Investigation into Itadori Knotweed as a Control of Bank Erosion in New Hampshire Rivers

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Why is studying erosion important?

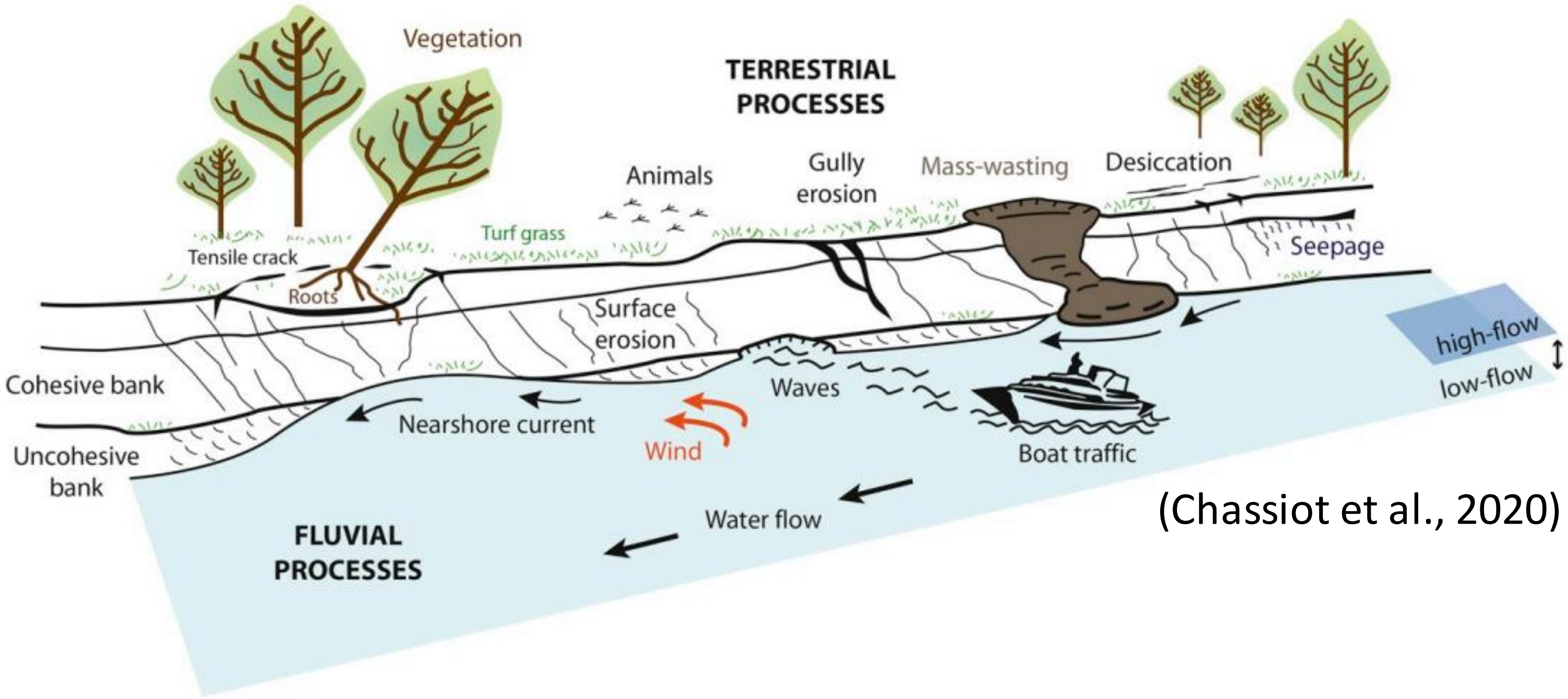
- Erosion is a natural process which drives geomorphic change in river systems
- Erosion can damage infrastructure
- Excessive erosion can harm ecosystems by increasing sediment load

https://conservationdistrict.org

www.cbsnews.com

How does erosion happen?

- Mechanisms of bank erosion
  - Fluvial entrainment
  - Mass failure
  - Subaerial processes



(Chassiot et al., 2020)

When does fluvial entrainment happen?

When applied shear stress exceeds critical shear stress:

$$E = k(\tau_a - \tau_c)$$

E = Lateral erosion rate

k = Erodibility coefficient

τ_a = Applied shear stress

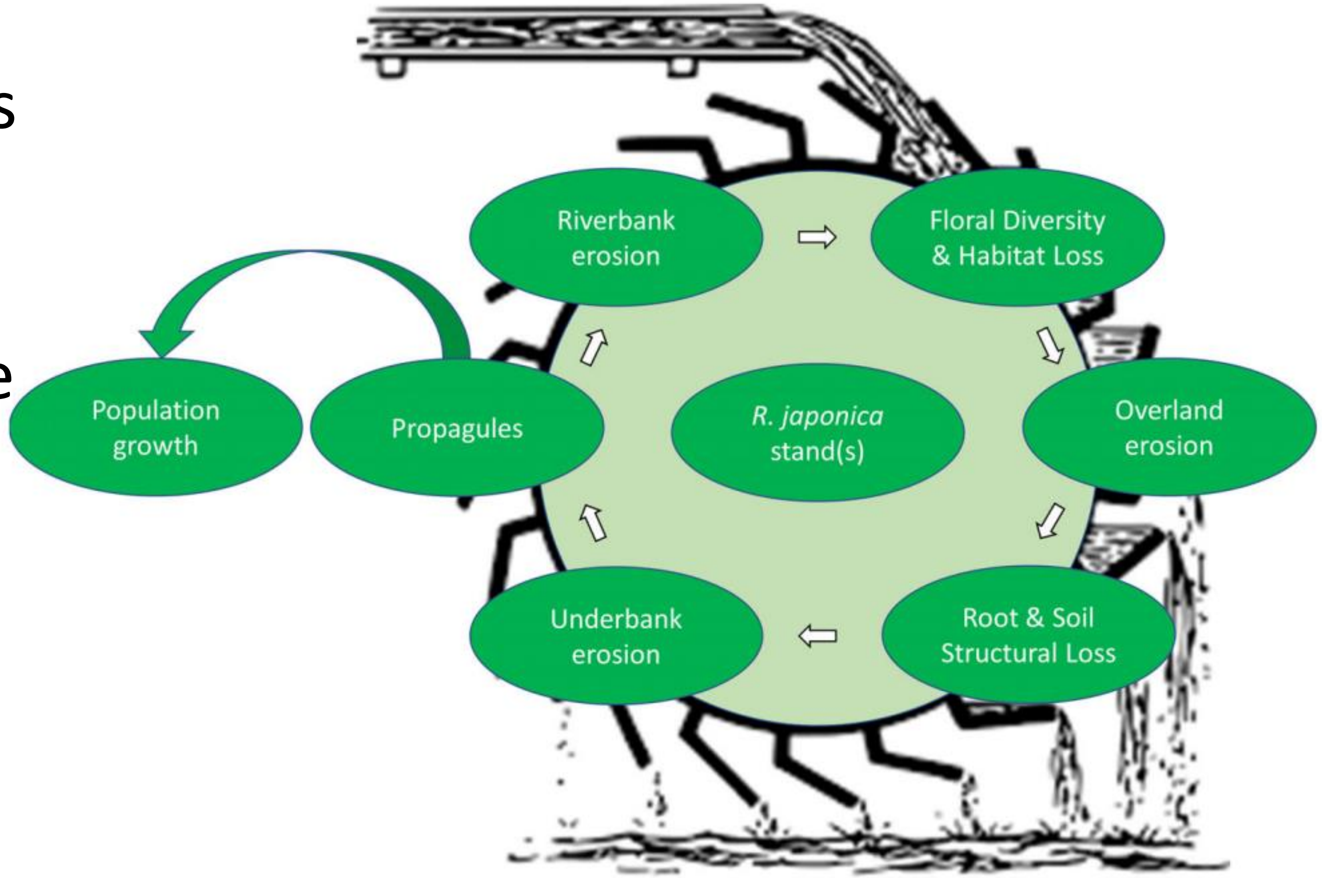
τ_c = Critical shear stress

How does vegetation influence bank erosion?

- Vegetation can stabilize riverbanks
- *Reynoutria japonica* (Itadori Knotweed) is suspected to promote erosion of riverbanks

What is Itadori knotweed?

- A highly invasive plant which has spread throughout the Europe and North America from Asia
- It has a rhizomatic root structure
- It dies back in winter exposing soil to erosion



(Colleran et al., 2020)

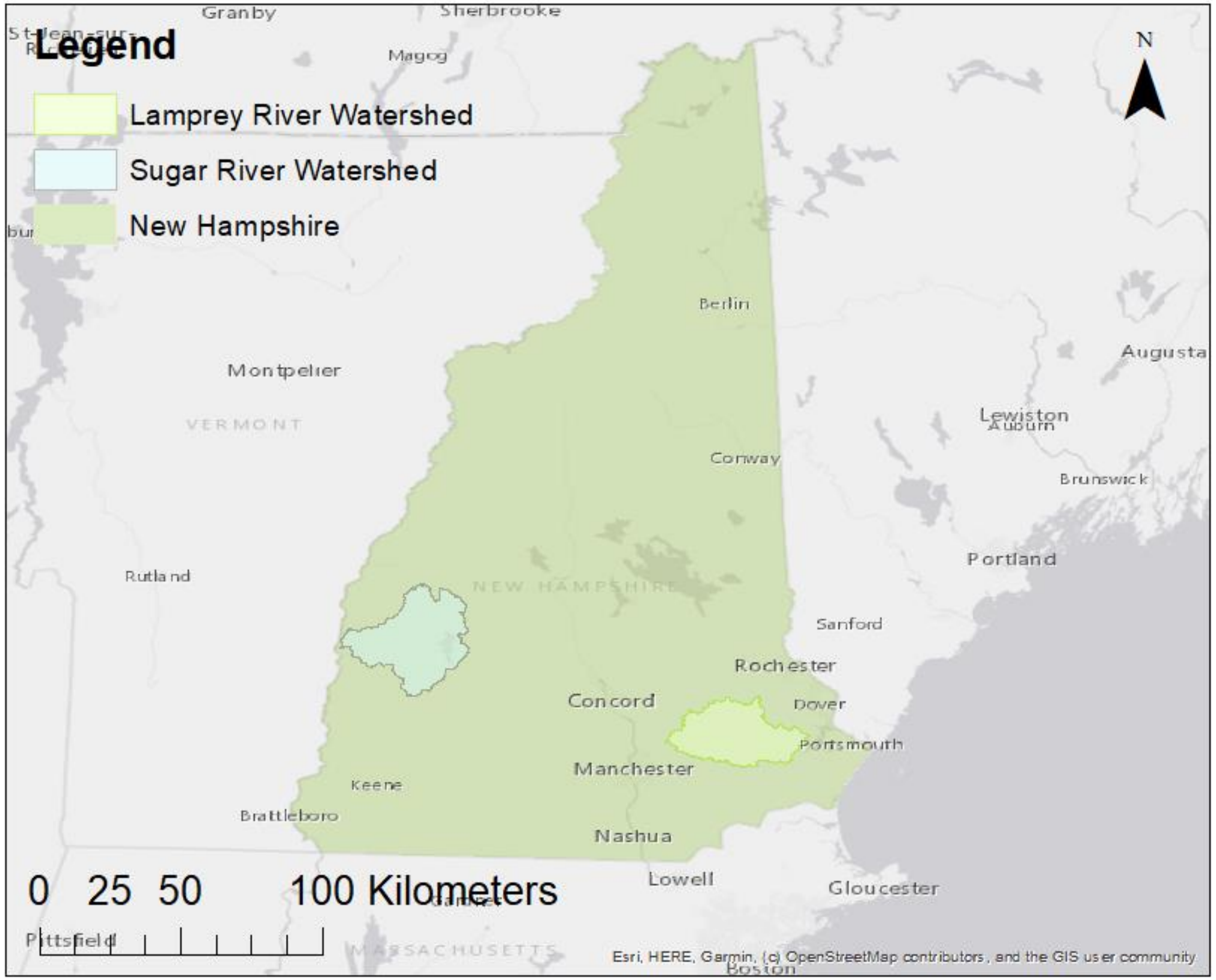
Hypothesis

Higher amounts of erosion occur near knotweed patches than vegetation patches of native species

Fluvial entrainment, caused by applied shear stress exceeding critical shear stress, is a dominant cause of bank erosion around knotweed patches

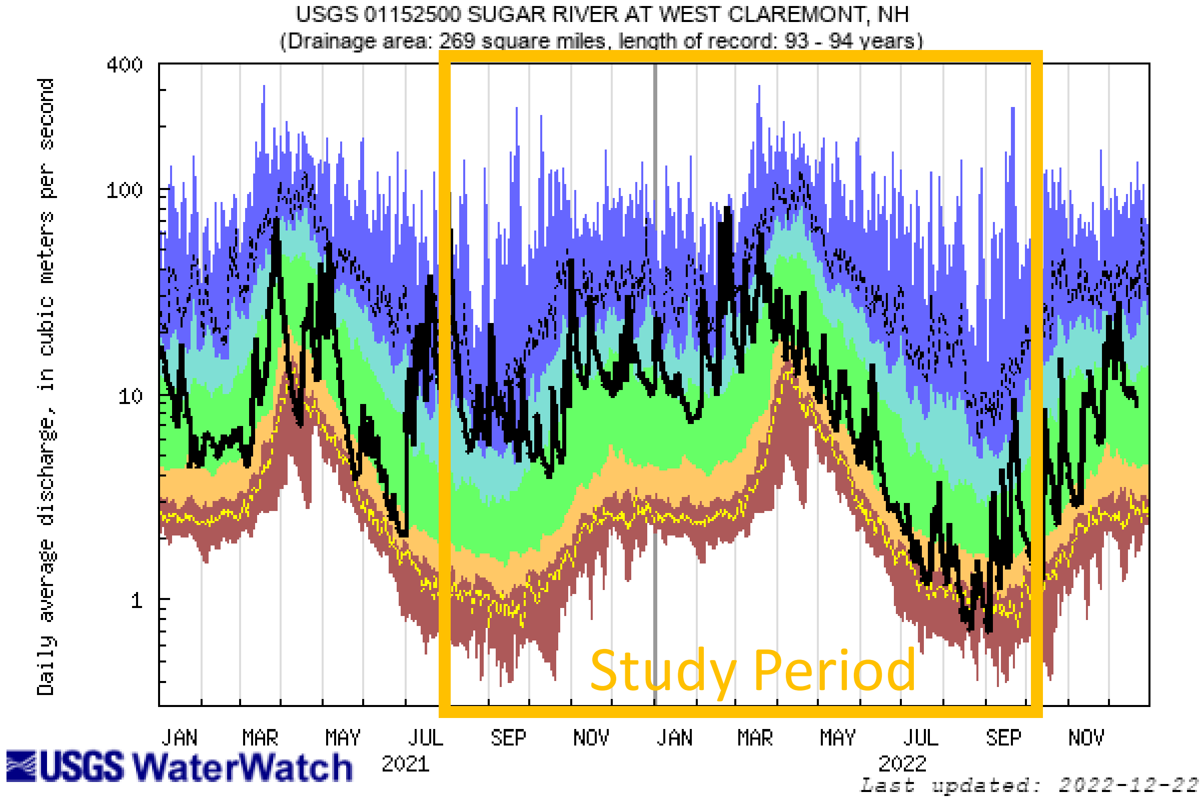
Study Rivers

	Sugar River	Lamprey River
Watershed Area (km2)	553	715
Channel Slope (%)	12.35	6.24
Precipitation (cm)	167.60	114.3
Bed Material	Gravel/Cobble/ Boulder	Sand/Gravel
Gauge Station	USGS 01152500	USGS 01073500

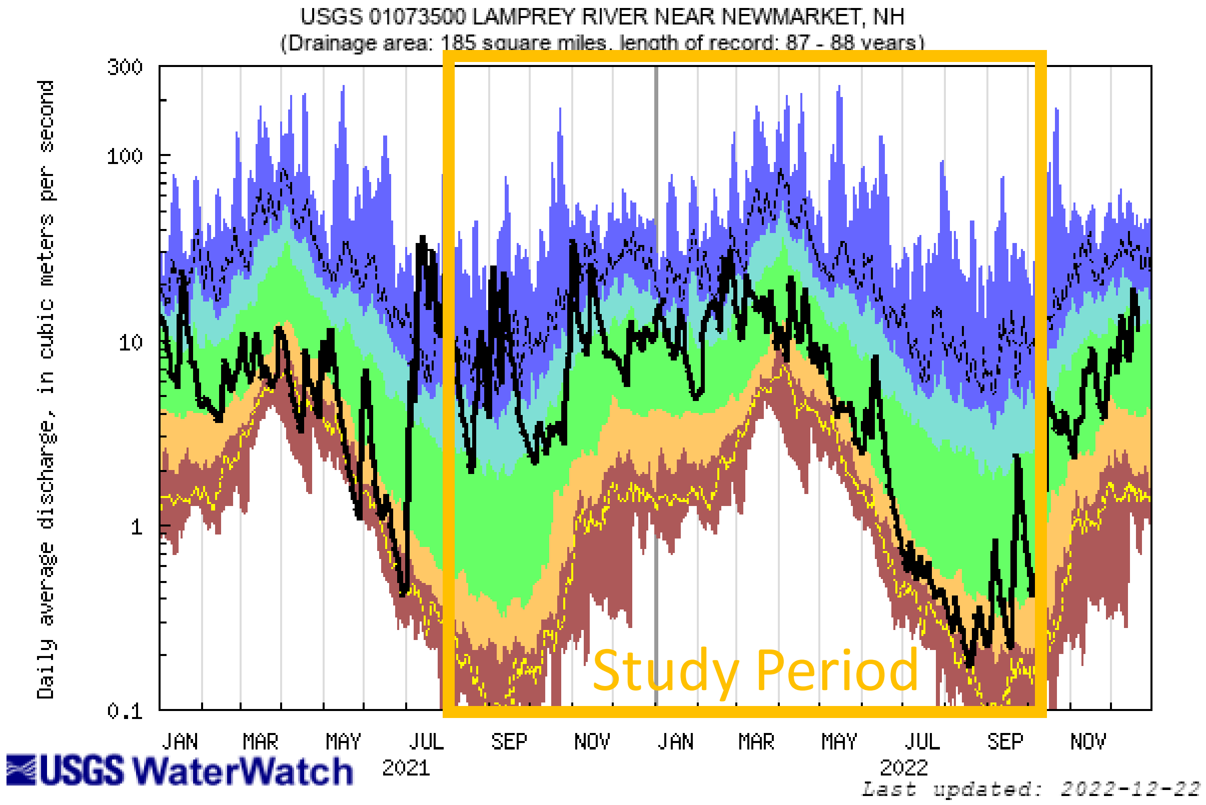


Hydrographs

Sugar River



Lamprey River



Explanation - Percentile classes

lowest-10th percentile	5	10-24	25-75	76-90	95	90th percentile -highest	Flow
Much below Normal		Below normal	Normal	Above normal	Much above normal		

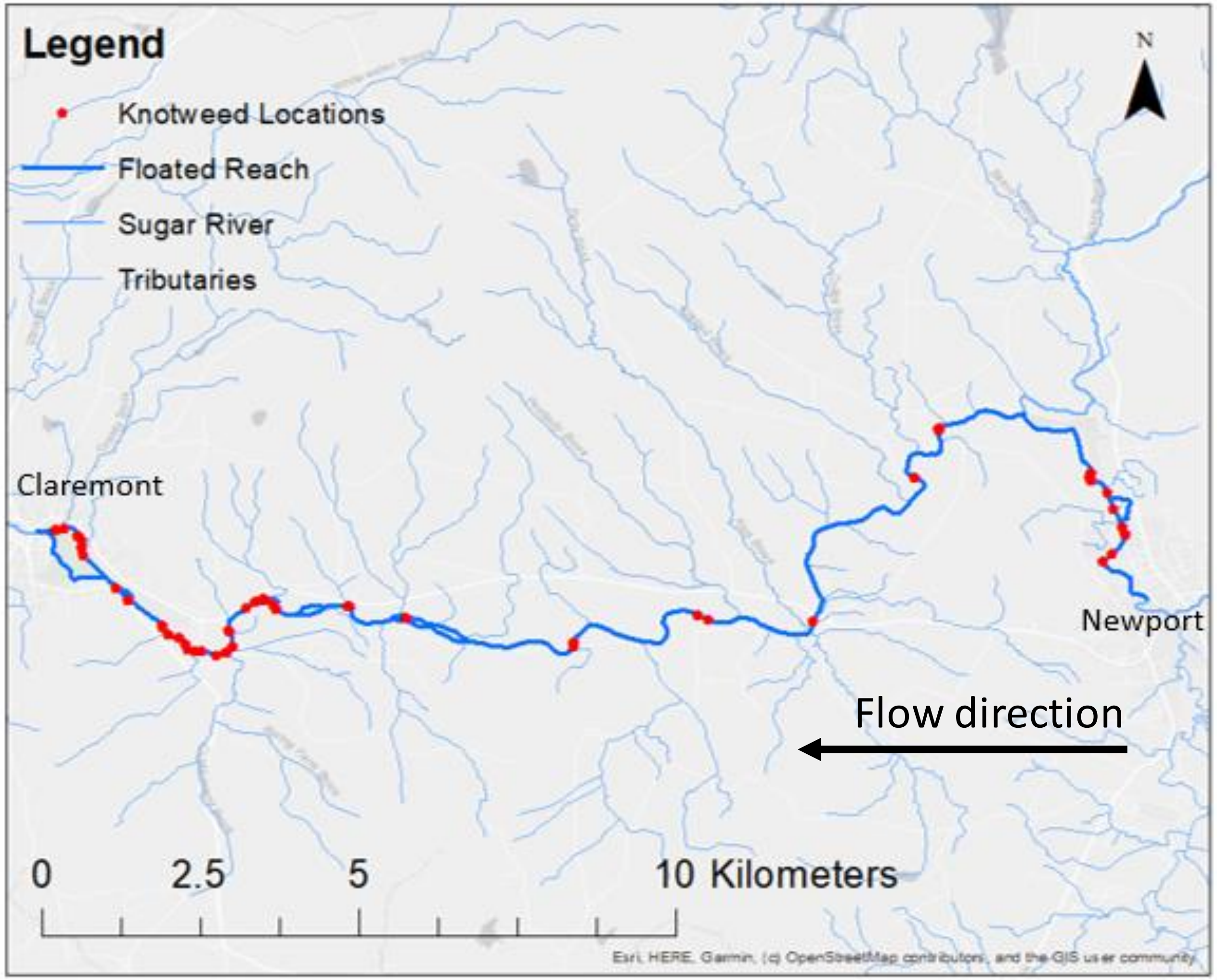
Canoeing the Study Rivers

Lamprey River, May 5th, 2021

Sugar River, June 1st, 2021

Knotweed Patches Along the Sugar River

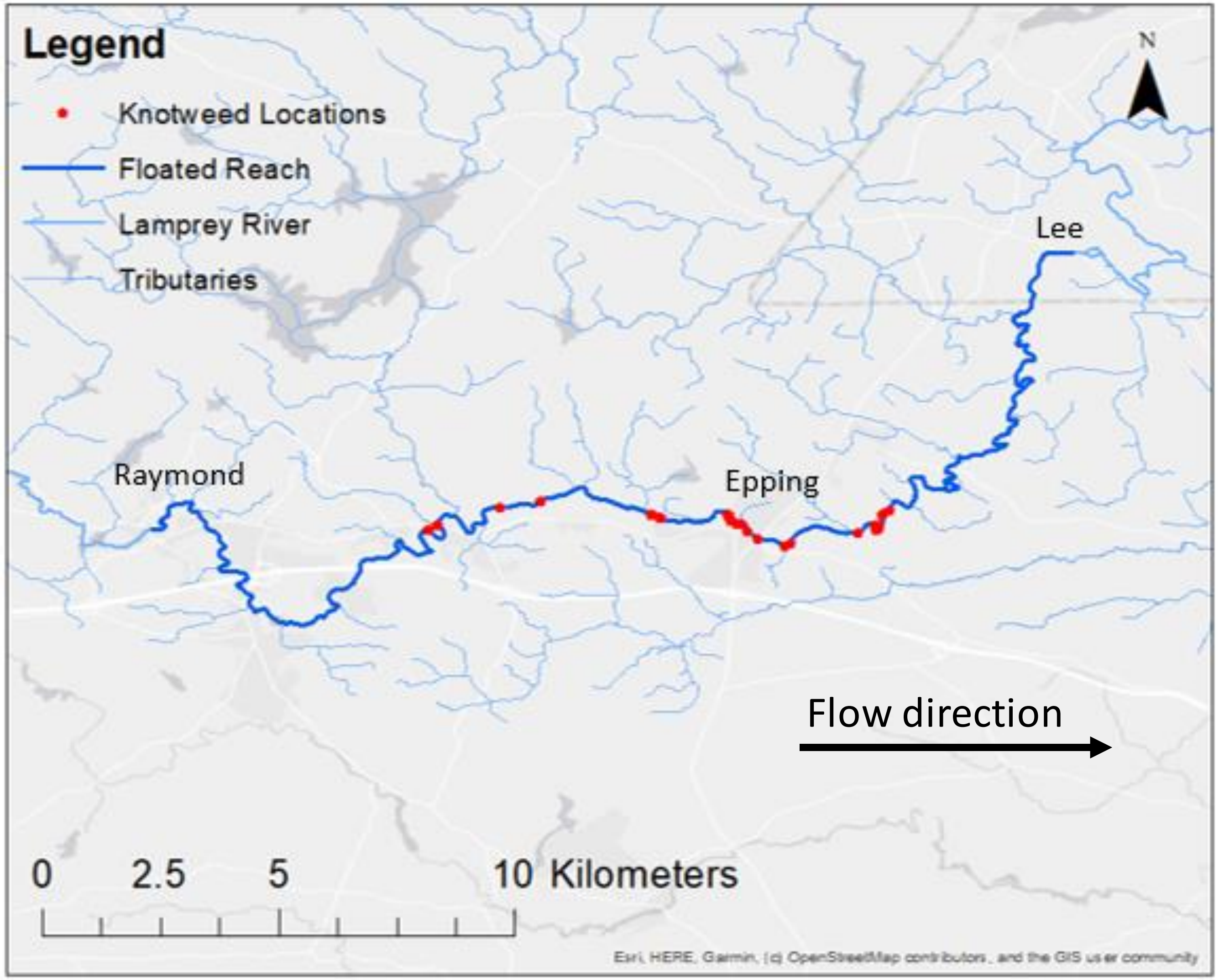
50 patches were identified along 21 km of the river



Knotweed was focused around urban areas of Claremont and Newport, NH

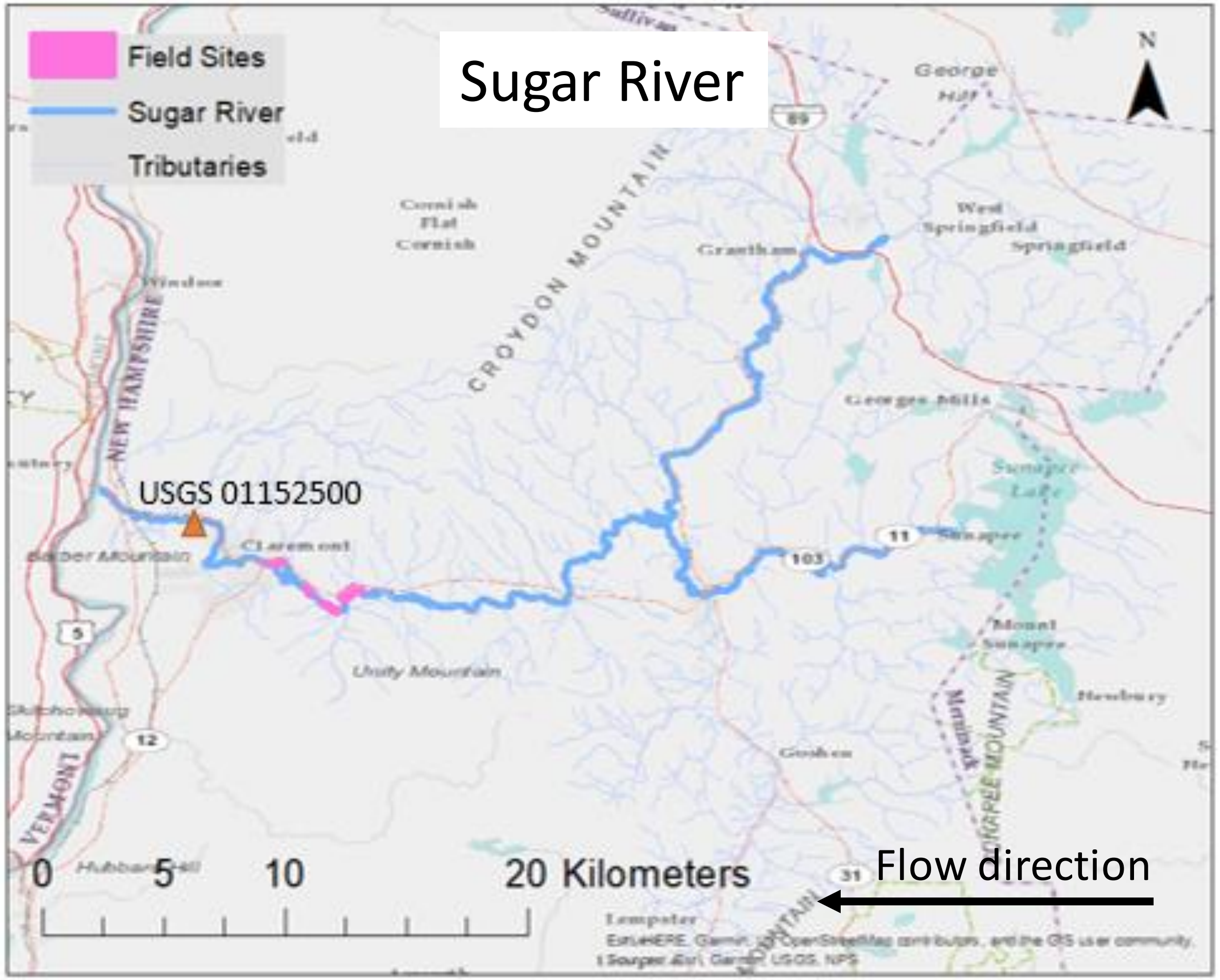
Knotweed Patches Along the Lamprey River

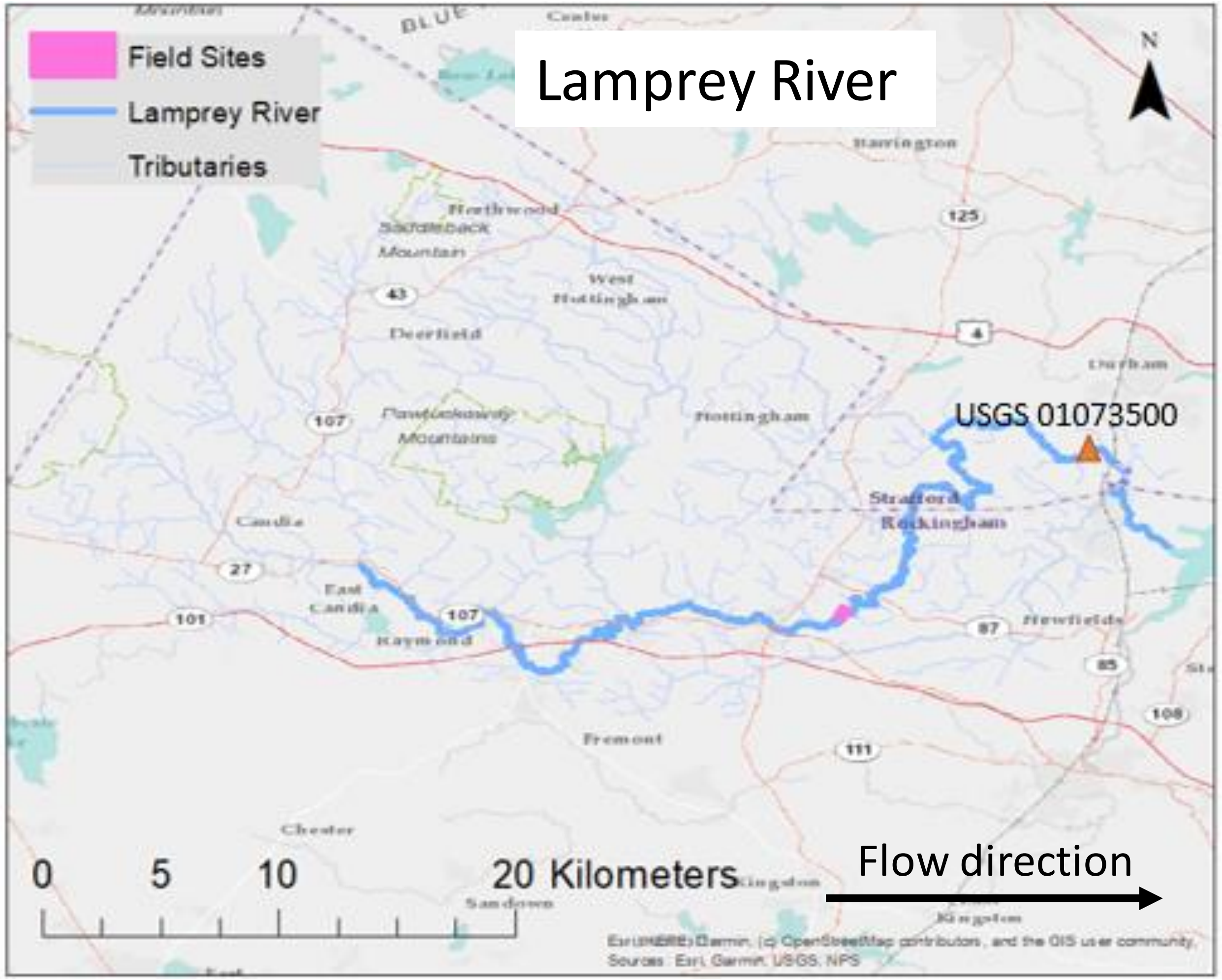
26 patches were identified along 26 km of the river



Knotweed was focused around urban area of Epping, NH

Study Sites


Field Sites
Sugar River
Tributaries
Sugar River
N
USGS 01152500
0 5 10 20 Kilometers
Flow direction


Field Sites
Lamprey River
Tributaries
Lamprey River
N
USGS 01073500
0 5 10 20 Kilometers
Flow direction

Methods and Results

- Vegetation Survey (Focal Sites)
- Soil Property Testing (Focal Sites)
  - Critical Shear Stress
- Erosion Monitoring
  - Bank Pins (All Sites)
- Hydraulic Modelling (Focal Sites)
  - Applied Shear Stress

Methods and Results

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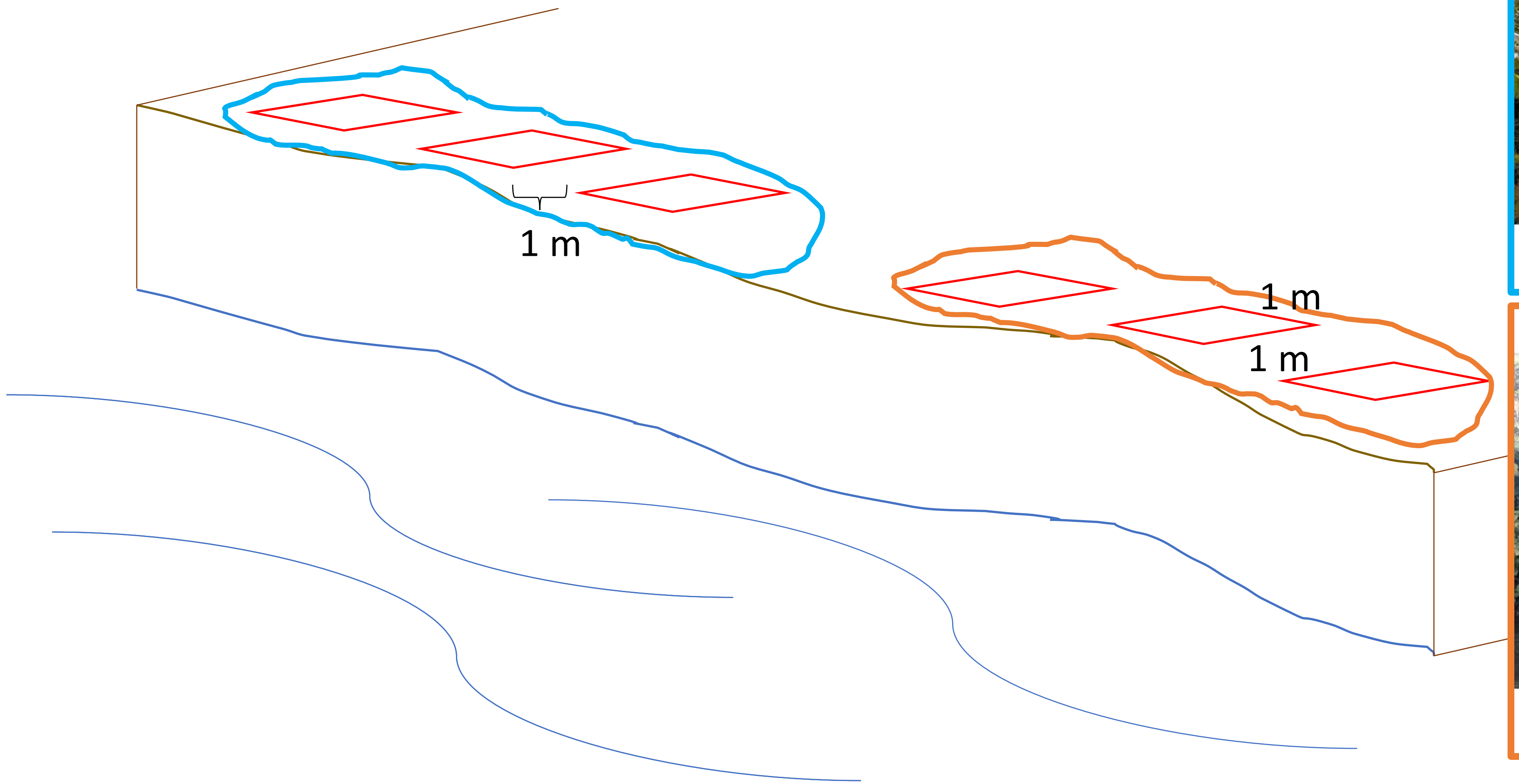
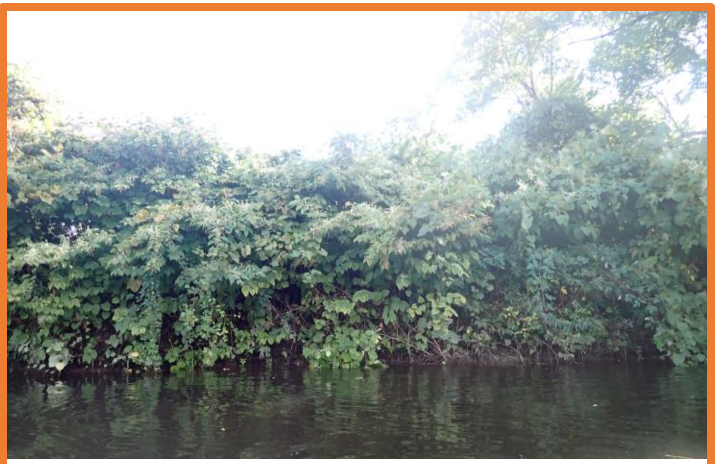
Vegetation Survey



Sugar Site 6 Native Patch



Sugar Site 6 Knotweed Patch

Vegetation Survey

	Sugar Site 2		Sugar Site 6		Lamprey Site	
Quadrats	**Species**	**Stem Count**	**Species**	**Stem Count**	**Species**	**Stem Count**
Native 1	*Boehmeria cylindrica*	1	*Athyrium filix-femina*	4	*Cornus amomum*	73
	Celastrus scandens	1	*Boehmeria cylindrica*	18	*Solidago flexicaulis*	2
	Solidago flexicaulis	45	*Solidago flexicaulis*	23		
Native 2	*Athyrium filix-femina*	7	*Boehmeria cylindrica*	10	*Cornus amomum*	57
	Boehmeria cylindrica	1	*Fraxinus nigra*	1	*Solidago flexicaulis*	1
	Robinia pseudoacacia	1				
	Solidago flexicaulis	9				
Native 3	*Ambrosia artemisiifolia*	1	*Boehmeria cylindrica*	35	*Boehmeria cylindrica*	1
	Boehmeria cylindrica	14	*Solidago flexicaulis*	7	*Cornus amomum*	69
	Solidago flexicaulis	10			*Solidago flexicaulis*	4
Knotweed 1	*Reynoutria japonica*	13	*Reynoutria japonica*	13	*Reynoutria japonica*	18
	Solidago flexicaulis	1				
Knotweed 2	*Reynoutria japonica*	11	*Reynoutria japonica*	15	*Reynoutria japonica*	7
Knotweed 3	*Reynoutria japonica*	12	*Reynoutria japonica*	8	*Reynoutria japonica*	10

Vegetation Survey

	Taken September 29th, 2021	Taken April 29th, 2022
Sugar 2 Knotweed Patch		
Sugar 2 Native Patch		

Vegetation Survey

Main Takeaway:

Vegetation type and density is similar between native vegetation patches and knotweed patches, respectively

Methods and Results

- Vegetation Survey (Focal Sites)
- Soil Property Testing (Focal Sites)
  - Critical Shear Stress
- Erosion Monitoring
  - Bank Pins (All Sites)
- Hydraulic Modelling (Focal Sites)
  - Applied Shear Stress

Soil Property Testing

1. Weigh (Wet Weight)
2. Dry Soil in Oven at 105^{o}C for 24 hours
3. Weigh (Dry Weight)
4. Wet Sieve
5. Dry remaining soil in oven at 105^{o}C for 24 hours
6. Weigh (Dry Sand Weight)

Calculated:

- Bulk Density (Dry Weight/Volume)
- Soil Moisture ((Wet Weight – Dry Weight)/Dry Weight)
- % Silt-Clay ((Dry Weight – Dry Sand Weight)/Dry Weight)

Soil Property Testing

Estimating Critical Shear Stress (τ_c):

$$\tau_c = 0.1 + 0.1779(SC\%) + 0.0028(SC\%)^2 - 2.34e^{-5}(SC\%)^3$$

(Julien and Torres, 2005)

Soil Property Testing

Site Name	Silt and Clay %	Bulk Density (g/cm^3)	Soil Moisture Content (%)	Estimated Critical Shear Stress (N/m^2)
Sugar Site 2 Native	24%	0.35	24%	5.85
Sugar Site 2 Knotweed	26%	0.35	24%	6.71
Sugar Site 6 Native	32%	0.39	24%	8.57
Sugar Site 6 Knotweed	59%	0.32	19%	20.25
Lamprey Native	35%	0.28	57%	9.69
Lamprey Knotweed	22%	0.49	27%	5.52

Soil Property Testing

Main Takeaway:

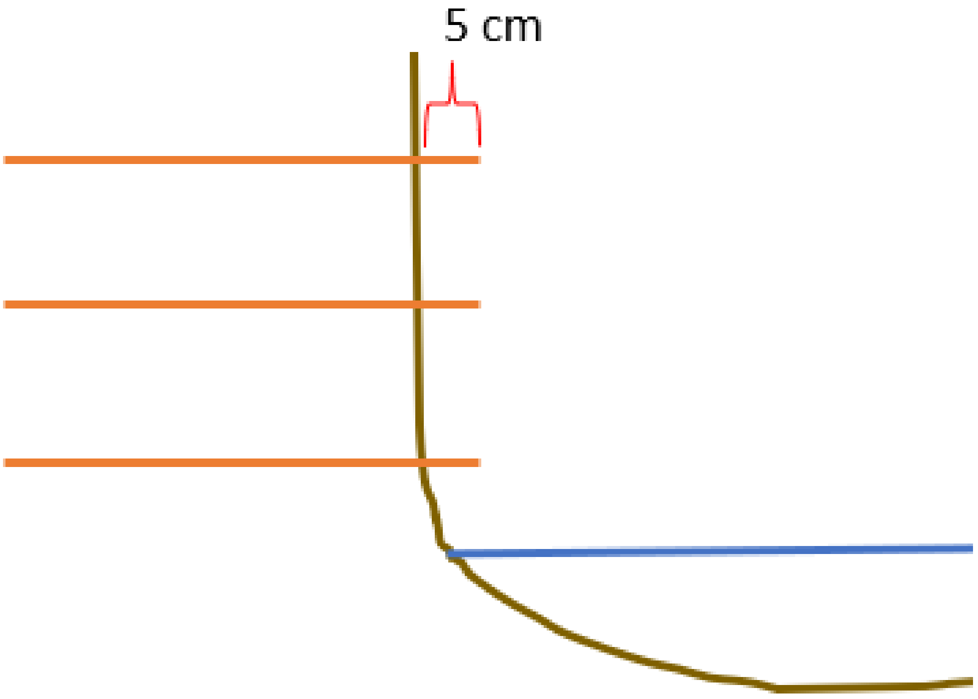
Soil Properties, including critical shear stress, are similar between paired vegetation patches apart from the Sugar Site 6 knotweed patch

Methods and Results

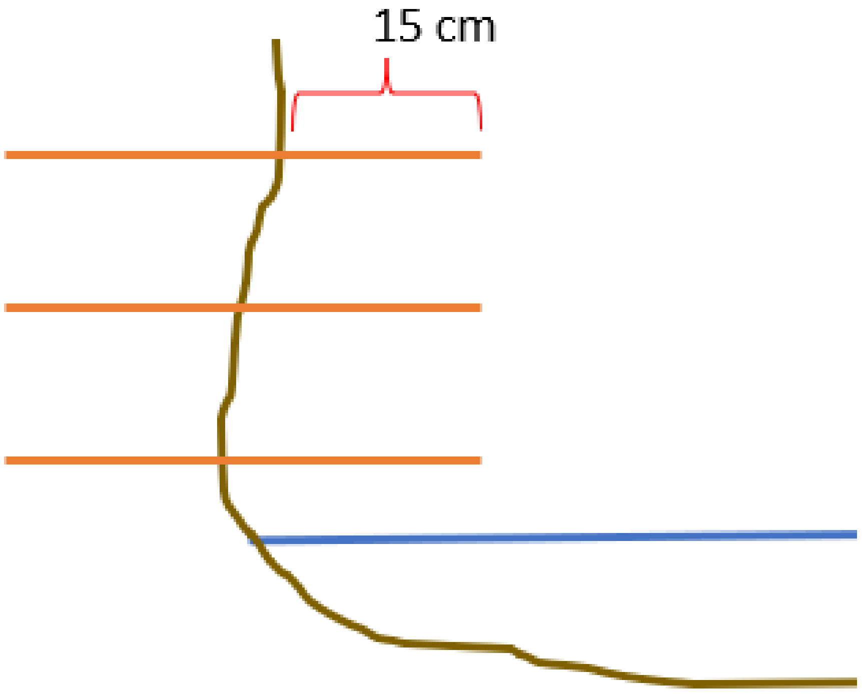
- Vegetation Survey (Focal Sites)
- Soil Property Testing (Focal Sites)
  - Critical Shear Stress
- Erosion Monitoring
  - Bank Pins (All Sites)
- Hydraulic Modelling (Focal Sites)
  - Applied Shear Stress

Erosion Monitoring

Day of Installation

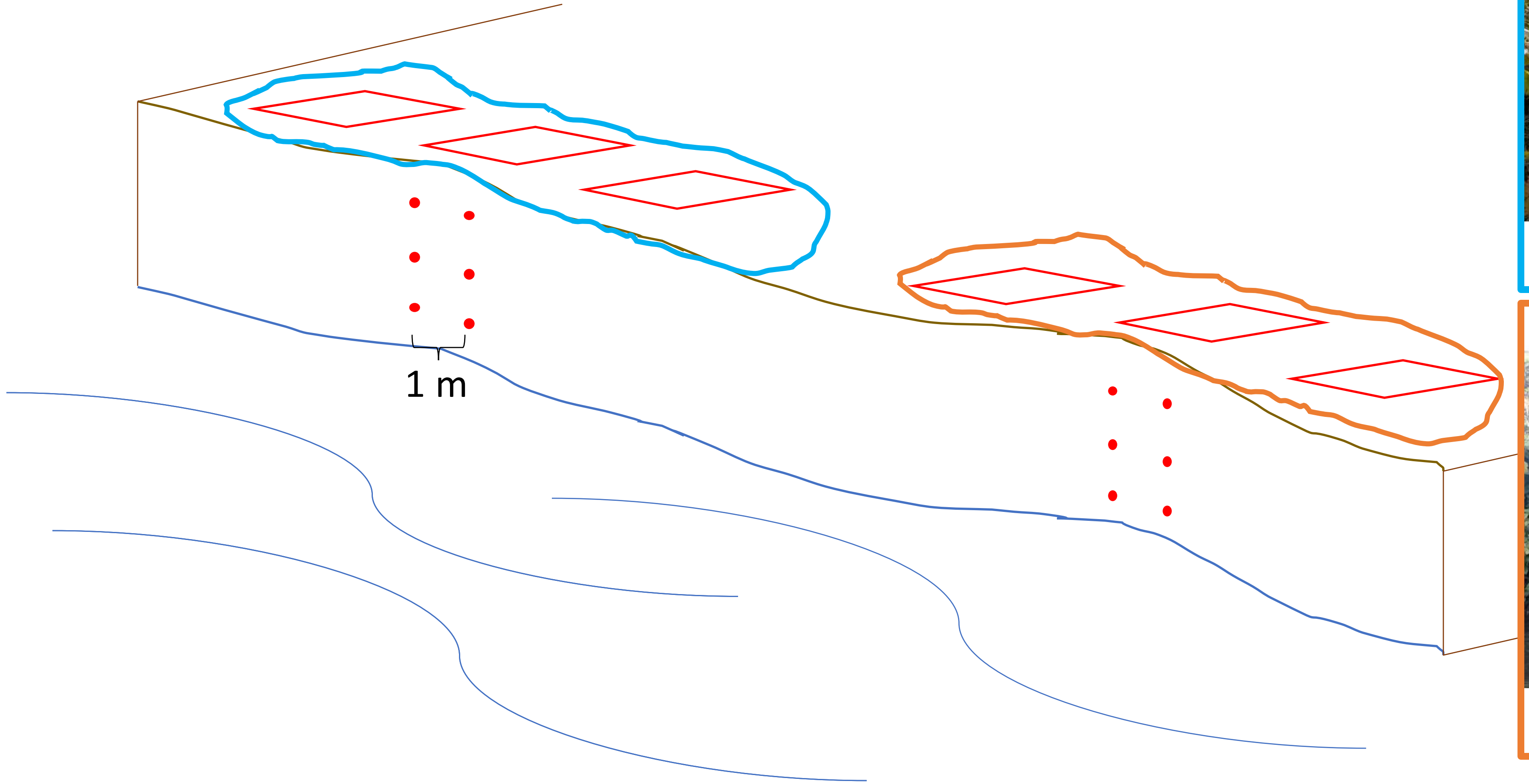


Day of Removal

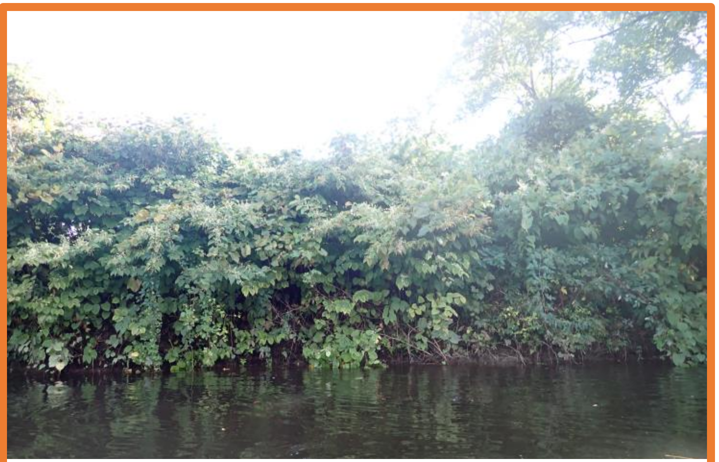


15 cm – 5 cm = 10 cm of erosion

Erosion Monitoring



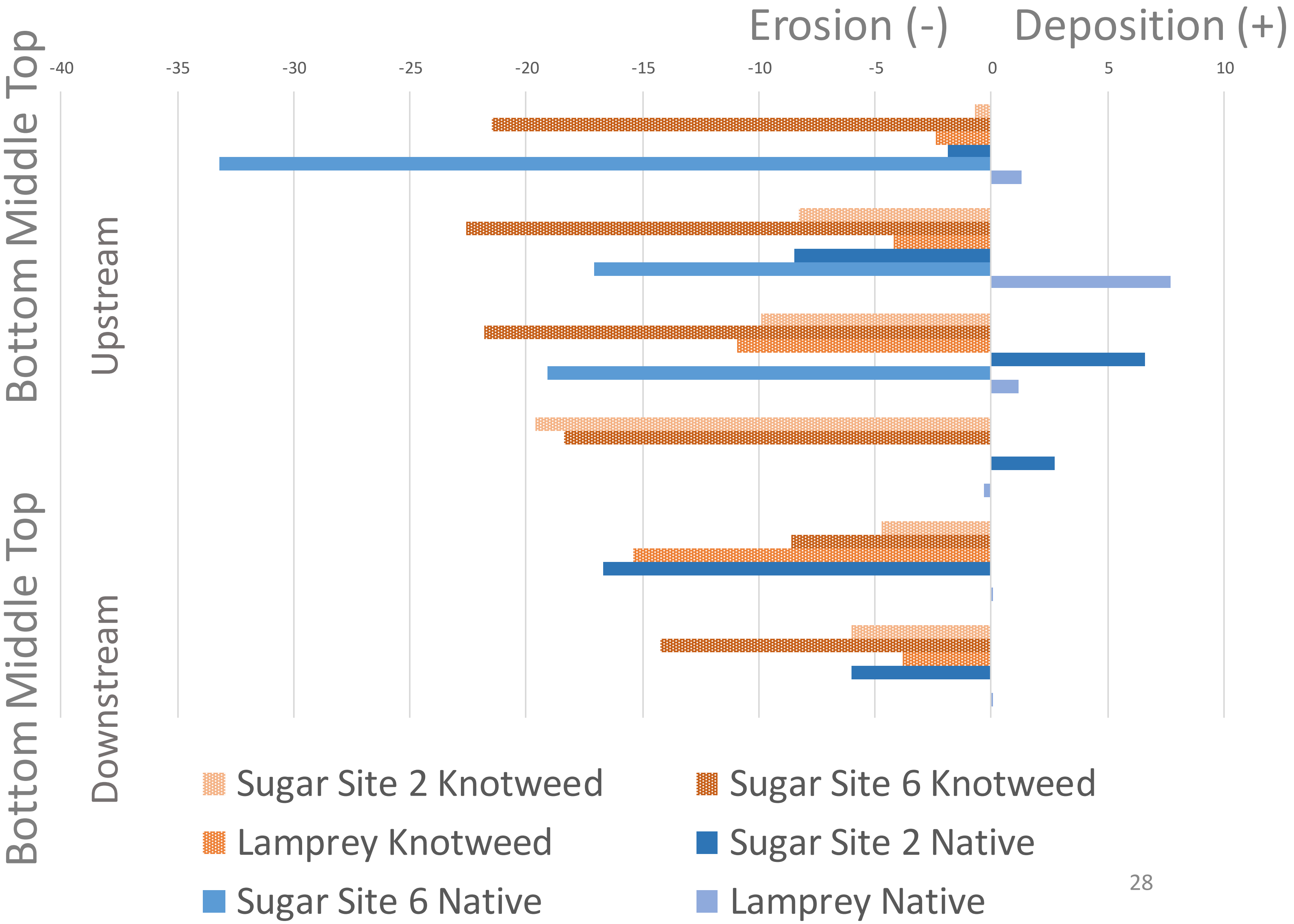

Sugar Site 6 Native Patch


Sugar Site 6 Knotweed Patch

Erosion Monitoring

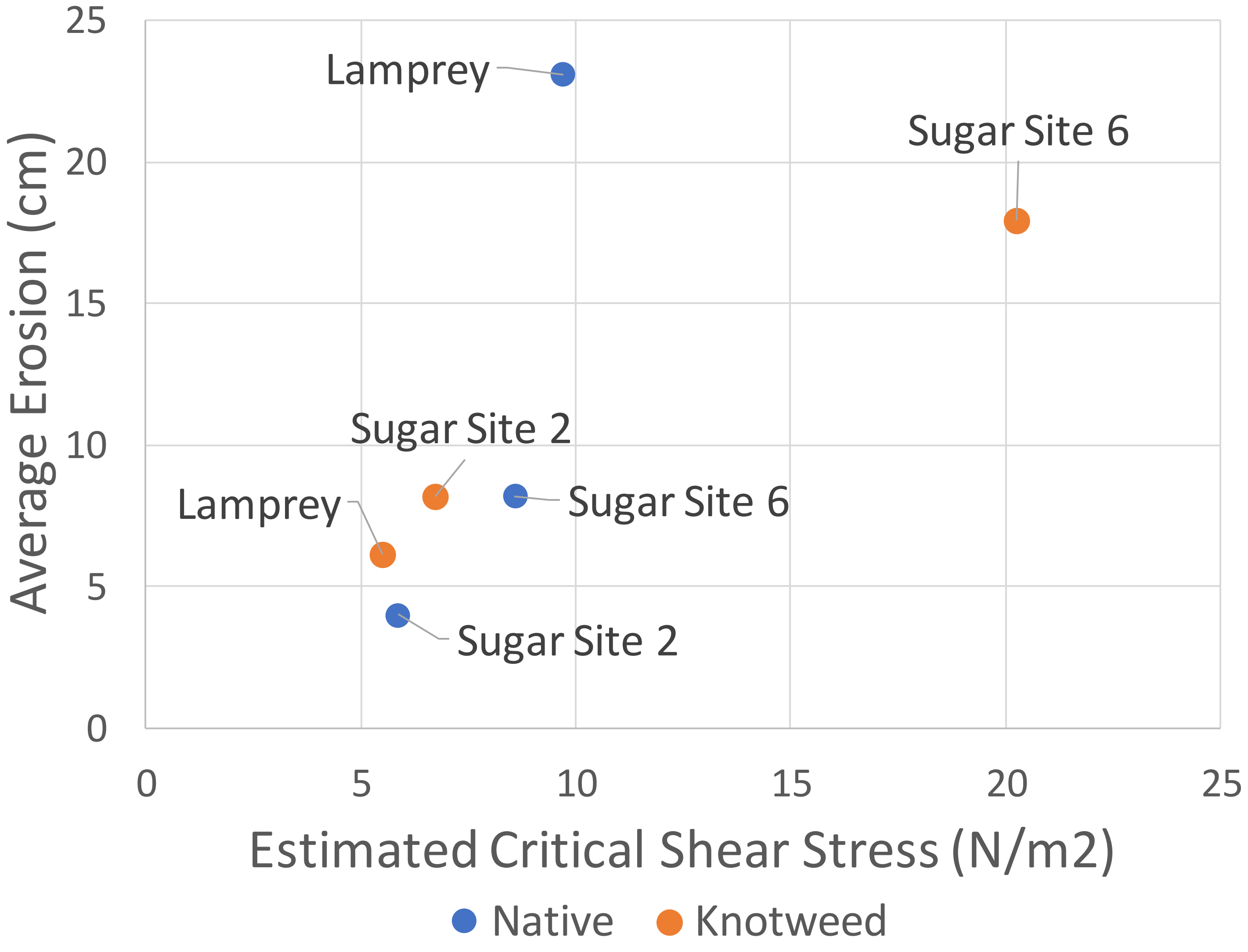
More erosion was recorded at knotweed patches than native patches

There was no difference in erosion between upstream and downstream pins or between top, middle, and bottom pins



Erosion Monitoring

No correlation was found between the amount of erosion and estimated critical shear stress at the focal sites



Erosion Monitoring

Main Takeaway:

Banks with knotweed experienced more erosion on average than banks with native vegetation

Methods and Results

- Vegetation Survey (Focal Sites)
- Soil Property Testing (Focal Sites)
    - Critical Shear Stress
- Erosion Monitoring
    - Bank Pins (All Sites)
    - Structure from Motion (Focal Sites)
- Hydraulic Modelling (Focal Sites)
    - Applied Shear Stress

Hydraulic Modeling

Inputs:

- Digital Elevation Model (DEM)
  - Topographic data
  - Bathymetric data
  - Combine data
- Discharge
- Downstream stage

Outputs:

- Applied streamwise shear stress

Hydraulic Modeling

Inputs:

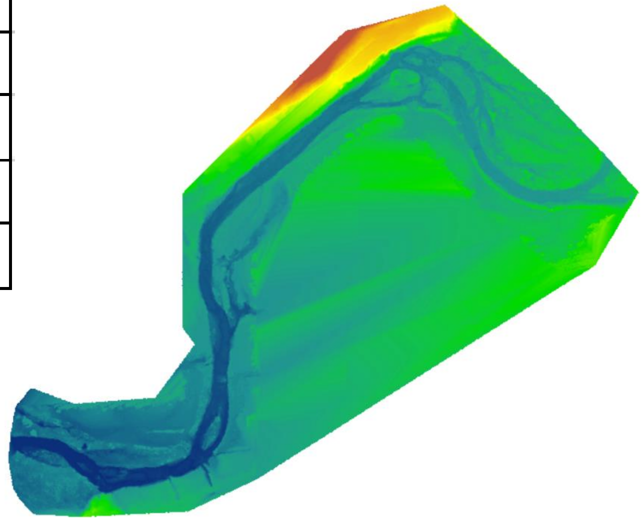
- Digital Elevation Model (DEM)
  - Topographic data
  - Bathymetric data
  - Combine data
- Discharge
- Downstream stage

Outputs:

- Applied streamwise shear stress

DEM: Topographic Data

Site	Flight Date	Area Covered (km^2)	Number of Photographs	Number of Points in Point Cloud	Point Density (points per m^3)
Sugar Site 2	4/2/2022	0.346	958	8805925	22.3
Sugar Site 2	9/16/2022	0.458	5670	65761585	20.54
Sugar Site 6	4/2/2022	0.16	382	3841163	22.3
Sugar Site 6	9/16/2022	0.397	2500	7765957	7.14
Lamprey Site	5/5/2022	0.752	1129	29801064	20.1
Lamprey Site	9/16/2022	1.1	3252	33373673	20.42



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Inputs:

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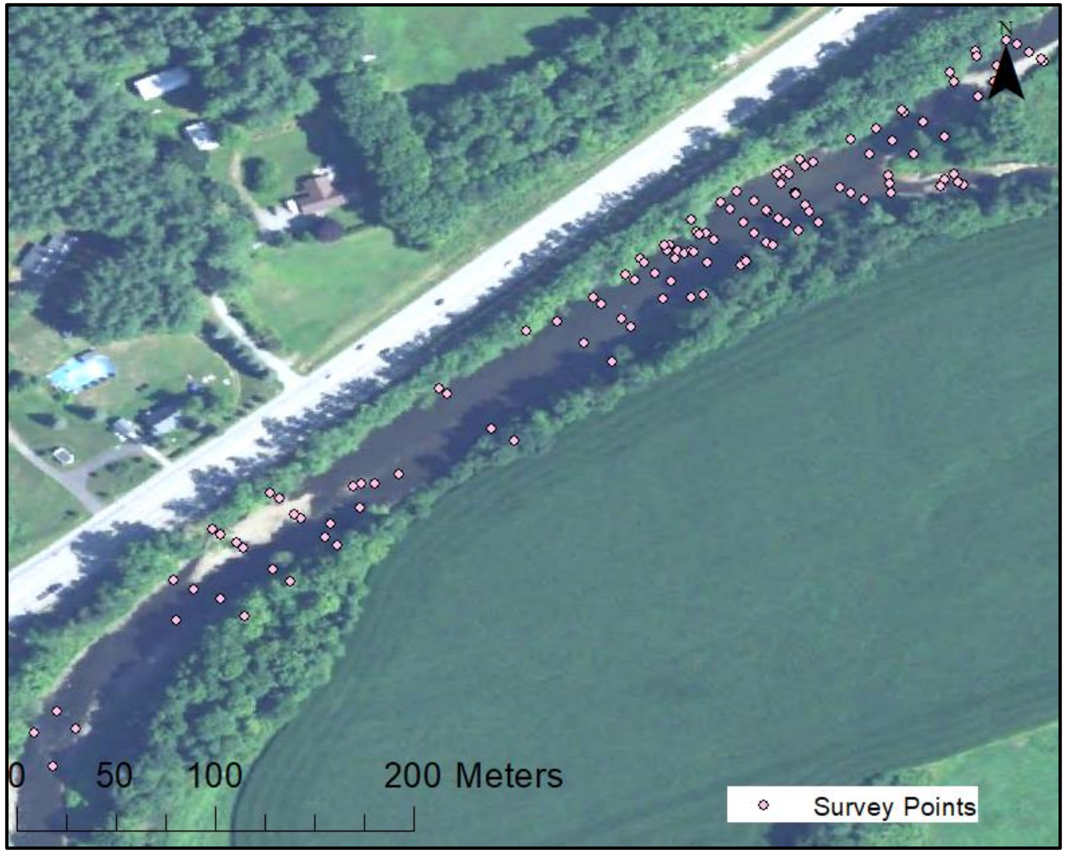
- Discharge
- Downstream stage

Outputs:

- Applied streamwise shear stress

DEM: Bathymetric Data

- Generally, points were surveyed in cross sections
- More points were surveyed in bathymetrically complex regions



Hydraulic Modeling

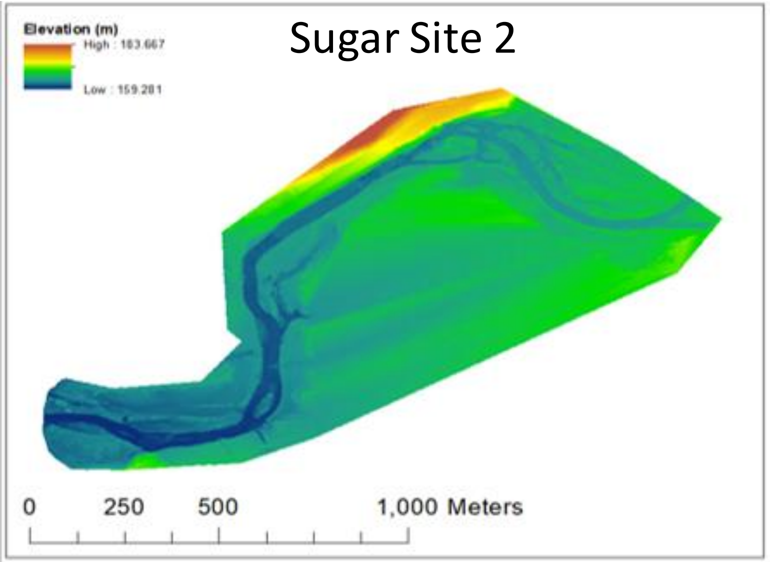
Inputs:

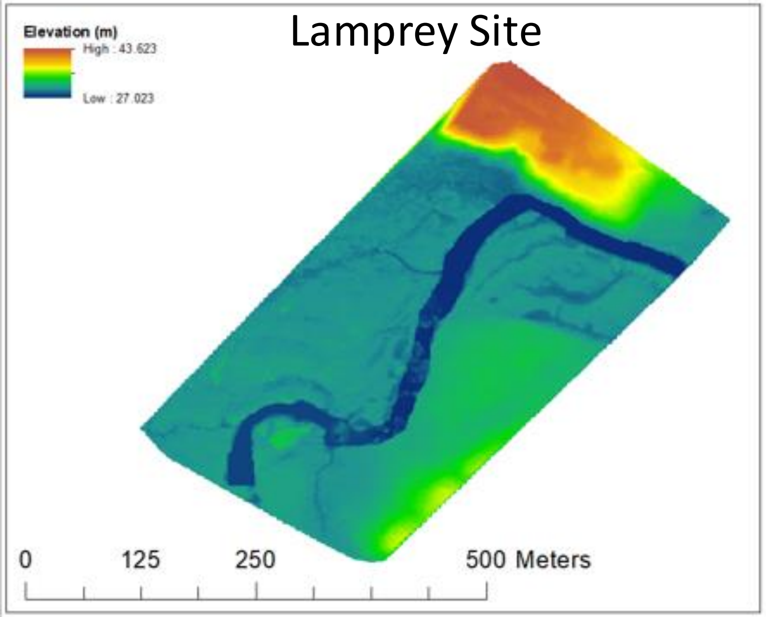
- Digital Elevation Model (DEM)
  - Topographic data
  - Bathymetric data
  - Combine data
- Discharge
- Downstream stage

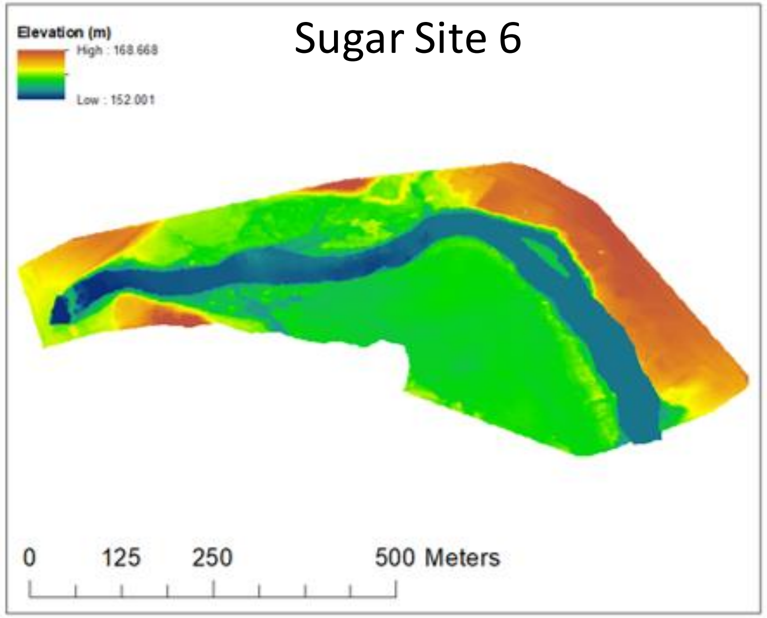
Outputs:

- Applied streamwise shear stress

DEM: Combing Data







Hydraulic Modeling

Inputs:

- Digital Elevation Model (DEM)
  - Topographic data
  - Bathymetric data
  - Combine data
- Discharge
- Downstream stage

Outputs:

- Applied streamwise shear stress

Discharge

	Upstream Watershed Area (km2)	Low Discharge (cms)	Medium Discharge (cms)	High Discharge (cms)
Sugar Gauge Station	713.98	5.15	110.32	272.72
Lamprey Gauge Station	553.48	4.14	35.84	251.16
Sugar Site 2	624.39	4.51	96.48	238.50
Sugar Site 6	652.52	4.71	100.82	249.24
Lamprey Site	283.50	2.12	18.36	128.65

Hydraulic Modeling

Inputs:

- Digital Elevation Model (DEM)
  - Topographic data
  - Bathymetric data
  - Combine data
- Discharge
- Downstream stage

Outputs:

- Applied streamwise shear stress

Downstream Stage

Manning's equation:

$$Q = VA = \left(\frac{1}{n}\right) R^{2/3} S^{1/2}$$

Q = discharge (m3/s)

V = flow velocity (m/s)

A = cross-sectional area of the channel (m2)

n = Manning's roughness coefficient

R = hydraulic radius (m)

S (m/m) = channel slope

Downstream Stage

Weir equation:

$$Q = CLH^{3/2}$$

Q = discharge (m^3/s)

C = is the discharge coefficient (m$^{0.5}$s^{-1})

L = length of the weir (m)

H = height of the water (m)

Hydraulic Modeling

Inputs:

- Digital Elevation Model (DEM)
  - Topographic data
  - Bathymetric data
  - Combine data
- Discharge
- Downstream stage

Outputs:

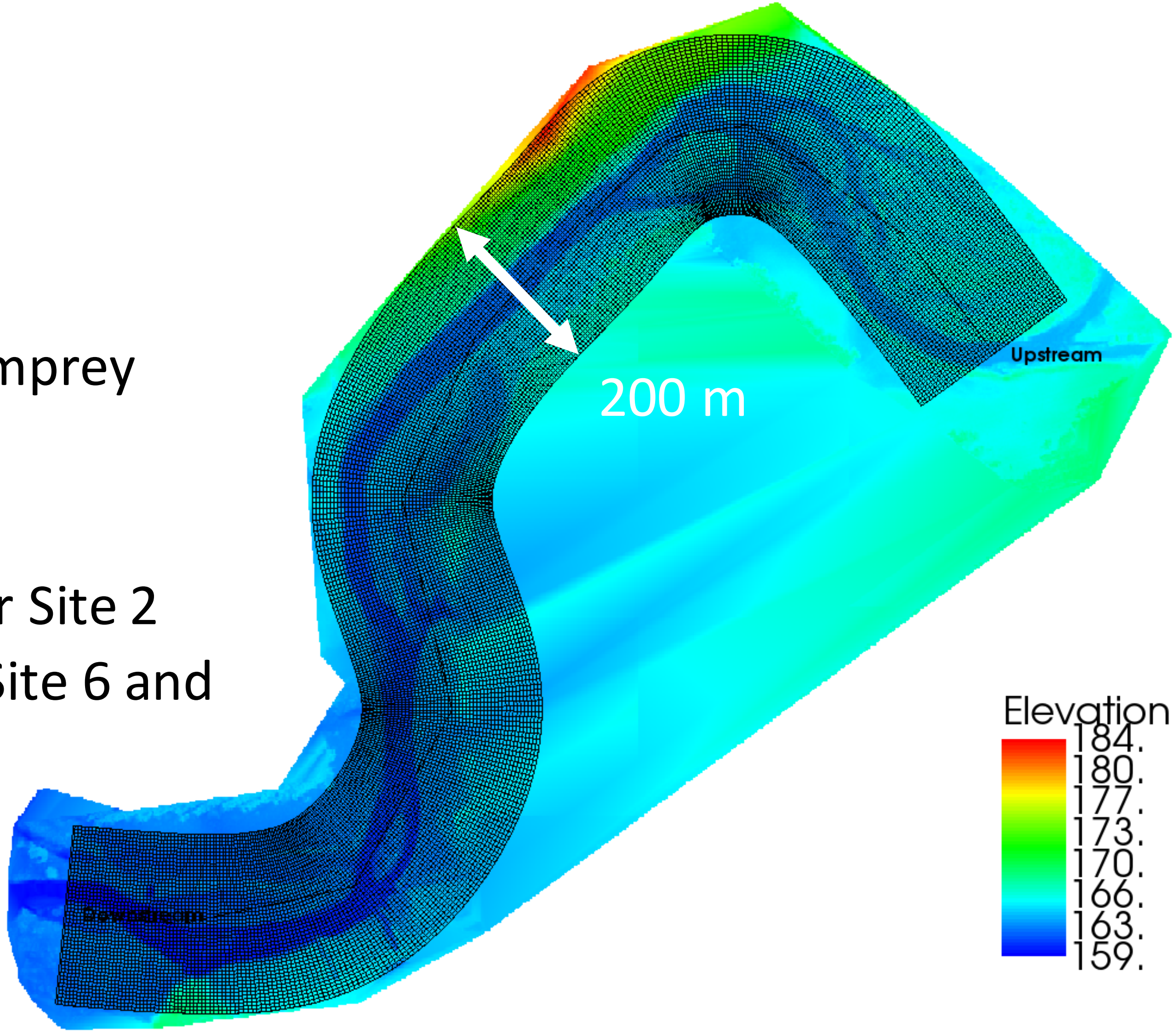
- Applied streamwise shear stress

Hydraulic Modeling

- Flow and Sediment Transport with Morphological Evolution of Channels (FaSTMECH)
  - Developed by the United States Geologic Survey (USGS)
  - Offered by International River Interface Cooperative (iRIC)
  - Two-dimensional model which uses the continuity and Navier-Stokes equations for the conservation of fluid mass and momentum
  - Solves for velocity and shear stress along an orthogonal curvilinear grid

Hydraulic Modeling

- Grid width
  - 200 m for Sugar Site 2
  - 100 m for Sugar Site 6 and the Lamprey Site
- Grid size
  - 1-meter square grids for the Sugar Site 2
  - 0.5-meter square grids for Sugar Site 6 and the Lamprey Site



Sugar Site 2

Hydraulic Modeling

Inputs:

- Digital Elevation Model (DEM)
  - Topographic data
  - Bathymetric data
  - Combine data
- Discharge
- Downstream stage

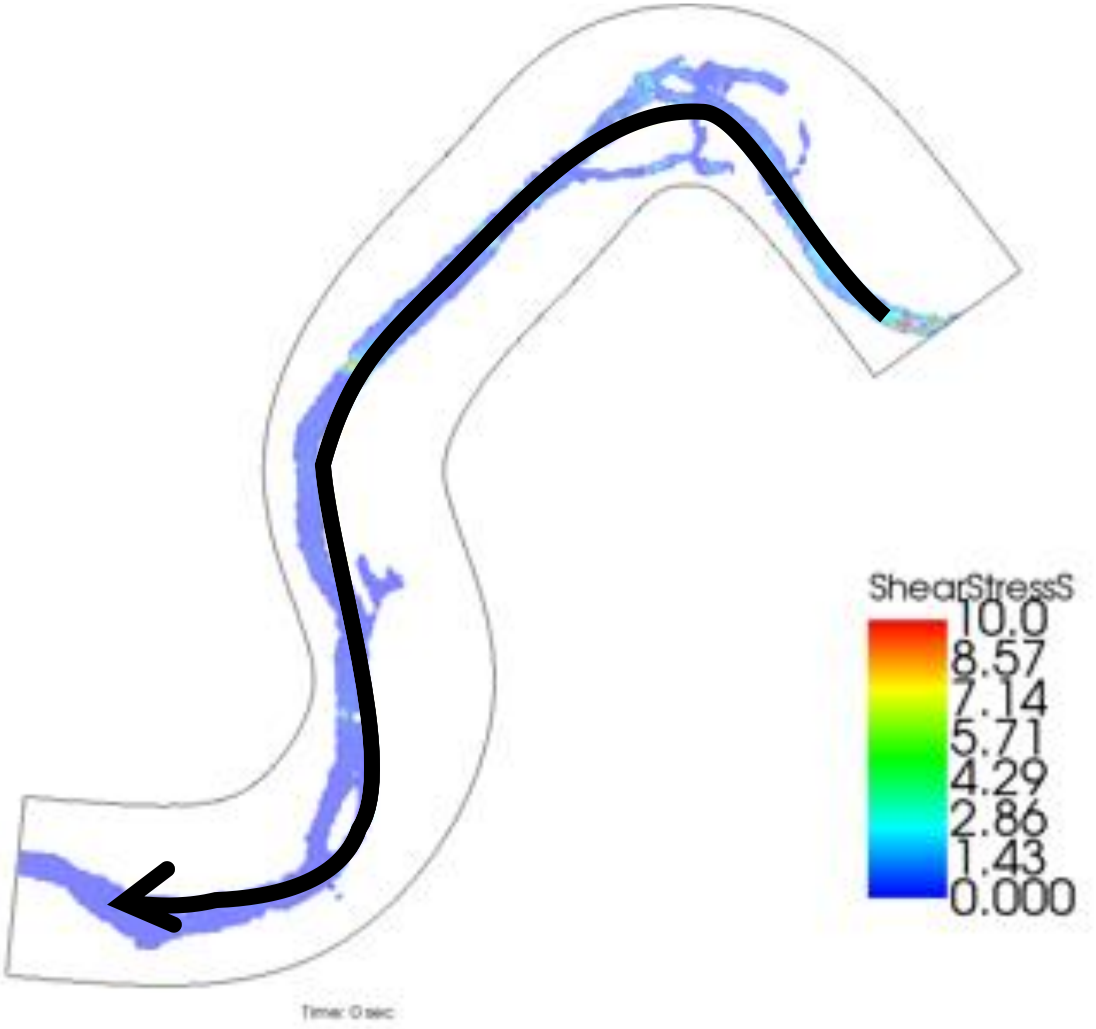
Outputs:

- Applied streamwise shear stress

Hydraulic Modeling

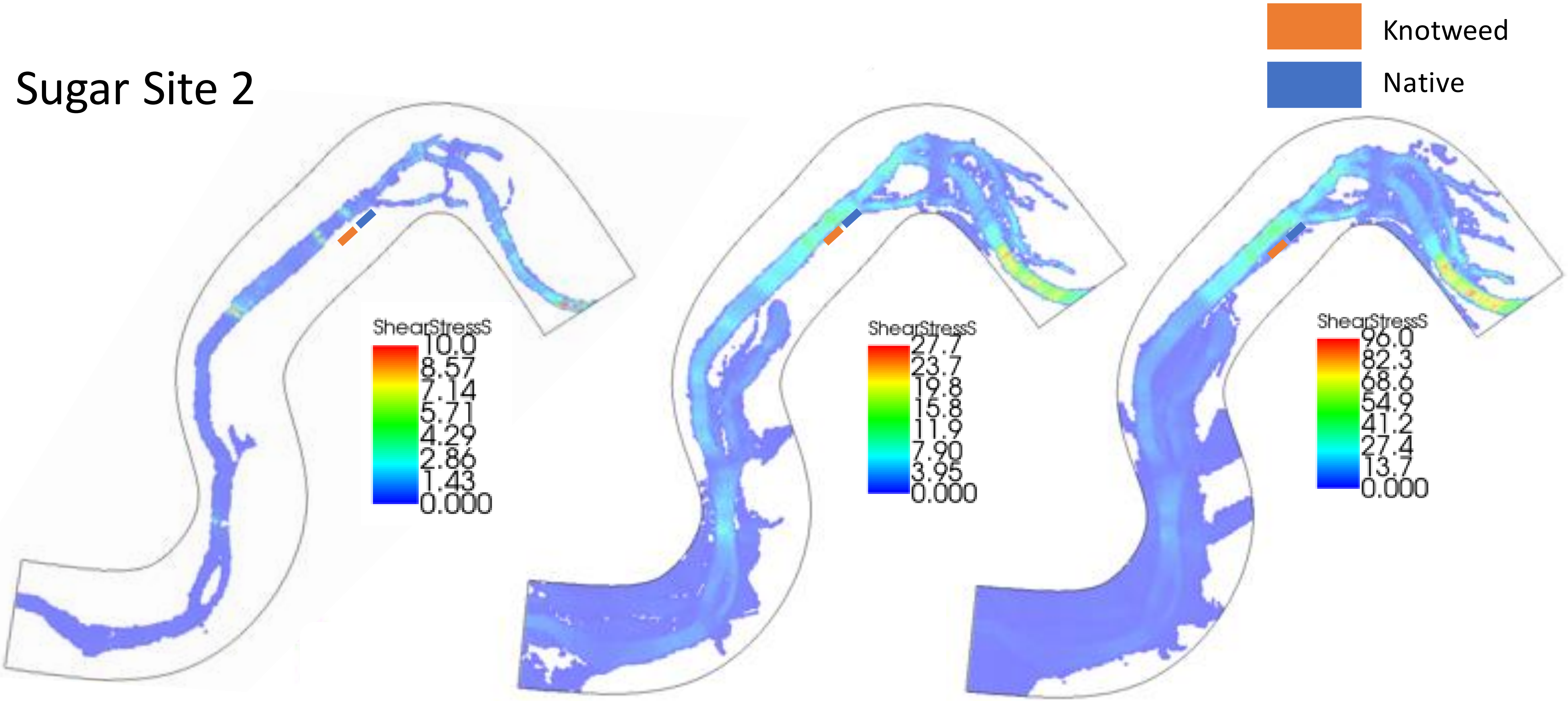
Applied shear stress in the streamwise direction

Sugar Site 2



Hydraulic Modeling

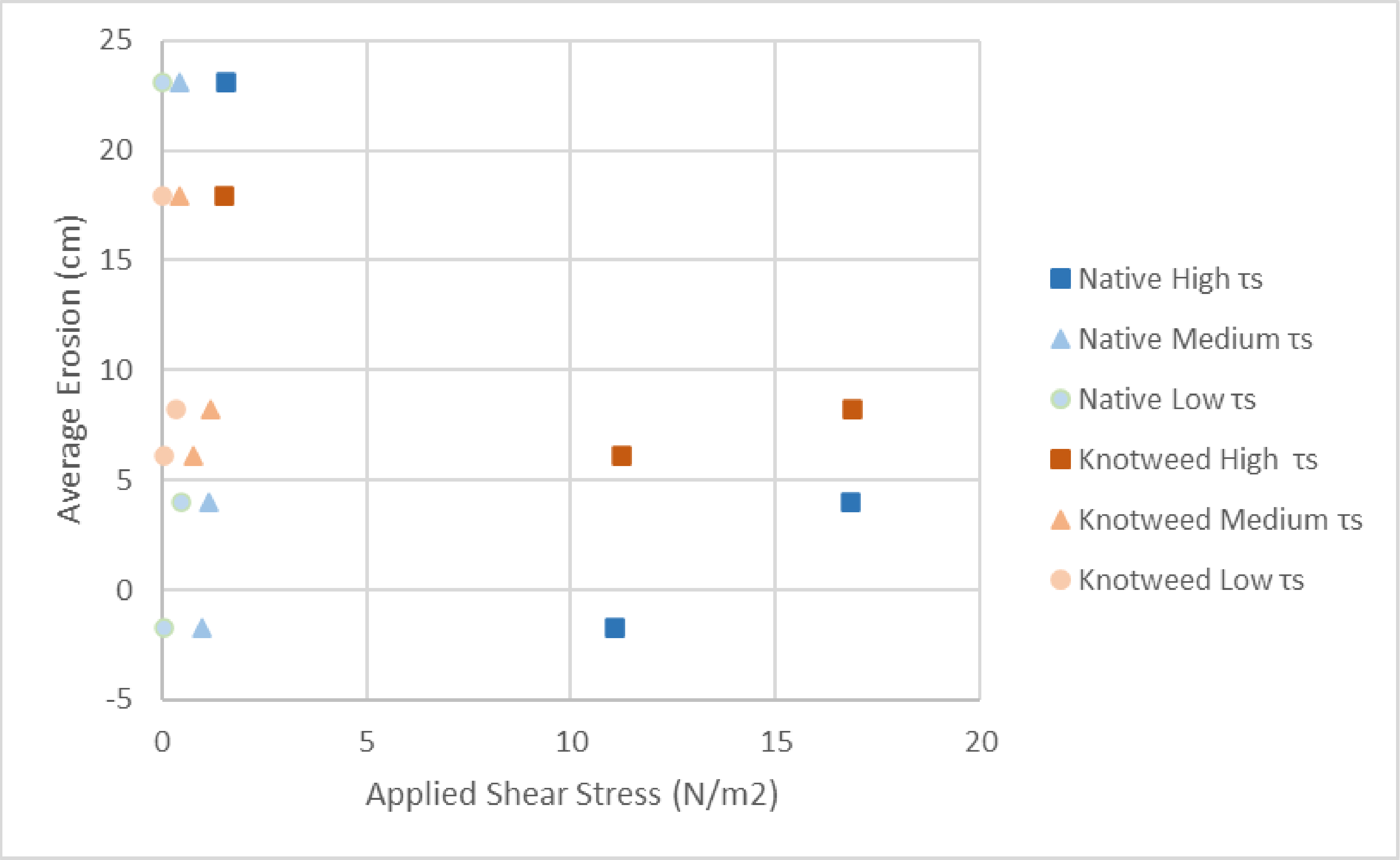
Sugar Site 2



Low Medium High

Hydraulic Modeling

There was no correlation between applied shear stress and erosion



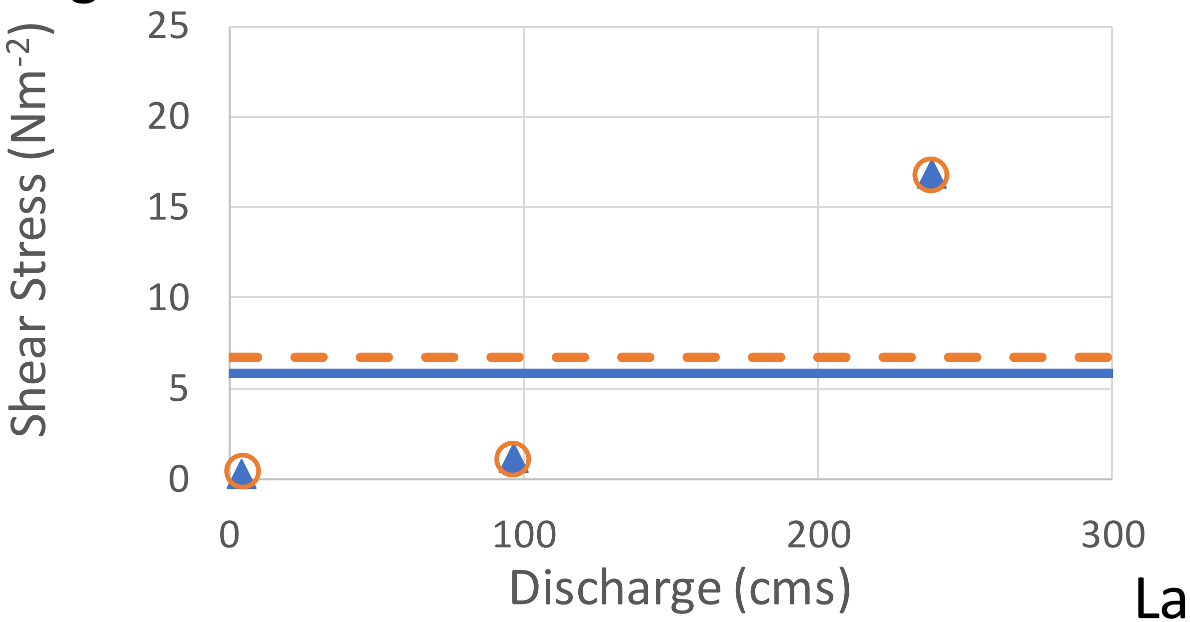
Hydraulic Modeling

Main Takeaway:

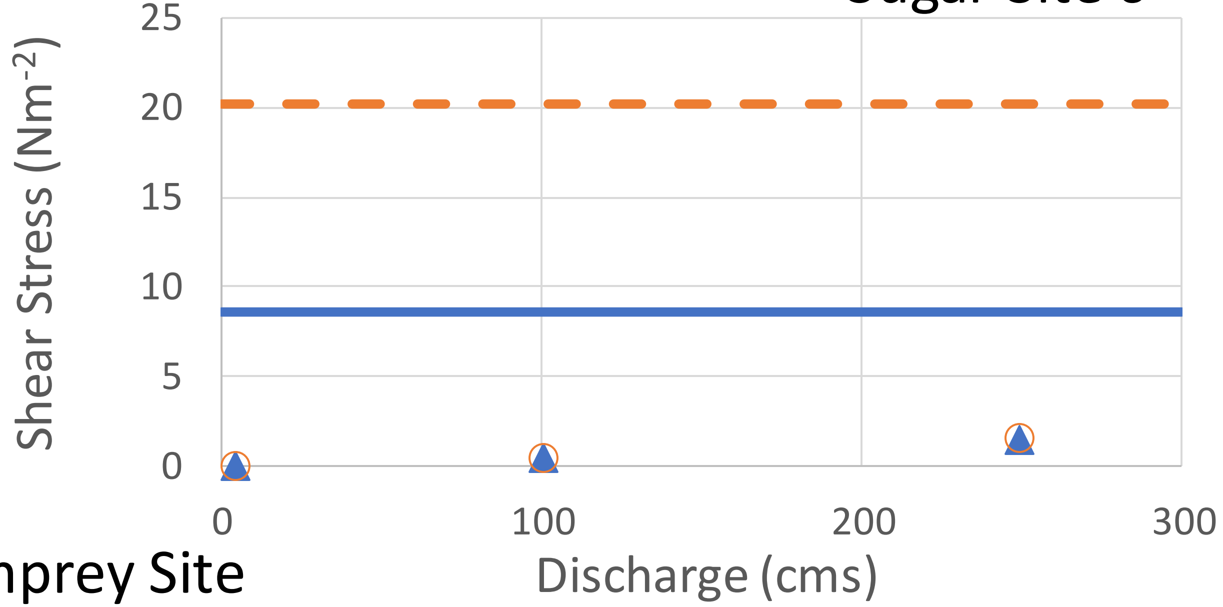
Paired vegetation patches experienced similar amounts of applied shear stress

Combining Erosion Monitoring and Hydraulic Modeling Results

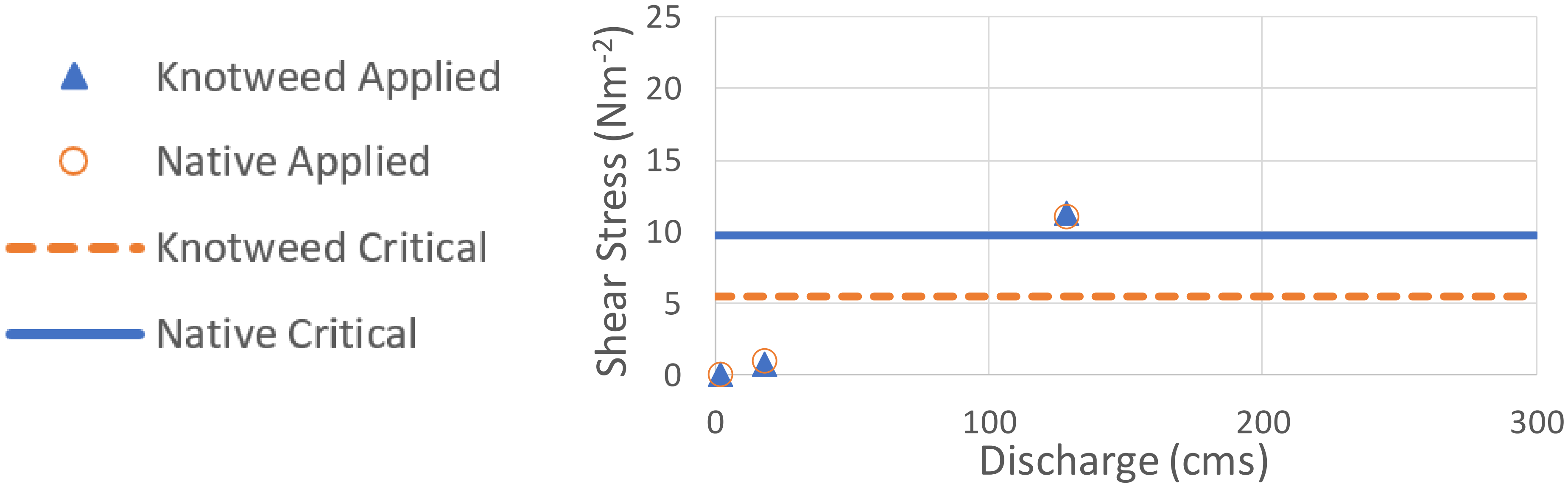
Sugar Site 2



Sugar Site 6



Lamprey Site



Combining Erosion Monitoring and Hydraulic Modeling Results

Main Takeaway:

Fluvial entrainment is not the dominant mechanism of bank erosion taking place at the study sites

Limitations

- Small number of study sites and short study period
- Focus on fluvial entrainment instead of all erosional processes
- Potential inaccuracies

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Conclusion

- Similar bank soil properties, vegetation, and amounts of erosion were observed between the Lamprey and Sugar Rivers
- Paired vegetation patches had mostly similar soil types and similar local hydraulics
- Knotweed patches experienced more erosion than native patches
- River management should consider removing knotweed, planting more native species, or removing infrastructure from high-risk locations before the need for expensive revetment or any major ecological impacts

References

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