Big Spring Run Floodplain/Wetland Restoration

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www.bsr-project.org

Maryland DNR Stream Information Exchange, November 15th, 2017

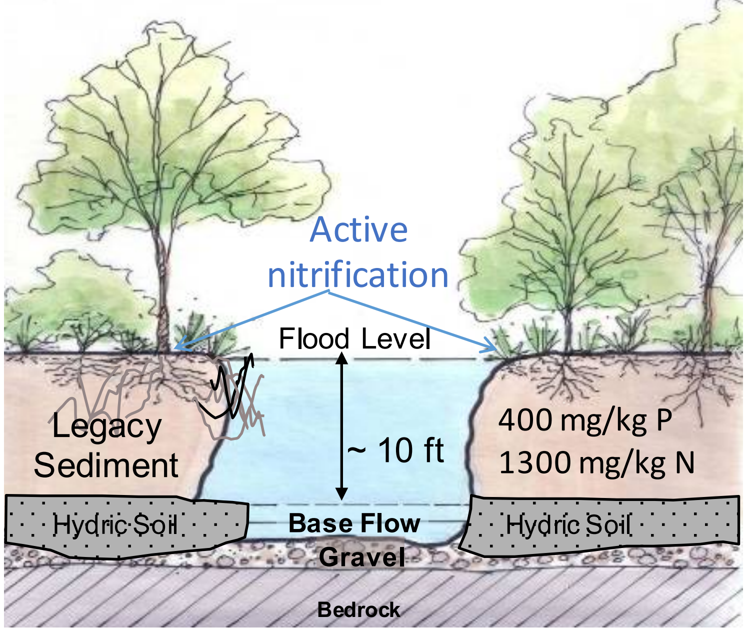
After (June 2013)

Before (April 2004)

BSR Legacy Sediment Removal – Floodplain-Wetland Ecosystem Restoration

Existing Condition

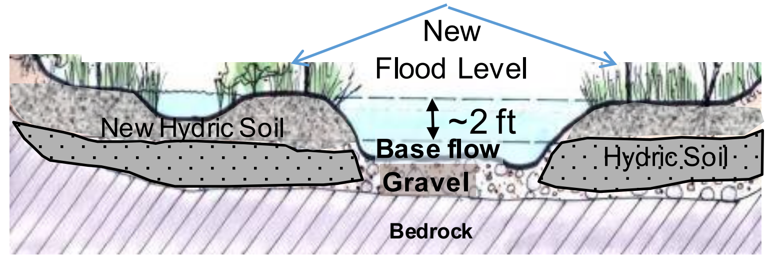
Mesic Wasteland



Low DOC & deN, high N, P & Sed

Restoration Target

Tussock-Sedge Wet Meadow



Increase DOC & deN, reduce N, P & Sed

Acknowledgements

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

Professional Colleagues:
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 (Landstudies, Inc.), Drew Altland (RKK), Andrew Donaldson (JMT), Rob Sternberg (F&M), Jerry Ritchie (deceased, USDA), Art Parola (Univ. Louisville), Paul Mayer and Ken Forshay (EPA), Candace Grand Pre (F&M), Lou Kaplan (Stroud Water Research Center), Laurel Larsen (Univ. of California, Berkeley), Jason Kaye, Julie Weitzman and Peter Wilf (Penn State).

Student Colleagues:
Lauren Manion '04, Graham Boardman '05, Christina Arlt '05, Caitlin Lippincott '05, Sauleh Siddiqui '07, Yoanna Voynova '06, Andrey Voynov '05, Alexandra Sullivan '06, Adam Ross '07, Mark Voli '08, Chris Scheid '08, Zach Stein '08, Julie Weitzmann '08, Colette Buchanan '08, Douglas 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, Joe Galella, '11, Erik Olsen, '11, Ali Neugebauer, '11, Elvis Andino, '12, Peter Rippberger, '12, Aakash Ahamed, '12, Conor Neal, '12, Danielle Verna , '12, Jordan Appleyard, '13, Kayla Schulte, '13. Aaron Blair, '13, Erin Peck, '14, Xinyu Deng, '15, Amber Carter, '15, & Peter Limberg, '16, Yuning Bai, '17.

Landowners:
Sweeney Family, Kirchner Family, Fry Family, Keener Family, Houser Family & Groff Family (Big Spring Run), Don and Roseann Mann (Little Conestoga), Moore Family (Marsh Creek), Stroud Water Research Center (White Clay Creek).

Stream Restoration Targets*
Applied to Big Spring Run

i. Reduce suspended sediment load - reduce TSS & TP

ii. Increase surface water retention time on floodplain

iii. Add DOC – enable frequent overbank flow to interact with DOC

iv. Attenuate flows – slow water velocity

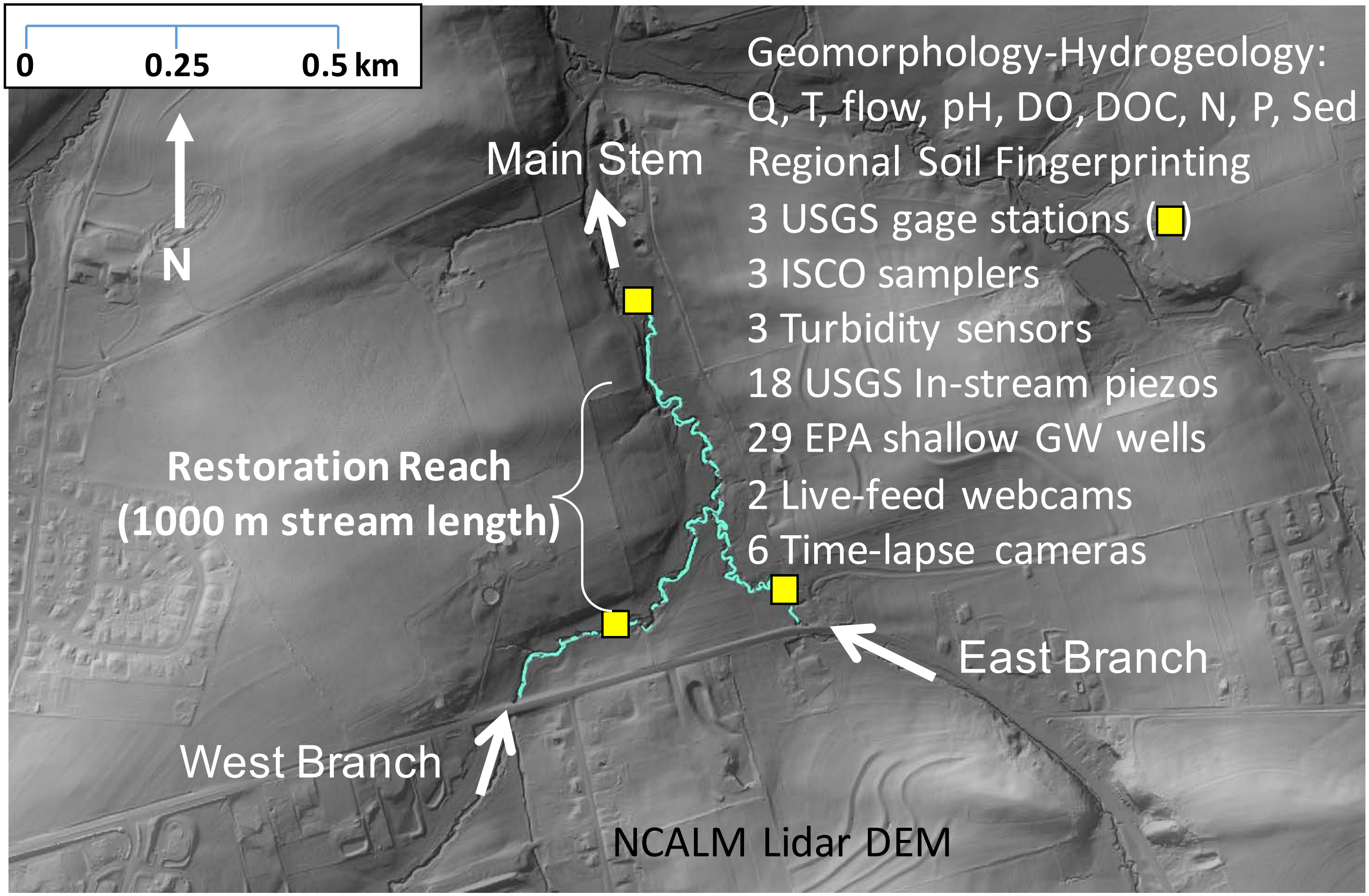
v. Reconnect floodplain wetlands with surface water and groundwater – enable denitrification of NO_3-N (via ii-v)

*Recommendations of EPA/CBP Expert Panel on Stream Restoration (2014)
Sections 3.2 and 3.3

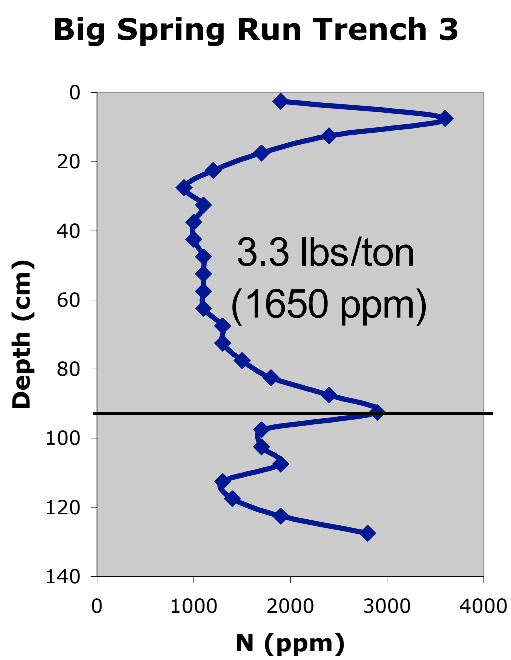
BSR Sediment and Nutrients

1. Composition of Streambanks and Upland Soils
2. Pre-restoration sources of sediment (suspended sediment load)
3. Pre-restoration nitrogen and phosphorus dynamics
4. Post-Restoration sources of sediment (deposition on floodplain)
5. Post-restoration nitrogen, phosphorus and carbon processing

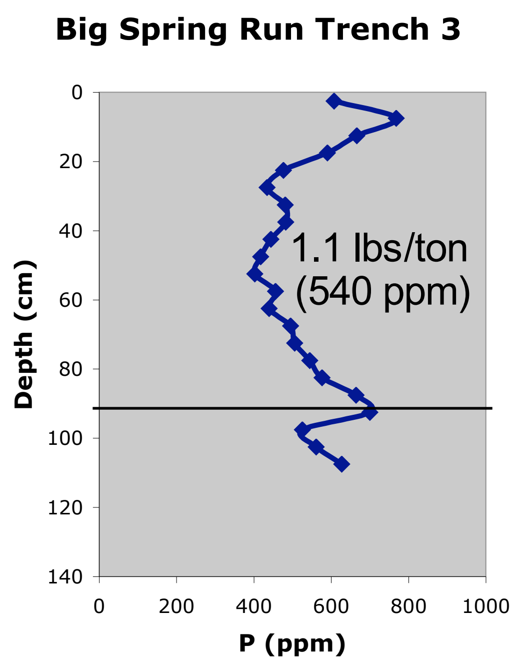
Pre-Restoration Monitoring – 2008-2011



Pre-Restoration Nutrient Contents of Stream Banks



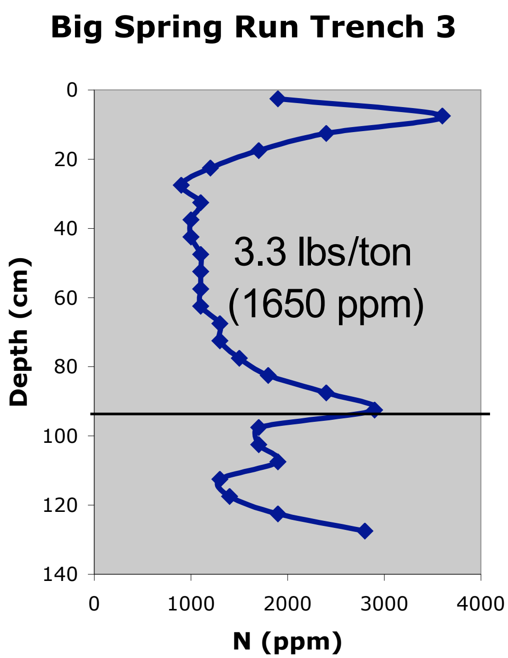
Total Nitrogen (ECA)



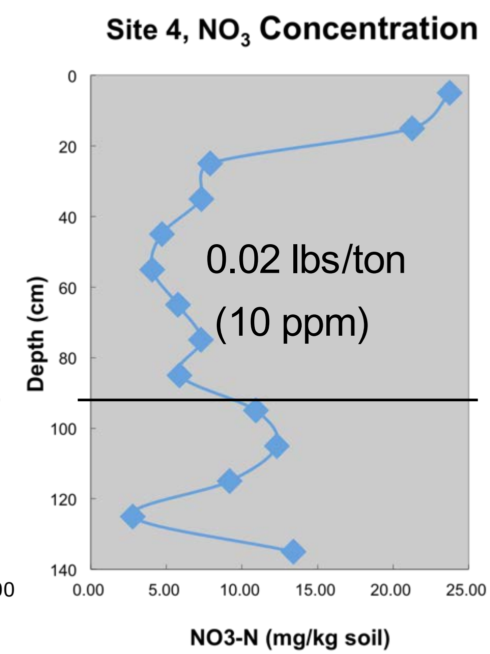
Total Sorbed Phosphorus (ICP/EPA 3051)

Voynova 2006 & Weitzman 2008, Franklin and Marshall College BA Theses

Pre-Restoration Nitrate-N in Stream Banks



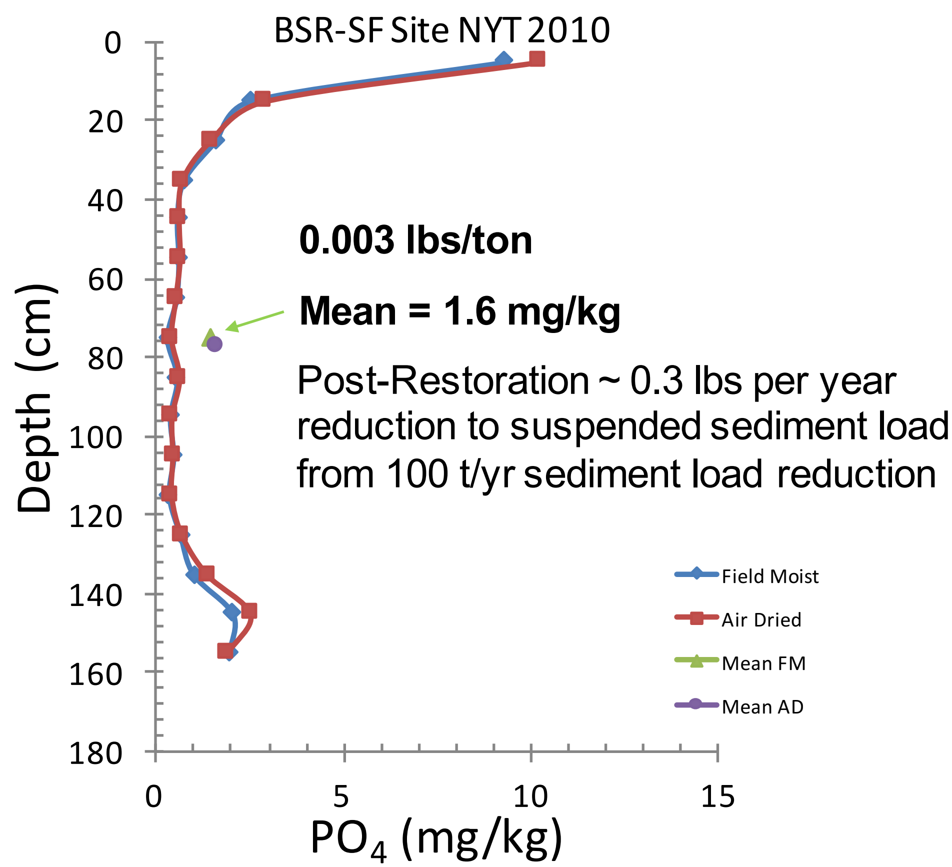
Total Nitrogen (ECA)



Nitrate-N
(KCl-Extraction)

Zhao 2010, Franklin and Marshall College BA Thesis

Pre-Restoration Orotho-Phosphate in Stream Banks

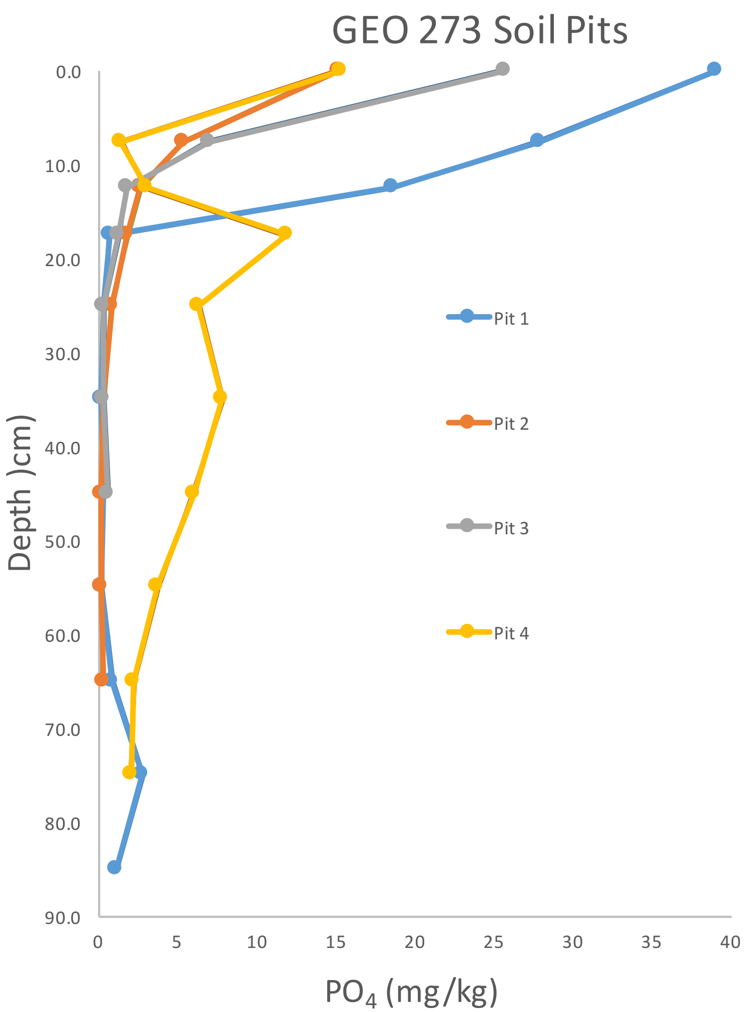


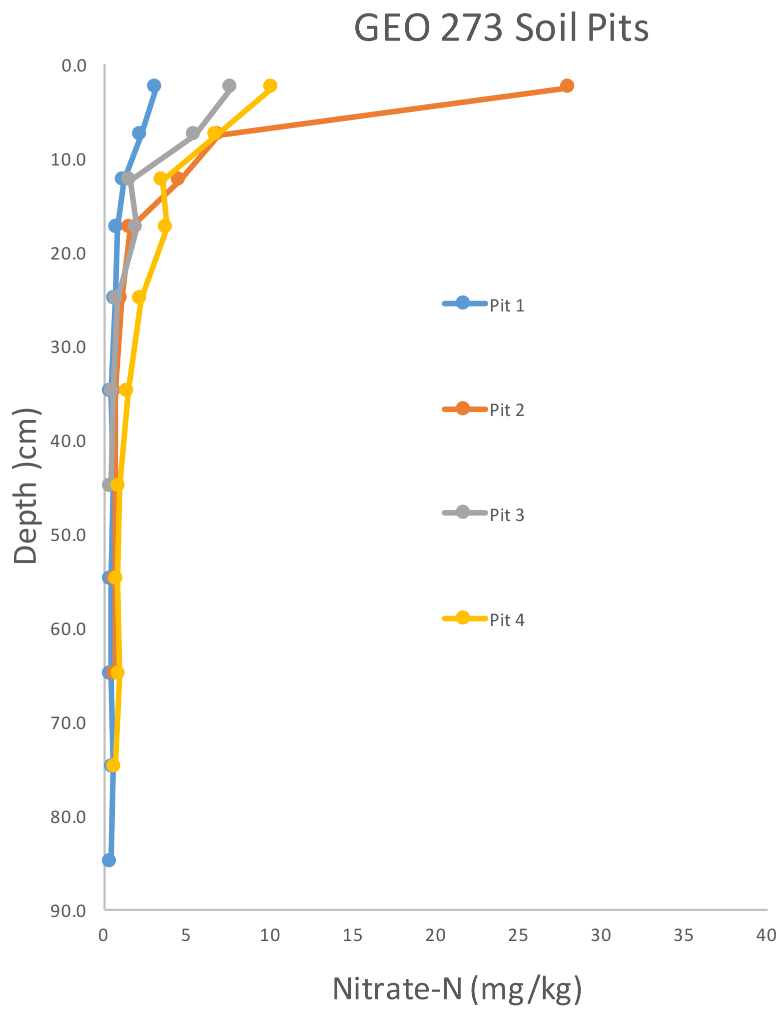
Fullinwider, 2010 Franklin and Marshall College BA Thesis

Nutrient Analyses of Upland Soils Adjacent to Big Spring Run

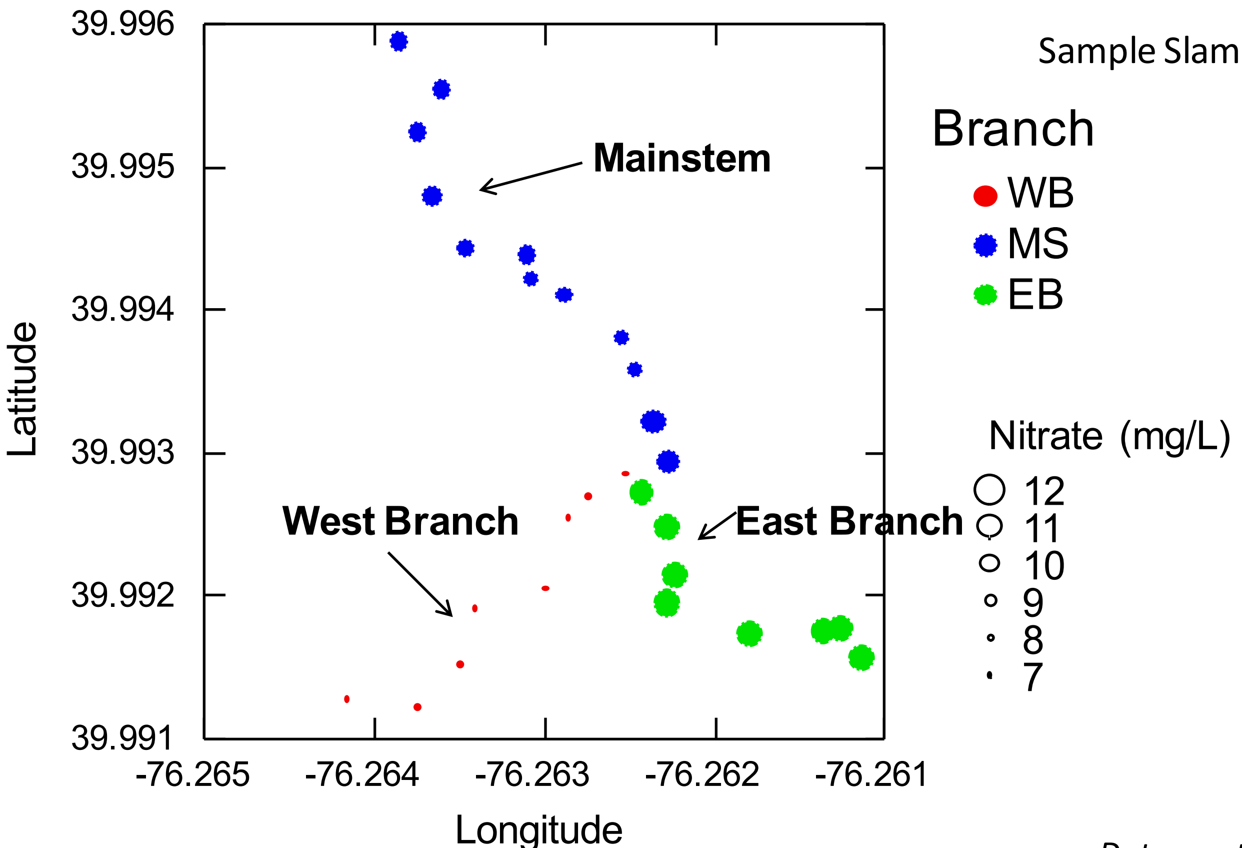
GEO 273 Landscape Geochemistry Soil Pits 1-4, 9/29/08

Nutrient Content of Upland Soils Adjacent to Big Spring Run





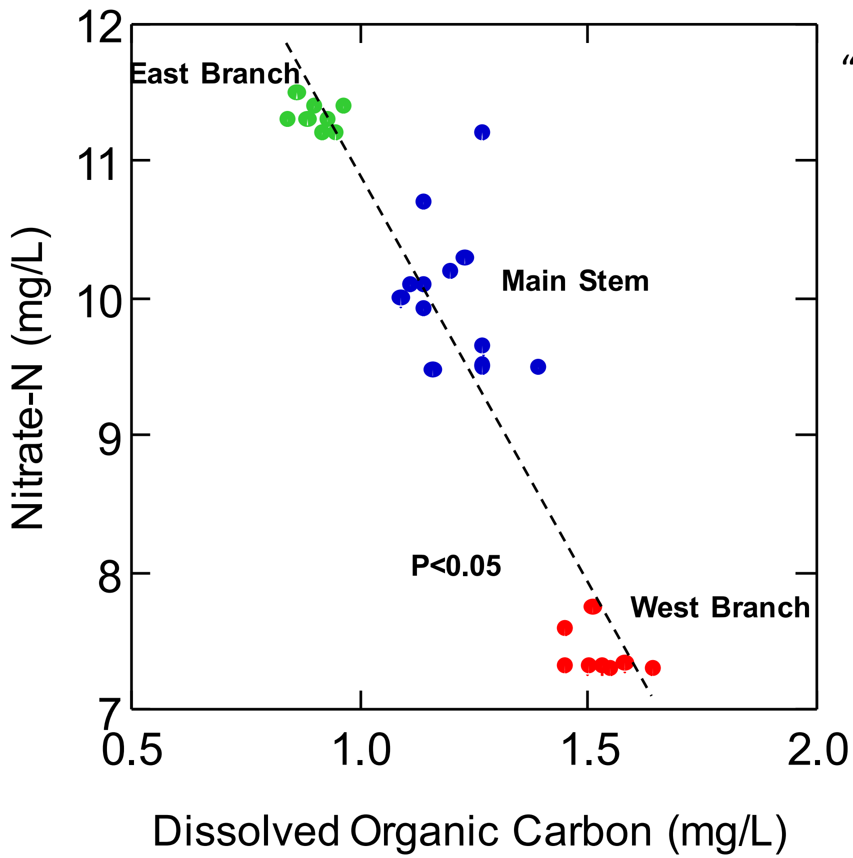
Pre-Restoration Surface Water Nitrate-N differs by branch, and mixes to an average concentration in the Main Stem



Sample Slam April 7, 2010

Data courtesy of Paul Mayer, EPA

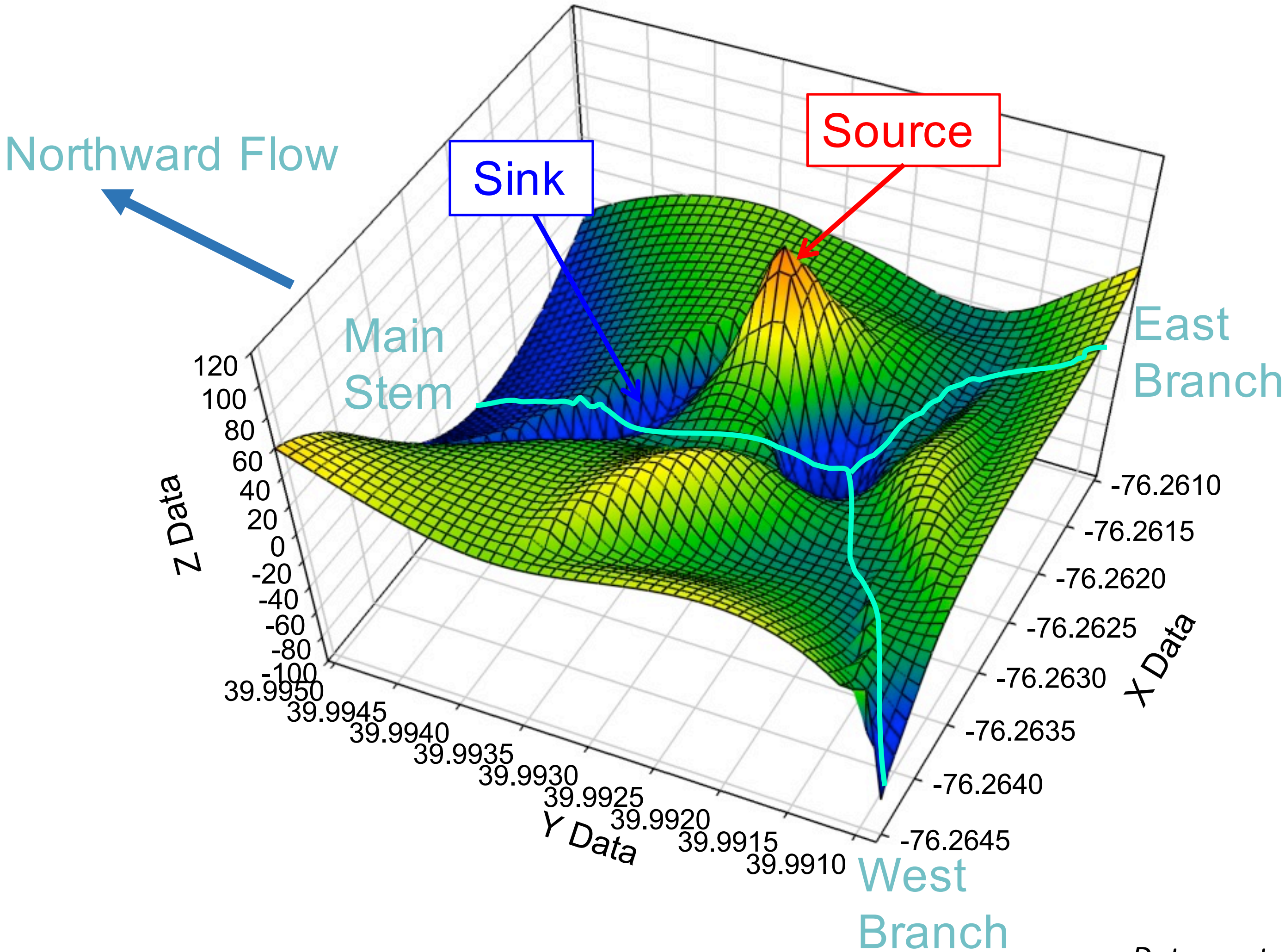
Pre-Restoration Nitrate and DOC are inversely related – due to denitrification?



“Sample Slam” April 7, 2010

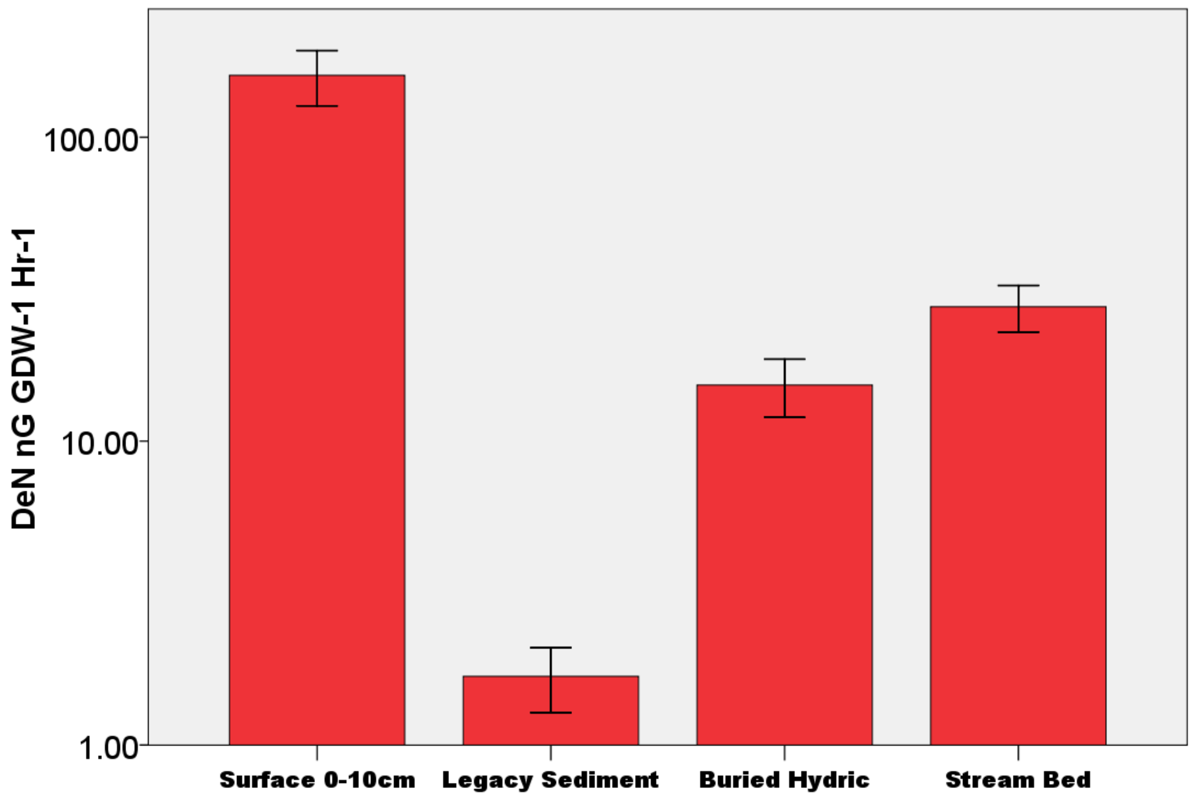
Data courtesy of Paul Mayer, EPA

Groundwater Nitrate Sources & Sinks at BSR



Data courtesy of Paul Mayer, EPA

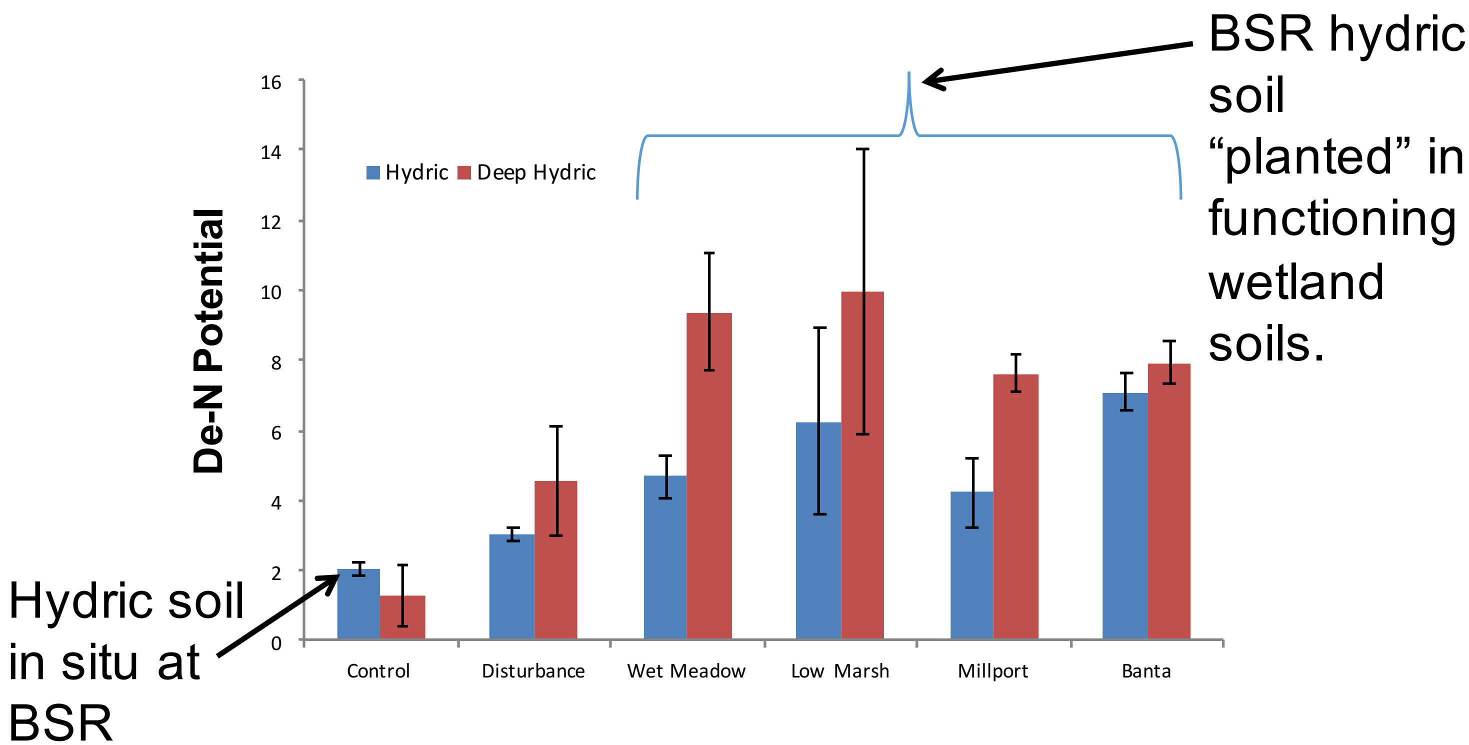
Pre-Restoration buried hydric soils have greater DeN rates and DeN potential than Legacy Sediments.



Error bars ± 1 s.e.
n = 72 p<0.05

Source: Forshay et al 2016 (Ecological Society of America)

Pre-Restoration Denitrification Potential of Buried Hydric Soil



J. Koval, MSc Thesis Results, U. Illinois, 2011

Data courtesy of Ken Forshay, EPA

Total C & N in Stream Bank Sediments

%C

%N

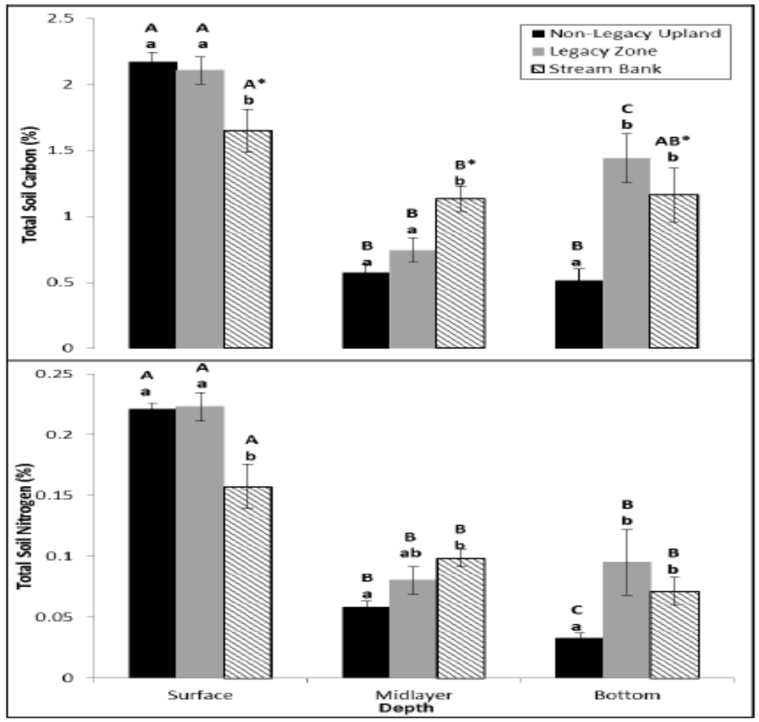


Figure 4-1: Total soil carbon and total soil nitrogen expressed as averages across landscape positions and depths. Vertical bars denote one standard error of the mean. For a given depth, bars with different lowercase letters represent statistically significant ($p < 0.05$) differences between land positions. For a given land position, bars with different uppercase letters represent statistically significant ($p < 0.05$) differences with depth. At the stream bank landscape position depth was not statistically significant ($p = 0.071$) for total soil carbon, but a post-hoc test was still performed.

Weitzman 2011, MSc Thesis, Penn State University; and Weitzman et al., 2014, Potential nitrogen and carbon processing in a landscape rich in milldam legacy sediments. Biogeochemistry, 120, pp 337–357

Nitrification Potential of Stream Bank Sediments

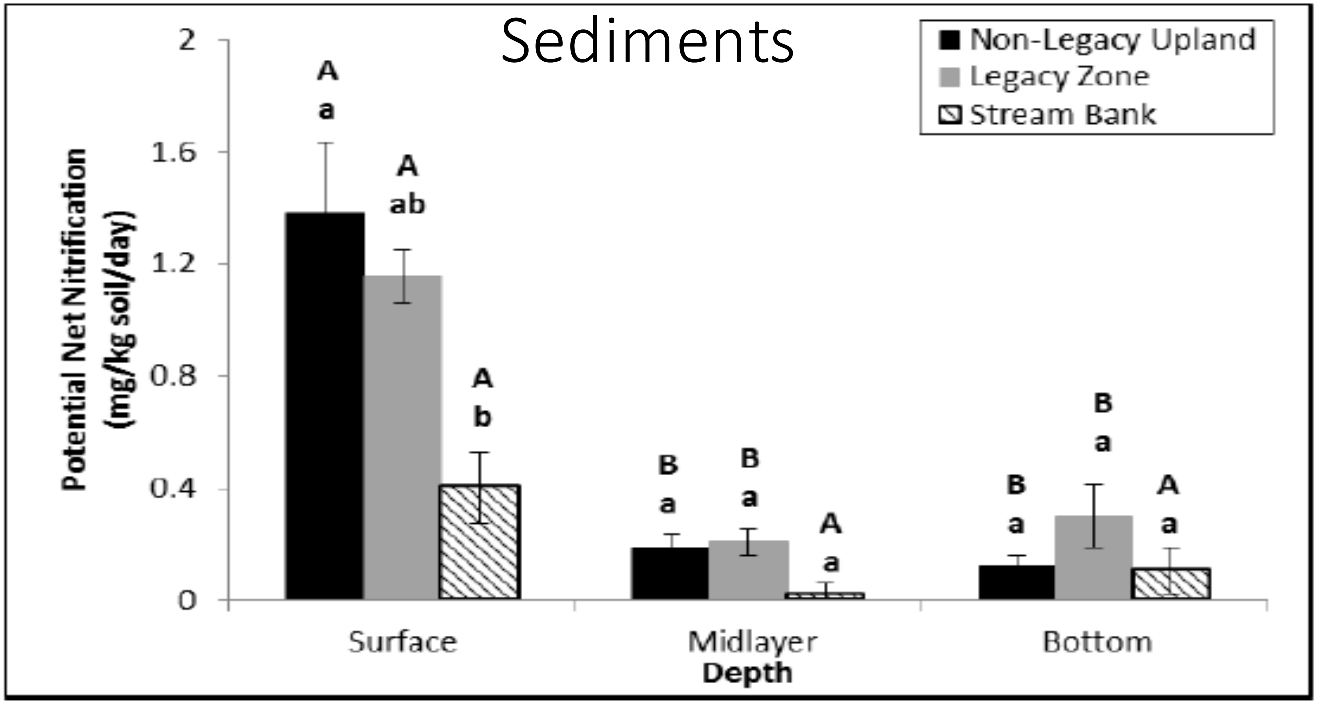
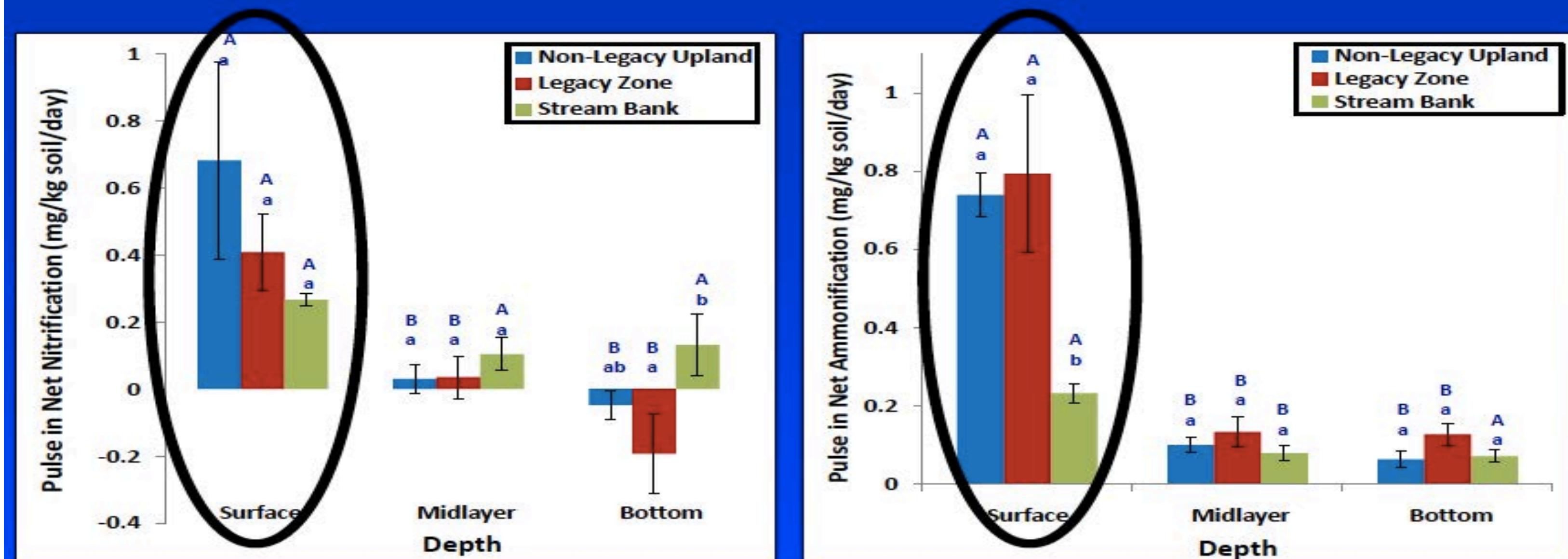


Figure 4-2: Potential net nitrification rates expressed as averages across landscape positions and depths. Vertical bars denote one standard error of the mean. For a given depth, bars with different lowercase letters represent statistically significant ($p < 0.05$) differences between land positions. For a given land position, bars with different uppercase letters represent statistically significant ($p < 0.05$) differences with depth.

Weitzman 2011, MSc Thesis, Penn State University; and Weitzman et al., 2014, Potential nitrogen and carbon processing in a landscape rich in milldam legacy sediments. Biogeochemistry, 120, pp 337–357

NO_3^- pulses in the surface soils of the uplands and legacy zone coincided with an increased pulse in NH_4^+

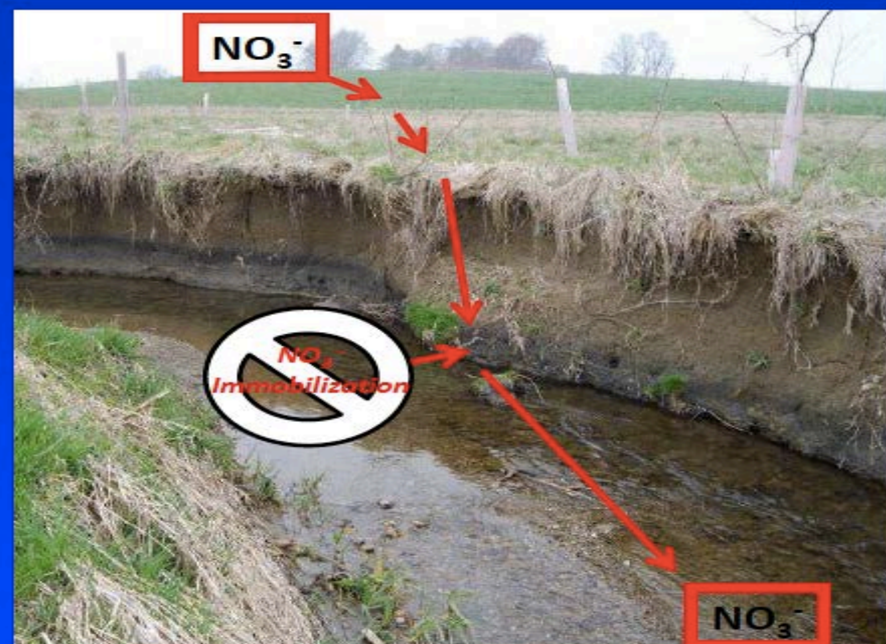


Weitzman 2011, MSc Thesis, Penn State University; and Weitzman et al., 2014, Potential nitrogen and carbon processing in a landscape rich in milldam legacy sediments. Biogeochemistry, 120, pp 337–357

In conclusion, legacy sediments have the potential to release high concentrations of NO_3^- to nearby streams following dry-rewetting events

NO_3^- that is generated in surface soils is not being filtered in the buried hydric soil:

- Low C activity
- Not strong NO_3^- immobilization
- Low denitrification rates

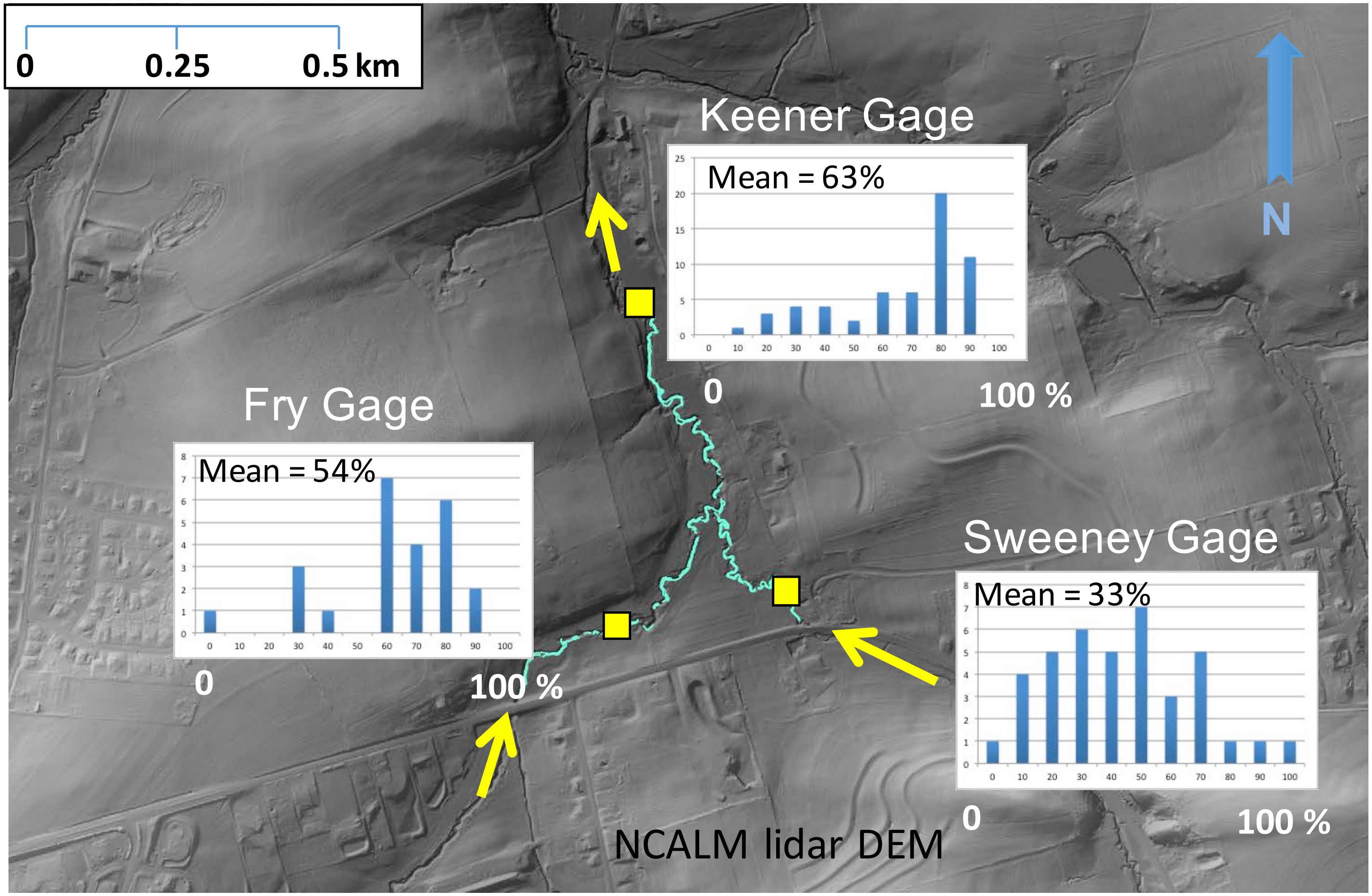


Weitzman 2011, MSc Thesis, Penn State University; and Weitzman et al., 2014, Potential nitrogen and carbon processing in a landscape rich in milldam legacy sediments. Biogeochemistry, 120, pp 337–357

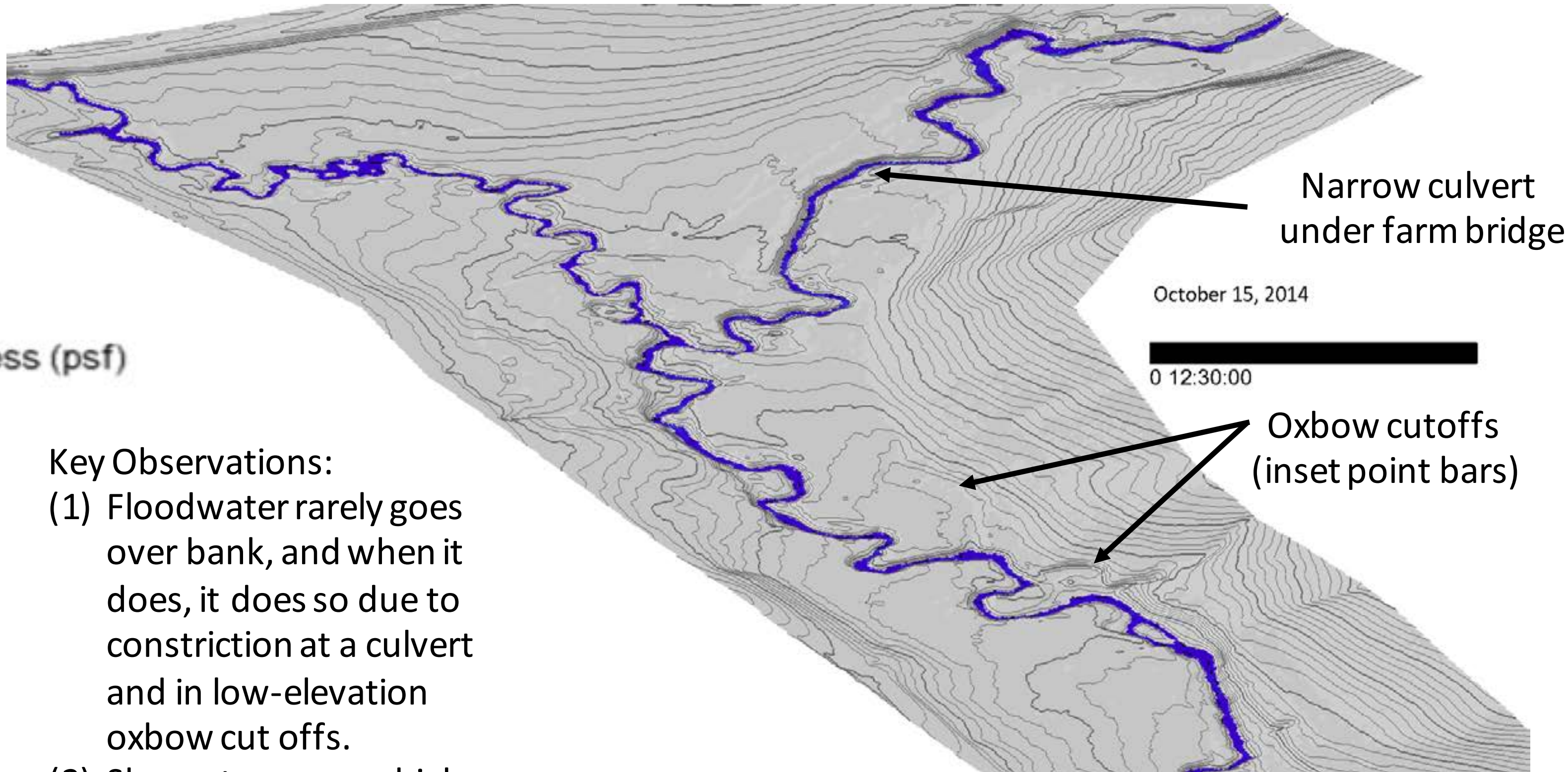
Pre-Restoration Suspended Sediment Load and Source Study

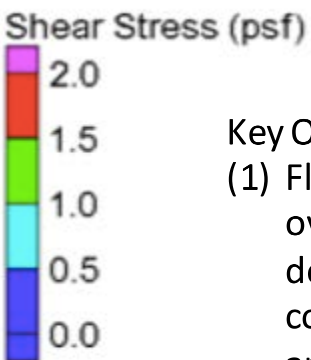
One day after Hurricane Hanna, September 7, 2008

Sources of Suspended Sediment: % Contribution from Stream Banks



Pre-Restoration 2-D Hydraulic Modeling





Key Observations:

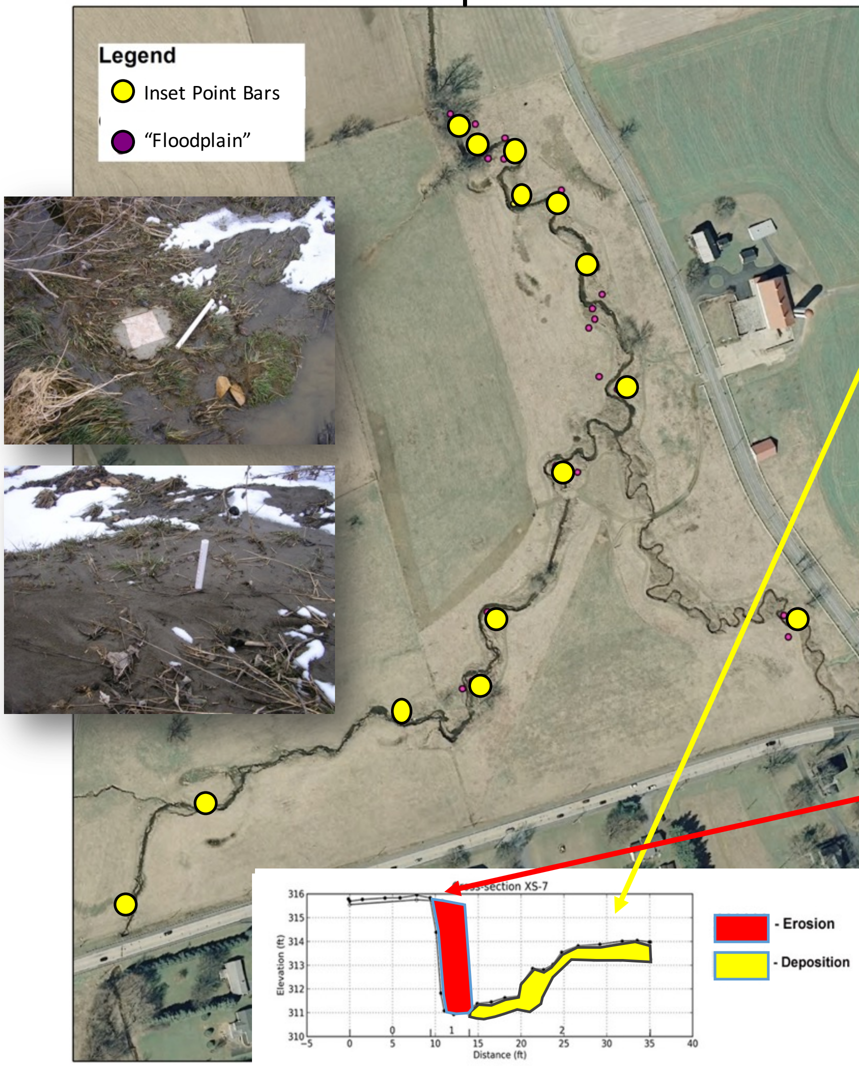
(1) Floodwater rarely goes over bank, and when it does, it does so due to constriction at a culvert and in low-elevation oxbow cut offs.

(2) Shear stresses are high.

Art Parola and Dorothy Merritts

For video link see:
http://www.bsrproject.org/visualizations.html

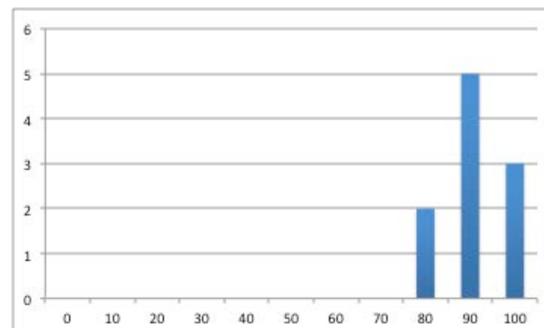
Pre-Restoration Tile Pad Experiment – Where Did Deposition Occur?



1. Tile pads installed on legacy sediment terrace three years prior to restoration.

2. 80-100% of deposition on "tile pads" on inset point bars is from bank erosion.

% Bank Erosion

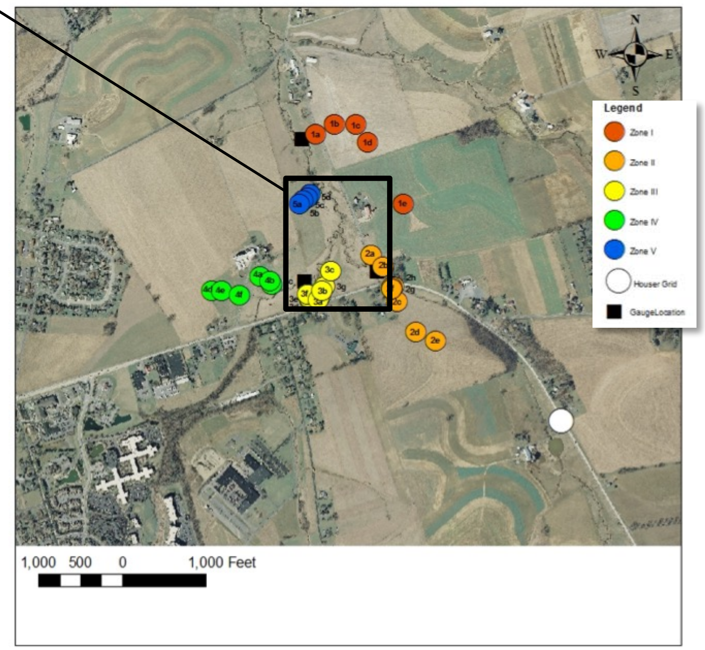


3. No deposition on tile pads on "floodplain" (i.e., on legacy sediment terrace).

BSR Sample Sites for Fingerprint Study

Stream Bank Sediments

Upland Soils



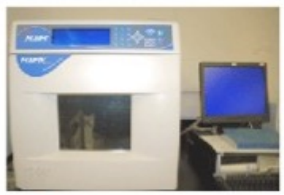
Big Spring Run Pre-Restoration Stream Bank Sampling

Zach Stein and Eric Ohlson, June 5, 2007, BSR Site 1

Trace Element Sediment Fingerprinting

Sample Collection

Partial Acid Digestion



ICP Analysis

Statistics

Removal of Non-Conservative Elements – Dot Plots

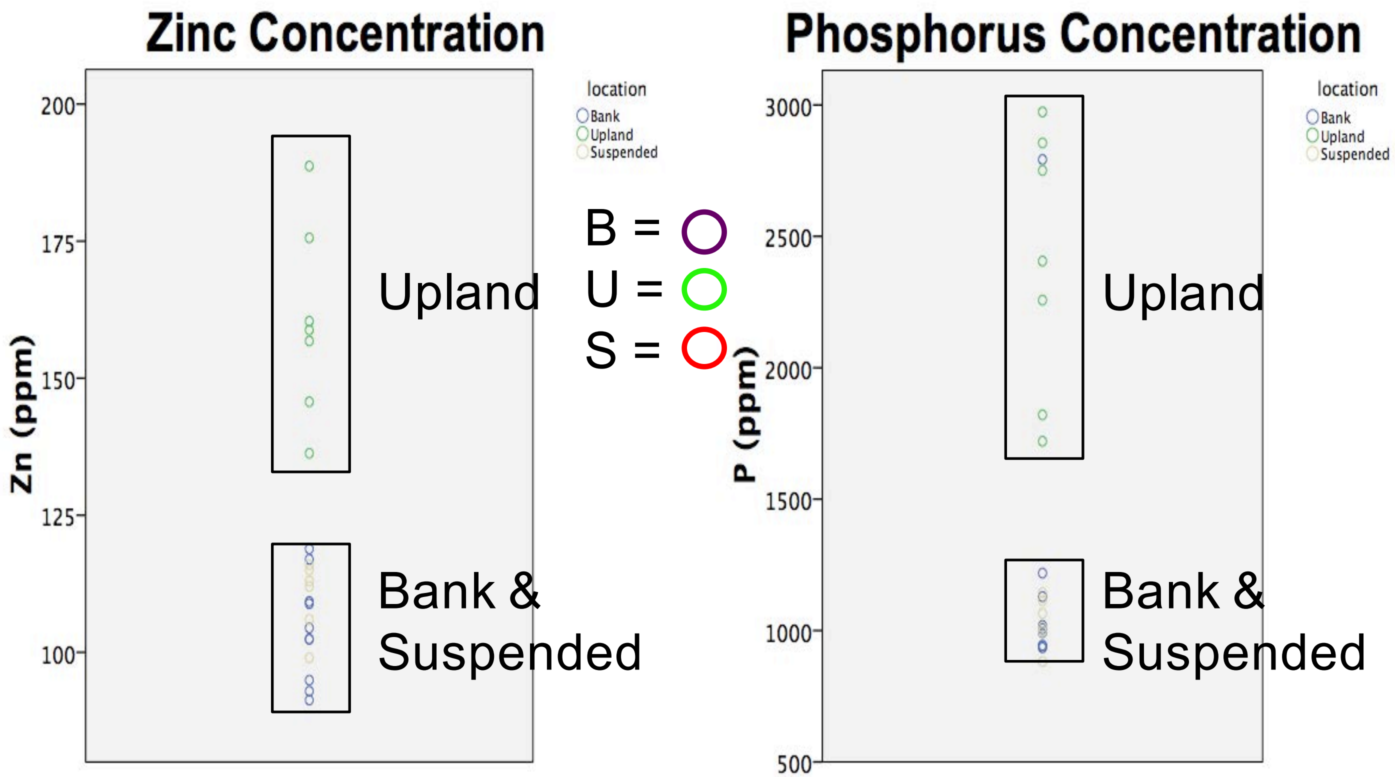
Removal of Elements that Do Not Differentiate Among Sources – Kruskal-Wallis H-Test

Determination of the Best Tracers – Stepwise Discriminate Function Analysis After Shapiro-Wilk Test

$$E = \left(\frac{1}{T}\right)\sum_{t=1}^{T} \frac{\left| v_t - \sum_{s=1}^{n} f_s A_{st} \right|}{\sqrt{\sum_{s=1}^{y} f_s^2 \left(\frac{VAR_{st}}{n_s}\right)}}$$

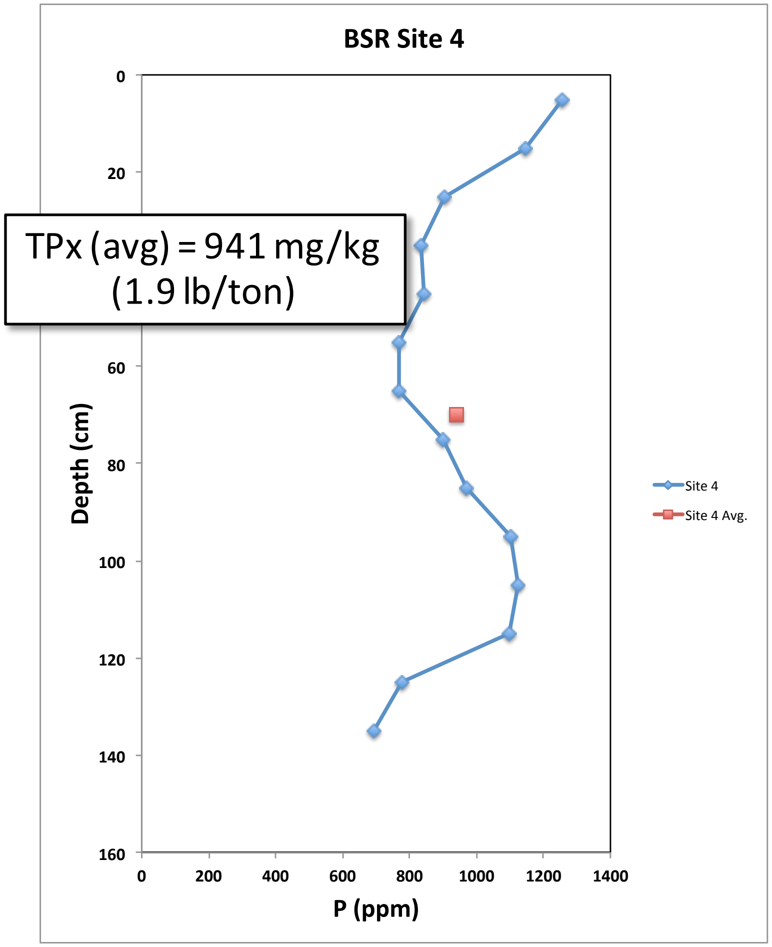
Bayesian Inference Analysis (Massoudieh et al., 2012)

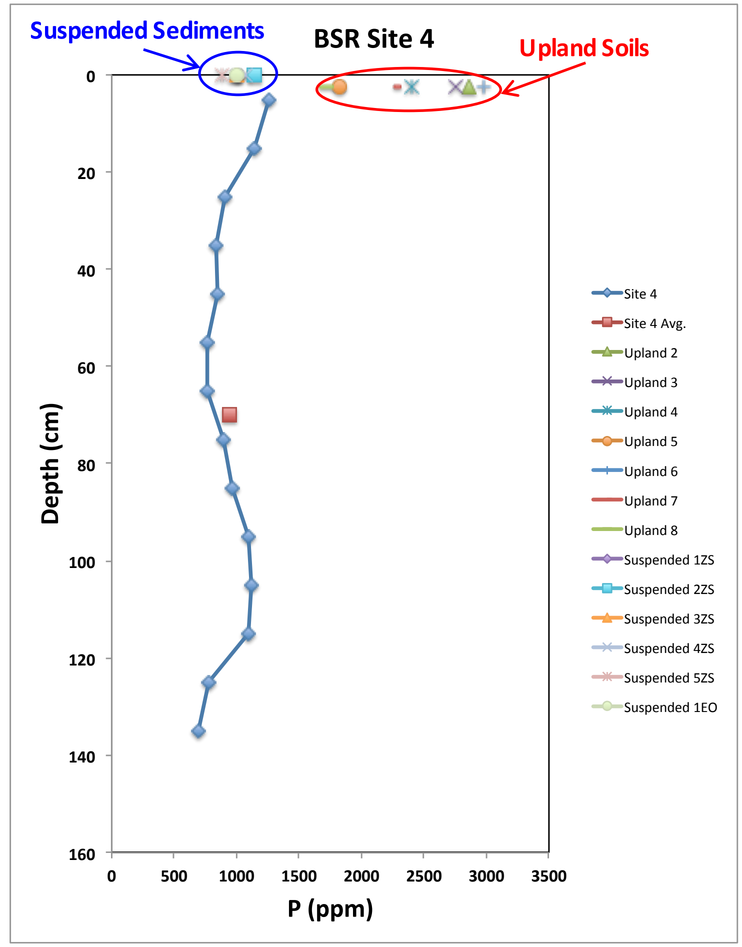
Pre-Restoration Sediment Sources – Dot Plots



XRF (9 major and 20 trace elements) + ANOVA + Bonferroni

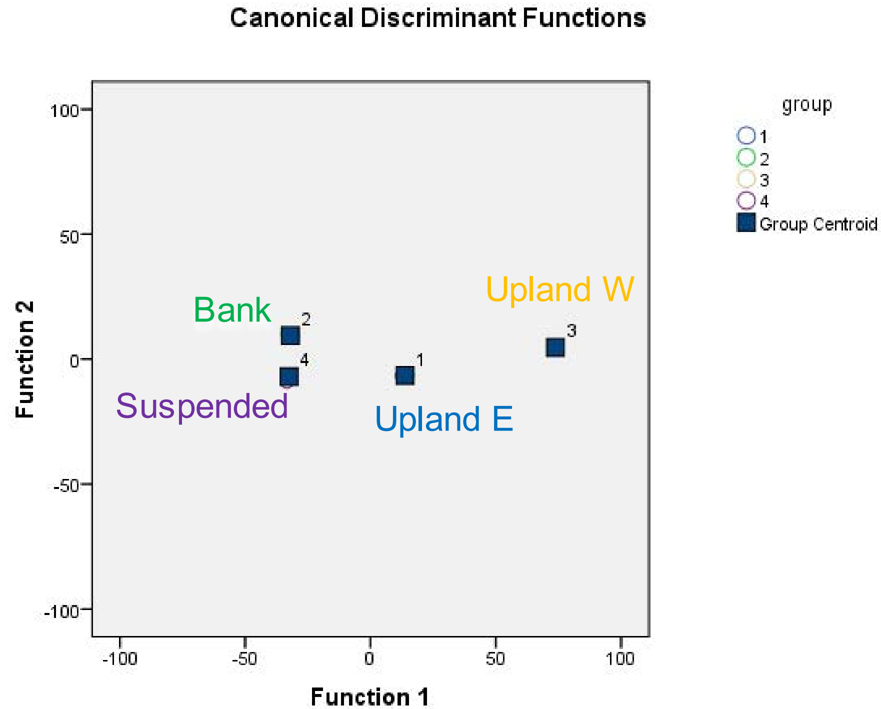
Pre-Restoration BSR Stream Bank Total Phosphorus (TPx)





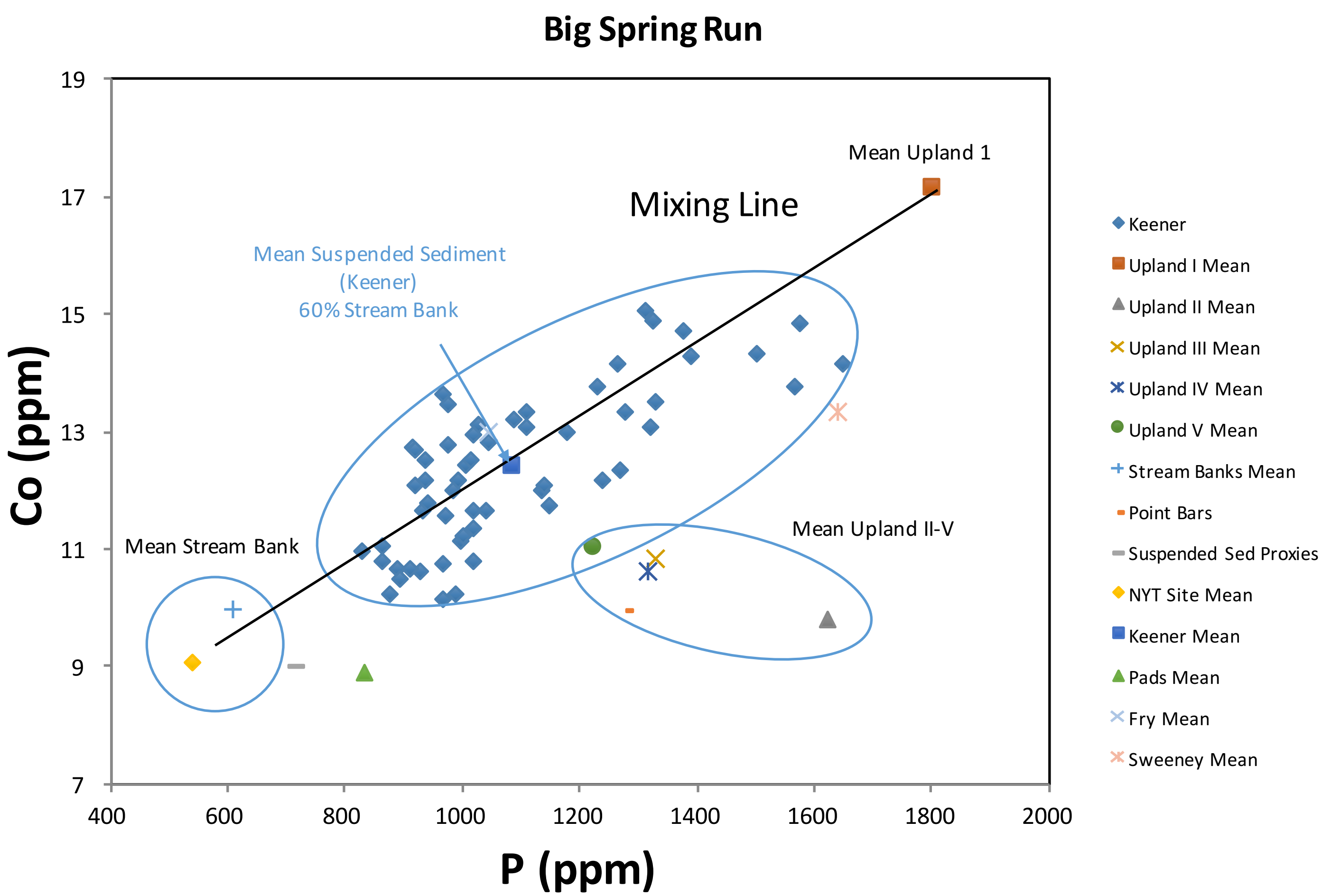
Pre-Restoration Sediment sources – DFA

Standardized Canonical Discriminant Function Coefficients			
	Function		
	1	2	3
Co	11.021	9.153	-2.147
Ba	14.002	4.191	-.743
Ce	-7.250	-4.449	1.832
Cr	-5.659	.260	1.762
Cu	7.155	-2.272	-.543
Ga	-2.265	2.323	1.210
La	-22.266	7.981	-.986
Nb	6.498	-2.669	1.489
Ni	-1.570	-17.654	2.859
Pb	-12.761	3.859	-.798
Rb	-1.359	-3.845	-3.303
Sc	9.321	4.690	.852
U	21.458	-.743	1.227



Group 1 = BSR Sweeney-Kirchner Farm Upland East
Group 2 = BSR Pre-Restoration Stream Banks
Group 3 = BSR Frey Farm Upland West
Group 4 = BSR Suspended Sediment

Pre-Restoration Sediment Sources – Mixing Model

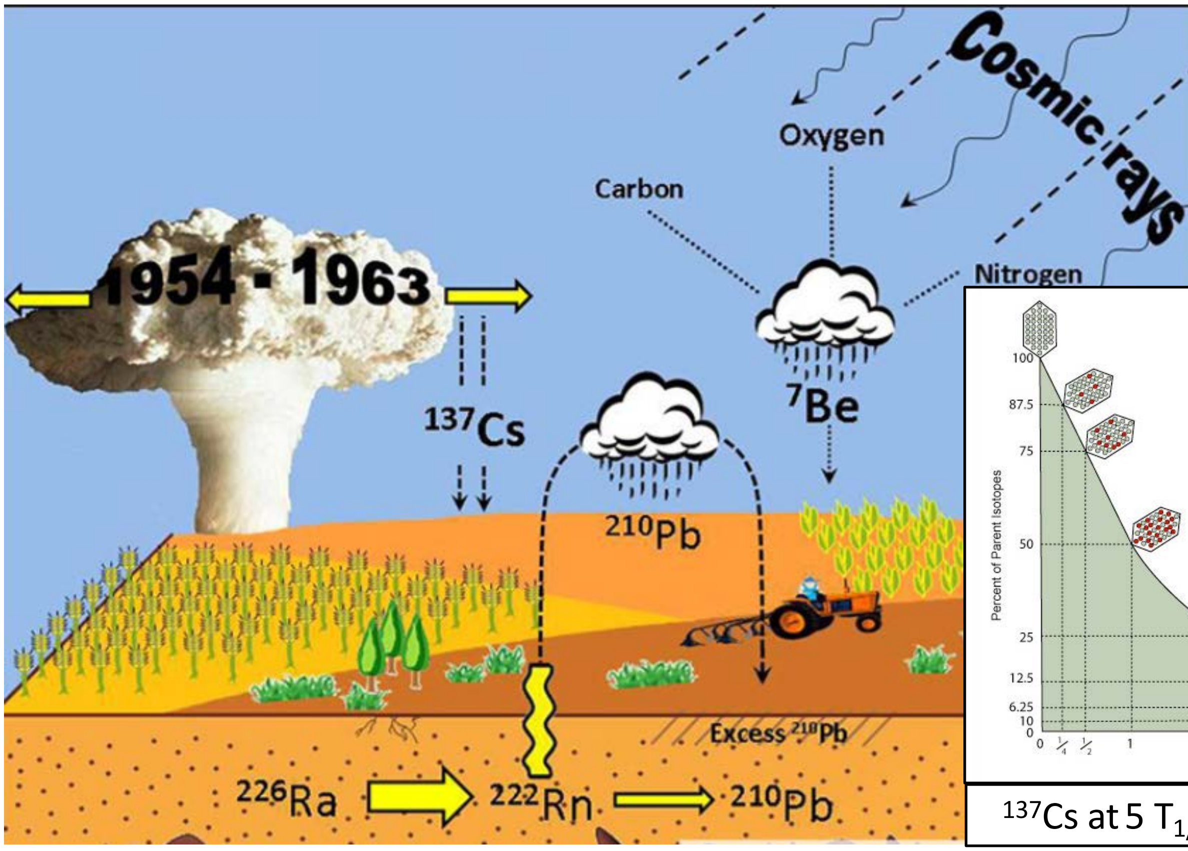


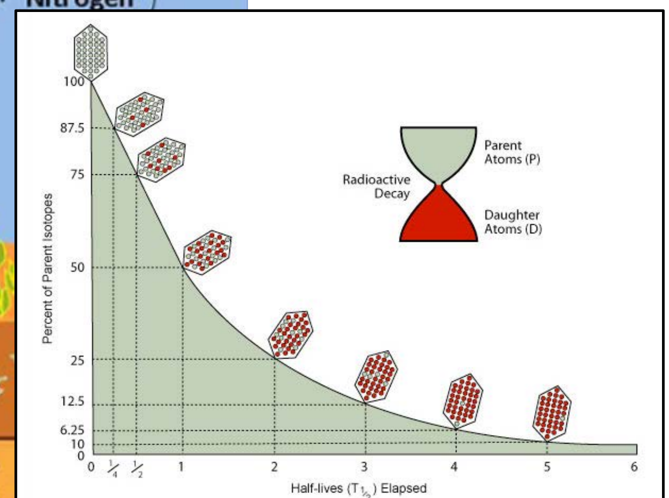
Isotope Systematics of ^{210}Pb, ^{137}Cs and ^{7}Be

^{210}Pb $T_{1/2}$ = 22.3 yr

^{137}Cs $T_{1/2}$ = 30.2 yr

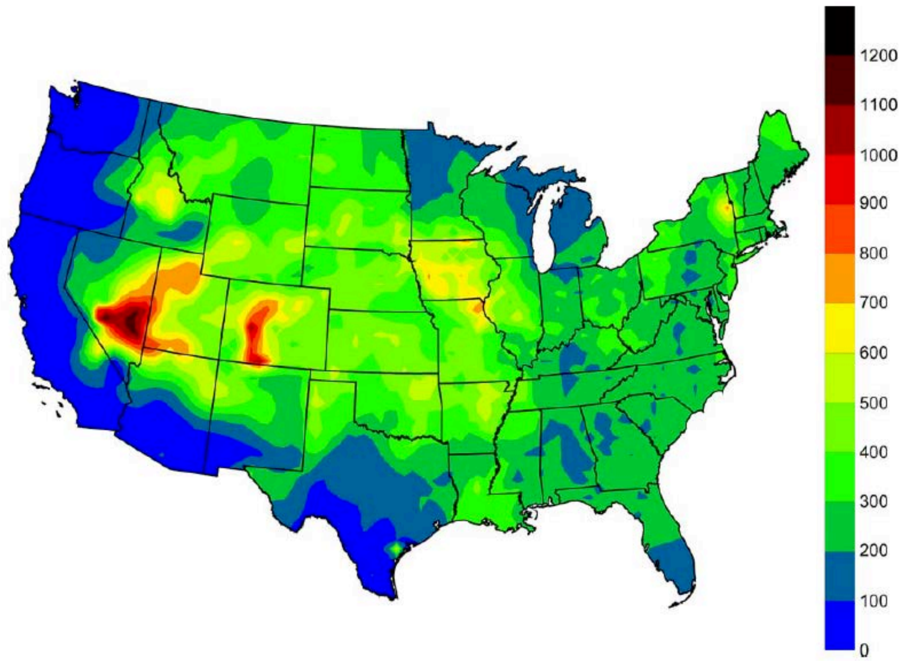
^{7}Be $T_{1/2}$ = 53.1 d





^{137}Cs at 5 $T_{1/2}$ = 151 years (AD 2114)

^{137}Cs Fallout from Bomb Tests in US



Bq m^{-2}

Fig. 2. Estimated ^{137}Cs deposition density (Bq m^{-2}) from NTS fallout across the continental US.

^{137}Cs Fallout from Global Bomb Tests

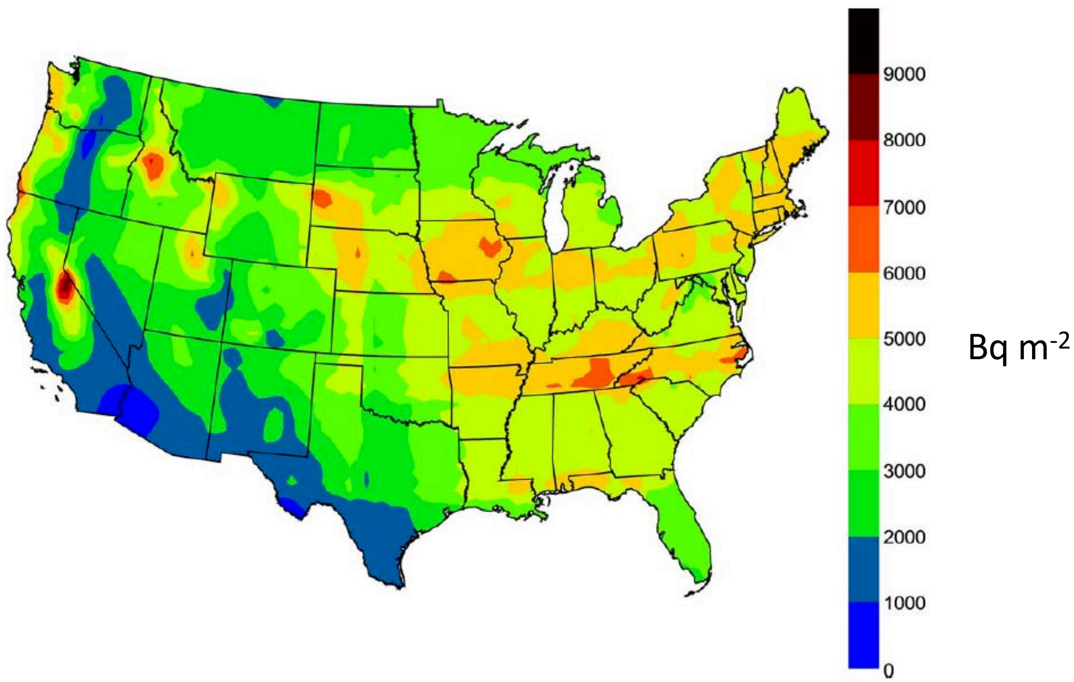
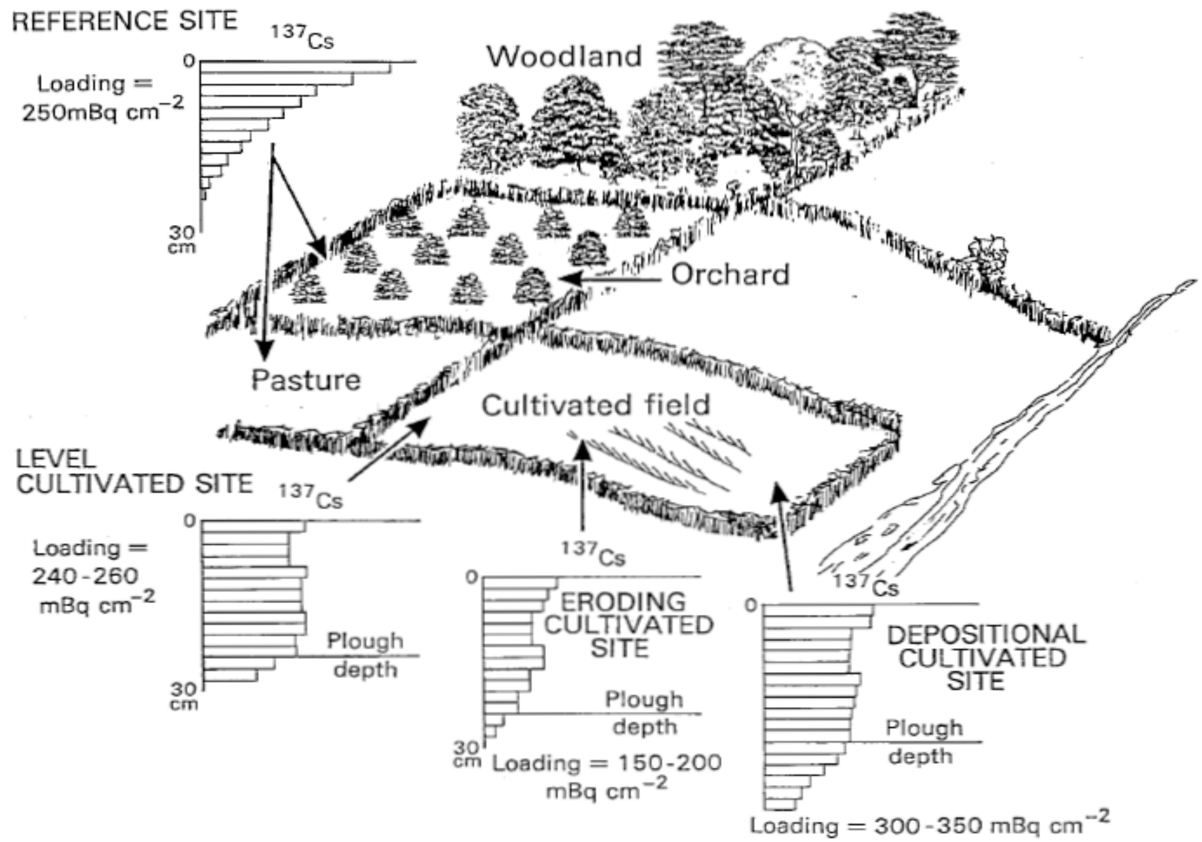


Fig. 3. Estimated ^{137}Cs deposition density (Bq m^{-2}) from global fallout across the continental US.

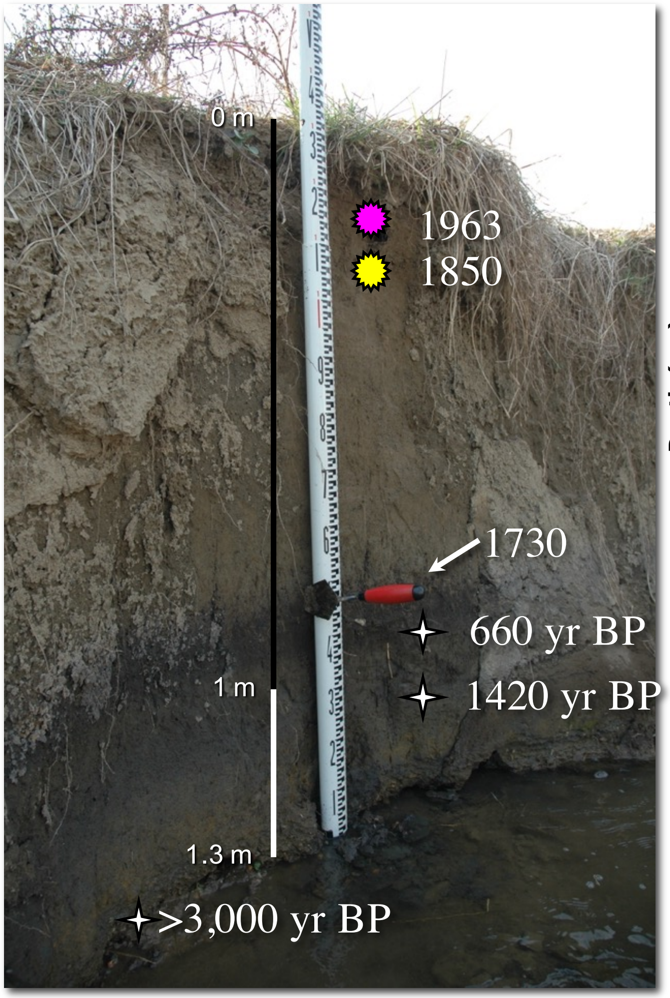
In 1963, three (UK, US, Soviet Union) of the four nuclear states signed the Limited Test Ban Treaty, pledging to refrain from testing nuclear weapons in the atmosphere, underwater, or in outer space. France continued atmospheric testing until 1974, and China continued until 1980. Neither has signed the treaty

How ^{137}Cs Data Are Used

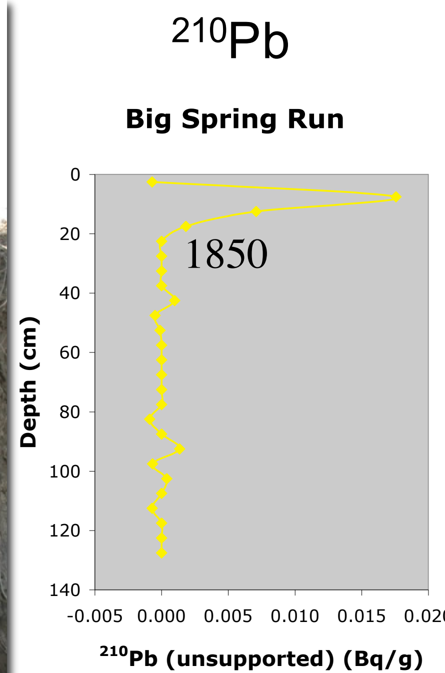


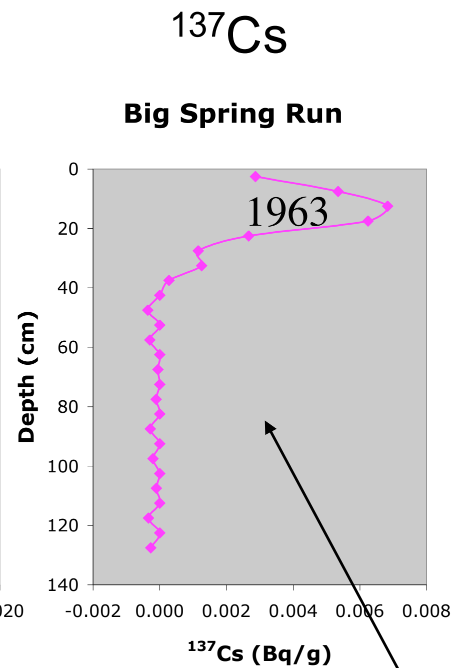
Walling and Quine 1990

Pre-Restoration Stream Bank Isotope Isotope-Stratigraphy



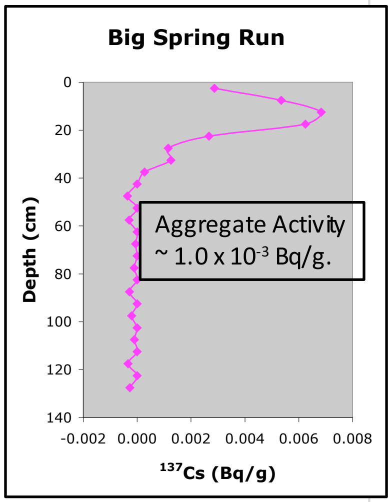
AMS Dates

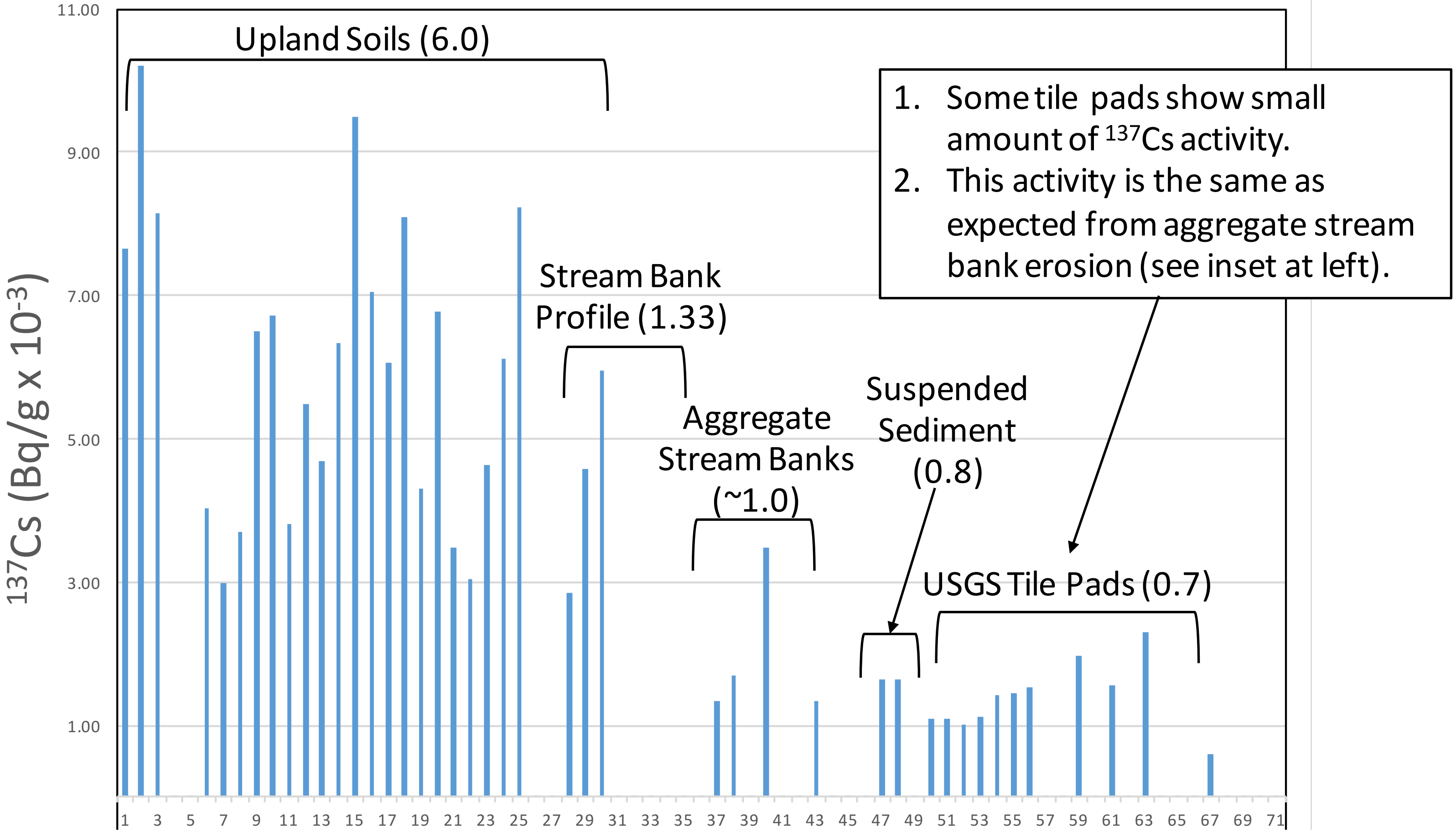




Note: The aggregate “legacy sediment” stream bank ^{137}Cs value is not zero (~1.0-3.0 x10-3 Bq/g)!!

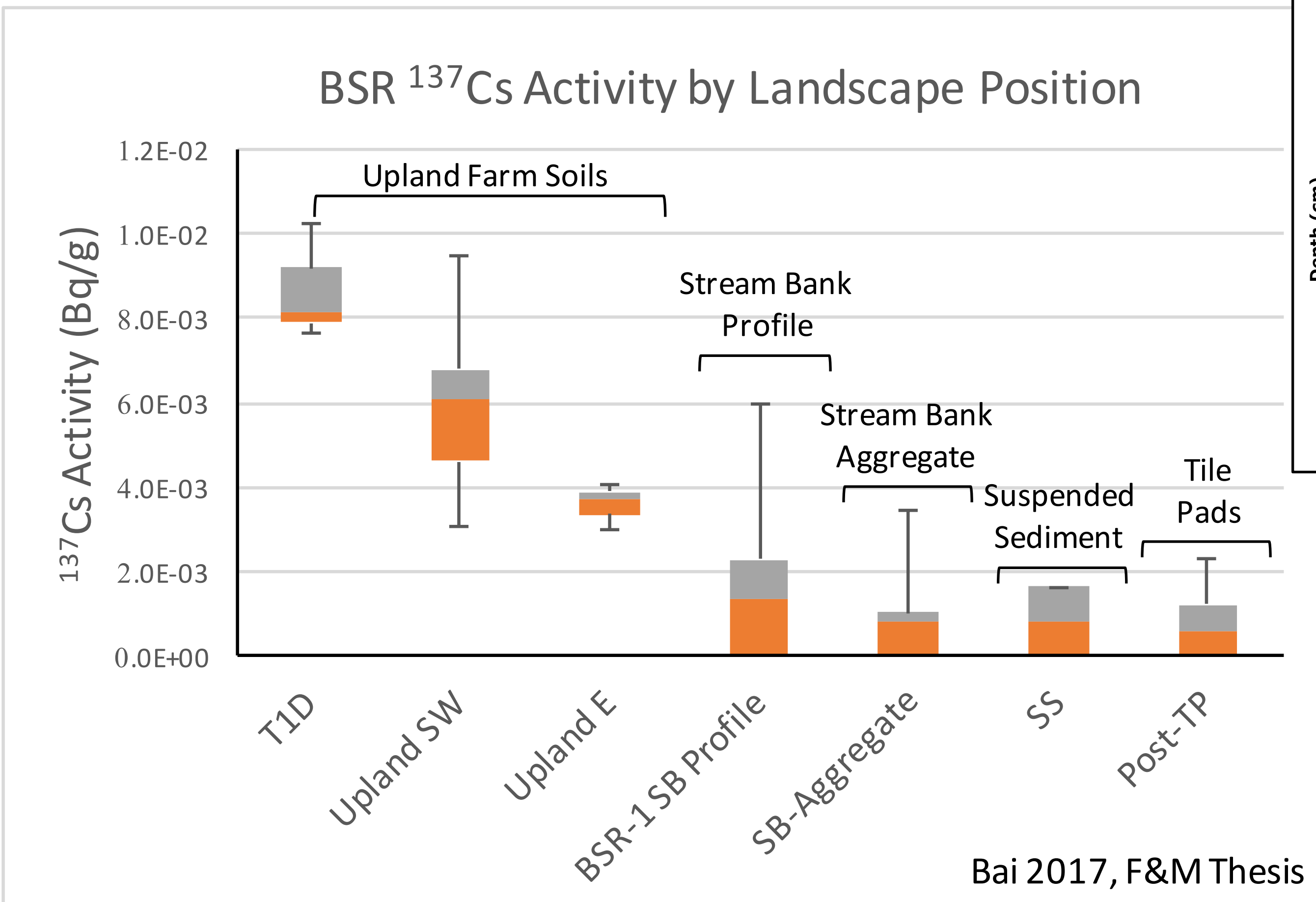
Pre- and Post-Restoration ^{137}Cs Activity by Landscape Position

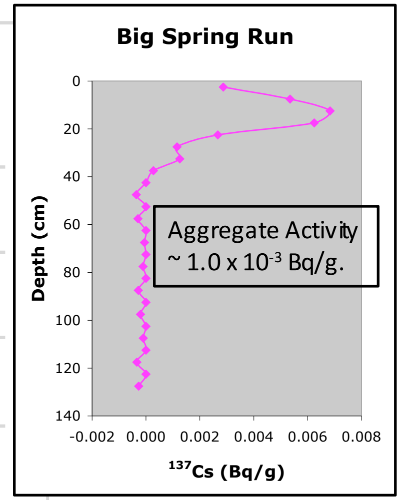




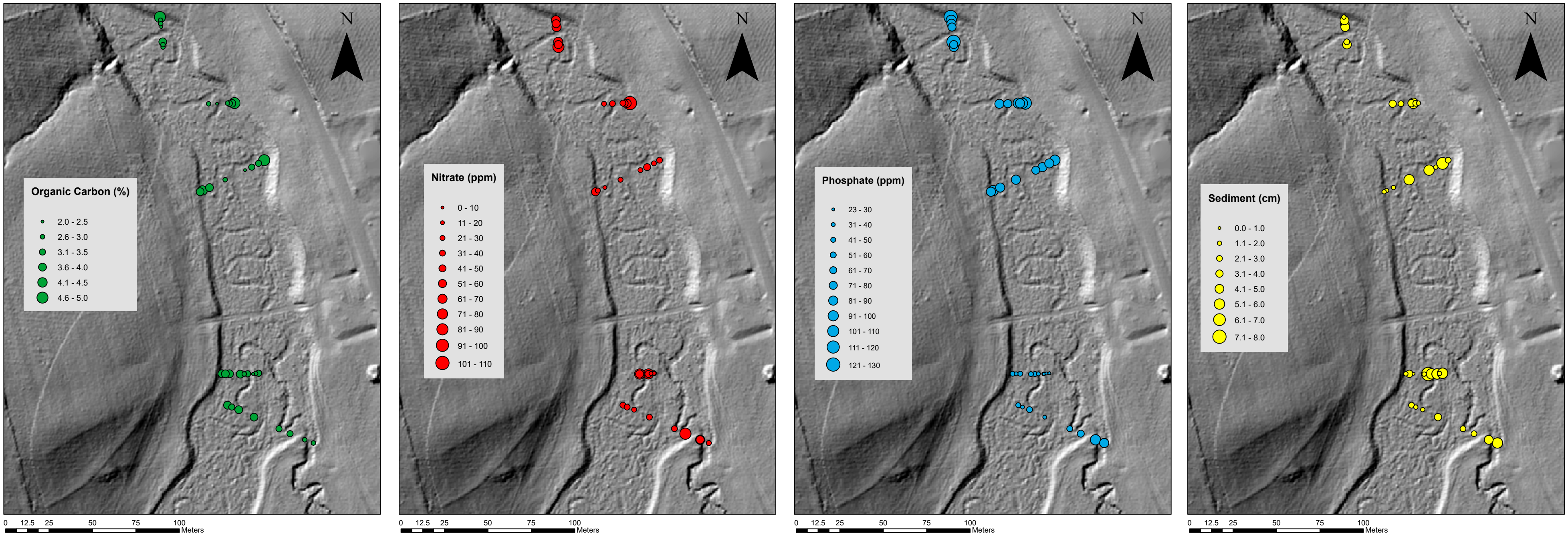
^{137}Cs Activity (Average Bq/g) by Landscape Position
(Note: Blank lines indicate no ^{137}Cs activity)

BSR ^{137}Cs Activity by Landscape Position





Post-Restoration Tile Pad Study



Distribution of C, NO_3, PO_4 & Sediment on the Restored Floodplain

BSR Suspended Sediment Study

One day after Hurricane Hanna, September 7, 2008

Key Outcomes

1. 85-100% of pre-restoration and post-restoration suspended sediment storm load from stream bank sources.

2. Consistent with trace element data.

3. Upland farm slopes contribute little soil to the suspended sediment supply.

Walter et al., 2017

Big Spring Run Before Wetland Restoration

Typical Existing Conditions (April 2005) – Three Years of Pre-Restorartion Monitoring (2008 to 2011)

Big Spring Run After Wetland Restoration

November 2011 – Six Years of On-Going Post-Restoration Monitoring (2011 to Present)

Big Spring Run Floodplain Wetland Restoration

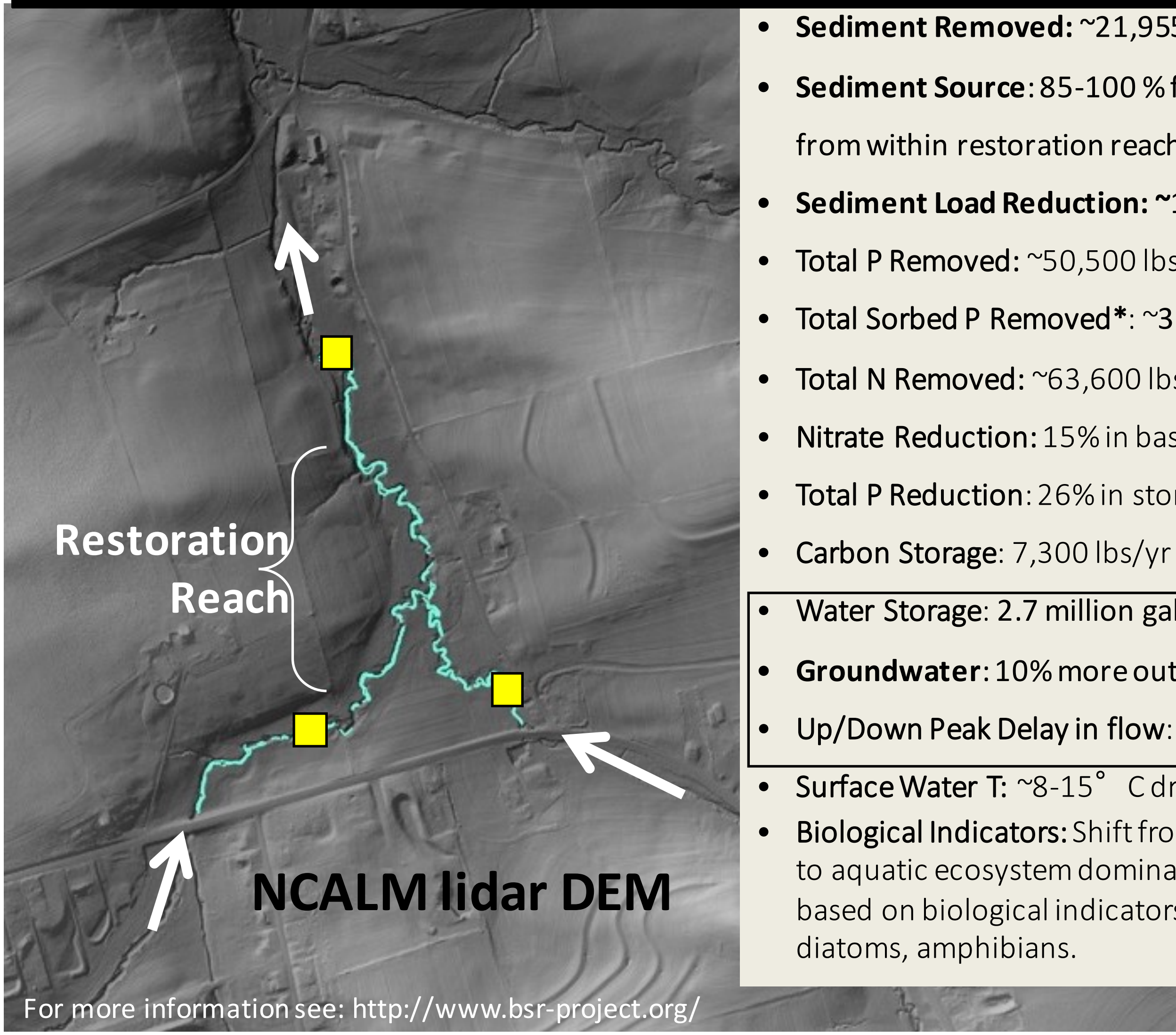
Restoration Completed November 2011- Designed and Engineered by LandStudies Inc.

For video link see: http://www.bsrproject.org/visualizations.html

Big Spring Run Floodplain Wetland Restoration

June 2012

Big Spring Run Floodplain/Wetland Restoration Outcomes (2008-2017)



- **Sediment Removed:** ~21,955 tons
- **Sediment Source**: 85-100 % from banks (~100% from within restoration reach) before restoration
- **Sediment Load Reduction: ~**150 tons/yr
- Total P Removed: ~50,500 lbs
- Total Sorbed P Removed*: ~35,128 lbs
- Total N Removed: ~63,600 lbs
- Nitrate Reduction: 15% in base flow
- Total P Reduction: 26% in storm flow
- Carbon Storage: 7,300 lbs/yr
- Water Storage: 2.7 million gallons inc. (50 %)
- **Groundwater**: 10% more output
- Up/Down Peak Delay in flow: 17 min inc.
- Surface Water T: ~8-15° C drop
- Biological Indicators: Shift from upland dominated to aquatic ecosystem dominated floodplain area based on biological indicators - vascular plants, diatoms, amphibians.

Big Spring Run Site 1

Before Excavation 9/13/11 **After Excavation 9/28/11**

Observation 1: Remove the impairment… the eroding stream banks that contribute to high suspended sediment and nutrient loads.

Big Spring Run Site 1

Before Excavation 9/13/11

After Excavation 6/18/13

Observation 1: Remove the impairment… the eroding stream banks that contribute to high suspended sediment and nutrient loads.

Big Spring Run Site 1

Before Excavation 9/13/11

After Excavation 9/28/11

Observation 2: Reconnect the groundwater and spring flow with a low, hydric floodplain. Increase hyporheic exchange

Big Spring Run Site 1

Before Excavation 9/13/11

After Excavation 6/18/13

Observation 2: Reconnect the groundwater with a low, hydric floodplain. Increase hyporheic exchange

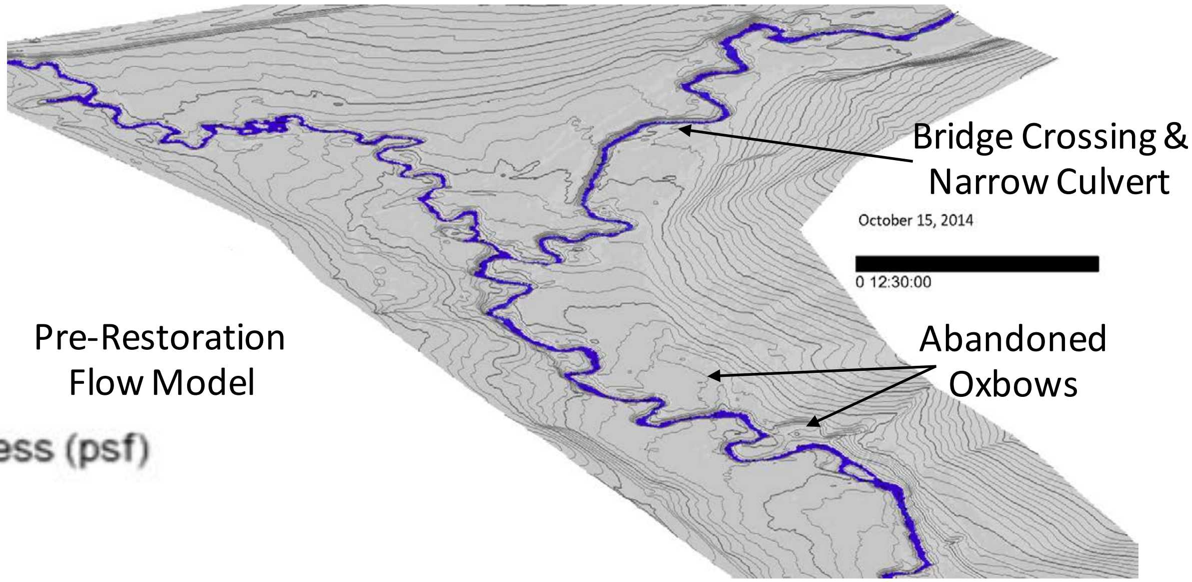
Wetlands and Their Value

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

Ecosystem services they provide:

- Habitat for fish and wildlife (e.g., Bog Turtles)
- Improved water quality
- Storing floodwaters
- Maintaining surface water flow
- Provide Denitrification
- Reduce surface water T

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



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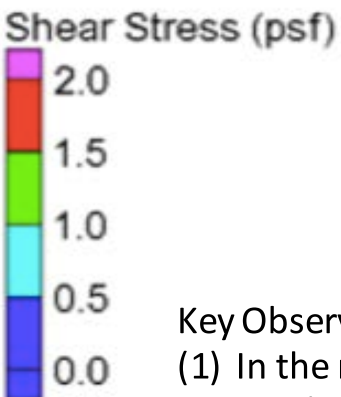
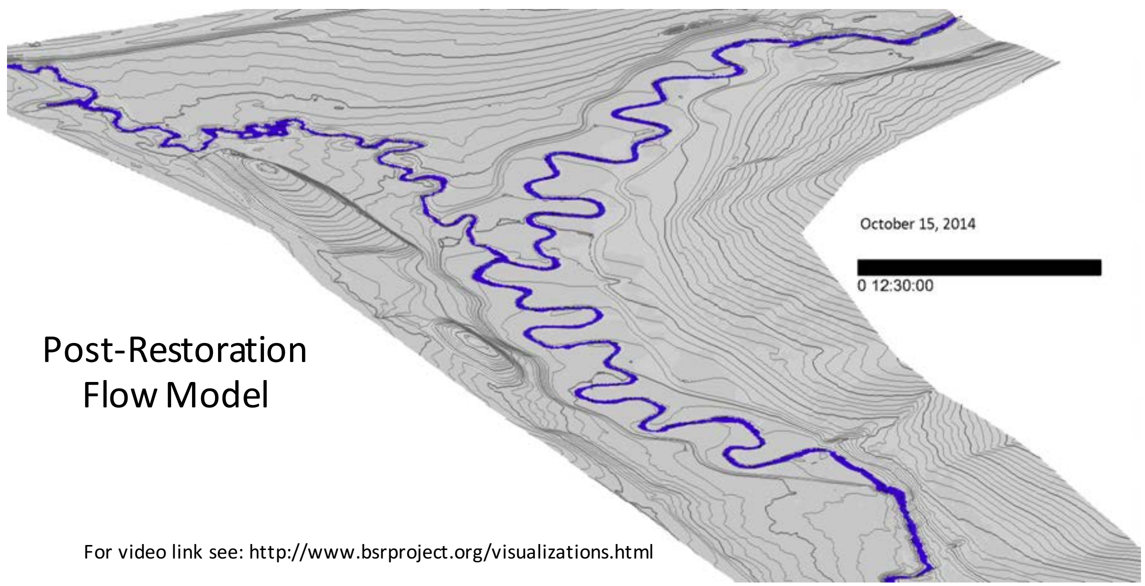
Dorothy Merritts, F&M



Key Observations:
(1) In the restored condition, floodwater goes over bank frequently and at low flow.
(2) Shear stresses are low.



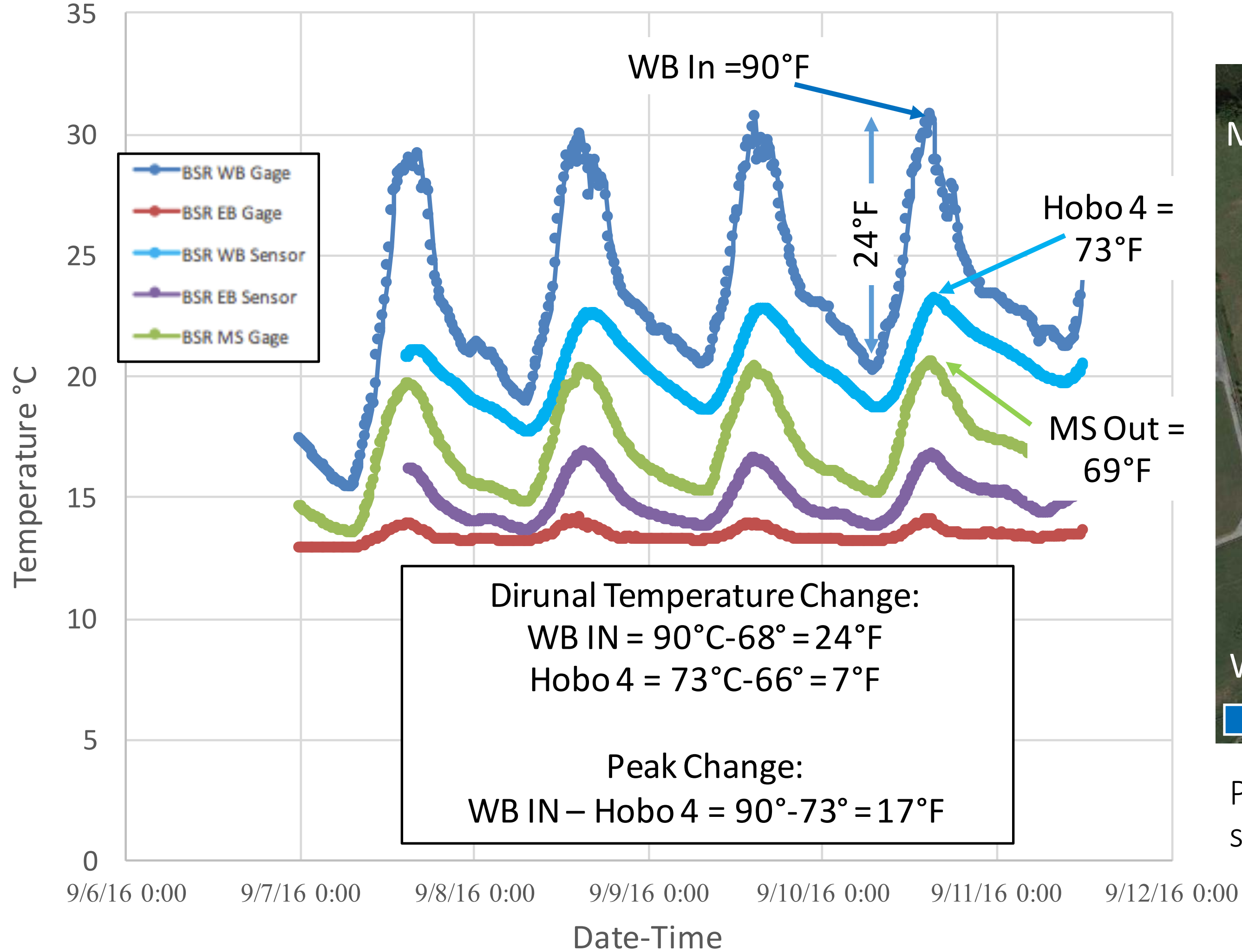
For video link see: http://www.bsrproject.org/visualizations.html

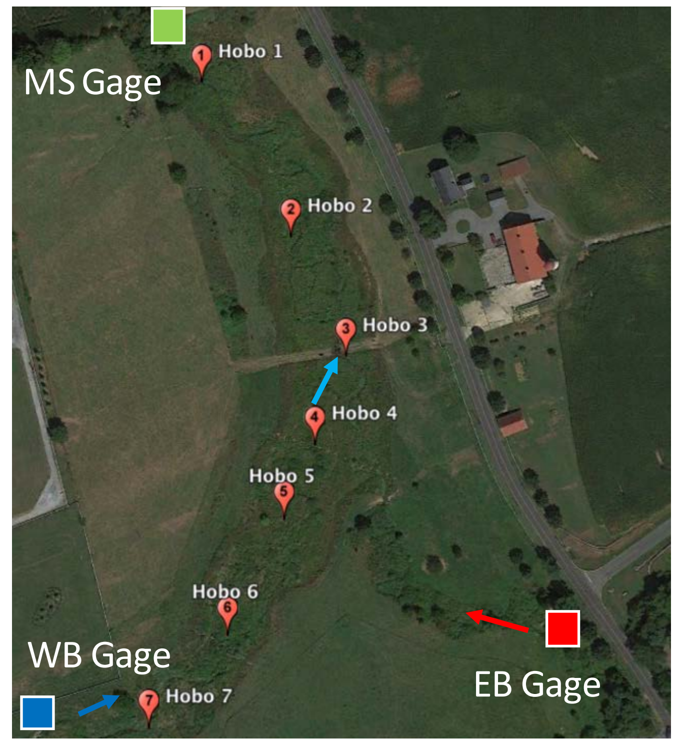
Big Spring Run Floodplain Wetland Restoration

Storm of 18 September 2012

For video link see: http://www.bsrproject.org/visualizations.html

Legacy Sediment Removal Decreases Peak Summer Surface Water Temperature by Nearly 20° F





Presumably due to the "daylighting" of springs by legacy sediment removal.


9/7/16 (Air T = 90°F)
66.0
Gage
63.5
63.7
61.7
59.2
59.0
WB-
66.2
EB-
56.3
56.3
Gage
84.2
Gage
58.8
Seep

BSR Restoration Experiment Research and Funding Partners