Southern Ohio Veterans Memorial Highway
STATE ROUTE 823
ODOT TEAM

- District Deputy Director
  Vaughn Wilson, PE
- Project Manager
  Tom Barnitz, PE
- Design/Construction Manager
  Mike Loeffler, PE
- Public Information Officer
  Kathleen Fuller
- Scioto County Manager
  Chris Niziol
- ch2m
  Bryan Parsell, PE
  Ram Nunna, PE
  Sam Houdeshell, PE

Wick Drain Installation
PORTSMOUTH GATEWAY GROUP

Developer – Portsmouth Gateway Group, LLC

- Chief Executive Officer and Project Manager: Bill Maddex
- Lead Operations and Maintenance Manager: Mike Smith

Design-Build Contractor – Portsmouth Joint Venture

- Lead Contractor Project Manager: Hugo Fontirroig
- Lead Contractor Deputy Project Manager: Chad Ratkovich
- Lead Contractor Construction Manager: Steve Feix
- General Superintendent: Todd Thatcher / Jeramiah Johnson

Independent Quality Firm – HDR

- Independent Quality Manager: Jim Bretinger, PE
- Independent Design Quality Manager: Doug Voegele, PE
- Independent Construction Quality Manager: Neil Richards, PE
PORTSMOUTH GATEWAY GROUP

Design Team – ms consultants/S&ME:

- Design Team Project Manager: Todd Long, PE
- Design Quality Manager: Larry Shannon, PE
- Lead Roadway Engineer: Jason Hodges, PE / Sean Riffle, PE
- Lead Drainage Engineer: Sean Riffle, PE
- Lead Structural Engineer: Jonathan Hren, PE
- Lead Geotechnical Engineer: Rich Weigand, PE / Chris Nye, PE
- Deputy Geotechnical Engineer: Brian Sears, PE
PROJECT PURPOSE AND NEED

- Completes Appalachian Highway in Ohio
- The Appalachian Highway system is designed to:
  - Generate economic development;
  - Connect Appalachia to interstate system;
  - Improved Regional & National market access.
- Currently the “through” traffic disburses over 6 different routes
- reduces current 26 mile travel time by avoiding:
  - 30 traffic signals,
  - 80 intersections,
  - 500 driveways
- Improves safety and congestion
PROJECT TIMELINE

CONSTRUCTION PERIOD: 3 yrs – 8 mo.

OPERATING PERIOD: 35 years

Financial Close

NTP: Design Work start

Commencement of Construction

Construction Substantial Completion Date

Design Substantially Complete

Final Acceptance Date

120 days

120 days

Funding of Handback Reserve

End of Term

April 2015

June 2015

July 2016

Dec. 2018

2 years

120 days
PROJECT ROUTE

Begin SR-823

End SR-823
DESIGN PHASING

ODOT Current Designation

Phase 1    Segment 2B/3A
Phase 2    Segment 3B/4
Phase 3    Segment 1/2A

Buildable Unit Deliverables:

1. Line and Grade
2. SWPPP
3. Grading and Culverts
4. MOT
5. Bridges
6. Detailed Design (Pavement, Lighting, Storms, Markings, Signs, etc.)
CONSTRUCTION SCHEDULE

Financial Close
April 2015

Commencement of Construction
June 2015

2016

Design

2017

Utilities

Wick Drains

Culverts

Excavation – Segment 1

Excavation – Segment 2

Excavation – Segment 3

2018

Excavation – Segment 4

Pavement

2019

Structures

Finishes

Dec 2018

Substantial Completion

April 2019

Final Acceptance

June 2015

April 2015

2016

2017

2018

2019
MAJOR PROJECT COMPONENTS

- Greenfield project
- ODOT Preconstruction Activities
- 5 Interchanges
- Approx. 20 Million cubic yards of earthwork
- Earthwork balancing within each of 4 segments (some waste areas required)
- Wick drains
- 23 Bridge Structures including steel girder, prestressed concrete, Conspan arch and cattle crossing box
- 26 MSE Walls, 1 CIP Concrete Wall
- Drilled shafts, driven piles, shallow foundations
MAJOR PROJECT COMPONENTS

DRAINAGE

- More than 80 Culverts
- Fills over Culverts in excess of 100’ (Camber included to mitigate settlement)
- Culvert Installation Plans
- Slope of culvert flow lines as much as 20%
- Ditch locations considered in slope stability analyses
- Culvert Differential Settlement concerns under large fills with variable in-situ materials
CULVERT GEOTECHNICAL DESIGN

- Geotechnical Design Services Included:
  - Perform additional soil borings to address modifications to culvert alignments during bidding phase
  - Assess subsurface conditions from project borings (previously performed by others) and/or supplemental borings drilled during design
  - Estimate settlement profile along culvert length
    - Account for skew by using appropriate cross sections
    - Account for excavation to planned culvert bearing
  - Estimate shallow foundation bearing and sliding resistance for headwalls
  - Provide foundation remediation recommendations, where necessary
CULVERT GEOTECHNICAL DESIGN - SETTLEMENT

LOG OF: Boring R-449

Description:
- Topsoil: 7'
  - Stiff brown SLT AND CLAY (A-6a), little fine to coarse sand, trace gravel, contains sandstone fragments; damp.
  - Stiff brown SILTY CLAY (A-6b), trace fine to coarse sand, trace gravel, contains sandstone fragments; damp to moist.
  - @ 6.0' contains shale fragments
- Sev. weathered gray SHALE argillaceous.
- Very soft gray SILT SHALE interbedded with SANDSTONE; very fine grained, decomposed, argillaceous, micaceous, laminated to thinly laminated, broken, rust stained.

LEFT MID-SLOPE

Boring No: R-449
Ground Elev: 779.1 MSL

<table>
<thead>
<tr>
<th>Soil Layer</th>
<th>Depth (ft)</th>
<th>Description</th>
<th>N</th>
<th>C' (psi)</th>
<th>C (psi)</th>
<th>V' (psf)</th>
<th>W_s (%)</th>
<th>LL</th>
<th>PL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>A-6a</td>
<td>15</td>
<td>188</td>
<td>1792</td>
<td>27</td>
<td>125</td>
<td>14</td>
<td>32</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>A-6b</td>
<td>10</td>
<td>688</td>
<td>1359</td>
<td>14</td>
<td>125</td>
<td>18</td>
<td>37</td>
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<tr>
<td>3</td>
<td>15.5</td>
<td>A-6b</td>
<td>40</td>
<td>1488</td>
<td>1101</td>
<td>44</td>
<td>85</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>20.5</td>
<td>Withd SHALE</td>
<td>100</td>
<td>2313</td>
<td>0.953</td>
<td>95</td>
<td>425</td>
<td>135</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>25</td>
<td>SHALE</td>
<td>1977</td>
<td>0.869</td>
<td>-</td>
<td>1000</td>
<td>145</td>
<td>-</td>
<td>-</td>
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<tr>
<td>6</td>
<td>7</td>
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<tr>
<td>10</td>
<td>11</td>
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<td>-</td>
</tr>
</tbody>
</table>

Comments:
- C' determined as average value from the following methods:
  - $C' = 0.009(\text{LL} - 10)$
  - $C' = 0.37(C_\text{cc} + 0.003\text{LL} + 0.0004W_s - 0.34)$
  - $C' = 0.046 + 0.0104\Pi$
  - $C' = 0.00234(\text{LL})(G_s)$
  - $C' = 0.01W_s$
- C determined as: $C = 0.1C'$
CULVERT GEOTECHNICAL DESIGN - SETTLEMENT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Left Toe</th>
<th>Left Mid-Slope</th>
<th>Left Crest</th>
<th>Center Line</th>
<th>Right Crest</th>
<th>Right Mid-Slope</th>
<th>Right Toe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skew (degrees)</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Applicable X Sec Sta.</td>
<td>672+50</td>
<td>673+00</td>
<td>673+00</td>
<td>673+23</td>
<td>673+50</td>
<td>673+50</td>
<td>673+50</td>
</tr>
<tr>
<td>Crest Width (ft)</td>
<td>88</td>
<td>83</td>
<td>88</td>
<td>88</td>
<td>88</td>
<td>88</td>
<td>88</td>
</tr>
<tr>
<td>Centerline to Toe (ft)</td>
<td>379</td>
<td>405</td>
<td>356</td>
<td>350</td>
<td>194</td>
<td>198</td>
<td>200</td>
</tr>
<tr>
<td>Crest Elev (ft)</td>
<td>889.5</td>
<td>889.5</td>
<td>889.5</td>
<td>889</td>
<td>888.5</td>
<td>888.5</td>
<td>888.5</td>
</tr>
<tr>
<td>Existing Grade (ft)</td>
<td>775</td>
<td>793</td>
<td>792</td>
<td>800</td>
<td>813</td>
<td>815</td>
<td>820</td>
</tr>
<tr>
<td>a (ft)</td>
<td>335</td>
<td>312</td>
<td>306</td>
<td>150</td>
<td>154</td>
<td>156</td>
<td></td>
</tr>
<tr>
<td>b (ft)</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>x (ft)</td>
<td>379</td>
<td>224.5</td>
<td>44</td>
<td>0</td>
<td>44</td>
<td>121</td>
<td>200</td>
</tr>
<tr>
<td>Fill Height (ft)</td>
<td>114.5</td>
<td>96.5</td>
<td>97.5</td>
<td>89</td>
<td>75.5</td>
<td>73.5</td>
<td>68.5</td>
</tr>
</tbody>
</table>

Crest Width

Fill Height

Centerline to Toe

\[ \text{Crest Width} \]

\[ \text{Fill Height} \]

\[ \text{Centerline to Toe} \]
CULVERT GEOTECHNICAL DESIGN - SETTLEMENT

Overconsolidated Soils - Case I ($\sigma'_{oc} + \Delta \sigma(z) \leq \sigma'_{oc}$)

$$S_c = \frac{H}{1+e_0} C_r \log \left( \frac{\sigma'_{oc}}{\sigma'_{oc}} \right) \quad \text{Modified from Eqn. 1.66}$$

Overconsolidated Soils - Case II ($\sigma'_{oc} + \Delta \sigma(z) > \sigma'_{oc}$)

$$S_c = \left[ \frac{H}{1+e_0} \right] \left[ C_r \log \left( \frac{\sigma'_{oc}}{\sigma'_{oc}} \right) + C_t \log \left( \frac{\sigma'_{oc}}{\sigma'_{oc}} \right) \right] \quad \text{Eqn. 10.6.2.4.3-1}$$

Normally Consolidated Soils ($\sigma'_{oc} = \sigma'_{oc}$)

$$S_c = \frac{H}{1+e_0} \left( C_r \log \left( \frac{\sigma'_{oc}}{\sigma'_{oc}} \right) \right) \quad \text{Eqn. 10.6.2.4.3-2}$$

Cohesionless Soils ($\sigma'_{oc} = \sigma'_{oc}$)

$$S_c = \frac{H}{1+e_0} \log \left( \frac{\sigma'_{oc}}{\sigma'_{oc}} \right) \quad \text{Eqn. 10.6.2.4.2-3}$$

Reference for $\sigma(z)$ eqn.: USACE EM 1110-1-1904 "Settlement Analysis", Table C-1. Other eqns. derived from trigonometric function definitions.

<table>
<thead>
<tr>
<th>No.</th>
<th>Settlement, $S_n / S_i$</th>
<th>Total Settlement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.127 ft, 1.5 inches</td>
<td>0.133 feet</td>
</tr>
<tr>
<td>2</td>
<td>0.003 ft, 0.0 inches</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.003 ft, 0.0 inches</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>1.6 inches</td>
</tr>
</tbody>
</table>

Boring Profile
C-102
CULVERT GEOTECHNICAL DESIGN - SETTLEMENT
CULVERT GEOTECHNICAL DESIGN – BEARING RESISTANCE AND SLIDING COEFFICIENTS

## NOMINAL BEARING RESISTANCE

<table>
<thead>
<tr>
<th>Structure</th>
<th>q&lt;sub&gt;N&lt;/sub&gt; (ksf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet</td>
<td>9.1</td>
</tr>
<tr>
<td>Outlet</td>
<td>7.3</td>
</tr>
</tbody>
</table>

## BEARING RESISTANCE FACTORS

<table>
<thead>
<tr>
<th>Limit State</th>
<th>Resistance Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service</td>
<td>1.0</td>
</tr>
<tr>
<td>Strength</td>
<td>0.5</td>
</tr>
<tr>
<td>Strength</td>
<td>0.45</td>
</tr>
</tbody>
</table>

**Article 10.5.5.1**

**Table 10.5.5.2.2-1 (cohesive)**

**Table 10.5.5.2.2-1 (non-cohesive)**

## FACTORED BEARING RESISTANCE

<table>
<thead>
<tr>
<th>Limit State</th>
<th>q&lt;sub&gt;N&lt;/sub&gt; (ksf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service</td>
<td>Inlet Headwall: 4.0 Outlet Headwall: 4.0</td>
</tr>
<tr>
<td>Strength</td>
<td>4.1</td>
</tr>
</tbody>
</table>

**Table C10.6.2.6.1-1**

### SLIDING COEFFICIENTS

**Sandy Silt (A-4a)**

For Cohesionless Soils (i.e. φ<sub>t</sub> > 0):

- Reference Boring: C-102
- D<sub>1</sub> = 2.5 ft below existing grade, bearing in:

  - N = 10 bpf
  - φ<sub>t</sub> = 30 degrees

- Coefficient of Friction = \(\tan δ = \tan(φ_t)\) for concrete cast against soil
- \(= 0.8 \tan(φ_t)\) for precast concrete footing

**Headwall Type:** Precast Footing

\[\tan δ = 0.8 \tan(30) = 0.46\]

For Cohesive Soils (i.e. φ<sub>t</sub> = 0):

- Based on hand
- \(q_u = 0\) ksf

For Sandy Silt (A-4a)

- soil, the unit sliding resistance equals the undrained shear strength (Su)
- Therefore, sliding resistance = \(N/A\) ksf
REMEDIATION RECOMMENDATIONS

- Alternatives Included:
  - Undercut poor, wet or weak soils
  - Overexcavate and replace deeper soil deposits where shallow rock was encountered at one end of profile
  - Geogrid and aggregate mat to reduce differential settlement
  - Construct culvert on a camber generally following estimated settlement profile
  - Utilize “sacrificial” outer culvert or oversize culvert
  - Divert or redirect flow to minimize culvert size
  - Overexcavate bedrock and replace with cohesive soil to remove high points in middle of culvert
CULVERT HYDRAULIC DESIGN

SCOPE REQUIREMENTS

- 50 year design and 100 year check frequencies
- Larger drainage areas and hilly terrain – USGS Rural Regression equations
- Normal ODOT controls for Headwater
  - 2 feet above inlet crown or 4 feet above for culverts in deep ravine for 50 year
  - 2x culvert diameter for 100 year
- D+1 requirement for developer maintained culverts
- 42” minimum diameter for freeway classification and fills > 16 feet
- 75 year service life
CULVERT HYDRAULIC DESIGN

HIGH FILL CULVERTS OVERVIEW

- 42 culverts with more than 16 feet of cover
  - Min. = 26 feet
  - Max. = 135 feet
  - Average = 79 feet

- Culvert Lengths
  - Min. = 251 feet
  - Max. = 826 feet
  - Average = 510 feet

- Drainage Areas and Design Flows
  - Min. = 4 acres/13 cfs
  - Max. = 947 acres/804 cfs
  - Average = 75 acres/129 cfs
CULVERT MATERIAL SELECTION

- Culvert shape
  - Round vs. Box. vs. Arch
- Material types considered
  - Reinforced Concrete Pipe
  - Corrugated Metal Pipe
    - Aluminized Type 2
    - Galvanized
    - Polymer Coated
  - Structural Plate
- Most economical to supply, build and maintain.
  - CMP was most economical for choice for all high fill installations
CULVERT HYDRAULIC DESIGN

VELOCITIES

- High velocities present
  - Min. = 5 fps
  - Max. = 21 fps
  - Average = 14 fps
- Steep slopes
  - Min. = 0.5%
  - Max. = 18.8%
  - Average = 6.8%
- CMP vs. RCP
  - Deeper Corrugations and Internal Dissipaters to control velocities
- Riprap Basins
  - HEC 14 requirements
VELCITIES (continued)
CULVERT HYDRAULIC DESIGN

VELOCITIES (continued)
CULVERT HYDRAULIC DESIGN

VELOCITIES (continued)
CULVERT HYDRAULIC DESIGN

VELOCITIES (continued)

- Abrasion
  - FHWA abrasion guidelines

<table>
<thead>
<tr>
<th>Abrasion Level</th>
<th>Abrasion Condition</th>
<th>Bed Load</th>
<th>Flow Velocity (fps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Non-Abrasive</td>
<td>None</td>
<td>Minimal</td>
</tr>
<tr>
<td>2</td>
<td>Low Abrasion</td>
<td>Minor</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>3</td>
<td>Moderate Abrasion</td>
<td>Moderate</td>
<td>5 - 15</td>
</tr>
<tr>
<td>4</td>
<td>Severe Abrasion</td>
<td>Heavy</td>
<td>&gt; 15</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Application</th>
<th>Roadway Classification</th>
<th>Design Service Life</th>
<th>Abrasion Level</th>
<th>Rural 25</th>
<th>Minor 50</th>
<th>Major 75</th>
<th>Urban 100</th>
<th>Rural 25</th>
<th>Minor 50</th>
<th>Major 75</th>
<th>Urban 100</th>
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</tbody>
</table>

1. Based on Table 1 - Recommended Environments.
2. Smooth Cor™ Steel Pipe combines a corrugated steel exterior shell with a hydraulically smooth interior liner.
3. Service life estimates for ULTRA FI® and Smooth Cor™ Pipe assume a storm sewer application. Storm sewers rarely achieve abrasion levels 3 or 4.
4. For applications other than storm sewers or abrasion conditions above Abrasion Level 2, please contact your ConTech Sales Representative for gauge and coating recommendations.
5. Design service life for 8-gage galvanized is 97 years.
6. Abrasion protection to consist of velocity reduction structures.
7. Asbestos-coated and lined invert or velocity reduction structures are needed.
8. Requires a field-applied concrete lined invert with minimum thickness 1" above corrugation crests.
9. 75 year service life for polymer coated is based on a pH range of 4.5 and resistivity greater than 750 ohm-cm.
10. 100 year service life for polymer coated is based on a pH range of 5.9 and resistivity greater than 1500 ohm-cm.
CULVERT HYDRAULIC DESIGN

VELOCITIES (continued)

- Abrasion (cont’d)
  - 18 culverts with Paved inverts
CULVERT HYDRAULIC DESIGN CHALLENGES

HIGH FILLS & LARGE CULVERT DIAMETERS

- Roadway fills up to 135 feet
  - 12 locations with fill heights > 75 feet
  - 11 locations will fill heights > 100 feet
- Diameters range from 42” to 126”
  - 42” and 48” = 12 locations each
  - 54” = 3 locations
  - 60” = 5 locations
  - 66” = 6 locations
  - 72”, 78”, 90” and 126” = 1 location each

90” at Sta. 111+05
CULVERT HYDRAULIC DESIGN CHALLENGES

HIGH FILLS & LARGE CULVERT DIAMETERS (continued)

90" at Sta. 111+05
CULVERT HYDRAULIC DESIGN CHALLENGES

HIGH FILLS & LARGE CULVERT DIAMETERS (continued)

- Structural calculations to determine gauge/thickness
CULVERT HYDRAULIC DESIGN CHALLENGES

HIGH FILLS & LARGE CULVERT DIAMETERS (continued)

- Routing to reduce flows for high fill/large diameter culverts
  - Capture flows at the top of slopes
  - Route to downstream end of culvert opposed to flowing through the culvert
HIGH FILLS & LARGE CULVERT DIAMETERS (continued)

- Double barrel culverts at 4 locations
  - Required to meet required hydraulic opening and structural requirements for maximum allowable height of cover

- SR 823 Sta. 238+93
  - 511 foot length
  - (2) 66” CMP @ 1.91% slope
  - 8 gauge, 1” corrugation
  - 99 foot fill height
CULVERT HYDRAULIC DESIGN CHALLENGES

HIGH FILLS & LARGE CULVERT DIAMETERS (continued)

- SR 823 Sta. 238+93 (continued)
CULVERT HYDRAULIC DESIGN CHALLENGES

HIGH FILLS & LARGE CULVERT DIAMETERS (continued)

- SR 823 Sta. 238+93 (continued)
HIGH FILLS & LARGE CULVERT DIAMETERS (continued)

- Structural Plate considered for high fills/large diameters
- Multi-plate culvert installation at SR 823 Sta. 299+76
  - 764 foot length
  - 126” diameter, 135 foot fill height
  - 3/8” thickness, 2” corrugation
  - 1.06% slope, Velocity = 13.7 fps
  - 947 acre drainage area
    - Q<sub>50</sub> = 804 cfs
    - Q<sub>100</sub> = 949 cfs
CULVERT HYDRAULIC DESIGN CHALLENGES

HIGH FILLS & LARGE CULVERT DIAMETERS (continued)

- Multi-plate Sta. 299+76 (continued)
CULVERT HYDRAULIC DESIGN CHALLENGES

HIGH FILLS & LARGE CULVERT DIAMETERS (continued)

- Multi-plate Sta. 299+76 (continued)
CULVERT HYDRAULIC DESIGN CHALLENGES

HIGH FILLS & LARGE CULVERT DIAMETERS (continued)

- Multi-plate Sta. 299+76 (continued)
CULVERT HYDRAULIC DESIGN CHALLENGES

HIGH FILLS & LARGE CULVERT DIAMETERS (continued)

- Multi-plate Sta. 299+76 (continued)
CULVERT HYDRAULIC DESIGN CHALLENGES

HIGH FILLS & LARGE CULVERT DIAMETERS (continued)

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CULVERT HYDRAULIC DESIGN CHALLENGES

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CULVERT HYDRAULIC DESIGN CHALLENGES

HIGH FILLS & LARGE CULVERT DIAMETERS (continued)

- Multi-plate Sta. 299+76 (continued)
CULVERT HYDRAULIC DESIGN CHALLENGES

UNIFORM SETTLEMENT

- Coordination between hydraulic design engineer, geotechnical engineer, contractor, and culvert manufacturer
- Geotechnical analysis and recommendations
  - Max. = 58 inches
  - Average = 8 inches

| Table 5: Summary of Estimated Settlement at Various Locations along Culvert (inches) |
|----------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Culvert                         | Left Toe        | Left Mid-Slope  | Left Crest      | Centerline      | Right Crest     | Right Mid-Slope | Right Toe       |
| SR 823 Sta. 600+71              | 0.1             | 3.0             | 4.7             | 4.6             | 4.6             | 3.5             | 0.1             |
| SR 823 Sta. 610+38              | 0.3             | 2.4             | 4.0             | 3.5             | 2.9             | 0.2             | 0.0             |
| SR 823 Sta. 617+50              | 0.1             | 2.1             | 2.6             | 1.3             | 1.3             | 1.0             | 0.1             |
| SR 823 Sta. 622+50              | 0.1             | 3.1             | 1.5             | 1.5             | 1.4             | 4.0             | 0.3             |
| SR 823 Sta. 636+07              | 0.2             | 2.3             | 2.8             | 2.8             | 5.4             | 3.6             | 0.0             |
| SR 823 Sta. 647+61              | 0.0             | 0.7             | 1.3             | 1.3             | 0.9             | 0.8             | 0.1             |
| SR 823 Sta. 658+72              | 0.0             | 0.7             | 2.9             | 2.8             | 2.8             | 1.5             | 0.1             |
| SR 823 Sta. 673+33              | 0.1             | 7.4             | 10.2            | 9.8             | 8.7             | 1.6             | 0.1             |
| SR 823 Sta. 693+63              | 0.1             | 2.5             | 1.9             | 2.1             | 2.0             | 1.4             | 0.1             |
| SR 823 Sta. 699+51              | 0.0             | 7.5             | 5.2             | 5.3             | 5.1             | 4.5             | 0.1             |
CULVERT HYDRAULIC DESIGN CHALLENGES

UNIFORM SETTLEMENT (continued)

- Cambered flow lines
  - Geometry in form of vertical curve designed to mitigate settlement
  - Pipe laid to cambered bed and gapped as needed at the top of joints
  - Flat bands and gaskets used at joints
CULVERT HYDRAULIC DESIGN CHALLENGES

DIFFERENTIAL SETTLEMENT

- Settlement profile varies significantly along length of culvert
  - Varying depth bedrock
  - Location of cohesive/compressible soils

- Mitigation alternatives explored:
  - Geogrid/high-strength geosynthetic
  - Hydraulically oversized culvert
  - Over-excavation/backfill
  - Geopiers
DIFFERENTIAL SETTLEMENT (continued)

- Geogrid installed at 4 locations
  - Two layers of TX190L Geogrid
  - Two layers of 12” #1 and #2 aggregate
  - Type D Subgrade Fabric
- Trench application will mitigate abrupt differential settlements
CULVERT HYDRAULIC DESIGN CHALLENGES

DIFFERENTIAL SETTLEMENT (continued)

- Geogrid
CULVERT HYDRAULIC DESIGN CHALLENGES

DIFFERENTIAL SETTLEMENT (continued)

- Geogrid
CULVERT HYDRAULIC DESIGN CHALLENGES

DIFFERENTIAL SETTLEMENT (continued)

- Geogrid
LESSONS LEARNED

- Communication is key – Many parties involved (designer, geotech, manufacturer, contractor, reviewers).

- Communication is key – Changes to design of one buildable unit often affect another.

- Teamwork – Nothing beats a conference call or site meeting to bring ideas together and decide on a resolution. Blessing of co-location.
Thank you!