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Merchants Bridge West Approach Reconstruction DB

GEO-Omaha 2021

February 5, 2021

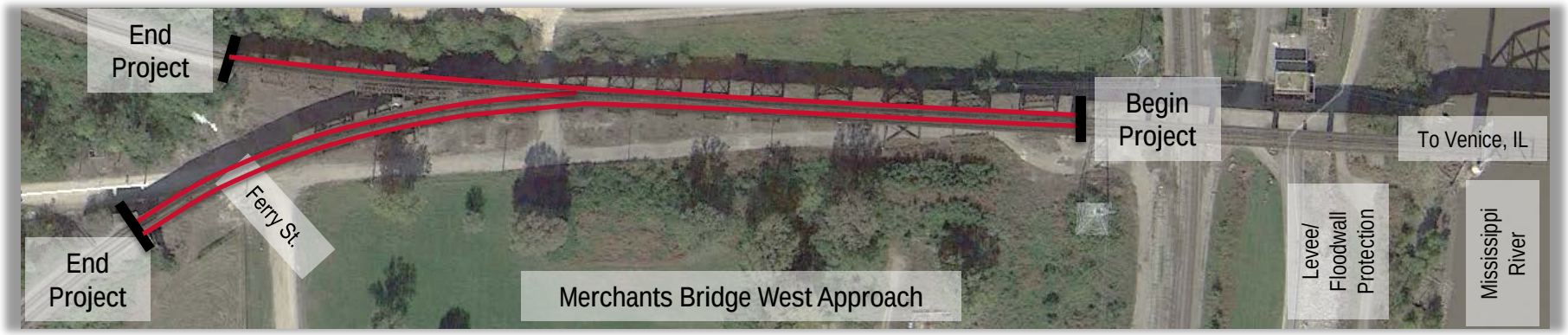
01

Project Overview

Project Overview

- Originally opened in 1890
- Crosses the Mississippi River between St. Louis, Missouri and Venice, Illinois.
- Owned and Operated by Terminal Railroad Association of St. Louis (TRRA).
- More than 32 trains/day in 2014.
- Full reconstruction of bridge is planned. Funded as separate projects.

Project Overview



Needs for Railroad Bridge Reconstruction:

- Aging infrastructure has decreased load capacities while rail demands are increasing.
  - Existing two track bridge operating as a single track
  - Other rail bridges in the area are also aging and cannot handle the increased demand
  - St. Louis is nation's 3rd largest railroad hub and 3rd largest inland port
  - Forecasts show rail demands increase nearly 20% between 2010 and 2040.

Proposed Project:

- Reconstruct 1600 feet west approach of Merchants Bridge while minimizing track outages

Looking east towards main river spans (Bent W6)

Straddle bents just west of Bent W6

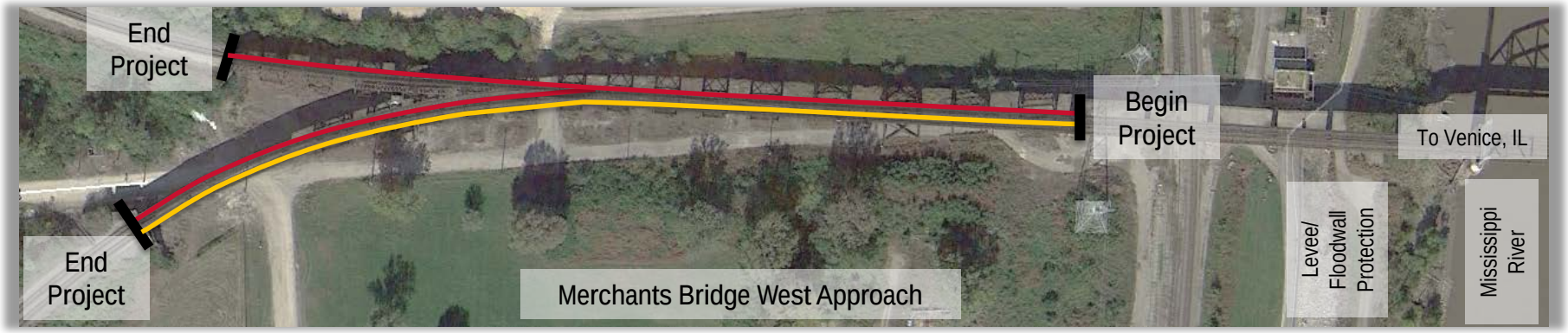
Looking east towards neck of the wye where May and Bremen legs merge

Existing Bremen leg spanning Ferry Street

02

Project Constraints

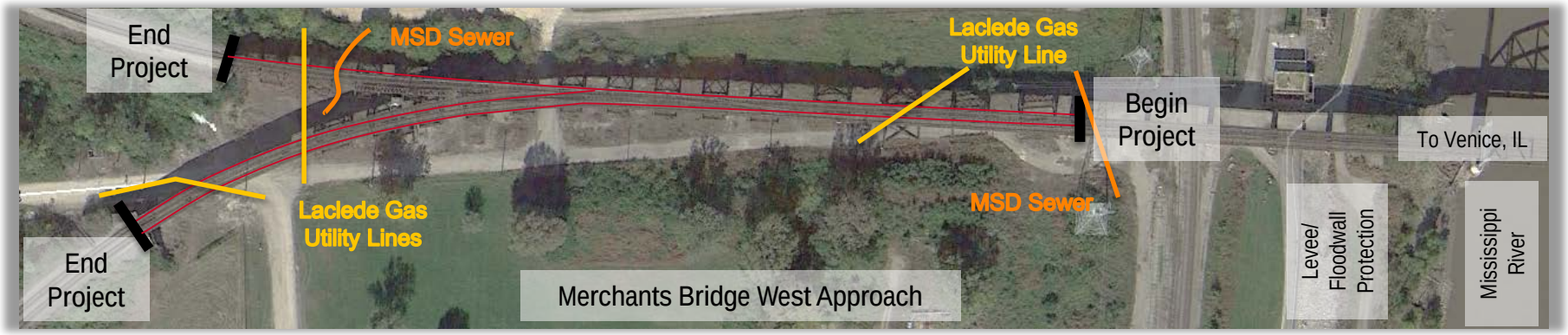
Project Constraints



Operational

- North track to remain in operation throughout majority of construction
- Limited total closures:
  - 16 hour outage for transfer to operation to new south track (Dec 2016)
  - 48 hour outage for opening new north track (March 2017)

Project Constraints



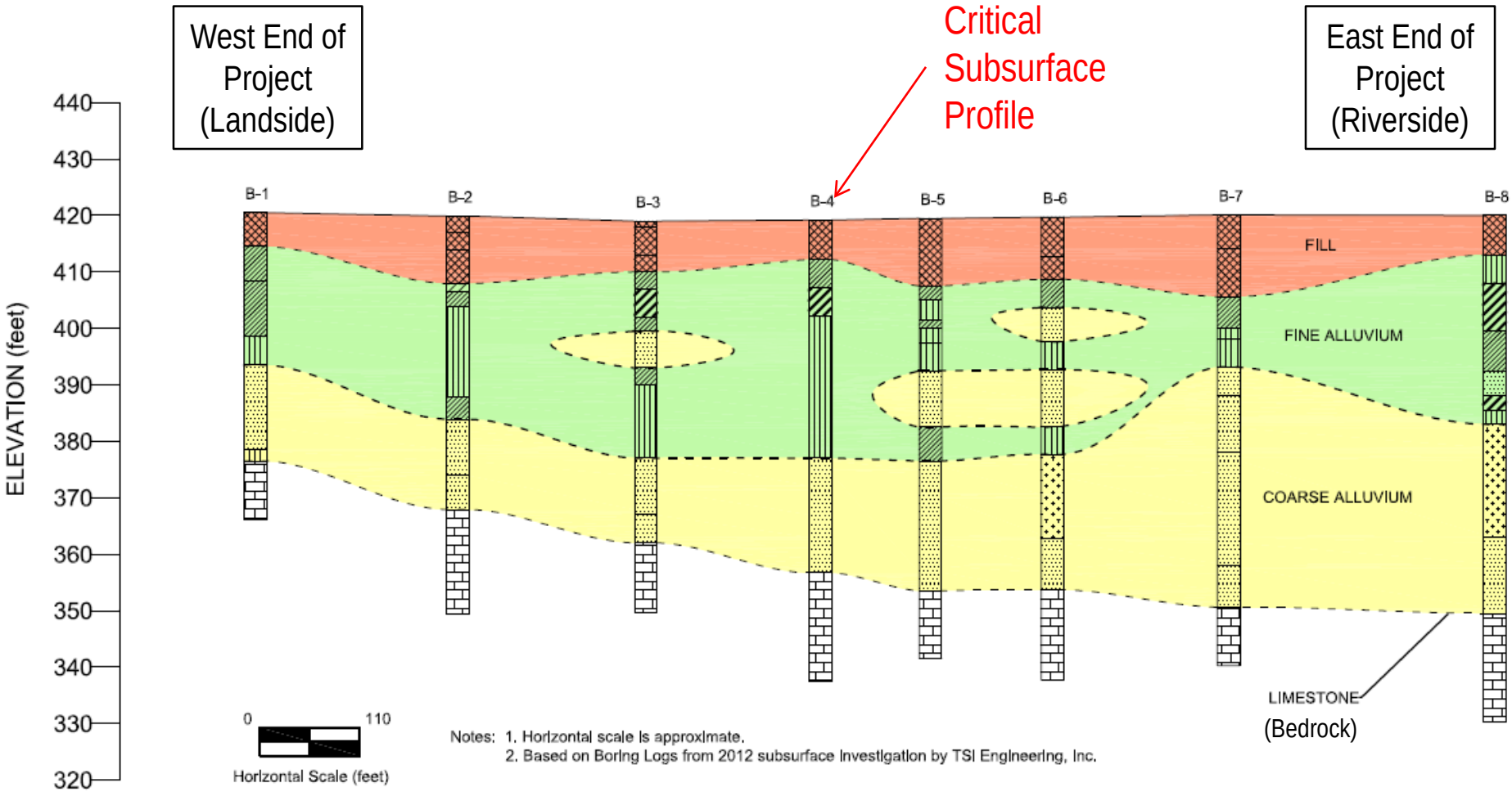
Physical

- Low overhead clearances (working beneath existing structure)
- Existing steel frame piers/foundations
- Existing utility crossings
- Limited right-of-way

03

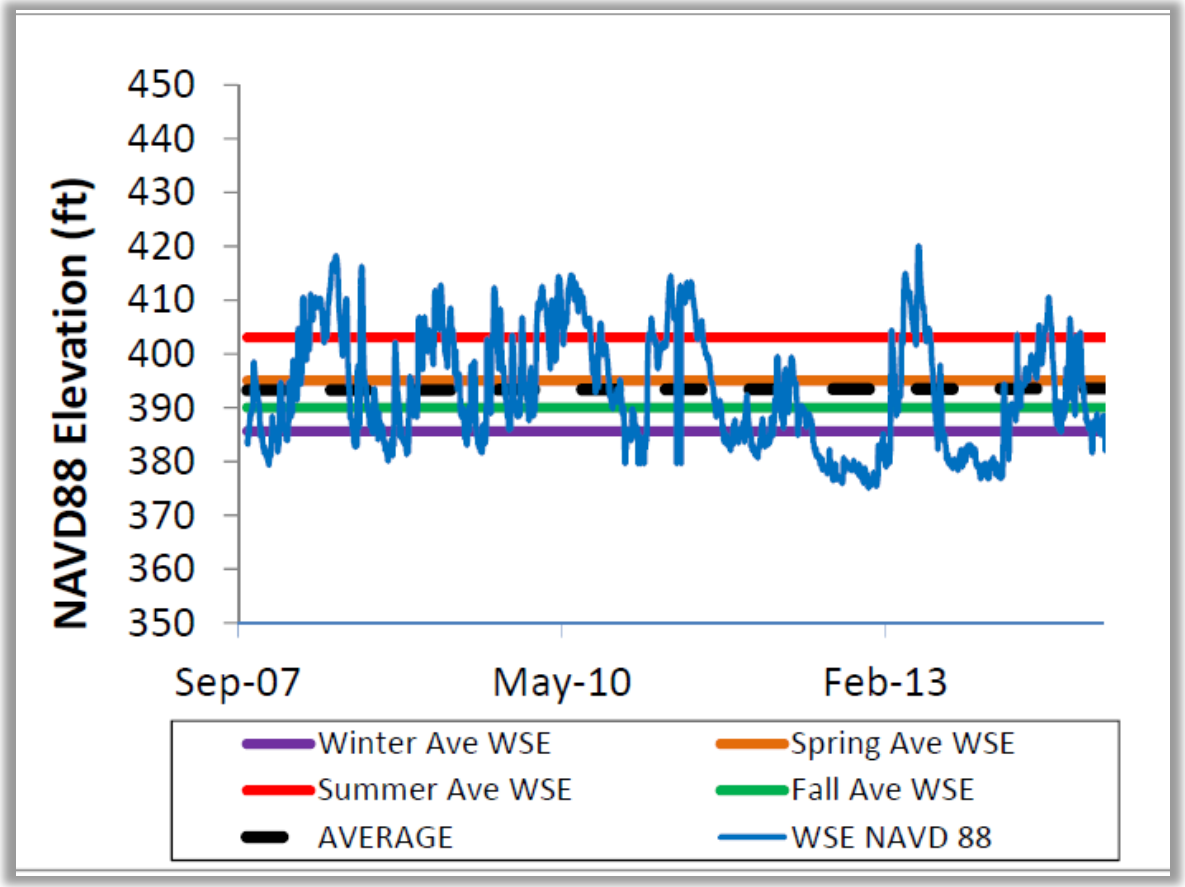
Site Characteristics

Subsurface Profile



Flood Risk and Groundwater

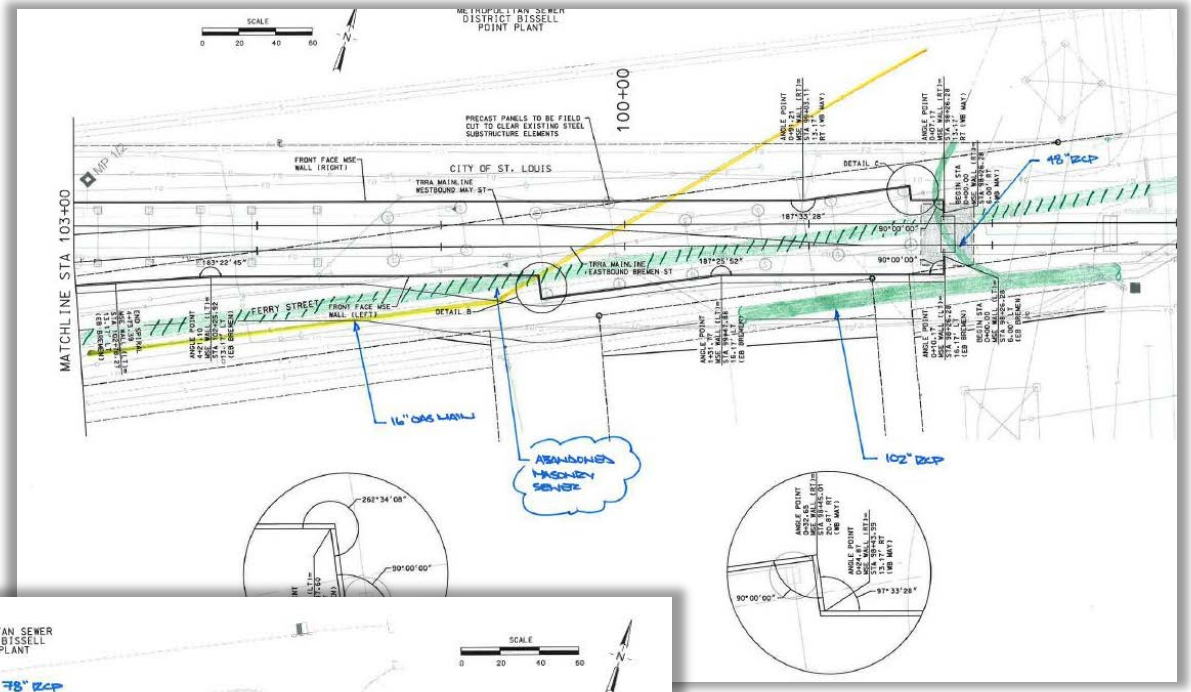
- Project limits protected by existing levee/floodwall systems
- Design groundwater table elevation based on average water surface elevations of the Mississippi River from October 2007 to January 2015

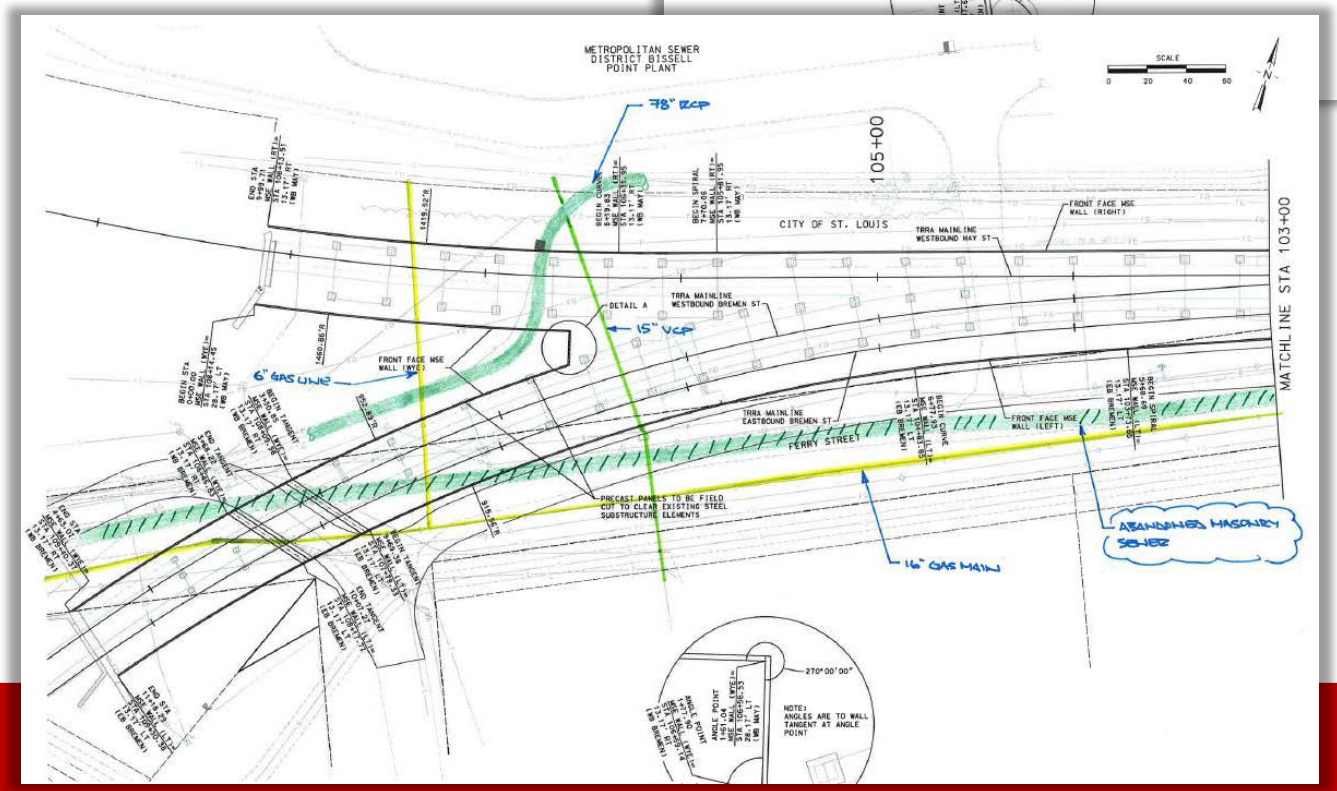


Utilities

Laclede Gas

- 16” Gas Main
- 6” Gas Line





MSD

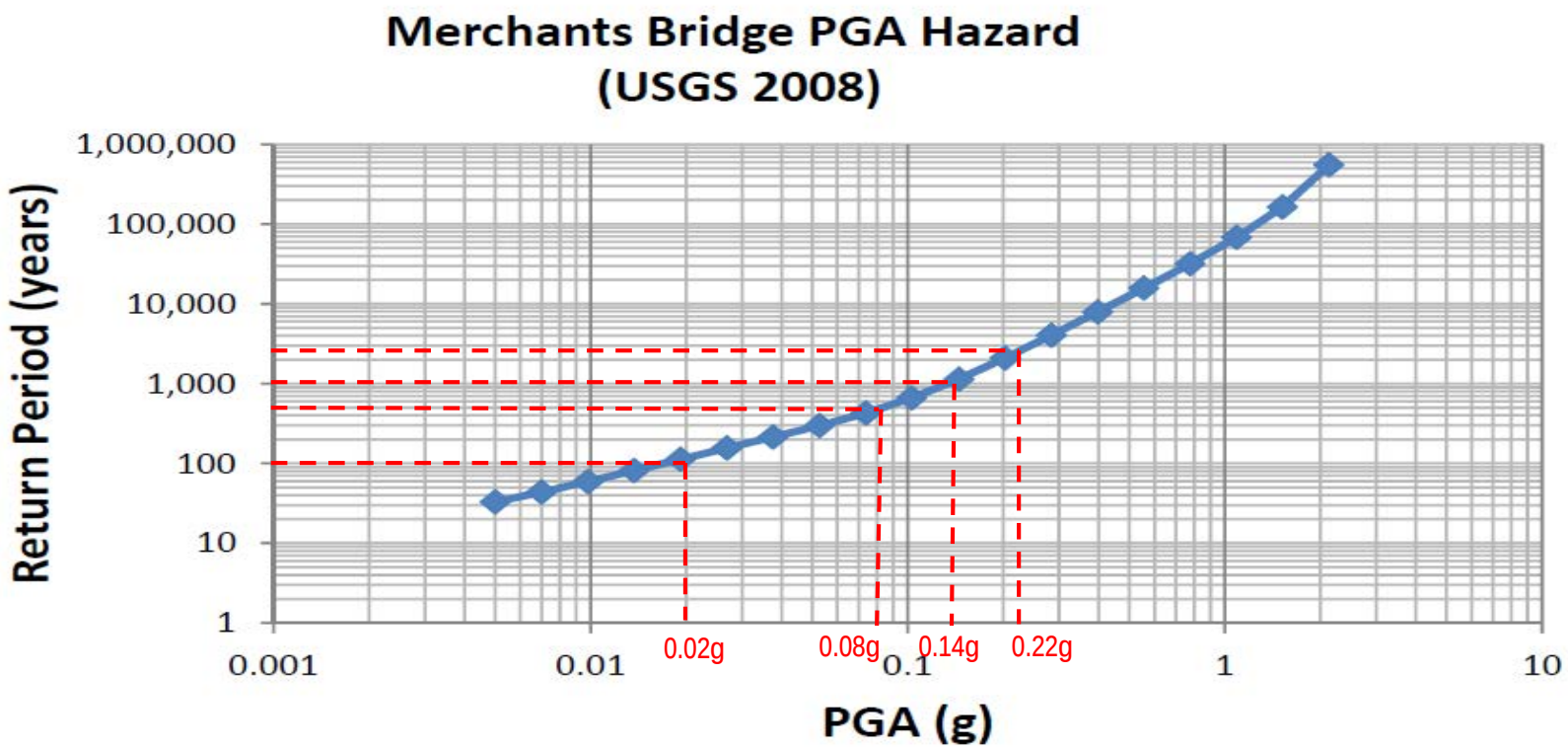
- 78” RCP Sewer
- 15” VCP Sewer
- 102” RCP
- 48” RCP
- Abandoned Mansonry Sewer

04

Seismic Design

Seismic Hazard

- Project site affected by the New Madrid and Wabash Valley seismic zones and the Commerce Geophysical Lineament.
- AREMA specifies 3 design earthquakes: Level I, II and III events represent spectral accelerations having average return periods of 100, 475 and 2475 years, respectively.



Design and Performance Criteria

- Level I – The embankment structure should remain intact with no permanent deformation (i.e. the seismic loads must remain within the elastic range of the stress-strain curve of the embankment);

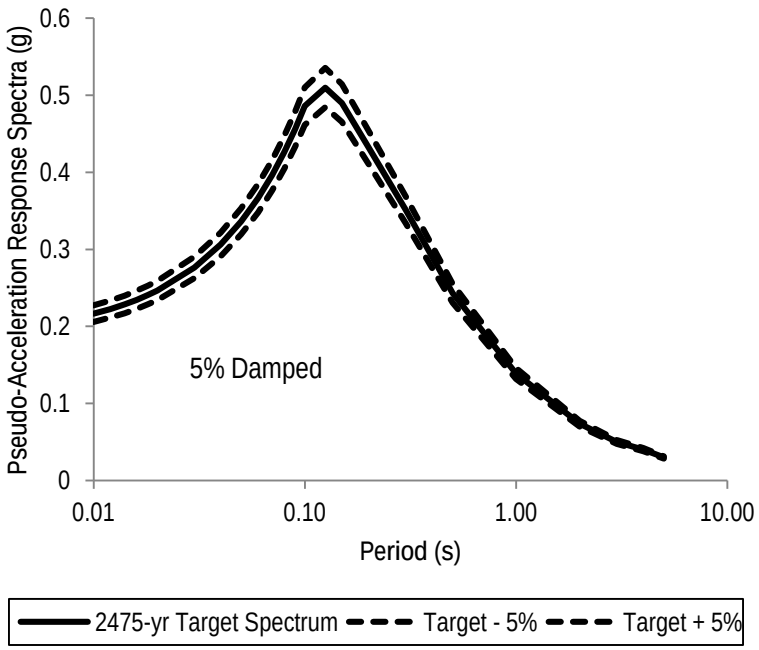
- Level II – The embankment structure should be repairable, with only minor permanent deformation;

- Level III – The “No Collapse Event”. The embankment structure must not collapse after experiencing permanent deformations.

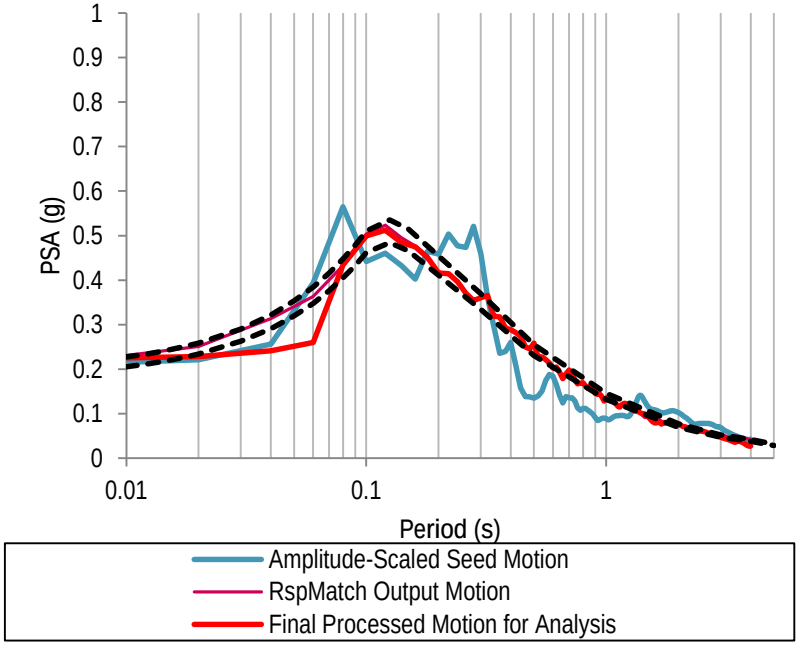
Spectral Matching

- Target bedrock acceleration response spectra were developed for the 475-year (Level II) and 2475-year (Level III) return period seismic hazard levels.
- Seven design ground motions were selected and spectrally matched to the target bedrock acceleration response spectra.

AREMA Level III bedrock target acceleration response spectrum



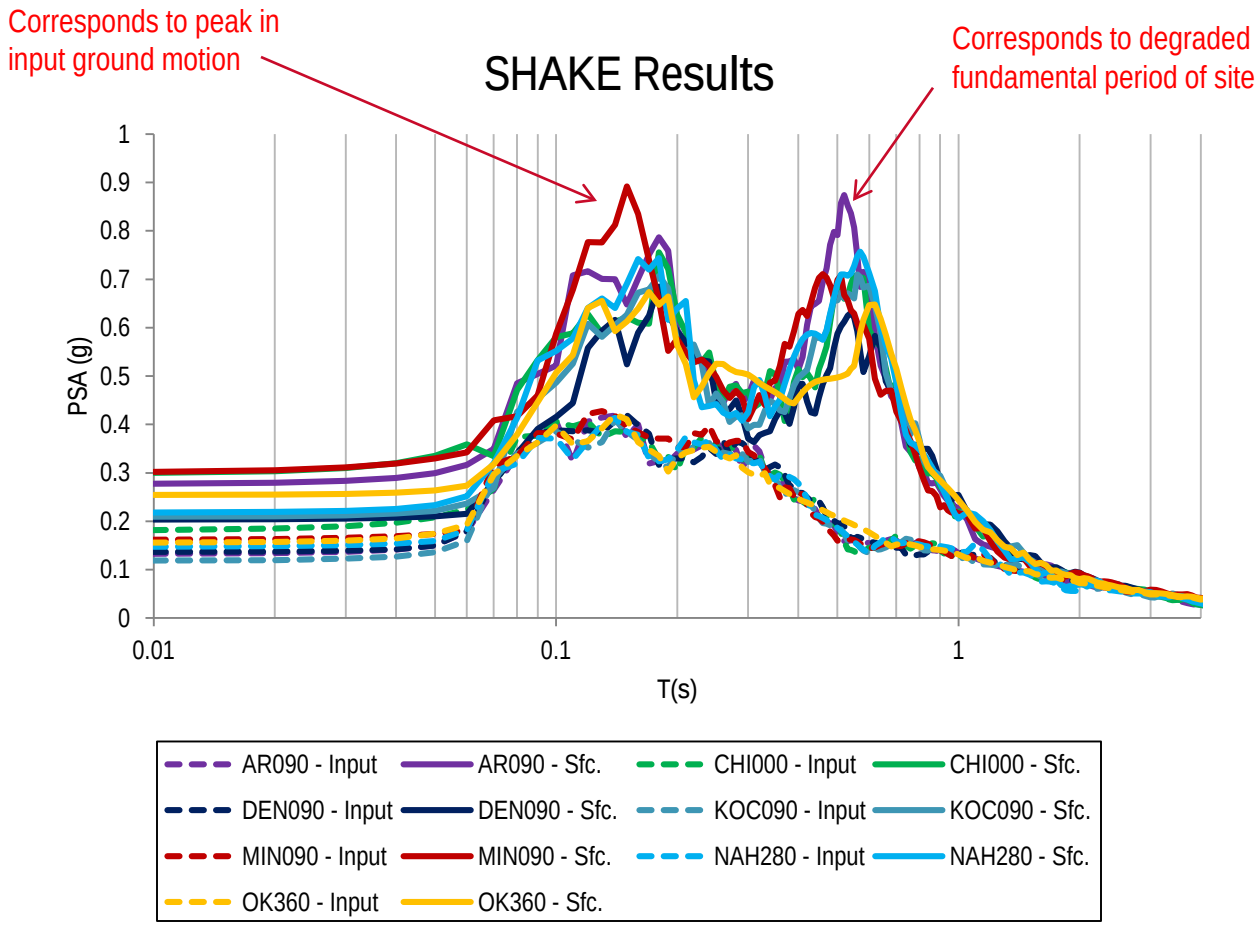
Pseudo-acceleration response spectrum of CHI000 motion compared to target spectrum



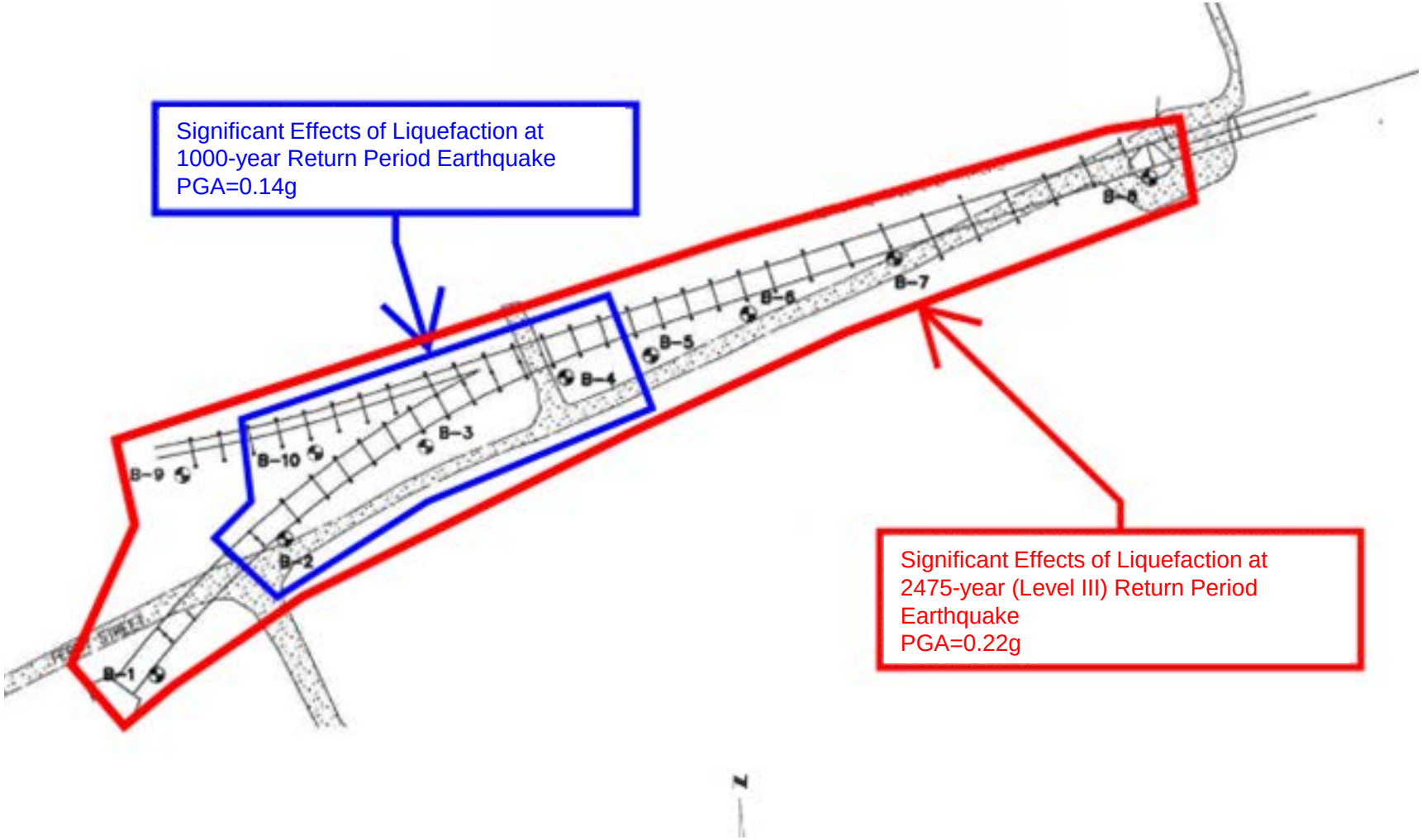
SHAKE2000 Analyses

- One-dimensional, equivalent linear, seismic site response analyses were performed using the computer program SHAKE2000 for the 475-year (Level II) and 2475-year (Level III) return period seismic hazard levels.

SHAKE2000 Results for pseudo-acceleration response spectra for the seven design ground motions at the 2475-year return period seismic hazard level (AREMA Level III).

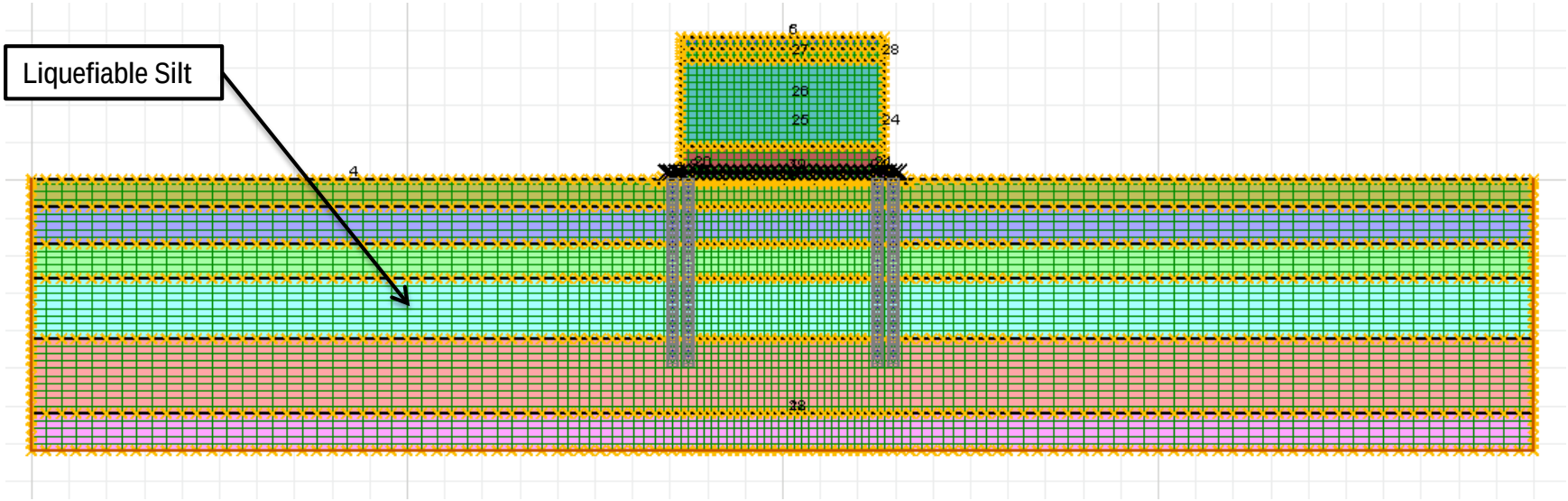


Liquefaction Potential



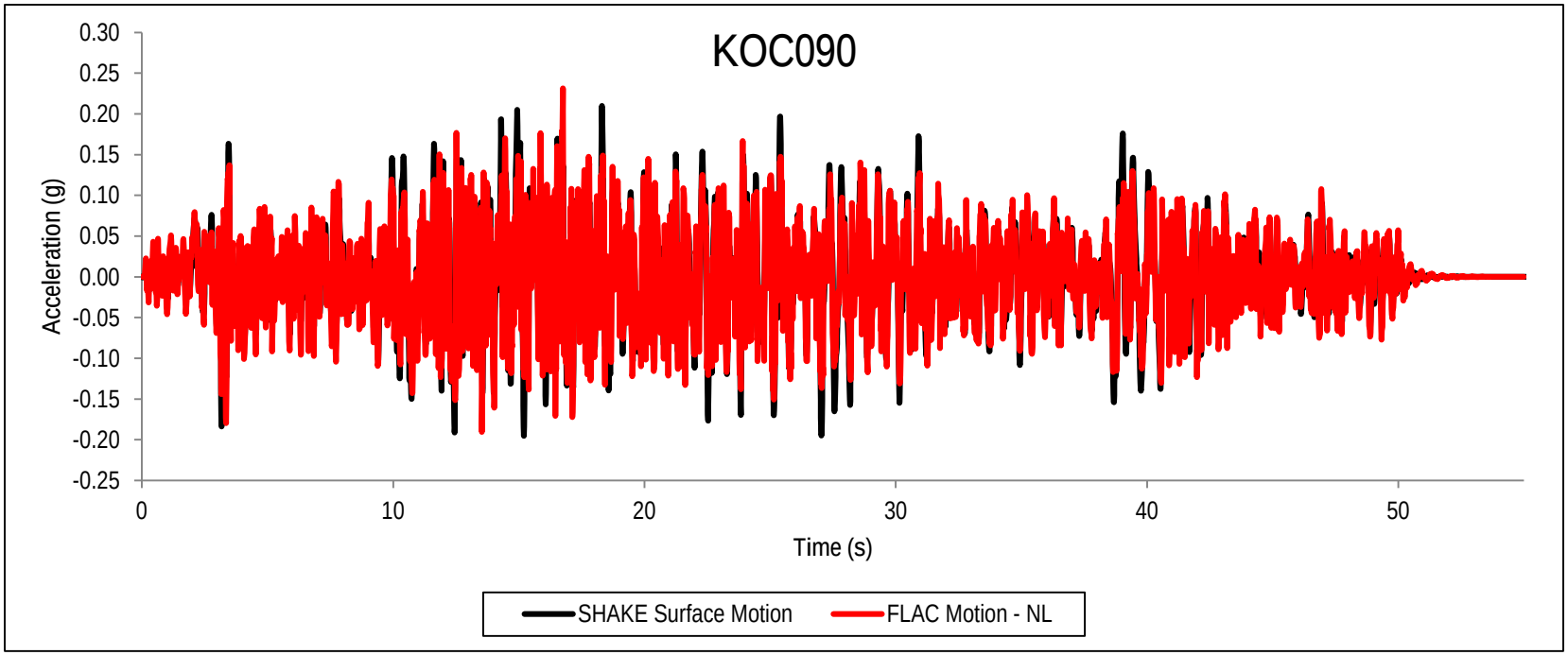
FLAC Analyses

- Two finite-difference, two-dimensional models were analyzed:
  - One model assumed liquefaction of soils has occurred
  - Second model assumed liquefaction was not triggered
- Level III Seismic Event was found to control. Thus, FLAC models were only analyzed for the 2475-year return period.

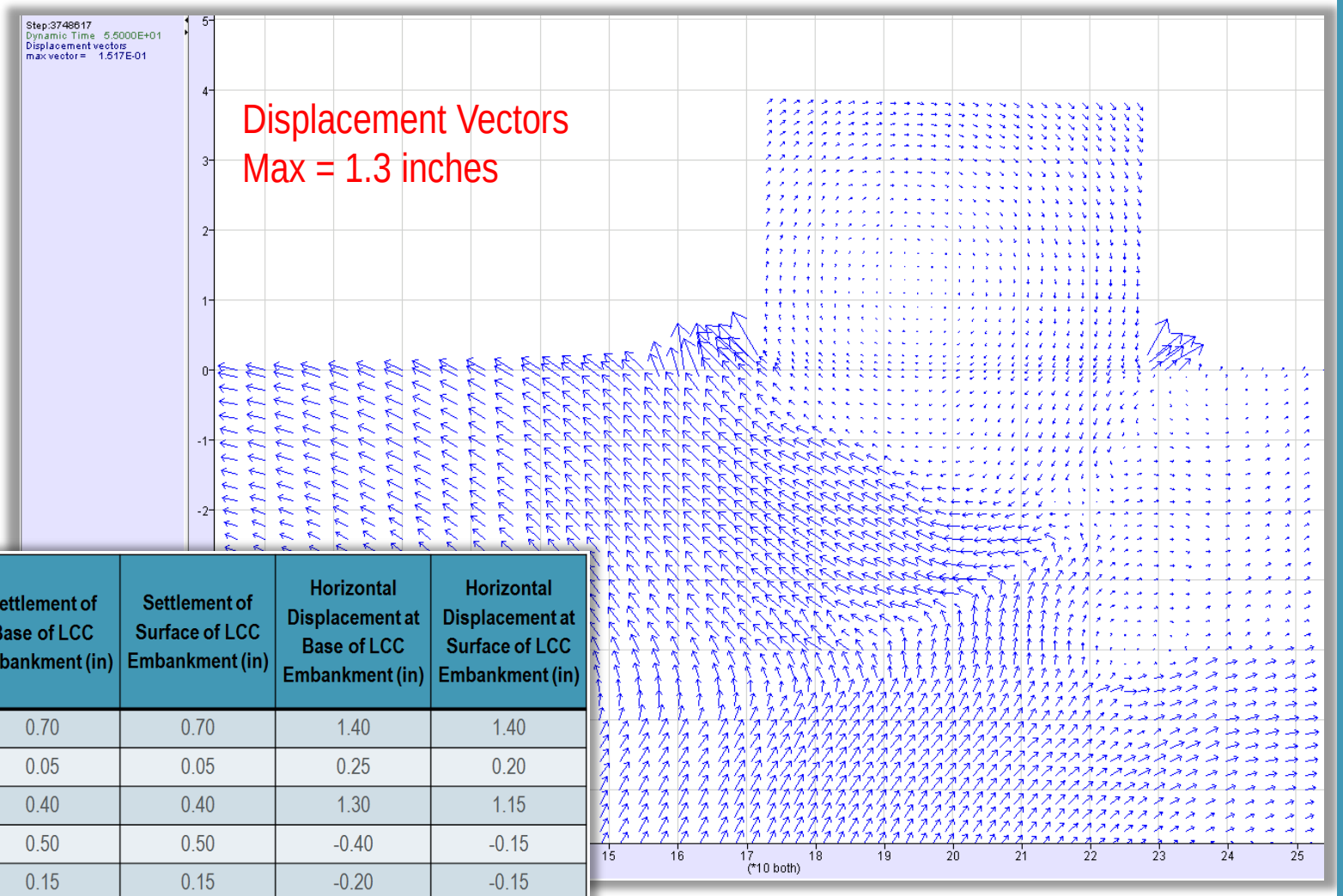


FLAC / SHAKE2000 Comparison

- SHAKE2000 analyses were used to check that the site response calculated using the non-liquefaction FLAC model was reasonable.
- Ground surface acceleration-time histories calculated using both programs are generally similar.



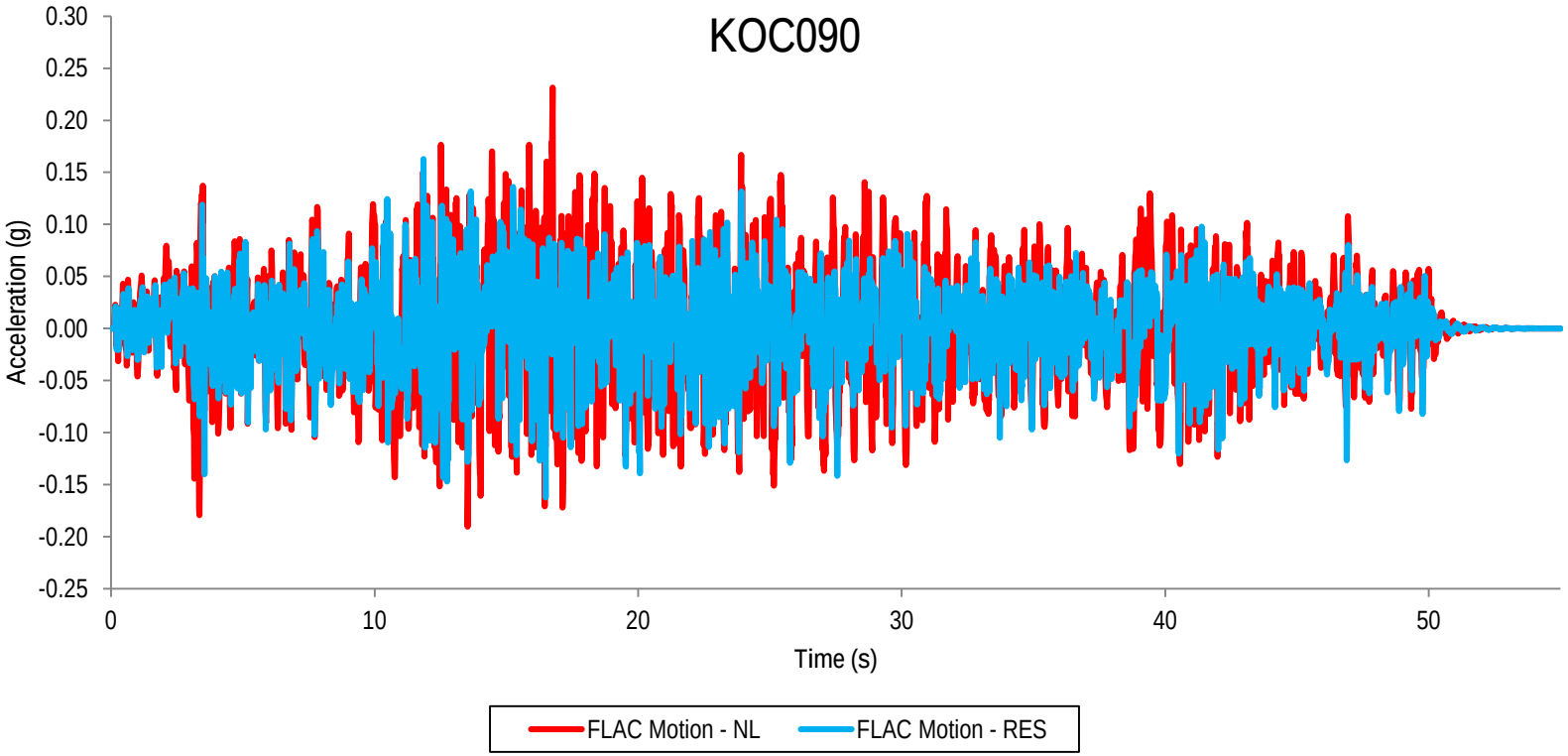
Non-Liquefaction FLAC Results



Ground Motion ID	Settlement of Base of LCC Embankment (in)	Settlement of Surface of LCC Embankment (in)	Horizontal Displacement at Base of LCC Embankment (in)	Horizontal Displacement at Surface of LCC Embankment (in)
AR090	0.70	0.70	1.40	1.40
CHI000	0.05	0.05	0.25	0.20
DEN090	0.40	0.40	1.30	1.15
KOC090	0.50	0.50	-0.40	-0.15
MIN090	0.15	0.15	-0.20	-0.15
NAH280	0.05	0.05	0.05	0.05
OK360	0.20	0.20	-0.40	-0.60

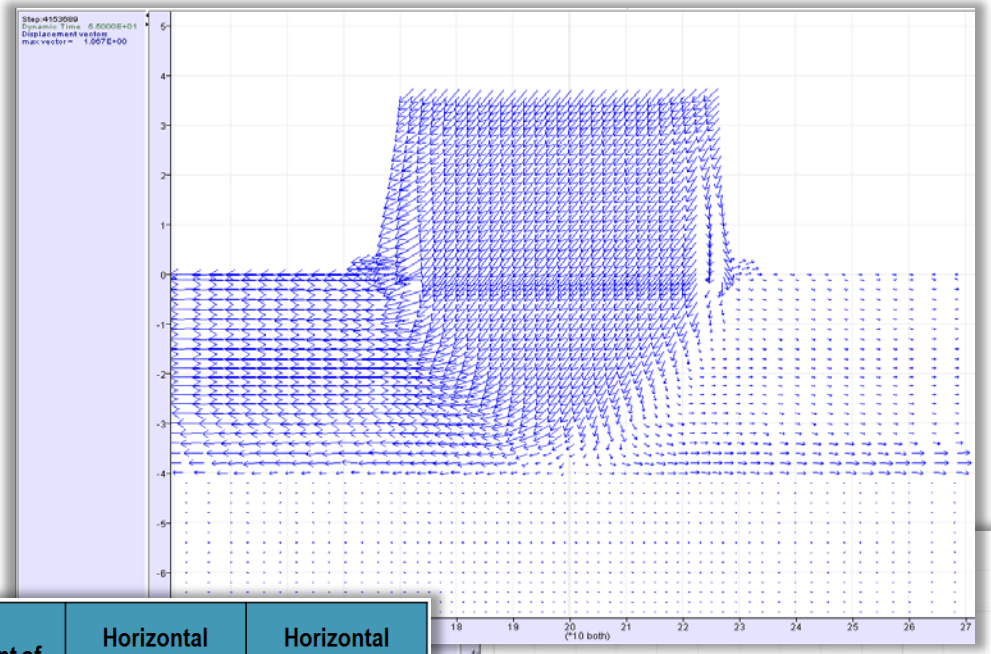
Non-Liquefaction / Residual Strength (Liquefaction) Comparison

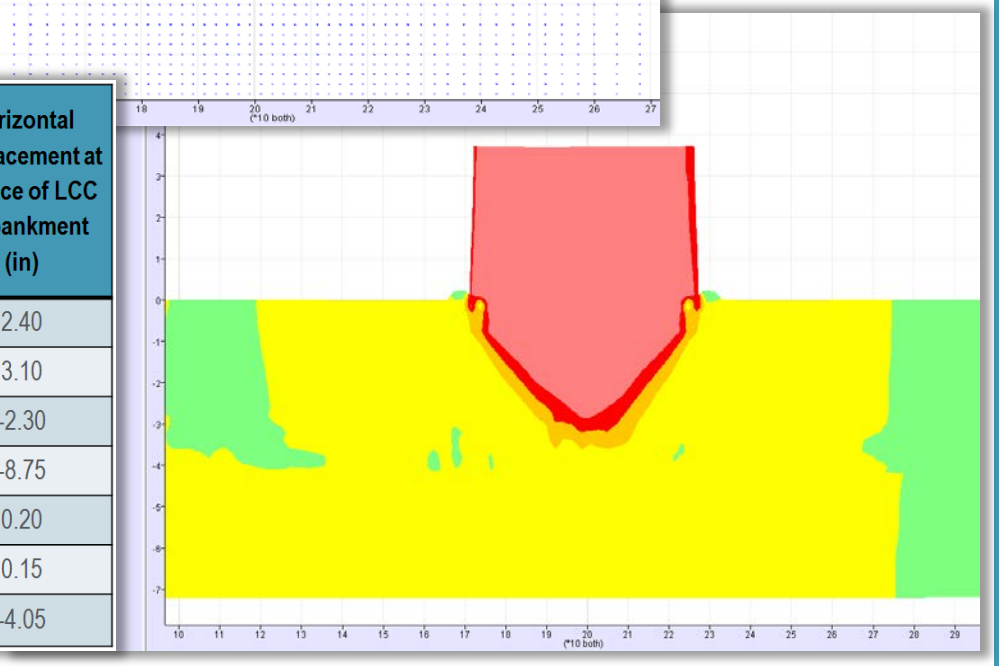
- Ground surface acceleration-time histories calculated from both FLAC models were compared to check that the differences in model behaviors were reasonable.
- Ground motion amplitudes are in general reduced for the Residual Strength FLAC model, relative to the Non-Liquefaction model.



Liquefaction FLAC Results

Displacement Vectors
Max = 22.4 inches





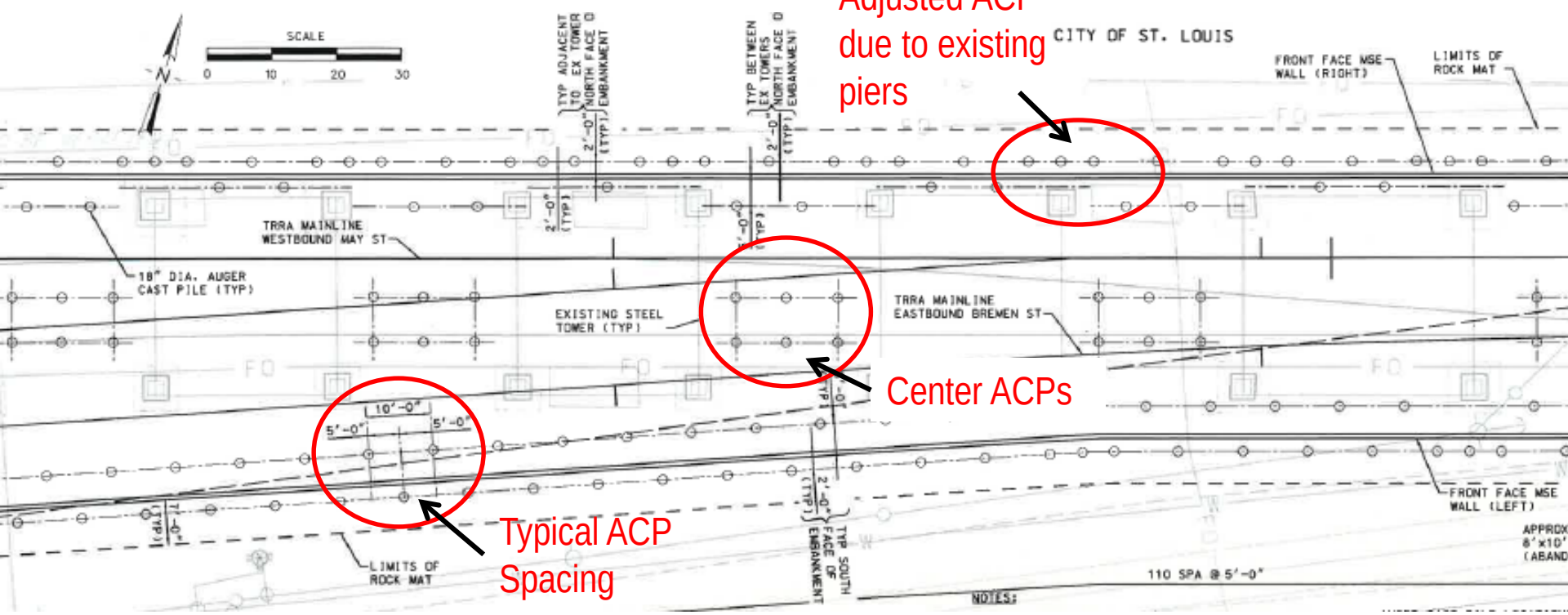
Ground Motion ID	Settlement of Base of LCC Embankment (in)	Settlement of Surface of LCC Embankment (in)	Horizontal Displacement at Base of LCC Embankment (in)	Horizontal Displacement at Surface of LCC Embankment (in)
AR090	9.30	9.30	2.40	2.40
CHI000	2.65	2.65	3.20	3.10
DEN090	5.10	5.10	-2.70	-2.30
KOC090	11.25	11.25	-8.35	-8.75
MIN090	2.40	2.40	0.10	0.20
NAH280	0.20	0.20	0.10	0.15
OK360	7.80	7.80	-3.85	-4.05

05

Embankment Design

Foundation System

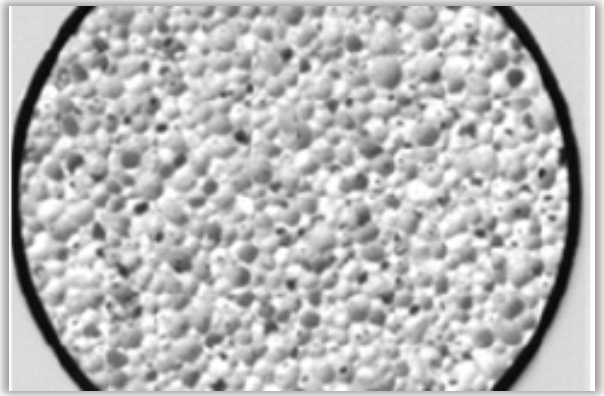
- Existing bridge founded on timber piles tipped in coarse alluvium soil layer
- Reinforced rock mat used to transfer embankment loads to auger-cast piles
- Auger-cast piles spaced to increase bearing capacity at the MSE wall panel footings
- Auger-cast piles placed in the center of embankment to reduce stresses caused by the “hard points” (i.e. utility bridges)
- Foundation system designed to allow movement/settlement of the embankment to minimize stresses in the LCC



Lightweight Cellular Concrete (LCC)

Low density material

- Homogeneous cell structure formed by the addition of preformed foam or by the generation of gas within the fresh cementitious mixture.
- Required Compressive Strength of LCC determined from Load/Deformation analyses:
  - Class II (120 psi)
  - Class IV (220 psi)



TYPICAL NEAT CEMENT (NO SAND) MIXES

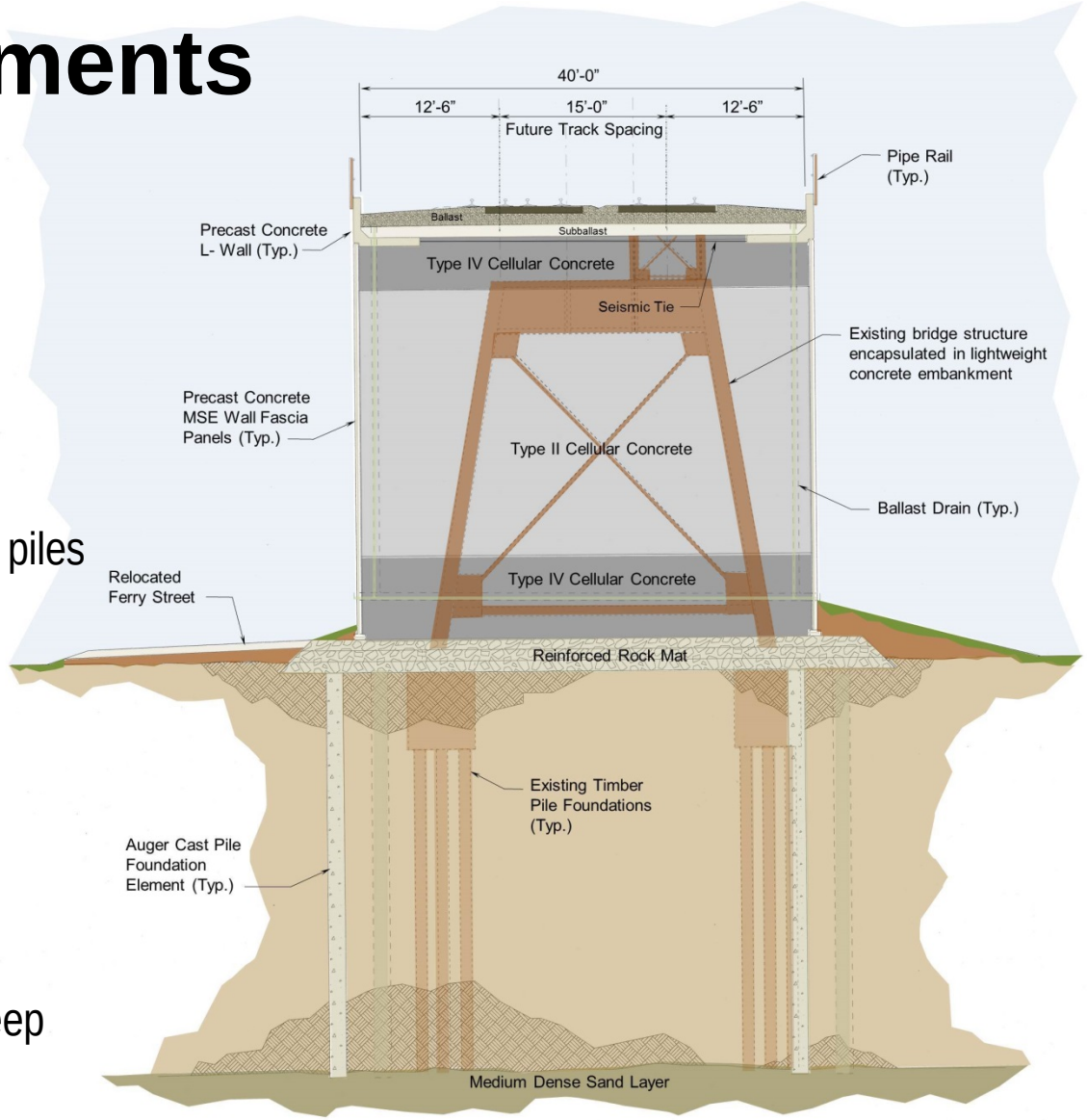
The following chart illustrates the various typical properties **of Weight Density** (lb./c.f.), **Compressive Strength**, (psi), and **Thermal Conductivity** values attainable with various volumes of preformed foam additions to Neat Cement Mixes.

Wet Cast Density lb/ft^3	Dry Density lb/ft^3	Compressive Strength * (28 Days) lb/in^2	Typical Values "k" Thermal** Conductivity Btu in/h ft^2 °F	Portland Cement lbs/yd^3	Foam Volume ft^3/yd^3	Foam Liquid Concentrate Weight,lb/yd^3
20	16	50	0.54	328	22.7	2.17
25	20	80	0.60	420	21.5	2.06
30	25	140	0.67	512	20.3	1.94
35	29	210	0.76	603	19.1	1.83
40	34	330	0.87	695	17.9	1.71
45	38	450	0.98	787	16.7	1.60
50	43	640	1.06	878	15.5	1.48
55	47	790	1.20	970	14.3	1.37
60	51	930	1.33	1062	13.1	1.25

LCC Engineered Properties

Key Design Elements

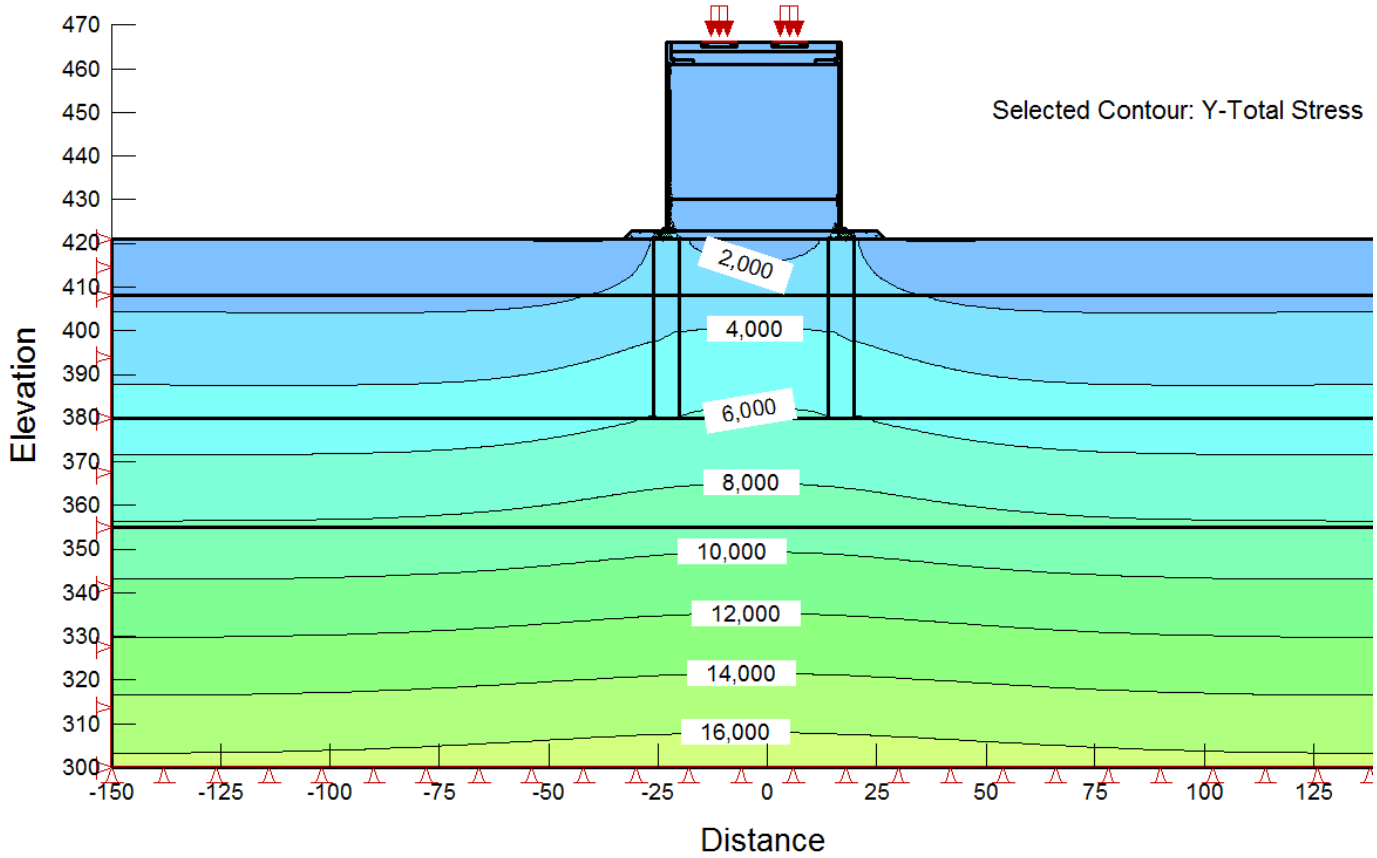
- Existing bridge remains intact and is encapsulated by Lightweight Cellular Concrete (LCC).
- Zoning of LCC embankment based on material stresses to minimize costs
- Foundation system utilizing auger-cast piles and geogrid-reinforced rock mat
- Minimizing “pinch points” within the embankment using geofoam
- Precast L-wall System to speed construction
- Utility Bridge design for shallow and deep utilities



TYPICAL SECTION THROUGH EMBANKMENT

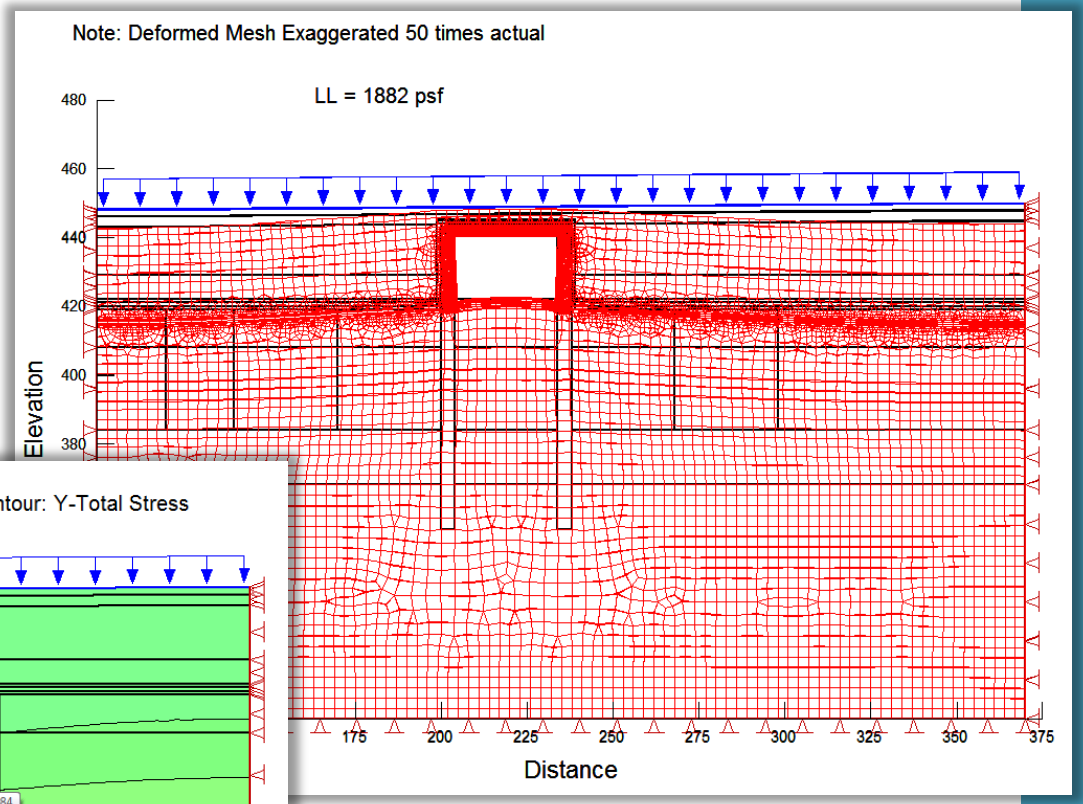
Service Load/Deformation Analyses

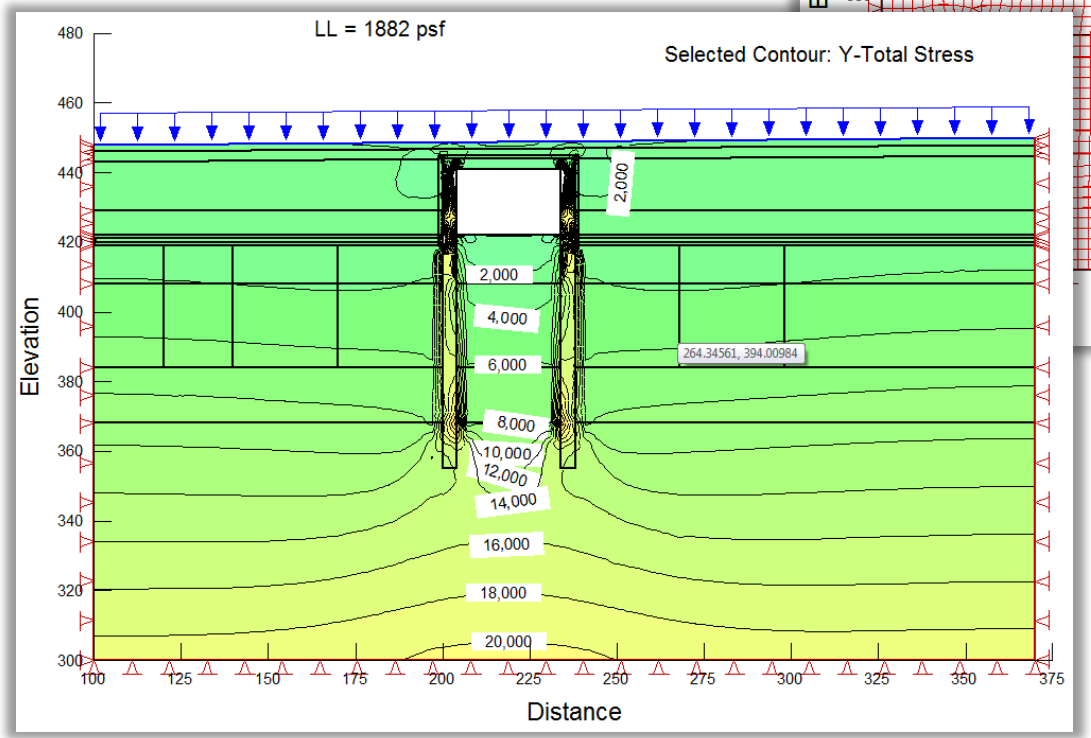
- Load/Deformation analyses were performed using computer program SIGMA/W
- Two-Dimensional, Linear-Elastic models were developed for the following critical sections:
  - Typical cross-section at maximum height;
  - Centerline of embankment at Ferry Street Bridge;
  - Centerline of embankment at W6 abutment; and
  - Centerline of embankment at utility bridges



Service Load/Deformation Analyses

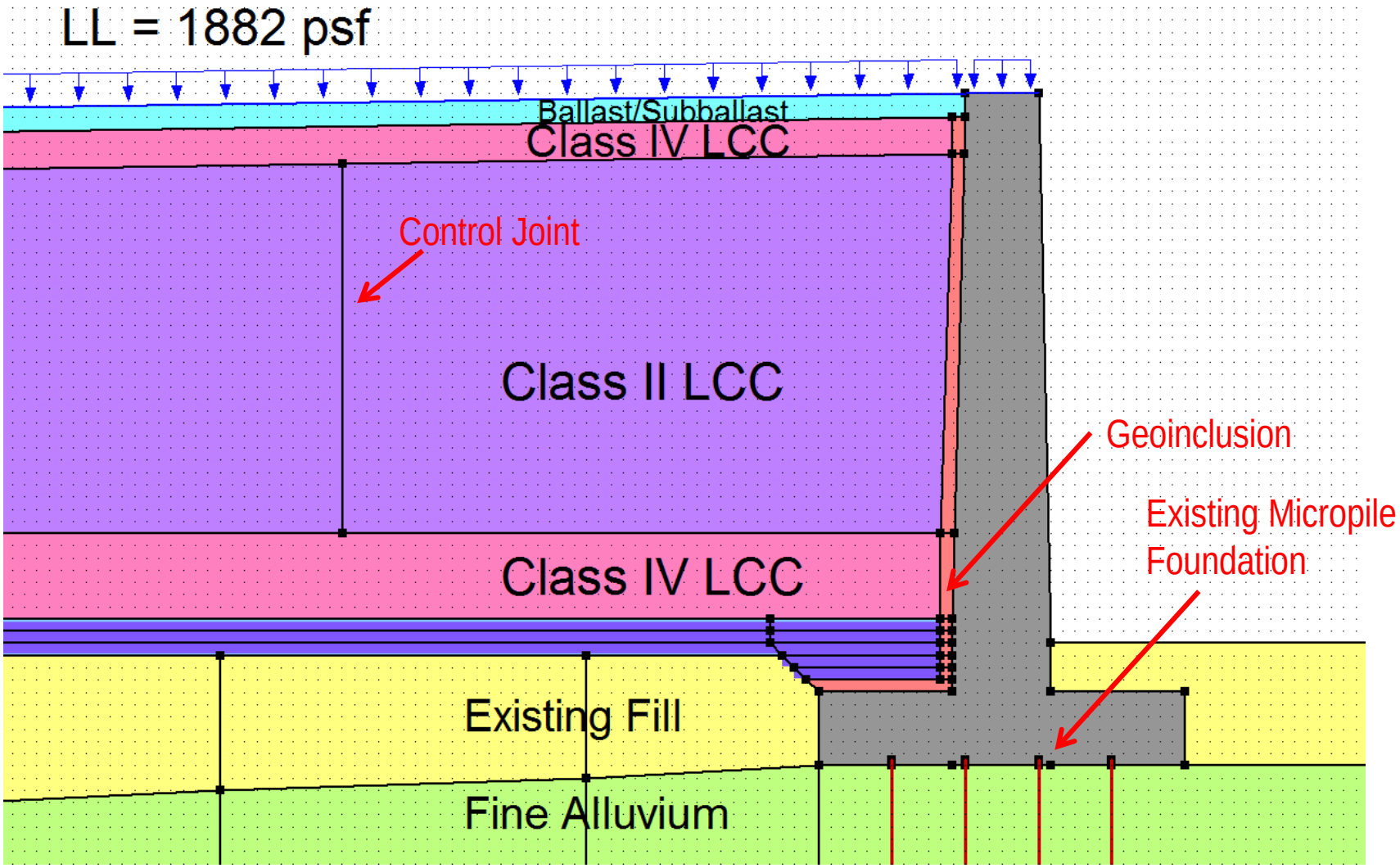
Ferry Street Bridge





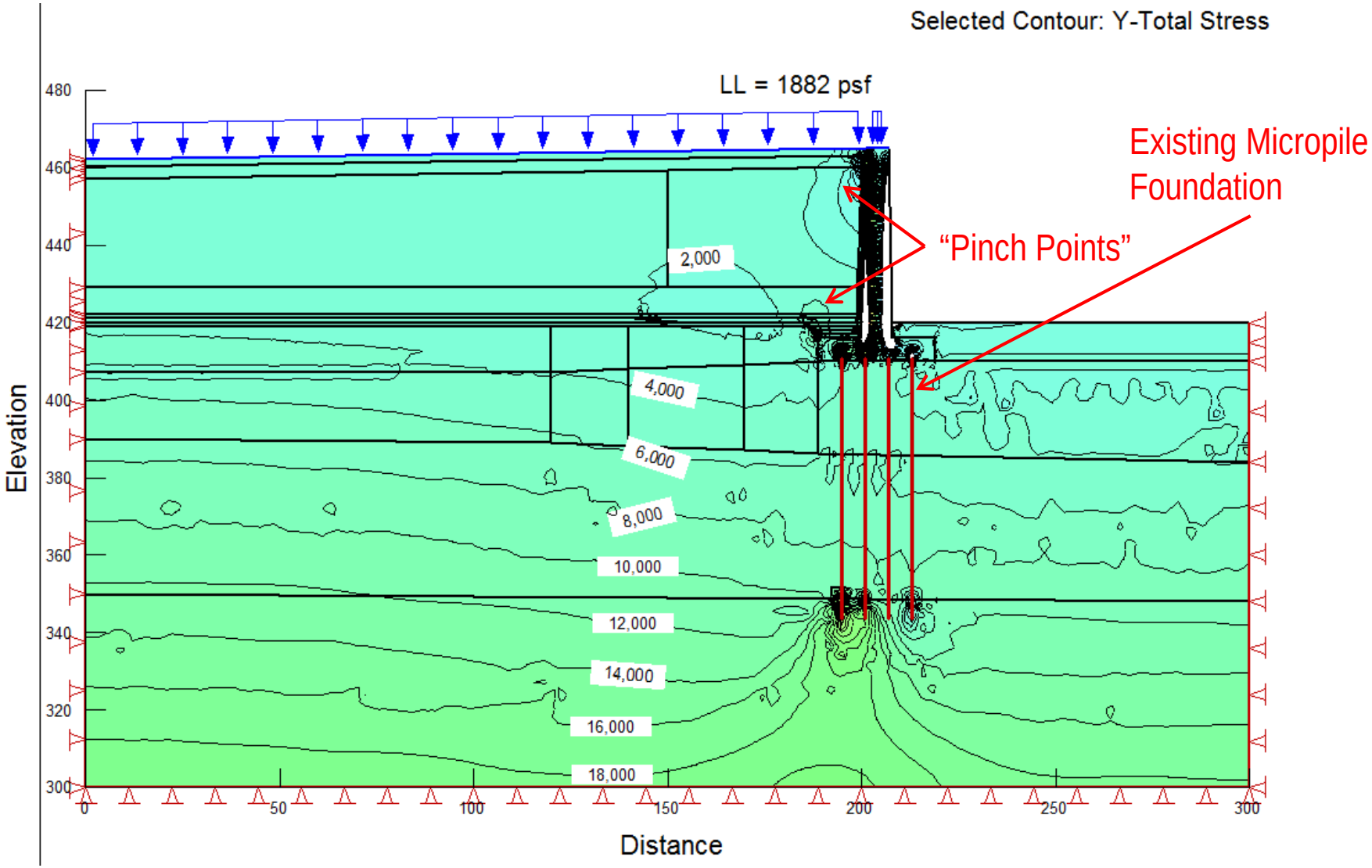
Service Load/Deformation Analyses

W6 Abutment



Service Load/Deformation Analyses

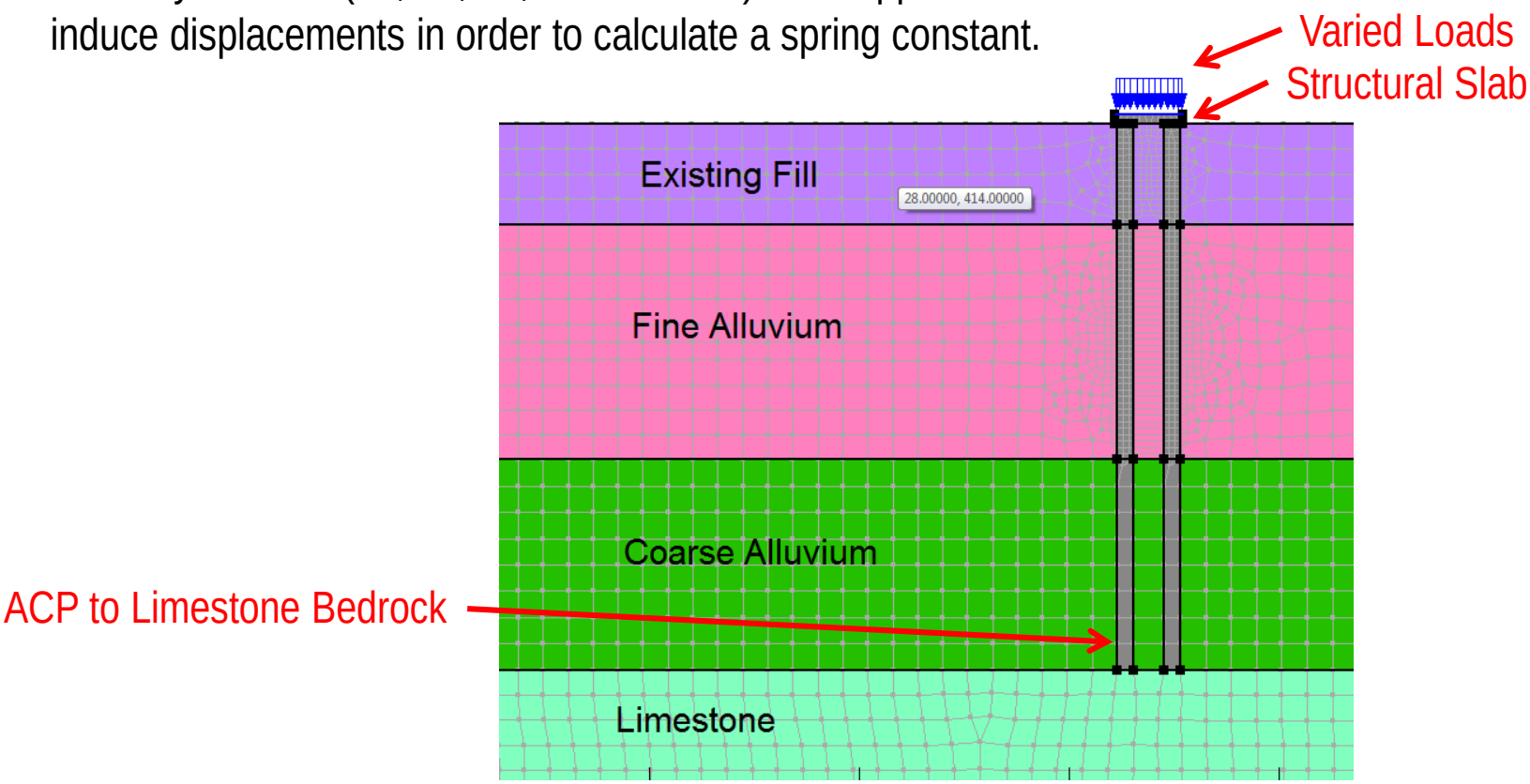
W6 Abutment



Service Load/Deformation Analyses

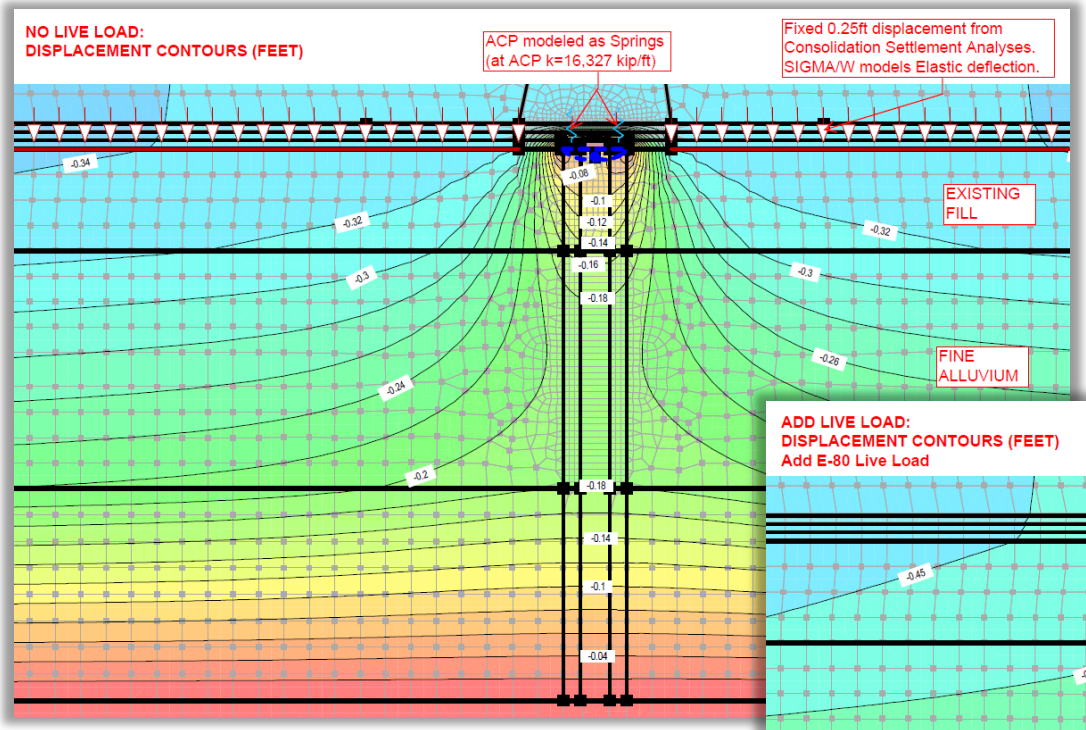
Utility Bridges

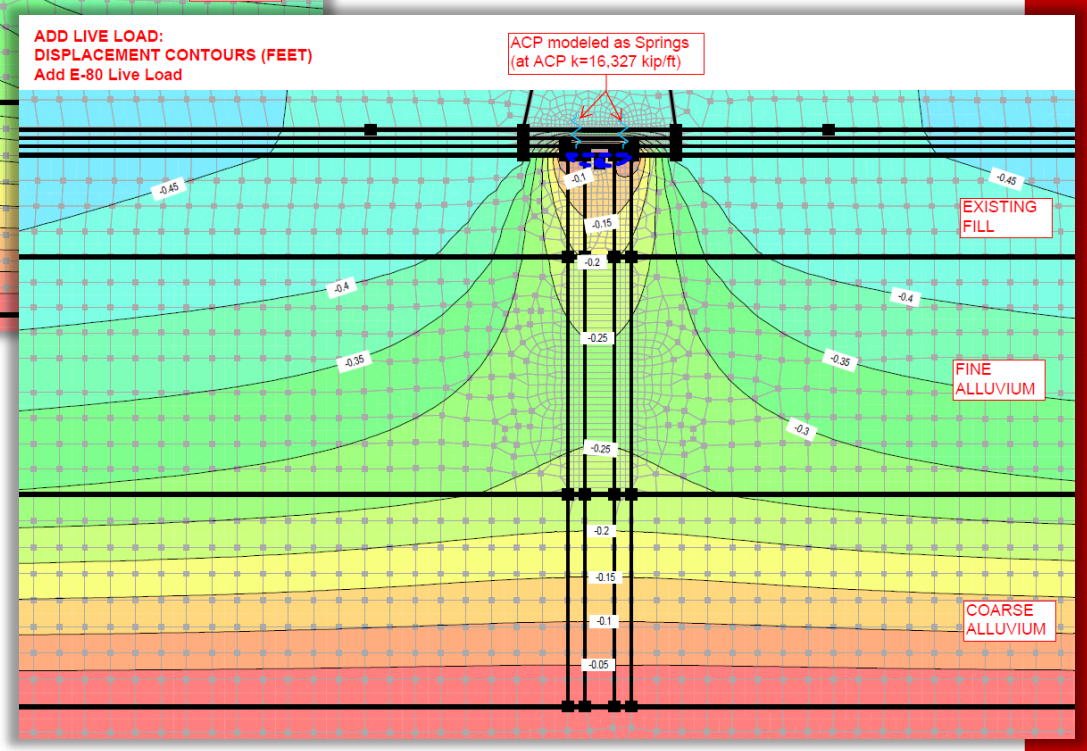
- Concrete ACP in the 2-D model unrealistically prevented the displacement due to the embankment and live loads from propagating beyond the ACP.
- Solution: Modeled ACP to bedrock as a spring. Developed by additional SIGMA/W analyses.
- A variety of loads (10, 20, 50, and 100 ksf) were applied to an 8-foot wide structural slab to induce displacements in order to calculate a spring constant.



Service Load/Deformation Analyses

Utility Bridges

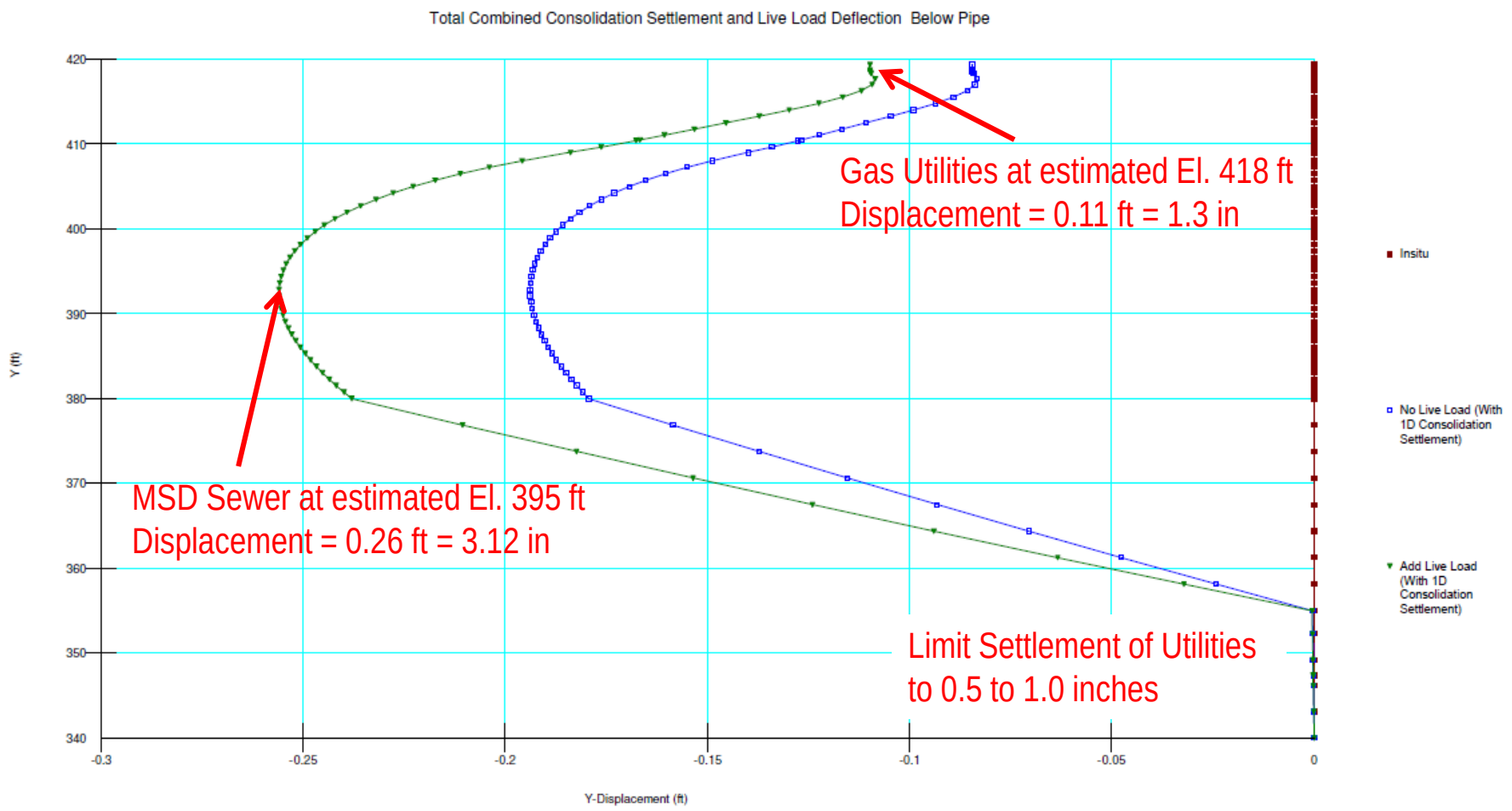




- Used fixed displacement of embankment (calculated from 1-D Consolidation Settlement Analyses) in the “No Live Load” step.

Service Load/Deformation Analyses

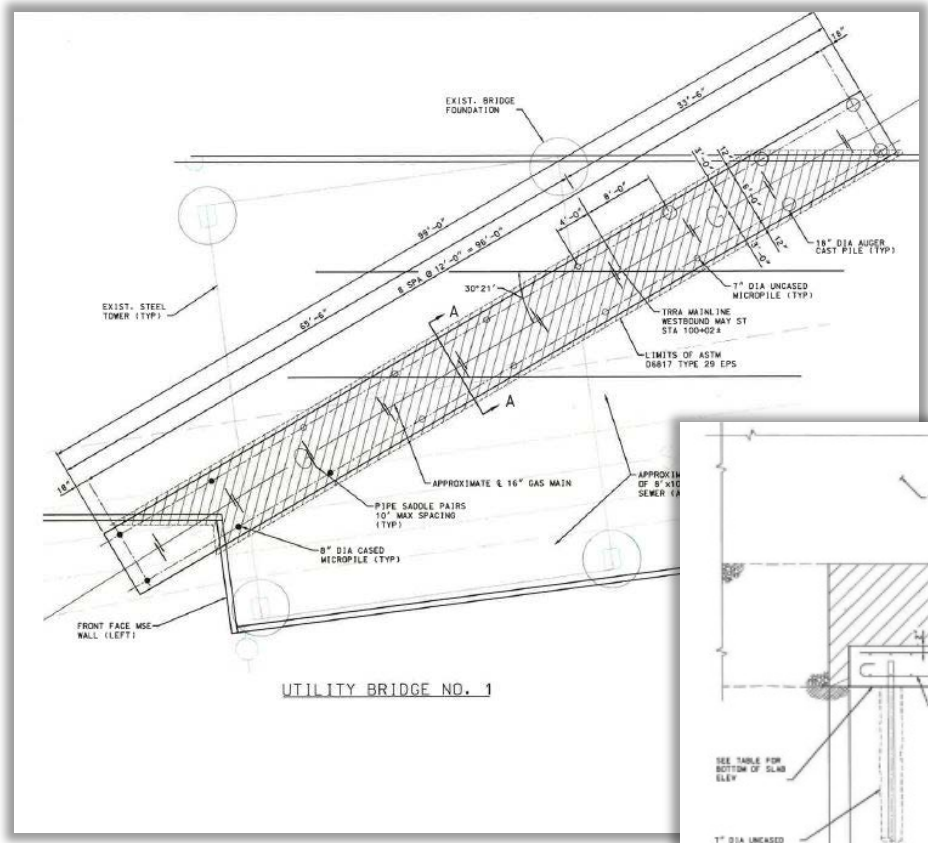
Utility Bridges

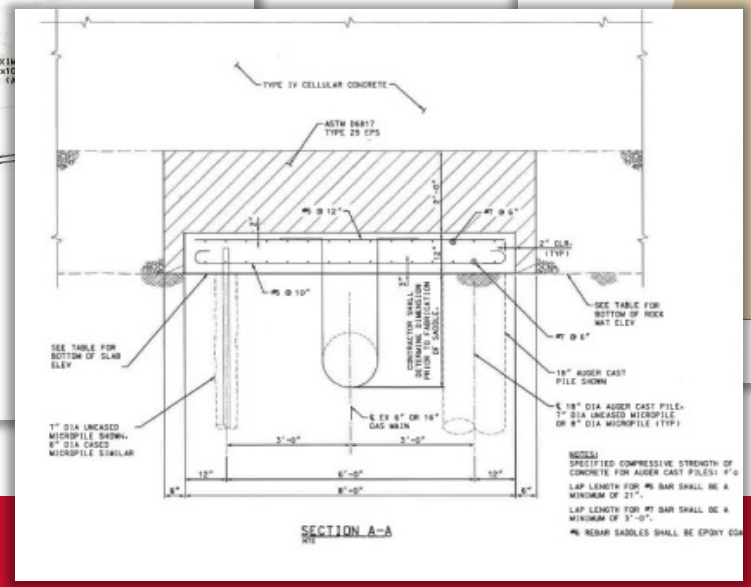


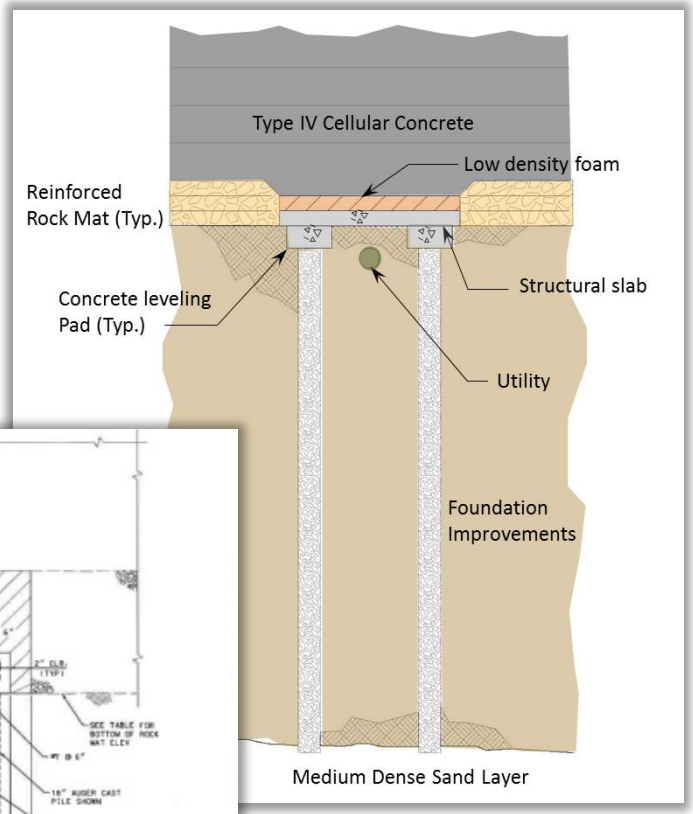
Constraint Resolution – Laclede Gas

Utility Bridges

- Solution to Gas Utility (shallow lines): attach utility to structural slab using a pipe hanger





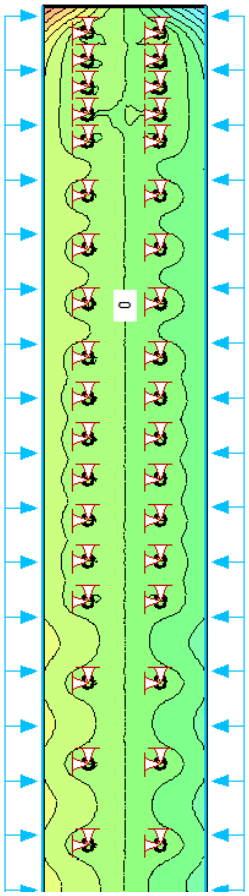


Constraint Resolution – MSD

Utility Bridges

- Solution to Sewer (deep utilities): Reduction of displacement from soil arching

Displacement Contours



S = 2*D = 3 ft

92% Reduction

S = 4*D = 6 ft

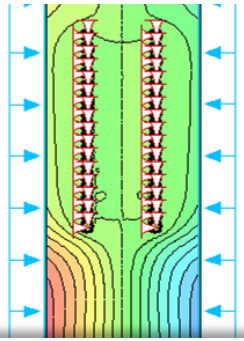
69% Reduction

S = 3*D =

78% Reduc

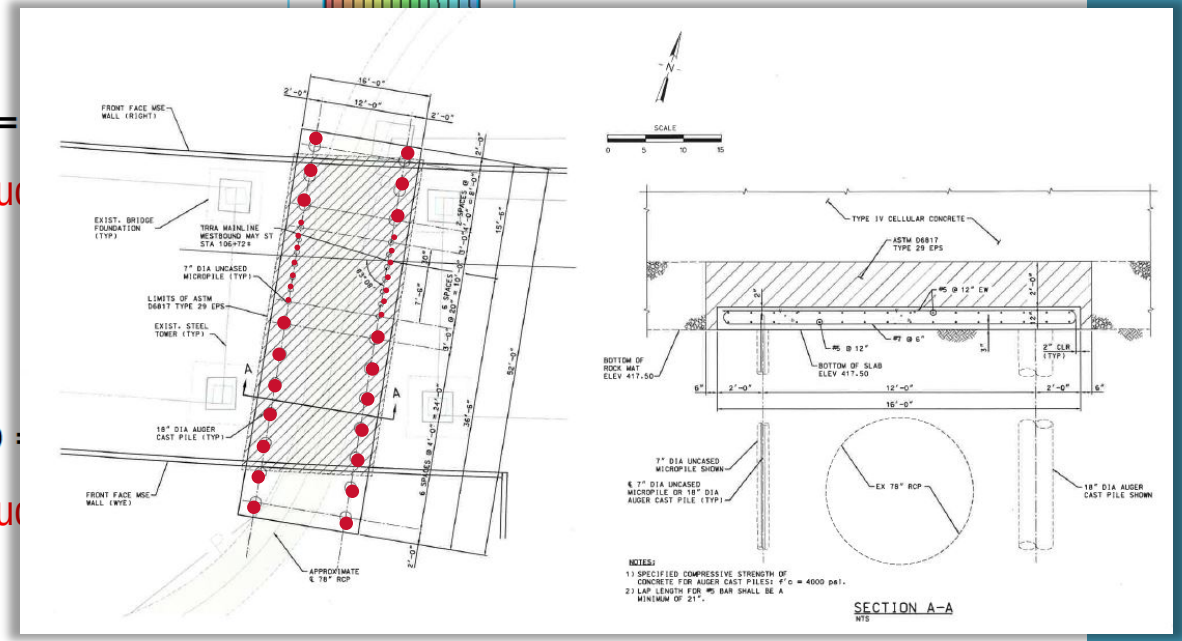
S = 6*D =

62% Reduc



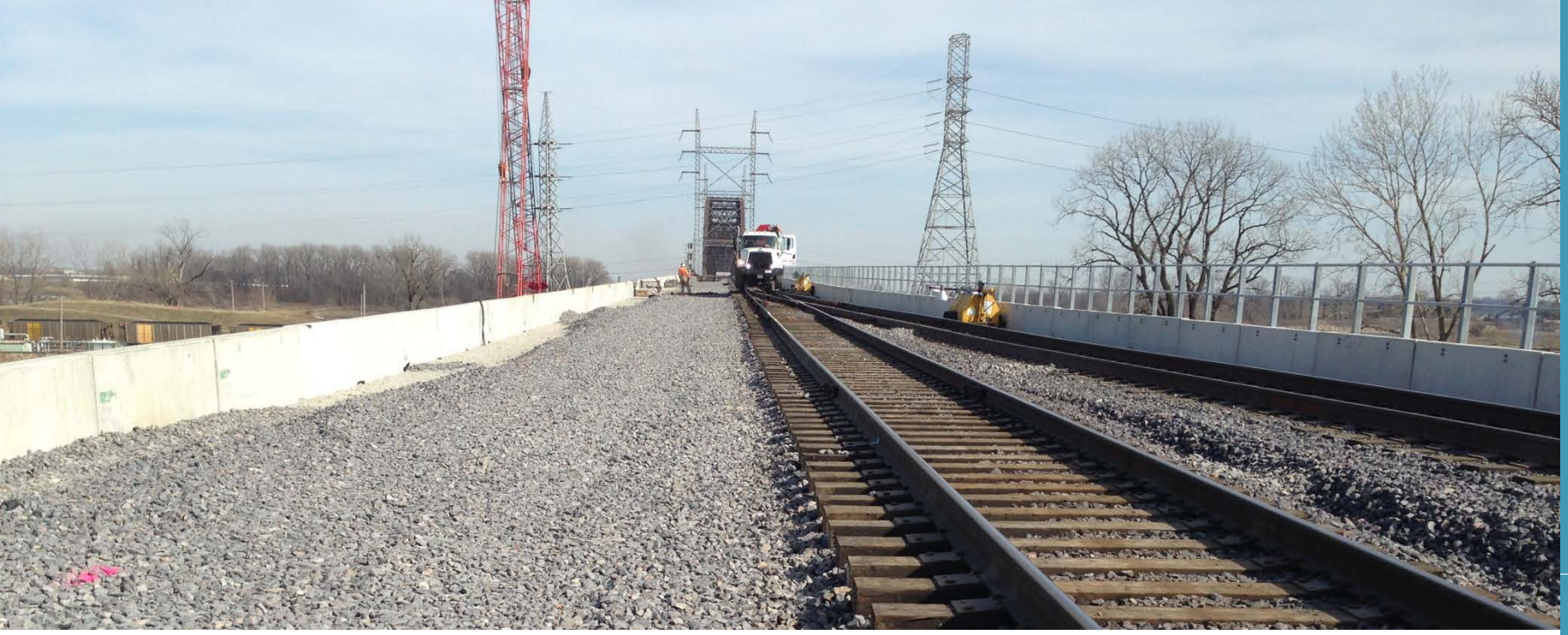
S = 1*D = 1.5 ft

100% Reduction



Key Findings

- Cellular concrete embankment remain stable under all service load conditions.
- Cellular concrete embankment will not yield under AREMA Level I and Level II seismic loading (F.S. > 1.0).
- 3 inches (+/-) permanent displacement expected with AREMA Level III earthquake (no liquifaction).
- If liquefaction occurs (likely only at a Level III event) expected uniform displacement of 20 inches (+/-).



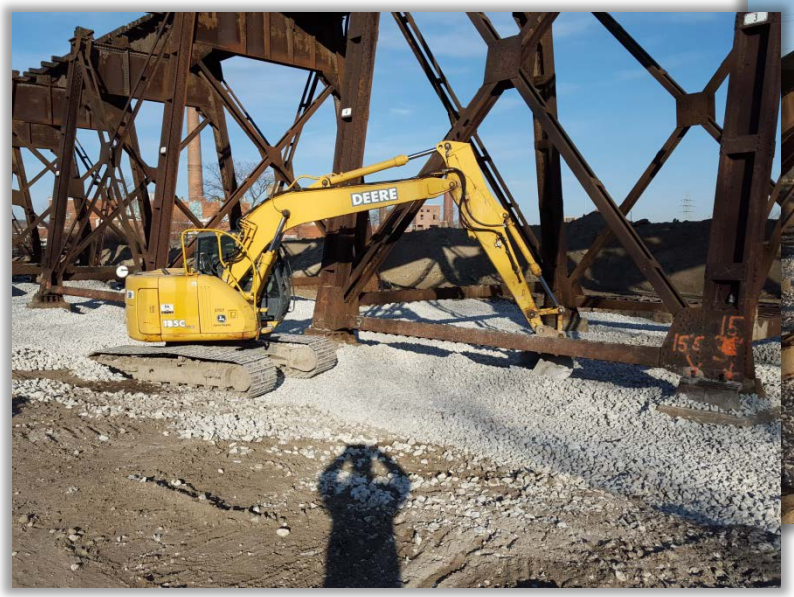
06

Construction

ACP Installation

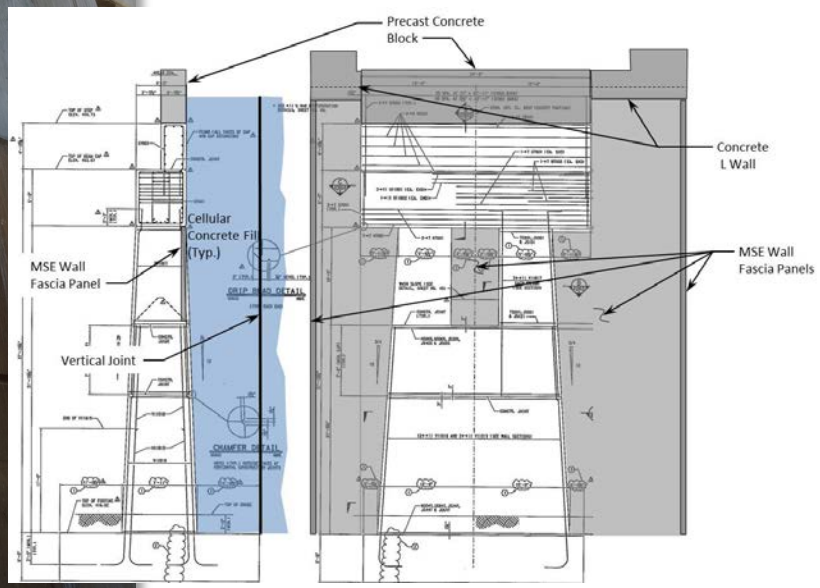
Utility Bridges

Rock Mat Installation

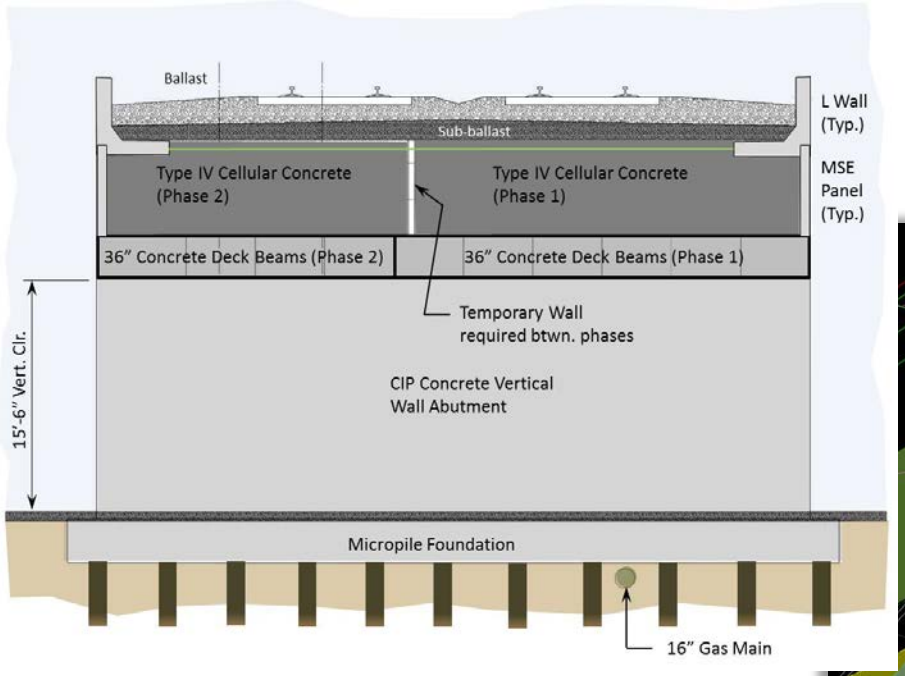


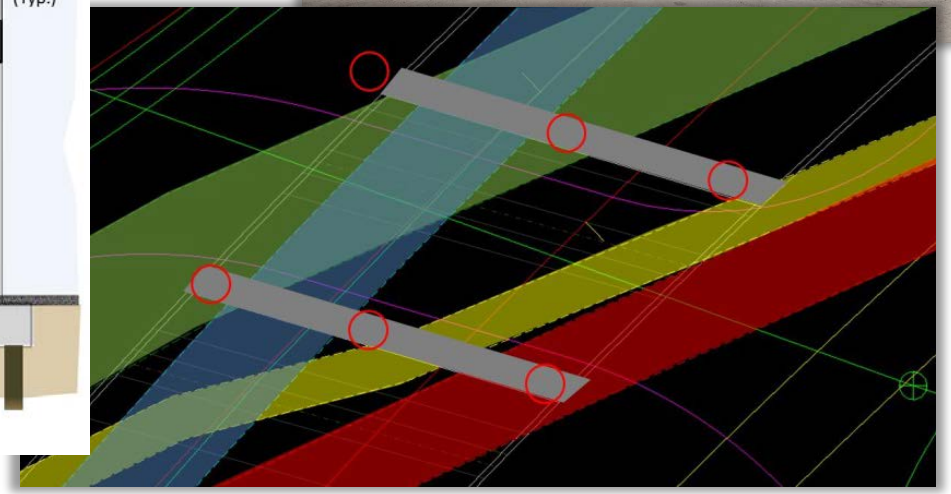
MSE Wall Panel/ Straps Installation

Bent W6 Modifications



Ferry Street Bridge





LCC Placement

LCC Placement
Ferry Street Bridge

LCC Placement
Ferry Street Bridge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UNDERPINNING
EARTH RETENTION
TIEBACK ANCHORS
PRESSURE GROUTING

LCC Placement Issues

LCC Placement Complete

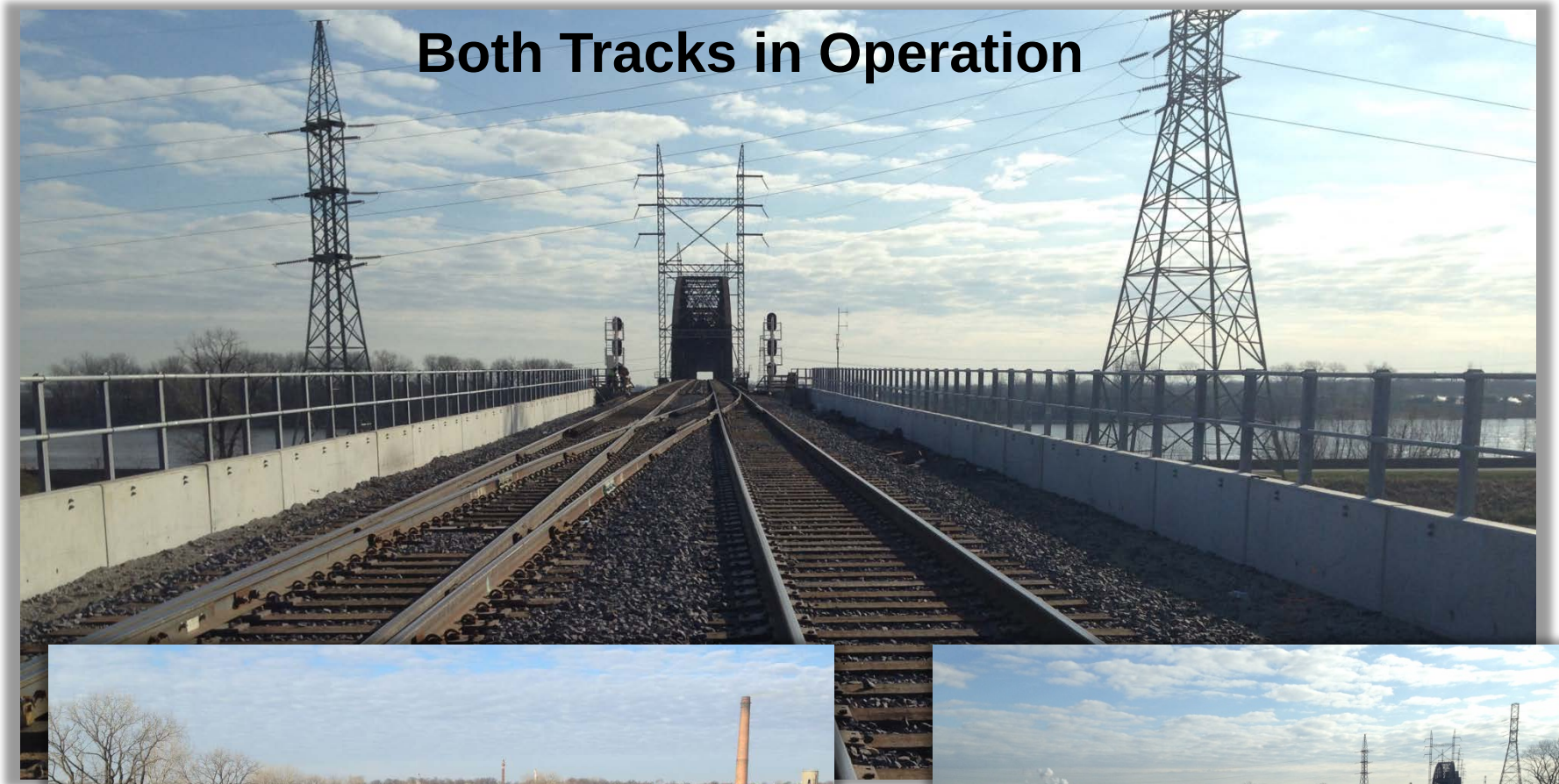
Placement of Sub-base

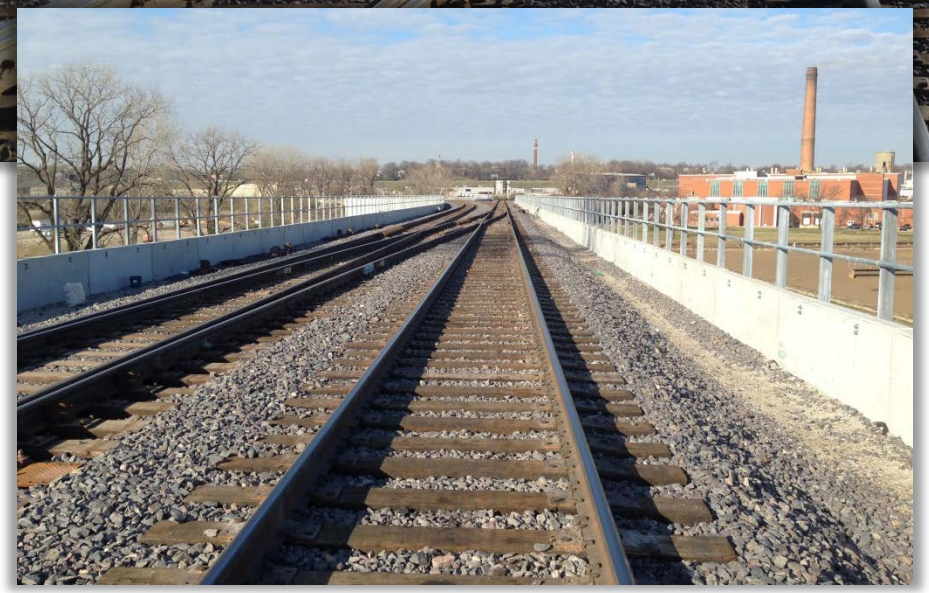
MSE Wall Complete

West Approach Bent Modifications Complete

South Track in Operation

Both Tracks in Operation





Acknowledgements

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HDR

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Q&A