MONTANA
MDT
DEPARTMENT OF TRANSPORTATION

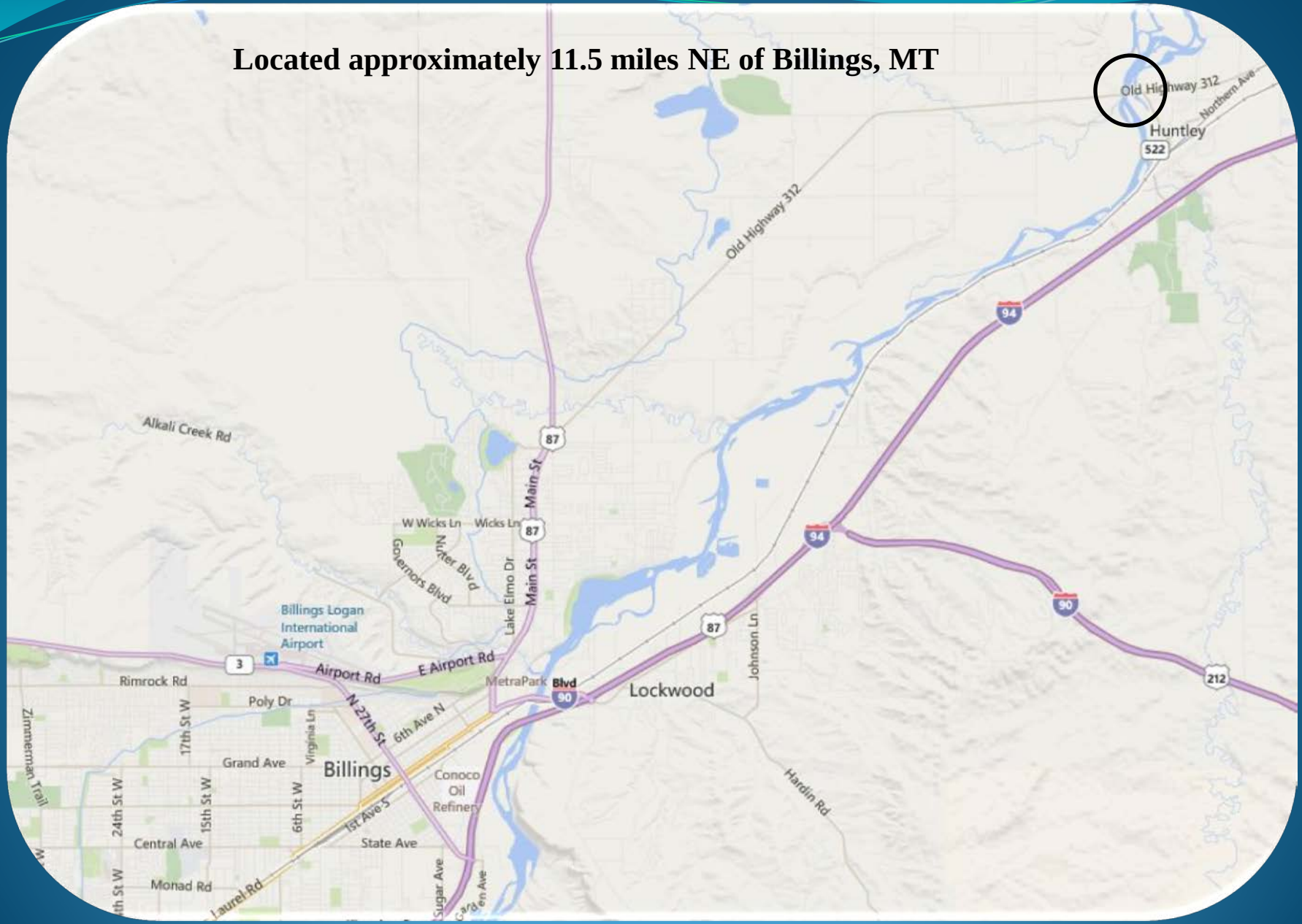
Yellowstone River at Huntley, MT

Bridge Scour Countermeasure Failure Investigation

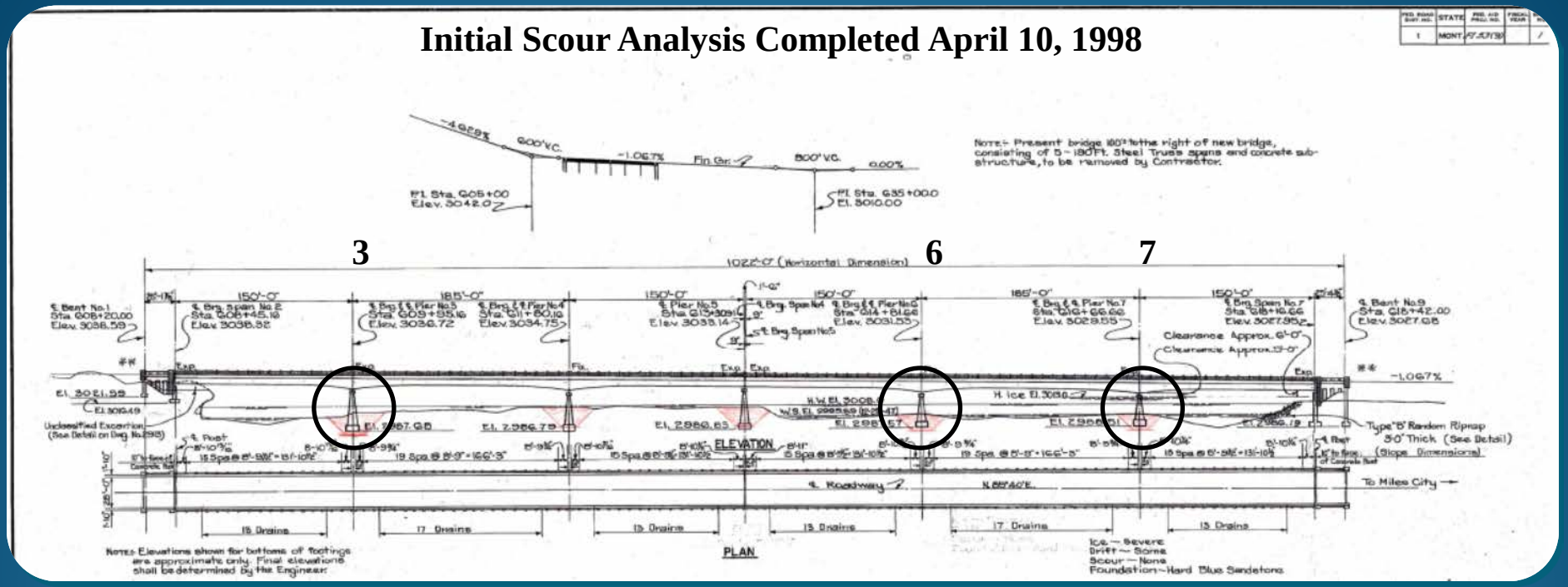
Russell Brewer, P.E.

Old US Highway 312 Crossing the Yellowstone River at Huntley, MT

Located approximately 11.5 miles NE of Billings, MT



Old US Highway 312 Crossing the Yellowstone River at Huntley, MT

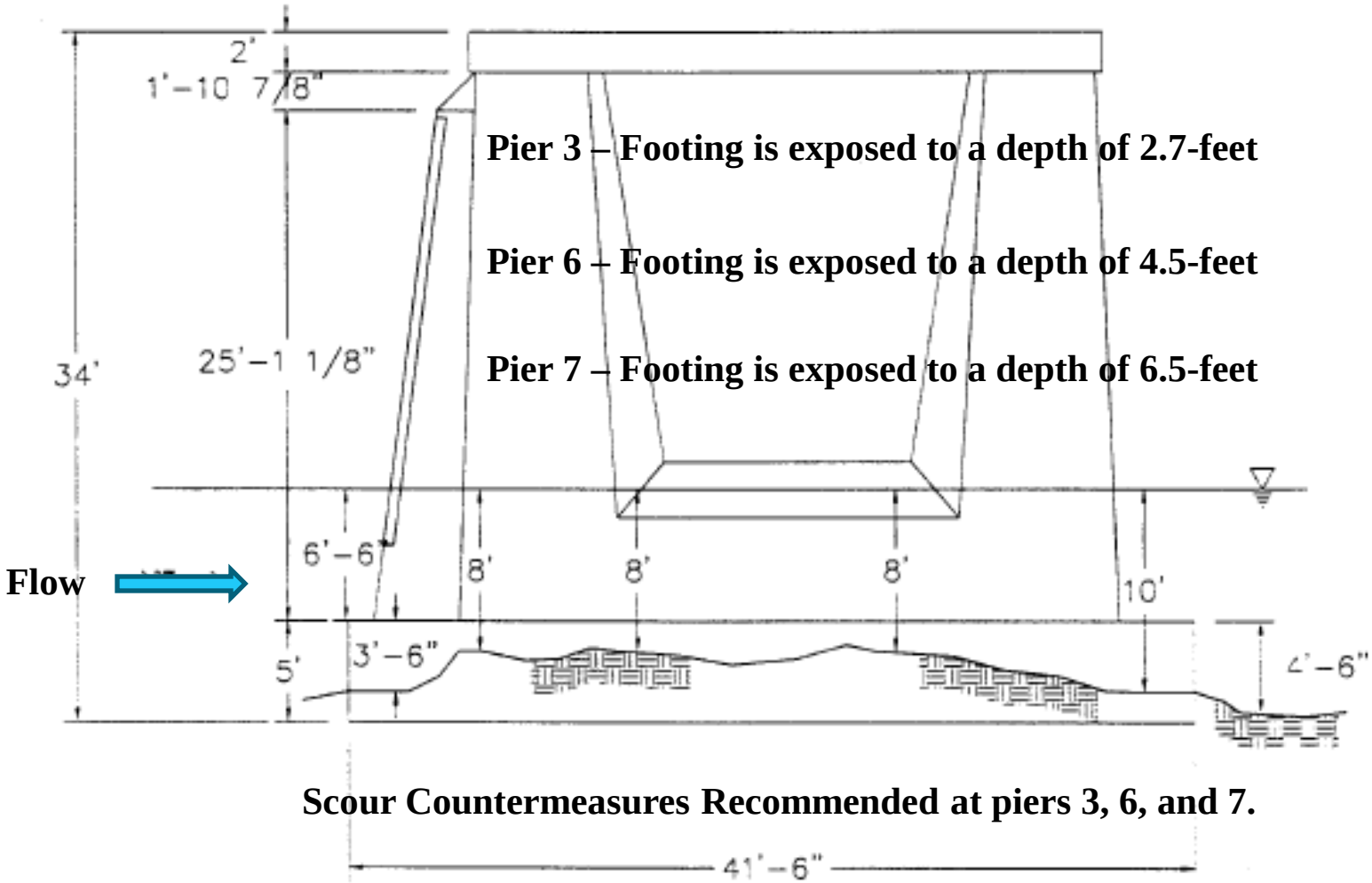


- Total pier scour estimated at 18.2-feet
- Estimated Scour plots below the bottom of the footing elevations at piers 3, 6, and 7
- Footings “keyed” about 2-feet into Hard Blue Sandstone
- Structure placed on District Emergency Watch List (NBIS Item 113 Code 3)

Old US Highway 312 Crossing the Yellowstone River at Huntley, MT

EAST ELEVATION

9-23-1998 UW Inspection



Pier 3 – Footing is exposed to a depth of 2.7-feet

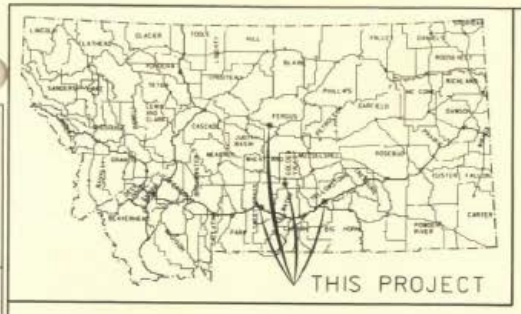
Pier 6 – Footing is exposed to a depth of 4.5-feet

Pier 7 – Footing is exposed to a depth of 6.5-feet

Scour Countermeasures Recommended at piers 3, 6, and 7.

Old US Highway 312 Crossing the Yellowstone River at Huntley, MT

Scour mitigation project completed December 2006



MONTANA DEPARTMENT OF TRANSPORTATION

AS-BUILT DRAWINGS

FEDERAL AID PROJECT NO. BH 0002(745)

D5 – SCOUR PROTECTION

YELLOWSTONE, SWEETGRASS, FERGUS & GOLDEN VALLEY COUNTIES

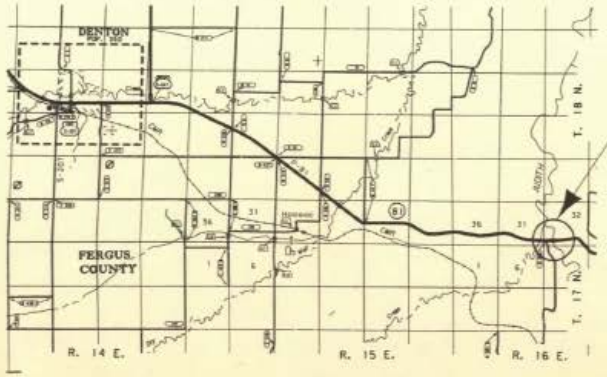
DESIGN DATA

LETTING DATE - Nov. 1, 2005

Completion Date - Dec. 11, 2006

SITE 1 – L56788
Yellowstone River

SITE 2 – ~~L49125~~ X81014
Upper Deer Creek



SITE 3 – P81
Judith River

SITE 4 – S300
Mussellshell River

RELATED PROJECTS

ASSOCIATED PROJECT AGREEMENT NUMBERS

R/W & I.C.	BH 0002(794)
P.E.	BH 0002(578)

MONTANA DEPARTMENT OF TRANSPORTATION

APPROVED September 27 '05

JIM LYNCH
DIRECTOR OF TRANSPORTATION

BY

BRIDGE ENGINEER

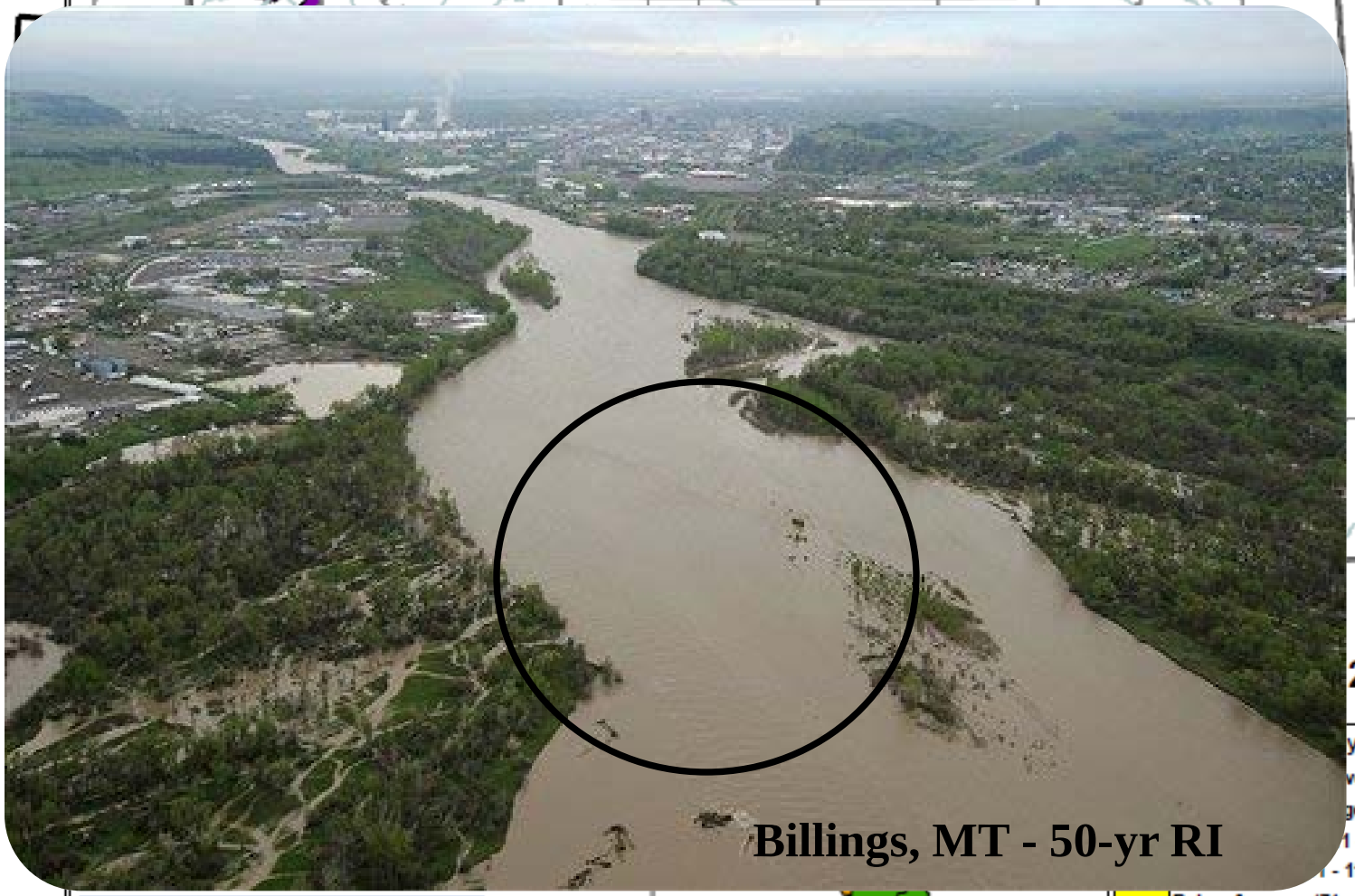
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

APPROVED

DIVISION ADMINISTRATOR — DATE

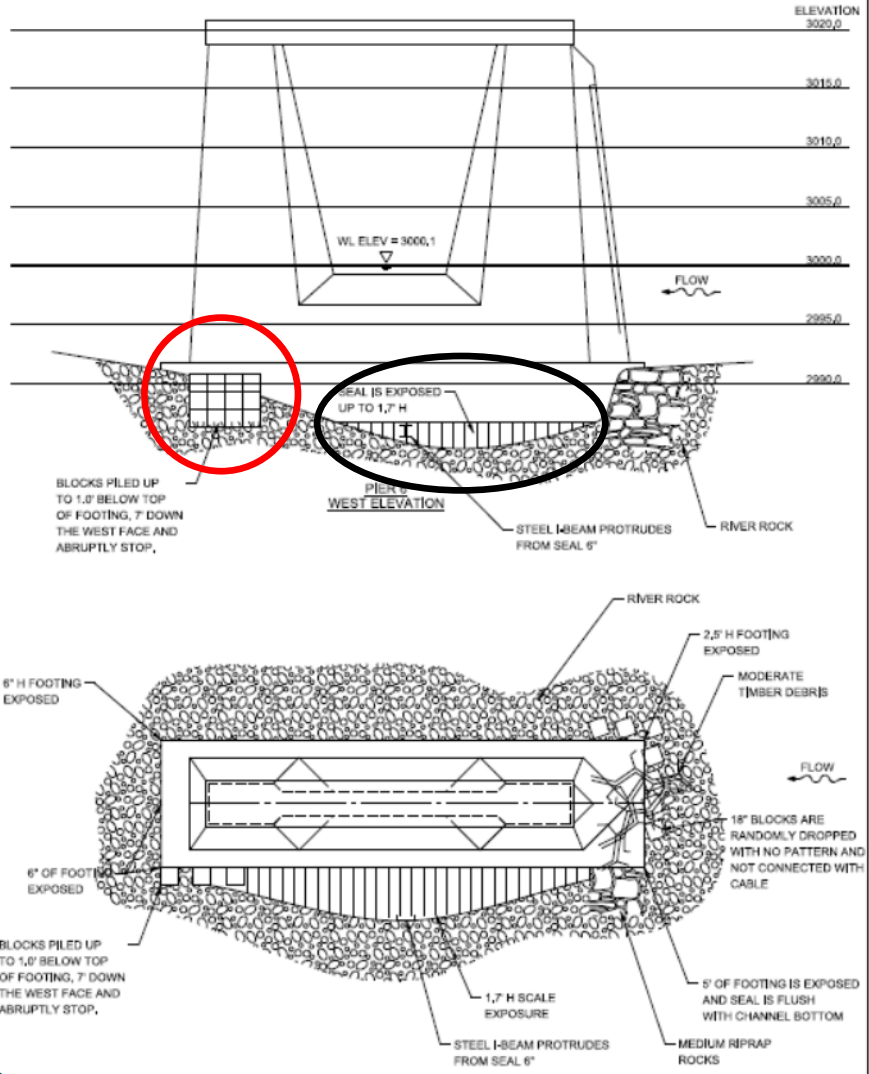
DRAWING NO. 154177

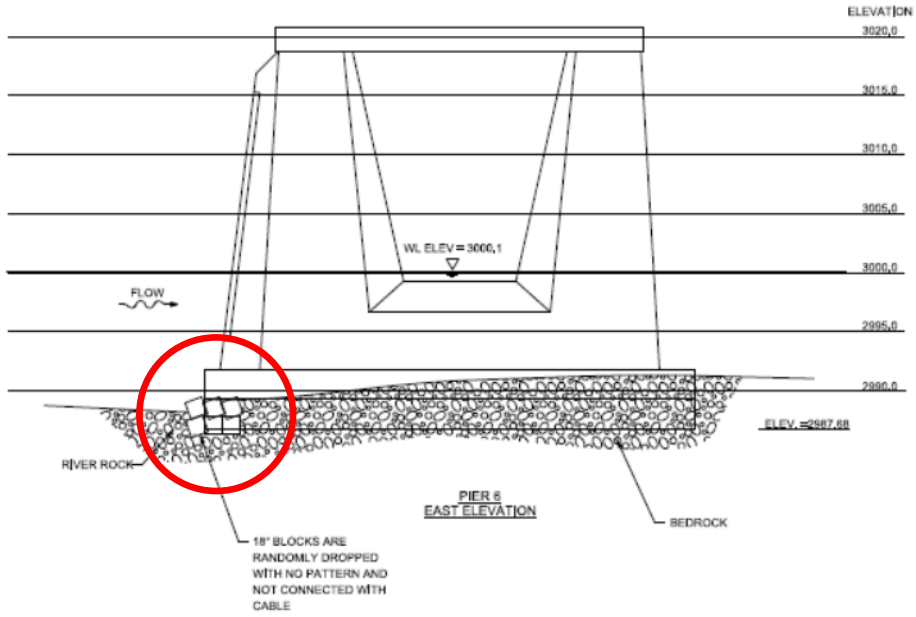
Old US Highway 312 Crossing the Yellowstone River at Huntley, MT



Old US Highway 312 Crossing the Yellowstone River at Huntley, MT

Underwater Inspection Report September-2011





Indicates Counter Measures at pier 6 failed

Scour extends below bottom of footing elevation

GRAPHIC SCALE MEASURED IN FEET	DATE		ROUTE 56788 OVER YELLOWSTONE RIVER BRIDGE NO. L56788012+07001
0 10 20 1" = 10'	SEPT 2011	INFRASTRUCTURE ENGINEERS, INC.	PIER 6

Old US Highway 312 Crossing the Yellowstone River at Huntley, MT

What Happened?

MDT Scour Team

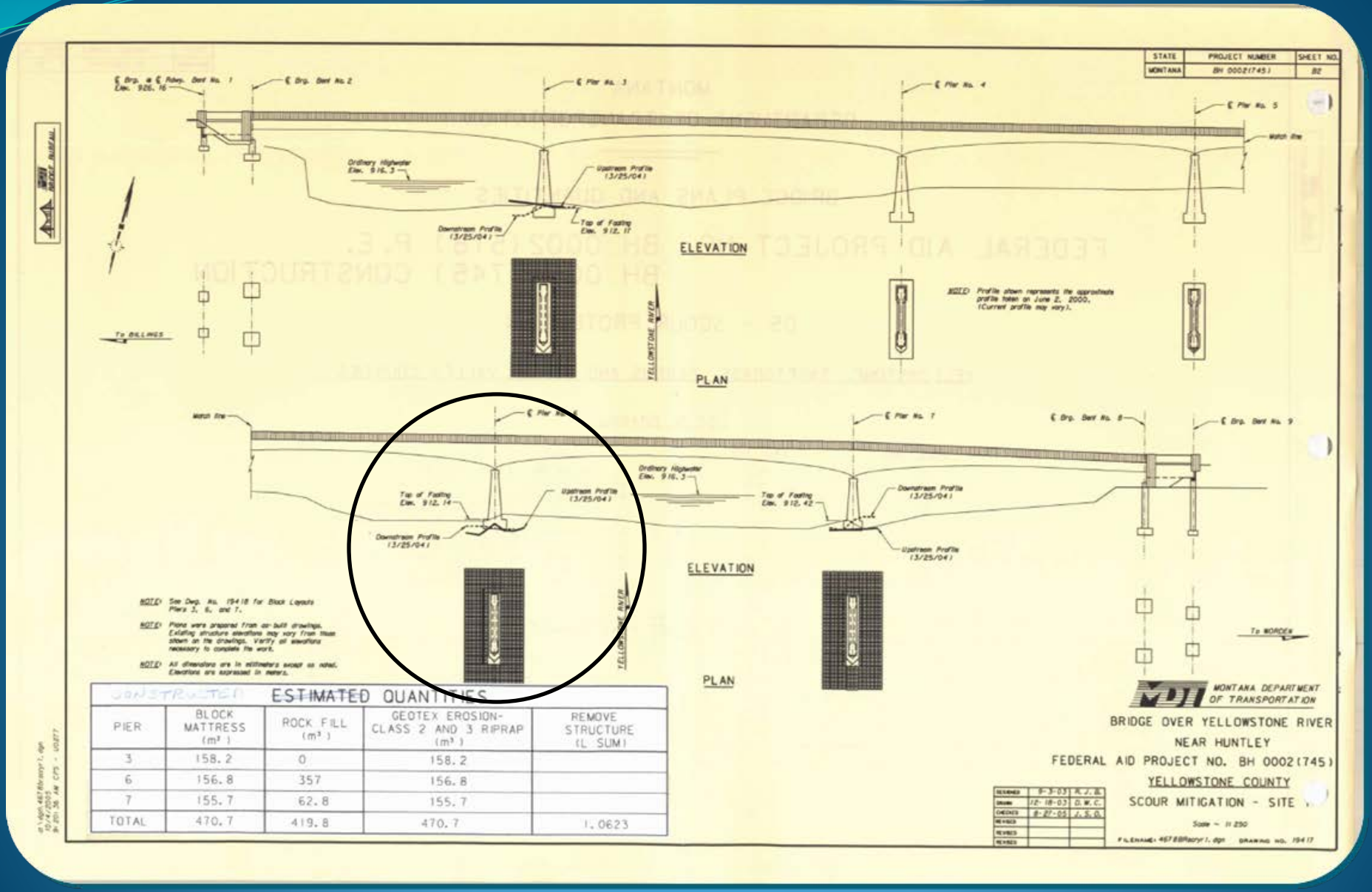
- Implement POA due to CM Failure
- Review Available Data
- Request Additional Data
- Determine what led to CM Failure
  - Design Features
  - Construction Techniques
  - Hydraulic Forces
  - Other Factors

Old US Highway 312 Crossing the Yellowstone River at Huntley, MT

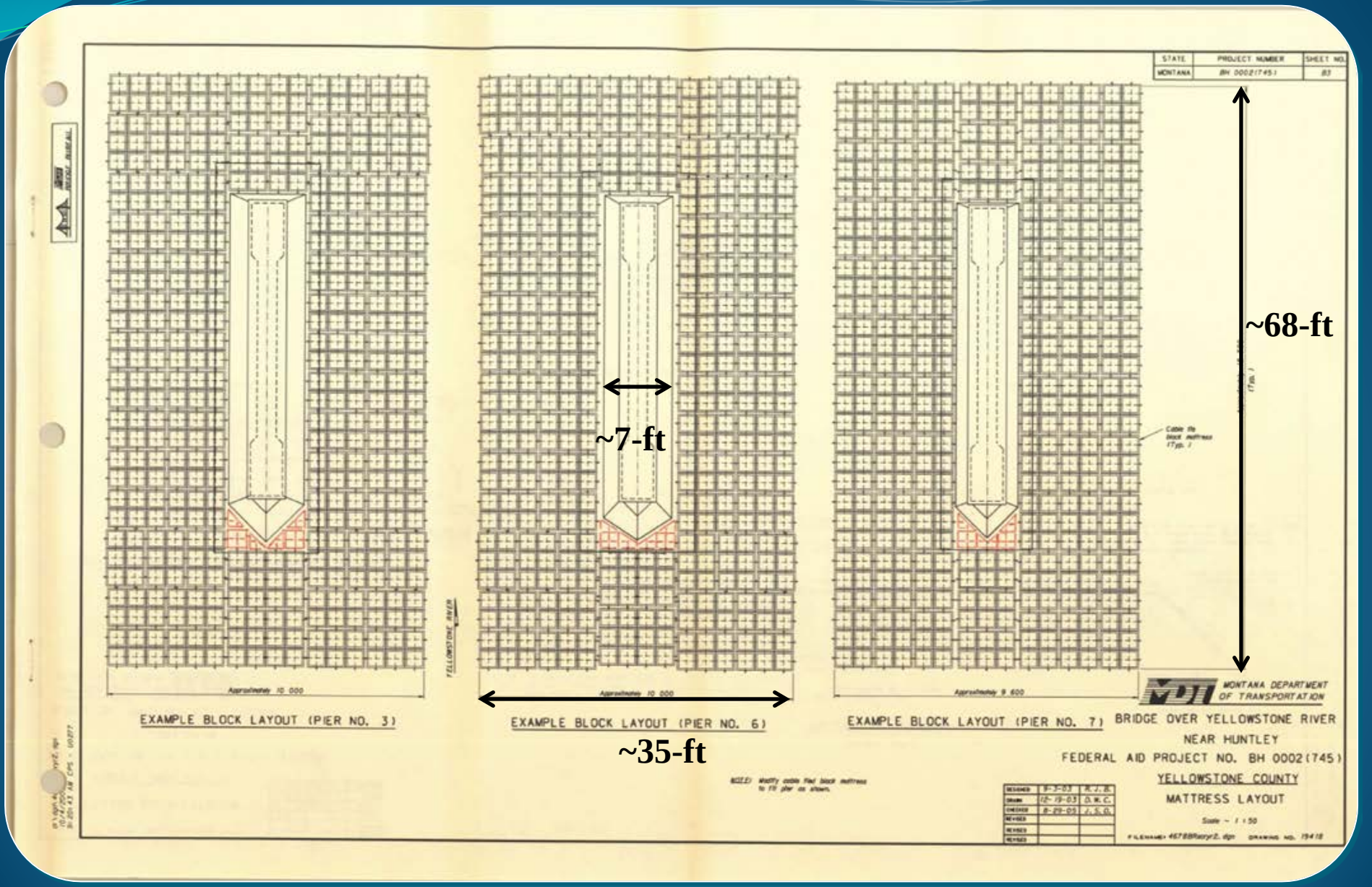
Determine Mechanisms of failure:

- **Design Features**
  - Review Plans

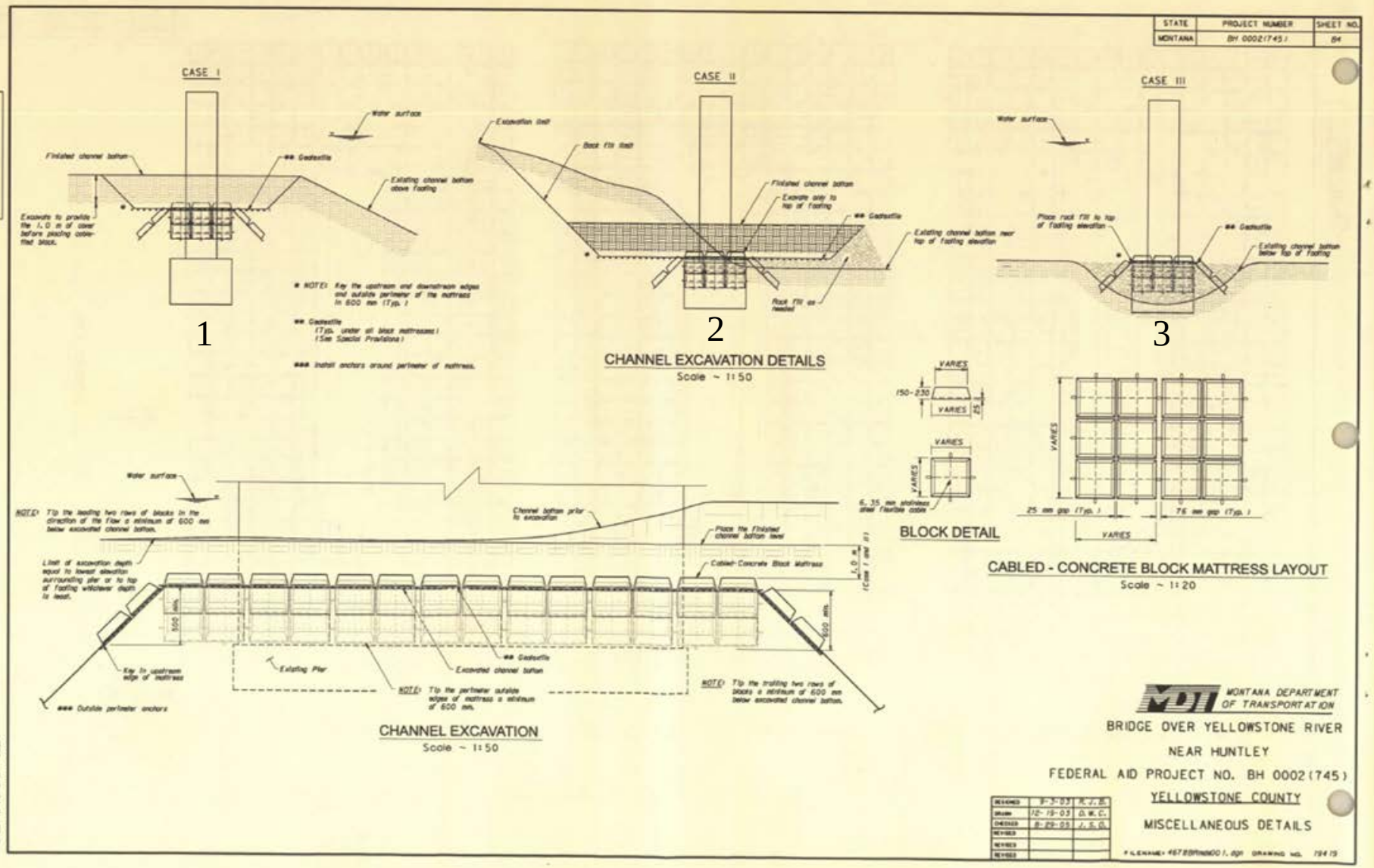
Old US Highway 312 Crossing the Yellowstone River at Huntley, MT



Old US Highway 312 Crossing the Yellowstone River at Huntley, MT



Old US Highway 312 Crossing the Yellowstone River at Huntley, MT



Old US Highway 312 Crossing the Yellowstone River at Huntley, MT

Determine Mechanisms of failure:

- **Design Features**
  - Review Plans
- **Construction**
  - Method of Construction
  - Review Placement of ACB's

US Highway 312 Crossing the Yellowstone River at Huntley, MT

Challenges

- Site access
- Water depth at low flow = 9-feet
- How to isolate the work area?

Contractors Solution

- Earthen Cofferdams

US Highway 312 Crossing the Yellowstone River at Huntley, MT

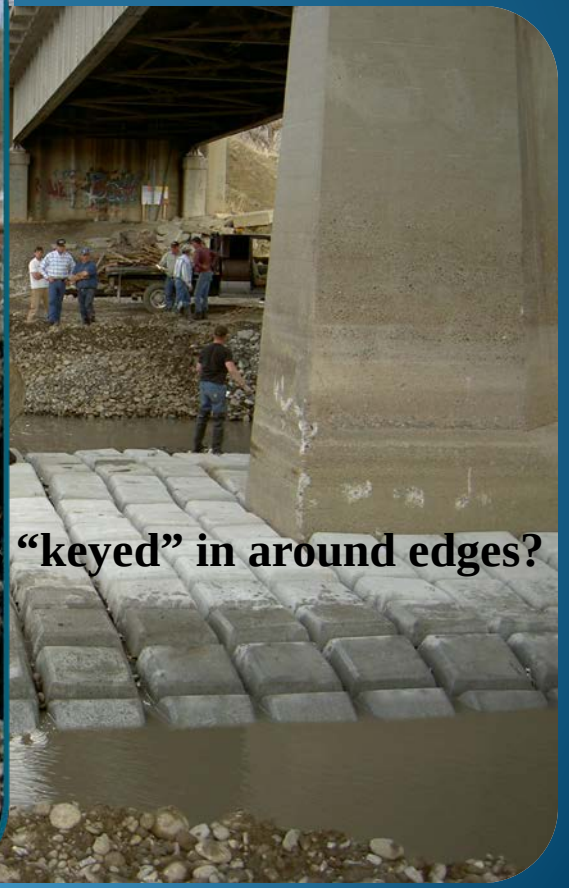
- Excavate to Depth

Old US Highway 312 Crossing the Yellowstone River at Huntley, MT

Block protrusion minimized?

- Place ACB Mattress

ACB Mattress anchored US and DS?



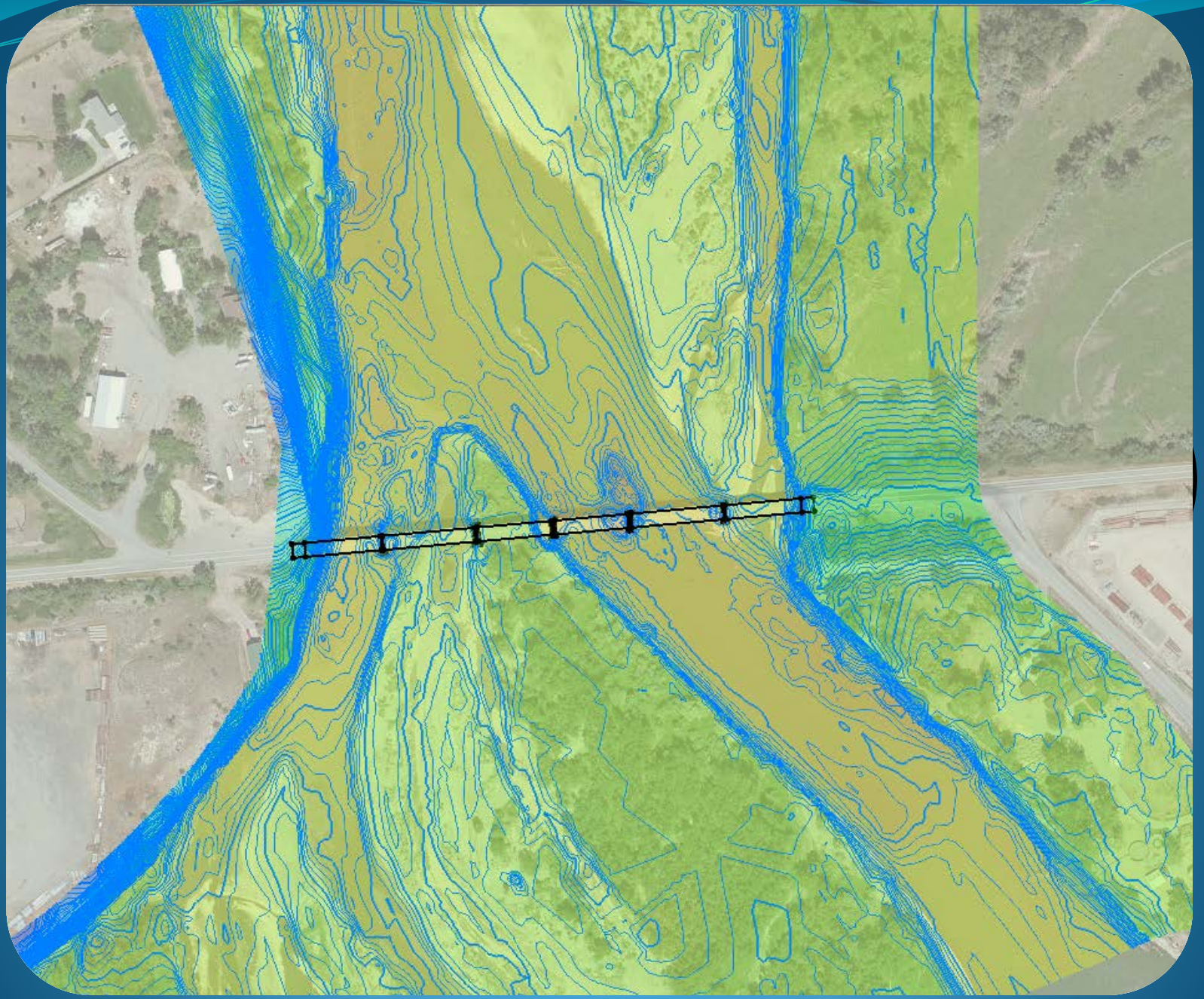
ACB Mattress “keyed” in around edges?

Old US Highway 312 Crossing the Yellowstone River at Huntley, MT

Determine Mechanisms of failure:

- **Design Features**
  - Review Plans
- **Construction Techniques**
  - Review Methods of Construction
- **Data Requested**
  - Bathymetric Survey

Old US Highway 312 Crossing the Yellowstone River at Huntley, MT



Old US Highway 312 Crossing the Yellowstone River at Huntley, MT

Determine Mechanisms of failure:

- **Design Features**
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- **Construction Techniques**
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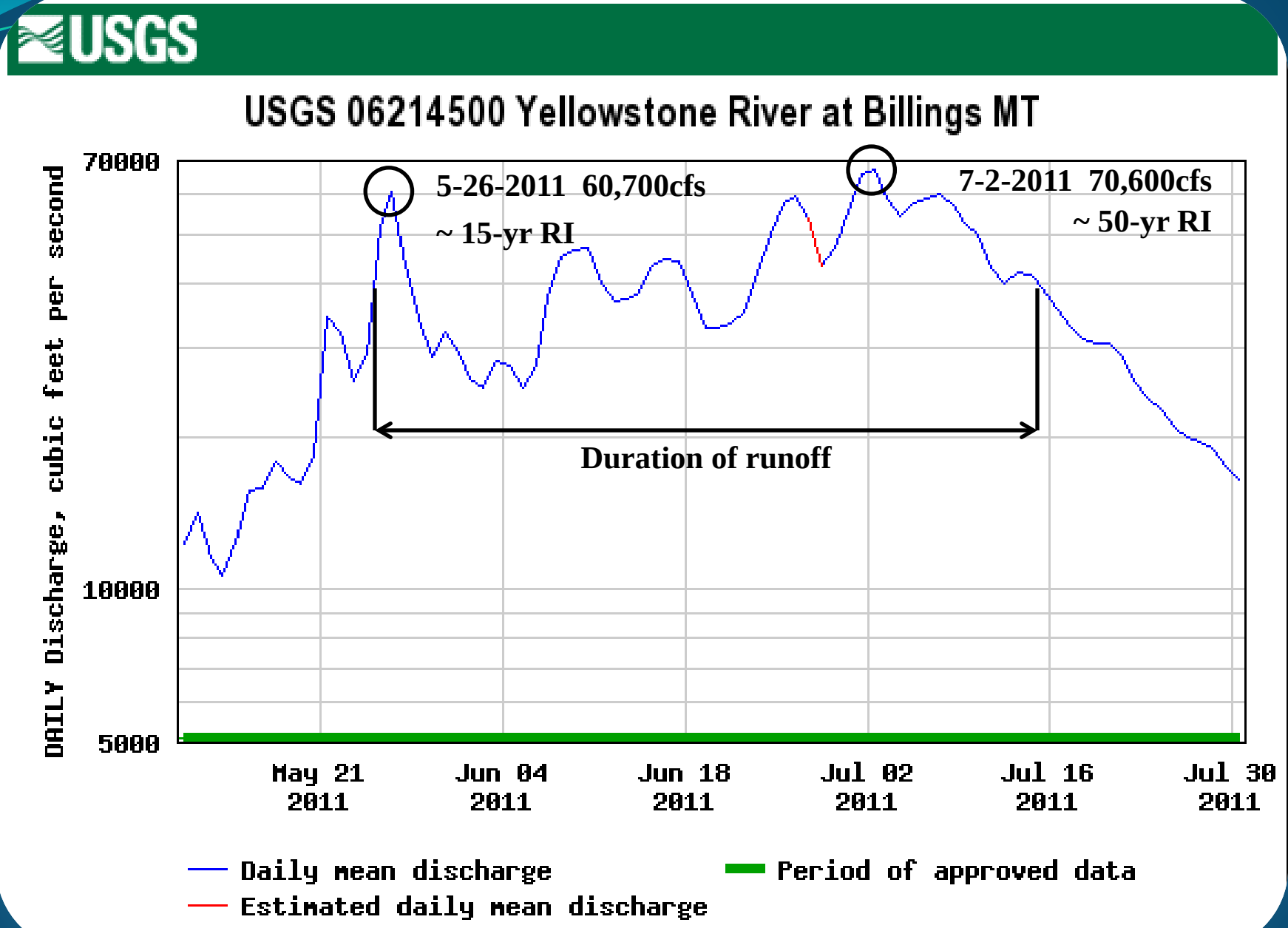
- **Data Requested**
  - Bathymetric Survey
- **Hydraulic Forces**
  - Flood Flow

Old US Highway 312 Crossing the Yellowstone River at Huntley, MT

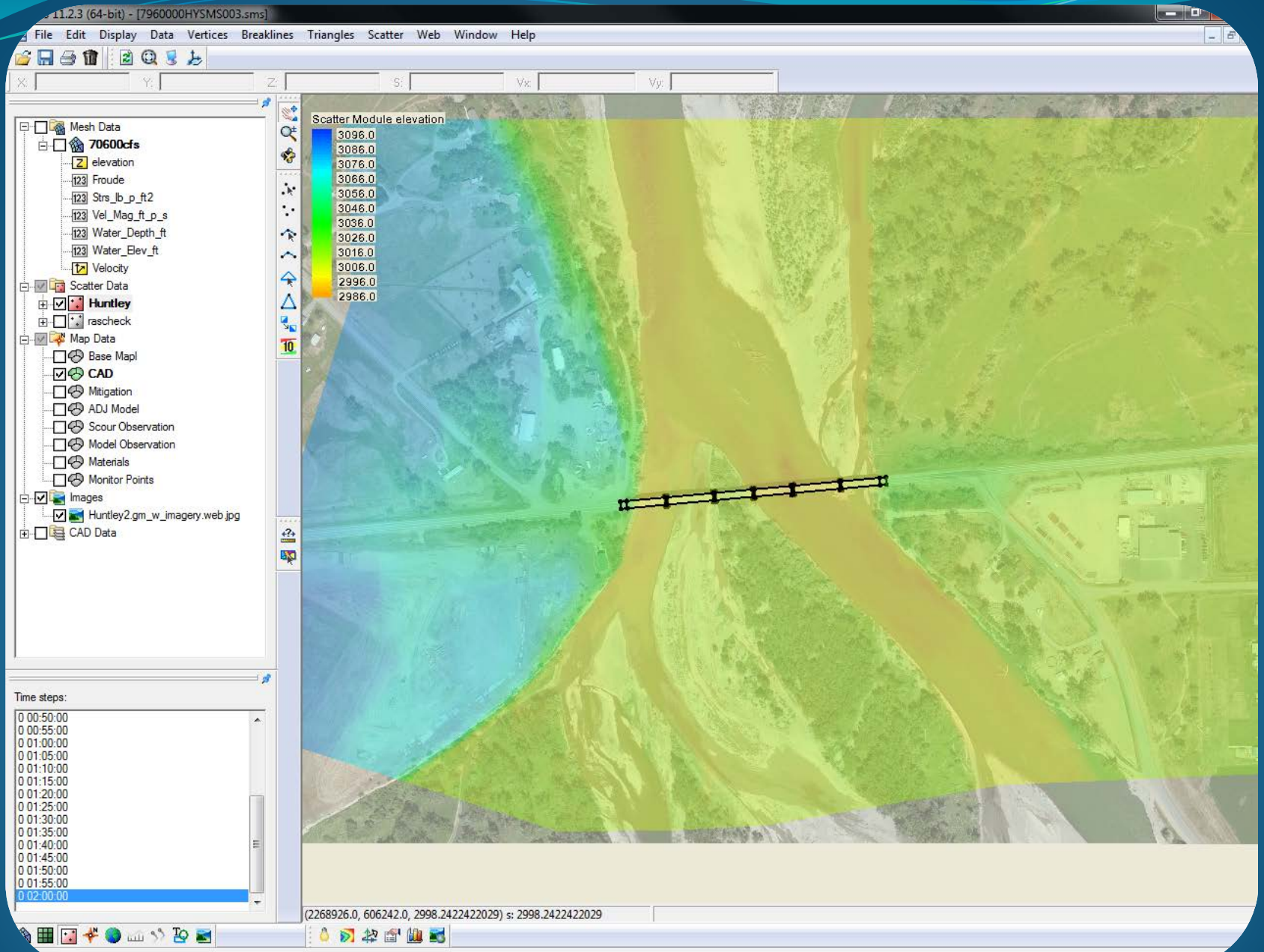


Old US Highway 312 Crossing the Yellowstone River at Huntley, MT

Determine Mechanisms of failure:

- **Design Features**
  - Review Plans
- **Construction Techniques**
  - Review Methods of Construction
- **Data Requested**
  - Bathymetric Survey
- **Hydraulic Forces**
  - Flood Flow
  - Hydraulic Modeling

Old US Highway 312 Crossing the Yellowstone River at Huntley, MT



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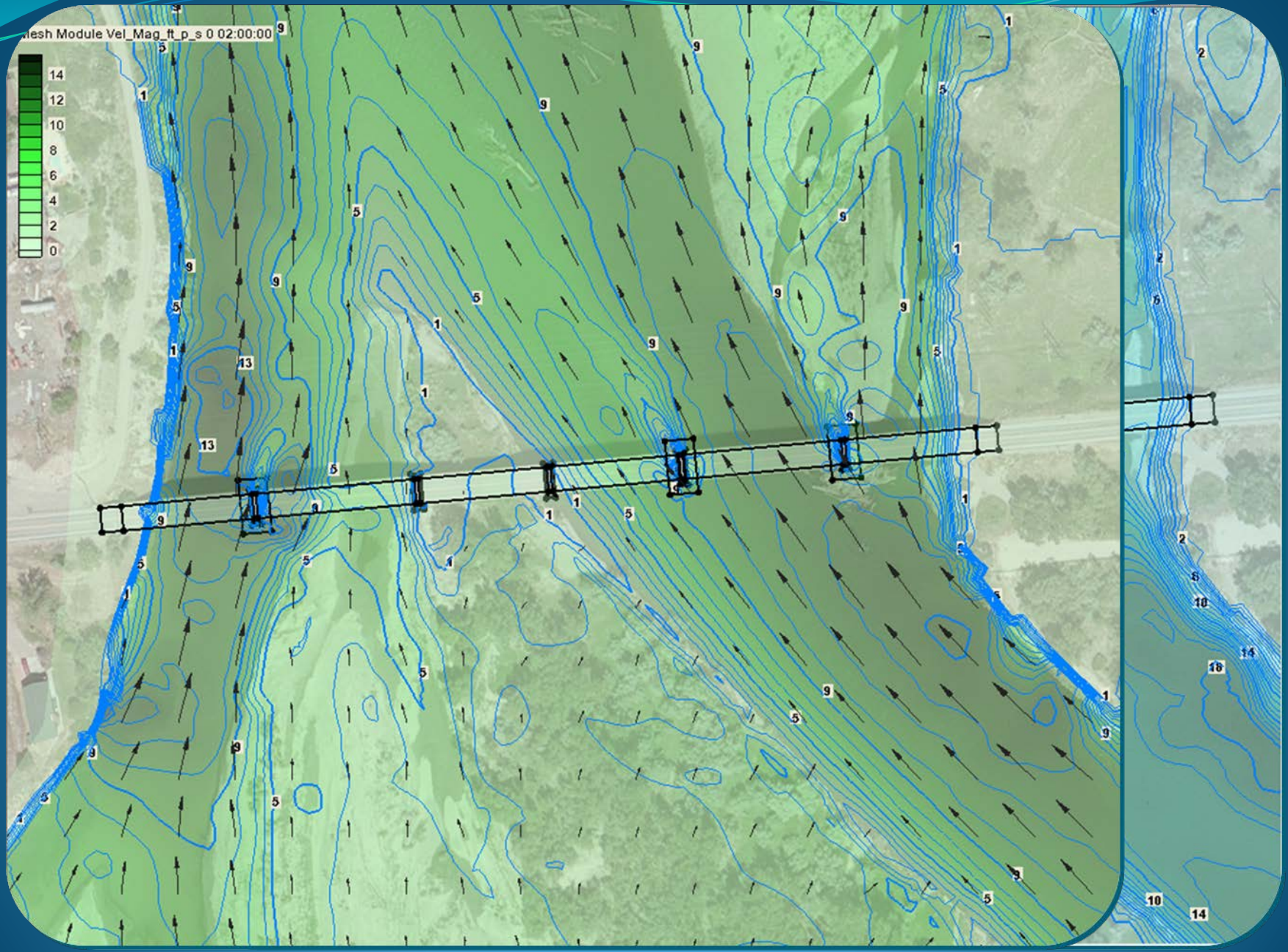

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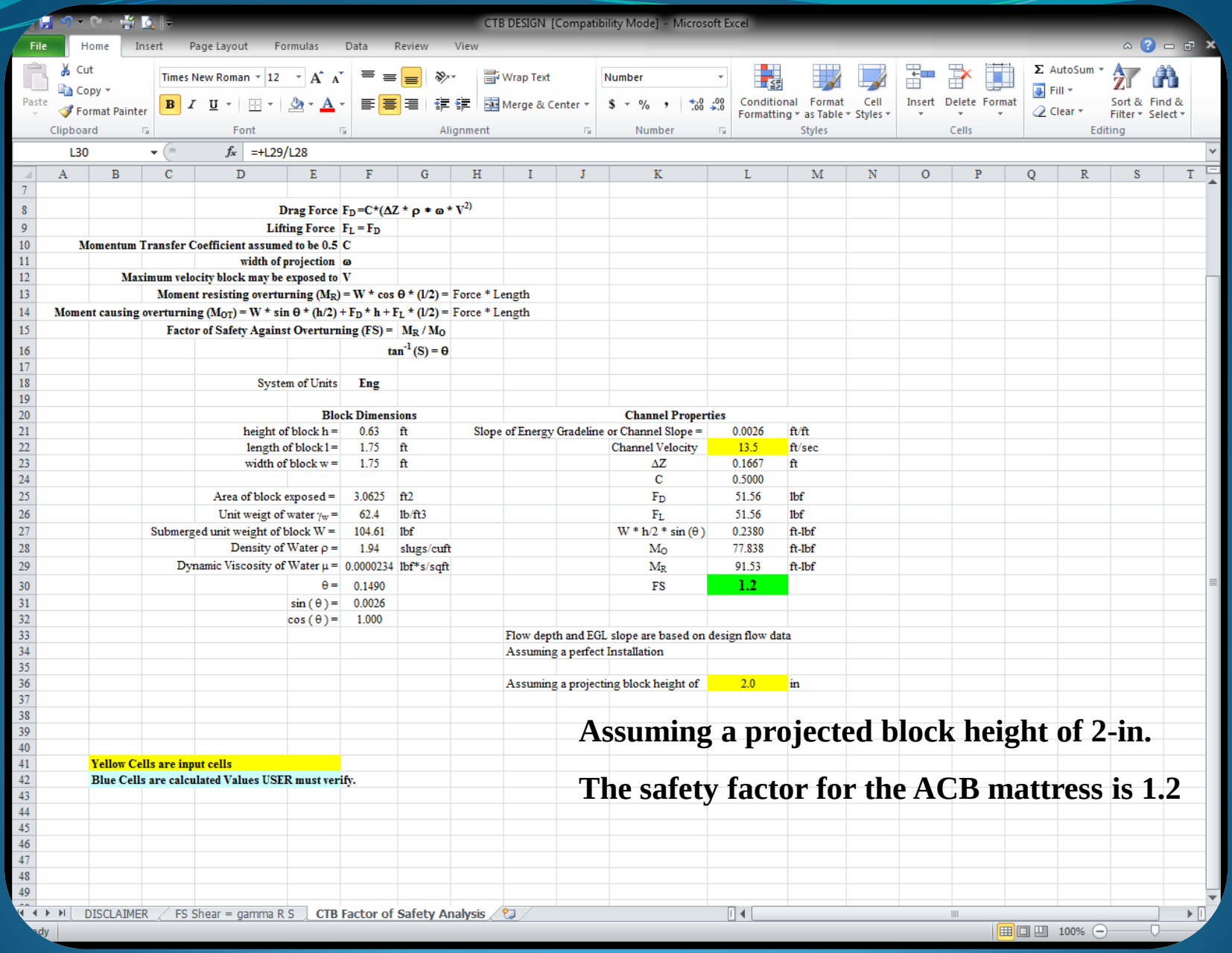


CTB DESIGN [Compatibility Mode] - Microsoft Excel

File | Home | Insert | Page Layout | Formulas | Data | Review | View

Cell L30: =+L29/L28

8					Drag Force	$F_D = C^*(\Delta Z * \rho * \omega * V^{2})$													
9					Lifting Force	$F_L = F_D$													
10				Momentum Transfer Coefficient assumed to be 0.5		C													
11					width of projection	ω													
12				Maximum velocity block may be exposed to		V													
13					Moment resisting overturning (M_R) = W * cos θ * (l/2) =	Force * Length													
14				Moment causing overturning (M_{OT}) = W * sin θ * (h/2) + F_D * h + F_L * (l/2) =		Force * Length													
15					Factor of Safety Against Overturning (FS) =	M_R / M_O													
16						$\tan^{-1}(S) = \theta$													
17																			
18					System of Units	Eng													
19																			
20					Block Dimensions							Channel Properties							
21					height of block h =	0.63	ft					Slope of Energy Gradeline or Channel Slope =	0.0026	ft/ft					
22					length of block l =	1.75	ft					Channel Velocity	13.5	ft/sec					
23					width of block w =	1.75	ft					ΔZ	0.1667	ft					
24												C	0.5000						
25					Area of block exposed =	3.0625	ft2					F_D	51.56	lbf					
26					Unit weigt of water γ_w =	62.4	lb/ft3					F_L	51.56	lbf					
27					Submerged unit weight of block W =	104.61	lbf					W * h/2 * sin (θ)	0.2380	ft-lbf					
28					Density of Water ρ =	1.94	slugs/cuft					M_O	77.838	ft-lbf					
29					Dynamic Viscosity of Water μ =	0.0000234	lbf*s/sqft					M_R	91.53	ft-lbf					
30					θ =	0.1490						FS	1.2						
31					sin (θ) =	0.0026													
32					cos (θ) =	1.000													
33												Flow depth and EGL slope are based on design flow data							
34												Assuming a perfect Installation							
35																			
36												Assuming a projecting block height of	2.0	in					
37																			
38																			
39																			
40																			
41				Yellow Cells are input cells															
42				Blue Cells are calculated Values USER must verify.															
43																			
44																			
45																			
46																			
47																			
48																			
49																			

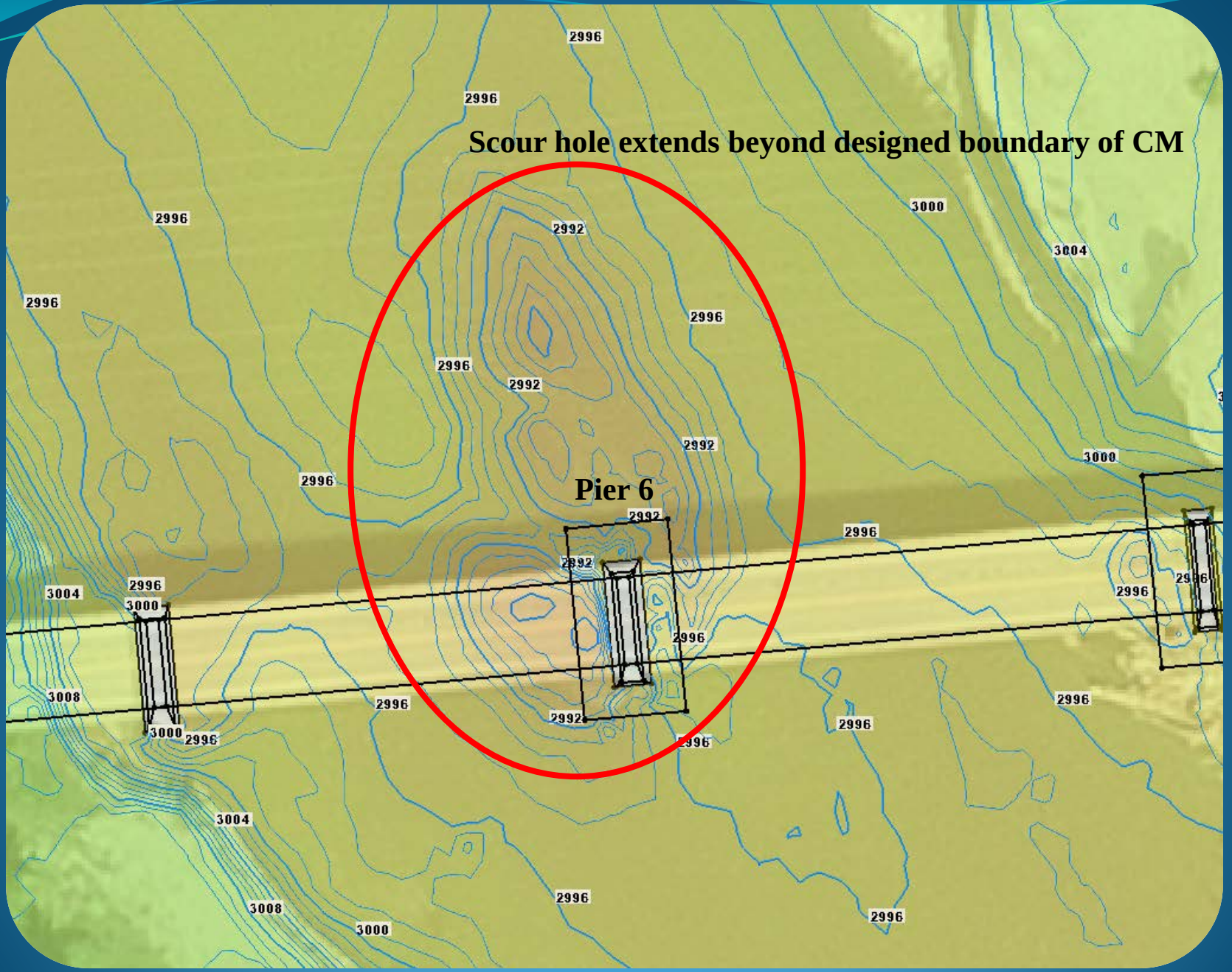
Assuming a projected block height of 2-in.

The safety factor for the ACB mattress is 1.2

DISCLAIMER | FS Shear = gamma R S | CTB Factor of Safety Analysis

100%

Old US Highway 312 Crossing the Yellowstone River at Huntley, MT



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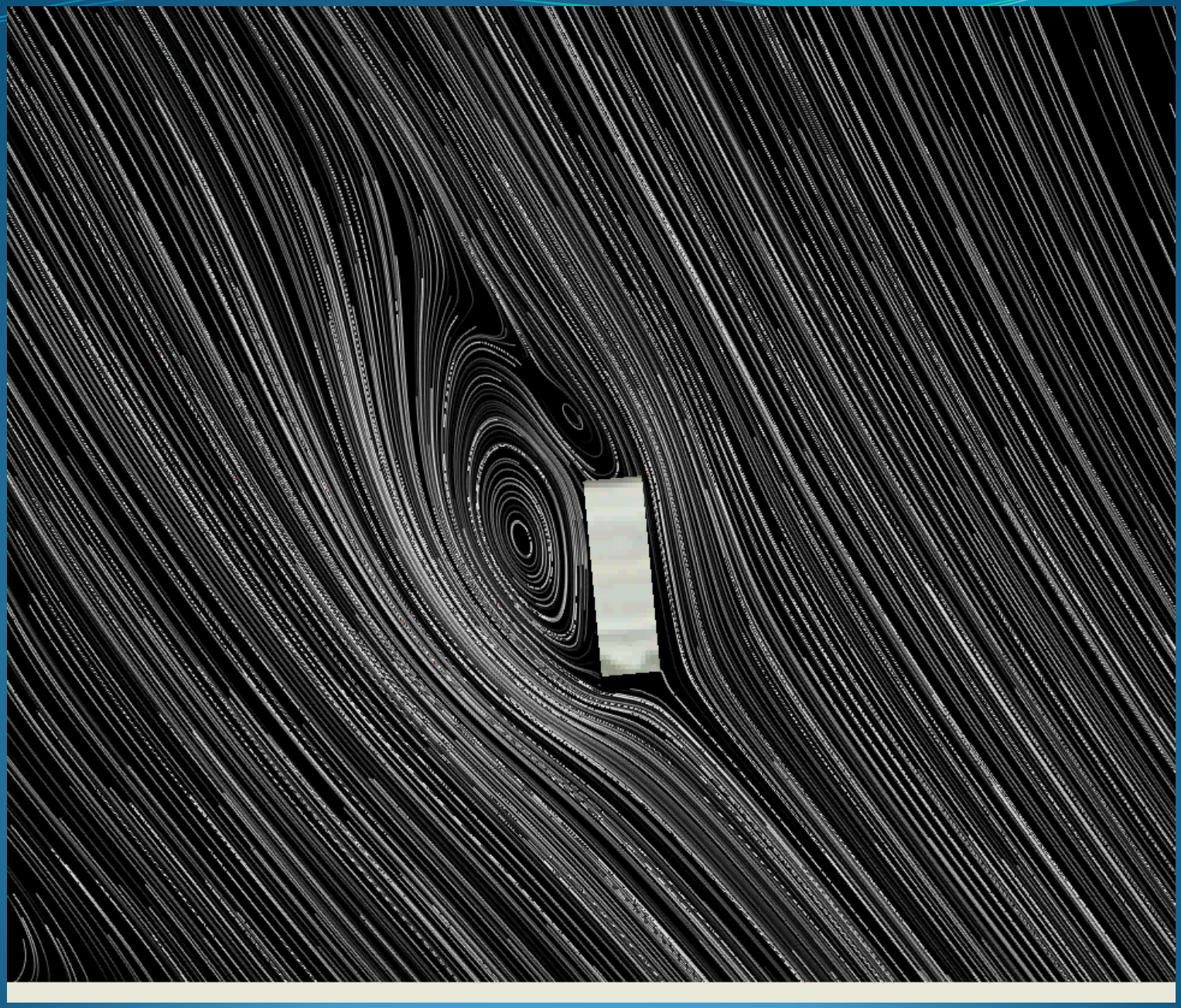

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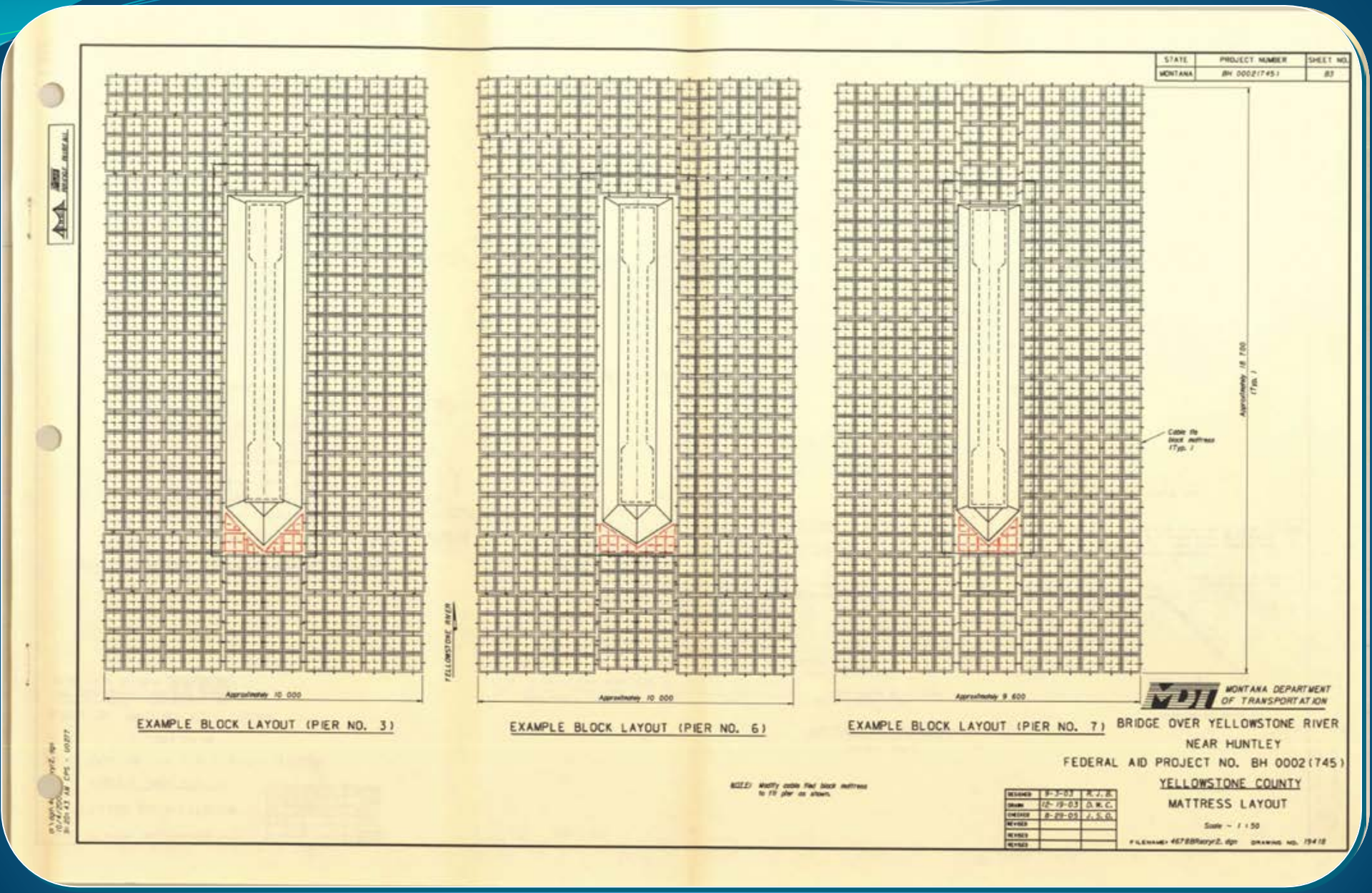
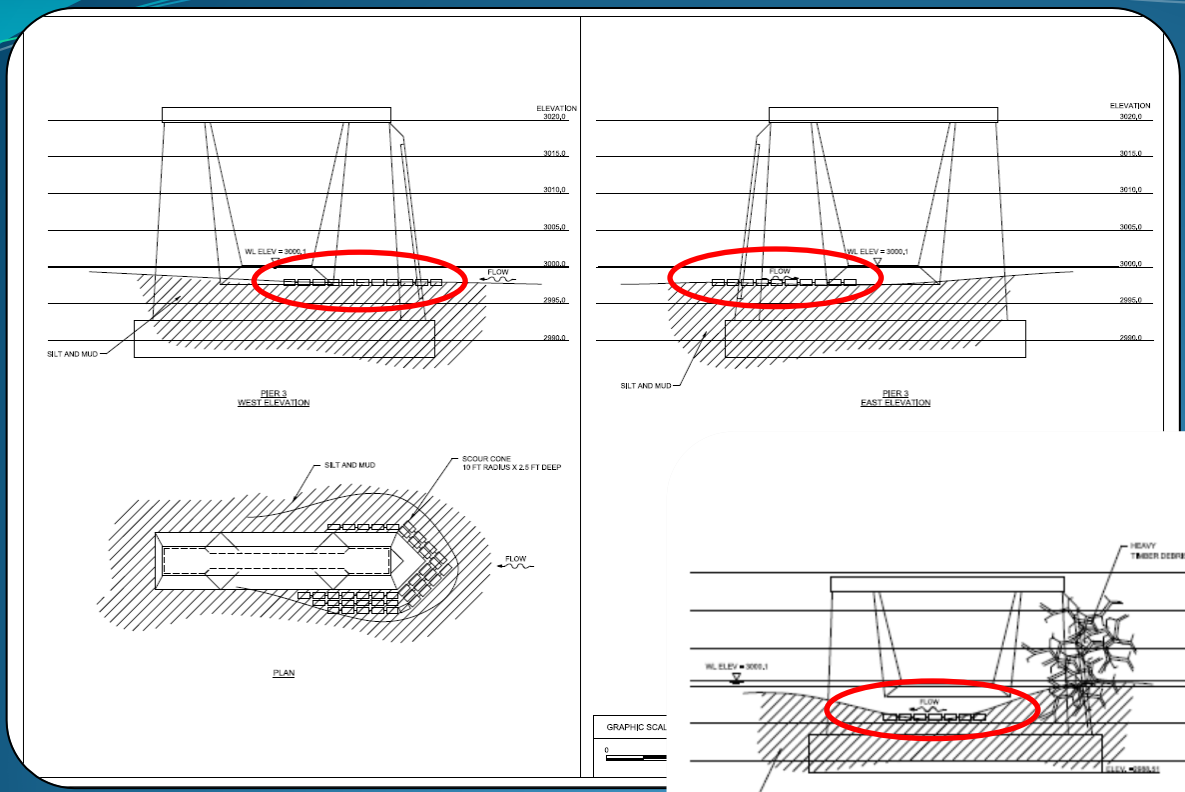


US Highway 312 Crossing the Yellowstone River at Huntley, MT

Contractors Solution

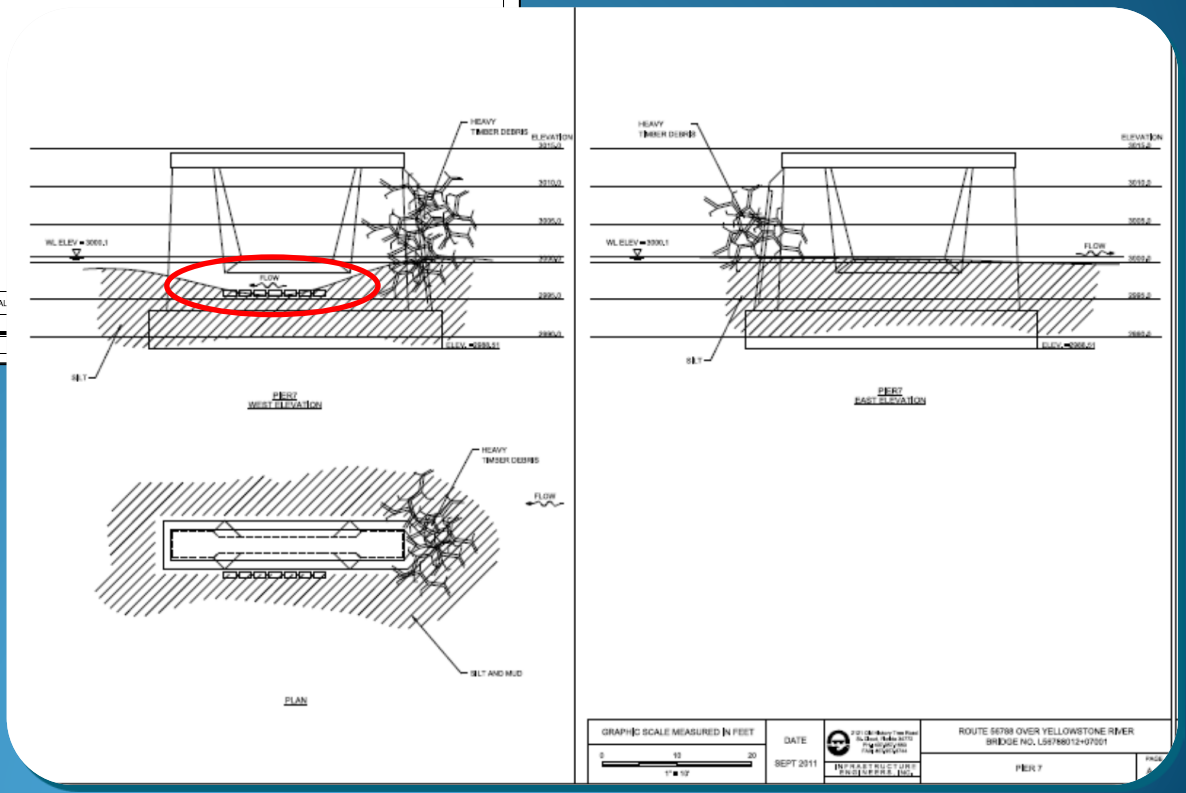
- Earthen Cofferdams
- Excavate to Depth

Old US Highway 312 Crossing the Yellowstone River at Huntley, MT



2011 Underwater Inspection report

Counter Measures were installed approximately 5-feet above footing at pier 3.



Counter Measures installed approximately 2-feet above the footing at pier 7.

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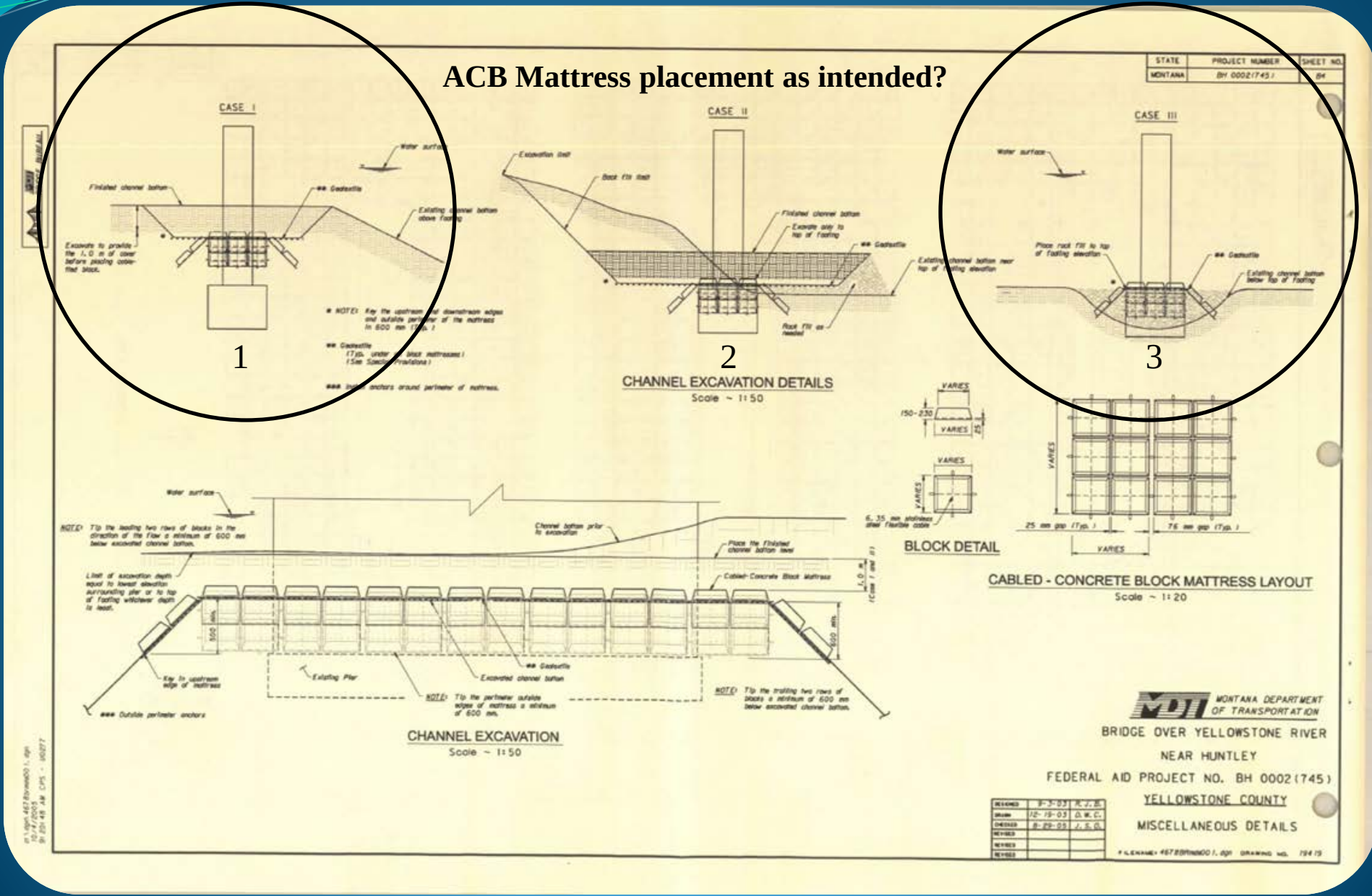

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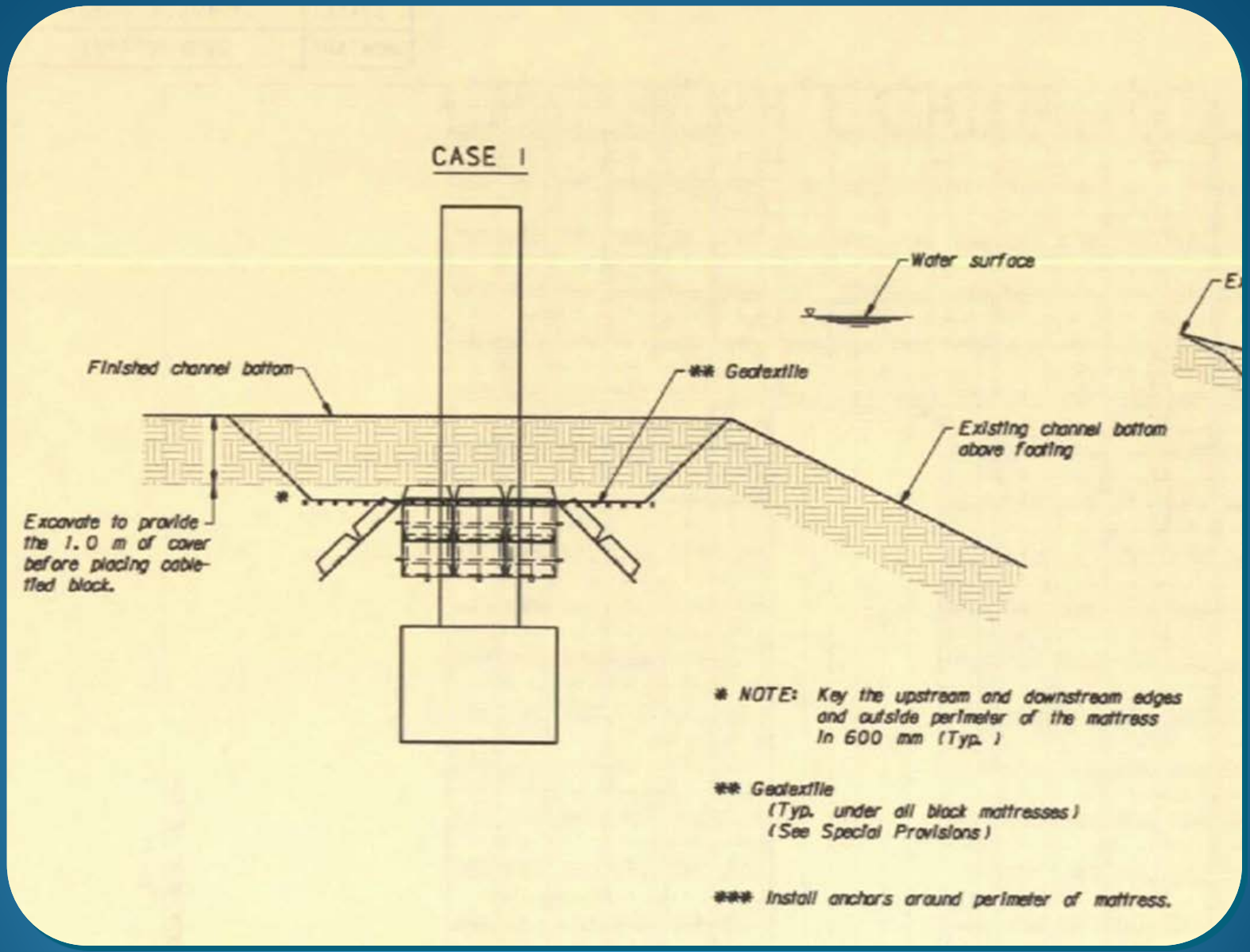

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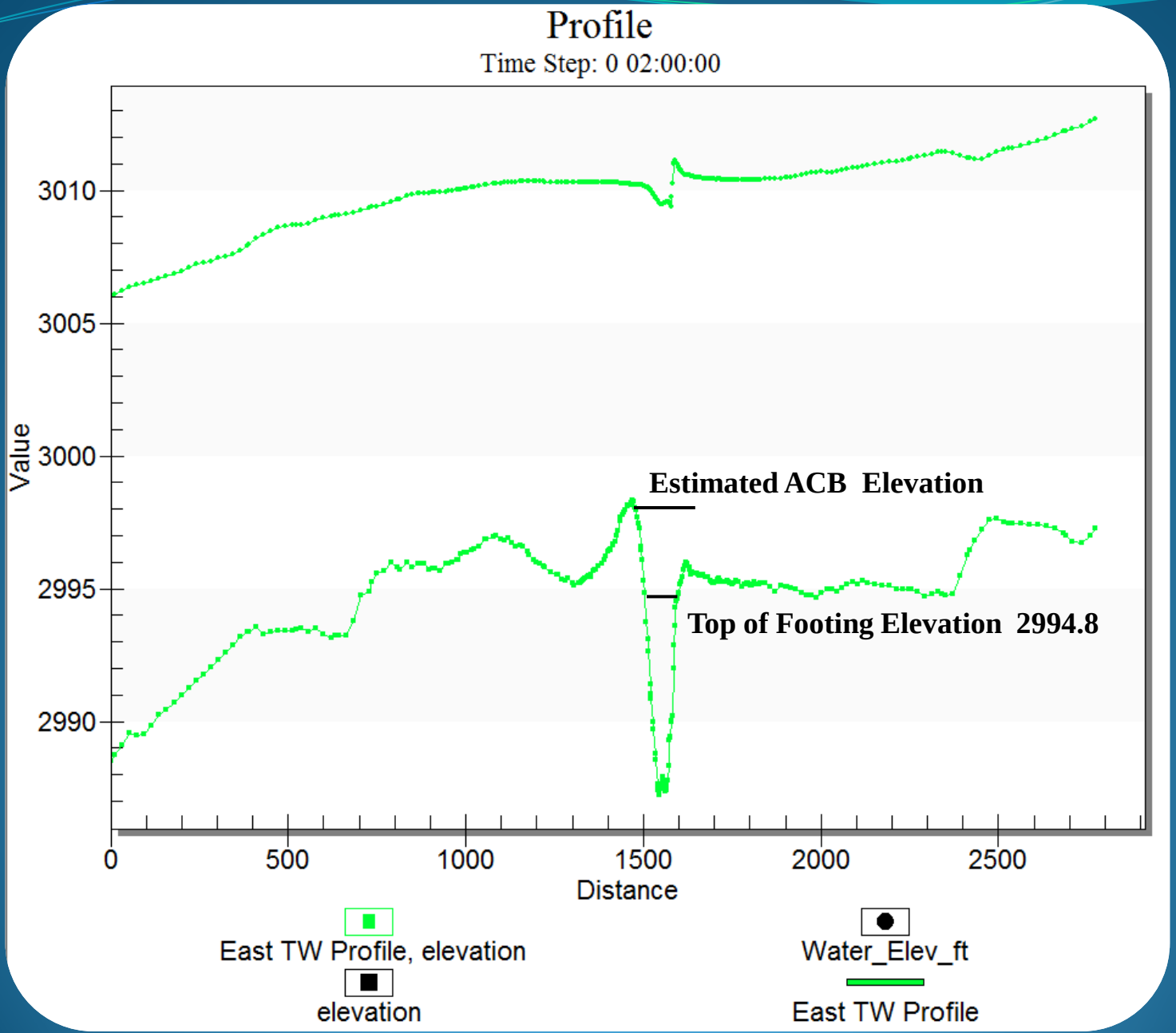

Old US Highway 312 Crossing the Yellowstone River at Huntley, MT

Conclusion:

- **ACB Failure combination of factors.**
  - **Minimal Survey**
  - **ACB Elevations not specified**
  - **Plan Interpretation**
    - **Contractor**
    - **Construction PM**
    - **Designer**
  - **ACB' s placed above channel thalweg.**
  - **Material beneath ACB mobile and likely washed away.**
  - **Experience**

Old US Highway 312 Crossing the Yellowstone River at Huntley, MT

- **Initial Site Survey/Evaluation**
  - Better description of what is going on underwater.
  - Aid in CM Selection process.
  - Allow for more detailed hydraulic modeling
  - Allow for better plan preparation
- **Design**
  - Define final elevations of countermeasures.
  - Extend depth of mattress “key” to minimum of exposed Footing Height.
- **Construction**
  - Technique and Experience
  - Plan Interpretation
  - Better communication
    - Construction Project manager
    - Design Engineer
    - Contractor.

Old US Highway 312 Crossing the Yellowstone River at Huntley, MT