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NextScour: Case Studies Evaluating Scour

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NextScour: Case Studies Evaluating Scour

Source: TN DOT

Presentation agenda

- FHWA NextScour Initiative
- Hydraulic design parameters
- Geotechnical resistance to erosion
- Current practice: HEC-18
- Implementation: Case histories
  - Pooled fund
  - MI – Saginaw River Bridge
  - NC - I-6064/I-95 Bridge
- Opportunities for collaboration

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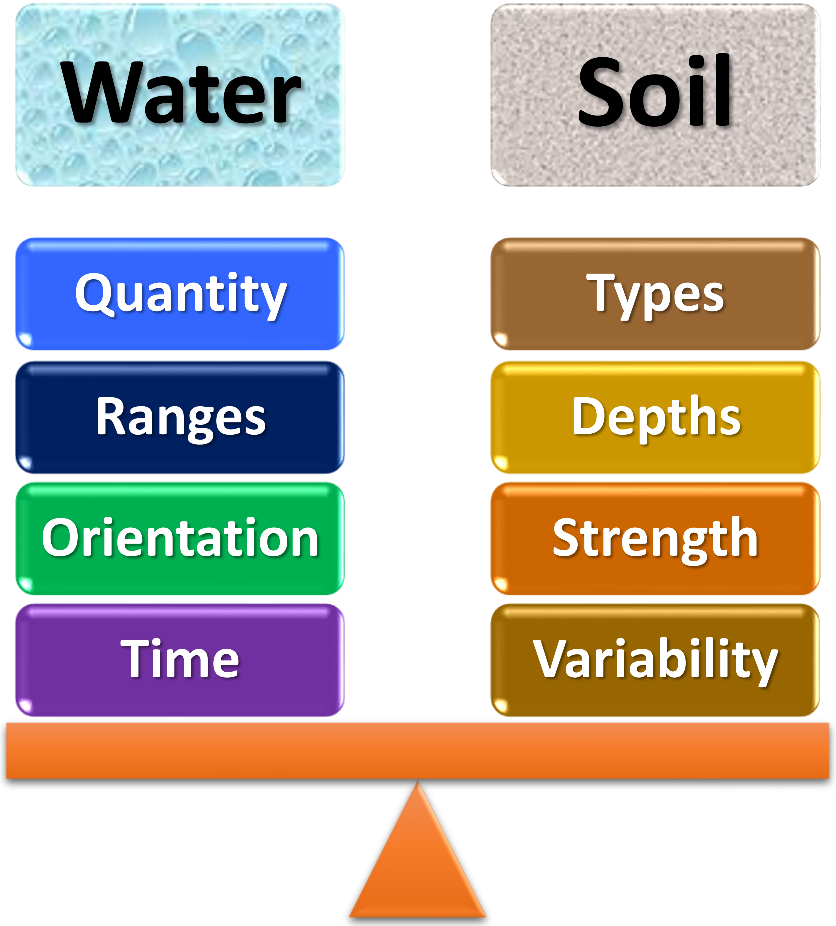
NextScour – Hydraulic and Geotech

Hydraulic parameters –

- Flow rate
- Velocity
- Depth
- Site conditions

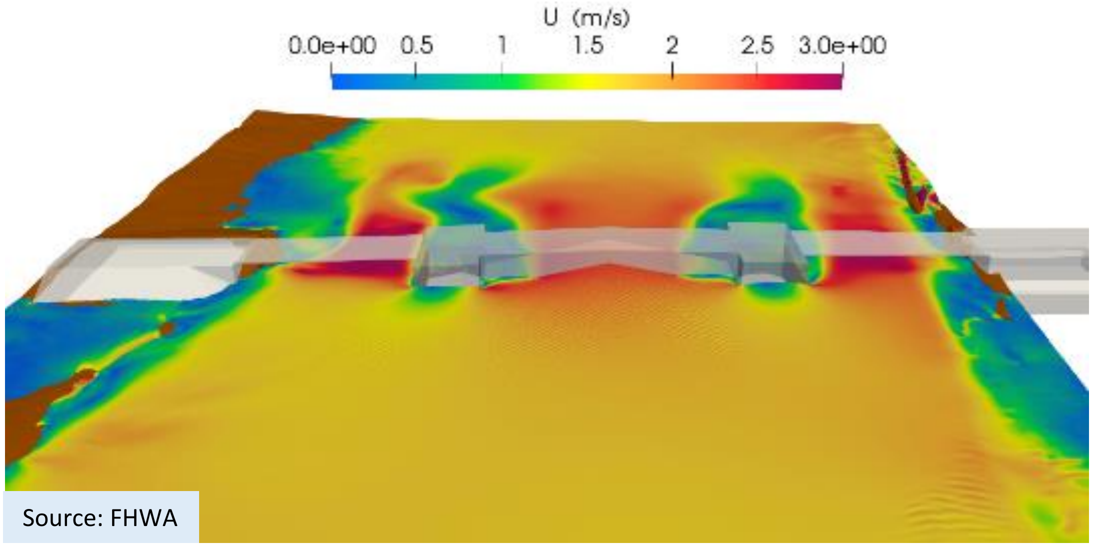
Geotechnical resistance –

- Material type and properties
- Geotechnical profile
- Depth and thickness of layers
- Continuity



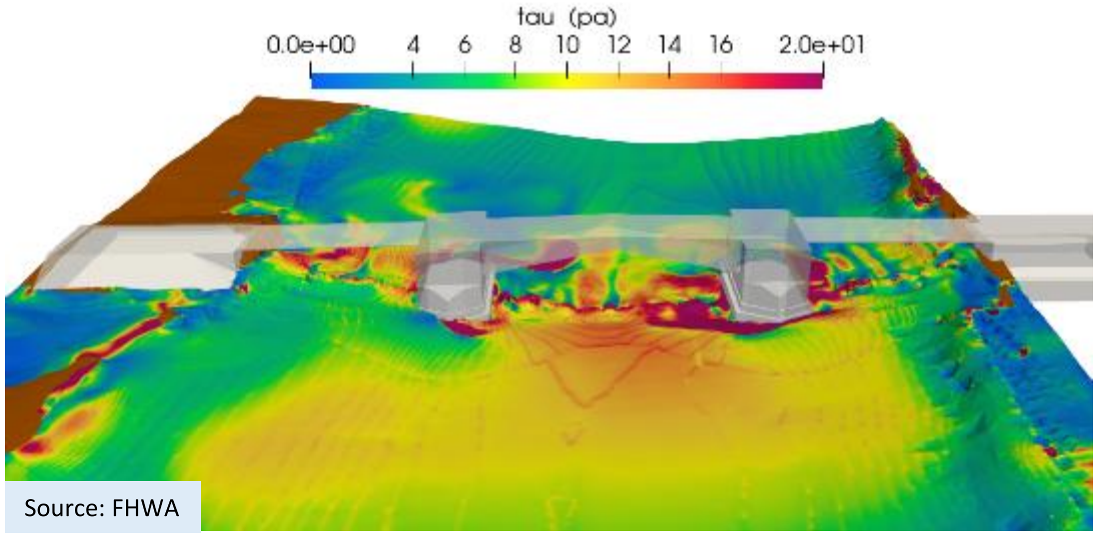
Hydraulic Parameters from Hydraulic Model

Velocities



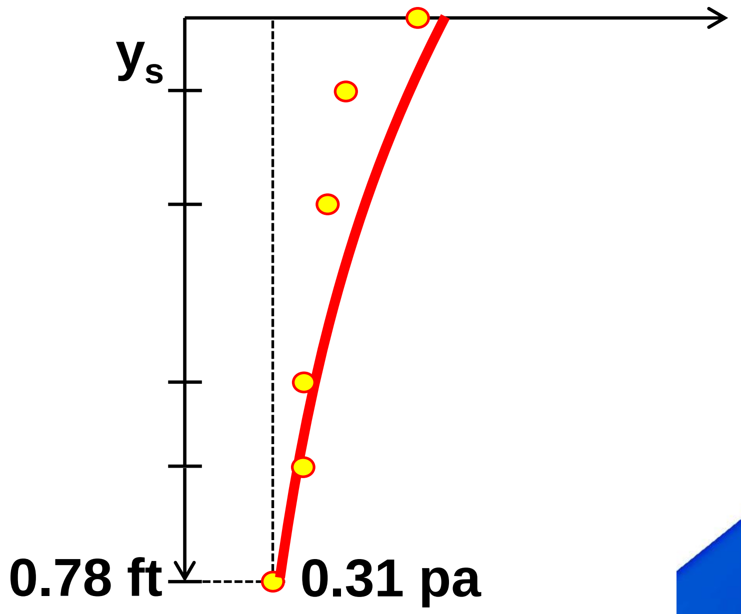
Source: FHWA

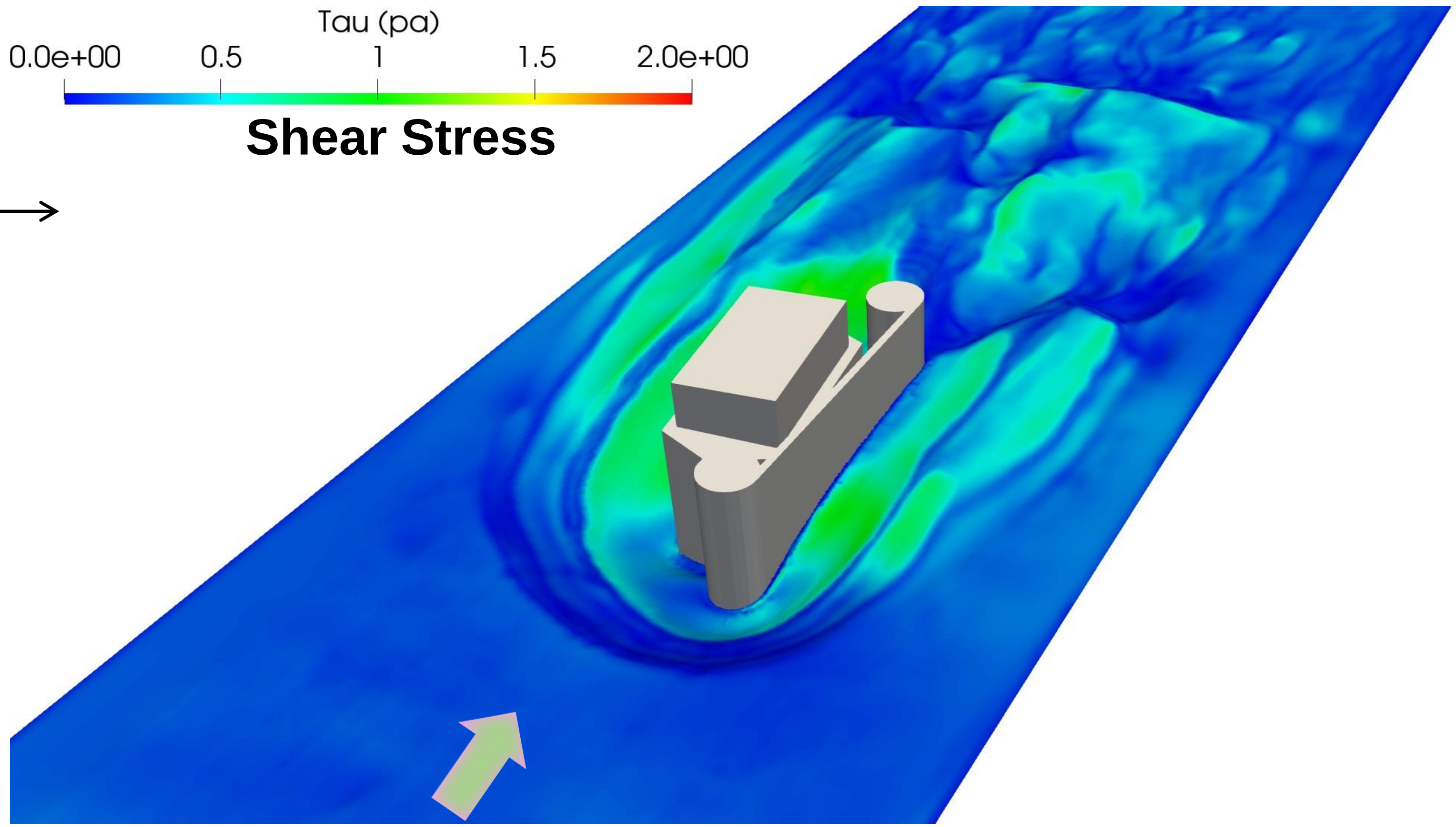
Bed shear stresses



Source: FHWA

Hydraulic forces impacting scour – Decay Function





Source: FHWA

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Geotechnical Resistance to Erosion

Chapter 4 of HEC-18 discusses the impact of soil type/gradation when predicting scour depth

Source: FHWA HEC-18

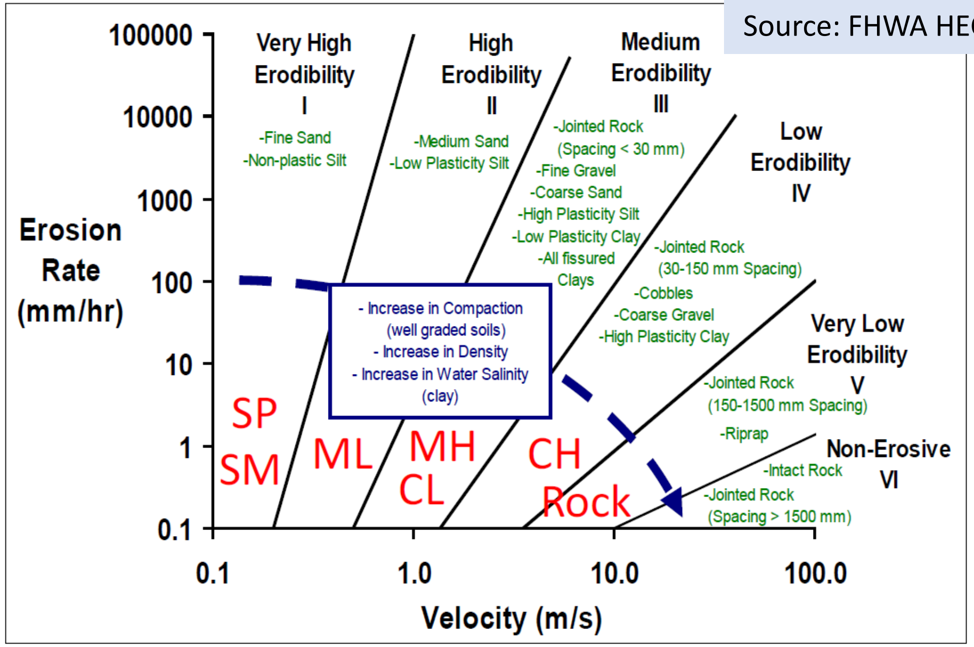

Figure 4.7. Erosion rate vs. velocity for a wide range of geomaterials (Briaud et al. 2011).

Source: FHWA HEC-18

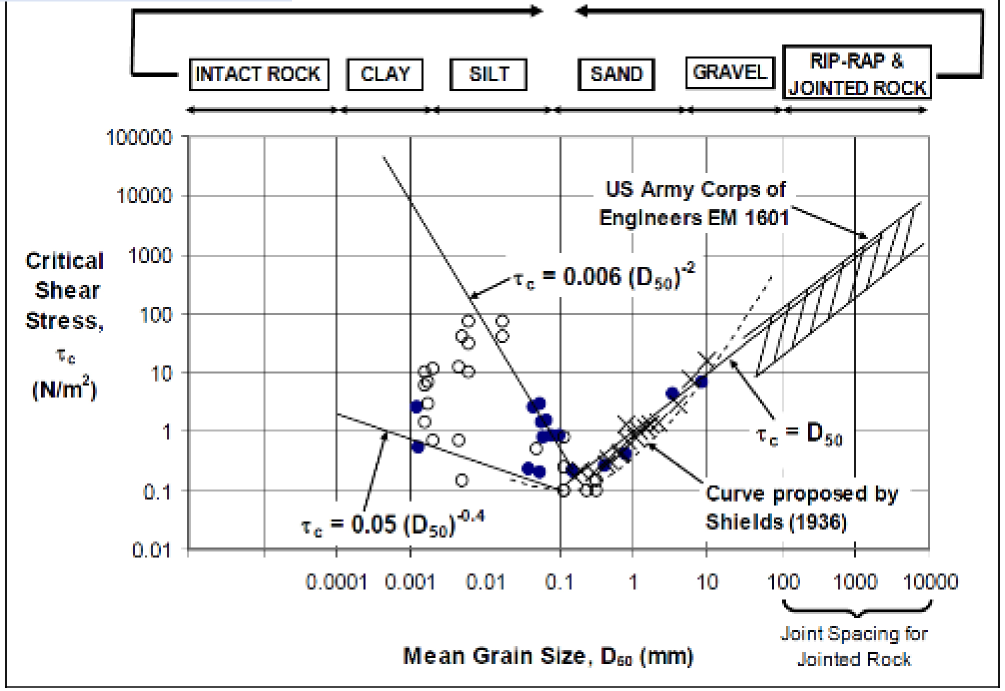

Figure 4.6. Critical shear stress vs. particle grain size (Briaud et al. 2011).

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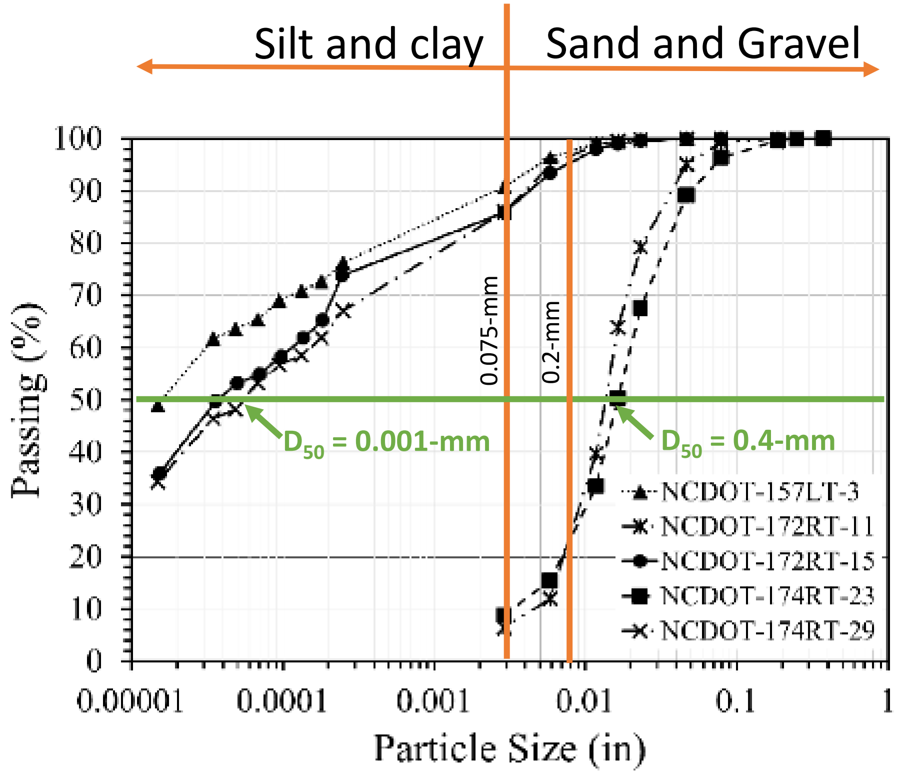
Grain Size Distribution

Table 4-2 Descriptive terms for soil particle size ranges.

Soil	Particle Size Ranges	Descriptive Term
Coarse-Grained	>12 in. (305 mm)	Boulders
	3 in. – 12 in. (75 mm – 305 mm)	Cobbles
	¾ in. – 3 in. (19 mm – 75 mm)	Coarse Gravel
	No. 4 Sieve – ¾ in. (4.75 mm – 19 mm)	Fine Gravel
	No. 10 – No 4 Sieve (2.00 mm – 4.75 mm)	Coarse Sand
	No. 40 – No. 10 Sieve (0.0425 mm – 2.00 mm)	Medium Sand
	No. 200 – No. 40 Sieve (0.075 mm – 0.0425 mm)	Fine Sand
Fine-Grained	0.075 mm – 0.002 mm	Silt
	< 0.002 mm	Clay

Source: FHWA-NHI-16-072



Source: FHWA.

When a material with a D_{50} < 0.2-mm is encountered

- It is common practice to use 0.2-mm to calculate scour depth. (Since HEC-18 equation 6.4 is not appropriate for use with a D_{50} < 0.2-mm)
- This can generate overly conservative results

<u>Alternatively</u>:

- Use a critical shear stress corresponding to this material based on erosion testing.
- Use equation in HEC-18 for ultimate scour based on critical shear (HEC-18 section 6.7)

Geotechnical Site Characterization

The primary objectives of geotechnical site characterization:

- Obtain information on subsurface stratigraphy and soil/rock behavior
- Identify and address risks associated with subsurface conditions
- Define conditions that impact performance

Scour:

- needs geotechnical data to determine the behavior of the materials
- is a risk that needs to be considered for the site
- is a conditions that can impact performance of structures

Consider discussion with Hydraulics to understand needs.

Adjust site investigation to identify and characterize erosion resistant layers.

Pooled Fund Case Histories

Lafayette Ave bridge over Saginaw River

Bay City, MI

Source: FHWA

I-6064/I-95 Bridge over Lumber River

Lumberton, NC

Source: Google Earth Image © 2022 Maxar Technologies

Lafayette Ave bridge over Saginaw River

Source: FHWA

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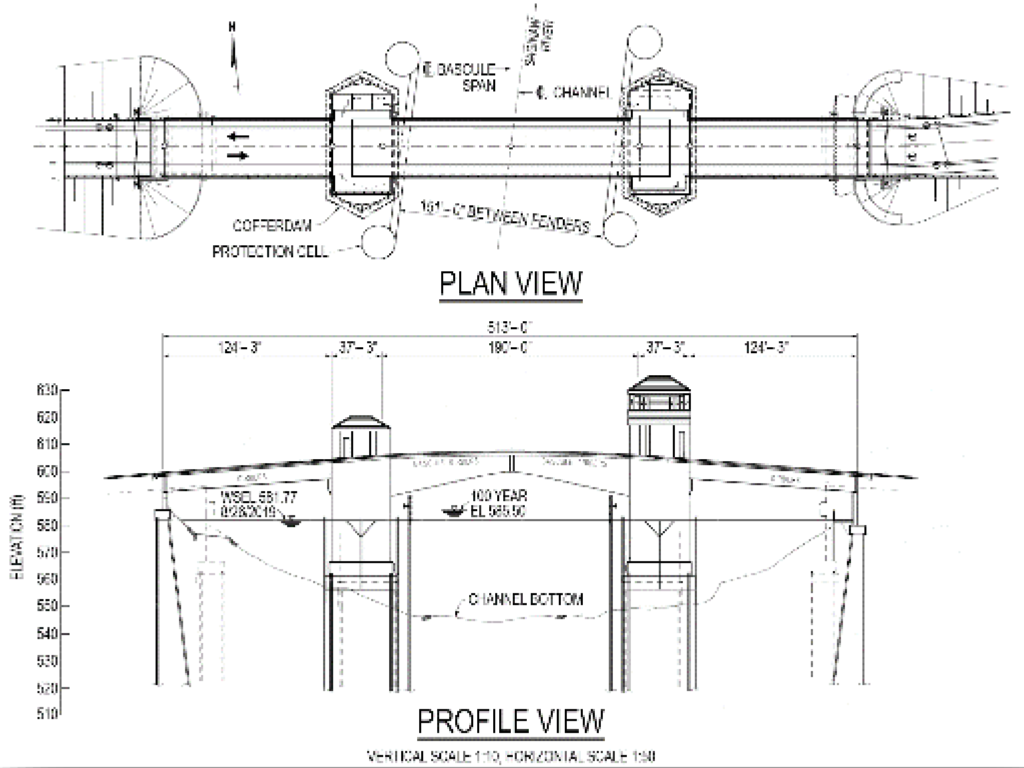
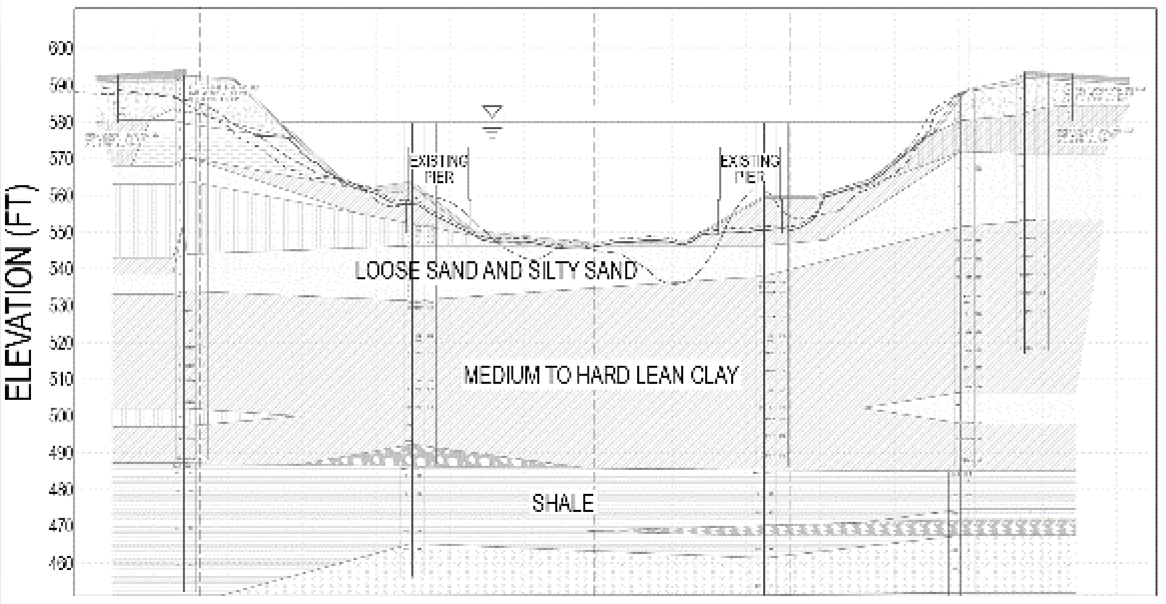
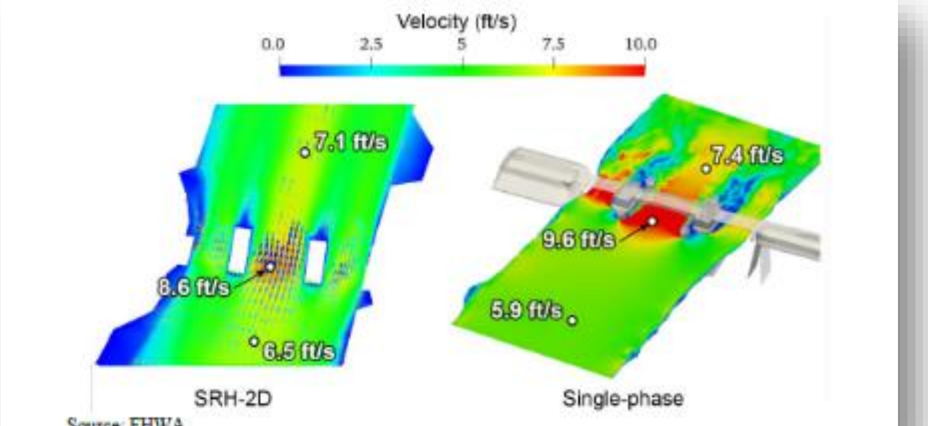
Lafayette Ave bridge over Saginaw River



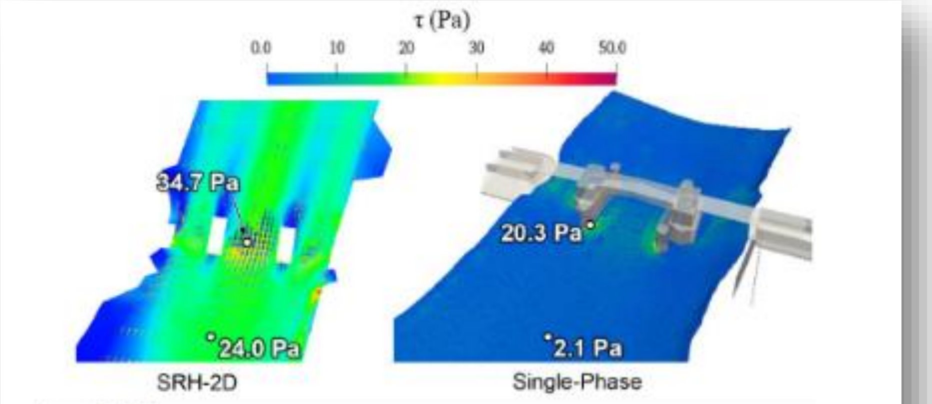


Source: © 2020 MDOT.
Modifications by FHWA.

Lafayette Ave bridge over Saginaw River



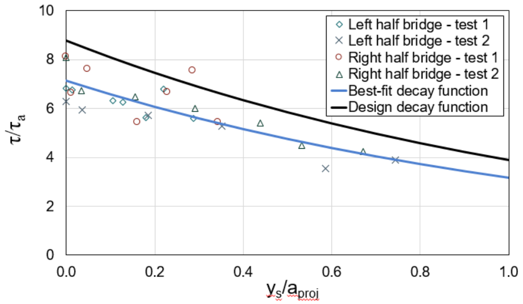
Source: FHWA.



Source: FHWA.
Note: 1 Pa = 0.021 pounds per square ft (psf).

Flow	Flow rate (cfs)	WSE (ft)	Average velocity (ft/s)	Blockage area (ft^2)	CFD shear stress at left fender (Pa)	CFD shear stress at right fender (Pa)
Q_{10}	42,785	580.9	4.4	865.7	8.2	7.1
Q_{50}	54,510	581.3	5.5	875.7	12.1	11.6
Q_{100}	59,360	581.5	5.9	880.5	14.5	14.1
Q_{500}	70,130	582.0	6.8	893.2	20.2	19.7
Q_{2000}	79,295	582.3	7.5	899.3	26.2	24.5

Decay Function Update



Design

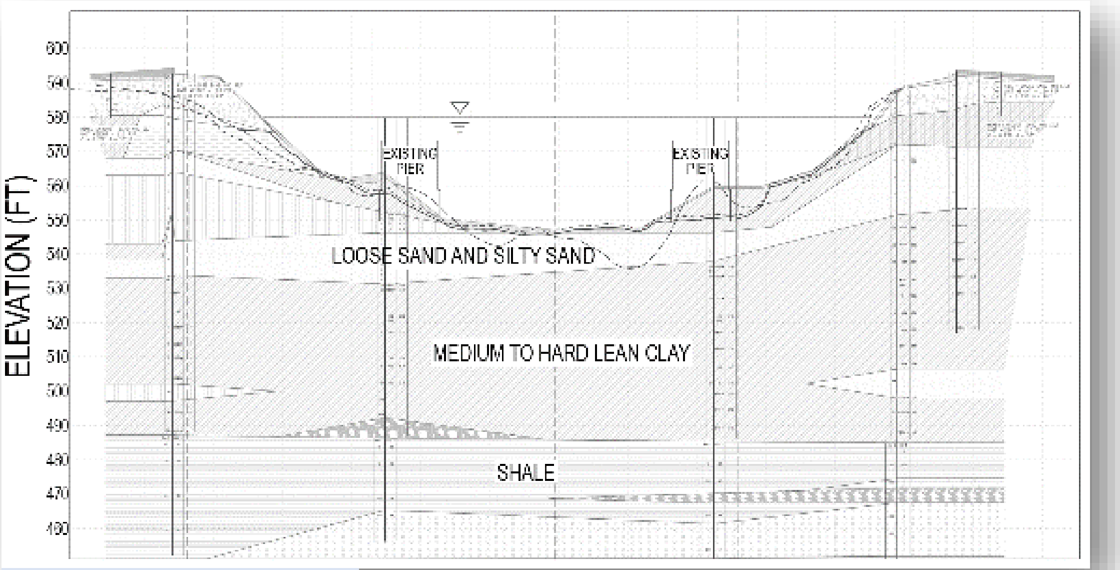
$$\frac{\tau}{\tau_a} = 8.78e^{-0.81\frac{y_s}{a_{proj}}}$$

Best-fit

$$\frac{\tau}{\tau_a} = 7.14e^{-0.81\frac{y_s}{a_{proj}}}$$

Source: FHWA (all images)

Lafayette Ave bridge over Saginaw River



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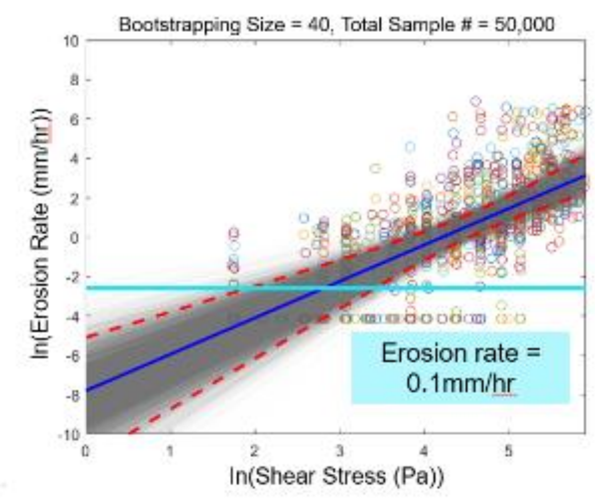
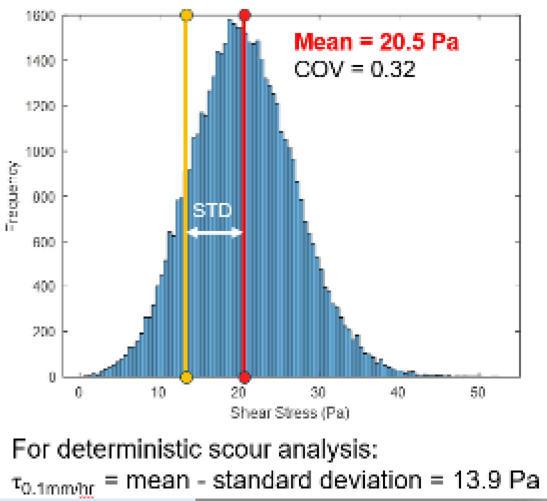
Bootstrapping

- A statistical technique that uses random sampling with replacement to estimate the mean, COV and confidence interval, etc.



Source: FHWA



Source: FHWA

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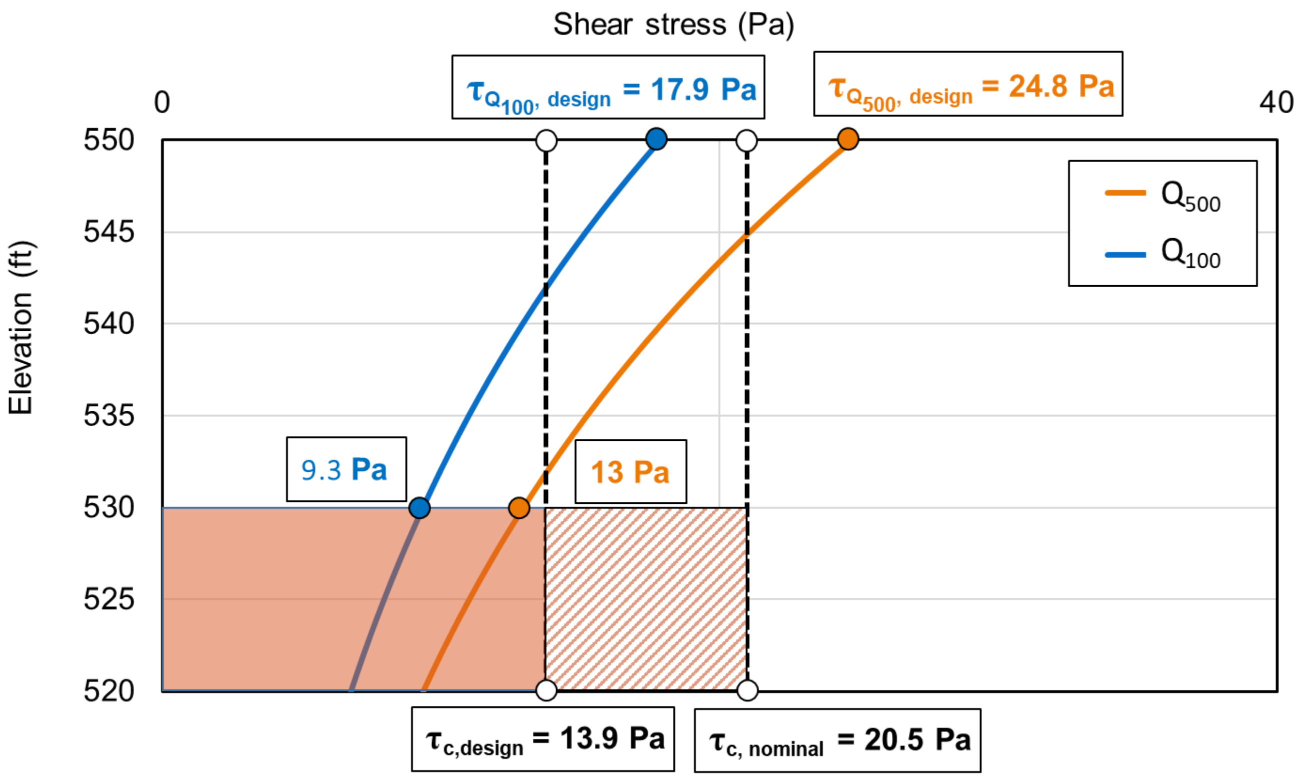
Lafayette Ave bridge over Saginaw River

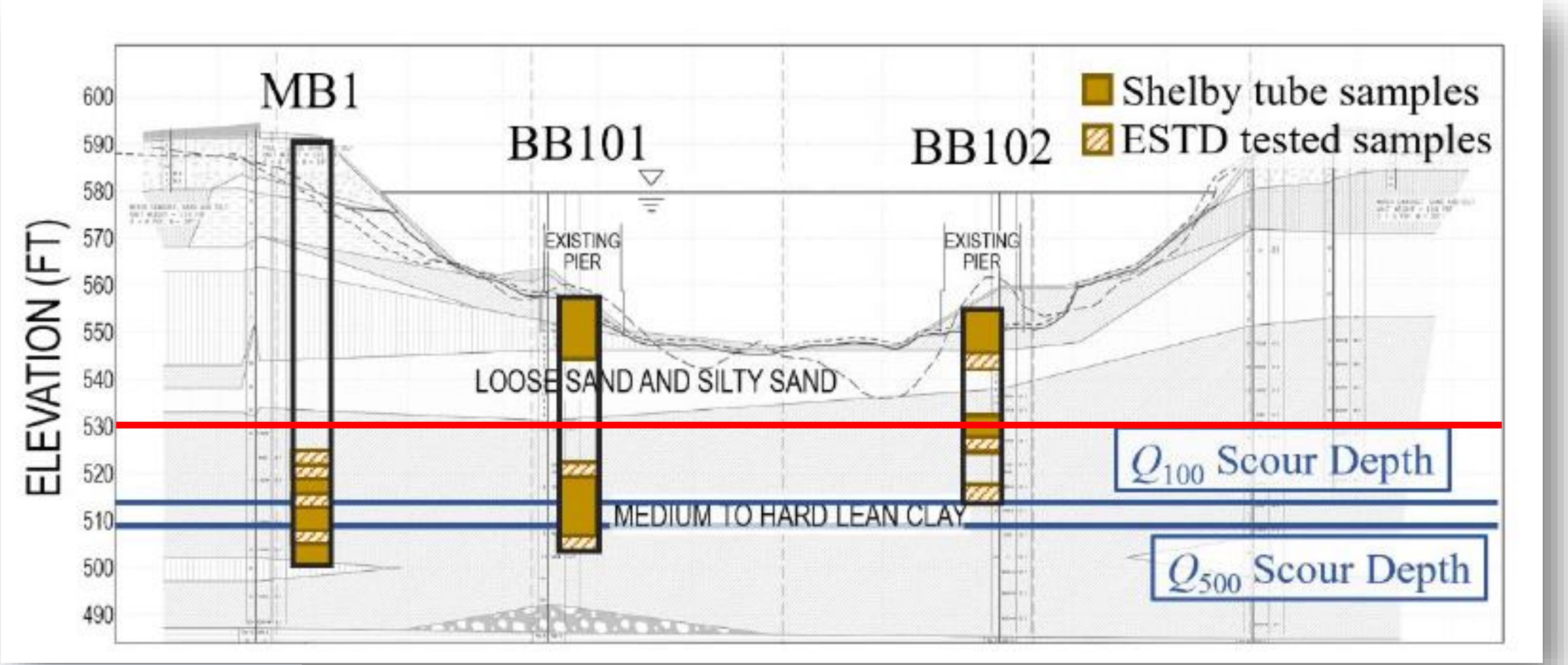
Deterministic NextScour Analysis for Total Pier Scour



Flow	Flow rate (cfs)	WSE (ft)	Average velocity (ft/s)	Blockage area (ft^2)	CFD shear stress at left fender (Pa)	CFD shear stress at right fender (Pa)	Design shear stress at fender (Pa)
Q_{10}	42,785	580.9	4.4	865.7	8.2	7.1	10.1
Q_{50}	54,510	581.3	5.5	875.7	12.1	11.6	14.9
Q_{100}	59,360	581.5	5.9	880.5	14.5	14.1	17.8
Q_{500}	70,130	582.0	6.8	893.2	20.2	19.7	24.8
Q_{2000}	79,295	582.3	7.5	899.3	26.2	24.5	32.2

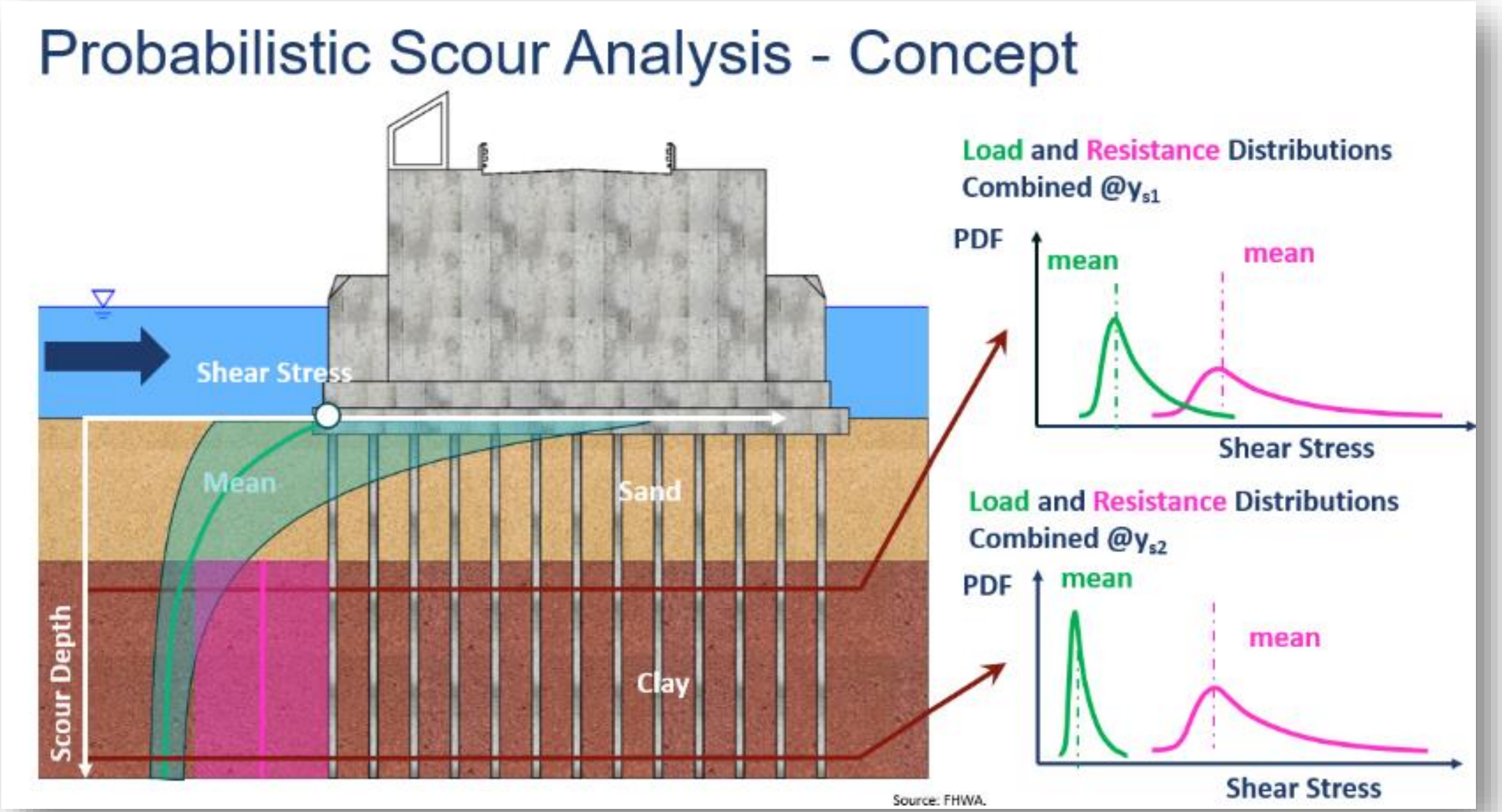
Source: FHWA (all images)

Lafayette Ave bridge over Saginaw River

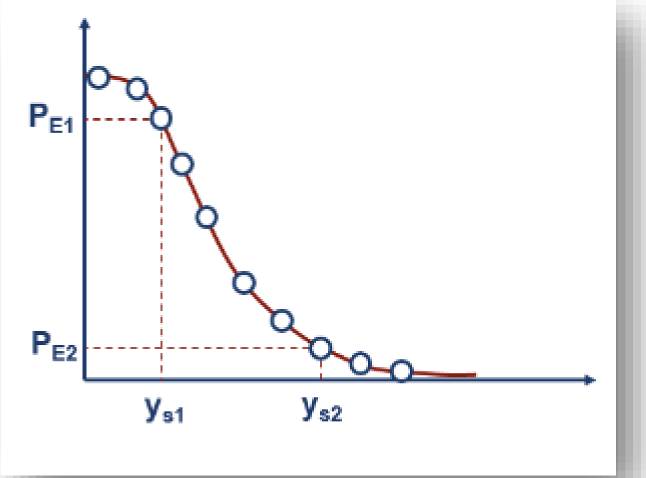


Source: © 2020 MDOT. Modifications by FHWA.

Lafayette Ave bridge over Saginaw River



Scour Depth Exceedance Probabilities



Source: FHWA (all images)

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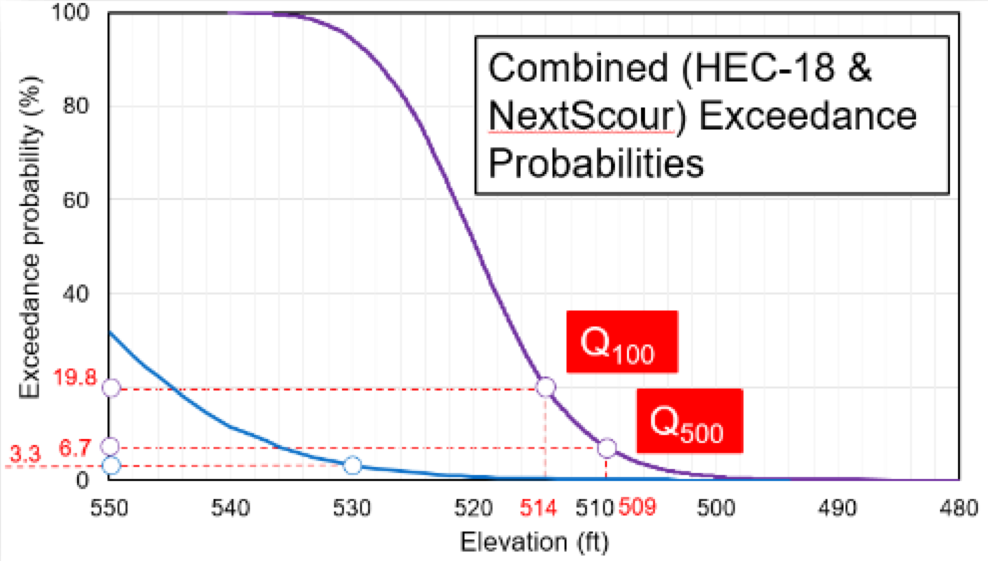
Lafayette Ave bridge over Saginaw River

Comparing Exceedance Probabilities



Flood Frequency	Exceedance Probability in 75-year
Q_{100}	53%
Q_{500}	14%
Q_{1000}	7%

Total Pier Scour

Elevation (ft)	HEC-18 (Sand)	NextScour (Clay)
530 (Clay Layer)	94%	3.3%
514 (HEC-18 Q_{100})	19.8%	0.3%
509 (HEC-18 Q_{500})	6.7%	0.1%

Source: FHWA (all images)

I-6064/I-95 Bridge over Lumber River

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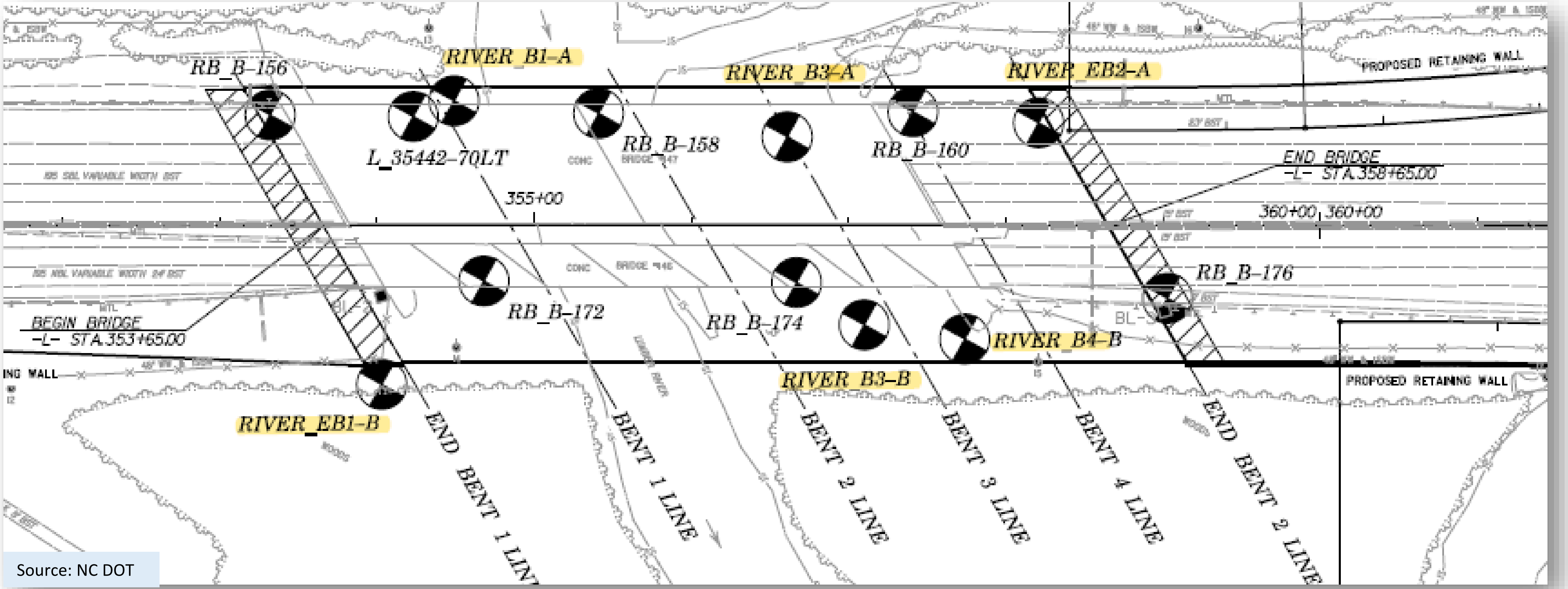
I-6064/I-95 Bridge over Lumber River



Source: NC DOT

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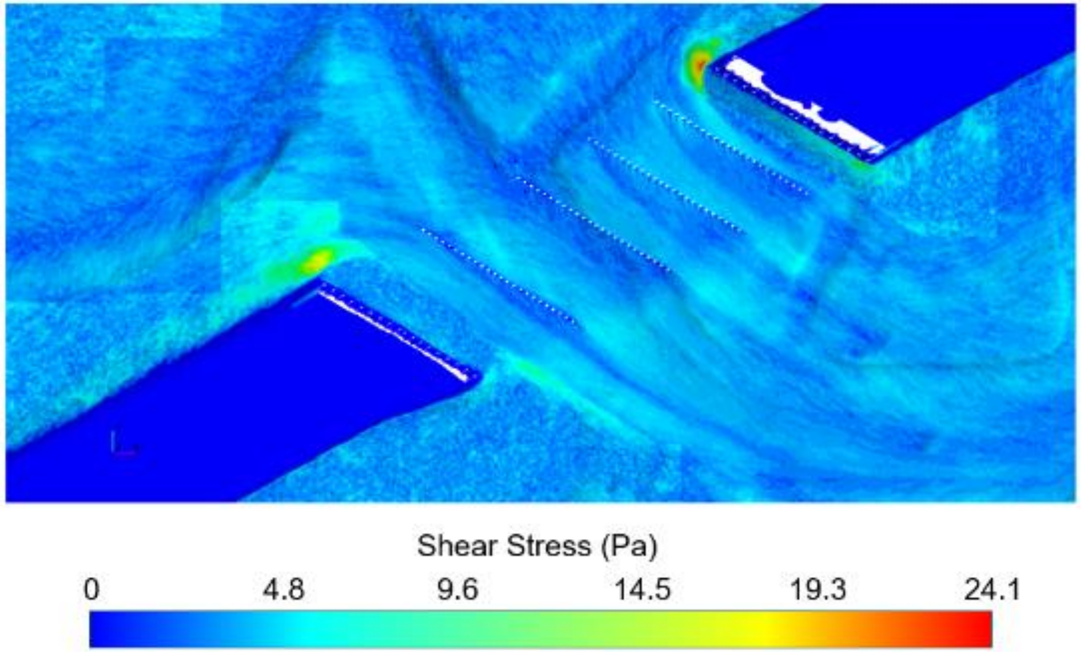
I-6064/I-95 Bridge over Lumber River

CFD Shear Stress Distribution: Q100

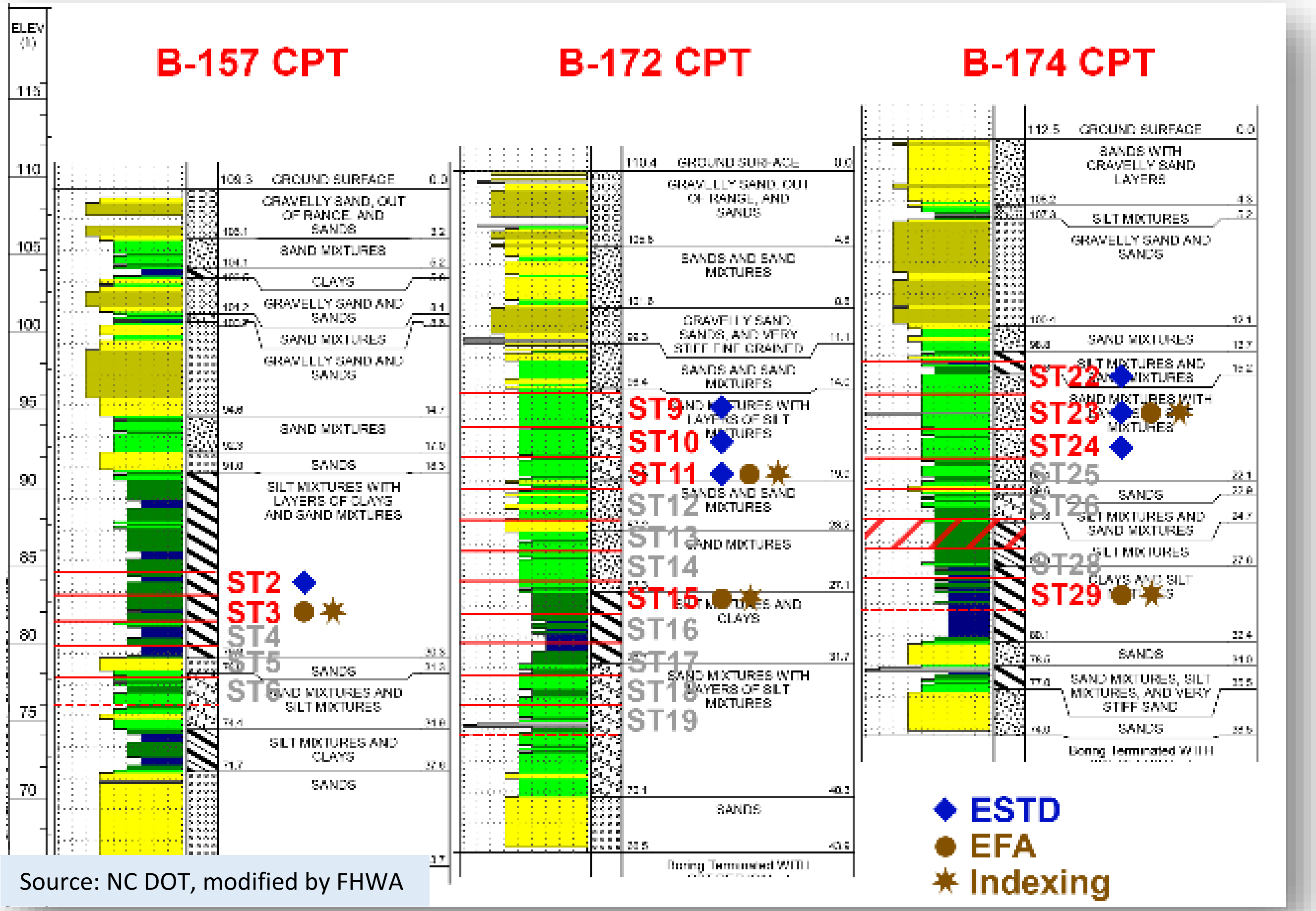


CFD Nominal Shear Stresses

	Q_{100}		Q_{500}	
	Projected area (m^2)	Nominal shear stress (Pa)	Projected area (m^2)	Nominal shear stress (Pa)
Pier	88	**4.0**	109	**4.2**
Left abutment	47.9	**17.8**	65.8	**16.5**
Right abutment	48.1	14.9	65.8	16.0

Source: FHWA (all images)

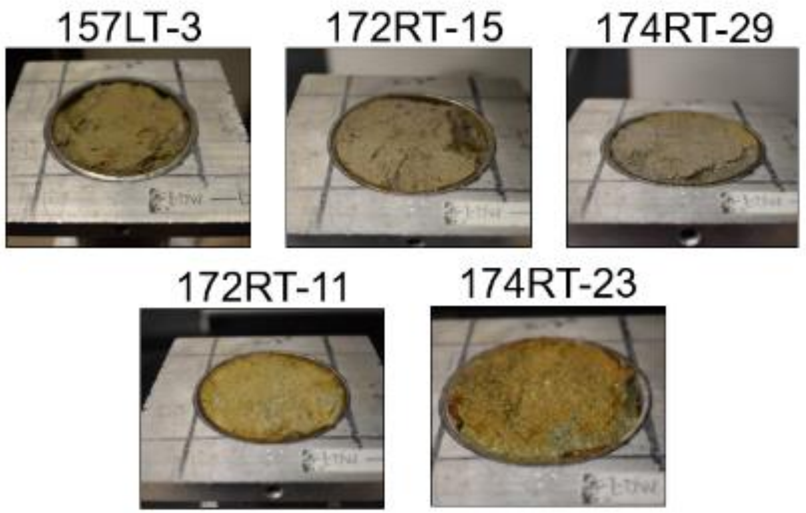
I-6064/I-95 Bridge over Lumber River



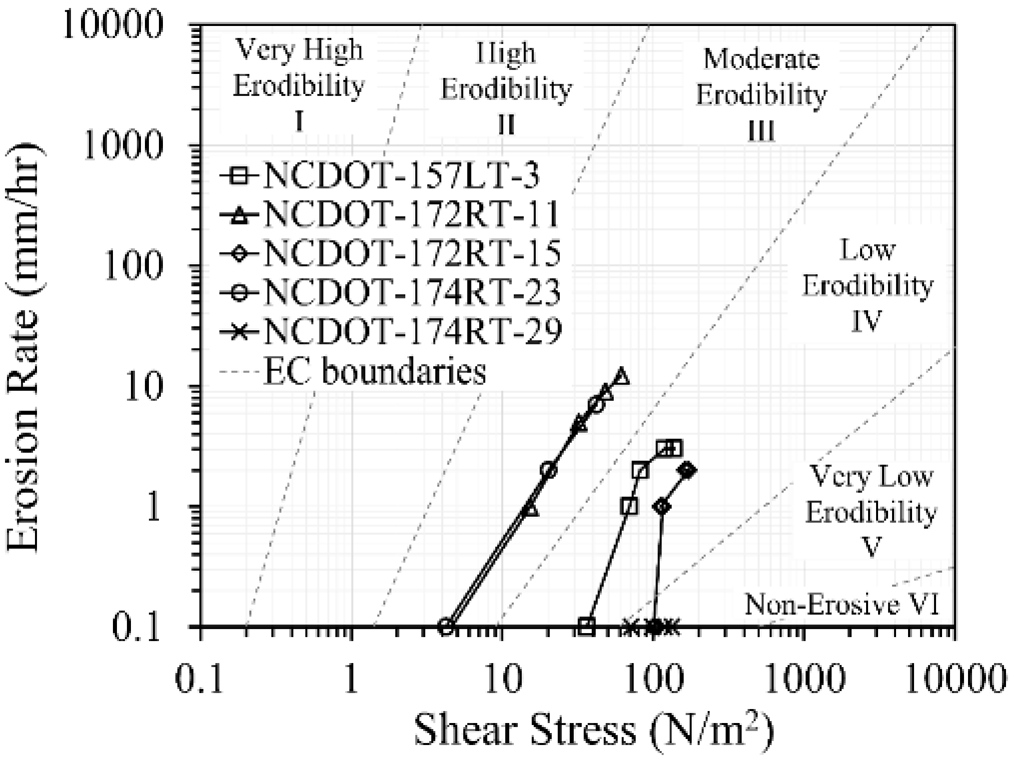
Source: NC DOT, modified by FHWA

I-6064/I-95 Bridge over Lumber River

EFA Test Results



Sample ID	USCS	v_c (m/s)	τ_c (N/m^2)
157LT-3	CH	3.0	36.23
172RT-11	SP-SM	1.0	4.59
172RT-15	CH	4.8	100.56
174RT-23	SP-SM	1.0	4.24
174RT-29+	CL	> 5.8	> 132.97



Source: FHWA (all images)

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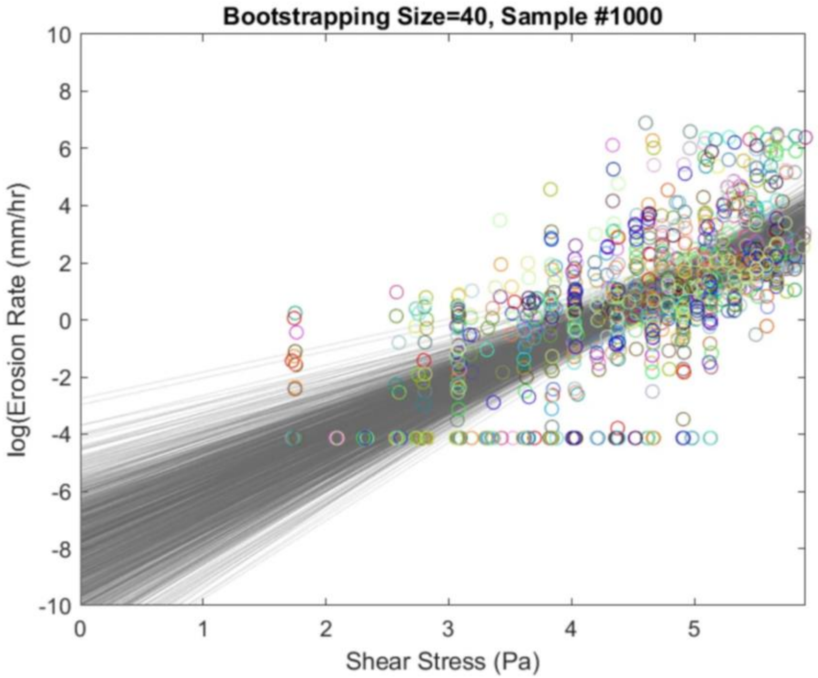
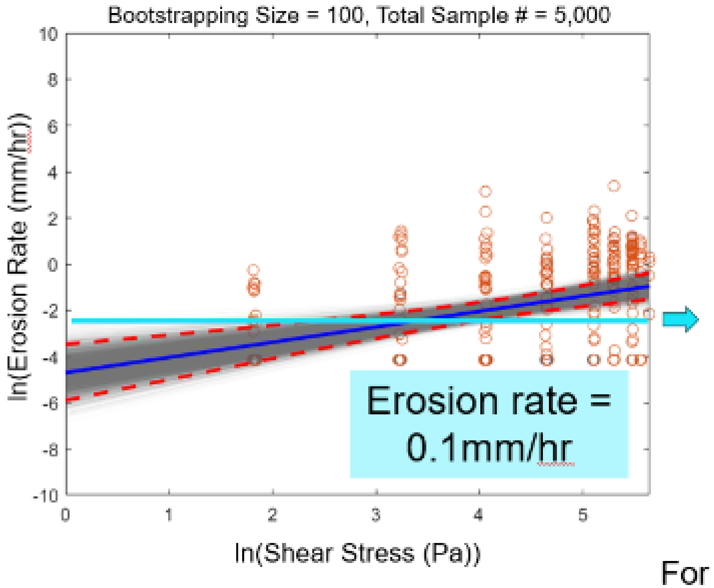
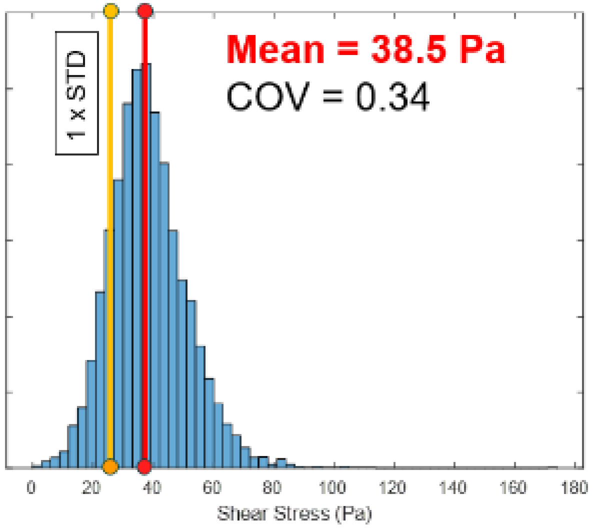






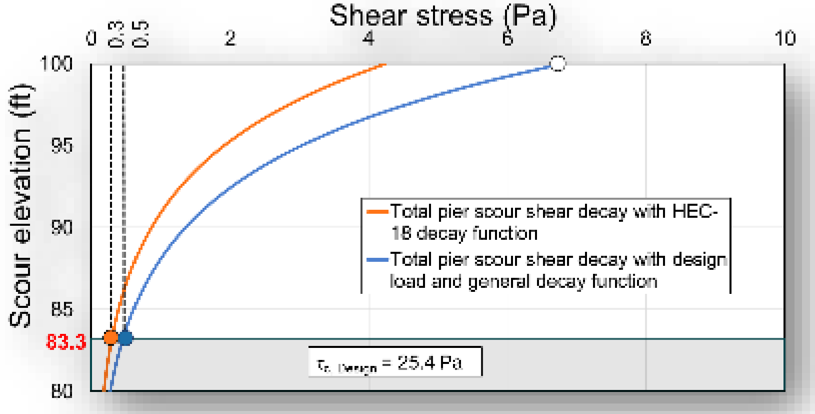
For deterministic scour analysis:

$\tau_{0.1mm/hr}$ = mean - standard deviation = 25.4 Pa

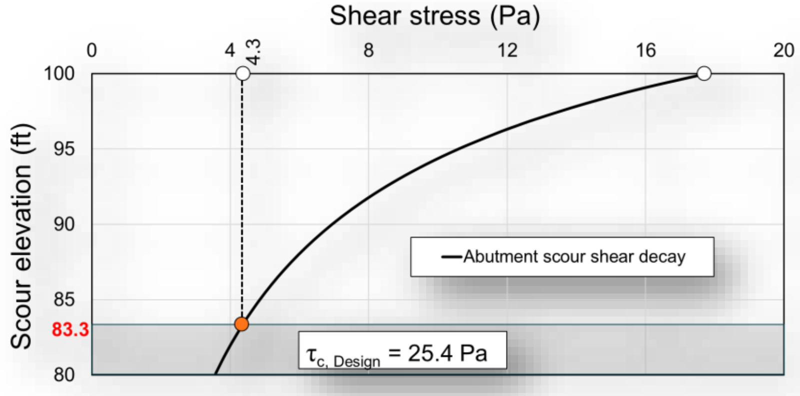
Source: FHWA (all images)

I-6064/I-95 Bridge over Lumber River

Deterministic Total Pier Scour Analysis: Q_{500}



Deterministic Abutment Scour Analysis: Q_{100}



	Q_{100}		Q_{500}	
	Projected area (m^2)	Nominal shear stress (Pa)	Projected area (m^2)	Nominal shear stress (Pa)
Pier	88	**4.0**	109	**4.2**
Left abutment	47.9	**17.8**	65.8	**16.5**
Right abutment	48.1	14.9	65.8	16.0

	Scour depth (ft)			
	Q_{100}		Q_{500}	
	HEC-18	NextScour	HEC-18	NextScour
Pier scour	11.4		12.1	
Contraction scour	29.1		38.3	
Total pier scour	40.5	16.7	50.4	16.7
Abutment scour	N/A	16.7	N/A	16.7

Source: FHWA (all images)

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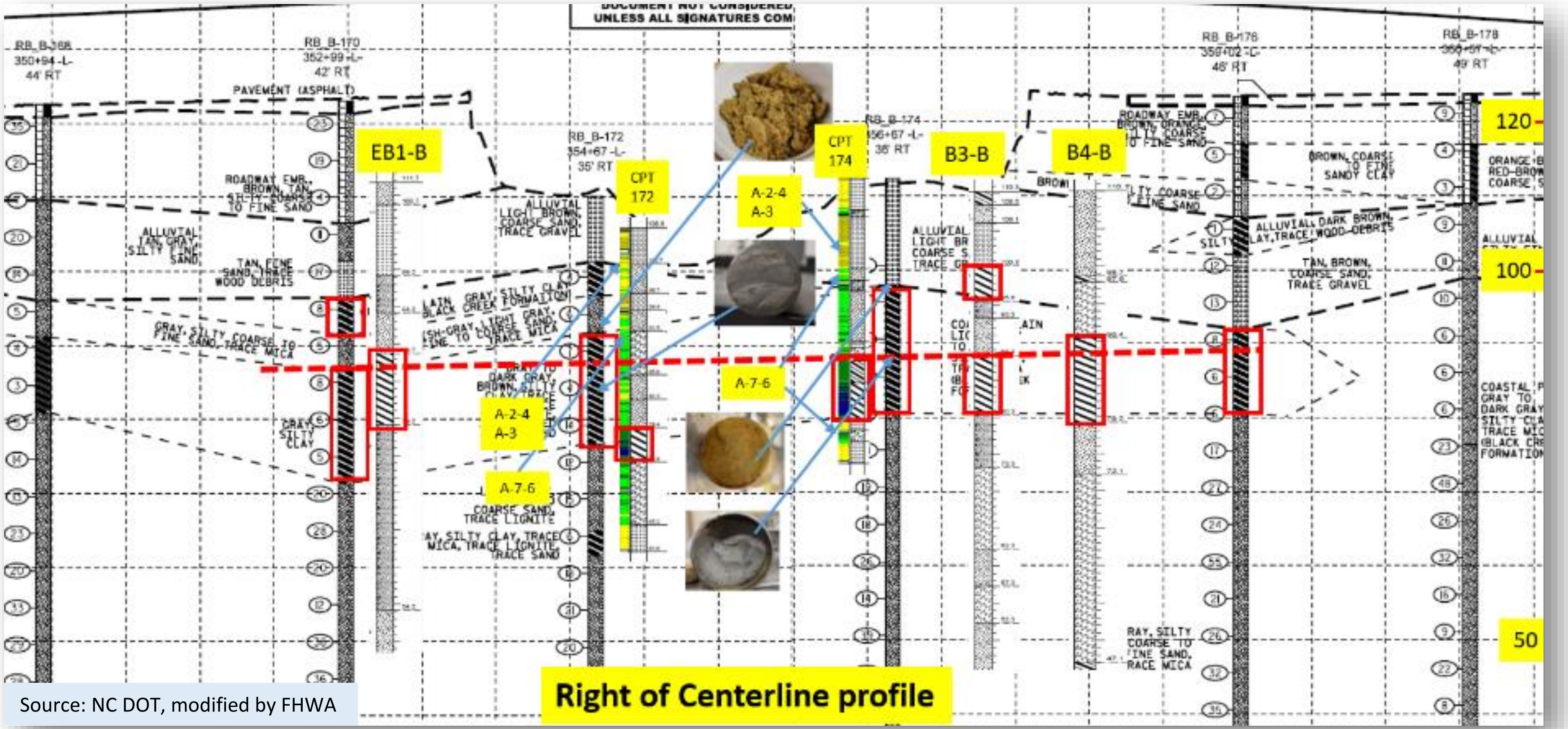
I-6064/I-95 Bridge over Lumber River



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Opportunity for Collaboration

- These example projects demonstrate the benefits of collaboration between the disciplines
- We already invest in geotechnical site investigation to manage design, construction, and performance risk
- Consider -
  - discussions between disciplines to better understand the needs for hydraulics to improve predictions on scour depth
  - developing specific geotechnical recommendations for hydraulics
- May need –
  - additional investigation and samples at locations different than typically considered
  - different types of in-situ tests and samples
- Include early discussions between disciplines

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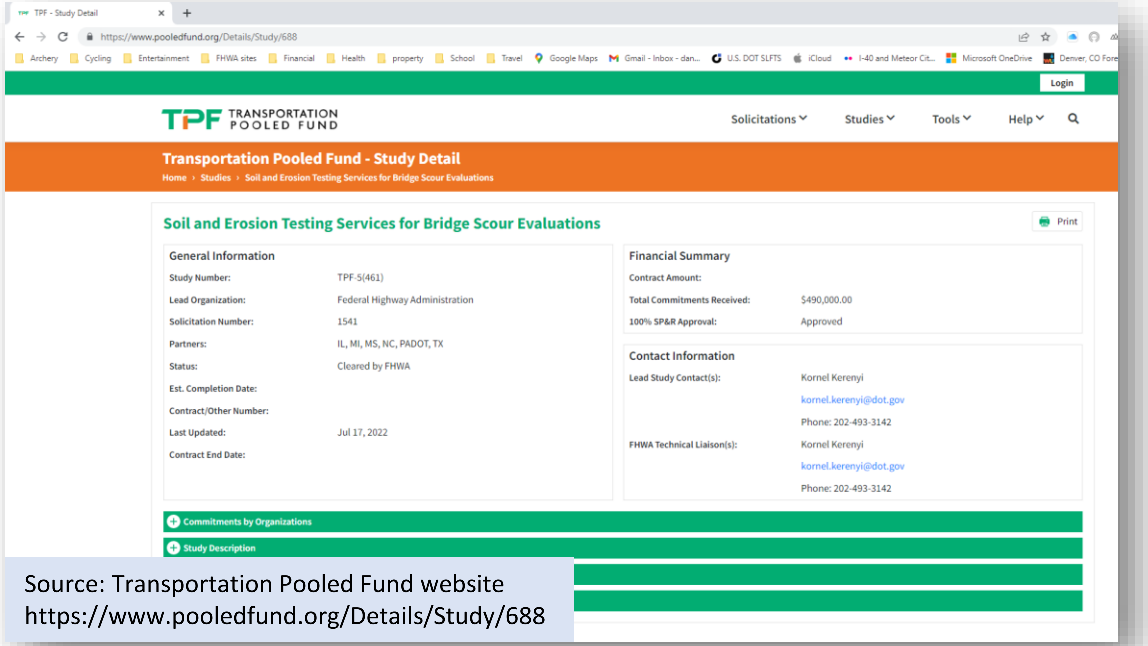
<u>**Daniel Alzamora, P.E.**</u>

Senior Geotechnical Engineer

FHWA – Resource Center

Transportation Pooled Fund – TPF-5(461)

Encourages collaboration between the geotechnical and hydraulic disciplines to include the hydraulic component as well as the erosion resistance of soils for prediction of scour depth.



Source: Transportation Pooled Fund website
https://www.pooledfund.org/Details/Study/688

Scope of work:

1. Soil Erosion Test in the TFHRC Hydraulics and/or Geotechnical Lab for various bridge projects
2. Soil Erosion Test in the field for various bridge projects
3. Laboratory and In-situ Soil Testing
4. Fabrication of an Erosion Testing Device
5. Soil Erosion Tests Support conducted by DOT
6. Laboratory and In-situ Soil Testing Support conducted by DOT

NCDOT’s Scour Evaluation Procedure is Unique compared to other DOT’s

The procedure…

- Is highly dependent on field visual classification…no specialized testing as recommended by FHWA is done…does not follow current FHWA HEC 18 procedures

- Has been in place a long time and places a lot of responsibility on the Geotechnical Unit

NCDOT and NextScour Research Relationship…

- Thanks to Matt Lauffer in our Hydraulics…understood importance of improving/confirming current methods/procedures

- Results presented by Daniel, corroborate our adjustment to the Theoretical Scour for the Lumber River case history he discussed

- We still have items to address…lab testing, internal roles and responsibilities, validity of use without specific specialized testing (EFA, ESTD, etc.), would following FHWA recommended procedures more closely negate the need to adjust Theoretical Scour via current methods

We look forward to continuing our relationship with NextScour Research Project

Hydraulics Unit Computes Live Bed Contraction Scour – Equation 6.2, HEC 18

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{6/7} \left(\frac{W_1}{W_2}\right)^{k_1}$$

- Equation 6.4 – Clear-Water Contraction Scour is Ignored
- D_{50} <= 0.2 mm is assumed – No lab testing to verify

Bridge Scour Report (BSR) created

Hydraulics Unit's Effort Complete at approximately 30% Bridge Plans

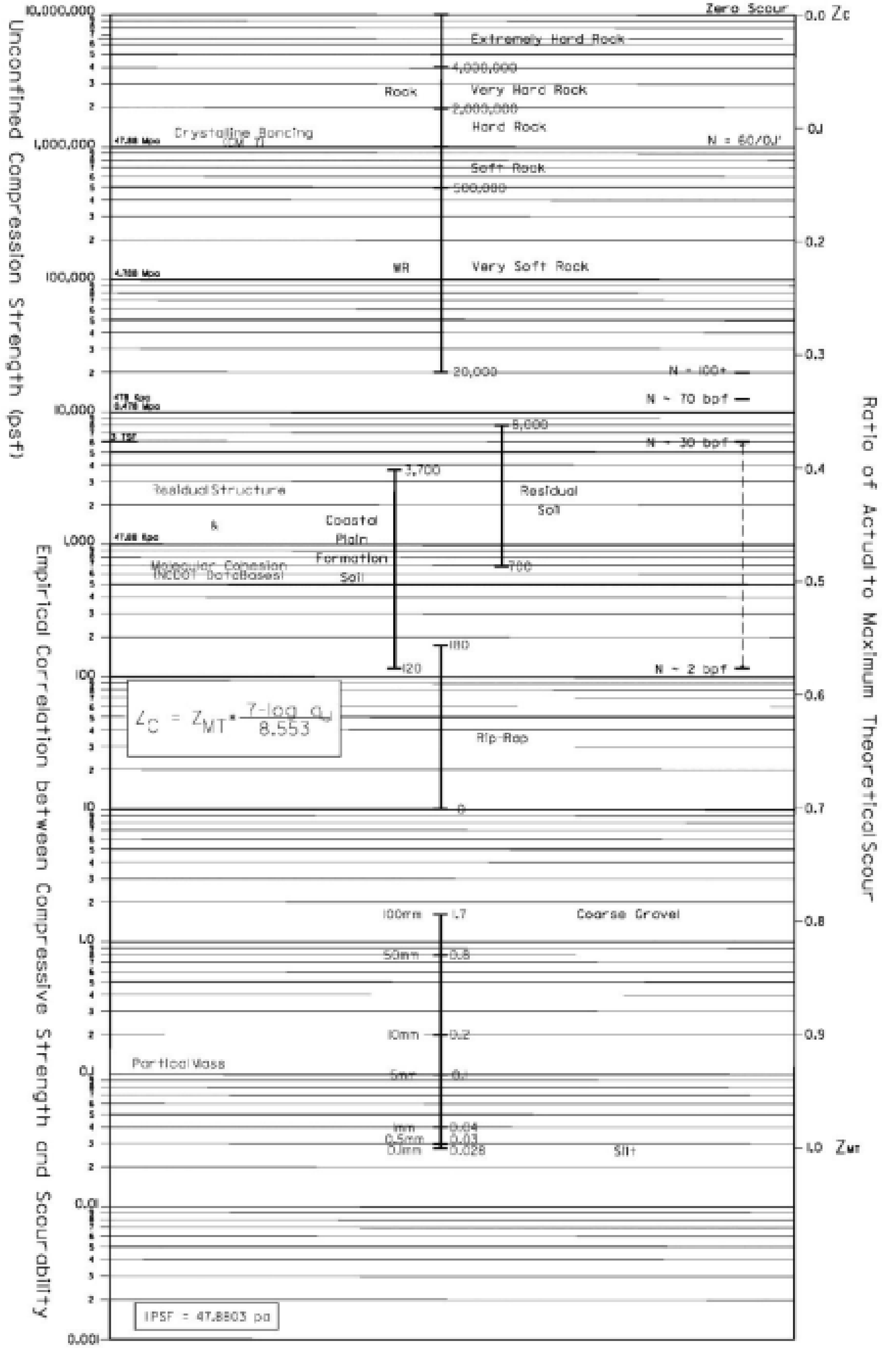
Geotechnical Unit then…

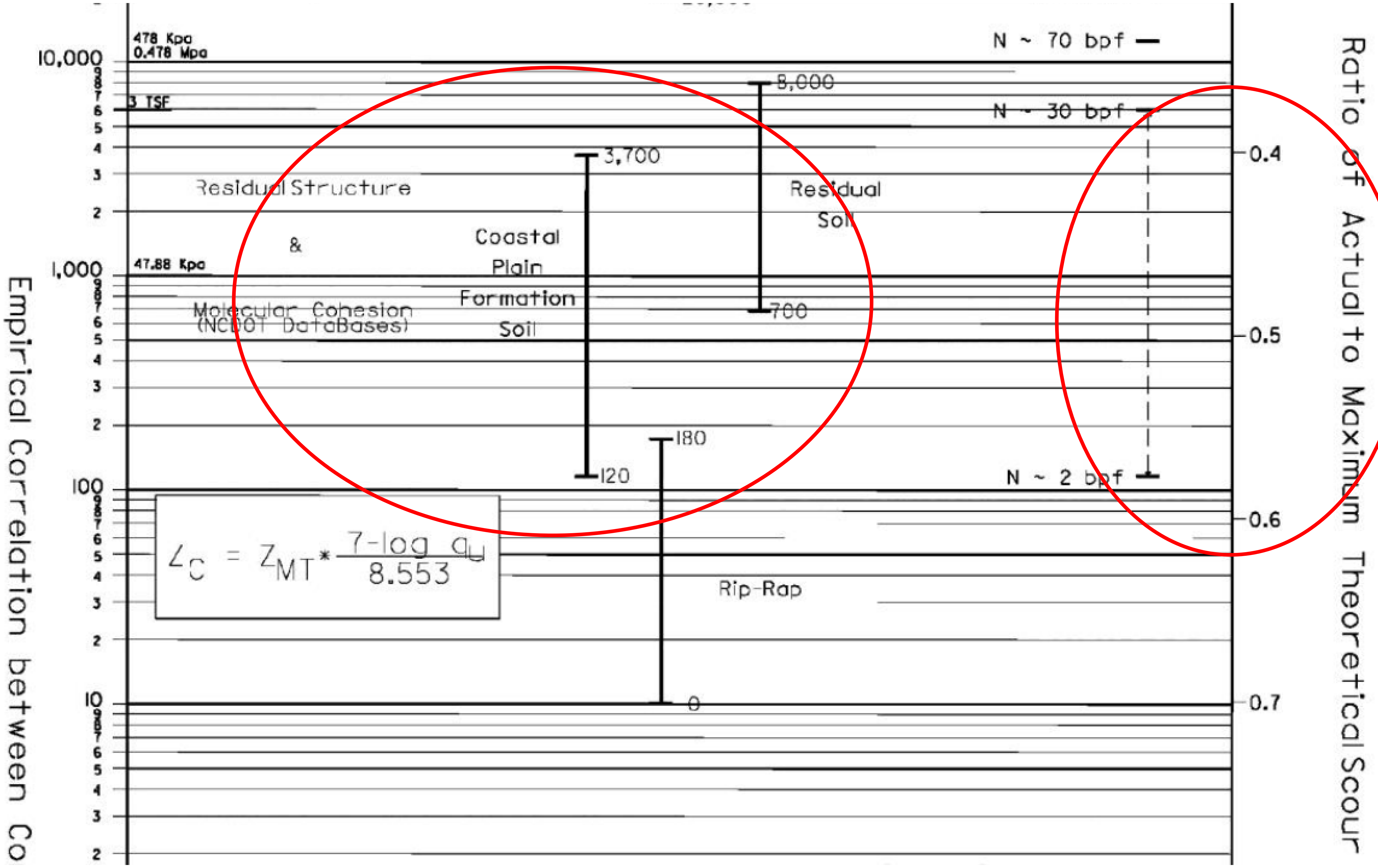
Evaluates Scour Resistance of Soils and reduces Theoretical Scour depth

Basis of evaluation is generally via visual classification in the field by a field geologist

Geotechnical Investigation and Recommendations Manual – Pages 47 – 52 – See Section 5.1.3.4

Jim Keane Scour Reduction Chart





478 Kpa
0.478 Mpa
10,000
3 TSF
1,000
47.88 Kpa
100
10
N ~ 70 bpf
N ~ 30 bpf
N ~ 2 bpf
8,000
3,700
700
180
120
9
Residual Structure
&
Molecular Cohesion
(NCDOT DataBases)
Coastal
Plain
Formation
Soil
Residual
Soil
Rip-Rap
$Z_C = Z_{MT} * \frac{7 - \log q_u}{8.553}$
0.4
0.5
0.6
0.7
Empirical Correlation between Co
Ratio of Actual to Maximum Theoretical Scour