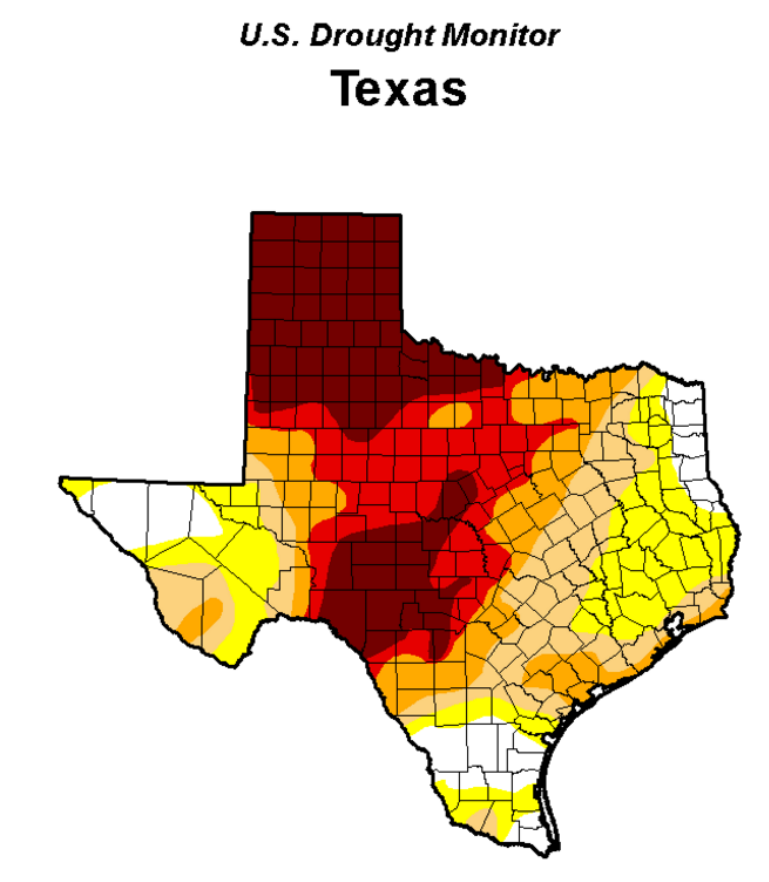
IT'S FLOODING DOWN IN TEXAS

LESSONS LEARNED FROM SIX MASS FLOOD EVENTS IN THIRTEEN MONTHS

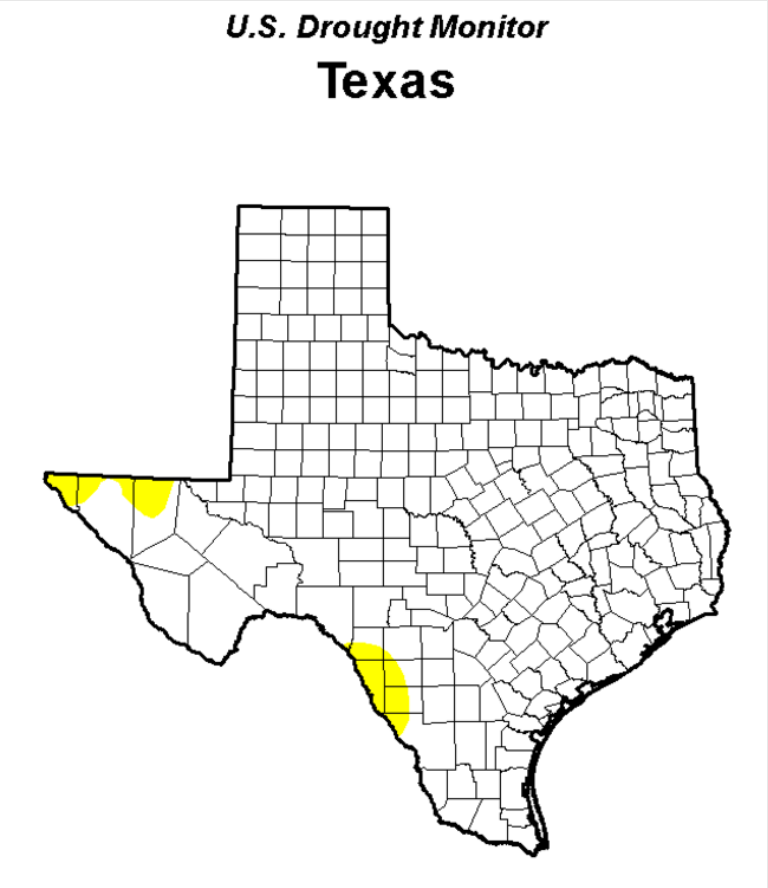
2017 Southeast Bridge Preservation Partnership

Graham Bettis, P.E.

And then the rains came…



Late 2014

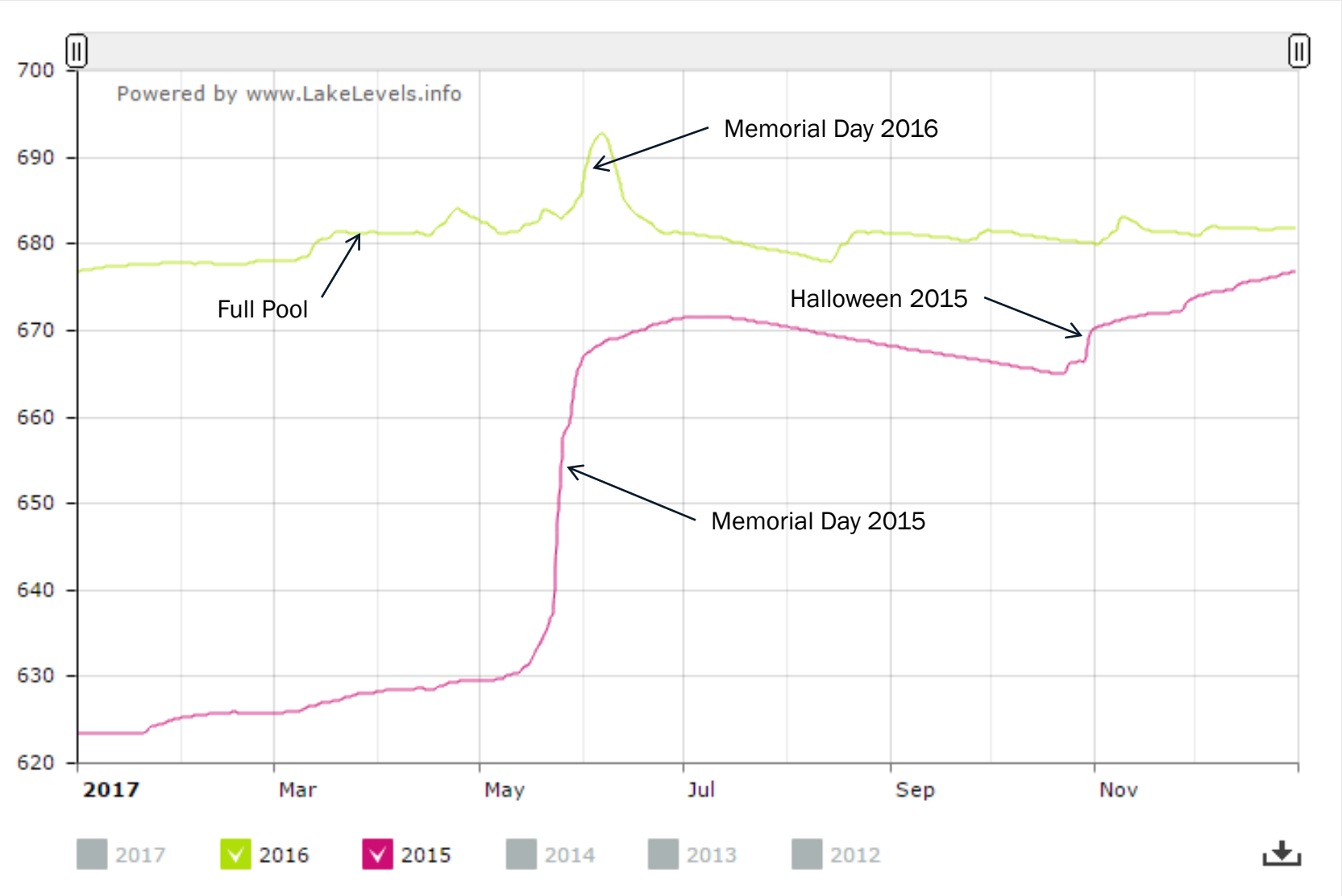


Early 2017

Texas Flooding in 2015 and 2016

1. Memorial Day 2015 in Central Texas
2. Summer 2015 North Texas (Red River)
3. Halloween Flooding 2015 in Central Texas
4. Spring Break (March) 2016 East Texas (Sabine River)
5. Sustained Rain Events April, May, and June 2016 East Texas (especially Houston)
6. June 2016 Central Texas

Central Texas Reservoir (Lake Travis) in May 2015



Memorial Day 2015

Resilient Superstructure

Lesson No. 1 – Setting up a Bridge Command Center

- Establish Bridge-Specific Command Center
- Identify Personnel Available to Report
- Separate from Mass/Overall State Command Center
- Not Everyone Gets to Go in the Field
  - Several Knowledgeable Personnel in Command Center to Direct Field Teams
  - Gather (Query) and Analyze Data
  - Generate Maps
  - Prioritize Structures for Evaluation
  - Provide All Necessary Data to Field Personnel
- Bridge Command Center Can Be in Damage Area (e.g. District Office)
  - Regular Communication with District and Other Authorities
  - Field Teams Can Remain Focused on Evaluations
  - Proximity Allows for Evaluation on Major Field Issues

Lesson No. 1 – Setting up a Bridge Command Center

- Effective Communication Devices
  - Have Radio or Walkie Talkie Devices Available
  - FaceTime Extremely Effective for Showing Damage to Engineers in Other Areas
  - Utilize Applications to Track Team Locations (GoogleMaps, Find My Friends)
- Account for Fatigue
  - Tell Field Teams When They Need to Report (and make sure they actually do so…)
  - Force Rest When Needed
  - Prepare for Extreme Fatigue and Stress for Field Personnel During Prolonged Responses (e.g. Houston in Spring/Summer 2016)
  - The Public Gets Tired, Too

Lesson No. 2 – Don't Get Ahead of Yourself

- Weather Events Can Shift Dramatically from Predictions (e.g. Memorial Day Flooding 2015)
- Often Little to Accomplish by Responding While Event is Ongoing
  - Maintenance Personnel Must Check Roadways and Bridges, but…
  - Often Little that Can Be Evaluated
  - Focus on Identifying Critical Structures, Especially Scour
- Be Prepared as Soon as Water Recedes

Yep, it's flooded.

Lesson No. 3 – Initial Evaluations

- Don’t Use the Experts to Perform Initial Evaluations
- Vast Majority of Structures Do Not Sustain Damage, Even in Extreme Events
- Better Served to Direct Initial Investigations Performed By Others
  - Provide Checklist
  - Allow Experts to Focus on Structures Where Damage is Identified
- Scour Critical is an Exception

Initial Evaluation - Checklist

Things to look for in structures:

1. Signs of settlement
   - Look at vertical misalignment of rail and curbs, rail impacted, damaged, or completely gone.
   - Exposed drilled shafts or bridge settlement.

2. Alignment for lateral movement
   - Look at striping, rail, curbs – misalignment will be a sign of lateral movement
   - Uneven expansion joint openings – Downstream side of the joint open wider than upstream side

3. Severe Scour
   - Look at abutment back wall.
   - Header slope erosion, rip rap failure.
   - Exposed drilled shafts.
   - Approach slabs that have been undermined or failed.

4. Debris needing removal
5. Channel Stability – slope failure
6. Structural Damage
   - fresh spalls
   - impact damage
   - rail damage – debris build up on rails can cause damage at anchorage.

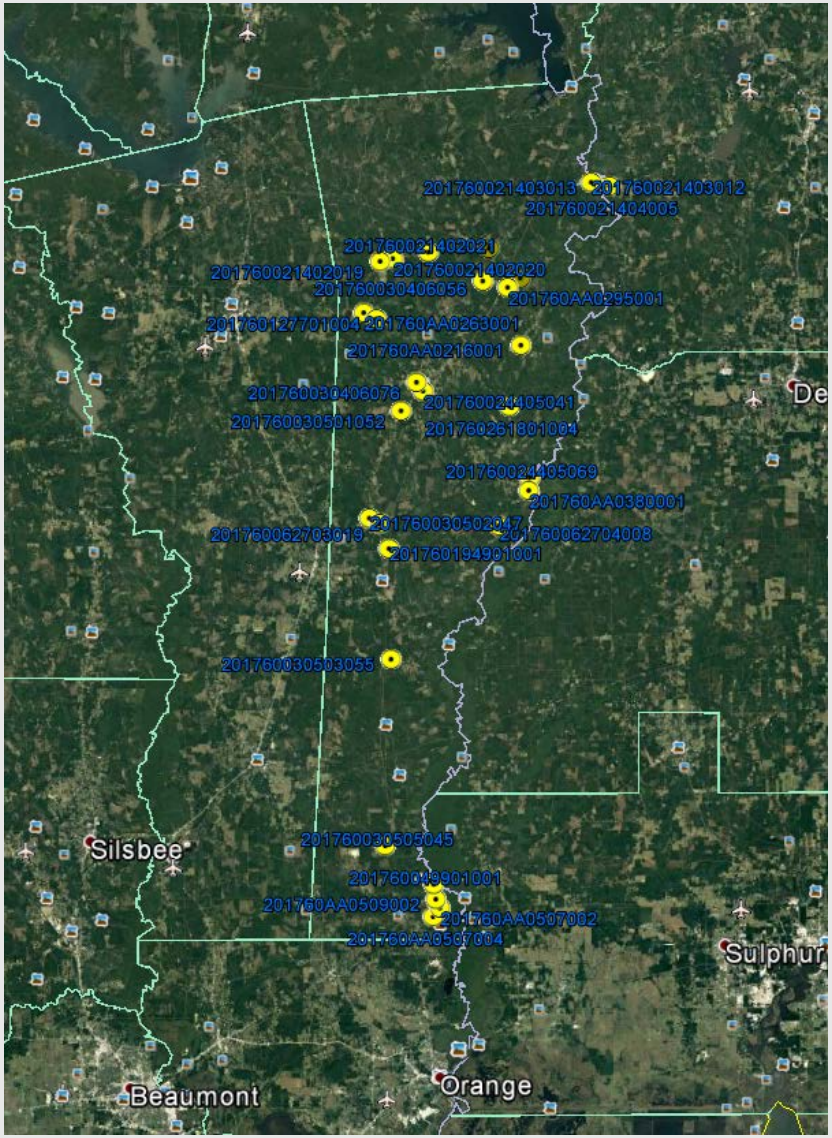
7. Photos to take:
   1. Upstream
   2. Downstream
   3. Roadway view – showing deck with some of approach (if possible)
   4. Elevation view of entire structure (multiple photos if needed)
   5. Picture showing high water mark relative to bridge
   6. Damage
   7. Other pictures you feel are necessary to document damage from flooding

Lesson No. 4 – Effective Communication

- Emergency Response
  - Overall Command/Control Center (DOT, NWS, USGS, DMV)
  - Bridge Command Center
  - Regular Conference Calls
- Field Response
  - Time Is of the Essence – Often the List of Bridges to Evaluate is Long
  - Bridge Command Center Does the Leg Work
  - Have Overall Leads Attend Tailgate Meetings, Briefings, etc.
  - Allow Field Personnel to Remain Focused on Field Evaluations
- Stay in Regular Contact with Team Leads

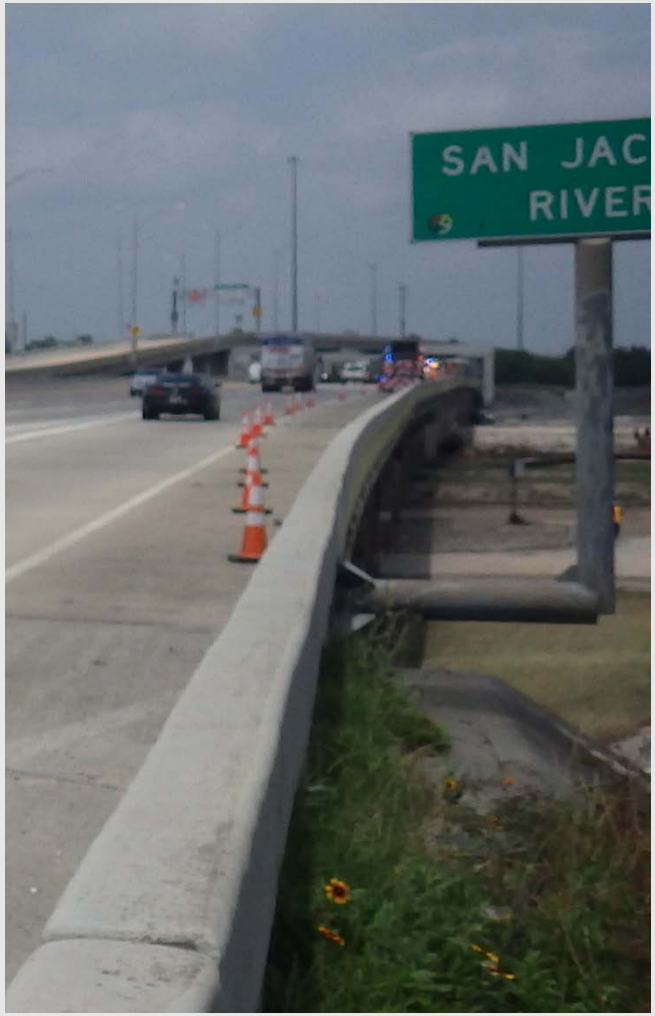
Lesson No. 4 – Effective Communication

- Generate Lists of Bridges and Place Them on a Map (e.g. KMZ files imported to GoogleEarth)
- Plan According to Geographic Regions, Not Just Bridge Criticality
- Teams May Be Covering Large Geographic Areas, Avoid Bouncing around



Lesson No. 4 – Effective Communication

- Traffic Control – Striking a Good Balance
- Overly elaborate TCP can take 2+ hours to set up, severely limiting the number of bridges that can be evaluated.
- Inadequate TCP can lead to unacceptable levels of exposure.
- Communicate intent and duration.
- Typically needed to measure channel profiles and to identify scour.
- Establish formal guidelines and requirements for TCP in emergency response situations.
- Having two traffic control teams can vastly increase productivity (e.g. Houston 2016).



Lesson No. 5 – Standard Procedures

- Prepare Standard Operating Procedures for Primary Tasks
- Short and Sweet (we're aiming for one page each)
- Tasks
  - Command Center Responsibilities
  - Querying Data, Generating Maps
  - Initial Bridge Evaluations
  - Setting up Traffic Control
  - Measuring Channel Profile

Lesson No. 6 – Establish Statewide Standards

- How to Determine Bridge Criticality?
- How to Determine Susceptibility to Catastrophic Damage?
- Over the course of the various flood responses we found that criteria differed significantly from District to District.
- Must avoid overly-conservative criteria to permit truly critical structures to be identified.
- Establish Statewide Criteria for Categorizing Structures as Scour Critical

Lesson No. 6 – Establish Statewide Standards

1,102 Bridges!

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Bridge/ Culvert	BRKEY	DIST	CNTY	" F " Inspection needed due to FLOODING	CTRL	MAINT_SEC	SEC	STRUC	RTE	BRDG_DSCR	FEAT_CROSS	LOCN	BRDG_TYPE_CD
1059	Bridge	121020050801255	12	102	F	0508	19	01	255	IH 10 EB FR	5 Simple Span P/S Concret	GREENS BAYOU	1.0 MI E OF FEDERAL	B
1060	Bridge	121020050801317	12	102	F	0508	09	01	317	IH 10 EB	21 - Span (3 - Continuous S	SAN JACINTO RIVER	IH 10 @ SAN JACINTO	B
1061	Bridge	121020050801457	12	102	F	0508	19	01	457	IH 10 WB	5 Simple Span P/S Concret	GREENS BAYOU	1.0 MI E OF FEDERAL	B
1062	Bridge	121020263301202	12	102	F	2633	09	01	202	FM 526 NB	9 - Simple PS Concrete Gi	GREENS BAYOU	1.5 MI S OF US 90	B
1063	Bridge	121020263301234	12	102	F	2633	09	01	234	FM 526 SB	9 - Simple PS Concrete Gi	GREENS BAYOU	1.5 MI S OF US 90	B
1064	Bridge	121020325603051	12	102	F	3256	09	03	051	BW 8 NB FR	12 - Simple Span P.S. Con	UP RR, CARPENTER	0.20 MI N OF IH 10	B
1065	Bridge	121020325603052	12	102	F	3256	09	03	052	BW 8 SB FR	13 - Simple Span P.S. Con	UP RR, CARPENTER	0.10 MI N OF IH 10	B
1066	Bridge	121020017706081	12	102	F	0177	10	06	081	US 59 SBML	26 - Continuous Span Steel	SAN JACINTO RIVER	1.7 MI N OF FM 1960	B
1067	Bridge	121020017706134	12	102	F	0177	10	06	134	US 59 NBML	26 - Simple Span Prestress	SAN JACINTO RIVER	1.7 MI N OF FM 1960	B
1068	Bridge	121020017706224	12	102	F	0177	10	06	224	US 59 SBFR	3 - Simple Span Prestresse	SAN JACINTO RI REL	1.0 MI N OF FM 1960	B
1069	Bridge	121020017706226	12	102	F	0177	10	06	226	US 59 W CONN	3 - Simple Span Prestresse	SAN JACINTO RIVER	1.0 MI N OF FM 1960	B
1070	Bridge	121020017706230	12	102	F	0177	10	06	230	US 59 NBFR	18 - Simple Span Prestress	SAN JACINTO RIVER	1.7 MI N OF FM 1960	B
1071	Bridge	121020017706231	12	102	F	0177	10	06	231	US 59 HOV	27 - Span (8 - Continuous S	SAN JACINTO RVR 8	1.7 MI N OF FM 1960	B
1072	Bridge	121020017706232	12	102	F	0177	10	06	232	US 59 SBFR	21 - Simple Span Prestress	SAN JACINTO RIVER	1.7 MI N OF FM 1960	B
1073	Bridge	121020017706233	12	102	F	0177	10	06	233	US 59 NBFR	3 - Simple Span Prestresse	SAN JACINTO RI REL	1.0 MI N OF FM 1960	B
1074	Bridge	121020017706236	12	102	F	0177	10	06	236	US 59 NB OFF-RP	3 - Simple Span Prestresse	SAN JACINTO RI REL	1.0 MI N OF FM 1960	B
1075	Bridge	121020072003073	12	102	F	0720	10	03	073	SH 249 SBFR	Three Simple Span Prestres	WILLOW CREEK	2.10 MI S OF FM 2920	B
1076	Bridge	121020072003074	12	102	F	0720	10	03	074	SH 249 NBFR	Three Simple Span Prestres	WILLOW CREEK	2.10 MI S OF FM 2920	B
1077	Bridge	121020100501005	12	102	F	1005	10	01	005	FM 525	3 - Simple Span Prestresse	GREENS BAYOU	3.5 MI E OF IH 45	B
1078	Bridge	121020294102001	12	102	F	2941	10	02	001	FM 2920	Six Simple Spans Reinforce	WILLOW CREEK	2.2 MI SE OF FM 2978	B
1079	Bridge	121020325602006	12	102	F	3256	10	02	006	BW 8 EBFR	7 - Simple Span Prestresse	GREENS BAYOU	1 MI W OF JFK BLVD	B
1080	Bridge	121020325602007	12	102	F	3256	10	02	007	BW 8 WBFR	7 - Simple Span Prestresse	GREENS BAYOU	1 MI N OF JFK BLVD	B
1081	Bridge	121020325602082	12	102	F	3256	10	02	082	BW 8 WB FR	3 Simple Span P.S. Concre	GARNERS BAYOU	3.78 MI E OF US 59	B
1082	Bridge	121020325602083	12	102	F	3256	10	02	083	BW 8 EB FR	3 - Simple Span P.S. Conci	GARNERS BAYOU	3.75 MI E OF US 59	B
1083	Bridge	121020325602099	12	102	F	3256	10	02	099	BW 8 WBFR	5 - Simple Span Prestresse	GREENS BAYOU	1.5 MI E OF ANTOINE	B
1084	Bridge	121020325602100	12	102	F	3256	10	02	100	BW 8 EBFR	5 - Simple Span Prestresse	GREENS BAYOU	1.5 MI E OF ANTOINE	B
1085	Bridge	121020325602101	12	102	F	3256	10	02	101	BW 8 EBFR	5 - Simple Span Prestresse	GREENS BAYOU	1.9 MI E OF ANTOINE	B
1086	Bridge	121020325602102	12	102	F	3256	10	02	102	BW 8 WBFR	5 - Simple Span Prestresse	GREENS BAYOU	1.9 MI E OF ANTOINE	B
1087	Bridge	121020325602105	12	102	F	3256	10	02	105	BW 8 WBML	3 - Simple Span Prestresse	GREENS BAYOU	.5 MI E OF ALDINE W F	B
1088	Bridge	121020325602106	12	102	F	3256	10	02	106	BW 8 EBML	3 - Simple Span Prestresse	GREENS BAYOU	.5 MI E OF ALDINE W F	B
1089	Bridge	121700011004118	12	170	f	0110	25	04	118	IH 45 SBFR	8 Span (3 Cont. Steel Girde	SPRING CR	AT HARRIS C/L	B
1090	Bridge	121700011004119	12	170	f	0110	25	04	119	IH 45 SBML	8 Span (3 Cont. Steel Girde	SPRING CR	AT HARRIS C/L	B
1091	Bridge	121700011004120	12	170	f	0110	25	04	120	IH 45 NBML	8 Span (3 Cont. Steel Girde	SPRING CR	AT HARRIS C/L	B
1092	Bridge	121700011004121	12	170	f	0110	25	04	121	IH 45 NBFR	8 Span (3 Cont. Steel Girde	SPRING CR	AT HARRIS C/L	B
1093	Bridge	121700011004122	12	170	f	0110	25	04	122	IH 45 SBFR	Three Simple Span Prestres	SPRING CR REL	0.2 MI N OF HARRIS C	B
1094	Bridge	121700011004165	12	170	f	0110	25	04	165	IH 45 SBFR	11- Simple Span P. S. Con	W FK SAN JAC RI N	0.90 MI N OF FM 1488	B
1095	Bridge	121700011004166	12	170	f	0110	25	04	166	IH 45 SBFR	3 - Cont. Span Steel Girder	W FK SAN JACINTO	0.65 MI N OF FM 1488	B
1096	Bridge	121700011004167	12	170	f	0110	25	04	167	IH 45 SBFR	Four Simple Span Prestres	W FK SAN JACINTO	0.20 MI N OF FM 1488	B
1097	Bridge	121700011004168	12	170	f	0110	25	04	168	IH 45 NBFR	11- Simple Span P. S. Con	W FK SAN JAC RI N	0.90 MI N OF FM 1488	B
1098	Bridge	121700011004169	12	170	f	0110	25	04	169	IH 45 NBFR	3- Cont. Span Steel Girder	W FK SAN JACINTO	0.65 MI N OF FM 1488	B
1099	Bridge	121700011004170	12	170	f	0110	25	04	170	IH 45 NBFR	Four Simple Span Prestres	W FK SAN JACINTO	0.20 MI N OF FM 1488	B
1100	Bridge	121700017705119	12	170	f	0177	05	05	119	CREEKWOOD LN	3 Simple Span Reinforced C	PEACH CREEK	1.20 MI N OF SH 242	B
1101	Bridge	121700072002033	12	170	f	0720	05	02	033	SH 249 SB	26 Simple Span Reinforced	SPRING CREEK	4.35 MI SE OF FM 149	B
1102	Bridge	121700072002042	12	170	f	0720	05	02	042	FM 149	4 -Simple Span Reinforced	LAKE CREEK	7.50 MI S OF SH 105	B
1103	Bridge	121700106201011	12	170	f	1062	05	01	011	FM 1485	7 Simple Span Reinforced C	E FORK SAN JACINT	5.4 MI E OF LP 494	B
1104	Bridge	121700141603020	12	170	f	1416	05	03	020	FM 1486	Three Simple Span Prestres	MILL CREEK	1.50 MI N OF FM 1774	B
1105	Bridge	121700305002001	12	170	f	3050	05	02	001	FM 2978	24 -Simple Span Reinforced	SPRING CREEK	6.80 MI S OF FM 1488	B

To Close or Not to Close?

Lesson No. 7 – Be Willing to Make Difficult Decisions

- Cannot afford to be overly conservative in assessing damage.
- Closing bridges, especially during emergencies, can have serious ramifications to traveling public and emergency responders.
- Close when appropriate, but don't play it too safe. This is a difficult thing for many engineers.

Lesson No. 7 – Be Willing to Make Difficult Decisions

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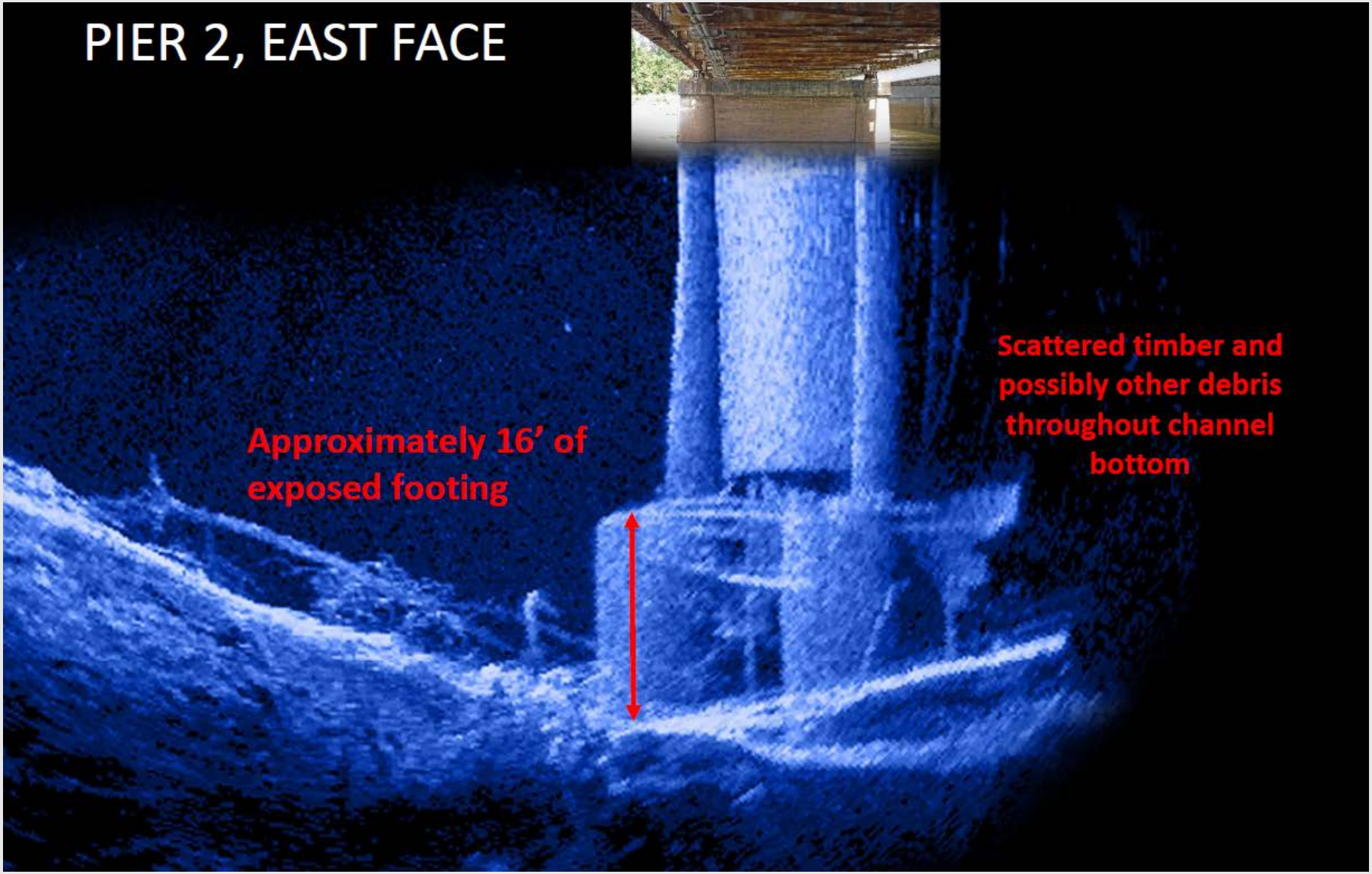
Lesson No. 8 – Effective Scour Evaluation

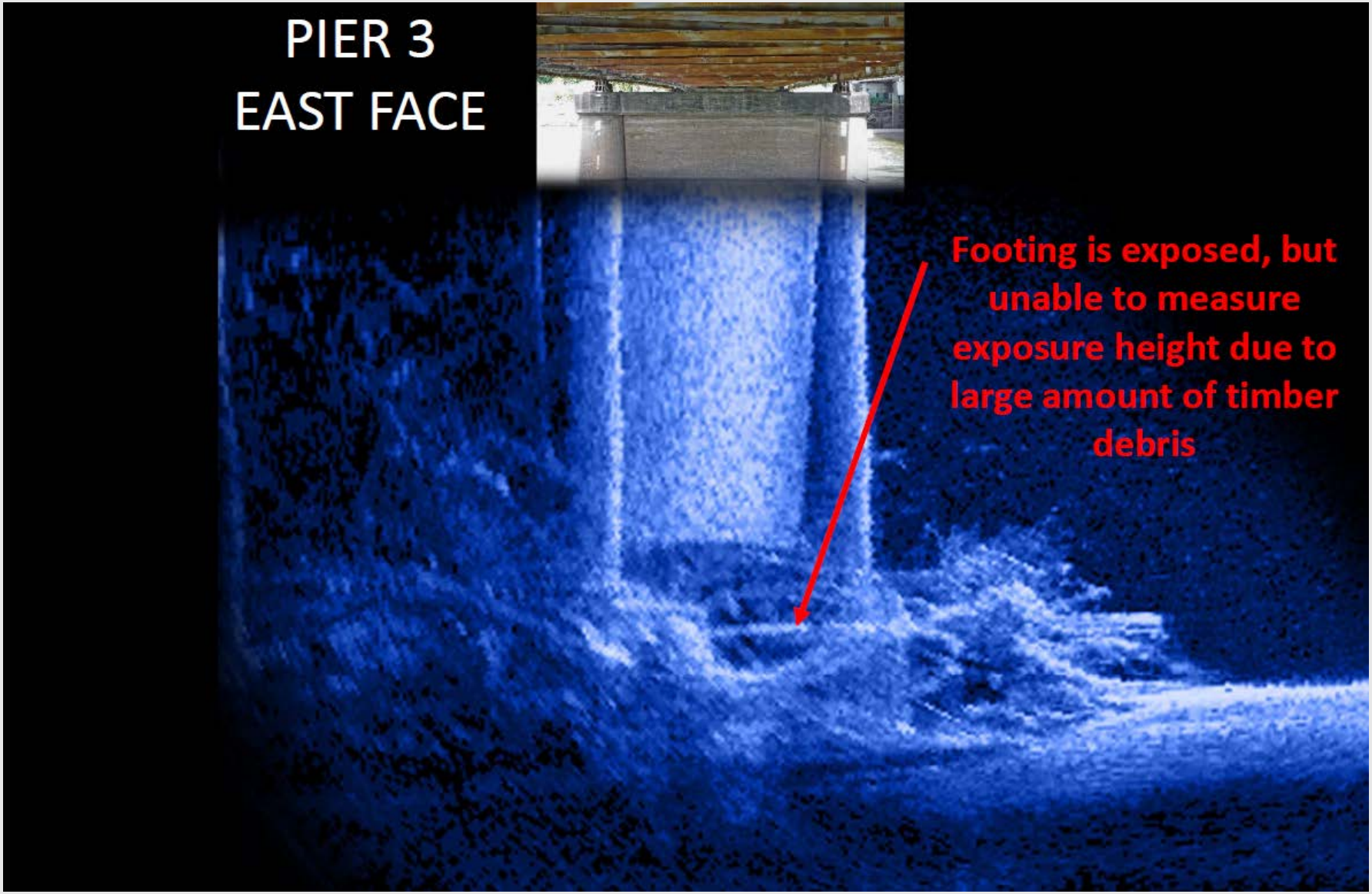
- Ensure that scour evaluations are performed at the appropriate time.
  - The second scour event, when water recedes, can be more severe than the initial event.
- Oftentimes unable to get divers in the water.
- Depth Detection Devices
- Expanded Use of Underwater Imaging/Side Scan Sonar

Pier 10 – North Face

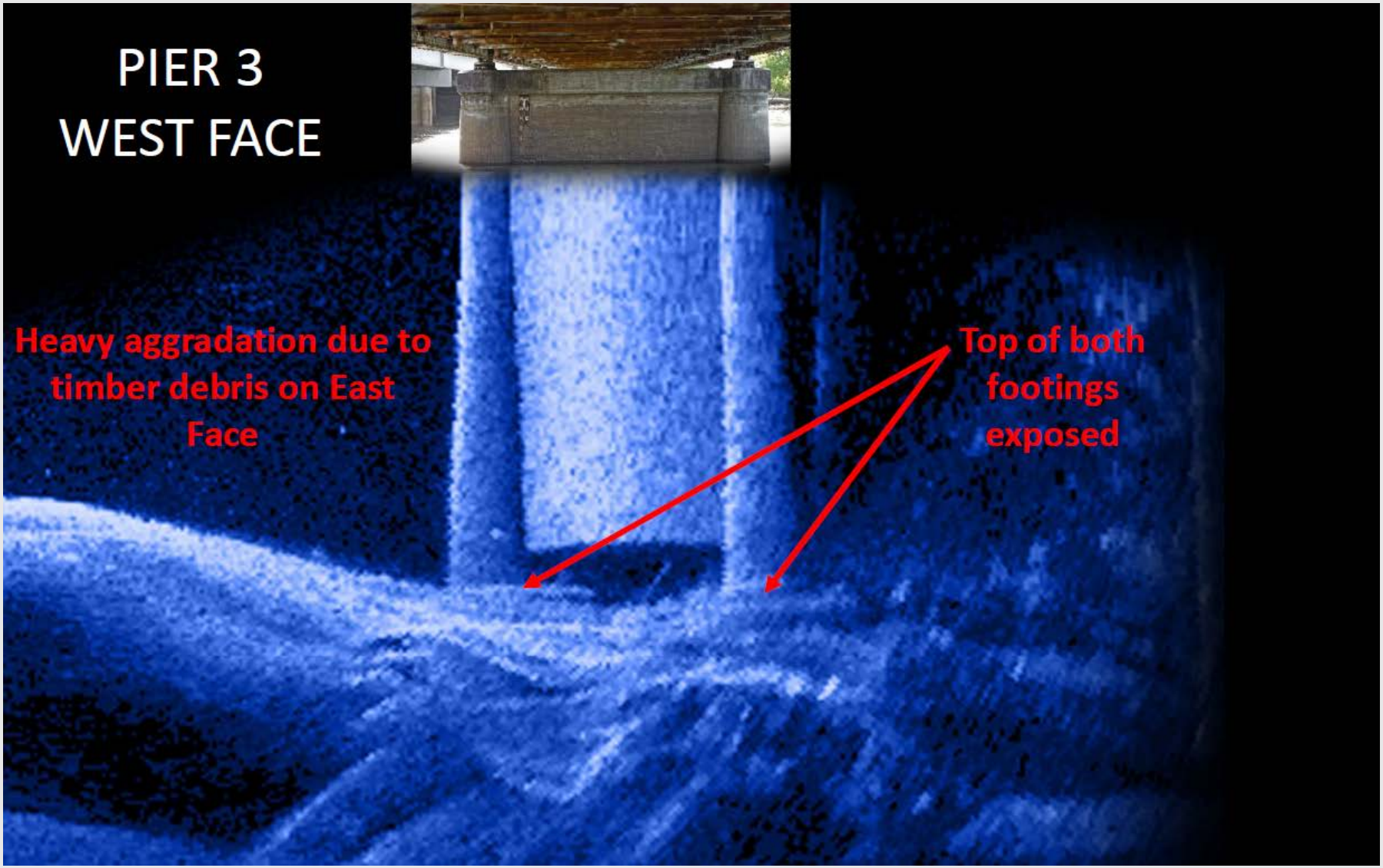
Side Scan Sonar



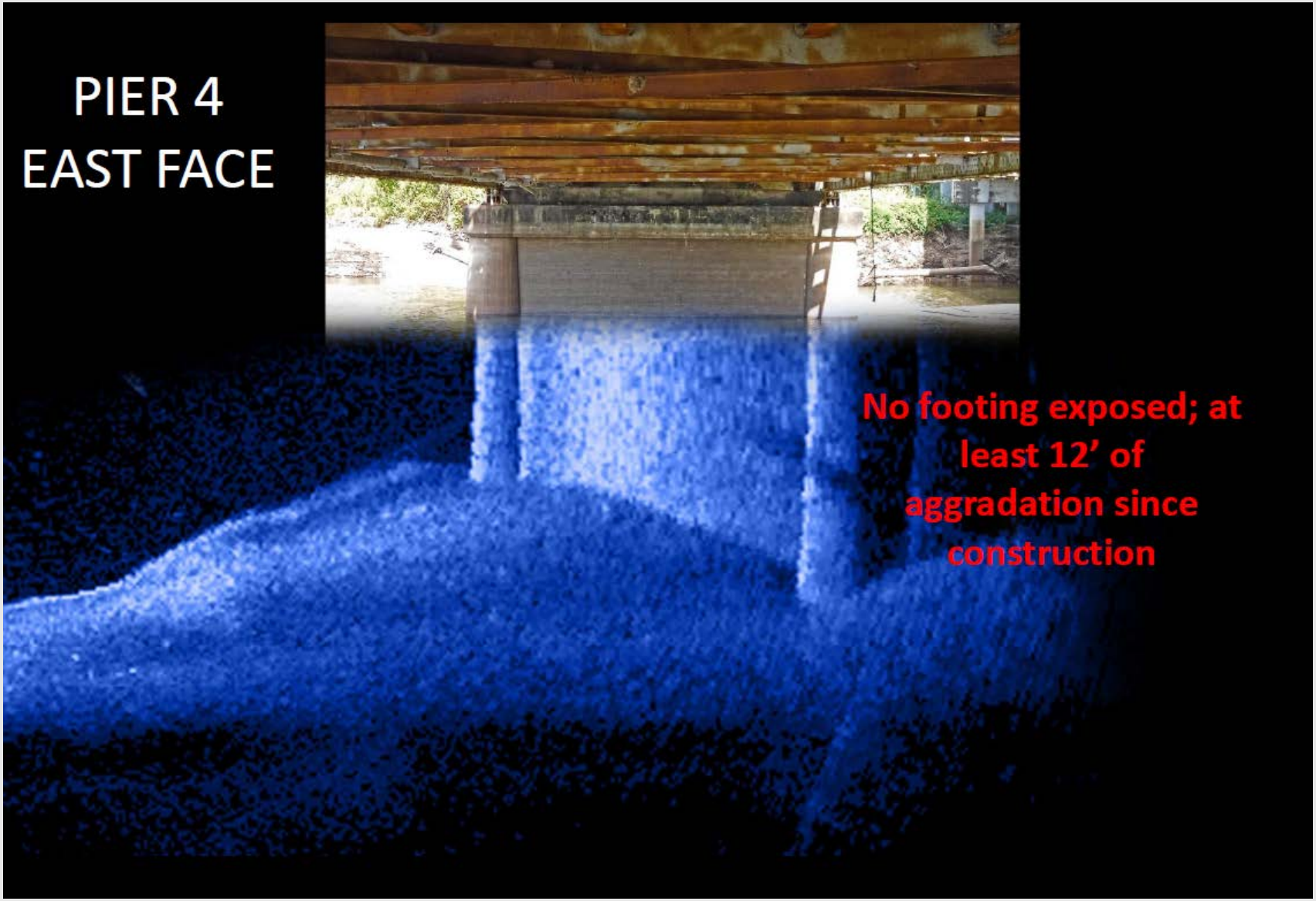
Side Scan Sonar



Side Scan Sonar



Side Scan Sonar



Lesson No. 9 – Bridge Approaches REALLY Don't Like Water

- As water levels rise and debris clogs hydraulic openings, water moves to the bridge approaches.
- For approaches built well out of the main channels there are frequently no effective erosion controls in place.

Lesson No. 9 – Bridge Approaches REALLY Don't Like Water

But the Bridge Survived!

That's an abutment, not a bent.

Bank Erosion

Erosion

The concrete aprons didn't work.

Erosion

Lesson No. 10 – Damage Isn't Always Obvious

- Look under all bridges along flooded waterways – damage (sometimes even severe damage) isn't always obvious from the roadway.

Lesson No. 10 – Damage Isn't Always Obvious

Debris

- Debris is a major problem with no easy solutions.
- Particularly problematic where older bridges with short spans have lots of columns and other superstructure elements to collect debris.
- What NOT to do? Seems obvious but we've seen it happen:
  - DO NOT try to set the debris on fire.
  - DO NOT pick up debris from one side of the bridge and place it in the waterway on the other side of the bridge.

Debris

Debris

Debris

Equipment and Tools

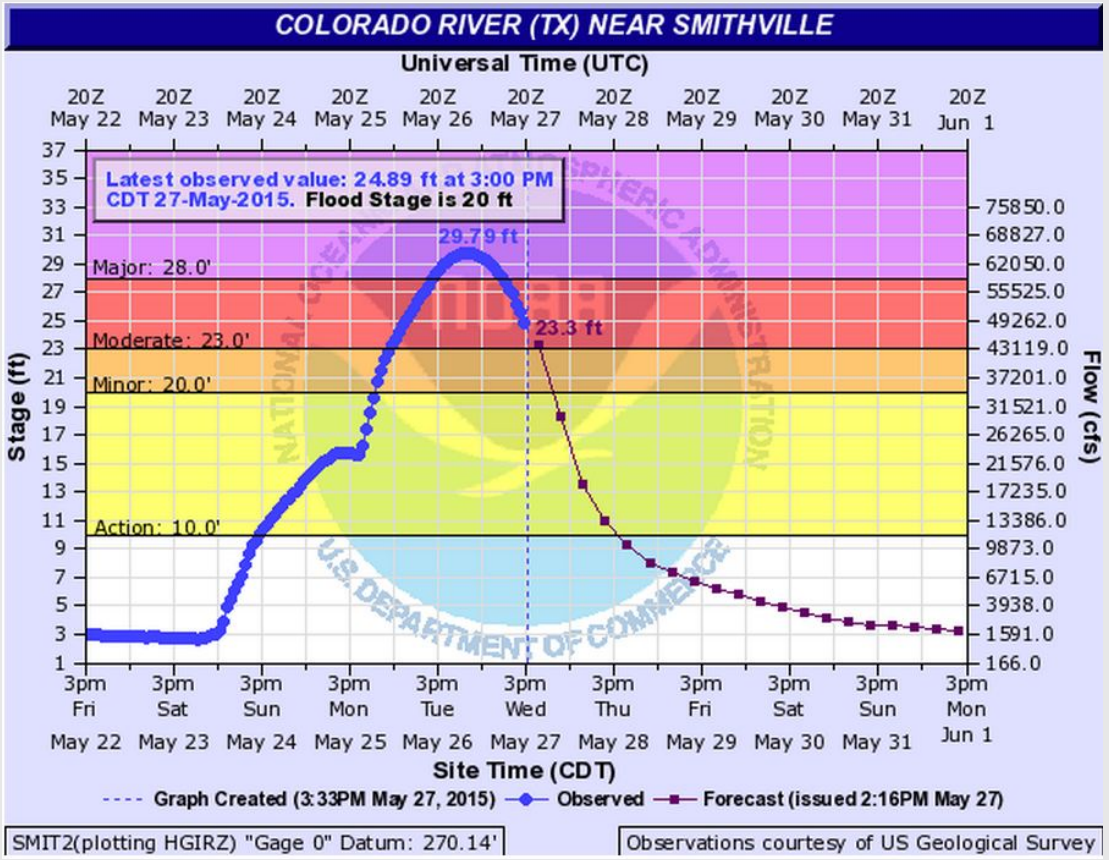
- Keep Equipment Readily Available.
  - Depth-Detection Devices
  - Weighted Tapes
  - GPS-Enabled Cameras (FEMA Reimbursement)
  - Safety Equipment and Other Standard Tools
- Ensure that out of date equipment is replaced.
- Make sure there are sufficient numbers of personnel that know how to use the equipment.

Design Considerations

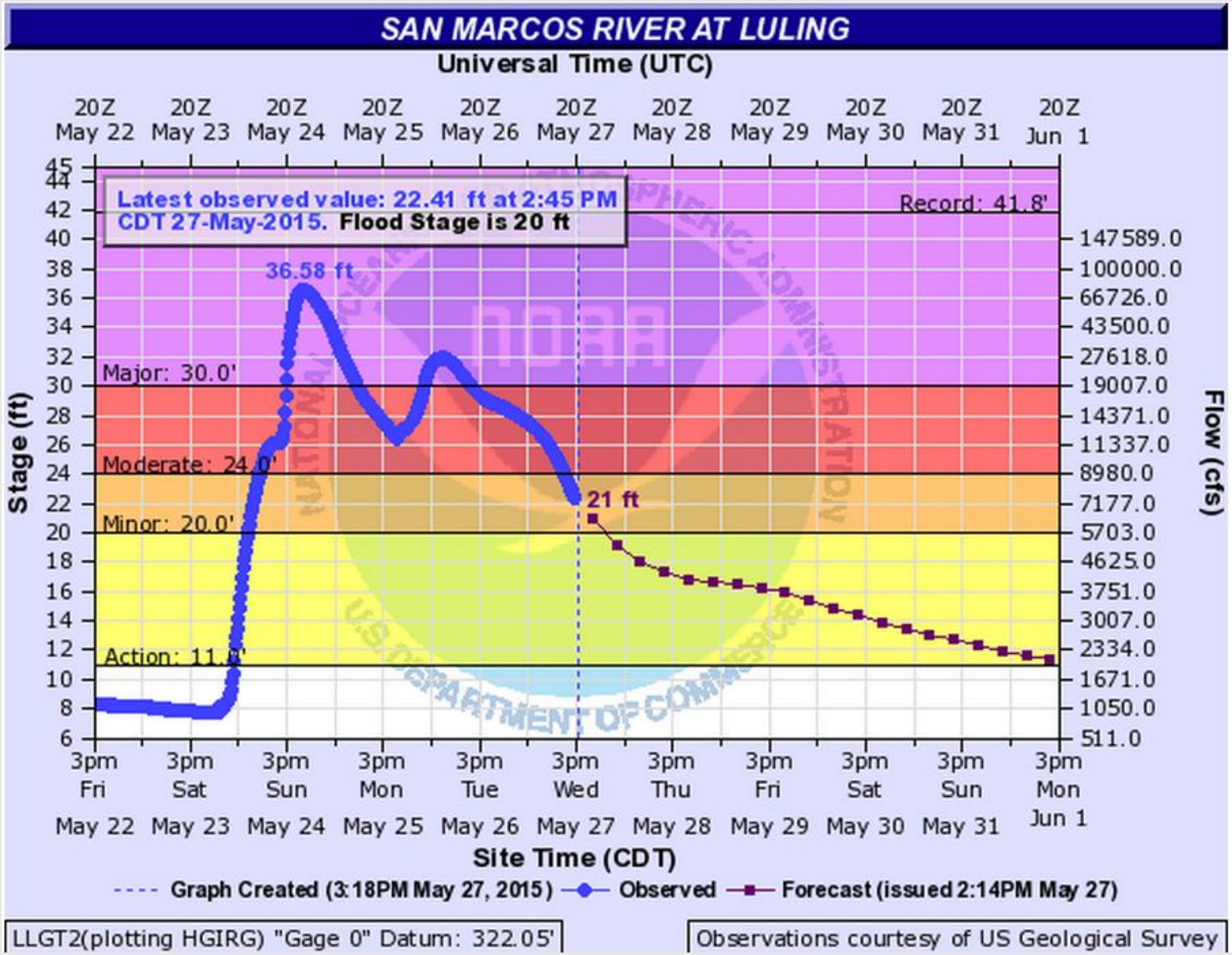
- Shear keys = Good.
  - TxDOT is using them on essentially any waterway where the superstructure could be flooded.
- Shear Walls = Not Always So Good.
  - Effective as long as flow is parallel to walls but that can change drastically over the life of a bridge or even during a single event. They can become debris catchers.
- Tie beams = Usually Good.
  - Tie beams have been extremely effective in limiting distress and don't catch nearly as much debris as the walls.

Hydrographs

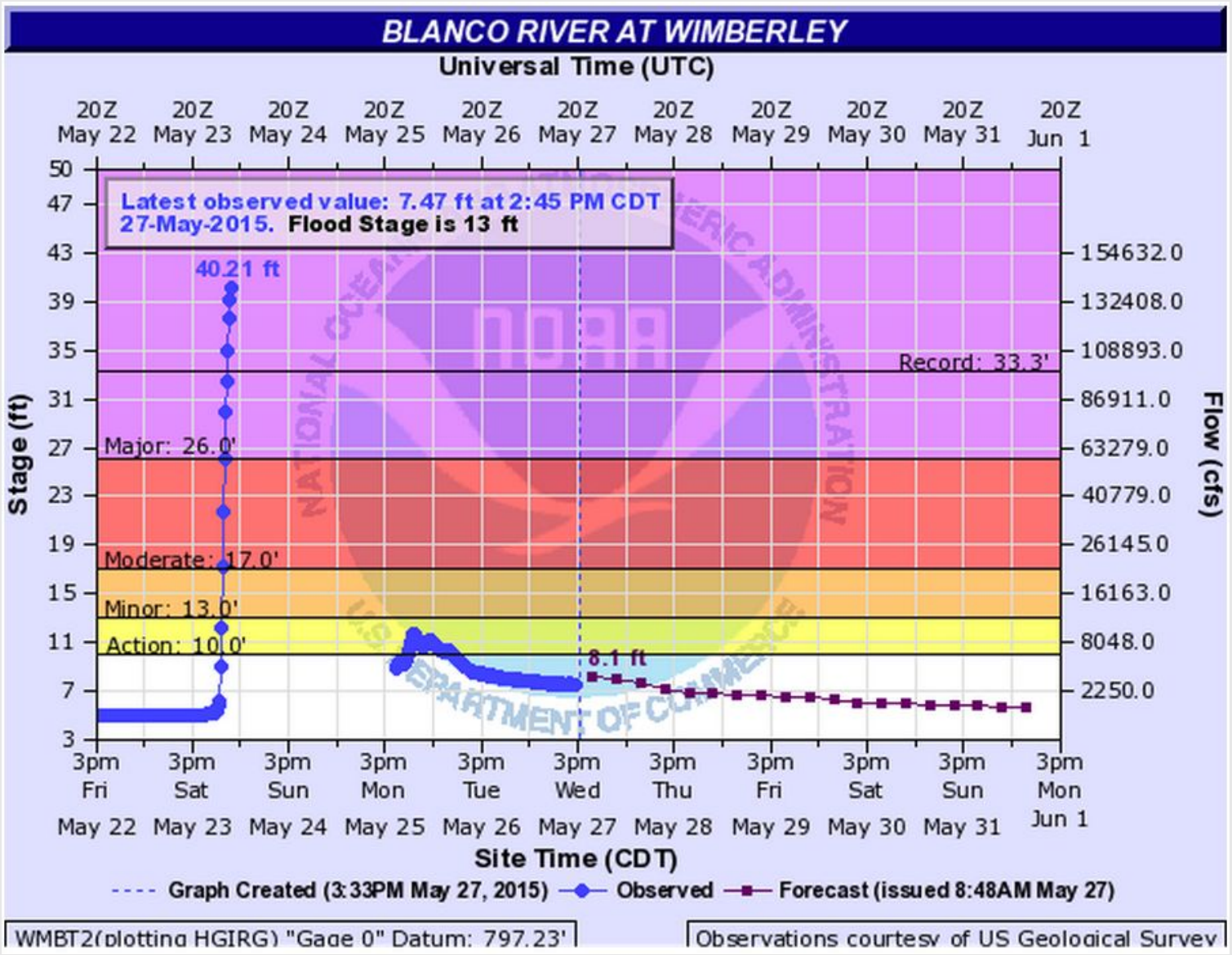
- Hydrographs are an extremely powerful and useful tool.
- TxDOT is currently working with the National Weather Service and USGS to vastly expand the number of gages installed on bridges over waterways that are susceptible to flooding.



Hydrographs



Hydrographs



Additional Lessons

- Geography Matters
  - In the end, we had surprisingly little bridge damage in Houston and other areas of East Texas where flooding was prolonged and severe, but areas are generally flat and allow for wide flood plains.
  - Damage to structures was far more severe in rocky hill country.
- Maintain inventory of temporary bridges, and make sure maintenance crews know how to install them.
- Many consultants reached out to us offering assistance. Take them up on it!
- Maintain list of contractors that can quickly mobilize to get damaged structures reopened as quickly as possible.

The Aftermath

- Develop standard procedures that allow for rapid design, plan preparation, permitting, bidding, and construction.
- When feasible, work with maintenance crews to develop solutions that can be implemented in-house.

Truss Bridge at Sabine River (Repeat Offender)

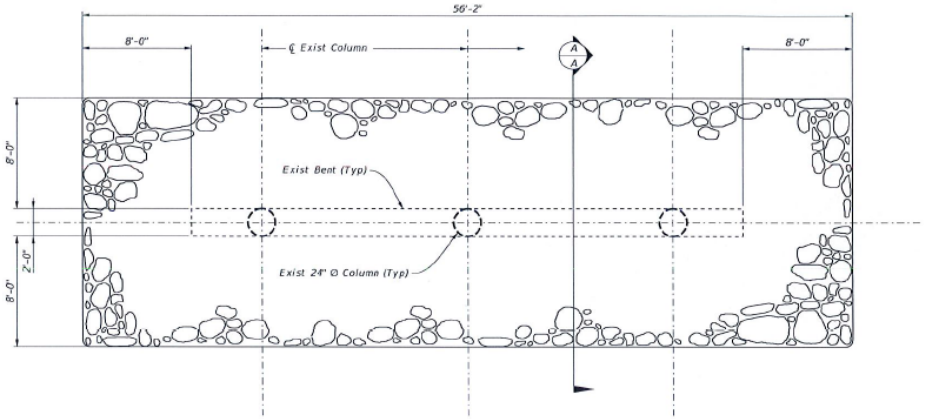
Truss Bridge at Sabine River

Truss Bridge at Sabine River

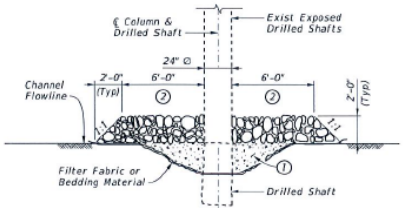
Simplified Scour Repair

Simplified Scour Repair – Load Test

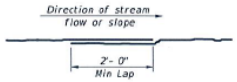
Simplified Scour Repair



PLAN VIEW - COLUMN ON DRILLED SHAFT



SECTION A-A



FILTER FABRIC LAP

NOTES:

① Scour damage may be filled with a material having a gradation equal to the bedding material but will not be more coarse than stone protection being placed, as specified in Item 432, "RIPRAP", approval of the engineer is required.

② Surface of stone protection will slope away from the bent, but not to exceed 2:1.

GENERAL NOTES:

Refer to Item 432 for the gradation of stone protection and bedding material, alternate gradations are not permitted. Placement of stone protection will not be performed in a manner that will cause segregation such as dumping or pushing material in place.

See Layout for limits and thickness of riprap specified. All work will be performed in accordance with Item 432.

The bridge should remain closed until all scour countermeasures are in place.

Placement of Stone Protection is a temporary remedial measure to get this structure open to traffic while it is being programmed for replacement.

Since this is a temporary remedial measure, it is the responsibility of the District to monitor the condition of the Stone Protection after a flood event.

If additional scour occurs, the District needs to close the bridge and notify the Engineer of Record to determine if the bridge is safe to be re-opened.

Complete debris removal from the channel and adjacent upstream area is required.

Upon completion of placement of Stone Protection, spray paint the top of the rocks near the exposed drilled shafts and the perimeter of all exposed drilled shafts (at each Bent) so that any additional scour in the future can be easily noticed.

Filter Fabric will be Type 2 (6 oz/sy) as per DMS 6200.

SUMMARY OF ESTIMATED QUANTITIES

BID ITEM / BID CODE	0432 6033	7000 6002
BID ITEM DESCRIPTION / BRIDGE ELEMENT	RIPRAP (STONE PROTECTION) (18 IN)	REML & DISPL DRIFTWOOD & DEBRIS
	CY	LS
Bents 5, 6, 7, 8	300	1
OVERALL TOTALS:	300	1

STATE OF TEXAS · MARIE MASTERS FISK · 95790 · LICENSED · PROFESSIONAL ENGINEER

Marie Masters Fisk 6/9/16

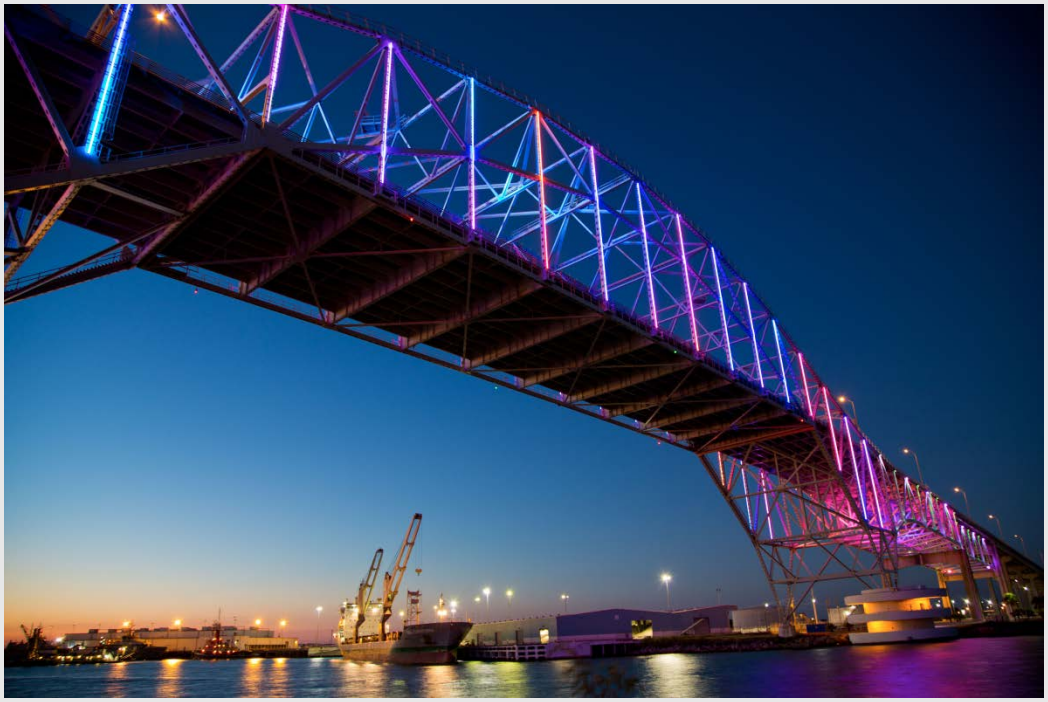
Texas Department of Transportation — Bridge Division

FLEXIBLE RIPRAP STONE PROTECTION

POND CREEK BRIDGE

FILE: sp087503.dgn	DN: MMF	CK: GC	DW: MRM-JBS	CK: MMF
©TxDOT JUNE 2016	CONT	SECT	JOB	HIGHWAY
REVISIONS				SH 53
	DIST	COUNTY		SHEET NO.
	WAC	FALLS		

Simplified Scour Repair



QUESTIONS?

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