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CENTER FOR RESILIENT WATER SYSTEMS

# Needs, Challenges, and Solutions for Green Stormwater Infrastructure (GSI) Implementation

SAN Stormwater Workgroup

February 2024

by

Dr. Virginia Smith

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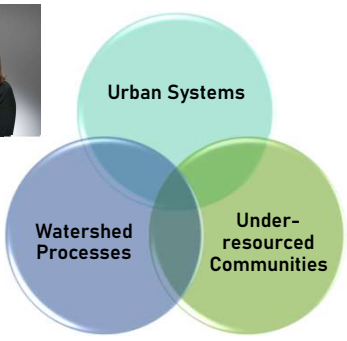
## Villanova Center for Resilient Water Systems




**Mission: To engage with society to create resilient engineered solutions for global water challenges.**

**Water Resilience Issues:**

- Flooding: Coastal / Urban (Climate Change)
- Urban Stormwater (Combined Sewers Overflows)
- Watershed Impact (Erosion / Sedimentation, Environmental, Flooding)
- Estuary Impact
- Water Supply
- Social and Environmental Justice
- Resilient (Green) Infrastructure
  - Life Cycle / Maintenance / Effectiveness
  - Coping with Climate Change
  - Social Justice

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# The Needs

## The Challenges

## The Solutions

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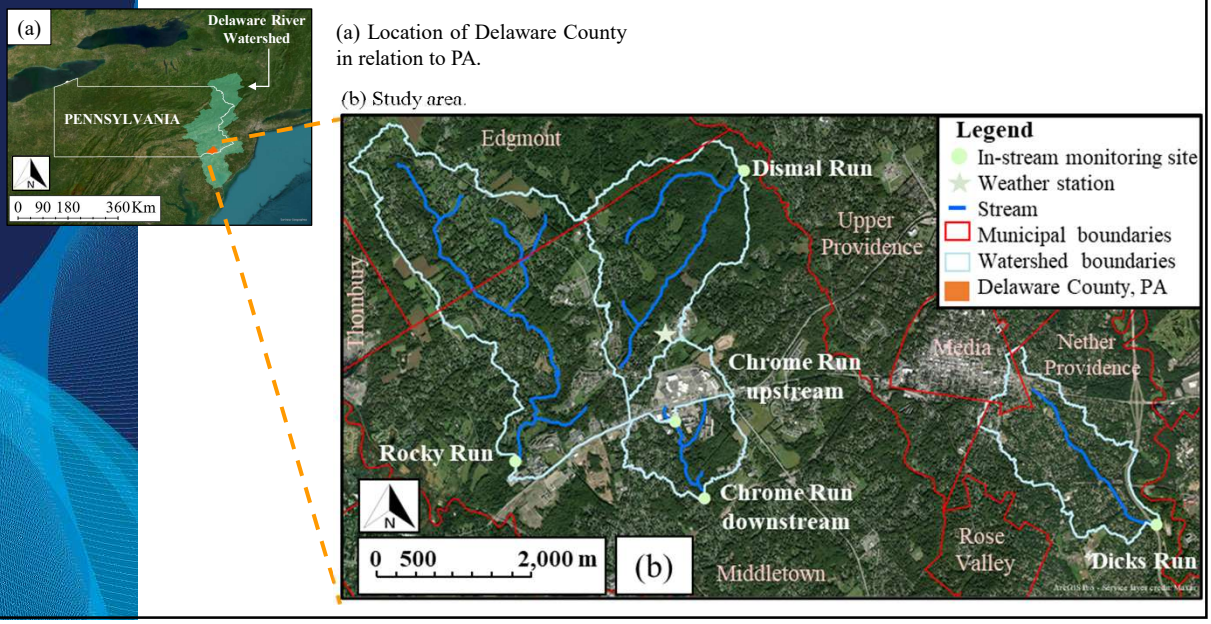
# STUDY AREA – Location




(a) Location of Delaware County in relation to PA.

(b) Study area.

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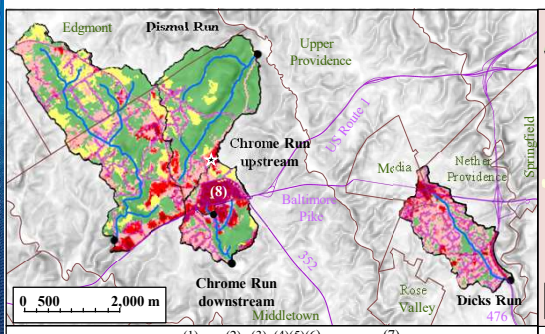
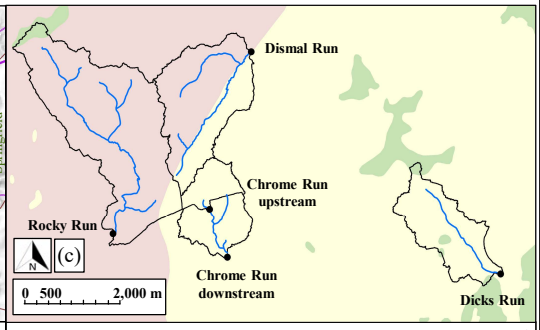
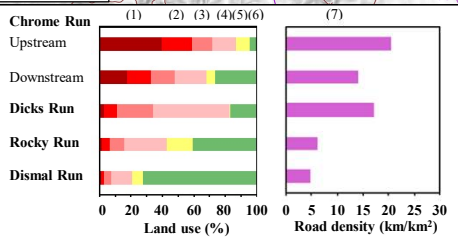
# STUDY AREA – Watershed characterization




Note:
(8) Promenade at Granite Run (mall)
(*) Land use (%) and road density (Km/Km²) include the upper Chrome Run sub-watershed.

(d)

**Legend**
- In-stream monitoring site
- Weather station
- Stream
- Main roads (7)
- Municipal boundaries
- Watershed boundaries

**Lithology**
- Tertiary
- Lower Paleozoic
- Precambrian

| Land use | Impervious coverage (%) |
|---|---|
| **Urban** | |
| (1) High intensity | > 80 |
| (2) Medium intensity | 50 – 79 |
| (3) Low intensity | 20 – 49 |
| (4) Open space | < 20 |
| (5) **Agriculture** | |
| (6) **Forest** | |

**Slope** (degrees): 70 (steep) – 0 (flat)

*Kuchinski et al. 2001; Danielson and Tyler 2015*
*Dewitz and USGS 2021*

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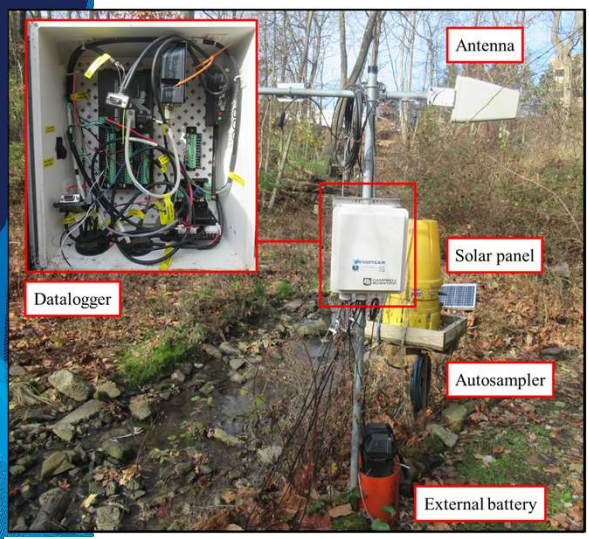
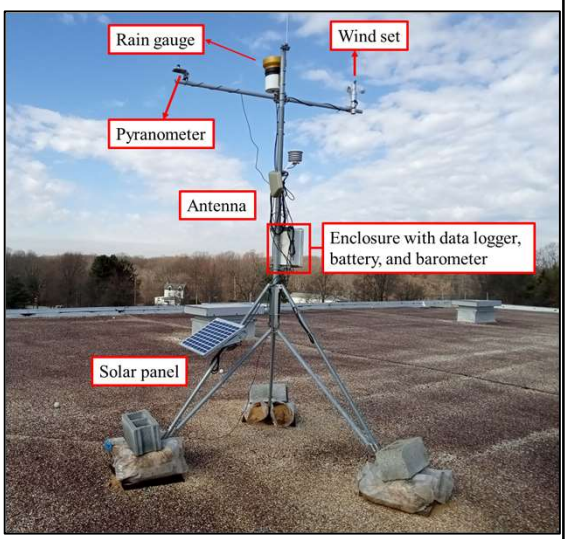
# METHODOLOGY– Monitoring stations




In-stream monitoring site at Chrome Run-upstream
[Photography credits: Jerez, L.A.M.]




Weather monitoring station
[Photography credits: Jerez, L.A.M.]

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# METHODOLOGY– Monitoring

| HYDRO-GEOMORPHOLOGY | PHYSICAL-CHEMISTRY | BIOLOGY |
|---|---|---|
| Field observations | Continuous and event-based monitored data | Fish and benthic sampling |

*Chrome Run-upstream*

*Dismal Run*

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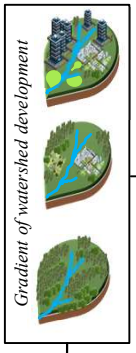
# METHODOLOGY



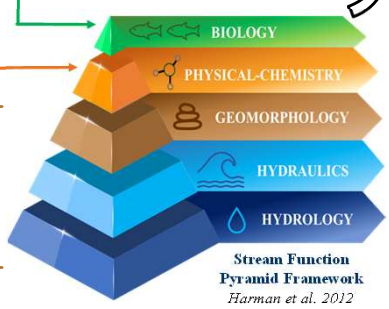

Summer
Fall
Spring

BIOLOGY

PHYSICAL-CHEMISTRY

HYDRO-GEOMORPHOLOGY

Stream health signature




Stream Function Pyramid Framework
*Harman et al. 2012*

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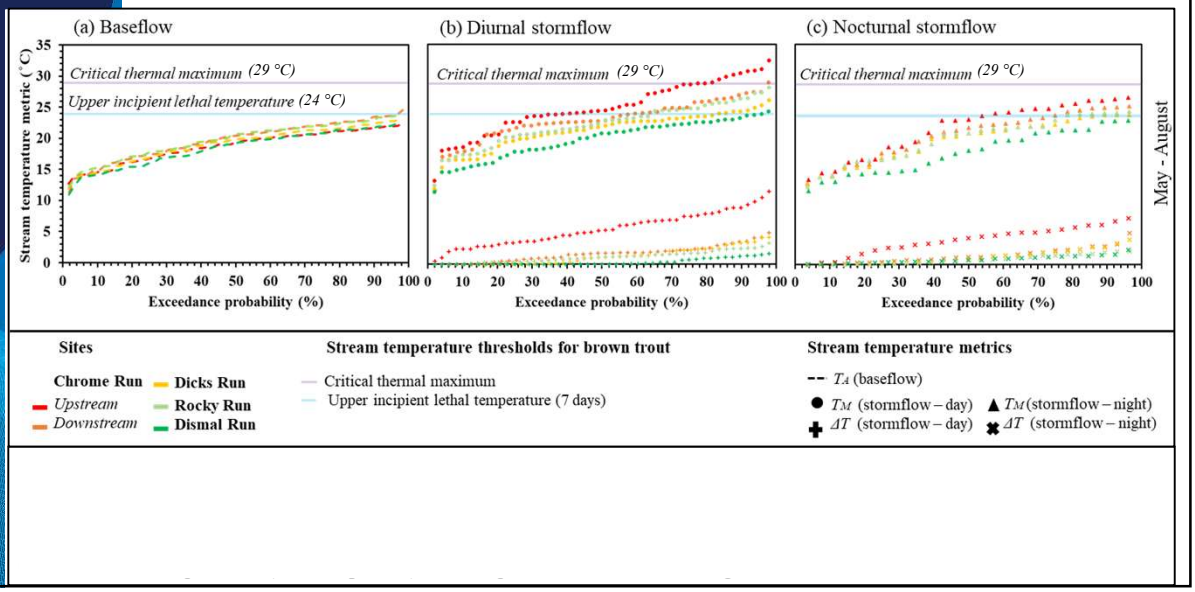
# RESULTS: Stream temperature

## Cumulative probability curves of 2018-2021 stream temperature metrics (summer)

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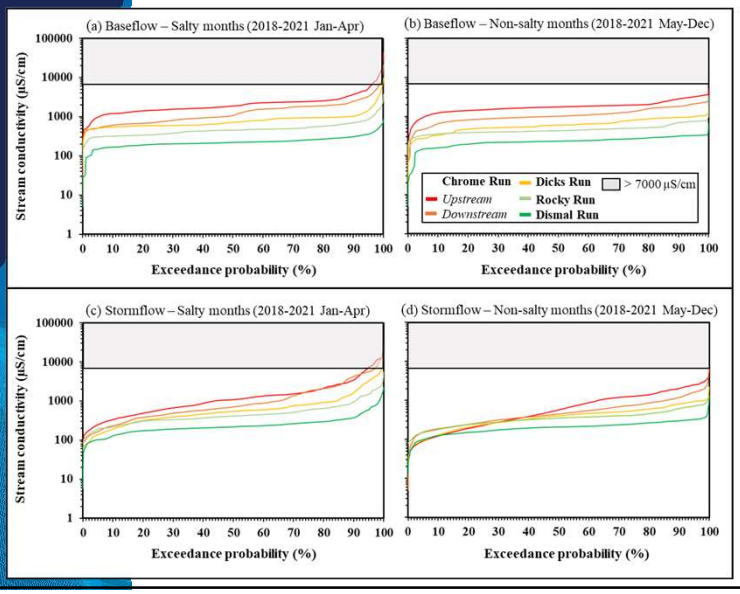
# RESULTS: Stream conductivity

## Cumulative probability curves of 2018-2021 stream temperature metrics (summer)

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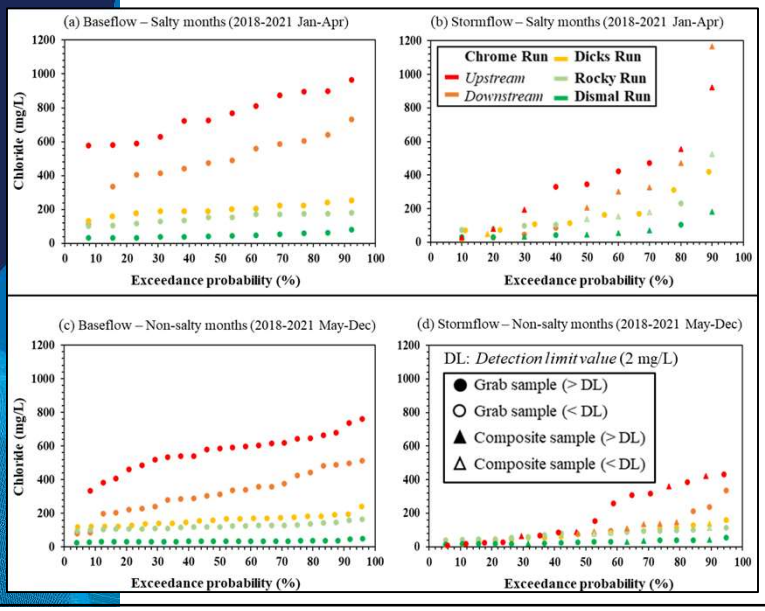
# RESULTS: Stream chloride

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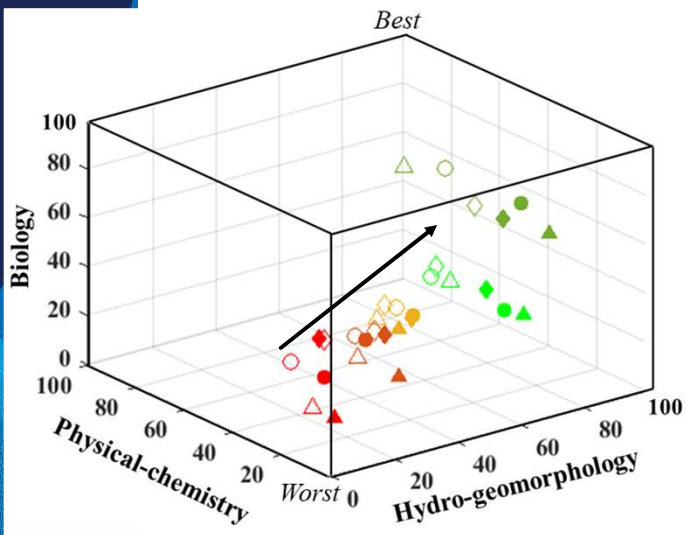
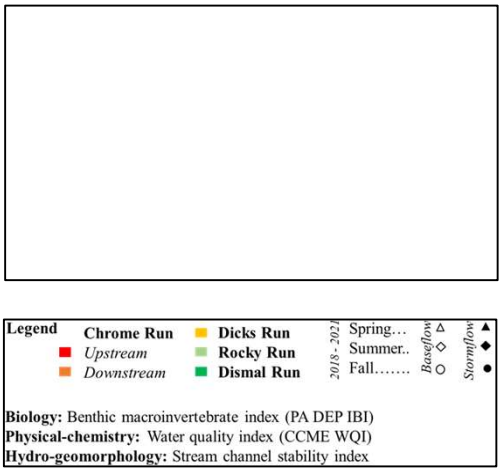
# RESULTS: Stream health signature

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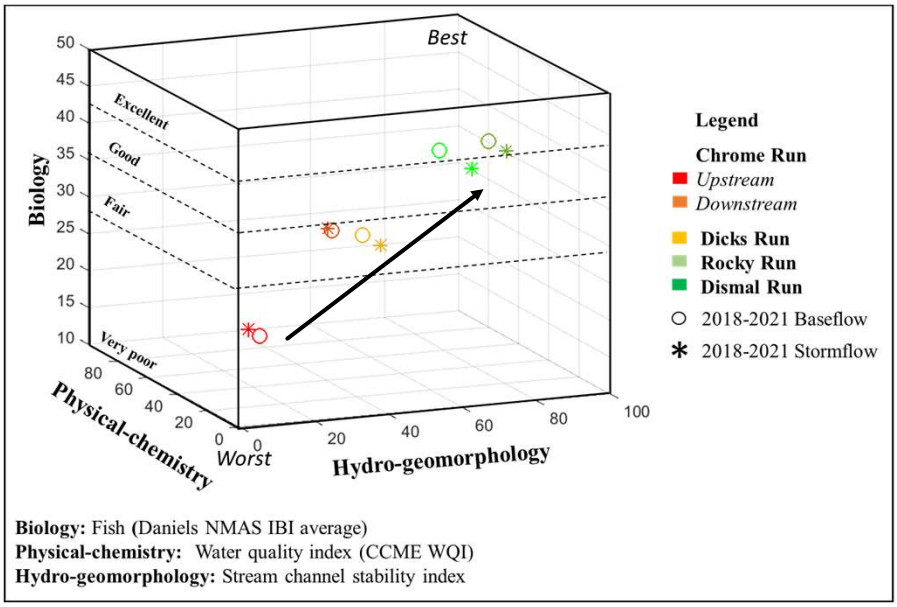
# RESULTS: Stream health signature




**Biology:** Fish (Daniels NMAS IBI average)
**Physical-chemistry:** Water quality index (CCME WQI)
**Hydro-geomorphology:** Stream channel stability index

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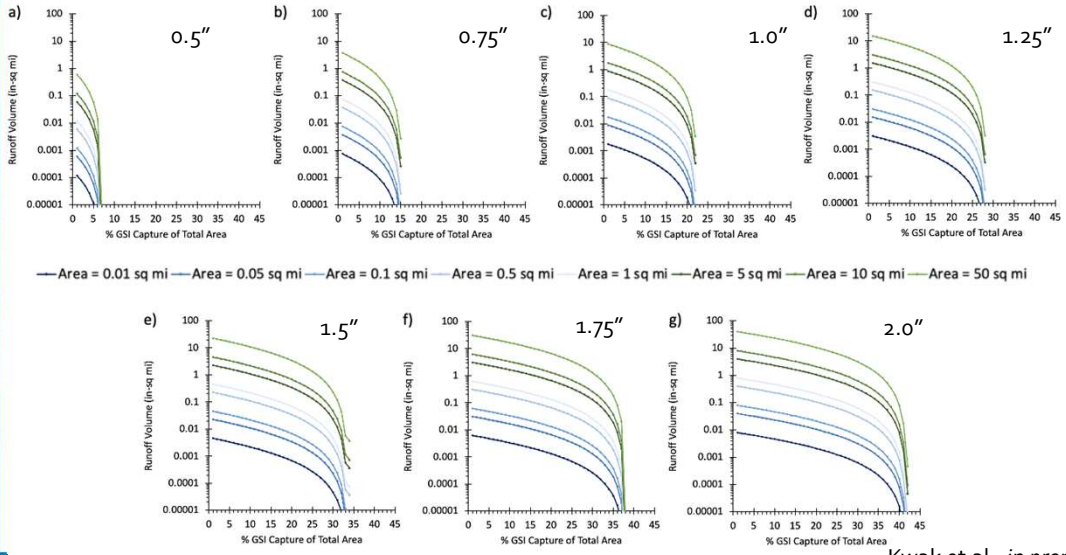
# Not all watersheds are created equally – Small watersheds are more responsive to GSI




Kwak et al., *in prep*

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# The Needs
# **The Challenges**
# The Solutions

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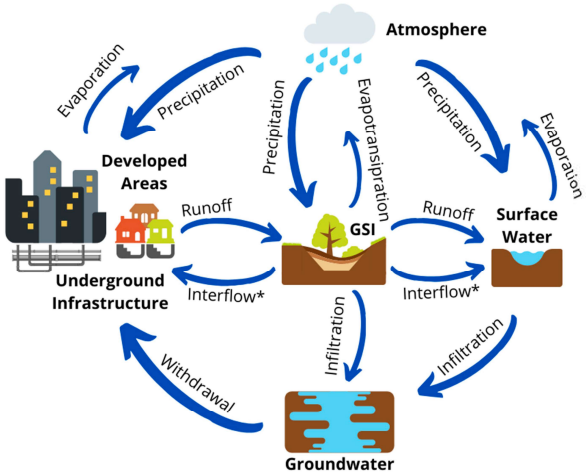
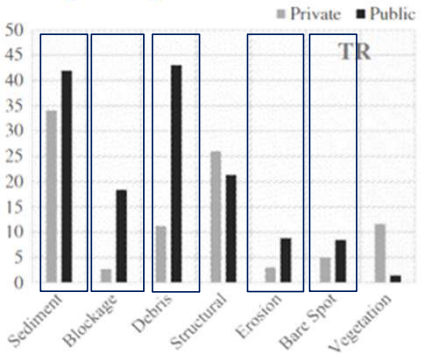
## GSI Are Open – Often Messy - Systems




[ Taguchi et al., 2020]




*[DelGrosso et. al, 2019]*

What does this mean for the function of the systems?

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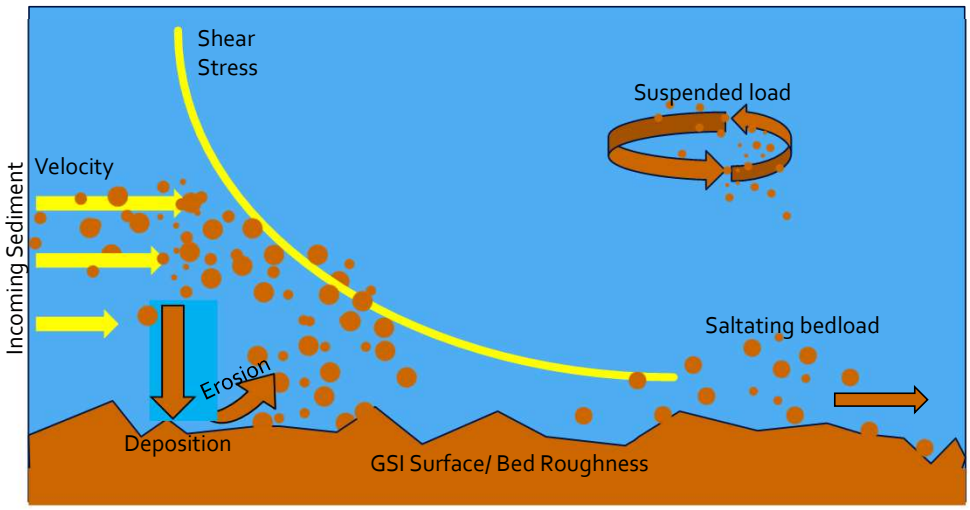
## Sediment Advects and Disperses through GSI

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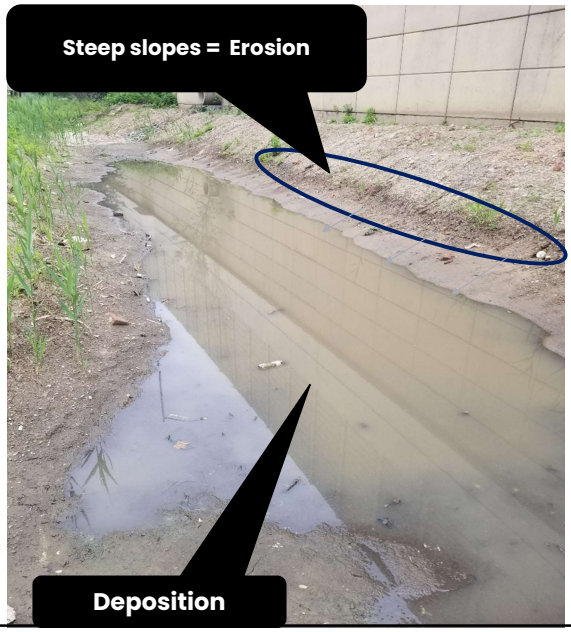
## Sediment Movement

- Sediment can cause
  - TSS in stormwater
  - Drives erosion and sedimentation
  - Clogged media and sustained ponding

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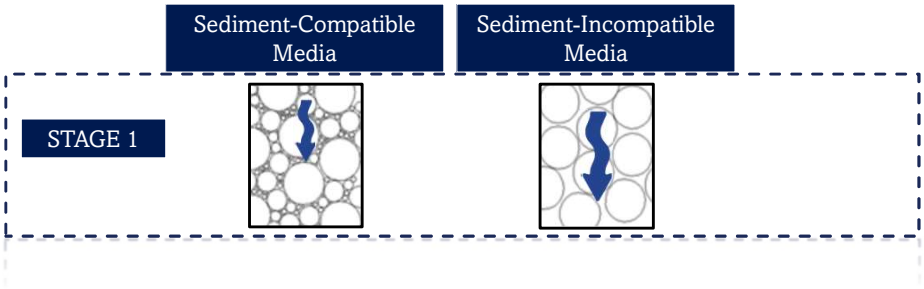


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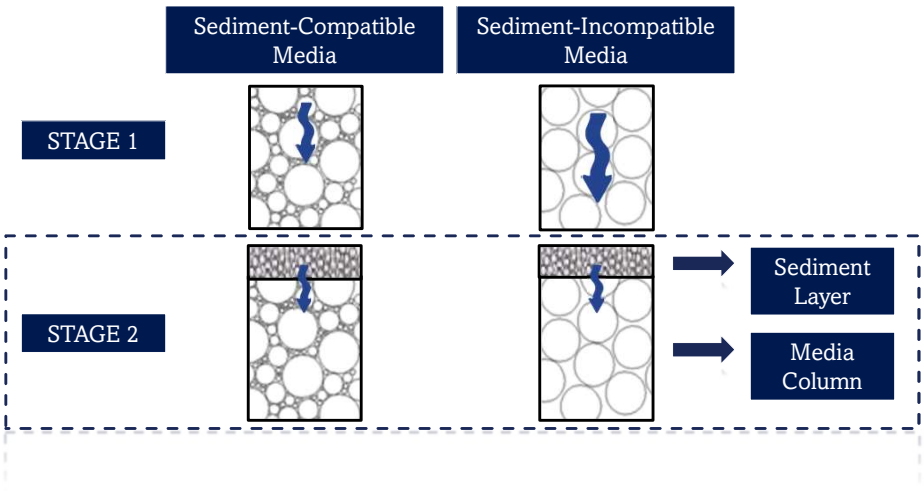


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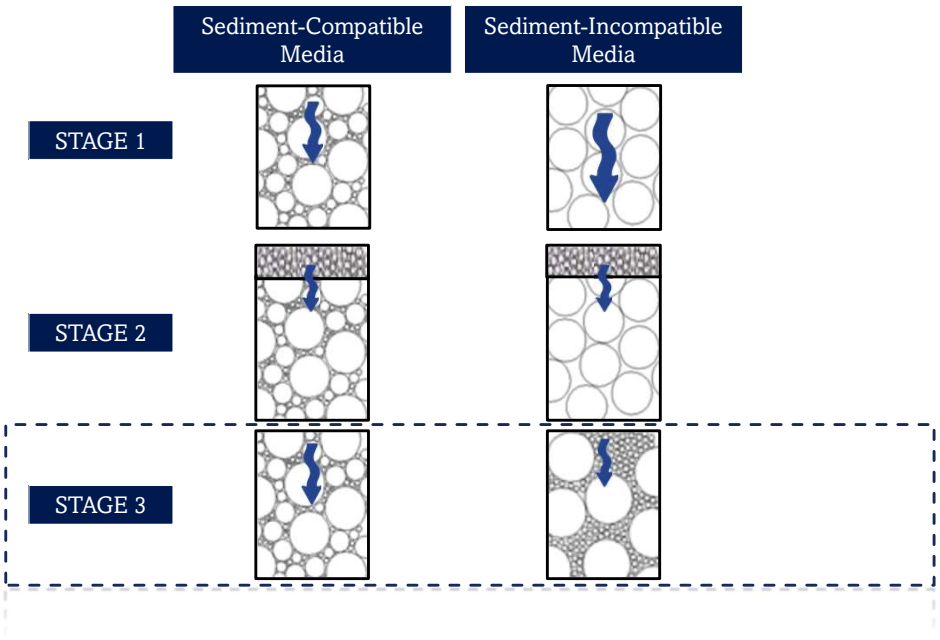


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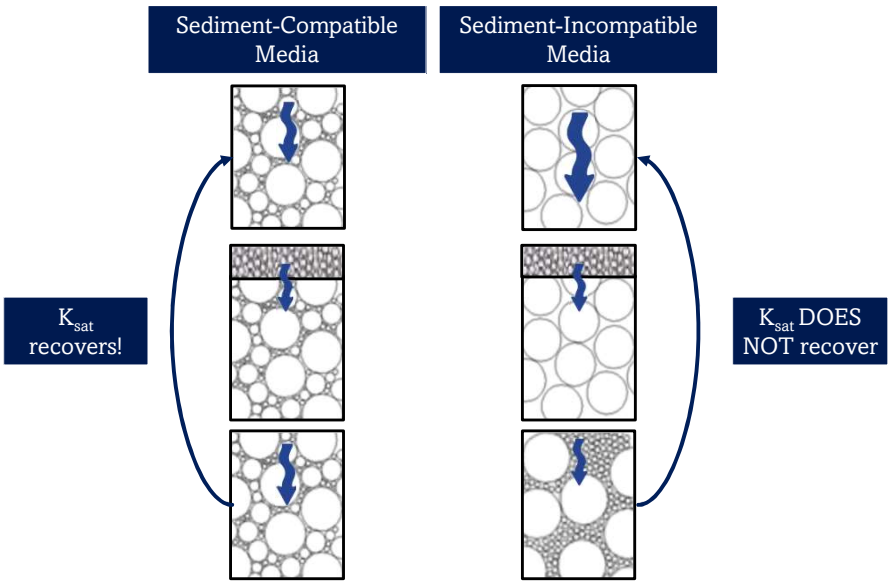


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# The Needs
# The Challenges
# **The Solutions**

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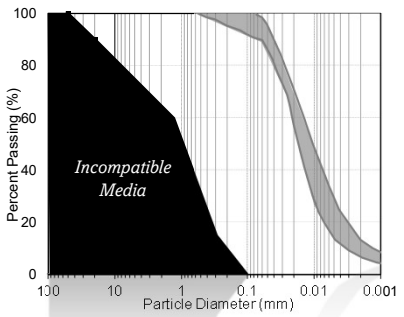


***Figure A:*** *Fine Highway Sediment*

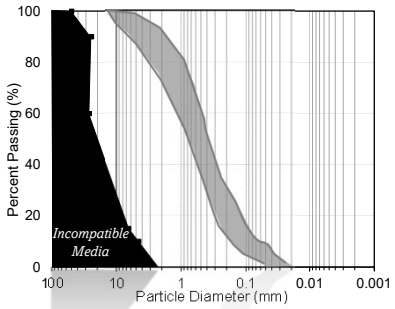


***Figure B:*** *Sandy Highway Sediment*

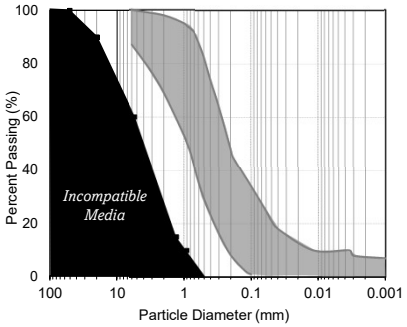


***Figure C:*** *I-95 Highway Sediment*

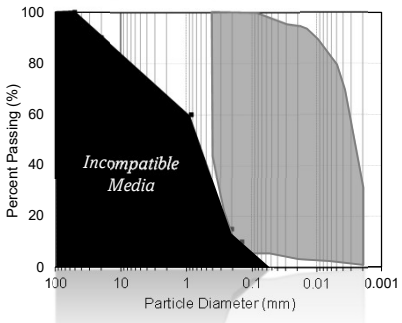


***Figure D:*** *Parking Lot Sediment*

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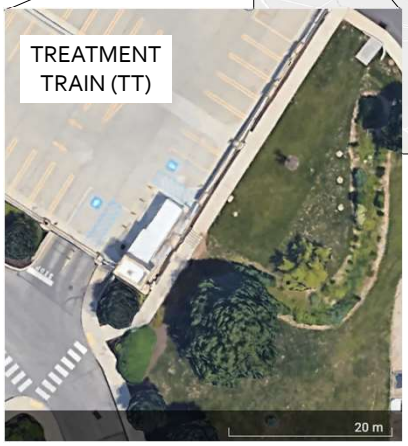
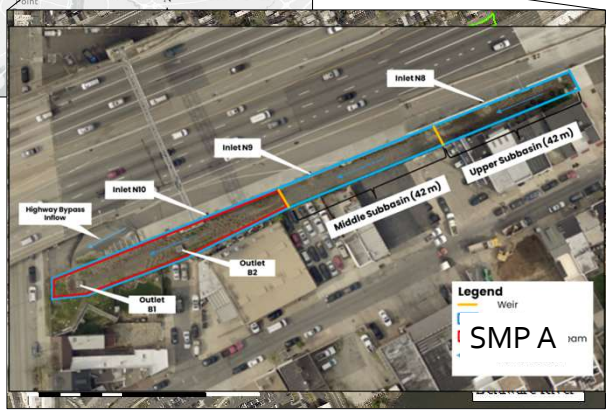
# A Tale of 2 Sites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# Multi-Step Approach

- Topographic Survey
- Design Storms
- Landcover
- Soil Samples

Data Collection

Input Variables

26

26

VS0

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# Surface Sample Collection

- Samples collected:
  - On center
  - Areas of changes in PSD
- PSD Analysis:
  - Sieve
  - Hydrometer



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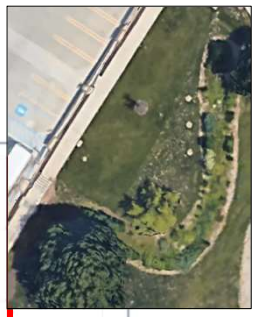
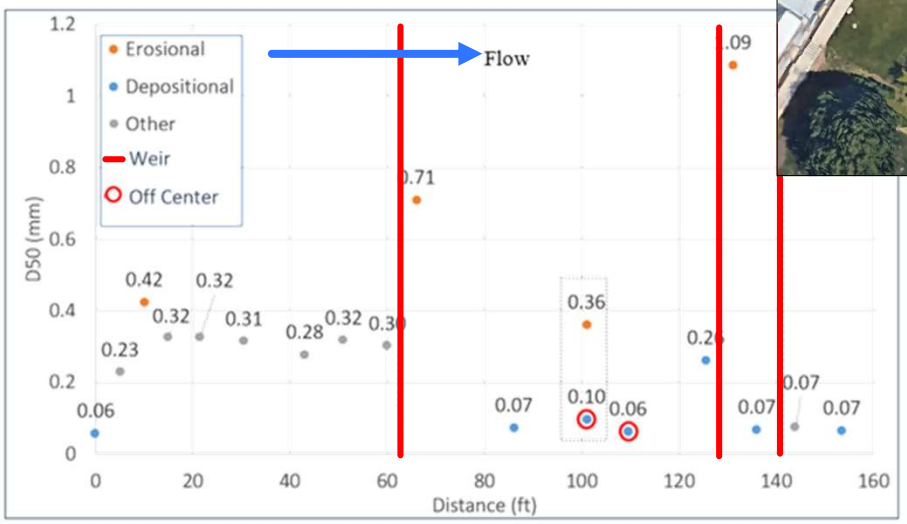
# Grain Samples Along the TT Step Down at Weirs






28

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**Slide 27**

**VS0** Make points a different color
Virginia Smith, 2023-05-05T18:50:10.255

**JE0 0** Do you want the sample points over the aerial imagery as shown here or on a map of the DEM as discussed for the paper figures?
Jessica Erben, 2023-05-06T17:43:21.851

**VS0 1** [@Jessica Erben] The DEM here is fine, but the points can't be blue drops. Please change this to black dots with labels. No title on the image. Please make the legend have a white background and black boarder and make it a separate image from the figure.
Virginia Smith, 2023-05-17T17:49:09.447

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# Grain Sizes Along the SMP A Decrease from the Weir to the Outlet



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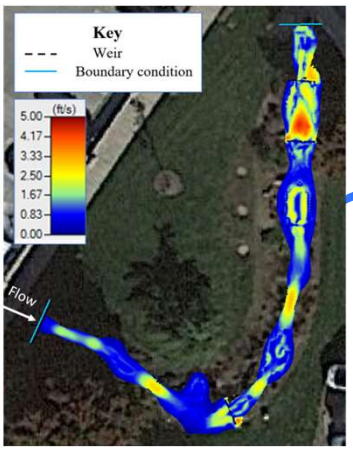
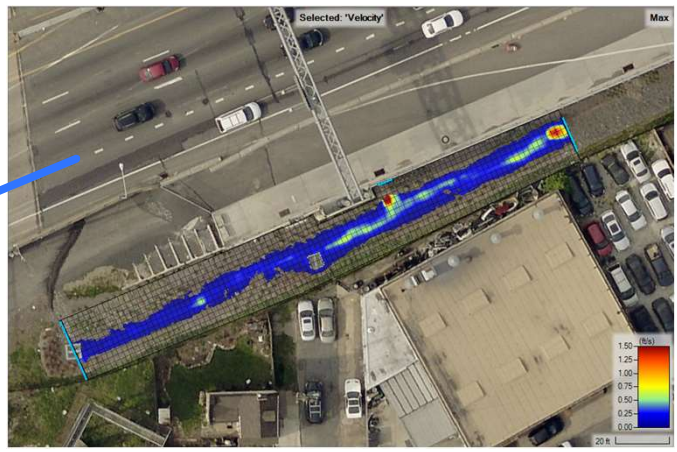
# Velocity Dissipates, but Accelerates After Weirs

TT




SMP A

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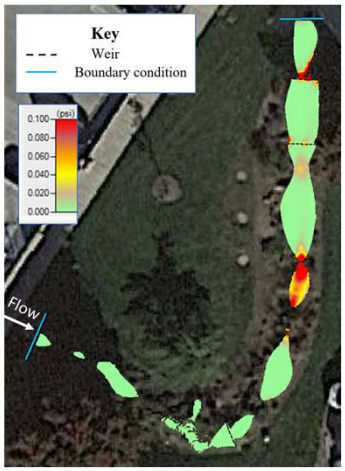
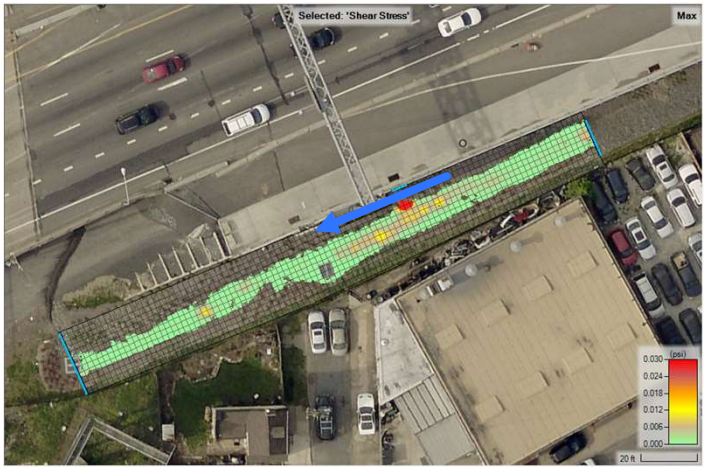
# Shear Stress Shows a Similar Trend

TT




SMP A

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VS0

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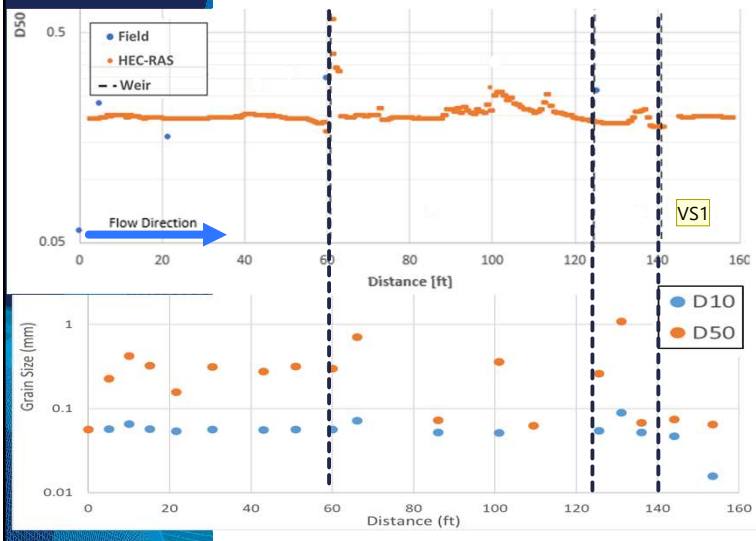
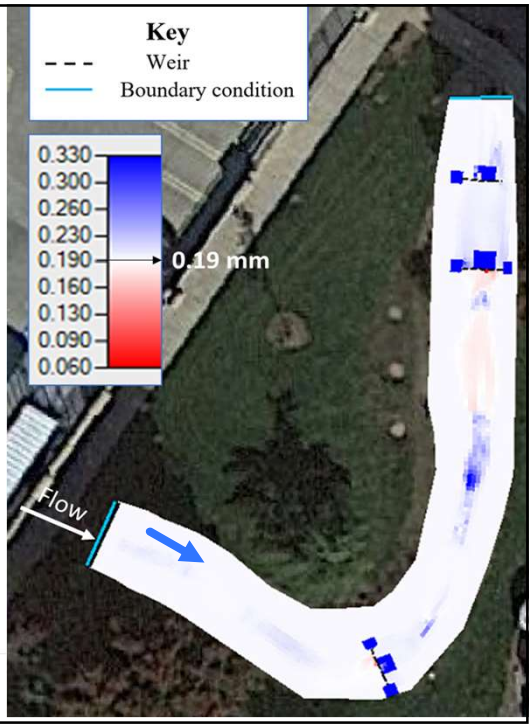
## $D_{50}$ Along the Centerline
## 1 inch 2-hour Design

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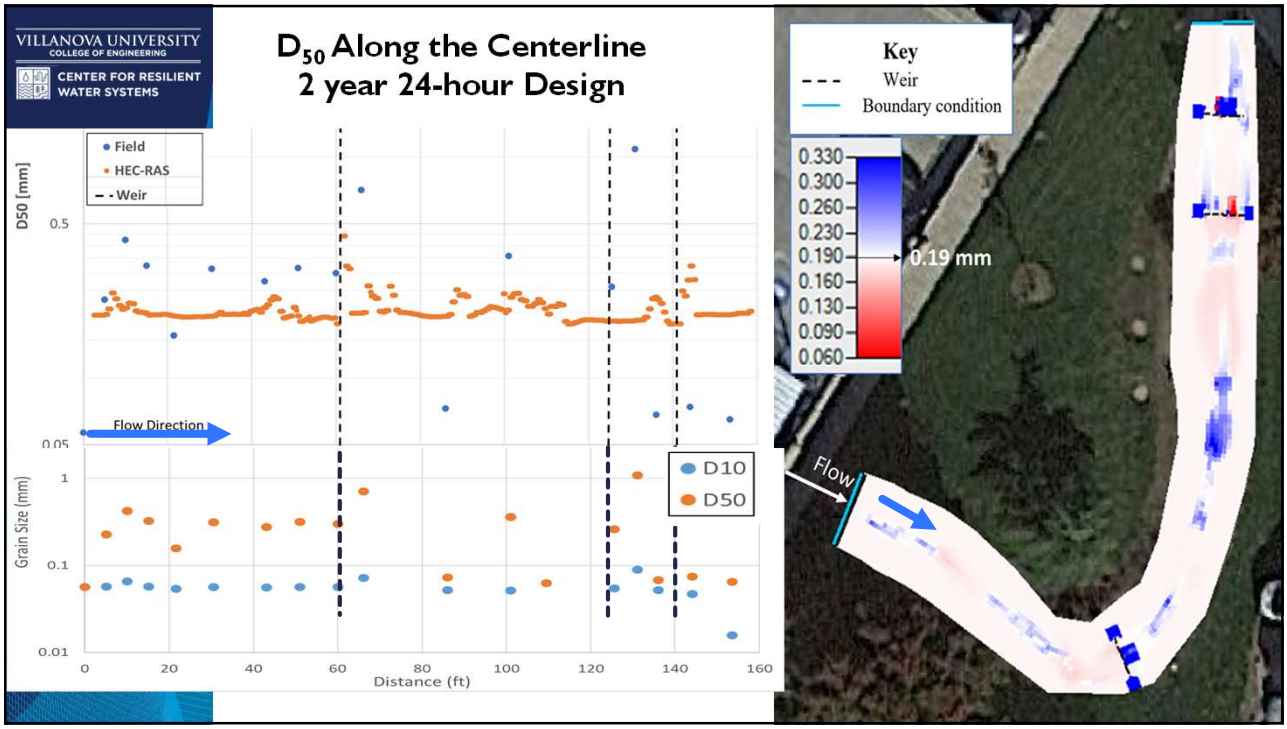
**Slide 32**

**VS0** Make legend larger
Call out OG D50
Virginia Smith, 2023-05-05T18:54:34.907

**VS1** Which storm? Can we add more?
Virginia Smith, 2023-05-05T18:55:03.340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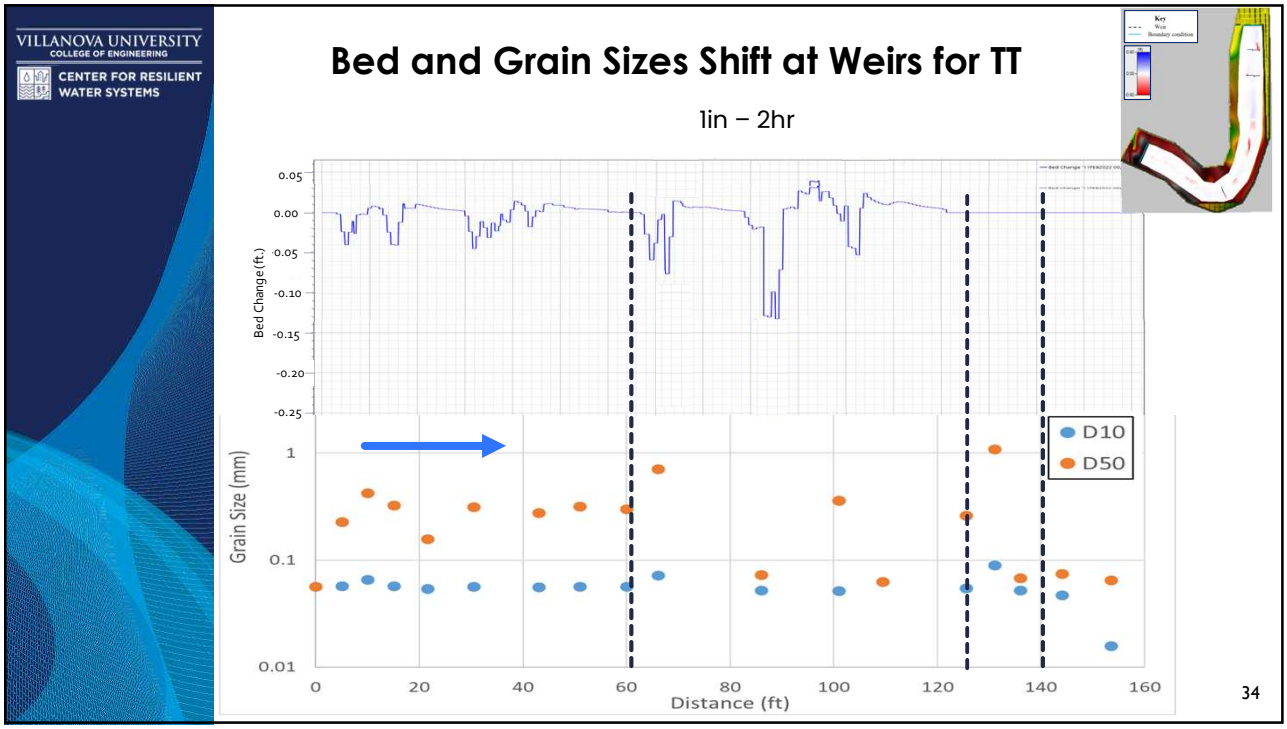
D50 Along the Centerline
2 year 24-hour Design
Field
HEC-RAS
Weir
D50 [mm]
Flow Direction
Grain Size (mm)
D10
D50
Distance (ft)
Key
Weir
Boundary condition
0.330
0.300
0.260
0.230
0.190
0.160
0.130
0.090
0.060
0.19 mm
Flow

33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Bed and Grain Sizes Shift at Weirs for TT
1in – 2hr
Bed Change (ft.)
Grain Size (mm)
D10
D50
Distance (ft)
34

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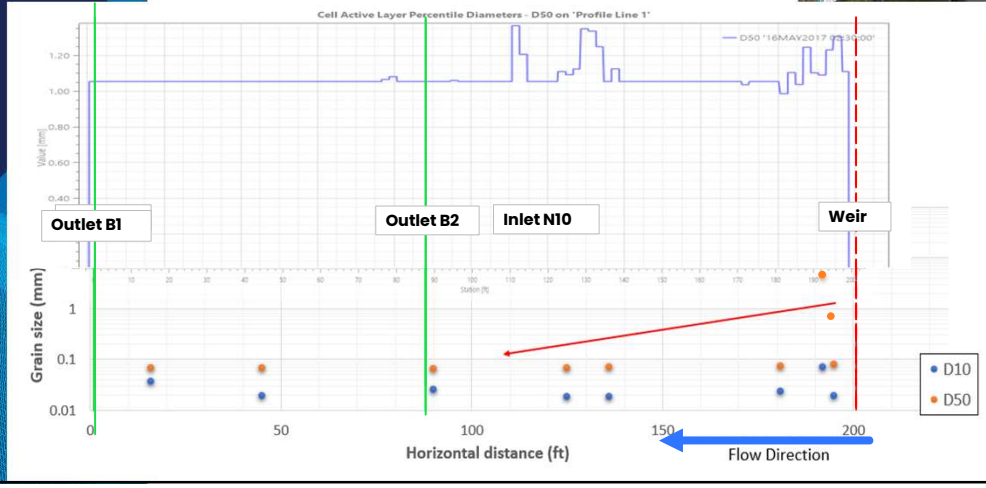
## Bed and Grain Sizes Show a Linear Trend for SMP A

1in – 2hr

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## Conclusions

- The level of development within a watershed has substantial downstream impacts
  - There is a need for intervention
  - The types of environmental indicators have different response times
- Sediments can be very challenging for the management of SCMs
- Design can mitigate to these challenges
  - Media can be designed to aid in the resilience of these systems depending on their drainage area
  - Areas can be identified as at risk

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# Thank you!
# Questions ?

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