Linking Local TMDLs to the Chesapeake Bay TMDL in the James River Basin

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About This Study

The goal of this study was to assess the extent to which local TMDL implementation plans can also address pollutant reductions required of James River Basin localities to meet the Chesapeake Bay TMDL. The pollutant reductions presented in this study are estimates based on what is currently known about crediting bacteria reduction practices for nutrient and sediment removal, and are likely to change as new BMPs are approved and/or pollutant removal efficiencies are refined by the Chesapeake Bay program (CBP). Localities developing stormwater management strategies are advised to check with the status of the latest CBP panel recommendations, which are available at: http://stat.chesapeakebay.net/?q=node/130&quicktabs_10=3.

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Linking Local TMDLs to the Chesapeake Bay TMDL in the James River Basin

Urban stormwater is the fastest growing source of pollution to the James River and needs to be controlled effectively and efficiently in order to restore the health of the river. Moreover, achieving needed pollution reductions from existing developed areas through improved stormwater management is the most difficult element of the Virginia watershed implementation plan (WIP) to meet the Chesapeake Bay total maximum daily load (TMDL). Local governments have raised significant concerns about being able to meet the pollutant reduction goals for total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS).

The James River Association is working with localities to develop feasible plans to meet their water quality goals. One area where economies of scale and efficiency can be achieved is to coordinate best management practices (BMPs) and strategies recommended in TMDLs that address local impairments with those needed to meet the Bay TMDL goals. To quantify areas of overlap and potential coordination, the Center for Watershed Protection (CWP) conducted a study for JRA to assess the extent to which local TMDL implementation plans can also address pollutant reductions required at the local level as part of the WIP.

Methods

For this study, CWP selected three local bacteria TMDLs in the James River Basin for which implementation plans had been developed. JRA was particularly interested in TMDLs for the cities of Lynchburg, Williamsburg and Richmond. Only one TMDL implementation plan was found for each of these three jurisdictions, and these were selected as the focus of this study (Table 1). The Williamsburg area TMDL watershed having an implementation plan (Mill Creek and Powhatan Creek) was primarily (99%) located in surrounding James City County; therefore, the county was used as the jurisdiction of focus for this analysis. The Mill Creek and Powhatan Creek plan contained significantly less detail than the other plans in terms of the specific recommendations for implementation. As a result, the analysis for James City County reflects only the recommendations for which specific details (e.g., number of rain barrels) were available.

Table 1. TMDL Implementation Plans Included In This Study

Locality	Plan	Pollutant	Year Developed	Implementation Timeframe
City of Richmond	Bacterial Implementation Plan for the James River and Tributaries-City of Richmond Technical Report	Bacteria	2011	25 years
City of Lynchburg	James River and Tributaries TMDL Implementation Plan	Bacteria	2010	20 years
James City County	Implementation Plan for Fecal Coliform TMDL for Mill Creek and Powhatan Creek	Bacteria	2011	15 years

For each TMDL, a spreadsheet was developed to estimate the nutrient and sediment reductions associated with implementation of the strategies in the local implementation plans so that these results could be compared to the required local nutrient and sediment reductions to meet the Chesapeake Bay TMDL. The methods used for this analysis are as follows:

1. Each implementation plan was reviewed and the BMPs recommended in each document were compiled in a spreadsheet. All BMP types listed in the plan were included, with the exception of agricultural practices (listed in the Richmond and Lynchburg area plans) since there is no agricultural land within these localities, and combined sewer overflow (CSO) practices because the Chesapeake Bay TMDL process will be implemented through the National Pollutant Discharge Elimination System (NPDES) Program municipal separate storm sewer system (MS4) permits, which do not include CSOs.

2. Using GIS, TMDL subwatersheds were clipped to the jurisdiction boundaries in order to determine the percent of each subwatershed located within the jurisdiction. This percentage was applied to the number of BMPs recommended for each subwatershed to come up with an estimated number of urban BMPs that would be implemented within the jurisdictional boundaries.

3. Nutrient and sediment removal performance data were added to the spreadsheet for the BMPs included in the implementation plans. The Chesapeake Bay Program (CBP)'s Watershed Model was a major source of these data (CBP, 2011). Recently released expert review panel reports on urban stream restoration and stormwater retrofits were also used in this study. For BMPs not approved by the CBP (e.g., septic repairs, rain barrels, pet waste programs), some limited research was conducted to derive pollutant removal estimates (see Appendix A for assumptions).

4. Land use loading rates and septic system loads for each municipality were derived from the Virginia Assessment and Scenario Tool (VAST) and added to the spreadsheet. These values were used in conjunction with the pollutant removal performance data to calculate annual pollutant reductions associated with BMP implementation.

5. The total nutrient and sediment load reduction associated with full implementation of the BMPs recommended in the local plans was calculated. A second calculation was made to determine the pollutant reduction for which credit can currently be received from the CBP, based on its approved list of BMPs and established pollutant removal efficiencies.

6. The resulting load reductions were compared to the target load reductions for each municipality to meet the Chesapeake Bay TMDL The load reductions established for the urban sector in the WIP will be enforced through the MS4 permits; however, final numbers are not yet available. For this study, we estimated the required reductions for each municipality using calculation tables provided in the General Permit for Discharges of Stormwater from Small Municipal Separate Storm Sewer Systems (4VAC50-60-1240), which calculate the target nutrient and sediment reductions for each MS4 permit cycle, based on inputs of regulated impervious and pervious lands. Most municipalities are still in the process of calculating these acreages so the targets used in this report are

likely to change. Regulated impervious and pervious acres for Lynchburg were taken from VAST. For Richmond and James City County, preliminary estimates were provided by municipal staff.

Table 2 presents the BMPs included in this analysis with a description of the pollutant removal crediting method and associated efficiency, if relevant. Appendix A describes the assumptions and adjustments made to develop nutrient and sediment reduction estimates for BMPs not currently credited by the CBP. The gray shading in Table 2 indicates BMPs that the CBP recognizes as providing quantifiable nutrient and/or sediment reduction.

Table 2. BMPs and Pollutant Removal Efficiencies Used In This Study

BMP	How Credited	TN Reduction (%)	TP Reduction (%)	TSS Reduction (%)	Source
Forest buffers	Land use change + efficiency (treats adjacent acreage)	25	50	50	CBP (2011)
Pet waste programs	Load reduction	N/A	N/A	N/A	See Appendix A for assumptions
Pet waste stations	Load reduction	N/A	N/A	N/A	
Pet waste education	Load reduction	N/A	N/A	N/A	
Pet waste composters	No credit given*	N/A	N/A	N/A	
Septic pumpouts	Efficiency	5	N/A	N/A	CBP (2011)
Connection to sewer	Systems change	N/A	N/A	N/A	CBP (2011)
Septic repair	Load reduction	N/A	N/A	N/A	See Appendix A for assumptions
Septic installation/ replacement	Load reduction	N/A	N/A	N/A	
Alternative wastewater treatment system	Load reduction	50	N/A	N/A	CBP (2011)
Wet ponds and wetlands	Efficiency	20	45	60	CBP (2011)
Infiltration trench (w/ sand, veg.)	Efficiency	85	85	95	CBP (2011)
Permeable pavement (w/o sand, veg., A/B soils, no underdrain)	Efficiency	75	80	85	CBP (2011)
Bioretention (C/D soils, underdrain)	Efficiency	25	45	55	CBP (2011)
Rain gardens (A/B soils, no underdrain)	Efficiency	80	85	90	CBP (2011)
Rainwater harvesting-cisterns	Efficiency	12	12	12	See Appendix A for assumptions
Rainwater harvesting – rain barrels	Efficiency	6	6	6	

Table 2. BMPs and Pollutant Removal Efficiencies Used In This Study					
BMP	**How Credited**	**TN Reduction (%)**	**TP Reduction (%)**	**TSS Reduction (%)**	**Source**
Vegetated roofs	Efficiency	60	60	60	VADCR (2011)
Wet pond retrofits	Efficiency	14	22	27	Schueler and Lane (2012)
Stream restoration- original efficiencies	Load reduction/length	0.02 lbs/ft	0.003 lbs/ft	2 lbs/ft	CBP (2011)
Stream restoration- recommended interim efficiencies	Load reduction/length	0.2 lbs/ft	0.068 lbs/ft	54.5 lbs/ft	Schueler and Stack (2013)
Wetland restoration	Efficiency	20	45	60	CBP (2011)

*No data were found on the effectiveness of pet waste composters to reduce nutrients. The resulting compost is intended to be applied as fertilizer to lawns and gardens; therefore, it was conservatively estimated that this practice has no quantifiable nutrient reduction benefits.

Results

City of Richmond Pollutant Reductions

The bacteria TMDL for the James River and tributaries in the City of Richmond contained a mix of stormwater BMPs, septic system improvements, and pet waste programs to achieve the required reductions. Table 3 presents the recommended units treated by each BMP (apportioned to the City portion of the watershed) and the associated nutrient and sediment load reductions. Gray shaded BMPs in Table 2 are approved by the CBP.

Table 3. Estimated Nutrient and Sediment Reductions Resulting from Implementation of Recommendations for meeting the Bacteria TMDL for the City of Richmond Portion of the James River and Tributaries				
BMP	**Units Treated Under Local TMDL**	**TN Reduction (lbs/yr)**	**TP Reduction (lbs/yr)**	**TSS Reduction (lbs/yr)**
Pet waste stations	1,095,000 bags	29,122	3,799	0
Pet waste education	632389 mailings	326	43	0
Pet waste composters	186 systems	0	0	0
Septic pumpouts	64 systems	24	0	0
Connection to sewer	15 systems	111	0	0
Septic repair	18 systems	37	43	1,708
Septic installation/ replacement	40 systems	83	95	3,795
Alternative wastewater treatment system	9 systems	33	0	0

Table 3. Estimated Nutrient and Sediment Reductions Resulting from Implementation of Recommendations for meeting the Bacteria TMDL for the City of Richmond Portion of the James River and Tributaries				
BMP	**Units Treated Under Local TMDL**	**TN Reduction (lbs/yr)**	**TP Reduction (lbs/yr)**	**TSS Reduction (lbs/yr)**
Wet ponds and wetlands	248.49 impervious acres, 883.96 pervious acres	1,889	489	263,191
Infiltration trench (w/ sand, veg.)	248.49 impervious acres, 1,368.26 pervious	10968	1,165	501,139
Permeable pavement (w/o sand, veg., A/B soils, no underdrain)	22.03 impervious acres	208	40	20,833
Bioretention (C/D soils, underdrain)	250.47 impervious acres, 1,368.26 pervious acres	3,232	619	291,345
Rain gardens (A/B soils, no underdrain)	248.49 impervious acres, 883.96 pervious acres	7,557	924	394,786
Rainwater harvesting- cisterns	5 impervious acres	8	1	667
Rainwater harvesting – rain barrels	89.88 impervious acres	68	12	6,000
Vegetated roofs	2.83 impervious acres	21	4	1,891
TOTAL		**84,718**	**15,696**	**3,191,982**

City of Lynchburg Pollutant Reductions

The bacteria TMDL for the James River and tributaries in the City of Lynchburg included pet waste programs, septic system improvements and stormwater BMPs to achieve the required reductions. Table 4 presents the recommended units treated by each BMP (apportioned to the City portion of the watershed) and the associated nutrient and sediment load reductions. Gray shaded BMPs in Table 2 are approved by the CBP.

Table 4. Estimated Nutrient and Sediment Reductions Resulting from Implementation of Recommendations for meeting the Bacteria TMDL for the City of Lynchburg Portion of the James River and Tributaries				
BMP	**Units Treated Under Local TMDL**	**TN Reduction (lbs/yr)**	**TP Reduction (lbs/yr)**	**TSS Reduction (lbs/yr)**
Forest buffers	5.88 pervious acres	51	7	1,550
Pet waste programs	1 program	10,897	1,421	0
Pet waste composters	784 composters	0	0	0
Septic pumpouts	3,106 systems	1,179	0	0
Connection to sewer	27 systems	205	0	0
Septic repair	137 systems	292	333	13,314
Septic installation/ replacement	85 systems	181	207	8,261
Alternative wastewater treatment system	332 systems	1,260	0	0
Bioretention (C/D soils, underdrain)	171.5 impervious acres	196	37	10,793
Rain gardens (A/B soils, no underdrain)	49 impervious acres	182	21	5,525
TOTAL		**14,442**	**2,027**	**39,443**

James City County Pollutant Reduction

The bacteria TMDL for Mill Creek and Powhatan Creek in James City County included a variety of recommendations for sanitary sewer system improvements, septic system programs, and stormwater quality programs. In this case, the TMDL implementation plan was intended to prioritize management actions and extensive monitoring is being conducted to help refine the specific recommendations. As a result of this adaptive management approach, the plan did not provide enough detail to quantify pollutant reductions for all the recommended actions. Therefore, the estimated load reductions for the County are conservative as they do not reflect the full suite of recommendations contained in the local TMDL implementation plan. It is expected that additional nutrient and sediment reductions can be achieved as more specific projects are identified and implemented to meet the local bacteria TMDL.

Table 5 presents the BMPs for which sufficient detail was available (apportioned to the County portion of the watershed) and the associated nutrient and sediment load reductions. The CBP's original and recommended interim removal efficiencies for urban stream restoration were both used in this study for comparison purposes. Gray shaded BMPs in Table 2 are currently approved by the CBP.

Table 5. Estimated Nutrient and Sediment Reductions Resulting from Implementation of Recommendations for meeting the Bacteria TMDL for the James City County portion of the Mill Creek and Powhatan Creek Watersheds				
BMP	**Units Treated Under Local TMDL**	**TN Reduction (lbs/yr)**	**TP Reduction (lbs/yr)**	**TSS Reduction (lbs/yr)**
Pet waste stations	674,109 bags	29,880	8,858	0
Rainwater harvesting – rain barrels	9.41 impervious acres	4	1	230
Wet pond retrofits	682.92 impervious acres, 682.92 pervious acres	1,551	326	85,127
Stream restoration- original efficiencies	9,756 linear feet	195	29	19,512
Stream restoration-recommended interim efficiencies		1,951	663	531,702
Wetland restoration	60.98 impervious acres, 60.98 pervious acres	198	60	16,890
Septic pumpouts	117 systems	47	0	0
Connection to sewer	1 system	8	0	0
Septic installation/ replacement	12 systems	101	49	1,969
TOTAL*		**33,740**	**9,957**	**635,918**

* total does not include reductions from stream restoration with original efficiencies so as not to double count this practice.

Comparison to Required Reductions

The results of this analysis were intended to be compared to the nutrient and sediment load reductions required of James River Basin localities as part of Virginia's Phase II WIP. The State has since decided to allocate pollutant load reduction on a basin scale rather than the jurisdiction scale. Therefore, calculations provided in the General Permit for Discharges of Stormwater from Small Municipal Separate Storm Sewer Systems (4VAC50-60-1240) were used to estimate the necessary pollutant of concern load reductions for each of the three municipalities to meet the Chesapeake Bay TMDL. The calculations require regulated impervious and pervious acreage as inputs. For James City County (Middaugh, 2012) and Richmond these estimates were provided by City staff and for Lynchburg were taken from VAST. The resulting load reduction estimate will ultimately be refined as the localities develop more accurate acreage calculations for their MS4 areas; however, these were determined to be the best available estimates at this time.

Table 6 compares the target load reductions with the estimated reductions associated with implementation of 1) all BMPs in the local TMDL and 2) only the BMPs and efficiencies that are approved by the CBP. The percent of the required reductions achieved through both scenarios is shown in parentheses in Table 6.

Table 6. Portion of Bay TMDL Pollutant Load Reduction Targets Met through Implementation of Local TMDLs in City of Richmond, City of Lynchburg and James City County, VA				
Pollutant Load Estimates (lbs/yr)		**City of Richmond**	**City of Lynchburg**	**James City County**
Target Load Reduction by 2025	TN	15,055	6,385	6,277
	TP	2,655	1,123	1,117
	TSS	1,080,608	456,790	456,391
Total Reduction for all BMPs (% of target)	TN	84,718 **(563%)**	14,442 **(226%)**	33,740 **(538%)**
	TP	15,696 **(591%)**	2,027 **(180%)**	9,957 **(891%)**
	TSS	3,191,982 **(295%)**	39,443 **(9%)**	635,918 **(139%)**
Total Reduction for CBP-Approved BMPs (% of target)	TN	24,023 **(160%)**	3,073 **(48%)**	3,755 **(60%)**
	TP	3,237 **(122%)**	66 **(6%)**	1,049 **(94%)**
	TSS	1,471,292 **(136%)**	17,868 **(4%)**	633,719 **(139%)**

Discussion

When accounting solely for the practices currently accepted by the CBP, all of the City of Richmond's Bay TMDL targets are estimated to be fully met through implementation of the local bacteria TMDLs, as is James City County's sediment target. Progress towards TMDL targets is much lower in the City of Lynchburg, and this is likely the result of the relatively low number of BMPs implemented in the City to meet the local TMDL, as the TMDL watershed is much broader than the City limits. However, if the estimated reductions from all practices are considered, the localities are able to meet all their targets, with the exception of sediment in the City of Lynchburg. Additional reductions can be estimated for James City County once more specific projects have been identified as part of the local TMDL implementation.

In general, expected progress towards achieving Bay TMDL load reductions is lower for sediment compared to nutrients, because the BMPs in the local TMDLs are designed to address bacteria, and these same practices are not typically good at removing sediment. In Lynchburg, meeting phosphorus goals with the local TMDL is also challenge because the suite of BMPs primarily includes septic practices, with limited implementation of stormwater BMPs that are effective at phosphorus removal. It is expected that implementation of local TMDLs for nutrients and sediment will result in much greater progress towards Bay TMDL goals (compared to implementation of local bacteria TMDLs).

The results indicate that it is to the localities' benefit to encourage the state and CBP to review certain BMPs for inclusion in the Bay Model as well as to conduct local monitoring studies to quantify the resulting pollutant load reductions. For example, although the estimates are based on limited data and assumptions, installation of pet waste stations appears to result in significant reductions in nutrients. On the other hand rooftop management practices (cisterns, rain barrels, vegetated roofs) do not appear to be as effective for pollutant removal per impervious acre treated compared to other structural practices. In the case of stream restoration, the estimated reductions are 10, 22, and 27 times greater (for TN, TP and TSS, respectively) using the proposed interim efficiencies compared to the original approved CBP values. In addition, septic system repair and replacement have potential to provide moderate reductions of phosphorus and sediment, although the current CBP crediting procedures for septic system BMPs do not recognize these benefits because the models assume that all septic systems are functioning properly. Expert review panels for septic system BMPs will convene over the next year or two to discuss these and other issues.

Overall, this study shows that the James River Watershed localities can make significant progress towards Bay TMDL goals through implementation of local TMDL plans, although to what extent depends somewhat on the local pollutants of concern, as well as which BMPs and pollutant removal performance values are accepted by the CBP. Because this study focused on local bacteria TMDLs, the results provide a good snapshot of potential nutrient reductions associated with implementation of bacteria reduction strategies and identify BMPs that can reduce both bacteria and nutrients. This information may be of particular interest to communities in the Lower James where, of the 52 TMDLs that have been developed to date, 38 are for bacteria (EPA's Watershed Assessment, Tracking and Environmental ResultS database). In the Upper James, where seven TMDLs have been developed for TN and TP, it will likely be more feasible to align local TMDL implementation plans directly with Chesapeake Bay WIP goals.

Recommendations

- Integrated TMDL implementation planning to address all local and regional impairments would allow localities to select the most cost-effective mix of BMPs to achieve all their water quality targets. The District of Columbia is currently developing such a consolidated plan for their local TMDLs, as required by their MS4 permit. The process and resulting plan may serve as a model for other communities to use.
- To assist in developing integrated TMDL implementation planning, localities require comparative data on how effective the available BMPs are at reducing each pollutant of concern. This is currently a data gap, especially for pollutants such as bacteria and for emerging BMPs.
- One gap that may impede the integration of TMDL plans is the lack of detail provided in existing TMDL implementation plans. For example, in the current study, it was assumed that 100% of the required bacteria load reductions would be met through full implementation of the local implementation plans; however, a specific breakdown by each practice was not provided. It would be helpful if states and others developing TMDL implementation plans would provide details on what portion of the load will be reduced by each recommended practice.
- Localities may wish to explore the use of emerging BMPs as well as BMPs for which water quality benefits have not yet been quantified, and encourage the state and CBP to review them for inclusion in the Bay Model. For example, the preliminary analysis in this study shows that pet waste programs can be very cost-effective for pollutant reduction; yet there is little research available to support a credit at this time. Localities can also get involved in conducting local monitoring studies for emerging BMPs to quantify the resulting pollutant load reductions.

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Appendix A: Development of Pollutant Reduction Estimates

Rainwater Harvesting

Efficiencies for rain barrels (50 gallons) and cisterns (500 gallons) were assumed to be equivalent to the runoff reduction achieved. Runoff reduction values were derived using the Rainwater Harvesting Spreadsheet, available from the Virginia Stormwater BMP Clearinghouse (http://vwrrc.vt.edu/swc/NonProprietaryBMPs.html). The following assumptions were made to model runoff reduction values:

1. Each cistern captures runoff from 5,000 square feet of rooftop, and each rain barrel captures runoff from 1,000 square feet of rooftop.
2. For rain barrels and cisterns, it is assumed that usage for irrigation consists of 100 and 1,000 gallons per week, respectively. This irrigation is required for six months of the year, between March 21 and September 23.
3. There is no indoor demand
4. Rainfall data from the Richmond International Airport were used to run the scenarios.

Using these assumptions, rain barrels achieved an effective runoff reduction and pollutant removal of 6%, and cisterns achieved 12%.

Vegetated Roofs

Nutrient removal efficiencies for vegetated roofs were derived from the Virginia Department of Conservation and Recreation's Stormwater Design Specification for Level 2 Vegetated Roofs (VADCR, 2011) and the sediment removal efficiencies were assumed to also be the same as the runoff reduction percent for this practice, as described in VADCR (2011).

Structural Stormwater BMPs

For some structural stormwater BMPs, the CBP provides pollutant removal efficiencies based on soil type and the design of the practice. Because the implementation plans provided varying levels of detail about practice design, assumptions were made to determine which efficiencies to use for the recommended BMPs. The bioretention facilities recommended for Lynchburg and Richmond were assumed to have C/D soils and an underdrain, while the rain gardens were assumed not to have an underdrain (equivalent to having A/B soils). In Richmond, the recommended infiltration trenches were assumed to have the pollutant removal capacity of an infiltration practice with sand and vegetation as defined by the CBP, and the recommended Level 2 permeable pavement was assumed to have the pollutant removal capability of permeable pavement with the following characteristics: no sand, A/B soils and no underdrain (as defined by CBP). Where no information was provided about the drainage area characteristics, it was assumed that bioretention and rain gardens treated 50% impervious cover and 50% pervious cover.

Septic Systems

Efficiencies for septic system related BMPs were applied to the annual per-system load for septic systems, which were derived from VAST for each jurisdiction. According to CBP (2011), septic pumpouts achieve a 5% reduction in nitrogen and alternative wastewater treatment systems reduce 50% of the nitrogen load. The CBP models connection to sewer as a systems change, which reduces the load from (properly functioning) septic systems by removing the load associated with those systems and sending it to the WWTP.

Septic pumpouts were annualized based the time period of implementation and the assumption that each pumpout lasts 5 years. Therefore, the number of pumpouts was divided by 4 for Lynchburg (with a 20 year timeframe), 3 for James City County (with a 15 year timeframe), and by 5 for Richmond (with a 25 year timeframe).

Septic repairs and septic replacement were assumed to correct failing systems such that water quality benefits are calculated as the pollutant load delivered to surface waters from failing systems minus the pollutant load delivered to surface waters from functioning (conventional) systems. The following formula was used to estimate the pollutant load from failing systems:

*[[Wastewater generation (gallons per capita per day) * individuals per dwelling unit * 365 days/yr * 3.785 liters per gallon * pollutant concentration in wastewater (mg/L)] / 453,592 mg/lb] * delivery ratio*

The value for wastewater generation was taken from Salvato (1982), which is consistent with data cited in CBP (2010). The concentrations of TSS and TP in wastewater were derived from Metcalf and Eddy (1991). The lower end of the range for phosphorus was used to account for programs to reduce phosphorus in wastewater. The TN concentration in wastewater was derived from Burks and Minnis (1994).

The number of individuals per dwelling unit was derived using methods consistent with the Chesapeake Bay Program's Watershed Model assumptions. In particular, the number of individuals was "back calculated" using the edge-of-stream septic system loads provided in VAST, groundwater delivery ratios used in the Bay Model, and edge-of-field septic load of 4.0 kg N/person-year (Metcalf and Eddy, 1979, as referenced in the CBP, 2010). The resulting number of individuals per system is equal to the following:

Edge of Stream Loading per System (lb/year)/[(4.0 kg N/person-year)(.454 lb/kg)*0.4(groundwater delivery ratio)]*

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A delivery ratio of 50% was taken from Caraco (2001) for delivery of nutrients from failing septic systems to surface waters not located within 100' of a shoreline.

The methodology used in this report to document repair or replacement is consistent with CBP methodology where possible, with one major difference. While the CBP Watershed Model estimates the load from *functioning* systems, this methodology assumes that some systems are failing, and consequently flow to the surface without treatment. These modifications were made because there is no way to account for loads from failing systems using Bay Program assumptions alone.

Pet Waste Programs

Pollutant reductions resulting from educational programs, such as pet waste programs, are not readily available and are difficult to measure. Therefore, a number of assumptions were used to develop an initial estimate of performance for pet waste programs. This estimate should be treated with caution.

The two major components of a pet waste program for which specific pollutant reductions were calculated included installation of pet waste stations complete with signs, basket and bags for picking up pet waste in parks and public places, and an educational component where mailings are used to inform residents of the pet waste pickup law and encourage/teach them how to properly dispose of pet waste. In order to determine the pollutant reduction associated with these activities, we identified a number of pet waste stations installed, number of residents targeted through the educational program, and the number of bag refills needed per year. These units were taken from the *Bacterial Implementation Plan for the James River and Tributaries- City of Richmond* (Maptech, 2011) for the City of Richmond and modified for the City of Lynchburg and James City County based on population.

For pollutant reduction associated with pet waste stations, it was assumed that a certain nutrient load was captured and properly disposed of on an annual basis in pet waste bags located in public places such as parks. The following formula was used:

*# of bags * waste production (lbs/dog/day) * concentration of pollutant in dog waste (lb/lb) * fraction of daily waste captured per bag * fraction of pollutant delivered to stream * fraction of bags used to properly dispose of pet waste * 365 days/yr * fraction of dog walkers who rarely clean up after their dogs*

We assumed that only some portion of bags taken from the pet waste stations would actually be used to properly dispose of pet waste, while some (25%) were either not used or were not properly disposed of. We also assumed that each bag would be taken by a dog owner and would capture approximately 1/3 of their dog's daily waste. Finally, we assumed that some portion of the bag users would have brought their own bag and properly disposed of the waste anyway, so the pollutant load reduction estimate was discounted based on data from Swann (1999) regarding the proportion of dog owners who typically do not clean up after their dogs. The resulting value is considered to be somewhat conservative.

For the educational component of the pet waste program, we first estimated the maximum potential annual nutrient load reduction using the following formula, assuming that all dog owners targeted by the outreach change their pet waste disposal behavior:

*# households reached * waste production (lbs/dog/day) * concentration of pollutant in dog waste (lb/lb) * fraction of households with a dog * fraction of pollutant delivered to stream * 365 days/yr*

Then, we discounted the maximum potential nutrient load reduction to account for the fact that not all households targeted by the outreach actually walk their dog, some already properly dispose of pet waste, some will never look at the flyer and others will be unwilling to change their behavior. We used the following formula:

*Potential pollutant load reduction per year (if everyone that has a dog changes behavior) * of households with dogs, fraction who walk them (0.50) * of dog walkers, fraction that rarely clean up after their dog (0.40) * of those, fraction who are willing to change behavior (0.60)* awareness factor (0.08)*

It was assumed that the annual benefits from one pet waste mailing lasted 5 years. Therefore, the total number of mailings was divided by 5 for Richmond (with a 25 year timeframe).

The above values were taken from a variety of sources as described below. Note that none of the studies below attempted to evaluate the effectiveness of pet waste programs. Given the lack of research that directly addresses this topic, we used the information available and best professional judgment to make conservative assumptions that can be updated with more recent/accurate studies as they become available.

- % of households with dogs (Swann, 1999; American Pet Product Manufacturing Association, 1998)
- % of dog owners who walk their dogs (Swann, 1999)
- % who rarely clean up after their dog (Swann, 1999)
- % who are willing to change behavior (Swann, 1999)
- Daily waste production (Godfrey, 1992)
- N concentration in dog poop (Schueler, 1999)
- P concentration in dog poop (Schueler, 1999 using assumptions: 80% digestibility, mid-size dog)
- Delivery factors for N and P (Caraco, 2001)
- Awareness factor for mailings (Pellegrin Research Group, 1998; NSR, 1998)
- % of bag takers who use the bags to properly dispose of pet waste (best professional judgment)
- % of daily waste captured in one bag (best professional judgment)

No data were found on the effectiveness of pet waste composters to reduce nutrients. The resulting compost is intended to be applied as fertilizer to lawns and gardens; therefore, it was conservatively estimated that this practice has no quantifiable nutrient reduction benefits.

Wet Pond Retrofits

Pollutant removal effectiveness of stormwater retrofits was determined based on recommendations by a CBP review panel. The final draft report (Schueler and Lane, 2012) was approved by the Water Quality Goal Implementation Team on October 9, 2012. The panel classified retrofits into two broad project categories -- new retrofit facilities and retrofits of existing BMPs. These two categories encompass a broad range of potential retrofit application, including new constructed wetlands, green streets or rain gardens, as well as conversion, enhancement or restoration of older BMPs to boost their performance. Given the diversity of possible retrofit applications, the panel decided that assigning a single universal removal rate was not practical or scientifically defensible. Every retrofit is unique, depending on the drainage area it treats, the treatment mechanism employed, its volume or size and the antecedent degree of stormwater treatment, if any. Instead, the panel elected to develop a protocol whereby the removal rate for each individual retrofit project is determined based on the amount of runoff it treats and the degree of runoff reduction it provides.

The panel conducted an extensive review of recent BMP performance research and developed a series of retrofit removal adjustor curves to define sediment, nitrogen and phosphorus removal rates. Removal rates for new retrofits are derived from the adjuster curves based on the runoff depth captured by the practice and whether the BMP is defined as a "runoff reduction" or "stormwater treatment" practice. Removal rates for retrofits that involve conversion of an existing BMP to another BMP type can be done in one of two ways. For older BMPs that provide no water quality treatment, the removal rate for the converted practice is derived from the CBP modeling efficiencies associated with that practice (CBP, 2011), or from the retrofit removal adjustor curves if the conversion involves multiple treatment mechanisms. The second method defines the removal rate for BMP conversions as the incremental difference between the removal rate for the converted BMP and the removal rate for the original BMP, which are derived using the retrofit removal adjustor curves.

Wet pond retrofits described in the Mill Creek and Powhatan Creek TMDL implementation plan include design modifications such as: increasing light conditions in the water column, providing a minimum 48 hour detention time for stormwater, designing inlet and outlet structures to prevent re-suspension of bacteria-laden bottom sediments, reducing turf and open areas around ponds to discourage geese and waterfowl populations, and adding shallow benches and wetland areas to enhance the plankton community and increase bacterial predation. Under the guidance provided by Schueler and Lane (2012), we classified this as an "enhancement" retrofit and in the absence of site specific information, made the following assumptions based on a "typical" facility to estimate nutrient and sediment reduction.

- Each pond has a drainage area that is 50% impervious with 50% pervious cover
- Each facility was originally designed to older standards that only required that the "first flush" of stormwater runoff be treated and the ponds were sized to capture only 0.3 inches of runoff per impervious acre.
- Collectively, the design enhancements created an additional 0.3 inches of new runoff treatment volume per impervious acre, for a total runoff of 0.6 inches.

According to Schueler and Lane (2012), for BMP enhancement retrofits, the removal rate is defined as the incremental difference between the new removal rate and the original removal rate, as follows:

Rate	Efficiency (%)		
	TN	TP	TSS
Original	14	22	28
Enhanced	28	44	55
Incremental	14	22	27

Wetland Restoration

Wetland restoration described in the Mill Creek and Powhatan Creek TMDL implementation plan re-establishes 1-5 acres of degraded forested bottomland wetlands to improve filtering. The restoration would take place in the most degraded portions of the watersheds on land that has been inundated with sediment or eroded by increased stream lows and will complement the stream restoration program. The CBP provides credits for wetland restoration on agricultural land and for creation of stormwater wetlands, and based on the information provided, it was determined that the planned restoration would function more like a stormwater wetland. Therefore the CBP credits for stormwater wetlands were used. Since only the acres of wetlands to be restored were provided, we assumed that the wetland surface area was 4% of the total drainage area to the wetland and that 50% of the drainage area was impervious and 50% was pervious. The 4% assumption is the same one used by King and Hagan (2011) in their BMP cost study. The method for crediting in-stream and floodplain nutrient processing during baseflow developed by the urban stream restoration expert review panel (Schueler and Stack, 2013) may be more applicable to estimate reductions from this practice, and can be applied once more detailed information about the proposed restoration sites is available.