Evaluation of Selected Abutment-Scour Equations — NCHRP Project 24-20(2) —

by

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Presentation Topics

Photograph courtesy of H. H. Weldon

Presentation Topics

- Project objective for NCHRP 24-20(2)
- Overview of field data
- Overview of equations
- Preliminary findings
- Upper bound of scour in laboratory and field data

NCHRP Project 24-20(2)

Objective:

Use laboratory and field data to evaluate the performance of 2 abutment-scour prediction equations recently developed under the direction of the NCHRP.

- *NCHRP Project 24-15(2)*
  Abutment Scour in Cohesive Materials (Briaud and others, 2009)

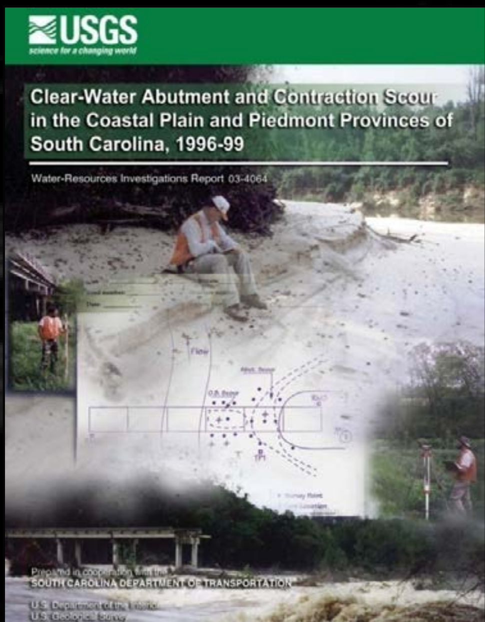
- *NCHRP Project 24-20*
  Estimation of Scour Depth at Bridge Abutments (Ettema and others, 2010)

Abutment Scour Field Data:

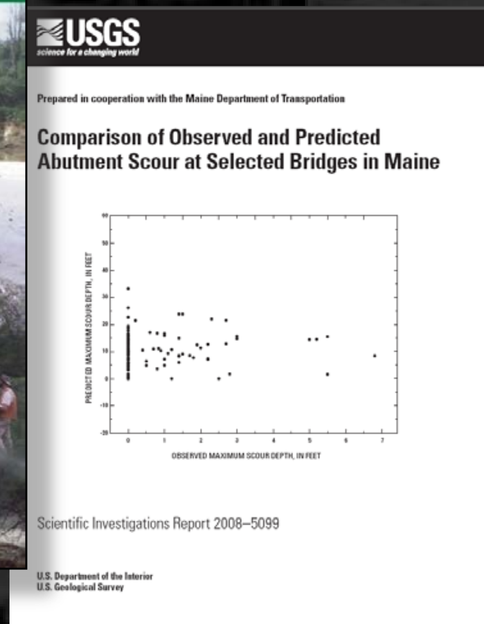
Abutment Scour Field Data:

- Four primary sources:

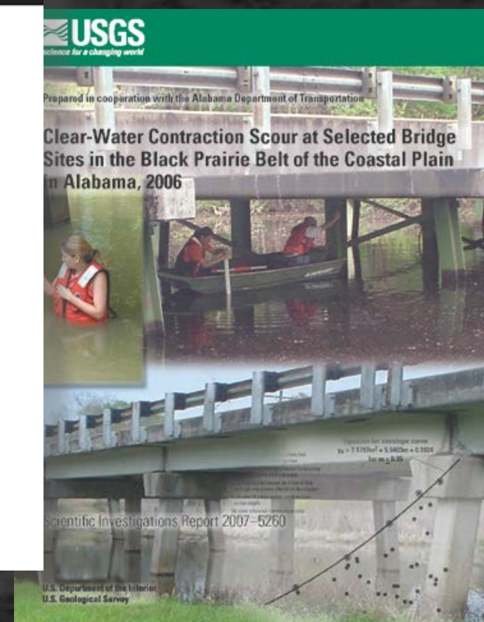
South Carolina



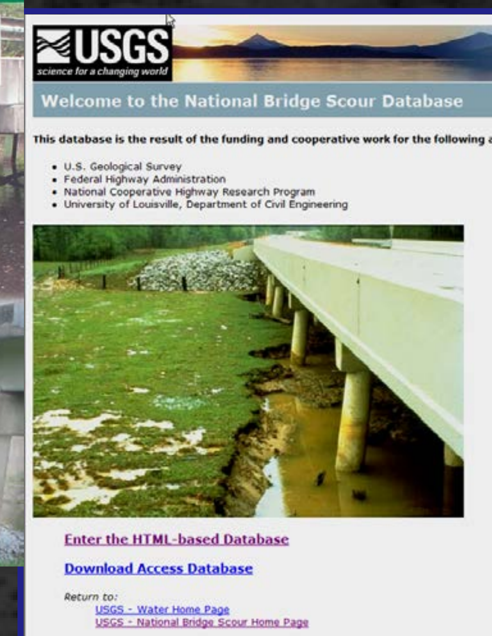
Maine



Alabama



National Data



Abutment Scour Field Data:

Range value	Drainage area (miles^2)	Channel slope (ft/ft)	Average approach velocity (ft/s)	Average approach depth (ft)	Embankment length blocking flow (ft)	Median grain size (mm)	Observed abutment-scour depth (ft)
South Carolina Piedmont (92 observations)							
Minimum	11	0.00015	0.1	1.0	18	< 0.062	0.0
Median	75	0.0012	0.9	5.4	276	0.073	1.3
Maximum	1,620	0.0029	3.2	14.6	953	0.99	18.0
South Carolina Coastal Plain (106 observations)							
Minimum	6	0.00007	0.1	1.5	87	< 0.062	0.0
Median	120	0.0005	0.5	4.7	557	0.18	7.0
Maximum	8,830	0.0024	1.5	17.4	7,440	0.78	23.6
Maine (93 observations)							
Minimum	4	0.001	0.9	1.1	0	0.25	0
Median	20	0.004	3.9	6.8	30	45	0
Maximum	95	0.044	10.2	15.3	370	180	6.8
Alabama (23 observations)							
Minimum	10	0.0004	0.1	3.3	43	0.001	1.4
Median	80	0.0008	0.6	5.3	400	0.0091	4.7
Maximum	607	0.0016	1.2	8.8	1141	0.17	10.4
National Bridge Scour Database (15 observations)							
Minimum	836	0.00006	0.5	1.4	15	0.001	0.0
Median	1,330	0.00032	0.8	4.6	539	0.15	4.6
Maximum	16,000	0.0046	3.5	14.3	3,446	35.	18.0

Large database:

- 329 measurements
- Smaller drainage areas
- Wide range in slope and grain size
- 93% of data are clear-water scour
- Data are limited and not always ideal

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Limitations of USGS Field Data:

1. Historic abutment scour – Post-flood measurements
2. Hydraulics estimated with 1-D model with index flows
   - 1-D models will underestimate velocity at abutment
   - SBR method was used to compensate for this limitation
3. Limitations will introduce error into the analysis and must be kept in mind when reviewing results
   - Currently best available data
   - Large number of measurements will provide a good indicator of equation trends

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National Cooperative Highway Research Program

NCHRP REPORT 24-15 (2)

ABUTMENT SCOUR IN COHESIVE MATERIALS

J.-L. Briaud, H.-C. Chen, K.-A Chang, S. J. Oh, X. Chen

October 2009

Transportation Research Board

National Research Council

NCHRP 24-15(2)

(Briaud and others, 2009)

Focus:

Abutment-scour in cohesive sediments

- Extended for non-cohesive sediments
- Includes two prediction methods:
  - time dependent method
  - the maximum scour-depth equation
- Evaluation was limited to use of the maximum scour-depth equation, because of insufficient data for the time-dependent method

NCHRP 24-15(2)

(Briaud and others, 2009)

Maximum Scour-Depth Equation

$$y_s/y_1 = K_1 K_2 K_L K_G K_p 243 \mathrm{Re}_{f2}^{-0.28}\left(1.65 Fr_{f2} - Fr_{fc}\right)$$

- y_s is the abutment scour depth
- y_1 is the approach flow depth
- K_1 is the correction factor for *abutment shape*
- K_2 is the correction factor for *abutment skew*
- K_G is the correction factor for *channel geometry*
- K_L is the correction factor for *abutment location*
- K_p is the correction factor for *pressure flow*
- Fr_{f2} is the Froude number around the toe of the abutment
- Fr_{fc} is the sediment critical Froude number
- Re_{f2} is the Reynolds number around the toe of the abutment

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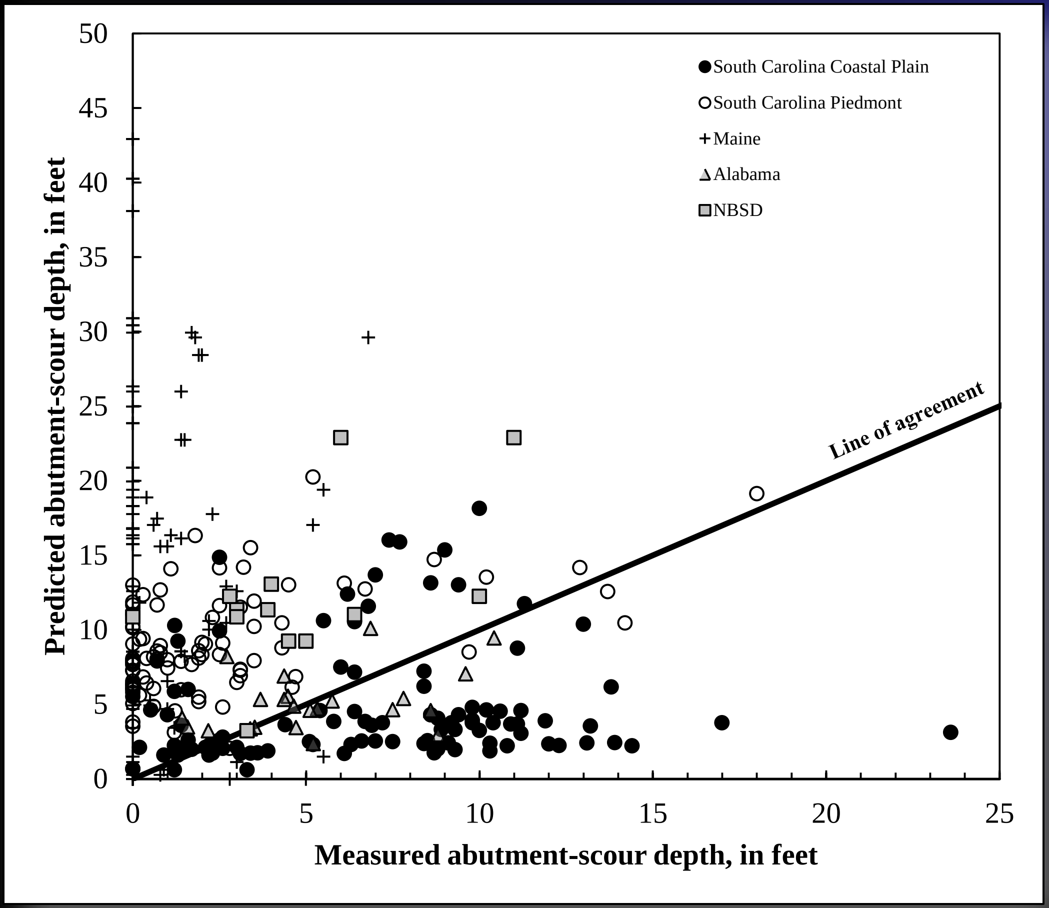
(Briaud and others, 2009)

Predicted vs. Observed for Field Data

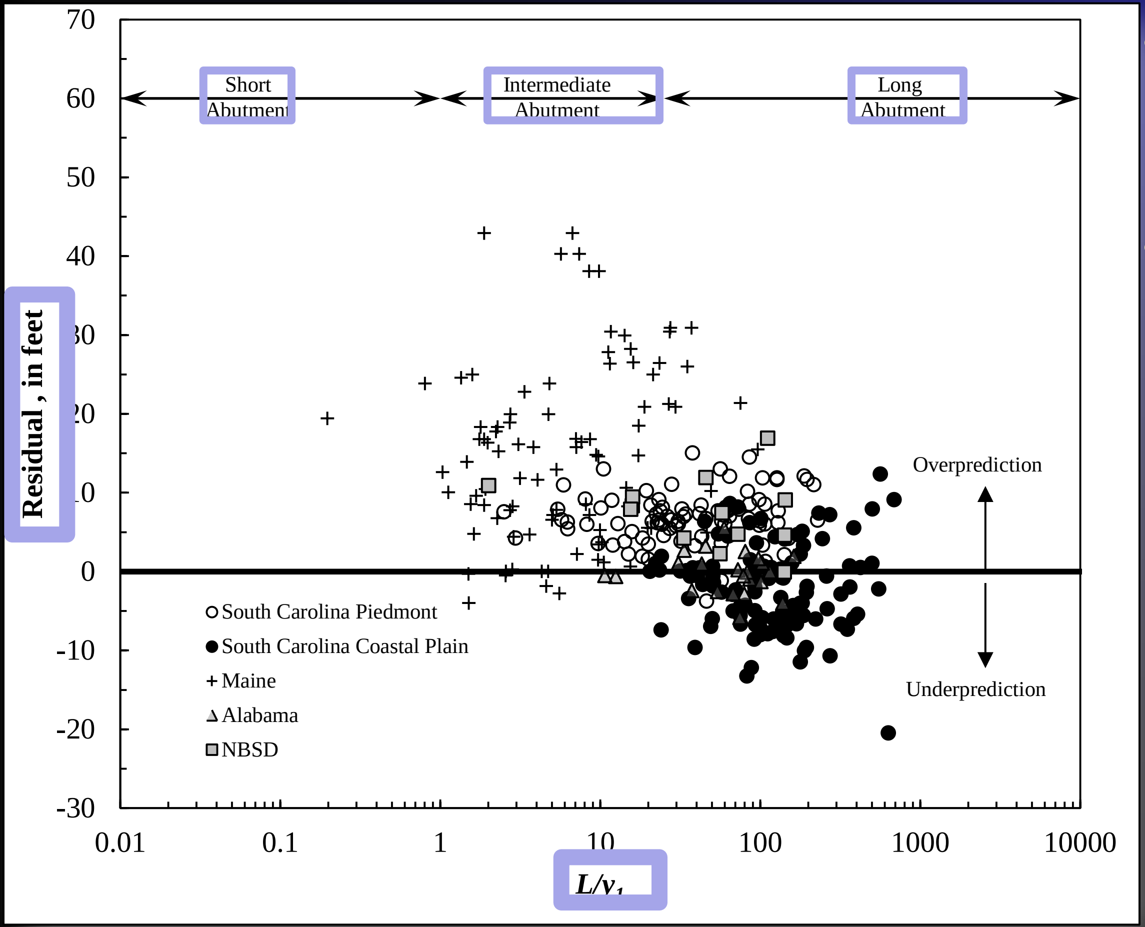


- Performs better with cohesive sediments
- More frequent underprediction for rectangular channels (K_G= 0.42)
- Recommending that K_G be set to 1.0 for rectangular channels (Melville and Coleman, 2000)
- Largest overpredictions at protruding abutments (K_L= 1.35)
- Recommending that K_L be set to 1.0 for protruding abutments

NCHRP 24-15(2)

(Briaud and others, 2009)

Residuals vs. Relative Abutment Length



- Larger magnitude and frequency of underprediction for long abutments
- Recommending that Melville (1992) correction for long abutments be included for non-cohesive sediments

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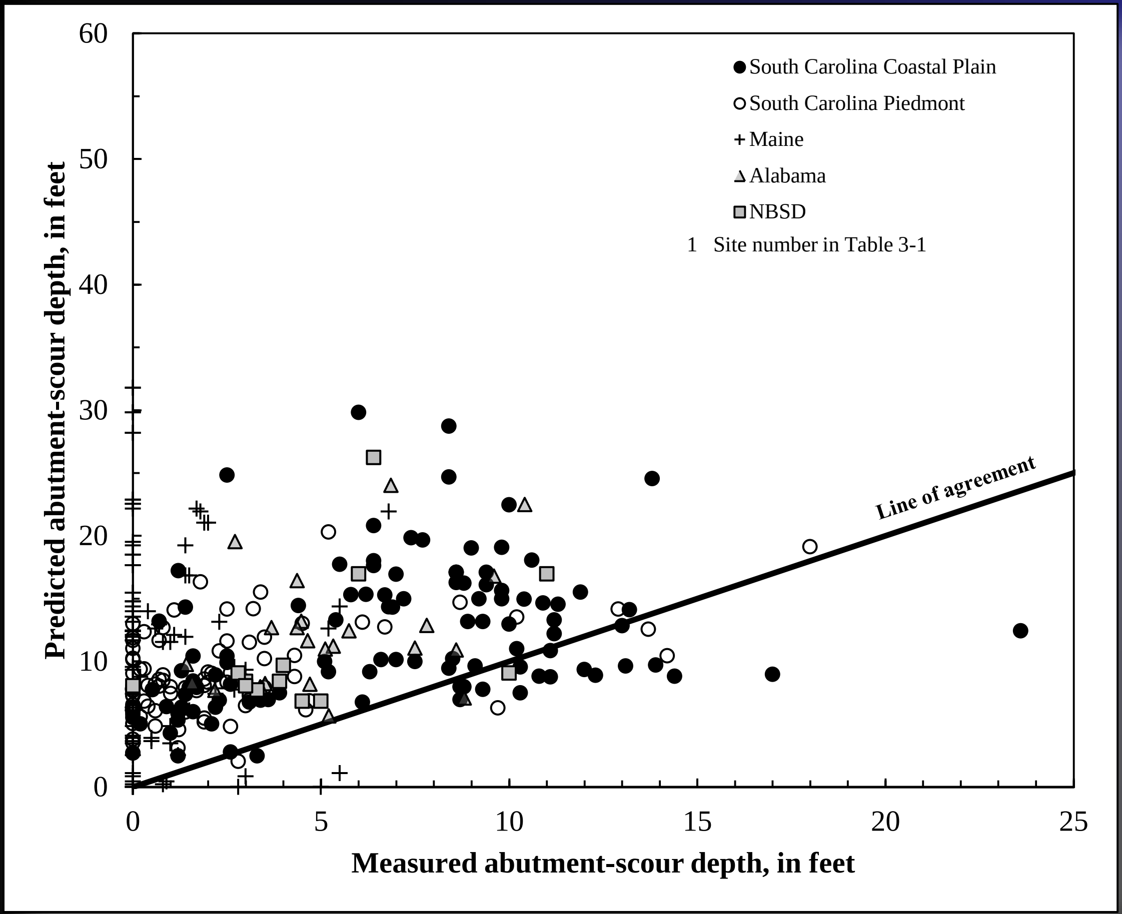
NCHRP 24-15(2)

(Briaud and others, 2009)

With Recommended Modifications



- K_G =1.0 for rectangular channels
- K_L =1.0 for protruding abutments
- Include Melville's correction for long abutments for non-cohesive sediments
- Remaining underprediction is likely caused by under estimates of flow velocity from 1-D models

NCHRP Project 24-20(2)

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

DRAFT FINAL REPORT

ESTIMATION OF SCOUR DEPTH AT BRIDGE ABUTMENTS

NCHRP 24-20

Robert Ettema, Tatsuaki Nakato, and Marian Muste
The University of Iowa
Iowa City, Iowa 52242
USA

Subject Areas
Highway and Facility Design • Bridges, Other Structures, and Hydraulic and Hydrology •Soils, Geology, and Foundations • Materials and Construction

Research Sponsored by the American Association of State Highway and Transportation Officials in Cooperation with the Federal Highway Administration

TRANSPORTATION RESEARCH BOARD
WASHINGTON, D.C.
January 2010
www.TRB.org

NCHRP 24-20
(Ettema and others, 2010)

Focus:

Abutment-scour in non-cohesive sediments

- **Conceptually, abutment scour is a function of contraction scour**
- **Includes scour at erodible embankments**
  - **tends to produces smaller scour depths than fixed embankment**

NCHRP 24-20

(Ettema and others, 2010)

Scour Equation

$$Y_{MAX} = \alpha Y_C$$

- Y_{MAX} is the maximum flow depth in the abutment-scour area
- Y_C is the mean flow depth in contraction scour
  - Use Laursen (1960, 1963) live-bed or clearwater contraction scour equation
- α amplification factor accounting for additional scour at the abutment
  - laboratory derived relations for selected abutment conditions

$$y_s = Y_{MAX} - y_1$$

- y_s is the abutment-scour depth
- Y_1 is the approach-flow depth

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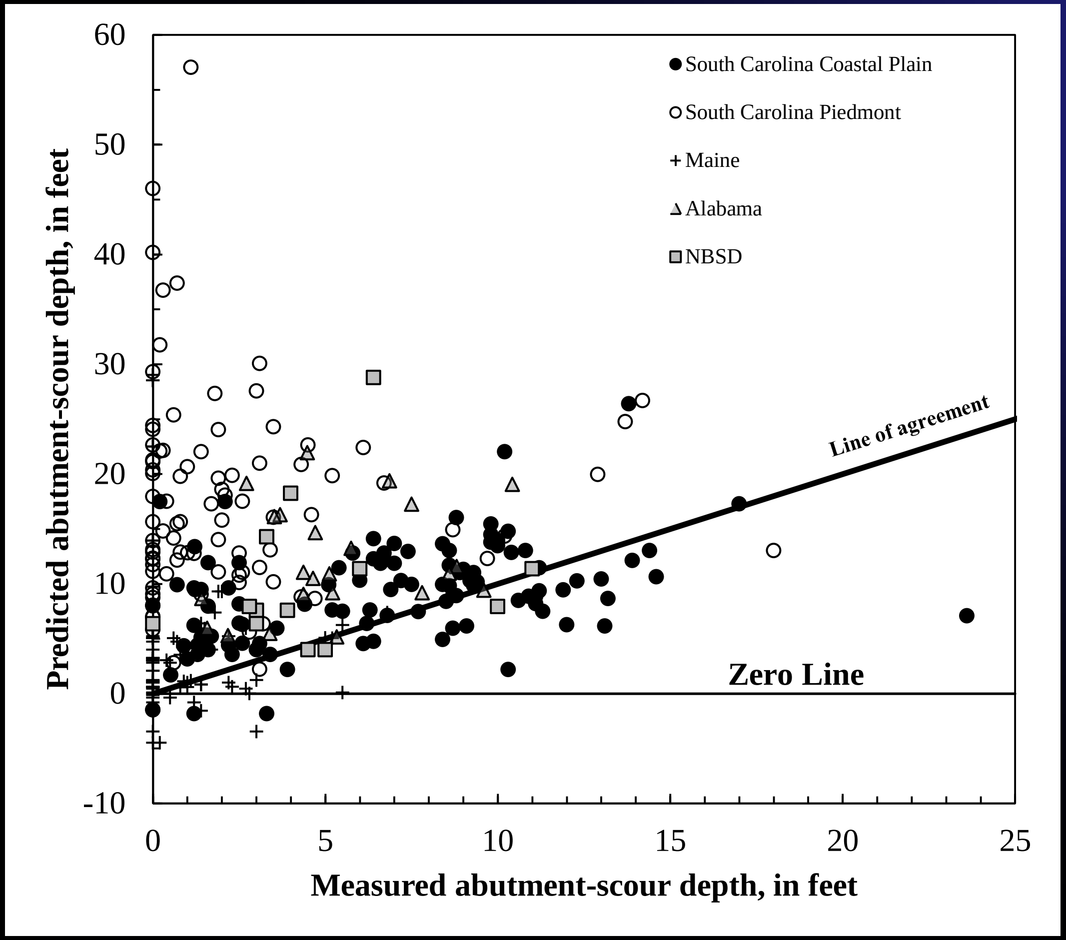
NCHRP 24-20

(Ettema and others, 2010)

Predicted vs. Observed for Field Data



- Underprediction is associated with relatively long abutments that may contribute to underprediction
- Underprediction is likely caused, in part, by under estimates of flow velocity at abutments

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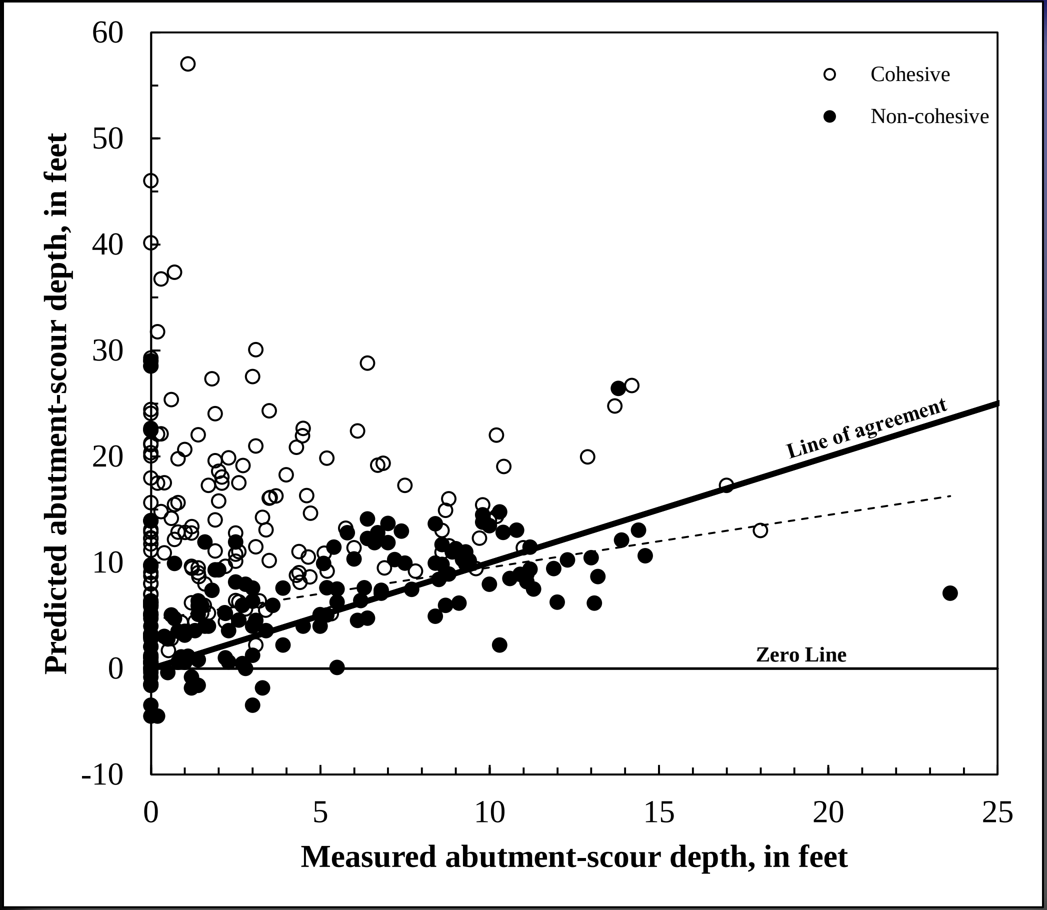
(Ettema and others, 2010)

Predicted vs. Observed for Field Data

Cohesive and Non-Cohesive



- Non-cohesive sediments have an approximate symmetric scatter around the line of agreement
- However, trend of more frequent underprediction as the scour depth increases
- Cohesive sediments have infrequent underprediction but at times excessive overprediction

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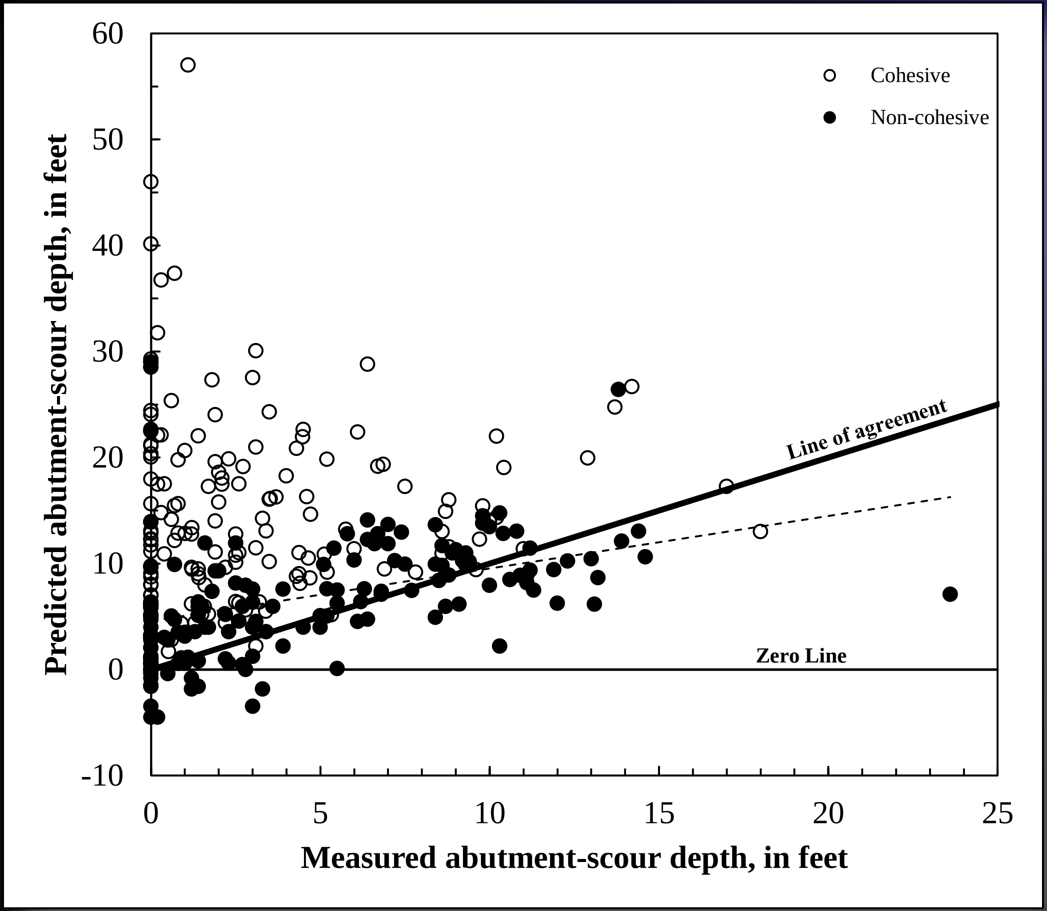
(Ettema and others, 2010)

Predicted vs. Observed for Field Data

Cohesive and Non-Cohesive



- Performs better with non-cohesive sediments
- Recommend considering an adjustment for long abutments
- Important to obtain good estimate of increased velocity at abutment

- Conclusions -

NCHRP 24-15(2)

- Performs better with cohesive sediments
- Recommend:
  - K_G = 1.0 for rectangular channels
  - K_L = 1.0 for protruding abutments
  - Include Melville's correction factor for long abutments with non-cohesive sediments
  - Obtain good estimate of velocity at abutment (2-D model)

NCHRP 24-20

- Performs better with non-cohesive sediments
- Recommend:
  - Include a correction factor for long abutments with non-cohesive sediments
  - Obtain good estimate of velocity at abutment (2-D model)

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Investigation of Long Abutments

The USGS outdoor flume can be used to investigate long abutments

- 4,400 feet in length
- 300 feet wide
- 10-feet wide, 1-foot deep channel
- Can study scour at near field scales

Upper Bound of Scour

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Prepared in cooperation with the South Carolina Department of Transportation

A Pier-Scour Database: 2,427 Field and Laboratory Measurements of Pier Scour

Data Series 845

U.S. Department of the Interior
U.S. Geological Survey

2014 USGS Pier-Scour Database

- **569 laboratory measurements**
- **1,858 field measurements**
  - **23 states**
  - **6 countries**
- **Online spreadsheet: http://pubs.usgs.gov/ds/0845/**

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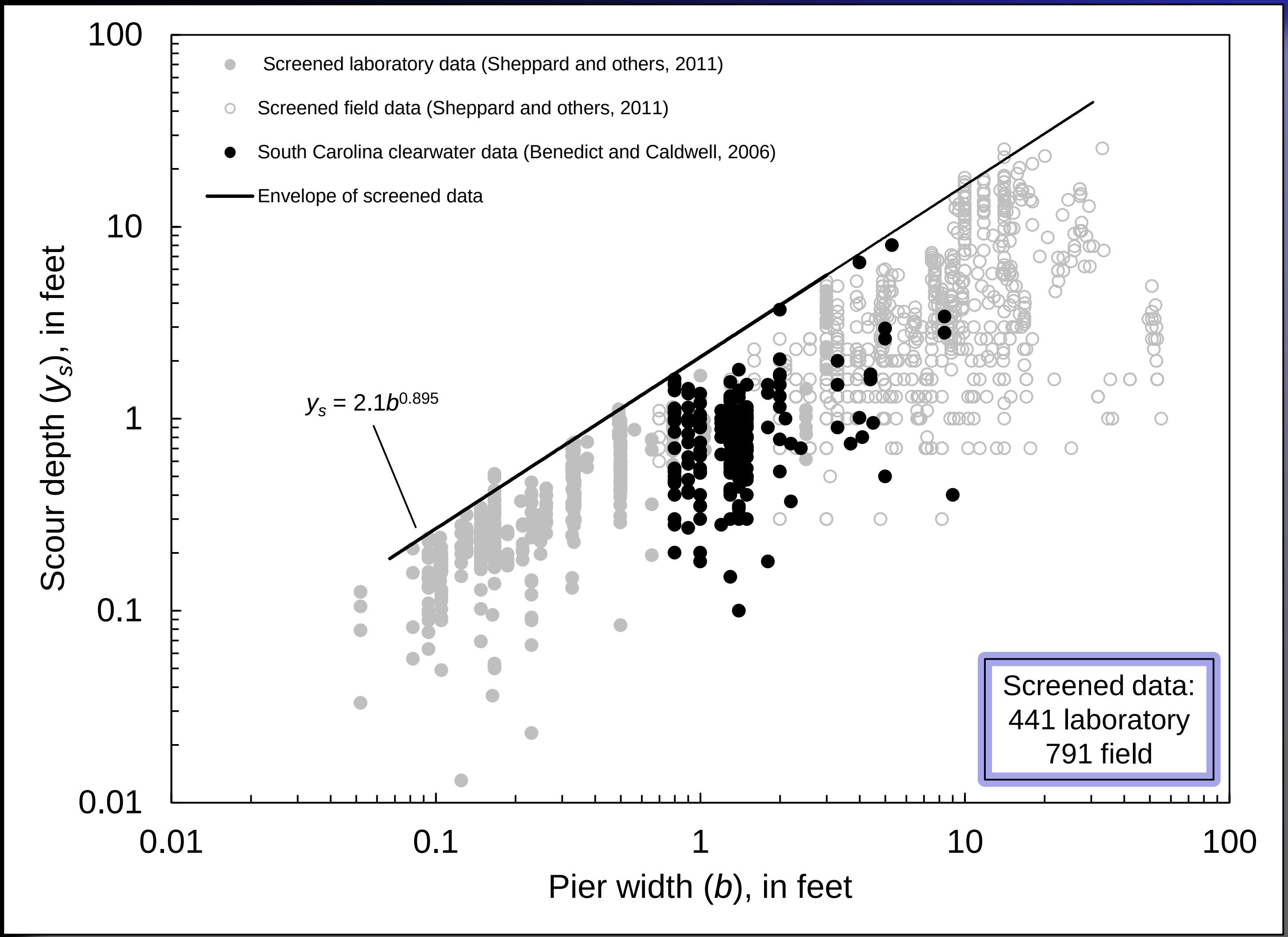
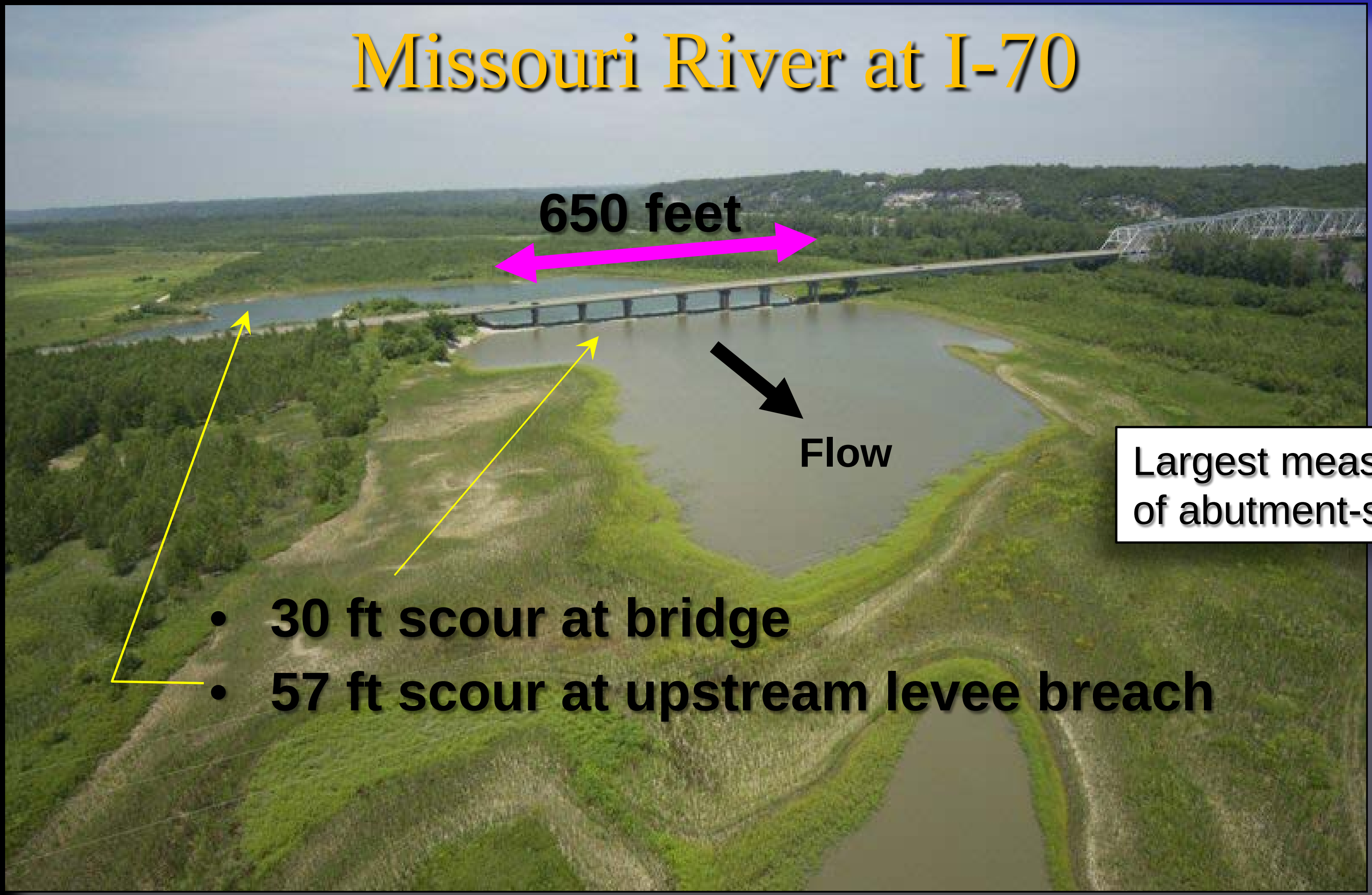
Upper Bound of Scour

- Upper Bound of Pier Scour -



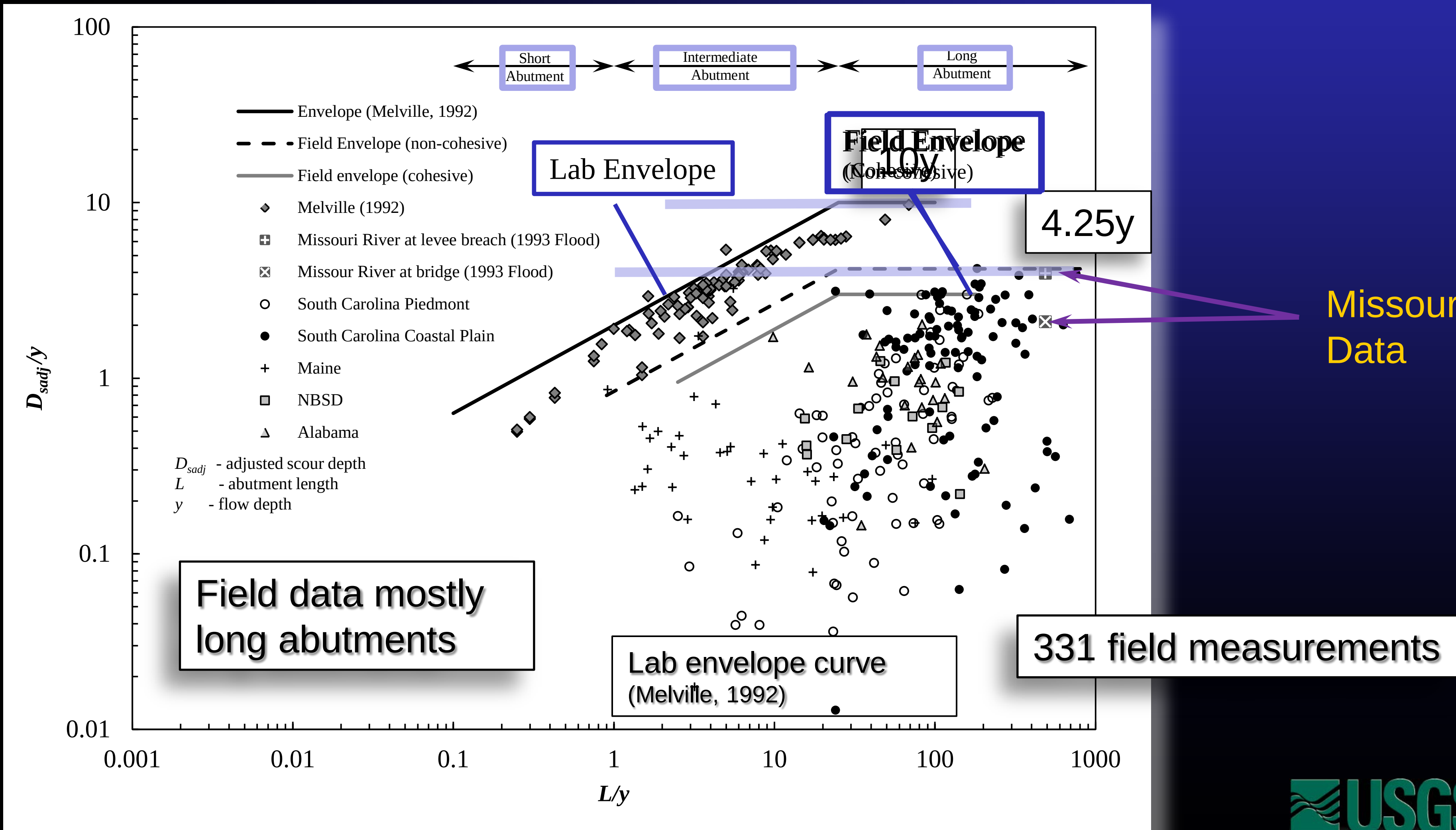
Upper Bound of Scour



Scour at I-70 bridge over Missouri River from 1993 flood, looking upstream (Photo by U.S. Army Corps of Engineers as cited in Headrick and Galat, 2007).

Upper Bound of Scour

- Upper Bound of Abutment Scour -



- Conclusions -

Upper-bound envelope curves are useful supplementary tools to assist in evaluating scour potential

Upper Bound of Pier Scour

- Strong envelope curve based on very large dataset

Upper Bound of Abutment Scour

- Good envelope curve, but additional data would be helpful to verify

Questions?

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