You Want it When!?
(Rapid Construction of the Backgate Interchange Embankments)

MYRTLE BEACH, SOUTH CAROLINA

SCDOT

October 22 - 25, 2012

GeoStellar Engineering

STV 100 Years

Presented By:

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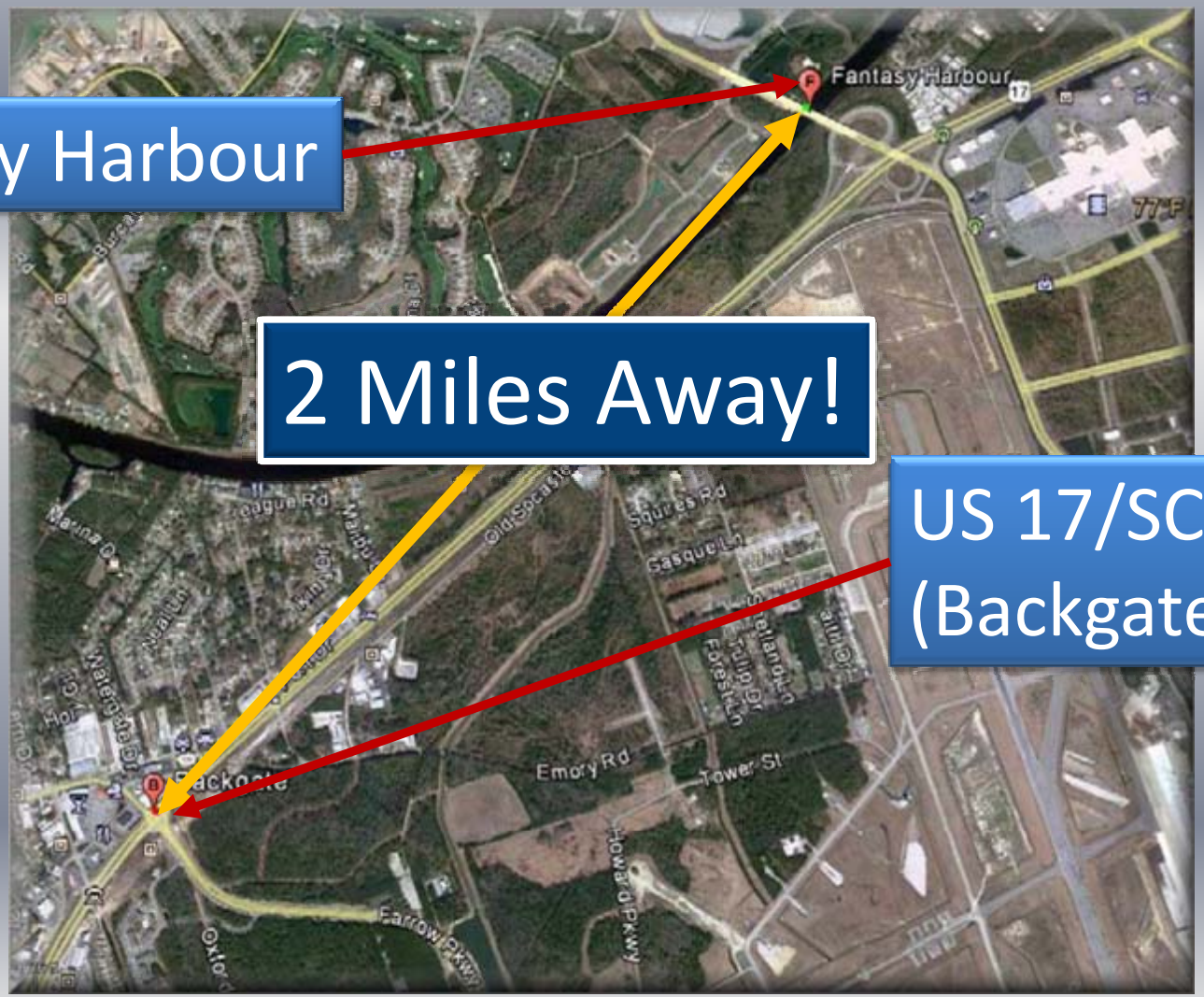
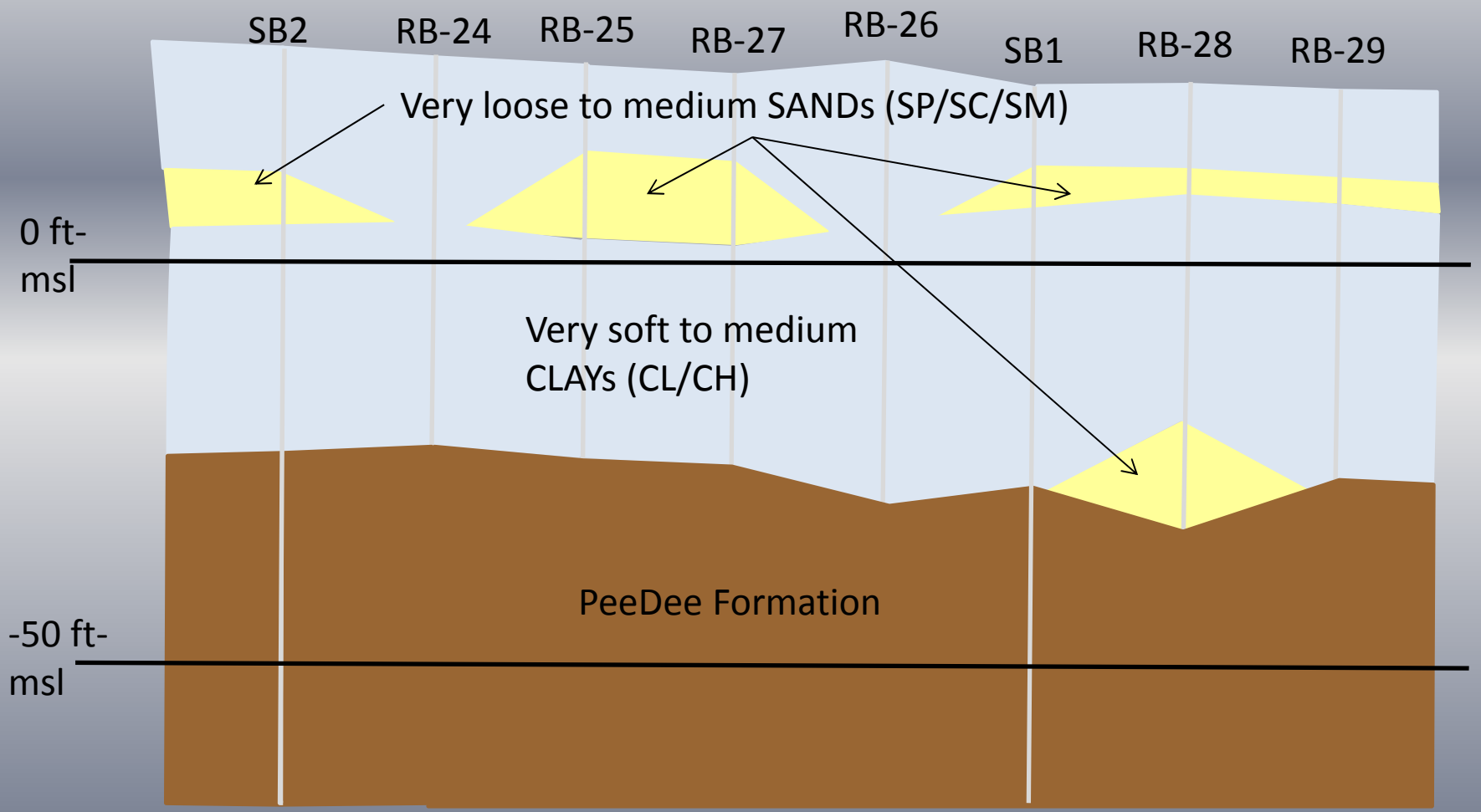
Regional Experience



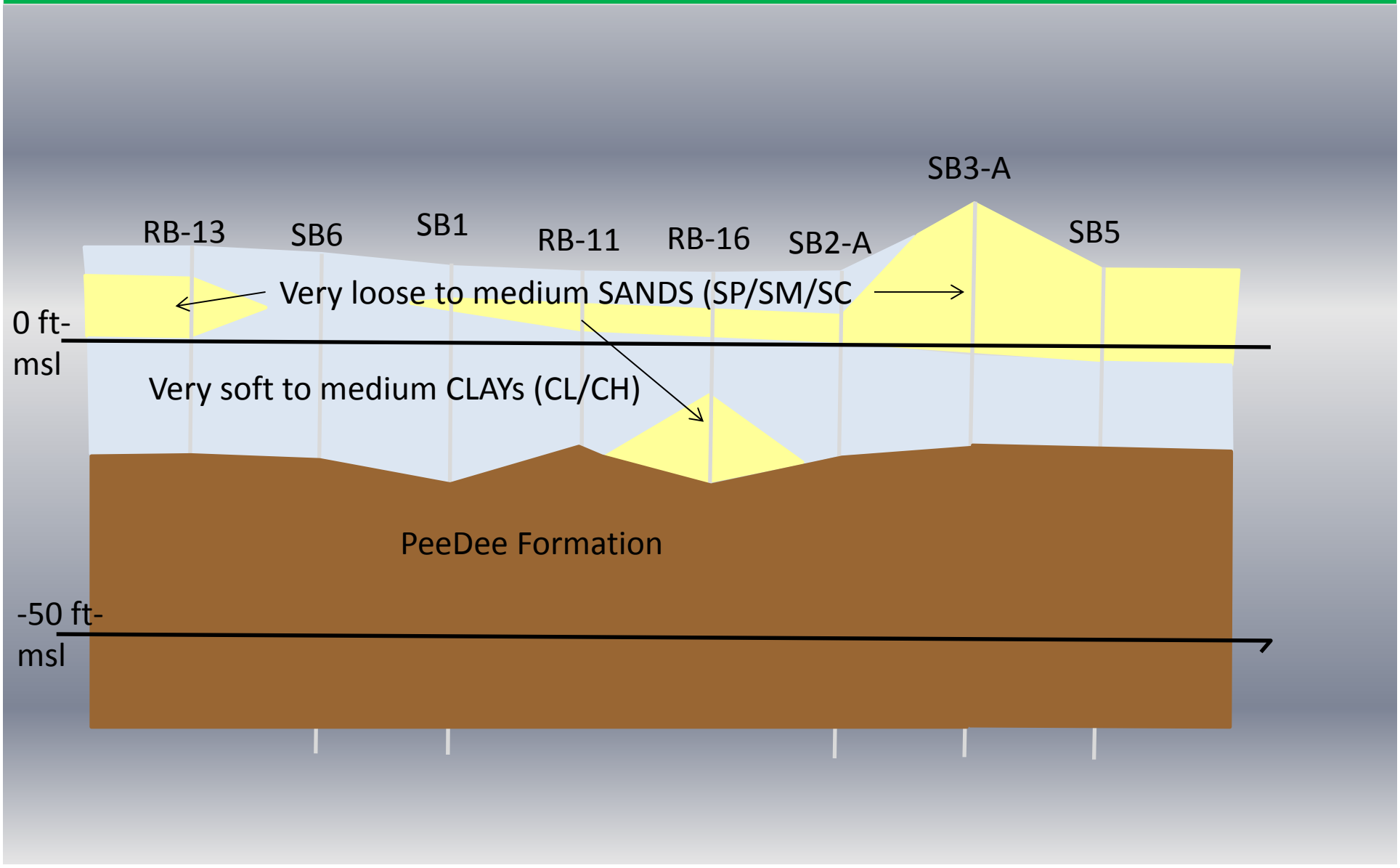
Fantasy Harbour

- 2 Miles North of Project
- New Alignment
- 35‘ Very Soft to Firm Clay
- Pockets of Loose Sand upper 15’
- Pockets of Loose sands Above Pee Dee Formation
- Pee Dee Formation (Top Elev. -20’ msl)

Fantasy Harbour Bridge
West Abutment



Fantasy Harbour Bridge
East Abutment



Fantasy Harbour

- Liquefaction – Loose Sands
- Embankments Unstable (Static/Seismic)
- Ground Improvement!!!
- 2 Year Embankment Construction Contract
- 2-3 Year Bridge Construction Contract

Ground Improvement

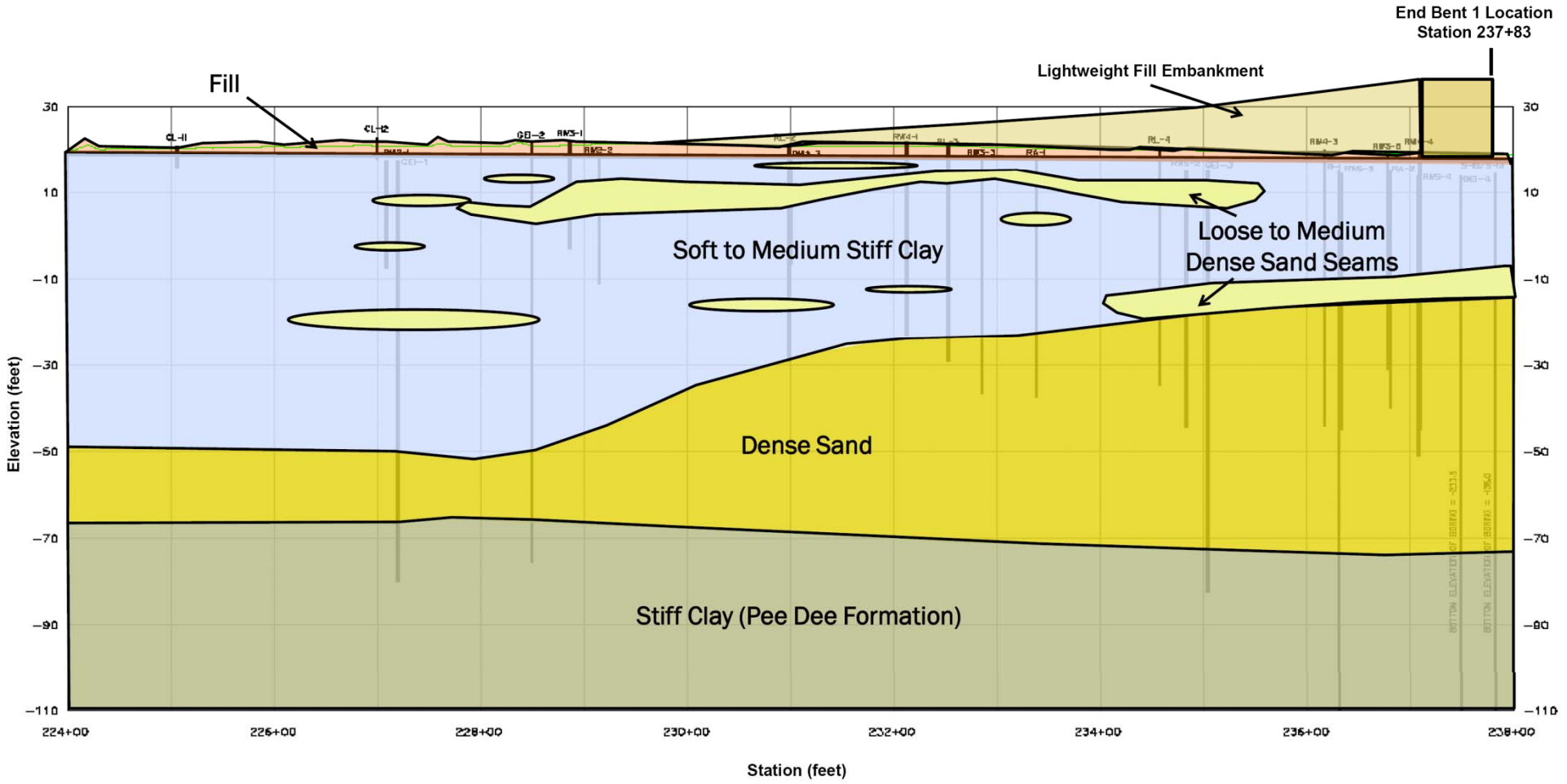
- Stone Columns
  - Increase density of soil
  - Add shear resistance
  - Assist in decreasing settlement time
- Prefabricated Vertical Drains
  - Decrease time for settlement
  - Increase in shear strength gain rate
- Vertical Stage Construction
  - Allow for settlement
  - Increase in shear strength gain rate

Staged Vertical Construction

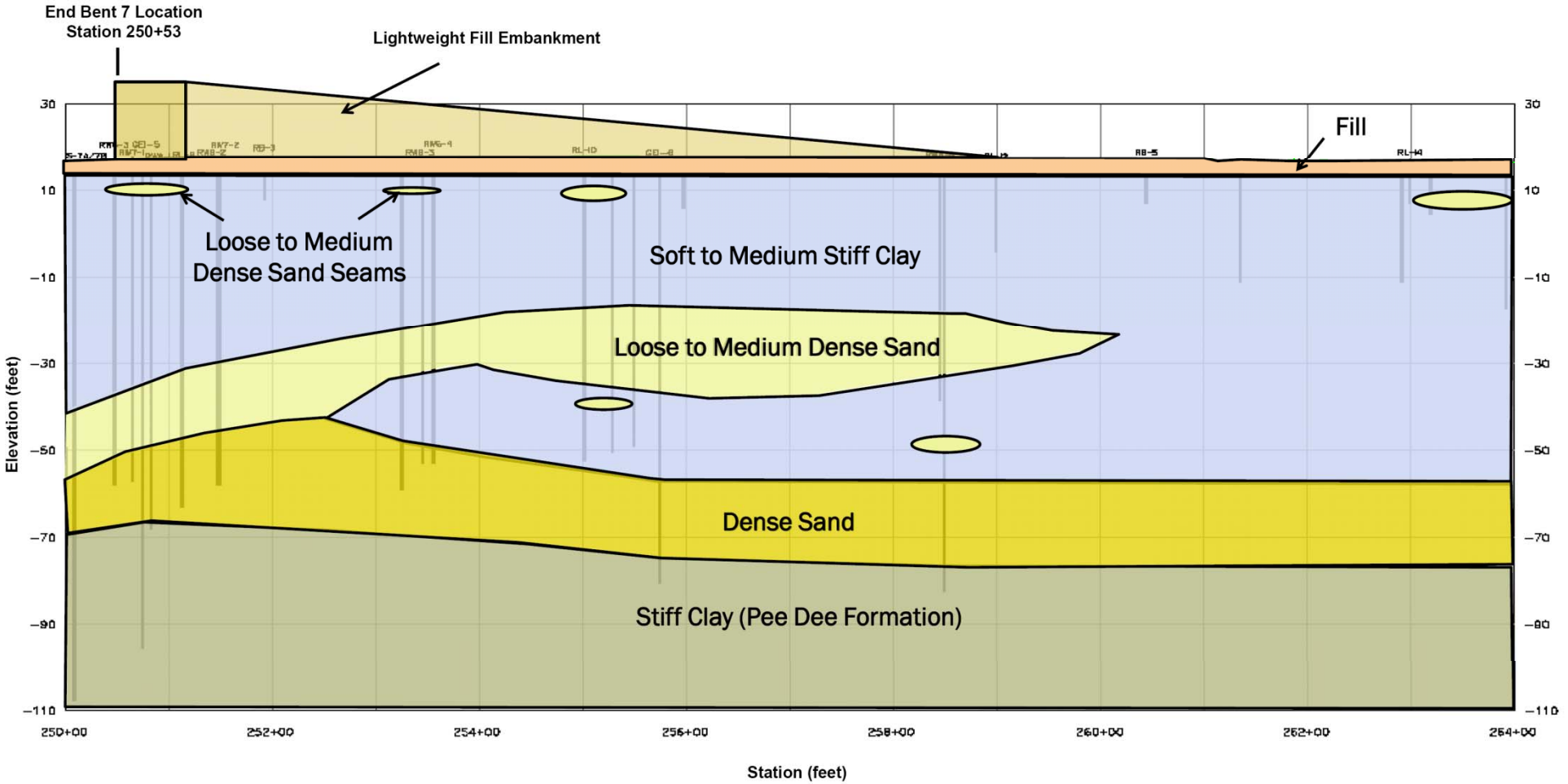
- Embankment Construction Sequence
  - 15 feet; anticipated settlement 21 inches; waiting period ~6 months
  - Additional 10 feet; anticipated incremental settlement 22 inches, total settlement 43 inches; waiting period ~6 months
  - Final Grade achieved; anticipated incremental settlement 24 inches, total settlement 67 inches; final waiting period ~ 6 months

Let's Return To US 17/ SC707 Interchange (Backgate)

South Subsurface General Profile



North Subsurface General Profile



Geotechnical Challenges

- 30’ to 60’ - Soft to Firm Clay
- 5’ to 10’ Loose Sands
- Intermediate Medium Sands (253+00 to 256+00)
- Pee Dee Hard Clay Formation Elevation -70’ msl
- Poor Site Subgrade (Bridging Required)
- Excessive Settlement – (Total & Diferential)
- Short & Long-Term Embankment Instability
- Seismic Slope Instability (Liquefaction)

Project Constraints

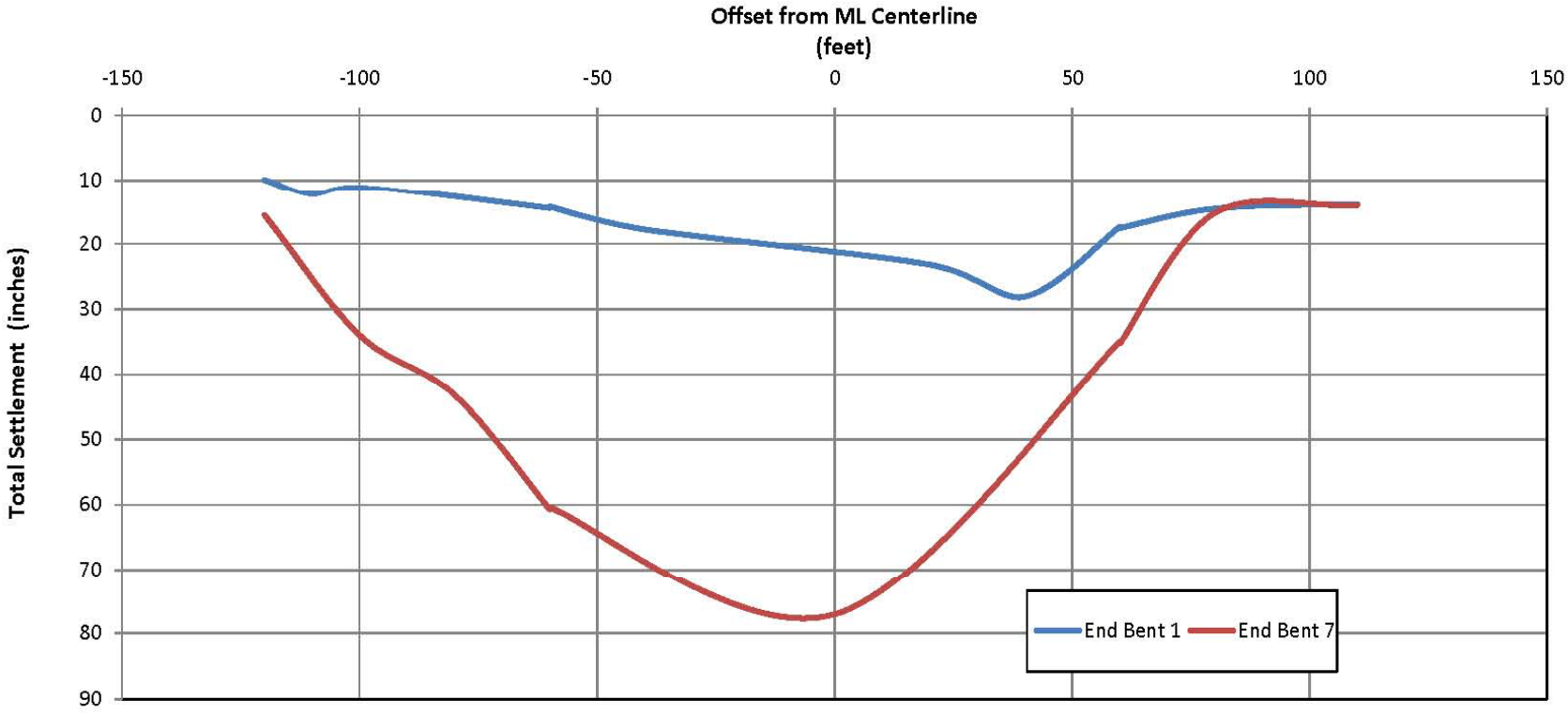
- Project Geometry and Layout
  - Existing Alignment
  - Limited R/W
  - Maintain all traffic movements & business access
- Limited Construction Staging Areas
- High Traffic Volume Combined
- Complex Traffic Control Staging Plan – Embankment construction occur primarily in Stages **2**, **3**, and **4**
- Construction Time Requirements – **3.5** years

Rapid Embankment Construction

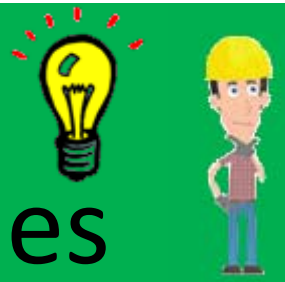
Geotechnical Key Issues

- **Consolidation Settlement** - Total and Differential
- **Slope Instability** – During Construction and Seismic Event (Liquefaction)
- **Bridge Abutment Foundation Performance** - Extreme Events I and II

Bridge Abutment Settlement
(Normal Weight Fill)



Geotechnical Construction Techniques

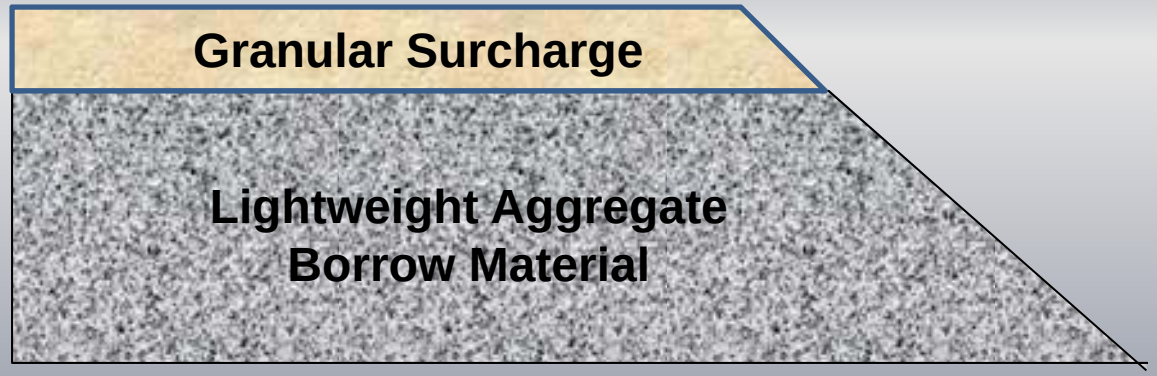


- **Lightweight Aggregate Borrow Material** – Reduce Magnitude of Settlement
- **Granular Surcharges / Prefabricated Vertical Drain (PVD)** – Increase Settlement and Rate of Settlement During Construction
- **Deep Soil Mixing** – Improve Seismic Slope Stability and Bridge Abutment Foundation Performance
- **Mechanically Stabilized Earth (MSE) Walls** – Required for Traffic Staging and Staying within R/W

Granular Surcharge & Lightweight Aggregate Borrow

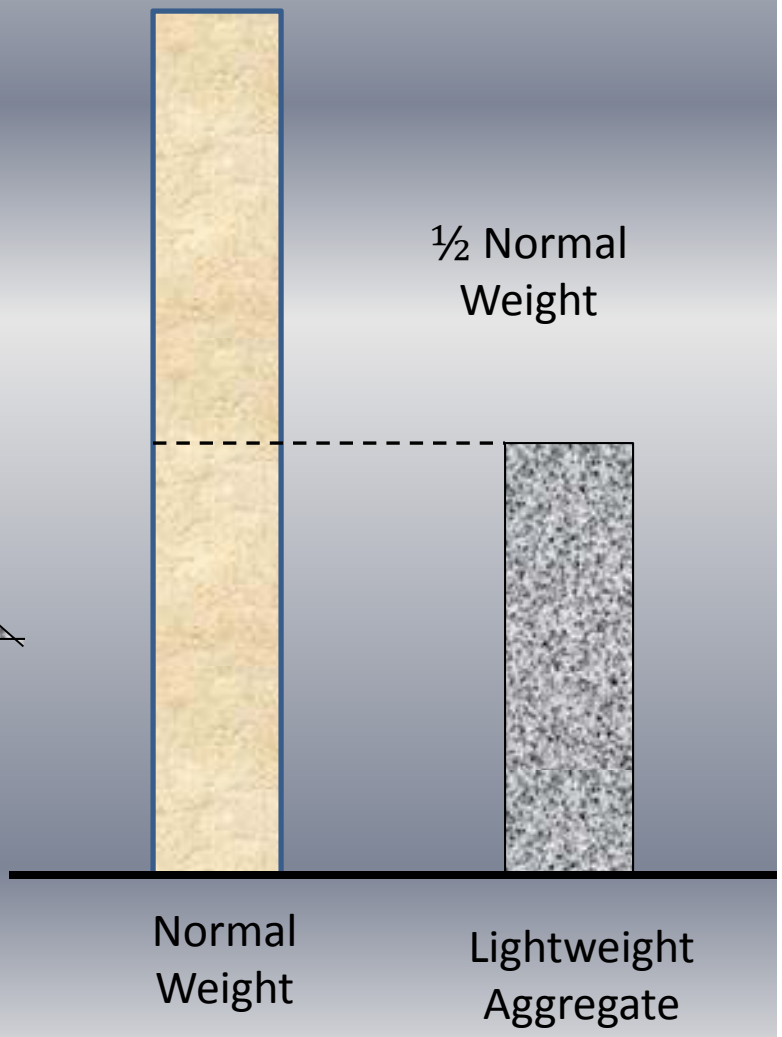
Granular Surcharge Properties:

- ϕ = 32 degrees
- Unit Weight: 125 pcf



Lightweight Aggregate Properties:

- ϕ = 40 degrees
- Short Term Unit Weight: 60 pcf
- Long Term Unit Weight: 70 pcf
- MSE Wall Backfill Properties



Lightweight Aggregate Borrow
(Rotary Kiln Produced)

Lightweight Aggregate Borrow
(Proposed New Material)

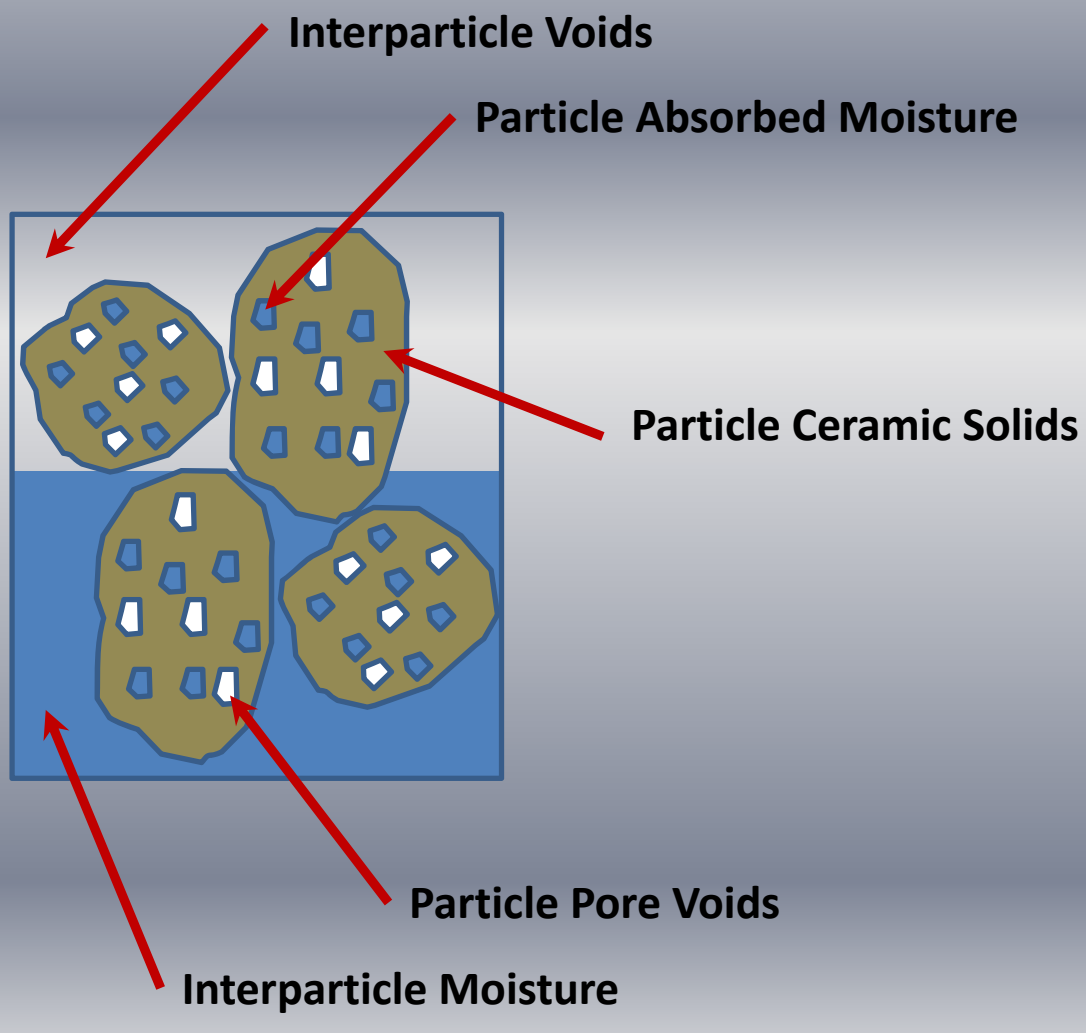
Lightweight Aggregate Borrow
(Proposed New Material Differences)

- Higher Fines Content
- Lighter Dry Unit Weight
- Total Unit Weight 15% Lighter
- High Absorption
- Gradation – Coarse Sand Instead of an Aggregate
- Compaction Verification Required

Test Section (Dry)

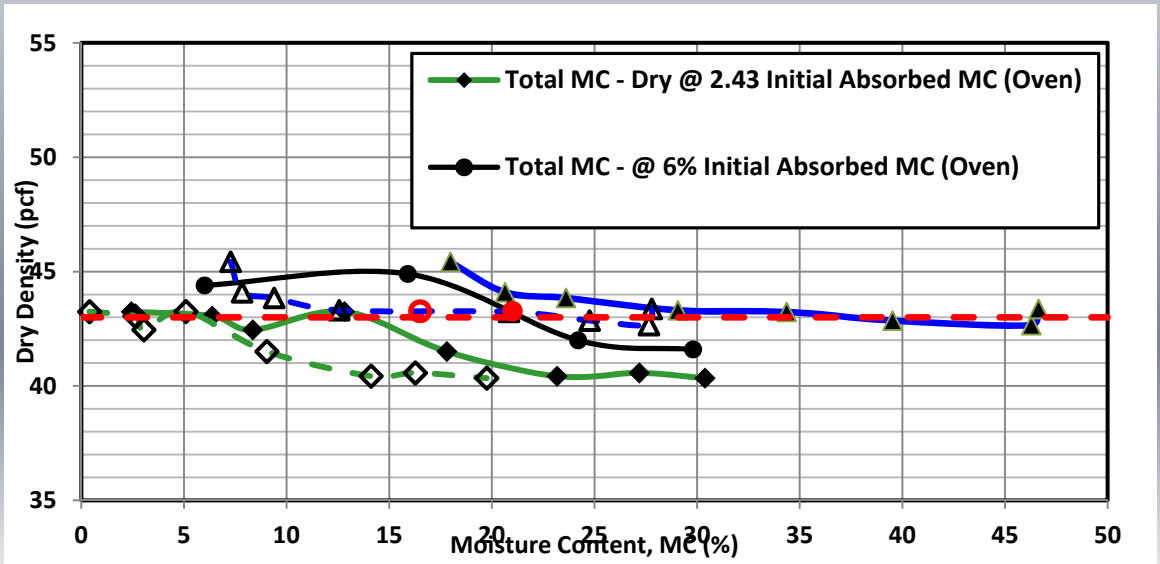
Test Section (Wet)

Lightweight Aggregate Borrow Compaction Verification Challenges



Compaction Control

- Laboratory Compaction Curves
- Moisture Content Varied Significantly for the same Dry Density
- Target 95% Max Dry Density = 43 pcf

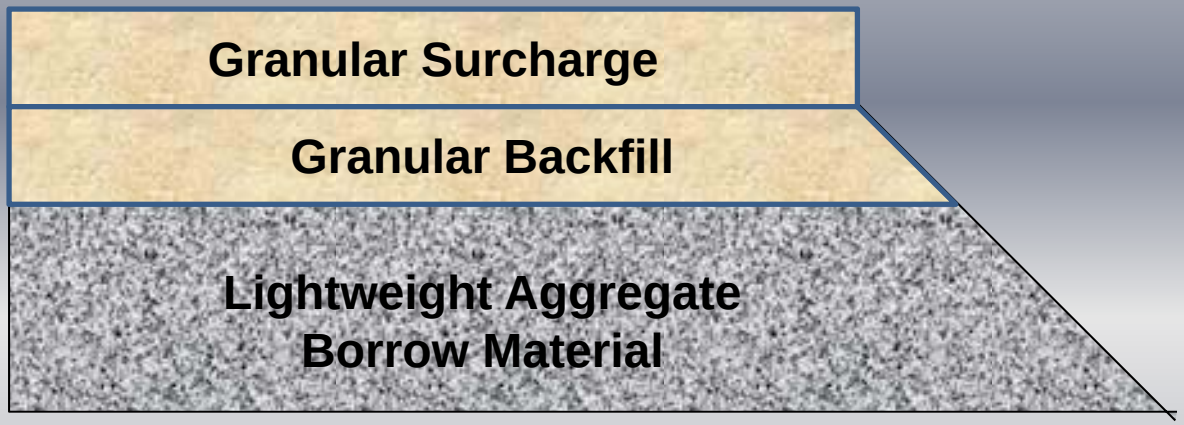


Compaction Control

- Conducted Test Section #2 to Evaluate Compaction Control Methods
- Compaction Control - Calibrated Nuclear Density Gauge, Sand Cone, 1 ft^3 Steel Box, and EDG.

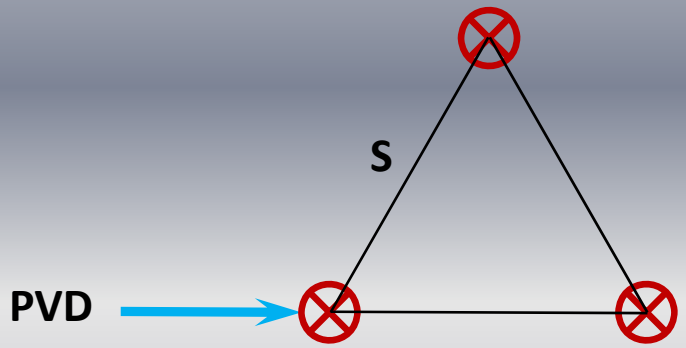
Compaction Control
Calibrated Nuclear Gauge

Granular Surcharge & Lightweight Aggregate Borrow



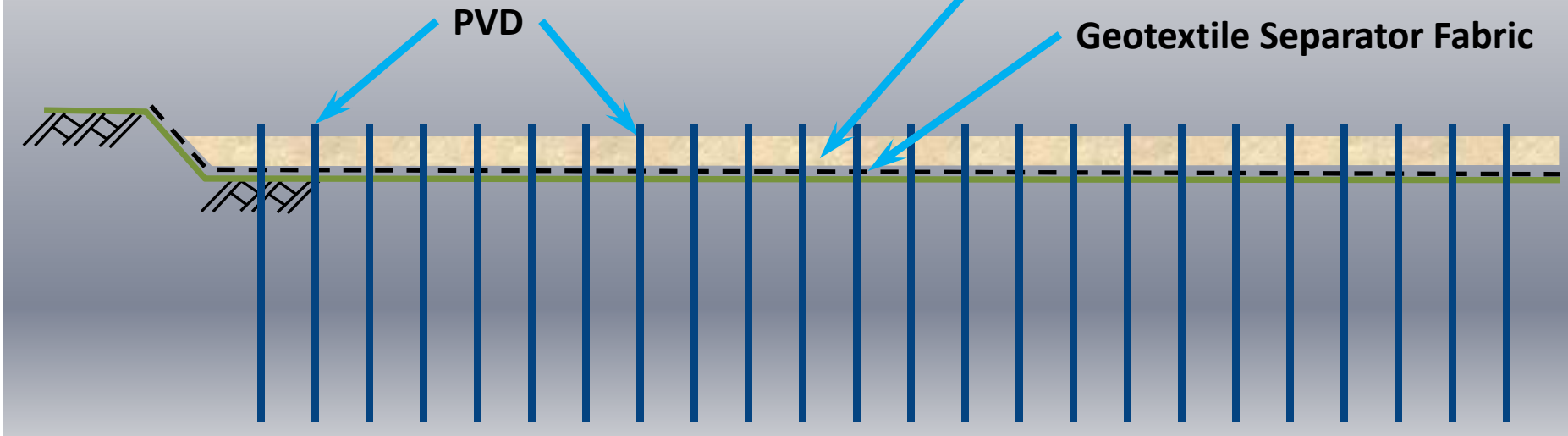
- Design Team Performed a Redesign
- Reduced the Lightweight Quantity by 15%
- Saved Horry County **$2 Million**

PVD Installation

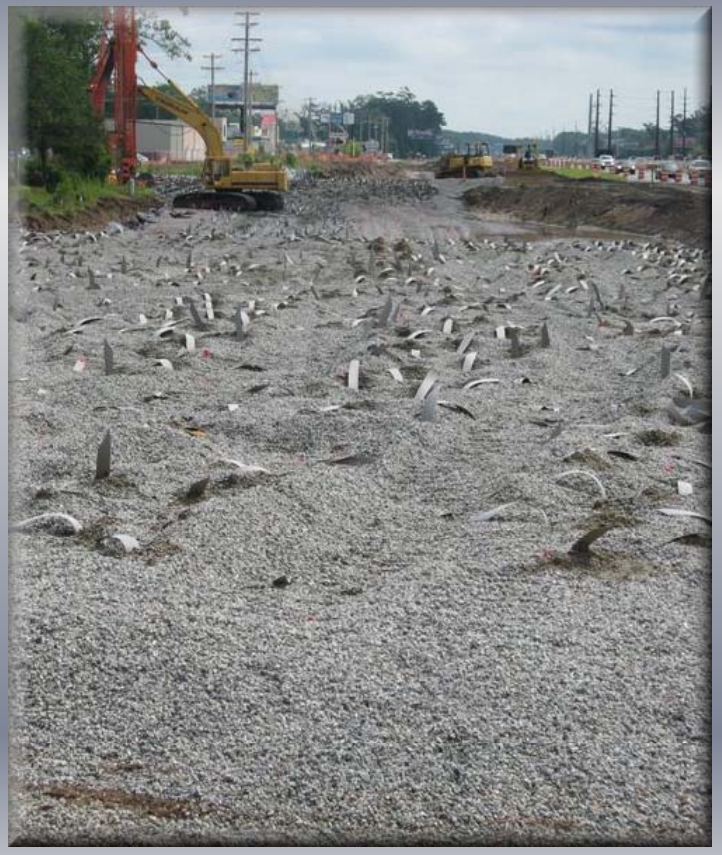


PVD Triangular Installation Pattern

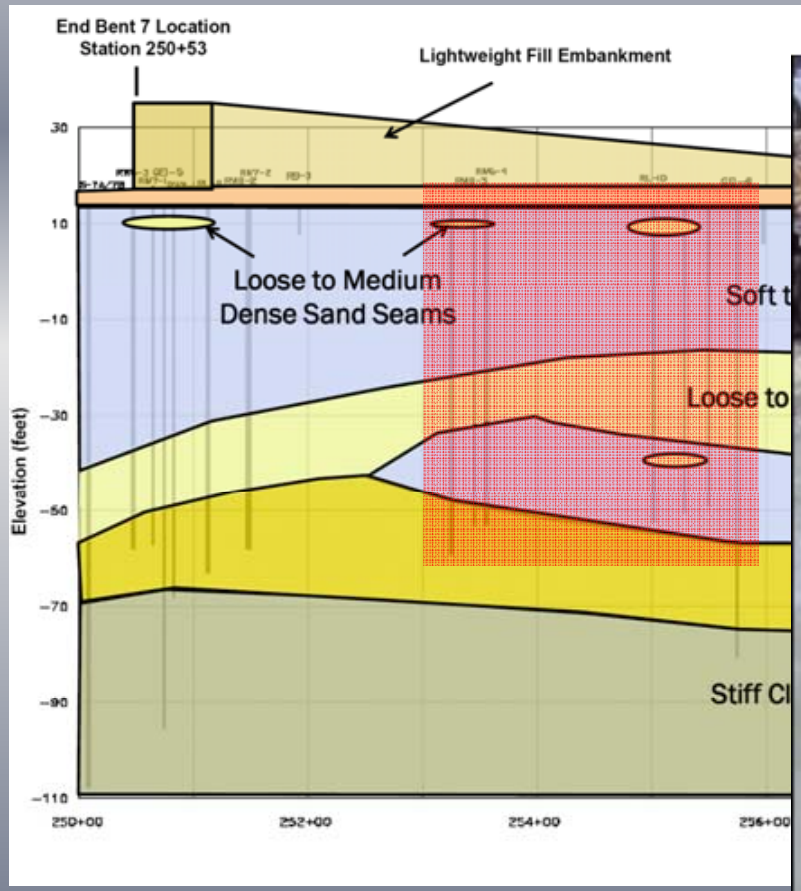
s = 3’ and 4’



PVD Installation



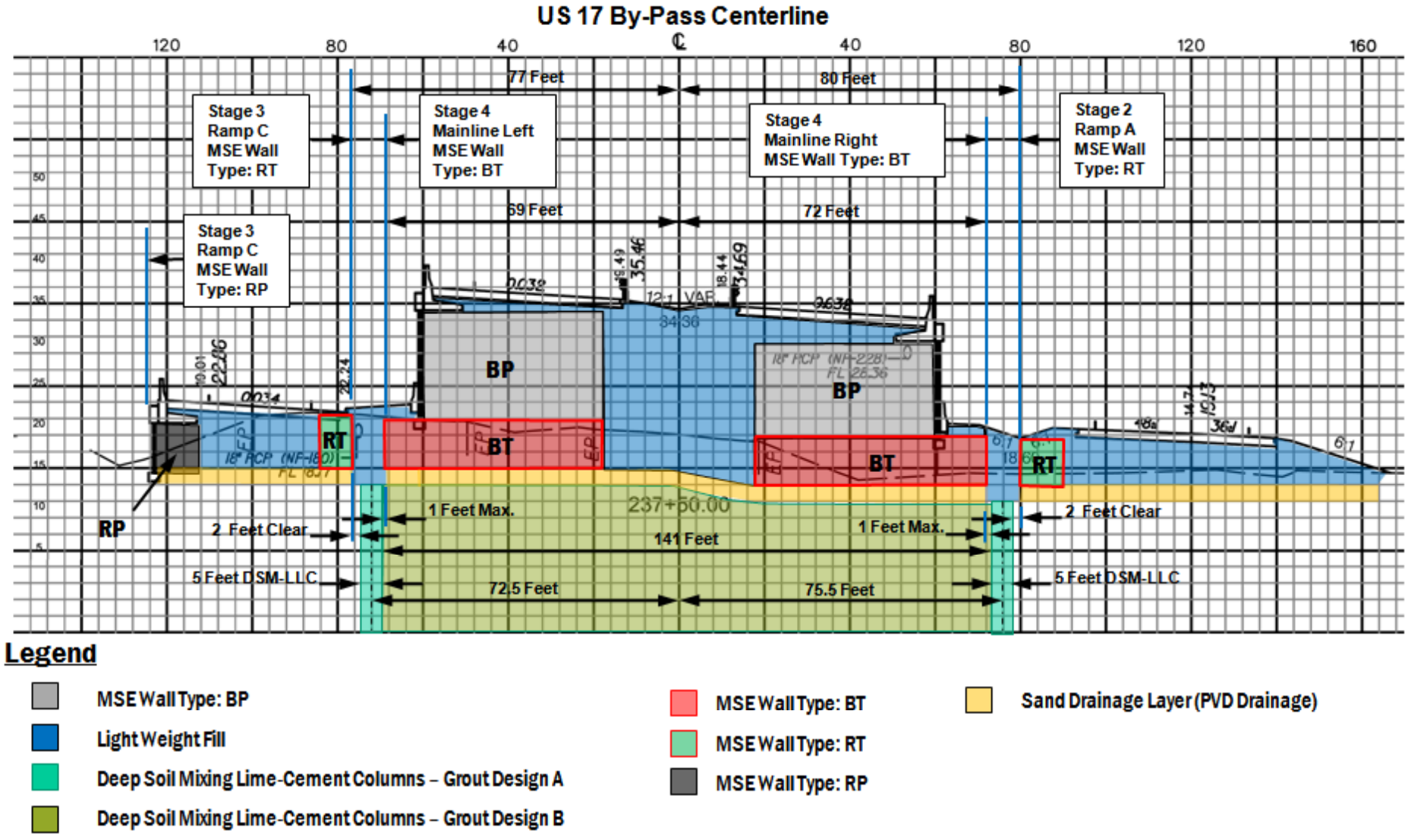
PVD Installation Obstructions!!!



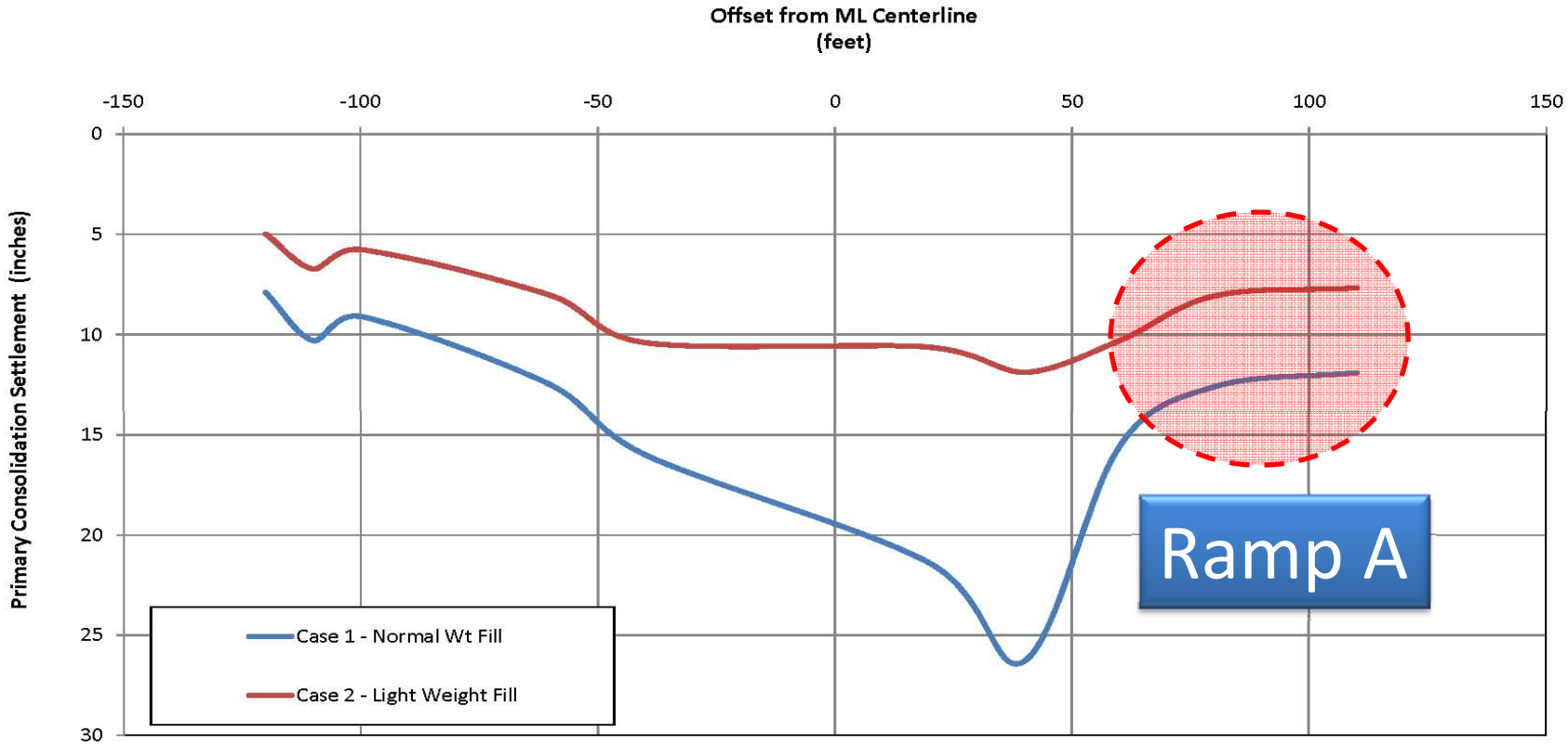
Predrilling

PVD Installation

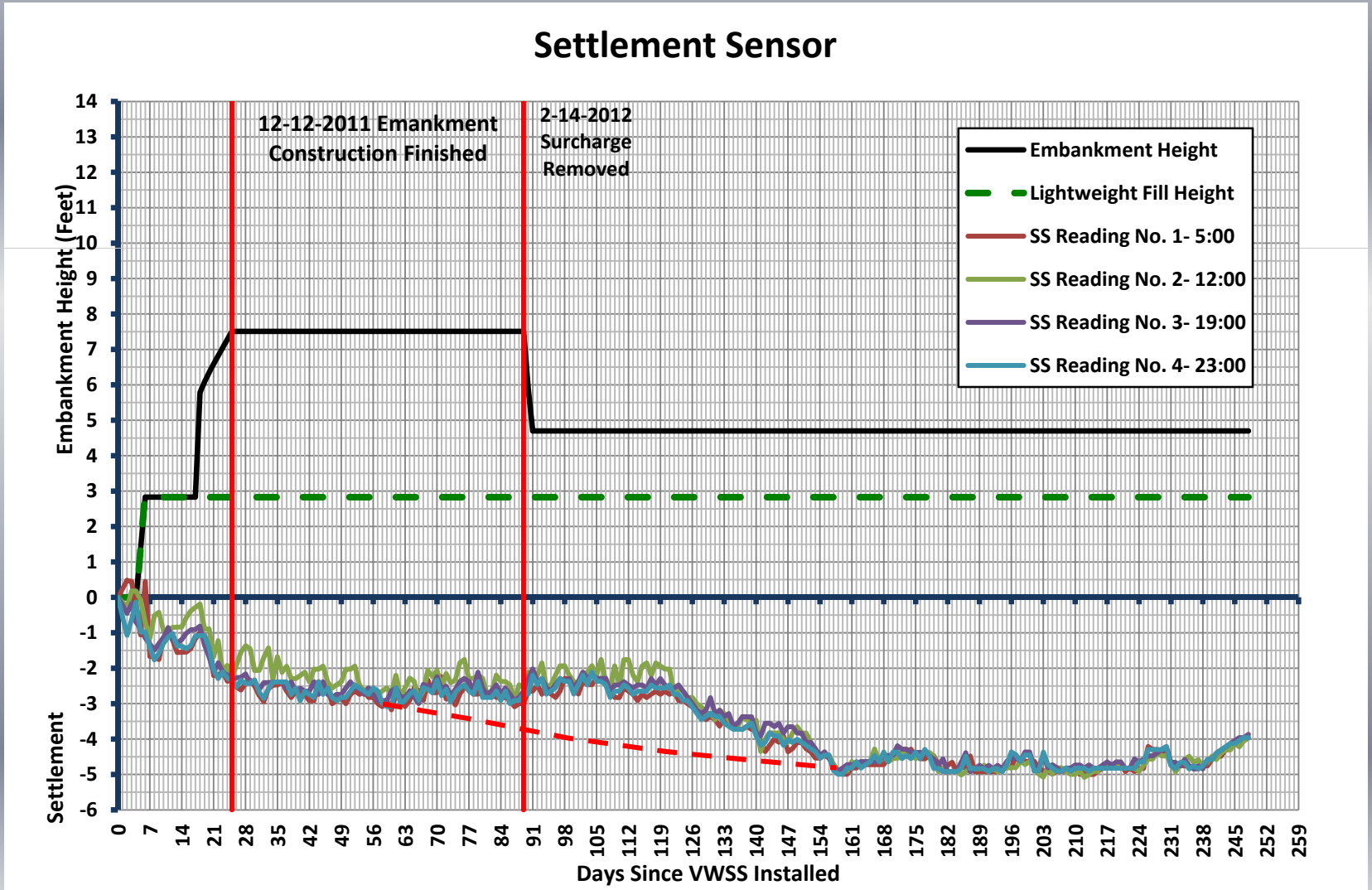
X-Section End Bent 1
(South Bridge Abutment, 237+50)



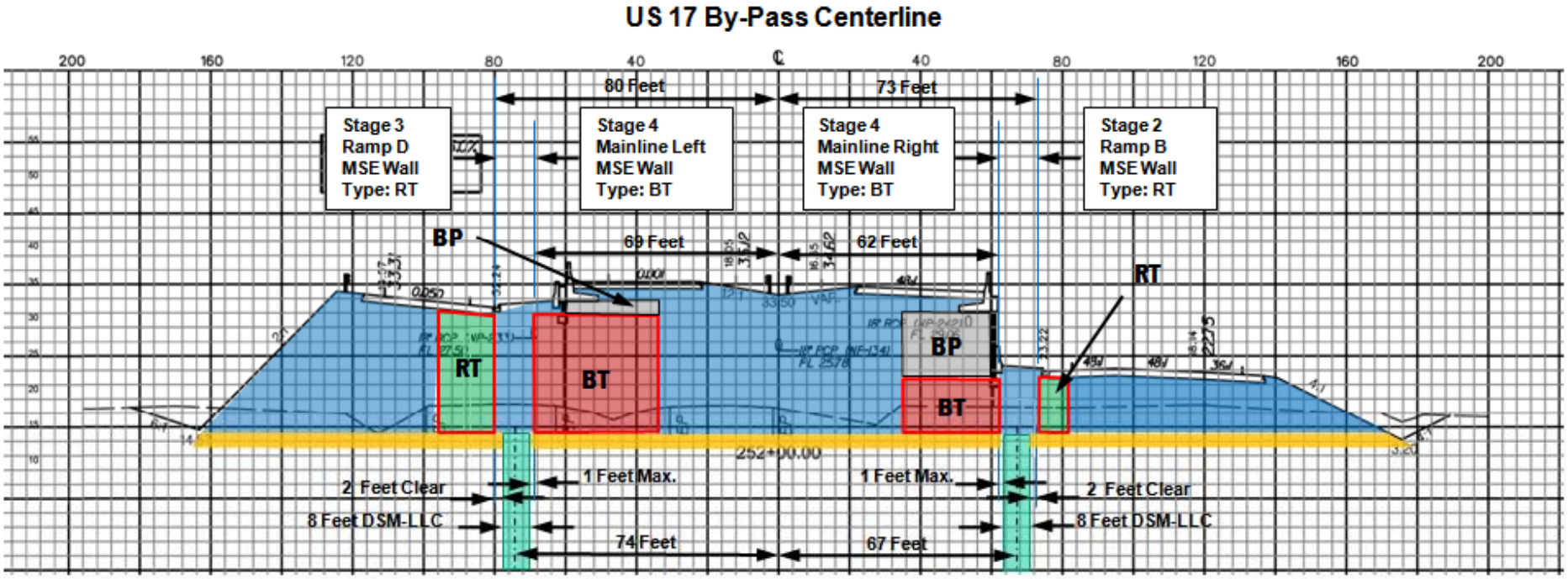
Settlement Transverse Profile
(South Bridge Abutment – 237+83)



Ramp A
Settlement Measurements



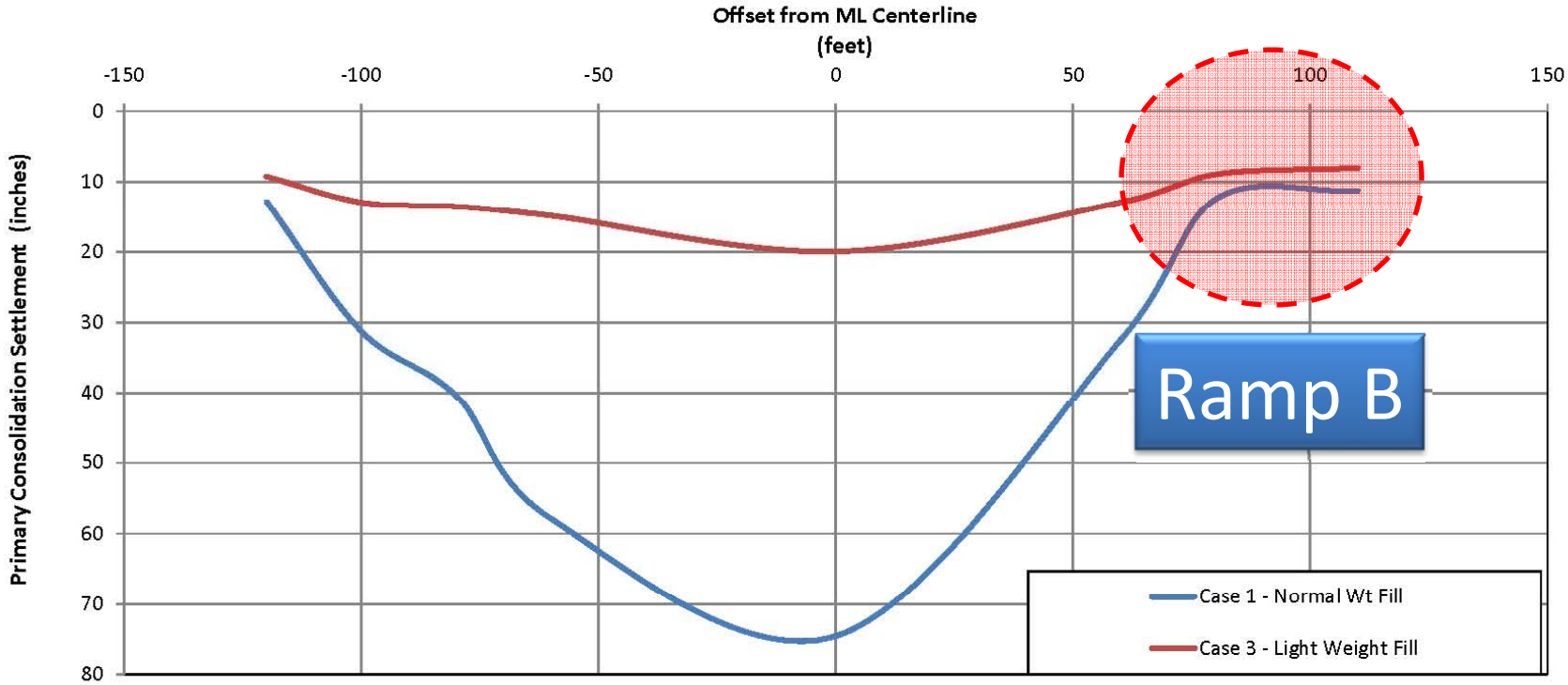
X-Section End Bent 7
(South Bridge Abutment, 250+26)



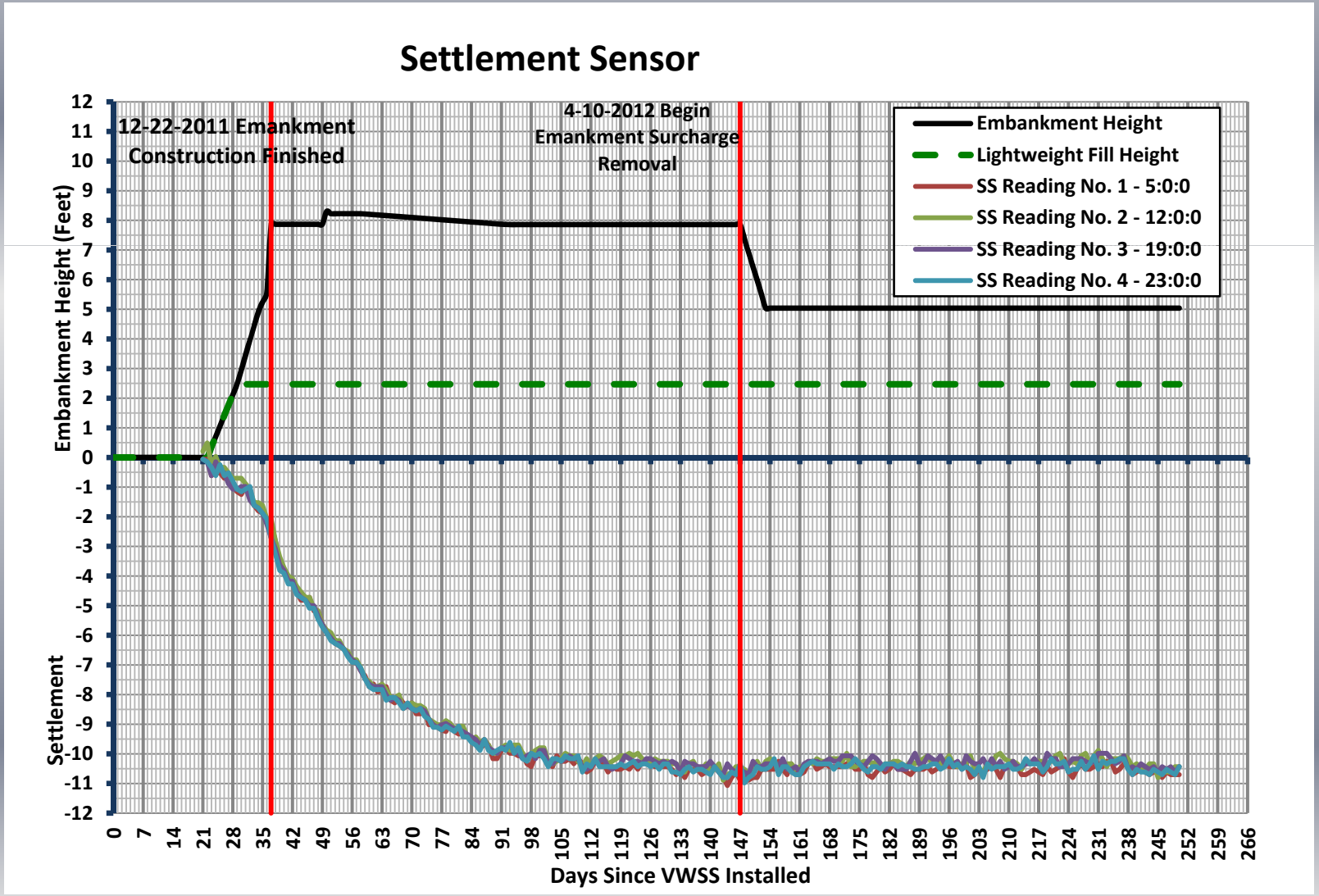
Legend

- MSE Wall Type: BP
- Light Weight Fill
- Deep Soil Mixing Lime-Cement Columns – Grout Design A
- MSE Wall Type: BT
- MSE Wall Type: RT
- MSE Wall Type RP
- Sand Drainage Layer (PVD Drainage)

Settlement Transverse Profile (North Bridge Abutment - 250+26)

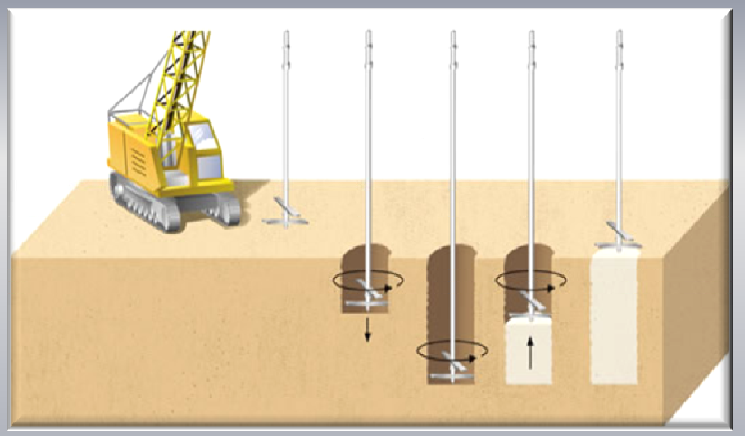


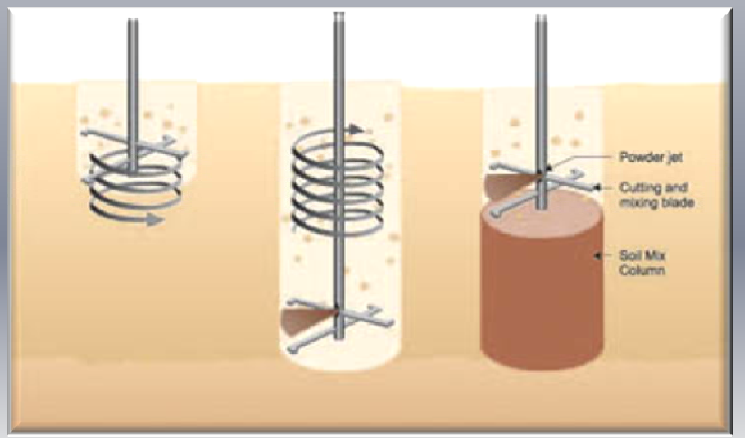
Ramp B
Settlement Measurements



Deep Soil Mixing Columns
(Overlap – Block Pattern)

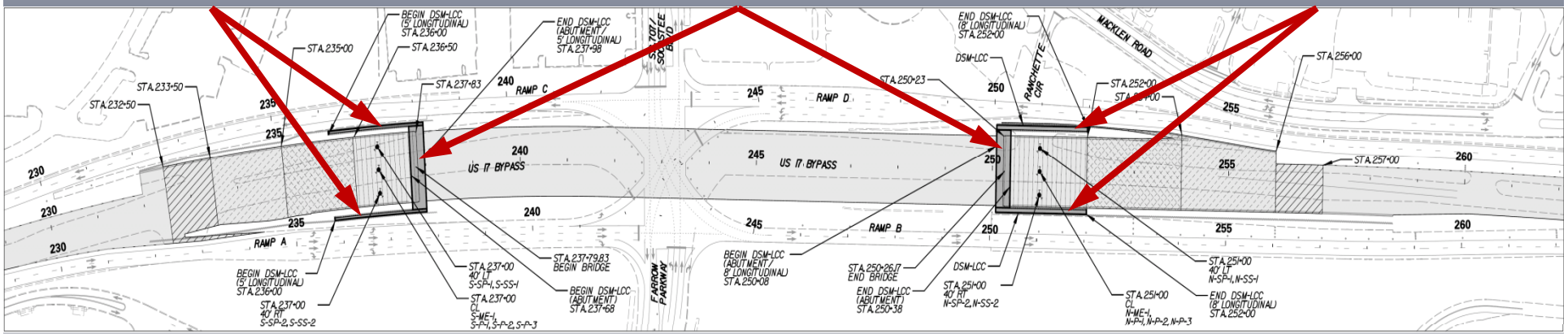
- **Seismic Slope Stabilization – Shear Key**
- **Improved Performance of Bridge Abutment Foundations**
- **2013**

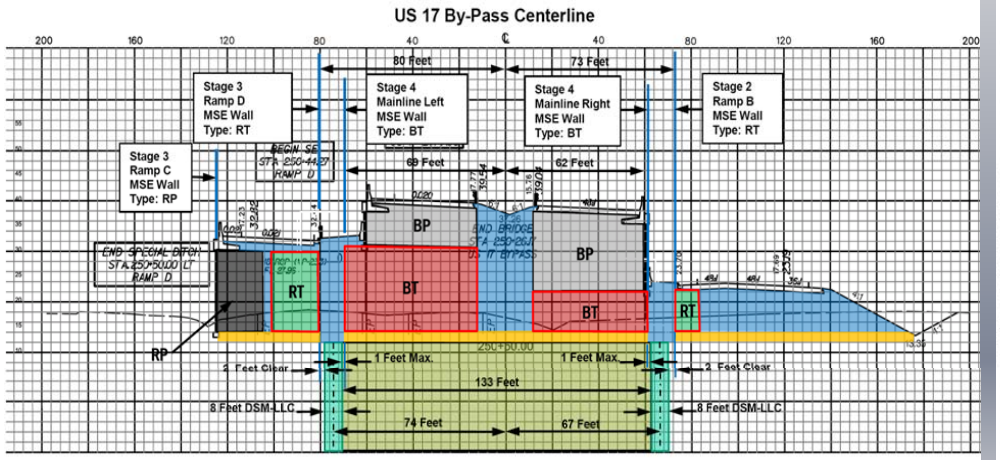


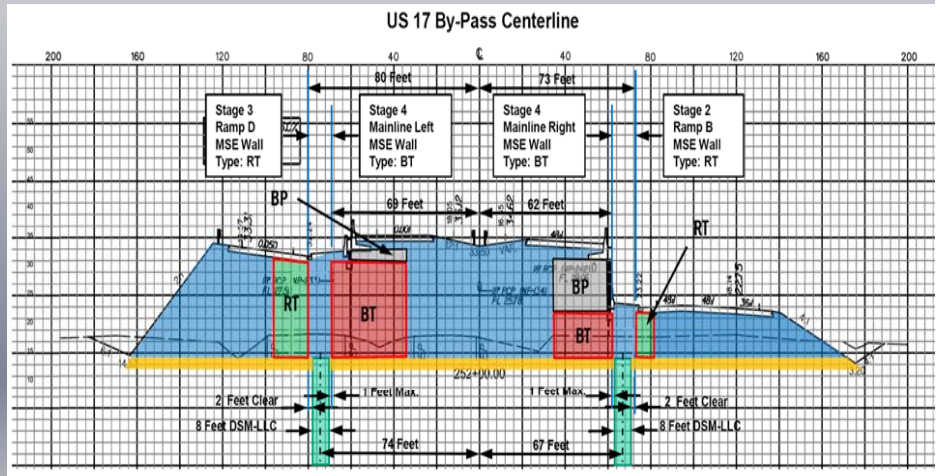


Deep Soil Mixing Columns
(Overlap – Block Pattern)

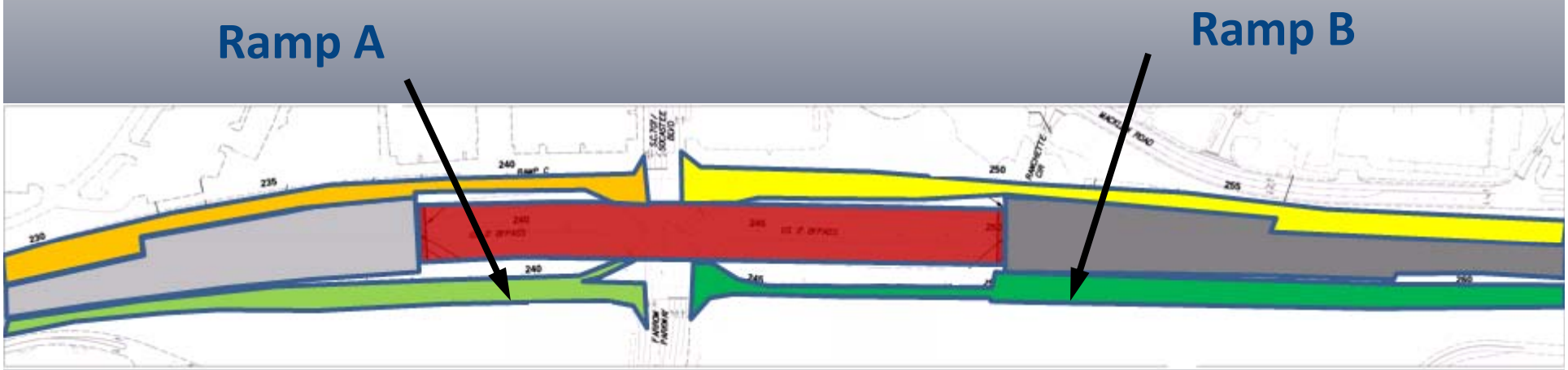
Longitudinal DSM **Bridge Abutment DSM** **Longitudinal DSM**







Traffic Control Stage 2



- MSE Walls
- Lightweight Aggregate Borrow Material
- 2’, and 3’ Granular Surcharge (Normal Weight)
- 3’ and 4’ Triangular Spacing PVD
- Geotechnical Instrumentation

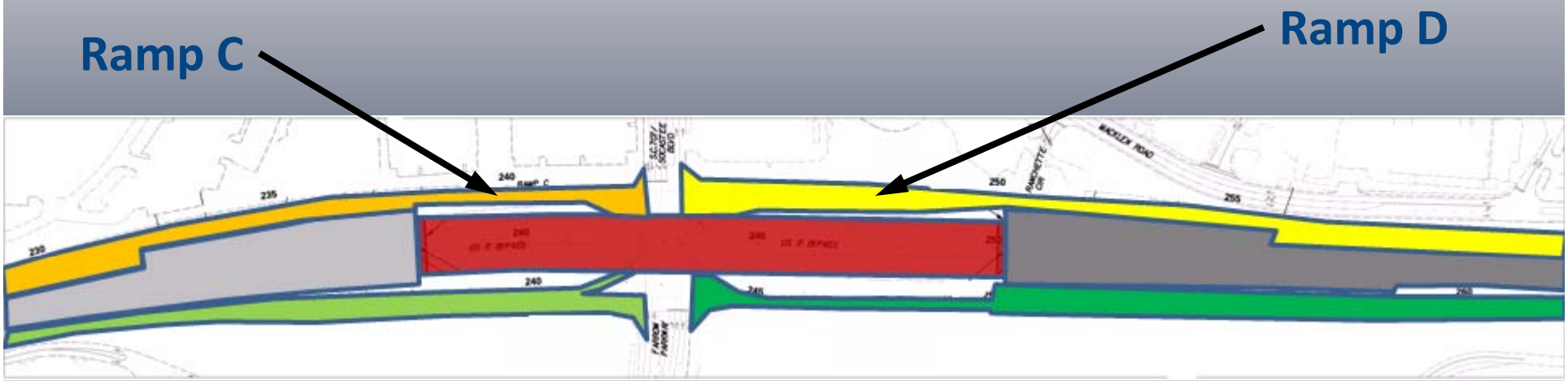
Construction Ramp A & B
(PVD Installation)

Construction Ramp A & B
(MSE Wall Embankment Construction)

Construction Ramp A & B
(MSE Wall Embankment Construction)

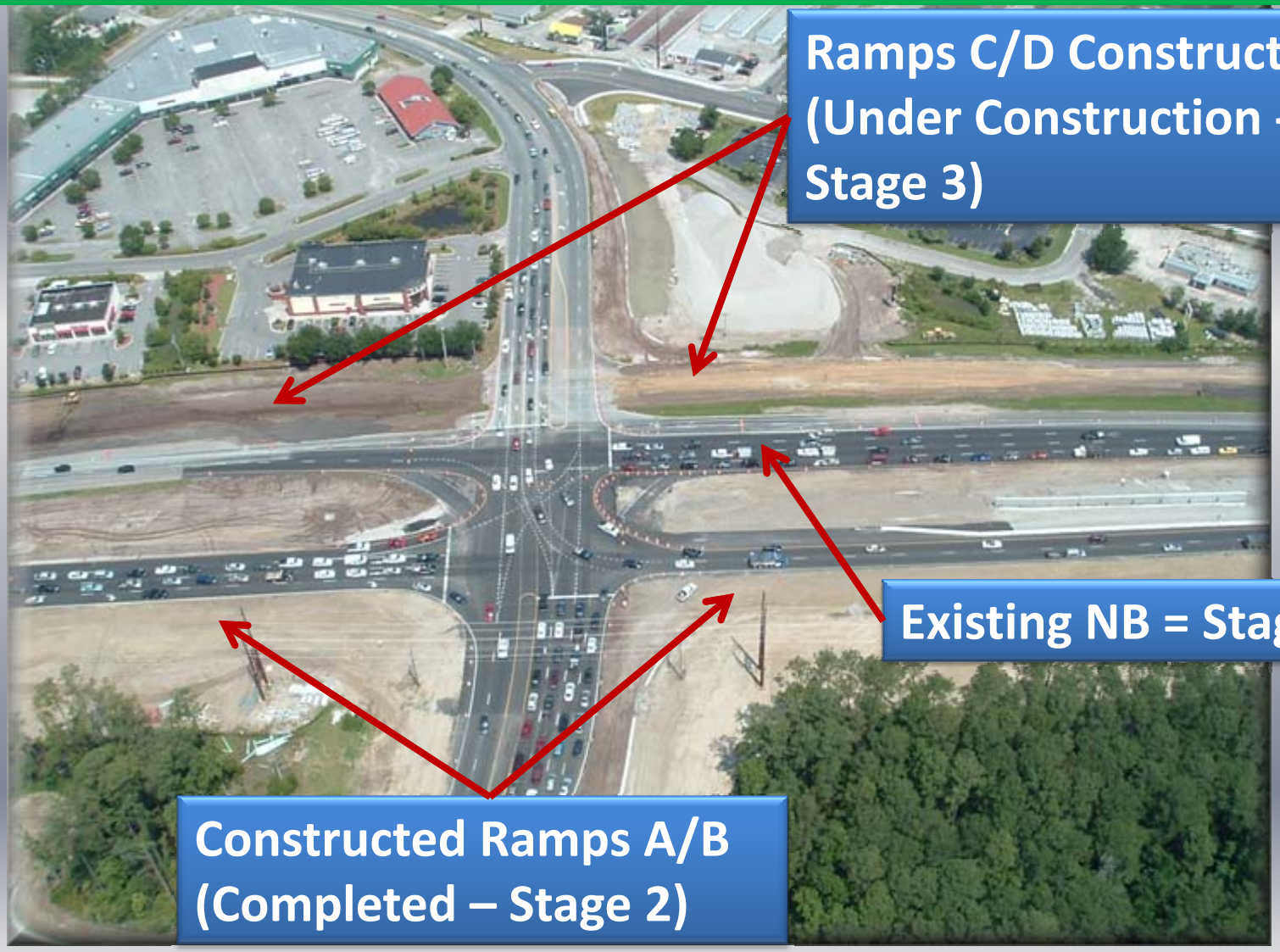
Construction Ramp A & B
(MSE Wall Embankment Construction)

Traffic Control Stage 2



- MSE Walls
- Lightweight Aggregate Borrow Material
- 1’, 2’, and 4’ Granular Surcharge (Normal Weight)
- 3’ and 4’ Triangular Spacing PVD
- Geotechnical Instrumentation

Traffic Control Stage 3
(Ramps A & B Completed)



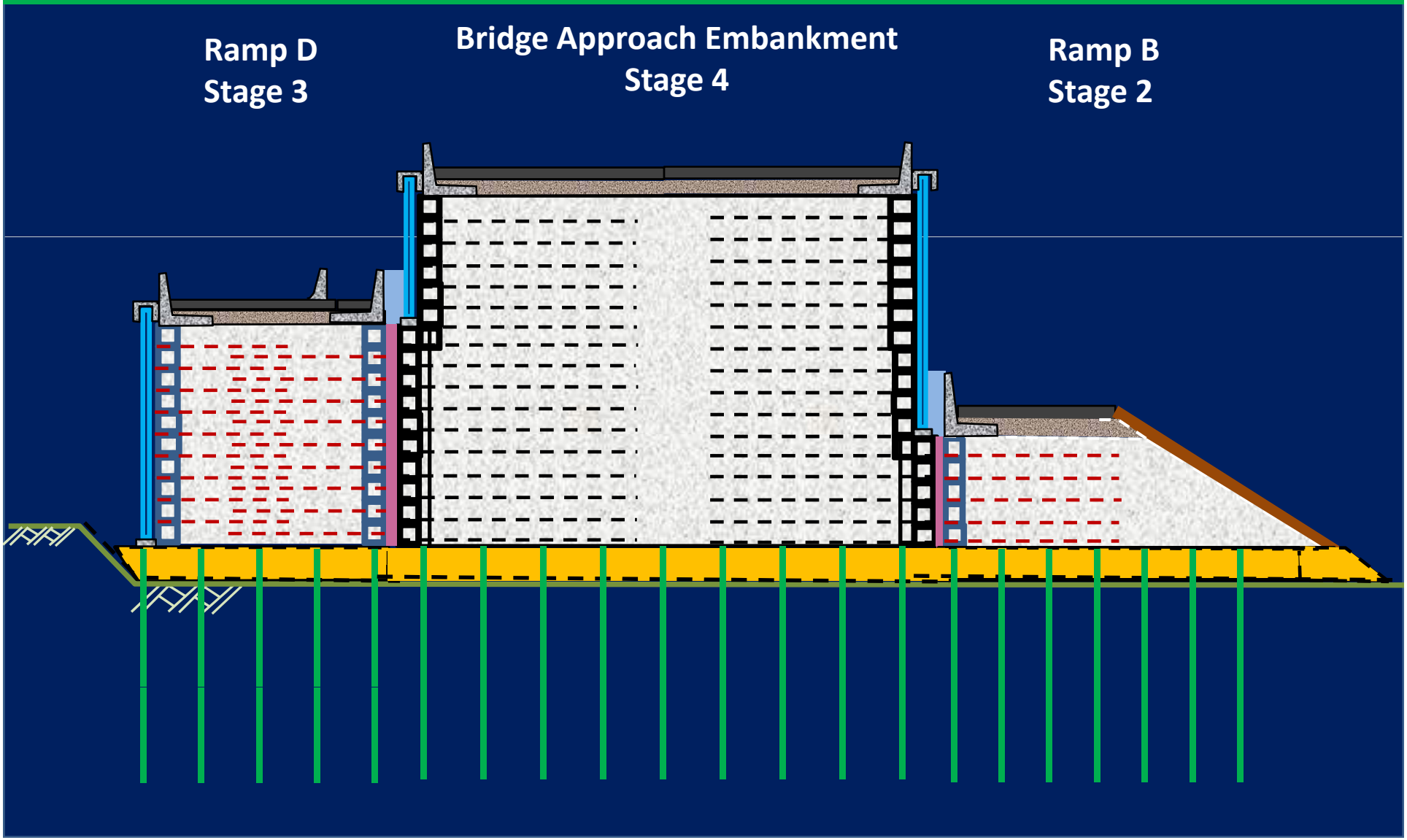
Construction Ramp C & D
(Ramps A & B Completed)

Traffic Control Stage 4

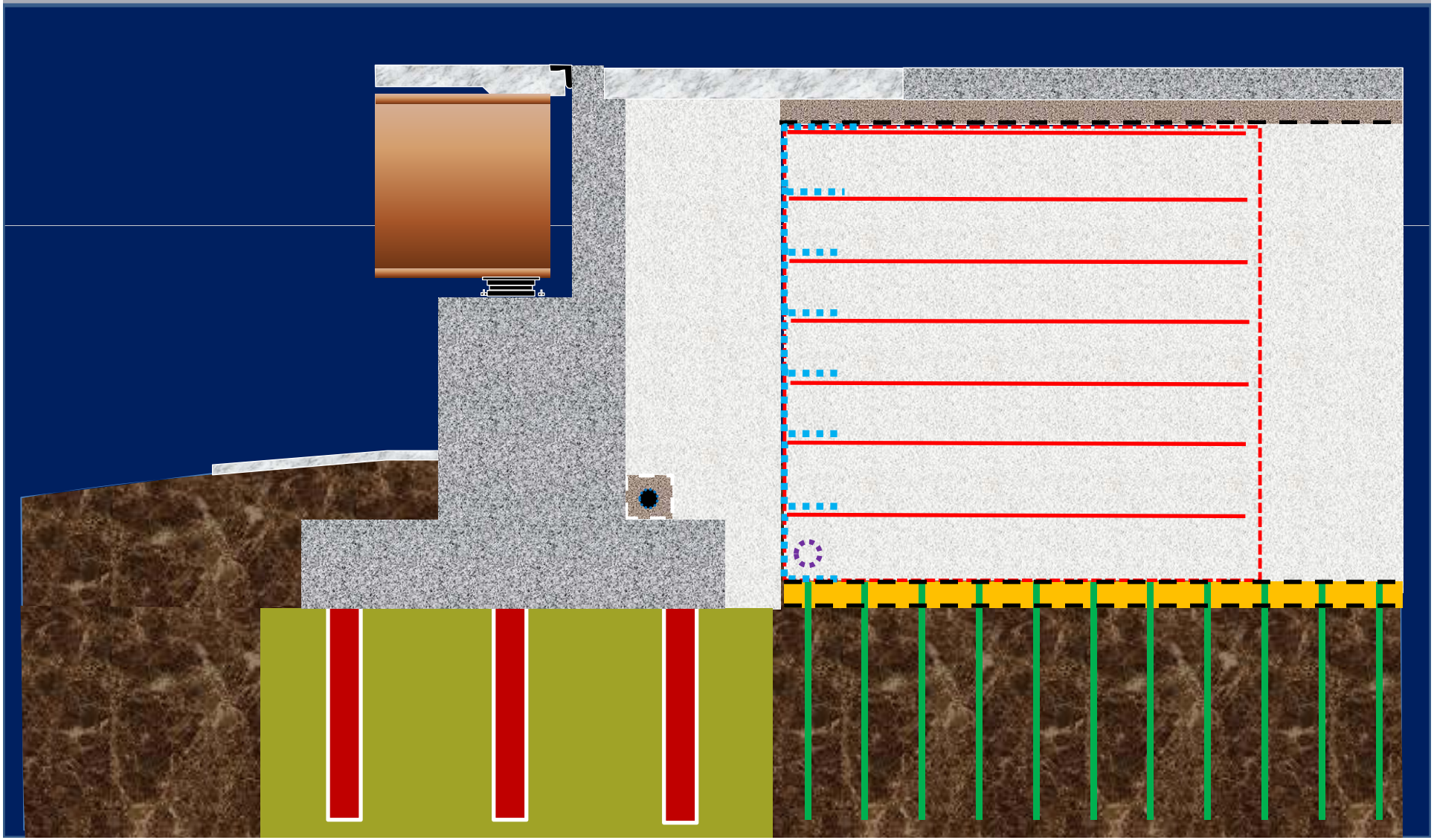
South Bridge Approach **Backgate Bridge** **North Bridge Approach**

- MSE Walls
- Lightweight Aggregate Borrow Material
- 1’, 2’, and 3’ Granular Surcharge (Normal Weight)
- 3’ Triangular Spacing PVD
- Geotechnical Instrumentation
- Bridge Abutment DSM
  (South 30’ x 133’ x 50’deep – North 30’ x 141’ x 70’deep)
- Longitudinal DSM (South 5’ Wide / North 8’ Wide)

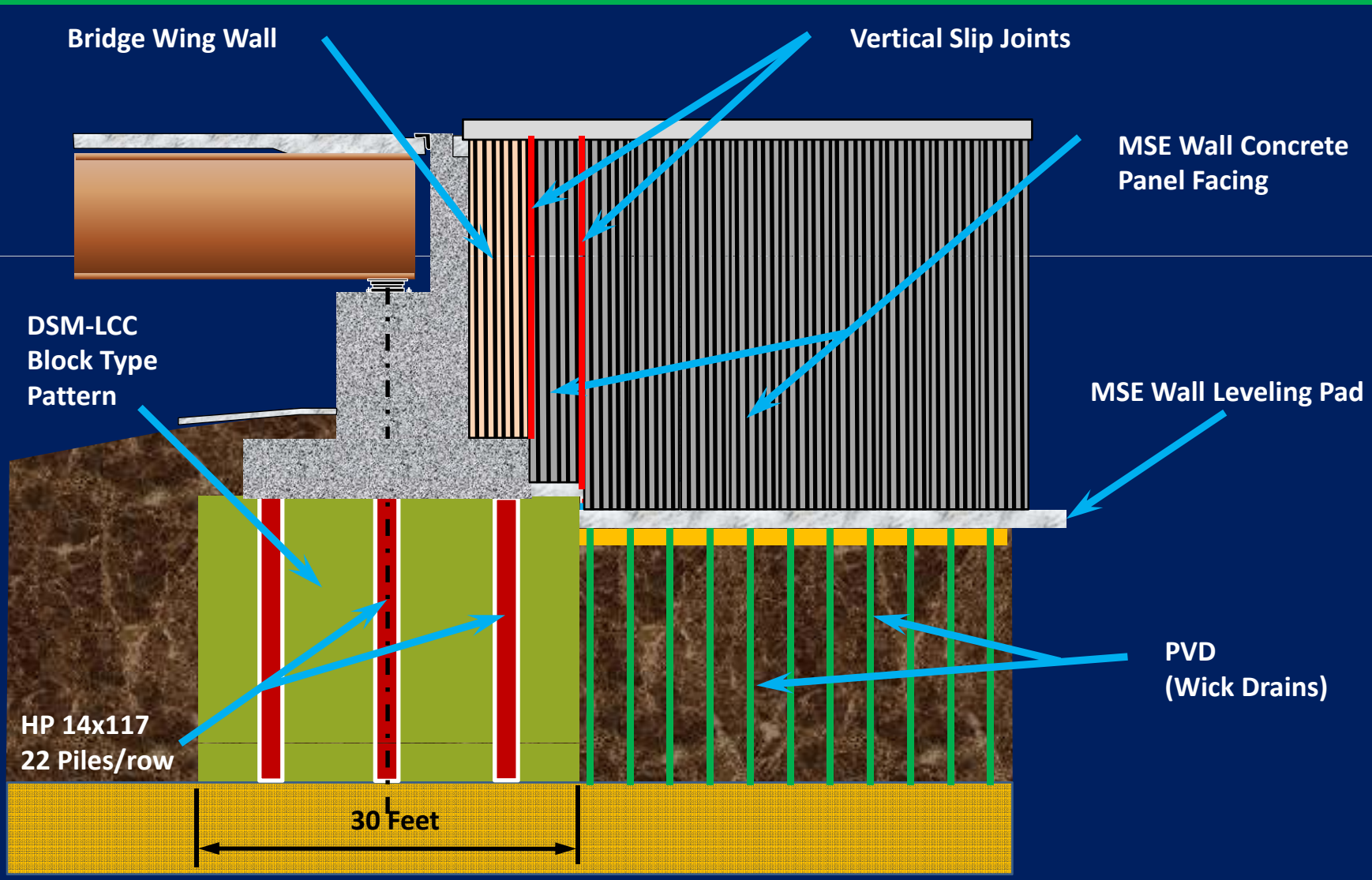
Project Construction Stages
(North Abutment 252+01)



Bridge Abutment Construction (North Abutment – End Bent 7)



Bridge Abutment Construction



Geotechnical Instrumentation

Settlement Monitoring

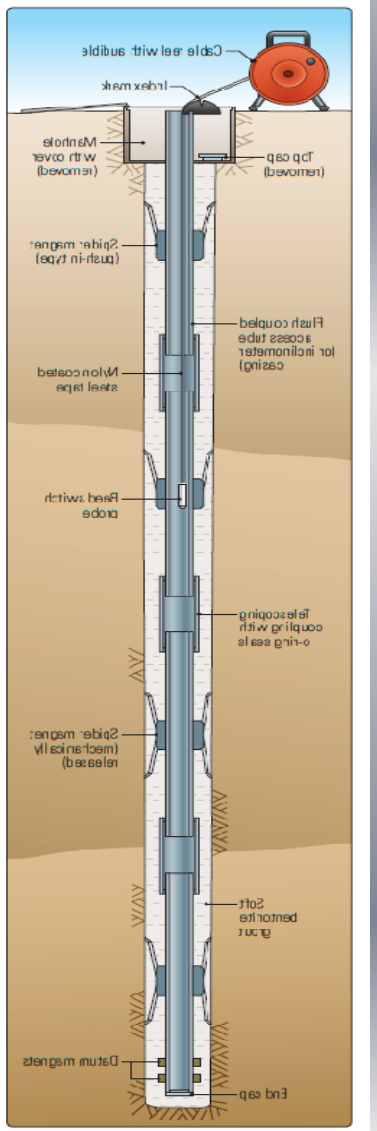
- 10 Settlement Plates (SP)
- 4 Magnetic Extensometer (ME)
- 12 VW Settlement Sensors (VWSS)
- 17 VW Piezometers (VWP)
- 2 VW Data Collection Centers (VWDCC)

Slope Stability

- 6 Slope Indicator (SI)

Settlement Plates

VW Magnetic Extensometers

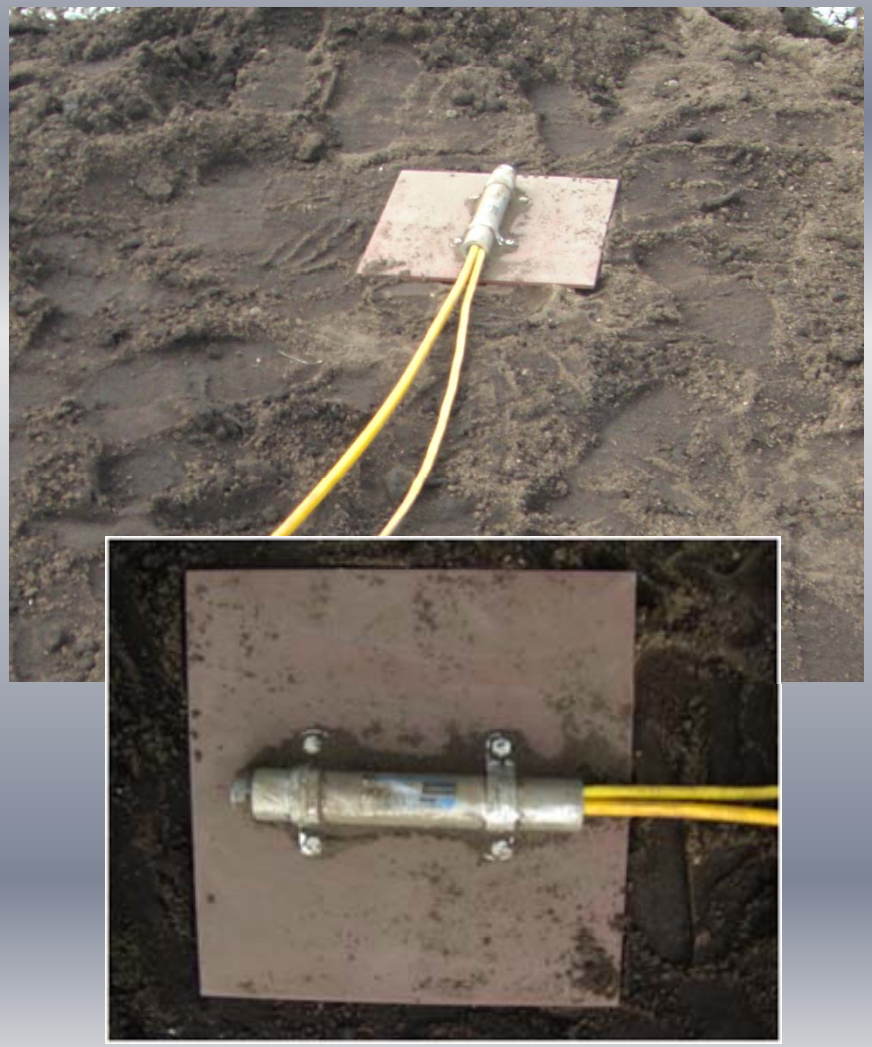


Pre-Assembled ME

Spider Magnet

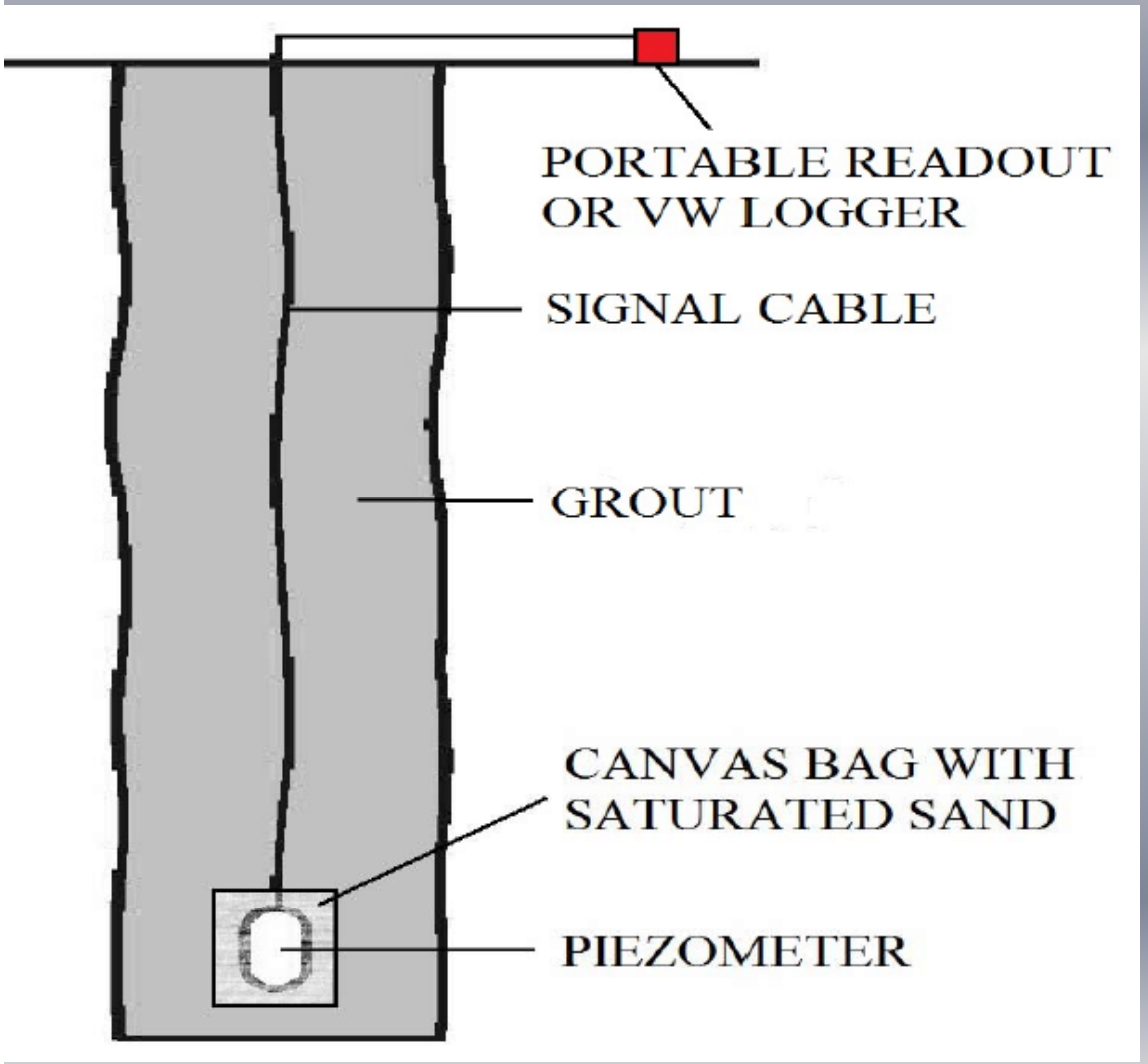
Telescoping Section

VW Settlement Sensors

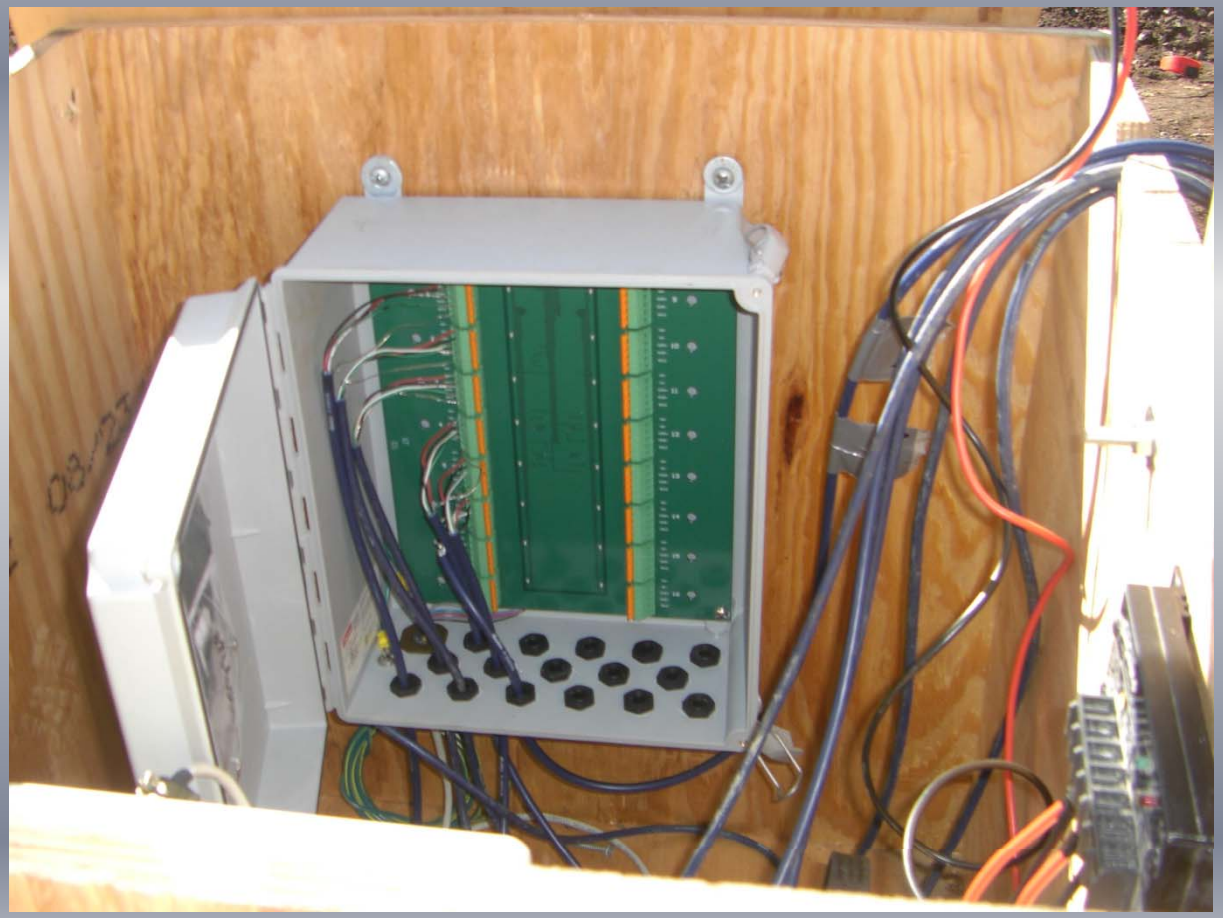


VW Settlement Sensor Data Collection

VW Piezometers

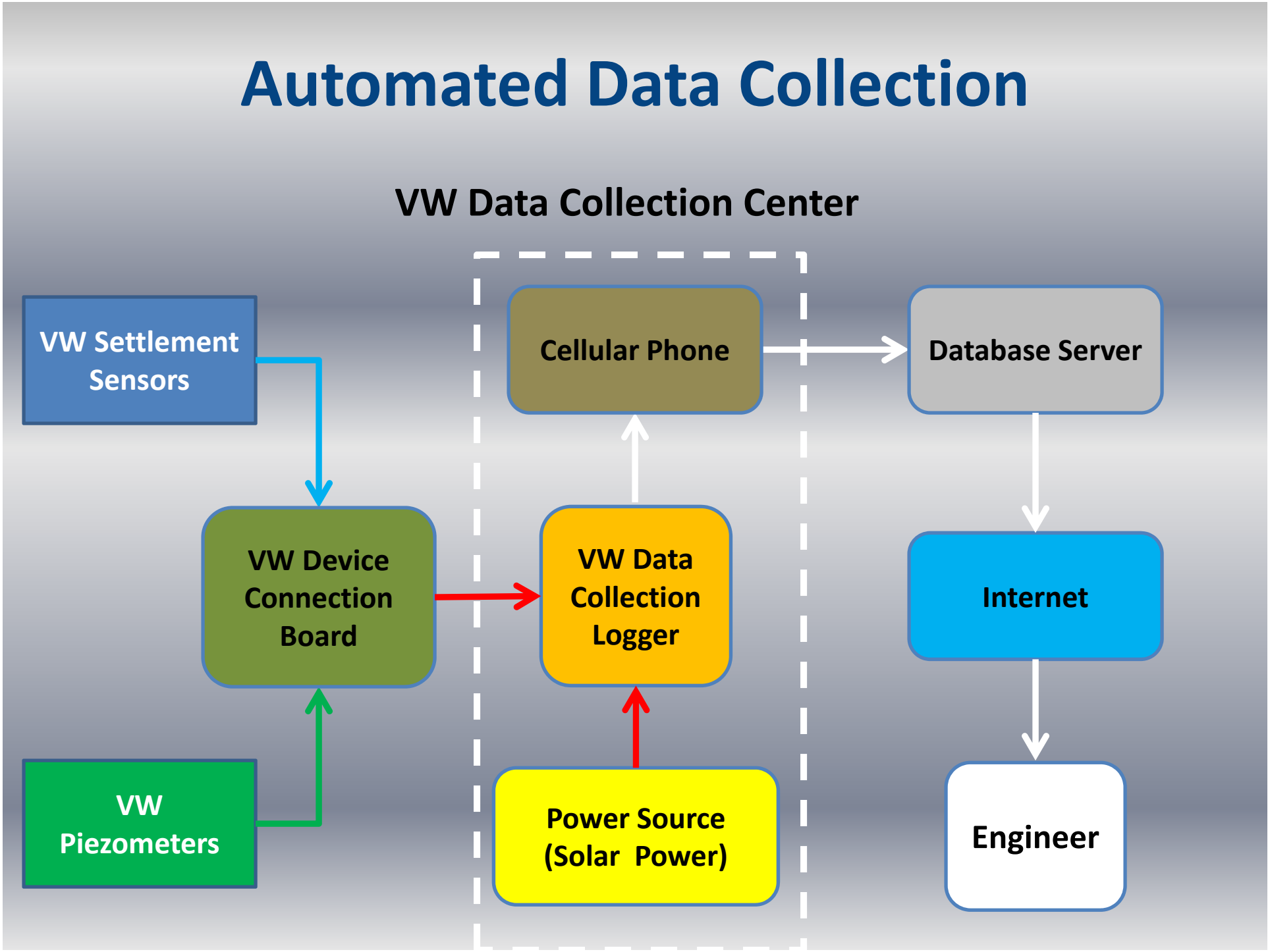


VW Device Connections



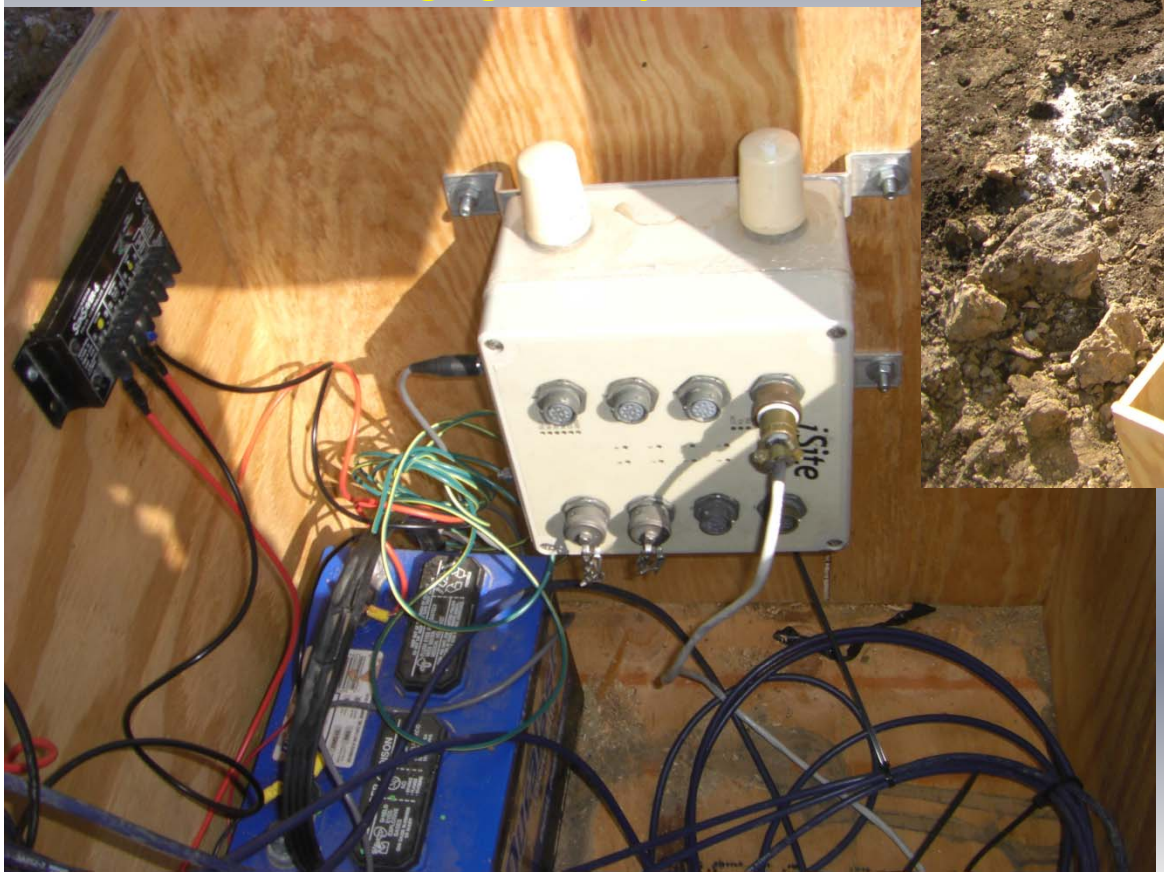
VW Devices connected to 16-channel Board

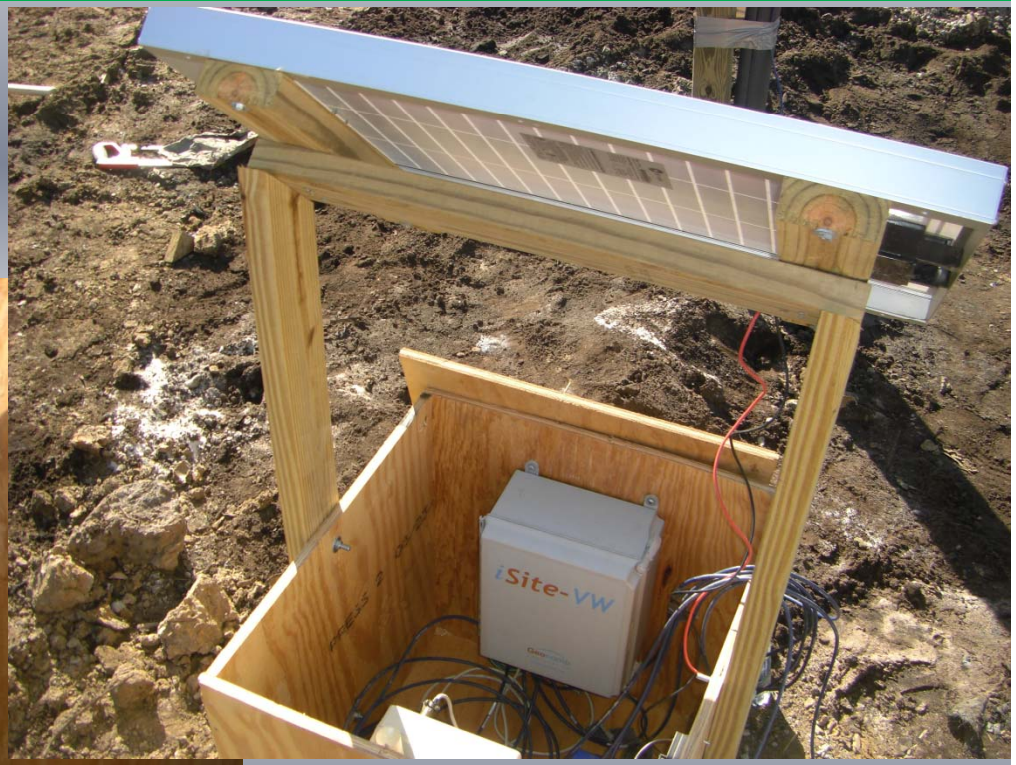
Automated Data Collection



Data Collection Center

iSite Logger with Solar Controller Charging Battery





Inside DCC Enclosure & Solar Panel