Roadside Safety Pooled Fund Program Research Update

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Roadside Safety Pooled Fund Program – Fall Meeting 2018
Denver, Colorado
September 18th 2018

On-going Projects

- Engineering Support Services and Recommendations for Roadside Safety Issues/Problems for Member States
- MASH TL3 T-Intersection (Short Radius) System Design Variations
- MASH Testing of W-beam Guardrail in Concrete Mow-Strip
- Testing of Midwest Guardrail Systems with Reduced Post Spacing for MASH Compliance
- Testing and Evaluation of MGS System w/ Critical Flare at MASH TL3 Conditions
- Thrie/W-Beam/Tubular Barrier Gap Rail for MASH TL-3
- Placement of Guardrail on Slopes Phase IV: MASH TL-3 Testing of Guardrail on 1:1 Slope
- Accommodating Inlets with Transitions (TL-3)

Engineering Support Services and Recommendations for Roadside Safety Issues/Problems for Member States

TTI Researcher: William Williams

Technical Representative: James Danila (MassDOT)

Engineering Support Services and Recommendations for Roadside Safety Issues/Problems for Member States

- Problem
  - There is a need for an assessment of roadside safety barrier systems and hardware without necessarily performing full-scale crash testing.
  - The objective of this research is to provide engineering support services and recommendations for those roadside safety barrier hardware and barrier systems that are prioritized/requested by pooled fund member states

Engineering Support Services and Recommendations for Roadside Safety Issues/Problems for Member States

- Work Plan
  - Task 1 – Gathering of Information
    - Prioritize projects/needs from pooled states
    - Conduct literature review and review past crash testing
    - Collaborate with other testing houses on
  - Task 2 – Evaluation and Assessment
    - Perform engineering calculations as necessary
    - Use resent research, NCHRP 22-07, recent MASH crash testing
    - Provide assessment of the barrier/hardware system
      - Use FHWA Eligibility Form Approach
      - Provide justification why certain crash tests do not need to be performed
      - … or provide justification that warrants crash testing

Engineering Support Services and Recommendations for Roadside Safety Issues/Problems for Member States

- Current Priority Work List:
  - 1.) MGS median barrier (TL-3) – 12” Blockouts or no blockouts? Further clarification needed.
  - 2.) Does 32” F-shape CIP barrier Meet MASHTL-3? – Currently working on this task. We have this near complete and MASH compliant.
  - 3.) 18’9” Thrie Beam Transition (TL-3) – Currently working on this task. We have collected information from MwRSF and others.
  - 4.) Using a transition from guardrail to concrete shape different than crash tested – Vertical to sloped faced connection (?)
  - 5.) Michigan temporary concrete barrier limited deflection – Further definition on barrier design needed
  - 6.) Concrete shape transitions (transitioning from different shapes) – currently gathering information on this task.

MASH TL3 T-Intersection (Short Radius) System Design Variations

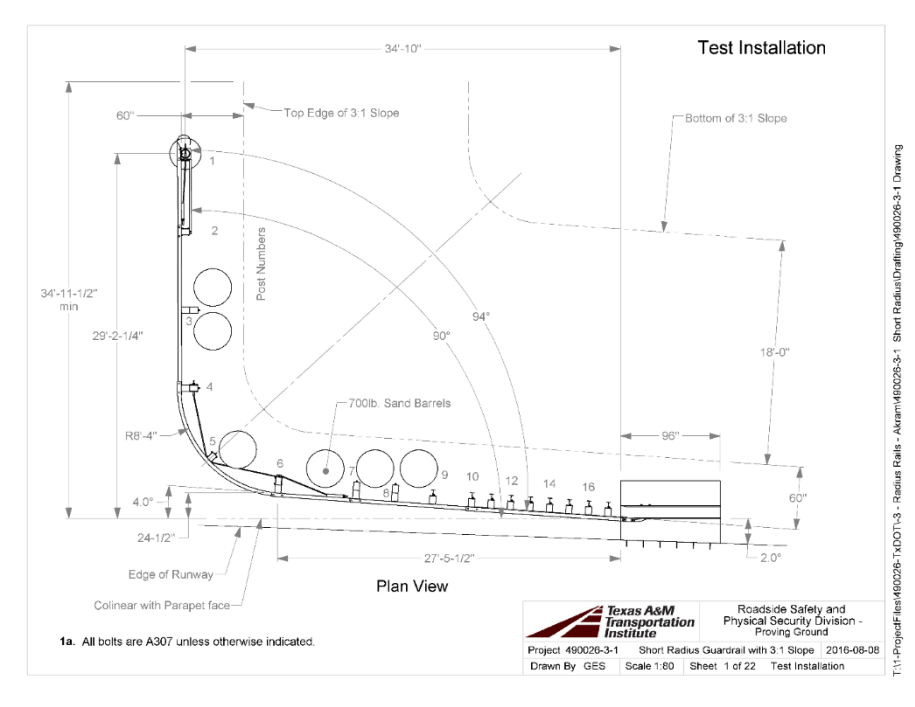
TTI Researcher: Akram Abu-Odeh

Technical Representative: Christopher Lindsey (TxDOT)

T-intersection Design Variations

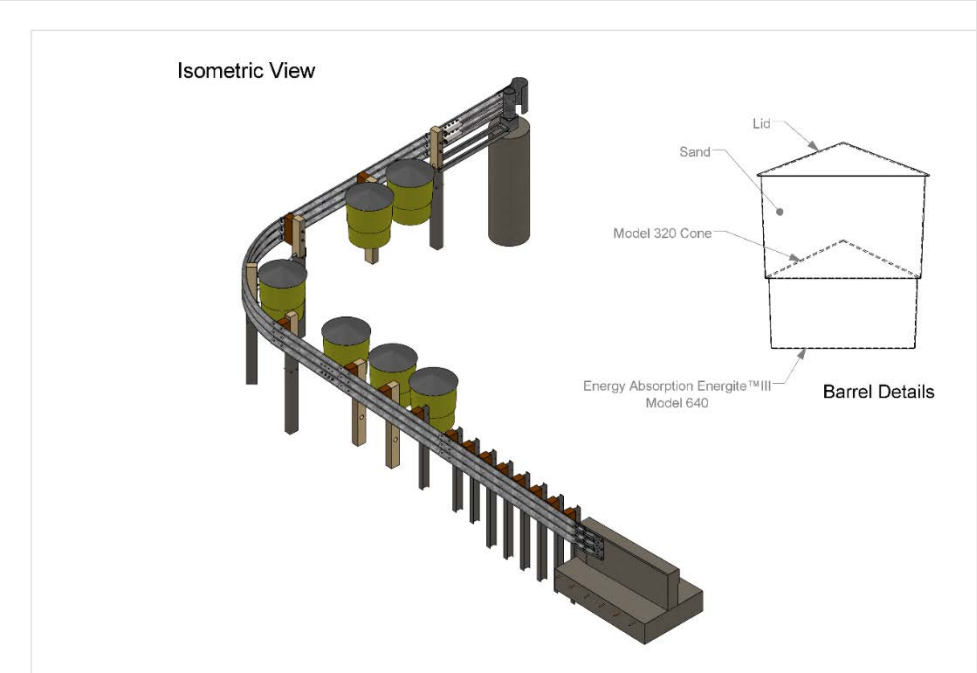
- Use design elements from successful studies (TxDOT, TL-3 and TL-2)
  - Keep small foot print short radius with 3TO1 ditch
  - Goal for MASH TL-3
  - Use drums instead of barrels (still 700 lb sand/unit).
  - Account for secondary roadway.

TxDOT TL-3 System



- MASH TL-3
- All thrie-beam rail, Nose 8 ft 4 in radius
- Six 700 lb sand barrels

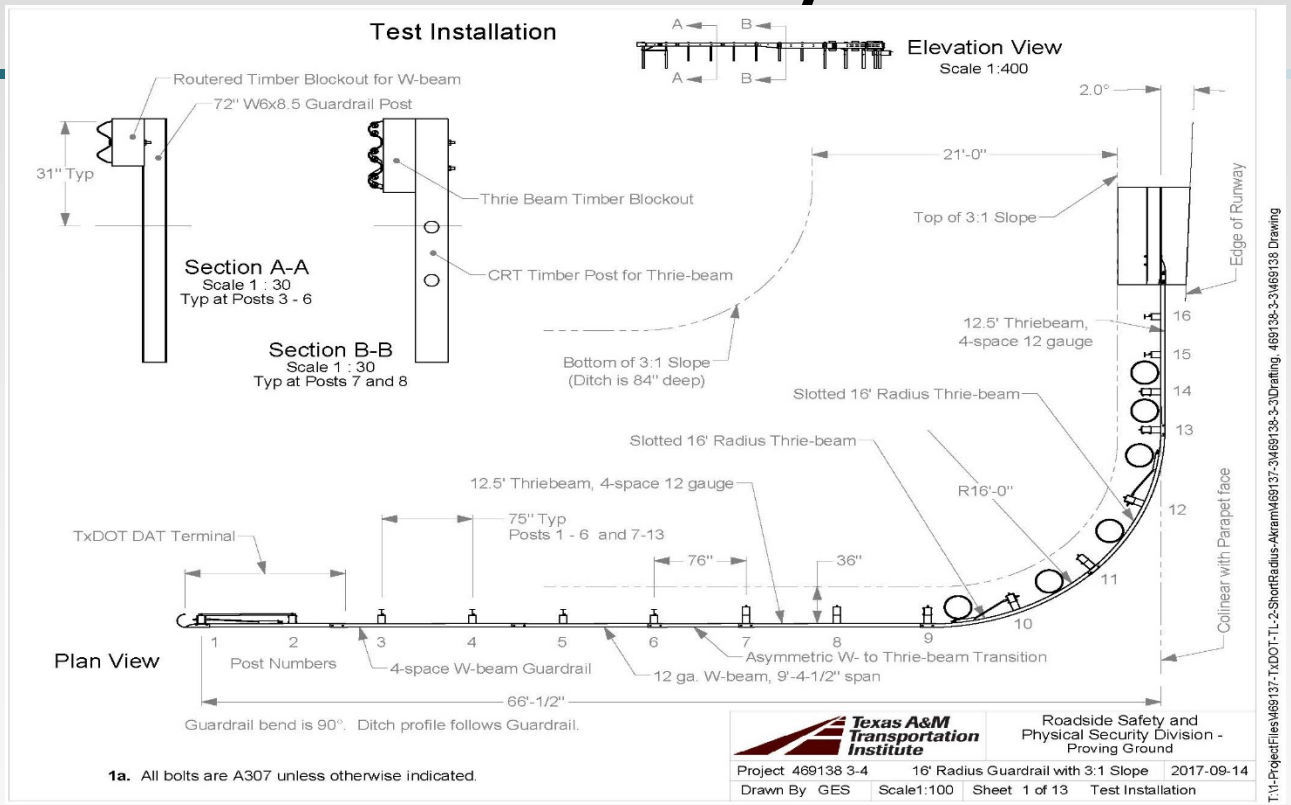
TxDOT TL-3 System (cont'd)



- Secondary driveway
- Rotating driveway anchor
- Five feet platform before the sloped ditch (3:1)

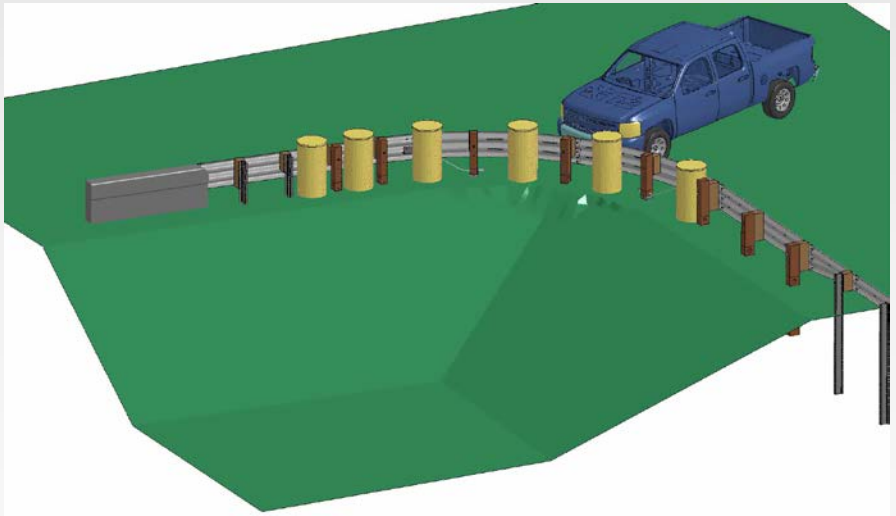
TxDOT TL-3 System (cont'd)

TxDOT TL-2 System



- MASH TL-2
- All thrie-beam rail on primary and then transition to W-beam on secondary roadway
- Six 700 lb sand drums

TxDOT TL-2 System (cont'd)

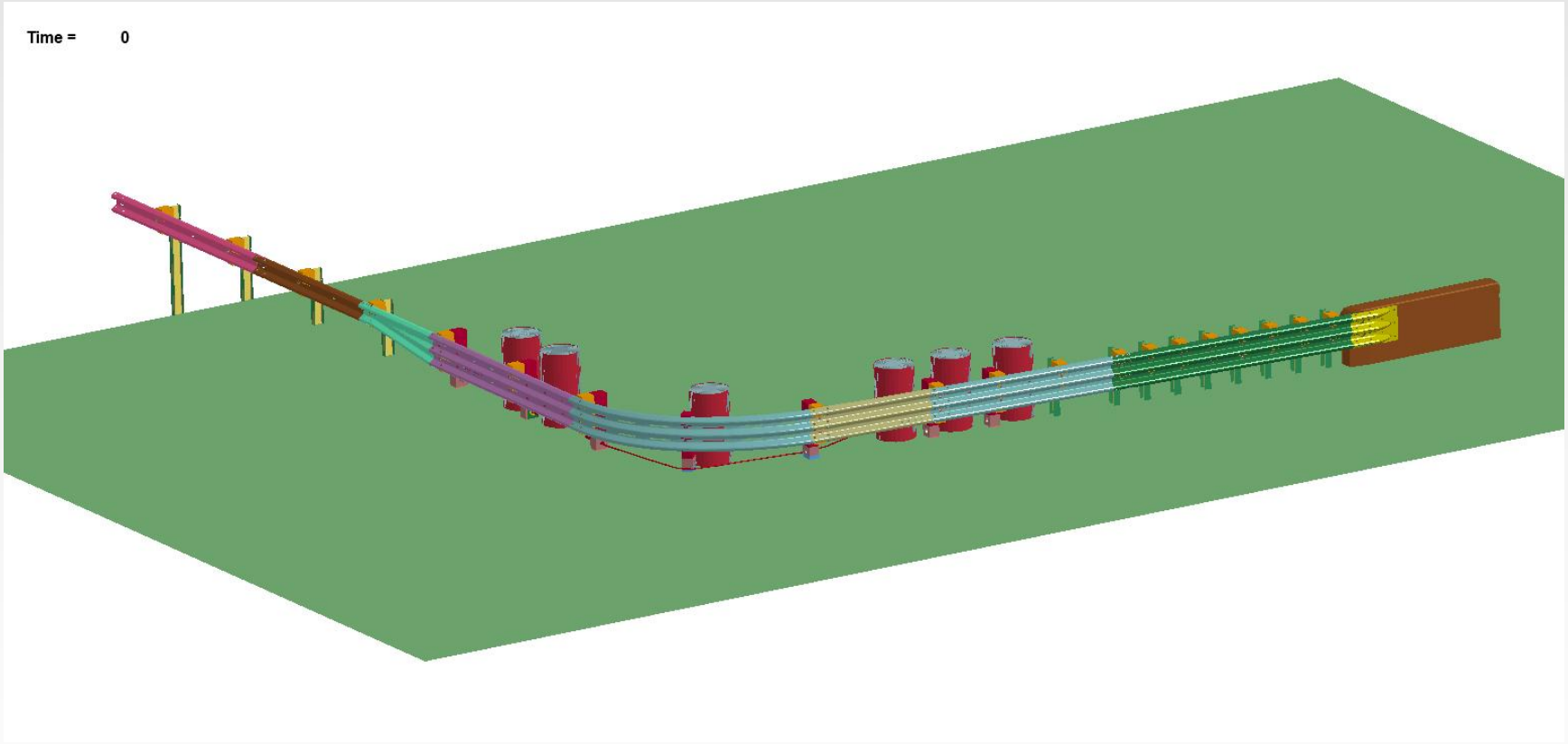


- Nose 16 ft radius
- Three feet of platform then sloped ditch (3:1)
- Terminal on secondary roadway

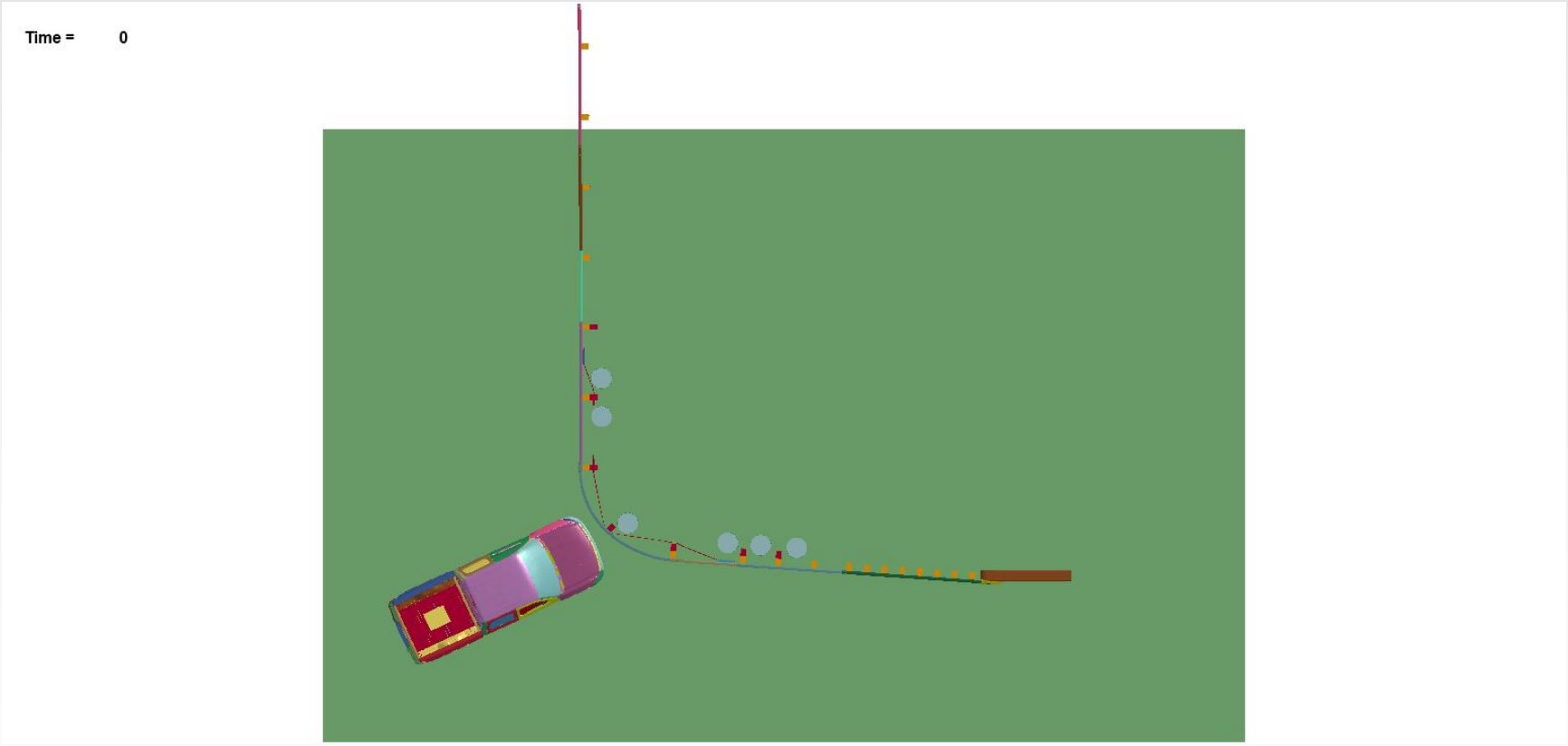
Pool Fund System

- MASH TL-3
- 8-ft 4-in nose radius
- Sand drums
- Three-foot platform
- Secondary roadway
- Thrie-beam on primary roadway becoming w-beam on secondary roadway using an asymmetric transition rail element

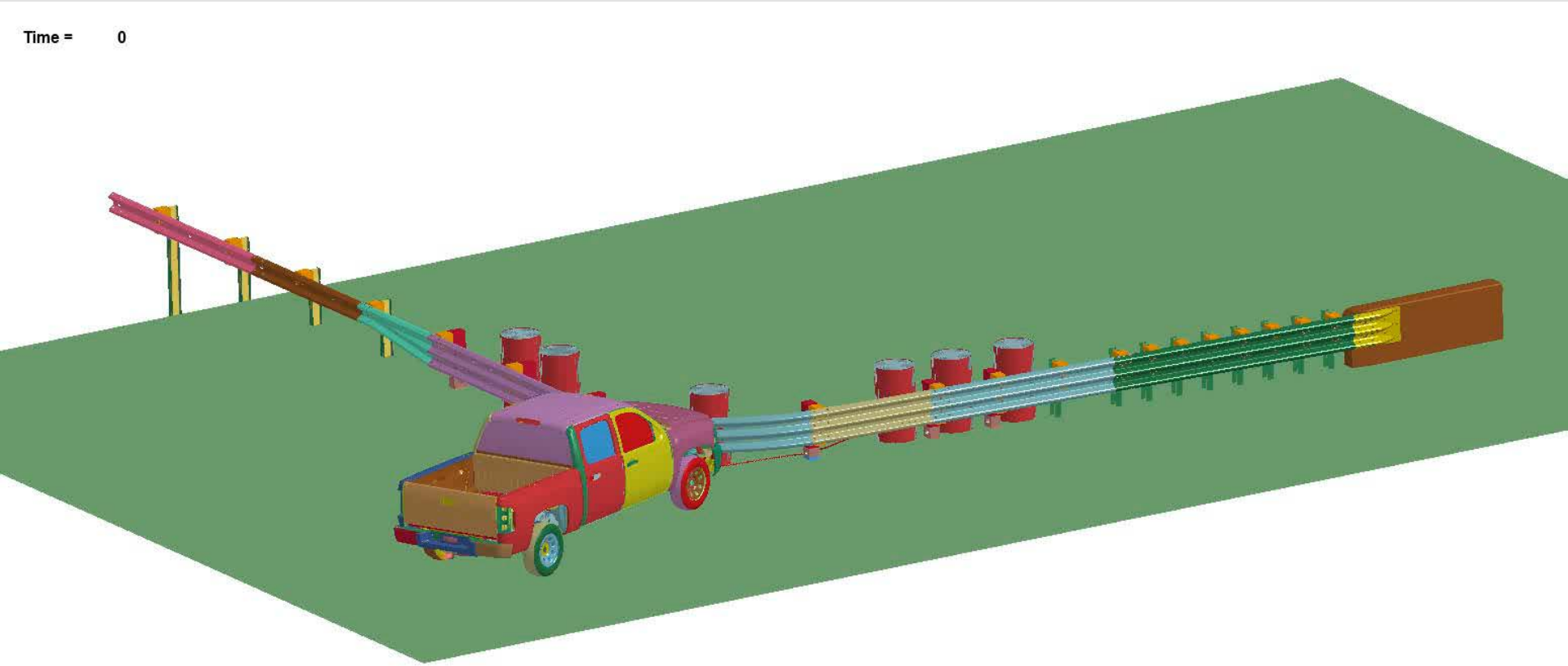
Pool Fund System (cont'd)



Pool Fund System (cont'd)



Pool Fund System (cont'd)



Upcoming Activities

- Simulating different ditch conditions
  - 3TO1 ditch (underway)
  - 2TO1 ditch if feasible

MASH Testing of W-beam Guardrail in Concrete Mow-Strip

TTI Researcher: Nauman Sheikh

Technical Representative: Michael Elle (MNDOT)

Guardrail in Concrete Mow-Strip

Objective:

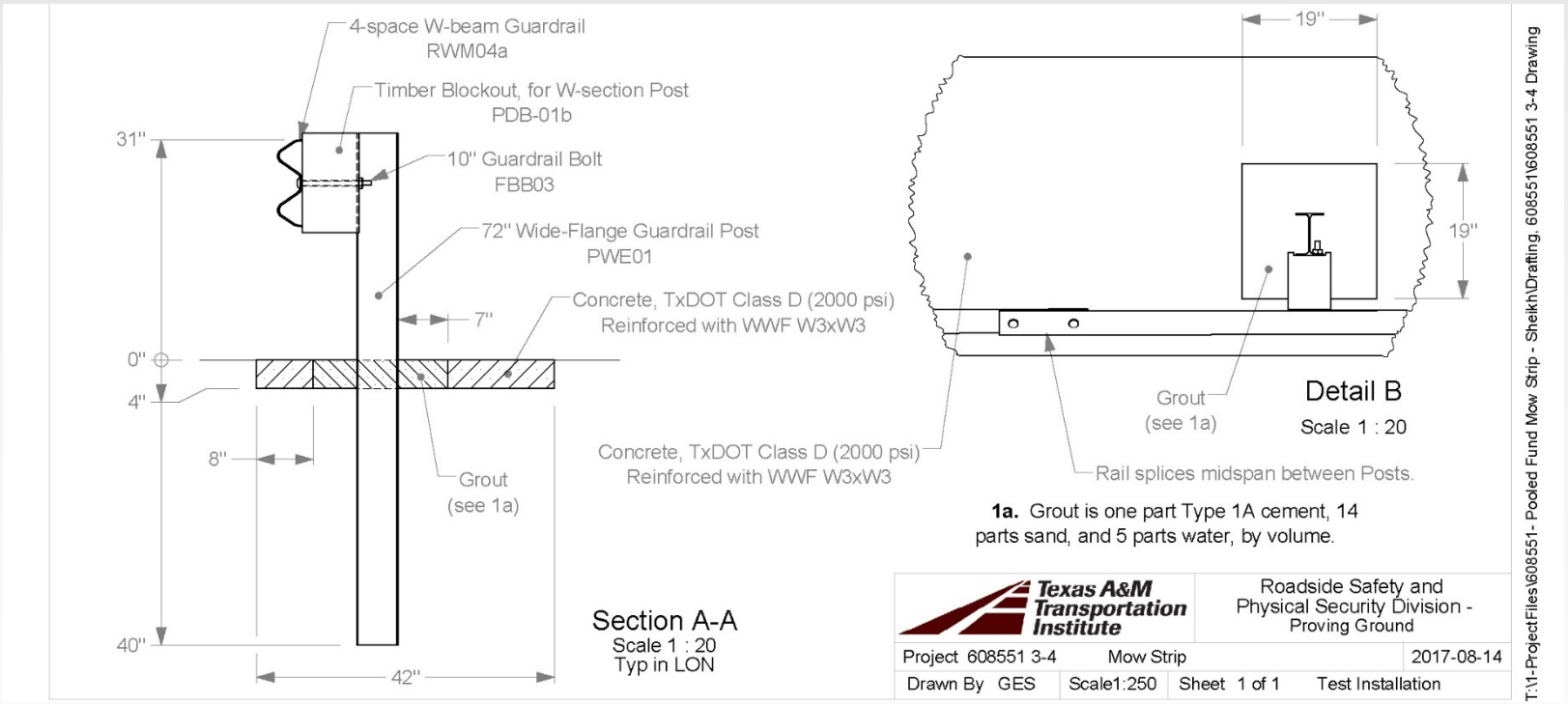
Determine MASH TL-3 compliance of the W-beam guardrail installed in concrete mow-strip

Scope:

- Steel post guardrail
  - Test 3-10 and Test 3-11
- Wood post guardrail
  - Test 3-10 and Test 3-11

Guardrail in Concrete Mow-Strip

Test Installation (Steel Post):



Guardrail in Concrete Mow-Strip

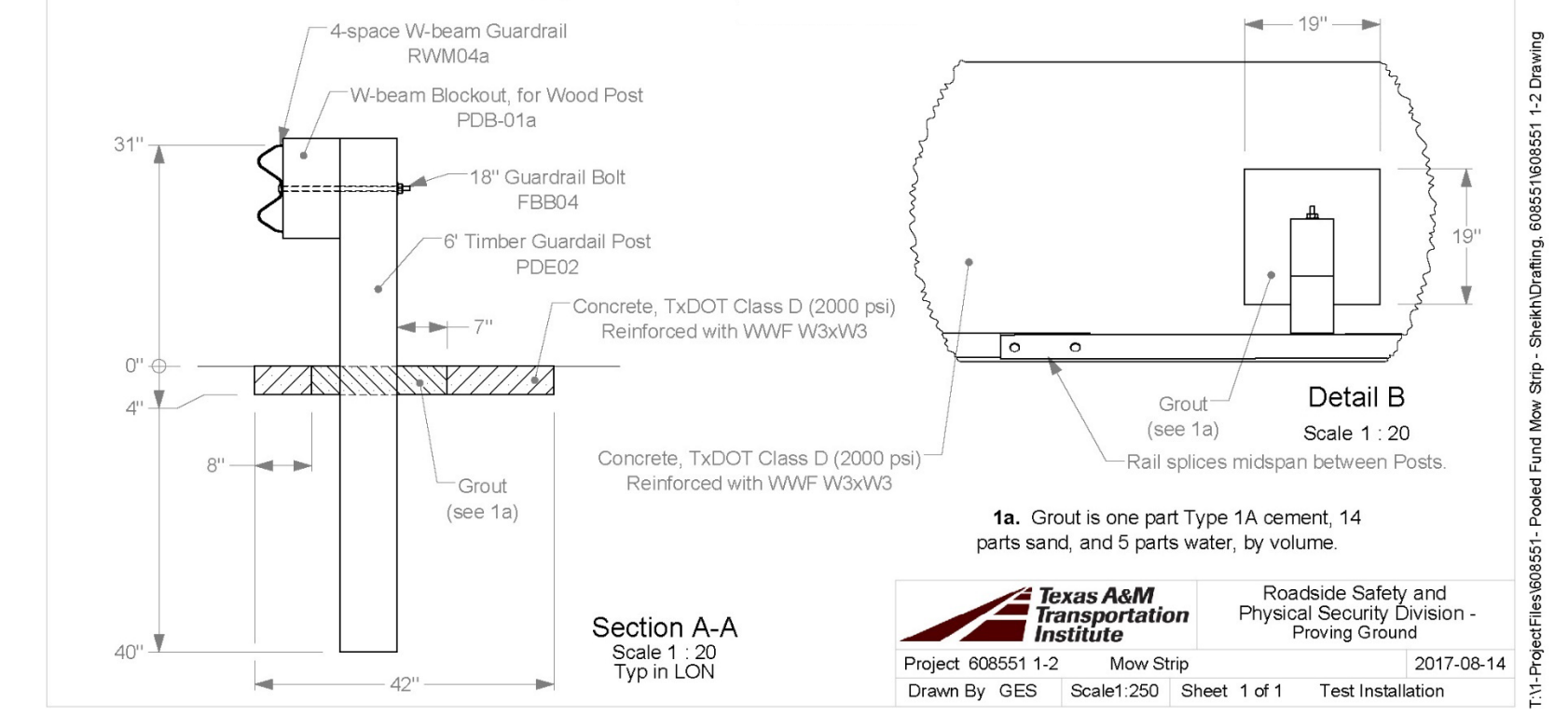
Test Installation (Steel Post):

181’-3” installation length (including terminals)

100’ concrete mow-strip in the center

Guardrail in Concrete Mow-Strip

Test Installation (Wood Post):



Guardrail in Concrete Mow-Strip

Test Installation (Wood Post):

Same installation and mow strip length as steel

Low-strength grout properties

- Specified as: 1 part Type 1A cement, 14 parts sand, and 5 parts water, by volume
- Achieves maximum strength approximately ranging from 120 psi to 200 psi

Guardrail in Concrete Mow-Strip

Steel Post (Test 3-10):

Guardrail in Concrete Mow-Strip

Steel Post (Test 3-11):

Guardrail in Concrete Mow-Strip

Results (Steel Post)

Max. deflection:
3-10: 27.4 dynamic / 17.0 perm.
3-11: 50.8 dynamic / 21.0 perm.

Both tests passed MASH

Guardrail in Concrete Mow-Strip

Wood Post (Test 3-10):

Guardrail in Concrete Mow-Strip

Wood Post (Test 3-11):

Guardrail in Concrete Mow-Strip

Results (Wood Post)

Max. deflection:
3-10: 27.4 dynamic / 17.0 perm.

Test 3-10 passed but 3-11 failed MASH

Guardrail in Concrete Mow-Strip

- Conclusion
  - The steel post system successfully passed MASH
  - The wood post system failed to pass MASH due to failure with pickup truck test
  - Current Status:
    - Additional Test 3-11 with wood post system is scheduled with reduced post embedment depth of 36 inches
      - Reducing post embedment may prevent sudden failure of wood posts, which may lead to a successful design

Testing of Midwest Guardrail Systems with Reduced Post Spacing for MASH Compliance

TTI Researcher: James Kovar

Technical Representative: Joe Hall (WVDOT)

Research Need

- Joint implementation agreement between AASHTO and FHWA requiring the use of MASH compliant hardware
- Reduced post spacing guardrail systems used when lower deflections are required
- Pooled Fund prioritized this project in the last meeting

Research Plan

- Three systems
  - Quarter Post Spacing (18 3/4-inches)
  - Half Post Spacing (37 1/2-inches)
  - Transition between Full (75-inches) and Quarter Post Spacing
- Otherwise, typical MGS system with 31-inch tall w-beam guardrail and W6x9 posts

Research Plan

- Four Tests
  - Quarter Post Spacing with 3-10
  - Quarter Post Spacing with 3-11
  - Half Post Spacing with 3-11
    - 3-11 viewed as critical test because snagging and occupant risk danger is much higher with quarter post spacing 3-10 test
  - Transition between Full and Quarter Post Spacing with 3-21
    - 3-21 viewed as critical test because snagging and occupant risk danger is much higher with quarter post spacing 3-20 test

Research Status

- First Installation is constructed (will be repaired after each test)
- Expecting all four tests to be completed by end of October
- Expecting report to be issued January 2019

Testing and Evaluation of the MGS System with Critical Flare at MASH Test Level 3 Conditions

TTI Researcher: Chiara S. Dobrovolny

Technical Representative: Jeff Jeffers (AKDOT)

MASH TL-3 Testing of the MGS w/ Critical Flare

- **Previous Work Performed**
  - MwRSF evaluated MGS flare rate of 13:1, 7:1 and 5:1 according to NCHRP Report 350 TL-3.
- **Issue**
  - Test and Evaluate the MGS with critical flare rate at MASH TL-3 conditions.
- **Solution and Work Proposed**
  - Use engineering analysis and computer simulation to select critical flare rate for full-scale crash tests.
  - Conduct full-scale crash tests according to MASH TL-3 criteria.

Testing and Evaluation of the MGS System with Critical Flare at MASH Test Level 3 Conditions

Impact Severity

Test Objective	Vehicle Type	Test Criteria	Angle	Velocity (mph)	Impact Severity (kips-ft)	Difference
Straight MGS	Small Car	NCHRP 350	20	62	27	105%
		MASH	25	62	56	
	Pickup Truck	NCHRP 350	25	62	101	14%
		MASH	25	62	115	
13:1 Flare	Small Car	NCHRP 350	24.4	62	40	89%
		MASH	29.4	62	75	
	Pickup Truck	NCHRP 350	29.4	62	137	14%
		MASH	29.4	62	155	

Testing and Evaluation of the MGS System with Critical Flare at MASH Test Level 3 Conditions

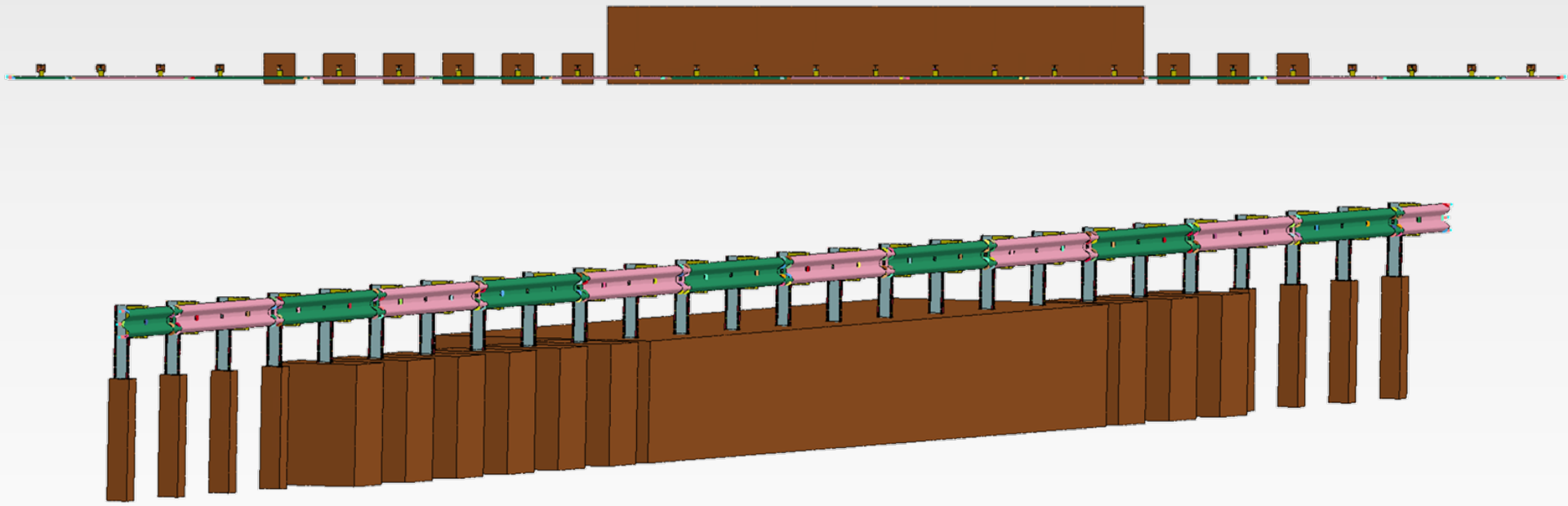
Impact Severity

Test Objective	Vehicle Type	Test Criteria	Angle	Velocity (mph)	Impact Severity (kips-ft)	Difference
7:1 Flare	Small Car	NCHRP 350	28.13	62	52	80%
		MASH	33.13	62	93	
	Pickup Truck	NCHRP 350	33.13	62	169	14%
		MASH	33.13	62	192	
5:1 Flare	Small Car	NCHRP 350	31.31	62	63	74%
		MASH	36.31	62	109	
	Pickup Truck	NCHRP 350	36.31	62	199	14%
		MASH	36.31	62	225	

MASH TL-3 Testing of the MGS w/ Critical Flare

FE model validation (on-going)

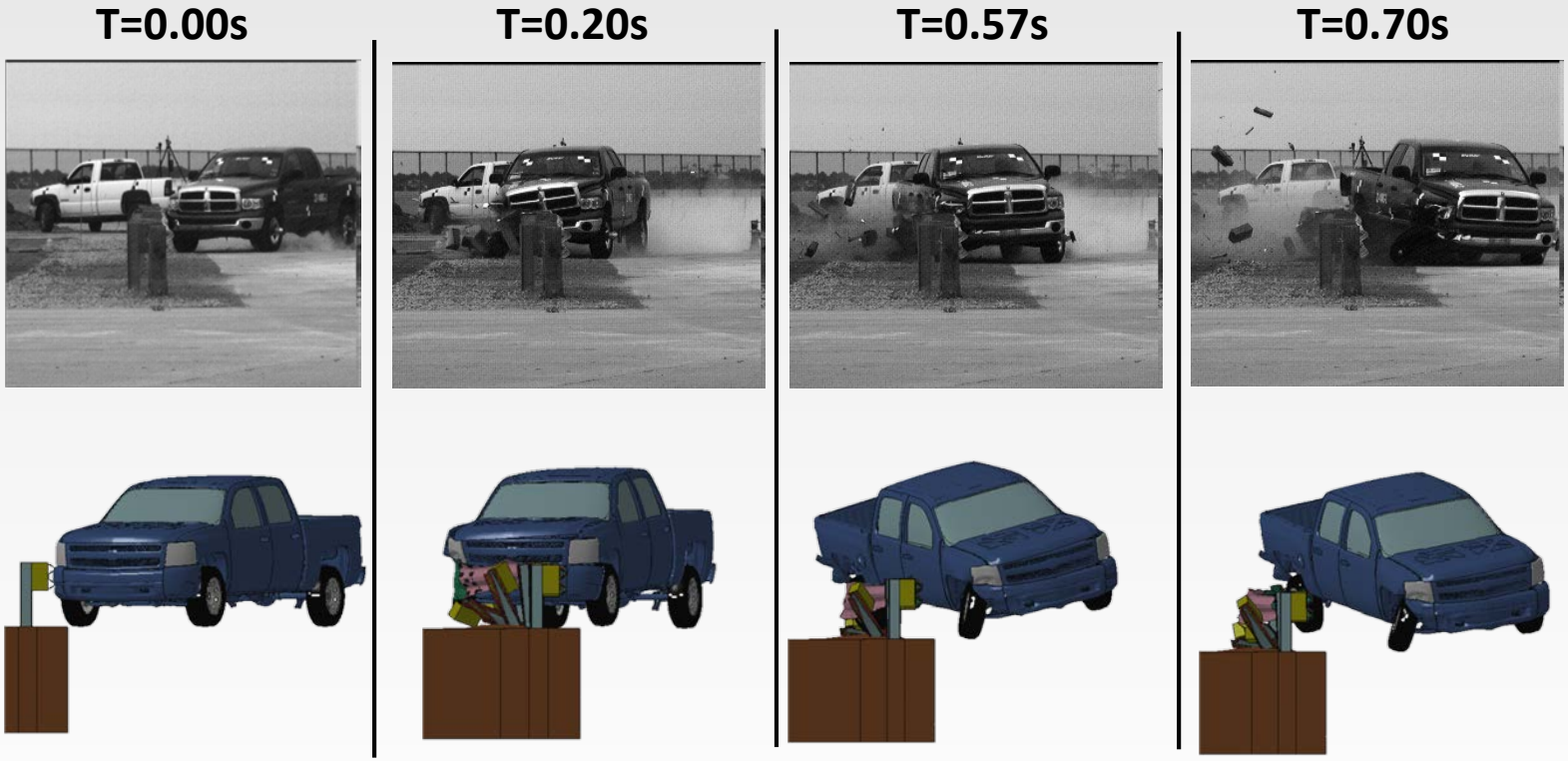
- Straight MGS system model with soil



MASH TL-3 Testing of the MGS w/ Critical Flare

FE model validation (3-11)

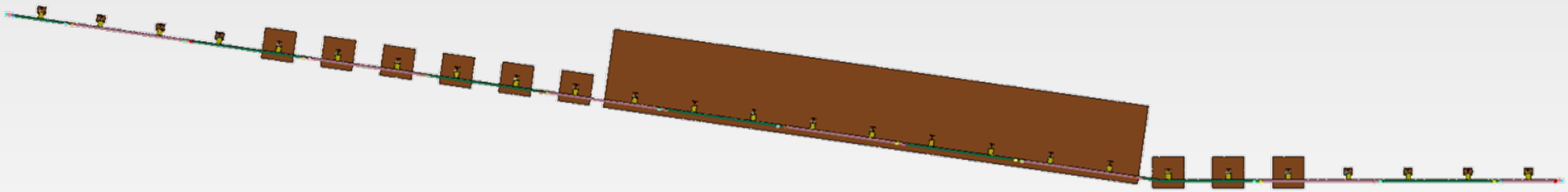
– Compare with MwRSF Update to NCHRP 350 crash tests



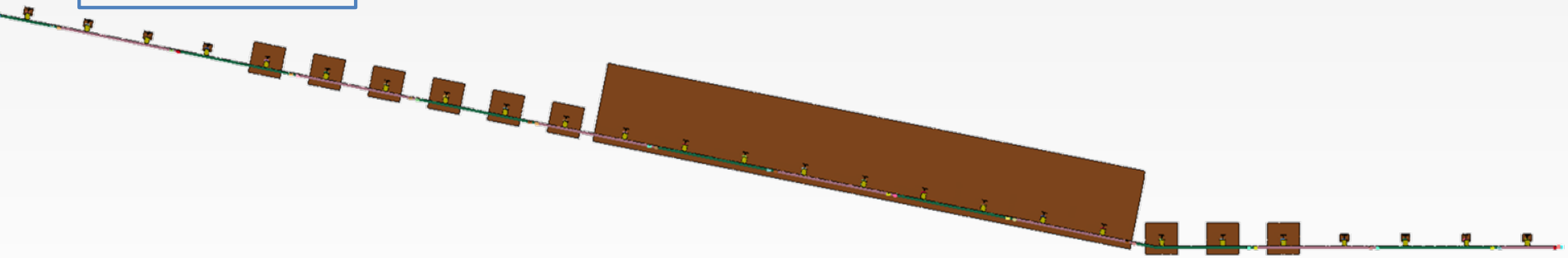
MASH TL-3 Testing of the MGS w/ Critical Flare

FE model of selected flared MGS (3-11)

1:7 flare rate



1:5 flare rate



MASH TL-3 Testing of the MGS w/ Critical Flare

- **Current Status**
  - Calibrate the FE models based on real crash tests
  - Determining the impact point for small car and pickup truck tests
  - Conducting simulations according to MASH test 3-11 and 3-10

Thrie/W-Beam/Tubular Barrier Gap Rail for MASH TL-3

TTI Researcher: William Williams

Technical Representative: Mike Elle (MNDOT)

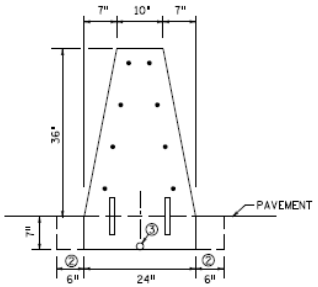
Thrie/W-Beam/Tubular Barrier Gap Rail for MASH TL-3

- Problem
  - Sometimes manholes and other features in the alignment of barriers
  - Need to provide 8-foot maximum wide gap to access manhole/features
  - Need to provide structural barrier that is removable for access
  - Removable barrier needs to meet crash requirements of MASH TL-3

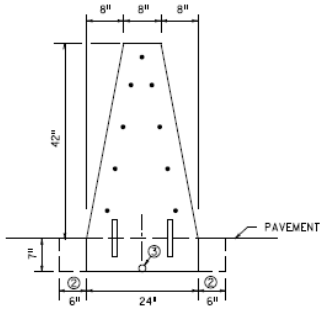
Thrie/W-Beam/Tubular Barrier Gap Rail for MASH TL-3

- Work Plan
  - Task 1 – Engineering Analyses & Detailing
    - Option 1 – W-beams with brace frames
    - Option 2 – Steel Tubes with Slotted Plates
  - Task 2 – Construction & Drafting
  - Task 3 – Perform Full Scale Crash Test
    - Perform Mash Test 3-10 (1100C, 25 degs., 100km/hr.)
    - Perform Mash Test 3-11 (2270P, 25 degs., 100 km/hr.)

Details of the Minnesota Barrier to use in the Design



TYPE 36 A



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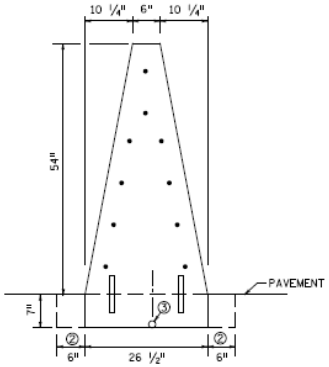
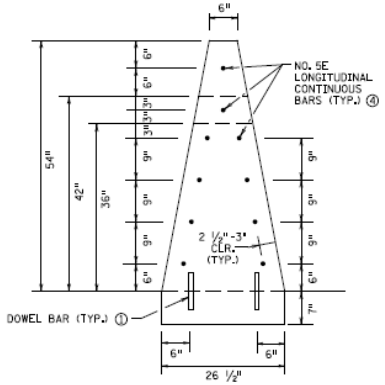
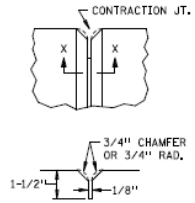


TYPE 54 A



REINFORCEMENT DETAIL



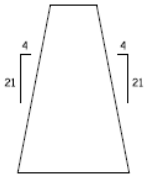
SECTION X-X

CONTRACTION JOINT
(TYPE A, TYPE A STEP, AND TYPE A-A MEDIAN BARRIERS; END ANCHOR BARRIER; AND LIGHT POLE FOUNDATION/SIGN BASE TRANSITION BARRIER)

CONTRACTION JOINT NOTES:

IF JOINT SPACING IS NOT INDICATED IN THE PLANS, THE BASIS OF JOINT SPACING IS AS FOLLOWS:

1) BITUMINOUS SECTION ADJACENT TO THE BARRIER; 15 FT. SPACING.
2) CONCRETE SECTION ADJACENT TO THE BARRIER; BARRIER CONTRACTION JOINTS SHALL ALIGN WITH JOINTS IN CONCRETE SECTION, NOT TO EXCEED 15 FT.
3) REINFORCING TO BE CONTINUOUS THROUGH JOINT.
4) IF FOOTING IS CONSTRUCTED SEPARATELY, PLACE BARRIER JOINTS DIRECTLY ABOVE FOOTING JOINTS.



BARRIER FACE SLOPE VALUE
(ALL TYPE A BARRIERS)

SINGLE SLOPE BARRIER
BILL OF REINFORCEMENT

BARRIER TYPE	LONGITUDINAL BAR SIZE	NUMBER OF BARS EACH
36 A	5E	8
42 A	5E	9
54 A	5E	10

NOTES:

ALL BARS EPOXY COATED PER SPEC. 3301, UNLESS OTHERWISE NOTED.

USE 3/4" CHAMFER OR 1" RADIUS ON ALL EXPOSED SHARP EDGES UNLESS OTHERWISE NOTED.

DURING SLIP-FORM CONSTRUCTION, PROVIDE ALL NECESSARY SUPPORTS NEEDED TO MAINTAIN LONGITUDINAL REINFORCEMENT BARS AT SPECIFIED DIMENSIONS (INCIDENTAL).

DURING FIXED-FORM CONSTRUCTION, MAINTAIN LONGITUDINAL REINFORCEMENT BARS AT DIMENSIONS SHOWN ON THE PLAN BY PROVIDING VERTICAL SUPPORT BARS AT 2'-0" MAX. SPACING (INCIDENTAL).

① IF FOOTING IS CONSTRUCTED SEPARATELY, PROVIDE TWO 1" DIA. DOWEL BARS (OR REBARS) 8" LONG AND SPACED EVERY 2'-0" ON CENTER. PROVIDE A ROUGH TEXTURE ON SURFACE OF FOOTING.

② 6" ADDITIONAL FOOTING WIDTH REQUIRED WHEN CONCRETE MEDIAN BARRIER IS ADJACENT TO BITUMINOUS PAVEMENT OR BITUMINOUS SHOULDER.

③ WHEN REQUIRED, PROVIDE A 1-1/2" NOMINAL DIAMETER PVC-TYPE I CONDUIT (SPEC. 3803). LOCATE AS DIRECTED BY PLAN OR ENGINEER.

④ CONTINUOUS NO. 5E LONGITUDINAL REINFORCEMENT BARS WITH 2 1/2" - 3" MINIMUM CLEARANCE EVENLY SPACED AS SHOWN IN THE DETAILS. MINIMUM LAP SPLICE IS 3'-1" FOR ALL BARS. SEE TABLE FOR BAR QUANTITIES.

MINNESOTA DEPARTMENT OF TRANSPORTATION

STATE DESIGN ENGINEER

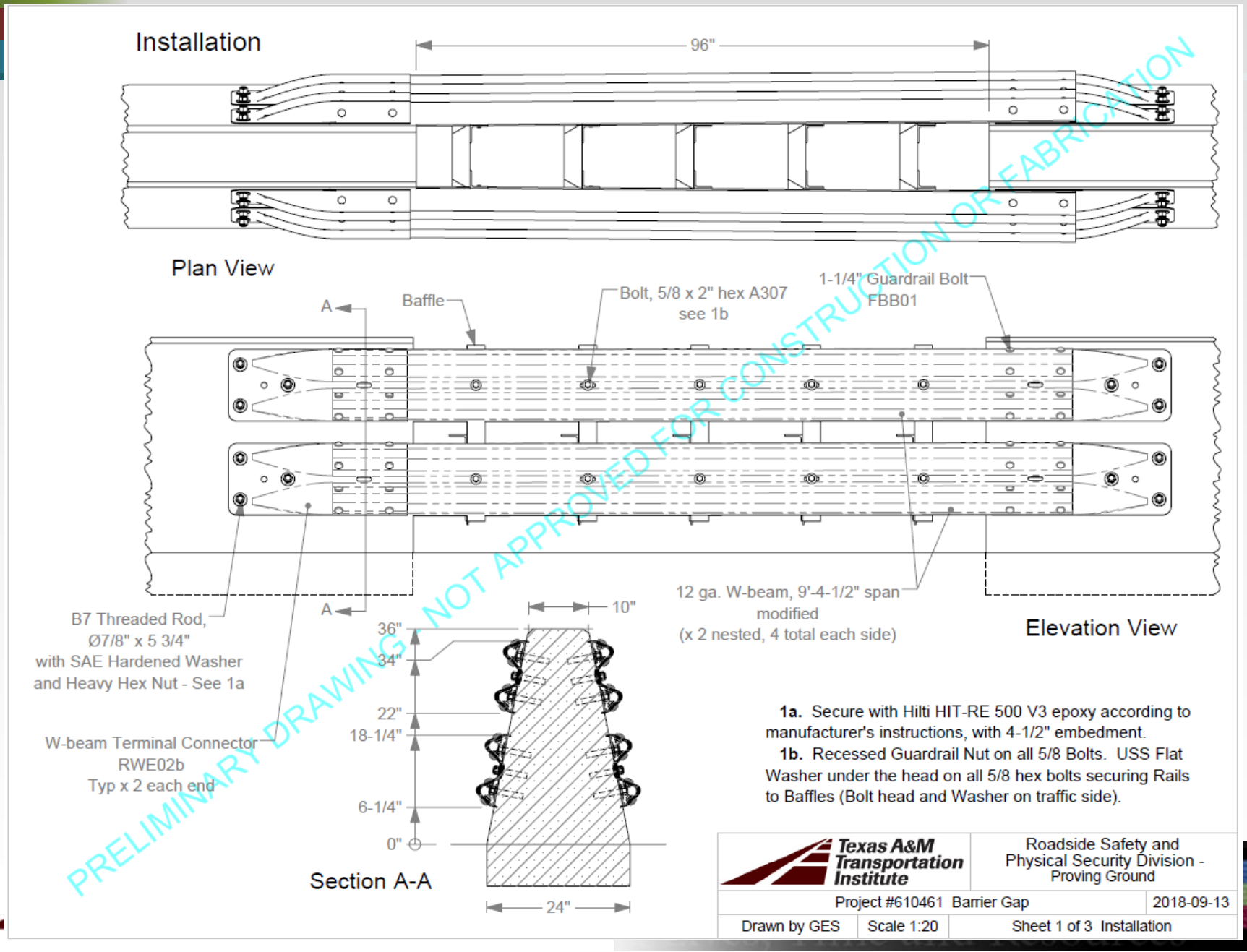
REVISED:

APPROVED:
8-10-2016

CONCRETE MEDIAN BARRIER SINGLE SLOPE
TYPE 36A, 42A, AND 54A

STANDARD PLAN 5-297.681 | 1 OF 6

Option 1 – W-Beams with Brace Frames

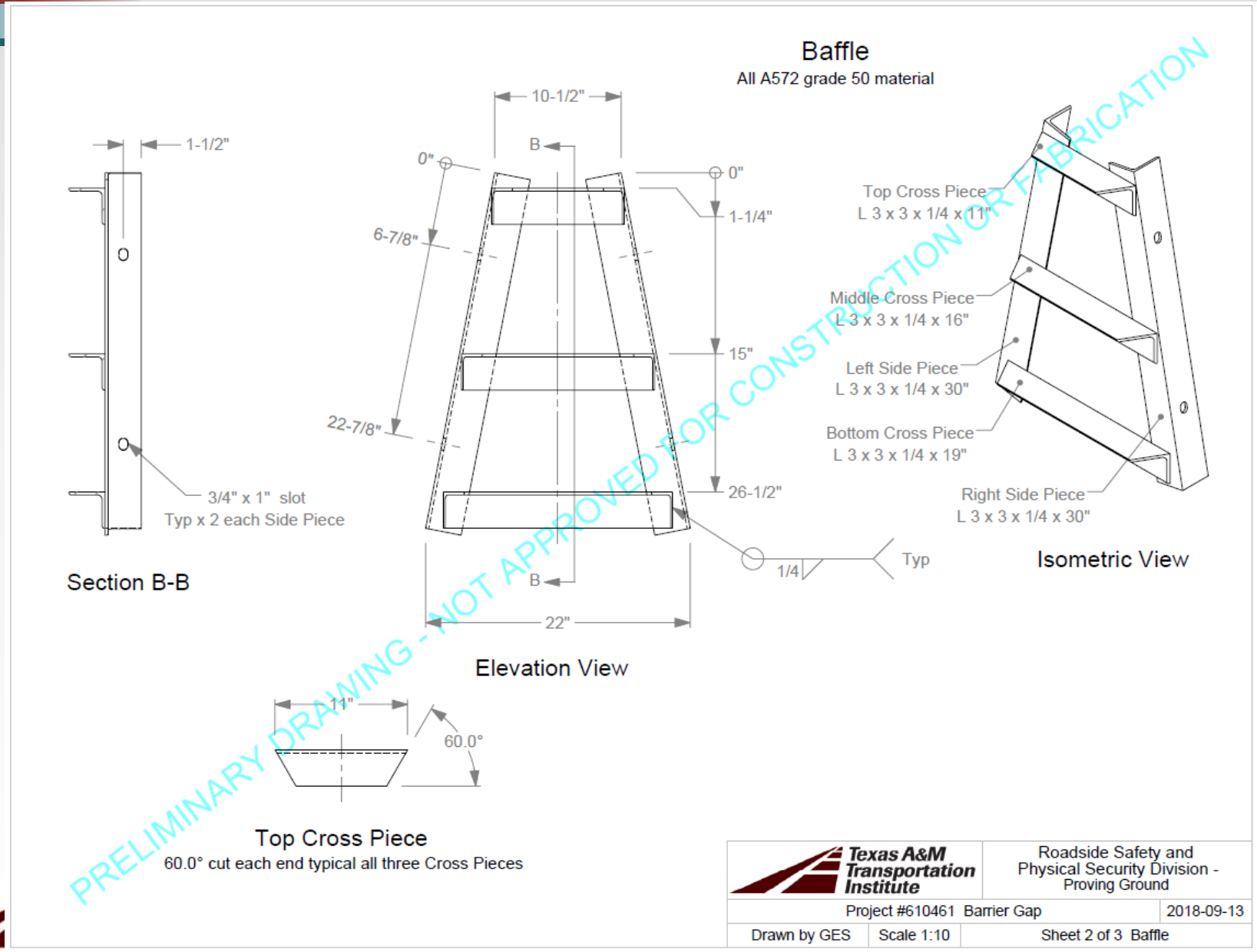


1a. Secure with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 4-1/2" embedment.

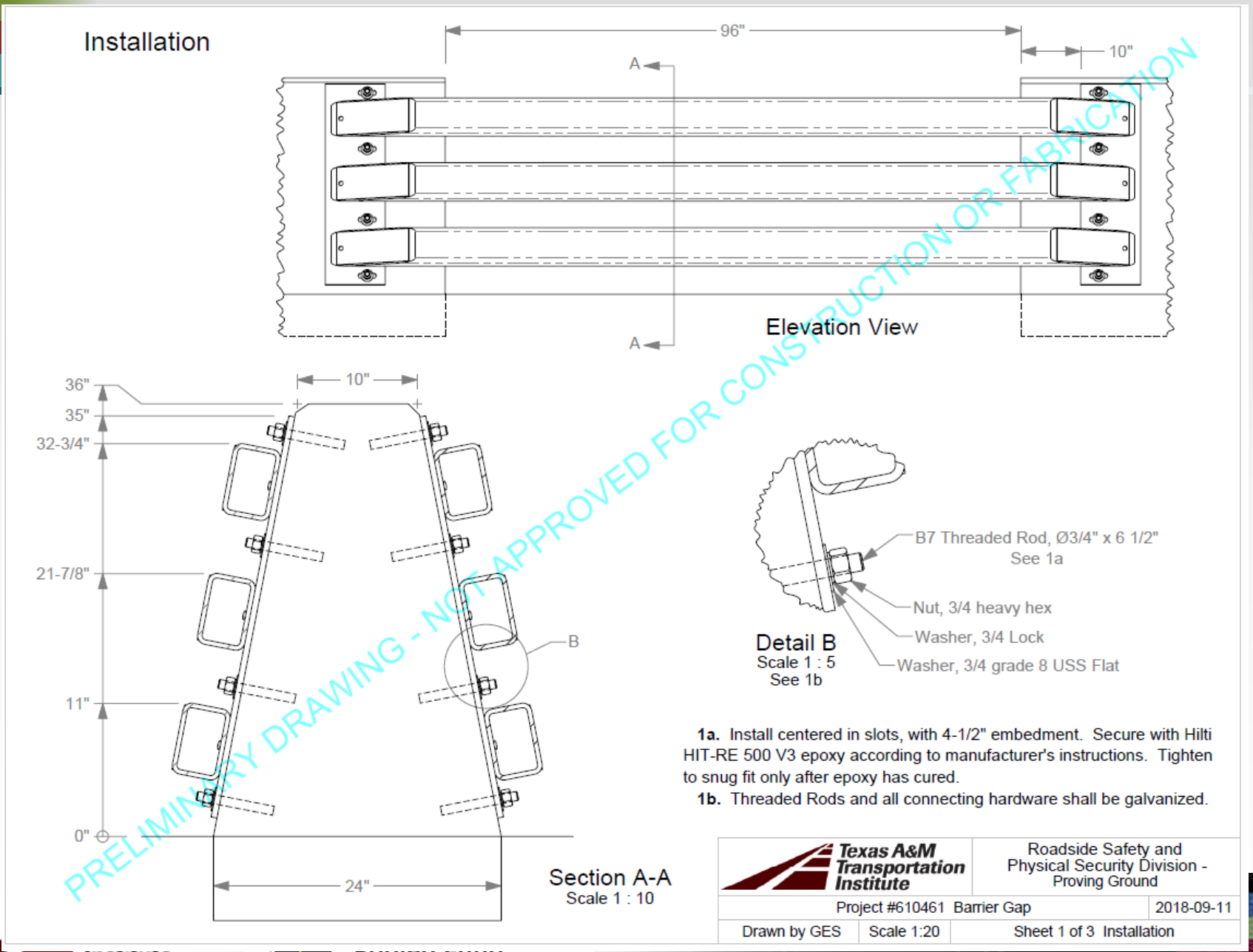
1b. Recessed Guardrail Nut on all 5/8 Bolts. USS Flat Washer under the head on all 5/8 hex bolts securing Rails to Baffles (Bolt head and Washer on traffic side).

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #610461 Barrier Gap		2018-09-13
Drawn by GES	Scale 1:20	Sheet 1 of 3 Installation

Option 1 – W-Beams with Brace Frames



Option 2 – Steel Tubes with Slotted Plates



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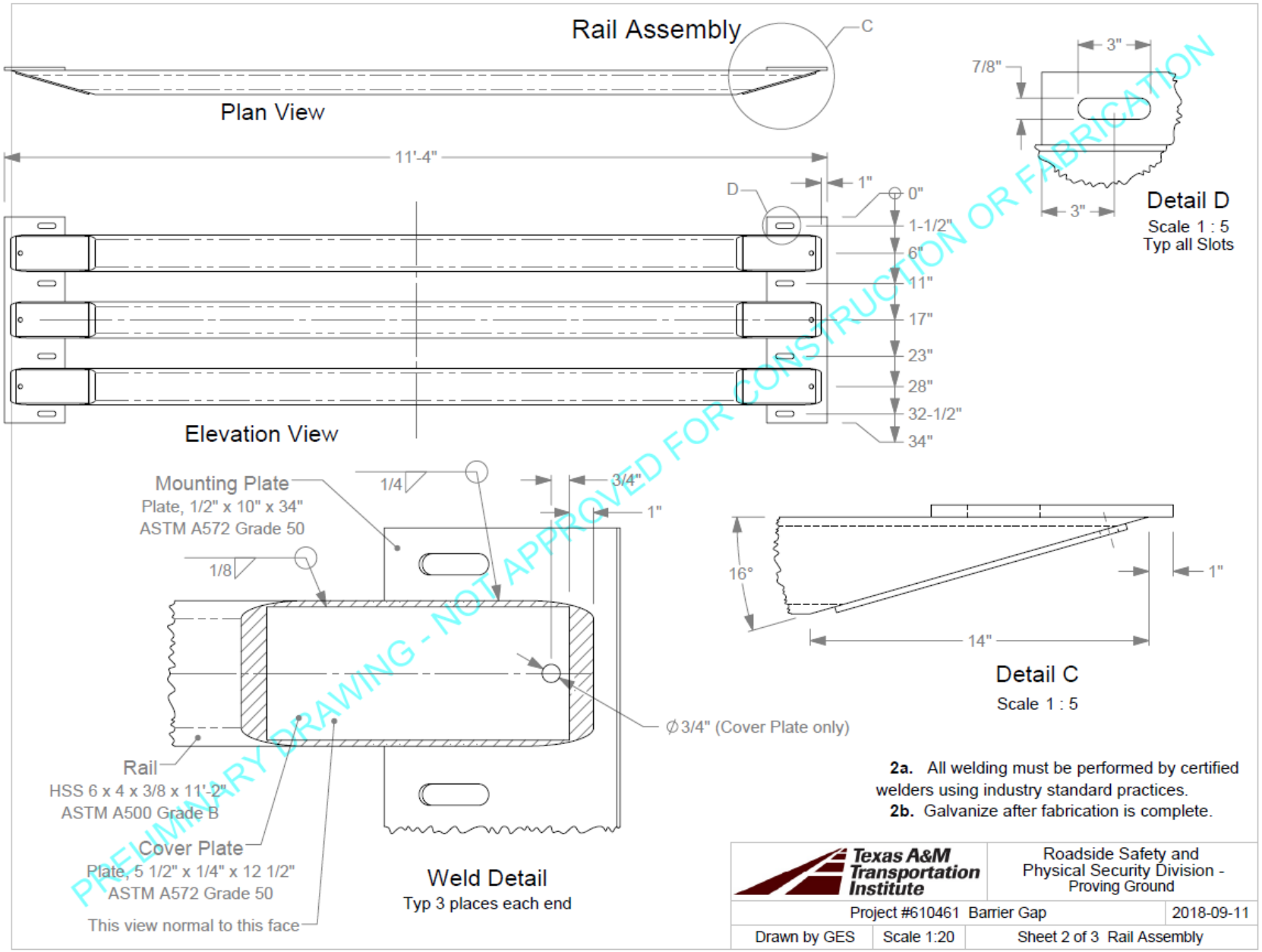


2a. All welding must be performed by certified welders using industry standard practices.
2b. Galvanize after fabrication is complete.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #610461 Barrier Gap		2018-09-11
Drawn by GES	Scale 1:20	Sheet 2 of 3 Rail Assembly

Placement of Guardrail on Slopes Phase IV: MASH TL-3 Testing of Guardrail on 1:1 Slope

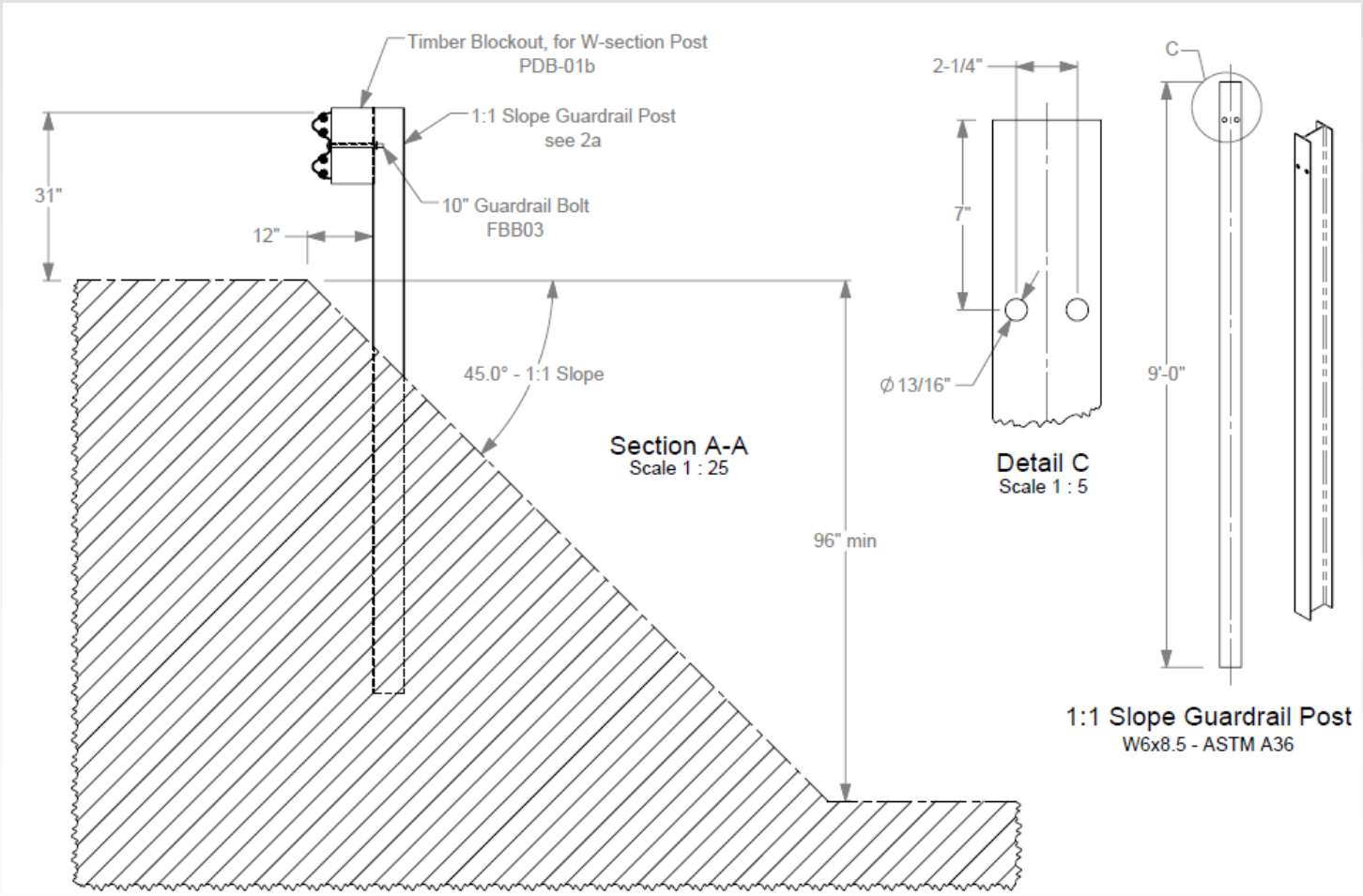
TTI Researcher: Akram Abu-Odeh

Technical Representative: Joe H. Hall (WVDOT)

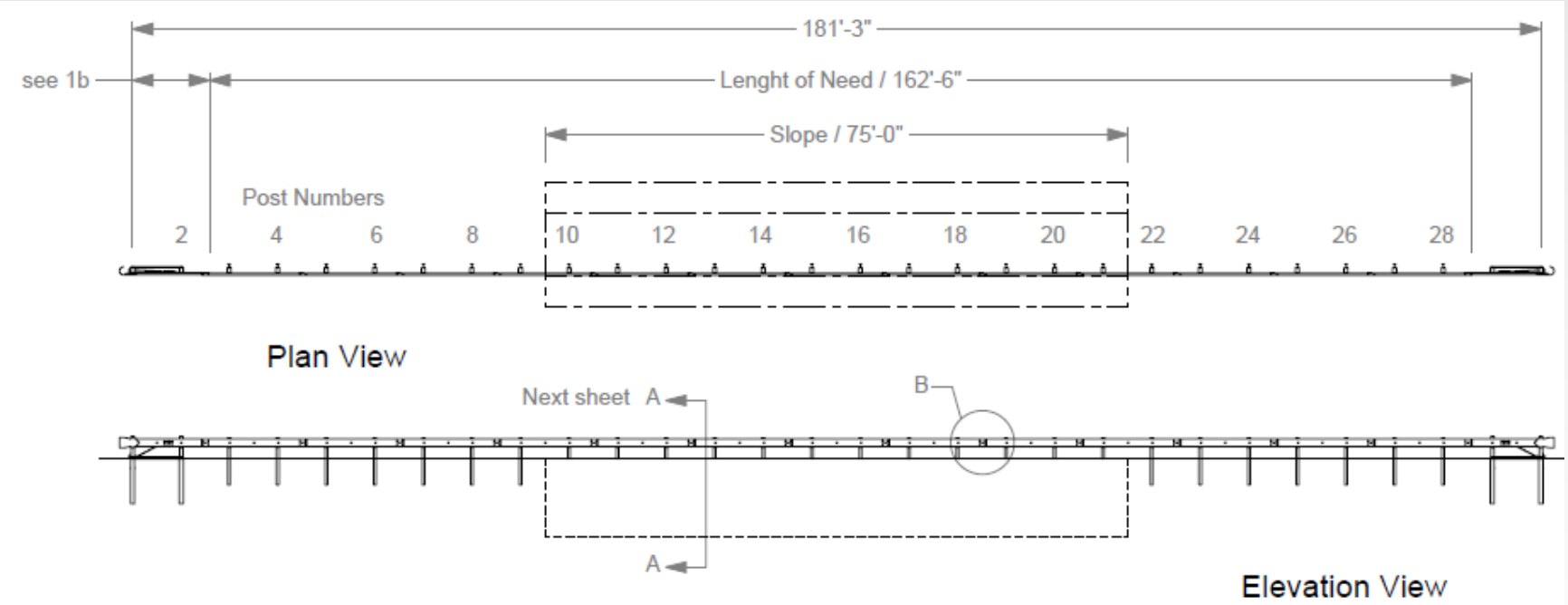
MASH TL-3 Guardrail on 1:1 Slope

- A new guardrail design to be evaluated under MASH TL-3 test conditions
- 31-inch w-beam system.
- Splices are in between posts with standard post spacing.
- 9-ft posts are installed on the slope so the face of the guardrail aligned with the slope break.

MASH TL-3 Guardrail on 1:1 Slope



MASH TL-3 Guardrail on 1:1 Slope



MASH TL-3 Guardrail on 1:1 Slope

MASH Test 3-10

MASH TL-3 Guardrail on 1:1 Slope

MASH TL-3 Guardrail on 1:1 Slope

MASH TL-3 Guardrail on 1:1 Slope

MASH TL-3 Guardrail on 1:1 Slope

MASH TL-3 Guardrail on 1:1 Slope

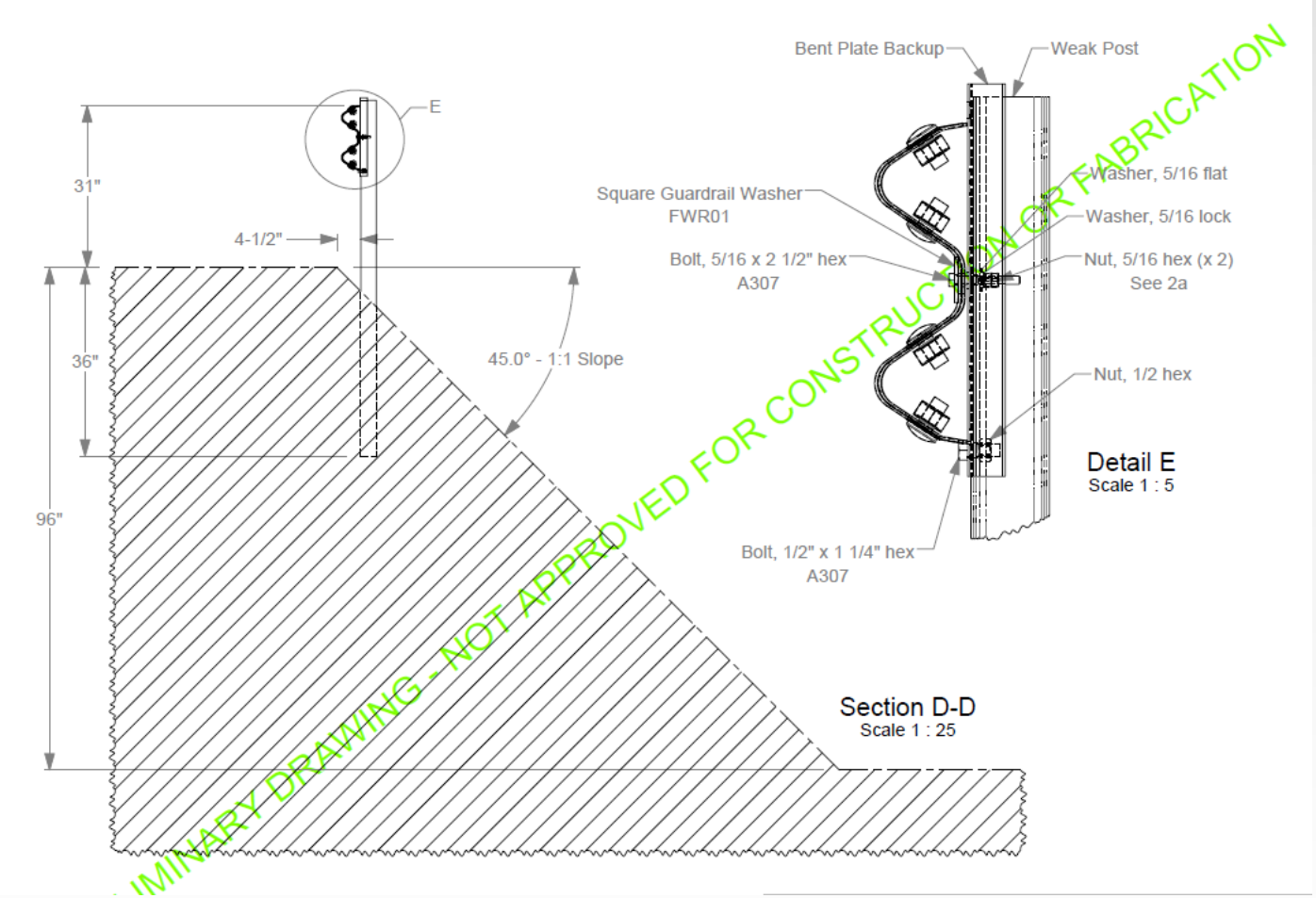
MASH TL-3 Guardrail on 1:1 Slope

- It is assessed that the rail edge engaged with a sharp interior edge behind the fender
- The rail system seems to be stiffer than desired
- Two recommended ways for reducing the rail stiffness
  - Shortening rail embedment
  - Using weaker posts

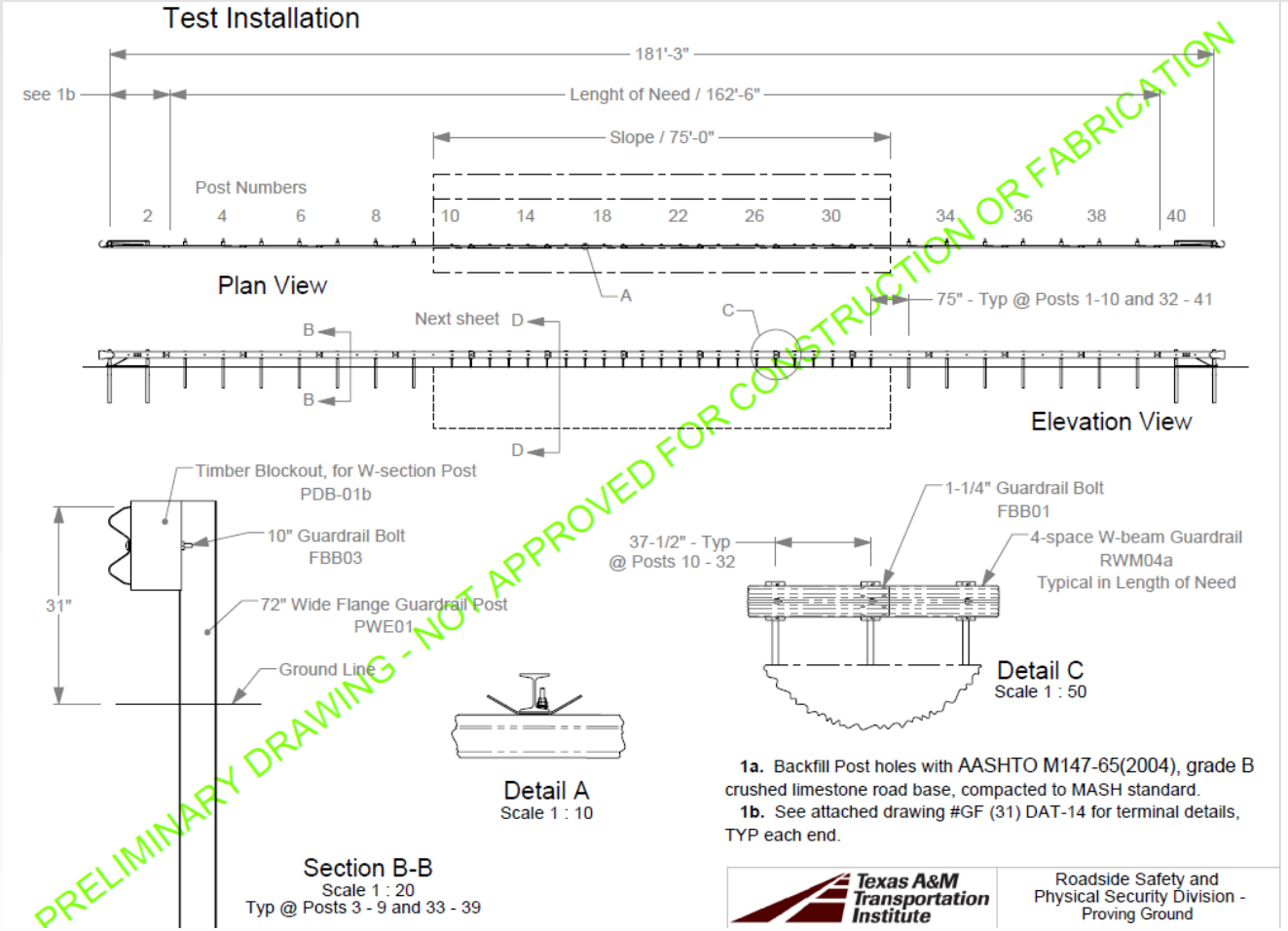
MASH TL-3 Guardrail on 1:1 Slope

- Using weak post system seems to be more practical
  - Easier and consistent in terms of installation (S3 x 5.7), especially given the mountainous rock formations
  - Less embedment depth
  - Reduced soil dependency
  - Closer the slope break

MASH TL-3 Guardrail on 1:1 Slope



MASH TL-3 Guardrail on 1:1 Slope



MASH TL-3 Guardrail on 1:1 Slope

- Items left to complete the project
  - Request time extension
  - LS-DYNA analysis with pickup truck
  - Request additional funds to test the truck and potential the small car
  - The testing could be in an extension to the current project or a new testing project for the weak post system

Accommodating Inlets with Transitions (TL-3)

TTI Researcher: Akram Abu-Odeh

Technical Representative: Derwood C. Sheppard, (FDOT)

Accommodating Inlets with Transitions

- Develop a transition design to be evaluated under MASH TL-3 test conditions
- Hydraulic inlets configurations to be accommodated in the design
- Proposal being prepared for the following research activities.
  - Polling State DOT's with these inlets configurations
  - Perform nonlinear finite element analyses
  - Perform MASH TL 3 transition test for the 2270P test vehicle