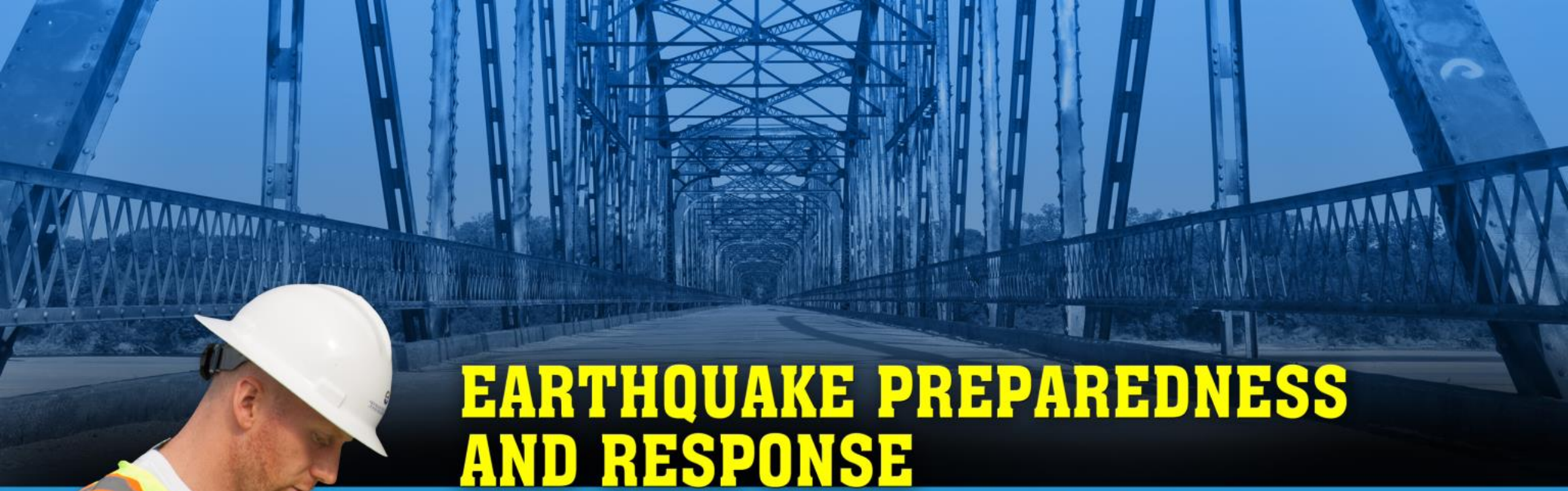


EARTHQUAKE PREPAREDNESS AND RESPONSE

Oklahoma DOT's Proactive Approach for Bridges

PRESENTERS:

WALT PETERS, P.E.
Oklahoma Department of Transportation
Oklahoma City, OK

GREGG A. HOSTETLER, P.E.
Infrastructure Engineers, Inc.
Edmond, OK

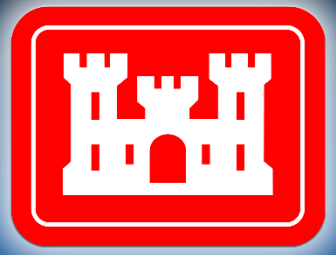
NATIONAL BRIDGE PRESERVATION PARTNERSHIP CONFERENCE 2018

nbppc

BRIDGE PRESERVATION: PRACTICES WE CAN NOT AFFORD TO DEFER

April 10, 2018

Project Team



The Problem

MENU TIME

LATEST MAGAZINE VIDEOS

The U.S.'s New Earthquake Capital: Oklahoma

PREDICTIVE ANALYTICS COULD HELP IMPROVE YOUR BUSINESS PERFORMANCE.

Sony World Photography Awards Winners Revealed

Behind TIME's Photo Shoot with Renowned Artist Yayoi Kusama

See Colorized Photos of a Young Queen Elizabeth II

What We Learned From Chris Hondros and Tim Hetherington

See GIFs of New York Voting on Primary Day

LIGHTBOX OKLAHOMA

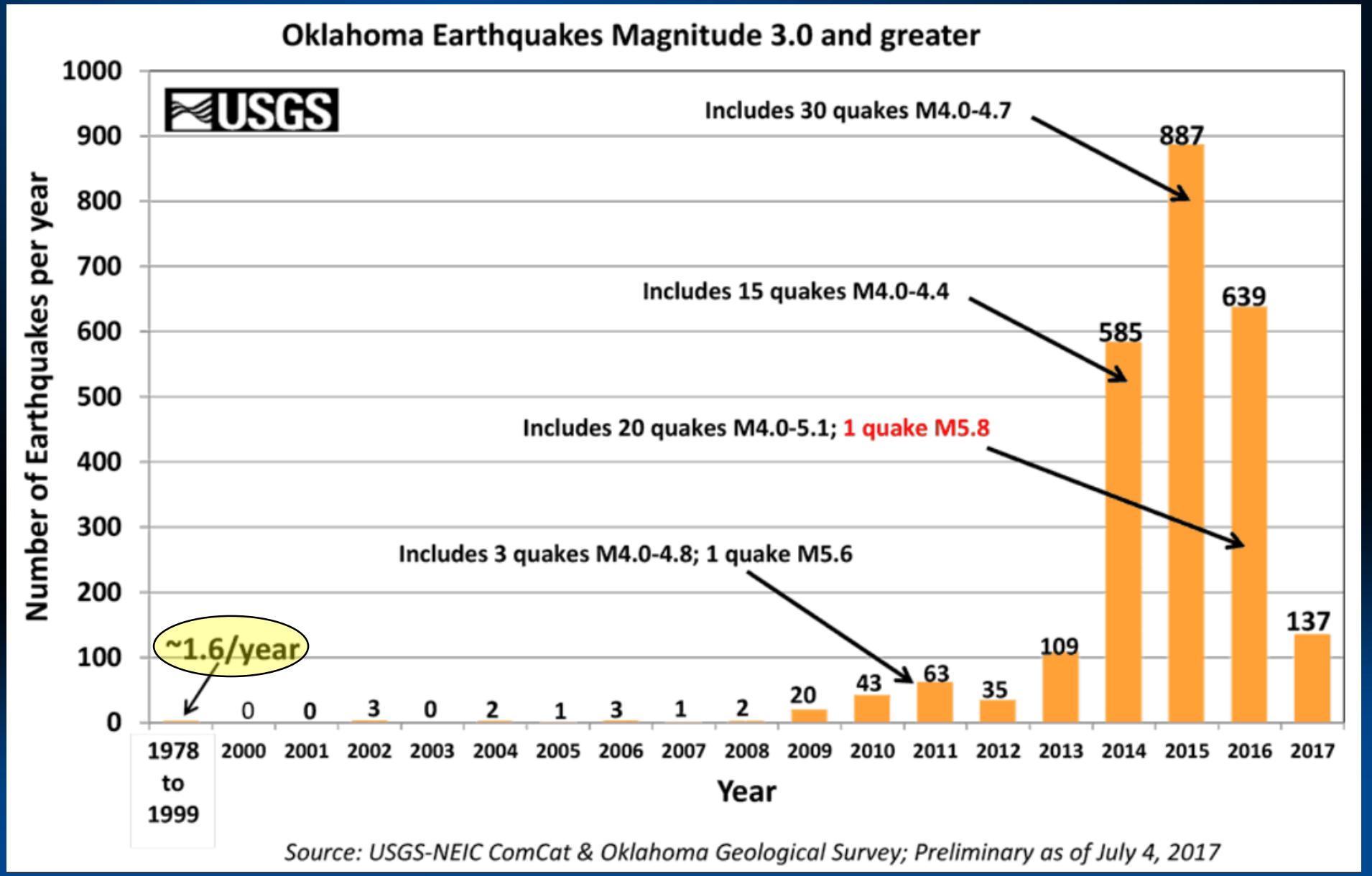
The U.S.'s New Earthquake Capital: Oklahoma

Josh Sanburn @joshsanburn | March 14, 2016

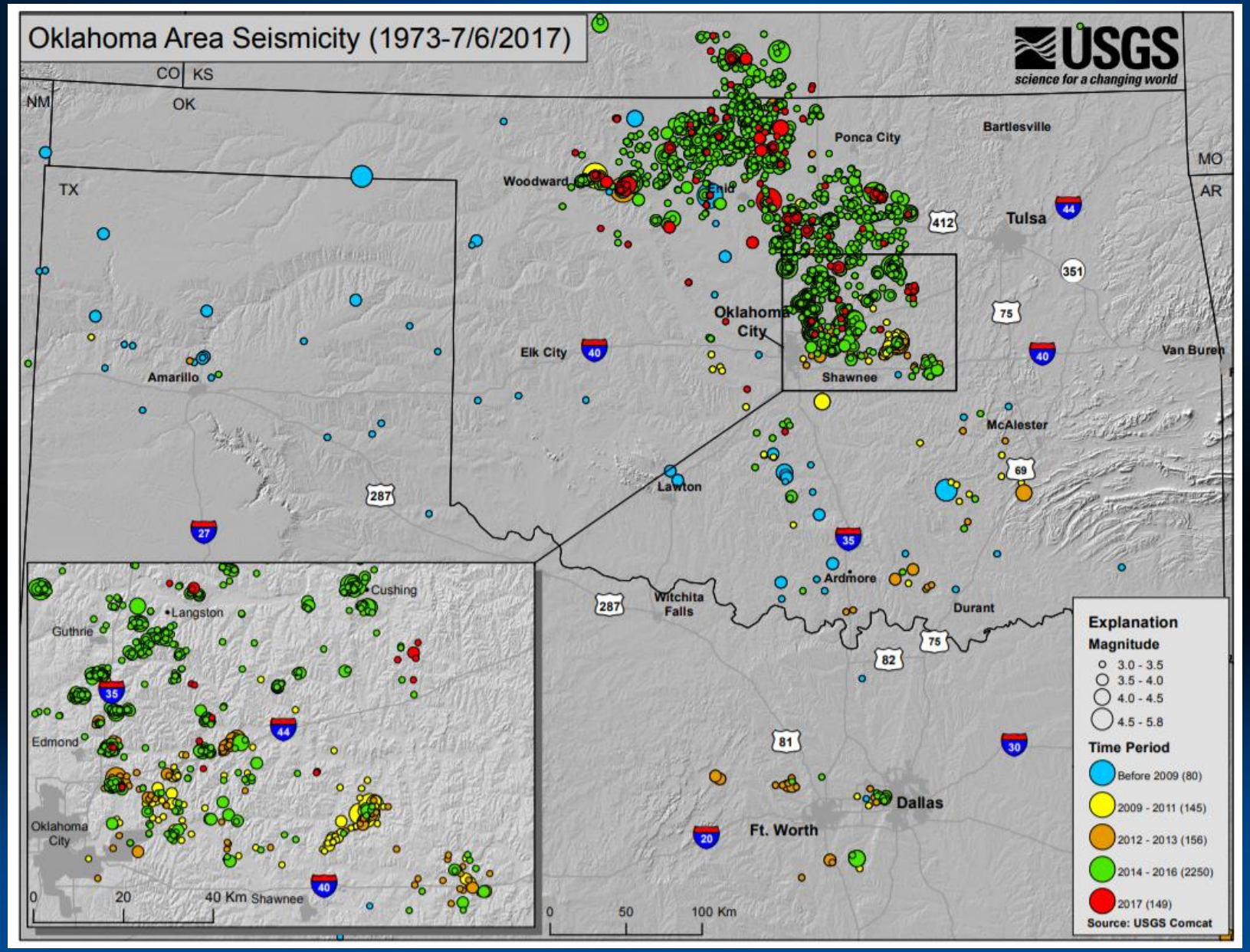
Photographer John Francis Peters captures how the ground is shifting—both seismically and politically—in Oklahoma

The Problem

Data from US Geological Survey



The Problem



Data from US Geological Survey

The Problem

M5.8 - Pawnee, OK (September 3, 2016)
Largest Quake in Oklahoma History
Cosmetic Bridge Damage

Figure 14: Observations of damage at the West Abutment of Belford Bridge (Latitude/Longitude: (36.505°, -96. 8493°)): a,b) concrete spalling of abutment; c) approx. 4 cm wide gap between backfill soil and abutment

The Problem

M5.8 - Pawnee, OK (Sept 3, 2016) – Sand Boil

The Geotechnical Aspects of the

September 3, 2016 M5.8 Pawnee, Oklahoma Earthquake

Authors:

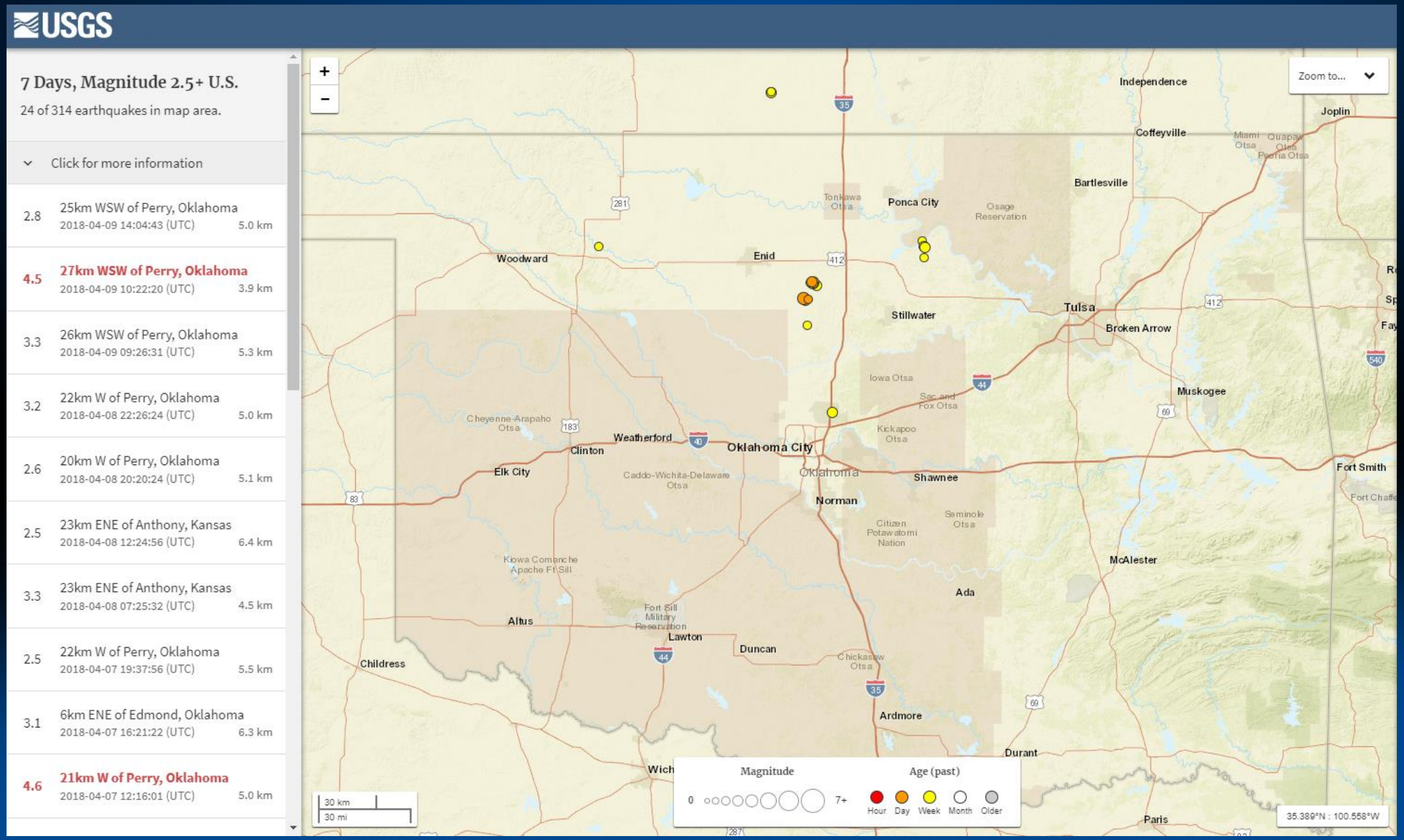
Patricia Clayton, George Zalachoris, Ellen Rathje (Univ. of Texas at Austin)

Tejo Bheemasetti, Santiago Caballero, Xinbao Yu (Univ. of Texas at Arlington)

Scott Bennett (USGS)

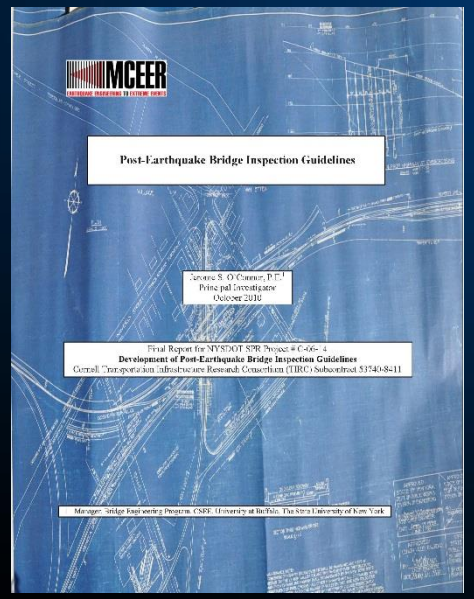
Report Date: October 17, 2016

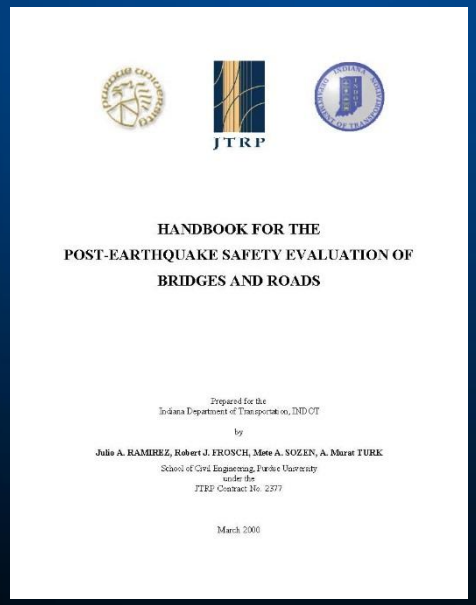
The Problem

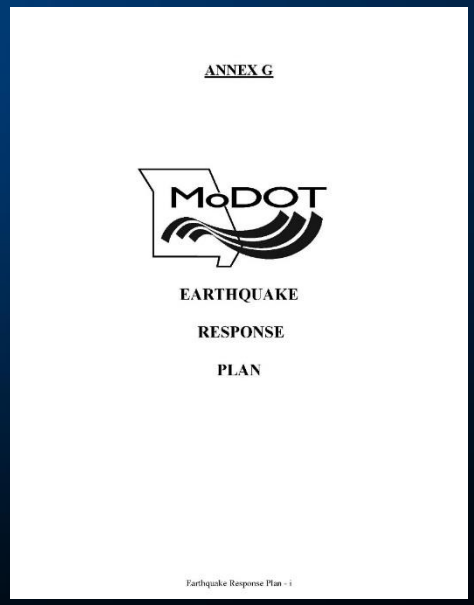


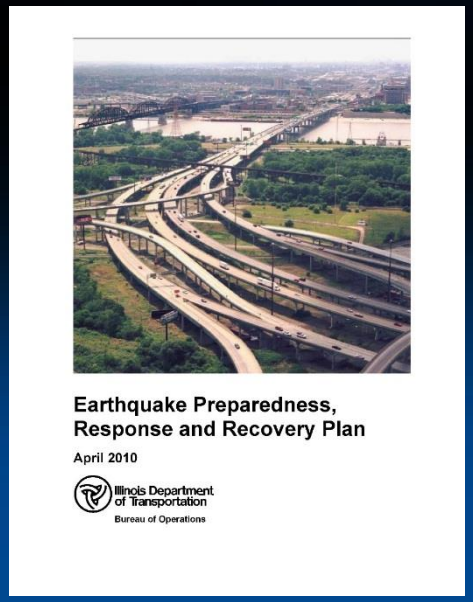
Oklahoma Seismic Events for 7-day period ending 4/9/2018

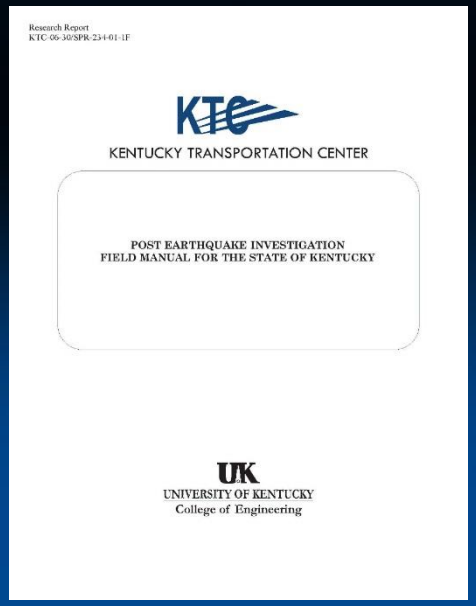
Resources and Research

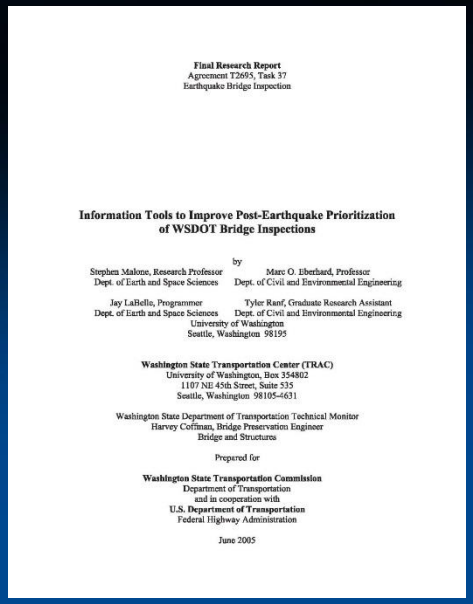












Scope of Work

Phase 1 (May 2015 through August 2016)

I. Interim Post-Earthquake Bridge Inspection Protocol

II. ShakeCast-OK Cost/Benefit Analysis

III. Field Inspection Manual

IV. Draft Earthquake Response Plan

V. Training

VI. Seismic Review of Three Bridges

VII. Meetings and Senior Staff Briefings

Phase 2 (Started September 2016 - Ongoing)

I. Final development and implementation of ShakeCast-OK

II. Update response protocol to incorporate ShakeCast-OK

III. Update Response Plan and Inspection Manual to incorporate ShakeCast-OK

IV. Training

a) Stage 3 Inspection training

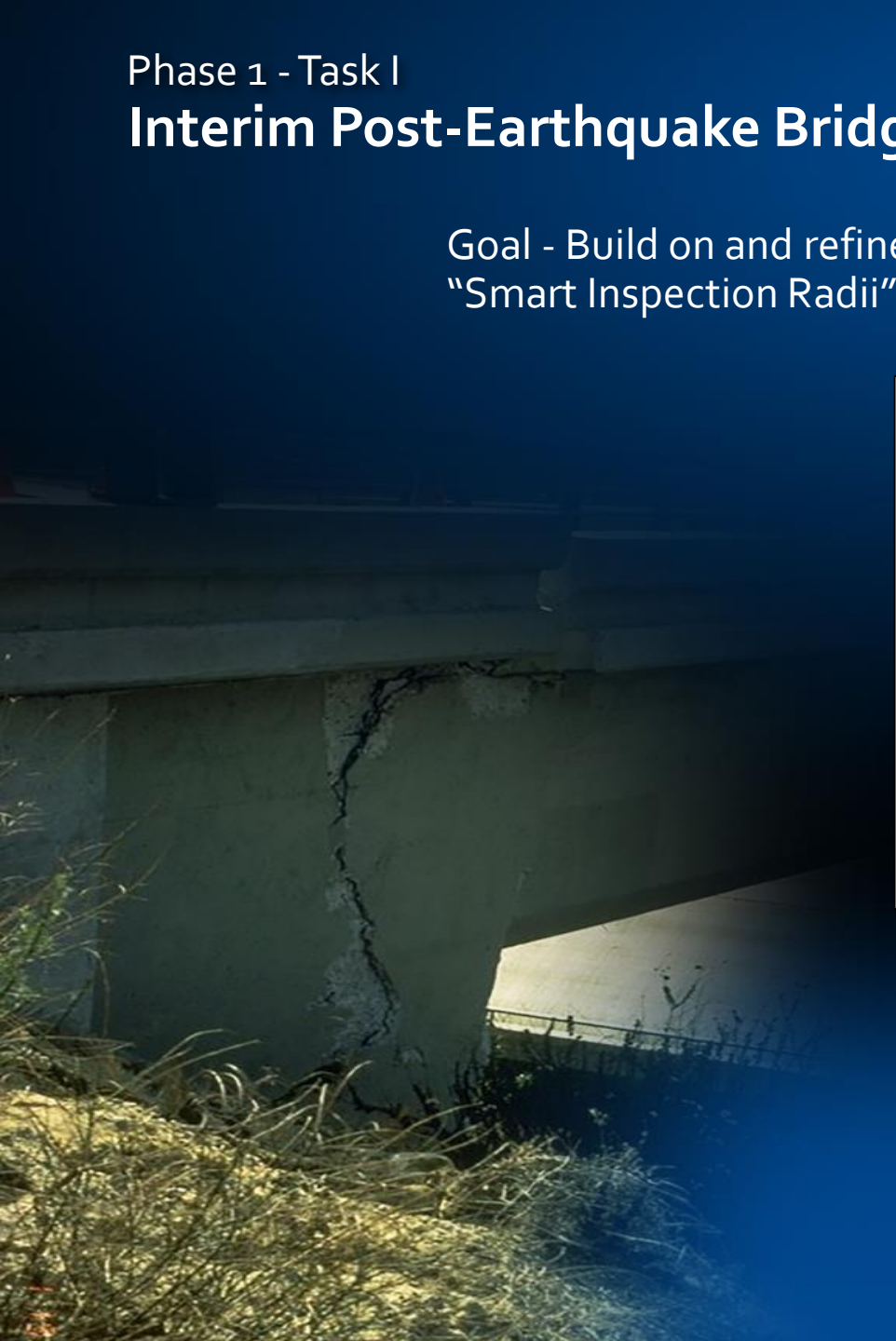
b) ODOT management training

V. Monthly progress meetings

Phase 1 - Task I

Interim Post-Earthquake Bridge Inspection Protocol

Goal - Build on and refine current ODOT protocol; move to "Smart Inspection Radii" approach



OKLAHOMA DEPARTMENT OF TRANSPORTATION
200 NE 21st Street Oklahoma City, OK 73105 (405) 521-4675

January 22, 2015

To: Field Division Engineers

From: Paul Green, Director of Operations

Re: Earthquake Protocol & Procedures

Please find attached the "ODOT Post Earthquake Inspection Protocol & Procedures". While we have been following the criteria in this document, it is important that we have a standardized system and a form that can be used statewide to document earthquake event structure. Please share this information with your Bridge Engi be inspecting structures for damage after an earthquake event. ODOT's official guidance for Earthquake Protocol & Procedu been developed and accepted for implementation.

ODOT – Post Earthquake Inspection Protocol & Procedures

Magnitude	
3.0 to 3.9	Inspect at the discretion of the Division Engineer
4.0 to 4.9	Inspect Bridges within a 5 Mile radius of Epicenter*
5.0 to 5.5	Inspect Bridges within a 25 mile radius of Epicenter*
5.6 or larger	Inspect Bridges within a 50 Mile radius of Epicenter*

*Increase radius at 5 mile increments if damage found

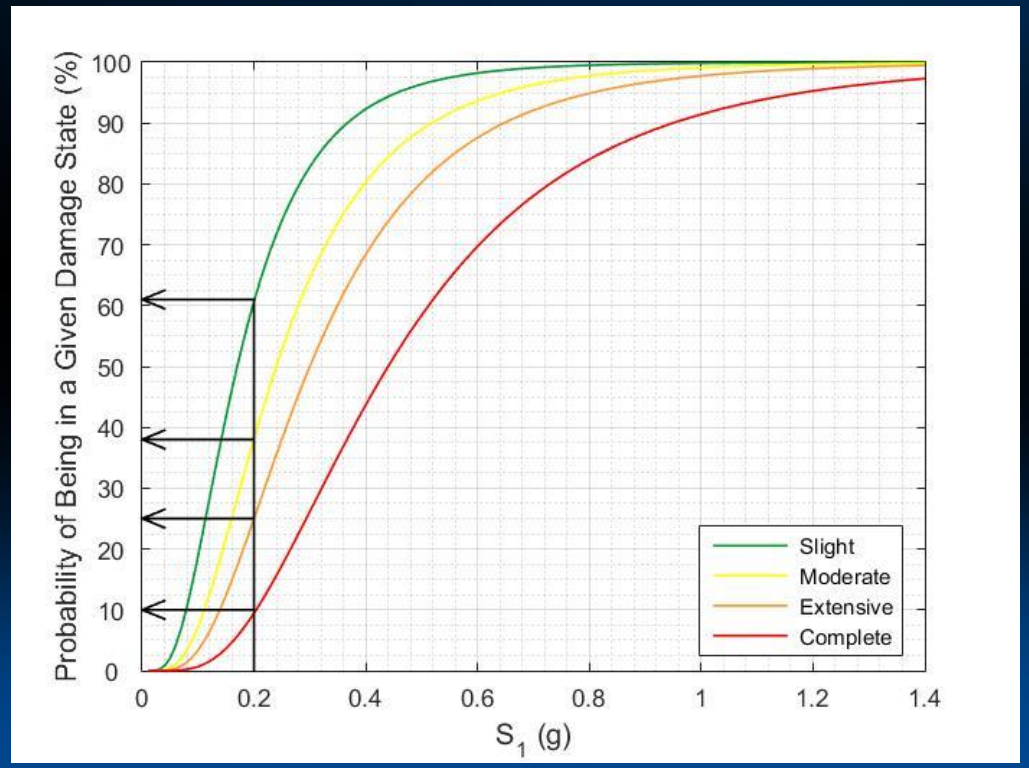
Phase 1 - Task I

Interim Post-Earthquake Bridge Inspection Protocol

Smart Inspection Radii – Overview

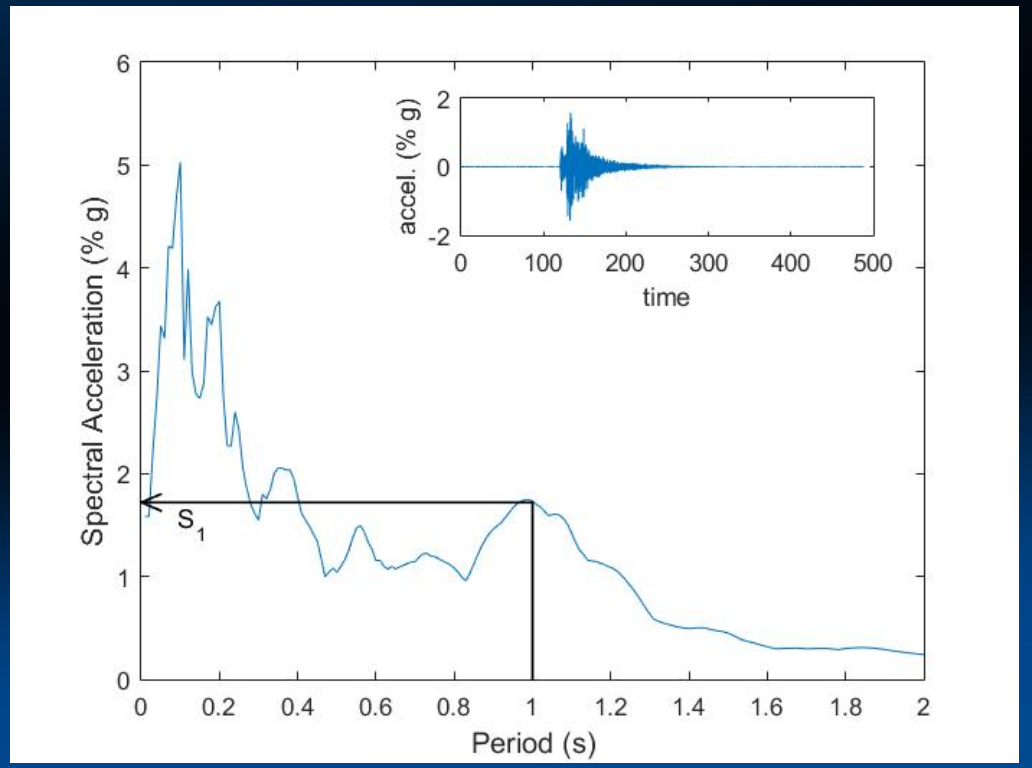
- Within **what distance** from the earthquake epicenter do we expect demand to exceed capacity?

CAPACITY



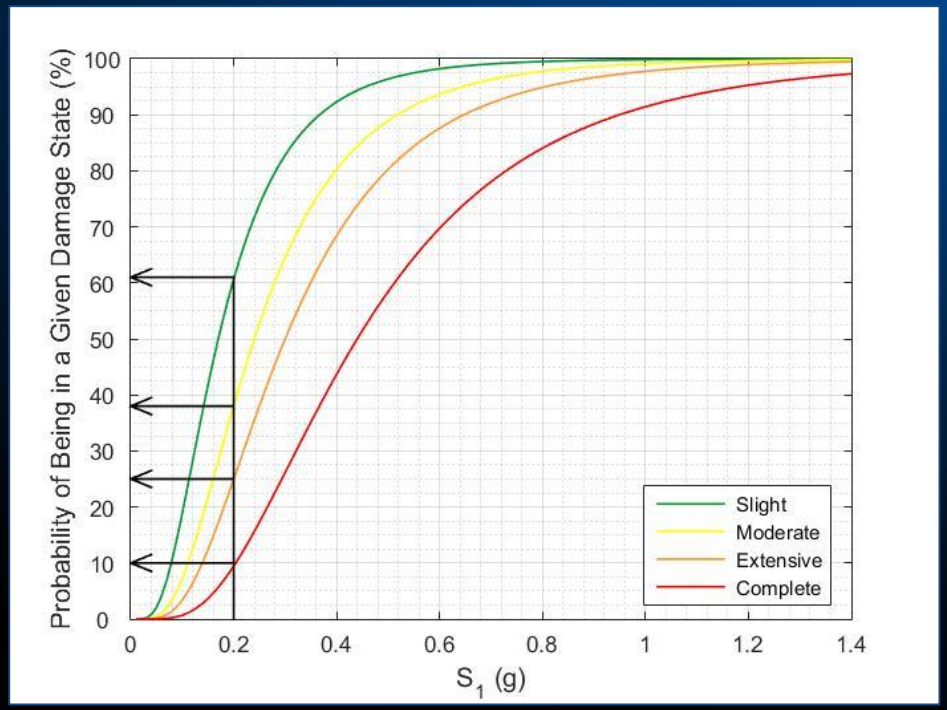
<

DEMAND



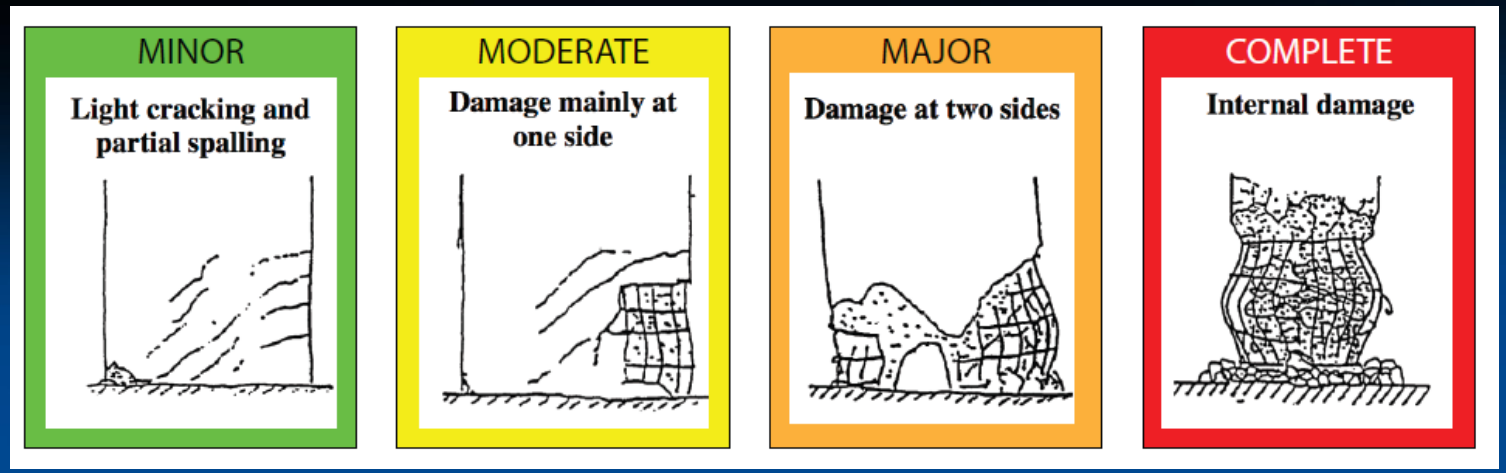
Phase 1 - Task I

Interim Post-Earthquake Bridge Inspection Protocol



Capacity – Fragility Curves

Interpretation: For a given level of shaking, what level of damage is expected?

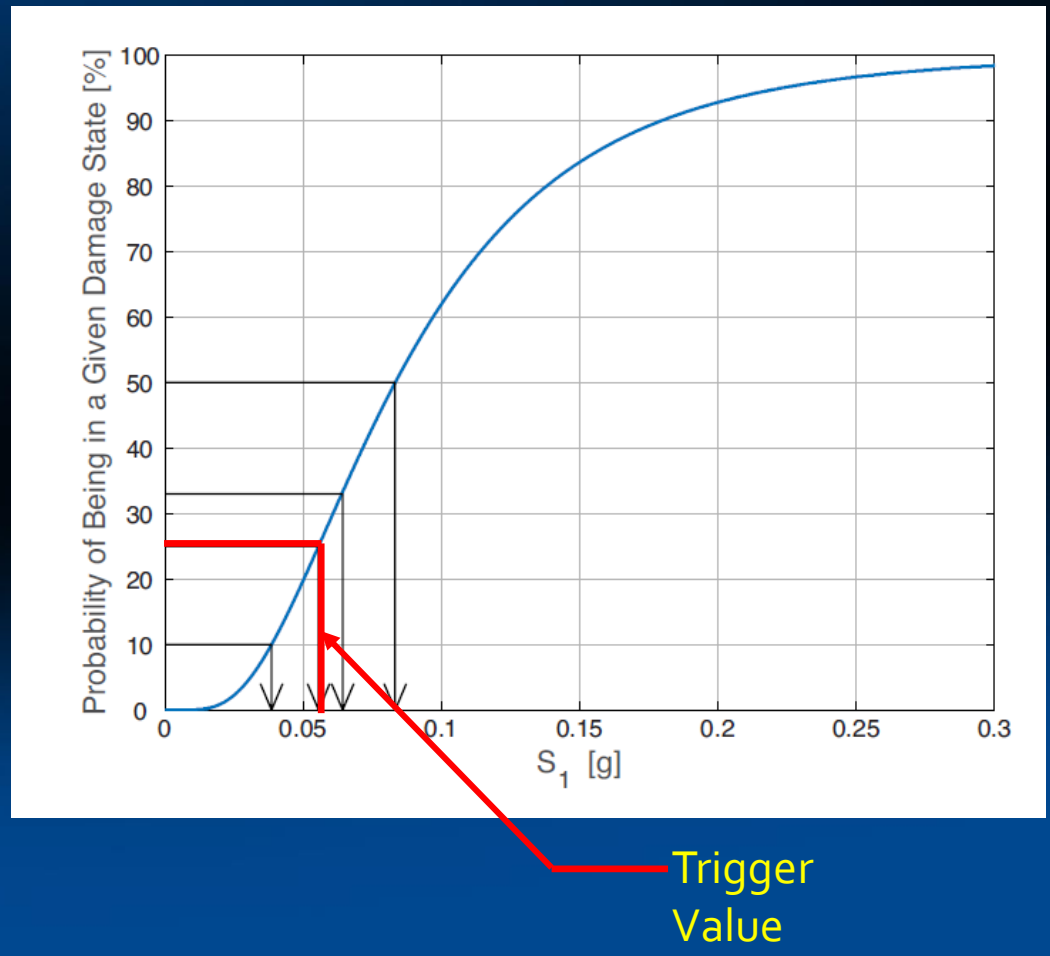


Phase 1 - Task I

Interim Post-Earthquake Bridge Inspection Protocol

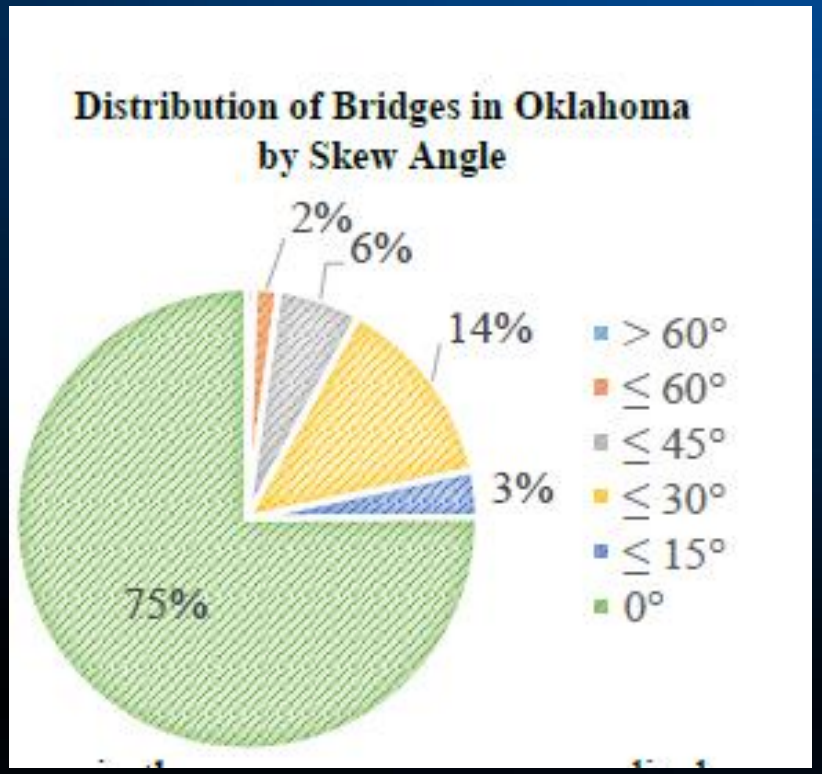
Capacity – Fragility Curves

- HAZUS gives fragility curves for "standard bridges" adjusted for:
  - Year built
  - Number of spans
  - Skew angle
  - Main span material
  - Total bridge length
- Inspection deemed necessary for $S_1 > 5.56\%g$
  - Input from Caltrans (California DOT)
  - Comparison of CA to non-CA bridges in HAZUS

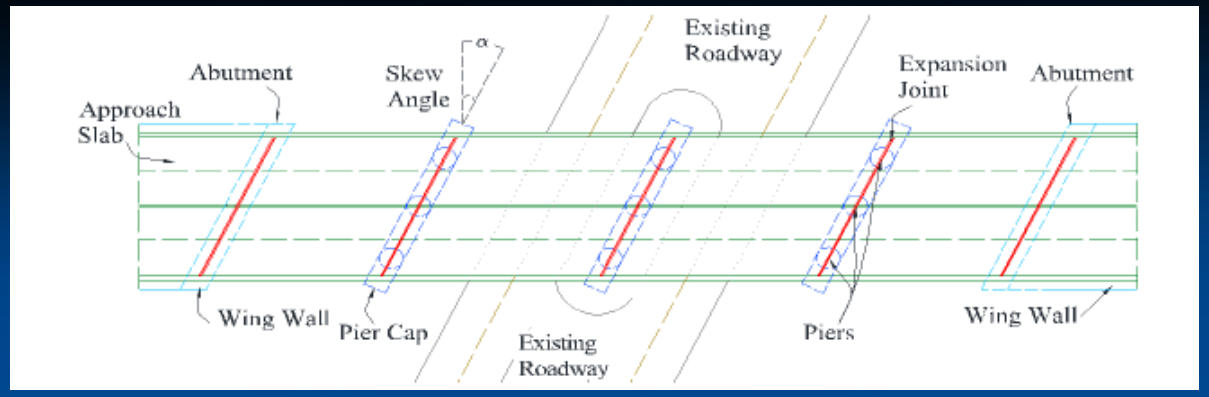


Phase 1 - Task I

Interim Post-Earthquake Bridge Inspection Protocol

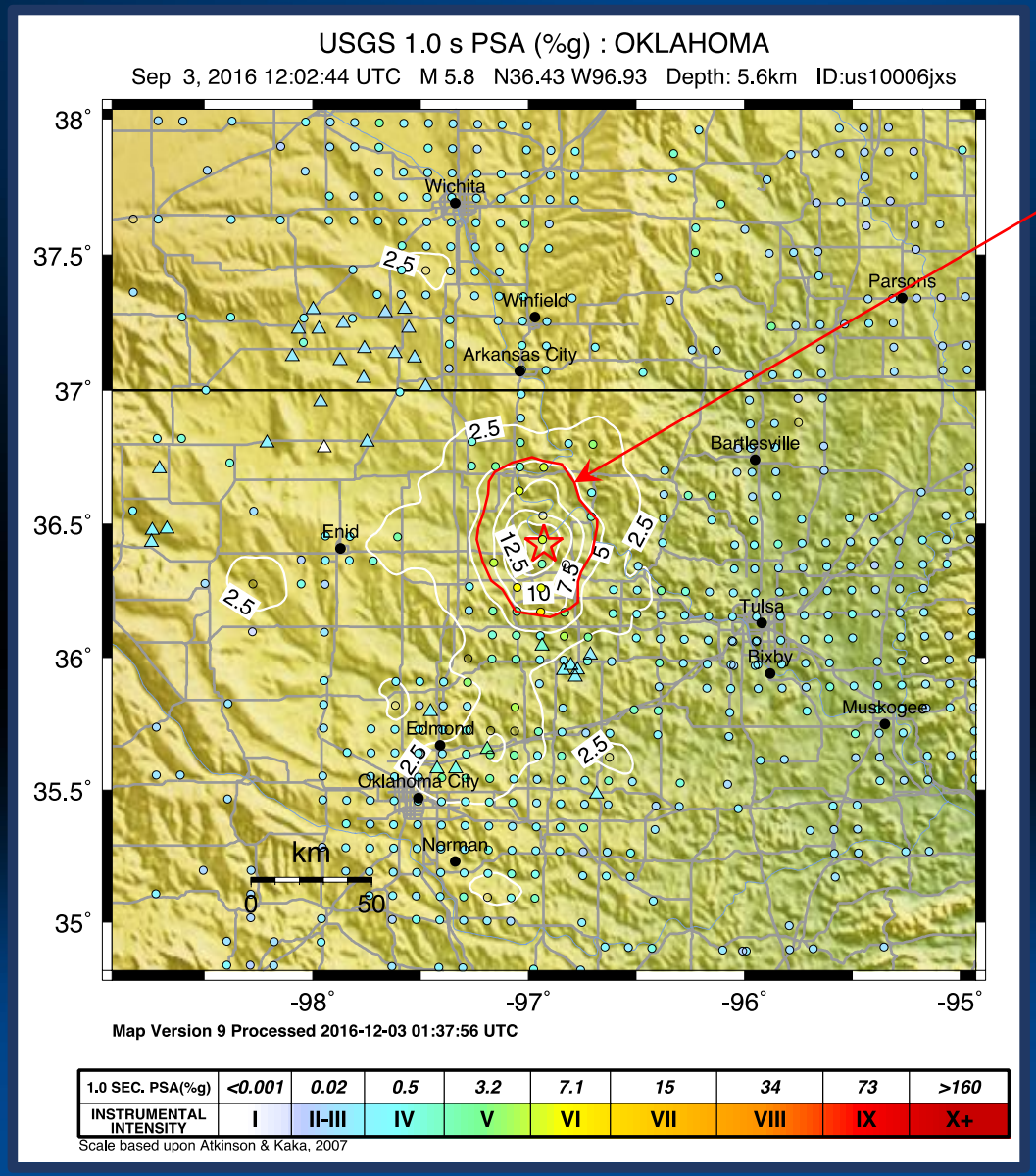


Prioritizing Bridge Inspection: Higher priority for fracture critical, structurally deficient, and variable skew bridges.



Phase 1 - Task I

Interim Post-Earthquake Bridge Inspection Protocol



5.56%
Trigger Value

Demand – Ground Motion Intensity

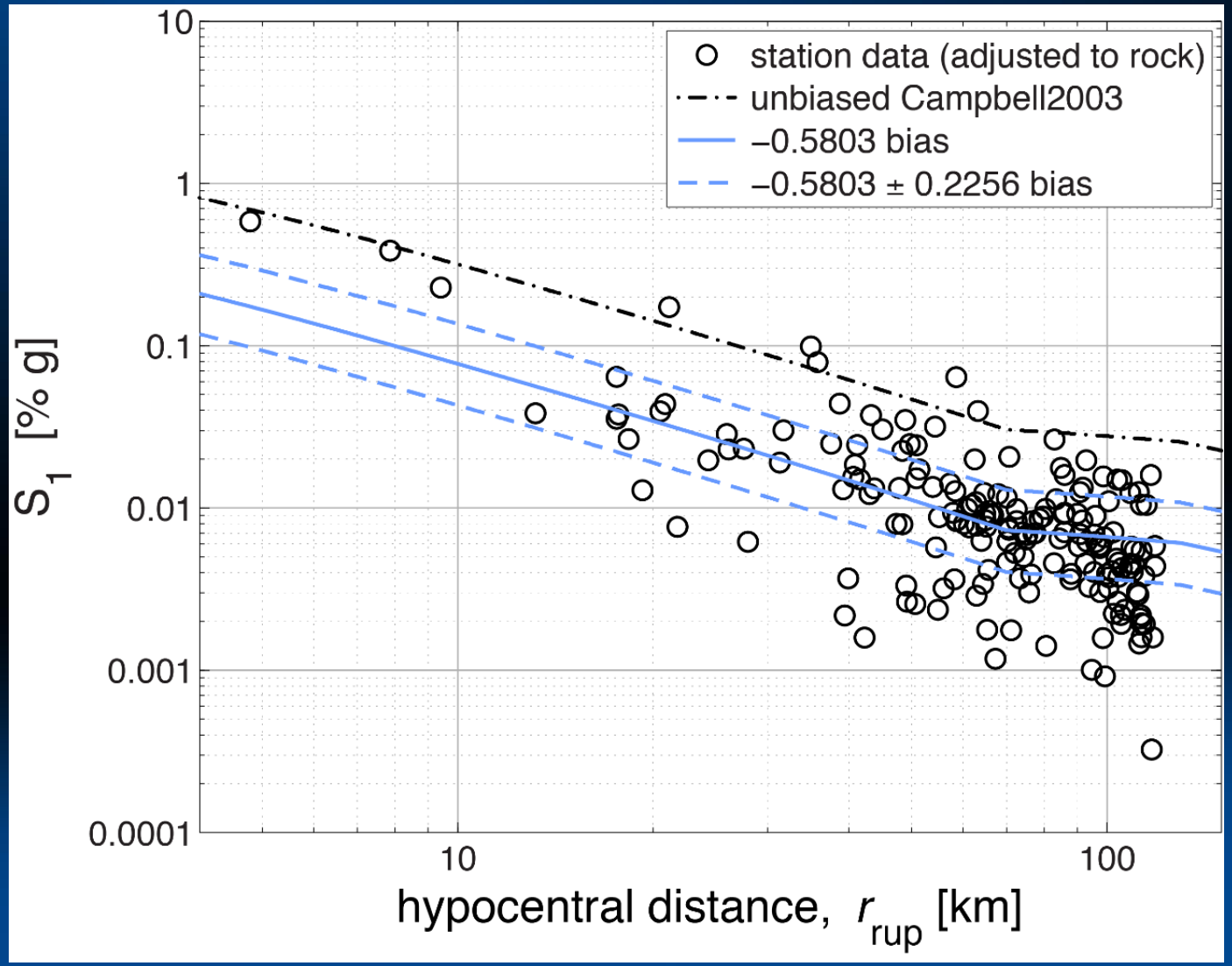
USGS provides maps of ground-motion intensity after an earthquake

Phase 1 - Task I

Interim Post-Earthquake Bridge Inspection Protocol

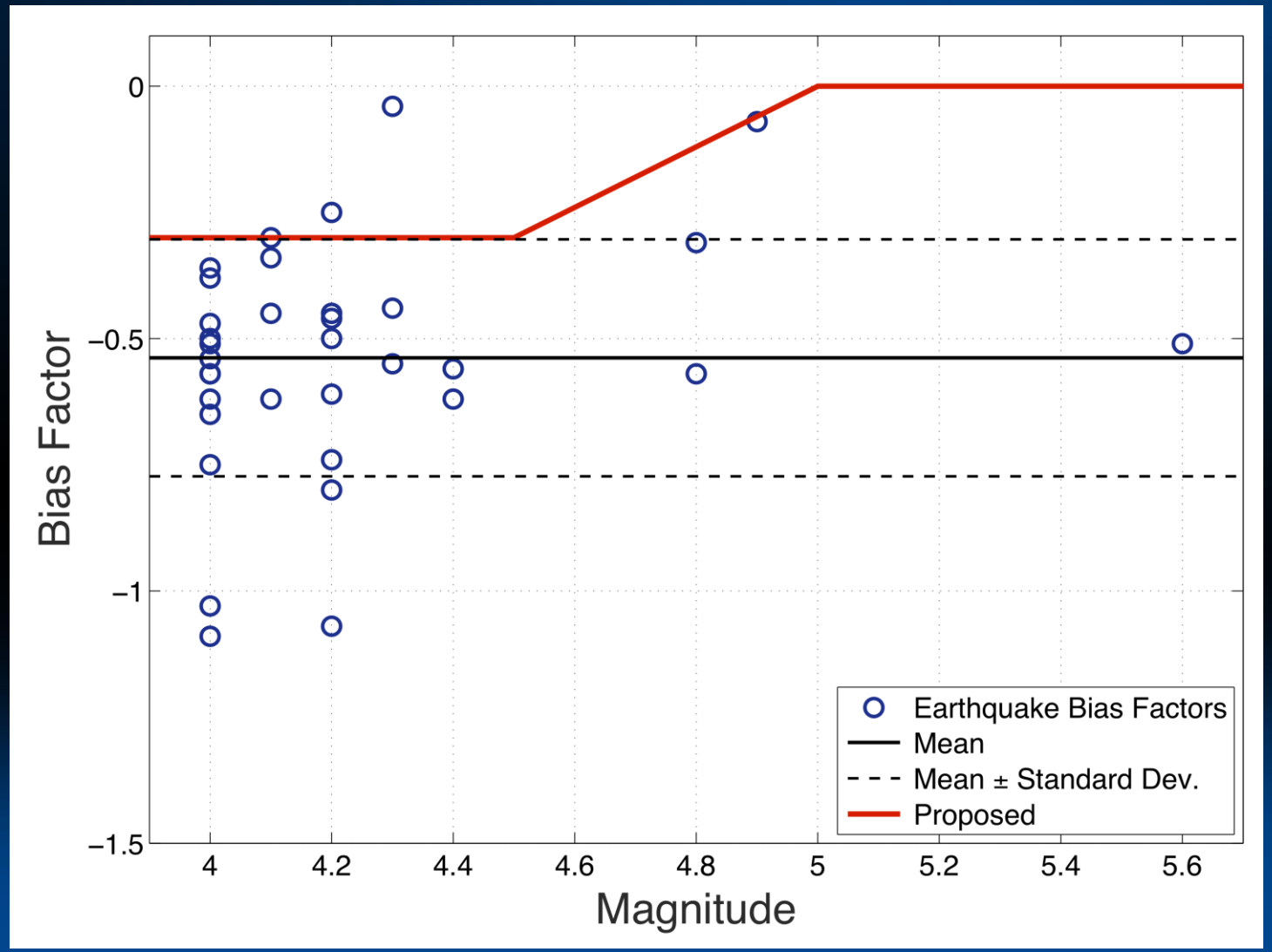
Demand – Ground Motion Prediction

Campbell (2003) tends to over predict ground motions



Phase 1 - Task I

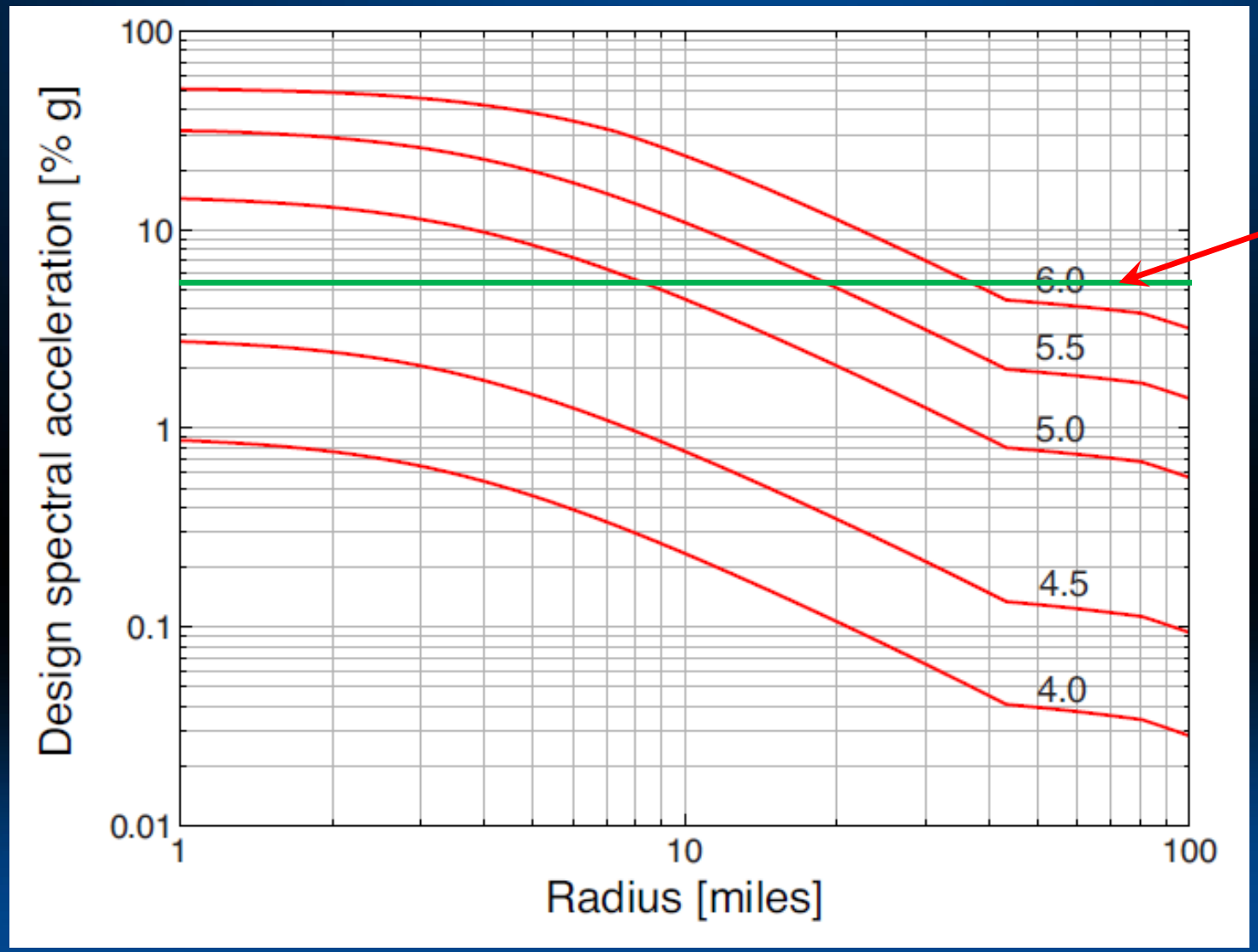
Interim Post-Earthquake Bridge Inspection Protocol



Calibrated Campbell (2003) Ground Motion Prediction Equation (GMPE) for Oklahoma station data – Magnitude of the earthquake plus the bias factor yields the best fit to the station data

Phase 1 - Task I

Interim Post-Earthquake Bridge Inspection Protocol



5.56%
Trigger Value

Demand – Attenuation Curves

Phase 1 - Task I

Interim Post-Earthquake Bridge Inspection Protocol

- Combining capacity and demand analysis gives the proposed inspection radii

Previous ODOT Protocol

Magnitude Range	Inspection Radius (miles)
4.0 to 4.9	5
5.0 to 5.5	25
5.6 +	50

Smart Radii Inspection Protocol

Magnitude Range	Inspection Radius (miles)
4.4 to 4.7	5
4.8 to 5.3	15
5.4 to 5.8	30
5.9 to 6.2	60
6.3 +	120

Radius increased at discretion of Division Engineer; i.e. to account for USGS location uncertainty

Phase 1 - Task II

ShakeCast-OK Cost/Benefit Analysis

ShakeCast – Web-based application developed by USGS and Caltrans for situational awareness following an earthquake.

Benefits:

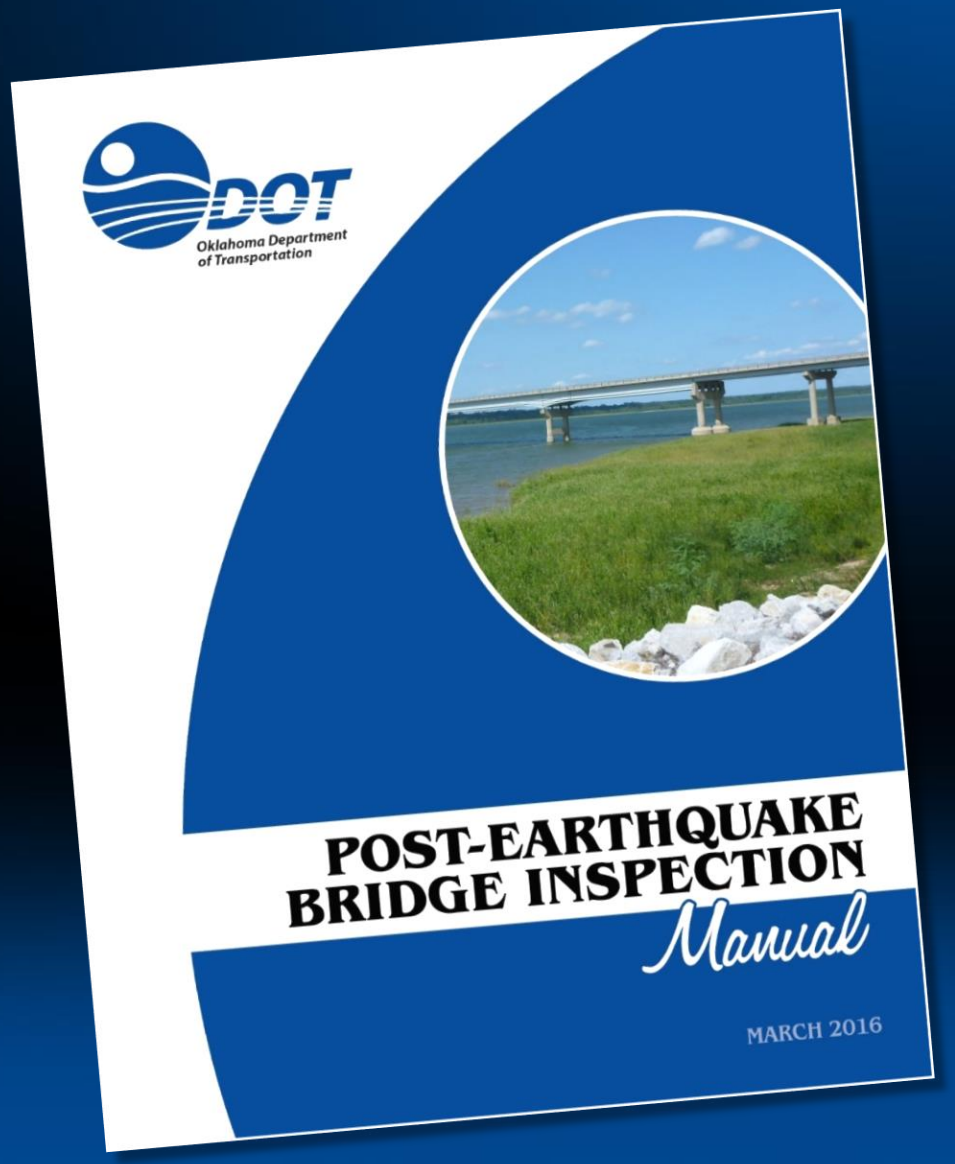
- ✓ Improved ground-motion prediction
  - ✓ Reduction in frequency of triggered responses
  - ✓ Less bridges flagged for inspection than with radius based protocol
- ✓ Automated inspection prioritization
- ✓ Streamlined inspection mobilization

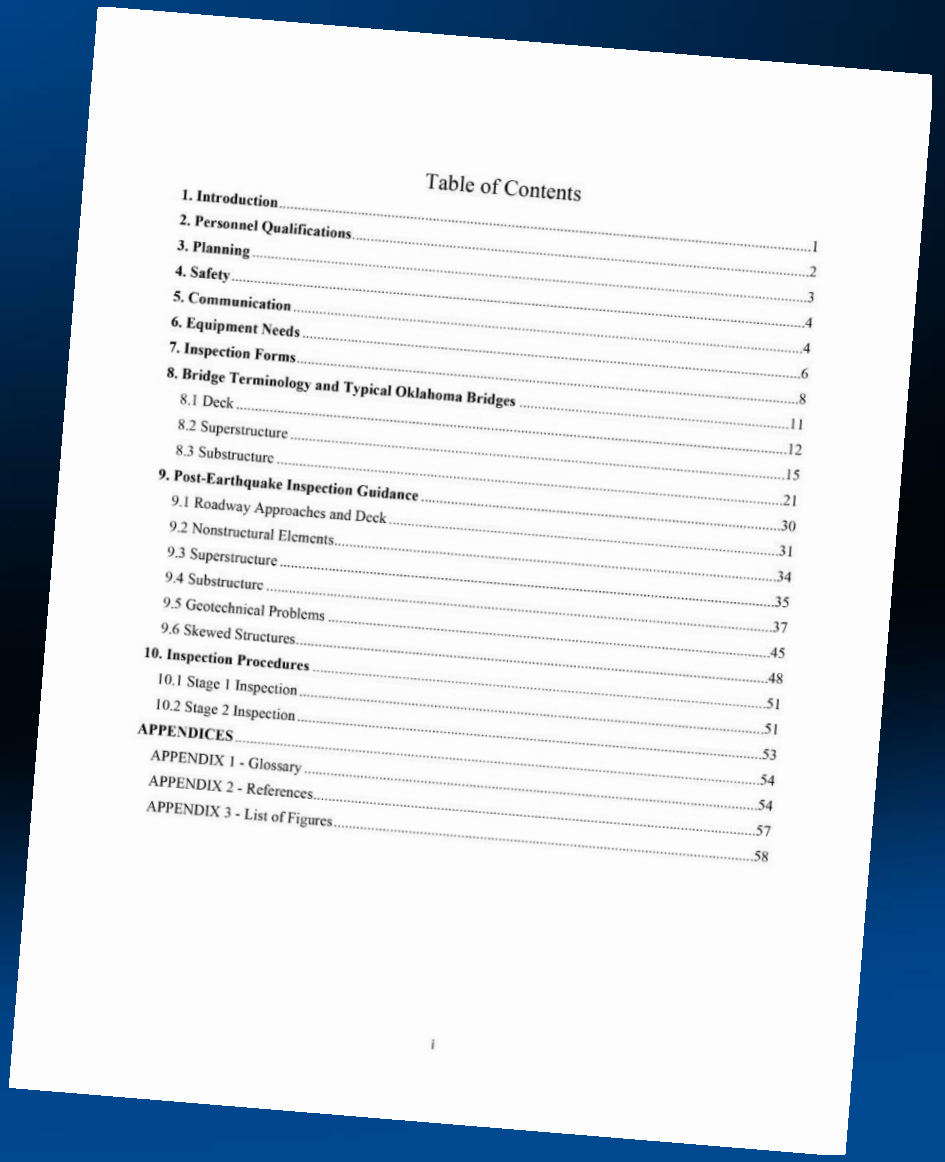
Costs:

- ✓ Installation and hosting costs
- ✓ Maintenance and upkeep

Phase 1 - Task III

Field Inspection Manual





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Phase 1 - Task III

Field Inspection Manual

The intent of the manual is to:

- ✓ Prepare personnel to properly assess and report bridge earthquake damage
- ✓ Define personnel qualifications, responsibilities, and recommended equipment
- ✓ Discuss inspection personnel safety
- ✓ Establish inspection procedures and provide clear guidance on what to look for
- ✓ Define basic bridge terminology; illustrate common bridge types and components
- ✓ Illustrate typical examples of post-earthquake bridge damage
- ✓ Provide standard post-earthquake inspection forms
- ✓ Define and describe stages of response
- ✓ Describe appropriate inspection follow-up actions

Phase 1 - Task III

Field Inspection Manual

Stage 1 Inspection

- Completed immediately after an earthquake for assigned bridges
- Quick, accurate ground level safety evaluation
- Categorize bridges as:
  - Green – Safe
  - Yellow – Minor damage
  - Red – Bridge Closed

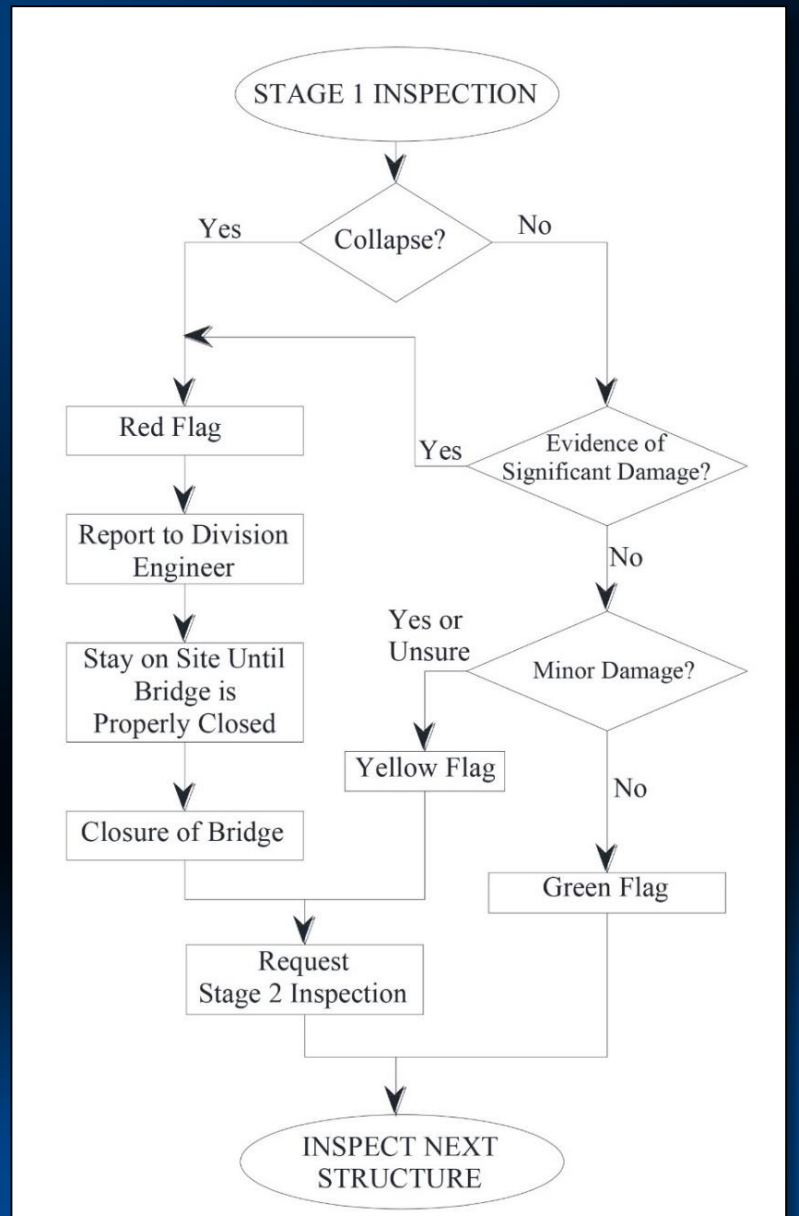


Figure 120: Stage 1 Inspection flowchart

Field Inspection Manual

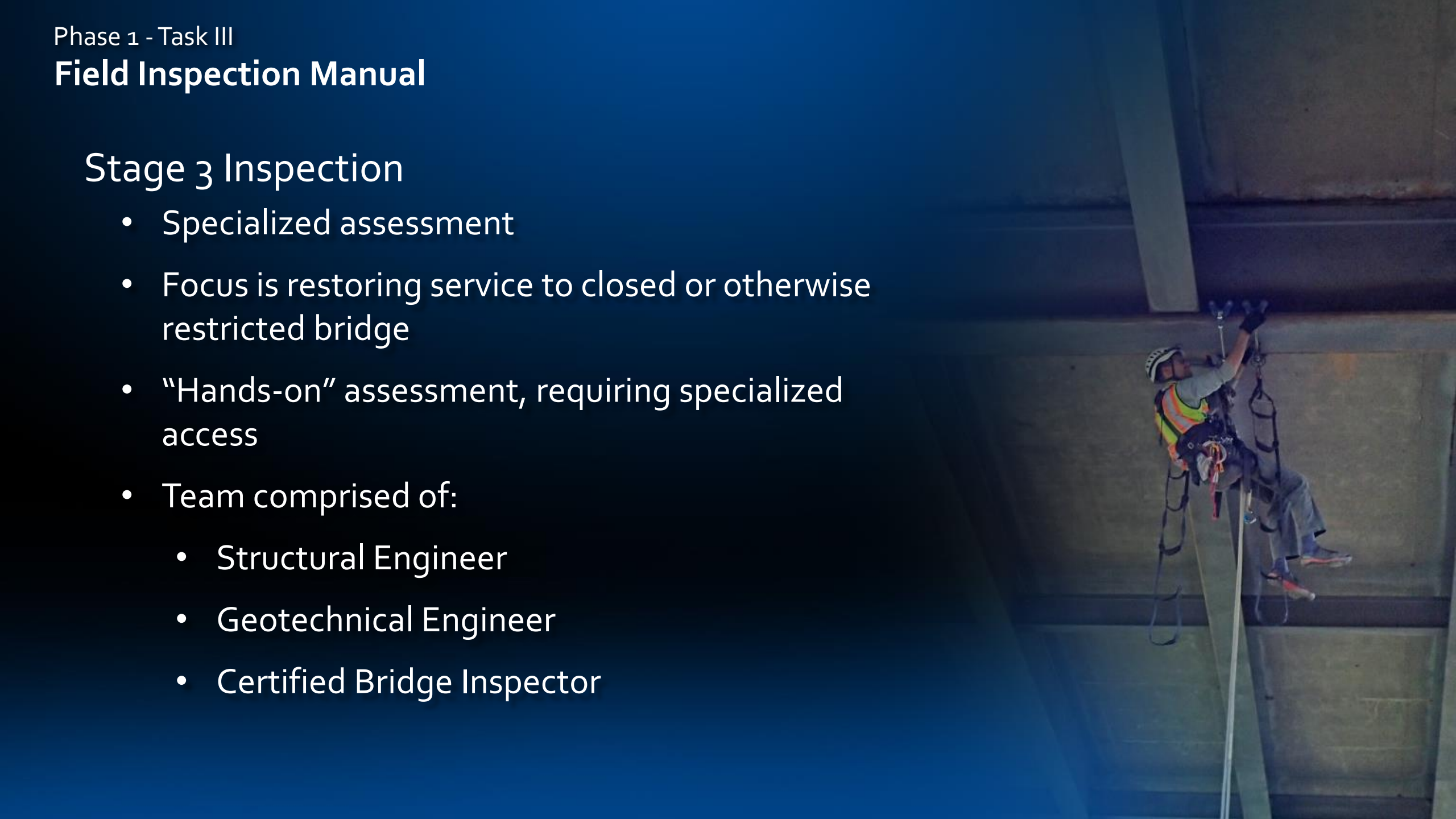
Stage 2 Inspection

- Initiated when "Further Evaluation Required" requested by Stage 1 inspector
- Team typically deployed within 8 hours or less
- "Hands-on" assessment, requiring specialized access
- May only include portions of the bridge
- Categorize bridges as:
  - Green – Safe
  - Yellow – Minor damage
  - Red – Bridge Closed

Field Inspection Manual

Stage 3 Inspection

- Specialized assessment
- Focus is restoring service to closed or otherwise restricted bridge
- “Hands-on” assessment, requiring specialized access
- Team comprised of:
  - Structural Engineer
  - Geotechnical Engineer
  - Certified Bridge Inspector



Phase 1 - Task III

Field Inspection Manual

STAGE 1 - POST-EARTHQUAKE INSPECTION FORM

OKLAHOMA DEPARTMENT OF TRANSPORTATION

Inspector(s): BOB INSPECTOR
MR. PERFECT

Date: 1/11/2016 Division: 3

Event ID: 0111-08-01

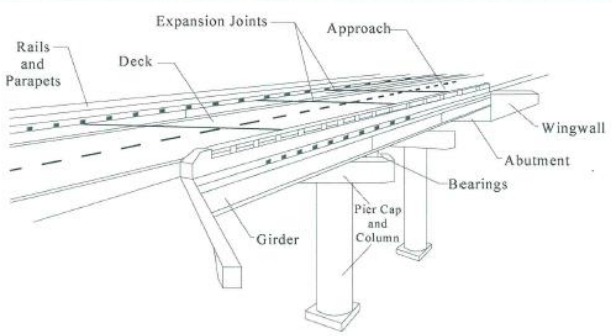
General Comments:
UNEVEN ROADWAY APPROACHING BRIDGE
(CASE STUDY)

		Needs To Be Closed	Span Collapse	Partial Collapse	Approach Roadway Damage	Deck Damage (Expansion Joints, Rails, Parapets)	Superstructure Damage (Girders, Diaphragms, Stringers)	Bearing Damage	Substructure Damage (Piers, Pier Caps, Abutments, Wingwalls)	Soil Problems (Geotechnical)	Non-Structural Elements (Utilities)
Bridge ID No.: 17594 Structure No.:	No		X			X		X		X	
Route: S.H. 56 Intersects: WEWOKA CREEK	Yes	X		X	X		X		X		X
Arrival Time: 2:30 PM Departure Time: 3:30 PM.	F.E.R.										

*F.E.R.: Further Evaluation / Stage 2 Inspection Required

OVERALL RATING ☐ Green (Safe) ☐ Yellow (Minor Damage) ☒ Red (Bridge Closed)

Observations:
- SETTLED ROADWAY APPROACH AT SOUTHEAST CORNER
- BROKEN UTILITY PIPE AT EAST SIDE OF NORTH ABUTMENT.
- SPALLED CONCRETE AT SOUTH END OF NORTH ABUTMENT.
- SPALL AT WEST END OF PIER 2 WITH EXPOSED REBAR
- WALL AT PIER 4 IS COLLAPSED.



STAGE 2 - POST-EARTHQUAKE INSPECTION FORM (1 OF 2)

Inspector(s): BOB INSPECTOR MR. SMART
Date and Time of Arrival: 04/11/2016 9:30AM Departure Time: 11:30 AM.
Bridge ID No.: 18758 Structure No.: 4603 1838EZ
Bridge Type: STEEL GIRD Route: 66 Intersects: US-266

Overall Damage: ☑ Minor ☐ Moderate ☐ Severe ☐ Collapsed ☐ None

1. APPROACH ROADWAYS
☐ Excessive Settlement ☐ Excessive Transverse Movement ☐ Approach Slab Off Bridge Seat ☑ Misalignment ☐ Other (Specify): _____
Damage ☐ None ☑ Minor ☐ Moderate ☐ Severe
Comments: THE SOUTH APPROACH IS MISALIGNED HORIZONTALLY UP TO 1".
Photograph ID: 3128

2. DECK
☐ Joint Displacement ☐ Deck Cracked / Spalled ☐ Damaged Non-Structural Elements (Lighting, Utilities) ☐ Misalignment ☐ Damaged Parap ☐ Displacement / ☐ Other (Specify)
Damage ☐ None ☑ Minor ☐ Moderate
Comments: NO EQ DAMAGE WAS FOUND.
- WIDESPREAD MAP CRACKING (UP TO 1/16") TYPICAL
- SPALLS AT RANDOM LOCATIONS

3. SUPERSTRUCTURE
Beams/Girders/Floorbeams/Stringers ☐ Concrete ☑ Steel
☐ Flexural / Shear Cracks (circle type(s) that apply) ☐ Concrete Spalling ☐ Local Buckling ☐ Partially Dropped Span ☐ Fracture ☐ Connection Fai ☐ Plastic Deform ☐ Displacement / ☐ Diaphragm / Br ☐ Other (Specify)
Damage ☑ None ☐ Minor ☐ Moderate
Comments: NO EQ DAMAGE FOUND

Steel Truss Members
☐ Local Buckling (Specify): _____ ☐ Connection Failure (Specify): _____ ☐ Displacement / ☐ Fracture (Speci ☐ Other (Specify)
Damage ☐ None ☐ Minor ☐ Moderate
Comments: N/A

STAGE 2 - POST-EARTHQUAKE INSPECTION FORM (2 OF 2)

4. BEARINGS
Type ☐ Rocker ☐ Roller ☑ Elastomeric ☐ Other _____
☐ Failure ☐ Excessive Movement ☐ Sheared / Pullout of Bolts ☐ Toppled ☐ Other (Specify): _____
Damage ☐ None ☑ Minor ☐ Moderate ☐ Severe
Comments: THE BEARINGS AT THE SOUTH ABUTMENT HAVE DEFORMED A MAX OF 1" AFTER EARTHQUAKE LOADING.
Photograph ID:

5. SUBSTRUCTURE
Piers
☐ Flexural / Shear Cracks (circle type(s) that apply) ☐ Spalling ☐ Local Buckling ☐ Settlement ☐ Foundation Movement ☐ Other (Specify): _____
Damage ☑ None ☐ Minor ☐ Moderate ☐ Severe
Comments: NO EARTHQUAKE DAMAGE WAS FOUND.
Photograph ID:

Abutments
☐ Flexural / Shear Cracks (circle type(s) that apply) ☐ Wall Movement/Rotation ☐ Backfill Settlement ☐ Foundation Movement ☐ Other (Specify): _____
Damage ☑ None ☐ Minor ☐ Moderate ☐ Severe
Comments: NO EARTHQUAKE DAMAGE FOUND
Photograph ID:

6. GEOTECHNICAL
☐ Slope Failure ☐ Lateral Spreading of Slopes ☐ Liquefaction ☐ Other (Specify): _____
Damage ☑ None ☐ Minor ☐ Moderate ☐ Severe
Comments:
Photograph ID:

ACTION
☐ Repair Request: _____
☐ Further investigation required (Specify): _____
Recommendations: MONITOR ELASTOMERIC BEARINGS TO VERIFY NO DAMAGE IS HELD WHEN DEEMED BY DIVISION ENGINEER

OVERALL RATING ☒ Green (Safe) ☐ Yellow (Limited Access) ☐ Red (Bridge Closed)

Phase 1 - Task III

Field Inspection Manual

Figure 62: Approach slab settlement and cracking of the concrete barrier *(NISEE)*

ACTION: May require closure. Inspect for settlement and superstructure or substructure damage. Further evaluation is required.

Figure 63: Settlement of the approach slab *(NYSDOT)*

ACTION: Close bridge. Report findings immediately.

Phase 1 - Task III

Field Inspection Manual

Figure 68: Vertical displacement observed in expansion joint *(NISEE)*

ACTION: Close bridge. Report findings immediately and request Stage 2 Inspection.

Figure 69: Transverse joint movement *(NYSDOT)*

ACTION: Close bridge. Report findings immediately and request Stage 2 Inspection.

Field Inspection Manual

Figure 76: Damage to beam caused by movement of the structure *(NISEE)*

ACTION: Close bridge. Report findings immediately and request Stage 2 Inspection.

Figure 77: Superstructure spalled at bearing location *(NISEE)*

ACTION: Report findings and recommend Stage 2 Inspection.

Phase 1 - Task III

Field Inspection Manual

Figure 78: Rocker bearing failure *(NISEE)*

ACTION: Close bridge. Report findings immediately and request Stage 2 Inspection.

Figure 79: Failure of bearing, complete lateral displacement *(NISEE)*

ACTION: Close bridge. Report findings immediately and request Stage 2 Inspection.

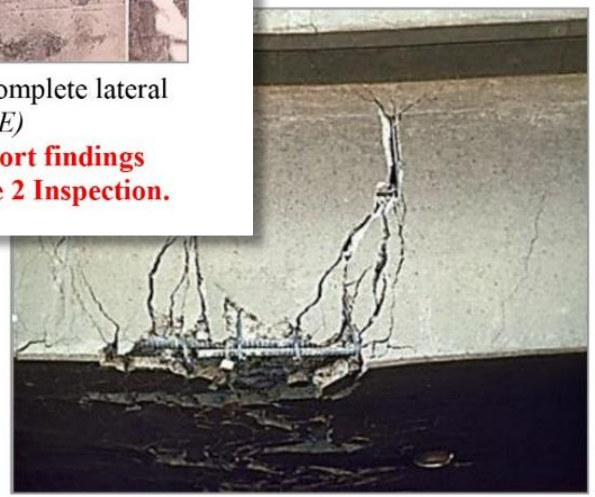


Figure 73: Severely spalled concrete beams, significant flexural cracks *(NISEE)*

ACTION: Close bridge. Report findings immediately and request Stage 2 Inspection.

Figure 74: Cracking in web of concrete beams *(NYSDOT)*

ACTION: Close bridge. Report findings immediately and request Stage 2 Inspection.

Phase 1 - Task III

Field Inspection Manual

Figure 86: Cracking and rotation of wingwall (*NISEE*)

ACTION: Close bridge. Report findings and immediately request Stage 2 Inspection.

Figure 87: Wingwall released from superstructure after earthquake tremors *(NISEE)*

ACTION: Close bridge. Report findings immediately and request Stage 2 Inspection.

Figure 92: Full collapse of pier *(NISEE)*

ACTION: Close bridge. Report findings immediately and request Stage 2 Inspection.

Figure 93: Failure of column *(NISEE)*

ACTION: Close bridge. Report findings immediately and request Stage 2 Inspection.

Phase 1 - Task III

Field Inspection Manual

Figure 94: Shear cracks in column *(NISEE)*

ACTION: Bridge remains open. Report findings immediately and request Stage 2 Inspection.

Figure 95: Compression failure on the top of concrete bridge pier *(INDOT)*

ACTION: Report findings immediately and request Stage 2 Inspection.

Figure 96: Confinement failure in single column *(NISEE)*

ACTION: Close bridge. Report findings immediately and request Stage 2 Inspection.

Figure 100: Ground movement indicating possible foundation problems *(INDOT)*

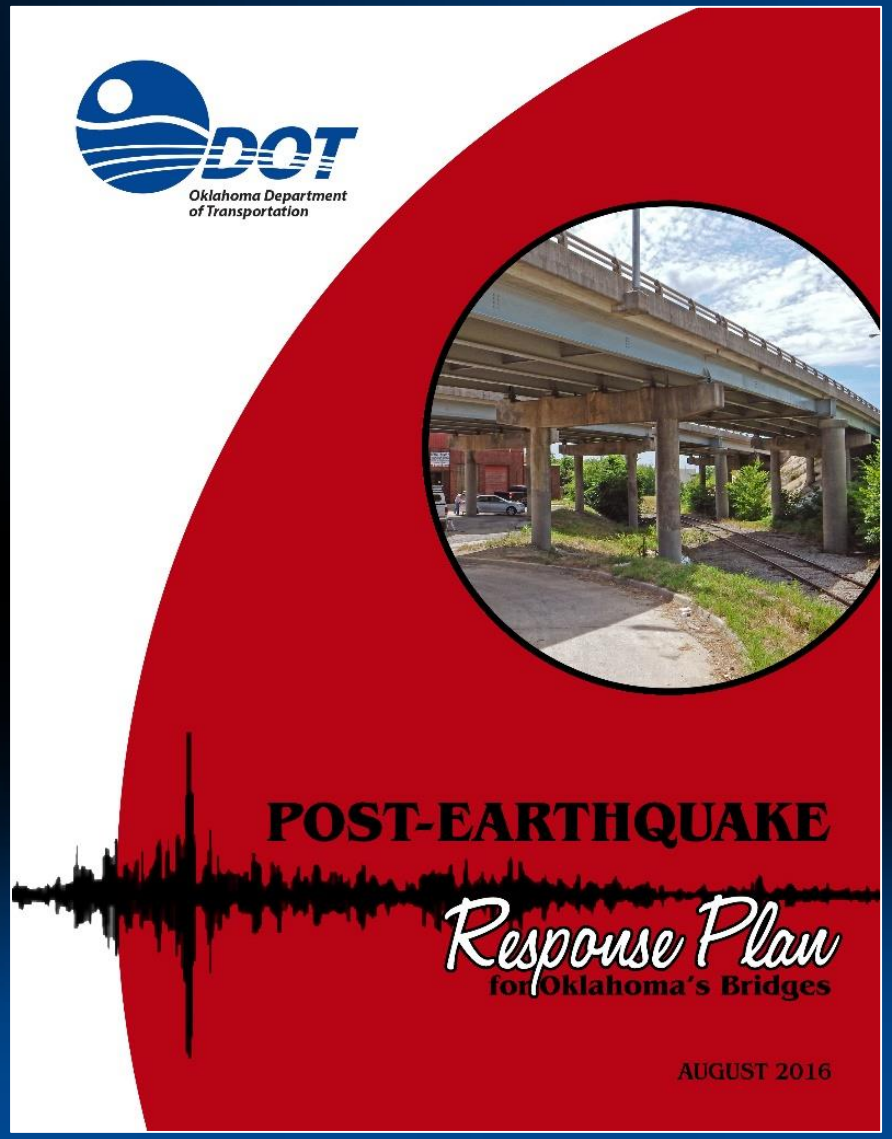
ACTION: Report findings immediately and request Stage 2 Inspection.

Figure 102: Liquefaction sand boil

ACTION: Report findings immediately and request Stage 2 Inspection. Close bridge when sand boils are present near substructure.

Phase 1 - Task IV

Draft Earthquake Response Plan



The intent of the response plan is to:

- ✓ Educate personnel on earthquake fundamentals and Oklahoma seismicity
- ✓ Provide a clear & concise earthquake response protocol
- ✓ Define levels of response & stages of inspection
- ✓ Outline minimum qualifications and training for response personnel
- ✓ Provide guidance on temporary shoring and repair techniques

Phase 1 - Task V

Training – Stage 1

Learning Outcomes:

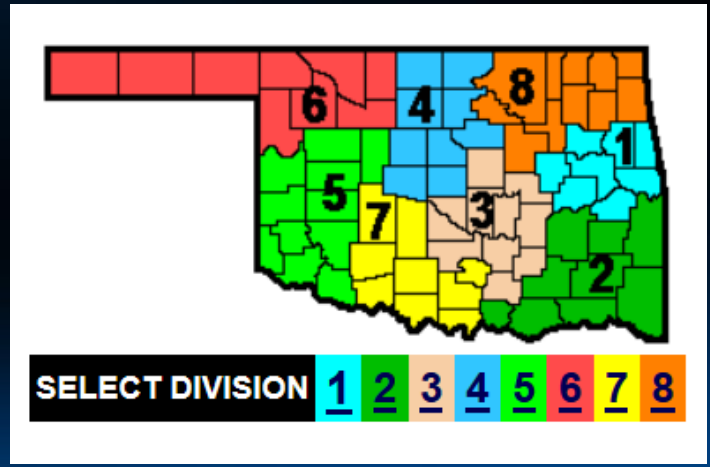
- ✓ Understand ODOT's Post-Earthquake Bridge Inspection Manual
- ✓ Define the qualifications and role of the Stage I inspector
- ✓ Define basic bridge terminology and identify Oklahoma common bridge types and components
- ✓ Describe ODOT's Stage I inspection process
- ✓ List safety concerns for post-earthquake inspections

Phase 1 - Task V

Training – Stage 1

ODOT Division or Other Agency	Training Date	Start Time	Finish Time	# Participants		
				ODOT	Other	Total
ODOT Division 4	June 22, 2016	8:00 a.m.	11:30 p.m.	29	24	53
ODOT Division 3	July 13, 2016	10:00 a.m.	3:00 p.m.	21	0	21
ODOT Division 5	July 27, 2016	8:30 a.m.	12:00 p.m.	22	0	22
ODOT Division 1	August 17, 2016	8:30 a.m.	12:00 p.m.	29	6	35
ODOT Division 8 Session 1	August 18, 2016	8:30 a.m.	12:00 p.m.	52	0	52
ODOT Division 8 Session 2	August 18, 2016	1:00 p.m.	4:30 p.m.	24	2	26
ODOT Division 7	August 25, 2016	8:00 a.m.	11:30 a.m.	24	20	44
ODOT Division 6	September 15, 2016	9:00 a.m.	12:30 p.m.	28	4	32
ODOT Division 2 Session 1	September 22, 2016	8:00 a.m.	11:30 a.m.	17	17	34
ODOT Division 2 Session 2	September 22, 2016	1:00 p.m.	4:30 p.m.	16	5	21
Oklahoma Turnpike Authority	September 22, 2016	1:00 p.m.	4:30 p.m.	0	37	37
USACE Tulsa	September 22, 2016	1:00 p.m.	4:30 p.m.	0	18	18
Totals				**262**	**133**	**395**

Organization - Eight Field Divisions and a Central Office

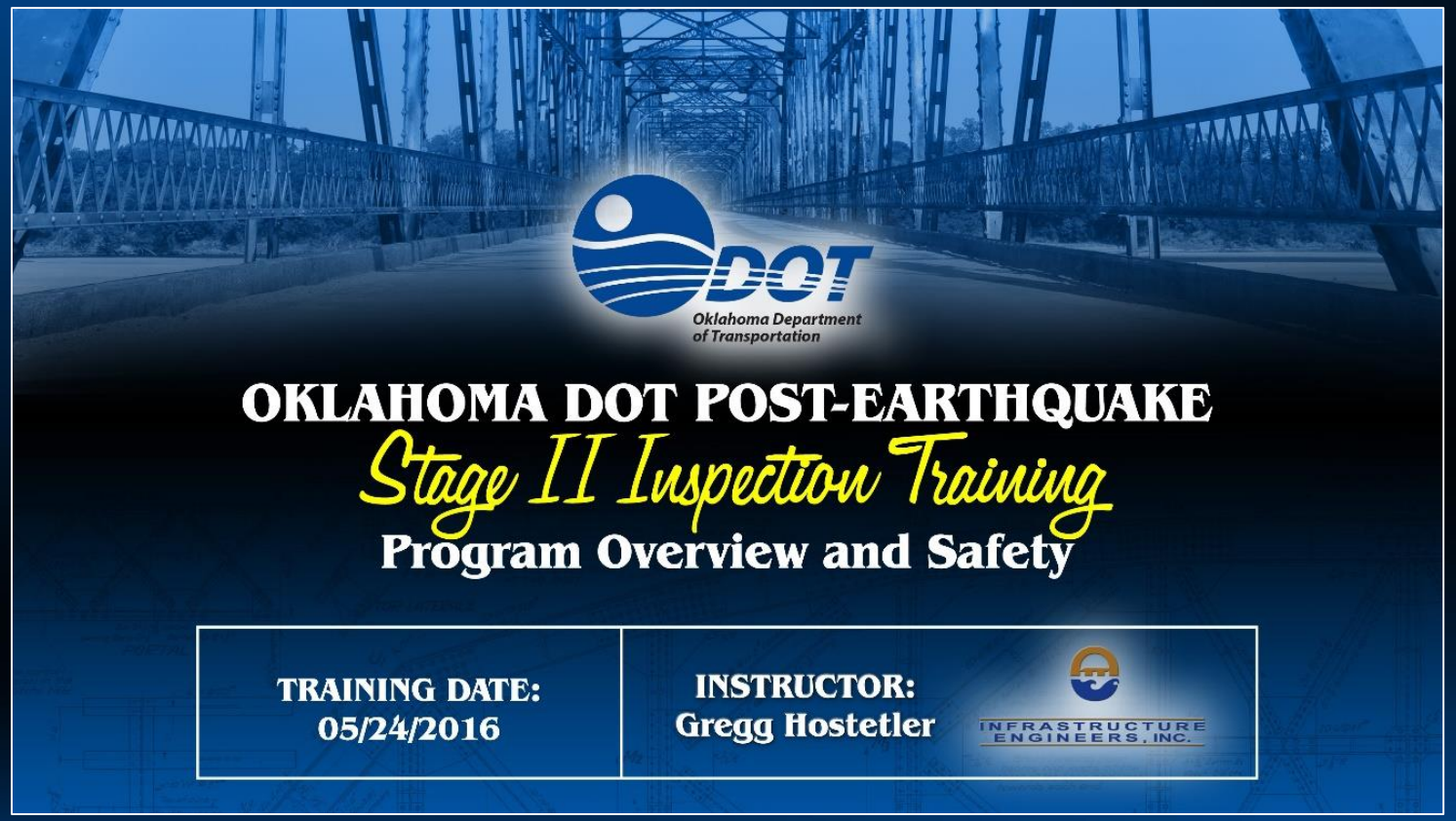


Phase 1 - Task V

Training – Stage 2

Learning Outcomes:

- ✓ Understand ODOT's Post-Earthquake Bridge Inspection Manual
- ✓ Define the qualifications and role of the Stage II inspector
- ✓ Describe ODOT's Stage II inspection process
- ✓ List safety concerns for post-earthquake inspections



Approximately 200 NBIS & ODOT certified bridge inspectors received training during ODOT's Annual QCQA Workshop.

Phase 1 – Task VI

Seismic Review of Three Bridges

- I-35 over Canadian River (top)
- I-35 over Cimarron River (bottom right)
- SH-11 over I-35 (bottom left)

Phase 1 – Task VI

Seismic Review of Three Bridges

Key findings:

- Validation of S1 trigger values
- Very low potential for liquefaction
- Bearings are most vulnerable to damage
- Transverse loading most critical
- Cost per bridge for site specific analysis:
  - $21k for geotechnical
  - $15k for structural

Phase 1 - Task VII

Meetings and Senior Staff Briefings

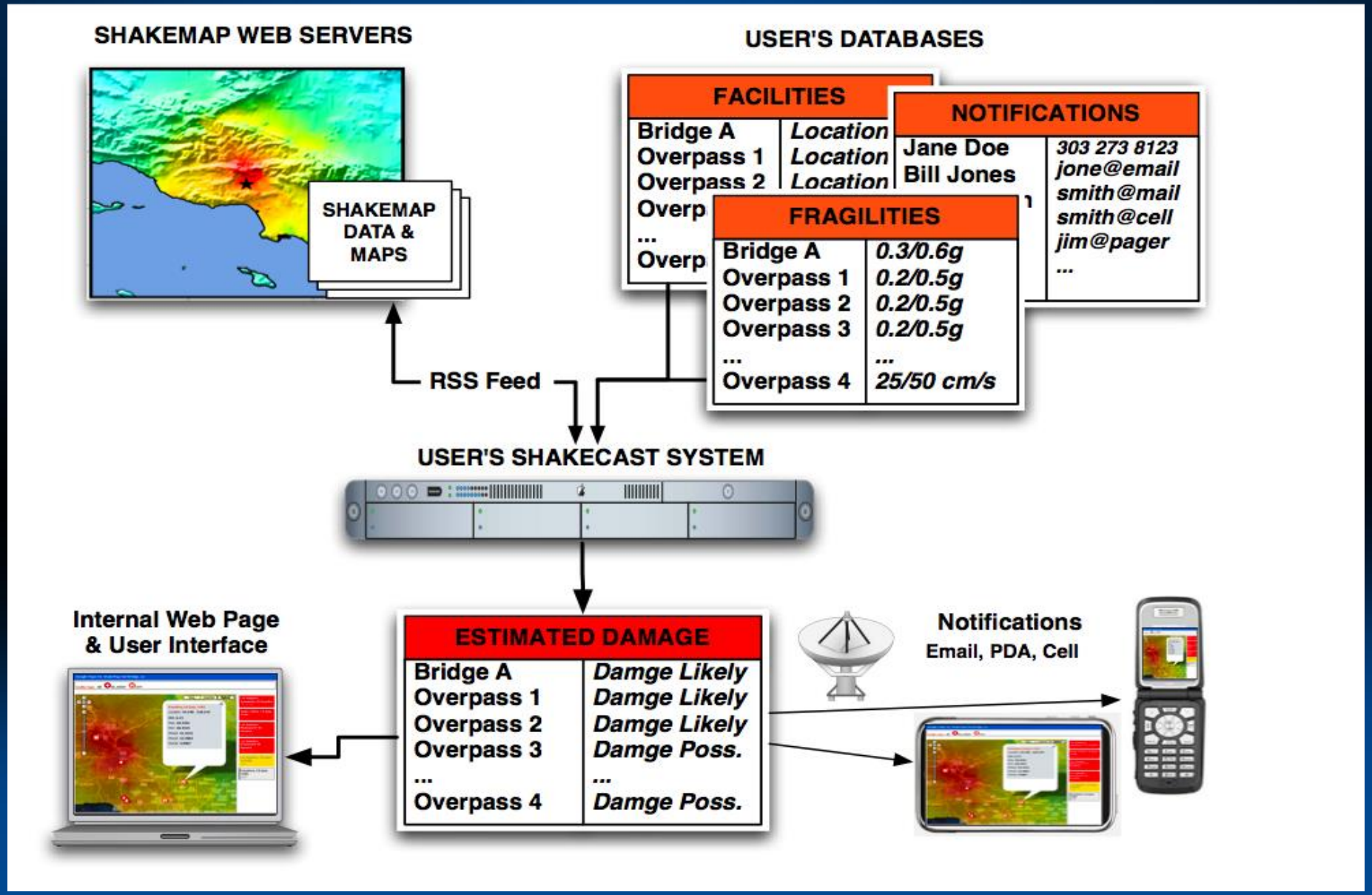
EC-1609 – Post-Earthquake Inspection Guidelines
Progress / Team Strategy Meeting
April 11, 2016

Attendees:

Initials	Name/Organization	Phone	E-mail
	Abraham Jauregui (IEI)	(415) 794-6030	ajauregui@go-iei.com
	Bill Wilkinson (ODOT)	(580) 332-1526	bwilkinson@odot.org
	Casey Shell (ODOT)		cshell@odot.org
	Dan Knickmeyer (ODOT)	(405) 521-4009	dknickmeyer@odot.org
	Gregg Hostetler (IEI)	(405) 227-0531	ghostetler@go-iei.com
	Ivanna Kaid Bay (OU)		i.kaidbay@ou.edu
	Joshua Pogue (ODOT)	(918) 323-6900	jpogue@odot.org
	Karthik Radhakrishnar (Kleinfelder)	(918) 549-8121	karthik@kleinfelder.com
	Matt Mitchell (ODOT)	(405) 436-5173	mmitchell@odot.org
	Muralee Muraleetharan (OU)	(405) 325-4247	muralee@ou.edu
	Paul Green (ODOT)	(405) 521-4675	pdgreen@odot.org
	Randy Leonard (FHWA)	(405) 254-3331	Randall.leonard@odot.org
SH	Samantha Heinrich (OU)	(618) 420-3405	Samantha.k.Heinrich-1@ou.edu
	Scott Harvey (OU)	(405) 325-3836	harvey@ou.edu
	Steven Jacobi (ODOT)	(405) 521-2606	sjacobi@odot.org
	Tim Tegeler (ODOT)	(405) 521-6916	ttegeler@odot.org
TLT	Tracy Terrill (ODOT)	(580) 255-7586	tterrill@odot.org
	Walt Peters (ODOT)	(405) 521-2606	wpeters@odot.org
	Wes Kellogg (ODOT)	(405) 522-2606	wkellogg@odot.org
	Zia Zafir (Kleinfelder)	916-366-2382	zzafir@kleinfelder.com
	David Jarvis (USACE)		David.jarvis@usace.army.mil
	Jeff Roberts (USACE)		Jeffery.m.roberts@usace.army.mil
JB	Jeremy Boak (OGS)	(405) 325-7968	jboak@ou.edu
	Christopher R. Clarke (ODOT)	405 522-4998	cclarke@odot.org

Phase 2 – Task I

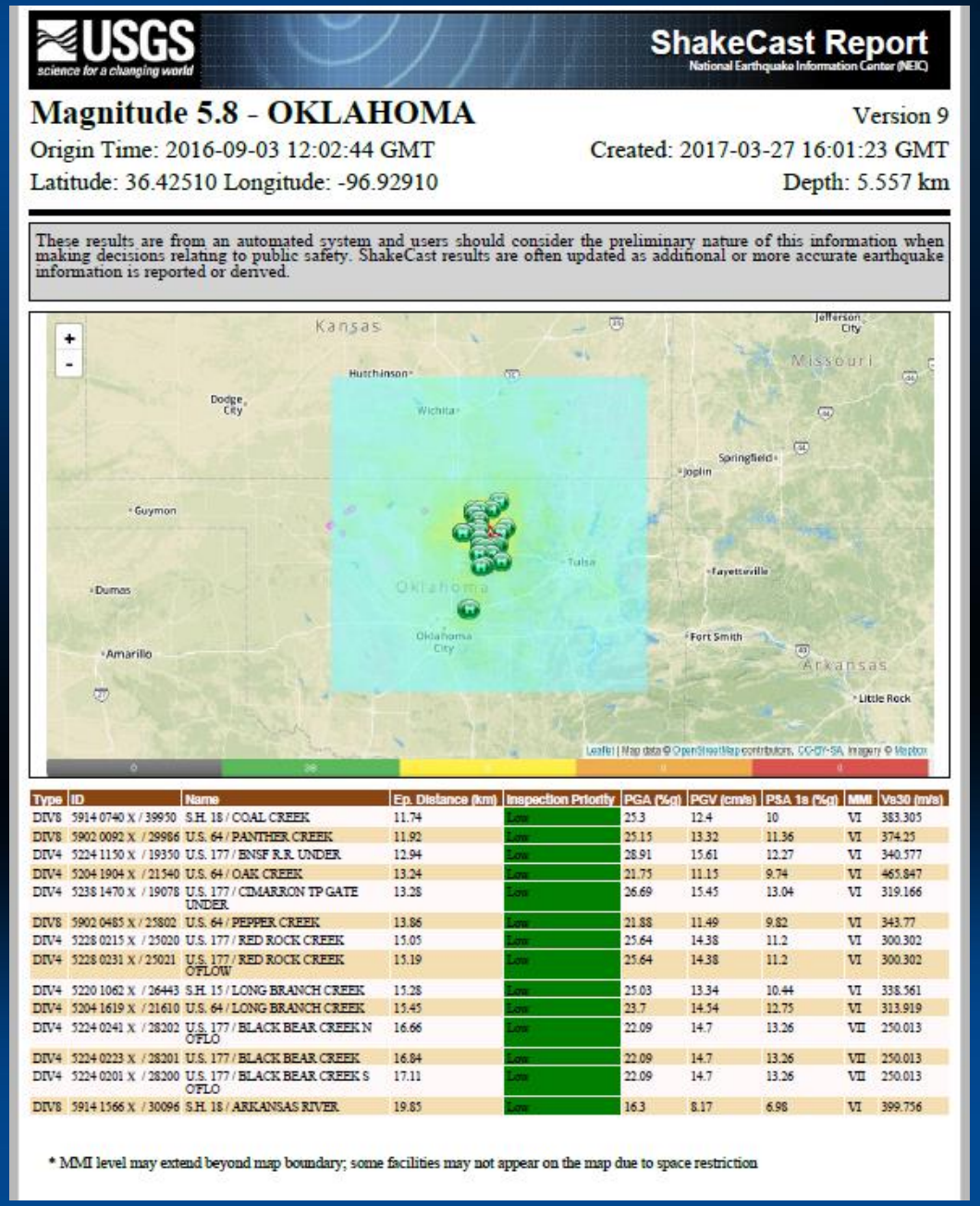
ShakeCast-OK



Phase 2 – Task I

ShakeCast-OK

Test of Oklahoma ShakeCast based on M5.8 in Pawnee, OK
Note: Report includes Oklahoma 5 Digit NBI No., Str. No., & location



USGS science for a changing world

ShakeCast Report
National Earthquake Information Center (NEIC)

Magnitude 5.8 - OKLAHOMA
Version 9
Origin Time: 2016-09-03 12:02:44 GMT
Created: 2017-03-27 16:01:23 GMT
Latitude: 36.42510 Longitude: -96.92910
Depth: 5.557 km

These results are from an automated system and users should consider the preliminary nature of this information when making decisions relating to public safety. ShakeCast results are often updated as additional or more accurate earthquake information is reported or derived.

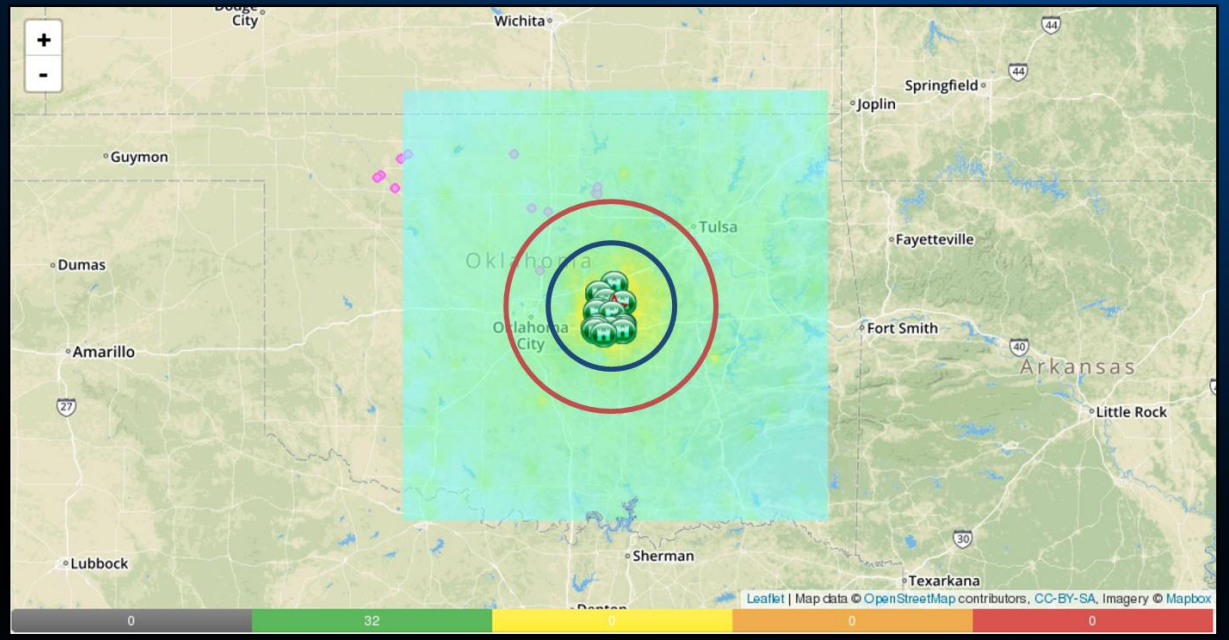
Type	ID	Name	Ep. Distance (km)	Inspection Priority	PGA (%g)	PGV (cm/s)	PSA 1s (%g)	MMI	Vs30 (m/s)
DIV8	5914 0740 X / 39950	S.H. 18 / COAL CREEK	11.74	Low	25.3	12.4	10	VI	383.305
DIV8	5902 0092 X / 29986	U.S. 64 / PANTHER CREEK	11.92	Low	25.15	13.32	11.36	VI	374.25
DIV4	5224 1150 X / 19350	U.S. 177 / BNSF R.R. UNDER	12.94	Low	28.91	15.61	12.27	VI	340.577
DIV4	5204 1904 X / 21540	U.S. 64 / OAK CREEK	13.24	Low	21.75	11.15	9.74	VI	465.847
DIV4	5238 1470 X / 19078	U.S. 177 / CIMARRON TP GATE UNDER	13.28	Low	26.69	15.45	13.04	VI	319.166
DIV8	5902 0485 X / 25802	U.S. 64 / PEPPER CREEK	13.86	Low	21.88	11.49	9.82	VI	343.77
DIV4	5228 0215 X / 25020	U.S. 177 / RED ROCK CREEK	15.05	Low	25.64	14.38	11.2	VI	300.302
DIV4	5228 0231 X / 25021	U.S. 177 / RED ROCK CREEK OFLOW	15.19	Low	25.64	14.38	11.2	VI	300.302
DIV4	5220 1062 X / 26443	S.H. 15 / LONG BRANCH CREEK	15.28	Low	25.03	13.34	10.44	VI	338.561
DIV4	5204 1619 X / 21610	U.S. 64 / LONG BRANCH CREEK	15.45	Low	23.7	14.54	12.75	VI	313.919
DIV4	5224 0241 X / 28202	U.S. 177 / BLACK BEAR CREEK N OFLO	16.66	Low	22.09	14.7	13.26	VII	250.013
DIV4	5224 0223 X / 28201	U.S. 177 / BLACK BEAR CREEK	16.84	Low	22.09	14.7	13.26	VII	250.013
DIV4	5224 0201 X / 28200	U.S. 177 / BLACK BEAR CREEK S OFLO	17.11	Low	22.09	14.7	13.26	VII	250.013
DIV8	5914 1566 X / 30096	S.H. 18 / ARKANSAS RIVER	19.85	Low	16.3	8.17	6.98	VI	399.756

* MMI level may extend beyond map boundary; some facilities may not appear on the map due to space restriction

Phase 2 – Task I

ShakeCast-OK

M5.6 - Prague, OK (Nov 6, 2011)

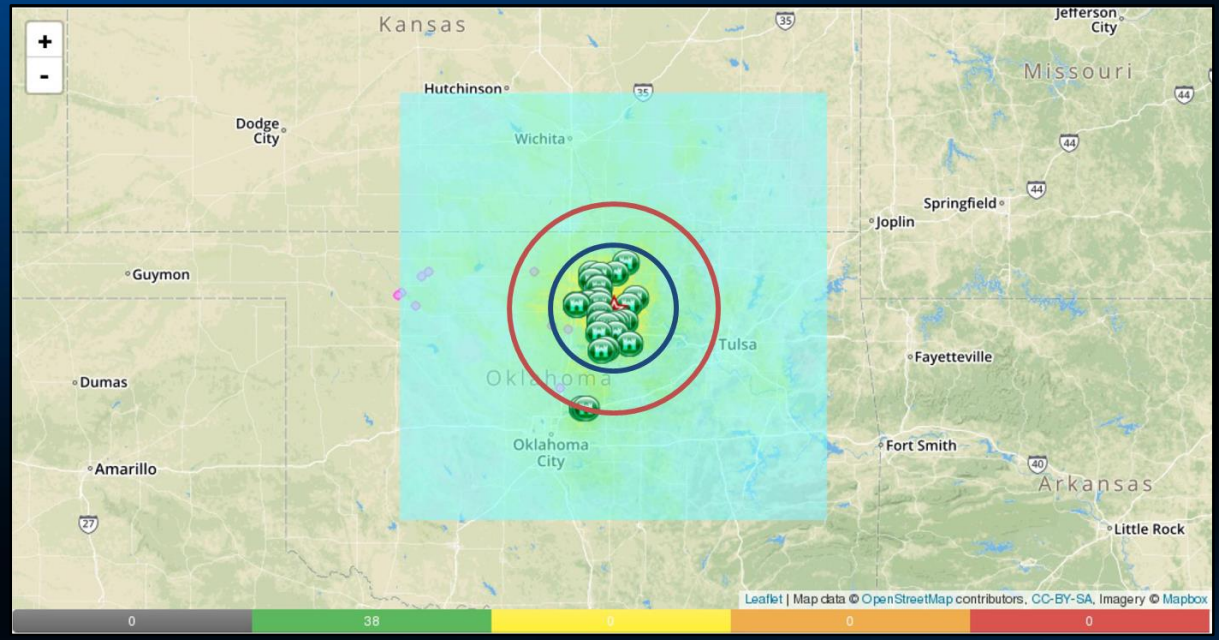


Old Protocol (50 miles): 772 bridges

Interim Protocol (30 miles): 189 bridges

ShakeCast: 32 bridges

M5.8 - Pawnee, OK (Sept 3, 2016)



Old Protocol (50 miles): 366 bridges

Interim Protocol (30 miles): 167 bridges

ShakeCast: 38 bridges

Oklahoma Department of Transportation

INFRASTRUCTURE ENGINEERS, INC.

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QUESTIONS?

nbppc NATIONAL BRIDGE PRESERVATION PARTNERSHIP CONFERENCE 2018

PRACTICES WE CAN NOT AFFORD TO DEFER