



# Cost-Effective Strategies For the Bay

**C** Smart Investments  
for Nutrient and  
Sediment Reduction

DECEMBER 2004



With limited dollars  
available and 2010  
quickly approaching,  
where should we focus  
available funds to achieve  
the most efficient use of  
taxpayer dollars?



CHESAPEAKE BAY COMMISSION  
*Policy for the Bay*

# **Cost-Effective Strategies for the Bay**

## *Smart Investments for Nutrient and Sediment Reduction*

### **Part 1**

Introduction

PAGE 2

### **Part 2**

Menu of the Most Cost-Effective Measures

PAGE 6

### **Part 3**

Conclusion

PAGE 19

### **Appendix A**

Chesapeake Bay Program Practices  
Included in the Watershed Model

PAGE 20

PART 1

## Introduction

The Chesapeake Bay Commission's January 2003 report, *The Cost of a Clean Bay*, placed a price tag of \$19 billion on the Bay restoration, as outlined in the *Chesapeake 2000* agreement. The lion's share of both the cost and the associated funding gap was identified with water quality attainment, specifically, efforts to reduce nutrient and sediment loads to the Bay by 2010. Closing that funding gap has been the primary focus of the Commission to date.

Since publication of *The Cost of a Clean Bay*, the states and other interested parties have further refined cost and funding estimates. While new data moves components of the price tag up and down, the following key issues raised in the report's findings remain on target, and are the drivers for this follow-up report: With limited dollars available and 2010 quickly approaching, where should we focus available funds to achieve the most efficient use of taxpayer dollars? Which control measures and management practices are both cost effective and widely applicable, thereby yielding potentially large nutrient reduction opportunities? Most importantly, which practices will deliver the largest nutrient and sediment load reductions for the least cost?

*Cost-Effective Strategies for the Bay* lays the foundation for developing answers to these questions. It explicitly acknowledges that more analysis needs to be done. In identifying a short list of the most cost-effective and widely applicable nutrient control measures, we have employed a screening process that looks at opportunities Baywide. The variability in soils, climate, topography and land use, to name a few, that exists across the 64,000 square mile watershed will influence whether these top six practices are among the most cost effective at a local or tributary scale.

Nevertheless, this analysis indicates that, based on a review of state-wide results as well as best professional judgment, many of these control practices will be among the most cost effective in a majority of locations and circumstances. Our goal is to lay out the rationale for their selection, to clearly articulate obstacles and opportunities for large-scale adoption, and to provide food for thought to the states as they develop and refine

their individual tributary strategies and seek the policy changes necessary to implement them.

It is important to note that this report *does not* claim that the six practices chosen are the only means to achieve the *Chesapeake 2000* goals. Even with full implementation of these six practices, we would be only three quarters towards the needed nitrogen and phosphorus reductions. The other quarter must come through reliance on other practices. Furthermore, these six practices are not able to be implemented in every tributary and under every circumstance in the watershed, nor are they always the most cost-effective. As is already taking place through the development of state tributary strategies, decisions must be made on how best to achieve nutrient reductions at the individual state and local scale.

Regardless, once those decisions are made, they must be implemented. For implementation to be successful, there must be financial support, and this brings us back to the purpose of this report — how can public dollars be focused to achieve the largest reductions for the least cost in the Bay watershed as a whole?

This report’s findings highlight the valuable role that point sources and agriculture play in the restoration of the Bay. The very fact that five of the six practices chosen are agricultural further underscores the costliness of poorly planned urban development in the watershed.

Despite the challenges that lie ahead, the options

identified in *Cost-Effective Strategies for the Bay* should be encouraging. Our analysis shows that significant nutrient reductions can take place with a targeted investment of public dollars. Most of the remaining reductions will be urban and these challenges will be enormous. The Commission may choose to tackle this subject in a future report.

## The Selection Process

The Commission initially evaluated some 34 nutrient and sediment reduction practices representing a wide range of specific actions associated with wastewater treatment plants, agriculture, urban stormwater, land preservation, forestry and air pollution. Obviously, there are many more. However, we limited our examination to those already accepted by the states, used in the tributary strategies and incorporated into the Bay Program’s watershed model. Appendix A provides a list of the nonpoint and point source controls included in the computer model that were part of the screening process for this analysis.

In identifying the top ranking measures, the Commission used a number of criteria in addition to the dual filters of cost effectiveness and nutrient reduction potential. Priority was given to measures that keep nutrients out of the environment in the first place, or at least reduce the amount introduced. The lowest rating was given to



**FIGURE 1**  
NUTRIENT AND SEDIMENT LOADINGS IN BAY WATERS

POLLUTANT	1985 Load	17 years	2002 Load	8 years	2010 Goal
Nitrogen (m lbs/yr)	338		278		175
Reduction		60		103*	
Phosphorus (m lbs/yr)	27.1		19.5		12.8
Reduction		7.6		6.7	
Sediment (m tons/yr)	5.83		5.05		4.15
Reduction		0.79		0.90	

\* Includes an estimated 8 million pound reduction from Clean Air Act implementation allocated to EPA.

practices that reduce the impact of nutrients after they are placed in the environment.

In some cases, particularly for air pollution controls, inadequate data and limited modeling tools hampered our ability to accurately assess the potential for nutrient reduction opportunities and costs within the watershed. Refinement of tools which allow us to track the transport and fate of emissions both within and outside the watershed is crucial, particularly given the fact that air pollution controls offer both significant public health as well as environmental benefits for the investment.

Finally, the Commission's choices considered reliability of the practice, sensitivity to different conditions, consistency of success in nutrient and sediment reduction, political reality and the likelihood of a reliable source of financing over time.

## Summary of Results

In order to place the nutrient reduction opportunities of the highest ranking practices in perspective, it is necessary to review the total reductions that are needed to be achieved under the *Chesapeake 2000* agreement, "C2K." In 1999, the Chesapeake Bay was listed as an impaired water body under the Clean Water Act due to low dissolved oxygen levels and poor water clarity. C2K describes the process to be used to set the nutrient and sediment reductions necessary to delist the Bay (restore water quality) by 2010, in order to avoid

## THE TOP CHOICES

1. Wastewater Treatment Plant Upgrades
2. Diet and Feed Adjustments
3. Traditional Nutrient Management
4. Enhanced Nutrient Management
5. Conservation Tillage
6. Cover Crops

federal regulatory action in 2011. As shown in Figure 1, the reductions agreed to in 2000 will require the region to accomplish twice as much in half the time.

*Chesapeake 2000* sets the overall reduction goals for the Bay at 103 million pounds per year for nitrogen, 6.7 million pounds per year for phosphorus and 900,000 tons per year for sediment. In setting these goals, the signatories recognized that the reductions needed to be clearly assigned to each jurisdiction and tributary. Figure 2 provides a summary of the Bay states' pollution reduction responsibilities. Capturing the remaining load is the responsibility of New York, West Virginia, Delaware and EPA.

Based upon our analysis, the six measures described within this report could achieve a substantial part of the 103 million pound nitrogen reduction goal set for the period 2002-2010 (Figure 3). Similar conclusions can be drawn for

phosphorus and sediment. When added to practices currently underway and likely to continue or expand, they provide real assurance that the nutrient goals of C2K are achievable.

The potential nutrient load reductions ascribed to each practice assume "maximum feasible" levels of implementation. Realistically, reaching these maximum implementation levels is dependent upon a number of factors. Some of the recommended measures require nothing more than enhanced

**FIGURE 2**  
POLLUTION REDUCTION RESPONSIBILITIES OF THE CHESAPEAKE BAY COMMISSION STATES FOR THE PERIOD 2002-2010

	Maryland	Pennsylvania	Virginia
Nitrogen (millions of pounds per year)	19	37	26
Phosphorus (millions of pounds per year)	1.0	1.3	3.8
Sediment (tons per year)	300,000	120,000	440,000

funding of existing programs and can contribute handsomely to the timely achievement of the 2010 water quality goals. Others, like enhanced nutrient management and diet and feed formulation, represent emerging technologies or practices which need further research and program development, as well as financial and political support, if they are to reach their full potential.

While discussed in more detail below, these measures include the following:

## Current Opportunities

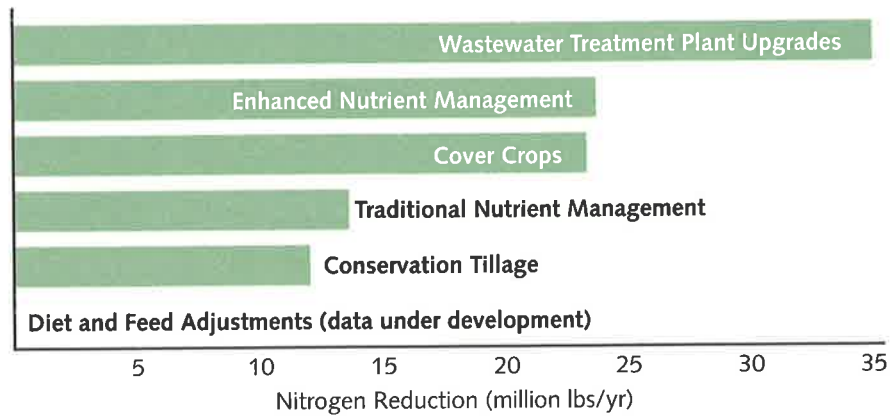
- Widespread utilization of advanced nutrient reduction technology at wastewater treatment plants.
- Broad-scale coverage of agricultural lands in Nutrient Management Plans (NMP), thereby closely matching fertilization application rates with crop needs.
- Enhanced use of conservation tillage in order to minimize soil disturbance and associated erosion and leaching.
- Enhanced adoption of late cover crops and use of early cover crops to absorb excess nutrients in the soil.

## Emerging Opportunities

- Commercial testing and application of diet and feed changes which increase animals' ability to utilize nutrients, thereby reducing the nutrient content of manure.
- Reduced application of fertilizer to cropland beyond NMP levels, with the goal of maintaining



**FIGURE 3**  
MAXIMUM POTENTIAL NITROGEN REDUCTION BAYWIDE\*  
FOR INDIVIDUAL BEST MANAGEMENT PRACTICES (2002 BASELINE)



\*All of the practices and associated percentages have been analyzed at their maximum feasible implementation levels, based on a 2002 baseline. The reductions attributed to each practice may be less when combined with other practices. All reductions except Wastewater Treatment Plant Upgrades and Diet and Feed Adjustments are estimated for the edge of the field, and experts suggest they should be reduced as noted in Figure 4 to accurately reflect loads delivered to the Bay, which is the basis for the 103m lb. reduction goal.

yields while more closely matching application rates to crop nutrient requirements.

These are surely not the only measures jurisdictions should consider as tools for meeting nutrient and sediment reduction goals. There are many well-proven practices already in place, and there are other innovative and well-targeted practices proposed in the emerging tributary strategies that warrant encouragement and funding. It should not be inferred that those practices not selected should be eliminated or ratcheted down. Nor should readers assume that the Commission is advocating widespread adoption of all six practices everywhere in the watershed. Our intent is to illuminate large nutrient and sediment reduction opportunities for further consideration by the states.

Regardless, the Commission does conclude that these six top opportunities, if broadly applied and implemented in the near term, can go a long way toward reaching our goals in a cost-effective manner. They can be viewed as the first heavy hitters in a game with many players, involving a long line-up of technologies, retrofits and best management practices necessary to meet our water quality goals. ■

PART 2

# Menu of the Most Cost-Effective Measures

The following section describes the individual practices, their estimated costs and potential for substantial nutrient and sediment reductions. The reported annual reductions are those possible beyond levels of those practices in effect in the baseline year of 2002. Where phosphorus and sediment reductions accrue as added benefits based on an initial expenditure for nitrogen removal, they are so noted. Otherwise, nitrogen, phosphorus and sediment costs are calculated individually. To review a description of the full range of nutrient and sediment reduction measures for which cost and efficiency data is available, visit the Chesapeake Bay Program website at [www.chesapeakebay.net](http://www.chesapeakebay.net) and look under “trib tools.”

## 1. WASTEWATER TREATMENT PLANT UPGRADES

Potential for annual additional reduction at the maximum feasible level of implementation:

---

**Nitrogen:** 35 million lbs. @ \$8.56/lb.

---

**Phosphorus:** 3 million lbs. @ \$74.00/lb.

---

**Sediment:** Not applicable

---

Upgrading wastewater treatment plants to remove nutrients presents the most sure-fire way to reduce their impact on our waterways. This nutrient reduction technology, while expensive, provides immediate benefits to the Bay and its rivers, since treatment plants release directly to surface water (many other measures that impact the land rely on delivery of reduced nutrients through groundwater, which can take years). Of the six practices chosen, this technology-based approach provides the highest degree of confidence for consistent, long-term reductions. Furthermore, the cost of this technology has continued to decline in recent years, and can be quite reasonable if spread across a broad user base.

A January 2004 Chesapeake Bay Program document, *What's the Status of Point Source Nitrogen Reduction in the Chesapeake Bay Watershed?*, outlines progress to date and future potential for reducing nitrogen loads from the 310



## A Note on Estimating Costs and Levels of Effectiveness

Estimating the cost and effectiveness of nutrient reduction measures is not an exact science. That said, the Chesapeake Bay Program has more information and experience than any other effort in the world in defining best management practices and developing measures of cost and effectiveness. Yet, there are many issues left to be resolved. For example, in some cases different states within the watershed are using different cost assumptions for the same measures in state tributary strategies. And while there is comparatively good consensus on the effectiveness of many of the measures proposed in this report, there are also a number of new innovative and emerging control strategies for which cost estimates and efficiencies are still preliminary.

Luckily, there is a host of scientists, economists and other professionals in the region with tremendous experience and expertise. In preparing this report, the Commission staff and its consultants have met extensively with the experts, conducted literature reviews, examined available data, and analyzed and conducted model runs. In every case, we have used the best available information to establish the numbers. In no case have we included cost or effectiveness estimates where there is so wide a range of disagreement that the utility and affordability of the proposed practice might be questioned. We have relied on what we call “BPJ”—“best professional judgment.”

sewage treatment plants and the 58 industrial sources that provide significant nitrogen loadings to the Bay. The report focuses on nitrogen as the main nutrient controllable from point sources, although there are phosphorus reduction benefits to be achieved as well.

These 368 waste treatment sources contribute 59 million pounds of nitrogen annually, which represents a 26 million pound reduction since 1985. Nutrient reduction technology (NRT) at sewage treatment plants accomplished much of this reduction. Laudably, as of the beginning of 2004, about 55 percent of flow from all facilities was under some form of NRT.

Still, NRT continues to advance at a rapid rate, providing significant opportunities for further improvements. As recently as 10 years ago, experts considered reductions of nitrogen to 8 milligrams

per liter of effluent as state of the art, and the estimated cost per pound reduced was \$35. Now 2 mg/l is state of the art, and reductions to 3 mg/l are widely feasible. Costs are less than \$10 per pound for facilities without NRT, and as low as \$4 for those plants with some treatment already in place. These numbers represent both capital and operating costs, amortized over 20 years. It is also encouraging to note that the same January 2004 document reported new studies that suggest that earlier cost estimates to take a facility to 3 mg/l may have been overestimated by 23-32 percent.

To assist the states in the formulation of their tributary strategies, the Bay Program developed a series of scenarios for further point source reductions. The most far-reaching takes all facilities to 3 mg/l for a maximum savings of 40.6 million pounds annually at a cost of \$4.5 billion. Even reductions to 8 mg/l or 5 mg/l, according to the report, would save 13.9 and 28.6 million pounds, respectively. Clearly, opting for 3 mg/l wherever feasible will provide the greatest reductions.

However, as the draft tributary strategies illustrate, this “best case scenario” may not be the first choice in some situations.

To arrive at the figures for this report, the Commission assumed that states would seek to avoid the most technically difficult retrofits to 3 mg/l, as they are generally the most expensive projects. It is difficult to estimate the precise number of these “most challenging” facilities. There are potential cost savings in proposals to establish multi-facility permits with trading potential, so that some facilities might purchase more cost-effective additional reductions from other plants. Also, there may be some decisions as to whether to go to 3 mg/l or not based on geographic location.

Taking all this into account, it appears that a reasonable reduction expectation for point sources is about 35 million pounds per year of nitrogen,

which represents one third of the total amount of nitrogen required to be reduced Baywide. This leaves 5.6 million pounds of flexibility below the maximum 40.6 million pounds of reductions that could be achieved if all facilities were to go to 3 mg/l. It assumes use of NRT in all places where reasonably feasible, and use of multi-facility permits with some nutrient trading potential for both public and private facilities.

For phosphorus removal, the most far-reaching scenario achieves a potential 3.34 million pounds per year reduction. This gets the plant to a discharge of 0.1 mg/l phosphorus - an equivalent reduction (in rigor) to 3 mg/l nitrogen. Assuming, as with nitrogen, that some facilities are not taken down to this level, and that a type of trading program is also developed for phosphorus, a reasonable target for phosphorus is a 3 million pound annual reduction goal. This would account for 45 percent of the total reductions needed.

By eliminating the least cost-effective NRT projects, it should be possible to capture the entire nitrogen removal cost reduction estimate of 32 percent. This sets the estimated cost of a 35 million pound reduction at \$3.2 billion. Using the Chesapeake Bay Program's average amortization factor to spread the cost over the estimated 20-year life of the facility results in an annual cost of nitrogen reduced (including operating and maintenance costs) of \$8.56 per pound.

To reduce phosphorus by 3 million pounds would require an additional \$1.2 billion, at an annualized cost of \$74.00 per pound.

## 2. DIET AND FEED ADJUSTMENTS

Potential for annual additional reduction at the maximum feasible level of implementation:

<b>Nitrogen:</b>	Data under development
<b>Phosphorus:</b>	0.22 million lbs. @ no add'l. cost (poultry only)
<b>Sediment:</b>	Not Applicable

**B**y far, the most cost-effective way to minimize the environmental impact of the large volumes of manure generated within the watershed is through adjusting feed formulation for

poultry and livestock. Nitrogen and phosphorus are essential nutrients for animal health, but because animals are unable to fully utilize nutrients in feed, only a fraction of the nitrogen and phosphorus supplied in feed are actually absorbed by the animal. The remainder must be properly managed as excretion.

A growing body of research suggests great potential for reducing the nutrient concentrations of both livestock and poultry feed by improving its digestibility. Nitrogen reductions of 30–50 percent and phosphorus reductions of 40–60 percent are achievable using a variety of diet modification techniques for poultry, dairy, cattle and swine, according to the July 2002 report of the Council for Agricultural Science and Technology. The report notes, however, that translating these research findings to large scale animal production systems remains a work in progress.

Dairy provides a classic illustration of both the opportunity and the challenge. On a typical dairy farm 70–80 percent of the nitrogen contained in feed is excreted in manure. Given the average dairy cow's production of 100 pounds of manure per day, the reduction of its nutrient content could offer significant benefits from a water quality perspective. Still there are hurdles even beyond questions of diet and feed adjustments. Due to the lack of consolidation and integration in the dairy industry, the implementation of large scale nutritional advances — not to mention the monitoring of these advances — will be difficult to quantify.

At drafting time, we are unable to reliably calculate the costs and nutrient reduction benefits for the Bay region associated with the full suite of animal diet modification techniques (swine, dairy, poultry, etc.). Available data is currently limited to poultry, due to the industry's experience with phytase additives in the Bay region. As such, the reduction numbers provided in this analysis are limited to poultry and must be further extrapolated to estimate potential reductions through expanding to other animal groups. And while the data is limited, it must be noted that phytase has been successfully used in swine in the upper watershed.

Over the last several years, phosphorus concentrations in poultry litter have declined by about 16 percent, due in large part to

## Measuring the Cumulative Effects of Multiple Management Practices

In considering the variety of agricultural practices available for reducing nutrient loadings, the Commission has made every effort to measure effectiveness and true cost of implementation of each practice on its own. However, it is impossible to ignore the cumulative benefits that can arise when implementing multiple practices. For example, implementation of nutrient management results in fewer nutrients being spread on a field; this means there is less to treat with conservation tillage or cover crops and therefore less potential benefit from these subsequent practices. Model results from the Bay Program estimate that combining diet and feed changes (poultry phytase), advanced nutrient management (yield reserve), cover crops and conservation tillage at maximum reasonable levels of implementation as defined in this report would result in an annual reduction of 53.6m lbs of nitrogen and 2.93m lbs of phosphorus. This compares to a total of 72.6m lbs of nitrogen and 4.85m lbs of phosphorus if the practices were considered individually and their benefits simply summed.

In short, the cumulative benefit of a group of practices applied to the same land, as we sometimes envision in this report, cannot be determined by simply adding the individual benefits.

Pennsylvania's nearly complete voluntary use and Maryland's law requiring integrators to use phytase in poultry feed. This enzyme allows birds to absorb more of the phosphorus in corn, soy and other grains used as feed, thereby reducing the need for supplemental phosphorus. Further diet refinements could credibly achieve a 30-40 percent reduction in excreted phosphorus, compared with pre-phytase levels. Within this range, this analysis assumes the Bay states can accomplish a 32 percent reduction by adding phytase and other additives, such as probiotics and beneficial enzymes that reduce the need for supplemental phosphorus.

The expected cost of the 32 percent reduction, reported here as zero, is very likely a net savings, due to reduced expenditures for supplemental phosphorus. In fact, the Chesapeake Bay Program reports a net savings of \$365 per 100,000 birds, which, when applied to the 190 million poultry population in the watershed, yields a net savings of

approximately \$3.00 per pound of phosphorus reduced.

Diet and feed adjustments make both economic and environmental sense. A Chesapeake Bay Program report on agricultural innovation estimates that overfeeding for nitrogen alone costs the dairy industry close to \$18 million per year in the Chesapeake Bay watershed. Minimizing or eliminating overfeeding of both nitrogen and phosphorus should be a central focus of our nutrient reduction efforts for both the monogastric and ruminant. A wide range of diet and feed formulation approaches are available to more precisely tailor nutritional requirements to the age, sex and growth phase of animals. Furthermore, by adjusting the ration, formulation and additives used, it is possible to increase the digestibility of ingredients, thereby reducing manure production, while at the same time increasing milk and meat production.

For diet and feed formulation to effectively reduce nitrogen content in manure, "phase feeding," the practice

of matching nutritional needs to the growth curve of an animal group, must be further developed. Coupled with this research and utilization of synthetic amino acids, less cereal grains will be required to meet the nutritional demands of a growing animal. The reductions can be further maximized by the incorporation of new cereal grain varieties.

Clearly, given the costs associated with proper storage, transport and utilization of manure borne by farmers and related industries, a shift in incentives provided by state/federal cost-share programs is needed to promote dietary changes that reduce the impact of animal wastes. At the same time, commercial testing of a wide range of approaches to reduce the nutrient content of poultry, dairy, cattle and swine manure is warranted, given the promising results of research to date. Improving upon this "prevention of pollution" technique presents extraordinary

# The Impacts of Development

Developed lands are a major contributor of nutrient and sediment loadings to the Chesapeake. Yet none of the measures to deal with the impacts of development come up on the list of most cost-effective actions to help meet the 2010 nutrient goals of the Chesapeake Bay Agreement. This is essentially because corrective actions in urban and suburban areas are costly. And the measures of effectiveness of those actions are at best highly variable, and at worst open to question by the experts. In addition, some of the best understood measures, such as planting forest buffers along urban and suburban streams, take many years beyond our current focus of 2010 to provide maximum benefits.

As seen in the table at right, developed areas are an important source of nutrient and sediment loadings in all three Commission states. What the data does not show is that urban and suburban sources are the only areas where loadings are growing. Estimated loadings from agriculture and point sources are both trending down, and even air sources show some promise of improving before 2010. But loadings from developed land are still on the rise.

How do we turn around this trend? The major source is stormwater, which runs off of hard surfaces and tears out urban streambeds. New national stormwater regulations from EPA are now under implementation by states in urban areas. The new measures called for will be a mix of government actions and new requirements on developers and managers of large properties. And they will deal with toxic pollutants and bacteria as well as nutrients and sediment.

But the job to reduce stormwater impacts from developed land will be expensive, difficult to measure and effective only over the long-term. In order for measures to be highlighted in this Report, they must be cost effective and able to reduce sizable amounts of nutrient and/or sediment pollution. Actions to reduce the loadings from

CHESAPEAKE BAY NUTRIENT AND SEDIMENT LOADS BY LAND USE AND STATE (Percentages)

	VA	MD	PA
<b>Land Cover</b>			
Urban/suburban	22	29	15
Forest	56	45	63
Agriculture	22	27	22
<b>Nitrogen Sources</b>			
Urban/suburban	23	21	14
Agriculture	29	39	49
Point sources	33	26	11
Other	15	14	26
<b>Phosphorus Sources</b>			
Urban/suburban	32	35	15
Agriculture	41	43	63
Point sources	24	20	18
Other	3	2	4
<b>Sediment Sources</b>			
Urban/suburban	19	21	12
Agriculture	55	70	71
Other	26	9	18

Source: Materials prepared by the Chesapeake Bay Program for the Blue Ribbon Finance Panel.

developed areas will help; but they are not the best place to spend public money to get timely and efficient results to benefit the Bay.

Why is this? First, handling urban stormwater is extremely complex. Until we began to understand how important local stream flow and groundwater recharge are to the health of downstream natural systems, the goal of all stormwater management was to get as much of the water off-site as fast as possible. So we must change the way people think about stormwater. On-site infiltration through better site design is far more preferable. Plus, every combination of buildings, topography, surfaces and subsurface strata is different. This makes it nearly impossible for impact reduction practices to be measured, or even modeled, for effectiveness.

# Chesapeake Bay

Add to this the high cost of controls, especially in already built-up areas where they must be retrofitted. In even those few cases where experts have dared to attach a number to a given practice, the cost per pound of nitrogen removed is many hundreds of dollars. The one exception is urban forest buffer replacement; where it can be done, the cost is estimated at \$53 per pound of nitrogen, making it among the most cost-effective of urban practices.

The actions to be taken to reduce nutrients and sediment from developed land fall into a number of categories:

- 1. Low-impact Development Practices.** When rural land is converted to development, there are ways to reduce the impact of stormwater from the outset. These have been gathered into a set of principles which are often referred to as Low Impact Development or Better Site Design. They deal with such issues as reducing street widths, roof areas and driveway lengths to cut back on paved surfaces; protecting mature trees and natural low areas, and restoring the site hydrology after construction. By following these principles, developers can substantially reduce stormwater pollution, thereby controlling future costs at the onset of the project.
- 2. Forest Buffers Along Streams.** Forests absorb nutrients and are especially important near streams, where their extensive root systems intercept pollutants and prevent stream bank erosion. Urban and suburban areas can benefit as much as rural from forest buffers, but often there are practical limits to the width and extent of buffers. Measures must be taken to protect existing buffers from development as well as to restore them where practical.
- 3. Reducing Impermeable Surfaces.** Runoff from parking lots, roads, roofs, driveways and

other paved areas overloads nearby land and streams, and the impact from impervious areas is three times that of permeable. New permeable materials are being offered for new construction as well as for retrofitting existing impervious surfaces. While costs are still high and maintenance remains an issue, over time local requirements and buyer preference are likely to see more widespread use.

- 4. Green Buildings.** Usually offices, “green buildings” are structures using the latest in environmentally-friendly technologies, including many which deal with stormwater and runoff issues. Roof gardens, reuse of rainwater, and assuring that all pervious surfaces drain into green areas designed to absorb stormwater are examples of design features. Architecture and engineering firms specializing in green buildings are beginning to proliferate.
- 5. Homeowner Actions.** The cumulative impact of millions of urban and suburban residents can be significant. Things to consider:
  - Reduce fertilizer use on lawns, either by cutting back on concentrations or by replacing lawn with natural areas, or both.
  - Capture roof runoff in rain barrels or rain gardens, and keep it on site for gardens and other greenery.
  - Keep grass longer to encourage growth of extensive root systems to absorb water.
  - Replace asphalt or concrete driveways with a permeable surface.
  - Consolidate automobile trips and purchase low-emission vehicles to reduce nitrogen emissions from tail pipes. ■

opportunities, both for the Bay region and nationwide.

### 3. TRADITIONAL NUTRIENT MANAGEMENT

Potential for annual additional reduction at the maximum feasible level of implementation:

---

**Nitrogen:** 13.6 million lbs. @  
\$1.66/lb.

---

**Phosphorus:** 0.8 million lbs. @  
\$28.26/lb.

---

**Sediment:** Not Applicable

---

**N**utrient management plans (NMPs) are the most widespread management practice currently in use in the Chesapeake Bay watershed for the control of nitrogen and phosphorus. Nutrient Management Plans prescribe the use and timing of nutrients in manure or commercial fertilizer to reduce or eliminate excess application while assuring no loss of yield. Recently, plans addressing poultry and other manures have been focusing on phosphorus rather than nitrogen. As of 2002, Nutrient Management Plans had been prepared for approximately 85 percent of the cropland in Maryland, 45 percent of the cropland in Pennsylvania and 40 percent of the cropland in Virginia.

NMPs can be written for a mix of nitrogen and phosphorus for acres receiving commercial fertilizer, since the mix in the fertilizer can be adjusted for relative content. Where animal manures are being used as nutrients, phosphorus-based plans are especially important, since nitrogen-based plans will likely result in over-application of phosphorus, which is more prevalent in manure than needed for crops. The deficit in nitrogen is then made up with commercial fertilizer.

## Precision Agriculture

**P**recision agriculture employs state-of-the-art computer and satellite technology to plant crops and to apply fertilizer and pesticides as needed, thereby achieving greater accuracy than previously possible. This practice is on the cutting edge of agricultural innovation. Since it has only been tested on a pilot scale, Baywide efficiencies, cost estimates and reductions are not yet available. While insufficient information prevented our inclusion of this practice in the ranking, it shows great promise as a tool for more precise nutrient application.

The major components of precision agriculture include:

- A global positioning system (GPS) that allows satellites to track agricultural machinery in the field and provides guidance for on-the-ground operations.
- A geographic information system (GIS) mapping software program that plots field variables such as soil type, topography, drainage, rainfall data, irrigation and cropping history. This collection of data allows for a comprehensive analysis of management practices and optimal strategies for field operations.
- Machine control systems that automate equipment to save time and costs associated with field operations.
- Advanced sensors to better predict yield potential at the time of nutrient application and to vary the application rate to match that potential.

Conversion to precision agriculture will require a concerted investment in new equipment and operator training, although regular advances in technology will provide ever more user-friendly and affordable equipment. More advanced technologies are in development to expand the parameters measured, to increase the accuracy and speed of information gathering and to incorporate it comprehensively and instantly as machinery moves across the crop field. By applying inputs only where needed and in precise amounts, farmers will realize a more efficient and effective operation, tremendous savings in fertilizer and chemicals, increased yields and a higher level of pollution prevention. Meanwhile, education about required levels of nutrients should continue so that as the technology becomes available, better assumptions can be used to accurately program the system with crop nutrient needs.

In reality, many areas that should be under phosphorus-based plans are just now shifting from nitrogen-based plans.

Nutrient Management Plans should be fully implemented wherever feasible. Most experts agree that, whether due to changes in cropping patterns,

concern about weather conditions, or merely a disregard for them, no more than 60 percent of the plans are being fully implemented. This is not to say that we are only seeing 60 percent of the potential benefit from nutrient management planning. Indeed, of the 40 percent not being fully implemented, we are seeing a benefit even from partial implementation. Nevertheless, if we can assist those farmers, who have already gone through the process of nutrient management plan development and partial implementation, to achieve full implementation, large nutrient reductions at minimal cost can be achieved.

Thus, the first order of business is to implement already written NMPs. All told, we would realize additional reductions of 8.2 million lbs of nitrogen runoff and 424,000 lbs of phosphorus as a result. It is important to note that from a “bookkeeping” perspective, states cannot receive “credit” for these gains because the Bay jurisdictions’ nutrient reduction goals already assume full implementation of all NMPs written to date.

The second order of business is to develop and implement NMPs for the remaining acres; this would yield an additional reduction of 13.6 million lbs of nitrogen and 800,000 lbs of phosphorus.

The cost of developing and implementing a NMP is \$7 per acre. Of course, the gains in nutrient reductions from implementing plans already written would come at minimal cost. The total cost for developing and implementing new NMPs on the row crop and hay acreage lacking plans is \$22.7 million. This would result in an estimated reduction of 13.6 million pounds of nitrogen per year, or 0.8 million pounds of phosphorus, at \$1.66 per pound of nitrogen and \$28.26 per pound of phosphorus.

We recognize that applying less manure to cropland means more manure will have to be managed through methods other than land application. This creates its own set of environmental challenges associated with manure transport, storage and alternative use. Despite this, the Commission is advocating that nutrients be applied based on crop phosphorus and nitrogen needs and that other methods of using excess manure in environmentally sensitive ways be developed. [See sidebar on manure transport on Page 14.]

## 4. ENHANCED NUTRIENT MANAGEMENT

Potential for annual additional reduction over traditional nutrient management at the maximum feasible level of implementation:

---

**Nitrogen:** 23.7 million lbs. @ \$4.41/lb.

---

**Phosphorus:** 0.8 million lbs. @ \$95.79/lb.

---

**Sediment:** Not Applicable

---

**E**nhanced Nutrient Management (ENM), also referred to as “yield reserve,” provides a 15 percent further reduction in nutrients applied to cropland beyond traditional nutrient management. This maximizes the efficiency of nutrient use in most years.

The implementation of ENM on all row crops and hay acreage would significantly reduce nitrogen runoff beyond the reductions achievable from traditional NMPs. In fact, an astounding 23.7 million more pounds of nitrogen, or over 20 percent of the total nitrogen reduction goal, could be captured through this single management practice.

The cost of ENM is approximately \$40/acre. This cost includes an assumed \$30/acre incentive payment to the farmer, \$8.50/acre insurance fee and \$1.50/acre technical administration cost. These incentive and insurance costs would provide a “safety net” for farmers, who are reluctant to risk lower yields that they fear will result from the reduced application rate.

At \$40 per acre, the total cost for both row crops and hay acreage would be just under \$255 million dollars or an average of \$4.41 per lb for reducing nitrogen by 23.7 million lbs. Phosphorus reductions of 0.8 million lbs would be achieved at a higher unit cost of \$95.79 per pound.

Currently no state is set up to operate an Enhanced Nutrient Management program, although the practice is being investigated on a pilot scale and included in a number of the emerging state tributary strategies. In addition, the farming community can be expected to be hesitant to adopt a proposal that might reduce potential optimum yield. This accounts for the relatively high cost per acre, because the incentive payments are estimated to be generous, at least at the outset until farmers

## Transport and Alternative Uses for Excess Manure

Across the watershed, in areas where confined animal operations are concentrated, we are seeing the production of more manure than local cropland and pastureland can assimilate. The challenges of manure management will only intensify as new federal regulations addressing concentrated animal feeding operations are implemented. Under the EPA regulations, some large livestock and poultry producers would have to meet either a nitrogen-based or phosphorus-based application standard, depending on local soil conditions.

By seeking to more precisely match fertilizer application with actual crop needs, nutrient management planning and precision agriculture will result in greater volumes of manure requiring transport and alternative uses. For example, although manure is typically spread year round, optimal use of its nutrients occurs only during the growing season, and fall/winter application has been pinpointed as a major source of nutrient pollution.

Several obstacles stand in the way of widespread use of manure on cash-crop or other "green industry" operations. Historically, farmers without their own supply of manure, and even some who do, have looked to chemical fertilizer to replenish soil nutrients rather than use manure. This is because manure is not a standardized product. The levels of nutrient content, nutrient concentration and odor can vary greatly between sources of manure and even over time from the same source.

Due to its high moisture content and associated weight and volume, transportation costs represent another limiting factor, making transportation over long distances impractical. Further aggravating this limitation is continued urban sprawl. As traditional farming communities are increasingly encroached upon by urban development, eligible fields for manure application become farther and farther apart. This further increases transportation costs or prevents transportation altogether.

There are two approaches to increasing the desirability of manure as a nutrient source on all farms. The first is to decrease the levels of nutrients in the manure through adjustments to diet and feed, allowing more to be applied on the same acreage; the second is to process the manure into a standardized product that is concentrated, stable and has a reliable nutrient content.

The first approach is discussed in detail on page 8. Regarding the second approach, some progress has been made to explore the feasibility of processing alternative uses of manure. The USDA estimates that alternative uses

could process as much as 376,000 tons, or 65 percent of the poultry litter produced in the Shenandoah and Delmarva regions, by 2010. Much of the work has focused on poultry manure, due to its relatively low moisture content and weight.

One example of a current project is the Perdue AgriRecycle plant on the Delmarva Peninsula. At that facility approximately 60,000 tons per year are being pelletized for use on golf courses, sports fields, specialty horticultural crops and other uses. However, the estimated transportation costs are \$10/ton, even within a 25-mile radius. Currently Maryland and Delaware provide assistance and/or subsidies for manure transportation.

If transportation costs can be lessened, processing of manure can be a viable option. The USDA study indicated that the annualized costs of building the processing facilities are often less than the cost of land application. The economic feasibility of industrial processing of livestock wastes remains unresolved. Technologies exist to reduce moisture content and transform the manure into a more homogeneous and stabilized fertilizer product. Biodigesters and other uses of biomass as fuel present additional opportunities. As a further indication of the need to expand and refine processing and transportation efforts, the draft tributary strategies for Maryland, Delaware and West Virginia anticipate transporting some portion of their states' poultry litter to areas outside the watershed. The need for answers becomes even more immediate as new requirements for phosphorus-based plans further limit manure application to land.

Clearly, there is a need to adjust land application practices throughout the watershed to ensure that manure is only applied according to crop needs. These adjustments can only occur with enhanced research and funding to provide a more formal, regional transportation and marketing structure and to produce consistent, standardized products.

The important role that agriculture plays in the cultural and economic landscape of the Chesapeake Region requires us to further explore the technologies that will enhance the viability of that industry and benefit the environment. This includes technologies such as feed additives or manure processing that will reduce farmers' input costs and increase the beneficial utilization of manure produced in the region while reducing excessive use of chemical fertilizers. In order for these to be feasible options, current research and pilot projects will need to be expanded in size and beyond the scope of poultry.





**FIGURE 4**  
ANNUAL BAYWIDE NUTRIENT AND SEDIMENT REDUCTION POTENTIAL  
FOR THE SIX MOST COST-EFFECTIVE MEASURES

MEASURES	NITROGEN		PHOSPHORUS		SEDIMENT	
	M lbs.	\$/lb.	M lbs.	\$/lb.	M tons	\$/ton
1. Waste Treatment Upgrades	35.0	8.56	3.0	74.00	na	
2. Diet and Feed Changes	Data under dev.		0.22	0.00	na	
3. Nutrient Management	13.6	1.66	0.80	28.26	na	
4. Enhanced Nutrient Mgmt.	23.7	4.41	0.80	95.79	na	
5. Conservation Tillage	12.0	1.57	2.59	—	1.68	—
6. Cover Crops	23.3	3.13	0.44	—	0.22	—

na = not applicable      — = No additional cost

### IMPLICATIONS

Total potential reductions for nonpoint sources (2–6) at the edge of field*	53.6m lbs.	2.93m lbs.	1.35m tons
Total potential reductions for nonpoint sources (2–6) delivered to the Bay**	45.4m lbs.	1.99m lbs.	0.90m tons
Total potential reductions for all six practices (1–6) delivered to the Bay	80.4m lbs.	4.99m lbs.	0.90m tons
Bay Agreement reduction goal (2002–2010)	103m lbs.	6.7m lbs.	0.90m tons

\*The reductions attributed to each agricultural practice are less when combined with other practices on the same land (see sidebar on page 7). Therefore, the expected total reduction from combining agricultural practices is less than their sum.

\*\*Agricultural reductions are measured at edge of field and are reduced by the time they reach the Bay; this results in total reductions in loadings from those six practices to the Bay as indicated. Waste treatment plant reduction estimates are as delivered to the Bay.

become comfortable with the concept. Yet the immense potential of enhanced nutrient management to achieve significant pollution reductions makes the effort worth undertaking in the eyes of many in the states.

## 5. CONSERVATION TILLAGE

Potential for annual additional reduction at the maximum feasible level of implementation:

<b>Nitrogen:</b>	12.0 million lbs. @ \$1.57/lb.
<b>Phosphorus:</b>	2.59 million lbs. @ no add'l. cost
<b>Sediment:</b>	1.68 million tons @ no add'l. cost

**C**onservation tillage refers to planting crops with minimal cultivation of the soil and retaining cover crops and crop residues that cover a minimum of 30 percent of the field. While this provides some nitrogen reduction benefits, more important, it is the single most beneficial agricultural management practice for both phosphorus and sediment control (see Figure 4), providing 38 percent of the phosphorus reduction and 100 percent of the sediment reduction needed Baywide. Conservation tillage includes:

- No-till, in which no plowing of the soil takes place and crop seeds are planted through perennial residue cover.
- Strip-till, in which narrow planting strips are

tilled, leaving the majority of the field untilled and under residue cover.

- Ridge-till, used in cold, wet areas in which tilled ridges are built up and planted with residue cover between the rows.
- Other variations of minimum tillage with degrees of permanent cover.

Continuous no-till is the most common version of conservation tillage, and it is in widespread use in the Chesapeake Bay watershed. The greatest potential for expansion of conservation tillage is in Pennsylvania.

Conventional plowing turns soil over, making it vulnerable to erosion and hastening the decomposition of crop residues by mixing soil and oxygen. When rainfall strikes a conventionally plowed field, unprotected soil particles are easily dislodged, infiltration is minimized and runoff carries soil particles with chemicals and fertilizers attached to them to the nearest body of water.

In contrast, conservation tillage provides the following benefits:

- Improves water quality and reduces erosion by not disturbing the soil and maintaining a protective cover that maximizes infiltration, minimizes runoff and keeps fertilizers and pesticides in place.
- Improves soil quality by making it easier for plants to root, increasing organic content and moisture retention and harboring populations of earthworms and beneficial soil microbes.
- Saves costs in time and equipment by requiring as little as one trip across a field for planting a crop (versus several with conventional tilling).
- Improves air quality by reducing dust, reducing machinery use (and thus their emissions) and sequestering carbon.

While conservation tillage plays an important role in proper nutrient management, it should be noted that this practice limits the land available for incorporation of manure into the soil, which is also an effective agricultural best management practice. Injecting livestock manure is possible on no till areas but it is costly. Conservation tillage on a greater number of acres will increase the need for

manure transport and alternative use. [See sidebar on manure transport.]

The reduction figures presented in this section assume an annual cost of \$9/acre applied to 2.1 million acres of cropland not in conservation tillage as of 2002. The \$9/acre includes a \$15/acre incentive cost paid for the first four years to promote the practice plus \$3/acre/year for operating costs.

## 6. COVER CROPS

### LATE

Potential for annual additional reduction at the maximum feasible level of implementation:

---

**Nitrogen:** 15.2 million lbs. @ \$3.50/lb.

---

**Phosphorus:** 0.22 million lbs. @ no add'l. cost

---

**Sediment:** 0.11 million tons @ no add'l. cost

---

### EARLY

Potential for annual additional reduction over late cover crops at the maximum feasible level of implementation:

---

**Nitrogen:** 8.1 million lbs. @ \$2.33/lb.

---

**Phosphorus:** 0.22 million lbs. @ no add'l. cost

---

**Sediment:** 0.11 million tons @ no add'l. cost

---

**C**over crops are small grain crops planted in the fall for the purpose of consuming any excess nutrients remaining in the field after harvesting row crops. The primary purpose of cover crops is to capture nitrogen, though they also provide phosphorus reduction and soil erosion benefits. The source of the excess nitrogen is both post-harvest organic material remaining in the soil and unabsorbed fertilizer.

Cover crops, unlike winter grain crops grown for harvest, are not fertilized. Rye, wheat or barley work best for nutrient removal. In the spring, the cover crop is killed or plowed under. Traditional cropping patterns and winter grain crops make it difficult to apply cover crops to more than about half of row crop acreage in the Chesapeake region each year. Nevertheless, the potential to cover half of the approximately 4.1 million acres of cropland in the watershed still allows for a 17-fold increase

## Air Emissions

Surprisingly, air emissions contribute between a quarter and a third of the nitrogen load reaching the Bay. This reflects airborne nitrogen that is deposited directly to the Bay and tidal waters, and air deposition to the watershed lands, which reaches tidal waters as the result of runoff.

Runoff of airborne nitrogen deposited to the watershed is directly influenced by land use. While forests in our watershed typically retain up to 88 percent of the nitrogen deposited from the air, impervious urban areas retain very little, and a large portion of the airborne nitrogen deposited on urban lands is washed into nearby streams as polluted urban stormwater runoff.

To date, air emission controls have largely resulted from implementation of federal Clean Air Act regulations addressing the two major air pollution sources: motor vehicles and electric power plants. The Environmental Protection Agency has committed to delivering an 8 million pound reduction from these sources by 2010 towards attainment of the Bay's water quality goals. Clearly, full implementation and strong enforcement of Federal air pollution regulations are among the most cost-effective measures to reduce nutrient loads to the Bay. These actions are required for clean air purposes and affect sources in a much wider region than the Chesapeake watershed.

Potential state actions to further reduce air emissions from mobile and stationary sources were considered as part of this analysis, but did not appear to be among the most cost effective, based on available data. Due to complexities in understanding the transport and fate of air pollutants, there is a need for improved modeling tools in order to thoroughly evaluate additional air pollution control opportunities and their impact on the Bay.

While agriculture's contribution to atmospheric deposition is relatively small, its importance may rise with the increasing size and concentration of animal operations, and its impact is directly tied to several of the practices analyzed in this report.

For example, land application of manure is a primary agricultural source of ammonia. Nutrient management practices that reduce the application of fertilizer to cropland will also reduce total ammonia emissions. Conversely, practices that minimize soil disturbance, such as conservation tillage, may exacerbate ammonia problems if they discourage manure incorporation. This is particularly important for dairy and livestock operations, where wet slurries applied to the land show large and rapid ammonia losses. Ammonia volatilization can be reduced by as much as 80-90 percent if this manure is incorporated into the soil the same day it is applied. Further reductions can be achieved through the use of feed additives and dietary changes which increase the acidity of manure and reduce its nitrogen content.

Animal housing represents another major source of agricultural ammonia emissions. Given the predominance of the poultry industry in the Bay region, monitoring studies are underway to estimate emissions from poultry houses, which can hold upwards of 25,000 birds. Biofilters installed on poultry house exhaust fans may be able to capture as much as 60 percent of the ammonia emanating from these facilities, at a cost of approximately \$5,000-8,000 per house.

Ammonia emissions are not currently regulated under the Clean Air Act. California is the only state currently developing regulations to reduce these emissions. Maryland and Pennsylvania have identified control practices in their draft Tributary Strategies.

over current levels (approximately 100,000 acres per year).

There are two different cover crop approaches, early and late application. Current programs apply "late" cover crops, which are sown after the harvest of the row crop and up to 14 days after the long-term average date of the first killing frost in the area. Assuming a maximum 50 percent coverage of crop acres, the potential for nitrogen load reduction

is 15.2 million pounds throughout the watershed. In northern or mountainous areas, where growing seasons are shorter and crop harvests are later, the benefits may be less, because the row crop takes up nutrients almost to harvest, leaving less excess in the soil. The best areas for cover crops are where the growth slows at the end of a long growing season before harvest, when there are more likely to be unabsorbed nutrients on the field.

“Early” cover crops provide additional benefits by being planted more than seven days before the average date of the first killing frost. In many cases this means planting before harvest of the row crop. This is accomplished by flying on the cover crop or otherwise dispersing the seed through the unharvested crop. Experience shows that this approach works and there is anecdotal evidence that the harvest of the row crop is actually aided by the emerging cover crop root structure. Early cover crops instead of late cover crops on 50 percent of the crop acres would provide an additional 8.1 million pound reduction of nitrogen, for a total annual reduction of 23.3 million pounds, compared to current levels of effort and planting times.

The major portion of the cost of cover crops is the payment to farmers to undertake the planting. There is no consensus on what it will take to achieve the annual 50 percent level of coverage that is possible. Unlike other practices, cover crops provide no immediate direct benefit to the farmer other than the payment for planting. And since experience to date is limited, predicting the necessary payment level is problematic.

In order to calculate costs, the Commission selected a \$27 per acre figure developed by the Bay Program. This figure is about in the middle of the range of estimates used by the states in their tributary strategies. Applying this to late cover crops results in a cost of \$3.50 per pound of nitrogen removed. Because early cover crops allow for substantially more root development before winter, the cost per pound of nitrogen removed is lower, at \$2.33 per pound.

The most important consideration for cover crops is assurance of long-term commitment by the states to fund the program. At an annual cost of \$27 per acre for an estimated 2.1 million acres, the cost is \$56 million watershed-wide. At present, available funds are limited to approximately 10 percent of this amount. And unlike investments in sewage treatment plants, where the total capital costs are amortized, cover crop costs recur each year. Therefore, reliance on cover crops as one of “The Top Choices” requires the capacity and commitment to provide yearly funding. ■

## PART 3

# Conclusion

In our 2003 report, *The Cost of a Clean Bay*, the Commission concluded that the effort to clean up the Chesapeake would require enormous expenditures beyond the capacities of current programs and that it was incumbent on each state to maximize the environmental benefits realized from each dollar spent. The Commission also realized that to get the most benefit out of limited resources, the Bay Program partners will need to further target their pollution control resources toward those practices that result in the greatest reduction per dollar spent — the most cost-effective practices.

In preparation for this report, the Commission took an intensive look at a broad suite of pollution control options and for the first time, measured not only their ability to reduce nutrients but also what was the environmental benefit to be gained by widespread adoption. From this analysis, we have derived the six practices that give us “the biggest bang for the buck.” Overall, the six present a wide range of maturity:

- Some are in wide use and we just have to do more.
- Some are in wide use, yet need to undergo changes to become more effective.
- Some are opportunities we are currently missing out on.
- Some are obvious but we are not doing nearly as much as we could.
- Some are great new ideas that offer true promise only after additional research and program development.
- Many fall into more than one of these categories.

Fundamentally though, this report should hearten us all — it demonstrates that significant water quality benefits can be had at reasonable cost. Figure 4 provides a summary of the Baywide potential nitrogen, phosphorus and sediment reductions from the six practices identified. When the benefits are added together, even discounting them where they overlap on the same land, and applying them only where they make sense, we have to conclude that **THE JOB CAN BE DONE**. There are huge benefits to be derived from these six alone

and when taken along with riparian forest buffers, wetlands restoration and other measures proposed by the Bay partners, they maximize our chances to achieve our goals.

The Commission clearly recognizes that there is geographic and economic variability among the jurisdictions in the watershed. We are not suggesting that the practices identified in this report represent the only way to achieve the restoration of the Chesapeake. However, it is critical that the states begin targeting their limited resources toward those practices that hold the most promise for achieving the allocated reductions. This report is intended to be a tool for that effort and can be used to direct programmatic and funding priorities.

We acknowledge that several of the practices, including enhanced nutrient management and diet and feed adjustments, represent emerging technologies and additional research and study is needed before they can be fully implemented. The Commission also realizes that lack of sufficient money, both at the state and federal level, is a significant barrier to implementation of these practices. The reality is that the task before us is to choose nutrient and sediment reduction practices that will control the most pollution for the least cost in the near term and then ensure we have the policies, programs and funding in place to accomplish them. The Commission offers this report to assist the states in making these choices. ■

## APPENDIX A

# Chesapeake Bay Program Practices Included in the Watershed Model

### **Agricultural Practices**

- Conservation Tillage
- Cover Crops
- Carbon Sequestration
- Nutrient Management Plans
- Enhanced Nutrient Management
- Conservation Plans
- Forest Buffers
- Grass Buffers
- Wetland Restoration
- Tree Planting
- Land Retirement
- Off-Stream Watering with Fencing
- Off-Stream Watering without Fencing
- Off-Stream Watering with Fencing and Rotational Grazing
- Animal Waste Management
- Poultry Litter Transport
- Livestock Manure Transport
- Poultry Phytase

### **Urban/Suburban Practices**

- Urban Forest Buffers
- Urban Tree Planting
- Urban Nutrient Management
- Mixed Open Nutrient Management
- Urban Stream Restoration
- Urban Filtering Practices
- Urban Infiltration Practices
- Wet Ponds and Wetlands
- Dry Extended Detention Ponds
- Dry Detention Ponds and Hydrodynamic Structures
- Urban Growth Reduction
- Septic Denitrification and Pumping

### **Point Source Controls**

- Wastewater Treatment Plant Nutrient Reduction Technology

## Acknowledgements

*Cost-Effective Strategies for the Bay* was prepared by the Commission and its staff with the contractual assistance of Bill Matuszeski and Bob Hoyt. Both men brought an extraordinary depth of knowledge to the table, which helped to ensure the excellence of this work. The Commission would also like to express its appreciation to Jeff Sweeney of the Chesapeake Bay Program, who offered his thorough understanding and time, responding to our constant demands for new model runs and further analysis of the data. Many of our colleagues helped us to review the document to ensure accuracy, balance and readability. You know who you are. To all of you, we express our gratitude.

Finally, we thank the Keith Campbell Foundation, whose financial support helped to make this project both doable and timely.

## Chesapeake Bay Commission

The Commission maintains offices in Maryland, Virginia and Pennsylvania. Commission staff are 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.

### **Headquarters and Maryland Office**

60 West Street, Suite 406  
Annapolis, MD 21401  
Phone: 410-263-3420 · Fax: 410-263-9338

### **Virginia Office**

502B General Assembly Building  
P.O. Box 406  
Richmond, VA 23218  
Phone: 804-786-4849 · Fax: 804-371-0659

### **Pennsylvania Office**

634 Main Capitol Building  
Harrisburg, PA 17102  
Phone: 717-772-3651 · Fax: 717-772-3707

### **Web Site**

[www.chesbay.state.va.us](http://www.chesbay.state.va.us)