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Estimating knickpoint migration in the Deep Loess Region of western Iowa

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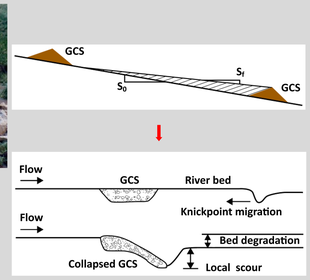
Knickpoints: water moves down, they move up

Stream channelization in Iowa during the first half of the 20th century caused the riverbed to become unstable. To establish a new equilibrium, downcutting and erosion takes place.(1)

...which migrates upstream initiating a wave of problems:
- ***Bank instabilities***
- ***Undermining of hydraulic structures***
- ***River habitat degradation***

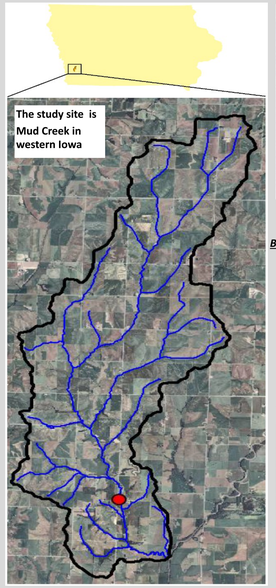
Knickpoint migration is difficult to avoid

Grade Control Structures (GCS) are built to halt this migration and induce a new, stable slope S_f.



GCS fail due to the inability to predict accurately:(2)
1) ***Knickpoint migration rate***
2) ***Stable channel slope***
3) ***Scour extent***

From continuous field monitoring...



Surveys ↓ ***Bathymetry***

Pressure transducers ↓ ***Flow Depth***

Bed & Bank samples ↓ ***Soil Erodibility***

...to numerical modeling

Knickpoint evolution over time occurs due to two main mechanisms depending on the soil type.(3)

which can be simulated numerically using the *Advection-Diffusion Equation* (ADE):

$$\frac{\partial z}{\partial t} + A\frac{\partial z}{\partial x} - D\frac{\partial^2 z}{\partial x^2} = 0$$

The Advection (A) and Diffusion (D) coefficients depend on the *flow conditions* and the *soil properties*.

Bed geometry → $A \propto q_s$

Cohesive sediment → $A = k_d(\tau - \tau_c)$

$A = k_d(\gamma R S_0 - \tau_c)$

Sediment continuity → $D \propto \frac{\partial q_s}{\partial x}$

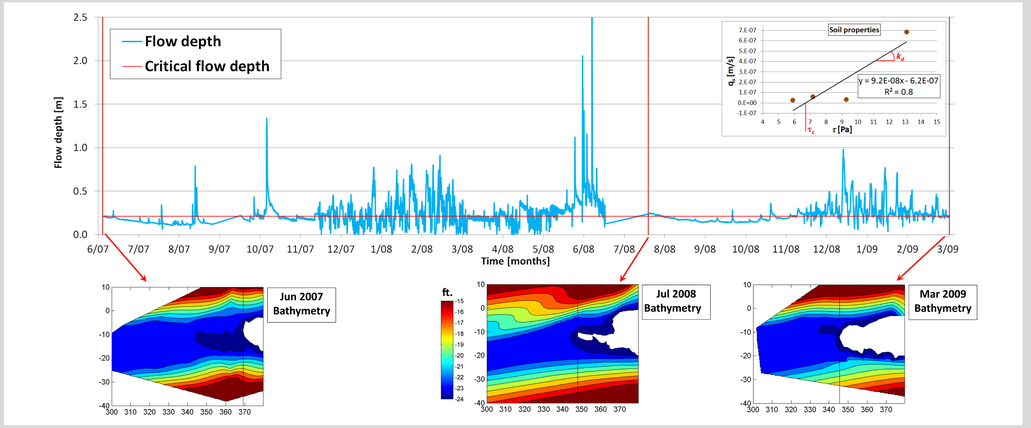
$D = \frac{\gamma\, h_{KP} k_d R}{\varepsilon}$

***Our objectives were*:**

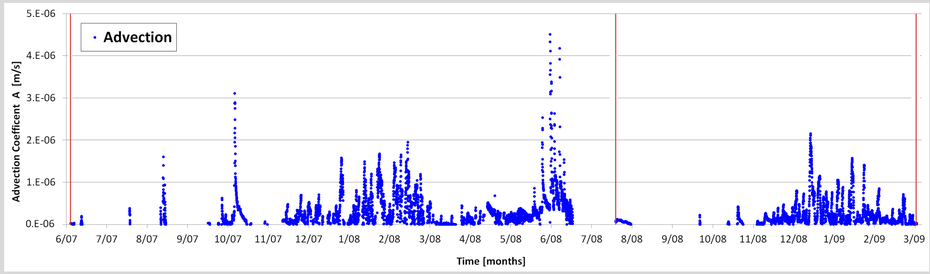
1) Use the field surveys to estimate the model parameters

2) Use the numerical model to predict knickpoint evolution

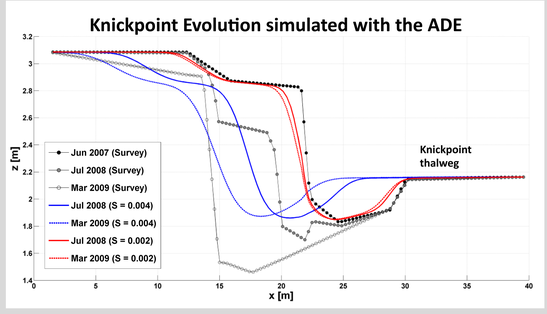
Results: capturing the knickpoint upstream migration



The knickpoint migrated ~25 ft or 7.5 m during the above study period. It exhibited a *parallel retreat* during moderately high flows, but experienced *inclination* during extreme floods (e.g. June 2008).



The parallel retreat of the knickpoint was correctly estimated using the *advection coefficient* only and it occurred when the stress was above the critical value.



CONCLUSIONS & FURTHER RESEARCH

1) The advection-diffusion model was able to predict knickpoint migration and can be used to determine a stable slope for the design of GCS.

2) The knickpoint inclination was overestimated due to an inaccurate estimation of the diffusion coefficient.

3) The downstream scour hole and the knickpoint steepening were not captured by the model. These probably require a non-linear equation.

Bibliography

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Acknowledgements

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