19th Annual NJDOT Research Showcase

Project

Scour Evaluation Model (SEM) Implementation Phase

Presented by

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Scour Evaluation Model (SEM) Implementation Phase

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- Ali Khan, P.E., Ph.D., Project Consultant
- USGS New Jersey Water Science Center, including scientists Tom Suro and Kara Watson.

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Overview

- Research Objectives and Justification
- How SEM Works
- Selected Input Parameters and Protocols
- Transfer of SEM into Practice
- Applying Envelope Curves in New Jersey
- Summary and Conclusions

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Bridge Scour

"Bridge scour is the result of erosive action by running water, which excavates and carries away material from the bed and bank of a stream."

Research Objectives

Overall: Develop a new, rational tool for evaluating scour at existing bridges in New Jersey.

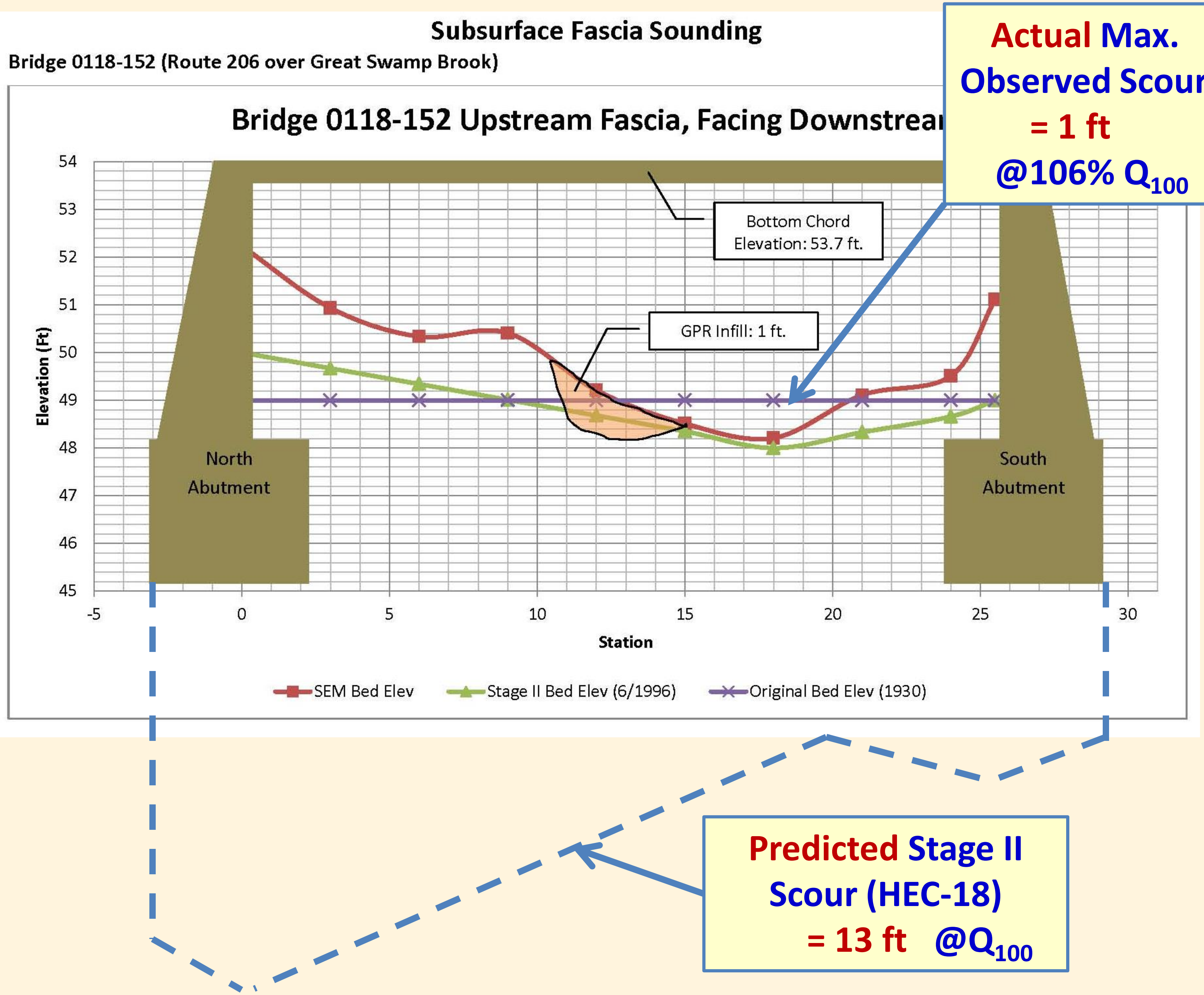
TO-89:

- Conduct critical review of scour theory and practice.
- Investigate geotechnical, hydraulic, and hydrologic factors with focus on New Jersey.
- Develop a new method known as the Scour Evaluation Model (SEM).

TO-114:

- Transfer the SEM method into state-wide practice.
- Provide a tool for the Department to manage and resolve bridges on the Scour Critical List.

Justification for SEM



Actual Max. Observed Scour = 1 ft @106% Q_{100}

Predicted Stage II Scour (HEC-18) = 13 ft @Q_{100}

Justification for SEM

Bridge 2107-156

Stage II study showed widespread boulders & cobbles in the stream bed. Scour calcs. still used a sieve analysis of sediments collected "in between" oversize particles: 3.85 mm (0.15 in).

The downward bias of median grain led to overly conservative estimate of scour depth!

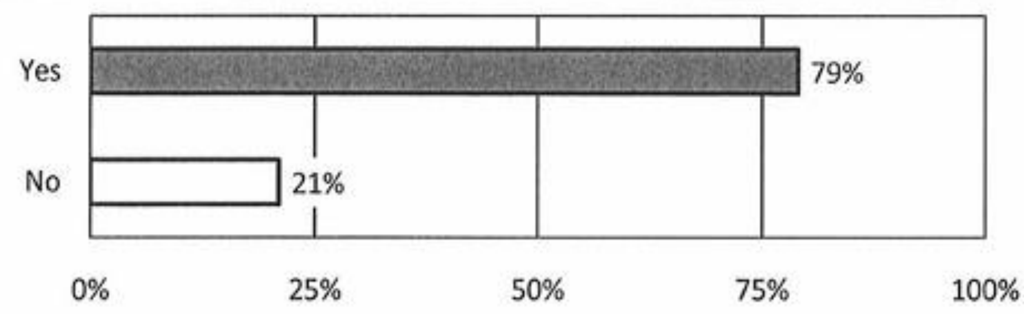
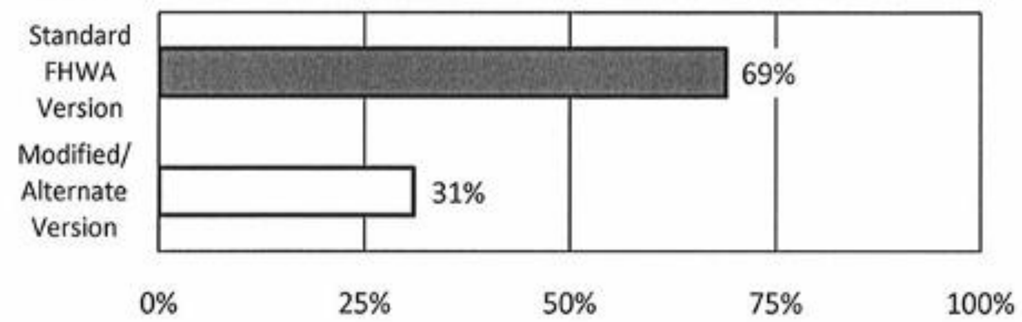
Bridge 1810-155

Stage II study showed footings were embedded ~2 ft into sedimentar rock. Scour calcs. still used D_{50} from a thin veneer of sediments on top of the rock.

The scour analysis completely ignored the rock embedment!

Nationwide Survey of Scour Practice

- 10-question survey sent to all US DOTs & other TAs.

Q6: In the light of your experience of different types of bridge scour, is there a need to modify current HEC-18 design procedures?	
Q8: What scour procedures and equations do you use in the evaluation of <u>existing</u> bridges?	

HEC-18 is a valued "state of scour practice."
It is not a mandatory, prescriptive standard.

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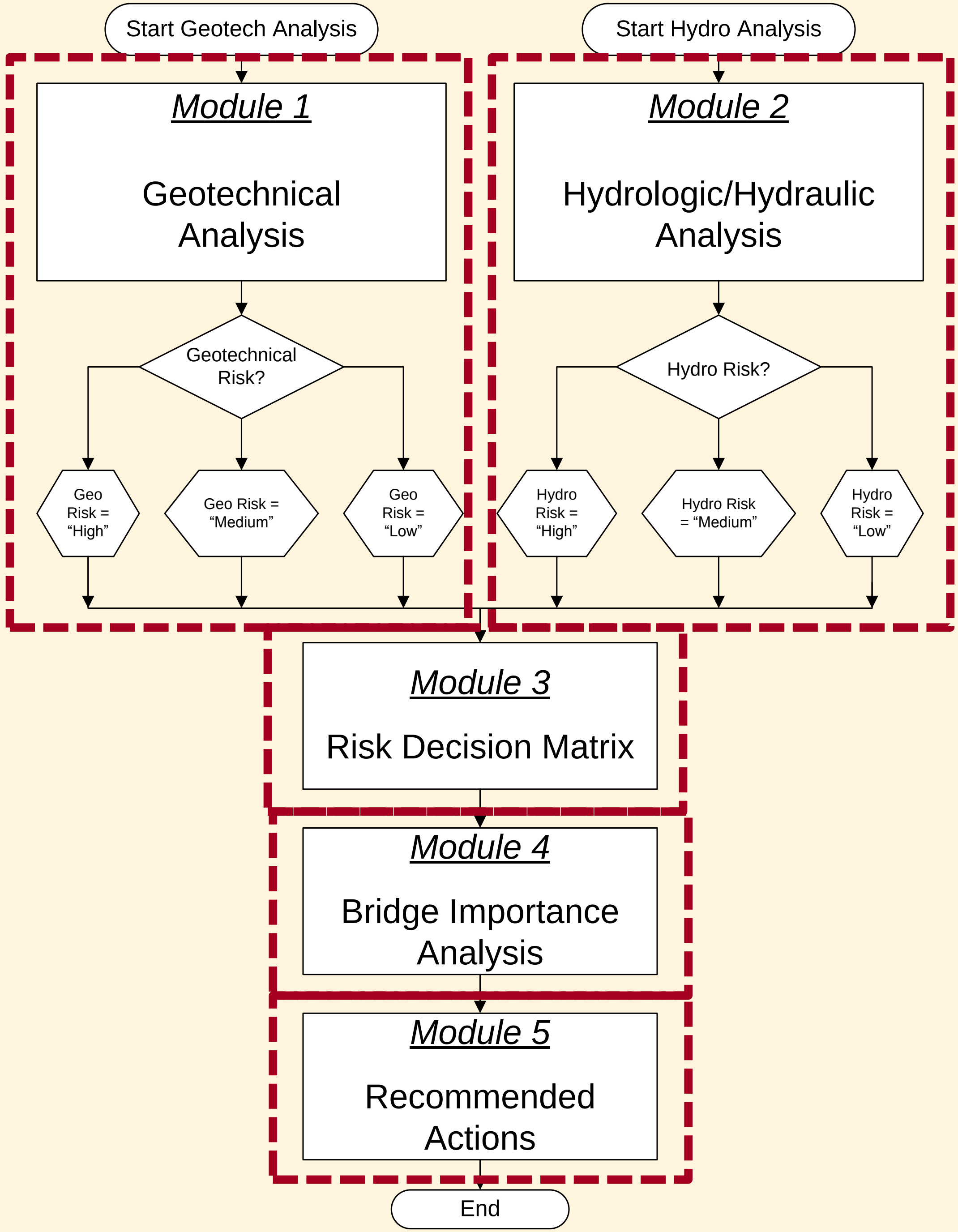
Main Features of the Scour Evaluation Model (SEM)

- **Risk-based** decision making tool.
- **Standard protocols** are provided.
- **New Jersey's unique** geology, physiography, and hydrology are reflected.
- **Past performance** and **longevity** are considered**.**
- **Bridge importance** is factored.
- **Prioritizes** bridges and makes and generates **specific recommended actions** for repair or delisting.

SEM Master Flowchart



Risk Factors of SEM

Model input parameters:

- Erosion class of streambed?
- Bridge age?
- Is substantial field scour present?
- Has bridge seen Q_{100} flow?
- Is channel stable?
- Perform HEC-18 scour calculations (selected relationships)
- Envelope curve check (for some NJ provinces)

SEM is a "multidimensional, holistic" approach that functions like an expert system.

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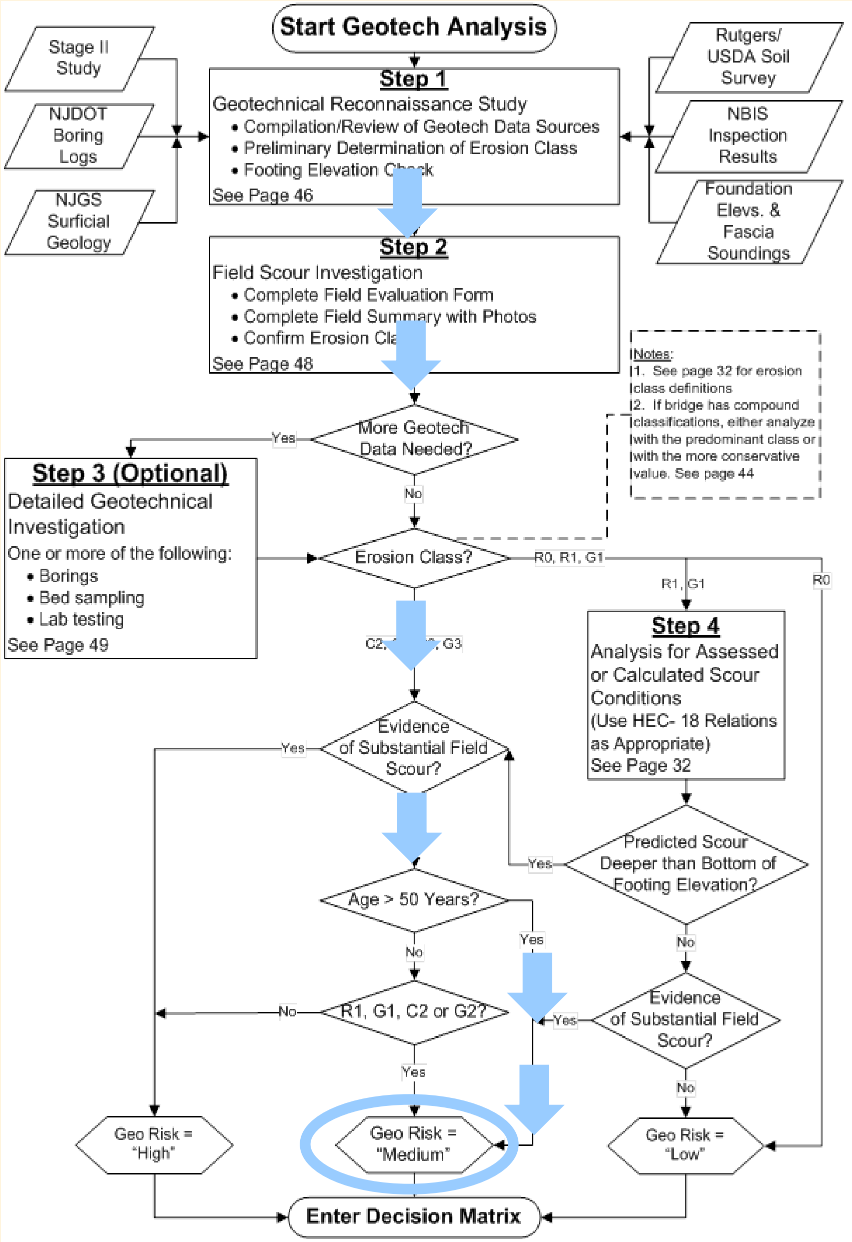
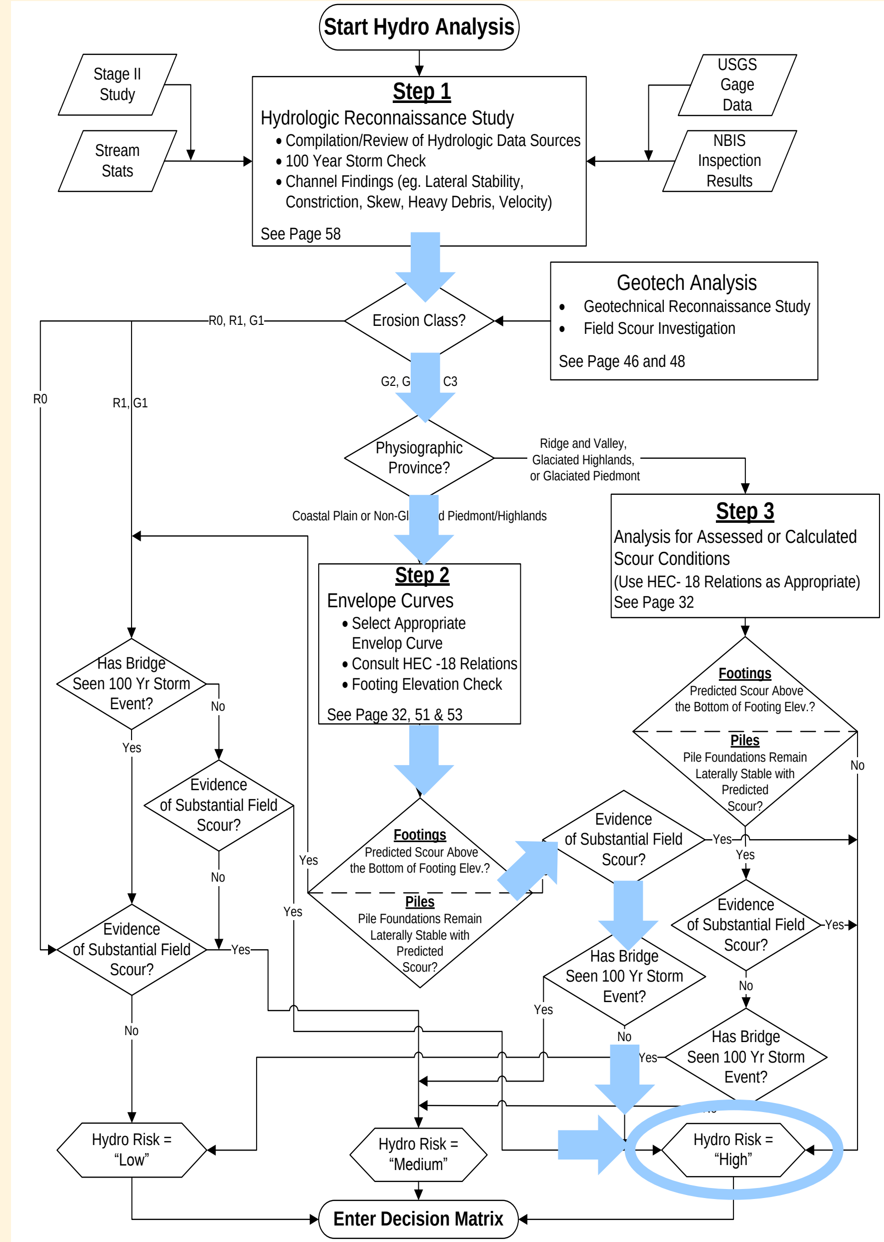
Geotechnical and Hydrologic/Hydraulic Risk Analyses





SEM Risk Decision Matrix

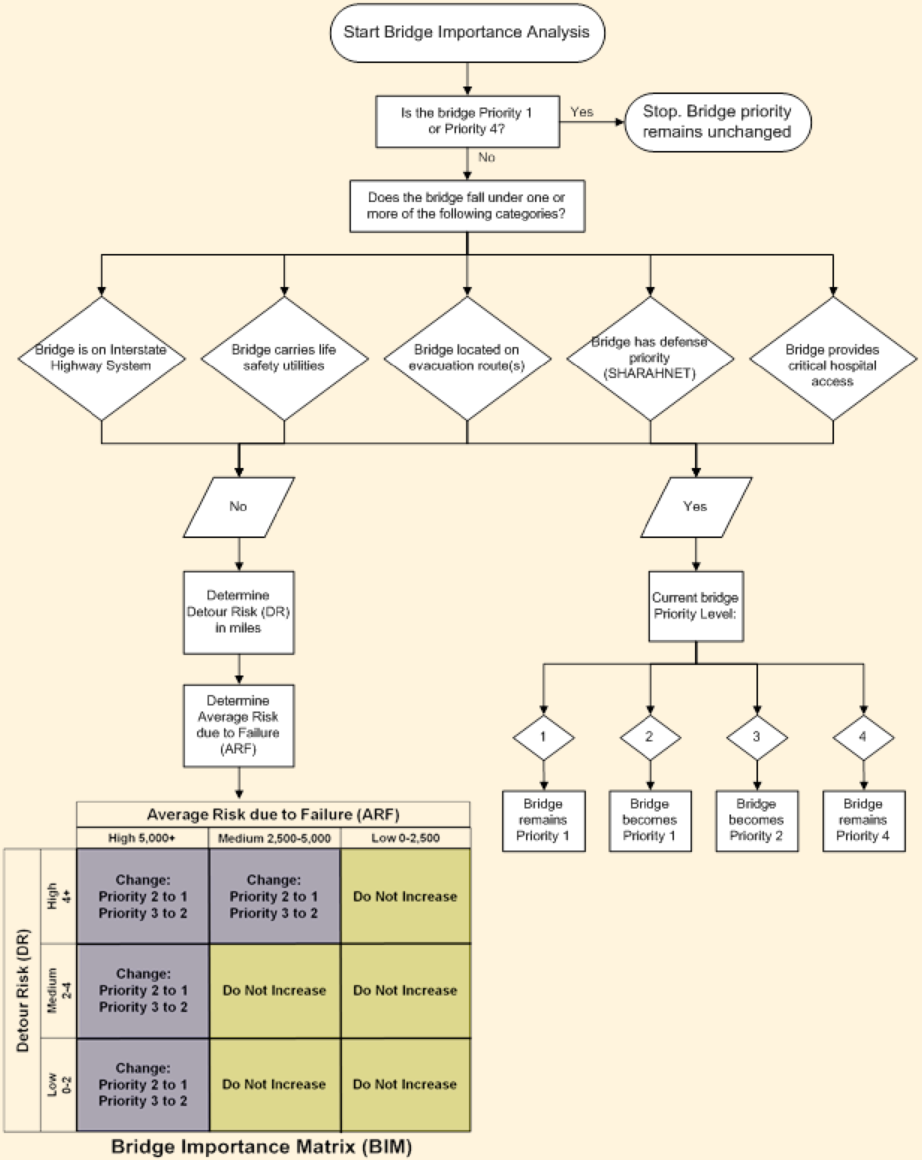
		Geotechnical Risk		
		High	Medium	Low
Hydrologic/Hydraulic Risk	High	Scour Priority 1	Scour Priority 2	Scour Priority 3
	Medium	Scour Priority 2	Scour Priority 3	Scour Priority 4
	Low	Scour Priority 4	Scour Priority 4	Scour Priority 4

Bridge Importance Analysis

Evaluates:

- Special Importance, e.g. Interstate, Evacuation Route
- Average Daily Traffic (ADT)
- Detour Distance
- Bridge Length

Any of these will elevate bridge priority by 1 unit.



Priority Levels and Recommended Actions

Priority Level	**Matrix Risk Combinations** (Geo-Hydro)	**Recommended Actions** (All listed actions for a given priority level must be performed)
Priority 1	High-High	(1) Continue Flood Watch or Install Real-time Monitoring System Until Repaired (2) Continue Annual NBIS Inspection with Fascia Soundings Until Repaired (3) Install Protective Measures As Soon As Possible
Priority 2	High-Med Med-High	(1) Continue Flood Watch Until Repaired (2) Continue Annual NBIS Inspection with Fascia Soundings Until Repaired (3) Install Permanent Real-time Monitoring System <u>or</u> Install Protective Measures
Priority 3	Med-Med High-Low	(1) Continue Annual NBIS Inspection with Fascia Soundings (2) Consider Erosion Monitoring for an Intermediate Period (3+ years), Then Revisit Risk Analysis
Priority 4	All Others	Bridge is Candidate for Removal from the Critical List - Recommend Continued M&R to Control Debris and Minor Erosion Zones

*FHWA Item 113 Coding is also addressed.

SEM Streambed Classification

EROSION RESISTANCE

HIGH ← → **LOW**

R0 Sound Rock	G1 Extremely Coarse Granular Soil	R1 Weak Rock	C2 Hard Cohesive Soil / G2 Coarse Granular Soil	C3 Soft Cohesive Soil / G3 Fine to Medium Granular Soil
Erosion over engineering life not significant	Highly erosion resistant; develops natural armoring	Erosion over engineering life normally minor	Scour behavior dominated by cumulative flow over time	Scour behavior dominated by high flow events

LOW ← → **HIGH**

SCOUR RISK

R0-R1 G1 G2 G3

SEM Hydrologic Analysis

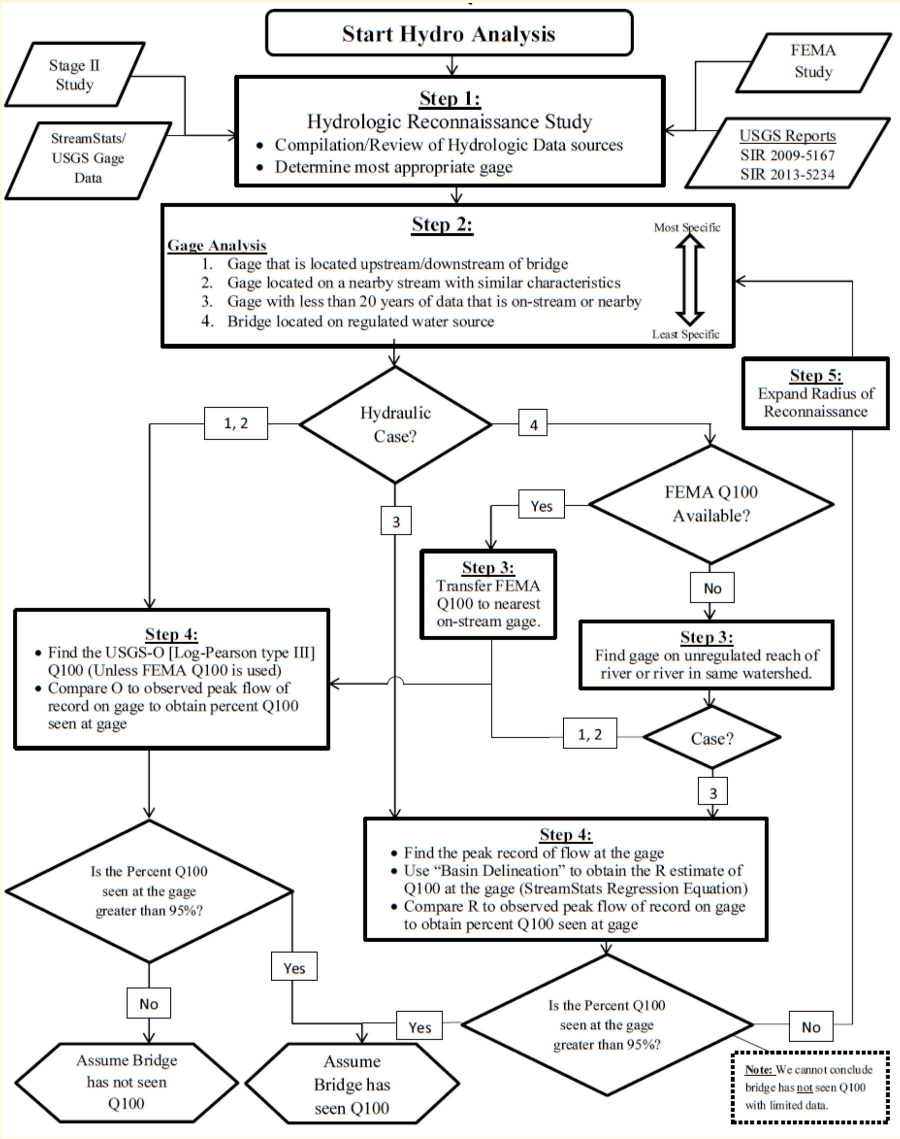
Methodology to assess whether bridge has seen Q100 flow:

Case 1: Gage(s) with ~20+ years data analyzed using Log-Pearson Type III equation based on the historical observed peak flow.

Case 2: Same as Case 1 but performed on nearby stream with similar hydrologic characteristics.

Case 3: Utilizes USGS StreamStats software to estimate Q100.

Case 4: Regulated stream.



Flowchart for Hydrologic Analysis of SEM Bridges

Sample Hydrologic Calculation

Hydrologic Analysis Calculations
for Bridge Scour Investigation

Structure: **2003-162** Route/Stream: **US 22 WB over Rahway River** County/Town: **Union/ Springfield**

Stage 2 Study:	
Date Published: October-05	Cooridinates: 40.688558, -74.311835
Year Built: 1941	Q100 (CFS): 6000
Method: HEC-RAS	
StreamStats/USGS Gage Data:	
Gage Used: 01394500	Bridge Location Relative to Gage: 0.05 mi Upstream
Drainage Area At the Bridge: 25 mi^2	Drainage Area at the Gage: 24.9 mi^2
Hydrologic Province of Drainage Area: Glaciated Piedmont	Regression - Q100 (CFS): N/A (Sufficient Gage Data)
Observed Peak Flow after Year Built (CFS): 8620	Record Date: 8/28/2011
Regression (StreamStats) - Q100 at the Bridge (CFS): 4780	
USGS Reports (SIR 2009-5167/SIR 2013-5234):	
Transfer Coefficient (from Hydro Province): 0.68	O [Log-Pearson Type III] - Q100 (CFS): 7532

Calculated:

Q100 at Bridge Transference (CFS):

$$Q_{100(u)g} = \left(\frac{DA_u}{DA_g}\right)^b Q_{100(o)g}$$ = [(25/24.9)^0.68]*7532 = **7553**

%Q100 Seen at Gage:

$$\%Q100 = \frac{Peak\ Flow}{Q100}(100\%)$$ = (8620/7532)*100% = **114.4%**

Conclusion: **Yes, Q100 Seen**

Notes: Case 1 (Gage upstream/downstream of bridge, where transfer equations are applicable)

Standardized Scour Field Inspection Form

Page 2 of ___

UPSTREAM CHANNEL (continued):

Bed Description:

Bed Exposed/Visible during Visi

General Textural Description:

Predominant Erosion Class (refe

R0: Sound Rock___
G1: Extr. Coarse Granular___
R1: Weak Rock___

Est. % Boulders:___
Est. % Cobbles:___

Additional Comments (e.g. compo

Results of Rod Probing (if done):

Textural Description: Hard

Depth of Penetration:___in

Results of Shallow Sampling (if

Description

Est. % Vegetative Cover:

Bank Condition:

N S E W: Est. % Vegetative Co
Bank Material
Bank Erosion: None

N S E W: Est. % Vegetative Co
Bank Material
Bank Erosion: None

Tributary Drain Outlets? Yes

Countermeasures Present? Yes

Additional Channel Comments:

Page 1 of ___

Version 6.0 7-1-11

FIELD INSPECTION FORM
FOR BRIDGE SCOUR INVESTIGATION

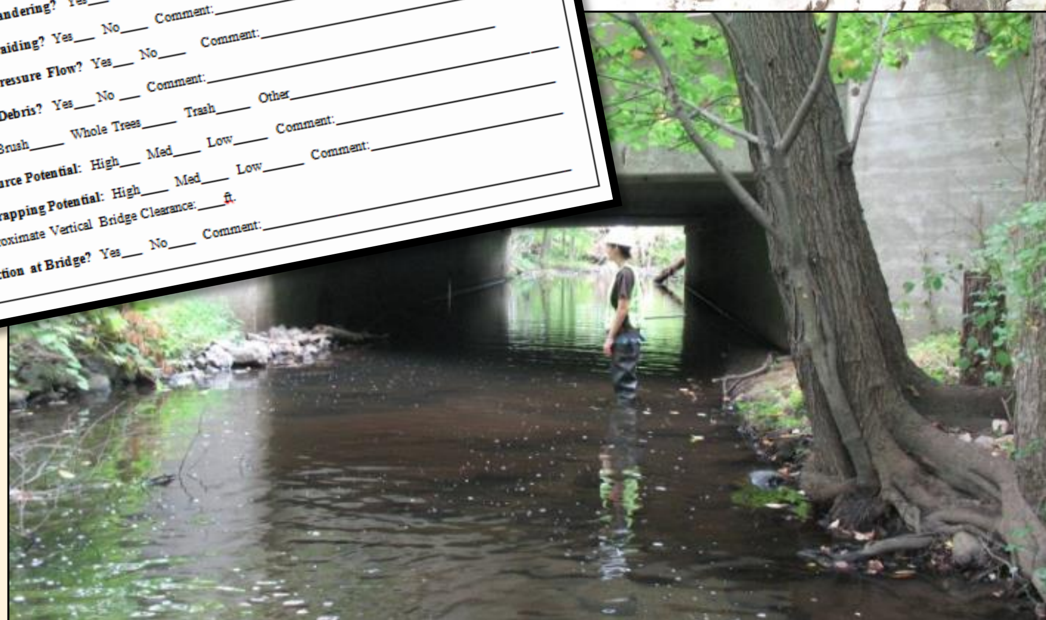
Date:
Time of Arrival:

GENERAL DATA:
Structure Number:
Time of Departure:
Route Number/Stream Name:
County:
Reconn. Report Reviewed? Yes___ No___
Township:
Physiographic Province:
(Notes)
Field Team:

Bridge Type: Beam/Slab___ Girder/Stringer___ Arch___ Truss___ Other:
Support: Simple___ Continuous___
Comment:

Visible Channel Slope: Flat___ Mild___ Moderate___ Steep___

UPSTREAM CHANNEL:
Estimated Skew Angle: 0-15 deg___ 15-30 deg___ 30-45 deg___ > 45 deg___
Average Water Depth during Visit:___ft.
Evidence of Overtopping? Yes___ No___ Comment:
Evidence of Meandering? Yes___ No___ Comment:
Evidence of Braiding? Yes___ No___ Comment:
Evidence of Pressure Flow? Yes___ No___ Comment:
Evidence of Debris? Yes___ No___ Comment:
Type: Brush___ Whole Trees___ Trash___ Other:
Debris Source Potential: High___ Med___ Low___ Comment:
Debris Trapping Potential: High___ Med___ Low___ Comment:
Approximate Vertical Bridge Clearance:___ft.
Contraction at Bridge? Yes___ No___ Comment:



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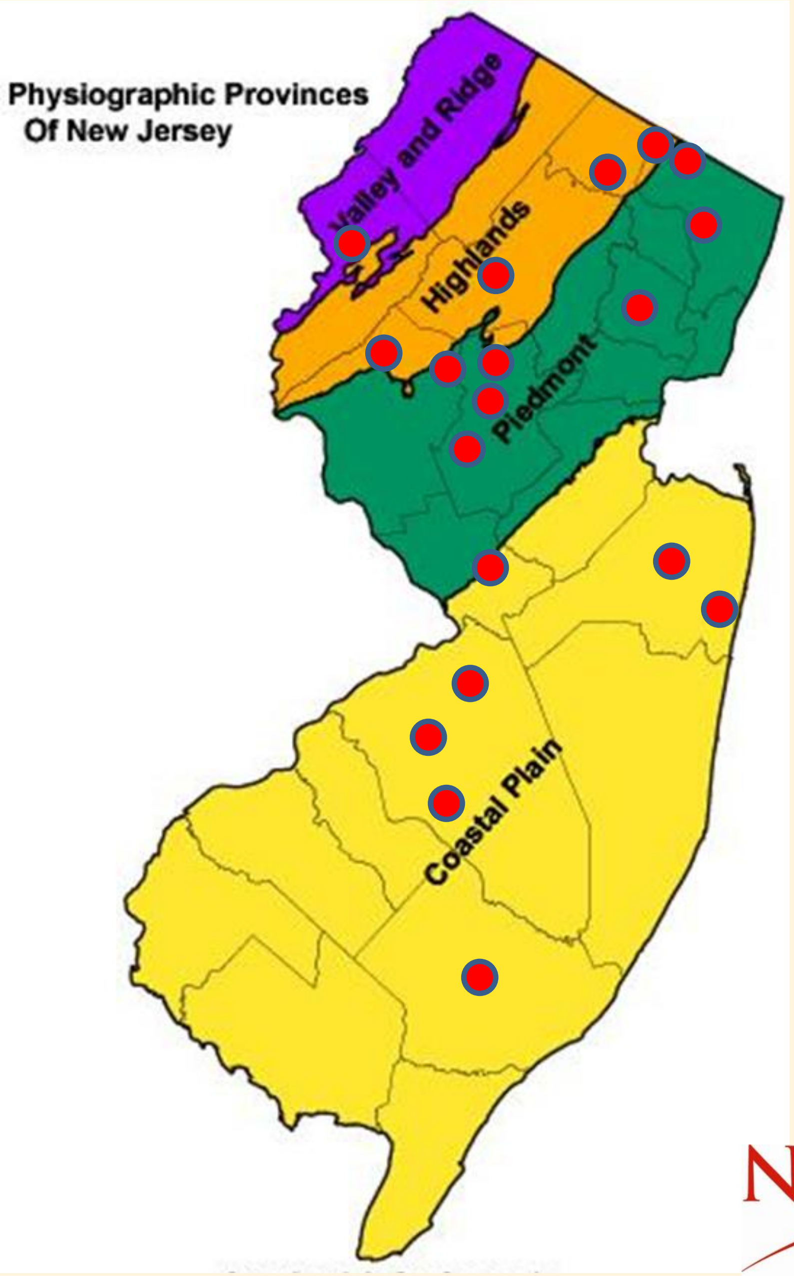
Implementation Phase: Transfer of SEM into Practice

- Recently, the method was launched by into practice by performing the full SEM evaluations of 19 scour critical bridges across the State.
- Participating Consultants:
  - **AECOM, Piscataway Office**
  - **McCormick Taylor, Mount Laurel Office**
  - **Mott McDonald, Iselin Office**
- Evaluations performed June 2016 to July 2017.

Geographic Distribution of SEM Study Bridges

Evaluated bridges had a wide variety of characteristics:

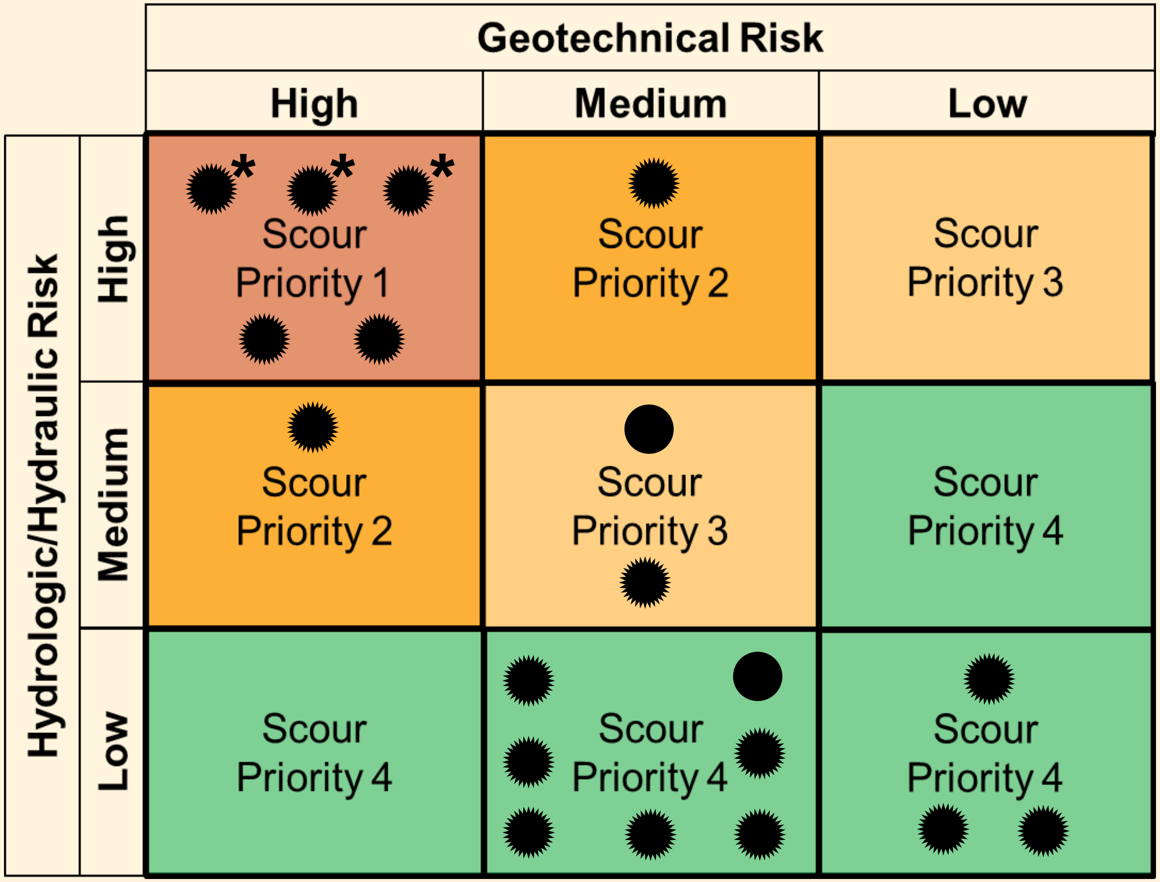
- All four of New Jersey's physiographic provinces represented.
- Bed conditions: sand, silt, clay, cobbles, boulders, & bedrock.
- Flooding history:
  70 to 276 %Q100.
- Drainage basin size:
  2.1 to 67.3 sq. miles.
- Age: 47 to 90 years.
- No. spans: 1 to 5.
- Many structure types.



Locations of 19 SEM bridges

Some SEM Study Bridges

Summary SEM Results from Consultant Evaluations



Summary:

- 5 bridges are Priority 1
- 2 bridges are Priority 2
- 2 bridges are Priority 3
- 10 bridges are Priority 4

Envelope Curve Auxiliary Study

What are envelope curves?

1. A straightforward procedure to estimate scour depth in granular sediments.
2. The method relates an easily measurable parameter, e.g. embankment length, with predicted scour depth.
3. Method has been validated using many hundreds of bridges in numerous states.
4. Objective of this project task was to develop a database so that envelope curves can be used in New Jersey.

<u>Abutment/Contraction Scour (Benedict and Caldwell, 2003):</u>

NBSD: $y_s = 3.385 - 00795L + 3.675\ (10^{-5})\ L^2$

South Carolina Piedmont: $y_s = -9\ (10\text{-}^{6})\ L^2 + .0276L$

South Carolina Coastal Plain: $y_s = .0338L$ for $L \leq 426$

<u>Pier Scour (Benedict et al, 2016)</u>:

$y_s = 2.1\ (b)^{0.9}$ (applicable where $b \leq 30$ feet)

Where: y_s = scour depth (ft.)

L = Length of embankment-blocking flow (ft.)

b = pier width (ft.)

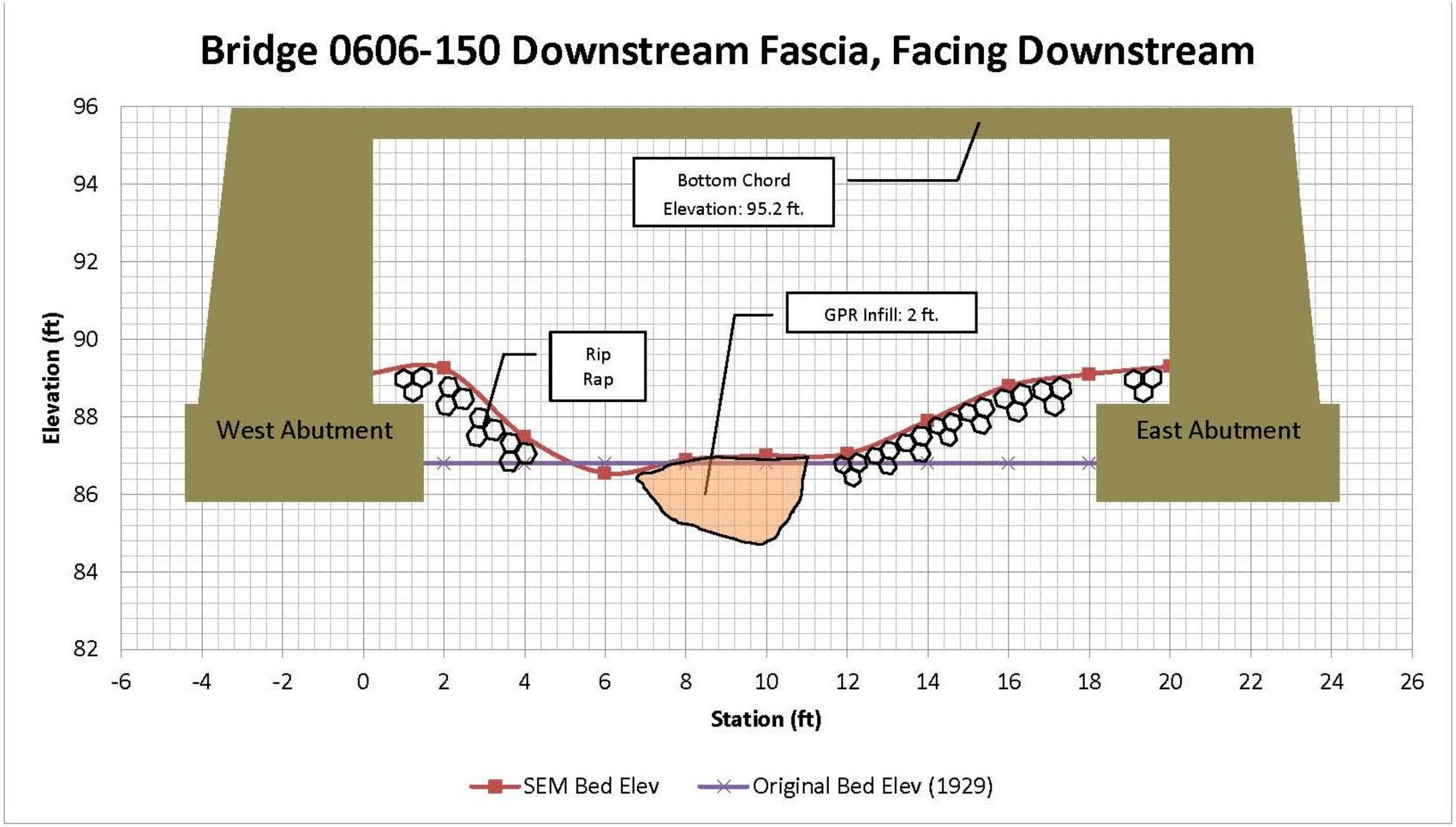
Envelope Curve Field Methodologies

Ground Penetrating Radar (GPR), Fascia Soundings
Bed Probing, and Soil Sampling

Envelope Curve Results

Subsurface Fascia Soundings

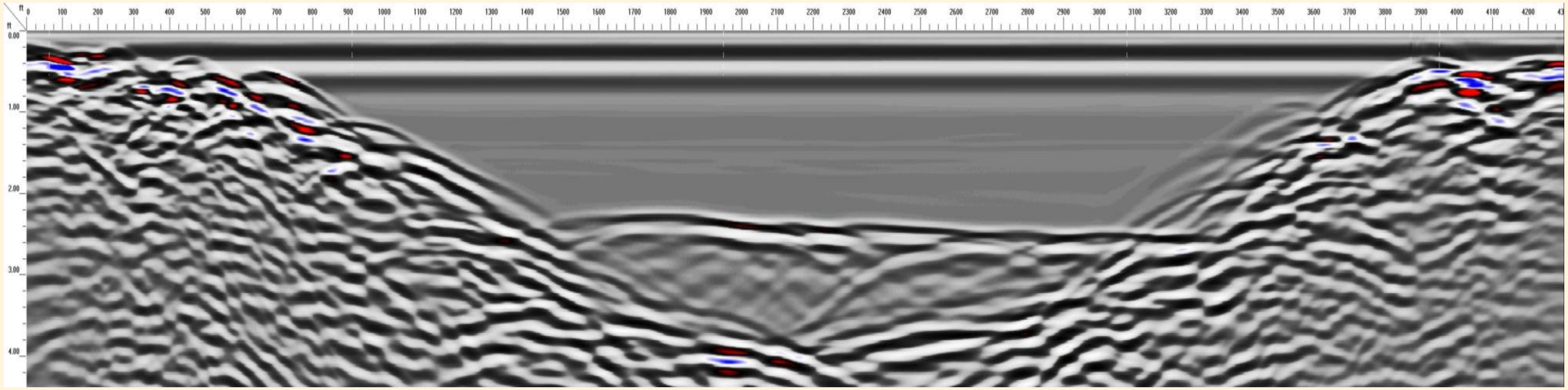
Bridge 0606-150 (Route 49 over Menantico Creek)



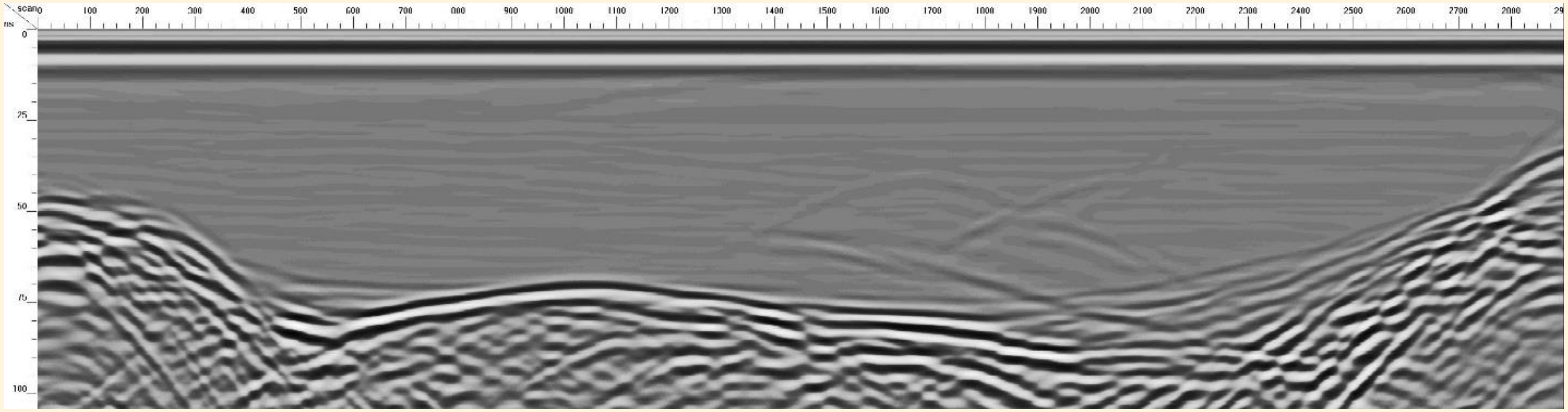
Notes:

- Vertical scale is exaggerated.
- All soundings are measured from the elevation of the chord as shown above, and assuming that the deck was level.
- SEM visit date 8/29/16.
- Reference elevation at bridge is based on Stage 2 data and NVGD 1929.

Envelope Curve Results



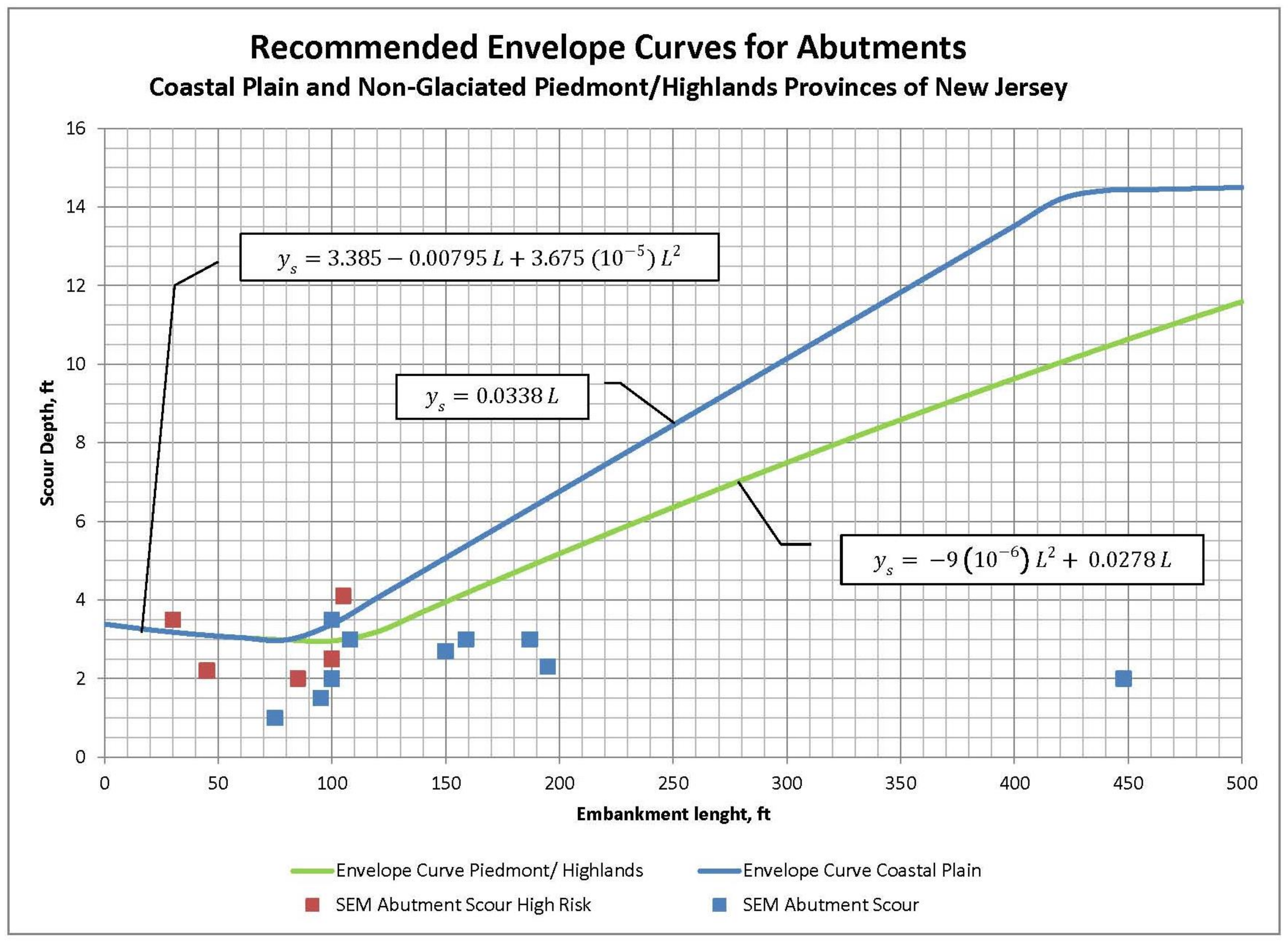
Bridge 0606-150



Bridge 1304-151

Envelope Curve Recommendations

- New Jersey data show good consistency with published curves.
- Method is now approved for existing bridges in the Coastal Plain, Non-Glaciated Piedmont, and Non-Glaciated Highlands.
- The method supplements other evaluative procedures of SEM.



Summary and Conclusions

- The Scour Evaluation Model (SEM) offers new analysis procedures and protocols, while still retaining the applicable parts of HEC-18.
- The model helps discern bridges that require repair from others that have low scour risk and can be removed from the Critical List.
- SEM was recently transferred into practice by three New Jersey consulting firms with the analysis of 19 bridges.
- The method is now approved by FHWA and NJDOT to evaluate the scour risk of existing bridges throughout the State.
- The overall goal of this research is improve public safety and to expend bridge repair funds more strategically.

Educational Dividends

The NJIT Scour Team

(and Dr. John Schuring, photographer)

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Thank You!

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