ORX SECTION 3 – GEOTECHNICAL SEISMIC DESIGN CHALLENGES

Presented by:

Scott T. Roosa, PE – SME

SME

INTRODUCTION - BIO

SCOTT T. ROOSA, PE

Scott has more than 20 years of experience providing geotechnical engineering services and is a registered engineer in Indiana and Michigan. His experience and expertise includes work focused primarily on publicly funded transportation projects with geotechnical involvement ranging from bridge foundations, earthen embankments, earth retention systems, dams, slide corrections, and pavement design. Scott has experience performing pressuremeter and pile driving analyzer (PDA) testing, as well as installing and monitoring geotechnical instrumentation for transportation and tunneling projects. Scott has split his career between Indiana and Michigan, and has spent most of the last 10 to 12 years focusing on design-build projects.

Scott is a graduate of Michigan Technological University in Houghton, Michigan, and resides in Kalamazoo, Michigan, with his wife and two children.

OUTLINE

- Project Team and Overview
- Pursuit Phase
  - Performance criteria and design requirements
  - RID subsurface information and geotechnical baseline report.
- Design Phase
  - Supplemental geotechnical information
  - Iterative design
  - Collaboration with INDOT team
- Construction
  - Static uplift test + PDA
  - Pile evaluation throughout construction

ORX 69 OHIO RIVER CROSSING

PROJECT TEAM

INDOT

HNTB, PARSONS, TERRACON

ORX CONSTRUCTORS

WALSH CONSTRUCTION

TRAYLOR BROS. CONSTRUCTION

AMERICAN STRUCTUREPOINT

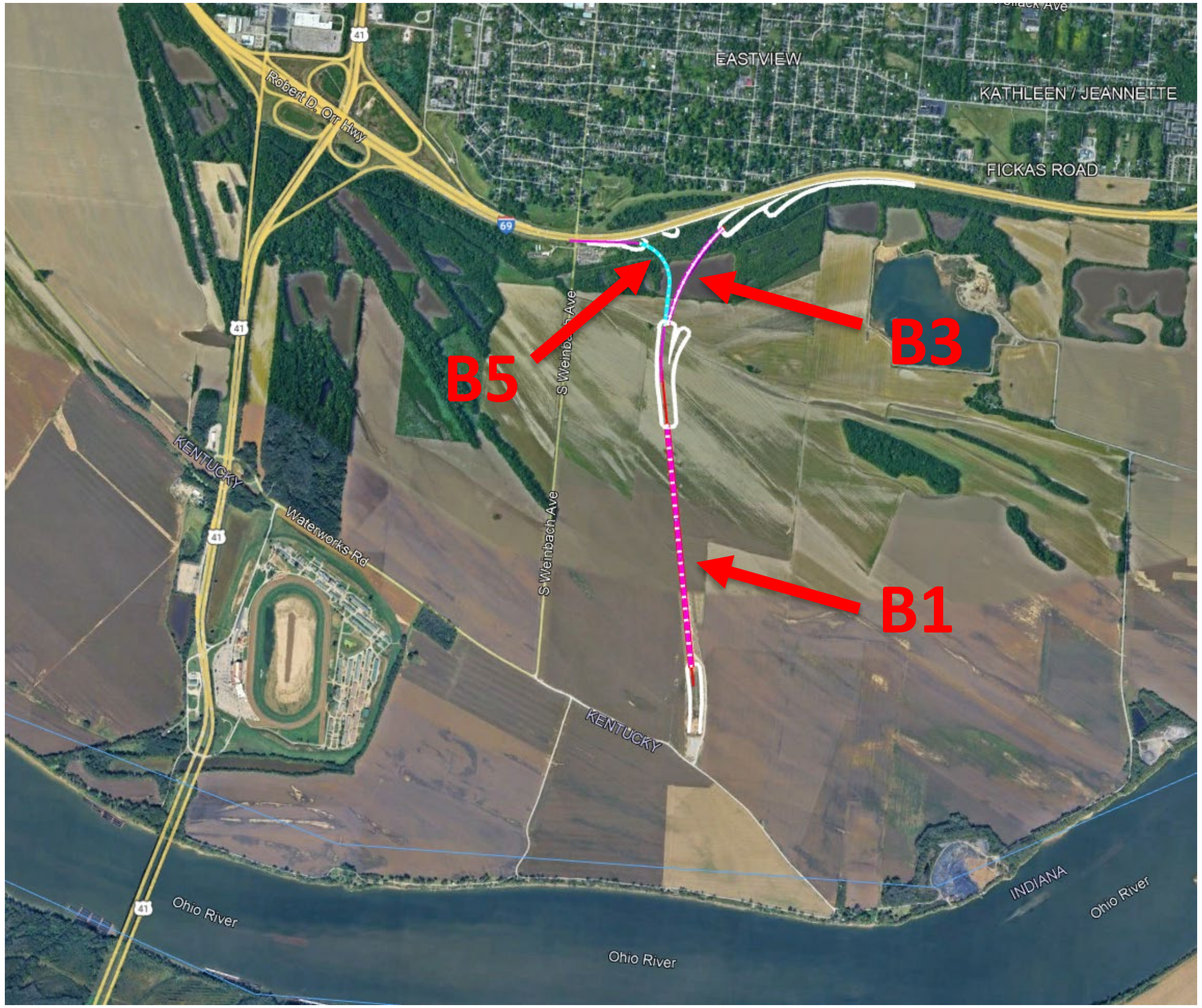
JACOBS ENGINEERING

SME

PROJECT

- APPROXIMATELY $200M DESIGN-BUILD
  - Early meetings in April 2023
  - Pursuit from June to November 2023
  - Letting November 2023

- BRIDGES 1, 3, & 5
  - BRIDGE 1 – SB I-69 OVER FLOODPLAIN
    - 21* SPANS – ABOUT 4,000 FT LONG
  - BRIDGE 3 – SB I-69 OVER EAGLE CREEK
    - 12 SPANS – ABOUT 1,800 FT LONG
  - BRIDGE 5 – EB VMP TO SB I-69
    - 11 SPANS – ABOUT 1,700 FT LONG



DESIGN PERFORMANCE CRITERIA

HIGHLIGHTS

- Section 3 construction complete in time to facilitate Section 2
- No pavement in Section 3*
- Seismic – Excerpt from Contract Documents:

a. Design shall have the following general performance requirements:

b. 1,000-yr event. The structures shall resist earthquake loads with only minor damage and remain open to traffic with only minimal inspections and/or repairs; and;

c. 2,500-yr event. The structures may be subject to significant (but repairable damage) but shall be available to emergency/security vehicles immediately and re-opened for public use within a few months after repairs have been completed

RID GEOTECHNICAL INFORMATION

Geotechnical Data Report

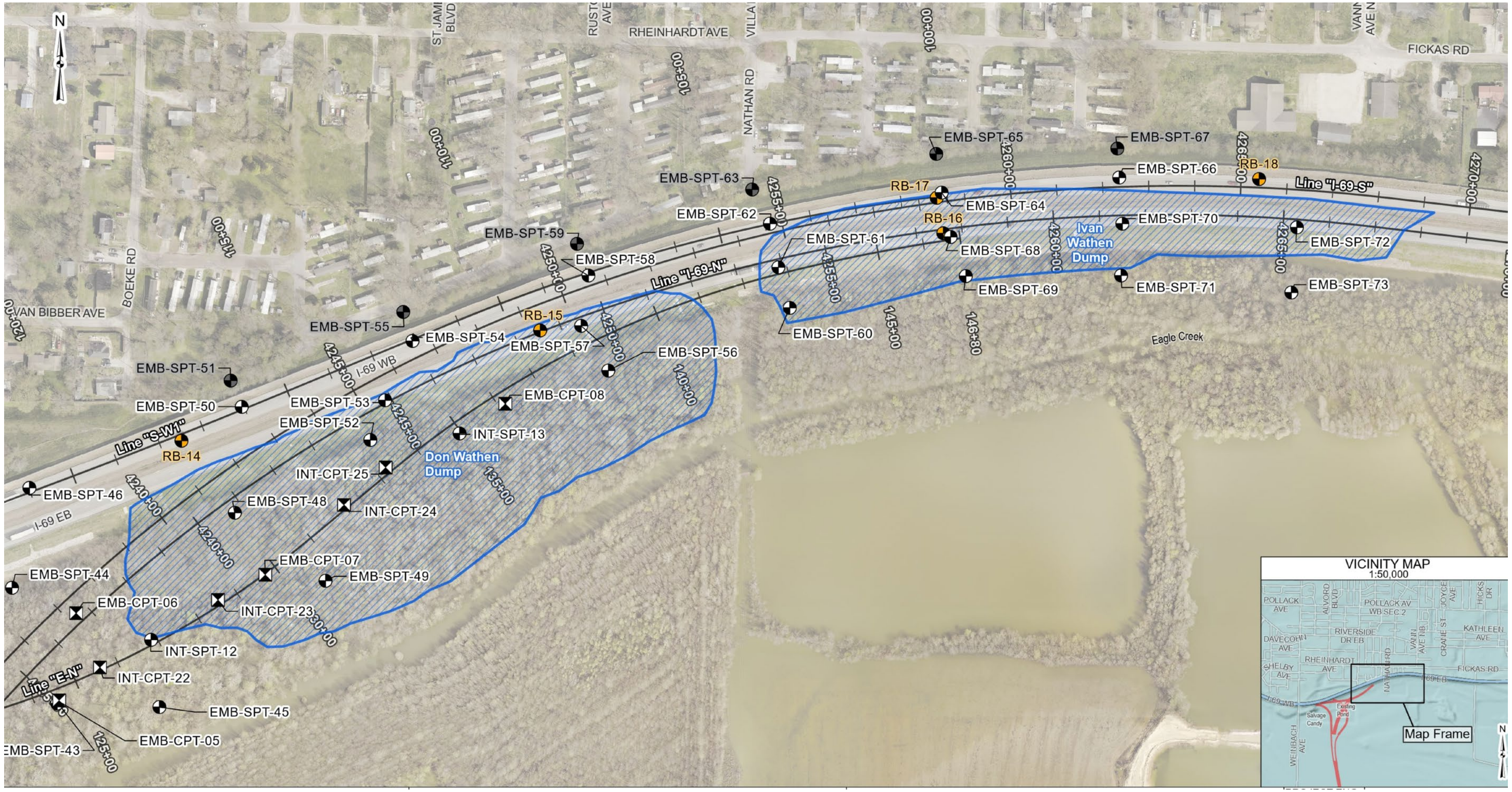
- <u>Summary</u> of subsurface information obtained including:
  - SPT/CPT Borings at most proposed bents/piers and islands;
  - Geophysical testing including MASW and refraction profiles; and
  - Laboratory testing

RID GEOTECHNICAL BASELINE REPORT

Geotechnical Baseline Report (GBR)

- Intended to establish contractual baseline for anticipated ground conditions. Document included:
  - Site-specific seismic response spectra;
  - Liquefaction considerations for design – spreading + settlement;
  - Static and seismic loading conditions for global stability analyses;
  - Design and testing requirements for deep foundations (UPLIFT!)
  - Anticipated outline of former urban landfill

GEOTECHNICAL BASELINE REPORT



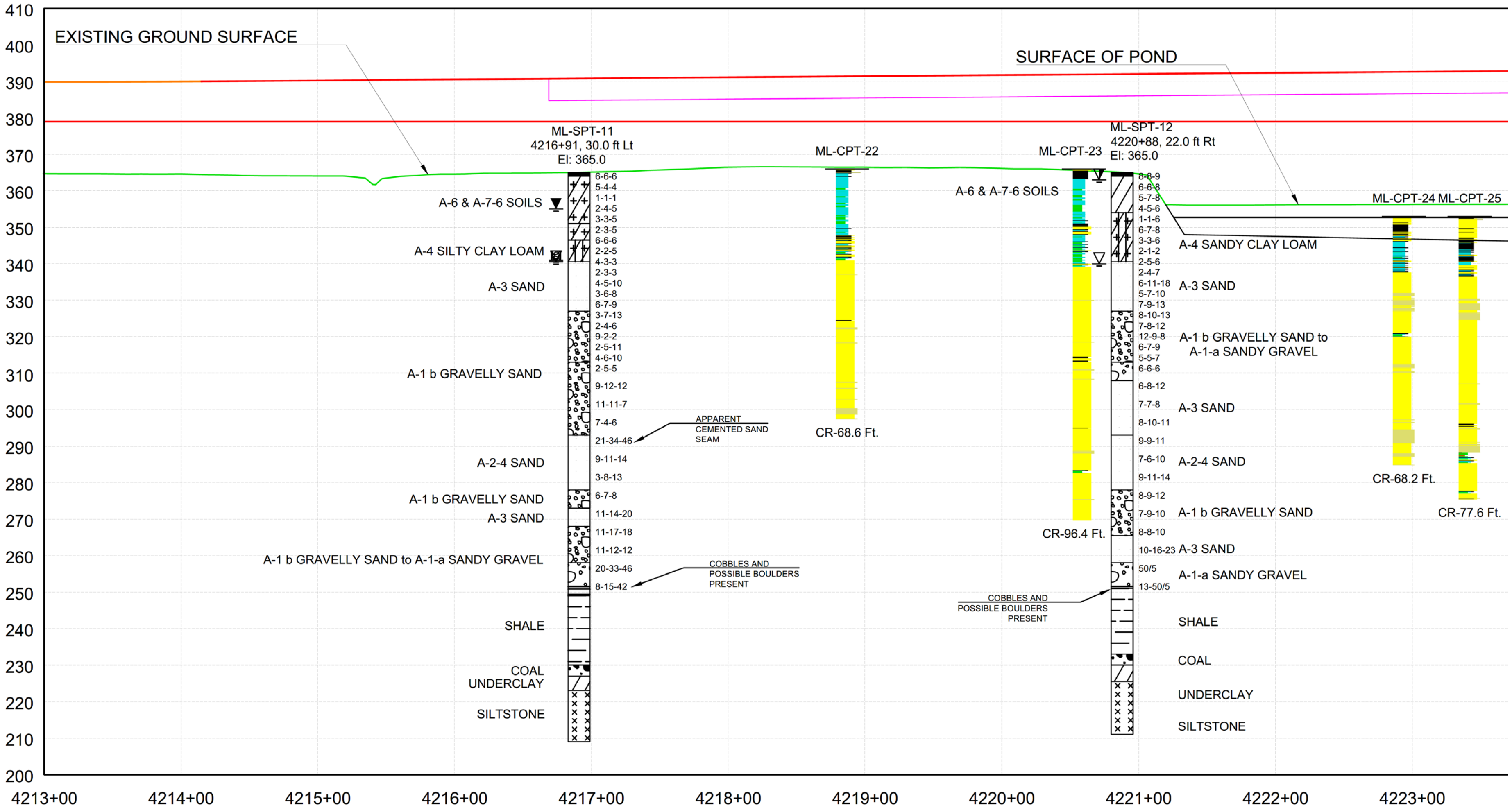
Excerpt from GBR depicting urban landfill limits near existing VMP

Table 6.3.2.1: Summary of Embankment Seismic Stability Performance

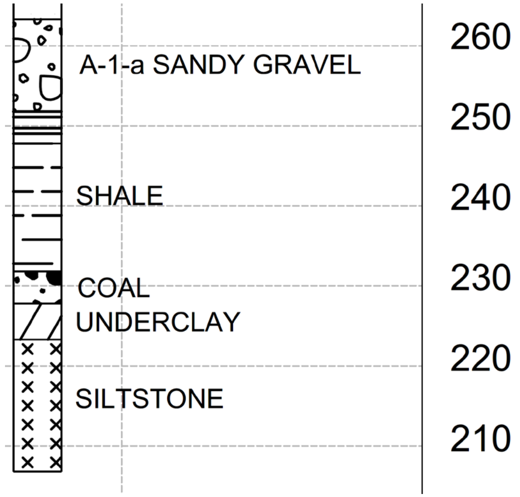
Embankment	Station[1]	Location	A_s (2,500-yr)[2]	S_{D1}[3]	H (ft)[4]	α[5]	$0.5\alpha A_s$[6]	FS[7]	k_y[8]	Disp. (in.)[9]	Disp. 84% Confidence (in.)[10]	Shake Avg Disp. (in.)[11]	Shake Disp. 84% Confidence (in.)[12]
South	4151+00	Bridges 1 & 2 South Abutments	0.394	0.342	22	0.868	0.171	0.8	0.094	4.0	7.9	1.4	1.9
Middle	4205+00	Bridges 1 & 2 North Abutments & Bridges 3 & 4 South Abutments	0.428	0.331	26	0.841	0.180	0.8	0.089	4.4	8.7	1.6	2.1
North	4235+00	Bridges 3 & 4 North Abutments	0.439	0.363	30	0.827	0.182	0.8	0.107	3.5	7.1	0.6	0.9
E-N Ramp	135+50[13]	Bridge 7 East Abutment	0.451	0.316	26	0.831	0.187	0.9	0.141	1.6	3.1	1.3	1.7
Pond Bank[14]	4221+00	Underneath Bridges 3 & 4	0.467	0.261	(19)[15]	N/A[16]	0.234	1.0	0.234	0.4	0.7	Negligible	Negligible
E-S Ramp	110+00	Bridge 5 West Abutment	0.439	0.363	39	0.771	0.169	0.9	0.114	2.8	5.6	0.8	1.0

[1]Along I-69 Mainline unless otherwise noted
[2]Peak Ground Acceleration for a 2,500-yr seismic event
[3]Spectral response acceleration parameter at 1 sec
[4]Max embankment or slope height
[5]Embankment height reduction factor (GEC 3 Eq 6-3)
[6]Seismic load coefficient used in pseudo static analysis assuming 1 to 2 in. of permanent displacement are permissible
[7]Factor of safety resulting from pseudo static analysis. If 1.1 or greater, the embankment meets seismic stability requirements without further analysis
[8]Seismic acceleration coefficient where factor of safety in pseudo static analysis is 1.0 (used to calculate displacement)
[9]Estimated permanent seismic displacement in the down slope direction from GEC 3 Eq 6-7
[10]Estimated displacement at the 84% confidence level (twice the estimated displacement)
[11]Estimated permanent seismic displacement from SHAKE Newmark analysis. Average of 14 different time histories
[12]Estimated displacement from SHAKE analysis at the 84% confidence level. Average plus standard deviation
[13]Along E-N Ramp, near Mainline Station 4245+00
[14]Not an embankment, but the slope at the pond underneath Bridges 3 & 4
[15]Height of slope neglecting sediment at the bottom of the pond
[16]Not used for existing slopes or embankments less than 20 ft in height

GEOTECHNICAL BASELINE REPORT



TYPICAL ROCK PROFILE:
10-15 FT OF SOFT SHALE
3-5 FT OF COAL
2-5 FT OF "UNDERCLAY"
HARD SILTSTONE

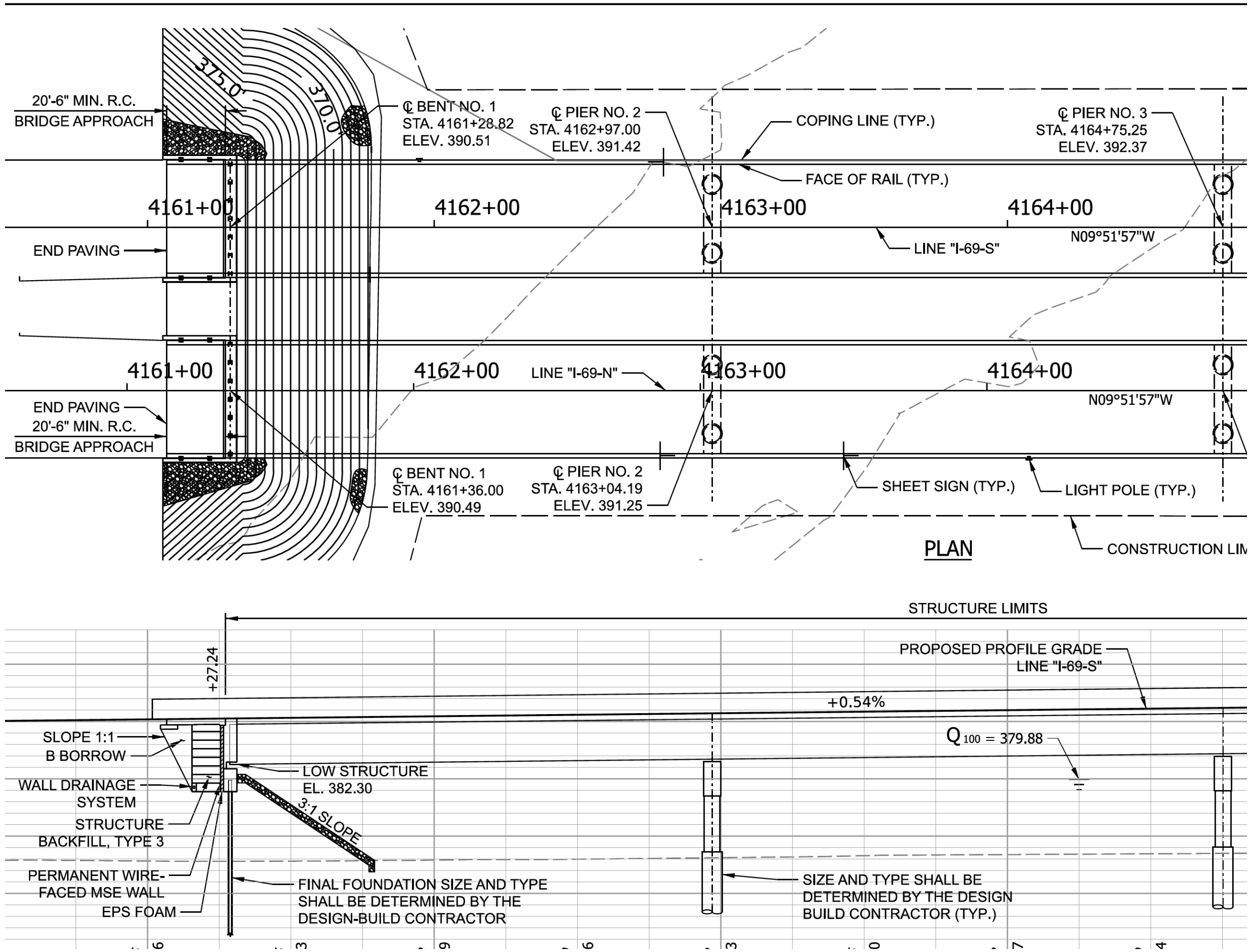


Excerpt from GBR depicting subsurface profile at Bridge 3

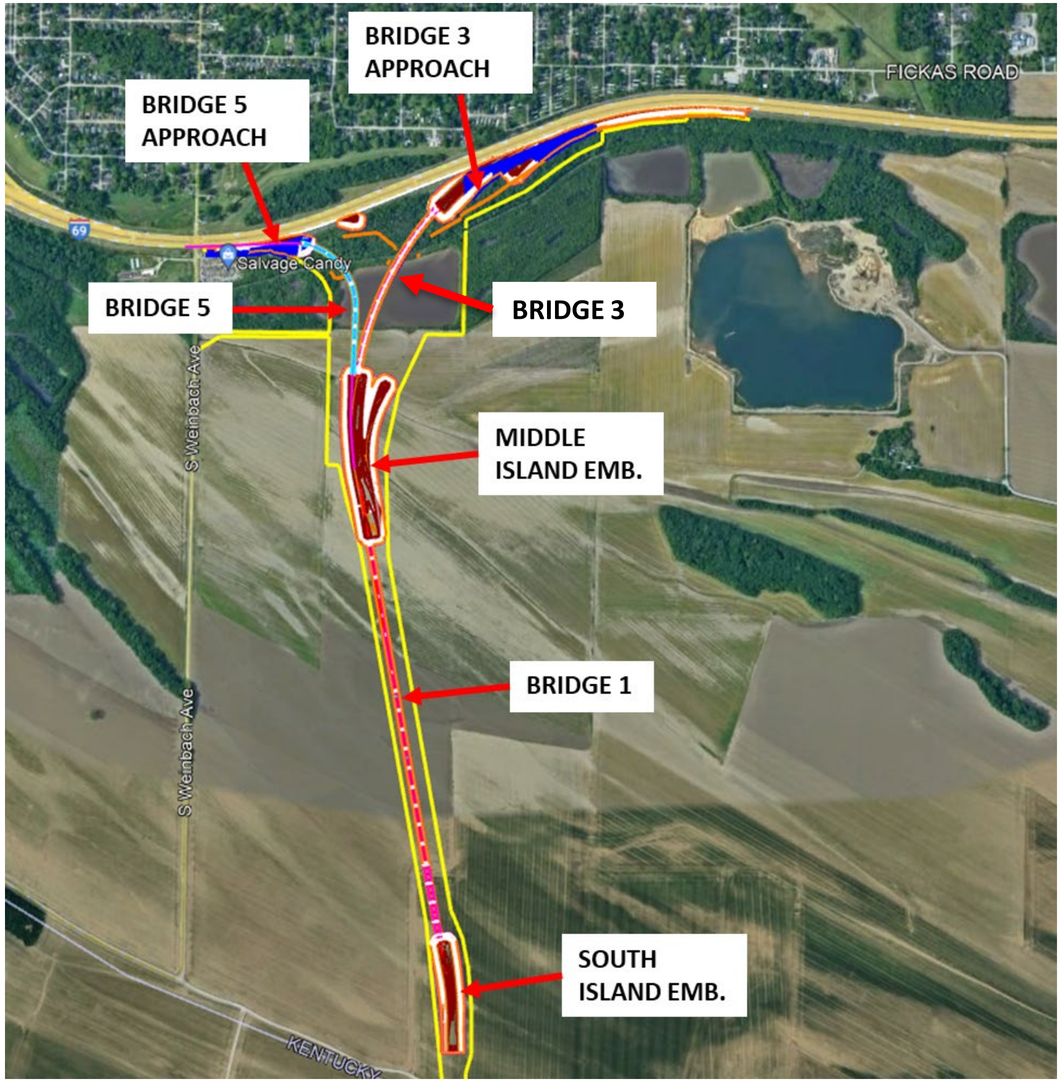
PURSUIT PHASE

PILES OR SHAFTS?!?

Photo by Traylor Bros.



CONGRATULATIONS – YOU'RE BEHIND!



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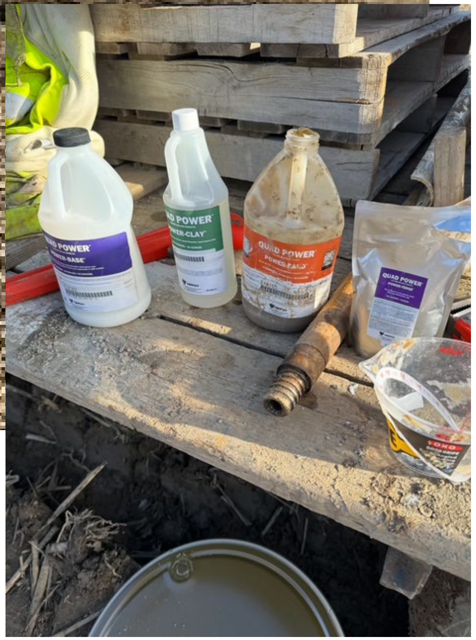


COLLABORATION

DESIGN-BUILD TEAM AND INDOT TEAM WORKING TOGETHER

- Design "over the shoulder" reviews
- From Geotech perspective, started with subsurface investigation plans
  - Intent was to include design rationale and assumptions with early subsurface plans to begin dialogue between teams.

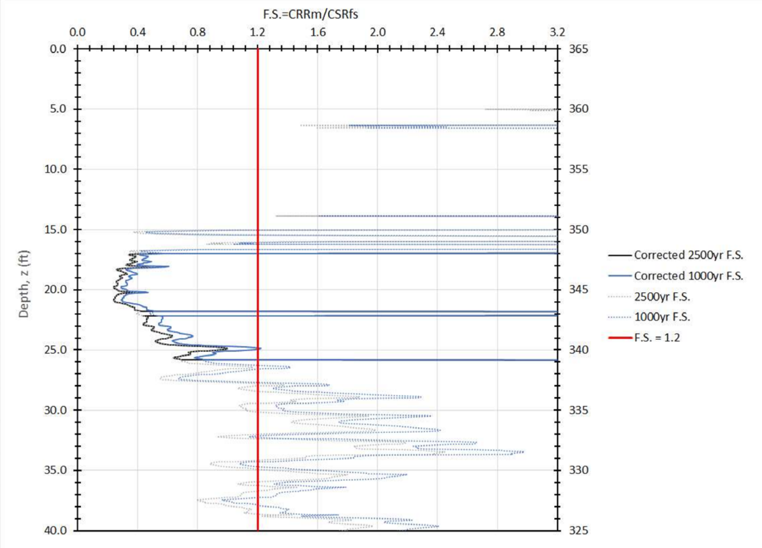
KEY GEOTECHNICAL ELEMENTS

- Settlement – No Pavement!
- Liquefaction determination – Performance criteria
- Global stability analyses
- Deep foundation analyses – static and seismic conditions – 18-in. SEC Pipes
- Uplift

LIQUEFACTION DETERMINATION

Liquefaction Potential and Settlement

- Designation: Bridge 3 Pier 2
- Station: Line "I-69" 4218+04
- CPT: ML-SCPT-09
- SPT: TB302
- 2500 year Event: Magnitude, MW = 6.47, Peak Ground Acceleration, PGA = 0.439
- 1000 year Event: Magnitude, MW = 6.58, Peak Ground Acceleration, PGA = 0.345
- Elevation: 365 ft
- Ground Water Table: 360 ft
- Surcharge Height: 0 ft



Liquefiable Layer based on Factor of Safety

Summary of Liquefiable Layer

Event	Liquefiable Layer Thickness	Depth	Elevation	Liquefaction Settlement
	ft	ft	ft	inch
2500 year	9.0	17.0-26.0	348-339	2.0-4.0
1000 year	9.0	17.0-26.0	348-339	2.0-4.0

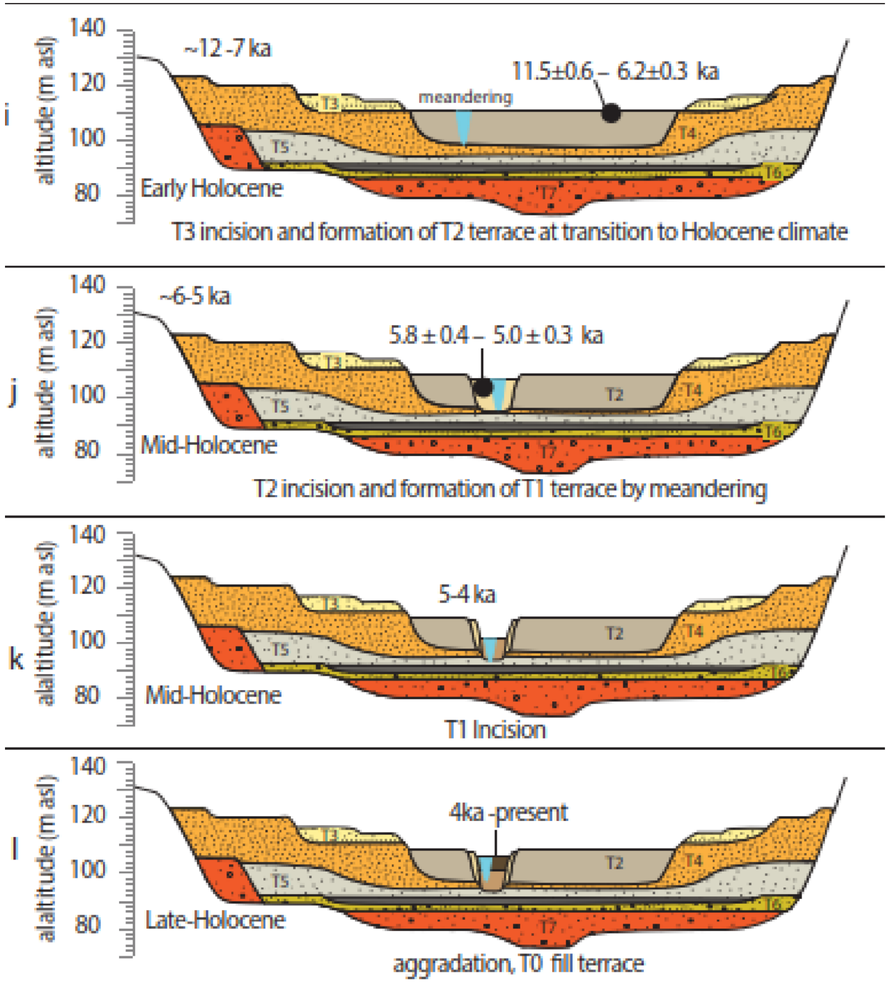
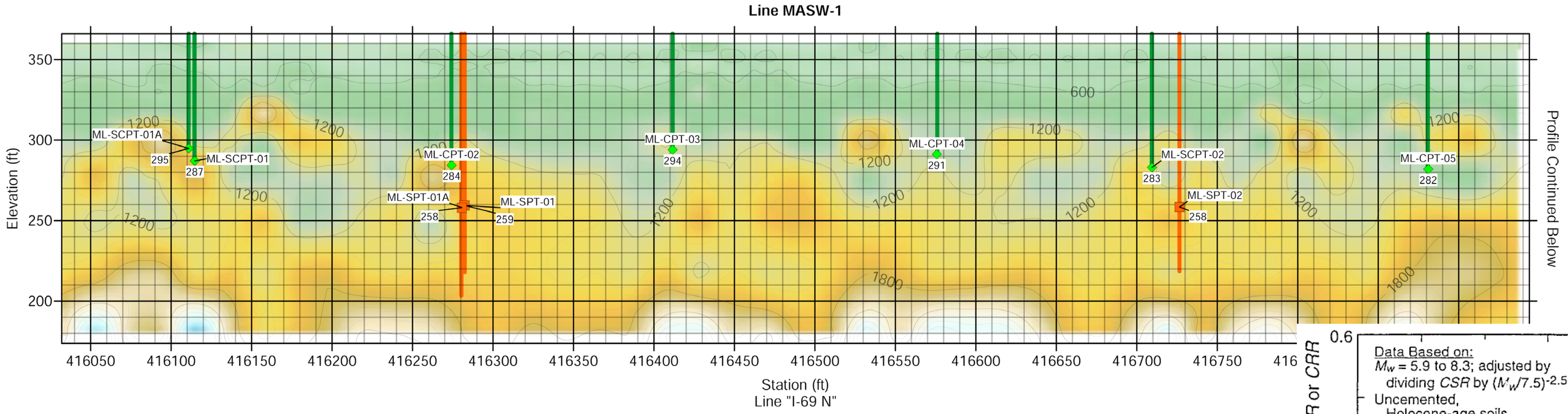
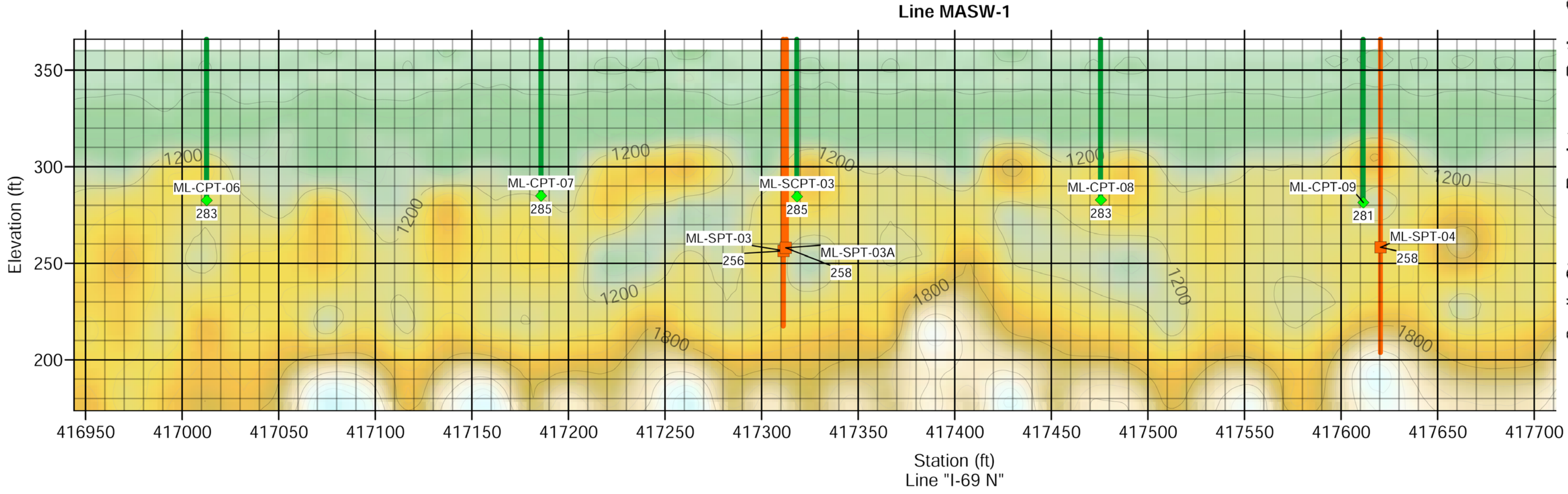
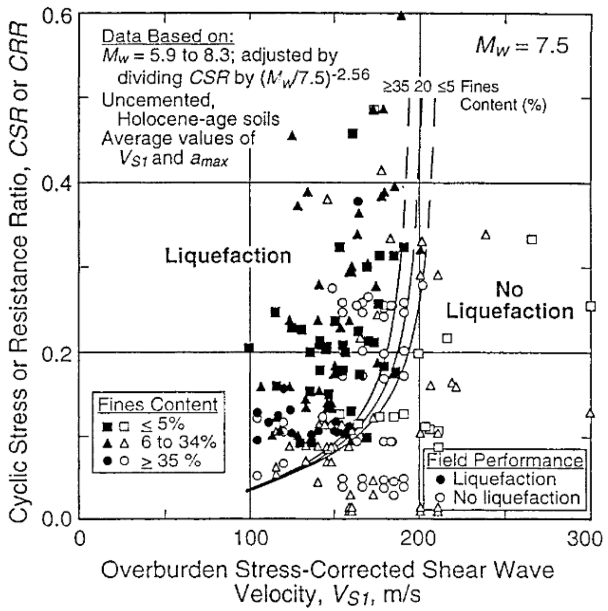


Image 2: Terrace development over the past 22,000 years, from Counts, et all (2004)

LIQUEFACTION DETERMINATION

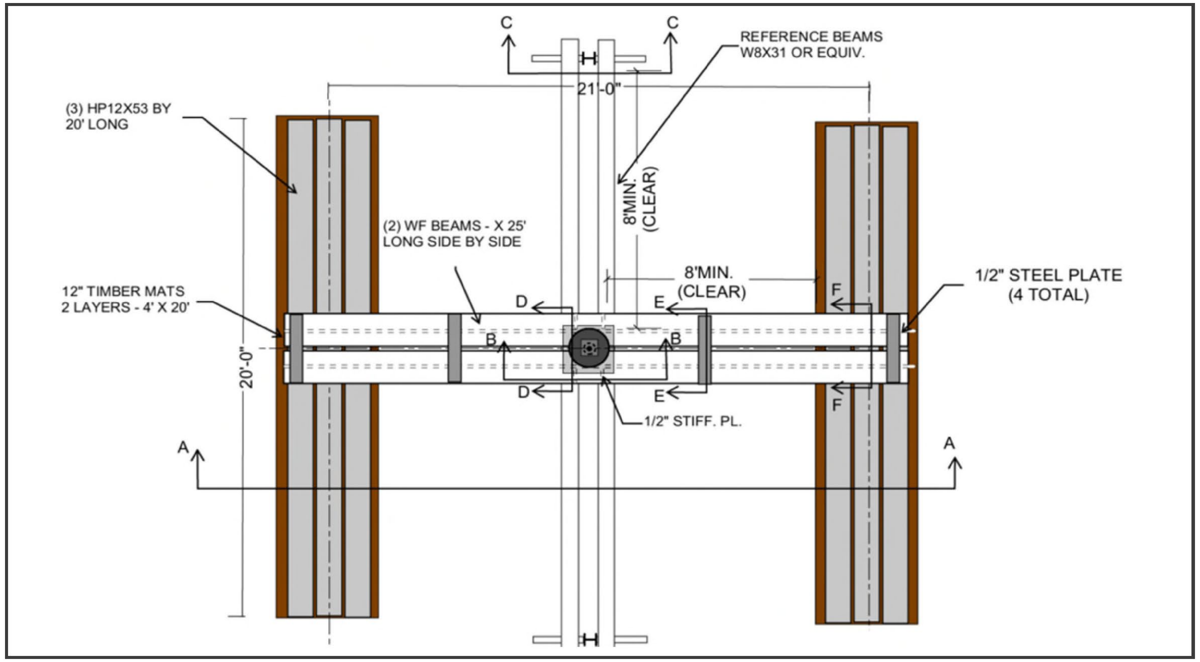


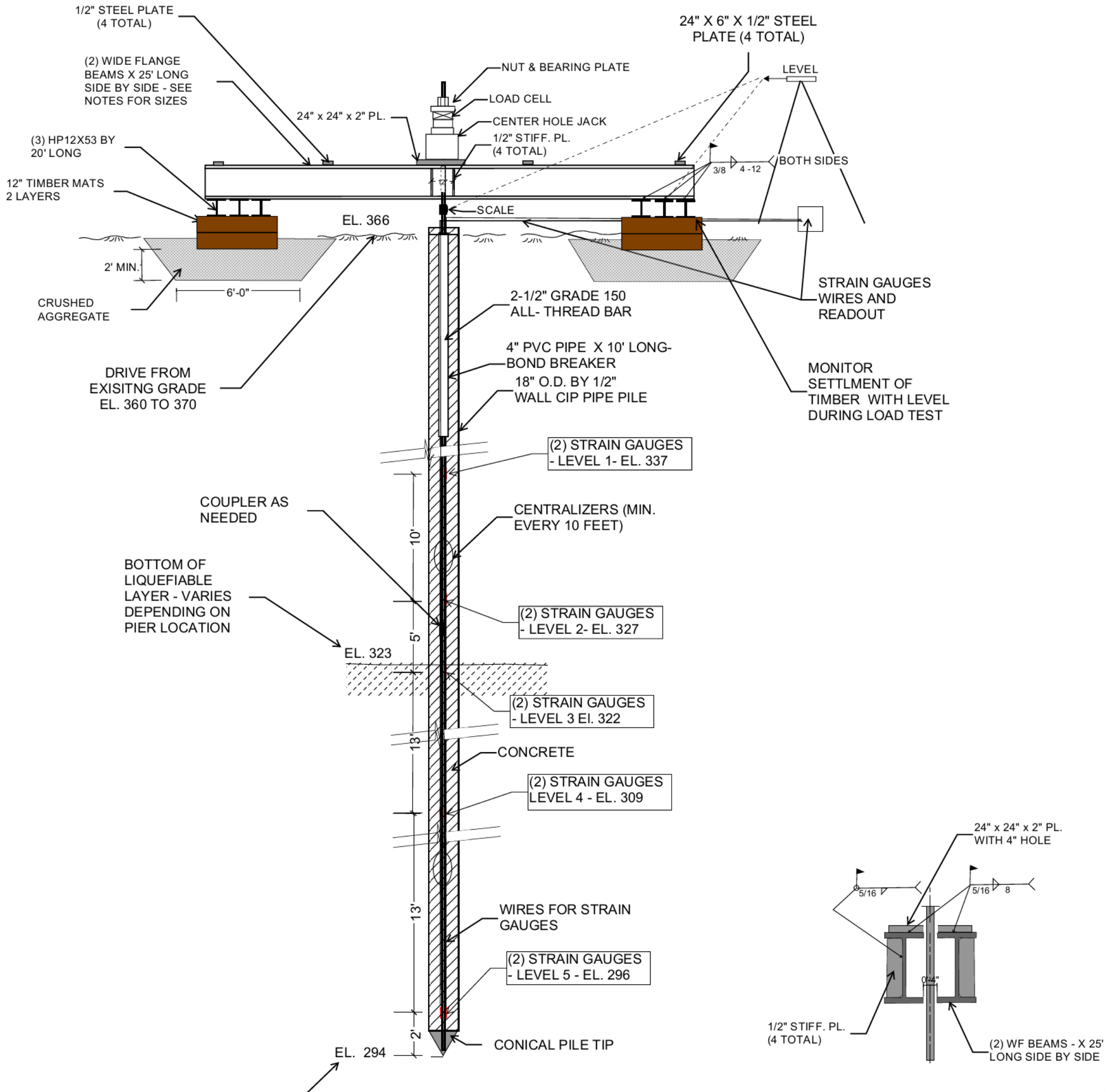




ANDRUS AND STOKOE 2000

UPLIFT TESTING

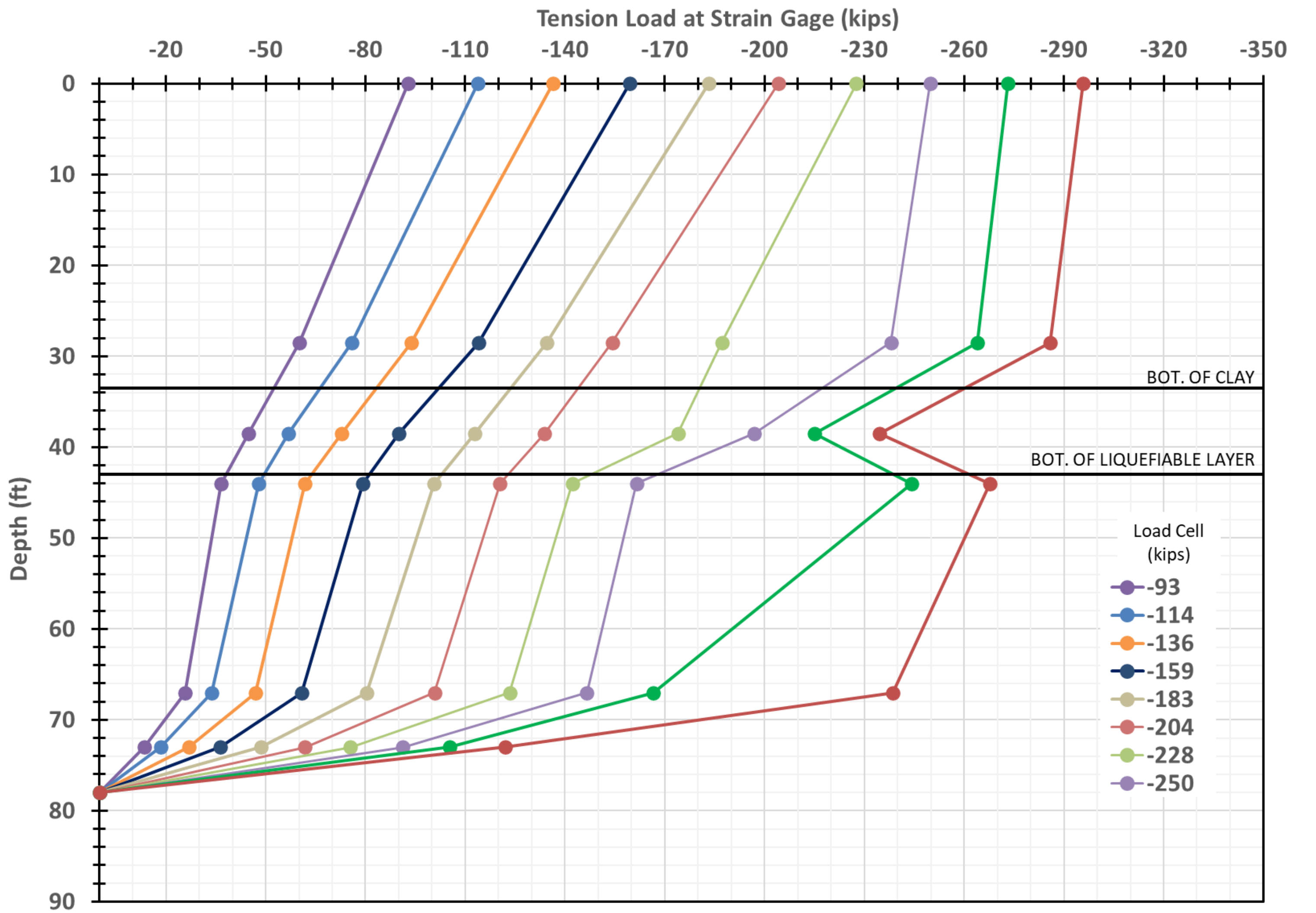




SECTION D-D DETAIL
1/2" = 1'-0"

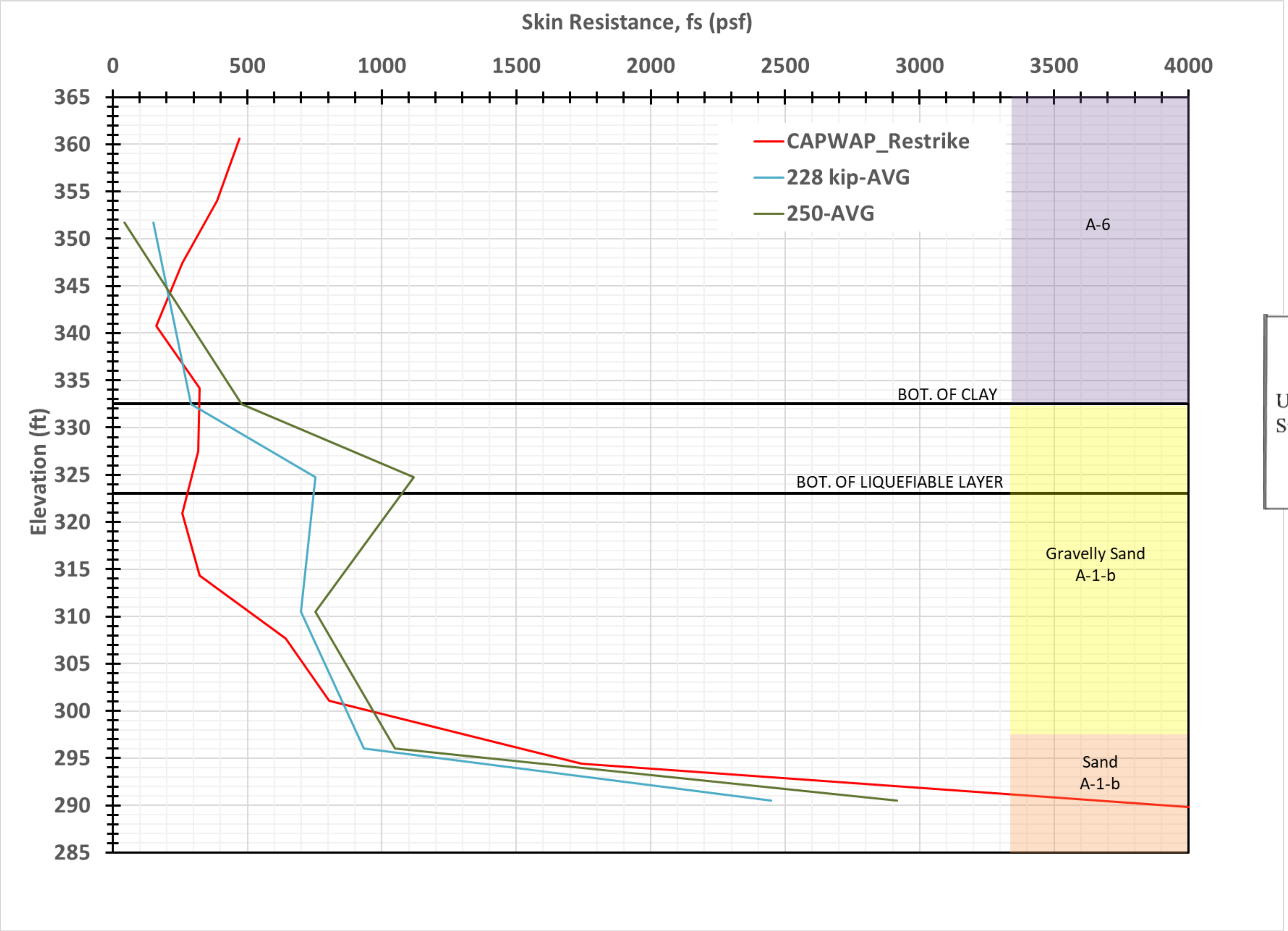
UPLIFT TESTING

UPLIFT TESTING



*Strain corrected for cracked concrete at an applied load of -250, -273, and -296 kips

UPLIFT TESTING



Uplift Resistance of Single Piles, φ_{up}	Nordlund Method	0.35
	α-method	0.25
	β-method	0.20
	λ-method	0.30
	SPT-method	0.25
	CPT-method	0.40
	Static load test	0.60
	Dynamic test with signal matching	0.50

PILE DRIVING AND ANALYSIS

Bent	No.5		No.6		No.7		No.8	
Pile Size, Type & Grade	18"x1/2" Pipe Pile, Gr. 50		18"x5/8" Pipe Pile, Gr. 50		18"x5/8" Pipe Pile, Gr. 50		18"x5/8" Pipe Pile, Gr. 50	
Case	Static	Seismic	Static	Seismic	Static	Seismic	Static	Seismic
Permanent Pile Load (Q) - Service (kips)	N/A		N/A		N/A		N/A	
Factored Design Load, Q_p (kip)	253	303	253	311	163	303	214	312
Factored Design Soil Resistance, R_r (kips)	253	303	253	311	163	303	214	312
Resistance Factor, φ_{dyn}	0.7	1.0	0.7	1.0	0.7	1.0	0.7	1.0
Nominal Soil Resistance, R_n (kips)	365	303	365	311	235	303	310	312
Scour Zone Friction, $R_{s\,scour}$ (kips)	29	N/A	35	N/A	38	N/A	37	N/A
Est. Skin Resistance at Btm. Of Liquefiable Soil (ft)	N/A	38	N/A	53	N/A	58	N/A	55
Nominal Driving Resistance, R_{ndr} (kips)	394	341	400	364	273	361	347	367
Factored Uplift (kips)	41	157	42	160	N/A	164	N/A	142
Uplift Resistance Factor	0.5	0.8	0.5	0.8	N/A	0.8	N/A	0.8
Nominal Soil Resistance, $R_{n\text{-}uplift}$ (kip)	82	197	84	200	N/A	205	N/A	178
Nominal Drag Load (kips)(DL)	N/A	38	N/A	53	N/A	58	N/A	55
Estimated Pile Tip Elevation (ft.)	277		276		281		282	
Testing Method	Standard Specifications Section 701.05(b)							

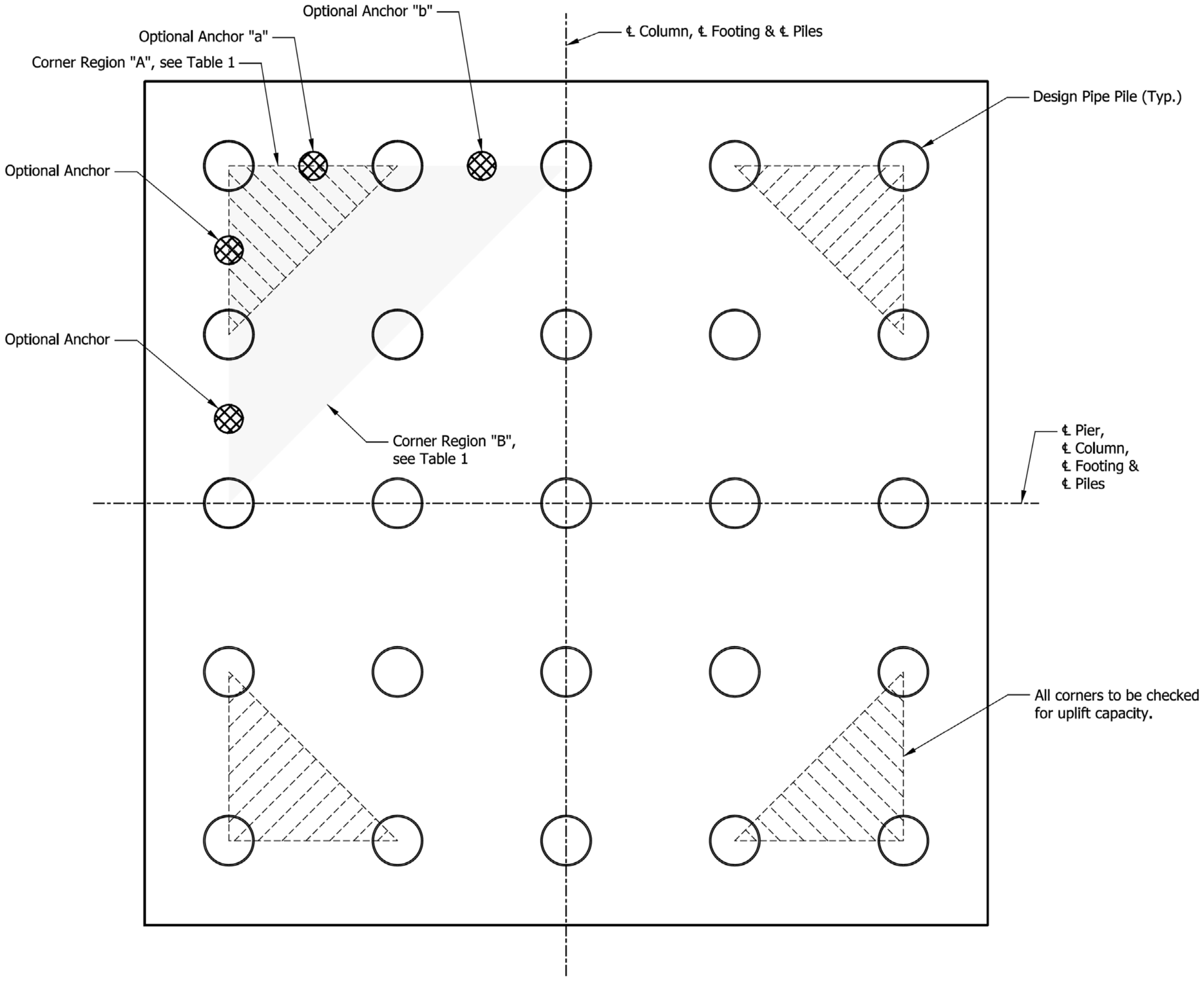
Bent	No.9		No.10		No.11		No.12	
Pile Size, Type & Grade	18"x5/8" Pipe Pile, Gr. 60		18"x5/8" Pipe Pile, Gr. 50		18"x5/8" Pipe Pile, Gr. 50		18"x1/2" Pipe Pile, Gr. 50	
Case	Static*	Seismic**	Static*	Seismic**	Static*	Seismic**	Static	Seismic
Permanent Pile Load (Q) - Service (kips)	N/A		N/A		N/A		201	
Factored Design Load, Q_p (kip)	266	518	249	413	249	406	357	267
Factored Design Soil Resistance, R_r (kips)	266	518	249	413	249	406	357	267
Resistance Factor, φ_{dyn}	0.7	1.0	0.7	1.0	0.7	1.0	0.7	1.0
Nominal Soil Resistance, R_n (kips)	380	518	360	413	360	406	510	267
Scour Zone Friction, $R_{s\,scour}$ (kips)	35	N/A	48	N/A	47	N/A	N/A	N/A
Est. Skin Resistance at Btm. Of Liquefiable Soil (ft)	N/A	62	N/A	46	N/A	51	N/A	41
Nominal Driving Resistance, R_{ndr} (kips)	415	580	408	459	407	457	510	308
Factored Uplift (kips)	N/A	115	11	70	11	105	N/A	N/A
Uplift Resistance Factor	N/A	0.8	0.5	0.8	0.5	0.8	N/A	N/A
Nominal Soil Resistance, $R_{n\text{-}uplift}$ (kip)	N/A	144	22	88	22	132	N/A	N/A
Nominal Drag Load (kips)(DL)	N/A	62	N/A	46	N/A	51	147	41
Estimated Pile Tip Elevation (ft.)	260		281		282		264	
Testing Method	Standard Specifications Section 701.05(b)							

* Static loads consider the application of post tensioning force and construction sequence of soil anchor application. Controlling strength leve design loads are reported in all cases where pretensioning does not control.

** Seismic Loads include load sharing with soil anchors and corner pile group effects. See Sheet 101 for load sharing details.

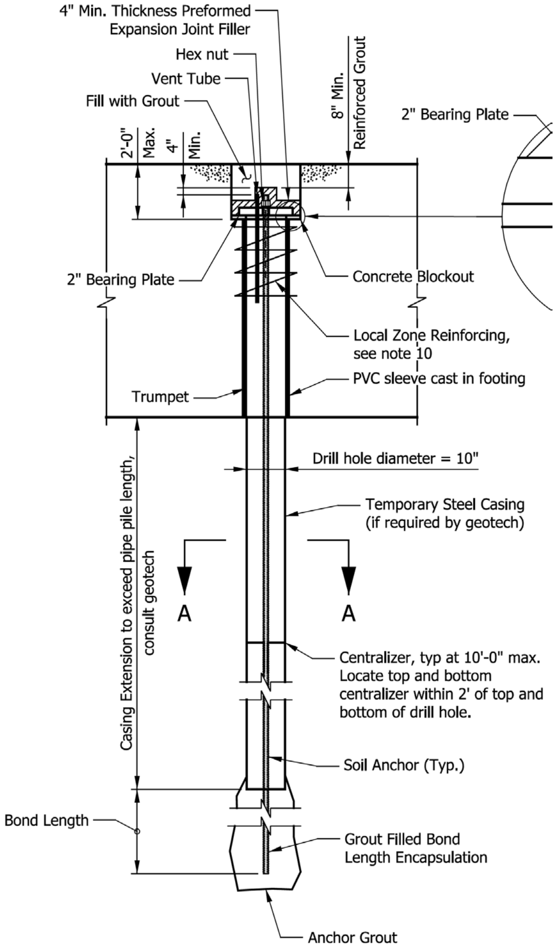
Bent	No.9	
Pile Size, Type & Grade	18"x5/8" Pipe Pile, Gr. 60	
Case	Static*	Seismic**
Permanent Pile Load (Q) - Service (kips)	N/A	
Factored Design Load, Q_p (kip)	266	518
Factored Design Soil Resistance, R_r (kips)	266	518
Resistance Factor, φ_{dyn}	0.7	1.0
Nominal Soil Resistance, R_n (kips)	380	518
Scour Zone Friction, $R_{s\,scour}$ (kips)	35	N/A
Est. Skin Resistance at Btm. Of Liquefiable Soil (ft)	N/A	62
Nominal Driving Resistance, R_{ndr} (kips)	415	580
Factored Uplift (kips)	N/A	115 *
Uplift Resistance Factor	N/A	0.8
Nominal Soil Resistance, $R_{n\text{-}uplift}$ (kip)	N/A	144
Nominal Drag Load (kips)(DL)	N/A	62
Estimated Pile Tip Elevation (ft.)	260	
Testing Method		

PILE DRIVING AND ANALYSIS



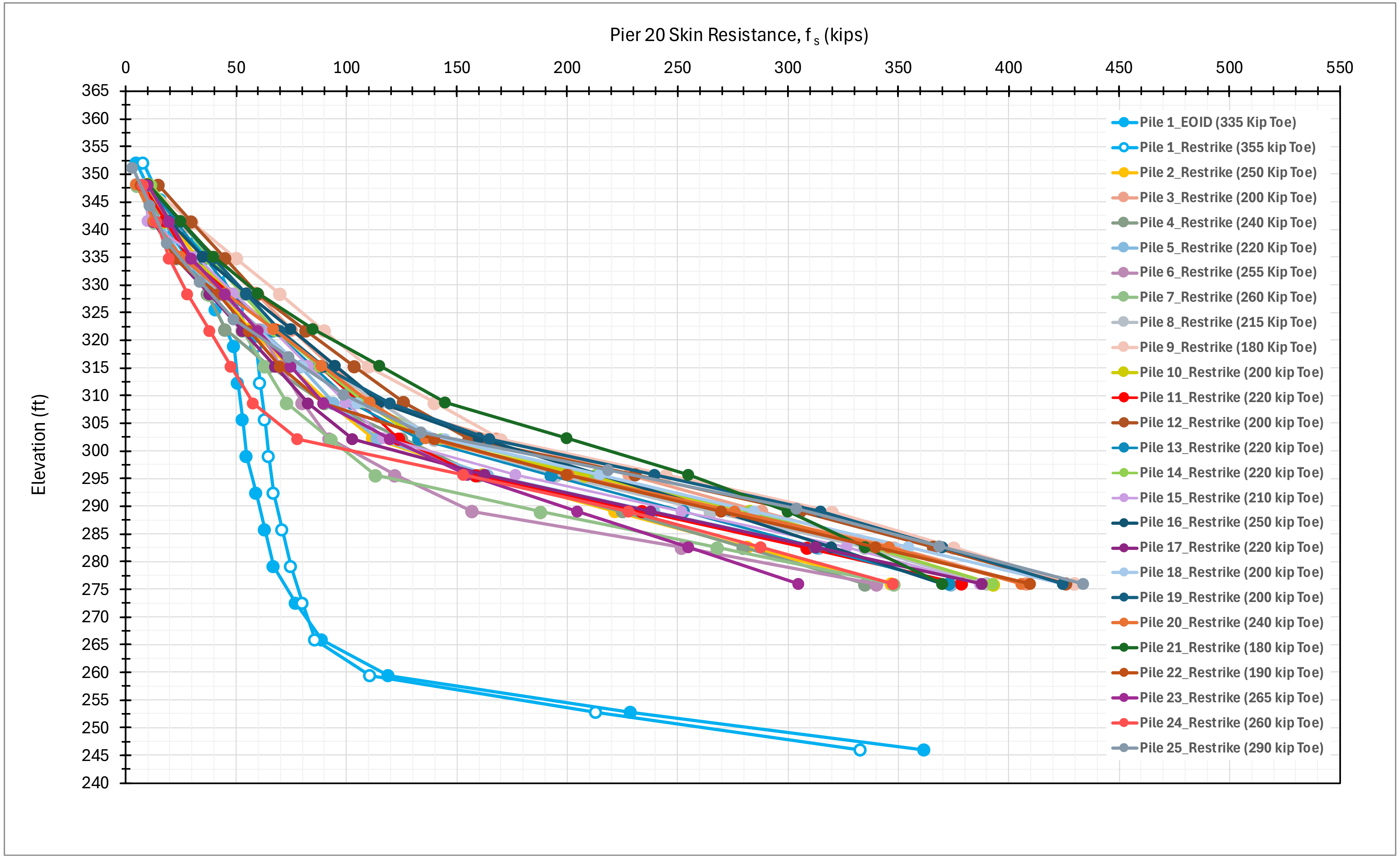
PILE GROUP LAYOUT WITH SOIL ANCHOR OPTIONS

Detail shown is for soil anchors on one corner region. Details are similar for any and all corners where the minimum uplift capacity is not met.



SOIL ANCHOR DETAIL

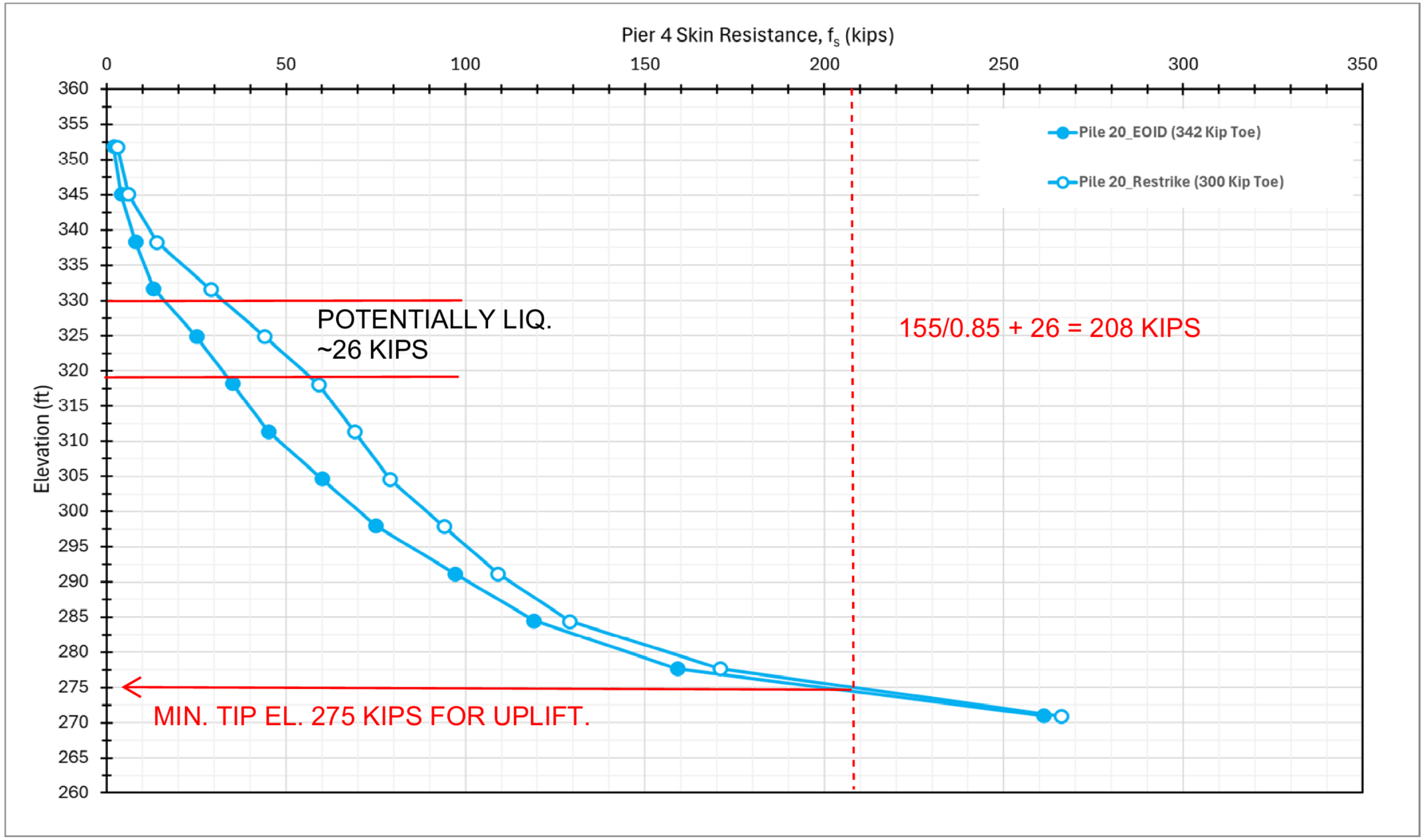
PDA + CAPWAP ANALYSIS



PDA + CAPWAP ANALYSIS

Pier	Strength Max Comp. (kips)	Seismic Max Comp. (kips)	Max Tension (kips)	Required Uplift Resistance (kips)	Required R_ndr (kips)	Liq Layer H (ft)	Est. Skin Resistance in Liq. Layer (kips)	CAPWAP Skin Resistance (kips)	Nominal Uplift Resistance (kips)	
4	273	462	123	155	516	11	26	266	200.1	OK

Pier 4 Example: 266*0.85 - 26 = 200.1 kips => 200 > 155 kips OK!



ALL PILES IN PLACE!!!

Bridge 5 Pier 11 Footing Form – 8/13/25

Photo by ORX Constructors