Effects of Spatial and Temporal Variability in Erosion Pin Measurements on Erosion Rating Curves for the BANCS Model

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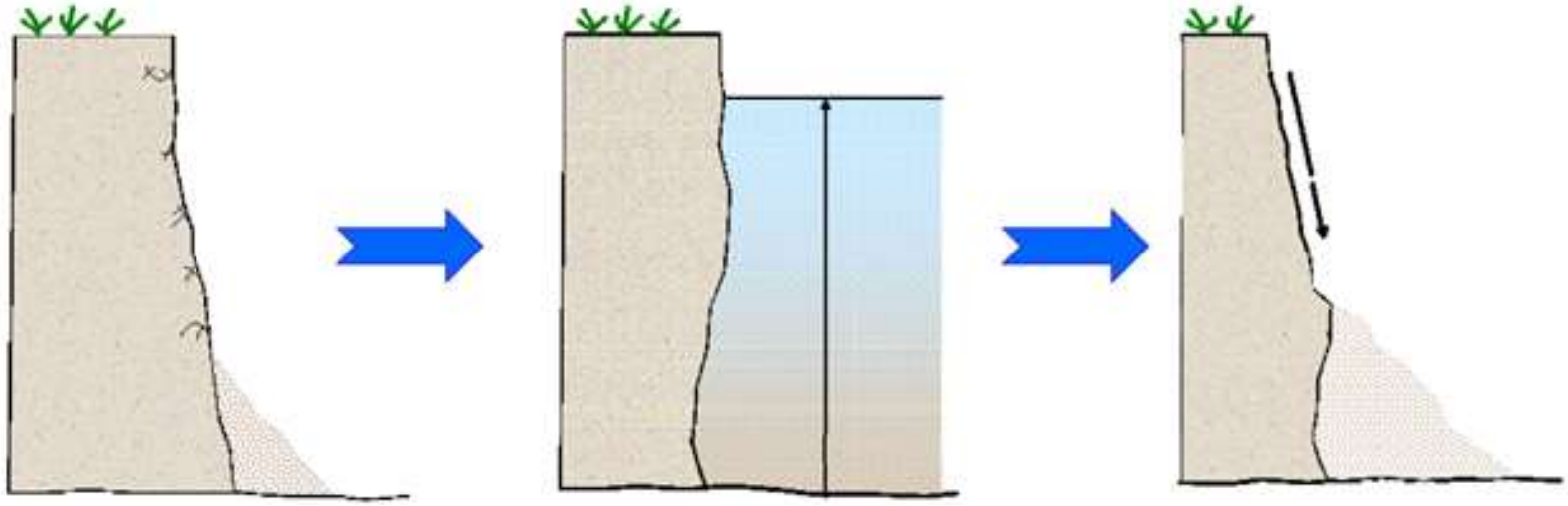
Introduction

What is Streambank Retreat?



Streambank Retreat = (Subaerial Processes) + (Fluvial Erosion) + (Mass Wasting)

(Wynn, 2006)

Stream restoration is a common tool used to decrease sediment pollutants

Planned stream restoration lengths by 2025:

- 2010 - 97 mi. (156 km)
- 2020 - 784 mi. (1262 km)

https://www.nrcs.usda.gov/Internet/FSE_MEDIA/stelprdb1046486.png

(Rosgen, 2006)

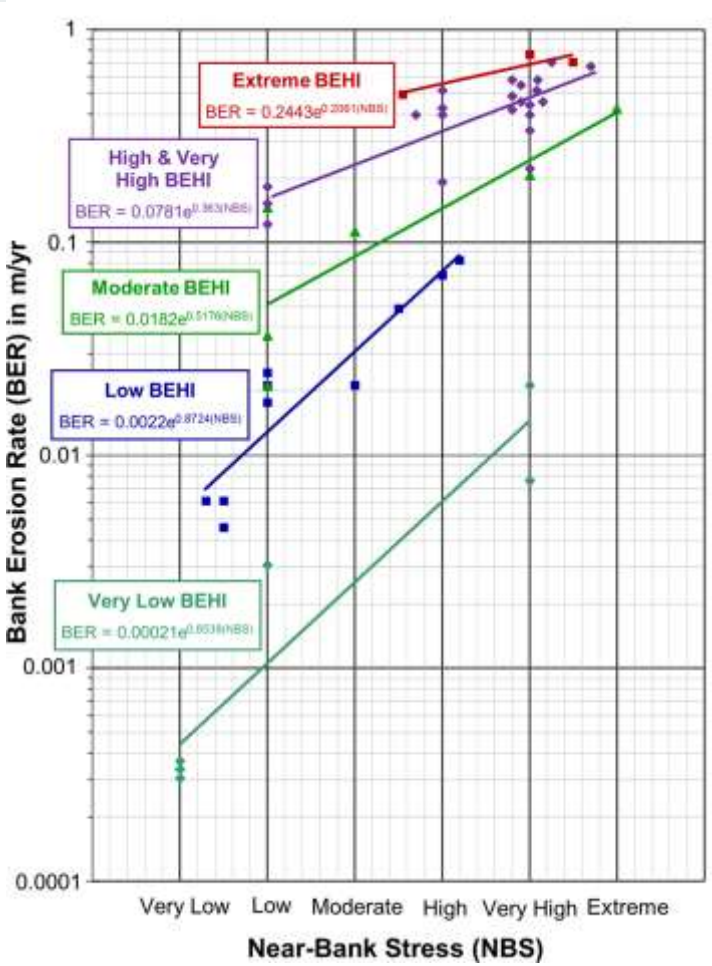
BANCS

Regression of:

- Erosion Rate at Bankfull Flow
- BEHI ∝ Bank stability
- NBS ∝ Erosive ability of stream

Use:

1. Assess BEHI & NBS in field
2. Apply curve



Goals & Objectives

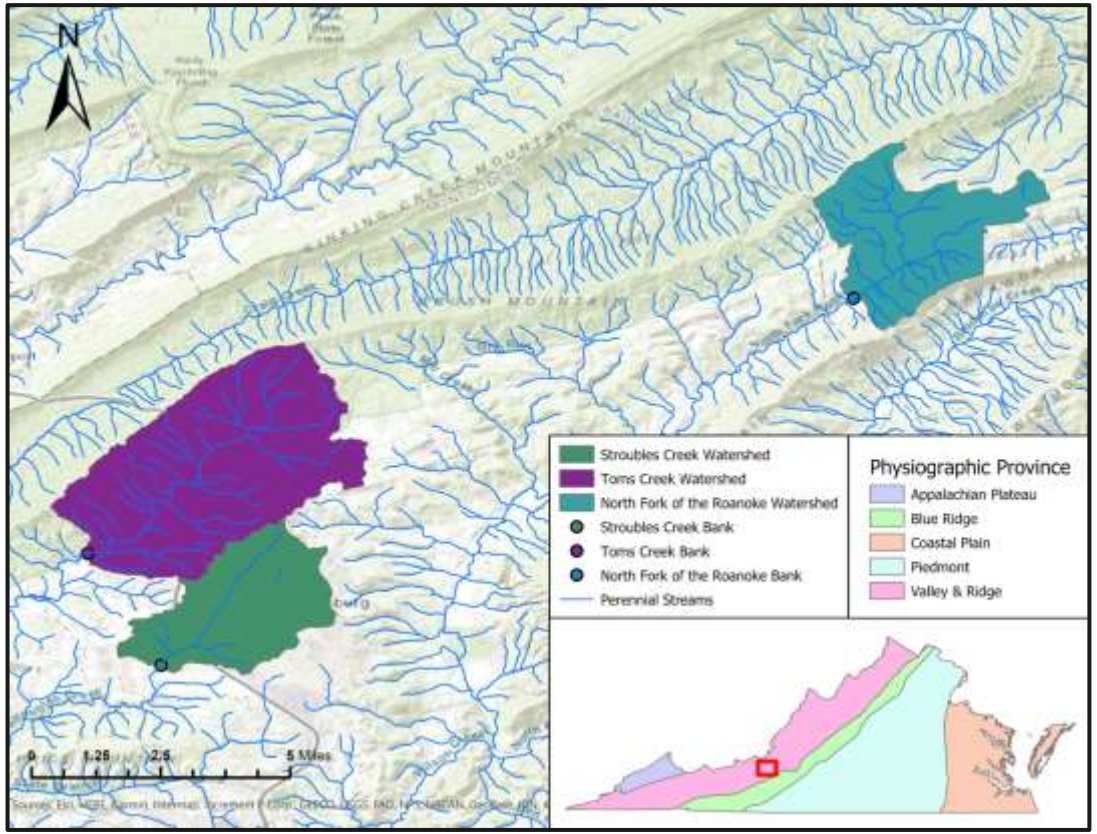
Study Goals & Objectives

Overall Goal: Evaluate BANCS for predicting bank retreat sediment loads

1. Assess the spatial and temporal variability of erosion pin measurements
2. Evaluate the sensitivity of the BANCS model to the quantity and variability of input erosion data
3. Create curves that replaces standard NBS estimates with modified NBS (Hydrograph & DuBoys)
4. Quantify the error of bank retreat predictions from the BANCS models

Field Sites & Measurements

Methodology - Field Sites



Stroubles Creek = SC

Toms Creek = TC

North Fork of the Roanoke River = NFR


SC, Historic


TC


SC, Present

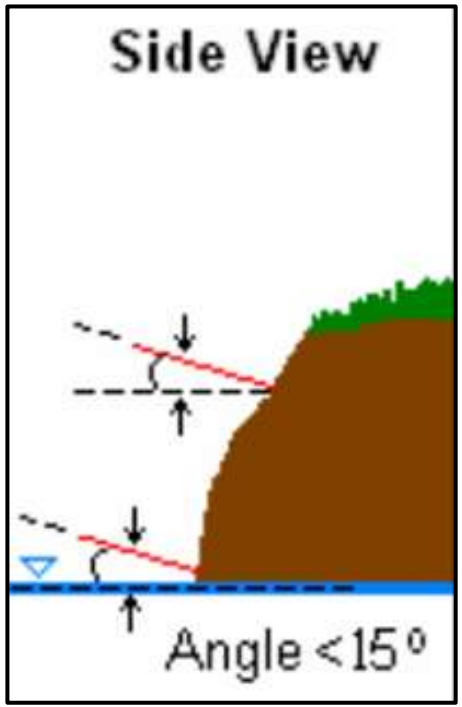

NFR

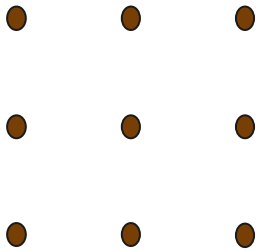
Methodology - Field Measurements

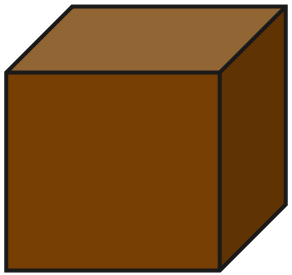
- Erosion Data:
  a. 249 Pins (Historic, 2005 - 2007)
  b. 71 Pins (Present, 2020 - 2021)
- Survey Data:
  a. Stroubles Survey
  b. Other Site Surveys
- Water Depth:
  a. StREAM Lab
  b. Water level loggers

https://www.onsetcomp.com/products/data-loggers/u20-001-01/

Erosion pins are cheap and simple but only measures points







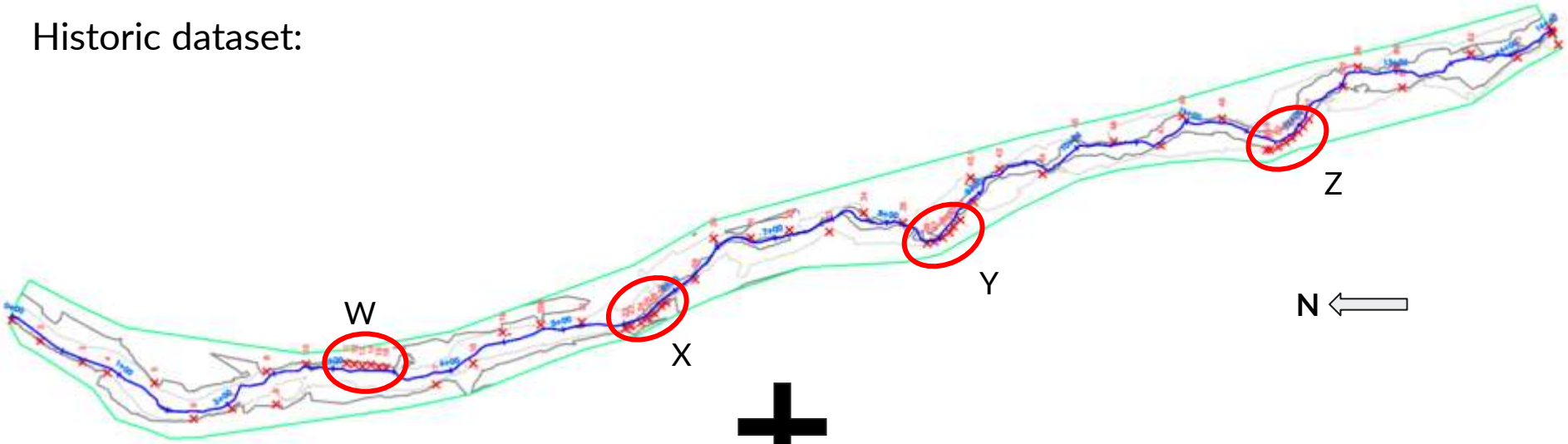
(Thompson et al, 2006)

Methodology, Results & Discussion

Objective 1:
Assess the spatial and temporal variability of erosion pin measurements

Spatial Question:
Does the erosion volume calculation method affect the erosion volume estimate?

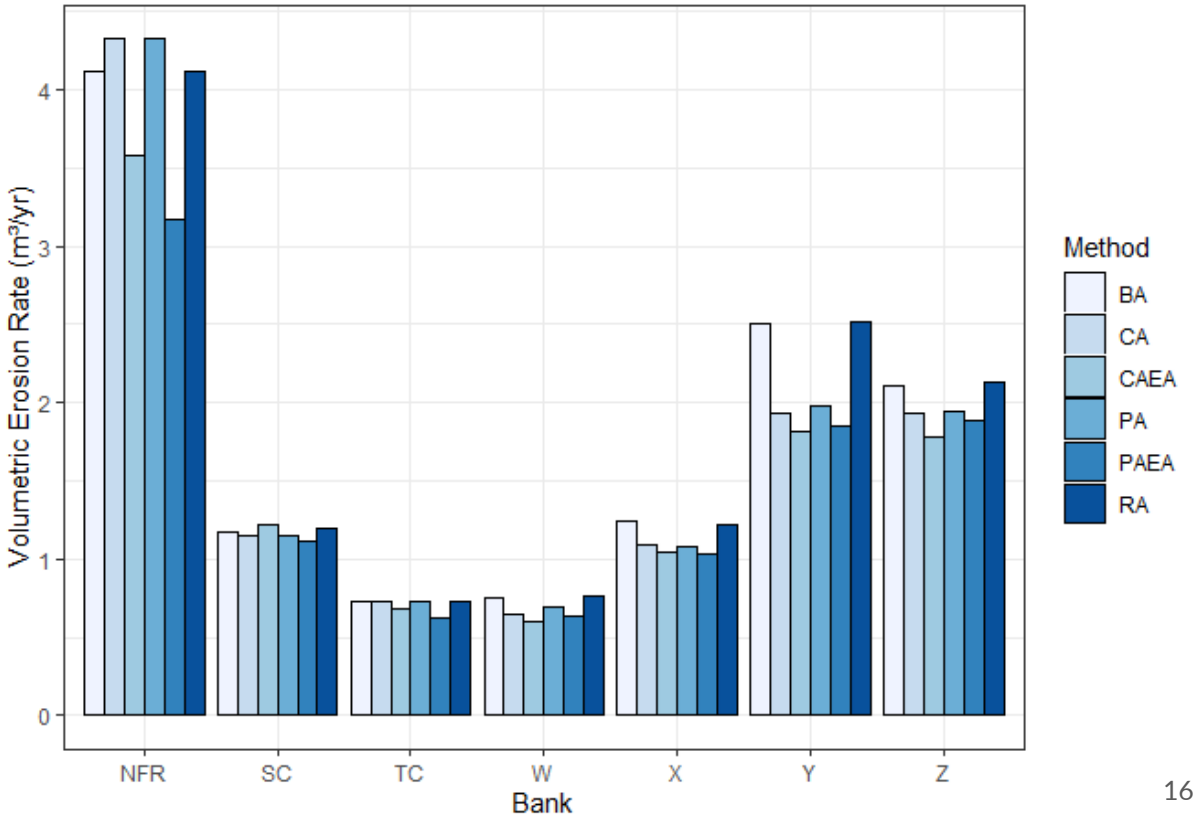
Historic dataset:



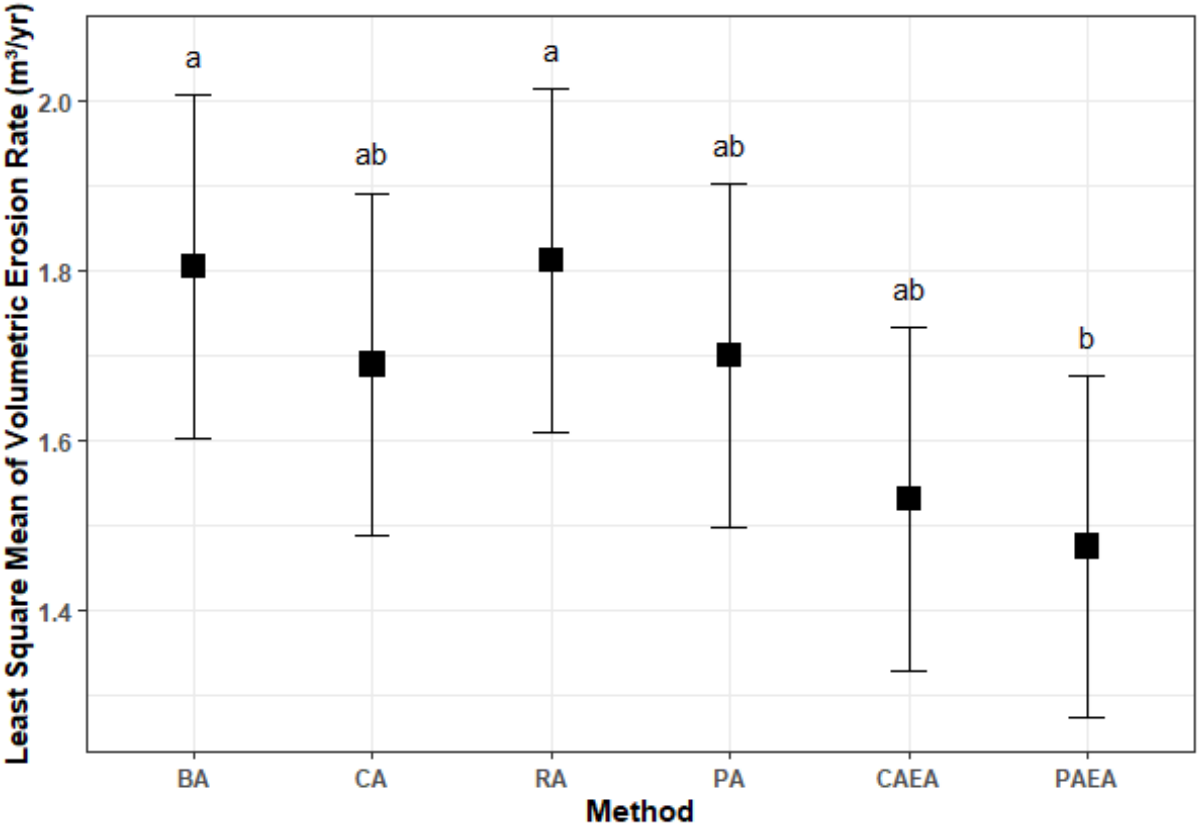
Present dataset:

Erosion rate does vary with method, but is it significant?

BA = Bank Average
CA = Column Average
RA = Row Average
PA = Pin Area
CAEA = Column Average End Area
PAEA = Pin Average End Area

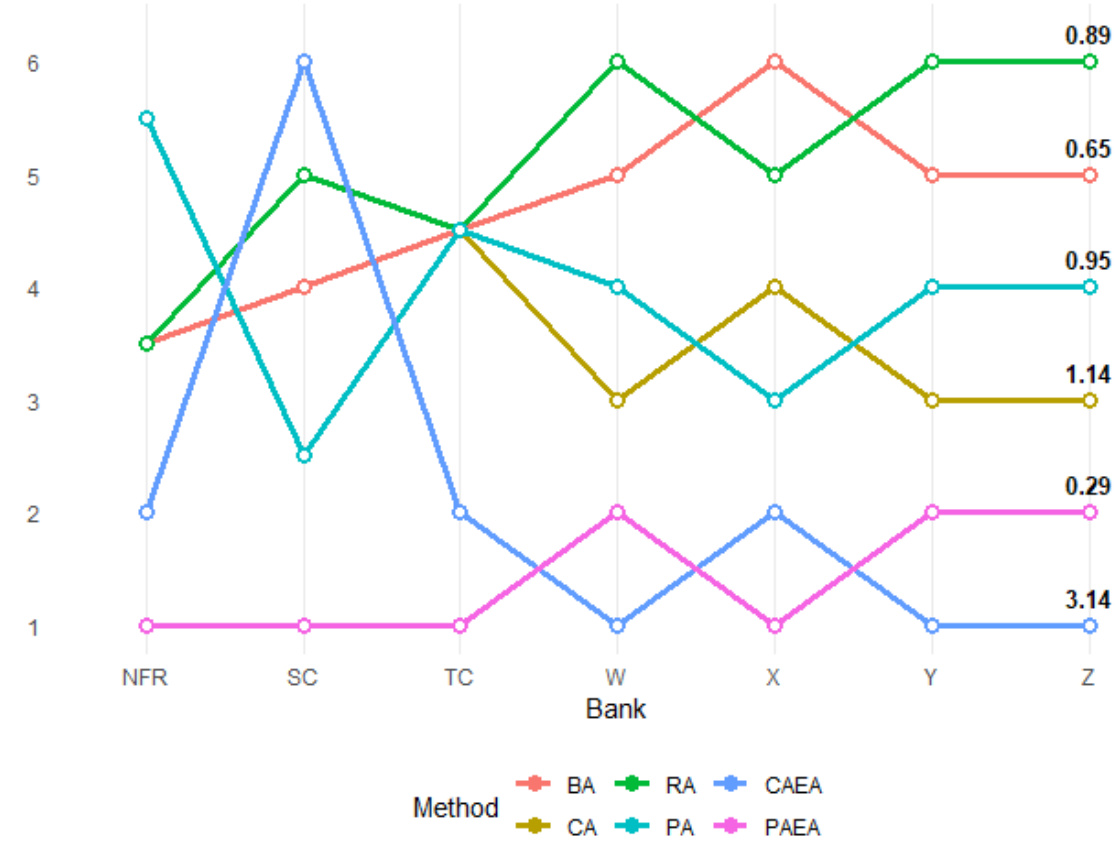


Erosion rate does significantly vary with method, but which is best?



BA = Bank Average
CA = Column Average
RA = Row Average
PA = Pin Average
CAEA = Column Average End Area
PAEA = Pin Average End Area

PAEA method is least sensitive to the individual pins

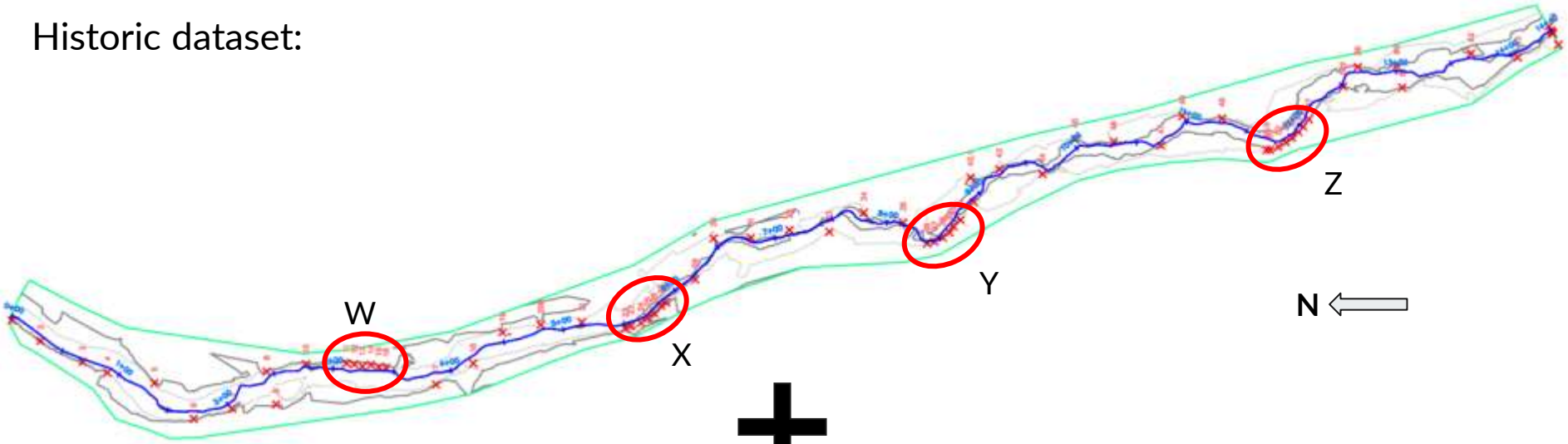


BA = Bank Average
CA = Column Average
RA = Row Average
PA = Pin Average
CAEA = Column Average End Area
PAEA = Pin Average End Area

Objective 1:
Assess the spatial and temporal variability of erosion pin measurements

Spatial Question:
Can measurements of a single column or row of pins adequately reflect the soil volume lost from an entire bank?

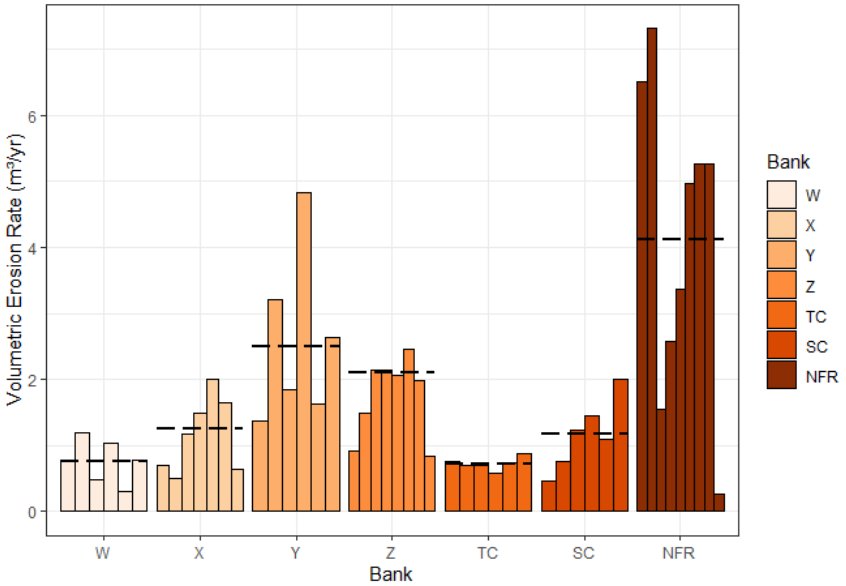
Historic dataset:



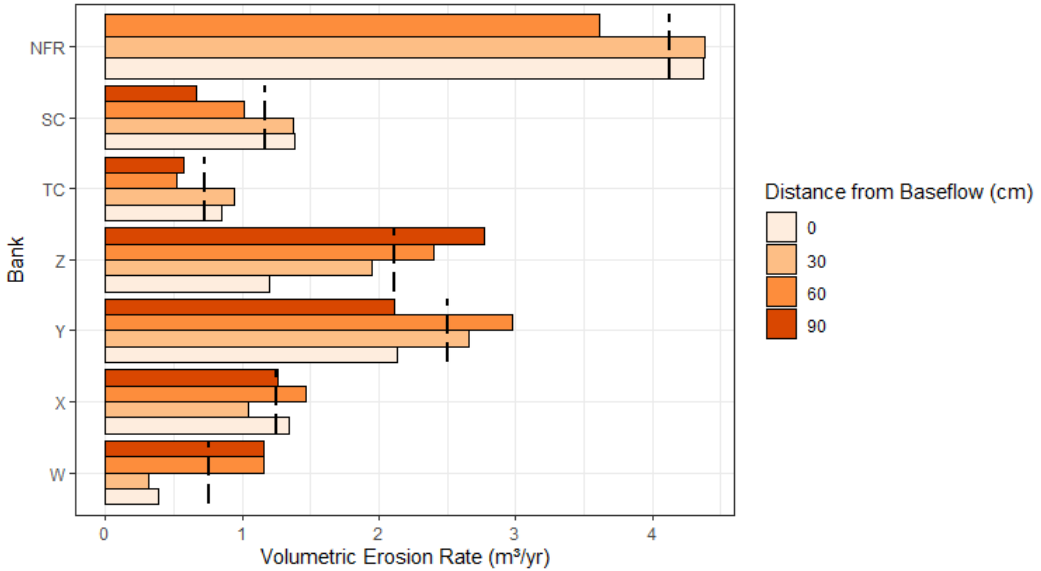
Present dataset:

There is considerable variability in erosion estimates when using one column/row

Column Estimates:

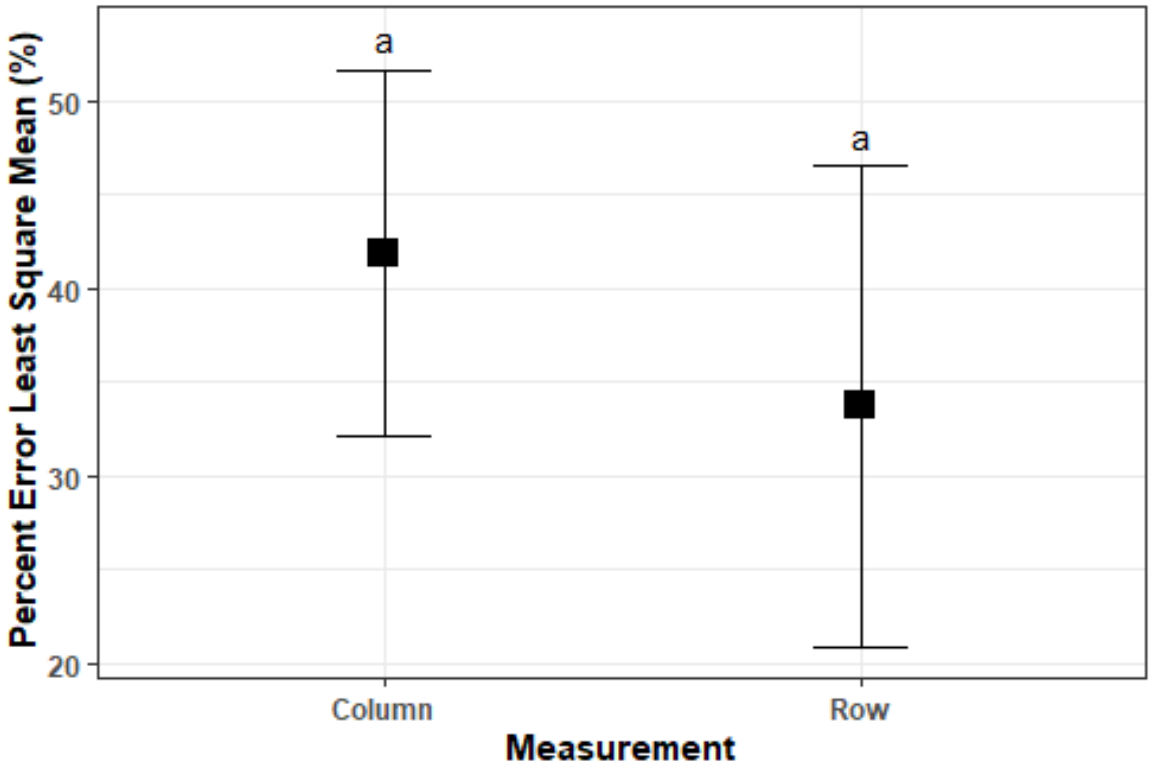


Row Estimates:



Which is better?

While not statistically significant, using rows appears to be more representative

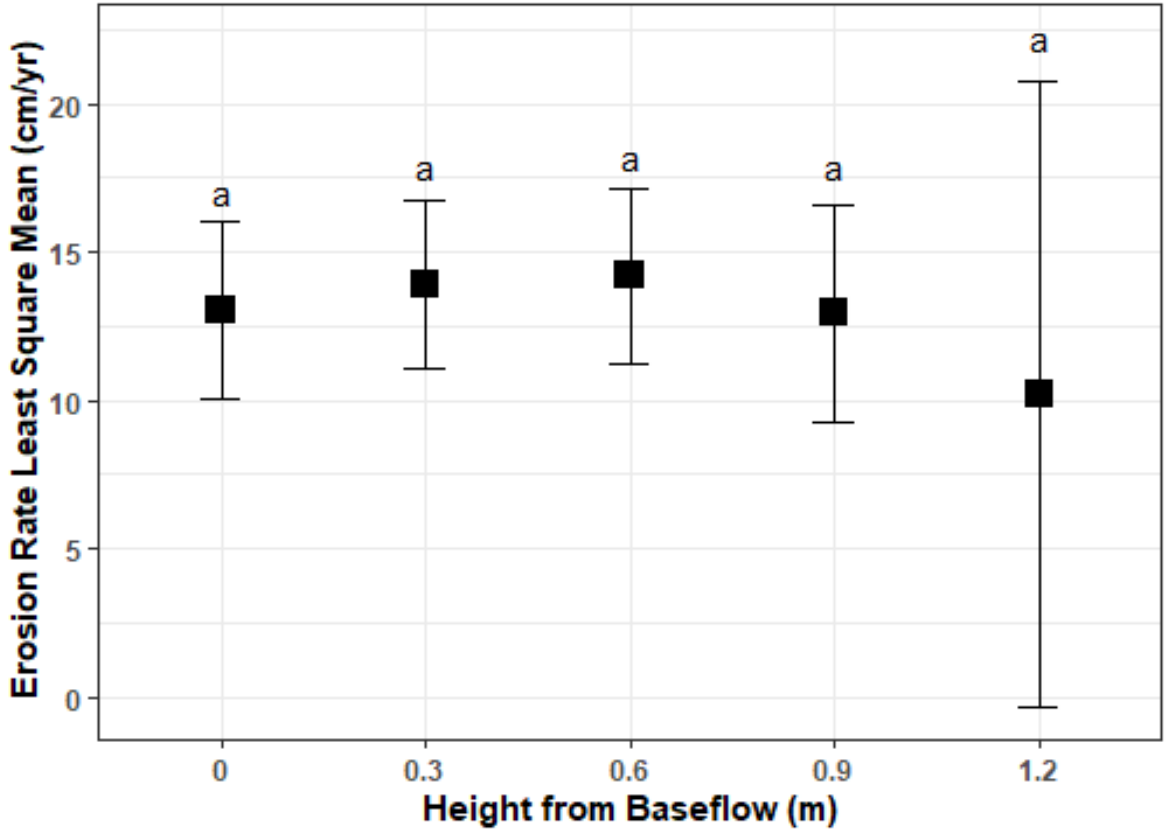


Objective 1:
Assess the spatial and temporal variability of erosion pin measurements

Spatial Question:
Does vertical pin placement affect the total reach erosion rate estimate?

Historic dataset:

No statistical difference between pin rows over long periods of time

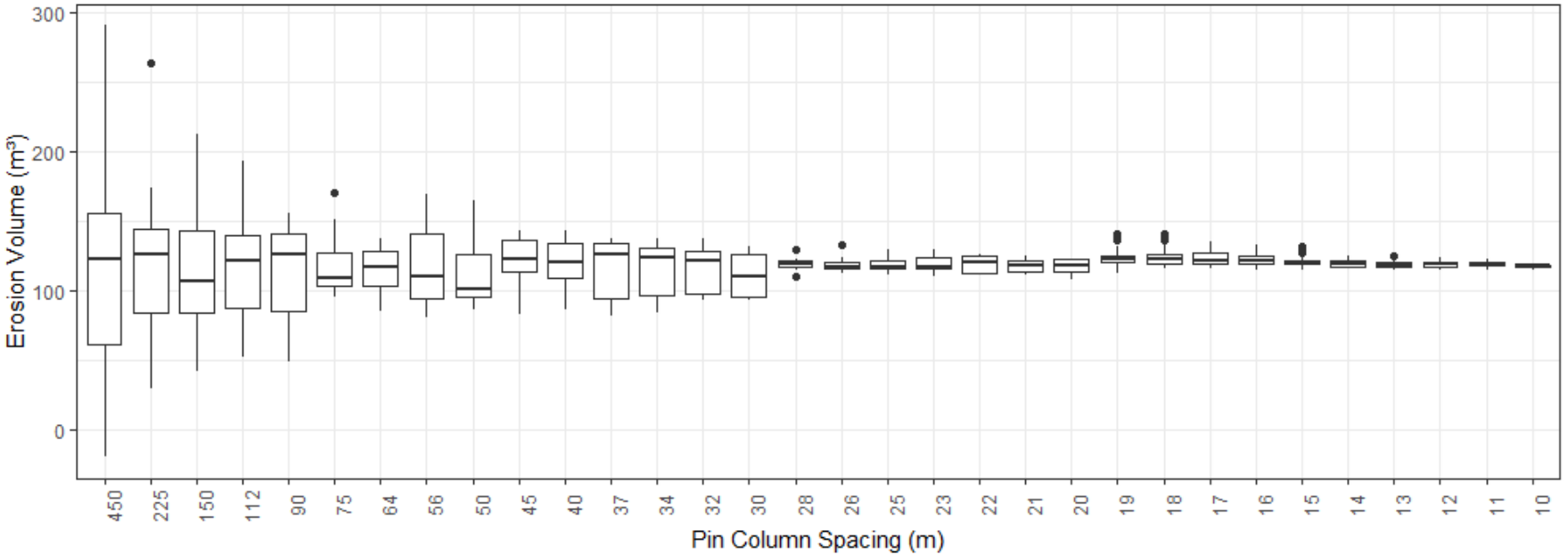


Objective 1:
Assess the spatial and temporal variability of erosion pin measurements

Spatial Question:
How does longitudinal pin spacing and number along the reach affect the total estimated reach erosion volume?

Historic dataset:

Reach scale erosion estimates converge as the number of pins increase and spacing decreases.



Chesapeake Bay Recommended Spacing =200-500 ft. (60-150 m)

Stroubles Creek Measurement Spacing ≈ 92 ft. (28 m) ≈ 3 channel widths

Objective 1 Conclusions (Spatial)

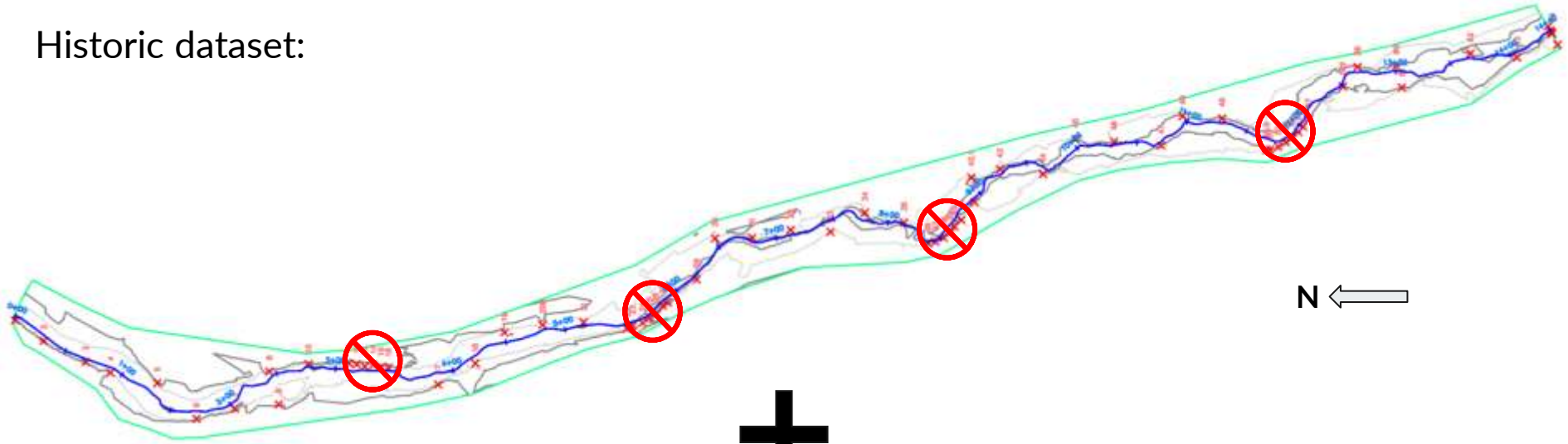
Objective 1: Assess the spatial and temporal variability of erosion pin measurements

- The PAEA method of averaging erosion rates for a grid of pins is recommended
- Measuring a single row along a bank is preferential to measuring a single column
- Rows at different vertical placements estimate the same erosion rate over long periods of time
- On a reach-scale, a measurement spacing of three channel widths is recommended

Objective 1:
Assess the spatial and temporal variability of erosion pin measurements

Temporal Question:
How does erosion vary by season?

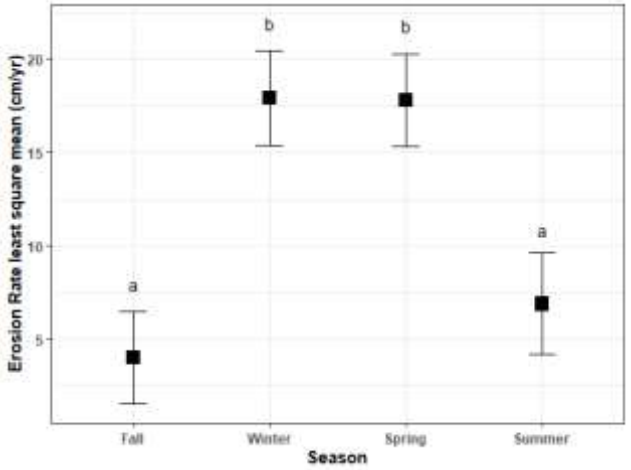
Historic dataset:



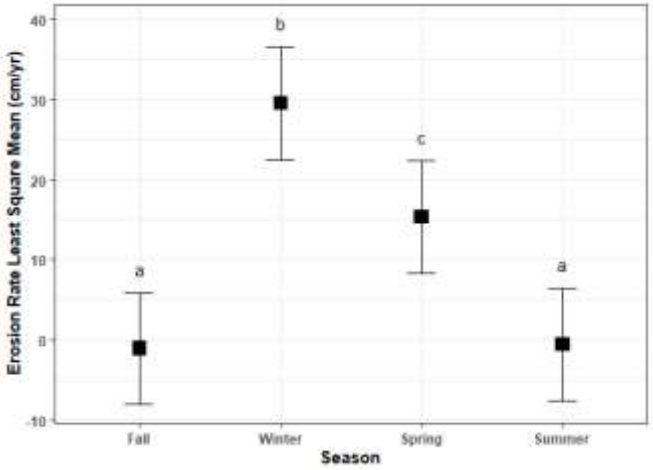
Present dataset:

Erosions rates can vary by season

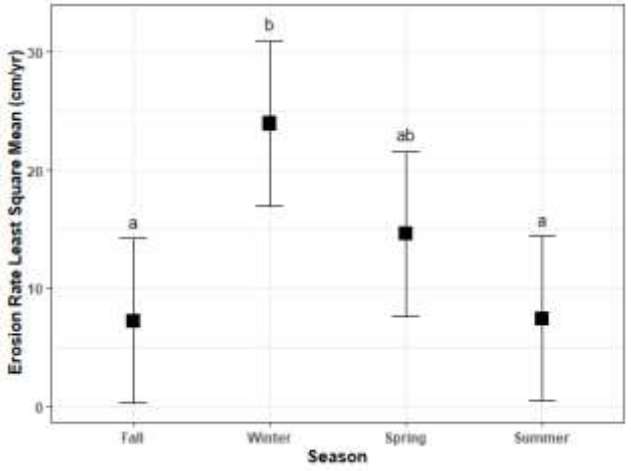
SC, Historic



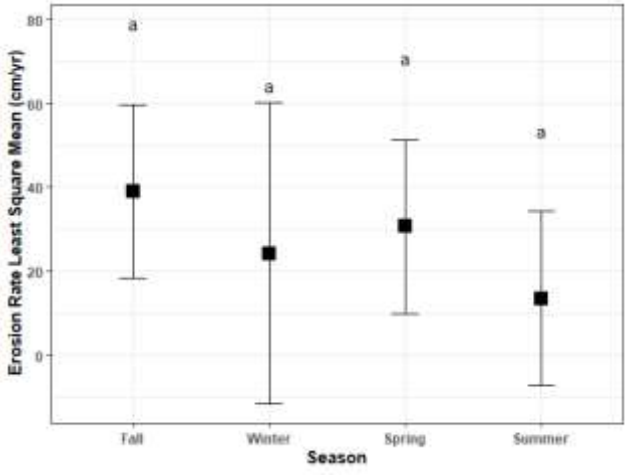
TC



SC, Present



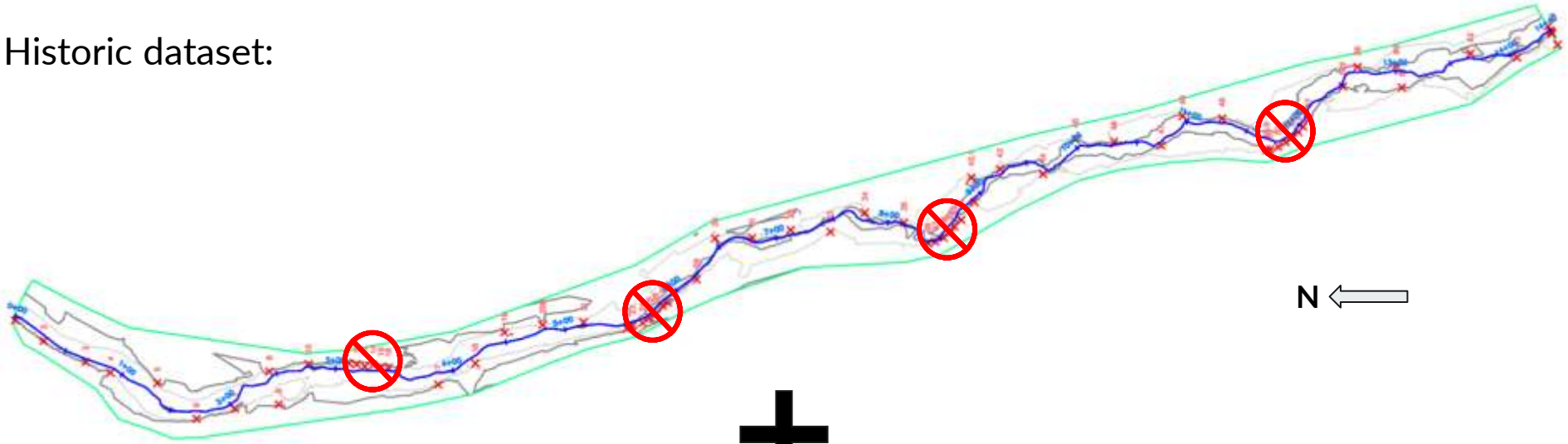
NFR



Objective 1:
Assess the spatial and temporal variability of erosion pin measurements

Temporal Question:
How many months of data is needed for the mean and variability of the erosion rate to not vary appreciably

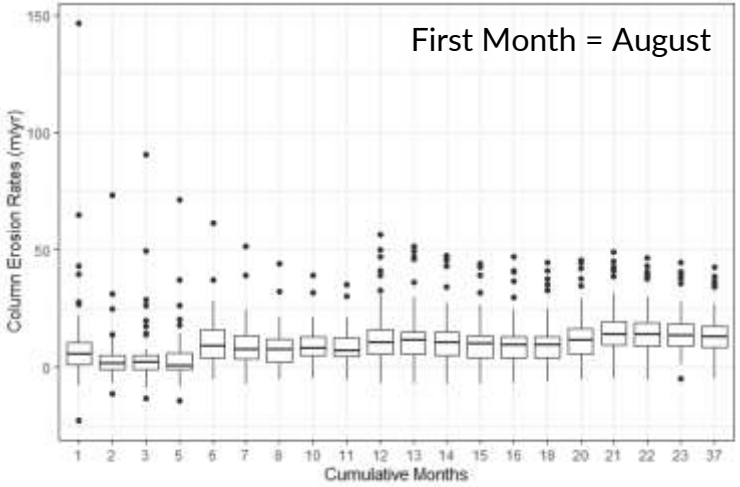
Historic dataset:



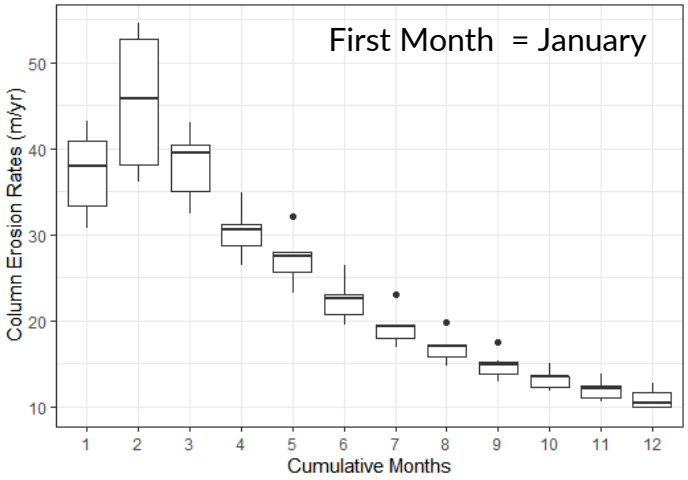
Present dataset:

Time-Averaged erosions rates may or may not level in 12 months

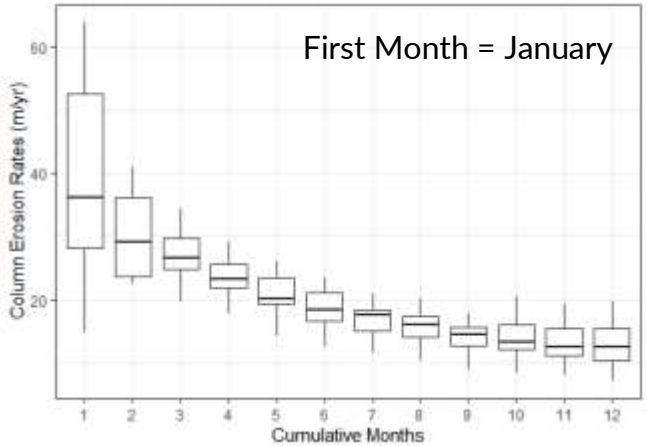
SC, Historic



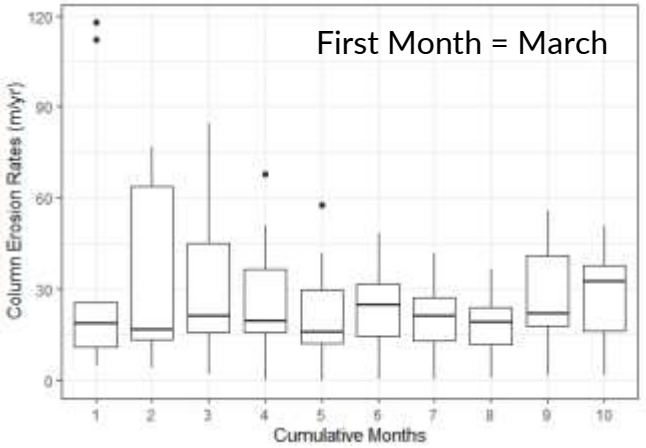
TC



SC, Present

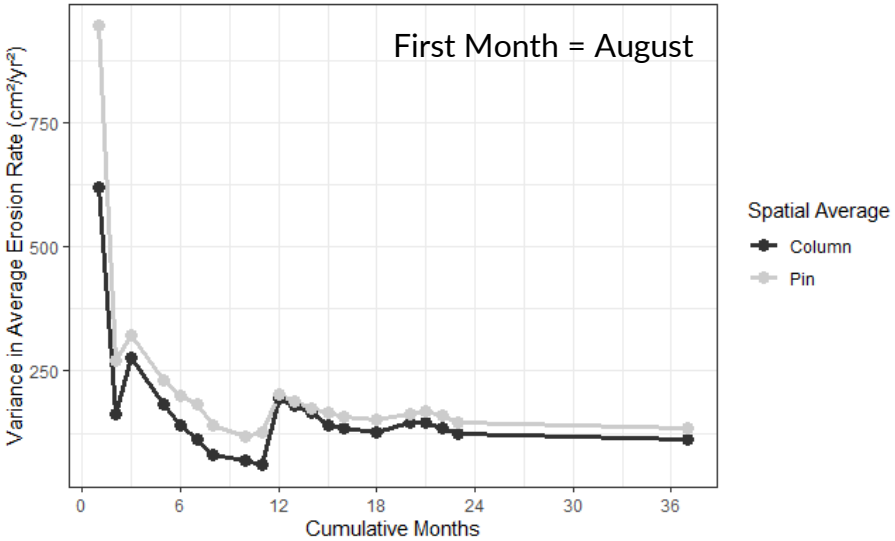


NFR

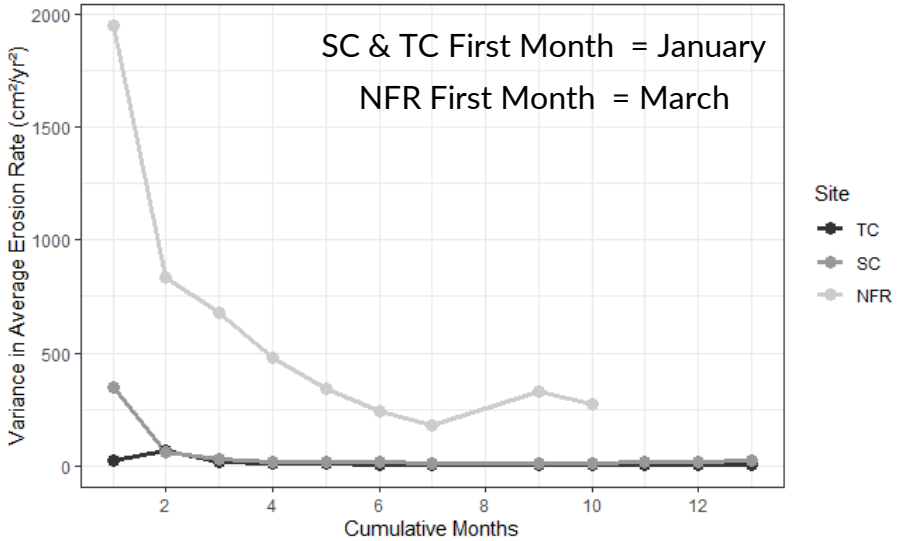


Variance of time-averaged erosion rate decreases in 12 months

Historic Dataset:



Present Dataset:



Objective 1 Conclusions (Temporal)

Objective 1: Assess the spatial and temporal variability of erosion pin measurements

- Erosion rates can be significantly affected by seasonality
- A sampling time of 12 months is recommended to account for seasonal variability

Objective 2:
Evaluate the sensitivity of the BANCS model

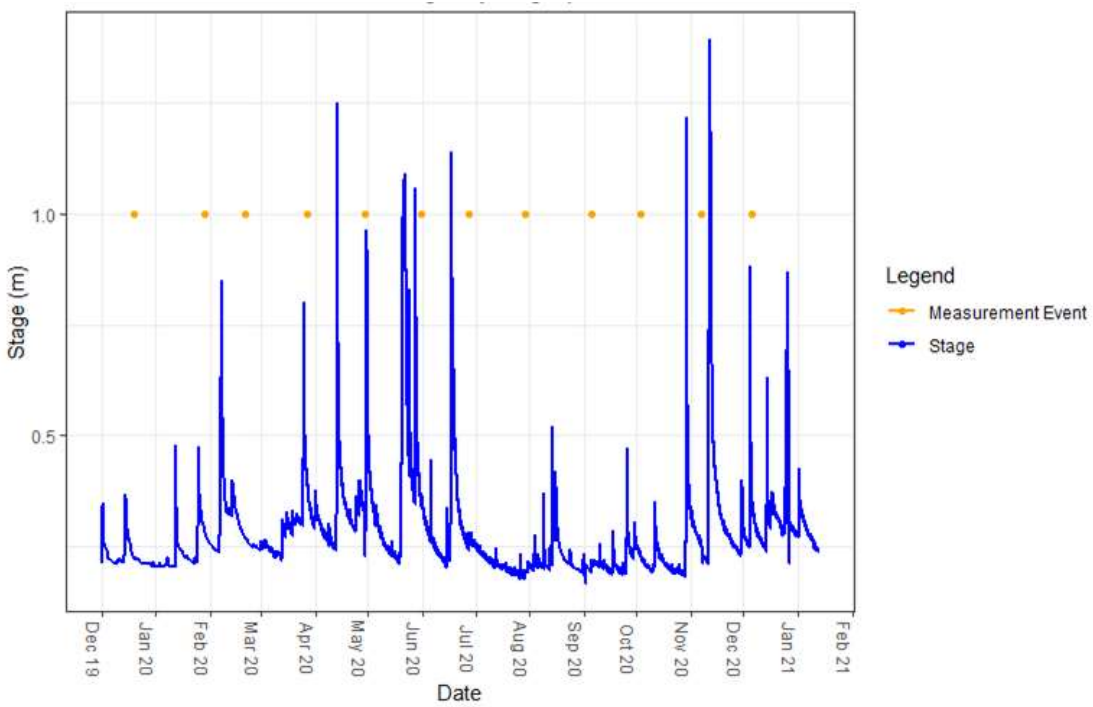
Question:
How does BANCS respond to different NBS and erosion rate inputs?

Historic dataset:

Tested three different input erosion rates

Input Erosion Rates:

1. Bankfull Erosion Rates
2. All Monthly Erosion Rates
3. One Year Time-Averaged Erosion Rates

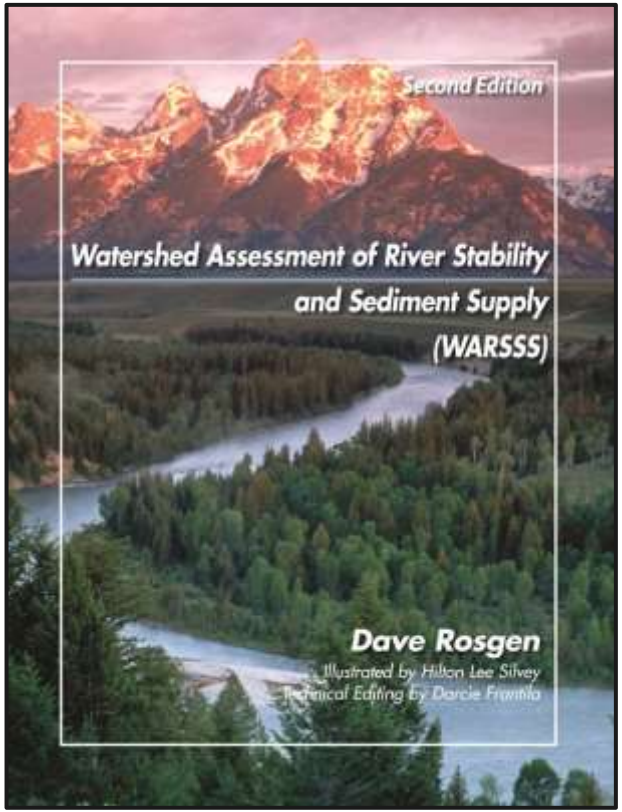


Need to classify banks with BEHI & NBS

BEHI - one method

NBS (7 Methods):

- 2 - Radius of curvature / Bankfull width
- 3 - Pool slope / Average slope
- 4 - Pool slope / Riffle slope
- 5 - Thalweg proximity to study bank



Performed regression analysis with linearization of power relationship

3
Erosion Rate Inputs

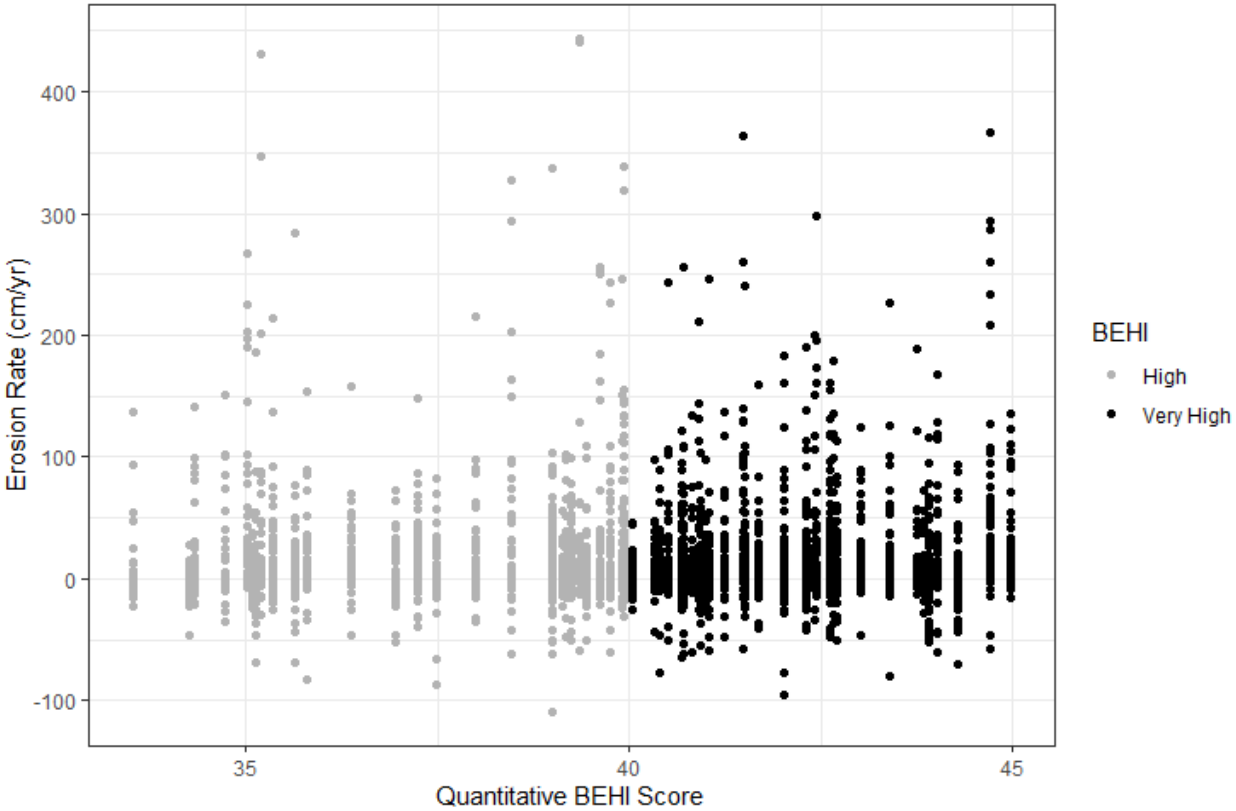
1. Bankfull Erosion Rates
2. All Monthly Erosion Rates
3. One Year Time-Averaged Erosion Rates

5
NBS Options

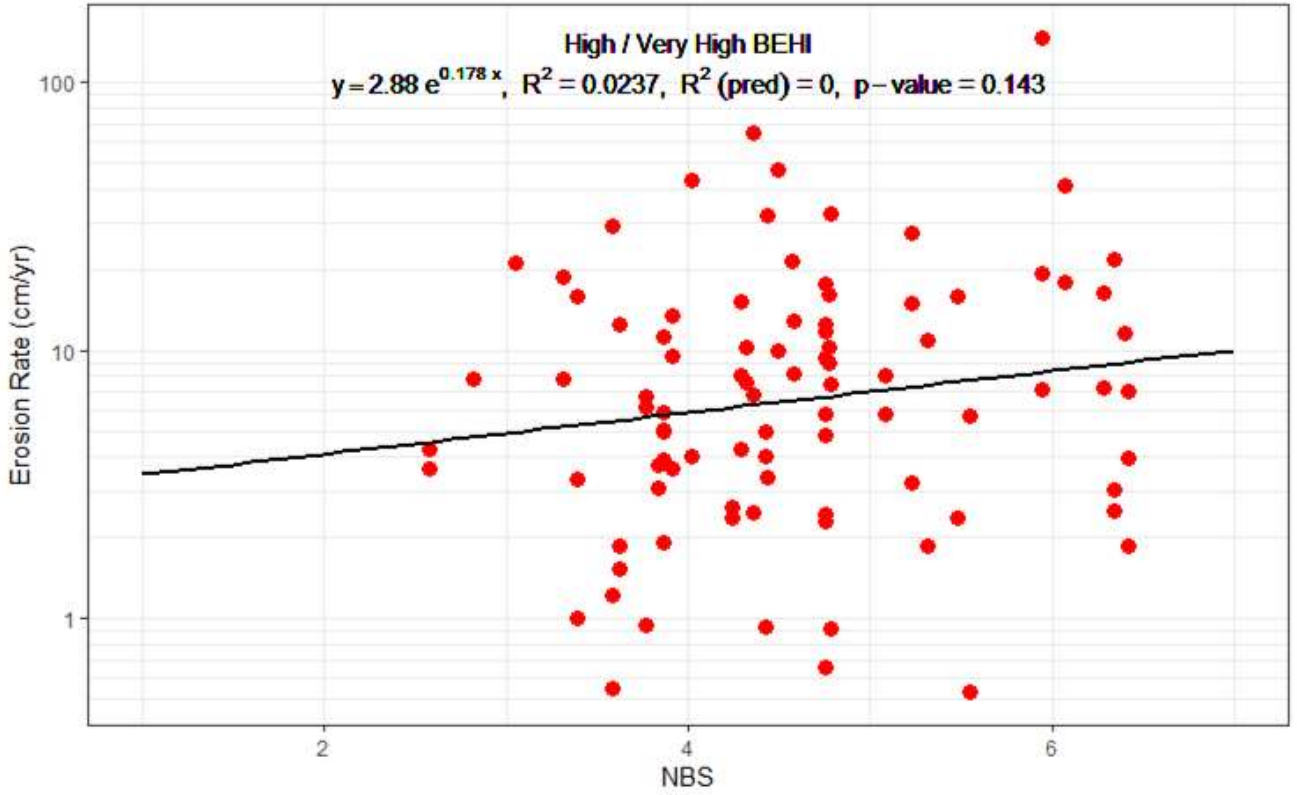
1. Method 2
2. Method 3
3. Method 4
4. Modified Method 5
5. Highest of all methods applied

15
Regressions per BEHI Category

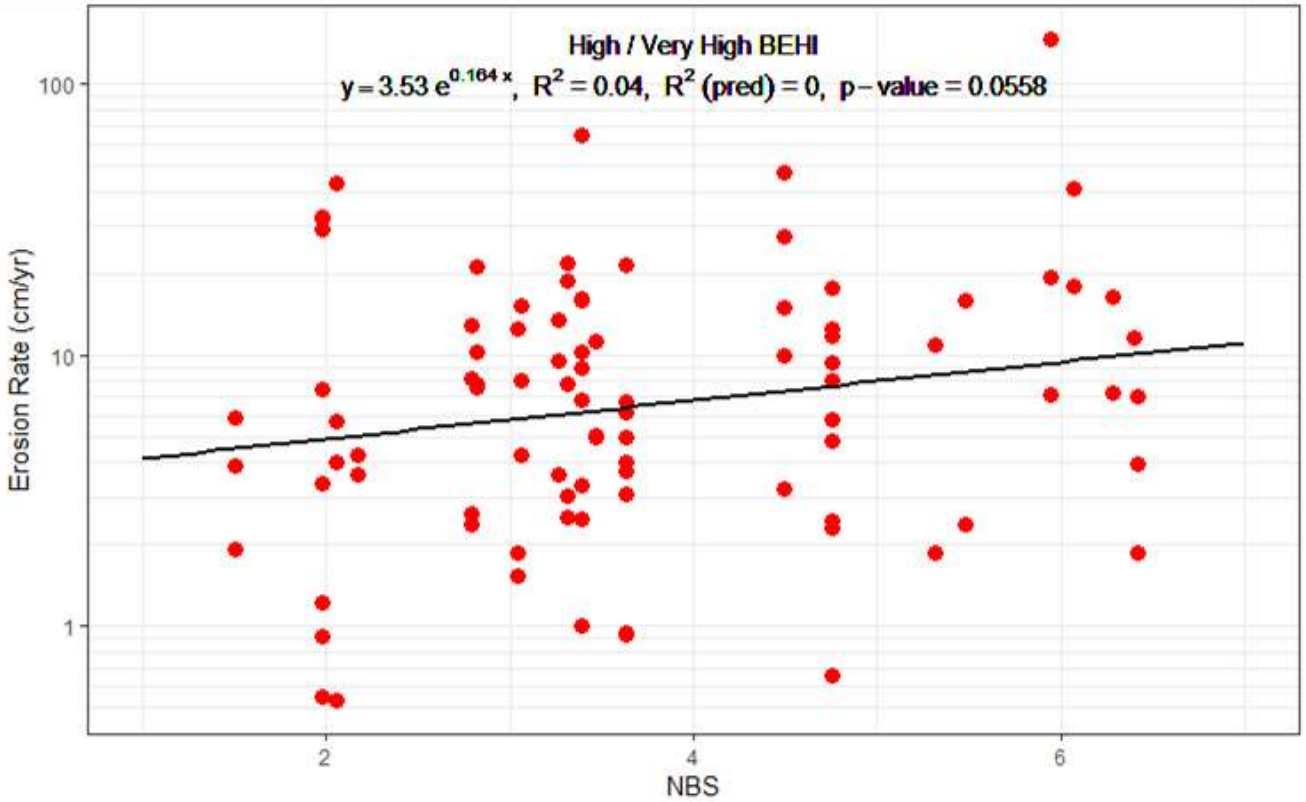
No distinction in erosion rate between “High” and “Very High” BEHI



Traditional BANCS curve did not have a statistically significant relationship



Only one of the 15 regression curves had a statistically significant relationship (Method 3)



Objective 2 Conclusions

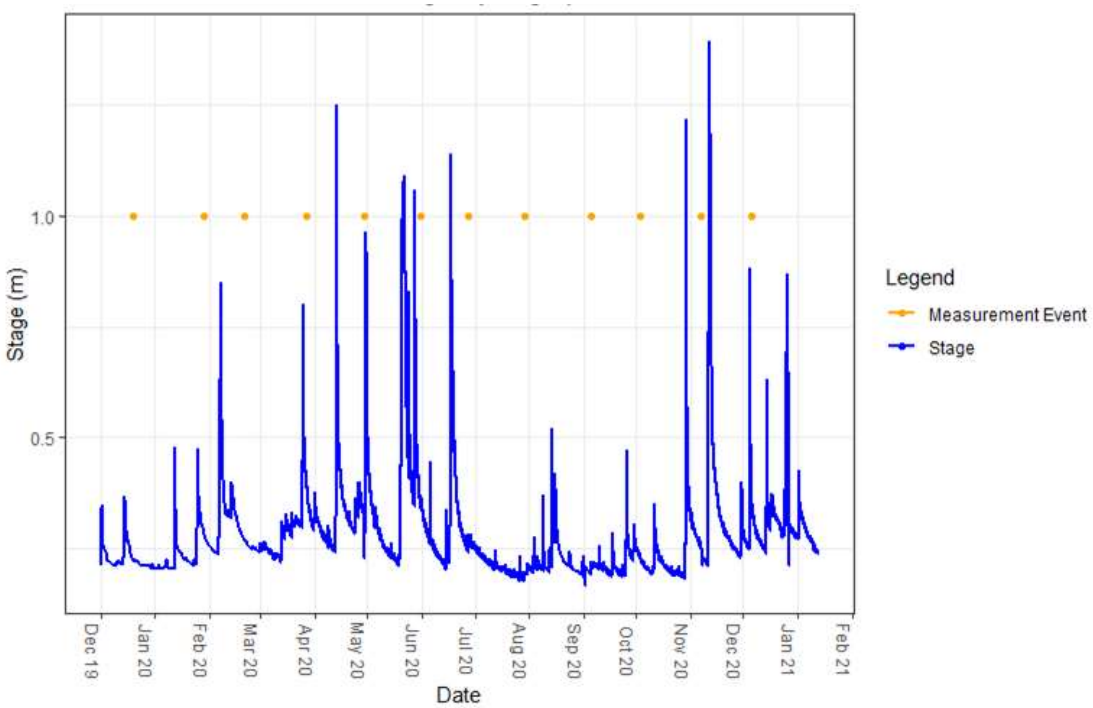
Objective 2: Evaluate the sensitivity of the BANCS model

- Only bankfull erosion rate had a statistically significant relationship
- Only Method 3 had a statistically significant relationship
- Weak relationship between traditional NBS and bank retreat rate:
  - Bank retreat rate is dominated by other erosion processes
  - Bank retreat is just naturally variable

Objective 3:
Create and compare BANCS curve with modified NBS

Question:
What are some NBS alternatives?

NBS can be based off a hydrograph



Peaks above Baseflow

% Duration above Baseflow

NBS can be based off DuBoys Equation

$$\tau_b = \rho g R S \begin{cases} \rightarrow NBS_{mod,1} = hS \\ \rightarrow NBS_{mod,2} = \dfrac{hS}{\left(\frac{R_c}{W}\right)} \end{cases}$$

Keeping track of regressions

Hydrograph-based:

1	✖	**2**	=	**2**
Erosion Rate Inputs		NBS Options		Regressions per BEHI Category

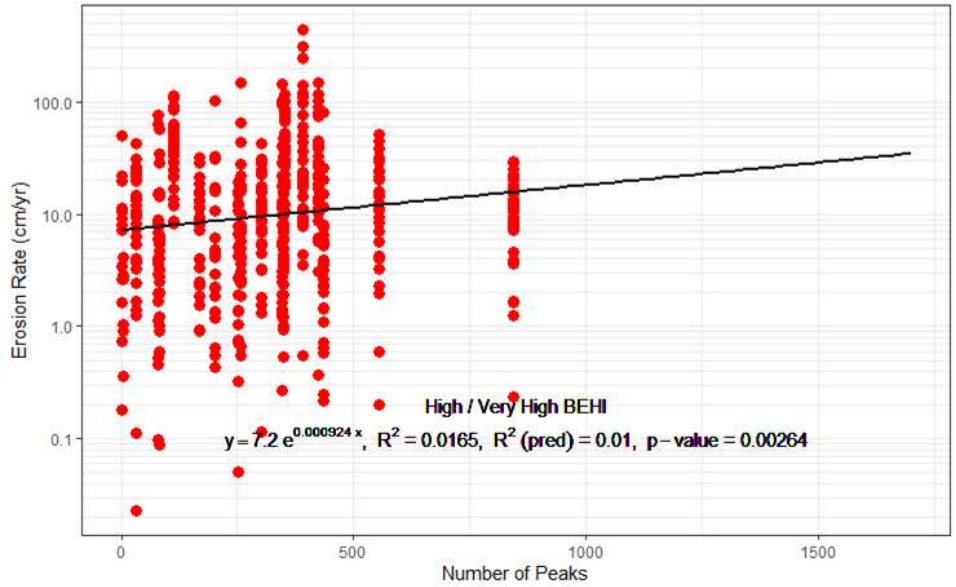
Modified DuBoys:

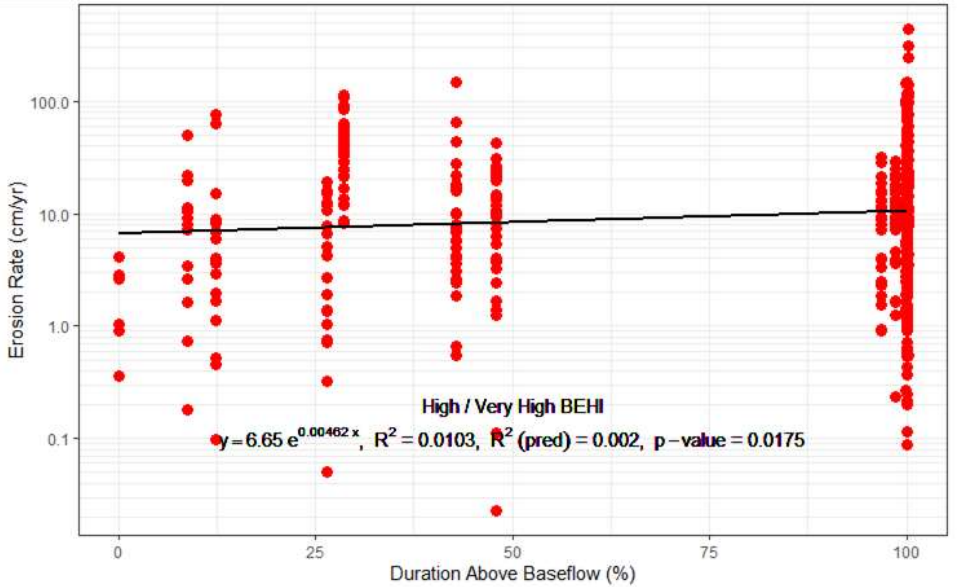
3	✖	**2**	=	**6**
Erosion Rate Inputs		NBS Options		Regressions per BEHI Category

8

Regressions per BEHI Category

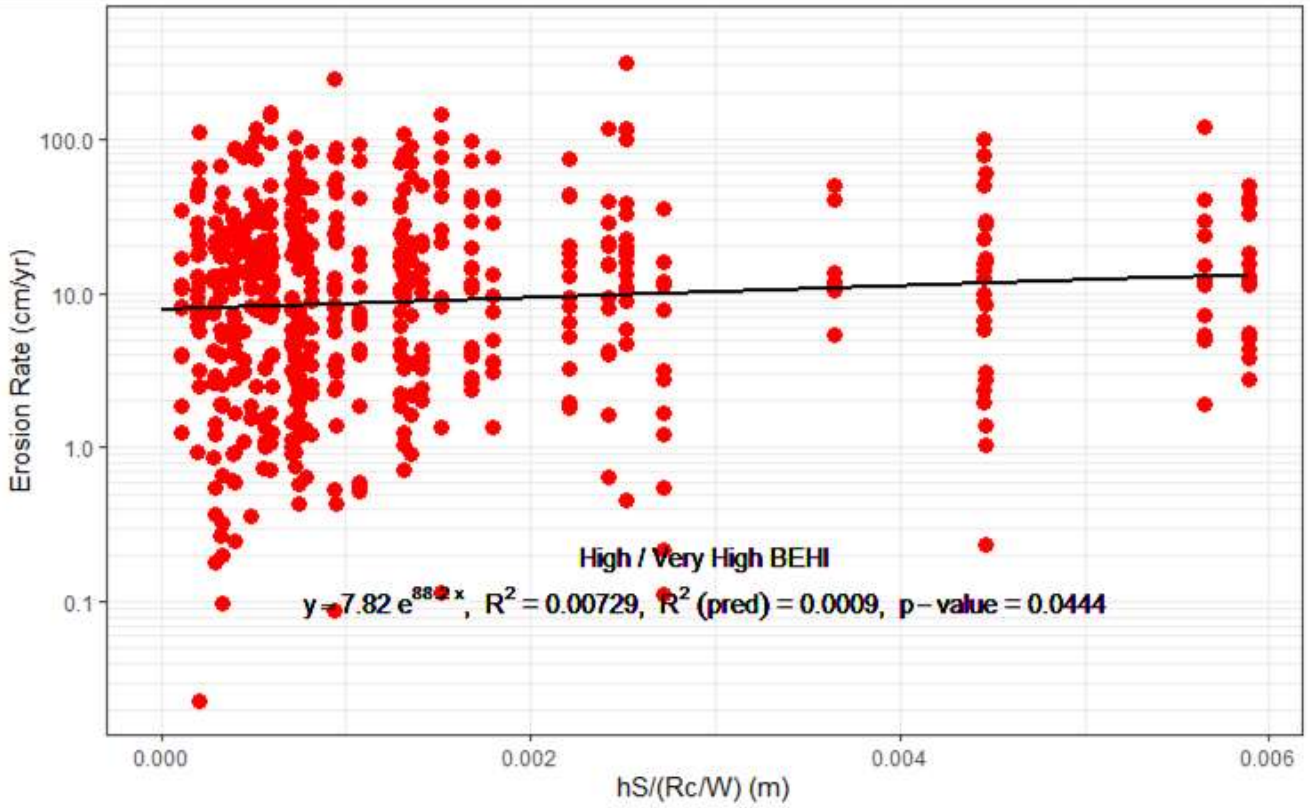
Both hydrograph-based methods were statistically significant





Impractical for crediting

Three of the six modified DuBoys had significant relationships



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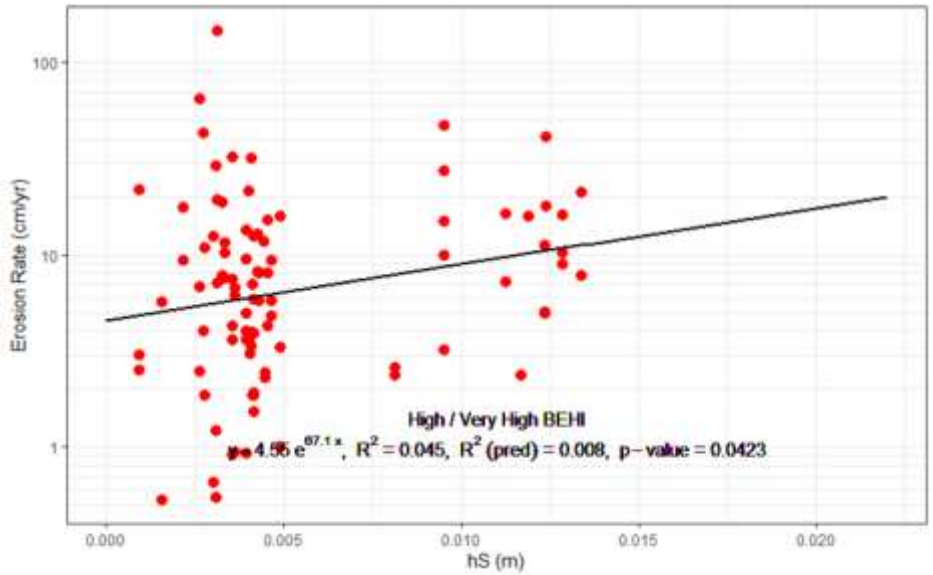
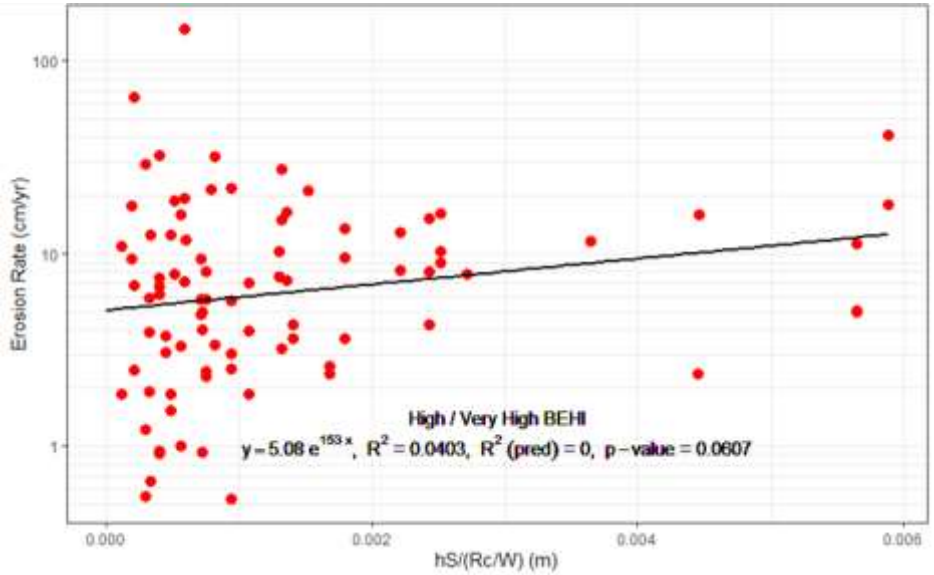




No time-averaged curves had significant relationships

Objective 3 Conclusions

Objective 3: Create and compare BANCS curve with modified NBS

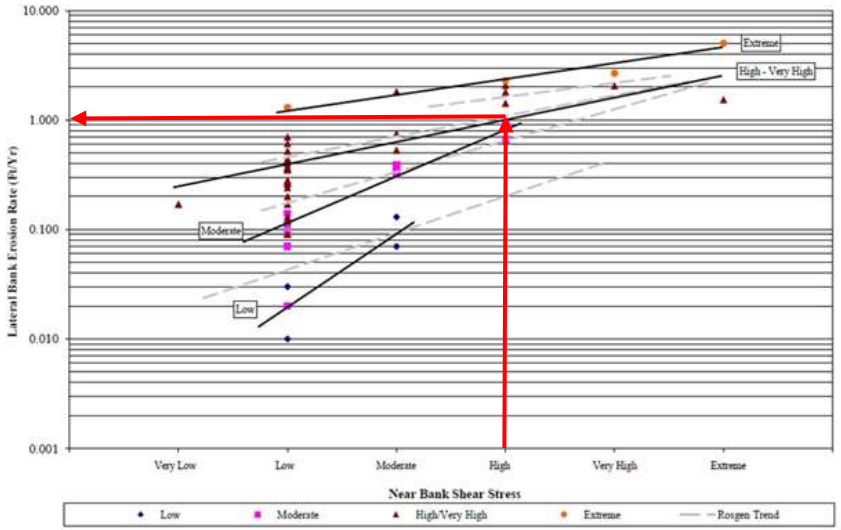
- Modified NBS has moderately more statistically significant relationships
- Weak relationship between ALL NBS and bank retreat rate
  - Bank retreat rate is dominated by other erosion processes
  - Bank retreat is just naturally variable

Objective 4:
Quantify the error of bank retreat predictions from the BANCS model

Question:
How is error affected by input erosion rate, NBS method, the use of a constructed or existing curve?

Predicted and measured erosion rates were compared as percent errors

$$Percent\ Error = \frac{|Predicted - Measured|}{Measured} \times 100$$

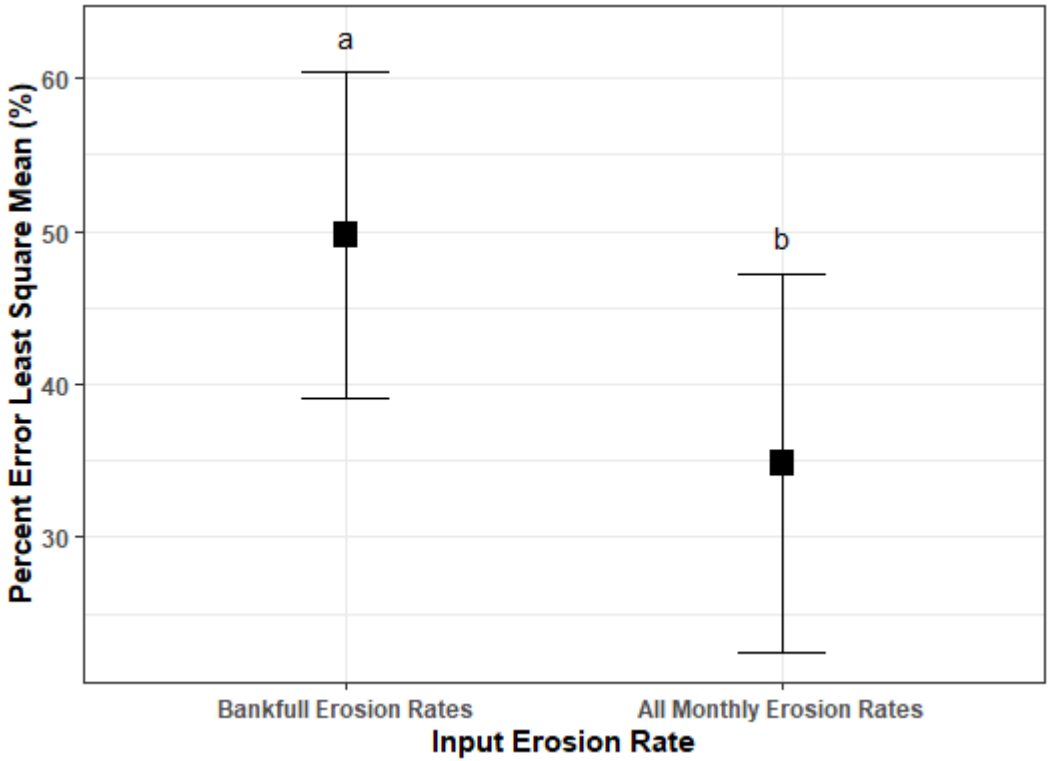


(Rathbun, 2009)

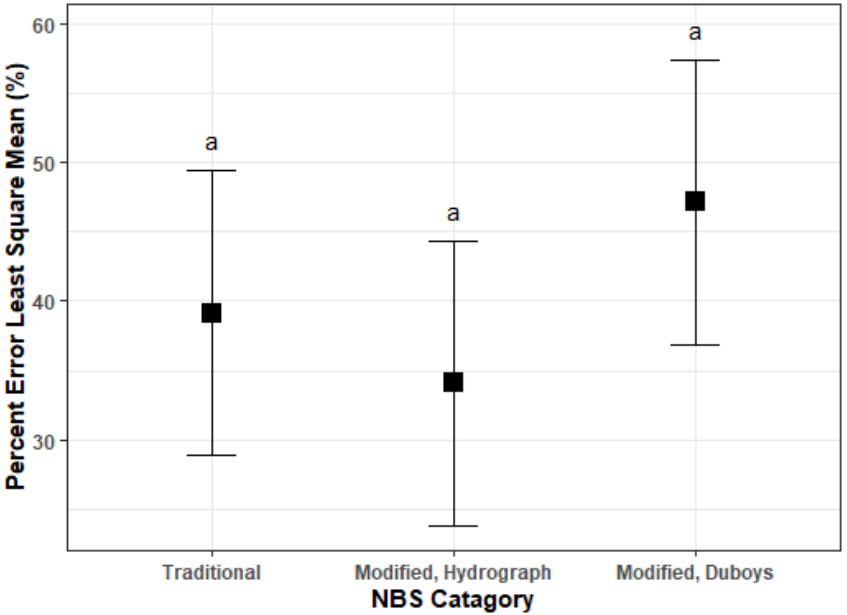
VS.

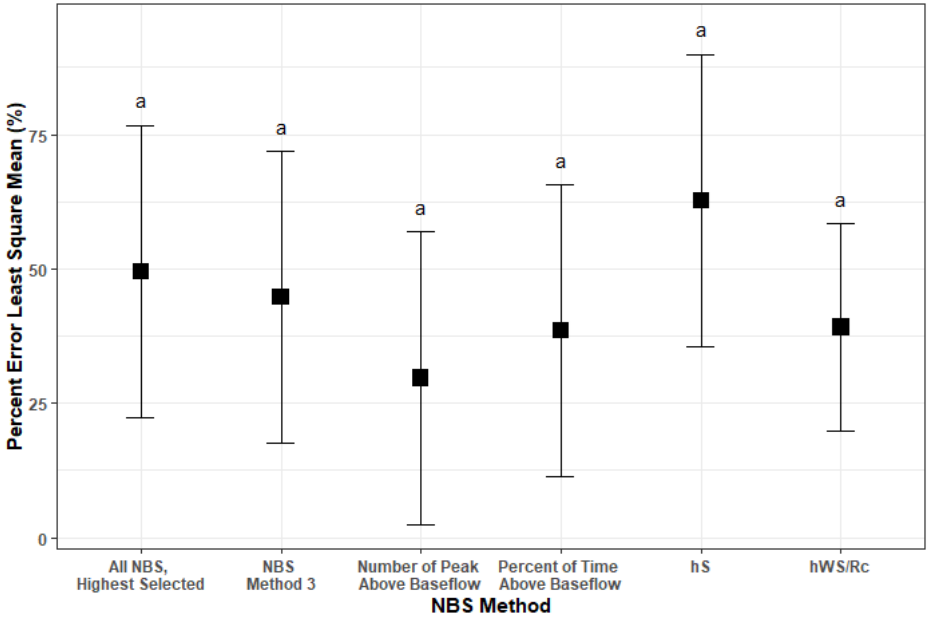
Measured pin data at TC , SC, and NFR

The bankfull erosion rate input has a higher prediction percent error

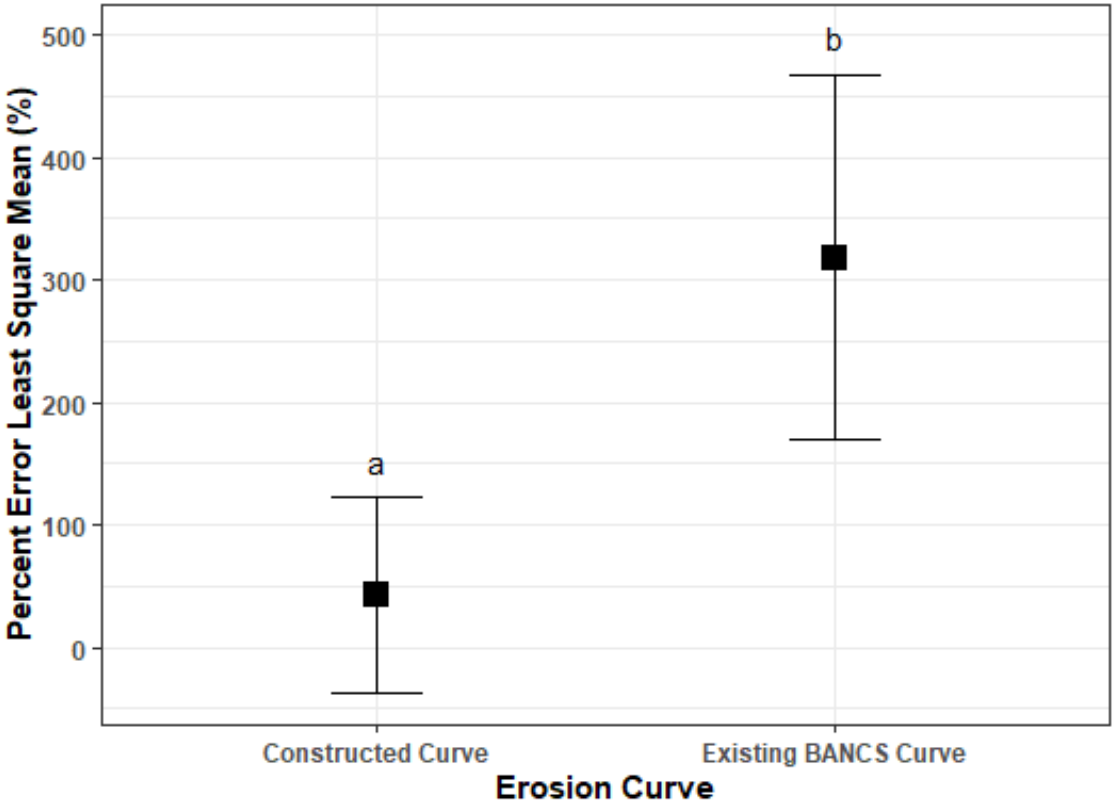


NBS categories and NBS methods predictions are not statistically different





Existing BANCS curves have much greater percent errors



Objective 4 Conclusions

Objective 4: Quantify the error of bank retreat predictions from the BANCS model

- NBS category and method did not significantly affect prediction percent error
- Predictions based on erosion curves with bankfull erosion rate input have a higher percent error
- Constructed BANCS predictions had a high percent error (95% CI: -36% to 123%)
- Applying BANCS curves created in other physiographic provinces yields higher prediction percent errors (95% CI: 169% to 467%)

Comparison to the Universal Soil Loss Equation (USLE)

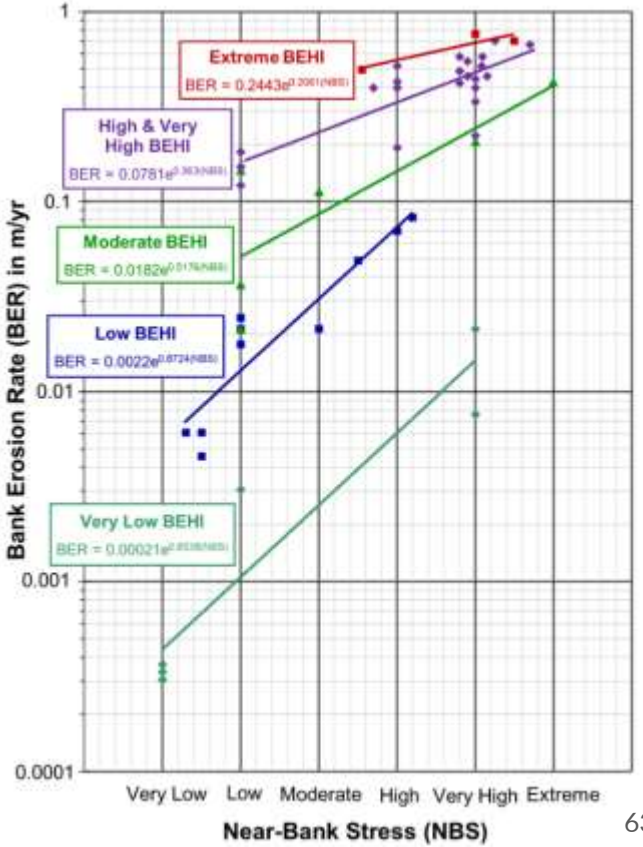
The USLE is an empirically derived model that predicts non-point source sediment erosion

$$A = R\ K\ LS\ C\ P$$

- A is the soil loss per unit area
- R is the rainfall and runoff factor
- K is the soil erodibility factor
- L is the slope-length factor
- S is the slope-steepness factor
- C is the land cover and management factor
- P is the erosion control factor

The USLE and BANCS are similar, but are treated very differently

- Similarities:
  - Empirically derived
  - Area/Region variability
- Development:
  - USLE
    - 10,000 data points over decades
    - Updated since publication (MUSLE & RUSLE)
  - BANCS
    - 3 to 22 data points per BEHI category
    - Very little change since publication
- Treatment:
  - BOTH models should be treated as a management/planning tool
- Measurement Alternatives:
  - Overland Erosion - VERY difficult
  - Bank Erosion - Plausible but time-consuming



Conclusions

Measurement Conclusions

- The PAEA method of averaging erosion rates for a grid of pins is recommended
- Measuring a single row along a bank is preferential to measuring a single column
- On a reach-scale, a measurement spacing of three channel widths is recommended
- Erosion rates can be significantly affected by seasonality
- A sampling time of 12 months is recommended to account for seasonal variability

BANCS Conclusions

- Weak relationship between ALL NBS and bank retreat rate
  - Bank retreat rate is dominated by other erosion processes
  - Bank retreat is just naturally variable
- Predictions based on erosion curves with bankfull erosion rate input have a higher percent error
- Constructed BANCS predictions had a high percent error (95% CI: -36% to 123%)
- Applying BANCS curves created in other physiographic provinces yields higher prediction percent errors (95% CI: 169% to 467%)
- BANCS should be treated as a planning tool rather than a crediting tool

Future Research

- Further testing of reach-scale erosion measurement spacing
- Creation of a NBS that better represents processes driving bank retreat

Thank you!