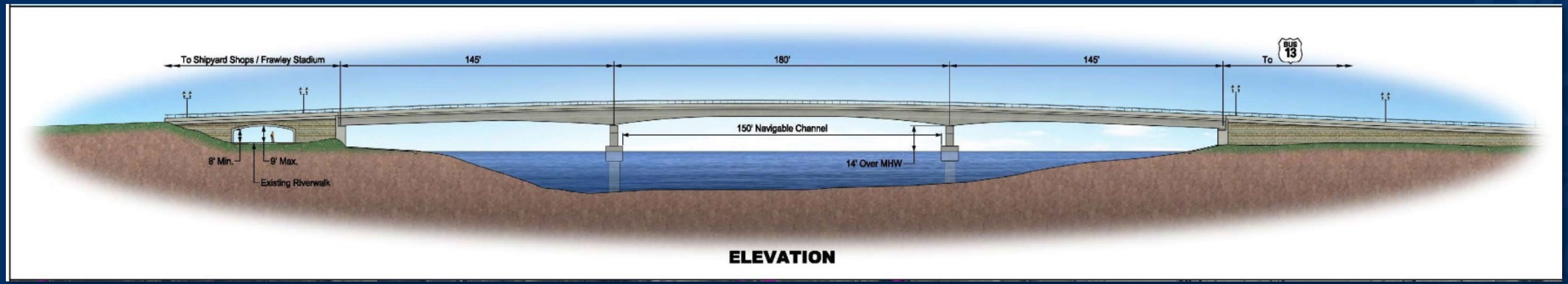
CHRISTINA RIVER BRIDGE & APPROACHES



Ground Modification Techniques for the Christina River Bridge Approaches

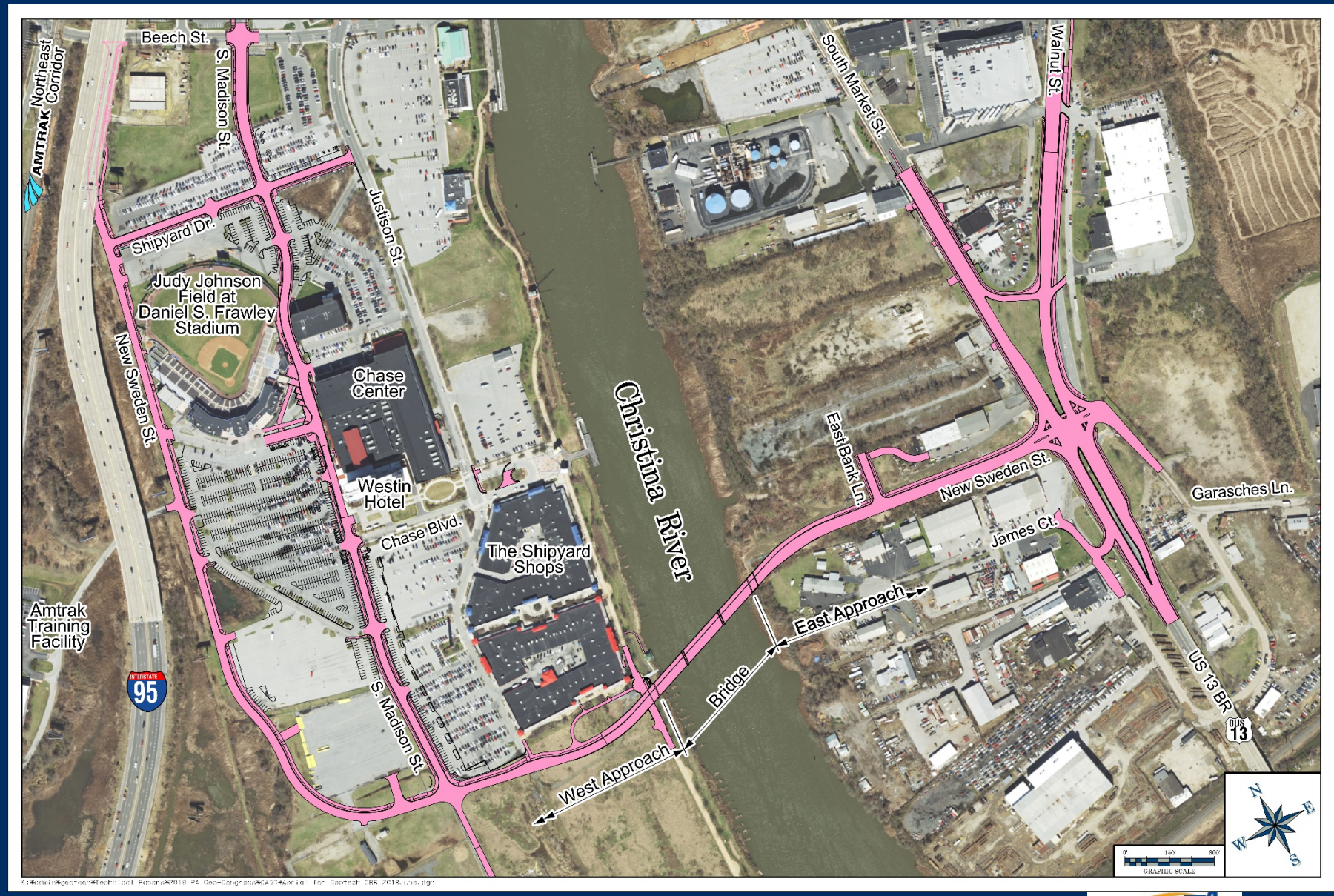
Wilmington, Delaware

DelDOT Contract T201612101

DelDOT

Geo3

RK&K


Beech St.
Northeast Corridor
AMTRAK
S. Madison St.
Shipyard Dr.
Justison St.
Judy Johnson Field at Daniel S. Frawley Stadium
New Sweden St.
Chase Center
Westin Hotel
Chase Blvd.
The Shipyard Shops
Christina River
South Market St.
Walnut St.
East Bank Ln.
New Sweden St.
Garasches Ln.
James Ct.
East Approach
Bridge
West Approach
US 13 BR
Amtrak Training Facility
INTERSTATE 95
S. Madison St.
GRAPHIC SCALE
N
E
W
S

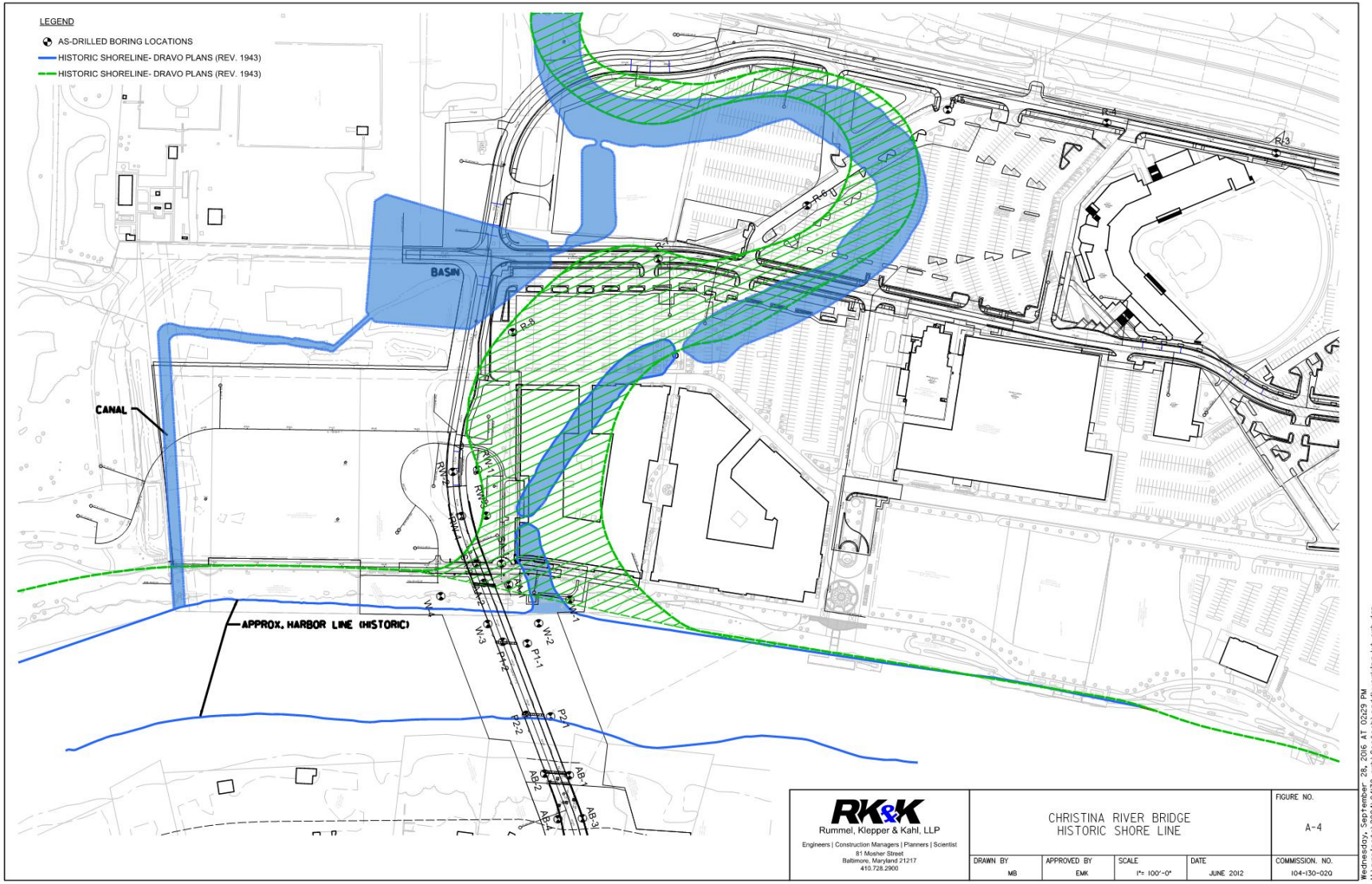
Site Plan

Site History

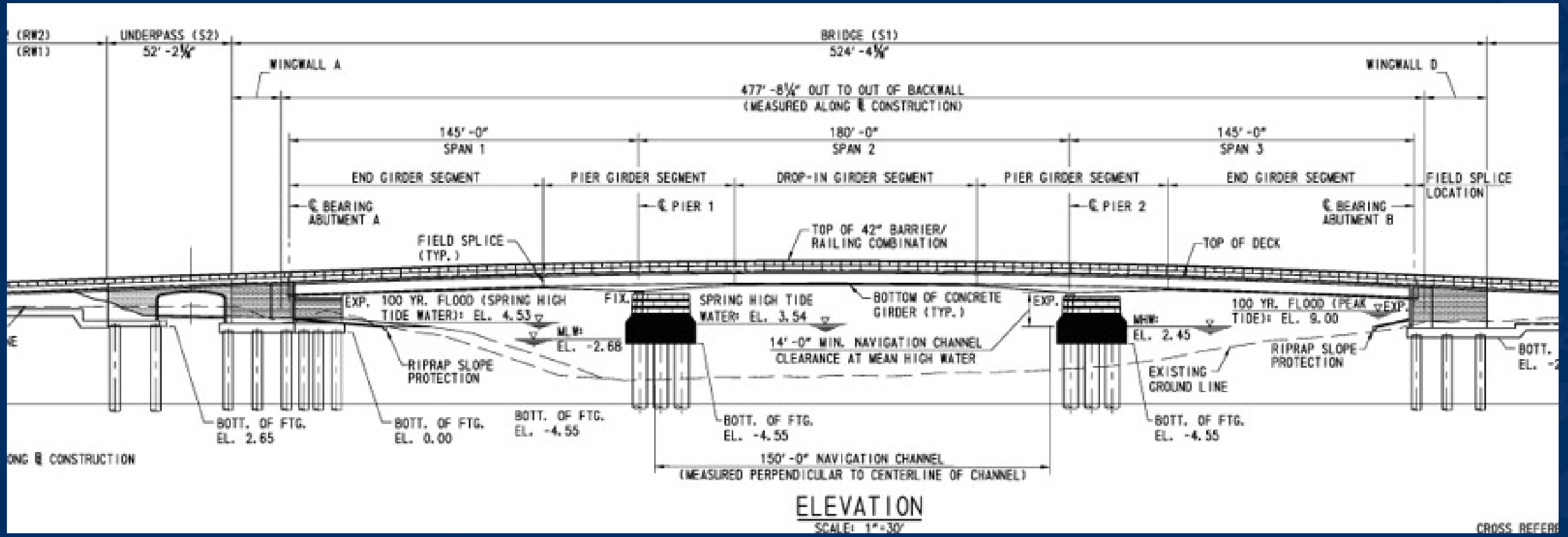
- Leather Tannery – There were 12 tanneries along the Christina River.
- Ship Building – Dravo shipyard was located on the Westside of the project site.
- Wilmington Coal and Gas – also occupied the Westside of the project site.

Contamination

- Shallow soil contains lead, arsenic, polychlorinated biphenyls (PCBs) and polynuclear aromatic hydrocarbons (PAHs)
- Groundwater contains arsenic, lead, vanadium and methyl tertiary butyl ether (MTBE).



Historic Shore Line

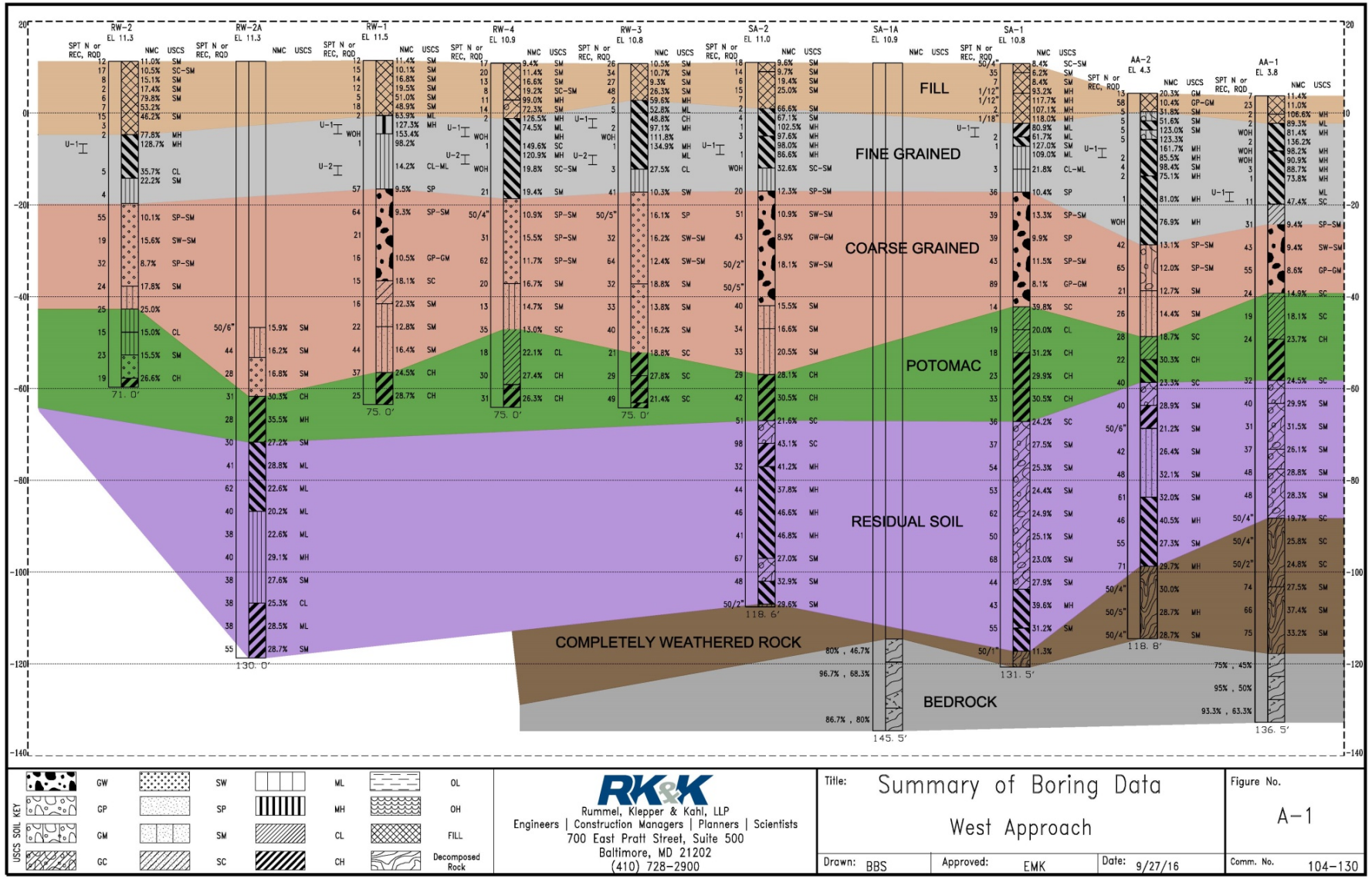


- 470-ft long bridge
- 180-ft mid-span
- Two 145-ft approach spans
- 26-ft wide underpass

- 100-year Flood Elevation
  - Spring High Tide EL +4.53
  - Peak Tide EL +9.00

- Navigation Channel
  - 150-ft Wide
  - 14-ft Min. clearance at MHW

Bridge Plan – 100-Yr Flood



RK&K
Rummel, Klepper & Kahl, LLP
Engineers | Construction Managers | Planners | Scientists
700 East Pratt Street, Suite 500
Baltimore, MD 21202
(410) 728-2900

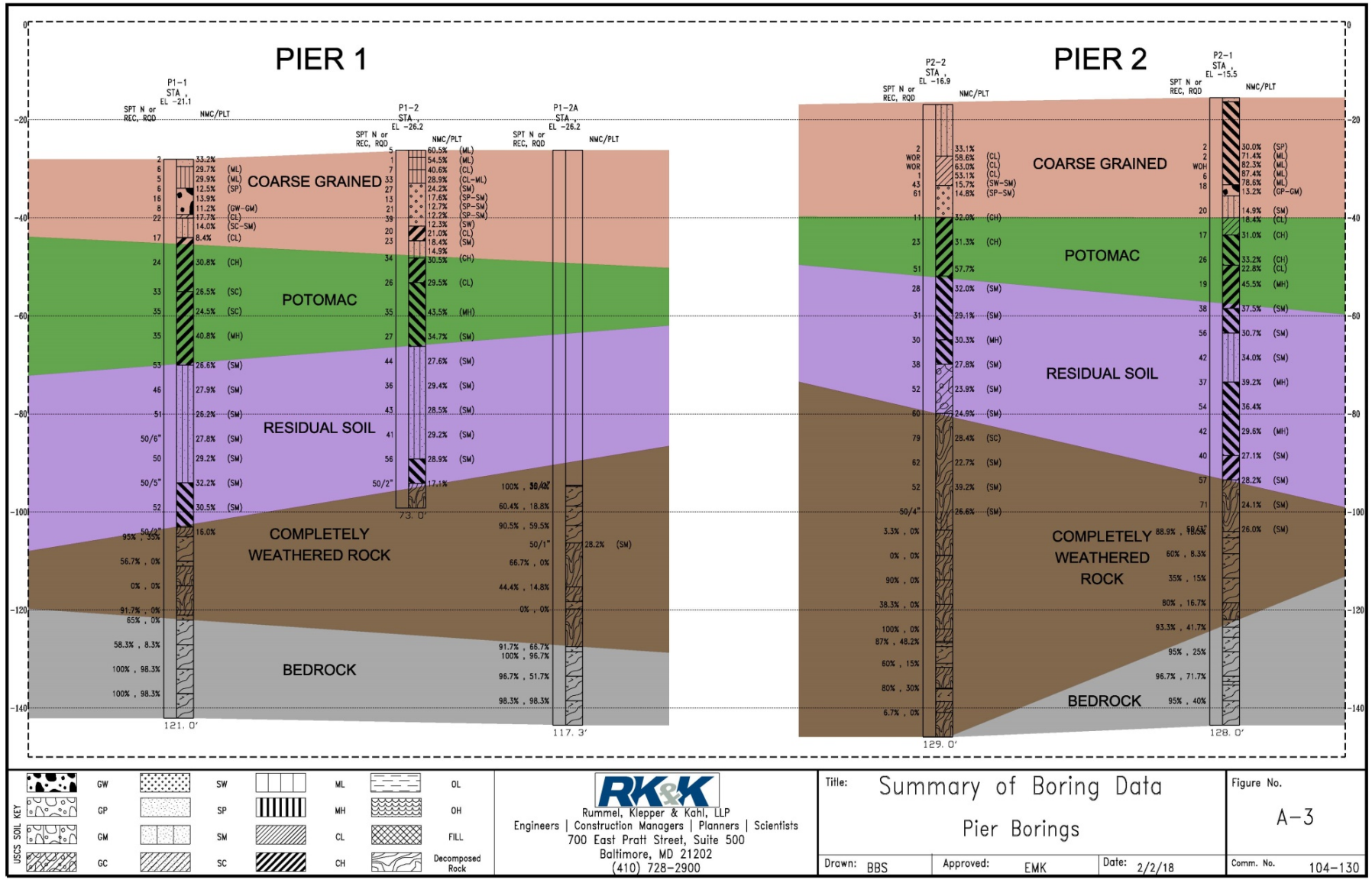
Title: Summary of Boring Data
West Approach

Figure No. A-1

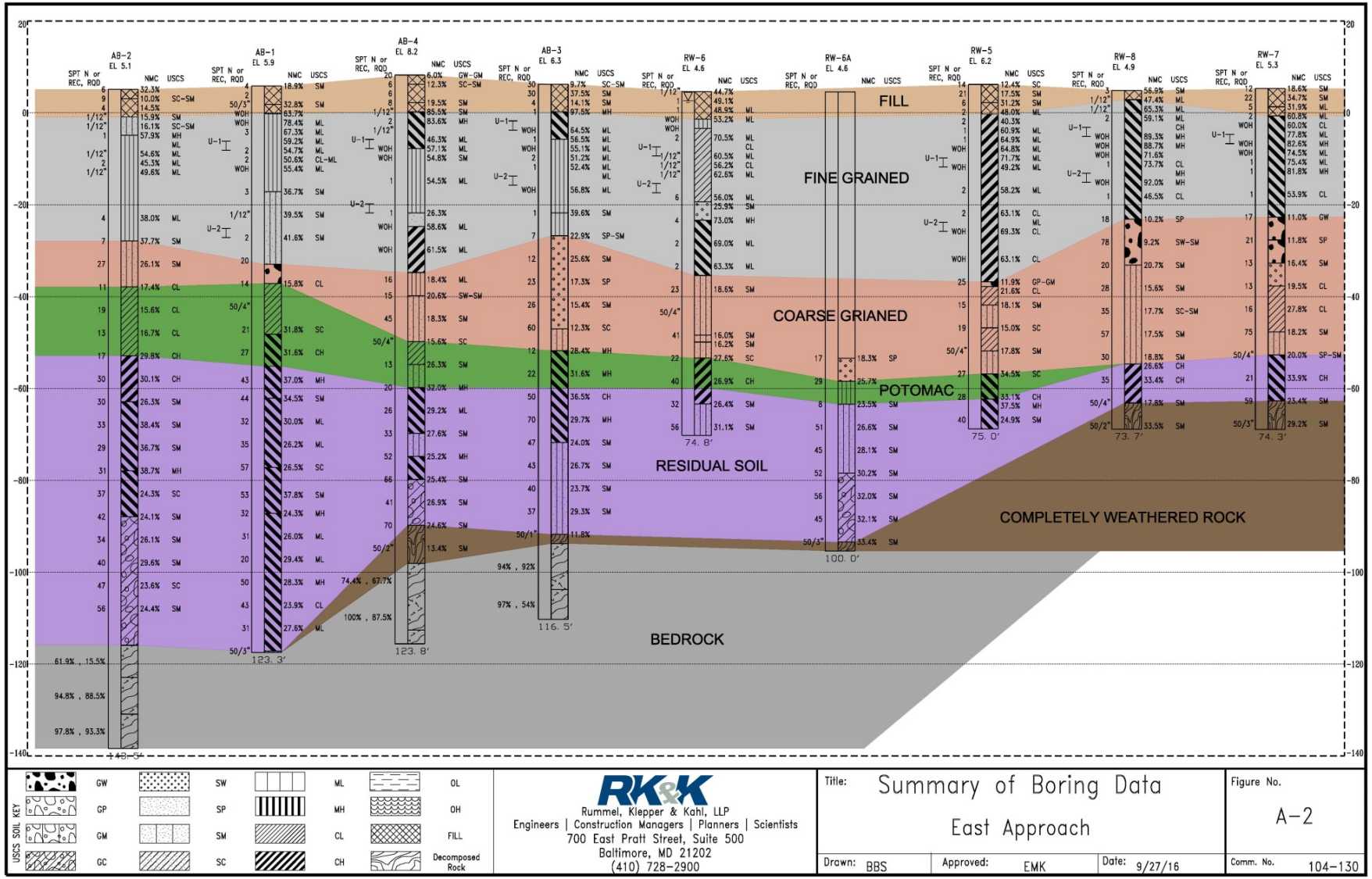
Drawn: BBS | Approved: EMK | Date: 9/27/16 | Comm. No. 104-130

RKK FENCE - USCS (DEFAULT) CRISTINA RIVER BRIDGE.GPJ RKK_CURRENT.GDT 9/27/16

West Approach Soil Profile



Pier 1 and Pier 2 Soil Profile



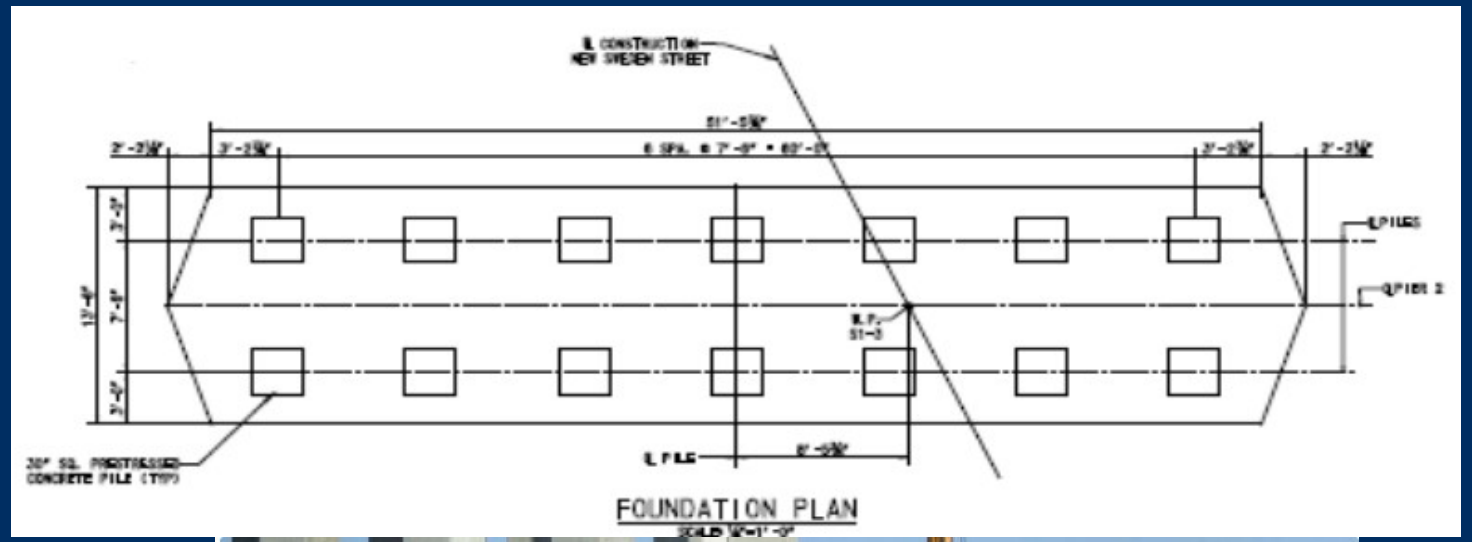
East Approach Soil Profile

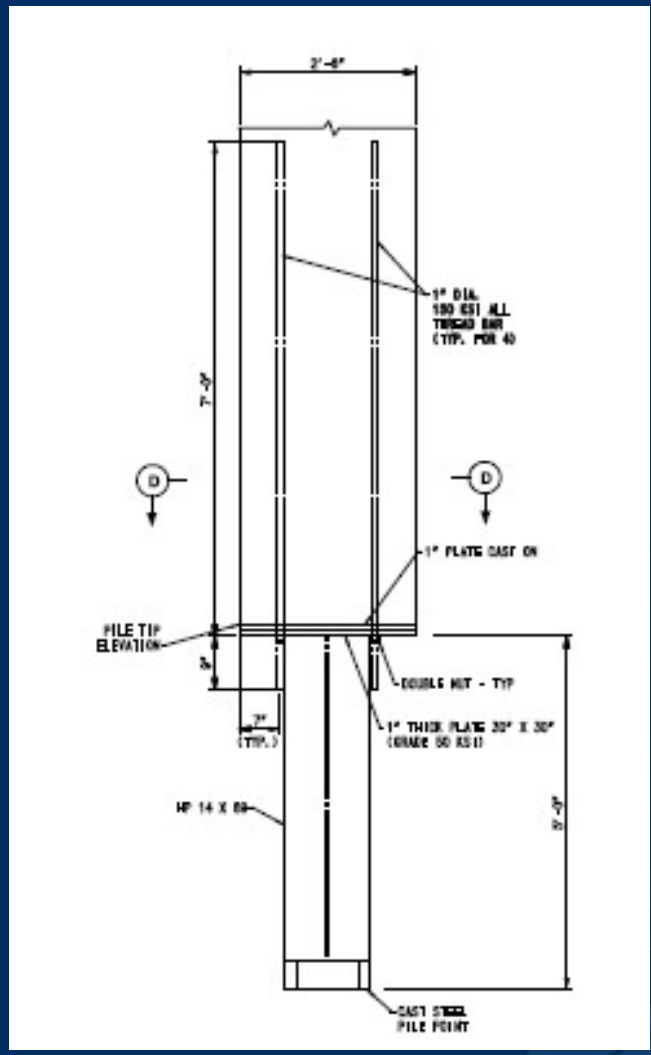
Bridge Foundation Alternative Analysis

- Drilled Shaft
  - 4-ft Diameter for Abutments
  - 6-ft Diameter for Piers with Rock Socket

- Driven Precast Concrete Piles
  - 24-inch Square Piles for East Abutment
  - 30-inch Square Piles for Piers and West Abutment

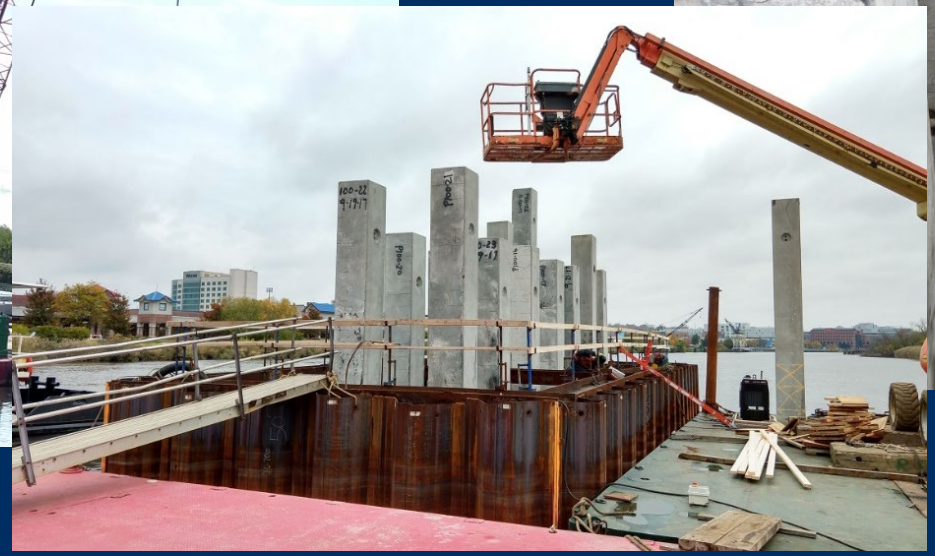
Driven Precast Concrete Pile Foundation





Pier Foundation Plan

Driven Precast Concrete Pile Foundation



Bridge Approach Alternative Analysis

Structural Options

- Conventional Abutment with Extended CIP Wingwalls on Deep Foundation
- U-Shaped CIP Concrete Wall supported on Deep Foundation
- Bridge Back Spans

Geotechnical Options

- Preloading Embankment and MSE Wall Approach
- Total Load Balance with Expanded Polystyrene (EPS)
- Deep Mixing Method (DMM) with MSE Walls
- Stone Columns/Densified Aggregate Piers

Preloading Embankment – Staged Construction

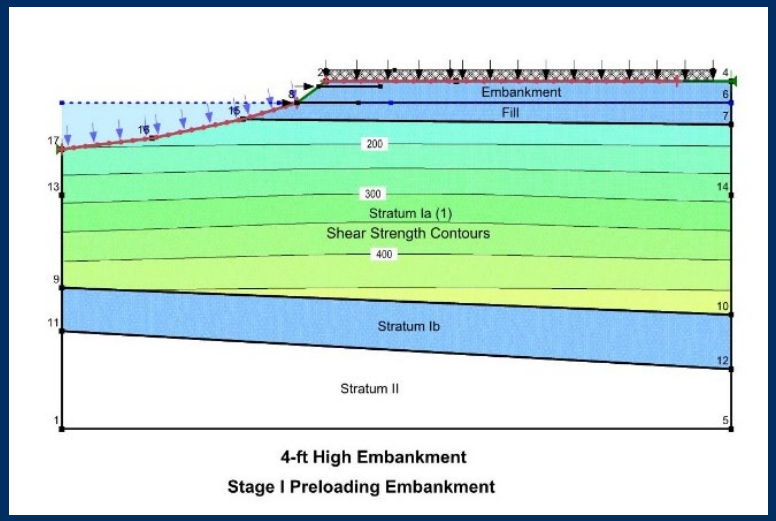
Staged Construction for Shear Strength Gain

- 5-Stage Construction for 17-ft high embankment
- PVD's with Quarantine Period - 90% Consolidation
- 90-days between Stages for Strength Gain

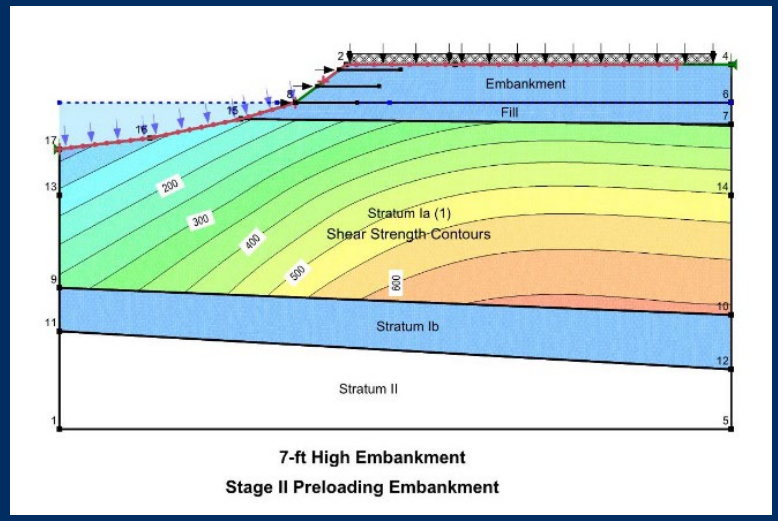
General Equation: $S_u = 0.25\ (OCR)^{0.8}\sigma_v'$
Upper Range: $S_u = 0.4\ \sigma_v'$
Calibrated Equation: $S_u = 0.31\ (OCR)^{0.8}\sigma_v'$
Power Curve: $S_u = 0.4099(\sigma_v')^{1.3207}$
WSDOT Method based on Ladd (1991)
Shear Strength Gain: $\Delta\ S_u = \Delta\sigma_v \tan\varphi_{consol.}$

where : $\tan\varphi_{consol.} = \frac{\sin\varphi_{cu}}{1-\sin\varphi_{cu}}$

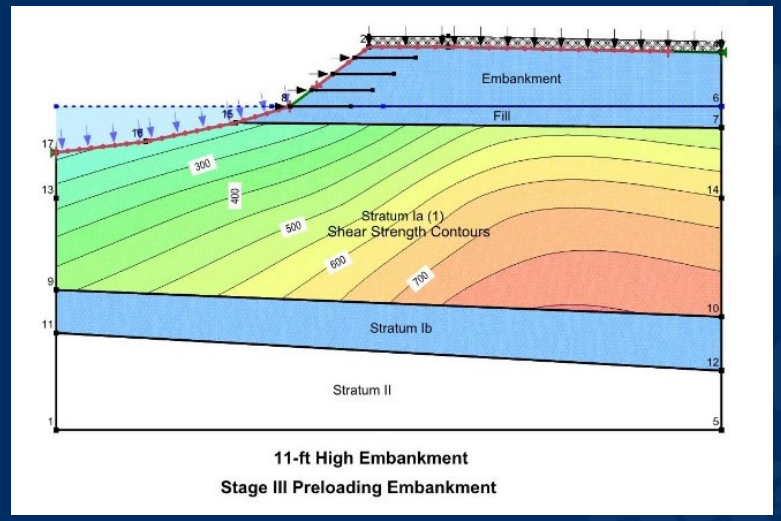
Preloading Embankment – Staged Construction



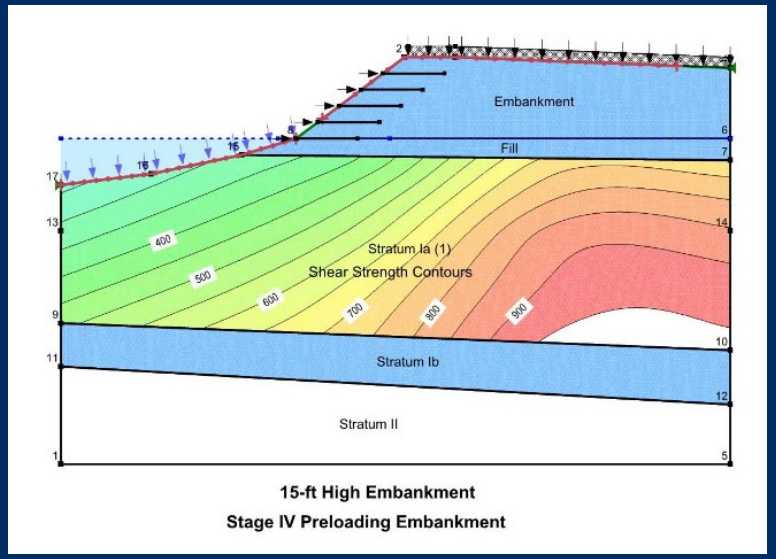
4-ft High Embankment
Stage I Preloading Embankment



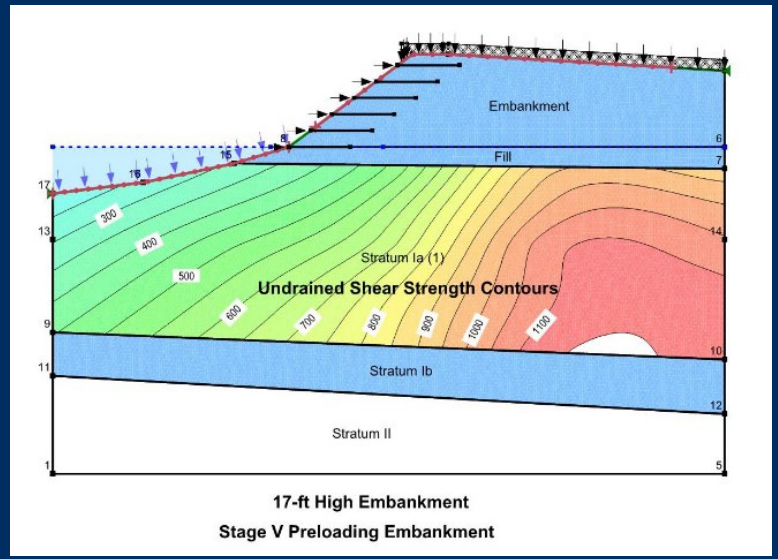
7-ft High Embankment
Stage II Preloading Embankment



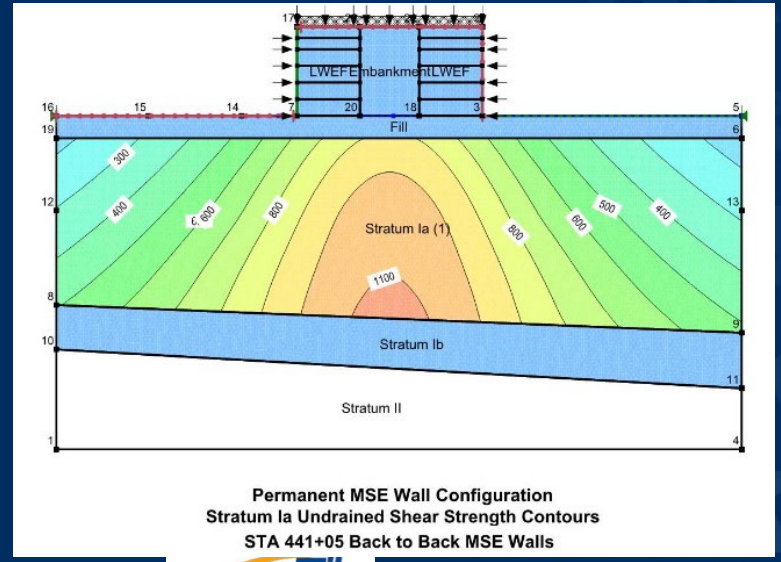
11-ft High Embankment
Stage III Preloading Embankment



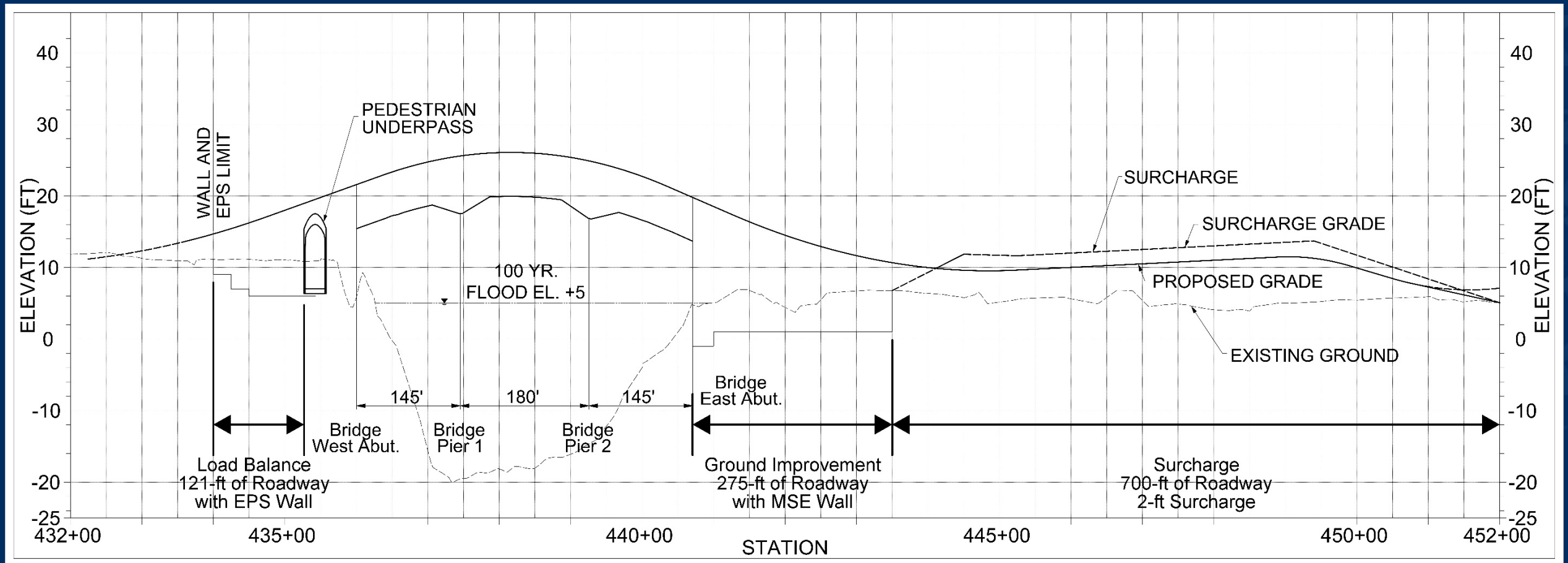
15-ft High Embankment
Stage IV Preloading Embankment



17-ft High Embankment
Stage V Preloading Embankment

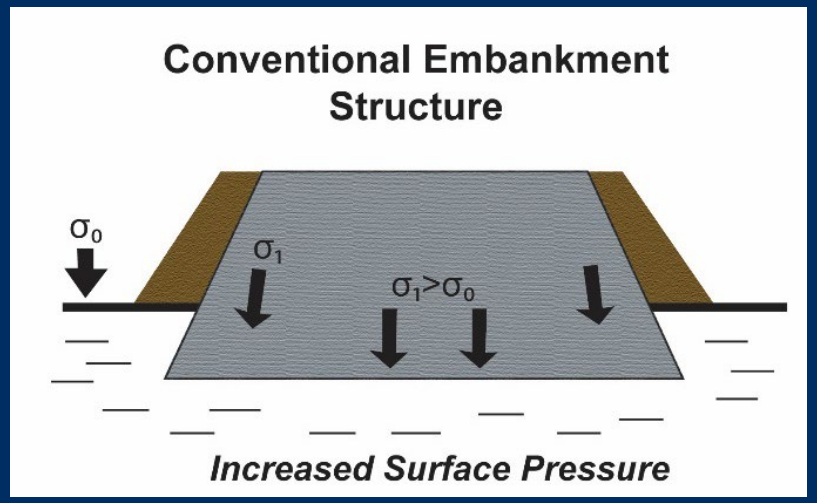


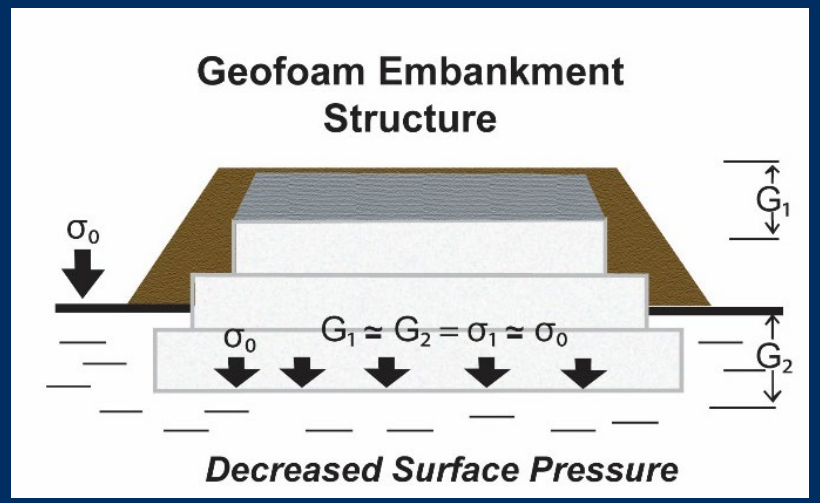
Permanent MSE Wall Configuration
Stratum Ia Undrained Shear Strength Contours
STA 441+05 Back to Back MSE Walls

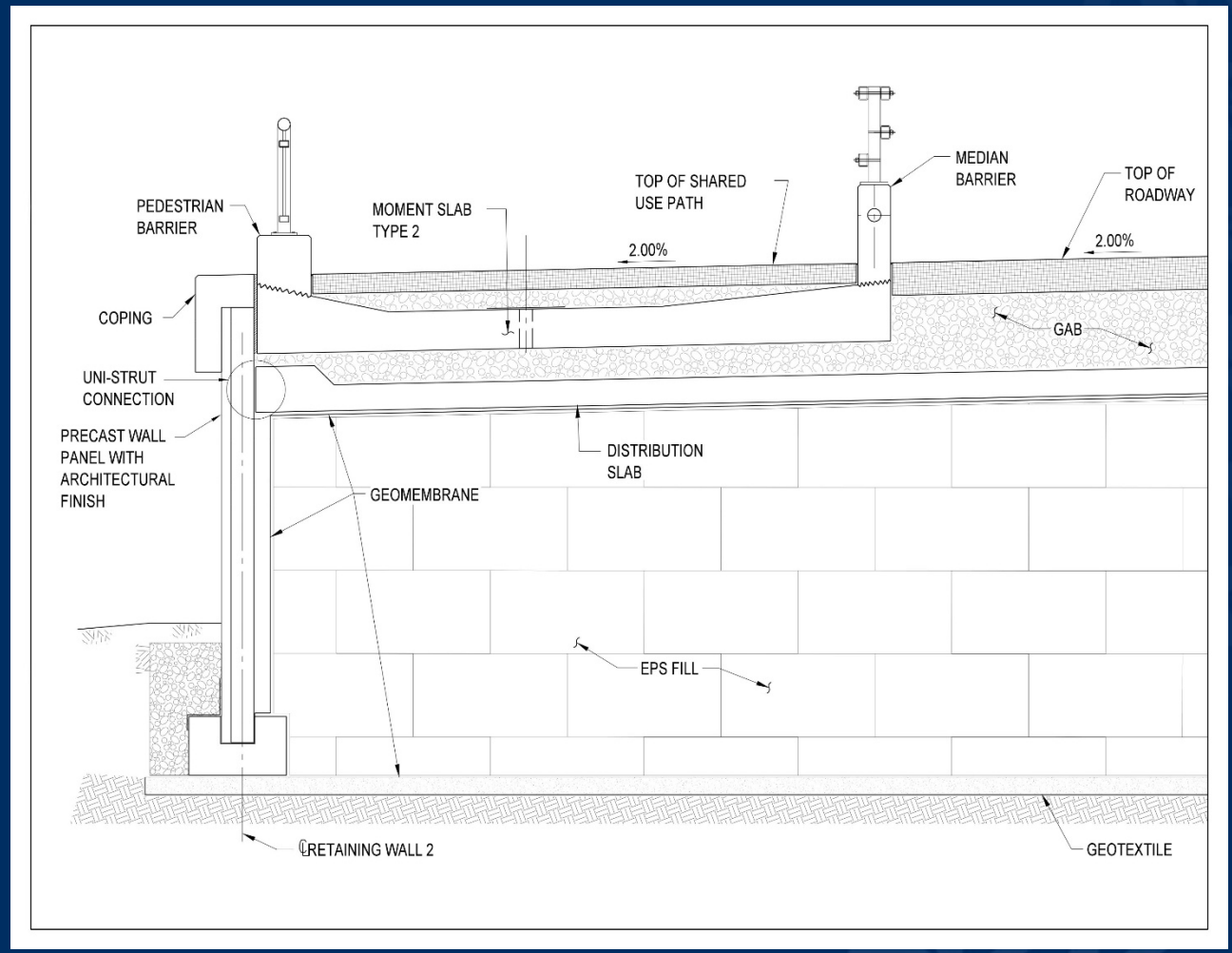


Roadway Profile

Bridge West Approach Ramp







Expanded Polystyrene (EPS) Embankment

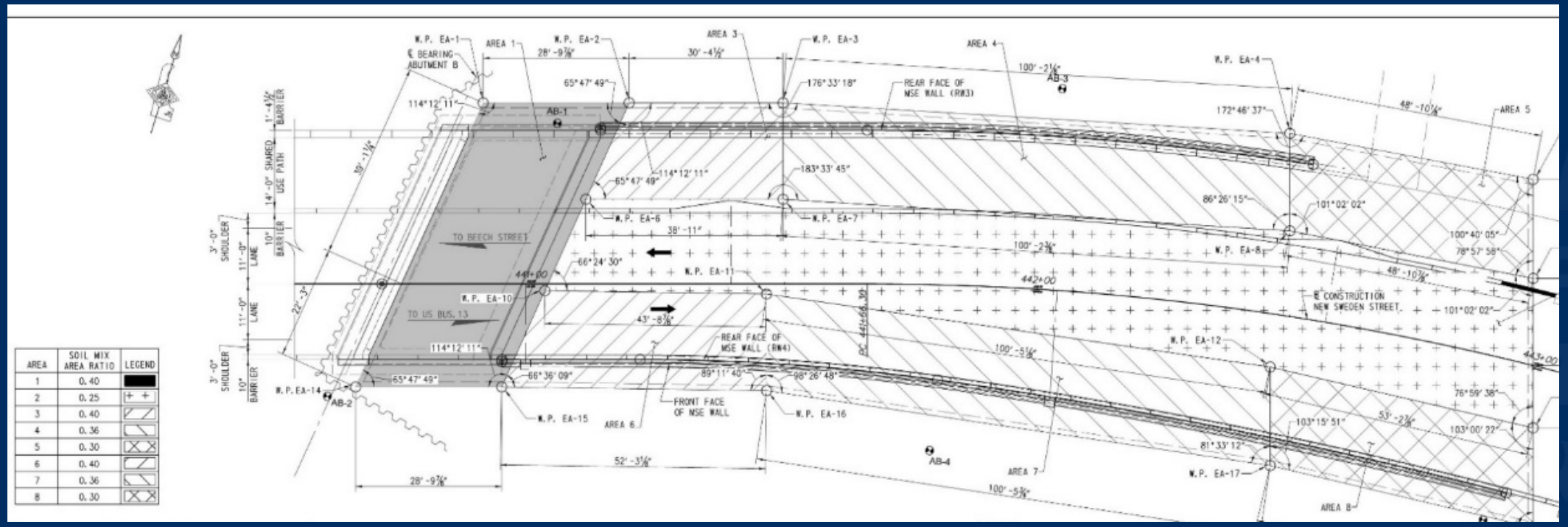
Bridge West Approach Ramp

EPS Construction

EPS Encapsulated with Geomembrane

Bridge West Approach Ramp

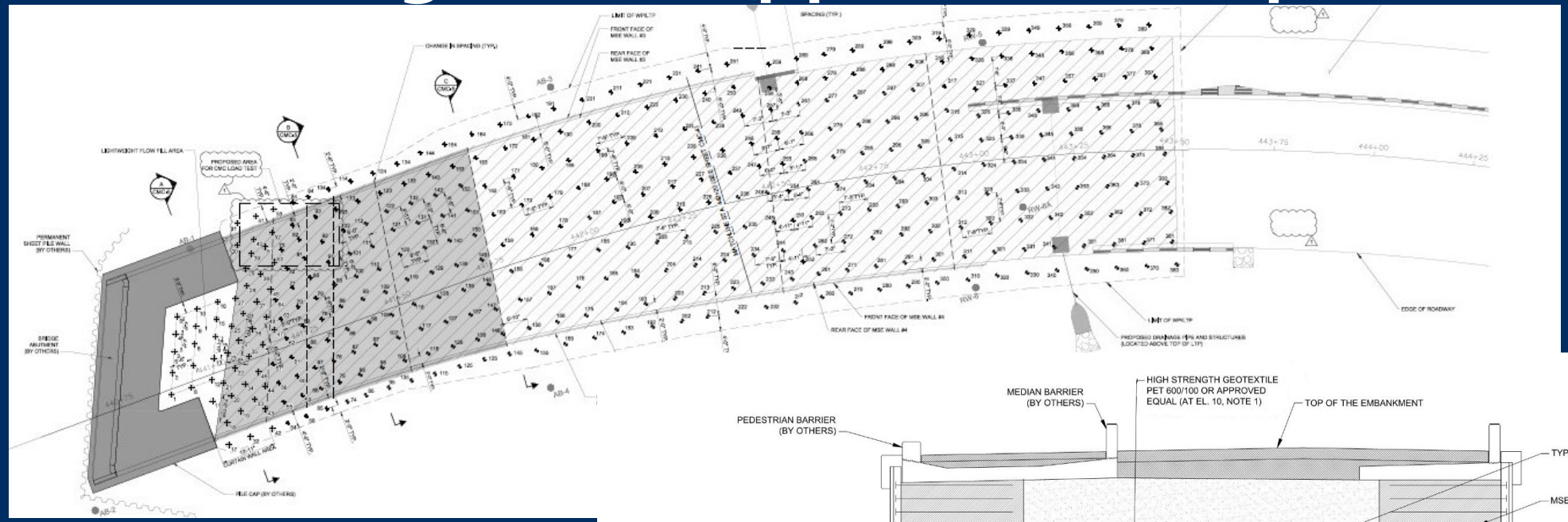
Bridge East Approach Ramp

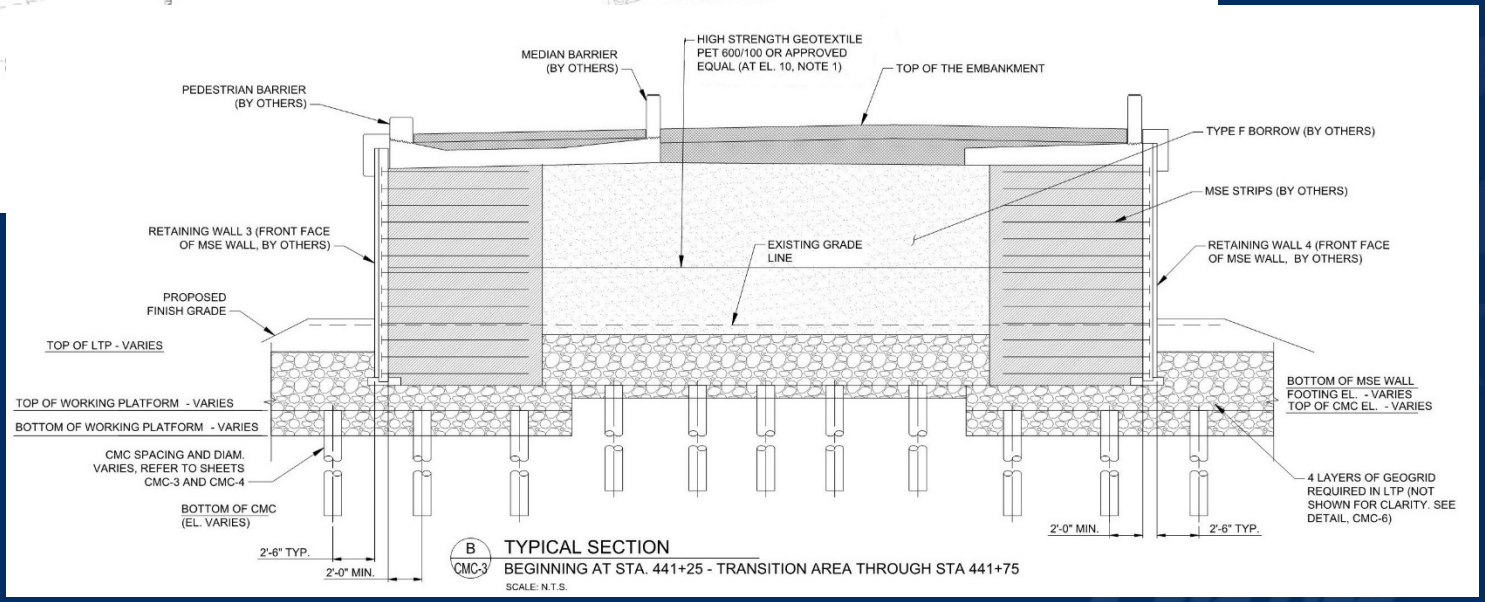


Preliminary Design of DMM

- Bench Scale Testing
- Unconfined Compressive Strength: 120-psi
- Diameter of DMM: 3-ft Min and 5-ft Max
- Length of DMM: 40-ft to 50-ft
- Area Ratio: 25% to 40%

Bridge East Approach Ramp





- Diameter of CMC: 15.6-inch and 12.5-inch
- 388 CMCs installed
- CMC Spacing: 5-ft to 7.5-ft
- CMC Length: 40-ft to 70-ft, Avg. 54-ft
- LTP Thickness: 3.5-ft and 2.5-ft

Bridge East Approach Ramp

Controlled Modulus Column (CMC) Installation

Bridge East Approach Ramp

Deep Mixing Method (DMM)

- ❑ Bench Scale Testing
- ❑ Performance Specification
- ❑ Contractor's Design
  - ❑ Bench Scale Testing (Optional)
  - ❑ Final Design
  - ❑ Preproduction DMM Test Program
  - ❑ Production DMM
  - ❑ DMM QA/QC Program

Controlled Modulus Column (CMC)

- ❑ Performance Specification
- ❑ Contractor's Design
  - ❑ Final Design
  - ❑ Static Load Test
  - ❑ Production DMM
  - ❑ CMC Logs for QA/QC
- ❑ Minimum Amount of Spoils

Bridge East Approach Ramp

15.6-inch Diameter CMC

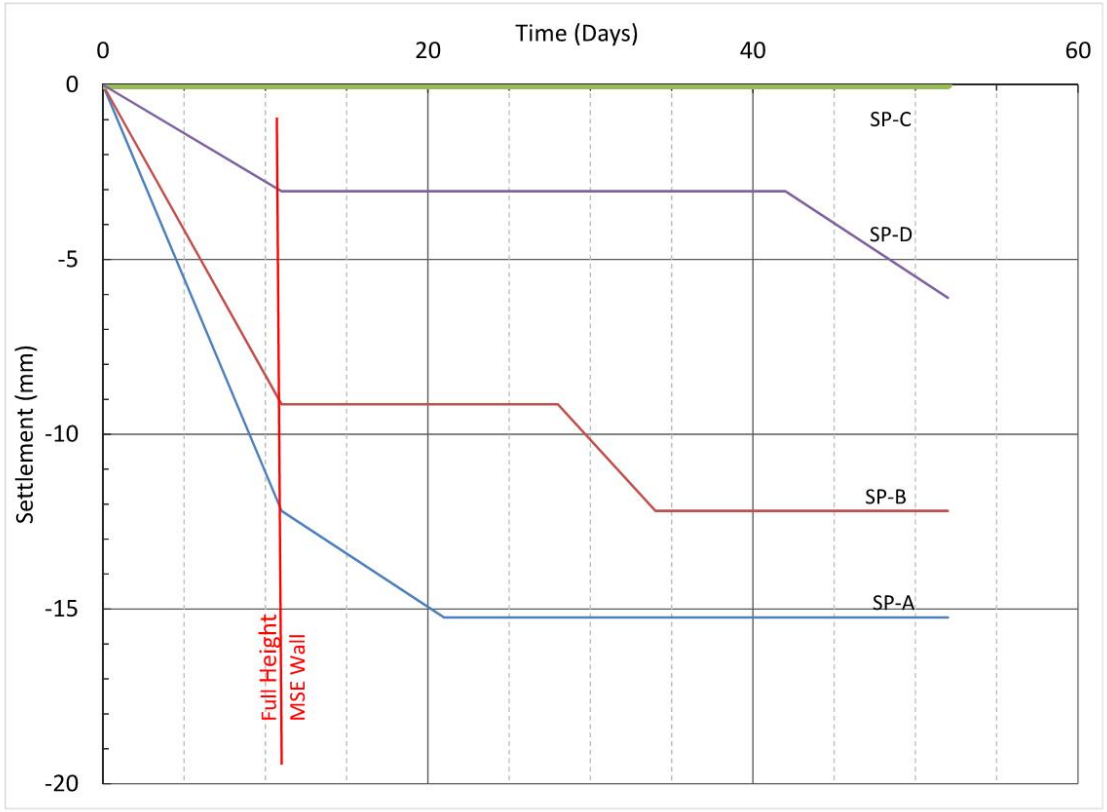
- ❑ 55-kips Design Load
- ❑ Center to Center Spacing
  3′-6″

12.5-inch Diameter CMC

- ❑ 92-kips Design Load
- ❑ Center to Center Spacing
  6′-0″ to 7′-6″

Preloading & Instrumentation

- ❑ 7-ft Embankment
- ❑ 4 Settlement Plates

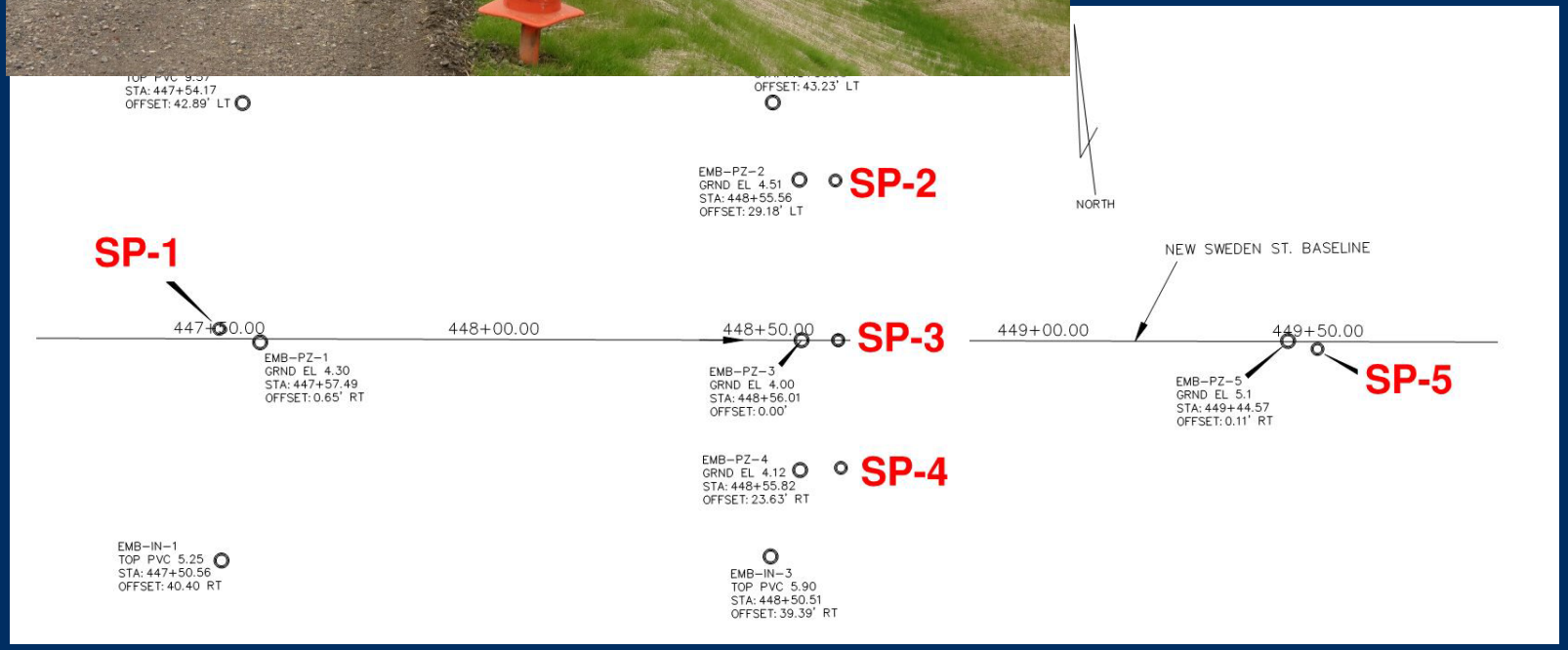


Bridge East Approach Ramp

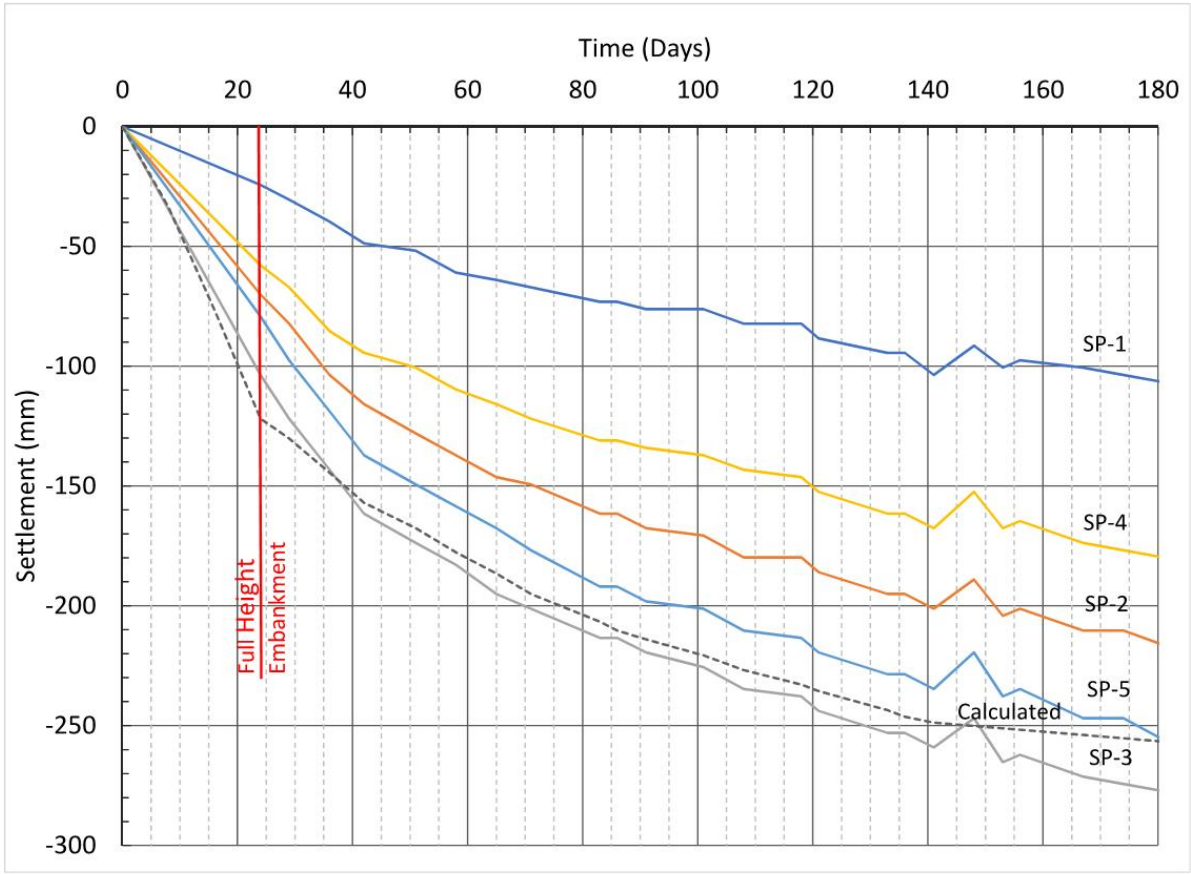
East Approach Embankment and Surcharge

Embankment Surcharge

- ❑ Height of Embankment: 7-ft
- ❑ Additional Surcharge: 2-ft
- ❑ Quarantine Period: 5-months
- ❑ Total Est. Settlement: 10-inches



East Approach Embankment and Surcharge



Embankment Settlement Plates

References

Expanded Polystyrene (EPS)

- NCHRP Web Document 65 (Project 24-11), Geofoam Applications in the Design of Highway Embankments (July 2004)
- NCHRP Report 529, Guideline and Recommended Standard for Geofoam Applications in Highway Embankments

Ground Improvement

- Publication No: FHWA-NHI-16-027, FHWA GEC 013, Ground Modification Methods (April 2017)
- Publication No: FHWA-HRT-13-046, FHWA Design Manual: Deep Mixing for Embankment and Foundation Support (October 2013)
- Collin, J.G., Han, J., and Huang, J., "Geosynthetic-Reinforced Column-Support Embankment Design Guidelines".

Thank You