Bringing It All Together: Accounting for Practices Across the Watershed

IMPROVING AND PROTECTING
REGIONAL WATER QUALITY
Stormwater Best Practices Workshop

November 21, 2014

Acknowledgements

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EPA's Assessment and Watershed Protection Division
Watershed Branch

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What Is A TMDL?

A calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources

** The TMDL comes in the form of a technical document or plan.*

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TMDLs Are Expressed As:

- Mass (e.g., pounds per day)
- Toxicity (e.g., toxic units)
- Energy (e.g., heat in temperature TMDLs)

***Emphasis on TMDLs expressed as daily loads**

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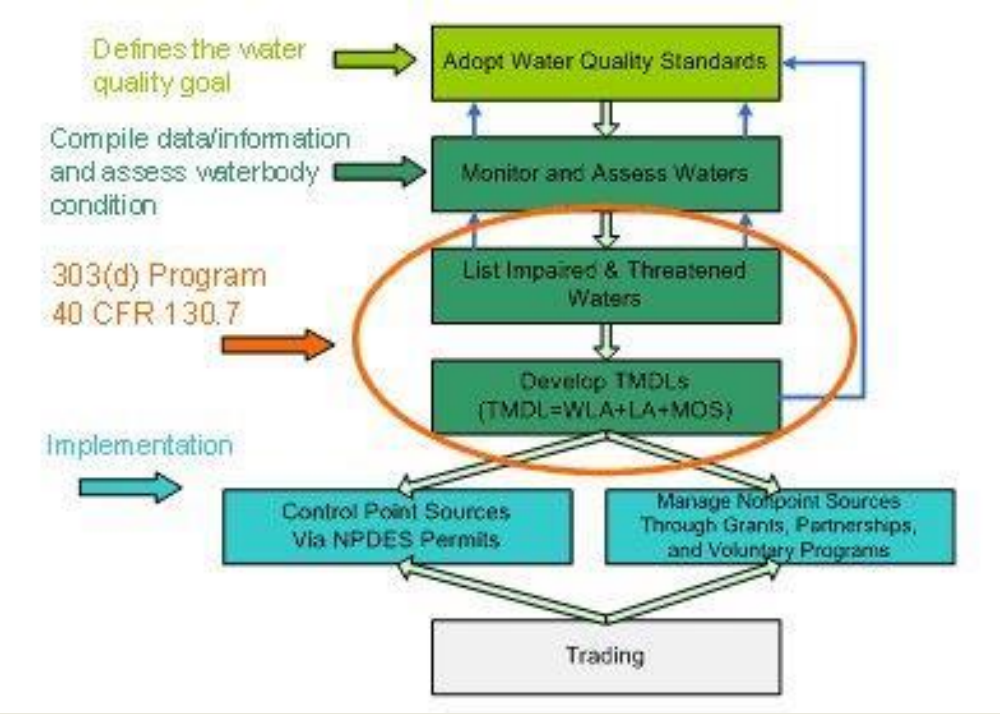
TMDL Process



Listing of Impaired Waters

- Over 41,000 listed waterbodies, with one or more impairments
- Approximately 71,000 waterbody-pollutant combinations reported
  - Indication of TMDLs that will need to be completed
- Top causes of impairment (updated November 2011)
  - Pathogens: 15%
  - Metals (other than Mercury): 11%
  - Nutrients: 10%
  - Organic enrichment/oxygen depletion: 9%
  - Sediment: 9%
  - Polychlorinated Biphenyls (PCBs): 8%

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TMDL Calculation

$$TMDL = \Sigma WLA_i + \Sigma LA_i + MOS$$

ΣWLA_i: Sum of waste load allocations (point sources)

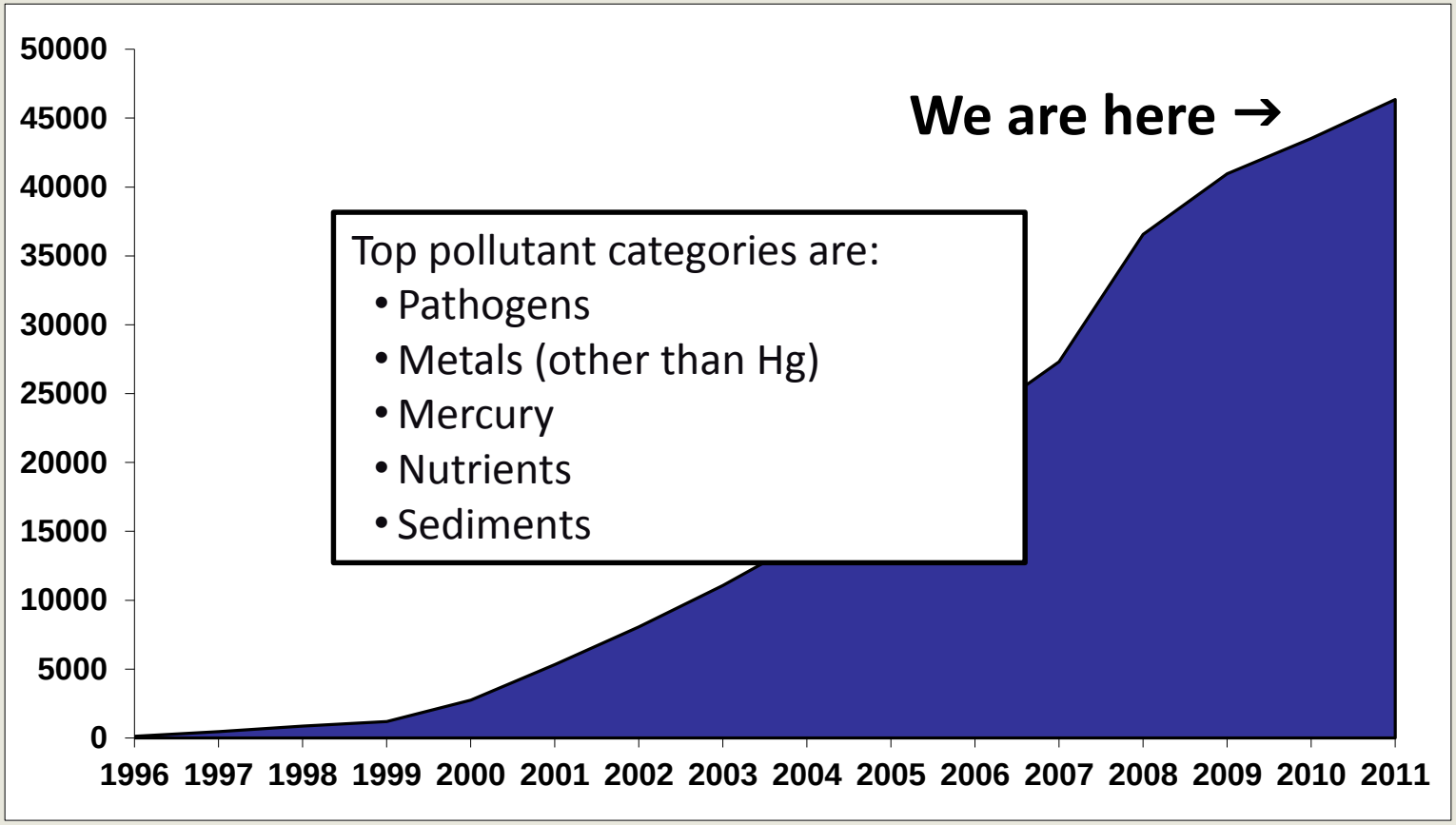
ΣLA_i: Sum of load allocations (nonpoint sources)

MOS: Margin of Safety

Completed for each waterbody/pollutant combination

7

Over 46,000 TMDLs Completed



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Examples of major TMDLs in US

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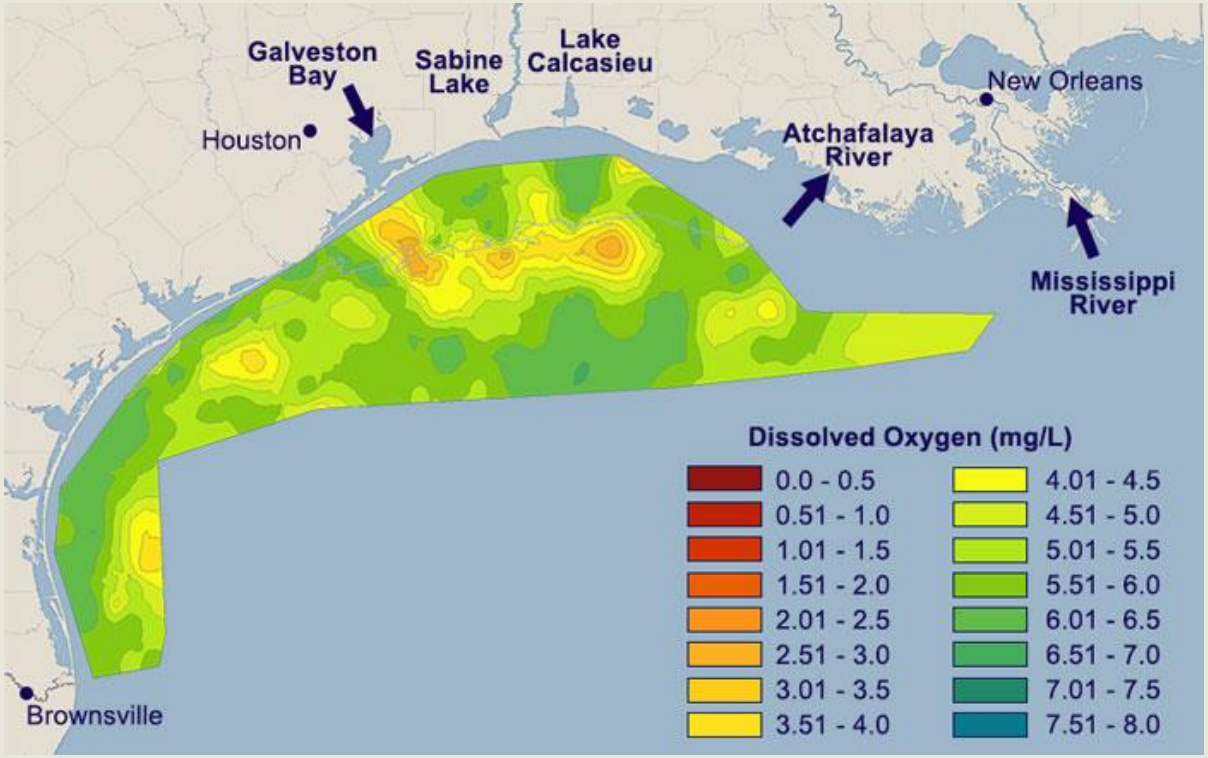
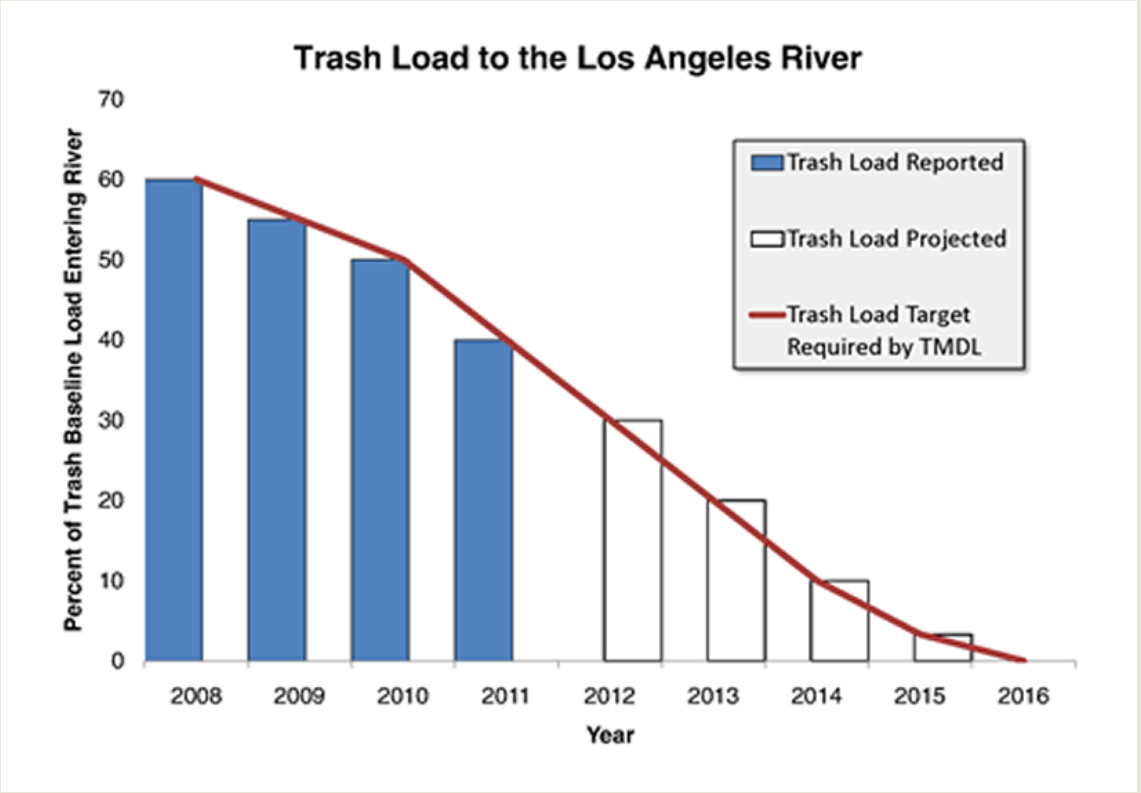
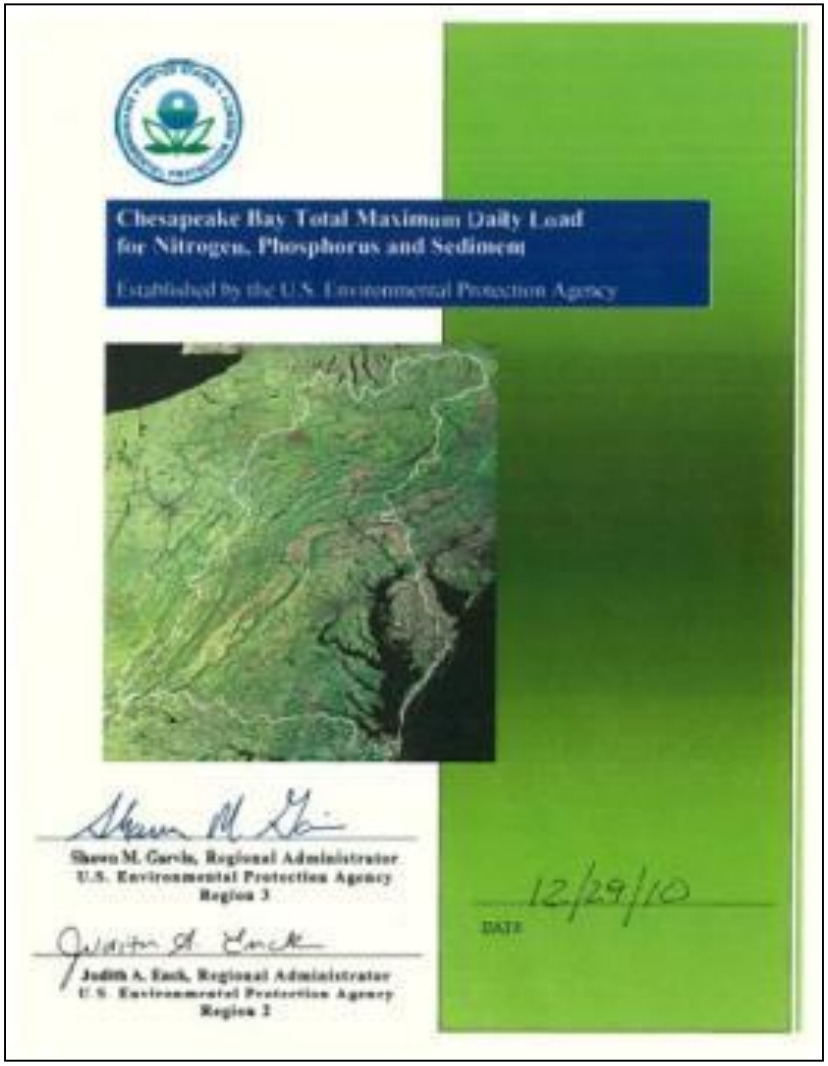
Gulf of Mexico Dead Zone TMDL for Mississippi basin under development

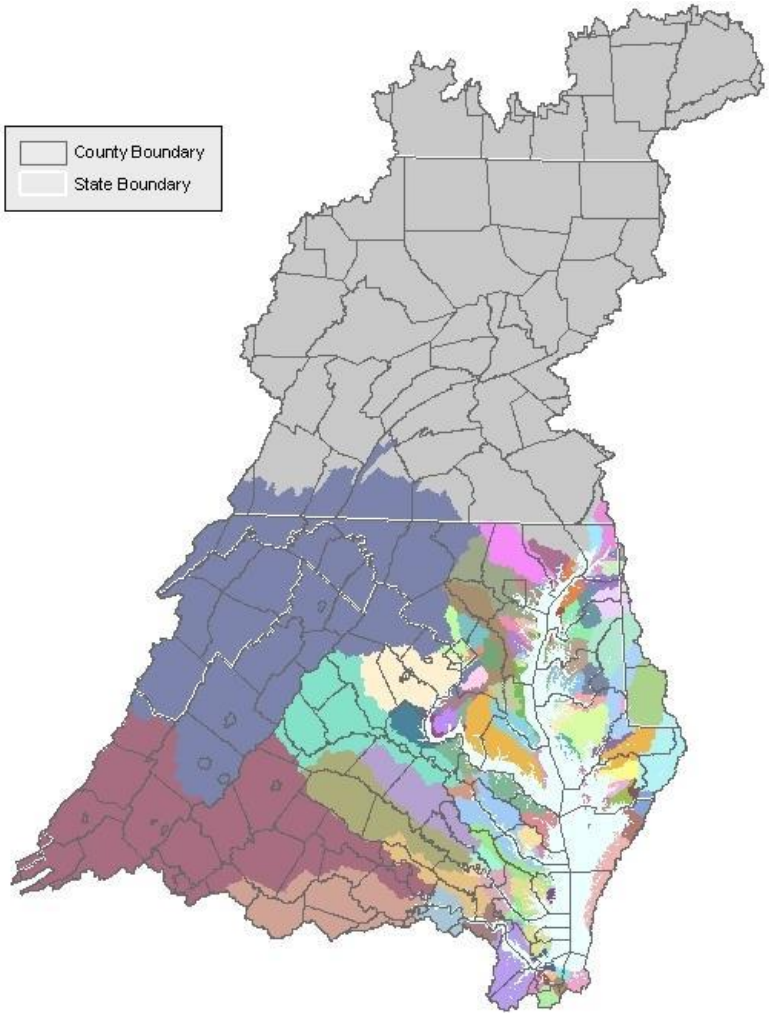


Los Angeles Trash TMDL



Chesapeake Bay TMDL: Pollution Diet for All Sectors and Sources

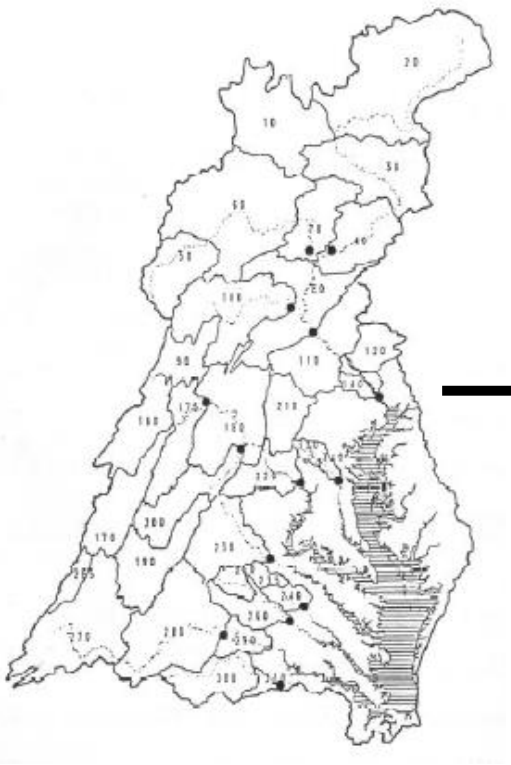




Chesapeake Bay Program
A Watershed Partnership

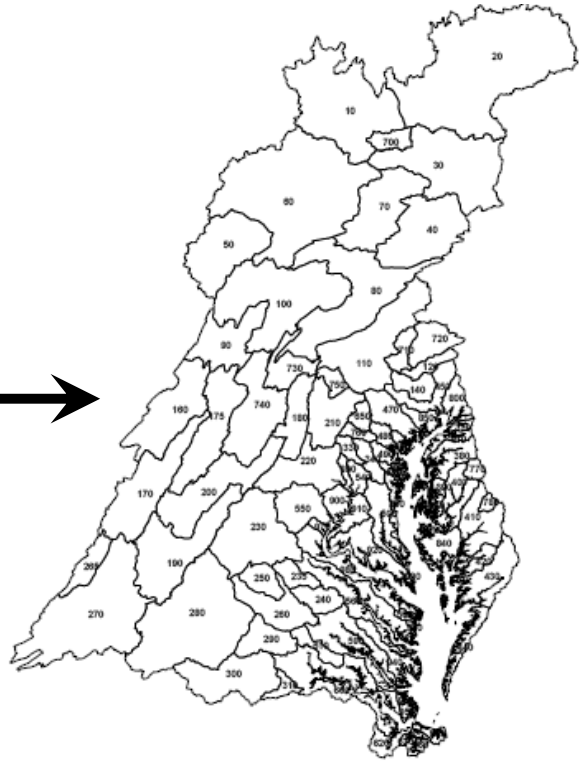
History of the Bay Watershed Model

Phase 1



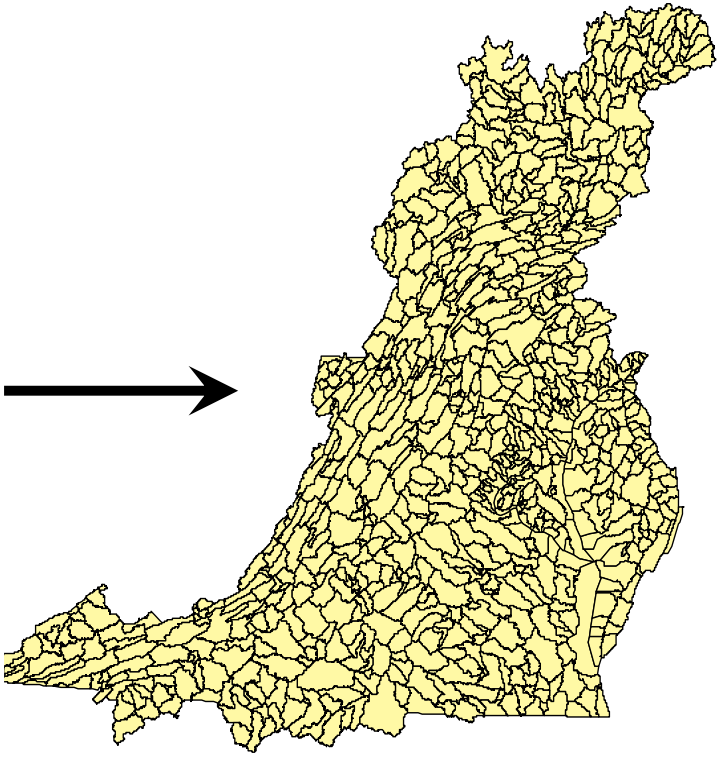
- Completed in 1982
- 63 model segments
- 5 land uses
- 2 year calibration period
- No BMPs simulated

Phase 4



- Completed in 1998
- 94 model segments
- 9 land uses
- 14 year calibration period
- 20 BMP designations

Phase 5

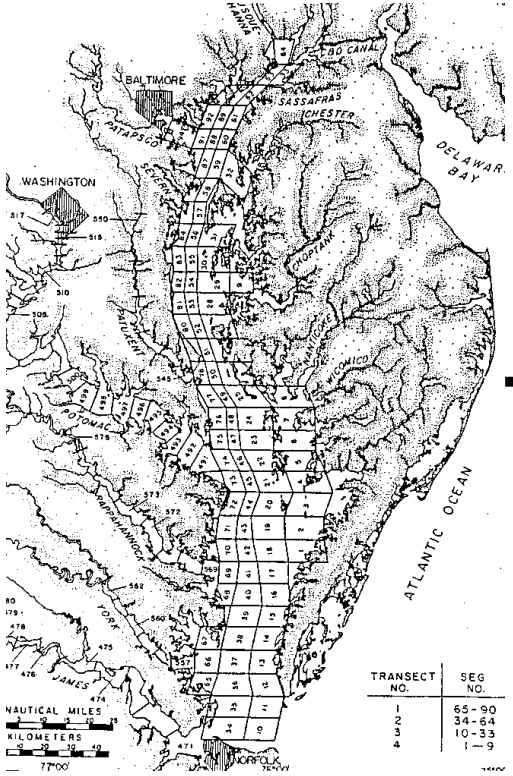


- Completed in 2010
- 1,000+ model segments
- 30 land uses
- 21 year calibration period
- 1400 BMP designations

History of the Bay Water Quality Model

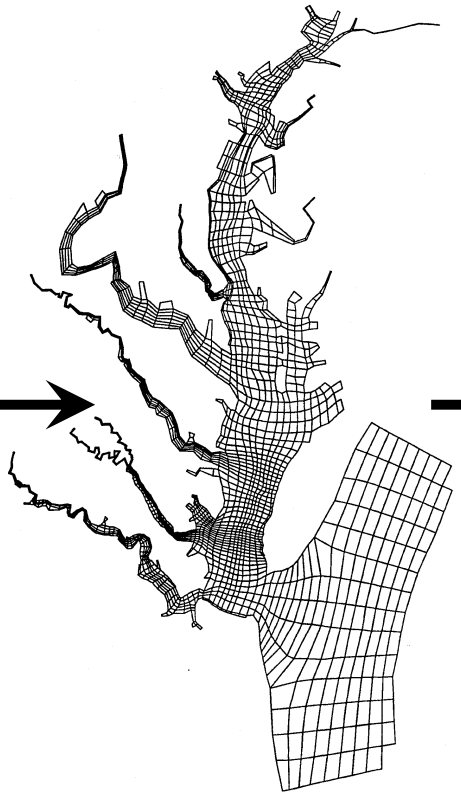
Chesapeake Bay Program
A Watershed Partnership

1987



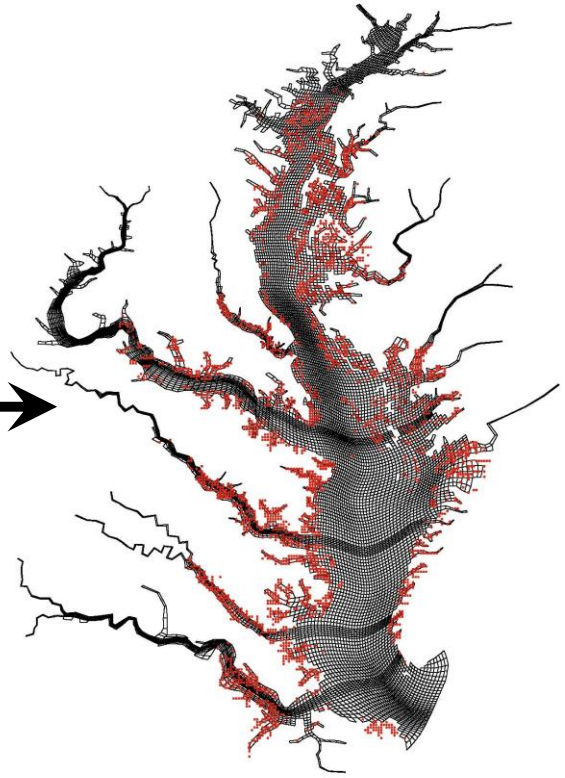
- Steady State
- Advanced Bay Science
- Contributed to initial "40%" goal

1997



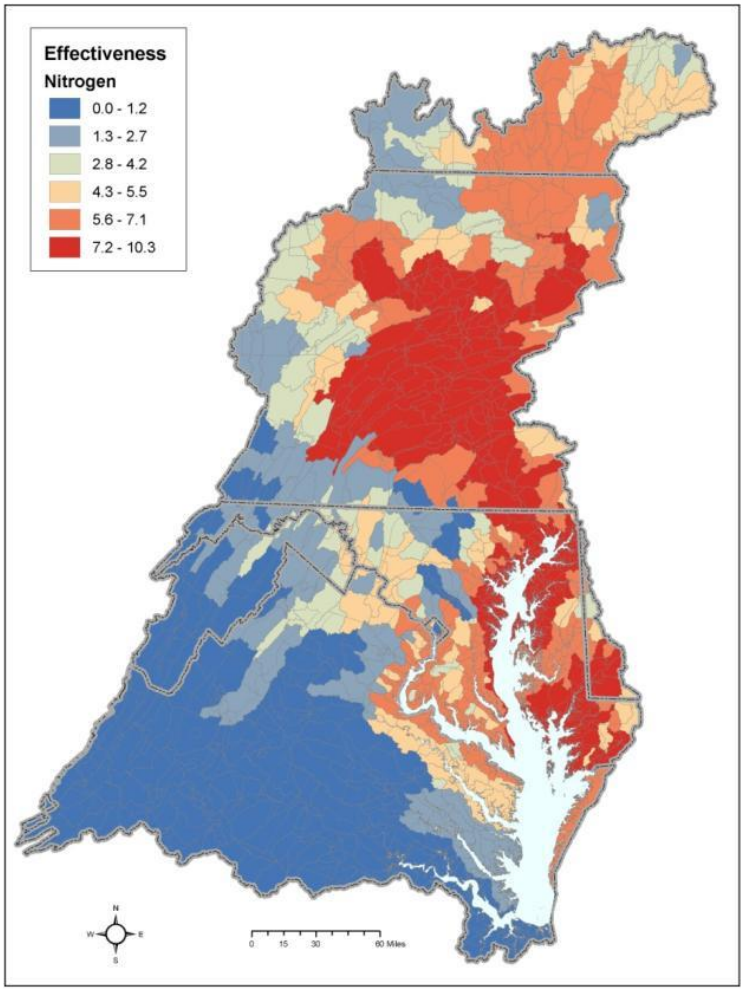
- 10,000 cells
- Sediment/water interaction
- Included living resources
- Used for tributary strategies

2008

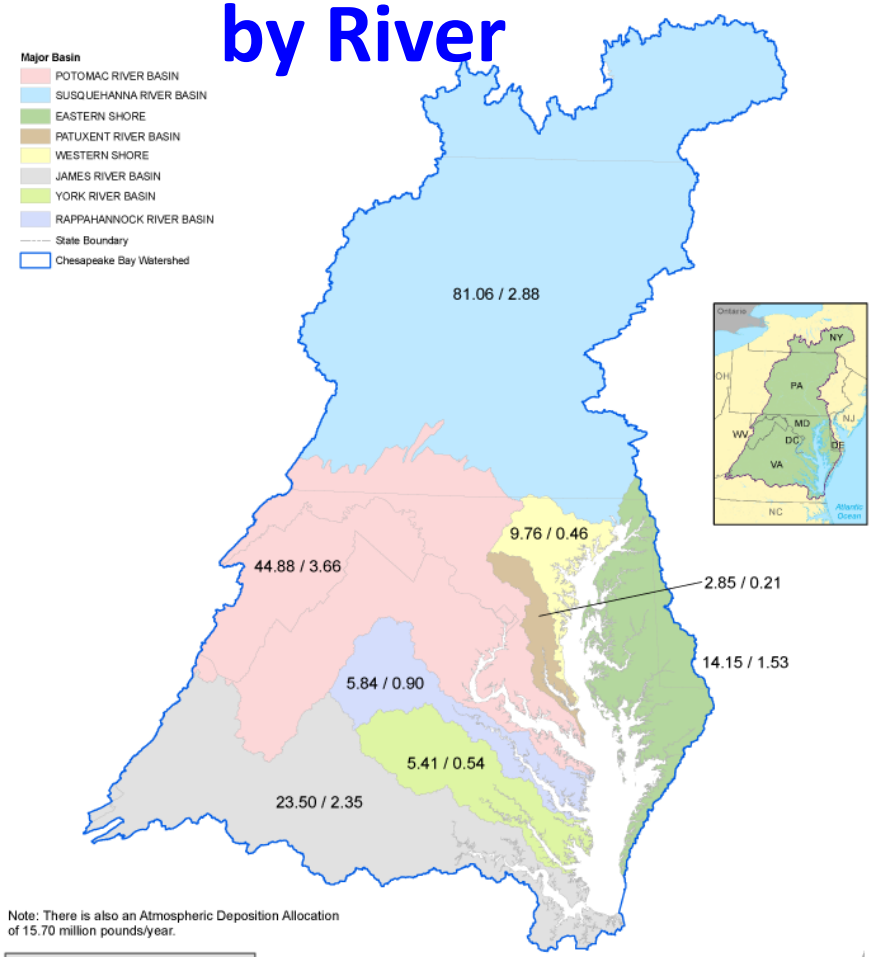


- 57,000 cells
- Sub-hour hydrodynamics
- Oysters
- Menhaden

Relative Effect of a Pound of Pollution on Bay Water Quality

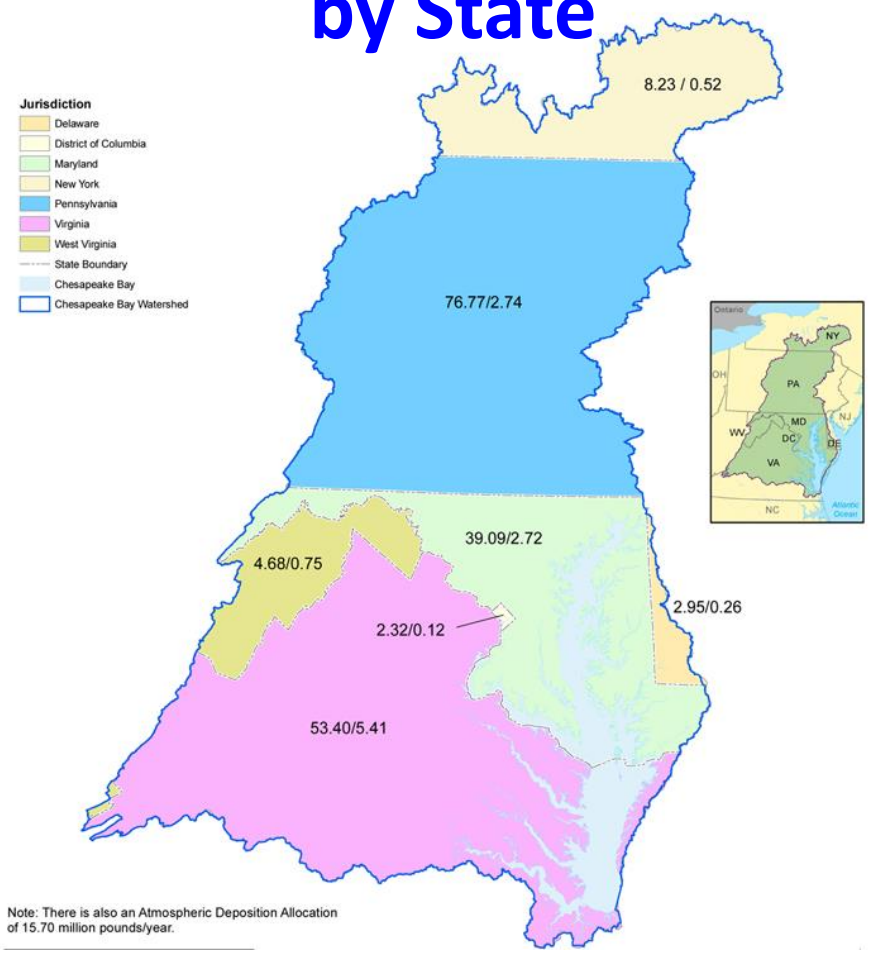


TMDL by River



Note: There is also an Atmospheric Deposition Allocation of 15.70 million pounds/year.

TMDL by State



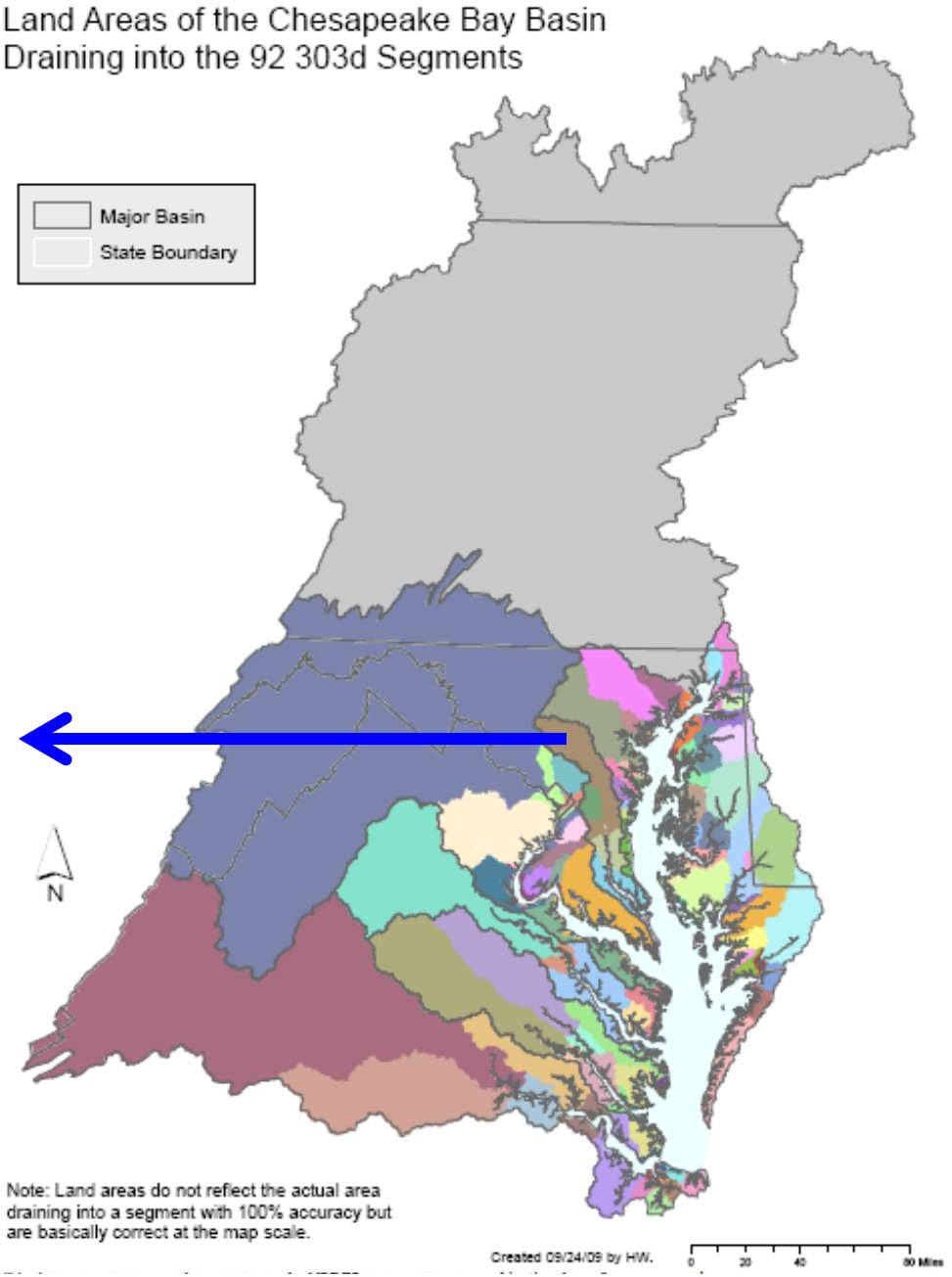
Note: There is also an Atmospheric Deposition Allocation of 15.70 million pounds/year.

Jurisdictions' Watershed Implementation Plans

92 Individual TMDLs

Table B2. Format for Submitting Phase I Watershed Implementation Plan Outputs t

St.	Maj. Basin	Impaired Segment Drainage	Unique Code	Source Sector[b]	Type[c]	NPDES Permit
MD	W. Shore	PAXTF	MWPTF	Agriculture-CAFO	Agg. WLA	
				Agriculture-CAFO	Ind. WLA	MD356913
				Agriculture	LA	
				Subtotal: Agriculture		
				Wastewater: POTW#1	Ind. WLA	MD012452
				Wastewater: POTW#2	Ind. WLA	MD013943
				Wastewater: Indus #1	Ind. WLA	MD821672
				Wastewater: Indus #2	Ind. WLA	MD853653
				Subtotal: Wastewater		
				Onsite	LA	
				Urb/Suburb Runoff: MS4	Agg. WLA	MD546195
				Urb/Suburb Runoff: Non-MS4	LA	
				Urb/Suburb Runoff: MS4	Ind. WLA	MD892645
				Industrial Stormwater	Agg. WLA	
				Industrial Stormwater	Ind. WLA	MD246139
				Construction	Agg WLA	
				Subtotal: Urb/Suburb		
				Forest	LA	
MD	W. Shore	SEVMH	MWSeM	Agriculture-CAFO	Agg. WLA	MD382614
				Agriculture	LA	
				Subtotal: Agriculture		
				Wastewater: POTW#1	Ind. WLA	MD083699
				Wastewater: POTW#2	Ind. WLA	MD054732
				Wastewater: Indus #1	Ind. WLA	MD836679
				Wastewater: Indus #2	Ind. WLA	MD854469
				Subtotal: Wastewater		
				Onsite	LA	
				Urb/Suburb Runoff: MS4	Agg. WLA	MD588578
				Urb/Suburb Runoff: Non-MS4	LA	
				Subtotal: Urb/Suburb		
				Forest	LA	
	...					
MD	W. Shore			Reserve for Growth	WLA/LA	
MD	**W Shore**		**MW**	**Total**		



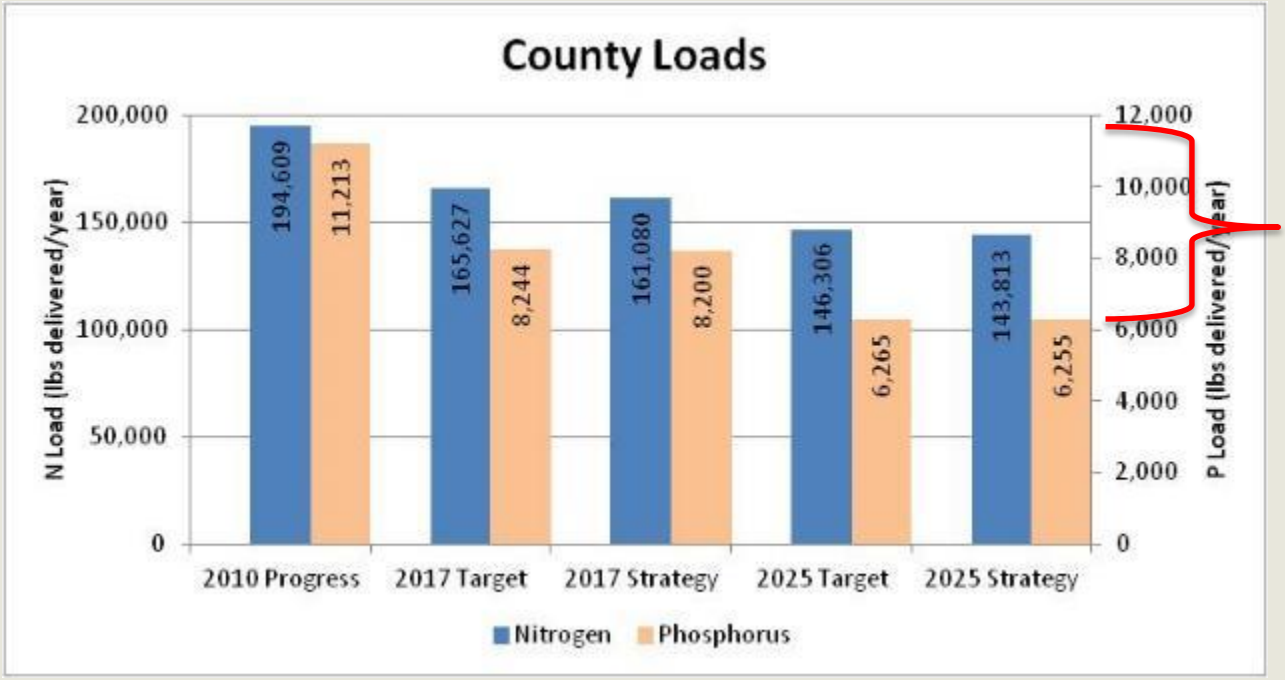
Phase II Watershed Implementation Plan (WIP) Commitments: Load Reductions from 2009 to 2025

	% Reduction in Statewide Loads			% Reduction in Urban Loads			% Total Load Reductions Attributable to Urban Sector		
	N	P	TSS	N	P	TSS	N	P	TSS
Delaware	26%	31%	27%	13%	12%	5%	4%	2%	5%
D.C.	19%	-68%	5%	13%	22%	16%	5%	N.A.	255%
Maryland	21%	20%	16%	24%	28%	29%	21%	30%	66%
New York	13%	30%	25%	8%	20%	10%	7%	9%	12%
Pennsylvania	30%	29%	28%	41%	45%	50%	20%	24%	39%
Virginia	18%	25%	24%	13%	21%	30%	10%	14%	23%
West Virginia	8%	31%	32%	3%	44%	50%	6%	18%	37%

Negative values indicate increases in loads from 2009 to Phase II WIP planning targets, typically due to increases in wastewater treatment flow up to design capacity.

Nutrient reductions at a county level

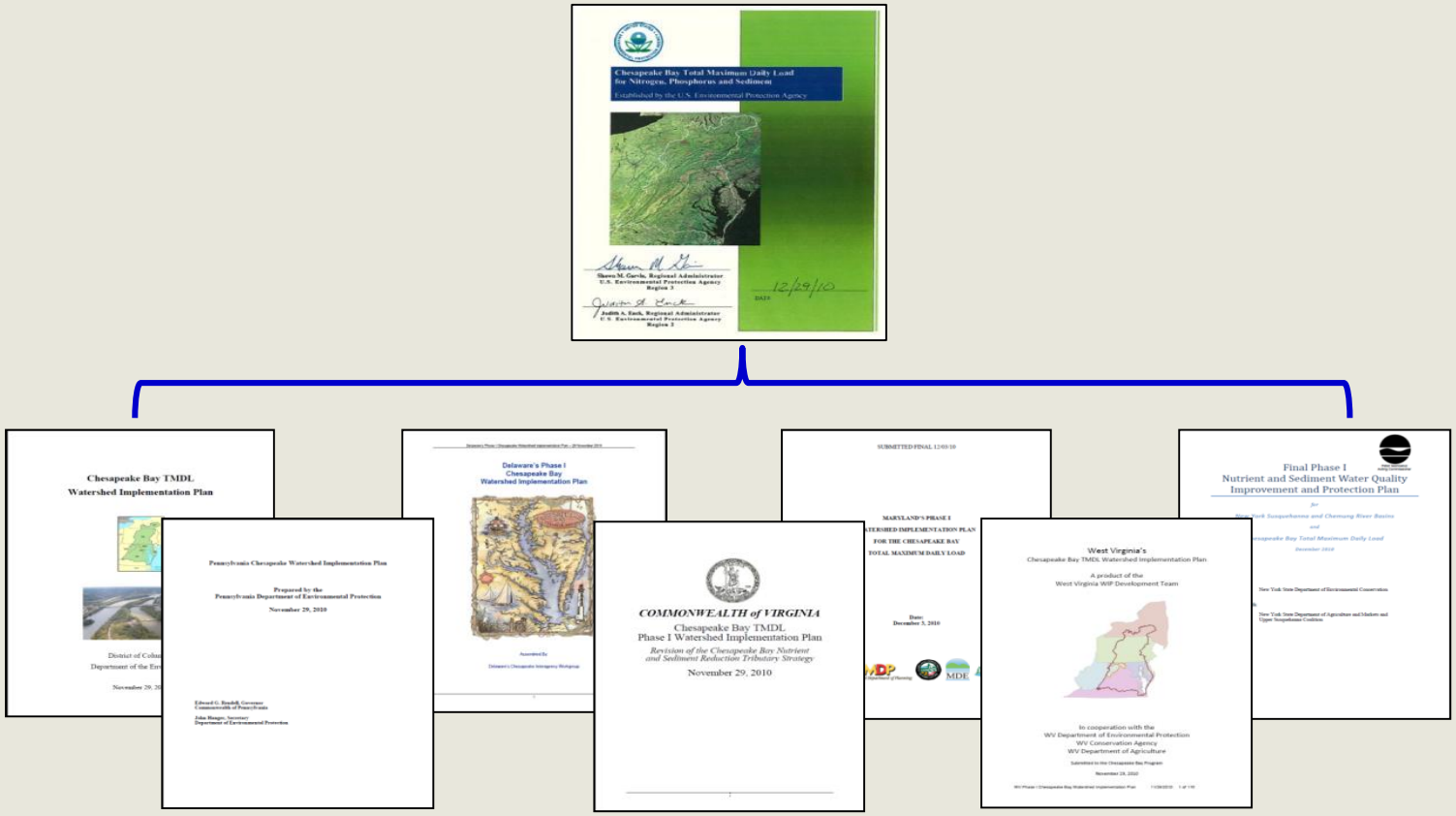
Wicomico County Urban TN and TP Loads for 2010 Progress, 2017 Interim Strategy and Target, and 2025 Final Strategy and Target.



TN = 26%
TP = 44%

Source: MDE Nutrient Allocation Files (CBP Model 5.3.2.), MDE prepared 2010 Progress MAST loading decks, and the Core Planning Team Loading Decks

Chesapeake Bay TMDL Based on 7 Watershed Implementation Plans



MS4 incorporated into WIP's

E. Restoration Plans and Total Maximum Daily Loads

Section 402(p)(3)(B)(iii) of the Clean Water Act (CWA) states that municipal storm sewer system permits must require controls to reduce the discharge of pollutants to the MEP. By regulation at 40 CFR §122.44, EPA further requires that BMPs and programs implemented pursuant to this permit must be consistent with applicable WLAs developed under EPA approved TMDLs (see Part V.C. of this permit attached and incorporated as Attachment B). The goals of Maryland's NPDES municipal stormwater permit program are to control stormwater pollutant discharges by implementing the BMPs and programs required by this permit, show progress toward meeting WLAs, and contribute to the attainment of water quality standards according to the CWA.

TMDL WASTE LOAD ALLOCATIONS

b. By the end of this permit term, Baltimore City shall commence and complete the implementation of restoration efforts for twenty percent of the City's impervious surface area consistent with the methodology described in the MDE document cited in paragraph a. above, to be restored to the MEP.

20% Impervious Cover Treatment

The CBP Process for BMP Crediting: TP, TN, TSS

- CBP ranks BMPs in order of importance and assembles Expert Panel
- Expert panel uses literature, new data and best professional judgment to develop sediment and nutrient reduction credits
- Long CBP Committee approval process

1 -1.5 year process

Expert Panel formed to define removal rates for BMP Retrofitting

Recommendations of the Expert Panel to Define Removal Rates for Urban Stormwater Retrofit Projects

Ray Bahr, Ted Brown, LJ Hansen, Joe Kelly, Jason Papacosma, Virginia Snead, Bill Stack, Rebecca Stack and Steve Stewart

Accepted by Urban Stormwater Work Group: **April 30, 2012**
Revised based on Watershed Technical Work Group feedback: **May 29, 2012**
Resubmitted to Watershed Technical Work Group: **July 15, 2012**
Conditionally Approved by Watershed Technical Work Group: **August 1, 2012**
Conditionally Approved by Water Quality Goal Implementation Team: **August 13, 2012**
Resubmitted to WQGIT: **September 28, 2012**
Final Approval by WQGIT: **October 9 2012**

Prepared by:
Tom Schueler and Cecilia Lane
Chesapeake Stormwater Network

The Charge

The Panels were asked to:

- Provide a specific definition for each class of retrofits and the qualifying conditions under which a locality can receive a nutrient/sediment removal rate.
- Assess whether the retrofit class can be addressed by using existing CBP-approved BMP removal rates, or whether new methods or protocols need to be developed to define improved rates.
- Evaluate which load estimation methods are best suited to characterize the baseline pre-retrofit for the drainage area to each class of retrofit.

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The Battle between lumper's and splitters

The Splitters

4 categories for bioretention BMP's

2010 CBP BMP Removal rates

Table 1. Urban Stormwater BMPs Included in the Study				
BMP	Current Status (as of April 2013)	TN Efficiency (%)	TP Efficiency (%)	TSS Efficiency (%)
Bioretention/raingardens (new - suburban), A/B soils, no underdrain	Approved by CBP	80	85	90
Bioretention/raingardens (new - suburban), A/B soils, underdrain	Approved by CBP	70	75	80
Bioretention/raingardens (new - suburban), C/D soils, underdrain	Approved by CBP	25	45	55
Bioretention (retrofit, highly urban, C soils)	CBP panel recommendations approved by Water Quality Goal Implementation Team October 9, 2012	51	59	63
Bioswale (new)	Approved by CBP	70	75	80
Dry Detention Ponds (new)	Approved by CBP	5	10	10
Dry Extended Detention Ponds (new)	Approved by CBP	20	20	60
Filtering Practices (sand, above ground)	Approved by CBP	40	60	80
Filtering Practices (sand, below ground)	Approved by CBP	40	60	80
Forest Buffers	Approved by CBP	25	50	50
Hydrodynamic Structures (new)	Approved by CBP	5	10	10
Illicit discharges- correction of cross-connections	Under review by CBP	100	100	100

The Lumper's Won

All practices sorted into 2 categories:
Runoff Reduction (RR) &
Stormwater Treatment (ST)

Classification of Retrofits	
Runoff Reduction Practices (RR)	***Stormwater Treatment Practices (ST)***
Bioretention	Constructed Wetlands
Dry Swale	Filtering Practices
Infiltration	Proprietary Practices
Permeable Pavement	Wet Swale
Green Roof	Wet Ponds

Achieve at least 25% reduction of annual runoff volume

Traditional Practices

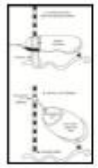
Retrofit Categories

A. New Retrofit Facilities

1. Near Existing Stormwater Outfalls
2. Within the Conveyance System
3. Adjacent to Large Parking Lots
4. Green street retrofits
5. On-site LID retrofits

Figure 1. Examples of New Retrofit Facilities and their Potential Applications

New retrofit facilities provide stormwater treatment in places that treatment did not previously occur. There are many opportunities for new retrofit facilities in the urban landscape. Some common examples are listed below.



Near Existing Stormwater Outfalls

Within the Existing Stormwater Conveyance System

Adjacent to Large Parking Lots

Green Street Retrofits

On-Site LID Retrofits

Retrofit Categories

B. Existing BMP Facilities

1. BMP Conversions:
2. BMP Enhancements:
3. BMP Restoration:

Protocol for determining BMP removal rates

- Each BMP has its own unique removal rate based on the amount of runoff it treats and the degree of runoff reduction it provides
- Extensive review of current BMP performance research
- Developed a series of retrofit/BMP removal rate adjustor curves

Removal Rates

BMP removal rates are a function of runoff depth captured and the amount of stormwater treatment (ST) or runoff reduction (RR) achieved by the practice

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Rainfall Frequency Analysis

Rainfall Depth Controlled (inches)	% of annual rainfall	Phosphorus		Nitrogen		Sediment	
		ST	RR	ST	RR	ST	RR
0.05	9%	6	8	6	7	7	8
0.1	18%	11	16	11	14	14	16
0.25	41%	26	35	26	33	33	35
0.5	65%	41	56	41	52	52	56
0.75	80%	50	68	50	63	63	68
1.0	88%	55	75	55	70	70	75
1.25	92%	58	79	58	74	74	79
1.5	95%	60	81	60	76	76	81
2.0	98%	61	84	61	78	78	84
2.5	99%	62	85	62	79	79	85

Data plotted and converted to a series of curves…

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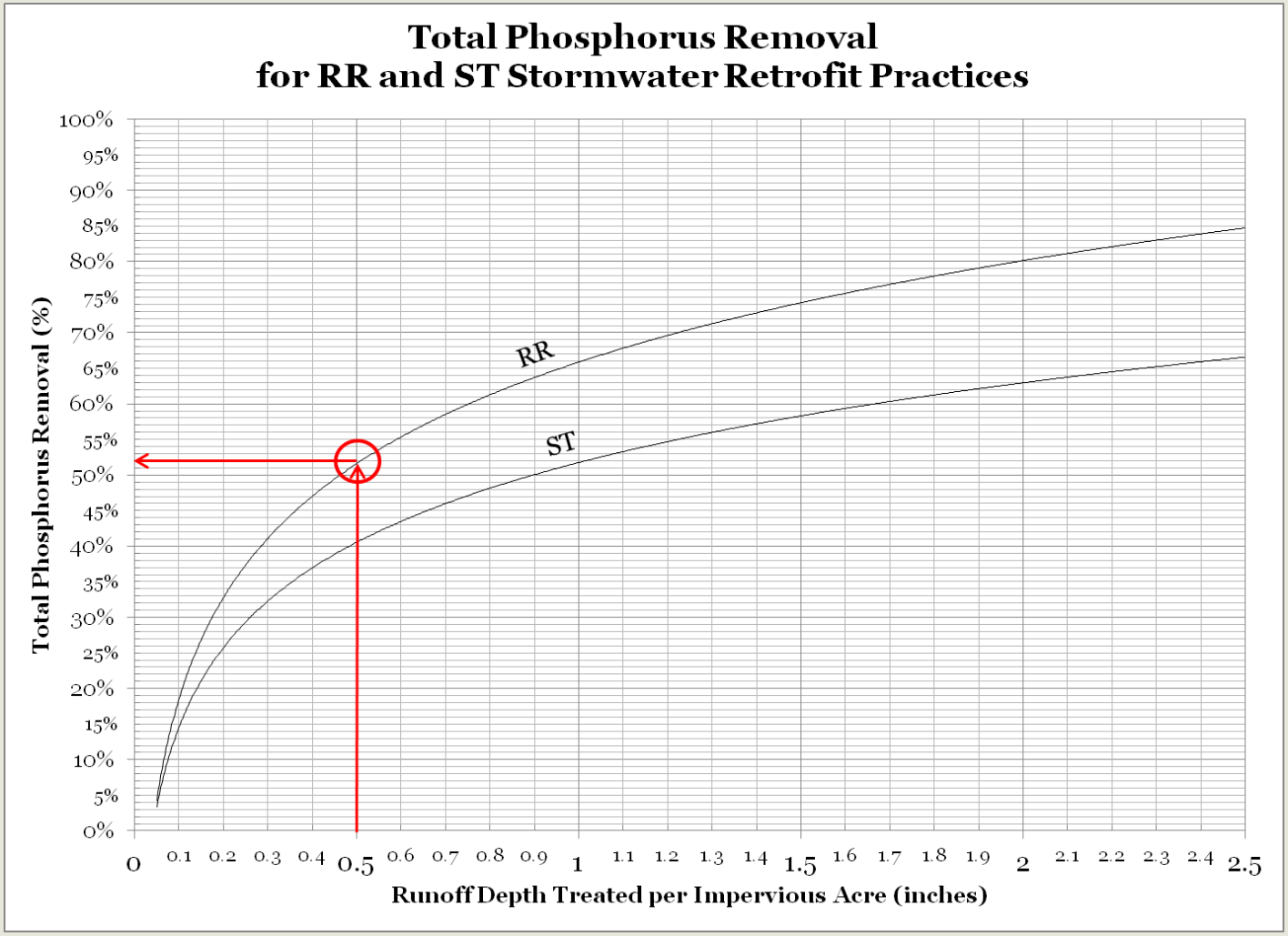

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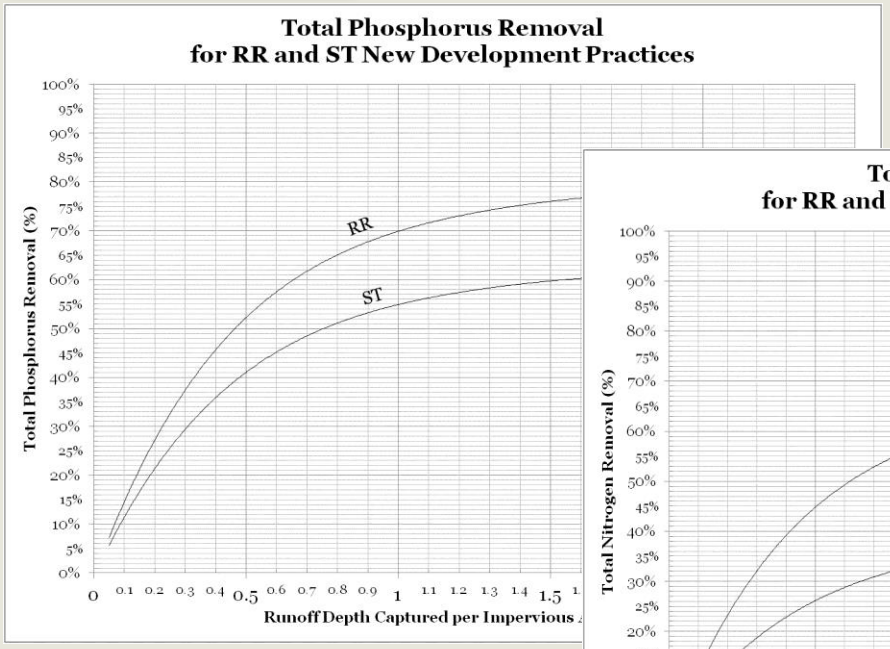

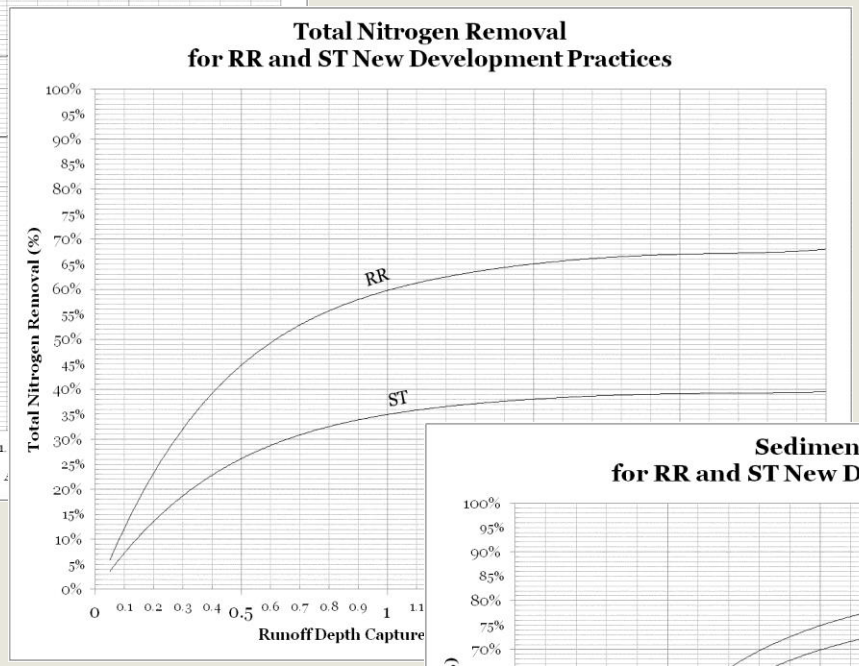

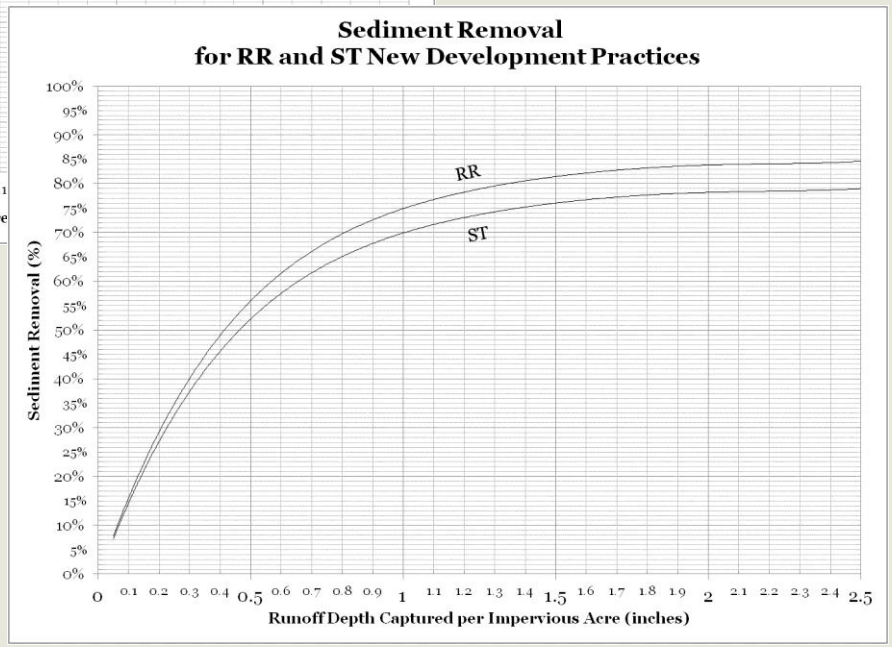

Figure 1. Pollutant Removal Rates for ESD to the MEP:

- *Sediment - 90%*
- *Total Phosphorus - 85%*
- *Total Nitrogen - 72%*

Accountability

1. Duration of Retrofit Removal Rate:
   - 10 yrs MAX
     - Can be renewed based on field performance inspection
   - 5 yrs for on-site LID
     - Can be renewed upon visual inspection
2. No Double Counting!
   - Rate cannot be used if retrofit is an offset for new development
3. Initial Verification of Performance
   - Installed to design standards, functioning properly

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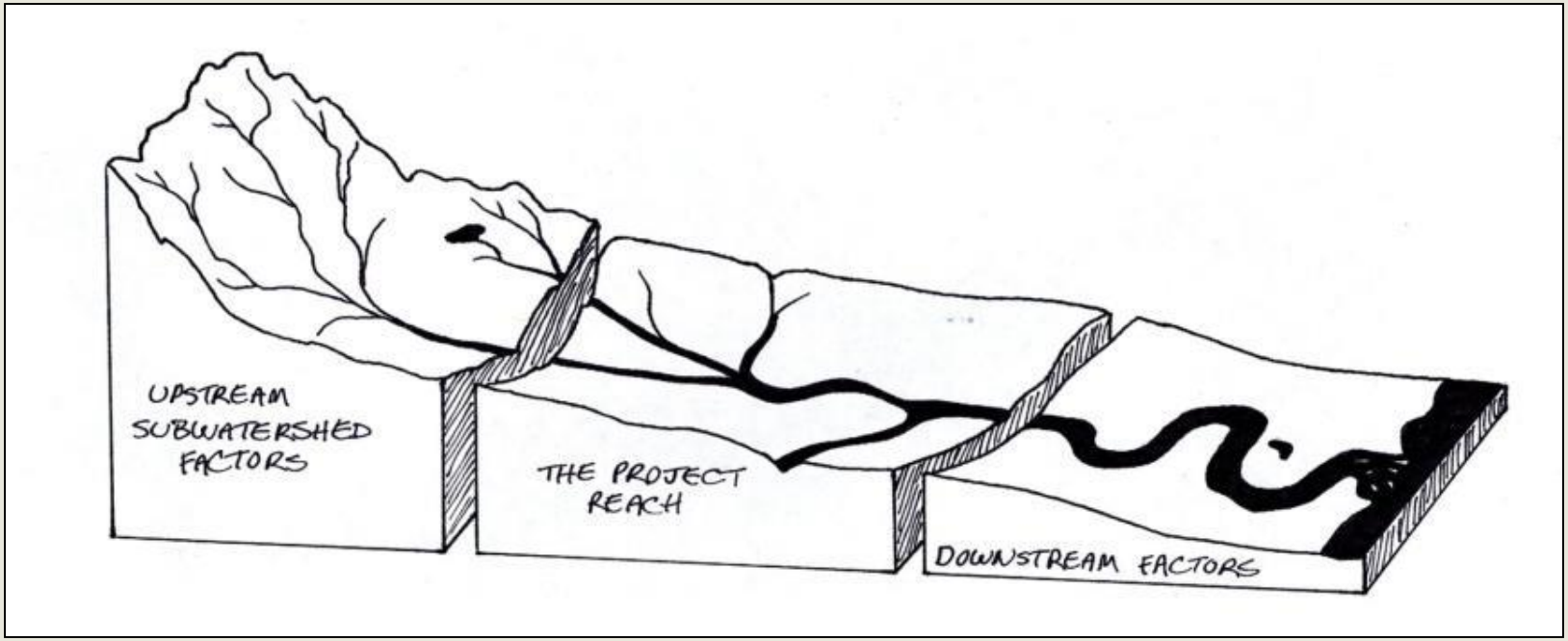
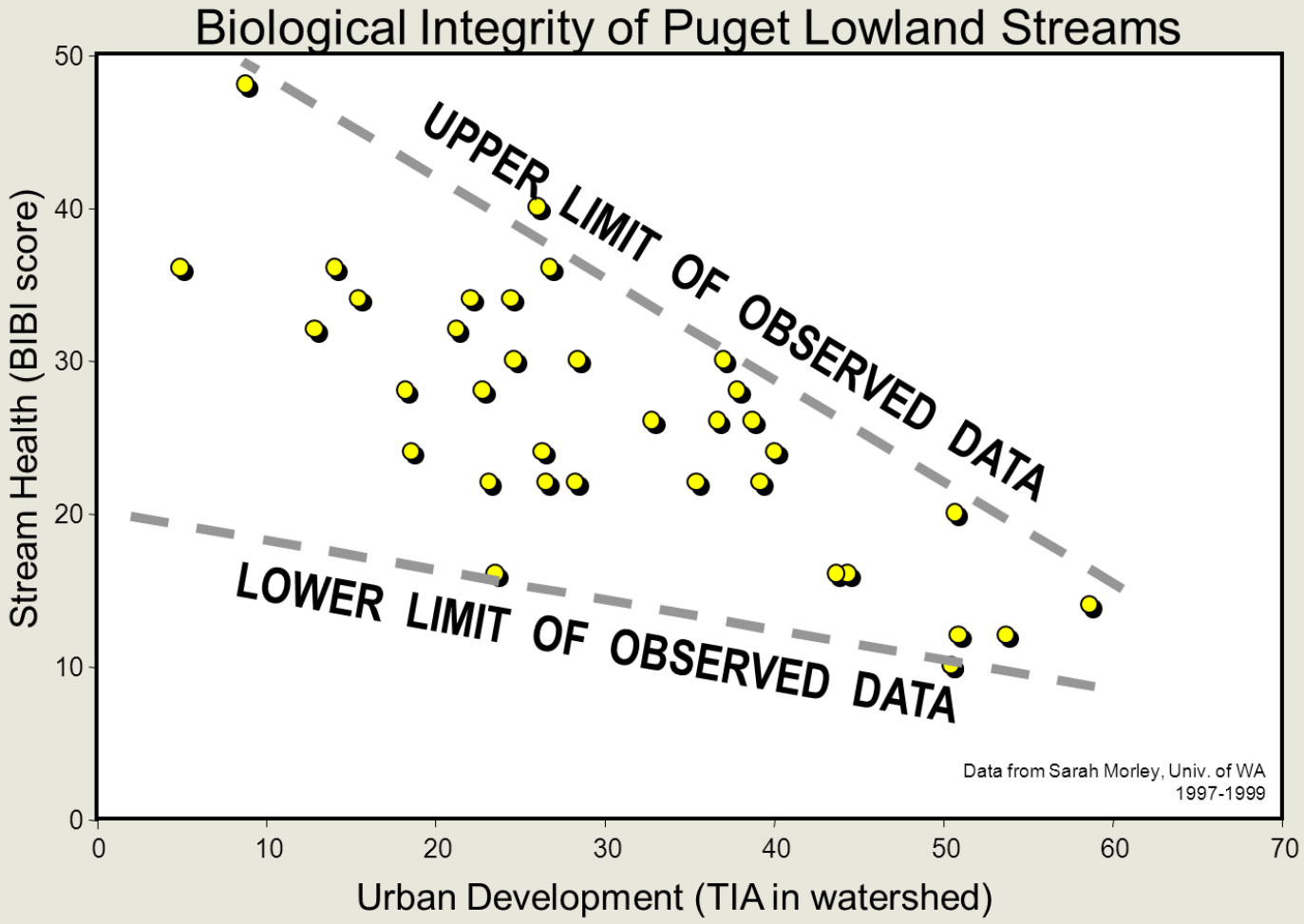
Upland Restoration vs. Stream Restoration



Setting Realistic Expectations



Expert Panel formed to define removal rates for Stream Restoration

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

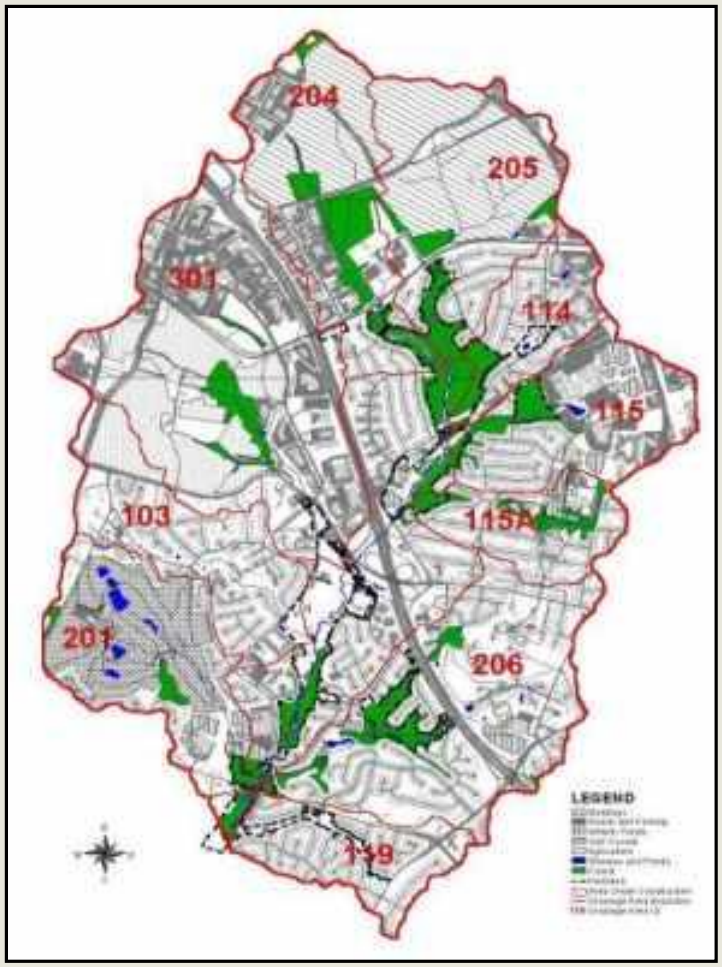
Accepted by Urban Stormwater Work Group: **February 19, 2013**
Approved by Watershed Technical Work Group (WQTWG): **April 5, 2013**
Final Approval by Water Quality Goal Implementation Team (WQGIT): **May 13, 2013**
Test-Drive Revisions Approved by the Expert Panel: **January 17, 2014**
Test-Drive Revisions Approved by the WQTWG: **August 28, 2014**
Test-Drive Revisions Approved by the WQGIT: **September 9, 2014**

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

Comprehensive Watershed Restoration Approach

- Stream Panel endorsed a comprehensive watershed approach to install restoration practices in the uplands, the stream corridor, and in appropriate settings, within the stream itself.

- No current science to recommend what proportion of practices should be applied to uplands vs. stream corridor.



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What is Missing From These Pictures?
Part of the stream!

Johns Hopkins University study (1982) found channel and flood plain deposits to be a major source of sediment loadings in the Lake Roland Watershed, Baltimore, MD.

However, it is not clear that this areal export rate reflects continuing upland erosion in contrast to channel and flood deposit erosion. Jacobson(1980) has tentatively shown that floodplain deposits in the Upper Jones Falls and other Piedmont watersheds were produced during the mid-Nineteenth Century intensive agricultural development. These deposits appear to be mobilized by meandering stream channels under current conditions suggesting that they serve as a major source of SS during storm runoff events.

Consequently, there may be a substantial reservoir of sediment stored in streambeds and nearby floodplain deposits available for fluvial transport during runoff events.(Erosion controls implemented on upland agricultural sites may not produce immediate reductions in sediment inputs to Lake Roland.

Streambank erosion is a major source of sediment

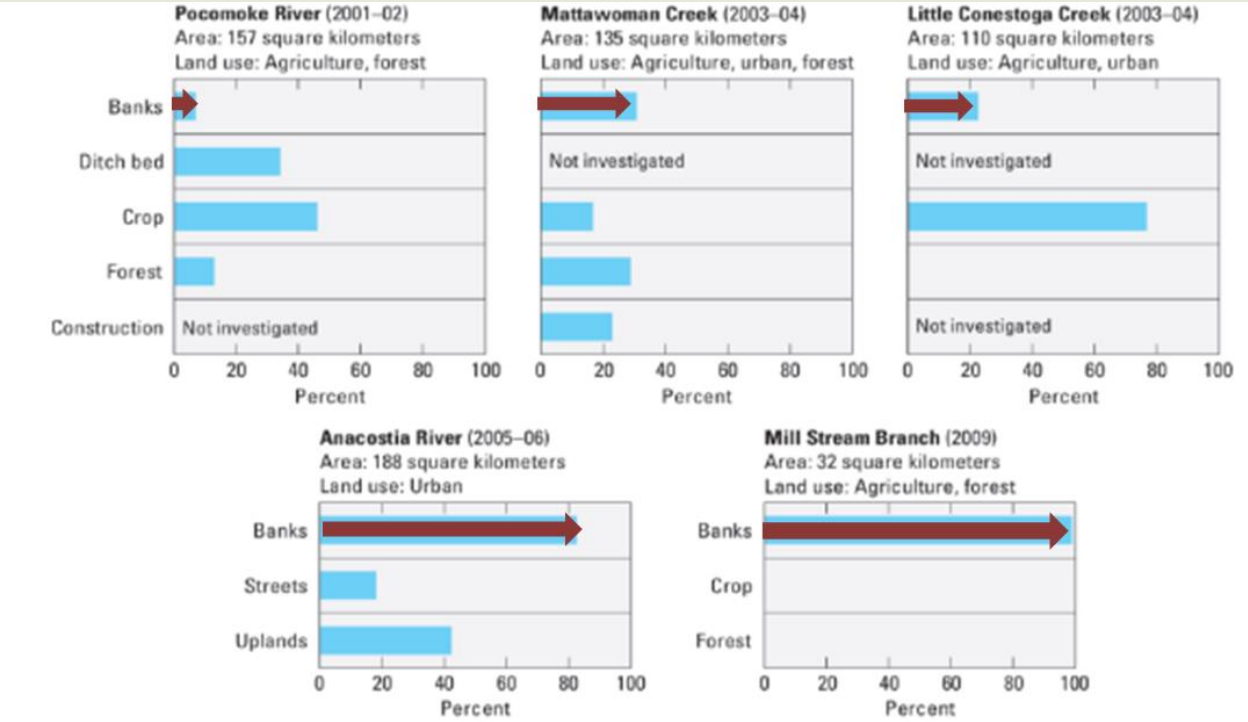

Figure 3. Sediment sources in small watersheds in the Chesapeake Bay watershed in which U.S. Geological Survey sediment fingerprinting studies were conducted or are ongoing (modified from Gellis and Walling, 2011; Devereux and others, 2010; Gellis and others, 2009).

Sediments are also rich in nutrients

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

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Review of the Old Rate compared to New

Used for planning purposes and for projects that do not conform to the protocol requirements.

Edge-of-Stream 2011 Interim Approved Removal Rates per Linear Foot of Qualifying Stream Restoration (lb/ft/yr)			
Source	**TN**	**TP**	**TSS***
Initial CBP rate based on Spring Branch	0.02	0.0035	2.55
Revised Default Rate	0.075	0.068	44.88 non-coastal plain 15.13 coastal plain
Derived from six stream restoration monitoring studies: Spring Branch, Stony Run, Powder Mill Run, Moore's Run, Beaver Run, and Beaver Dam Creek located in Maryland and Pennsylvania *To convert edge of field values to edge of stream values, a sediment delivery ration (SDR) was applied to TSS. The SDR is 0.181 for non-coastal plain streams and 0.061 for coastal plain streams. Additional information about the sediment delivery ratio is provided in Section 2.5 and Appendix B.			

TP reduction from 1,000 ft. of stream restoration = **Load from 40 acres of impervious cover!**

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What is Stream Restoration?

Refers to any NCD, RSC, LSR or other restoration project that meets the qualifying conditions for credits, including environmental limitations and stream functional improvement.

The Panel agreed that any single design approach was not superior to the others, as any project can fail if it is inappropriately located, assessed, designed, constructed, or maintained.

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Stream Restoration Protocols

1. Prevented sediment approach

2. In-stream denitrification

3. Floodplain reconnection

4. The "tweener" Dry Channel RSC

Protocol 1:
Credit for Prevented Sediment during Storm Flow

This protocol provides an annual mass nutrient and sediment reduction credit for qualifying stream restoration practices that prevent channel or bank erosion that would otherwise be delivered downstream from an actively enlarging or incising urban stream.

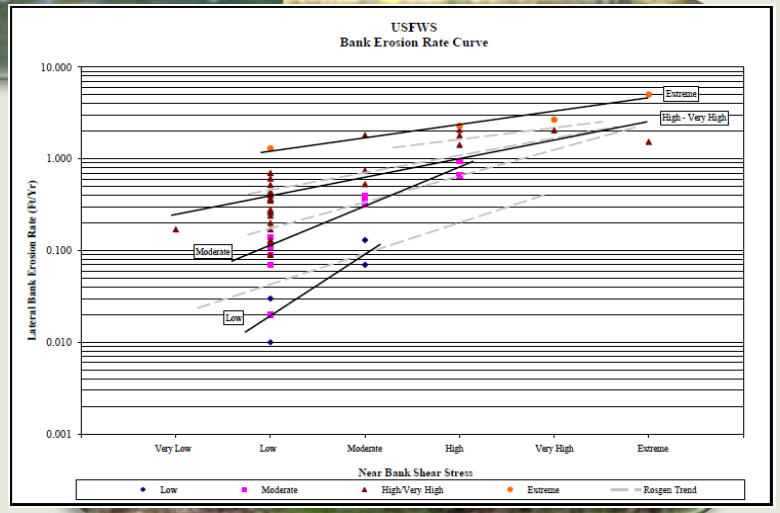
- Estimate stream sediment erosion rates
- Convert erosion rates to nitrogen and phosphorus loadings
- Estimate reduction efficiency attributed to restoration

Protocol 1:
Credit for Prevented Sediment during Storm Flow

Stony Run Before and After Surveys

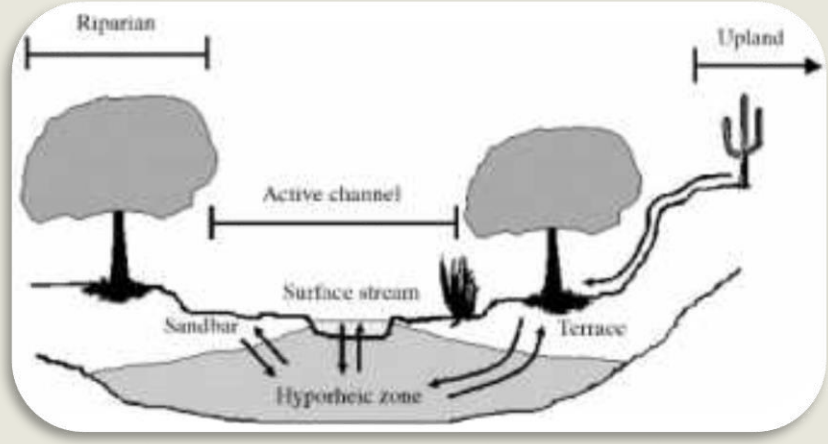
High BEHI and NBS

Low BEHI and NBS



Protocol 2:
Credit for Denitrification in the Hyporheic Zone during Base Flow

This protocol provides an annual mass nitrogen reduction credit for qualifying projects using empirical measurements of denitrification during base flow within a stream's hyporheic zone (stream, riparian and floodplain).



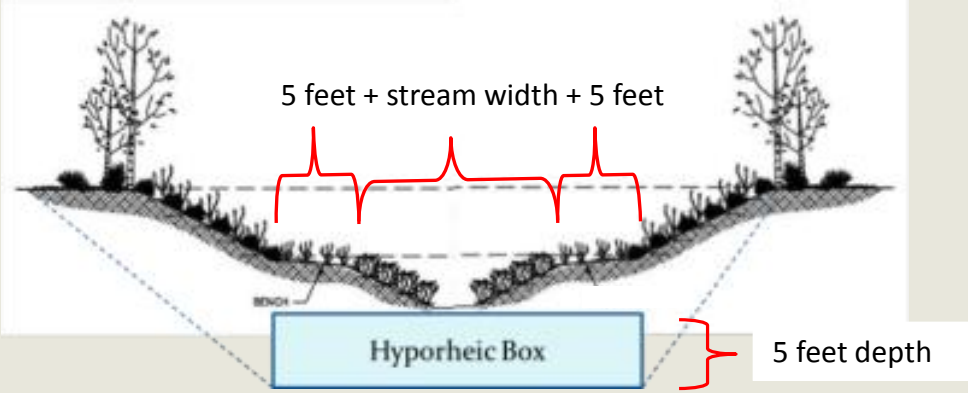
Functional ecomorphology: Feedbacks between form and function in fluvial landscape ecosystems. Stuart G. Fisher, , James B. Heffernan, Ryan A. Sponseller, Jill R. Welter

Protocol 2:
Credit for Denitrification in the Hyporheic Zone during Base Flow

Step 1. *Determine the total post construction stream length that has been reconnected using the bank height ratio of 1.0 or less (for NCD) or the 1.0 inch storm (other design approaches that do not use the bank full storm)*

Step 2. *Determine the dimensions of the hyporheic box*

Step 3. *Multiply the hyporheic box mass by the unit denitrification rate*



Protocol 3:
Credit for Floodplain Reconnection

Floodplain Reconnection Through Legacy Sediment Removal

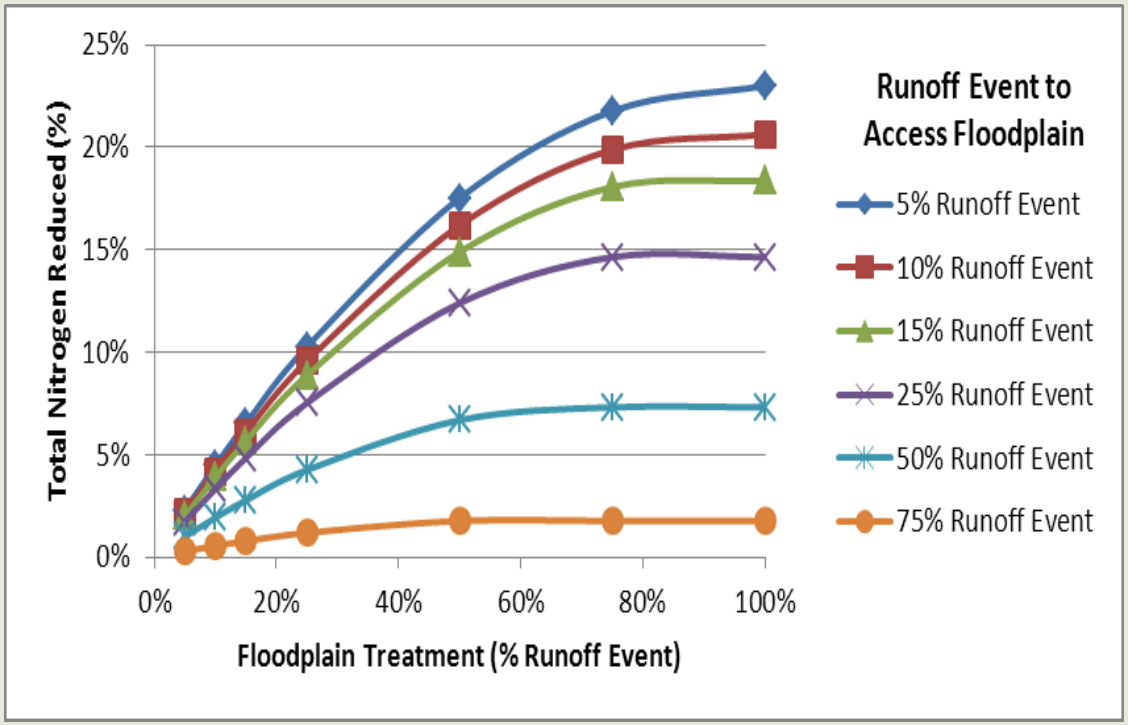
Big Spring Run
Lancaster PA

Photos courtesy of Jeff Hartranft, PADEP

Protocol 3:
Credit for Floodplain Reconnection

Step 1. *Estimate the floodplain connection volume*

Step 2. *Estimate the N and P removal rate attributable to floodplain reconnection (using Jordan 2007 study)*



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How do stream restoration projects compare to other BMPs?

Cost-Effectiveness of Urban Stormwater BMPs			
BMP	Cost Effectiveness ($/lb)		
	TN	TP	TSS
Bioretention (new - suburban), A/B soils, no underdrain	$339.00	$2,934.83	$5.82
Bioretention (new - suburban), C/D soils, underdrain	$1,084.81	$5,543.56	$9.53
Bioretention (retrofit, highly urban C soils)	$2,078.97	$12,500.51	$22.25
Bioswale (new)	$309.13	$2,653.91	$5.23
Dry Detention Ponds (new)	$4,597.20	$21,143.16	$44.43
Dry Extended Detention Ponds (new)	$1,149.30	$10,571.58	$7.41
Filtering Practices (sand, below ground)	$1,065.38	$4,940.56	$7.04
Forest Buffers	$150.86	$1,851.00	$7.66
Urban Stream Restoration (recommended 2014 default efficiencies)	$696.86	$768.59	$1.16
Illicit discharges- correction of cross-connections	$17.70	$70.79	$6.69
Illicit discharges- sewer repair	$8.86	$35.43	$0.89

Source: Cost-Effectiveness Study of Urban Stormwater BMPs in the James River Basin, 2013. CWP

Qualifying Conditions

- Stream restoration projects that are primarily designed to protect public infrastructure by bank armoring or rip rap **do not** qualify for a credit.
- The urban stream reach must be greater than 100 feet in length.
- The project must utilize a comprehensive approach to stream restoration design, involving the channel and banks.
- Stream restoration project must provide functional lift and be part of a comprehensive watershed management plan.
- No removal credit will be granted for any project that is built to offset, compensate, or otherwise mitigate for an impact to a stream or waterway elsewhere in the watershed.

Verification of Stream Restoration Credit

- Max duration for the removal credits is 5 years
- Credit is renewed based on a field performance inspection that verifies the project still exists, is adequately maintained and operating as designed.
- Credit is lost if project cannot be verified (i.e., does not pass inspection).
- Protocols have to be reapplied and credits adjusted if changes occur in watershed (e.g., BMP implementation)

Next Steps

- Updates for Phase 6 of the Chesapeake Bay Watershed Model.
  - Modeling streams as a land cover?
  - Accounting for nutrient loss associated with deposition
  - Better apportioning of watershed loading to stream channels

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How does stream restoration fit it to restoring the Jordan River ?