Nutrient Credit Trading for the Chesapeake Bay

An Economic Study

CHESAPEAKE BAY COMMISSION

MAY 2012

Economics of Trading Advisory Council

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To Our Readers:

The Chesapeake Bay Commission is a policy leader in the restoration of the Chesapeake Bay. As a tri-state legislative commission representing the General Assemblies of Maryland, Pennsylvania and Virginia, its mission is to identify critical environmental needs, evaluate public concerns and advance state and federal actions to improve water quality and sustain the living resources of the Chesapeake Bay.

One of the responsibilities the Chesapeake Bay Commission exercises in fulfilling its mission is to provide policy research and options to its member states in their Chesapeake Bay restoration efforts. This report examines the economics of nutrient credit trading. Trading is one tool among many designed to achieve pollution reduction goals. All three member states of the Chesapeake Bay Commission are already implementing trading programs as part of their efforts to reduce the excess levels of nitrogen and phosphorus that are polluting local waters and the Chesapeake Bay.

This report does not offer a critique of the state programs. Instead, it generates data from which sound policy can evolve. It offers a foundational economic analysis that provides insights into how markets can minimize the cost of pollution reductions, with cost being one of several factors for policymakers to consider.

The members of the Economics of Trading Advisory Council were instrumental in assuring the accuracy and applicability of this work to our region. The Council's advice, coupled with the extraordinary expertise of the contractors, made the project possible.

RTI International researched and prepared this report. RTI is an independent, nonprofit institute that provides research, development, and technical services to government and commercial clients worldwide. Its mission is "to improve the human condition by turning knowledge into practice."

HOPE Impacts managed the development of the project, providing expertise on policy and technical issues as well as drafting and editing. Roy A. Hoagland, Esq., is the principal/owner of HOPE Impacts and partners with nonprofits, foundations, and government agencies on complex issues facing Chesapeake Bay restoration.

The Linden Trust for Conservation provided the funding for the research, preparation, and development of this report. As part of its mission, it seeks "to advance the use of conservation finance and environmental markets in ways that address major environmental challenges." The Commission thanks The Linden Trust for its investment in, and commitment to, a healthier Chesapeake Bay.

We thank you one and all,

Emmett W. Hanger, Jr.
Virginia Senator, District 24 &
Chairman, Chesapeake Bay Commission

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List of Abbreviations

AgrNPS	agricultural nonpoint sources
BMPs	best management practices
CAFOs	concentrated animal feeding operations
CBPO	Chesapeake Bay Program Office
CBWM	Chesapeake Bay Program Phase 5.3.2 Watershed Model
CRP	Conservation Reserve Program
CSO	combined sewer overflow
ENR	enhanced nutrient removal
EPA	U.S. Environmental Protection Agency
MGD	million gallons per day
MS4	municipal separate storm sewer system
NRCS	Natural Resources Conservation Service
O&M	operation and maintenance
SigPS	significant point source dischargers
TMDL	Total Maximum Daily Load
WIPs	Watershed Implementation Plans
WLAs	waste load allocations
WWTPs	wastewater treatment plants

Section 1

Introduction

The Chesapeake Bay ecosystem is under stress. Among an onslaught of pressures, the primary cause of this stress is the overabundance of nutrients flowing into its rivers, streams, and estuaries. The two main nutrients—nitrogen and phosphorus—are naturally occurring substances that are essential for living organisms. However, large amounts of these nutrients, most often generated by human activity, result in excess algae growth. This excess algae depletes oxygen from the water, blocks sunlight for underwater plants, and upsets the functioning of a healthy aquatic ecosystem.*

The Chesapeake Bay is particularly vulnerable to nutrient overload because it drains an area of over 64,000 square miles and averages a mere 21 feet in depth. All of the rivers, streams, and drainage systems located within this watershed eventually discharge their water into the Bay. According to the U.S. Environmental Protection Agency (EPA), during a year with average rainfall, this water carries with it over 250 million pounds of nitrogen and almost 20 million pounds of phosphorus. These nutrients come from a wide variety of sources, including sewage treatment plants, industrial facilities, runoff from agricultural fields and urban areas, and even air pollution. With the human population in the watershed expected to grow by over 2 million people over the next 20 years (Ref. 1), new strategies will be necessary to manage and reduce nutrient loads from all sources in order to restore and protect the health of the Bay ecosystem.

In response to these pollution problems, and pursuant to the requirements of the federal Clean Water Act, EPA established a Total Maximum Daily Load (TMDL) for the Chesapeake Bay in December 2010. This "nutrient diet" sets load limits (to be achieved by 2025) on the annual amount of nitrogen, phosphorus, and sediment that may enter the Bay from each of its main tributaries. These load limits were

* See *Science*, January 6, 1984, for basic information on the nutrient pollution problems of the Chesapeake.

developed in partnership with the states located in the watershed—Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia—as well as the District of Columbia, the Chesapeake Bay Commission, and the EPA. As part of the TMDL, these jurisdictions are responsible for developing and implementing Watershed Implementation Plans (WIPs) that specify how each jurisdiction will reduce nutrient and sediment pollution to meet its specific load allocation of the TMDL.

Reducing nutrient loads in the watershed is essential for restoring the Bay, which is the largest and most productive estuarine ecosystem in the United States; however, achieving these reductions will not come without a price. Installing control technologies and implementing practices that reduce nutrient pollution require both economic resources and investments. Although the total costs required to meet the TMDL goals cannot currently be defined precisely—due in part to the extensive mix of potential implementation tools and strategies—at least two things are certain: 1) the costs of these activities will, in the end, be borne by a host of sources: households, farms, businesses as well as federal, state and local governments, and 2) there is a need to place a high priority on developing and implementing strategies that reduce these costs.

Nutrient trading has emerged as one promising strategy for meeting nutrient load limits in a more cost-effective way. Under this market-based approach, certain nutrient sources, such as municipal and industrial wastewater discharge facilities, are given more flexibility for how they achieve their individual load limits. In essence, they are given two options: 1) implement pollution control practices on site, or 2) purchase the load reductions from *other* sources that reduce loads by *more* than their requirement.* In either case, the end result is the achievement of the necessary pollution reductions. However, the second option—nutrient credit trading—will likely be chosen if the other source is able to provide and sell the load reduction for a lower cost than the first option and the purchased reduction is certain and verifiable.

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* Under the Clean Water Act and state laws, there are rules requiring facilities to install treatment technologies to achieve pollutant load limits.

Again, both options, to be legitimate, must result in at least the same amount of nutrient load reductions, but the trading option offers the opportunity to do so at a lower cost.

The main purpose of this study is to investigate the *potential* cost savings that could be achieved when considering different nutrient trading scenarios. These scenarios differ in two main respects: 1) the types of nutrient sources allowed to participate, and 2) the geographic boundaries within which a trade is allowed to occur. Although four states in the watershed have initiated nutrient trading programs, it is *not* the purpose of this analysis to estimate the cost savings from each of these state-specific programs. Rather, we define a series of alternative scenarios, mixing source types and geographic restrictions, and apply these alternative trading approaches to the watershed as a whole.

This emphasis on *potential* savings is important for describing and interpreting the results of this study. It stresses that the estimates from our analysis represent the cost savings that could be achieved from trading under best-case conditions. Specifically, the study incorporates conditions where all of the available gains from trading are identified and acted on by potential buyers and sellers. The potential cost savings we estimate in this study are therefore expected to be larger than the cost savings actually achieved with trading. To mitigate any overstating of the potential savings from trading, we have incorporated in the study several conditions. See Section 6.

In practice, a variety of factors are likely to interfere with and limit the gains from trading. For instance, uncertainties and lack of information about market opportunities, or governmental policy decisions placing restrictions on trades, will discourage or restrict some buyers and sellers from participating, thus reducing the "potential" savings. Our inclusion, where feasible, of these types of factors reflects a fundamental principle to be conservative in our estimates of the potential cost savings. Unavoidably, however, this study does not capture all of the relevant market obstacles to trading. See Section 10.

Section 2

Sources of Nutrient Loads and the Bay TMDL

As shown in Figure 2-1, the Chesapeake Bay watershed includes portions of six states plus the District of Columbia. It can also be geographically subdivided into eight major river basins, whose waters drain into the Bay. The two largest basins are the Susquehanna River Basin, which includes portions of New York, Pennsylvania, and Maryland, and the Potomac River Basin, which includes portions of Maryland, Virginia, West Virginia, Pennsylvania, and Washington, D.C. Three of the basins are located entirely within a single state—the Rappahannock and York River Basins in Virginia, and the Patuxent River Basin in Maryland.

The millions of pounds of nitrogen and phosphorus that flow into the Bay each year originate from a wide variety of sources throughout the watershed. Loads from all of these sources occur despite the widespread use of technologies and practices designed to limit the flow of pollution.

As shown in Figure 2-2, recent data show that about 42% of the nitrogen and 54% of the phosphorus loads are attributable to runoff from agricultural lands, much of which is the result of animal manure and chemical fertilizer application. Practices that reduce nutrient runoff from these lands are considered as part of our trading analysis.

Another 20% of the nitrogen and 19% of the phosphorus comes from wastewater discharge facilities, both municipal and industrial, with a large majority of these loads from "significant" point sources (SigPS). These significant point sources are a major focus of our trading analysis.

Stormwater runoff from urban areas accounts for 16% of the nitrogen and 17% of the phosphorus loads. Roughly half (52%) of these urban nitrogen loads and 39% of the urban phosphorus loads come from areas that are federally regulated under rules for municipal separate storm sewer systems (MS4s). We specifically include nutrient loads from these regulated urban stormwater sources in our trading analysis.

Figure 2-1

The Chesapeake Bay Watershed and Its Major River Basins

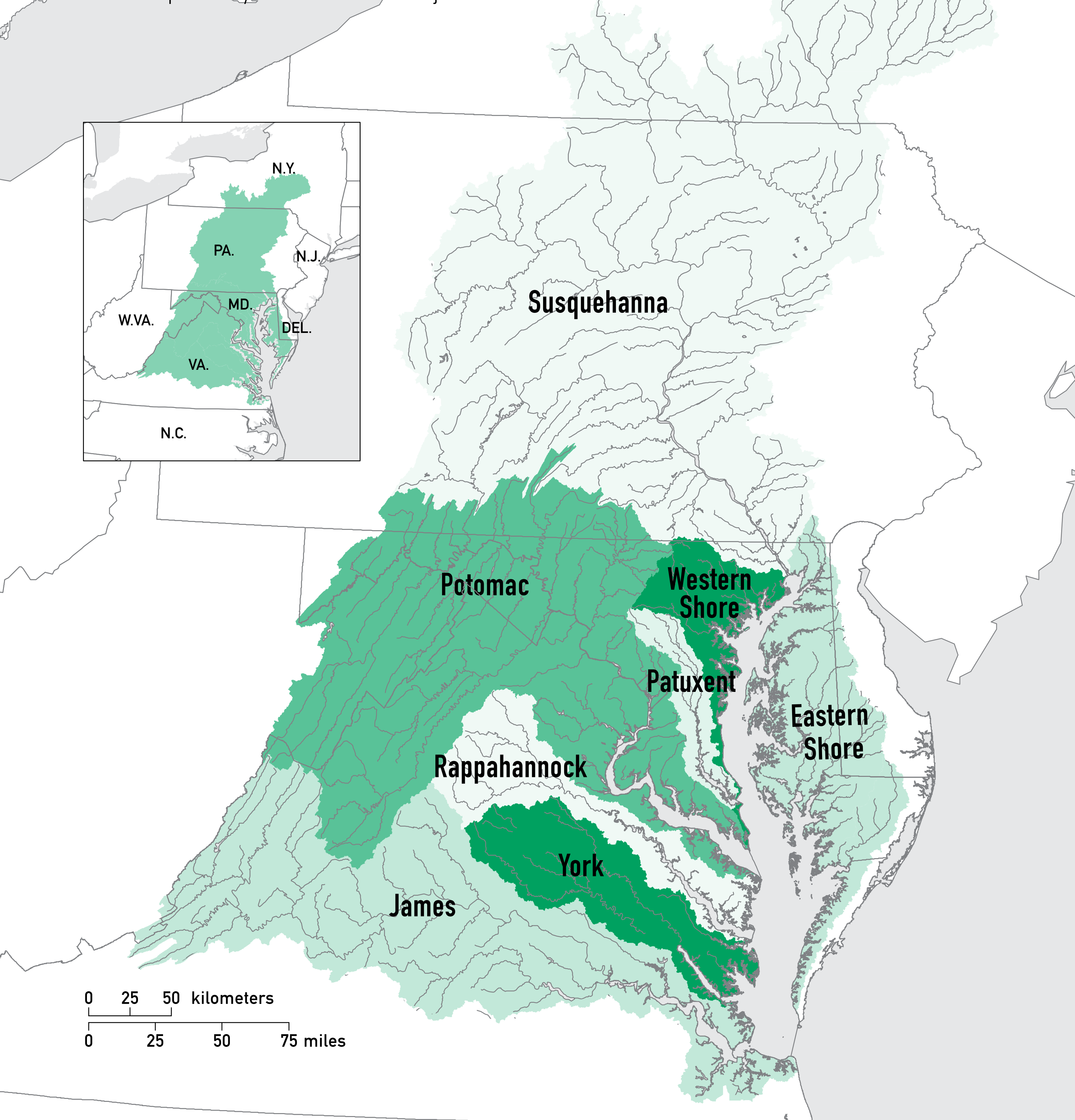
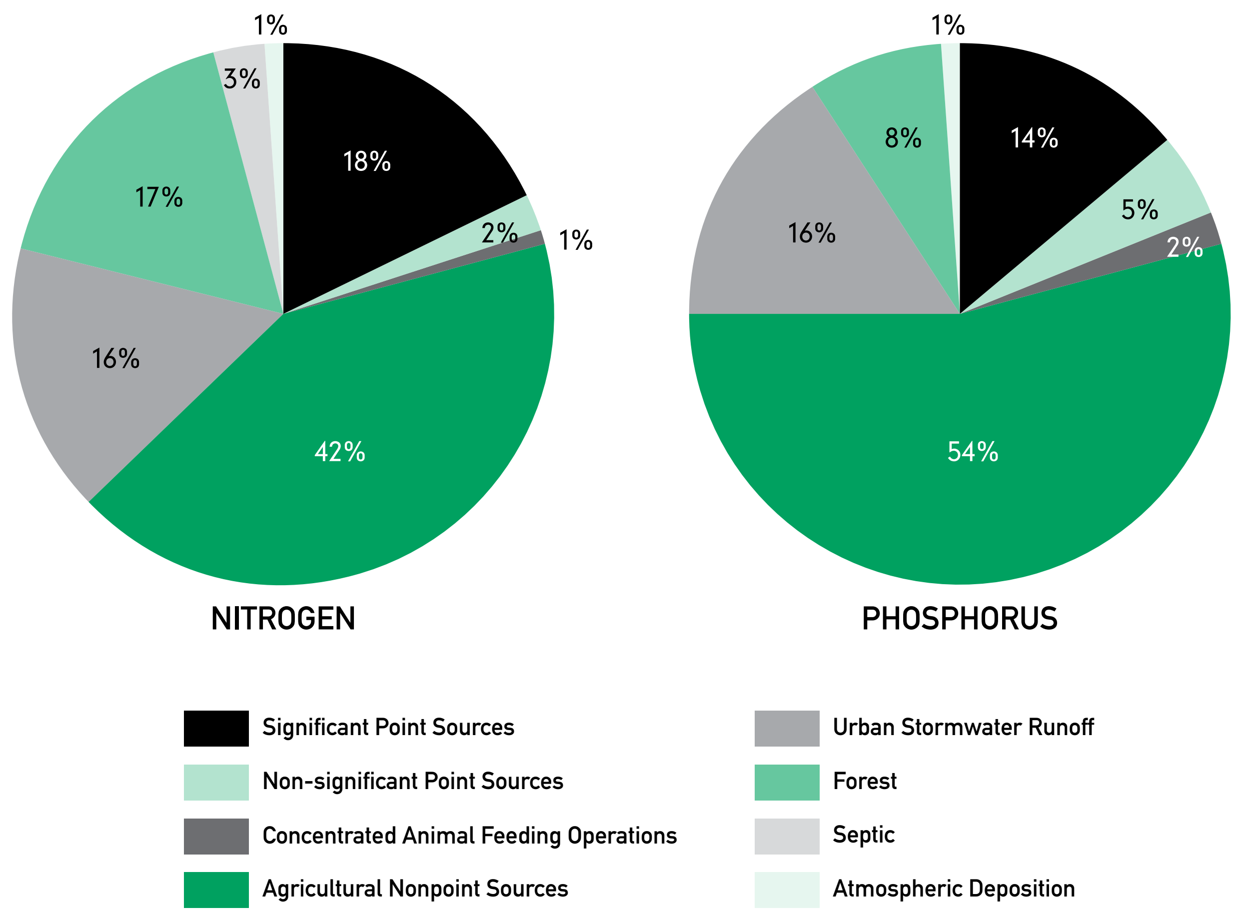


Figure 2-2

Contributions of Nutrient Loads Delivered to the Chesapeake Bay from Different Sources



SOURCE: CHESAPEAKE BAY PROGRAM PHASE 5.3.2 WATERSHED MODEL (2010 PROGRESS SCENARIO)

The other main source categories account for 25% of the nitrogen and 16% of the phosphorus loads; however, they are not included in our trading analysis. For example, concentrated animal feeding operations (CAFOs), which are defined as point sources under the federal Clean Water Act and are the only federally regulated agricultural source, account for 1% and 2% of the nitrogen and phosphorous loads, respectively.

The Chesapeake Bay TMDL, which establishes the annual load limits for nitrogen and phosphorus, subdivides the tidal area of the Chesapeake Bay into 92 segments, each with a separate drainage area.

"SigPS" Means . . .

"Significant" point sources (SigPS) include municipal wastewater treatment facilities with wastewater capacity exceeding 0.4 million gallons per day (MGD) and industrial wastewater discharge facilities with ≥ 3,800 lbs/yr annual total phosphorus or ≥ 27,000 lbs/yr total nitrogen loads. SigPS do not include any federally regulated urban stormwater sources (MS4s) or CAFOs as defined under the Clean Water Act. There are some differences within this definition of SigPS among the Bay jurisdictions (Ref. 2). In our analysis, we used each jurisdiction's actual definition of SigPS. There are a total of 475 SigPS in the watershed.

It specifies annual nitrogen and phosphorus load limits for each of these 92 segments. The states' plans for achieving these 184 (92 x 2) limits are detailed in their WIPs. In particular, the WIPs define specific annual load limits (i.e., allocations) for individual point sources and for nonpoint source sectors located in the Bay watershed, or in the unique case of Pennsylvania, aggregate allocations for each source sector by river basin. Some WIPs include nutrient credit trading among the strategies for achieving the states' pollution allocation under the TMDL.

Section 3

Nutrient Trading: A Strategy for Encouraging Cost-Effective Reductions in Nutrient Loads

Nutrient trading is a market-based strategy for meeting nutrient-related water quality goals. The idea is to harness the benefits offered by a competitive marketplace and use it to achieve environmental goals in a more cost-effective way.

A nutrient market works by establishing a mandatory cap on the *combined* pollution loads from multiple sources. It then allows trading of *individual* loads among individual sources to determine where and how the load reductions occur to meet the cap. It takes advantage of the fact that the multiple sources face different costs when seeking to accomplish the load reductions. The differences in costs occur due to myriad factors ranging from an individual source's production processes to its location or size to available technologies for reducing the load. Trading allows those sources with relatively low costs to generate "nutrient credits" by reducing loads by more than is required. The generator of the credits can then sell these credits to relatively high-cost sources, allowing the purchaser to de facto "reduce" its load at less cost.

The combined result is an overall achievement of pollution load reductions at a lower total cost. The potential costs savings from nutrient trading are illustrated in Figure 3-1 with an example involving two nutrient sources. Under the TMDL, the first source (Facility A) is required to reduce nitrogen loads to the Bay by an extra 10,000 lbs per year, but installing additional treatment technology to meet this requirement costs $200,000 per year. The second source (Facility B) is not required to further reduce its nitrogen loads, but it could achieve an additional 10,000 pound reduction for $120,000 per year. If Facility A purchases the reductions (i.e., credits) from Facility B, the cost of achieving the 10,000 lb reduction would be reduced by $80,000 per year. In other words, the total *cost savings* would be $80,000 per year. How the two parties share in these benefits depends on the price of the credits.

Figure 3-1

A Simple Example Illustrating the Potential Gains from Nutrient Credit Trading

NO TRADING

	Facility A	Facility B	Total
Cost of technology upgrade ($/yr)	$200,000	—	$200,000
N credits bought ($/yr)	—	—	—
N credits sold ($/yr)	—	—	—
Net cost (revenue) ($/yr)	$200,000	—	$200,000
Reduced N load to the Bay (lb/yr)	10,000	—	10,000

$80,000 savings from trade

TRADING

	Facility A	Facility B	Total
Cost of technology upgrade ($/yr)	—	$120,000	$120,000
N credits bought ($/yr)	$140,000	—	$140,000
N credits sold ($/yr)	—	$140,000	$140,000
Net cost (revenue) ($/yr)	$140,000	$(20,000)	$120,000
Reduced N load to the Bay (lb/yr)	—	10,000	10,000

10,000 credits at $14 each

If, for example, they agree on a credit price of $14/lb ($140,000 in total), then Facility A would benefit by $60,000 from the trade ($200,000 – $140,000), and Facility B would benefit by $20,000 ($140,000 – $120,000).

To take advantage of these potential cost-saving benefits, a large number of nutrient trading markets have begun to emerge across the country. Most importantly, four states in the Chesapeake Bay watershed—Virginia, Maryland, Pennsylvania, and West Virginia—have already initiated their own separate nutrient trading programs. Although these programs share a number of important similarities, they have also evolved independently and therefore differ in many respects. For example, all four programs allow trading of both nitrogen and phosphorus credits, include significant wastewater facilities as eligible participants, and require most new or expanding point sources to offset their loads through credit purchases. In contrast, their rules differ

Why Is the "Cap" So Important To Successful Trading?

For a nutrient credit trading system to work, the first and most critical requirement is to define a measurable and enforceable "cap." For nutrient pollution to the Chesapeake Bay, the cap is defined by the TMDL's total allowable pollution loads. The TMDL is allocated among the various sources, such that the sum of the individual allocations equals the cap. The cap ensures that the overall objective of the TMDL— in other words, reduced pollution loads to achieve healthy water quality — is attained. It also, importantly, provides the impetus for buyers and sellers to enter the marketplace.

regarding eligibility requirements and restrictions for participating in trades and required credit exchange ratios between different types of sources. Additional details about selected differences between programs are discussed in this report and briefly summarized on pages 20–21. More detailed reviews are available in the literature (Ref. 3).

Although these state-specific programs provide an important backdrop for our analysis, it is important to emphasize that **it is *not* the purpose of this report to model or predict the results of the individual states' nutrient trading programs.** Rather, we examine the potential cost-saving implications of a more simplified, generic, and uniform trading approach applied across the entire watershed.

Section 4

Framework for Analyzing the Potential Cost Savings from Nutrient Trading to Meet the Bay TMDL

To analyze the potential cost savings from trading, our fundamental approach was to find the "least-cost solution" for meeting the TMDL nutrient load reduction goals or offsetting new loads from future growth. In other words, we identified the mix of available nutrient control measures in the Bay watershed that achieves or maintains the TMDL at the lowest possible cost.

A natural question might be: *Why "potential" cost savings and not "actual" cost savings?*

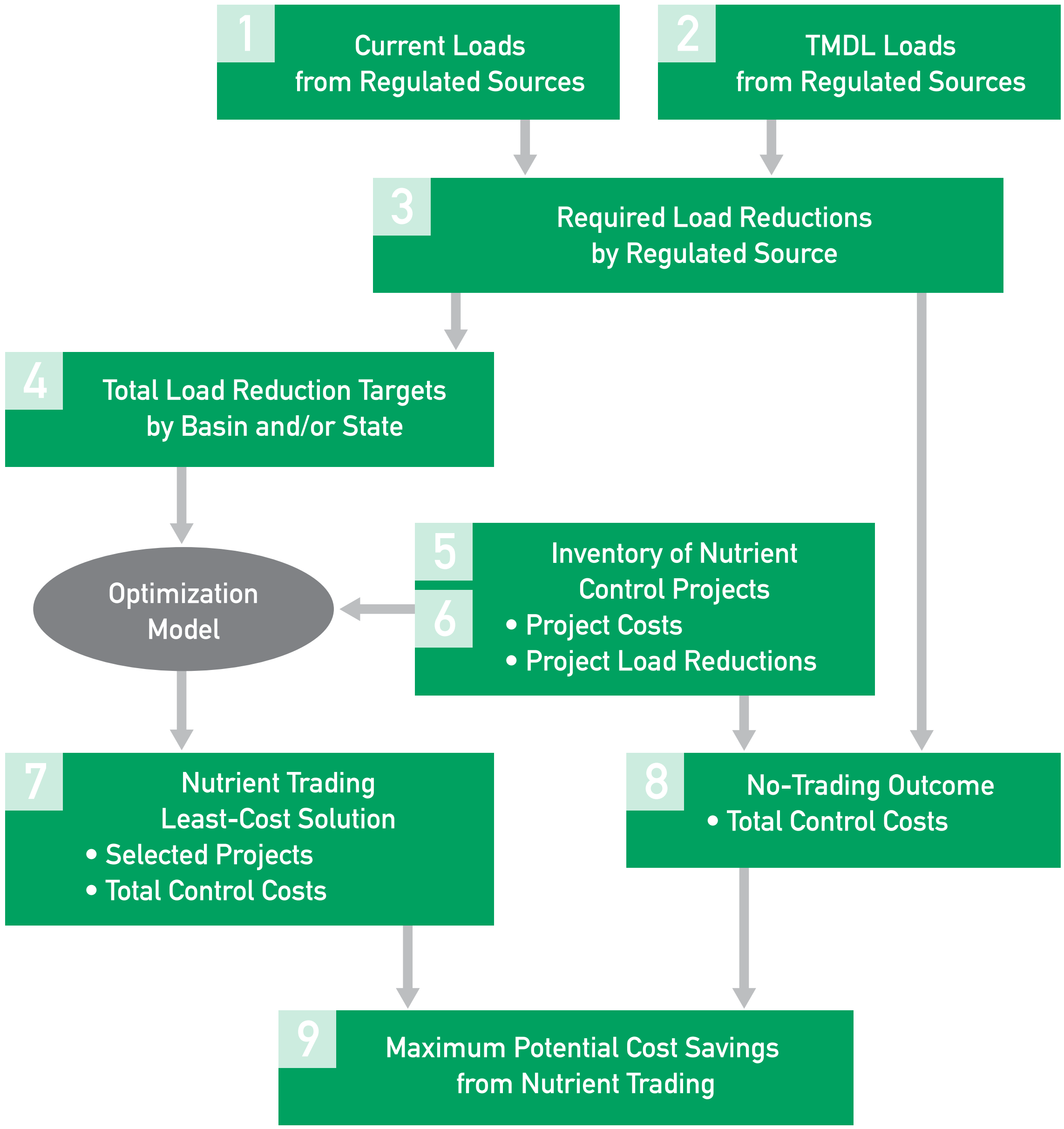
It is very important to emphasize that the least-cost solution represents the most optimistic outcome from nutrient trading. While markets provide strong incentives to reduce costs, they do not work perfectly. For these reasons, the least-cost solution of our study is best interpreted as the best-case outcome from an economic perspective, and the estimated cost reductions associated with trading are best interpreted as the upper-bound estimates of cost savings from trading. However, even these upper-bound estimates we have tempered with certain conditions and restrictions. See Section 6.

In addition, economic considerations are not the only factors used in designing and implementing trading programs. Other considerations may also result in restrictions on trading activity, which will reduce the amount of savings achieved. In particular, policy makers and program administrators must often consider factors such as certainty of reductions and social equity implications, balancing these against cost considerations. Figure 4-1 provides a simple representation of the process and framework we used to identify the least-cost solution, which we then used to estimate the potential cost savings from nutrient trading.

- **Step 1: Specify the current level of nutrient loads to the Chesapeake Bay from two categories of federally regulated sources.** Our analysis focused on

Figure 4-1

Representation of the Framework and Process for Estimating Potential Cost Savings from Nutrient Trading



annual (in 2010) nitrogen and phosphorus loads from two categories of federally regulated (under the Clean Water Act) sources in the watershed:

- significant point sources, and
- urban stormwater sources.

These sources are the potential buyers of nutrient credits in our analysis. Mainly because of data limitations, our analysis did not include other federally regulated sources such as CAFOs, non-significant point sources, and combined sewer overflows (CSO); however, as shown in Figure 2-2, these sources account for a relatively small portion of annual loads to the Bay.

- **Step 2: Specify the level of nutrient loads from these two sources under direct compliance with the TMDL.** Load limits for each source were based on information contained in the state's Phase I WIPs and the representation of these loads in the Chesapeake Bay Program Phase 5.3.2 Watershed Model (CBWM). We were unable to use Phase II WIP information due to timing issues.
- **Step 3: Calculate the required load reduction for each regulated source.** This step took the difference between current loads (Step 1) and the TMDL loads (Step 2) for each regulated source.
- **Step 4: Calculate the state-level and basin-level total load reduction targets.** For each state, the total load reduction target was equal to the sum of the required load reductions (Step 3) across all regulated sources in the state. The total basin-level targets were calculated in the same way, except the required load reductions were summed across all regulated sources in each basin.
- **Step 5: Create an inventory of available nutrient control projects for selected sources in the watershed.** Based on available wastewater treatment technologies, this step identified multiple tiers of nitrogen and/or phosphorus controls for the SigPS. For federally regulated urban sources, it identifies nine distinct best management practices (BMPs) for removing nutrients from urban stormwater runoff. The inventory

also included a total of 13 BMPs for agricultural sources. Data from the CBWM provided the location of these sources and the available projects at each source location.

- **Step 6: For each nutrient control project in the inventory, estimate 1) its annual cost, and 2) its annual reduction in loads to the Bay.** Costs were based primarily on estimates of average capital, installation, operation and maintenance (O&M), and land costs for each project type. They are expressed in annual terms, using the assumed lifespan of the project, and an assumed 7% interest rate. Reductions in nutrient loads were based mainly on estimates of current annual load levels (e.g., from Step 1) and average rates of nitrogen and phosphorus removal for each project type. Load reductions were also adjusted to account for downstream distance from each project location to the Bay (details for SigPS, agricultural BMPs, and urban stormwater BMPs are reported in Appendices A, B, and C, respectively).

- **Step 7: Simulate the nutrient trading least-cost outcome for each state or basin.** Combining the results of Step 5 and Step 6, this step applied a well-established mathematical optimization method (see Appendix D) to identify and select the mix of control projects from the inventory that achieves the basin- or state-level load reduction targets at the lowest total annual cost. It also calculated the combined annual cost of these selected projects.

- **Step 8: Estimate the costs of a No-Trading approach.** Based on the state's Phase I WIPs (as represented in the CBWM), this step identified the nutrient control projects that meet the Step 3 load reduction requirements at each individual regulated source. In this case, the load reduction requirements for a regulated source cannot be met by reducing loads from different sources. The combined annual costs of these projects represent the total annual costs of the No-Trading approach.

- **Step 9: Estimate the maximum potential cost savings associated with nutrient trading.** The final step was to calculate the difference between the total annual costs of the No-Trading approach (Step 8) and the total annual costs of the nutrient trading least-cost solution (Step 7). These cost savings can be calculated at the state or river basin-level.

The framework shown in Figure 4-1 describes the steps we took to estimate the least-cost solution for reducing current loads to achieve the TMDL. We also used this framework to examine the least-cost approach for offsetting future growth to maintain the TMDL (see Section 5's description of the "long-term" trading scenario). When examining the maintenance of the TMDL, the required load reductions are those that are needed to offset the increased loads from new or expanded wastewater treatment facilities.

A fundamental feature of this nutrient trading framework is that it is built around and expands on the Bay Program's Phase 5.3.2 CBWM. We used the CBWM because it provides the most comprehensive, integrated, and up-to-date structure available for representing conditions and nutrient control options in the watershed. The CBWM geographically subdivides the watershed into an interconnected network of 2,448 "land-river segments,"* and it simulates the flow of river and stream water through this network to the Bay. In addition, the model estimates nutrient loads to rivers and streams and simulates the movement of nutrients through the network. The CBWM also estimates the effects of a large range of management actions on nutrient loads to the Bay.

For these reasons, the nutrient trading framework was designed to incorporate and to be as consistent as possible with the CBWM. However, our framework adds to the CBWM in several important ways. Most importantly, it includes cost estimates for a broad range of nutrient control options and a mathematical optimization model to identify the least-cost approach for achieving load reduction targets.

* Note that the 2,448 land-river segments in the CBWM are different from the 92 tidal segments defined in the Bay TMDL.

Snapshot of State Trading Programs

There are several state-specific trading programs currently operating in the Chesapeake Bay watershed states. These states have created their trading programs through different mechanisms, ranging from the issuance of guidance documents to the passage of state statutes. Not only do the processes of creation differ, but also the substantive content. For a wide variety of reasons, no one state program is identical to another. In fact, the differences among the state programs are substantial. For a thorough comparison of the various state trading programs, see the World Resource Institute's "Comparison Tables of State Nutrient Trading Programs in the Chesapeake Bay Watershed" (*http://www.wri.org/publication/comparison-tables-of-state-chesapeake-bay-nutrient-trading-programs*).

Here is a snapshot comparison of some of the elements of the trading programs in the Chesapeake Bay Commission member states:

PA

The PA program is governed by a set of regulations. It allows existing point sources to purchase credits from other point sources or from nonpoint sources to reach permit-specific nutrient load limits. The baseline for credit generation by agricultural nonpoint sources focuses on a farm 1) achieving compliance with existing state laws governing nutrient management and soil and erosion control, and 2) meeting one of three additional threshold requirements. PA's trading ratios for purchase by a point source from a nonpoint source is 1:1; however, it does have a 10% reserve ratio as well as an edge of segment ratio and a delivery ratio for all certified credits.

The MD program is governed by a set of policy documents. When compared with PA and VA, the MD program is more restrictive with point source trading. This state program does not allow significant municipal wastewater treatment facilities to purchase credits to reach their TMDL reduction goals. Rather, they must implement "enhanced nutrient removal" (ENR) technology. In MD, agricultural credit generation focuses on both local and Bay water quality goals with baselines dependent upon which goal is more environmentally stringent. For all trades involving agricultural nonpoint credits, MD requires a 10% retirement ratio.

The VA program is governed by a state statute and a set of regulations. VA allows its significant point sources to purchase credits to reach their TMDL reduction goals. Unlike MD and PA, VA established a private Nutrient Credit Exchange Association to facilitate trading among Association members. In VA, state cost-shared agricultural BMPs are not eligible for generating credits. VA does require a trading ratio of 2:1 when a new or expanding point source purchases a credit from a nonpoint source.

Section 5

Nutrient Trading Scenarios

Nutrient trading programs can be configured in a number of different ways. Not surprisingly, the potential cost savings from trading will depend significantly on how a program is structured. To account for differences in program design and their effects on costs, we therefore specified a limited number of trading scenarios. These scenarios vary in two main dimensions, which are described below.

5.1 Which Sources are Eligible to Participate in the Nutrient Market?

In the **short term**, the presence of trading activity in nutrient markets will depend importantly on whether *existing* regulated sources that are *currently* exceeding their individual TMDL limits are allowed to meet their requirements by buying credits. To examine trading in the short term, we assumed that these types of trades are allowed, and we examined the following three market scenarios:

- **SigPS-Only: Trading Only Among Significant Point Sources.** This scenario examines trading under "current" conditions, as represented by data from 2010. It assumes that all 475 SigPS are eligible to buy credits to meet their TMDL reduction requirements, as defined by their Waste Load Allocations (WLAs). SigPS that reduce loads by more than their TMDL requirements are eligible to sell these additional reductions as credits. The "Snapshot of State Trading Programs" on pages 20–21 notes that some current programs restrict SigPS trades.

- **SigPS-AgrNPS: Trading Among SigPS and Agricultural Nonpoint Sources (AgrNPS).** This scenario expands on the SigPS-Only scenario by also allowing agricultural nonpoint sources to participate as credit sellers. AgrNPS do not include Concentrated Animal Feeding Operations (CAFOs), as they are federally regulated as point sources under the Clean Water Act. Additional limits and requirements for agricultural nonpoint source participation are discussed below in Section 6.

- **SigPS-AgrNPS-Urban: Trading Among SigPS, AgrNPS, and Regulated Urban Stormwater Sources (Urban).** This scenario further expands eligibility by allowing regulated sources of urban stormwater to participate. In our analysis, these sources are included as potential buyers (not sellers) of nutrient credits.

In the **long term**, trading may occur when new sources of new loads, or existing sources seeking to increase their loads, are allowed to buy credits. Credits that are used to compensate for new or additional loadings from new sources or expanded existing sources are frequently referred to as *offsets* (i.e., in trading parlance, all offsets are credits but not all credits are offsets). To examine trading in the long term, we also examined the following additional scenario:

- **Offset-Only: Trading Only to Offset Growth in SigPS.** This scenario examines trading beyond 2025, and assumes: 1) the TMDL is being met; 2) there is continued compliance among trading partners; and 3) only nutrient discharges from new municipal wastewater treatment capacity (compared with 2010) at SigPS are eligible to buy credits. 2025 is the end date for achieving the cap under the TMDL. The methods for predicting and locating new significant municipal wastewater treatment capacity are described in Section 9. All new or expanded capacity is assumed to use enhanced nutrient removal (ENR) technology. Like the SigPS-AgrNPS scenario, only SigPS and AgrNPS meeting their baseline requirements are eligible to sell credits in this scenario.

5.2 What Geographic Limits are Placed on Market Participation?

For each of the eligibility scenarios described above, we also examined the effects of different types of geographic limits on nutrient trading. Other than the No-Trading approach, the narrowest approach we examined is one that restricts trading to eligible sources located within the same basin and the same state. The most flexible approach is to allow credit trading to occur between any two eligible sources, as long as both the buyer and seller are located within the Chesapeake Bay watershed. This most flexible approach is expected to provide the largest potential cost savings when compared with the No-Trading approach.

To examine how different geographic boundaries affect the potential cost savings from nutrient trading, we examined the following four scenarios:

- **In-Basin-State Trading: Trades Only Allowed Within the Same State and Basin.** For each trade, the credit buyer and seller must be located in the same state and the same basin.
- **In-State Trading: Trades Only Allowed Within the Same State.** The credit buyer and seller must be located in the same state, but they can be located in different basins.
- **In–Basin Trading: Trades Only Allowed Within the Same Basin.** The credit buyer and seller must be located in the same basin, but they can be located in different states.
- **Watershed-wide Trading: Trades Allowed Between States and Basins.** Trading can occur between any two eligible sources, as long as both the buyer and seller are located within the Chesapeake Bay watershed.

Section 6

Additional Conditions and Restrictions on Nutrient Trading

A number of other features are also expected to affect the potential cost savings from nutrient markets. To capture these features, we included the following conditions:

6.1 Baseline Requirements for Agricultural Sources

For agricultural sources to generate nutrient credits, they must generate real reductions in nutrient loads above and beyond their "baseline" obligations. A baseline is the load allocation the source must achieve before it is eligible to generate credits from additional pollution reductions.

The Bay states have specified different baseline requirements as part of their trading programs. For example, Maryland has adopted a performance-based standard that included compliance with existing regulatory requirements and the implementation of BMPs equivalent to TMDL-based loading rates (as determined by an on-farm calculation). In contrast, Virginia has adopted a practice-based standard that requires the adoption of five specific BMPs. Differences such as these can impact the trading market. In both cases, only upon achieving additional reductions above and beyond those achieved by these baseline requirements does the farm qualify for credit generation.

For our analysis, the agricultural baseline is defined as the level of BMP implementation specified in the state's Phase I WIPs (as represented in the CBWM's TMDL scenario). According to this definition, BMP projects included in the TMDL scenario are incorporated in the baseline and are therefore not eligible to generate credits.

6.2 Baseline Requirements for Significant Point Sources

In our analysis, there are two main requirements for a SigPS to generate credits: 1) it must reduce nutrient loads to a level below its wasteload allocation (WLA), and 2) it must reduce nutrient loads below its current

(2010) level. The first condition ensures that credits are not awarded for load reductions required under the TMDL. The second condition implies that if a SigPS is currently discharging loads below its WLA level, it cannot sell credits for this difference between its current loads and its WLA. It can only generate credits if it further reduces its nutrient loads below its current level.

It is important to note that the second requirement is not always used in existing trading programs. For example, under Virginia's program for nutrient trading, wastewater treatment plants (WWTPs) discharging below their required limits can sell their excess to WWTPs that are discharging above their limit. These trades give the purchasing WWTPs additional time to implement required technology upgrades, but the trades inherently provide a temporary solution. In the interim, the load limits are met and costly short-term upgrades are avoided; however, no reductions in nutrient loads from current levels occur.

We included the second condition in our analysis to ensure that the same total amount of nutrient load reduction occurs under both the No-Trading and Trading scenarios. That way, none of the estimated cost savings from the Trading scenarios can be attributed to lower nutrient load reductions compared with the No-Trading scenario.

6.3 Transaction Costs

Transaction costs in nutrient credit markets refer to the costs of establishing a legally binding contract between buyers and sellers, including negotiation, approval, monitoring, enforcement, and insurance costs (Refs. 4, 5). Higher transaction costs make it more expensive to generate and exchange credits; therefore, they tend to reduce the volume of credit trading that occurs. Transaction costs can, of course, vary over time; for example, if contract negotiation reaches a certain level of standardization due to multiple trades over time, those transaction costs can decline.

Although most of the work to date on transaction costs has been qualitative in nature, a few studies have attempted to directly estimate transaction costs of environmental markets or conservation programs.

The transaction costs estimates from these few studies range between 10% and 50% of the other costs of generating credits.*

To account for the effects of transaction costs on nutrient trading, in our analysis we included a 38% cost adjustment factor for trades involving agricultural nonpoint sources. To apply the adjustment factor, we augmented the annual costs of all agricultural BMPs (see Appendix B for details) by 38%. We focused on transaction costs for these sources, because the costs of monitoring and verifying the performance of agricultural BMPs tend to be particularly time and resource intensive.

We adopted the 38% adjustment factor because it corresponds with estimates from a study analyzing the U.S. Department of Agriculture's (USDA's) Natural Resources Conservation Service (NRCS) programs, which target similar agricultural BMPs (Ref. 6), and a study of a nutrient program in the Minnesota River Basin (Ref. 7). Considering the range of estimates from the literature, a 38% estimate represents a relatively high adjustment factor for transaction costs; it is also consistent with the decision to be conservative in our analysis and guard against overstating the potential cost savings from trading.

This approach to including transaction costs assumes that these costs increase in direct proportion with 1) the number of acres on which the BMP is applied, and 2) the other annual costs of the BMP. This approach also assumes that the transaction cost factor is the same for all agricultural BMPs. In practice, some of the costs of identifying trading opportunities, negotiating agreements, and monitoring and verifying performance may be more fixed relative to other costs and the number of acres; however, we used these simplifying assumptions to make the analysis tractable.

By using a relatively high transaction cost factor, we assume that it includes expenses that are typically borne by the government, such as

* Galik et al. (Ref. 8) estimate that the transaction costs of U.S. forest carbon offset programs could be as high as 25% per credit sold. Heimlich (Ref. 9) assessed transaction costs of USDA-NRCS programs, finding a factor 10% to 15% for the Conservation Reserve Program (CRP), but a much higher rate for the Environmental Quality Improvement Program (40% to 50%). McCann and Easter (Ref. 6) also find relatively high transaction cost factors for NRCS technical assistance programs (38%). Finally, Fang et al. (Ref. 7) found a 35% transaction cost factor for a nutrient program in the Minnesota River Basin.

costs from providing technical support or establishing a state registry. For these costs to affect trading behavior, we assume they are passed on to credit buyers or sellers, for example, through a fee levied on each trade.

In contrast, our analysis does not include transaction costs for SigPS credit sellers. Although these transaction costs are likely to be relatively small because of existing monitoring, reporting, and verification of nutrient loads, they may nonetheless have an effect on trading activity. If so, including these transaction costs would slightly reduce the cost savings from all of the trading scenarios.

6.4 Trading Ratios

As a general rule, load reductions from nonpoint sources, like agricultural BMPs, are more uncertain than those from point source control technologies, in part because they are more difficult to monitor and verify. To address this difference in uncertainty, one commonly used approach by trading programs is to impose a "trading ratio" for credit exchanges between point and nonpoint sources. Virginia, for example, currently requires a 2:1 trading ratio for nonpoint source credits purchased by a new or expanding point source. That is, for every credit needed, the point source must purchase two credits from the nonpoint seller. Other programs, for example Maryland, require purchasers of nonpoint credits to also purchase a set aside equal to 10% of the credit value. For our analysis, we include a 2:1 trading ratio for credits generated from agricultural BMPs. This relatively high trading ratio is also consistent with our decision to be conservative in the analysis and guard against overstating the potential cost savings from trading,

6.5 Loss of Productive Farmland

One other concern about trades involving agricultural nonpoint sources is that some BMPs remove land from agricultural production. For example, using riparian buffers, wetland restoration, or land retirement to reduce nutrient loads also diminishes traditional farming activities. For this reason, Maryland, Pennsylvania, and West Virginia have all placed restrictions on credit sales that idle substantial areas of productive farmland.

The maximum acreage that can be enrolled in the USDA's Conservation Reserve Program (CRP) and Wetland Reserve Program cannot exceed 25% of cropland in a county. Consistent with this, we restricted the conversion of agricultural land due to BMP implementation to 25% within each unique land-river segment and land use combination.

6.6 Limits on Total Credit Trades

As discussed above, the TMDL consists of nitrogen and phosphorus load limits for 92 tidal segments in the Bay. In practice, a major factor in determining these segment load limits was the need to improve water quality in the main channel, or mainstem, of the Bay. That is, the total segment load limit for each of the 92 tidal segments is a combination of that which is protective of the segments' water quality plus that which is protective of the mainstem.

One result of this is that most of the 92 segments' load limits are lower than what is necessary to protect water quality in the segment. This "overshooting" means that load limits can be safely exceeded in some segments without risk to that segment's local tidal water quality. To account for this mix of local and Bay mainstem load limits, EPA provided a conservative estimate of a total of 9 million pounds of nitrogen and 200,000 pounds of phosphorus that could be traded without causing water quality impacts in the tidal segment receiving the increased, or credited, load (see Appendix E for a description of EPA's analysis). Thus, in our scenarios, we limited the total potential tradable loads to these amounts as specified by EPA.

Ensuring Local Water Quality Protection

The issue of limiting trades and ensuring local water quality protection underscores one of the fundamental concerns that arises as a result of nutrient trading. In addition to reducing the overall costs of nutrient reductions, nutrient trading can also change the geo-spatial pattern of load reductions. It can allow for relatively more pollution load reductions in one receiving water and less in another (when compared to conditions without trading). There may be instances, particularly in upstream freshwater areas of the watershed, where localized limits on nutrient pollution exist for the purpose of protecting local freshwater quality, as opposed to protecting the tidal waters of the Bay or the Bay mainstem. Trades cannot be allowed if they result in violations of these upstream local water quality load limits.

Ensuring that any redistribution of loads from trading is legally protective of local, non-Bay TMDL nutrient load limits is a critical element of a viable and successful nutrient trading program. For the purpose of our trading analysis, we assume that current (2010) load levels do not violate these other localized limits nor does the shifting of loads from trading. Nevertheless, we acknowledge that these assumptions may not always hold and that there may be additional restrictions on trading as a result.

Section 7

Load Reduction Targets (Steps 1 Through 4)

As described in Figure 4-1, the main objective of the first four steps of the analysis is to define the total annual nitrogen and phosphorus load reduction targets. These targets vary depending on the scenarios described in Section 5. That is, they depend on 1) the types of sources included in the trading scenario, and 2) the geographic limits placed on trading.

7.1 Load Reduction Targets for Significant Point Sources

There are currently 475 SigPS (399 municipal and 76 industrial wastewater discharge facilities) in the Chesapeake Bay watershed. Using data from EPA, we first estimated the annual 2010 "delivered" nitrogen and phosphorus loads for each facility.* The measurement of delivered loads accounts for two main factors: 1) the amount of nutrients that are discharged from the facilities to nearby surface water, and 2) the natural attenuation of nutrients as they travel from the point of discharge through the river network to the tidal waters of the Bay. All else being equal, facilities that are located farther upstream from the Bay will have lower delivered loads due to this attenuation process.

Second, we estimated annual delivered loads from each facility assuming direct compliance with the TMDL requirements. Direct compliance means that facilities meet their requirements without nutrient trading. For facilities currently discharging at levels above their annual WLA, we assumed that each facility installs the nutrient control technology that would be needed to meet their WLA if they were operating at full capacity. Section 8 of this report provides more detail on the technology options used in our analysis.

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* EPA's facility loading data are for 2009. We projected these estimates to 2010 by assuming that each facility's loads increased at the same rates as total population growth from 2009 to 2010 in its county.

Third, we calculated the required delivered load reduction for each facility as the difference between the previous two estimates. Finally, for each basin, state, basin-state combination, and for the watershed as a whole, we estimated the total load reduction targets for SigPS. These totals are equal to the sum of required load reductions for facilities in each geographic segment. These load reduction targets are reported in Table 7-1.

7.2 Load Reduction Targets for Regulated Urban Stormwater Sources

According to the Chesapeake Bay Program Phase 5.3.2 Watershed Model (CBWM), in 2010 roughly 4.8 million acres in the watershed were categorized as urban lands.* Of this total, roughly 52% is categorized as regulated urban land within the CBWM and therefore required to meet WLAs under the TMDL. To estimate the load reduction targets for these sources, we used a very similar 4-step process as described for SigPS, in this case comparing loadings with additional urban BMPs under the TMDL and loadings without those additional BMPs. However, rather than using facilities as the unit of analysis, we used regulated urban acres in each land-river segment (from the CBWM). Table 7-1 also summarizes the load reduction targets for these sources.

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* This acreage includes only pervious and impervious urban areas. Urban construction and extractive areas were excluded from our trading analysis.

Table 7-1.

Delivered Load Reduction Targets for SigPS and Regulated Urban Stormwater Sources, by Basin, State and Basin-State (millions of lbs/year)

		SigPS		Regulated Urban Stormwater	
BASIN	STATE	NITROGEN	PHOSPHORUS	NITROGEN	PHOSPHORUS
Eastern Shore	Delaware	16,265	0	213	9
	Maryland	271,242	21,579	7,918	514
	Pennsylvania	0	0	19,998	627
	Virginia	198,746	2,274	0	0
	EASTERN SHORE TOTAL	486,253	23,853	28,129	1,150
James	Virginia	9,565,746	596,542	168,553	23,637
	West Virginia	0	0	0	0
	JAMES TOTAL	9,565,746	596,542	168,553	23,637
Patuxent	Maryland	47,552	15,571	56,141	5,970
	PATUXENT TOTAL	47,552	15,571	56,141	5,970
Potomac	District of Columbia	1,530,618	0	15	2
	Maryland	218,557	36,411	113,191	9,536
	Pennsylvania	55,572	32,775	35,694	2,146
	Virginia	716,517	112,135	159,182	11,784
	West Virginia	109,952	78,777	0	0
	POTOMAC TOTAL	2,631,216	260,098	308,082	23,467
Rappahannock	Virginia	57,861	18,922	9,356	1,108
	RAPPAHANNOCK TOTAL	57,861	18,922	9,356	1,108
Susquehanna	New York	614,862	121,018	7,089	540
	Maryland	0	0	4,393	198
	Pennsylvania	4,725,252	256,906	2,625,468	70,408
	SUSQUEHANNA TOTAL	5,340,114	377,924	2,636,950	71,146
Western Shore	Maryland	4,650,796	178,742	128,179	11,219
	Pennsylvania	0	0	0	0
	WESTERN SHORE TOTAL	4,650,796	178,742	128,179	11,219
York	Virginia	502,936	19,790	21,765	2,823
	YORK TOTAL	502,936	19,790	21,765	2,823
	DC Total	1,530,618	0	15	2
	Delaware Total	16,265	0	213	9
	Maryland Total	5,188,147	252,303	309,820	27,437
	New York Total	614,862	121,018	7,089	540
	Pennsylvania Total	4,780,824	289,681	2,681,161	73,180
	Virginia Total	11,041,806	749,663	358,856	39,352
	West Virginia Total	109,952	78,777	0	0
	GRAND TOTAL	23,282,474	1,491,442	3,357,154	140,519

Section 8

Inventory of Nutrient Control Projects (Steps 5 Through 6)

8.1 Significant Point Sources

As previously noted, 475 SigPS are located in the watershed. Under the No-Trading scenario, each facility discharging above its WLA must employ a technology that directly complies with its TMDL requirement. In other words, direct compliance is the *only* option. In contrast, under the trading scenarios, they have the following additional options: 1) install a more advanced nutrient removal technology than the compliance option and sell credits for the above-compliance removal, or 2) make no change or reduce loads by installing a less advanced removal technology (compared with the compliance option) and purchase credits to make up the shortfall.

To represent these additional technology options faced by SigPS, we used data from EPA to define 16 discrete "tiers" of nutrient removal (see Appendix A for details). These tiers represent combinations of targeted nitrogen and phosphorus concentrations in wastewater discharges. For nitrogen, the options are 8 mg/l, 5 mg/l, and 3 mg/l and for phosphorus they are 1 mg/l, 0.5 mg/l, and 0.1 mg/l. In addition, each facility has the option to stay at its current (2010) concentration of nitrogen or phosphorus. Importantly, however, facilities cannot choose options with concentrations that are higher than their current concentration levels. For example, a facility with current concentrations of 6 mg/l of nitrogen and 0.6 mg/l of phosphorus does not have the option to choose the technology tiers resulting in 8 mg/l of nitrogen or 1 mg/l of phosphorus. Choosing these options would imply increasing their nutrient loads, which is not an allowable option.

For each facility, the annual load reductions from these technology options depends on 1) the facility's annual wastewater flow, and 2) the reduction in nutrient concentrations in this flow (compared with current concentrations). To calculate the reduction in *delivered* loads to the Bay, we also accounted for the natural in-stream attenuation process between the point of discharge and the downstream tidal area of the Bay.

To estimate the annual costs of these technology options for each facility, we also relied primarily on estimates reported in studies by EPA and Chesapeake Bay Program Office (CBPO) (Refs. 10, 11) as well as more recent analyses currently being conducted by the CBPO. Based on these sources, we estimated an average capital cost per million gallons per day of wastewater capacity for each technology tier. We converted this estimate to an annual cost, assuming a 20-year lifetime and a 7% discount rate. We also estimated average annual O&M costs per unit of wastewater flow (in 2010). For each facility, we estimated the total annual cost of each technology option as the sum of these two average annual costs.

8.2 Agricultural BMPs

To incorporate nutrient trading with AgrNPS (agricultural nonpoint sources), we included in our analysis 13 commonly used BMPs for controlling nutrient runoff from farmland.* A list of these BMPs is shown in Figure 8-1 and descriptions of the practices are included in Appendix B. All of the BMPs are also included in the CBWM. Although many BMPs can be applied to any type of farmland, some are only applicable on cropland (e.g., cover crops and continuous no-till agriculture) or pastureland (e.g., livestock exclusion and offstream watering).

We used results from the CBWM to identify where these BMPs can be applied to generate nutrient credits. Based on information provided by the states in their Phase I WIPs, for each land-river segment in the watershed, the CBWM provides estimates of the number of farmland acres that will need to be treated by these BMPs to meet the TMDL allocations for agriculture. We interpreted these estimates as the baseline

* Recognizing that farmland can be treated by more than one BMP, we actually include a total of 53 BMP combinations in the analysis.

for agriculture's participation in the nutrient market (see Section 6.1 for discussion of agricultural baseline), and we used them as the point of reference for our analysis.

In other words, we used these estimates from the CBWM to identify the *remaining* acres in each land-river unit that are available to generate credits by implementing *additional* BMPs.

To estimate the nitrogen and phosphorus load reductions provided by these additional BMPs, we used data from the CBWM to first estimate 1) the average per-acre load on available farmland under baseline conditions (as defined in Section 6.1), and 2) the average percentage reduction in loads (i.e., removal efficiency) for each BMP. Multiplying these two estimates gives us per-acre load reduction estimates for each BMP.

Using data from a summary of BMP cost studies and estimates (Ref. 12), we also estimated a per-acre annual cost for each BMP. As relevant, they include one-time installation and capital costs, annual O&M costs, and land costs. Like the capital costs for SigPS, the one-time costs for the BMPs were converted to annual terms using a fixed project lifetime and a 7% discount rate. The project lifetime varies across BMPs (from 1 year for cover crops to 15 years for conversion of farmland to forestry). The land costs apply only to the BMPs that require removing land from traditional farm production, and they represent the resulting foregone farm income (i.e., opportunity cost). These land costs are approximated by the average annual rental rate for cropland or pastureland in the county and adjusted by state-specific payment adjustments for BMP implementation (e.g., Maryland pays three times the annual rental rate for acres converted to forest buffers and two and a half times for grass buffers). As a result, the size of the land cost component depends on where the BMP is applied in the watershed.

As described in Section 6.3, in our trading analysis, we further augmented these agricultural BMP costs by 38% to account for transaction costs. We included these additional costs mainly to capture the costs of performance monitoring and verification, which can be particularly high for these types of nonpoint source controls.

One way to evaluate these different BMPs is to compare their "cost-effectiveness" in removing nutrients. The cost-effectiveness of a BMP can be represented by the cost per pound of delivered nitrogen or phosphorus load it removes each year. The more cost-effective BMPs have lower cost-removal ratios. For each agricultural BMP, Figures 8-1 and 8-2 present the range (from 25th to 75th percentile) of estimated cost-effectiveness for nitrogen and phosphorus removal. Note from the graphs that it is generally less costly to remove a pound of nitrogen from runoff than a pound of phosphorus. For nitrogen, the median (50th percentile) costs for agricultural BMPs are mostly below $100 per pound. For phosphorus, they are higher, but all are below $1,000 per pound. Transaction costs are not included in these reported values, but if they were they would simply increase all of the values for agricultural BMPs by 38%.

8.3 Urban Stormwater BMPs

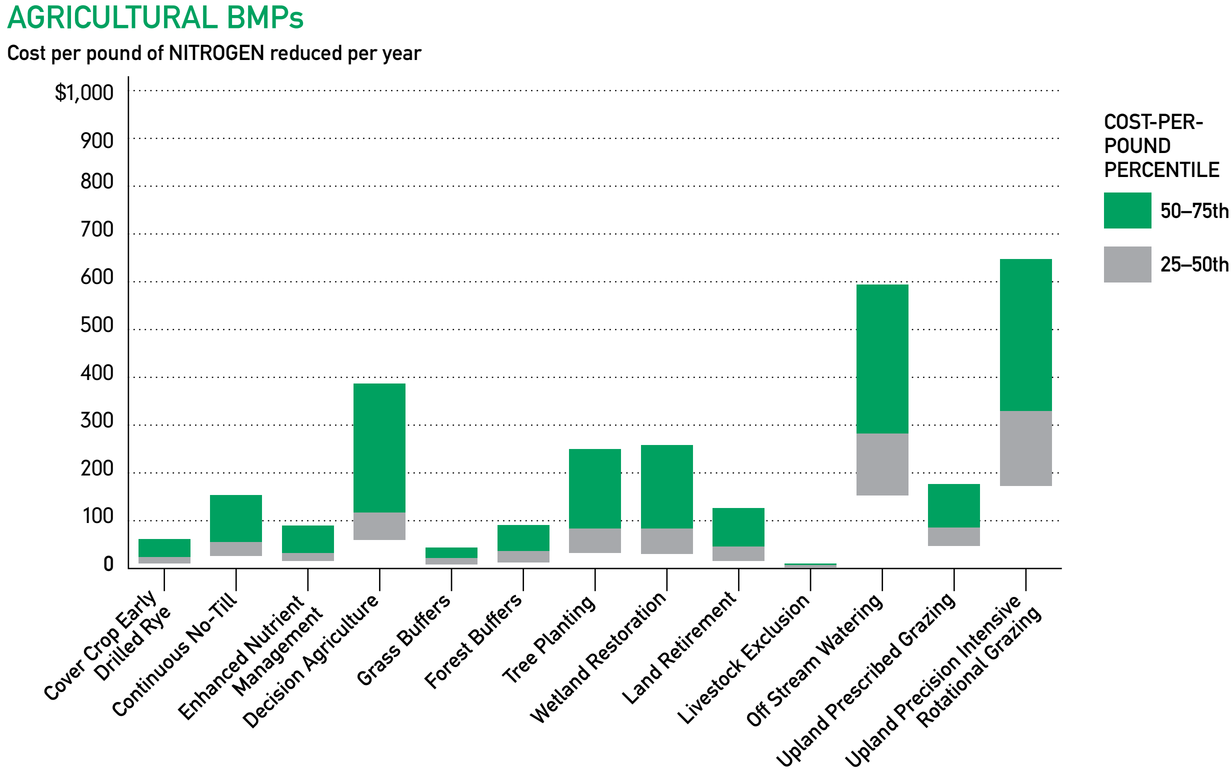
We also include nine BMPs for controlling nutrients from urban stormwater runoff. The list of these BMPs is also shown in Figures 8-1 and 8-2 and descriptions of the practices are included in Appendix C. All of these BMPs are also included in the CBWM. Two of these BMPs are restricted to urban acres with pervious surface areas—urban forest buffers and urban nutrient management—while one BMP is restricted to impervious surface areas—street sweeping.

In contrast to agricultural sources, we did not include urban sources as potential sellers of credits. In our analysis, they are only purchasers of credits. This assumption is due primarily to the relatively high costs of urban stormwater BMPs—these high costs make urban sources much more likely to be a purchaser rather than a seller when looking to meet Bay TMDL reduction goals. However, it is important to note that 1) not all jurisdictions allow urban sources to meet their TMDL goals by purchasing credits (e.g., Maryland), and 2) there are situations where urban sources, both regulated and nonregulated, might be a seller of credits (e.g., where an urban source implements a practice to improve local water quality for purposes other than nutrient pollution reduction yet nutrient reductions occur, creating saleable credits).

We again relied on the CBWM to determine the reference point for credit trading. For each land-river segment in the watershed, the CBWM provides estimates of the number of regulated urban acres that will need

Figure 8-1

Comparison of Nitrogen Removal Cost-Effectiveness for Agricultural and Urban Stormwater BMPs



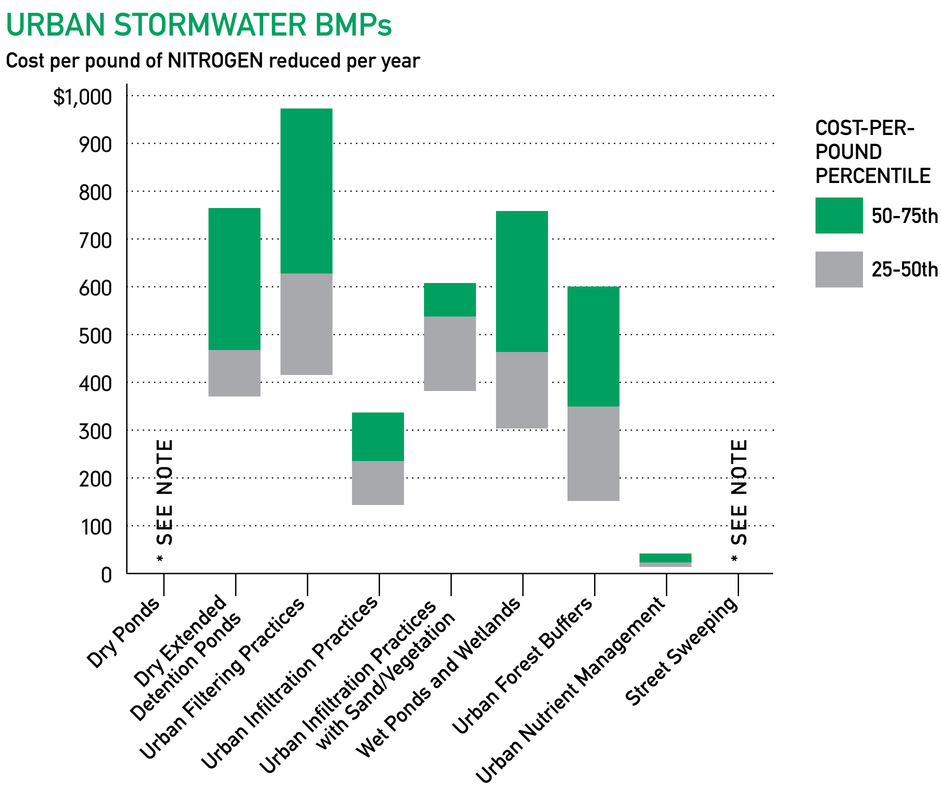


FIGURE 8-1 NOTES

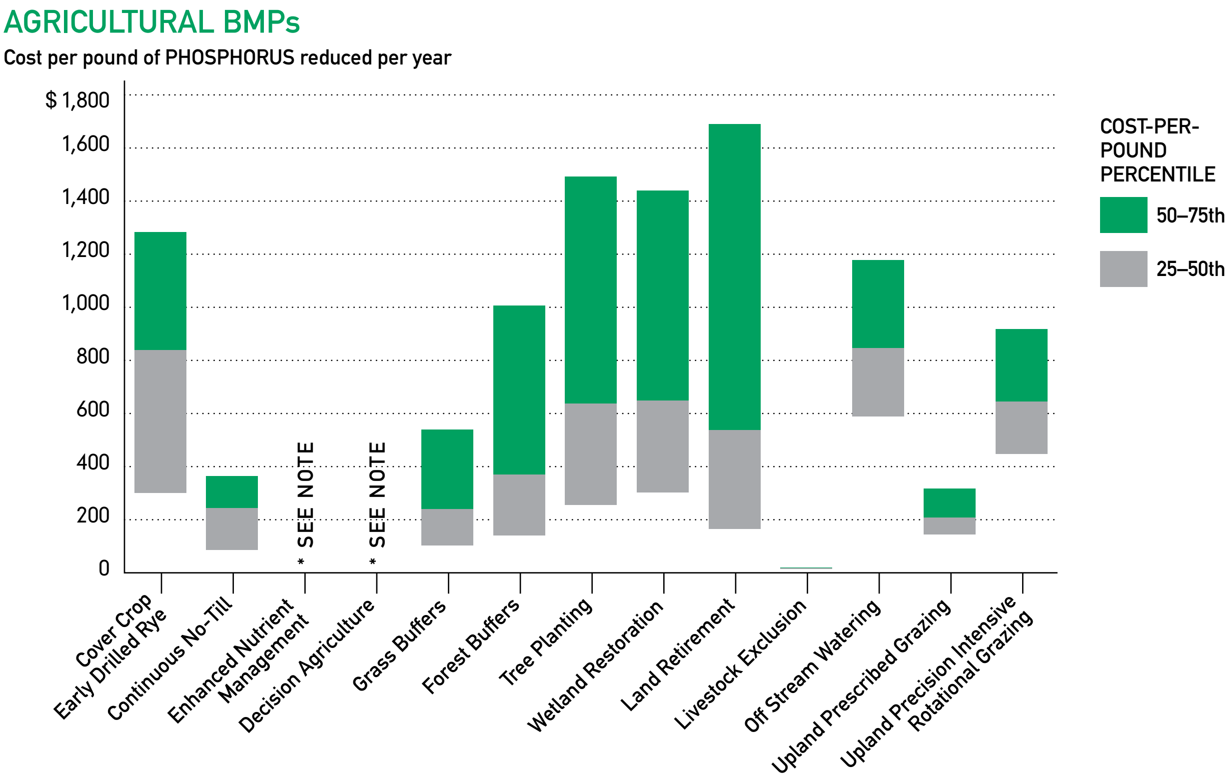
The reported value ranges cover all areas available for BMP application, including areas where the cost per pound removed is relatively high (i.e., not cost-effective) and the BMPs are therefore less likely to be implemented.

* The value ranges for Dry Ponds and Street Sweeping BMPs are not shown because they are all above $1,000/lb.

In constructing the range of BMP opportunities, we incorporated early drilled rye as the only cover crop option because, according to the available estimates, it accomplishes the most reductions for the least cost compared to other cover crops. However, in parts of the watershed, this BMP is not preferred because of its invasive characteristics.

Figure 8-2

Comparison of Phosphorus Removal Cost-Effectiveness for Agricultural and Urban Stormwater BMPs



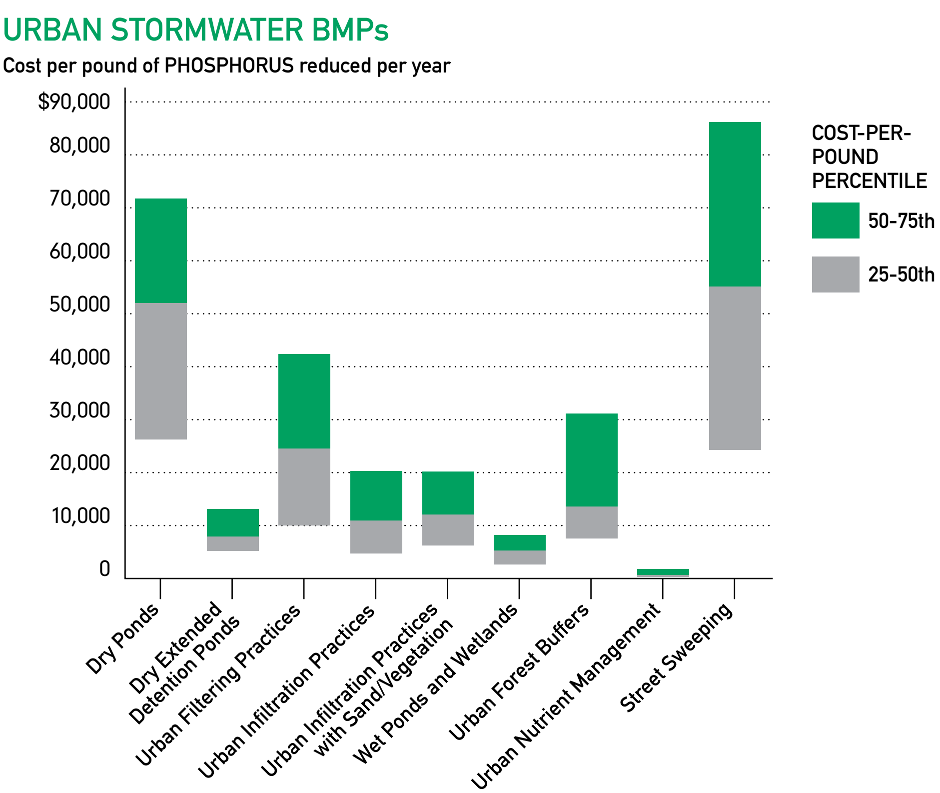


FIGURE 8-2 NOTES

The reported value ranges cover all areas available for BMP application, including areas where the cost per pound removed is relatively high (i.e., not cost-effective) and the BMPs are therefore less likely to be implemented.

* The values for Enhanced Nutrient Management and Decision Agriculture are not present because they do not have associated phosphorus reductions.

In constructing the range of BMP opportunities, we incorporated early drilled rye as the only cover crop option because, according to the available estimates, it accomplishes the most reductions for the least cost compared to other cover crops. However, in parts of the watershed, this BMP is not preferred because of its invasive characteristics.

to be treated by these BMPs to meet their TMDL waste load allocation. These estimates are also based on information provided by the states in their Phase I WIPs. Our analysis allowed urban areas to not implement these BMPs; however, they must replace the foregone nutrient load reductions with equivalent reductions from other sources.

To estimate the load reductions provided by these urban BMPs, we used the same approach as for agricultural BMPs. That is, we used data from the CBWM to estimate: 1) the average per-acre load (without the BMP) from urban land in the land-river segment, and 2) the average nutrient removal efficiency for each BMP.

To estimate the per-acre annual cost for each BMP, we again relied on a summary of existing BMP cost studies and estimates (Ref. 12). In general, the number of available studies and cost estimates for urban stormwater BMPs is less than for agricultural BMPs, which have been more intensively studied. As a result, the cost estimates for urban BMPs are subject to more uncertainty. The cost estimates for these BMPs also include one-time installation and capital costs, annual O&M costs, and land costs. The one-time costs for the BMPs were converted to annual terms using a fixed project lifetime and a 7% discount rate. The project lifetime varies across BMPs (from 3 years for urban nutrient management to 20 years for extended detention ponds). The land costs apply only to the BMPs that require removing land from other productive uses—all but street sweeping and urban nutrient management—and were assumed to be $100,000 per acre.

For each BMP, Figures 8-1 and 8-2 present the range (from 25th to 75th percentile) of estimated cost-effectiveness for nitrogen and phosphorus removal. For both nutrients, the urban stormwater BMPs tend to be much less cost effective (i.e., have a high dollar per lb reduced ratio) than the agricultural BMPs. For nitrogen, the median (50th percentile) costs are mostly above $300 per lb reduced, whereas only one of the agricultural BMPs has a median cost in this range. For phosphorus, the differences are even larger; therefore, they are reported on different scales in the figures. The median costs for the urban stormwater BMPs are mostly above $10,000 per lb of phosphorus removed, compared to less than $1,000 per lb removed for the agricultural BMPs.

Section 9

Potential Cost Savings From Trading (Steps 7 Through 9)

The results summarized in the previous sections define: 1) nutrient load reduction targets for the different sources under different trading scenarios, and 2) the inventory of control projects that are available in the watershed for achieving those targets. As shown in Figure 4-1, the next step in the analysis is to apply these results in an optimization model to find the combination of control projects that achieves these targets for the lowest total cost. We interpreted this least-cost solution as a representation of the best-case outcome from nutrient trading. Next, we compared these cost estimates with those from a No-Trading scenario. We interpreted the difference between these cost estimates as the maximum potential cost-savings from nutrient trading. Below, we summarize the results from applying these final steps (see Appendix F for more detailed results).

9.1 Potential Cost Savings from SigPS-Only and SigPS-AgrNPS Trading

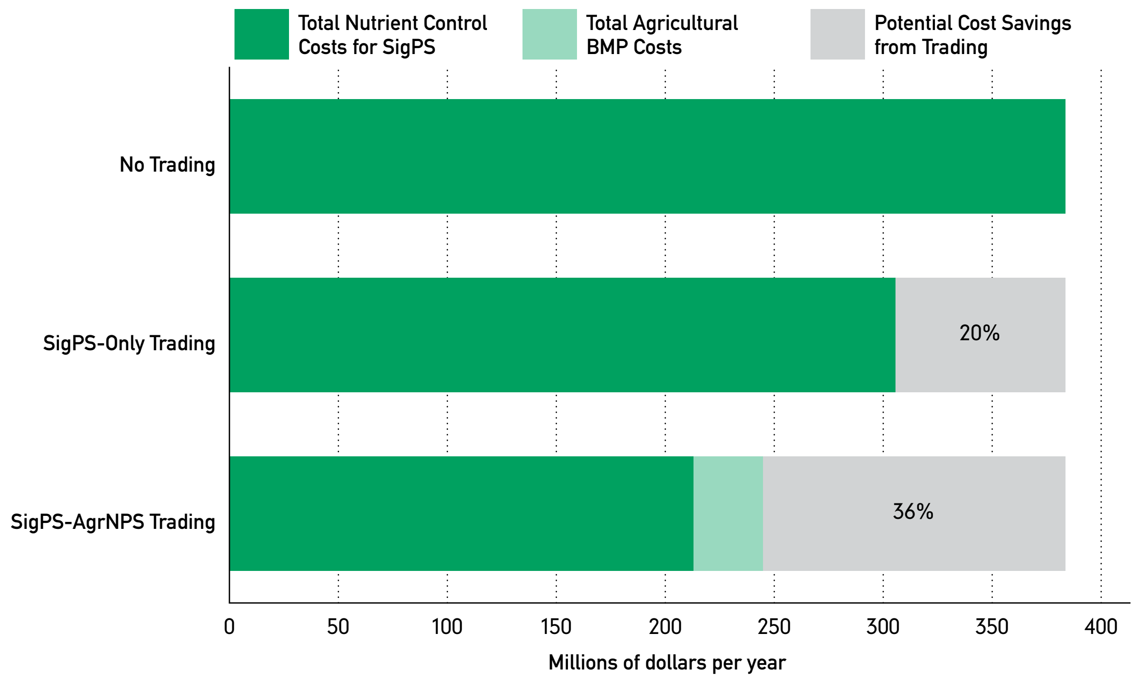
Figure 9-1 summarizes results for the scenarios where SigPS are the only buyers of nutrient credits (SigPS-Only and SigPS-AgrNPS) and trading is limited to sources that are located within the same basin and the same state (In-Basin-State Trading). Under the No-Trading scenario, we estimated the total annual costs of TMDL compliance for SigPS to be roughly $385 million per year.

If SigPS are allowed to trade, but only with other SigPS in the same basin and state, we estimated that the total annual costs of achieving the same load reductions targets (in each basin-state) could be as much as 20% lower than the No-Trading scenario. Applying this 20% cost savings to the total estimated cost of $385 million yields a cost savings of as much as $78 million per year.

If SigPS are allowed to also purchase credits from AgrNPS (agricultural nonpoint sources applying eligible BMPs), we estimated that the total annual costs could be reduced by as much as an additional

Figure 9-1

Costs of Achieving SigPS Load Reduction Targets and Potential Cost Savings from Nutrient Trading (In-Basin-State Trading)



16 percentage points, compared with the SigPS-Only scenario. In this case, the total annual costs of nutrient controls could be as low as $245 million per year. Figure 9-2 shows how the additional agricultural BMP controls costs are distributed. Implementation of additional cover crops and grass buffers account for over two-thirds of these costs. All of these cost estimates include the previously described 38% transaction cost factor. See Section 6.3.

Figure 9-3 expands on these results shown in Figure 9-1 by also showing results for the In-State, In-Basin, and Watershed-wide Trading scenarios. When the geographic scope of trading expands and SigPS are offered a wider range of trading opportunities, we expect the potential cost savings to be even larger. This result is confirmed in our findings. For example, under the In-Basin scenario with trading allowed between SigPS and agricultural sources, the estimated potential cost savings increase to as much as 44% of the No-Trading costs. This is an increase in cost savings of 21% over the comparable In-Basin-State scenario.

Figure 9-2

Relative Contribution of Agricultural BMPs to the Costs of Nutrient Control Under the SigPS-AgrNPS Trading Scenario (In-Basin-State Trading)

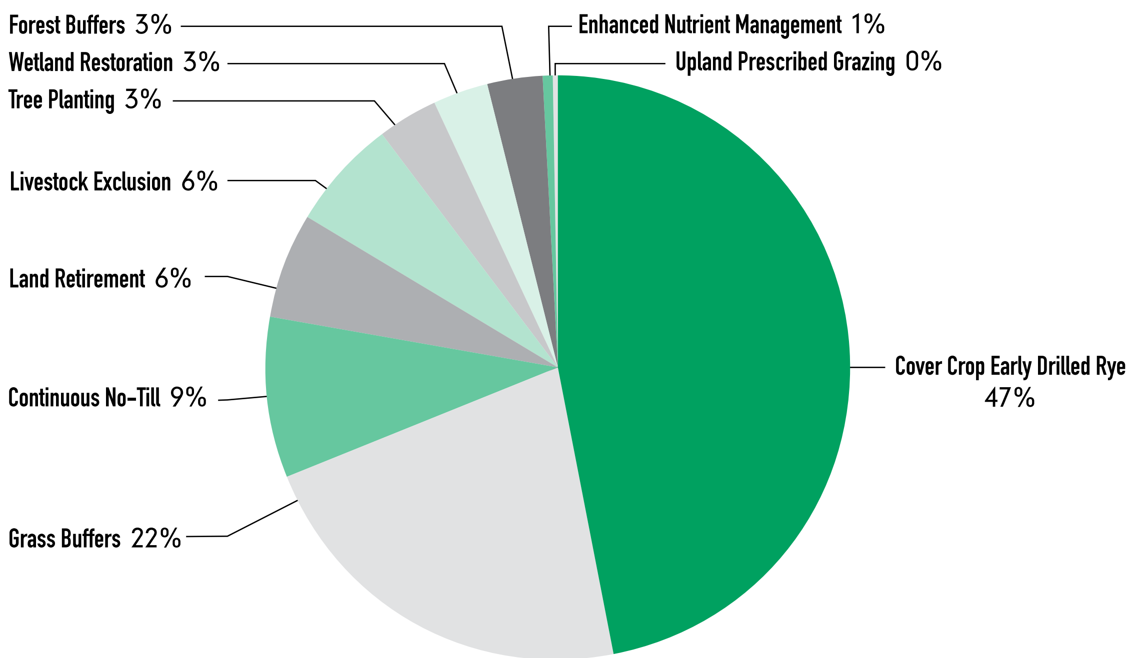
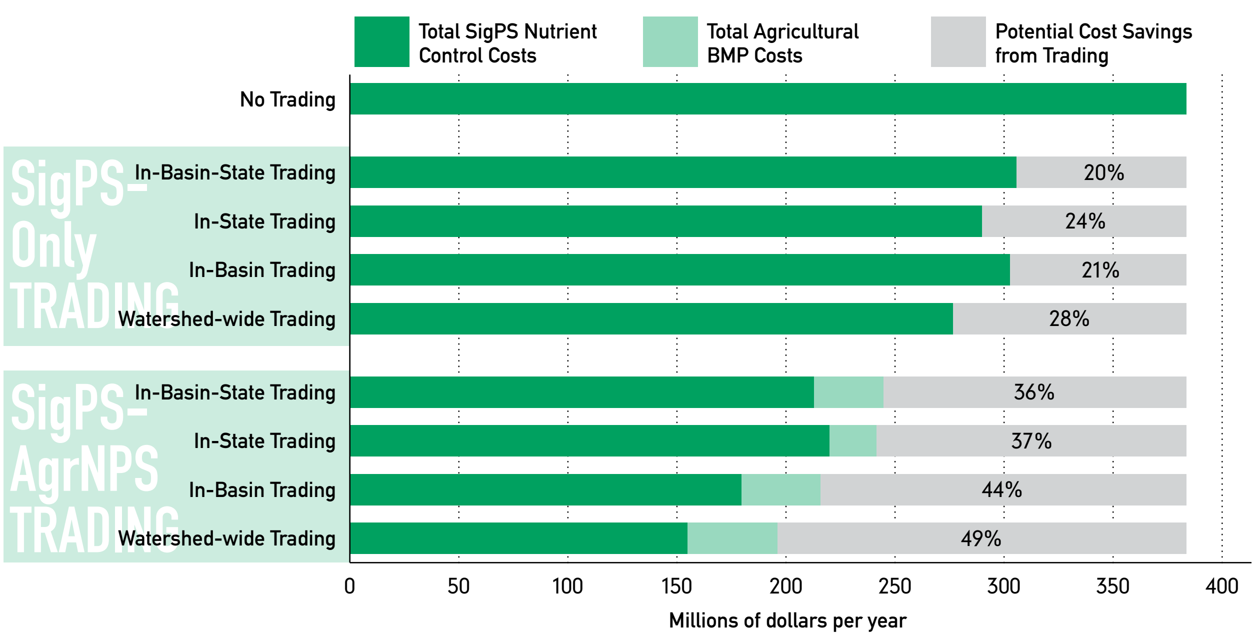


Figure 9-3

Costs of Achieving SigPS Load Reduction Targets and Potential Cost Savings from Alternative Trading Scenarios



Expanding trading further from in-basin to watershed-wide increases the estimated potential cost savings another 5 percentage points to 49% of the No-Trading costs—a 35% increase in cost-savings over the In-Basin-State scenario.

The results in Figure 9-3 also indicate that expanding the geographic scope of trading has less of an upward impact on potential cost savings than expanding participation to include agricultural sources. For example, expanding from In-Basin-State trading to Watershed-wide trading increases the potential cost savings by 8 to 13 percentage points, whereas going from SigPS-Only to SigPS-AgrNPS trading increases the potential savings by 16 to 21 percentage points.

The estimated cost savings also vary substantially across basins and states. Figure 9-4 compares total control costs and potential cost savings across basins for the In-Basin trading scenario. Not surprisingly, both the largest costs and the largest cost savings are in the three largest basins—James, Potomac, and Susquehanna River Basins. In the case of the James, high costs are also driven by localized water quality parameters.

In percentage terms, the Potomac River Basin, which includes four states plus the District of Columbia, benefits the most from allowing point and nonpoint sources to trade nutrient credits across state lines. Under the SigPS-AgrNPS trading scenario, the potential costs savings are estimated to be 61% relative to the No-Trading scenario in the Potomac Basin. Although not shown in the figure, the savings in the Potomac Basin are only 32% when trading is not allowed across state lines (i.e., the In-Basin-State scenario).

Figure 9-5 compares total control costs and potential cost savings among states for the In-State trading scenario. In this case, the largest costs and potential cost savings in actual dollars (as opposed to percentages) are found in Virginia. The potential benefits of allowing point and nonpoint sources to trade nutrient credits across basins are particularly large in this state because it includes part or all of five river basins. In Virginia, under the SigPS-AgrNPS trading scenario, the potential costs savings were estimated to be $82 million per year, which is 43% relative to the No-Trading scenario.

Figure 9-4

Comparison of Potential Cost Savings at the Basin Level from the In-Basin Trading Scenario

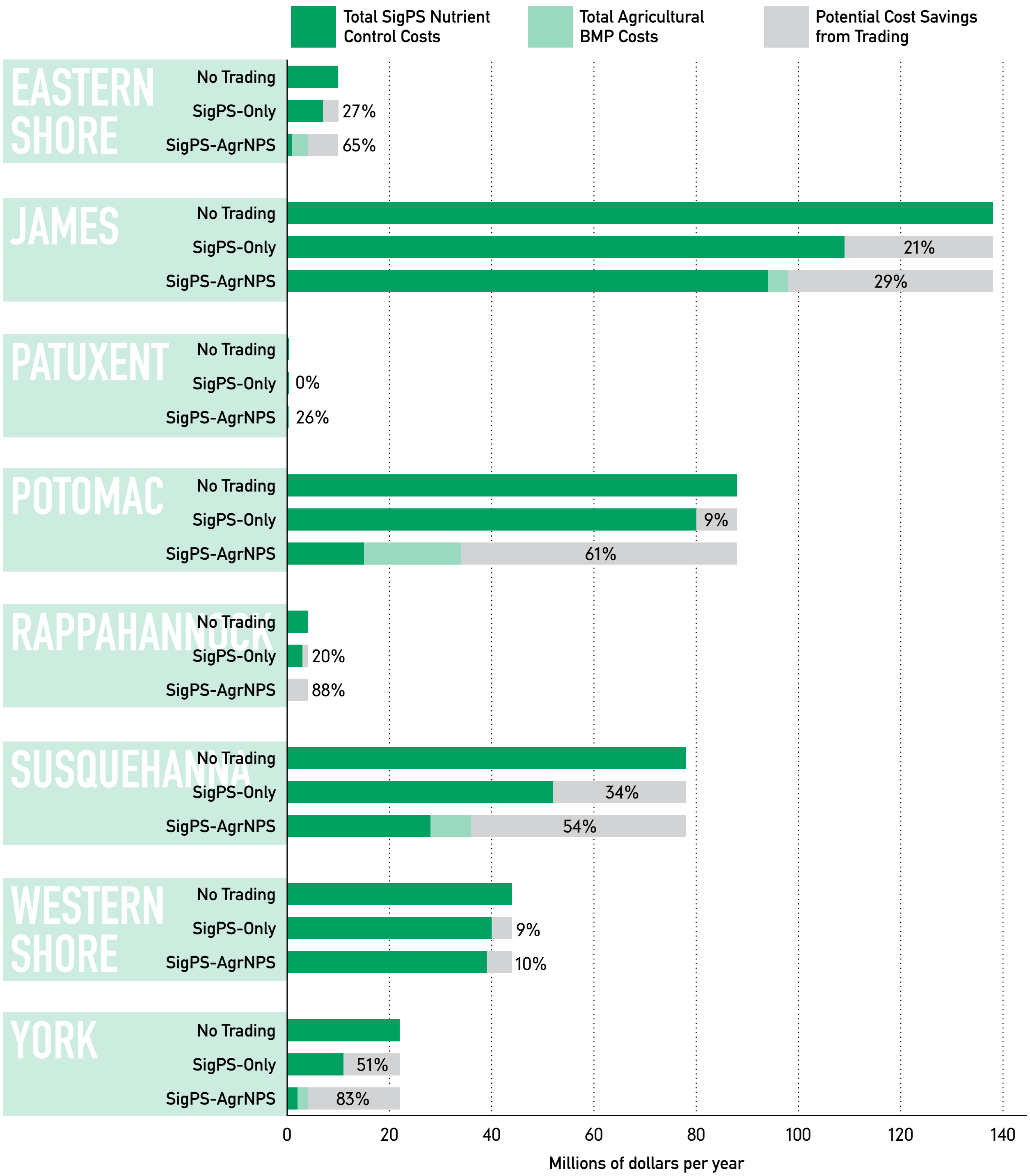
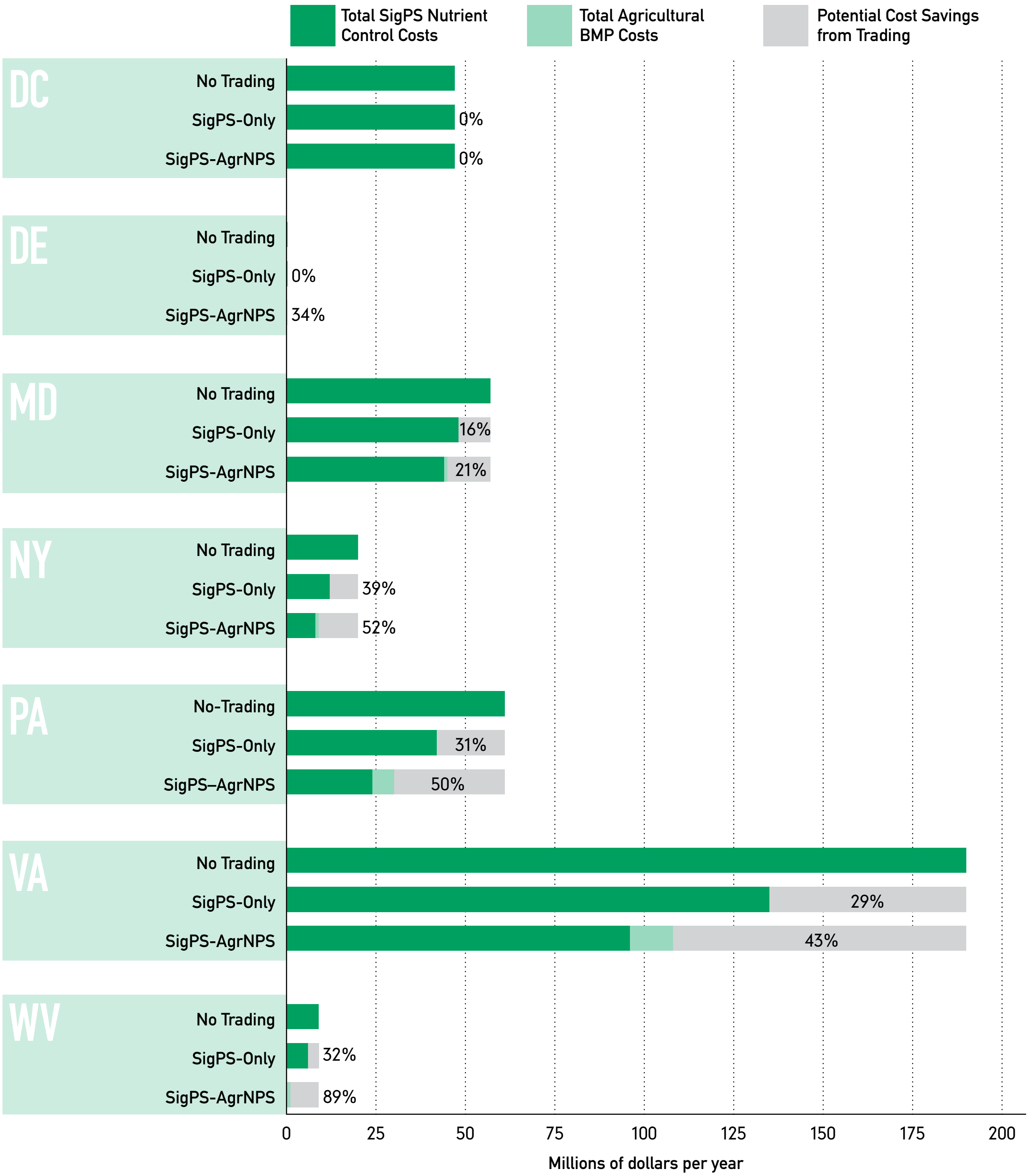


Figure 9-5

Comparison of Potential Cost Savings at the State Level from the In-State Trading Scenario



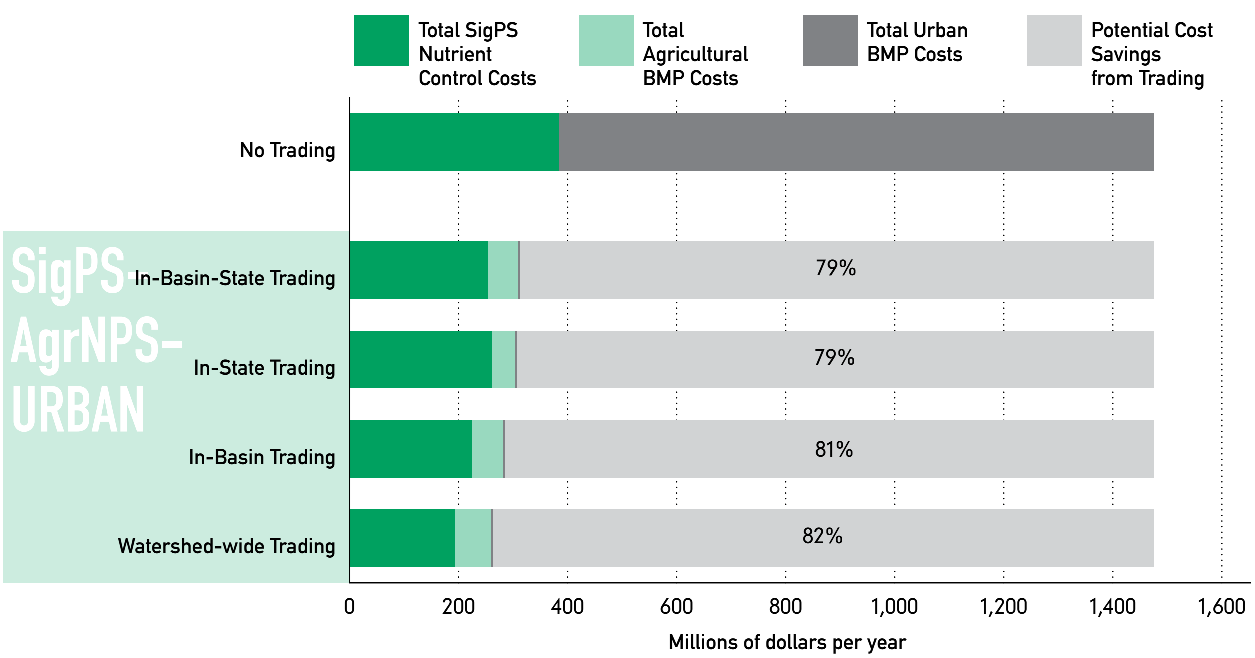
9.2 Potential Cost Savings from SigPS, AgrNPS, and Regulated Urban Stormwater Trading

When trading is expanded to include regulated stormwater sources, we found that the potential cost savings increased substantially. The main reason for this increase is that, as shown in Section 8, implementing urban stormwater BMPs tends to be a much less cost-effective way of reducing nutrient loads than agricultural BMPs.

In Figure 9-6, the estimated cost of the No-Trading scenario includes costs for both SigPS and regulated urban stormwater sources in the watershed. The combined total costs are estimated to be $1.47 billion per year, with 74% of these costs attributable to urban sources. When trading is allowed to occur, and SigPS and urban sources can purchase credits from other SigPS and agricultural nonpoint sources, it potentially reduces these cost by as much as 79% to 82%. These large cost savings occur mainly because the available agricultural BMPs can achieve the same reductions as the urban stormwater BMPs at a

Figure 9-6

Costs of Achieving SigPS and Regulated Urban Stormwater Load Reduction Targets and Potential Cost Savings from Nutrient Trading (In-Basin-State Trading)



much lower cost. Under the least-cost solution, very few of the urban stormwater BMPs would be implemented for the purposes of Bay TMDL nutrient pollution reduction. The large potential cost savings shown in Figure 9-6 rely on two important assumptions. First, the costs of the No-Trading scenario (which are based on urban BMP implementation estimates from the CBWM and the states' Phase I WIPs) are assumed to be directly attributable to the TMDL. That is, they would not occur without the TMDL load reduction requirements. Second, under the trading scenarios, regulated urban sources are free to meet their TMDL load reduction requirements by purchasing credits from other sources.

The potential cost savings from trading will be lower if these assumptions do not hold. In particular, if some of the urban stormwater BMPs installed under the No-Trading scenario (after 2010) are needed to address other regulations or requirements (e.g., flood control), then the costs of these BMPs will not be avoidable through nutrient trading.

9.3 Potential Cost Savings from an Offset-Only Scenario

This trading scenario is substantively different from the others for two main reasons. First, it looks to the future (2025) by accounting for population growth and its effects on wastewater treatment capacity at significant municipal facilities. Second, it restricts credit purchases such that only *additions* to capacity at significant municipal facilities are eligible to buy them. In this case, these facilities would be *required* to purchase "offset" credits, either from other significant facilities or from agricultural operations, to counteract the nutrient loads generated by their new wastewater capacity.

Importantly, this scenario only accounts for growth and development in the watershed through their effect on significant municipal wastewater treatment facilities and the need for additional treatment capacity. Due mainly to data limitations, the analysis does not account for changes in land use and their effects on nutrient loads. With increasing urban development in the watershed, urban stormwater sources are also likely to be a significant source of demand for offset credits; however, including these future sources was beyond the scope of our analysis.

To approximate the location and size of new wastewater capacity we assumed that, from 2010 to 2025, annual wastewater flows at each of the 399 significant municipal facilities (of the total 475 SigPS) would grow at the same rate as total population in the counties where they are located.* For each county in the Chesapeake Bay watershed, we then compared combined annual wastewater flows from all of its significant municipal facilities in 2025 to combined annual current design capacity at these facilities. If the combined flow estimate for a county exceeded 80% of the combined capacity estimate, we interpreted the difference as the new capacity needs in 2025. Based on this approach, we estimated that 100 million gallons per day (MGD) in new municipal wastewater treatment capacity would be needed, with 35% in Maryland, 35% in Virginia, and 21% in Washington, DC.

Next, we assumed that all of the new municipal wastewater treatment capacity would be required to use ENR technology. For our analysis, we defined ENR as achieving 3 mg/l nitrogen and 0.3 mg/l phosphorus (Ref. 16). This ENR requirement and definition corresponds with the Maryland program; however, it should be noted that the requirements for new wastewater capacity differ somewhat across the Bay states.

Using these projections and assumptions, we estimated the size and location of annual nutrient loads that would need to be offset through credit purchases. Going back to the framework for the trading analysis, these estimates represent the new load reduction targets (Step 4 in Figure 4-1) that need to be achieved to maintain the cap. The optimization framework was then used to identify the available nutrient control projects that would meet those targets at the lowest cost, and this result is interpreted as the best-case nutrient trading outcome.

It is important to emphasize that, in this long-term context, the No-Trading scenario is not an option. Loads from new capacity must be offset, and the only way to do that (absent new technologies) is through

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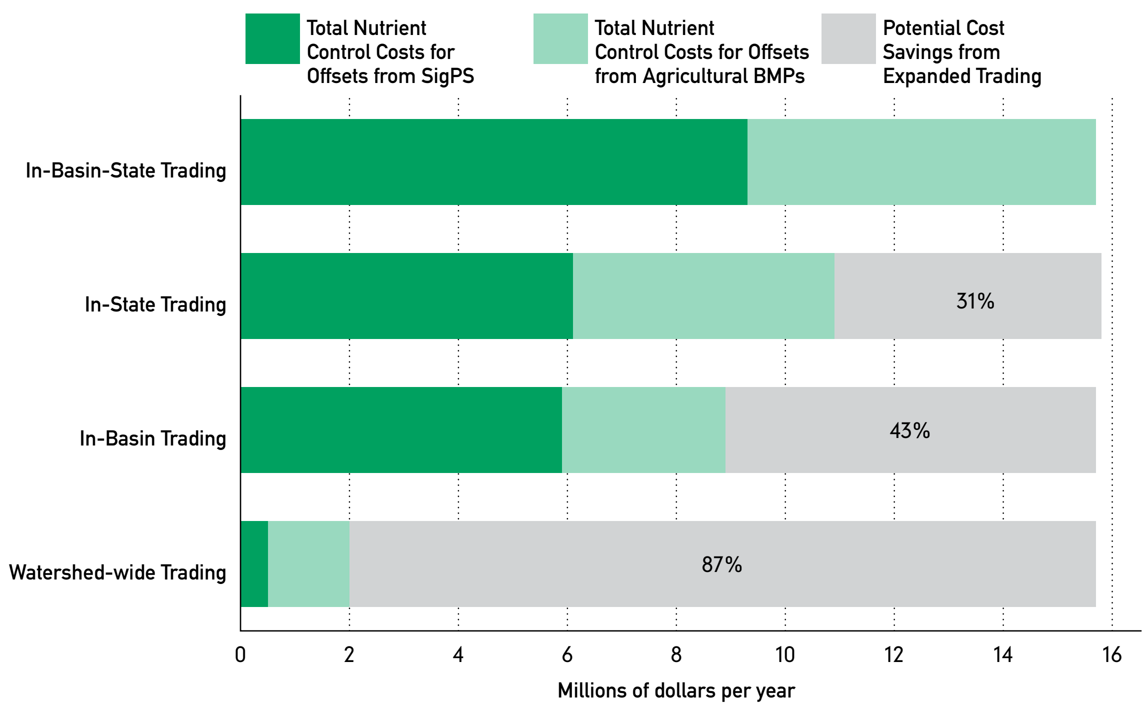
* County-level population growth rate projections for Delaware, Pennsylvania, Maryland, and Virginia were taken from *Woods & Poole Economics, Inc.* (Ref. 13). For New York they were taken from *http://pad.human.cornell.edu/counties/projections.cfm* (Ref. 14), and for West Virginia, they were from *http://www.be.wvu.edu/demographics/documents/WVPopProjectionbyCounty2011_001.pdf* (Ref. 15).

trading. Therefore, unlike the previously analyzed short-term trading scenarios, it is not meaningful to estimate potential cost savings relative to no trading. Instead, we estimated and compared the sources and annual costs of the offset load reductions under alternative trading scenarios.

Figure 9-7 summarizes these results and comparisons. In this figure, we use the results of the In-Basin-State trading scenario as the point of reference. We estimated the total costs of offset nutrient controls in this scenario to be $15.7 million per year, with 59% of these costs from nutrient controls at SigPS and the remainder from agricultural BMPs. With In-State trading, the costs are reduced by 31% to $10.9 million, and with In-Basin trading they are reduced by 43% to $8.9 million. With Watershed-wide trading, the costs are further reduced by 87% in total, yielding an estimated overall cost of as little as $2 million per year. Thus, in this Offset-Only Scenario, watershed-wide trading is estimated to offer a significant increment in cost savings.

Figure 9-7

Costs of Nutrient Controls to Offset Loads from New SigPS Capacity



Section 10

Caveats and Uncertainties

Despite the encouraging findings of this study, the results must be interpreted with caution and with an understanding of the inherent uncertainties and limitations of the analysis. In particular, the emphasis on *potential* savings is important for interpreting the results of this study. It stresses that the estimates from our analysis represent the cost savings that could be achieved from trading under best-case conditions, as restricted by the various assumptions we earlier described and discussed. In practice, a variety of factors are likely to interfere with and limit the gains from trading. Below, we describe other potential limitations and areas of uncertainty that deserve consideration.

- The analysis assumes that, under the trading scenarios, SigPS have the option to *not* upgrade their treatment technologies from 2010 levels and regulated urban sources have the option *not* to install new stormwater BMPs. Instead, they can buy credits from other sources to meet their load reduction requirements. In practice, other regulatory requirements (e.g., state-specific statutory requirements) may disallow this "status quo" option, thus lowering the potential cost savings from trading. Maryland, for example, currently does not allow either source to trade in this manner. However, it is important to note that, if these other requirements are the reason for SigPS to upgrade their treatment technology and for urban areas to install BMPs, then the costs of these upgrades and BMPs should not be attributed to the Chesapeake Bay TMDL (i.e., the costs of the No-Trading scenario in our analysis would also be lower).

- The analytical framework for the trading analysis relies heavily on the data and structure provided by the CBWM. In particular, it relies on the model's estimates of land use, nutrient loads, BMP implementation (current and with TMDL), and BMP nutrient removal efficiencies for the entire Chesapeake Bay watershed. Although the CBWM provides the most comprehensive, integrated, and updated system for our purposes, there are inherent uncertainties and limitations associated with that model, which carry over to our trading analysis.*

- The nutrient control cost estimates for SigPS are based on average per-MGD cost estimates for different tiers of nutrient removal, which are derived from a combination of engineering cost models and facility-specific data. The actual costs for individual facilities will differ from these estimates depending on their specific conditions and configurations. If these unit-cost estimates tend to overstate or understate the actual costs for facilities, then the total estimated costs of the No-Trading scenario and the estimated potential cost savings from trading will be similarly overestimated or underestimated.
- The nutrient control costs for agricultural and urban stormwater BMPs are also subject to uncertainty. Because of data limitations, this uncertainty is generally greater for urban stormwater BMPs. The capital and O&M costs for agricultural and urban BMPs are based on state-level averages. The land estimates for agricultural BMPs rely on county-level land rental rates, with no adjustment for within-county variation. The land cost estimates for urban BMPs rely on a single value, $100,000 per acre, throughout the watershed. Therefore, any within-county or within-state variation or uncertainty associated with these estimates is not captured within the trading analysis or the results.
- The agricultural baseline for trading used in our analysis assumes full compliance with the TMDL by agricultural sources. If less than full compliance is achieved, then the opportunities to sell credits will be lower, as will the potential cost savings from trading with agricultural nonpoint sources.
- The trading analysis greatly simplifies the timing and duration of credits and their impact on trading decisions. As a result, the framework is likely to overstate the amount of trading that would occur in any given year. In particular, the main (short-term) analysis does

* References for scientific peer reviews of the CBWM are provided in *http://www.epa.gov/reg3wapd/pdf/pdf_chesbay/FinalBayTMDL/AppendixBIndexofDocuments_final.pdf* (Ref. 17).

not account for variation over time in nutrient control costs, nutrient reductions, or other conditions. Instead, it evaluates all of the components on an average annualized basis, based on conditions in 2010. In reality, decisions to invest in nutrient controls on site or to buy or sell credits are based on current and future nutrient reduction capabilities and needs, the timing of current and future costs, and expectations about future credit prices. Uncertainties about these future conditions are likely to discourage participation in nutrient credit markets. Unfortunately, developing a dynamic modeling framework that incorporates these timing issues was beyond the scope of this study.

- Local water quality protection requirements not considered in this analysis (e.g., a stream in upper Pennsylvania with a stream-specific phosphorus TMDL) may impact and constrain the trading market, reducing the potential cost savings by an undetermined amount.
- The Offset-Only trading scenario addresses one aspect of timing by estimating growth in municipal wastewater flows and treatment capacity needs by 2025. These estimates were based on county-level population growth projections, which are subject to uncertainty and may not correspond to growth in wastewater flows at specific facilities. In particular, other sources that could contribute to future flows, such as connecting septic systems, were not included.
- To incorporate urban stormwater sources into the trading analysis, we only included urban areas designated as "regulated" in the CBWM as eligible to purchase credits (rather than implement the required urban BMPs). Therefore, the potential cost saving estimates for the SigPS-AgrNPS-UrbanSW trading scenario depend importantly on this designation in the CBWM and the assumption that only these areas would be eligible to participate.
- The main unit of analysis for agricultural (and urban) sources is the land-river segment, rather than individual farms or farm acres. Although these segments are further subdivided according to patterns of land use, existing BMP implementation, riparian areas, and soil type (hydric and/or erodible), all acres within each of these subdivision areas were treated as identical for the modeling analysis.

Section 11

Conclusion

The results of this study indicate that nutrient trading offers the potential to significantly reduce the costs of achieving the TMDL water quality goals for the Chesapeake Bay. If trading is successful in shifting nutrient reduction and control activities toward the most cost-effective alternatives, then the annual costs of the TMDL could be substantially reduced. For example, compared to a scenario without trading, we estimate that the costs of meeting TMDL load reduction targets for SigPS could potentially be reduced by as much as 36% if these sources were allowed to trade with other SigPS and with agricultural nonpoint sources located in the same basin and state.

The potential savings from trading increase as more source categories are allowed to participate in the market. In particular, allowing agricultural nonpoint sources to participate opens the door to a number of relatively low-cost options for reducing nutrients. Even after accounting for high transaction costs and including a 2:1 trading ratio to address performance uncertainty, we find that the potential cost savings from including agricultural BMPs are significant. For example, in our trading scenarios involving SigPS, we find that potential savings increase by 50–100% when agricultural nonpoint sources are also allowed to participate.

The potential benefits from trading are particularly high when urban sources are allowed to purchase credits. The possibility of large savings for urban areas is due primarily to the relatively high cost of controlling nutrients from urban stormwater runoff. In our analysis, we assume that regulated urban sources are free to meet all of their TMDL load reduction requirements by purchasing credits from other sources.

Under these conditions, it is almost always more cost-effective to reduce loads through agricultural BMPs or SigPS controls, and the total costs of achieving the combined SigPS and regulated urban stormwater load reduction targets can potentially be reduced by roughly 80%.

The potential cost savings also increase as the geographic scope of trading activity increases. For example, in our trading scenarios involving SigPS and agricultural nonpoint sources, we find that potential savings increase by about 35% when the geographic scope is increased from basin-state level to the entire watershed. This increment is not as large as when agricultural nonpoint sources are included in the trading scenario, but it is still substantial.

Although the potential cost savings from trading are significant, in practice, trading activity will be limited by: 1) transaction costs and uncertainties for buyers and sellers of credits, and 2) other regulatory restrictions and non-economic considerations (including sellers' and buyers' willingness to trade). Our analysis has incorporated these elements in a few simple ways; however, it cannot capture the full complexity of these factors in the decision-making process for market participants. Over time, some of the transaction costs should come down as participants become more familiar with the procedures and opportunities offered by trading. Nevertheless, federal, state, and local governments can all play a role in reducing these transaction costs by clearly defining trading rules and protocols, providing information and technical assistance, and ensuring compliance and enforcement. Governmental decisions not focused exclusively on costs will greatly impact the outcomes of a trading program and market.

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Chesapeake Bay Commission

The Chesapeake Bay Commission is a tri-state legislative commission. The Commission maintains offices in Maryland, Virginia and Pennsylvania. Commission staff is available to assist any member of the General Assembly of any signatory state on matters pertaining to the Chesapeake Bay and the Chesapeake Bay Program.

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