INTERNATIONAL SYMPOSIUM
ON EROSION AND
LANDSCAPE EVOLUTION

Anchorage, AK
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Modified Slake Durability Test Applicability for Soil

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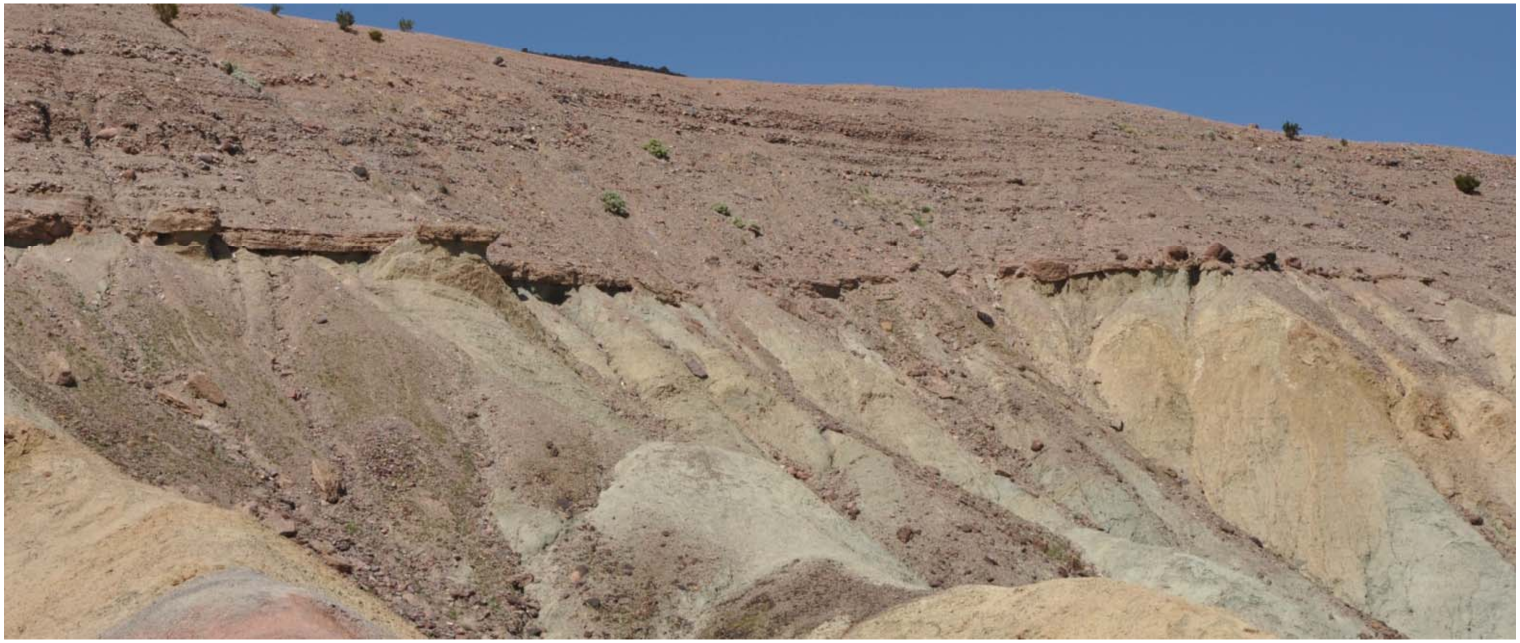


Today's Rill Track

- General objective
- Slake durability test
- Modification for rock scour
- Stream power
- Horton's belt of no erosion
- Cumulative effects of sheet wash

General Objective

- Selected lessons from Rock Scour research
- Modified slake durability test
  - Promote modified slake durability test as useful for index of degradable earth material response
- Stream power
  - Promote stream power as useful hydraulic parameter for progressive erosion of degradable earth materials

Slake Durability Test

- Slake durability index (ASTM D4644) is defined as
  - "the percentage by dry mass of a collection of shale pieces retained on a 2.00 mm (No. 10) sieve after two cycles of oven drying and 10 minutes of soaking in water with a standard tumbling and abrasion action."

- Reported as a single index value (e.g., 92 or 18)

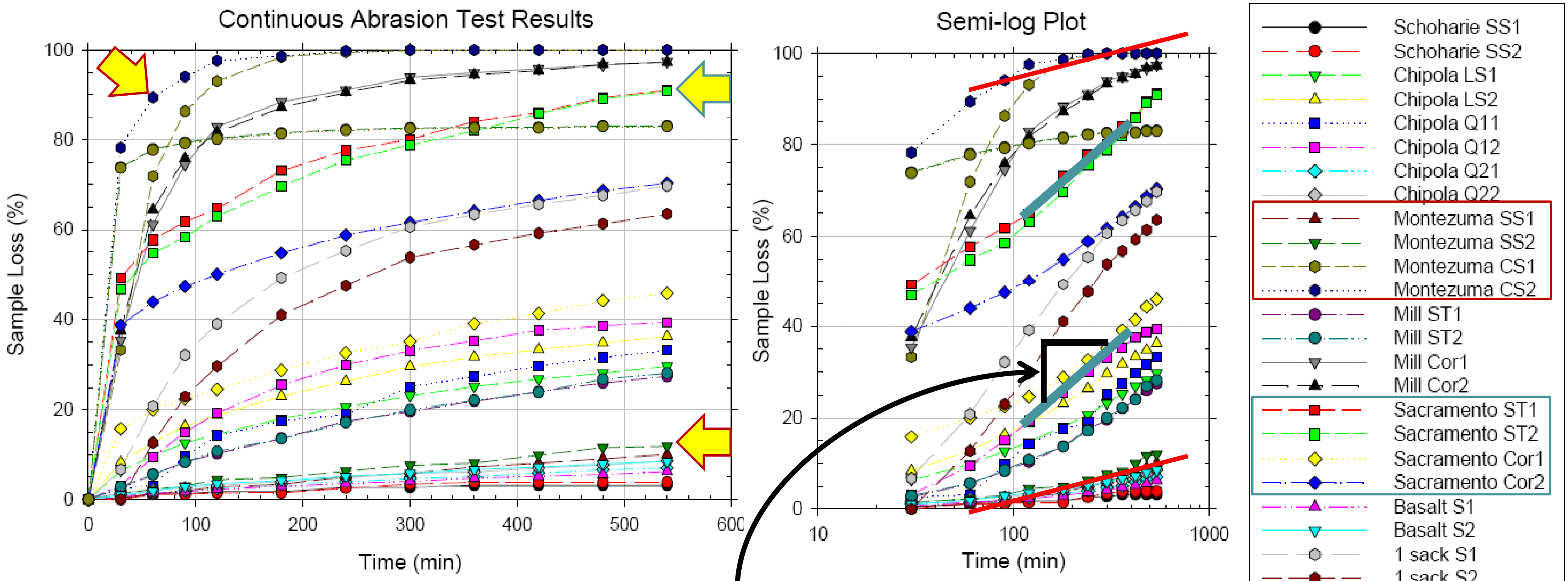
Continuous Abrasion Test

- Developed by Dickenson and Baillie (1999) at Oregon State University

- Eliminated oven drying ("SSD" ASTM 6473)
- Performed 30- or 60-minute test increments
- Plotted results on semi-log graph
- Abrasion number = slope of log-linear regression

Sacramento River
Siltstone Core Sample

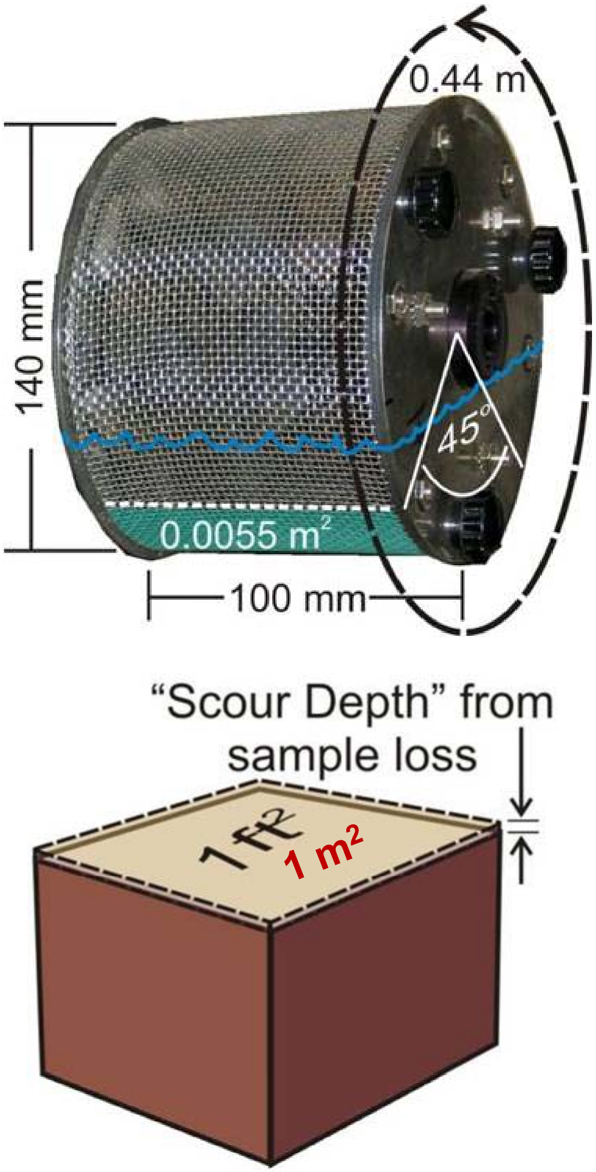
Continuous Abrasion Test



Abrasion Number

(%/ln min)

Abrasion Number → Scour vs. Power



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)

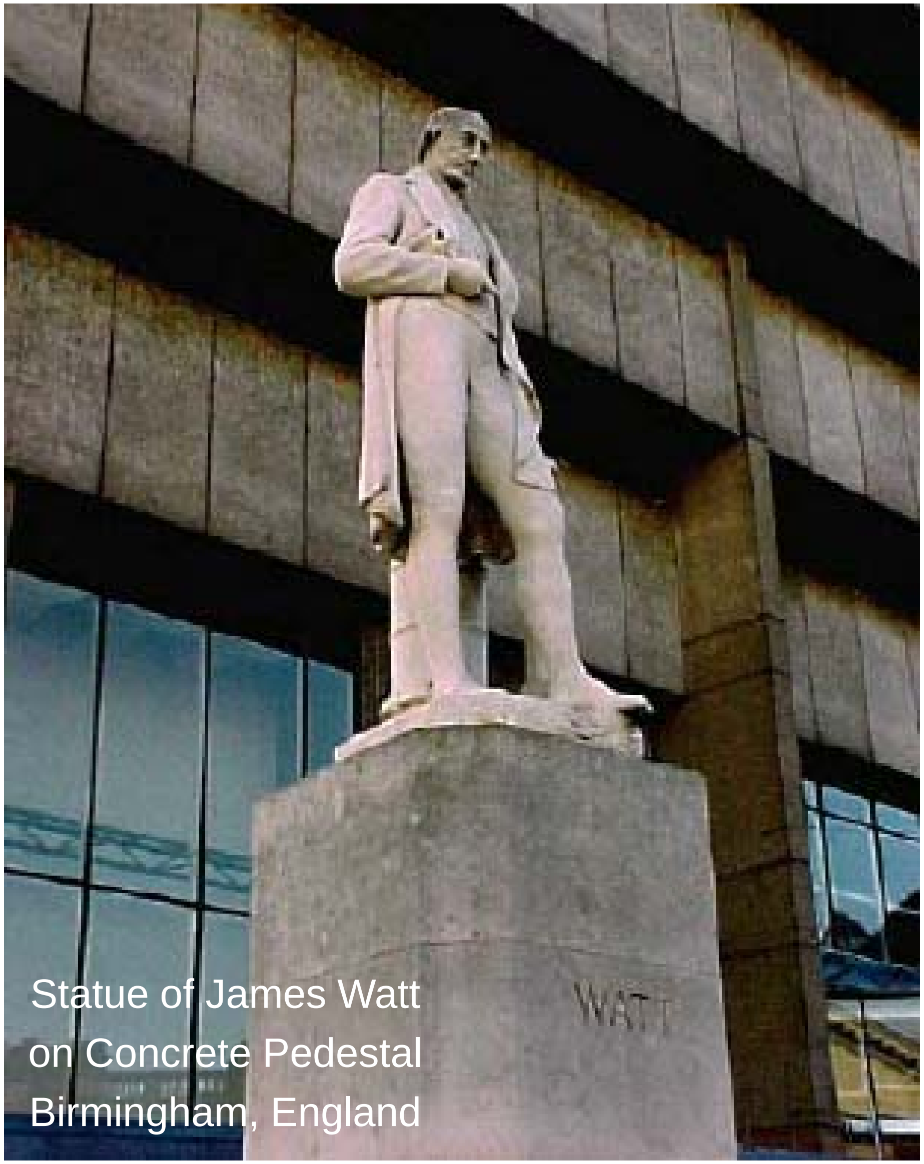
Sample residence area (m^2, ft^2)

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 to unit area)

Stream Power



Statue of James Watt on Concrete Pedestal Birmingham, England

Unit stream power

$$\omega = \gamma\, d\, S\, v = \tau\, v$$

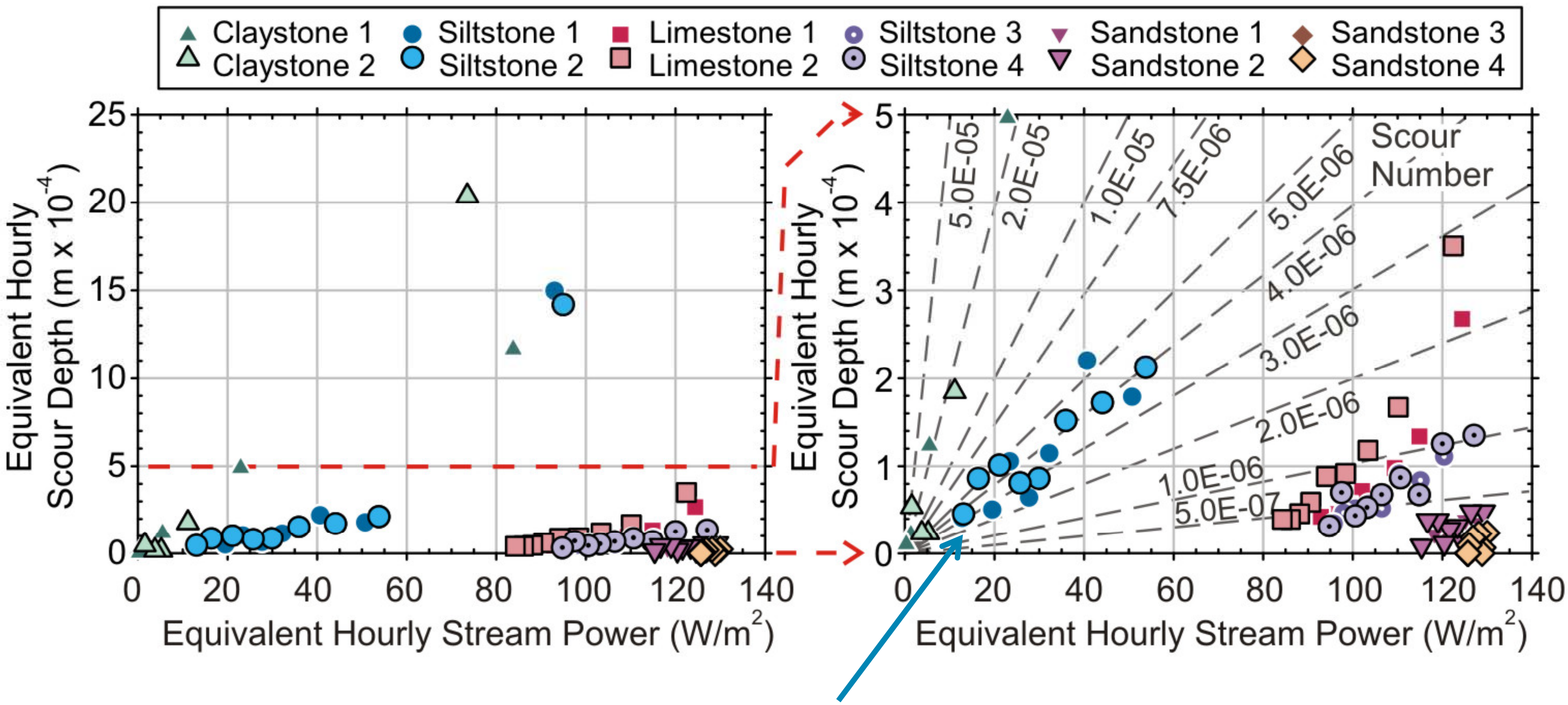
$$\tau = \left(\frac{nv}{1.486}\right)^2 \left(\frac{\gamma}{d^{1/3}}\right)$$

$$\omega \propto v^3$$

$$\frac{lb}{ft^2}\,\frac{ft}{s} = \frac{\frac{ft \cdot lb}{s}}{ft^2}$$

$$\frac{N}{m^2}\,\frac{m}{s} = \frac{\frac{N\,m}{s}}{m^2} = \frac{\frac{J}{s}}{m^2} = \frac{W}{m^2}$$

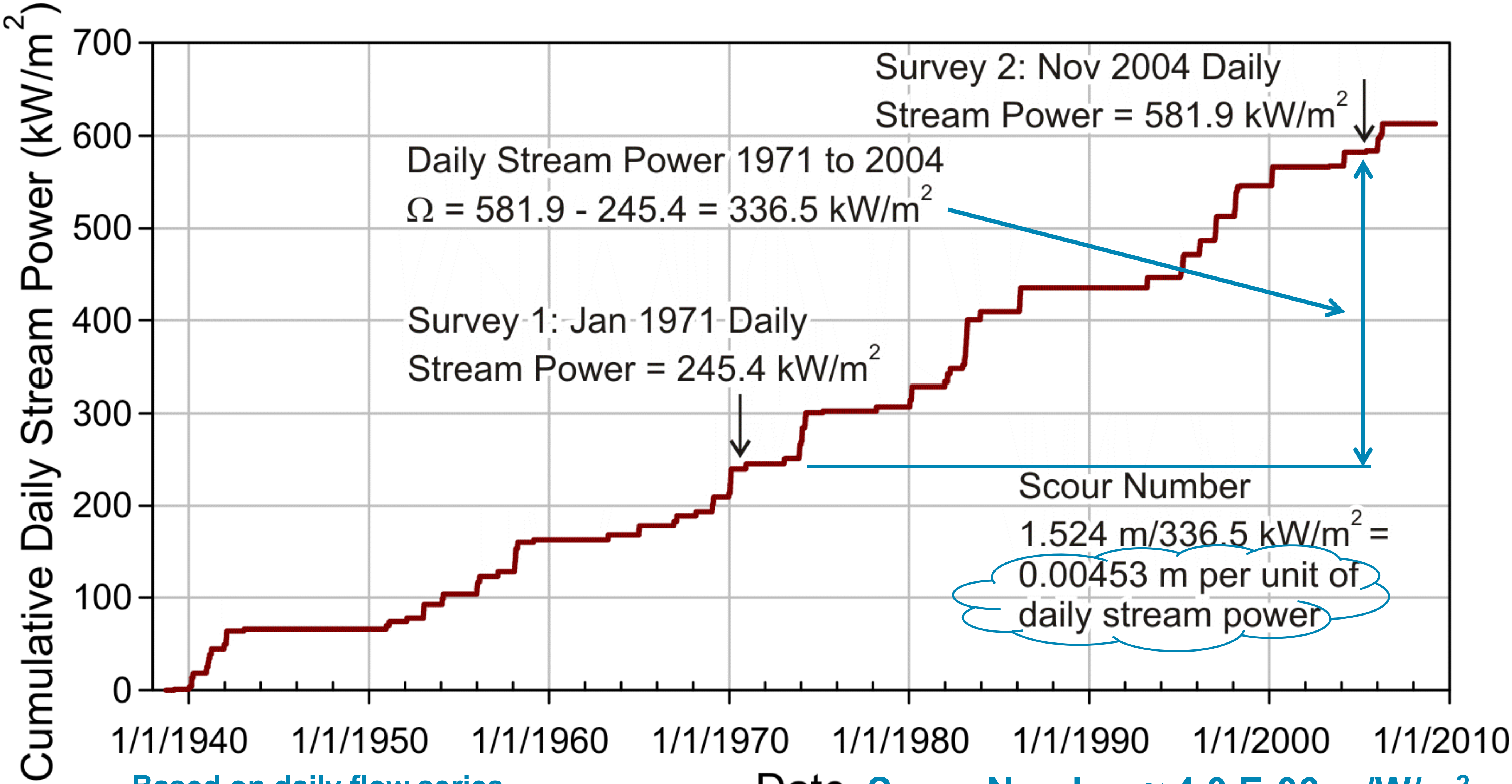
Modified Slake Durability Test



Scour Number ≈ 4.0 E-06 m/W/m²

(Sacramento River at Redding, CA)

Cumulative Daily Stream Power



Based on daily flow series

Scour Number ≈ 4.0 E-06 m/W/m²

(Sacramento River at Redding, CA)

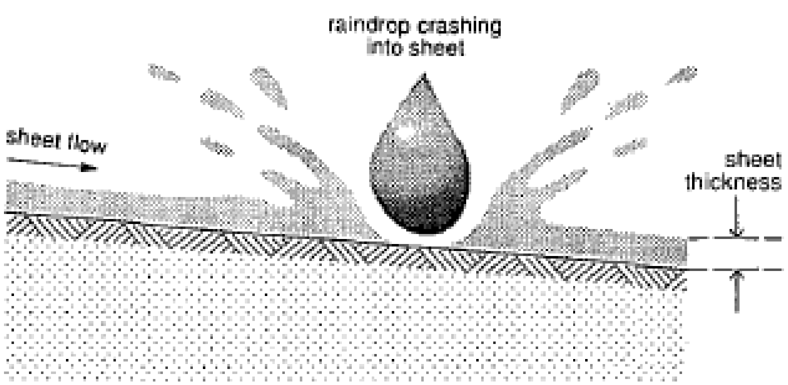
Applicability to Soil

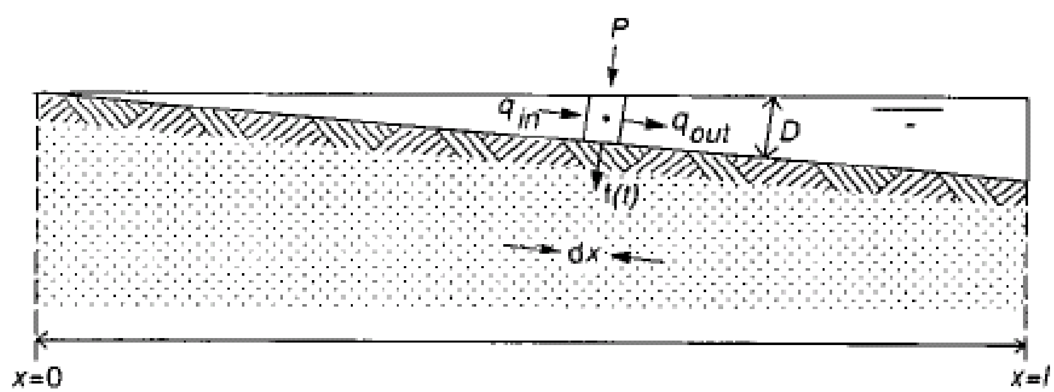
- Cohesionless sand
  - Traditional prediction (e.g., Shield's parameter)

- Modified slake durability test should work on soil with a minimum amount of cohesion or cementation
  - Soil cubes that will stand unsupported on a lab bench
- Problem soil samples
  - Sticky clay (stick to the basket or each other)
  - Gravelly clay or silt (durable particles retained in the basket)
  - Weakly cemented soil, too friable to cut, too strong to break by hand
  - Soil samples that wear very rapidly during single test interval

Horton's Belt of No Erosion

- Horton (1945) → geomorphology of convex ridge crests
- Distance from ridge crest to uppermost rill controlled by threshold relation between runoff force and earth material resistance
- Anderson and Anderson (2010) (new geomorphology text) used
  - uniform slope
  - nonlinear increase in flow thickness and shear stress
  - constant precipitation, infiltration, and roughness
- Boers (1994) used kinematic-wave model and realized that sheet flow would be turbulent and interrupted by rainfall





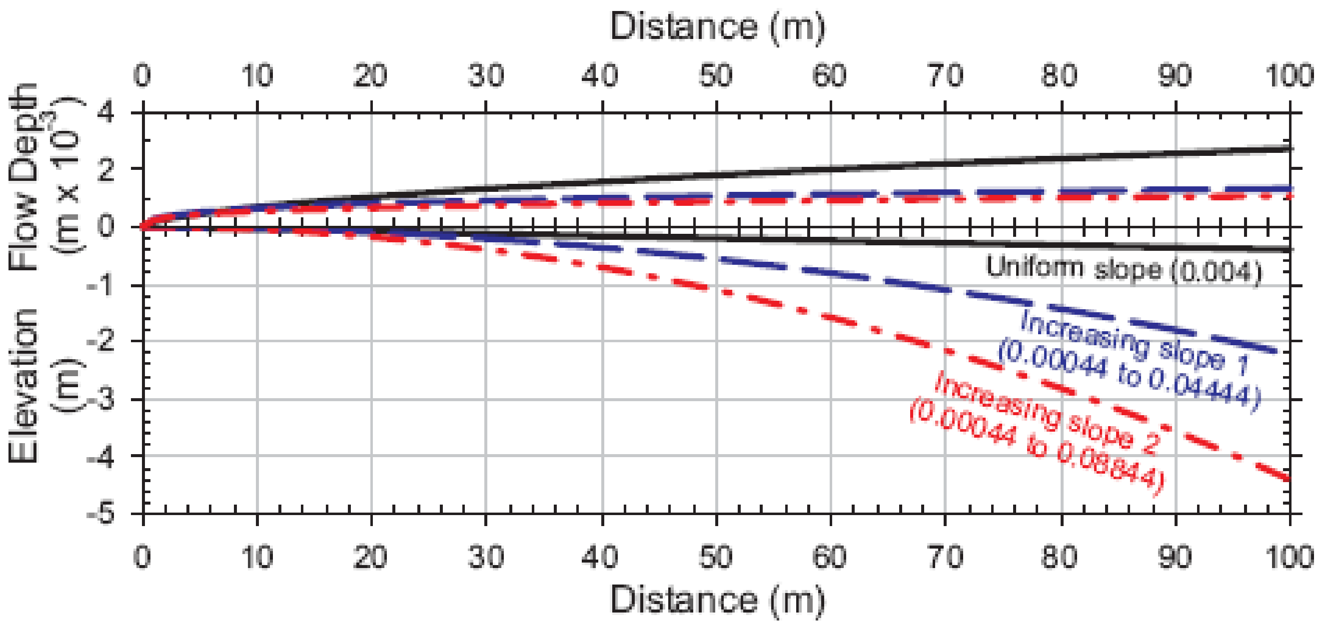
Stream Power in Sheet Flow

- Sediment particles dislodged by raindrops → unit weight of fluid
- Turbulence induced by raindrops → velocity enhancement factor

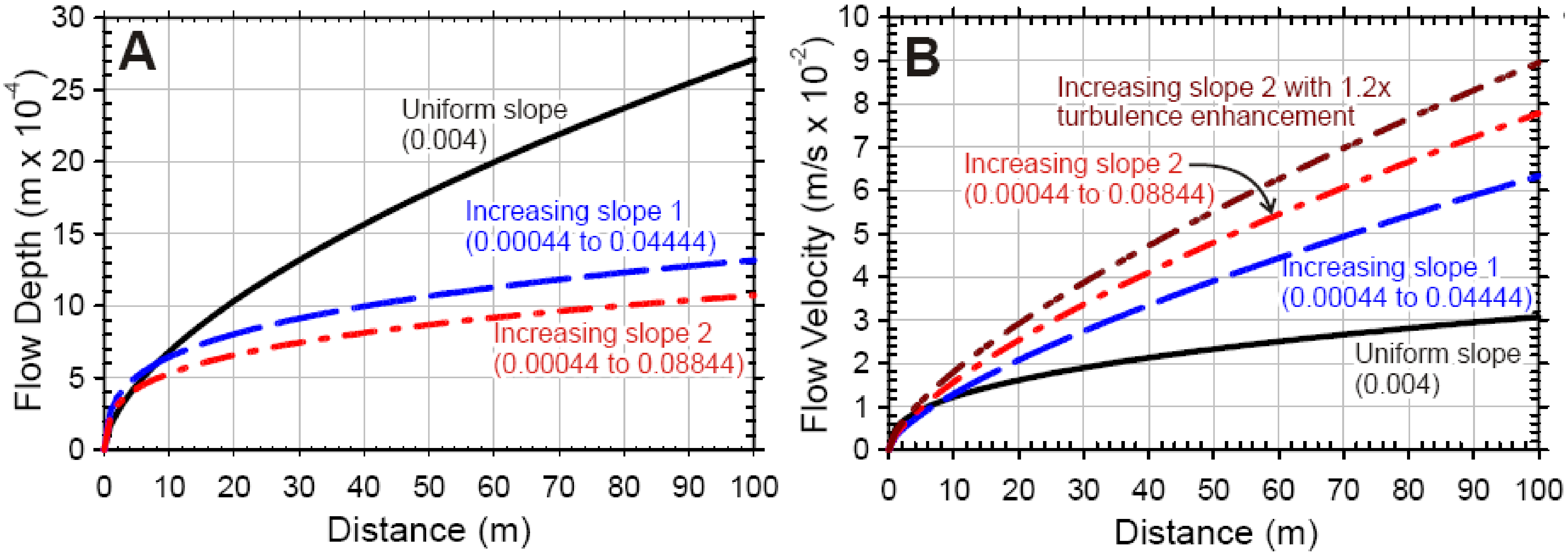
- Flow properties $\omega = \tau \, \overline{V}$ and $\tau = \rho \, g \, y \, S$
  Sediment concentration up to 0.25 by weight
  Rain falls uniformly on entire slope

- Slope properties →

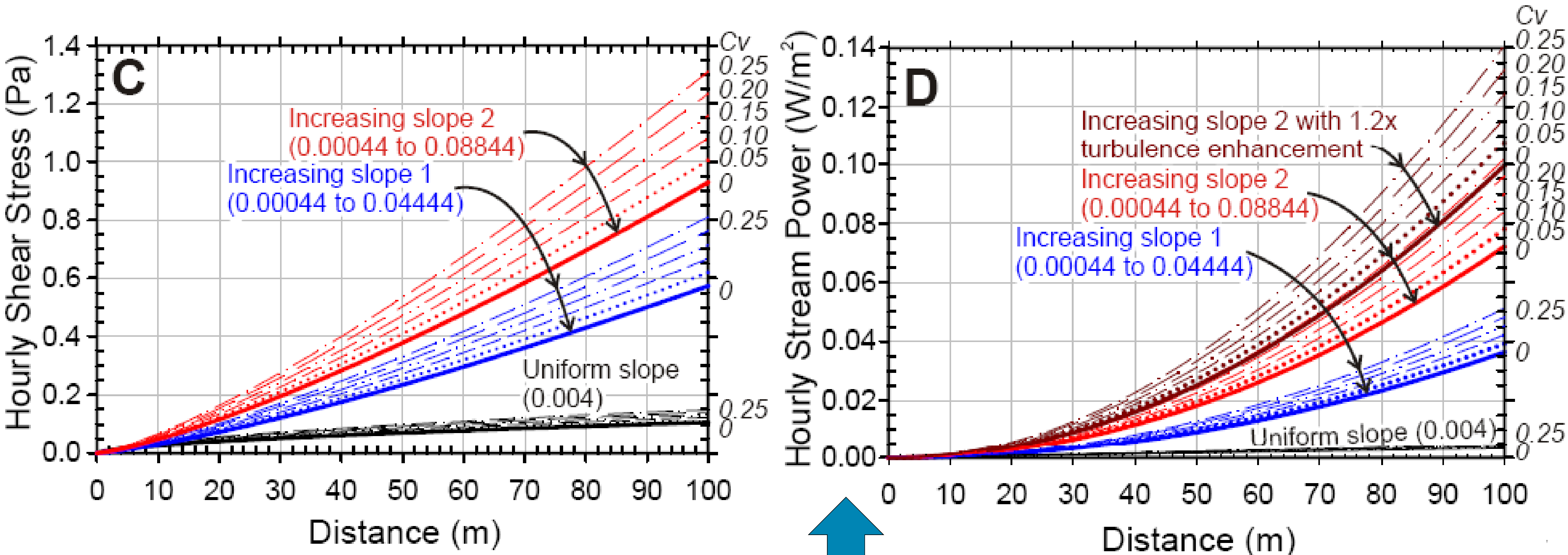
- Velocity enhanced by turbulence (1.2 used here, 1.5 for round piers, 1.7 for square piers)



Sheet Flow Properties

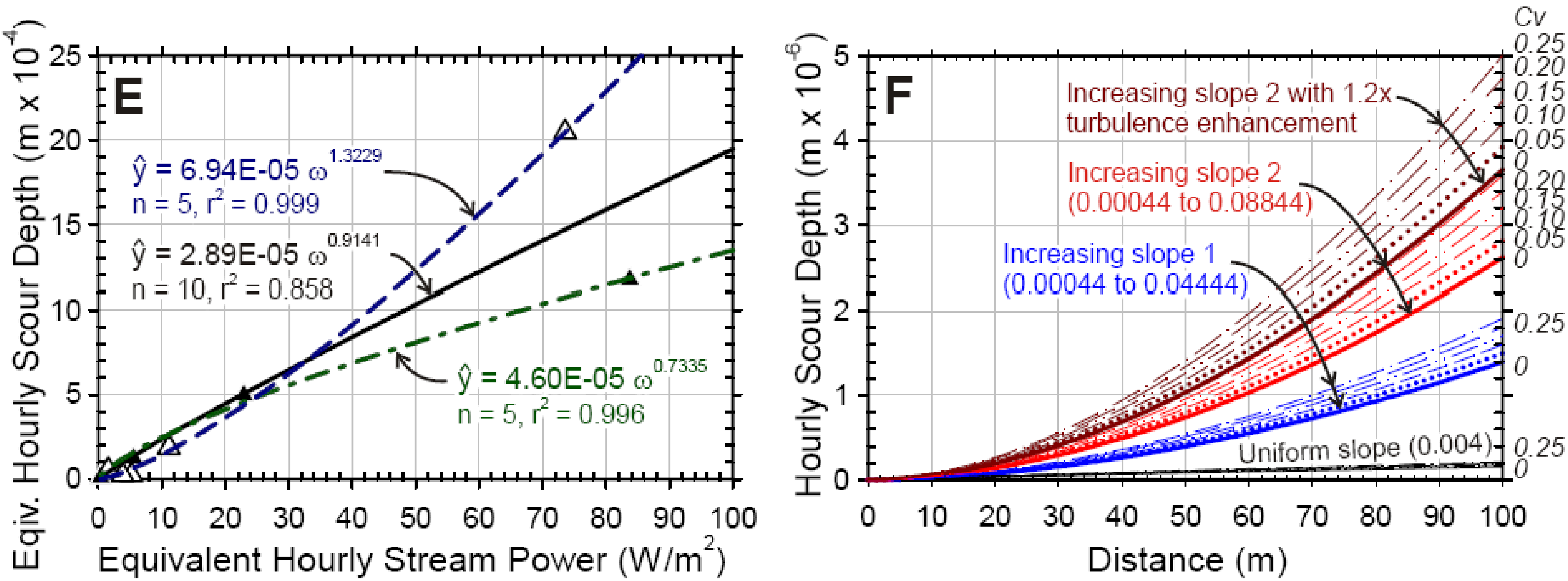


Sheet Flow Properties



Note hourly stream power range is less than 1 W/m^2

Estimated Soil Erosion Properties



Note hourly stream power range is less than 1 W/m^2

Scour Number ≈ 2.0 E-05 $m/W/m^2$

(Montezuma Creek claystone, Utah)

Conclusions

- The modified slake durability test appears to have value for soil with minimum cohesion or cementation
- Stream power is a valuable hydraulic parameter for progressive erosion of degradable rock material because it can be accumulated; it should be useful for sheet flow on soil slopes, also
- Sediment concentration in thin sheet flow could be significant because soil particles dislodged by raindrops could be a large percentage of the flow volume
- Hopefully, other researchers will consider these conclusions in future soil erosion studies

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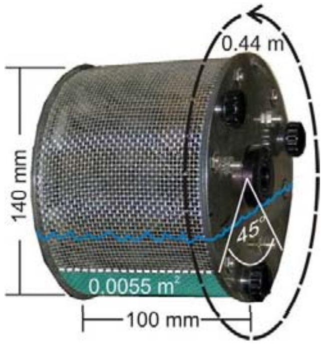

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