P'_o\ +\ \Delta P'}{P'_o})$$

C′is taken from Figure 10.6.2.4.2 *of AASHTO LRFD*



$E_m =$ 80

Water Table = 667 ft.

	Soil Classification from Log	e	$\gamma\ (psf)$	$\bar{Q}_u$ (tsf)	$\bar{N}$	C_b	C_R	N_{60}	$\bar{M}\%$	$P'_o(psf)$	$\Delta P'(psf)$	$P'_f(psf)$	$\overline{N_{1_{60}}}$	C'	$P_c(psf)$	Case #	C_r	C_c	S	C_{vf}	Single	Time with Drainage Double	Expected
677.3																							
			120																				
	V. Stiff Brown Silty Clay	0.405	120	3.1	11	1	0.75	11	15	786.6	673.4273	1460.03	17.5	N/A	2000	I	0.00675	0.045	0.20	1.5	34579.85	8644.96	8644.96
664.19																							
			130																				
	Dense Silty Fine Sand	0.594	67.6	0	32	1	1	42.67	22	1708.4	529.7931	2238.19	46.2	150	N/A	N/A	N/A	N/A	0.04	300	6.51	1.63	1.63
660.19																							
			120																				
	Hard Clay Loam Till	0.432	57.6	4.5	12	1	0.75	12	16	1944.4	484.4961	2428.90	12.2	N/A	5000	I	0.0108	0.072	0.03	1.5	997.25	249.31	249.31
656.69																							
			130																				
	Dense Silty Fine Sand	0.27	67.6	0	32	1	1	42.67	10	2095.9	726.4957	2822.40	41.7	150	N/A	N/A	N/A	N/A	0.02	300	175532.64	43883.16	43883.16
655.19																							
			135																				
	Very Stiff Silty Clay Till	0.351	72.6	5.6	21	1	0.85	23.8	13	3159.007	525.4049	3684.41	18.9	N/A	25454.55	I	0.00405	0.027	0.07	0.471	201666.83	50416.71	50416.71
627.3																							

Not accurate. No Test Data.

🟦 Not Accurate. Grossly Estimated. Not determined from laboratory testing
🟨 Infromation from Consolidation Test Results
▨ Information from Borings Log SB-1
▧ Calculated Data

Sum of Settlement =	**0.35**	**inches**			
Time for 90% of Consolidation =		**min**	**412783.1**	**103195.8**	**103195.8**
		days	**286.7**	**71.7**	**71.7**
		months	**9.6**	**2.4**	**2.4**
		years	**0.8**	**0.2**	**0.2**

This time seems too quick for the amount of settlement. Using the procedure explained in the NAVFAC Manual 7.01 the t90 is greater than 10 years to complete.

e = Void Ratio from Laboratory Test Results
$\gamma'\ (psf)$ = Effective Unit Weight = Unit Weight from Laboratory testing - 62.4 pcf (Unit Wt. of Water)
$\bar{Q}_u$ (tsf) = Average Unconfined Compressive Strength from field RIMAC testing, info found on boring logs
$\bar{N}$ =Average N-value from SPT testing. The N-value is calculated by adding the last two blow counts of an 18" SPT penetration test.
C_b = Borehole Diameter Factor, used in calculating the N_{60} value
C_R = Rod Length Factor, used in calculating the N_{60} value
$\overline{N_{60}}$ =SPT N value corrected for field procedures
$\bar{M}\%$ =Average moisture content
$P'_o(psf)$ = Initial stress on soil at the midpoint of the layer
$\Delta P'(psf)$ = Change in stress in the soil layers below the fill
$P'_f(tsf)$ = Final Pressure
$\overline{N_{1_{60}}}$ = SPT N value corrected for effective stress
C' = Bearing Capacity Index, AASHTO
P_c(psf) = Preconsolidation Pressure
C_r = Recompression Index
C_c = Compression Index
P'_m = Overconsolidation Margin
S = Settlement, inches
C_{vf} = Coefficient of Consolidation at P'_f

Preliminary Settlement Calculations for Proposed Mill at Boring SB-2

Calculated by Terry McCleary 6/12/17
Revised 12/02/17

For Normally Consolidated Cohesive Soils: **NC**

$$S = \left(\frac{C_c \cdot H}{1 + e_o}\right)\log(\frac{P'_o + \Delta P'}{P'_o})$$

For Overconsolidated Cohesive Soils, CASE I: $\sigma'_{z0} < \sigma'_{zf} \le \sigma'_c$

$$S = \left(\frac{C_r \cdot H}{1 + e_o}\right)\log(\frac{P'_o + \Delta P'}{P'_o})$$

For Overconsolidated Cohesive Soils, CASE II: $\sigma'_{z0} < \sigma'_c \le \sigma'_{zf}$

$$S = \Sigma\left[\frac{C_r}{1 + e_o} \cdot \mathrm{H} \cdot \log\left(\frac{P'_c}{P'_o}\right) + \frac{C_c}{1 + e_o} \cdot H \cdot \log\left(\frac{P'_f}{P'_c}\right)\right]$$

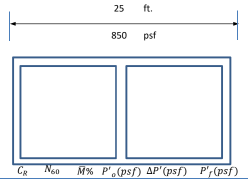
For Granular Soils:

$$S = \left(\frac{H}{C'}\right)\log(\frac{P'_o + \Delta P'}{P'_o})$$

C' *is taken from Figure* 10.6.2.4.2 *of AASHTO LRFD*

$E_m =$ 80

Water Table = 667 ft.



	Soil Classification from Log																				Time with Drainage		
677.3		e	$\gamma\ (psf)$	$\bar{Q}_u$ (tsf)	$\bar{N}$	C_b	C_R	N_{60}	$\bar{M}\%$	$P'_o(psf)$	$\Delta P'(psf)$	$P'_f(psf)$	$\overline{N_{1_{60}}}$	C'	$P_c(psf)$	Case #	C_r	C_c	S	C$_{vf}$	Single	Double	Expected
	Dense Silty Fine Sand	0.675	100 100	0	7	1	1	9.333	25	185	791.4339	976.43	30.7	150	N/A	N/A	N/A	N/A	0.21	300	186723.61	46680.90	46680.90
673.6																							
	Hard Clay Loam Till	0.459	120 57.6	4.5	16	1	0.75	16	17	560.08	664.0625	1224.14	30.2	N/A	2000	I	0.00945	0.063	0.17	1.5	3546.13	886.53	886.53
667																							
	Dense Silty Fine Sand	0.594	130 67.6	0	26	1	1	34.67	22	881.98	633.383	1515.36	52.2	150	N/A	N/A	N/A	N/A	0.07	300	6.19	1.55	1.55
663.1																							
	Very Stiff Silty Clay Till	0.27	135 72.6	5.6	32	1	0.85	36.27	10	1068.25	716.6948	1784.94	49.6	N/A	25454.55	I	0	0	0.00	0.471	113997543.53	28499385.88	28499385.88
661.6																							
	Dense Silty Fine Sand	0.54	130 67.6	0	26	1	1	34.67	20	1224.1	758.9286	1983.03	44.3	150	N/A	N/A	N/A	N/A	0.05	300	3.66	0.92	0.92
658.6																							

Not accurate. No Test Data.

$$S = \left(\frac{H}{C'}\right)\log(\frac{P'_o + \Delta P'}{P'_o})$$

🟦	Not Accurate. Grossly Estimated. Not determined from laboratory testing
🟨	Infromation from Consolidation Test Results
▨	Information from Borings Log SB-1
▨	Calculated Data

Sum of Settlement =	**0.51**	**inches**			
Time for 90% of Consolidation =		**min**	**114187823.1**	**28546955.8**	**28546955.8**
		days	**79297.1**	**19824.3**	**19824.3**
		months	**2643.2**	**660.8**	**660.8**
		years	**220.3**	**55.1**	**55.1**

This time seems too quick for the amount of settlement. Using the procedure explained in the NAVFAC Manual 7.01 the t90 is greater than 10 years to complete.

e = Void Ratio from Laboratory Test Results
$\gamma'\ (psf)$ = Effective Unit Weight = Unit Weight from Laboratory testing - 62.4 pcf (Unit Wt. of Water)
$\bar{Q}_u$ (tsf) = Average Unconfined Compressive Strength from field RIMAC testing, info found on boring logs
$\bar{N}$ =Average N-value from SPT testing. The N-value is calculated by adding the last two blow counts of an 18" SPT penetration test.
C_b = Borehole Diameter Factor, used in calculating the N_{60} value
C_R = Rod Length Factor, used in calculating the N_{60} value
$\overline{N_{60}}$ =SPT N value corrected for field procedures
$\bar{M}\%$ =Average moisture content
$P'_o(psf)$ = Initial stress on soil at the midpoint of the layer
$\Delta P'(psf)$ = Change in stress in the soil layers below the fill
$P'_f(tsf)$ = Final Pressure
$\overline{N_{1_{60}}}$ = SPT N value corrected for effective stress
C' = Bearing Capacity Index, AASHTO
P_c(psf) = Preconsolidation Pressure
C_r = Recompression Index
C_c = Compression Index
P'_m = Overconsolidation Margin
S = Settlement, inches
C$_{vf}$ = Coefficient of Consolidation at P'$_f$