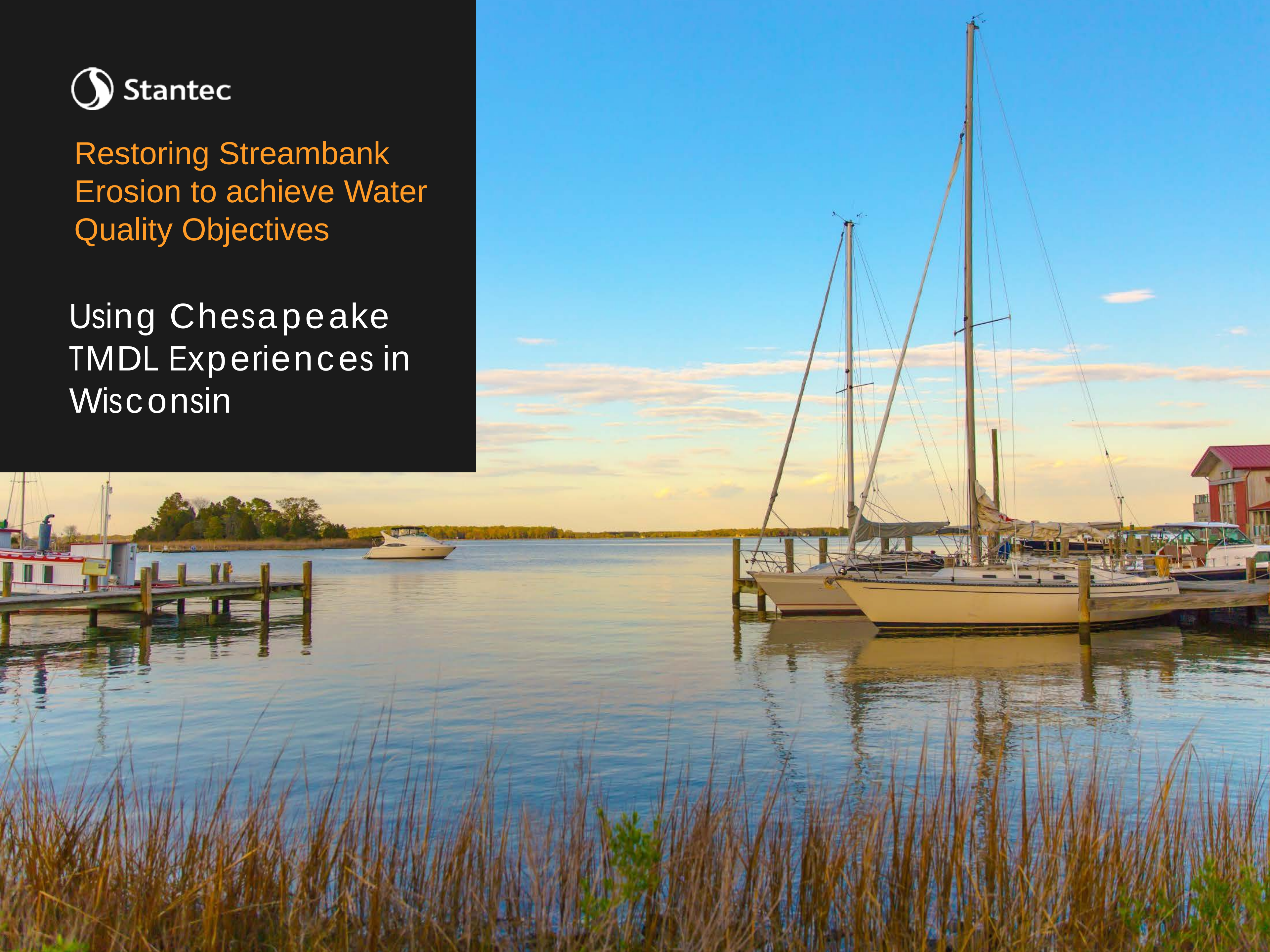
Stantec

Restoring Streambank Erosion to achieve Water Quality Objectives

Using Chesapeake TMDL Experiences in Wisconsin



Agenda

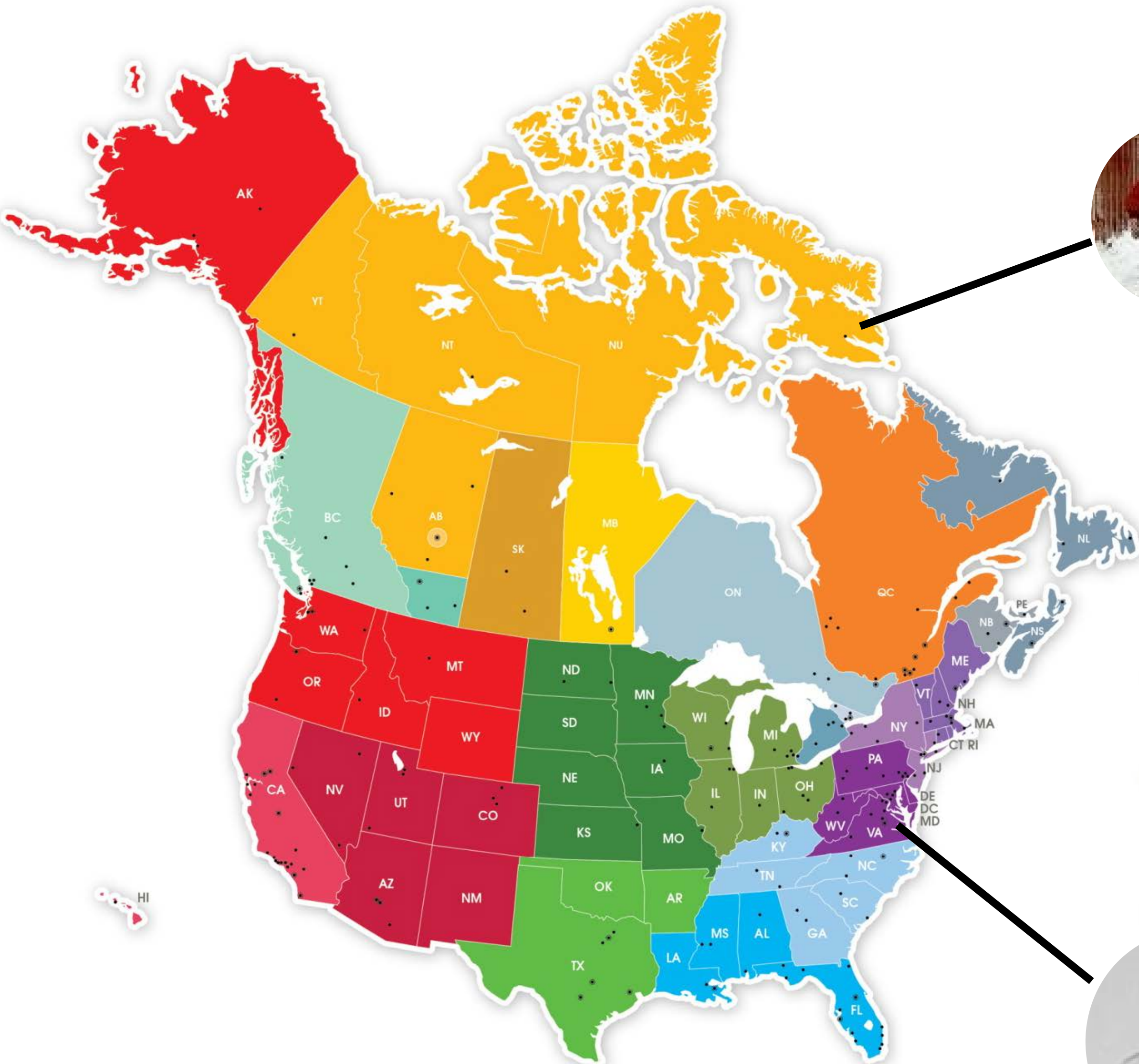
1. Brief and boring introductions
2. Background on Chesapeake Bay and SR as a nutrient offset for TMDL purposes
3. Costs associated with SR
4. Variables that affect ROI
5. The Wisconsin Connection!
6. Discussion points and questions

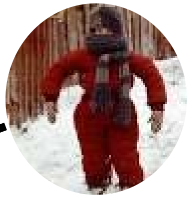
Safety Moment

Safety Culture:
- Assess Risk
- Be Aware
- Wear the Proper PPE

1. Introduction

Who is this guy and when am I going to get these 50 minutes of my life back?





Josh Running

- National Technical Lead – *Ecosystems Restoration (US)*
- Williamsburg, VA
- 19 years of experience


Douglas
Bayfield
Ashland
Iron
St Croix R.
Namekagon R.
Chippewa R.
Turtle Flambeau
Flowage
Vilas
Burnett
Washburn
Lake
Chippewa
Sawyer
Willow
Reservoir
Price
Oneida
Forest
Florence
Menominee R.
Marinette
Polk
Apple R.
Lincoln
Wisconsin R.
Langlade
Peshtigo R.
Saint Croix
Eau Claire R.
Marathon
Pierce
Lake
Du Bay
Portage
Waupaca
Wood
Petenwell
Lake
Waushara
Lake
Poygan
Trempealeau
La Crosse
Monroe
Juneau
Castle Rock
Lake
Marquette
Adams
Fond du Lac
Sheboygan
Green Lake
Milwaukee R.
Vernon
Kickapoo R.
Baraboo R.
Beaverdam
Lake
Richland
Sauk
Columbia
Washington
Ozaukee
Crawford
Wisconsin R.
Dodge
Dane
Lake
Mendota
Waukesha
Milwaukee
Iowa
Grant
Rock R.
Jefferson
Lake
Koshkonong
Racine
Walworth
Kenosha
Lafayette
Green
Rock
0
50 KM
50 Miles
© geology.com

Racine


HOUSE
DIVIDED
SNUGGLE
IS
REAL

2. Stream Restoration as a Nutrient Reduction Offset (credit)

Note: The purpose of this presentation is focused on costs and the application of stream restoration as a nutrient reduction offset. However, it is recognized that there are many other benefits to a stable stream and that doing restoration purely for the nutrient benefit is not the intention of this discussion

Quick Ches-Bay Download

The Chesapeake Bay (CB)

- **1983**: CB Agreement leading to formation of CB Program Office and CB Executive Council
- **1987 & 2000**: CB Landmark Agreements
- **2009**: E. O. declaring CB a National Treasure
- **2010**: CB TMDL established; 6 Bay States and DC begin WIP development to achieve 2025 goals
- **2013**: Regulatory changes in Virginia alter way MS4 localities & agencies plan and develop in the Bay
- **2018 & 2023**: Incremental Numeric Reduction Target dates for VA MS4s ~1.25% & ~8.75%)
- **2025 Target Date**: Reduction of Pollution Levels **by 20-25%** over 2009 levels*

**Cost estimated at $7-10 Billion.*

Costs are for SWM only (Total = $13.6-15.7B if include Ag, WW) and are attributed to Local Governments and State Agency in Virginia. Costs (source: VA Senate Finance Committee).

Largest Polluter in the Chesapeake is Sediment. Also Carries with it other Macro Nutrients (N &P)

The Role of Stream Restoration

- Degraded and Eroding Urban streams are and can be a significant source of sediments and nutrients. Some estimates have found:

  "almost ¾ of the sediment…in streams…comes from channel and bank erosion with only about ¼…coming from upland soil erosion".
  (Osmond et al. 2012 summarizing several watershed studies)

  Some Debate Here

- Stream restoration is very cost effective solution ($/lb basis compared to traditional SWM)

- CBPO estimates that 418 miles of Urban Stream Restoration will be implemented in VA and MD alone by 2025*

**(NOTE: estimates include historical projects and is derived from Phase 2 WIP submissions to EPA in 2012 and summarized by Jeff Sweeney of EPA CBPO.)*

CBPO Stream Restoration Expert Panel Report

*Stantec invited to "**test drive**" Report*

~ May 2013 – Oct 2013

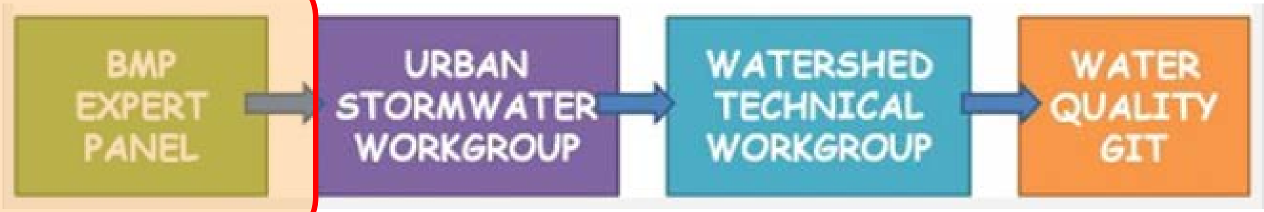
Developed to outline methods to quantify sediment and nutrient reductions from individual projects in an effort to "credit" projects to help offset reduction requirements

Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects

Joe Berg, Josh Burch, Deb Cappuccitti, Solange Filoso, Lisa Fraley-McNeal, Dave Goerman, Natalie Hardman, Sujay Kaushal, Dan Medina, Matt Meyers, Bob Kerr, Steve Stewart, Bettina Sullivan, Robert Walter and Julie Winters

Accepted by Urban Stormwater Work Group (USWG): **February 19, 2013**
Approved by Watershed Technical Work Group (WTWG): **April 5, 2013**
Final Approval by Water Quality Goal Implementation Team (WQGIT): **May 13, 2013**
Test-Drive Revisions Approved by the USWG : January 17, 2014
Test-Drive Revisions Approved by the WTWG: August 28, 2014
Test-Drive Revisions Approved by the WQGIT: September 8, 2014

Prepared by:
Tom Schueler, Chesapeake Stormwater Network
and
Bill Stack, Center for Watershed Protection



CBPO Stream Restoration Expert Panel Report

Methods to Quantify Reductions:

- Default Removal Rate
  - Fixed rate of TN, TP, TSS reductions per L.F. of stream restoration (ex: 0.068 lbs/LF/yr x 1,000 LF = 68 lbs TP/yr)

Table 3. Edge-of-Stream 2011 Interim Approved Removal Rates per Linear Foot of Qualifying Stream Restoration (lb/ft/yr)

Source	TN	TP	TSS*
Revised Default Rate	0.075	0.068	44.88 non-coastal plain 15.13 coastal plain

OR

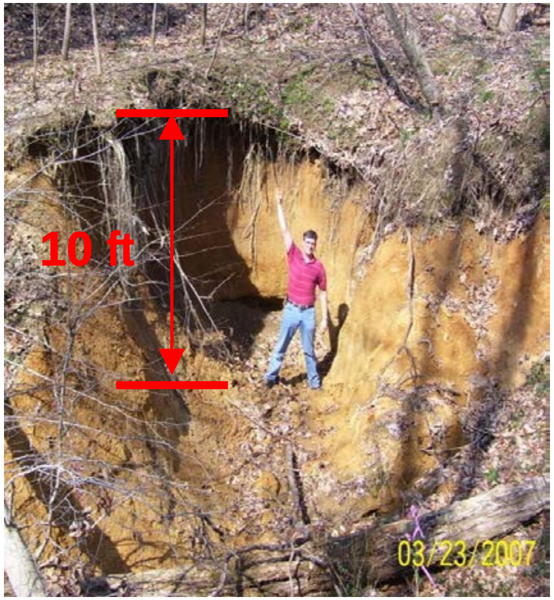
- Application of 4 Protocols from Expert Panel Report…they are:
  1. Credit for Prevented Sediment During Storm Flow
  2. Credit for Instream & Riparian Nutrient Processing
  3. Credit for Floodplain Reconnection Volume
  4. Dry Channel RSC as an Upland Stormwater Retrofit

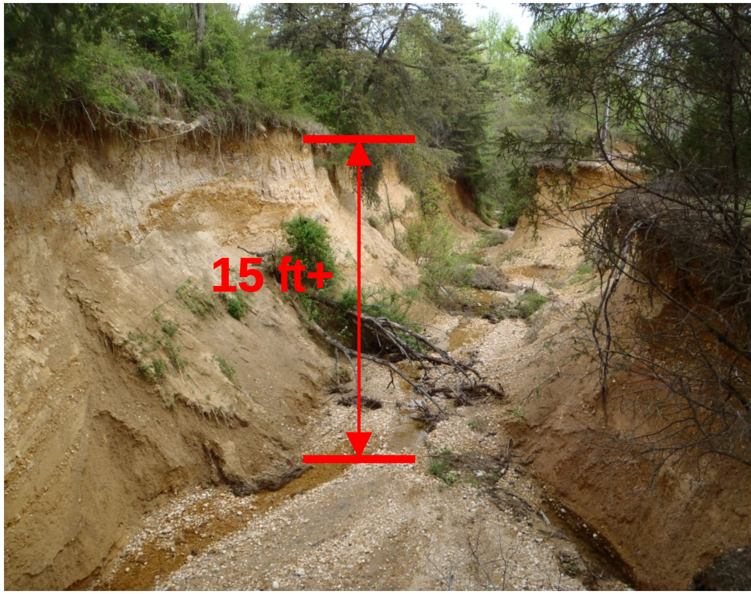
Interim/Default Removal Rate

One Size fits all?

<u>0.068 lbs TP/ft/yr</u>

Sediment loss from stream banks varies depending on many factors including rate of lateral erosion, bank heights, hydrology and hydraulics, channel geometry, landscape position, sediment dynamics, historical development, conditions in upland watershed, soils, vegetation, etc.

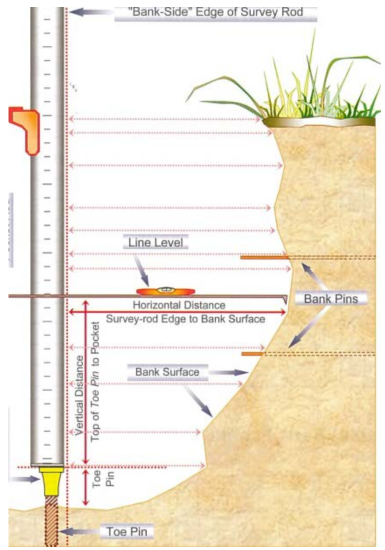




<u>0.068 lbs TP//ft/yr</u> = <u>0.068 lbs TP/ft/yr</u> = <u>0.068 lbs TP/ft/yr</u>

CBPO SR Expert Panel Report: 4 Protocols

- **P1**- Credit for Prevented Sediment During Storm Flow



- **P2**- Credit for Instream & Riparian Nutrient Processing within the Hyporheic Zone During Base Flow

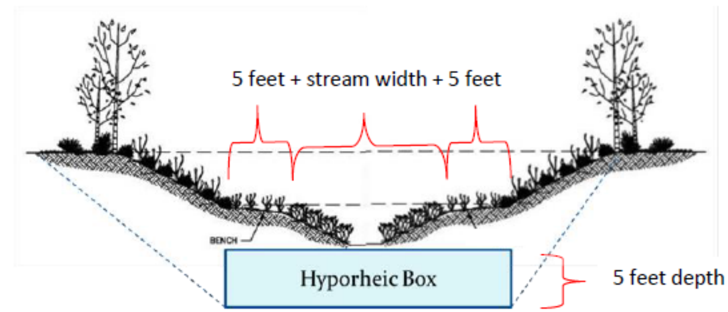
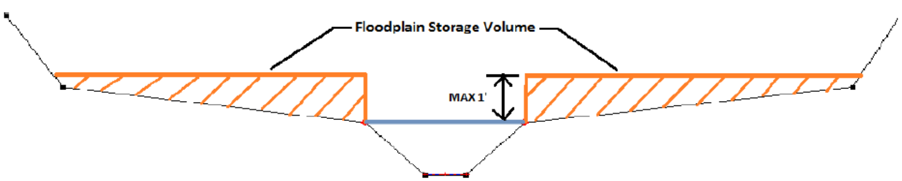
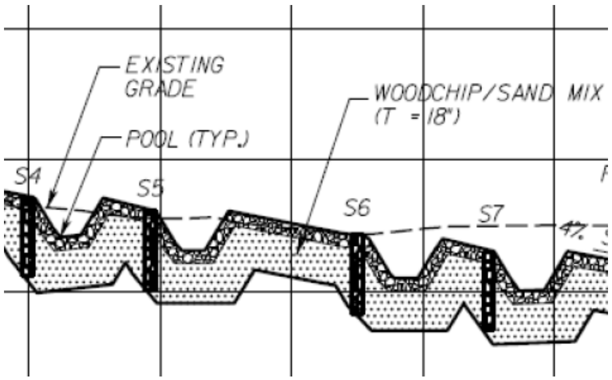


Figure 2. Hyporheic box that extends the length of the restored reach

- **P3**- Credit for Floodplain Reconnection Volume



- **P4**- Dry Channel RSC as an Upland Stormwater **Retrofit**



Protocol 1 – Prevented Sediment

Acceptable Approaches to Application of P1:

- **<u>METHOD 1: BANCS -</u>** (BEHI/NBS) for yearly tonnage with default concentration of 1.05 lb P/ton Sed, 2.28 lb N/ton Sed

- **<u>METHOD 2: Direct Measurement</u>** - Site monitoring with bank pins/toe pins/cross-section surveys, soil samples and precipitation monitoring

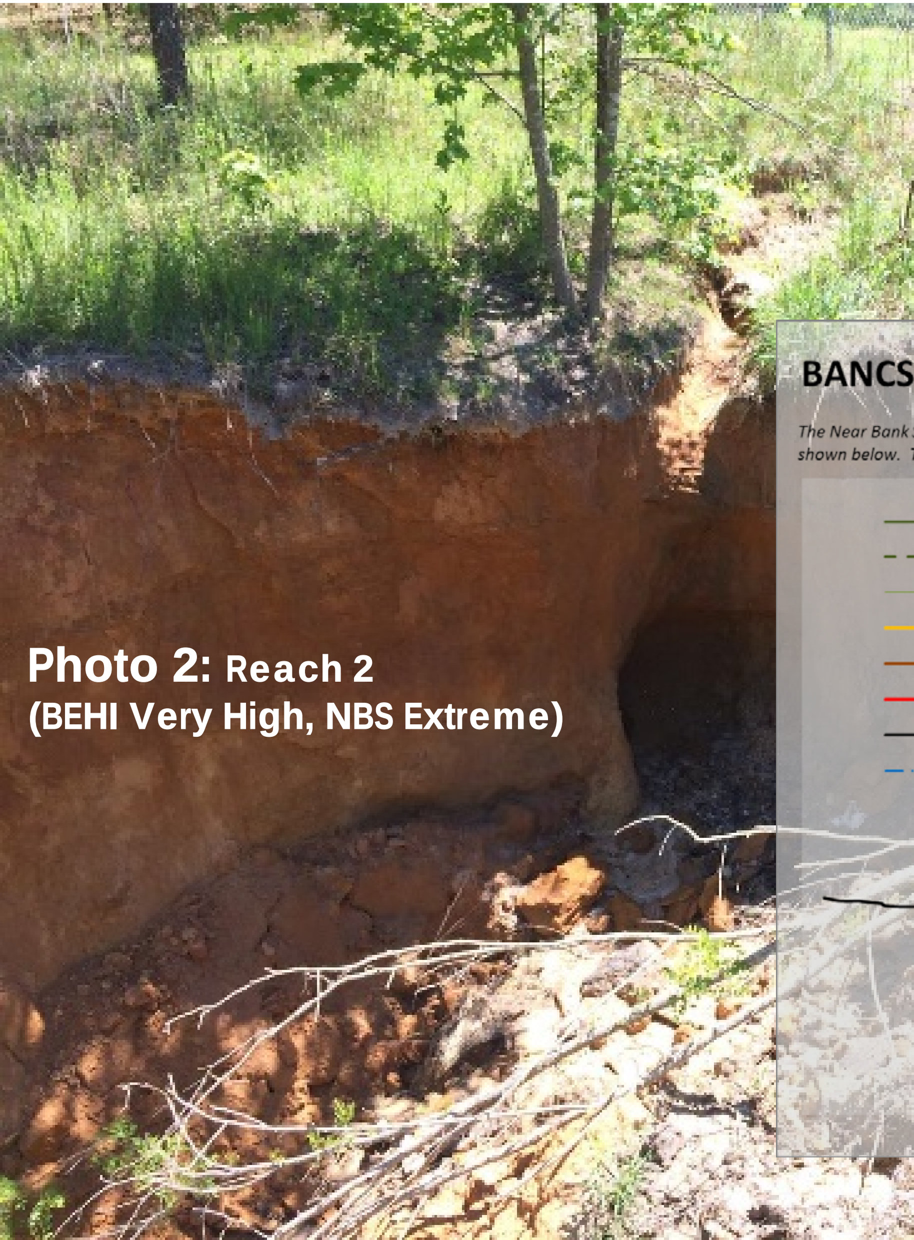
- **<u>METHOD 3 Alternative</u>**- Modeling Approach

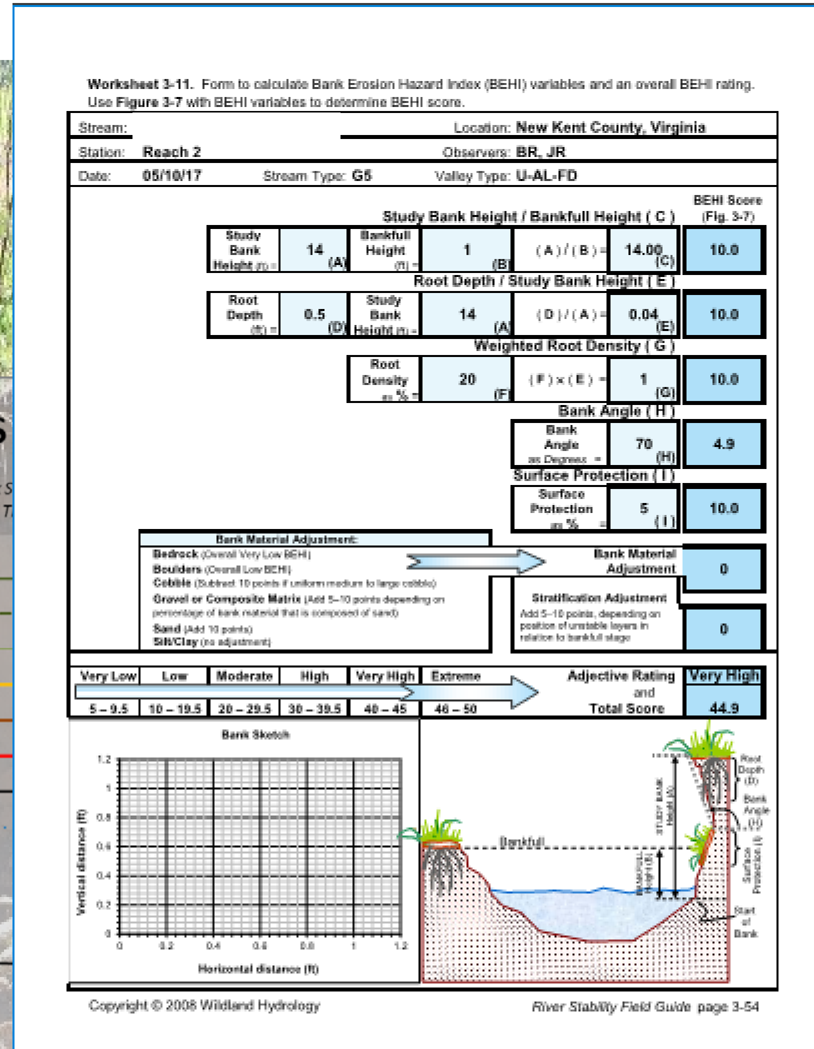
P1 Method 1 – BANCS

Prevented Sediment

Protocol 1: Method 1 – BANCS

BEHI/NBS Field Assessments





Worksheet 3-11. Form to calculate Bank Erosion Hazard Index (BEHI) variables and an overall BEHI rating. Use **Figure 3-7** with BEHI variables to determine BEHI score.

Stream: Location: New Kent County, Virginia
Station: Reach 2 Observers: BR, JR
Date: 05/10/17 Stream Type: G5 Valley Type: U-AL-FD

						BEHI Score (Fig. 3-7)
Study Bank Height / Bankfull Height (C)						
Study Bank Height (ft) =	14 (A)	Bankfull Height (ft) =	1 (B)	(A) / (B) =	14.00 (C)	10.0
Root Depth / Study Bank Height (E)						
Root Depth (ft) =	0.5 (D)	Study Bank Height (ft) =	14 (A)	(D) / (A) =	0.04 (E)	10.0
Weighted Root Density (G)						
		Root Density as % =	20 (F)	(F) x (E) =	1 (G)	10.0
Bank Angle (H)						
				Bank Angle as Degrees =	70 (H)	4.9
Surface Protection (I)						
				Surface Protection as % =	5 (I)	10.0

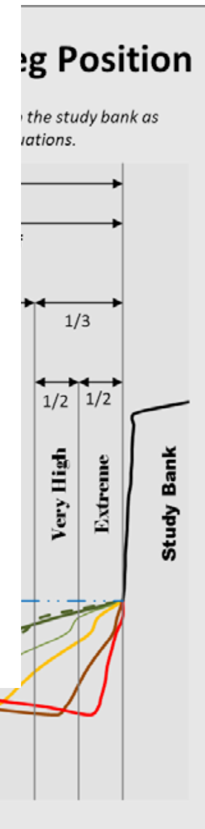
Bank Material Adjustment:
Bedrock (Overall Very Low BEHI)
Boulders (Overall Low BEHI)
Cobble (Subtract 10 points if uniform medium to large cobble)
Gravel or Composite Matrix (Add 5–10 points depending on percentage of bank material that is composed of sand)
Sand (Add 10 points)
Silt/Clay (no adjustment)

Bank Material Adjustment: 0

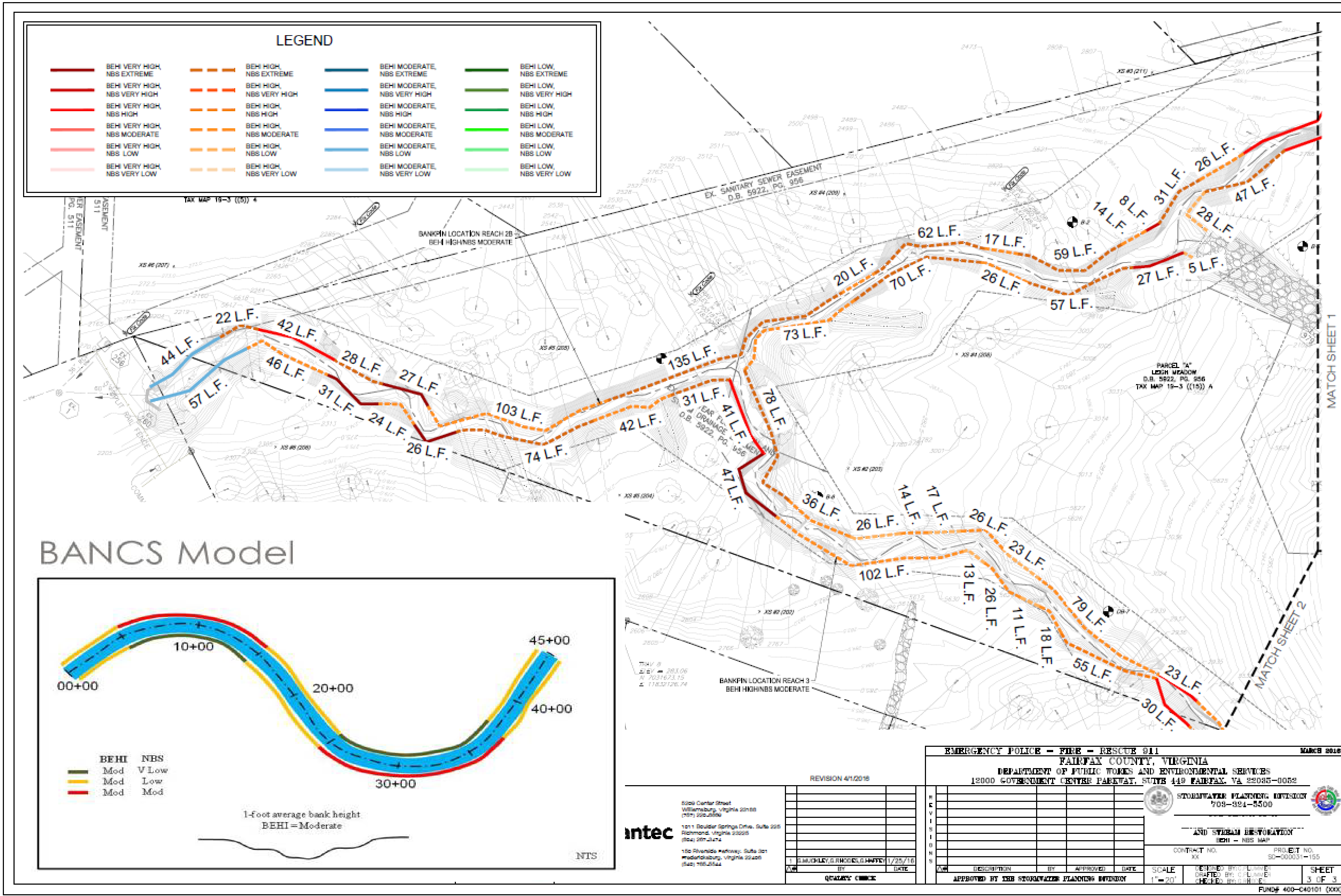
Stratification Adjustment
Add 5–10 points, depending on position of unstable layers in relation to bankfull stage: 0

Very Low	Low	Moderate	High	Very High	Extreme	Adjective Rating and Total Score
5 – 9.5	10 – 19.5	20 – 29.5	30 – 39.5	40 – 45	46 – 50	Very High 44.9

Bank Sketch



BEHI/NBS Field Maps



Protocol 1: Method 1 – BANCS

Bank Erosion Rate (BER) Curve

- USFWS
  (Hickey Run)
- NC Revised

- Colorado
- Yellowstone
- Sequoia
- Local Curves

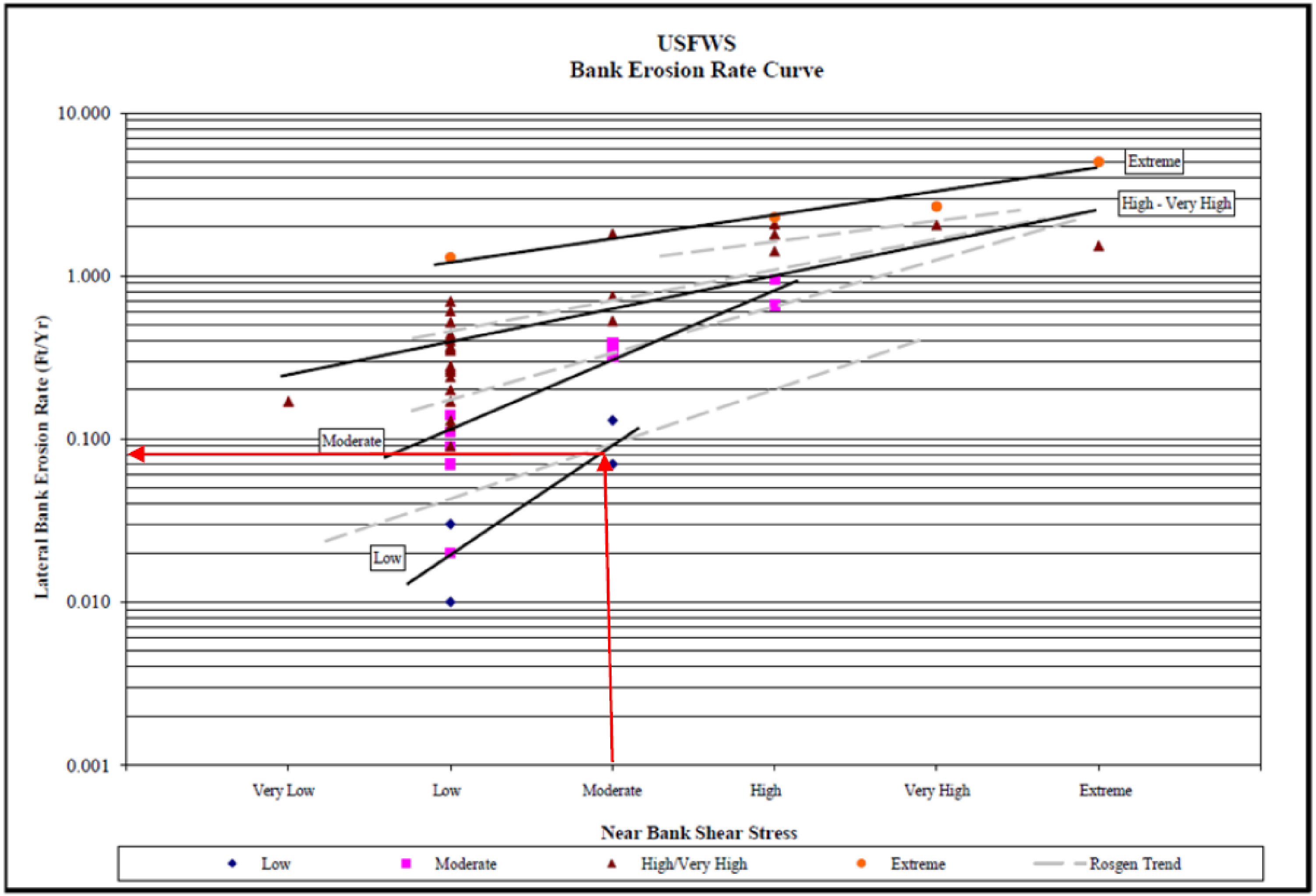


Figure B-1. Bank Erosion Rate Curve Developed by the USFWS [Hickey Run]. Appendix B, Protocol 1 Supplemental Details. Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects. 2014, Sept 8.

Protocol 1: Method 1 – BANCS

Sediment & Nutrient Reduction Estimates

NC Rev. BER Curve

Total Erosion (tons/yr)	TP Concentration (lb/ton)	TN Concentration (lb/ton)	TP Loading Rate (lb/yr)	TN Loading Rate (lb/yr)
190.78	1.05	2.28	200.3	435.0
	Nutrient Load Reduction (50%)		100.2	217.5

Hickey Run BER Curve (USFWS)

Total Erosion (tons/yr)	TP Concentration (lb/ton)	TN Concentration (lb/ton)	TP Loading Rate (lb/yr)	TN Loading Rate (l
259.65	1.05	2.28	272.6	592.
	Nutrient Credits (50%)		136.3	296.

Default Rate Comparison

Curve	Length	Reductions
NC	172 LF	100.2 lbs TP/yr
Hickey	172 LF	136.3 lbs TP/yr
Default*	172 LF	11.7 lbs TP/yr

** Default/interim rate = 0.068 lbs TP/LF/yr x 172 LF = 11.7 lbs TP/yr*

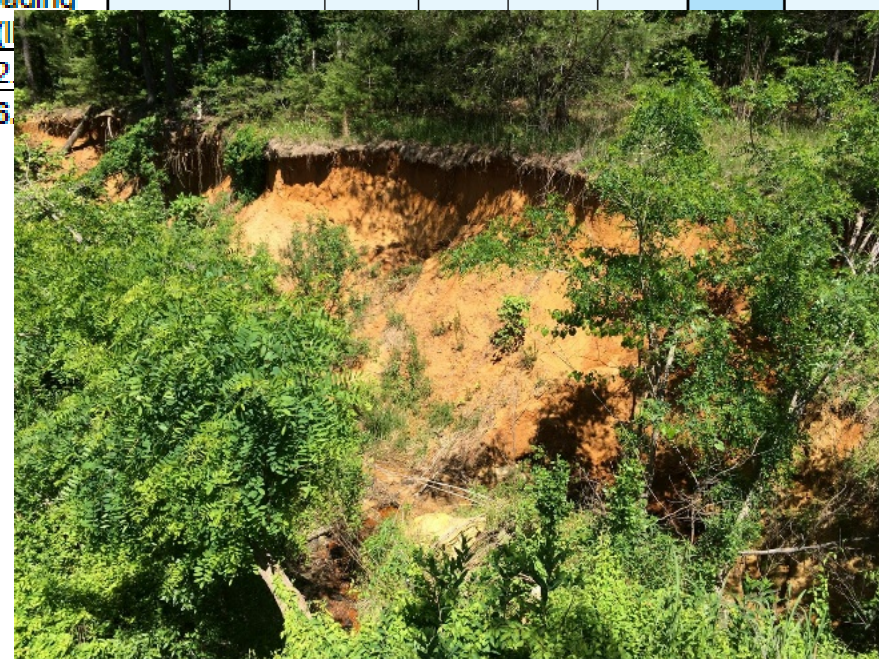
of annual streambank erosion estimates for various study reaches.

Location:

Total Stream Length (ft): 172 Date: 5/10/2017

Observers: BR, JR Valley Type: Stream Type:

(1) Station (ft)	(2) BEHI rating (Worksheet 3-11) (adjective)	(3) NBS rating (Worksheet 3-12) (adjective)	(4) Bank erosion rate (Figure 3-9 or 3-10) (ft/yr)	(5) Length of bank (ft)	(6) Study bank height (ft)	(7) Erosion subtotal [(4)×(5)×(6)] (ft^3/yr)	(8) Erosion Rate (tons/yr/ft) {[(7)/27] × 1.69 / (5)}
1. Reach 1A	High	Moderate	0.620	39.0	1.5	36.27	0.05821
2. Reach 1B	High	High	1.000	37.0	1.5	55.50	0.09389
3. Reach 2	Very High	Extreme	2.600	80.0	14.0	2912.00	2.27837
4. Reach 3	Very High	Moderate	0.620	111.0	14.0	963.48	0.54330
5. Reach 4	Very High	Moderate	0.620	73.0	4.0	181.04	0.15523
6.							
7.							
8.							
9.							
10.							
11.							
12.							



Protocol 1: Method 1 – BANCS

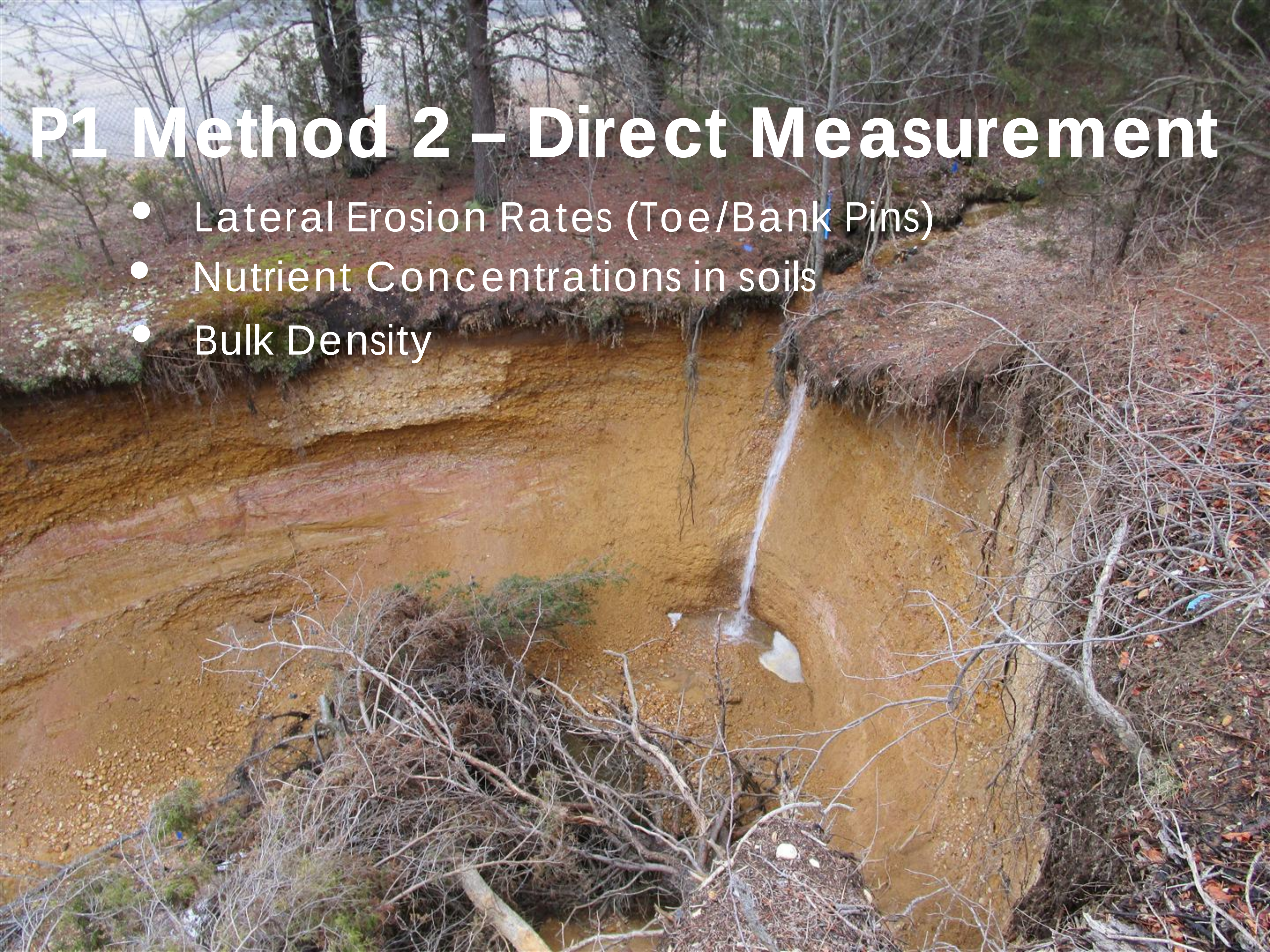
Comparing Application of Various Bank Erosion Rate (BER) Curves

Project ID	Restoration Length (LF)	NC Curve (lbs TP/yr)[1]	USFWS Curve (lbs TP/yr)[1]	Default (lbs TP/yr)
Project A	3,620	148	400	246
Project B	1,500	46	126	102
Project C	477	47	117	32
Project D	863	134	245	59
Project E	419	551	NA	28.5
Project F	172	100	136	12
Project G[2]	952	3.5	NA	65
Project H[2]	384	2	NA	26
Project I	4,688	267	956	319
Project J[2]	2,793	81	315	190
Project K	305	2	13	21
Project L	409	39	77	28

[1] Most projects utilizing default nut. concentrations & 50% efficiency
[2] Utilized measured nutrient concentrations in stream bank soils for low estimate.

P1 Method 2 – Direct Measurement

- Lateral Erosion Rates (Toe/Bank Pins)
- Nutrient Concentrations in soils
- Bulk Density

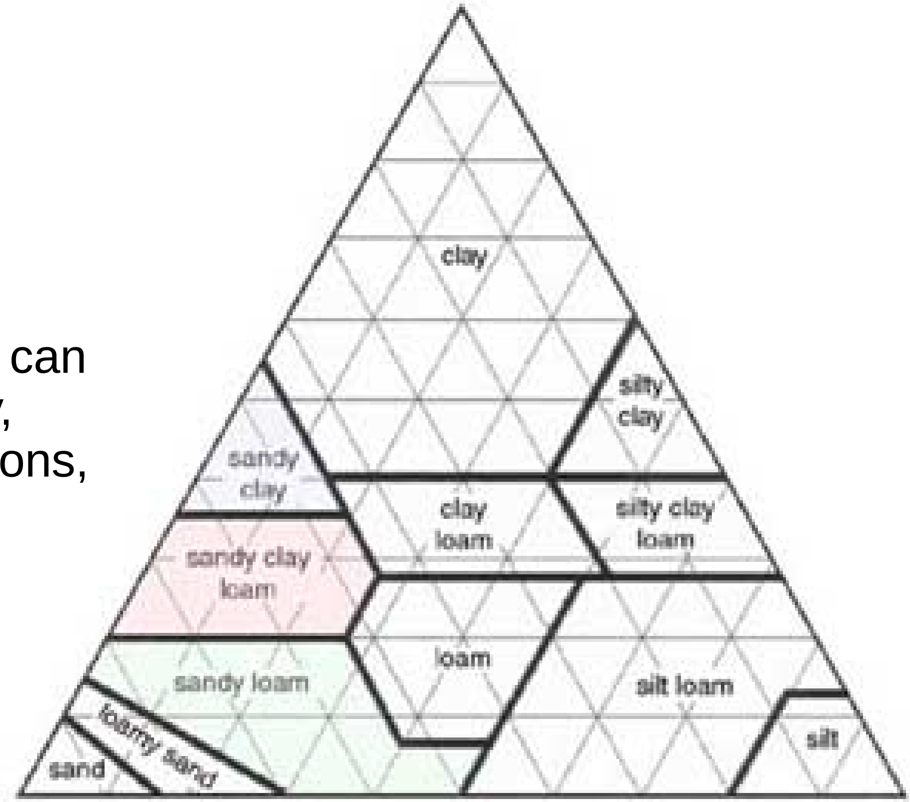


Default Nutrient Concentration in Stream Bank Soils (P1 BANCS)

One Size fits all?

1.05 lbs TP/ton Sediment

Nutrient Concentration in stream bank soils can vary widely depending on soil type, geology, vegetation, historical land use, soil applications, and other factors



Protocol 1: Method 2 – Direct Measurement

(Nutrient Concentrations in Stream bank Soils)

- **CBPO Default TP concentration:**

Table 5. TN and TP Concentrations in Sediments in Different Parts of the Urban Landscape[1]

Location	Mean TP	TP Range	Mean TN	TN Range	Location	Reference
Upland Soils	0.18	0.01-2.31	3.2	0.2-13.2	MD	Pouyat et al., 2007
Street Solids	2.07	0.76-2.87	4.33	1.30-10.83	MD	Diblasi, 2008
Catch Basin [3]	1.96	0.23-3.86	6.96	0.23-25.08	MD	Law et al., 2008
BMP Sediments	1.17	0.06-5.51	5.86	0.44-22.4	National	Schueler, 1994
Streambank Sediments	0.439	0.19-0.90	--	--	MD	BDPW, 2006
	1.78		5.41		MD	Stewart, 2012
	1.43	0.93-1.87	4.4	2.8-6.8	PA	Land Studies, 2005 [2]
	1.05	0.68-1.92	2.28	0.83-4.32	PA	Walter et al., 2007 [2,4]

[1] all units are lb/ton
[2] the Pennsylvania data on streambank sediments were in rural/agricultural subwatersheds
[3] catch basin values are for sediment only, excluding leaves
[4] median TN and TP values are reported

1.05 lbs** TP/ton sediment (~525mg/kg) selected as CBPO default value for ALL projects. However, range is **0.19 – 1.92 (10 x)

- **2013 White Paper Sample Findings:**

Looked at 16 past Restoration Reaches w/ 124 bankline soil samples

Protocol 1: Method 2 - Direct Measurement
(Nutrient Concentrations in Stream bank Soils)

Appendix C. Nutrient Concentrations in Stream Bank Soils

Project Number	Location by Physiographic Province	Test Year	# Samples	Total N Conc. Range (ppm)	Total N Conc. Avg. (ppm)	Total P Conc. Range (ppm)	Total P Conc. Avg. (ppm)
1	Coastal Plain	2013	2	n/a	n/a	<100-504	302
2	Coastal Plain	2011	n/a	n/a	n/a	n/a	133
3	Coastal Plain	2011	5	n/a	n/a	<100-138	112
4	Coastal Plain	2011	5	n/a	n/a	168-204	189
5	Coastal Plain	2011	5	n/a	n/a	<100-188	136.6
6	Coastal Plain	2011	5	n/a	n/a	<100-249	164
7	Coastal Plain	2013	1	n/a	n/a	103	103
8	Coastal Plain	2013	1	n/a	n/a	<100	100
9	Piedmont, lowlands	2010	4	120-890	445	40-130	90
10	Piedmont, lowlands	2010	4	40-560	255	50-100	65
11	Piedmont, lowlands	2010	4	50-660	273	20-180	130
12	Piedmont, lowlands	2010	2	200-290	245	40-110	75
13	Coastal Plain	2011	10	30-1560	340	109-2120	568
14	Piedmont, upland	2008	12	n/a	n/a	10-200	101
15	Piedmont, upland	2008	48	n/a	n/a	100-740	280
16	Piedmont, upland	2009	16	n/a	n/a	10-150	61
TOTAL			124				
AVERAGE					312		163
MEDIAN					273		121

NOTE 1: Soil concentrations reported as "<100" reported here as 100; therefore actual average will be less.

NOTE 2: All samples tested at A&L Eastern Laboratories in Richmond, VA.

NOTE 3: Project 9, 10, 11, and 12 are at one project location, which contained 4 physically disparate reaches grouped into a large watershed.

NOTE 4: In all cases, USEPA SW-846 method was used to measure Total Phosphorus

Protocol 1: Method 2 - Direct Measurement
(Nutrient Concentrations in Stream bank Soils)

- WEG (Stantec) 2013 White Paper Findings:

Number of Projects	Sample Locations by Physiographic Province[1]	Test Year	Total # of Samples[1]	TKN Conc. Range (lbs TN/ton SED)[2]	TKN Conc. Avg. (lbs TN/ton SED)	TP Conc. Range (lbs TP/ton SED)[2]	TP Conc. Avg. (lbs TP/ton SED)
16	Piedmont lowland & upland, Coastal Plain	2008-2013	124	0.06-3.12	0.62	0.02-4.24	0.33

[1] All projects in tidewater and northern Virginia; most projects tested 2-5 samples; three projects contained a large number of samples;
[2] TKN as Total Kjeldahl Nitrogen; TP tested with USEPA SW-846 method; total samples for TKN less than TP
[3] All samples tested at A&L Eastern Laboratories in Richmond, VA and reported as ppm; results coverted to lbs/ton of SED by WEG.

Yikes!

Summary:

124 sample Average = **0.33 lbs** TP/Ton Sediment

w/ range of 0.02 – 4.24 (vs. **1.05 lbs** TP/Ton Sediment CBPO default)

(High value is *100 x greater* than low value)

Protocol 1:Method 2 – Direct Measure

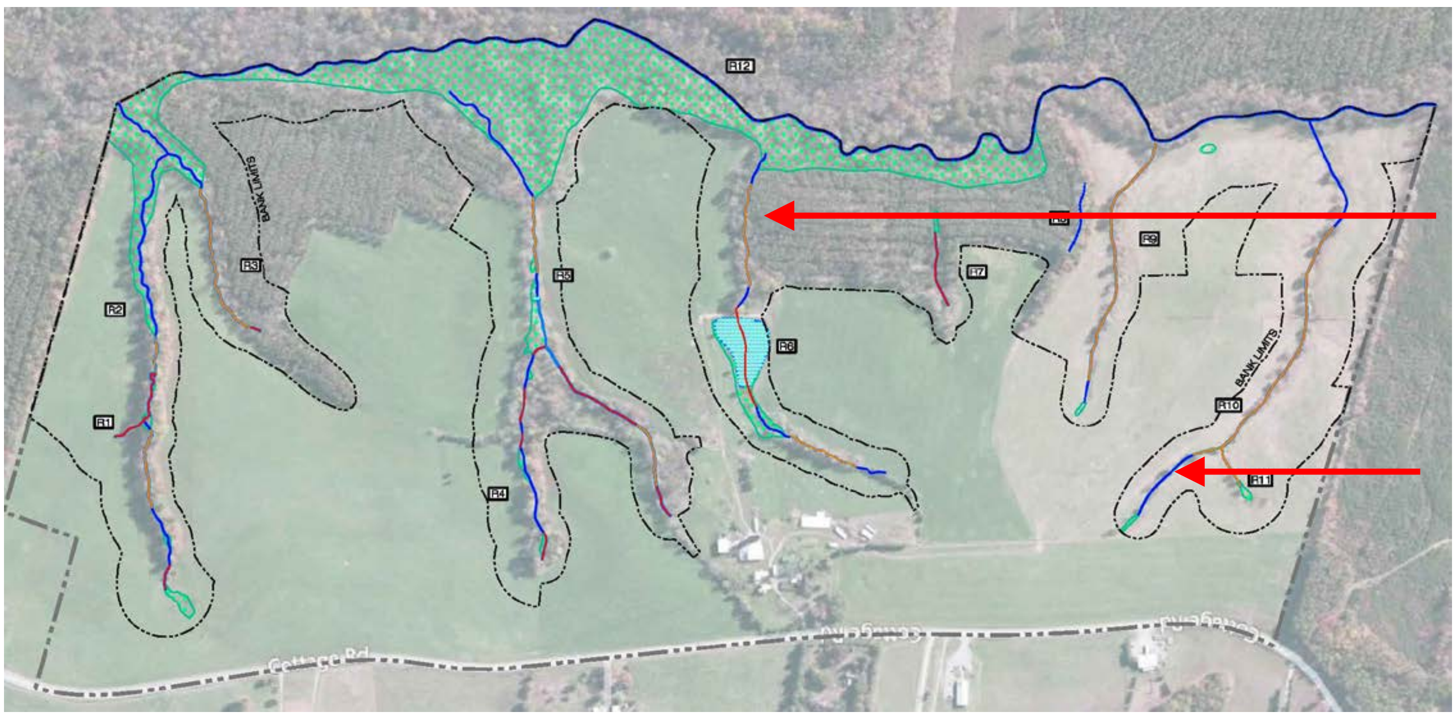
(Example Project)

- Didn't have time to monitor the site for even ½ year.
- Performed a BANCS (NC Curve) : 358 tons/year
- Collected soil samples within the channel and in the field

A&L Eastern Laboratories, Inc.
7621 Whitepine Road Richmond, Virginia 23237 (804) 743-9401 Fax (804) 271-6446
www.aleastern.com

REPORT OF ANALYSIS

Lab No	Sample ID / Sample Date and Time	Nitrogen, Total (Inorganic + … CALCULATION	Total Kjeldahl Nitrogen SM-4500-NH3 C-TKN	Total Phosphorus SW 6010C
			ppm	
20787	COMPOSITE	2000	2000	1250
20788	SITE 1	1500	1490	325
20789	SITE 2	1600	1590	308
20790	SITE 3	933	930	309



Forest TP = 314 ppm

Field TP = 1250 ppm

Protocol1 : Method 2 – Direct Measurement

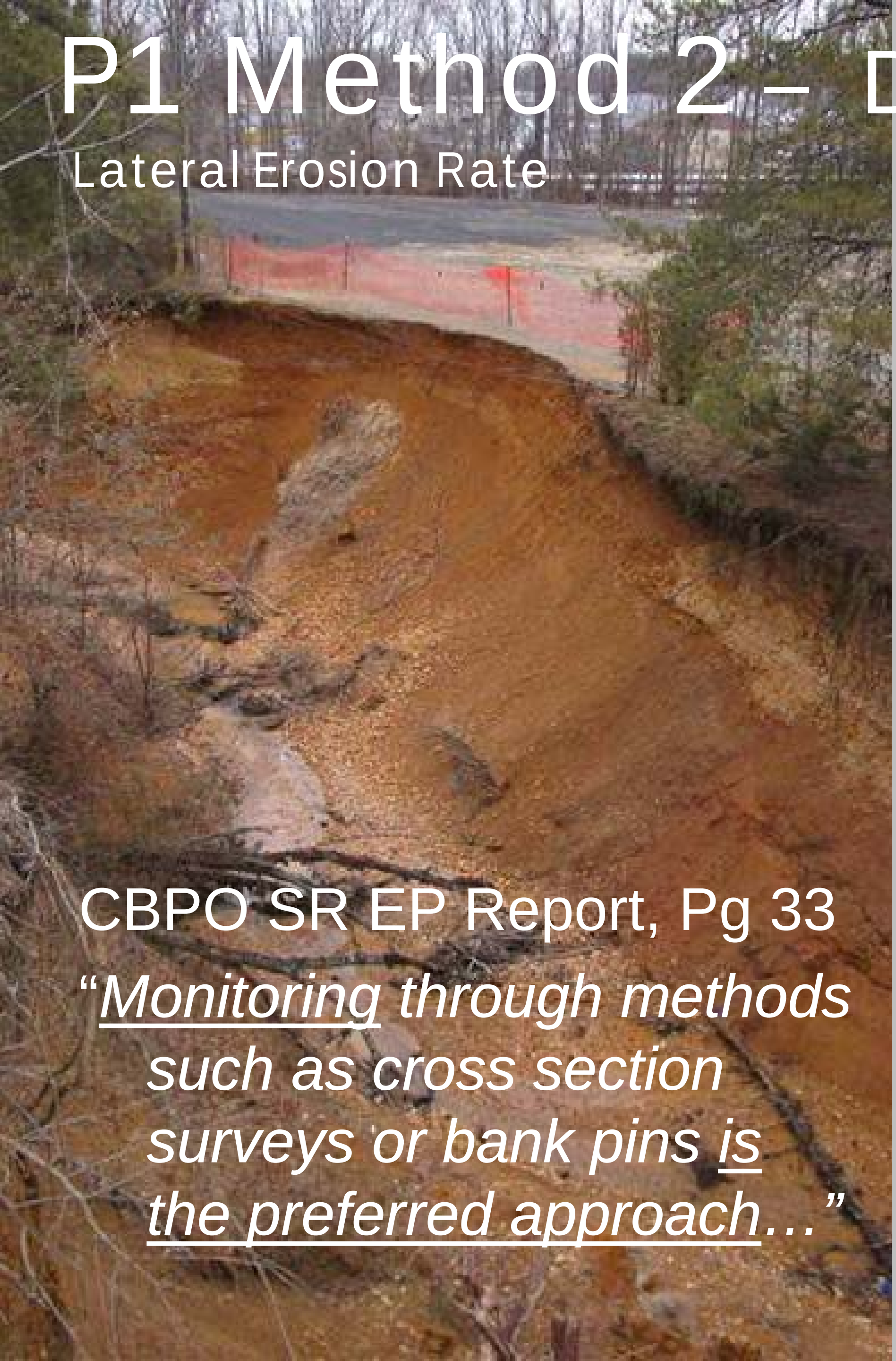
Nutrient Concentrations in Stream bank Soils (Example Project)

- Potential Mitigation Bank Located in the Piedmont
- Required to show uptick in water quality value to proceed
- Spring-fed streams eroding into pasture, minimal wooded riparian corridor

Nutrient Contributions	Quantities
Erosion Rate (tons/yr)	358
Wooded Contributions	*(lb/yr)*
Total Phosphorus	224.8
Total Nitrogen	962.3
Field Contributions	*(lb/yr)*
Total Phosphorus	895.0
Total Nitrogen	1432.0

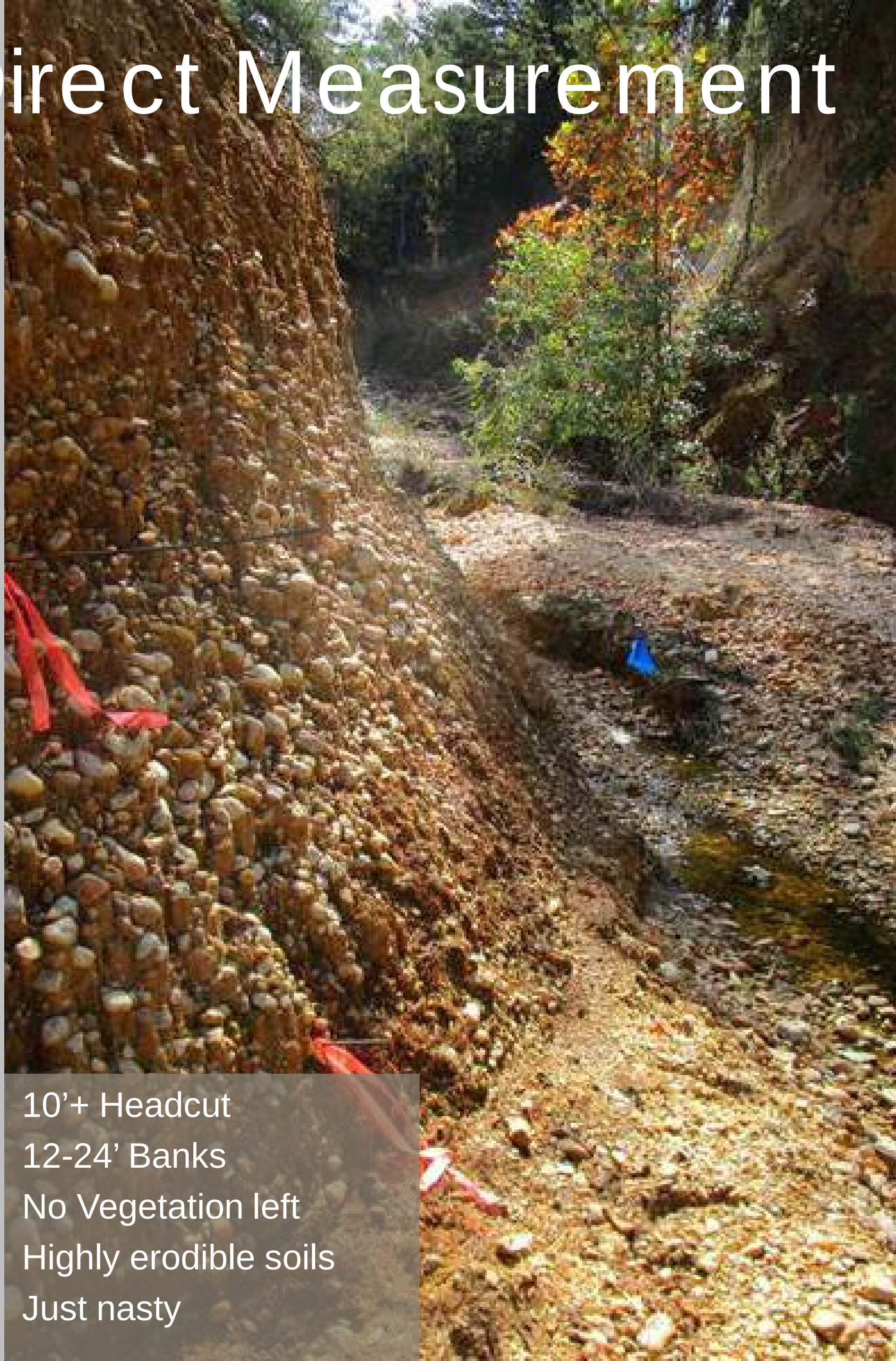
P1 Method 2 – Direct Measurement

Lateral Erosion Rate



CBPO SR EP Report, Pg 33

"*<u>Monitoring</u> through methods such as cross section surveys or bank pins <u>is the preferred approach</u>…*"



10'+ Headcut
12-24' Banks
No Vegetation left
Highly erodible soils
Just nasty

Monitoring Needed
(Project Application)

- Network of Bank Pins
- Soil Concentrations
- Rainfall Observation
- ½ year – No Bankfull events (conservative)

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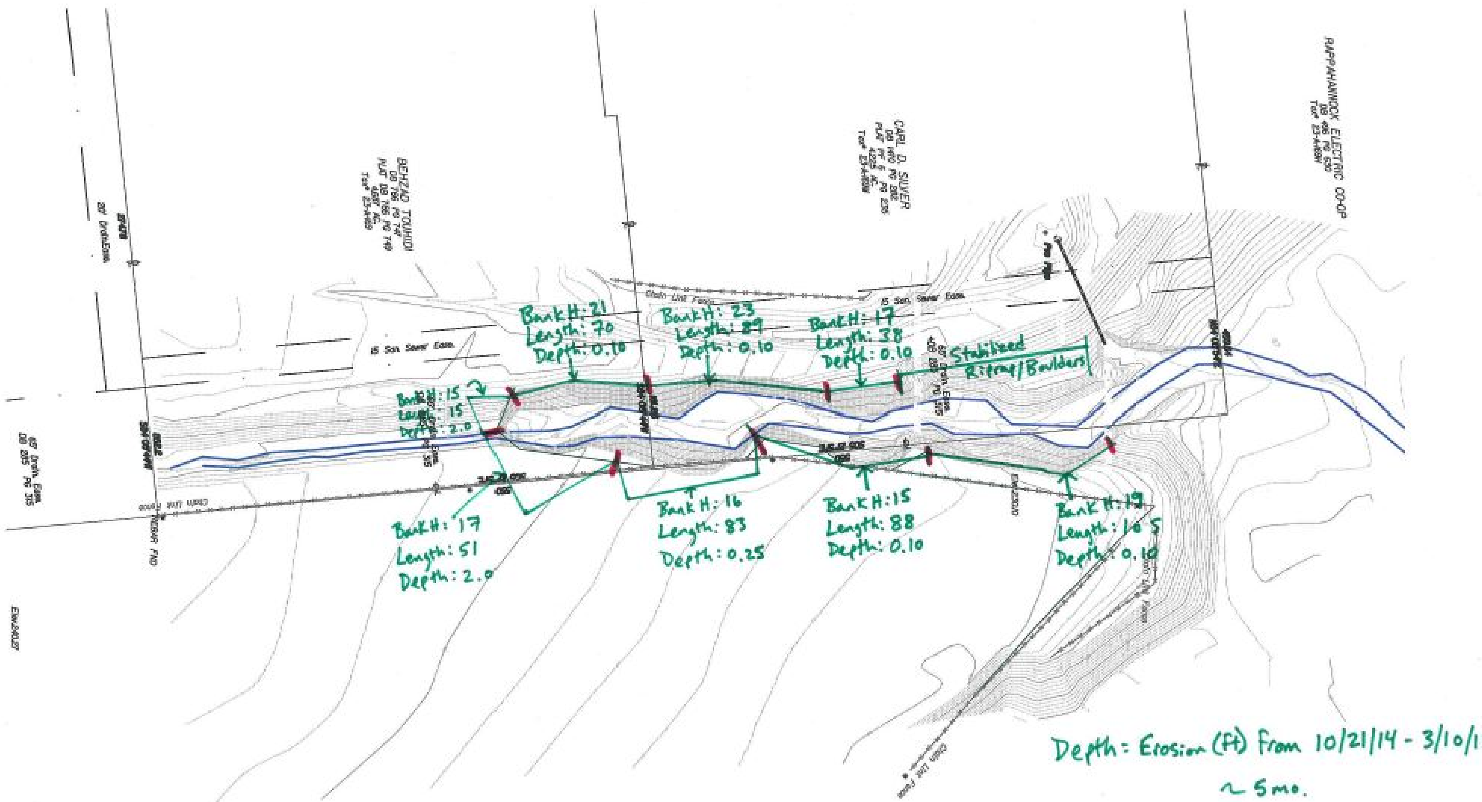
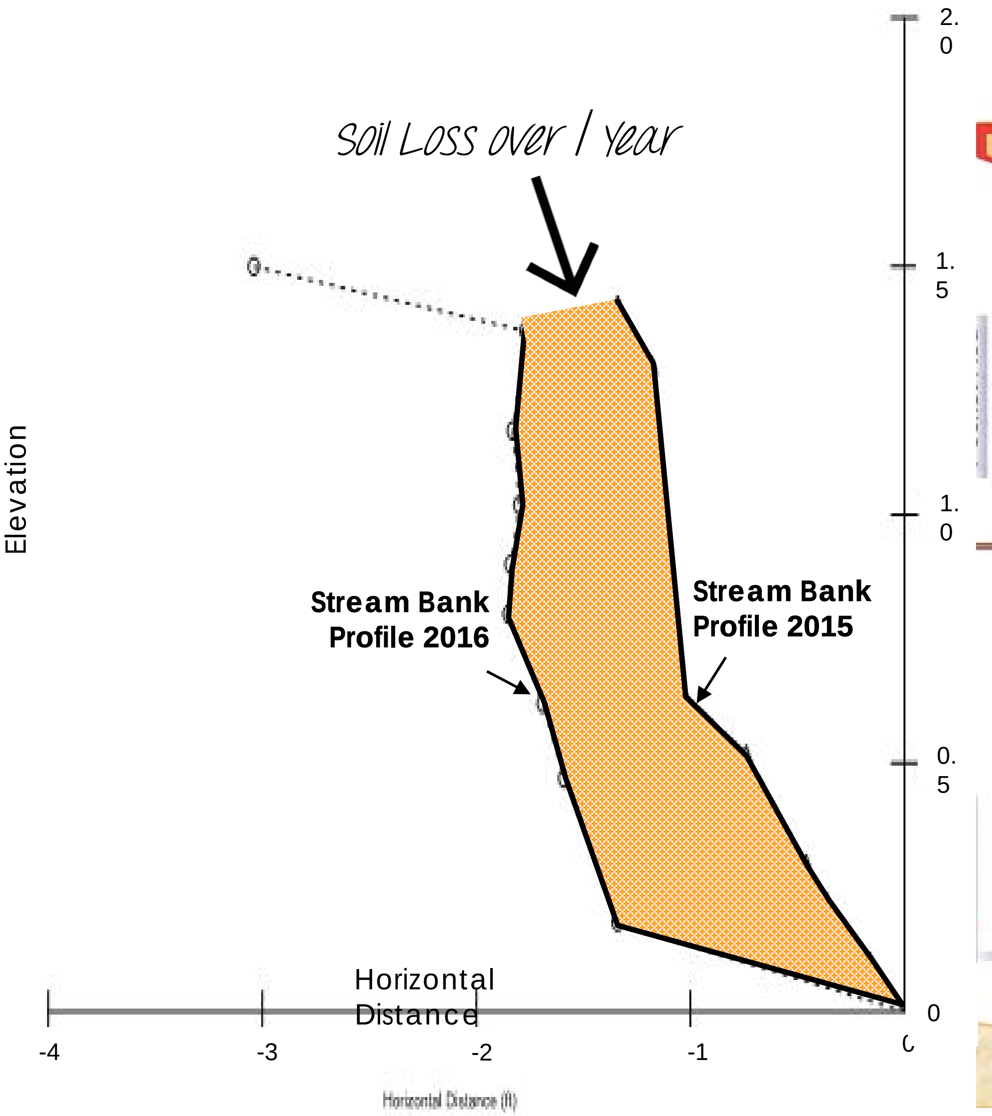
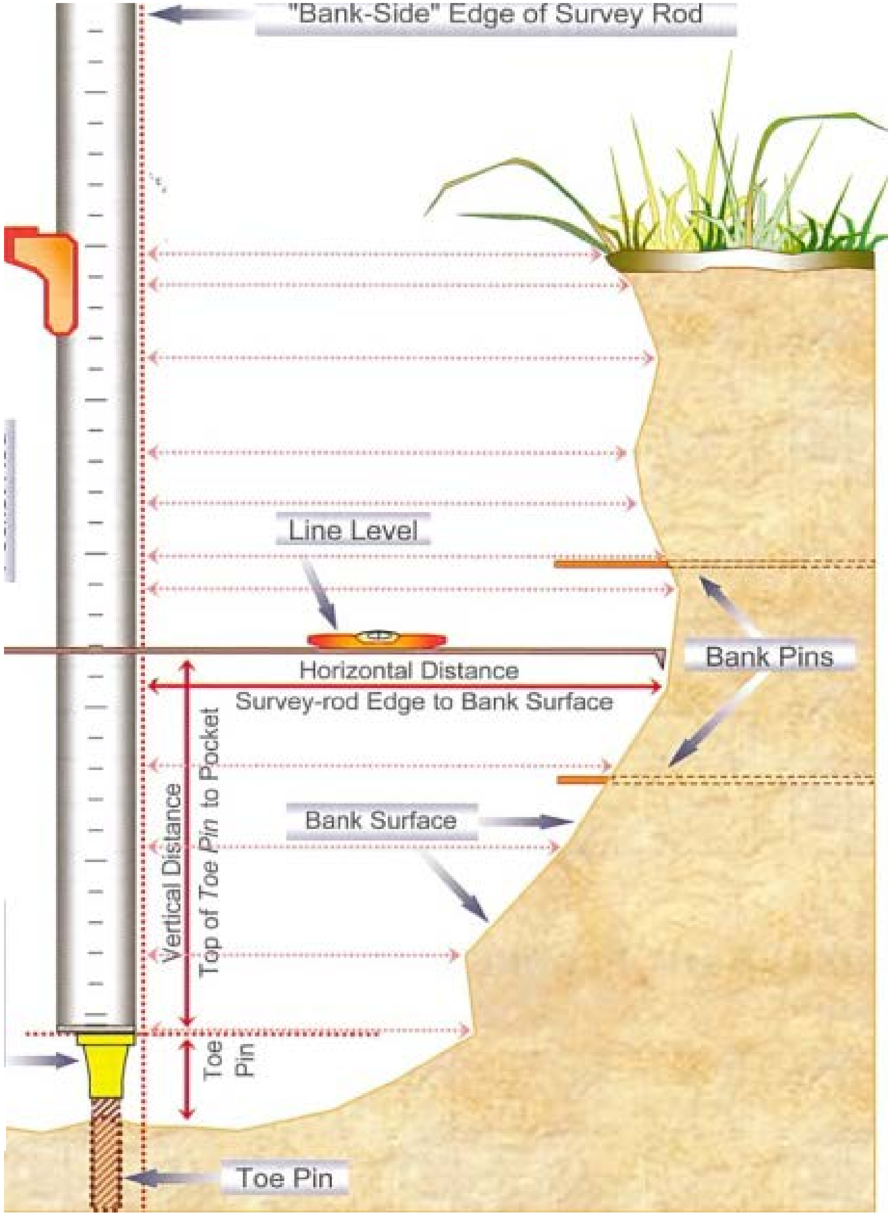
REPORT OF ANALYSIS

Lab No	Sample ID / Sample Date and Time	Nitrogen, Total (Inorganic + CALCULATION	Total Kjeldahl Nitrogen SM-4500-NH3C-TKN	Total Phosphorus SW 6010C
			ppm	
07099	1	821	820	155
07100	2	281	280	< 100



Toe/Bank Pin Monitoring





>50% efficiency Spotsylvania County, VA (400 LF)

CBPO SR EP Report, Pg 36 :

“The Panel felt that efficiencies greater than 50% should be allowed for projects that have shown through monitoring that the higher rates can be justified subject to approval by the states. This will hopefully promote monitoring (e.g., Big Spring Run in Pennsylvania) of stream restoration projects.”

Monitoring Results

(Lateral Erosion Rate)

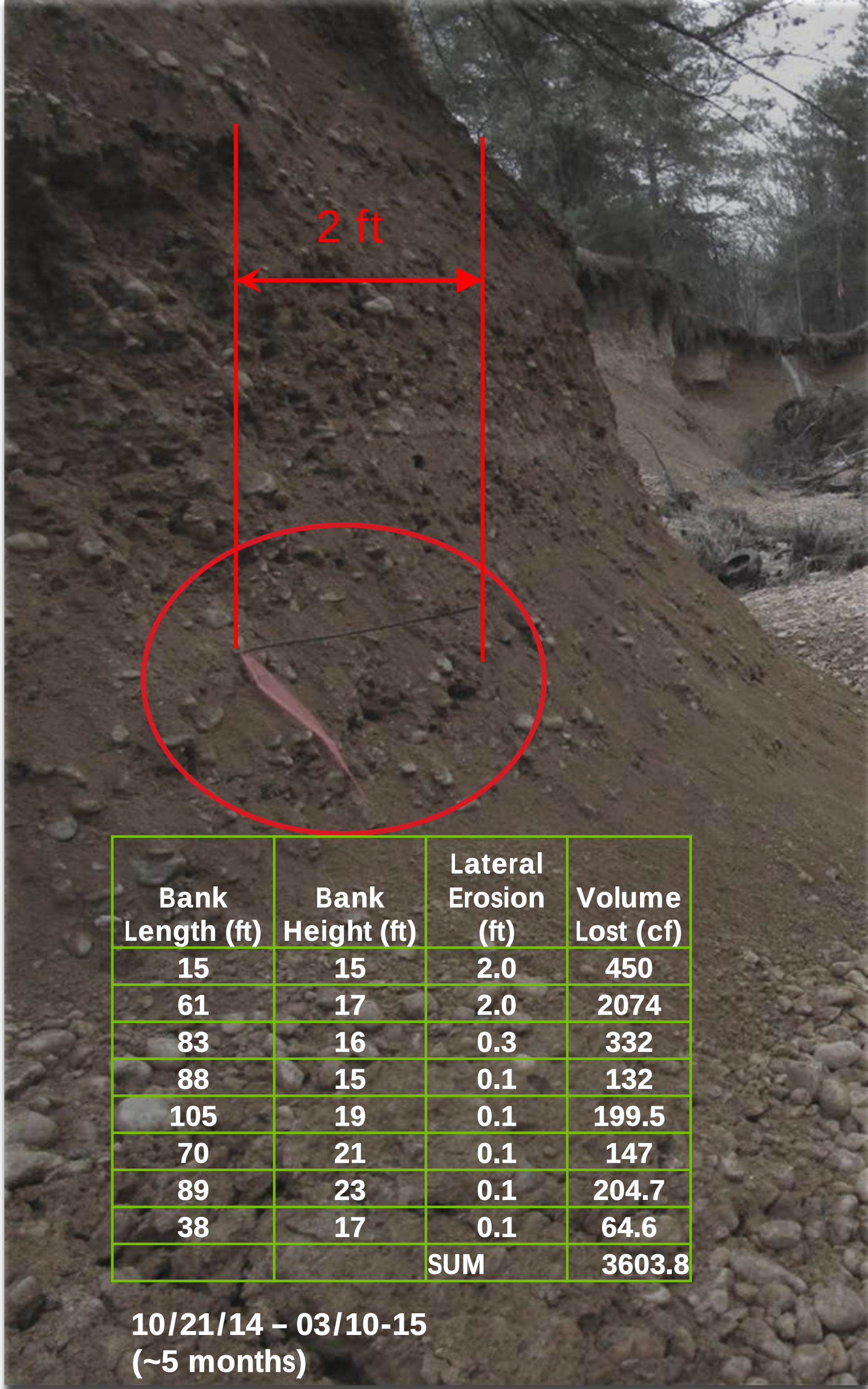
- Extrapolated for 1 year
- Provided range using lower soils concentration
- 90% efficiency was estimated (rather then 50%)

	TP (lb/yr)		TN (lb/yr)[3]		TP Reductions (90%)[2]		TN Reductions (90%)[3]	
	Low[1]	High[1]	Low	High	Low	High	Low	High
Soil Sample 1	129.10	167.82	683.79	888.93	116	151	615	800
Soil Sample 2	83.29	108.27	234.04	304.25	75	97	211	274
Average	106.19	138.05	458.92	596.59	96	124	413	537

[1]Low vs. High values based on bulk densities of 96 lbs/ft3 from Rivermorph and 125 lbs/ft3 from Bay Protocol. Low and high bulk densities yield sediment erosion rates of 416.44 tons/year and 541.37 tons/year, respectively.

[2] The CBP TP concentration default value is 525 ppm versus the average measured value of 128 ppm used here. If the default concentration had been utilized instead, the TP annual reported reductions would have averaged approximately453 lbs/yr at 90% efficiency.

[3] The CBP TN concentration default value is 1,140 ppm versus the average measured value of 551 ppm used here. If the default concentration had been utilized instead, the TN annual reported reductions would have averaged approximately 983 lbs/yr at 90% efficiency.



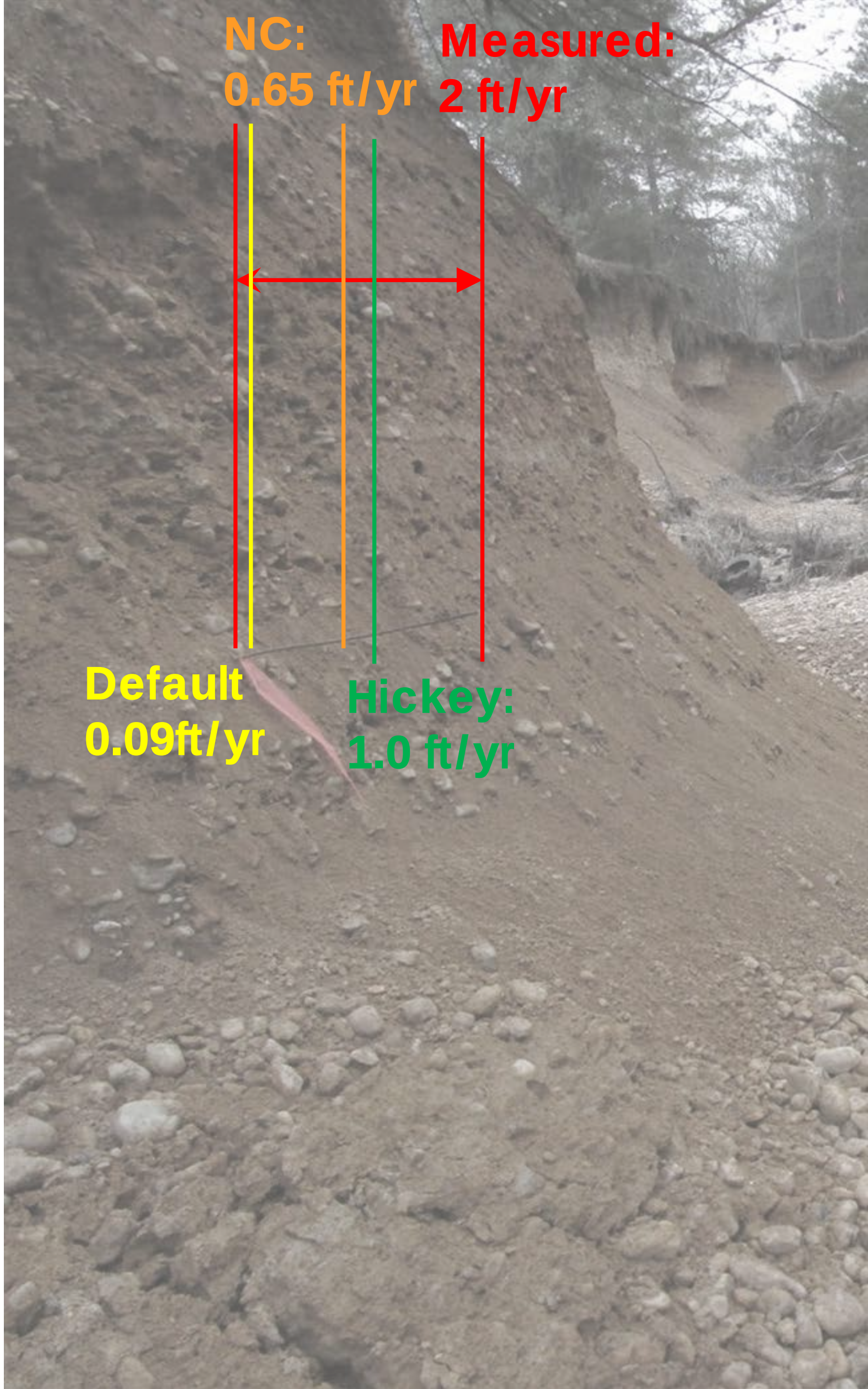
Bank Length (ft)	Bank Height (ft)	Lateral Erosion (ft)	Volume Lost (cf)
15	15	2.0	450
61	17	2.0	2074
83	16	0.3	332
88	15	0.1	132
105	19	0.1	199.5
70	21	0.1	147
89	23	0.1	204.7
38	17	0.1	64.6
		SUM	3603.8

10/21/14 – 03/10-15
(~5 months)

Monitoring Results
(Comparison Applying Various Lateral Erosion Rate)

	Method Description	Notes	TP (lbs/yr)	TN (lbs/yr)
1	Default Removal Rate	Fixed Rate	28.5	31.4
2	BANCS	15ft - 23ft bank hts	1,322	2,871
3	BANCS	10ft max bank hts	551	1,196
4	Monitoring (bank pins) @90%	w/525 ppm TP (default)	502	1,090
5	Monitoring (bank pins) @90%	w/128 ppm TP (measured)	110	475

NOTE:
Lateral erosion rates for NC and Hickey in graphic are adjusted to BEHI/NBS VH/Extr 5 month rate.
Default rate estimated from TP removal, bank ht and other factors.



3. Costs Associated with Stream Restoration and Nutrient Removal

Costs for removal – Traditional Stormwater

Table 2. Properties of BMPs Selected for Cost Estimation

BMP ID	BMP Type	4-digit HUC	Impervious Area Treated (acres)	WQV Treated (ft^3)	Annual Phosphorus Removal (lb)	Removal Efficiency
1	Extended detention basin[a]	York	2.44	8414.34	1.85	35%
2	Extended detention basin[a]	York	2.56	8828.16	1.94	35%
3	Extended detention basin[a]	York	8.01	27622.49	6.08	35%
4	Extended detention basin[b]	Potomac	4.27	14725.10	3.24	35%
5	Extended detention basin[b]	Potomac	7.33	25277.51	5.57	35%
6	Extended detention basin[b]	Potomac	7.42	25587.87	5.64	35%
7	Extended detention basin[b]	Potomac	15.15	52244.78	11.51	35%
8	Sand filter[c]	Potomac	4.40	7586.70	6.21	65%
9	Extended detention enhanced basin[c]	Potomac	9.20	31726.20	9.98	50%

BMP = best management practice; HUC = hydrologic unit code; WQV = water quality volume.
[a] Functional class: rural collector rolling undivided.
[b] Functional class: rural principal arterial.
[c] Functional class: urban minor arterial.

Table 3. Component Costs of BMPs Selected for Cost Estimation

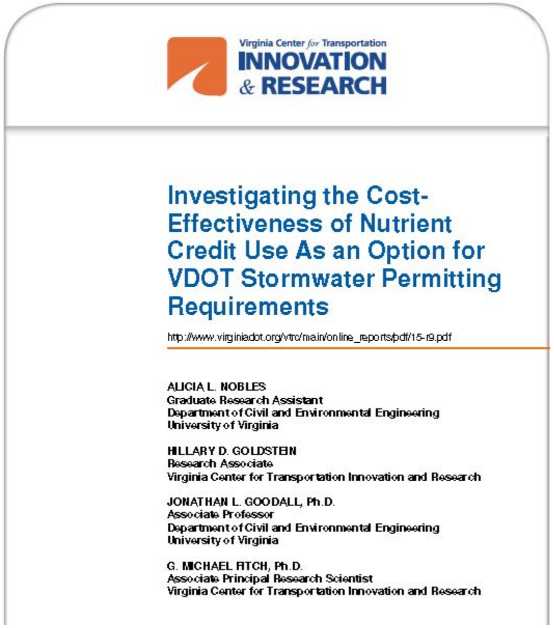
BMP ID	Pre-Construction	Construction	Lifetime O&M	ROW	Total		Per Pound of Annual Phosphorus Removal	
					Including ROW	Excluding ROW	Including ROW	Excluding ROW
1	$7,487.90	$23,399.69	$3,481.28	$24,081.55	$34,368.87	$58,450.43	$18,545.89	$31,540.61
2	$15,049.60	$47,030.01	$6,996.88	$35,691.84	$69,076.49	$104,768.33	$35,527.32	$53,884.30
3	$20,083.53	$62,761.02	$9,337.26	$30,077.16	$92,181.80	$122,258.96	$15,152.52	$20,096.50
4	$15,265.14	$47,703.55	$7,097.08	$35,327.13	$70,065.77	$105,392.89	$21,604.80	$32,497.93
5	$48,580.29	$151,813.40	$22,586.00	$57,992.14	$222,979.68	$280,971.82	$40,052.86	$50,469.73
6	$46,085.87	$144,018.34	$21,426.29	$62,088.79	$211,530.50	$273,619.28	$37,535.42	$48,552.88
7	$79,023.29	$246,947.78	$36,739.59	$53,814.44	$362,710.66	$416,525.10	$31,522.45	$36,199.35
8	$29,889.55	$93,404.84	$166,755.37	$49,801.21	$290,049.76	$339,850.97	$46,735.48	$54,759.91
9	$88,069.13	$275,216.03	$184,253.38	$200,549.55	$547,538.54	$748,088.08	$54,852.59	$74,943.71

BMP = best management practice; O&M = operation and maintenance; ROW = right of way.

20-75K

Phosphorus Credit Cost

Fixed prices for 1-pound phosphorus credits in the James, Potomac, Rappahannock, and York watersheds were provided by VDOT's Location and Design Division. The cost of a 1-pound phosphorous credit in the James and Potomac watersheds is $10,430 and $18,700, respectively. The cost of a 1-pound phosphorous credit in the York and Rappahannock watersheds in on a sliding scale from $17,000 to $20,000 and $14,700 to $16,450, respectively. The cost of credits in the York and Rappahannock watersheds decreases as more credits are purchased. The credits are managed through a clearinghouse, which generates the credits by converting agricultural land to forest land or building urban BMPs.


Virginia Center for Transportation
INNOVATION & RESEARCH

Investigating the Cost-Effectiveness of Nutrient Credit Use As an Option for VDOT Stormwater Permitting Requirements

http://www.virginiadot.org/vtrc/main/online_reports/pdf/15-r9.pdf

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Project A Spotsylvania County, VA (400 LF)

Phosphorous Removed – 111 LB/YR
Total Project Cost - 700K

Per Pound of P - $6,306
Value in Watershed – 1.65 Million
(15k/LB x 111lbs)

Project B

York County, VA

Phosphorous Removed – 141 LB/YR
Total Project Cost 1.2 Million

York County, Virginia
800 LF

Per Pound of P - $8,511
Value in Watershed – 2.4 Million
(17k LB X 141 LBS)

Project C

Harford, MD (5288 LF)

Phosphorous Removed – 2575 LB/YR
Total Project Cost 6.6 Million +/-
Estimated – Not constructed yet

Per Pound of P - $2,563
Value in Watershed – N/A

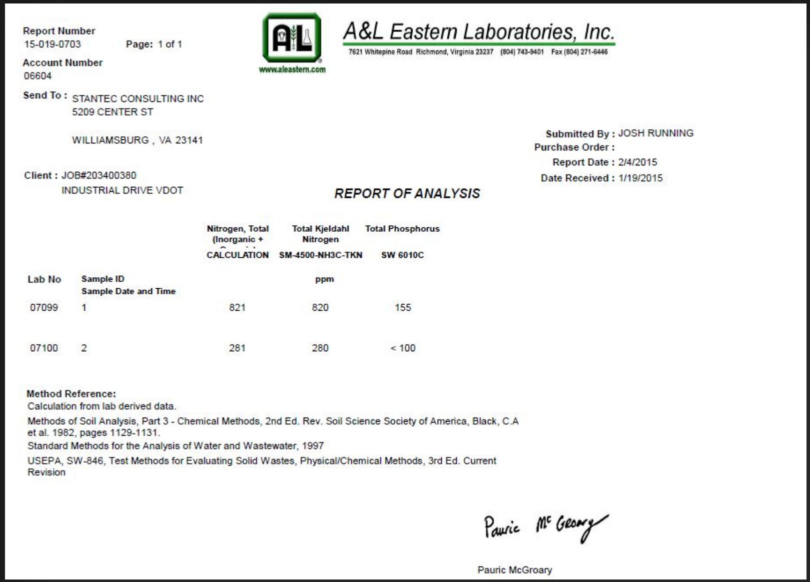
Nutrient Removal Cost Summary

• Traditional Stormwater	$20-75K per LB P
• Nutrient Bank (in VA only)	$15-20K per LB P
• Project A*	$6,306 per LB P
• Project B**	$8,511 per LB P
• Project C***	$2,563 per LB P

** Construction completed. Numbers reflect actual measured bank recession and soil concertation rates. Project efficiency was 90% (not 50%).*

*** Construction completed. Number reflect actual measured soil concentration rates but utilized NC Curve. Project efficiency was 50%.*

**** Construction cost estimated. Numbers reflect actual measured soil concentrations, bulk densities and recession rates. Project efficiency was 50%.*



Report Number
15-019-0703 Page: 1 of 1

Account Number
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Submitted By : JOSH RUNNING
Purchase Order :
Report Date : 2/4/2015
Date Received : 1/19/2015

Client : JOB#203400380
INDUSTRIAL DRIVE VDOT

REPORT OF ANALYSIS

		Nitrogen, Total (Inorganic +	Total Kjeldahl Nitrogen	Total Phosphorus
		CALCULATION	SM-4500-NH3C-TKN	SW 6010C
Lab No	Sample ID Sample Date and Time		ppm	
07099	1	821	820	155
07100	2	281	280	< 100

Method Reference:
Calculation from lab derived data.
Methods of Soil Analysis, Part 3 - Chemical Methods, 2nd Ed. Rev. Soil Science Society of America, Black, C.A et al. 1982, pages 1129-1131.
Standard Methods for the Analysis of Water and Wastewater, 1997
USEPA, SW-846, Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods, 3rd Ed. Current Revision

Pauric McGroary

Pauric McGroary

4. Variables that affect ROI on Nutrient Stream Restoration Projects

Bulk Density

- Expert Panel Recommendations - 125 lb/ft3
- Rivermorph Software default – 96 lb/ft3
- Project C – 87 lb/ft3

Summary of Calculations - Expert Panel Method (per field data)

Stream Reach	Bulk Density of soil	Nitrogen Concentration	Phosphorus Concentration	Total Nitrogen Removed	Total Phosphorus Removed	Total Sediment Removed
	[lb/ft^3]	[lb/ton]	[lb/ton]	[lb/yr]	[lb/yr]	[ton/yr]
HB01	87.2	1.92	0.92	111.6	53.5	10.1
HB02	87.0	2.54	1.51	140.4	83.5	9.6
HB03	87.0	2.69	1.09	4901.5	1986.1	317.0
UT01 (US)	89.2	5.62	1.23	13.9	3.1	0.4
UT01 (DS)	89.0	1.63	1.09	101.4	67.8	10.8
UT02	87.2	1.92	0.92	95.5	39.6	6.5
UT03	87.0	2.69	1.09	311.5	126.2	20.1
			Total	**5675.8**	**2359.7**	**374.7**

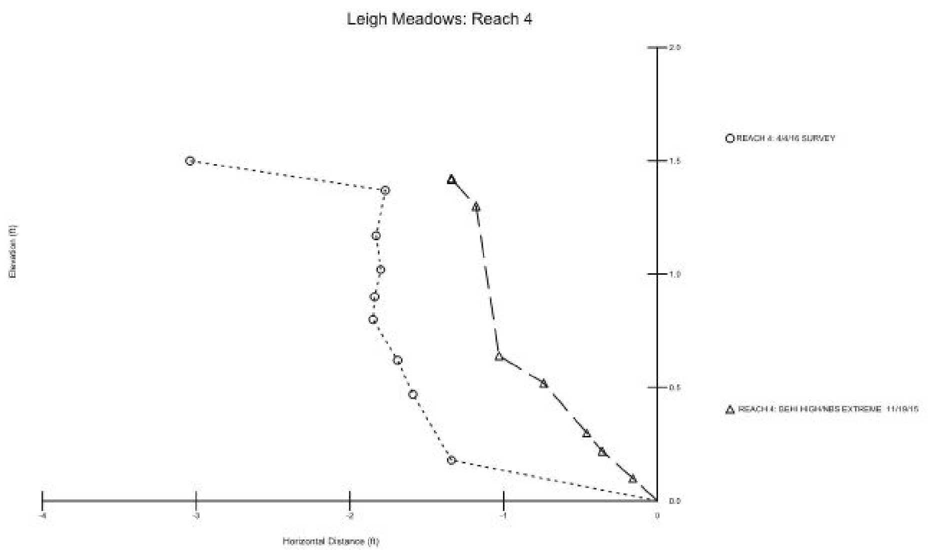
Note: The USDA has some quick methods to help get a fairly accurate idea of bulk density.

Soil Nutrient Concentrations

- Expert Panel Recommendations - 1.05 LB P/ton of sed (range 0.19 – 1.9 LB/Ton)
- 124 Samples (Stantec paper) - 0.33 LB P/ton of sed (range .02 – 4.24 LB/ton)
- Project C – 1.10 LB/Ton of P (18 samples)
- Observation –nutrient concentrations are typically higher in fields then forested environments

Bank Recession Rates

- BEHI/NBS Highly Variable & Subject to Evaluator’s BPJ.
- Using a High/High combination (BEHI/NBS)
- North Carolina Curve – 0.2 FT/YR
- Hickey Run Curve – 1.0 FT/YR
- Measured at Project C 2.3 – 2.5 FT/YR*
- (Project A > 2.0’ +/- (Bank Pins Fell Out)



** Measurements occurred for 9 months and were extrapolated for a year.*

WISCONSIN DEPT. OF NATURAL RESOURCES

BUREAU OF WATERSHED MANAGEMANT
PROGRAM GUIDANCE

Storm Water Management Program

TMDL Guidance for MS4 Permits:
Planning, Implementation, and Modeling Guidance

Effective: October 20, 2014
Guidance #: 3800-2014-04

Notice: This document is intended solely as guidance, and does not contain any mandatory requirements except where requirements found in statute or administrative rule are referenced. This guidance does not establish or affect legal rights or obligations, and is not finally determinative of any of the issues addressed. This guidance does not create any rights enforceable by any party in litigation with the State of Wisconsin or the Department of Natural Resources. Any regulatory decisions made by the Department of Natural Resources in any matter addressed by this guidance will be made by applying the governing statutes and administrative rules to the relevant facts.

APPROVED:

Pam Biersach, Director
Bureau of Watershed Management

10/28/14
Date

1

- **Stabilization of MS4** – Stabilization of eroding streambanks are eligible for a 50% cost share match through DNR's Runoff Management Grant Program. DNR considers streambank stabilization activities an important step in reducing the discharge of sediment. However, TMDL baseline modeling already assumes that drainage systems are stable; therefore, it is not appropriate to take credit against the WLA or percent reduction in the TMDL for stabilization of a drainage ditch or channel of the MS4. However stabilization projects should be identified in the TMDL implementation plan and can serve as a compliance benchmark toward meeting overall TMDL goals.
- **Streambank Stabilization Outside of the Permitted MS4** – Permitted MS4s may take credit through pollutant trading for stabilization of channels and streambanks which are outside of the area served by their MS4. Applicable credit thresholds and trade ratios would apply.

5. The Wisconsin Connection

Its available as an opportunity (DNR Docs)

- Some discussion and clarification needed on application.

The Wisconsin Connection

It is available as an opportunity (DNR Docs)

- Shown below as a factor for P

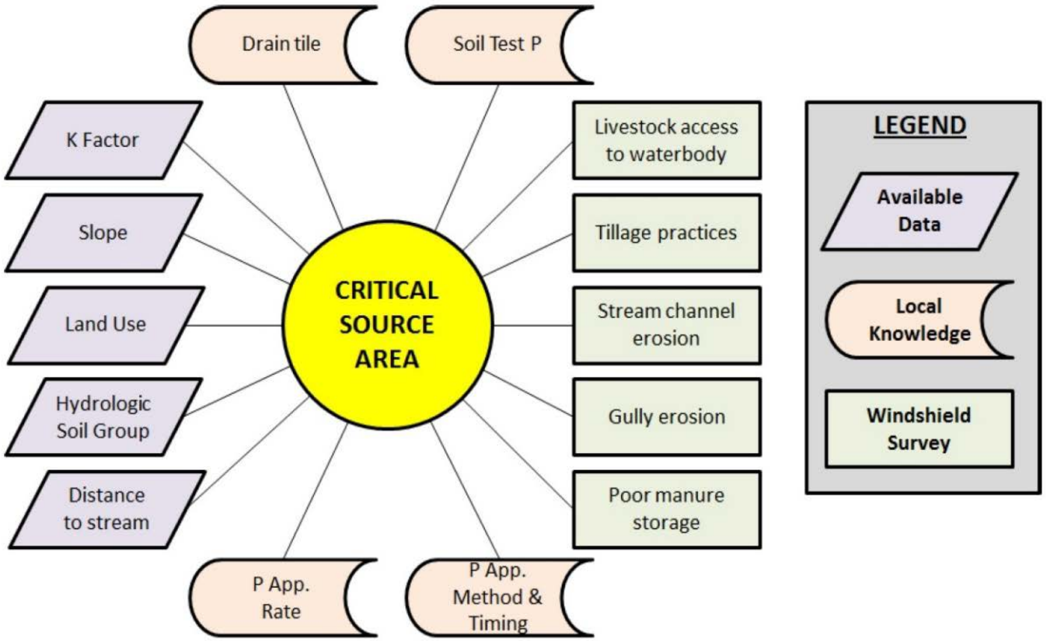


Figure 9. Example source and transport factors to identify critical source areas for phosphorus.

BUREAU OF WATER QUALITY
PROGRAM GUIDANCE

Guidance for Implementing Water Quality Trading in WPDES Permits

Guidance Number: 3800-2013-04
Wisconsin Department of Natural Resources
08/21/2013

8/21/13
Date

A Water Quality Trading How To Manual

Guidance on developing a water quality trading strategy based on protocols specified in "Guidance for Implementing Water Quality Trading in WPDES Permits"

Guidance Number: 3400-2013-03
Wisconsin Department of Natural Resources
09/09/2013

This document is intended solely as guidance, and does not contain any mandatory requirements except where requirements found in statute or administrative rule are referenced. This guidance does not establish or affect legal rights or obligations, and is not finally determinative of any of the issues addressed. This guidance does not create any rights enforceable by any party in litigation with the State of Wisconsin or the Department of Natural Resources. Any regulatory decisions made by the Department of Natural Resources in any matter addressed by this guidance will be made by applying the governing statutes and administrative rules to the relevant facts.

APPROVED:

Susan L Sylvester — 9/9/13
Susan L. Sylvester — Date
Director, Bureau of Water Quality

The Wisconsin Connection

Spec references to stream restoration practices

2.11.5. Aquatic Habitat Adjustment Factor

Many of Wisconsin's listed surface waters are impaired due to a combination of chemical, biological, and aquatic habitat impairments. In many cases, habitat restoration may be necessary for the listed surface water to achieve its full designated use. Therefore, activities that generate credits and include an aquatic habitat restoration element may qualify for an aquatic habitat adjustment to the trade ratio. To qualify, the surface water must be listed by WDNR as impaired for the traded pollutant and the management measure or practice must address both the traded pollutant and specific habitat impairments. Habitat restoration efforts must meet applicable WDNR and NRCS standards as listed in Table 5. Suggested adjustments to the trade ratio are provided in Table 4, p. 20. Additional guidance will be developed as more experience is gained.

Table 5. Applicable NRCS Technical Standards.

Number	Description
395	Stream Habitat, Improvement and Management
658	Wetland Creation
657	Wetland Restoration

2.9. Technical Standards for Management Practices

To generate credits, urban and agricultural management practices must be constructed and maintained in accordance with applicable technical standards from the United States Department of Agriculture's Natural Resources Conservation Service (NRCS) or WDNR's technical standards. NRCS standards may be found at: http://efotg.sc.egov.usda.gov/toc.aspx?CatID=16855 and WDNR technical standards can be found at: http://dnr.wi.gov/topic/stormwater/.

Table 4. Management practices with recommended credit generation and use information.

Management Practice	Uncertainty Factor[1]	Applicable Technical Standard	Method for Calculating Pollutant Load Reductions	Notes
Streambank Stabilization and Shoreline Protection Without aquatic habitat restoration With aquatic habitat restoration	 3 2	 NRCS 580 NRCS 382 NRCS 580 NRCS 395	Contact WDNR to discuss project and develop a method to quantify impact of stabilization. Appropriate methods include NRCS regression calculation.	For livestock producers, streambank stabilization must be accompanied by riparian fencing or other controls to prevent destruction of streambanks.

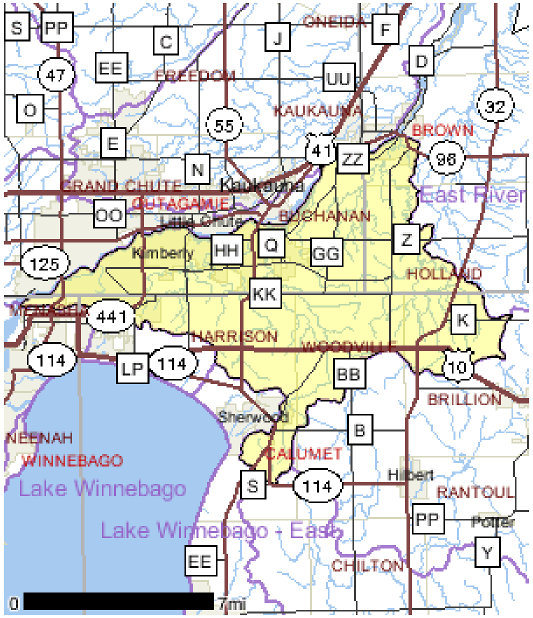
The Wisconsin Connection

Plum Creek (2016 DNR Grant) as an example…

- 24 of 43 miles eroding (45% of TSS loads?)

Project Location:
Plum Creek sub-watershed

Problem Statement:
Plum Creek is part of the Total Maximum Daily Load (TMDL) and watershed management plan for total phosphorus (TP) and total suspended solids (TSS) in the Lower Fox River Basin. The small watershed of 35 mi^2 has almost 20 miles of stream length on the Wisconsin state impaired waters list for TSS. Plum Creek is located about 10 miles upstream of the Green Bay/Fox River AOC. The AOC has proposed BUI targets for eutrophication and undesirable algae based on achieving the load reductions identified in the TMDL for 7 subbasins, including Plum Creek. Based on SWAT modeling results, Plum Creek produces an estimated 31,600 lbs/yr of TP and 5,500 metric tons/yr of TSS (Cadmus, 2012). The TMDL goal is to reduce the TP loading by 77 percent and the TSS load by 70 percent. Based on a SWAT model output, agricultural land in Plum Creek is estimated to contribute 94 and 95 percent of the annual loading of TP and TSS, respectively. Natural areas are estimated to contribute 1 percent of the TP and TSS. TP and TSS from bank erosion sources were not included in the modeling (Cadmus, 2012). However, recent stream inventories of Plum Creek by Outagamie County indicate that 24 of the 43 miles inventoried had actively eroding banks. Preliminary estimates are that these banks could be contributing 45 percent of the TSS annual loading measured at the USGS gage. If stream processes are producing almost half of the annual loading of TSS, the proposed TMDL goal to reduce TSS by 70 percent will not be achievable through upland soil conservation practices alone.



One of the first steps in the sediment TMDL process along with identifying targets is to identify the major sources of sediment. A stream corridor-based sediment budget and source apportionment study is needed to quantify the proportion of the TP and TSS loading originating from in-stream sources of bank and channel erosion compared to soil erosion. Gullying associated with headward extension of stream networks also needs to be quantified as a possible TP and TSS source. This proposal describes a combined sediment budget/fingerprinting approach that will help identify the proportion of annual loading of TP and TSS originating from stream corridor sources. The results from this study will be compared to expected field contributions based on RUSLE2 calculations and measured TP and TSS loadings from the USGS water quality monitoring stations. The source assessment results can be used in all subsequent steps of the TMDL process, including monitoring and targeted implementation of the plan.

! and ?

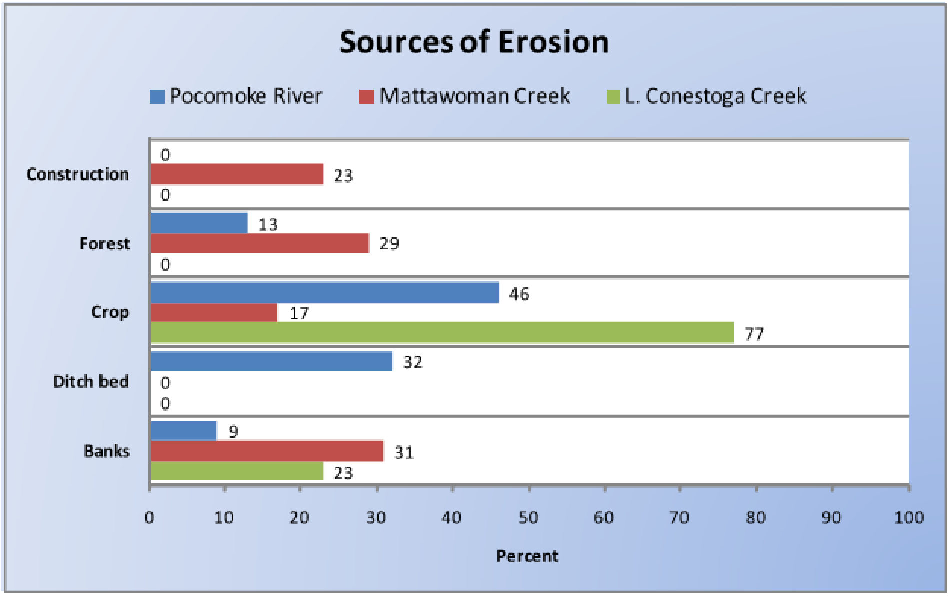
6. Discussion Points and Questions

Discussion Points (#1)

1. There is come uncertainty on how much stream channel erosion was considered in WI TMDL modeling, and therefore the allocations generally do not consider them.

- The Chesapeake Model did not predict stream erosion as a major source of sediment initially. It was not considered a significant source until the landuse models did not correspond with their in-stream WQ monitoring stations.

- **2010 EPA CB TMDL Documents began to include some estimates for bank erosion….followed by the 2012 studies that further built upon it.**
- Watershed Dependent (Urbanization and geologically dependent)
- Bank erosion just became to big of a concern to ignore…thus the 2014 document for SR removal rates.



Source: Gellis et al. 2009

Discussion Points **(#2)**

2. MS4 communities are expected to stabilize and maintain the streams within the extents of the regulated areas.

- Chesapeake Localities are expected to maintain outfalls as well. All stormwater originating onsite must be discharged to stable, competent channels. But, with streams and rivers, much of the problems can pass though these areas, typically a result of activates upstream that are not the responsibly of the MS4 locality.

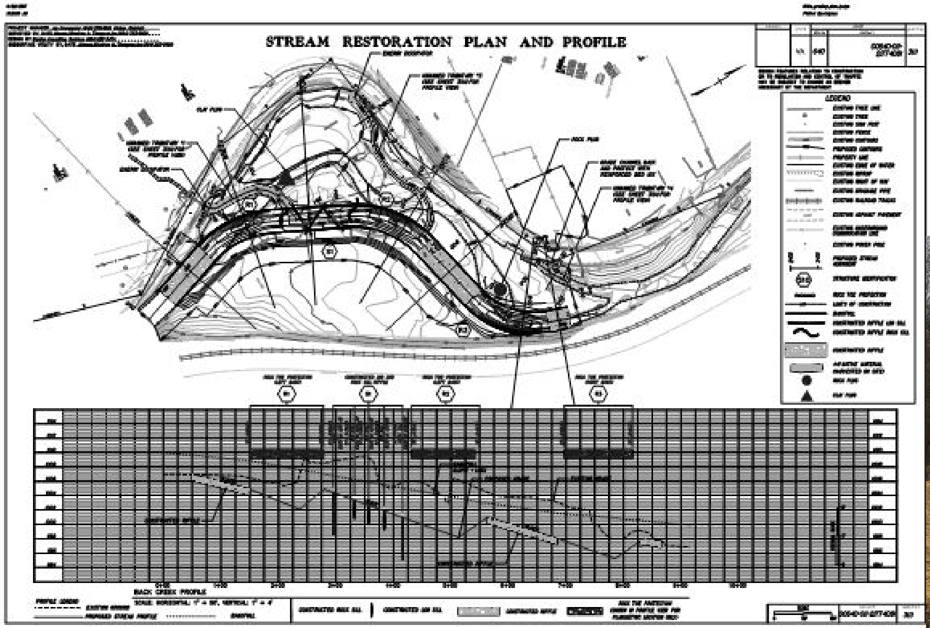
- Project examples Lithia Road.

Project Example:
VDOT Troutville, VA – Lithia Rd Back Creek

- Aggrading channel a result of watershed conditions. Upstream of road, further exasperated by a poor restoration attempt.
- Impassible 5 times a year....major road for the area.

Project Example:
VDOT Troutville, VA – Lithia Rd Back Creek

- Natural Channel Design, Fish Habitat, Proper Geomorph, and improved flood conveyance.



Discussion Points **(#3)**

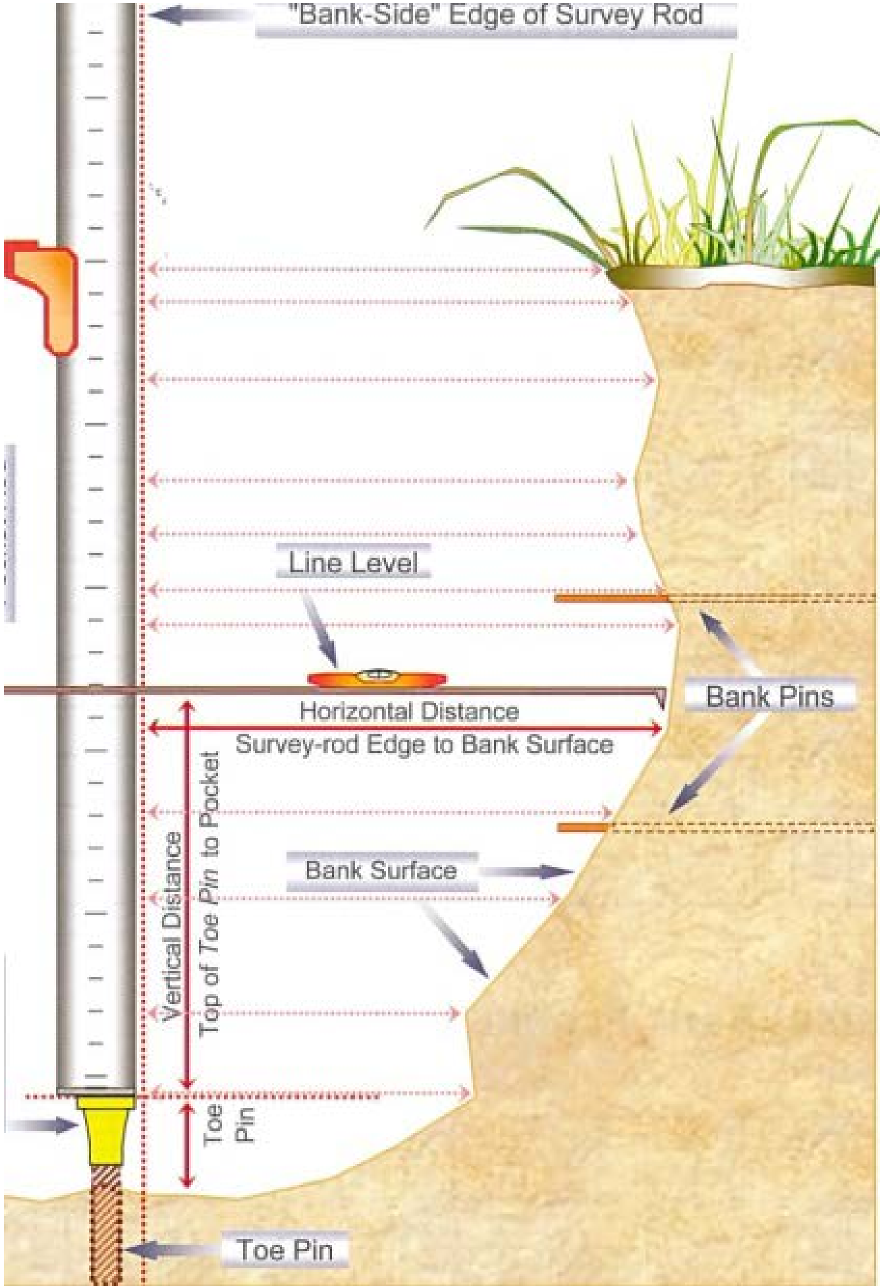
3. We don’t have the data to support the widespread use, and do not have the resources to expend on getting it.

- The accumulation of data and understanding its reliability takes time and money. But, things can be done NOW to start building that data set while focusing on specific project monitoring to start.

Local Bank Erosion Rate Curve

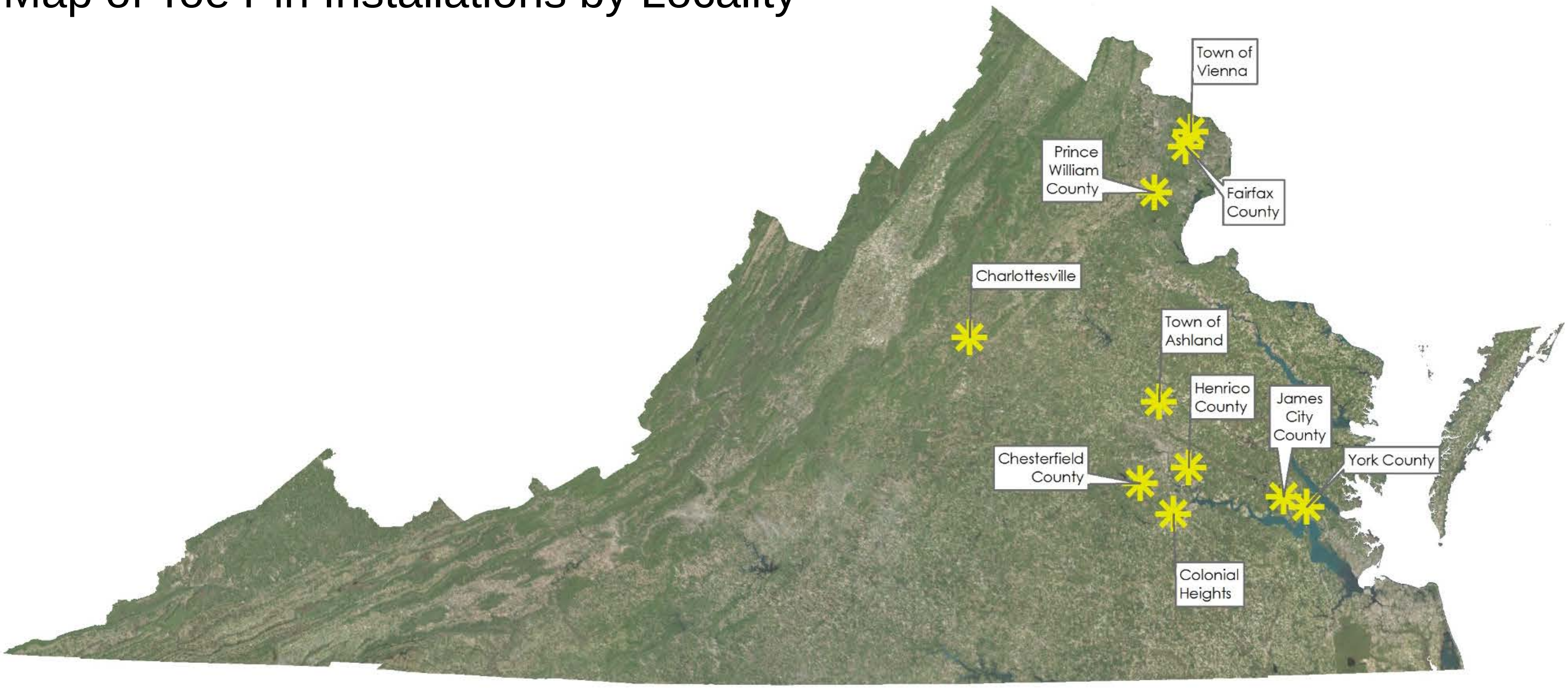
*One of the research needs identified is to "**Provide support for the development of regional stream bank erosion curves for the BANCS method using local stream bank erosion estimates throughout the watershed and a statistical analysis of their predicted results.** Ideally, measured bank erosion rates within each subwatershed or County would be used to validate the BANCS Method specific to that location."*

CBPO Stream Restoration Expert Panel
Section 8.2 Research Management and Needs



Local Regional Bank Erosion Rate Curve

Map of Toe Pin Installations by Locality

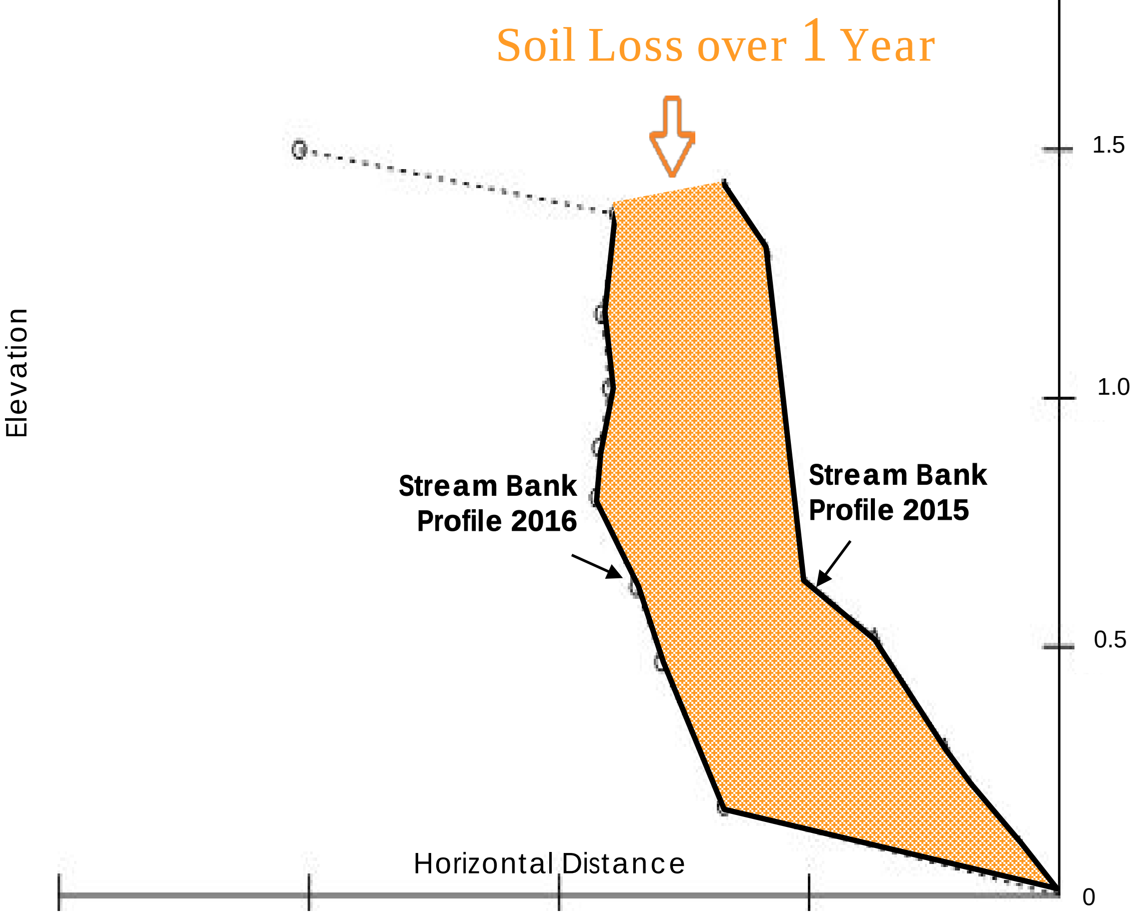


New Data Collection Effort Began in 2015:

- 26 project sites
- 62 Toe pin installations
- Collaboration with Local Gov. partners, Fairfax, USFWS, others;
- DEQ, recent increased interest/participation

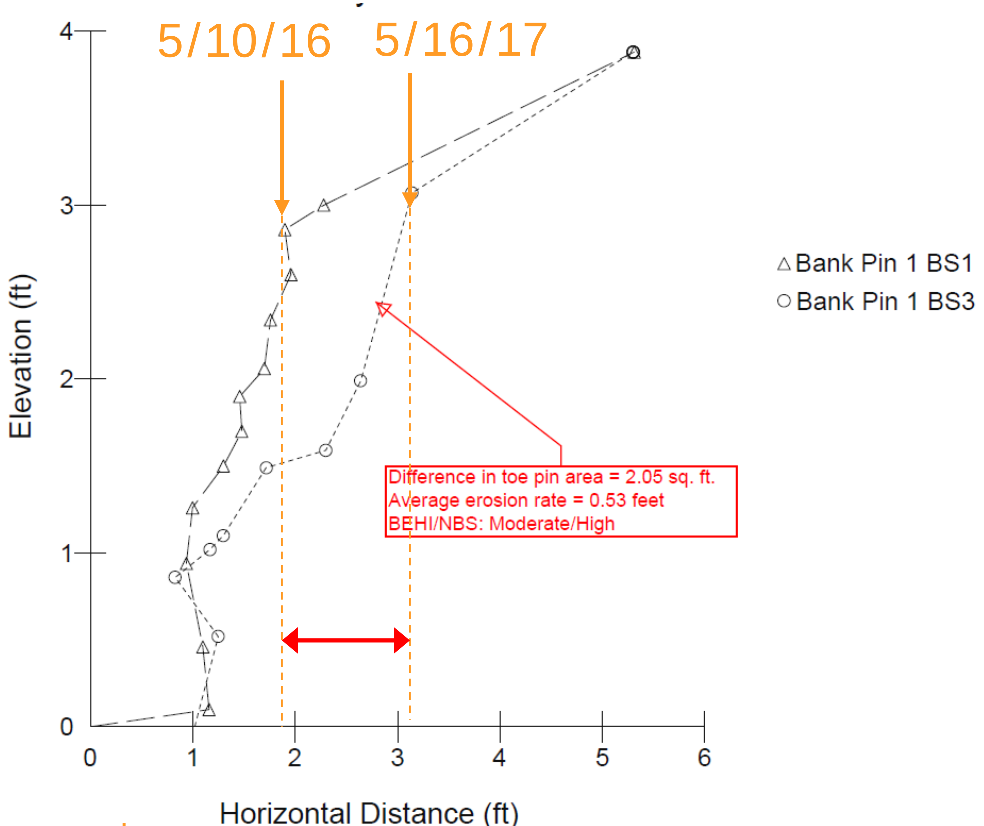
Measuring Bank Profile

Toe Pin Installation



Local Regional Bank Erosion Rate Curve

Cross Section Overlays



Date	Rainfall (inches)
9/19/2016	3.08
10/9/2016	3.92
1-YR 24Hour	2.77
2-YR 24Hour	3.36

tims

Bank Pin #	BEHI/NBS	Erosion Rate: BS1: BS3	Erosion Rate: NC Curve	Erosion Rate: FWS Curve
Bank Pin 1	Moderate/High	0.53	0.11	0.81
Bank Pin 2	Moderate/Moderate	0.15	0.06	0.30
Bank Pin 3	High/High	0.09	0.20	1.00
Bank pin 4	High/High	0.05	0.20	1.00
Bank Pin 5	High/Moderate	0.08	0.16	0.61
Bank Pin 6	High/Moderate	0.13	0.16	0.61
Bank Pin 7	Moderate/Moderate	0.17	0.06	0.30

Regional Bank Erosion Rate Curve

BEHI/NBS Combo Bank/ Toe Pin Installations

	BEHI	NEBS	Target # Data Points	Actual # New Data Points Stantec	Hickory Run (USFWS) # Data Points[1]	NC Rev # Data Points[1]	Total # Data Points[1]	Potential Need
1	Very Low	Very Low	3	0	0	0	0	X
2	Very Low	Low	3	0	0	0	0	X
3	Very Low	Moderate	3	0	0	0	0	X
4	Very Low	High/VH	2	0	0	1	0	X
5	Very Low	Extreme	0	0	0	0	0	
6	Low	Very Low	3	0	0	0	0	X
7	Low	Low	3	1	2	0	3	
8	Low	Moderate	3	0	2	0	2	X
9	Low	High/VH	3	2	0	0	2	X
10	Low	Extreme	3	0	0	0	0	X
11	Moderate	Very Low	3	1	0	1	2	X
12	Moderate	Low	3	2	5	0	7	
13	Moderate	Moderate	3	9	3	3	15	
14	Moderate	High/VH	3	7	3	5	15	
15	Moderate	Extreme	3	0	0	1	1	X
16	High/VH	Very Low	2	0	1	0	6	
17	High/VH	Low	3	1	16	1	18	
18	High/VH	Moderate	3	11	3	0	14	
19	High/VH	High/VH	3	27	4	6	37	
20	High/VH	Extreme	3	1	1	3	5	
21	Extreme	Very Low	2	0	0	0	0	X
22	Extreme	Low	3	0	1	1	2	X
23	Extreme	Moderate	3	0	0	1	1	X
24	Extreme	High/VH	3	0	2	2	4	
25	Extreme	Extreme	3	0	1	1	2	X
TOTAL			**68**	**62**	**44**	**31**	**137**	

[1] # of points approximate and for planning purposes only

Bank Erosion Rate (BER)

Preliminary Comparison of Lateral Erosion rates at select cross section applying various Methods[1]

	BEHI/NBS	Bank Height (ft)	NC Rev (ft/yr)	Hickey (ft/yr)	Default[2] (ft/yr)	Toe Pin Measurement[1]	Elapsed
Project A, BP1	Moderate/High	5	.11	.81	.27	.53 ft/yr	12 mo
Project A, BP2	Moderate/Mod	4.5	.06	.30	.30	.15 ft/yr	12 mo
Project B, BP1&2	High/Moderate	4.25	.16	.61	.32	.08 - .13 ft/yr	12 mo
Project B, BP3&4	Moderate/Mod	3.5	.06	.30	.39	.09 - .24 ft/yr	12 mo
Project C, BP3	High/Moderate	4	.16	.61	.34	.75 ft/yr	15 mo
Project C, BP4	Very High/Mod	10	.73	.61	.13	1.86 ft/yr	4 mo
Project D, BP2A	High/High	3.5	.20	1.00	.39	.39 ft/yr	15 mo
Project D, BP4	High/Extreme	1.5	.38	2.60	.90	1.15 ft/yr	15 mo
Project E, BP_up	Very High/Extreme	15	1.50	2.60	.09	2.00 ft/yr	5 mo
Project F, BP2&8	Very High/VH	7.5	1.20	1.75	.18	.76 - 1.55 ft/yr	13 mo
Project F, BP1	High/Moderate	4	.16	.61	.34	.42 ft/yr	13 mo

[1] Values presented herein represent a preliminary sample of findings and are subject to change. Lateral rates (ft/yr) represent average rate and differ along bank height.

[2] Default avg. erosion rate represents estimate of TP default removal rate converted from lbs TP/LF/yr to ft/yr assuming 1.05 lbs TP/ton Sed, 96 lbs/cf, and noted bank height.

In the Mean time…

Once you identify a project…start monitoring it right away….then quantify.

Most projects take over a year to design (NR studies, topo, engineering, permitting etc..) before implementation.

Conclusions and Discussions

- The Chesapeake Bay localities has studied their watershed and TMDL's and have begun to use stream restoration as a wide spread tool for nutrient and sediment reduction.
- Wisconsin is just beginning to get into the discussion of its use, but hurdles remain.
- Consider using lessons learned and application techniques to get a jump on implementation.

Stantec

Questions?