Evaluating and comparing channel adjustment of reference and restored streams in the North Carolina Piedmont

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Stream Restoration

- **Reference Conditions -** provide a basis for analog, empirical and analytical approaches to stream restoration design (Hey et al., 1986; Julien and Wargadalam, 1995; Rosgen, 1997; Shields et al., 2003)

Reference Streams

- Stable hydraulic geometry that represents a ***long-term*** average of a channel's form that has developed under ***relatively constant boundary conditions***

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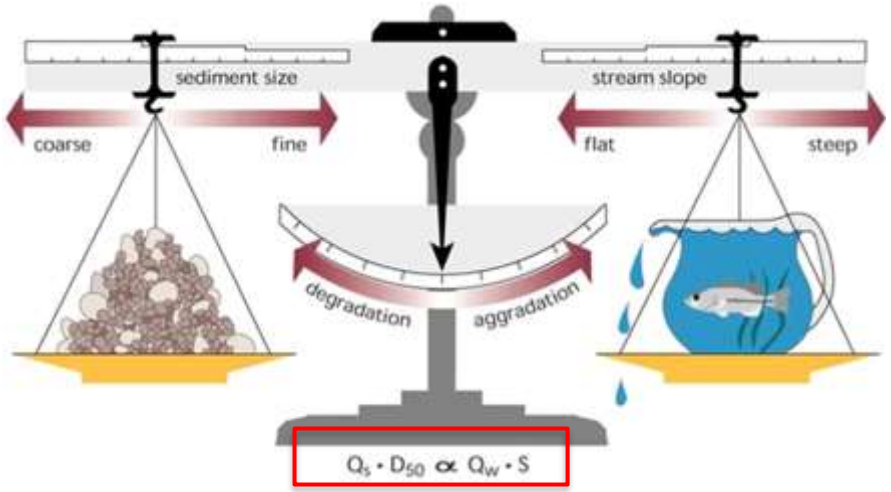
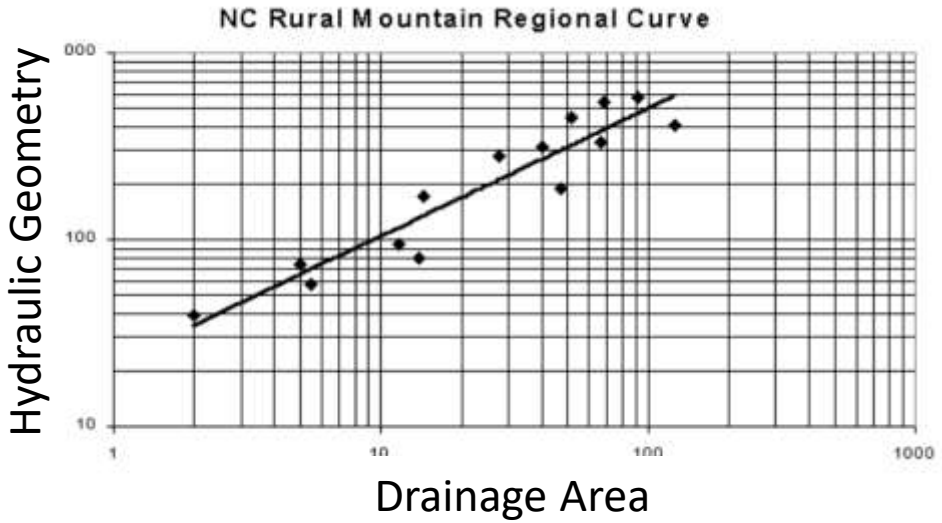


Q_s- sediment Q_w -water

Lane, 1955

Reference Streams

- "**Quasi-equilibrium**" - a condition where the stream transports water and sediment *without excessive erosion or deposition*
  - How much adjustment is expected?
  - Can we relate changes in Q_s and Q_w to changes in channel geometry ?



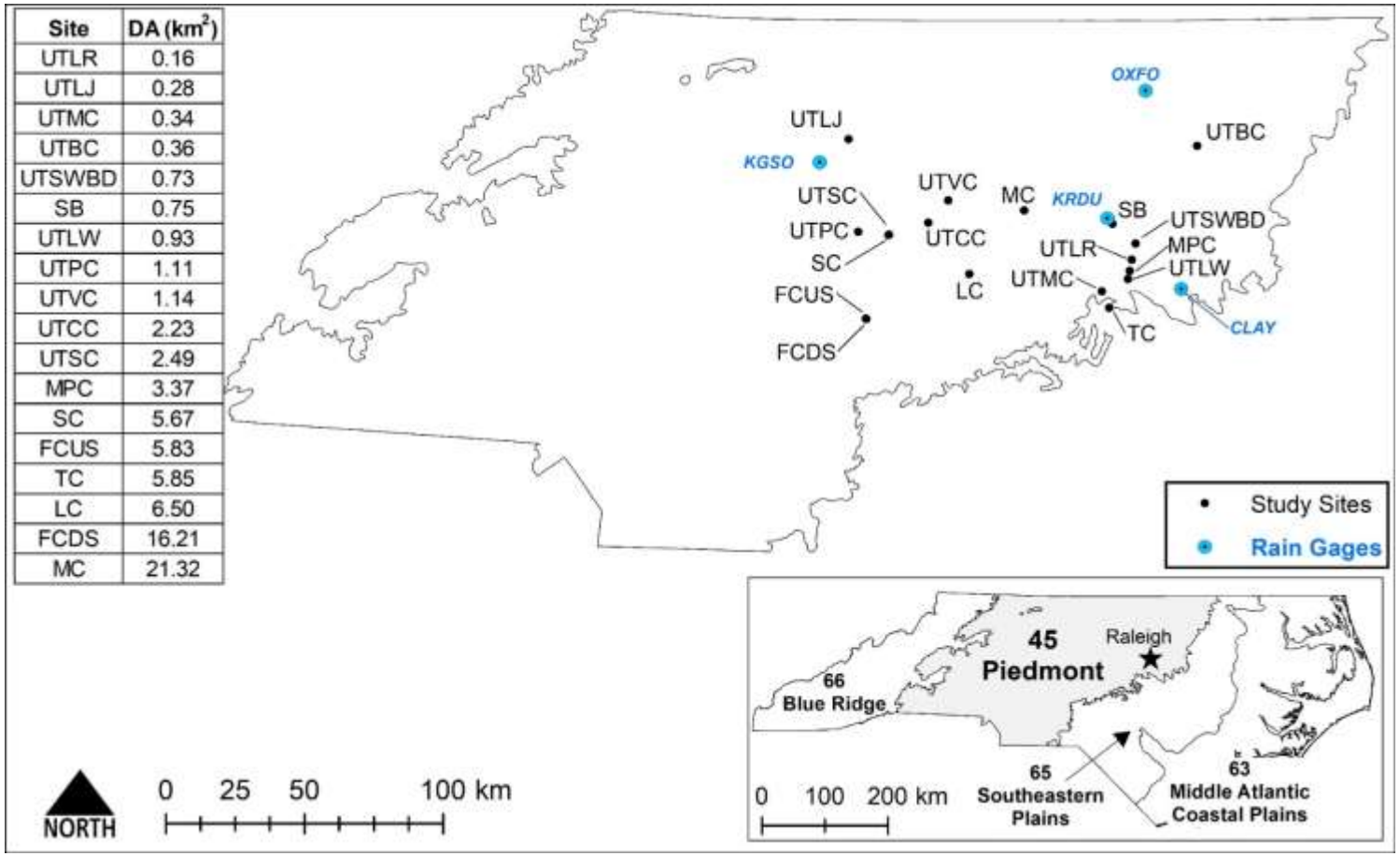
Objectives

1. *Quantify the long-term adjustment of channel geometry in reference streams*
2. *Compare to post-restoration adjustment in restored stream mitigation projects*

Project Location

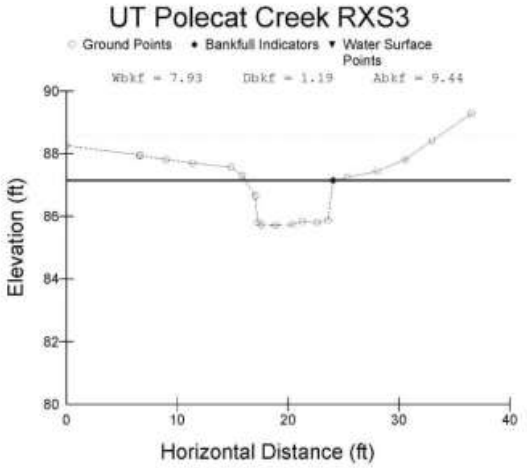
- Lowther (2008) surveyed 18 reference stream in 2007
- Resurveyed by NCSU in Winter/Spring of 2018

Site	DA (km^2)
UTLR	0.16
UTLJ	0.28
UTMC	0.34
UTBC	0.36
UTSWBD	0.73
SB	0.75
UTLW	0.93
UTPC	1.11
UTVC	1.14
UTCC	2.23
UTSC	2.49
MPC	3.37
SC	5.67
FCUS	5.83
TC	5.85
LC	6.50
FCDS	16.21
MC	21.32

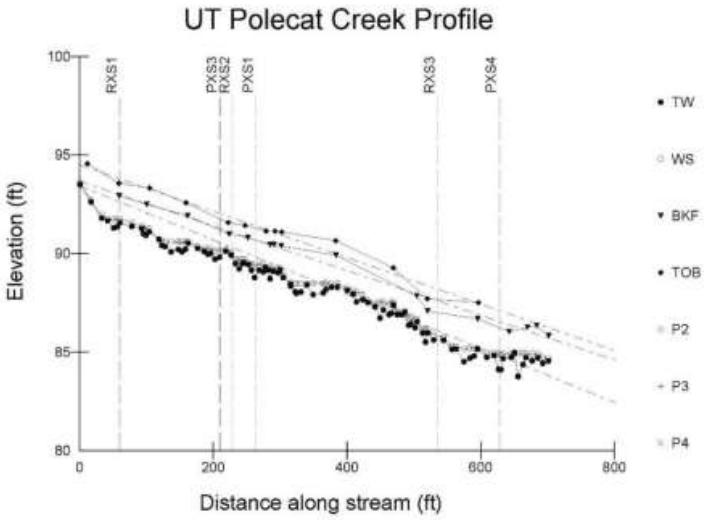


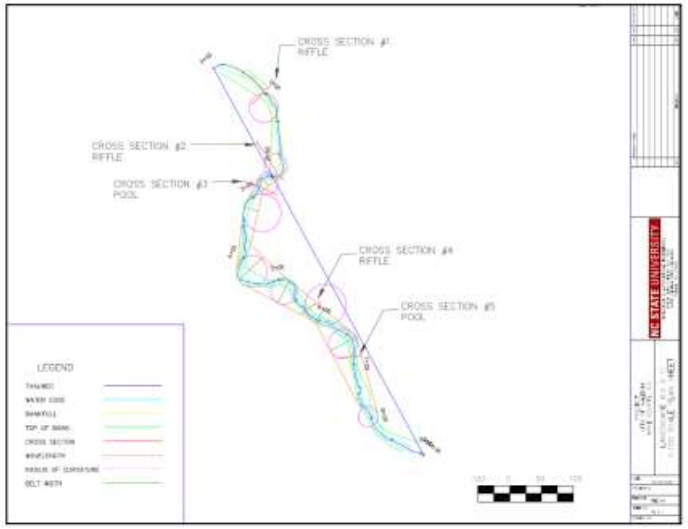
2018 Surveys

- Survey
  - Cross sections, Long Pro, Pattern, Pebble Counts, Bank Erosion



- Calculations
  - $\Delta HG_{bkf} = \frac{HG_{bkf}^{2018} - HG_{bkf}^{2007}}{HG_{bkf}^{2007}}$
  - Q_{bkf}



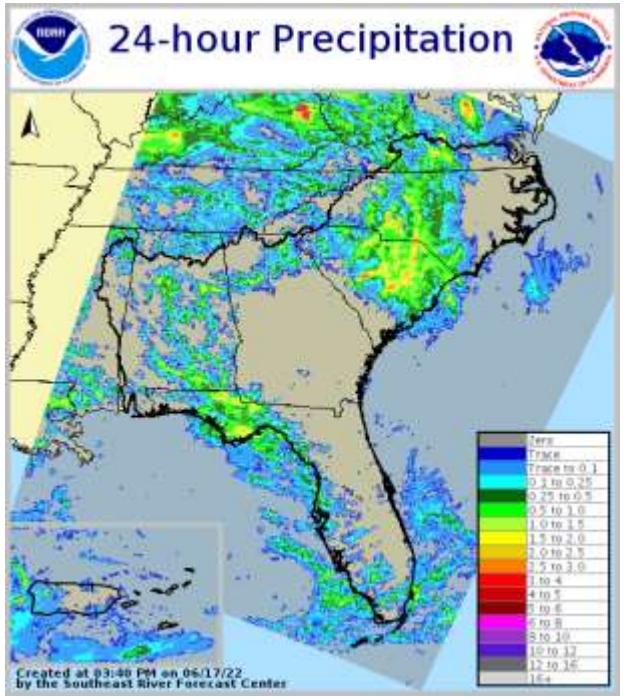


Evaluating Changes in Boundary Conditions

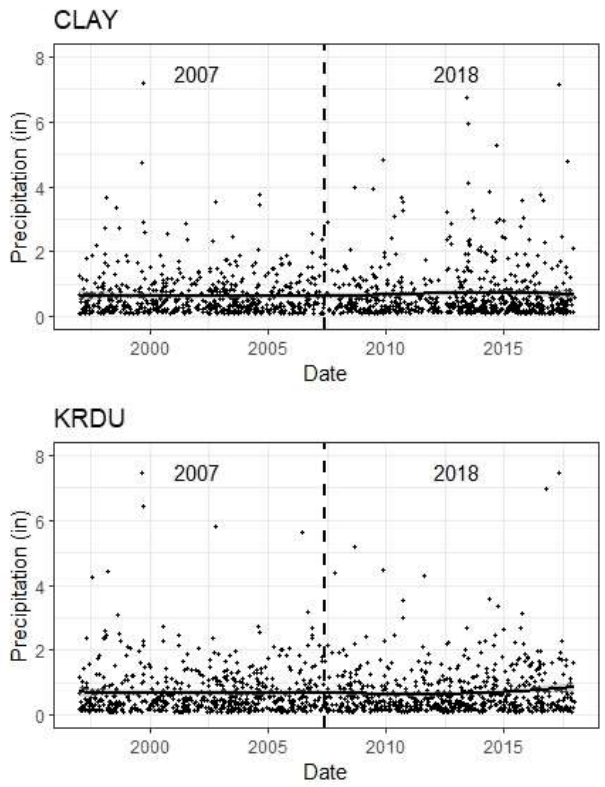
- Changes in Q_w (hydrology) or changes in Q_s (sediment)

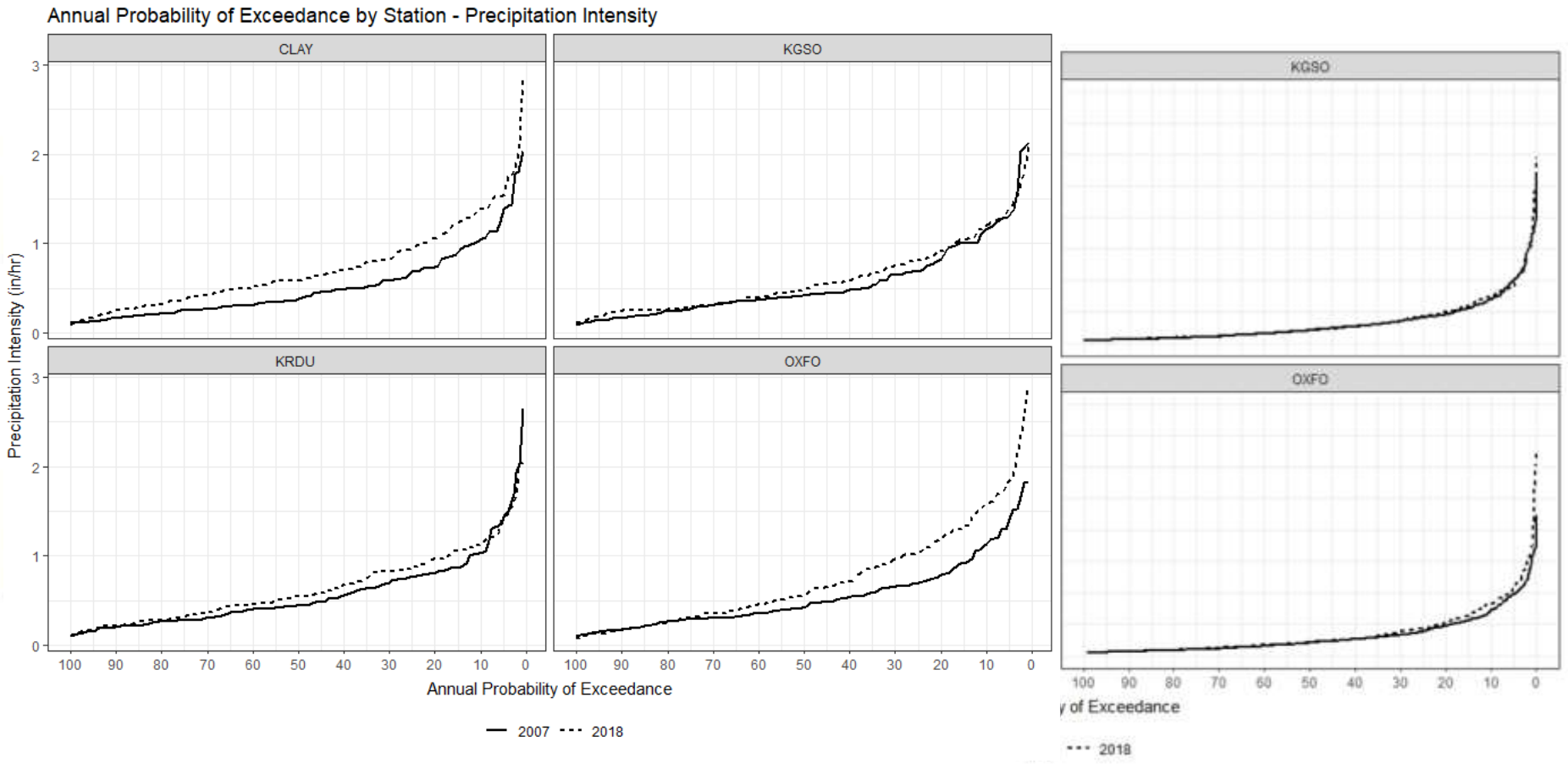
Impervious Cover

Land Cover



Results - Rainfall

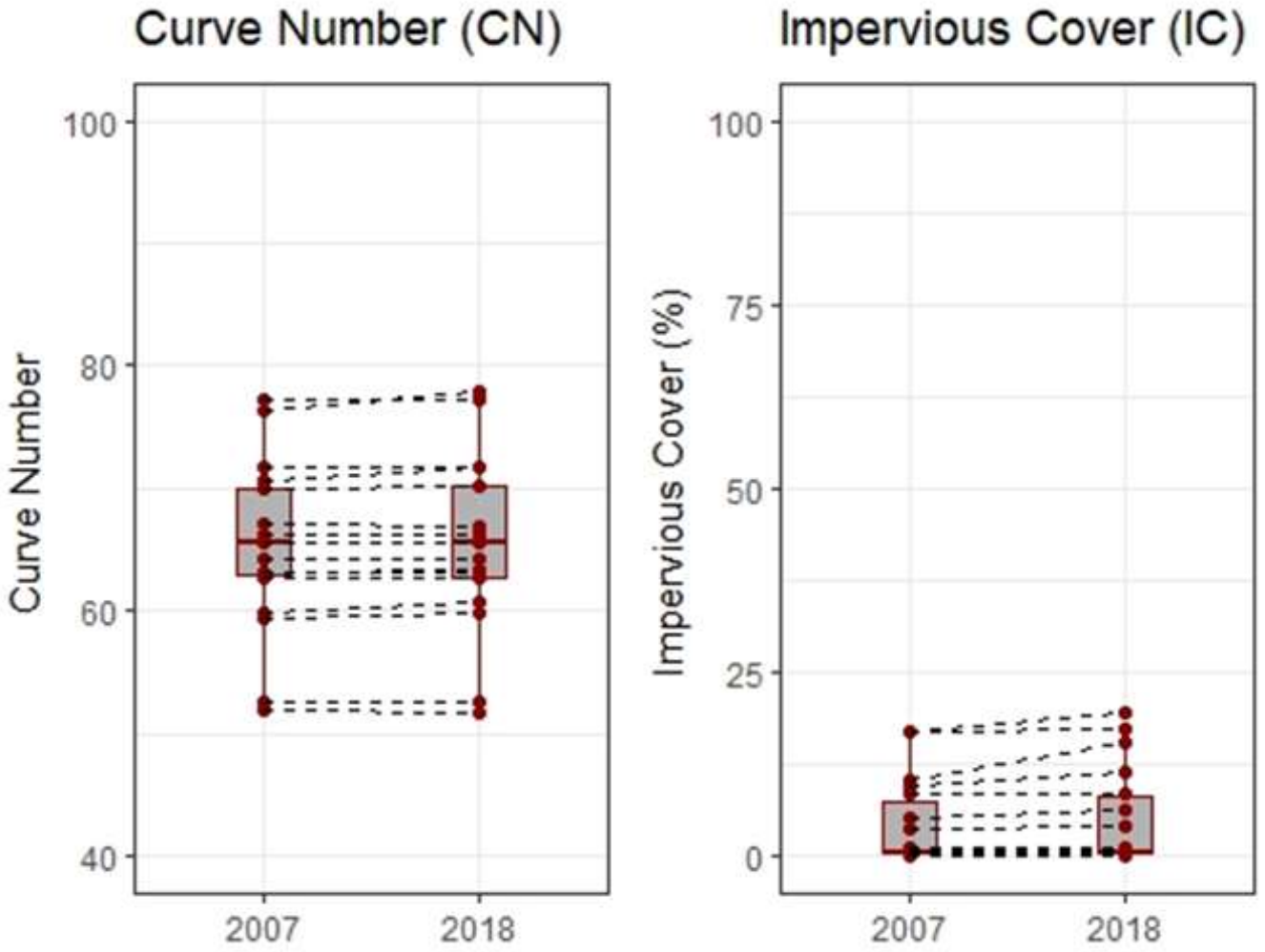




- No systematic shift in rainfall patterns for 10 year prior to survey
- Potential spatially variable increases in peak storm intensity

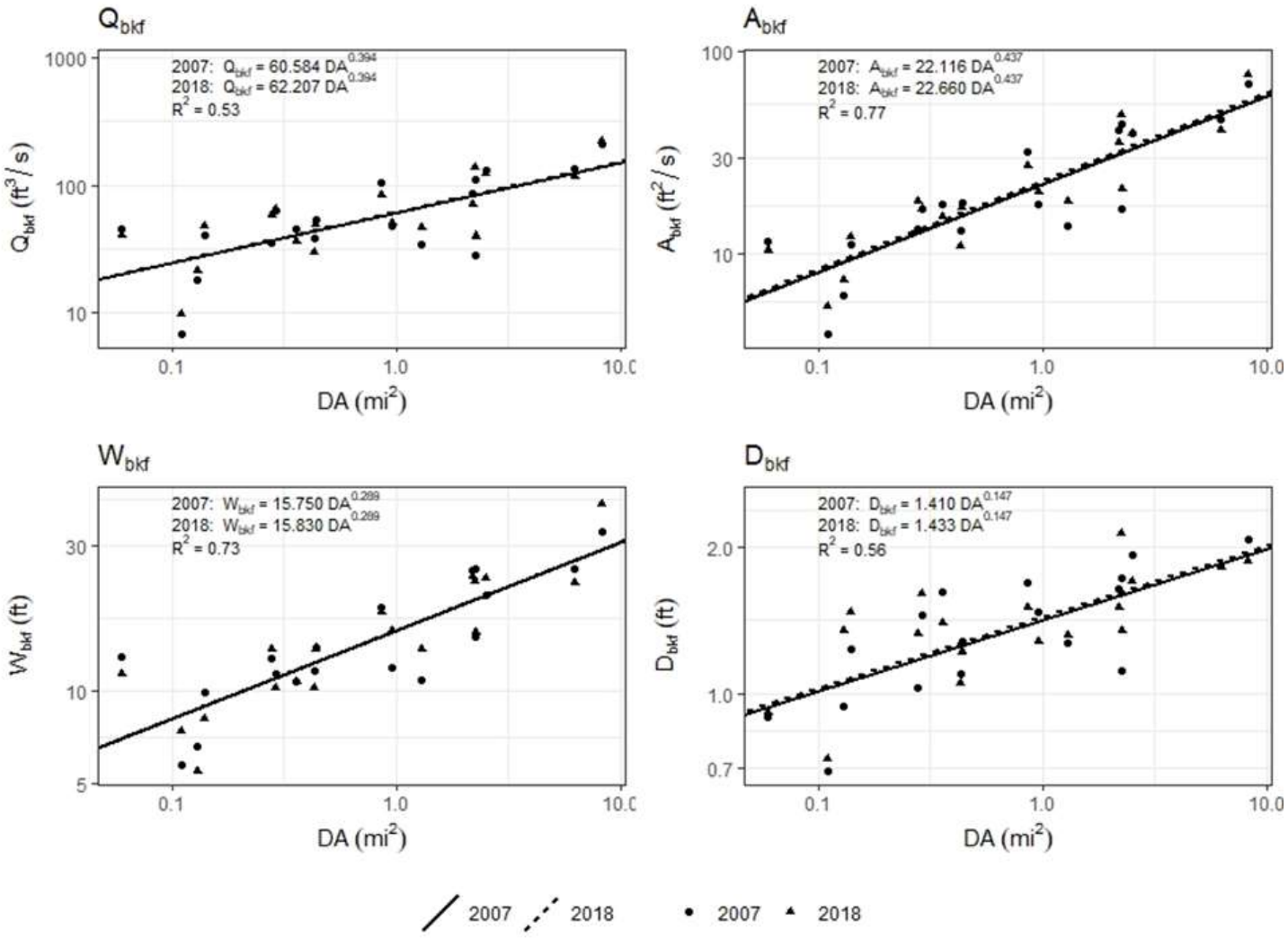
Results - Land Cover Changes

- Changes in Q_w, Q_s
- Mostly minor changes
- Rapidly developing Raleigh-Durham

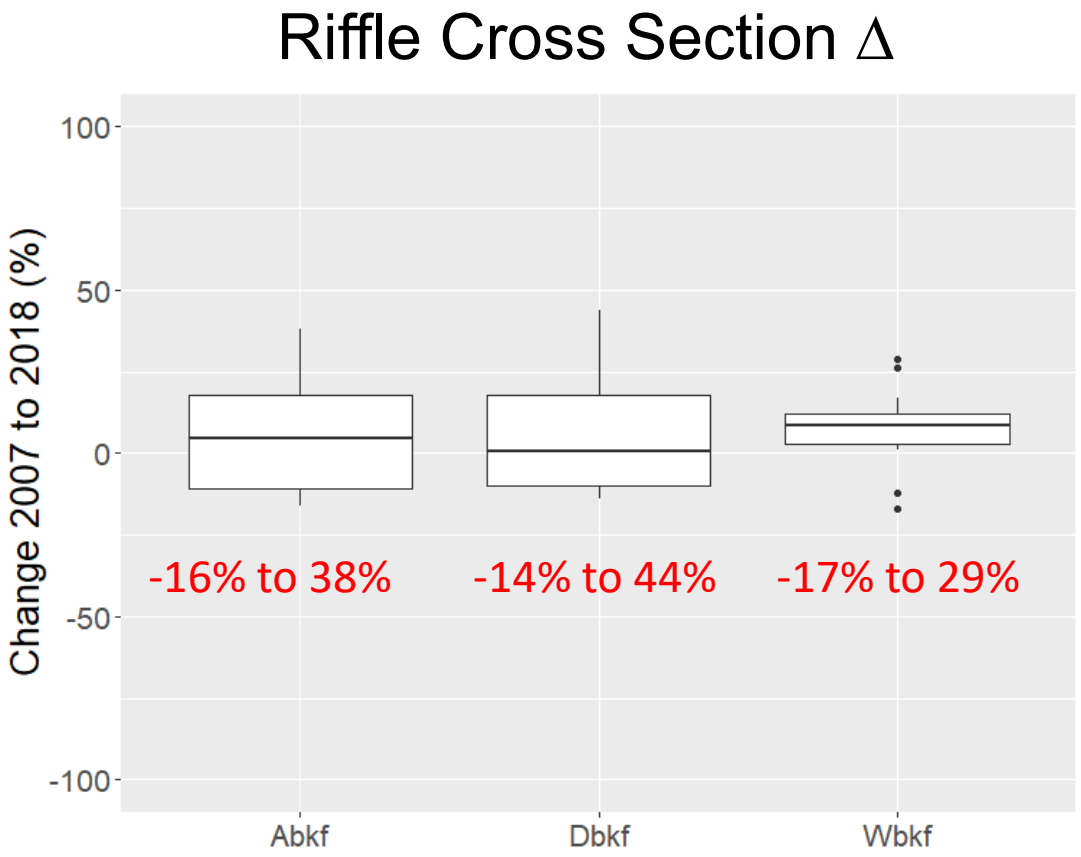


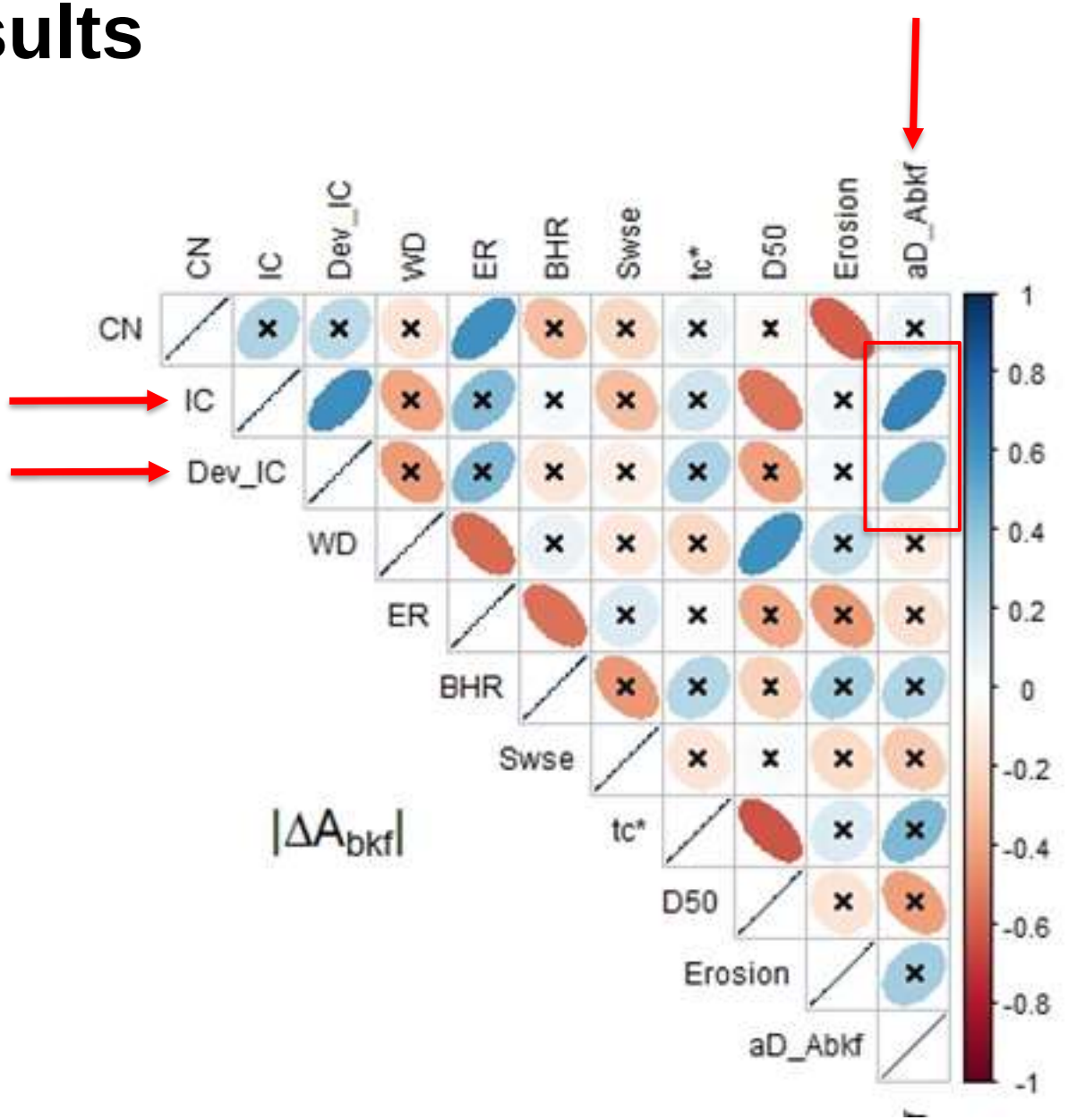
Results – Riffle Cross Sections

- Regional curve comparison
  - No difference ($p<0.01$)

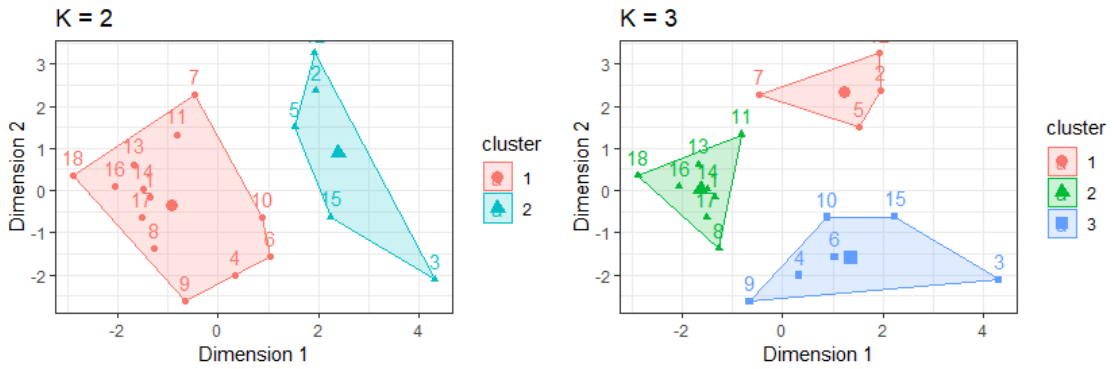


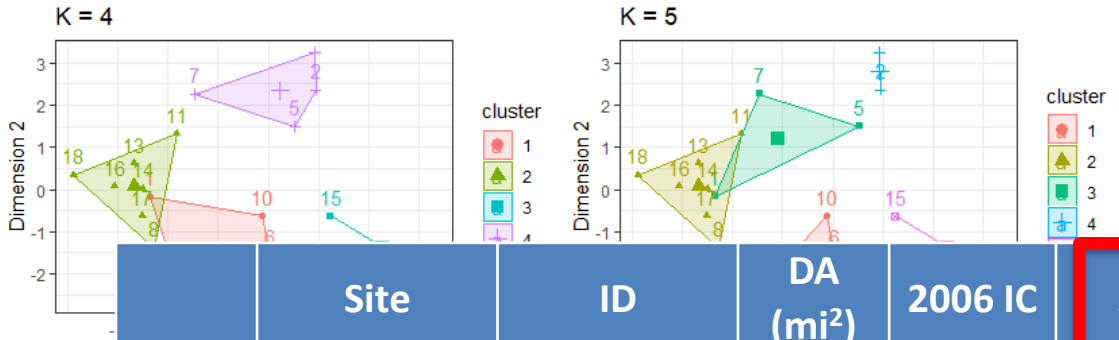
Results


Riffle Cross Section Δ
Change 2007 to 2018 (%)
100
50
0
-50
-100
-16% to 38%
-14% to 44%
-17% to 29%
Abkf
Dbkf
Wbkf


CN
IC
Dev_IC
WD
ER
BHR
Swse
tc*
D50
Erosion
aD_Abkf
|ΔAbkf|
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

Cluster Analysis





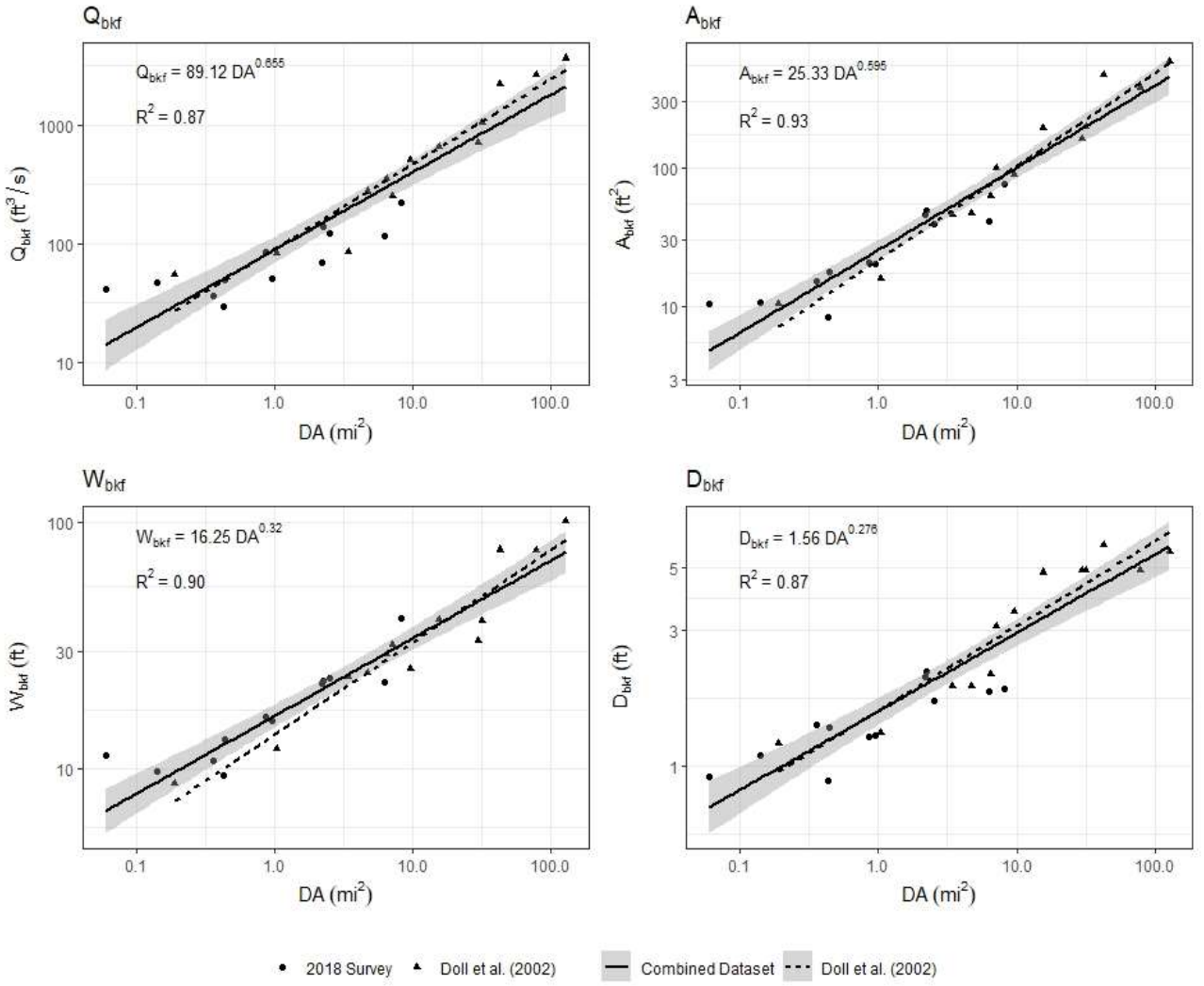
	Site	ID	DA (mi²)	2006 IC	Δ IC	t*	WDR	ER	BHR	% Eros.	Δ A_{bkf}
1					Cluster 1 Summary						
	Minimu									0.03	0%
	Mean									0.13	10%
	Maximu									0.36	16%
2					Cluster 2 Summary						
	Minimu									0.03	19%
	Mean									0.17	30%
	Maximu									0.35	38%

Quasi-Equilibrium

Disequilibrium

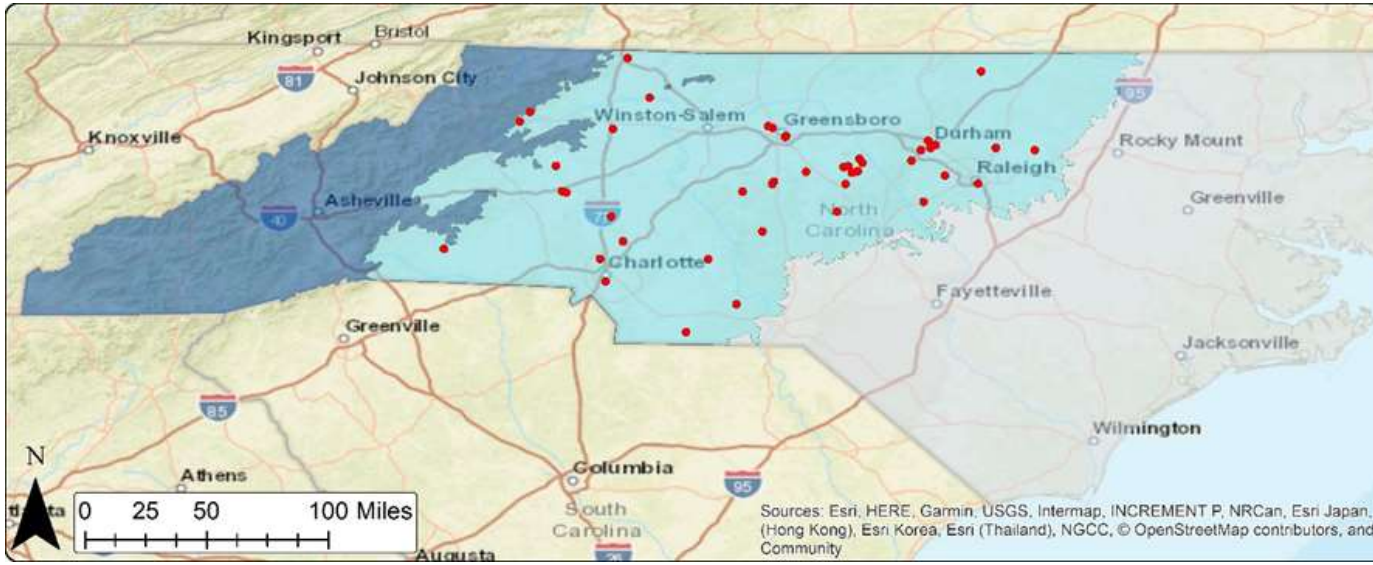
Results – Reference Streams

- "Quasi-Equilibrium"
  - $\Delta\ |A_{bkf}| < \sim 15\%$
- "Disequilibrium"
  - $\Delta\ |A_{bkf}| \sim > 20\%$
  - Higher IC and increasing IC



Restored Sites

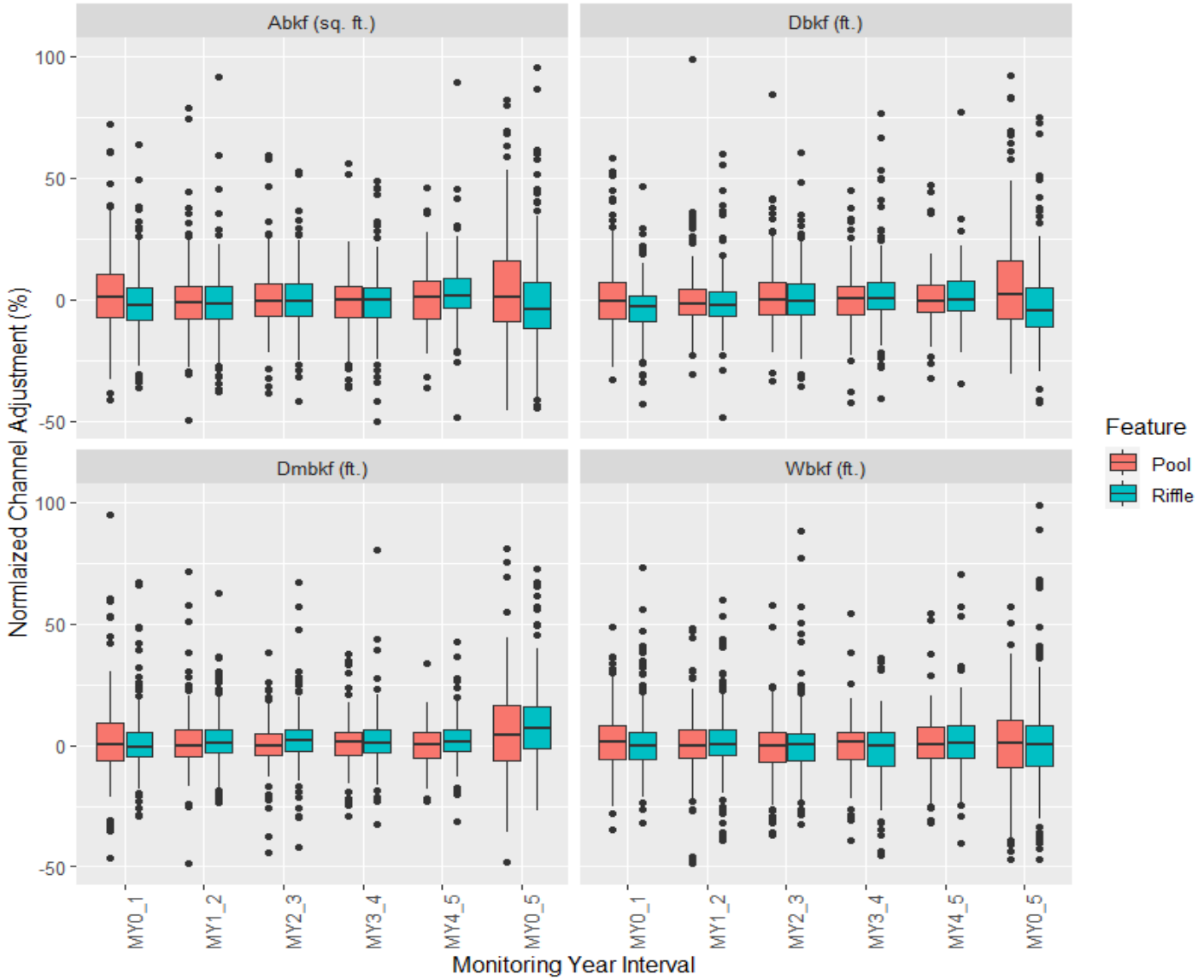
- NC Division of Mitigation Services
  - 44 projects
    - 205 riffle cross sections
    - 6 years of data



- ΔA_{BKF}, ΔW_{BKF}, ΔD_{BKF}, Tw_{elev}
- Variables
  - DA, WS CN, slope, W/D, K, ER, etc.

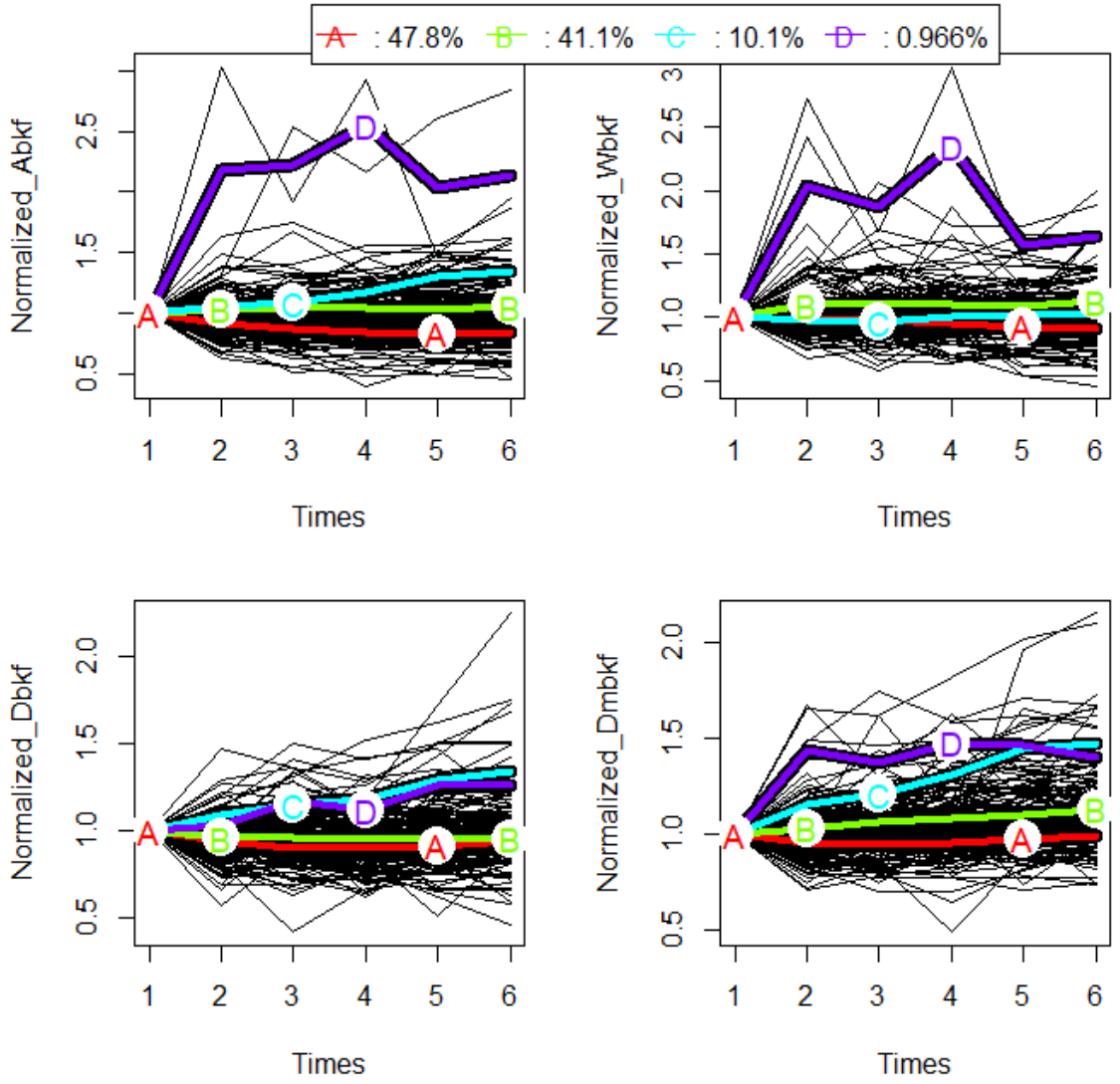
Channel Adjustment in Restored Streams

- Median absolute adjustment of 11% from as-built to year 5
- Range of -50% to 200%
- Less than 25% area adjustment in 80% of cross sections



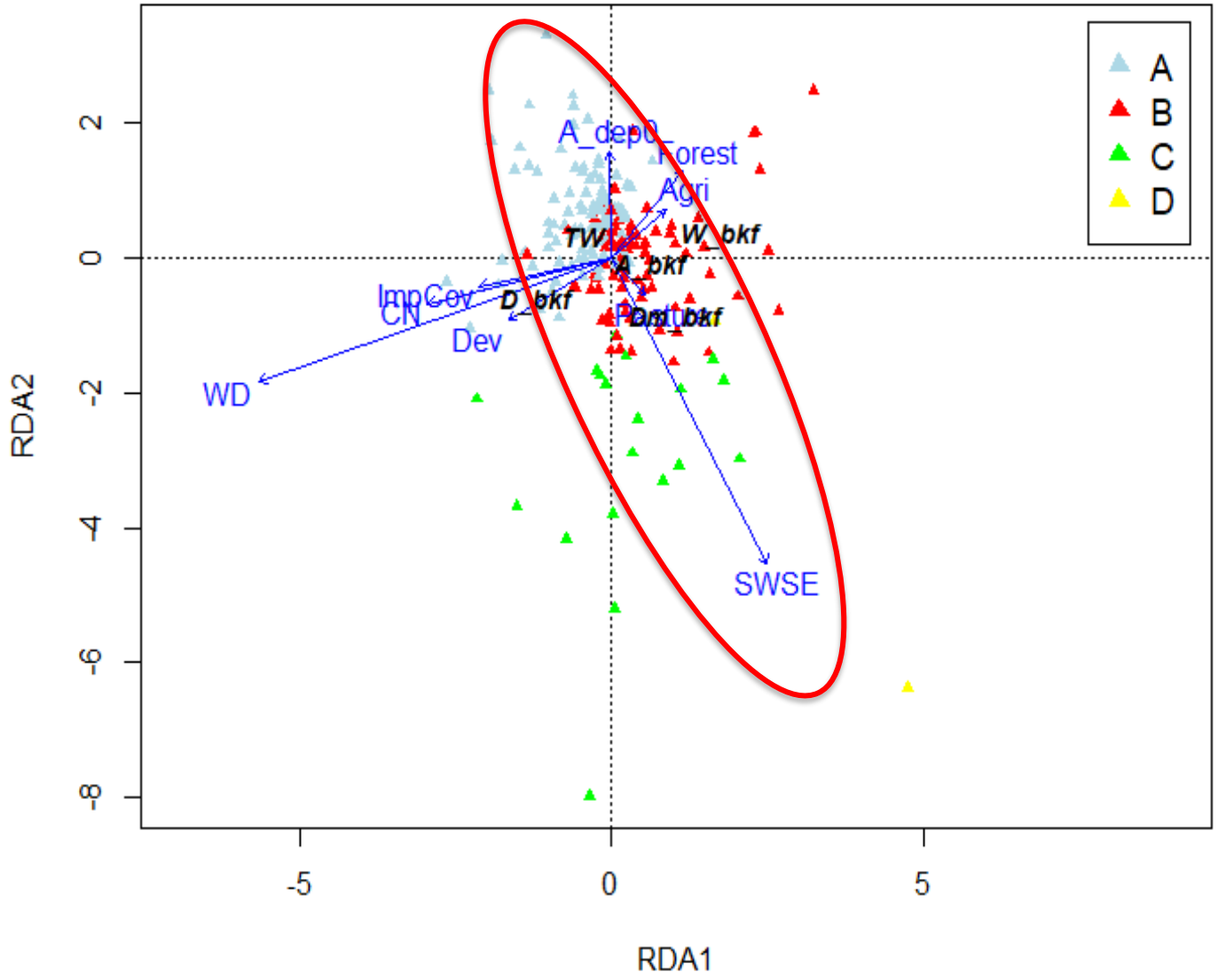
Clustering of Channel Trajectories

- A: 48% minor aggradation
- B: 41% minimal change
- C: 10% Incision
- D: 1% Incision and widening

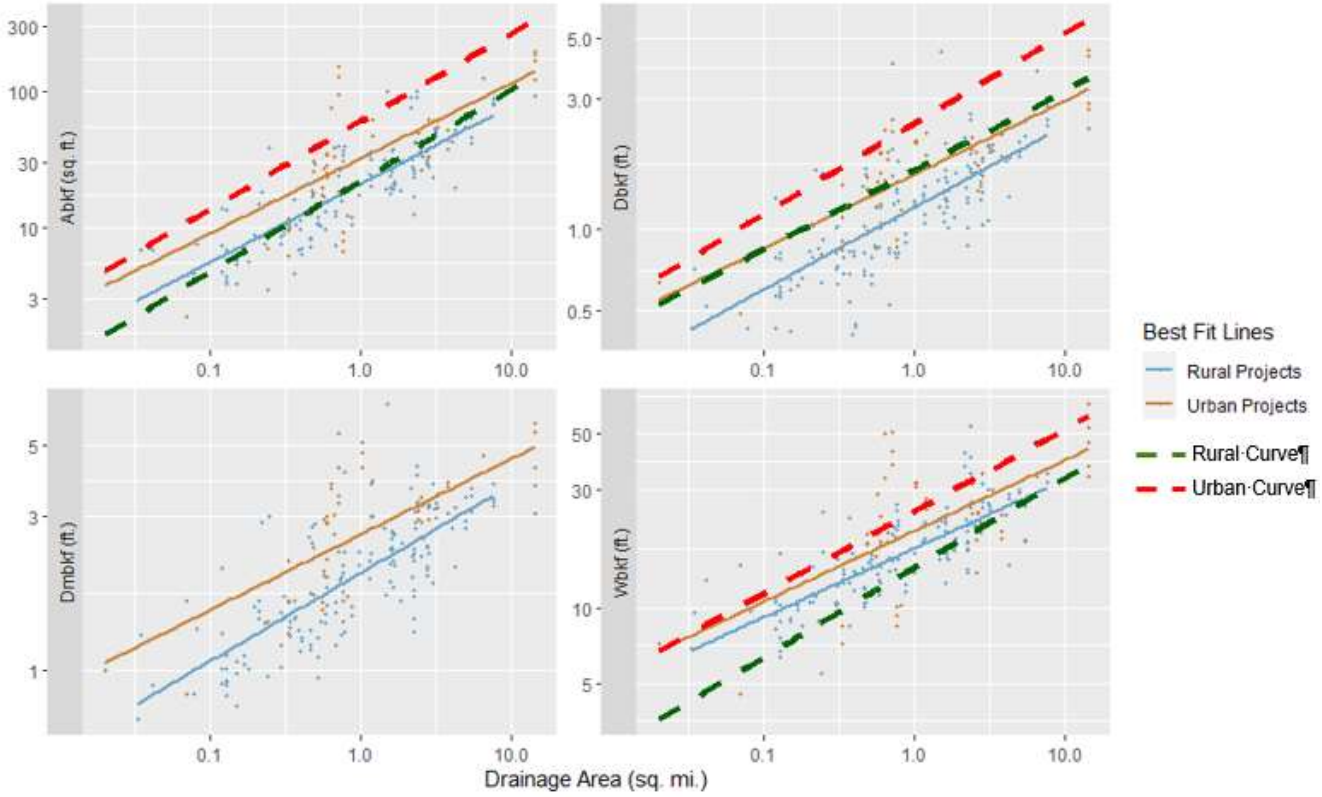


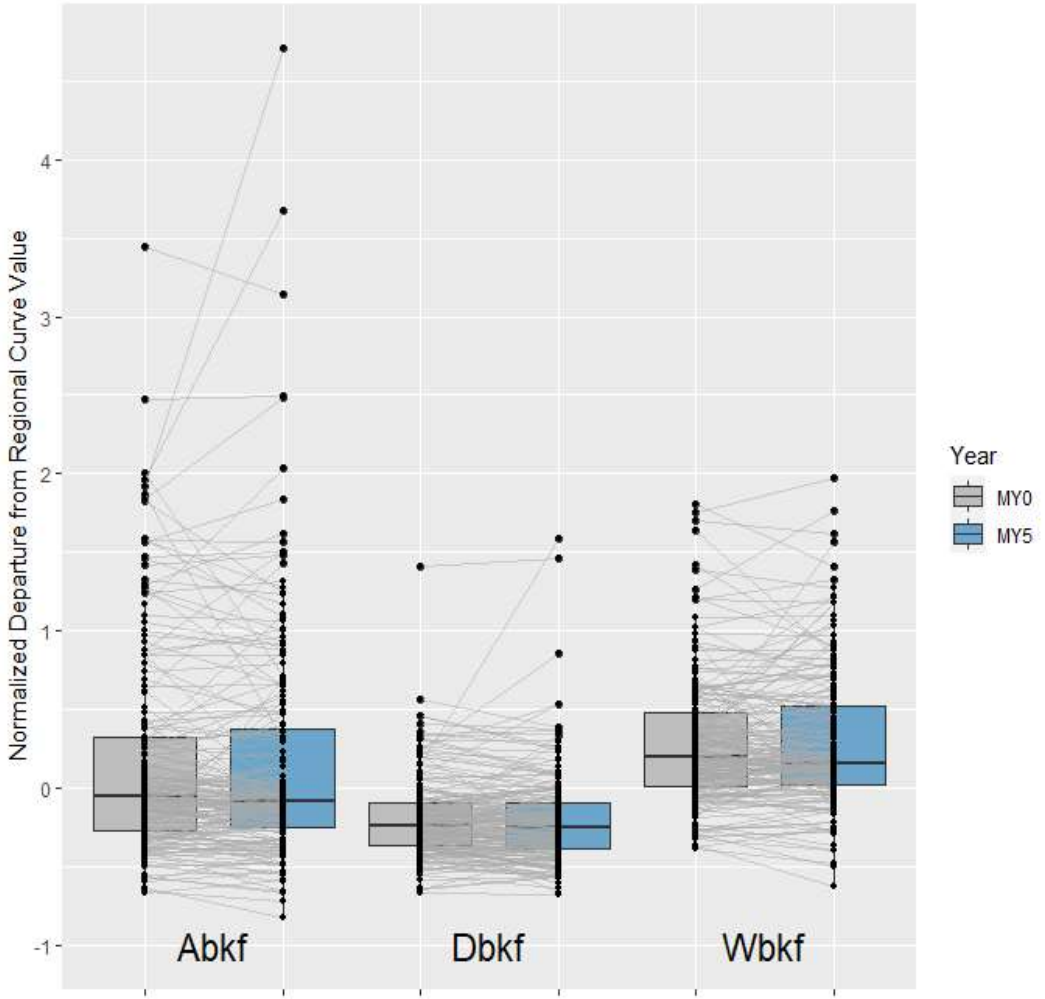
Predicting Channel Adjustment

- Mixed Linear Models
  - ➢ $y = \beta X + uZ + \epsilon$
  - – $R^2 < 0.1$
- Redundancy analysis

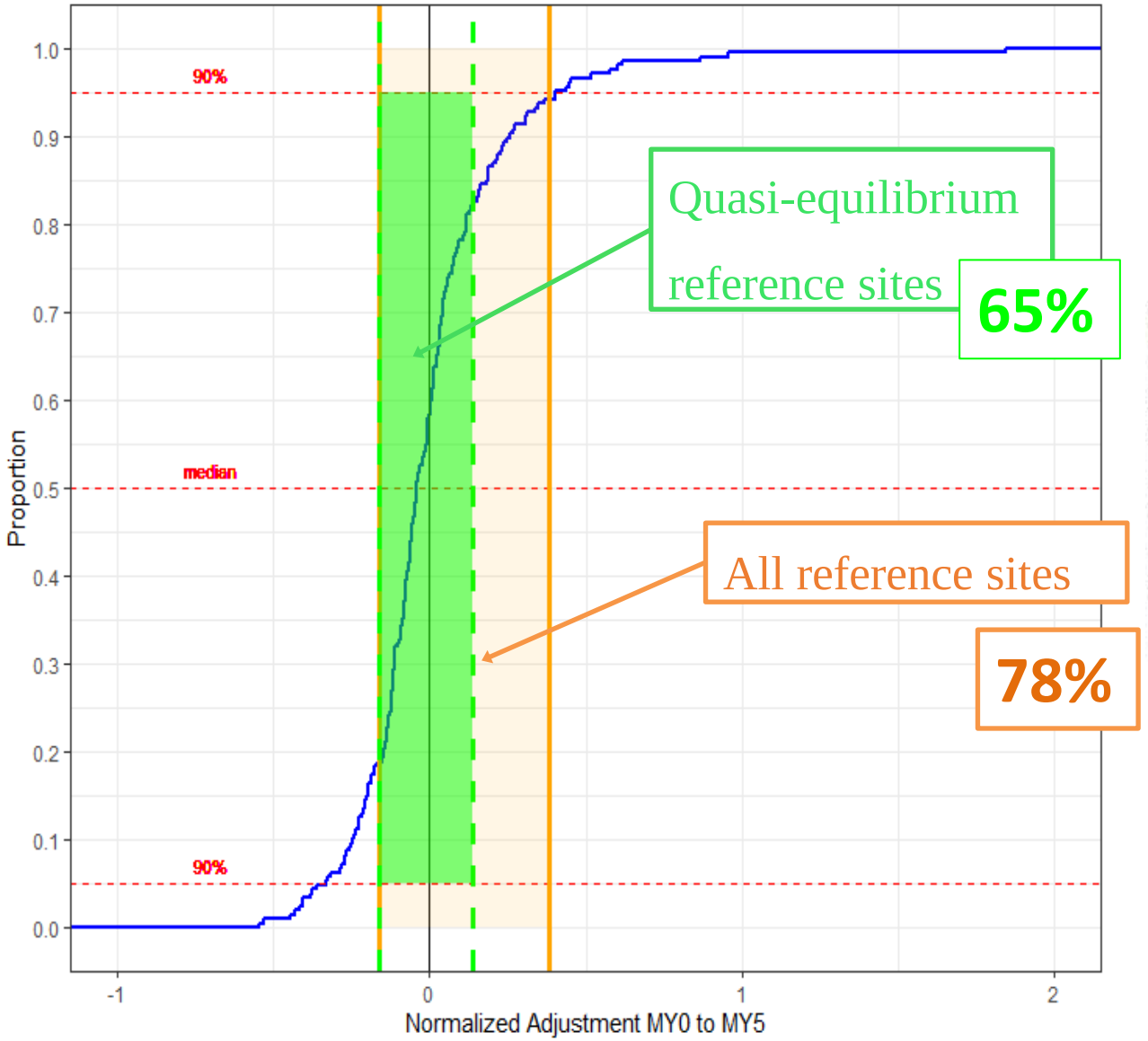


Comparisons to Regional Curves





Comparison of Restored Sites to Reference

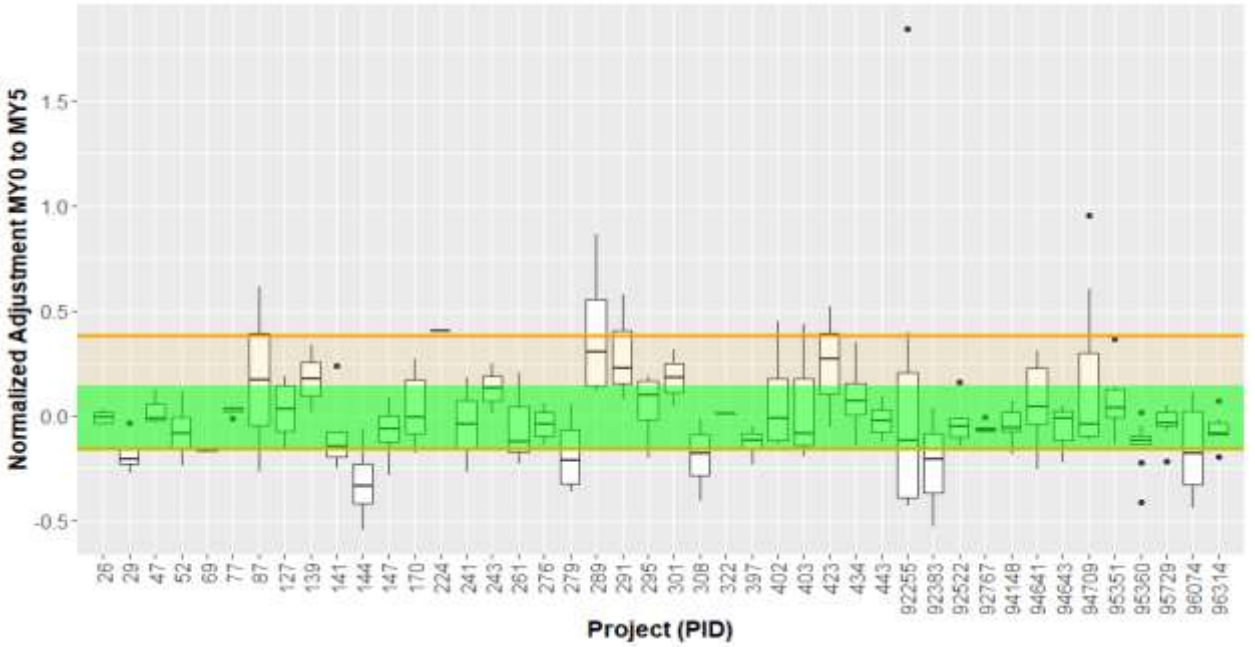


Quasi-equilibrium reference sites

65%

All reference sites

78%



Conclusions

Reference Streams

- No systematic shift in hydraulic geometry for reference streams

- ΔA_{bkf} was significantly correlated with Impervious Cover (IC) and increasing IC - changes to boundary conditions – Q_w and Q_s

Restored streams

  - Median absolute adjustment in channel area ~10%
  - Large range observed – greater in pools
  - Predicting adjustment with current data set not possible
- 65% of restored cross section adjustment within reference range
- Adjustment << previous studies ☺

Questions?

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