# 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?

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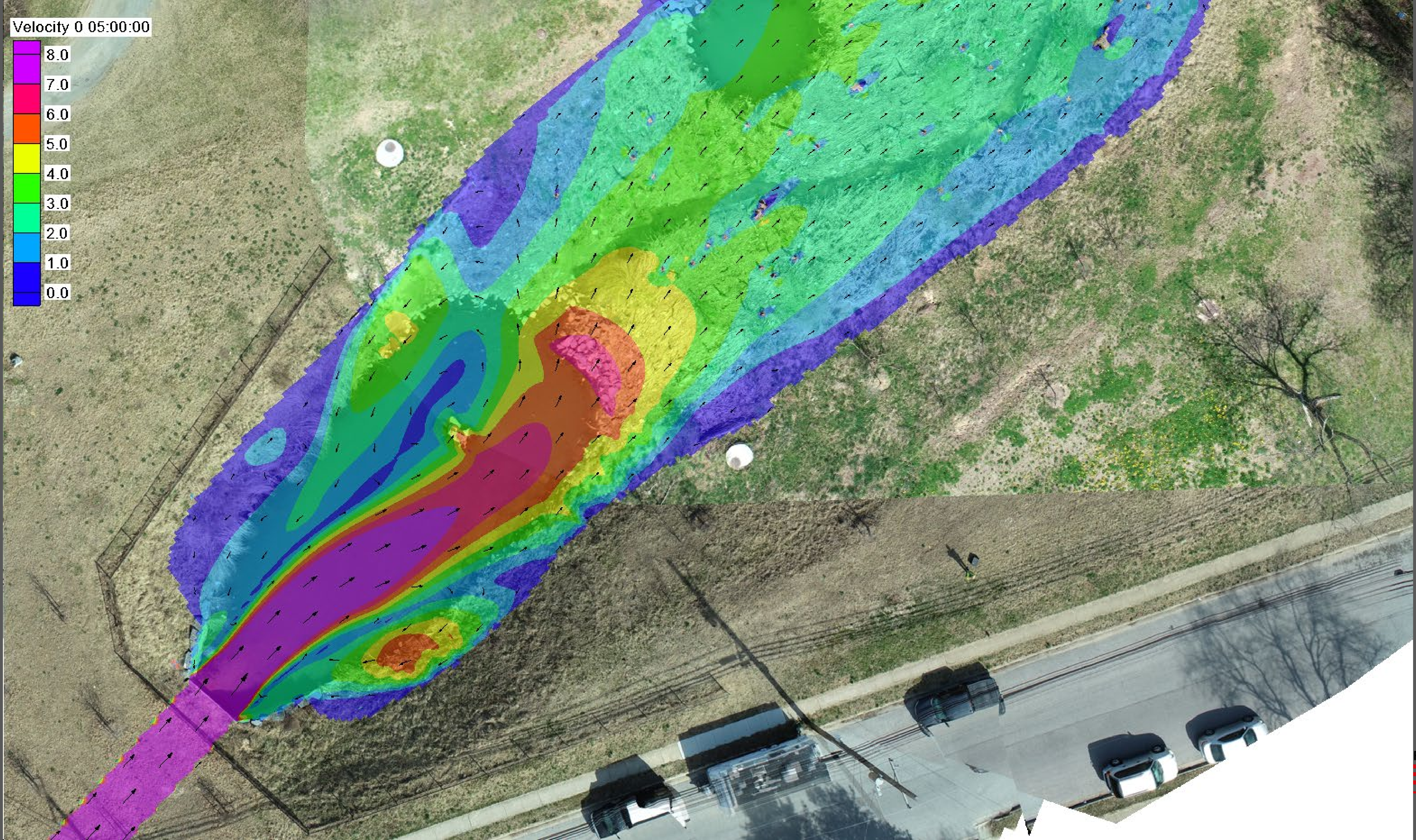
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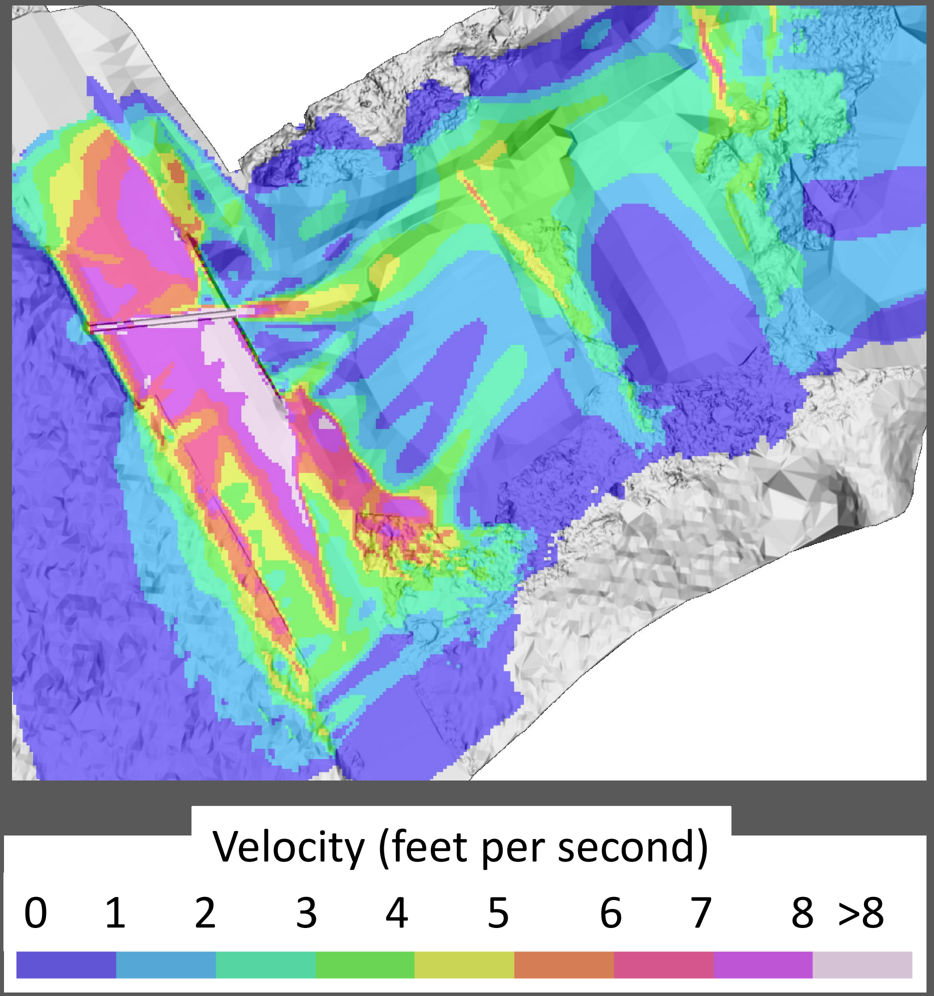
# Motivation: Reliable 2D models would be useful under current and future climate conditions

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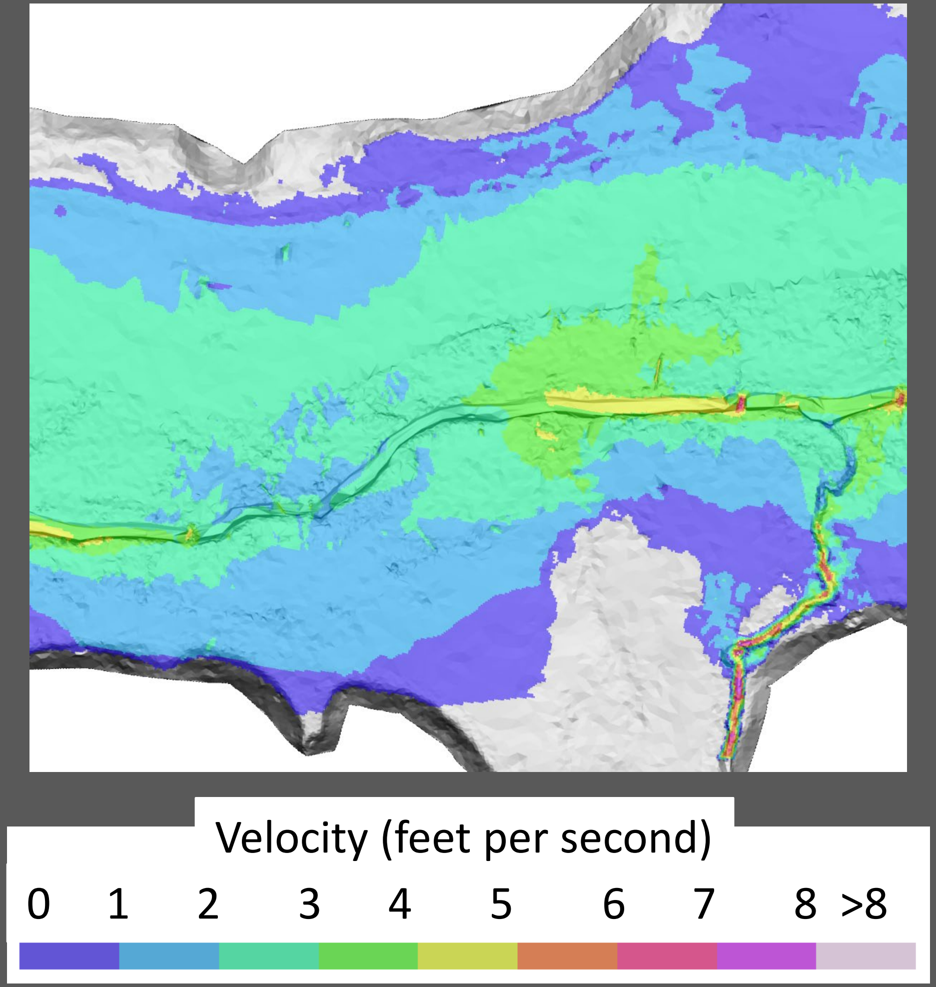
# Motivation: Reliable 2D models would be useful under current and future climate conditions

## <u>2D Models for Evaluating Expected Functions</u>

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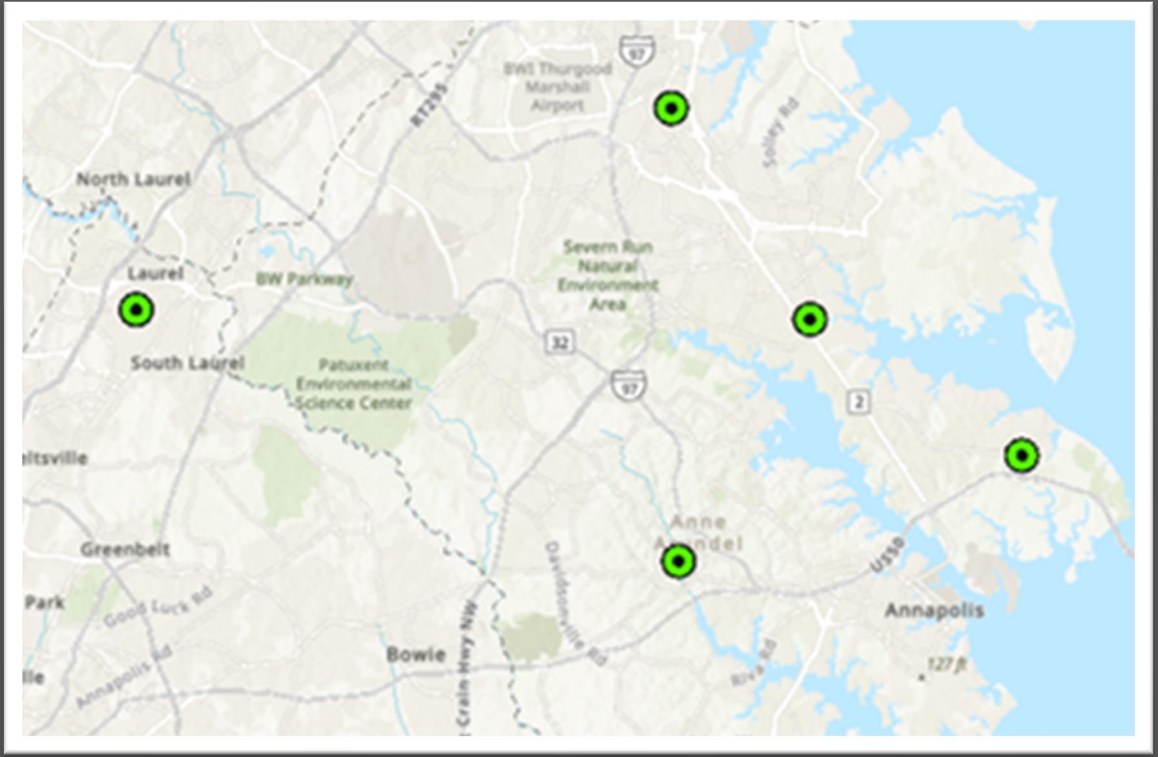
# Are 2D Hydrodynamic Models a reliable tool for stream restoration design?

**Research Approach:**

- <u>Phase I</u>: Evaluate 2D model reliability at 5 sites

- <u>Phase II</u>: Evaluate the susceptibility of different restoration approaches to damage under current and future climate conditions

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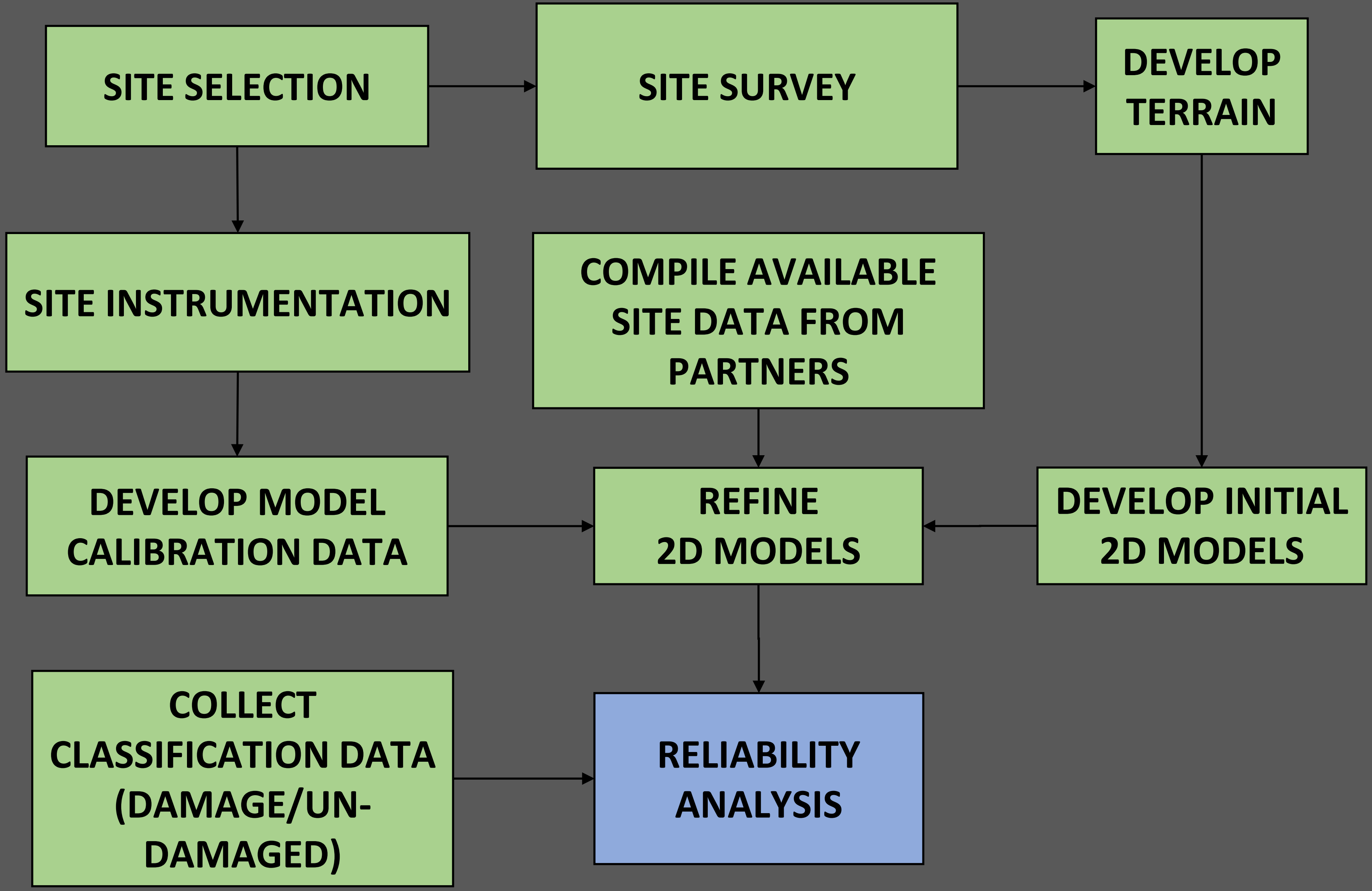
# Phase I: 2D Model Reliability Analysis




## Project Status

- COMPLETED
- IN PROGRESS
- NEXT STEPS

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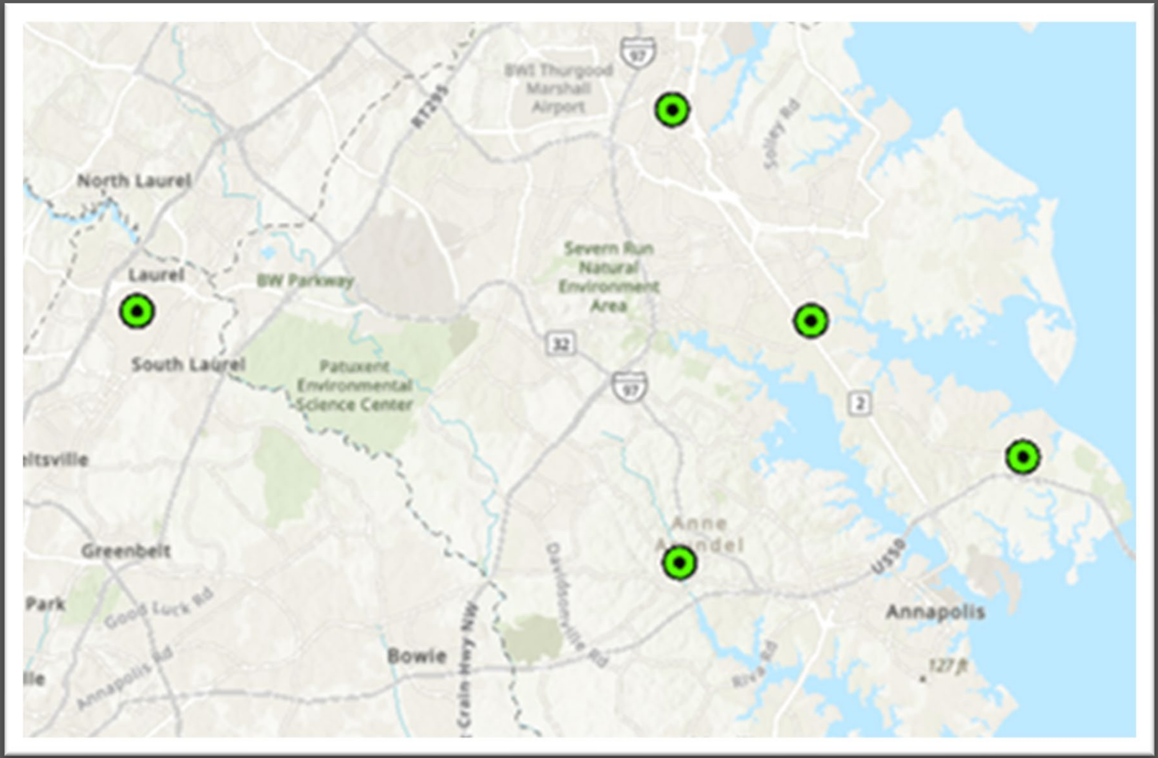
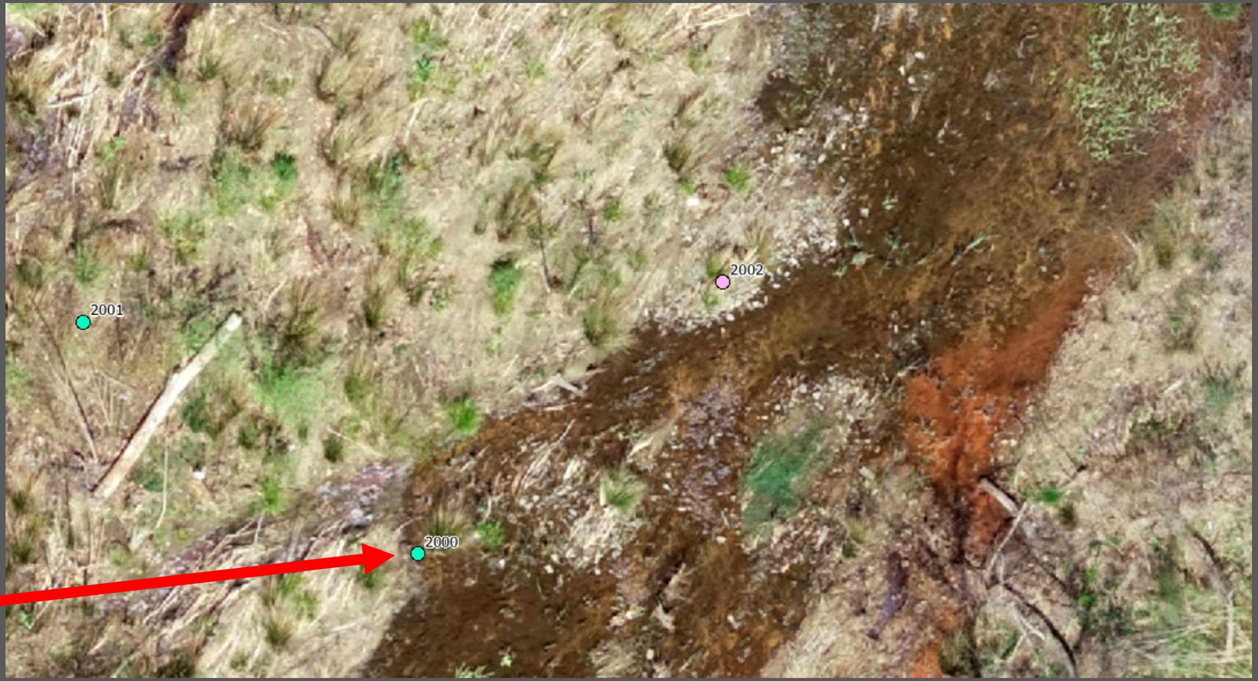
# Study Sites – MD Coastal Plain

| 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 |



# Phase I: Collecting Classification Data

- Approach to classifying areas <u>expanded</u> 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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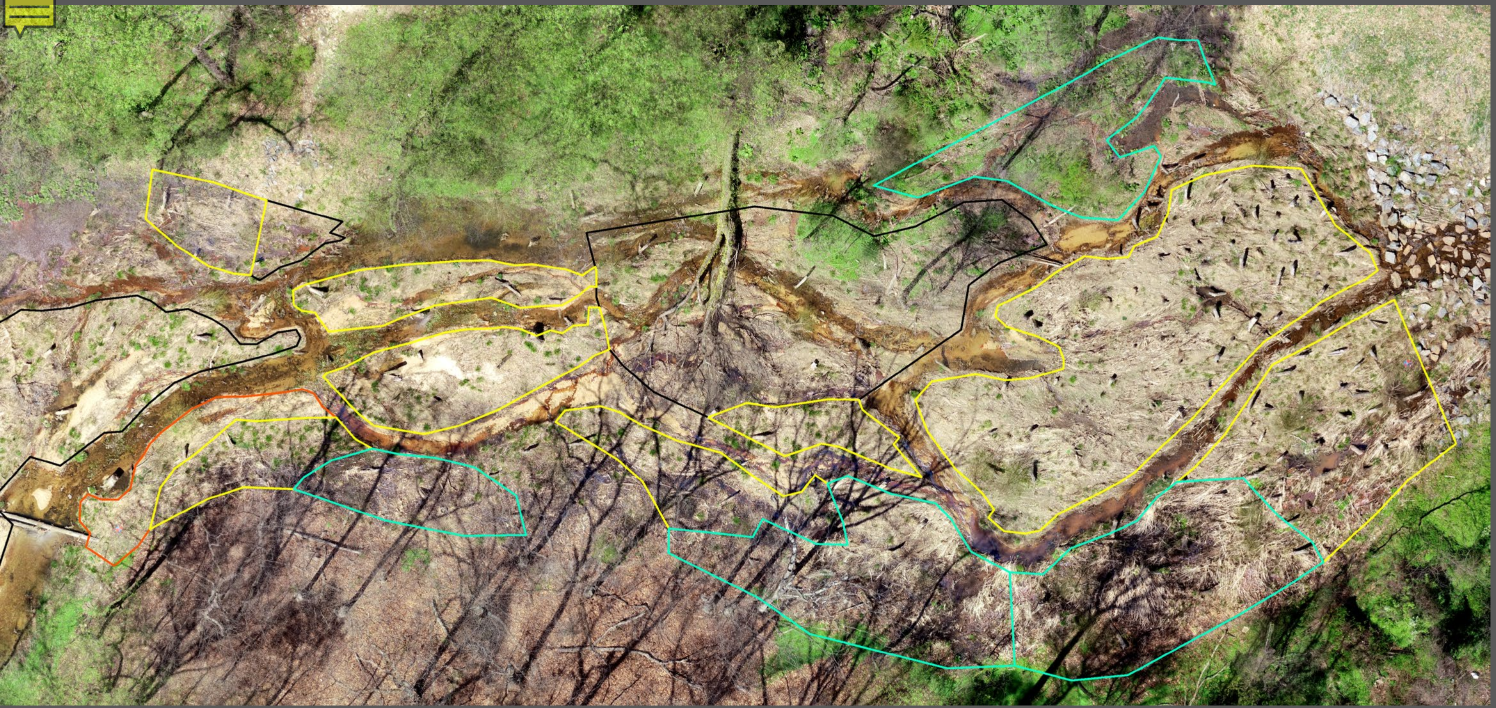
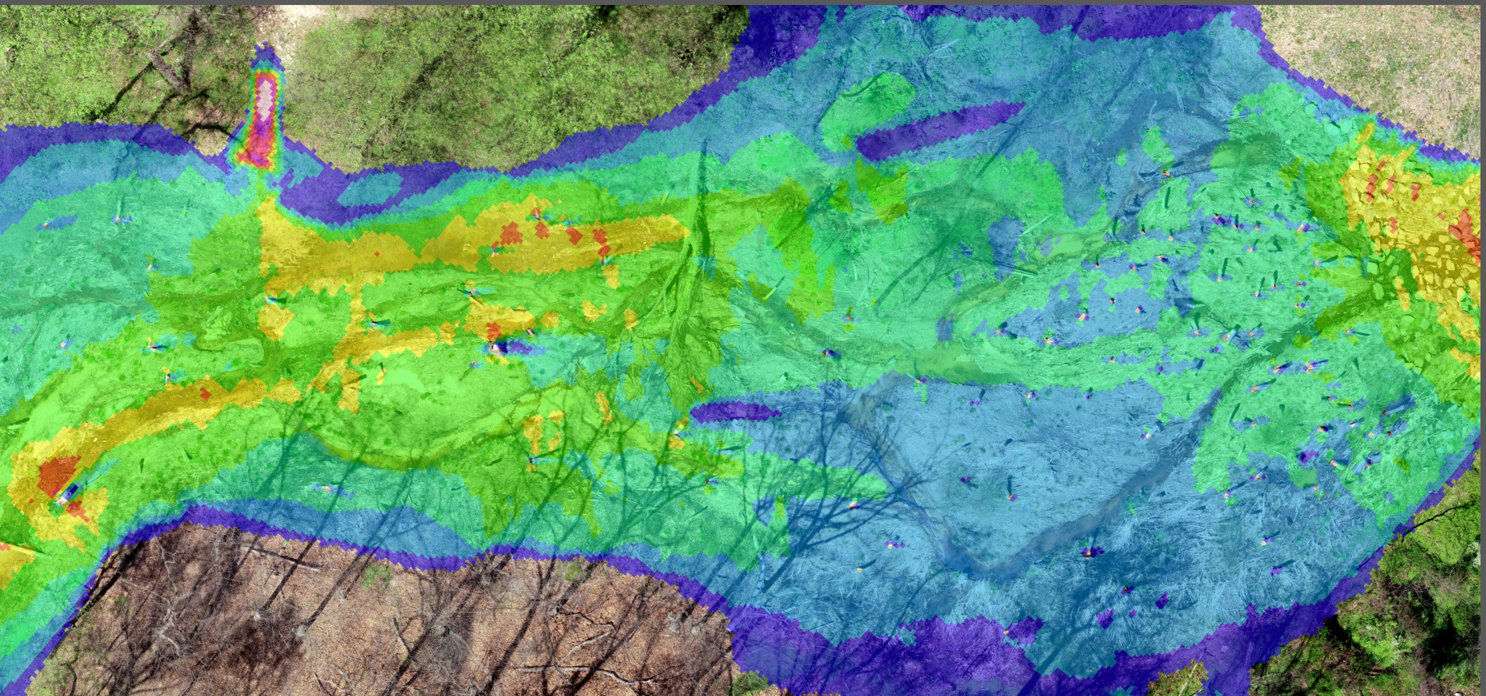
# Floodplain Damage Classification: Wetland Vegetation




# 2-D Model Calibrated to Highest Flood Observed

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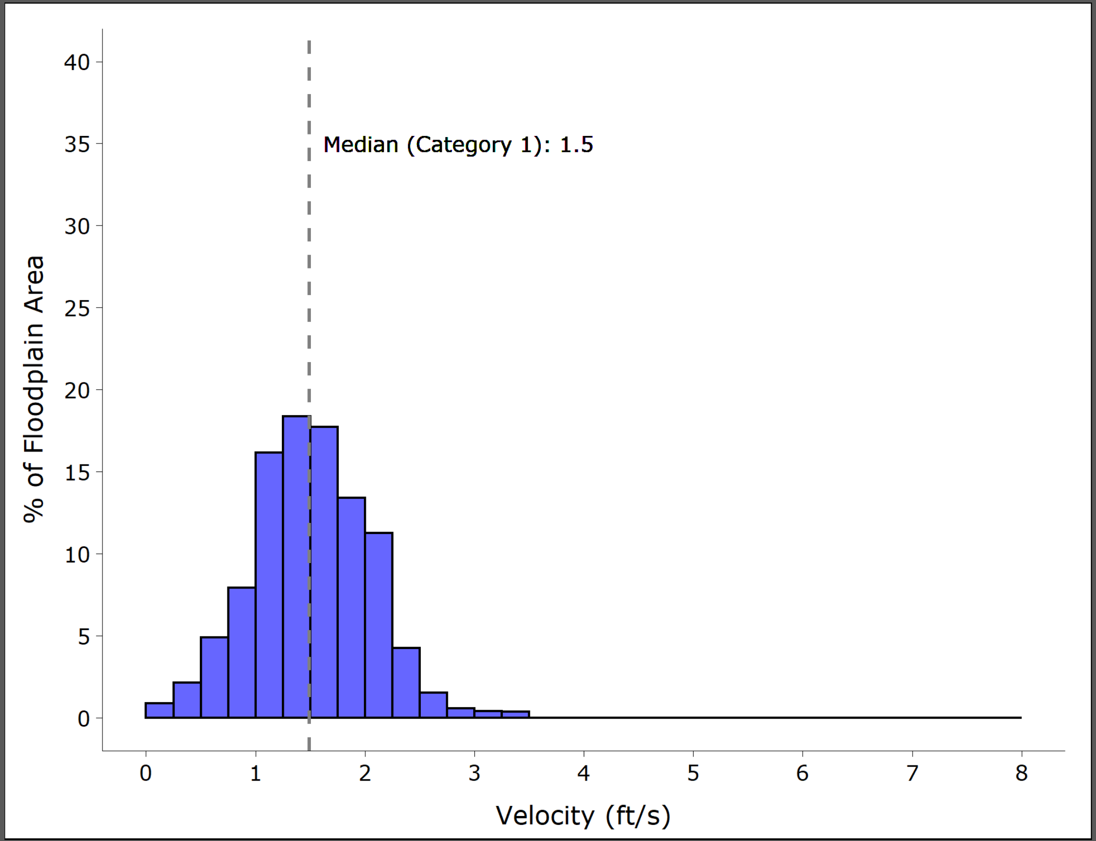
# Floodplain Stress Classification: Wetland Vegetation




## Category 1

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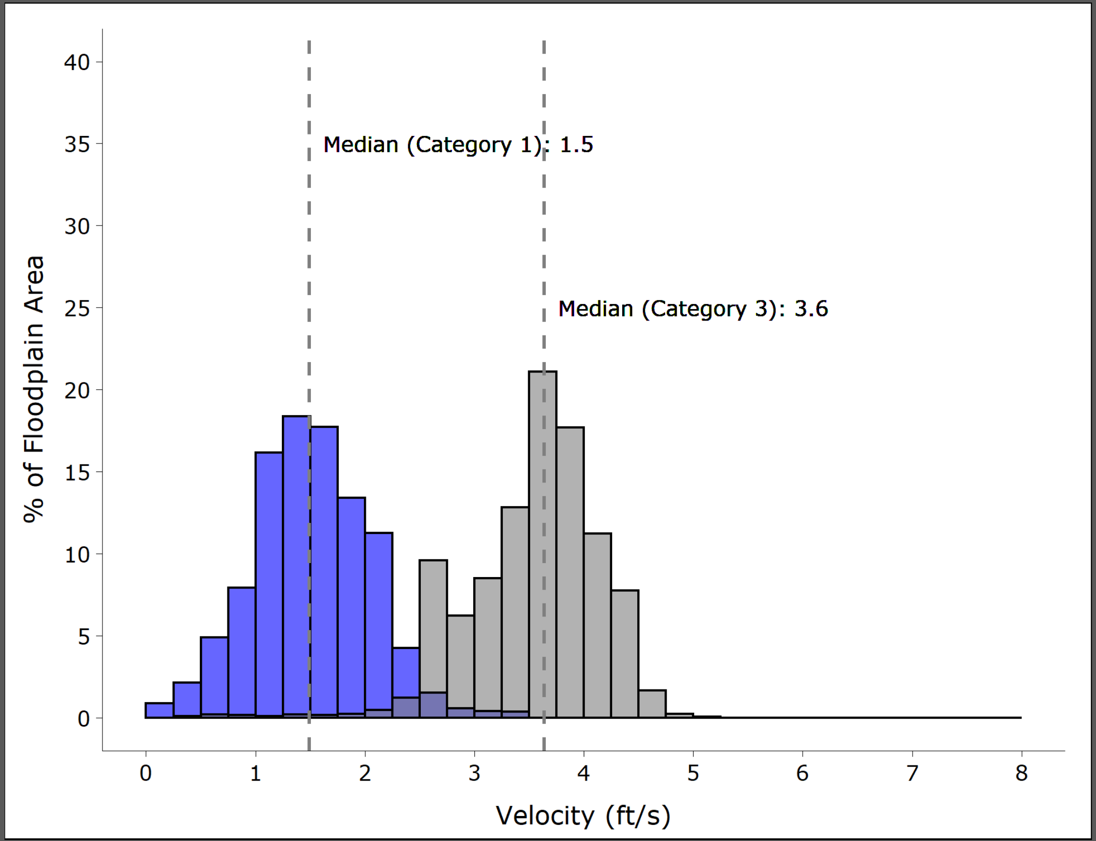
# Floodplain Stress Classification: Wetland Vegetation




## Category 3

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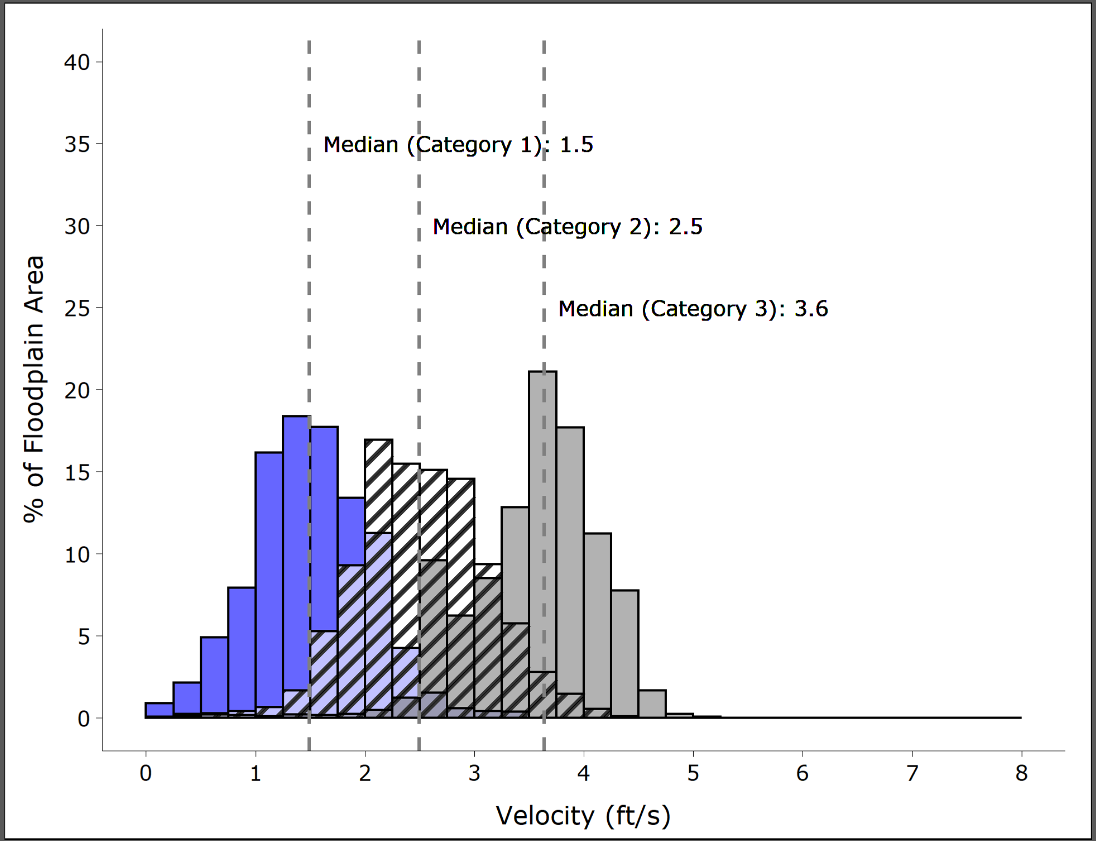
# Floodplain Stress Classification: Wetland Vegetation




## 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

# 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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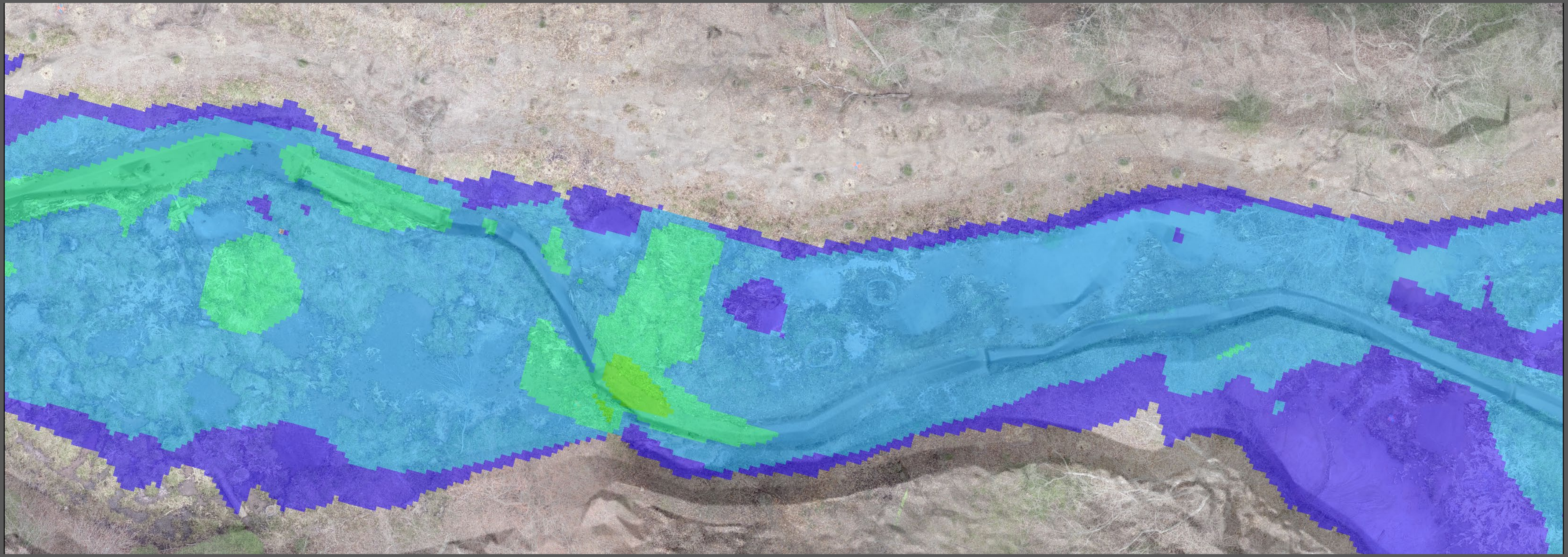
# Channel Bank Damage Classification

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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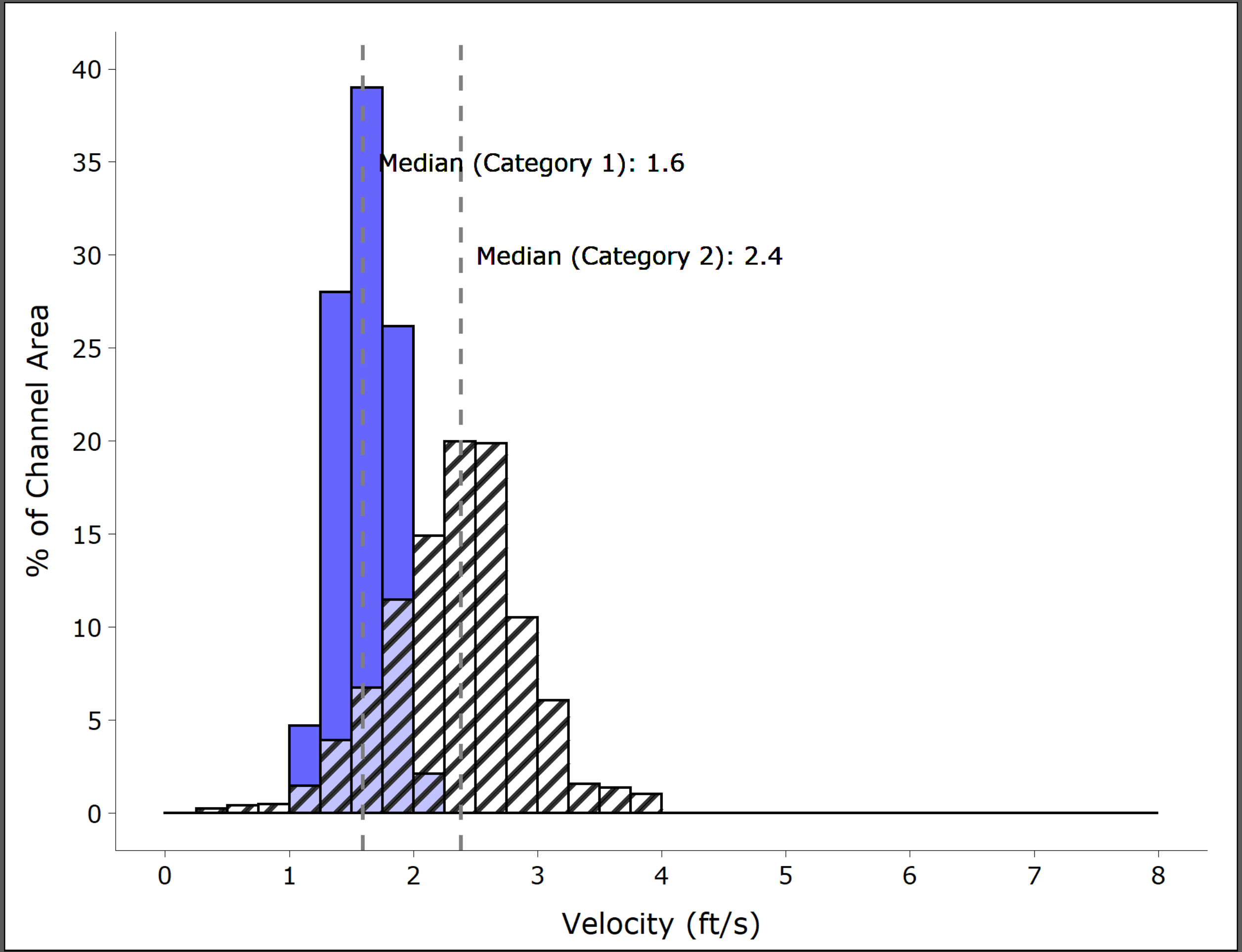
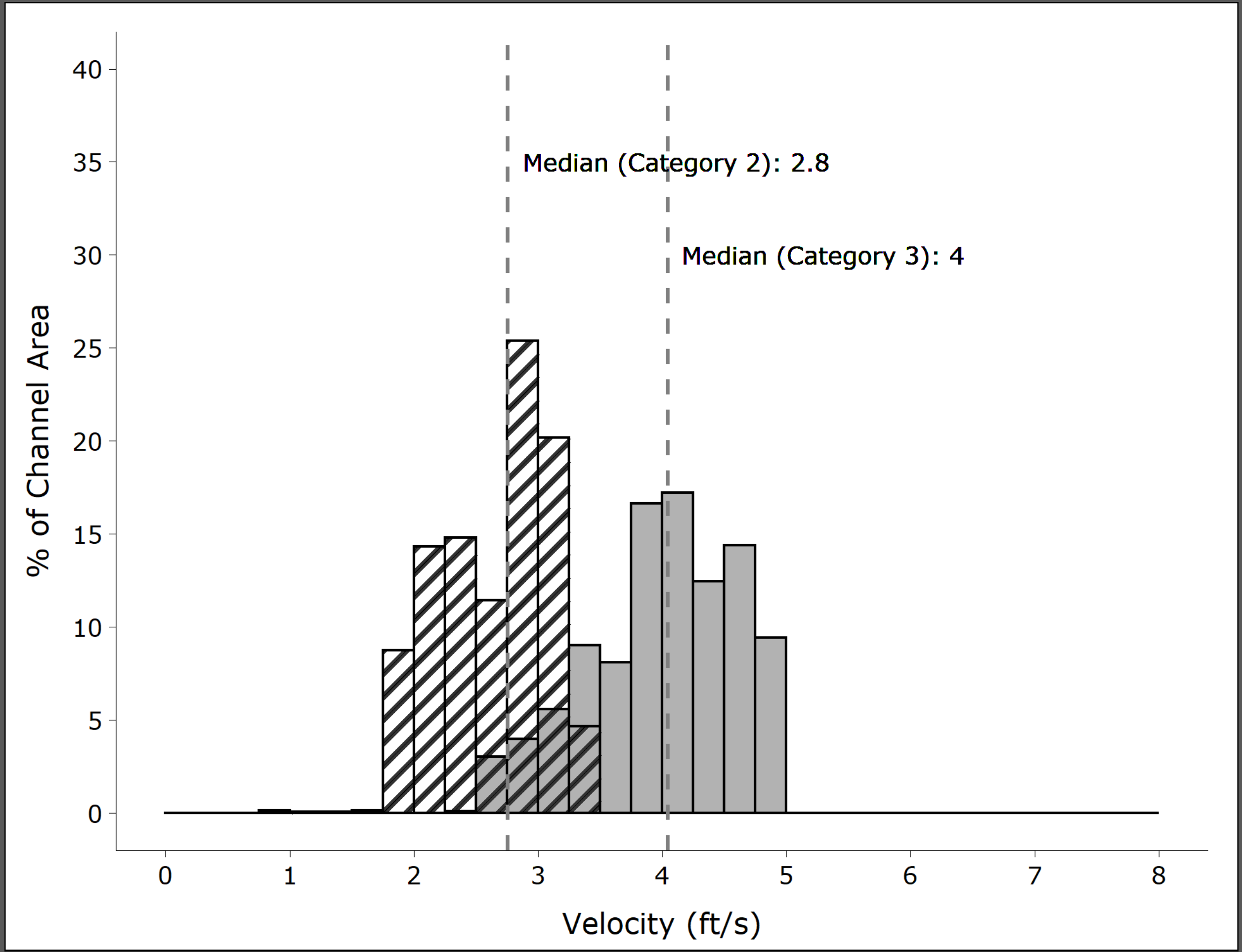
# Channel Bank Damage Classification




Cat Branch




Furnace Creek

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Velocity and Shear Stress Thresholds

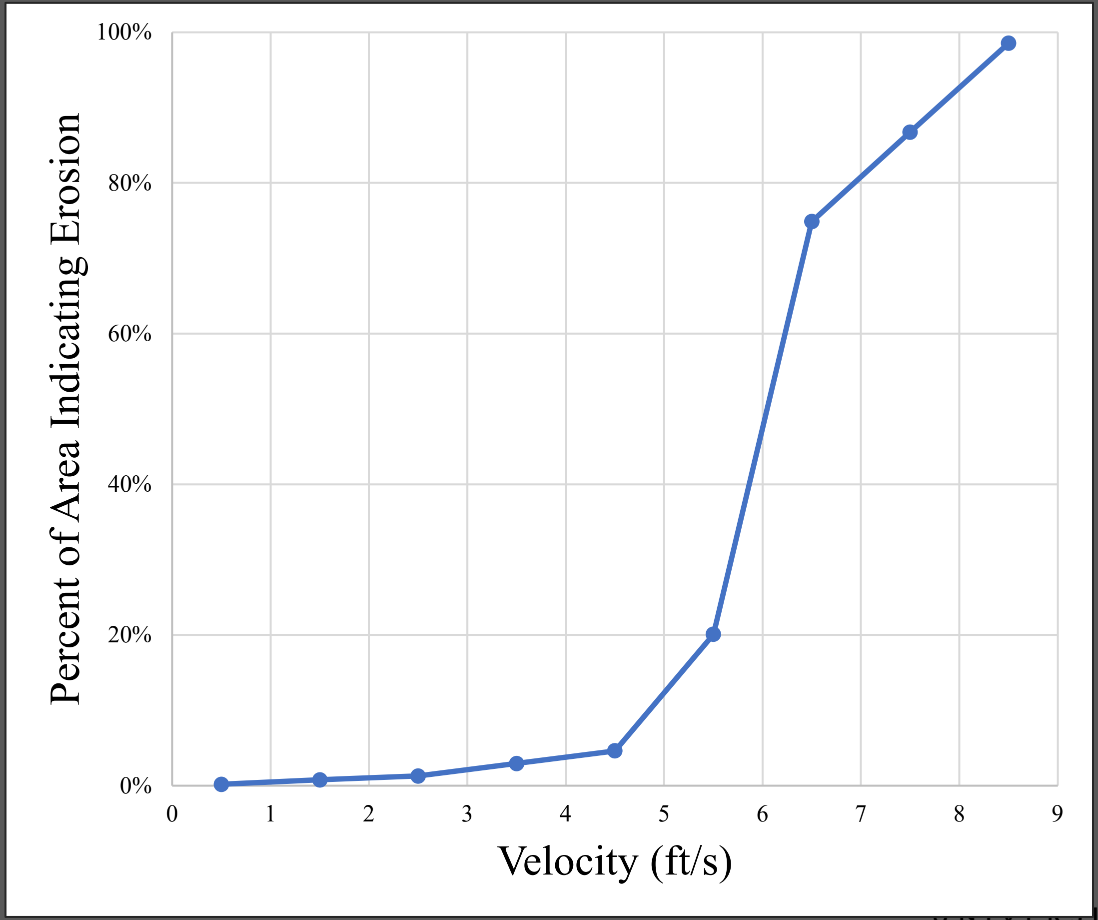
*Fischenich, C. (2001). "Stability Thresholds for Stream Restoration Materials," EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-29), U.S. Army Engineer Research and Development Center, Vicksburg, MS.*

**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 |

# 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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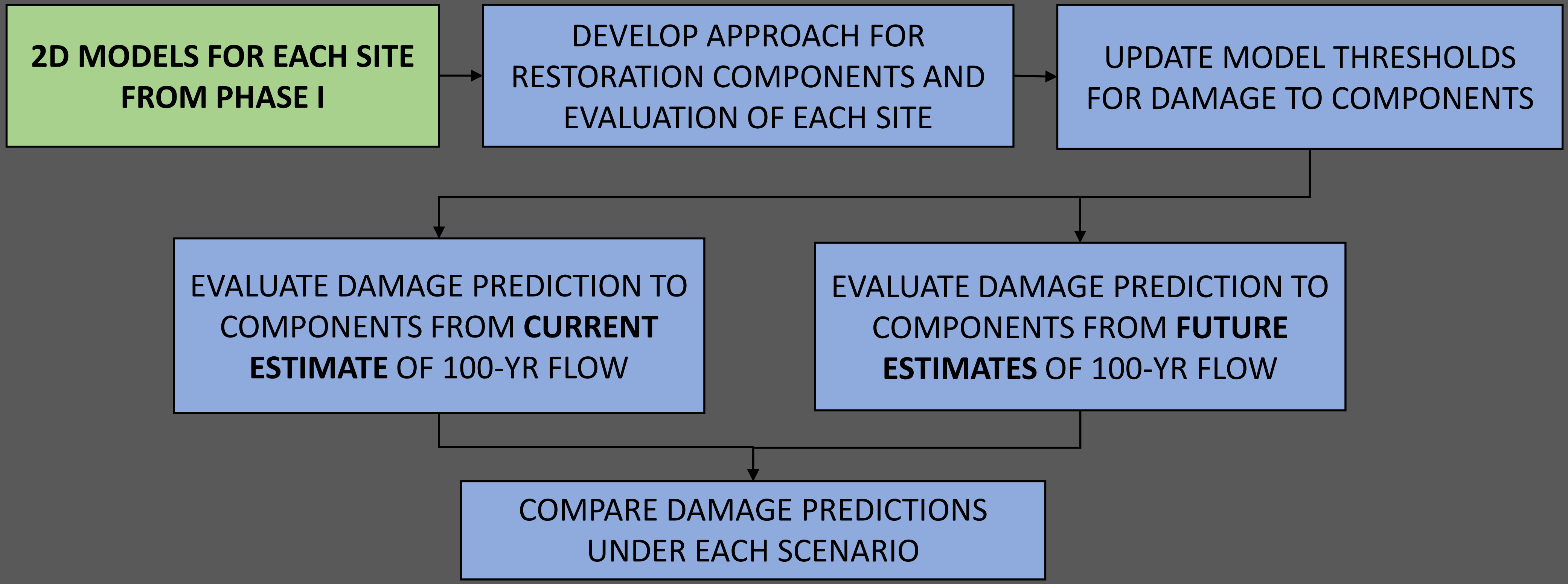
# Phase II: Current and Future Climate Conditions Analysis




## Project Status

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

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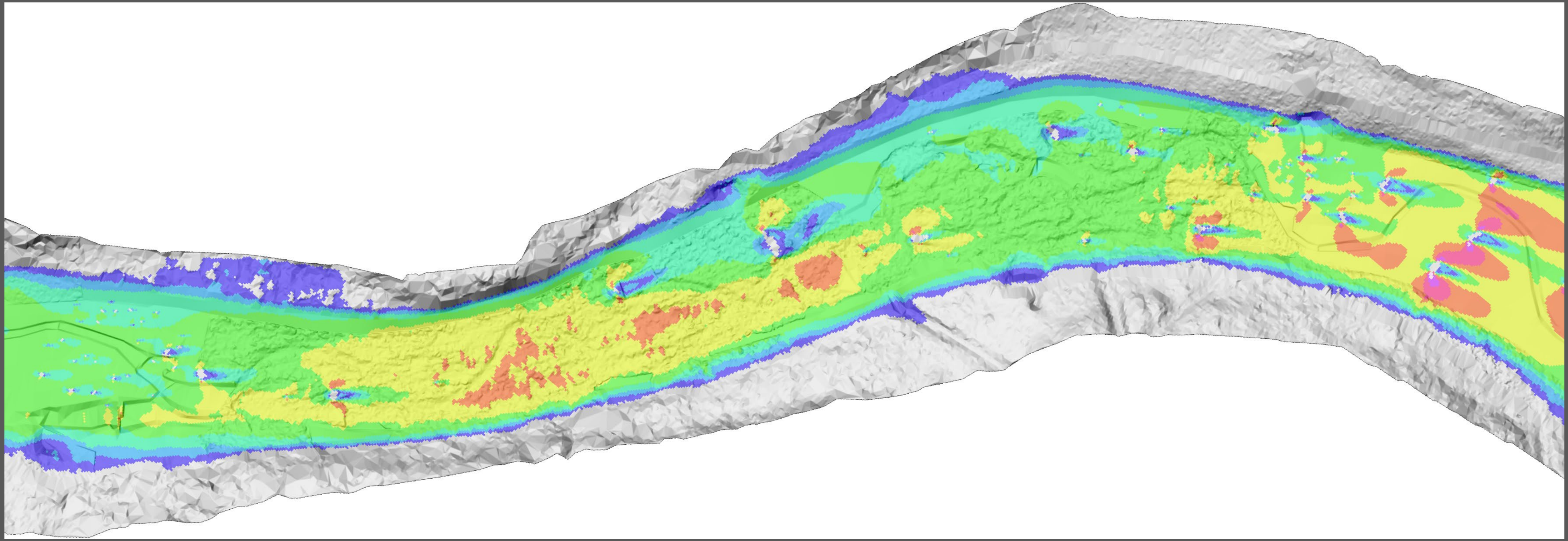
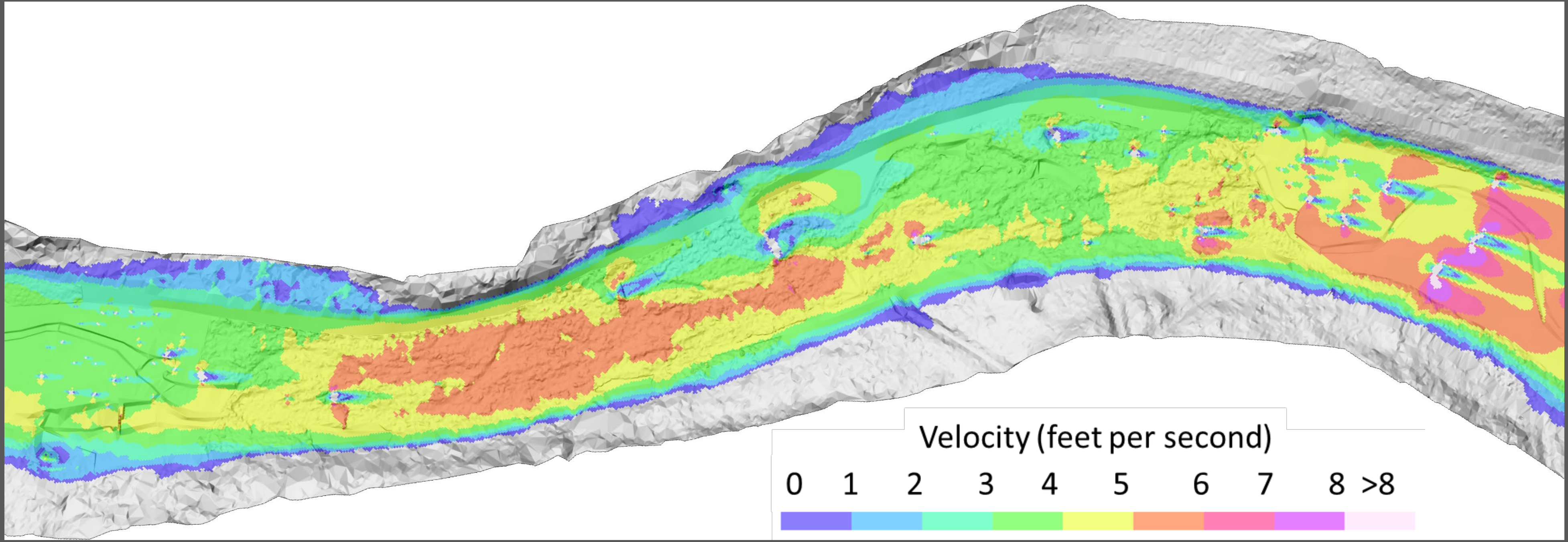


Current Climate

100-yr Event




Climate Change 100-yr Event

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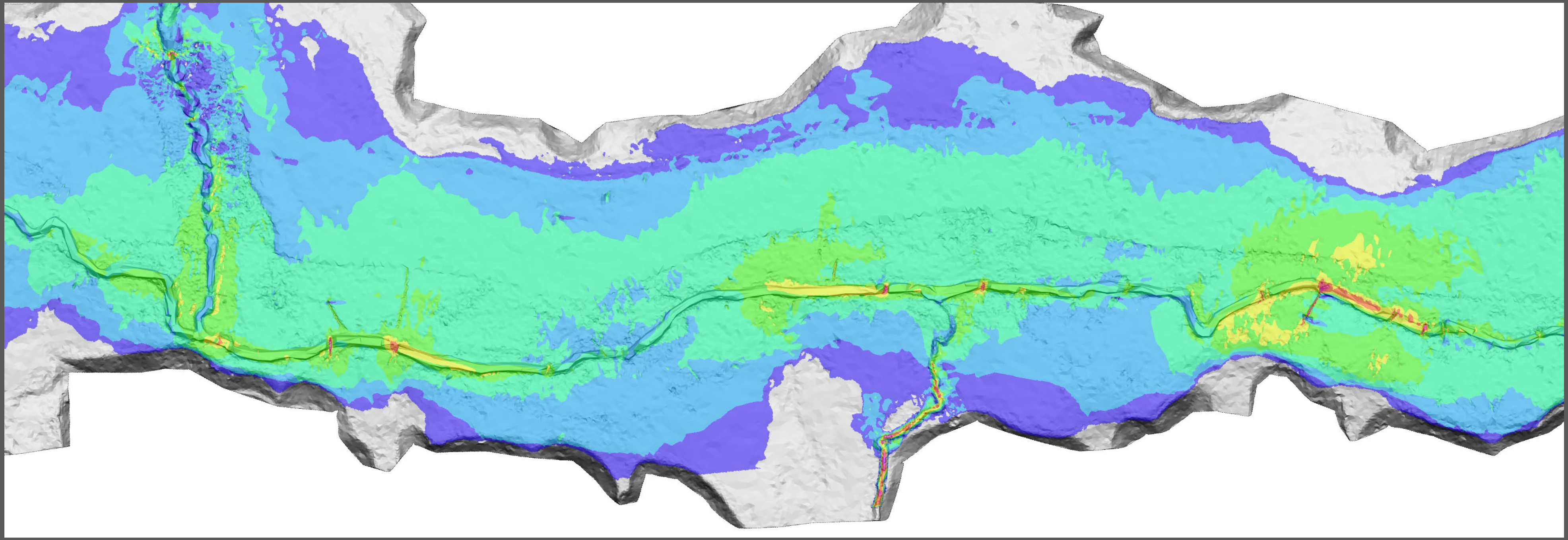
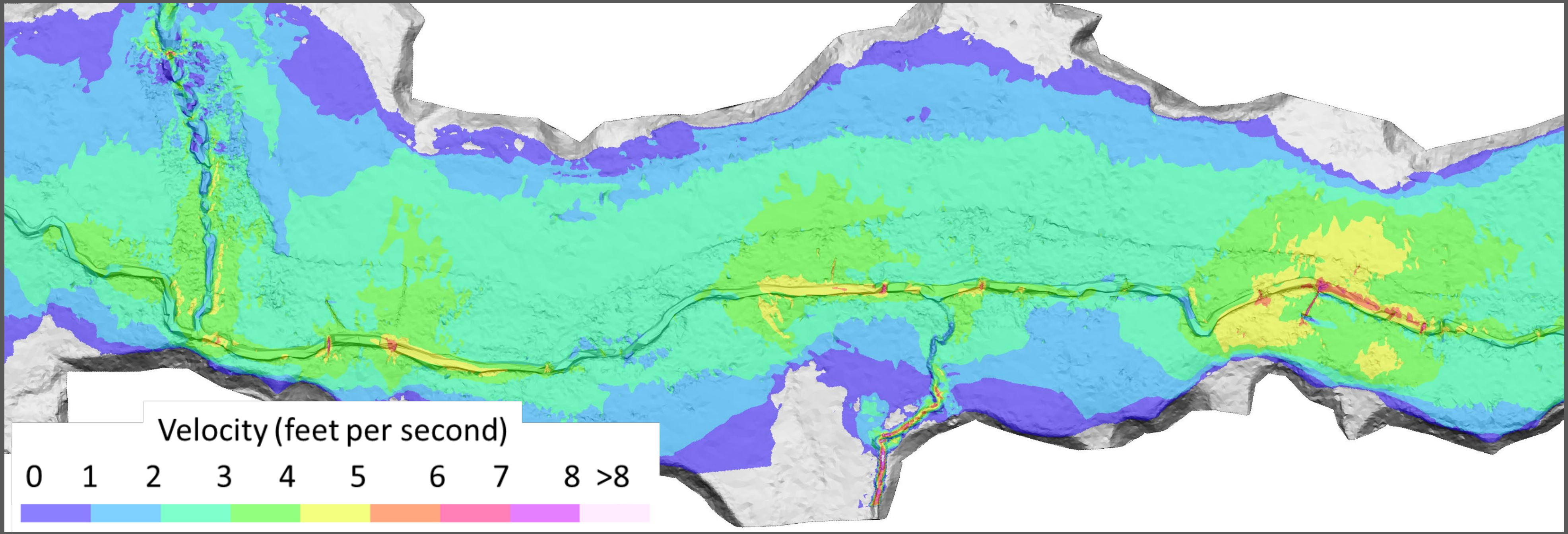
Current Climate

100-yr Event



Climate Change

100-yr Event

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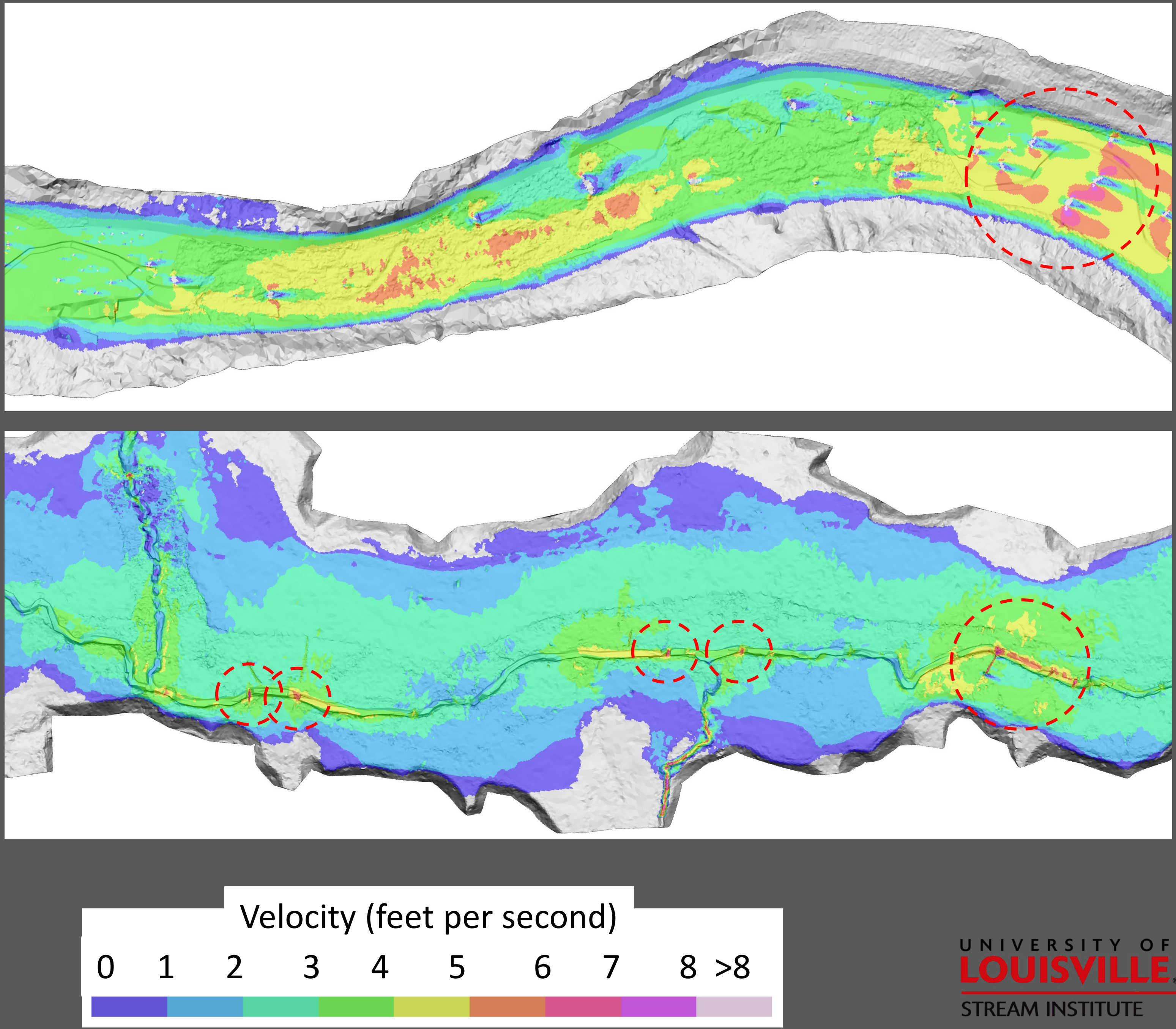
# Understanding vulnerability for changing climate

- 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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**Partners and collaborators:**
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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