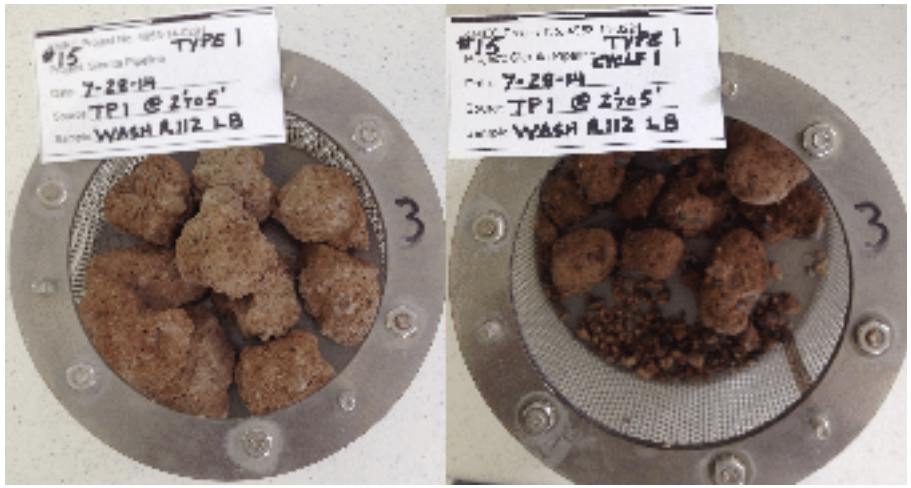
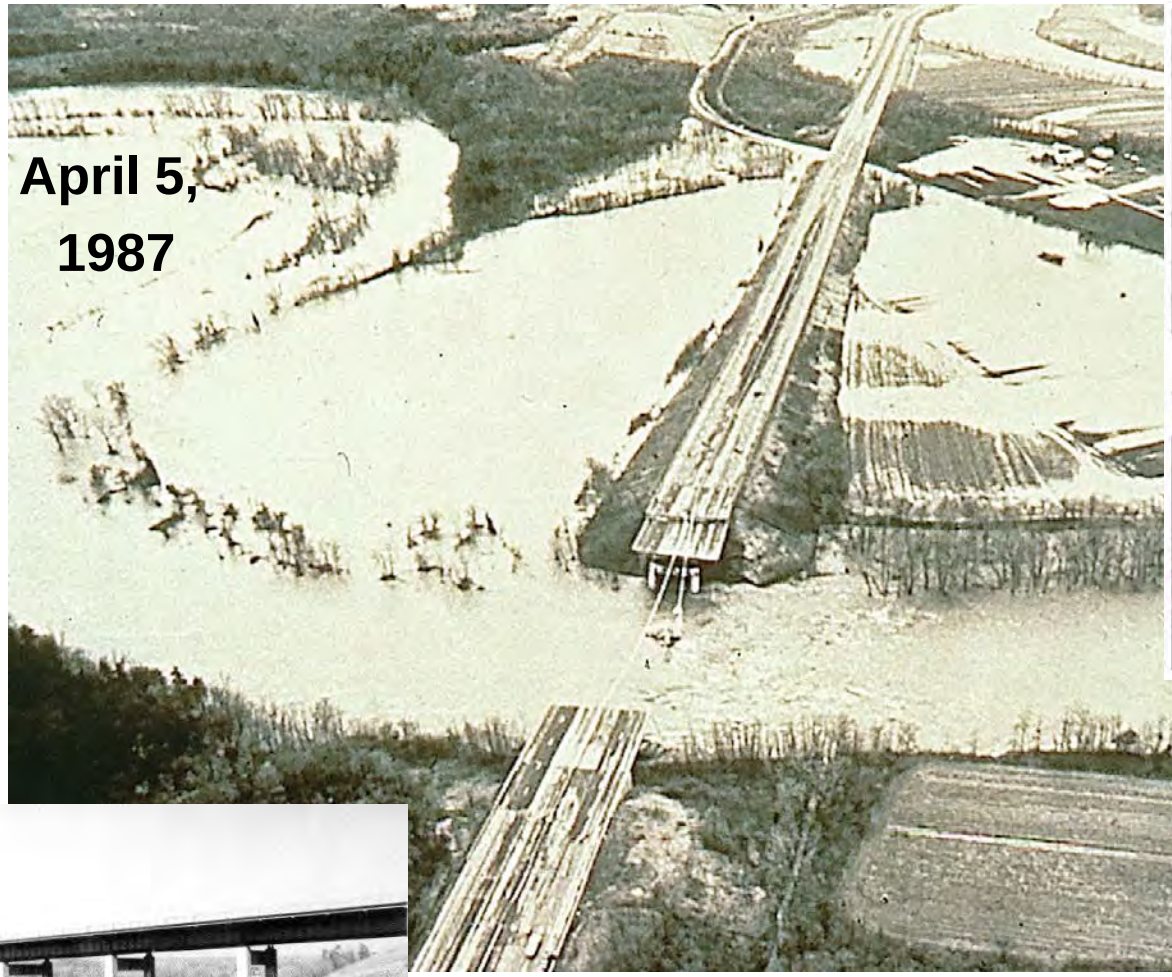
Stream Power and Scour of Weak Rock and Cemented Earth Materials – an Update

Jeffrey R Keaton, PhD, D.GE, ENV SP

AMEC Americas, Los Angeles, CA, USA



I-90 at Schoharie Creek, New York



FHWA mandate for scour-critical bridges to be evaluated

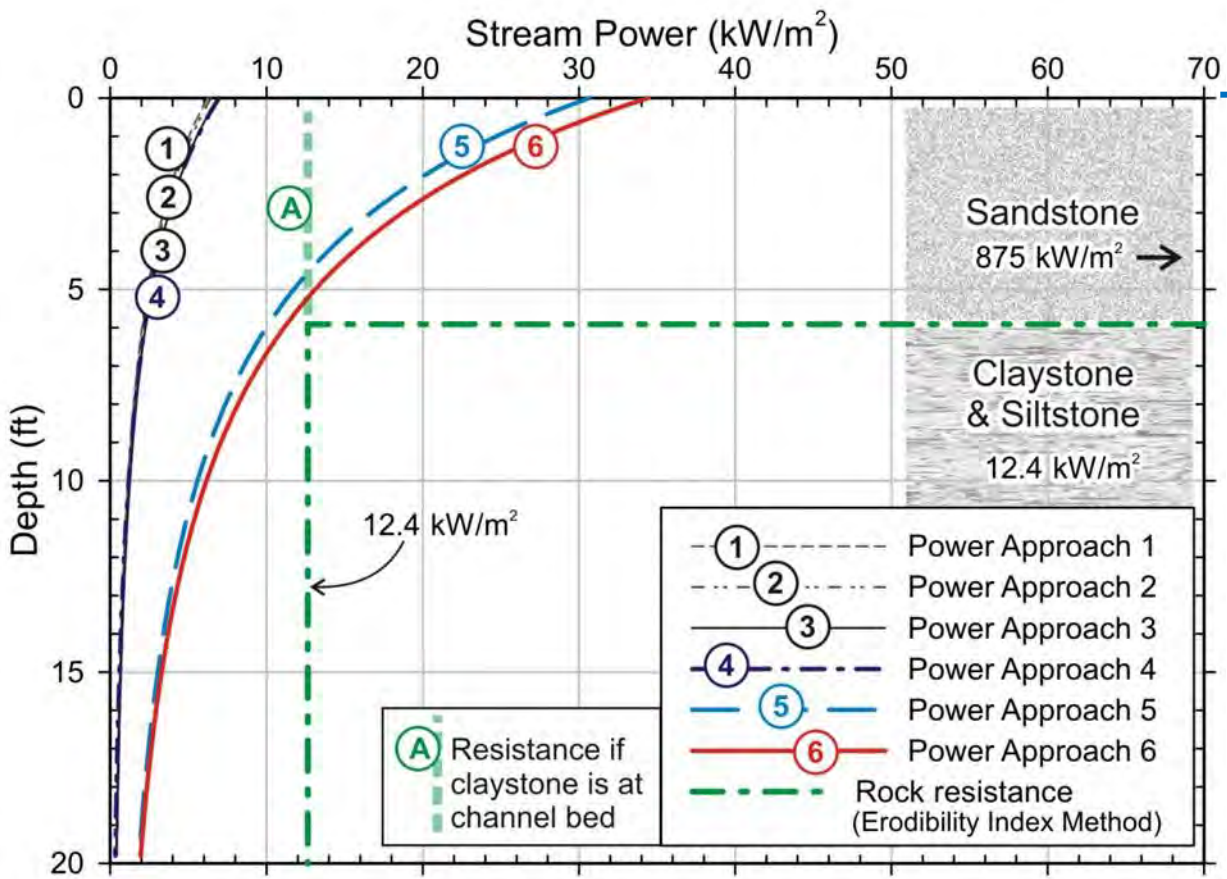
Research Objectives

- Develop a methodology for determining
  - Design Scour Depth
  - Time-Rate of Scour
- Develop design and construction guidelines for applying the methodology

- NCHRP Project 24-29 → NCHRP Report 717 (2012)
- Jeff Keaton, Su Mishra, and Paul Clopper

General Soil and Rock Application

- Erodibility Index Method; Annandale (2006)



Water flow with peak stream power at the channel

Channel bottom

Geotechnical profile expressed in terms of power

Definition of Scour-Resistant Rock

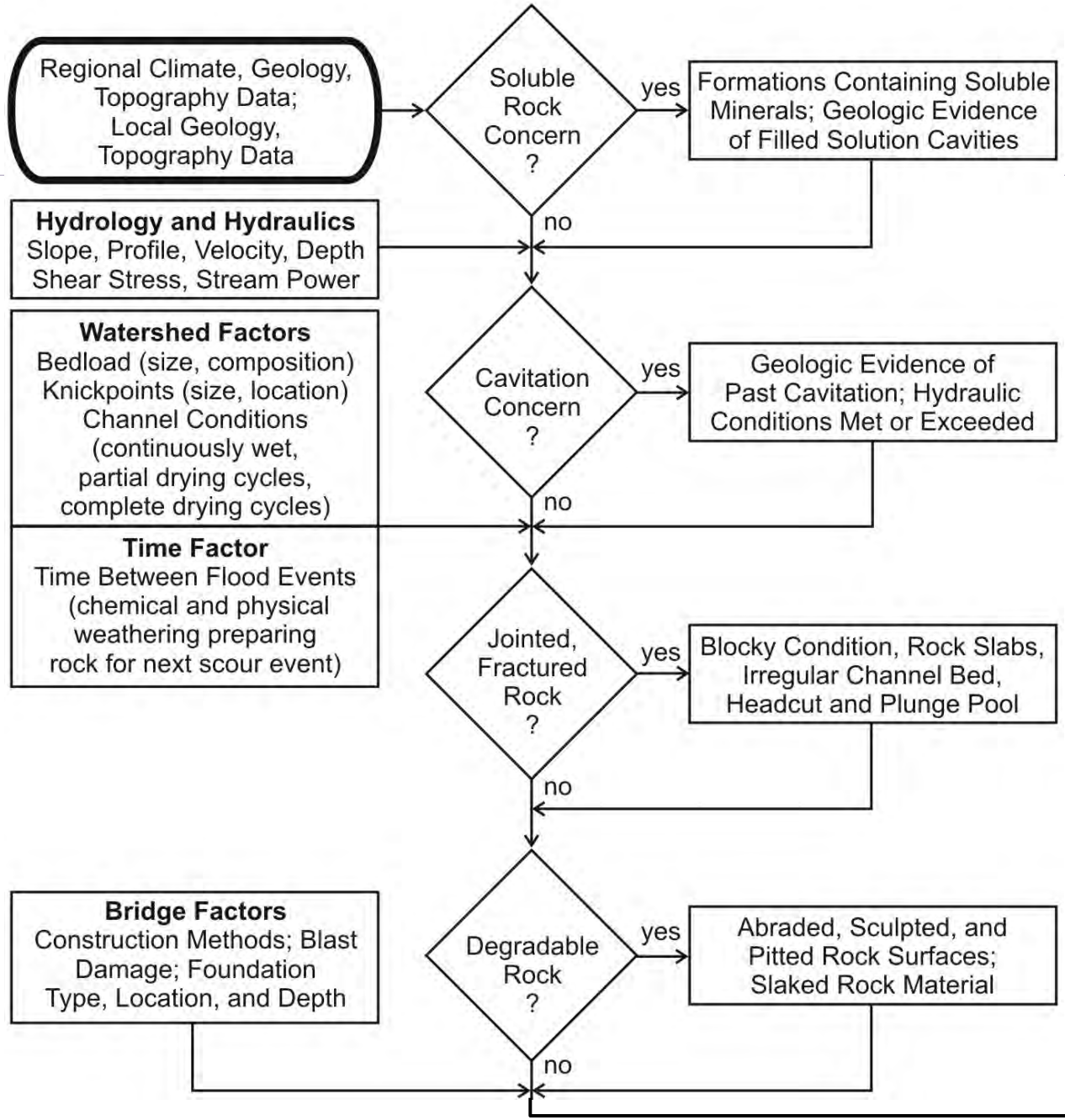
- Scour-Resistant Rock - material likely to withstand flowing water without substantial scour; generally consistent with concrete because concrete …
  - looks like rock
  - is strong enough to support loads
  - does not slake
  - remains in place when large blocks are subjected to relatively swiftly flowing water
  - has been used in engineering applications for scour protection

Rock material not as good as concrete might be scour-resistant;

All rock erodes, the question is 'how fast?'

Reality indicates that it is a 'rock-water interaction' problem

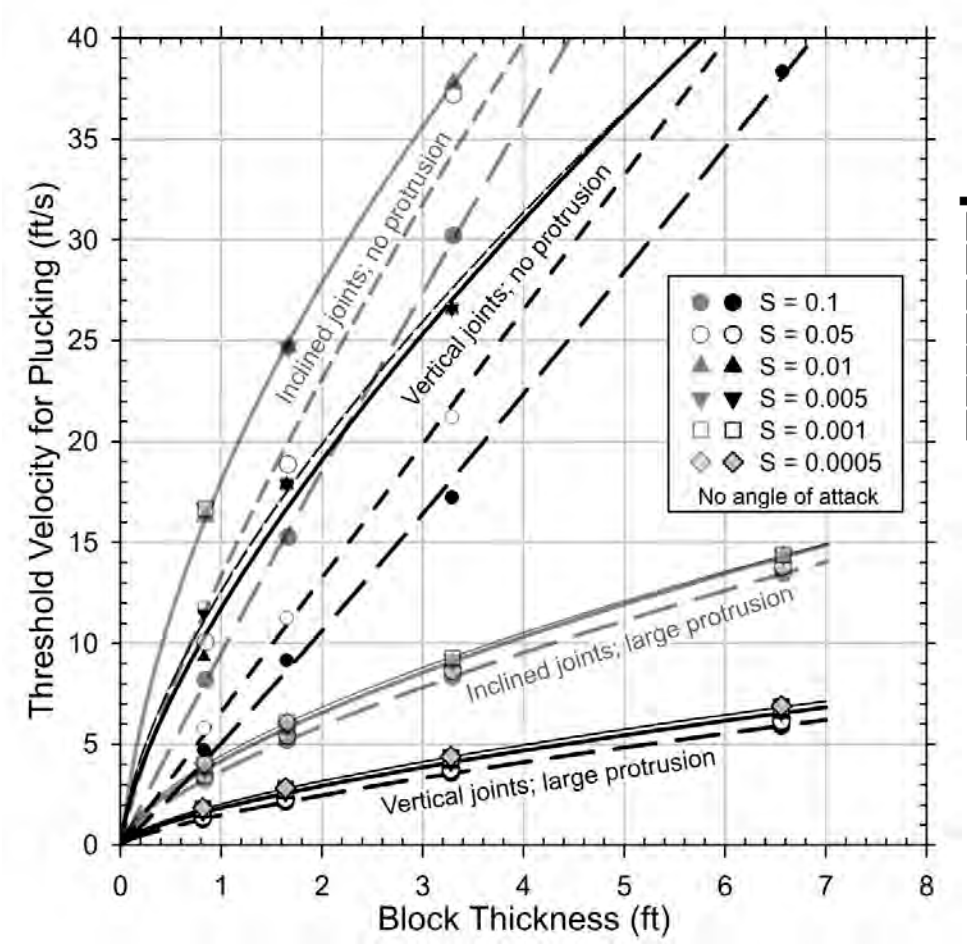
Rock Scour Modes



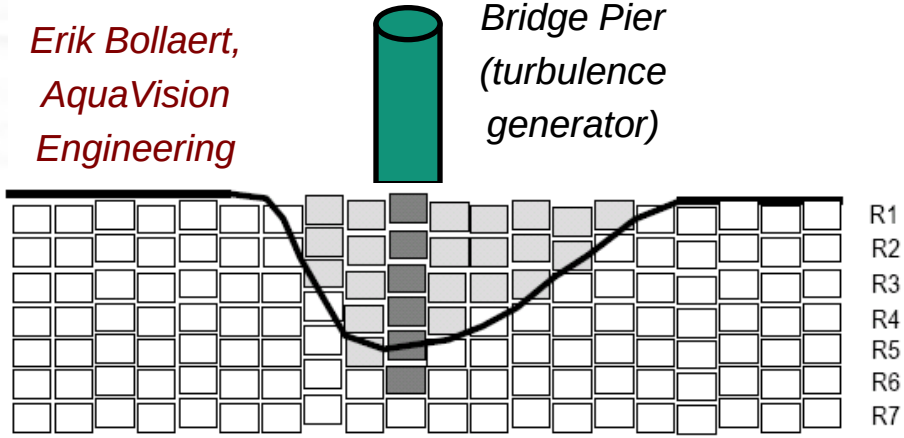
- Identify Relevant Scour Modes
- Dismiss Non-relevant Modes

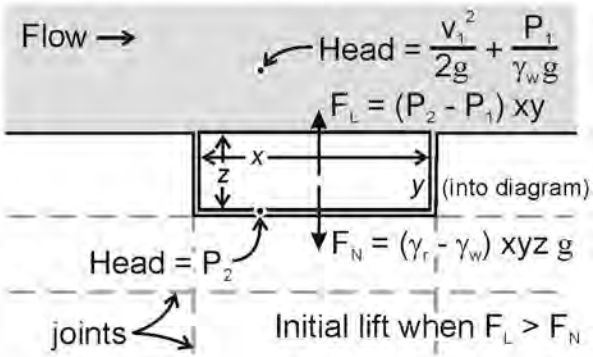
Durable Rock Blocks

- **Pier Scour**



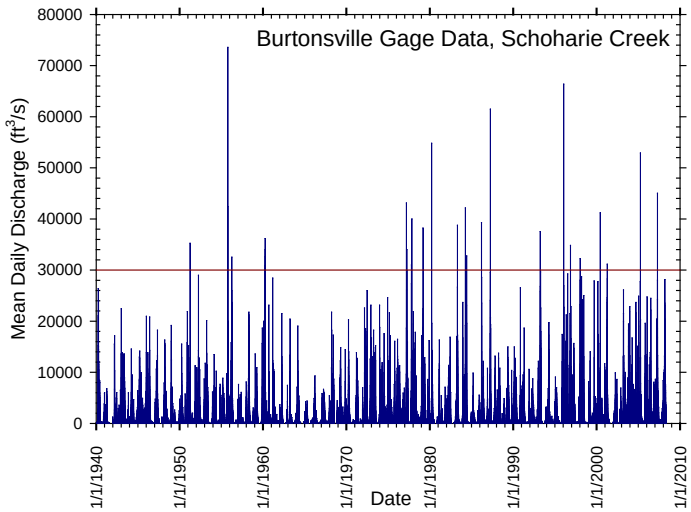
Erik Bollaert, AquaVision Engineering

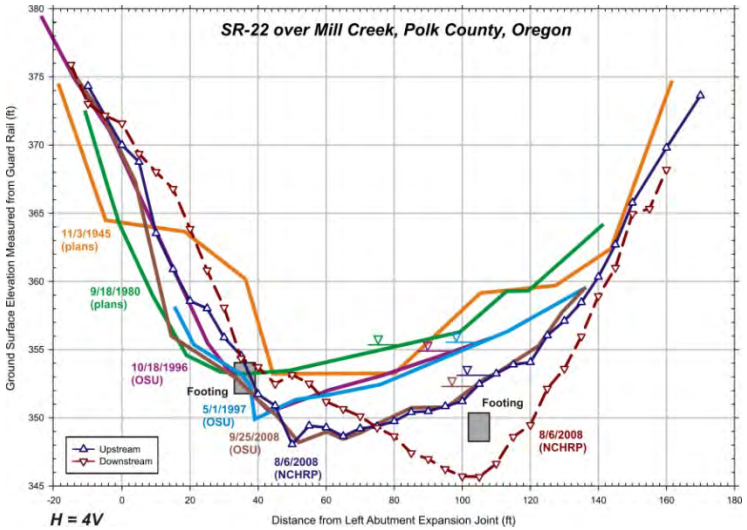


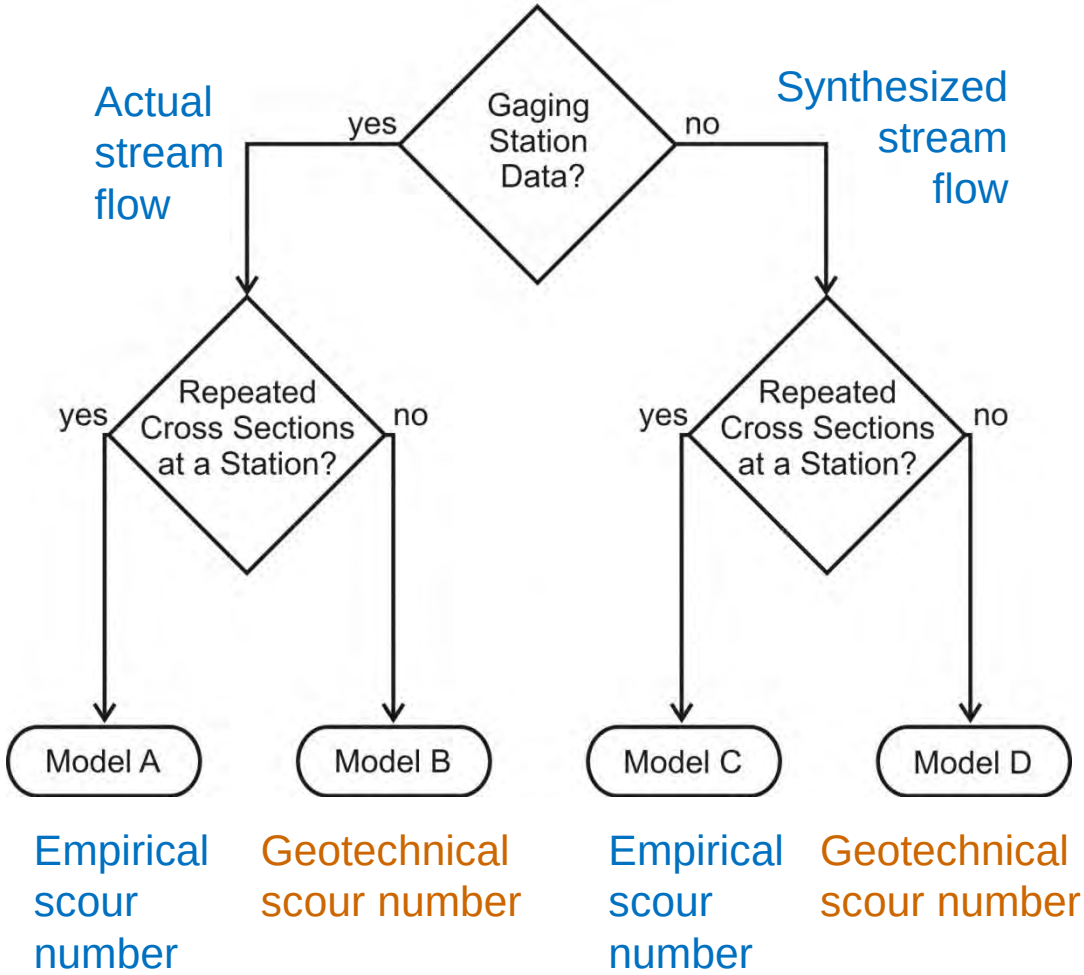


Hancock et al., 1998

Degradable Rock Scour

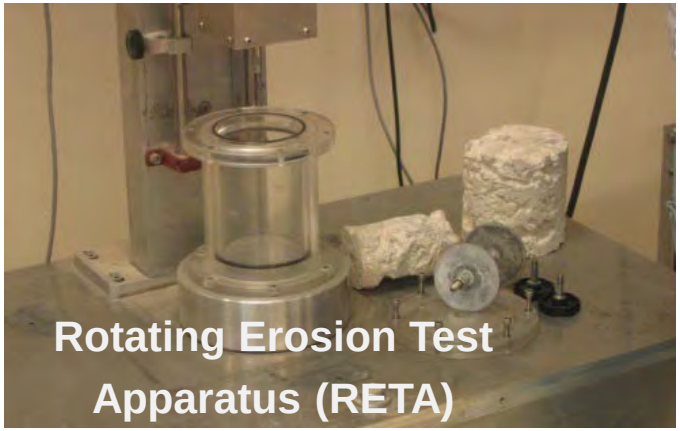






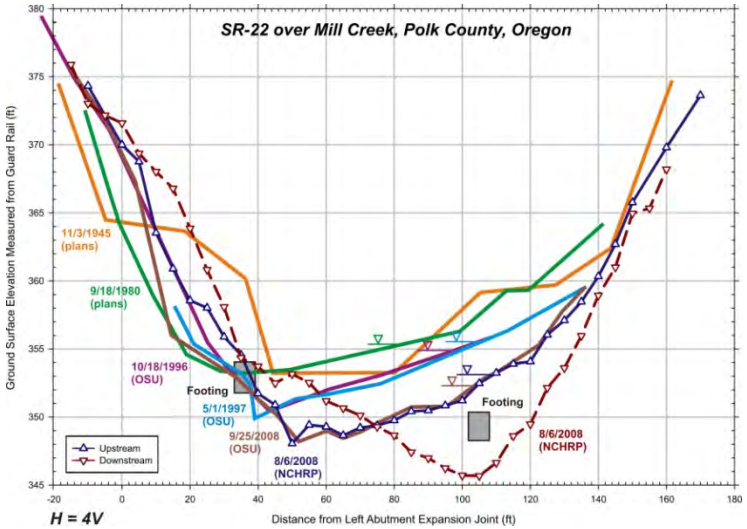
Rock scour is a "rock-water interaction" problem

I-10 Bridge Over Chipola River



Oligocene marine dolomitic limestone

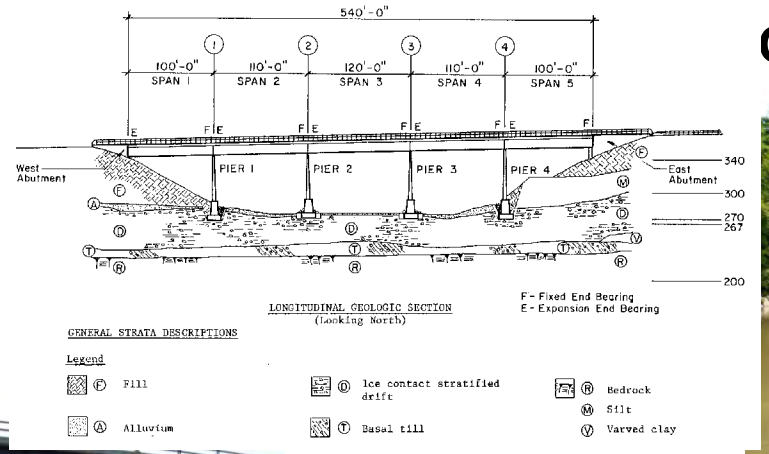
SR-22 Bridge Over Mill Creek



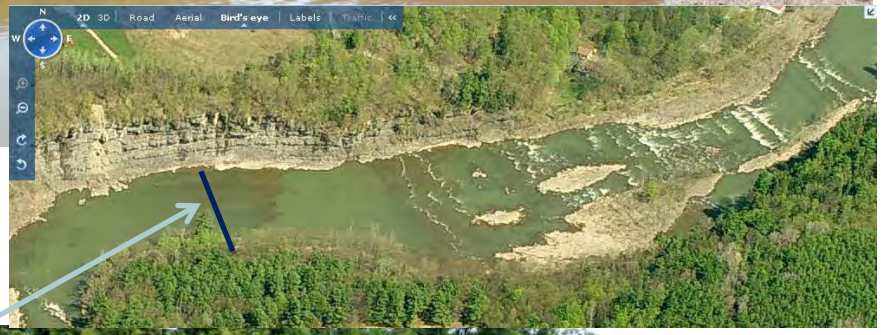
Water
Flow

Oligocene marine siltstone

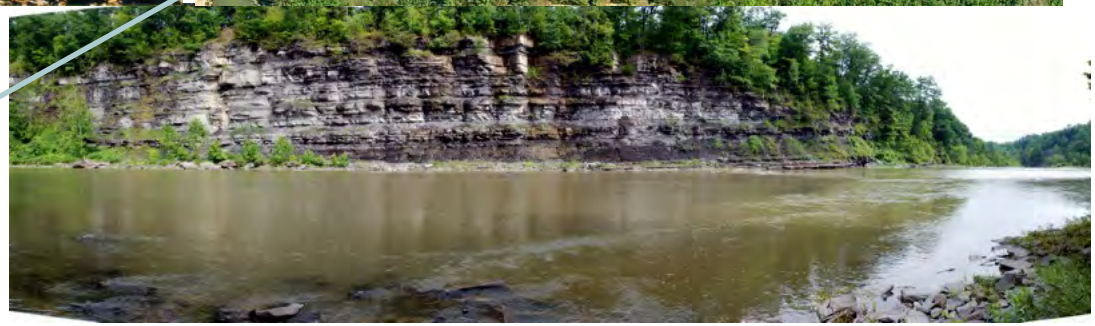
I-90 Bridge Schoharie Creek



Quaternary ice-contact stratified drift

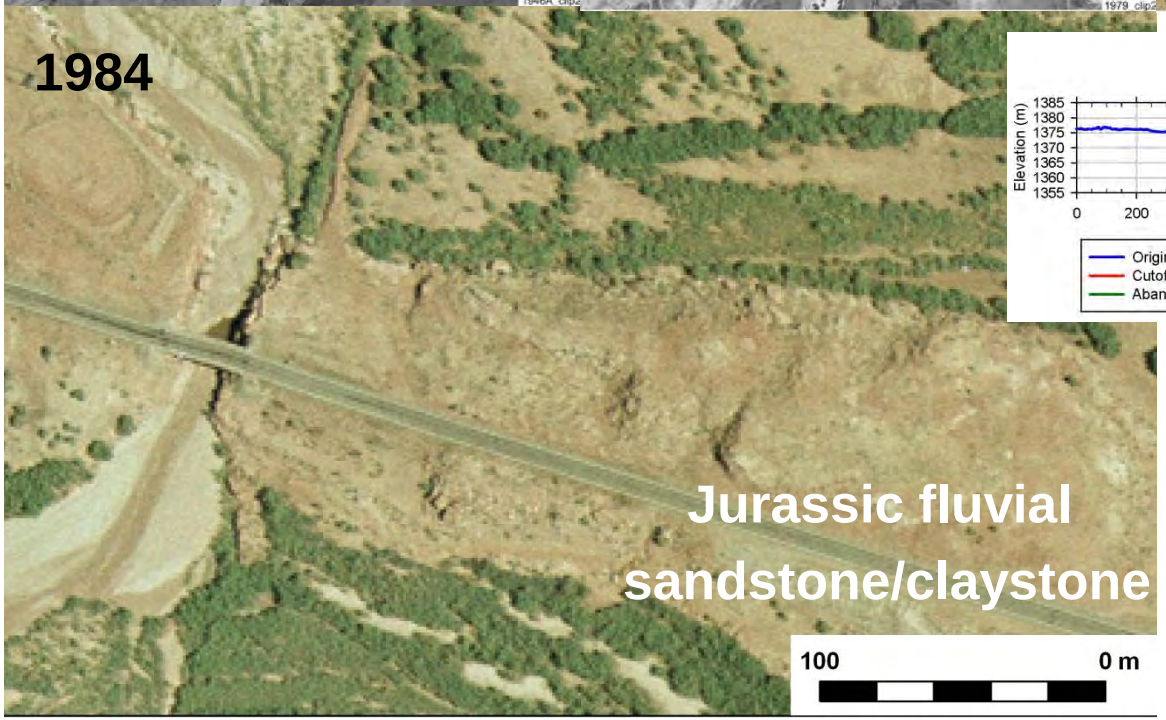


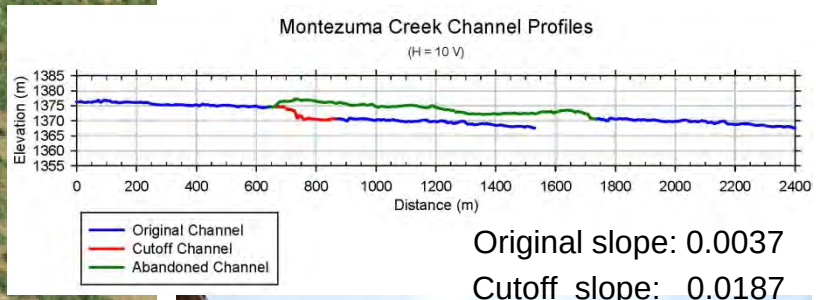
Schoharie Creek Gage



Paleozoic marine sandstone

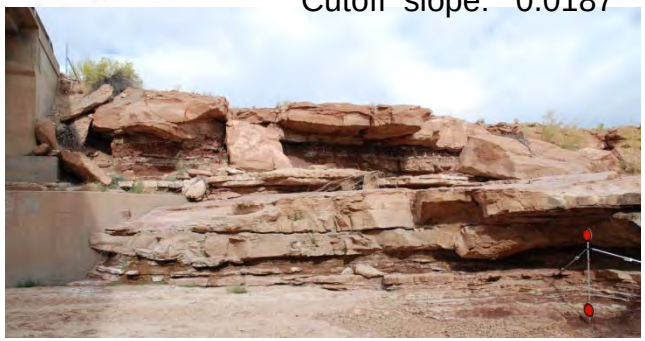
SR-262 Montezuma Creek





Original slope: 0.0037

Cutoff slope: 0.0187

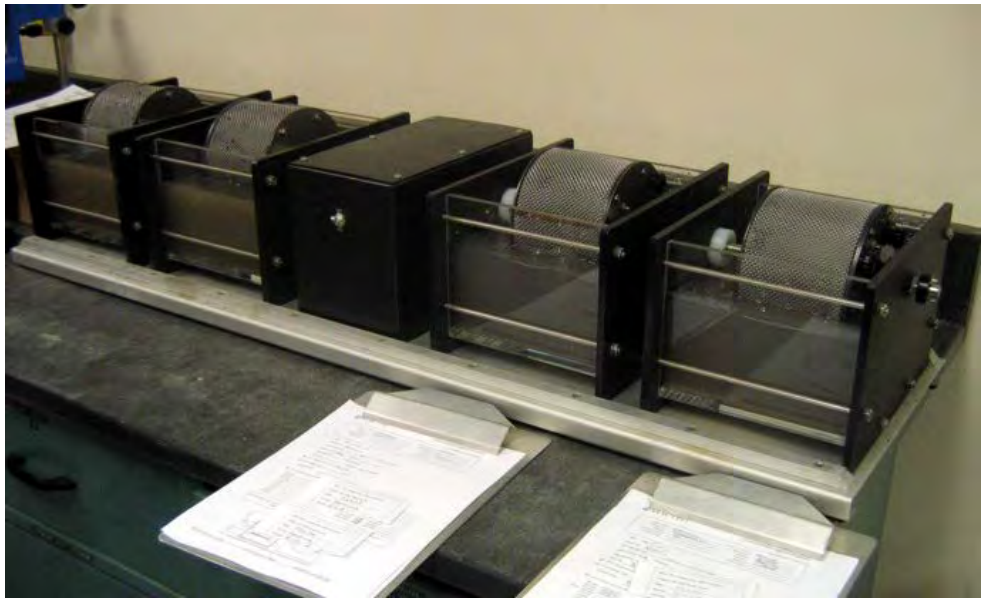


SR-273 Bridge Over Sacramento River

Cretaceous marine siltstone

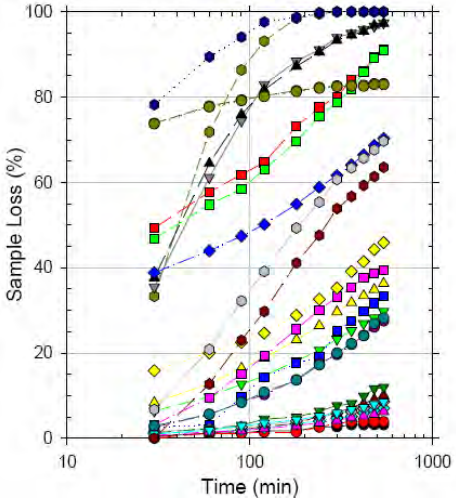
California DOT core samples

Modified Slake Durability Test



ASTM D4644 -08 *Standard Test Method for Slake Durability of Shales and Similar Weak Rocks*

Slake durability equipment used to perform continuous abrasion test modified from Dickenson and Baillie (1999)

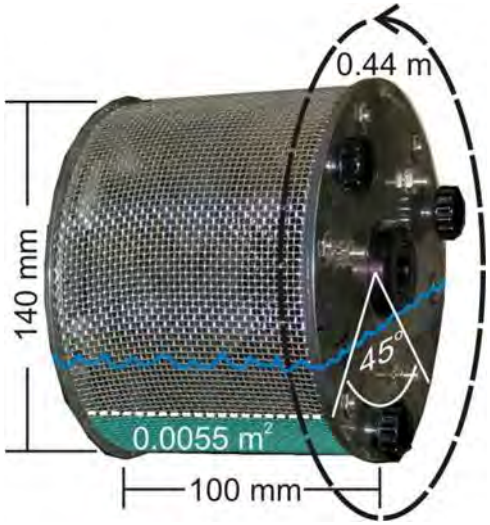


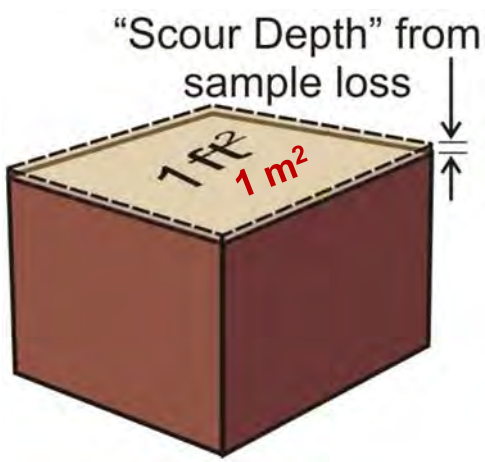
Start

1 hr

5 hrs

Modified Slake Durability Test





Average mass during test increment (N, lb) [*normalized to 500 g initial mass*]

Circumference x rpm x time of rotation = equivalent distance traveled (m, ft)

60-min (3600-s) test increment (s)

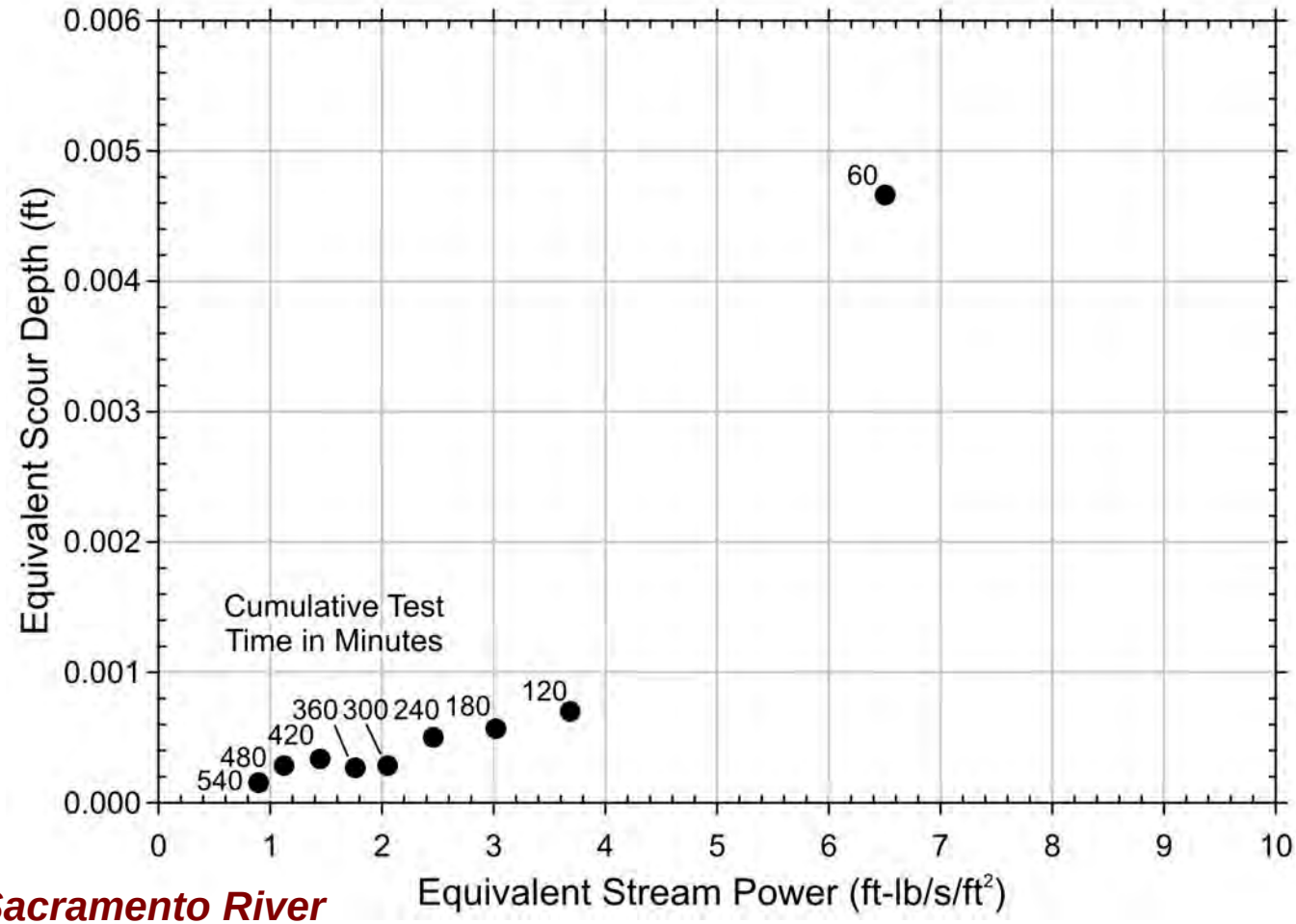
Sample residence area (m^2, ft^2)

N-m = J; J/s = W → W/m^2 [= ft-lb/s/ft^2]

Unit weight of rock material (N/m^3, lb/ft^3)

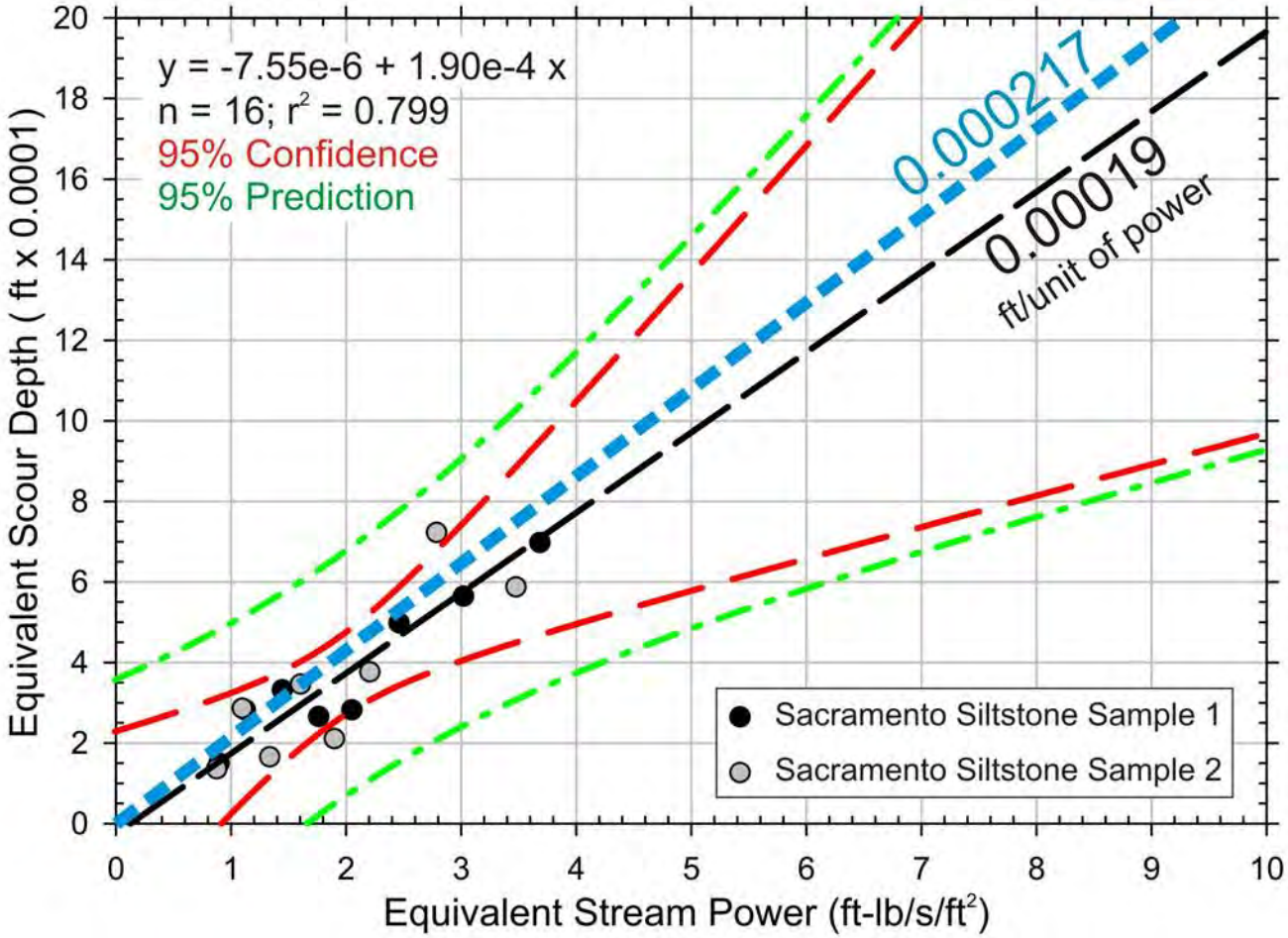
Sample loss N/N/m^3, lb/lb/ft^3 = m^3, ft^3 → m, ft (normalized)

Modified Slake Durability Test

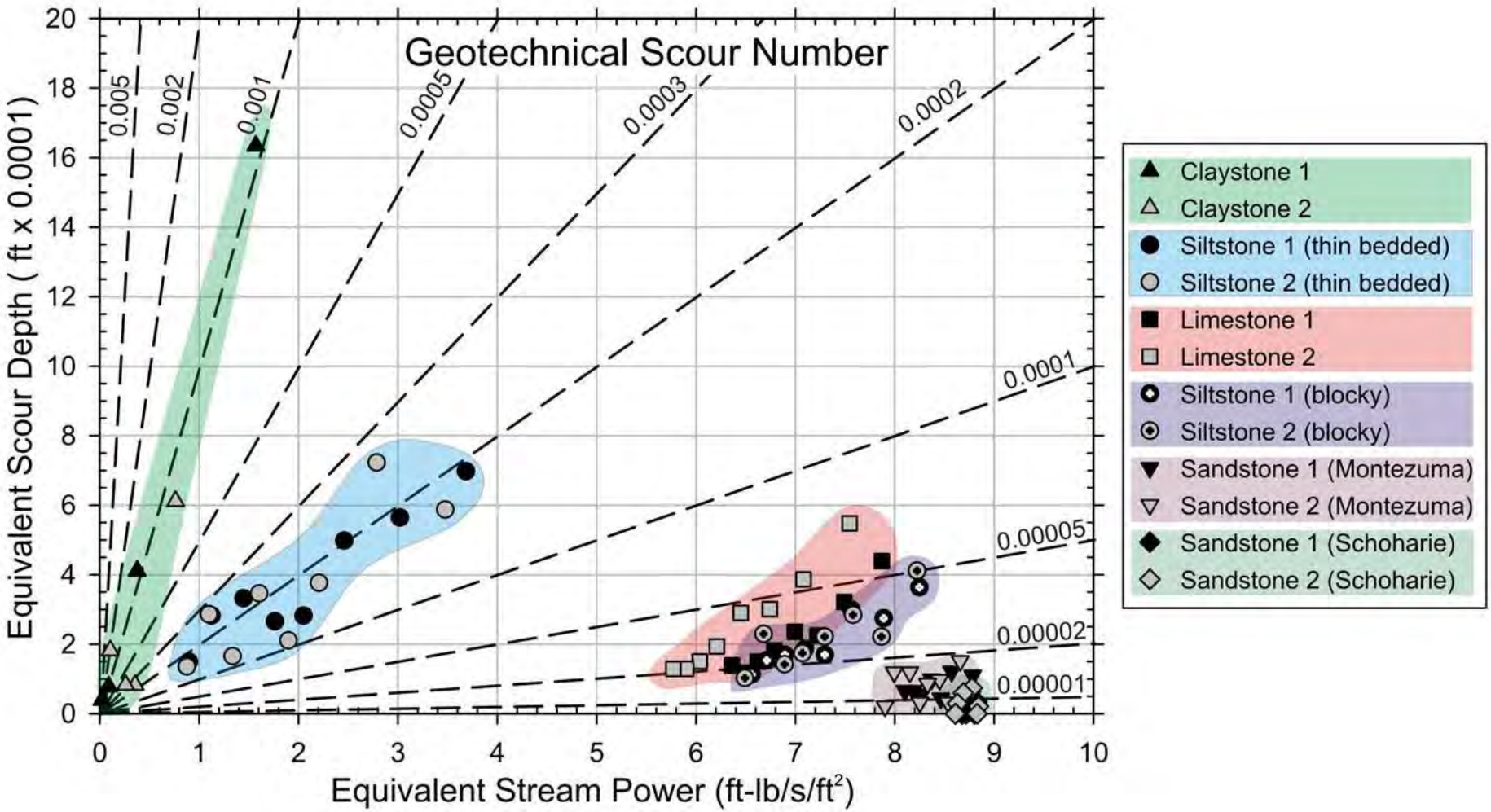


Sacramento River Siltstone Samples

Geotechnical Scour Number



Geotechnical Scour Number



What's New?

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Estimating Erodible Rock Durability and Geotechnical Parameters for Scour Analysis

JEFFREY R. KEATON[1]

AMEC Americas, Inc., 6001 Rickenbacker Road, Los Angeles, CA 90040

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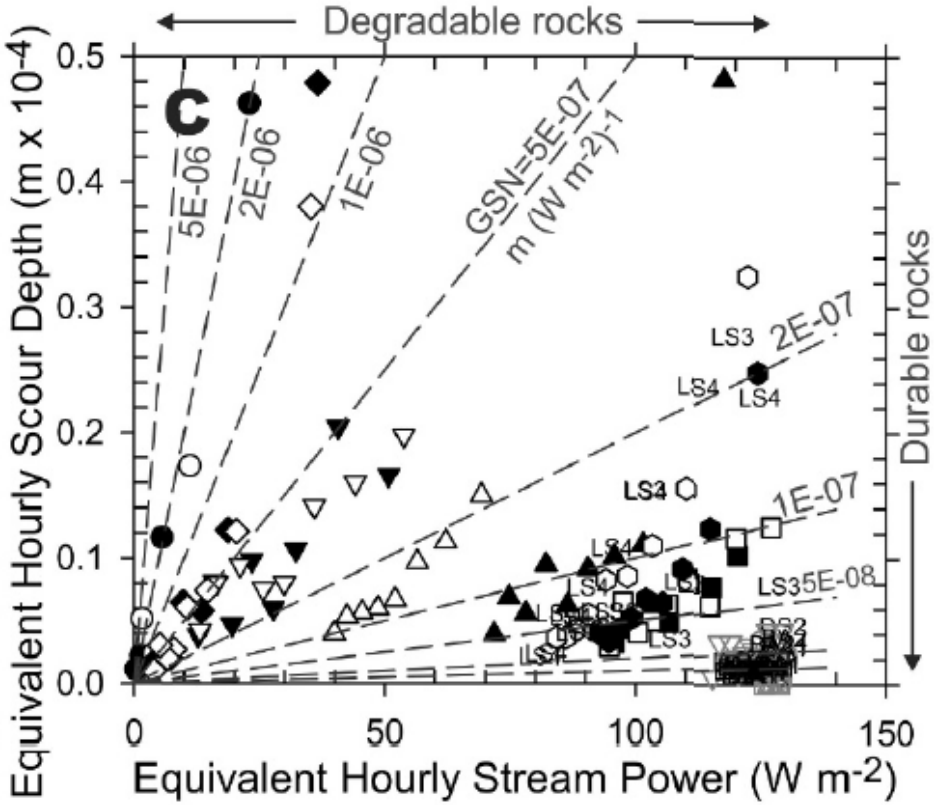
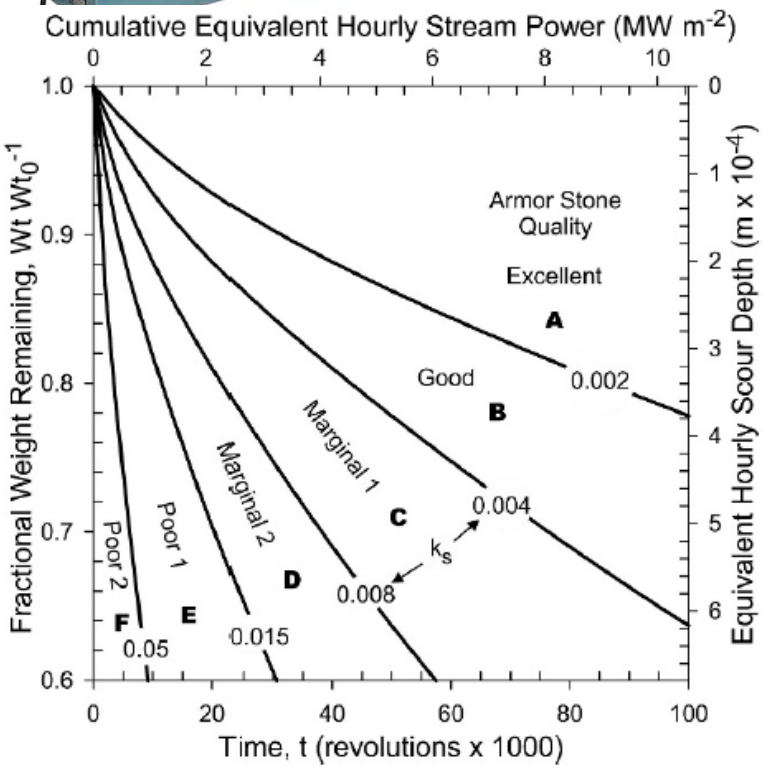
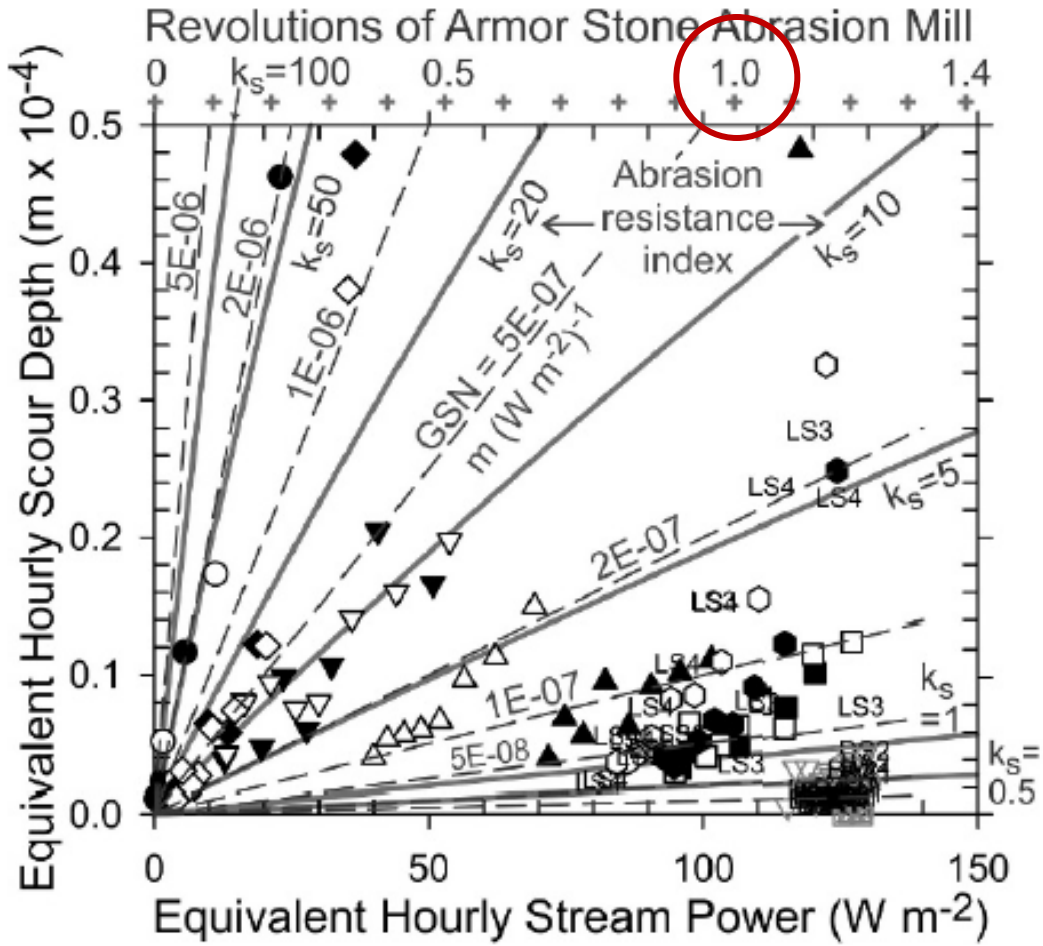


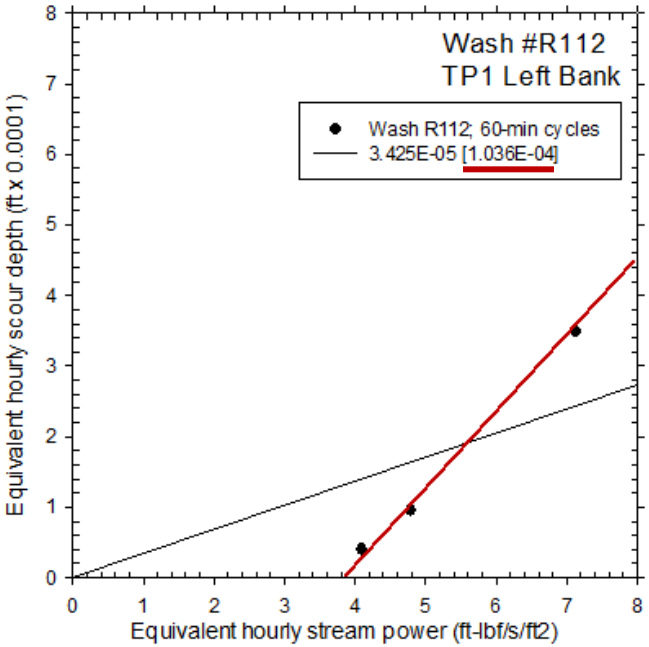
Armor Stone Quality Test





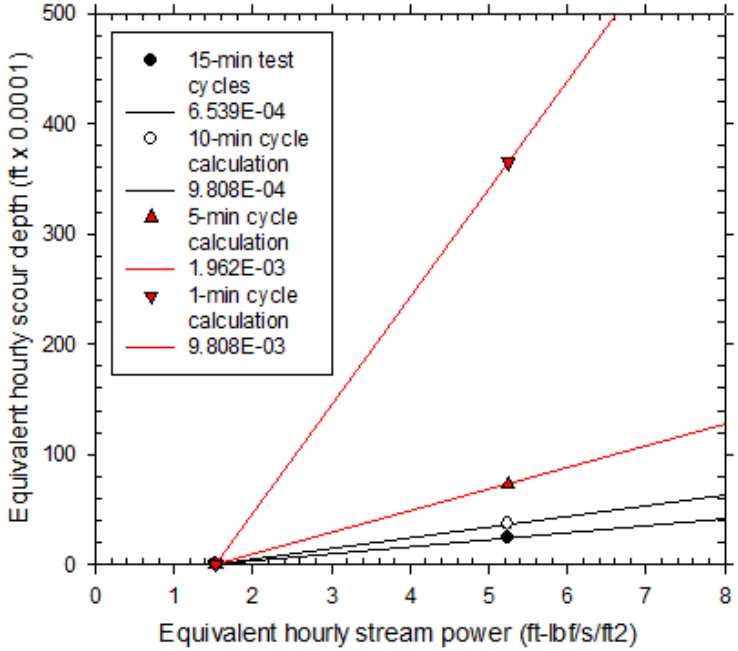
Natural Gas Pipeline, Pima Co, AZ

Weakly Cemented Alluvial Fan Deposits



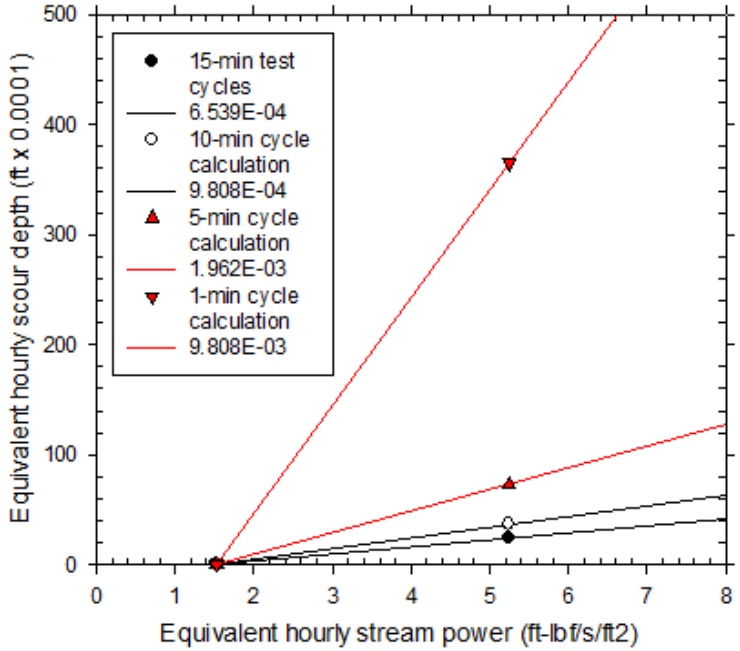
Durable grains accumulating in test basket

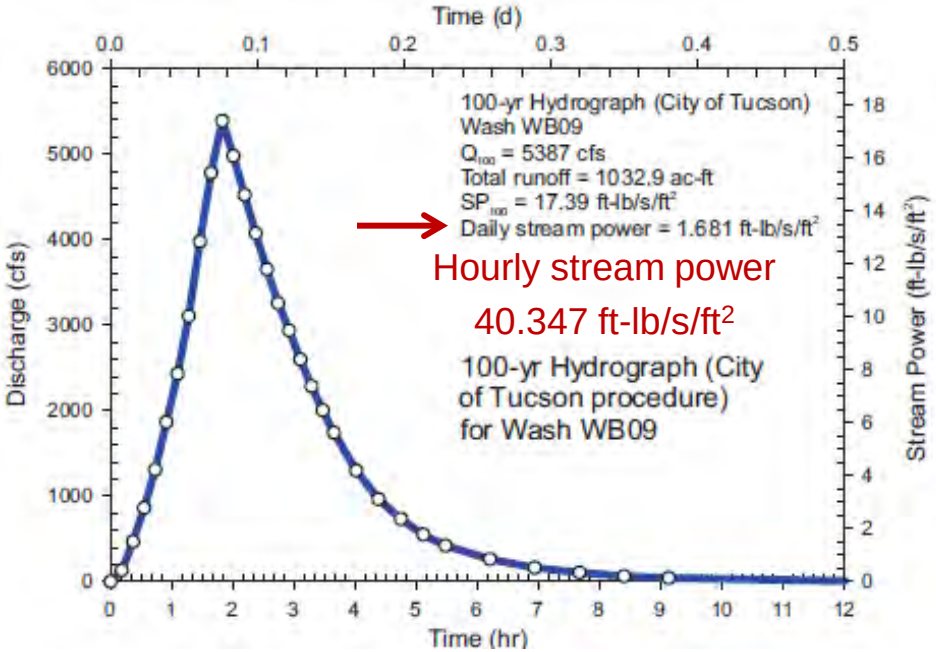
Weakly Cemented Alluvial Fan Deposits



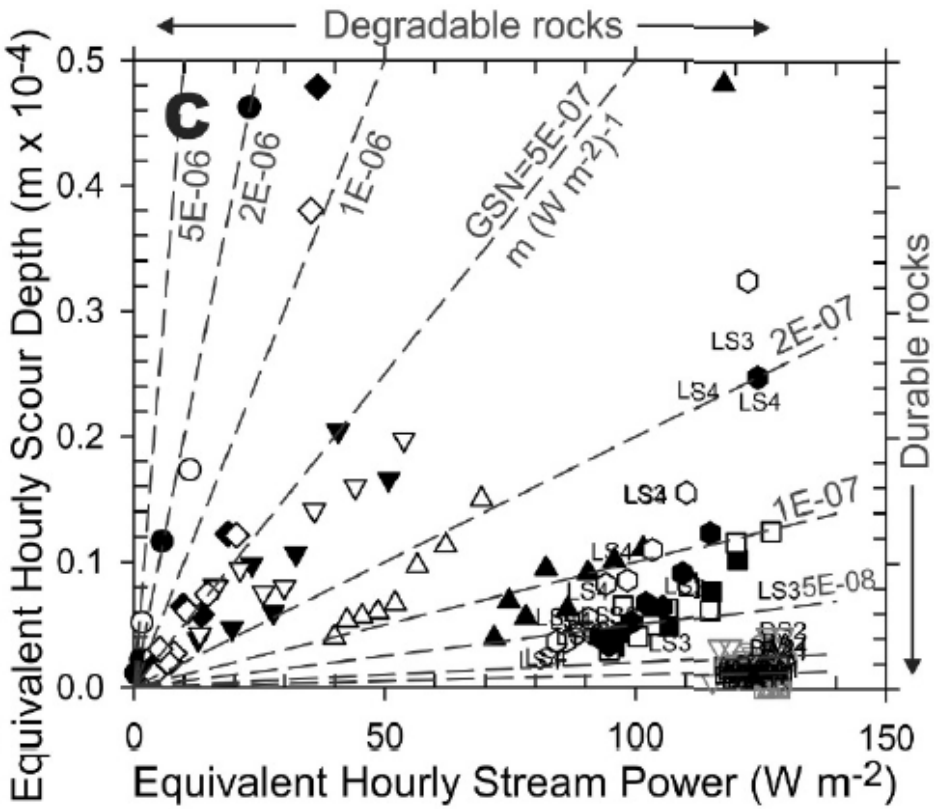
Rock-Water Interaction

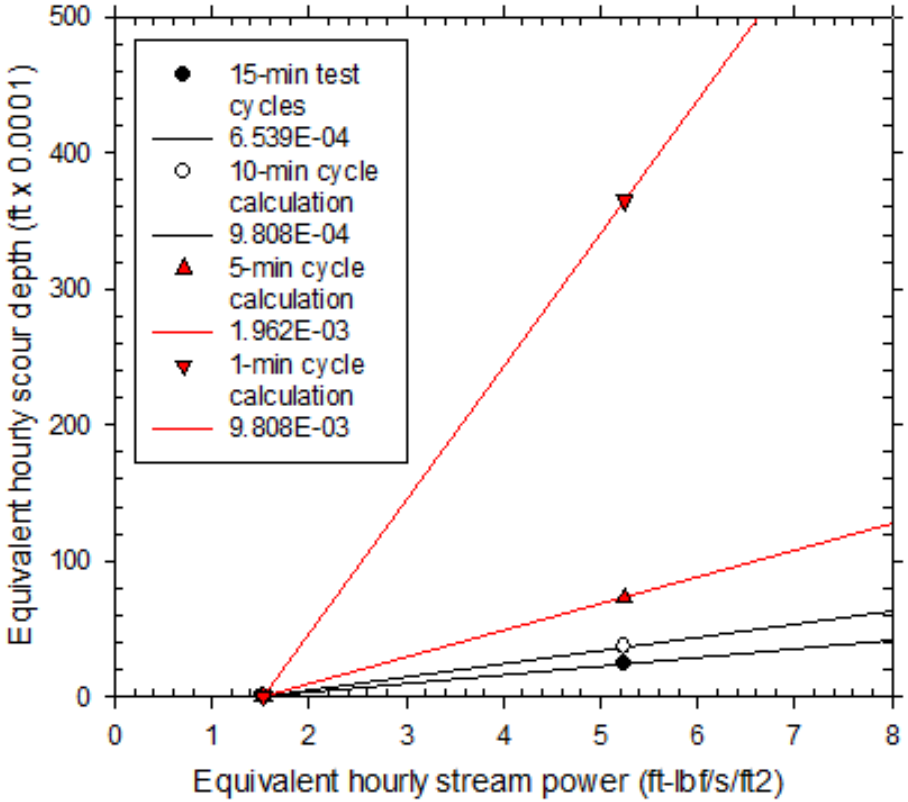
- Equivalent scour depth for Geotechnical Scour Number from
  15-min measurement → 0.03 ft
  10-min calculation → 0.04 ft
  5-min calculation → 0.08 ft
  1-min calculation → 0.4 ft



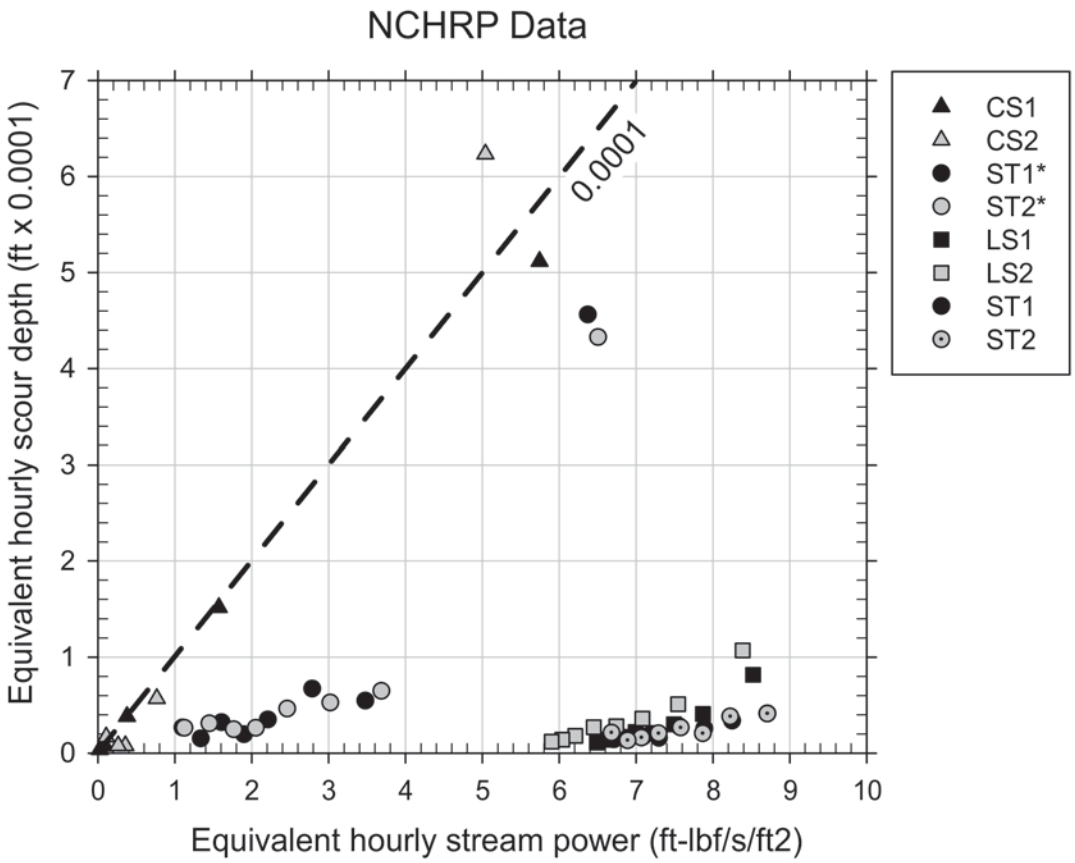


Degradable vs. Durable Materials

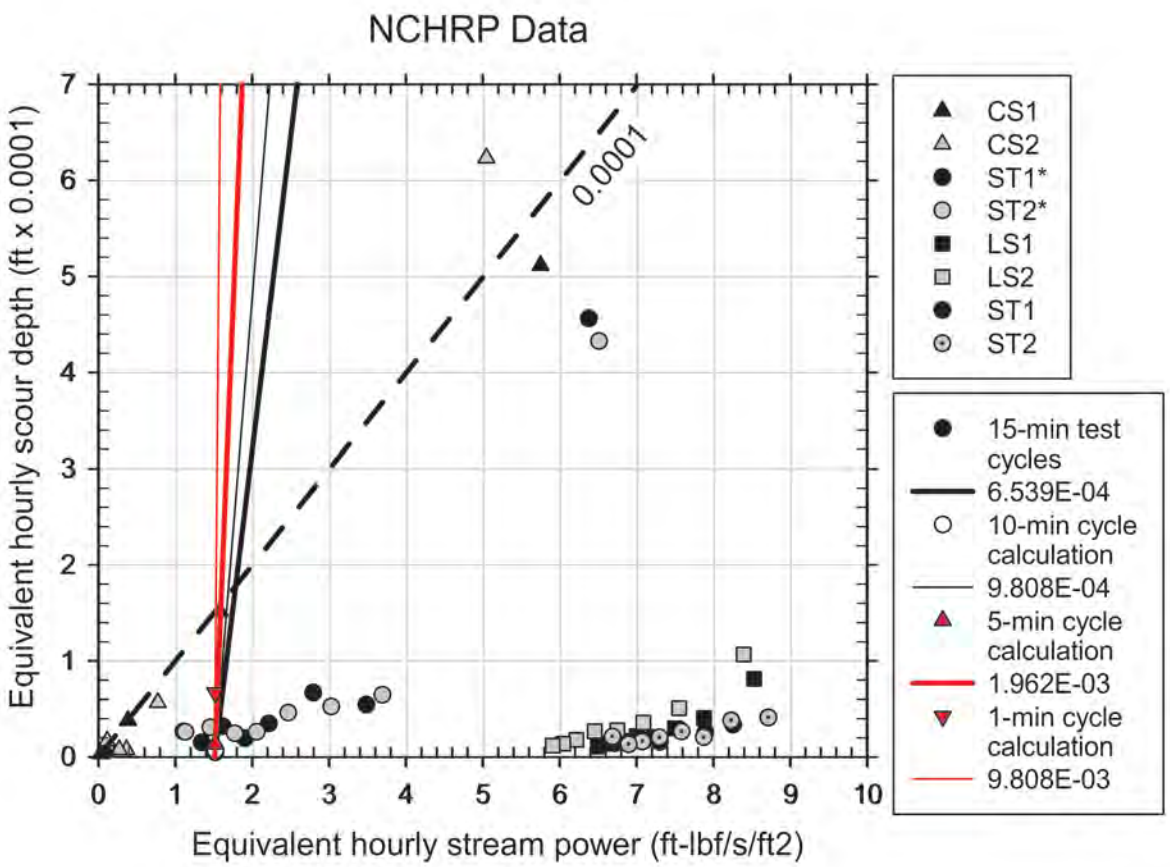




Degradable vs. Durable Materials



Degradable vs. Durable Materials



Future Research

- Flume tests for comparison to modified slake durability tests for Geotechnical Scour Number
- Further consideration of accumulating durable grains in test basket
- More bridges with measured cross sections showing progressive scour

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