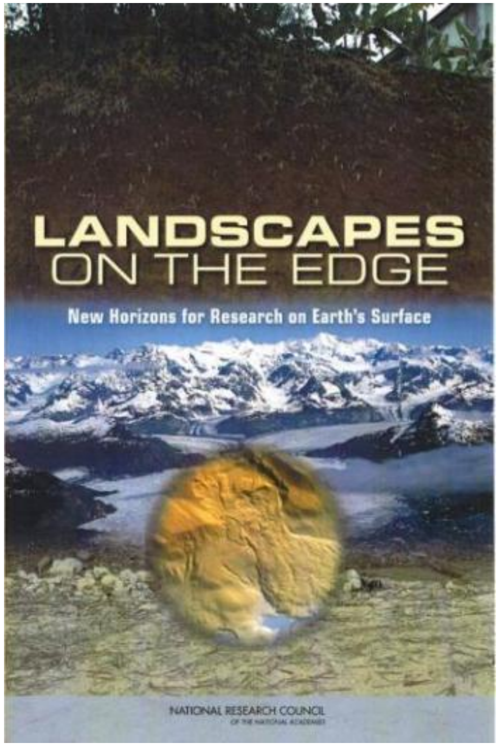
Widespread 18th-20th c. Burial of Holocene Wet Meadows in the Mid-Atlantic Region, USA, and their Restoration Potential

Typical mid-Atlantic streams incised into millpond sediment
Big Spring Run (top) and White Clay Creek (bottom), PA

Dorothy Merritts (F&M), Robert Walter (F&M), Allen Gellis (USGS), Jeff Hartranft (PA DEP), William Hilgartner (JHU), Michael Langland (USGS), Paul Mayer (US EPA), Ward Oberholtzer (LandStudies, Inc.), and Michael Rahnis (F&M)



“Time Telescope” (i.e., Methods)

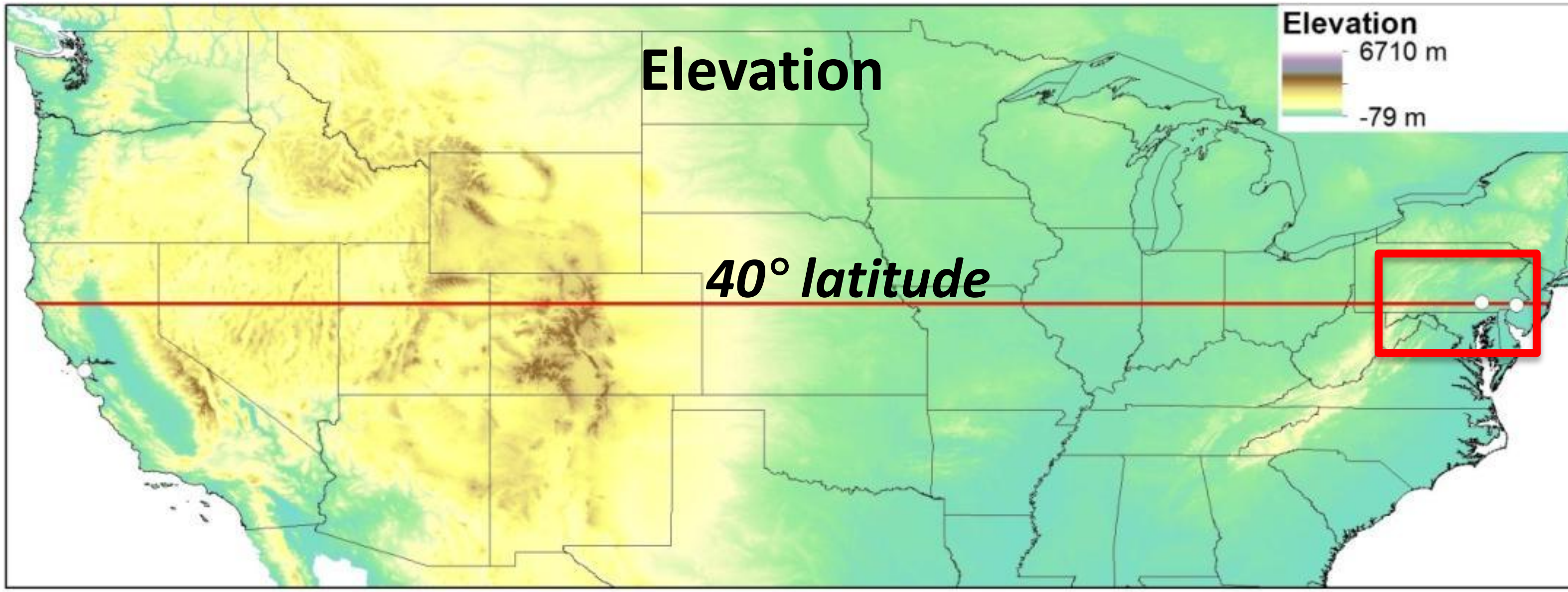
Examine stratigraphy, buried landforms, and buried soils exposed in and along:

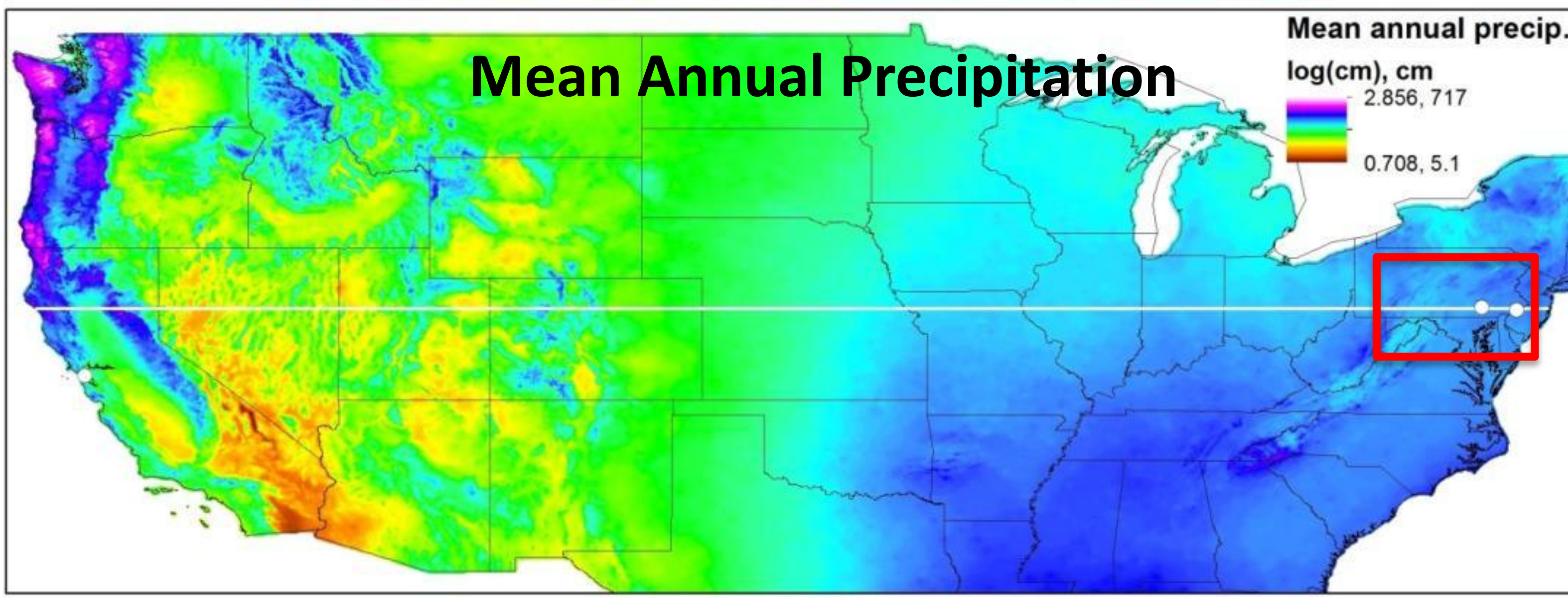
- Incised streams
- Quarry walls
- Road cuts
- Backhoe trenches

- Rare patches of landscape not buried by historic sediment

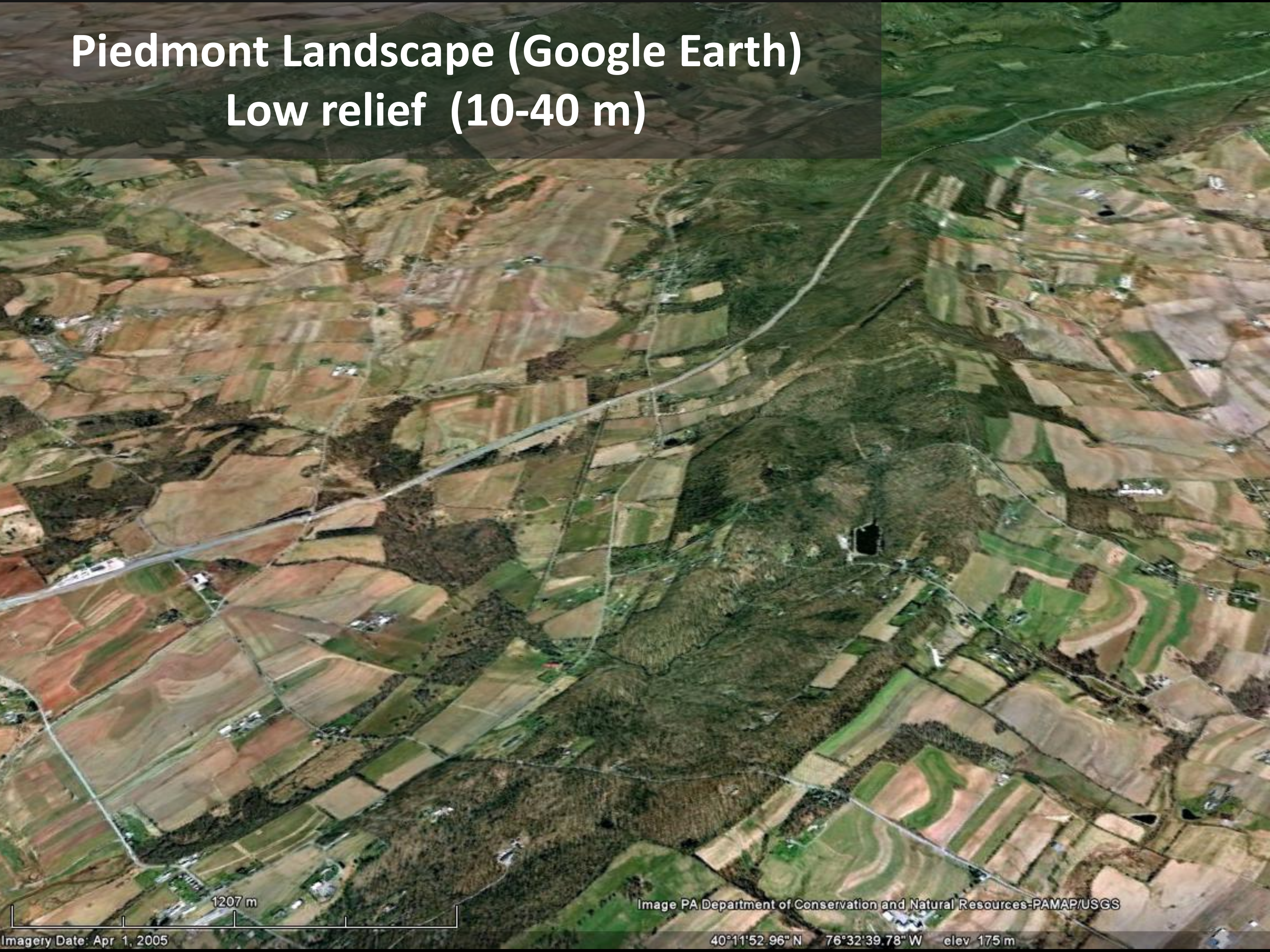
i.e., ”living fossil landscapes”

Study Area has Low Elevation and High Precipitation



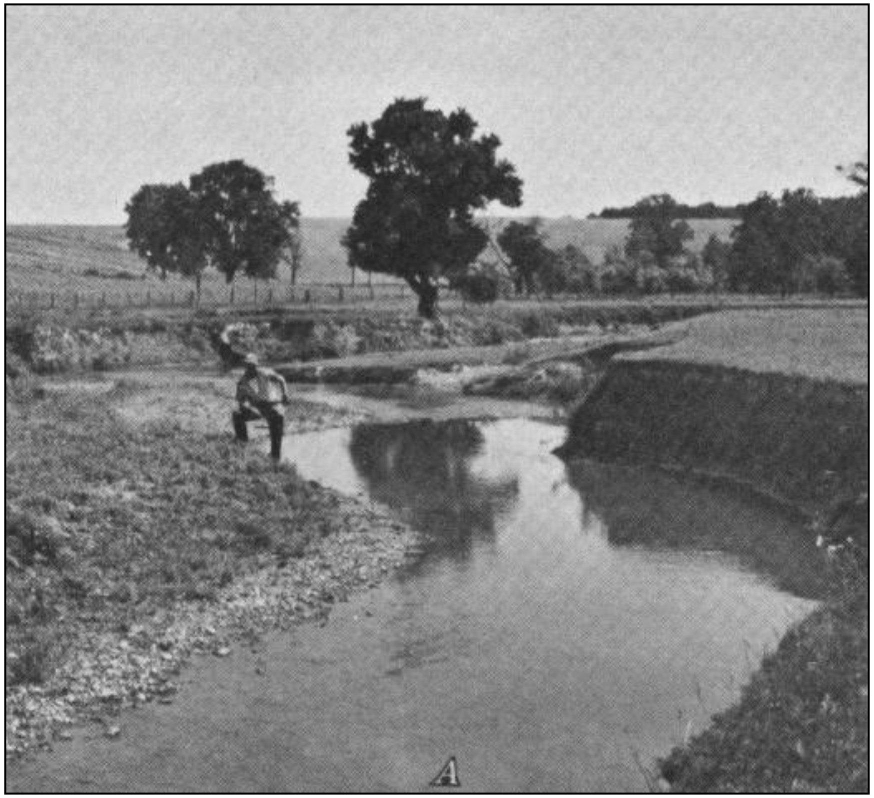


Piedmont Landscape (Google Earth)
Low relief (10-40 m)



New Interpretation of Landscape Evolution and Channel Formation

The Classic Model of Channel and Flood Plain Formation and Evolution



Seneca Creek, MD
(Wolman & Leopold, 1957)

"This flood plain is typical of many rivers in the Eastern United States and illustrates the type of deposition and stratigraphy commonly found in this area." **(Wolman & Leopold, 1957)**

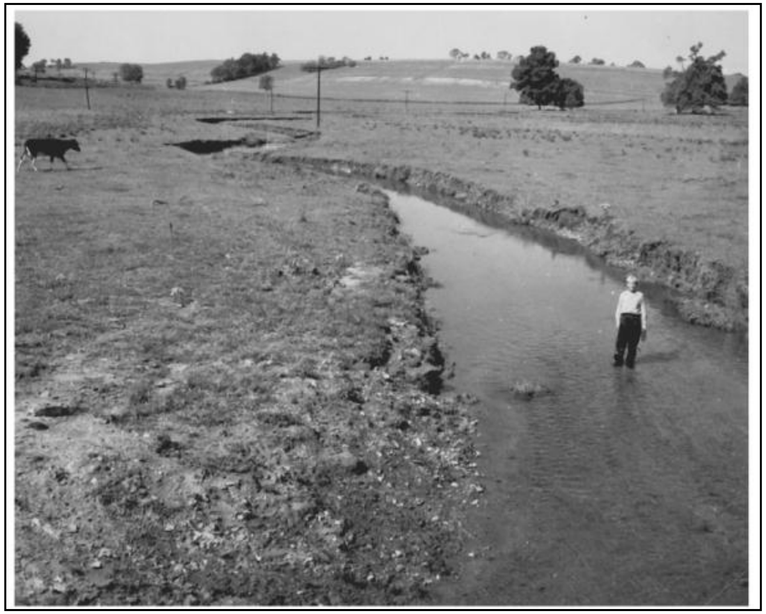
River Flood Plains:
Some Observations
On Their Formation

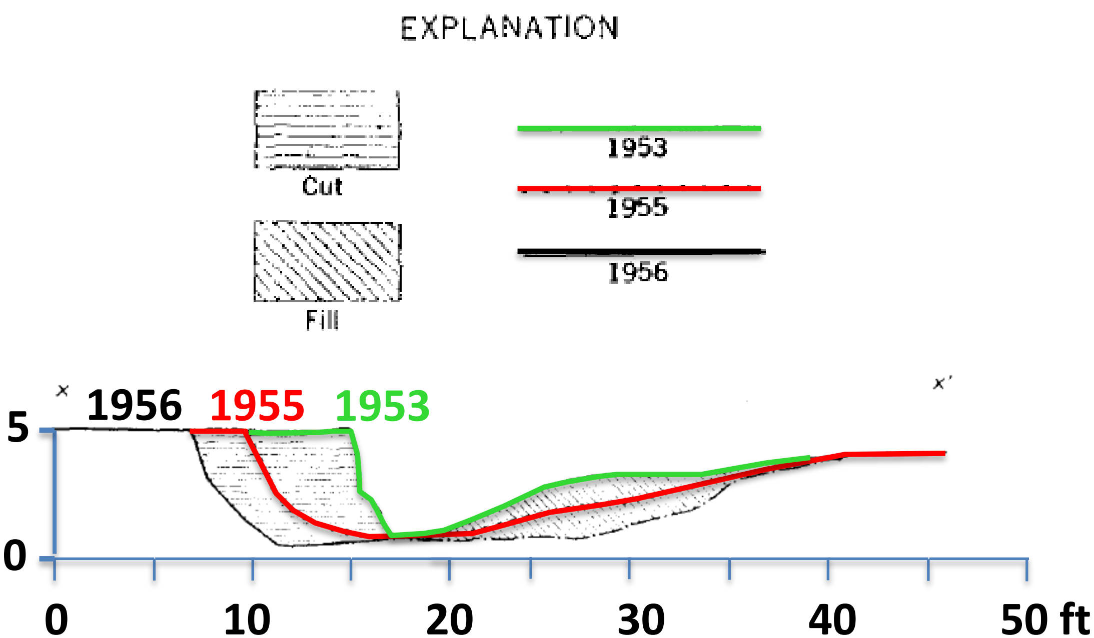
By M. GORDON WOLMAN and LUNA B. LEOPOLD

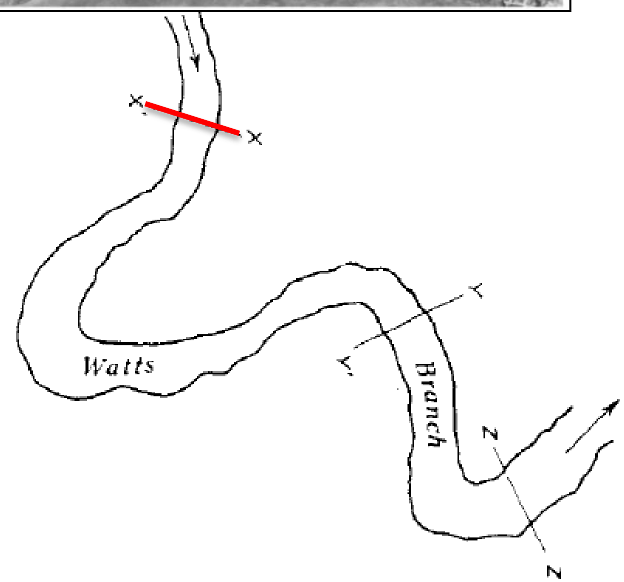
PHYSIOGRAPHIC AND HYDRAULIC STUDIES OF RIVERS

GEOLOGICAL SURVEY PROFESSIONAL PAPER 282-C

Watts Branch, MD – interpreted as stream that meandered across valley with time, depositing channel bed/point bar gravel and overlying fine floodplain sediment







(from Wolman and Leopold, 1957, and Leopold et al, 2005)

Denlinger's Mill Reservoir Sediment and Stratigraphy, 2002

View downstream at breached Denlinger's milldam

- Fine-grained
- Finely laminated
- Rare cut/fill features
- Draped on pre-existing VB topography
- Sub-planar fill surface

5-m high dam, 1919
Breached ~1936

W. Br. Little Conestoga, PA
L. Manion (F&M, 2003)
Sampling millpond sediment

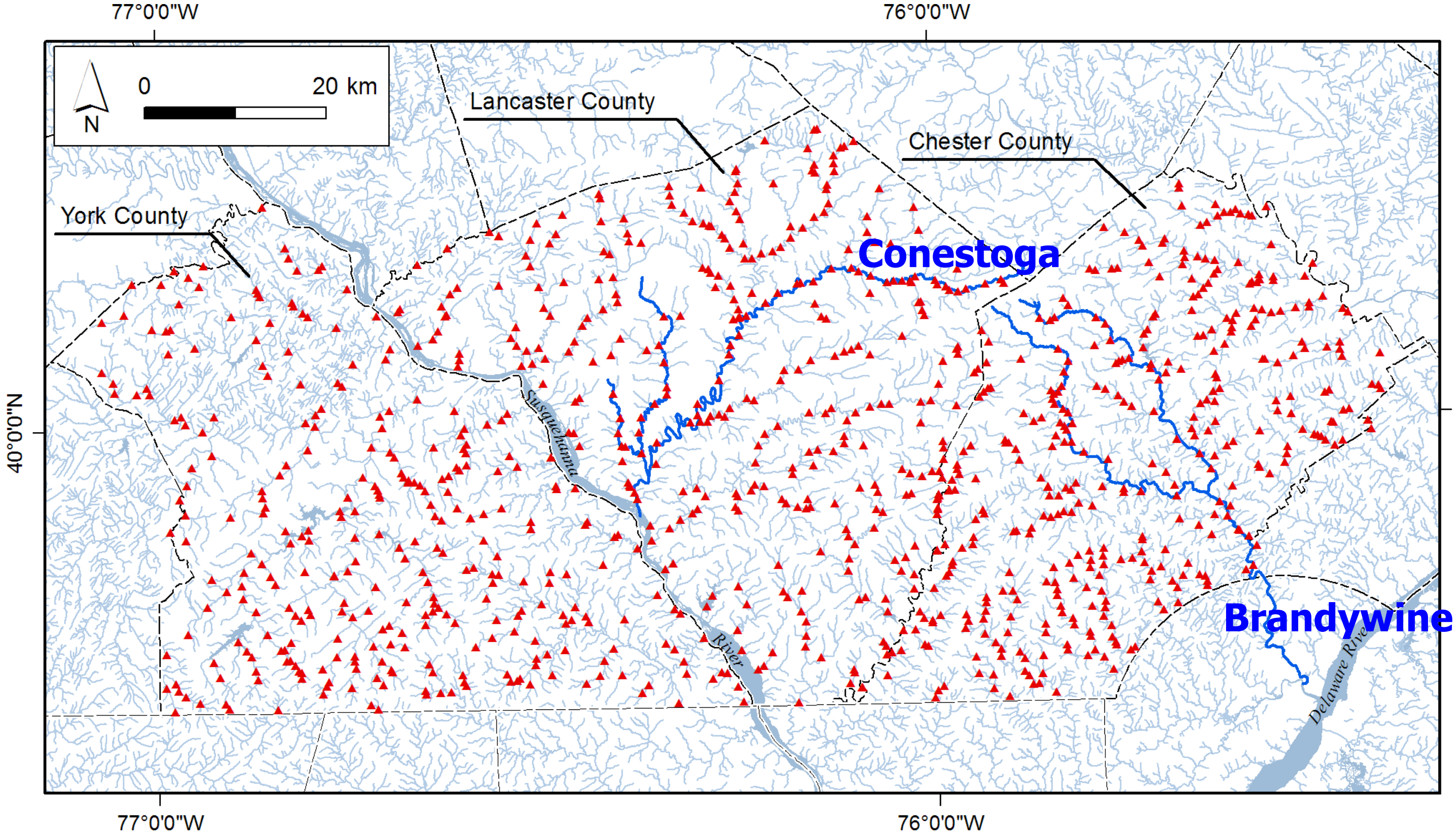
View upstream of intact Denlinger's milldam

Historic Maps of Milldams, Ponds, and Races

1868 Wissahickon Creek near Philadelphia, PA

> A dozen dams and ponds

Anthropogenic Impacts on Valley Bottom Landscapes [Note: These dams are not in the NID database.]



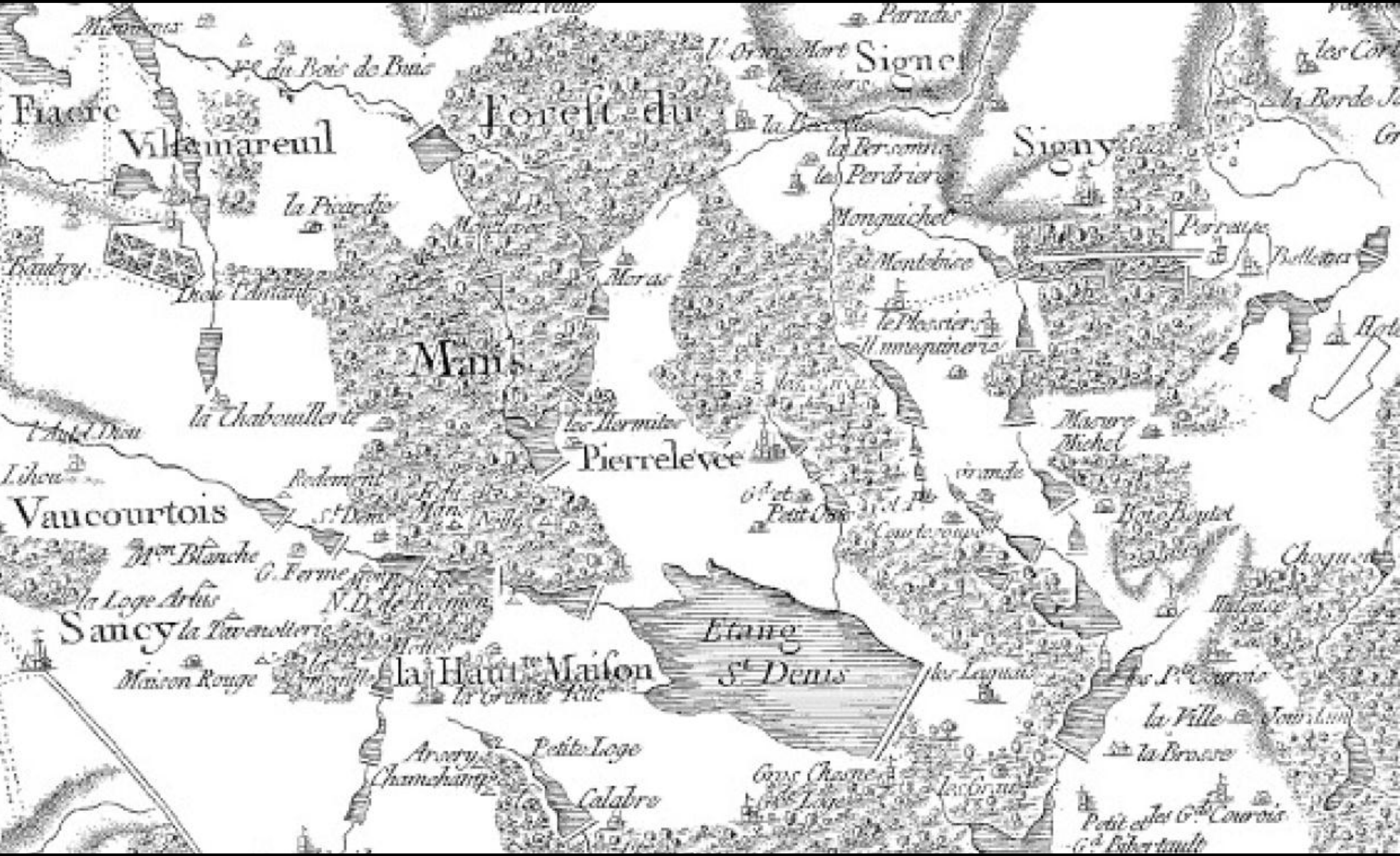
Over 1,000 mill dams in 19th C. Atlases of York, Lancaster & Chester Counties

▲ **Location of mill dams**

From Walter and Merritts, 2008

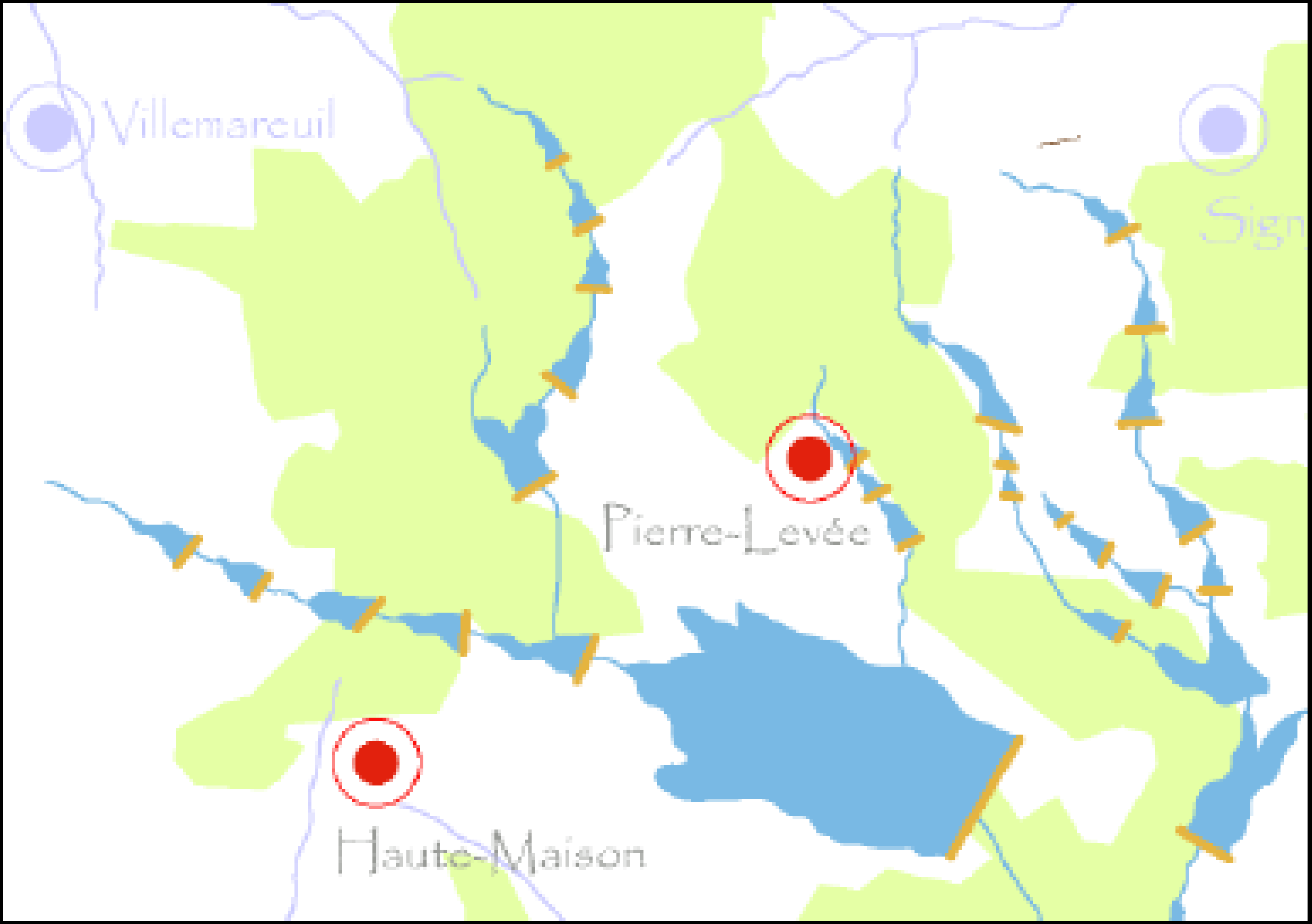
http://edisk.fandm.edu/michael.rahnis/ex-census.html

Historic Maps of Milldams, Ponds, and Races



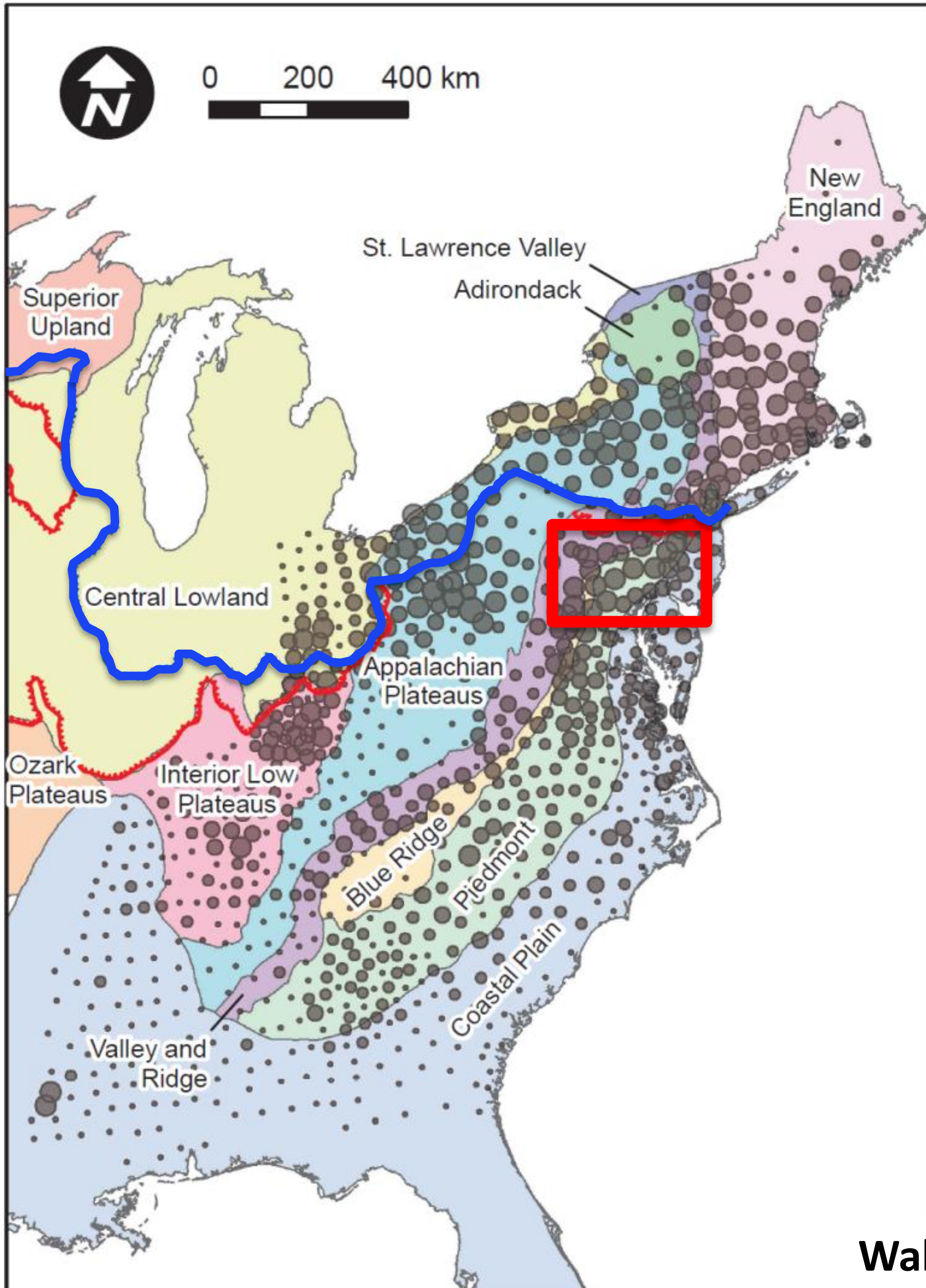
Carte de Cassini, France, 19th c. map

Historic Maps of Milldams, Ponds, and Races



Carte de Cassini, France, 19th c. map

Mill Density 1840 US Census
~65,000 Water-powered Mills



Glacial Limits

Pre-Wisconsin

Wisconsin

Mills per 100 sq-km (# counties)

0.0 - 2.1 (299)

2.1 - 4.8 (258)

4.8 - 8.8 (170)

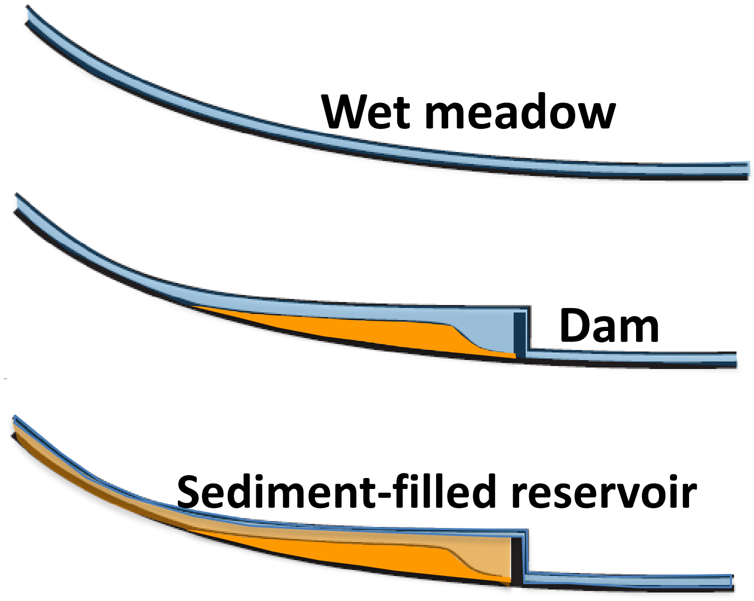
8.8 - 23.6 (108)

23.6 - 61.2 (1)

"There is no neighborhood in any part of the United States without a water gristmill." **Thomas Jefferson, 1786**

Walter and Merritts compilation, 2008, *Science*
Map and GIS database by M. Rahnis

Widespread, rapid sedimentation and burial of the pre-settlement VB landscape (the “Pompeii-effect”)



Munger’s Mill and Dam, Wisconsin, 1895
(Photographer: H. H. Bennett)

Evidence of Mills, Dams, and Reservoir Sedimentation

- Historic maps and photos (air and ground)
- Topography (lidar)
- Stratigraphy
- Geochronology

Dam removal and breaching lead to incision and lateral bank erosion

Flume experiments and video footage
Dr. Allesandro Cantelli,
University of Minnesota

http://www.nced.umn.edu/Stream_Restoration_Toolbox.html

Big Spring Run:
Typical Incised Mid-Atlantic Stream

Dam removal and breaching lead to incision and lateral bank erosion

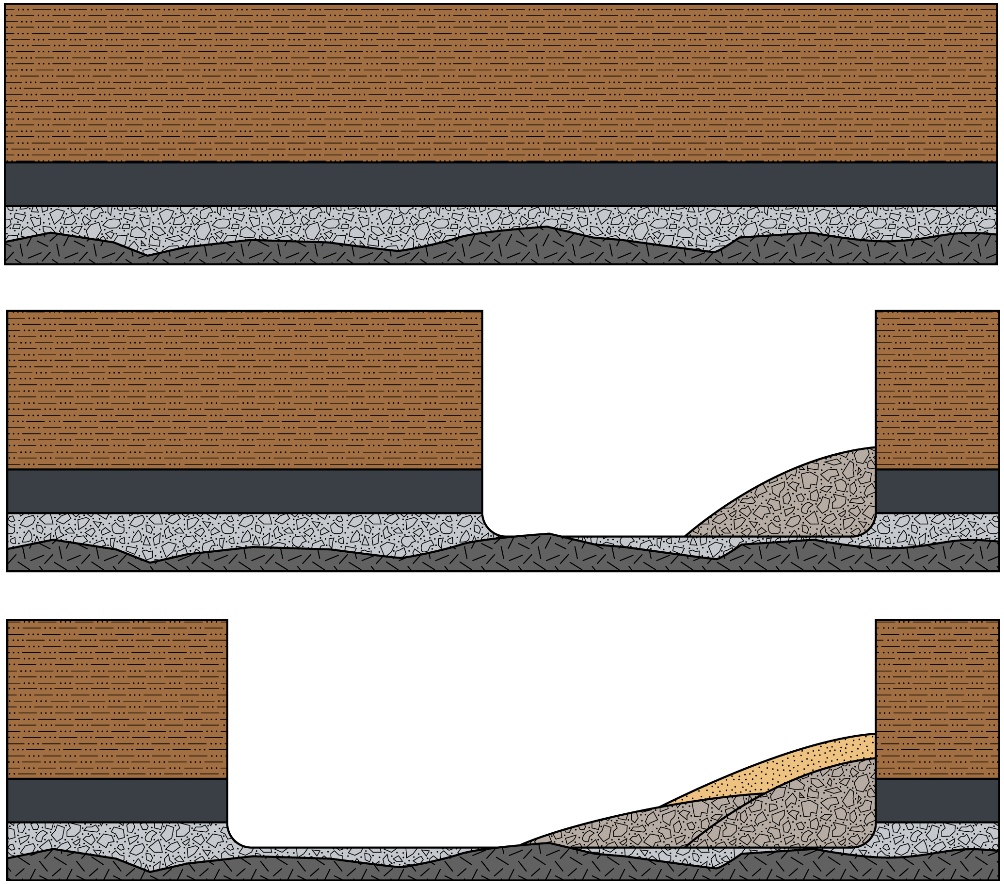
Flume experiments and video footage
Dr. Allesandro Cantelli,
University of Minnesota

http://www.nced.umn.edu/Stream_Restoration_Toolbox.html

Big Spring Run:
Typical Incised Mid-Atlantic Stream

Stobers Dam breach after hurricanes, 2011

Stobers Dam breach after hurricanes, 2011



Previous Interpretations:

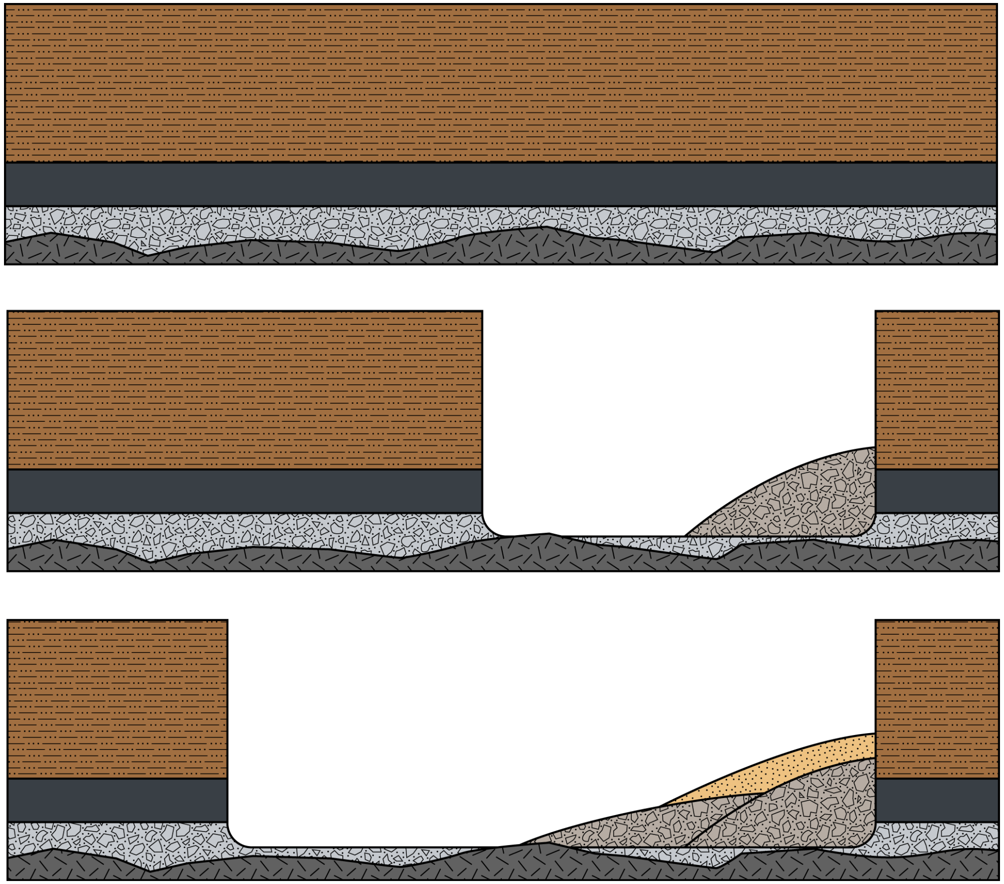
Channel migrates back and forth for thousands, <u>perhaps 10s of thousands of years</u> (*Leopold, 1994*).

Valley bottom deposits are result of meander migration and fluvial processes.

Sand and gravel deposited in bars.

Overbank deposition (flooding) of fine sediment across a self-formed floodplain.

Wolman and Leopold, 1957
Leopold, 1973, 1994



New Interpretation:

Wet meadow wetland system with small channels throughout Holocene (*Merritts et al, 2011*).

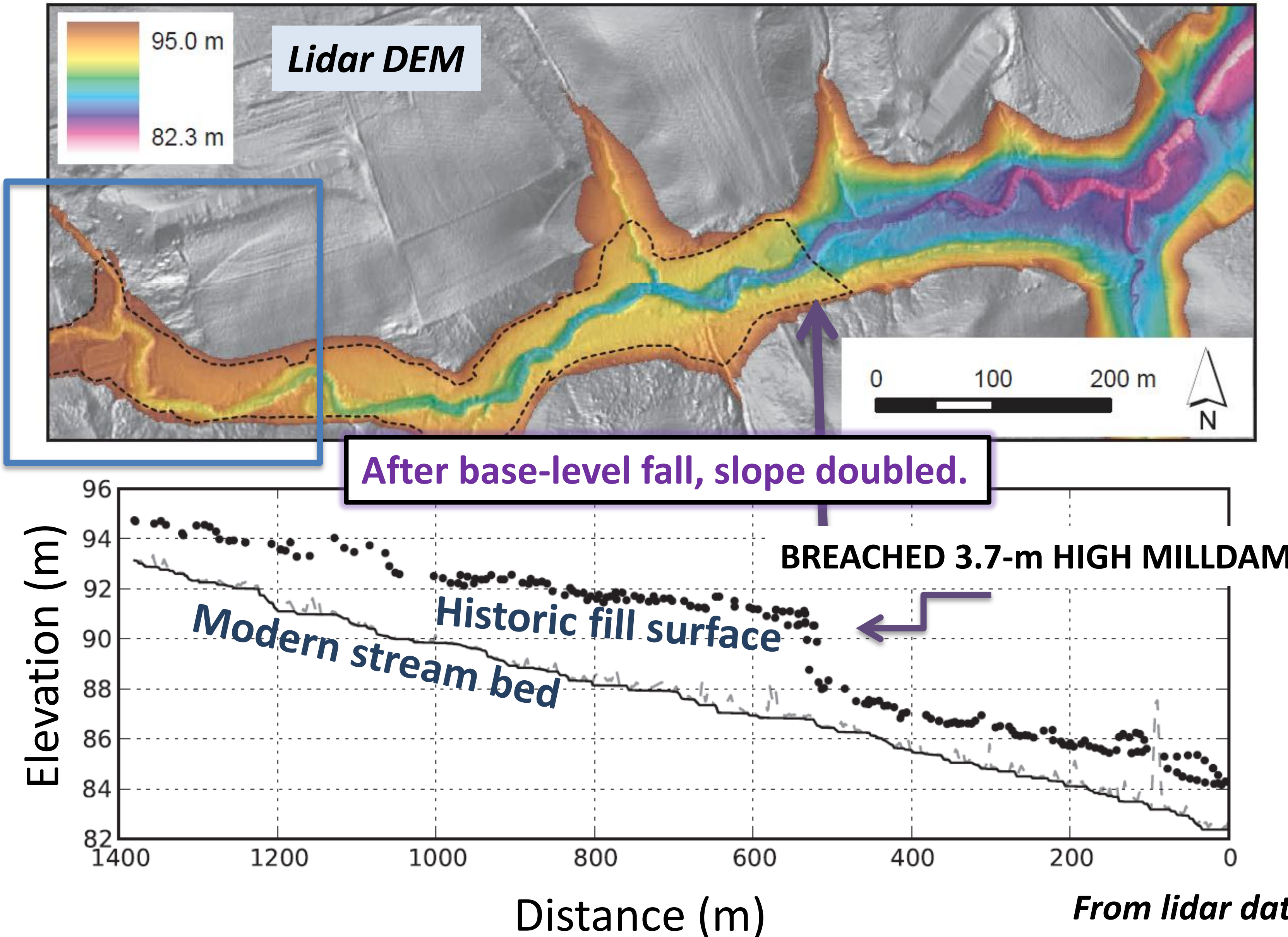
Valley bottom deposits are result of millpond sedimentation (Walter and Merritts, 2008).

Sand and gravel deposited in bars after milldam breaching.

Overbank deposition (flooding) of fine sediment across fill terrace where historic sediment is thin.

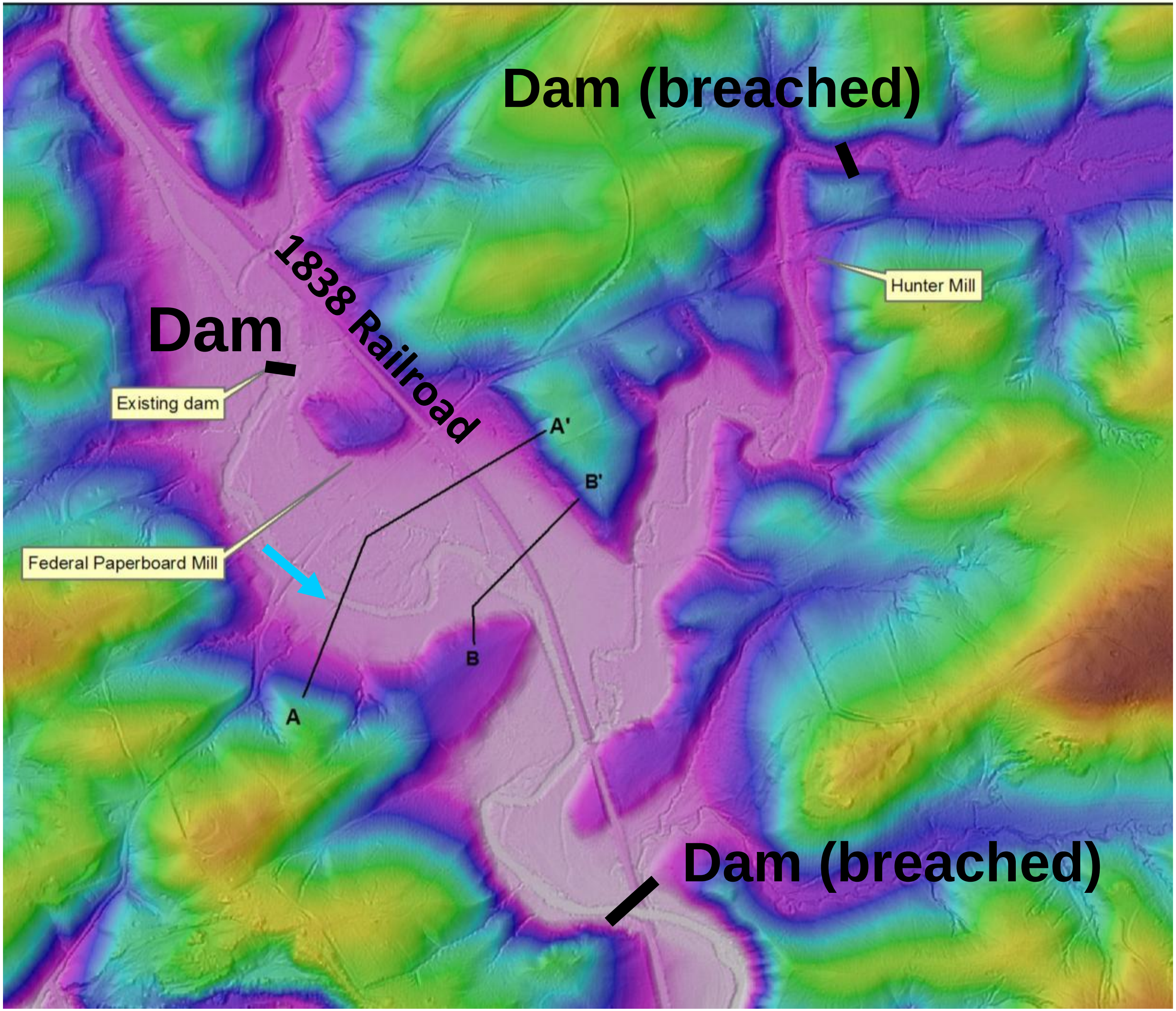
Channel corridor increases in width with time since dam breaching.

Sedimentation and Incision Revealed with High-Resolution Topography (PA MAP lidar)



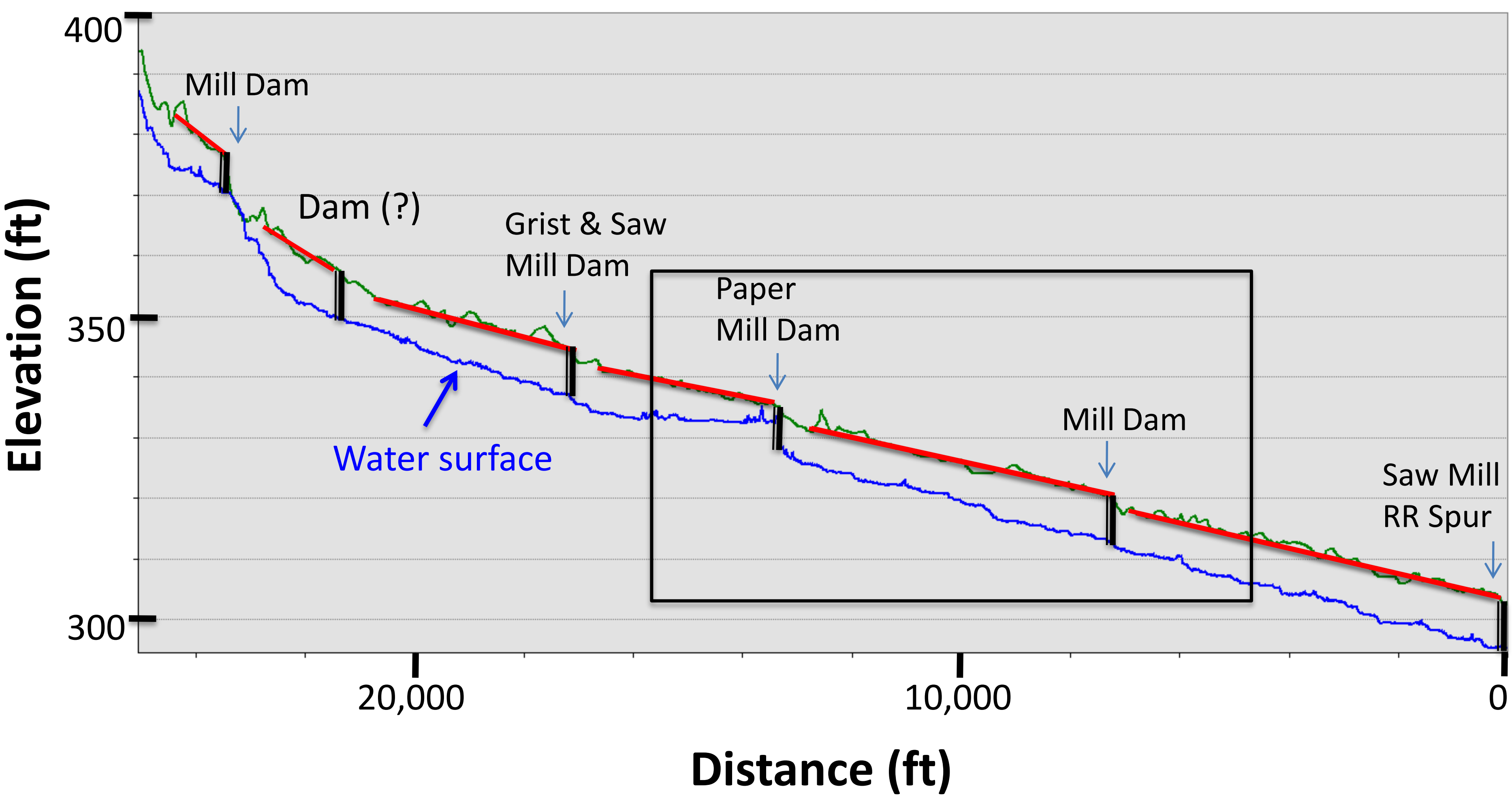
From lidar data

Backwater Effects and Mill Pond Sediment, Little Falls, MD



Historic Mill Dams and Reservoir Fill Surfaces, Little Falls, MD

Can trace pond surfaces (fill terraces) to crests of dams



Long profiles from LiDAR

The Pre-Settlement Wetland Landscape

Modern incised channel condition (top)
Pre-Settlement (historic) wet meadow condition (middle)

Wet meadow (Obligate wetland)

- Water-loving grasses and sedges; commonly 2-3 dominant species.
- Habitat contains ~100% vegetation cover and little open water.
- Anastomosing channels, high-density roots, high surface roughness.
- Frequently saturated and mucky (Tiner, 1998).

Buried wetland soil at ground-water table

Paleo-wet meadow seeds from buried hydric soil (Holocene)

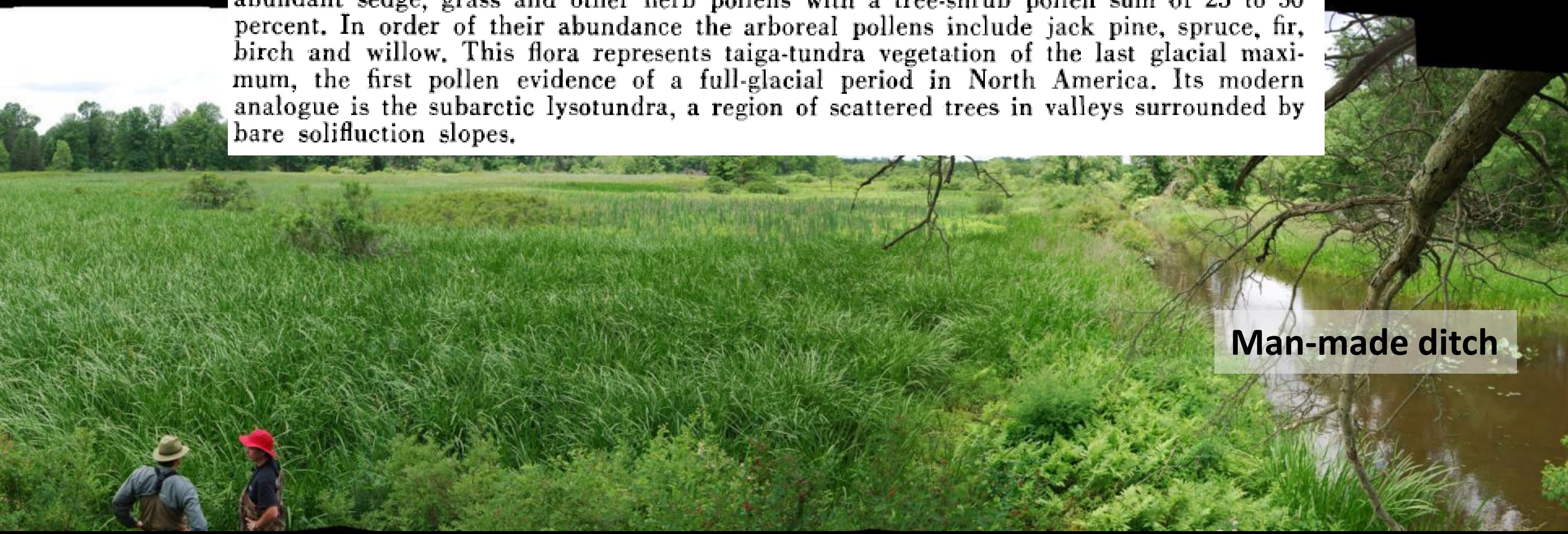
The Great Marsh – A Rare Vestige of a Late Pleistocene-Holocene Wetland

[American Journal of Science, Vol. 256, Summer 1958, P. 470-502]

TAIGA-TUNDRA AND THE FULL-GLACIAL PERIOD IN CHESTER COUNTY, PENNSYLVANIA

PAUL S. MARTIN

ABSTRACT. Two shallow cores from a marsh in the unglaciated piedmont of southern Pennsylvania reveal a late Pleistocene pollen sequence. Below 70 cm gritty clays contain abundant sedge, grass and other herb pollens with a tree-shrub pollen sum of 25 to 50 percent. In order of their abundance the arboreal pollens include jack pine, spruce, fir, birch and willow. This flora represents taiga-tundra vegetation of the last glacial maximum, the first pollen evidence of a full-glacial period in North America. Its modern analogue is the subarctic lysotundra, a region of scattered trees in valleys surrounded by bare solifluction slopes.

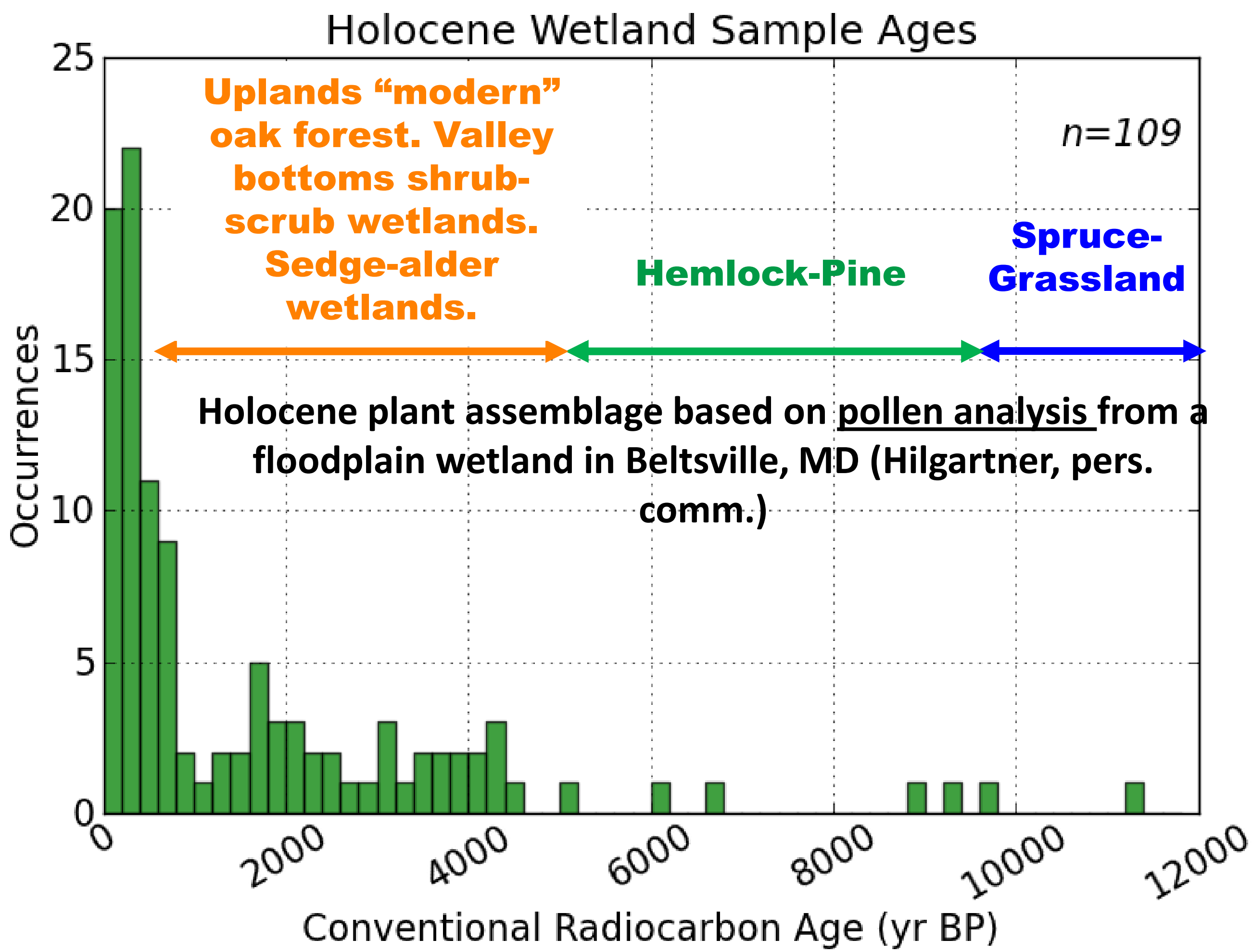


A remnant, late Pleistocene-Holocene tussock-sedge wet meadow

The Great Marsh – A Rare Vestige of a Late Pleistocene-Holocene Wetland

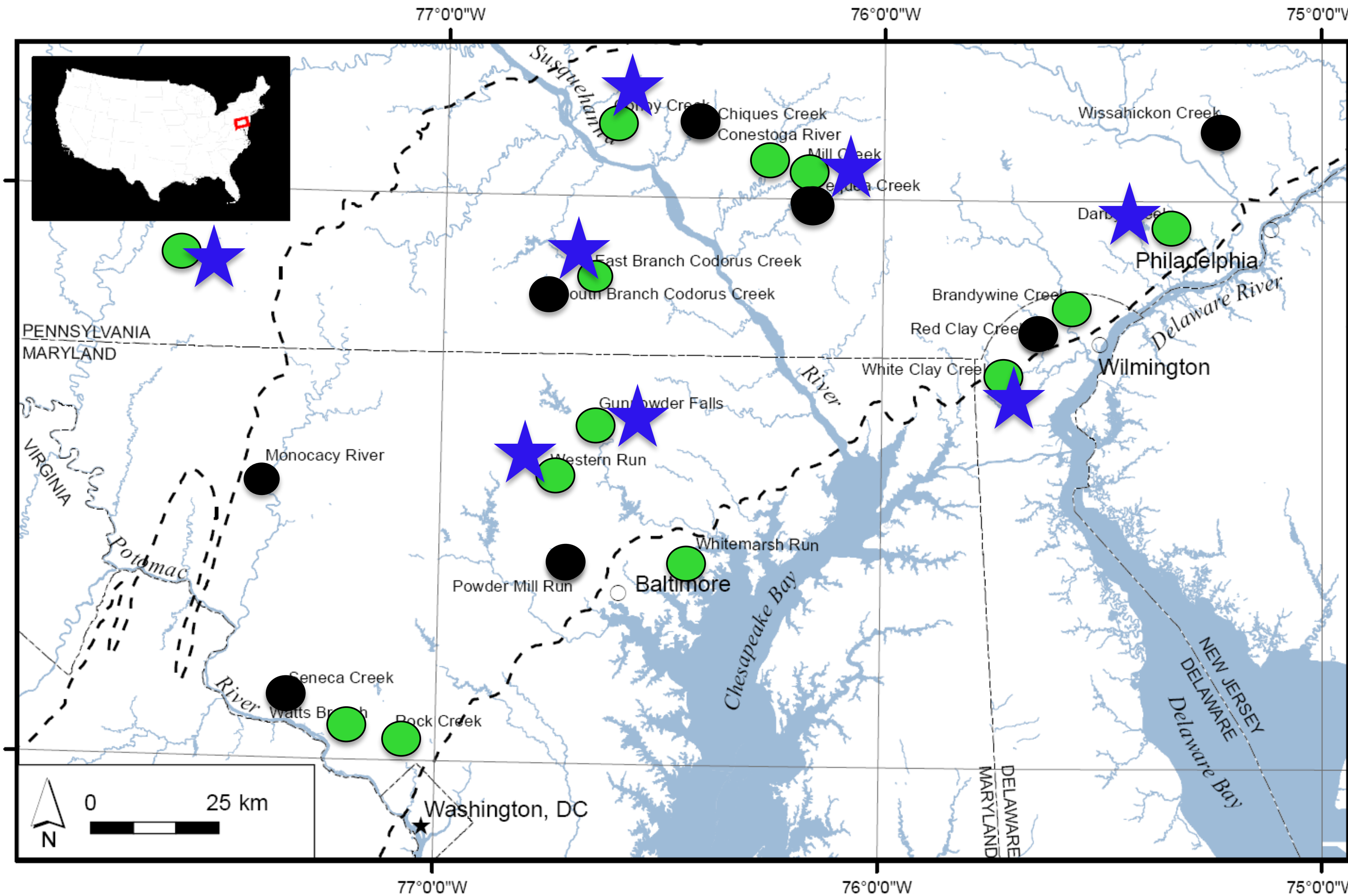
Paleoecologist C. Grand Pre and Palynologist C. Bernhardt

^{14}C Dates for Mid-Atlantic Buried Wetlands



70% of dates are AMS. All dates (Conventional and AMS) on individual pieces of organic material (e.g., seeds, nuts)

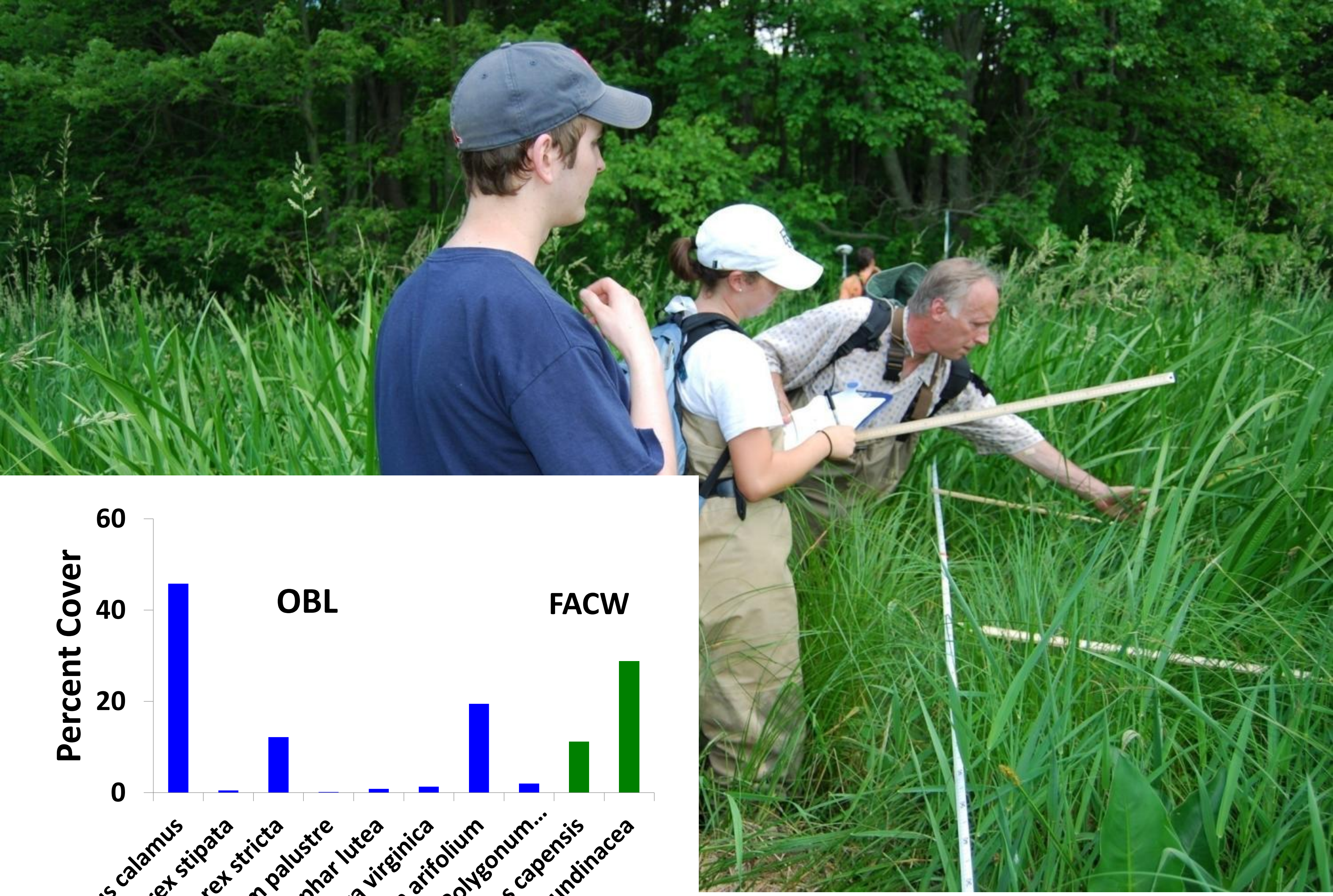
Study Region includes 21 Unglaciated Mid-Atlantic Watersheds
Drainage areas range from 4 to 150 km^2



Sites with radiocarbon age control

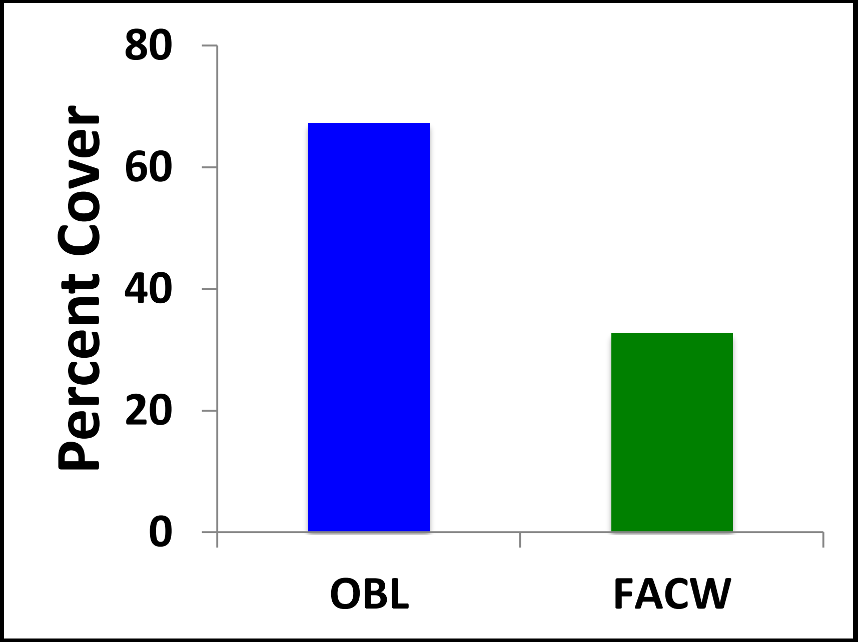
Sites with paleo-seed analysis

Holocene Wet Meadow Versus Historic Sediment Surface Vegetation

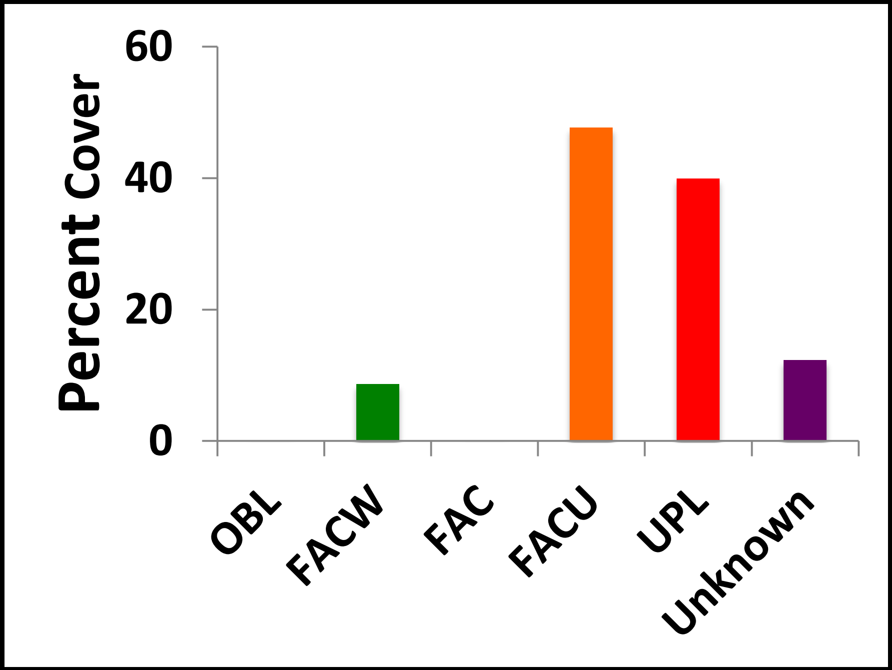


Great Marsh Transect 1

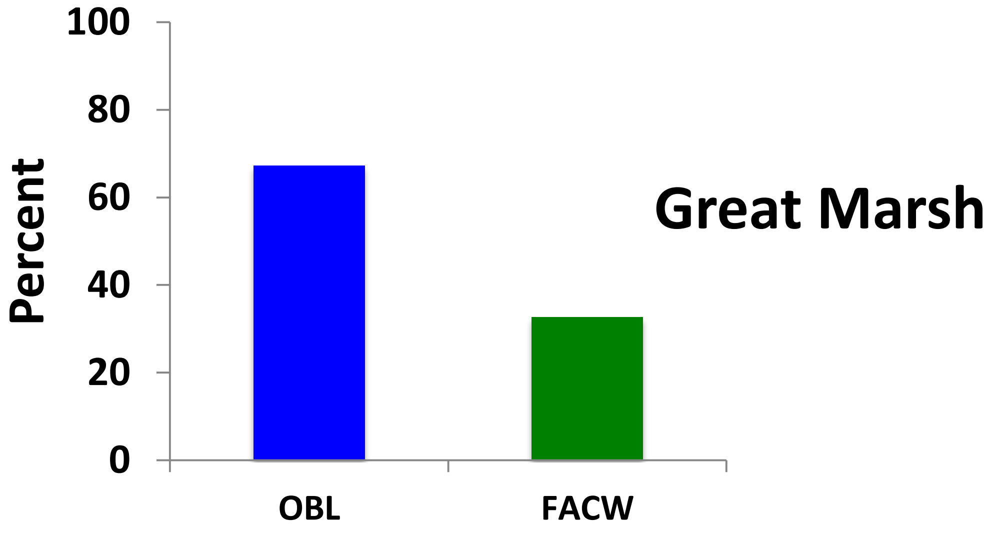
Great Marsh Wetland Indicator Status

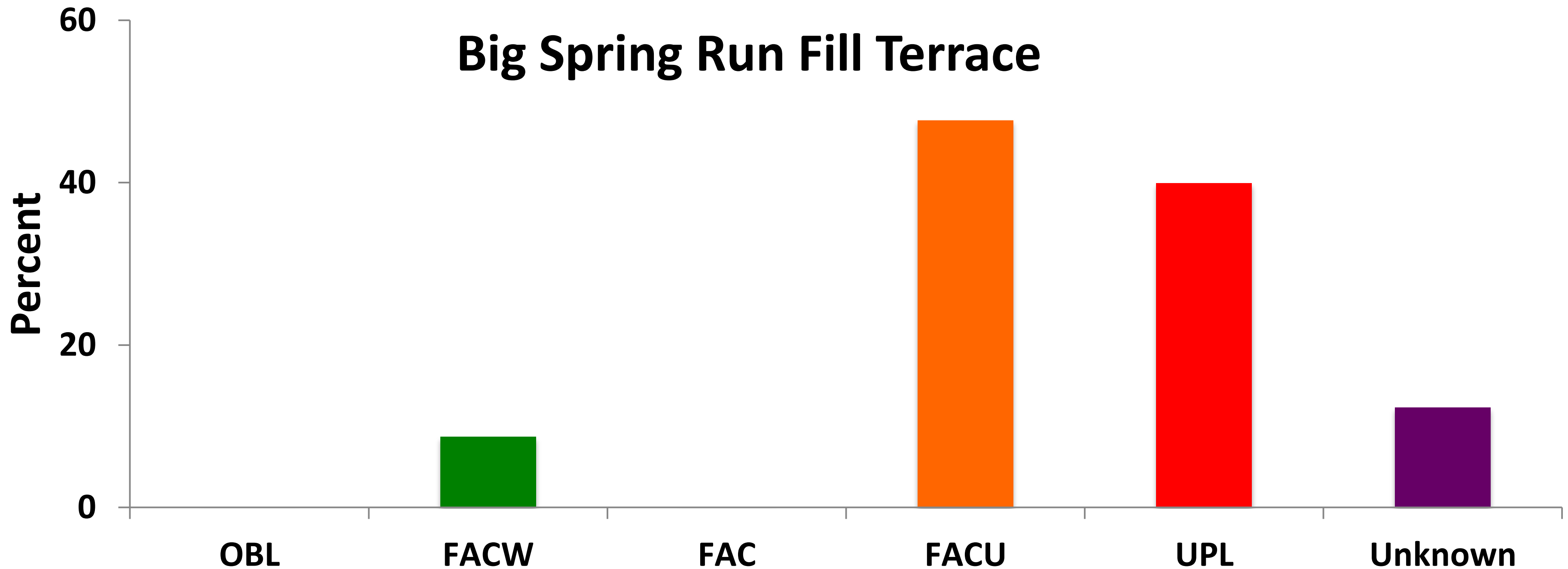


Big Spring Run
Wetland Indicator Status



Wetland Indicator Status



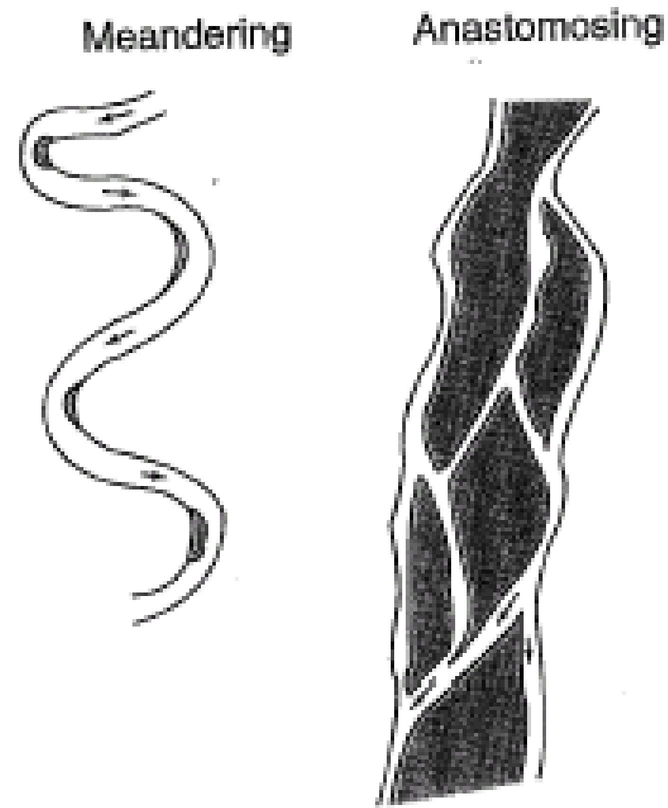


Implications of New Findings for Stream Restoration

Holocene Streams in Low-Relief Landscapes

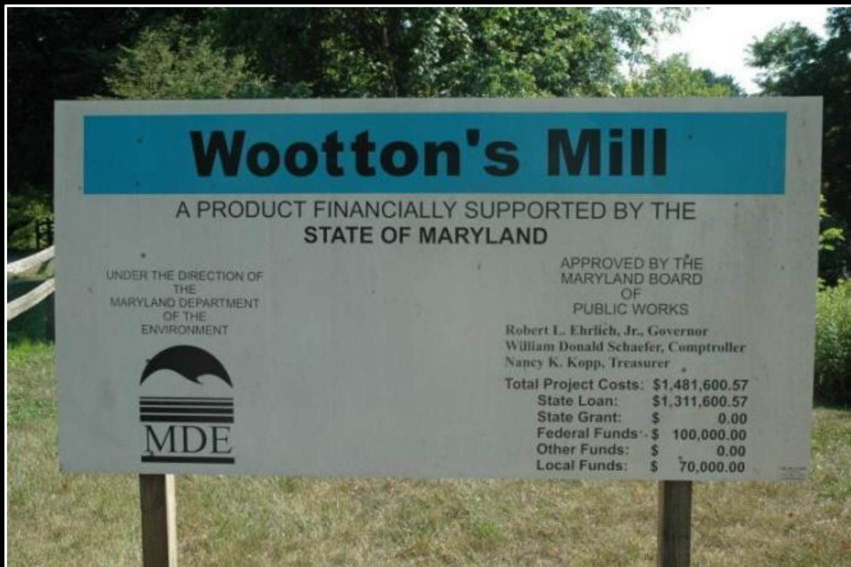
Although anabranching channels are considered relatively uncommon today, a review of archaeological, historic and geomorphological evidence indicated that anastomosing channels and floodplain wetlands ‘were formerly of considerable significance’ in lowlands of England and Wales [Lewin, p. 267].

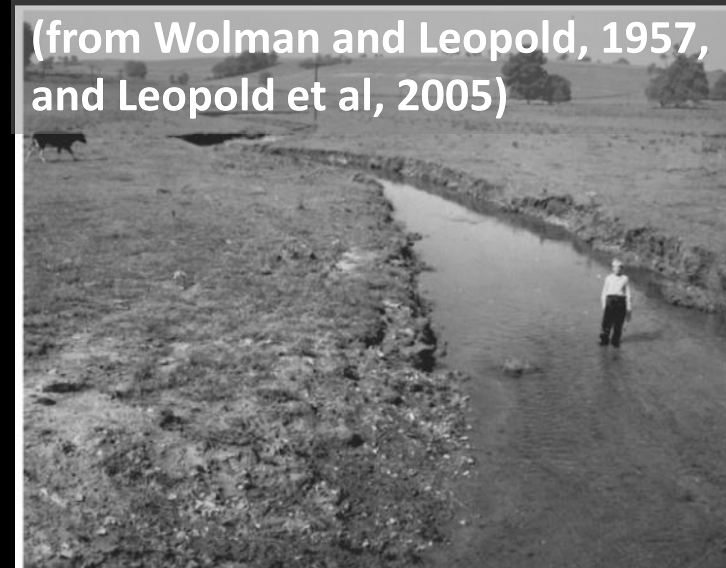
From Merritts et al, 2011, Anthropocene streams



Lewin, J. 2010 Medieval environmental impacts and feedbacks: The lowland floodplains of England and Wales. *Geoarchaeology* ***25, 267–311.***

Watts Branch, MD, 2 years after stream restoration, in 2007

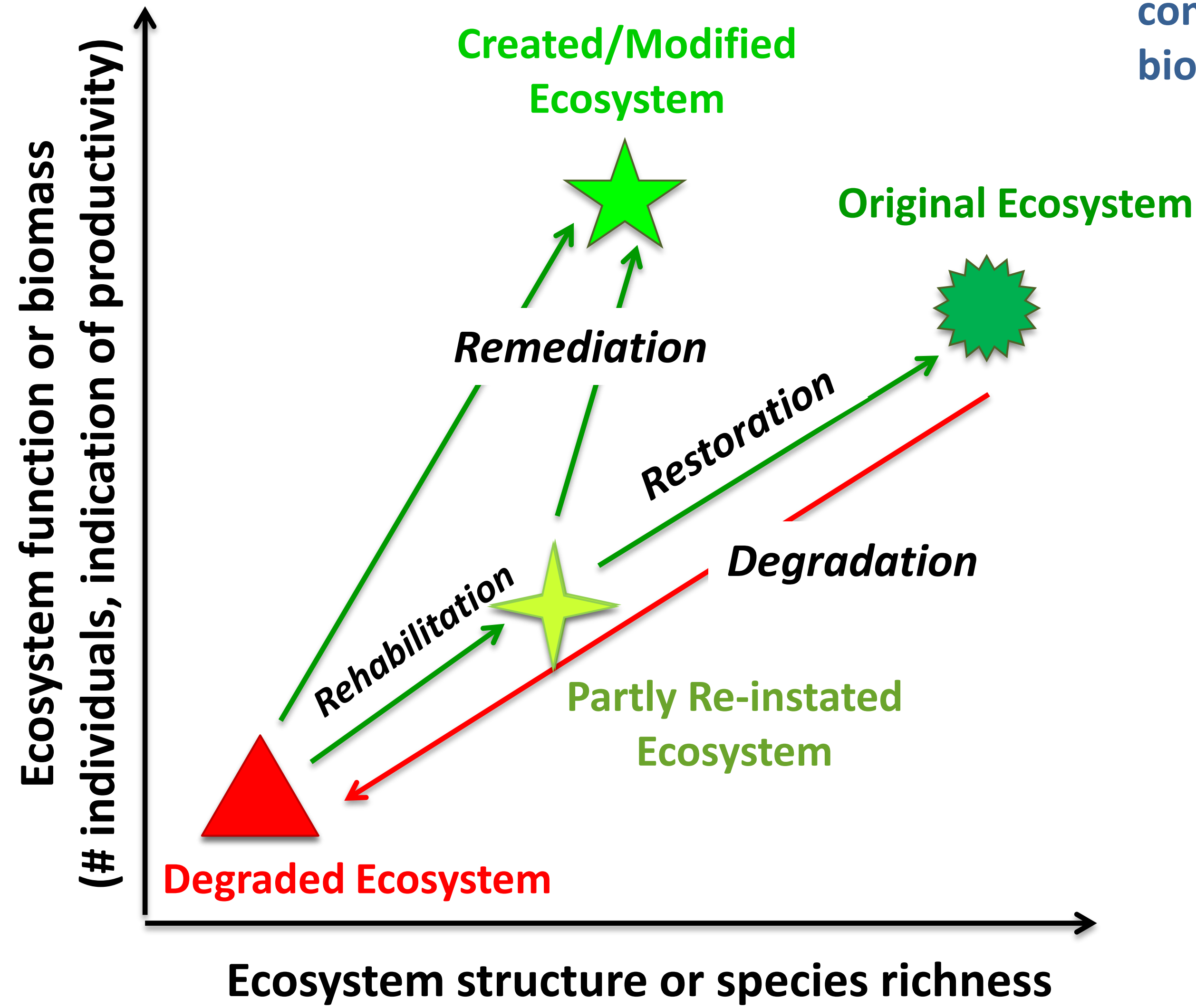




(from Wolman and Leopold, 1957, and Leopold et al, 2005)

~$1.5 million restoration

sides of shape signifies system complexity and biodiversity

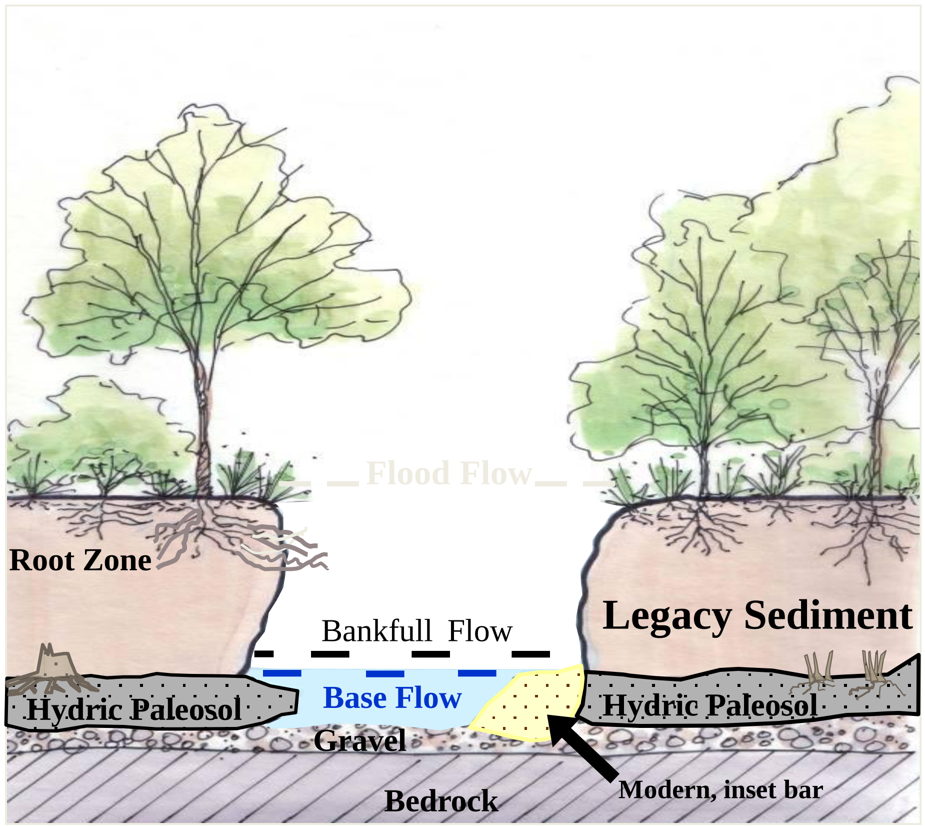


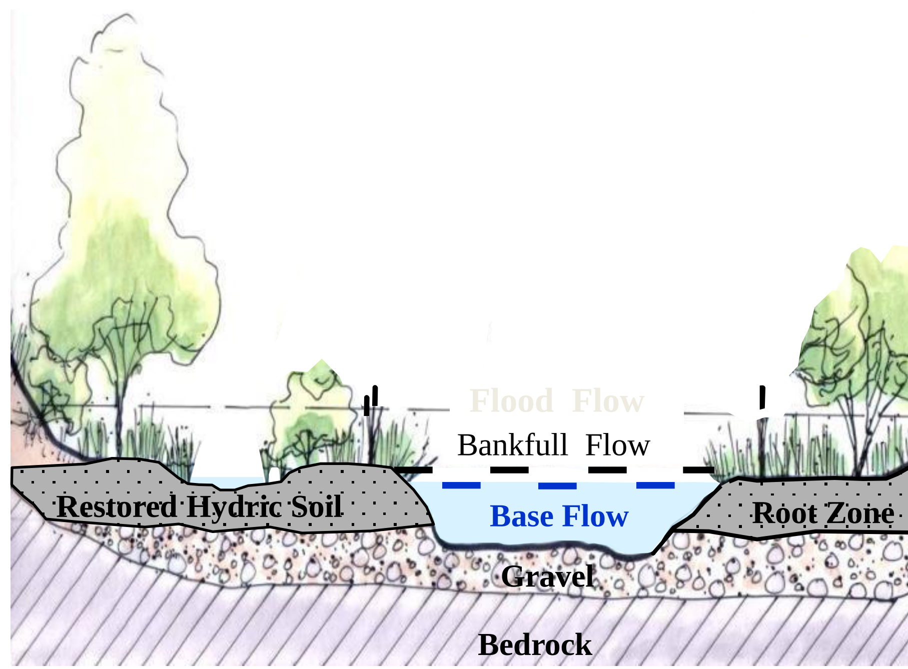
From: Findlay and Taylor, 2006, ***Why rehabilitate urban river systems?*** , Area, v. 38, p. 312-325. (Modified from Rutherfurd et al, 2000.)

Natural Floodplain, Stream and Riparian Wetland Restoration Best Management Practice

Conceptual Design

Typical Existing Conditions ⇨ **Proposed Restoration**





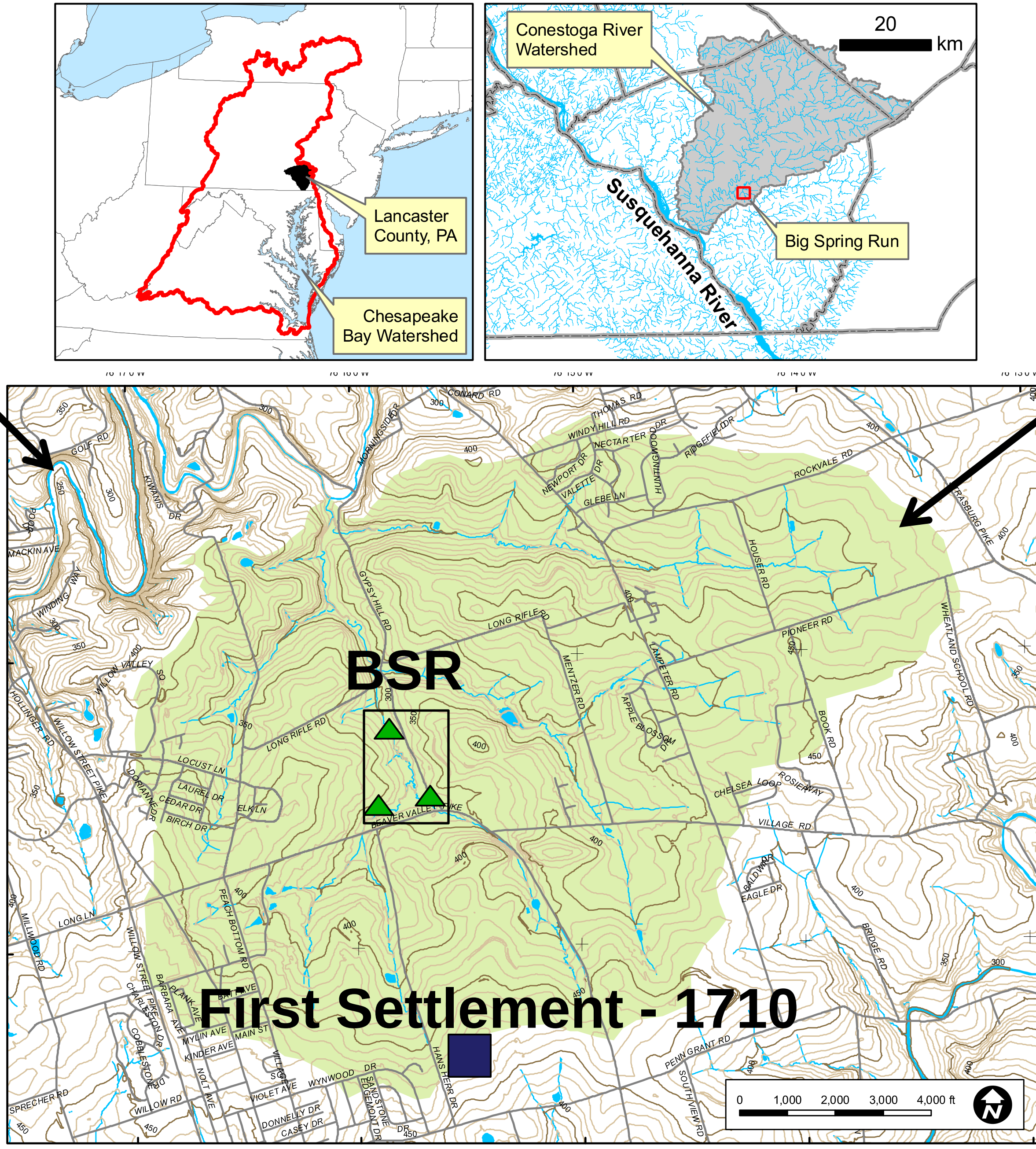
Existing Valley Morphology ⇨ **Natural Valley Morphology**

Big Spring Run, Lancaster County, PA

Mill Creek

USGS Gage stations

H. Herr house



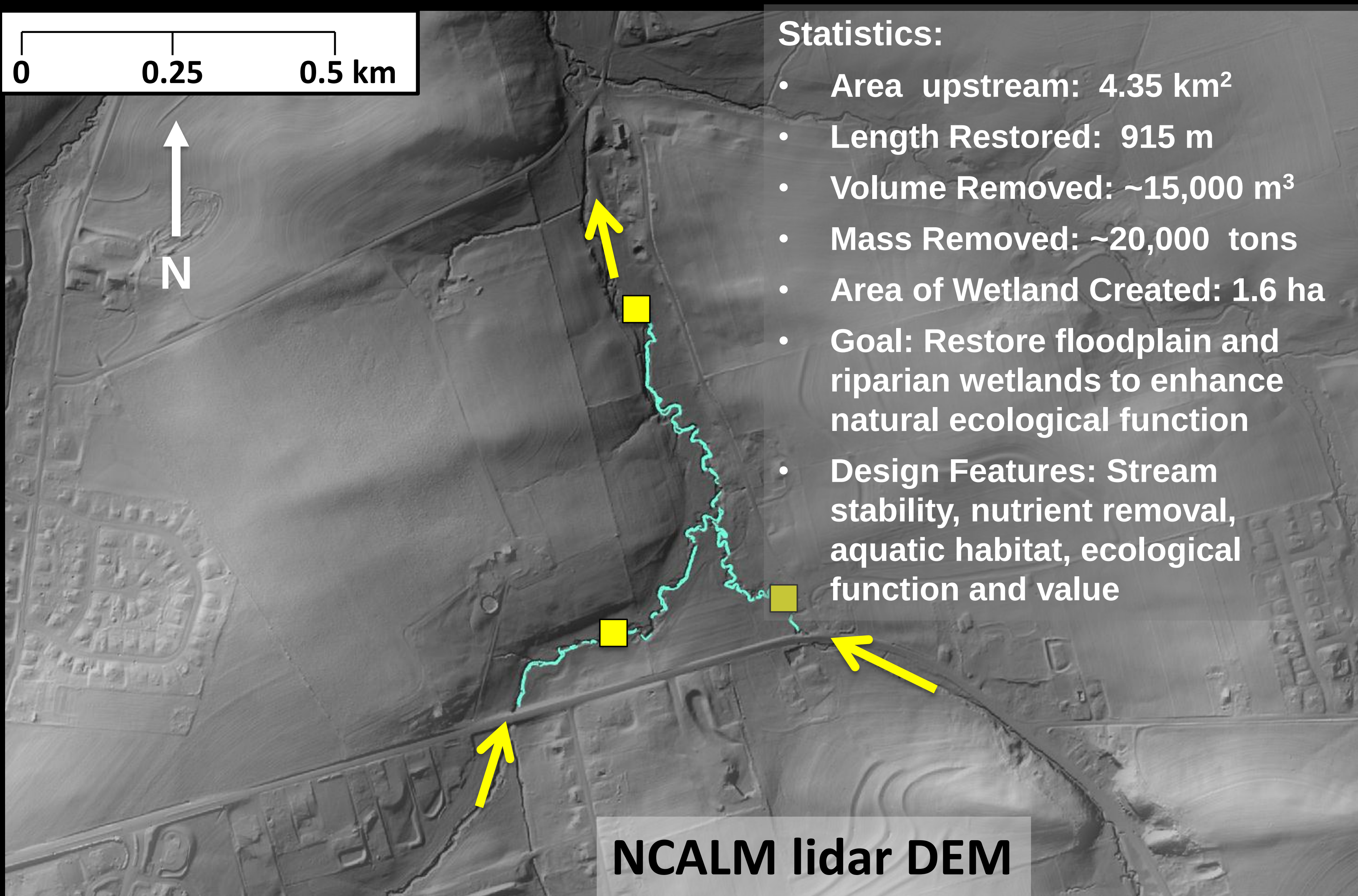
BSR Watershed ($15.0\ km^2$)

Big Spring Run: What is the cause of impairment?

- No urbanization
- Farm in no-till for 10 yr
- 4000 CREP trees planted in “riparian zone”, fewer than 24 survived ($17k)
- Despite existing BMPs, N, P, Sed loads remain high

Incised streams are conduits for transport of sediment and nutrients

Big Spring Run Floodplain/Wetland Restoration



Statistics:

- Area upstream: 4.35 km^2
- Length Restored: 915 m
- Volume Removed: ~15,000 m^3
- Mass Removed: ~20,000 tons
- Area of Wetland Created: 1.6 ha
- Goal: Restore floodplain and riparian wetlands to enhance natural ecological function
- Design Features: Stream stability, nutrient removal, aquatic habitat, ecological function and value

BSR Stream Bank Excavation

Began September 2011

Wetland-Floodplain Restoration Experiment, Big Spring Run, PA

Restoration by *LandStudies, Inc.*, Lititz, PA

Top: Big Spring Run pre-restoration (2011)
Bottom: Analog conditions and restoration goal (Great Marsh, SE PA)

Big Spring Run: Restoration Goals

Before Excavation

After Excavation

Objective 1: Reconnect the groundwater with buried hydric floodplain; design goal is frequent overbank flow

Objective 2: Remove the impairment… the eroding stream banks that contribute to high suspended sediment and nutrient loads.

Restoration by *LandStudies, Inc.*, Lititz, PA

Wetlands and Their Value

Banta Restoration (2004) on Lititz Run, Warwick Twp., Lancaster Co., PA

Ecosystem services they provide:

- Habitat for fish and wildlife
- Improved water quality
- Storing floodwaters
- Maintaining surface water flow
- Denitrification

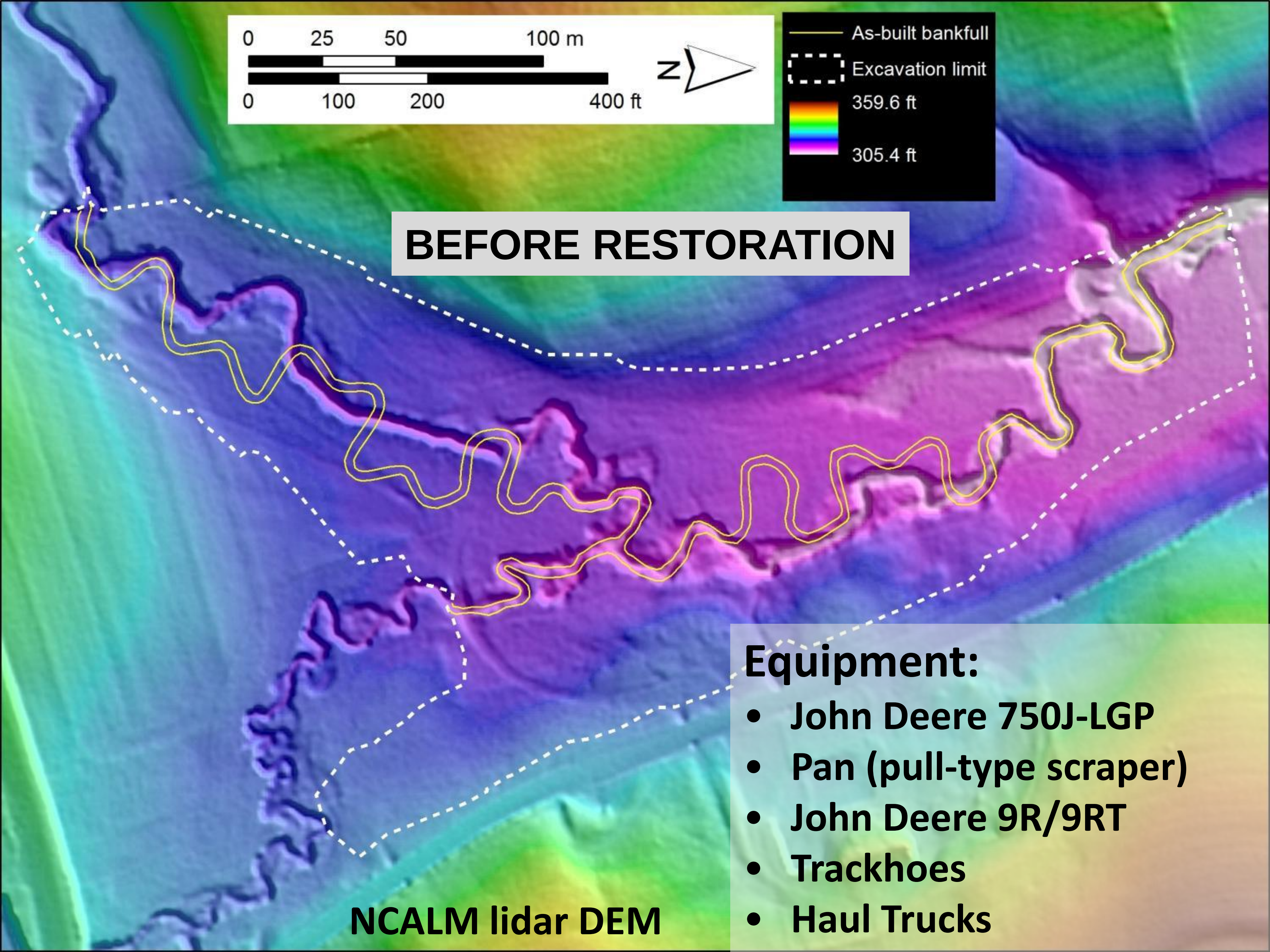
Objective 3: Rejuvenate the ecological function of the buried wetland.

Big Spring Run Floodplain Wetland Restoration

Completed November 2011- Designed and Engineered by LandStudies Inc.

Big Spring Run Floodplain Wetland Restoration

Completed November 2011- Designed and Engineered by LandStudies Inc.

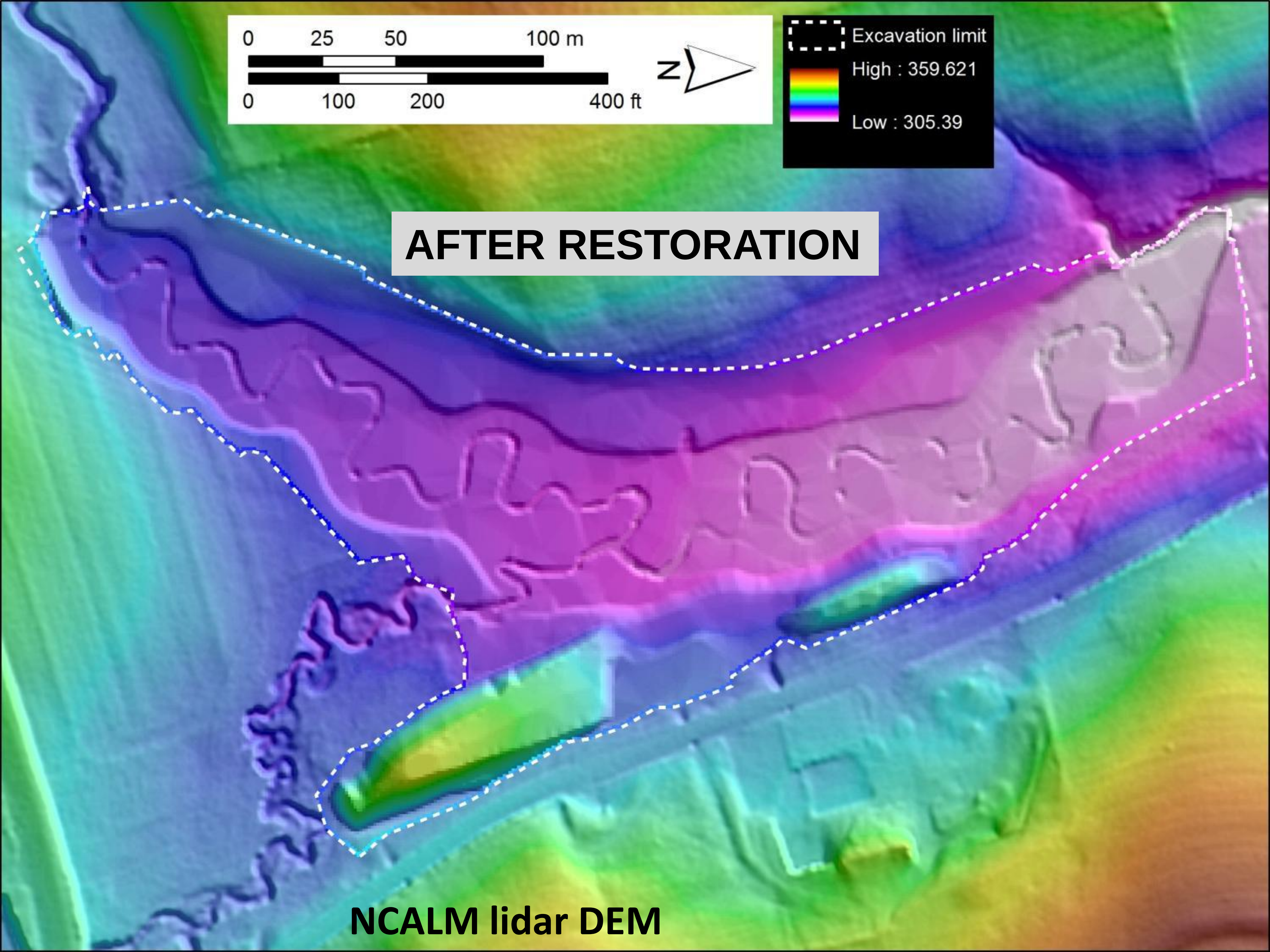


BEFORE RESTORATION

Equipment:

- John Deere 750J-LGP
- Pan (pull-type scraper)
- John Deere 9R/9RT
- Trackhoes
- Haul Trucks

NCALM lidar DEM

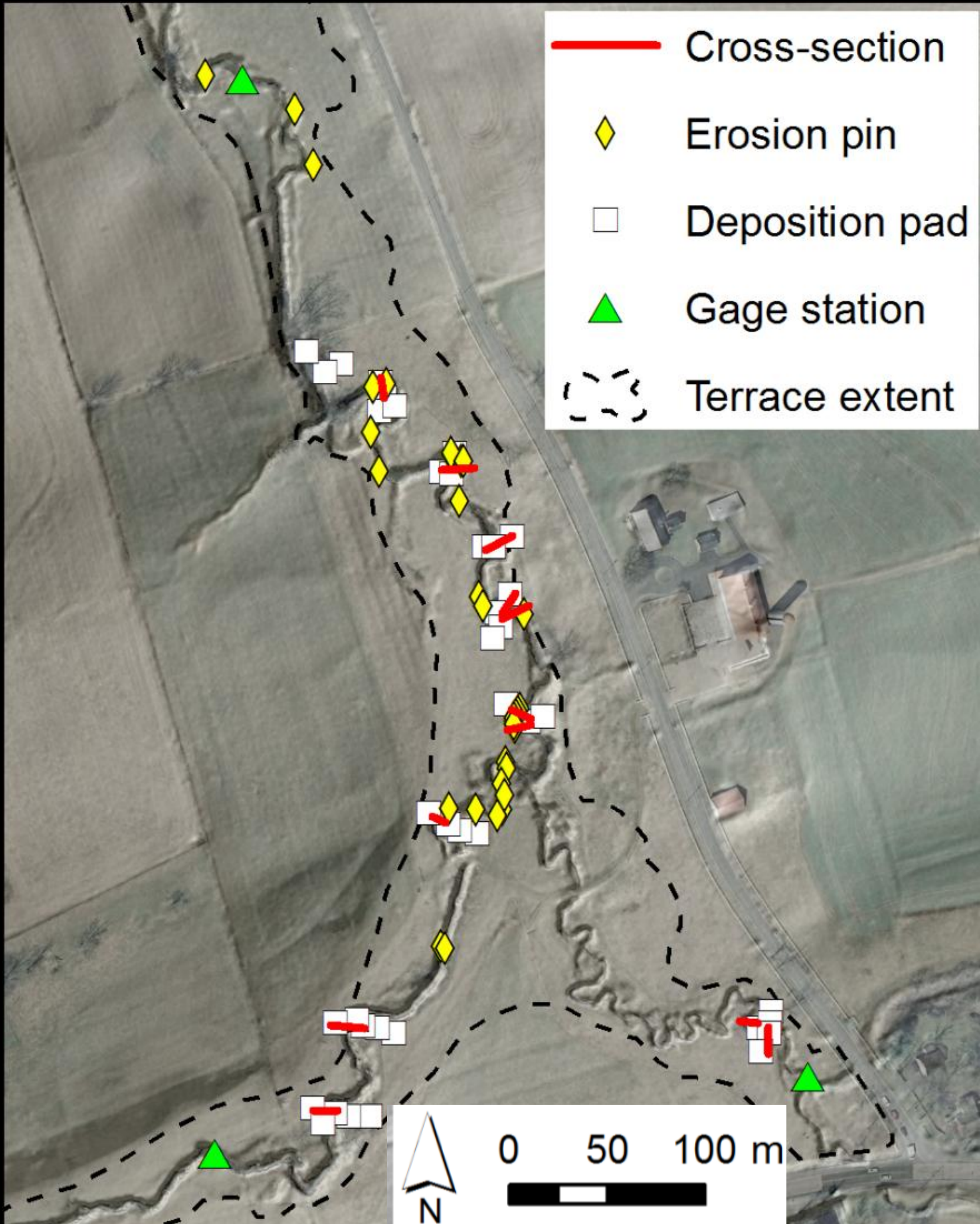


0 25 50 100 m
0 100 200 400 ft
N
Excavation limit
High : 359.621
Low : 305.39
AFTER RESTORATION
NCALM lidar DEM

Stream Restoration Targets* Applied to Big Spring Run

1. Hydrology – Slow down stream velocity
2. Add organic carbon
3. Reconnect floodplain wetlands with surface water and groundwater
4. Combine with infrastructure improvements: e.g., sewer line relocations

<u>*EPA/CBP Panel on Stream Restoration</u>



Ongoing Research at BSR

Collaborators include

- **37 researchers,**
- **11 institutions**
- **3 agencies**
  USGS (M. Langland, A. Gellis), PA DEP (J. Hartranft), EPA (P. Mayer, K. Forshay)
- **4 graduate**
- **~19 undergrad**
- **Restoration by *LandStudies, Inc.***

Legacy Sediment Removal/Riparian Wetland Restoration Best Management Practice

- The BMP proposed by PADEP is an ecological restoration and management strategy.
- Restoration and management actions are proposed to re-establish natural stream, wetland, floodplain and riparian conditions and functions.
- Monitoring at BSR and future implementation sites are necessary to fully quantify and document the BMP benefit (i.e., load reduction).
- Contact Jeff Hartranft, PADEP: jhartranft@pa.gov

… more information and definitions

www.state.pa.us

PA Keyword : Chesapeake Bay

Workgroup Products

Legacy Sediment Workgroup

Acknowledgements

Funding:
Franklin and Marshall College, PA Dept of Environmental Protection, PA Chesapeake Bay Commission, EPA, and NSF (MRI and NCALM)

Professional Collaborators:
Karen Mertzman (F&M), Jeff Hartranft (PA DEP), Bill Hilgartner (Johns Hopkins University, Milan Pavich, Allen Gellis, and Mike Langland (*USGS*), Scott Cox (PA DEP), Ward Oberholtzer, Mark Gutshall, and Drew Altland (Landstudies, Inc.), Rob Sternberg (F&M), Jerry Ritchie (deceased, USDA), Noel Potter (Dickinson College), Art Parola (Univ. Louisville), Paul Mayer and Ken Forshay (EPA), Hannah Jantzi and Candace Grand Pre (F&M), Stroud Water Research Center

Student Collaborators:
Lauren Manion ‘04, Graham Boardman ‘05, Christina Arlt ’05, Caitlin Lippincott ‘05, Sauleh Siddiqui ‘07, Yoanna Voynova ‘06, Andrey Voynov ‘05, A. Sullivan ‘06, Adam Ross ‘07, Mark Voli ‘08, Chris Scheid ‘08, Zach Stein ‘08, Julie Weitzmann ‘08, Colette Buchanan ’08, Doug Smith, ‘08, Alison Winterer, ‘09, Zain Rehman ‘09, Brian Hughes, ‘09, Erik Ohlson ‘10, Franklin Dekker ‘10, Stacey Sosenko ‘09, Liz Cranmer ‘09, Matt Jenschke ’09, Wanlin Deng ‘12, Katie Datin ‘12, Laura Kratz ’11, Andrea Shilling, ‘10, Yupu Zhao, ’10, Derek Matuszewski, ‘10, Austin Reed, ‘10, Alex DiIonno, ‘10, Erik Olsen, ‘11, Ali Neugebauer, ’11, Elvis Andino, ‘12, Peter Rippberger, ‘12, Aakash Ahamed, ‘12, Conor Neal, ’12, Danielle Verna , ‘12, and Joe Galela, ‘11.

Landowners
Joe Sweeney, Kirchner Family, and H. Keener (Big Spring Run), Don and Roseann Mann (Little Conestoga), Moore Family (Marsh Creek), Stroud Water Research Center (White Clay Creek), Hempt Quarry, Pine Grove Furnace State Park, and Mt Holly Nature Conservancy (Mt. Creek)

Special Thanks to Cheryl Shenk, Photographer