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URBAN STORMWATER POLLUTION IN VIRGINIA

ADAM PREVOST

FRANK BATTEN SCHOOL OF LEADERSHIP AND PUBLIC POLICY

On my honor as a student, I have neither given nor received unauthorized aid on this assignment.

Disclaimer: The author conducted this study as part of the program of professional education at the Frank Batten School of Leadership and Public Policy at the University of Virginia. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments, analysis and conclusions are solely those of the author, and are not necessarily endorsed by the Batten School, the University of Virginia, the Center on Budget and Policy Priorities, or by any other agency.

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VML
Virginia Municipal League

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ACRONYMS AND ABBREVIATIONS

BMP	Best Management Practices
CBF	Chesapeake Bay Foundation
CAST	Chesapeake Assessment Scenario Tool
CBP	Chesapeake Bay Program
DO	Dissolved Oxygen
DCR	Department of Conservation and Recreation
DEQ	Department of Environmental Quality
EDU	Equivalent Residential Unit
EPA	Environmental Protection Agency
HAB	Harmful Algal Blooms
ID	Intensity of Development
NMP	Nutrient Management Plans
NRCS	Natural Resources Conservation Services
NRDC	Natural Resources Defense Council
OMB	Office of Management and Budget
LID	Low Impact Development
SAV	Submerged Aquatic Vegetation
SLAF	Stormwater Local Assistance Fund
SWCD	Soil and Water Conservation Districts
TMDL	Total Maximum Daily Load
WIP	Watershed Implementation Plan
WQIF	Water Quality Improvement Fund

EXECUTIVE SUMMARY

Every year, millions of pounds of nutrient pollution from Virginia's urban stormwater is deposited into the Chesapeake Bay. Since 2009, Virginia has spent millions of dollars on cleanup costs and implementing best management practices on the state's urban areas. Despite best efforts, Virginia's urban stormwater pollution has continued to increase between 2009 and 2017. I analyze previous policy interventions to curb nutrient pollution in the Chesapeake Bay and find that Virginia lacks sustainable financing sources for stormwater management. I also conduct a cost-effective analysis on different stormwater best management practices over a 20 year period. The results of these analyses, leads me to believe that policymakers should target stormwater financing on urban nutrient management planning on all non-federal lands within Virginia's Chesapeake Bay Watershed.

PROBLEM STATEMENT

The annual amount of nutrient pollution put into the Chesapeake Bay from Virginia's urban stormwater sector is too high. Unabsorbed rainfall and snowmelt carries nutrients off of the land and eventually deposits these nutrients into local waterways flowing towards the Chesapeake Bay. Nutrient pollution encourages harmful algal growth, which in turn creates low-oxygen "dead zones" and blocks out available sunlight from reaching the Bay's submerged aquatic vegetation. While there has been moderate success in restoring the Bay's water quality in recent years — in large part due to pollution reductions from Virginia's wastewater and agriculture sectors — the total amount of nutrient pollution coming from Virginia's urban stormwater sector has continued to grow over the past 30 years. In the United States, urban stormwater is considered by the US Environmental Protection Agency (EPA) to be the second leading cause of estuary pollution behind only agriculture (U.S. EPA, 1996).

Although there is no way to measure exact quantities, models created by the Chesapeake Bay Program (CBP), the comprehensive governmental partnership responsible for watershed restoration, estimates that the amount of nitrogen pollution emitted from Virginia's urban stormwater sector increased from 10.12 million pounds in 2009 to 11.2 million pounds in 2017 (CBP, 2017). As shown in Figure 1, in order to meet federal cleanup targets by 2025 set by the EPA, the Commonwealth will need to reduce 2.41 million pounds of nitrogen from stormwater pollution. This equates to a 21 percent reduction in nitrogen in the next eight years over 2017 pollution levels.

Figure 1. Virginia's Nitrogen Loads to the Bay, 2009, 2017, and 2025

	Nitrogen				
	Load[1]			Reduction (%)	
	Actual 2009	Actual 2017	Projected 20252	2009 - 2017	2017 to 2025
All Other Sectors[3]	58.01	46.13	43.8	20%	5%
Stormwater	10.12	11.2	8.79	-11%	21%
Total	**68.13**	**57.33**	**52.59**		

1. All loads are annual, in millions of pounds
2. Final Figures are itemized in the EPA Final Chesapeake Bay TMDL Plan
3. All Other Sectors represents nutrient loads from Agriculture, Agriculture-Regulated, Forest, Onsite, Non-Tidal Water Deposition, Wastewater and Wastewater-CSO

Note: Data on Nitrogen Loads was retrieved from the Chesapeake TMDL Tracker. Loads simulated using 5.3.2 version of Watershed Model and wastewater discharge data reported by Bay jurisdictions. Progress data updated 6/15/2017.

JUSTIFICATION FOR INTERVENTION

Urban stormwater is transient by nature with the ability to move large quantities of nutrient pollution hundreds of miles from its original source. This creates a significant environmental externality not reflected in the market that spills costs onto Virginian's downstream, and ultimately onto those that rely on the economic value of the Chesapeake Bay.

COST TO SOCIETY

Nitrogen pollution indirectly contributes to ecological consequences such as harmful algal blooms (HABs) and low rates of dissolved oxygen (DO). The primary costs from nitrogen pollution in the Bay is lost economic value. This includes lost revenues from the Bay's seafood and commercial fishing industry, tourism and recreation industry, and costs to human health in the form of emergency room visits from respiratory illness. Additionally, residential waterfront property values can been used as an indicator of economic loss. The following values are used to contextualize the contraction in the Bay economy associated with *not* controlling nutrient pollution and provide relative estimates in order of magnitude. All monetary estimates have been adjusted for inflation and are represented in 2018 dollars.

Seafood and Commercial Fishing

- A reduction in dissolved oxygen levels to below 4 mg/L associated with HABs on Maryland's Patuxent River led to a 49 percent reduction in blue crab harvests and caused $327,805 in annual damages (Mistiaen, Strand, & Lipton, 2003).
- Nitrogen pollution contributes to the loss of submerged aquatic vegetation (SAVs) throughout the Chesapeake Bay. SAV species such as eel grass (*Zostera marina*) and widgeon grass (*Ruppia maritima*) serve as habitat for juvenile fish and blue crab. Approximations suggest that an 80 percent reduction in Bay SAVs resulted in $26.4 million in annual damages to commercial striped bass fishing that rely on underwater grasses for habitat (Kahn and Kemp,1985).
- A 1997 bloom of algae known as *Pfiesteria spp.* in several Chesapeake Bay tributaries caused a contraction in the demand for seafood costing approximately $72 million in seafood sales to Maryland producers (Hoagland, Anderson, Kaoru, & White, 2002).
- Low oxygen "dead zones" can increase oyster mortality, weaken oyster immune systems and increase their susceptibility to disease (Chesapeake Bay Foundation, 2010). Nitrogen pollution plays a contributing role in the decline of industries related to oyster harvesting. Research from the National Oceanic Atmospheric Administration (2010) suggests that the cumulative annual losses to Virginia and Maryland was $4.6 billion between 1981and 2008 (National Oceanic Atmospheric Administration as cited in Chesapeake Bay Foundation, 2010).

Tourism-Related Industries and Recreation

Tourism-related industries and recreation are economic drivers that can also be negatively affected by nutrient pollution. The Bay provides a wide assortment of both recreational and aesthetic amenities. Tourism and recreation activities include fishing, boating, swimming, and nature viewing.

- The 1997 *Pfiesteria spp.* outbreak directly caused $3.42 million in lost revenues from a decline of 28,000 fishing trips. Factoring in other industries that support Maryland's recreational fishing industry the upper estimate on economic losses is $6.69 million dollars (Lipton, 1998).
- Research on the effects of dissolved oxygen on striped bass catch rates and recreational consumer surplus on the Patuxent River in Maryland estimate $11,600 in annual damages when DO is constrained to 3 mg/L (Lipton & Hicks, 2003).

Health Costs

A 2015 EPA report on nutrient control and pollution specifies that HABs can adversely affect human health through direct contact with the skin during recreation, consumption through drinking water, or consumption of contaminated shellfish. A temporal study on behalf of University of Maryland's Center for Environmental Science found that between 1991 to 2008 there was a yearly average of 19 bloom events and the median number of HAB events increased from approximately 13 per year in the 1990's to 23 in the 2000's (Li, Glibert, & Gao, 2015).

- Research from Florida found that the number of emergency room visits for respiratory illnesses resulting from algal blooms cost between $22,885 and $151,039 in human health impacts (Hoagland et al. 2009).

Property Values

Measuring changes in waterfront property values are an alternative method of determining the impacts of nutrient pollution on the value of the Bay. Typically, local housing markets are able to capitalize on the close proximity to natural and recreational amenities offered by the Chesapeake Bay and its tributaries. As of 2017, there is limited research on the effects of nutrient pollution has on Chesapeake Bay property values.

- Using over 225,000 property sales across 14 Maryland counties to estimate implicit household prices, researchers found that a 10 percent decrease in water clarity could lead to declines in waterfront property values between $2,576 and $26,497 depending on the county (Walsh, Griffiths, Guignet, & Klemick, 2017).
- Hedonic property model to measure ambient water clarity on household price value. Using annual water clarity data along the St. Mary's River in Maryland indicated that a one-unit change (mg/L) in the dissolved inorganic nitrogen corresponded to a $24,066 or 11.39 percent decrease in average housing prices (Poor, Pessagno, & Paul, 2007)

SCOPE OF THE CHESAPEAKE BAY

The Chesapeake Bay watershed covers an area of 64,000 square-miles stretching from upstate New York to southeast Virginia and includes over 50 major tributaries draining from five physiographic provinces (Jantz, Goetz, & Jantz, 2005). As of 2010, the population in the Bay watershed was 17.4 million and is expected to reach to 20.3 million by 2030 (United States Geological Survey, 1996) (Chesapeake Bay Program, 2015). *The scope of this paper will focus solely on the state of Virginia and hold all other state trends constant*.

According to the USDA Natural Resources Conservation Service (NRCS), Virginia has 15.3 million acres in the watershed boundary, making up approximately 37 percent of the watershed's total land area. In terms of population, nearly 75 percent of Virginia's population, 6.4 million people, live within the watershed boundary. By 2030, the state's population is expected to grow by an additional 1.08 million people; a majority of whom will live in the more urbanized areas including Northern Virginia and the Tidewater region (Weldon Cooper Center, 2017). Virginia's population growth coupled with increasing rates of urbanization places additional strain on the health of the Chesapeake Bay.

Urbanization and Land Use

Directly related to the environmental impacts of stormwater pollution is land use. One study on the effects of impervious surfaces (including hardtop pavement and sidewalks, among other surfaces) published by the Center for Watershed Protection (2003), indicated that significant declines in biological integrity and habitat quality are observable in watersheds with impervious cover ranging between 10 to 25 percent. Other findings from the Natural Resources Defense Council (NRDC) (2011), only 10 to 20 percent of rain that hits land in its natural state runs off, with the rest absorbed by soil and plants. Without soil and plants to capture rainwater, like when an area is heavily covered with hard surfaces, close to 100 percent of the rain that falls on concrete and other hard surface becomes runoff.

STORMWATER POLLUTION

Stormwater runoff is defined as rainfall and snowmelt that flows over land or impervious surfaces, such as paved streets, parking lots, and building rooftops, and does not soak into the ground (U.S. EPA, 2003). As rainfall falls on urban areas it picks up excess nutrient pollutants, animal feces, oil, chemicals, and sediment and pushes them into local waterways eventually flowing into the Chesapeake Bay. Stormwater can be classified either as point source and nonpoint source pollution. The discussion below will outline both types of stormwater, but the following analysis will predominately focus on Virginia's unregulated nonpoint source stormwater pollution.

Regulated Stormwater (Point Source Pollution)

At the federal level, point source pollution is legally defined under Section 502 (14) of the Clean Water Act (CWA) (1972)

> The term "point source" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture (33 USCS § 1362 (14).

Stormwater is classified as point source when it is regulated through the EPA's National Pollution Discharge Elimination System (NPDES). The NPDES is the Clean Water Act's primary program for eliminating point source pollution. Stormwater permits are required for medium and large municipal separate storm sewer system (MS4s) in incorporated areas and counties with populations of more than 100,000, certain industrial activities, and construction activities disturbing five acres or more (U.S. EPA, 1999). NPDES permits are also required for small MS4s in "urbanized areas" and small construction activities disturbing between one and five acres of land.

According to the Virginia Department of Environmental Quality (DEQ), there are 117 MS4 permits in the state of Virginia (Virginia DEQ, Municipal Separate Storm Sewer System Listing, 2016). By 2017, the discharge from these regulated facilities accounted for 59 percent of nitrogen pollution from stormwater and 12 percent of Virginia's total nitrogen pollution (Chesapeake Bay TMDL Tracker, 2017)

Unregulated Stormwater (Nonpoint Source Pollution)

Stormwater runoff can also considered a nonpoint source pollutant. Nonpoint pollutants are considered to be 'diffuse' pollution because their inputs come from a wide variety of sources. The variety of inputs and transient nature of stormwater makes it difficult to regulate. The recent figures from the CBP (2017), states that unregulated stormwater accounts for 41 percent of stormwater nitrogen pollution and 8 percent of Virginia's total nitrogen pollution.

WATER QUALITY METRICS

Researchers use a variety of metrics to assess water quality in the Chesapeake Bay and its tributaries. At a basic level, nutrients such as nitrogen and phosphorus are two naturally occurring elements that all living plants and animals need for growth and reproduction. Nutrient pollution, also referred to as eutrophication, occurs when there is an excess or overabundance of nutrients and minerals in the body of water (Boesch, Brinsfield, & Magnien, 2001). Eutrophication in the Chesapeake Bay can eventually lead to reduced concentrations of DO suitable to support flora and fauna. Second, eutrophication can also increase algal growth which contributes to reduced levels of water clarity[1]. Due to the negative effects that eutrophication can have on DO concentrations, chlorophyll-*a* concentrations, and water clarity, researchers often use nitrogen and phosphorus inputs proxies for overall Bay water quality. The scope of this analysis will focus on nitrogen pollution measured in pounds per year (lbs/year) as a proxy for Chesapeake Bay water quality.

An analysis of Virginia's major pollution sectors shows that in 2017, Virginia emitted 57.33 million pounds of nitrogen into the Chesapeake Bay. This is equivalent to 23 percent of total nitrogen pollution watershed-wide. Table 2. below shows Virginia nitrogen pollution across all sectors in 2017. The data shows that Virginia's regulated stormwater sector produced 6.66 million pounds of nitrogen while the state's non-regulated stormwater produced 4.54 million pounds of nitrogen. This equates to 20 percent of Virginia's total nitrogen pollution in 2017.

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[1] Total suspended solids (sediment) are a third pollutant affecting the water quality of the Chesapeake Bay. Sediment is typically carried by erosion is deposited into the water column. The more sediment in the water, the more murkier it seems and the higher the turbidity. Although sediment is an important factor affecting water quality in the Chesapeake Bay, it is outside the scope of this analysis.

Table 1. Virginia's Total Nitrogen Pollution Loads by Sector in 2017 (lbs/year)

Pollution Sector	2017 Nitrogen Load	% of Total Nitrogen Pollution
Agriculture	15,595,750	27%
Agriculture - Regulated	244,135	(<1%)
Forest	12,503,276	22%
Non-Tidal Water Deposition	578,001	1%
Onsite	2,619,392	5%
Regulated Stormwater	6,663,542	12%
Unregulated Stormwater	4,536,739	8%
Wastewater	14,332,985	25%
Wastewater - CSO	259,513	(<1%)
Total Nitrogen Pollution	**57,333,333**	**100%**

Note: Data on Nitrogen Loads was retrieved from the Chesapeake TMDL Tracker. Loads simulated using 5.3.2 version of Watershed Model and wastewater discharge data reported by Bay jurisdictions. Progress data updated 6/15/2017.

Monitoring Water Quality

Tracking annual nitrogen loads flowing into the Chesapeake Bay requires extensive water quality monitoring. This involves coordinated data collection from 115 monitoring stations that make up the Bay's non-tidal monitoring network. There are an additional nine River Input Monitoring stations that track pollution loads delivered directly to the Bay's tidal waters. The data from both monitoring networks is used to calculate pollution trend loads over time. According to the EPA (2013), pollution loads are typically defined as the mass of a substance that pass a particular point of a river, such as a monitoring station, in a specified amount of time (U.S. EPA, 2013). The time frame used to calculate trend loads is often daily or annually. Monitoring efforts are overseen by the CBP. The responsibility to monitor water quality is divided between the US EPA, the individual environmental agencies representing the six Bay states and Washington DC, the Susquehanna River Basin Commission and the United States Geological Survey.

PREVIOUS POLICY INTERVENTIONS

Records show that hypoxic (lack of oxygen) conditions in the portions of the Chesapeake Bay date back as early as the 1930s. Scientific controversy surrounding whether or not hypoxia in the Chesapeake Bay had intensified since the 1950s and the significance of anthropogenic eutrophication continued into the late 1970s and early 1980s (Boesch, Brinsfield, & Magnien, 2001). By the 1980s, there was a growing consensus among researchers on the significance of anthropogenic eutrophication as well as advancements in the scientific community on how to properly measure the Bay's water quality.

Politically, efforts to restore the Bay have historically fallen short. One of the first major political partnerships occurred in 1983 Chesapeake Bay Agreement, which was signed by the governors of Maryland, Virginia, and Pennsylvania, the mayor the District of Columbia, and the EPA administrator. The Agreement was politically "toothless" but stakeholders did promise to establish an executive council and acknowledge that the Bay's water quality needed to be addressed (Chesapeake Bay Agreement, 1983). A revised version of the Agreement was introduced in 1987 and promised to achieve a 40 percent reduction of nitrogen and phosphorus entering the main stem of the Chesapeake Bay by 2000 (Chesapeake Bay Agreement, 1987). By the end of 20th century, little progress had been made to the 1987 Agreement's goal to reduce nutrients pollution. Although the nutrient reductions were admirable, researchers had set overly ambitious metrics and had failed to account for population growth and changing climate from year to year that could affect bay water quality (Powledge, 2005).

The latest controversy came shortly after the EPA's decision to establish a Total Maximum Daily Load (TMDL) in 2010, when the American Farm Bureau Federation (AFBF) and the Pennsylvania Farm Bureau filed a federal lawsuit against the EPA claiming they had usurped the power of the states in the watershed to regulate pollution flowing into the Chesapeake Bay (*American Farm Bureau Federation et al. v. EPA*, 2011) The three primary complaints of the plaintiffs in were that the pollution limits exceeded the EPA's authority, the pollution limits were based on faulty science, and that the length of the public comment period was insufficient and not an adequate length of time. The original plaintiffs against the EPA's establishment of pollution limits were then joined special interest groups representing agriculture, livestock, fertilizer and construction Chesapeake Bay Foundation, 2011). The lawsuit also garnered support from 21 state generals, who signed an amicus briefing voicing their opposition for cleaning up the Chesapeake Bay. The Court ultimately ruled that the pollution limits that the EPA established for the Chesapeake Bay were within the Agency's legal authority.

FEDERAL LAWS, AGENCIES & ENFORCEMENT

Federal Water Pollution Control Act

At the Federal level, the first law to address water quality and pollution was the Federal Water Pollution Control Act of 1948. As amended and approved by Congress in 1972, the law became commonly known as the Clean Water Act (CWA). The law established the basic structure for regulating discharges of pollutants and water quality standards for surface water. This means that federal stormwater mandates are clearly defined as point source pollution programs that are enforceable by the EPA and state environmental agencies.

In 2010, the EPA exercised its authority under section 303(d) of the Clean Water Act to set a Bay-wide total maximum daily load (TMDL). The language of section 303(d) requires states, territories, and authorized tribes to develop lists of impaired waters that are too polluted to meet water quality standards. The TMDL set federal requirements on the amount of annual nitrogen, phosphorus and sediment allowed to flow into Chesapeake Bay. Annual limits are calculated and used as a proxy to determine how much pollution a particular waterbody can receive and still meet individual water quality standards for DO, chlorophyll-*a*, and water clarity that support healthy ecosystems (U.S. EPA, 2010). Like most environmental standards, the enforcement of federal standards is left to the states. Information from the EPA states that if a bay jurisdiction fails to meet TMDL limits, the EPA can impose a number of different consequences including (but not limited to) expanding NPDES permit coverage to currently unregulated sources, require additional pollution reductions from point sources and issuing standards for nutrient pollution in local waters if the jurisdiction has not developed criteria to protect downstream waters (Perciasepe, 2017). Beyond increasing EPA enforcement, states risk being exposed to third-party lawsuits for failing to keep pace with TMDL limits.

Unlike point source stormwater, nonpoint source water pollution is not directly regulated under the Clean Water Act. In order to encourage states, territories, and delegated tribes to address nonpoint source water pollution within their designated boundaries, the federal government uses incentive mechanisms. Under Section 319 of the Federal Clean Water Act states, territories, and delegated tribes are required to develop nonpoint source pollution management programs if they wish to receive Section 319 funds. Once it has approved a state's nonpoint source program, the EPA provides grants to these entities to implement nonpoint source pollution management programs under section 319(h).

Watershed Implementation Plans

Central to the TMDL are Watershed Improvement Plans (WIPs) created by the six states and the District of Columbia. Each jurisdiction's WIP outlines how they will reach specific nutrient and sediment pollution control measures in two year increments. According to the final agreement, by 2017, each watershed jurisdiction is expected to have reduced their nutrient and sediment loads by 60 percent compared to 2009 levels (U.S. EPA, 2010).

Each jurisdiction's WIP has three phases. In Phase I, each of the six states and Washington DC submitted information to the EPA on how pollutant loads would be allocated among each sector and described the steps that would be taken over time to meet 2025 goals (U.S. EPA, 2010). Phase II WIPs, completed in 2012, built on the initial Phase I WIPs and provided information on how the involvement of local governments. By 2018, each watershed jurisdiction will submit their Phase III plans to the US EPA specifying how they will make the final nutrient and sediment reductions.

VIRGINIA LAWS, AGENCIES & ENFORCEMENT

In the Commonwealth of Virginia, the DEQ is the primary agency responsible for managing the state's stormwater programs. Formed in 1993 following the consolidation of various environmental departments and control boards, the DEQ acts as the lead agency for developing and implementing statewide stormwater management and nonpoint source pollution programs (Virginia DEQ, 2017).

Managing Nonpoint Source Pollution

The DEQ works alongside the Department of Conservation and Recreation (DCR) and other local government stakeholders to prevent water quality degradation and to reduce and prevent nonpoint source pollution from impacting Virginia's waterways. This network of environmental stakeholders makes up Virginia's Nonpoint Source Pollution Management Program (VA DEQ, 2017).

The legislative backdrop for Virginia's Nonpoint Source Pollution Management Program is a combination of federal and state laws. In order for Virginia to receive federal grants associated with section 319(h) of the Clean Water Act, the state must develop and implement a nonpoint source pollution program. Section 319(h) funding is used to support state and local activities such as technical assistance, financial assistance, education, training, technology transfer, demonstration projects and monitoring associated with nonpoint source projects (Virginia DEQ, 2017).

At the state level, legislation such as the Virginia Water Quality Improvement Act of 1997 (§10.1-2117 - 2134) established a statewide program to address both point and nonpoint source water pollution. In accordance with the Improvement Act is the Virginia Water Quality Improvement Fund (WQIF) which is a special permanent, non-reverting fund in the State Treasury. The WQIF offers grants to "local governments, soil and water conservation districts (SWCDs), institutions of higher education and individuals for point and nonpoint source pollution prevention, reduction and control programs" (§10.1-2128.B.). Historically, WQIF grants support projects ranging from installing agricultural best management practices (BMPs), nutrient management, septic system rehabilitation, and shoreline erosion control.

The other state funding source for nonpoint source pollution is the Stormwater Local Assistance Fund (SLAF). The SLAF was created in 2013 by the Virginia General Assembly included Item 360 in Chapter 860 of the Acts of Assembly (the Commonwealth's 2013-2014 Budget). The SLAF provides matching grants to local governments to plan, design, and implement cost-effective BMPs.

SPENDING ON CHESAPEAKE BAY RESTORATION

Projected Costs to Restore the Bay

Due to the scope of water pollution affecting the Chesapeake Bay, the responsibility to restore the Bay is divided between federal, state, and local governments. Projections on the needed investments to restore the Chesapeake Bay to water quality standards able to support ecological life, set by the EPA vary drastically. A report from the Chesapeake Bay Commission (2003) projected cleanup costs across the entire region to be upwards of $25.15 billion (adjusted to 2018 dollars). The investment alone needed to retrofit the Bay's stormwater systems was $3.41 billion (Chesapeake Bay Commission, 2003).

Another source reported the costs associated with implementing the state's WIP would be upwards of $11.26 billion (adjusted to 2018 dollars) between 2011 and 2025 (Senate Finance Committee, 2011). The range of annual costs to implement Virginia's stormwater management were calculated to be between $1.0 to $1.2 billion.[2]

It should be noted that differing costs associated with stormwater runoff in the Bay can be attributed to the cost-effectiveness of removing different pollutants. The median value of nitrogen treated per pound ranges as low as $26 dollars per pound to upwards of $300 dollars per pound (Environmental Finance Center, 2015) (Van Houtven, Loomis, Baker, Beach, & Casey, 2012).

Federal Spending

According to the Chesapeake Bay Restoration Crosscut issued by the Office of Management and Budget (OMB), the federal government spent $569.4 million dollars on Chesapeake Bay Watershed restoration in FY 2017 (OMB, 2017). Spending was divided between six federal agencies including the U.S. Departments of Agriculture,

[2] The costs analysis associated with implementing Virginia's stormwater management plan were performed by a private engineering firm. The assumptions made financing over 30 years at 5.5 percent interest rate and O&M costs estimated at 5% of construction cost.

Commerce, Defense, Homeland Security, and Interior and the EPA. Of the six federal agencies, the EPA spent the most at $204 million in FY 2017.

Central to restoration efforts is the CBP, which is the regional partnership that directs and conducts the restoration of the Chesapeake Bay. The CBP receives funding from the EPA that goes towards watershed restoration and monitoring. In FY 2016, the CBP received a total of $73 million in funding (Office of Budget and Management, 2017). Nearly two-thirds of the CBP’s funding from the EPA is spent by the six bay states and Washington DC in the form of grants to help work toward meeting the goals of the Chesapeake Bay Watershed Agreement.

State Funding

In total, all six states and DC budgeted approximately $1.53 billion dollars in FY 2017 on watershed restoration. In FY 2017, Virginia had an operating budget of $228.1 million with approximately $49.4 million coming from federal funds (OMB, 2017). A large portion of Virginia’s funding goes towards implementing nutrient and sediment pollution reductions from the state’s agriculture sector.

There are multiple grants that Virginia receives on behalf of the CBP that go towards financing stormwater and other nonpoint source pollution projects. Major grants include Nonpoint Source Management Implementation grants, Chesapeake Bay Regulatory and Accountability Program (CBRAP) grants, and Chesapeake Bay Implementation Grants (CBIG). In FY 2017, the Virginia DEQ received a total of $7.56 million in grant money (Office of Budget and Management, 2017).

Virginia’s Stormwater Funding

The figures in Table 2. below outlines the state spending on activities related to stormwater and nonpoint source pollution into the Chesapeake Bay. These figures include expenditures from the WQIF, SLAF, and federal implementation grants. As shown in the table, federal grant money has remained relatively constant between 2014 and 2017. In contrast, state spending for stormwater and nonpoint source pollution programs has experienced noticeable fluctuations during the same time period. The four-year spending averages from the SLAF and WQIF were $19.96 million and $34.87 million, respectively.

The WQIF is capitalized annually via real estate recordation fees. Additionally, the Fund is capitalized with 10 percent of any state surplus general funds in fiscal years when there is a surplus. Funds can be added to the WQIF by means of a budget allocation approved by the General Assembly and Governor. The WQIF is non-reverting, meaning that unspent money left at the end of the fiscal remains in the Fund for use in future years.

Table 2. Spending levels from major state and federal sources for nonpoint source pollution reduction in Virginia, 2014 - 2017 ($ Thousands)					
	FY 2014	FY 2015	FY 2016	FY 2017	Annual Average
FEDERAL					
Environmental Protection Agency					
Nonpoint Source Mgmt. Implementation Grants	1,873	1,944	1,680	1,731	1,807
Chesapeake Bay Regulatory and Accountability (CBRAP)	3,087	2,308	2,849	3,589	2,959
Chesapeake Bay Implementation Grants (CBIG)	3,438	3,920	3,448	2,777	3,396
STATE					
Department of Environmental Quality					
Stormwater Local Assistance Fund	35,000	20,000	5,000	19,856	19,964
Water Quality Improvement Fund	8,235	32,062	27,497	71,709	34,876
Note: Spending figures come from the 2017 Chesapeake Bay Restoration Spending Crosscut (2017) and https://www.usaspending.gov.					

The Code of Virginia (§ 62.1-44.15:29.1) states that SLAF funding can either come from bonds authorized by the General Assembly or sums appropriated to it by the General Assembly and other grants, gifts, and money made available from other sources, public or private.

Similar to the WQIF, the SLAF is a non-reverting fund. The range in funding for stormwater projects varies extensively year to year. Inconsistent funding patterns have led to a backlog in stormwater projects pivotal to reducing Virginia's nonpoint source stormwater pollution in the amount of nearly $51 million.

INFRASTRUCTURE BEST PRACTICES

Traditional stormwater management has focused on diverting runoff from developments and towards structures that carry water away and prevent flooding. The drawbacks of designing traditional stormwater systems to rapidly transport water away from development include increased risk of flooding, high water levels, altered stream channels, and the loss of the floodplains (Holm et al., 2014).

Technological advancements and a greater understanding of the role that pervious surfaces play in reducing runoff has lead a growing number of city managers and engineers using more holistic stormwater management practices. Often referred to as Low Impact Development (LID), these practices are employed at the site level to manage stormwater as close to the source as possible. As noted by the EPA (2009a), “LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than a waste product” (p. 1). There a number of different best management practices (BMPs) categorized either as structural or non-structural. Each BMP varies in cost and efficiency of nutrient removed.

Structural Best Management Practices

A structural BMP is defined as a “stationary and permanent BMP that is designed, constructed and operated to prevent or reduce the discharge of pollutants in stormwater" (p.15). The following are the major structural BMPs that are outlined in Virginia’s WIP, categorized by their primary stormwater function.

- *Infiltration BMPs:* BMPs that maximize the infiltration of stormwater to reduce the volume of runoff discharging to surface waters Many factors influence the rate and volume of stormwater infiltration, including soil and rainfall characteristics. Once stormwater infiltrates into the soil, it has the potential to enter the groundwater, become part of the subsurface flow, or be taken up by vegetation (Minnesota Stormwater Manual, 2008). Examples of infiltration BMPs include infiltration basins and bioretention/rain gardens.
- *Restoration BMPs:* Practices such as stream restoration and forest buffers involve replanting trees and shrubs adjacent to waterways. Restoring stream buffers with vegetation helps restore ecologically sensitive habitat and improve water quality by reducing high nutrient loads.
- *Runoff Quality:* Structures designed to treat and control the quantity of stormwater. Practices such as constructed wetlands and wet ponds store and treat incoming stormwater runoff over longer periods times.
- *Peak Rate BMPs:* Standard and extended detention basins that temporarily store stormwater in order to control peak runoff flows to receiving bodies such as rivers and streams.

Non-Structural Best Management Practices

In contrast to large, structural BMPs, non-structural BMPs focus on institutional and pollution-prevention practices. Notable advantages of non-structural BMPs are the low costs compared to structural BMPs, broader pollution coverage, and the ability to use regulation and/or enforcement programs to target certain individuals and sectors that are polluting (Taylor & Wong, 2002). Examples of non-structural BMPs include

- *Source Control*: Practices include street sweeping that removes larger debris material and smaller particulate pollutants, preventing this material from clogging the stormwater management system and washing into receiving waterways/waterbodies.
- *Reduce Impervious Cover*: Removing constructed hard surface that impedes the infiltration of rainfall by minimizing street width and length or reducing the imperviousness of parking areas.
- *Urban Nutrient Management Plans*: Nutrient management plans (NMPs) are plans prepared by certified nutrient management planners in order to "manage the amount, placement, timing and application of fertilizer, biosolids, or other materials containing plant nutrients in order to reduce nutrient loss to the environment (JLARC, 2005).

FINANCING BEST PRACTICES

General Fund Appropriations

The most common source of funding for stormwater system programs is General Fund revenues. Revenues included in the General Fund come from a wide range of sources such as property taxes (ad valorem tax), incomes tax, and utility taxes on municipal services. One advantages of using General Fund revenues as a financing option is that there are limited constraints on possible uses. General fund revenues are not dedicated for long-term use, meaning that they are not a sustainable financing method for stormwater infrastructure projects.

General Obligation and Revenue Bonds

Bonds are a form of borrowing often used by municipalities for stormwater and other major capital improvement projects. Two advantages of borrowing municipal bonds are that they allow cities to expedite start dates infrastructure projects and they give municipalities the flexibility to design debt service (e.g. pay as you go). The caveat of general obligation and revenue bonds is the risk of incurring long-term debt that municipalities take on when they borrow for capital improvement projects.

Grant Funding

The EPA estimate that the total capital investment needed nationwide for publicly owned stormwater management to meet Clean Water Act water quality goals was $19.1 billion. These capital costs, particularly for those designated for retrofitting old stormwater infrastructure, have spurred municipalities to find various ways to finance stormwater and green infrastructure projects. As noted before, in the state of Virginia the primary grants used by municipalities are the SLAF and WQIF.

Other cities, such as Philadelphia have invested upwards of $2.4 billion to finance stormwater management. The Philadelphia Water Department and Philadelphia Industrial Development Corporation offer two grant-based programs that incentivize private-public partnerships (P3s). The first program, the Stormwater Management Incentive Program, offers direct grants capped at $100,000 per impervious acre to non-residential property owners to construct stormwater retrofit projects. Grant applications are evaluated on criteria including total volume of runoff managed, cost-competitiveness, environmental and education benefits. The 36 projects approved to date have cost the department $15.2 million, resulting in 205 greened acres at a cost of $75,000 per greened acre (WEF, 2014). According the City of Philadelphia, funding for projects include but is not limited to detention and retention basins, green roofs, porous paving, and rain gardens. The second program, known as the Greened Acre Retrofit Program, offers grants to contractors, companies or project aggregators to design and install stormwater best management practices with the intent of targeting large-scale stormwater retrofits. Preference is given to project applications that span multiple properties inside Philadelphia's combined sewer overflow zone and are a minimum of 10 acres.

Stormwater Service Charges (Utilities)

Similar to utilities for other municipal services such as sewage and water, stormwater utilities charge a fee for controlling stormwater runoff. The fee covers the service costs for construction, operation and maintenance of a stormwater system (U.S. EPA, 2009b). There are three basic ways to determine stormwater utility fees. The first, and used by more than 80 percent of all stormwater utilities in the U.S. is the Equivalent Residential Unit (ERU) which bills residents an amount proportional to the impervious area on their parcel of land, regardless of the parcel's total area (U.S. EPA, 2009b). The second fee structure, the Intensity of Development (ID), charges residents based on the percentage of impervious relative to the entire parcel's size. Vacant, undeveloped, and developed parcels are all billed based on their intensity of development. The final fee structure the Equivalent Hydraulic Area (EHA) bills parcels based on the amount of stormwater generated by both impervious and pervious area. Impervious areas are charged a significantly higher rate.

A 2017 analysis of stormwater utility data from Brookings (2017) found that almost half of the 1,583 permitted stormwater utilities are concentrated in five states: Minnesota (197), Florida (180), Wisconsin (126), Washington (117), and Ohio (105) (Kane & Shivram, 2017). In Virginia, stormwater utilities are codified (§ 15.2-211) but as of 2016 there were only 27 municipalities in the state that had established or enacted a stormwater utility fee (Campbell, Dymond, Key, & Dritschel, 2016).

Stormwater utilities typically offer incentive programs to parcel owners to reduce impervious area or volume of runoff discharged from their property in exchange for discounted monthly or annual stormwater fees. Stormwater utility fee discounts have been implemented in Prince William County in Northern Virginia, which offers businesses and nonprofits the opportunity to earn a 30 percent rebate from their previous year's stormwater management bill for completing stormwater education sessions, implementing nutrient management plans, or performing on-site cleanups businesses (EPA, 2009b).

A second example is the City of Chesapeake, which offers utility fee credits to non-residential property owners for providing water quality improvements and/or water quantity improvements (reduced peak discharge). Property owners that use BMPs can earn a 20 percent credit (based on their stormwater fee) that can either be uses for on-site control measure or to improve water quality such as installing detention lakes, retention ponds, vegetated buffer strips and grassed swales.

Water Funds and Consumption Fees

States including Minnesota and Maryland use state water funds to finance a broad range of water quality improvement projects. In Minnesota, the Clean Water, Land and Legacy Amendment of 2008 increases the state sales tax by three-eighths of one percent to fund conservation and cultural efforts across the state. Under the CWLA, 33 percent of the sales tax revenue is allocated to the state's clean water fund.

Maryland's Bay Restoration Fund was signed into law as Senate Bill 320 in 2004 with the purpose of creating a dedicated fund for removing nutrient loads in the Chesapeake Bay and Coastal Bay watersheds (SB320, 2004). The Bay Restoration Fund is financed through fees placed on wastewater treatment plant users. This includes fees for domestic users, as well as industrial and commercial users who pay similar rates of $5.00 per month per equivalent dwelling unit (EDU).

The most recent example of a state water fund comes from Pennsylvania, where law makers have introduced legislation titled Pennsylvania Water Resource Act (HB2114) in the 2017-2018 legislative session. The Act would create a establish a fund financed by fees placed on water permit holders who withdraw on average 10,000 gallons or greater per day for non-agriculture and non-municipal uses. The fee would be set at 1/100th of a cent per gallon of water withdrawn and returned to the water source. A higher fee of 1/10th of a cent per gallon would be placed on water withdrawals not returned to the water source. According to the legislation, if enacted, the water resource use fee would be applied to 5.6 billion gallons of daily water withdrawals across the state potentially generating $250 million annually, based on current usage rates.

POLICY OPTIONS

The following represents different policy options that the state of Virginia can use to address urban stormwater pollution flowing into the Chesapeake Bay. The three alternative policy options incorporate pre-existing stormwater BMPs or nonpoint source programs approved by the CBP. Due to the number of available financing routes to fund urban stormwater pollution, after determining the best policy option I will address the financing options in a separate section.

Option 1: Let Present Trends Continue

The first option is to let present trends continue. Under this option, Virginia would be required to continue meeting the pollution reduction goals outlined by the EPA and the state of Virginia's Phase III WIP. In order to meet the targets for 2025, Virginia will need to reduce stormwater sector nitrogen pollution by 2.41 million pounds; a 21 percent reduction over the next eight years relative to 2017 pollution levels. The average spending on implementing Virginia's urban stormwater and nonpoint source BMPs between 2014-2017 was $ 54.84 million and $8.16 million on EPA grants. Spending projections are estimated to be $504 million between 2017-2025.

Option 2: Structural Best Management Practices

Under this option, the DEQ would prioritize implementing structural BMPs outlined in Virginia's Phase II WIP developed in collaboration with the EPA. This includes treating all of the available non-federal land with infiltration BMPs, bioretention/rain gardens, restoration practices, wet ponds, and dry extended basins.

Option 3: Non-Structural Best Management Practices

This option would implement non-structural BMPs outlined in Virginia's Phase II WIP developed in collaboration with the EPA. This option would include treating all available non-federal land inside Virginia's Chesapeake Bay Watershed basin with street sweeping and impervious surface reductions BMPs.

Option 4: Urban Nutrient Management Planning

Under this option, the DEQ and DCR would cross-collaborate to assist local Soil and Water Conservation Districts implement urban nutrient management planning for all available non-federal land inside Virginia's Chesapeake Bay Watershed Basin

EVALUATIVE CRITERIA

Cost-effectiveness

The first and most heavily weighted criterion will be cost-effectiveness. Due to the environmental and public health damages caused by stormwater pollution and high costs associated with Chesapeake Bay restoration efforts, each BMP will be evaluated by the average annual cost (over 20 years) and the annual nitrogen reduction in pounds. This means each BMPs will be measured in dollars per pound of total nitrogen reduced.

Ability to Implement

The second set of criterion is the ability to implement. Each option will be measured by; (1) degree of ownership displayed by the staff who will implement; (2) the complexity of the new program in terms of the number of rules and regulations that need to be promulgated; (3) the number of agencies that need to be involved and; (4) whether or not the program is so large that it needs to be phased in over a year or more. The policy alternatives will be scored on a measure of one to three according to the following scale:

1. Low Implementation Feasibility
2. Moderate Implementation Feasibility
3. High Implementation Feasibility

Equity

The third and final set of criterion is equity. Virginia's Chesapeake Bay watershed encompasses a wide range of communities in terms of population, land use, median income, and contribution to overall stormwater pollutants flowing from Virginia into the Bay. The equity measurement will be based on localities and municipalities who pay for stormwater BMPs versus those that receive the benefits in terms of nitrogen reductions. The policy alternatives will be scored on a measure of one to three according to the following scale:

1. Low Equity
2. Moderate Equity
3. High Equity

RESULTS OF POLICY ANALYSIS

Table 3. represents the results of the policy analysis. The following discussion will evaluate the four proposed policy options based on the evaluative criteria: cost effectiveness, political feasibility, implementation feasibility, and equity. Letting present trends continue will serve as the comparison baseline for the following analyses.

Table 3. Comparative Analysis of Stormwater BMP for the State of Virginia

COMPARATIVE ANALYSIS
State of Virginia
(2025 Urban Stormwater Baseline: 8.79 Million lbs. of Nitrogen)

	Policy Scenario	(Cost Per Ton N Abated) Cost-effectiveness ($/lb.)	Area Treated Per/Year (2017-2025) Unit/Year	Implementation	Equity
	Weights	**.6**		**.2**	**.2**
Status Quo		N/A		High	High
Structural BMPs	Infiltration Practices	$ 536.02	7,802.1 acres/year	Medium	High
	Bioretention/Raingardens	$ 656.61	2,304.4 acres/year	Medium	High
	Restoration: Urban Streams	$284.33	12,404.4 feet/year	Medium	High
	Restoration: Forest Buffers	$ 164.14	511.1 acres/year	Medium	High
	Wet Ponds/Wetlands	$ 757.96	7,512.1 acres/year	Medium	High
	Dry Basins	$ 5,001.93	4,709.6 acres/year	Medium	High
	Extended Dry Basins	1,250.48	14,369.2 acres/year	Medium	High
Non-Structural BMPs	Impervious Surface Reduction	$2653.68	3,060.9 acres/year	Medium	Medium
	Street Sweeping	$ 1,512.36	3,005 acres/year	Medium	Medium
Conservation	Urban Nutrient Management	$ 518.55	62,232.9 acres/year	Medium	High

Source: Virginia Department of Environmental Quality, Virginia's 2016-2017 Chesapeake Bay Nutrient and Sediment Reduction Milestones; http://www.deq.virginia.gov/Portals/0/DEQ/Water/ChesapeakeBay/Milestones/Virginia%202016-2017%20Programmatic%20Milestones.pdf
Cost-effectiveness estimates came from the Chesapeake Bay Assessment Tool (CAST) https://cast.chesapeakebay.net/PublicReports

DISCUSSION OF COST-EFFECTIVENESS

The values shown in Table 2. show that non-structural BMPs are on average less cost-effective than structural BMPs and nutrient management. The top four most cost-effective BMPs were: forest buffer restoration, urban stream restoration, urban nutrient management, and extended dry ponds. Multiplying each cost by the annual area treated, based on projections from Virginia's Phase III WIP, gives the annual cost to implement each BMP over the course of eight years. The annual for the top four BMPs were:

Annual Costs for Most Cost-effective BMPs

- Urban Nutrient Management = (62,232.9 acres/year x $518.55) = **$32.27 million**
- Extended Dry Ponds = (14,369.2 acres/year x $1,250.48) = **$17.97 million**
- Urban Stream Management = (12,404.4 feet/year x $284.33) = **$3.53 million**
- Forest Buffers Restoration = (511.1 acres/year x $164.14) = **$83,891**

Total Costs for Most Cost-effective BMPs between 2017-2025

- Urban Nutrient Management = **$258.16 million**
- Extended Dry Ponds = **$143.76 million**
- Urban Stream Management = **$28.21 million**
- Forest Buffers Restoration = **$671,138**

Methodology

The methodology and data analysis for each of the four policy options is based off of similar policies and programs in the Chesapeake Bay Watershed. This includes programs in Virginia as well as other Chesapeake Bay jurisdictions. Reports on baseline land use practices and nitrogen reductions came from the CBP's Chesapeake Bay Assessment Tool (CAST). The CAST program allows planners and engineers to find nutrient loads and per-unit cost for stormwater BMPs already approved by the CBP.

Due to population growth and seasonal rainfall, the amount of nitrogen pollution from stormwater has continued increased from 10.12 million pounds in 2009 to 11.2 million pounds in 2017. Given Virginia's growth trends and rate of urbanization, we would expect nitrogen pollution to increase despite into the future. Since the scope of this analysis defines the cost-effectiveness as the annual cost per pound of nitrogen reduced, it is determined that the status quo would not have an applicable or a comparable cost-effectiveness ratio under this definition.

Land use projections were calculated using CAST by first finding the amount of non-federal land before implementation of any urban stormwater BMPs in 2017. The amount of non-federal land, measured in acres treated, was then compared to projections reported in Virginia's Phase II WIP if they were to install all credited urban stormwater BMPs by 2025. The difference between the two values represents the annual amount of acres treated for urban stormwater BMPs between 2017 and 2025.

Assumptions

The values for cost-effectiveness came from previous research on nutrient pollution in Chesapeake Bay Watershed. The original figures came from King and Hagan (2011), who estimated the cost of implanting stormwater best management practices as part of Maryland's WIP. The unit cost estimates from King and Hagan were in impervious acres treated. In 2013, a report titled *Cost-Effectiveness Study of Urban Stormwater BMPs in the James River Basin* from the Center on Watershed Protection used King and Hagan's original figures to create unit cost estimates for the state of Virginia (Center for Watershed Protection, 2013). Each BMP, with the exception of street sweeping and urban stream restoration represents acres treated per year. All figures have been adjusted for inflation and are represented in 2018 dollars.

The formula used for cost-effectiveness was:

$$Cost - effectiveness\ TN\ (\$/lb) = \frac{Average\ annual\ cost\ over\ 20\ years\ (\$)}{Annual\ TN\ reduction\ (lbs)}$$

Where:

- *Average annual cost over 20 years = (annual maintenance cost + average annual intermittent maintenance cost + average annual County implementation cost) + annualized initial cost*

- *Annualized initial cost = annual bond payment required to finance the initial cost (construction costs + design costs + cost of land) of the BMP at 3% interest over 20 years*

It is assumed that due to annual maintenance of each BMP that they will continue to have constant removal rates every year over the 20 year timeframe.[3]

DISCUSSION OF IMPLEMENTATION

Determining the values for ease of implementation accounted for the complexity of the new program/policy in terms of the number of rules and regulations that need to be promulgated; the degree of ownership displayed by

[3] For a full list of assumptions please taken from King and Hagan (2011) and refer to the appendix section

the staff who will implement; the number of agencies that need to be involved and; whether or not the policy is so large that it needs to be phased in over a year or more.

A change from the status quo and choosing to implement any of the three policy alternatives would require no new legislation or change in regulation since each option incorporates BMPs already used in Virginia's Phase II WIP.

Both the structural and non-structural policy alternatives scored "medium" on ease of implementation. Structural stormwater BMPs, street sweeping, and impervious cover removal projects are often implemented at the local level and managed by the Virginia DEQ. For comparison, expanding urban nutrient management would require extensive collaboration between the DEQ, Department of Conservation and Recreation, and local Soil and Water Conservation Districts. In addition, implementing urban nutrient management by upwards of 64,000 annually between 2017-2025 implies that program coverage would need to be expanded in a multi-year phase-in. For this reason the conservation policy option was given a "low" ease of implementation score.

DISCUSSION OF EQUITY

Financing stormwater projects at the local level typically comes from a combination of general obligation bonds and grant funding from the state of Virginia. In cities and localities performing stormwater infrastructure projects, residents may experience higher property taxes or stormwater utility fees. Since the changes in property tax or monthly stormwater fees is typically negligible. Furthermore, general obligation bonds are often structured so that those who benefit from the good or service pay for it. In this case, the additional tax revenues or fees are being paid by the property owners or service consumers who benefit from stormwater abatement.

Determining the equity of the status quo option can be done by looking at previous SLAF funding for stormwater projects between 2014 and 2017. Over the course of four years, the SLAF was used to finance approximately $81 million dollars in stormwater projects. This funding covered 50 percent of the cost for 190 projects across Virginia. The allocation of funding was distributed primarily to counties and municipalities most "in-need" for stormwater BMPs. This includes highly populated areas such as Fairfax County and Newport News. In addition, relatively less populated areas such as Isle of Wight County received significant funding assistance based on the need to cut their jurisdiction's nutrient pollution. Due to this all assumptions all four policy alternatives score "high" on equitability.

POLICY RECOMMENDATION

From the discussion above, I believe that the best course of action for Virginia would be to fully implement urban nutrient management planning on all treatable non-federal land. Although implementing conservation BMPs such as urban nutrient management planning requires extensive collaboration between the DEQ and DCR, this option covers the most watershed area at a high rate of cost-effectiveness compared to many of structural and non-structural BMPs currently being used in Virginia's WIP.

In terms of financing, it is evident that there are significant fluctuations in available from the state to the SLAF and WQIF. In order to meet 2025 requirements provided by the EPA, localities will need to find more sustainable options for local stormwater projects to supplement inconsistent state funding. My top recommendation would be to explore a feasibility study for the establishment of establishing an independent financing fund for water quality improvement projects similar to Maryland and Pennsylvania.

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APPENDIX 1.

State Spending for Chesapeake Bay Watershed Restoration ($ Thousands)

	FY 2014	FY 2015	FY 2016	FY 2017
Delaware	$7.50	$7.50	$7.50	$7.50
District of Columbia	$28,29	$33.11	$26.54	$52.13
Maryland	N/A	$871.42	$870.45	$1,097.74
New York	$6.49	$6.28	$6.04	$6.99
Pennsylvania	$53.89	$86.59	$40.03	$33.67
Virginia	$177.11	$241.23	$255.86	$301.94
West Virginia	$17.68	$43.88	$86.06	$44.88
Total	**N/A**	**$1,283.28**	**$1,285.74**	**$1,538.09**

Note: Source for Chesapeake Bay Watershed Restoration spending was http://chesapeakeprogress.com/funding

APPENDIX 2.

Cost-effectiveness assumptions from King and Hagan (2011) and The Center for Watershed Protection (2013)

- The cost-estimating framework used develops full life cycle cost estimates based on the sum of initial project costs (design, construction and land costs) funded by a 20-year county bond issued at 3%, plus total annual and intermittent maintenance costs over 20 years. The annualized life cycle costs are estimated as the annual bond payment required to finance the initial cost of the BMP (20-year bond at 3%) plus the average annual routine and intermittent maintenance costs.

- Operational and maintenance (O&M) costs include annual routine annual maintenance, intermittent maintenance and county implementation costs. Intermittent or corrective maintenance tasks are those that accrue every 3-5 years and are averaged over the 20 year period. O&M costs over the 20-year life cycle are assumed to increase by 3%; however, a 3% discount rate is also assumed, thus "washing out" the effect of the increased cost and resulting in a constant present value annual cost throughout the 20-year period.

- The design life of all BMPs (excluding street sweeping) is 20 years or greater (e.g., the costs do not reflect replacement over the 20 year time period). For street sweeping, the life cycle was assumed to be 10 years.

- For all BMPs that require land it was assumed that: 1) the opportunity cost of developable land is $70,000 per acre and 2) 50% of projects that require land take place on developable land with the rest taking place on land that is not developable (e.g., stream valleys). This brings the opportunity cost of land for BMPs to $35,000 per acre. It was assumed that county-owned land dedicated to BMPs has opportunity costs that are similar to those associated with private land that may be diverted from development to a BMP, even though the county does not have to buy the land. The sources of the $70,000 was the Land Price Index (Davis and Heathcote, 2007), which accounts for the relative value of land in a time series. The Land Price Index is equal to 1.5801 in Virginia and 2.1875 in Maryland. Applying these values as a ratio, the cost of land in Virginia would be roughly 70% of the value of land in Maryland, which was estimated by King and Hagan as $100,000/acre.

Street Sweeping BMP

- Mass Loading Approach: For the mass loading approach, the street dirt collected is measured in tons at the landfill or ultimate point of disposal and converted to pounds. The TSS load is then estimated by multiplying the total particulate dry mass collected by 30%, or the fraction of material reflecting the particle size that dominates TSS (Law et al., 2008). The pounds of TN and TP can be calculated by multiplying the TSS load by 0.0025 and 0.001, respectively.

- For this study, the City of Baltimore provided an estimate of the lane miles swept and tons of debris removed per year for the period 1999-2008. We converted the lane miles swept to impervious acres swept, assuming a lane width of 10 feet. We converted tons of debris to pounds and converted the mass of solids to dry weight using a factor of 0.7. These values were used to determine the average pounds of debris removed per year from an acre of impervious cover. We increased the amount of debris removed/impervious acre by 1.5 timesbecause the City sweeps once per month, but the credit assumes a twice/month sweeping frequency. This estimate is considered conservative