Cost Estimates

for the

Chesapeake Bay TMDL

Prepared by the staff of the

HAMPTON ROADS PLANNING DISTRICT COMMISSION

AUGUST 2011

Cost Estimate for Chesapeake Bay TMDL

The Hampton Roads Planning District Commission (HRPDC), with consultant Greeley and Hansen, developed three cost estimates for the implementation of stormwater sector requirements per the Chesapeake Bay Total Maximum Daily Load (TMDL). The first cost estimate is based on the draft TMDL, while the subsequent two estimates are based on the final Virginia Phase I Watershed Implementation Plan (WIP). A summary of this effort is provided below.

In October 2010, HRPDC developed a regional cost estimate for the stormwater sector requirements in the draft Chesapeake Bay TMDL. The EPA included "backstops" in the draft Bay TMDL requiring Virginia localities to implement the following reductions:

> "…50 percent of urban MS4 lands meet aggressive performance standard through retrofit/ redevelopment; 50 percent of unregulated land treated as regulated, so that 25 percent of unregulated land meets aggressive performance standard; designation as necessary."

On December 28, 2010, the EPA released the final Bay TMDL, which removed the "backstops" and accepted Virginia's revised Phase I WIP. The Virginia Phase I WIP requires substantially less urban stormwater retrofits compared to the "backstops" in the draft Bay TMDL. The estimated cost of compliance for the urban stormwater requirements was reduced by a factor of about four.

Two cost estimates for the stormwater sector were developed based on Virginia's final Phase I WIP. One estimate assumes all stormwater nutrient reductions will be implemented with structural BMPs; the second cost estimate assumes that non-structural nutrient management plans will be implemented as well as structural BMPs. The second cost estimate is based on Table 6-4.1 in Virginia's Phase I WIP. This table assumes the non-structural BMP "Urban Nutrient Management" will be applied on 90% of urban pervious lands. The second cost estimate only includes the cost of structural BMPs; the cost of implementing "Urban Nutrient Management" was not included.

The estimated costs of implementing the backstops and the final Phase I WIP requirements are shown in Table 1. These costs represent the capital cost to construct BMPs; they do not include land acquisition or operation and maintenance costs. The construction of BMPs would be required by the 2025 deadline.

Table 1: Estimated Costs to Implement Backstops and Final Virginia Phase I WIP Requirements

Locality	Draft TMDL: October 2010	Final TMDL / Virginia's Phase I WIP: December 2011	
	Cost to meet EPA backstops	Cost based on WIP Table 2.2 (no nutrient management)	Cost based on WIP Table 6-4.1 (includes nutrient management)
	(millions)	(millions)	(millions)
Chesapeake	$1,367	$255	$255
Hampton	$1,053	$198	$198
Newport News	$1,166	$224	$224
Norfolk	$1,384	$318	$280
Portsmouth	$666	$125	$125
Virginia Beach	$1,737	$429	$323
Isle of Wight County	$231	$79	$40
James City County	$501	$149	$87
Poquoson	$90	$14	$14
Suffolk	$628	$211	$109
Williamsburg	$94	$21	$18
York County	$594	$94	$94
Gloucester County	$242	$33	$33
Surry County	$40	$13	$7
Hampton Roads	**$9,793**	**$2,163**	**$1,806**

The methodology used to develop these cost estimates is explained in the attached memo (see Attachment A). The cost estimates were based on applying the most effective types of structural BMPs to meet the stormwater nutrient reductions. The Phase I WIP cost estimates should be viewed as an order of magnitude estimate because one treatment scenario was applied across all localities in the region. In the Phase II WIP process, localities have an opportunity to identify nutrient management actions that may be more cost effective than the BMPs applied in the Phase I WIP cost estimate. An evaluation of opportunities and constraints in each locality will result in a more accurate estimate of the cost to implement the TMDL.

ATTACHMENT A

June 24, 2011 Greeley and Hansen Memorandum

Chesapeake Bay TMDL and Final Phase I WIP
Urban Stormwater Cost Estimates for Hampton Roads Communities

MEMO

GREELEY AND HANSEN

Date: **June 24, 2011**

Subject: **Chesapeake Bay TMDL and Final Phase I WIP**
Urban Stormwater Cost Estimates for Hampton Roads Communities

1. Introduction

On December 28, 2010, the U.S. Environmental Protection Agency (EPA) released the Chesapeake Bay Total Maximum Daily Load Final Report (Bay TMDL). In the final Bay TMDL, EPA removed the "backstops" from the Virginia Phase I Watershed Implementation Plan (WIP). However, EPA indicated that "enhanced oversight" of Virginia's urban stormwater sector was required to ensure that Waste Load Allocations (WLAs) and Load Allocations (LAs) are achieved and maintained. In general, the final Virginia Phase I WIP requires substantially less urban stormwater retrofits compared to the "backstops" in the draft Bay TMDL, which reduced the cost of compliance with the urban stormwater requirements by a factor of about four.

2. Summary of Regional Cost Estimates for Stormwater Retrofits

The Virginia Runoff Reduction Method of estimating BMP performance is the basis for the urban stormwater retrofit cost estimates. The Department of Conservation and Recreation (DCR) is updating the Virginia Stormwater Regulations. The proposed regulations incorporate the Runoff Reduction Method. The Virginia Runoff Reduction Method estimates the stormwater runoff volume reduction as well as the total load removed by specific stormwater Best Management Practices (BMPs). **Table 1** shows the urban stormwater retrofit capital cost estimates and the associated economic statistical information for the Hampton Roads localities.

Two sets of cost estimates are provided in **Table 1**. The first cost column is based on Table 2.1 and Table 2.2 in Virginia's Phase I WIP document. Table 2.2 identifies the pounds of Total Phosphorus (TP) allocated to urban stormwater in each basin. The cost estimate considered the retrofits required to reduce the nutrient loads from EPA's estimate of loads in 2009 to the urban runoff allocations required by 2025.

The second cost estimate in **Table 1** is based on Table 6-4.1 in Virginia's Phase I WIP. It sets stormwater implementation goals in terms of percentage of impervious and pervious land that must be treated with specific types of BMPs. This table assumes additional reductions will occur from applying the non-structural BMP "Urban Nutrient Management" on 90% of urban pervious lands. It should be noted that "Urban Nutrient Management" is not the same thing as the "Phosphorus Fertilizer Ban" that was passed by the General Assembly. The cost estimate in column 1 is more expensive than the cost estimate in column 2 because less stormwater retrofits would be required if nutrient management practices are implemented.

Table 1
Urban Stormwater Retrofit Cost Estimates for Hampton Roads Communities

Category	Row	Item	Method 1	Method 2
			Reductions to Meet WLA in WIP Table 2.2	Virginia WIP Assumptions in Table 6-4.1(1)
Estimated Costs	A	Estimated Capital Cost	$2,163,000,000	$1,806,000,000
	B	Estimated Annual Cost ($/yr)	$232,000,000	$194,000,000
Estimated Average Annual Stormwater Bills(2)	C	Residential House ($/yr)	$220	$190
	D	Convenience Store/ Gas Station ($/yr)	$1,980	$1,710
	E	Neighborhood Shopping Center ($/yr)	$13,200	$11,400
	F	Church ($/yr)	$4,400	$3,800
	G	Regional Mall ($/yr)	$198,000	$171,000
Financial Burden	H	2009 Medium Household Income Estimate	$55,404	$55,404
	I	Residential House Stormwater Fee as Percentage of MHI (Row "C" / Row "H")	0.4%	0.3%

Note: **(1) Includes performance of urban nutrient management**

(2) Costs estimates represent bills for 5 types of properties assuming a stormwater billing system with an Equivalent Residential Unit (ERU) of 2,000 sf of impervious area.

Row "A" of **Table 1** shows the capital cost to construct BMP retrofits. The estimated annual cost in Row "B" is based on financing the capital costs in Row "A" with a bond at a 5.5% interest rate[1] and a 30 year term plus O&M costs estimated at 5% of construction.

[1] The Virginia Clean Water Revolving Loan Fund (VCWRLF) is being expanded to allow the financing of stormwater projects. VCWRLF agreements typically have a 3% interest rate and a 20-year term.

In **Table 1**, the cost estimates in Rows "C" through "G" were based on the following assumptions.

- Average residential property has 2,000 square feet of impervious cover.
- Stormwater billing system would define an Equivalent Residential Unit (ERU) as 2,000 square feet of impervious cover.
- Stormwater bills would be based on the number of Equivalent Residential Units (ERU) on any type of property.
- The amount of impervious cover for each locality, based on EPA's Watershed Model Phase 5.3, was divided by 2,000 square feet to establish the number of ERUs in the locality.
- The total annual cost for each locality (Row B) was divided by the number of ERUs in each locality to determine a cost per ERU in each locality.
- Representative bills for different types of properties were calculated by assuming the type of property had a certain amount of impervious cover (**Table 2**). The number of ERUs in **Table 2** was multiplied by the cost per ERU to generate a representative bill for each type of property.

Table 2: Impervious Cover and Number of ERUs

Row	Item	Impervious Cover Sq. Ft.	Number of ERUs
C	Residential House (basis for ERU)	2,000	1
D	Convenience Store/ Gas Station	18,000	9
E	Neighborhood Shopping Center	120,000	60
F	Church	40,000	20
G	Regional Mall	1,800,000	900

3. Two Methodologies for determining urban stormwater nutrient reduction requirements according to Virginia's Phase I WIP

a. Method 1: Retrofit cost estimates based on meeting waste load allocations (WLAs) without Urban Nutrient Management

Method 1 estimates the cost of retrofits based on the allocations in Virginia WIP Table 2.2. This method assumes that all nutrient reductions for urban stormwater will be accomplished with structural BMPs.

Virginia WIP Table 2.2:
Virginia Chesapeake Bay TMDL Allocations
Total Phosphorus - 2025 [Million Pounds/Year]

Source Sector	Potomac	Rapp	York	James	Eastern Shore	VA TOTAL
Agriculture	0.674	0.533	0.157	0.622	0.111	2.097
Urban Runoff[1]	0.273	0.094	0.090	0.528	0.009	0.994
Wastewater[1]	0.278	0.079	0.155	0.967	0.008	1.487
On-Site[1]	0	0	0	0	0	0
Forest	0.205	0.183	0.126	0.543	0.015	1.072
Non-Tidal Dep	0.008	0.007	0.009	0.030	0.002	0.056
Total	**1.438**	**0.896**	**0.538**	**2.690**	**0.145**	**5.707**
Draft Allocations	**~~1.472~~[2]**	**0.900**	**0.540**	**2.340[4]**	**~~0.163~~[3]**	**5.3574**
	1.439				**0.145**	

1 Allocations for these source sectors can be attained through expansion of the VA Nutrient Credit Exchange Program
2 For Potomac Basin, a portion of the TP allocation is transferred to the TN allocation using 1:5 ratio [removed 34,000 lbs/yr from TP]
3 For E Shore, a portion of the TP allocation is transferred to the TN allocations using 1:5 ratio [removed 18,139 lbs/yr from TP]
4 Refer to James River Strategy section of the WIP for Virginia's approach to conform with EPA's draft July 1 TMDL allocations by 2025; 0.35 MPY will be included in the TMDL as an aggregated allocation for reduction in the wastewater sector; adjustments will be made, as warranted, in 2017 following completion of scientific review of chlorophyll standards

The percent reductions from the "2009 Progress" nutrient loads to the individual WLAs for the Phase I MS4 communities were used as the basis for the retrofit cost estimates as shown in **Table 3-1 and Table 3-2**. **Table 4** shows the urban stormwater percent reductions required to meet the allocations in Table 2.2 of Virginia's WIP. The basin level percent reductions from the "2009 Progress" nutrient loads to the "Virginia WIP Allocation" in **Table 4** were used as the basis for retrofit cost estimates associated with the Hampton Roads communities not receiving an individual WLA.

Table 3-1
Phase I MS4 Waste Load Allocations and Percent Reductions from 2009 Progress

Item	Chesapeake			Hampton			Newport News		
	TN	TP	TSS	TN	TP	TSS	TN	TP	TSS
EPA's 2010 No Action(1)	0.288	0.060	5.1	0.178	0.042	7.1	0.224	0.047	7.4
EPA's 2009 Progress(1)	0.268	0.053	4.4	0.173	0.041	6.8	0.217	0.045	7.0
EPA's TMDL Allocation(1)	0.255	0.048	3.4	0.158	0.034	4.8	0.198	0.037	4.9
Percent Reduction b/t "2010 No Action" & "Allocation"	11%	20%	34%	11%	20%	33%	12%	21%	33%
Percent Reduction b/t "2009 Progress" & "Allocation"	5%	10%	22%	9%	17%	30%	9%	18%	30%

Table 3-2
Phase I MS4 Waste Load Allocations and Percent Reductions from 2009 Progress

Item	Norfolk			Portsmouth			Virginia Beach		
	TN	TP	TSS	TN	TP	TSS	TN	TP	TSS
EPA's 2010 No Action(1)	0.279	0.056	10.2	0.150	0.028	4.2	0.342	0.072	10.9
EPA's 2009 Progress(1)	0.266	0.053	9.2	0.140	0.025	3.6	0.330	0.068	10.1
EPA's TMDL Allocation(1)	0.249	0.046	7.1	0.134	0.023	2.9	0.306	0.058	7.4
Percent Reduction b/t "2010 No Action" & "Allocation"	11%	19%	31%	11%	18%	30%	11%	19%	32%
Percent Reduction b/t "2009 Progress" & "Allocation"	6%	13%	23%	5%	7%	18%	7%	14%	27%

Table 4
Urban Stormwater Load Summary

Source	York River Basin			James River Basin		
	TN	TP	TSS	TN	TP	TSS
EPA's 2009 Progress(1)	0.515	0.112	33.8	2.918	0.650	189.6
Virginia WIP Allocation(1),(2)	0.445	0.090	14.0	2.534	0.528	109.6
Percent Reduction from "2009 Progress" to "Allocation"	14%	20%	59%	13%	19%	42%

Note: (1) Loads in million pounds per year
(2) TN based on WIP Table 2.1. TP based on WIP Table 2.2. TSS allocations based on Bay TMDL (TSS allocation was not included in WIP)

b. Method 2: Retrofit cost estimates based on Virginia WIP Table 6-4.1

Method 2 estimates the cost of retrofits based on the implementation strategy in Virginia WIP Table 6-4.1. This method assumes that nutrient reductions for urban stormwater will be accomplished with nutrient management plans and structural BMPs. If urban nutrient management, a non-structural BMP, is not fully implemented, the structural BMPs identified in Table 6-4.1 would not provide the total stormwater reductions required by the TMDL.

Virginia WIP Table 6-4.1:
Urban / Suburban Stormwater Scoping Scenario Level 2 Effective Net Reductions Using Phase 5.3 Land Loads

Land Use Category	Practice Description	Level 2 Practice % Coverage	Effective Net Reduction Prorated Over Entire Land Use Category Acreage		
			Total Nitrogen	Total Phosphorus	TSS
Impervious Urban High and Low Intensity	Impervious Cover Reduction	7.5%	0%	5%	6%
	Filtration Practices	7.5%	3%	4%	6%
	Infiltration Practices	8.0%	6%	7%	8%
	Total	23.0%	**9%**	**16%**	**20%**
Pervious Urban High and Low Intensity	Impervious Cover Reduction	-			
	Filtration Practices	5%	2%	3%	4%
	Infiltration Practices	5%	4%	4.25%	4.75%
	Total	10%	**6%**	**7.25%**	**8.75%**

Nutrient Reduction Efficiencies:
Impervious Cover Reduction: 2% N, 65% P, 85% Sediment
Filtration Practices: 40% N, 60% P, 85% Sediment
Infiltration Practices: 80% N, 85% P, 95% Sediment

Urban nutrient management is not the same thing as the Phosphate Fertilizer Band. Urban nutrient management is defined by EPA in the Scenario Builder documentation:

"*Urban nutrient management involves the reduction of fertilizer to grass lawns and other urban areas. The implementation of urban nutrient management is based on public education and awareness, targeting suburban residences and businesses, with emphasis on reducing excessive fertilizer use.*"

EPA has assigned removal efficiencies to Urban Nutrient Management of 17% for Total Nitrogen and 23% for Total Phosphorus[2].

The Virginia Phase I WIP did not clearly define the extent of nutrient management implementation required to meet the assumption in Table 6-4.1. Based on correspondence with DCR, urban nutrient management would include:

- 2,142 acres of nonagricultural state lands receiving nutrients.
- 5,000 acres of VDOT property annually receiving nutrients.
- Estimated 142,000 acres of lawn service in Bay watershed.
- 26,000 acres of golf courses in Bay watershed.

[2] Based on EPA's DOCUMENTATION FOR SCENARIO BUILDER VERSION 2.2, September 2010

- 90% of do-it-yourself home lawn fertilizer application through controls impacting both N and P use on 297,000 acres annually.
- 50,000 acres annually of nutrient management impacting general area fertilization (office parks, fertilizer municipal lands, etc.).

This list is not equal to 90% of urban pervious acres. It is a subset of acres estimated to receive fertilizer applications. For example, the 90% of do-it- yourself home lawn fertilizer acres would be 90% of the acres believed to be fertilized.

The Virginia Phase I WIP Table 6-4.1 shows the percent of impervious and pervious land area that must be treated with BMPs. **Table 5** shows the phosphorus reductions in the York River and James River basins if the BMPs identified in Table 6-4.1 were constructed. In the York River basin, the amount of phosphorous from urban stormwater would be reduced by 8.9%. In the James River basin, the amount of phosphorus from urban stormwater would be reduced by 9.4%.

Table 5
Composite Percent Phosphorous Reductions based on Total Area

Item	York River Basin				James River Basin			
	Area (Acres)	Percent of Area	Percent Reduction	Composite Percent Reduction	Area (Acres)	Percent of Area	Percent Reduction	Composite Percent Reduction
Impervious Cover	18,388	19%	16.00%	3.1%	127,631	24%	16.00%	3.9%
Pervious Cover	76,647	81%	7.25%	5.8%	399,743	76%	7.25%	5.5%
Total	**95,035**	**100%**		**8.9%**	**527,374**	**100%**		**9.4%**

4. Detailed Assumptions for the Basis of Retrofit Cost Estimates

The evaluation of the costs of the urban stormwater retrofit BMPs outlined in Virginia's WIP is based on Virginia Department of Conversation and Recreation (DCR) Virginia Runoff Reduction Method. This approach considers soil type, land cover, and BMP applicability for each land use. The assumptions used to estimate the performance and cost of potential urban stormwater retrofit BMPs and other stormwater controls (such as storage/reuse) to achieve pollutant reductions in the final EPA Chesapeake Bay TMDL are provided as follows.

a. Soil Type

Soil data (GIS layers) for each municipality is obtained from US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Data Mart. Hydrologic soil group (HSG) designations (A, B, C, D) are then assigned based on the soil type description. The percentage of land area for each hydrologic soil group is then calculated, as shown in **Table 6**.

Table 6
Calculate BMP Treatment Volume by Hydrologic Soil Group (example)

Row	Municipality	Units	Soil A	Soil B	Soil C	Soil D
A	Percent of Soil Type		0.1%	49.3%	18.6%	32.1%
B	Pervious Area (Pervious Area in EPA Model x Row "A")	Acres	7	5,787	2,187	3,768
C	Pervious Runoff Coefficient		0.15	0.20	0.22	0.25
D	Runoff Volume for Pervious Area (Row "B" x Row "C" x 1" of Rain)	Acre-inch	1	1,157	481	942
E	Impervious Area (Impervious Area in EPA Model x Row "A")	Acres	2	1,679	635	1,093
F	Impervious Runoff Coefficient		0.95	0.95	0.95	0.95
G	Runoff Volume for Impervious Area (Row "E" x Row "F" x 1" of Rain)	Acre-inch	2	1,595	603	1,039
H	**Locality Total Runoff Volume**	Acre-inch	**3**	**2,753**	**1,084**	**1,981**

Soil data is analyzed for the following reasons:

- Runoff coefficients for pervious areas vary with the underlying hydrologic soil group (**Table 7**).
- Pervious and impervious land areas for each urban stormwater system are converted to runoff volume by multiplying land cover area by runoff coefficient with 1" of rainfall.
- Runoff volume is the basis for evaluating performance and estimating cost of BMPs.
- Soil data is important to determine applicability of infiltration practices. A summary of the percent Hydrologic Soil Group by locality is shown in **Table 8**.
- Hydrologic soil groups that embody strong infiltration characteristics such as type A and B may eliminate the need for an underdrain component, and the associated cost, on most BMPs.

Table 7: Runoff Coefficients by Hydrologic Soil Group

Land Cover	Soil A	Soil B	Soil C	Soil D
Forest	0.02	0.03	0.04	0.05
Pervious	0.15	0.20	0.22	0.25
Impervious	0.95	0.95	0.95	0.95

Table 8
Hydrologic Soil Group from USDA NRCS Soil Data Mart

Community	Soil A	Soil B	Soil C	Soil D
Chesapeake	1%	15%	6%	78%
Hampton	0%	7%	24%	69%
Newport News	0%	47%	24%	29%
Norfolk	0%	32%	26%	43%
Portsmouth	0%	44%	18%	38%
Virginia Beach	3%	32%	9%	56%
Isle of Wight County	11%	17%	39%	34%
James City County	2%	35%	47%	16%
Poquoson	0%	35%	11%	55%
Suffolk	2%	31%	36%	31%
Williamsburg	1%	11%	76%	12%
York County	0%	53%	33%	13%
Gloucester County	11%	51%	19%	19%
Surry County	3%	16%	67%	14%

b. Urban Land Area

The land area for urban stormwater runoff consists of pervious and impervious areas. EPA estimated the quantity of pervious and impervious based on satellite imagery. EPA's land use data from their interpretation of the satellite imagery typically under estimated the amount of impervious cover. If a municipality has detailed planimetrics GIS layers (such as streets, sidewalks, buildings, parking lots, driveways, trees, zoning, parcel, etc.), the pervious and impervious areas could be calculated from the GIS layers which would provide more accurate land area data in the following analyses.

For each locality, the impervious and pervious area is broken into land use categories based on ownership and surface characteristics to identify applicable BMPs. Effective runoff area for each category is then calculated based on soil type and runoff coefficient. **Table 11** shows the effective runoff area break-down based on the GIS data from a representative locality in Virginia. The cost model has been developed to allow each locality to input their own land use percentages, which could replace the default values shown in **Table 9** and currently used in the spreadsheet.

Table 9
Percent of Runoff Volume by Land Use

	Right of Way	Parking	Driveway	Building	Pervious
Municipal Owned Areas	**21.8%**	**1.1%**	**0.4%**	**0.6%**	**1.6%**
Commercial and Industrial		**14.5%**	**1.2%**	**7.2%**	**7.4%**
Residential Areas		**3.7%**	**6.3%**	**10.3%**	**23.9%**

c. Selection of Applicable BMPs

Applicable urban stormwater retrofit BMPs were selected based on the performance values for runoff reduction and nutrient removal efficiencies in Virginia DCR's BMP Clearinghouse. **Table 10** shows the list of BMPs in the DCR BMP Clearinghouse and their respective runoff reduction (RR) rate and mass reduction for TP, TN and TSS. The highlighted values in **Table 10** denote the better performing BMPs that were included in the cost estimate. A municipality may choose different BMPs based on its own experience and local characteristics.

Table 10
Virginia DCR BMPs

BMP	Description	Percent Reduction			
		RR	TP	TN	TSS
1. Vegetated Roof	1.a. Vegetated Roof #1 (Spec #5)	45%	45%	45%	73%
	1.b. Vegetated Roof #2 (Spec #5)	60%	60%	60%	80%
2. Rooftop Disconnection	2.a. Simple Disconnection to A/B Soils (Spec #1)	50%	50%	50%	75%
	2.b. Simple Disconnection to C/D Soils (Spec #1)	25%	25%	25%	63%
	2.c. To Soil Amended Filter Path as per specifications (existing C/D soils) (Spec #4)	50%	50%	50%	75%
	2.d. To Dry Well or French Drain #1 (Microinfilration #1) (Spec #8)	50%	63%	58%	75%
	2.e. To Dry Well or French Drain #2 (Micro-Infiltration #2) (Spec #8)	90%	93%	92%	95%
	2.f. To Rain Garden #1 (Micro-Bioretention #1) (Spec #9)	40%	55%	64%	70%
	2.g. To Rain Garden #2 (Micro-Bioretention #2) (Spec #9)	80%	90%	92%	90%
	2.h. To Rainwater Harvesting (Spec #6)	78%	78%	78%	88%
	2.i. To Stormwater Planter (Urban Bioretention) (Spec #9, Appendix A)	40%	55%	64%	70%
3. Permeable Pavement	3.a. Permeable Pavement #1 (Spec #7)	45%	59%	59%	81%
	3.b. Permeable Pavement #2 (Spec #7)	75%	81%	81%	91%
4. Grass Channel	4.a. Grass Channel A/B Soils (Spec #3)	20%	32%	36%	44%
	4.b. Grass Channel C/D Soils (Spec #3)	10%	24%	28%	37%
	4.c. Grass Channel Compost Amended Soils as per specs (see Spec #4)	30%	41%	44%	51%
5. Dry Swale	5.a. Dry Swale #1 (Spec #10)	40%	52%	55%	64%
	5.b. Dry Swale #2 (Spec #10)	60%	76%	74%	76%
6. Bioretention	6.a. Bioretention #1 or Urban Bioretention (Spec #9)	40%	55%	64%	70%
	6.b. Bioretention #2 (Spec #9)	80%	90%	92%	90%
	6.c. Stormwater Planters (or Urban Bioretention) (Spec #9)	40%	55%	64%	70%
7. Infiltration	7.a. Infiltration #1 (Spec #8)	50%	63%	58%	75%
	7.b. Infiltration #2 (Spec #8)	90%	93%	92%	95%
8. Extended Detention Pond	8.a. ED #1 (Spec #15)	0%	15%	10%	50%
	8.b. ED #2 (Spec #15)	15%	28%	24%	58%
9. Sheetflow to Filter/Open Space	9.a. Sheetflow to Conservation Area with A/B Soils (Spec #2)	75%	75%	75%	75%
	9.b. Sheetflow to Conservation Area with C/D Soils (Spec #2)	50%	50%	50%	50%
	9.c. Sheetflow to Vegetated Filter Strip in A Soils or Compost Amended B/C/D Soils (Spec #2 & #4)	50%	50%	50%	75%
10. Wet Swale (Coastal Plain)	10.a. Wet Swale #1 (Spec #11)	0%	20%	20%	40%
	10.b. Wet Swale #2 (Spec #11)	0%	40%	20%	40%
11. Filtering Practices	11.a.Filtering Practice #1 (Spec #12)	0%	60%	20%	60%
	11.b. Filtering Practice #2 (Spec #12)	0%	65%	20%	60%
12. Constructed Wetland	12.a.Constructed Wetland #1 (Spec #13)	0%	50%	20%	50%
	12.b. Constructed Wetland #2 (Spec #13)	0%	75%	20%	50%
13. Wet Ponds	13.a. Wet Pond #1 (Spec #14)	0%	50%	20%	50%
	13.b. Wet Pond #1 (Coastal Plain) (Spec #14)	0%	45%	20%	50%
	13.c. Wet Pond #2 (Spec #14)	0%	75%	20%	50%
	13.d. Wet Pond #2 (Coastal Plain) (Spec #14)	0%	65%	20%	50%
14. Manufactured BMP	14.a. Bacterra/Filterra	0%	65%	45%	85%

d. Maximum Reductions by Urban Stormwater BMPs

Table 11 shows the assumed percentages of land area treated by each BMP for each land use category. With these assumptions, the total runoff volume (and the percentage) of runoff volume treated by each BMP is calculated, as shown in **Table 12**. Using the BMP performance data in **Table 12**, the runoff reduction and pollutant mass reduction for each BMP are then calculated as:

Formula: Runoff Volume Treated by BMP x Percent Reduction by that BMP / Total Runoff Volume

Table 11
Basis for Maximum Percentage of Runoff Volume Treated by BMPs

Land Use	Percent of Runoff Volume	Bioretention #2	Urban Bioretention (Curbside Planters)	Infiltration Trench / Basin (For A&B Soil)	Filter Strip	Rain Garden, Rain Barrel, Planter
Right of Way	21.8%	5%	5%	5%	5%	
Municipal Owned Parking	1.1%	40%				
Municipal Owned Driveway	0.4%	5%				
Municipal Owned Building	0.6%	30%				5%
Municipal Owned Pervious	1.6%	35%				
Townhouse, Apartment & Condominium Parking	3.7%	40%				
Residential Driveway	6.3%					
Residential Building	10.3%					5%
Residential Pervious	23.9%					5%
Commercial/Industrial Parking	14.5%	40%				
Commercial/Industrial Driveway	1.2%	5%				
Commercial/Industrial Building	7.2%	30%				
Commercial/Industrial Pervious	7.4%	35%				

Table 12
Percentage of Runoff Volume Treated by BMPs

Community	Bioretention #2	Urban Bioretention (Curbside Planters)	Infiltration Trench / Basin (For A&B Soil)	Filter Strip	Rain Garden, Rain Barrel	Total
Municipality	14.3%	1.1%	1.1%	1.1%	1.7%	19.4%

Table 13 shows the maximum mass reduction for total phosphorous by each BMP and the total reduction by all BMPs selected in **Table 11**.

Table 13
Maximum Total Phosphorous Reduction by BMPs

Community	Bioretention #2	Urban Bioretention (Curbside Planters)	Infiltration Trench / Basin (For A&B Soil)	Filter Strip	Rain Garden, Rain Barrel	Total
Municipality	12.9%	0.6%	1.0%	0.5%	1.2%	16.2%

e. Storage/Reuse

When the required reduction cannot be achieved by applying BMPs alone, it is assumed storage/reuse will be used to meet the reductions of the Bay TMDL.

Table 14 shows the calculation of storage volume required to achieve the TP removal required by the Virginia Phase I WIP. The storage volume is calculated based on 80% capture efficiency for the first 1-inch of rainfall. The reuse pumping capacity is determined based on an assumed 10-day dewatering rate. Depending on the land use, the storage facilities may be emptied faster, which may reduce the storage requirements.

Table 14
Required Storage Volume (Example)

A	B	C	D	E
Community	Percent Phosphorus Removal Required by Virginia WIP	Maximum Phosphorus Percent Reduction by BMPs	Percent TP Removal from Storage and Reuse (B - C)	Storage Volume(3) (MG)
Municipality	19%(1)	16.2%(2)	4.8%	20

Note:
(1) Based on percent phosphorus removal for the James River Basin "2009 progress" to the "Virginia WIP Allocation" in **Table 5** (above).
(2) Based on value in **Table 11**.
(3) Assume 10 days to empty and 80% efficiency to capture first 1" of rainfall and assumes that phosphorus is the limiting pollutant.

f. Cost Estimate for BMPs

Costs for BMPs are estimated by multiplying the total effective runoff area treated by each BMP by the unit cost of that BMP ($/acre of effective runoff area). Unit costs of BMPs are typically reported in terms of cubic foot of stormwater volume treated, square foot of BMP size, or acre of treated area, etc. These unit costs were normalized to $/acre of effective runoff area based on the BMP design criteria described in VA DCR's BMP Clearinghouse (**Table 15**). The unit costs of BMPs used to estimate the cost are based on the retrofit BMP costs reported by Center for Watershed Protection (CWP). We also referenced the BMP costs published by EPA (USEPA, 1999; USEPA, 2004).

The CWP costs were derived from literature and various demonstration projects. CWP costs were initially compiled in 2007 and the EPA costs were compiled in 2004. The CWP costs are "retrofit" costs which are generally about 2 to 3 times higher than the costs for new stormwater BMPs. The EPA documents do not specify whether the costs are for retrofits or new BMPs, but the costs for new BMPs reported by CWP are generally comparable to the EPA costs. Neither EPA nor CWP costs include land acquisition. The unit costs used to estimate stormwater retrofit costs are provided in **Table 15** (below).

Table 15
Unit Costs from Center for Watershed Protection

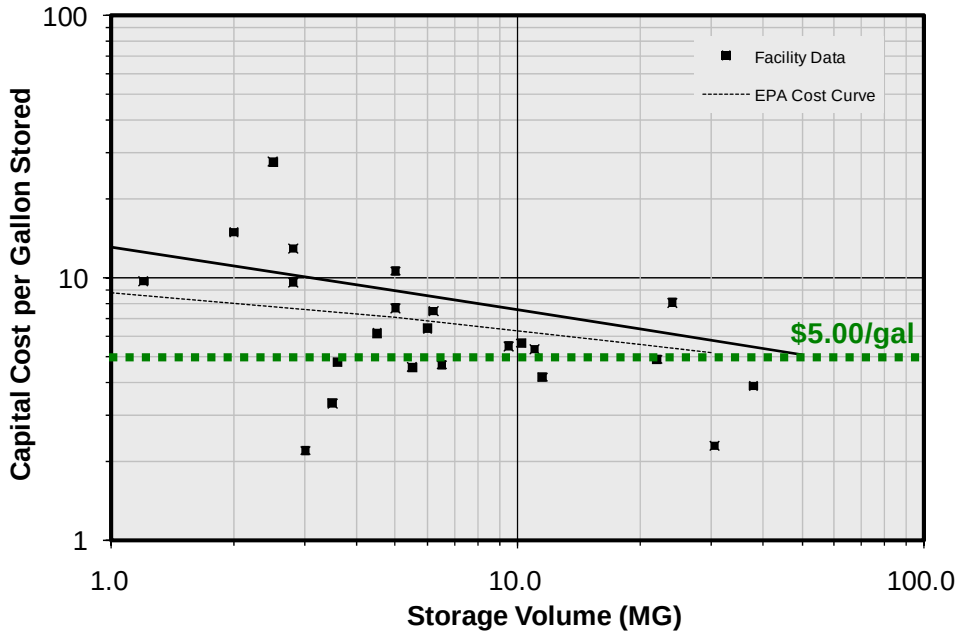
BMP	Description	Unit Cost per Effective Runoff Volume(4)	
		Construction(1)	Capital(2)
1. Vegetated Roof	1.a. Vegetated Roof #1 (Spec #5)	$701,000	$946,000
	1.b. Vegetated Roof #2 (Spec #5)	$771,000	$1,041,000
2. Rooftop Disconnection	2.a. Simple Disconnection to A/B Soils (Spec #1)	$4,200	$5,700
	2.b. Simple Disconnection to C/D Soils (Spec #1)	$4,200	$5,700
	2.c. To Soil Amended Filter Path as per specifications (existing C/D soils) (Spec #4)	$35,000	$47,000
	2.d. To Dry Well or French Drain #1 (Microinfilration #1) (Spec #8)	$52,000	$70,000
	2.e. To Dry Well or French Drain #2 (Micro-Infiltration #2) (Spec #8)	$56,000	$76,000
	2.f. To Rain Garden #1 (Micro-Bioretention #1) (Spec #9)	$66,000	$89,000
	2.g. To Rain Garden #2 (Micro-Bioretention #2) (Spec #9)	$81,000	$110,000
	2.h. To Rainwater Harvesting (Spec #6)	$103,000	$139,000
	2.i. To Stormwater Planter (Urban Bioretention) (Spec #9, Appendix A)	$128,000	$173,000
3. Permeable Pavement	3.a. Permeable Pavement #1 (Spec #7)	$104,000	$141,000
	3.b. Permeable Pavement #2 (Spec #7)	$544,000	$735,000
4. Grass Channel	4.a. Grass Channel A/B Soils (Spec #3)	$26,000	$35,000
	4.b. Grass Channel C/D Soils (Spec #3)	$26,000	$35,000
	4.c. Grass Channel Compost Amended Soils as per specs (see Spec #4)	$57,000	$77,000
5. Dry Swale	5.a. Dry Swale #1 (Spec #10)	$52,000	$70,000
	5.b. Dry Swale #2 (Spec #10)	$57,000	$77,000
6. Bioretention	6.a. Bioretention #1 or Urban Bioretention (Spec #9)	$62,000	$84,000
	6.b. Bioretention #2 (Spec #9)	$103,000	$139,000
	6.c. Stormwater Planters (or Urban Bioretention) (Spec #9)	$124,000	$167,000
7. Infiltration	7.a. Infiltration #1 (Spec #8)	$62,000	$84,000
	7.b. Infiltration #2 (Spec #8)	$68,000	$92,000
8. Extended Detention Pond	8.a. ED #1 (Spec #15)	$12,000	$17,000
	8.b. ED #2 (Spec #15)	$16,000	$21,000
9. Sheetflow to Filter/Open Space	9.a. Sheetflow to Conservation Area with A/B Soils (Spec #2)	(3)	(3)
	9.b. Sheetflow to Conservation Area with C/D Soils (Spec #2)	(3)	(3)
	9.c. Sheetflow to Vegetated Filter Strip in A Soils or Compost Amended B/C/D Soils (Spec #2 & #4)	$56,000	$75,000
10. Wet Swale (Coastal Plain)	10.a. Wet Swale #1 (Spec #11)	$52,000	$70,000
	10.b. Wet Swale #2 (Spec #11)	$65,000	$87,000
11. Filtering Practices	11.a.Filtering Practice #1 (Spec #12)	$82,000	$111,000
	11.b. Filtering Practice #2 (Spec #12)	$103,000	$139,000
12. Constructed Wetland	12.a.Constructed Wetland #1 (Spec #13)	$29,000	$39,000
	12.b. Constructed Wetland #2 (Spec #13)	$43,000	$59,000
13. Wet Ponds	13.a. Wet Pond #1 (Spec #14)	$21,000	$28,000
	13.b. Wet Pond #1 (Coastal Plain) (Spec #14)	$21,000	$28,000
	13.c. Wet Pond #2 (Spec #14)	$31,000	$42,000
	13.d. Wet Pond #2 (Coastal Plain) (Spec #14)	$31,000	$42,000
14. Manufactured BMP	14.a. Bacterra/Filterra	$75,000	$101,000

(1) Construction unit costs are in December 2010 dollars (ENR CCI 8952). Source: Center for Watershed Protection. Urban Subwatershed Restoration Manual (USRM) 3, Appendix E (where costs were reported in 2006 dollars. ENR CCI of 7880 was used for 2006 to convert the costs to 2010 dollars).
(2) Capital cost is calculated as construction cost times 135%.
(3) These costs are highly site specific and depend on availability of conservation areas.
(4) Effective Runoff Volume is in units of Acre-inch. The calculation of Effective Runoff Volume is described in Table 8.

a. Basis for Storage/Reuse Cost Estimates

Cost for storage facilities was estimated based on the cost data published by EPA, as shown in **Figure 1**. A unit cost of $5.00/gal was used to estimate the storage facility cost and $2.50/gal was used for water reuse pumping and distribution system. Cost estimates do not include tunnels or treatment of reused stormwater. It should be noted that the cost is generally for centralized storage facilities in an intense development area. Storage costs could be reduced if regional facilities already exist, but could be retrofitted with a new pumping facility. O&M and life cycle cost considerations would need to be factored into the decision to retrofit facilities.

Figure 1
Cost Data for Storage Facilities
(ENR=8920)



b. Estimated Capital Urban Stormwater Retrofit Costs

Table 16 summarizes the estimated capital urban stormwater retrofit costs. Column "B" represents the costs associated with 19% to 20% total phosphorus reductions if the urban nutrient management plans are not implemented. Since the required phosphorus reduction is greater than the 16% reduction that could reasonably be achieved with structural BMPs, this estimate includes the cost of centralized storage facilities to provide the additional nutrient reductions required to meet the TMDL.

Column "C" represents the costs associated with approximately an 8.9% to 9.4% phosphorus reduction from structural BMPs. Successful urban nutrient management plans would also be required but the cost associated with urban management plans is not included in Column "C" of **Table 16**. Since a phosphate fertilizer ban has been passed by the General Assembly, it is expected that Urban Nutrient Management will be successful at controlling phosphorus and the retrofit costs would be closer to the lower costs

shown in Column "C". However, an evaluation would be needed to determine if a pollutant other than phosphorus might drive the requirements for stormwater retrofits, such as sediment.

Table 16
Estimated Capital Urban Stormwater Estimated Retrofit Costs

A	B	C
Community	Reductions to Meet WLA in WIP Table 2.2 (Without Urban Nutrient Management) (millions)	Virginia WIP Assumptions in Table 6-4.1 (millions)
Chesapeake	$255	$255
Hampton	$198	$198
Newport News	$224	$224
Norfolk	$318	$280
Portsmouth	$125	$125
Virginia Beach	$429	$323
Isle of Wight County	$79	$40
James City County	$149	$87
Poquoson	$14	$14
Suffolk	$211	$109
Williamsburg	$21	$18
York County	$94	$94
Gloucester County	$33	$33
Surry County	$13	$7
Hampton Roads	**$2,163**	**$1,806**

5. Conclusion

The cost estimates described in this document are provided as an order of magnitude estimates. The underlying methodology for the developing the cost estimates is the application of the Runoff Reduction Method which Virginia has adopted in its draft stormwater regulations. Cost estimates were also based on the assumption that phosphorus is the pollutant driving retrofit requirements. However, EPA's final Bay TMDL indicates that total suspended solid (TSS) reductions may require more BMP retrofits than phosphorus. Finally, several model updates and new policies will impact the assumptions in the cost estimates. Therefore, the cost estimates should be revised as new data, requirements and opportunities are identified.