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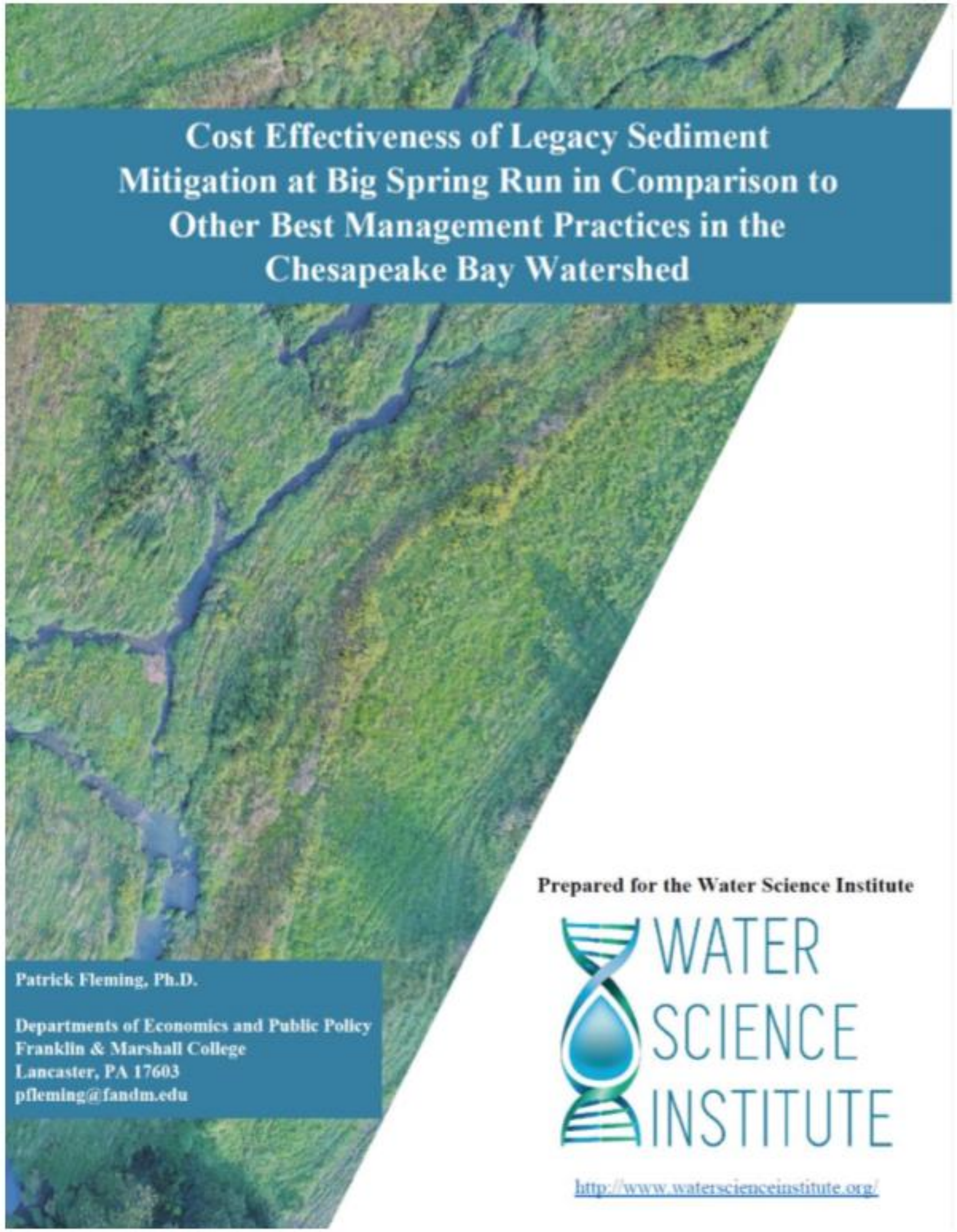

Cost Effectiveness of Legacy Sediment Mitigation at Big Spring Run in Comparison to Other Best Management Practices in the Chesapeake Bay Watershed

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Prepared for the Water Science Institute

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FEATURE

Legacy sediment erosion hot spots: A cost-effective approach for targeting water quality improvements

Patrick M. Fleming, Dorothy J. Merritts, and Robert C. Walter

As federal and state governments seek to address nonpoint source (NPS) water pollution, billions of dollars will be spent to implement conservation practices known to reduce sediment and nutrient runoff. Nonpoint source pollution has proven to be a "wicked" challenge for policymakers, characterized by uncertainty and complex interactions among socioeconomic, hydrologic, and other geodynamic systems along multiple dimensions (Shortle and Horan 2017). A recent summary of research indicates, in fact, that the adoption of conventional NPS conservation practices is not directly linked to measurable pollution reduction in most streams in the Chesapeake Bay watershed (Keisman et al. 2018). A primary reason cited for this disconnect is the temporal dynamic by which water quality improvements are delayed or offset by the ongoing effects of legacy pollutants in soils and groundwater (Keisman et al. 2018). (Legacy pollutants are those that remain in the geosphere decades to centuries after the pollution occurred.)Innovative approaches to NPS pollution reduction may be needed to address these legacy pollutants, and thereby meet goals for improved water quality, such as the Chesapeake Bay total maximum daily load (TMDL).

One such approach that has received increasing attention is legacy sediment (LS) mitigation. As shown in the research of Walter and Merritts (2008), LS and associated nutrient pollution accumulated for decades (and sometimes centuries) behind milldams and other historic stream impediments. As these impediments are removed, intentionally or otherwise, long-term elevated pollution loads have been left behind along numerous stream systems in the mid-Atlantic region. These loads are concentrated at LS "hot spots," characterized by near-vertical stream banks carved into the previously accumulated sediment (figure 1). (Here, we consider LS erosion hot spots as stream lengths that produce above 0.05 tn ft^{-1} yr^{-1} [0.15 Mg m^{-1} y^{-1}] of sediment erosion over at least a span of 2,000 ft [610 m]). Subsequent research has shown that LS mitigation—through removal of sediment to restore the wetland or other aquatic ecosystem long buried behind historic stream impoundments (Hartranft et al. 2011)—is a highly effective form of sediment, phosphorus (P), and nitrogen (N) abatement when implemented at identifiable LS erosion hot spots (Sharpley et al. 2013; Inamdar et al. 2017). However, less is known about the cost-effectiveness of LS mitigation projects in terms of their cost per unit of pollution reduced, especially in comparison to other NPS reduction practices.

In this article, we summarize the results of a recent study of the cost-effectiveness of LS mitigation in the Chesapeake Bay watershed in comparison to agricultural practices that are commonly considered low-cost forms of abatement, such as cover crops and grass and forest riparian buffers. We then describe two broader policy implications of these findings, using recently available technology to identify hot spots at a landscape scale. The importance of legacy pollutant sources has long been recognized—from P in soils, to nitrates (NO_3) in groundwater, to LS and nutrients along stream banks (USGS 2003; Garnache et al. 2016). As technology increasingly allows policymakers to identify LS erosion hot spots, we emphasize that greater awareness of LS mitigation should be promoted as a cost-effective tool in the suite of options available to reduce NPS water pollution.

LEGACY SEDIMENT MITIGATION

The problem of LS impaired waters is ubiquitous in the mid-Atlantic United

Figure 1

Erosion of legacy sediment following breach of Strobers Dam in Pennsylvania in 2011. Bank sediments are upstream of the breached dam, and the top of the bank matches the top of the dam.

Patrick M. Fleming is an assistant professor of economics and public policy at Franklin & Marshall College in Lancaster, Pennsylvania. **Dorothy J. Merritts** is Harry W. and Mary B. Huffnagle professor of geosciences at Franklin & Marshall College in Lancaster, Pennsylvania. **Robert C. Walter** is a professor of geosciences at Franklin & Marshall College in Lancaster, Pennsylvania. The authors are researchers with the Water Science Institute, Lancaster, Pennsylvania.

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TRIAGE MAPPING

Targeting Erosion Hotspots, Legacy Sediment Terraces and Canopy Layers with LiDAR Point Cloud Data

Dorothy Merritts, Michael Rahnis, Logan Lewis, Robert Walter, and Shelby Sawyer

Lancaster GIS Day, 11/11/19

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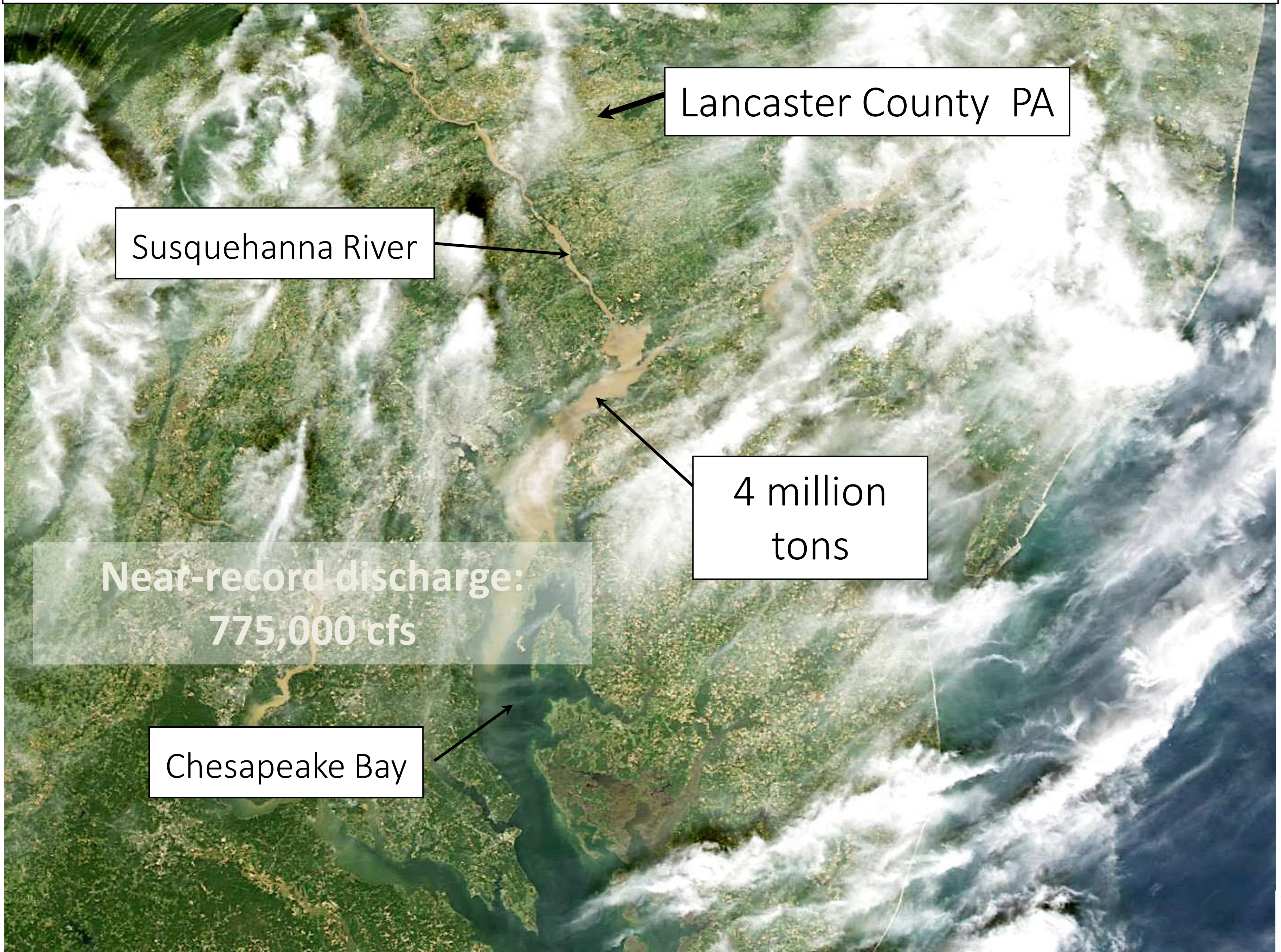
1864 map, Bridgen's Atlas

Walter and Merritts, 2008. Natural Streams and the Legacy of Water Powered Mills.

The Problem is Manifest--Sediment Plume from Hurricane Ivan 2004



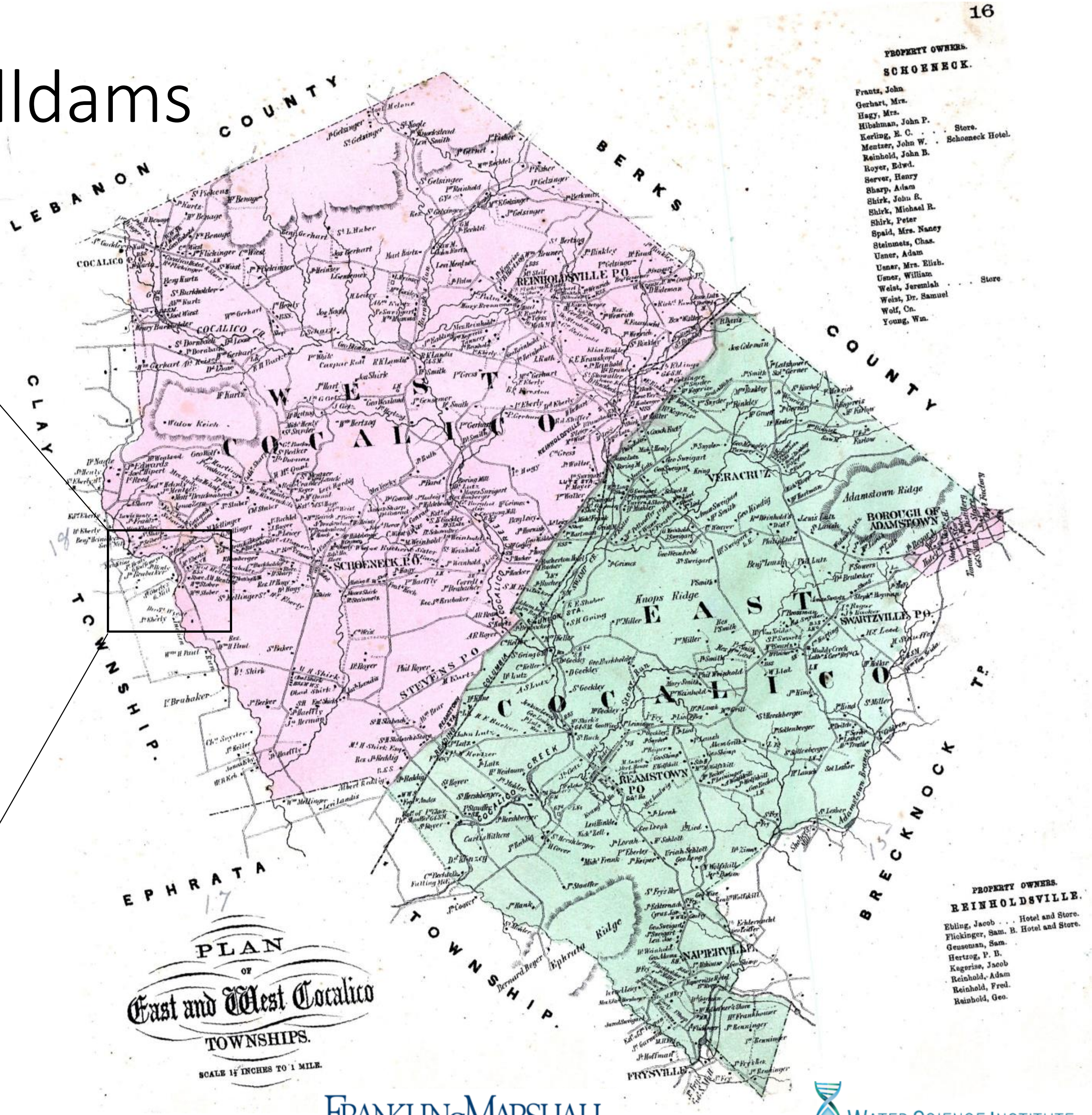
Sediment sources?

1. Upland farm fields?
2. Construction sites?
3. Stream Banks?

The History and Impact of Milldams

Stobers Mill Dam, Indian Run

Bridgen's 1864 Atlas



PROPERTY OWNERS.

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Gerhart, Mrs.
Hagy, Mrs.
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Kerling, E. C. . . . Store.
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Reinhold, John B.
Royer, Edwd.
Server, Henry
Sharp, Adam
Shirk, John R.
Shirk, Michael R.
Shirk, Peter
Spaid, Mrs. Nancy
Steinmets, Chas.
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Weist, Dr. Samuel
Wolf, Cn.
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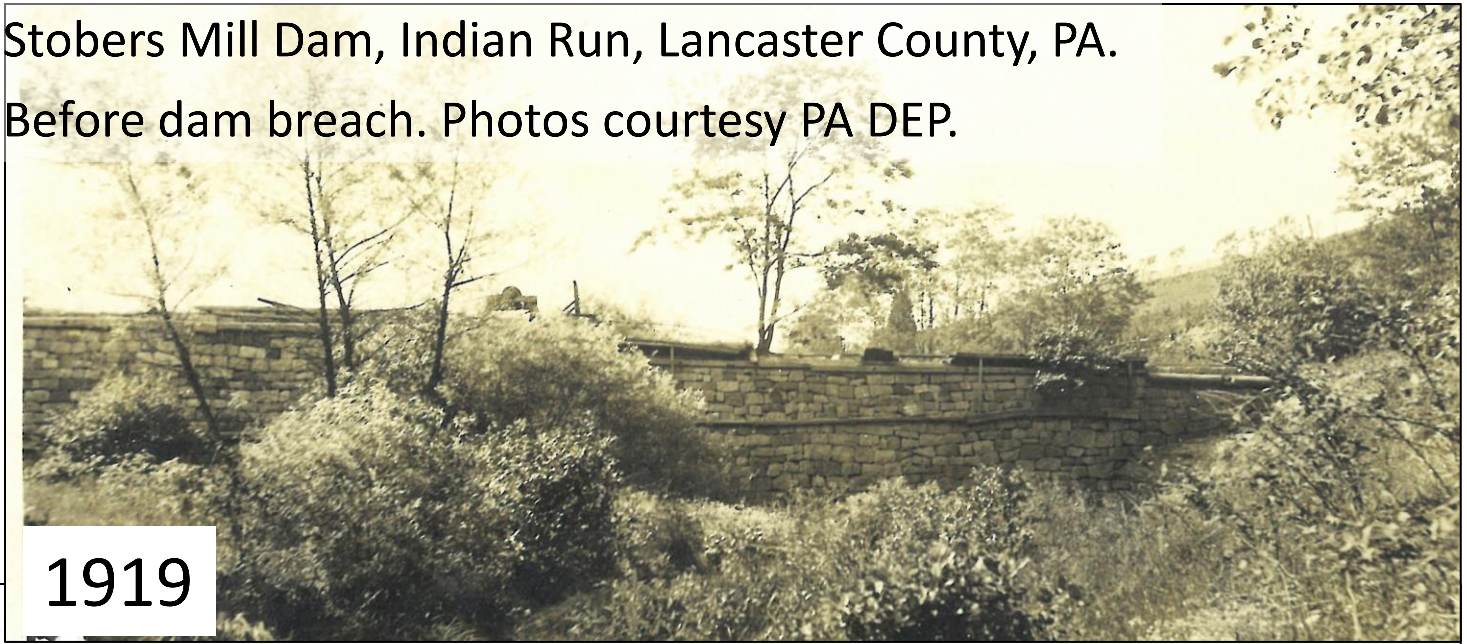
Geusoman, Sam.
Hertzog, P. B.
Kegerise, Jacob
Reinhold, Adam
Reinhold, Fred.
Reinhold, Geo.

Stobers Mill Dam, Indian Run, Lancaster County, PA.

Before dam breach. Photos courtesy PA DEP.



1919

1946

2007

2011

1972

2012

2012

Stobers Mill Dam, Indian Run, Lancaster County, PA. Before and after dam breach, 2011.

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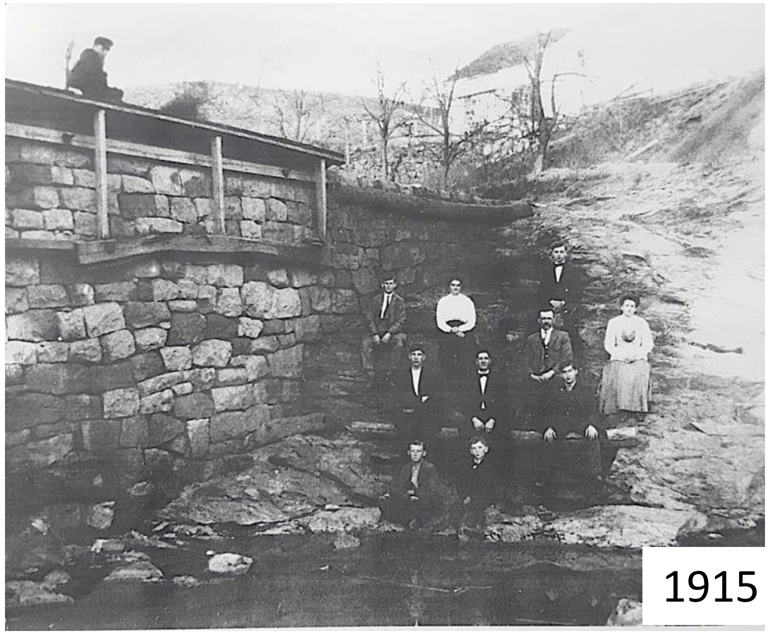
1915


2012


2012

Stobers Mill Dam, Indian Run, Lancaster County, PA. Before and after dam breach, 2011.

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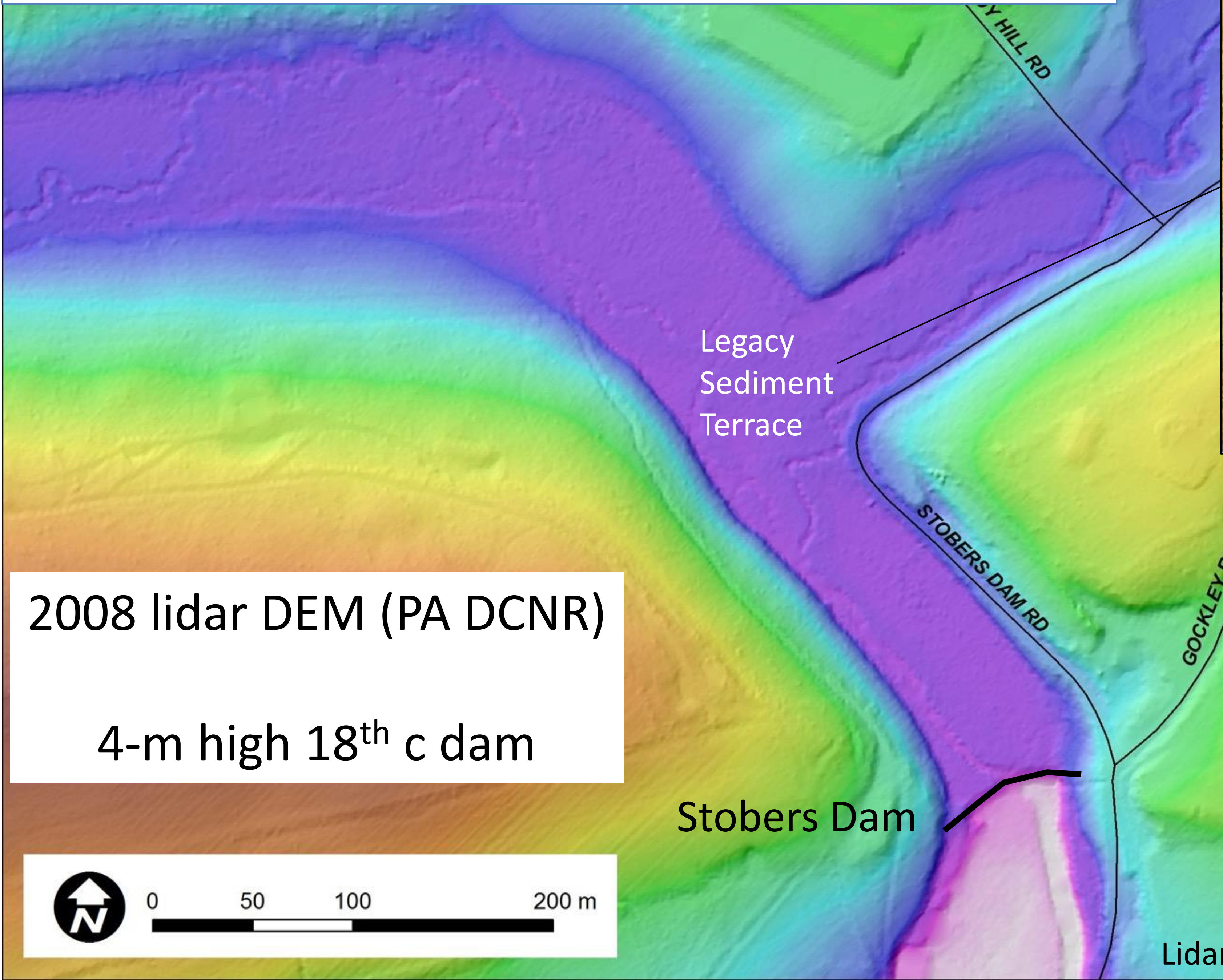
Indian Run, PA – Stobers Dam breach, 2011, Height 14 ft



2008 lidar DEM (PA DCNR)

4-m high 18th c dam

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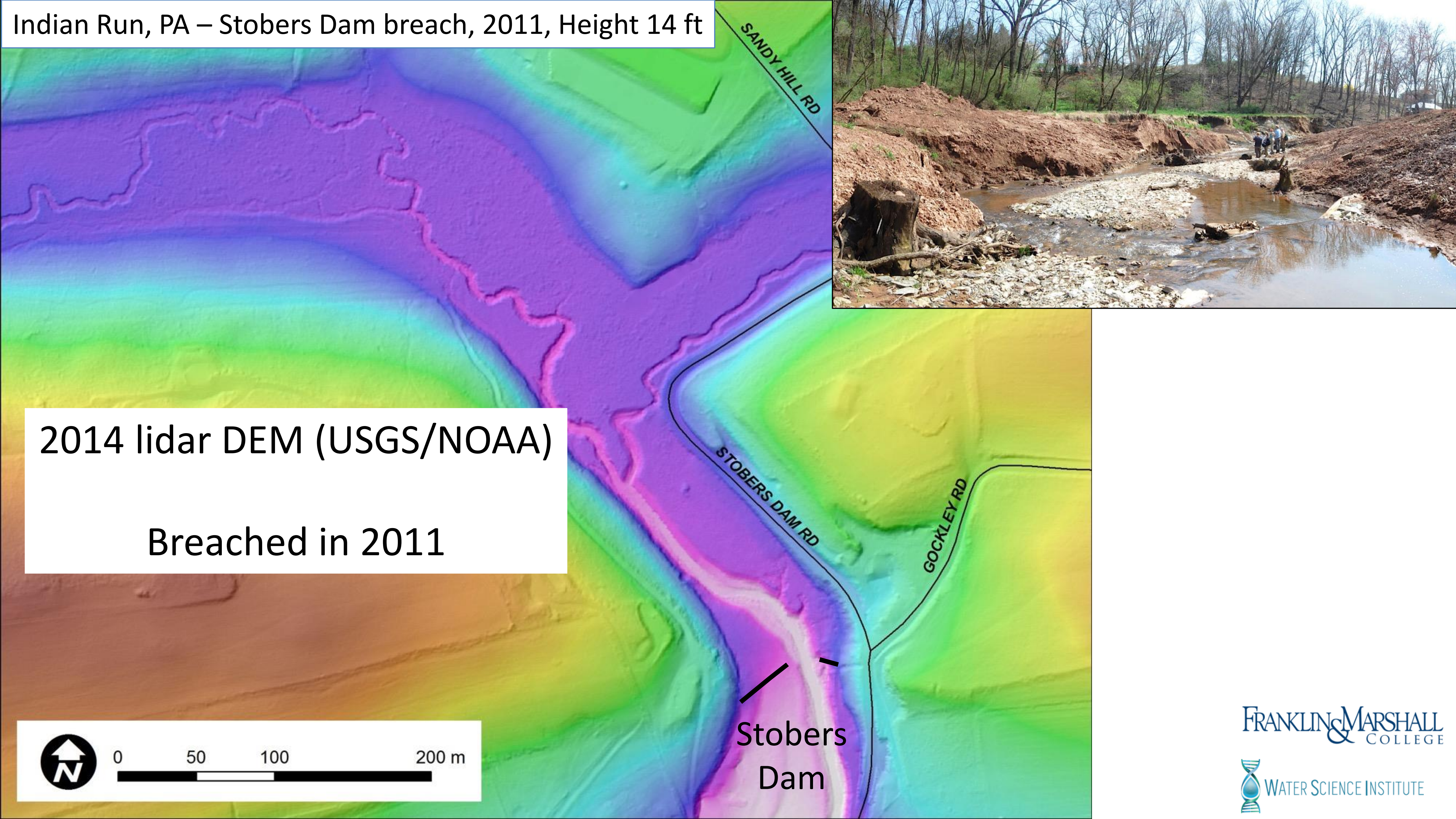
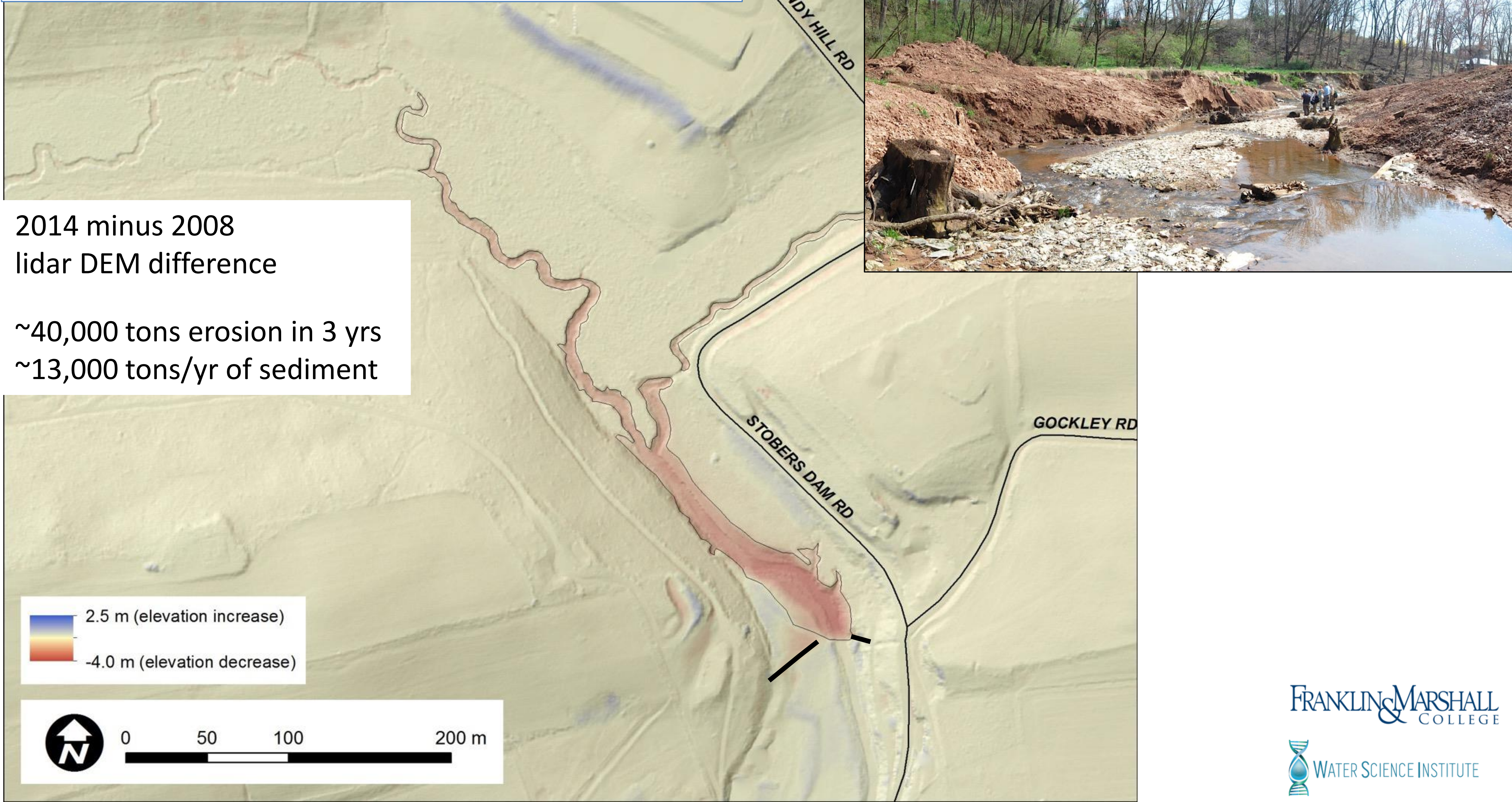
Indian Run, PA – Stobers Dam breach, 2011, Height 14 ft



2014 lidar DEM (USGS/NOAA)

Breached in 2011

Indian Run, PA – Stobers Dam breach, 2011, Height 14 ft



2014 minus 2008
lidar DEM difference

~40,000 tons erosion in 3 yrs
~13,000 tons/yr of sediment

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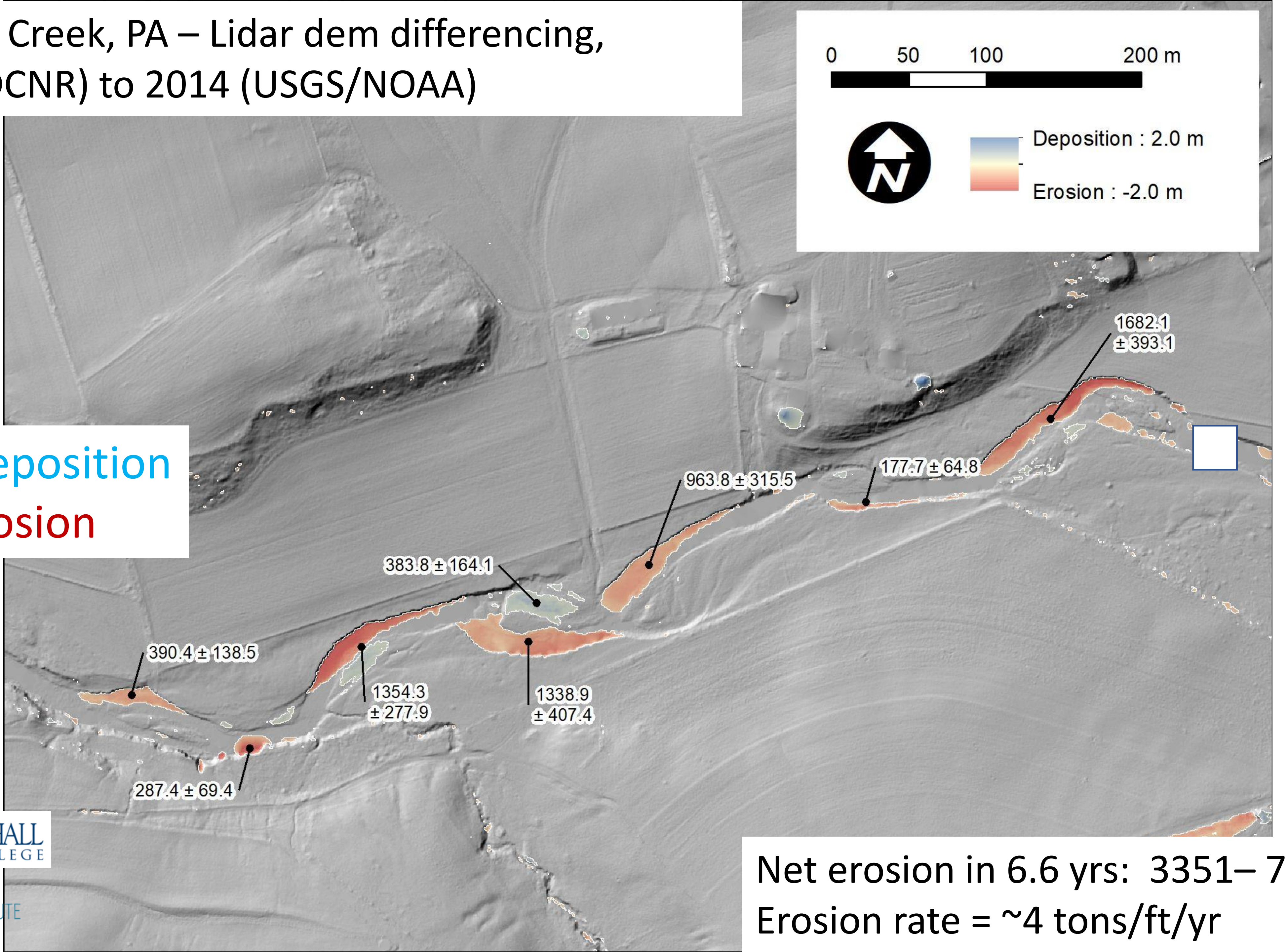
Big Beaver Creek, PA – Krantz millpond sediment – How can we measure bank erosion?

April 2009. Note apron of sediment from winter freeze-thaw.

Big Beaver Creek, PA – Lidar dem differencing, 2008 (PA DCNR) to 2014 (USGS/NOAA)



Blue = deposition

Red = erosion

Net erosion in 6.6 yrs: 3351– 7206 tons

Erosion rate = ~4 tons/ft/yr

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Mike Rahnis:

But, we need really good stream centerlines to map bank erosion.

Logan Lewis:

With good stream centerlines, high quality lidar data, and dem differencing, we can identify areas of high streambank erosion.

DEM Differencing

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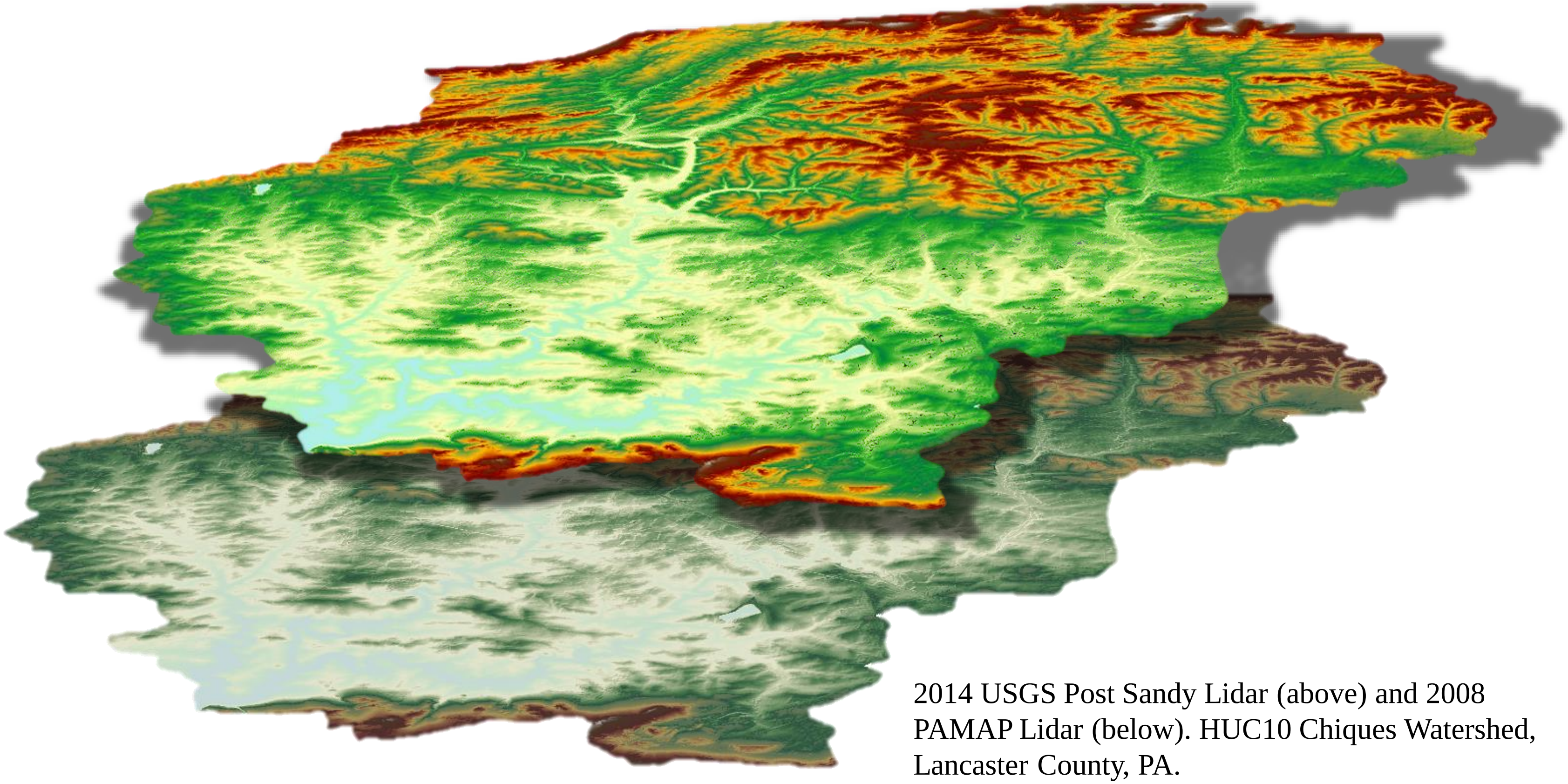
2014 Lidar

-

2008 Lidar

=

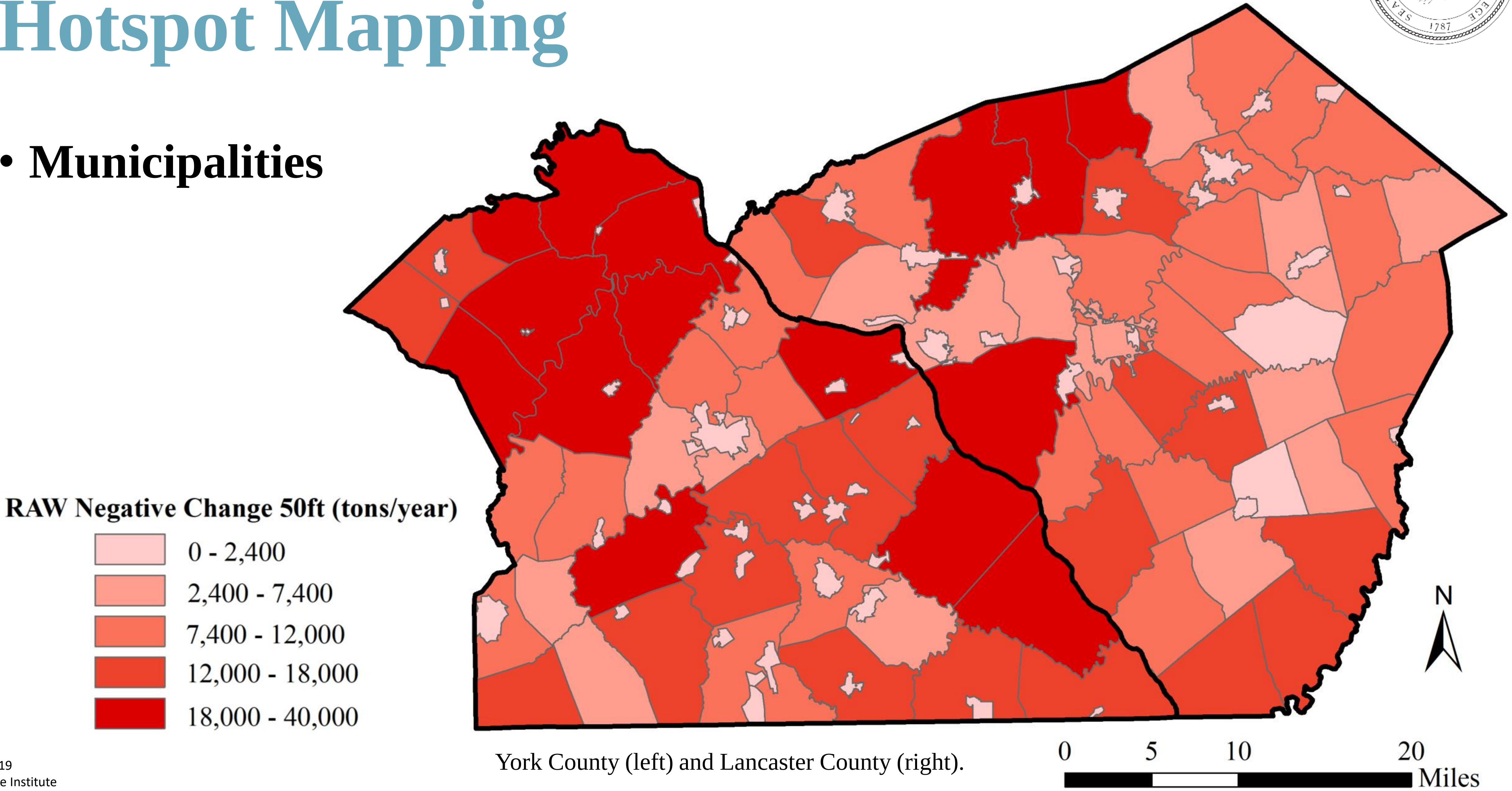
Vertical and horizontal Change



2014 USGS Post Sandy Lidar (above) and 2008 PAMAP Lidar (below). HUC10 Chiques Watershed, Lancaster County, PA.

Hotspot Mapping

- **Municipalities**



York County (left) and Lancaster County (right).

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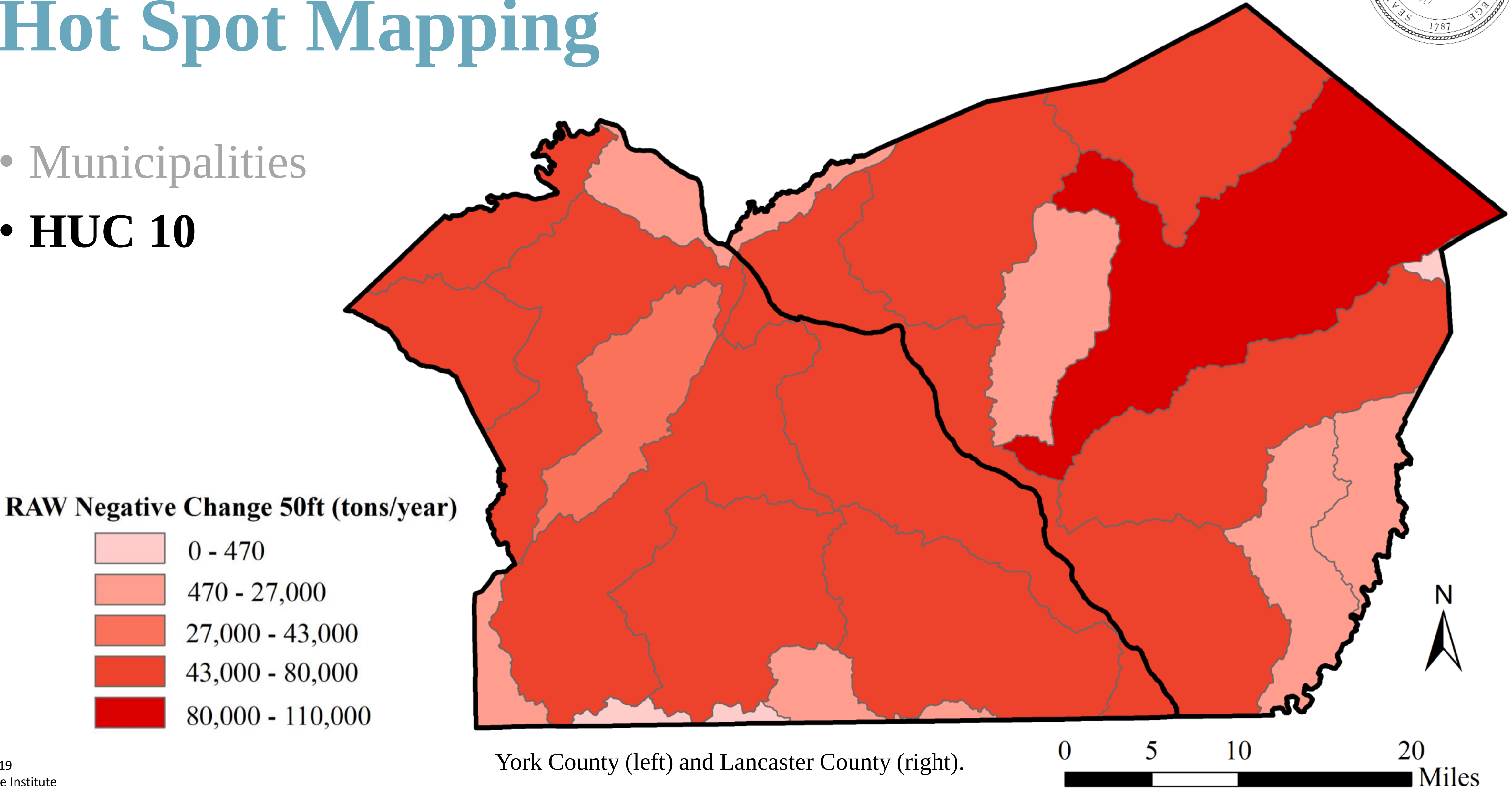
Hot Spot Mapping

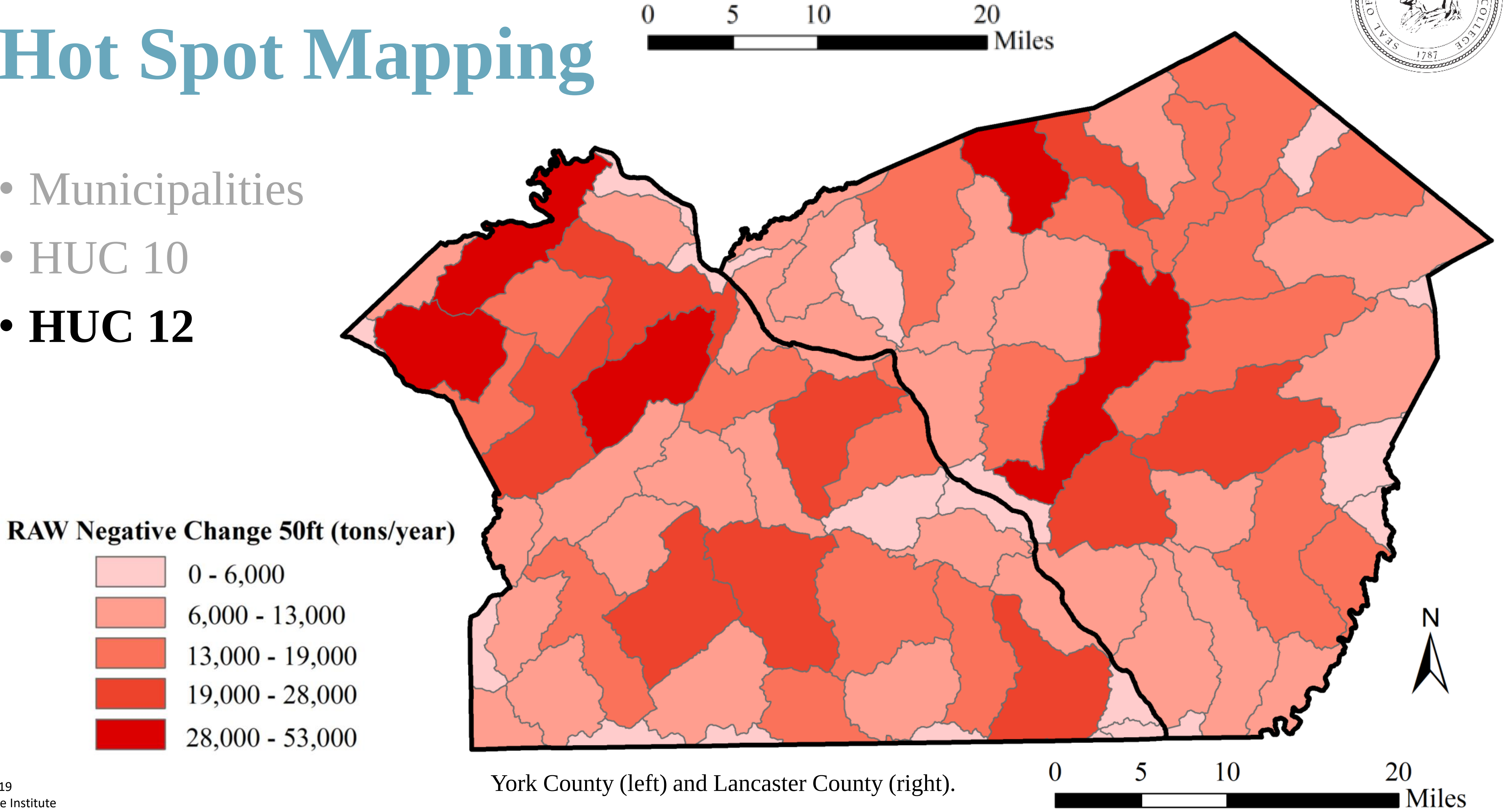
- Municipalities
- **HUC 10**



York County (left) and Lancaster County (right).

Hot Spot Mapping

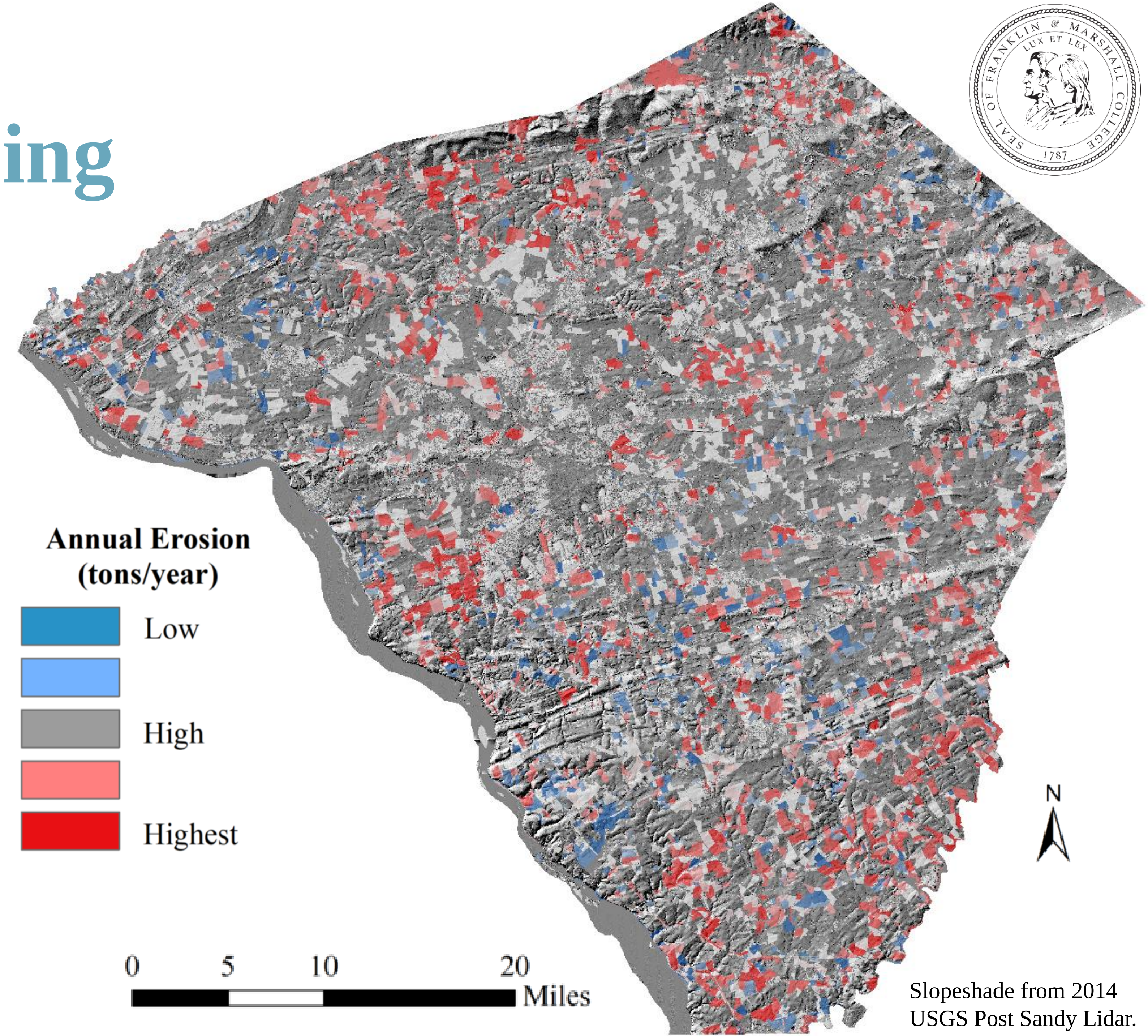
- Municipalities
- HUC 10
- **HUC 12**



York County (left) and Lancaster County (right).

Hot Spot Mapping

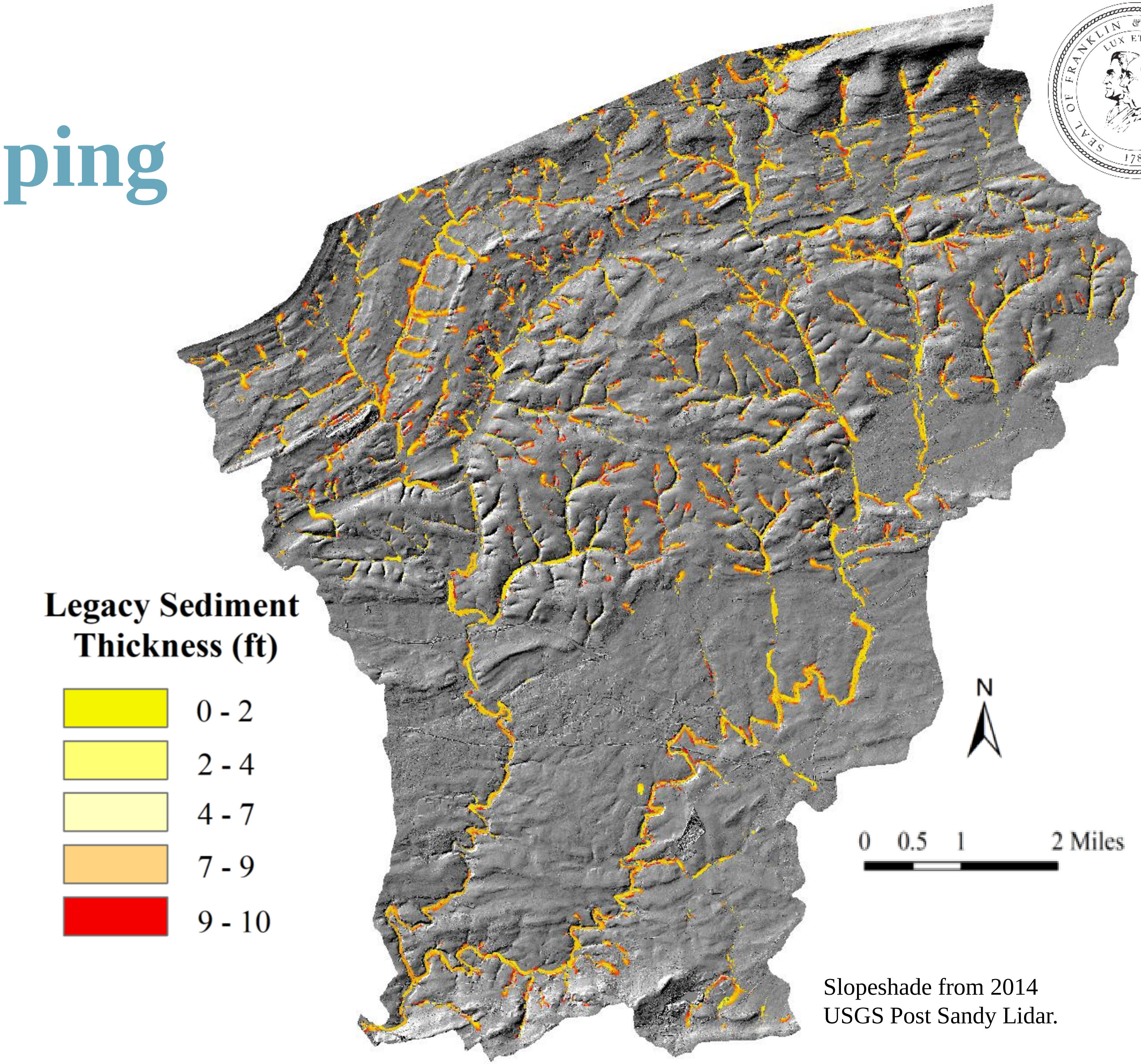
- Municipalities
- HUC 10
- HUC 12
- **Parcels**



Slopeshade from 2014
USGS Post Sandy Lidar.

Hot Spot Mapping

- Municipalities
- HUC 10
- HUC 12
- Parcels
- **Legacy Sediment Terrace Mapping**



Slopeshade from 2014 USGS Post Sandy Lidar.

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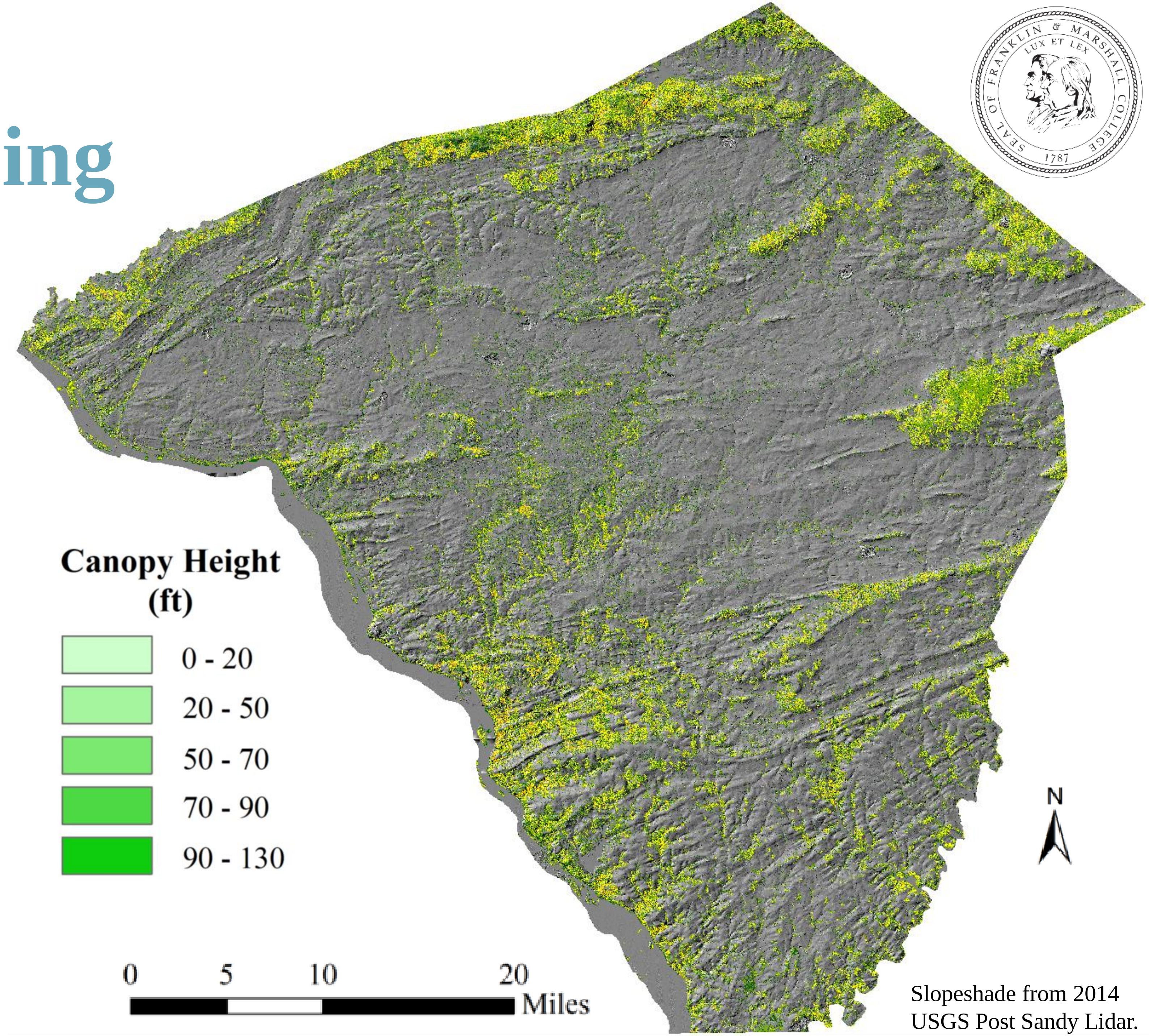
Hot Spot Mapping

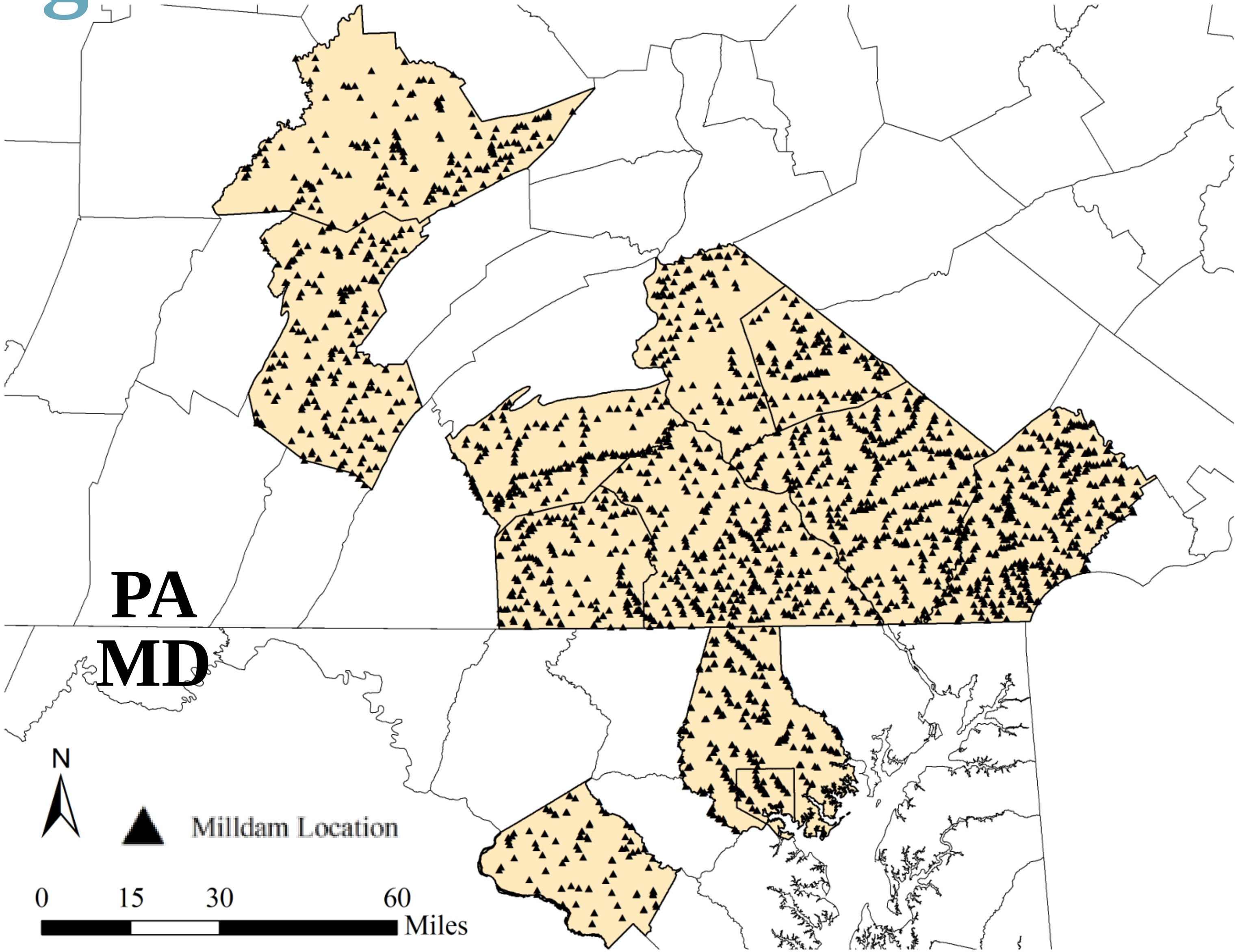
- Municipalities
- HUC 10
- HUC 12
- Parcels
- Legacy Sediment Terrace Mapping
- **Canopy**



Slopeshade from 2014 USGS Post Sandy Lidar.

Hot Spot Mapping

- Municipalities
- HUC 10
- HUC 12
- Parcels
- Legacy Sediment Terrace Mapping
- Canopy
- **Historic Milldams**



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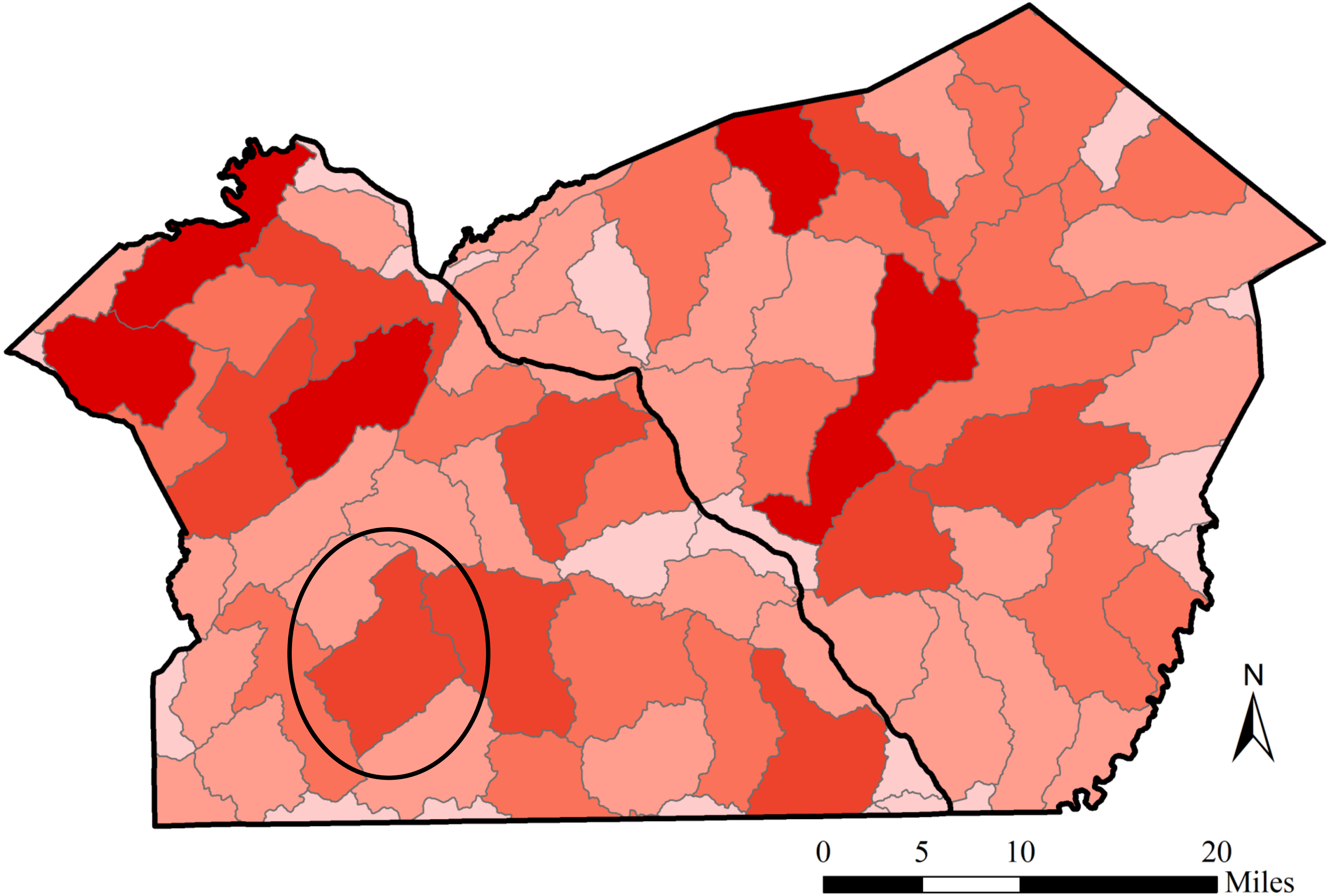

Heat Mapping – Watershed Analysis

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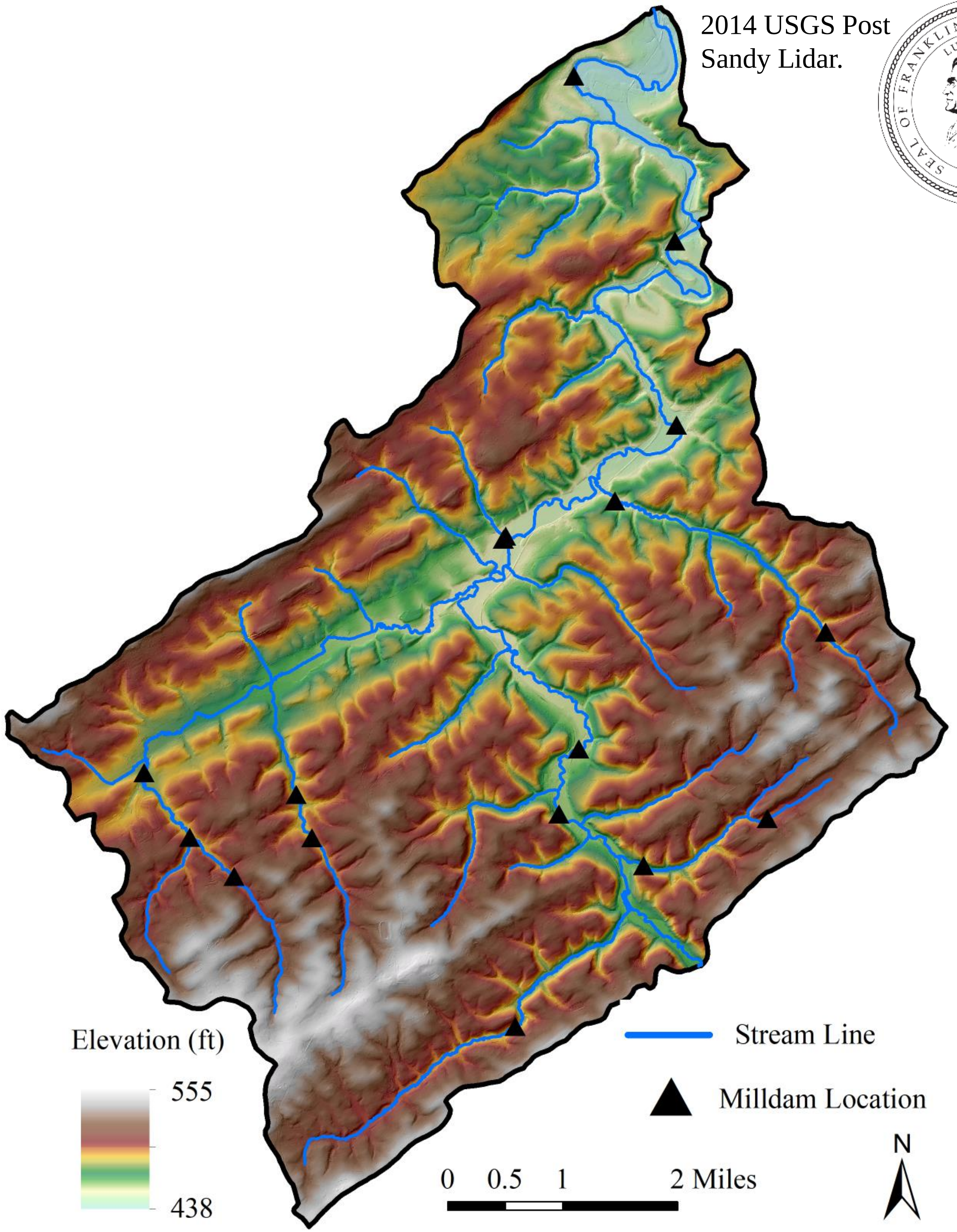
HUC 12 Lower South Branch Codorus Creek, York County

- Watershed Area: 40 square miles
- Historic Milldams:17



2014 USGS Post Sandy Lidar.

Heat Mapping – Watershed Analysis

HUC 12 Lower South Branch Codorus Creek, York County

- Watershed Area: 40 square miles
- Historic Milldams:17
- **Watershed Annual Erosion:**

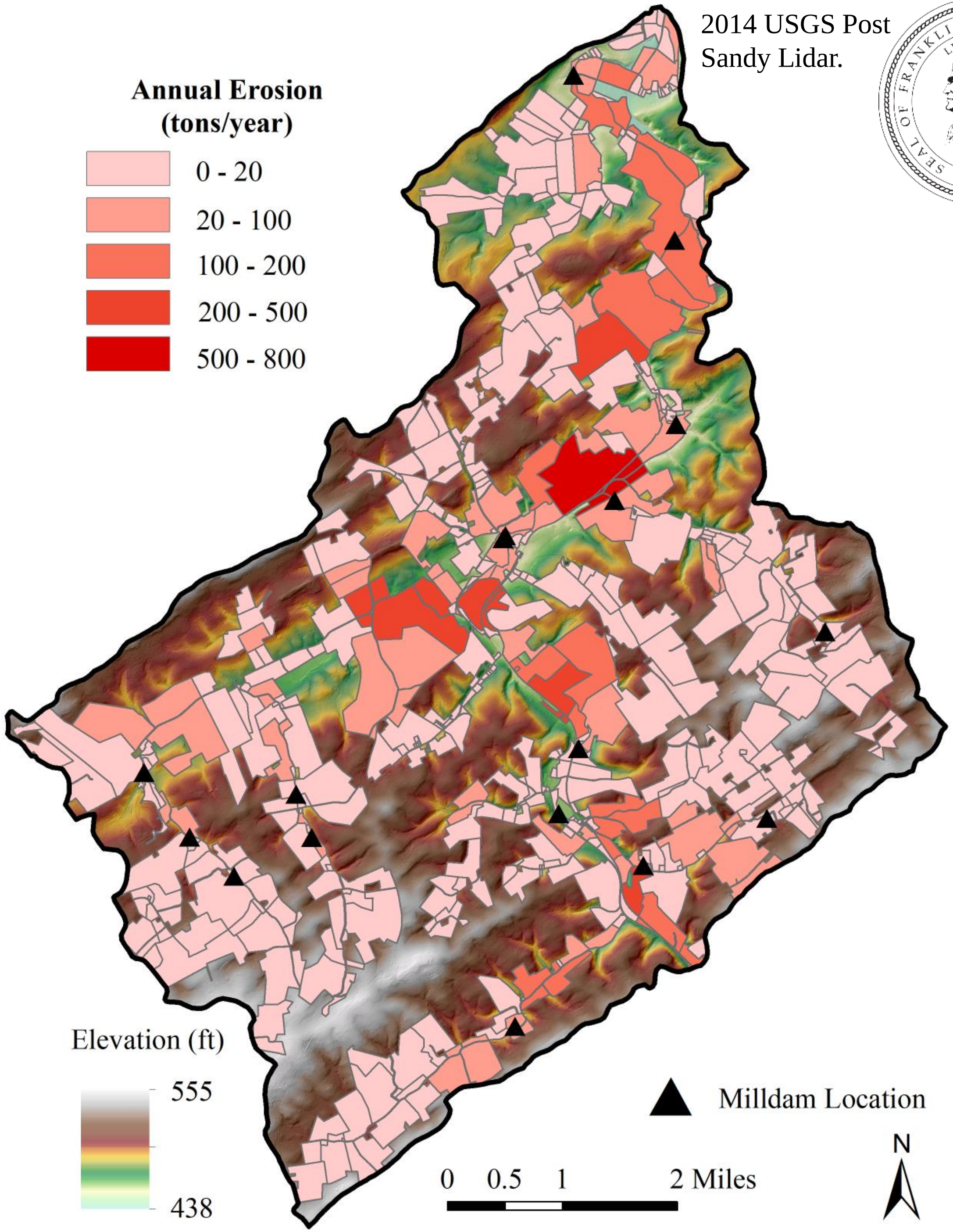
5,000 – 11,000 tons/yr

10,000,000 – 22,000,000 lbs/yr

- **Average Annual Erosion/Parcel:**

24 tons/yr

48,000 lbs/yr



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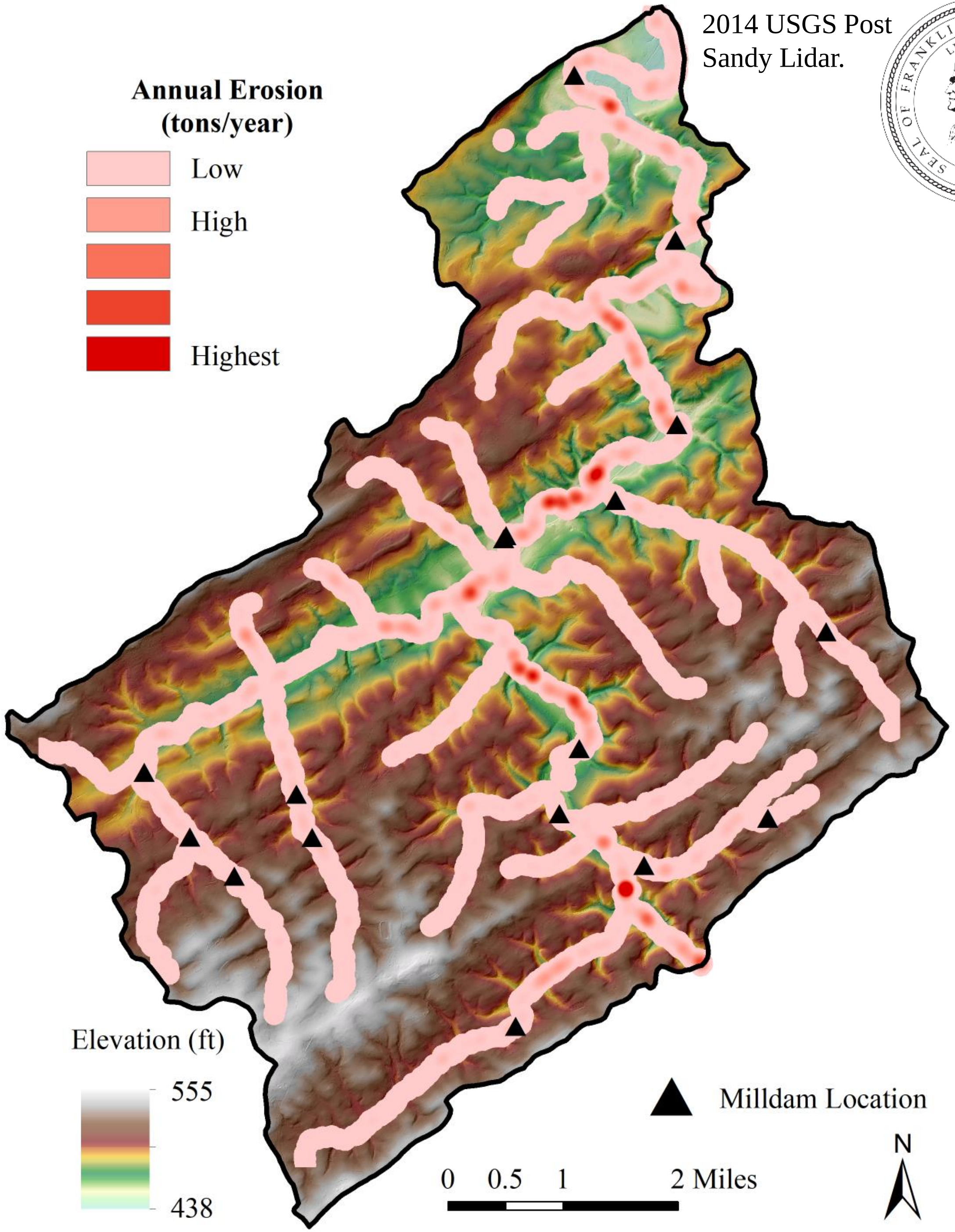
Heat Mapping – Watershed Analysis

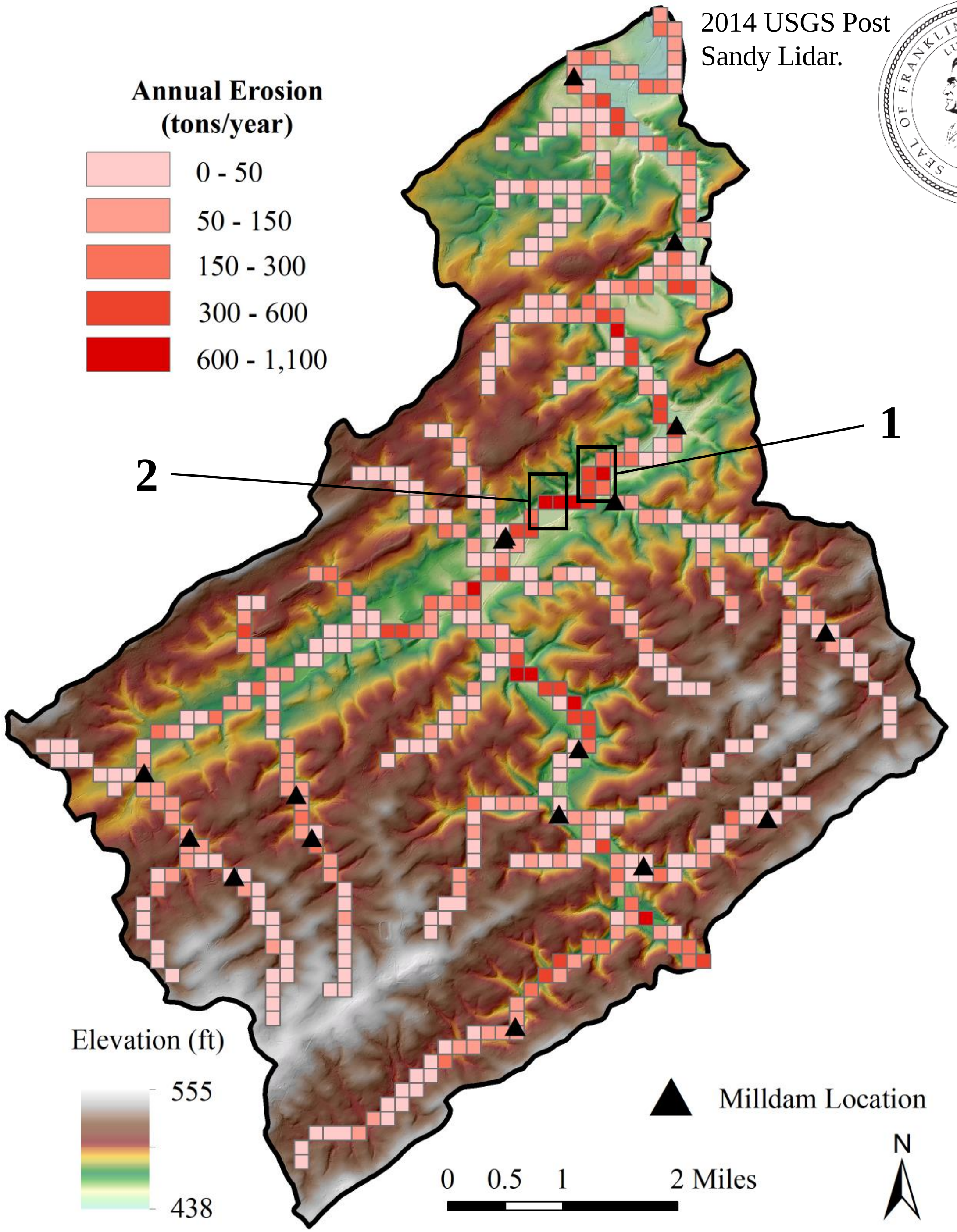
- **Kernel Density Heat Map**



2014 USGS Post Sandy Lidar.

Heat Mapping – Watershed Analysis

- Kernel Density Heat Map
- **Block Statistics Heat Map**



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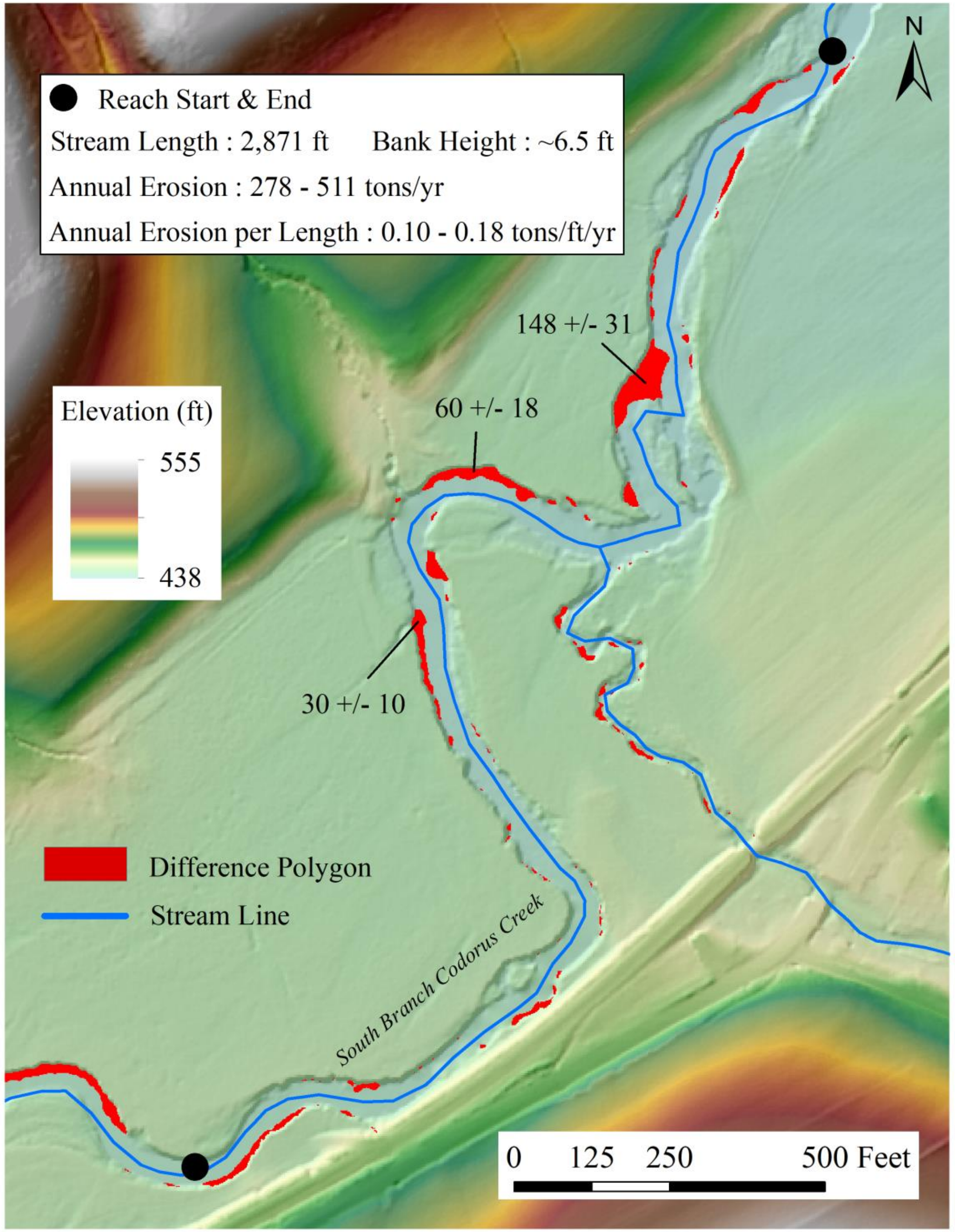
Heat Mapping – Watershed Analysis

- Kernel Density Heat Map
- Block Statistics Heat Map
- **Hotspots**

1

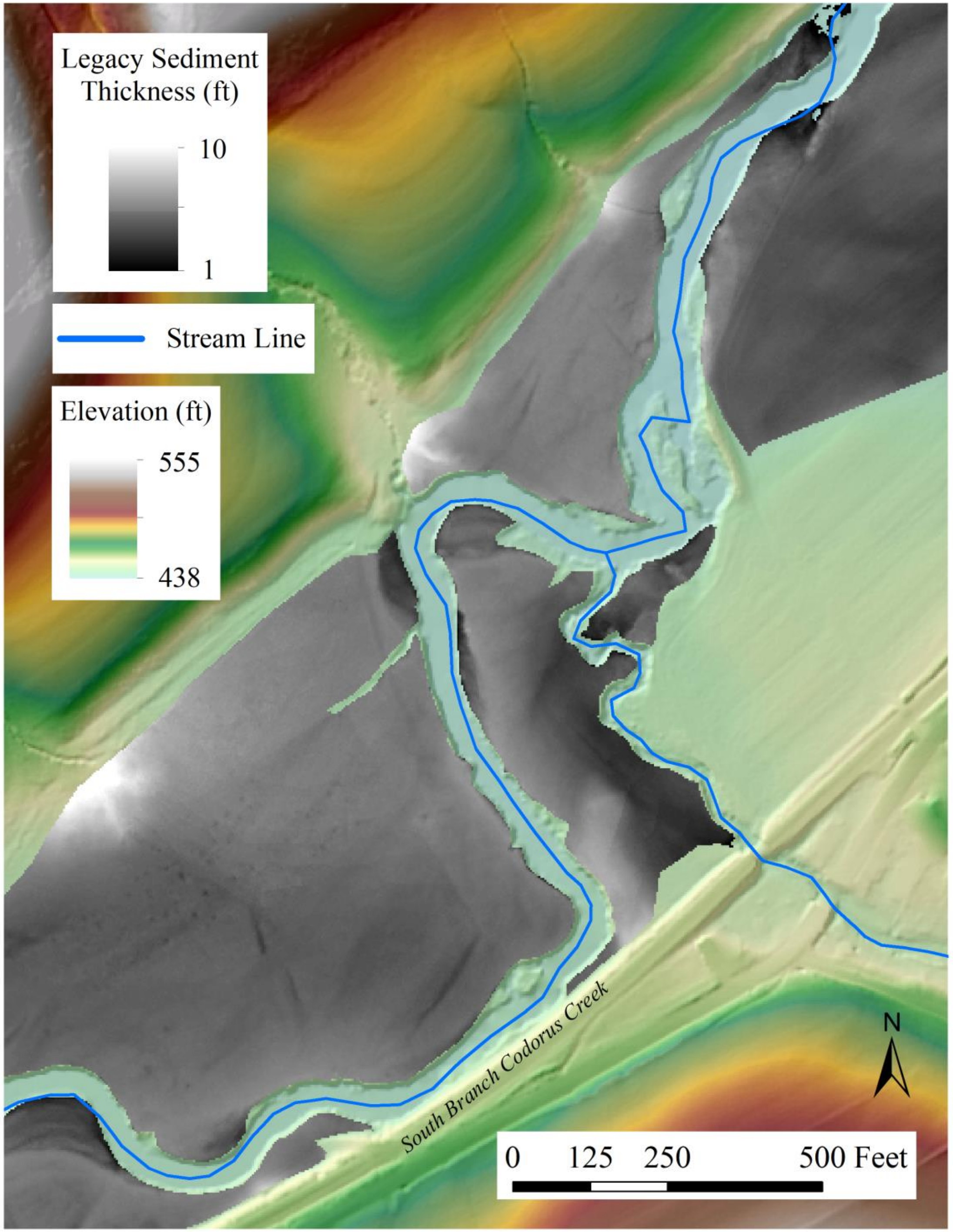


2014 USGS Post Sandy Lidar.

Heat Mapping – Watershed Analysis

- Kernel Density Heat Map
- Block Statistics Heat Map
- **Hotspots**

1



2014 USGS Post Sandy Lidar.

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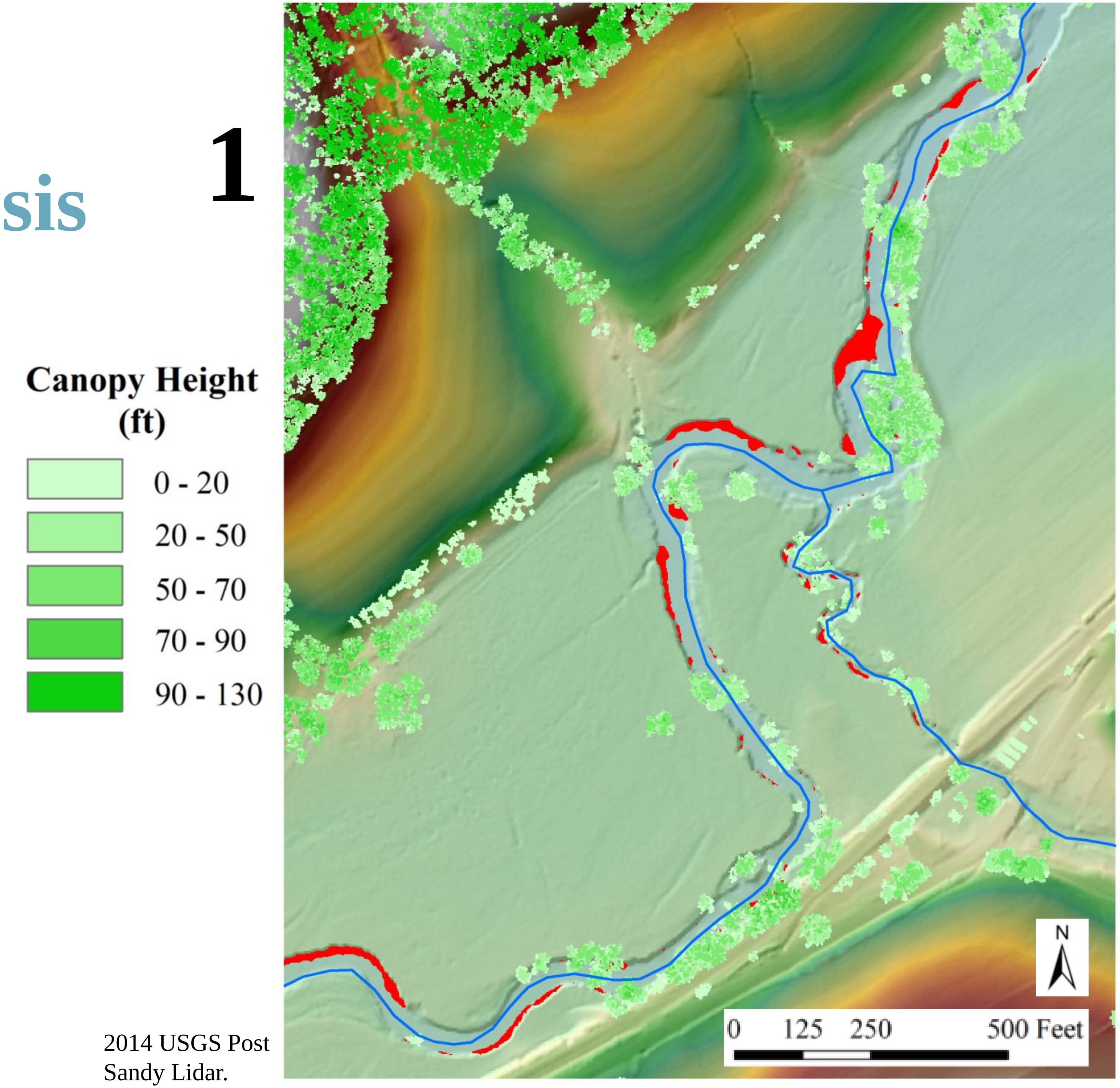
Heat Mapping – Watershed Analysis

1

- Kernel Density Heat Map
- Block Statistics Heat Map
- **Hotspots**



2014 USGS Post Sandy Lidar.

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2

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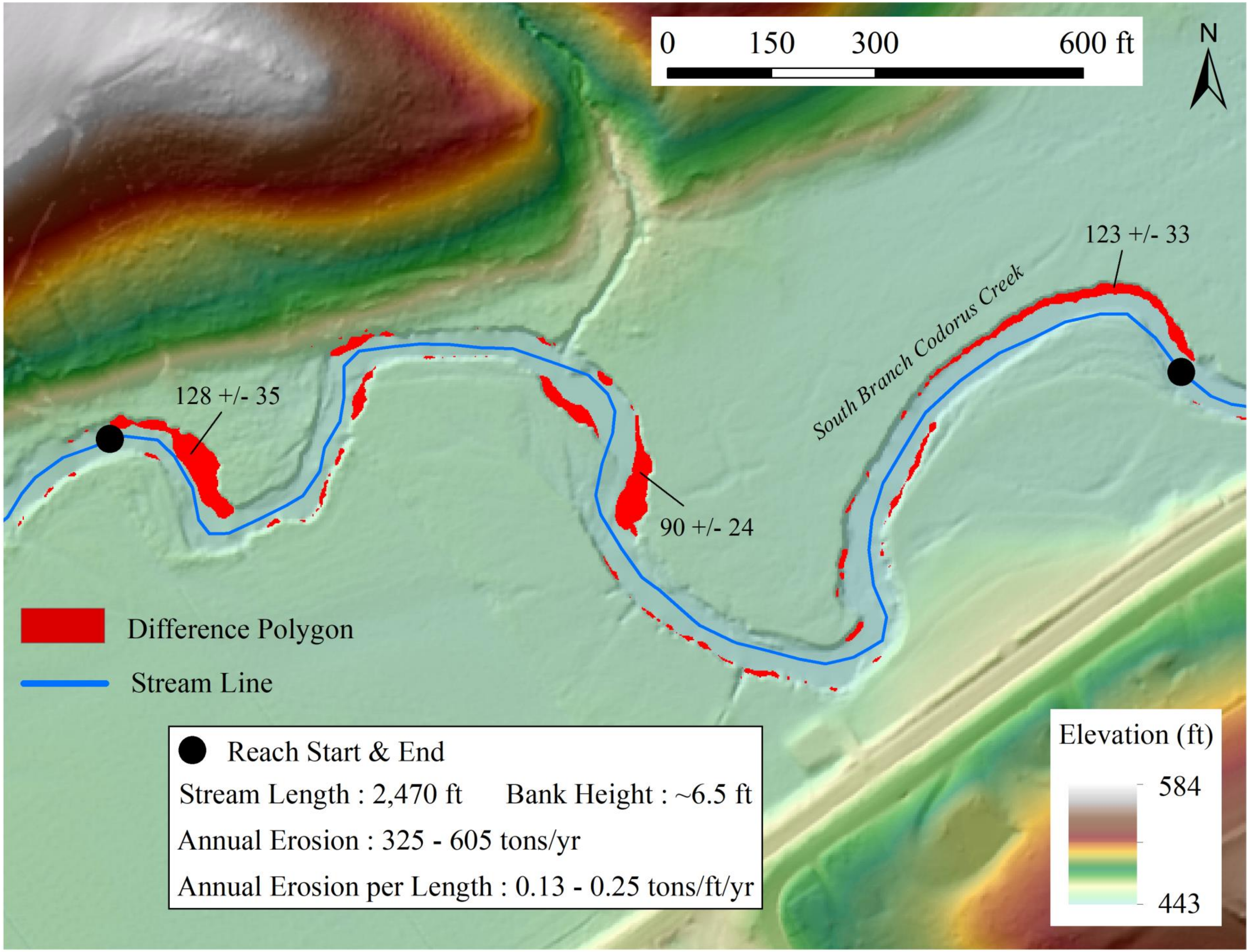

● Reach Start & End

Stream Length : 2,470 ft   Bank Height : ~6.5 ft

Annual Erosion : 325 - 605 tons/yr

Annual Erosion per Length : 0.13 - 0.25 tons/ft/yr

2014 USGS Post
Sandy Lidar.

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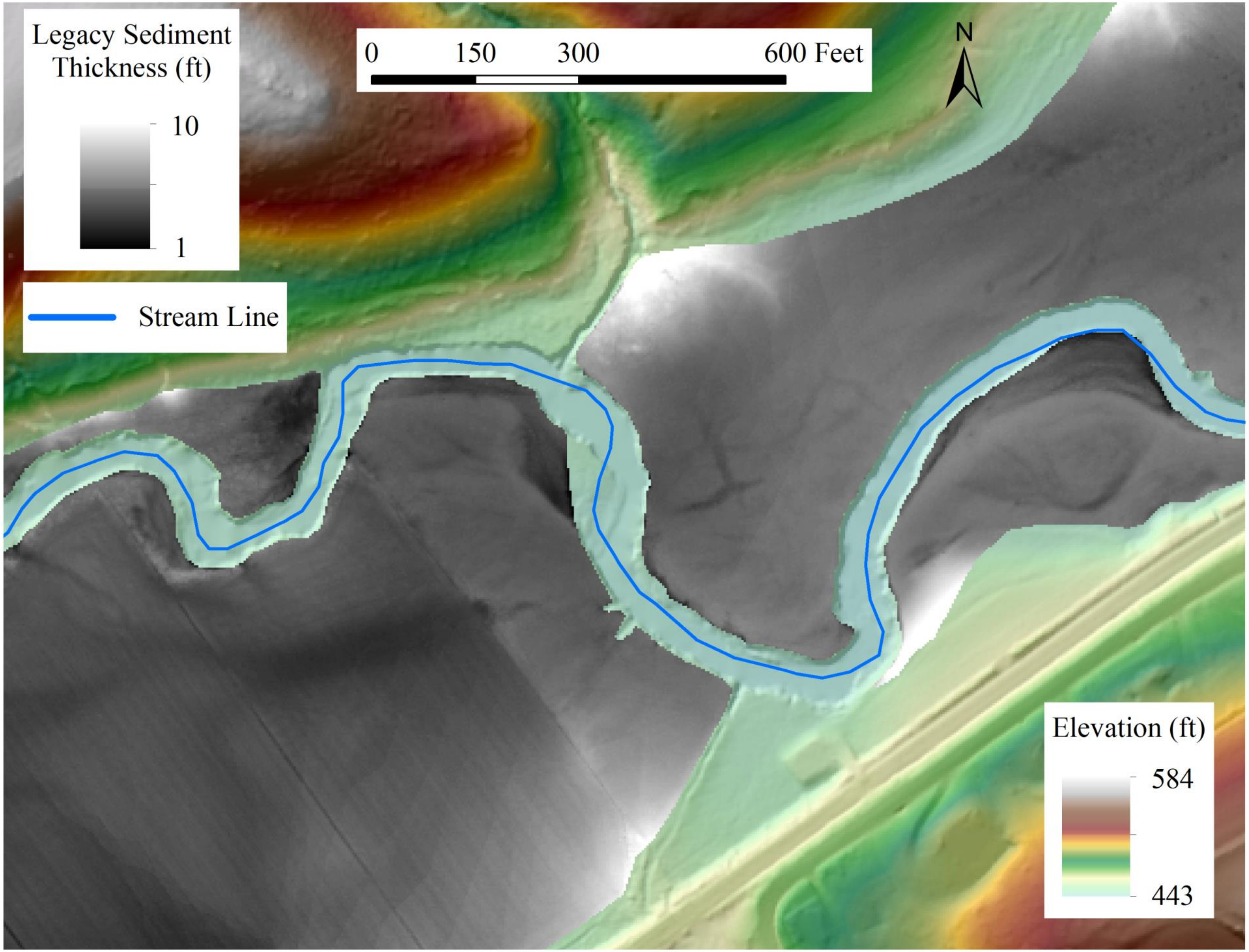

2014 USGS Post Sandy Lidar.

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Canopy Height (ft)

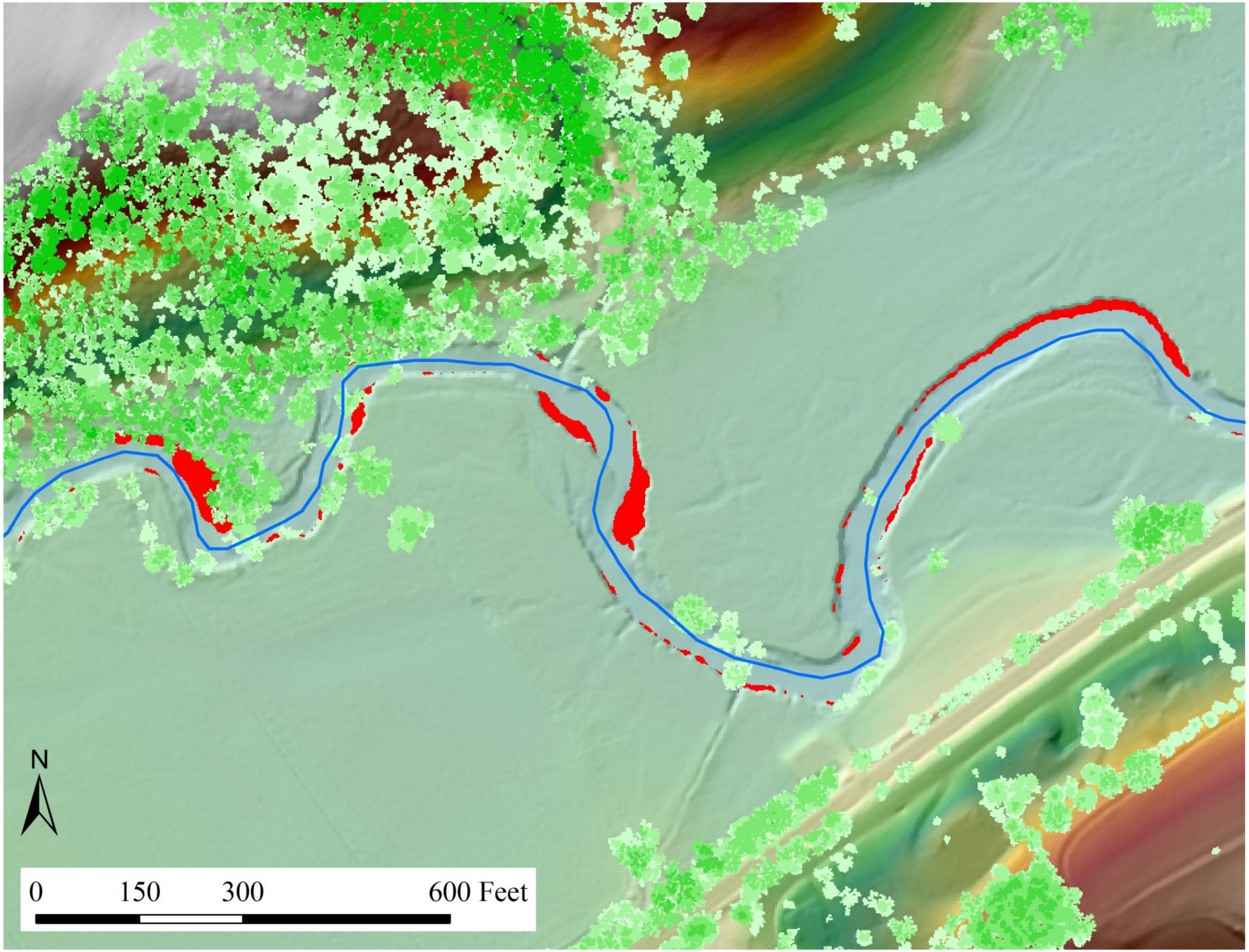
🟩 0 - 20

🟩 20 - 50

🟩 50 - 70

🟩 70 - 90

🟩 90 - 130



2014 USGS Post Sandy Lidar.

Drone Photogrammetry

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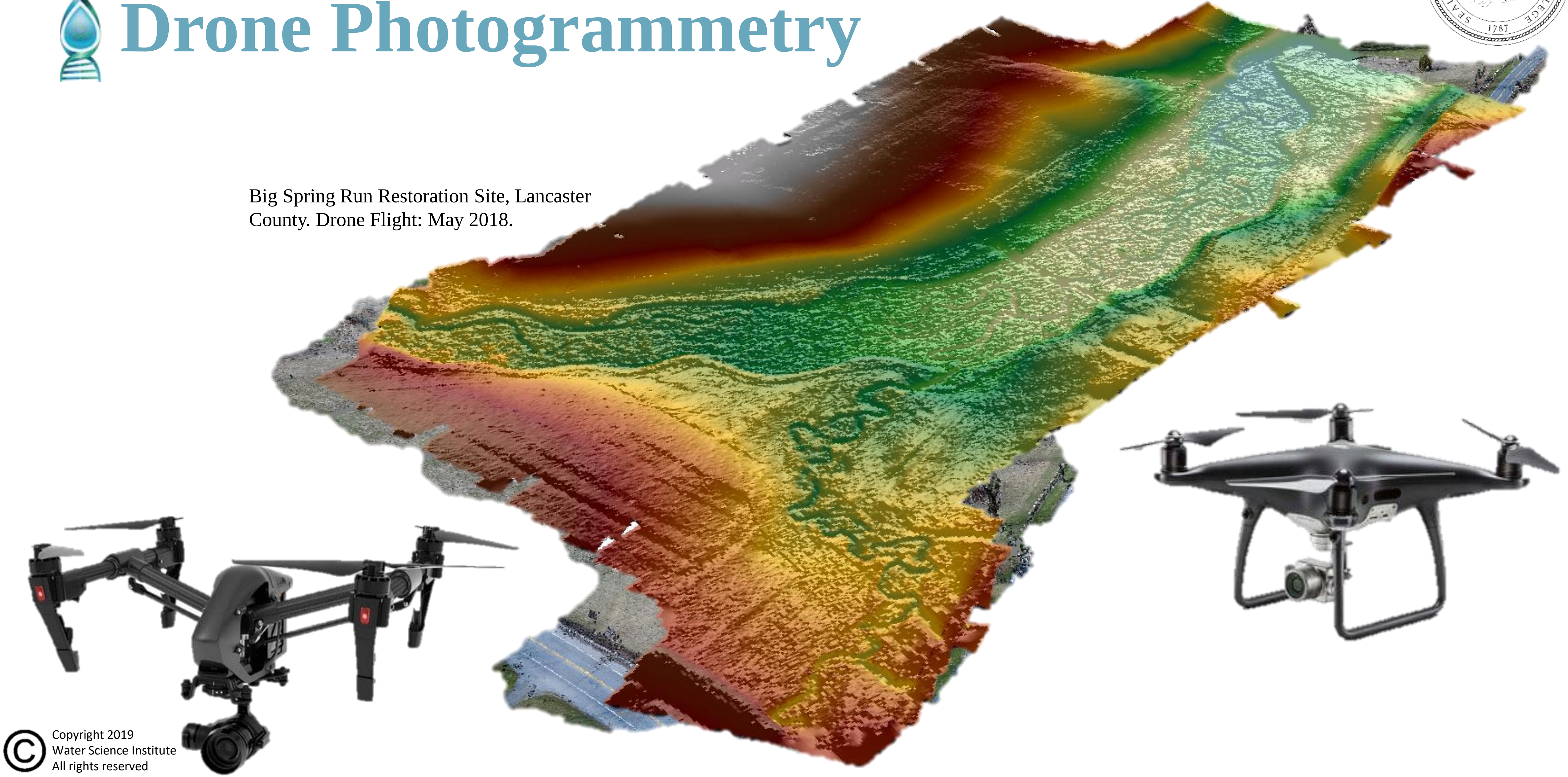

Big Spring Run Restoration Site, Lancaster County. Drone Flight: May 2018.

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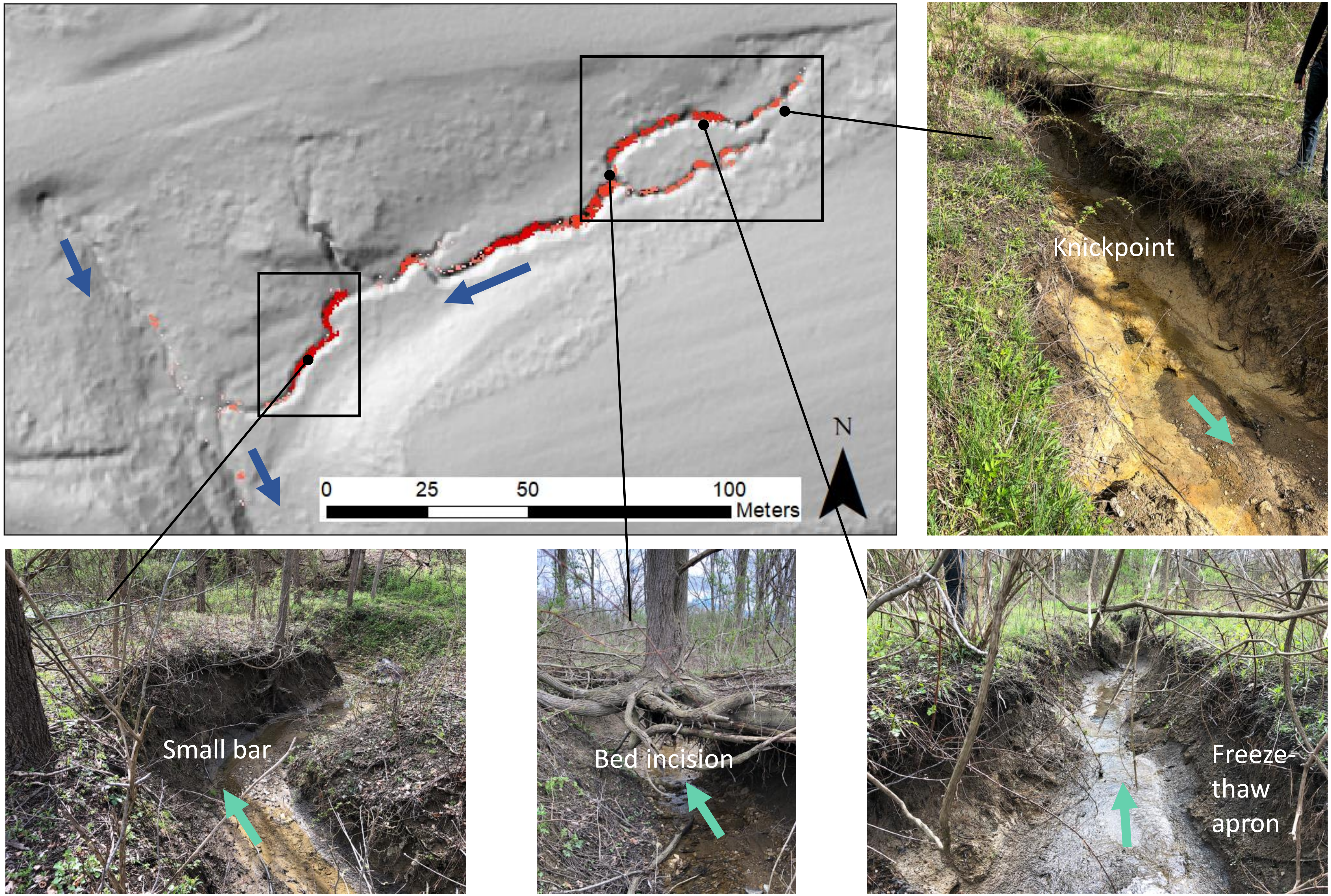
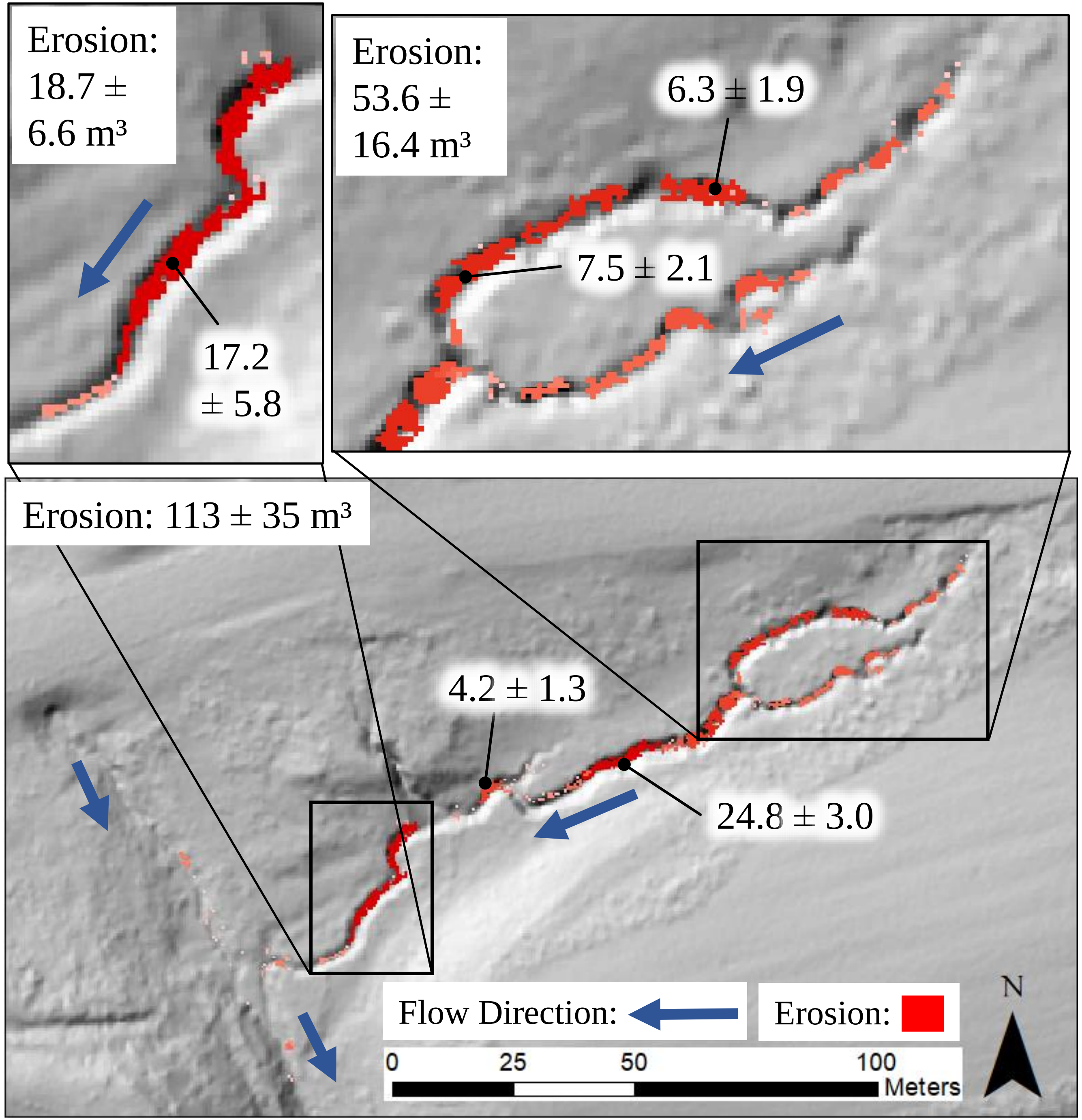


Slopeshade from 2016 USGS QL2 Lidar.

Veterans Park, Dauphin County

Lidar Date	3-24-2016
Drone Flight Date	11-28-2018
Period Duration	2.7 years 980 days
Stream length	285 m 935 ft
Total erosion volume	113 ± 35 m^3 147 ± 45 tons 294,000 ± 90,000 lbs
Erosion/year	42 ± 13 m^3/yr 59 ± 18 tons/yr 118,000 ± 36,000 lbs/yr
Erosion/stream length/year	~0.15 m^3/m/yr ~0.06 tons/ft/yr ~126 lbs/ft/yr

Slopeshade from 2016 USGS QL2 Lidar.



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