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

June 21, 2023, from 9 AM to 5 PM

Zoom/tech leads are Bridget Robey, brobey@cbtrust.org, 410-974 2941 xt 410 (all day), Megan Andreasen, mandreasen@cbtrust.org, 410-974 2941 xt 133, and (9am to 12pm), and Kayleigh Katzenberger, katzenberger@cbtrust.org, 410-974-2941 xt 112 (1pm to 5pm)

# Pooled Monitoring Forum Agenda

| | |
|---|---|
| 9-9:30 am | Morning Session with opening remarks from **Matt Rowe**, Assistant Director of Maryland Department of the Environment's Water and Science Administration |
| 9:30 am-12 pm | **Keith Eshleman** (University of Maryland Center for Environmental Science (UMCES)), **Arthur Parola** (University of Louisville Research Foundation, Inc.), **Erich Hester** (Virginia Tech), **Jon Butcher** (Tetra Tech, Inc.), and **Q&A** |
| 12-1 pm | Lunch Break – *provided by the Chesapeake Bay Trust* |
| 1-2 pm | **Dong Liang** (UMCES), **Josh Thompson** (Anne Arundel County), **DISCUSSION – Optimizing Sampling & Monitoring:** What is the science telling us? How are we using the latest science in our programs? How can we use the latest science in our programs? |
| 2-5 pm | **Tess Thompson** (Virginia Tech), **Claire Welty & Andy Miller** (University of Maryland Baltimore County), **Bob Hildebrand** (UMCES), **Lauren McPhillips** (PennState), **Q&A/Input from audience** |
| 5 pm to ? | Checkerspot Brewing Company, 1399 S Sharp St, Baltimore, MD 21230, provided by the Chesapeake Bay Trust |

# Meeting Materials

- Agenda, attendance list, and presentations are at: https://drive.google.com/drive/folders/1FUnKg41P3q6U4KASfdrkY54pGXcxAnlh?usp=drive_link
- 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/restoration-research/

# Morning Session

- **Welcome, charge for the day, and Pooled Monitoring Program overview, Sadie Drescher** Vice President of Restoration Programs, Chesapeake Bay Trust

- **Matt Rowe**, Assistant Director of Maryland Department of the Environment's Water and Science Administration
    - Opening remarks

# 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
  - **Partnerships and collaborations** – we are all a part of this effort!
- Increase power, objectiveness, and ability to know what works
- Bring science back to those that can use the research/data

Lauren McPhillips PI: MS student Alex Brown working on mesocosm to answer research question about deicers (about to be on the job market for stormwater-related positions in the DC area!)

# 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)
Final report and publication

# Restoration Research Award Program

- Supported 43 projects since FY 15 at >$8M
- 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/

Keith Eshleman (UMCES) Plum Branch stormwater monitoring station (Ellicott City, Howard County, MD)

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<u>Ask Questions:</u>

- In person – Raise hand
- Remote - Use chat/raise hand

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# Input from the Audience

- What are your top restoration questions?
- How are you using this research?
- Where should the research focus?

Purpose:

- Your questions can be addressed using this Pooled Monitoring Initiative's Restoration Research Award Program in the future.
- Hear how others are or are not using this research.

# Break Time


SHORT
SUMMARY!

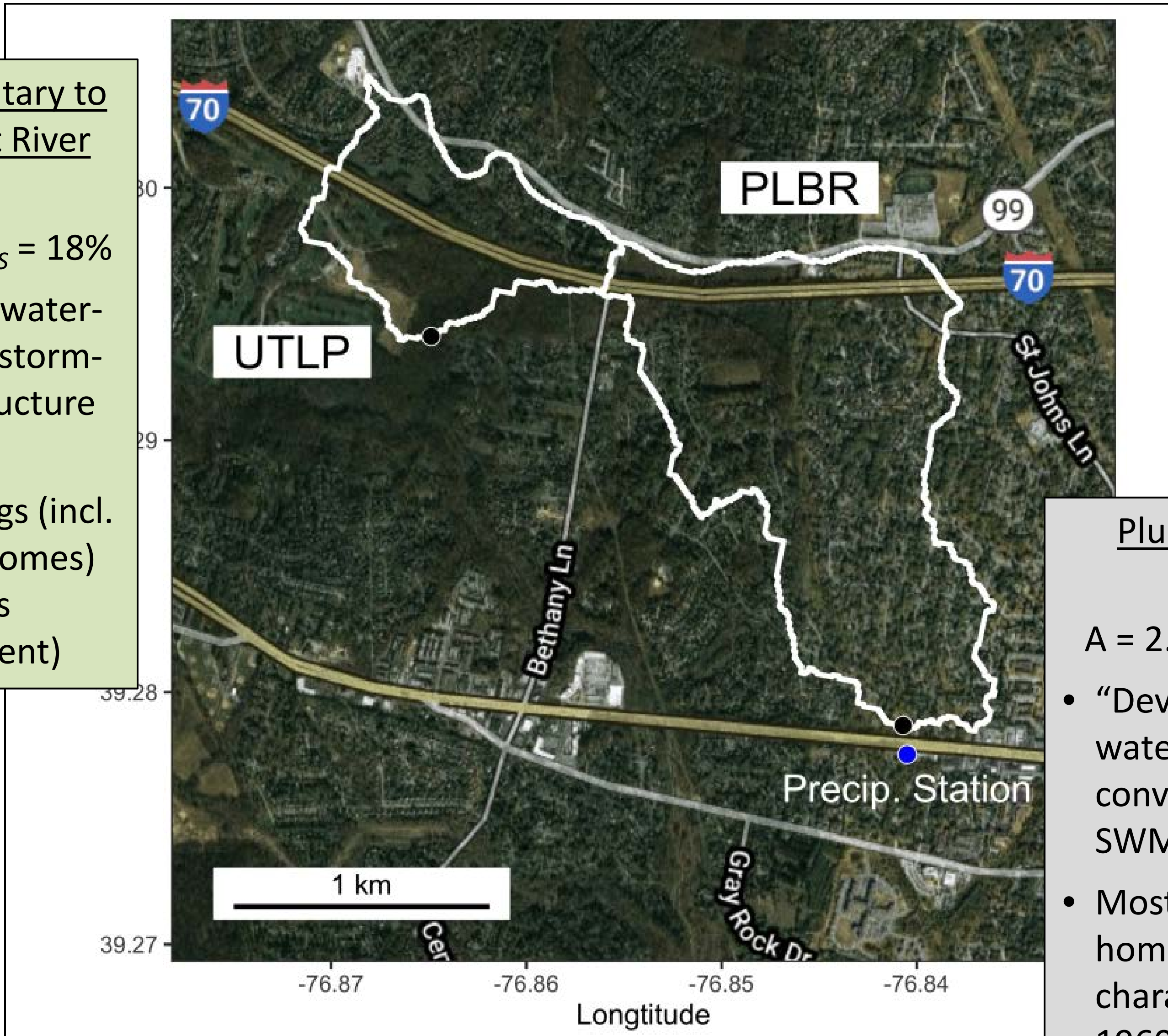

Thank You!

# A paired-watershed study to assess the aggregated effectiveness of green stormwater infrastructure in suburban residential development

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

Pooled Monitoring Forum: June 21, 2023

# Paired watershed study (2019 – present)




<u>Unnamed Tributary to Little Patuxent River</u> (UTLP)

A = 0.80 km$^2$; $I_S$ = 18%

- "Developing" watershed: green stormwater infrastructure (GSI)
- Larger buildings (incl. multi-family homes) on smaller lots (1990's – present)

<u>Plumtree Branch</u> (PLBR)

A = 2.15 km$^2$; $I_S$ = 28%

- "Developed" watershed: mostly conventional ("gray") SWM
- Mostly smaller homes on larger lots characteristic of 1960's - 1980's development

# Outline

- Review hypotheses/objectives/methods/project status
- Update on UTLP development/BMP implementation
- Water quantity results
  - Annual runoff comparison (UTLP anomaly)
  - Hydrograph separation
- Water quality results
  - Baseflow chemistry
  - Stormflow EMC's
  - Pollutant load comparisons
- Summary

# Paired watershed study (2019 – present)

<u>Objective:</u> determine the spatially-aggregated effectiveness of green stormwater infrastructure (GSI) at the watershed scale (relative to a comparable “control” watershed with conventional stormwater management)

- *lower stormflow runoff*
- *higher baseflow runoff*
- *lower runoff peaks*
- *lower storm runoff ratios*
- *less overland flow*
- *more attenuated unit-graphs*
- *lower EMC’s of N and P*

AquaTroll 500

UTLP stormwater monitoring station

<u>Common monitoring equipment:</u>

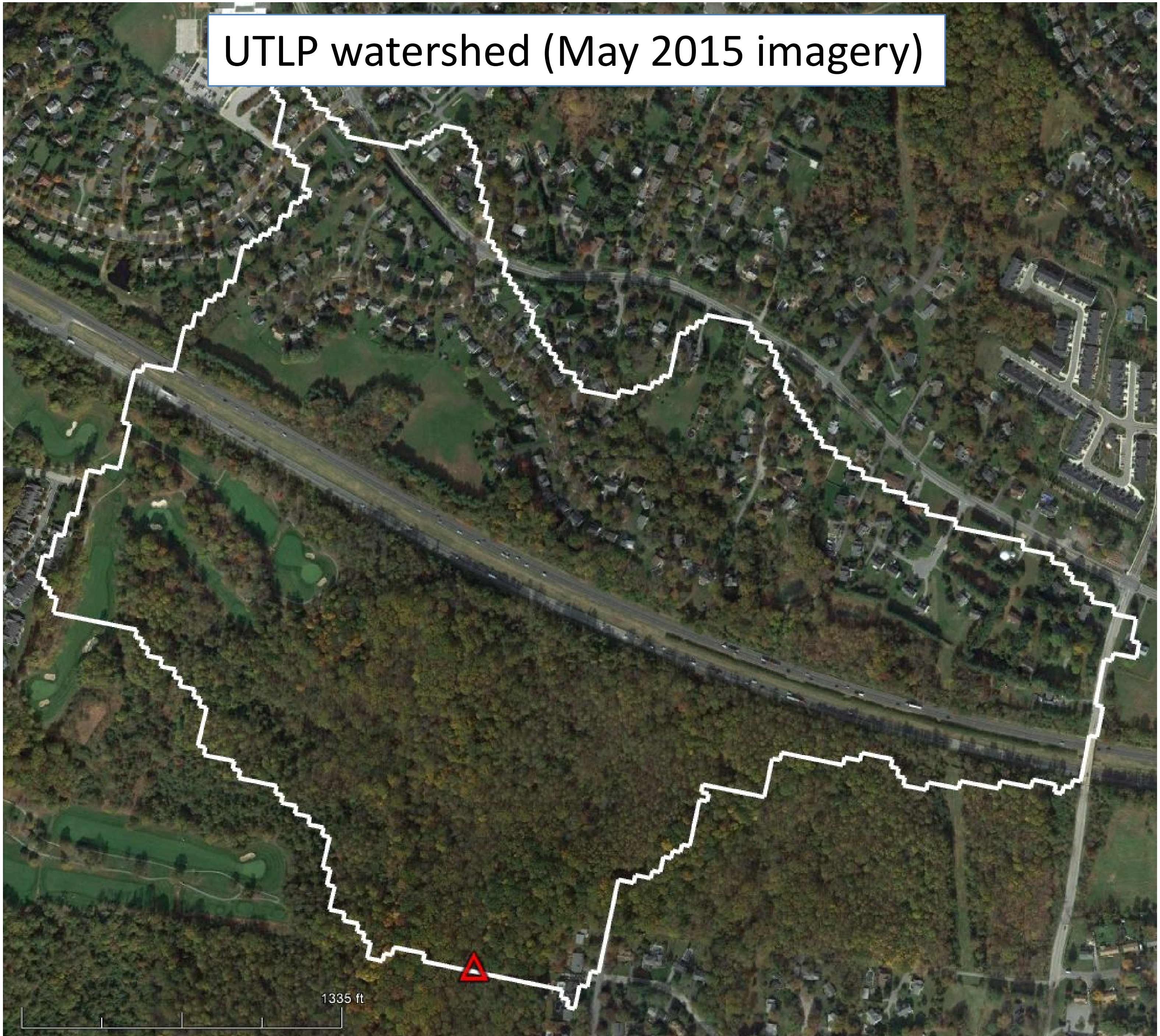
- Stilling well/instrument shelter housing digital water level recorder
- In Situ AquaTroll 500 and “tube” for transmitting data to HydroVu website
- Programmable sequential stormwater sampler
- Two unheated tipping bucket rain gauges (located nearby)

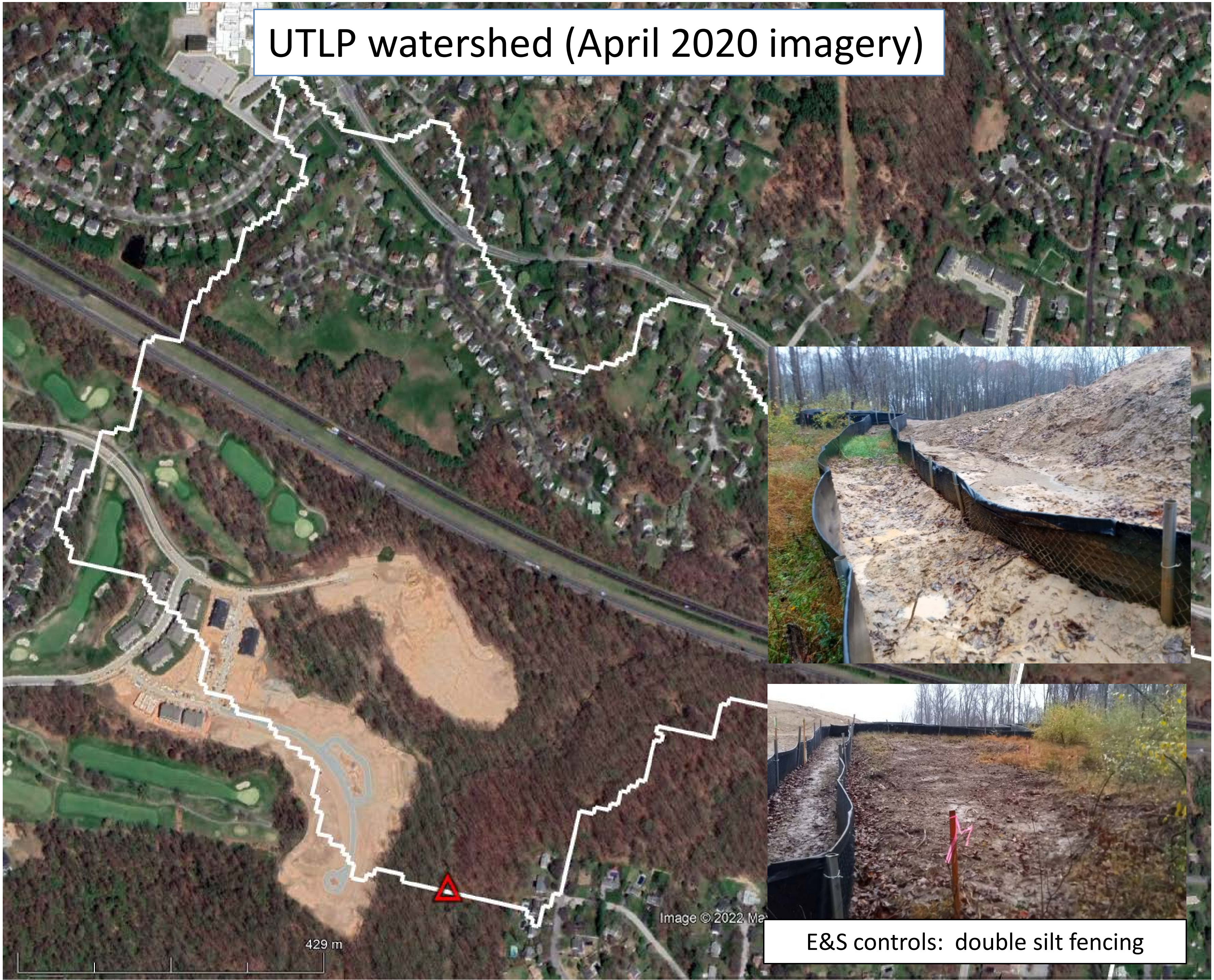
PLBR stormwater monitoring station

# Project Data Highlights (2019-present)

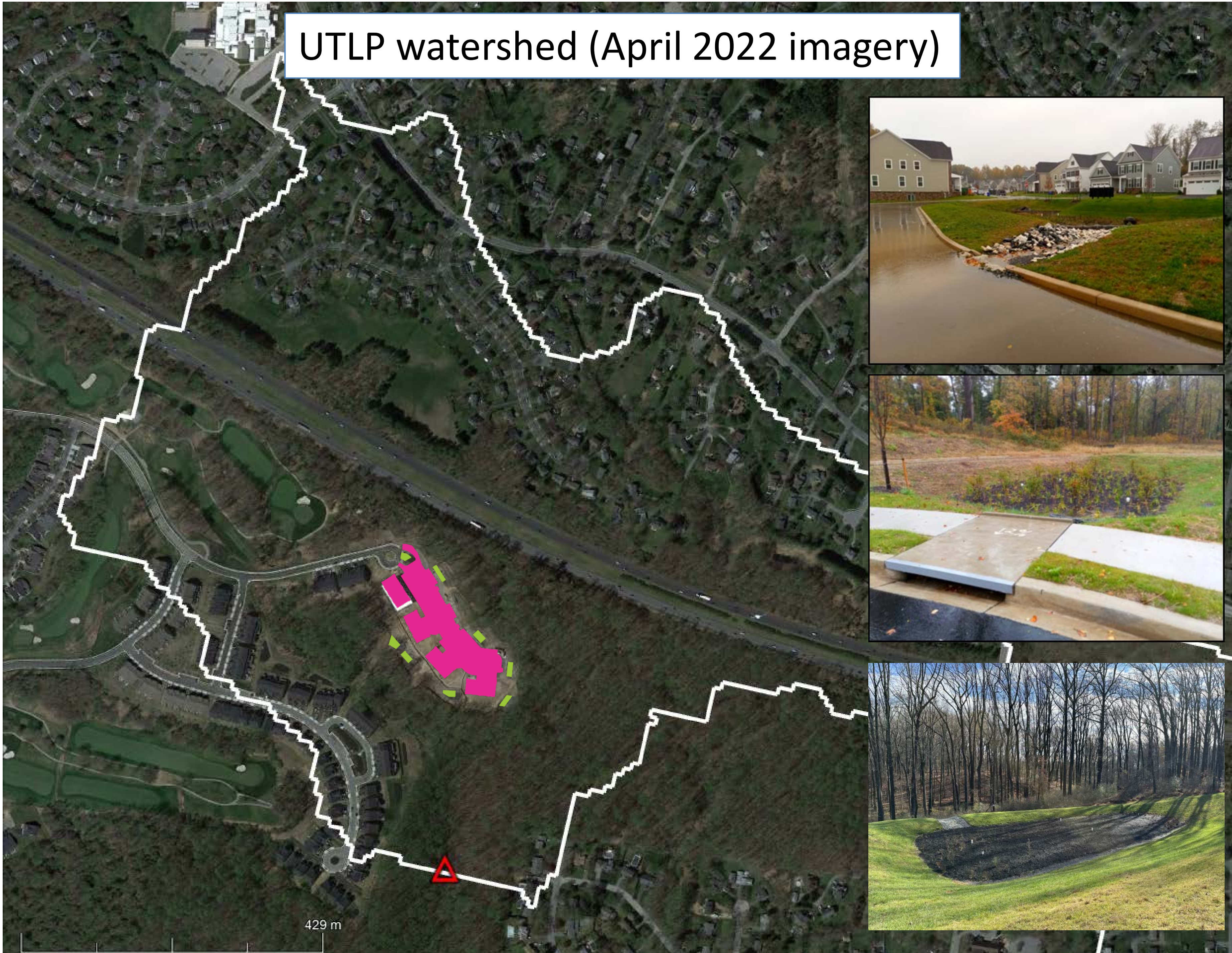
- Hydrologic/water quality monitoring (~3 years)
  - Rating curves; complete 5-min gage height/discharge records; hourly rainfall data (2 stations)
  - Sterling VA NEXRAD Level III data used to estimate (gage-adjusted) areal rainfall and identify "outlier" events
  - Monthly baseflow concentrations (both sites)
  - 83 major stormflow-producing events characterized: 76 common events (26 with intensive water quality sampling)
    - Max. one-hour rainfall mostly < 1-year R.I.
    - June 20, 2020: one-hour rainfall of ~2.3" at UTLP only (5-year R.I.)
    - June 22, 2020: one-hour rainfall of ~2.5" at both sites (20-year R.I.)
  - 5-min *in situ* conductivity, turbidity, temperature, water level data
  - ~1,150 surface water samples analyzed for TSS, TN, TP, nutrients, anions, etc. (both sites; "pre" and "during" phases of GSI implementation at UTLP)

# UTLP watershed (May 2015 imagery)




UTLP watershed (April 2020 imagery)
Image © 2022
429 m
E&S controls: double silt fencing

# UTLP watershed (April 2022 imagery)

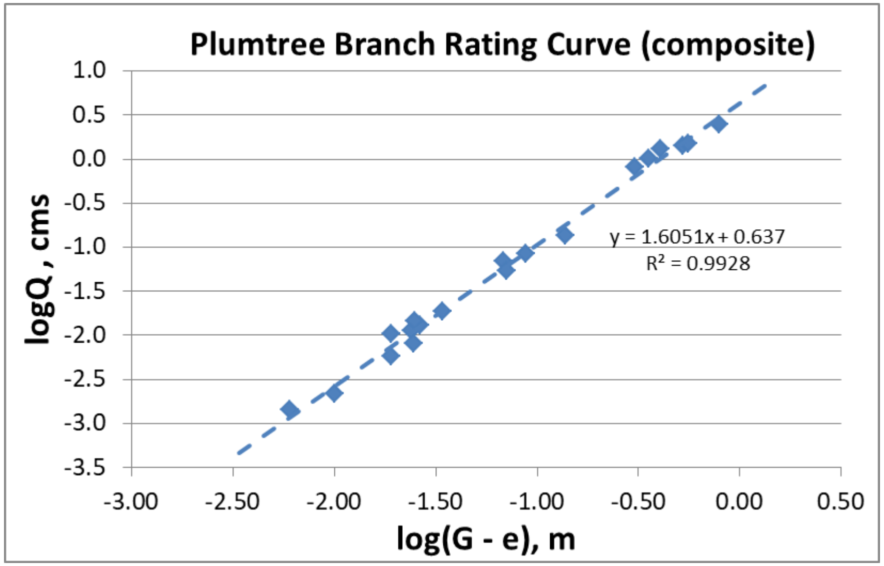


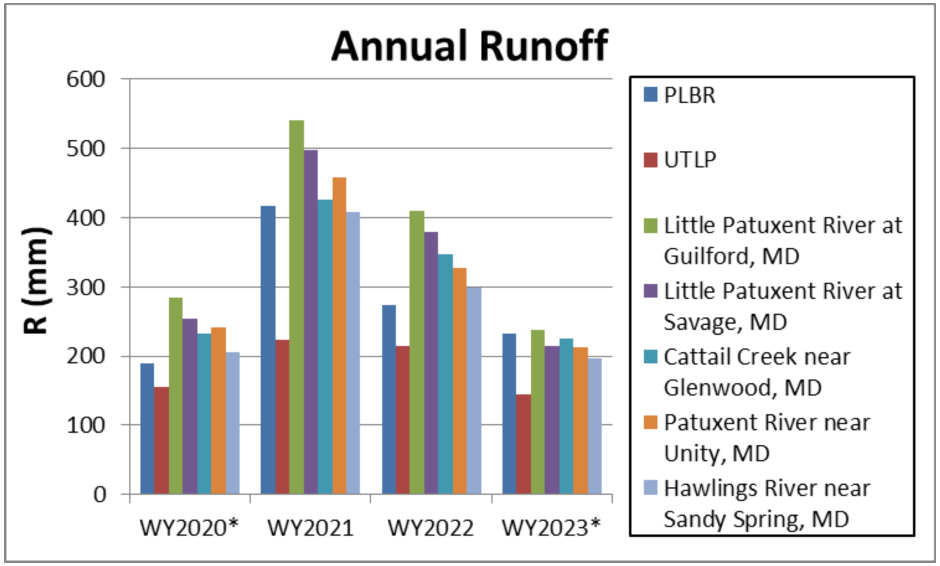
# Stormwater Management in UTLP Watershed

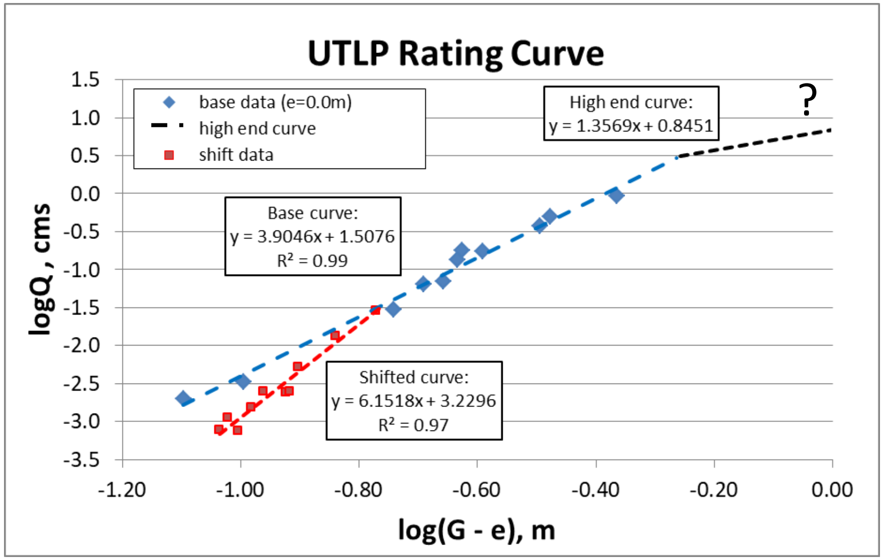
| Plan No. or BMP Name | SWM Code (no.) | SWM Type | Drainage Area ($ft^2$) | ISA ($ft^2$) | Notes |
|---|---|---|---|---|---|
| N/A | N/A (10) | 2A Grass Swales (abandoned) | 663,600 | 434,958 | I-70 legacy ISA (areas est.); SWM from MDOT-SHA NPDES SWMFAC |
| F-88-232_POND | N/A (1) | Wet Pond | 1,533,748 | 744,466 | MDE StormwaterPrint; ISA est. |
| F-87-188_POND | N/A (1) | Dry Pond | 217,800 | 105,718 | MDE StormwaterPrint; ISA est. |
| F-93-073_POND | N/A (1) | Wet Pond | 530,125 | 257,317 | MDE StormwaterPrint; ISA est. |
| F-07-158 | F-6 (2) | Bioretention | 28,750 | 28,750 | Resort Road extension #1 (areas est.) |
| F-16-004 | F-6 (1) | Bioretention | 43,560 | 43,560 | Resort Road extension #2 (areas est.) |
| F-17-095 | M-6 (2) | Microbioretention | 40,904 | 22,156 | Areas from development plan |
| F-17-095 | F-6 (1) | Bioretention | 60,657 | 32,753 | Areas from development plan |
| F-17-096 | F-6 (5) | Bioretention | 249,205 | 136,610 | Areas from development plan |
| F-17-096 | M-6 (1) | Microbioretention | 16,200 | 5,139 | Areas from development plan |
| F-17-096 | M-5 (44) | Dry wells | 35,640 | 35,640 | Areas est. from development plan (44 x 810) |
| F-18-027 | M-6 (1) | Microbioretention | 22,684 | 12,906 | Areas from development plan |
| F-18-027 | M-5 (14) | Dry wells | 11,550 | 11,550 | Areas from development plan |
| SDP-20-036 | M-6 (7) | Microbioretention | 131,983 | 123,042 | Areas from development plan (under construction) |
| Totals (acres), 2015 | | | 67.6 | 35.4 | |
| Totals (acres), 2023 | | | 82.3 | 45.8 | |
| Watershed area (acres) | | | 198.4 | | |
| **ISA (%), 2015** | | | | **17.8** | |
| **ISA (%), 2023** | | | | **23.1** | ~30% increase in ISA (2015 – 2023) |

- New residential development: estimated 30% increase in ISA (17.8 to 23.1%)
- GSI implementation: 9 bioretentions; 11 micro-bioretentions; 56 dry wells

# Rating Curves/Annual Runoff



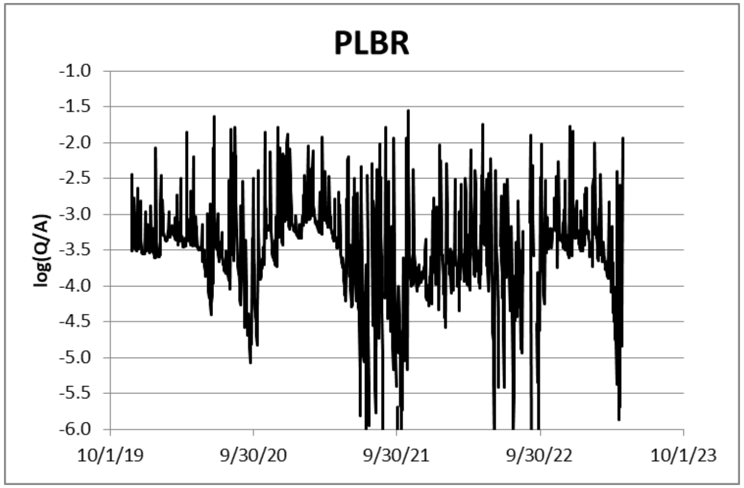



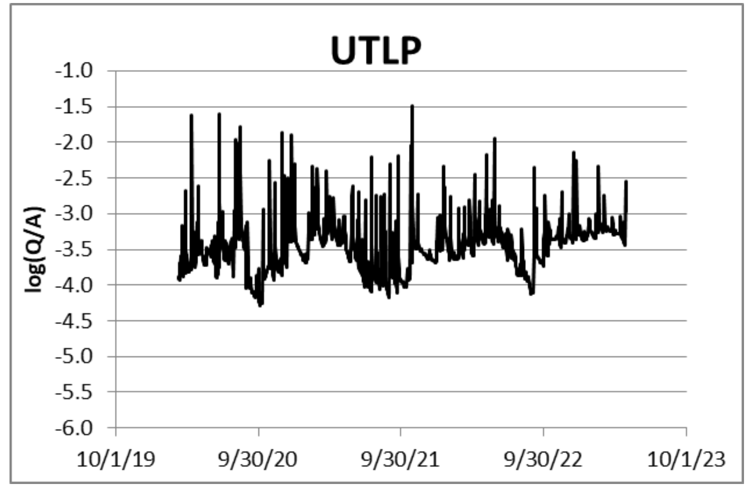



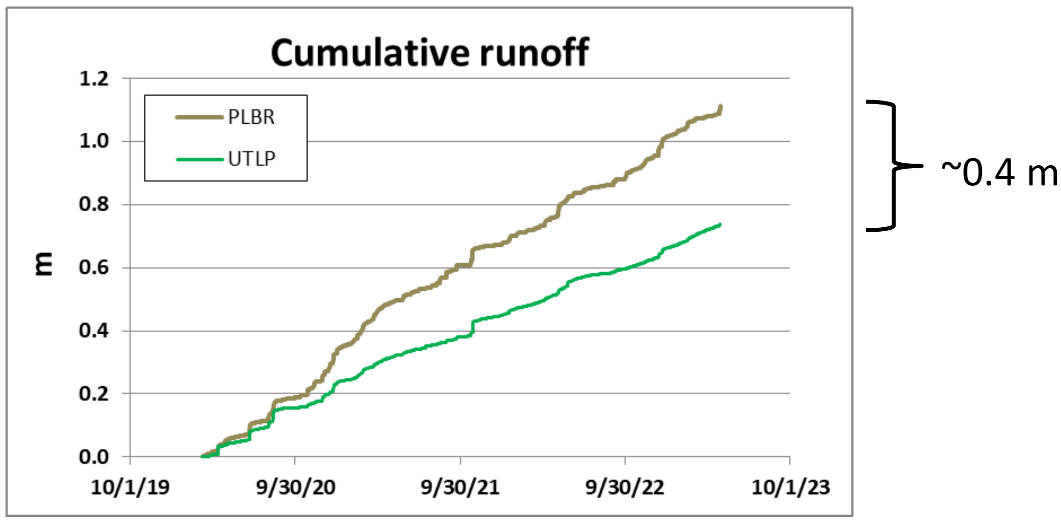

*partial water year data (3/10/20 – 9/30/20; 10/1/22 – 5/30/23)

- Very flashy streams gaged over 3 orders of magnitude
- Highest discharge measurements exceeded <0.05% of the time!
- PLBR annual runoff agrees well with data from nearby USGS watersheds
- UTLP runoff is lower (esp. in WY'21)

# Annual runoff anomaly

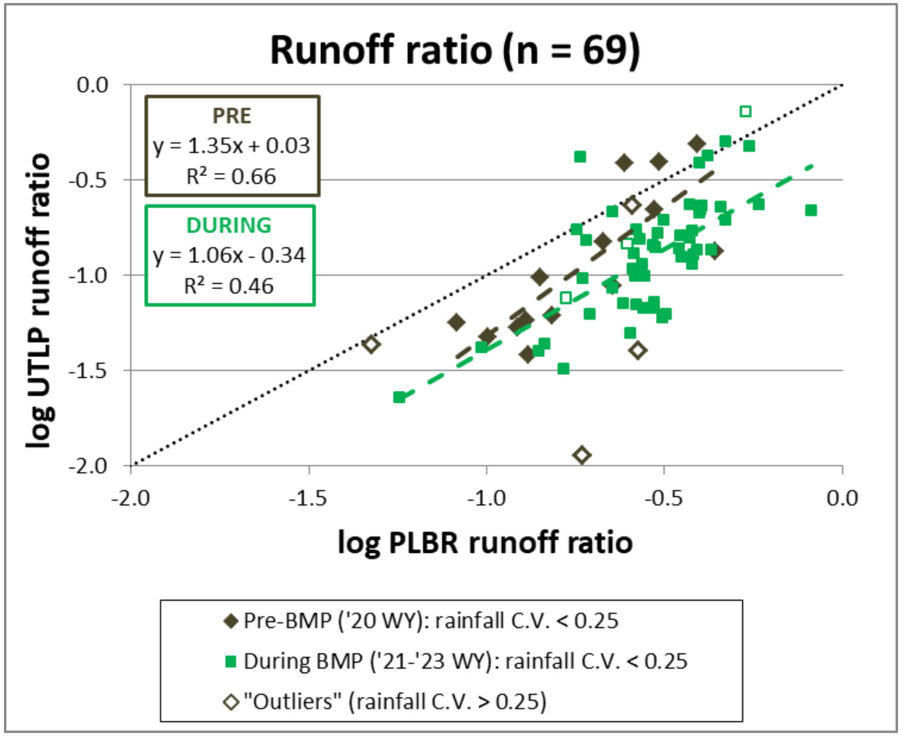


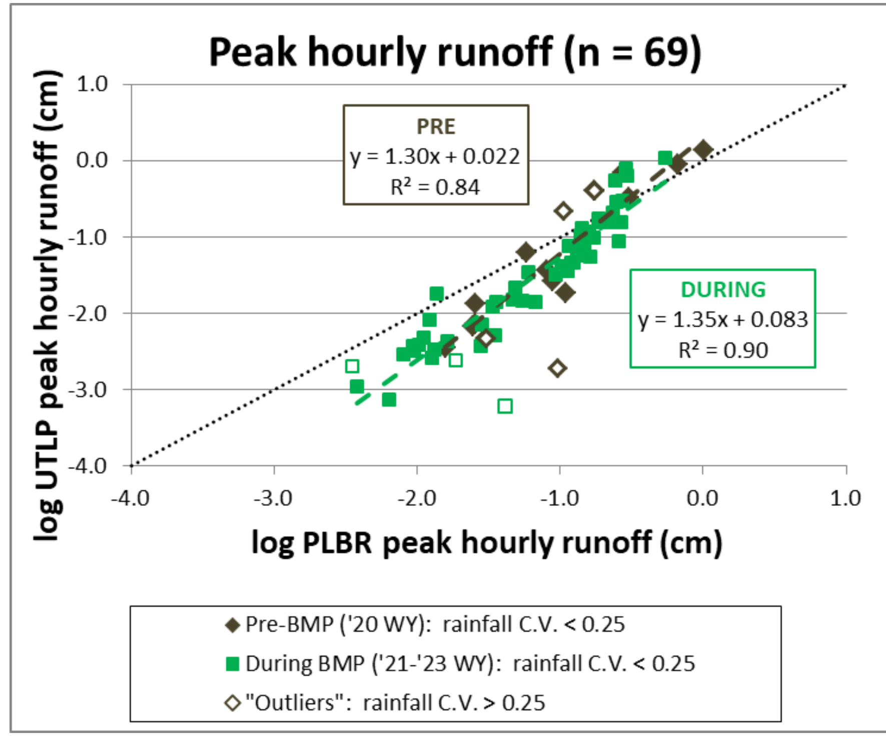




- Similar annual hydrographs: area-normalized mean daily discharge (log scale)
- Greater range at PLBR mostly due to lower summer baseflow
- Large UTLP runoff anomaly of ~ -40 cm (-33%) over 3+ years

# Paired Storm Event Analyses




One way ANCOVA: P < 0.05

One way ANCOVA: NS

- Paired data analysis (ANCOVA) (removed 7 "outlier" events)
- Statistically significant difference in adjusted mean event runoff ratio at UTLP (P < 0.05) in WY21 – WY23 compared to WY20 (pre-BMP period)
- No difference in adjusted mean peak hourly runoff, however

# Two-component hydrograph separation: natural tracer mass balance*

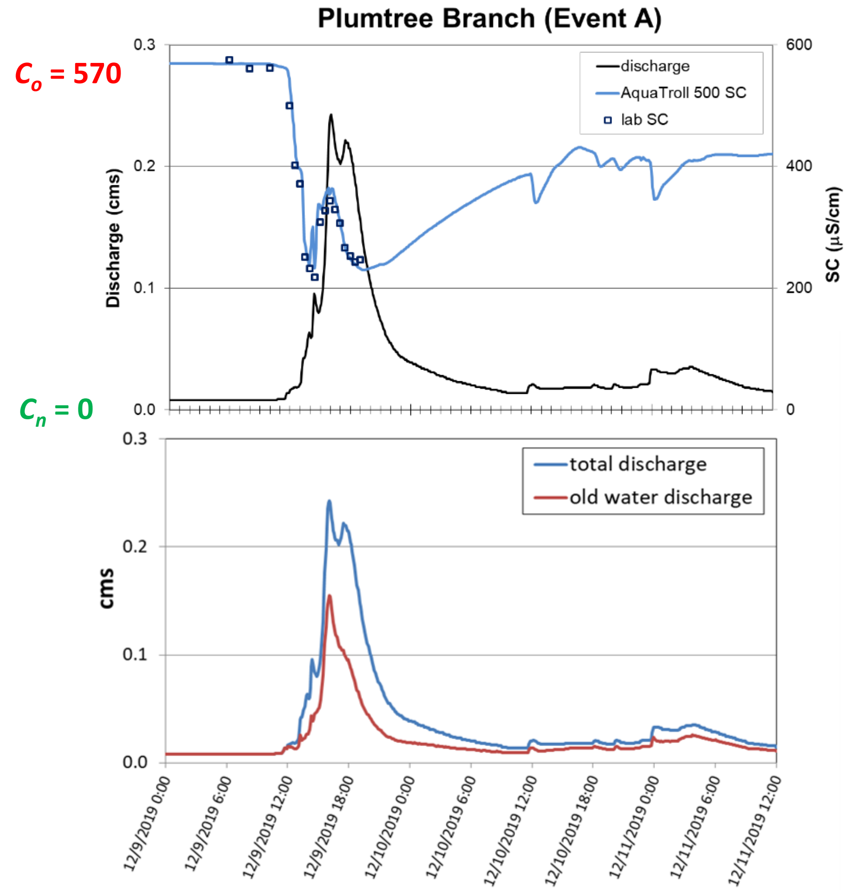
Mathematics is straightforward: solve two equations (two unknowns) simultaneously

- Water balance equation: $Q_T(t) = \boldsymbol{Q_n(t)} + \boldsymbol{Q_o(t)}$ [1]
- Tracer (SC) mass balance equation: $Q_T(t)C_T(t) = \boldsymbol{Q_n(t)}C_n + \boldsymbol{Q_o(t)}C_o$ [2]
- Substituting [1] into [2] and rearranging:

$$\boldsymbol{Q_n(t)} = Q_T(t)\left[\frac{C_o - C_T(t)}{C_o - C_n}\right] \quad [3]$$

- Substituting [3] into [1]: $\boldsymbol{Q_o(t)} = Q_T(t) - \boldsymbol{Q_n(t)}$ [4]

  where the *Q*'s are time-varying discharges and the *C*'s are concentrations ($C_n$ and $C_o$ are constants, but $C_T$ is time-varying). Equations [1] and [3] can be solved for each time (*t*) for which data on $Q_T(t)$ and $C_T(t)$ are available.

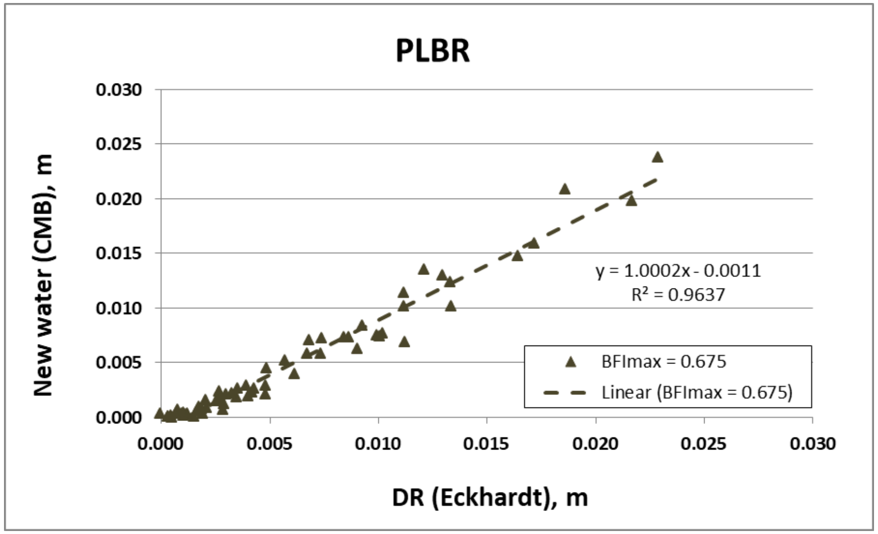


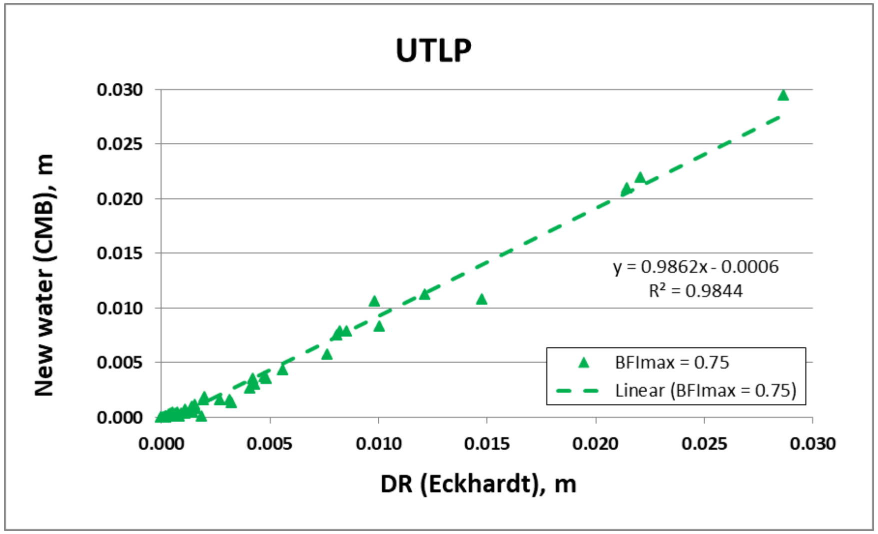

- In this example: $\frac{\int Q_o(t)dt}{A} = 0.23cm$; $\frac{\int Q_n(t)dt}{A} = 0.16cm$; $[Q_n(t)/Q_T(t)]_{max} = 60\%$
- Method was generally applicable to both watersheds (except for winter storms with road-salting)

*e.g., Sklash *et al.* (1976); Pellerin *et al.* (2008)

# Hydrograph Separation: recursive digital filtering (RDF, Eckhardt 2005)

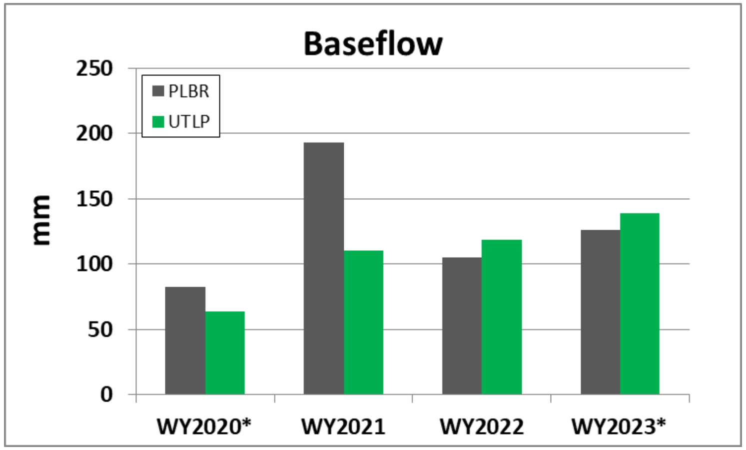
- Two-parameter RDF to separate hydrograph into two components: direct runoff (*DR*) and baseflow (*BF*)
- Linear reservoir assumption: *BF* decays exponentially (recession constant, $a$ ($0 < a < 1$) can be estimated independently from field data)
- Second parameter ($BFI_{max}$, the maximum value of the "baseflow index") is unknown
- Assume that $Q_o = BF$ and $Q_n = DR$; estimate $BFI_{max}$ using SC mass balance results for monitored storm events

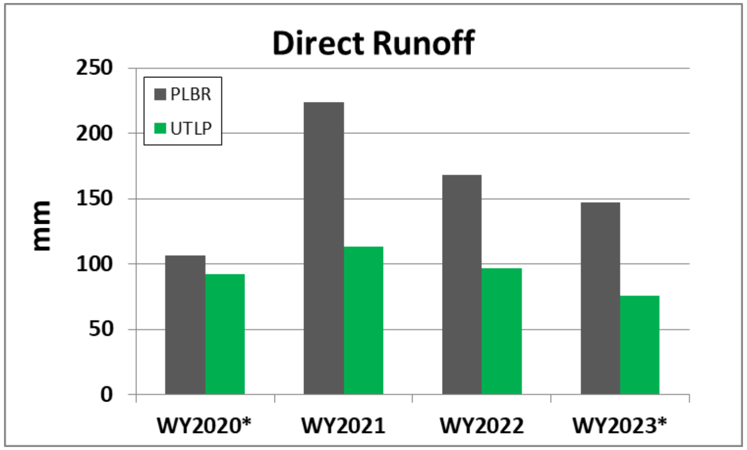


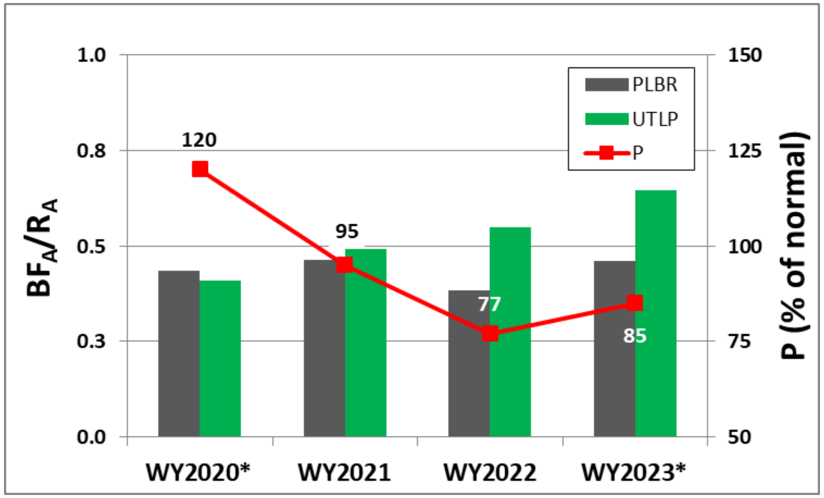




- Obtained ~1:1 linear relationships between new water runoff and direct runoff
- $BFI_{max}$ values = 0.675 (PLBR) and 0.750 (UTLP)

# Annual flow components based on calibrated RDF



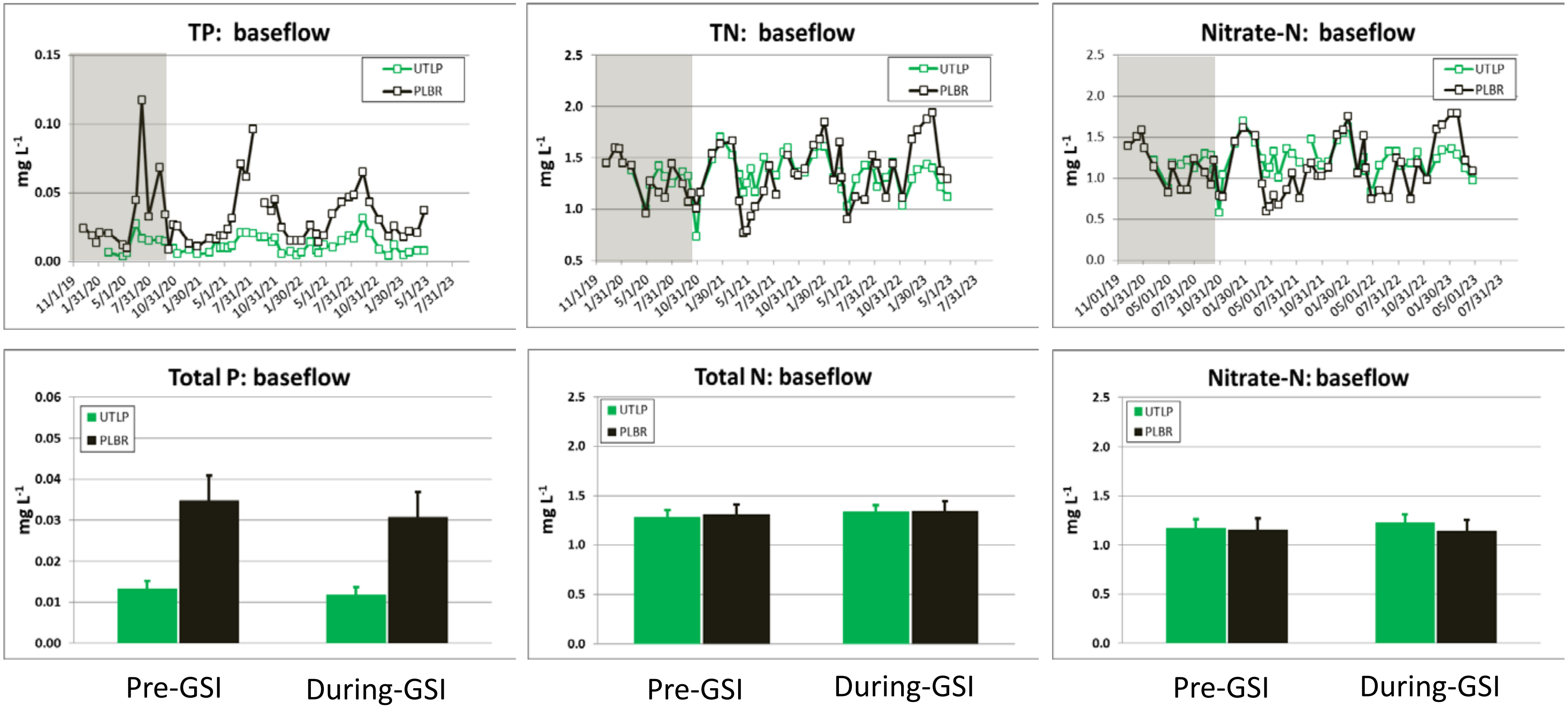




- The baseflow index ($BFI = BF_A/R_A$) has steadily increased at UTLP during GSI implementation, while *BFI* at PLBR has remained relatively constant
- Temporal pattern at UTLP seems largely independent of hydroclimatic variability

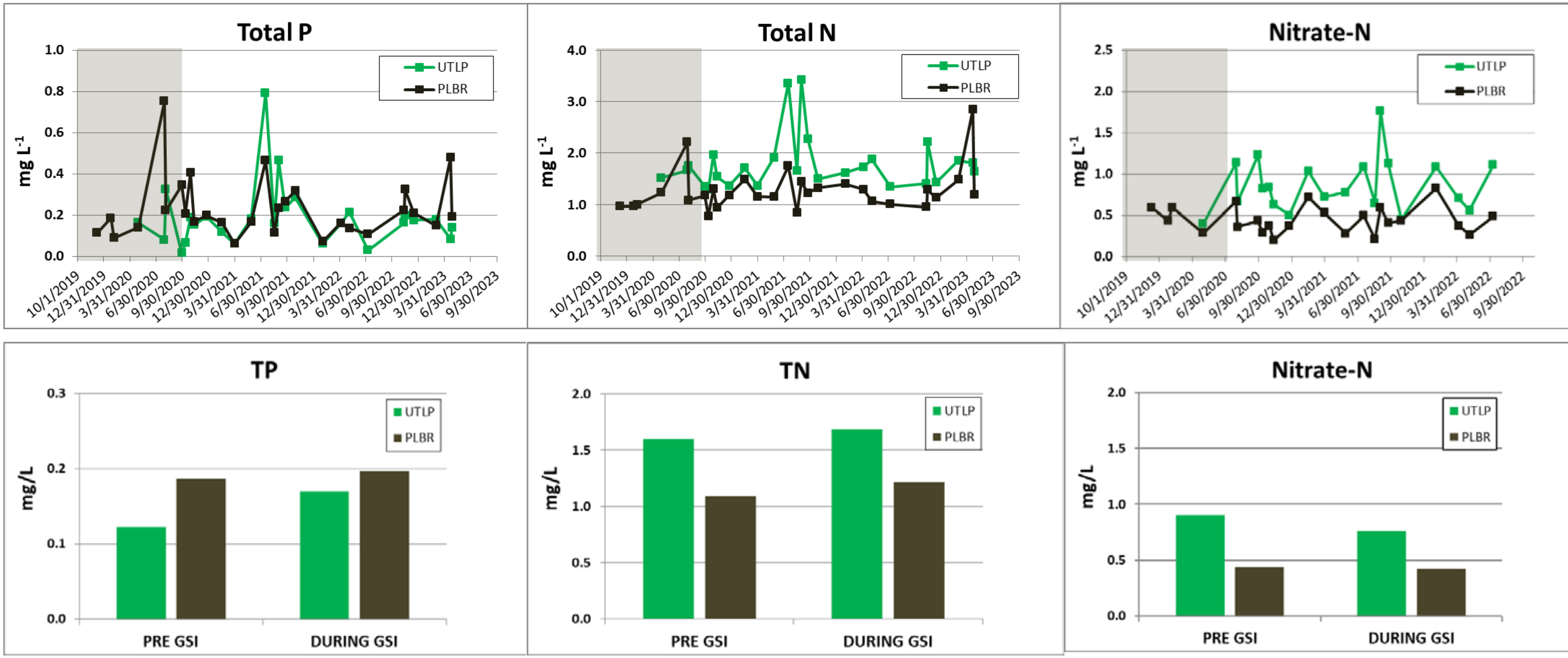
*partial water year data (3/10/20 – 9/30/20; 10/1/22 – 4/30/23)

# Baseflow water quality




- Repeating intra-annual variations are apparent: TN and TP out of phase
- Mean baseflow TP (and orthophosphate-P) concentrations lower at UTLP ($P < 0.001$), but stable over time (differences unlikely related to GSI implementation)
- No differences in mean baseflow TN or nitrate-N concentrations

# Stormflow EMC's




- EMC data are considerably "noisier" than baseflow concentrations
- Insufficient number of common events for pre-BMP period (n = 4) to use ANCOVA
- Statistically significant differences ($P < 0.05$; n = 26) in median TP, TN, and nitrate-N EMC's between watersheds (paired analysis)
- No statistically significant differences in median EMC's between pre-GSI and during-GSI periods for either watershed

# Pollutant Load Modeling

- LOADEST: widely-applied 7-parameter empirical loading model (Cohn *et al.*, 2003; Runkel *et al.*, 2004; 2013)

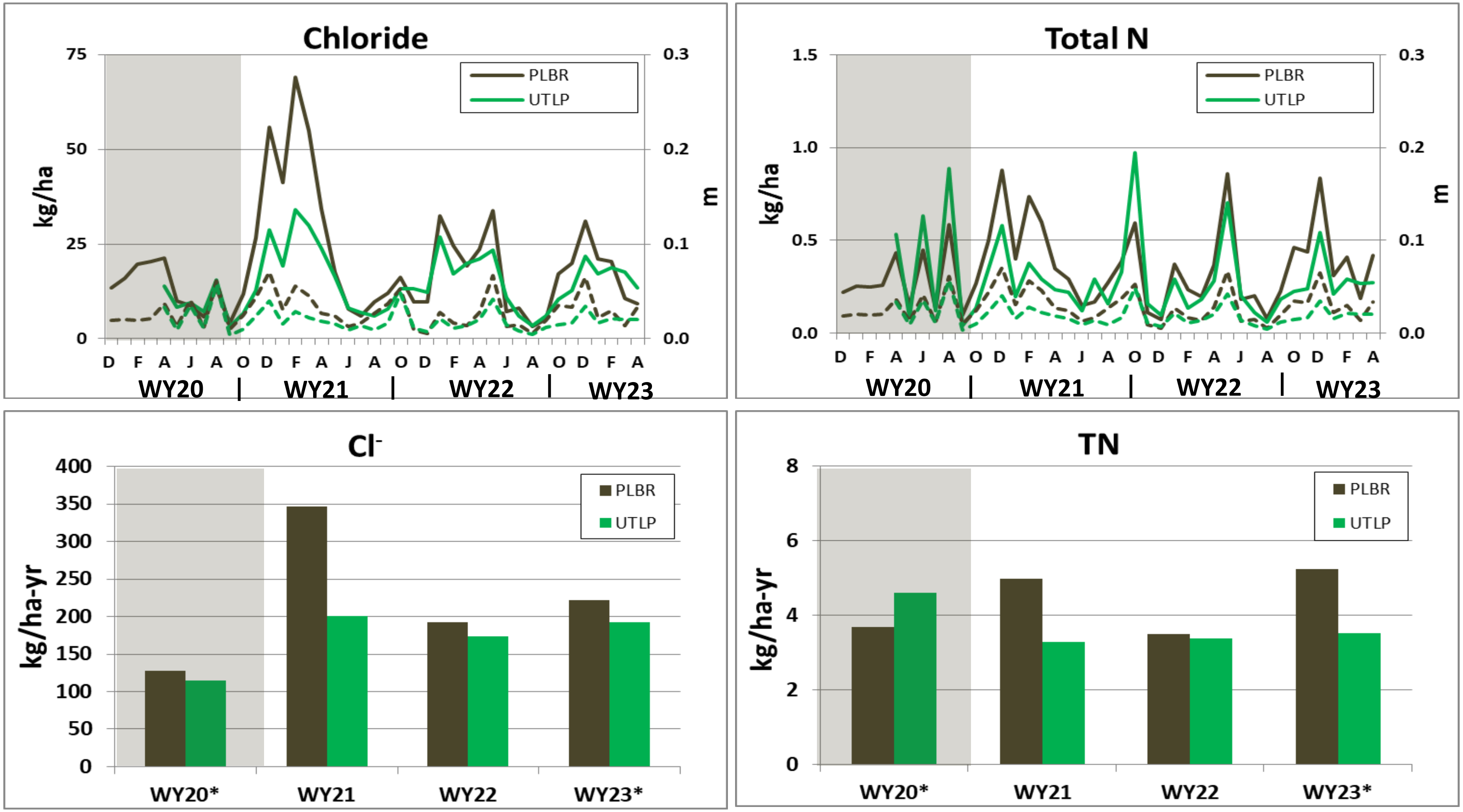
$$lnL = a_0 + a_1 lnQ + a_2 lnQ^2 + a_3 \sin(2\pi dtime) + a_4(cos2\pi dtime) + a_5(dtime) + a_6 dtime^2$$

where $L$ = load, $Q$ = stream discharge, and *dtime* is a decimal representation of time

- Instantaneous hourly *C-Q* data used to calibrate LOADEST for both watersheds
- Estimation for entire period of record (with aggregation to monthly and annual periods)

| Pollutant | PLBR | | | UTLP | | |
|---|---|---|---|---|---|---|
| | $R^2$ | $B_p$ (%) | E | $R^2$ | $B_p$ (%) | E |
| $Cl^-$ | *0.93* | *-3.6* | *0.52* | *0.89* | *-8.5* | *0.47* |
| SC | *0.97* | *0.0* | *0.72* | *0.95* | *-3.5* | *0.83* |
| $NO_3$-N | *0.95* | *-4.0* | *0.72* | *0.94* | *-7.1* | *0.78* |
| TN | *0.99* | *-4.3* | *0.91* | *0.98* | *0.5* | *0.81* |
| TP | *0.97* | *20.1* | *0.32* | *0.94* | *83.2* | *-1.36* |
| Ortho-P | *0.97* | *8.7* | *0.91* | *0.90* | *70.1* | *-1.84* |
| TSS | *0.95* | *40.9* | *-0.60* | *0.93* | *-197.8* | *-8.87* |

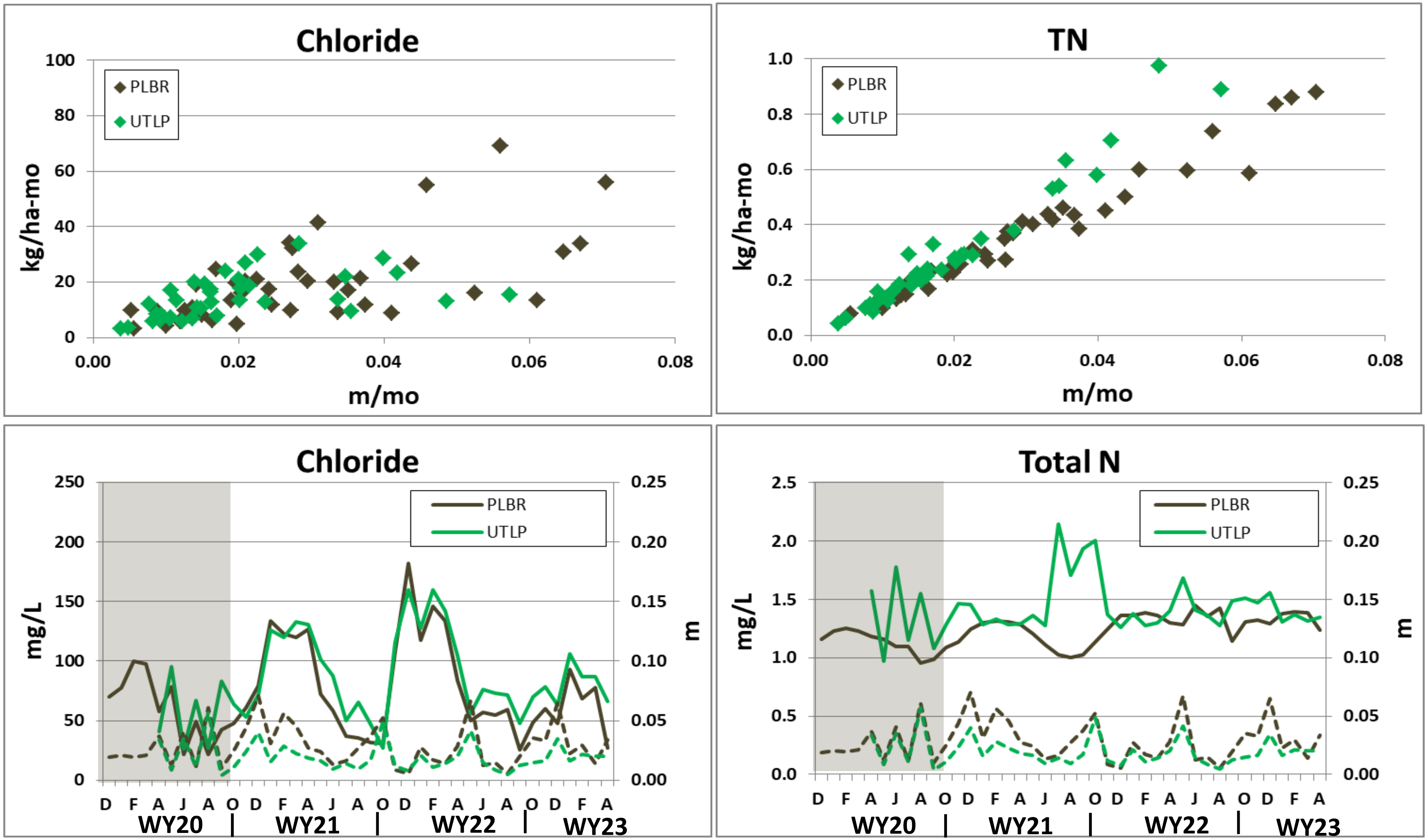
# Pollutant Load Modeling




- Seasonal variations in $Cl^-$ loads explained by timing/amount of road salt application
- Differences in annual $Cl^-$ loads between watersheds explained by UTLP runoff anomaly
- Monthly TN loads appear "random", but strongly correlated with runoff; TN load peaks can occur in any season

*partial water year data (3/10/20 – 9/30/20; 10/1/22 – 4/30/23)

# Pollutant Load Modeling




- As expected, TN loads very strongly correlated with runoff; chloride less well correlated
- Monthly flow-weighted concentrations: $Cl^-$ shows strong intra-annual pattern at both watersheds; intra-annual pattern for TN only evident at PLBR
- Does the TN graph suggest a response to GSI implementation at UTLP?

# Summary of Key Results

- Integration of conventional and newer field/analytical methods allowed detection of some important watershed-scale hydrologic changes at UTLP likely related to GSI implementation:
  - *Reduction in storm event runoff ratios*
  - *Increasing baseflow index (and commensurate decrease in direct runoff)*
- We have not detected any significant changes in:
  - *Peak storm event runoff*
  - *Baseflow chemistry*
  - *Event mean pollutant concentrations (TN, TP, etc.)*
- Full interpretation of pollutant loads is still in progress
- Data from natural hydrologic systems are often very noisy: role of PLBR as control watershed
- Development/GSI implementation in UTLP is on-going; lack of "post BMP" data is a major limitation

# Acknowledgments

- Chesapeake Bay Trust/MD-DNR: sponsorship
- Howard County (Mark Richmond *et al.*): ROE permits; site development plans
- Kimberly Grove: translation
- UMCES Appalachian Lab Water Chemistry/Hydro Lab team
  - Katie Kline
  - Briana Rice
  - Jim Garlitz
  - Ev Demott
  - Joel Bostic
  - Trevor Frissell
- Neal Eshleman
- Elizabeth Eshleman

# A PAIRED-WATERSHED STUDY:
## TRANSLATION OF KEITH ESHLEMAN'S PRESENTATION BY KIMBERLY L. GROVE, P.E. BALTIMORE CITY DPW

CBT Pooled Monitoring Forum
June 21, 2023

# MONITORING TIMEFRAME

Pre GSI = ESC

During GSI

GSI (ESD) practices are designed to treat the first 1 inch of rain storm and "mimic" natural hydrology for a 1-year, 24-hour storm.

# NORMALIZE TO COMPARE

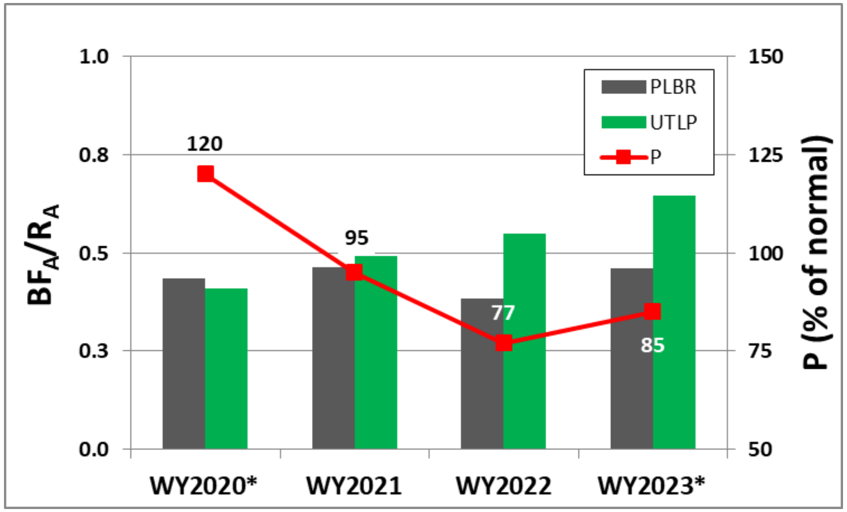
Annual runoff

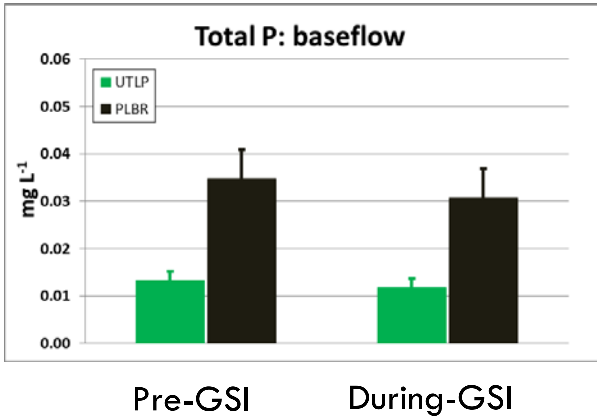
Storm events without “outliers”

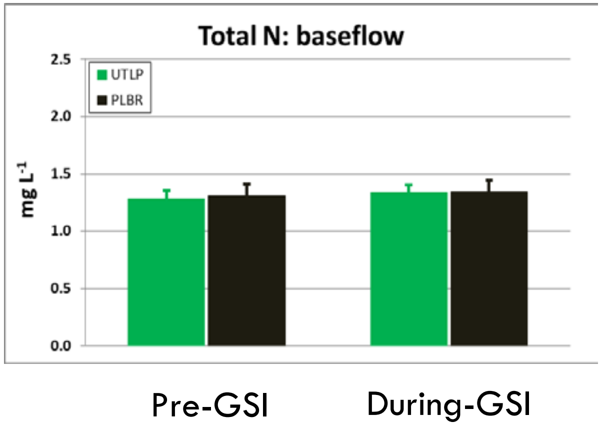
Base flow vs. runoff

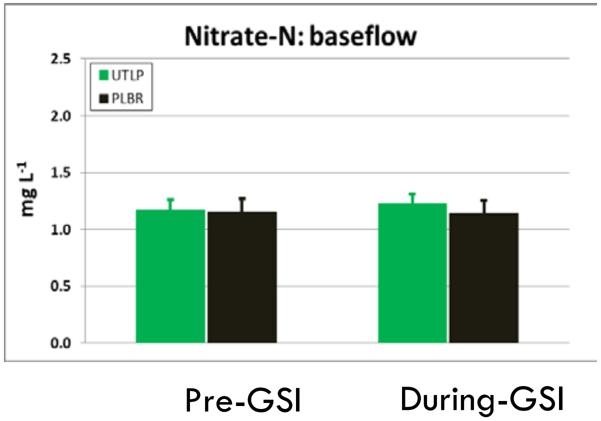
Base flow water chemistry

Storm flow event mean concentrations



# MAJOR TAKE-AWAYS

Comparison of developments, not to reference forest, to study the evolution of stormwater management.

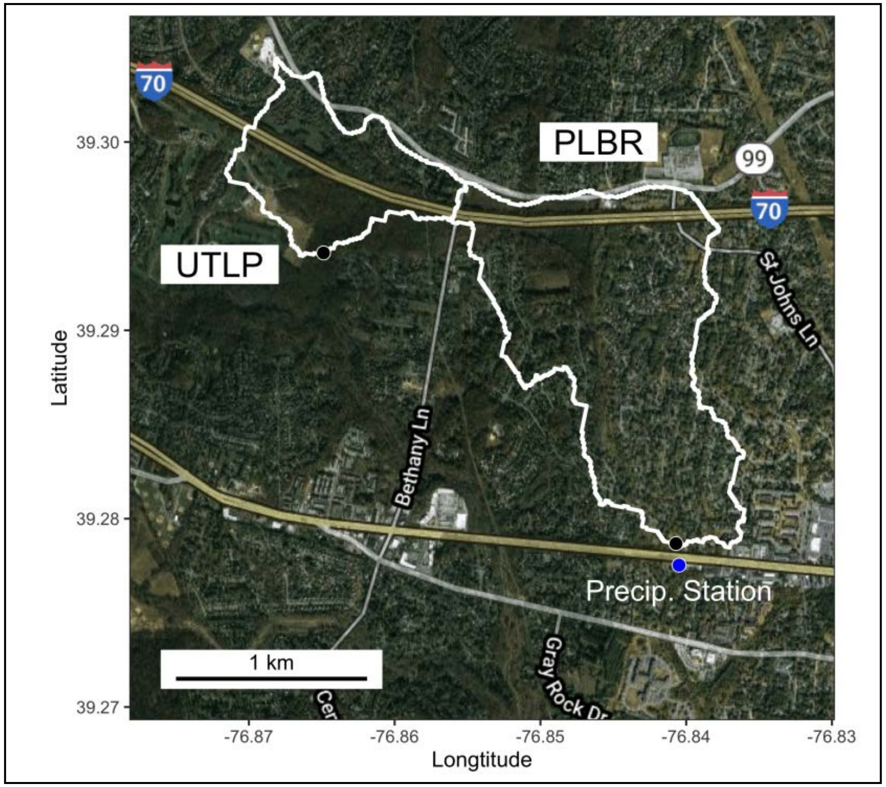
Usability of data is dependent on statistical analysis.

TN and TP are different.

Any "control" is better than none, but effectiveness would require a deeper dive into the basis of design.

GSI performance is improving over time.

Pollution loading is complex: GSI appears to help with the base flow but stream and riparian buffer conditions may still be a factor for wet weather loading.



# 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, and the Berrywood Community

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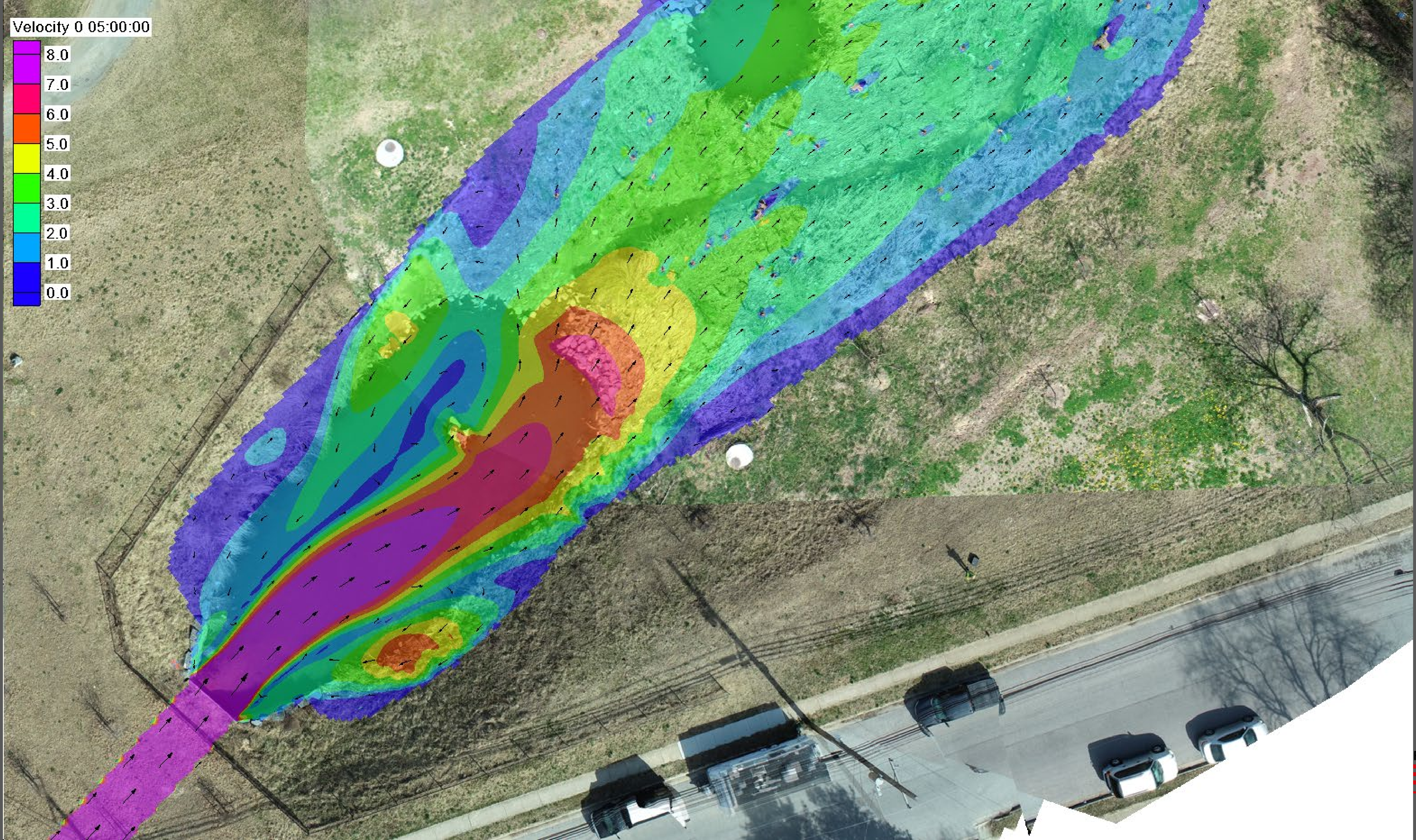

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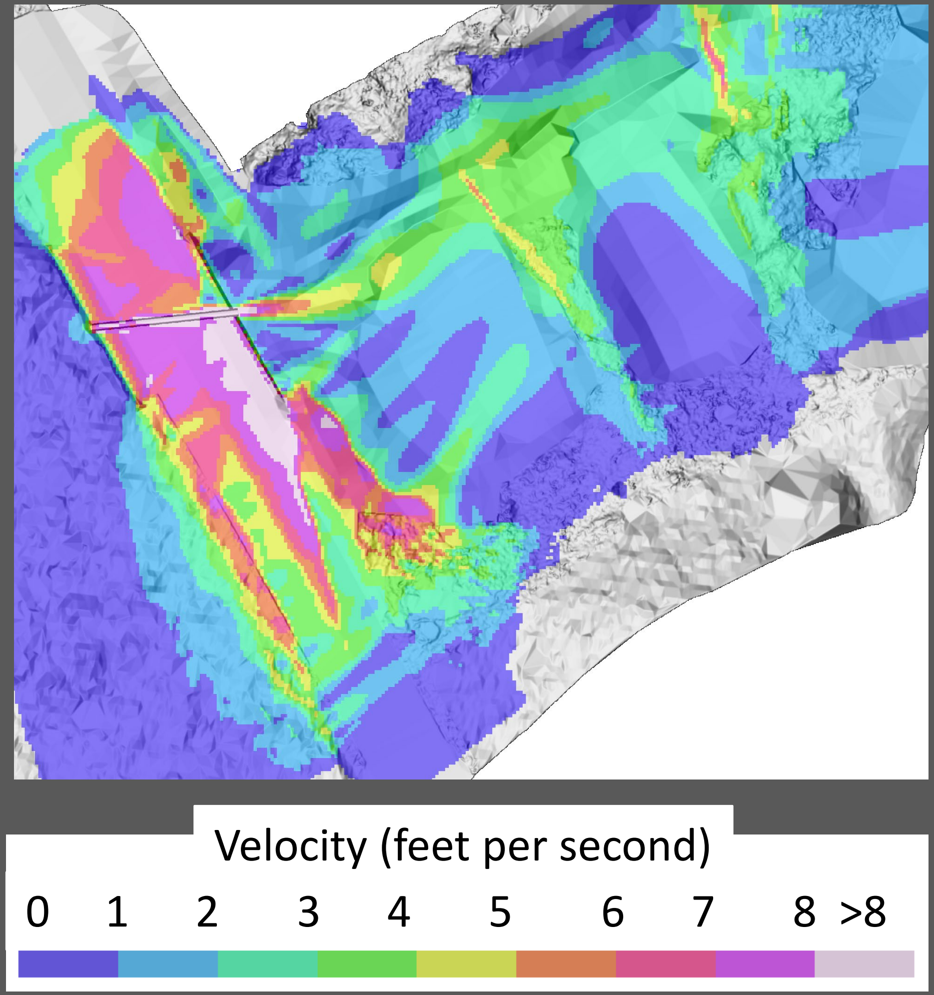
# Motivation: Reliable 2D models would be useful under current and future climate conditions

## 2D models for Stable Restoration Design

- Identify components of restoration that are vulnerable to flood damage
- Determine if rock protection or an erosion blanket is necessary
- Remove unnecessary rock and structures
- Minimize excavation and tree removal
- Compare the stability of restoration alternatives

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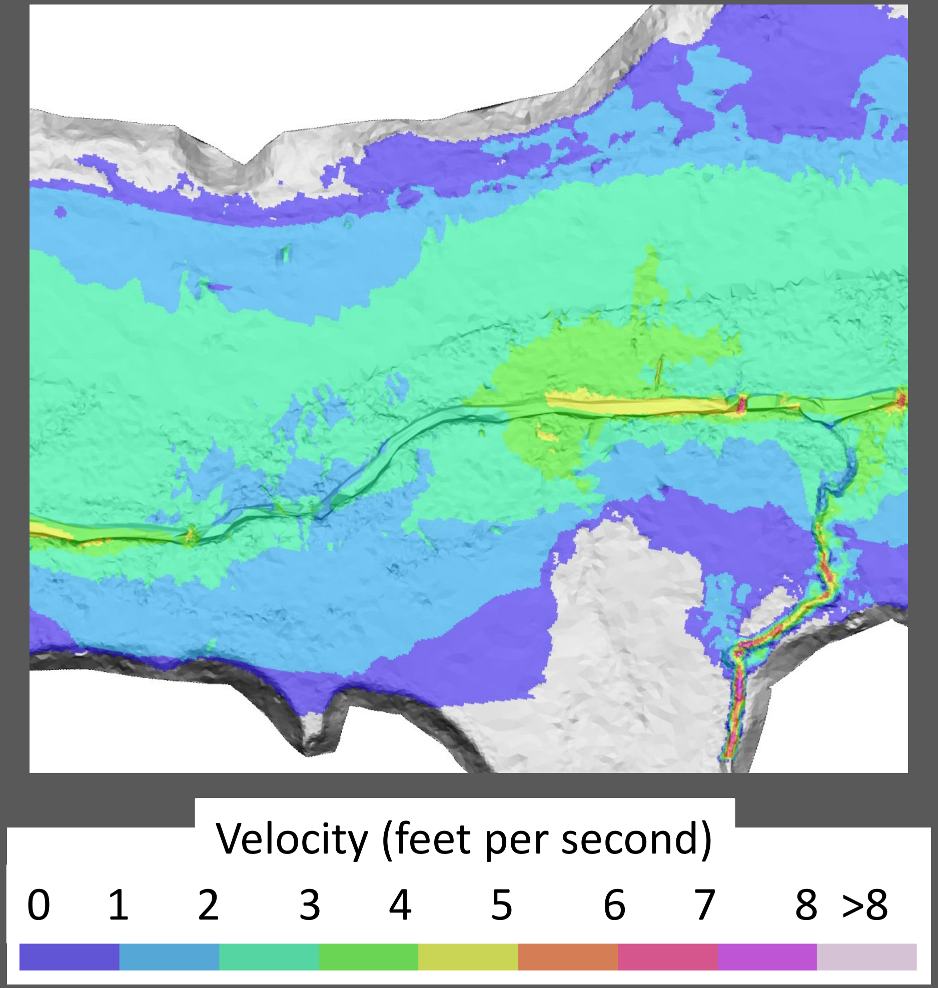
# Motivation: Reliable 2D models would be useful under current and future climate conditions

## 2D Models for Evaluating Expected Functions

- Determine the expected performance during the initial project phases
- Modify designs to increase key functions: retention of organic matter and sediments
- Improve ability to assess project vulnerabilities and costs associated with project structures

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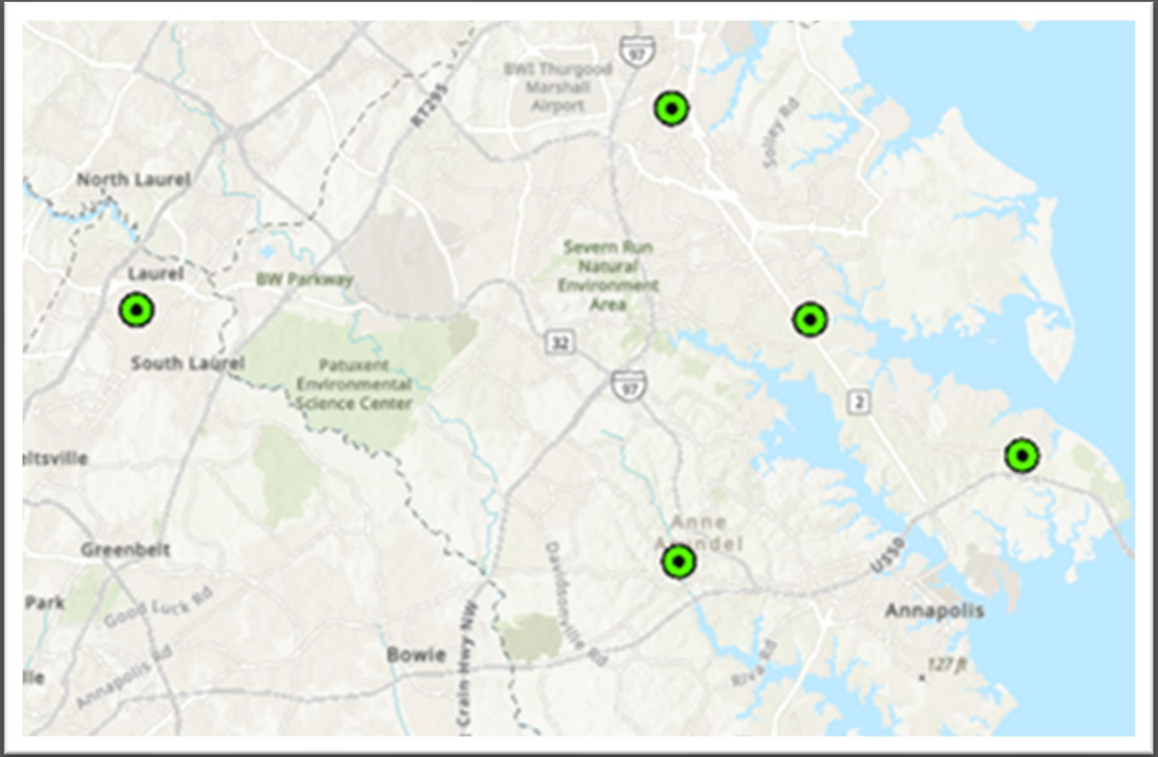
# Are 2D Hydrodynamic Models a reliable tool for stream restoration design?

**Research Approach:**

- Phase I: Evaluate 2D model reliability at 5 sites
- Phase II: Evaluate the susceptibility of different restoration approaches to damage under current and future climate conditions

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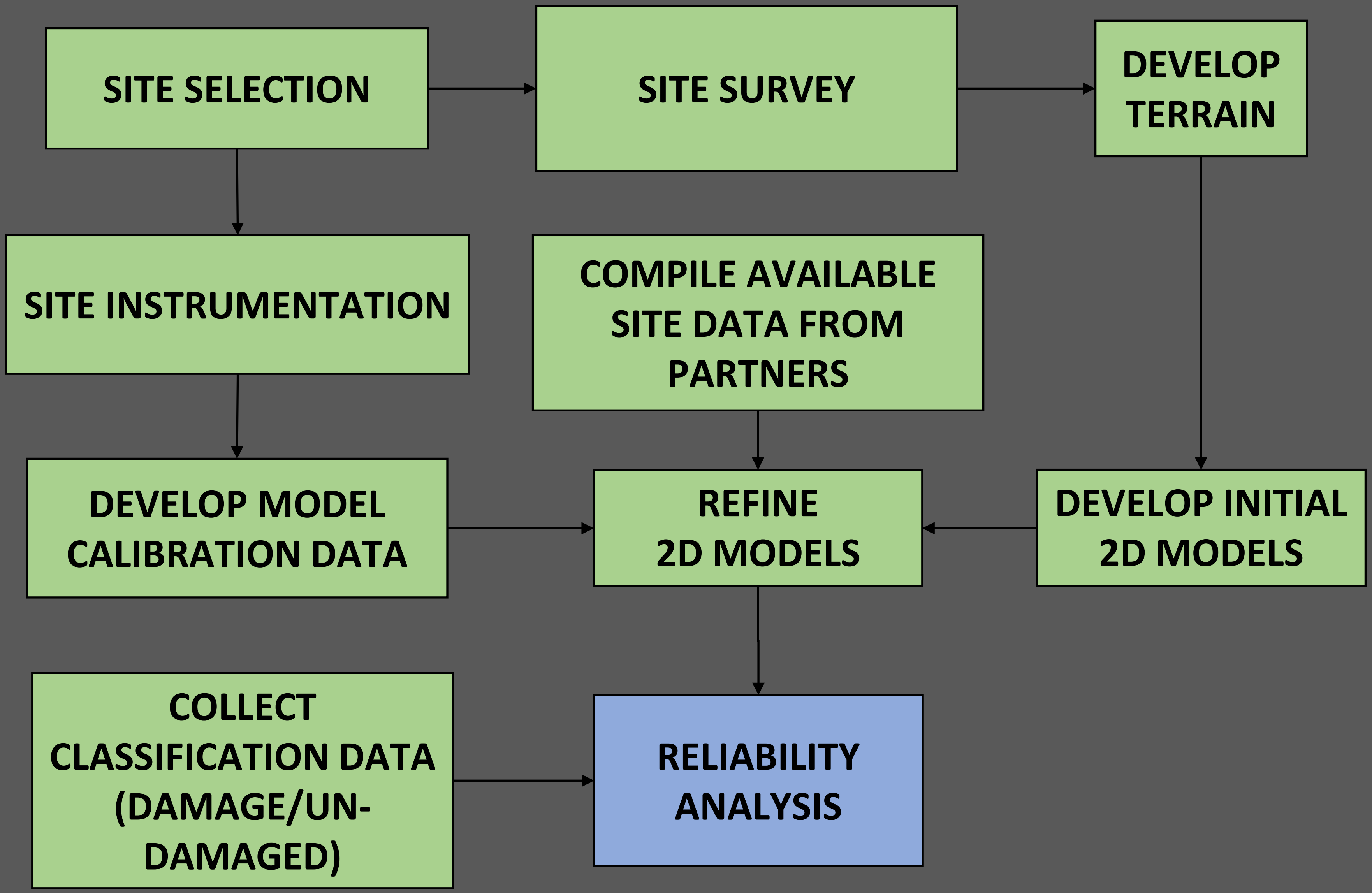
# Phase I: 2D Model Reliability Analysis




## Project Status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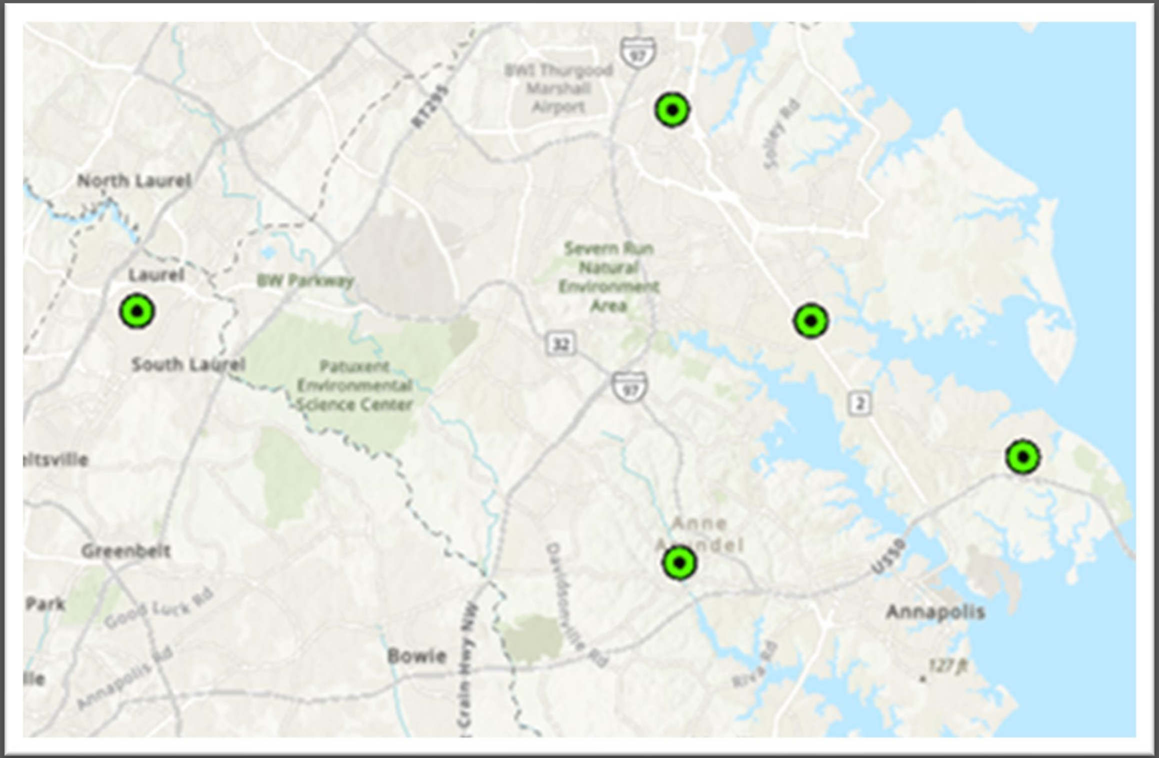
# Study Sites – MD Coastal Plain

| Site | Restoration Method/Type | Study Components |
|---|---|---|
| Furnace Creek | Floodplain Restoration and Stream- Wetland Complexes | Floodplain and Streambanks |
| Cat Branch | Floodplain Restoration and Stream- Wetland Complexes | Floodplain and Streambanks |
| Cattail Creek | Step Pool Storm Conveyance (SPSC) | Berm and Weir |
| Bear Branch | Modified Natural Channel Design | NCD Structures and Rock Riffles |
| Bacon Ridge Branch | Beaver Dam Analogs and Stream-Wetland Complex | Beaver Dam Analogs (BDA) and Floodplain |

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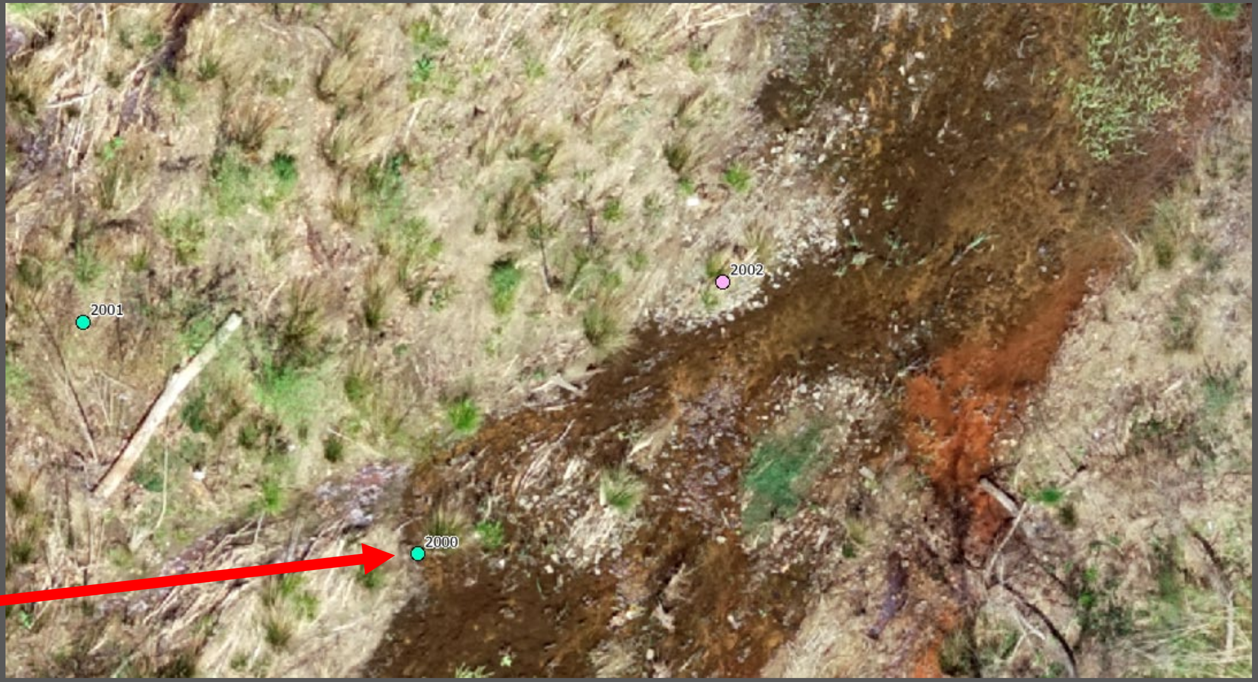
# Phase I: Collecting Classification Data

- Approach to classifying areas expanded to represent the range of observed conditions better
- Field reconnaissance --> desk --> field reconnaissance

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# Floodplain Damage Classification: Wetland Vegetation

## CATEGORY 1

**Stable Depositional**

Very retentive of organic (OM) matter and sediment

Vegetation type and density not impacted by flood stress

## CATEGORY 2

**Stable - Mostly Depositional**

Retentive of OM and sediment, likely in a patchy distribution.

Vegetation type and density modestly influenced by flood stress.

## CATEGORY 3

**Local Erosion**

Retention of (OM) matter and sediment only by trapping at obstacles.

Vegetation type and density influenced by flood stress. Sensitive species absent.

## CATEGORY 4

**Widespread Erosion**

Not retentive of OM and sediment- both are transient

Flood stresses heavily impact vegetation type and density.

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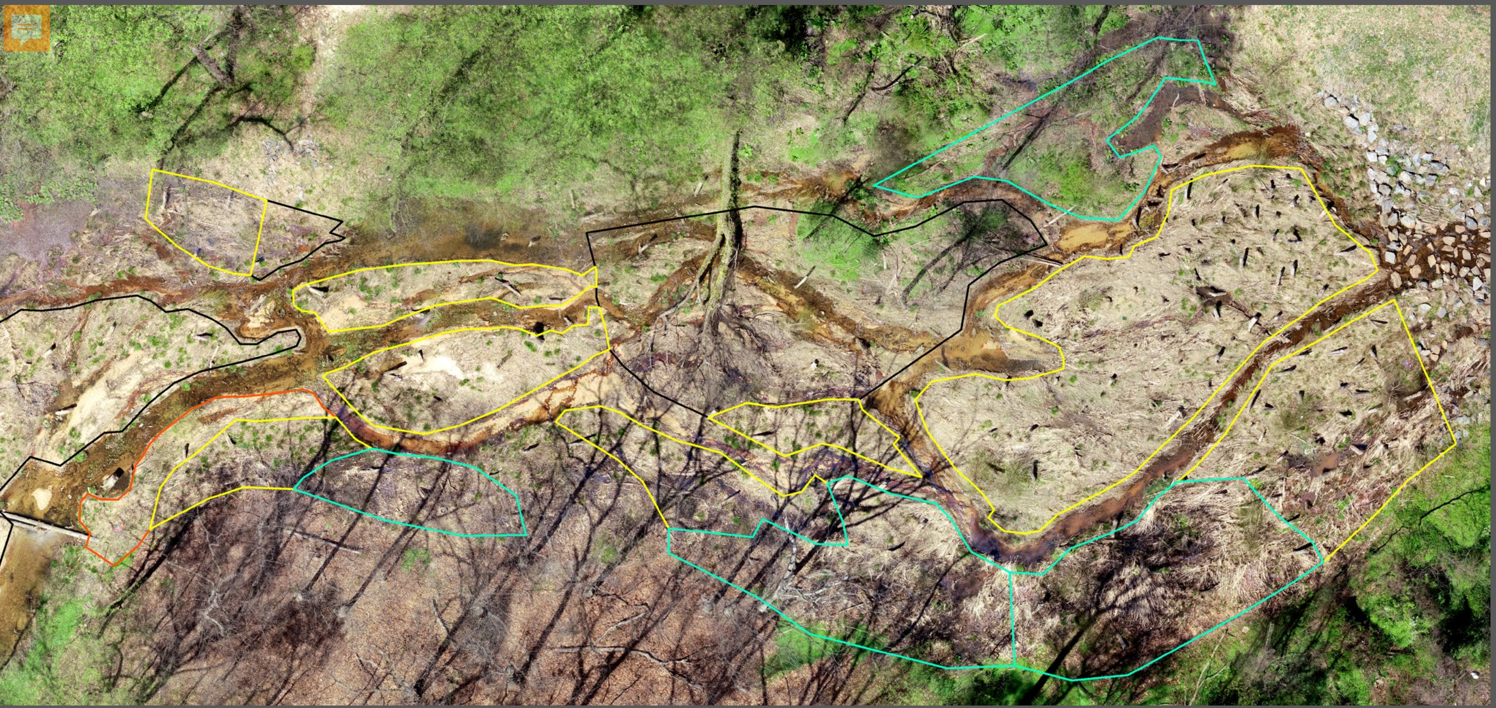
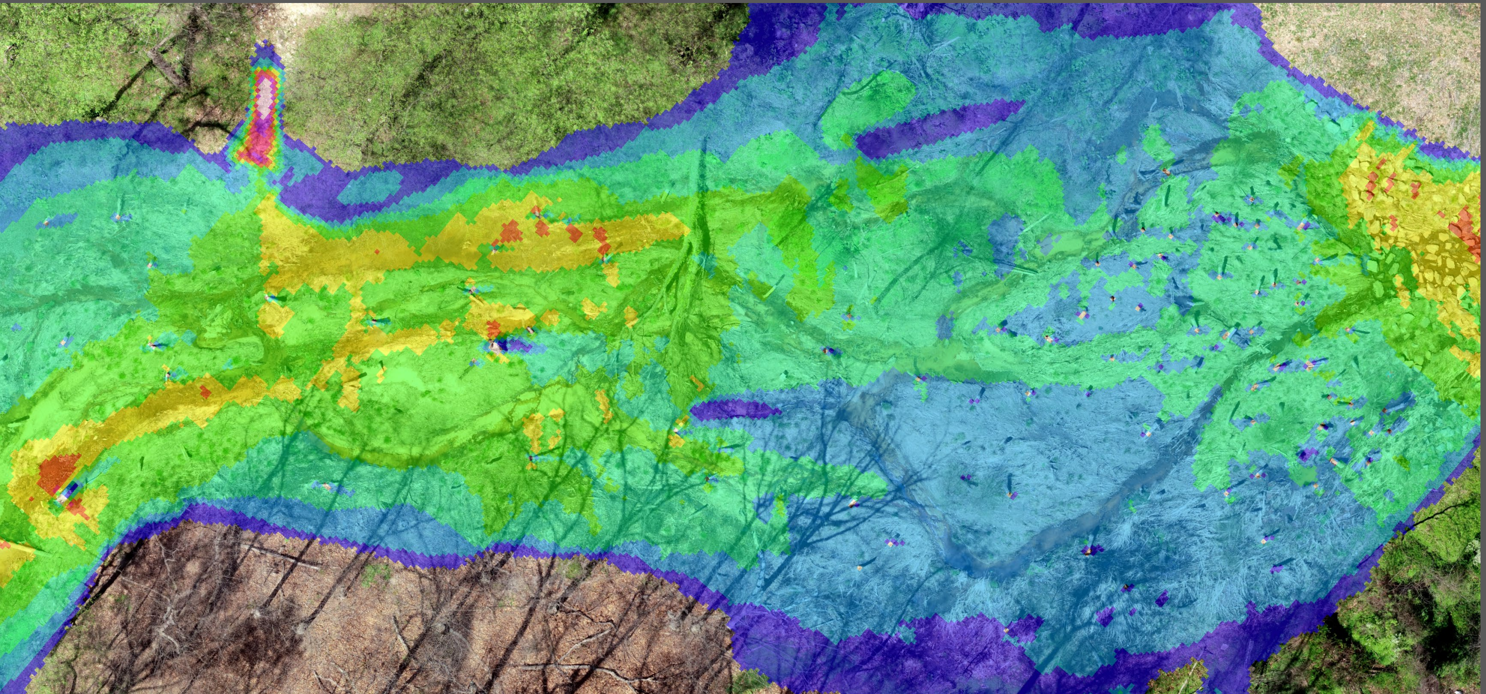


## Floodplain Damage Classification: Wetland Vegetation

Class
- Unclassified
- Category 1
- Category 2
- Category 3



## 2-D Model Calibrated to Highest Flood Observed

Velocity (feet per second)

0 1 2 3 4 5 6 7 8 >8

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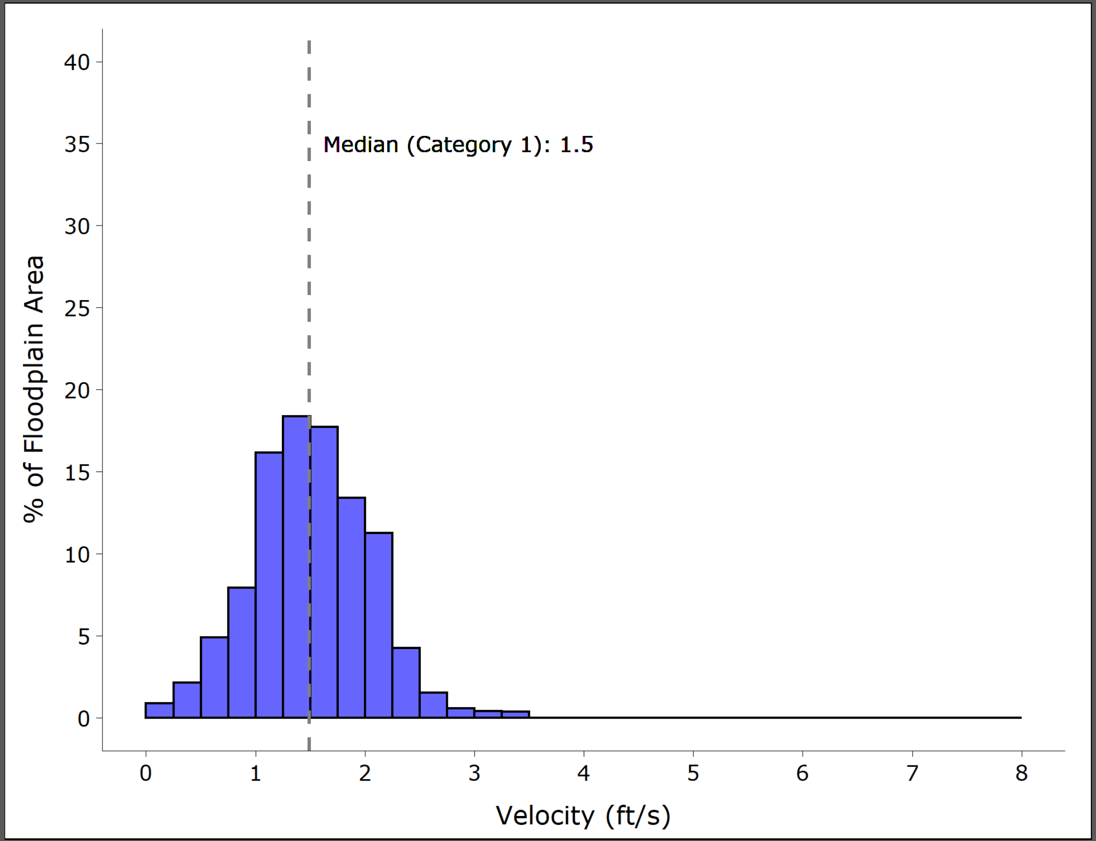
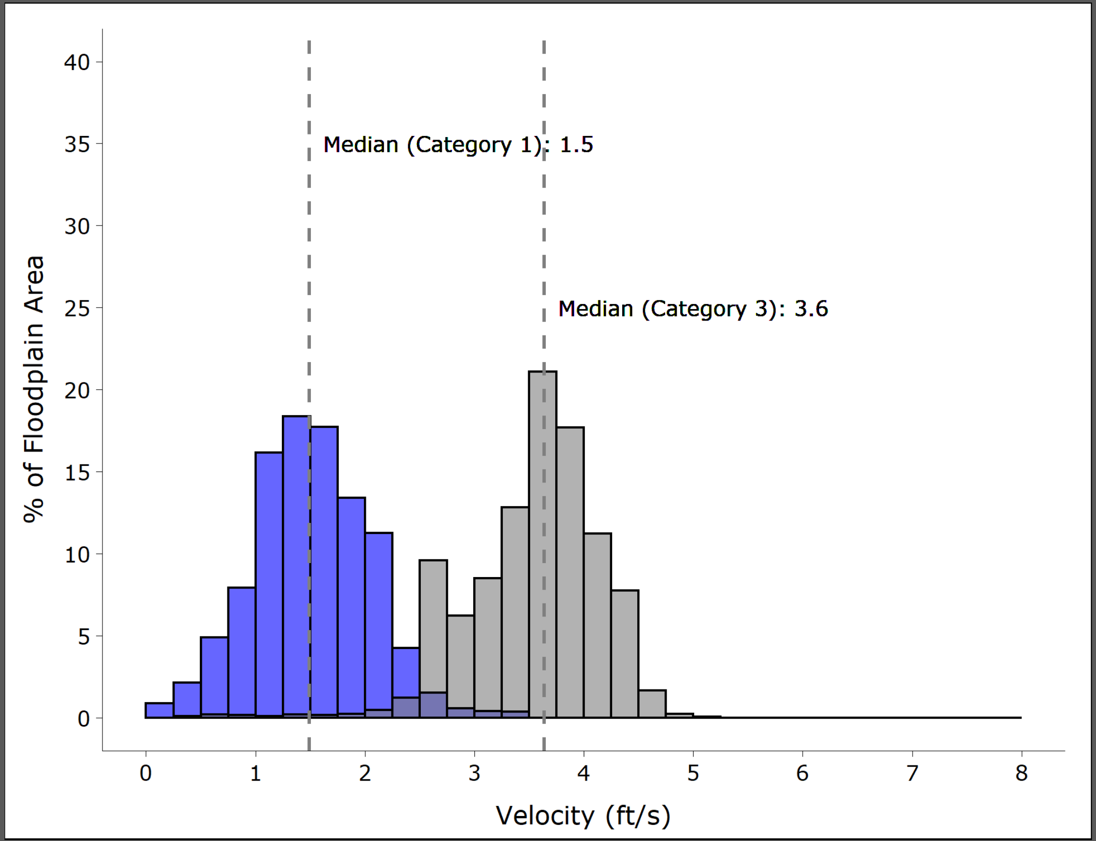
# Floodplain Stress Classification: Wetland Vegetation



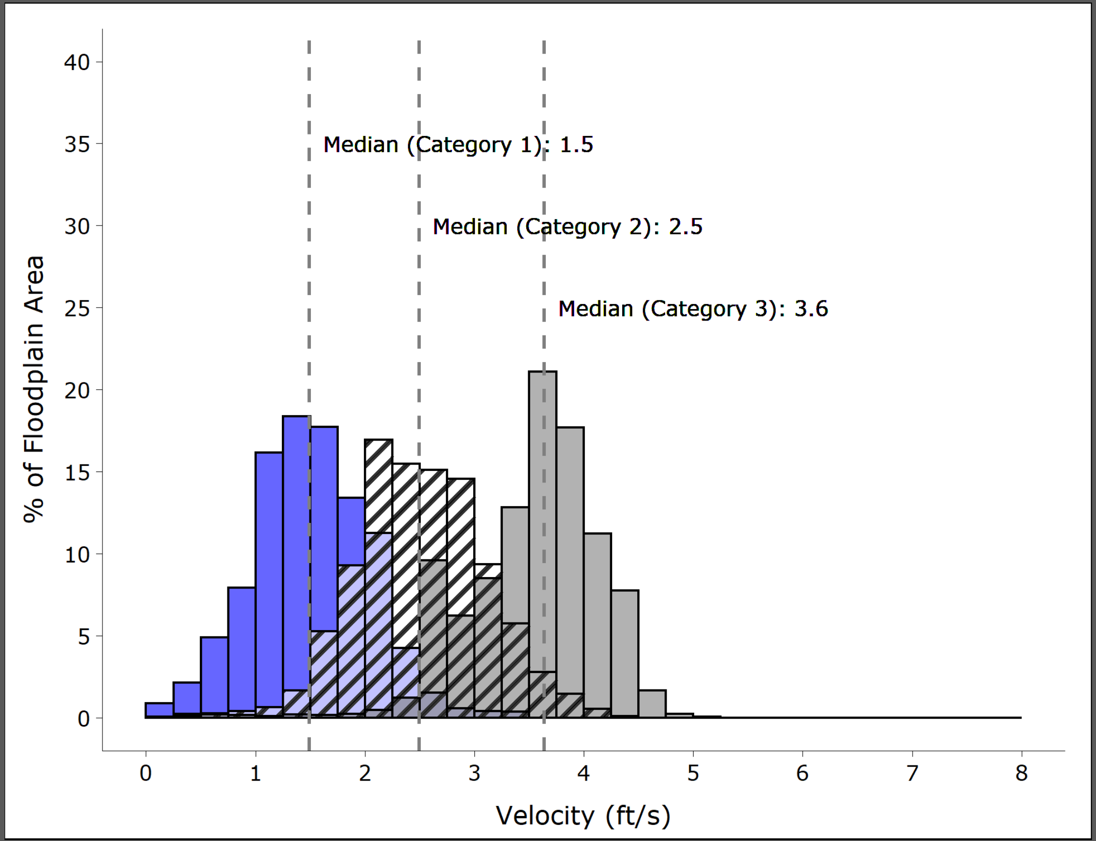

## Category 1

# Floodplain Stress Classification: Wetland Vegetation




## Category 3

# Floodplain Stress Classification: Wetland Vegetation




## Category 2

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# Additional Work on Floodplain Damage

- Differentiate for areas underlain by rock
- Other vegetation types
  - Scrub Brush
  - Forested
- More mature restoration sites

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# Channel Bank Damage Classification: Wetland Vegetation

CATEGORY 1

**Very stable**

Very retentive of organic (OM) matter and sediment. Roots may extend into channel.

Bank vegetation type and density not impacted by flood velocities

No bank erosion

CATEGORY 2

**Stable (UN-DAMAGED)**

Retentive of OM and sediment, likely in a patchy distribution on bed and banks.

Bank vegetation streamlined; clear separation between bank and bed

Minimal bank erosion

CATEGORY 3

**Widespread Bank Erosion**

Retention of (OM) matter minimal.

Vegetation streamlined; type limited by flood velocities. Bare areas due to vegetation removal

Bank(s) eroding

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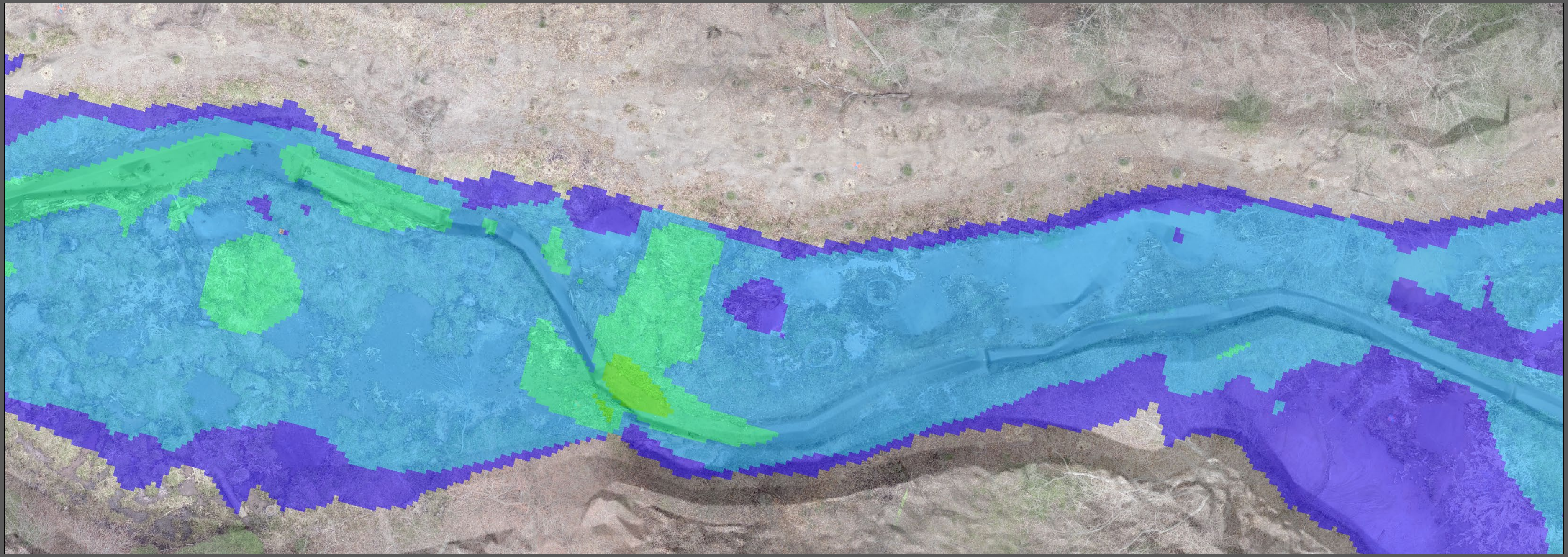
# Channel Bank Damage Classification


# 2-D Model Calibrated to Highest Flood Observed

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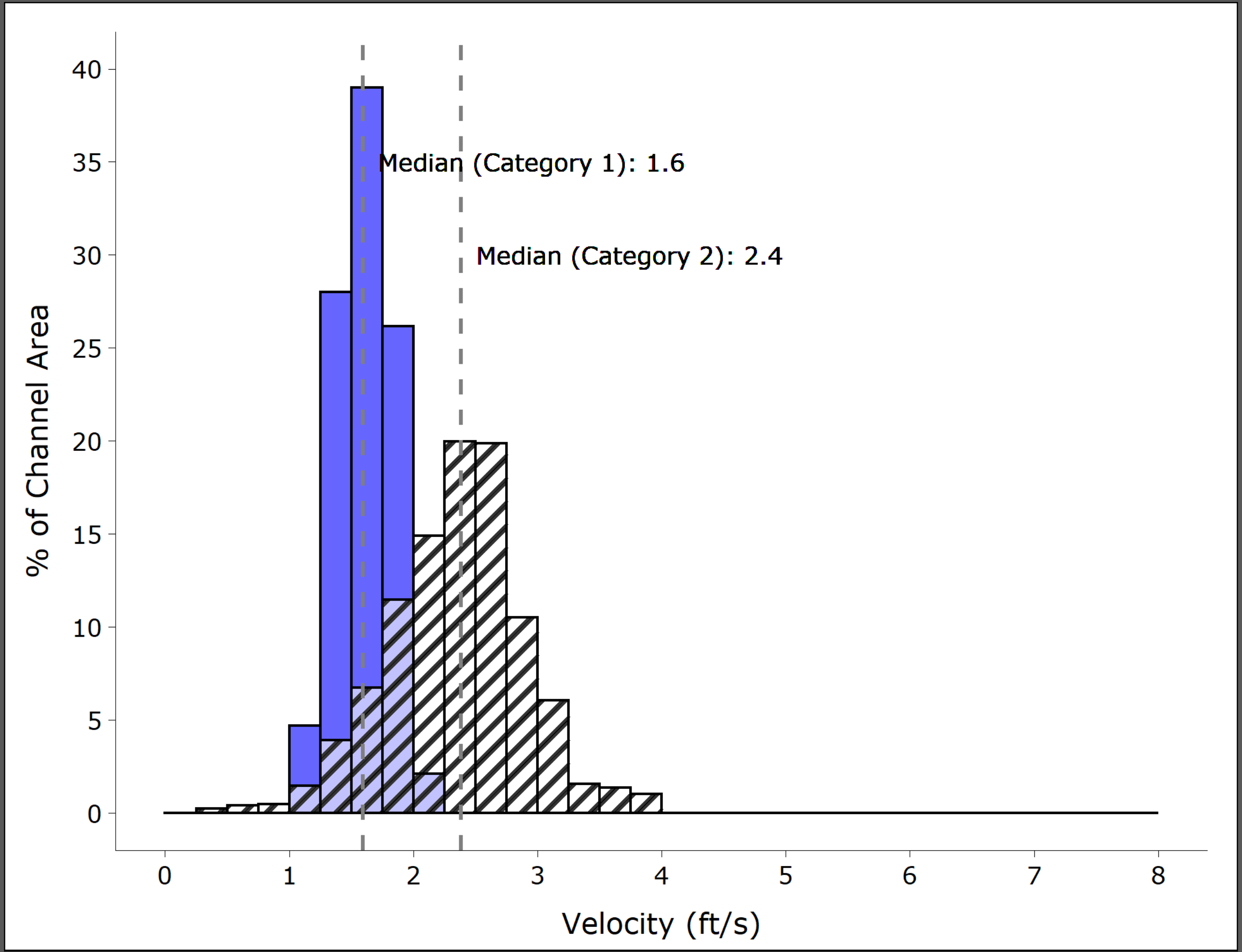
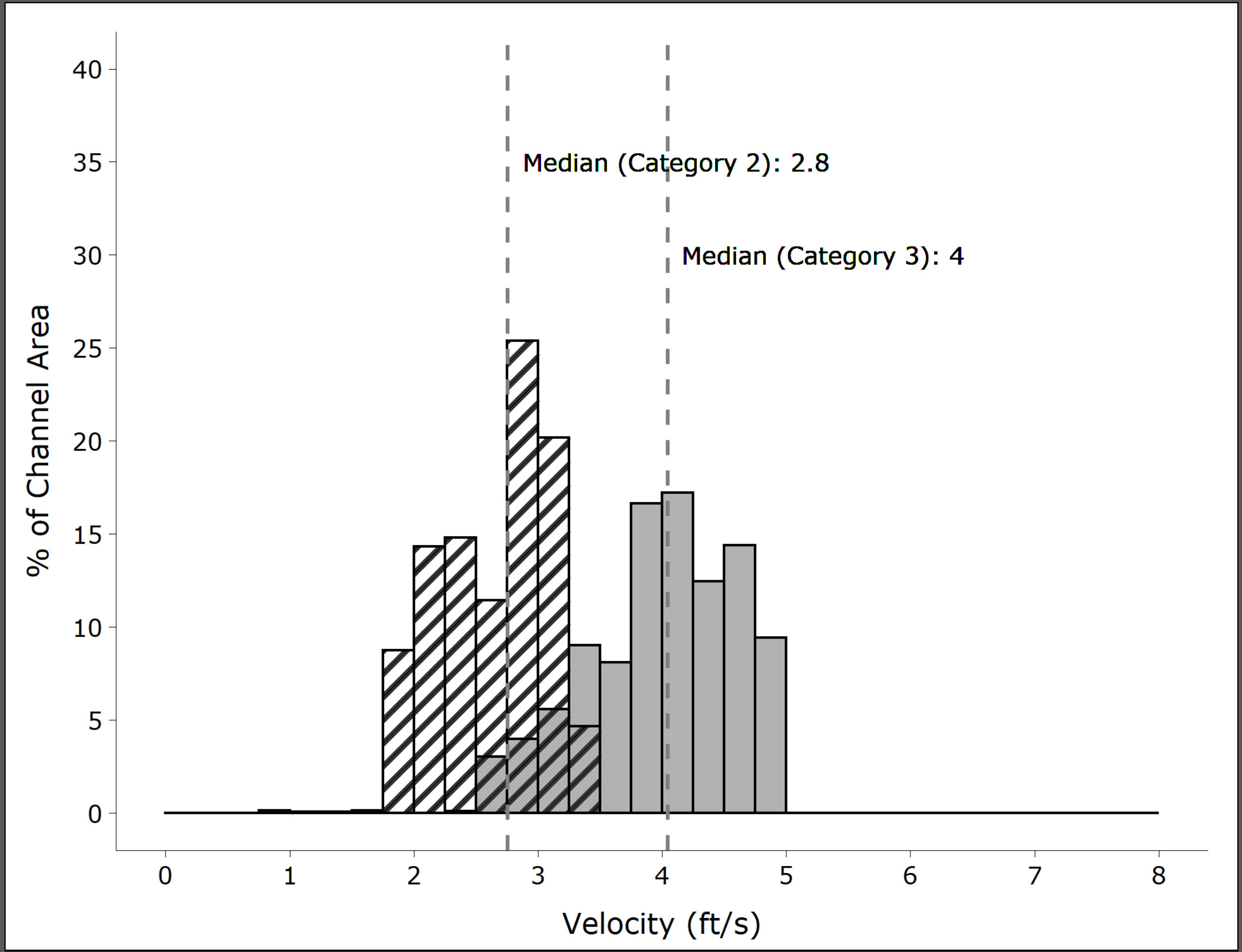
# Channel Bank Damage Classification




Cat Branch




Furnace Creek

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Velocity and Shear Stress Thresholds

*Fischenich, C. (2001). "Stability Thresholds for Stream Restoration Materials," EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-29), U.S. Army Engineer Research and Development Center, Vicksburg, MS.*

**Table 2. Permissible Shear and Velocity for Selected Lining Materials**[1]

| Boundary Category | Boundary Type | Permissible Shear Stress (lb/sq ft) | Permissible Velocity (ft/sec) | Citation(s) |
|---|---|---|---|---|
| Gravel/Cobble | 1-in. | 0.33 | 2.5 – 5 | A |
| | 2-in. | 0.67 | 3 – 6 | A |
| | 6-in. | 2.0 | 4 – 7.5 | A |
| | 12-in. | 4.0 | 5.5 – 12 | A |
| Vegetation | Class A turf | 3.7 | 6 – 8 | E, N |
| | Class B turf | 2.1 | 4 - 7 | E, N |
| | Class C turf | 1.0 | 3.5 | E, N |
| | Long native grasses | 1.2 – 1.7 | 4 – 6 | G, H, L, N |
| | Short native and bunch grass | 0.7 - 0.95 | 3 – 4 | G, H, L, N |
| | Reed plantings | 0.1-0.6 | N/A | E, N |
| | Hardwood tree plantings | 0.41-2.5 | N/A | E, N |
| Riprap | 6 – in. $d_{50}$ | 2.5 | 5 – 10 | H |
| | 9 – in. $d_{50}$ | 3.8 | 7 – 11 | H |
| | 12 – in. $d_{50}$ | 5.1 | 10 – 13 | H |
| | 18 – in. $d_{50}$ | 7.6 | 12 – 16 | H |
| | 24 – in. $d_{50}$ | 10.1 | 14 – 18 | E |

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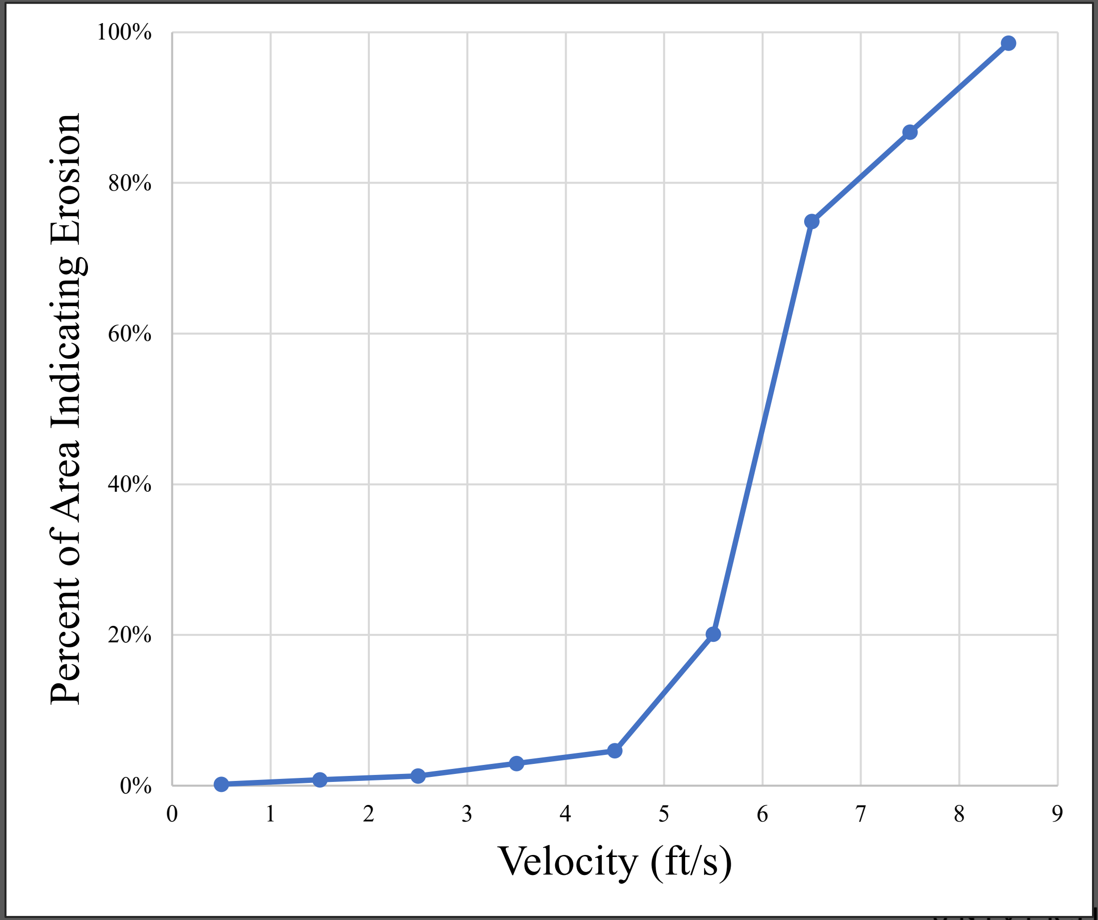
# Similar Results from 2-D Model Study of Site In Daniel Boone National Forest

Noorbakhsh, Fereshteh, "Susceptibility assessment of bank and floodplain erosion in stream restoration using a two-dimensional hydrodynamic." (2020). *Electronic Theses and Dissertations.* Paper 3380.

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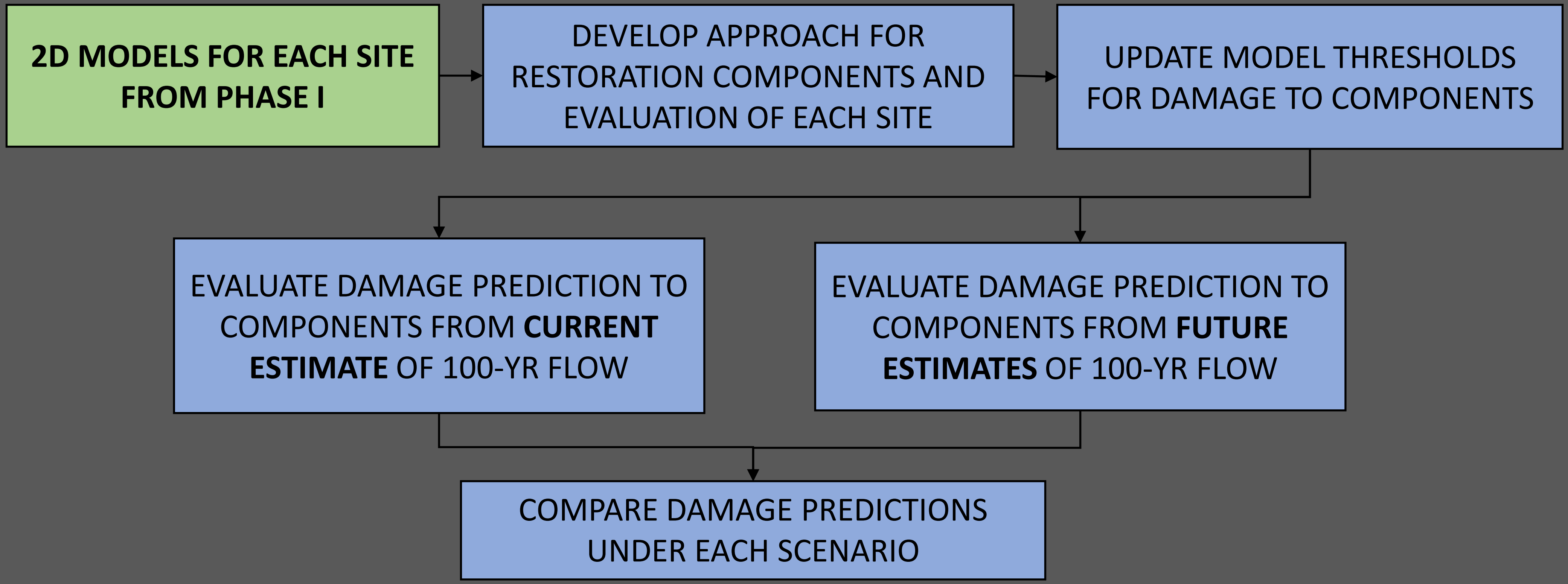
# Phase II: Current and Future Climate Conditions Analysis




## Project Status

**COMPLETED** | **IN PROGRESS** | **NEXT STEPS**

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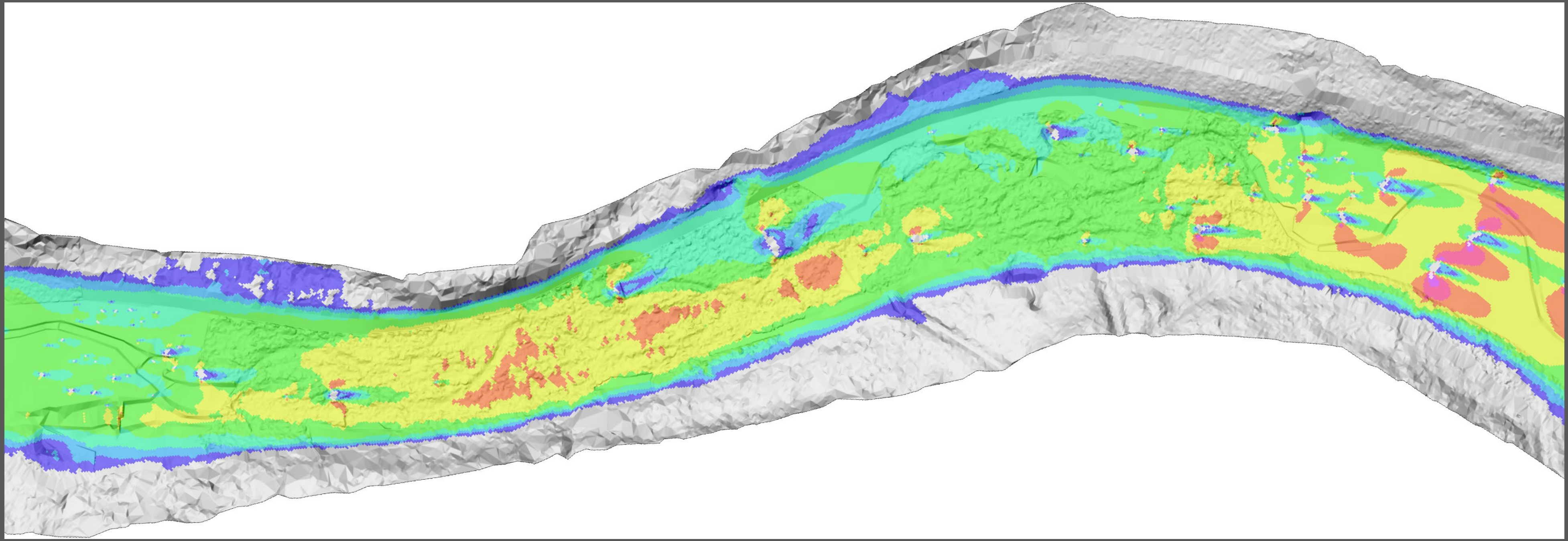
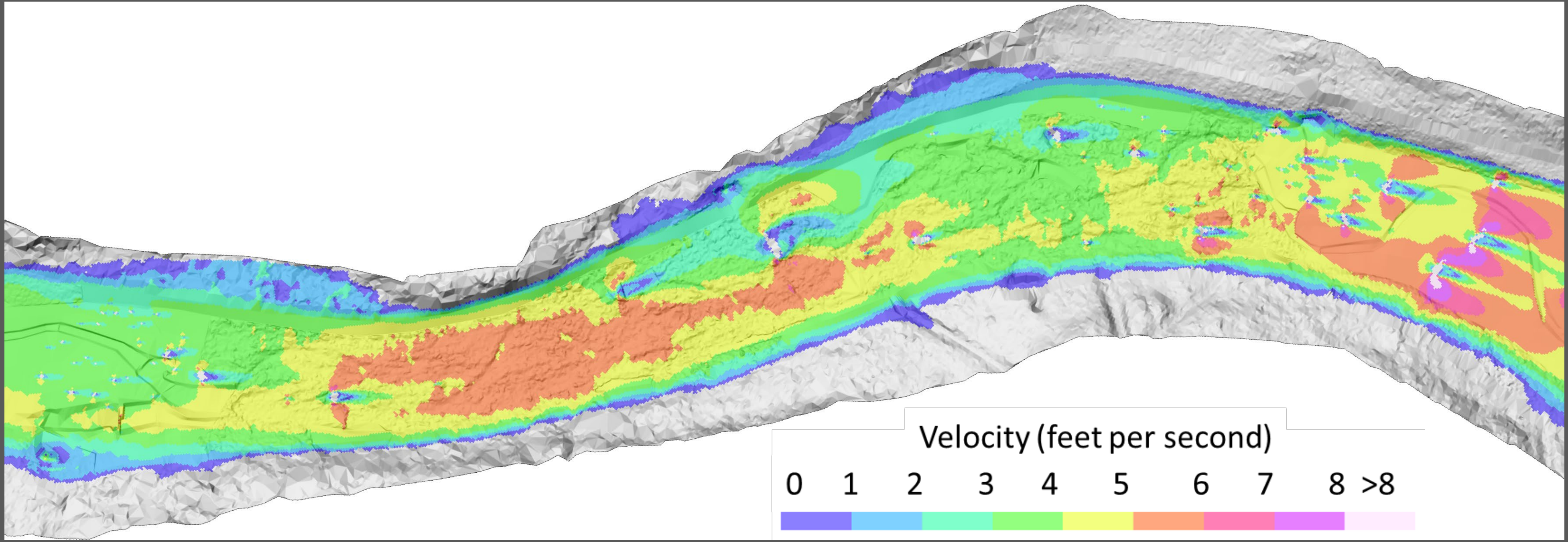


Current Climate

100-yr Event




Climate Change 100-yr Event

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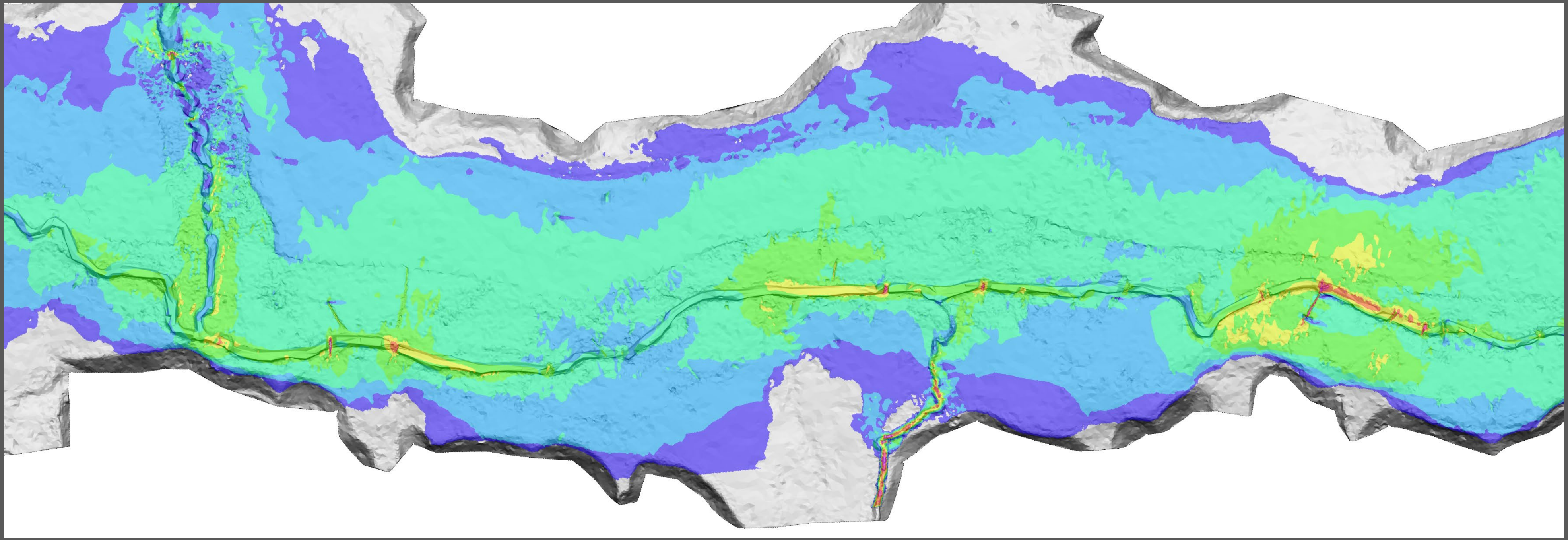
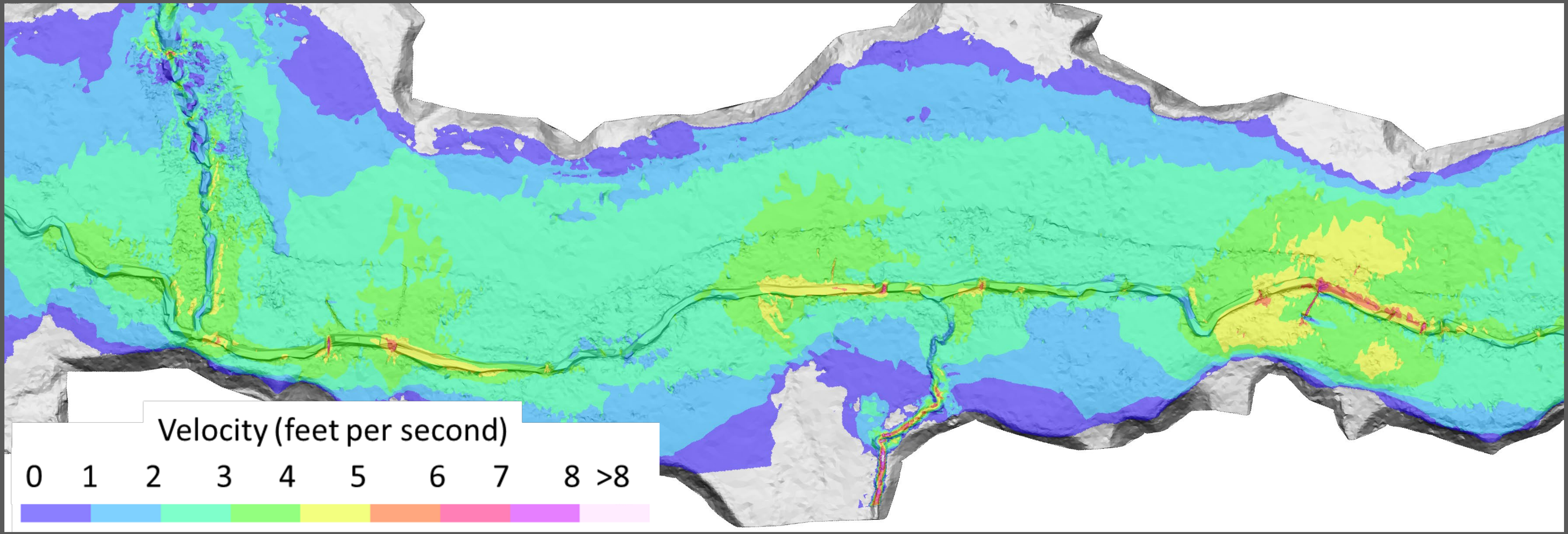


Current Climate

100-yr Event




Climate Change

100-yr Event

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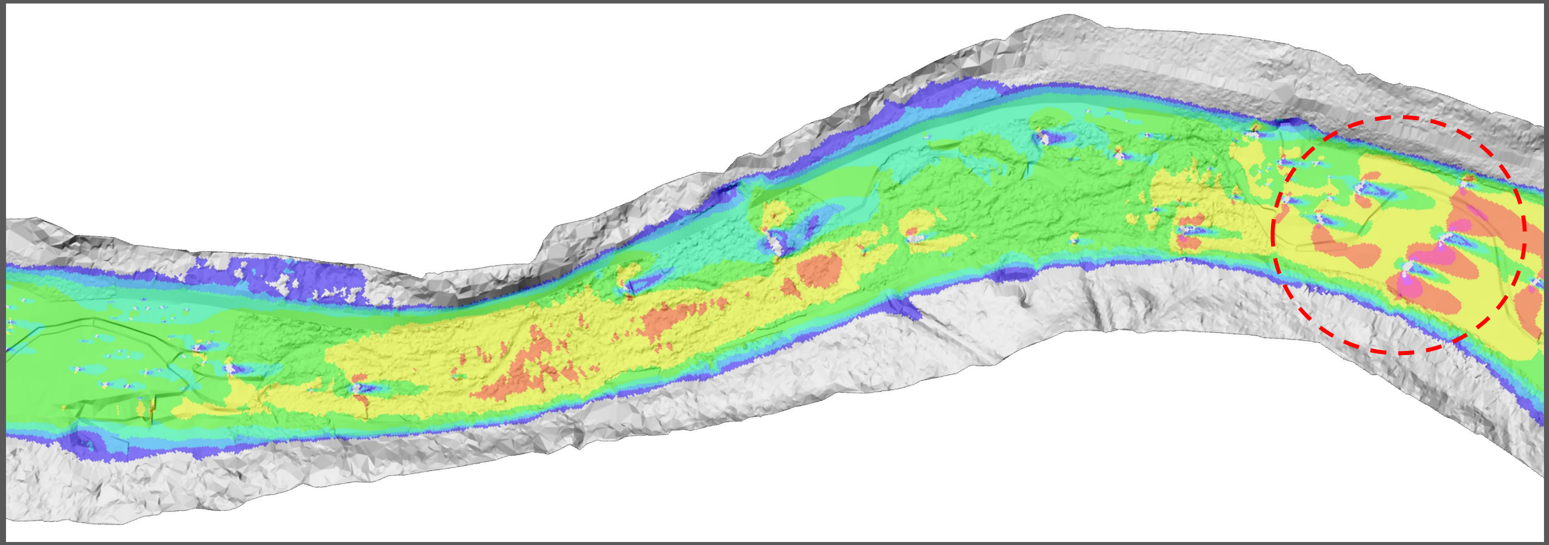
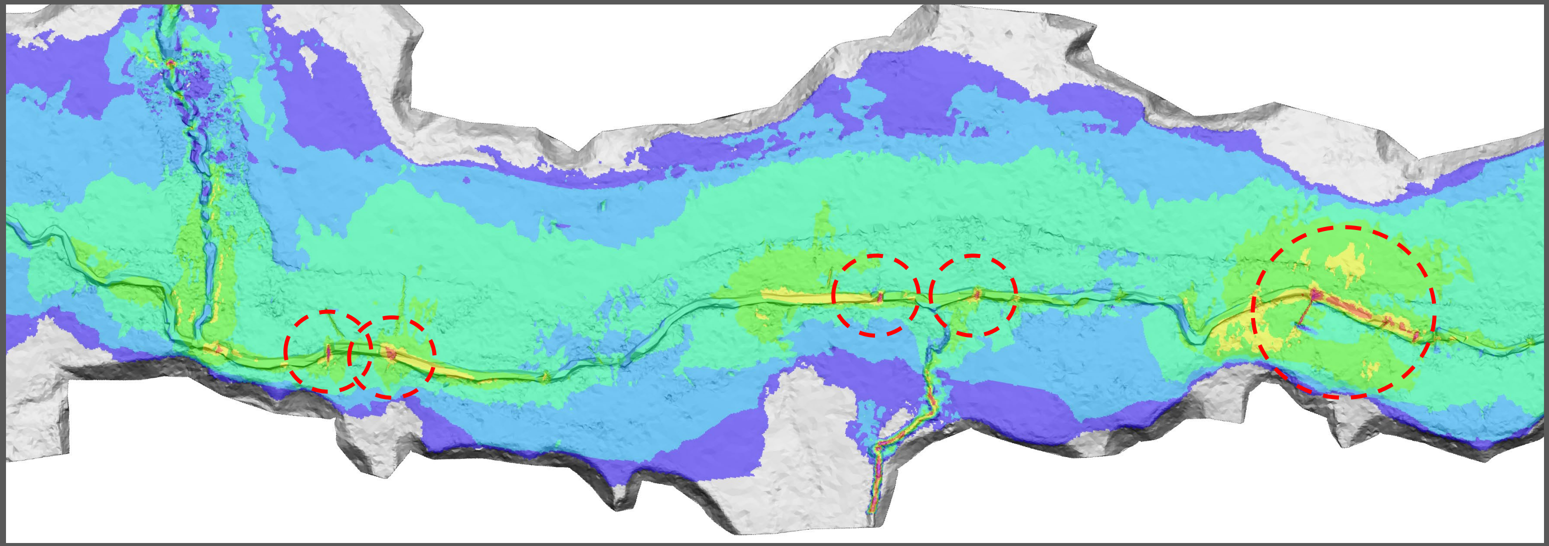
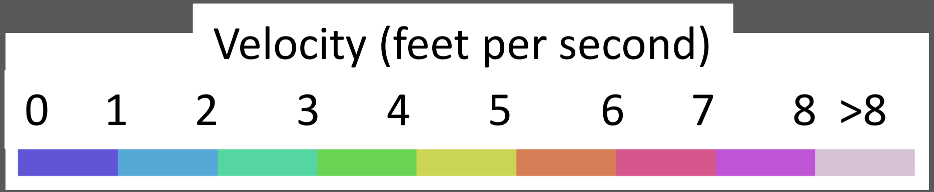
# Understanding vulnerability for changing climate

- Each site is unique, but there are common circumstances which affect vulnerability:
  - “Pinch points” in floodplain or at channel (shown at right, above)
  - Vertical drops (shown at right, below)
  - Where flow is concentrated
- Increased vulnerability due to climate change scenario (100-yr + 30%) is greatest for areas already vulnerable
- Floods conveyed over wide, vegetated floodplains are least vulnerable to increasing flows





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# Preliminary Conclusions

- 2 D models can be used to predict areas of wetland floodplain that **may** be vulnerable to flood damage.

- 2D models can be used to predict where different types of floodplain ecosystems are likely to develop – low-velocity carbon-rich depositional areas to higher stress and potentially eroding channel and floodplain areas.

- 2D models can provide a valuable tool for assessing the potential damage by increased flows associated with climate change.

- Areas most vulnerable to increased flows associated with climate change are
  - Areas that are near threshold conditions under the current climate
  - Pinch points – contraction in the floodplain areas
  - Areas of flow concentrations in and around obstructions
  - Locally steep slopes, such as areas around grade control structures
  - Narrow valley reaches

# Acknowledgements

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Thanks to Sadie and the collaborators who are making this project possible.

**Partners and collaborators:**
MD DOT SHA: Ryan Cole, Nora Bucke, Kevin Wilsey
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Prince Georges County: Joanna Smith, Jerry Maldonado, Mark McKibben, Frank Galosi
Montgomery County: Kenny Mack
SERC: Cynthia Gilmour
Ecotone: Drew Altland, Jason Coleman
Greenvest: Laura Kelm, David Merkey, Dana Cooper, Brett Berkley
Underwood & Associates: Keith Underwood, Chris Becraft, Keith Binsted, Heather Johnson, Beth Zinecker
Tetra Tech: Mark Sievers, Jasmine DunhamTyson
Berrywood Community: Molly LaChapelle, Bob Royer
Arundel Rivers: Jennifer Carr
McCormick Taylor: Scott Lowe
EQR: Katrina Davis

# Dr. Parola – Two-Dimensional Models for Assessing Susceptibility of Stream Restorations to Flood Damage – Translation Slides

Scott Lowe, Erik Michelson

# What does this mean for me?

- As a Practitioner:
  - For floodplain connection or creation, 2D models are vital to evaluate the stability and function of restoration features such as grade controls, habitat, and vegetation
  - Velocity and shear stress thresholds are critical for design decisions, especially those related to native wetland vegetation communities.
  - Models are helpful in evaluating design decisions for wood placement, landscaping, and structure selection
- As a Regulator:
  - 2-D Models allow V and T over 2, 10, and 100 YR Q's to be matched to grading and landscape plans easier
  - Useful for Avoidance and Minimization evaluations
  - Existing Conditions 2-D Modeling would be good to have for field walks

# WATERSHED EFFECTS ON SUCCESS OF STREAM RESTORATION FOR EXCESS NITROGEN MITIGATION

ERICH HESTER[1], DURELLE SCOTT[2], LUKE GOODMAN[2], CARLY FEDERMAN[1], AND NATALIE KRUSE DANIELS[3]

[1]CIVIL AND ENVIRONMENTAL ENGINEERING, VIRGINIA TECH

[2]BIOLOGICAL SYSTEMS ENGINEERING, VIRGINIA TECH

[3]ENVIRONMENTAL STUDIES, OHIO UNIVERSITY


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General Restoration Questions from RFP:

1. What are the cumulative effects of watershed restoration activities within a watershed?
2. What percentage of a catchment needs to be treated…? Does the location of [stream restoration] practices within the catchment make a difference…?

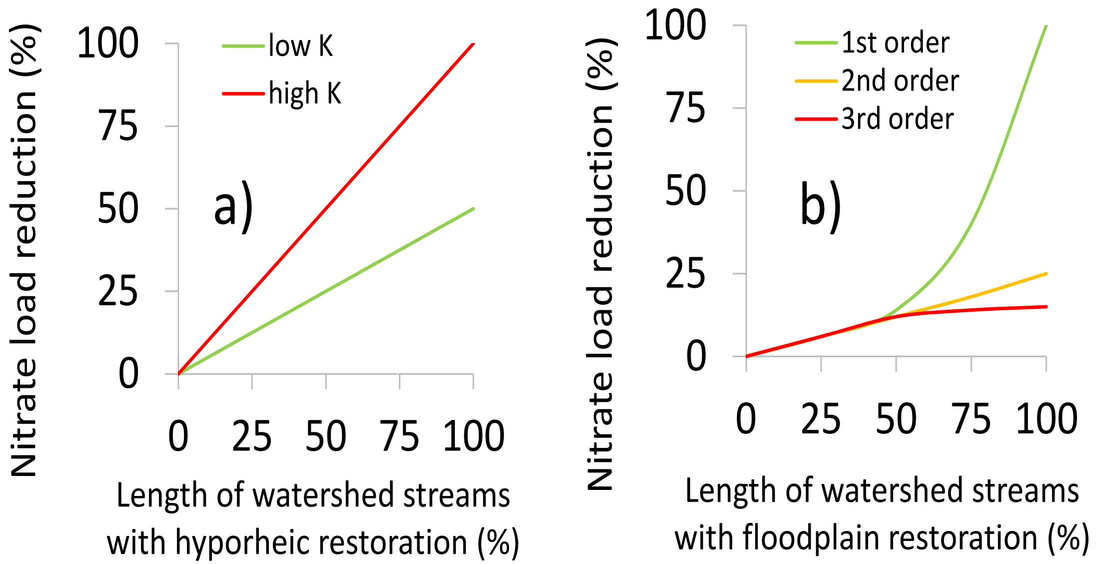
# Research Questions and Hypotheses

**Restoration Questions** from Proposal

1. What is the slope and shape of the relationship between percent of stream network restored and percent nitrate load reduction at the watershed outlet (i.e., linear, exponential, levelling off)?

2. How do the answers to Question #1 above vary with
   - Distribution of nitrate sources in the watershed
   - Restoration technique
   - Restoration location
   - Watershed topography
   - Soil type

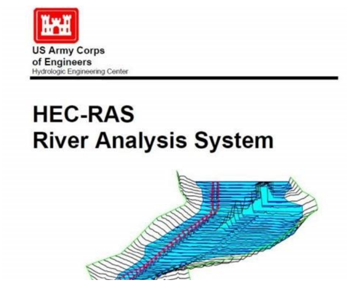
Example Graphic **Hypotheses**



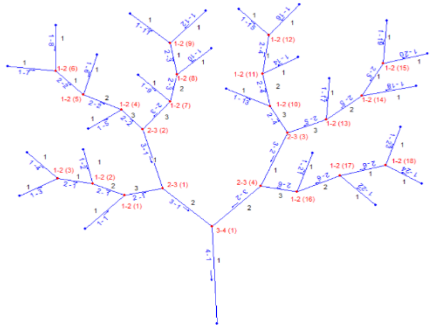
# Project Tasks

**Task 1 (mostly finished)**. Generate literature database of nitrate removal rates.

**Task 2 (finished).** Select model software (1D HEC-RAS w/auxiliary R script).




**Task 3 (partly finished)**. Model generic watershed with literature rates to answer research questions.



**Task 4 (not started).** Model case study watershed to demonstrate applied value.

# Task 1: Nitrate removal database finished, and analysis underway

Database finished

Currently analyzing variation of removal rates with controlling factors

- Restoration status (e.g., restored or not)
- Restoration technique (e.g., channel or floodplain)
- Hydrologic status (baseflow vs stormflow)
- Stream order
- Season
- Sample location (e.g., floodplain or channel)

# Task 3: Simulated flood attenuation from Stage 0/ floodplain restoration in 2$^{nd}$ order channel

Started with:

- 2$^{nd}$-order piece of larger 4$^{th}$ order watershed
- Hydraulics only, effect of restoration on flood wave attenuation

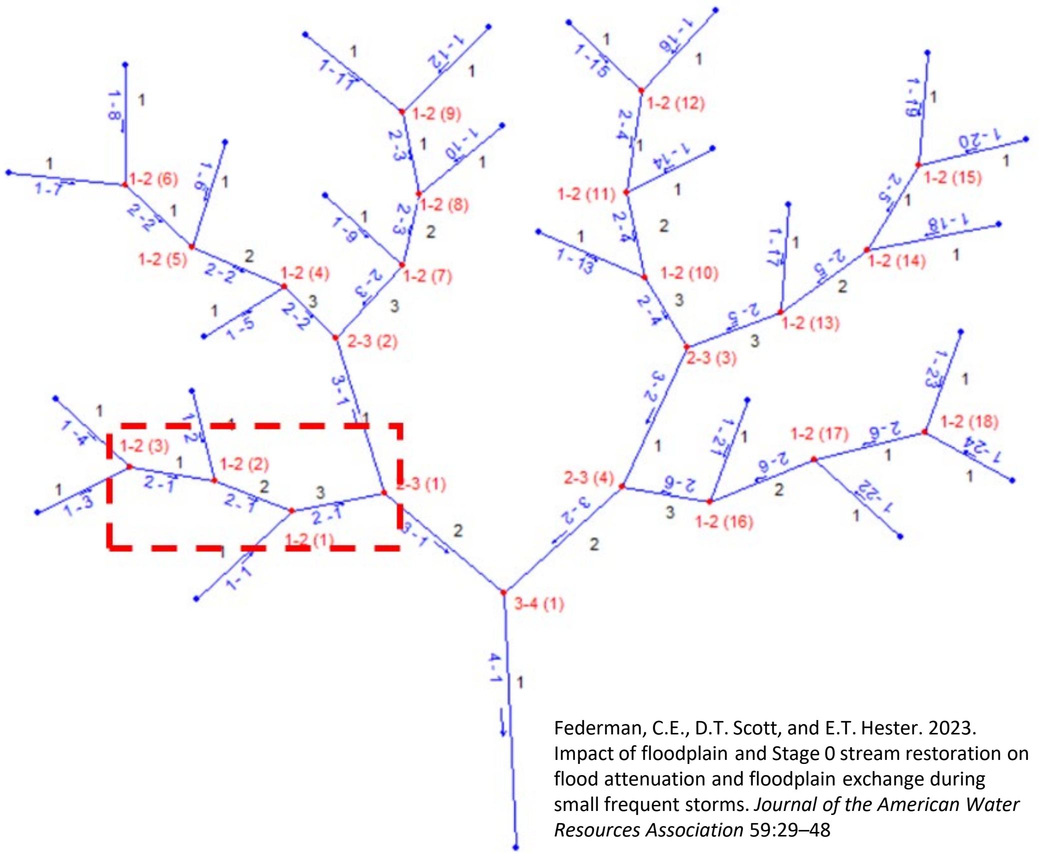
Varied:

- % channel length restored
- Restoration location along channel
- Restored bank height
  - <u>Stage 0: Low bank heights</u> w/frequent floodplain inundation imitating pre-colonization conditions; achieved by legacy sediment removal (LSR) in floodplain or raising the streambed (RSB)
  - <u>Bankfull floodplain restoration: Higher bank</u> heights with floodplain inundation ~1/year
- Restored floodplain width
- Storm size (monthly, 0.5 year, 1 year, and 2 year storms)

Similar study for channel restoration for hyporheic enhancement published earlier

Calfe, M.L., D.T. Scott, Hester, E.T. 2022. Nitrate removal by watershed-scale hyporheic stream restoration: Modeling approach to estimate effects and patterns at the stream network scale. *Ecological Engineering* 175:106498

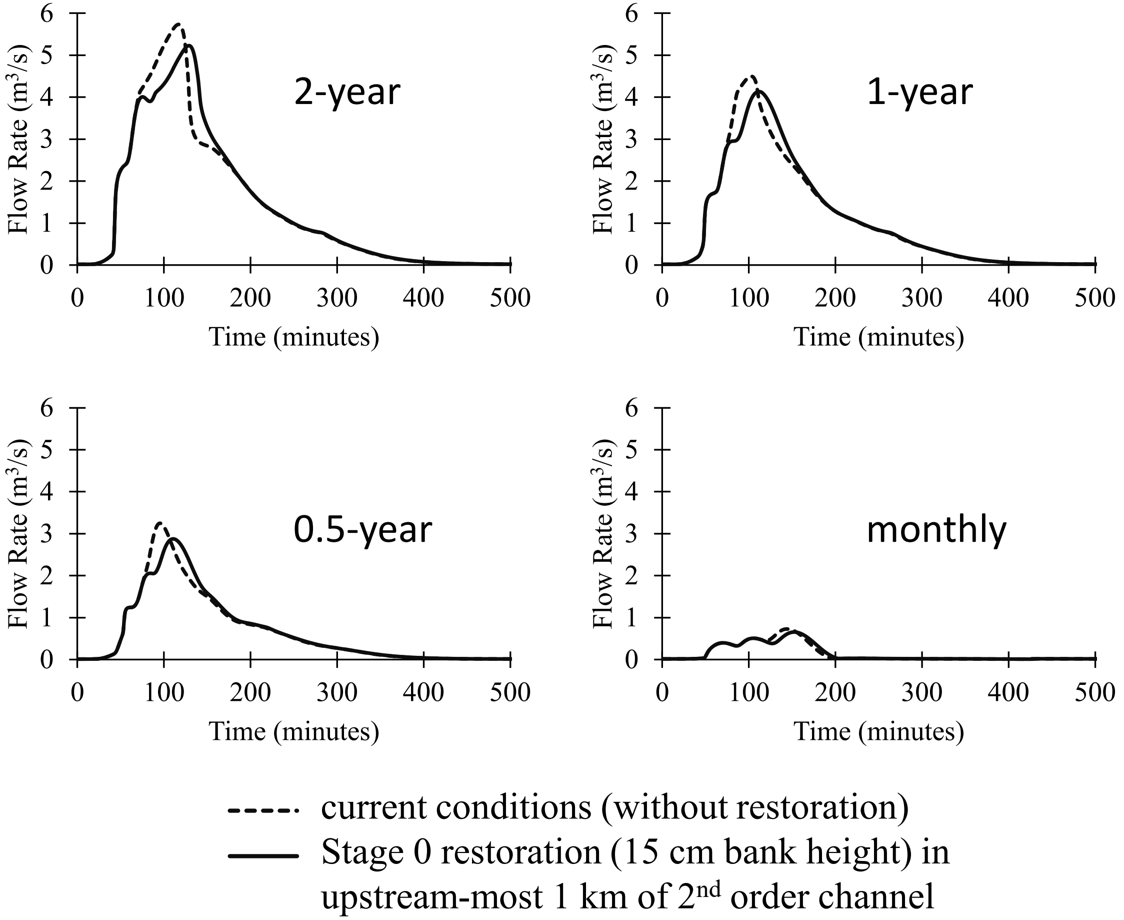
HEC-RAS model channel schematic




Federman, C.E., D.T. Scott, and E.T. Hester. 2023. Impact of floodplain and Stage 0 stream restoration on flood attenuation and floodplain exchange during small frequent storms. *Journal of the American Water Resources Association* 59:29–48

# Task 3: Restoration causes flood attenuation

Flood attenuation = reduced peak flow rate at downstream end of 2nd order channel for restored conditions

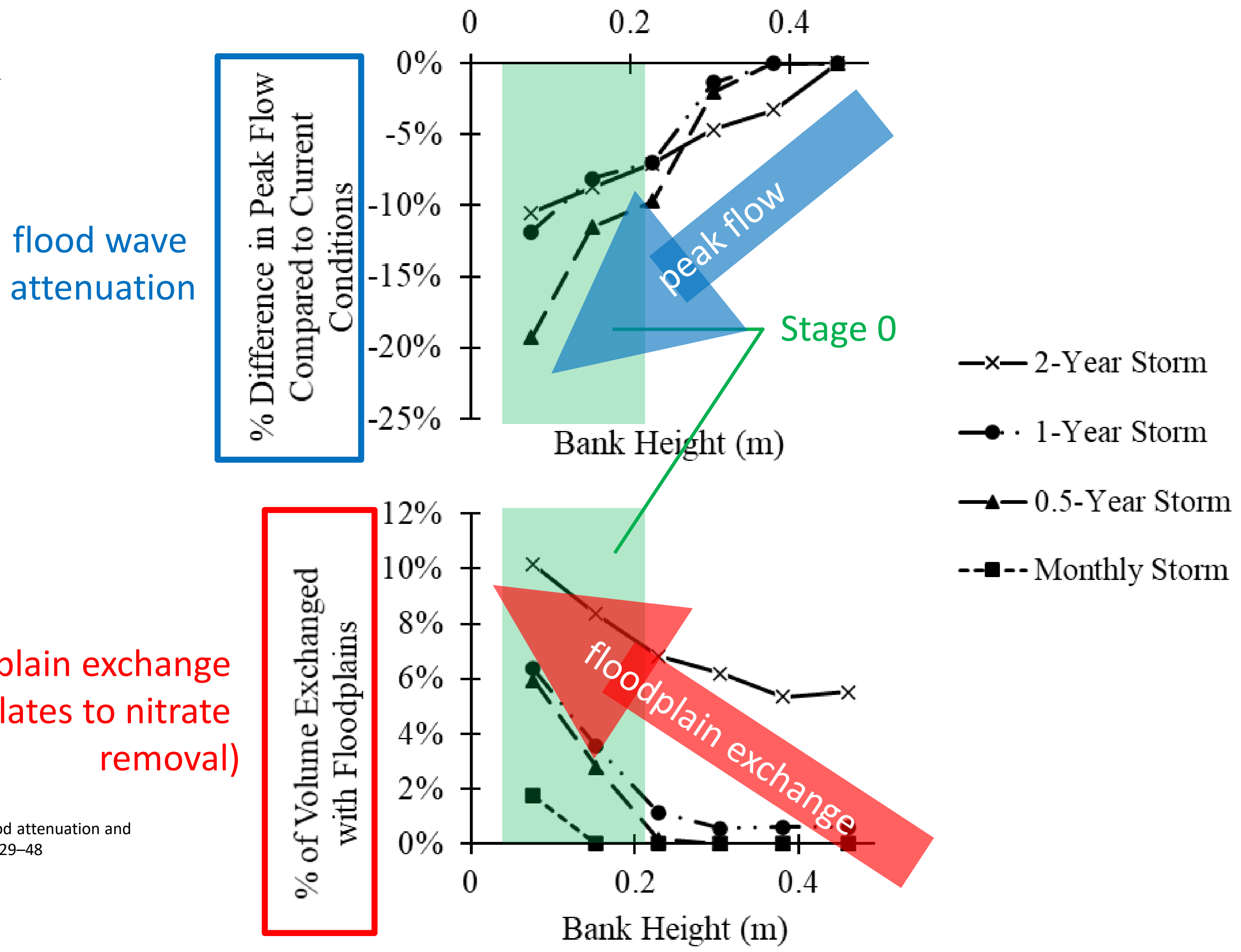



Federman, C.E., D.T. Scott, and E.T. Hester. 2023. Impact of floodplain and Stage 0 stream restoration on flood attenuation and floodplain exchange during small frequent storms. *Journal of the American Water Resources Association* 59:29–48

# Task 3: Project effectiveness varies with restoration technique

Stage 0 (low banks) more effective than high banks (bankfull floodplain)

No tradeoff among restoration benefits; lower banks enhances both flood attenuation and floodplain exchange (water quality)




Federman, C.E., D.T. Scott, and E.T. Hester. 2023. Impact of floodplain and Stage 0 stream restoration on flood attenuation and floodplain exchange during small frequent storms. *Journal of the American Water Resources Association* 59:29–48

# Task 3: Project effectiveness varies with location along channel

Individual projects were more effective if…

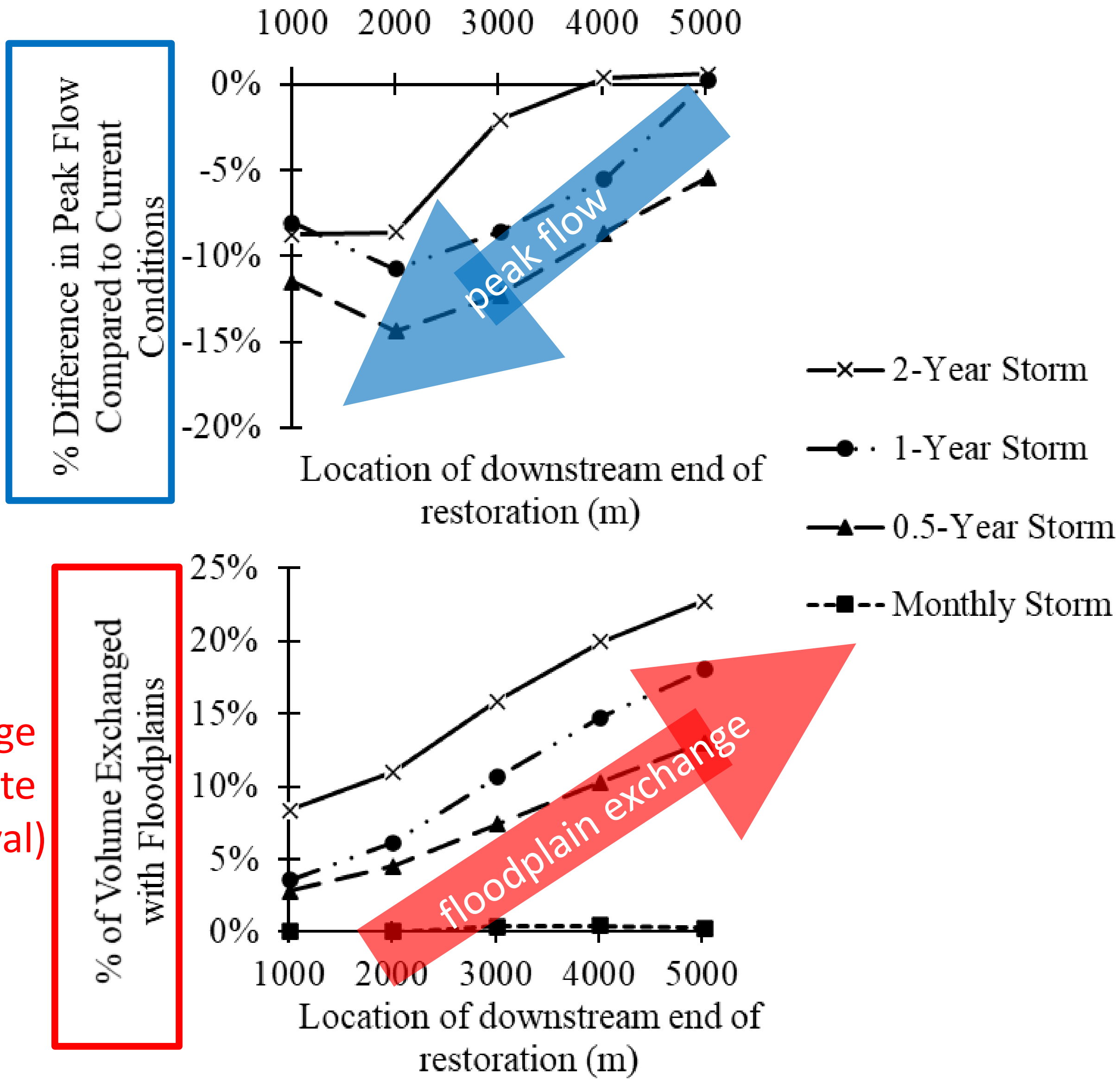
…located upstream along channel (for flood wave attenuation)

…downstream along channel (for floodplain exchange)

Tradeoff between flood attenuation and floodplain exchange

flood wave attenuation

floodplain exchange (relates to nitrate removal)




Federman, C.E., D.T. Scott, and E.T. Hester. 2023. Impact of floodplain and Stage 0 stream restoration on flood attenuation and floodplain exchange during small frequent storms. *Journal of the American Water Resources Association* 59:29–48

# Task 3: Project effectiveness varies with percent of stream network restored

Individual projects were more effective (i.e. greater slope of curve) if…

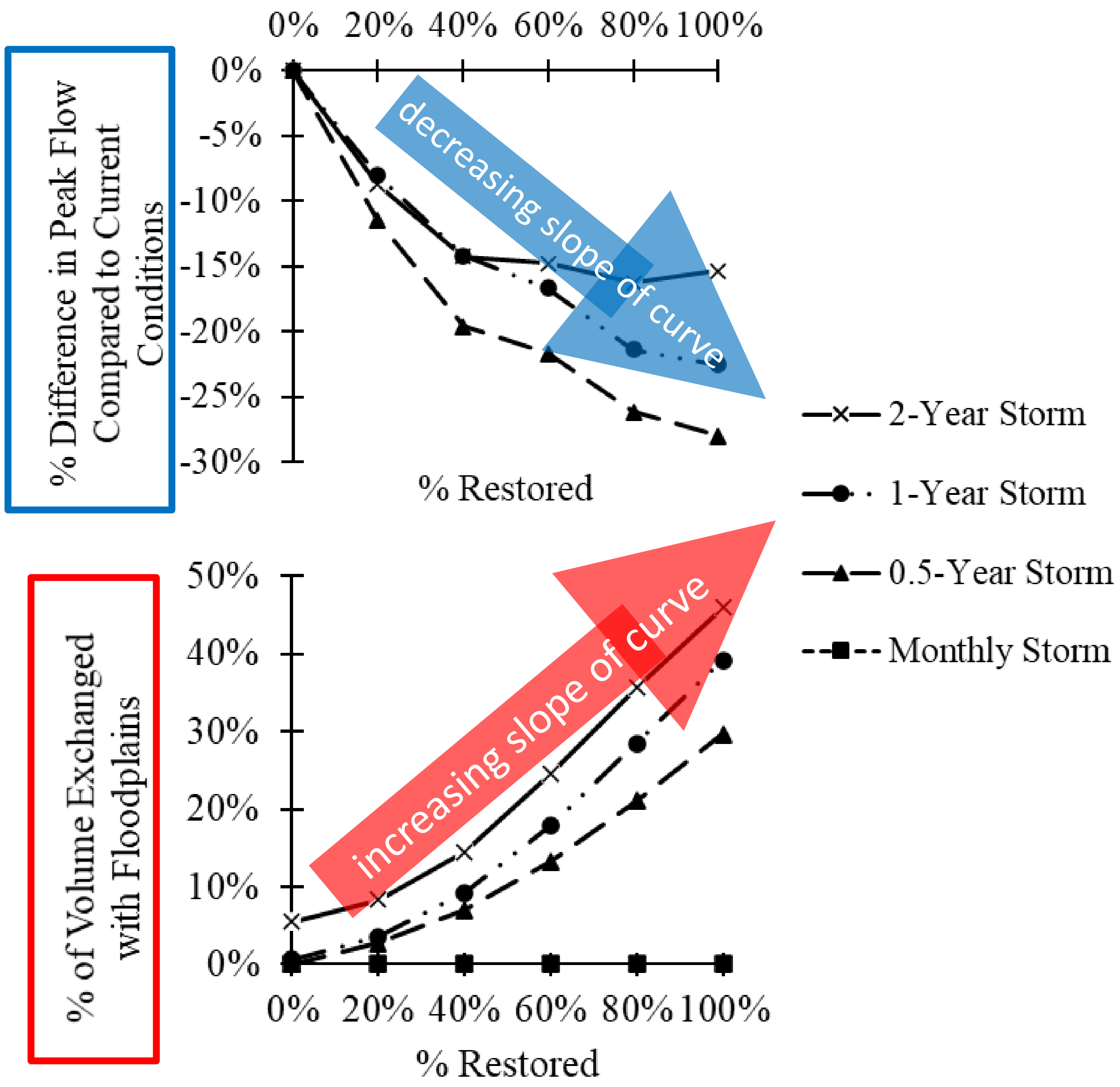
…less prior restoration (for flood wave attenuation)

…more prior restoration (for floodplain exchange)

Tradeoff between flood attenuation and floodplain exchange

flood wave attenuation

floodplain exchange (relates to nitrate removal)

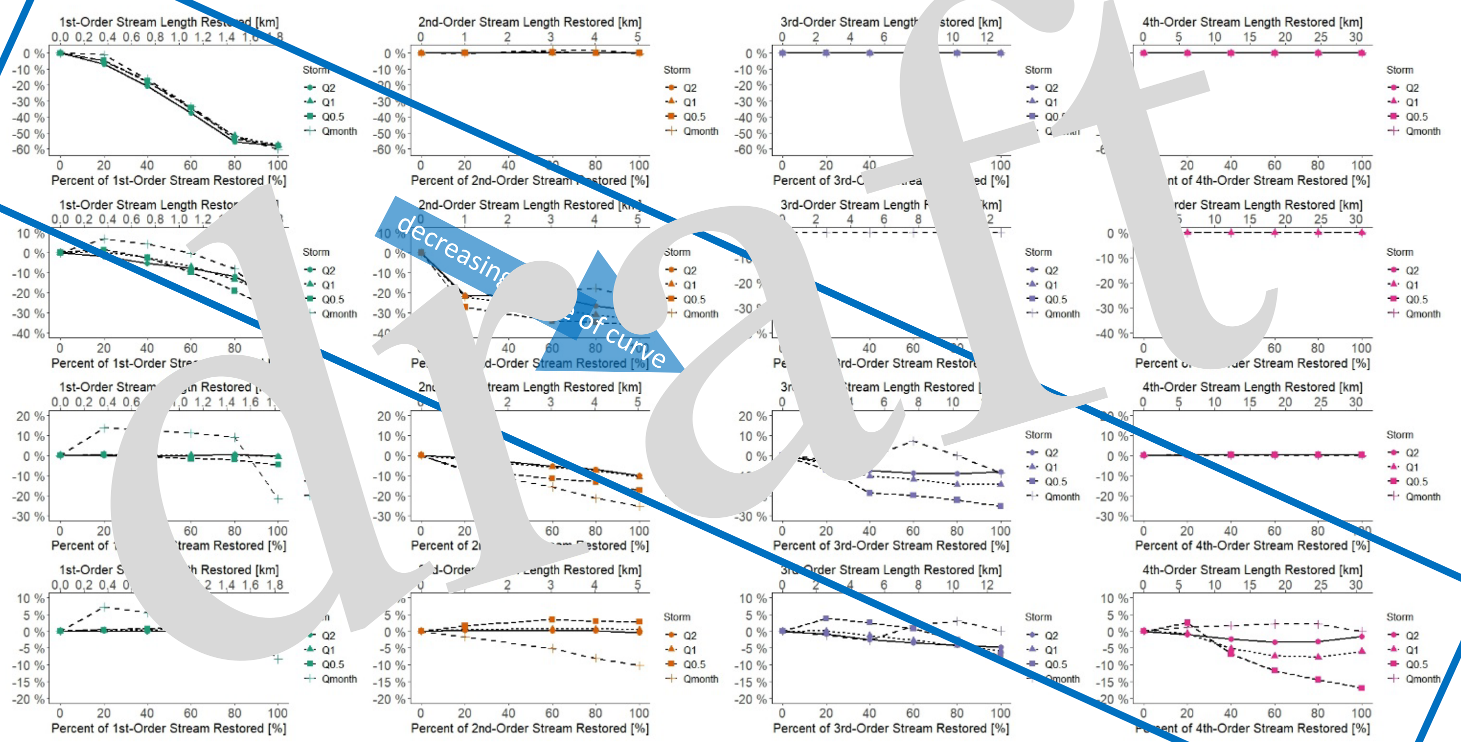



Federman, C.E., D.T. Scott, and E.T. Hester. 2023. Impact of floodplain and Stage 0 stream restoration on flood attenuation and floodplain exchange during small frequent storms. *Journal of the American Water Resources Association* 59:29–48

# Expand storm modeling to 4th order watershed

<u>Preliminary results for flood attenuation</u>

- Answer is more complicated
- Effect greatest at location of restoration
- Diminished effect downstream, no effect upstream
- 2nd order result same as before, but other stream orders different
- Work continues
- Watershed context is critical




Effect of restoration project location (i.e. stream order), percent of prior restoration, and storm size on flood attenuation quantified as percent reduction in peak storm discharge relative to unrestored condition. Rows differ in terms of the location where flood attenuation was quantified (i.e. downstream end of 1st-, 2nd-, 3rd-, and 4th-order channels, respectively.

# From here…

Task 1: Finish analyzing variation of rates, use in Task 3 and 4 models

Task 3: Add nitrate transport/removal

Task 4: Select and model case study watershed

Studies already published:

Calfe, M.L., D.T. Scott, and E.T. Hester. 2022. Nitrate removal by watershed-scale hyporheic stream restoration: Modeling approach to estimate effects and patterns at the stream network scale. *Ecological Engineering* 175:106498

Federman, C.E., D.T. Scott, and E.T. Hester. 2023. Impact of floodplain and Stage 0 stream restoration on flood attenuation and floodplain exchange during small frequent storms. *Journal of the American Water Resources Association* 59:29–48

# Thank you

The Chesapeake Bay Trust and partners the Maryland Department of Natural Resources, the National Fish and Wildlife Foundation through the Environmental Protection Agency's Chesapeake Bay Program Office, the Maryland Department of Transportation State Highway Administration, and the Montgomery County Department of Environmental Protection

Charles E. Via Endowment at Virginia Tech

# Translation Slides

## What are the take home points?
## What does this mean for me?

TRANSLATION SLIDES BY SHANNON MCKENRICK

MARYLAND DEPT. OF THE ENVIRONMENT

WATERSHED PROTECTION, RESTORATION, AND PLANNING PROGRAM

# What does this mean for me?

- Nitrate removal database presents a valuable dataset for evaluating stream restoration effectiveness at varying scales and considering design context
- There are tradeoffs between individual project effectiveness and collective watershed restoration water quality outcomes
- Project location and restoration activity impact on nitrate removal – spatial component to restoration activities

# What does this mean for me?

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

- All eyes on restoration technique and location – picking the best technique for the location
- Incorporating watershed context during the design process (depending on desired outcome – upstream for flood attenuation, downstream for floodplain exchange?)
- Managing expectations for design results – outcomes are dependent on design type, location related to channel, location within watershed, stream order, etc.

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

- How do we incorporate *watershed context* into the regulatory process?
- How do we evaluate projects while taking into account cumulative watershed restoration impacts?
- What types of project design information and personnel expertise to we need to examine designs using a more holistic approach?

# Climate Impacts to Restoration Practices

Restoration Research Question B.4 (Grant # 19278)

Chesapeake Bay Trust Pooled Monitoring Forum

June 21, 2023

TETRA TECH

Jon Butcher, Tetra Tech,

In conjunction with:

Dr. David Sample, Dr. Tess Thompson, Sami Towsif Khan, Virginia Tech

VIRGINIA TECH

# Prior work under Grant #16928 (2019-2021)

- Developed methods and estimated future climate-modified intensity-duration-frequency (IDF) curves for all MD NOAA Atlas 14 stations
- Evaluated impacts on infrastructure, BMPs, channel restoration stability
- Conclusions
  - Infrastructure such as road culverts likely inadequate to address future large storm events
  - Risk to channel stability will increase, should be a factor in restoration design
  - Smaller storms (e.g., current 90$^{th}$ percentile event will likely not increase in frequency; Environmental Site Design adequate to address future water quality
- Caveats:
  - Results depend on downscaled climate product (LOCA)
  - Analyses based on design storms may not reflect responses of real streams

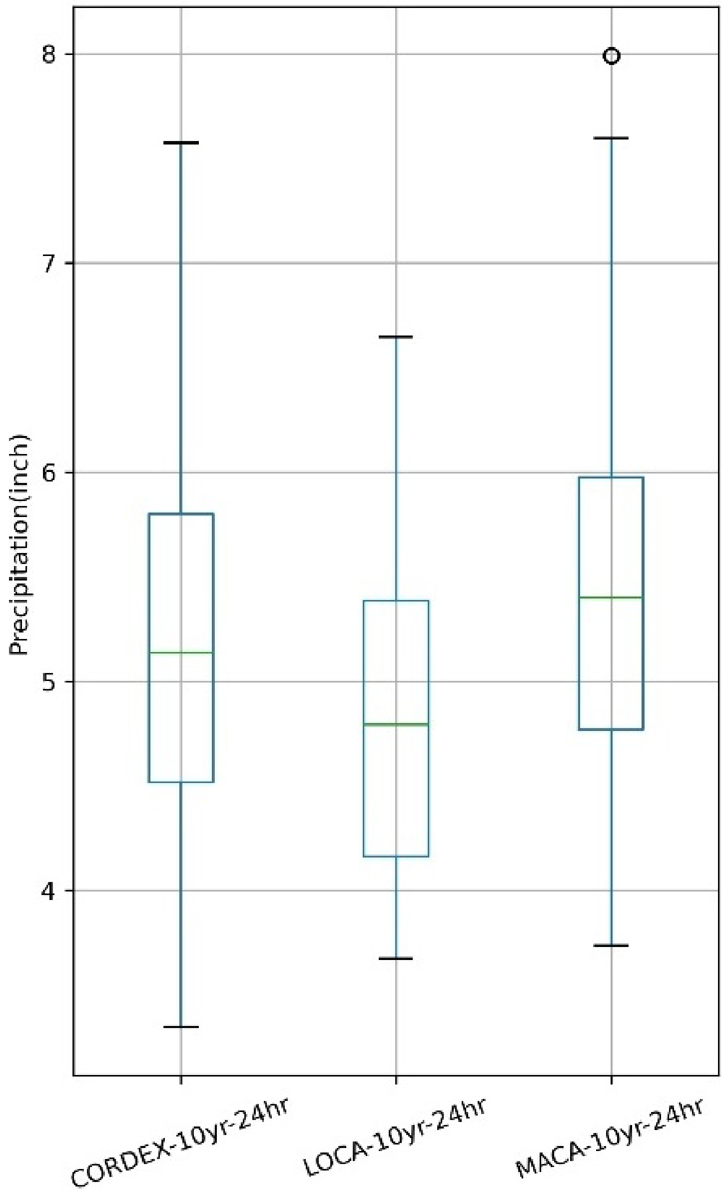
# Hypotheses for Grant 19278:

- **H1**. Downscaling methodology introduces biases
- **H2**. Current Environmental Site Design (ESD) requirements will be sufficient to meet management objectives under future climate
- **H3.** Conclusions will hold up under continuous simulation of real watersheds

*Results for H1 and H2 presented last year are summarized here. H3 is addressed in Dr. Thompson's presentation this afternoon.*

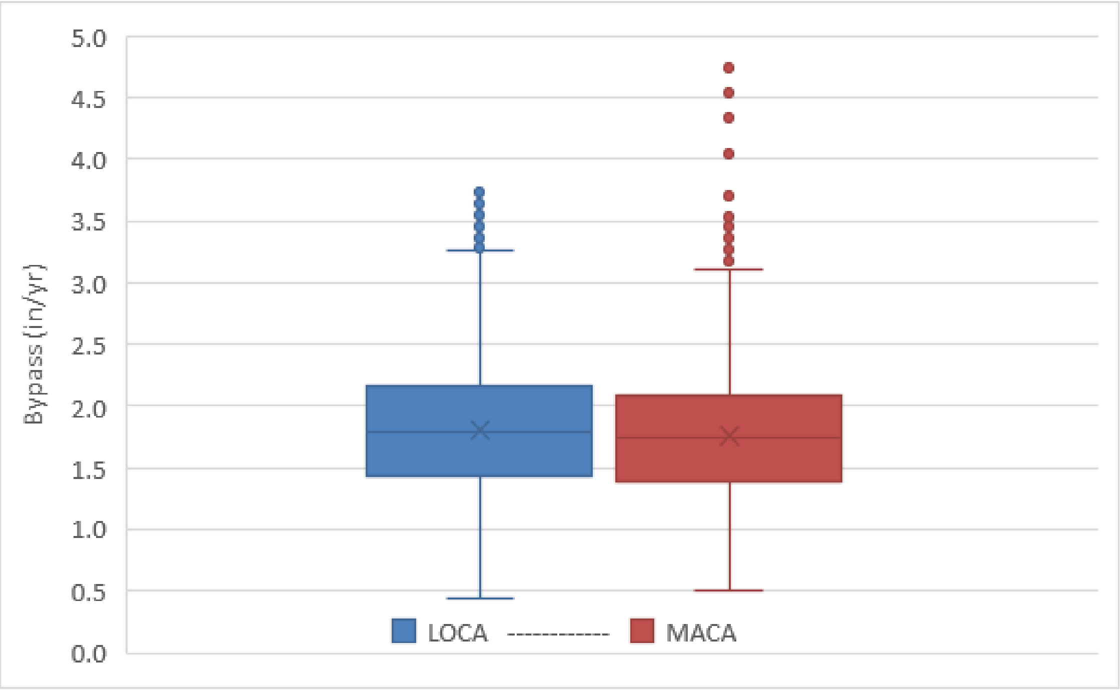
# (H1) Downscaling method <u>does</u> introduce biases, especially for extreme events

- Compared IDF results based on LOCA and MACA statistical downscaling and CORDEX dynamical downscaling
- On average, MACA > CORDEX > LOCA
- NA-CORDEX (dynamical) results change with spatial resolution



# (H2) ESD is likely to continue to meet goals of controlling runoff from smaller events

- ESD focus is on control of 1-yr and 90th percentile 24-hr storms; both LOCA and MACA suggest relatively small changes in that event
- Compare amount of flow from 90%le storm bypassing bioretention designed to ESD standards for 2070-2100 conditions at all MD Atlas 14 stations




Results are for HSG C soils, 50% impervious cover

# (H3) What might happen in the real world?

- ESD is a simplified approach to incorporate water quality controls and maintain hydrology approximating natural conditions for specific high recurrence events
- Channel stability in real streams will depend on the sub-daily sequence of flows and stresses exerted over long periods of time – not just IDF relationships
- Focus here on how to create such time series for future climate conditions
- Results of simulation are in Dr. Thompson’s presentation later today

# Constructing Future Climate Timeseries

- Channel stability analysis requires sub-daily flows at local scale
- Statistical downscaling products (LOCA, MACA) provide daily precipitation at ~5 km scale calibrated to point data
- Dynamical downscaling available through NA-CORDEX distributed at daily time step although shorter intervals (1 – 6 hr) are available on request. Results are spatial averages at 22 or 44 km scale
- IDF relationships summarize cumulative precipitation of a given duration and recurrence, not sequence within events. Future IDFs may be point gauge-based (depending on how derived).

# Continuous Timeseries from Downscaled Climate Projections

- Even the ~5 km scale of statistically downscaled climate products may not be representative of local precipitation event intensities
- Can correct for bias relative to an observed point-gauge sub-daily timeseries (e.g., 5-min) by applying empirical quantile mapping (eQM)
- eQM maps the change from historical to future conditions suggested by the downscaled GCM models to the cumulative distribution function of the historical observed data
- See general method implemented at svn.oss.deltares.nl/repos/openearthtools/trunk/python/applications/hydrotools/hydrotools/statistics/bias_correction.py

# Continuous Timeseries from Downscaled Climate Projections

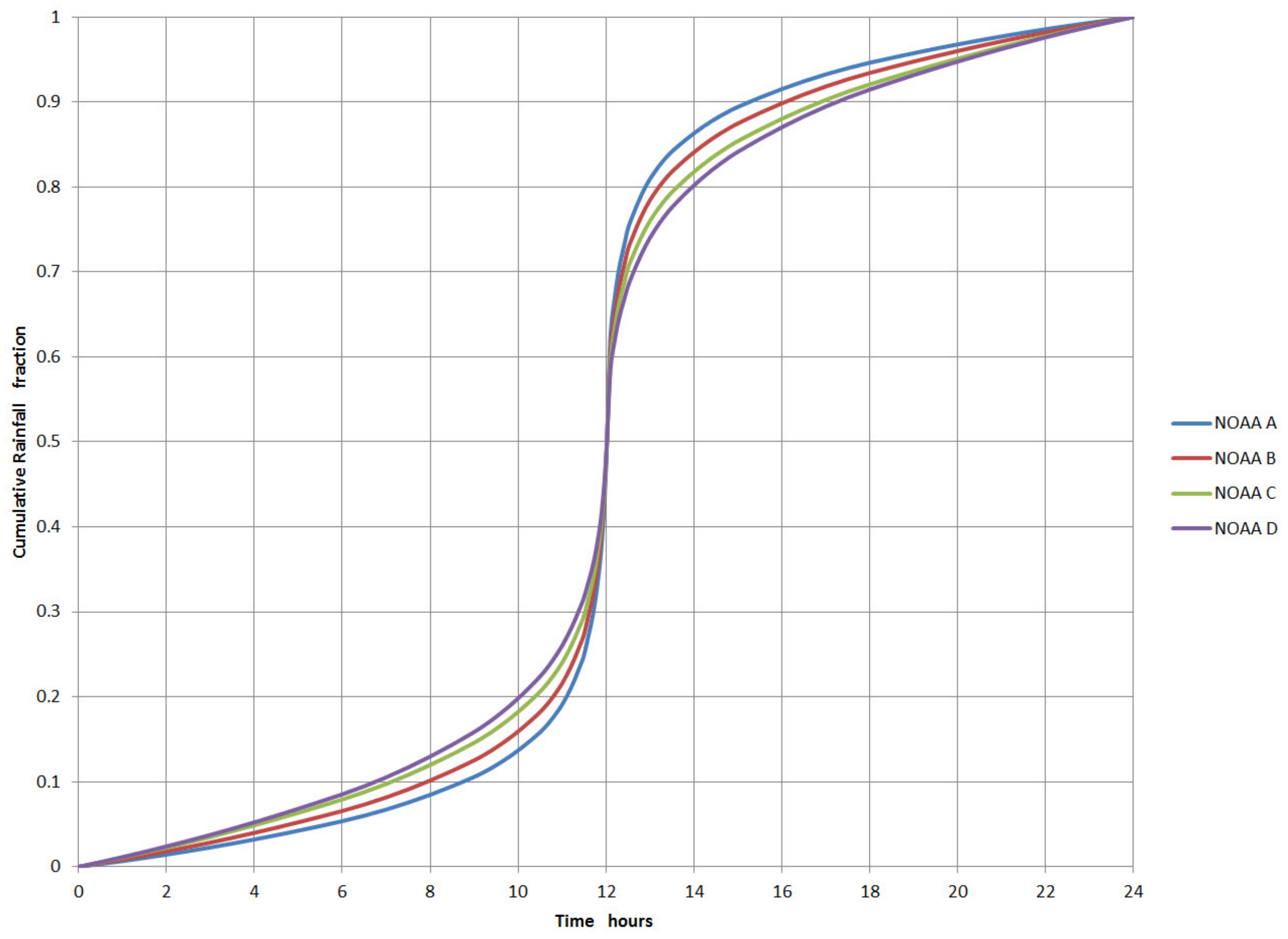
- Options for conversion from daily to sub-hourly time step

1. NRCS Design Storm approach
   - For each day with precipitation assign the sub-hourly distribution based on the cumulative precipitation curve as on previous slide
2. Constructed analog approach
   - Find a "similar" day in the historical record of sub-hourly data
   - Distribute the daily total according to that pattern
3. Fractal scaling
   - Assume the sub-daily pattern within rainfall events is self-similar to the pattern between daily and multi-day rainfall

❖ Many other approaches proposed

# Timeseries from IDF Results

- Traditionally apply SCS design storm to distribute cumulative results
- This is an "alternating blocks" method in which the estimated recurrence for each duration is nested within the same recurrence for the next longer duration – i.e., the 5-minute 10-yr total falls within the 10-minute 10-yr total
- NRCS EFH-2 recalculated cumulants from Atlas 14 – can apply same approach to estimated future IDF curves



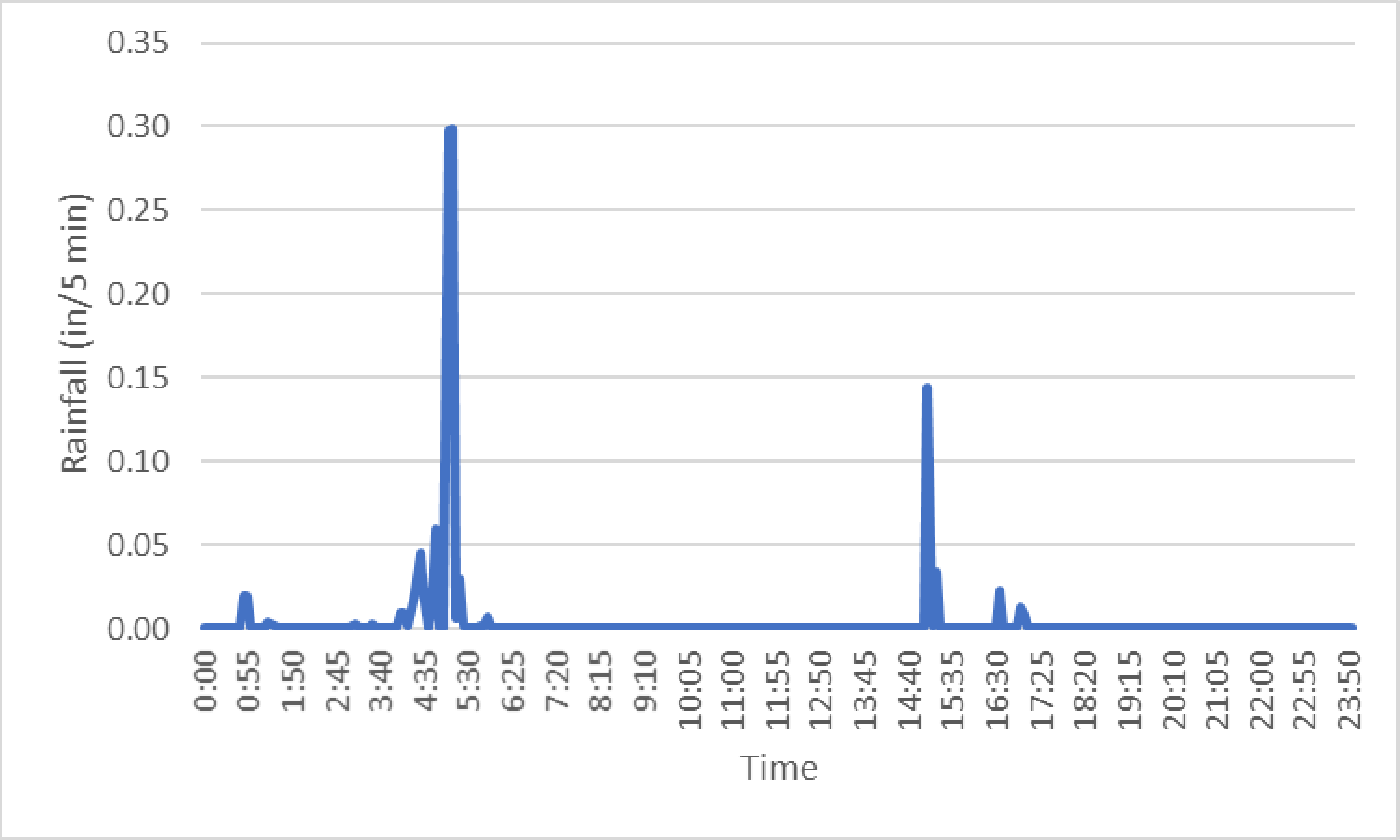

Maryland is Type C curve for Atlas 14 Volume 2

Figure from W.H. Merkel et al., 2017, Design Rainfall Distributions Based on NOAA Atlas 14 Rainfall Depths and Durations, https://acwi.gov/sos/pubs/3rdJFIC/Contents/1F-Merkel.pdf

# Fractal Scaling

- Most efficient method to yield plausible daily series
- Uses a random multiplicative cascade approach based on log Poisson distribution with intermittency factor
- Created 104 series spanning 1950-2100
- Full description and Python code provided in project deliverables

Example 1.12 inch (24-hr) precipitation of 7/13/2040 downscaled to 5-minute intervals for Montgomery CO., MD from bcc-csm-1-1 GCM



# Summary

Downscaling methods concur in predicting increases in extreme events; smaller changes in more common events

Maryland ESD is likely robust against predicted changes, but this may not be sufficient to maintain channel stability

Downscaling method does affect results, with intensities on average MACA > CORDEX > LOCA

Methods are provided to convert both IDF and continuous timeseries of future climate to model-ready sub-daily time steps.

Statistically downscaled products are prone to producing occasional extreme precipitation results that are not physically realistic

TETRA TECH

VIRGINIA TECH

# Acknowledgment Slide


- We thank the many partners who support the Restoration Research program for their funding and interest. Major funding for this phase of the work was provided by the U.S. Environmental Protection Agency.

# Translation Slides

What are the take home points?
What does this mean for me?

Translation Slides by Guido Yactayo

# What does this mean for me?

- Stormwater modeling can provide an accurate depiction of how climate change could affect stream channel stability, and these analyses require the creation of future climate patterns
- Creating future climate information is challenging and currently methods are being designed and compared, and strengths and weaknesses of these methods tested and evaluated

# What does this mean for me?

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

- It is important that methods on how to create future climate time-series are being developed, we'll need to incorporate these future climate patterns to our existing water quality models for scenario development
- Are there any other climate variable that needs to be included in the analysis? For example, does this analysis framework need to also include air temperature and solar radiation?

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

- MDE's plans to update stormwater management regulations.
- Incorporate resilient design to restoration projects to minimize risk in vulnerable communities.

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# A Power Analysis Tool in R to Enhance Monitoring Studies

## *Restoration Research Question*
## *What are the cumulative effects of watershed restoration activities within a watershed?*

Dong Liang, Associate Research Professor
Solange Filoso, Associate Research Professor
Lora Harris, Professor
Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science

Joshua Thompson, Senior Engineer
Watershed Protection & Restoration Program, Anne Arundel County Department of Public Works

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# What do we mean by monitoring?

- Monitoring means different things
  - Part of a hypothesis driven research project.
  - Requirement on a project, e.g. stream restoration.
  - Requirement for the MS4 permit.
- Monitoring designs
  - Paired watershed with control.
    - Combining these “one site monitoring” over time
  - Single watershed without control.
    - Monitoring for a long time.

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# Research effort: Optimizing Water Quality Monitoring

- Restoration Research Awards:
  - 13973: UMCES
  - 16925: Exponent
  - 20582: UMCES
- STAC 2023 Workshop

  *The State of the Science and Practice of Stream Restoration in the Chesapeake: Lessons Learned to Inform Better Implementation, Assessment and Outcome*

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Chesapeake Biological Laboratory

# Project #13973 Objectives

- What is the optimal temporal frequency for sampling of pollutant loads within a watershed?
  - Assessed using high quality SERC weekly composite sampling data
- What is the optimal spatial design and scale of monitoring to detect a signal in water quality improvement within a watershed?
  - Leveraging Baltimore LTER data and Bayesian statistical tools to evaluate spatiotemporal sampling frequencies

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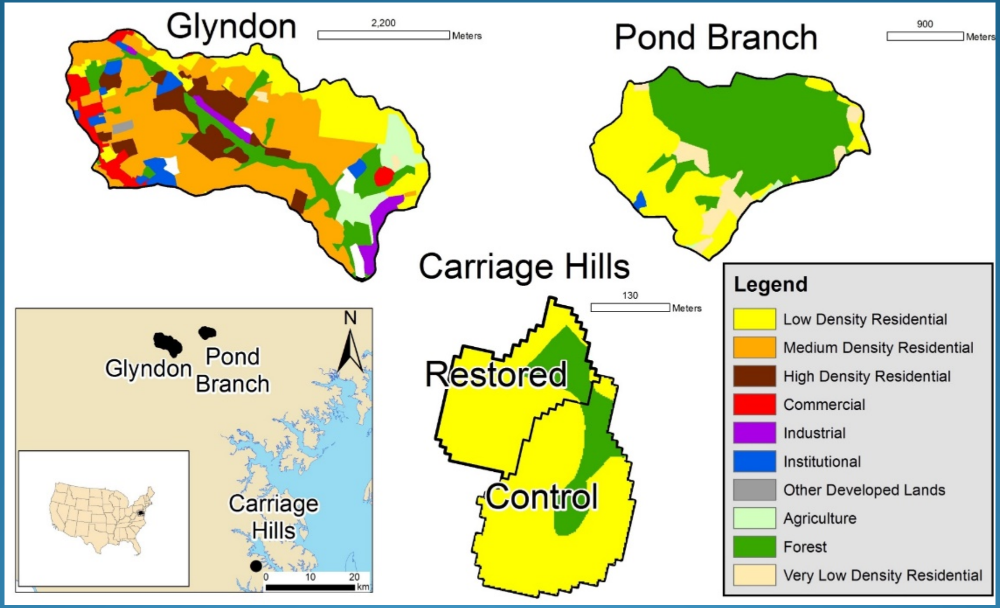
# Lesson 1: Monitor at the Right Spatial Scale




- Moderate load reduction from concentration changes (20%) was detected at project scale, but not at watershed scale.
  - Highlighting the challenges in matching the monitoring with the scales of restoration.

# Lesson 2: Select Good Controls

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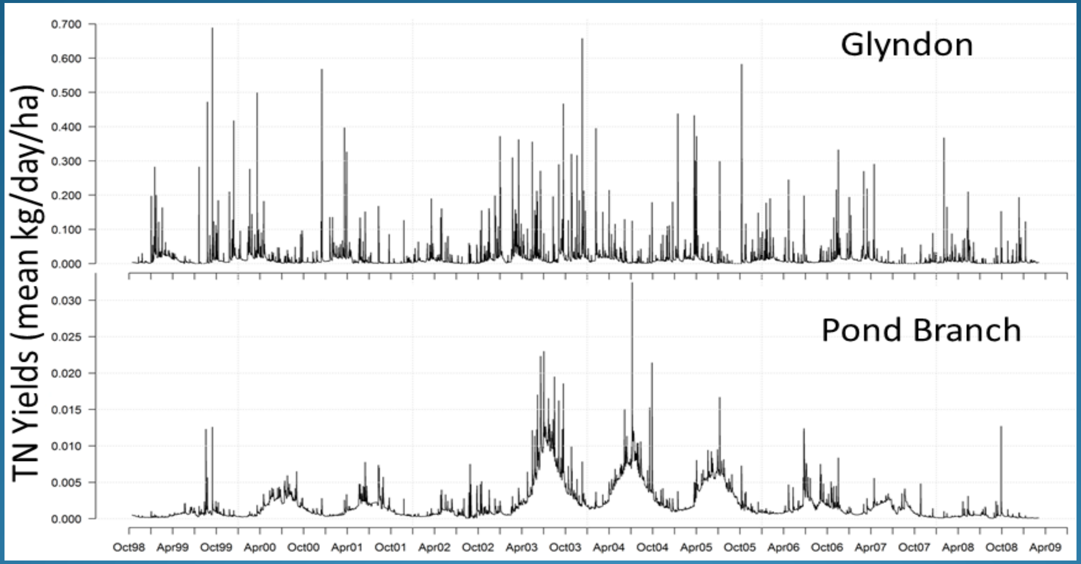


- Moderate load reduction from concentration changes (20%) was not detected.
  - Highlighting the challenges in designing a BACI monitoring using non-BACI data.

# Lesson 3: Value of Coordinated Assessments

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| Site | Scenario | BA | | BACI | | BACI (n=2) | |
|---|---|---|---|---|---|---|---|
| | | SRS | STS | SRS | STS | SRS | STS |
| Glyndon (TN) | 20% | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| | 50% | 1075(92) | 823(63) | 1216(101) | 1001(72) | 664(61) | 582(49) |
| | 80% | 71(2) | 69(1) | 82(2) | 83(2) | 42(1) | 47(1) |

- Pseudo-controls provide the biggest reduction in sample size for determining pollutant loads.

# Project #16925 Objectives

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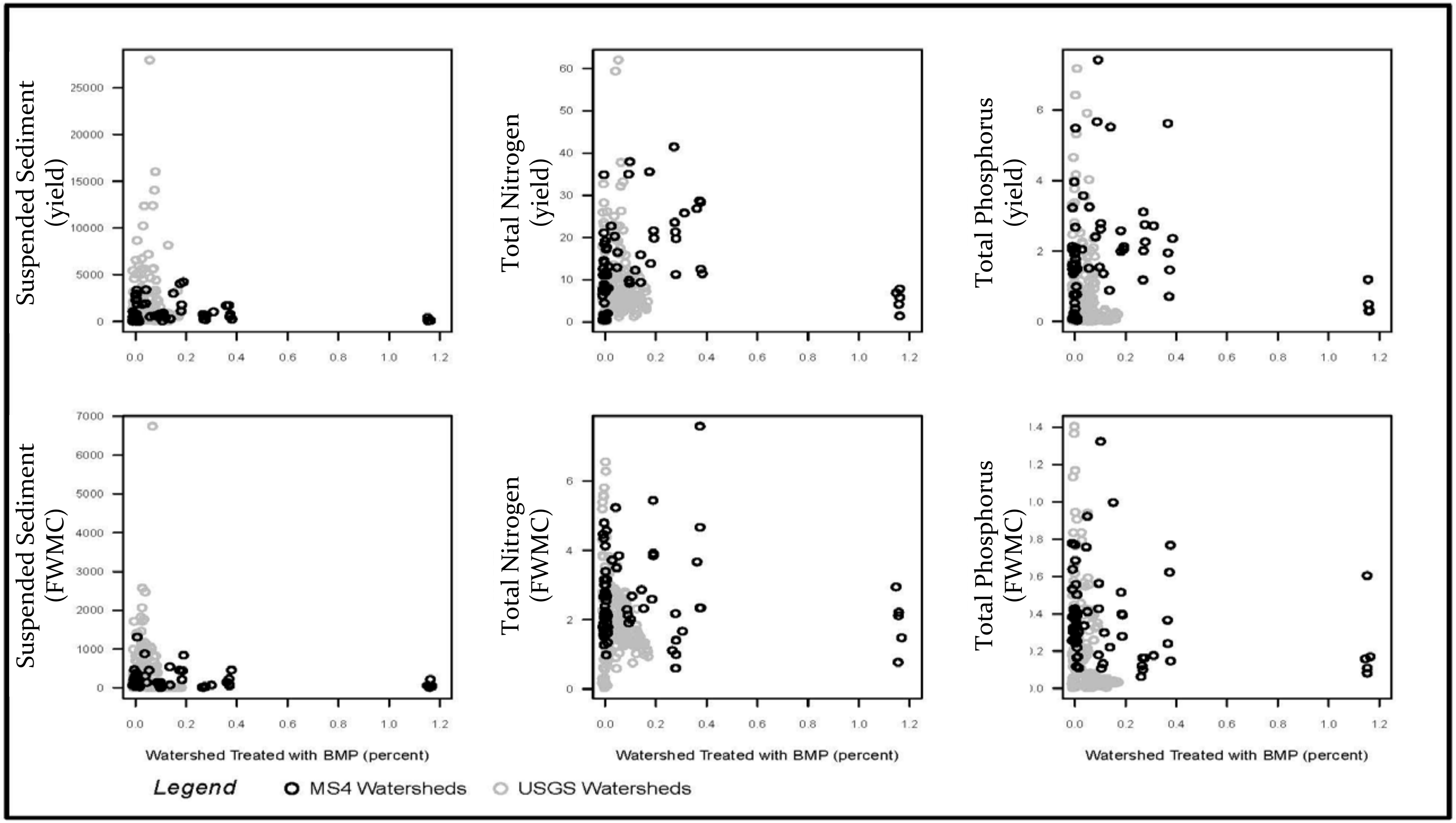
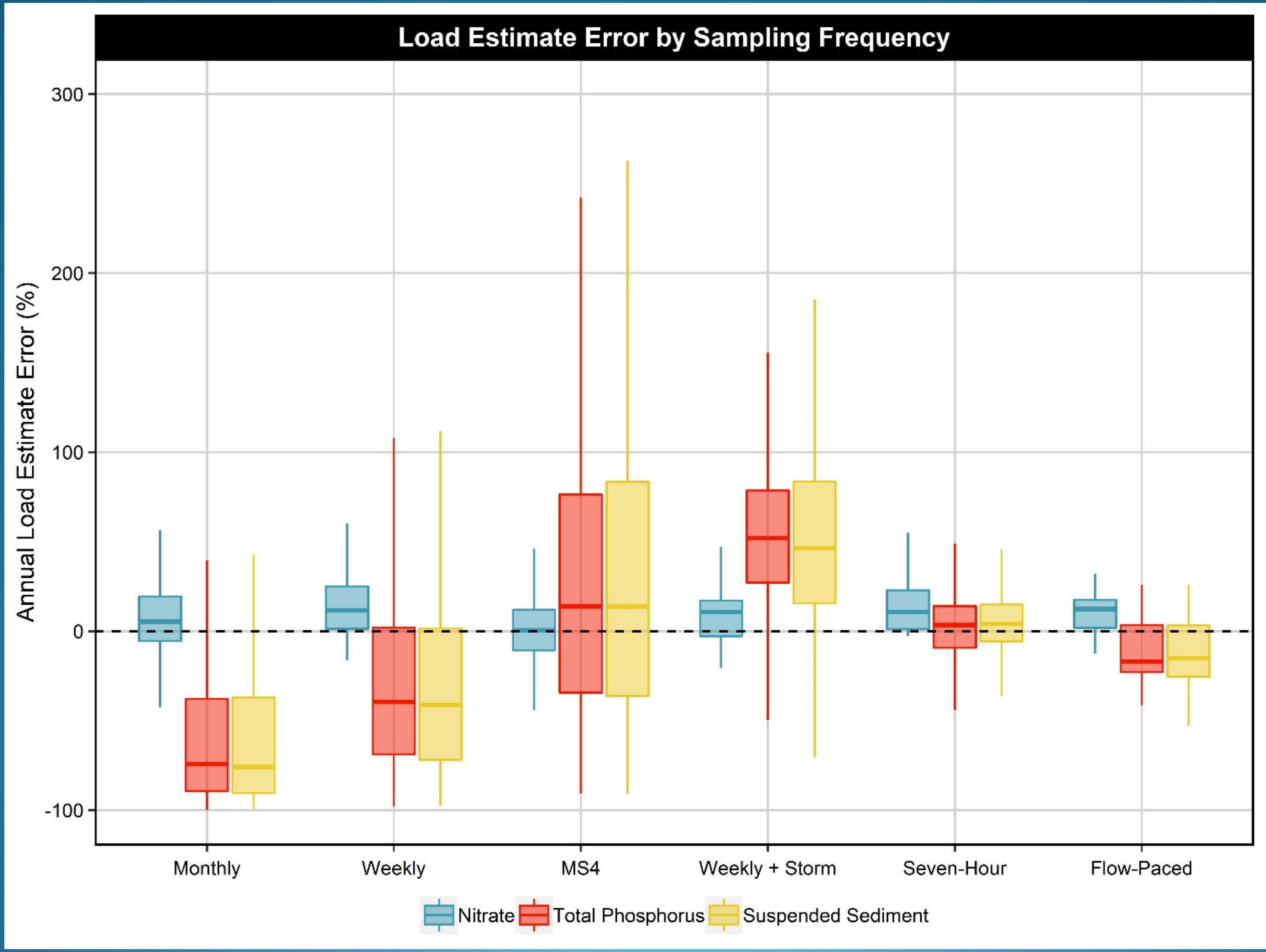
- What are the cumulative effects of restoration activities within a watershed?
  - Assessing Maryland MS4 monitoring data
- What degree of representative temporal sampling is required to determine accurate pollutant discharges?
  - Leveraging high-frequency data and surrogate parameters to evaluate temporal sampling frequencies

# Lesson 4: Determining the effect of stormwater restoration from existing monitoring programs is challenging



# Lesson 5: Sampling frequency and watershed characteristics influence load uncertainty



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# Lesson 5: Sampling frequency and watershed characteristics influence load uncertainty

**Table 1. Results of stepwise linear regression models for suspended sediment concentrations**

| Model Fit | Monthly | Weekly | Weekly+Storm | Seven-Hour | Flow-Paced | MDE MS4 |
|---|---|---|---|---|---|---|
| AIC | -12.19 | 28.76 | 125.78 | 111.72 | 98.28 | 77.91 |
| Adjusted R-squared | 62.7% | 69.3% | 13.0% | 35.7% | 23.6% | 3.5% |
| Overall p-value | <0.0001 | <0.0001 | 0.0094 | <0.0001 | 0.0005 | 0.1168 |
| Residual standard error (df) | 0.1972 (40) | 0.3110 (39) | 0.9661 (42) | 0.8146 (41) | 0.7067 (42) | 0.5607 (42) |

| Model Terms | Coef. | P-value | Coef. | P-value | Coef. | P-value | Coef. | P-value | Coef. | P-value | Coef. | P-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Intercept | 0.08140 | 0.4594 | -0.9875 | 0.0038 | -2.265 | 0.0003 | -0.7647 | 0.0054 | 1.148 | 0.1670 | -1.115 | 0.0018 |
| Log Watershed Size | -0.06871 | 0.0002 | -0.1657 | <0.0001 | -- | -- | -0.2140 | 0.0002 | -- | -- | -- | -- |
| Log Discharge | -- | -- | -- | -- | -- | -- | -- | -- | -0.1693 | 0.0005 | -- | -- |
| Baseflow Index | -- | -- | 2.253 | 0.0028 | 4.499 | 0.0094 | -- | -- | -- | -- | 1.537 | 0.1168 |
| Flashiness Index | -- | -- | 0.0203 | 0.0362 | -- | -- | -- | -- | -- | -- | -- | -- |
| % Developed Low Intensity | -0.5668 | 0.0858 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| % Woody Wetlands | -14.30 | <0.0001 | -18.00 | <0.0001 | -- | -- | -16.98 | 0.0773 | -- | -- | -- | -- |

- Watershed characteristics influence the accuracy and precision of load estimates from different temporal sampling frequencies.

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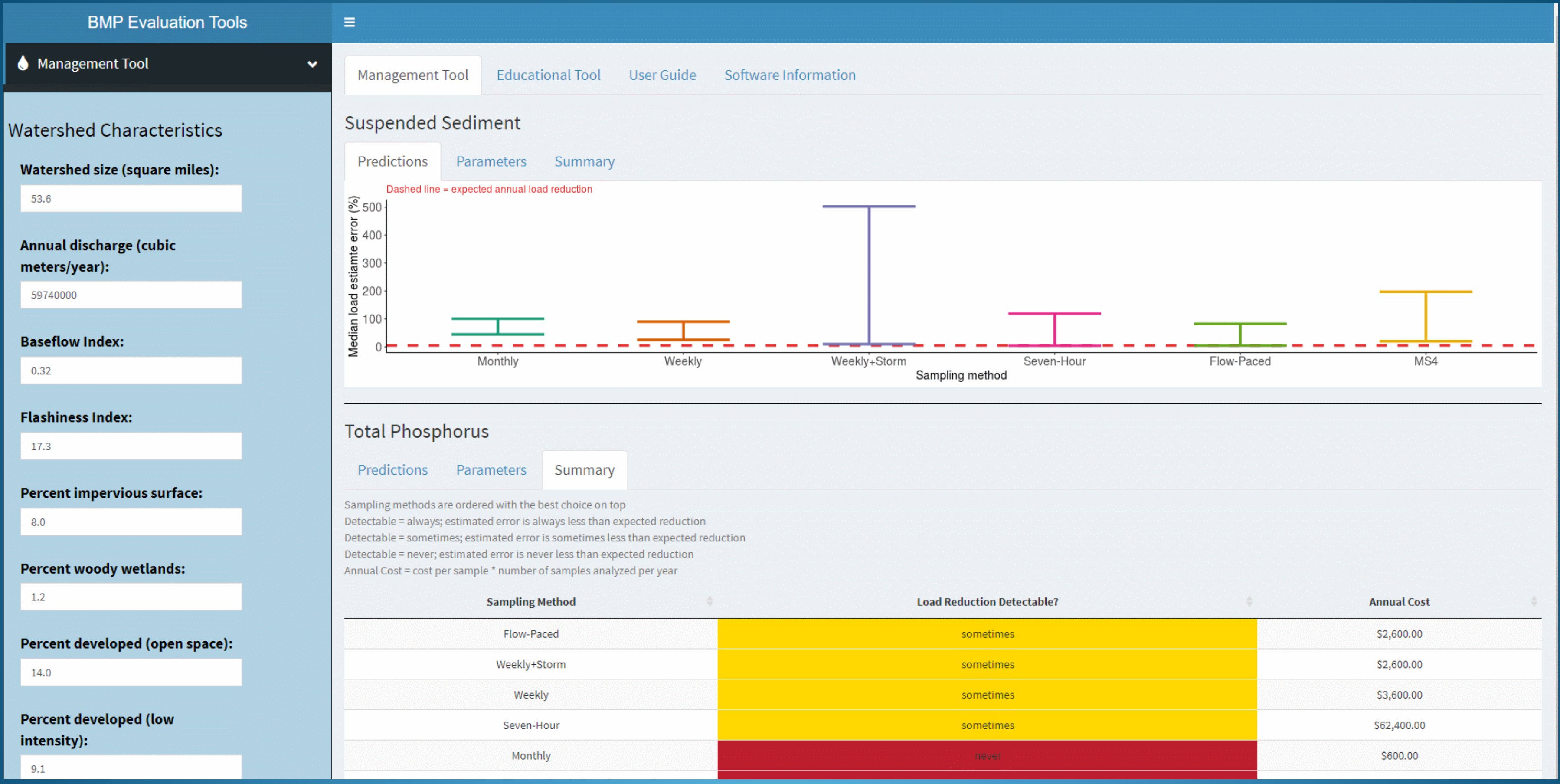
# Lesson 6: Decision support tools can help optimize monitoring programs



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# Project #20582 Objective

- To co-develop a software tool to help plan BMP monitoring studies and enhance restoration research.
  - Co-developed by practitioners and researchers, and data experts.
  - Informed by high frequency data
  - Deployed in an open source and web-enabled cyberinfrastructure.

# Co-Development Process

- Meeting with MDE State Regulatory Staff
- Target: County Scientists/Staff
  - Site visit to Anne Arundel County
  - Virtual meeting with Baltimore County
  - Site visit to Carroll County
- STAC workshop

# Acknowledgements


- Janis Markusic, Chris Victoria (Anne Arundel County)
- Kevin D Brittingham (Baltimore County)
- Byron Madigan (Carroll County)
- Mack, Kenny, Eric Naibert, Amy Stevens (Montgomery County)
- Bel Martinez da Matta (MDE), Shannon McKenrick (MDE), Jeff White (MDE).

# Translation Slides

# What does this mean for me?

- Experimental design can make or break a monitoring program. The choice of monitoring scale, BACI based-frameworks and controls, sampling size and frequency should be carefully considered before designing a monitoring study.

- Evolving from broader regulatory monitoring to hypothesis-driven monitoring, with greater coordination between researchers, practitioners, state, and local agencies, will help maximize the scientific value of monitoring dollars and better audit implementation dollars.

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# What do I take from this if I am a practitioner?

- The smaller the pollutant reductions from a project, the larger the investment needed in high-resolution monitoring and greater consideration of experimental designs able to detect expected water quality benefits.

- Decision support tools developed from these projects (current and forthcoming) can be beneficial when deciding whether monitoring will be a worthwhile component of a project, given the required resources.

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# What do I take from this if I am a regulator?

- Inadequate experimental designs and temporally coarse monitoring will likely be ineffective at evaluating a restoration program's success. The financial burden of a such a monitoring program can often outweigh the benefits of the information gained.

- Evolving from broader regulatory monitoring to hypothesis-driven monitoring, with greater coordination between researchers, practitioners, state, and local agencies, will help maximize the scientific value of monitoring dollars and better audit implementation dollars.

# Monitoring Discussion

# Questions for County Scientists/Staff

- *What is the goal of your stream monitoring?*
- *Within your department, what incentivize you to do monitoring?*
- *What resources are available "in-house" in county government?*
- *How have you designed your monitoring efforts in the past?*

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# Questions for County Scientists/Staff (Cont.)

- *What kind of stream restoration monitoring are you carrying out?*
- *Does it include automated flow-weighted composite sampling, hierarchical sampling of baseflow and storms....?*

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# Questions for County Scientists/Staff (Cont.)

- *How as the monitoring supported financially?*
- *Can you estimate the costs for supporting a station?*
  - *If possible, please break into analyte chemistry cost versus labor for data collection versus labor for interpretation and administration.*

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# Data Requirements?

- How can we get more “perfect” data?
  - Data format is “uniform”, and available for access/re-use?
- Open-source software development and sharing
  - R-Shiny based light-weight applications.
- Web-enabled cyberinfrastructure
  - Facilitate data sharing, visualization and modeling

# Effectiveness of stormwater management practices in protecting stream channel stability

2: Stormwater Management Assessment, under Theme A: Effectiveness of Restoration Programs at the Watershed Scale

4: Climate Change Impacts to Restoration Practices

VIRGINIA TECH

# Project partners and contributors

**Tess Wynn Thompson**, Associate Professor, Biological Systems Engineering, Virginia Tech

**David Sample**, Professor and Extension Specialist Biological Systems Engineering, Virginia Tech

**Mohammad Al-Smadi**, Senior Water Resources Engineer, Stantec

**Sami Towsif Khan**, PhD Candidate, Biological Systems Engineering, Virginia Tech

**Mina Shahed Behrouz**, Water Resources Designer, Stantec

**Andrew Miller**, Professor, Geography and Environmental Systems, University of Maryland, Baltimore County

**Jon Butcher**, Professional Hydrologist, TetraTech

# How can we develop land and protect streams?

1. Does environmental site design (ESD) protect channel stability under current and future climate?

While ESD provides environmental benefits, it does not protect channel stability.

2. How can we "tweak" ESD to protect channel stability?

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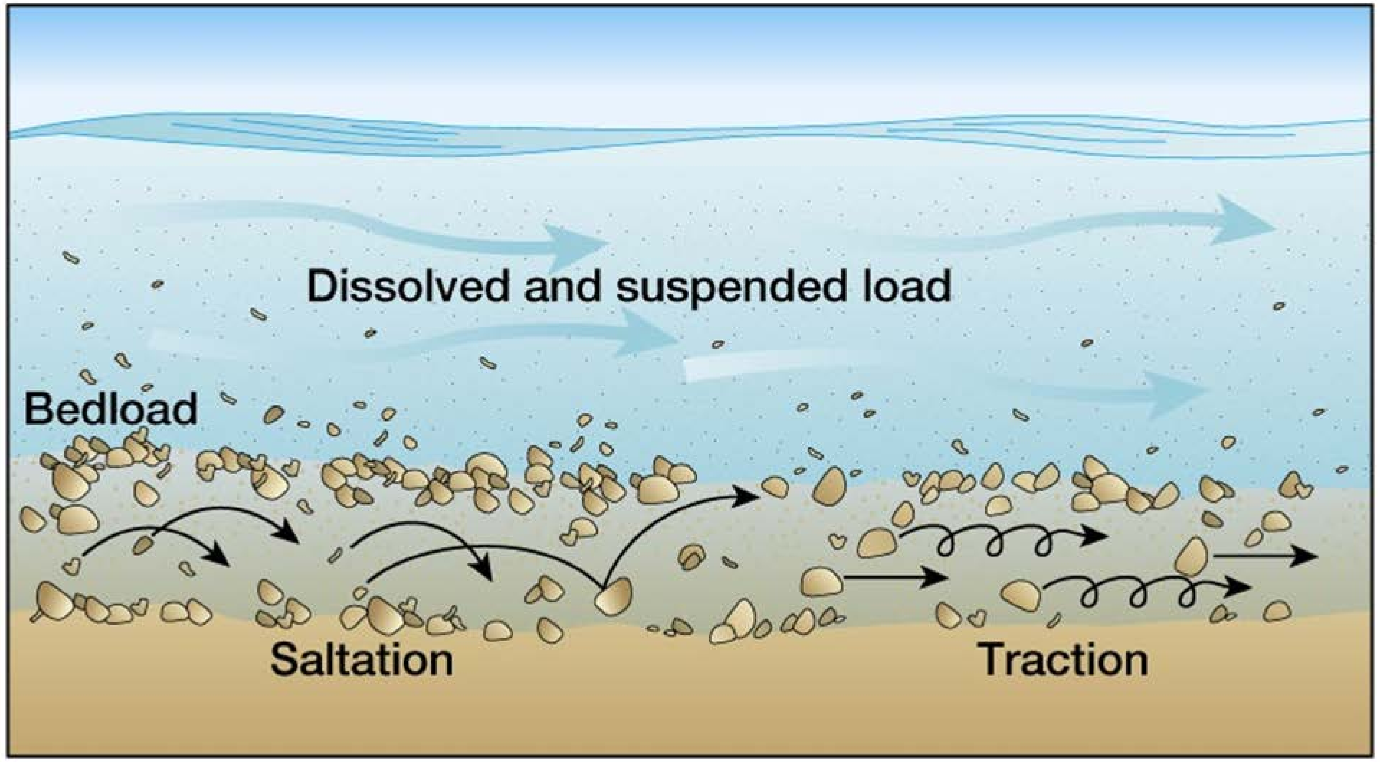
Gentle
Reminders!

# In this talk, “sediment” is not a four-lettered word.



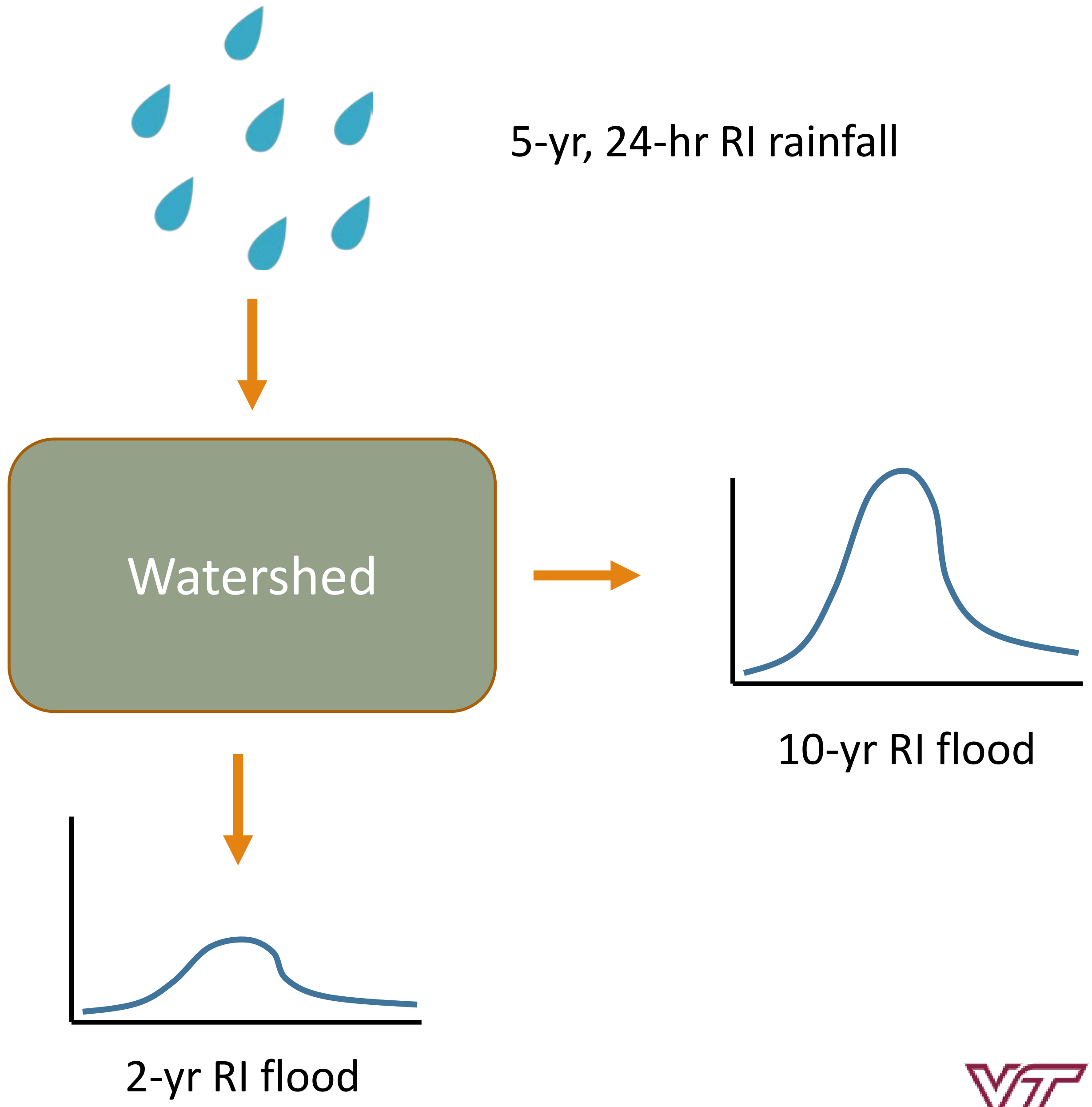

- Coarse sediment is naturally transported in suspension and along the channel bed.
- Fine sediment does not play a major role in channel morphology.

# In this talk, stream “stability” means the channel is not becoming deeper and/or wider


Google Earth

# The X-yr storm event does not produce the X-yr flood,

where X = 1, 2, 10, 100…



# All models are wrong, but some are useful

*- George Box, British statistician*

Adjust the model to match observed conditions.


Apply common sense.



http://www.clipartpanda.com/clipart_images/reality-check-ahead-59860852

http://www.clipartpanda.com/clipart_images/reality-check-ahead-59860852

# Ok, let’s talk research…

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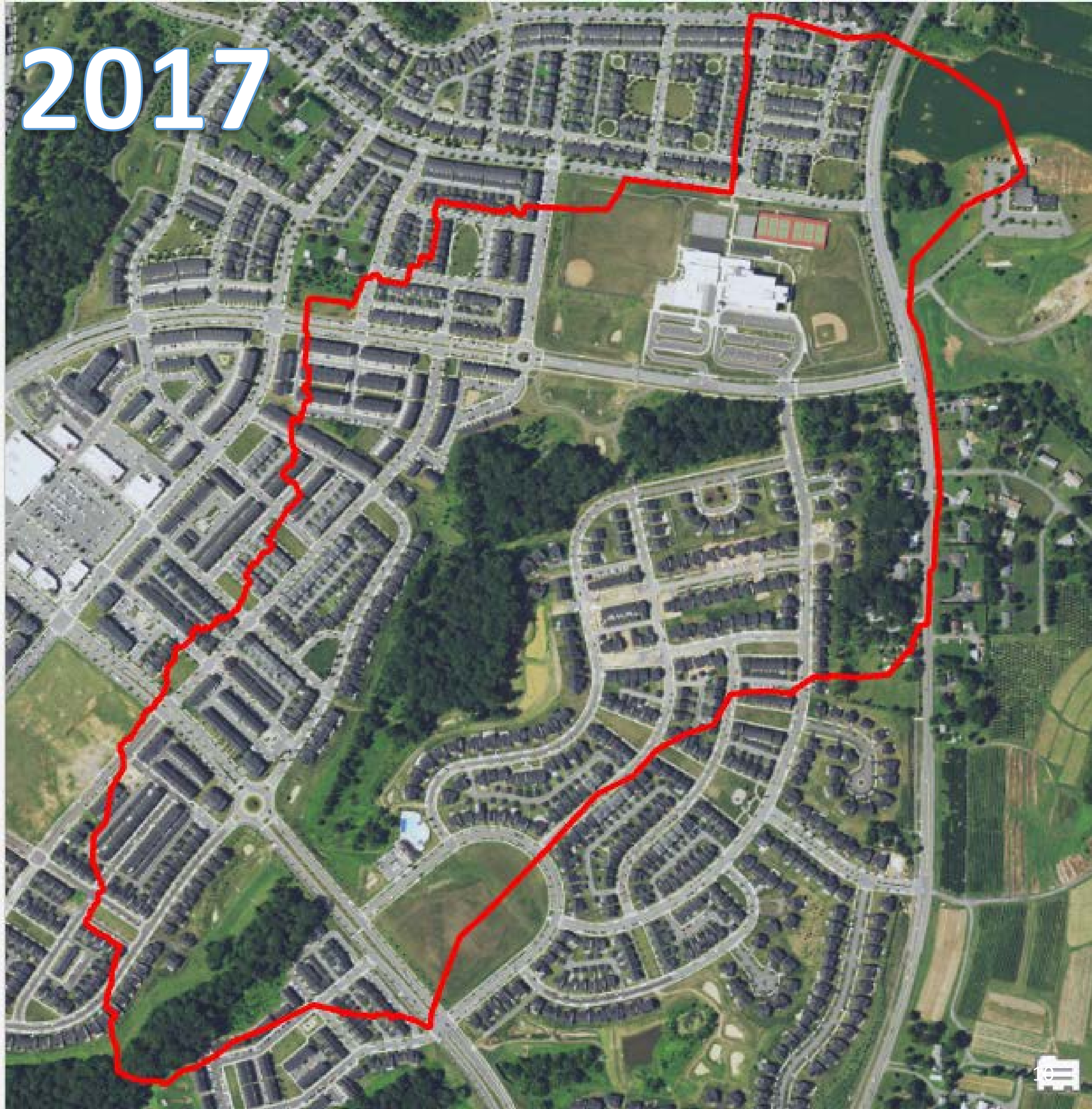
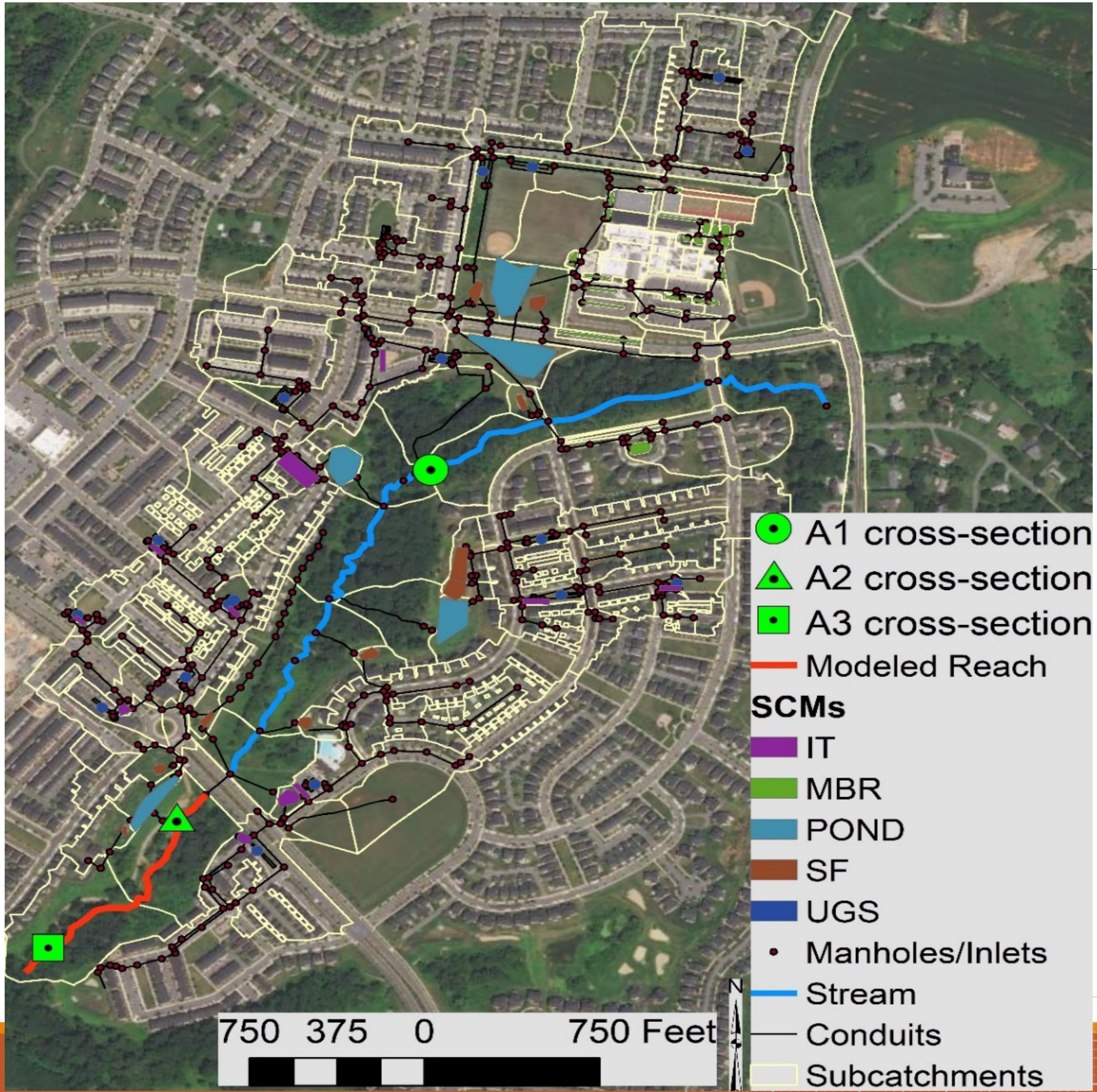
# Tributary 109 to Little Seneca Creek served as a case study

- 0.3 mi$^2$ drainage area, 44% TIA
- Developed 2006 - 2016
- USGS stream gage (2004)
- USGS rain gage
- Montgomery County data
  - Cross sections
  - Longitudinal profiles
  - Pebble counts
- Multiple lidar datasets

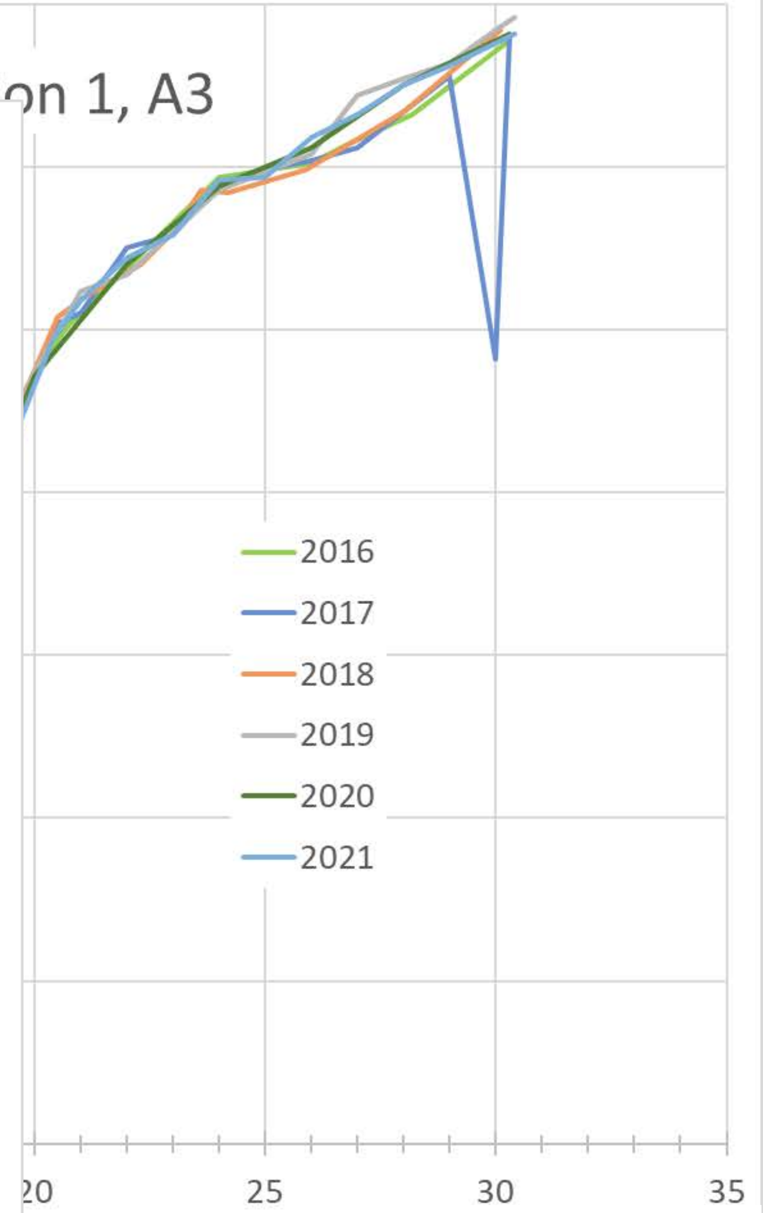


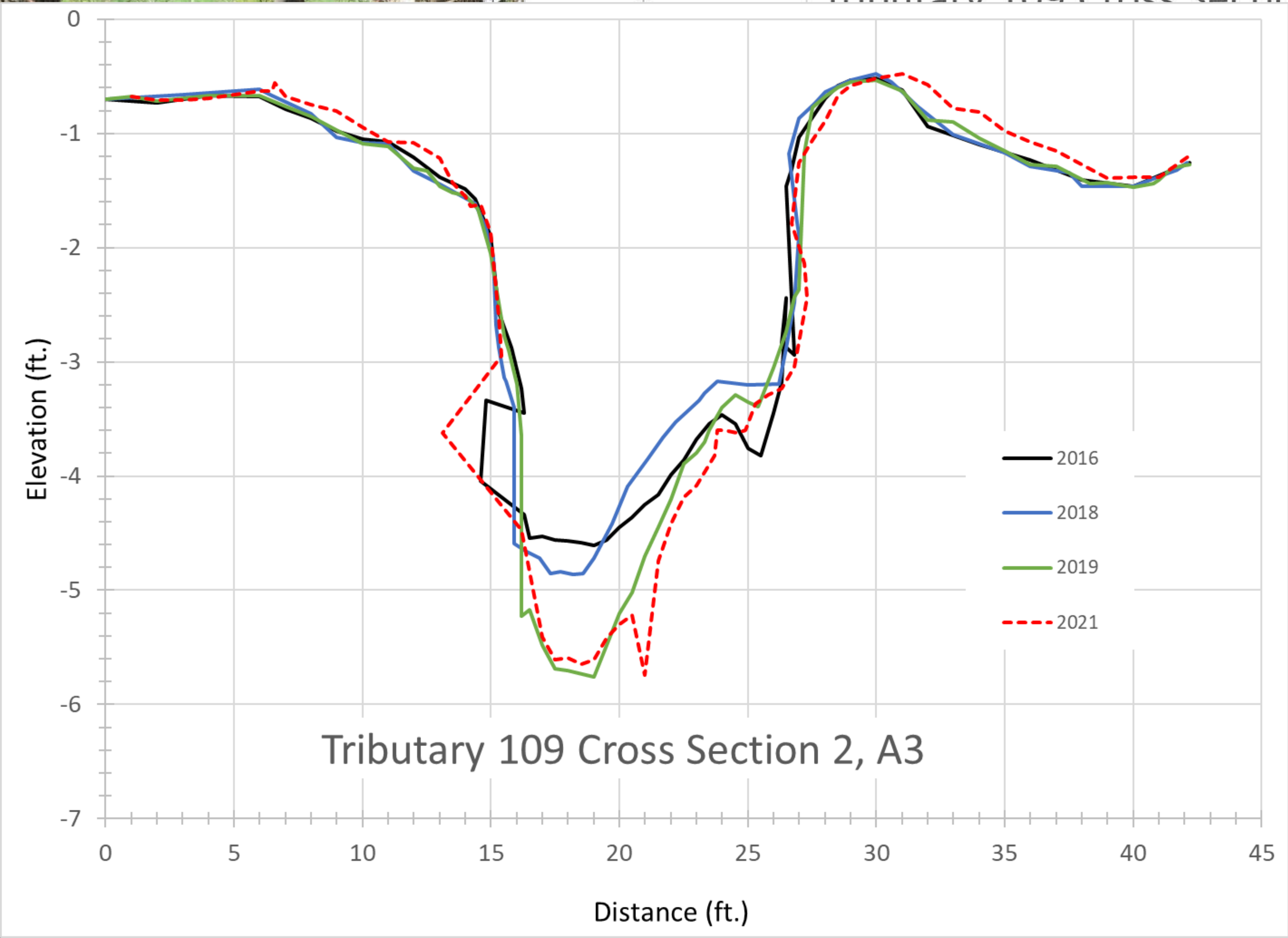



**Stormwater system was designed to meet the 2008 ESD requirements:**

- 5 ponds
- 26 micro bioretention (MBR)
- 10 infiltration trenches (IT)
- 11 sand filters (SF)
- 18 underground storage facilities (UGS)

“Distributed” stormwater control practices

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# Channel stability is a two-part problem

Water

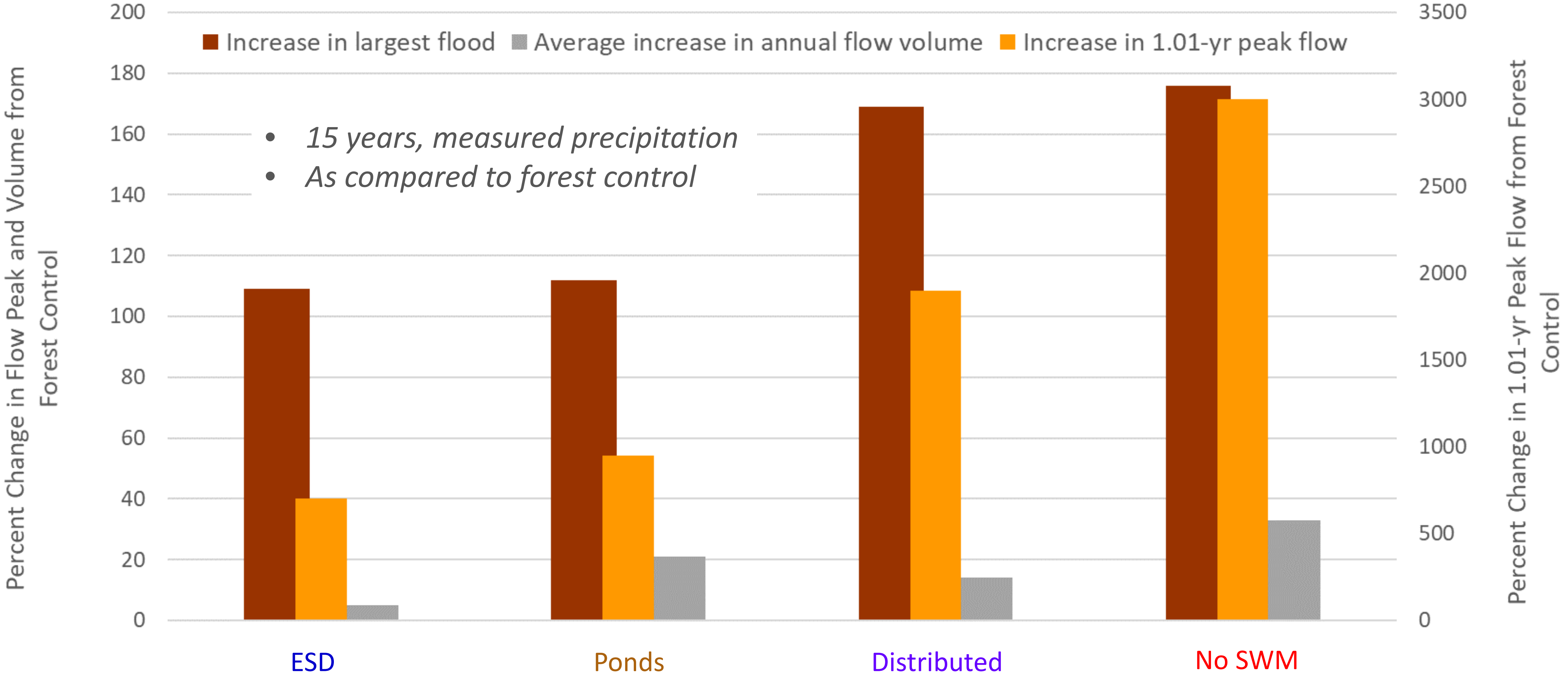
SWMM
Storm Water
Management
Model

Sediment

HEC-RAS 6.2

# Results…

# Both ponds (storage) and distributed SCMs are needed to minimize hydrologic impacts of development



# In the future, due to climate change…

- Precipitation will generally occur more frequently.
  - Example: the 50th percentile of *time between storms* will decrease from 3 to 2 days.
- However, when there are droughts (time between storms >5 days), they will last longer.
- Change in maximum flow (over 59 years) ranges from a decrease of 18% to an increase of 117% over current conditions.

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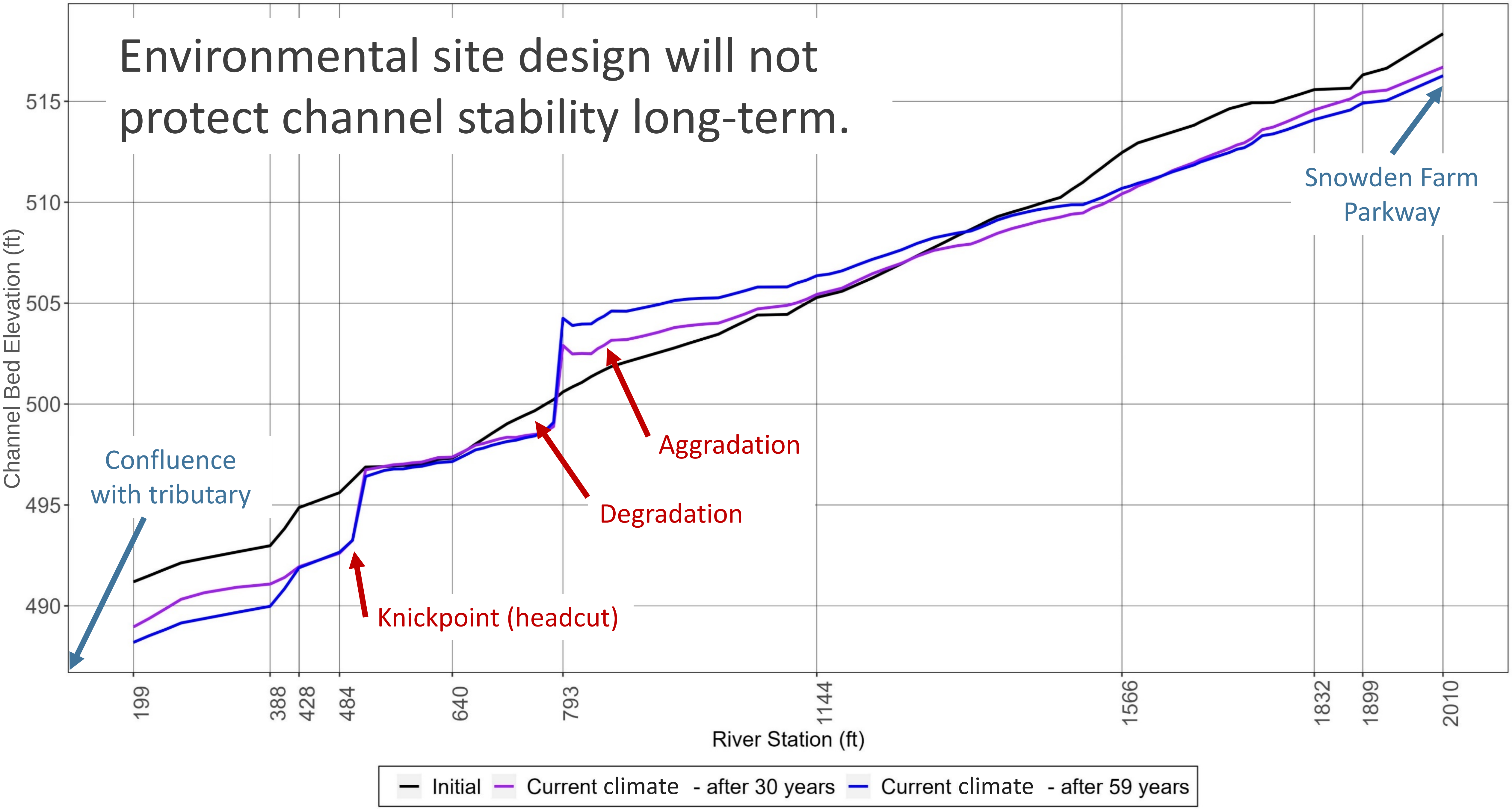
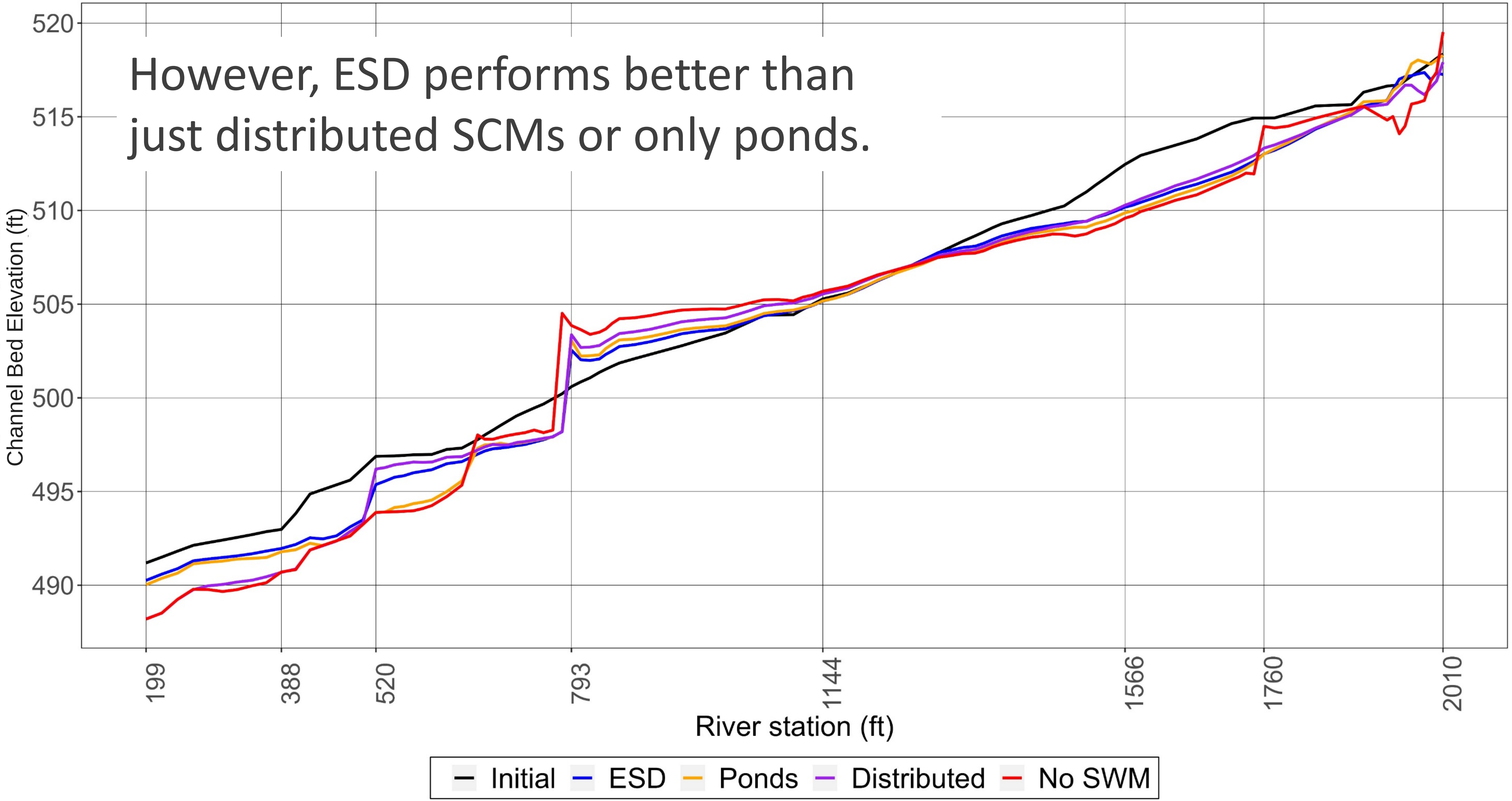
# What does the change in hydrology mean for channel stability?

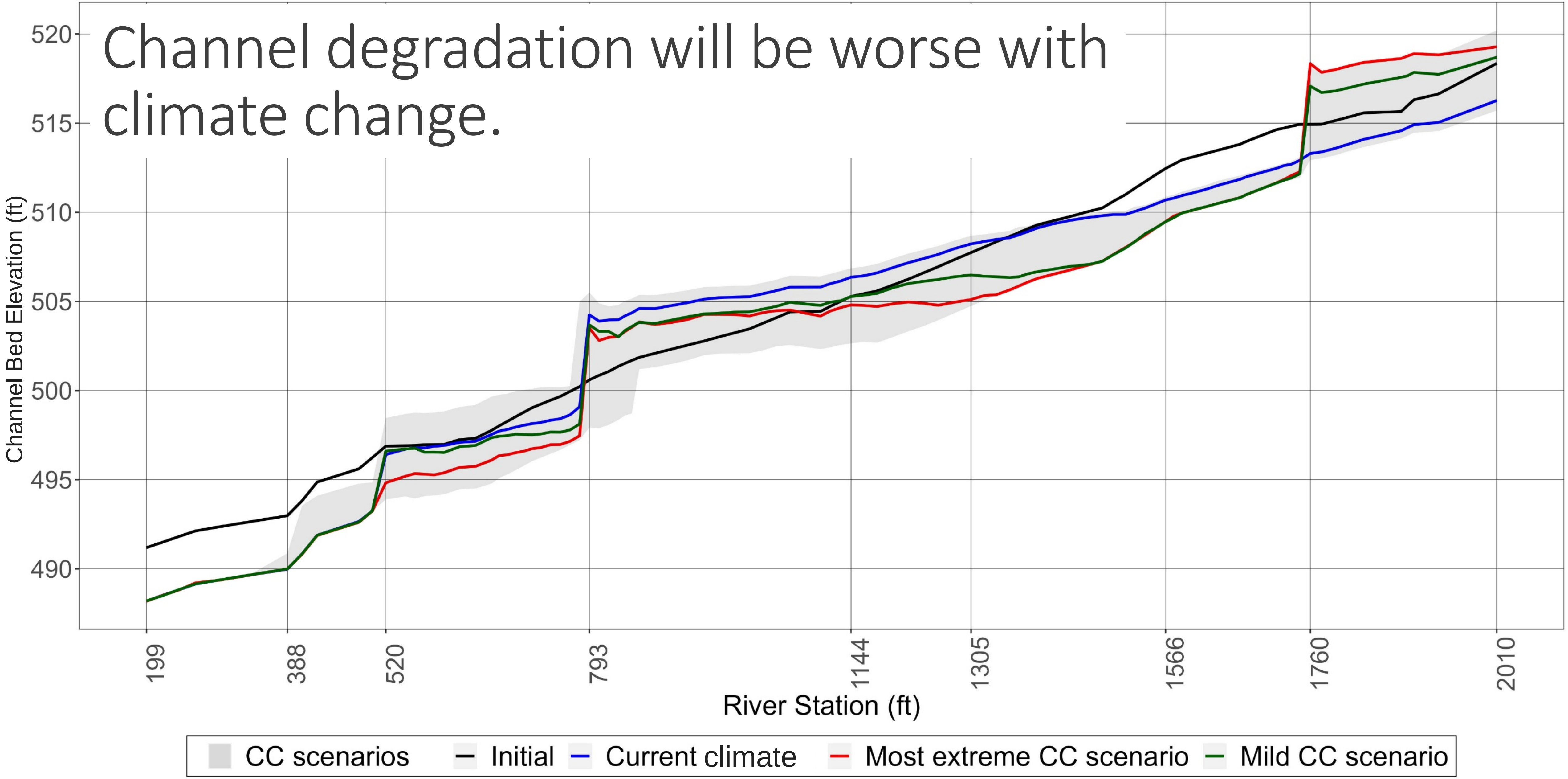
# Environmental site design will not protect channel stability long-term.



## However, ESD performs better than just distributed SCMs or only ponds.



# Channel degradation will be worse with climate change.



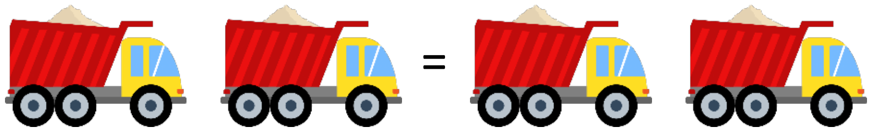
# Where do we go from here?

geograph.org.uk

# To protect channel stability, we need to consider sediment transport in the receiving stream.

1. Maintain pre-development erosion potential (Washington State)
   - ➢ Total mass sediment transported for a given duration

Pre-development = Post-development




- ➢ for continuous simulation
- ➢ for design storms

2. Maintain pre-development excess shear stress (Santa Clara, CA)
   - ➢ Total “excess shear stress” for a given duration

$$(\tau - \tau_c)$$

https://www.vhv.rs/

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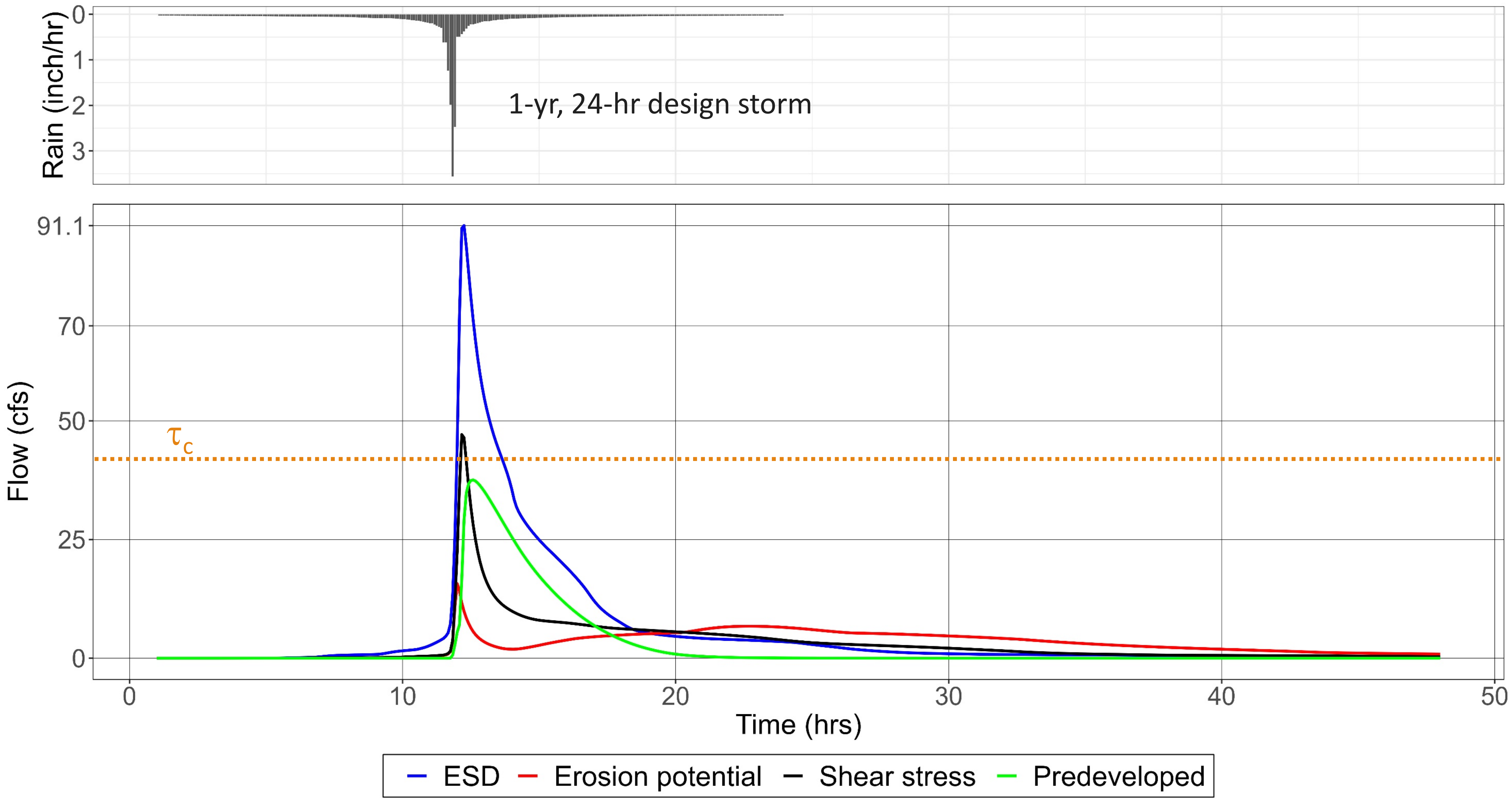
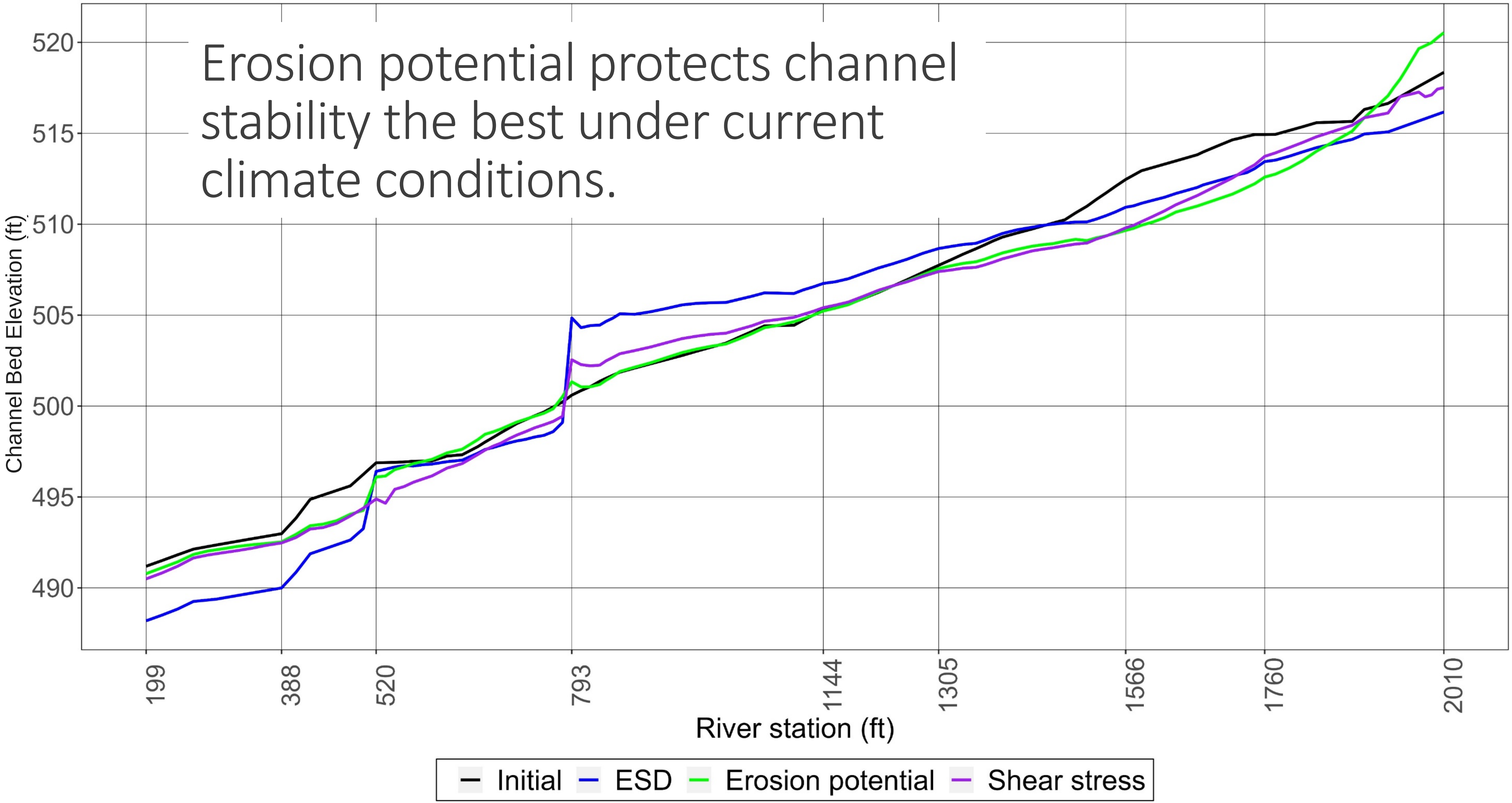
Hawley, Robert J., Kathryn Russell, and Kristine Taniguchi-Quan. 2022. “Restoring Geomorphic Integrity in Urban Streams via Mechanistically-Based Storm Water Management: Minimizing Excess Sediment Transport Capacity.” Urban Ecosystems 25 (4): 1247–64. https://doi.org/10.1007/s11252-022-01221-y.

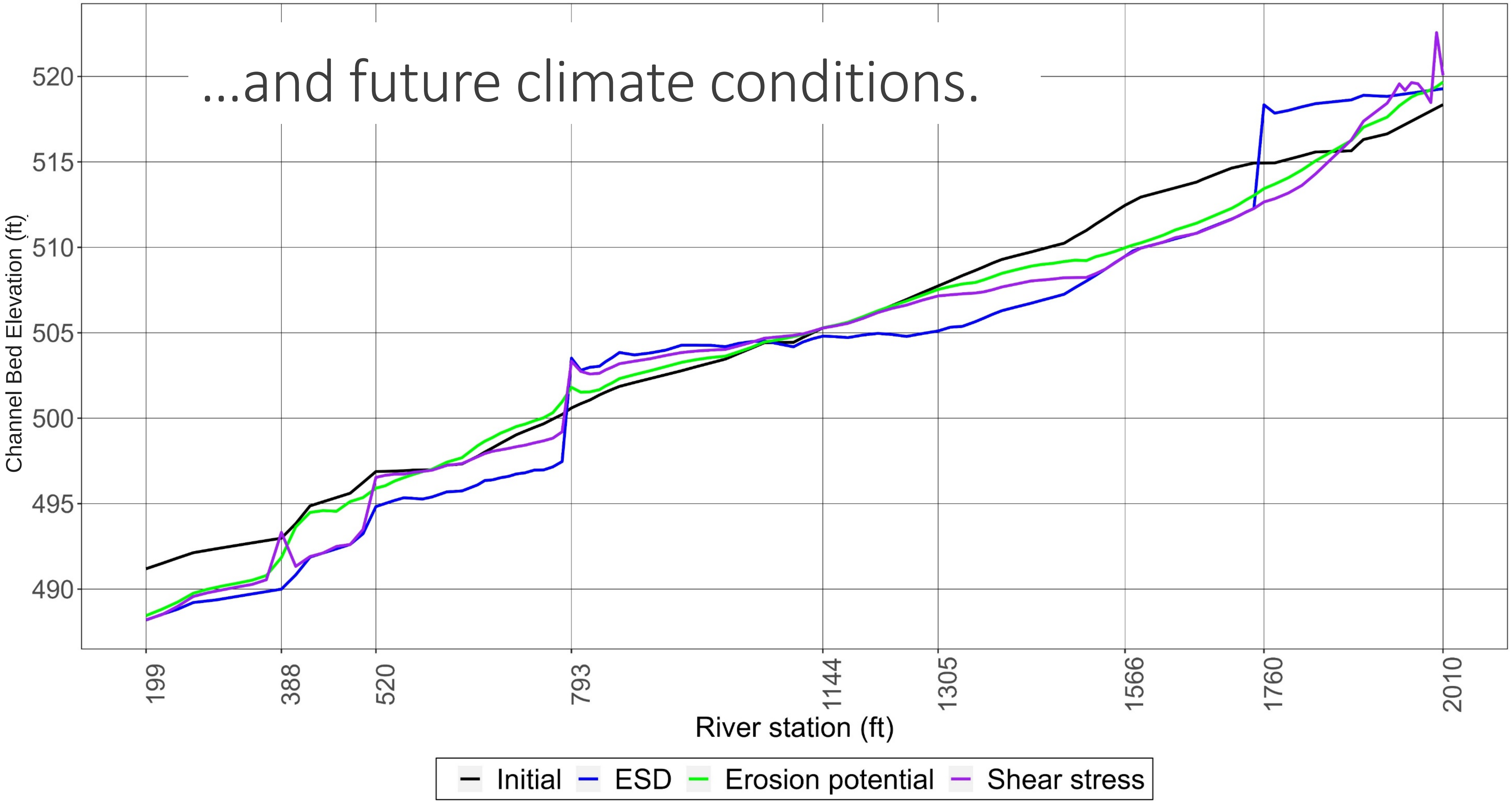


Rain (inch/hr)
0
1
2
3
1-yr, 24-hr design storm
Flow (cfs)
91.1
70
50
25
0
$\tau_c$
0
10
20
30
40
50
Time (hrs)
ESD
Erosion potential
Shear stress
Predeveloped

# Erosion potential protects channel stability the best under current climate conditions.



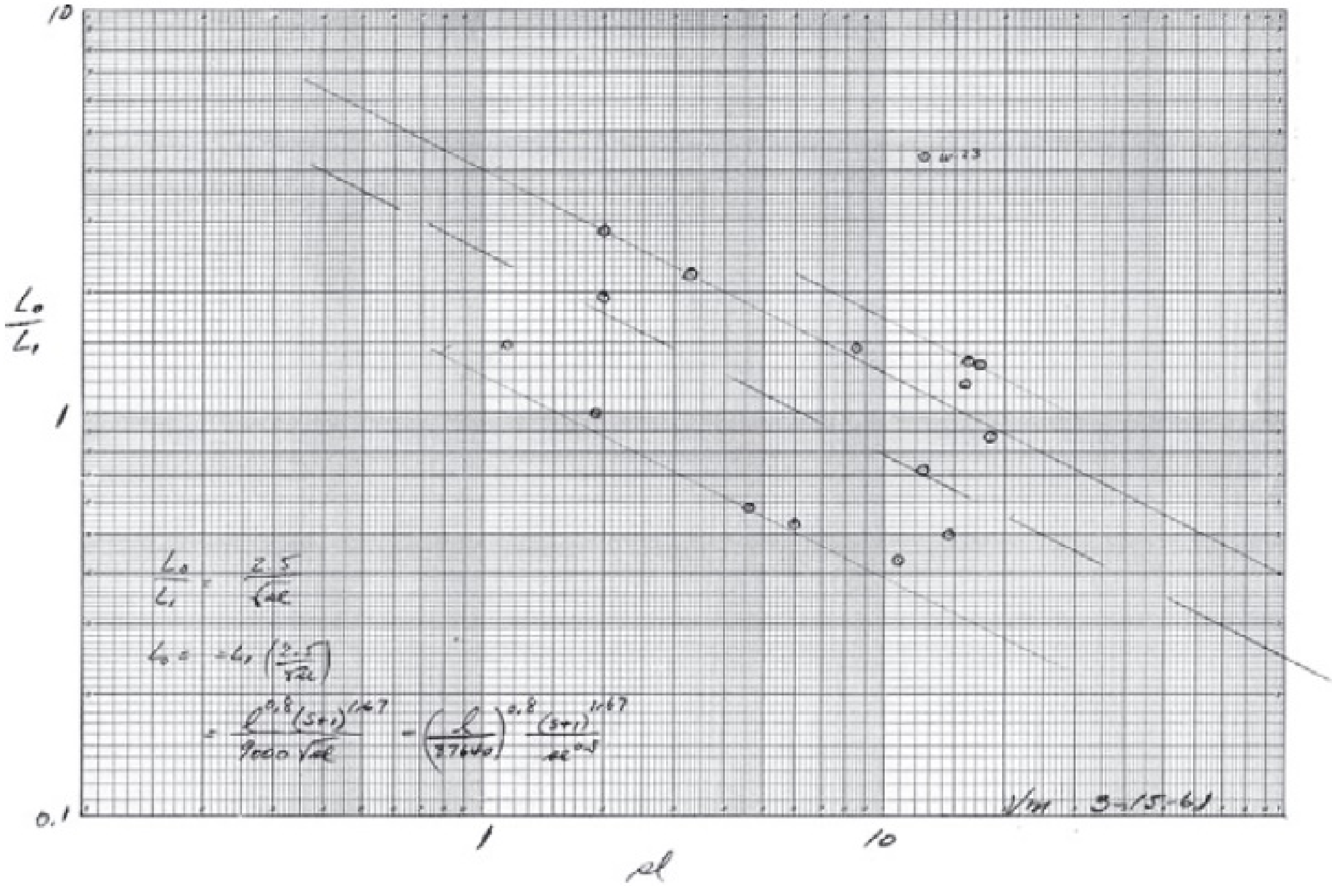
# …and future climate conditions.



# Summary

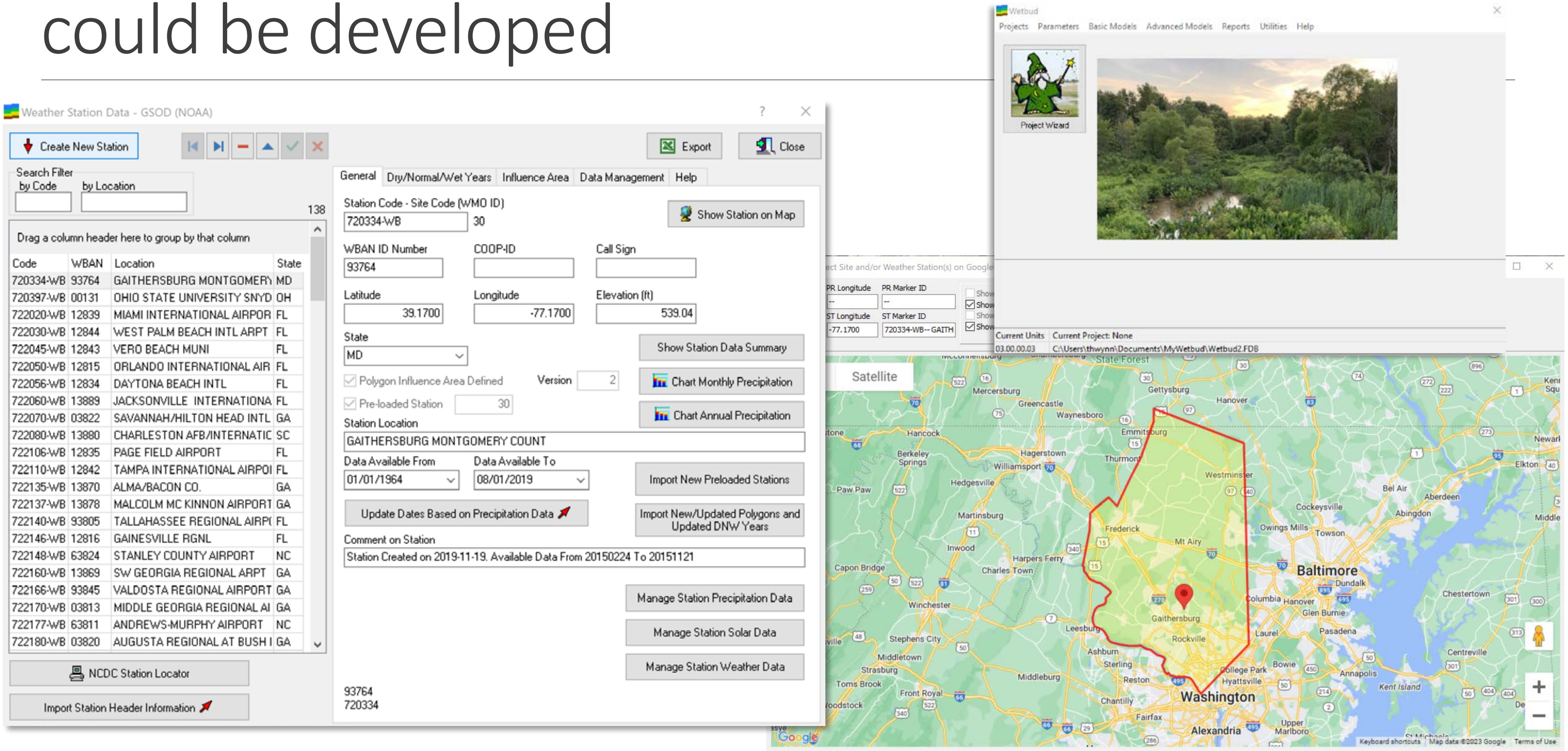
- Design storms do not translate directly to watershed response.
- Infiltration practices reduce annual runoff, but do little to reduce peak flows.
- Stormwater storage (ponds) is needed to manage high flows.
- Environmental site design is an improvement over conventional stormwater management, but will not protect channel stability.
- Climate change will exacerbate existing deficiencies in ESD.
- To protect channel stability, stormwater management needs to be designed to meet sediment transport targets.
- Erosion potential shows the most promise for protecting channel stability.
- Continuing this work with Minebank Run case study

# Recommendations




1984 computing power

# Software with Maryland-specific climate data could be developed




https://resourceprotectiongroup.org/wetbud/

*Wetbud was developed for mitigation wetland design*

# Acknowledgment Slide

We thank the many partners who support the Restoration Research program for their funding and interest.  Major funding for this phase of the work was provided by the U.S. Environmental Protection Agency.  We also thank the US Geological Survey and Montgomery County for sharing data and their personal observations of Tributary 109.

# What are the take home points?
# What does this mean for me?

TRANSLATION SLIDES BY [INSERT POOLED MONITORING ADVISORY COMMITTEE MEMBER NAME HERE]

# What does this mean for me?

PMAC member add take-home points of the presentation

# What does this mean for me?

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

PMAC member add ~2 ideas here

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

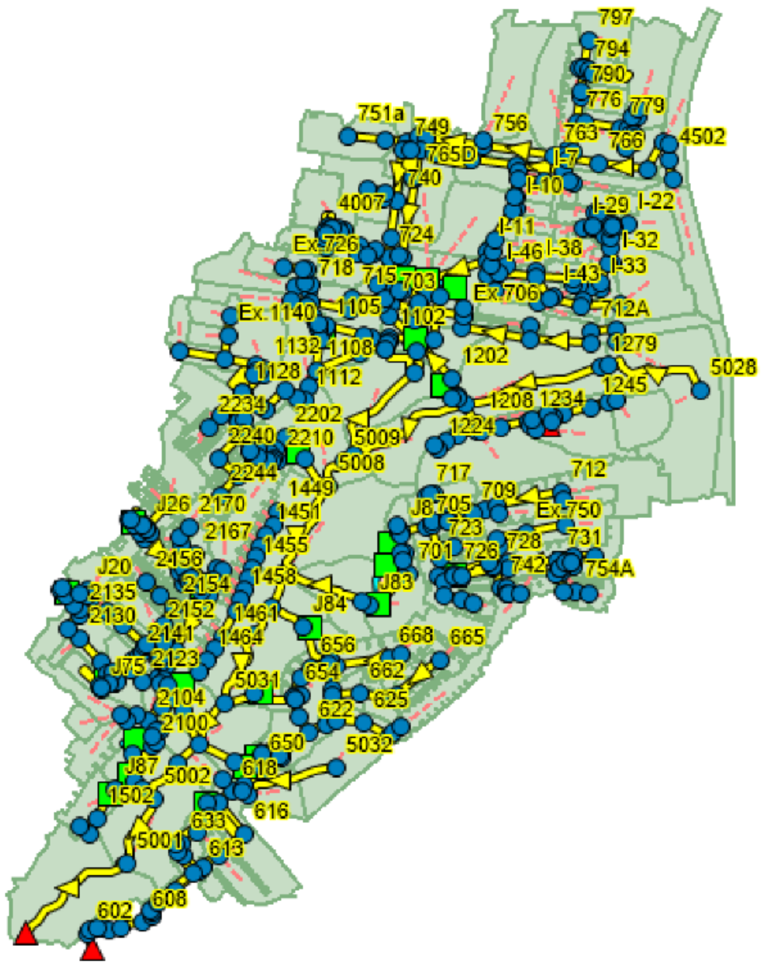
PMAC member add ~2 ideas here

# 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.

# SWMM model development

1. Watershed characteristics and stormwater infrastructure attributes entered into models
2. Models calibrated based on observed USGS flow data
3. Calibrated models used to explore 4 stormwater management and 64 climate change scenarios
4. SWMM-modeled stream discharge used as input to HEC-RAS model

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# HEC-RAS quasi-unsteady, 1-D model development

1. Lidar data and measured cross sections used to create channel geometry
2. Bed particle counts, bulk sediment samples, and USGS suspended sediment data (Fairfax, VA) used to parameterize sediment transport routines
3. Calibrated HEC-RAS to USGS stage data and measured cross section change
4. Modeled channel response to stormwater scenarios and climate change scenarios using SWMM output
5. Evaluated effectiveness of alternative stormwater management design techniques to protect channel stability

# Evaluation of watershed-scale impacts of stormwater management facilities on thermal loads to a Maryland Class IV stream using a high-frequency sensor network

Claire Welty, Andy Miller, Mary McWilliams,
John Lagrosa, Nick Simeone
UMBC/CUERE
in partnership with
Kevin Brittingham, Baltimore County DEPS





Translation Slides
Greg Golden, Maryland DNR

June 21, 2023

# Research question to be addressed

***What best management practice design and siting methods will reduce thermal impacts to Maryland's Use III and IV streams?***

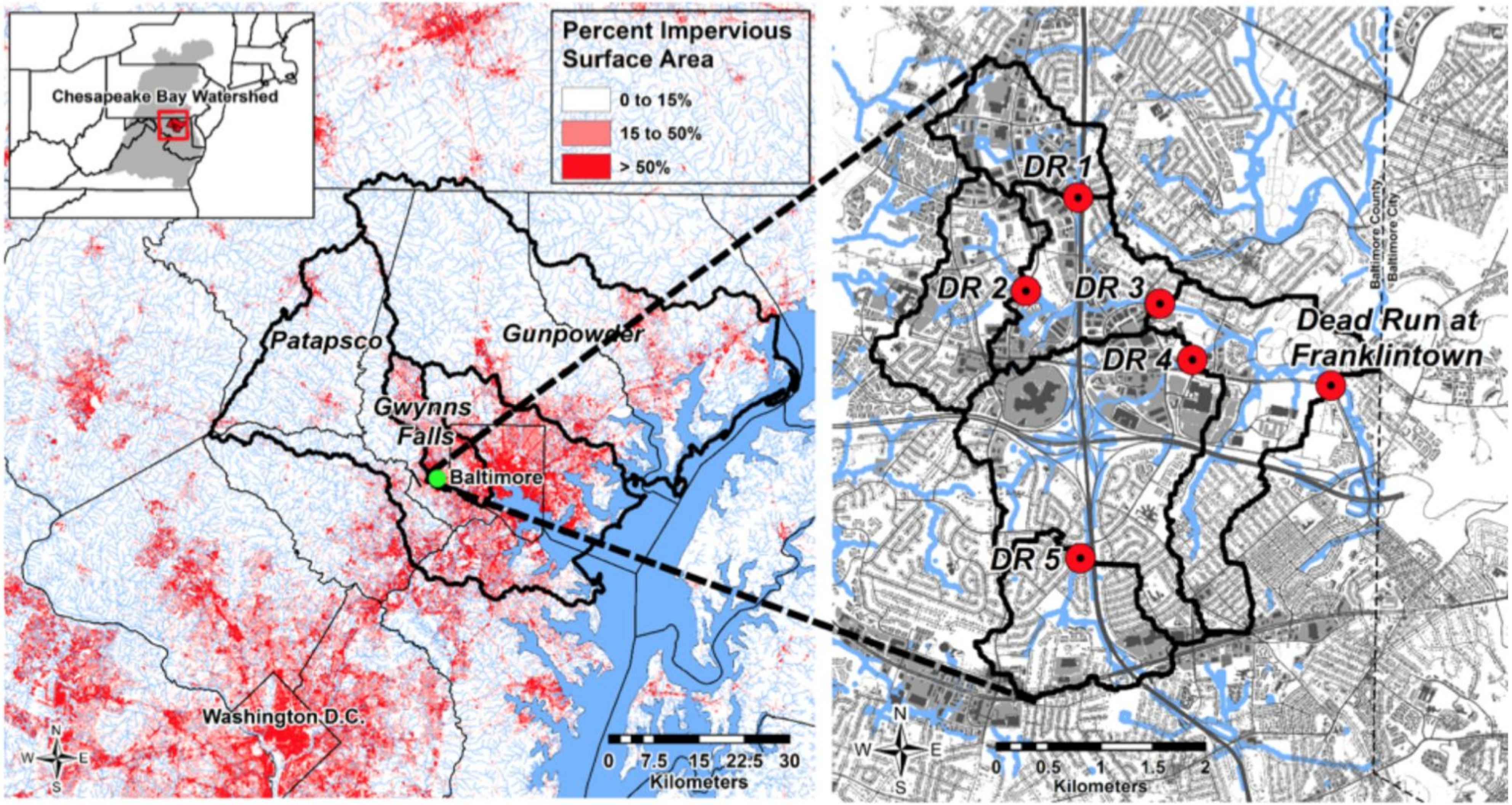
# Hypotheses

H1 High spatial- and temporal-resolution observations of stream water temperature reveal patterns of influence on thermal loading associated with land cover and stormwater management features.

H2 The thermal impact of surface stormwater facilities is comparable to that of directly-connected impervious surfaces at the watershed scale.

H3 Discharge from underground stormwater management facilities better mitigates thermal impacts to streams compared to drainage from surface stormwater facilities.

# Dead Run watershed study area - Use Class IV stream network



# 84 stormwater facilities permitted by Baltimore County located in Dead Run watershed

| Facility type | Number |
|---|---|
| Bioretention | 1 |
| Detention structure (dry pond) | 21 |
| Extended detention structure, dry | 34 |
| Infiltration basin | 1 |
| Infiltration trench | 1 |
| Microbioretention | 2 |
| Oil grit separator | 5 |
| Permeable pavement | 3 |
| Sand filter | 7 |
| Shallow marsh | 1 |
| Submerged gravel wetland | 1 |
| Underground filter | 1 |
| Wet pond/wetland | 2 |
| Other | 4 |

# Status update

- 6 air temperature sensors deployed Oct 2021
- 169 water temperature sensors deployed Dec 2021 – March 2022
- 35 additional water temperature sensors deployed Sept 2022/ Feb 2023
- Complete downloads of data:  July/Aug 2022; Jan/Feb 2023
- Next download scheduled for Nov 2023
- Video mapping workflow completed.
- Statistical analyses to be done in the coming year.

# Sensor deployment design

**HOBO TidbiT MX 2203 temperature data loggers (stream)**

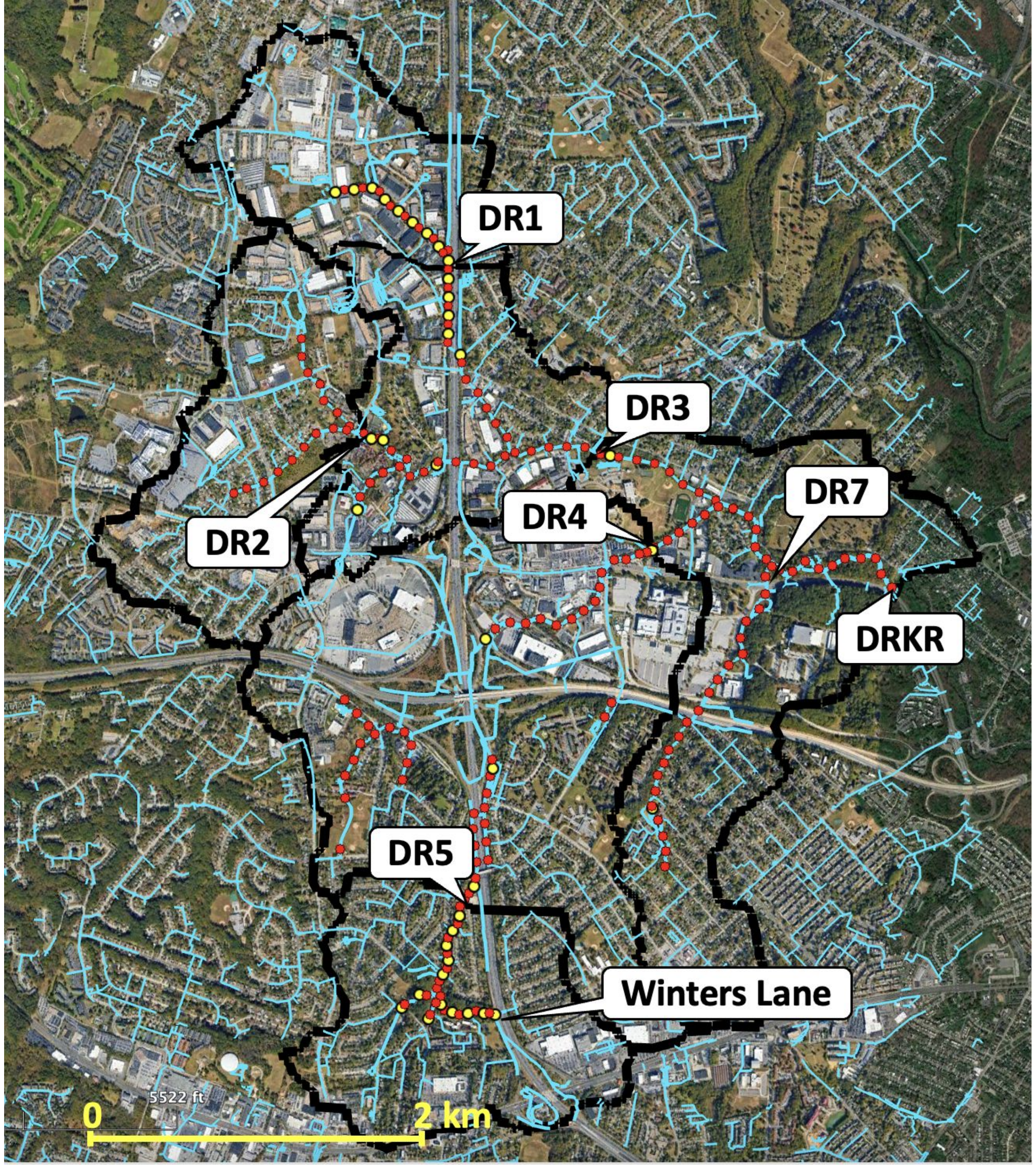
- 204 sensors
  - Every 50-100 m along all accessible stream segments of Dead Run, 16 km total
  - ~2 m downstream of all stormwater management facilities

**HOBO MX2305 temperature sensors (air)**

- 6 sensors
  - At 6 USGS stream gaging stations

https://www.onsetcomp.com/

# Sensor station map




- 204 locations over 16 km
- Red markers: 100 m spacing
- Yellow markers: 50 m spacing
  + 2 m downstream of SWM facilities

# Stream temperature animation using GIS and video editing software

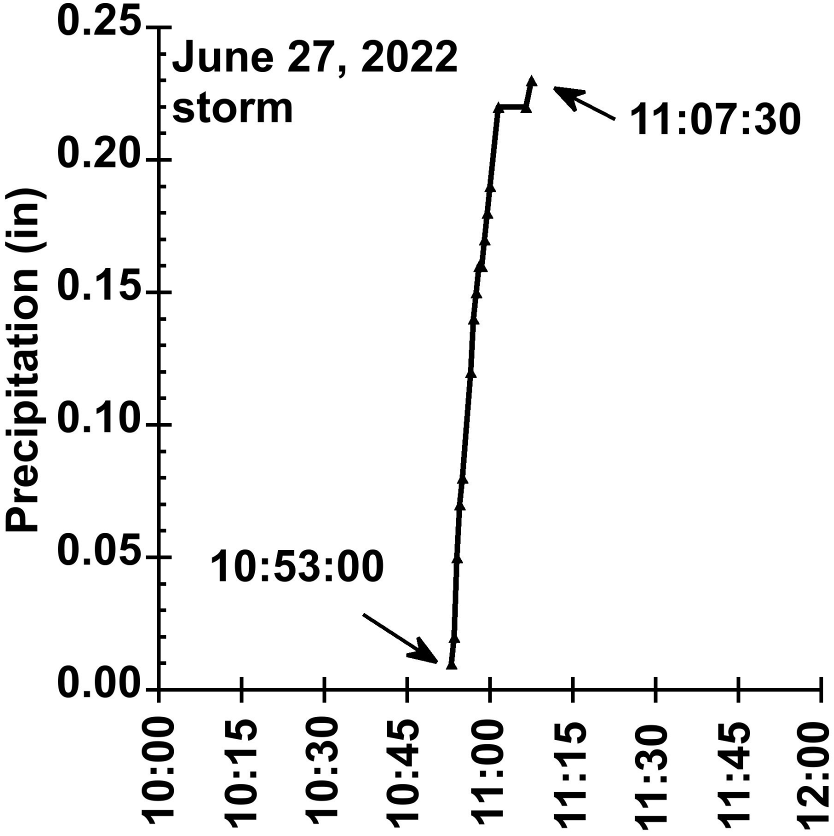
- Example animation: June 27, 2022 storm, 10:53 – 11:07 AM
  - Animation for 24 hours surrounding storm (@ 5 min time step)
  - 288 data snapshots = 288 maps

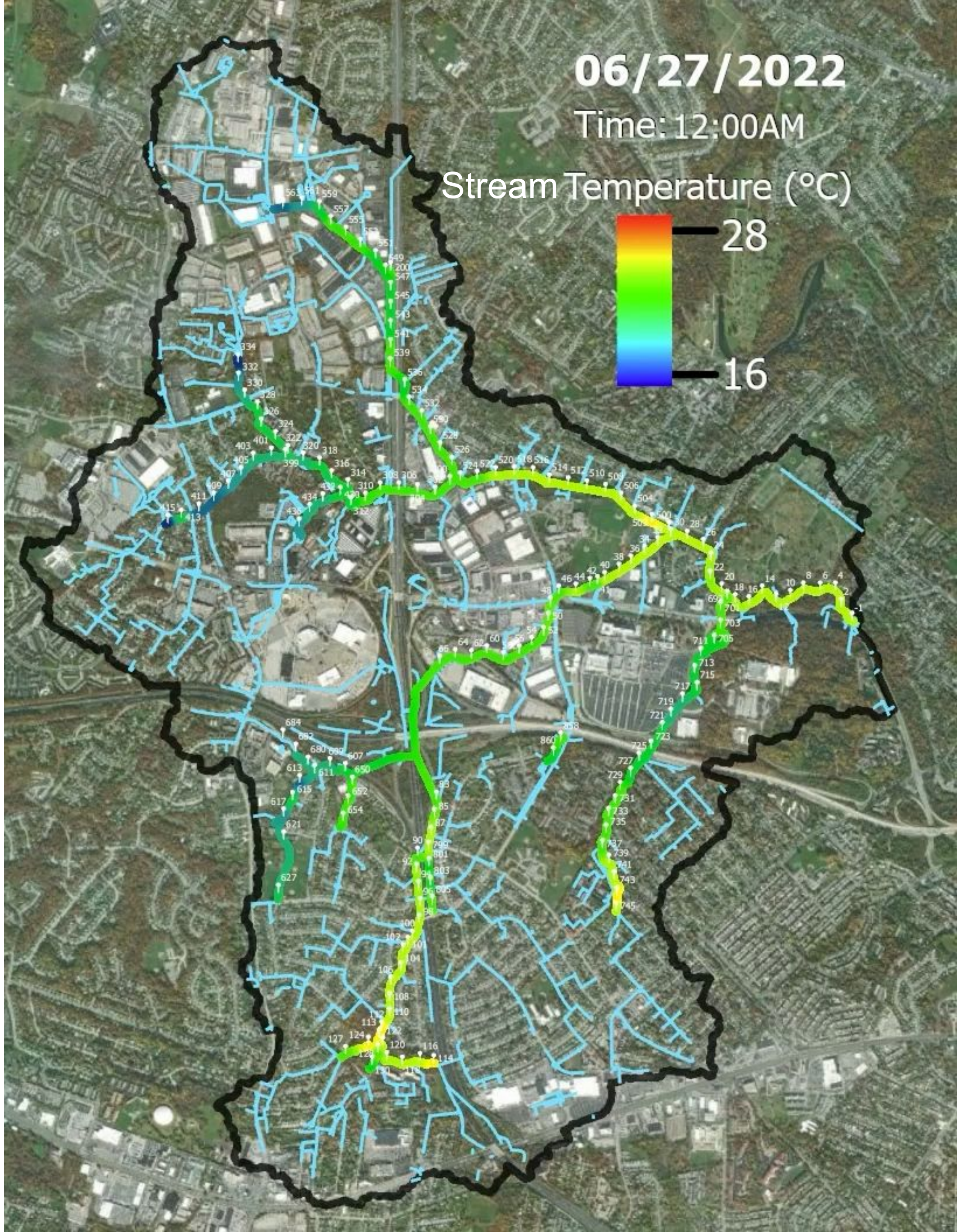
- We constructed a GIS model that automates map creation
  - Each map shows temperatures for all sensors in a "view" at a single snapshot in time.
  - The model then iterates for all 288 maps in one day.
  - We can do this for any view (e.g. one stream segment or all) and for any time period for which we have data.

# Stream temperature animation using GIS and video editing software

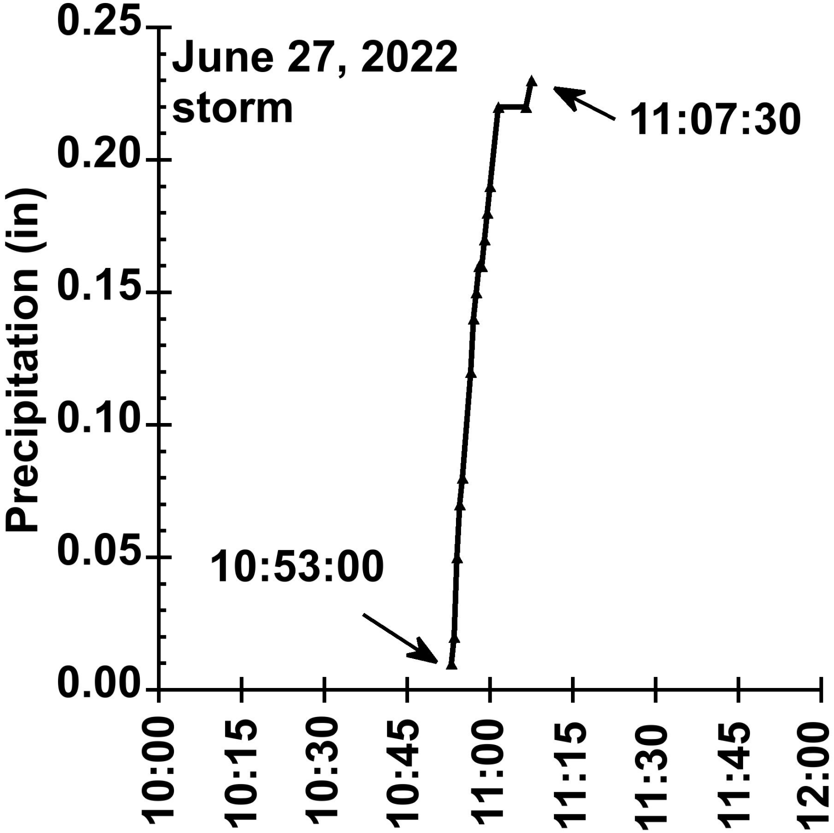
- Temperatures are displayed using an interpolated color gradient
- The collection of maps is then arranged
  - in sequence
  - for a set duration
  - analogous to a digital version of flip-books children play with

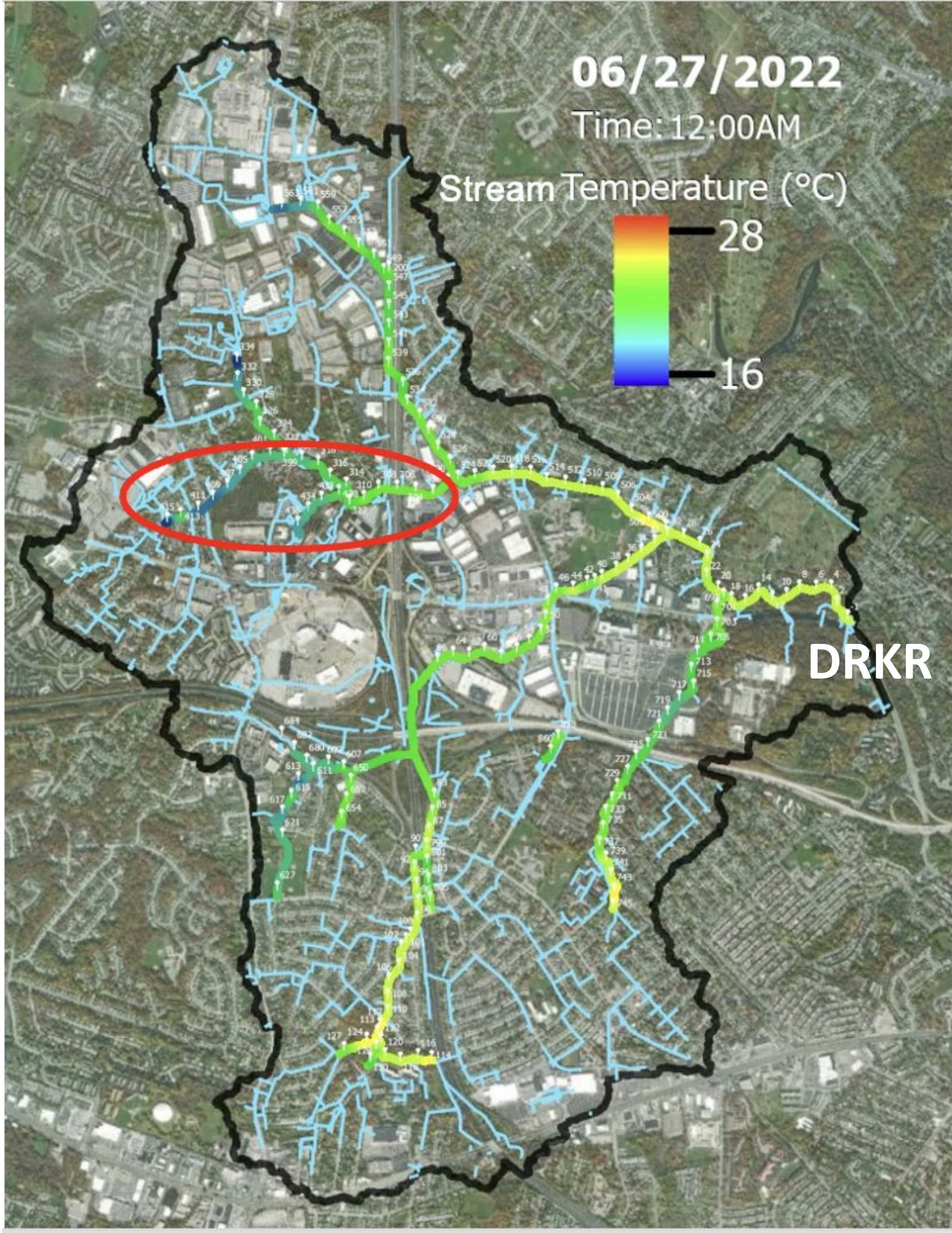
# Example animation: June 27, 2022 storm



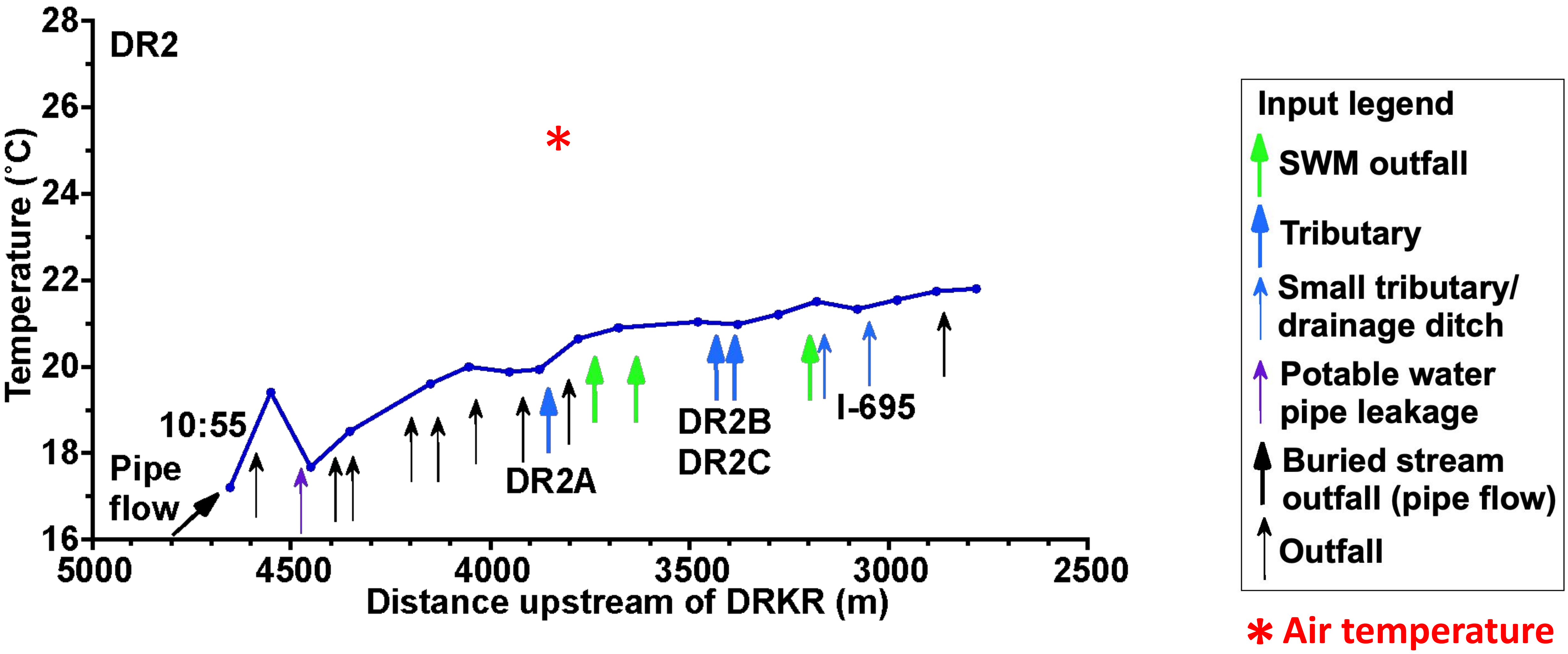



# Example animation: June 27, 2022 storm

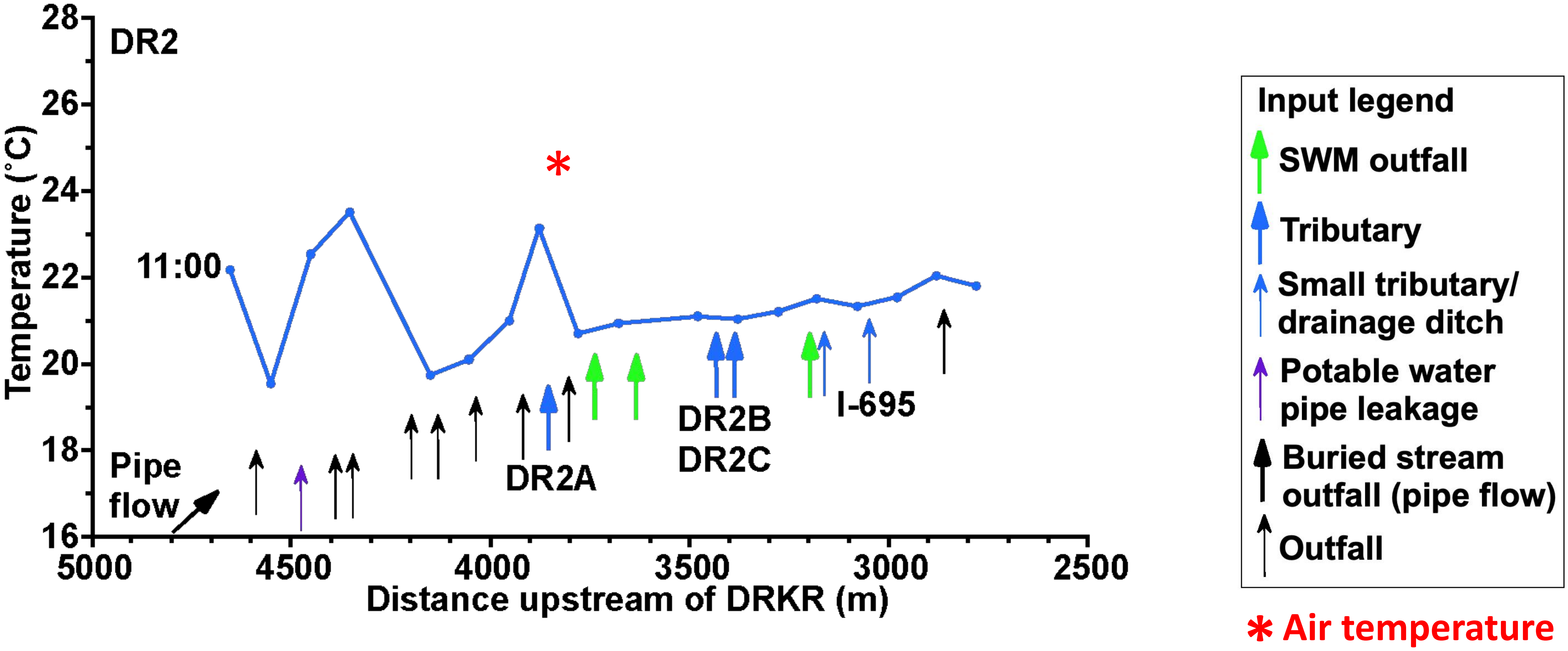


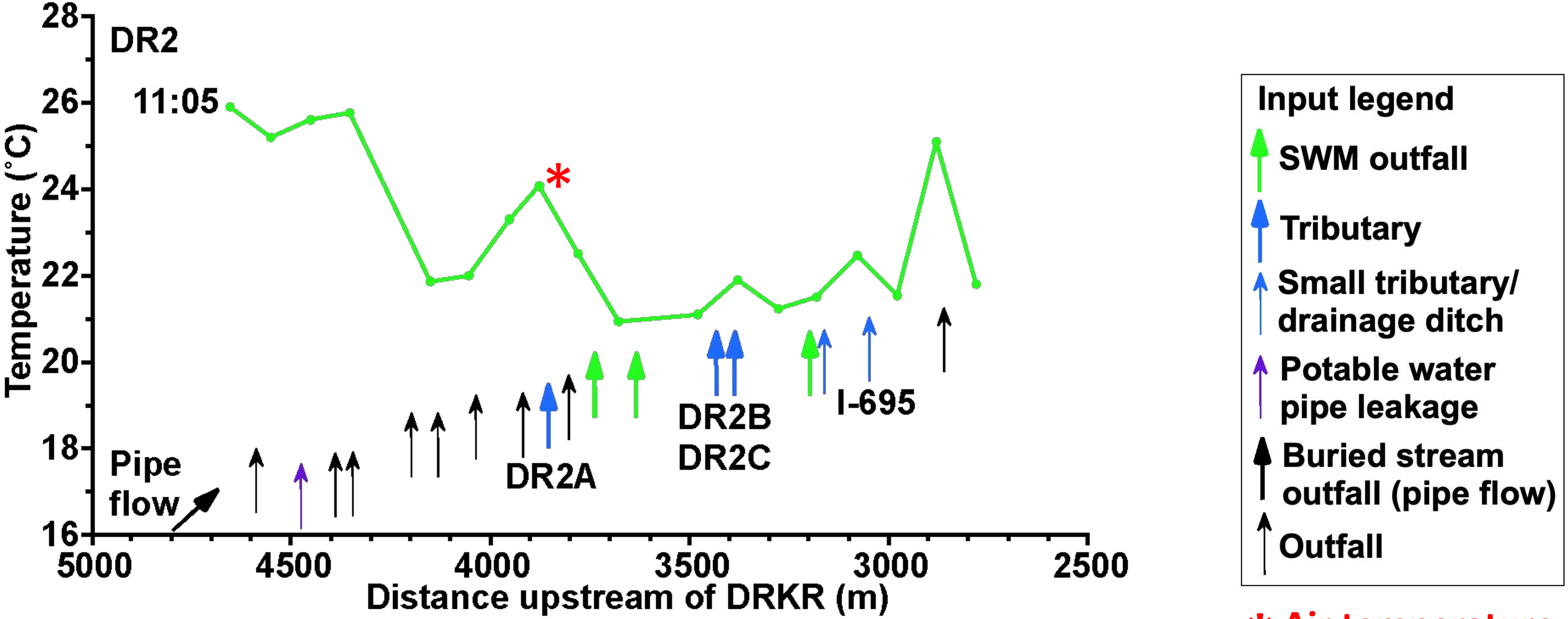
# Example plots: June 27, 2022 storm



# Example plots: June 27, 2022 storm

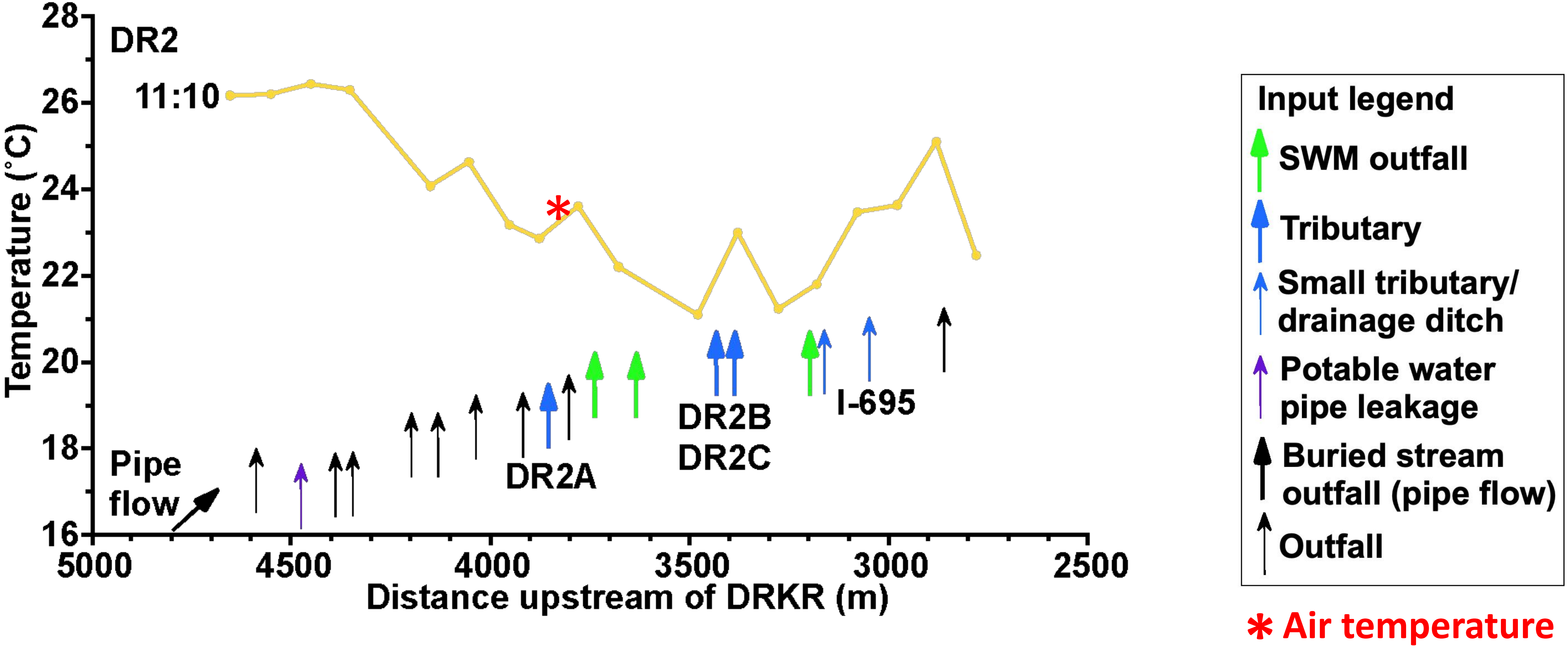


# Example plots: June 27, 2022 storm

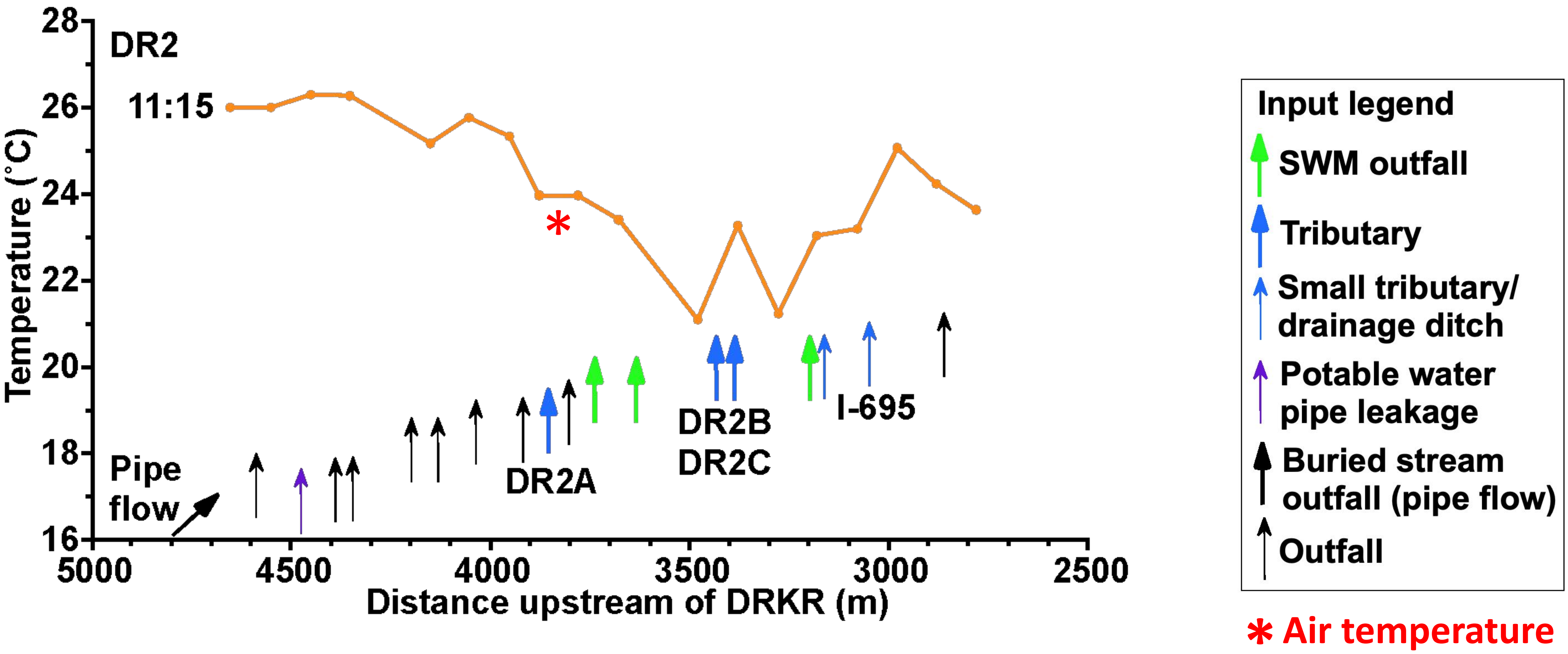



* Air temperature

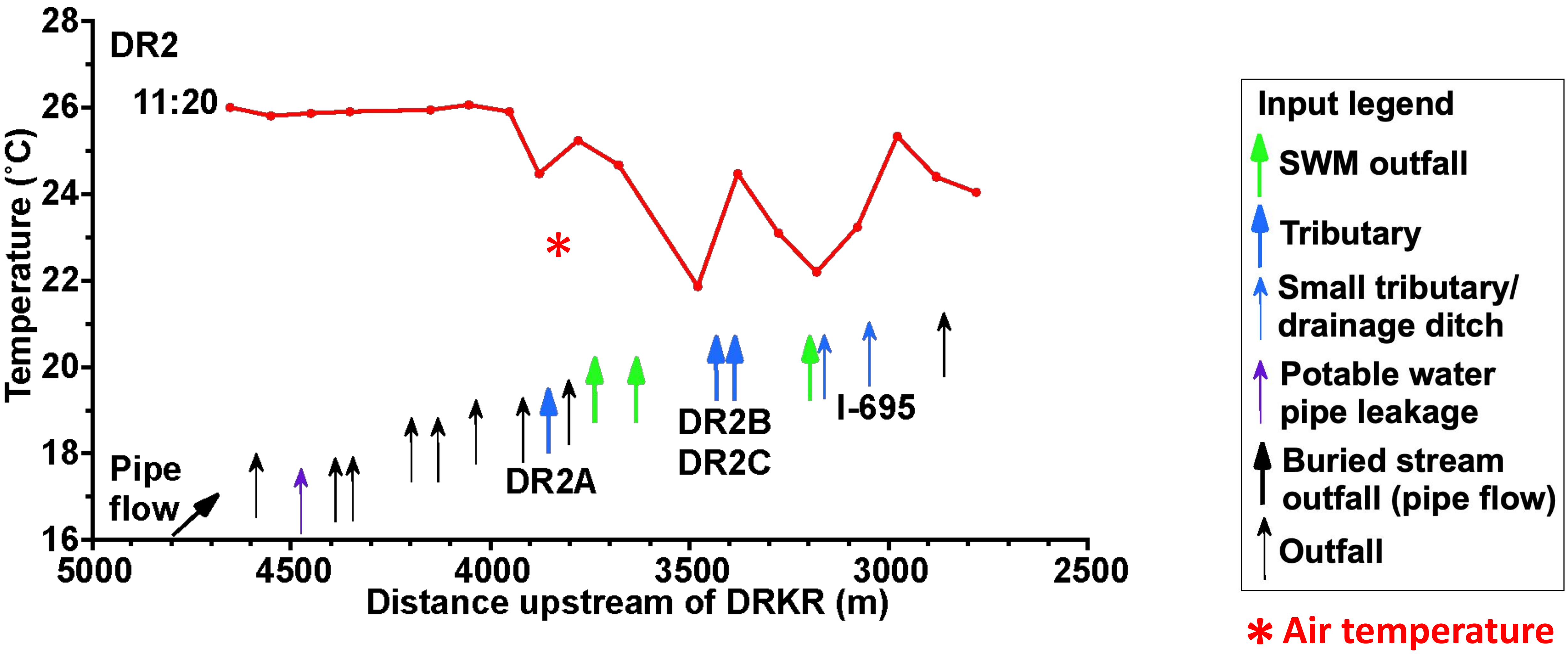
# Example plots: June 27, 2022 storm



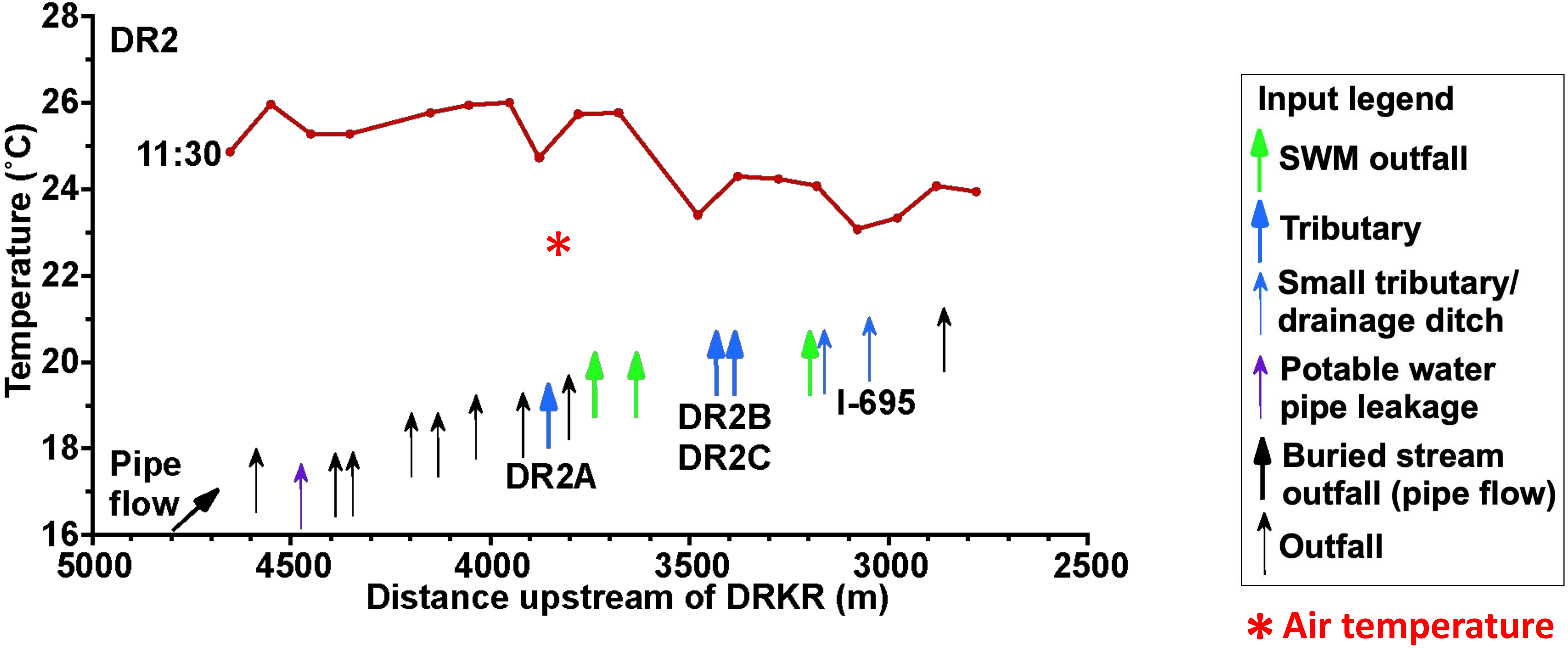
# Example plots: June 27, 2022 storm



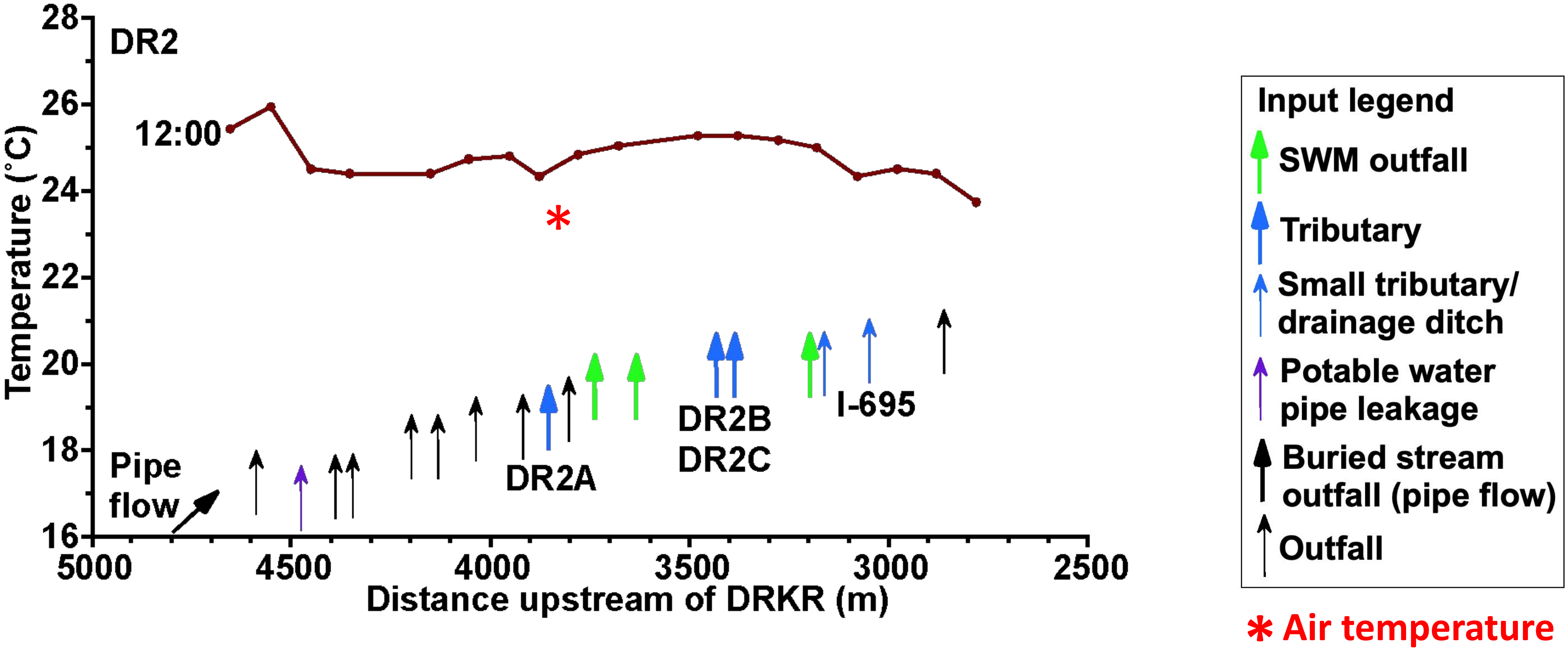
# Example plots: June 27, 2022 storm



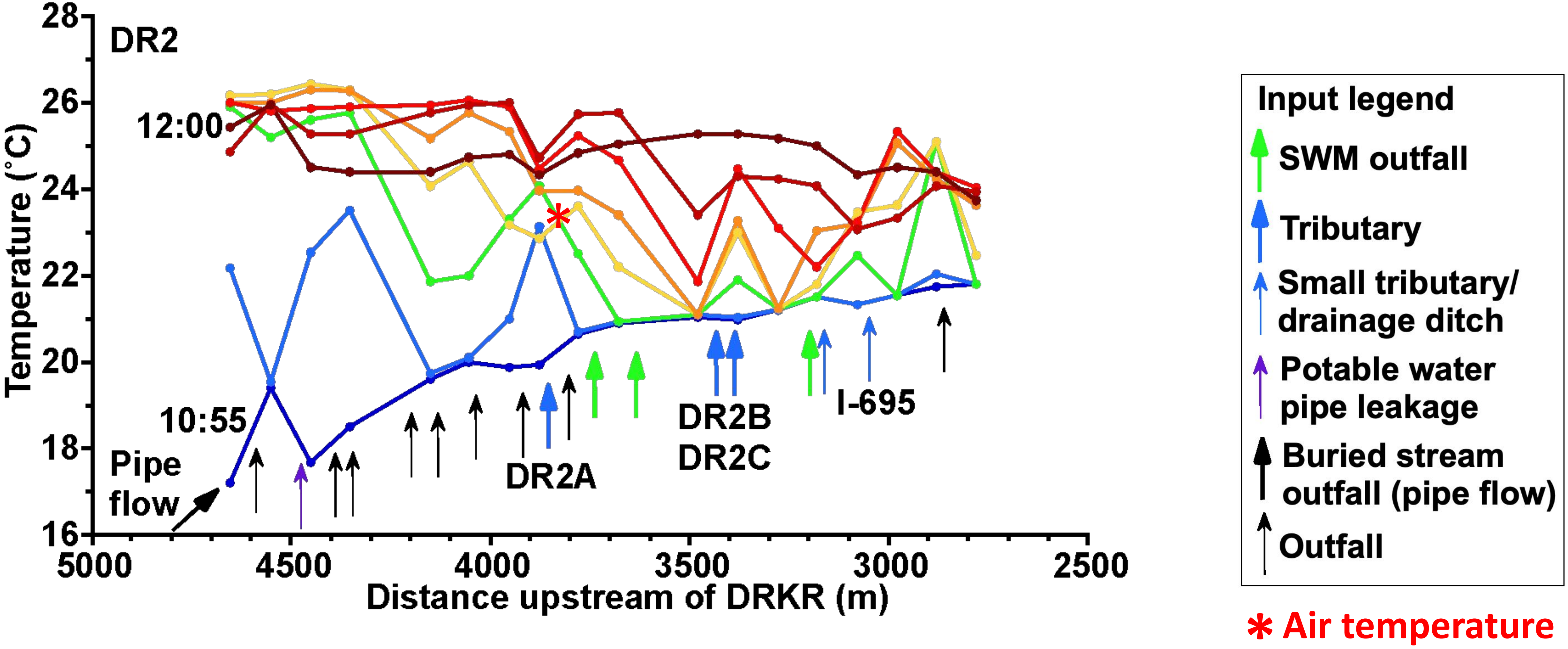
# Example plots: June 27, 2022 storm



# Example plots: June 27, 2022 storm



# Example plots: June 27, 2022 storm



# Summary

- High-density, high frequency temperature sensor network successfully deployed along 16 km of stream length.
- State-of-the-art GIS video mapping enables qualitative evaluation of stream-network thermal response to inputs from stormwater runoff.
- Example analysis points toward uncontrolled runoff contributing substantially to thermal impacts to the stream system.
- Comprehensive analysis of data across many storms and SWM facilities will be carried out next.

# Acknowledgments

CBT/DNR – Pooled Monitoring Fund

UMBC/CUERE staff

Samantha Volz, Amalie Rebstock, Hanna Donovan

USGS - Sarah Queen

# Translation Slides

What are the take home points?
What does this mean for me?

Translation Slides by Greg Golden, Environmental Review Program,
MD Department of Natural Resources

# What does this mean for me?

- Only in recent years has it been feasible to study stream thermal regime and thermal influences at this high level of resolution.
- Data sets and analysis are now feasible; this is among the earliest documentation in Maryland at this resolution.
- Preliminary analysis is revealing importance of temporal sequences and spatial / locational influences.
- Stormwater retrofits, riparian buffer improvement, and even development planning are better informed by this analysis.

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

- Off-the-shelf new & retrofit SWM designs and approaches for thermal protection are a start, but this study's data and analysis will be demonstrating that tuning designs to specific watershed factors will provide optimal resource protection opportunities.

- Practitioners can be preparing to address future thermal regime watershed management decisions by local governments, which have been informed by such watershed-specific data analysis.

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

- Future protection of stream thermal regimes ideally will take into account watershed characteristics and stream continuum (temporal and spatial profile) factors and data.

- Riparian buffers, SWM strategies and retrofits, untreated runoff sources, and impervious surface management all matter to stream thermal regimes, and now have better data collection and analysis tools available.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# Using eDNA methods to extend biological sampling and identify candidate restorations for species reintroductions

Key Research Question: The effectiveness of biological community restoration at the project scale

Bob Hilderbrand, Rodney Richardson, Regina Trott

UMCES Appalachian Lab, Frostburg, MD

Clay Raines

USGS Eastern Ecological Science Center, Leetown, WV

# Thanks to the many funders and partners

CBTRUST
Chesapeake Bay Trust

Baltimore County Maryland

Howard County Maryland

Anne Arundel County Maryland

Montgomery County Maryland
17 76
Gardez Bien

Chesapeake Bay Trust
Empowering people. Restoring nature.

Chesapeake Bay Program
A Watershed Partnership

Maryland Department of Natural Resources

United States Environmental Protection Agency

National Fish and Wildlife Foundation
NFWF

Baltimore City
DPW
Department of Public Works

MDOT
Maryland Department of Transportation
State Highway Administration

# Key idea(s): Stream restorations are effective, but the biota cannot be detected / become established

H1: Ecological recovery is limited by our inability to detect organisms present at such low abundances as to be undetectable using current sampling methods.

# Key idea(s): Stream restorations are effective, but the biota cannot be detected / become established

H1: Ecological recovery is limited by our inability to detect organisms present at such low abundances as to be undetectable using current sampling methods.

If yes: eDNA should identify additional taxa present, but not found in traditional monitoring AND

eDNA should identify additional taxa present in restored sections, but not found upstream of the restoration

# Key idea(s): Stream restorations are effective, but the biota cannot be detected / become established

H1: Ecological recovery is limited by our inability to detect organisms present at such low abundances as to be undetectable using current sampling methods.

If no: We assess H2 and H3:

H2: Ecological recovery is limited by a failure of fish and/or benthic macroinvertebrates to recolonize the stream.

H3: Ecological recovery is limited by the stream's ability to support the desired taxa.

# H2 and H3 are linked to microbial communities

H2: Ecological recovery is limited by a failure of fish and/or benthic macroinvertebrates to recolonize the stream. Indirect assessment.

Support for H2 will find no appreciable numbers of additional fish or benthic taxa, BUT the stream microbial community will indicate suitable conditions for taxa recovery (H3)

H3: The stream may be limited to support the desired taxa.

Stream sediment microbial communities may suggest suitable conditions for recovery of fish and benthos – possible candidate for reintroductions.

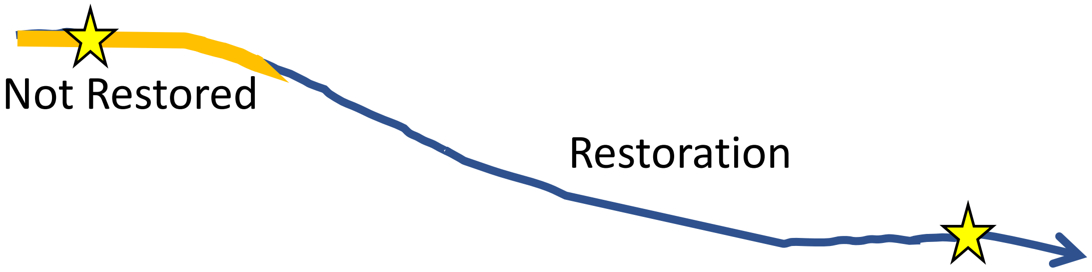
If microbes “say” NO, then conclude that the restoration has not provided suitable conditions for ecological uplift

# All three hypotheses use DNA sequencing methods

eDNA metabarcoding is used for identifying the fish and benthic invertebrates in the stream. Data are geographically filtered to include only those taxa found in the 20+ years of MBSS sampling.

26 restorations examined using water samples collected ~100m above the project and at the bottom of the restoration project

- Single eDNA sample collected in spring
- Across the urban gradient
- RSC-ish and NCD restorations
- Various times since restored




1. Compare taxa in restored vs above.
2. Compare taxa in eDNA vs physical collections

We should expect to see more taxa and more 'desirable' or sensitive taxa in restored sections.

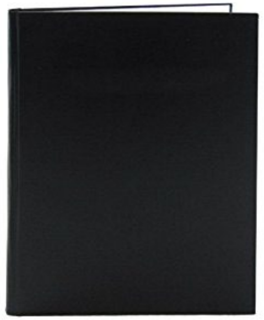
# How the bioinformatics works

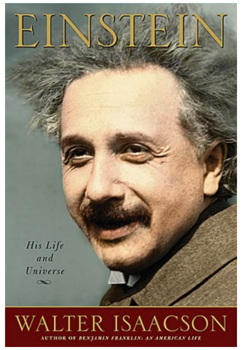
DNA sequences

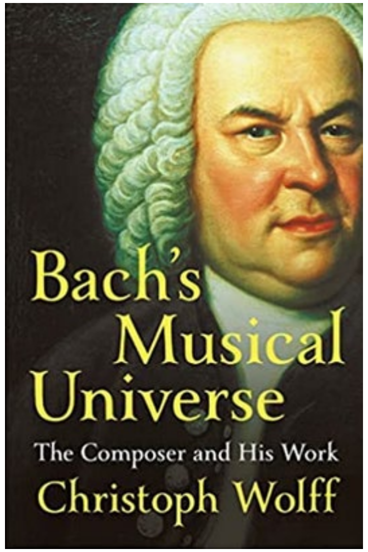
Imagine a library full of books. Each book is a different species. The specific letters on the page are the DNA base pairs of the genome

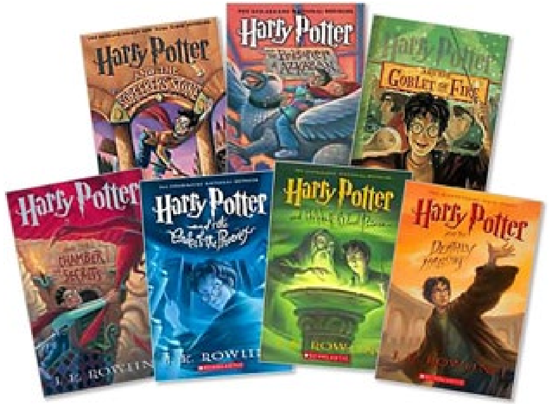
Database

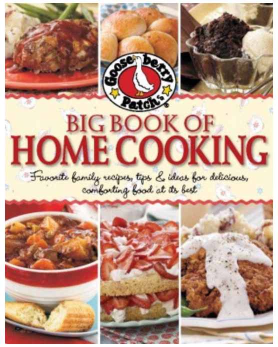
?
No reference sequence

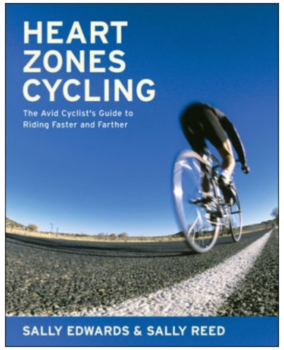






# H2: Ecological recovery is limited by a failure of fish and/or benthic macroinvertebrates to recolonize / establish in the stream.

We use the same samples and eDNA techniques as in H1

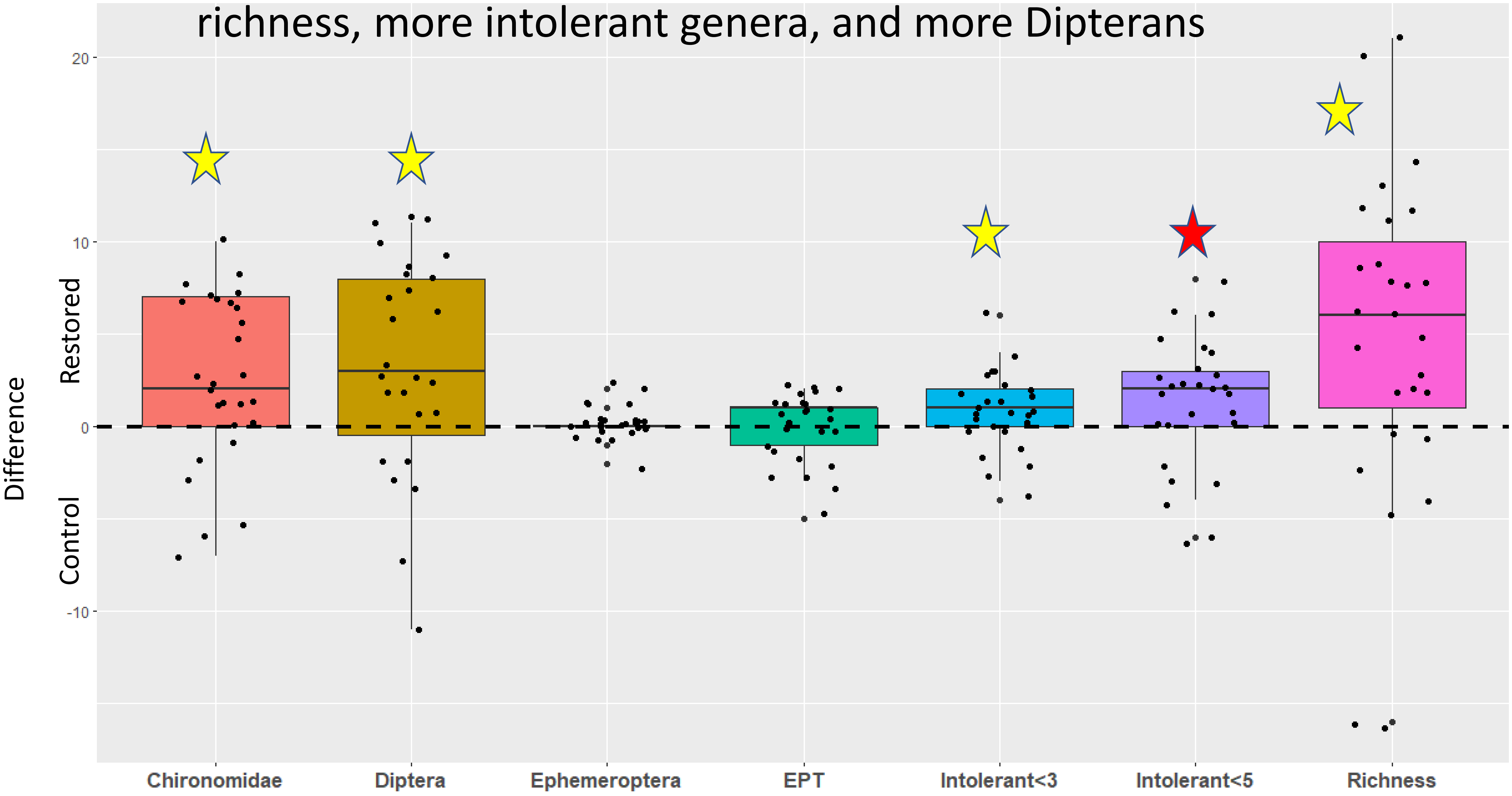
H2 is supported by a lack of difference between upstream and restored AND evidence from the stream microbial communities

We're not yet at the point to evaluate the microbial communities. We have the data, but have not yet run the models.....I figured you would be more interested in the eDNA results for fish and benthos for H1.

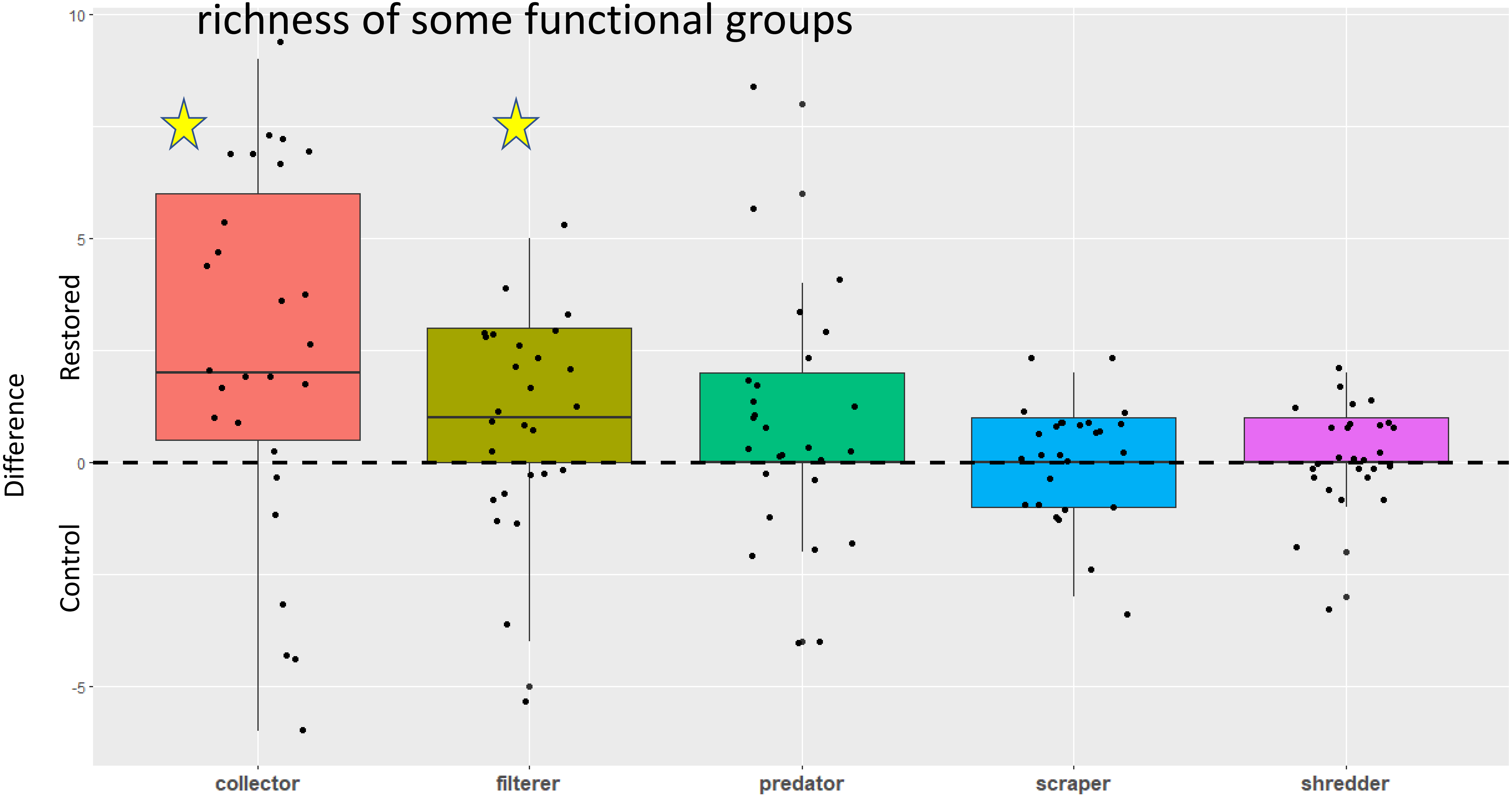
# ALL RESULTS ARE PRELIMINARY AND ARE VERY LIKELY TO CHANGE - ESPECIALLY FOR THE FISH!!!!!!!!!!!!!!!!!!!!!!!!!

# Benthos: eDNA suggests restored sections tend towards higher richness, more intolerant genera, and more Dipterans

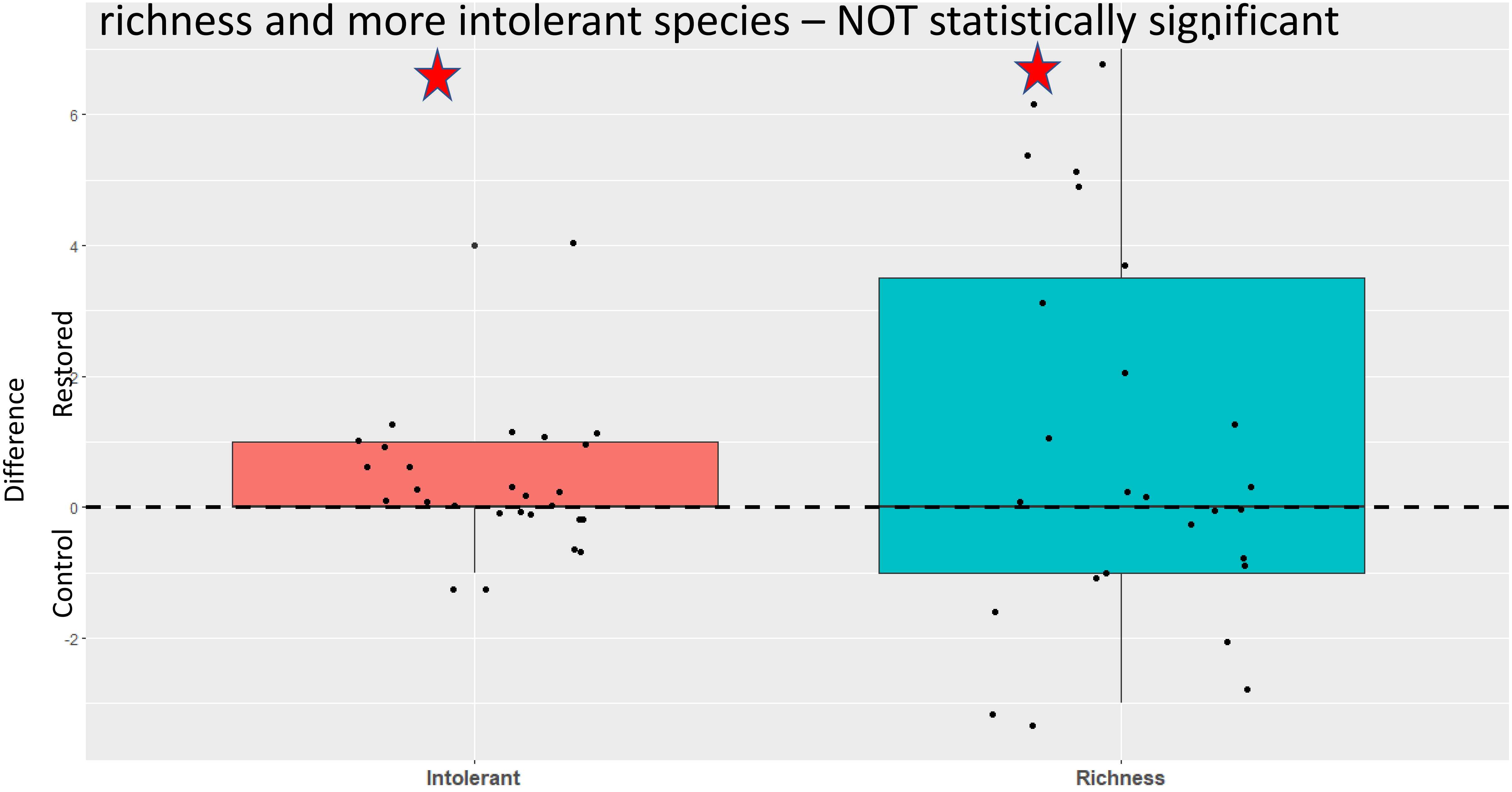




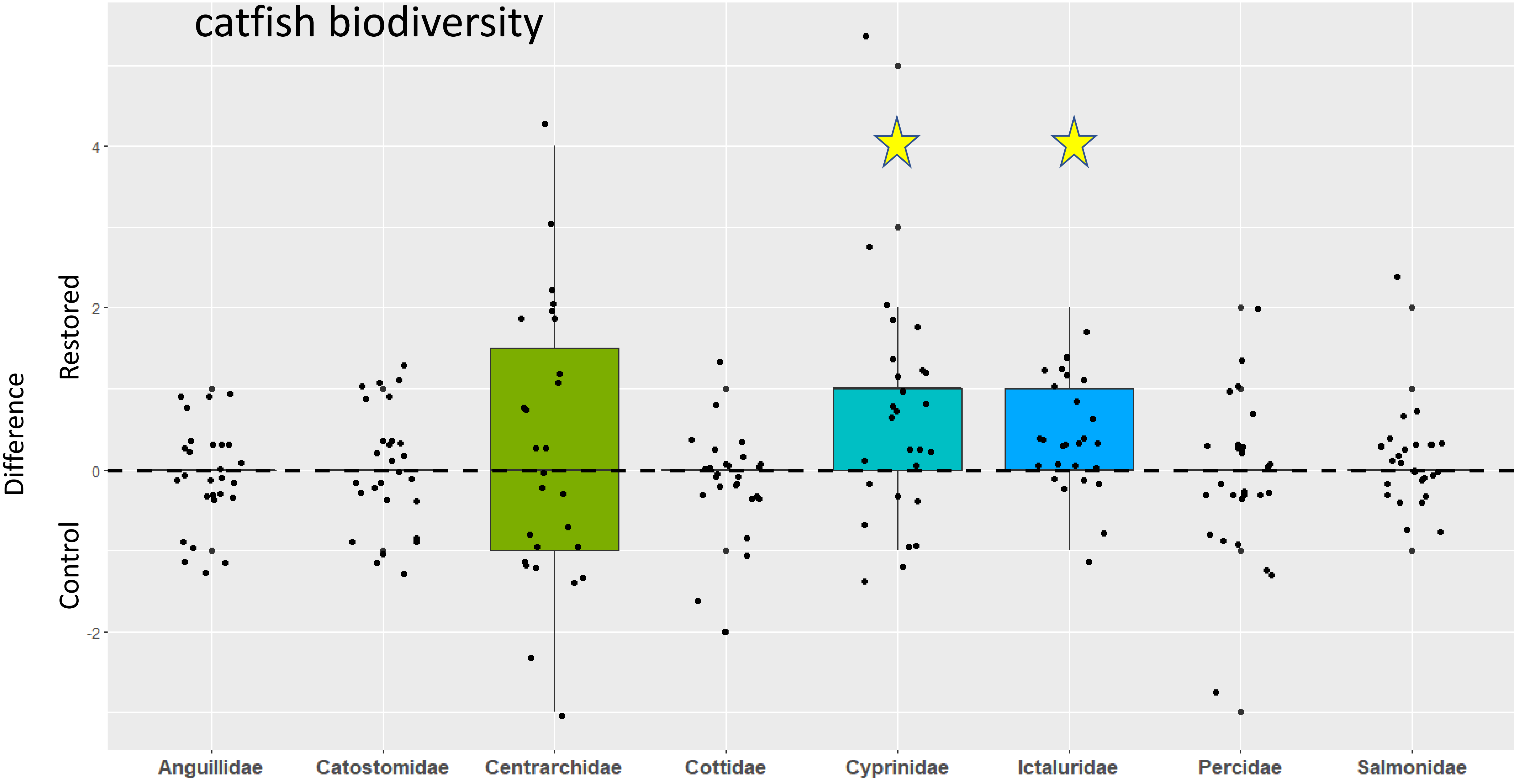
# Benthos: eDNA suggests restored sections tend towards higher richness of some functional groups



# eDNA suggests restored sections tend towards higher fish species richness and more intolerant species – NOT statistically significant

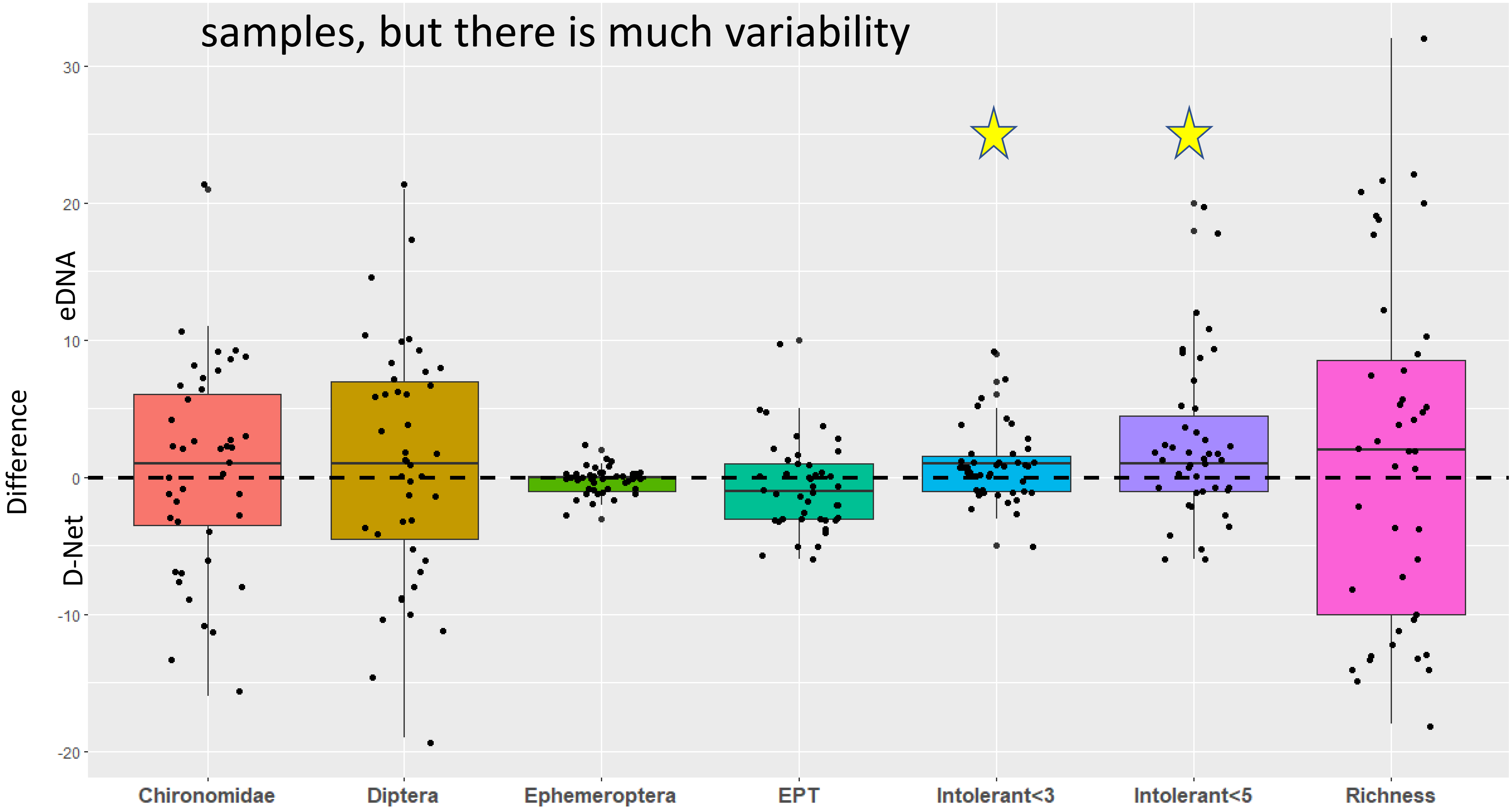


# eDNA suggests restored sections may have more minnow, and catfish biodiversity

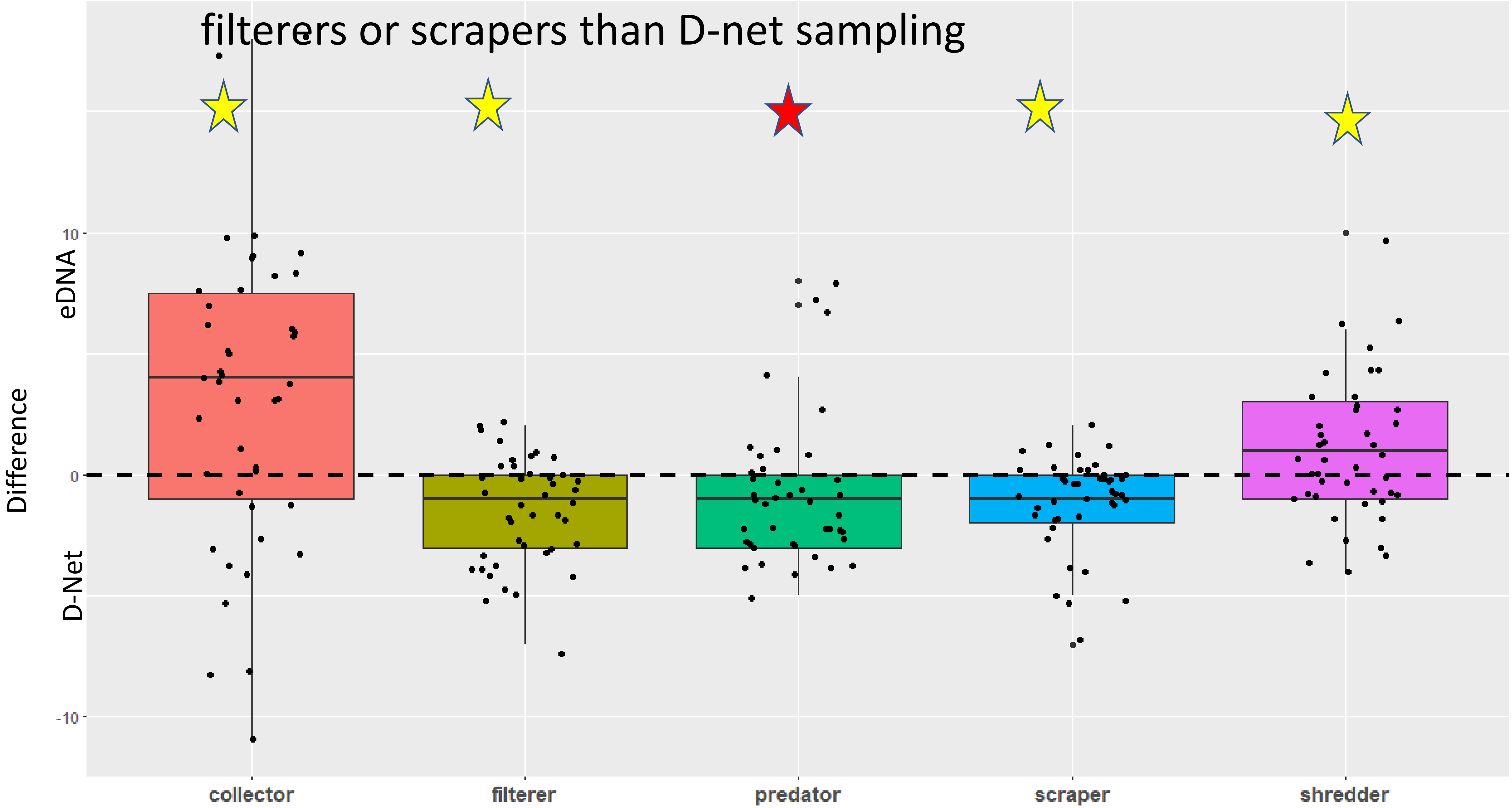


# Benthos: eDNA picks up more intolerant genera than D-net samples, but there is much variability



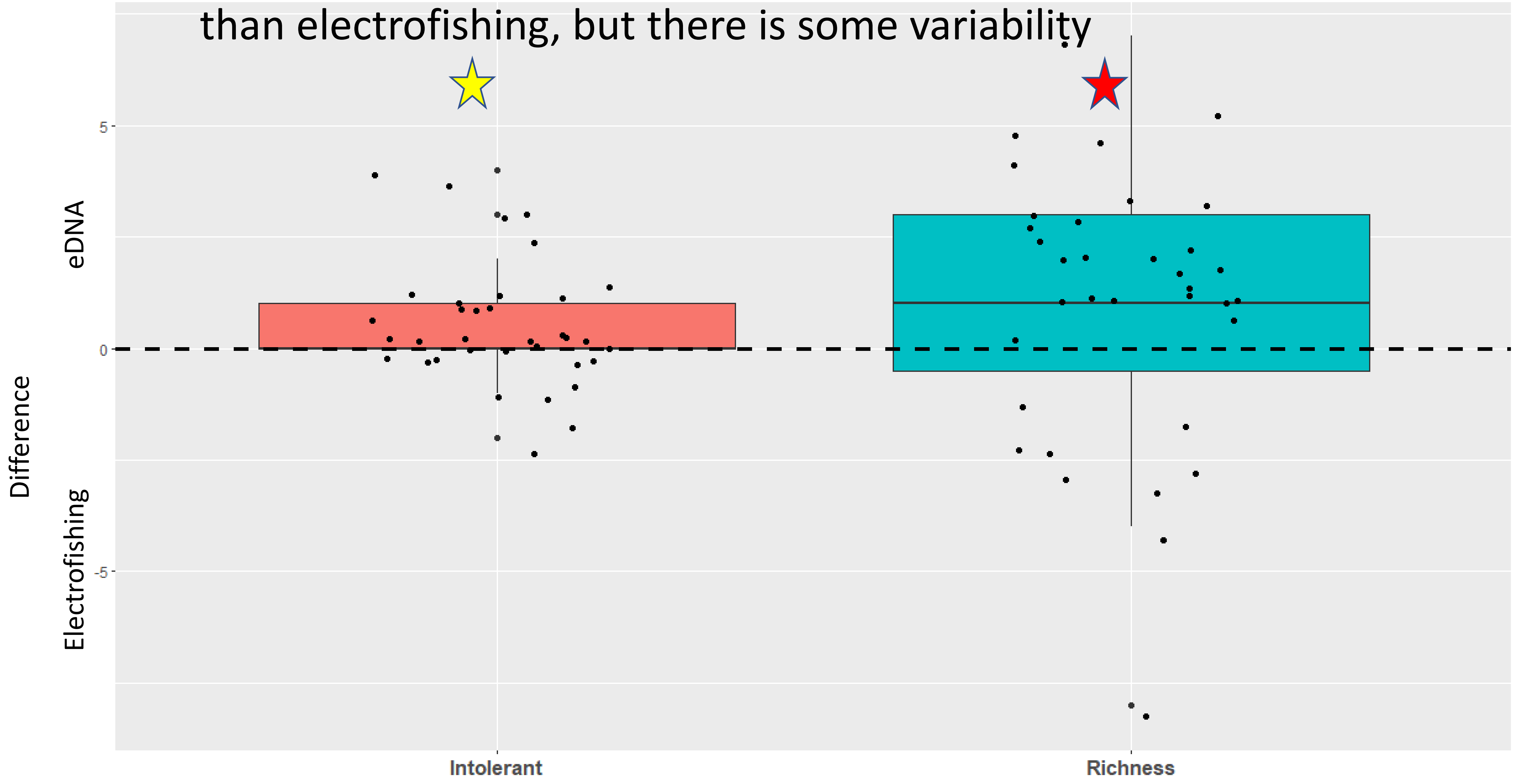


# Benthos: eDNA picks up more collectors and shredders, but fewer filterers or scrapers than D-net sampling



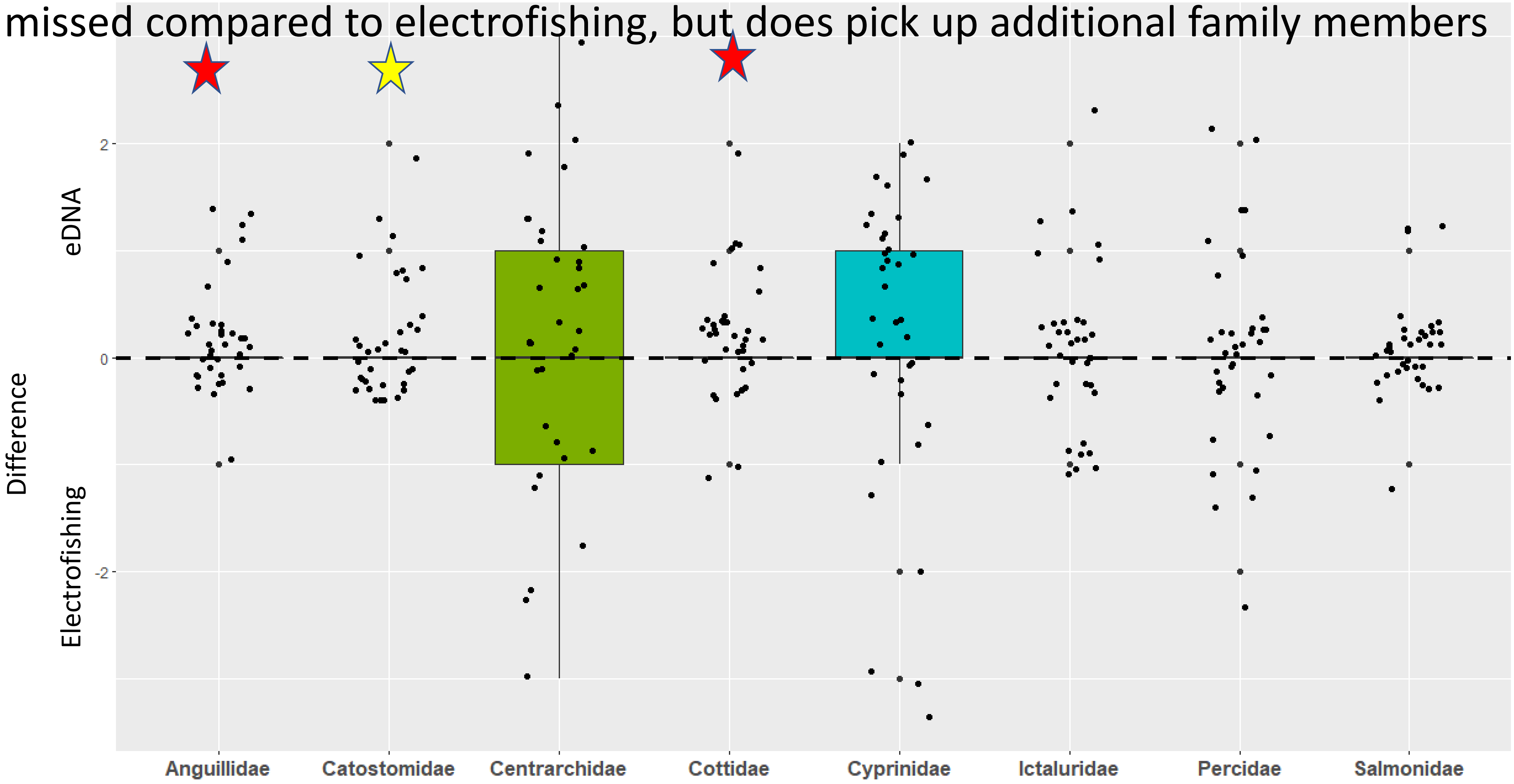
# Fish: eDNA picks up more species and more intolerant species than electrofishing, but there is some variability





Fish: eDNA does not appear to have a taxonomic bias in which species are missed compared to electrofishing, but does pick up additional family members





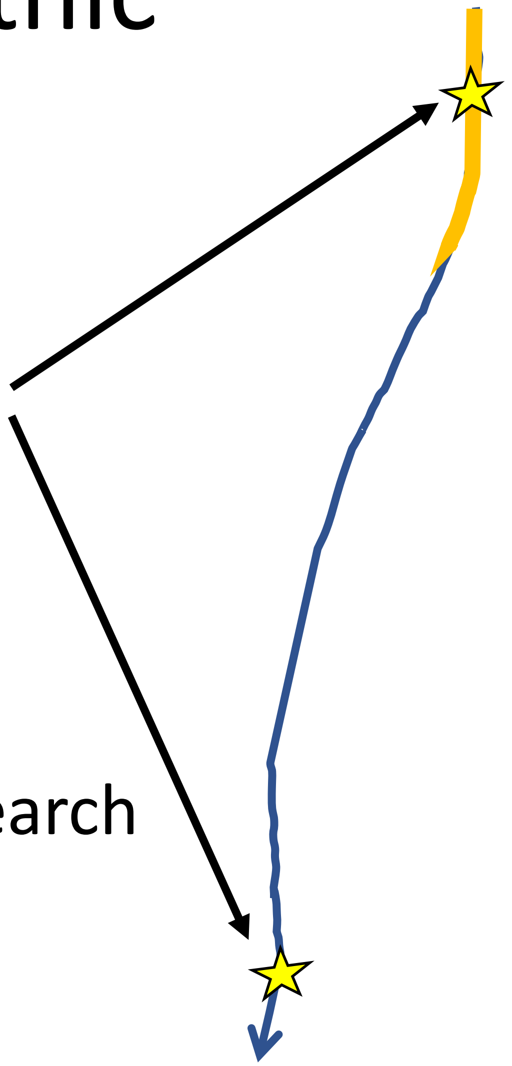
# eDNA suggests restorations have benthic taxa that sections upstream do not*

Higher overall biodiversity in restored sections

- Could be sampling effect: 2x more sampling for restored
- More analysis required

Greater numbers of sensitive taxa in restored sections

- Mostly from Diptera and NOT from EPT
- Could explain lack of IBI score differences in previous research



# eDNA suggests restorations may have positive fish response*

VERY PRELIMINARY and NOT STATISTICALLY SIGNIFICANT!!!!!!!

Trend towards more fish species and more sensitive species in restored sections

Could also be a sampling effect – 2x more sample in restored

Higher biodiversity of minnows and catfishes

Keep in mind this is only 1-2 more species

# eDNA results are mixed compared to D-net sampling for benthos

eDNA picks up more intolerant benthic genera than D-net sampling

Several functional group differences

- eDNA finds more collectors and shredders
- D-net finds more filterers and scrapers and possibly predators

# eDNA seems to pick up more fish species than electrofishing

Trend for more fish species with eDNA, but not statistically significant

Greater numbers of sensitive species with eDNA

eDNA will probably show more improvements once we clean up the taxa lists

> e.g., genome variation caused several eels and sculpins to be assigned to species not in the MBSS database, but were almost certainly American eel or Blue Ridge sculpin

# Final Thoughts

There have been some improvements in restorations that are not found in the upstream areas – Good News!

This should NOT be viewed as “Mission Accomplished”

Restorations are still missing most of the indicator taxa. There are still limitations.

- Habitat (in)stability and intolerant dipterans/chironomids
  - Substrates for reproduction by EPT?
- External gills of EPT indicators
  - Chemical sensitivity? Abrasion sensitivity?
- Might not be fixing the actual problems

Microbes still need to be evaluated to determine extent of potential uplift and reintroductions of benthos and fish

# Translation Slides

## What are the take home points?
## What does this mean for me?

Translation Slides by

Jay Kilian, MD Dept. of Natural Resources, Resource Assessment Service

# Take-home messages from this research:

- eDNA detects higher richness in benthic and fish communities not detected using traditional methods (e.g., D-net, electrofishing). This is likely due to:
  1) eDNA samples “all” habitats (e.g., not just 20 $ft^2$ of best available habitat)
  2) traditional rapid assessment methods do not provide a complete census of all taxa living in a stream.

- eDNA detected subtle biological changes (e.g., addition of taxa) associated with restoration
  - “New” intolerant taxa found downstream, but no changes observed in EPT and other important indicators

# Take-home messages from this research:

- eDNA used in tandem with traditional methods may provide a more complete picture of the biological changes resulting from restoration

- eDNA is a promising technique for stream bioassessments, however much research is still needed to:
  - Reliably compare results from eDNA and traditional sampling methods
  - Correlate abundance of eDNA with the abundance of actual taxa
  - Determine the best time of year to sample using eDNA
  - Evaluate eDNA performance over habitat types (e.g., blackwater), land use gradients, and biodiversity gradients.

# How it works - metabarcoding

Water sample is collected and DNA extracted

PCR for specific primers targeting fish or benthos

Index barcodes added so multiple samples can be sequenced together

DNA sequencing on Illumina MiSeq (or other platform; 20 million reads)

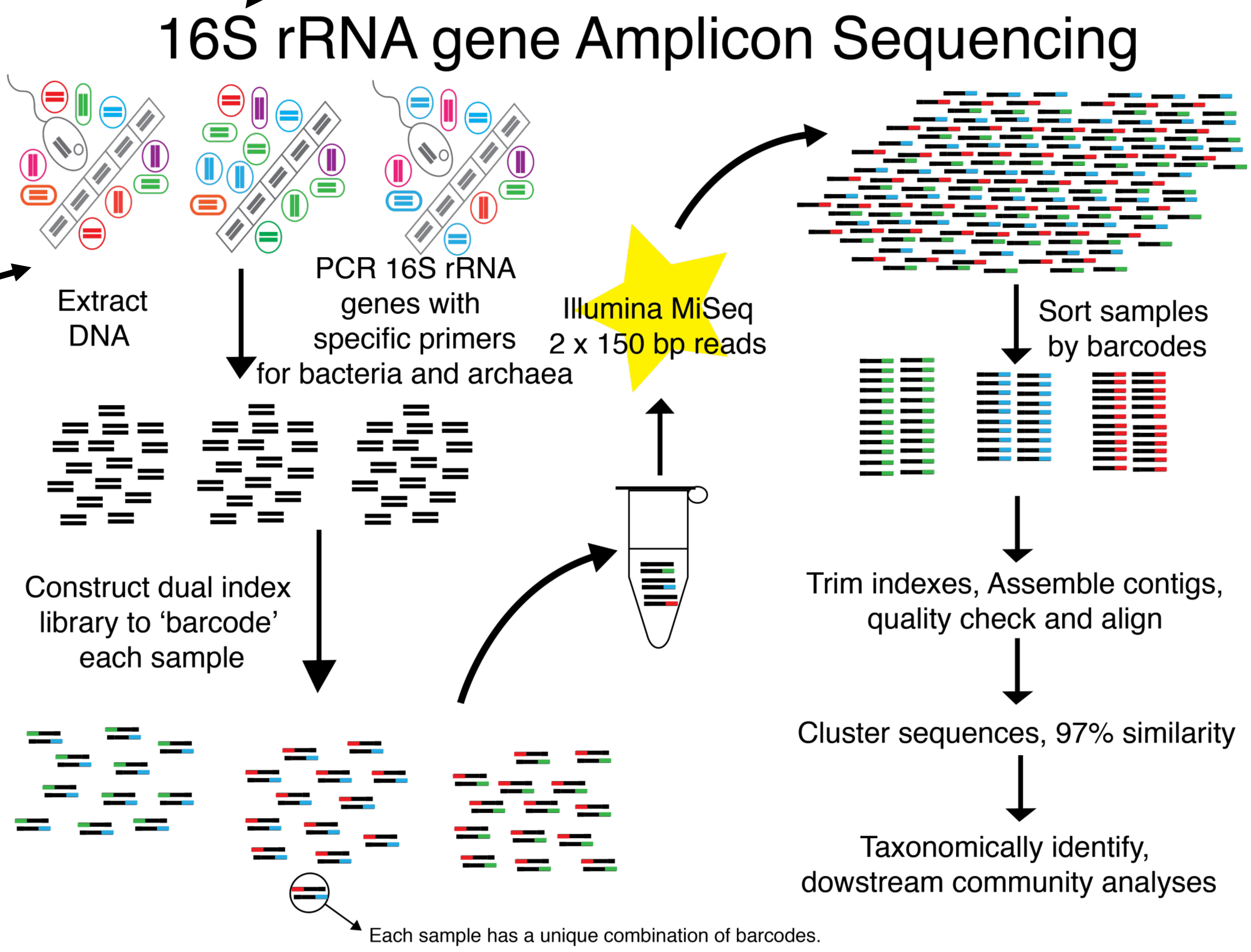
Bioinformatics: Trim indexes, QA/QC, compare against reference db,
cluster for similarity, assign taxonomic identity

# Typical workflow for eDNA

12S, 18S, COI, etc.

Collect water samples

Filter on-site or in the lab



# Impacts of salt loading on nutrient and metal processing in stormwater bioretention

Lauren McPhillips

Alex Brown, Bishwodeep Adhikari, Margaret Hoffman, Hong Wu, Shirley Clark

PennState

# Research Question(s) and Hypothesis(es)

*How do different levels of salt present in a BMP due to road application impact the BMP's nitrogen removal efficiency and export rates out of the BMP of pollutants such as heavy metals?*

Hypotheses:

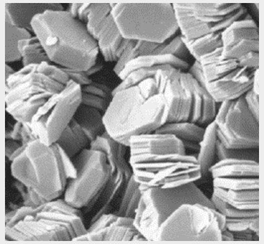
- Increased salt loading into stormwater BMPs is correlated to overall increased export or decreased removal efficiency of N and metals (Cu and Zn).
- Increased soil moisture, greater hydraulic residence times and more salt-tolerant vegetation in stormwater BMPs can moderate impacts of salt loading on N removal.

# Our thinking behind these hypotheses:
*impacts of de-icers*

## Physical

Clay dispersion

Colloid transport



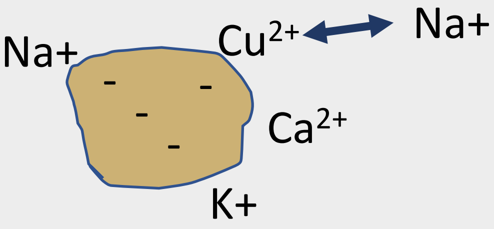
Clogging

## Biological

Cl and Na kill bacteria and plants, reduce denitrification, assimilation

## Chemical

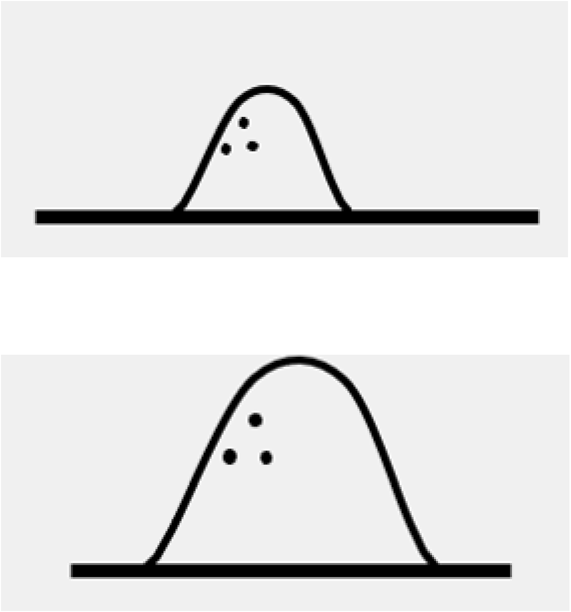
Sodium competes with other cations, and can exchange with metals previously sorbed to soils




Chloride complexes with heavy metals

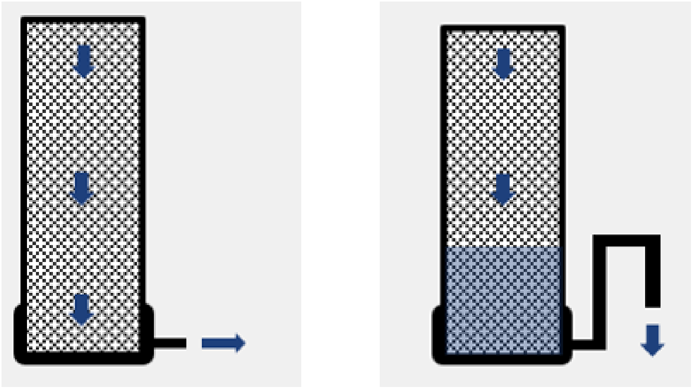
# Our thinking behind these hypotheses:

*ways to mitigate impacts*



*Salt loading*

*Plant selection*

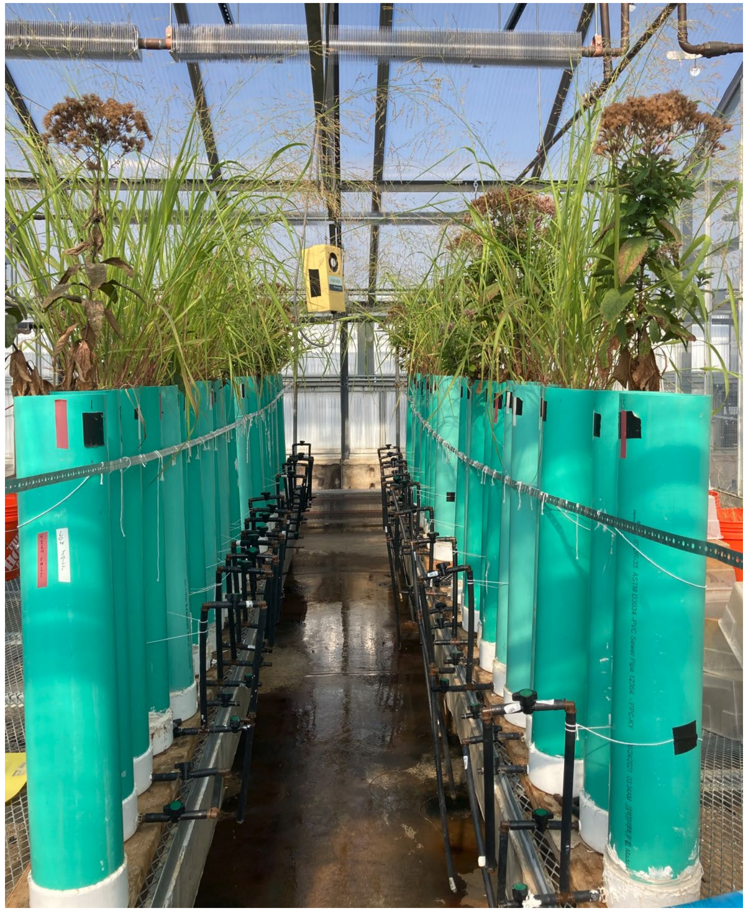


*Hydraulics/ moisture regime*

# Approach

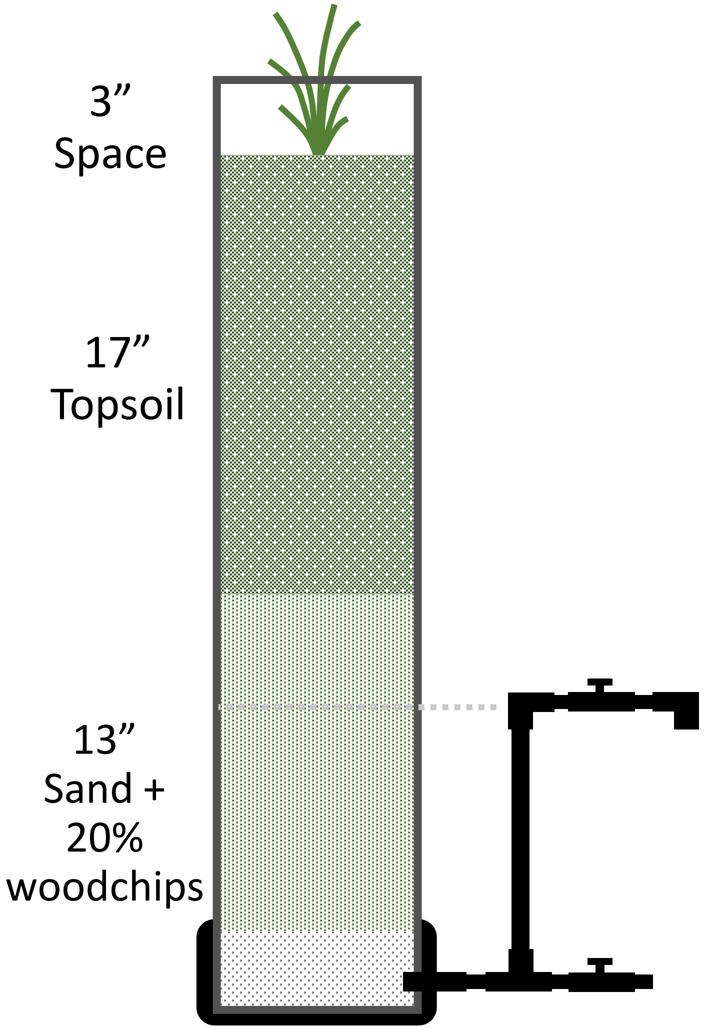
*Field study w/ two basins w/ different salt loading in Lancaster, PA*

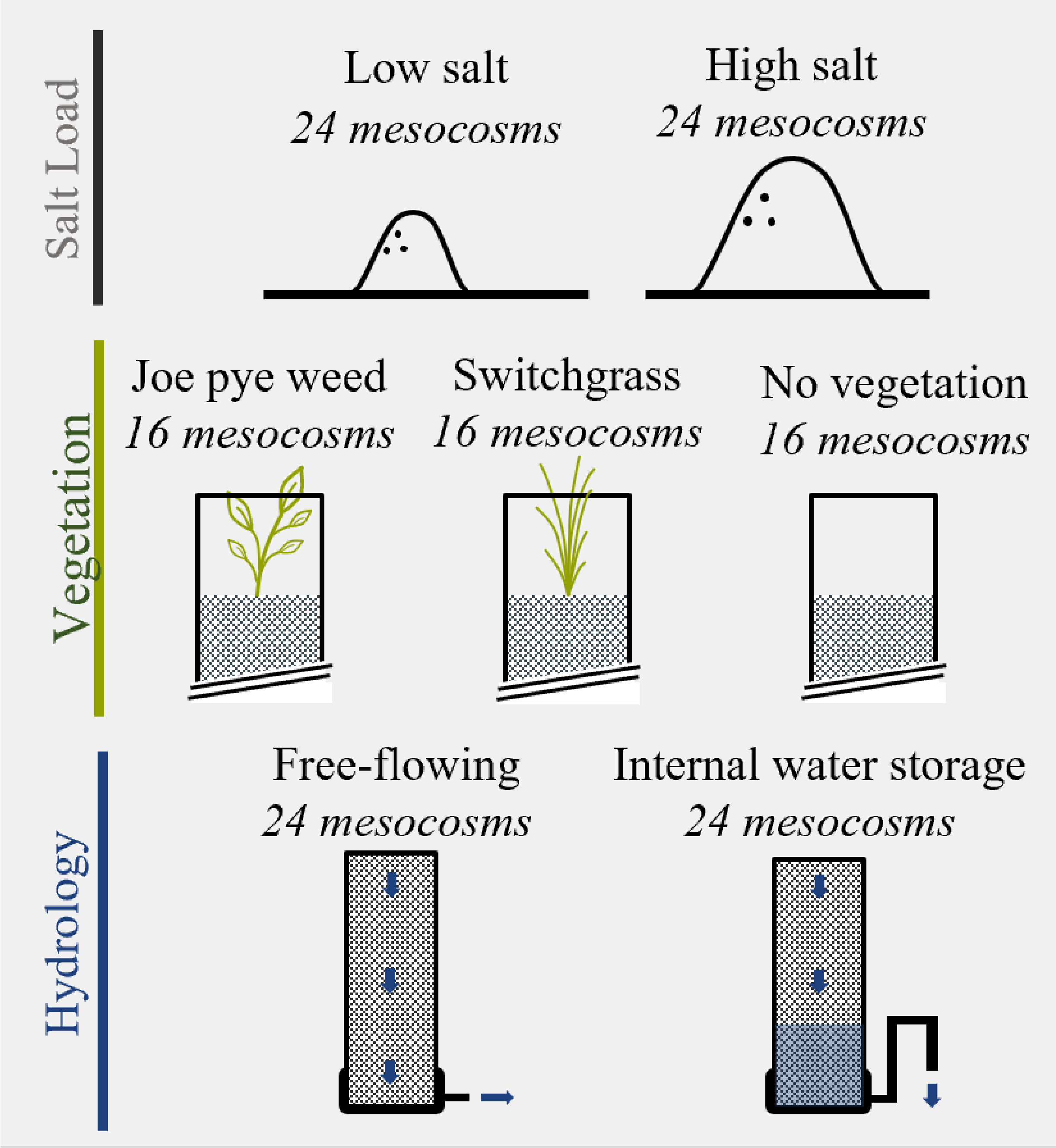
*Greenhouse mesocosm study*



Lead: MS student Alex Brown (who is about to be on the job market for stormwater-related positions in the DC area!)

# Greenhouse experiment treatments



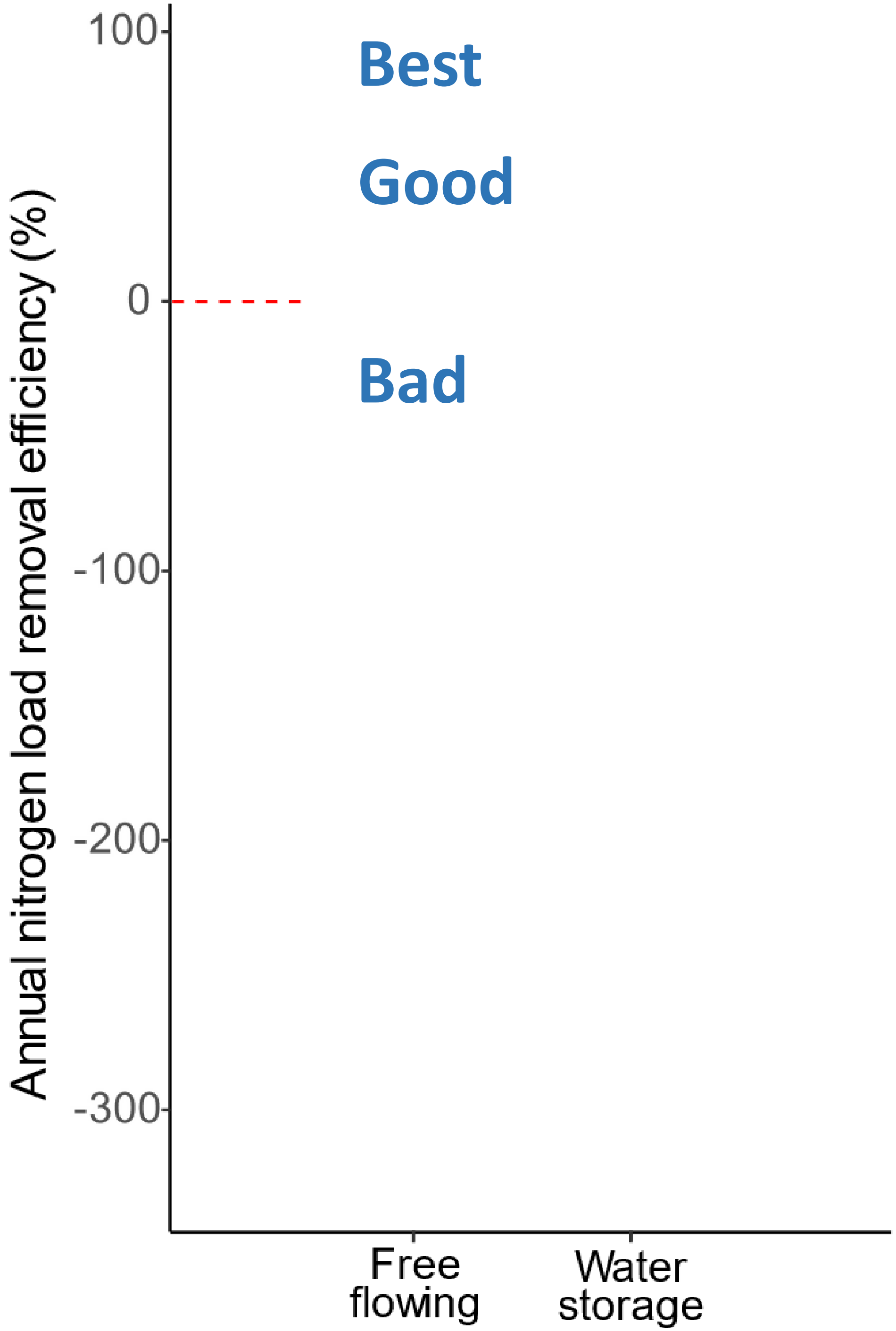
# Sampling

Mesocosms are dosed twice weekly with semi-synthetic stormwater

Water sampling occurs monthly, except during early spring

In spring 2022 and 2023, 'salty stormwater' is added, w/ bi-weekly sampling

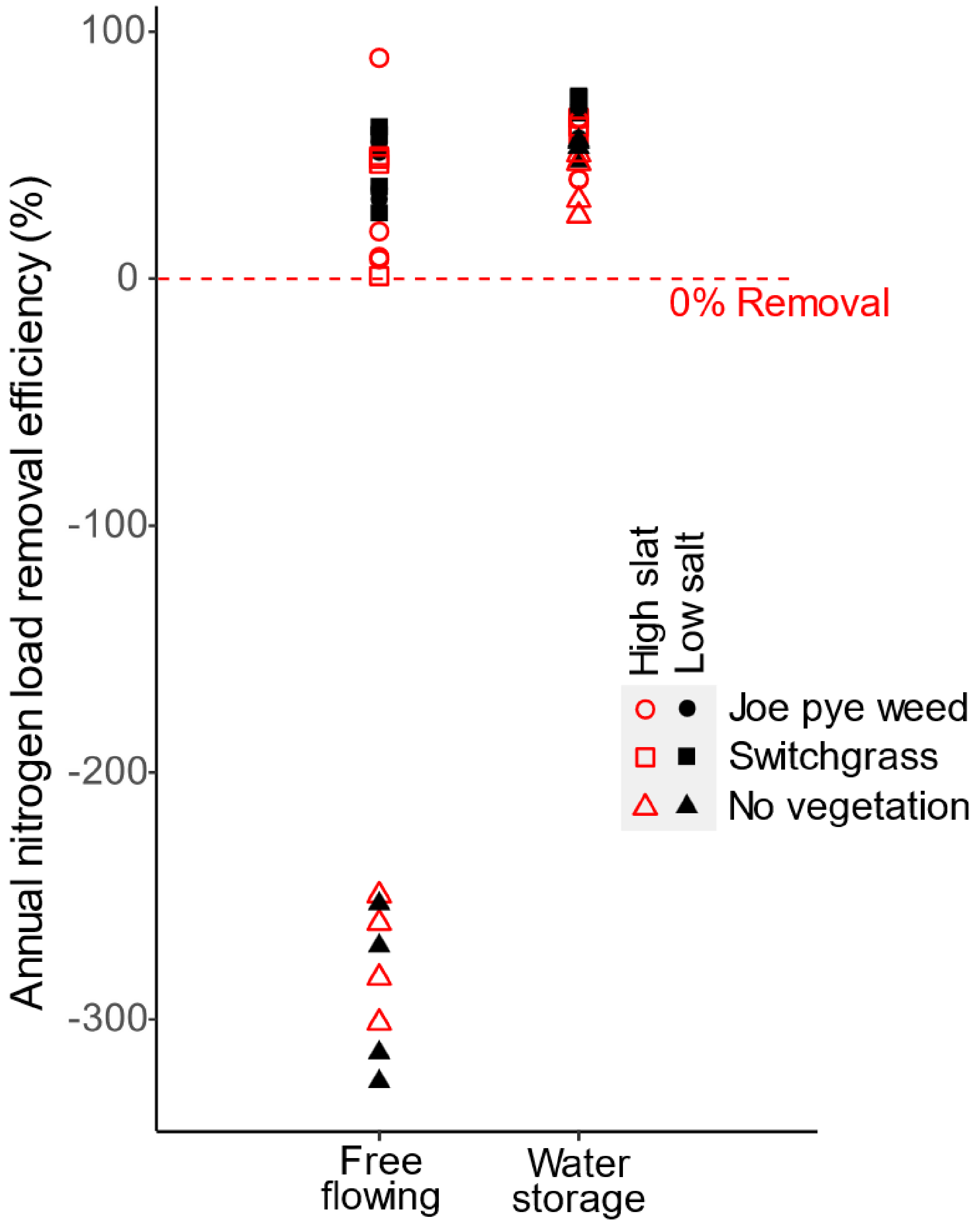
# Interpreting results



Nitrogen leaches in non-vegetated, free-draining bioretention

Internal water storage universally improves N retention

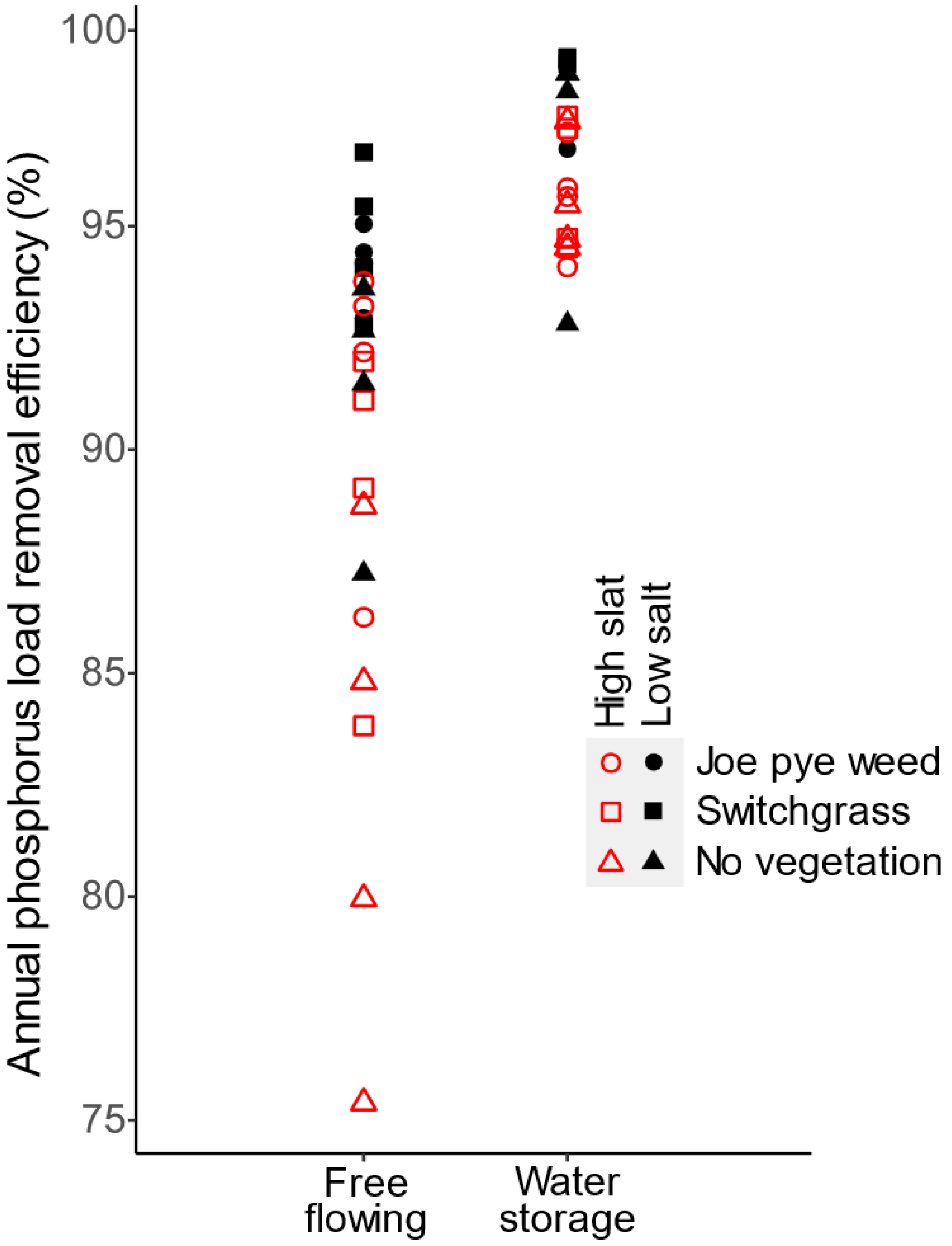
Salt load does not appear to impact N retention overall



Phosphorus is generally well removed

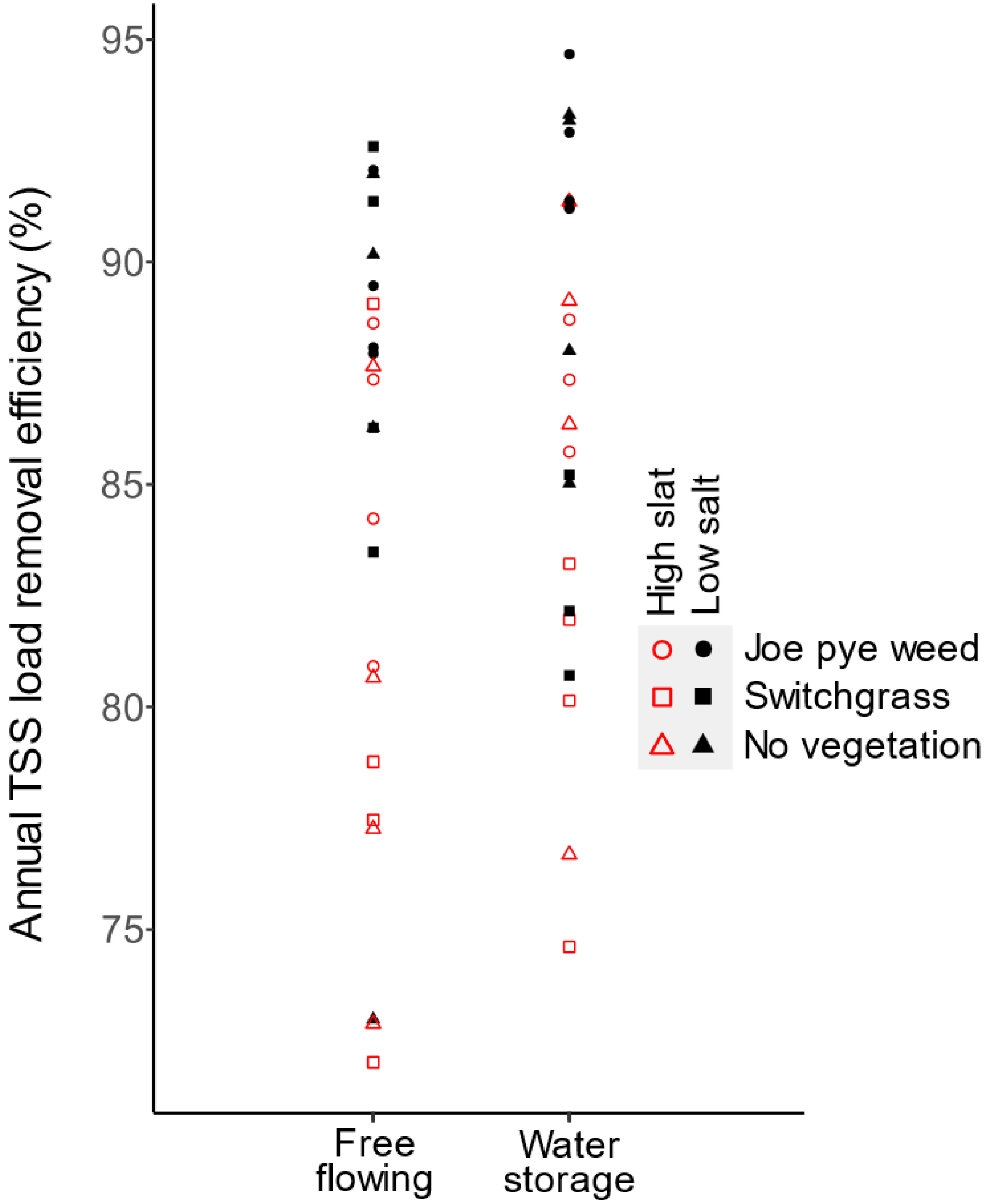
Higher salt load led to reduced P removal

Internal water storage (IWS) improved P retention, and appeared to buffer salt impacts



Total suspended solids (TSS) reduction is overall very good

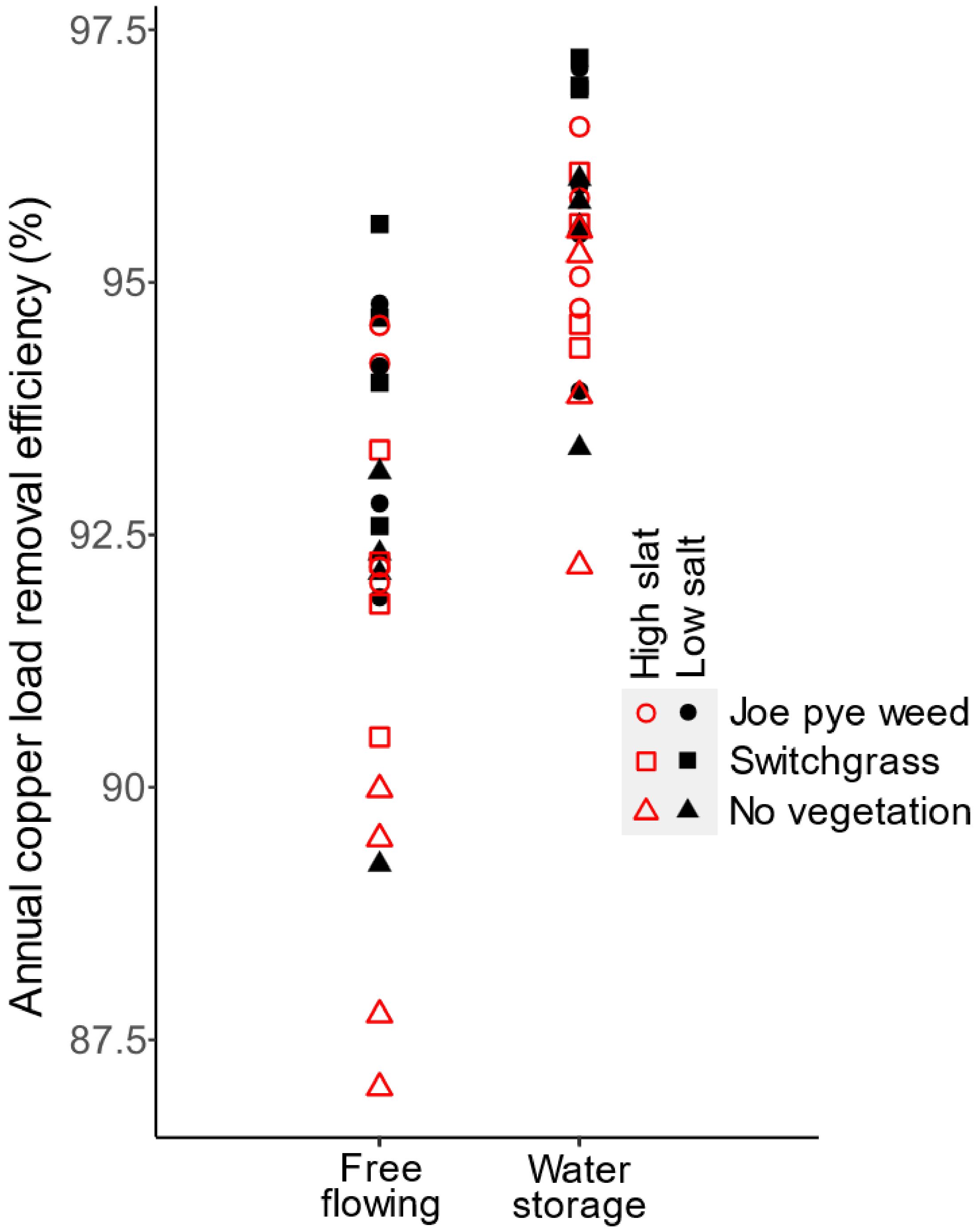
Higher salt load reduces TSS removal



Copper removal is overall very good

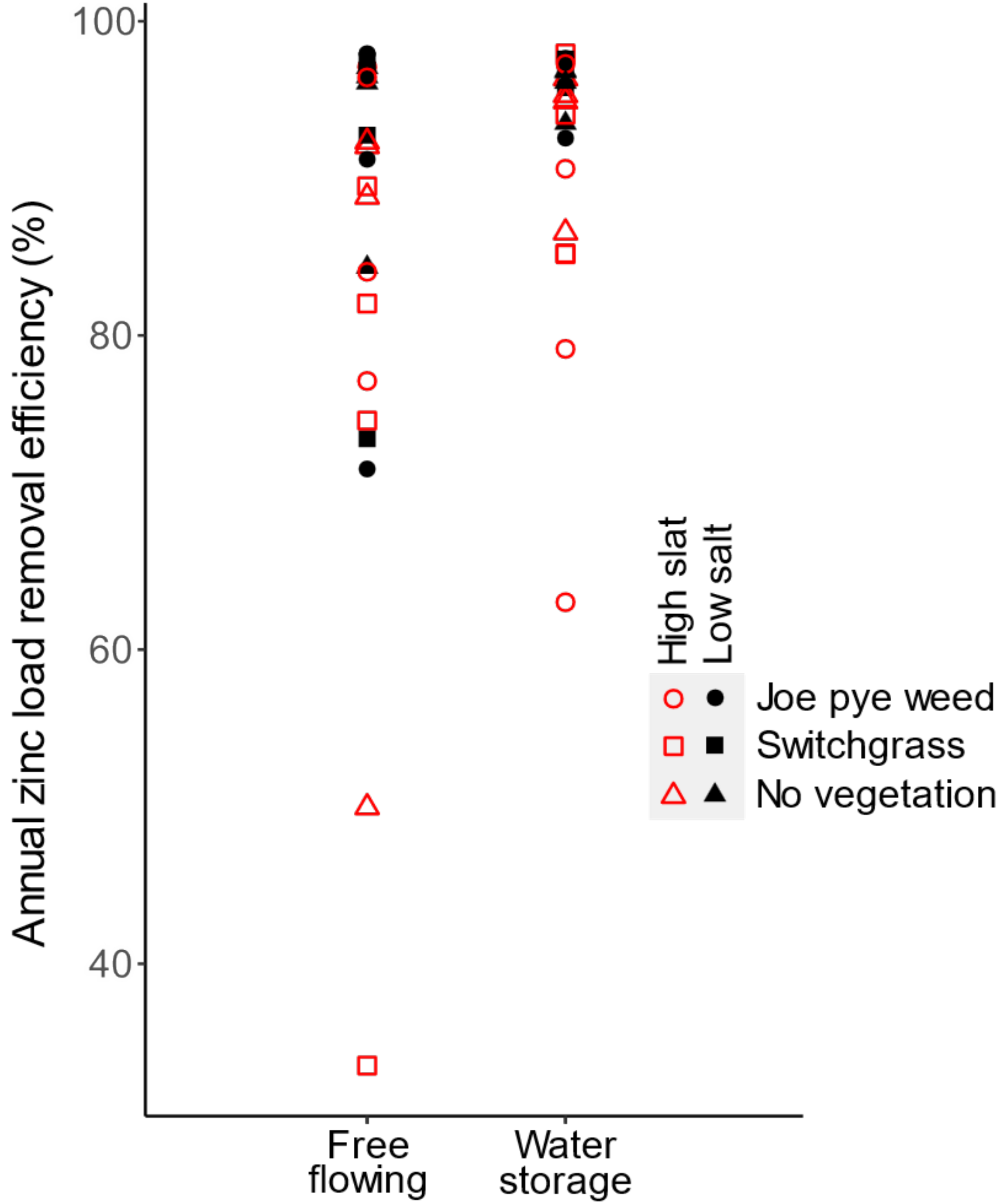
Higher salt load slightly reduces copper removal

Internal water storage slightly improves copper removal

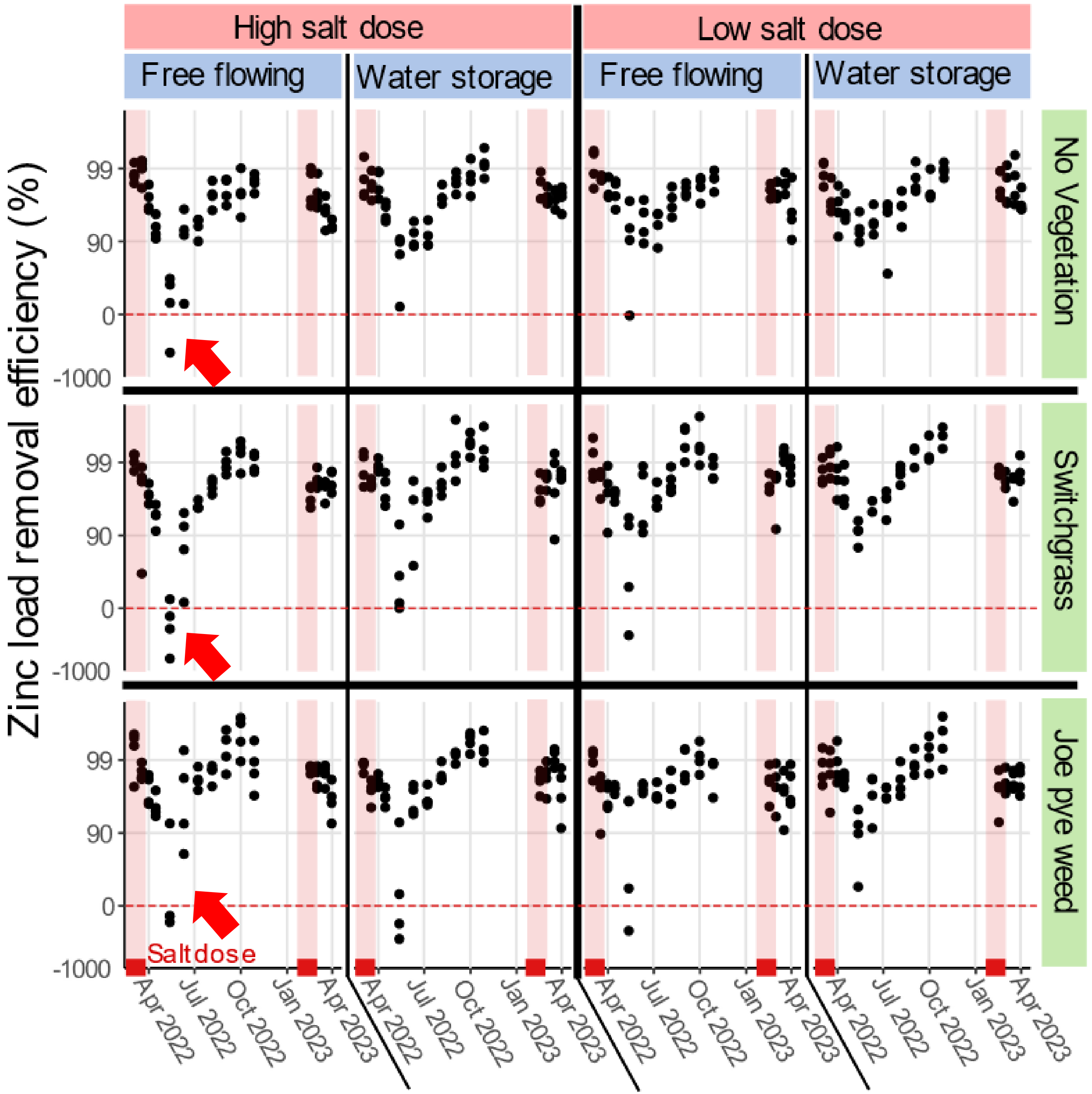


Zinc is removed well from inflowing stormwater

There were a few leaching events, mostly in free-flowing mesocosms



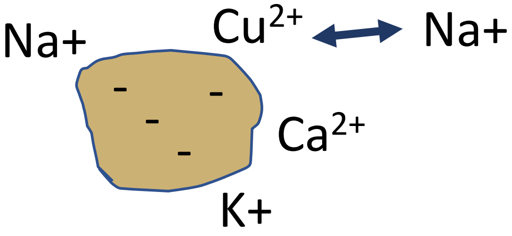
We attribute the zinc leaching to the salt events, as they occurred shortly after the last salty stormwater dosings



# Summary points: *salt loading*

NaCl deicing salt negatively affects bioretention performance

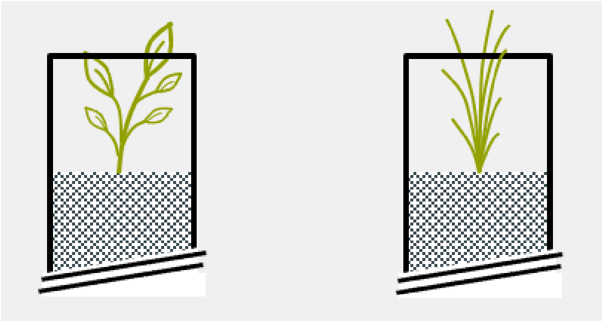
More salt loading led to….




- Reduced sediment and phosphorus retention
- Episodic zinc leaching
- Plant stress & death, particularly for Joe Pye Weed

# Summary points: *design implications*

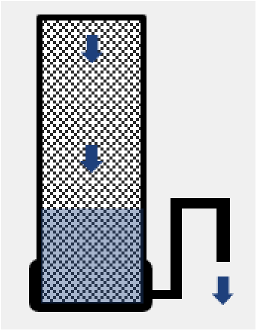
Presence of healthy plants was key for nitrogen retention



Internal water storage ….

Enhanced phosphorus and copper retention

Was essential for good nitrogen retention



# Thank you!!

Chesapeake Bay Trust, Maryland Dept of Natural Resources, US EPA, Chesapeake Bay Program, National Fish and Wildlife Foundation, and Anne Arundel County

Assistance with mesocosm construction: Randall Bock
Donation of material: North Creek Nurseries, Metzler Forest Products
Lab assistance: Mitchell Corsi, David Brock

Lingering questions? Lauren's email= stormwater @ psu.edu

# Translation Slides

What are the take home points?
What does this mean for me?

Translation Slides by Sadie Drescher, Chesapeake Bay Trust

# What does this mean for me?

- Salt reduction is key
- For  bioretention systems:
  - Plant health is essential to the system's function (as designed)
  - Plant selection should consider natives that are also salt tolerant (e.g., coastal natives)
  - Plant success/maintenance should be monitored, e.g., replacement of dead plants
  - Internal water storage helped the system remove P, Cu, and N
  - There can be leaching from the system
- Good news is that removal occurs in the systems, so how do we optimize this is our charge

*Adaptive management of BMPs is essential to maintain performance, especially where plants are relied upon for function*

# What does this mean for me?

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

- Consider the geographic location and future salt loading potential of the stormwater practice and adjust the plant palette to salt tolerant species, as needed
- Check plant success/health and replace dead/dying plants
- We could see clogging due to salt impacts to the soils/sediments

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

- Continue to keep an eye on salt loading to help assess and share where there are "salt success stories" – Who is doing well and how can others do the same?

For us all – There is still a lot to learn about the microbes that work in these systems