New Madrid Earthquake Hazard and Memphis Area Earthquake Engineering: The Hernando Desoto Bridge

U.S. Department of Transportation
Federal Highway Administration

TDOT

AHTD

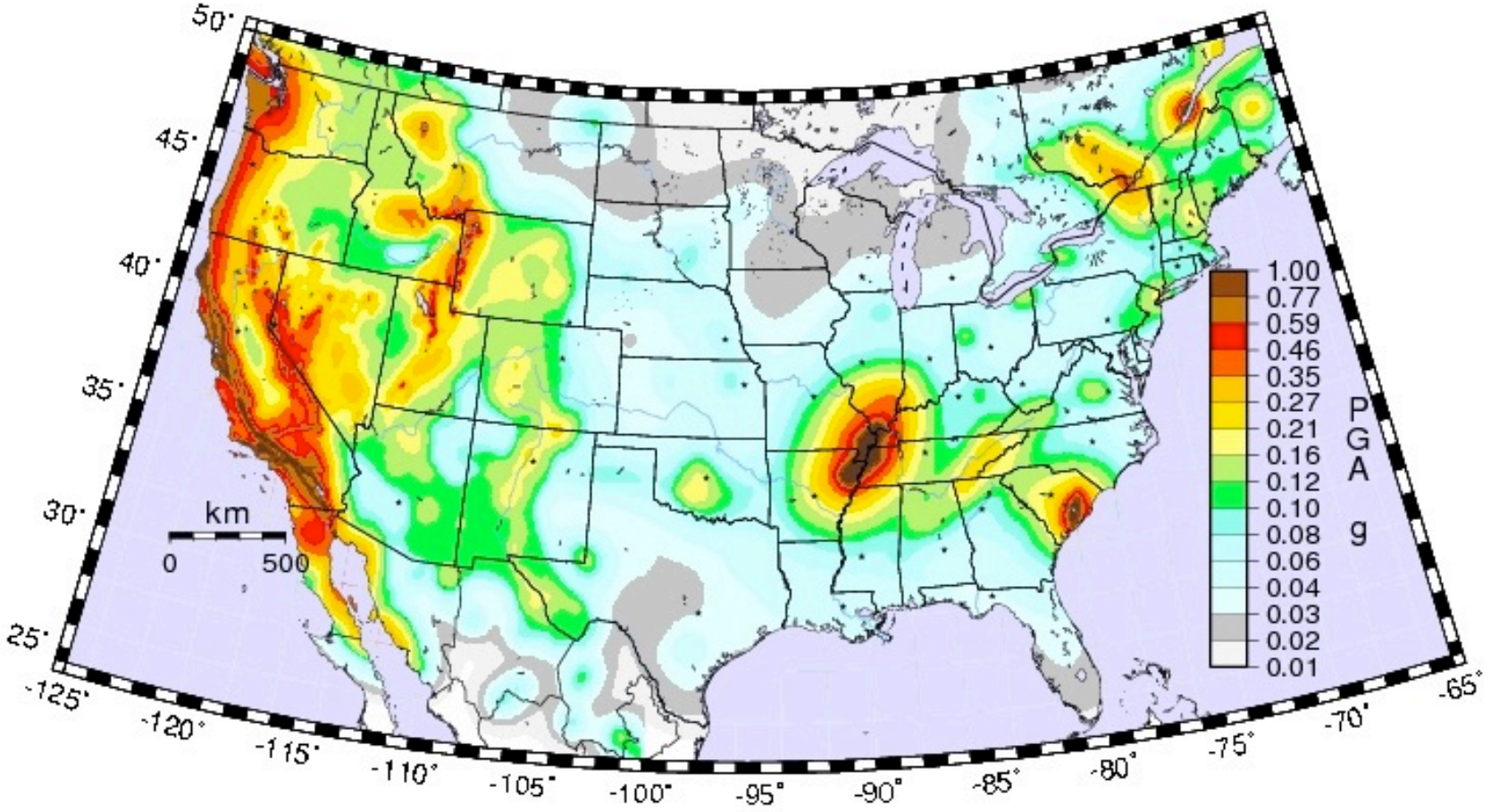
Mid-America Earthquake Center

USGS
science for a changing world

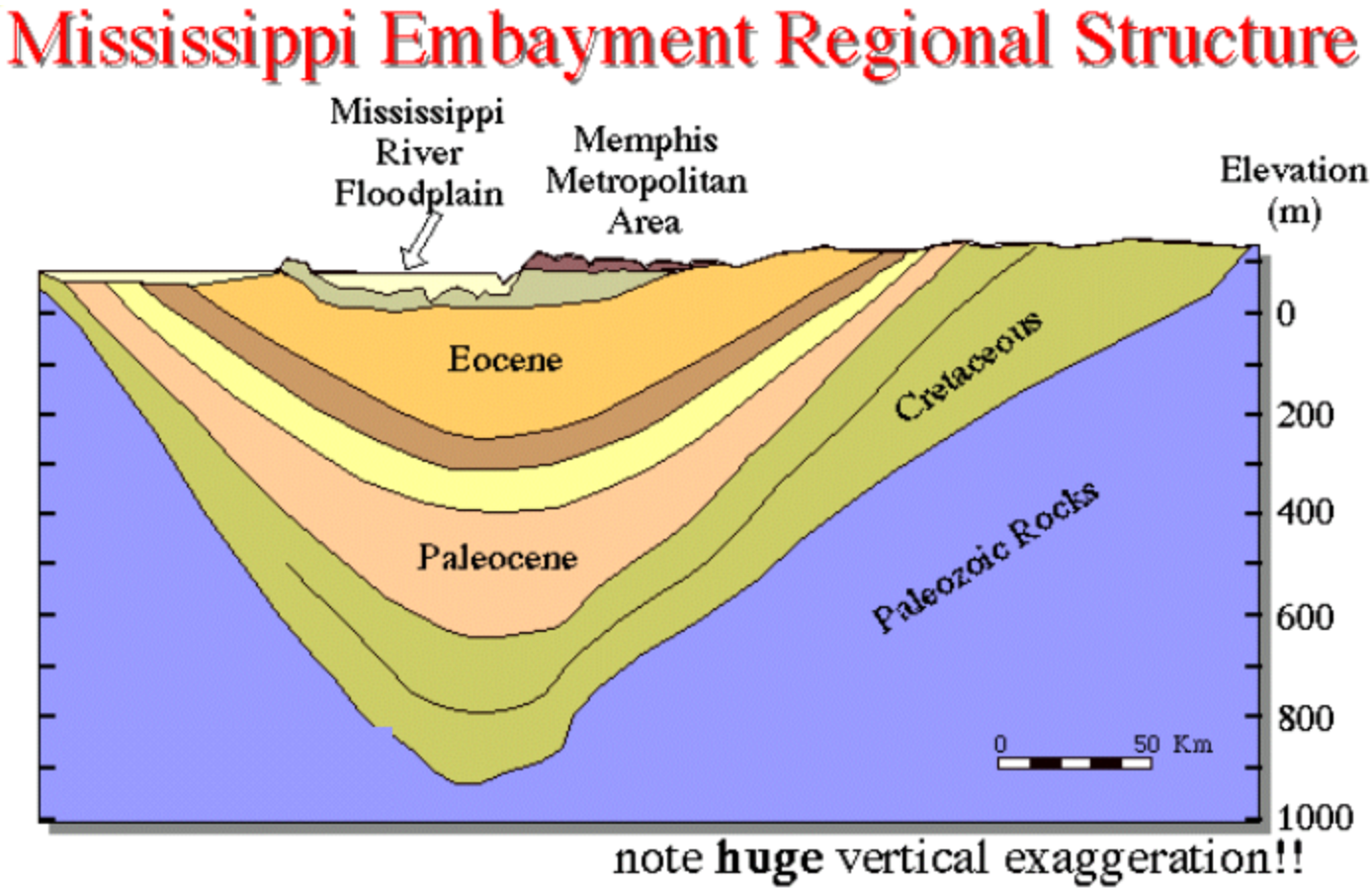
Seismicity of the Area

- Memphis is located close to the southwestern segment of the New Madrid seismic zone, which is regarded by seismologist, engineers, and public officials as the most hazardous seismic zone in the Eastern United States.

PGA with 2% in 50 year PE. BC rock. 2008 USGS



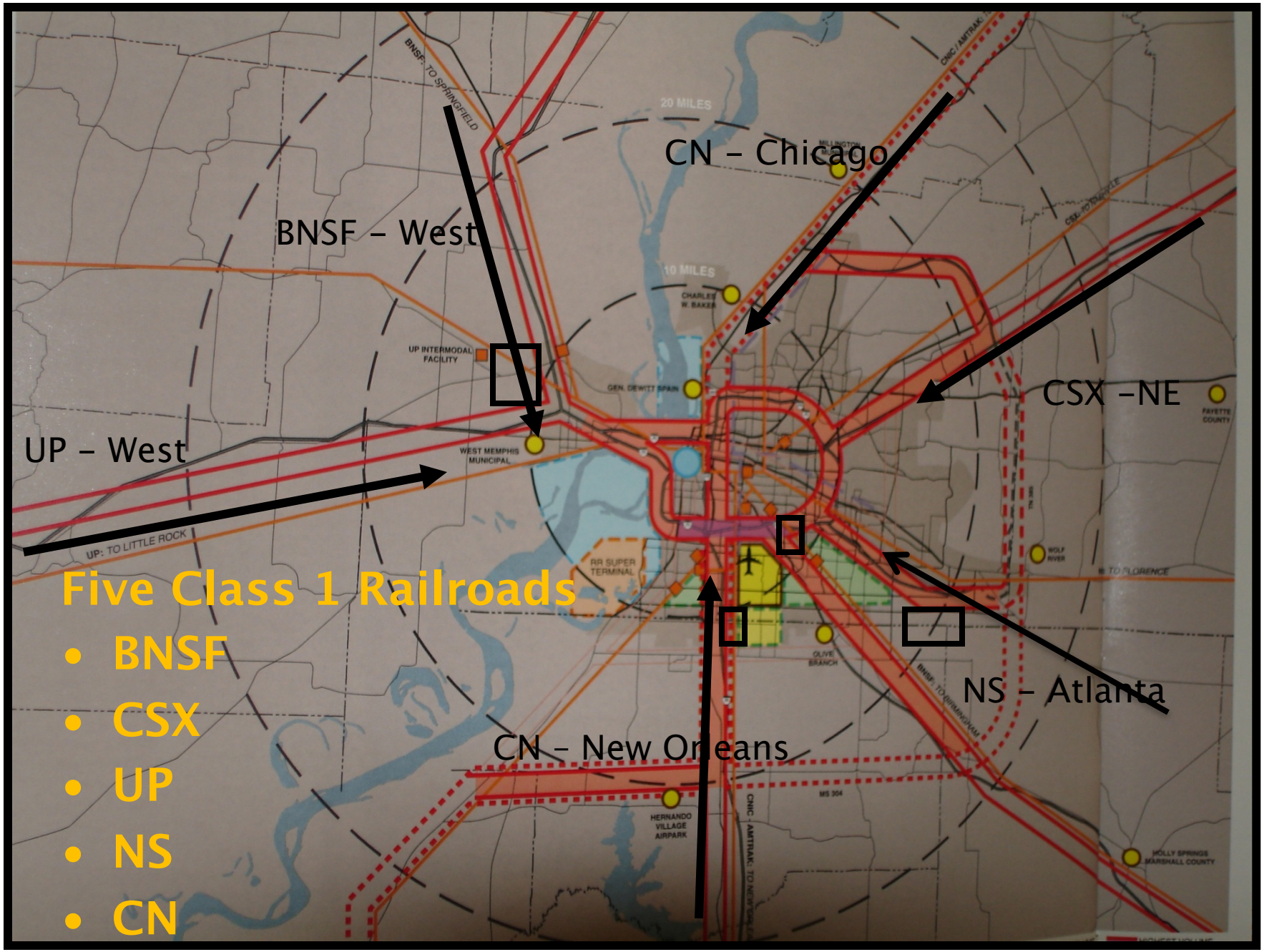
Regional Structure



America's Distribution Center

Air Ports

World's Largest Cargo Airport


BNSF – West
CN – Chicago
CSX –NE
UP – West
NS – Atlanta
CN – New Orleans
Five Class 1 Railroads
• BNSF
• CSX
• UP
• NS
• CN

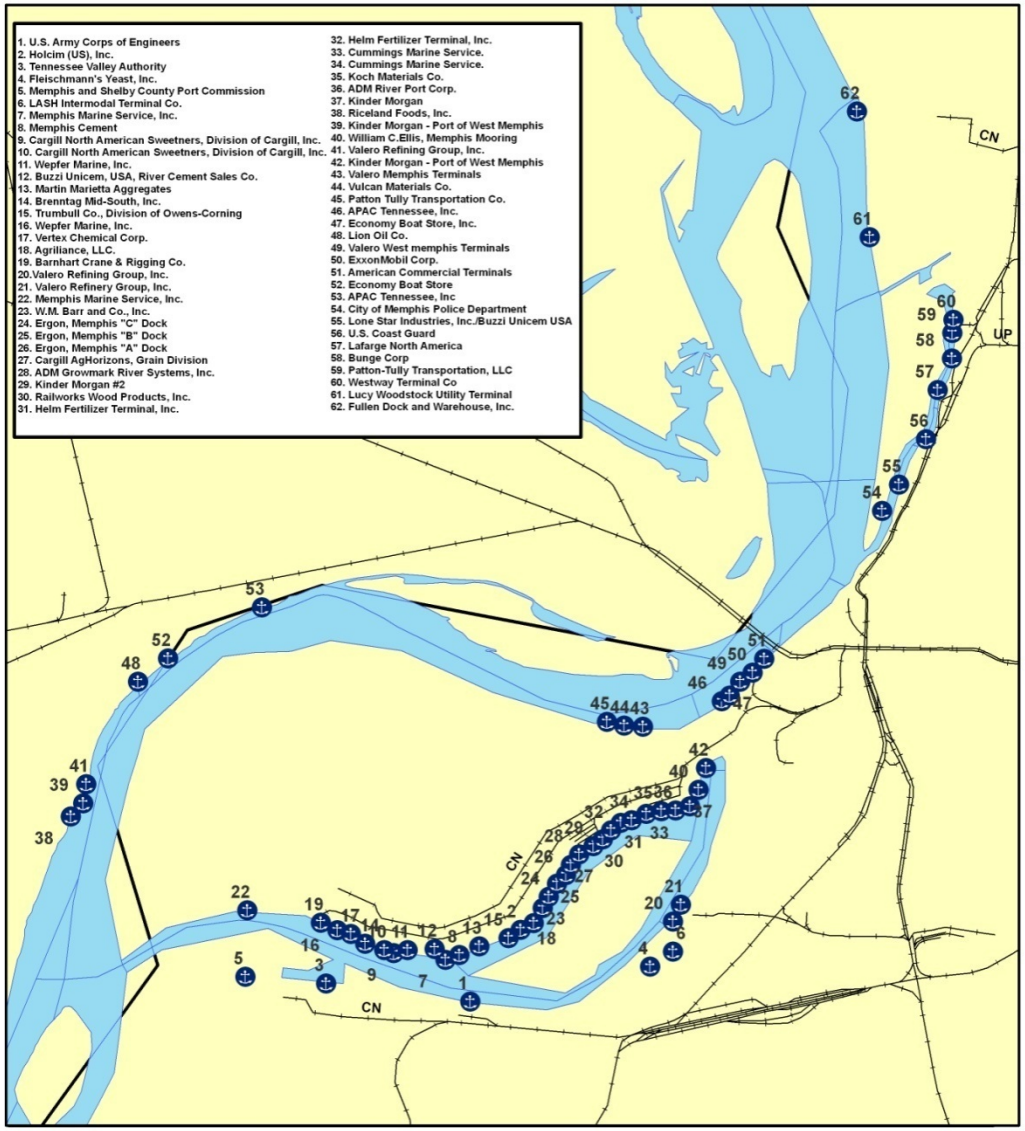
River Transportation – Memphis

Source: Phyllis J. Steckel

- Second-largest port on the Mississippi
- First in foreign import tonnage
- 28% of all US waterborne commerce
- $6.7 billion economic impact
- 5,500+ direct and 9,900+ indirect jobs


Inland Waterways
4th largest Port on
Inland Waterway system

Memphis Ports and Terminals Map

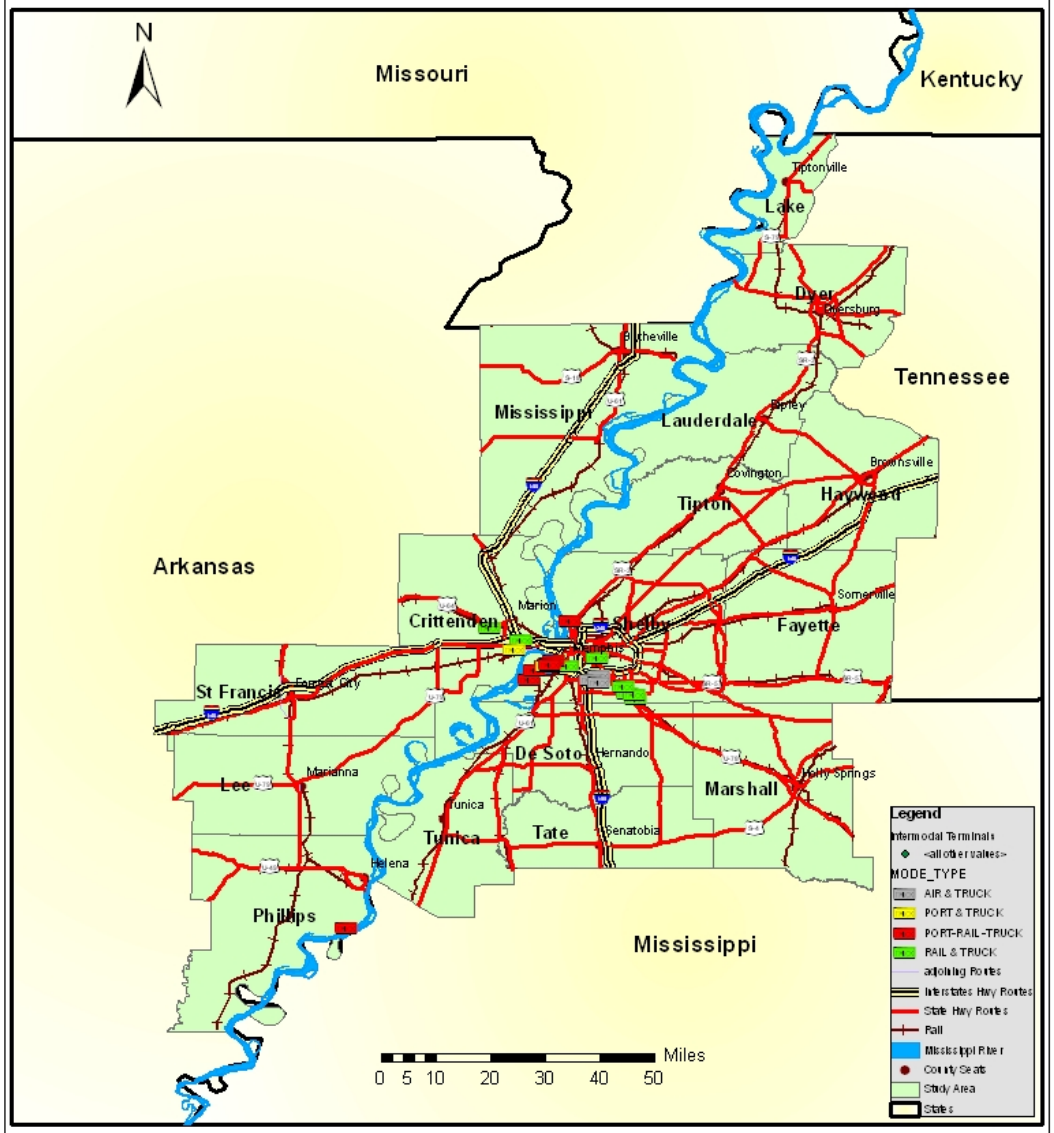


Memphis Area Chamber Infrastructure Study

CIFTS

Source: US Army Corps of Engineers

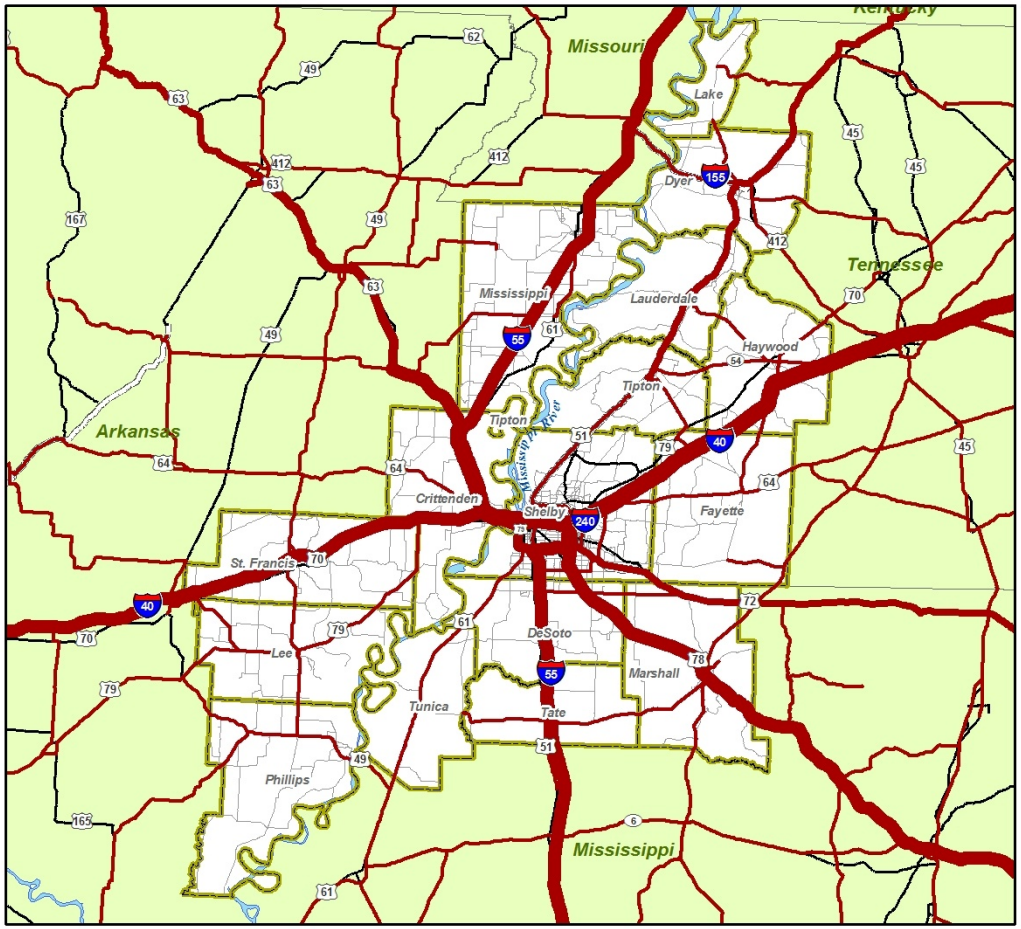
Intermodal Terminals



Memphis Area Chamber Infrastructure Study CIFTS

Data source: Research and Innovation Technology Administration (RITA) & University of Memphis

Inbound Truck Tons (Year 2006) for Memphis Study Area



Legend

Inbound Truck Tons (2006):

- Less than 1 Million
- 1 - 2.5 Million
- 2.5 - 5 Million
- 5 - 10 Million
- More than 10 Million

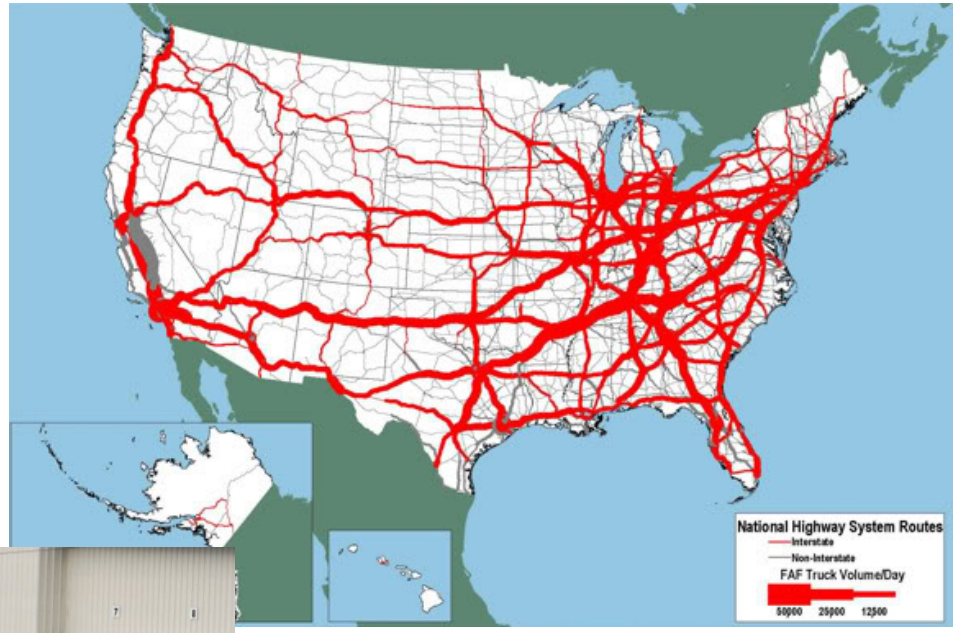
- Limited Access
- Highway
- Study Area Counties
- Water bodies (Lakes, Bays, ...)
- Study Area Counties

N W E S

Source: Global Insight, Transearch Data, 2006

Interstate Highways….

- Interstate 40 – busiest trucking corridor in US
- Interstate 55
- 490 trucking terminals



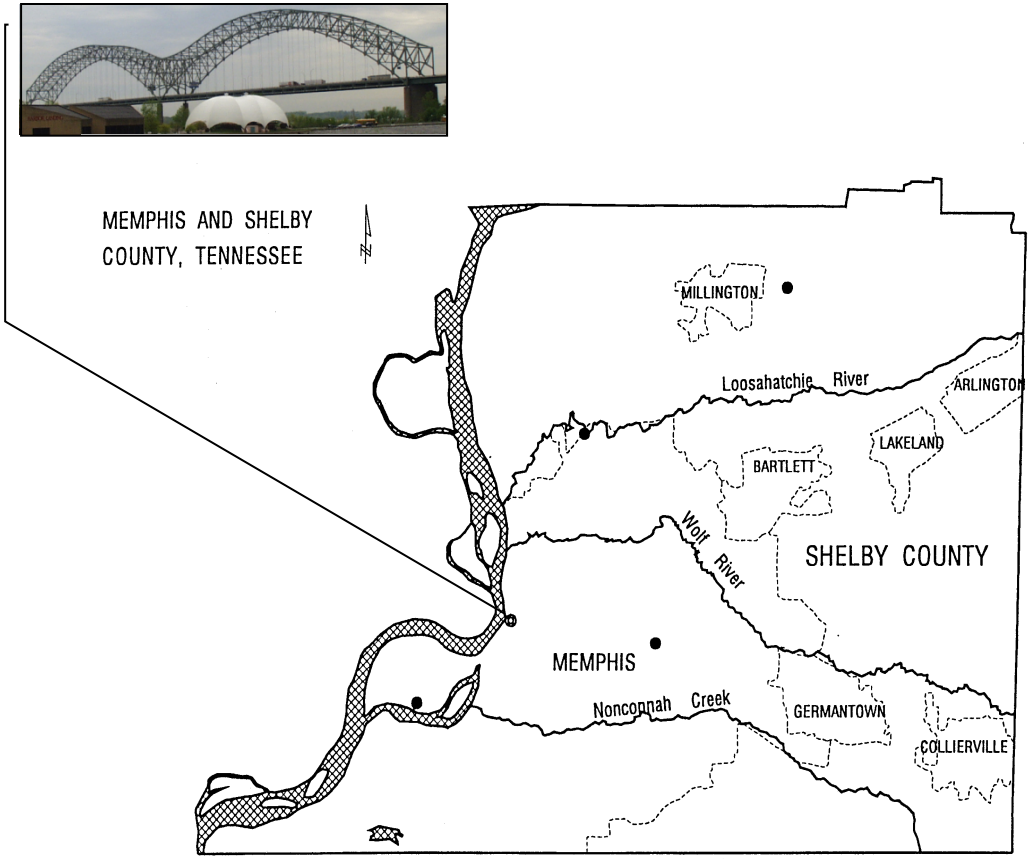
Source: Phyllis J. Steckel

Alternative Mississippi River Crossings

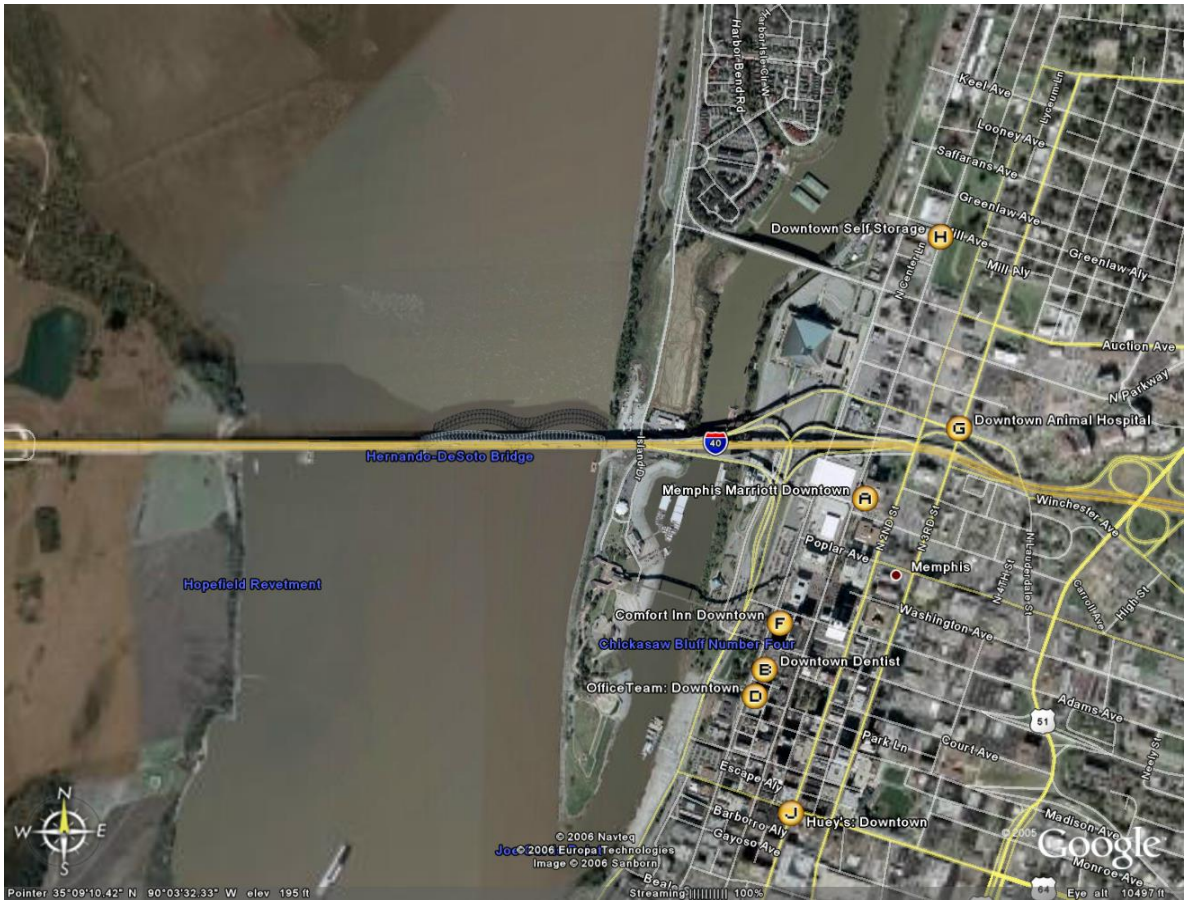
- I-40 Bridge
  - Constructed in 1960's
  - East-west Interstate
  - Major Route for Truck Traffic (35 to 40 percent)
- I-55 Bridge
  - Constructed in 1940's
  - North-south Interstate


2002. 5. 27 09:29

Location of the I – 40 Bridge



Vicinity Map



Alternate I-55 Crossing

I-55
Masonry Pier

Retrofit Program

- The I-40 Hernando DeSoto Mississippi River Bridge in Memphis, Tennessee has been retrofitted to withstand a magnitude 7.5 event at 65 km distance from the site with a depth of 20 km.

- The goal of the retrofit is to have this bridge fully operational following the maximum probable earthquake (2500 year return period).

Seismic Performance Criteria

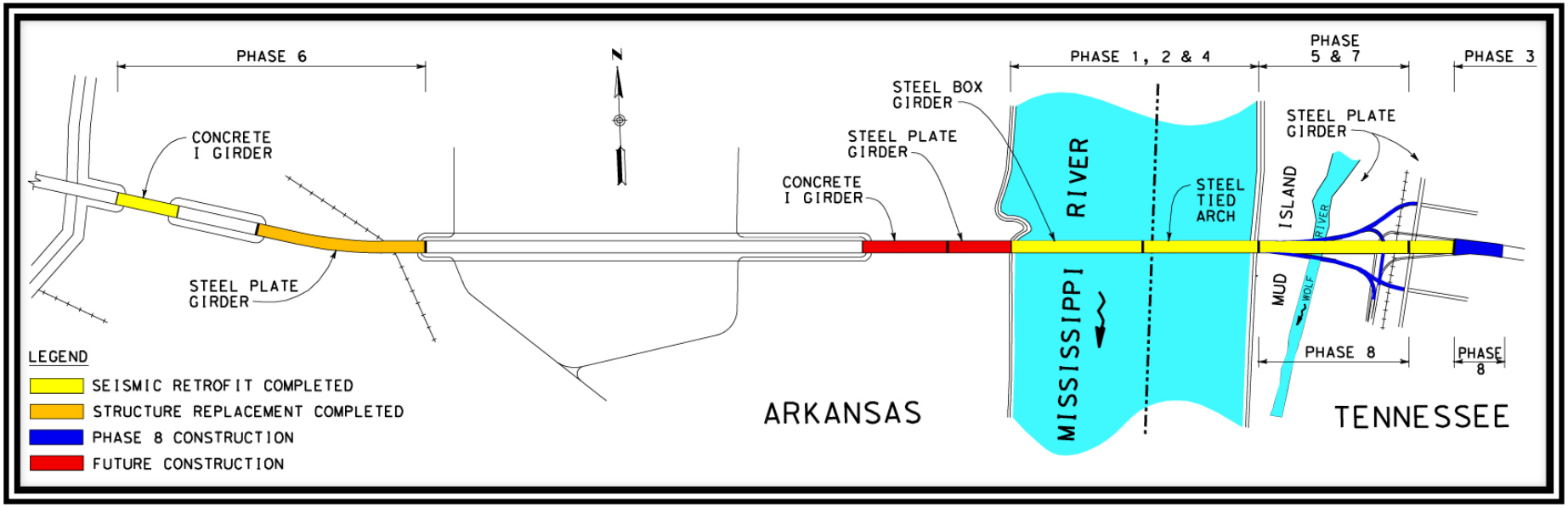
Seismic Performance Goals – Lifeline

- Ø Structure serviceable following "contingency level earthquake" (2500 year return period*)
- Ø 2 to 3 day closure for inspection
- Ø Repairs to secondary components performed under traffic
- Ø Structure functional for emergency vehicles immediately after the earthquake
- Ø Structure operational for general public following inspection

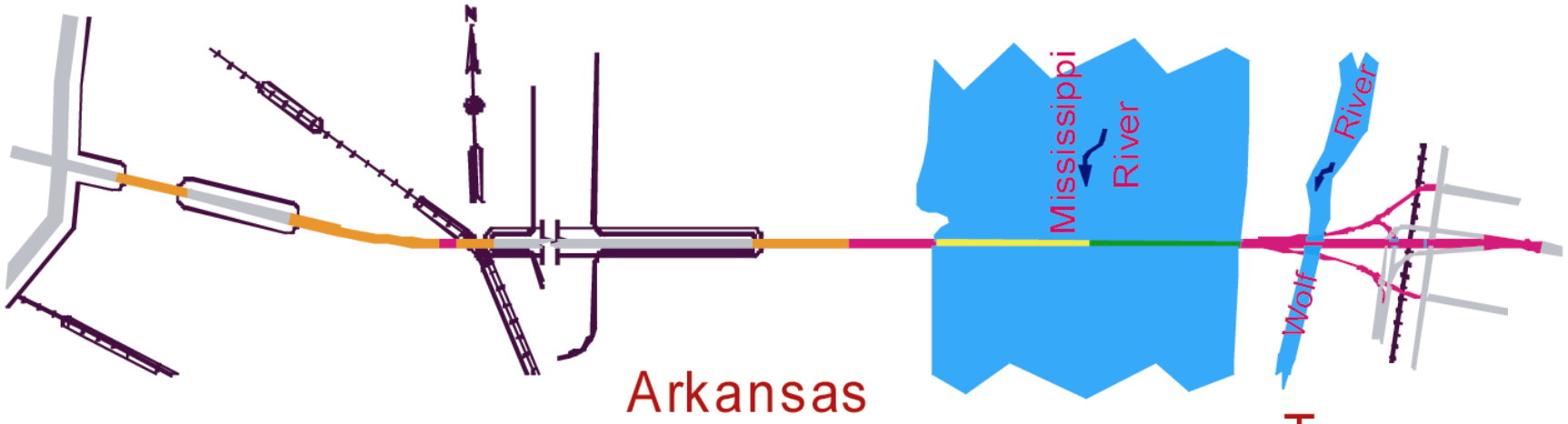
*Note: 7.5 magnitude earthquake

Retrofitting Separated into Construction Phases

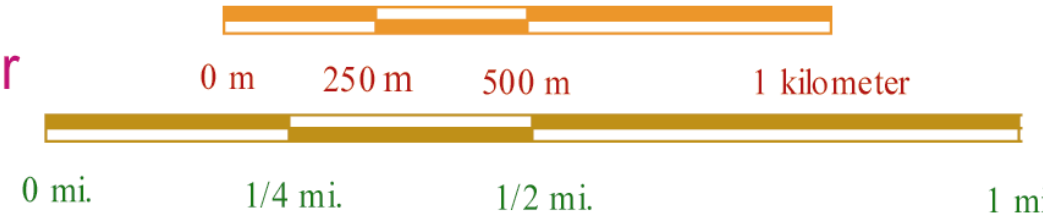
- Ø Construction phases based on available funding
- Ø Total Construction Cost: $275 million
  - § Phases 1 to 6 (completed): $175 million (2000–2008)
  - § Phase 7 : $16.5 million (2009–2011)
  - § Phase 8 (current): $43.2 million (2010–2013)
  - § Future Contract: $40 million (Group C/D)



I-40 Bridge over the Mississippi River Plan View



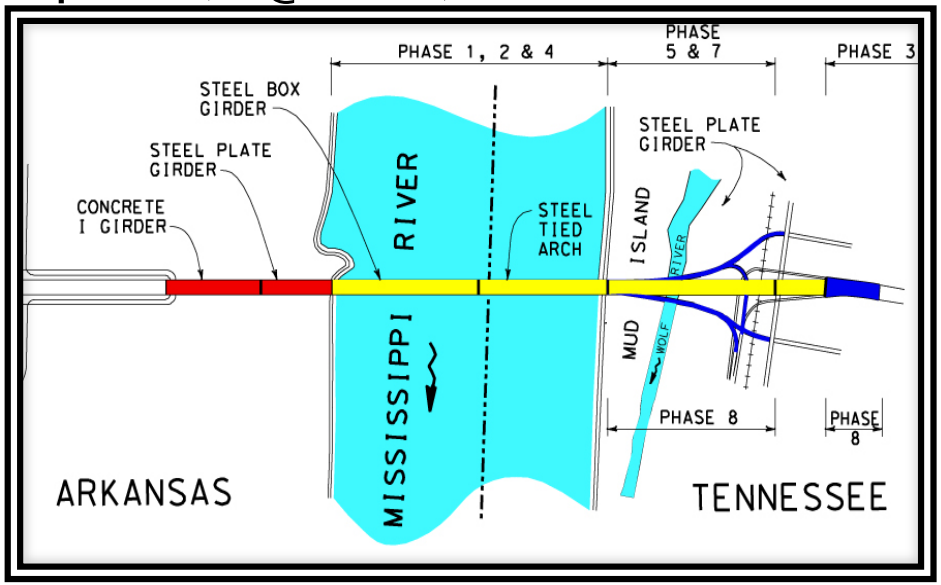
- Concrete I-Girder
- Steel Plate Girder
- Steel Box Girder
- Steel Tied Arch



Source: Roy Imbsen

Description of the I-40 Bridge & Approaches

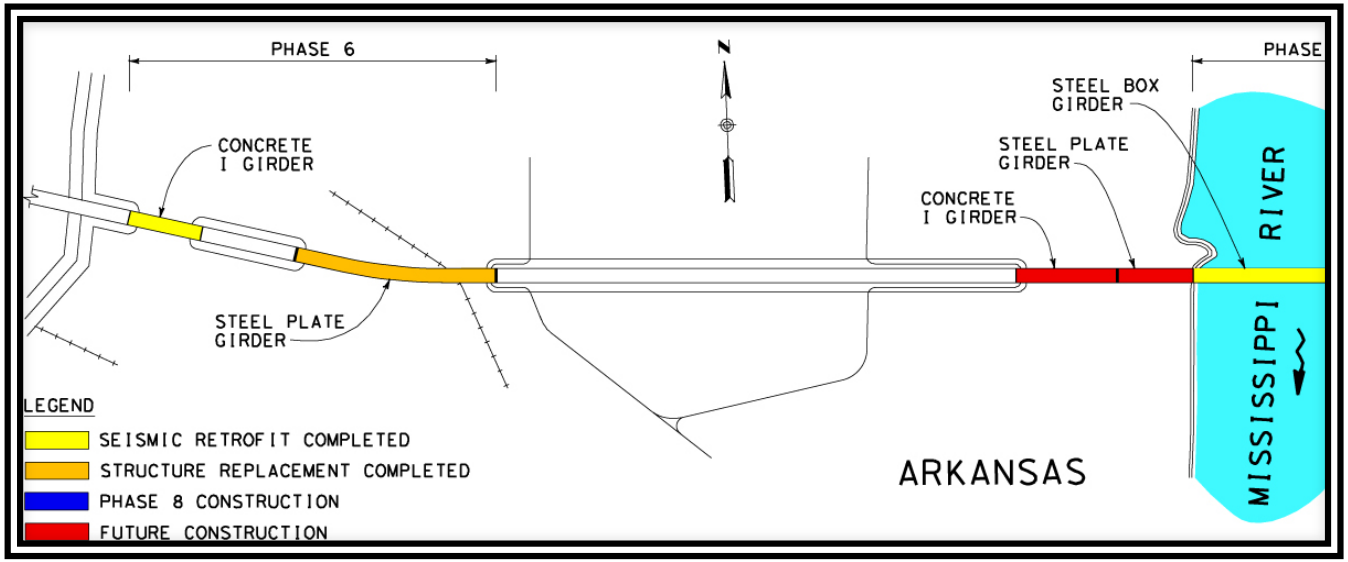
- Built in the late 1960's
- Total length – 3.3 miles long with 164 spans, 160 piers & 10 abutments
- Main channel spans – Phase 1, 2 & 4
  - Five steel box girder spans (2 @ 330' & 3 @ 400')
  - Two steel tied arch truss spans (2 @ 900')



Description of the I-40 Bridge & Approaches

Ø Arkansas West Approaches (Phase 6 & future)

- § P/S Concrete I Girder Spans (Group A) – Phase 6 Retrofit
- § Steel Plate Girder (Group B) – Phase 6 Replacement (Staged Construction)
- § P/S Concrete I Girder Spans (Group C) – Future Retrofit
- § Eleven Welded Steel Plate Girder Spans (Group D) – Future Retrofit

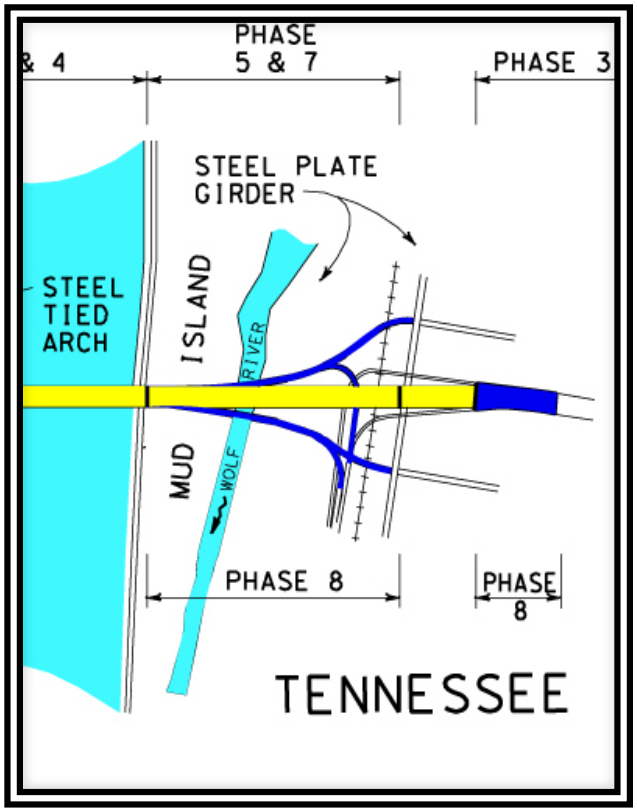


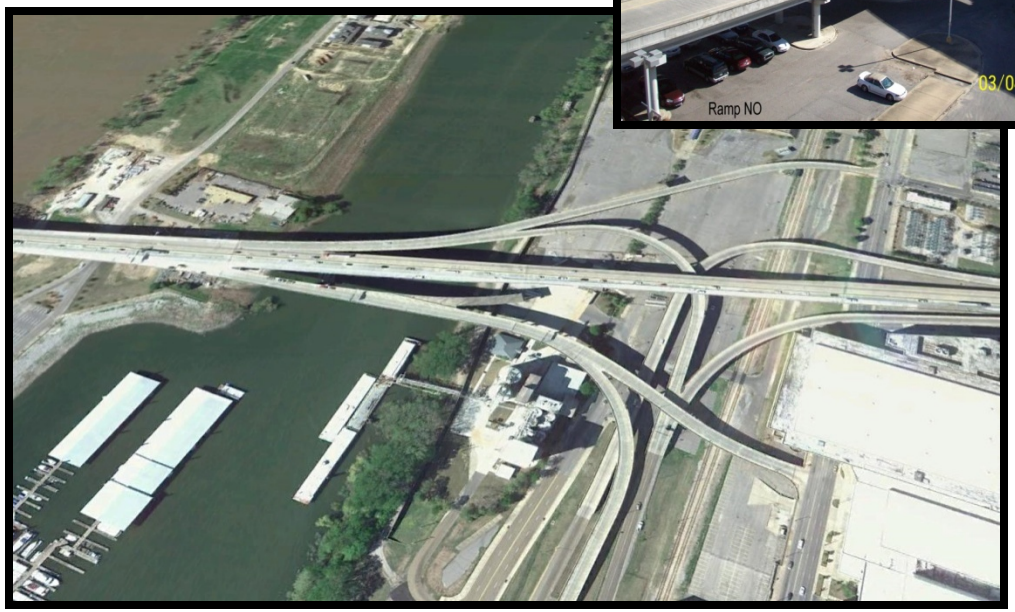
Group B Replacement

Description of the I-40 Bridge & Approaches

Ø Tennessee East Approach and Ramps (Phase 3, 5, 7 & 8)

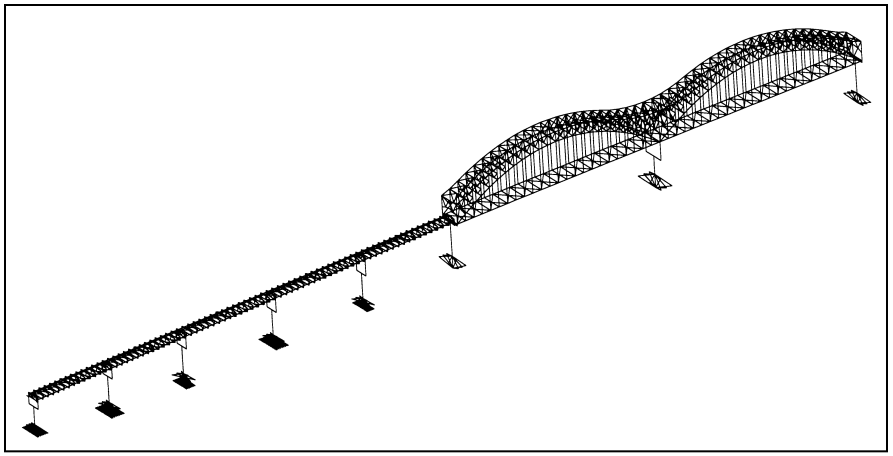
§ All Welded Steel Plate Girder Spans





Seismic Response Analysis

- Three-Dimensional Analytical Model
  - As-Built Model → Obtain Vulnerabilities
  - Retrofit Strategy Model → Isolation Bearings Viable & Cost



Box Girder and Tied Arch Portion

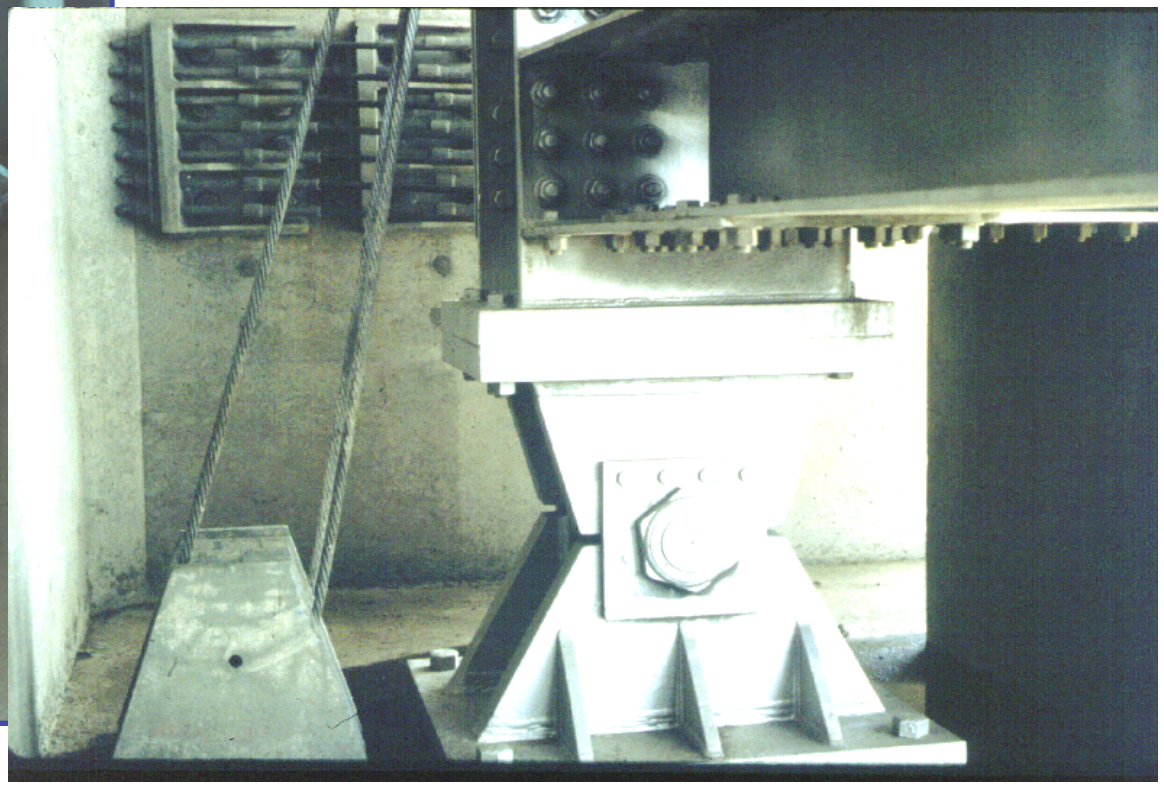
- Time-history seismic analysis
- Ground motion input with displacement time-histories at multiple supports
- Model also included soil-structure interaction

State-of-the-Art Technologies

State-of-the-Art Techniques in Design & Construction

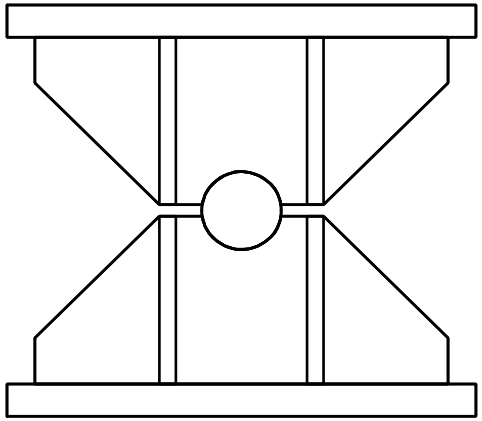
- I-40 Project has set new standards in seismic design of bridges in the U.S.
- Collaboration with the designer & owner, TDOT – New Seismic Standards
- Collaboration with Bearing and Joint Suppliers – New Technology

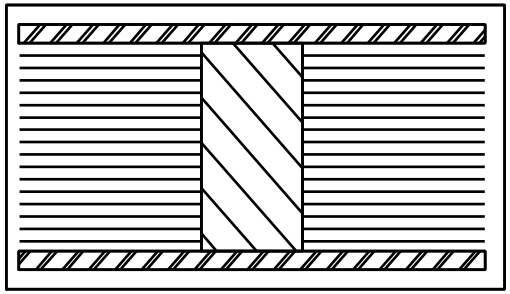
Existing Bearing at Pier B before retrofit



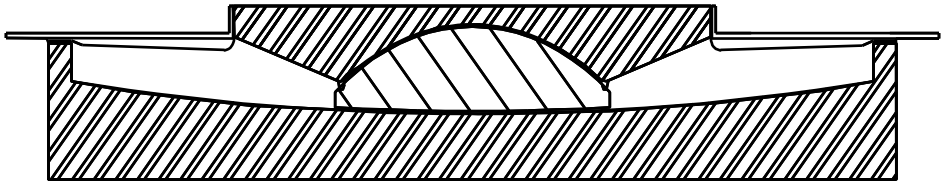
Bearing Replacement

Existing
Steel
Rocker
Bearings





Lead-Core Rubber
Approach Spans



Friction Pendulum
Truss Spans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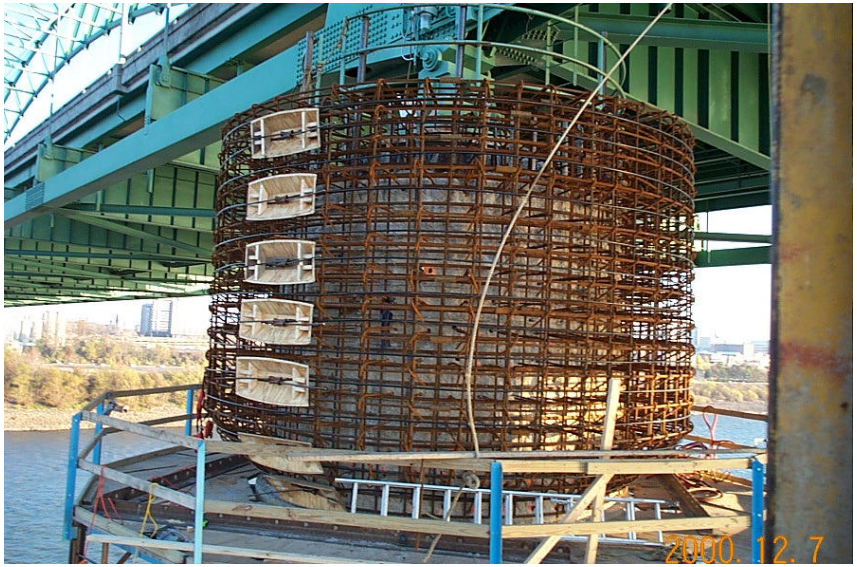
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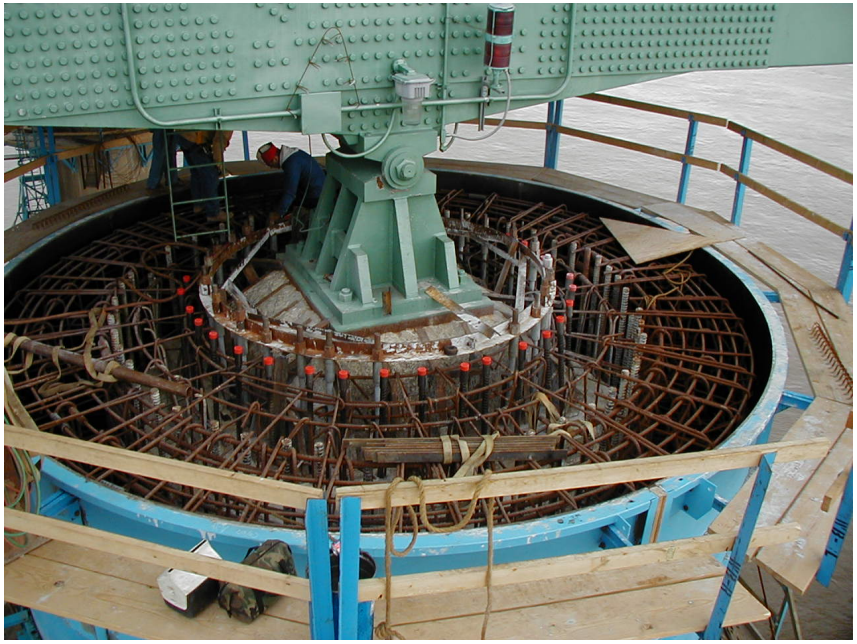


State-of-the-Art Technologies – Phase 1 & 2

- Friction Pendulum Bearings – Box Girder & Tied Arch
  - 12’ ø bearing on main span – one of the largest in the US
  - Carries highest axial load of any bridge-isolation bearing designed to date (11,300 kips at Pier B)
  - Seismic movements: 24” (+/–)
- Modular Swivel Expansion Joints – Pier A & C
  - Seismic movements: 48” (max long.)

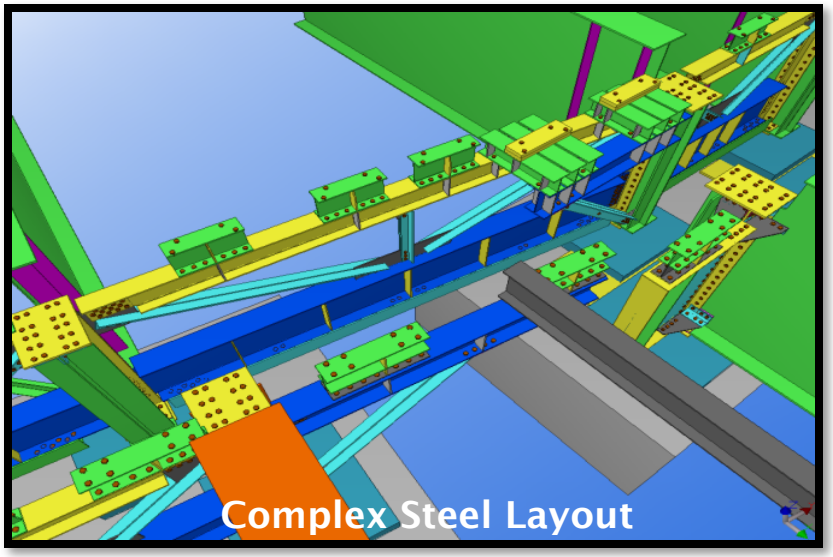
EPS Friction Pendulum Bearing

DS Brown Modular Expansion Joint

State-of-the-Art Technologies – Phase 7

- Lead-Core Rubber Isolation Bearings
  - Bearing Size: 32” to 48” ø (112 bearings installed)
  - Seismic Movements: 10” to 16” (+/-)
- Complex Steel Design Layout
  - Modular Joint Support Beams – Pier E3 / NO1

DIS Lead-Core Rubber Bearing



Footing Considerations – Phase 5

- Staged Footing Construction (prevents unloading of existing piles to maintain traffic) – Pier E8
  - Original Footing: 15'–9" x 13'–6" x 4'–6" deep
  - Enlarged Footing: 24'–0" x 22"–0" x 7'–0" deep

Foundation Demolition

Typical Substructure Retrofit – Phase 5

- Foundation Retrofit (Pier E12)
  - Additional Steel Pipe Piles (24” ø)
  - Enlarged Footing Caps

Typical Substructure Retrofit – Phase 5

- Column and Bent Cap Retrofit (Pier E12)
  - Column Strengthening
    - Longitudinal Steel (flexure capacity)
    - Steel Column Casings (confinement)
  - Bent Cap Widening / Strengthening

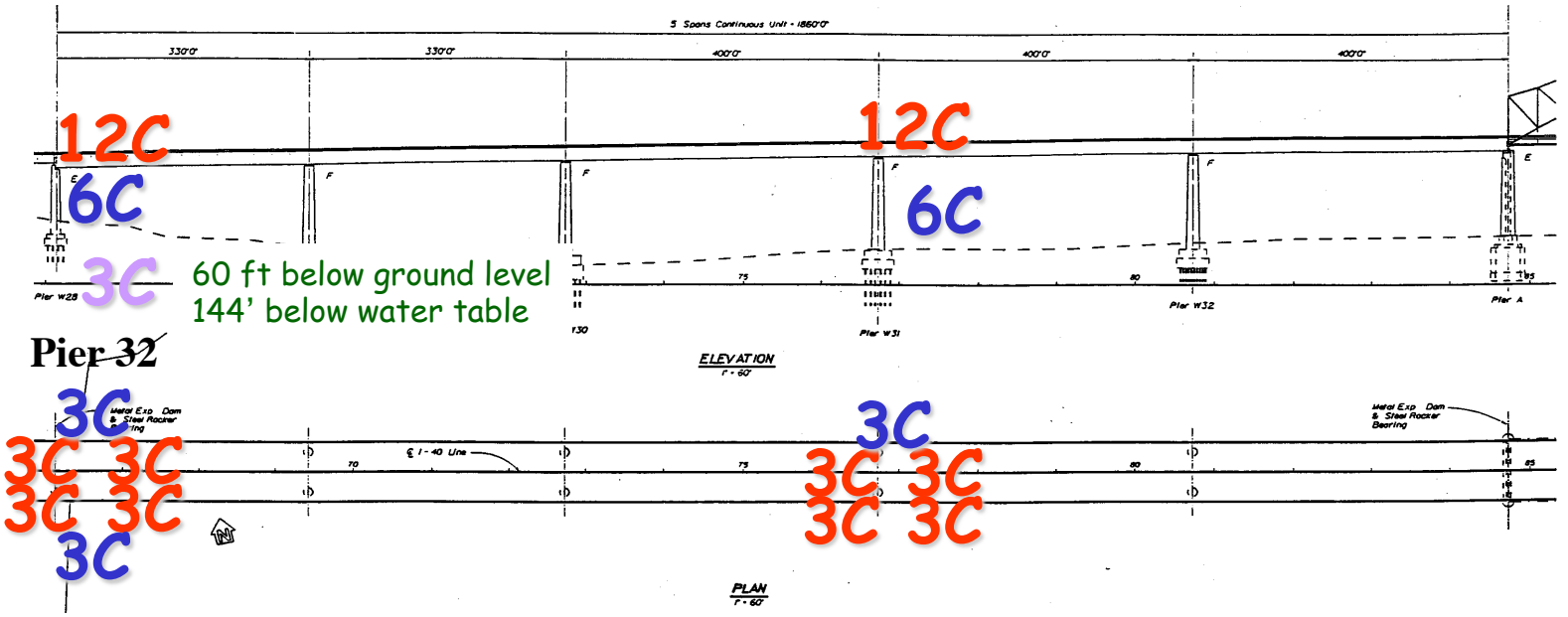
I – 40 Bridge Instrumentation

- The instrumentation system installed on the bridge will allow for the measurement of the effectiveness of this isolation system as well as providing important engineering information concerning the performance of the main span and western approach span of the structure during an earthquake.

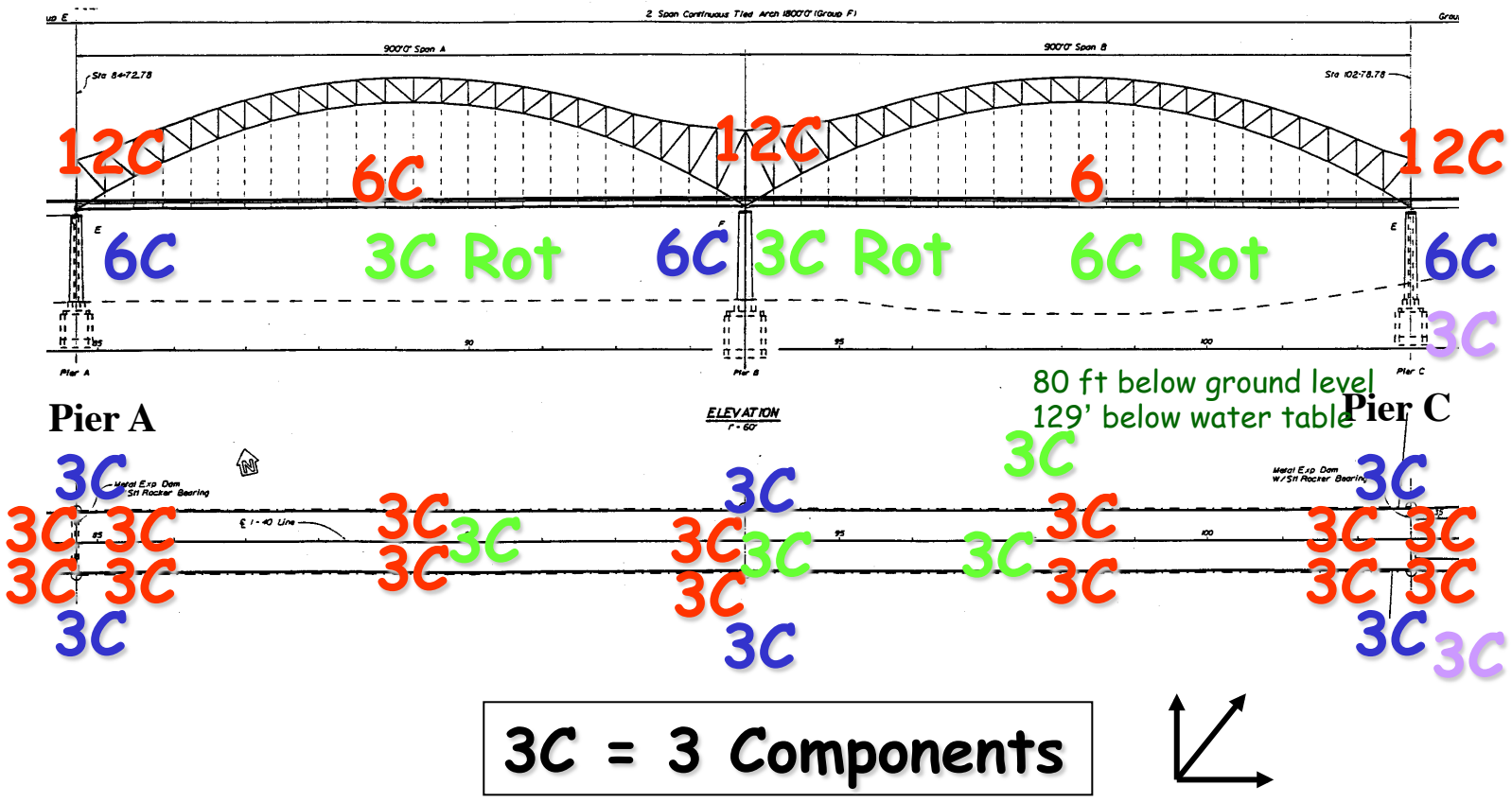
Project Plan

- To measure:
  - Free-field ground motion near the instrumented bridge
  - Motion of the bridge foundation
  - Motion of the bridge below the isolation bearings
  - Motion of the bridge above the isolation bearings
  - Spatial variation of ground motion along the total span
  - Lateral and torsional motion of the bridge

West Approach to the I-40 Bridge



Main Two – Span Tied Arch



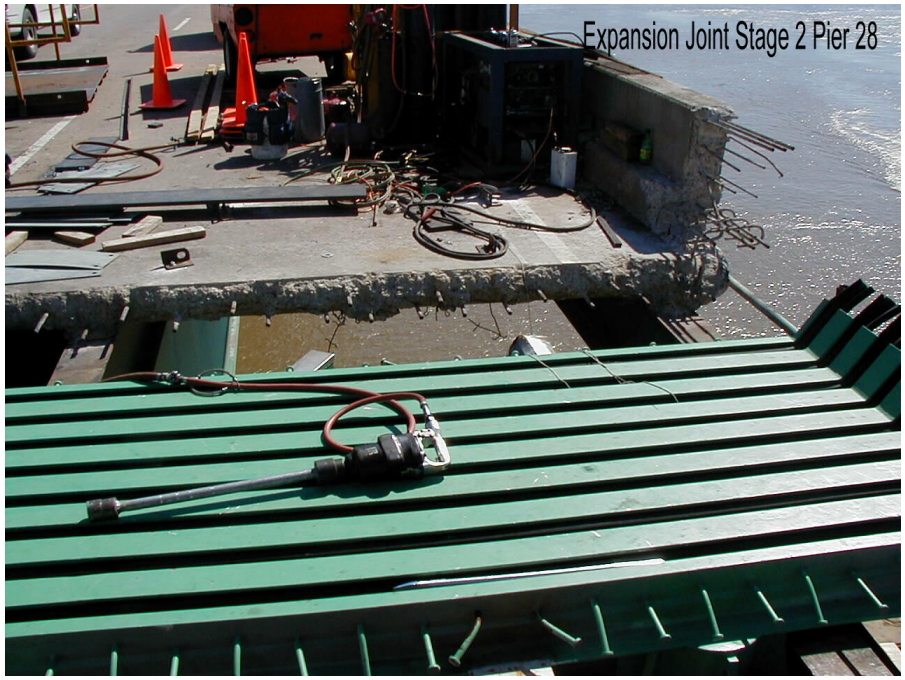
Downhole Sensors

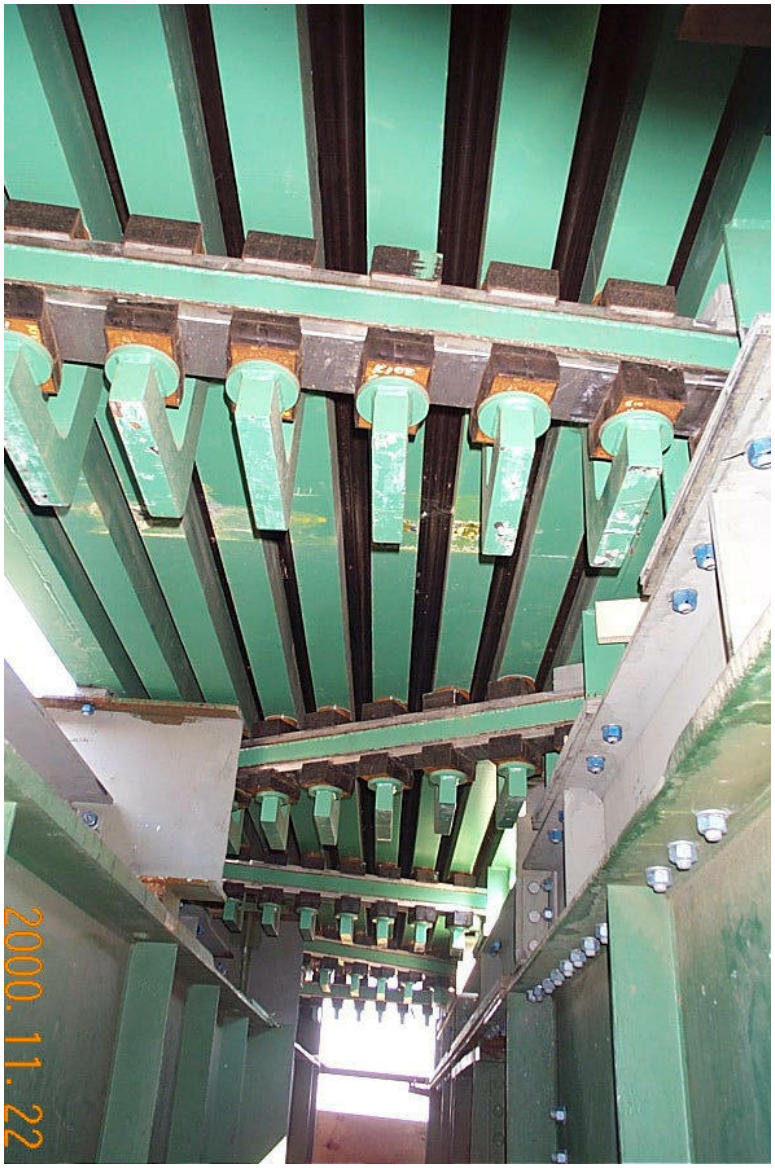

NO
PARKING


Traffic Control
Stage II
Looking West
2001. 3. 2 06:40


ASPEN AERIALS
B1
T1
T2
B2
TENNESSEE
WELCOME CENTER
EXIT 1
NO TRUCKS

B 4


Expansion Joint Stage 2 Pier 28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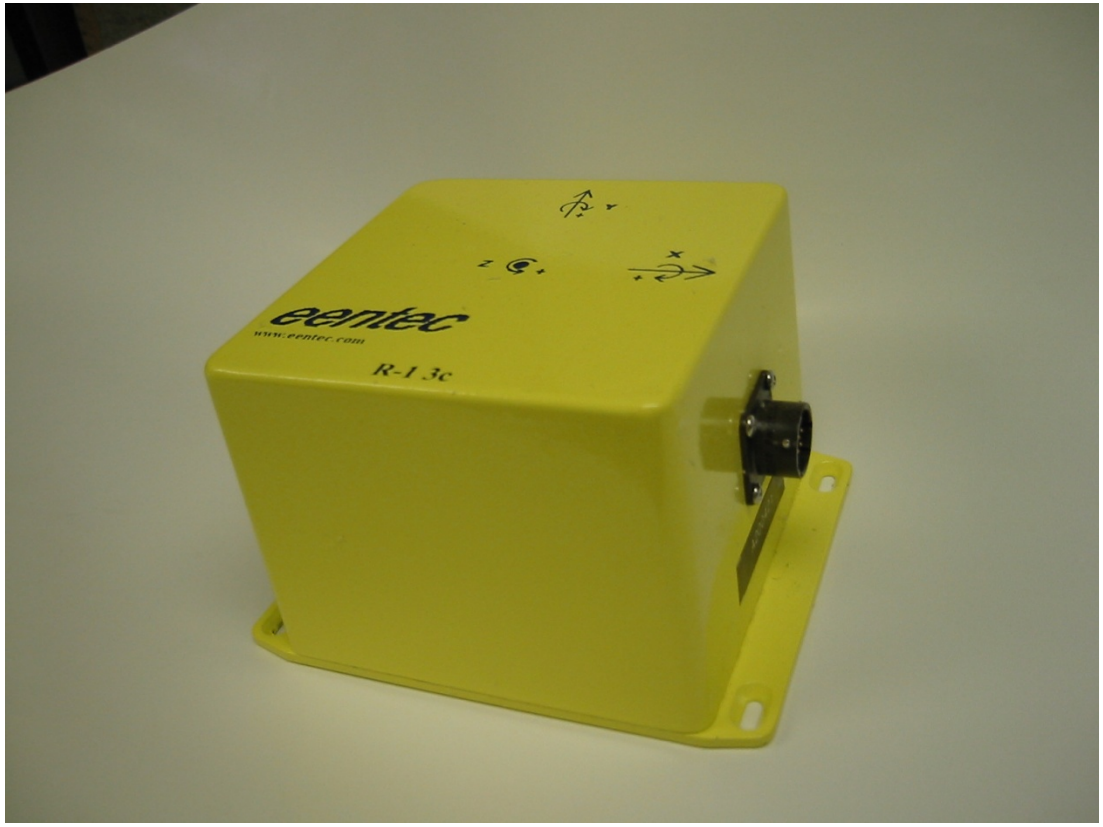
GPS


HERNANDO-DESOTO I-40 BRIDGE
STRONG MOTION
INSTRUMENTATION SYSTEM

Instrumentation

- The bridge monitoring system will consist of a clustered network of 30 triaxial accelerometers.
- Two sensor packages of broadband velocity sensors along with extremely low noise accelerometers will be located in boreholes near the bridge at 100 ft and 200 ft depths.
- A pair of rotational triaxial sensors will be located on center of the roadway at two locations and at center and end of the roadway at one location.

Rotational Sensor



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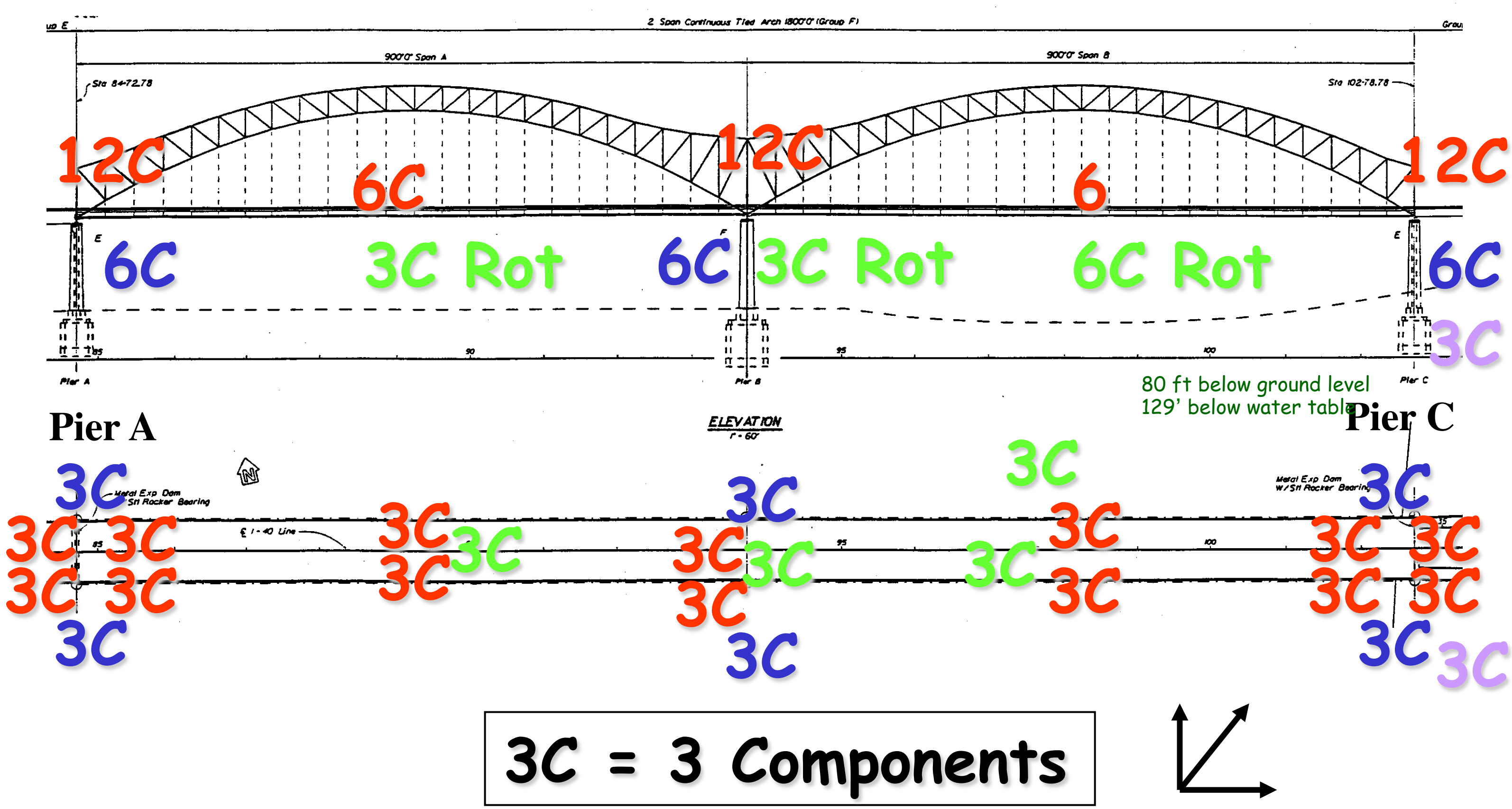
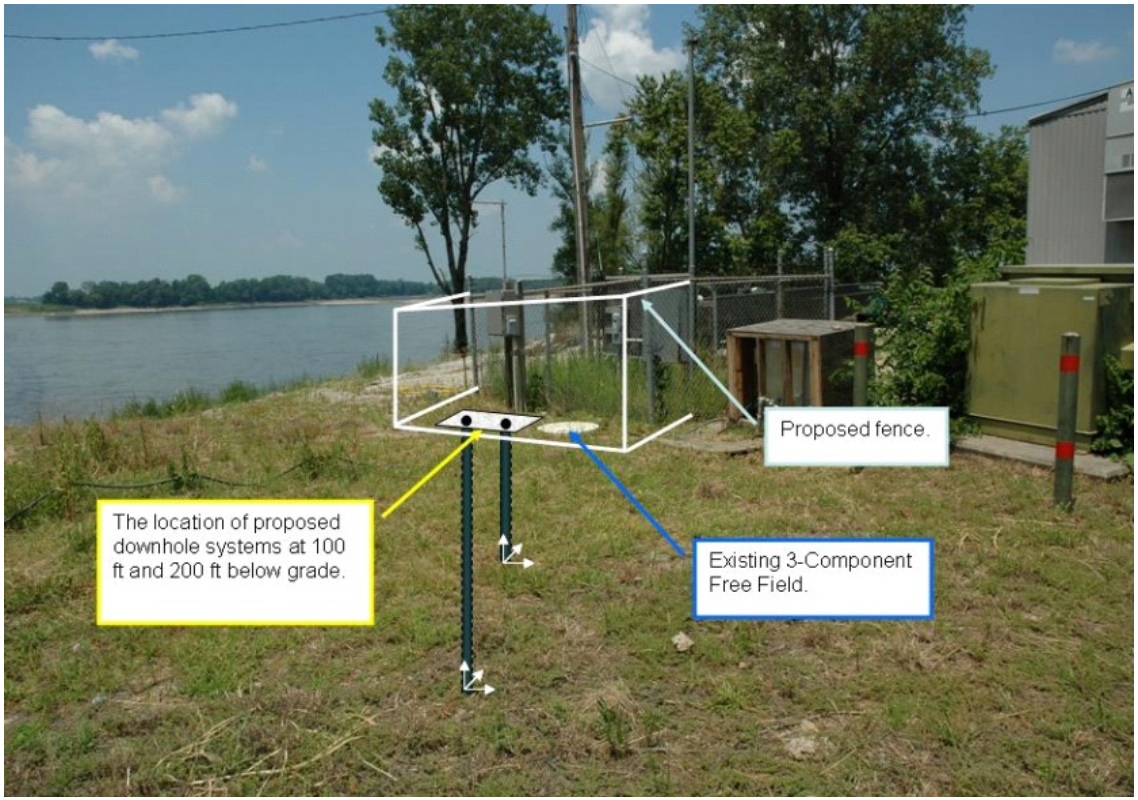
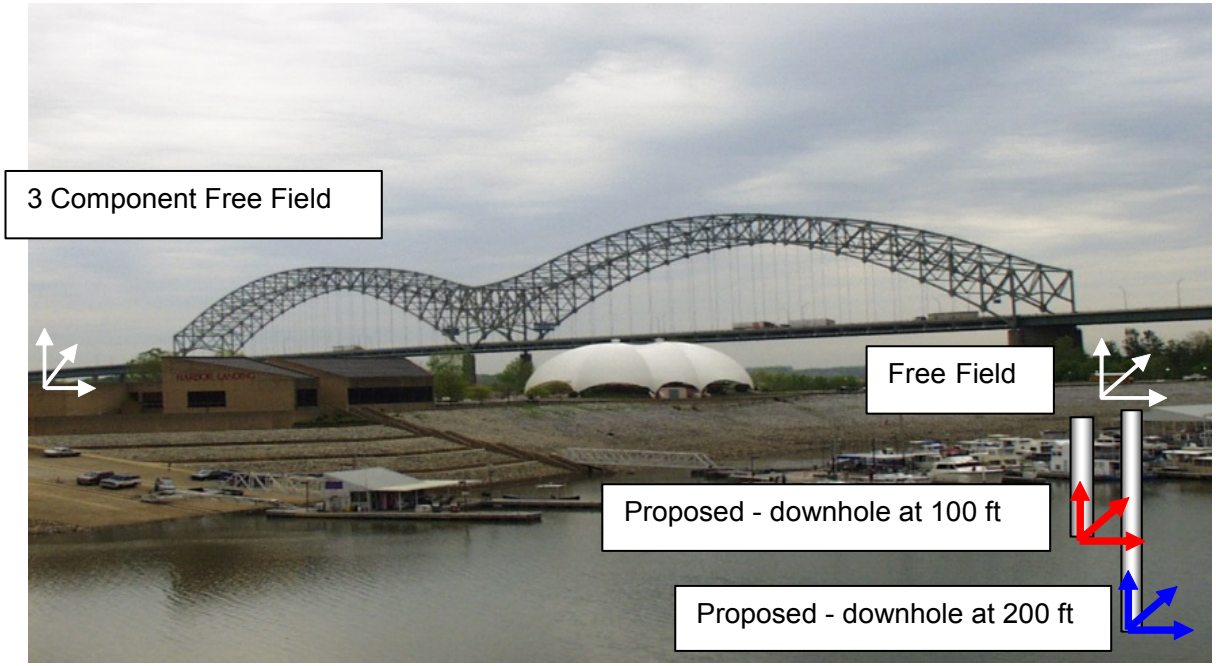


Sensors and Recorder

Free-Field Sensors

Downhole Array




3 Component Free Field
Free Field
Proposed - downhole at 100 ft
Proposed - downhole at 200 ft

Thank you