Pooled Monitoring Forum: Restoration Research to make Science and Regulatory Connections

Wednesday, June 16, 2021, from 9 AM to 5 PM















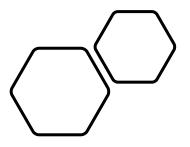


Morning Session

- Welcome, charge for the day, and Pooled Monitoring Program overview, Sadie Drescher Director of Restoration Programs, Chesapeake Bay Trust
- Lee Currey, Director of the Water and Science Administration, Maryland Department of the Environment (MDE) – Opening remarks for state priorities and how research has been used to guide policy

Pooled Monitoring Forum Agenda					
9 to 9:45 am	Morning Session with <u>opening remarks from Lee Currey</u> , Director of the Water and Science Administration, MDE				
9:45 to 10:30 am	Arthur Parola (University of Louisville Research Foundation, Inc.), Keith Eshleman (University of Maryland Center for Environmental Science), and Sujay Kaushal (University of Maryland College Park)				
10:30 to 11:45 am	Jamie Suski (EA Engineering, Science, and Technology, Inc., PBC), Mohammad Al-Smadi (Virginia Polytechnic Institute and State University), and Cindy Palinkas (University of Maryland Center for Environmental Science)				
11:45 am to 12:20 pm	Karen Dinicola, LG, LHG, EIT, Senior Policy Lead, Ecology Water Quality Program HQ (Lead for Washington State's Pooled Resources program) "Pooled Stormwater Monitoring"				
12:20 to 1 pm	Lunch Break				
1 to 3:30 pm	Sujay Kaushal (University of Maryland College Park), Deb Caraco (Center for Watershed Protection, Inc.), Theresa Thompson (Virginia Polytechnic Institute and State University), Tom Jordan (Smithsonian Environmental Research Center) in coordination with and for the awardee, Arundel Rivers Federation, Byron Madigan (Carroll County Government), and Vanessa Beauchamp and Joel Moore (Towson University)				
	What are your top restoration questions? Let's see what research questions rise to the top for next year's Request for Proposals.				

Meeting Materials



 Agenda is at: <u>Pooled Monitoring Forum:</u> <u>Restoration Research to make Science and</u> <u>Regulatory Connections - Google Docs</u>

Registration list: <u>Attendance List- Pooled</u>
 Monitoring (June 16, 2021) - Google Sheets

 This meeting is being recorded and both the recording and presentations will be posted on the Pooled Monitoring Initiative website after the meeting at:

https://cbtrust.org/grants/restorationresearch/

Pooled Monitoring Program - Science answers key restoration questions

- Desire to support the best, most cost-effective practices at the most optimal sites, but differences of opinion sometimes exist, and questions about the performance and function of some of these practices persist
- Pool resources to answer restoration questions posed by regulatory community & practitioners
- Increase power, objectiveness, and ability to know what works
- Bring science back to those that can use the research/data
- https://cbtrust.org/grants/restoration-research/



Kelsey Wood (UMD)
measuring groundwater for
"Tree Trade-Offs in Stream
Restoration Projects:
Impact on Riparian
Groundwater Quality"
project (PI is Sujay Kaushal)















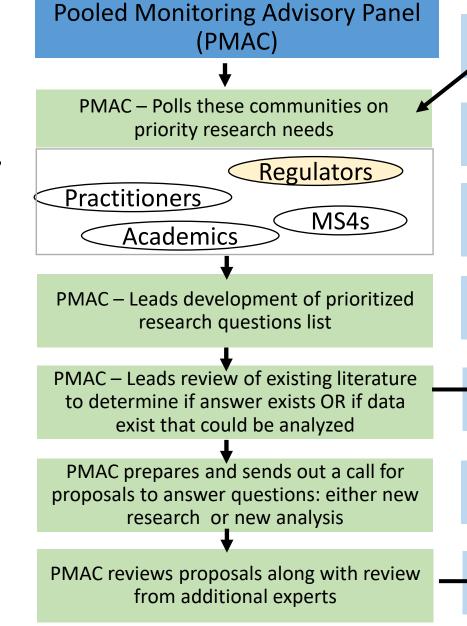






Process is Inclusive and Transparent

This is how the Pooled Monitoring Initiative works - integrating key partners, stakeholders, users, scientists, etc. throughout the process to share information and guide the feedback loop



Information disseminated to all groups Agency reps go back to agencies –training of permit review staff occurs Agency reps and AP meet again to get consensus on the feedback Agency rep takes info back to agency and gets input/feedback from their staff PMAC meets with 1 individual from each agency to communicate results and recommendations/interpretations PMAC interprets answers into application recommendations (particular to permitting) Research conducted; answers obtained



Pooled Monitoring Initiative Provides Solutions

- Regulators prioritize their concerns with input from practitioners
- Funders "pool" resources
- Top restoration questions issued in the Restoration Research Request for Proposals (RFP) in FY15 administered by the Chesapeake Bay Trust
- Scientific teams research these questions and deliver answers back to the regulators
- RFP open to any organization looking for best groups to answer your questions
- Results used in decisions, policy, practices, etc.



Claire Welty (UMBC)
quantifying the cumulative
effects of stream restoration
and environmental site design
on nitrate loads in nested
urban watersheds using a
high-frequency sensor
network(Baltimore County,
MD)

Restoration Research Award Program

- Supported 32 projects since FY 15 at ~\$6M
- Guided by the Pooled Monitoring Advisory Committee
- Uses scientific reviewers across the world to vet applications
- Runs all applications through a "management review"
- Projects are managed as contracts
- Questions are cycled off/on the RFP each year
- All awards, progress, and program products are online at: https://cbtrust.org/grants/restoration-research/



Monitoring stream banks in Carroll County, MD, to see if they recover after restoration

Morning Session

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Lee Currey, Director of the Water and Science Administration, Maryland Department of the Environment (MDE) – Opening remarks for the Pooled Monitoring Initiative's Forum 2021

Reliability of Two-Dimensional (2D) Hydrodynamic Models for Assessing Susceptibility of Stream Restorations to Flood Damage and Potential Effects of Climate Change

Research Question: How can different restoration approaches or techniques reduce the impacts of future climate change?

Presenter: Art Parola, Ph. D, P.E., Director, University of Louisville Stream Institute

Collaborators and contributors: Ann Arundel County, Prince Georges County, Maryland Department of Natural Resources, Maryland State Highway Administration, RK&K, Greenvest, Underwood & Associates, Berrywood Community

Are 2D Hydrodynamic Models a reliable tool for stream restoration design?

Research Questions Addressed:

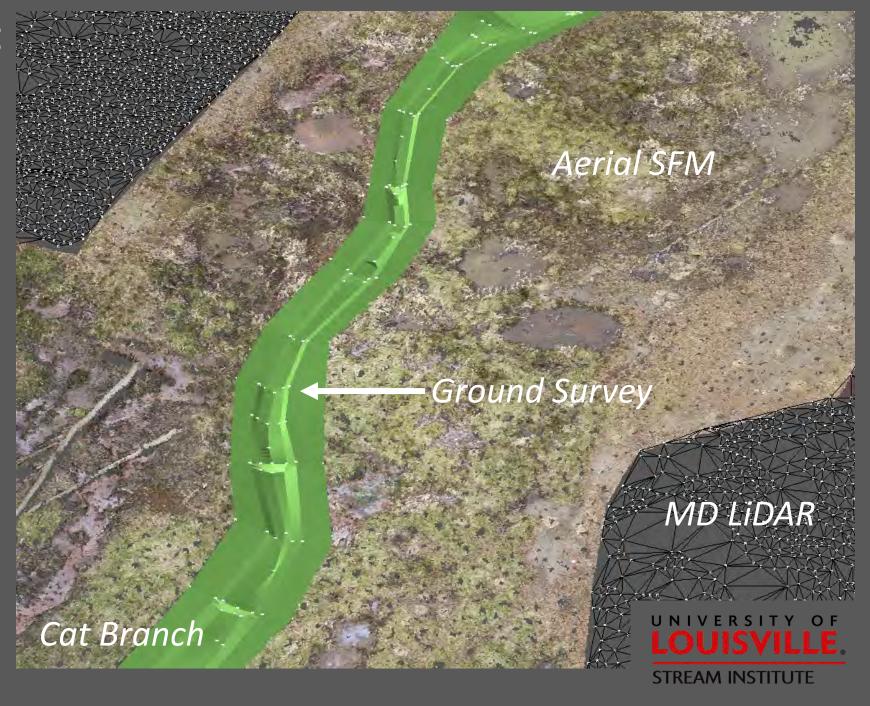
- Research Phase I: Evaluate a <u>design approach for stability</u>: use of 2D models to develop engineering design of restoration sites
- Research Phase II: <u>current and future climate conditions are evaluated</u> through different simulated flows

Expected Findings

- Areas of restoration sites with expected low or high velocities/stresses will be effectively predicted by 2D models. Moderate values / threshold conditions will help refine use of the 2D model as a tool
- 2D models will be conditionally effective- better definition of areas where
 models are reliable under current and future flooding scenarios

Reliability Analysis: Detailed Site Surveys

- 5 Sites in total
- 2D Hydrodynamic modeling requires a water-tight container (no holes)
- Resolution must be appropriate to capture key features



Reliability Analysis: Ground and Aerial Imagery to Define "Damaged" Areas

- Damaged and undamaged areas are used as training data in the model
- Damage does not mean poor design







Cattail Creek



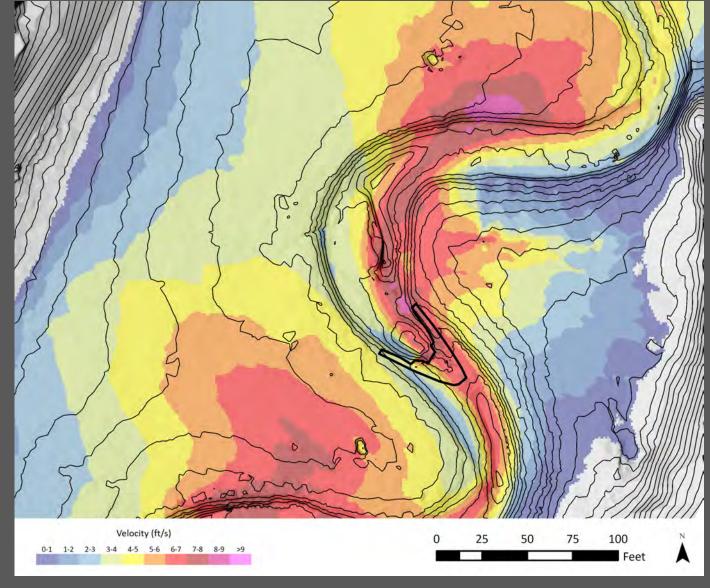


Furnace Creek



Reliability Analysis: 2D Hydrodynamic Modeling

- Determine predicted velocities and stresses in damaged/un-damaged areas
- Evaluate 2D model
 effectiveness in different
 restoration types and
 components





Reliability Analysis: 2D Hydrodynamic Modeling

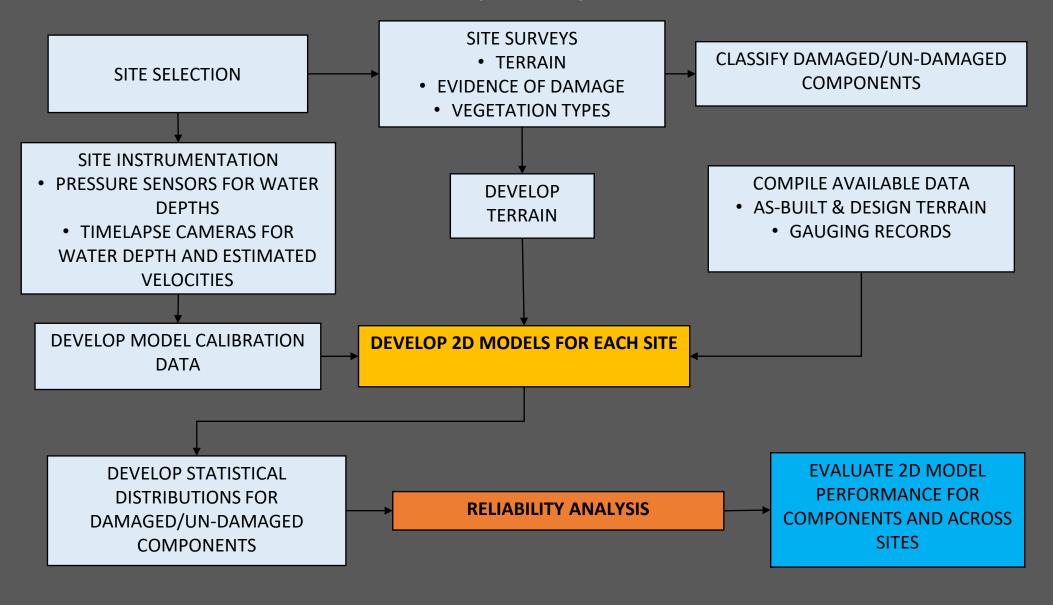
- Constrain / approximately calibrate models based on estimates of observed flooding (Phase 1)
- Use direct sensing of floods, partner observations and surrounding gage data
- Use extreme flood estimates for current and future conditions analysis (Phase 2)



Furnace Creek

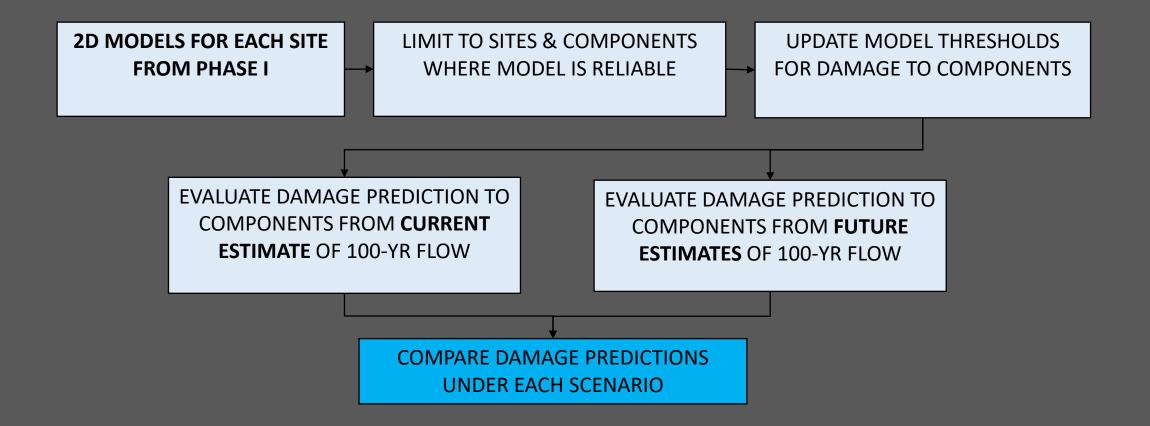


Phase I: 2D Model Reliability Analysis





Phase II: Current and Future Conditions Analysis





Acknowledgements

Thanks to the Chesapeake Bay Trust and all the funding partners for supporting this work. Thanks to Sadie and the collaborators who are making this project possible.

Partners and collaborators:

MD DOT SHA: Ryan Cole, Nora Bucke, Kevin Wilsey

MDE: Bill Seiger, Deb Cappuccitti, Jeff White

MD DNR: Ari Engelberg

Ann Arundel County: Erik Michelsen, Nasrin Dahlgren, Bryan Perry,

Karen Jennings

Prince Georges County: Joanna Smith, Jerry Maldonado, Mark

McKibben, Frank Galosi

Montgomery County: Kenny Mack

SERC: Cynthia Gilmour

<u>RK&K</u>: Drew Altland, Tom Earp, Aaron Maxwell, Jason Coleman <u>Greenvest</u>: Laura Kelm, David Merkey, Dana Cooper, Brett Berkley Underwood & Associates: Keith Underwood, Chris Becraft, Keith

Binsted, Heather Johnson, Beth Zinecker

<u>Tetra Tech</u>: Mark Sievers, Jasmine DunhamTyson

Berrywood Community: Molly LaChapelle, Bob Royer

<u>Arundel Rivers</u>: Jennifer Carr McCormick Taylor: Scott Lowe

EQR: Katrina Davis

















How effective is ESD/GSI in achieving stormwater management objectives in the Upper Little Patuxent River Watershed, Howard County, MD?

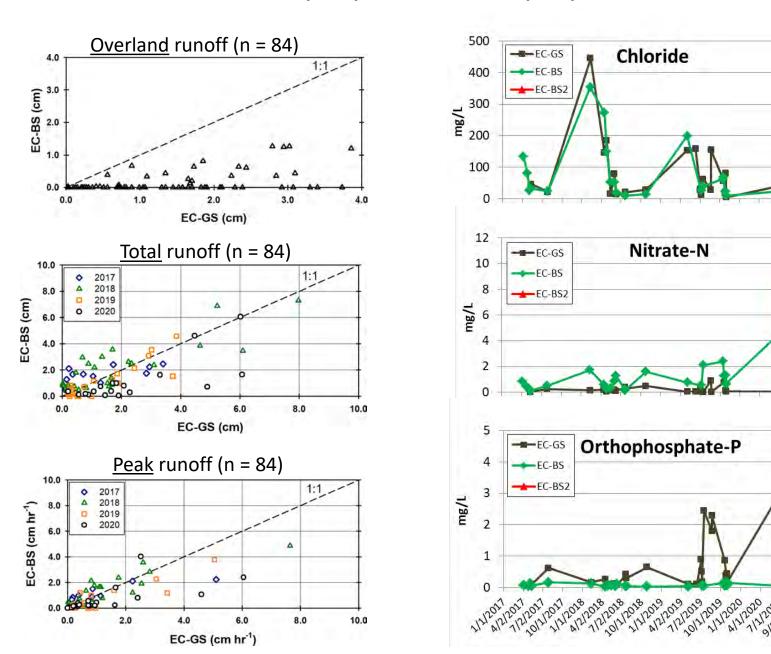
Keith N. Eshleman
University of Maryland Center for Environmental Science
Appalachian Laboratory
Frostburg, MD

Pooled Monitoring Forum: Restoration research to make science and regulatory connections (June 16, 2021)

Outline

- Motivation
- Research question/hypotheses
- Experimental design: study watersheds and data collection
- Progress-to-date
- Preliminary results
- Next steps

Grassed swale (GS)/bioswale (BS) results: 2017-20



Research question/hypotheses

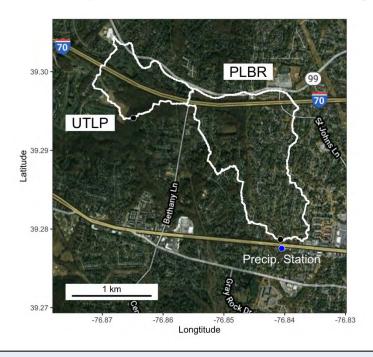
- Research question: What is the spatially-aggregated effectiveness of ESD BMP's at the watershed scale in achieving four primary stormwater management goals?
 - protection of receiving surface waters from nonpoint source pollution;
 - attenuation of stormwater discharge peaks;
 - diminishment of stormwater runoff volumes; and
 - enhancement of the recharge/discharge behavior of shallow groundwater

• Hypotheses:

- A watershed developed using ESD will be characterized by
 - lower stormflow runoff;
 - higher baseflow runoff;
 - lower peak discharges;
 - lower runoff coefficients;
 - longer centroid lag times;
 - o more attenuated unit-graphs; and
 - lower EMC's and EL's of N and P pollutants

than a comparable "control" watershed with traditional stormwater management (all else equal).

Experimental design: paired watershed study





PLBR stormwater monitoring station, Howard County, MD

- Plumtree Branch (PLBR; area = 2.15 km²)
 - "Developed" watershed
 - Conventional SWM
- <u>Unnamed Tributary to Little Patuxent River</u> (UTLP; area = 0.80 km²)
 - "Developing" watershed
 - Green stormwater infrastructure (GSI)
- Common equipment includes:
 - Stilling well (w/intake) and instrument shelter housing Unidata digital water level recorder
 - InSitu AquaTroll 500 and "tube" for transmitting data to HydroVu website



UTLP stormwater monitoring station, Howard County, MD

Development in UTLP













- Stream channel and wetlands protection ("buffers")
- Erosion and sediment control
- Green stormwater infrastructure (e.g., bioretentions, dry wells)

Progress-to-date

• <u>Site Selection/Permits/Instrumentation</u>

- PLBR station installed November 2019 on HOCO property (MOU)
- UTLP station installed March 2020 on HOCO property (David Force Park, MOU)
- Nov. 2019 Mar. 2020: "pilot period" used to refine sampling methods and logistics

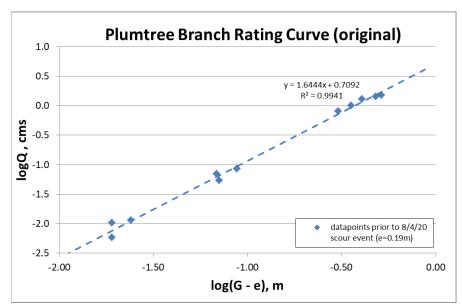
Hydrology

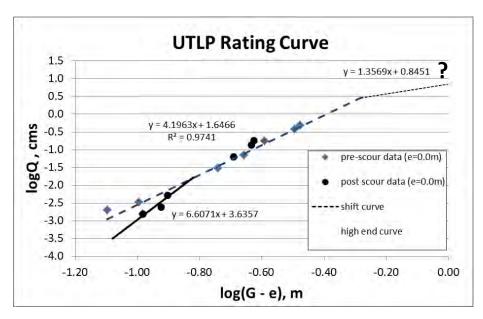
- Continuous 5-min stream stage records: <u>100% complete</u>
- Continuous 5-min discharge records based on rating curves derived from field discharge measurements (wading velocity-area method): <u>100% complete</u>
 - 8/4/20 scour event caused a section control change @ PLBR (rating curve shift)
 - 6/22/20 flash flood event required reconstruction of section control @ UTLP (rating curve shift)
- Continuous 15-min precipitation records from tipping bucket gages (from February 2020):
 100% complete

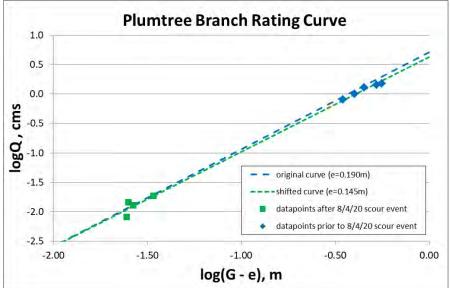
Water Quality

- Continuous 5-min in situ level, specific conductance, temperature, and turbidity data (from AquaTroll 500's): <u>88% complete</u> for PLBR; <u>84% complete</u> for UTLP (bioturbation, sedimentation, battery failures, data transmission failures)
- 524 discrete samples analyzed for SC, TSS, major anions, TN, N species, TP, P species (38 baseflow "grabs", 486 stormflow "ISCO's"): 16 events @ PLBR; 12 events @ UTLP

Rating Curves







Preliminary results: water balance

Station	Annual precipitation (m), 2021 WY = May 2020 – April 2021	Annual precipitation (m), normal (1981 – 2010)	Notes
BWI AIRPORT, MD (NWS)	1.415	0.983	2021 WY was ~44% wetter than normal
DAMASCUS, MD (NWS)	1.116	1.085	2021 WY was ~3% wetter than normal
PLUMTREE BRANCH (THIS PROJECT)	1.187	N/A	
"DELTA" (NATIONAL PIKE AT MARRIOTTSVILLE RD)	1.017	N/A	

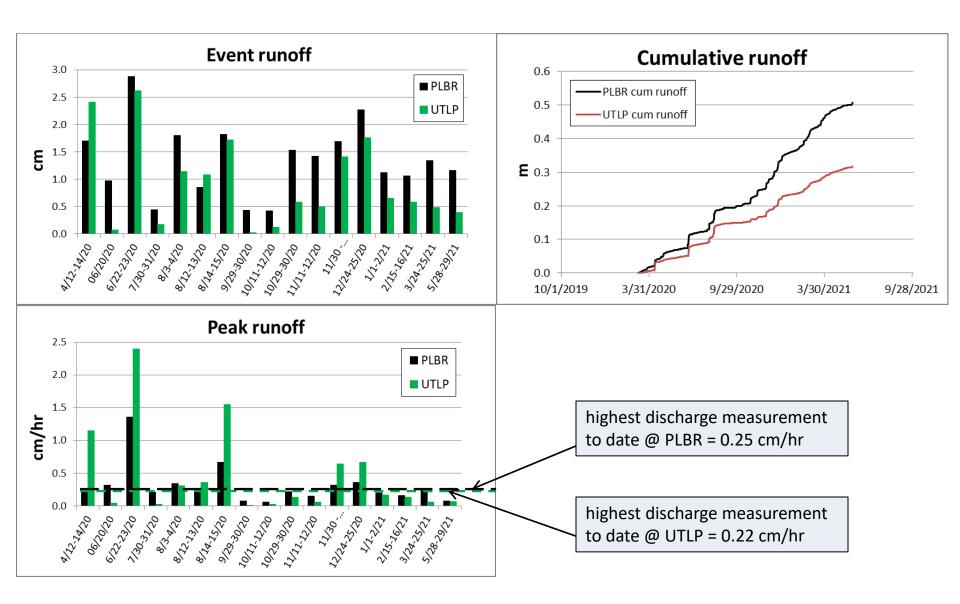
Watershed	Gaging station # (USGS)	Area (mi²)	Annual runoff (m), 2021 WY = May 2020 – April 2021)	Annual runoff (m), long-term normal	Notes
LITTLE PATUXENT RIVER AT GUILFORD, MD	01593500	38.0	0.59	0.47	Preliminary USGS data for 2021
LITTLE PATUXENT RIVER AT SAVAGE, MD	01594000	98.4	0.53	0.46	Preliminary USGS data for 2021
CATTAIL CREEK NEAR GLENWOOD, MD	01591400	22.9	0.43	0.45	Preliminary USGS data for 2021
PATUXENT RIVER NEAR UNITY, MD	01591000	34.8	0.47	0.45	Preliminary USGS data for 2021
HAWLINGS RIVER NEAR SANDY SPRING, MD	01591700	27.0	0.42	0.44	Preliminary USGS data for 2021
PLUMTREE BRANCH (PLBR)	N/A	0.83	0.43	N/A	Preliminary data (this project)
UNNAMED TRIBUTARY TO LITTLE PATUXENT RIVER (UTLP)	N/A	0.31	0.27	N/A	Preliminary data (this project)

Storm summary (March 2020 - present)

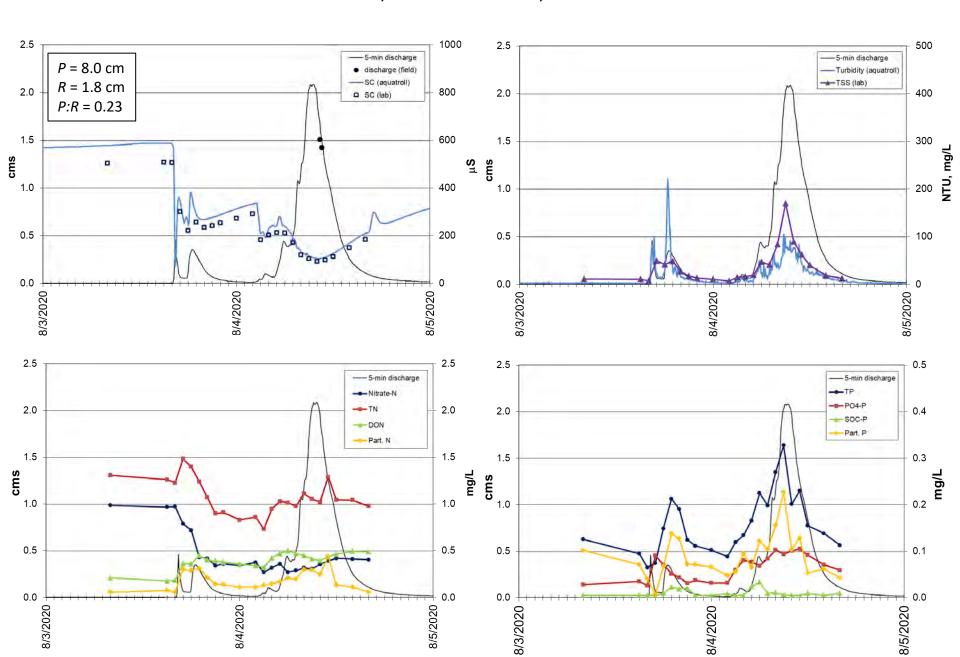
Storm ID	Date(s)	1-hr rainfall (cm)	2-hr rainfall (cm)	24-hr rainfall (cm)	R.I. (yr)- 1 hr*	R.I. (yr)- 2 hr*	R.I. (yr)- 24 hr*
N/A	4/12-14/20	1.02	1.55	5.46	<1	<1	<1
N/A	06/20/20	4.62	4.85	4.90	5	3.5	<1
N/A	6/22-23/20	5.97	6.07	6.07	25	10	<1
"E"	7/30-31/20	2.31	2.36	3.12	<1	<1	<1
"F"	8/3-4/20	1.55	2.95	8.00	<1	<1	2
N/A	8/12-13/20	1.14	1.30	2.84	<1	<1	<1
N/A	8/14-15/20	2.36	2.49	2.82	<1	<1	<1
" G "	9/29-30/20	1.65	1.65	2.39	<1	<1	<1
"H"	10/11-12/20	0.61	1.12	2.54	<1	<1	<1
"J"	10/29-30/20	1.19	2.21	5.66	<1	<1	<1
"K"	11/11-12/20	0.94	0.94	4.88	<1	<1	<1
N/A	11/30 - 12/1/20	1.73	2.31	4.57	<1	<1	<1
" <u>L</u> "	12/24-25/20	0.89	1.40	4.57	<1	<1	<1
N/A	1/1-2/21	0.84	1.50	3.28	<1	<1	<1
"N"	2/15-16/21	0.41	0.71	2.54	<1	<1	<1
N/A	3/24-25/21	1.63	2.87	4.78	<1	<1	<1
"R"	5/28-29/21	2.26	2.79	4.29	<1	<1	<1
Min		0.41	0.71	2.39			
Max		5.97	6.07	8.00			
Median		1.55	2.21	4.57			

^{*}Estimated from Bonnin et al. (NOAA Atlas 14, Point precipitation frequency estimates: Ellicott City, MD)

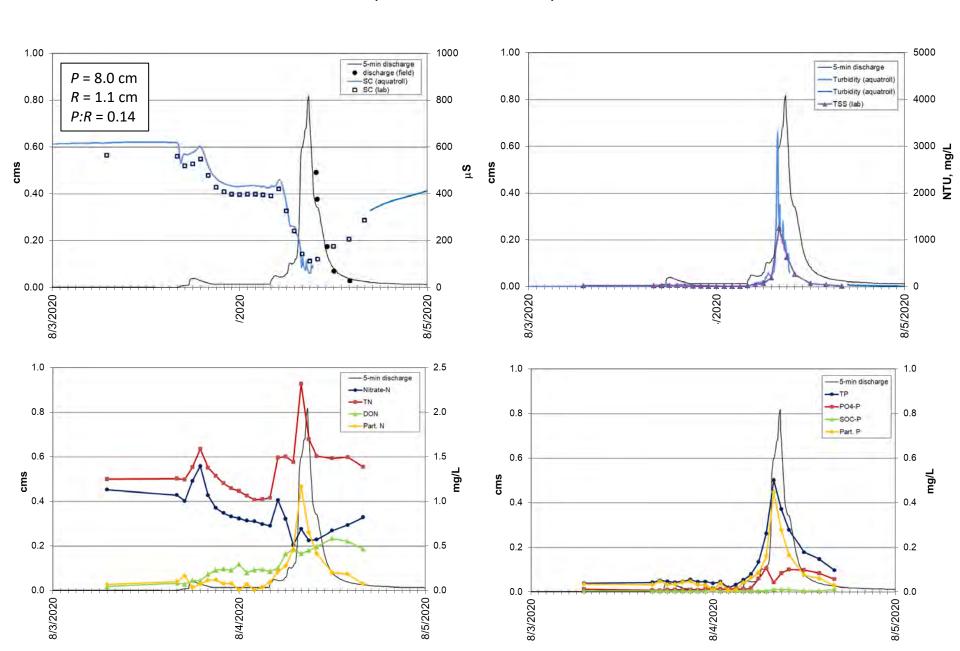
Hydrologic responses (March 2020 - present)



Plumtree Branch (Event F: T.S. Isaias): 1-hr P = 1.6 cm; 2-hr P = 3.0 cm; 24-hr P = 8.0 cm



UTLP (Event F: T.S. Isaias): 1-hr P = 1.6 cm; 2-hr P = 3.0 cm; 24-hr P = 8.0 cm



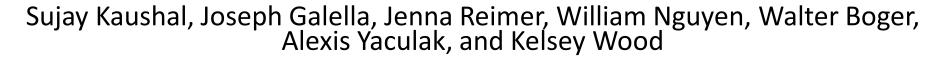
Next Steps

- Data collection to continue through end of calendar year 2022
 - Greater attention to stream gaging (especially high flows @ UTLP)
- First report to CBT (8/2021) focused on "during" phase of residential development and GSI implementation
- Expect to transition to "after" phase by end of calendar year
 2021
- Expanded data analysis including computation and statistical comparisons of:
 - Unit hydrographs
 - Pollutant loads
 - Event mean concentrations

Acknowledgments

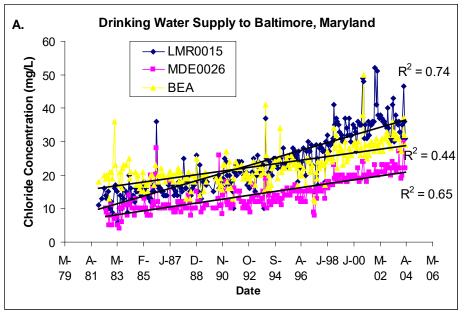
- Chesapeake Bay Trust/Maryland DNR: primary sponsorship
- Howard County (Mark Richmond et al.): permits, site development plans
- Briana Rice (AL)
- Katie Kline (AL)
- Jim Garlitz (AL)
- Joel Bostic (AL)
- Elizabeth Eshleman
- Neal Eshleman

Evaluating impacts of freshwater salinization syndrome on mobilization of nutrients and metals from stormwater best management practices

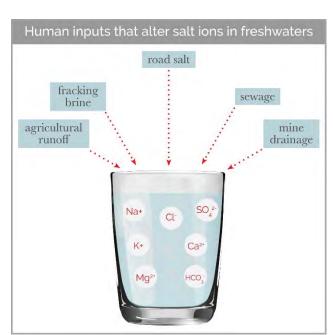




University of Maryland, Department of Geology & Earth System Science Interdisciplinary Center

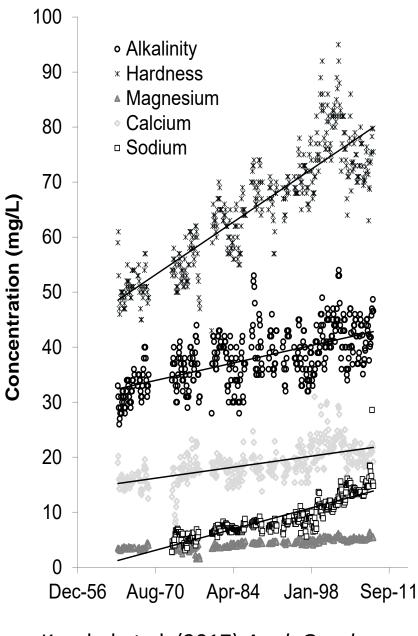


Kaushal et al. (2005) PNAS

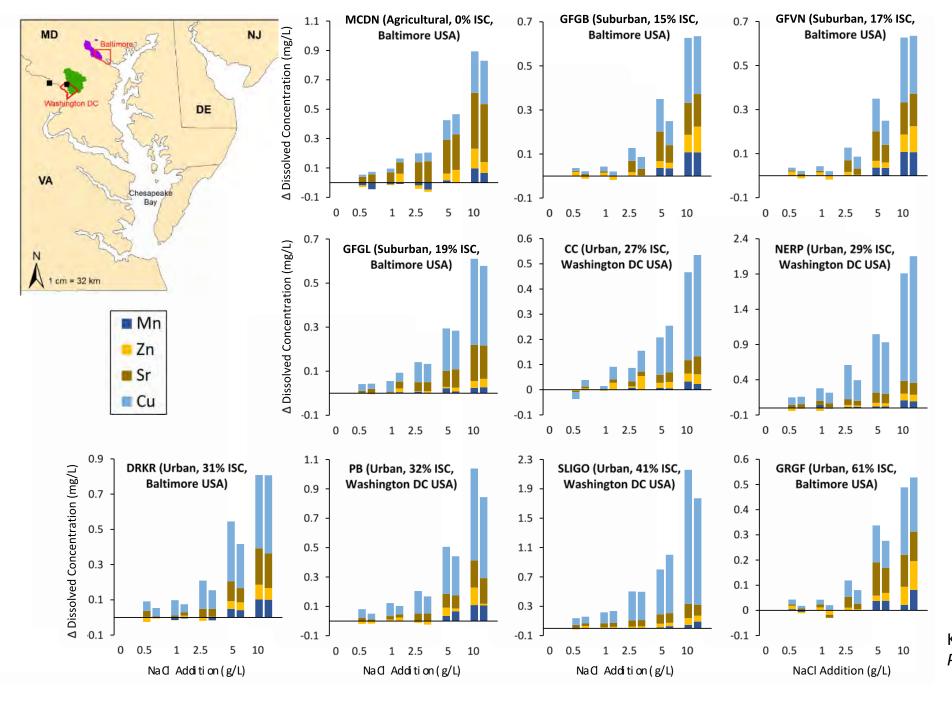


L. Quillen (2018) FSS Press Release

Freshwater Salinization Syndrome Impacts Maryland's Drinking Water



Kaushal et al. (2017) Appl. Geochem



Salinization
Mobilizes
Metals and
Nutrients to
Streamwater

Kaushal et al. (2018b) Philosophical Trans. Royal Society

Key Questions

• What are critical thresholds in concentrations of different road salt ions (Na⁺, Ca²⁺, Mg²⁺) which can mobilize nutrients and metals to surface waters across varying stormwater BMPs?

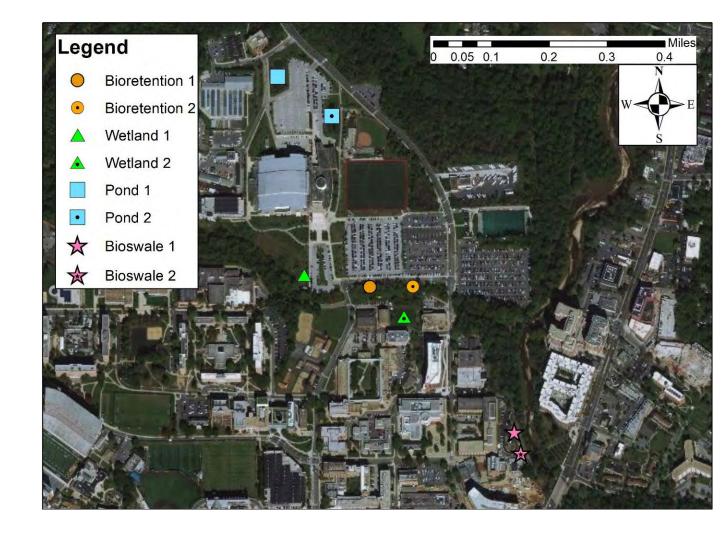
 What are the concentrations and loads of different road salt ions and associated metals and nutrients in nearby stream outfalls before, during, and after deicing events

Experimental Design & Examples of Study Sites



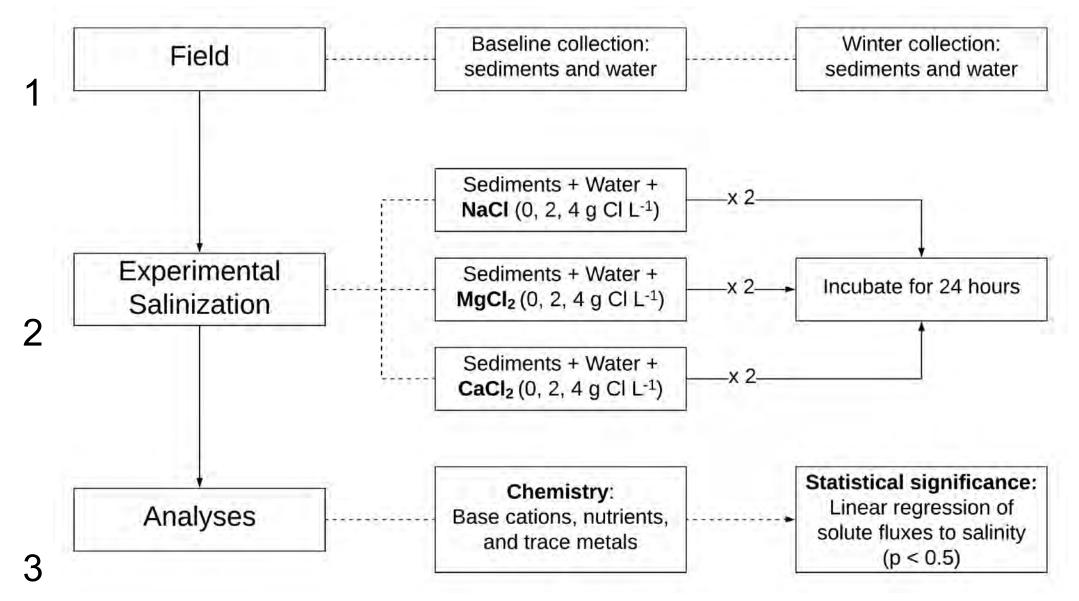
Bioswale #2

Bioretention #2



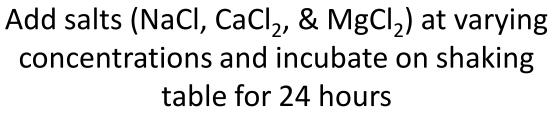
In addition, stream restoration/floodplain reconnection sites

Experimental Methods



Collect sediment and water from stormwater management feature













Analyze for major and trace elements, organic / inorganic carbon and nitrogen

Courtesy Joseph Galella

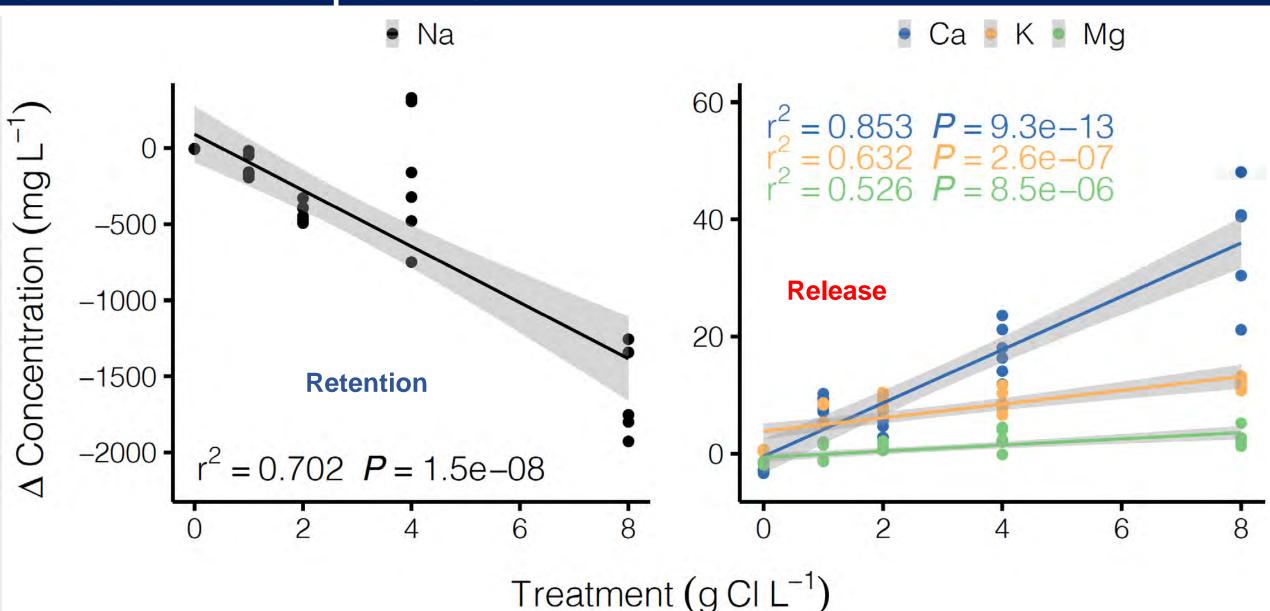
Hold the Salt: How Much Can Be Retained in Sediments?



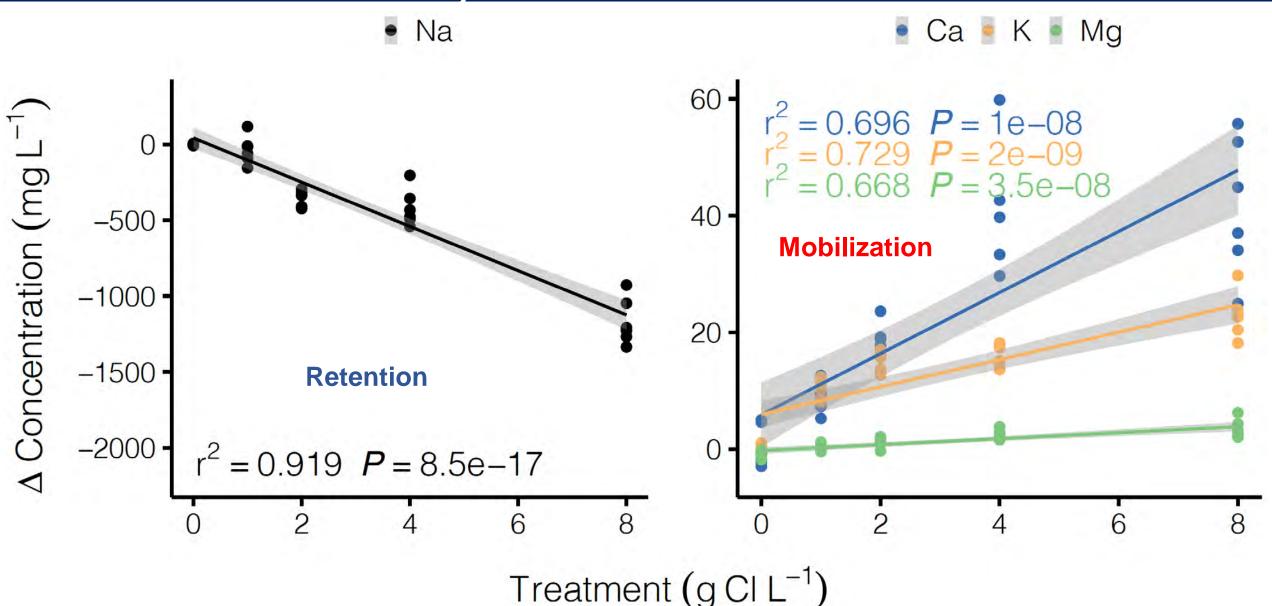
Retention and Release of Salts and Metals in Different Stormwater Management Features

Photo courtesy of Kelsey Wood (2019)

High Capacity for Sodium Retention in Restored Stream Floodplain Sediments



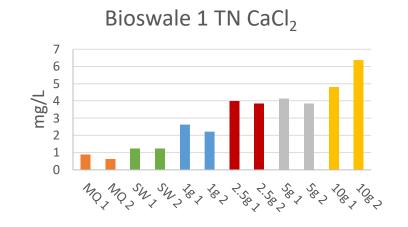
High Capacity for Sodium Retention in Regenerative Stormwater Conveyance Sediments

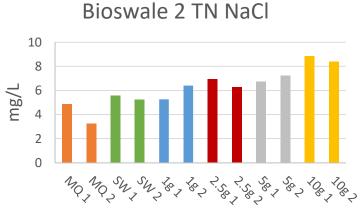


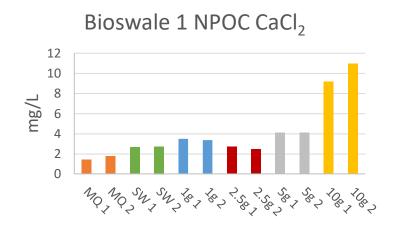
What are thresholds for nitrogen mobilization?

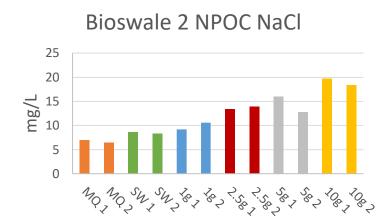
How much nitrogen is mobilized?

What are the effects of different road salt ions?





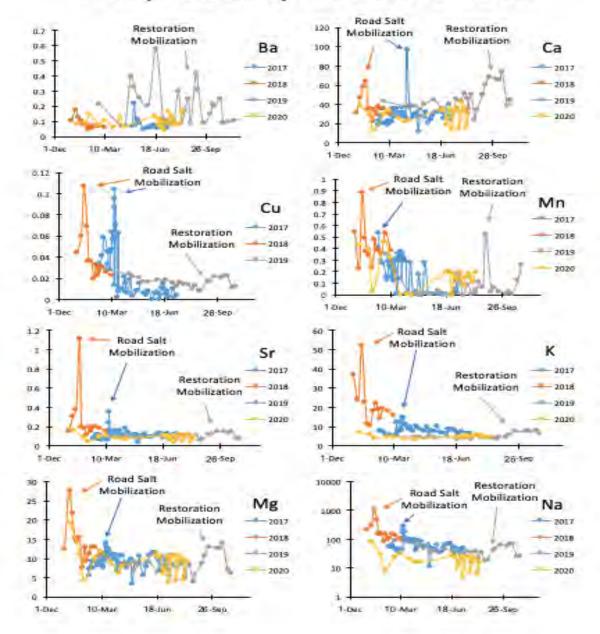




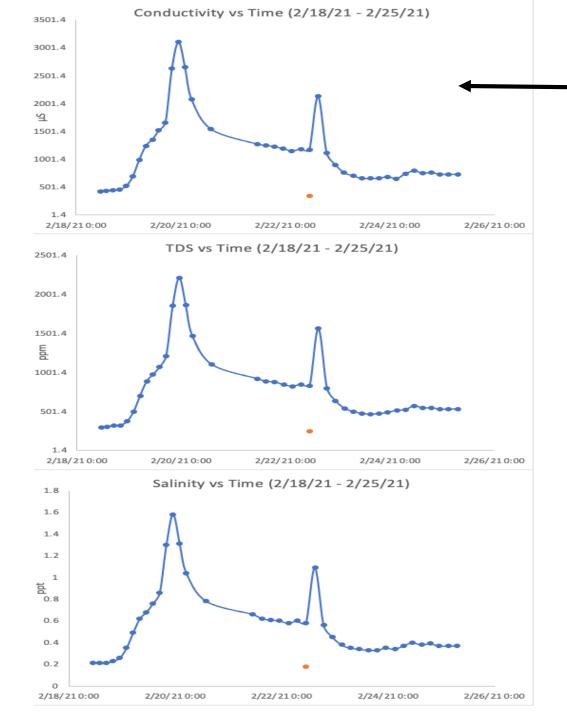
- Increased salt concentrations mobilize nitrogen and organic carbon
- Different salt ions can change magnitude of mobilization



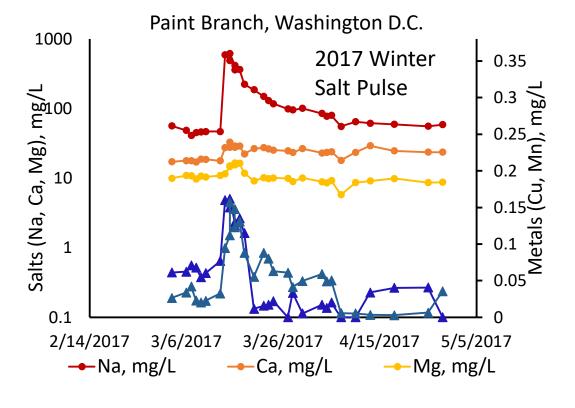
Mobilizing Chemical Cocktails: Comparison by Year and Season



There can be some recovery in water quality depending on amount of road salt use



2021 Large Winter Ion Pulses Retention, Release, and Recovery of Which Ions?

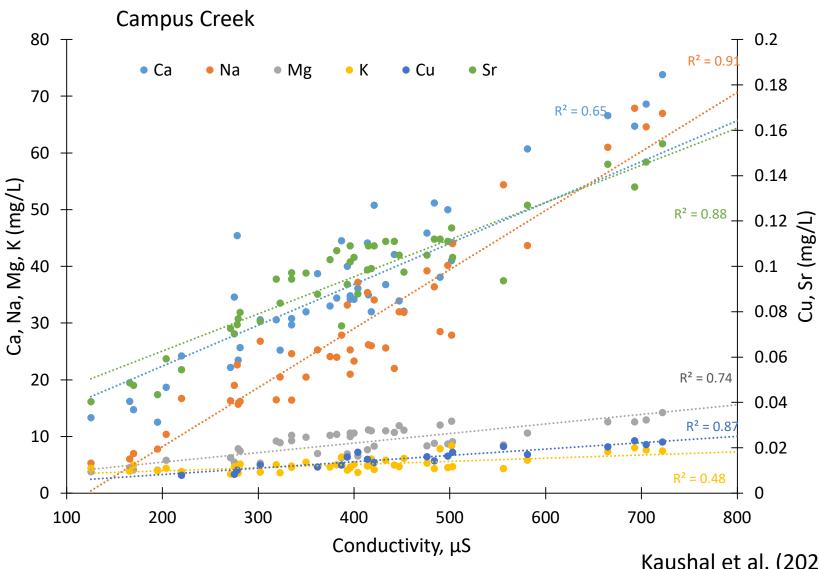


Kaushal et al. (2017, 2019)

Applied Geochemistry,

Philosophical Trans. Royal Society

Developing New Monitoring Approaches: Specific Conductance as a Proxy for Ions



Kaushal et al. (2021) and also see Galella et al. (2021)

Summary

Significant retention of salt ions in stormwater sediments

Release of elements depends on type of deicer ion and site

Large winter peaks – which ions are retained vs. released?

Developing new practical monitoring approaches using proxies

Management Implications

- Stormwater sediments/soils can have very high potential to enhance ion retention and ion exchange
- Reducing winter NaCl inputs can lead to rapid and year long recovery in some ions
- Water quality monitoring approaches using inexpensive proxies such as specific conductance can help predict concentrations of multiple ions and metals

Acknowledgments

 Thanks to the Maryland Department of Transportation and Maryland Department of Natural Resources for funding along with all the funding partners below.















Effects of Iron to Stream Communities





Prepared for:



Chesapeake Bay Trust: Pooled Monitoring Initiative's Restoration Research Forum

Prepared by:



EA Engineering, Science, and Technology, Inc., PBC

Jamie Suski, PhD, Mike Chanov & Jessica Ayers



Christopher Salice, PhD & Megan Gaesser

Research Objectives

Research Objectives in simplistic terms



3. Do either of the above questions appear to be related to Regenerative Stormwater Conveyance (RSC)?



Stream Characterization

Step-pool or Regenerative Stormwater Conveyance (RSC)



Materials can include a mix of granite or iron boulder to create the step-pools

Within pools is a mixture of woodchips/sand and microbial community that typically leads to 'reducing' conditions - potential for dissolved iron (Fe²⁺)



Water leaving pools and mixing with oxygen may create 'oxidizing' conditions – potential for particulate iron (Fe³⁺)

Stream Characterization

No Restoration



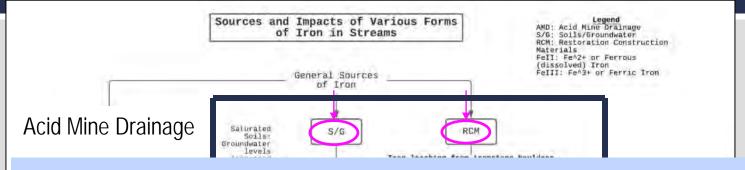
Low iron stream system



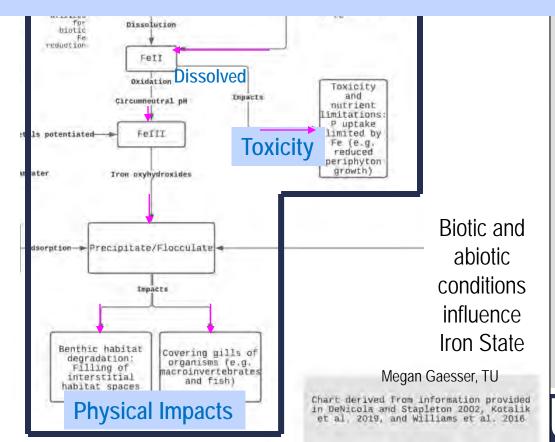
High iron stream system



Iron in Freshwater Steam Systems



COMPLEX SYSTEM & CHEMISTRY





Objectives

Multiple lines of evidence approach to address project objectives

1. Laboratory Experiment – Mesocosms

Objective: Determine effects of dissolved iron and iron flocculate to a representative benthic community



2. Field Experiment and Monitoring

Objective: Determine potential temporal fluctuations in iron chemistry and in-situ effects of iron to macroinvertebrates





Brief Methods



Setup

- 15 gallon HDPE plastic tubs
- 30.25L dechlorinated tap water
- 5.5L triple washed playground sand
- 1L cobble/sediment substrate (field collected)
- 3 large rocks
- 20 aged leaves (mixed deciduous)
- 1- 12" air stone

Organism	Source	Approximate Age	Number Loaded per Tank
Mayfly (Hexagenia)	ARO	~ 6 months	10
Amphipod (Hyalella azteca)	ARO	~15 days	10
Diptera (Chironomous dilutus)	ARO	10 days	10
Caddisfly (Hydropsychidae)	Field		5
Mayfly (Isonychiiadae)	Field		10
Mayfly (Heptageniidae)	Field		8





Brief Methods

Treatments	Total No. of Tanks	рН	lron (mg/L)	Termination Days	Number of tanks per termination day
Acidic	9	5.5-7	0	. 21	
Basic	9	7.5-9	0	2142	
Acidic + Iron	9	5.5-7	0.6	• 42 • 60	3
Basic + Iron	9	7.5-9	0.6	• 00	

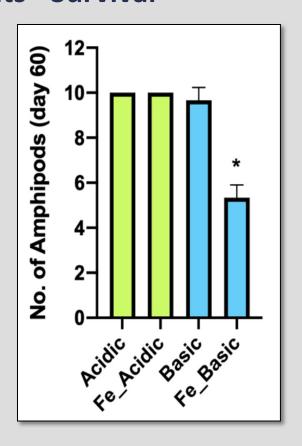








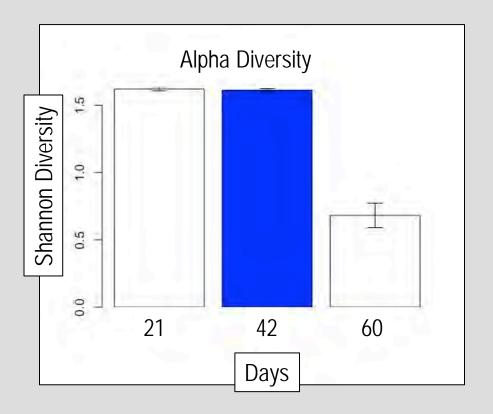
Results - Survival

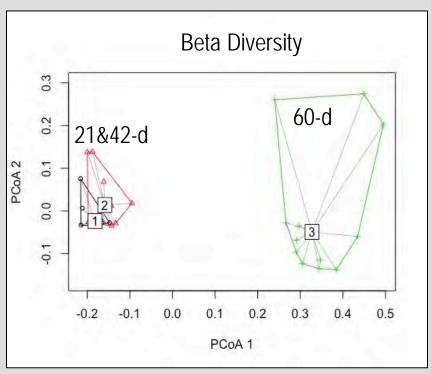




Reduced Survival in tanks with Fe_Basic treatment: Iron precipitate

■ Biodiversity Metrics: <u>Time</u>





There was a *significant effec*t of time on diversity indices: Tanks taken down on Day 60 had little survival compared to tanks removed at days 21 and 42





Take home message

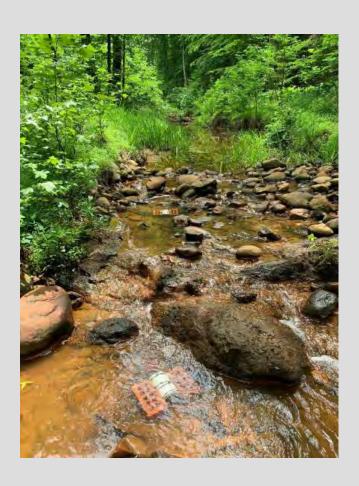
- Reduced survival in amphipods was noted at 0.6 mg/L Iron under basic conditions.
 - **◆** EPA Ecological Screening Criteria for chronic exposure to Iron in surface water is 1mg/L (US EPA 2015*).

 Future laboratory efforts using macro-invertebrate communities should be terminated prior to 60-days.



Field Investigations

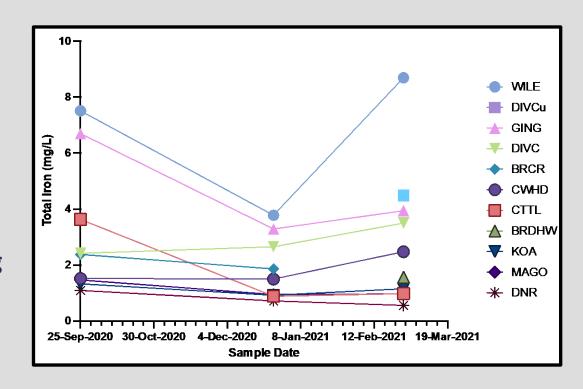
Methods: Iron and water chemistry field sampling every 8 weeks



- Iron measured in the field with Hach strips and in the laboratory on Flame Atomic Absorption Spectrometry (FAAS)
- Standard water quality measurements also collected with a YSI
- Collecting water for chloride analysis (new)

Field Investigations – Temporal

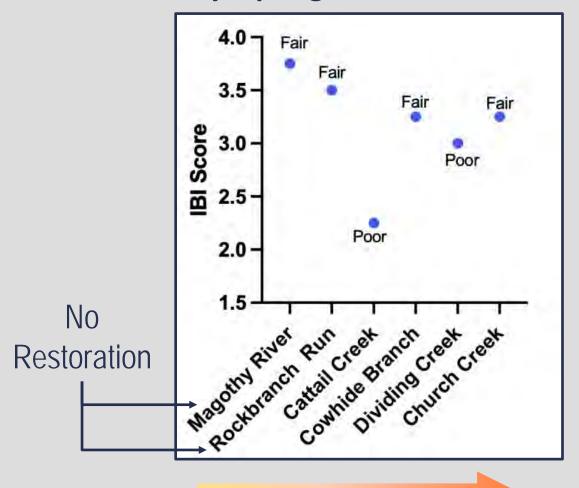
- Total iron as measured by FAAS
 - High Iron sites tend to be high through time
 - Confirmation of previous samples ongoing (change in personnel)
 - ◆ To strengthen dataset, an additional year of sampling and analysis is ongoing





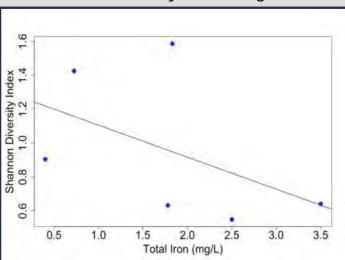
Field Investigations – Fish Diversity

Fish diversity: Spring 2020



Still an unclear picture

Shannon Diversity- Iron Regression



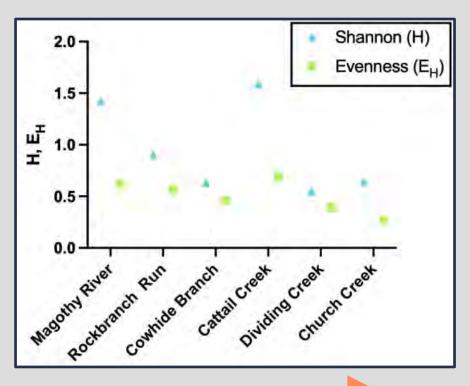
Increasing Iron Concentrations





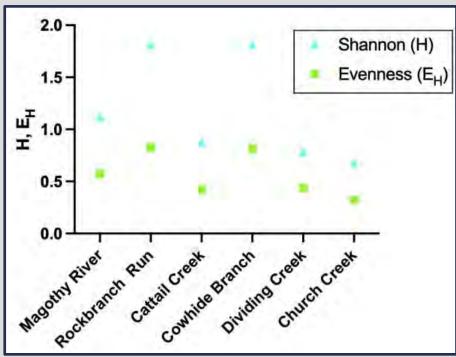
Field Investigation – Local Diversity





Increasing Iron Concentrations

Macroinvertebrates



Increasing Iron Concentrations





Field Experiment

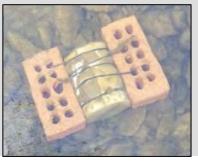
- In situ Pilot Study
 - Overall Objective determine the effects of iron to stream macroinvertebrates under in-field conditions
 - ◆ Pilot Objective determine most appropriate cage design and duration



8-12 macroinvertebrates placed in each enclosure

Survivorship following 6-days in the 4" PVC pipe = 80% Survivorship following 12-days in the 3" PVC pipe = 77%

Successful Design



Noticeable accumulation of algae, detritus and sediment accumulated on the enclosures at day 12





Preliminary Conclusions

 Iron concentrations in streams appear to show minimal temporal variation

 Iron flocculate appears to impact macroinvertebrates more than dissolved iron

Iron may impact stream communities

Definitive caged field experiments are ongoing

Acknowledgements



















Jamie Suski, EA Engineering

Translation Slides by David Hirschman, Hirschman Water & Environment, LLC

What does this mean for me?

- ✓ Iron is one factor in a complex system where there are many other stressors (urban streams).
- ✓ Even without restoration, there are a range of iron conditions; interventions such as RSC can influence the amount of iron floc.
- ✓ What role does iron play if the practitioner aims to take a system from, say, fair to good condition, and is that even a realistic possibility in many cases?
- ✓ How can we assess impacts to the restoration reach (e.g., from iron) vs. downstream benefits?



What does this mean for me?

What do I take from this if I am a practitioner:

- ✓ Condition assessment as part of design, e.g., iron levels in soil, groundwater.
- ✓ Reconnecting to floodplain is great objective, but may have other consequences; good communication needed through the process with regulators, community.

What do I take from this if I am a regulator:

- ✓ Consider reach vs. downstream impacts, benefits.
- ✓ Reducing sediment transport and energy downstream may be the more important thing to consider.



You are done!

Thank you for your hard work to do the research, communicate it clearly to the audience, and translate this into something the audience can do with the information in their work tasks.



Effectiveness of stormwater management practices in protecting stream channel stability

Mohammad Alsmadi, Adjunct Faculty – Virginia Tech (presenter)

David Sample, Associate Professor – Virginia Tech

Tess Wynn Thompson, Associate Professor - Virginia Tech

Andrew Miller, Professor - UMBC

Hypotheses

- 1. Channel instability in Minebank Run is caused by high shear stresses generated during even relatively frequent storm events.
- 2. Retrofitting the Minebank Run watershed with additional watershed stormwater controls will reduce channel incision and bank failure (will compare environmental site design (ESD) only, traditional downstream controls only, and combination of both).
- 3. Had Minebank Run been developed with ESD channel incision and degradation would have 1) been prevented, or 2) been reduced.
- 4. Current channel degradation in tributaries to Little Seneca Creek are the result of recent large magnitude storm events, which are typically not well controlled by ESD.
- 5. Had the Clarksburg watershed been developed using traditional stormwater control measures (SCMs), more extensive channel degradation would have occurred.
- 6. A combination of ESD controlling small storms and SCMs controlling larger events is necessary to protect stream channels against erosion.





Research Questions

- Results of this study will help in:
 - evaluating the effectiveness of environmental site design (ESD) in protecting channel stability.
 - providing insight into the causes of and potential solutions to channel degradation in:
 - a watershed with limited traditional stormwater management and;
 - a watershed where ESD was implemented during development.
 - Explore through modeling the expected difference in development impact on stream channel integrity if measures were done differently





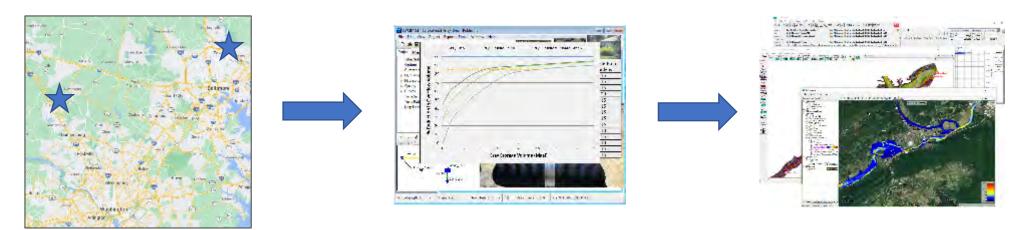
Performance of environmental site design (ESD)

• Is designing and implementing best management practices according to state stream channel protection regulations protective enough of the stream channels on a watershed level?





How these questions were answered...



Parameterize Two watersheds

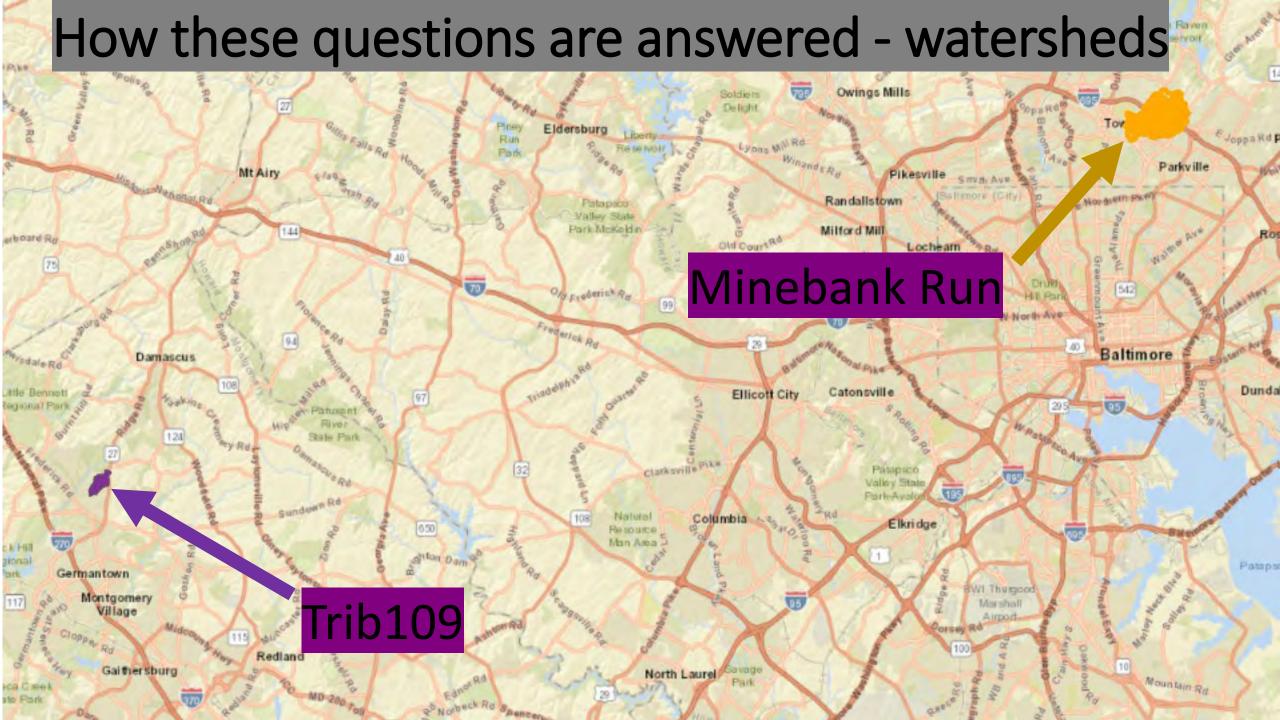
Flows modeled in SWMM

Channels modeled in HEC-RAS 6.0



Natural and man-made features represented within the two watershed models including low impact development measures as well as traditional stormwater management measures.





How these questions are answered - watersheds

- Two Maryland watersheds were used
- 1. Minebank Run watershed (1,425 acre) in Baltimore Co.
 - Bulk of development took place in the 1950s and 1960s
 - Minimum environmental site design implementation
 - Land cover imagery were analyzed since the 1930s to explore development timeline
 - Models were built since the 1940s when watershed experienced little development





How these questions are answered - watersheds

- Two Maryland watersheds were used
- 2. Tributary 109 to Little Seneca Creek (212 acre) in Montgomery Co.
 - Watershed development started in 2005
 - Extensive environmental site design measures were implemented during development
 - Land cover imagery were analyzed since the 2005 to explore development timeline
 - Models were built since the 2005 when watershed development started





Watershed changes through time – Minebank Run







Watershed changes through time – Trib109





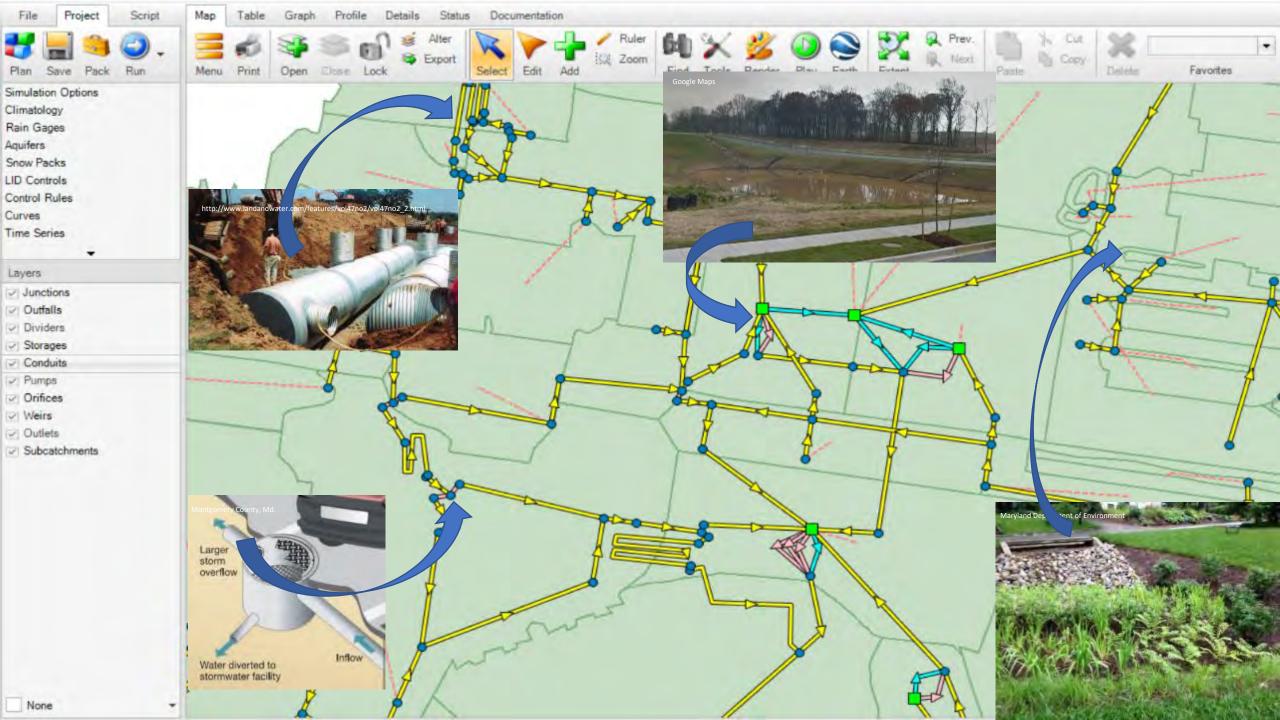


How these questions are answered - Modeling

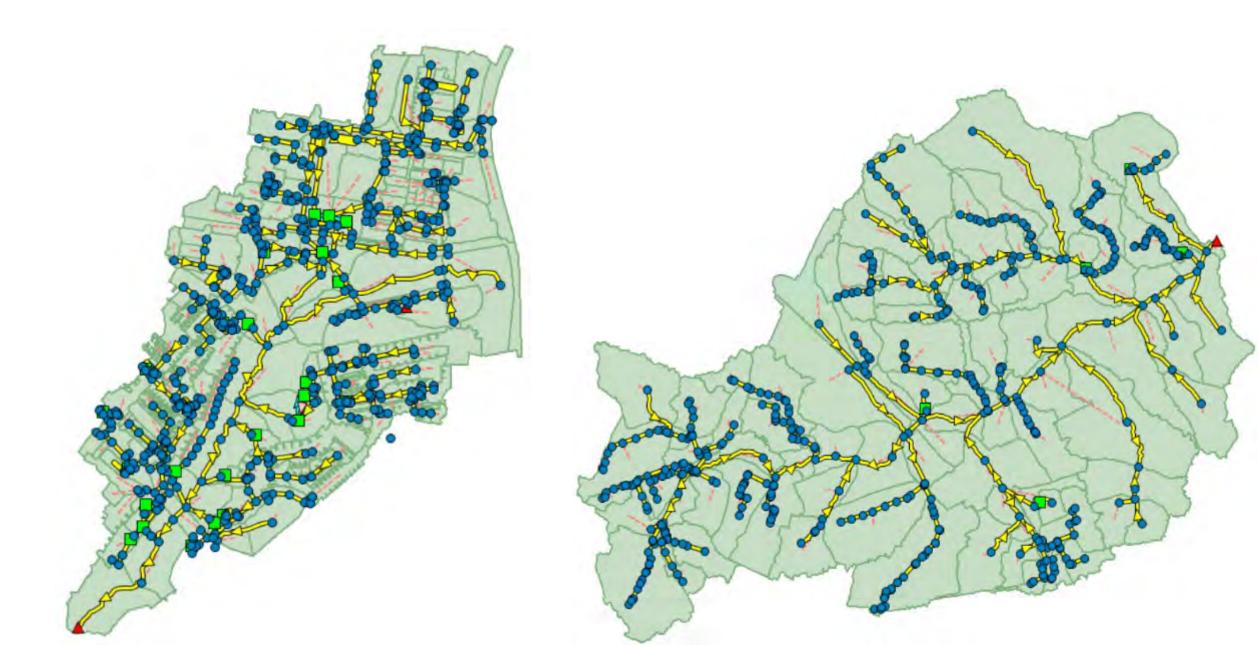
- Watershed characteristics as well as man-made stormwater infrastructure were entered into models
- Models were calibrated based on observed field data
- Calibrated models were used to explore multiple scenarios
- Modeling approach was performed in two tiers:
 - Watershed level (SWMM) simulating area characteristics and man-made facilities
 - Stream channel model utilizing output from SWMM into HEC-RAS 6.0



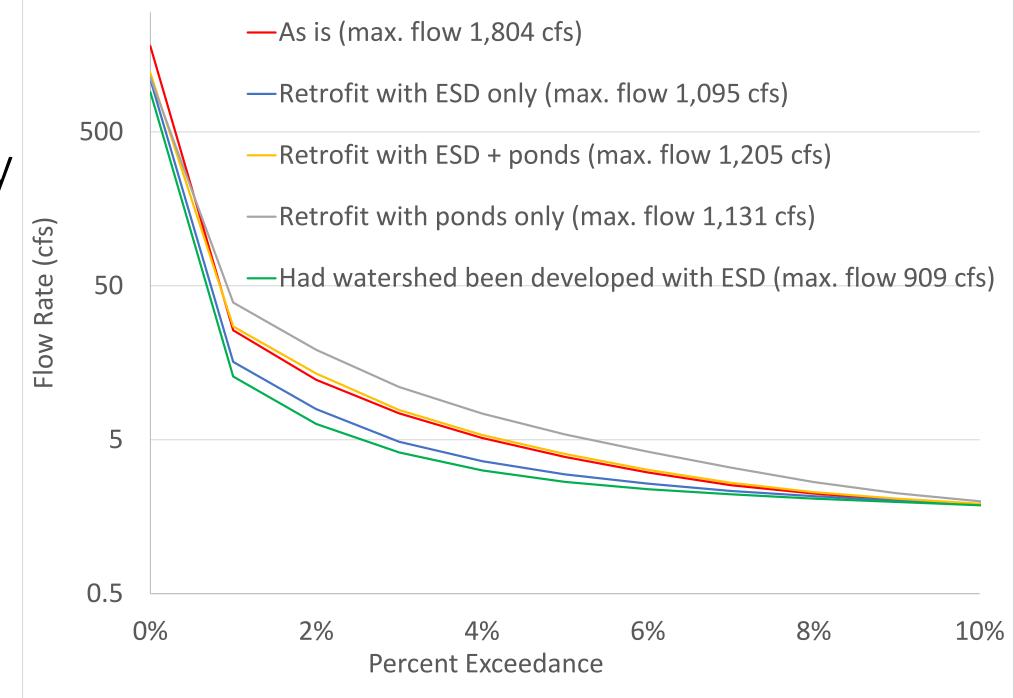




How these questions are answered – SWMM model



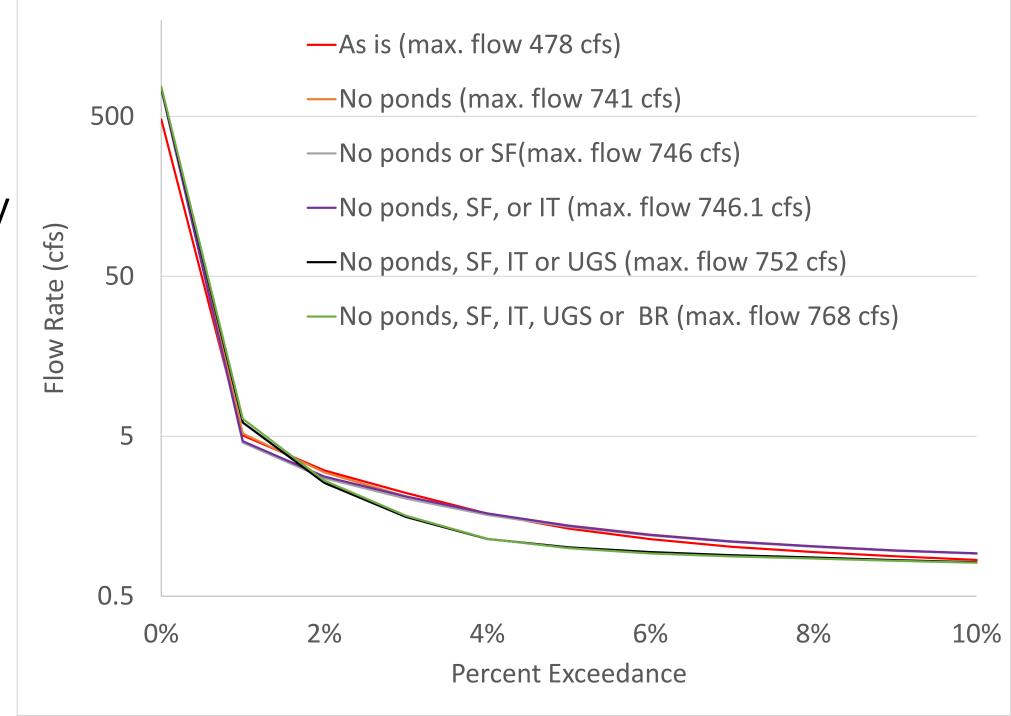
Preliminary Results – Minebank Run







Preliminary Results – Trib109







What's next?

- Finalizing the representation of ESD within the Minebank Run model
- For each one of the 6 hypotheses, the 5-minute flow timeseries for the entire period of simulation will be run in HEC-RAS 6.0.
- We are currently finalizing the HEC-RAS 2D model to incorporate the above mentioned flows along with channel geometry, channel bed and bank soil characteristics and other parameters to explore the impact of each scenario on channel degradation.





Acknowledgment Slide

 Many thanks to the Chesapeake Bay Trust and other partners for funding, providing critical data, and collaborating in developing this project.























Joe Berg, Biohabitats

What does this mean for me?

• ESD works for high frequency storms to reduce channel erosion forces

 ESD role in attenuating impacts from larger storm events on watershed level is being explored

• Our SWM practices need to continue to improve, perhaps targeting "no net increase in runoff" relative to the pre-development condition

Ultimate Outcomes (coming soon!)

What do I take from this if I am a practitioner:

- Utilizing a watershed-based approach allows for the quantification of net impact of upland practices on stream channel stability
- Practitioners may utilize modeling tools to quantify the anticipated impact of upland practices vs. traditional SWM practices or a mix of both on stream channel stability

What do I take from this if I am a regulator:

- Are current regulations protective enough of channel stability
- Effective retrofits may require ESD and quantity control basins
- We need to continuously improve our SWM practices

Appendix Minebank sensitivity (1-yr 24-hr storm)

	peak flow rate (cfs)	total volume (ft3)
as is	561.5	4,019,000
IMP reduced by 50%	300.9	2,626,000
depression storage doubled	531.5	3,431,000
depression storage X5	515.4	2,854,000
conductivity doubled	549.1	3,523,000
conductivity X5	528.2	3,273,000
route all impervious to pervious	204.2	2,667,000
route 50% of impervious to pervious	342.2	3,284,000
Ponds only scenario	337	3,969,000

Long-term impacts of living shorelines to SAV habitats in Chesapeake Bay

Cindy Palinkas, Lorie Staver

University of Maryland Center for Environmental Science
Horn Point Laboratory
Cambridge, MD

Restoration Research Questions:

How does impacting SAV compare to the benefit of creating intertidal wetland?

Under what conditions...is an SAV impact tolerable? How can indirect impacts...on SAV loss be better predicted?

NTER FOR ENVIRONMENTAL SCIENCE

Addressing shoreline erosion with living shorelines

- 1. Chesapeake Bay focus but ubiquitous problem; in the Bay,
 - 33% of the shoreline is eroding; 70% of the Maryland portion
 - 85% of the shoreline is privately owned
- 2. Past efforts focused on "hard" approaches like breakwaters and rip rap
 - ~25% of the Bay's shoreline already hardened, more than 50% in some areas, with generally negative ecosystem impacts
- 3. Recent push (including Maryland laws in 2008) for living shorelines as an alternative. These have habitat benefits (e.g. fish, wildfowl) but, how do they impact adjacent ecosystems, especially SAV? And, what are the trade-offs in ecosystem services?



Research Questions

Performance:

Q1: Are living shorelines effective in reducing shoreline erosion?

Impacts:

Q2: Do living shorelines alter SAV habitat and/or distributions?

Co-benefits:

Q3: What are potential trade-offs in ecosystem services (sediment and nutrient accretion)?

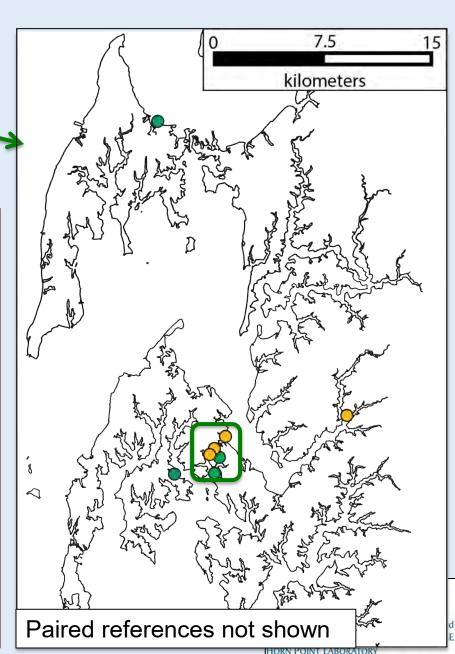


Chesapeake Bay

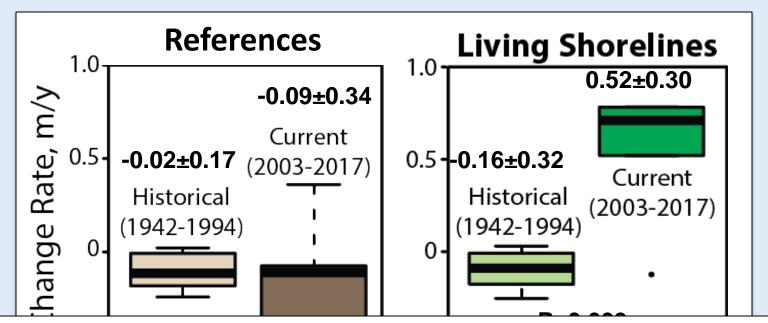
8 sites with paired reference sites (unaltered shorelines, typically within ~0.5 km, similar physical setting) in the mesohaline portion of Chesapeake:

- Installed 2004-2008
- Weighted-bed density of SAV from 1978-2005 (GIS analysis of VIMS aerial data)
- 4 sites with persistent, dense SAV before installation (green)
- 4 sites without SAV before installation (yellow)

Study Sites



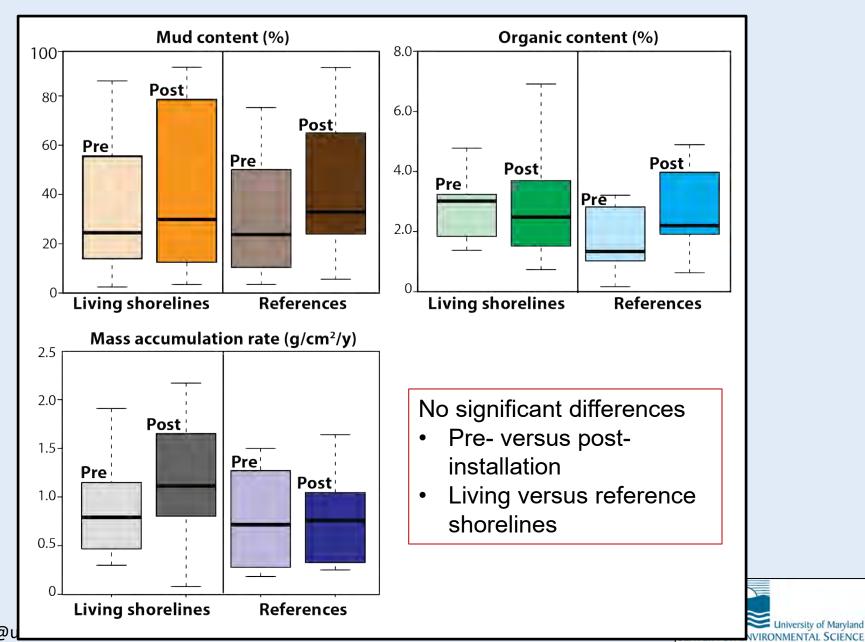
Performance: erosion rates before and after installation



Net accretion occurs at living shorelines due to installation, while erosion continues at or above historical rates at reference sites

- Negative change = erosion (shoreline moves landward); Positive change
 accretion (shoreline moves seaward)
- Trend of increasing erosion at reference shorelines but not statistically significant (p>0.10)
- Significant accretion at living shorelines from installation building shoreline seaward (~instantaneous change rather than rate)

Impacts: Do living shorelines alter SAV habitat?



cpalinkas@u

HORN POINT LABORATORY

University of Maryland

Changes can be significant at individual sites

	Site	Mud at site	Mud at reference	Rate at site	Rate at reference
	QL				
	OP				
	RU				
	HG				
	SD	NA*		NA*	
	EC		NA**		NA**
	MG				
	MM				

T-tests between pre- and post-installation

Gray = not significant (p<0.10)

Red = increase

Blue = decrease

*=not enough data in "after"

**=core not collected



Changes can be significant at individual sites

Site	Mud at site	Mud at reference	Rate at site	Rate at reference
MG				
MM				

No SAV at either the sites or their references since 1989



Some significant changes at individual sites

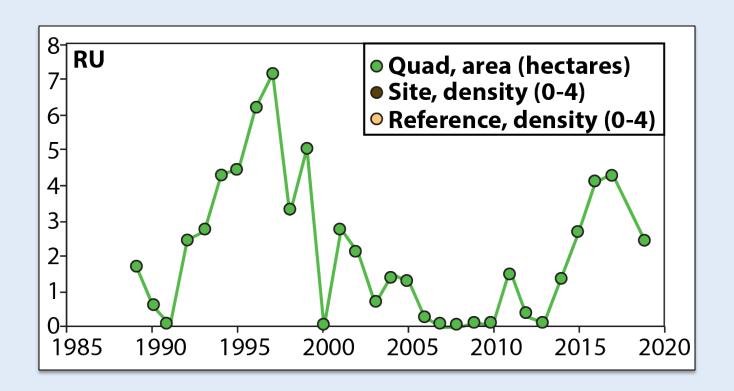
Site	Mud at site	Mud at reference	Rate at site	Rate at reference
RU				
HG				

Sites: both have increasing sedimentation rates, decreasing mud (more sand) **References:** both have no change in sedimentation rates, different trends for mud

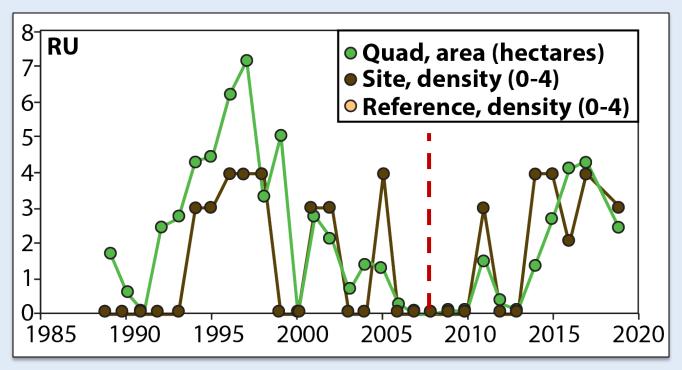
Conveniently – all are in the same SAV monitoring quad



SAV area within the quad – lots of variability!



SAV area at the site follows the quad

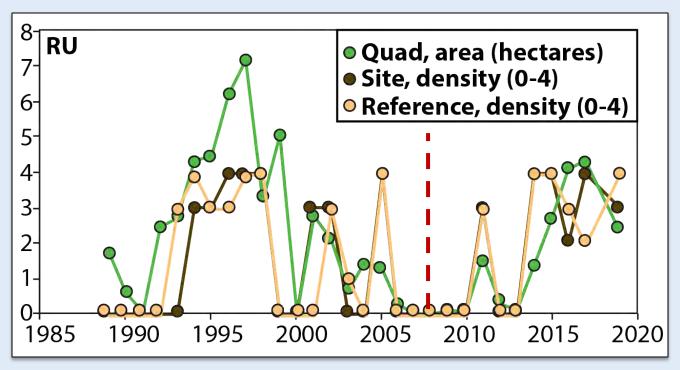


Install 2008 (red line)

Site: increasing sedimentation rate; decreasing mud (more sand) Reference: no change in sedimentation rate; decreasing mud (more sand)



SAV area at the reference site follows general trend

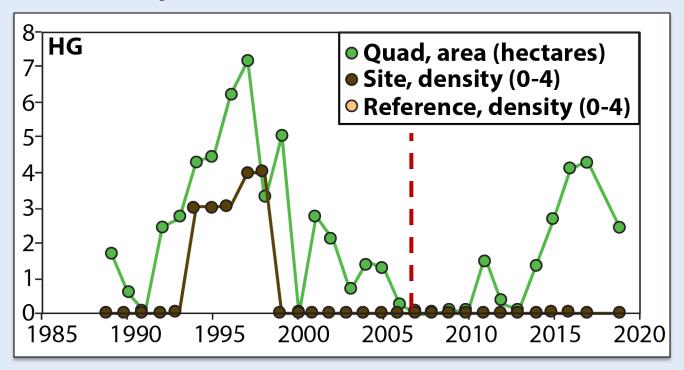


Install 2008 (red line)

Site: increasing sedimentation rate; decreasing mud (more sand)
Reference: no change in sedimentation rate; decreasing mud (more sand)
No difference between SAV at site and reference site; both follow quad



At a nearby site (same quad), SAV disappears many years before installation

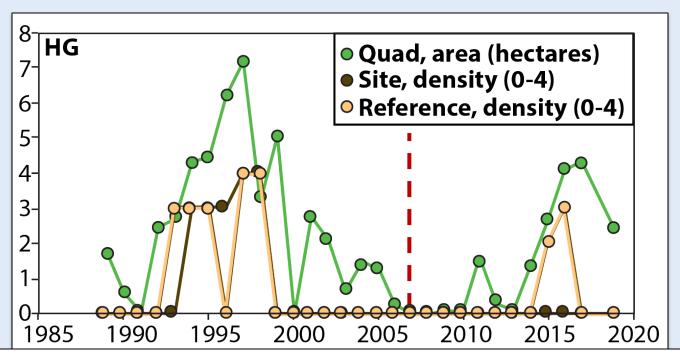


Install 2007 (red line)

Site: increasing sedimentation rate; decreasing mud (more sand) Reference: no change in sedimentation rate; increasing mud (less sand)



SAV disappears at a different site, same quad

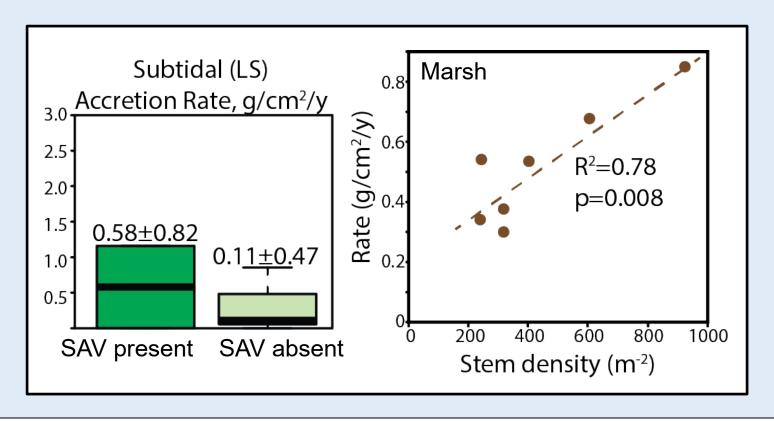


Living shoreline installation does not appear to influence SAV distributions, which generally follow regional trends except for some sites where local processes affect both living and reference shorelines

Reference: no change in sedimentation rate; increasing mud (less sand) SAV at site and reference follow the same trend, disappearing many years before installation and not returning, not influenced by divergence in mud trends.



Co-benefits: what controls burial rates in marsh and subtidal? Plants!



Subtidal (LS) = shallow water adjacent to living shorelines; rates tend to be higher at sites with SAV

Marsh accretion rates increase with stem density



Co-benefits: how do sediment and nutrient burial rates compare

SAV present	Accretion rate g/cm²/y	N burial mg/cm²/y (%)	P burial mg/cm ² /y (%)	C burial mg/cm²/y (%)
Living shoreline marsh	0.67	3.0 (0.45)	4.1 (0.62)	31.7 (4.8)
Living shoreline subtidal	0.42	0.19 (0.045)	1.8 (0.43)	1.58 (0.38)
Reference subtidal	0.15	0.18 (0.12)	0.55 (0.37)	1.5 (1.0)

SAV absent	Accretion rate g/cm²/y	N burial mg/cm ² /y (%)	P burial mg/cm ² /y (%)	C burial mg/cm ² /y (%)
Living shoreline marsh	0.45	3.6 (0.81)	3.6 (0.80)	41.8 (9.3)
Living shoreline subtidal	0.11	0.10 (0.09)	0.57 (0.52)	0.90 (0.82)
Reference subtidal	0.53	0.92 (0.18)	4.7 (0.90)	9.4 (1.8)

Living shorelines **increase** sediment and nutrient storage in the coastal zone due to the addition of marsh habitat that traps sediment



Summary

Performance: shoreline erosion rates

- Net accretion at living shorelines due to construction
- Continuing erosion at or above historical rates at reference shorelines

Impacts of living shorelines to SAV?

 SAV distributions at all shorelines appear to follow trends in larger area, with no obvious qualitative impact of living shoreline installation

Co-benefits: sediment/nutrient burial rates

- SAV and marsh plants effectively trap sediments and associated nutrients
- Net sediment and nutrient storage across the coastal zone is much higher for sites with living shorelines, due to the addition of marsh habitat; SAV presence may also enhance storage to a lesser extent



Jana Davis Chesapeake Bay Trust

Are living shorelines effective, and what does this mean for me?

- Living shorelines accrete sediment, and therefore protect against erosion compared to shorelines without protection.
- (We know from other studies LS are better habitat than armor, so if a landowner can't tolerate erosion, let's go with LS)
- (SAV beds also trap nutrients and accrete sediments, but not as much)
- You get the most nutrient trapping when both LS and SAV are present, so if your goal is nutrient removal, having both habitat types present is good

What about the trade-off(s), and what does this mean for me?

- SAV is really variable might disappear at a site at which a living shoreline was built, but if so, it likely disappeared in the region as a whole also
- Living shoreline installation didn't change conditions where SAV grows, so probably doesn't drive SAV changes
- If SAV disappears after living shoreline installation; it wasn't necessarily tied to the living shoreline

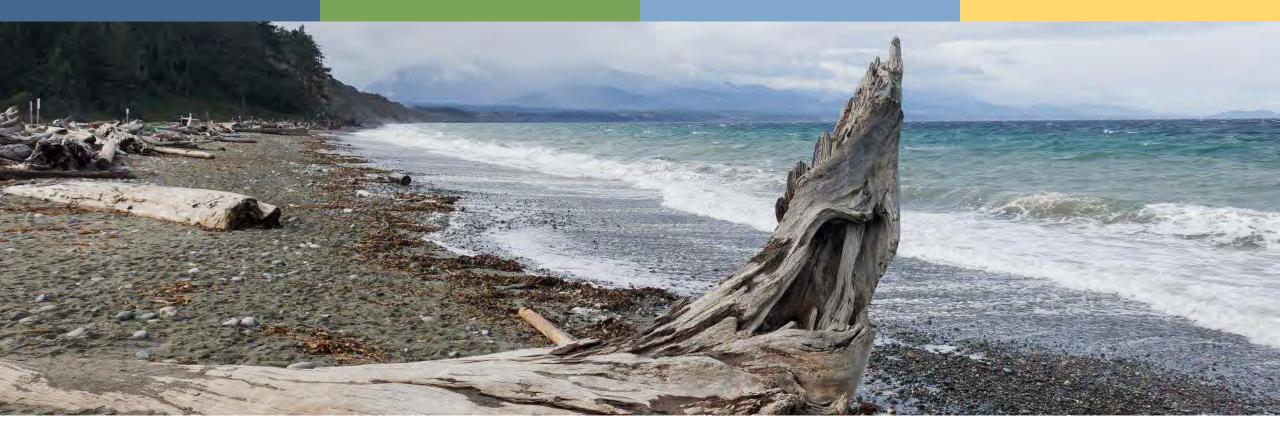
What does this mean for me?

What do I take from this if I am a practitioner:

- Both living shorelines and SAV are good from a nutrient and sediment removal perspective (and we know habitat). Considering designing to encourage SAV below the site
- Natural shoreline has nutrient reducing value too; don't use shoreline protection unless you have to

What do I take from this if I am a regulator:

- Diversity of vegetative habitats is good for critters we knew that already. It also appears good for nutrient and sediment removal
- I'd be careful to not attribute SAV loss to living shorelines it's possible any loss is due to larger patterns in the region
- Because both living shorelines and SAV have similar nutrient/sediment reducing value, I'd be balanced: In areas with lots of wetland but little SAV, perhaps don't encourage covering up the last SAV sprig with a living shoreline. In areas with lots of SAV but no wetland, consider allowing living shorelines





Pooled Stormwater Monitoring

Karen Dinicola, Senior Policy Lead

Is stormwater management working?

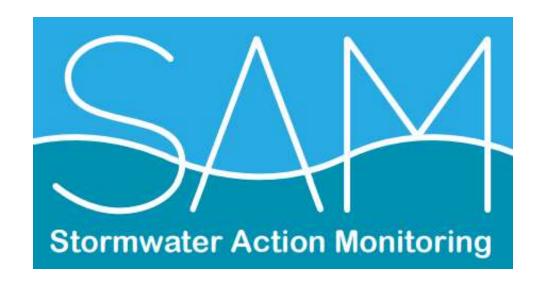
Where, and why or why not?







Our pooled regional monitoring program





We are not monitoring everything, everywhere

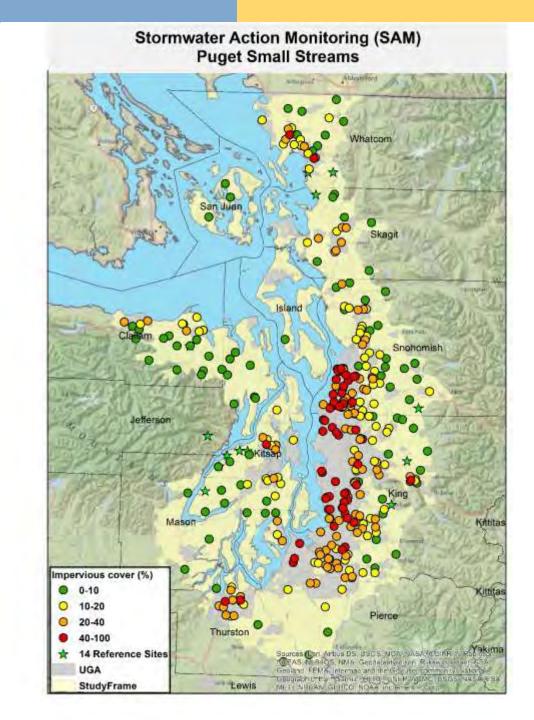
Stakeholders determine the priorities





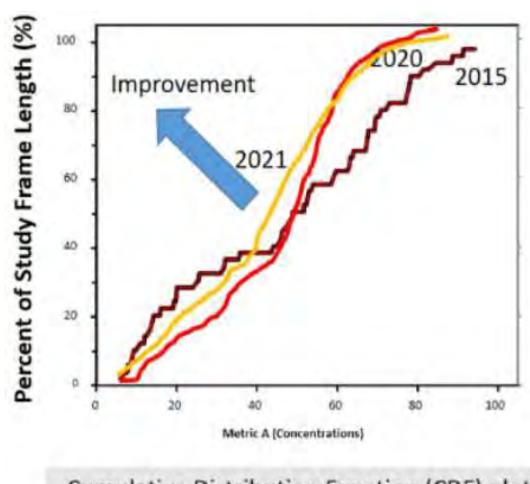
We have a solid monitoring design

- Rotating, probabilistic sampling sites
- Prioritized parameters
- Status assessments
- Trends assessments



Regional trend assessment

- Look at regional patterns by parameter
- Compare from year to year
- Permittees can evaluate their local conditions in a regional context



Cumulative Distribution Function (CDF) plot Example



14 studies completed since 2014

7 in progress, more in the pipeline Wide range of topics

- LID, amendments, and retrofits
- 0&M, E&O, IDDE

Why does this study matter?

What will we do with the findings?







Bioretention treatment of stormwater prevents toxicity

Well water (4 hr)



All 4 fish alive at 24 hr

Unfiltered stormwater (4 hr)



0 of 4 fish alive at 24 hr

Filtered stormwater (4 hr)



All 4 fish alive at 24 hr



Prevents acute mortality in spawners, juveniles, and alevin

What are we learning about 6PPD-quinone?

Multiple lines of inquiry

- Working with industry on 6PPD alternatives
- Developing accredited field and laboratory methods
- ✓ Identifying more stormwater best practices that remove the toxicity
- Working with stakeholders on priorities and funding to invest smartly
- ✓ Doing more research on fundamental questions: fate and transport, sub-lethal effects on multiple species

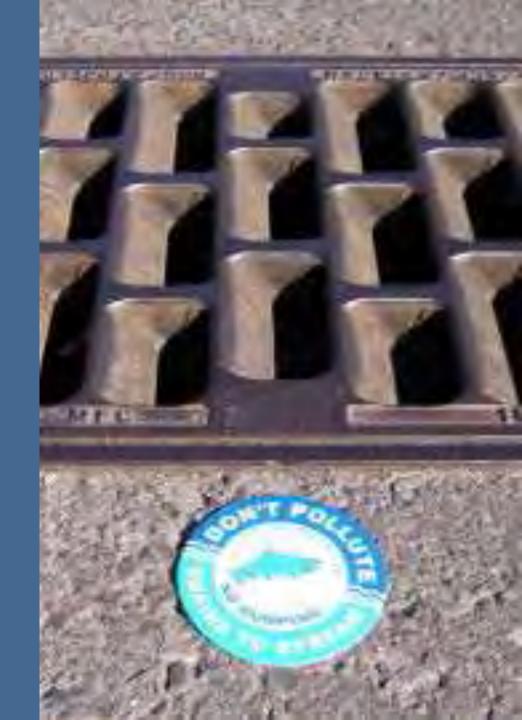




We've made it simple for the permittees

"It's so easy to just write a check!"





How does it work?

Permit monitoring condition

or

 Contribute to pooled funding accounts – amount calculated based on population

 Conduct outfall monitoring for representative land use conditions according to a detailed boilerplate QAPP



Who participates?

All Western Washington Phase I and Phase II Permittees have "opted in" to SAM to meet their permit monitoring requirements

- 4 Phase I and 5 Phase II counties
- 2 Phase I and 82 Phase II cities
- 2 major ports

Washington State Dept. of Transportation

US Navy sites



Recap:

- Know your questions
- Invest in solid design to get useful answers
- Make it simple for the permittees





Questions?

Karen.Dinicola@ecy.wa.gov (360) 407-6550 ecology.wa.gov/SAM

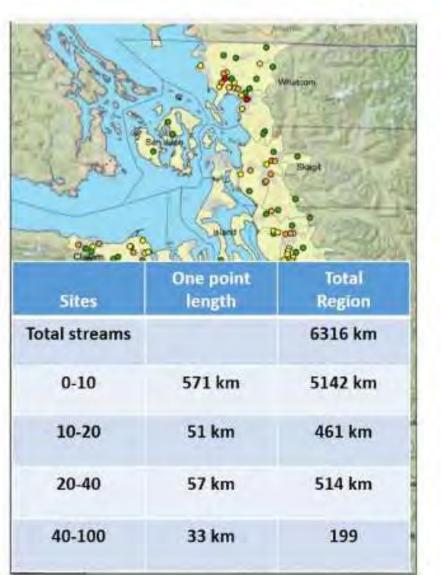


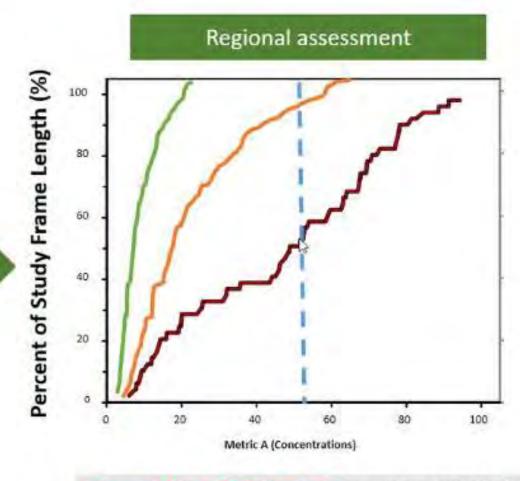




Regional results using CDF plot







Cumulative Distribution Function (CDF) plot

TREE TRADE-OFFS IN STREAM RESTORATION PROJECTS: IMPACT ON RIPARIAN GROUNDWATER QUALITY

Presenters: Sujay S. Kaushal¹ and Kelsey L. Wood¹

Research Team Includes: Philippe G. Vidon²
Joseph G. Galella¹

¹University of Maryland ²State University of New York ESF

Outline

- Overview/ Key Questions
- Methods/ Study Sites
- Results/ Discussion
- Management Implications

Outline

- Overview/ Key Questions
- Methods/ Study Sites
- Results/ Discussion
- Management Implications

Motivation

 Trees in riparian zones provide key water quality functions

 Trees can be removed from riparian zones during stream restoration

 There is a lack in our understanding of the effects of tree removal on water quality





Research Questions

- What is the impact of riparian tree removal during stream restoration and subsequent recovery (if any) on groundwater quality across restored, degraded, and forested reference sites in Maryland?
- Which type of broadly available data are best suited to predict both the nominal and cumulative impacts of riparian zones with various history of tree dynamics / disturbance on water quality at the watershed scale?

Experimental Design

- Chronosequence of restoration up to 20 years
- Variety of stream restoration types

 Paired riparian zones with undisturbed trees and with trees removed in same watershed

 Measure concentrations of common plant nutrients and contaminants in ground water

Restoration Chronosequence

	Campus Creek (19-14) Campus Creek (19-14) Paint Branch (19-14) (19-14)		Scott's Level (Uncut/ 5-year Cut)	Stony Run (10-year Cut)	Minebank Run (20-year Cut)	
Year restored	2019	2014	2014	2009	1999	
Area of Tree Canopy Removed (km²)	TBD	13.958	9.703	6.089	NA	
Geologic Province	Coastal plain (quaternary sediments)	Coastal plain (quaternary sediments)	Piedmont (quartz feldspar schist and granulite)	Piedmont (gabbro and norite)	Piedmont (schist and gneiss)	
USDA Soil Classification	ZS—Zekiah and Issue soils, frequently flooded	CF- Codorus and Hatboro soils, frequently flooded	hbA- Hatboro silt loams	50A- Hatboro-Codorus complex, frequently flooded	MmA- Melvin silt loam	
Soil Texture	Loam, silt loam, mucky silt loam, fine sandy loam, sandy loam	Silt loam, loam	Silt loam, silty clay loam, sandy loam	Silt loam, Gravelly silt loam, very gravelly silt loam	Silt loam, silty clay loam	
Riparian Zone Slope	0.05	0.12	0.07	0.09	0.1	
Riparian Zone Width (m)	32-35	40+	5-25	10-18	20-25	
Channel Width (m)	2-3	10-12	2-4	2-4	1-2	
NWI Wetland Classification	PFO1A Freshwater forested/ shrub wetland	PFO1A Freshwater forested/ shrub wetland	PEM5Ax- Freshwater emergent wetland PFO1Ax-Freshwater forested/ shrub wetland		PFO1/EM5A- Freshwater forested shrub wetland	
Vegetation	Mature Trees (Maple, Holly, Beech) Herbaceous near rive Mature trees upland (T Magnolia, Maple)		Transect A: Herbaceous Transect B: Mature trees (Hickory, Oak)	Young/relatively smaller trees (Redbud, Beech)	Mature trees (Sycamore, Beech, Oak) & herbaceous	
Drainage Basin Area (mi²)	0.59	29.3	1.19	0.64	0.41	
Impervious Surface Cover in Watershed	22.8 %	31.6 %	37.7%	39.6%	40.8	
Forest Cover in Watershed	24.9 %	24.9 % 25.6 %		12 %	25 %	

Tree Removal Area



Chronosequence of sites 5- 20 years and uncut comparisons



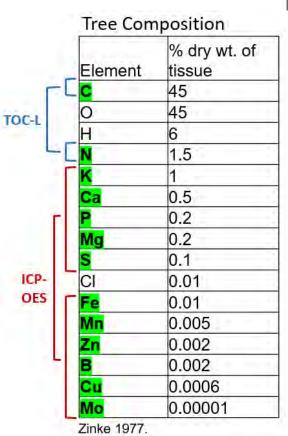


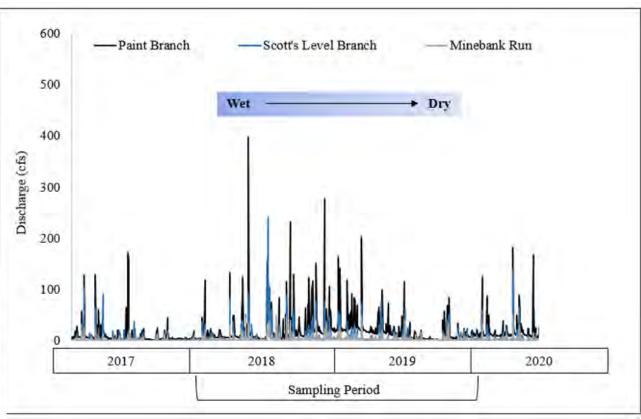
Wells installed in transects of 3

Results: Sites where trees were removed had higher nutrient concentrations than sites where no trees were removed

- Concentrations of common plant nutrients
 (nitrogen, potassium, calcium, etc.) were elevated in ground water in sites where trees were removed
- Concentrations of common plant nutrients in groundwater decrease downslope in riparian zones with trees, but increase downslope in riparian zones where trees were removed

190 samplescollected over a2 year period



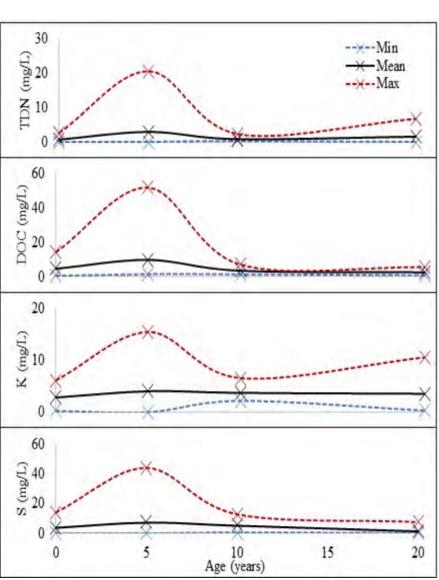


Multiple element approach

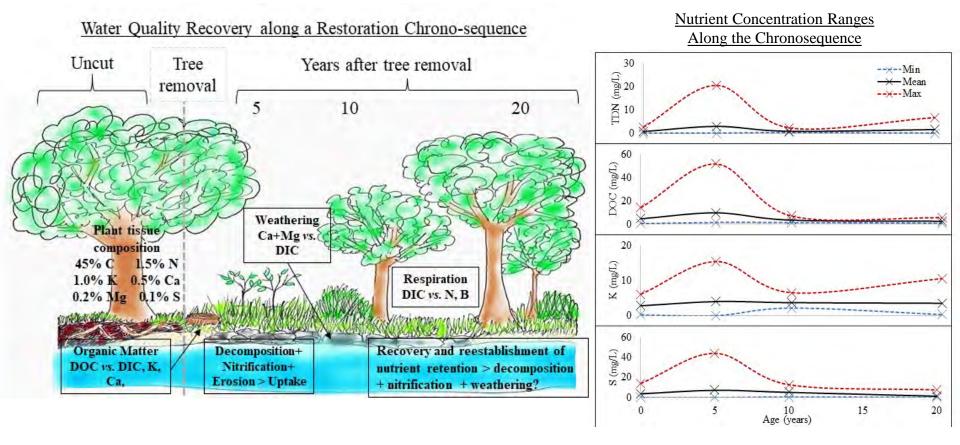
Nutrients and carbon were most elevated immediately following restoration/ tree removal

	DIC			DOC			TDN			Ca		
	Mean	SE	post- hoc*	Mean	SE	post- hoc*	Mean	SE	post- hoc*	Mean	SE	post- hoc*
Uncut	14.931		a	4.742	0.831	a	0.752	0.326	a	14.483		
5-yr cut	42.186	4.753	b	9.126	0.95	b	2.535	0.373	b	48.118	3.926	b
10-yr cut	68.235	8.913	с	3.576	1.782	a	0.867	0.699	a,b	70.389	7.465	С
20-yr cut	64.384	5.406	c	2.657	1.081	a	1.5	0.424	a,b	65.281	4.539	С
	<mark>K</mark>		Mg		Na			S				
	Mean	SE	post- hoc*	Mean	SE	post- hoc*	Mean		post- hoc*	Mean	SE	post- hoc*
Uncut	2.746	0.253	a	4.625	1.028	a	6.283	0.855	a,b	4.166	0.732	a
5-yr cut	3.777	0.291	a	8.691	1.184	b	8.435	0.985	a	7.143	0.843	b
10-yr cut	3.958	0.553	a	11.554	2.252	b	7.468	1.873	a,b	5.534	1.602	a,b
20-yr cut	3.5	0.336	i a	24.751	1.414	c	4.357	1.139	b	1.63	0.974	a

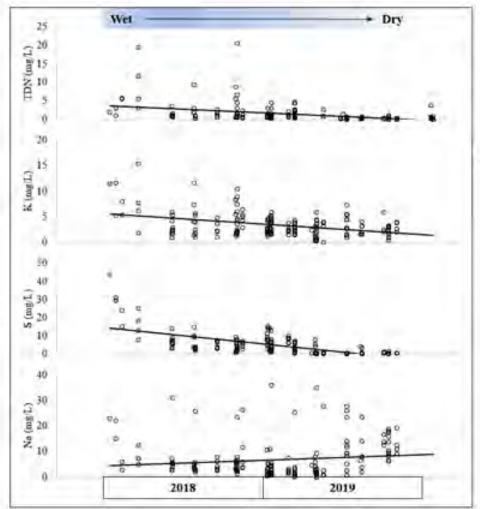
Tukey's (*post-hoc) results from restoration age-based ANOVA (Wood et. al. 2021)



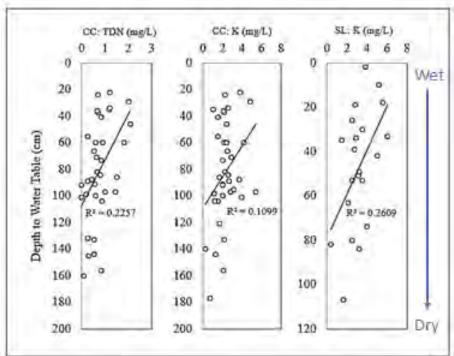
Wood et. al. (In Review)



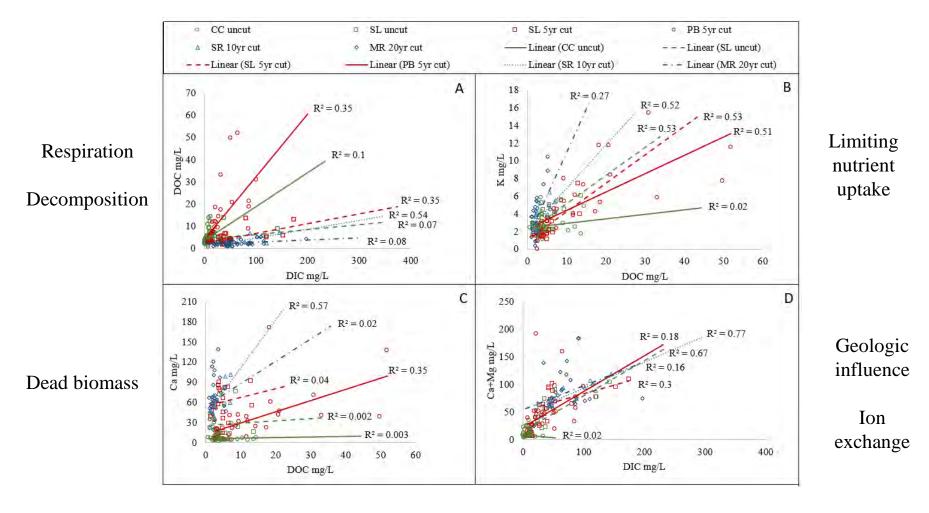
Nutrient concentrations peaked after restoration/tree removal and then declined with ecosystem recovery and riparian tree growth.



Plant Nutrient and Carbon Concentrations Decreased from Wet to Dry Conditions

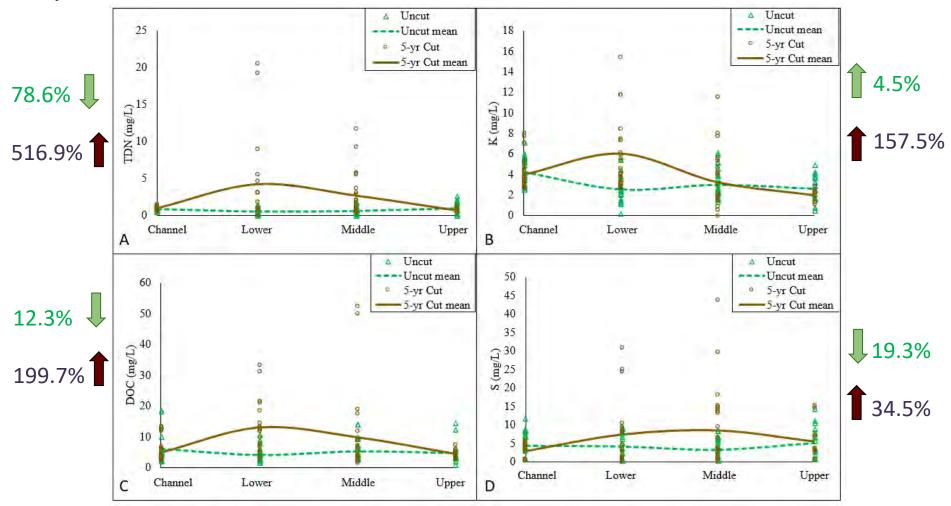


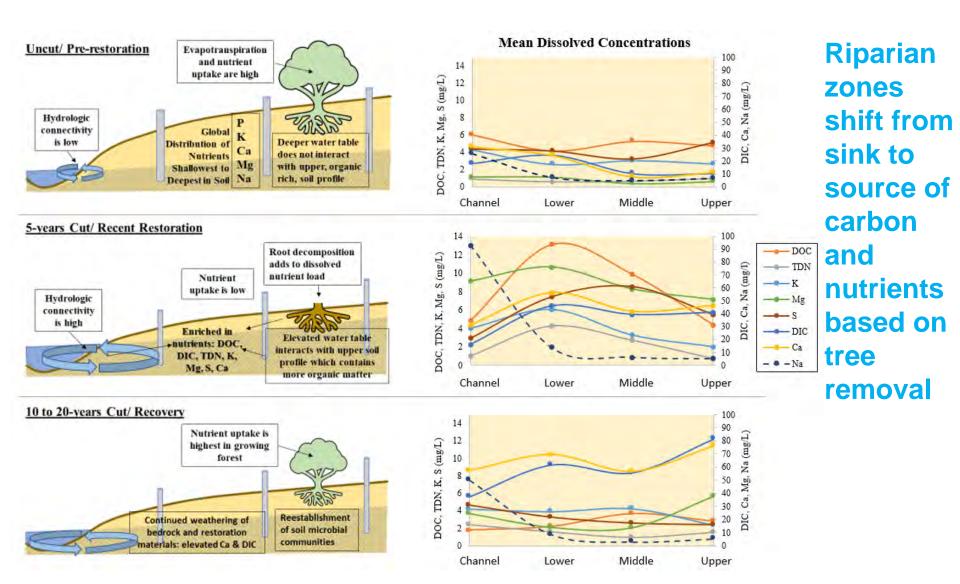
Plant biomass and organic matter can be a source or sink of nutrients.



Riparian zones are sources or sinks: restored/cut sites vs. uncut sites

Nutrient uptake along flowpaths (sink) at uncut sites and accumulation along flowpaths (source) at 5-year cut sites.





Wood et. al. (In Review)



streams

groundwater

Other studies have shown increased nutrient concentrations after tree removal in watersheds

Study	Water Chemistry Response after Tree Removal	Location
Löfgren et al. (2009)	Increased concentrations of Na, K, N, Cl, etc. in streams	Sweden
Martin and Pierce (1980)	Increased concentrations of Ca and N in streams	Northeastern U.S. /New England
(G. E. Likens et al. 1970))	Increased concentrations of N, Ca, K, Na, Mg, etc. in streams	New Hampshire, USA
Aubertin and Patric (1974)	Increased concentrations of nitrate and phosphate in streams	West Virginia, USA
Hewlett, Post, and Doss (1984)	Increased concentrations of N, K, Na, Ca, Mg, etc. in streams	Georgia, USA
Burns and Murdoch (2004)	Increased concentrations of nitrate in streams	Catskills, New York, USA
Swank, Vose, and Elliott (2001)	Increased concentrations of nitrate, K, Na, Ca, Mg, S, and Cl in streams	Southern Appalachian Mountains, North Carolina, USA
Feller and Kimmins (1984)	Increased concentrations of N, K, Mg, Ca, etc. in streams	Vancouver, British Columbia
Rusanen et al. (2004)	Increased concentrations of nitrate in groundwater	Finland aquifers
Kubin (1998)	Increased concentrations of nitrate in groundwater	Finland aquifers
Williams, Fisher, and Melack (1997)	Increased concentrations of nitrate, potassium, sodium, and chloride in groundwater	Amazonian rainforest in Brazil

Tree-Tradeoff: Take Home Points

- Significantly increased concentrations in riparian groundwater for at least 5 years following tree removal then subsequent recovery
- Increased concentrations during wet periods and decreased concentrations during dry periods
- Strong relationships with DOC (organic matter) across sites suggesting the importance of plant uptake and biomass (organic matter) as sources and sinks of nutrients
- Significant increases in concentrations along hydrologic flow paths from uplands to streams in riparian zones where trees were recently cut, and opposite patterns where trees were not cut – riparian zones can be nutrient source or sink

Translation Slides

by Sadie Drescher

What does this mean for me?

- True to the theme of this research project the restoration and short/long-term impacts are a "trade-off" for us to consider
- Now we have some data on this topic which has been longawaited
- There are impacts after stream restoration and there is a recovery period
- As always, other factors impact the concentrations entering the stream from the groundwater and the recovery, e.g., if it is a wet year or a dry year
- The stream restoration can improve ecosystem function, as intended, and the riparian zone can bounce back after a recovery period of >5 years

What does this mean for me?

What do I take from this if I am a practitioner:

- After restoration when trees are removed there will likely be a period of about 5 years where higher concentrations of nutrients enter the groundwater
- What can I do to lessen the impact?

What do I take from this if I am a regulator:

 After 5 years a "successful" stream restoration that removed trees will be accomplishing the restoration goals and regaining the riparian function (riparian tree growth and ecosystem recovery)

Acknowledgments

 Thanks to the Maryland Department of Transportation and Maryland Department of Natural Resources for funding along with all the funding partners below.



















A Novel Research Framework to Assess Water Quality Impacts of Urban Trees

Question B7, Water Quality of an Urban Tree

Neely L. Law, PhD Mitch Pavao-Zuckerman,

Deb Caraco, P.E. PhD

Bill Hodgins, P.E. Sarah Ponte Cabral

Nancy Sonti, USFS

Susan Day, PhD* Ted Weber Amy Blood*









^{*} University of British Columbia

Key Research Questions

- 1. Do urban forest characteristics that influence ecohydrology occur in common configurations and can these configurations be captured through the development of an urban forest typology?
- 2. Will more complex urban forest types (e.g., those having more canopy layers, greater density, more understory plants or shrubs, litter layers, etc.) reduce runoff volume to a greater extent than simpler configurations?
- 3. How do different tree species affect runoff response?

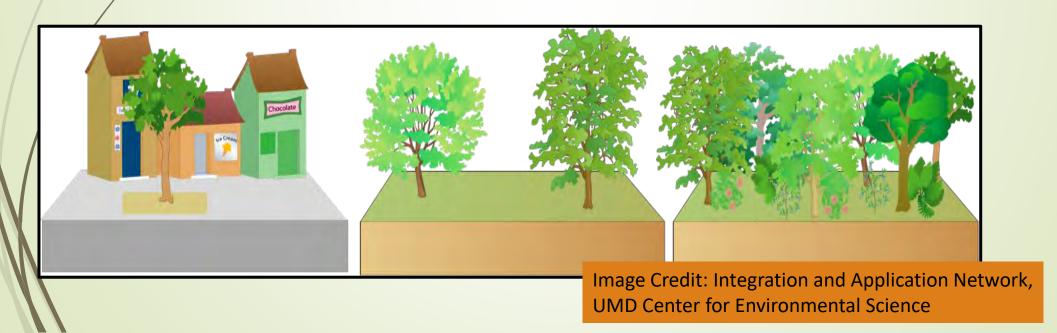
H1: Urban Tree Typology

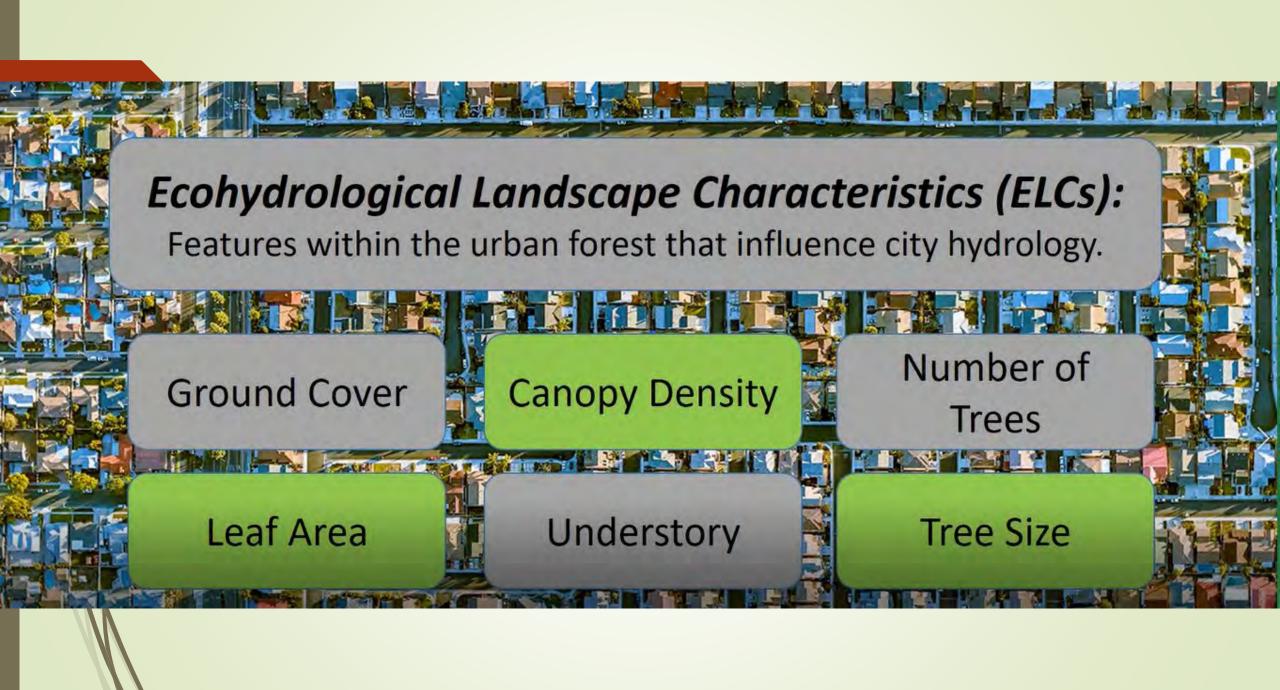
Urban forest characteristics that influence ecohydrology occur in common configurations and these configurations can be captured through the development of an urban forest typology.

- Use Available Ground-Based Data and Lidar to develop a classification scheme.
- Expected to find that data could be used to classify trees into meaningful typologies.

An Ecohydrological Typology

We recognize that trees will perform differently in terms of stormwater mitigation based on their immediate surroundings. We used ecohydrological landscape characteristics to develop a typology, grouping trees with others that have similar ecohydrological benefits. Qualitatively rank categories by benefit potential.

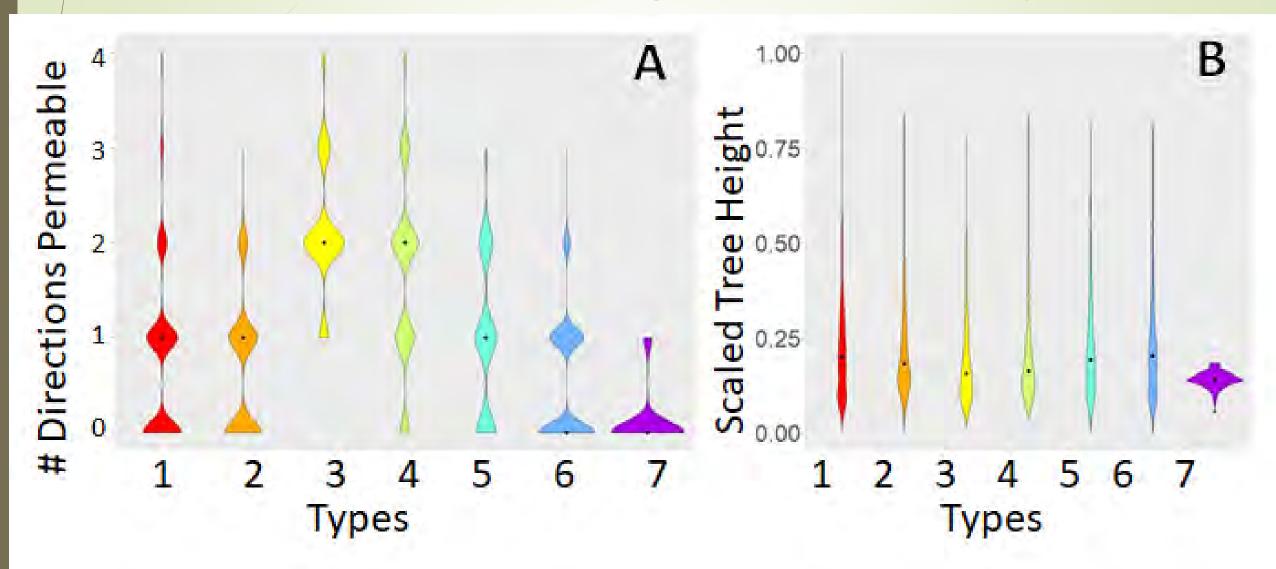




Method Takes into Account the Tree And Its Surroundings



Example Characteristics by Type (Distribution among Trees in Each Type)





Method Potentially Allows Planners to Understand Differences Among Tree Canopy Types

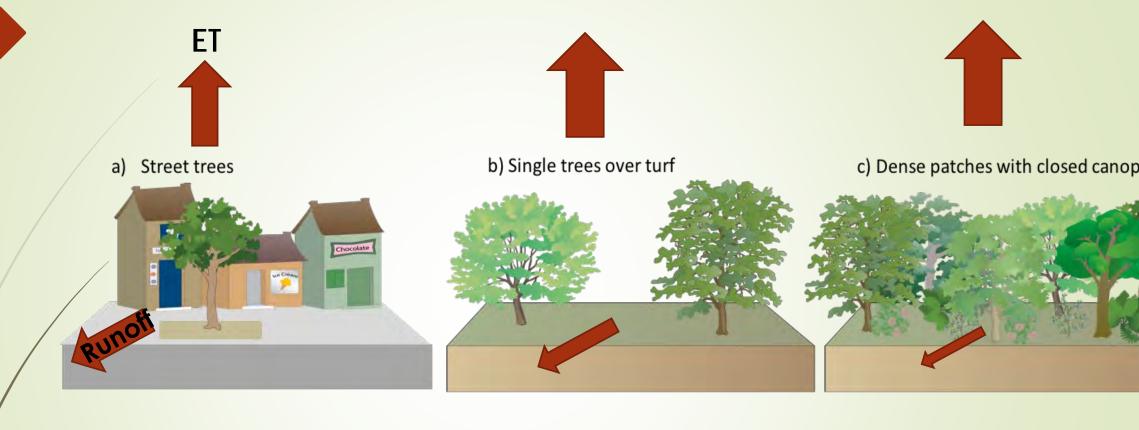


H2: Effects of Forest Types on Runoff Reduction

H2: More complex urban forest types (e.g., those having more canopy layers, greater density, more understory plants or shrubs, litter layers, etc.) will result in greater runoff volume reduction.

- Effects on Transpiration:
 - Expected: Closed Canopy types will have greater transpiration than Open Type
 - Expected: Evapotranspiration will be impacted by Vapor Pressure Deficit and Soil Moisture
- Effects on Interception and Runoff Volume
 - Expected: Closed Canopy Types will have Greater Interception
 - Expected: Closed Canopy Types will have Lower Runoff Volumes



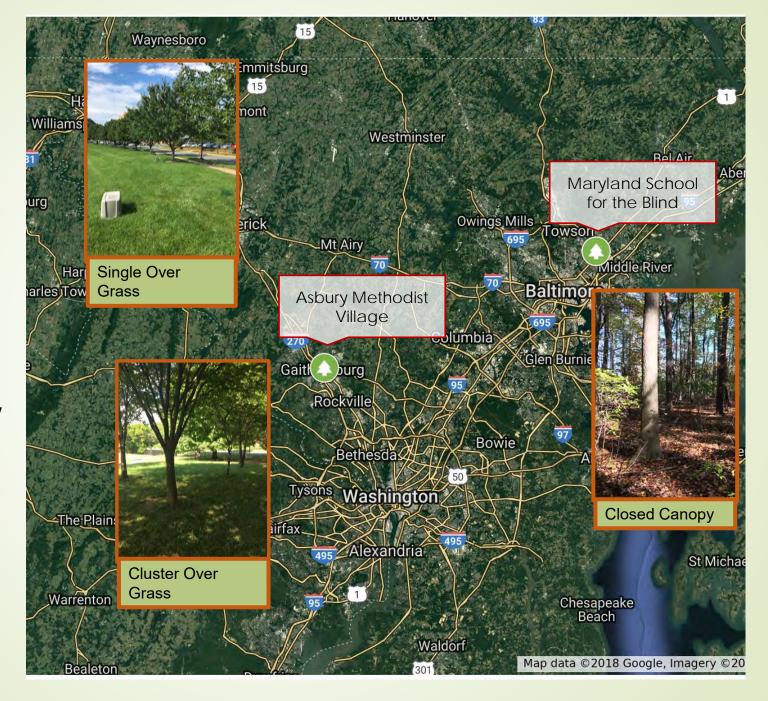


Examples of different urban tree typologies. (Images courtesy of the Integration and Application Network, UMD Center for Environmental Science)

Study Area

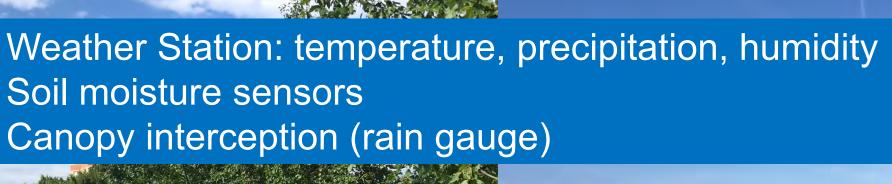
Criteria:

- Site accessibility
- Safety for the research equipment
- Recommended by the Montgomery County



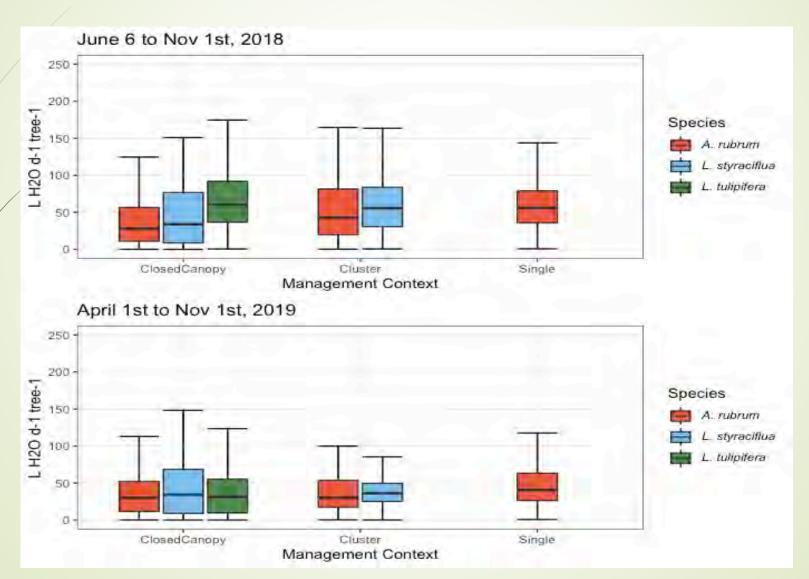
Transpiration Measurement Sap flux is a *proxy* for transpiration rates Granier-type thermal dissipation probe sap flux sensors



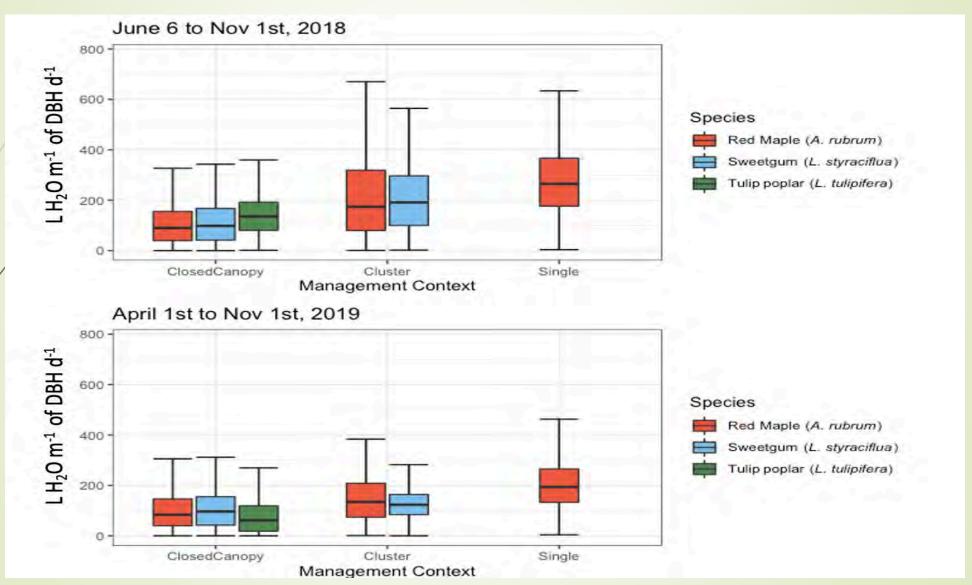




On a Per-Tree Basis, Trees in the "Single" Setting had the Greatest Transpiration.

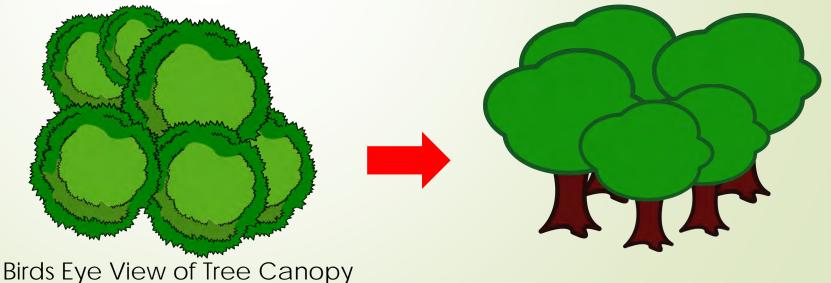


Results are Similar on a Per-DBH Unit

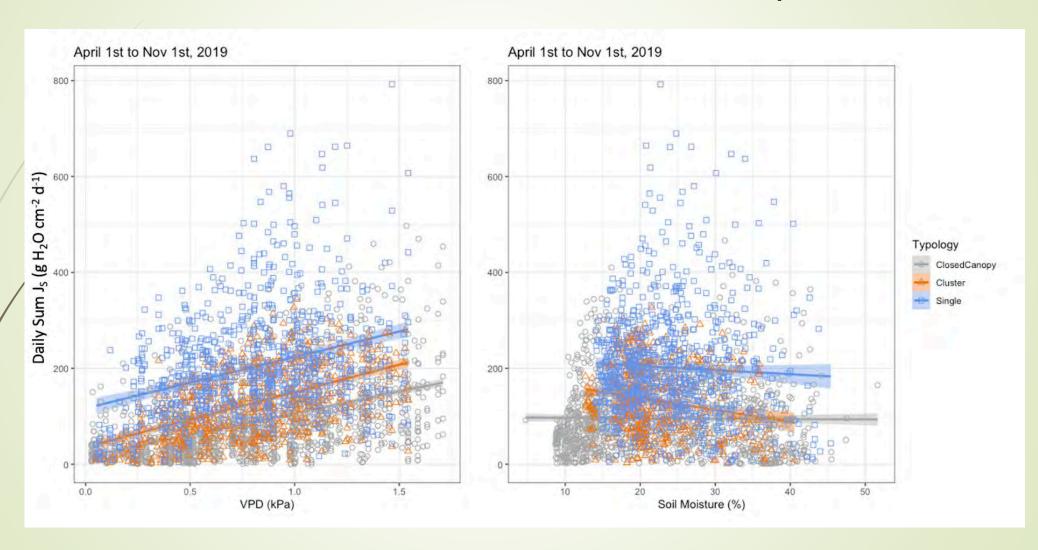


Why Do Individual Trees Have the Highest Per-Tree Transpiration Rates?

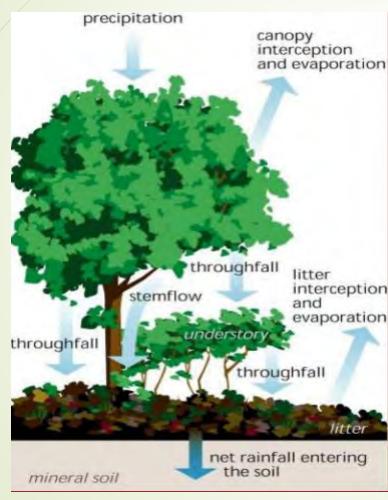
- Tree Density (Per-Tree or Per-DBH has different results than Per-Area)
- Exposure to Wind and Sun
- Greater Leaf Area for Single Trees



What Drivers Influence Transpiration?



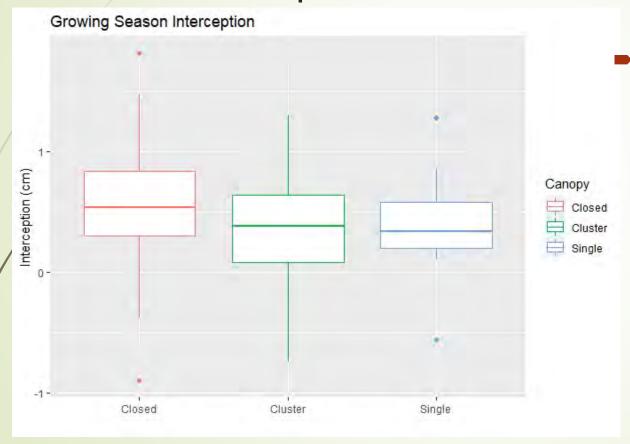
Interception: How Much Rainfall Is Intercepted by the Tree Canopy?



Penn State Extension

- We assume that a more complex canopy will provide more interception.
- We're measure interception as the difference between "Throughfall" (measured below the tree canopy and "Rainfall" measured outside the tree canopy.

Closed Canopy Has the Greatest Interception



- Interception (Rainfall Captured by Leaves)
 - Is greatest in the closed canopy
 - Median values range from about 0.3 cm for single trees to 0.6 cm for closed canopy.
 - Values are variable (especially depending on storm depth)

Interception Differences between Cluster and Closed Canopy Is Different but Not "Dramatic"

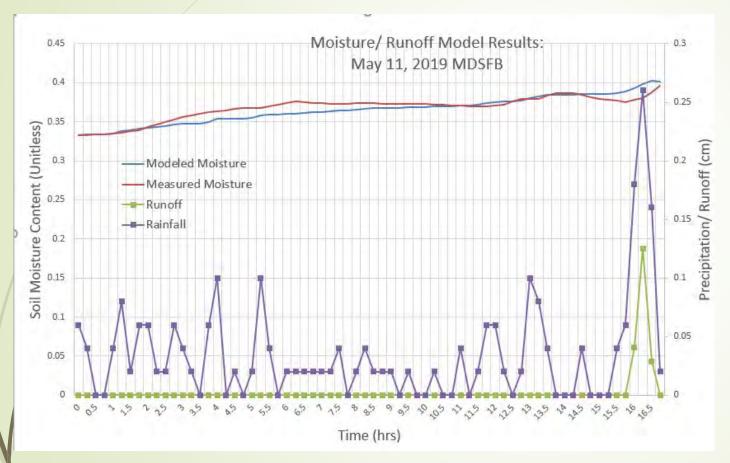


- This Closed Canopy Patch Does not have a complex understory
 - Missing Mid-Story
 - Missing the Shrub Layer
 - Missing the Herbaceous Layer
 - Little to no natural regeneration

How Do the Soils Compare at Each Site?

	Soil Type	Bulk Density (g/cc)	Organic Matter (%)
Closed - (NW)	Loam- Clay Loam	1.31	4.6
Closed - (SE)	Loam	1.22	2.6
Single	Loam	1.22	2.0
Cluster	Loam	1.33	2.7

- Soil types were mostly similar.
- The "Northwest" site at the Maryland School for the Blind (closed canopy) had high organic matter, and was also often saturated
- Single Tree setting had the lowest organic matter.
- The cluster setting had the highest bulk density (a measure of soil compaction)

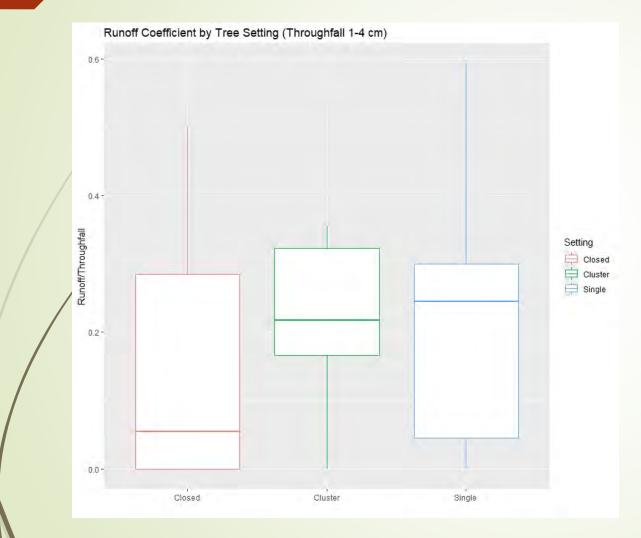


Runoff Computed Using the Green-Ampt Infiltration Model

Runoff when rainfall intensity exceeds infiltration rate

Calibrate to reproduce monitored soil moisture

Runoff Results



- Evaluated runoff from individual storm events with at least 1" but less than 4" of throughfall.
- The results suggest that the "Closed Canopy" setting produces the least runoff (similar to forest).
- Coefficients for Cluster and Single sites more similar to Turf on average.
- Results are highly variable, depending on initial soil moisture and storm (throughfall) depth.

Acknowledgment Slide

The Research Team gratefully acknowledges the Montgomery County Department of Environmental Protection for funding this work.

















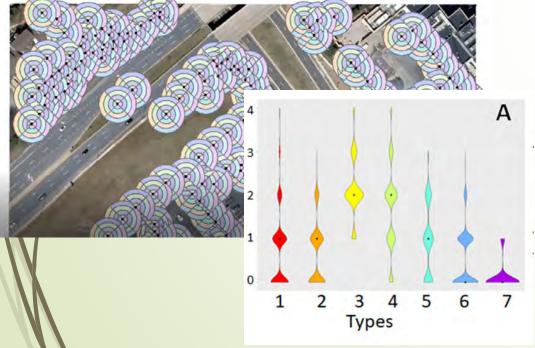
Translation Slides by:

Laura Miller, Montgomery County Department of Environmental Protection

What does this mean for me?

What do I take from this if I am a practitioner:

- Big leafy crowns really do make a difference. This adds to the growing body of evidence about the benefits of trees.
- Mapping can now be used to predict where life-spans of trees would be, on average, longer or shorter. This is a fabulous planning tool.





What does this mean for me?

What do I take from this if I am a regulator:

Forests and trees must be actively managed for overall health and sustainability to continue to provide optimal levels of benefits such as water quality and stormwater

management.

Provide support and funding for a variety of planting and maintenance programs and provide incentives to retain forests and trees.



Thank You!

Deb Caraco Center for Watershed Protection dsc@cwp.org



Photo Source: American Forests

Restoration Question #9 under the Stability theme.

Improving the Success of Stream Restoration Practices

Tess Wynn Thompson, Associate Professor, Biological Systems Engineering Eric Smith, Professor, Statistics

Students: Rex Gamble, Coral Hendrixs, Billy Paraszczuk, Ben Smith, U. Samuel Withers





Thanks to...







FWVIRONMENTAL PROTECT





STATE HIGHWAY ADMINISTRATION





Anne Arundel County Baltimore County Frederick County Harford County Howard County

Bill Buettner
Ken Choi
Heather Cobb
Ryan Cole
Michele Dobson
Jeremy Joiner
Christine Lowe
Heather McGee
Kerry McMahon
Erik Michelsen



This research focused on 3 questions:

- 1. Linking stream restoration success with watershed and design characteristics
- 2. Design, project, and watershed factors that affect structure success
- 3. Comparison of 1-D and 2-D HEC-RAS modeling for stream restoration design

Study 2:

Design, project, and watershed factors that affect structure success

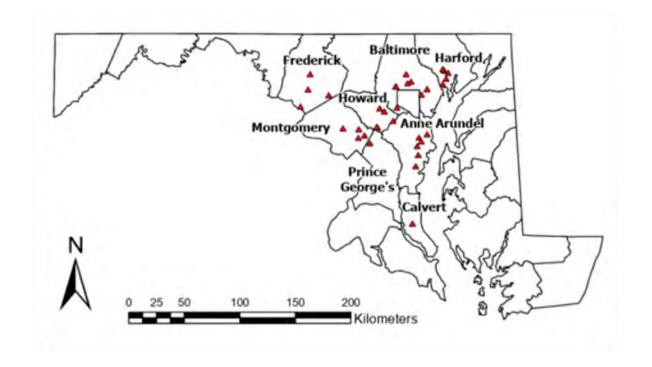
TESS WYNN THOMPSON, BIOLOGICAL SYSTEMS ENGINEERING

ERIC SMITH, STATISTICS

BENJAMIN SMITH, STANTEC, FORMER GRADUATE STUDENT

The goal of Study 2 is to evaluate existing instream structures with the aim of informing structure design and siting

- 1. Structures were evaluated in the field
 - > 38 Projects
 - > 536 Structures
- 2. Watershed, project, and design characteristics correlated to structure assessment



What is structure success?

Attribute	1	2	3	4	
Structure					
% remaining	0-25%	25-50%	50-75%	75-100%	
material movement	significant	moderate	slight	none	
Sediment					
unintended bank erosion or bed scour	significant	moderate	slight	none	
unintended aggradation	significant	moderate	slight	none	
Function					
serving intended purpose	no	partially	yes		



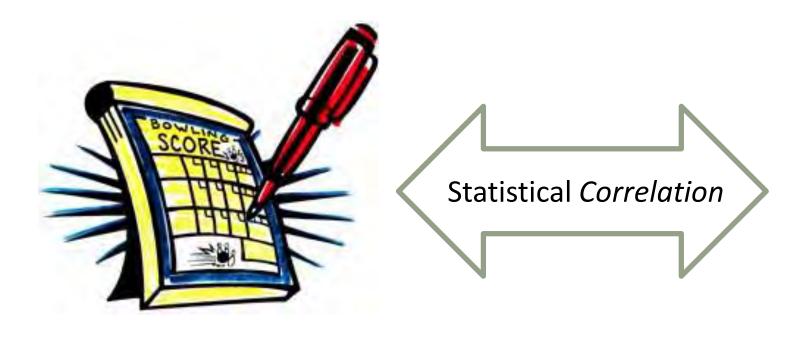
Structures were grouped by function and material

- Bank protection (n = 147)
- Full span vanes (n = 105)
- Partial span vanes (n = 68)
- Constructed riffles (n = 102)
- \triangleright RSC weirs (n = 57)
- > Step-pools (n = 31)

- > Rock (n = 282)
- \triangleright Log (n = 36)
- Combination



Design explanatory variables depended on structure family and were scaled by channel size.



Parameters which indicate:

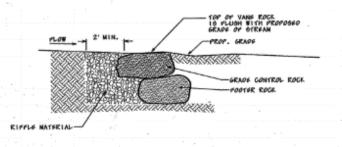
- Flow energy
- Erosion resistance
- Design approach

http://clipart-library.com/

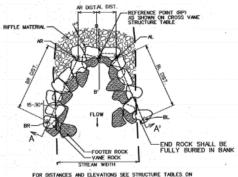
Correlation determined using simple and multiple linear regression and linear mixed-effects models

Structure-scale data was collected using multiple data sources.

Design Drawings



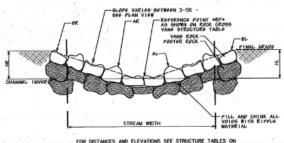
ROCK CROSS VANE SECTION B-B'



ROCK CROSS VANE PLAN VIEW- TYPICAL

RP STATION	RP ELEVATION	DISTANCE	AR DISTANCE	B DISTANCE	DISTANCE.	HL HEIGHT	HF. HEIGHT
12+10	467.5	3.3'	3.3	26.0"	13:0'	1.3	1,3
14+37	462.5	3,3'	3.3	28.0'	32.0'	1.3	1.3
14+90	462.0	3.3	3.3	31.0	16.0	1.3	1.3/

Structure Table



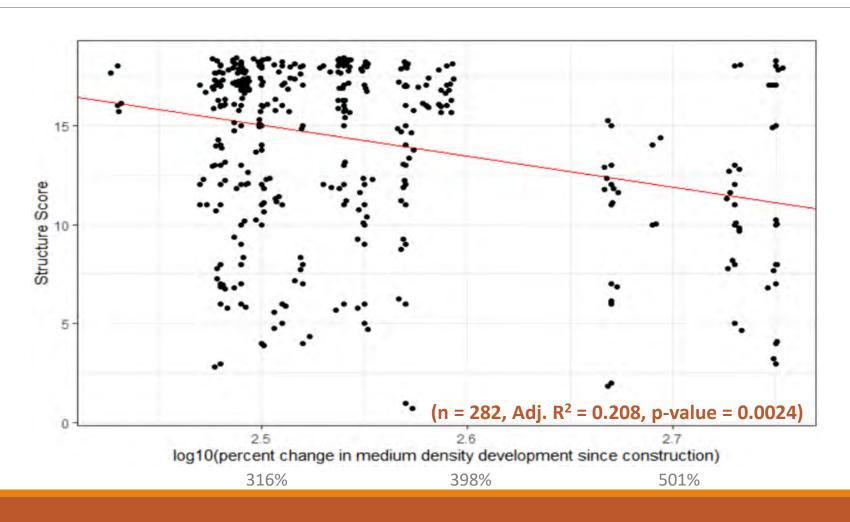
ROCK CROSS VANE SECTION A-A'

Main results...



- 1. Watershed factors
- 2. Project factors
- 3. Structure factors

Increased urbanization post-construction is negatively correlated with structure performance

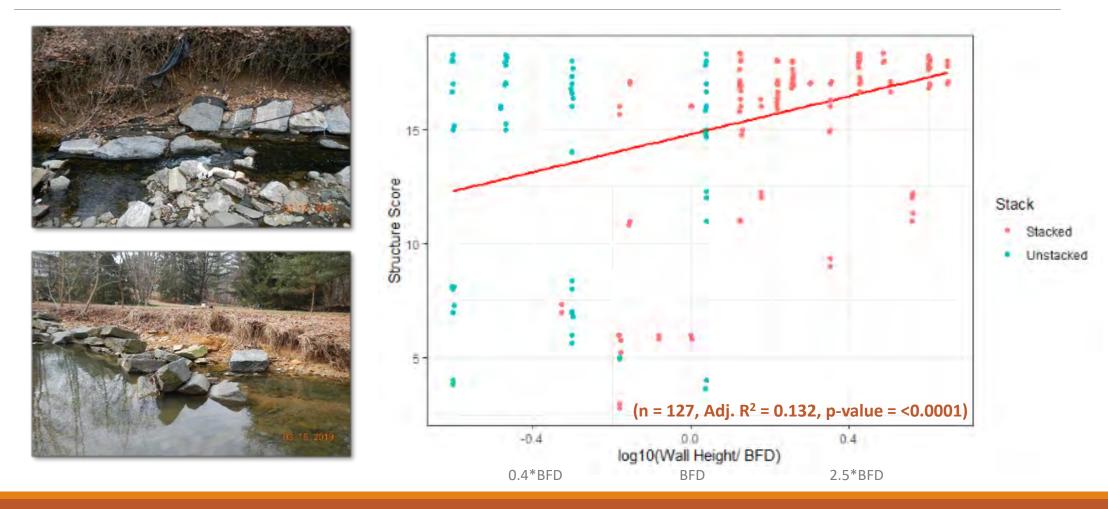


Structure performance is strongly influenced by the individual project.

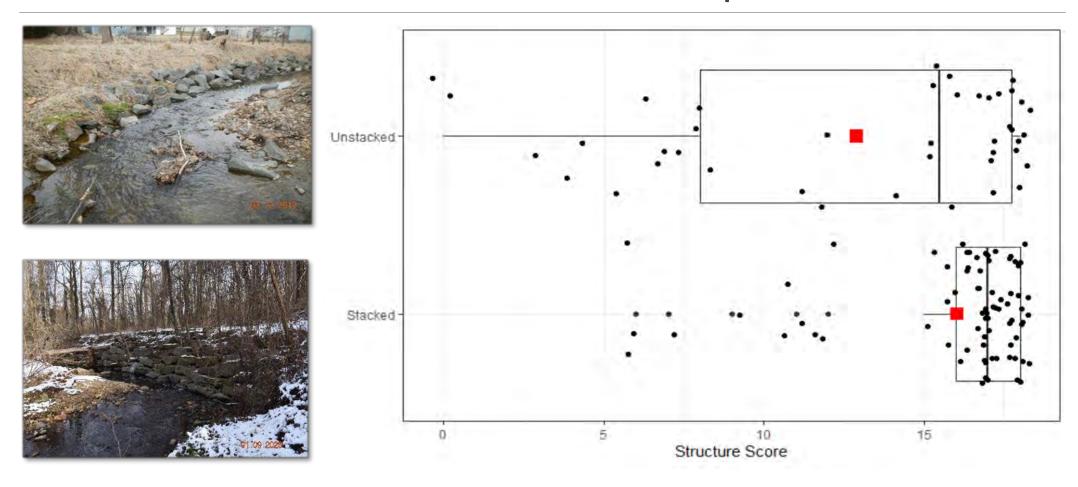


- Design quality
- Construction quality
- Vegetation
- Maintenance

Rock bank protection performance was positively correlated to wall height.



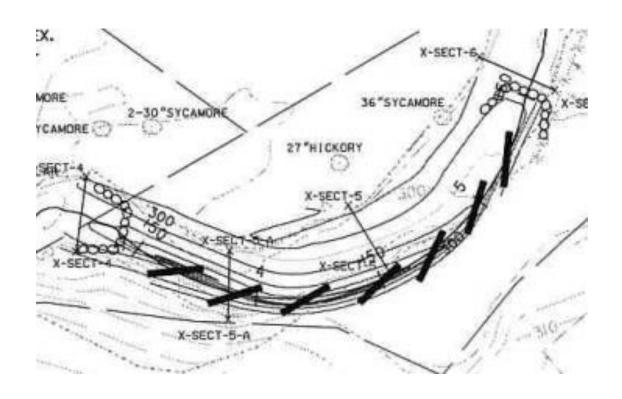
Stacked bank protection performed better than unstacked bank protection



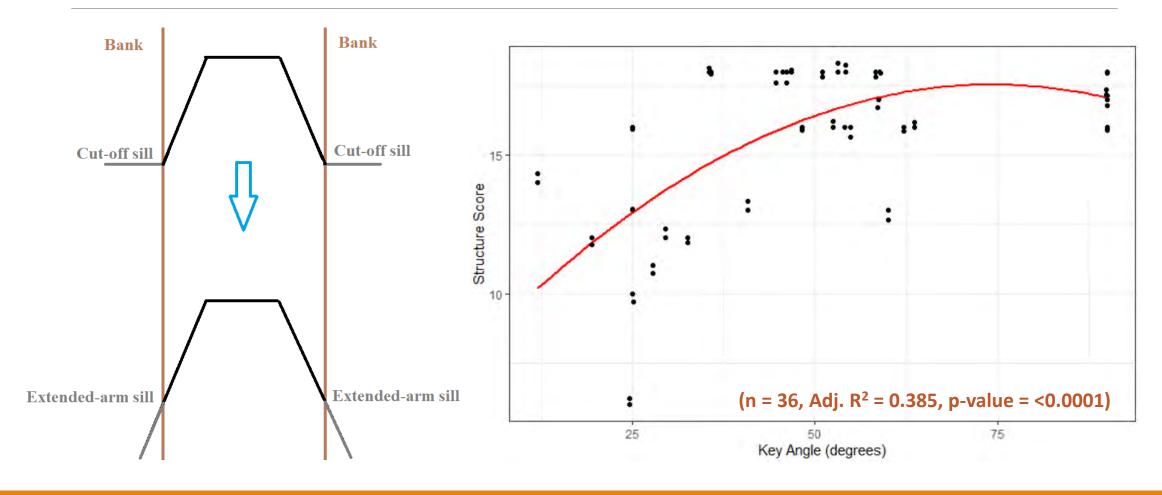
Log partial span vanes perform better when another structure is upstream.

Log partial span vanes success

- ↑ with proximity to other structures
- n = 10, adj. r^2 = 0.443, p = 0.0214

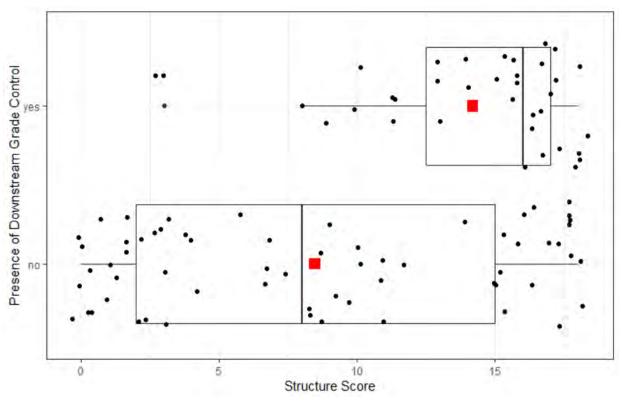


Full span vanes with angles of 35-90° between bank and sill performed better.

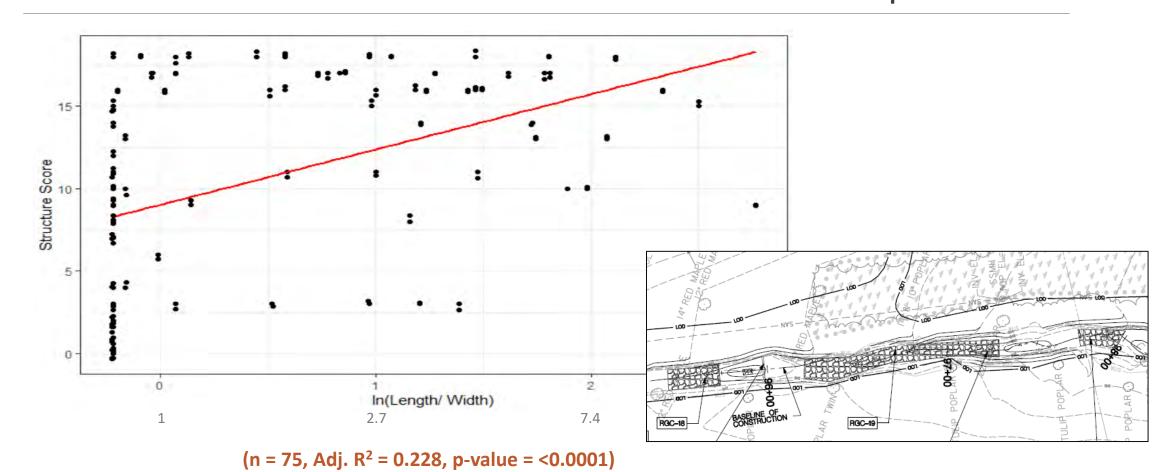


Constructed riffles with downstream grade control perform better.





Constructed riffle scores were positively correlated to the L:W and substrate depth.



Study limitations

- Did not assess impact of structures on ecological function
- Structure assessment was visual
- Design variables were based on design and as-built drawings, not measured in the field
- Maintenance



Something to think about...

Clean Water Act Goal:

"restore and maintain the chemical, physical, and biological integrity of our nation's waters."



Streams are highly dynamic ecosystems.



Healthy streams move – use structures only when absolutely necessary.

Study 3:

Comparison of 1D and 2D HEC-RAS modeling for stream restoration design

TESS WYNN THOMPSON, BIOLOGICAL SYSTEMS ENGINEERING

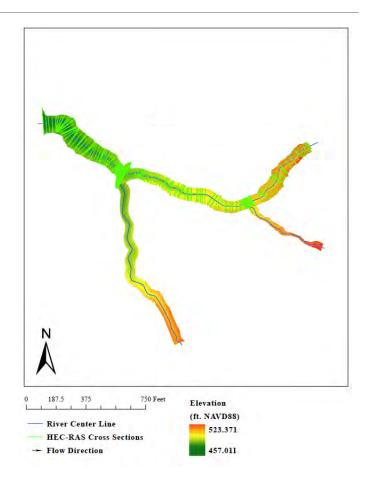
REX GAMBLE, GZA, FORMER GRADUATE STUDENT

William Paraszczuk, RES, Former graduate student

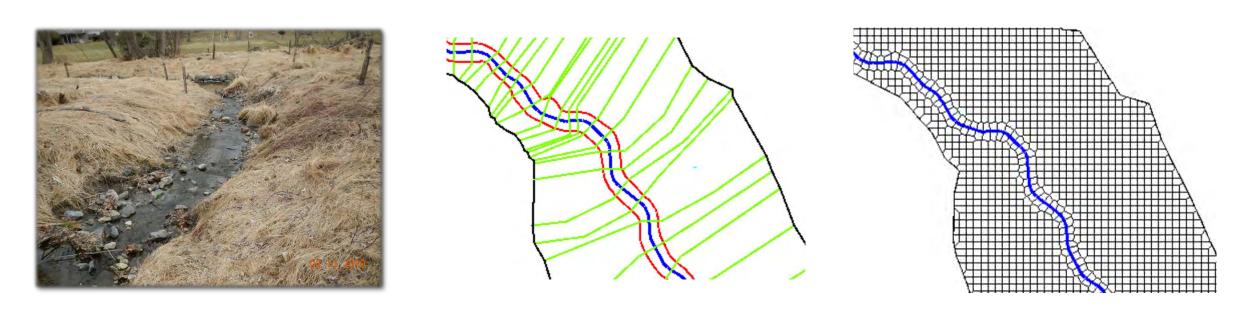
Six stream restoration projects modeled using HEC-RAS 5.07

- Range of watershed sizes, types of structures
- Models for each project
 - Original FEMA model (2 projects only)
 - Steady, 1D HEC-RAS, with structures
 - Unsteady, 2D HEC-RAS with full momentum eqn.
- Modeled 100-yr discharge worst-case scenario

Models were not calibrated, so differences between models are more important than absolute values of velocity and shear stress



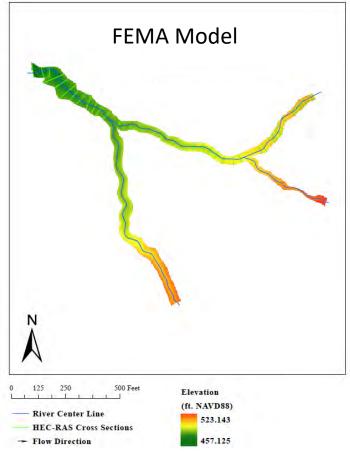
1D models view streams as a main channel and two floodplains

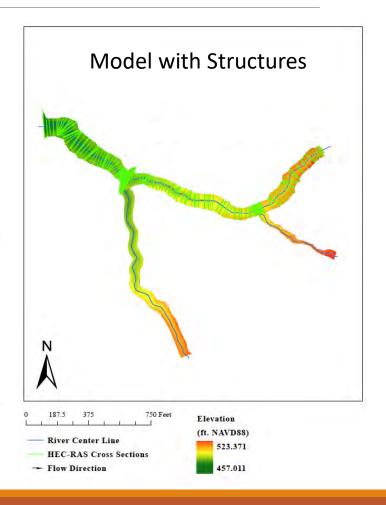


2D models view streams like a sidewalk made with pavers

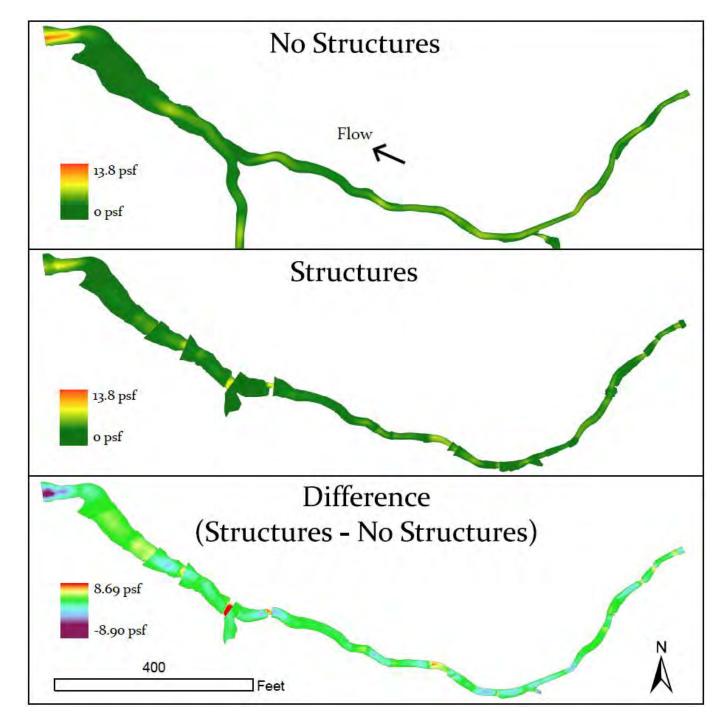
Incorporating structures into HEC-RAS required adding more cross-sections

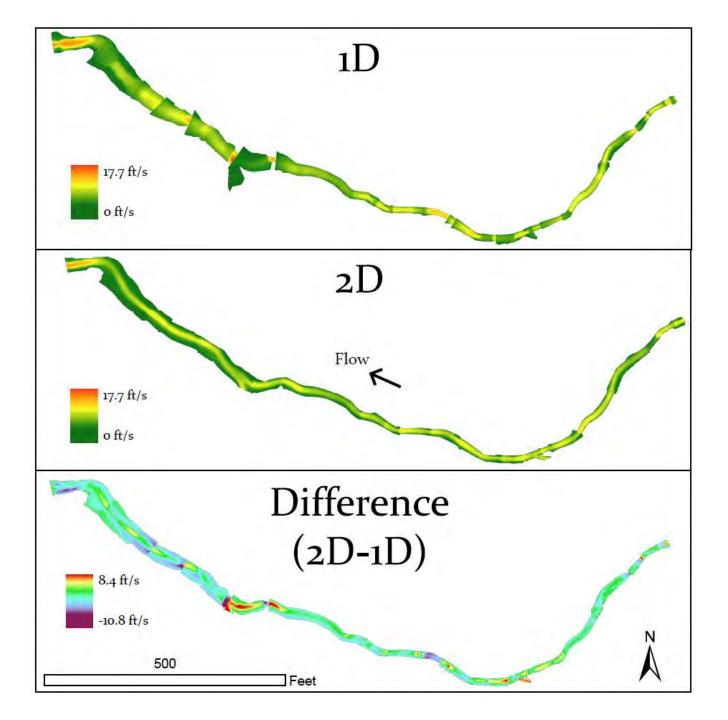




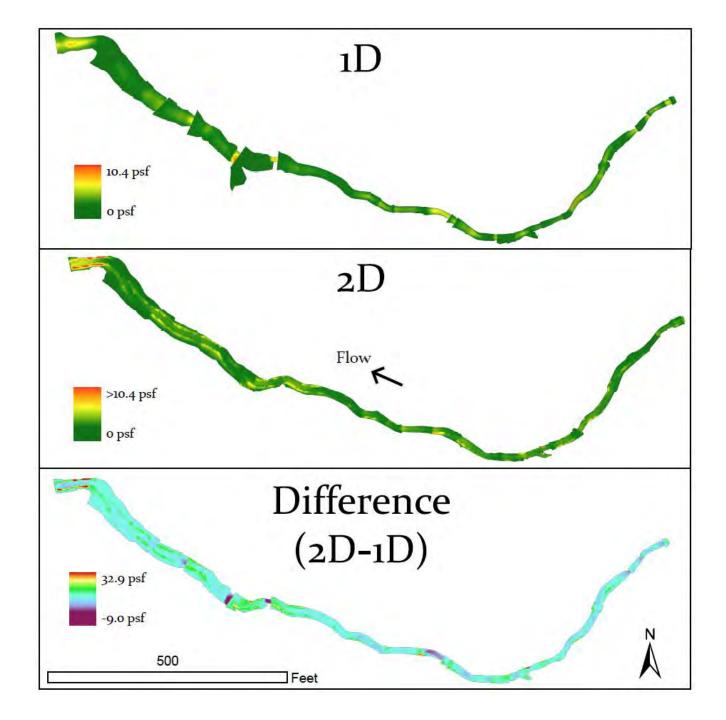


Decreased shear stress in pools and increased shear stress downstream of steps are not captured when structures are not explicitly included in HEC-RAS 1D models.



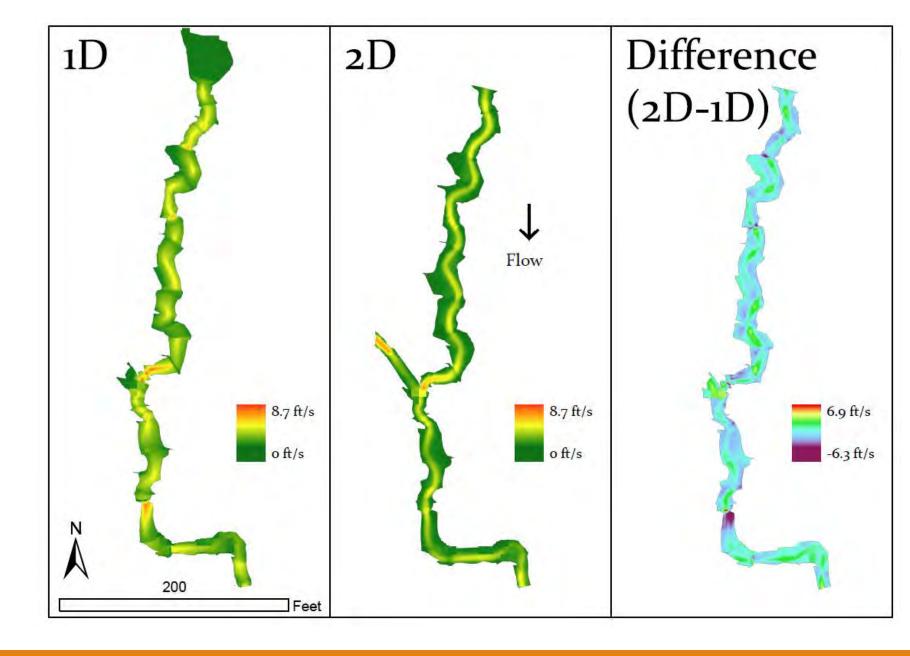


The 2D model better represented higher velocity in the center of the channel.

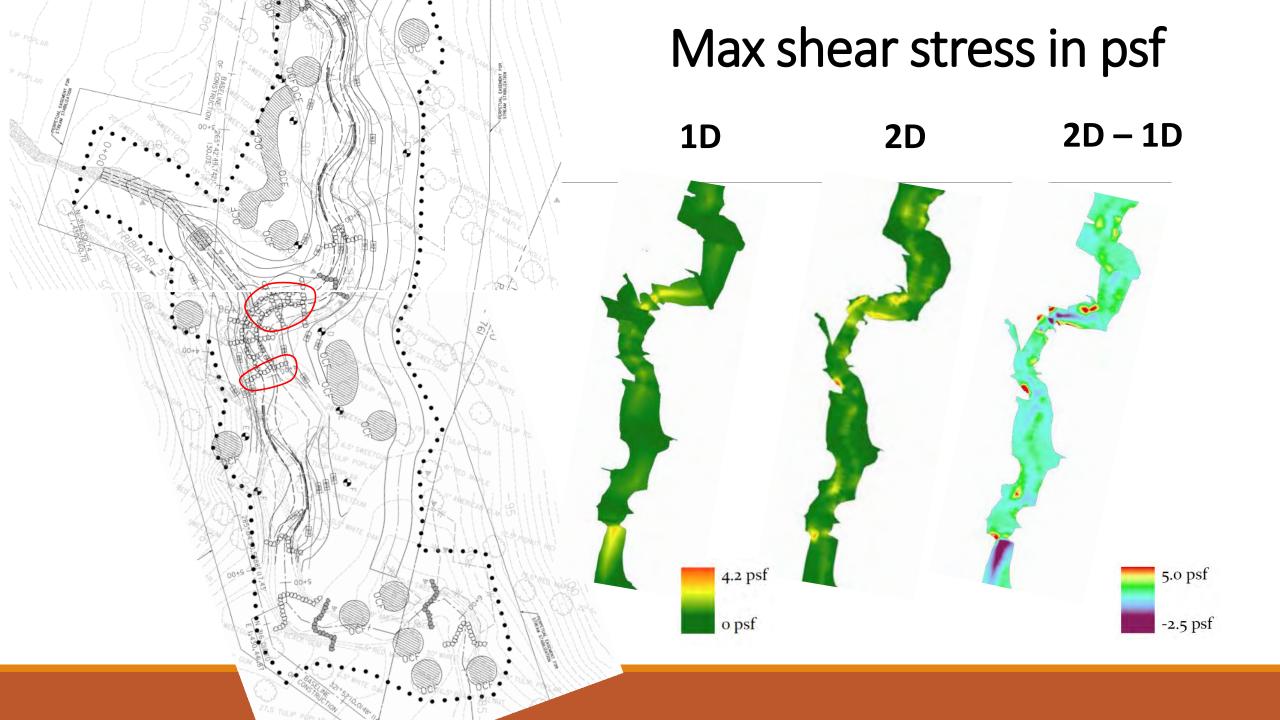


The 2D model better represented higher shear stress at the channel-floodplain interface.

Taking a closer look...







Questions?





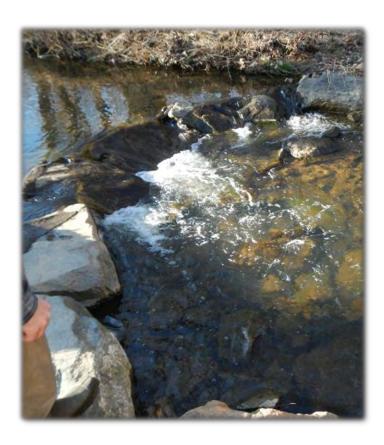
Study 2 research take-aways...



- Design in urban/urbanizing watersheds is challenging
- > Avoid reliance on structures when possible
- Structure performance is dependent on the project as much as the design of individual structures
- > Imbricated rock walls are more durable than stone toe
- ➤ Vane-type structures should be keyed into the bank at angles of 35-90°
- Constructed riffles with higher L:W, downstream support, and deeper substrate depth last longer

Observation: Rock structures are frequently used to hold streams in a specific form and to force habitat features.

Study 3 research take-aways...



> 1D models

- Representing structures requires the addition of a large number of cross sections
- Localized areas of high/low velocity and shear stress are not captured unless structures are explicitly included in models
- The structures produce a jagged flood extent as a result of rapidly changing cross sections through cross vanes and step pools

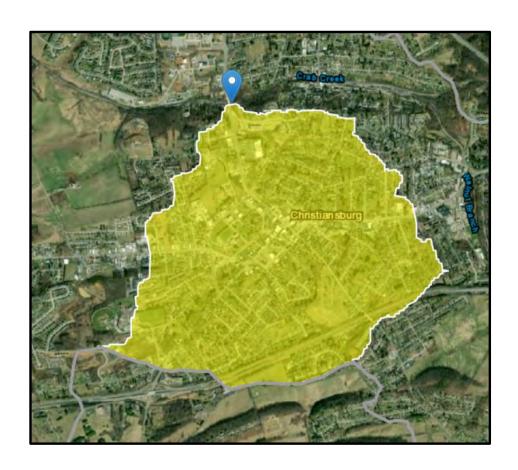
> 2D models

- Best represent areas of localized increases in velocity and shear stress
- Level of effort has decreased significantly with ability of HEC-RAS to use digital terrain models

Watershed-scale explanatory variables relate to flow energy and erosion resistance.

Flow energy

- Watershed area
- Stormwater BMP density
- Channel slope
- Land use
- Change in land use



Erosion resistance

- Watershed soil erodibility
- Streambank soil erodibility

Project-scale explanatory variables relate to flow energy, erosion resistance, and design approach.



Flow energy

- Flood prone width
- Bankfull discharge

Design approach

- Structure density
- Channel slope/sinuosity
- Width:Depth

Erosion resistance

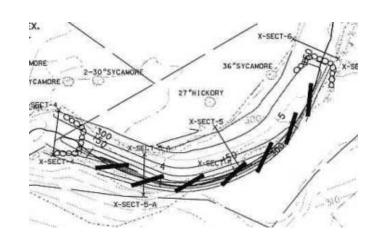
- Project bank erodibility
- Riffle D₅₀
- Upstream and downstream grade control

Methods 16

Structure-scale explanatory variables related to the design and placement of structures.



Certain structure-scale predictors relate to properties common to all structures.

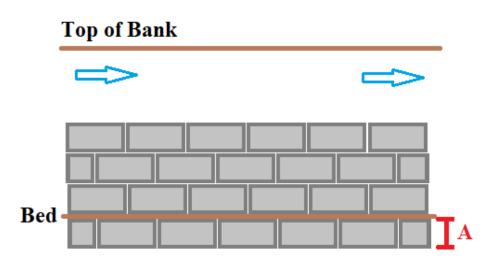


Proximity to other structures

Location in channel

- Planform location
- Bankfull width
- Bankfull depth



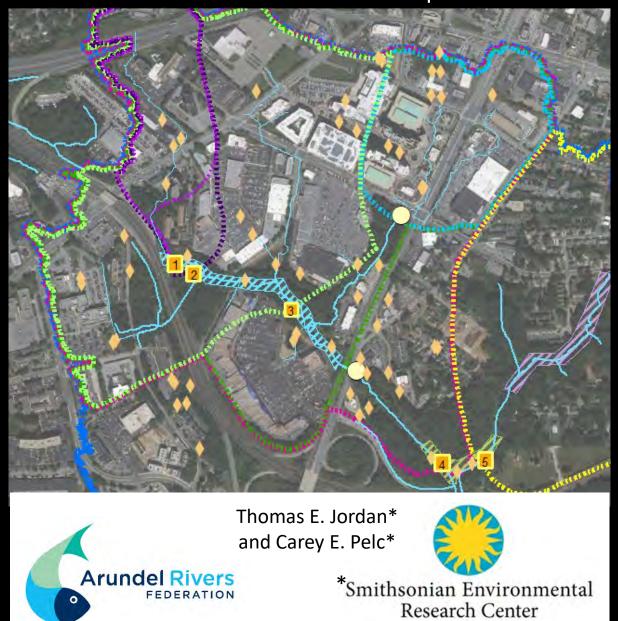


Design

- Material type and size
- Footer depth (A)

Methods

Watershed-Scale Effects of Urban BMPs on Loads of Nutrients and Suspended Solids



Two Main Questions:

- What are the effects of an urban stream restoration on loads of nutrients and total suspended solids (TSS)?
- What are the cumulative impacts of stream restorations and other BMPs on loads of nutrients and TSS in urban watersheds?

Hypotheses:

- Loads leaving the stream restoration will be lower than loads entering.
- Loads from watersheds will reflect the cumulative impact of BMPs within the watershed.
- Affects on loads of different forms of N and P will differ.

Why compare loads of different forms of N and P when TMDLs are for total N and total P?

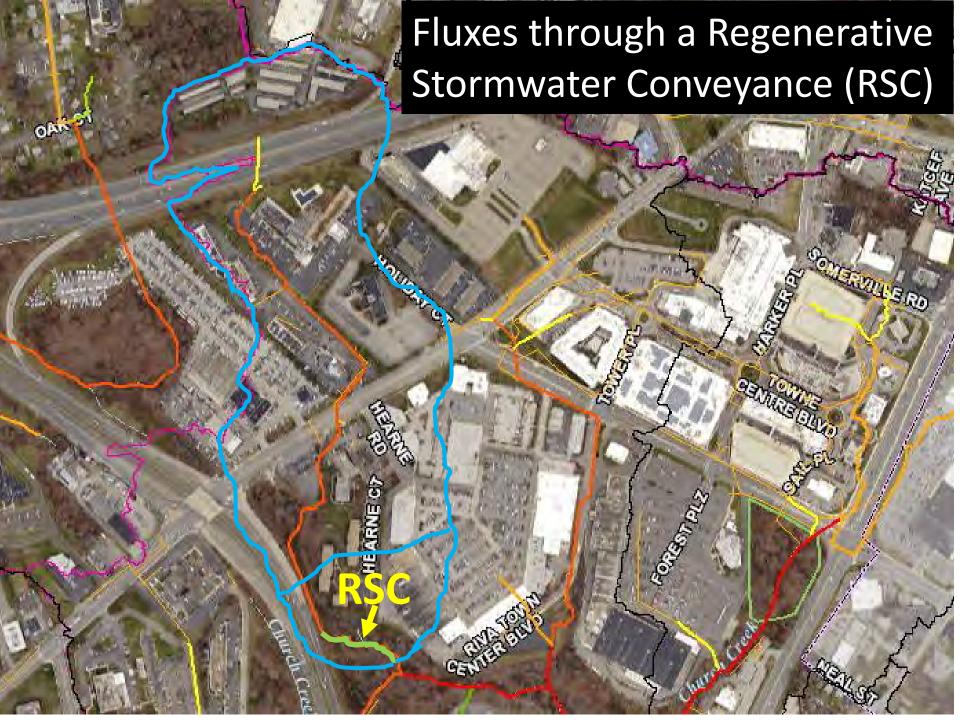
- Different forms of N and P have different potentials for causing algal blooms.
- Dissolved inorganic forms are more bio-available than particulate and organic forms (Glibert et al. 2016).
- Mechanisms of N and P removal differ for different forms of N and P.
- Nitrate may be removed from stream water by denitrification and particulate N and P may be removed by sedimentation.
- The Chesapeake Bay Program concluded that it is important to consider the different impacts of different forms of N and P to manage eutrophication (Shenk et al. 2020).

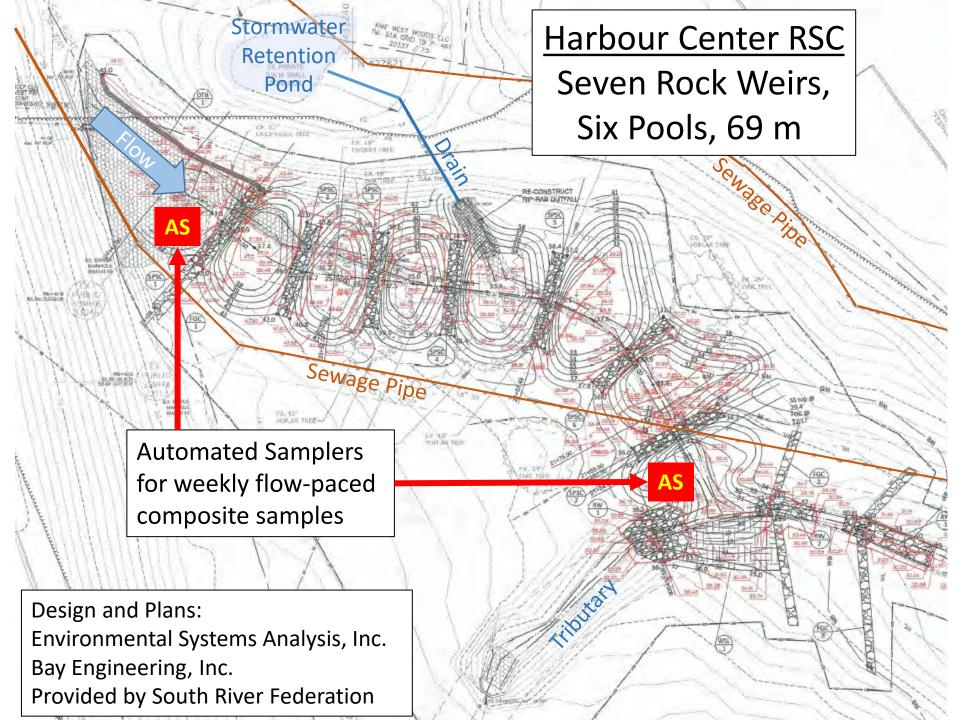
Glibert, P. M., Wilkerson, F. P., Dugdale, R. C., Raven, J. A., Dupont, C. L., Leavitt, P. R., Parker, A. E., Burkholder, J. M., and Kana, T. M. (2016), Pluses and minuses of ammonium and nitrate uptake and assimilation by phytoplankton and implications for productivity and community composition, with emphasis on nitrogen-enriched conditions. Limnology and Oceanography, 61: 165-197. Doi:10.1002/lno.10203.

Two Main Approaches for Assessing Effects of BMPs:

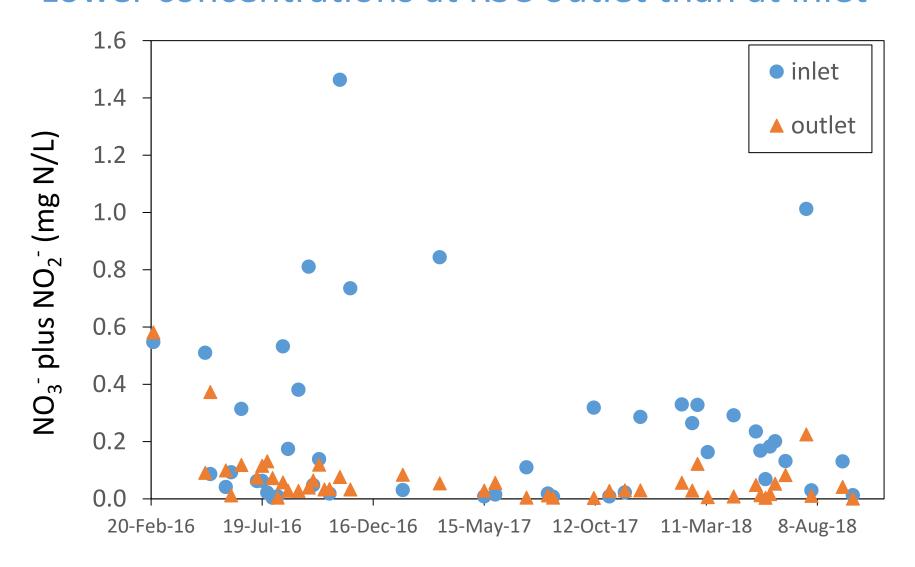
 Measured fluxes of nutrients and TSS through a stream restoration.

 Compared discharges of nutrients and TSS from watersheds with different management practices in place.

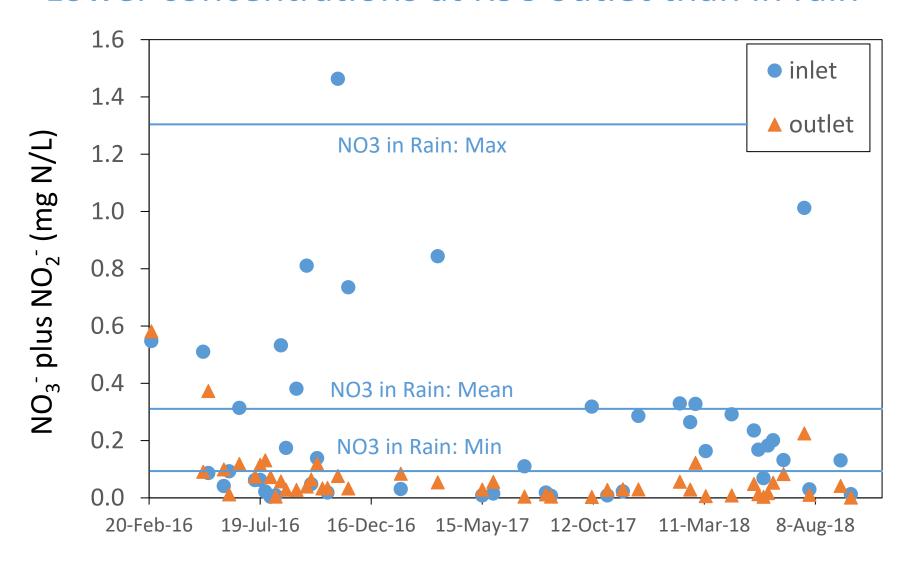




Evidence for redeuction of nitrate plus nitrite: Lower concentrations at RSC outlet than at inlet



Evidence for reduction of nitrate plus nitrite: Lower concentrations at RSC outlet than in rain



Calculating Reduction

Concentration X Water Flow = Load

Load in - Load Out = Amount Reduced

% Reduction = (Amount Reduced / Load In) X 100

Nitrate plus nitrite loads were reduced by 70%

Inlet and outlet loads were significantly different (p<0.01, paired T test)

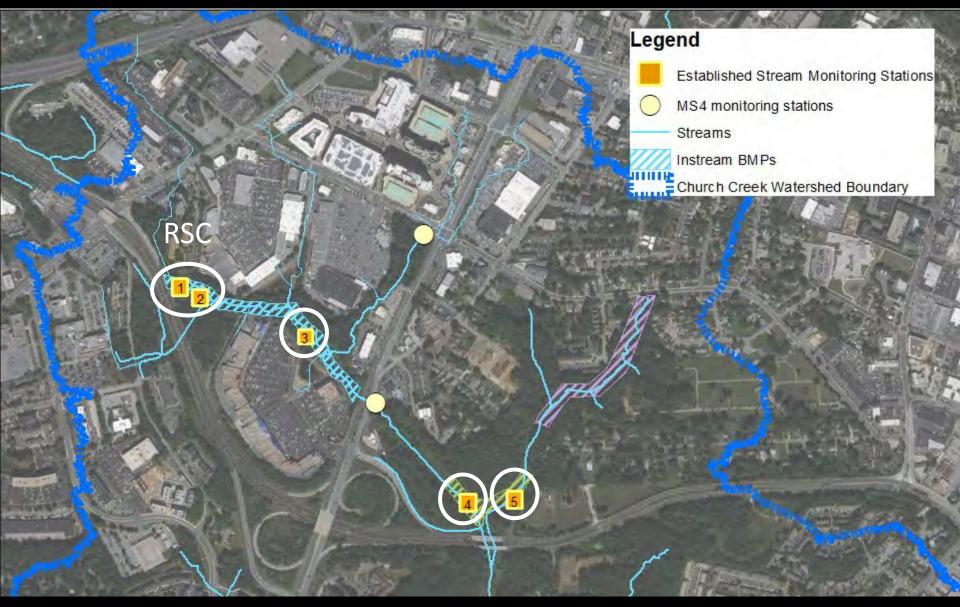
RSC effects on loads of other nutrients and TSS?

No significant differences between inlet and outlet loads of:

TSS, P forms, or N forms (except nitrate plus nitrite).

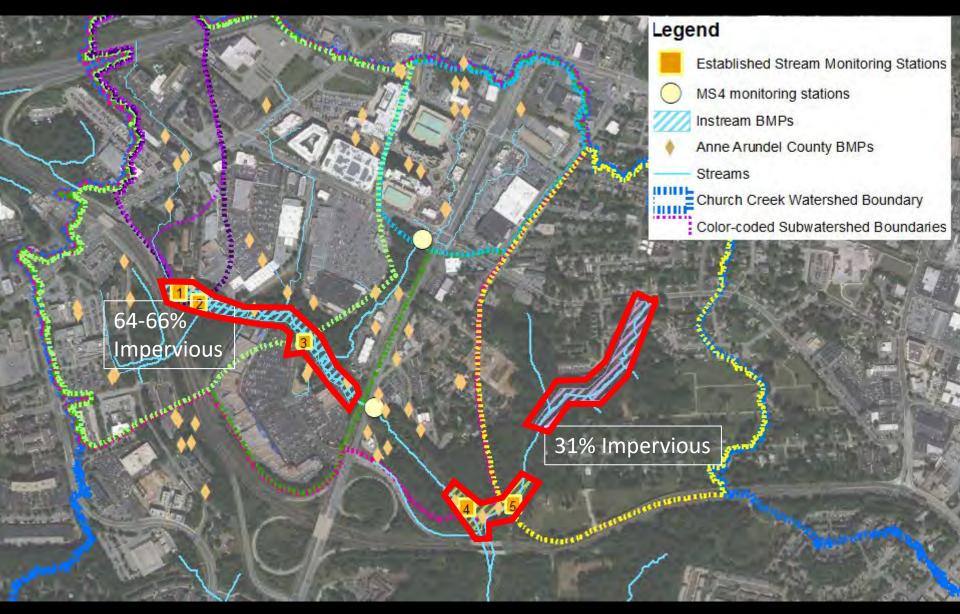
p>0.10 paired T test.

What are the watershed-scale effects of BMPs?



Comparing watersheds with different management practices.

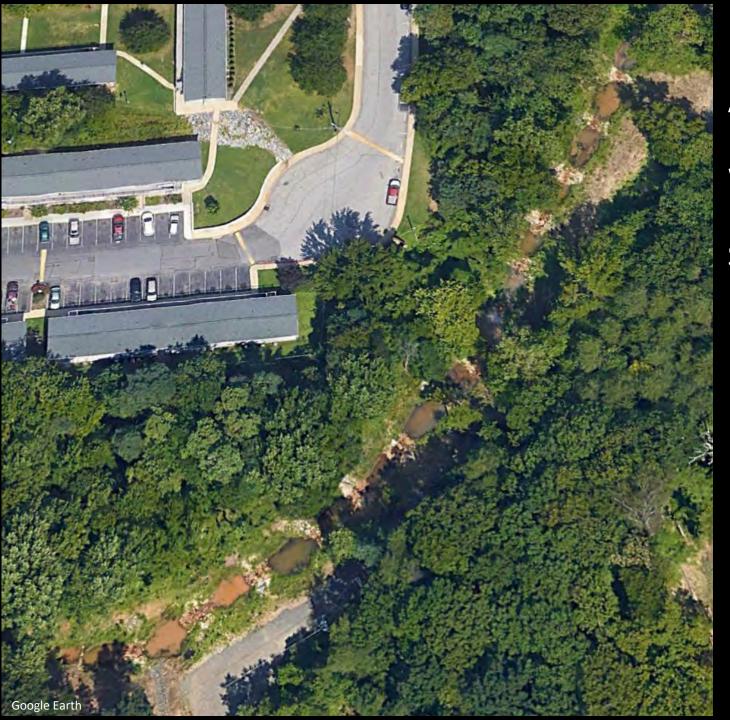
What are the watershed-scale effects of BMPs?



Comparing watersheds with different management practices.

Rock weirs at junction of West and Allen Branches: Automated Samplers 4 and 5

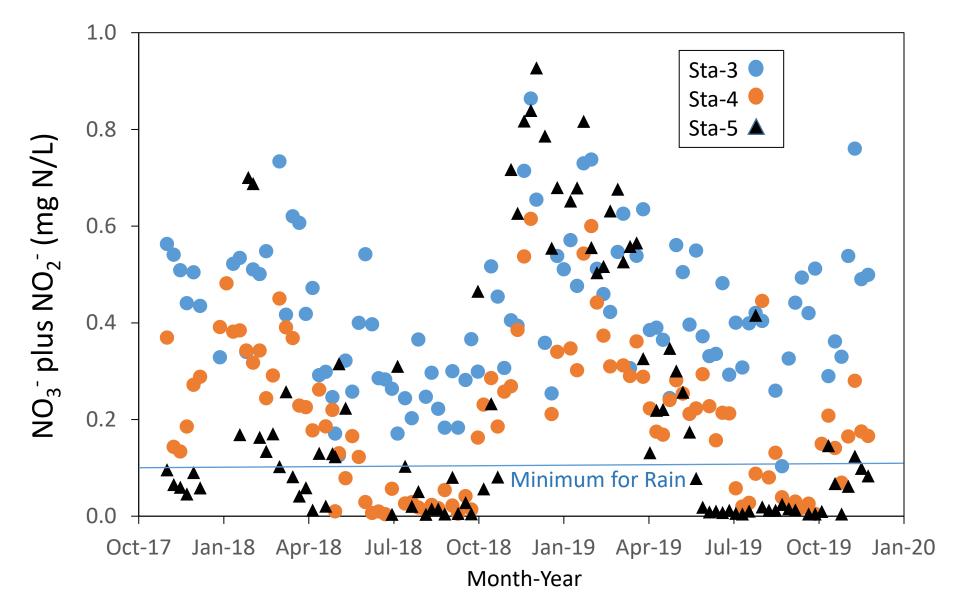




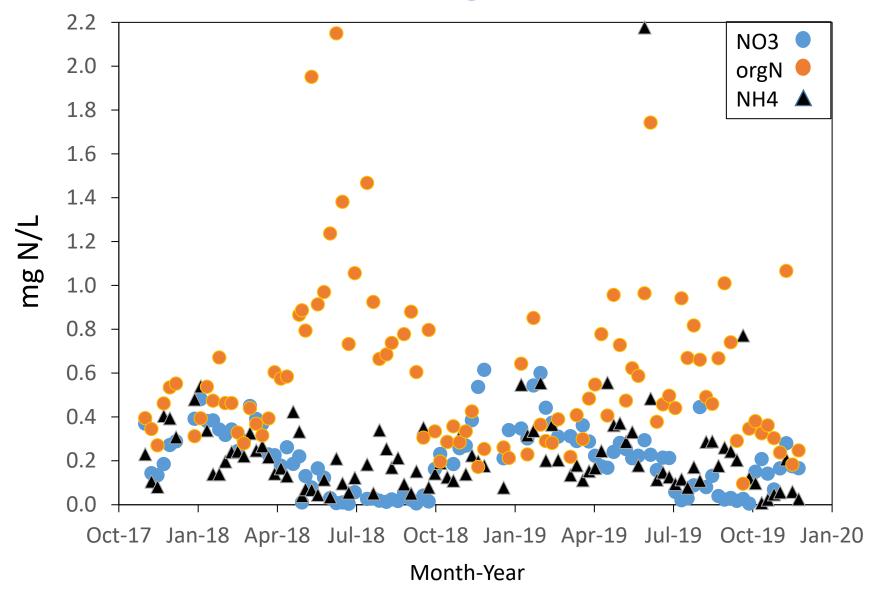
Allen Branch RSC Watershed 5

Step Pools and Rock Weirs

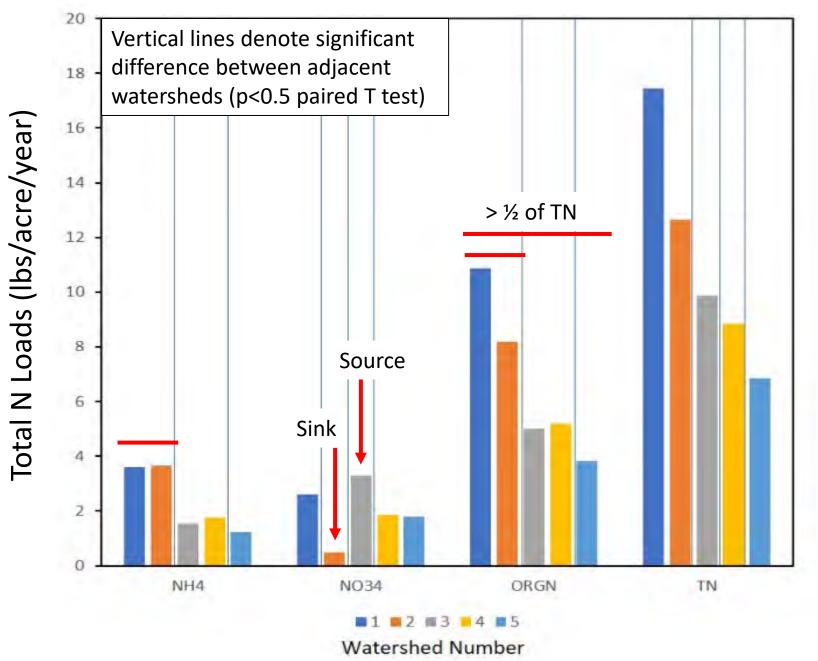
Evidence for reduction of nitrate plus nitrite: Summer drawdown below concentration in rain



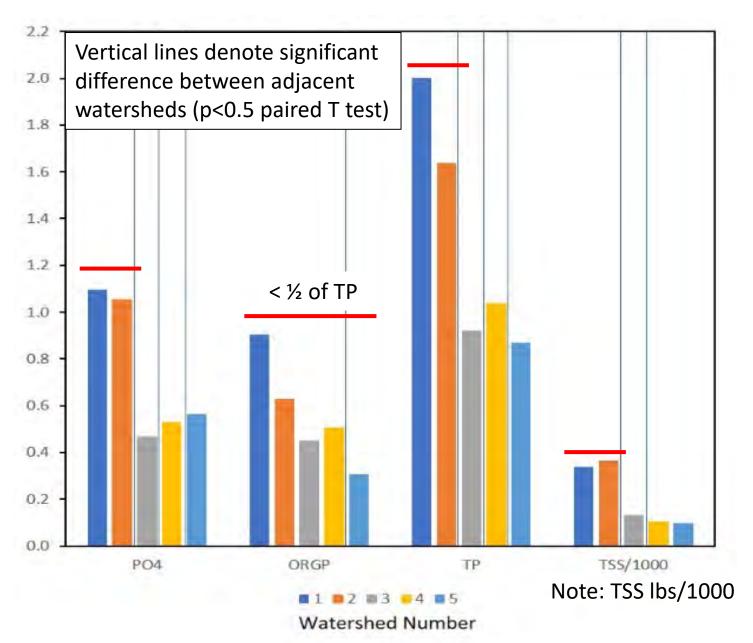
Evidence for reduction of ammonium and addition of organic N at station 4



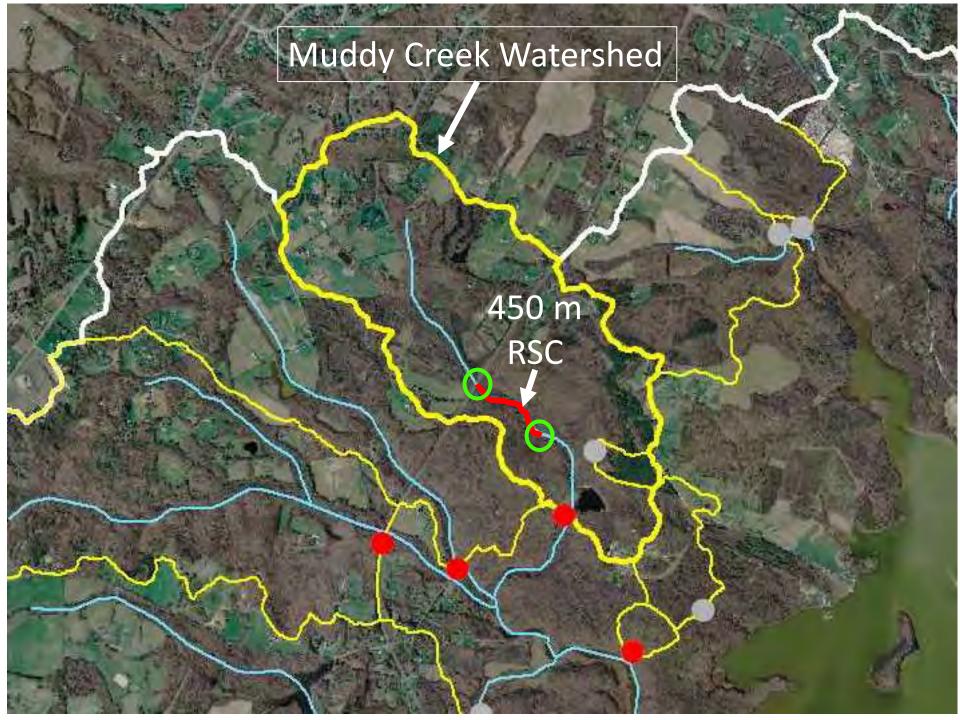
Do loads of total N reflect the effects of BMPs?



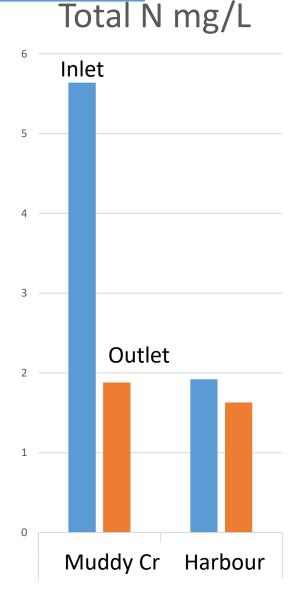
Do loads of total P and TSS reflect the effects of BMPs?



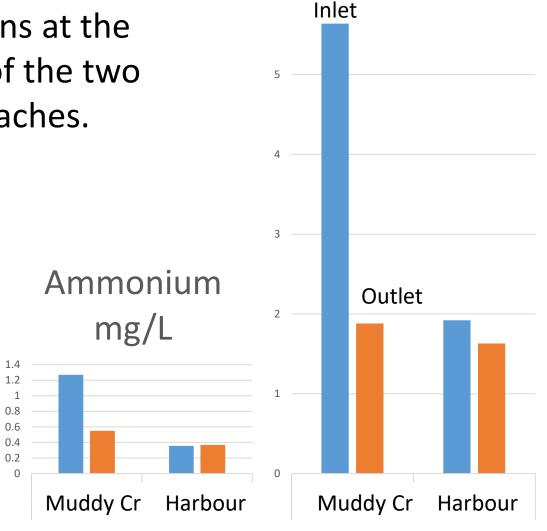
Why was nitrate plus nitrite the only nutrient reduced by the Harbour Center RSC and reduced to concentrations below those in rain?



Comparing flow weighted mean concentrations at the inlets and outlets of the two restored stream reaches.

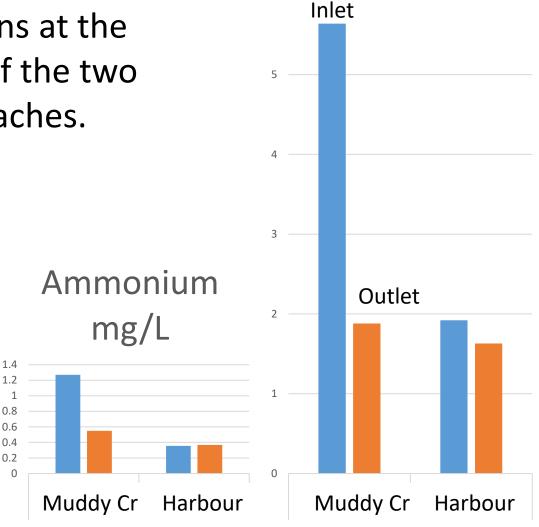


Comparing flow weighted mean concentrations at the inlets and outlets of the two restored stream reaches.



Total N mg/L

Comparing flow weighted mean concentrations at the inlets and outlets of the two restored stream reaches.



Total N mg/L

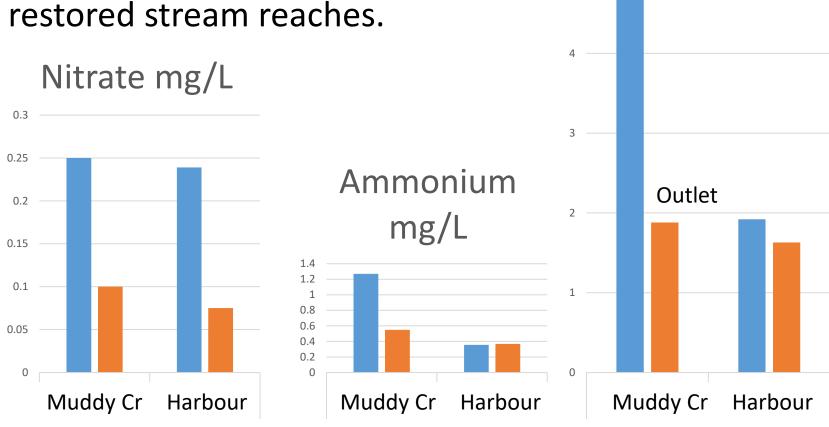
Nitrate mg/L

Output

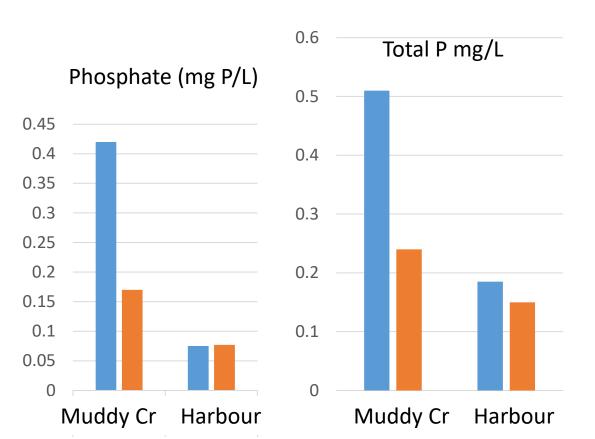
Total N mg/L

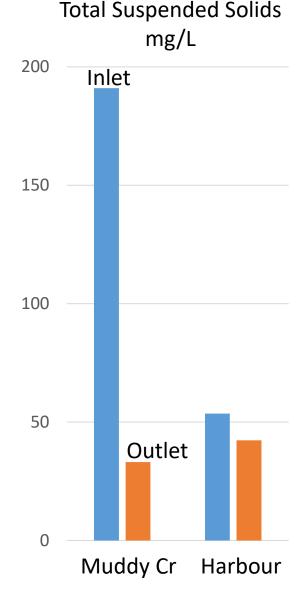
Inlet

Comparing flow weighted mean concentrations at the inlets and outlets of the two restored stream reaches.



Comparing flow weighted mean concentrations at the inlets and outlets of the two restored stream reaches.





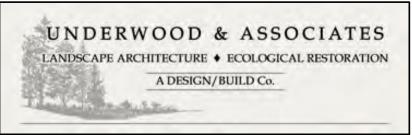
Implications for Management:

Low concentrations of nutrients and TSS may decrease the potential and the need for reductions.

Concentrations should be measured before restorations to gauge the need and expectations for reductions.

We thank these organizations for support:











Rathmann Family Foundation





Possible "Translation" Points:

For Regulators:

Stormwater BMPs, including stream restoration, particularly in series, appear to be effective in terms of reducing TN, TP, and TSS, even without accounting for the benefits of prevented sediment associated with stream restoration.

Urban environments may not be contributing nearly the same levels of nutrient and sediment pollution to downstream waterways as agricultural watersheds, particularly once stream corridors are stabilized.

For Regulators and Practitioners:

It will likely require a critical mass of stormwater practices installed in an individual subwatershed to achieve significant pollutant reductions.

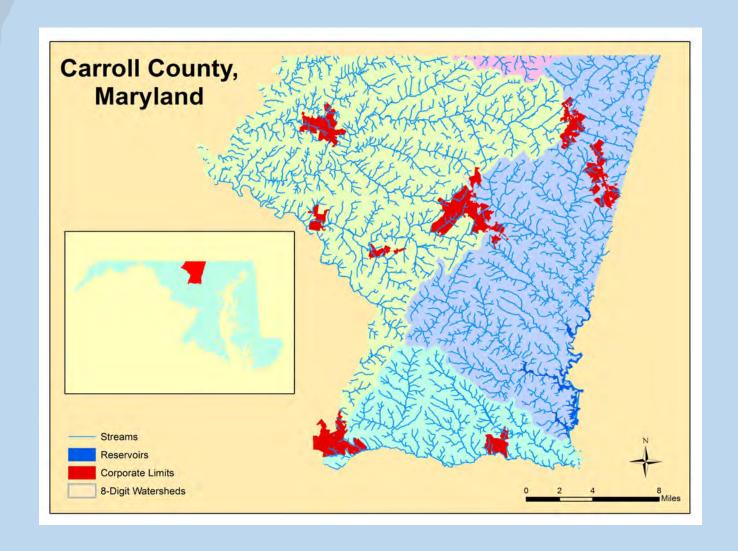
Practices need to be installed within the watershed locations where they will actually intercept/arrest pollutants.

The Self-Recovery of Stream Channel Stability in Urban Watersheds

Byron Madigan
Carroll County Government



- Background and Location
- Headwater County
- 4 Chesapeake Bay Segments





Research Question(s)

Will the implementation of specific retrofits create hydraulic conditions that lead to the self-recovery of channel stability and decrease sediment loadings downstream as a result of reduced bank erosion?

Hypothesis(es):

Hypothesis 1 - Hydrology

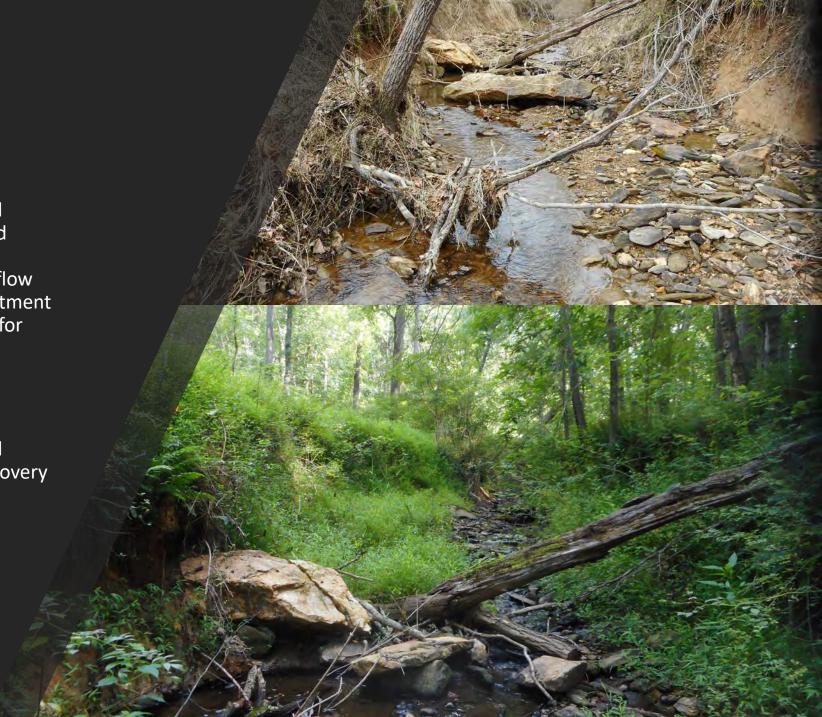
• The implementation of BMPs as retrofits will modify the runoff response from the watershed (hydrograph) resulting in a reduction of the magnitude, duration and frequency of erosive flow rates that meet and or exceed Maryland Department of Environment (MDE) performance standards for stream channel protection.

Hypothesis 2 - Geomorphology

• The implementation of BMPs as retrofits will create hydraulic conditions that lead to self-recovery of channel stability.

Hypothesis 3 – Load Estimation

• The implementation of BMPs will decrease sediment loadings downstream as a result of reduced bank erosion rates.



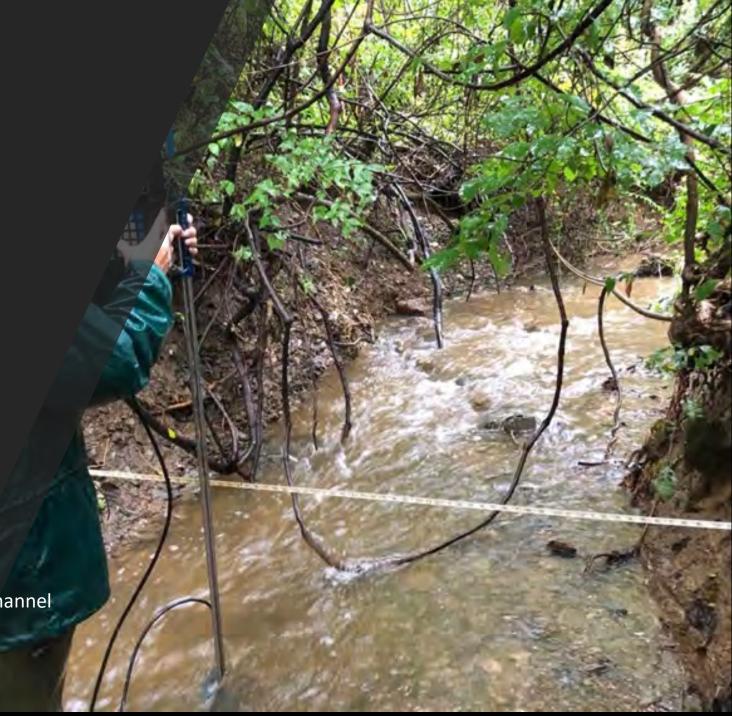
Monitoring Setup

H1 Hydrology

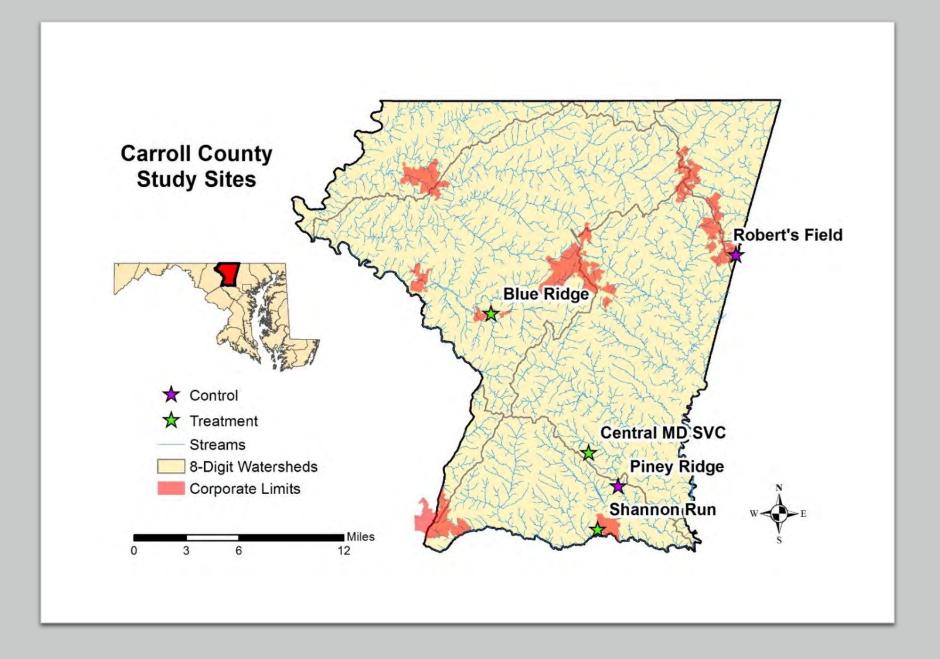
> H2 Geomorphology

H3 Load Estimation Rain gauge at 3 locations

- Central MD
- Roberts Field
- Blue Ridge
- Pressure Transducers
- Flow measurements
- Monumented Cross Sections
- Longitudinal Profiles
- Bank Pins
- Pebble Count
- Bulk density
- Riparian Vegetation
- BANCS
- Measured change in stream channel

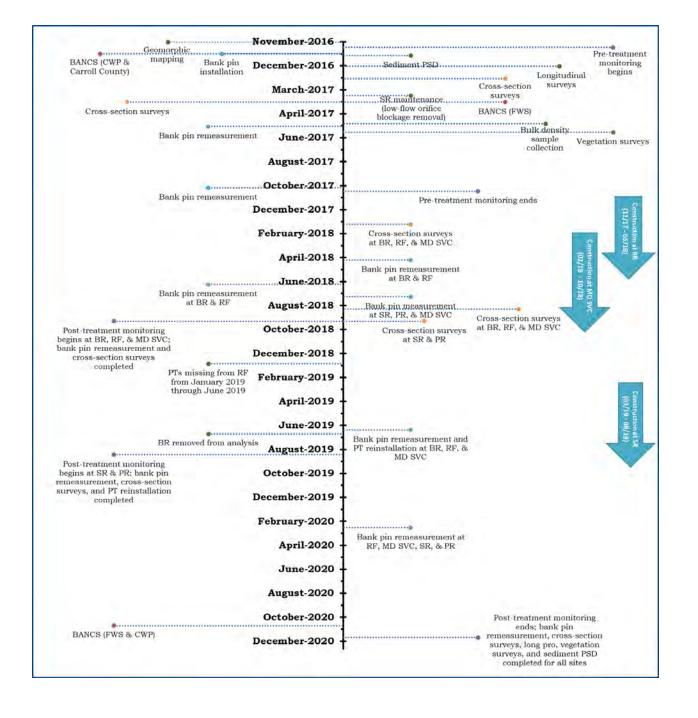


Paired Watershed Study Sites



Timeline

- Grant Awarded 2016
- Monitoring Plan/Baseline Field-work
 - Summer/Fall 2016
- Pre-Treatment Monitoring
 - November 2016 October 2017
- Post-Treatment Monitoring
 - October 2018 December 2020



Hypothesis 1:

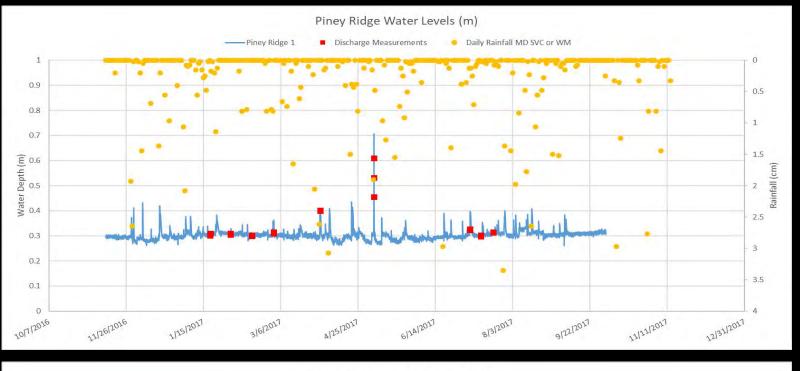
Hydrology-Hydraulics

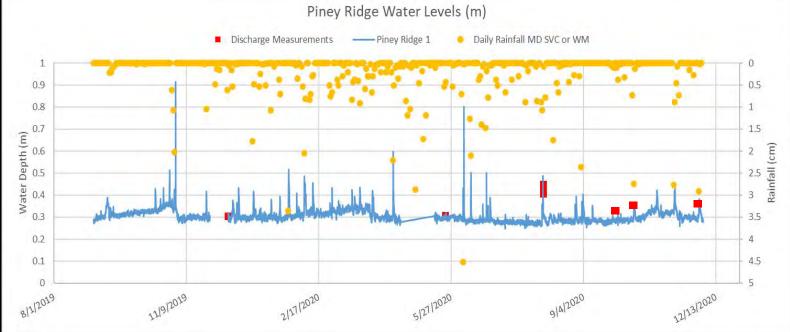
H1: Hydrology

Pre-treatment

Piney Ridge Village Control Site

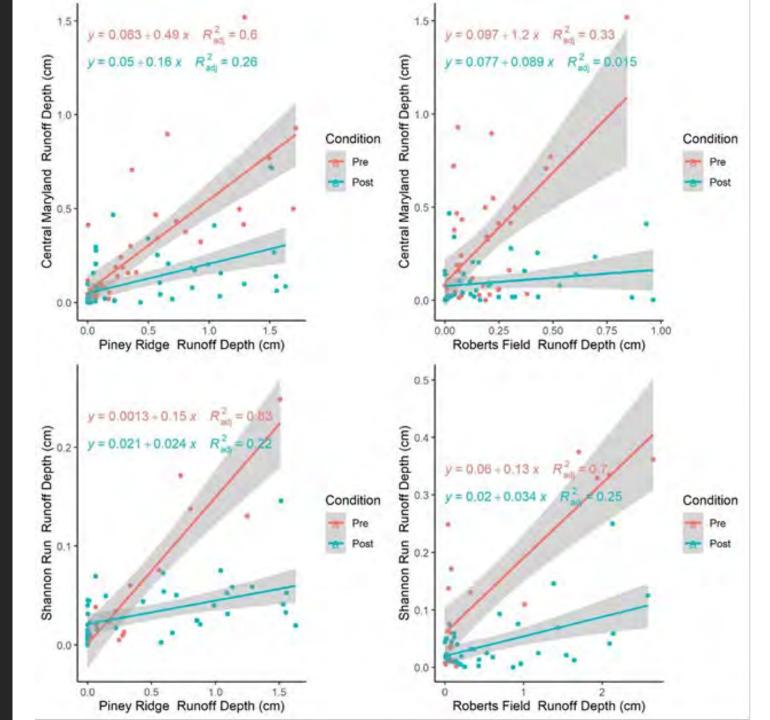






Runoff Response Relationship

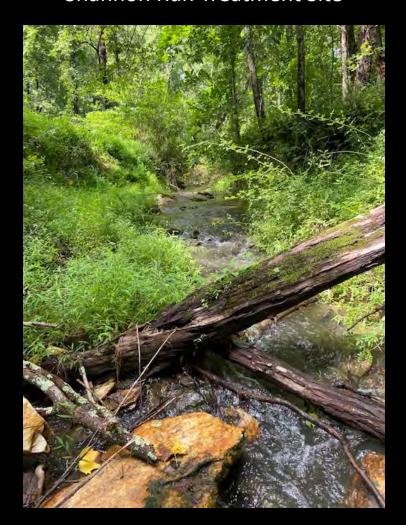


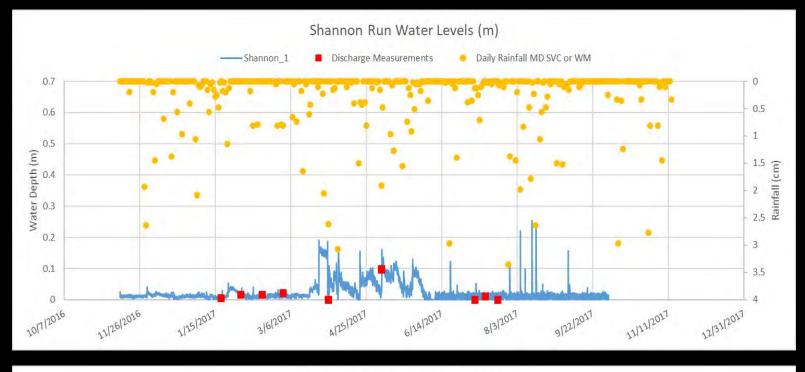


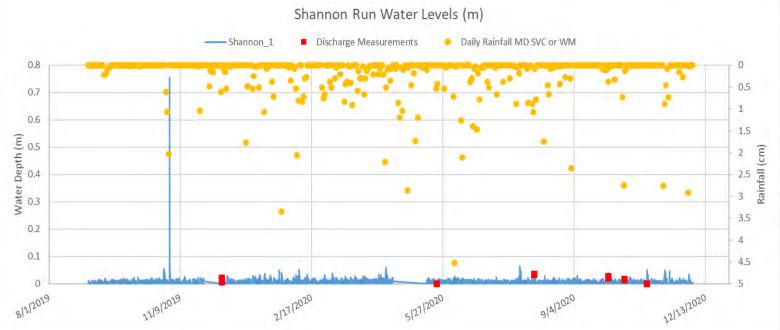
H1:Hydrology

Post-Treatment

Shannon Run Treatment Site







Hypothesis 2:

Geomorphology

- Cross Section Surveys
- Central Maryland (T)
- Robert's Field (C)

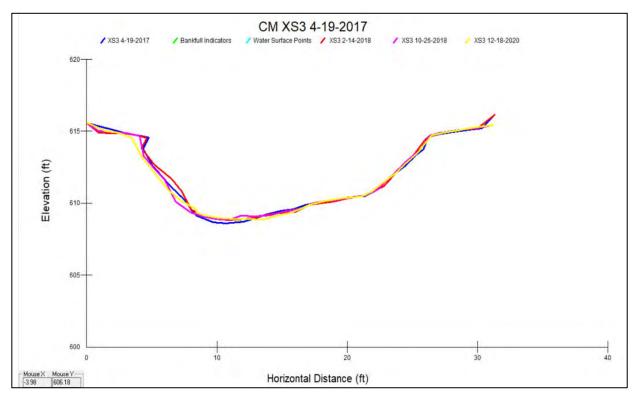
Central Maryland



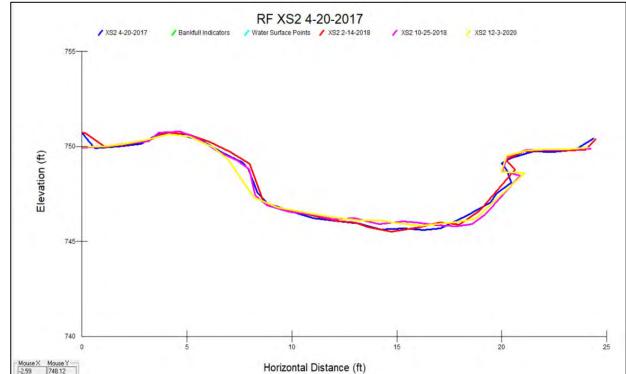


Robert's Field

Central Maryland – Treatment Site



Robert's Field - Control Site



- Cross Section Surveys
- Shannon Run (T)
- Piney Ridge (C)

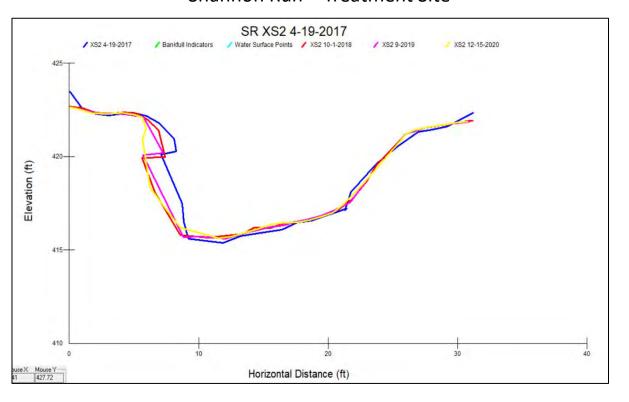
Shannon Run



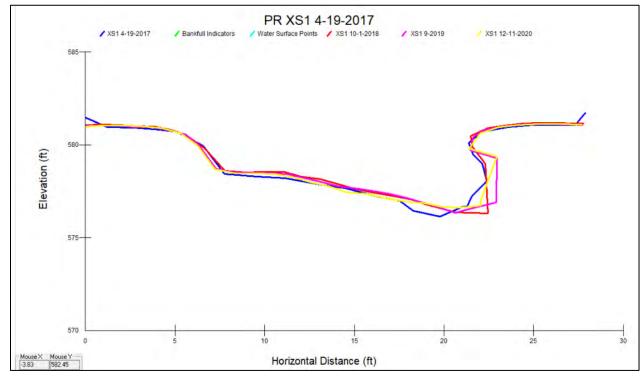


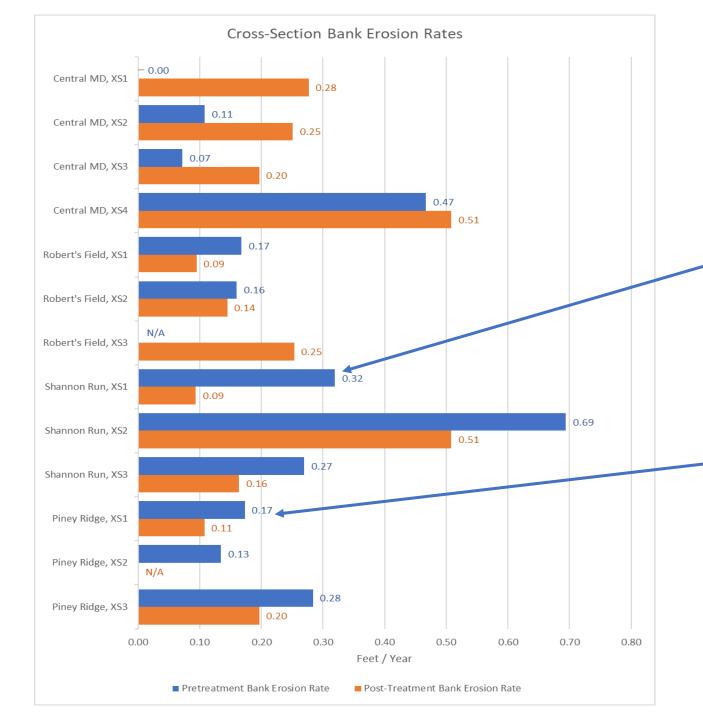
Piney Ridge Village

Shannon Run – Treatment Site



Piney Ridge—Control Site





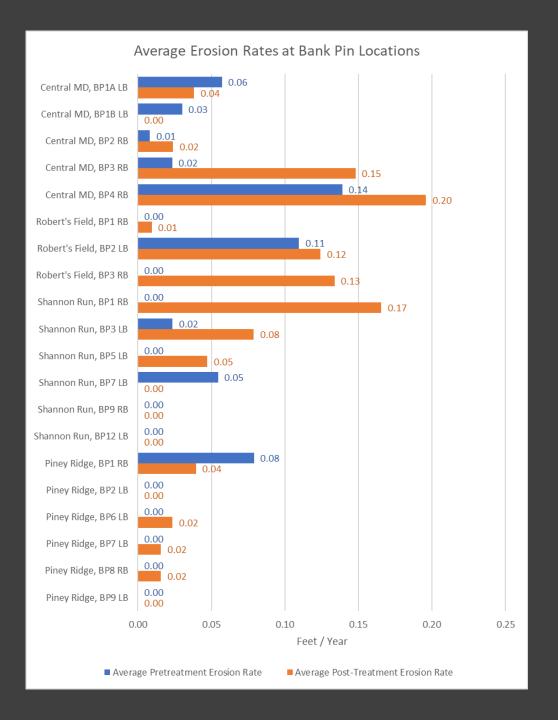
Cross Section Erosion Rates



Shannon Run Treatment Site XS 1

Piney Ridge Control Site XS 1





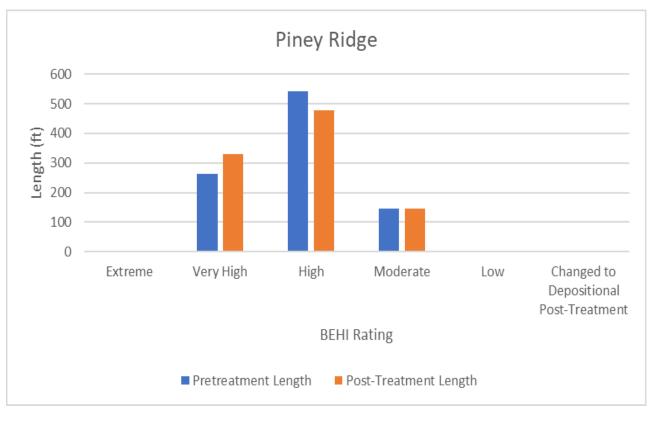


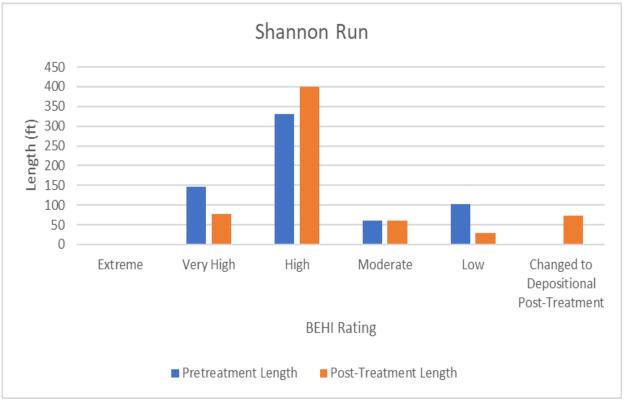
Bank Pin Erosion Rates



Hypothesis 3:

Load Estimation





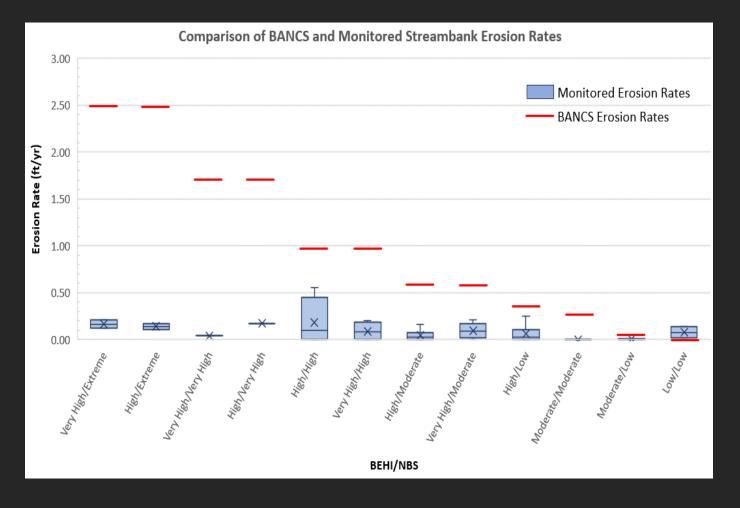
Control Site Treatment Site

BEHI Lengths

Pre and Post Treatment



H3: Load Estimation BANCS vs. Monitoring



H3: Load Estimation

BANCS vs. Monitoring Data



Table 17. Sediment loads estimated from BANCS and monitoring data for the study sites.

	BANCS		Monitoring Data		
Study Site	Pretreatment Total TSS Load ¹ (tons/yr)	Post- Treatment Total TSS Load ¹ (tons/yr)	Pretreatment TSS Load (tons/yr)	Post- Treatment TSS Load (tons/yr)	% of Total Bank Length with Representative Monitoring Location ²
Central MD SVC (T)	42.11	45.04	3.42	8.92	89.8%
Piney Ridge (C)	59.25	75.9	0.72	0.40	31.3%
Shannon Run (T)	54.49	56.54	11.06	7.35	52.5%
Robert's Field (C)	24.26	27.21	1.01	1.83	91.5%

¹The loads represent the total load at edge-of-stream without a sediment delivery factor or stream restoration efficiency applied as per the CBP stream restoration crediting protocols.

Mark Secrist FWS

²Total bank length obtained from the top of bank survey from the longitudinal profile and includes both the left and right bank lines.

Next Steps

- Continue Pressure Transducer Downloads
- Additional Storm Event Monitoring/Rating Curve Development
- Annual Cross Section Surveys



Shannon Run November 2016 Shannon Run October 2020

Final Thoughts

Partnerships...

- Chesapeake Bay Trust
- MD, Department of Natural Resources
- Center for Watershed Protection
- Carroll County Government

Special Thanks

- Ecosystem Planning & Restoration
- U.S. Fish and Wildlife Service













What does this mean for me?

- Monitoring has shown that stormwater BMP's designed to a certain criteria indicate self-recovery down stream.
- More time and monitoring is needed to show this for all indicators.
 - Peak discharge and flashiness show reductions at treatment sites.
 - Load estimation needs more monitoring to demonstrate impact.

What does this mean for me?

What do I take from this if I am a practitioner:

- Installing BMPs that maximize runoff treatment depths and provide channel protection volume will have a greater positive effect downstream on self-recovery of channel stability.
- Monitoring was done on first order streams. The downstream self recovery impacts of BMPs would be lessened on 2nd order streams and above.

What do I take from this if I am a regulator:

- Results are promising for effects of BMPs on downstream conditions.
- More monitoring is needed to understand load estimations and how far downstream effects are felt.

Determining the effects of legacy sediment removal and floodplain reconnection on ecosystem function and nutrient export



Presenters: Vanessa B. Beauchamp & Joel Moore Towson University

Co-authors: Patrick Baltzer, Patrick McMahon, Melinda Marsh, Kyle Bucher, Ryan Casey, Chris Salice

Acknowledgements

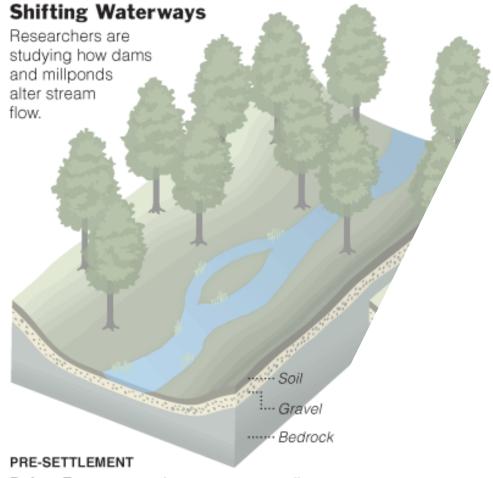
- Funding
 - Chesapeake Bay Trust (#13974), Towson University
- Logistical support Ecotone, Inc.
- Landowners Henry and David Pitts, Rigdon Family, Edwards Family, Harford County, City of Bel Air
- Students Patrick McMahon, Patrick Baltzer, Ginny Jeppi







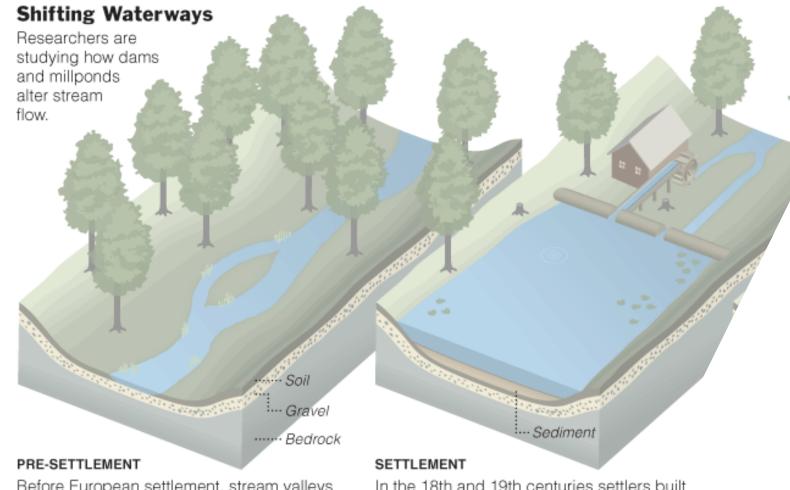
What are the goals and desired outcomes of restoration? What's the end point?



Before European settlement, stream valleys in the Middle Atlantic states were typically marshy, with shallow channels of water flowing in sheets over gravel stream beds.

Source: LandStudies

What are the goals and desired outcomes of restoration? What's the end point?



Before European settlement, stream valleys in the Middle Atlantic states were typically marshy, with shallow channels of water flowing in sheets over gravel stream beds. Source: LandStudies In the 18th and 19th centuries settlers built dams by the thousands. Trapped sediment runoff from logging and farming slowly filled in the millponds. If a dam failed another dam might be built on top of it, or just downsteam.

What are the goals and desired outcomes of restoration? What's the end point?



Before European settlement, stream valleys in the Middle Atlantic states were typically marshy, with shallow channels of water flowing in sheets over gravel stream beds. Source: LandStudies In the 18th and 19th centuries settlers built dams by the thousands. Trapped sediment runoff from logging and farming slowly filled in the millponds. If a dam failed another dam might be built on top of it, or just downsteam.

After hundreds of years the valley floor might be covered with 3 to 20 feet of sediment. Once a dam is gone, faster-flowing water cuts deep channels in the silt, eroding down toward the stream's historic elevation and leaving horizontal layers of sediment visible along the stream banks.

JONATHAN CORUM/THE NEW YORK TIMES



Likely outcomes & questions about Legacy Sediment Removal and Floodplain Reconnection

Vegetation

- Increased dominance of hydric vegetation
- Change in community composition
- Response to disturbance? Invasives?

Water chemistry

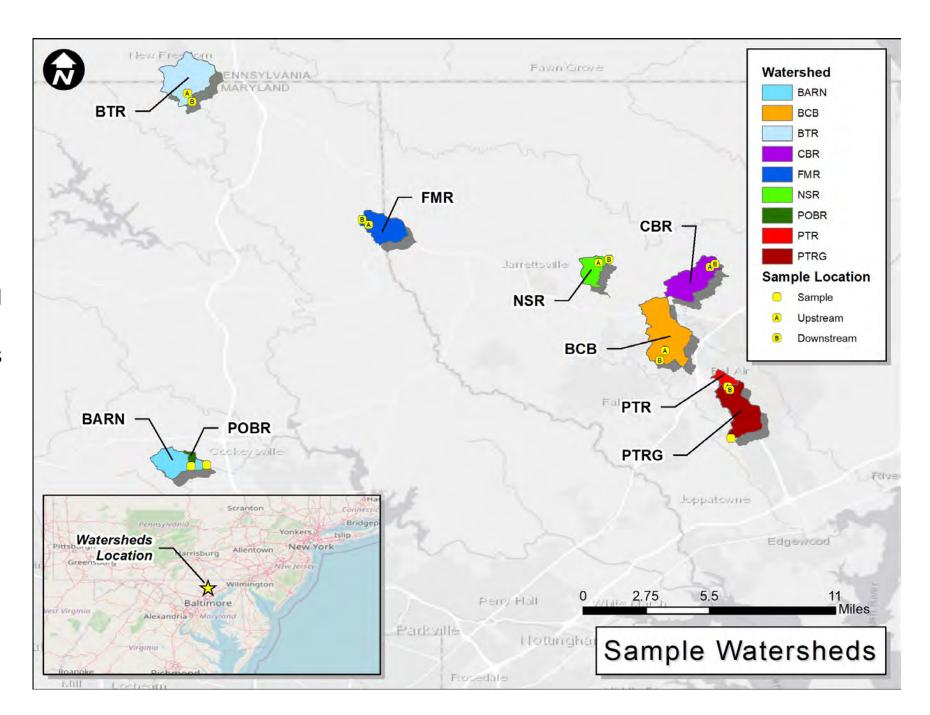
- Decrease in N, P and TSS due to increased overbank events and longer residence time
- Relationship with drainage area?
 Impervious cover? Project length?



Study sites

6 restored watersheds, 3 others

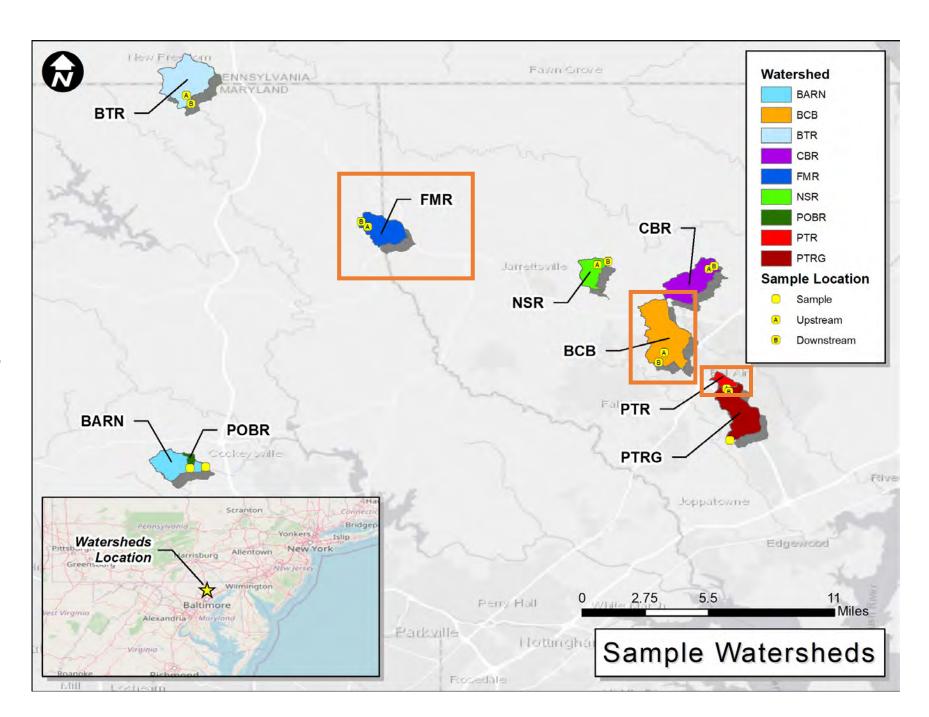
- 4 agricultural watersheds
 - 3 row crop
- 2 (sub)urban watersheds
 - + 1 larger scale watershed
- 2 (mostly) forested watersheds



Study sites

6 restored watersheds, 3 others

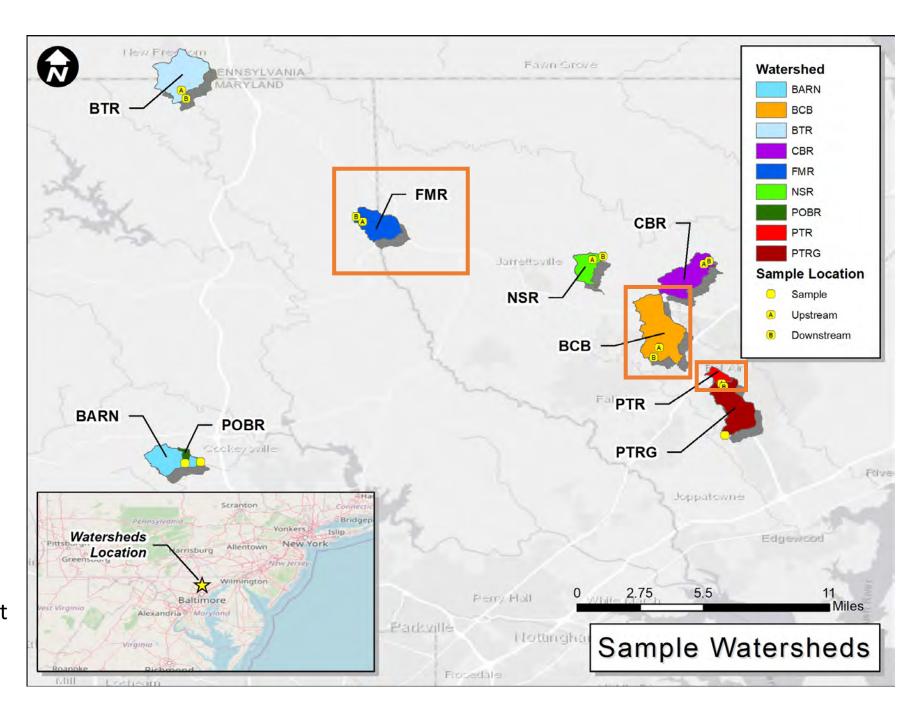
- 4 agricultural watersheds
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Study sites

6 restored watersheds, 3 others

- 4 agricultural watersheds
 - 3 row crop
- 2 (sub)urban watersheds
 - + 1 larger scale watershed
- 2 (mostly) forested watersheds
- All <8.2 km²
- Agricultural: 0 73%
- Impervious: 0 56%
- Restored length: 1240 5230 ft
- Restoration age: 1 5 years





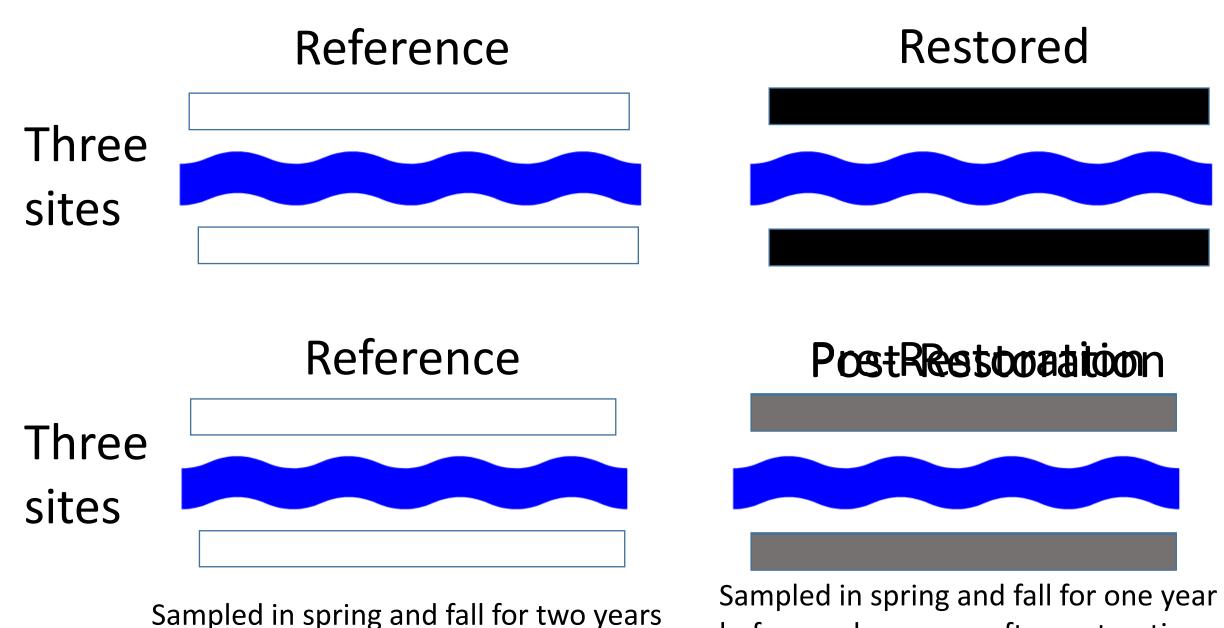


First Mine Branch



First Mine Branch

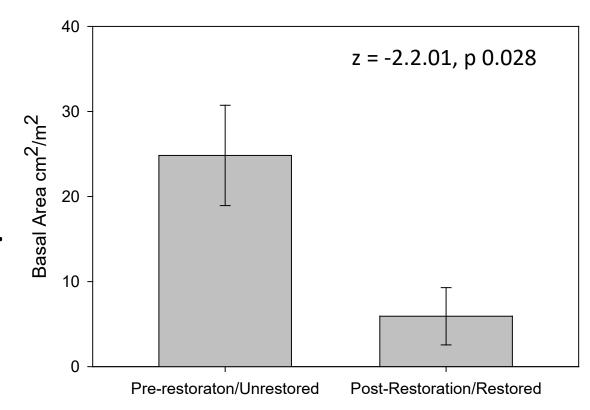
Vegetation: Sampled in spring and fall for two years



before and one year after restoration

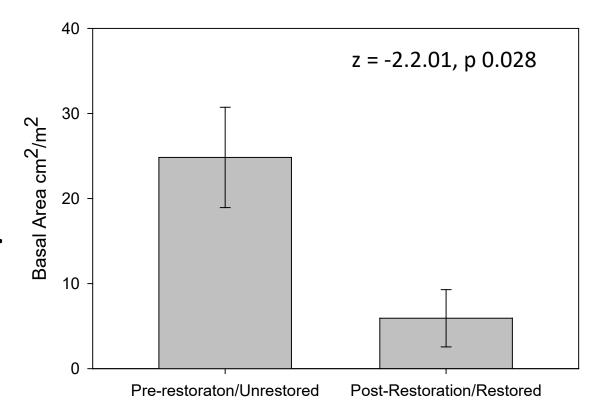
Woody vegetation: Decrease in area, mixed on diversity

- 81% decrease in basal area
- 20% decrease in species richness
- Areas within a site become more diverse
- But differences *between* sites decrease. Biotic homogenization?



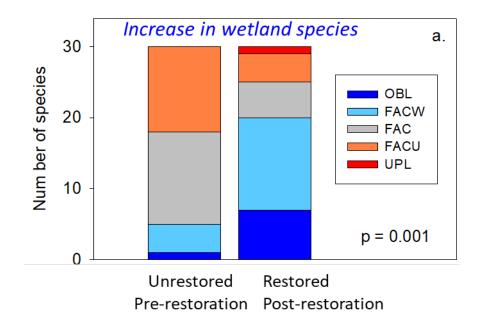
Woody vegetation: Decrease in area, mixed on diversity

- 81% decrease in basal area
- 20% decrease in species richness
- Areas within a site become more diverse
- But differences *between* sites decrease. Biotic homogenization?
- Similar species composition in unrestored and restored reaches
- No significant indicator species changed in importance due to planting



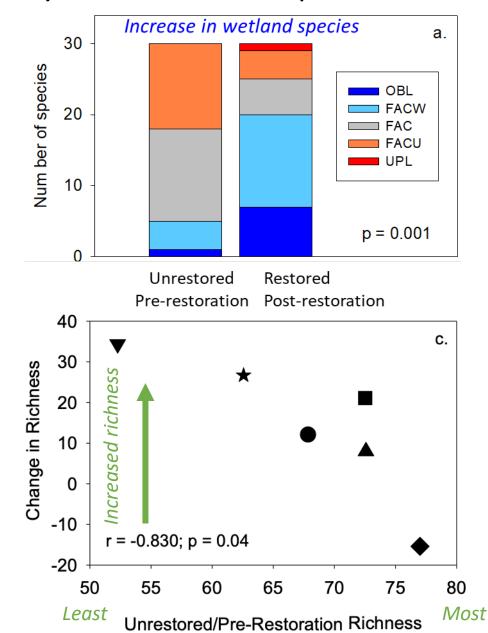
Herbaceous vegetation: More hydrophytic, other improvements

- Post-restoration is more hydrophytic (decrease in Wetland Indicator Score)
- Sites become more different from each other (upstream/seedbank contribution?)

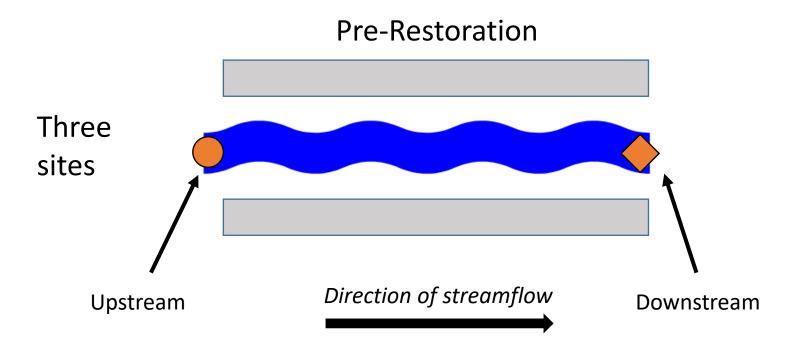


Herbaceous vegetation: More hydrophytic, other improvements

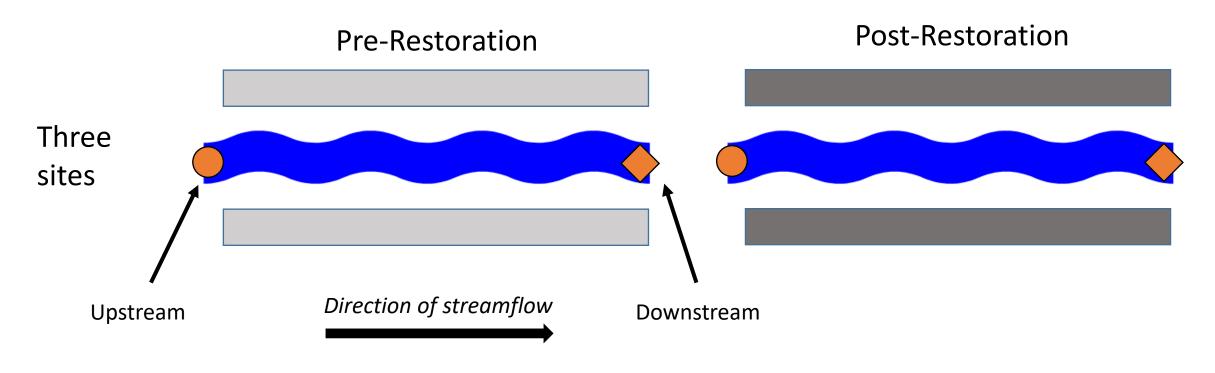
- Post-restoration is more hydrophytic (decrease in Wetland Indicator Score)
- Sites become more different from each other (upstream/seedbank contribution?)
- Slight increases overall in quality, richness, & diversity
- Sites that start with low quality vegetation improve, but sites with high quality vegetation decrease in quality
- 74% loss of skunk cabbage slow regeneration?



Sampling approach

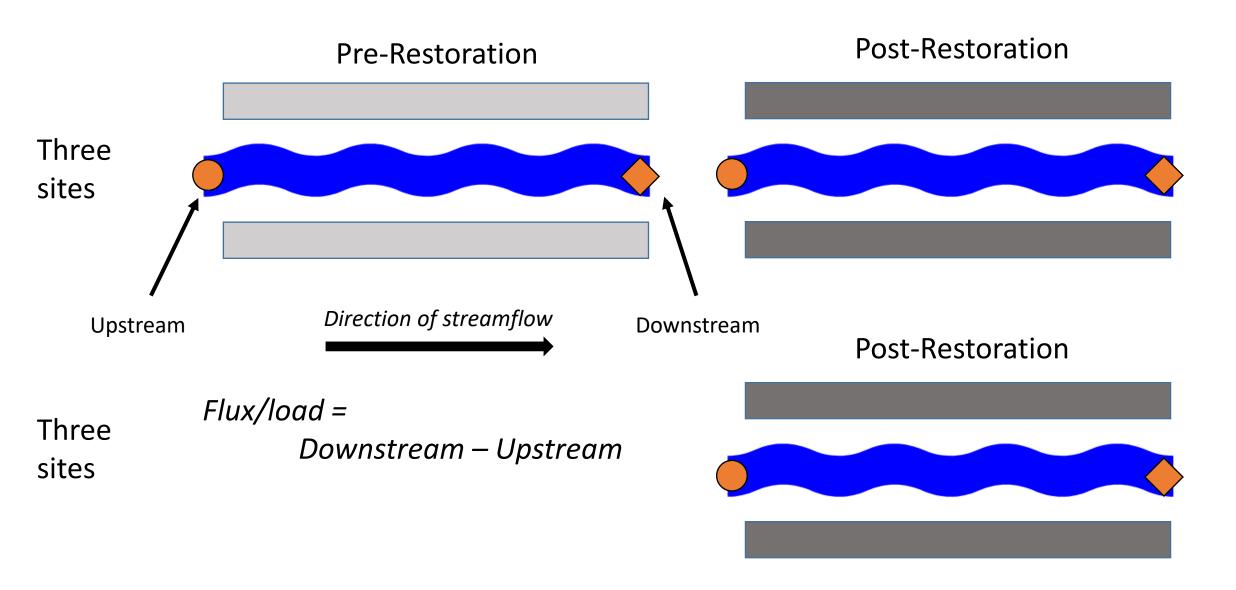


Sampling approach

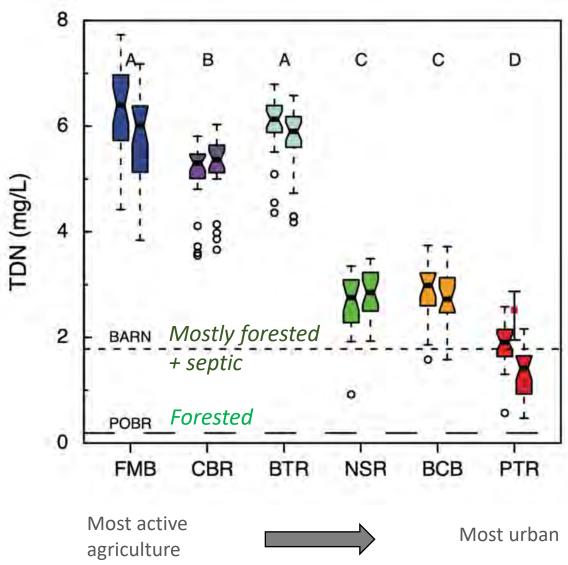


Flux/load =
Downstream - Upstream

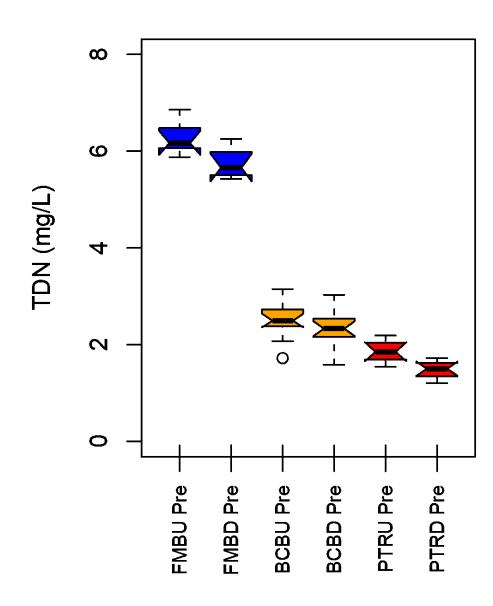
Sampling approach



Biggest control for baseflow N: land use

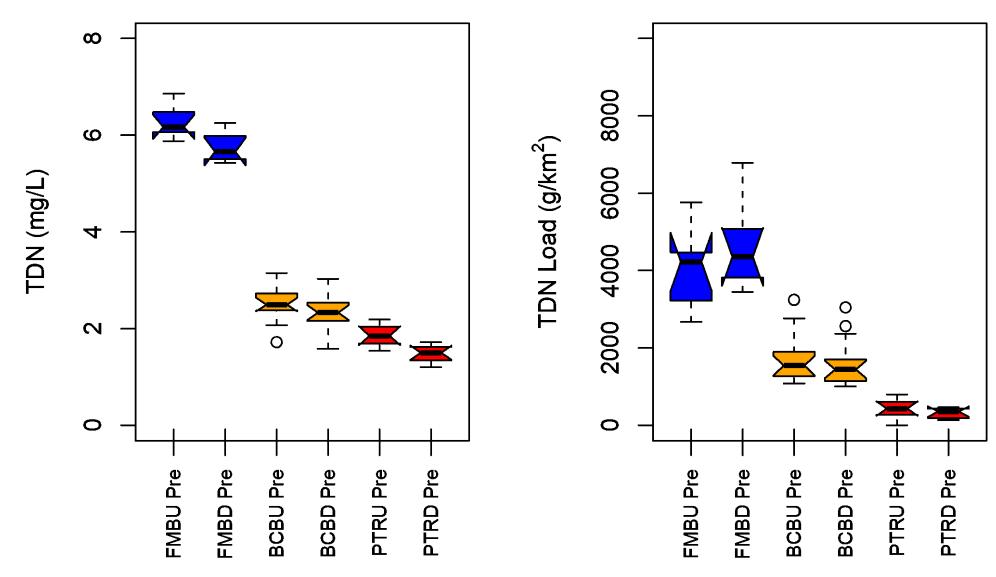


Pre-restoration baseflow N differences across reaches

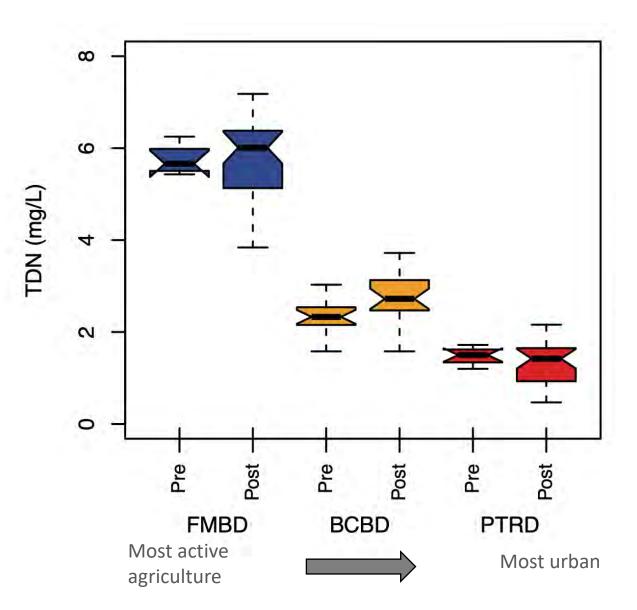


Pre-restoration baseflow N differences across reaches

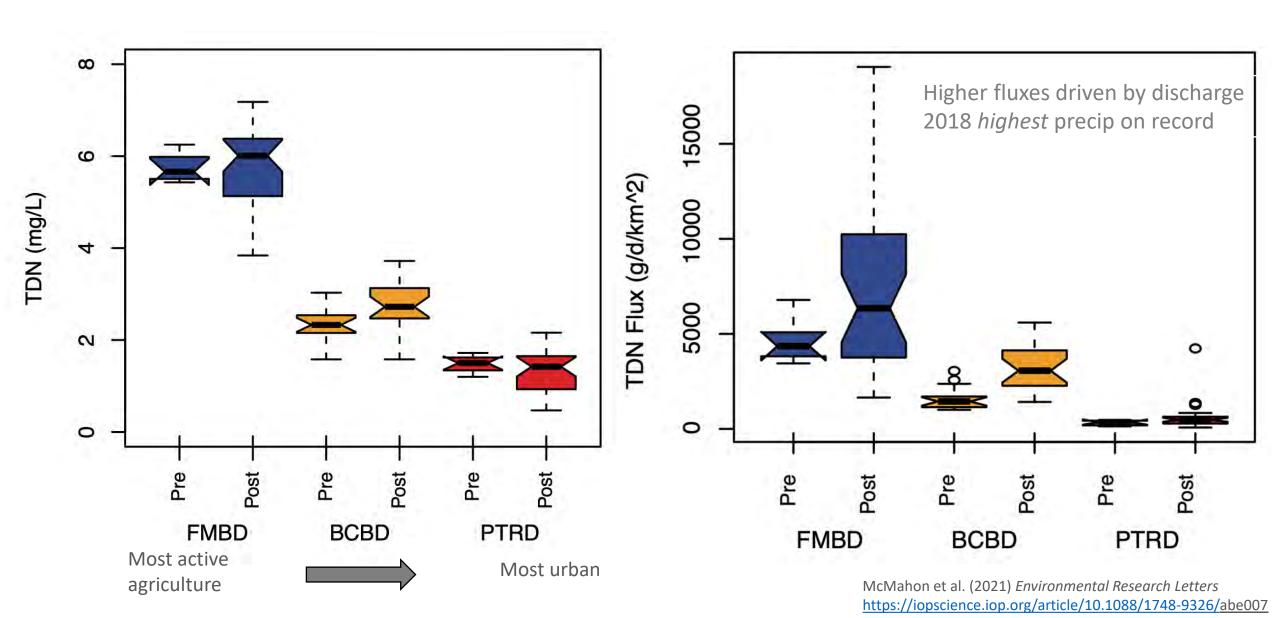
No substantial change post-restoration

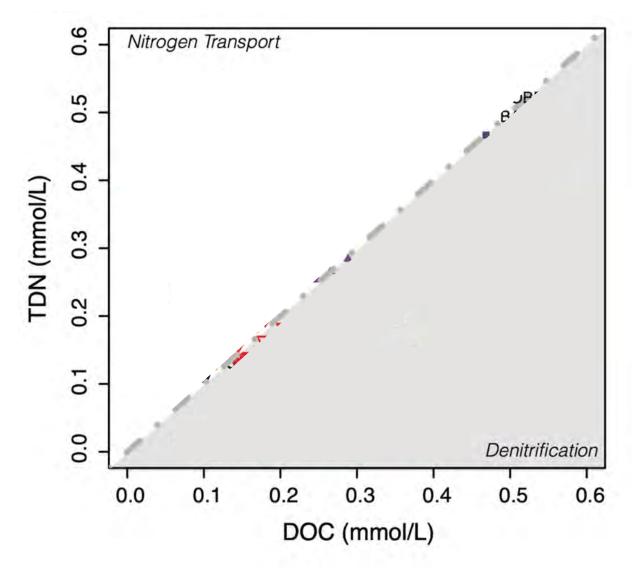


Baseflow N concentrations quite similar after restoration

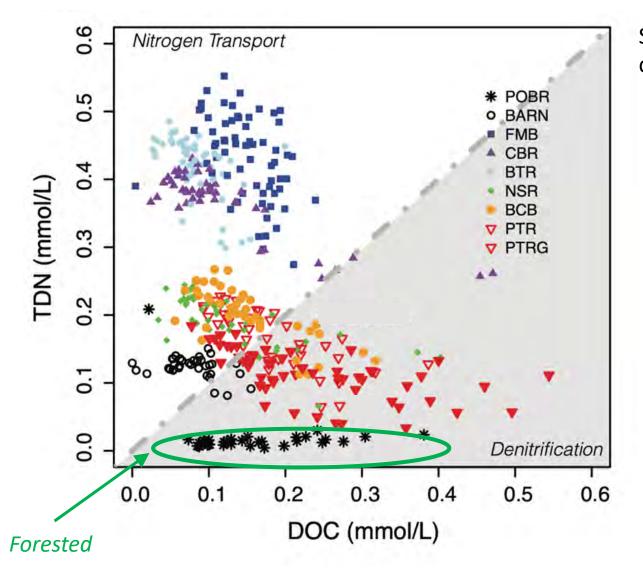


Baseflow N concentrations quite similar after restoration, fluxes higher

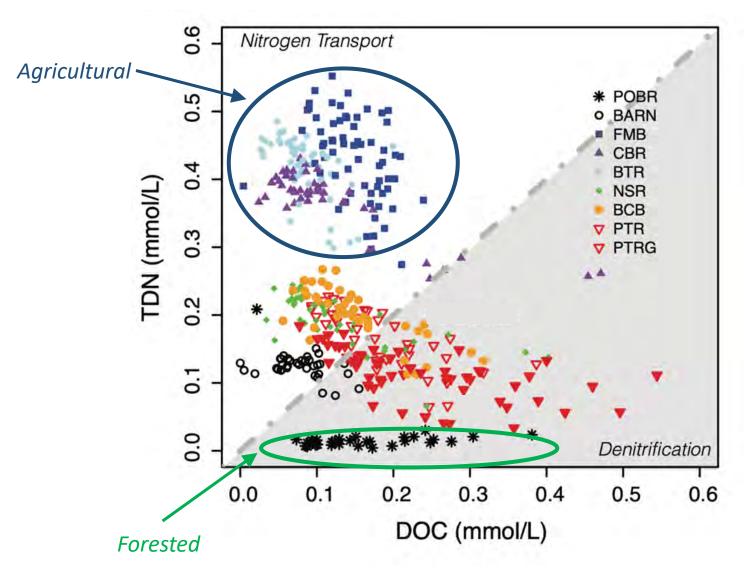




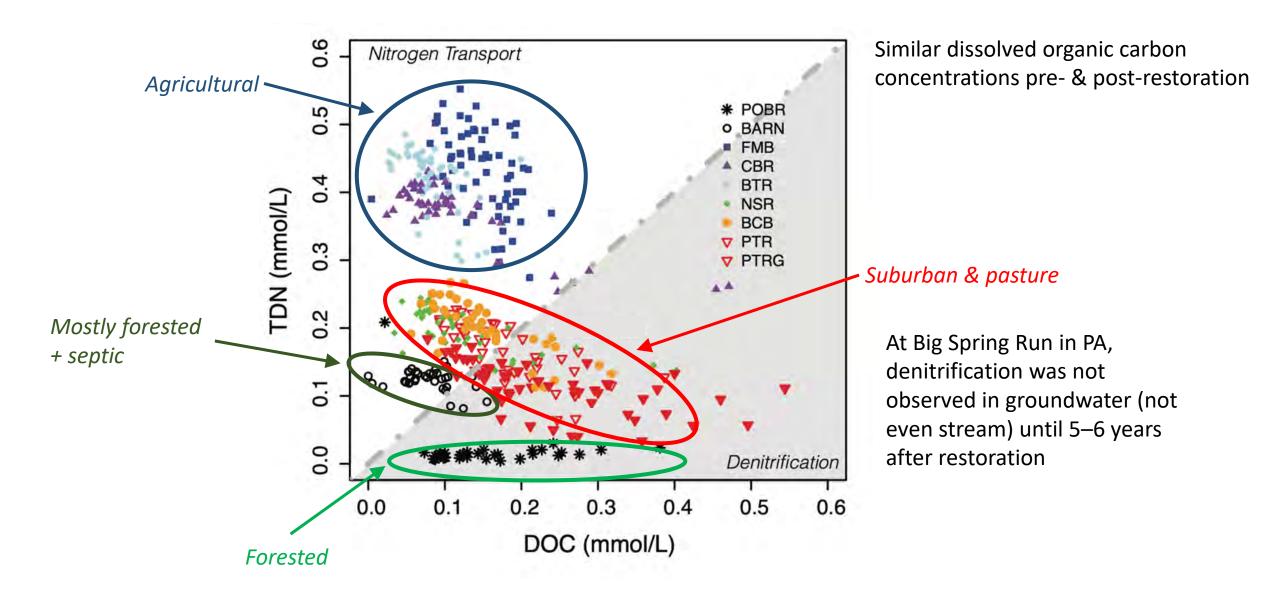
Similar dissolved organic carbon concentrations pre- & post-restoration



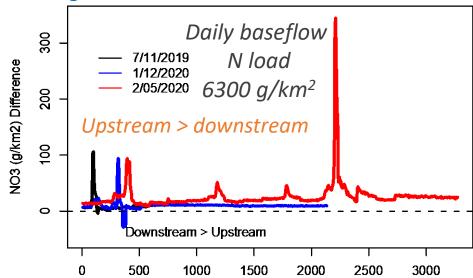
Similar dissolved organic carbon concentrations pre- & post-restoration



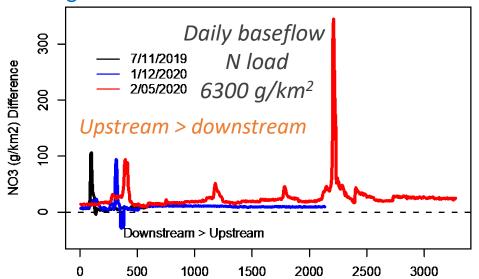
Similar dissolved organic carbon concentrations pre- & post-restoration

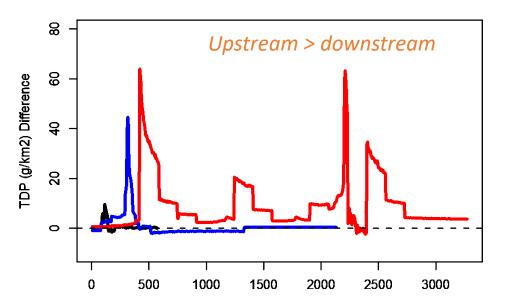


FMB: Most ag site

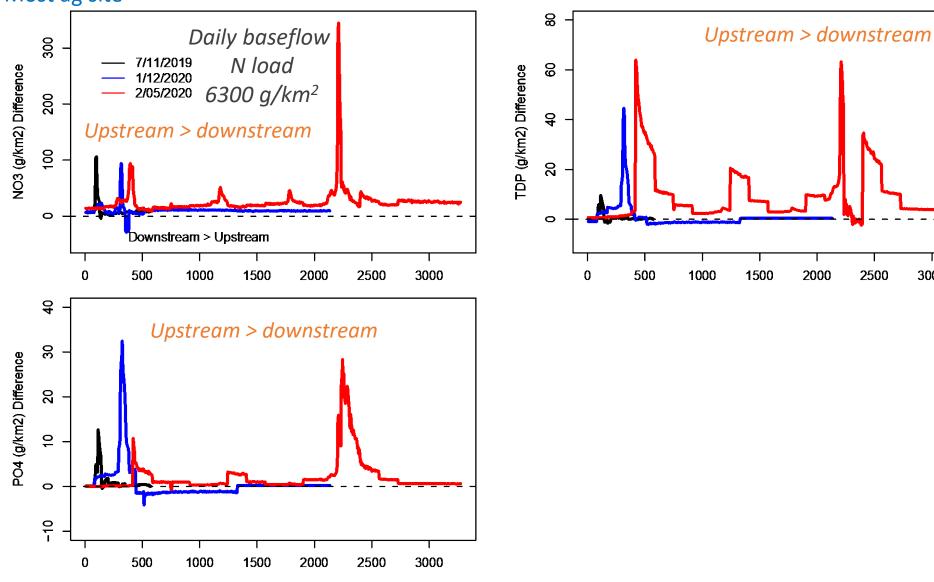


FMB: Most ag site





FMB: Most ag site

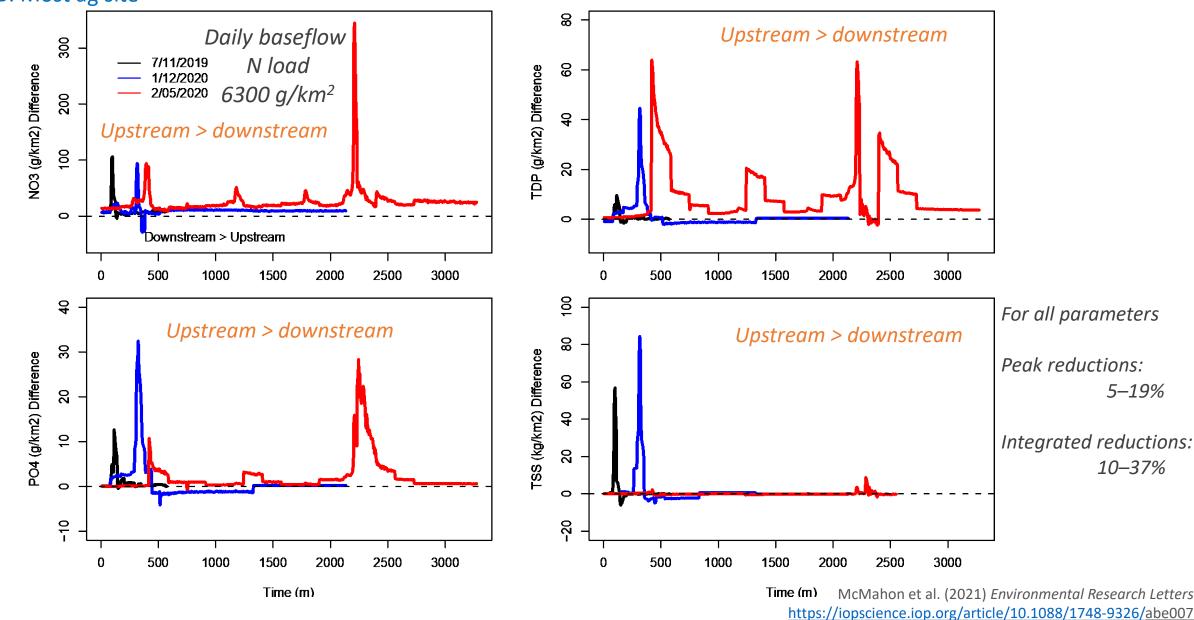


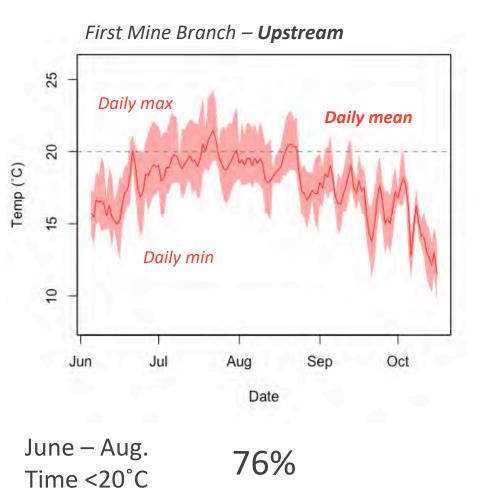
Time (m)

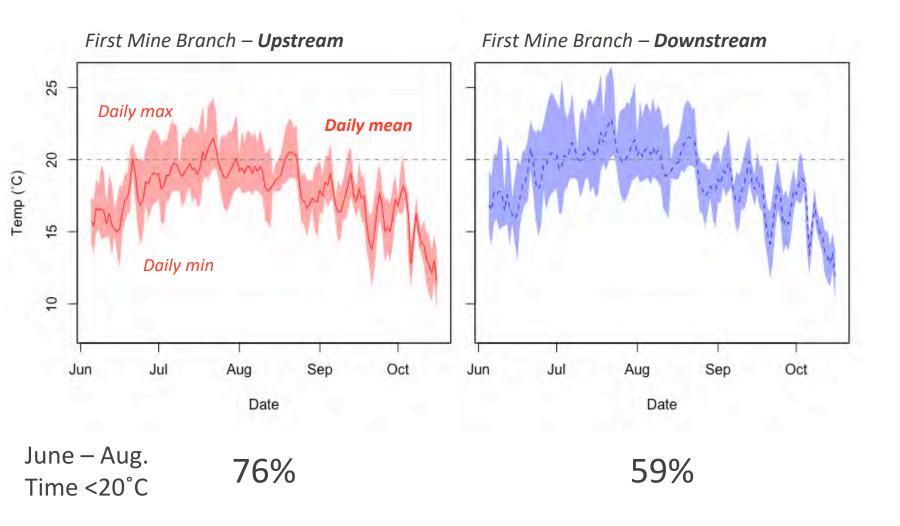
2500

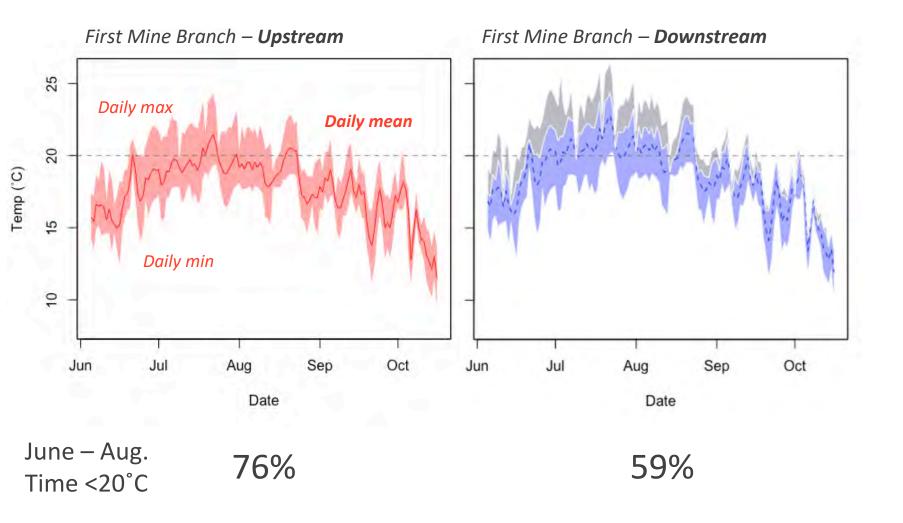
3000

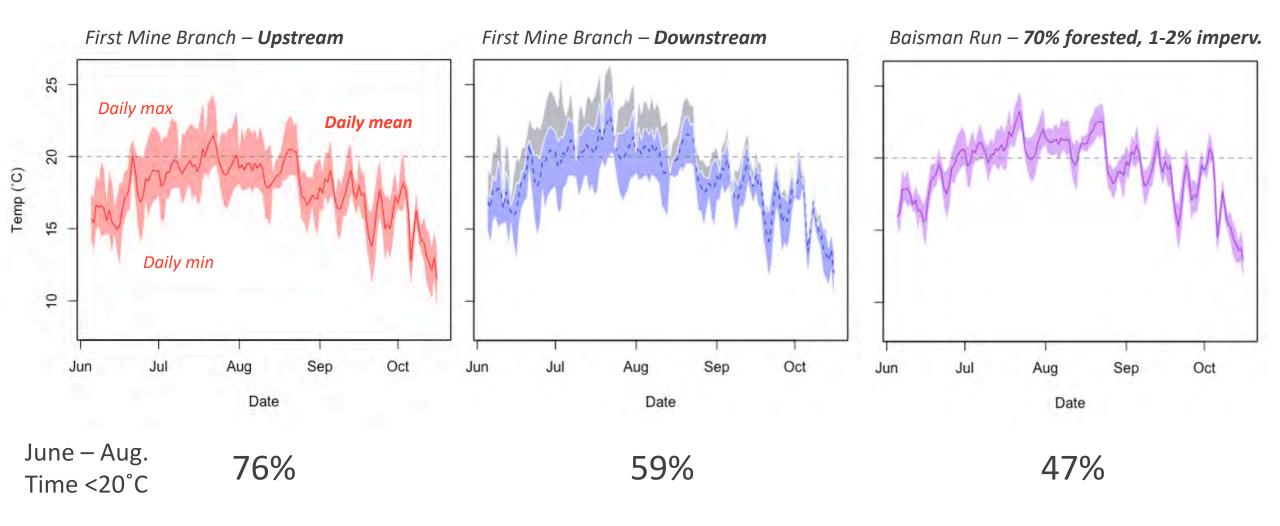
FMB: Most ag site











Summary - Water

- Weather (2018) made the study "interesting"
- Agricultural land use is the biggest driver of N concentrations
- Denitrification appears to be limited by carbon
- No significant difference in N after restoration
- During stormflow
 - Hints of slightly lower fluxes on downstream end
 - Of interest: storm N shifts with more ammonia & dissolved organic N (or NO₃⁻ decreases more than total dissolved N)



Vanessa B. Beauchamp and Joel Moore Towson University

Translation Slides by Scott Lowe

What does this mean for me?

- The wet year of 2018 obscured some results in research
 - Nutrients, Sediment, and Temperature inconclusive
 - Why no dilution in higher discharges?
- Land Use of Watershed has dominant impacts
 - Are urban loads correlating with Bay Model?
- Legacy Sediment Removal increases hydrophytic vegetation establishment and decreases invasives at these sites – at least initially
- Majority of herbaceous vegetation established was not planted, majority of woody vegetation was planted

What does this mean for me?

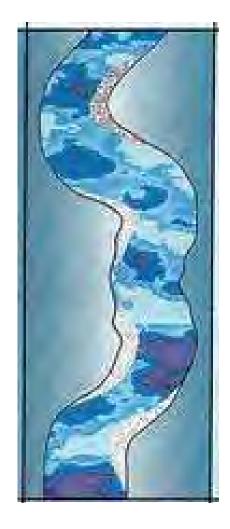
What do I take from this if I am a practitioner:

- What is optimal selection of floodplain access elevation? Significance of baseflow versus flood flow nutrient and sediment fluxes?
- Siting of projects relative to land use
- Planting plan strategies
- Look for ways to create more storage or increase retention time for storm flows

What do I take from this if I am a regulator:

- Temperature fluctuations may be negligible but additional data in normal year needed
- Lower risk of invasives at least initially
- Higher likelihood of self mitigating wetland impacts with hydrophytic vegetation quickly established?

What are the goals and desired outcomes of restoration?



Meandering

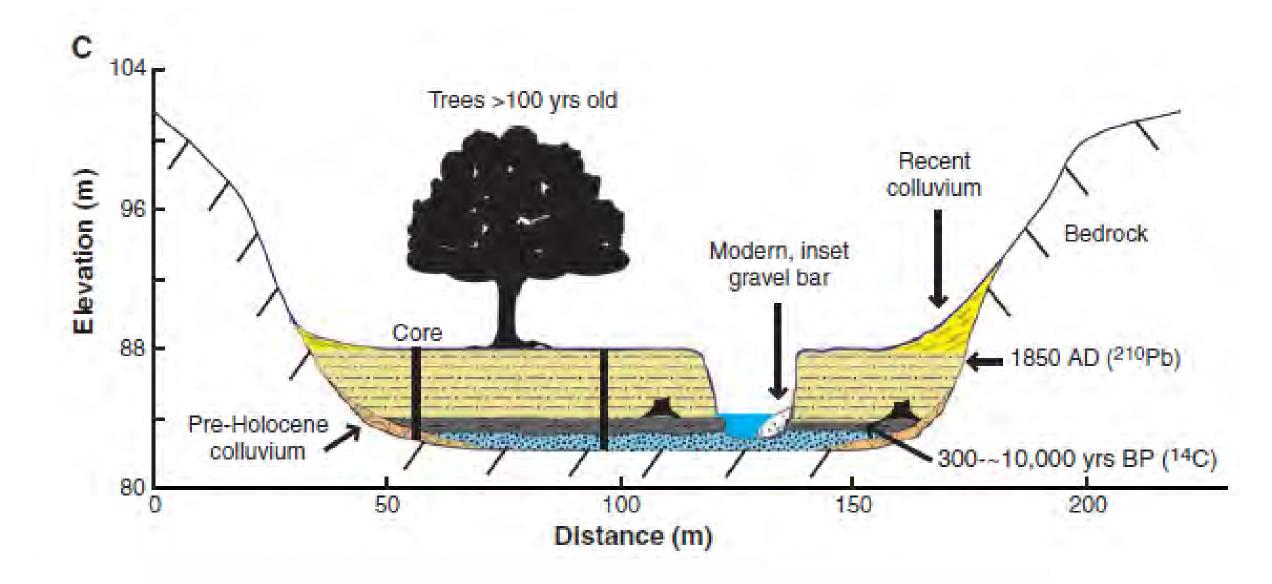
What are the goals and desired outcomes of restoration?



Meandering

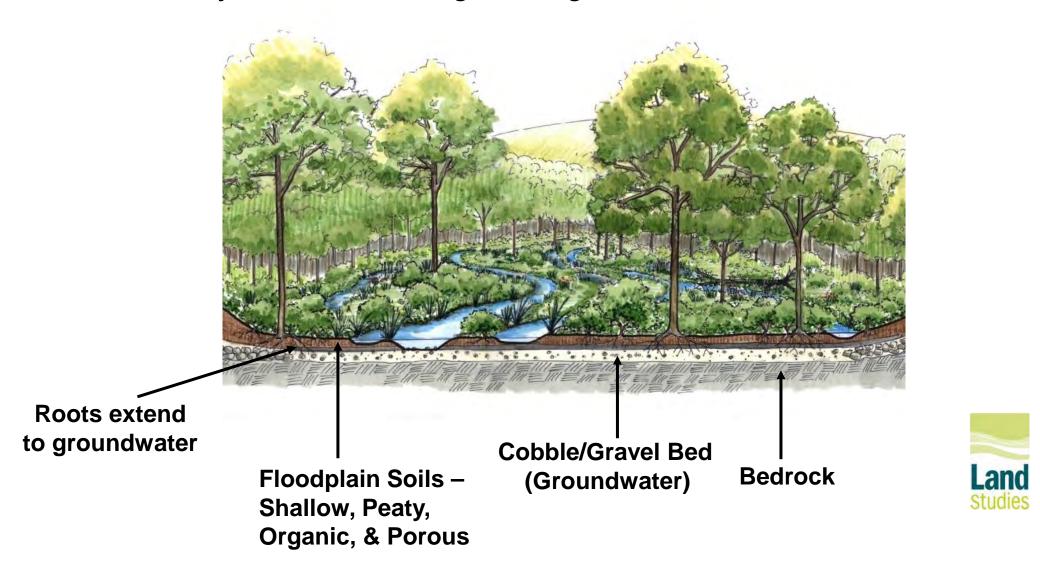


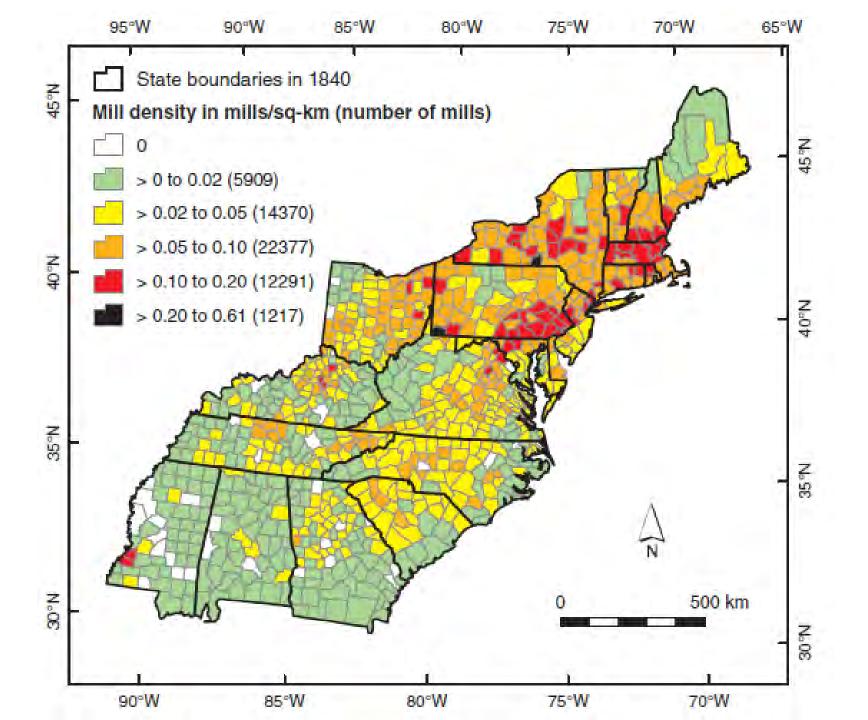
Anastomosing



Natural Piedmont Stream Valley

Connectivity between rooting zone, groundwater, and stream flow





Summary - Vegetation

- Decrease in woody vegetation
 - Removal of trees
 - Near-complete elimination of vines
 - Community similarity among sites increases
- Increase in hydrophytic, native vegetation
 - Loss of species (like skunk cabbage) that don't disperse/regenerate well from seed
 - Loss of forest understory species
 - Increase in graminoid species (grasses, rushes, sedges)
 - Response to hydrology and light

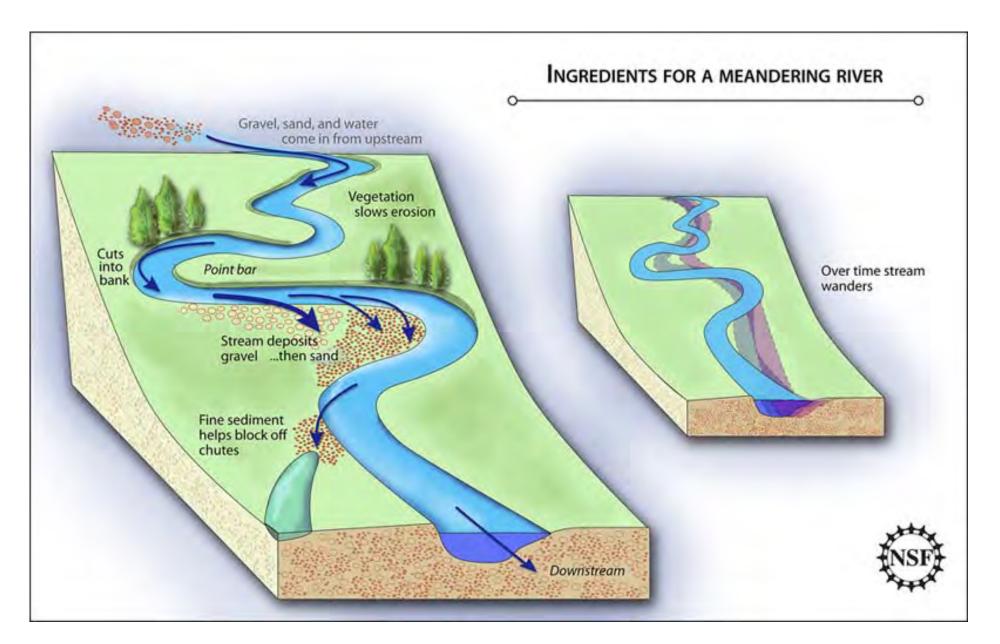




Study sites — for questions

Site	Drainage Area (km²)	Forest (%)	Impervious surface cover (%)	Restoration length (linear ft)	Usage
BTRD	6.55	14.5	1.26	5320	Reforesting / Retired Agricult-
BTRU	6.03	13.3	1.03		ural
FMRD	3.88	26.4	1.26	2400	Row crop with (former) forested buffer
FMRU	2.93	22.5	1.68		
NSRD	2.25	37.7	6.14	2600	Pasture / Active cattle farm
NSRU	1.83	43.8	7.51		
CABD	4.97	7.92	13.7	1340	Row Crop & Retired pasture
CABU	4.40	10.7	14.6		
BCBD	8.18	21.6	21.6	3675	Suburban / Retired Agricultural
BCBU	7.07	21.9	21.9		
PTRD	0.96	5.01	56.4	1240	Dense urban
PTRU	0.88	3.29	54.9		

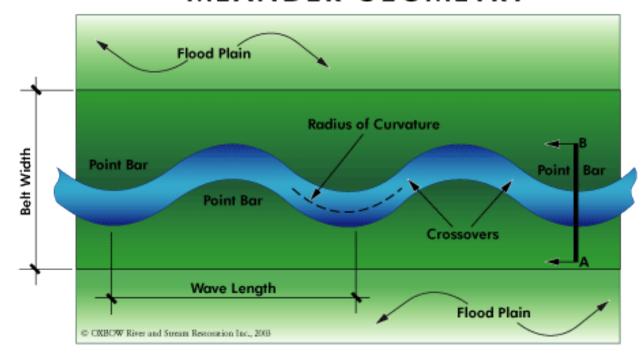




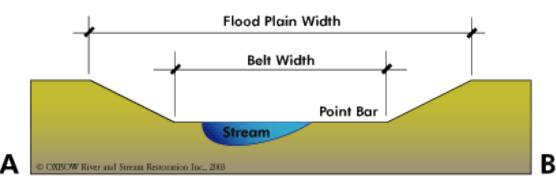


https://lternet.edu/research/keyfindings/river-corridors

MEANDER GEOMETRY



MEANDER CROSS SECTION AB





http://www.oxbowriver.com/Web_Pages/Services_Pages/Services_NCD/NCD_Meander.html





Bear Cabin Branch





Bear Cabin Branch



Plum Tree Run



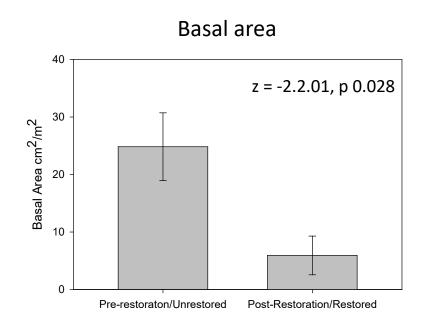


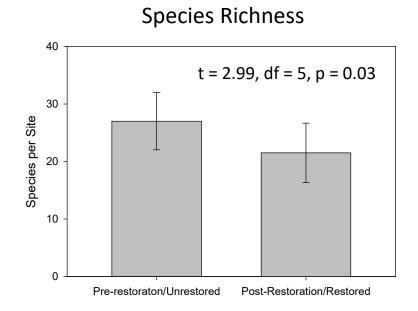
Plum Tree Run



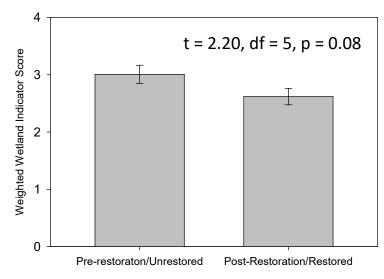
Plum Tree Run

Average 81% DECREASE in basal area and 20% decrease in woody species richness

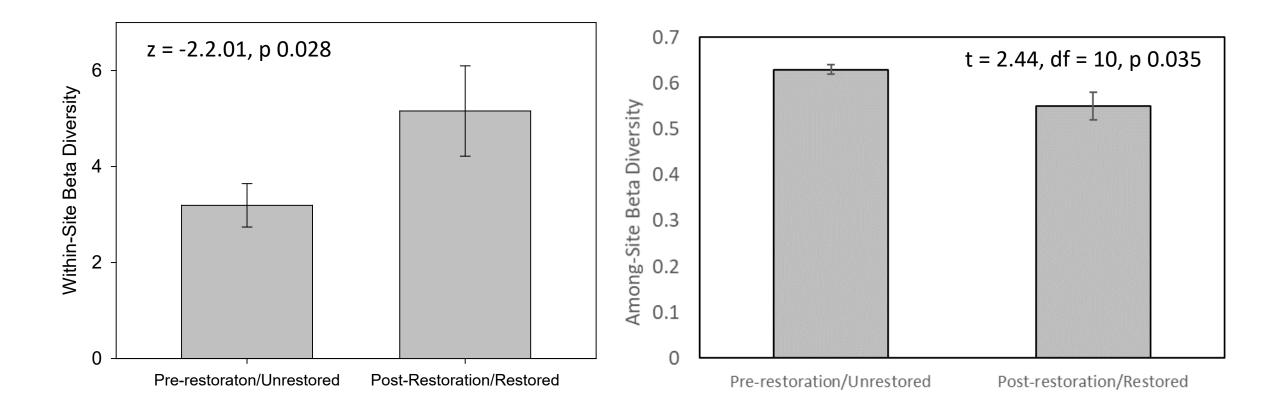




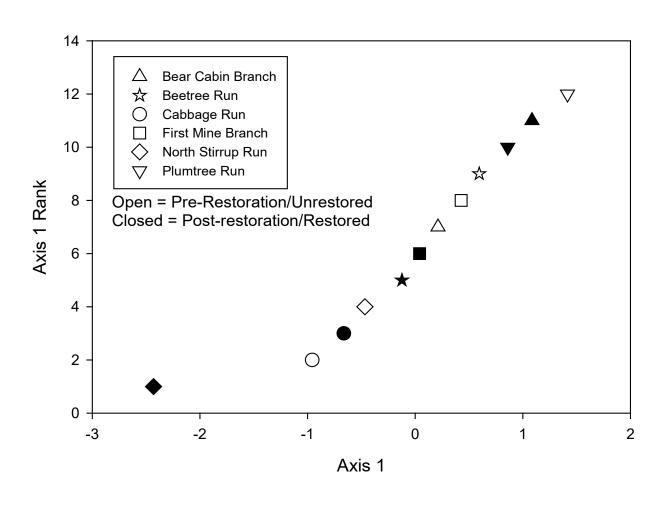




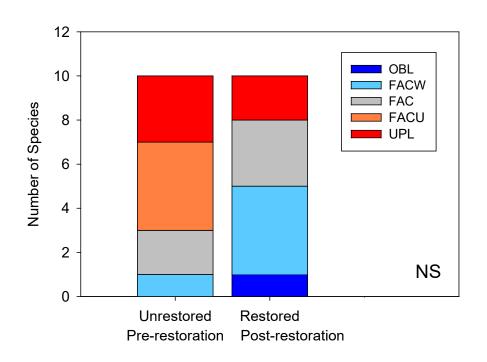
Woody Layer Beta Diversity

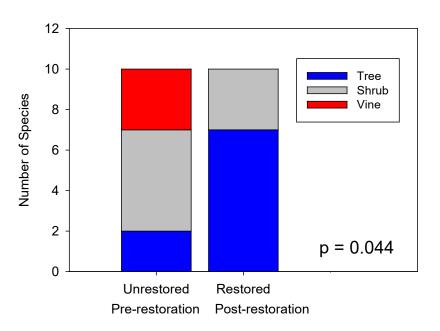


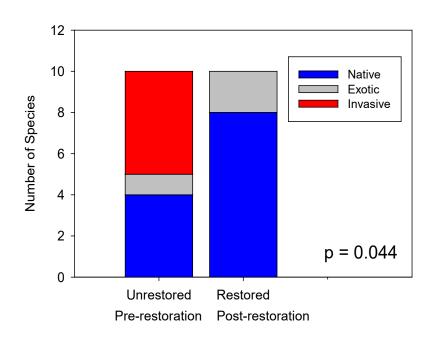
Woody Vegetation NMDS



Change in composition of important species (high indicator values)







Change in Indicator Value

Species	Common name	Un/Pre Restored IV	Restored IV	Change	Planted Sites
Salix purpurea	purpleosier willow	0	67	67	3
Viburnum prunifolium	blackhaw	19	60	41	2
Aronia arbutifolia	red chokeberry	4	37	33	1
Salix nigra	black willow	31	63	32	5
Quercus velutina	black oak	2	29	27	0
Acer platanoides	Norway maple	46	1	-45	0
	Japanese				
Lonicera japonica	honeysuckle	50	0	-50	0
Celastrus orbiculatus	oriental bittersweet	71	14	-57	0
Rubus occidentalis	black raspberry	60	2	-58	0
Rubus phoenicolasius	wineberry	63	1	-62	0

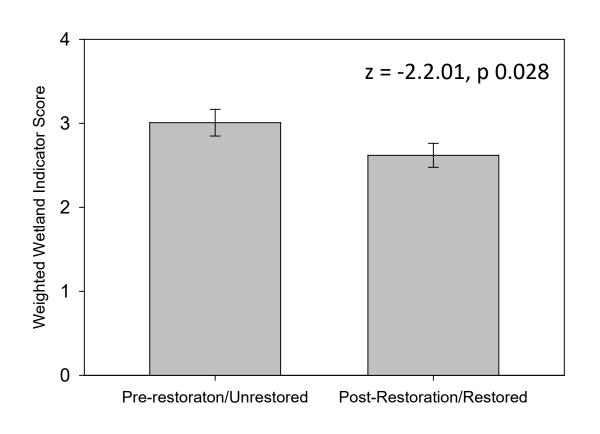
Woody Vegetation

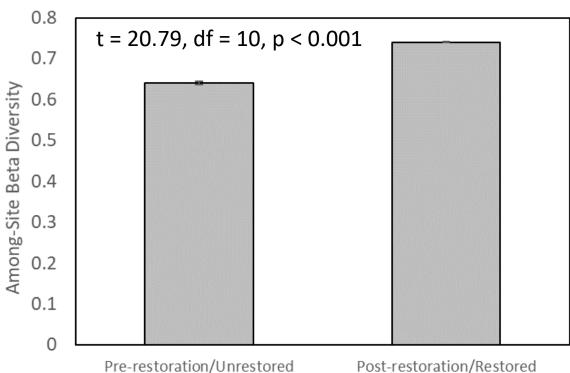
- Large decrease in basal area and species richness
- Areas within a site become more diverse, but differences between sites decrease. Biotic homogenization?
- Similar species composition in unrestored and restored reaches
- No significant indicator species Salix purpurea (purple osier or basket willow) importance increases due to planting

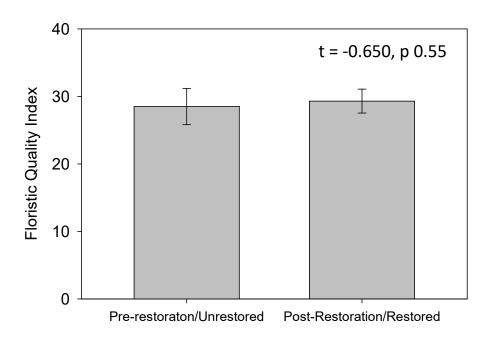


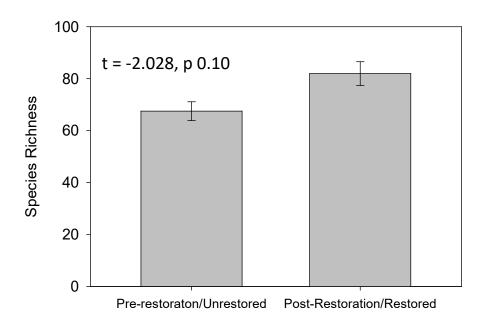
https://www.willowsvermont.com/purbl.html

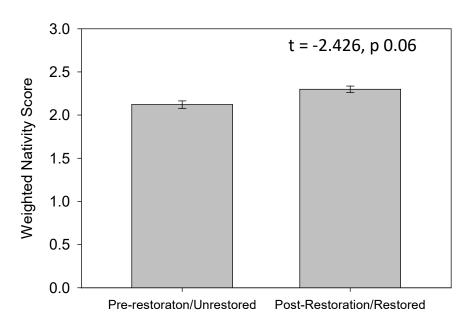
Herbaceous Layer Vegetation

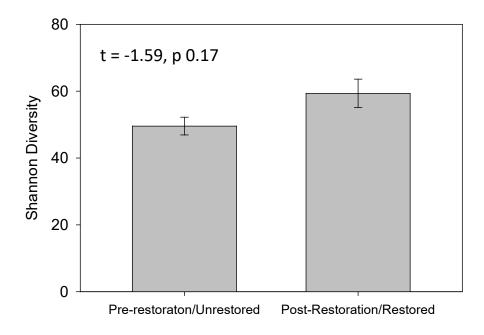


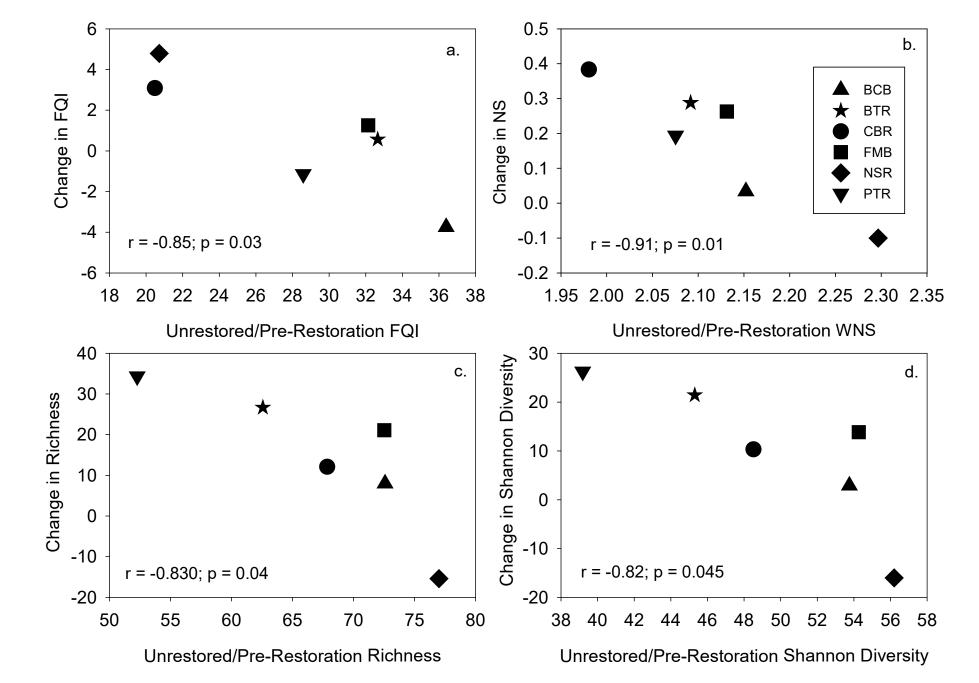




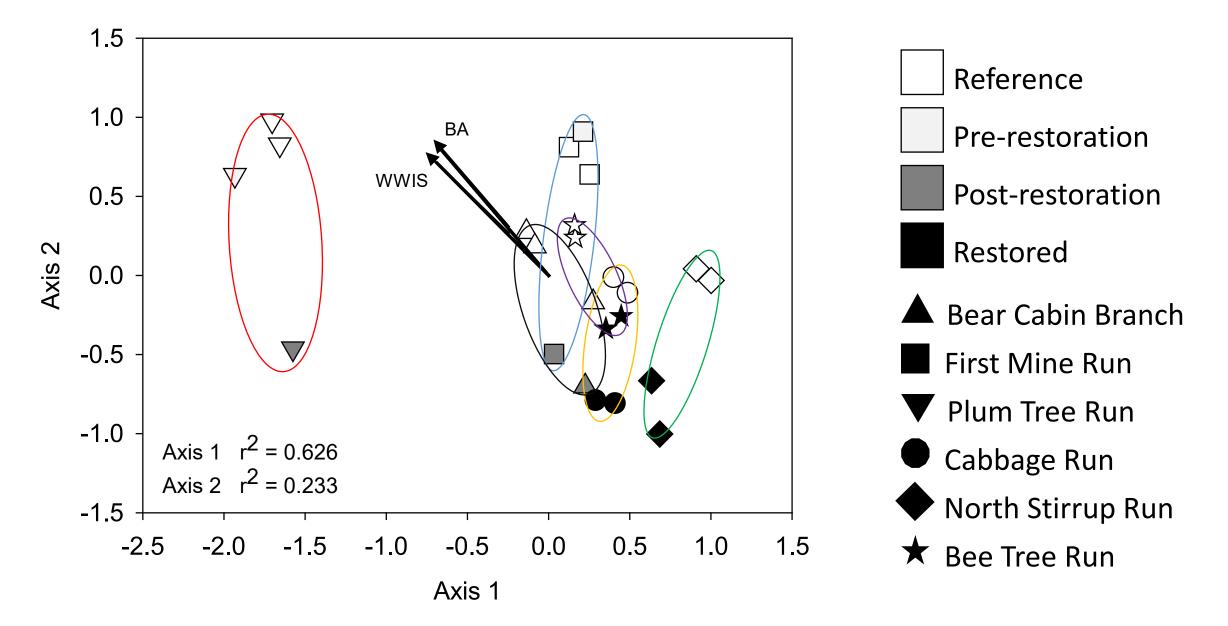


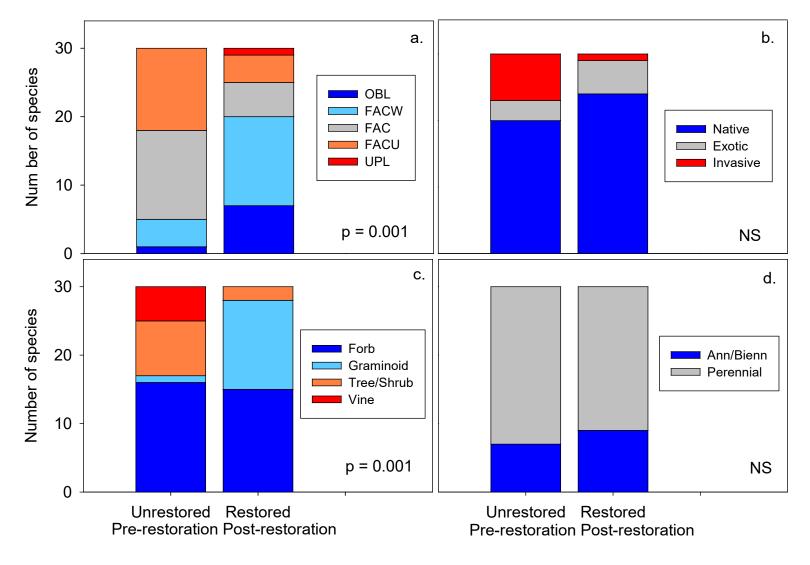


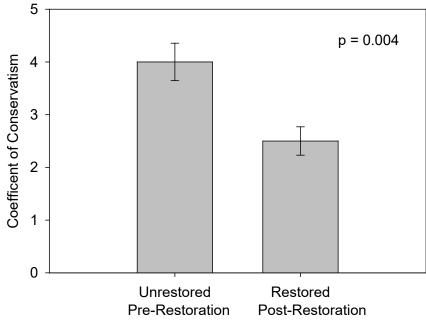




Herbaceous vegetation – Change in composition, sites maintain identity







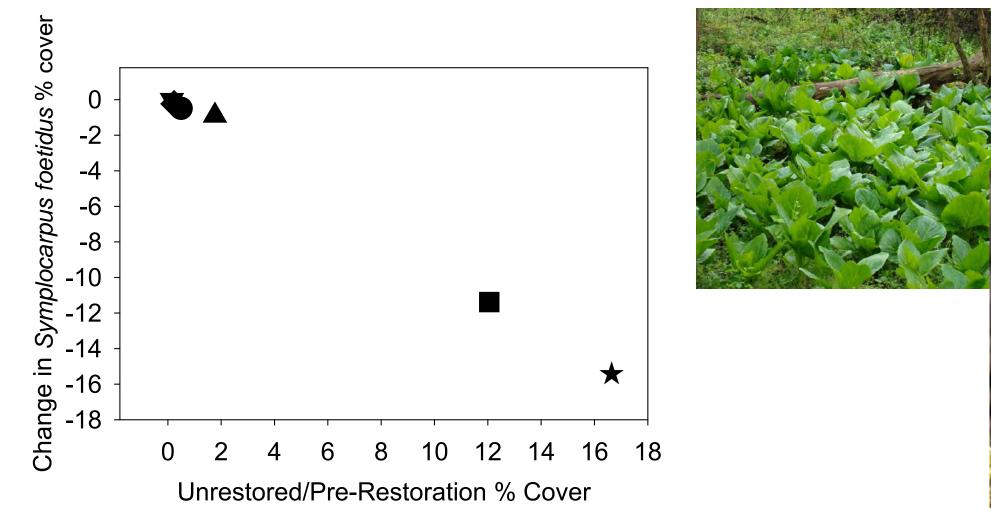
Indicators of unrestored reaches

Alliaria petiolata	garlic mustard		
Rosa multiflora	multiflora rose		
Symplocarpus foetidus	skunk cabbage		
Parathelypteris noveboracensis	New York fern		
Polystichum acrostichoides	Christmas fern		
Arisaema triphyllum	Jack in the pulpit		
Circaea alpine	enchanters nightshade		
Carpinus caroliniana	hop hornbeam		
Persicaria virginiana	Virginia jumpseed		
Clematis virginiana	virgin's bower		
Geum canadense	white avens		
Viola sororia	blue violet		
Lindera benzoin	spice bush		
Amphicarpaea bracteata	hog peanut		



https://www.inaturalist.org/photos/1840324 https://www.illinoiswildflowers.info/grasses/plants/ny_fern.htm https://www.prairiemoon.com/viola-sororia-common-blue-violet-prairie-moon-nursery.html

Average 74% DECREASE in skunk cabbage cover



Indicators of restored reaches





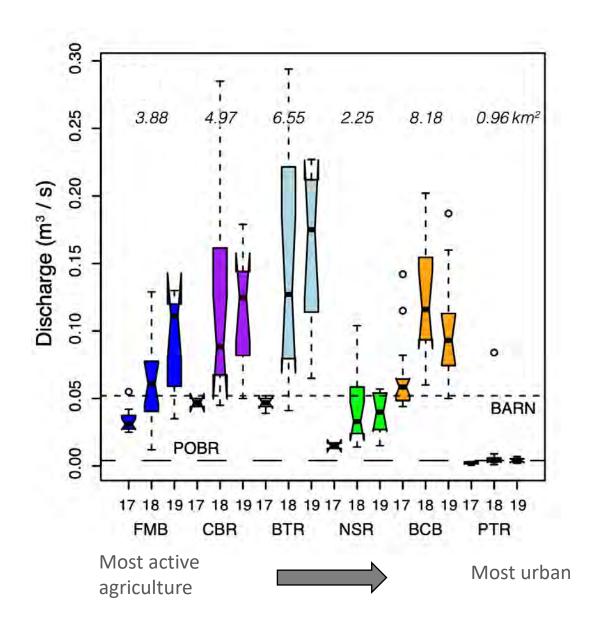
70 species identified

Herb/Graminoid = 96% Obligate/FACW = 50% Native = 70% Planted = 13%

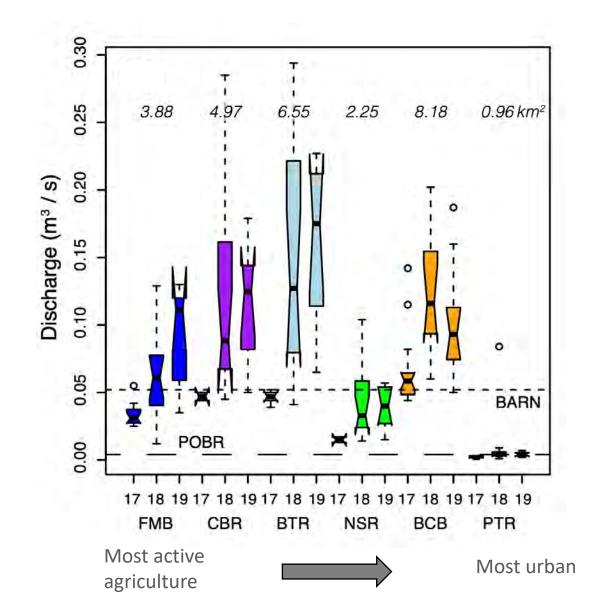
Majority of dominant/indicator species were NOT PLANTED

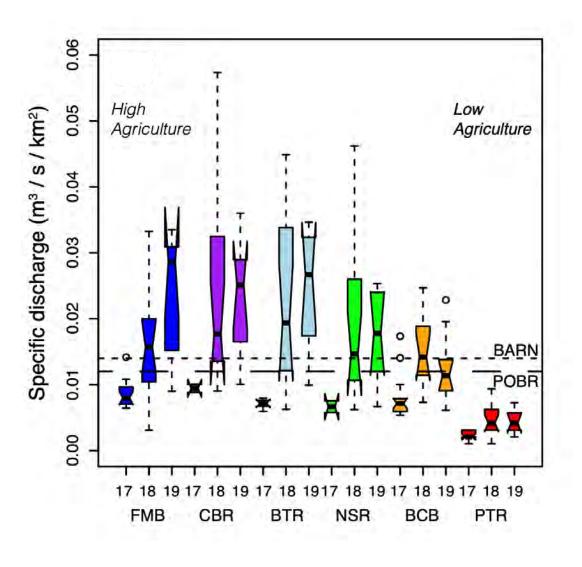
Evidence for seed bank or downstream dispersal?

Elevated baseflow discharge (& fluxes) in 2018 & 2019

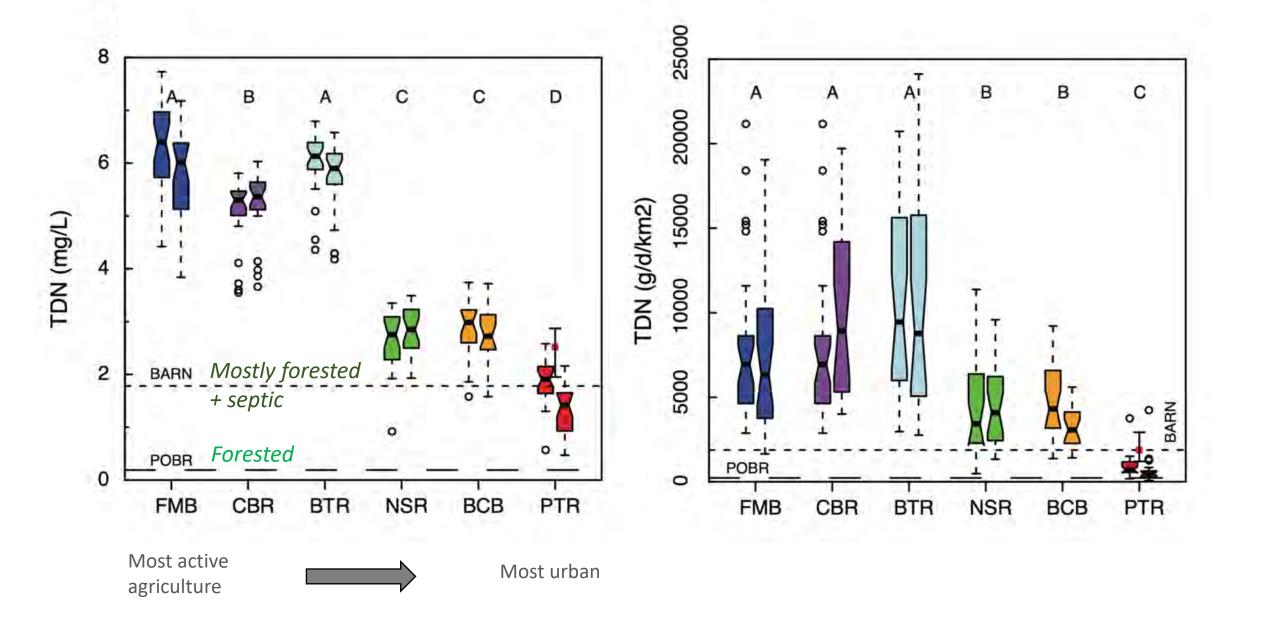


Elevated baseflow discharge (& fluxes) in 2018 & 2019

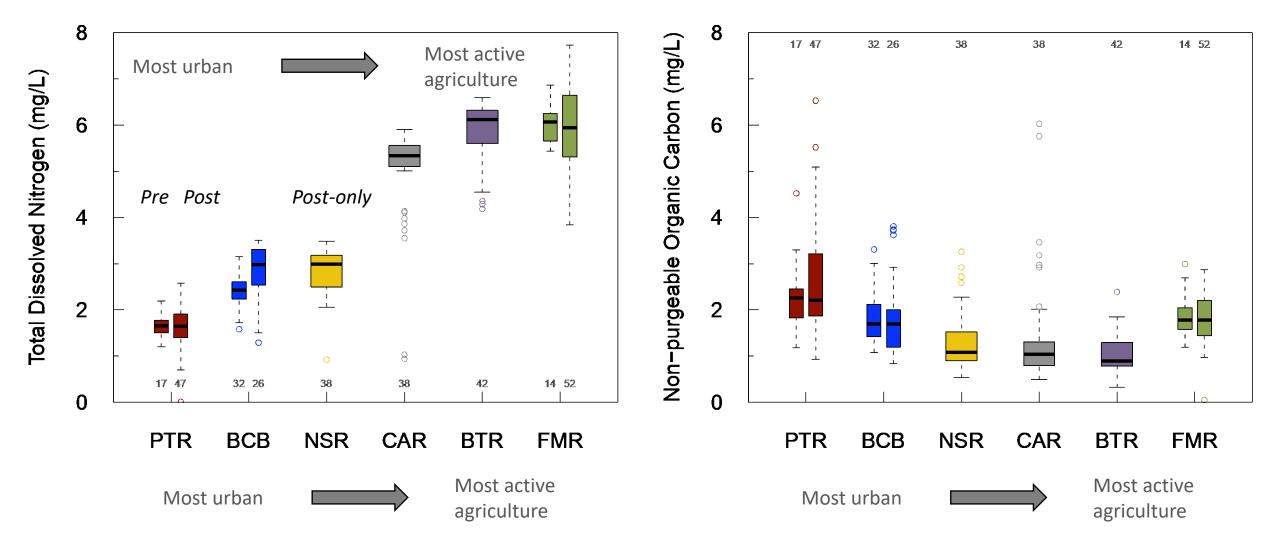


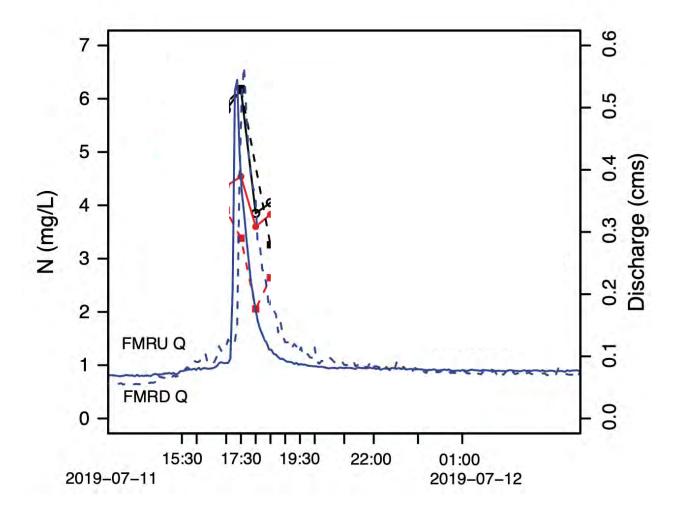


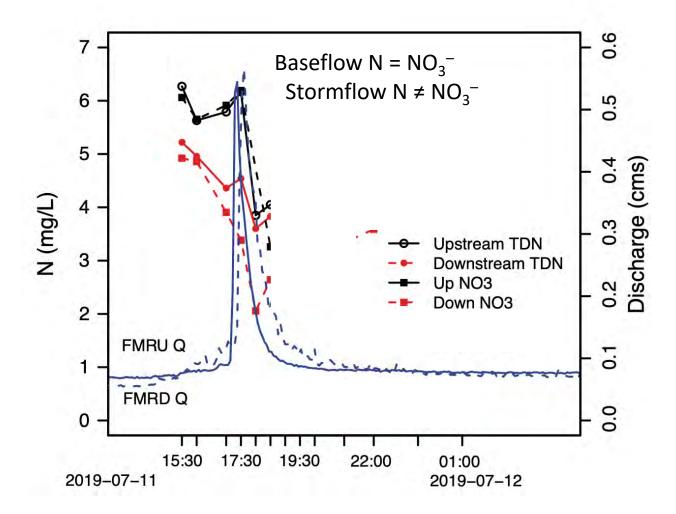
Biggest control for baseflow N: land use

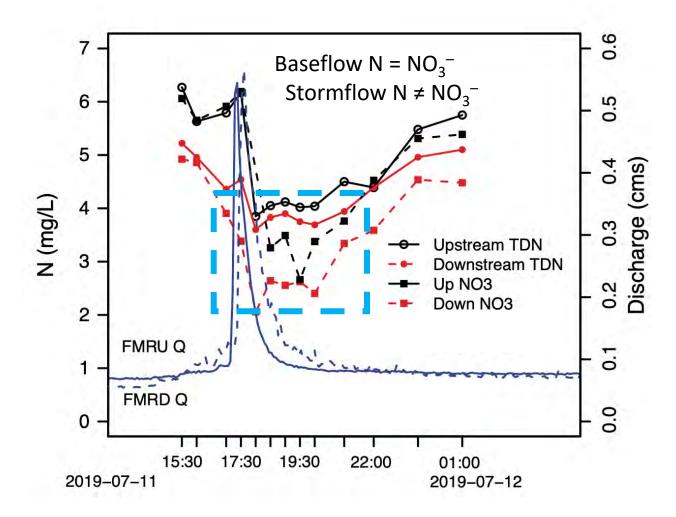


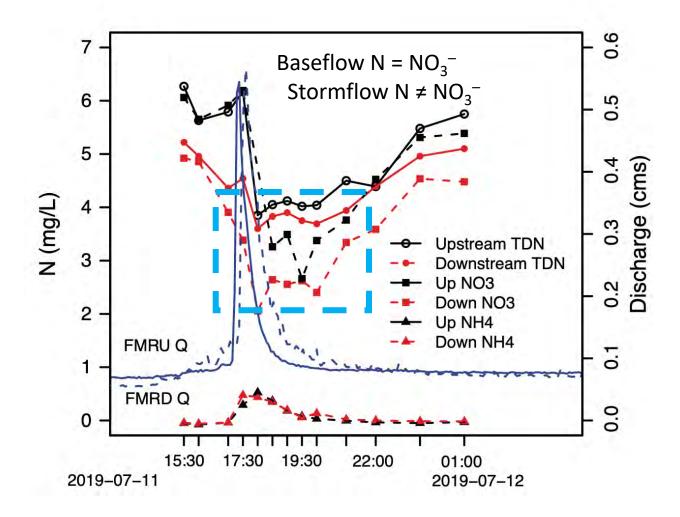
Biggest control for N: land use – *C also but generally opposite* Pre-/Post-restoration: no significant difference (yet)

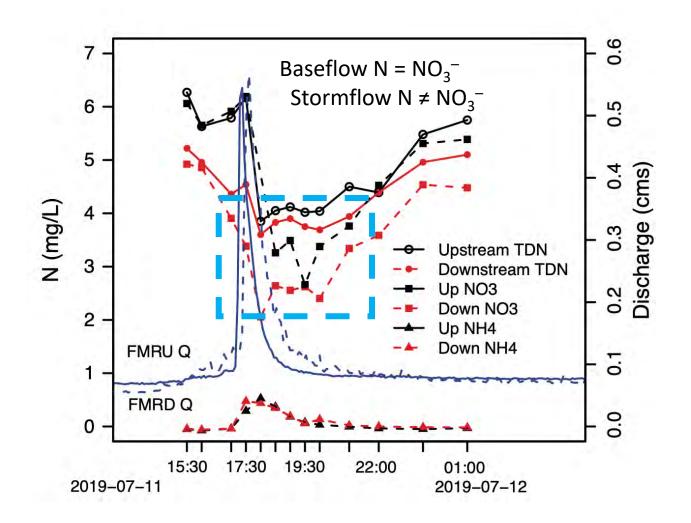


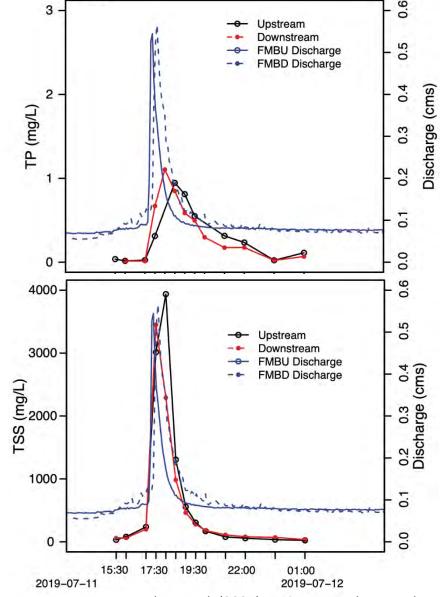








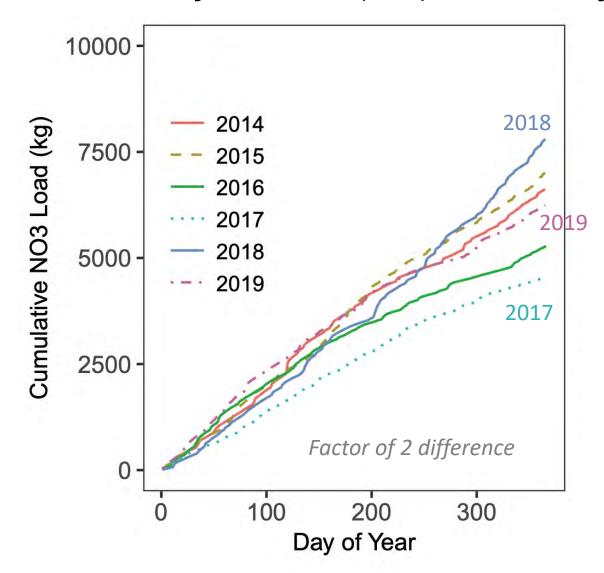




McMahon et al. (2021) *Environmental Research Letters* https://iopscience.iop.org/article/10.1088/1748-9326/abe007

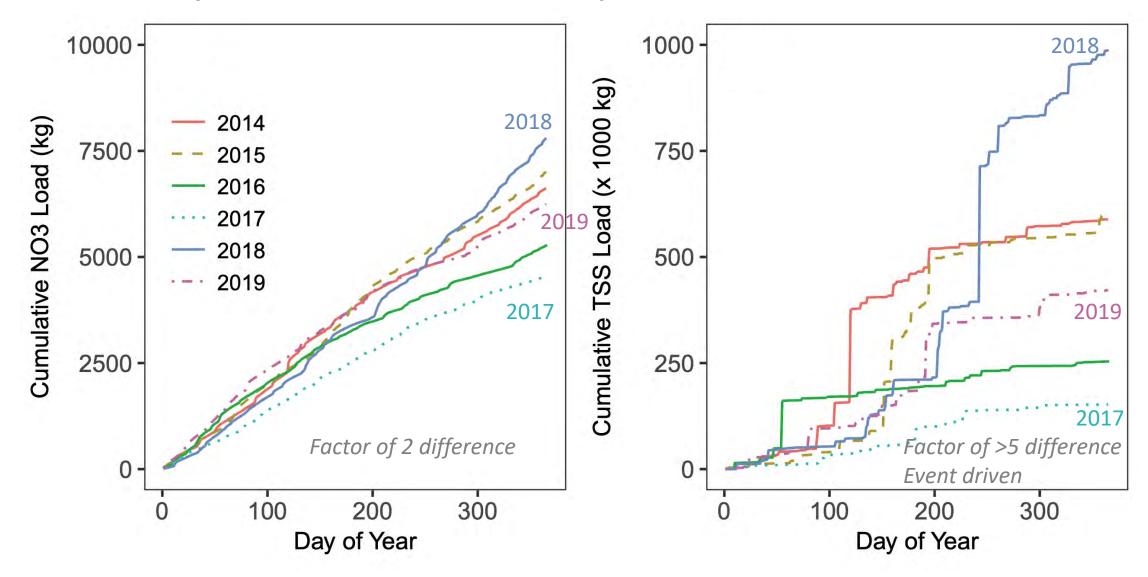
Restoration not detectable downstream (restoration 15% of watershed)

N via baseflow, TSS (&P) via stormflow downstream of most urban site



Restoration not detectable downstream (restoration 15% of watershed)

N via baseflow, TSS (&P) via stormflow downstream of most urban site



Quantifying the cumulative effects of stream restoration and environmental site design on nitrate loads in nested urban watersheds using a high-frequency sensor network

Restoration Research Question Addressed:

What are the cumulative effects of watershed restoration activities within a watershed?

Claire Welty, UMBC Andy Miller, UMBC Jon Duncan, Penn State





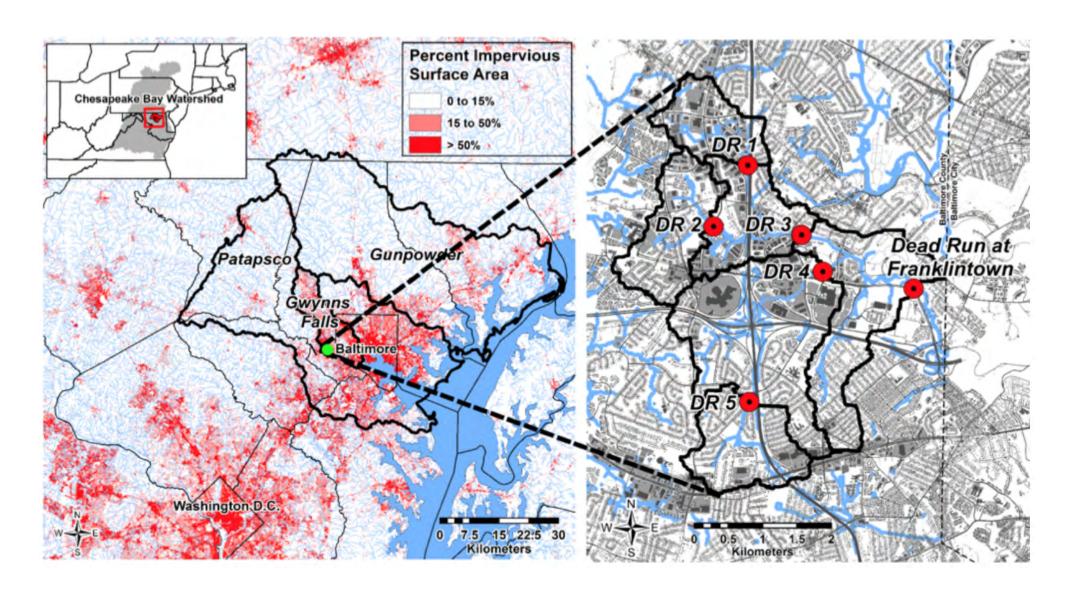


Research question and expected findings

- What are the cumulative effects of watershed restoration activities within a watershed?
- We expected to find that
 - Nitrate loads are reduced by a restored stream reach.
 - Distributed stormwater management reduces peak storm flow at the small watershed scale.

Part 1 How are nitrate loads reduced across a restored stream reach?

Dead Run watershed study area



Stream restoration in headwaters of Dead Run, 2017-2018

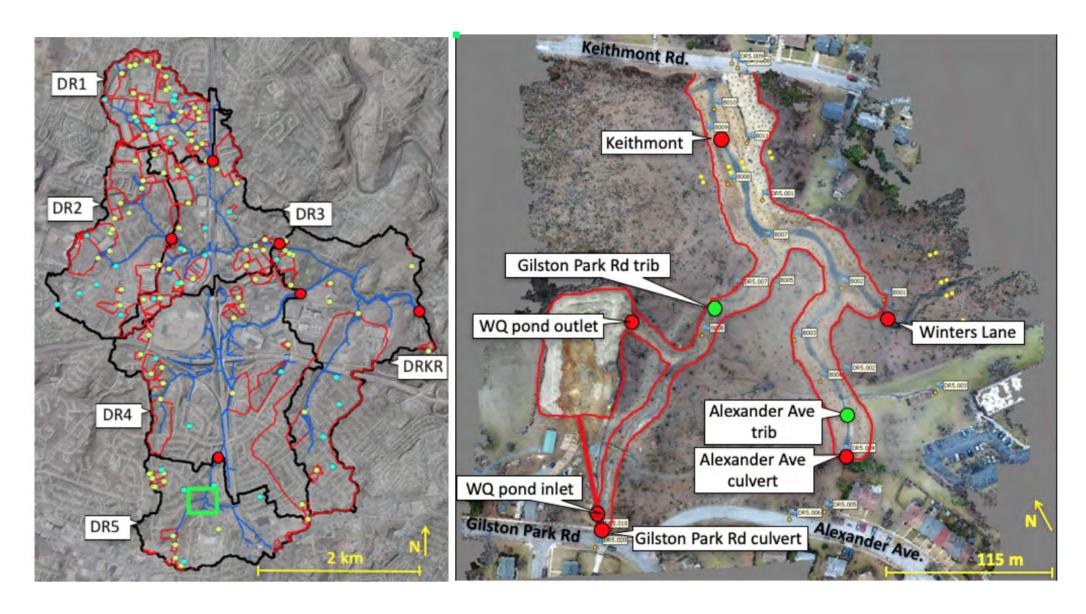
- Stream restoration was originally designed for stream stabilization and to protect infrastructure.
- Plans were revised to include installation of a wet pond with additional water quality credits.
- Nitrogen credits: stream restoration 60 kg TN/yr water quality pond 100 kg TN/yr
- The project was built in a watershed that was already highly instrumented.
- The project provided an opportunity to add instrumentation to assess effectiveness of restoration on N removal.

Before and after restoration





Extent of restoration; new sensor stations





Satlantic/Seabird SUNA
 <u>Submersible Ultraviolet Nitrate Analyzer</u>

- Ultraviolet absorption spectroscopy

- In-situ measurement of NO₃-N

- Range: 0.007 - 28 mg N/L

- Precision: 0.028 mg N/L

- Accuracy: ~ +/- 10% of reading

Onset Hobo U20-001-04 water level loggers

 Blue Siren ultrasonic depth sensors & microvelocity acoustic doppler sensors

Example instrumentation deployment: stream





Example instrumentation deployment: stream





Example instrumentation deployment: pipe



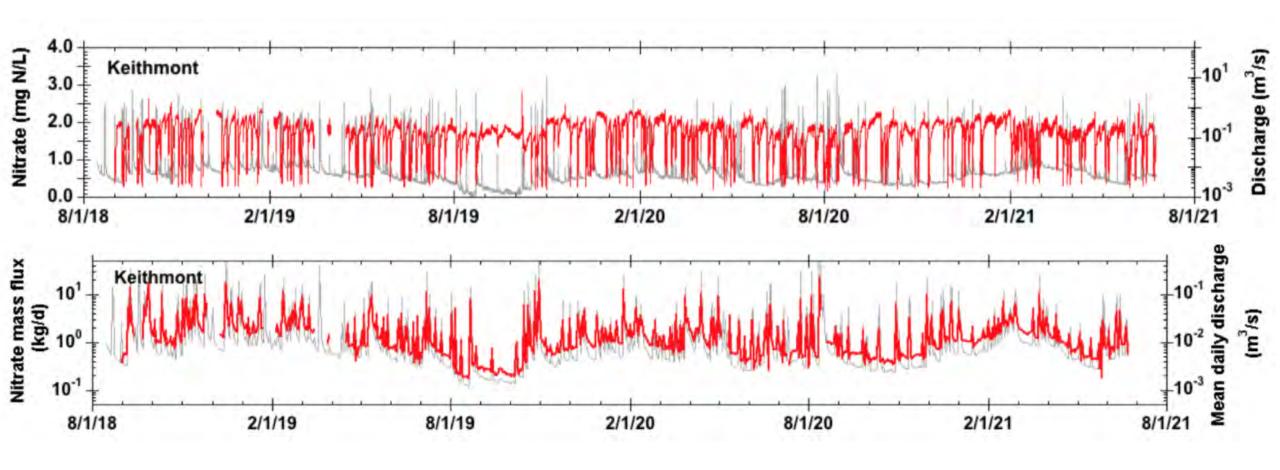


Example instrumentation deployment: pipe

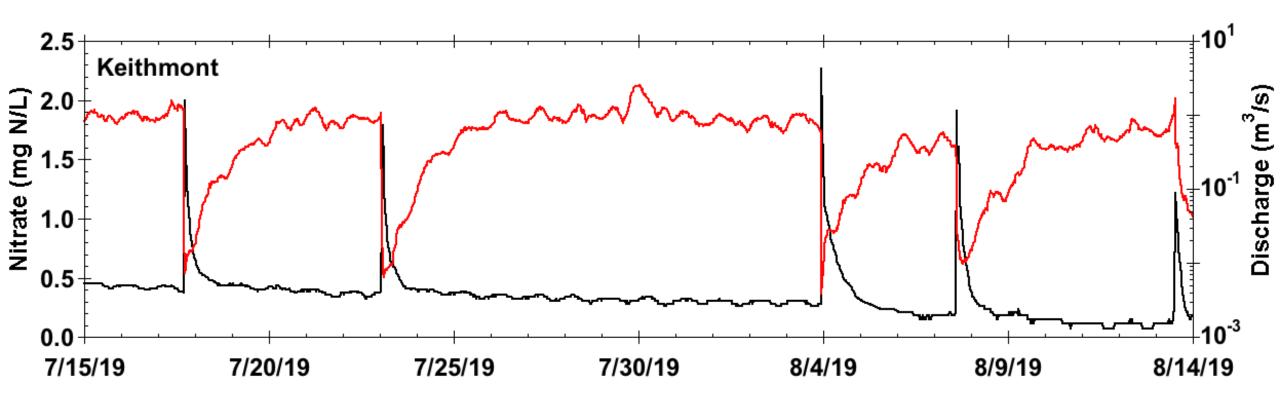




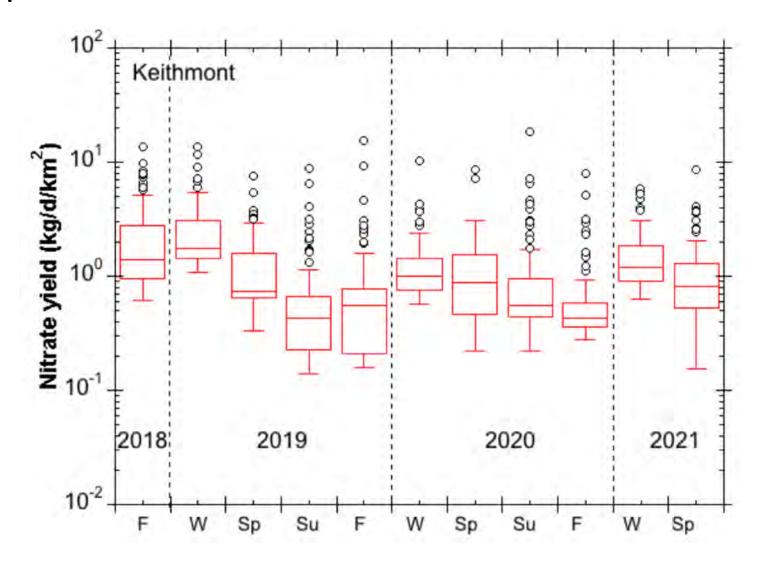
Sensors provide high-frequency nitrate & discharge data for calculating loads.



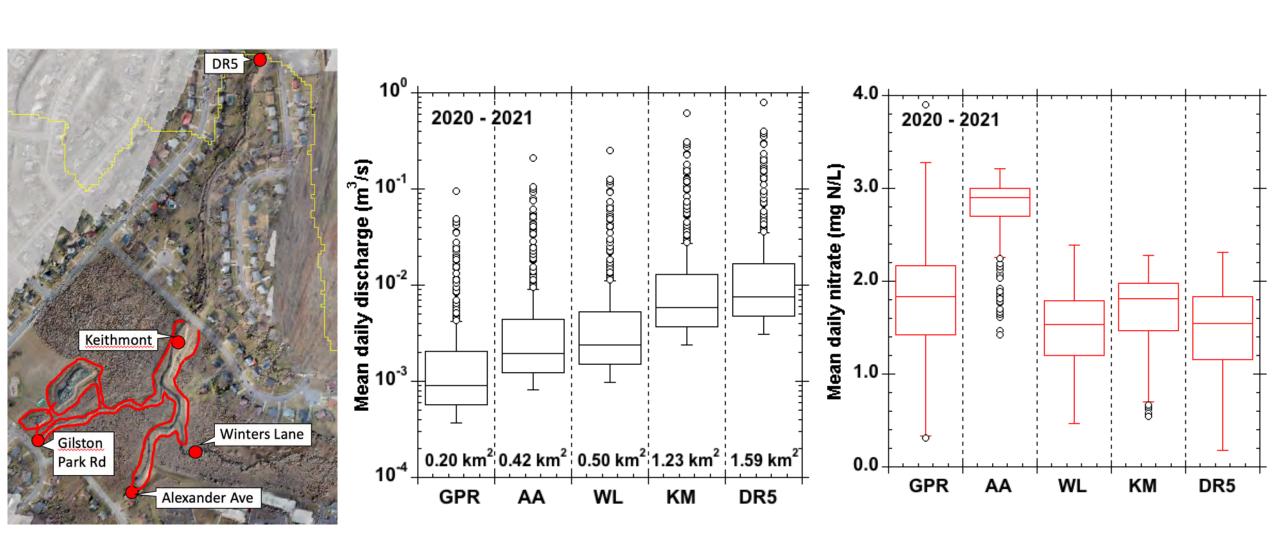
High-frequency data illustrates process details.



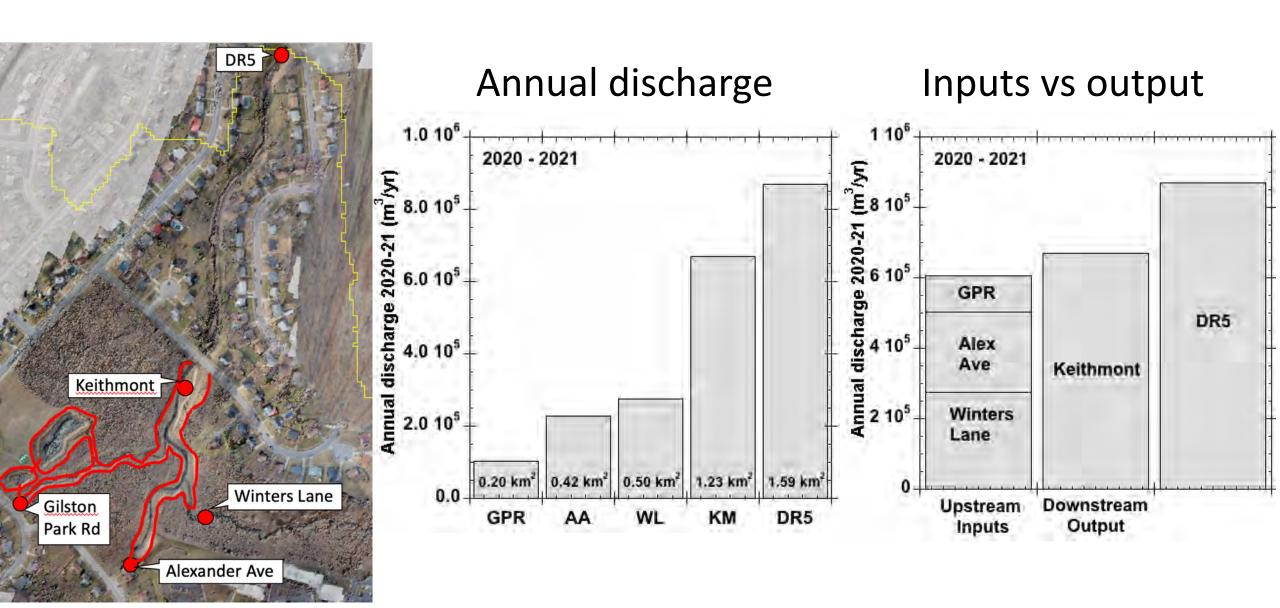
Seasonal and interannual variability of nitrate yield can be quantified.



Variability in mean daily concentration across stations can be calculated.



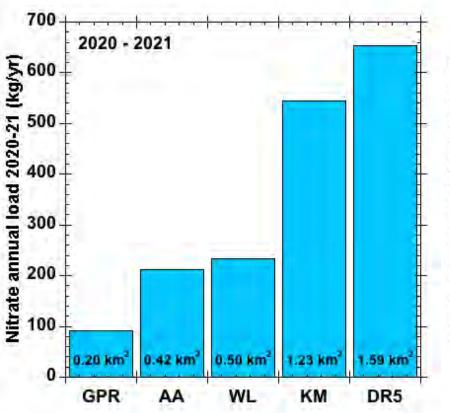
Mass balance of restored reach can be estimated.



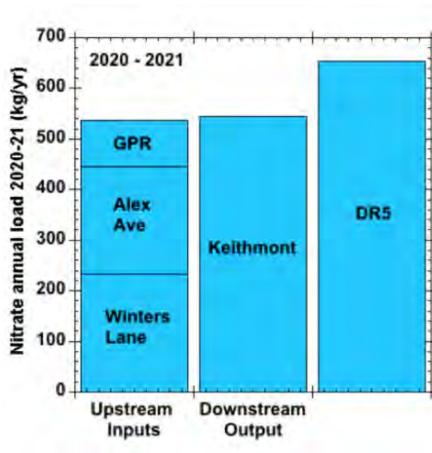
Mass balance of restored reach can be estimated.



Annual nitrate load



Inputs vs output



Part 2 How does distributed stormwater management reduce peak storm flow at the small watershed scale?

Hydrological Processes

RESEARCH ARTICLE

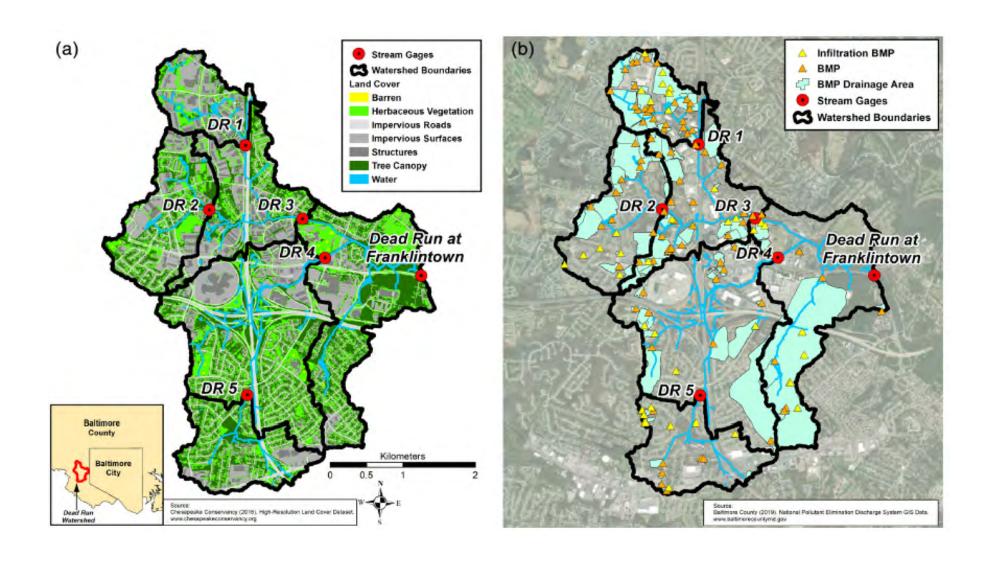
Assessing urban rainfall-runoff response to stormwater management extent

Andrew J. Miller , Claire Welty, Jonathan M. Duncan, Mary Lynn Baeck, James A. Smith,

First published: 27 June 2021 | https://doi.org/10.1002/hyp.14287

Funding information Chesapeake Bay Trust, Grant/Award Number: 15828; National Science Foundation, Grant/Award Numbers: 1444758, 1855277, 2012107, 2012340

Dead Run land cover and areas draining to SWM

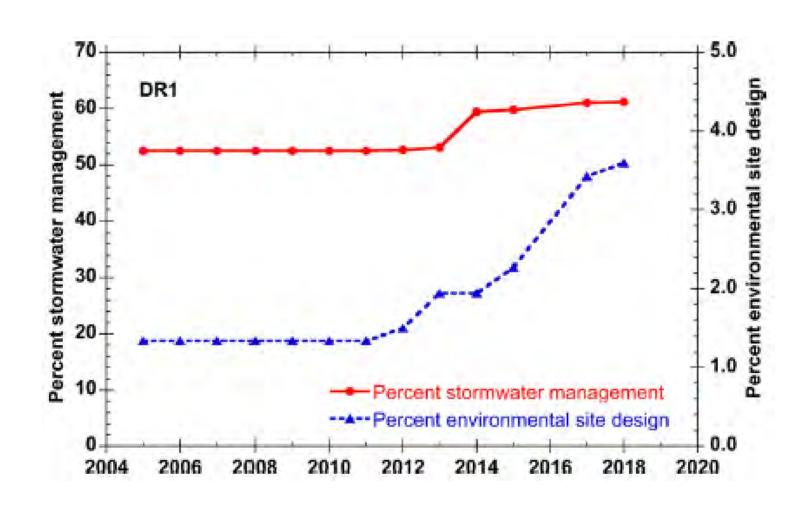


DR5 before and after restoration

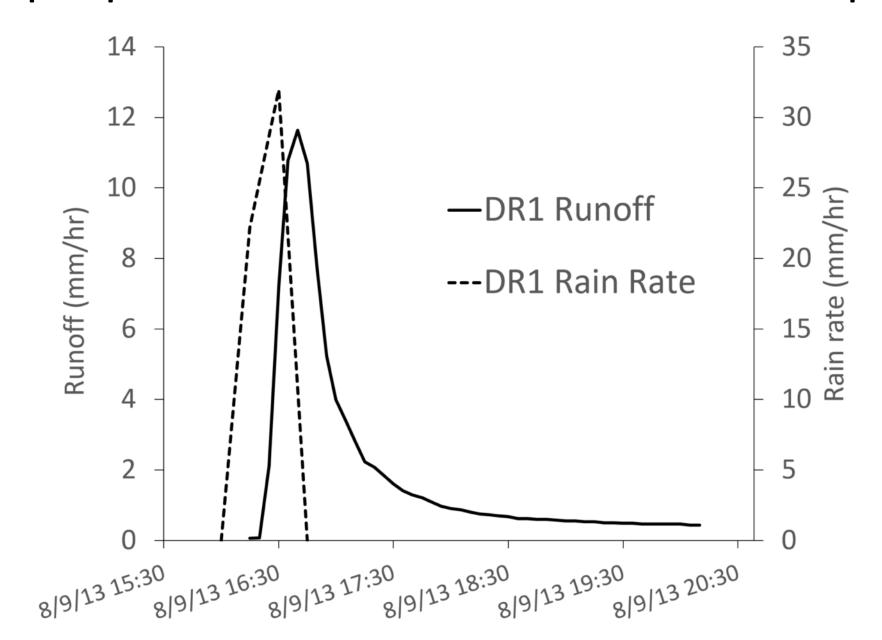




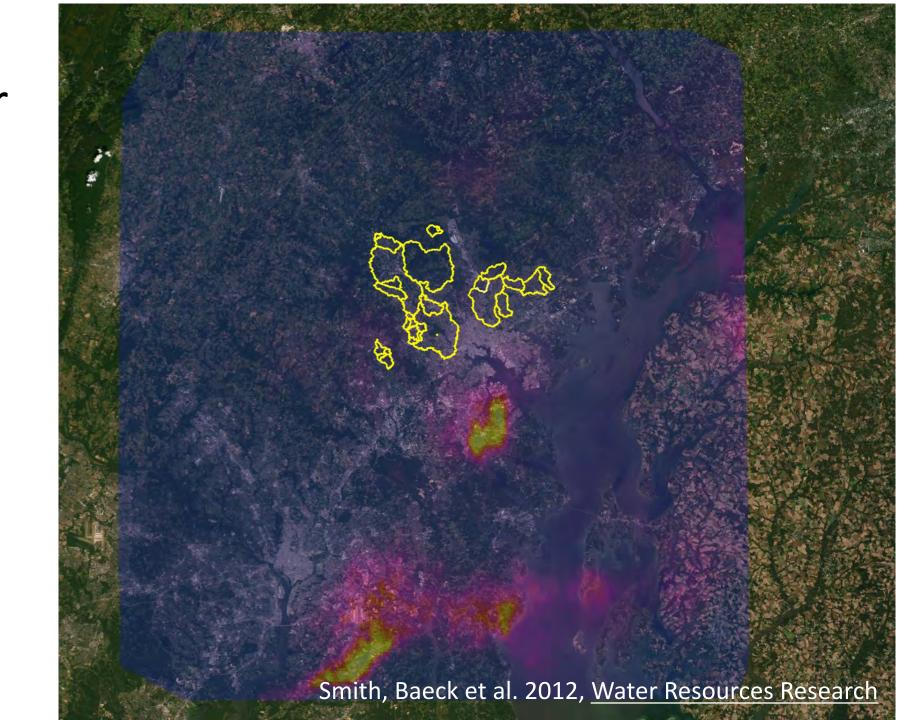
DR1 SWM and ESD features, 2004-2018



Example pulse rainfall event with runoff response



Long-term radar rainfall data set



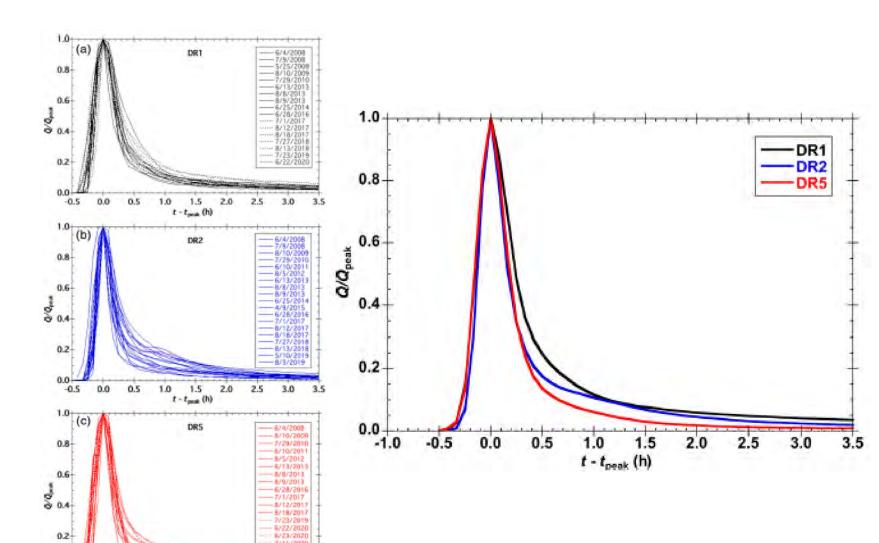
Comparison of pulse hydrographs 2008-2020

t-t_{peak} (h)

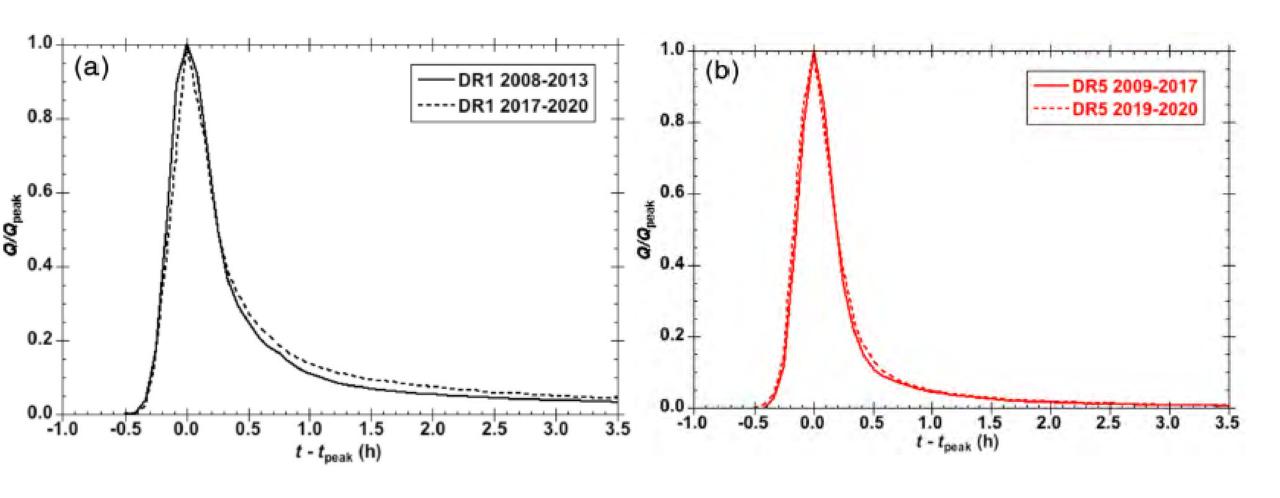
DR1
61.1% drainage
to SWM

DR2
33.0% drainage
to SWM

DR5
4.5% drainage
to SWM



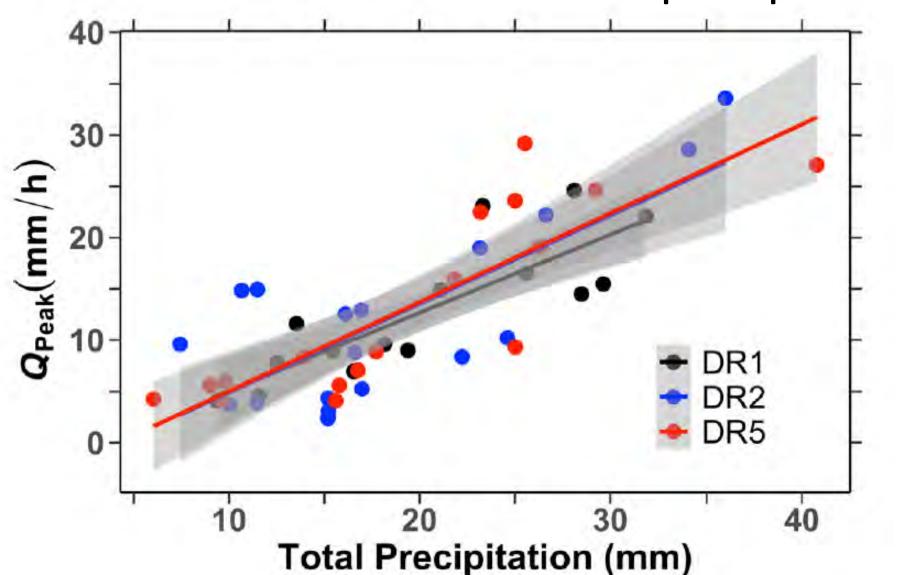
DR1 before/after ESD; DR5 before/after restoration



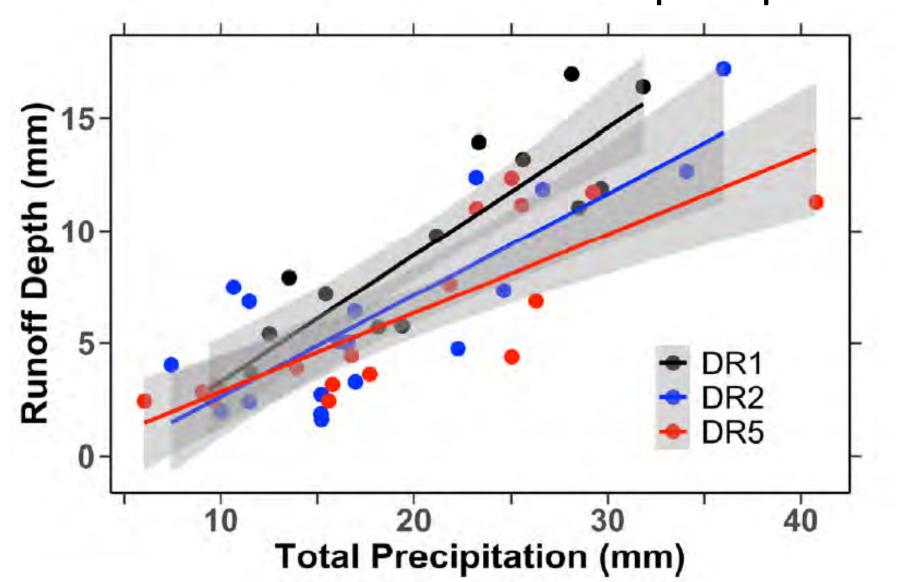
Watershed properties for headwater tributaries

: Watershed	Drainage area (km²)	% Impervious cover	% Drainage to SWM	Peak runoff intensity, median (mm/h)	Runoff ratio, median
DR1	1.19	67.0	61.1	9.6	0.40
DR2	1.92	49.1	33.0	9.9	0.31
DR5	1.63	45.9	2.7	8.9	0.28

Analysis of peak runoff response as a function of storm-total precipitation



Analysis of runoff depth as a function of storm-total precipitation



Summary: Part 1, Nitrate

- High-frequency data illustrates process details.
- Seasonal and interannual variability of nitrate concentrations, loads, and yields can be quantified across nested watersheds.
- For the restored stream reach instrumented, results so far (2020-21) do not demonstrate a reduction in nitrate load between upstream inputs and downstream output at Keithmont.

Summary: Part 2, Stormwater

- Comparison of composite hydrographs shows no difference in rising limb of hydrograph and time of peak flow, slightly longer recession curve for watersheds with more SWM.
- Comparison of composite hydrographs before and after restoration shows no change.
- Analysis of trends in peak runoff response to storm-total rainfall shows no significant difference for watersheds with large differences in SWM coverage.
- Analysis of runoff depth as a function of storm-total precipitation shows differences that are not statistically significant, with more runoff for the watershed with the highest SWM coverage and highest impervious cover.

Acknowledgments

- Chesapeake Bay Trust for Restoration Research Grant 15828 (2018)
- MD DNR for supporting the CBT project
- Baltimore County Department of Environmental Protection and Sustainability for partnership and land access
- USGS Maryland-Delaware-DC Water Science Center for stream gaging
- UMBC/CUERE staff members Benjamin Glass-Siegel and Mary McWilliams for maintenance of field equipment
- UMBC undergraduate students Dakota Blum, Joey Mowery, Mame Diarra Keinde, and Sean Gamble for assistance with installations







