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Improving a Streambank Stability Model for Seepage Processes

Garey Fox[1], Maria Chu-Agor[1], Glenn Wilson[2], Andrew Simon[2], and Eddy Langendoen[2]

[1] Oklahoma State University, Department of Biosystems and Agricultural Engineering, Stillwater, OK
[2] USDA-ARS National Sedimentation Laboratory, Oxford, MS

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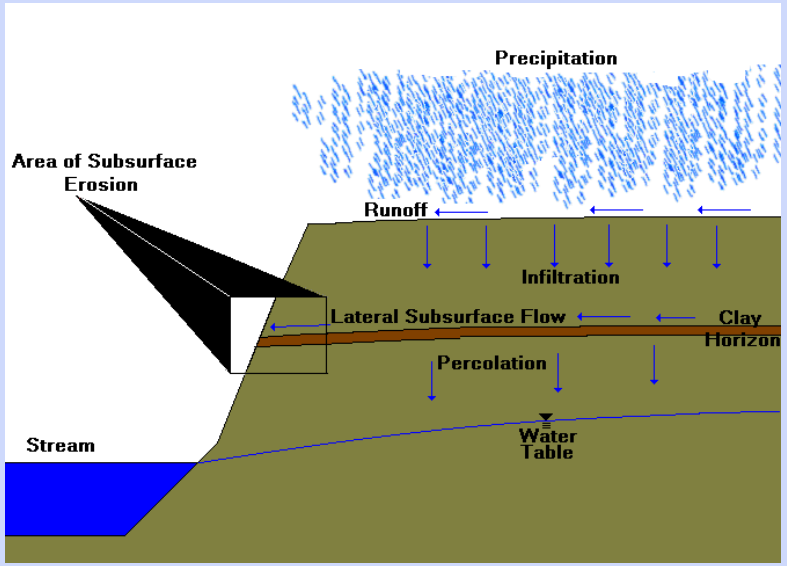
Introduction

- As much as 85% of sediment load in some watersheds is from the streambank
- Seepage erosion recently emphasized as an important bank instability mechanism



Seepage Erosion Conditions

Seepage Erosion due to Lateral Ground Water Flow

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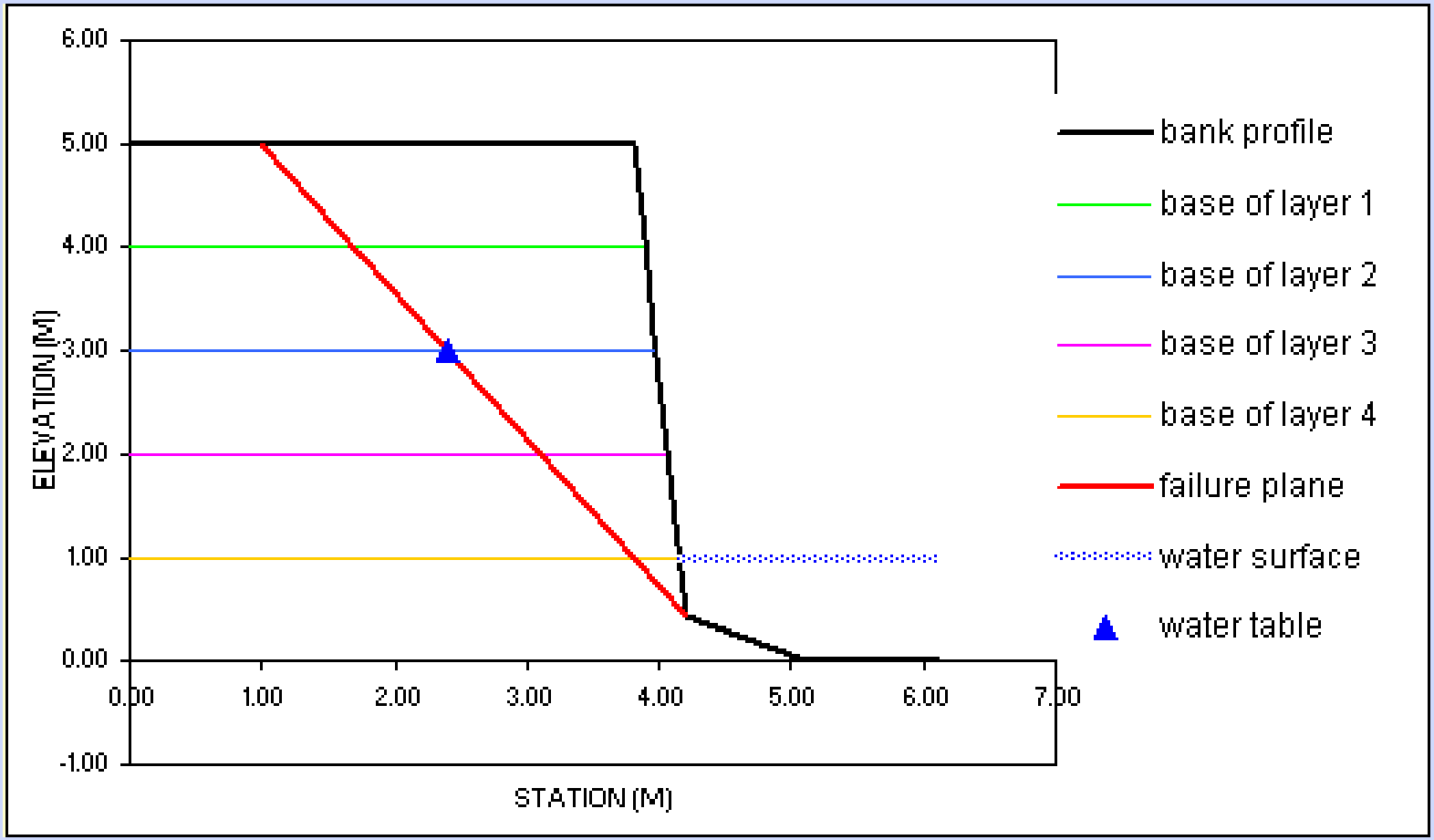
Introduction

- Ground water in current streambank stability models:



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Seepage Erosion along LTC

Seepage erosion

Bank failures from seepage erosion

Consolidated slump material

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Field Observations of Seepage Erosion

Seepage Flow/Sediment Measurements with Lateral Flow Collection Pans

Streambank Seep from Sloughed Deposits

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Initial 2-d Laboratory Experiments

- Replicated MS streambank:
  - 60 cm silt loam
  - 10 cm loamy sand
  - 5 cm clay loam

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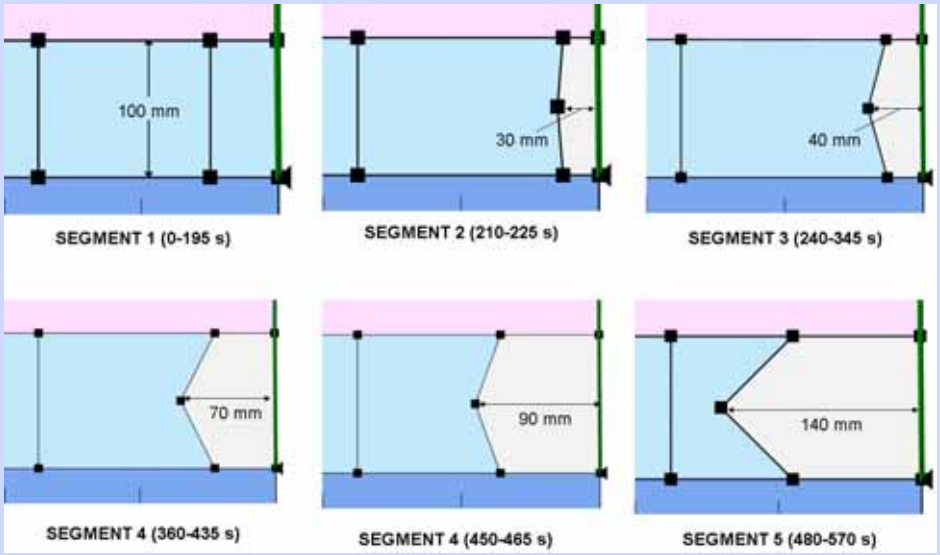
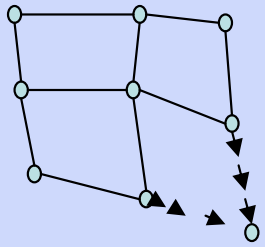
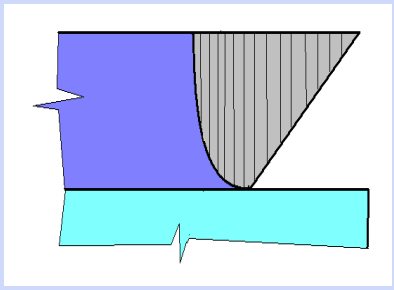
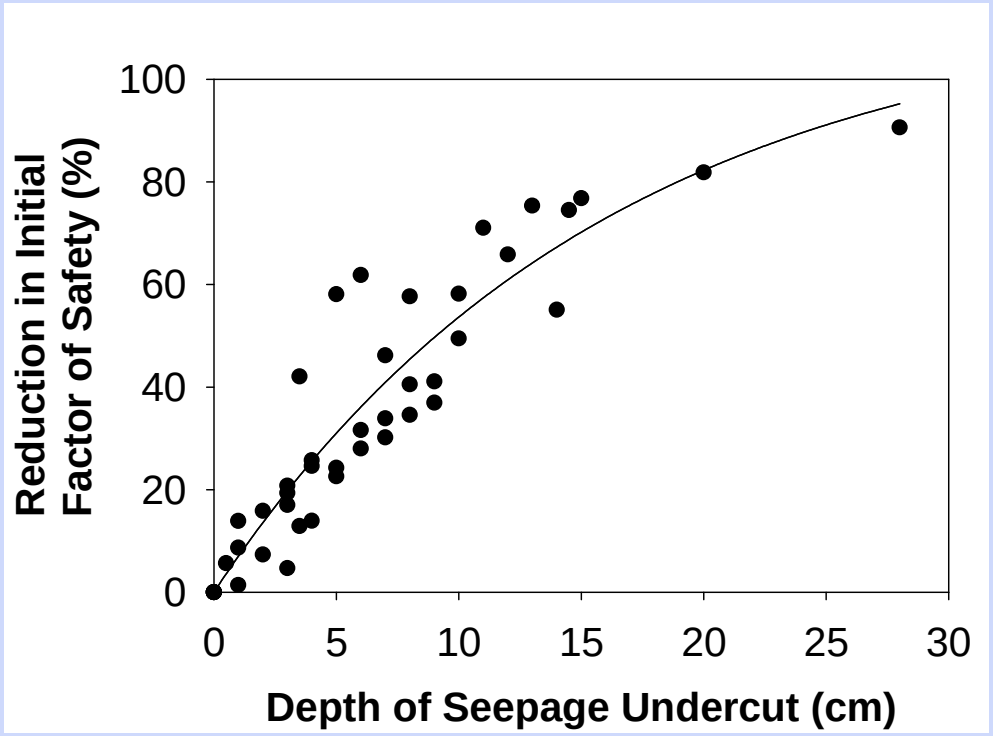
Numerical Modeling of Seepage Undercutting









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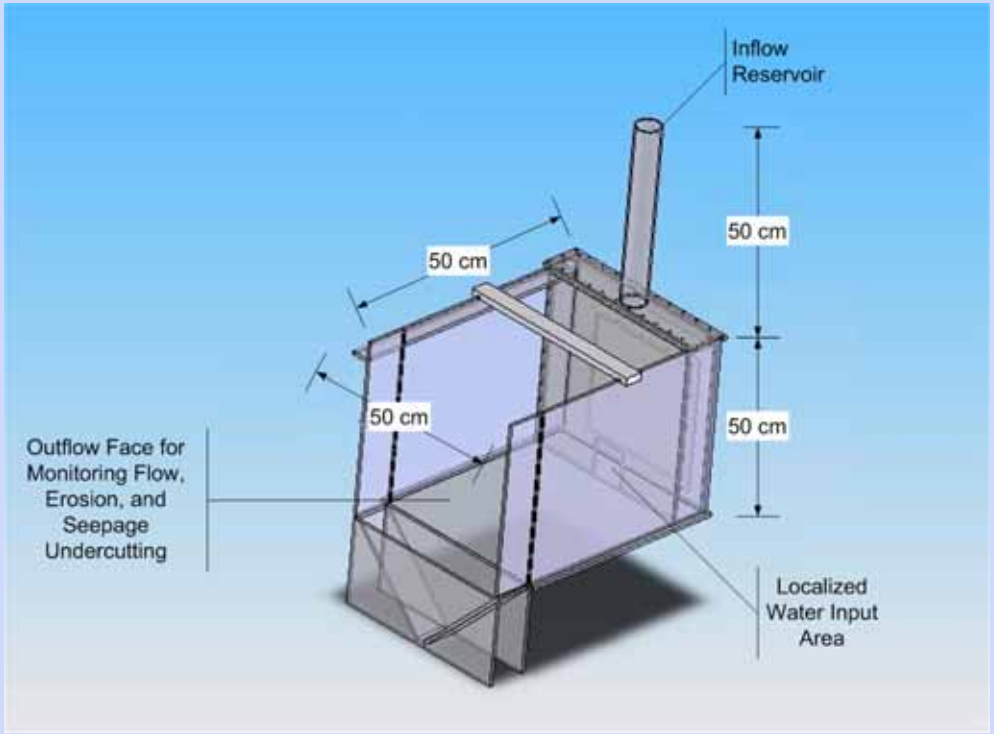
Objectives

- Investigate mechanisms of instability by seepage erosion
- Derive an improved sediment transport function for seepage
- Incorporate seepage mechanisms into bank stability model



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3-d Laboratory Experiments

- Experimental Variables:

Soil type	Sand (S), Loamy Sand (LS)
Soil bulk density (ρ_b)	S = 1.3, 1.45, 1.6 g cm^{-3}
	LS = 1.3, 1.45, 1.5, 1.6, 1.7 g cm^{-3}
Bank angle (α)	90^o, 75^o, 60^o
Water head (H)	15, 25, 35 cm

- 3D laser scanner utilized to collect seepage images (mm resolution)

3-d Laboratory Experiments

- Depending on soil type and packing, banks fail in two ways:
    1. Pop-out or Tension Failure
    2. “Seepage Undercut” Failure

3-d Laboratory Experiments

Soil Type	Sand
Bank angle (α)	90^{o}
Soil bulk density	1.30 g cm^{-3}
Water head (H)	15 cm

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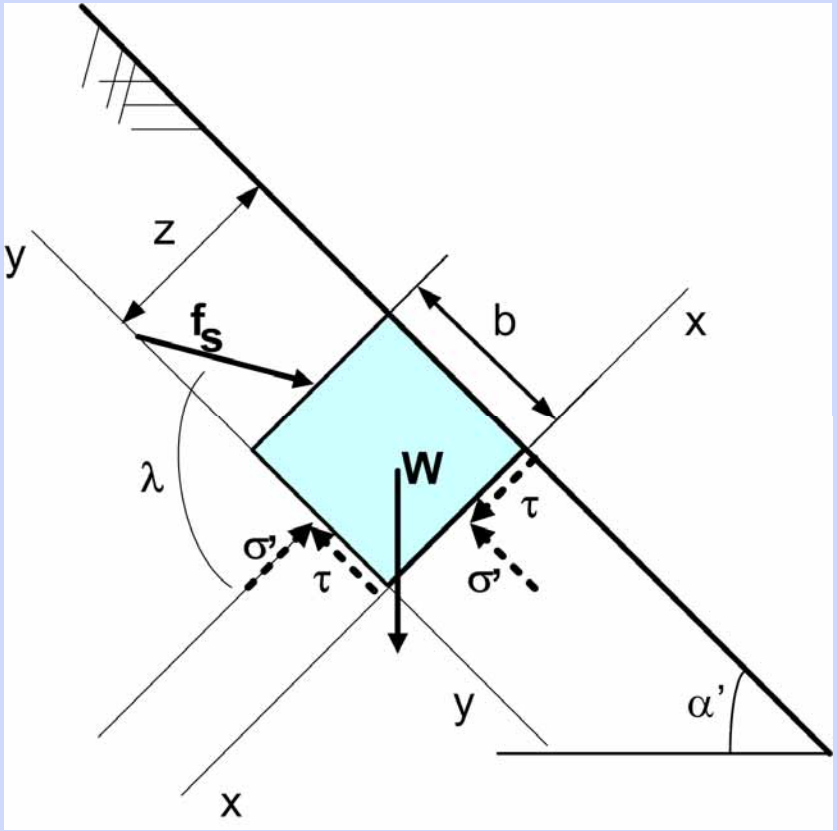
Improved Bank-Stability Models: Seepage Gradient Forces



$$FS = \frac{c'A + \sigma' \tan\phi'}{W \sin\alpha' + f_s \sin\lambda}$$

$$\sigma' = W \cos\alpha' - f_s \cos\lambda$$

$$FS = \frac{\dfrac{c'}{z\gamma_w} + \left(\dfrac{\gamma'}{\gamma_w}\cos\alpha' - \sin\alpha'\cot\lambda\right)\tan\phi'}{\left(\dfrac{\gamma'}{\gamma_w} + 1\right)\sin\alpha'}$$

3-d Laboratory Experiments

Soil Type	Sand
Bank angle (α)	90^{o}
Soil bulk density	1.45 g cm^{-3}
Water head (H)	15 cm

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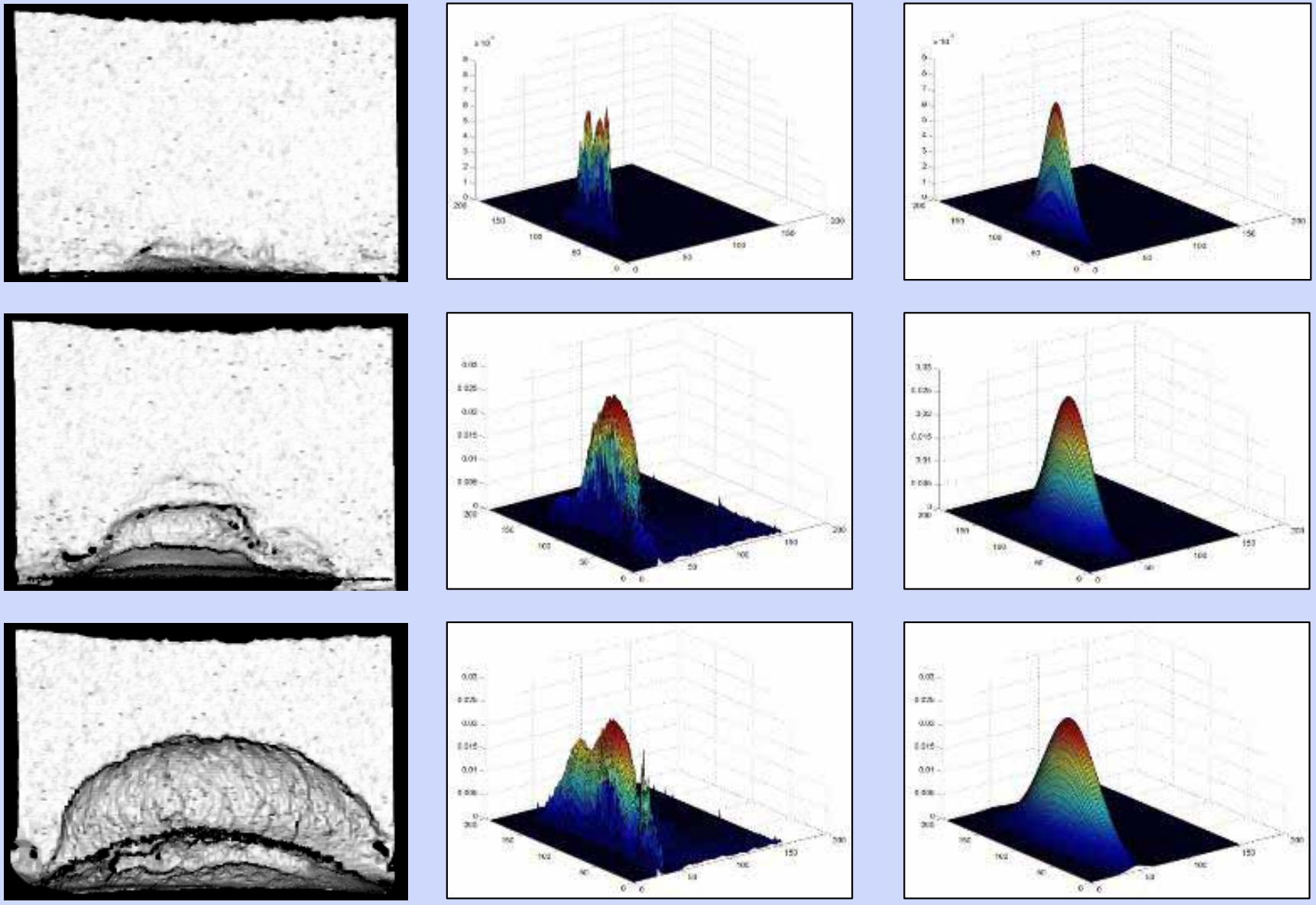
Experimental Results



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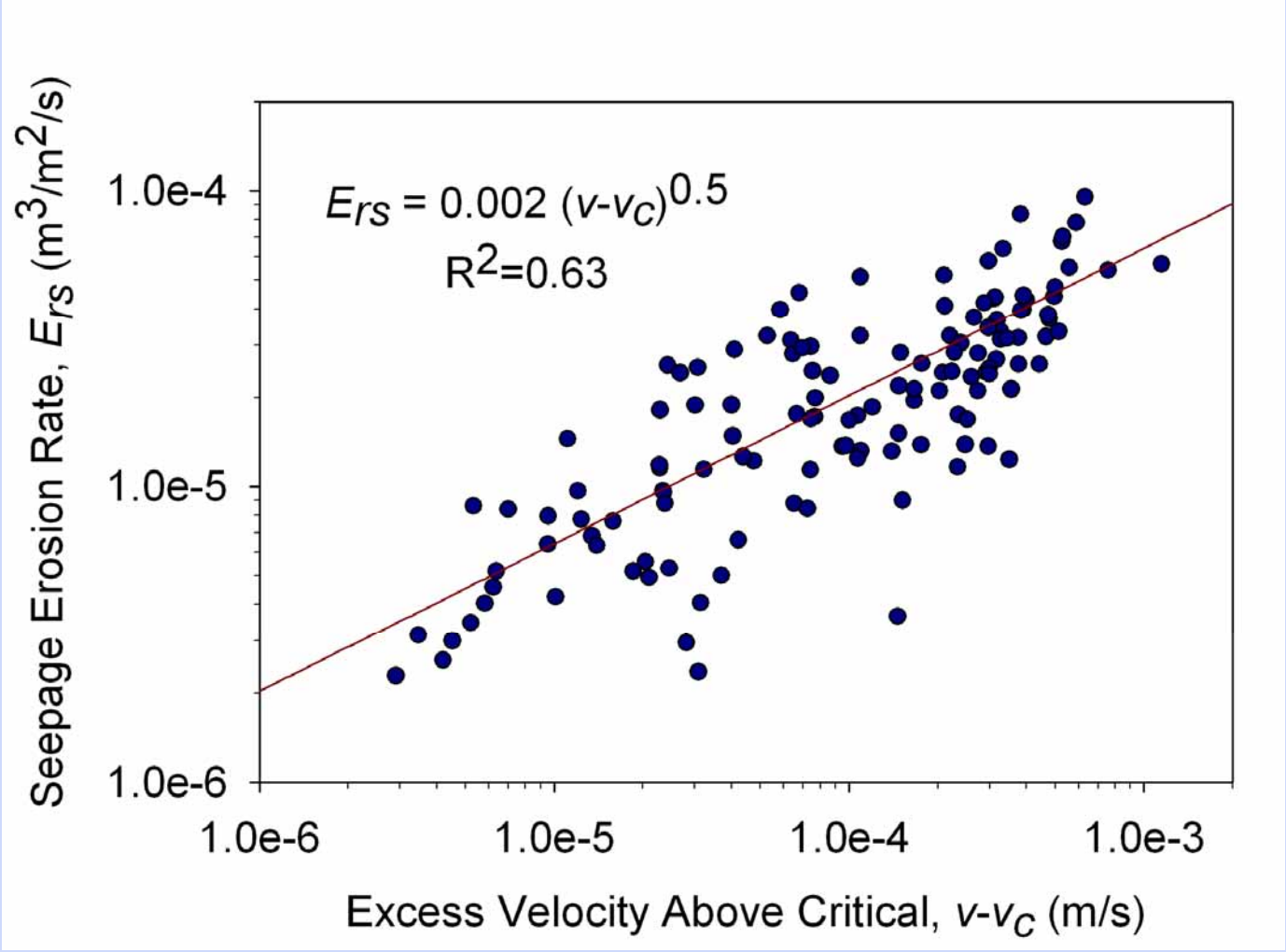
Experimental Results

- Sediment transport function…



Seepage Erosion

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Seepage Velocity

STM

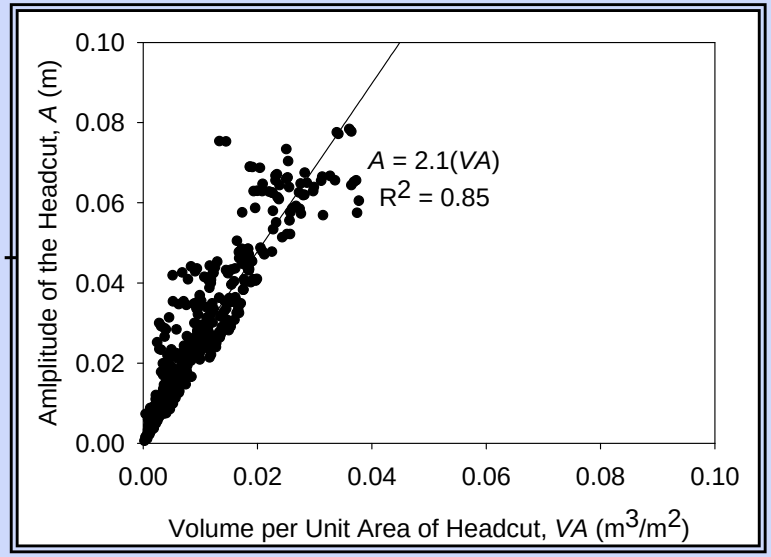
E_{rs}= volume/area

Amplitude of Undercut

Height and Width of Undercut

Gaussian Function

Dimensions of Undercut



Seepage Force

(and Reduced Fluvial Resistance)

Slope Stability Model (BSTEM)

Conclusions

- Ground water processes important for bank stability
- Integrated stability (BSTEM)/flow model with all ground water processes being developed
  - Seepage gradient forces
  - Seepage particle mobilization and undercutting
- Additional work needed on fluvial/ground water force interaction (reduced fluvial resistance)

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Questions?

E-mail:
garey.fox@okstate.edu

Research Website:
http://biosystems.okstate.edu/Home/gareyf

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Experimental Results

- Relationship between headcut A vs. width and height…