

# Assessing the Impact of Culvert Design on Three Ecosystem Functions in Northern Wisconsin Streams

James Olson<sup>1</sup>, Amy Marcarelli<sup>1</sup>, Sue Eggert<sup>2</sup>, Anne Timm<sup>2</sup>,  
Randy Kolka<sup>2</sup>

<sup>1</sup>Michigan Technological University

<sup>2</sup>USDA Forest Service



# Stream Restoration

- The most common restorations try to rehabilitate hydrologic connectivity or habitat heterogeneity
- Restoration projects are most often evaluated using ecosystem structure measurements



<http://peakwater.org/tag/dam-removal/>



<http://www.fws.gov/mountain-prairie/pfw/r6pfw2h.htm>

# Ecosystem Structure vs. Function

“Ecosystem processes are the transfers of energy and materials from one pool to another”

Chapin et al. 2011

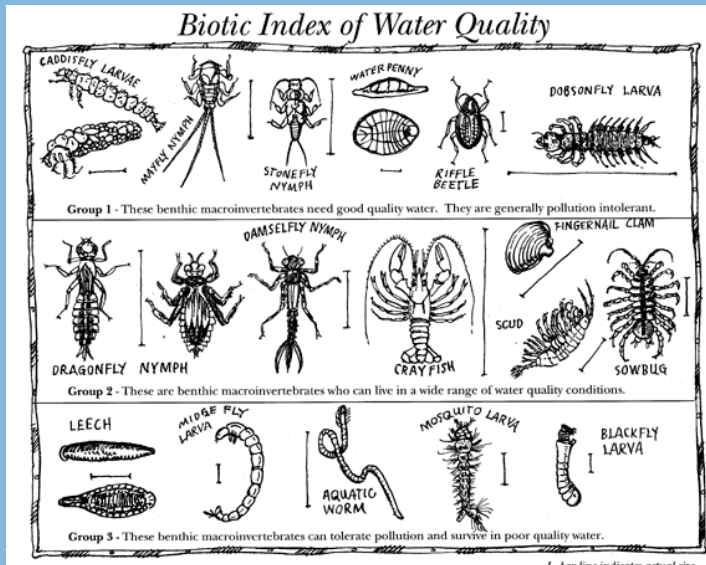
## Ecosystem structures

- Richness
- Biomass
- Abundance

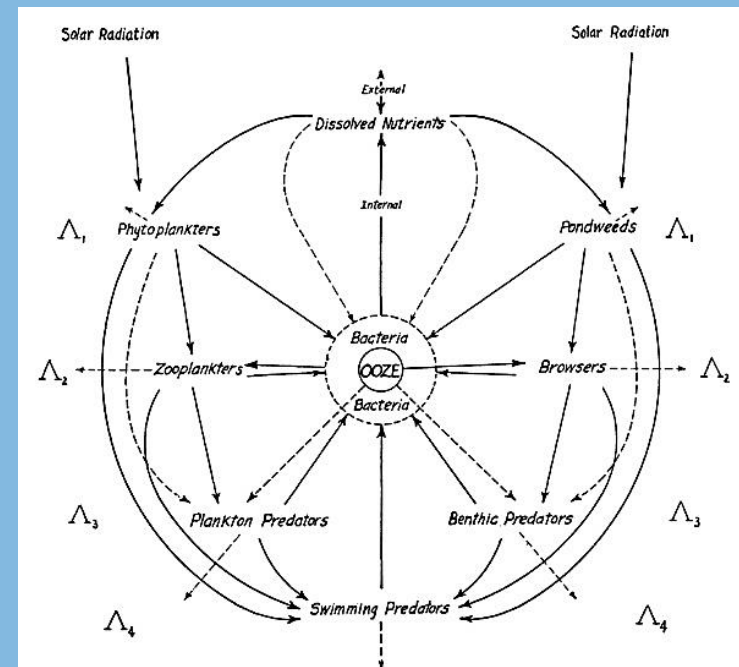


## Ecosystem functions

- Production
- Respiration
- Nutrient uptake



Lindemann 1942





# Culvert Issues



- Culverts can be barriers to aquatic organism movement
- Poorly designed culverts can alter natural stream flow and the balance between erosion and sedimentation



Photo Credits:  
S. Eggert



Non-Replaced



# Culvert Designs

- Stream simulation culverts are designed to improve hydrologic characteristics, aquatic organism passage, and ecosystem functions

Partial Stream Simulation



Full Stream Simulation





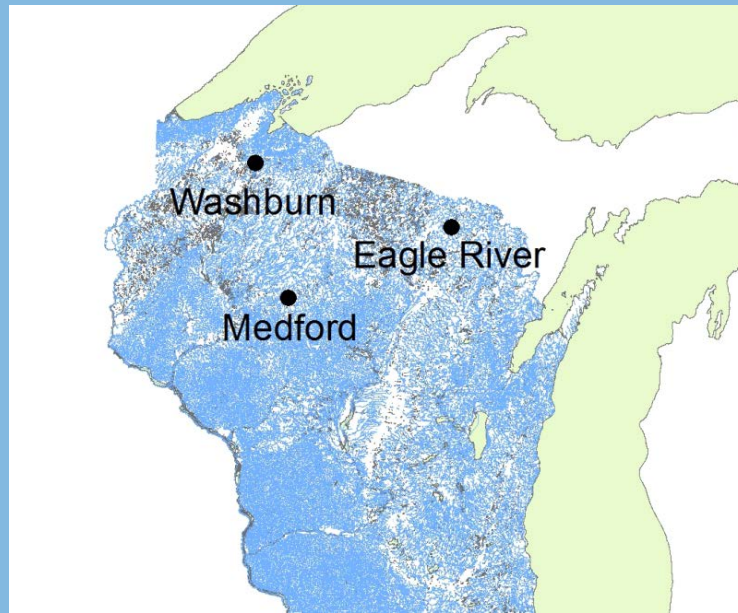
# Objective

- To evaluate the effectiveness of stream simulation culvert designs for restoring or maintaining ecosystem functions



# Two Comparisons

- Full Stream Simulation vs. Partial Stream Simulation
  - 6 streams (3 Full and 3 Partial)
  - 3 ecosystem functions
- Stream Simulations vs. Non-Replaced
  - 15 streams (5 Full, 6 Partial, 4 Non-replaced)
  - 2 ecosystem functions



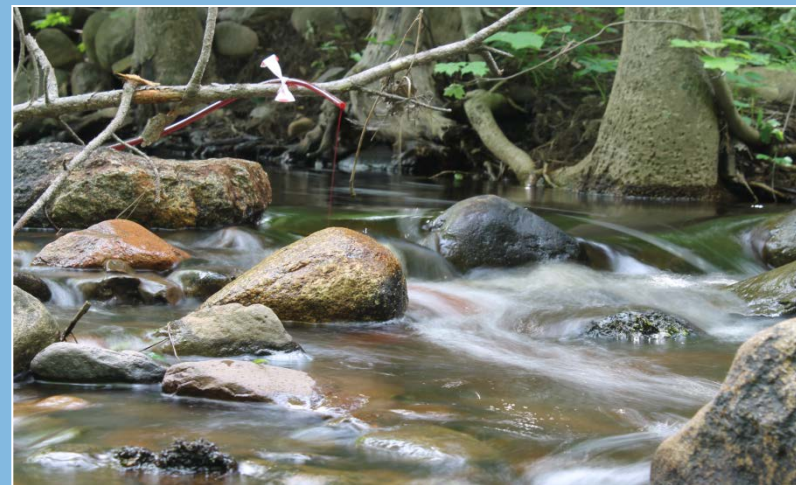
# Three Ecosystem Functions

- Hydrologic Connectivity →



- Nutrient Uptake

- Coarse Particulate Organic Matter (CPOM) Retention





# Full Stream Sim vs. Partial Stream Sim

## Hypotheses:

- Nutrient uptake velocity will be more similar upstream and downstream of full stream simulation culverts compared to partial stream simulation culverts
- Hydrologic connectivity and CPOM retention will be more similar upstream, through and downstream of full stream simulation culverts compared to partial stream simulation culverts

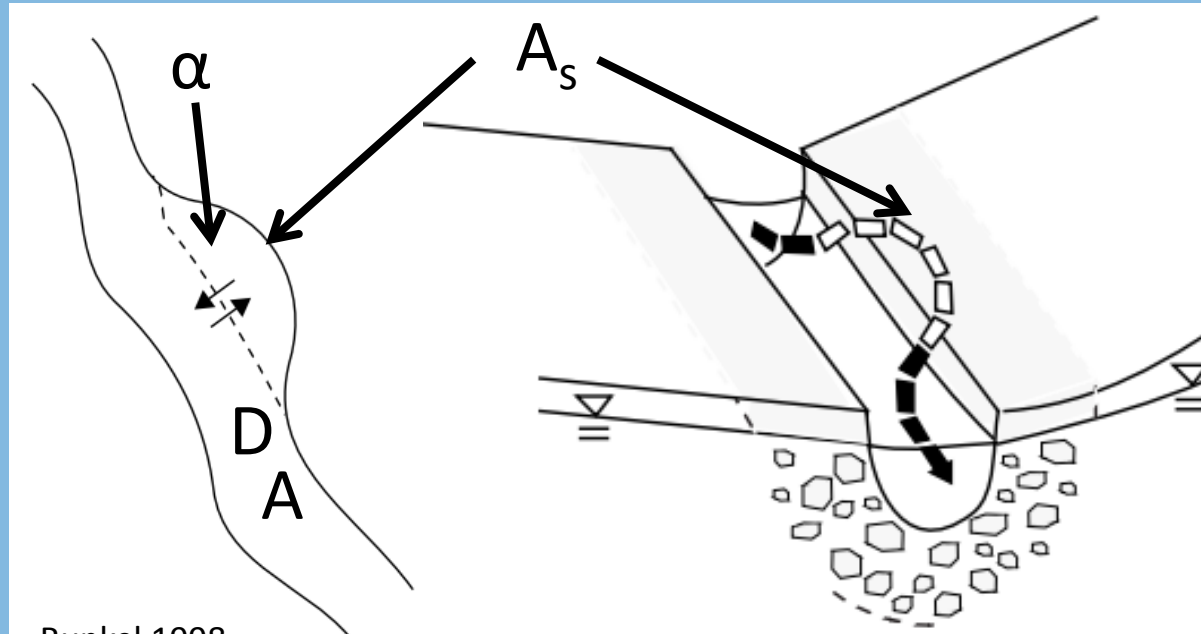


# Hydrologic Connectivity

- Transient storage characteristics estimated with One Dimensional Transport with Inflow and Storage (OTIS) Model

$$\frac{\partial C}{\partial t} = -\frac{Q}{A} \frac{\partial C}{\partial x} + \frac{1}{A} \frac{\partial}{\partial x} \left( AD \frac{\partial C}{\partial x} \right) + \frac{q_{LIN}}{A} (C_L - C) + \alpha (C_S - C)$$

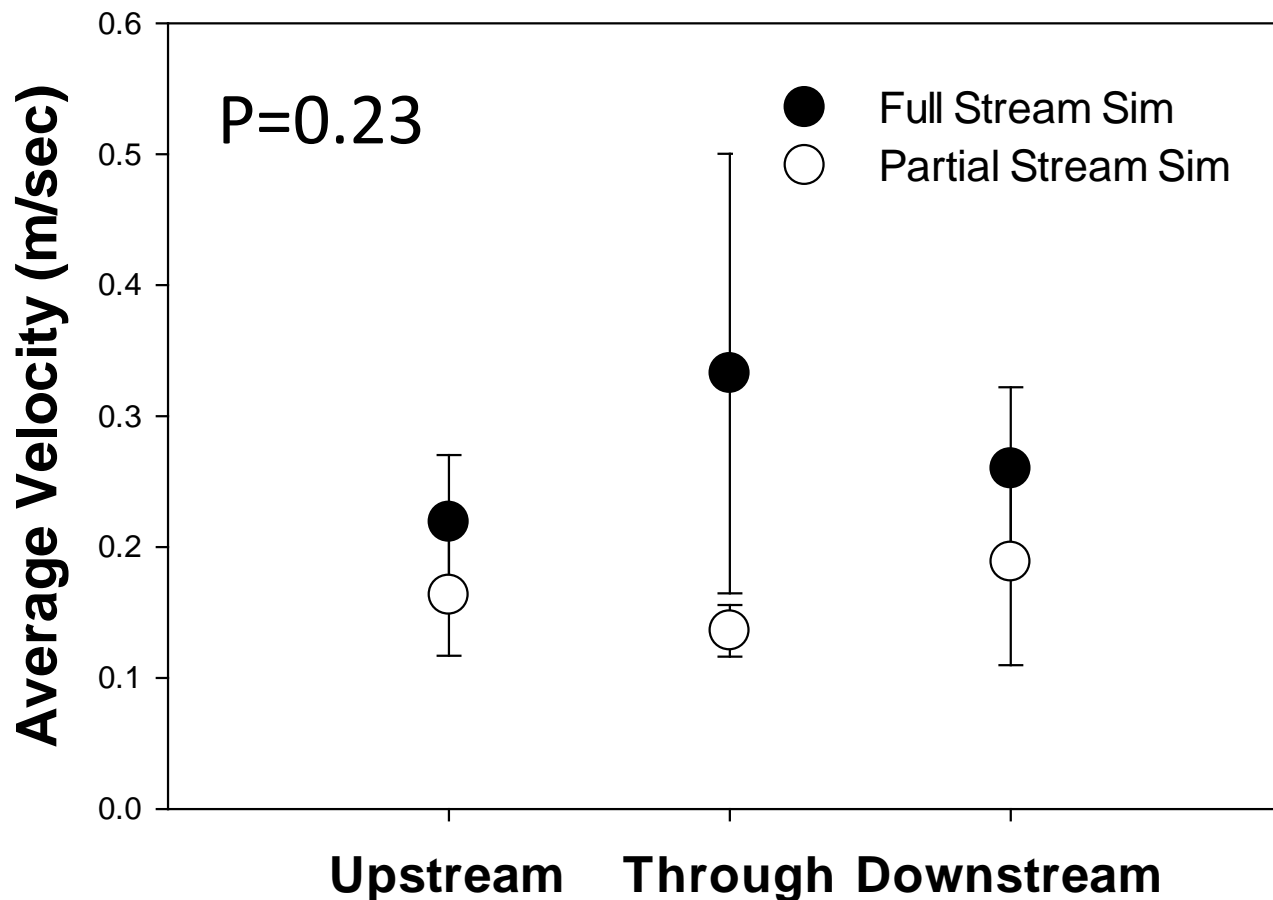
$$\frac{dC_s}{dt} = \alpha \frac{A}{A_s} (C - C_s)$$



Runkel 1998

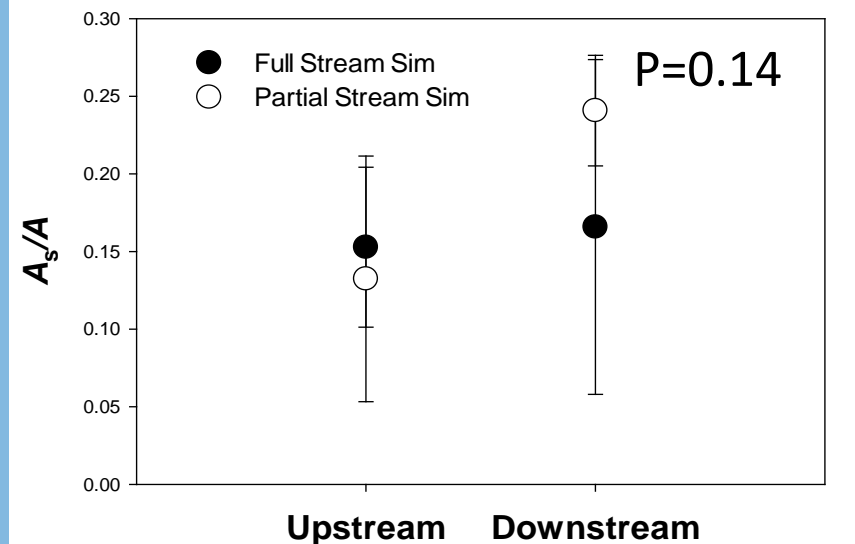
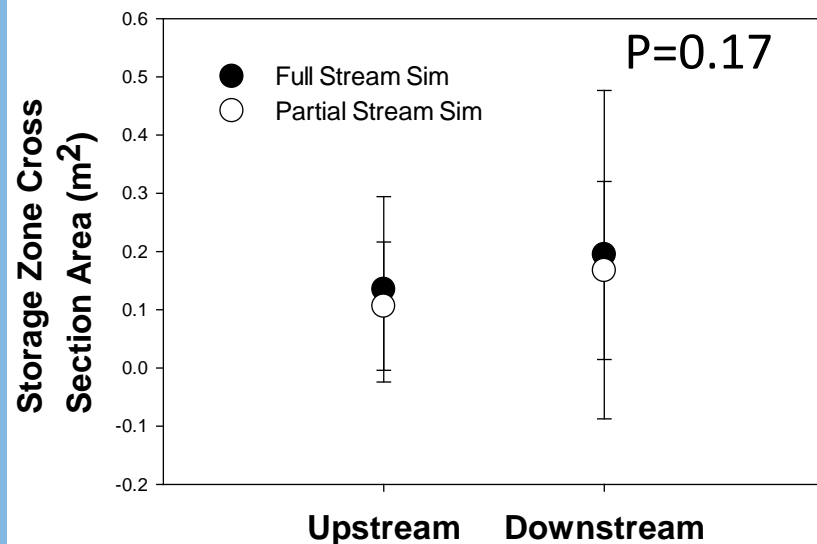
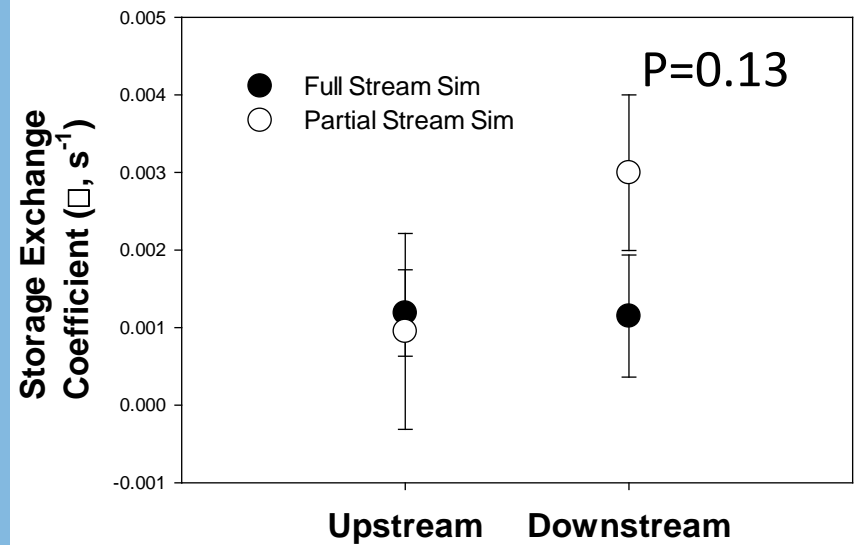
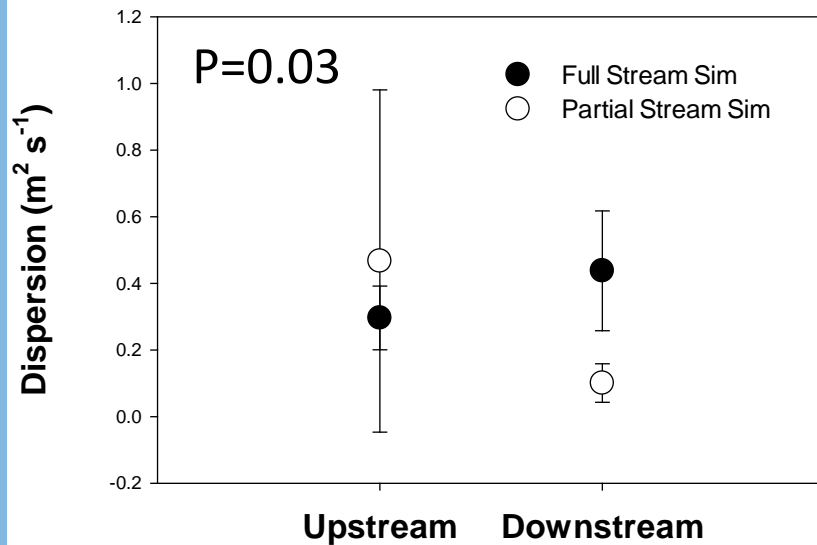
# Hydrologic Connectivity

## Average Velocity

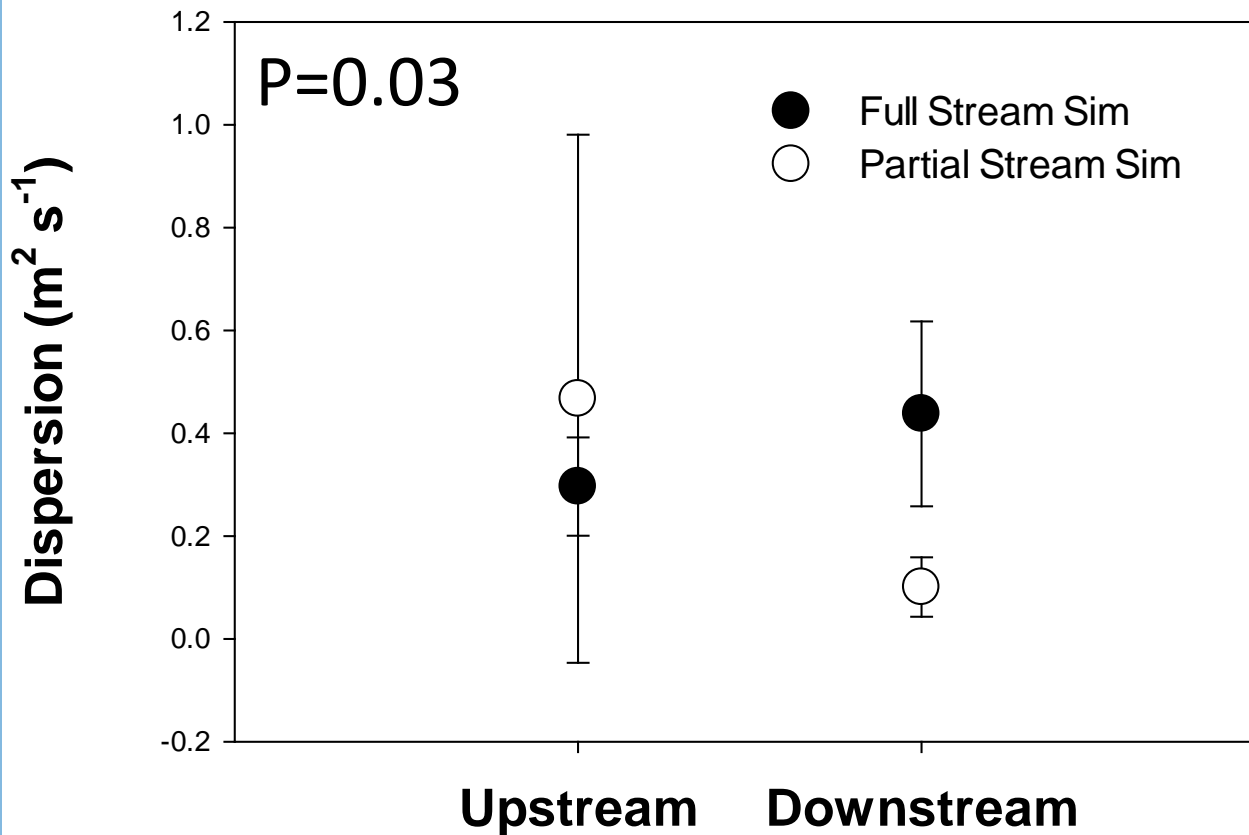




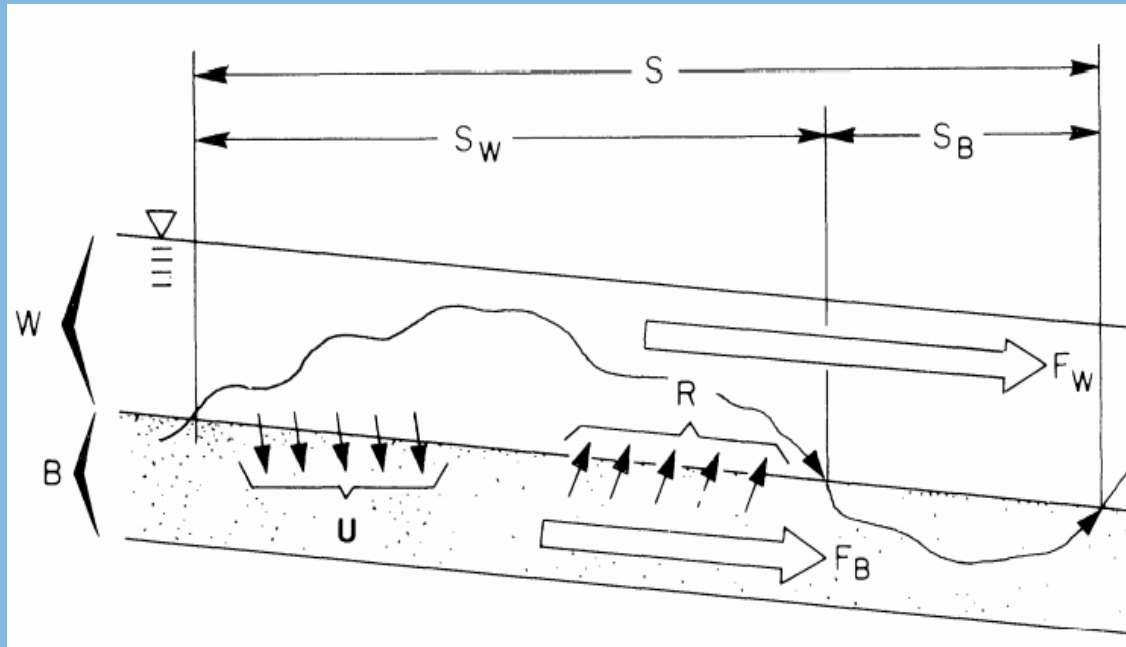
# Transient Storage Characteristics



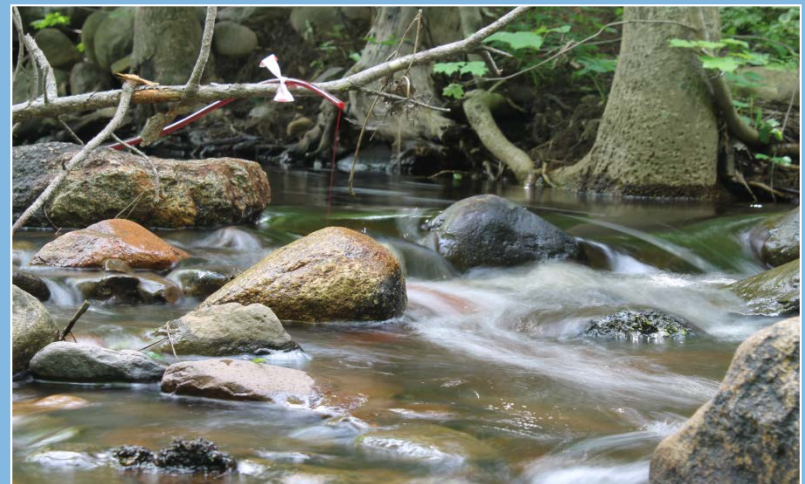
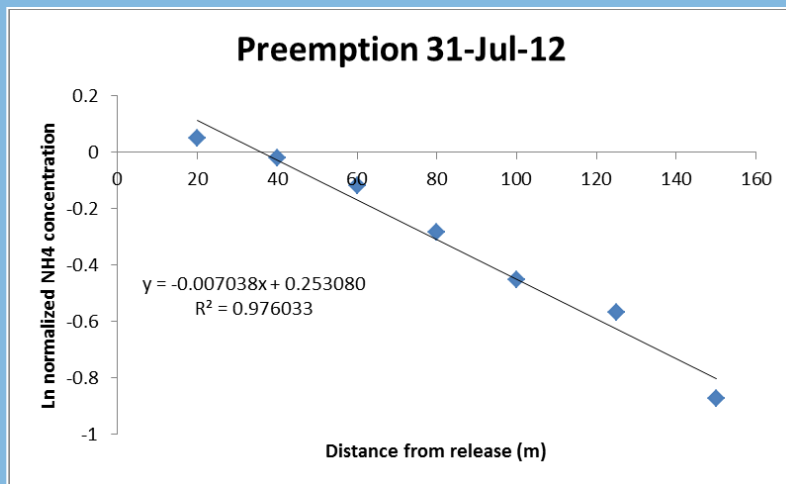
# Hydrologic Connectivity Dispersion



# Nutrient Uptake

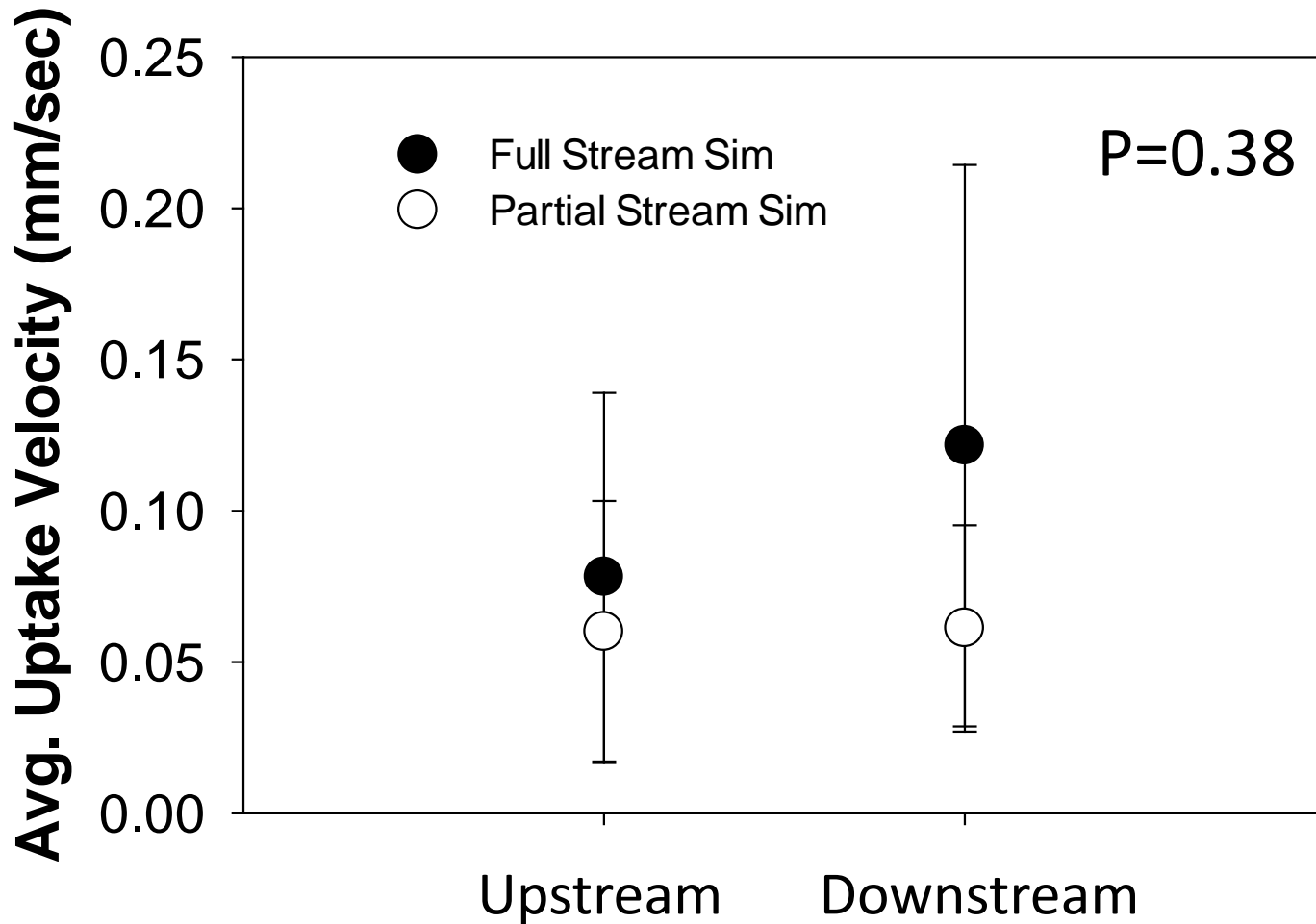


Newbold et al. 1982





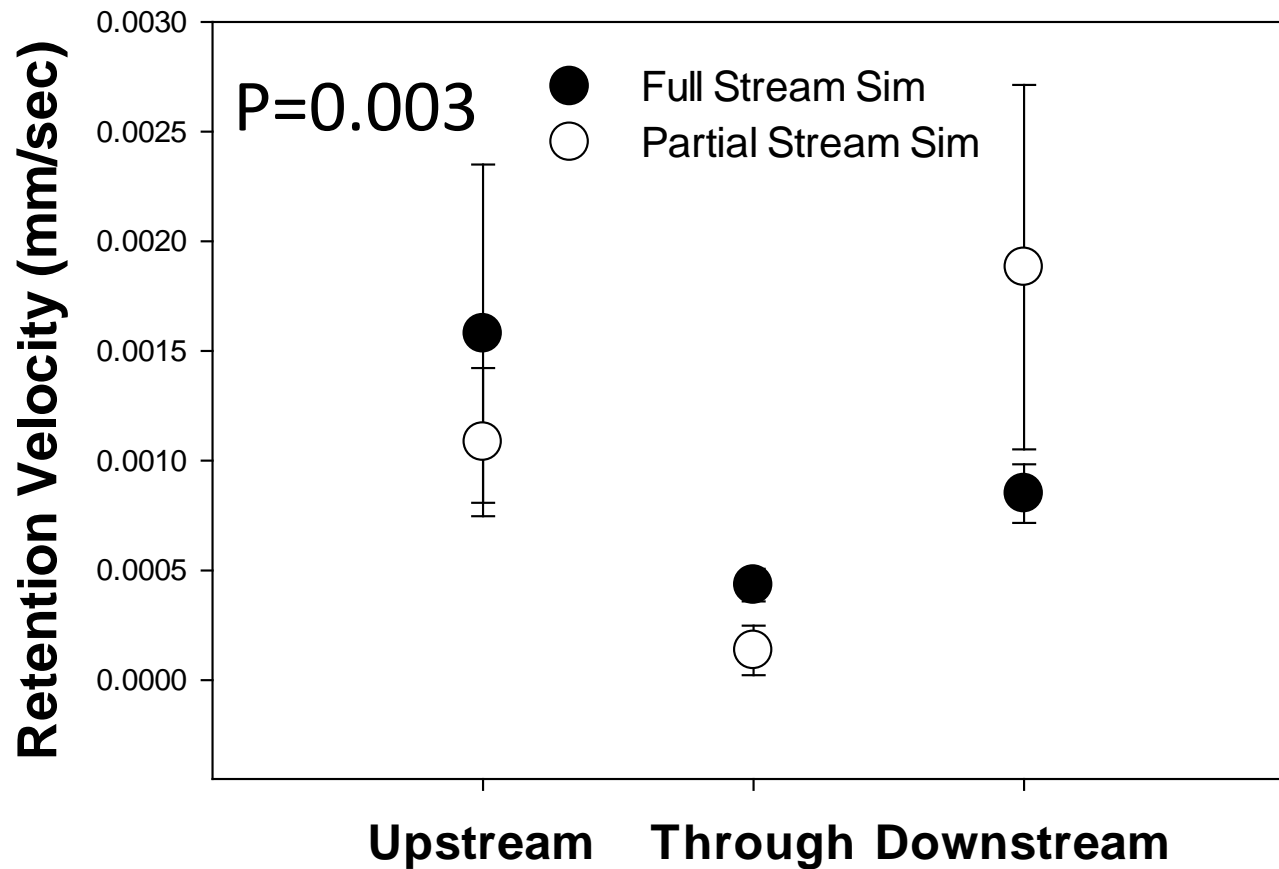
# Nutrient Uptake



# CPOM Retention



# CPOM Retention





# Summary of First Comparison

- Limited differences between full and partial stream simulations (CPOM, Dispersion)
- Is either stream simulation design better than non-replaced culverts?



# Stream Simulation vs. Non-Replaced

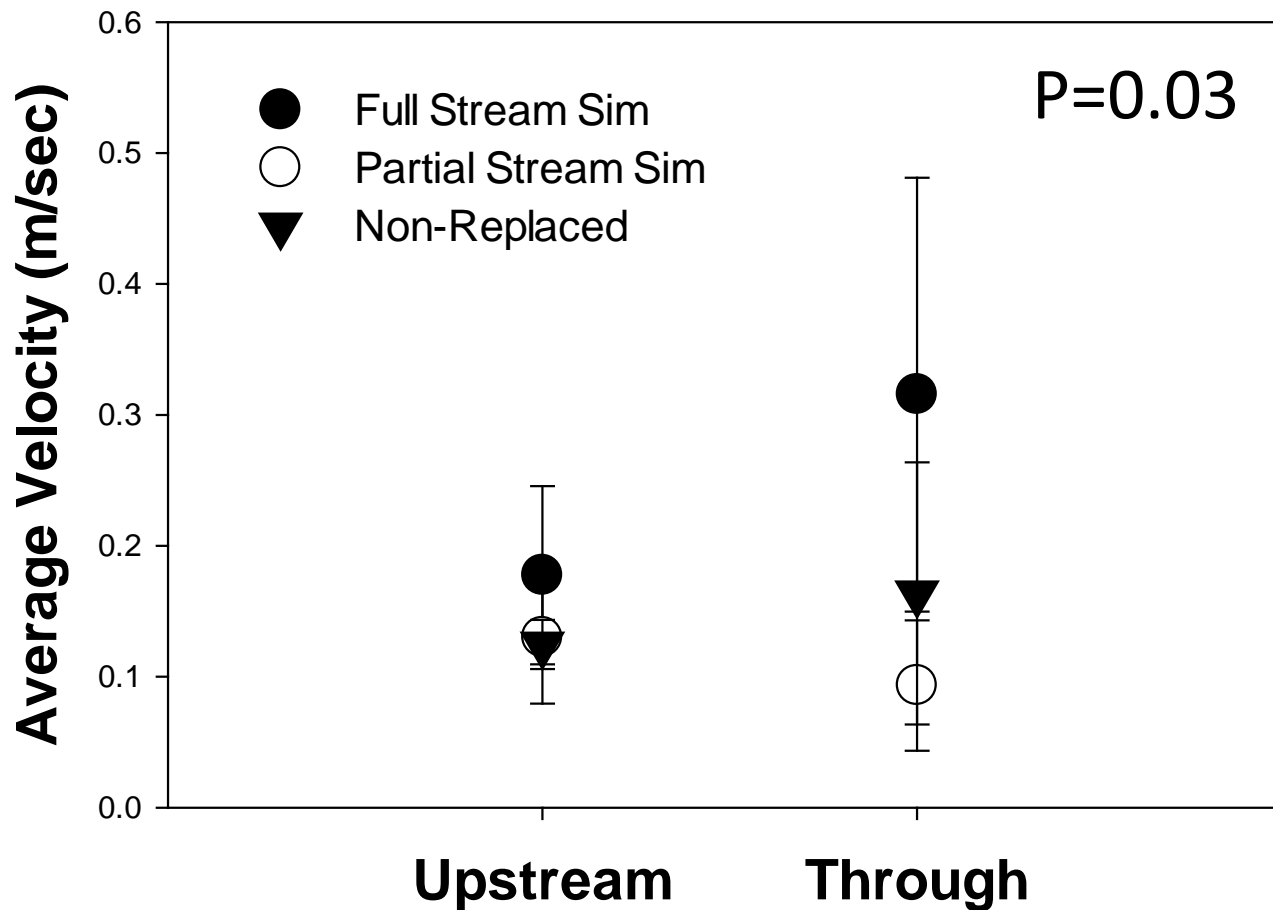
## Hypothesis:

- Hydrologic connectivity and CPOM retention will be most similar upstream and through full stream simulation culverts, less similar for partial stream simulation culverts and least similar for non-replaced culverts



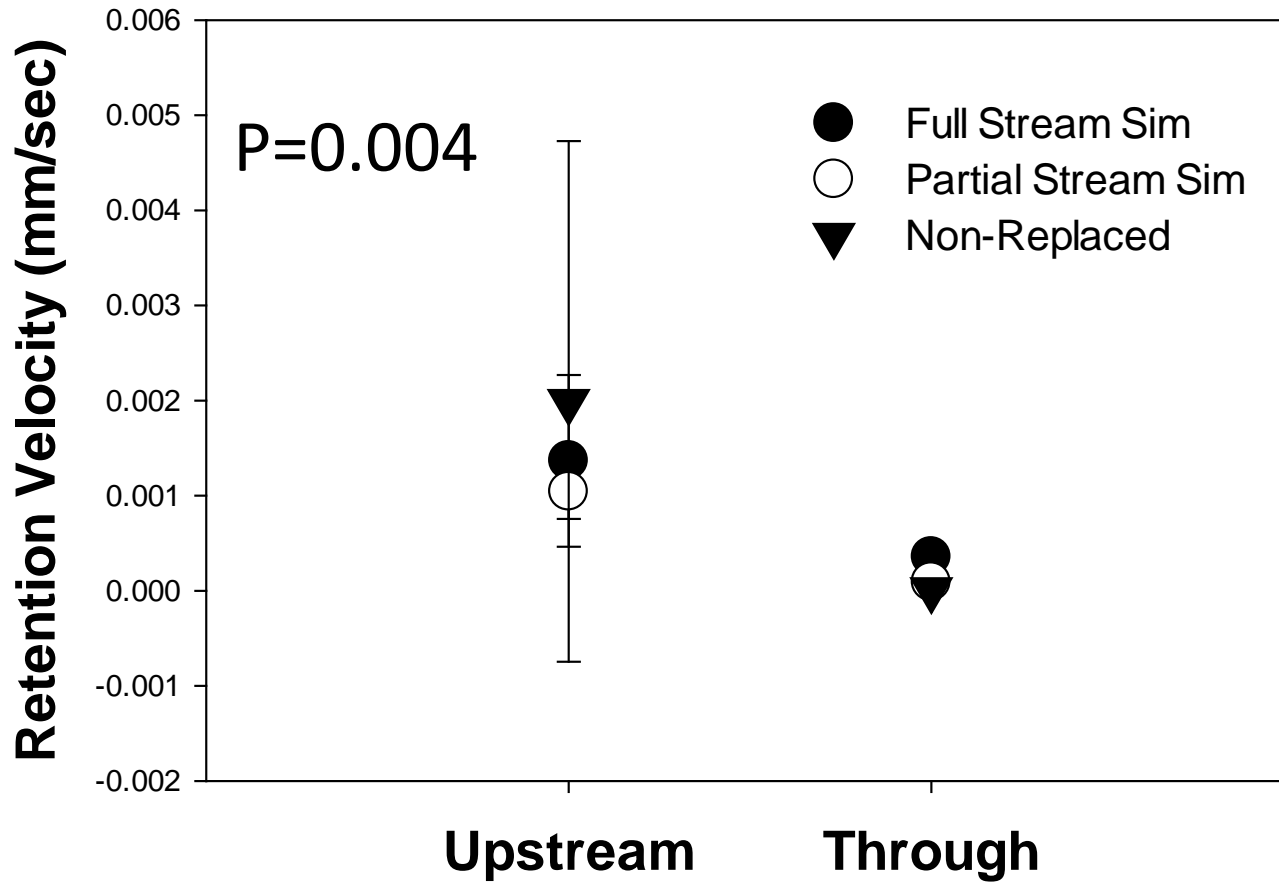
# Hydrologic Connectivity

## Average Velocity

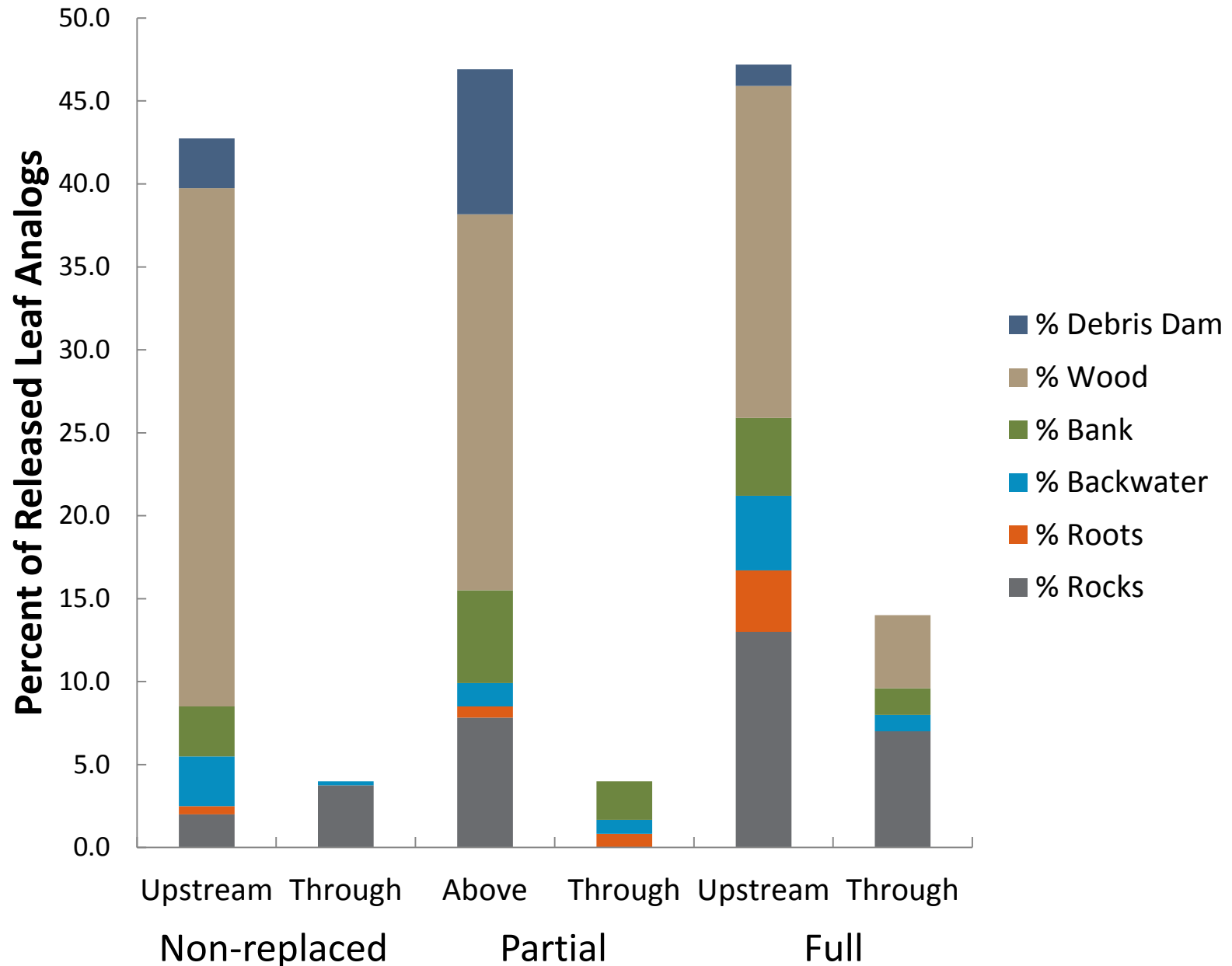




# CPOM Retention

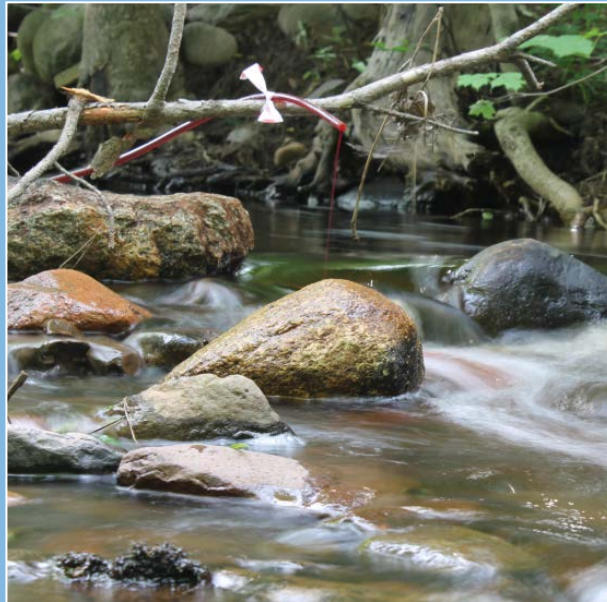


# CPOM Retention



# Summary

- Hydrologic connectivity and nutrient uptake were not different between culverts or between reaches (Dispersion\*)
- CPOM retention decreased drastically through all designs but least through full stream simulations



# Conclusions

- Major hydrologic issues are fixed by stream simulation designs but very little difference between them was observed in ecosystem functions
- Culverts with severe problems could not be represented in this study
- Ecosystem functions that can be measured at small scales are more likely to respond to small culvert restorations (CPOM)



# Acknowledgments

## Field and Lab Support

- Ashley Coble
- Jade Ortiz
- Kellie Heiden
- Brian Borowicz

