

OCTOBER 2014

# THE ECONOMIC BENEFITS OF CLEANING UP THE CHESAPEAKE

A VALUATION OF THE NATURAL BENEFITS GAINED BY  
IMPLEMENTING THE CHESAPEAKE CLEAN WATER BLUEPRINT



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The Chesapeake Bay Foundation  
gratefully acknowledges the generosity of

**Albert H. Williams**

for underwriting this report.

# Executive Summary

## The Economic Benefits of Cleaning Up the Chesapeake

### A Valuation of the Natural Benefits Gained by Implementing the Chesapeake Clean Water Blueprint

The Chesapeake Bay is a national treasure. Its forests, wetlands, and waters provide many natural benefits to the 17 million people and associated plants and animals that call this 64,000- square-mile region home. But those benefits have been greatly reduced by agricultural, urban and suburban, sewage treatment, and air pollution.



In 2010, the six Bay states, the District of Columbia, and the federal government began a renewed effort to restore the health of the Bay and its vast network of rivers and streams. That effort—the Chesapeake Clean Water Blueprint<sup>1</sup>—is designed to substantially reduce the amount of nitrogen, phosphorus, and sediment pollution that enters local waters and the Bay. Its goal: to restore the Bay’s ecological health. In doing so, implementing the Blueprint will reduce risks to our health, provide a legacy of clean water for our children and grandchildren, and increase economic benefits to the region.

Fully implementing the **Blueprint** is a big job. It requires the commitment, time, and resources of all sectors of our society and every individual in the watershed.

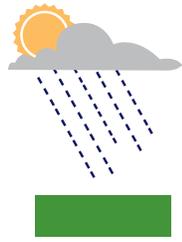
**So, what will be the return?** According to the peer-reviewed economic report, *The Economic Benefits of Cleaning Up the Chesapeake*, it will be tremendous. The report’s findings include the following:

1. In 2009 (before the Blueprint), the lands and waters of the Chesapeake Bay region provided economic benefits totaling \$107.2 billion annually. This serves as the baseline for our study. These benefits include air and water filtration, agricultural and seafood production, property valuation, and flood and hurricane protection.
2. The value of these same benefits will increase by \$22.5 billion to \$129.7 billion annually if the Blueprint is fully implemented. Once realized, those benefits would be enjoyed year after year.
3. If the Blueprint is not fully implemented, pollution loads will increase, and the value of the natural benefits will decline by \$5.6 billion annually to \$101.5 billion. The value of the Bay region’s natural benefits will decline further after 2025 as additional pollution continues to degrade our natural resources.

<sup>1</sup> The Blueprint includes the science-based pollution limits established by the Chesapeake Bay Total Maximum Daily Load and the state-specific implementation plans designed to achieve those limits. EPA and the Bay jurisdictions agreed to implement practices to achieve 60 percent of the necessary pollution reductions by 2017, and 100 percent of those practices in place by 2025.

## What Are Natural Benefits?

Our lands, waters, and associated plants and animals provide natural benefits that economists call ecosystem services. People depend on these services to sustain and enhance human life. In addition to the production of goods such as food and timber, these benefits from nature include life-supporting processes such as water and air purification and flood protection, and life-enhancing assets such as beautiful places to recreate and live. Despite their vital importance, these natural benefits are often taken for granted, their value not quantified. Over the past decade, however, the acceptance of forests, wetlands, and other ecosystems as vital economic assets has led to an increase in studies calculating these natural benefits in regions including the Everglades, the Mississippi Delta, the Puget Sound—and now the Chesapeake.



### CLIMATE STABILITY

Influence of land cover and biologically mediated processes on maintaining a favorable climate, promoting human health, crop productivity, recreation, and other services.

Chesapeake land uses that provide this benefit:

Forest Urban Open Wetland



### AIR POLLUTION TREATMENT

Purification of air through the absorption and filtering of airborne pollutants by trees and other vegetation, yielding cleaner, more breathable air (reduction of NO<sub>x</sub>, SO<sub>x</sub>, CO<sub>2</sub>), reduced illness, and an improved quality of life. (Note: Economists more commonly call this “Gas Regulation.”)

Chesapeake land uses that provide this benefit:

Forest Urban Open Wetland



### FOOD PRODUCTION

The harvest of agricultural produce, including crops, livestock, and livestock by-products; the food value of hunting, fishing, etc.; and the value of wild-caught and aquaculture-produced fin fish and shellfish.

Chesapeake land uses that provide this benefit:

Agriculture Open Water Wetland



### WASTE TREATMENT

Removal or breakdown of nutrient pollution and other chemicals by vegetation, microbes, and other organisms, resulting in fewer, less toxic, and/or lower volumes of pollutants in the system.

Chesapeake land uses that provide this benefit:

Forest Open Water Wetland



### WATER FLOW REGULATION

Modulation by land cover of the timing of runoff and river discharge, resulting in less severe drought, flooding, and other consequences of too much or too little water available at the wrong time or place.

Chesapeake land uses that provide this benefit:

Forest Urban Open Urban Other Wetland



### RECREATION

The availability of a variety of safe and pleasant landscapes—such as clean water and healthy shorelines—that encourage ecotourism, outdoor sports, fishing, wildlife watching, etc.

Chesapeake land uses that provide this benefit:

Agriculture Forest Open Water Urban Open Wetland Other



### WATER SUPPLY

Filtering, retention, storage, and delivery of fresh water—both quality and quantity—for drinking, irrigation, industrial processes, and other uses.

Chesapeake land uses that provide this benefit:

Forest Open Water Wetland



### AESTHETIC VALUE

The role that beautiful, healthy natural areas play in attracting people to live, work, and recreate in a region; often reflected in property values.

Chesapeake land uses that provide this benefit:

Agriculture Forest Open Water Urban Open Wetland Other

## The Methods

To analyze the benefits that the Chesapeake Bay's watershed (a six-state drainage area) provides, the authors first established a 2009 baseline. They considered the environmental condition of seven types of land use: agriculture, forest, wetland, open water, urban open space, urban other (e.g., paved areas), and other (mostly barren land). These land uses were derived from data from the Chesapeake Bay Program and the National Land Cover Database.

Next, they calculated how the amount and productivity of these land uses would change if the Chesapeake Clean Water Blueprint were fully implemented or, alternatively, not implemented, Business as Usual.

The authors then drew from existing economic studies to calculate the dollar value of eight benefits that we enjoy and that are supplied by these land uses. The eight are: climate stability, food production, water regulation, water supply, air pollution treatment, waste treatment, recreation, and aesthetic value.

Finally, for each land use they calculated the total value of the natural benefits under the three scenarios (Baseline, Blueprint, Business as Usual) by multiplying the acres and condition of each land-use type by the dollar value of the applicable eight natural benefits.

(The methodology is fully explained on pages 8 through 12 of the report, *The Economic Benefits of Cleaning Up the Chesapeake*.)

## The Results

When we implement the Blueprint, some highly polluting land uses will be converted to uses that produce more natural benefits. For example, agricultural fields that use proven conservation practices and urban spaces that incorporate common sense development solutions (rain gardens and paving that soaks in rain) will pollute less and provide increased benefits. In addition, the conversion of land from forests and wetlands to uses that produce fewer natural benefits (like parking lots and subdivisions) will occur at a slower pace. As we reduce the amount of nitrogen, phosphorus, and sediment pollution, that flows to our waters, the ecosystems on all the various land uses will become healthier, more capable of providing benefits.

If we fail to implement the Blueprint, we can expect to lose more forests and wetlands to development. Fewer pollution controls will be implemented on urban and suburban streets and agricultural fields. Increases in pollution will degrade ecosystems and as a result they will produce fewer natural benefits.

The report indicates that the benefits provided by the 64,000-square-mile Chesapeake Bay watershed, including its tidal areas, can be valued at more than \$107 billion annually. Furthermore, when the Blueprint is fully implemented, the region will generate more than \$22 billion in additional annual benefits. The report cites a decline in value of \$5.6 billion (in 2013 dollars) annually if the Blueprint is not fully implemented.

The authors found that the majority of the benefits of implementing the Blueprint will be generated by upstream land uses, rather than by the open water land use of the Chesapeake Bay and the tidal portion of its tributaries.

Each of the states in the watershed will see substantially enhanced benefits. Virginia, more than \$8.3 billion annually; Pennsylvania, \$6.2 billion annually; and Maryland \$4.6 billion annually. In all cases, forests generated the largest benefits, because more than half (55 percent) of the watershed is forested and because the services they provide—filtering drinking water, reducing flooding, providing recreation and beauty—are highly valued. Open water, however, had the largest percentage increase associated with implementing the Blueprint.

## The Costs

CBF's study addressed only benefits, not costs.

There are no recent estimates of the total costs of implementation, but an earlier estimate put costs in the range of roughly six billion per year.<sup>2</sup>

Considering federal, state, and local investments in clean water in the 10 years since that time, we estimate the current number is closer to five billion annually. And once capital investments are made, the long-term annual operations and maintenance costs will be much lower.

The Blueprint will return benefits to the region each year at a rate of more than four times the cost of the clean-up plan.

<sup>2</sup> Chesapeake Bay Watershed Blue Ribbon Finance Panel. 2004. Saving a National Treasure. Financing the Clean-up of the Chesapeake Bay. [www.chesapeakebay.net/content/publications/cbp\\_12881.pdf](http://www.chesapeakebay.net/content/publications/cbp_12881.pdf)

The tables below summarize the study's findings. In all cases, the values are expressed in terms of 2013 dollars.

### SUMMARY OF BENEFIT VALUE (ECOSYSTEM SERVICE VALUES) FOR SEVEN LAND USES, BY SCENARIO

Land Use	Baseline	Blueprint		Business as Usual	
	Benefit Value (billions)	Benefit Value (billions)	Change from Baseline	Benefit Value (billions)	Change from Baseline
Agriculture	\$12.258	\$13.434	10%	\$10.949	-11%
Forest	73.960	86.406	17%	69.639	-6%
Open Water	16.721	24.301	45%	16.549	-1%
Other	.467	.508	9%	.386	-17%
Urban Open	3.403	4.706	38%	3.727	10%
Urban Other	.011	.014	26%	.012	7%
Wetland	.356	.364	2%	.270	-24%
<b>Total</b>	<b>\$107.176</b>	<b>\$129.732</b>	<b>21%</b>	<b>\$101.531</b>	<b>-5%</b>

### SUMMARY OF BENEFIT VALUES. BY SCENARIO

Natural Benefit	Baseline	Blueprint		Business as Usual	
	Benefit Value (billions)	Benefit Value (billions)	Change from Baseline	Benefit Value (billions)	Change from Baseline
Aesthetic Value	\$38.446	\$47.407	23%	\$36.653	-5%
Climate Stability	5.498	6.508	18%	5.237	-5%
Food Production	12.129	13.313	10%	10.839	-11%
Air Pollution Treatment	3.471	4.061	17%	3.271	-6%
Recreation	3.071	4.099	33%	3.227	5%
Waste Treatment	12.155	16.470	35%	11.827	-3%
Water Regulation	12.386	14.448	17%	11.634	-6%
Water Supply	20.019	23.427	17%	18.843	-6%
<b>Total</b>	<b>\$107.176</b>	<b>\$129.732</b>	<b>21%</b>	<b>\$101.531</b>	<b>-5%</b>

### SUMMARY OF BENEFIT VALUE FOR CHESAPEAKE BAY JURISDICTIONS. BY SCENARIO

Jurisdiction	Baseline	Blueprint		Business as Usual	
	Benefit Value (billions)	Benefit Value (billions)	Change from Baseline	Benefit Value (billions)	Change from Baseline
Virginia	\$41.195	\$49.540	20%	\$38.066	-8%
Pennsylvania	32.637	38.828	19%	30.810	-6%
Maryland	15.892	20.449	29%	15.209	-4%
New York	10.361	12.276	18%	10.363	0%
West Virginia	6.330	7.668	21%	6.458	2%
Delaware	.735	.941	28%	.659	10%
District of Columbia	.025	.029	15%	.027	5%
<b>Total</b>	<b>\$107.176</b>	<b>\$129.732</b>	<b>21%</b>	<b>\$101.531</b>	<b>-5%</b>

## The conclusions are clear.

### 1 The Chesapeake region currently provides natural benefits of at least \$107.2 billion annually. **(Baseline Scenario)**

The lands and waters of the Chesapeake Bay drainage basin provide economically valuable benefits, including flood protection, water supply and filtration, food, waste treatment, climate regulation, recreation, and aesthetic value. A conservative estimate of these benefits shows economic value of at least \$107.2 billion per year in 2013 dollars, grounded in baseline conditions of 2009, prior to initiation of the Blueprint.

For comparison, this sum is approximately one-fourth the size of the gross product of the states that contain the Chesapeake Bay watershed and about one-sixth the size of the total labor earnings of all the residents of the Bay region's 207 counties.

### 2 Post Blueprint benefits are nearly \$130 billion annually, an increase of more than \$22 billion per year. **(Blueprint Scenario)**

The value of these benefits when the Chesapeake Clean Water Blueprint has been fully implemented and made effective is roughly \$129.7 billion per year, measured in 2013 dollars, or more than \$22 billion in additional annual benefits when compared to the baseline.

### 3 Without the Blueprint, benefits decline to \$101.5 billion annually, a loss of \$5.6 billion from the baseline. **(Business as Usual Scenario)**

A “business-as-usual” scenario—which calculates the natural benefits generated by a Chesapeake Bay ecosystem that has not profited from the restoration activities associated with a fully implemented Blueprint—shows an annual value of \$101.5 billion, in 2013 dollars. It is worth noting that the “business-as-usual” scenario includes many prescribed practices that were already underway as of 2014 and will continue to be implemented, including upgrading sewage treatment plants and reducing some urban and suburban polluted runoff. Post 2025, however, this decrease in value will only get larger as the population and associated pollution increase and the Chesapeake region's environment—absent the resiliency provided by the Blueprint's restoration projects—continues to degrade.

### 4 Benefits are enjoyed throughout the entire Chesapeake Bay watershed.

The Blueprint will improve the ecological health of the Chesapeake Bay and its rivers and streams, as well as the land that drains into those waterways. The states will see *increased* annual benefits. Virginia will realize benefits of more than \$8.3 billion, Pennsylvania \$6.2 billion, and Maryland \$4.6 billion annually. As percentages of the overall benefits, the states' increased benefits from the Blueprint are generally proportional to their land-area percentage of the Bay watershed, although Virginia, the second largest, has the greatest natural assets owing to the large amount of tidal wetlands and waterways.

## Full implementation of the Blueprint makes good economic and environmental sense.



# The Economic Benefits of Cleaning Up the Chesapeake

*A Valuation of the Natural Benefits Gained by Implementing the Chesapeake Clean Water Blueprint*

OCTOBER 6, 2014

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*Research and strategy for the land community.*

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## ABSTRACT

Information on the economic benefits of environmental improvement is an important consideration for anyone (firms, organizations, government agencies, and individuals) concerned about the cost-effectiveness of changes in management designed to achieve that improvement. In the case of the Chesapeake Bay TMDL (Total Maximum Daily Load of nitrogen, phosphorus, and sediment), these benefits would accrue due to improvements in the health, and therefore productivity, of land and water in the watershed. These productivity changes occur both due to the outcomes of the TMDL and state implementation plans, also known as a “Chesapeake Clean Water Blueprint” itself (i.e., cleaner water in the Bay) as well as a result of the measures taken to achieve those outcomes that have their own beneficial side effects. All such changes are then translated into dollar values for various ecosystem services, including water supply, food production, recreation, aesthetics, and others. By these measures, the total economic benefit of the Chesapeake Clean Water Blueprint is estimated at \$22.5 billion per year (in 2013 dollars), as measured as the improvement over current conditions, or at \$28.2 billion per year (in 2013 dollars), as measured as the difference between the Clean Water Blueprint and a business-as-usual scenario. (Due to lag times—it takes some time for changes in land management to result in improvements in water quality, the full measure of these benefits would begin to accrue sometime after full implementation of the Blueprint.) These considerable benefits should be considered alongside the costs and other economic aspects of implementing the Chesapeake Clean Water Blueprint.

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## ACKNOWLEDGEMENTS

The authors greatly appreciate the assistance and support of several individuals and institutions who made this research possible and better. First, we thank the members and financial supporters of the Chesapeake Bay Foundation, without whom this project could not have been completed. Next are CBF staff, including Dave Slater and Will Baker, whose ideas and questions inspired and framed this research; and Danielle Hodgkin and Molly Clark, who provided invaluable research assistance, editing, and design for the final report. Most especially, we thank EPA Chesapeake Bay Program staff, especially Peter Claggett and Matt Johnston, who provided, explained, troubleshoot, and explained again the crucial underlying land-use and water-quality data employed in our model.

Finally, we thank our external peer reviewers, Dr. Gerald Kauffmann of the University of Delaware, Dr. Valerie Esposito of Champlain College, Dr. Tania Briceno of Earth Economics, and Mr. Dan Nees of the University of Maryland Environmental Finance Center for their time, insights, and constructive criticism. Needless to say, these experts’ review does not constitute an endorsement of the report or its conclusions, any errors of fact, logic or, arithmetic are the authors’ alone.

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## BACKGROUND

The Chesapeake Bay is the largest estuary in the United States, with a 64,000-square-mile watershed that includes parts of six states and the District of Columbia. Home to more than 17 million people and 3,600 species of plants and animals, the Chesapeake Bay watershed is truly an extraordinary natural system marked by its rich history and astounding beauty. More than 100,000 rivers and streams flow to the Chesapeake and more than half the land is still forested. In total, the Bay watershed has 11,684 miles of shoreline, including tidal wetlands and islands—more than the entire West Coast of the United States. These natural resources provide valuable and quantifiable economic goods and services e.g., beautiful scenery that promotes recreation, tourism, and some of the country’s highest property values; food like fish, crabs, clams, and oysters; and flood protection and erosion control. Like many estuarine and coastal systems, however, the Chesapeake Bay is degraded.

Every summer, the main stem of the Bay and several of its tributaries are plagued by dead zones, where not enough dissolved oxygen exists to sustain many forms of aquatic life. The volume of water affected by these dead zones varies by year, but on average about 60% of the Bay and its tidal rivers have insufficient levels of oxygen (Chesapeake Bay Program, 2012). In addition, water clarity in the Chesapeake Bay has declined so that underwater grasses, critically important as fish and crab habitat, have decreased to roughly 20% of historic levels. Because of these problems, the Bay and most of its tidal rivers are categorized as “impaired” under the Clean Water Act (Chesapeake Bay Program, 2012).

In response to these water-quality problems the Environmental Protection Agency (EPA) promulgated a Total Maximum Daily Load (or TMDL) for the Chesapeake Bay, in December 2010 (US EPA, 2010). A TMDL, legally required under the Clean Water Act for impaired waters, is a scientific estimate of the maximum amount of pollution a body of water can accommodate and still meet water-quality standards that define healthy waters. The Bay TMDL set pollution limits for nitrogen, phosphorus, and sediment in the Chesapeake Bay needed to restore healthy levels of dissolved oxygen and water clarity. At the same time, the six Bay states and the District of Columbia, which comprise the Chesapeake Bay watershed, released their plans (known formally as Watershed Implementation Plans) describing the actions they would take to meet those limits by 2025. Together, the enforceable pollution limits (the TMDLs) and the states’ implementation plans comprise the Clean Water Blueprint for the Chesapeake and its rivers and streams.

The Chesapeake Clean Water Blueprint (Blueprint) will provide watershed-wide benefits because restoring the health of the Bay also entails improvements in both water in the streams and rivers that supply water to the Bay and in land use and land management throughout the watershed. Ecological benefits come from reductions in the amount of pollution, especially nitrogen, phosphorus, and sediment reaching the Bay and its tributaries. Higher levels of dissolved oxygen and improved water clarity in the Bay and its tributaries are the intended result.

These changes and the actions taken to achieve them will also produce economic benefits because land and water ecosystems that become more productive will supply more tangible and intangible goods and services that have value for people. And because these goods and services are valued by people, changes in the ability of the Bay’s ecosystems to deliver them will result in changes in the economic value of the watershed. These changes range from obvious, such as increased productivity in commercial and recreational fisheries, to the opaque, such as increased productivity, per acre, of forest and farmland, and the seemingly obscure, such as the increase in property values generated by healthier forests and waterways.

No matter how easy or difficult to see or measure, all of these economic benefits provided by “ecosystem services” are relevant to consider as part of the value secured by the Blueprint. The goal of this report is to provide a picture of the economic benefits that would accrue as a result of implementing the Blueprint.

## Objectives of the Study

With this study, we aim to provide three critical pieces of information. The first is an estimate of the dollar value of eight “ecosystem services” originating—and largely enjoyed—in the Chesapeake Bay watershed region, prior to the Blueprint. For this baseline we look at land-use patterns, water-quality indicators, and pollution loading in 2009. This 2009 scenario approximates the natural benefits, at least in financial terms, provided by the 64,000-square-mile Chesapeake Bay watershed today.<sup>1</sup>

Second is an estimate of the value of the same services, but for two future scenarios. In the “Blueprint” scenario, the Blueprint is fully implemented, land conversion (to urban uses) slows, forest areas expand, wetland loss slows, and land management changes reduce pollution loading. All of this change leads to improvements in water quality.

In the “Business as Usual” (BAU) scenario, the Blueprint is not fully implemented (although some of the plan’s prescribed practices, such as already-planned or completed wastewater treatment plant upgrades, are factored in according to Bay Program modeling). Land development and pollution loading continue according to current forecasts, resulting in lower water quality and lower ecosystem service productivity overall.

Third are simply calculations of the differences between the Baseline (i.e., 2009) and Blueprint scenarios and between the Blueprint and Business as Usual scenarios. The first of these is the annual incremental contribution to human well-being, over and above current conditions, that can be expected as a result of the Clean Water Blueprint. The second is an estimate of the annual benefit of living in a world with the Blueprint versus doing nothing more.

## ECOSYSTEM SERVICES FRAMEWORK

Every day in the Chesapeake Bay region, we make decisions that impact the natural systems in our environment. Most often, we do not realize those impacts, nor the fact that they also affect our quality of life and our region’s economy. It is crucial these decisions reflect both nature’s intrinsic value and its benefits for us.



**FIGURE 1: THE ECOSYSTEM SERVICE CASCADE**

The Chesapeake watershed’s residents benefit in many ways from nature. Some of those benefits are direct, such as the crabs, fish, and crops that have traditionally been enjoyed in abundance. Others are less obvious, such as trees that filter pollution out of our air and water, lands that slow or stop floods, and wetlands that reduce the impacts of storm surges created by increasingly frequent extreme weather events.

The idea that people receive benefits from nature is not new, but “ecosystem services” as a term of art describing the phenomenon is more recent, having emerged in the 1960s (Reid et al., 2005). Of several available definitions<sup>2</sup>, Gary Johnson of the University of Vermont provides a definition that emphasizes that ecosystem

<sup>1</sup> By “today,” we mean as measured under conditions for which the most recent data are available (i.e., 2009) and adjusted for inflation to 2013 levels.

<sup>2</sup> See, for example, Reid et al. (2005), Boyd (2011), and Boyd & Banzhaf (2006).

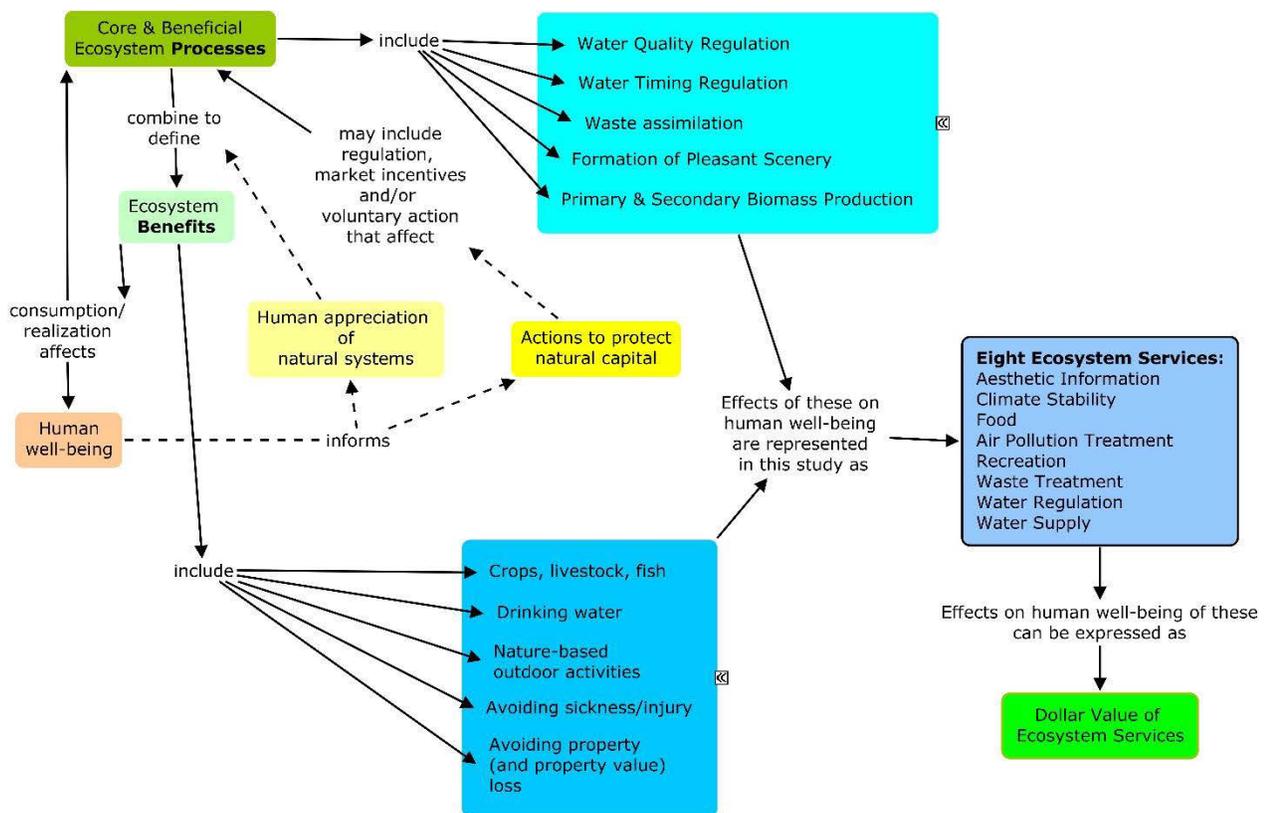
services are not necessarily things—tangible bits of nature like a cup of water, a bushel of crabs, or a sunset—but rather, sometimes the impacts on people of those bits of nature. To wit:

Ecosystem services are the effects on human well-being of the flow of benefits from an ecosystem endpoint to a human endpoint at a given extent of space and time (Johnson, 2010).

This definition provides a good overview, and Balmford, et al. (2010, 2013) present a framework for thinking about ecosystem services that adds clarity by “disaggregat[ing] ecosystem services into three interlinking sets, which differ in their proximity to human well-being: core ecosystem processes, beneficial ecosystem processes, and ecosystem benefits (p. 164).” This chain of relationships, illustrated in Figure 1, from core processes to beneficial processes to human benefits, is implicit in the definition.

By separating them, the authors provide terms to clarify when we are talking about ecological endpoints (or components of nature) versus economic endpoints (human enjoyment/consumption/use). It is the latter linkage from beneficial processes to benefits themselves that provides the basis for identifying the economic/human connections most relevant to the Blueprint.

It is worth putting a bit more complexity into our mental picture of ecosystem services. Figure 2 shows the same cascade in the form of a “concept map” of propositions, such as “Core Ecosystem Processes produce Beneficial Ecosystem Processes,” and “Beneficial Ecosystem Processes combine (with human appreciation of natural systems) to define Ecosystem Benefits.” (Follow the arrows to read other propositions. In this concept map, solid lines represent tangible, biophysical, or economic connections and dashed lines represent information flows.)



**FIGURE 2: ECOSYSTEM SERVICES, WITH FEEDBACK LOOPS**

In addition to the relationships depicted in Figure 1, the concept map illustrates what comes next: the consumption or realization of ecosystem services both enhances human well-being and affects core and beneficial ecosystem processes.

For example, human well-being informs both our appreciation of natural systems (drinking water makes us appreciate clean water, for example) and our actions to conserve or enhance the underlying conditions (dubbed critical natural capital) that

keep ecosystem processes going (Farley, 2012). Those actions may include the creation of market incentives or other initiatives to support core and beneficial ecosystem processes directly or to address stressors that damage them.

It is worth adding this complexity to our mental map of ecosystem services for two reasons. One is that Figure 1, which is typical of most diagrams intended to illustrate the ecosystems services concept, leaves out important feedback loops from the consumption of ecosystem services back to the condition of ecosystems that make further consumption possible. As much as we'd like for ecosystem services to become never-ending fountains of human happiness, they are invariably parts of complex systems that we can all too easily damage. We have to be willing to "give something back" to sustain those services.

The second reason is to place the Clean Water Blueprint and other remedial actions squarely within that system. They should be understood as necessary elements in the positive feedback loop from ecosystem benefits through actions all the way back to a better chance for the ecosystem benefits to continue.

## SELECT ECOSYSTEM SERVICES: RELATION TO THE BLUEPRINT

Studies focused on valuing natural capital often include as many as twenty or more different ecosystem service categories (See, for example, Costanza et al. [1997], Esposito et al. [2011], Swedeen and Pittman [Swedeen & Pittman, 2007], and Flores et al. [2013].) In the context of the Blueprint and Chesapeake Bay water quality, however, we focus on eight ecosystem services of greatest relevance: food production (crops, livestock, and fish), climate stability, air pollution treatment, water supply, water regulation, waste treatment, aesthetics, and recreation. Table 1, below, lists and briefly describes these ecosystem services and the land uses in the Chesapeake region that provide them.

**TABLE 1: ECOSYSTEM SERVICES SELECTED FOR BENEFIT ESTIMATION<sup>A</sup>**

<p><b>Water Supply:</b> Filtering, retention, storage, and delivery of fresh water—both quality and quantity—for drinking, irrigation, industrial processes, hydroelectric generation, and other uses.</p> <p><b>Chesapeake land uses that provide this ecosystem service:</b> Forest, Open water, Wetland</p>
<p><b>Water Flow Regulation:</b> Modulation by land cover of the timing of runoff and river discharge, resulting in less severe drought, flooding, and other consequences of too much or too little water available at the wrong time or place.</p> <p><b>Chesapeake land uses that provide this ecosystem service:</b> Forest, Urban open, Wetland, Urban Other</p>
<p><b>Waste Treatment:</b> Removal or breakdown of nutrients and other chemicals by vegetation, microbes, and other organisms, resulting in fewer, less toxic, and/or lower volumes of pollutants in the system.</p> <p><b>Chesapeake land uses that provide this ecosystem service:</b> Forest, Open water, Wetland</p>
<p><b>Air Pollution Treatment:</b> Purification of air through the absorption and filtering of airborne pollutants by trees and other vegetation, yielding cleaner, more breathable air (reduction of NO<sub>x</sub>, SO<sub>x</sub>, CO<sub>2</sub>), reduced illness, and an improved quality of life. (Note: Economists more commonly call this service "Gas Regulation.")</p> <p><b>Chesapeake land uses that provide this ecosystem service:</b> Forest, Urban open, Wetland</p>
<p><b>Food Production:</b> The harvest of agricultural produce, including crops, livestock, and livestock by-products; the food value of hunting, fishing, etc.; and the value of wild-caught and aquaculture-produced fin fish and shellfish.</p> <p><b>Chesapeake land uses that provide this ecosystem service:</b> Agriculture, Open water, Wetland</p>
<p><b>Climate Stability:</b> Influence of land cover and biologically mediated processes on maintaining a favorable climate, promoting human health, crop productivity, recreation, and other services.</p> <p><b>Chesapeake land uses that provide this ecosystem service:</b> Forest, Urban open, Wetland</p>
<p><b>Aesthetic Value:</b> The role that beautiful, healthy natural areas play in attracting people to live, work, and recreate in a region.</p> <p><b>Chesapeake land uses that provide this ecosystem service:</b> Agriculture, Forest, Open water, Urban open, Wetland, Other</p>
<p><b>Recreation:</b> The availability of a variety of safe and pleasant landscapes—such as clean water and healthy shorelines—that encourage ecotourism, outdoor sports, fishing, wildlife watching, etc.</p> <p><b>Chesapeake land uses that provide this ecosystem service:</b> Agriculture, Forest, Open water, Urban open, Wetland, Other</p>

A. (Balmford et al., 2010, 2013; R Costanza et al., 1997; Reid et al., 2005)

The following are examples of how these ecosystem services play out in the Chesapeake region and explanations of each service's connection to the Blueprint.

## **Food Production**

In 1940, H.L. Mencken called the Chesapeake Bay an “immense protein factory,” highlighting the food production capacity of the Bay and its tidal waters. Though some species, such as oysters, have declined markedly since then, the Chesapeake’s fisheries industry, including both shellfish and finfish, is still significant. For example, in 2012, the oyster harvest in Maryland and Virginia was 1.8 million pounds, the commercial blue crab harvest from the Bay and its tributaries was estimated at 60 million pounds, and the commercial catch for striped bass was roughly 4.7 million pounds (Chesapeake Bay Stock Assessment Committee, 2013; NOAA, 2014).

Agricultural lands account for approximately 22% of the acres in the Chesapeake watershed (US EPA, 2010) and the value of Chesapeake Bay region agricultural sales in 2007 was about \$9.5 billion—24% from crops and 76% from livestock (U.S. Department of Agriculture, 2007). In addition, the rivers, streams, and wetlands throughout the watershed also provide food to residents of the Bay watershed primarily through opportunities for fishing and hunting.

**Connection to the Blueprint:** In the tidal areas of the Chesapeake Bay, improvements in dissolved oxygen (DO) and underwater grasses mean cleaner water that is more conducive to finfish and shellfish production. For example, DO concentrations have been associated with blue crab harvests (Johan A. Mistiaen, 2003), disease resistance in oysters (R. S. Anderson, Brubacher, Calvo, Unger, & Burreson, 1998), and more recently with the number and catch rates of demersal fish species in the Chesapeake Bay (Buchheister, Bonzek, Gartland, & Latour, 2013). Increases in DO will also lead to greater benthic biomass production which in turn provides food for upper trophic level species like crabs and fish (Diaz, Rabalais, & Breitburg, 2012). Underwater grasses are critical to protect blue crabs and larval finfish from predation (Beck et al., 2001; Heck, Hays, & Orth, 2003).

Implementing the Best Management Practices (BMPs) called for in the Blueprint means more fertile and productive agricultural land. For example, increased implementation of practices like conservation tillage and cover crops will lead to better soil water retention, making cropland more productive and less susceptible to damage from droughts. A study in Pennsylvania found that under severe drought conditions, crops grown with these practices out-yielded conventionally grown crops by 70-90% (Lotter, Seidel, & Liebhardt, 2003). To the contrary, moderately eroded soils are capable of absorbing only seven-44% of the total rain that falls on a field. As a result, eroded soils exhibit significant reductions in crop productivity (Pimentel et al., 2003). Many conservation practices also build soil organic matter, which has a significant positive effect on crop yields (Pimentel et al., 2003). Finally, healthier streams and wetlands also add to food production benefits.

## **Water Supply**

Various habitats within the Chesapeake watershed help filter, retain, and store freshwater, contributing to both the quantity and the quality of our water supply. Forests and other vegetation filter rain into ground water and surface waterways from which residents of the Chesapeake watershed receive water for drinking, agriculture, and industry. Approximately 75% of the people living in the Bay watershed rely on surface water supplies for their drinking water (Sprague, Burke, Clagett, & Todd, 2006). For example, the Washington Aqueduct produces drinking water for approximately one million people in the District of Columbia metropolitan area by pulling and treating water from the Potomac River, removing roughly 10.5 million pounds of sediment annually (Sutherland & Pennington, 1999).

**Connection to the Blueprint:** One way to understand the economic value of protecting and enhancing the habitats that protect these drinking water sources is to compare it to the cost of building and maintaining water supply and treatment facilities. An EPA study of drinking water source protection efforts concluded that for every dollar spent on source water protection, an average of \$27 is saved in water treatment costs (Groundwater Protection Council, 2007).

The Blueprint will result in more land retained in land uses in which water retention, filtering, and aquifer recharge are effective (forests, urban open space). Implementation of Best Management Practices (BMPs) on urban and agricultural lands will increase infiltration and groundwater recharge and reduce sediment load. Less sediment and other pollutants reaching water supplies means cleaner drinking and processed water and reduced water treatment costs for residential and industrial users, including breweries and soft drink and water bottlers.

### **Water Flow Regulation**

The amount and timing of water flow in the rivers and streams that feed the Chesapeake Bay depends, in large part, on the storage capacity of the watershed. Impervious surfaces like roads, rooftops, and sidewalks stop precipitation from infiltrating into the soil. Instead, the rainwater washes rapidly into storm drains and stream channels. These high peak flows contribute to flooding and erosion of stream banks, which add additional pollution to the region's waterways. In addition, the same process that causes flooding during rain events leaves the stream dry during other times of the year. In the Bay region, groundwater contributes a high percentage of stream flow (Lindsey et al., 2003). Thus, if rain is not allowed to percolate into the soil to recharge groundwater, stream flows will be lower, especially during dry times. For example, a study of the Gwynns Falls watershed in Baltimore indicated that heavily forested areas reduced total runoff by as much as 26% and increased the low-flow volume of streams by up to 13% (Neville, 1996).

**Connection to the Blueprint:** Increases in forest cover, streamside grasses, and forests, and the implementation of urban practices focused on infiltration and retaining natural hydrology will mean the landscape will have greater capacity to absorb and then slowly release water into streams and rivers and the Chesapeake Bay. This increase in water regulation capacity will mean reduced flood damage and more natural stream flows.

For example, Maryland's Montgomery County has implemented over 400 green infrastructure projects, which include increased tree canopy, extensive rain gardens, infiltration practices, rain barrels, and restored wetlands that are capable of reducing polluted runoff volumes by 21.6 million to 34.6 million gallons a year. Additional stormwater mitigation called for by the Blueprint would reduce the volume of urban runoff entering the county's waterways by about 5.1 billion gallons a year, potentially decreasing the severity of flooding events for county residents (ECONorthwest, 2011). In addition, reductions in sediment loads and the restoration of normal stream flows improve aquatic habitats and fish populations. See, for example, Poff et al. (1997)

### **Waste Treatment**

In the tidal portions of the Chesapeake Bay, wetlands, underwater grasses, oysters, and other sedentary biota play a crucial role in removing nitrogen, sediment, and/or phosphorus from the water. For example, marshes of the tidal fresh portions of the Patuxent River remove about 46% and 74% of the total nitrogen and phosphorus inputs, respectively (Boynnton et al., 2008). The pollution removal capacity of oysters is widely acknowledged. Oysters indirectly remove nitrogen and phosphorus by consuming particulate organic matter and algae from the water column (Newell, Fisher, Holyoke, & Cornwell, 2005). In addition, some of the nutrients are deposited by the oysters on the surface of sediments and under the right conditions, the nitrogen can be transformed via microbial-mediated processes into nitrogen gas that is no longer available for algae growth (Higgins, Stephenson, & Brown, 2011). In addition, microorganisms in sediments and mudflats can also breakdown human and animal wastes and even detoxify chemicals, such as petroleum products.

In the non-tidal portions of the Bay regions, forests and wetlands are particularly effective at capturing and transforming nitrogen and other pollutants into less harmful forms. In addition, not only do forest buffers filter and prevent pollutants from entering small streams, they also enhance the in-stream processing of pollutants, thereby reducing their impact on downstream rivers and estuaries (Sweeney et al., 2004).

**Connection to the Blueprint:** Increased dissolved oxygen and underwater grasses result in more effective nutrient cycling and regulation in the tidal parts of the Bay. For example, Kemp et al. (2005) estimate that if underwater grasses in the upper Bay were restored to historic levels, they would remove roughly 45% of the current nitrogen inputs to that area. Indirect benefits of increased oyster production also will contribute to enhanced processing and removal of particulates and nitrogen. Maintaining and improving the health of forests, wetlands, and streams throughout the watershed will increase their ability to process and transform nitrogen and other pollutants. Furthermore, increases in streamside grasses and forests and the implementation of urban practices like green roofs and rain gardens will mean greater pollutant removal and processing, not just for nutrients and sediments, but also for other contaminants like agricultural pesticides, petroleum products, and bacteria.

### **Air Pollution Treatment**

Air Pollution Treatment refers to the role that ecosystems play in absorbing and processing air pollutants, such as nitrogen oxides, sulfur dioxide, particulates, and carbon dioxide. Trees are particularly effective at removing airborne pollutants. For example, the urban tree canopy in Washington, D.C., covers less than a third of the city, yet removes an amount of particulate matter each year equal to more than 300,000 automobiles (Novak, Hoehn, Crane, Walton, & Stevens, 2006).

Scientists estimate that the 1.2 million acres of urban forest in the Chesapeake region collectively remove approximately 42,700 metric tons of pollutants annually (Sprague et al., 2006).

Sequestration of carbon dioxide is also an important function of the region's habitats. It is estimated that Chesapeake forests are currently storing a net 17 million metric tons of carbon annually (Sprague et al., 2006). In addition, agricultural practices like conservation tillage, cover crops, and riparian buffers are all effective at removing carbon dioxide from the atmosphere. Agriculture as a whole, however, is a net emitter of many gases, so there are no values for agricultural air pollution treatment ecosystem services counted in this study. A recent study has also documented the significant carbon sequestration benefits of tidal wetlands (Needelman et al., 2012).

**Connection to the Blueprint:** Healthier forests and wetlands are able to better absorb and process airborne pollutants and increase carbon sequestration rates (Bytnerowicz et al., 2013). Increased tree canopy, particularly in urban areas, will lead to improved air quality, increased public health benefits, and reduced health care costs. For example, the estimated value to Lancaster City, Pennsylvania and its citizens of reduced air pollutant-related impacts is more than one million dollars per year from implementing practices in their Green Infrastructure Plan (US EPA, 2010, 2014). Implementation of agricultural BMPs at levels similar to what is called for in the Blueprint would reduce greenhouse gas emissions by approximately 4.8 million metric tons of carbon dioxide equivalents annually—comparable to the carbon dioxide emissions from residential electricity use across Delaware (Chesapeake Bay Foundation, 2007), though as noted above, we did not include or quantify these benefits in our assessment.

### *Climate Stability*

Climate stability refers to the influence that land cover and biologically mediated processes have on maintaining a stable environment. For example, in urban areas, natural filters to reduce polluted runoff and trees helps reduce the "heat island" effect by reducing the amount of paved surfaces that trap the most heat. For example, differences in summer temperatures between inner-city Baltimore and a rural wooded area are commonly seven degrees Celsius or more (Heisler, 1986). In addition, trees in both urban and suburban areas provide shade and act as wind breaks to surrounding dwellings, reduce indoor temperatures in the summer, and increase them in the winter, and in doing so reduce energy use and costs. Shaded houses can have 20-25% lower annual energy costs than the same houses without trees. In Washington, D.C., the urban tree canopy saves city residents approximately \$2.6 million dollars per year in energy costs (Novak et al., 2006). At a broader scale, land in forests, wetlands and agriculture provide similar environmental benefits of moderating our climate.

**Connection to Blueprint:** Implementation of the Blueprint will increase and improve habitats that can absorb and more slowly release solar radiation and increase evapotranspiration that helps with cooling. In urban and suburban areas, more tree canopy, open spaces, and green roofs will reduce the heat island effect and lower air temperatures, resulting in lower energy use associated with space cooling and human health benefits, such as reductions in the number of heat-related illnesses and associated health care costs (Philadelphia Water Department, 2009). For example, implementation of the City of Lancaster's Green Infrastructure Plan is estimated to have an annual benefit in reduced energy use of \$2.4 million dollars per year (US EPA, 2014). This figure represents the potential monetary savings for Lancaster and its residents in reduced heating and cooling needs.

### *Aesthetic Value*

Aesthetic value as an ecosystem service refers to our appreciation of and attraction to natural and pastoral land and scenic waterways (de Groot, Wilson, & Boumans, 2002). The existence and popularity of state parks, state forests, and officially designated scenic roads and pullouts in the Chesapeake Bay watershed attest to the social importance of this service.

More importantly from an economic perspective, beautiful, healthy natural areas attract people to live, work, and recreate in a region, and water bodies in particular are population magnets. With more than 100,000 streams and rivers, the Chesapeake Bay region is dominated by its waterways; it is said that one can reach a Bay tributary in less than 15 minutes from nearly everywhere in the 64,000-square-mile watershed. Kildow (2006) provides a literature survey of studies that link estuaries and other water bodies, including commercial harbors, to high property values.

Healthy forested areas also provide quantifiable aesthetic benefits for individuals and communities. A study in Baltimore, Maryland, for example, revealed that as the percent of tree canopy cover increases, residents are more satisfied with their community. The study also showed that when neighborhood forest cover is below 15%, more than half of the residents

consider moving away (Grove, 2004). Other studies substantiate the idea that degraded landscapes are associated with economic decline (Power, 1996).

**Connection to the Blueprint:** Reduced sedimentation, increased dissolved oxygen, and increased underwater grasses and water clarity indicate enhanced habitat health and aesthetics in tidal areas. These improvements will lead to greater enjoyment by residents and visitors of scenery in the Bay region, which translates into higher property values, more future visits, and other positive outcomes. For example, good water clarity has been shown to increase average housing value by four to five percent or thousands of dollars per household (Jentes Banicki, 2006; Poor, Pessagno, & Paul, 2007). In Delaware, property values within 1,000 feet of the shore have been projected to increase by eight percent due to improved water quality in the Chesapeake Bay watershed (Kauffmann, Gerald, Homsey, Anadrew, McVey, Erin, Mack, Stacey, & Chatterson, Sarah, 2011). On the whole, the Chesapeake Bay and its tidal tributaries have 11,684 miles of shoreline—more than the entire U.S. West Coast.

Increased urban green space creates more pleasant scenery and a more desirable living environment; several studies have demonstrated the economic value of this improvement (reviewed in McConnell and Walls, 2005). For example, the City of Philadelphia estimates that installation of green storm water infrastructure in the city will raise property values two to five percent, generating \$390 million over the next 40 years in increased values for homes near green spaces (Philadelphia Water Department, 2009).

### **Recreation**

People travel to beautiful places for vacation, but they also engage in specific activities associated with the ecosystems in those places. The Chesapeake Bay region's residents and visitors enjoy recreational fishing; swimming; hunting; boating under sail, power, and paddle; bird watching; and hiking. In 2009, tourists spent \$58 billion in Maryland, Pennsylvania, Virginia, and Washington D.C., directly supporting approximately 600,000 jobs and contributing \$14.9 billion in labor income and \$9.4 billion in taxes. Tourists spent \$25.7 billion in the Chesapeake Bay Gateways Network region alone (Stynes, 2012).

Similarly, in 2001 more than 15 million people fished, hunted, or viewed wildlife in the Chesapeake region's forests and contributed approximately three billion dollars to the regional economy (Sprague et al., 2006). In Virginia alone, it is estimated that 642,297 people use the Virginia Birding and Wildlife Trail annually and the total economic effect of the trail in 2008 was around \$8.6 million (Rosenberger & Convery, 2008).

**Connection to the Blueprint:** Improvements to water quality in the tidal portions of the Chesapeake will result in greater enjoyment of and participation in recreational activities such as boating, kayaking, fishing, and swimming (Bockstael, McConnell, & Strand, 1988). For example, Lipton and Hicks (2003) found that an increase in dissolved oxygen will dramatically increase striped bass catch rates, resulting in more pleasurable fishing experiences. A Virginia study found that "water quality, fishing quality, and other environmental factors" ranked among the most important criteria that influence boaters' decisions on where to keep their boats (Doug Lipton, Murray, & Kirkley, 2009).

BMP implementation on land and improved water quality would indicate more biologically productive natural areas. Cleaner, more productive landscapes provide a higher quality recreational experience. Riparian buffers and wetlands contribute to recreational fishing services by providing improved aquatic habitat and healthier aquatic communities that lead to increased fishing opportunities for gamefish popular among the region's anglers (Hairston-Strang, 2010; "The restoration of Lititz Run: Despite black marks, waterway benefits from groundbreaking inroads by a local coalition," 2008). Maintaining and improving forest health will also increase opportunities for hunting and bird-watching (Sprague et al., 2006).

## **ECOSYSTEM SERVICE BENEFIT ESTIMATION**

As noted above, the economic benefit associated with critical natural capital depends on the health—and therefore the productivity—of that capital. In these terms, the purpose of the Blueprint is to improve the productivity of the Chesapeake's critical natural capital. Accordingly, our estimation of the economic benefits of the Blueprint are rooted in anticipated changes in the underlying health of that natural capital, as well as the increased acres of forest, wetlands, and other natural habitats that will result from implementing the Blueprint. Attainment of the goals of the Blueprint will directly produce benefits associated with cleaner water, including more productive fisheries and an improved source of aesthetic and recreational value. In addition, because the Blueprint will be achieved through a variety of actions to protect and restore critical natural capital (Table 1)—such as expanded forest coverage, improved streetscapes, restored wetlands, and

more input-efficient agriculture—the Blueprint will also generate “co-benefits” like improved air quality, reduced flooding, and increased food production that also have economic benefits.

Economists have developed widely used methods to estimate the dollar value of ecosystem services and/or natural capital. The most widely known example was a study by Costanza et al. (1997) that valued the natural capital of the entire world. That paper and many others since employ the “benefits transfer method” or “BTM” to establish a value for the ecosystem services produced or harbored from a particular place.

As the name implies, BTM takes a benefit estimate calculated for one set of circumstances (a source area) and transfers that benefit to another set of reasonably similar circumstances (the subject area). As Batker et al. (2010) put it, the method is very much like a real estate appraiser using comparable properties to estimate the market value of the subject property. It is also very much like using an existing or established market price, say the price of a bushel of crabs, to estimate the value of some number of bushels of crabs to be harvested in the coming week. The key is to select “comps” that match the circumstances of the subject area as closely as possible.

Typically, comps are drawn from source studies that estimate the value of various ecosystem services from similar land cover types (sometimes called “biomes”). So, for example, if the source study includes the value of wetlands for recreation, one might apply per-acre values from the source wetlands to the number of acres of wetlands in the subject area. Furthermore, it is important to use source studies that are from regions with underlying economic, social, and other conditions that are similar to the subject area. Due to differences in wealth between countries and regions, for example, observed market prices and expressions of willingness to pay (as a substitute for market prices when no market good is involved) can vary widely.

Careful as one may be to select appropriate comps, estimates coming from the benefits transfer method must be understood to be an approximation of the true value of ecosystem services in the subject region. It is not the same as measuring the biophysical outputs of every acre of the subject area and then determining the willingness to pay for each of those outputs<sup>3</sup>. The latter would be prohibitively expensive, given that our subject area consists of 44 million acres. Moreover, even measuring the biophysical outputs would still entail a sort of benefit transfer in that one would apply an observed or estimated value-per-unit for some sample of outputs to those outputs estimated for the entire watershed.

The estimates of ecosystem service value presented below are certainly different from what the actual values would be if we could observe and measure them directly. However, we submit that the model and its resulting estimates are useful as a first approximation of the magnitude of those benefits. Decision makers and the public need an idea of the value provided by the Chesapeake Bay watershed and of the increment to that value that may accrue as a result of implementing the Blueprint.

So, with that caveat, we develop and apply an enhanced version of the benefits transfer method that both uses comparable sources of per-acre ecosystem service values and adjusts the estimates to account for differences in per-acre productivity in the subject area.

## Methods Specific to This Study

Following Esposito et al. (2011) and Esposito (2009), we employ a four-step process to evaluate the ecosystem service value of the Chesapeake Bay Watershed and the benefits (increment to value) associated with the Blueprint. These steps are described in greater detail below, but in summary, they are:

1. Assign land and water in the Chesapeake Bay watershed to one of seven land uses (forest, wetlands, open water, urban open space, other urban land, agriculture, and other) based on Chesapeake Bay Program data (M. Johnston, 2014b) and remotely sensed land cover data (Fry, J. et al., 2011). Acreage is taken from spatial tabular data covering the seven land uses in 2,862 “land-river segments” (portions of sub-watersheds lying in different counties). Land use is estimated for each of three scenarios: Baseline, Blueprint, and Business as Usual, or “BAU.” In the concept map (Figure 3) on the next page, this step is illustrated by the four boxes and connecting arrows at the top left of the map.

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<sup>3</sup> This is the “production function” approach to estimating ecosystem service value outlined, for example, in Kareiva et al. (2011)

2. Establish indicators of baseline ecosystem health/productivity for each river segment (sub-watersheds without distinctions for county or state political boundaries) in the watershed to estimate the current value of the Chesapeake Bay watershed ecosystem prior to implementing the Blueprint.

For the non-tidal portion of the watershed, our proxy for ecosystem health is derived from an existing index of “wildness” that reflects the relative lack of pollution and other human disturbance for each location in the watershed. We compute this proxy at the river segment level of geographic detail. For the tidal waters of the Bay itself, the proxy is the degree to which the river segment has attained the dissolved oxygen (DO) standard.

In the Figure 3 concept map, this step appears as yellow boxes near the top center.

3. To account for the effect of actions taken (or not taken) under the states’ Watershed Implementation Plans (WIPs) that would likely improve ecosystem service health/productivity in the Blueprint and BAU scenarios, we make one of the following adjustments, depending on the river segment in question.
  - a. Adjust baseline health according to modeled changes in pollutant (nitrogen, phosphorus, and sediment) according to this formula. This is the approach for the non-tidal portion of the watershed.
  - b. Apply the respective scenario’s dissolved oxygen attainment, replacing the baseline health number. For the Blueprint scenario, attainment is expected to be 100%. For the BAU scenario, we assume, conservatively, no further deterioration in DO, and use the same level of attainment as in the Baseline scenario.

This part of the process is illustrated by the red, yellow, and orange boxes in Figure 3.

4. Calculate the value of eight ecosystem services in each scenario (Baseline, Blueprint, and BAU) by multiplying land area (acres) times the relevant proxy for health/productivity, times dollars-per-acre-per-year for those services.

By comparing the Baseline to the Blueprint results we obtain an estimate of the value of natural capital that would be gained relative to current conditions. And by comparing the Blueprint to BAU results, we obtain an estimate of the value of Blueprint once implemented and effective, compared to what the value would be if nothing further is done.

The five lowermost boxes in Figure 3 represent this part of the procedure.

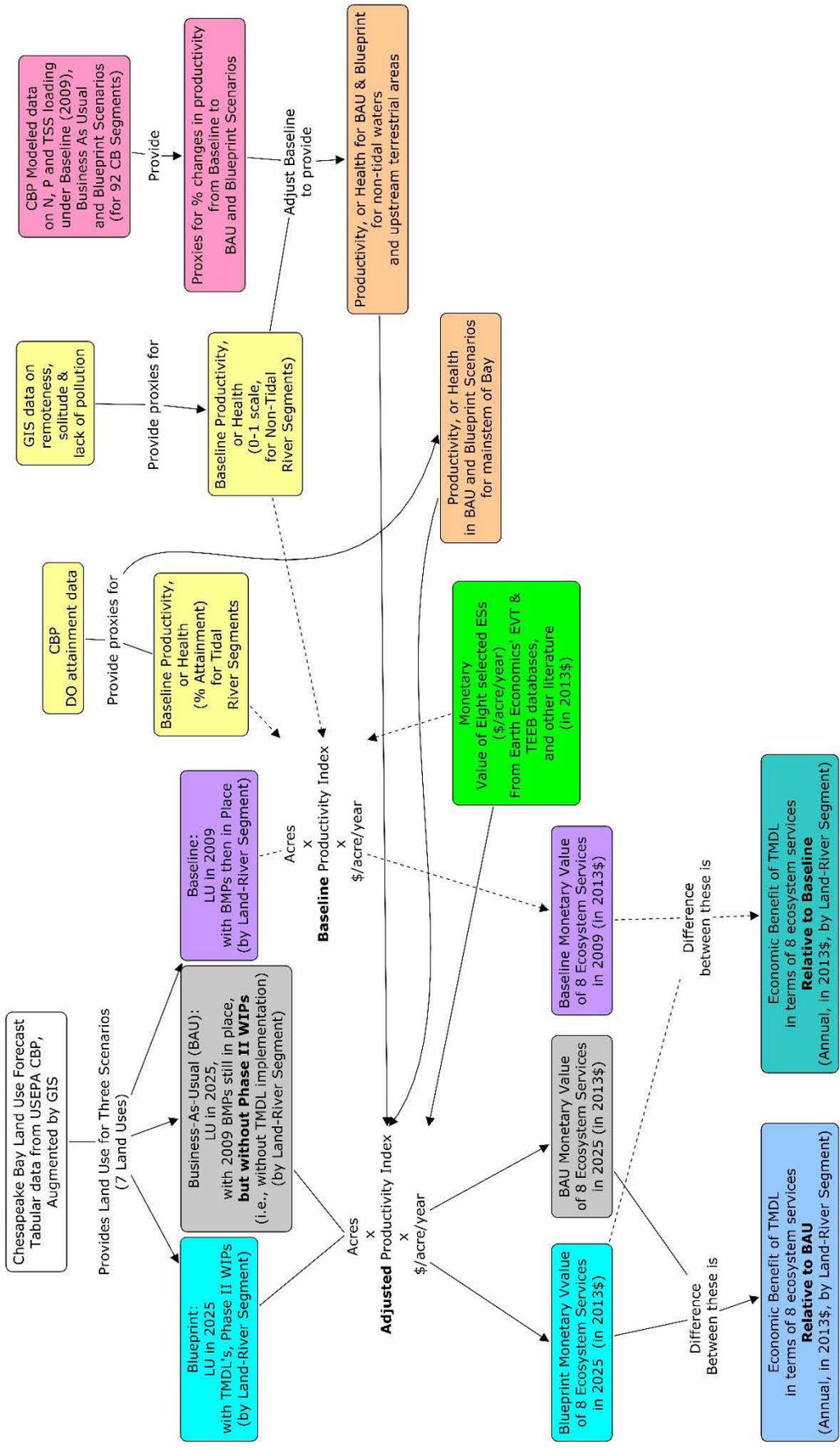


Figure 3: Conceptual Map of Ecosystem Services Valuation Process

### Assigning Land to Ecosystem Types, or Land Uses

As indicated in the summary above, the first step in the process is to determine the area in the seven land use groups or habitat types in the Chesapeake Bay watershed. This determination is made using two sources of data. Both sources begin with remotely sensed data from the National Land Cover Database (NLCD) (Fry, J. et al., 2011). These satellite data provide an image of land in up to 21 land cover types, 15 of which are present in the Chesapeake Bay Watershed (see Figure 4).

In addition, to address shortcomings in NLCD data as outlined by Chesapeake Bay Program (CBP) staff (Claggett, 2013), the Chesapeake Bay Land Change Model (CBLCM) incorporates county-level data from other sources and estimates land use in 31 detailed land uses in four broad categories: Agricultural, Forest, Urban, and Open Water (M. Johnston, 2014a).

Using the CBLCM, CBP staff provided us with estimates of land use and pollutant loadings for three scenarios, as follows.

**Baseline:** Land use as it was estimated in 2009, with various best management practices (BMPs) then in place.<sup>4</sup>

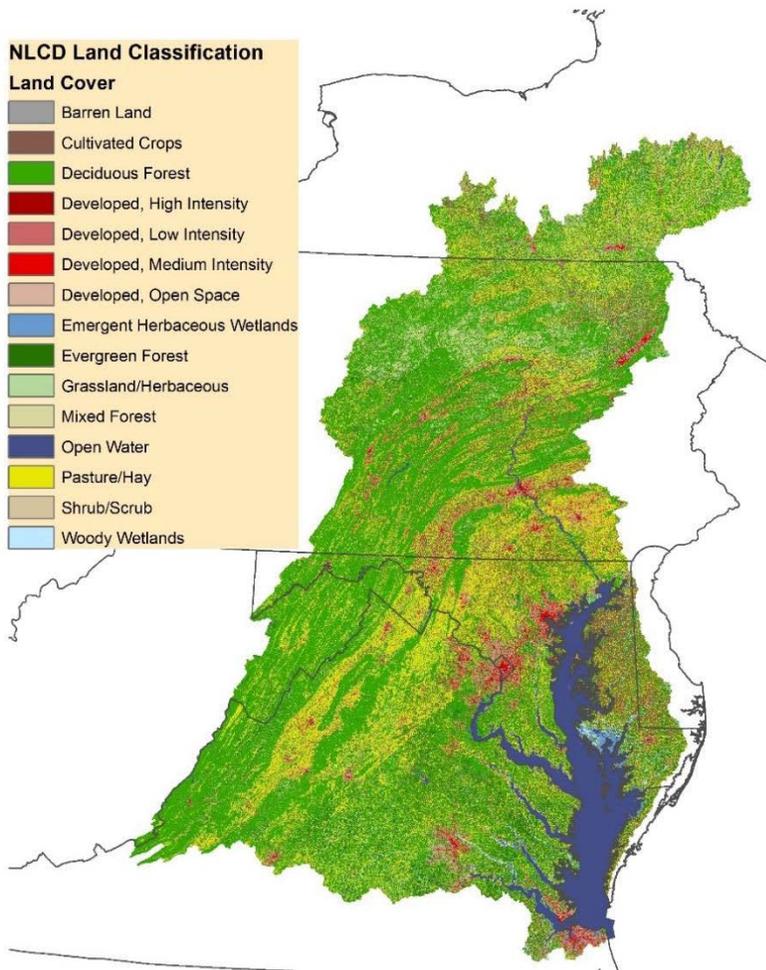
**Blueprint:** Land use projections to 2025, based on historic trends and with the 2009 same BMPs still in place *plus* full implementation of the Phase II Watershed Implementation Plans developed by the States pursuant to the Blueprint.

**Business as Usual (BAU):** Land use projections to 2025, based on historic trends and with practices expected to be implemented with or without the Blueprint due to state or federal regulations. These measures include upgrades to wastewater treatment plants and practices called for in storm water and concentrated animal feeding operation permits.

For the acreage estimates and projections in these scenarios, we made several adjustments.

First, the CBLCM covers only the portion of the watershed that is either terrestrial or, if open water, upstream from the tidal portion of the Bay and its tributaries. We therefore simply added these areas back in based on GIS layers provided by USGS (Claggett, 2013).

Second, because the CBP classification places the NLCD’s emergent wetlands and other land (consisting of barren land like shorelines, rock outcrops, etc.) in the “forest” category, and because these two land cover types can have very different ecosystem service profiles, we re-created “wetland” and “other” land categories. For this we turned to our own analysis of the NLCD data and calculated number of acres in each river segment that is herbaceous wetland (NLCD class 95), and the sum of acres that are either barren land or unconsolidated shore (NLCD classes 31 and 32). These latter classes constitute our “other” category. We then calculated the percentage of CBLCM’s “forest” acreage that the NLCD acreages represent and



**FIGURE 4: NLCD LAND CLASSIFICATION**

<sup>4</sup> Note that this is the “baseline” for this study only. Other periods may serve or be referenced as the “baselines” for Bay water quality or its attendant human or economic value elsewhere.

multiplied the wetland percentage times “forest” acreage to get wetland acreage and the “other” percentage times “forest” acreage to get other acreage. Finally, we subtracted the calculated wetland and other acreage from the original “forest” acreage to get a new forest acreage. In this way we retained a total acreage that is consistent with that of the CBLCM outputs while taking advantage of the finer detail available in the NLCD data.

**TABLE 2: LAND COVER / LAND USE TRANSLATION**

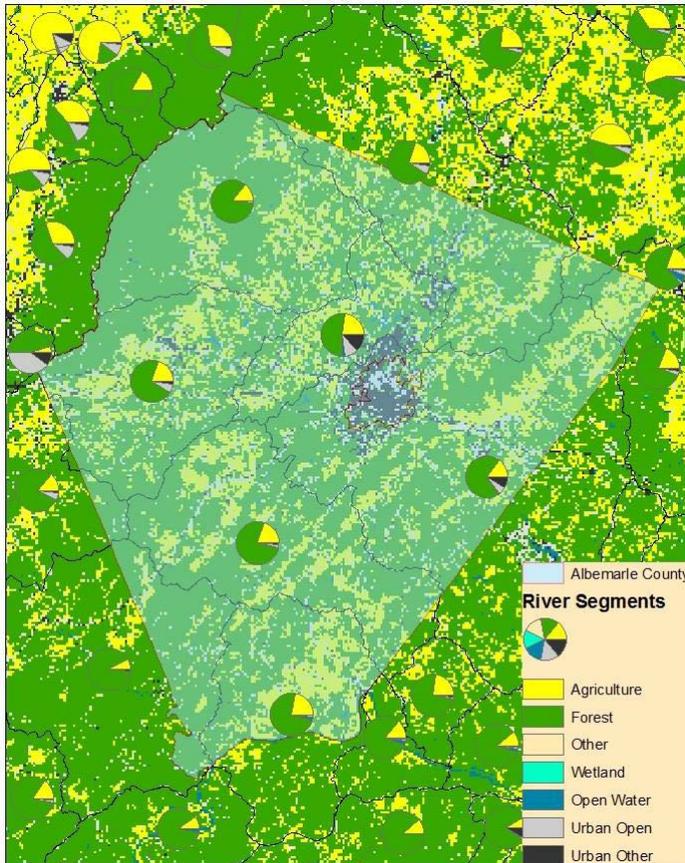
<b>NLCD Land Cover Class (Satellite Imagery)</b>	<b>CBP Land Use from CBLCM<sup>A</sup></b>	<b>Revised Land Use Used in Present Study</b>
<b>11</b> Open Water	Open Water	Open Water
<b>21</b> Developed, Open Space	Urban	Urban Open <sup>B</sup>
<b>22</b> Developed, Low Intensity	Urban	Urban Other
<b>23</b> Developed, Medium Intensity	Urban	Urban Other
<b>24</b> Developed, High Intensity	Urban	Urban Other
<b>31</b> Barren Land	Forest	Other <sup>C</sup>
<b>41</b> Deciduous Forest	Forest	Forest
<b>42</b> Evergreen Forest	Forest	Forest
<b>43</b> Mixed Forest	Forest	Forest
<b>52</b> Shrub/Scrub	Forest	Forest
<b>71</b> Grassland/Herbaceous	Forest	Forest
<b>81</b> Pasture/Hay	Agriculture	Agriculture
<b>82</b> Cultivated Crops	Agriculture	Agriculture
<b>90</b> Woody Wetlands	Forest	Forest
<b>95</b> Emergent Herbaceous Wetlands	Forest	Wetland <sup>C</sup>

Notes:

- A. CBLCM uses data beyond the NLCD imagery to assign land to these land uses.
- B. As explained in the text, acreage in this land use are the result of re-interpreting pervious urban land as urban open space.
- C. Acres in these land uses are calculated percentages, based on NLCD, multiplied by forest acreage from the CBLCM. Forest acreage also adjusted.

Third and finally, we split the CBLCM’s urban acreage into urban open space (or “Urban Open”) and other urban land (or “Urban Other”). The reason is that most of the dollars-per-acre estimates of natural capital value for urban areas come from studies of urban open space, not urban areas in general. Applying those per-acre estimates would produce over-estimates of the ecosystem service value of urban areas. To make this adjustment, we simply counted the CBLCM’s estimates of “pervious developed” area as urban open space and then took the balance of urban land to be “Urban Other.”

In the end, estimates of the surface area in seven land use or habitat categories were obtained: forest, wetlands, open water, urban open space, urban other, agriculture, and other land. The other land category is mostly barren land. Our forest habitat category includes “scrub/shrub” habitat as well as grasslands, and this is consistent with the Bay Program classification of these habitats. Part of the thinking is these areas frequently convert to forest. Historically, roughly 95% of the watershed was forested. The area in each habitat type was calculated for each of 973 “river segments” in the Chesapeake Bay Watershed. Figure 5 shows a sample of the final land use distribution for Albemarle County, Virginia. The background shows NLCD data as re-classified into the Chesapeake Bay Program categories, and the pie charts indicate the percentage of land in each category in each the river segments.



**FIGURE 5: LAND USE DISTRIBUTION, SHOWING DETAIL FOR ALBEMARLE COUNTY, VIRGINIA**

### Baseline Ecosystem Health

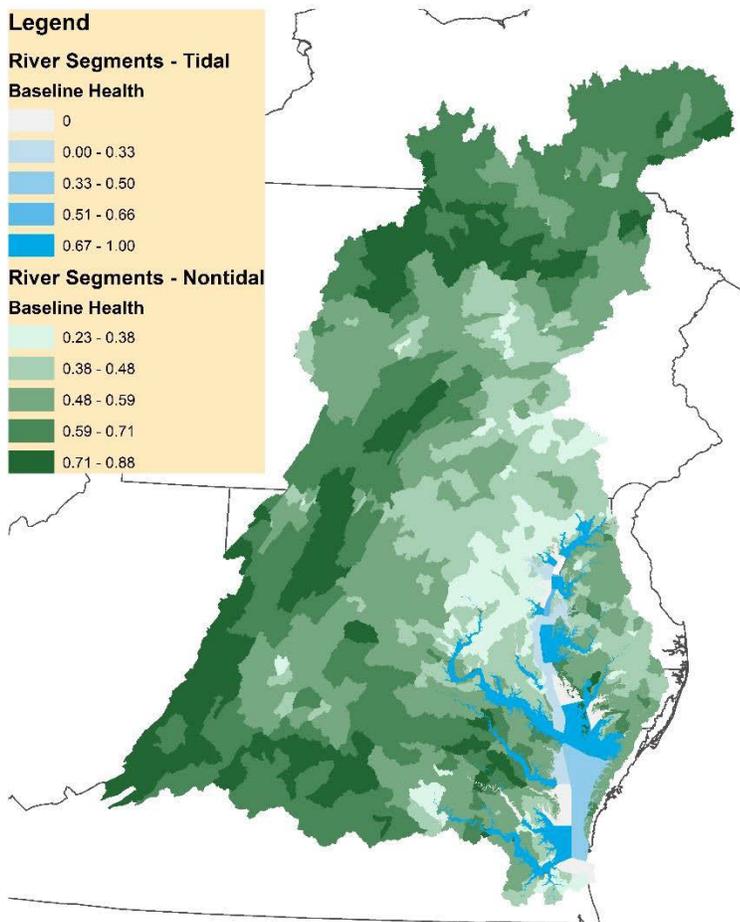
Estimates of the value of natural capital typically rely on a per-unit-area value for the various services provided. These estimates often reflect ideal or pristine conditions and not the actual health of the study area, where habitats and the associated ecosystem services productivity may be degraded by human activities. Consequently, our approach involves discounting ecosystem service values for the baseline condition using proxies for habitat condition or health.

For the upland areas, a variation of the “index of wildness” developed by Aplet, Wilbert, and Thomson (2000) is used. For a detailed description of the conceptual basis for the wildness index and its component measures, please see Aplet (1999); Aplet, Wilbert, and Morton (2005); and Aplet, Wilbert, and Thomson (2000). Briefly, however, and for the purposes of this study, we use data supplied by Wilbert (2013) for the following landscape attributes:

1. Solitude, measured by the population density of census block groups.
2. Remoteness, measured by the distance of 210-meter grid cell to the nearest class primary, secondary, or tertiary road.
3. Lack of pollution, measured by a combination of the darkness of the night sky, degree of stream impairment, and county-level cancer risk.

Each of these indicators is then turned into an index, with one being the most impacted and five being the least impacted. Summing these across the three indicators, the least healthy areas would score a three out of a possible 15, or 20%, and the healthiest areas would score a 15 or 100%. The average of this health proxy indicator was calculated for habitats in each of the upland segments. Figure 6 displays this index for the non-tidal river segments. As would be expected from the measures used, areas closest to cities tend to be the least healthy (indicated by the lightest green in the map), while areas farther away from large concentrations of people and built infrastructure tend to be more healthy.

We believe that this index, which indicates the degree to which a given point on the map is affected by human activity, supplies a fair proxy for the relative ability of those places to produce ecosystem services. Note, however, that the conversion of the ordinal wildness indicators into this continuous variable does mean that the lowest possible health index value is actually 0.200, rather than zero. We have chosen to use this truncated distribution and live with the fact that we know that for some river segments, this measure of health may be too generous rather to arbitrarily assign scores of one or two to some lower index number.



**FIGURE 6: BASELINE HEALTH/PRODUCTIVITY INDICES**

Note that the tidal and non-tidal indicators are based on different metrics, and the breakpoints between shades of color are not the same. The health indicator for the tidal portions of the watershed is shown in blue. For the non-tidal portions, the indicator is shown in green.

urban areas, for example) to more productive habitats (e.g., forest, wetlands, BMP agriculture, or urban open space), or at least that the conversion to less-productive land uses occurs at a slower pace. Second, the various habitat types (e.g., forests, agriculture, open water, urban areas) can become healthier as a result of management actions designed to reduce nutrient and sediment pollution to the Bay.

Conversely, failure to implement the Blueprint will mean that more land is converted to uses that produce less ecosystem services and result in a loss of natural capital in the Chesapeake region. In addition, increases in pollution loads without the Blueprint will degrade habitats and reduce habitat quality and ecosystem services.

Acreage by land use and scenario for the BAU scenario are obtained from the Chesapeake Bay Land Change Model run as described under “Assigning Land to Ecosystem Types, or Land Uses,” above (M. Johnston, 2014a). As with the baseline or current conditions, these projections require adjustment to split out the emergent wetlands from the forests and parse the urban land use into open space. Absent projections indicating otherwise, we assume that emergent wetlands will make up the same portion of the “forest” land use category in 2025 as they do today, and we calculate the area in wetlands in 2025 for the BAU and Blueprint scenarios as  $[(\text{wetland acres in 2009}) / (\text{forest acres in 2009}) \times (\text{projected forest acres in 2025})]$ . We make a similar adjustment to estimate the acreage in the “Other” land use category for 2025 in each scenario.

The second way in which Blueprint implementation will increase natural capital is through improvements in the health (and therefore productivity) of land in any land use category. To estimate the relative amount of improvement to the

As a proxy for the relative health of the tidal open water segments of the Chesapeake Bay, we used dissolved oxygen (DO) levels. Specifically, we used the DO criteria assessment for the 2009 Chesapeake Watershed Model scenario run and applied the methodology that CBP uses in their water quality standards indicator (US EPA Chesapeake Bay Program, 2014; US EPA, 2010). There are different DO standards for different portions of the water column known as “designated uses,” including 92 tidal segments containing the “open-water” habitat, 18 containing the “deep-water” habitat and 10 containing the “deep-channel” habitat. The approach considers each segment and designated use as either pass or fail, when it comes to the achievement of the DO standard (Shenk, 2014). For example, if all three designated uses apply to a segment and the 2009 model scenario indicated the segment achieved the DO standard in two of the three designated uses, our indicator score for that segment would be 2/3 or 66%. This indicator for the baseline scenario is depicted in shades of blue in the map in Figure 6.

**Changes in productivity with and without the Blueprint**

Implementation of the Blueprint will increase the natural capital within the Chesapeake Bay watershed. And, as noted above, that increase can occur in two complementary ways. First, land use can change in such a way that land is converted from less ecosystem-service-productive habitats (intensive agriculture or

productivity of terrestrial habitats due to implementing the Blueprint, we used expected reductions in sediment, phosphorus, and nitrogen loads delivered to the Bay as estimated by the Chesapeake Bay Watershed Model (M. Johnston, 2014b). For example, if implementation of the Blueprint results in an average 20% reduction in sediment, phosphorus, and nitrogen loads in a particular river segment, the production of ecosystem service value in this segment would improve by 20%.

We recognize this measure is a proxy for, and not an actual projection of, ecosystem service productivity. Several studies have highlighted the ecological benefits of reducing nutrient and sediment loads. For example, productivity of cropland increases when sediment erosion is reduced (Pimentel et al., 2003) and less sediment in surface water means reduced water treatment costs (Groundwater Protection Council, 2007). Deegan et al. (2012) found that excess amounts of nutrient loading contributes to coastal salt marsh loss. In addition, the management actions themselves—such as planting of cover crops, implementing no-till farming, and adding green infrastructure in urban areas—also have environmental benefits. Consequently, we believe that estimates of the *outputs* of those management changes (i.e., lower pollutant loadings) is as good an indicator of improved productivity as would be BMP adoption rates or other measures of changes in the management *inputs* (i.e., BMP implementation).

For open water in the tidal segments of the watershed, we do not employ an estimate of the *change* in health/productivity in the Blueprint and Business as Usual scenarios, but rather simply apply the expected outcome or endpoint of that change in those two scenarios. For the Blueprint, the goal is 100% attainment, so we assume full health of those waters in the Blueprint scenario.

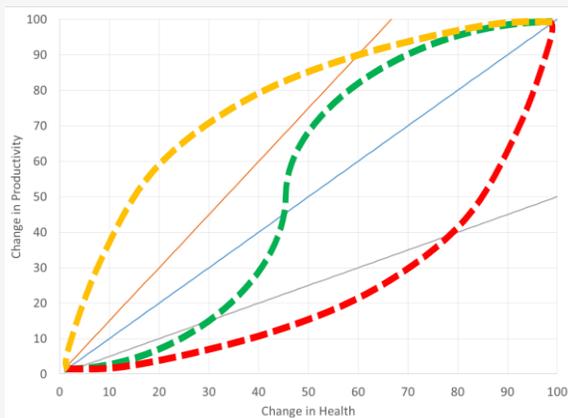
For the Business as Usual scenario, the productivity of terrestrial habitats was adjusted based on average expected change in nitrogen, phosphorus, and sediment loads between 2009 and 2025 that would be expected if the Blueprint were not to be implemented. For the tidal segments, we did not have projections of future dissolved oxygen attainment. We therefore assume there will be no deterioration in water quality in these tidal segments from current conditions. (This seems unlikely, given that nutrient and sediment loading upstream will increase. Our resulting estimates of ecosystem services value in the Business as Usual scenario will be higher than would be expected.)

The next step was to multiply the baseline health by the percentage change to obtain the health (or ecosystem service productivity) measure in each of the two future scenarios. For the Blueprint, those changes are positive for most river segments, and for Business as Usual they are mostly negative.

*The Loading-Health Relationship*

We are assuming that we assume the relationship between changes in pollution loading and changes in our proxy for land health or ecosystem service productivity is linear—that is, there is a fixed, one-to-one relationship between percentage changes in pollutant loading and the health/productivity of the land in a given area. We recognize that the actual relationship could show increasing or decreasing marginal changes in productivity, depending on the initial health of a particular area and the particular ecosystem service in question. The curve describing the relationship might also have different shapes over different ranges—starting out as an increasing function at low ranges and flattening out at higher ranges (see Figure 7). Lipton and Kasperski (2006) for example, found that the relationship between DO conditions in the Chesapeake Bay and blue crab harvests was roughly linear until the DO concentration reached 5 mg/L, above which there was no increase in harvest.

Ideally one would want to specify a different (and true-to-life) functional form for each combination of



**FIGURE 7: FUNCTIONAL FORMS FOR THE RELATIONSHIP BETWEEN CHANGES IN HEALTH AND PRODUCTIVITY**

These curves are for illustration purposes. The true functional forms of the various relationships between ecosystem health and the productivity of individual ecosystem benefits are unknown. They are assumed to be linear and one-to-one (the blue line). Other options include linear relationships that are greater than one to one (the red lines), less than one to one (grey), non-linear (dashed yellow and red lines) varying across the range of changes in health (the dashed green line).

therefore provide a sensitivity analysis below, for a band of possible errors on either side of the outcomes of the assumed relationship.

ecosystem benefit and each indicator of ecosystem health. But the existing research results on which to base such specifications are still fairly thin. Blue crabs, for example, are but one component of the “food” services category, and the available measure of future water quality in the tidal segments of the Bay is percent attainment, not DO concentration. So even for this well-studied component of the Bay ecosystem, there is not a suitable way of employing what might be a more precise functional form of the health-productivity relationship. Multiplied by the various components of eight different ecosystem benefits and by 971 river segments, each of which is starting out at a different point along the multiple health-productivity curves, the complexity of the quest for greater precision in these estimates is clear.

Some of these relationships may well be linear throughout the range of changes associated with the Blueprint and BAU scenarios. Others may be kinked after a certain point; still others could be non-linear. We recognize that we may be splitting the differences among the multitude of (unknown) relationships, and we

**TABLE 3: SUMMARY OF LAND USE AND HEALTH INDICATORS FOR BASELINE, BLUEPRINT, AND BUSINESS-AS-USUAL SCENARIOS**

Model Inputs	Scenario		
	Baseline (2009)	Blueprint	Business as Usual
Land Use area Tidal Segments Open Water	Estimated from GIS and National Land Cover Database	No change	No change
Health Tidal Segments Open Water	2009 modeled estimates of DO attainment	Improvement to 100% attainment of DO criteria	No change from Baseline
Land Use Area Non-tidal Segments All Land Uses	2009 estimates of land use by CBP as part of Blueprint development and adjusted to separate emergent wetlands and other land from CBP's "Forest" category, and separating urban open space from other urban areas.	Projected changes in land use by 2025 due to Blueprint implementation (i.e., with Phase II WIPs) as modeled by CBP plus adjustments for forests and urban open space.	Projected changes in land use by 2025 without Phase II WIPs, as modeled by CBP plus adjustments for forests and urban open space.
Health Non-Tidal Segments All Land Uses	Adjusted for the Index of Wildness.	Baseline habitat condition adjusted by the modeled percent change in projected sediment, nitrogen, and phosphorus loads delivered to the Bay from each segment, assuming Blueprint is fully implemented.	Baseline habitat condition adjusted by the modeled percent change in projected sediment, nitrogen, and phosphorus loads delivered to the Bay from each segment, assuming no Phase II WIPs.

Table 3 summarizes the origin and our derivation of the key land area and health inputs to our model, and Table 4 displays the results in terms of acreage in each land use and average health, on a zero-to-one scale, under each scenario. In general and relative to the baseline, implementing the Blueprint would result in more forested acreage, a smaller decrease in wetlands, and a smaller increase in urban area than would occur under a Business as Usual scenario.

Note that while overall forested acreage increases in the Blueprint scenario, total acreage in the wetland and other categories, which are calculated as a percentage of forest acres, decreases. This change occurs because the percentages are calculated for each river segment, and, as it happens, the percentage of forest land reclassified as wetlands or other is slightly greater for the segments that lose forest acreage than for those that gain forest acreage.

**TABLE 4: SUMMARY OF ACREAGE (BY LAND USE) AND HEALTH INDICATOR FOR TIDAL AND NON-TIDAL SEGMENTS IN THREE SCENARIOS**

	<b>Baseline (2009)</b>	<b>Blueprint</b>	<b>Business as Usual</b>
<b>Tidal Segments (Health Indicator, 0-1 scale)</b>	<b>0.709</b>	<b>1.000</b>	<b>0.709</b>
Open Water (Acres)	2,902,290	2,902,290	2,902,290
<b>Non-Tidal Segments (Health Indicator, 0-1 scale)</b>	<b>0.533</b>	<b>0.606</b>	<b>0.494</b>
Agriculture (Acres)	9,115,604	8,508,590	8,937,770
Forest (Acres)	26,087,310	26,146,565	25,599,783
Open Water (Acres)	418,638	418,638	418,638
Urban Open (Acres)	1,827,581	2,138,186	2,157,705
Urban Other (Acres)	3,272,272	3,519,108	3,627,798
Wetland (Acres)	245,895	238,374	232,321
Other (Acres)	130,960	128,794	124,252

**Translating to Monetary Values**

Finally, we reach the fourth step in which ecosystem service productivity per unit of land or water is converted to a value (i.e., dollars per year). Data for these calculations come from a custom dataset drawn from the Earth Economics’ Ecosystem Valuation Toolkit (Briceno & Klochmer, 2014). The toolkit includes an extensive database of ecosystem service valuation studies from which Earth Economics has extracted studies most applicable to the Chesapeake Bay region. These studies provide estimates of ecosystem service benefits for each habitat expressed as dollars per acre per year. From the more than 2,000 studies included in the database, estimates selected are those that are the best fit for the Chesapeake Bay region, either because the underlying studies were done in the Bay region itself or for a similar estuarine system, or because they come from studies of ecosystem services that are similar to those produced in the Bay watershed (e.g. shellfish or water-based recreation) (Briceno & Klochmer, 2014). Not all land use ecosystem services combinations were covered in the database, however, so to fill some of the gaps, we turned to other tools, including the “The Economics of Ecosystems and Biodiversity” (TEEB) project and studies of the value of natural systems in or near the Chesapeake Bay watershed (Kauffman, Homsey, Chatterson, McVey, & Mack, 2011; Kauffmann, Gerald et al., 2011; Van der Ploeg, Wang, Gebre Weldmichael, & De Groot, 2010; Weber, 2007).

Note that where a range of values for each habitat was available, we elected to use the minimum value, which produced a conservative estimate of baseline value as well as of the benefit from implementing the Blueprint. The selected values and the full list of “candidate” values from which we made these selections is included as Appendix A to this report.

## Putting It All Together

With the steps complete above, we now estimate the annual ecosystem service value for each scenario according to this general formula:

$$ESV = \sum_{i,j,k} [(Acres_{j,k}) \times (Baseline\ Health_k) \times (Health\ Adjustment_k) \times (\$/acre/year)_{i,j}]$$

Where:

$Acres_{j,k}$	<i>the number of acres land use (j) in river segment (k) (From Chesapeake Bay model output are remotely sensed data)</i>
$Baseline\ health_k$	<i>is the initial health proxy for river segment (k) (from DO attainment for tidal segments, and from the modified wildness index for non-tidal segments)</i>
$Health\ Adjustment_k$	<i>is an adjustment to take into account changes to pollutant loading for non-tidal segments between the baseline and 2025 scenarios (i.e., Blueprint and Business-as-Usual), applied for each river segment (k). (See details below.) (This adjustment applies to non-tidal segments only<sup>5</sup>.)</i>
$(\$/acre/year)_{i,j}$	<i>is the minimum of the dollar value of each ecosystem service (i) provided from each land use (j) each year. These values are drawn from the Ecosystem Valuation Toolkit and other sources listed in the Appendix.</i>

The health adjustment for non-tidal segments is equal the one minus the average percent change in loading for the three pollutants (nitrogen, phosphorus, and total suspended solids).

$$Change\ in\ Health\ Index = [1 - average(\% \Delta N\ loading, \% \Delta P\ loading, \% \Delta TSS\ loading)]$$

Health in the Blueprint scenario, for example, becomes

$$\begin{aligned} &Health\ in\ Blueprint\ for\ River\ Segment\ k \\ &= Baseline\ Health_k \times [1 - (Average\ \% \Delta\ in\ pollutant\ loading\ for\ Blueprint)_k] \end{aligned}$$

For the sensitivity analysis (below), we consider the extent to which the magnitude of the factor before the average change in loading affects estimated benefits in each of the Blueprint and BAU scenarios.

## BENEFIT ESTIMATES

For the Baseline scenario, the total estimated natural capital value of the Chesapeake watershed, as represented by the eight selected ecosystem services, is \$107.2 billion per year in 2013 dollars (see Table 5). Forests generate the majority of the ecosystem value in the region. This is due, in part, to the fact that the region is heavily forested—roughly 59% of the watershed area is still in forest. In addition, forests are particularly good at producing high-value services, like filtering

<sup>5</sup> For tidal segments we do not adjust baseline health; rather we apply the ending health proxy for each of the two 2025 scenarios. Specifically, health of the tidal segments in the Blueprint scenario is assumed to be 1.00, given the 100 percent DO attainment goal of the TMDL. For the Business-as-Usual scenario, attainment, and therefore health, are assumed to be remain unchanged from the baseline.

drinking water, reducing flooding, providing aesthetic benefits, and being excellent places for hunting, hiking, and other types of recreation.

These Baseline estimates are generally in line with other studies of the value of natural capital in comparable regions. In a study of the Delaware estuary, an area about one tenth the size of the Chesapeake Bay watershed, Kauffmann (2011) estimated a total of \$12.8 billion (adjusted to 2013 dollars) in ecosystem service value. If the Delaware watershed were increased in size to match the Chesapeake watershed, that estimate would come to nearly \$137 billion in annual value. Similarly, Mates (2007) finds that the ecosystem service value of New Jersey is about \$9.7 billion (adjusted to 2013 dollars). With the Chesapeake Bay watershed being about 8.2 times the size of New Jersey, that assessment would suggest that the ecosystem service value of the Chesapeake Bay watershed would provide approximately \$131 billion per year.

**TABLE 5: SUMMARY OF ECOSYSTEM SERVICE VALUES FOR SEVEN LAND USES, BY SCENARIO**

Land Use	Baseline	Blueprint			Business-as-Usual	
	ESV (millions of 2013\$)	ESV (millions of 2013\$)	Change from Baseline (%)	Difference from BAU (%)	ESV (millions of 2013\$)	Change from Baseline (%)
Agriculture	12,258	13,434	10%	23%	10,949	-11%
Forest	73,960	86,406	17%	24%	69,639	-6%
Open Water	16,721	24,301	45%	47%	16,549	-1%
Urban Open	3,403	4,706	38%	26%	3,727	10%
Urban Other	11	14	26%	18%	12	7%
Wetland	356	364	2%	34%	270	-24%
Other	467	508	9%	32%	386	-17%
<b>Total</b>	<b>\$107,176</b>	<b>\$129,732</b>	<b>21%</b>	<b>28%</b>	<b>\$101,531</b>	<b>-5%</b>

Relative to personal income and gross regional product, the \$107.2 billion is fairly modest, at least by the standard of Costanza et al. (1997). Costanza et al., using methods similar to those here but without the adjustment for ecosystem health, estimated that the world’s ecosystems produce approximately three times as much value each year as do the world’s economies. For this study, the ratio is much smaller, with the Baseline ecosystem service value being a small fraction (about 1/28) the size of the gross product of the states that contain the Chesapeake region and about one seventh the size of total labor earnings of all the residents of the watershed’s 207 counties (Bureau of Economic Analysis, US Department of Commerce, 2014a, 2014b)<sup>6</sup>.

The Bay’s ecosystem services estimate is relatively small, based on these comparisons, for a couple of reasons. First, our method entails discounting ecosystem service values according to the land health measure. Second, we have estimated the value of only a subset of ecosystem services. The Delaware, New Jersey, and global studies, by contrast, considered all services and did not adjust for land health or productivity. Third, with respect to the Gross State Product comparison, the gross product of the six states and the District of Columbia includes the entire economic output for three states—New York, Delaware, and West Virginia—that contain less than one sixth of the watershed.

Knowing the baseline value is important: it gives a sense of how much the natural systems of the Chesapeake Bay contribute to the region’s economy on an annual basis. But the true purpose here is to see how much value implementing the Blueprint could add to the natural capital value of the region.

With full implementation of the Phase II WIPs and ultimate achievement of the pollutant loading and water-quality goals of the Clean Water Blueprint, the total value of the Chesapeake watershed is estimated at \$129.7 billion annually (using these eight ecosystem services), which is an increase of more than \$22.5 billion per year, or roughly 21%, over the Baseline. This

<sup>6</sup> These measures are not comparable, of course. Gross regional product and total labor earnings are very different measures, and the six Bay states all contain significant lands outside, as well as within, the Chesapeake watershed. But the comparisons are useful for confirming that the estimates produced here are within the bounds of similar previous studies.

increase is largely due to improved habitat health associated with lower pollutant loads and higher water quality attainment. The remainder is due to some reallocation of land to biomes (e.g., forests) that are relatively more productive from an ecosystem services standpoint. It is not surprising given the distribution of land uses, but is still worth noting that the majority of the benefits of implementing the Blueprint will accrue to “upstream” habitats, rather than to the open water habitat that includes the Chesapeake Bay and its tidal rivers.

**TABLE 6: SUMMARY OF ECOSYSTEM SERVICE VALUE FOR EIGHT ECOSYSTEM SERVICES, BY SCENARIO**

Ecosystem Service	Baseline	Blueprint			Business-as-Usual	
	ESV (millions of 2013\$)	ESV (millions of 2013\$)	Change from Baseline (%)	Difference from BAU (%)	ESV (millions of 2013\$)	Change from Baseline (%)
Aesthetic Value	38,446	47,407	23%	29%	36,653	-5%
Climate Stability	5,498	6,508	18%	24%	5,237	-5%
Food Production	12,129	13,313	10%	23%	10,839	-11%
Air Pollution Treatment	3,471	4,061	17%	24%	3,271	-6%
Recreation	3,071	4,099	33%	27%	3,227	5%
Waste Treatment	12,155	16,470	35%	39%	11,827	-3%
Water Regulation	12,386	14,448	17%	24%	11,634	-6%
Water Supply	20,019	23,427	17%	24%	18,843	-6%
<b>Total</b>	<b>\$107,176</b>	<b>\$129,732</b>	<b>21%</b>	<b>28%</b>	<b>\$101,531</b>	<b>-5%</b>

Under the Business as Usual scenario, by contrast, ecosystem service value could drop somewhat as land continues to be converted from more productive to less productive habitats (from forests to developed urban land, for example), and as land health and water quality continue to deteriorate. Based on the Chesapeake Bay Program’s projections of land use change and of pollution loads, we estimate that total ecosystem service value could drop by \$5.6 billion per year (in 2013 dollars) to \$101.5 billion beginning in 2025.

Finally, if we compare the Business as Usual result to the Blueprint projections, we estimate that the Blueprint would produce about \$28.2 billion more each year in ecosystem service value than under the Business as Usual scenario. Tables 5 and 6 provide summary estimates by land use and by ecosystem service for the three scenarios.

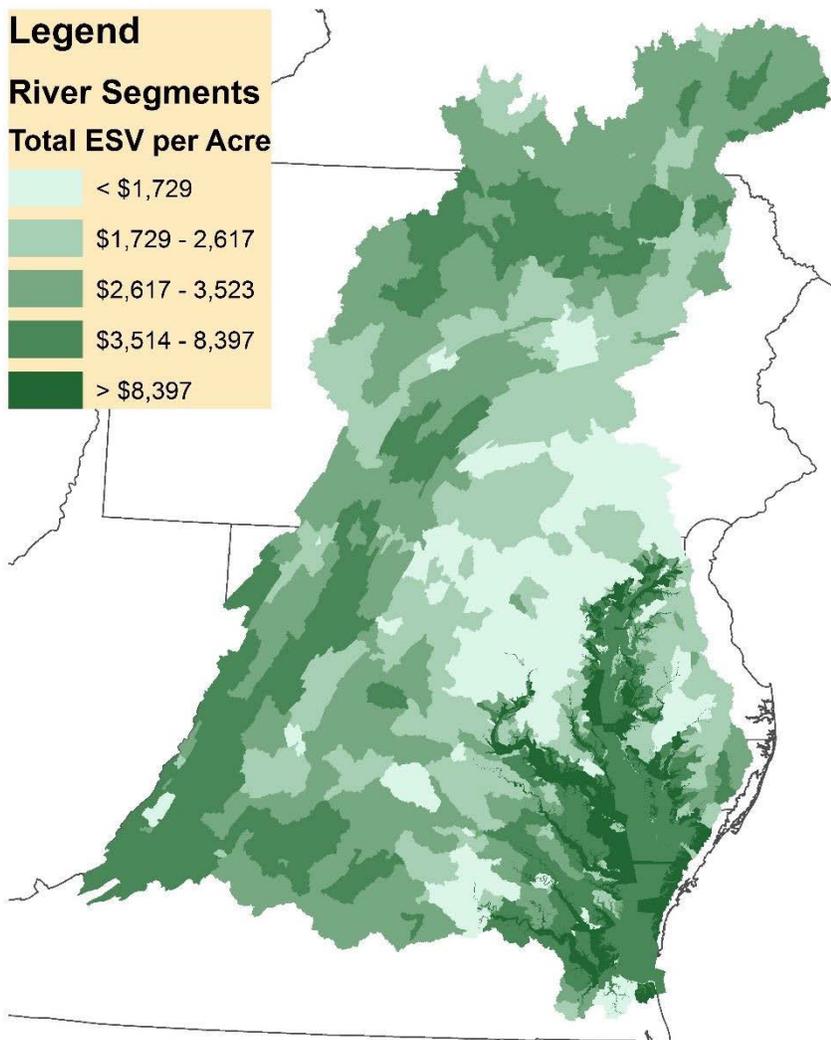
**TABLE 7: SUMMARY OF ECOSYSTEM SERVICE VALUE FOR CHESAPEAKE BAY JURISDICTIONS, BY SCENARIO**

Jurisdiction	Baseline	Blueprint			Business-as-Usual	
	ESV (millions of 2013\$)	ESV (millions of 2013\$)	Change from Baseline (%)	Difference from BAU (%)	ESV (millions of 2013\$)	Change from Baseline (%)
Virginia	41,195	49,540	20%	30%	38,006	-8%
Pennsylvania	32,637	38,828	19%	26%	30,810	-6%
Maryland	15,892	20,449	29%	34%	15,209	-4%
New York	10,361	12,276	18%	18%	10,363	0%
West Virginia	6,330	7,668	21%	19%	6,458	2%
Delaware	735	941	28%	43%	659	-10%
District of Columbia	25	29	15%	10%	27	5%
<b>Total</b>	<b>\$107,176</b>	<b>\$129,732</b>	<b>21%</b>	<b>28%</b>	<b>\$101,531</b>	<b>-5%</b>

If one considers the distribution of ecosystem service value and the benefits of the Blueprint by state (Table 7, Appendix B), the results are, for the most part commensurate with the distribution of land area in the watershed among the states. Virginia, which has 33.9% of the acreage would receive 38.2% of the ecosystem service value under the Blueprint scenario

(\$49.5 billion). Pennsylvania, which has a bit more of the acreage (35.2%) would receive a bit less than 30% of the ecosystem service value (\$38.8 billion).

Comparing the Baseline and Blueprint scenario, the states would see gains of between 18 and 29%. (D.C. would gain about 15%.) Differences in these relative gains are due to differences among the states in loadings and land use allocation stemming from the states and the District’s respective Watershed Implementation Plans.



**FIGURE 8: AVERAGE ANNUAL ECOSYSTEM SERVICE VALUE PER ACRE (IN 2013\$) UNDER THE BLUEPRINT SCENARIO**

(This map does not show boundaries between river segments.)

assumptions would seem no less arbitrary, we consider what the estimated benefits of the Blueprint would be if we had over- or under-estimated by 50% the strength of the relationship between changes in sediment loading and health/productivity.<sup>7</sup>

Ecosystem service value can also be explored for smaller geographic units, such as depicted in the map in Figure 8. This map shows the average value per acre of all eight ecosystem services under the Blueprint scenario by river segment. Lighter shades of green indicate lower per-acre values. Being a function of the land use (land cover), health and per-acre values for different ecosystem services, total ecosystem service value does tend to be higher in river segments with more forest cover and those near the tidal Bay which, under the Blueprint scenario, is assumed to be functioning at full health. Other high-value river segments are in the main stem of the Bay, where the area is larger, and per-acre water supply, aesthetic, and recreational values are high.

### Sensitivity Analysis

As noted above, we assume a linear relationship between our indicators of ecosystem health. While certainly not correct for all relationships, such an assumption provides a straightforward substitute for the myriad possible functional forms that could represent the actual relationships. Even so, it is useful to consider how our estimates could differ under different assumptions. For the sake of simplicity, and because positing some subset of alternative

<sup>7</sup>Such an analysis makes sense only for the terrestrial part of the watershed and not for the main stem of the Bay and its tidal tributaries. For those waters, health is either 100% for the Blueprint or unchanged for the BAU scenario, so there was no percentage change involved in the estimation itself.

In other words, we have asked how the estimates would change if each one percent decrease in pollutant load were to increase land health by only half a percent or, or alternatively, by one and a half percent. This modifies the equation above by inserting a factor of 0.5 and then 1.5 for “Z” in the following equation:

$$\begin{aligned} & \text{Health in Blueprint for River Segment} \\ & = \text{Baseline Health}_k \times [1 - Z(\text{Average } \% \Delta \text{ in pollutant loading for Blueprint})_k] \end{aligned}$$

And the answer is: “not very much.” For the Blueprint scenario, this procedure yields a range of estimates of total ecosystem service value of \$122.2 to \$136.7 billion, compared to the estimate above of \$129.7 billion. In terms of the benefit or added ecosystem service value of the Blueprint relative to the baseline scenario, the range is \$15 to \$29.6 billion dollars, compared to the estimate of \$22.6 billion. Thus even a major change in assumptions about the relationship between changes in pollutant loads and land health moves the ecosystem service value estimates by less than 6%. (The reason the change is a bit lopsided is that the model does not allow land health to exceed 100%, and for some river segments, multiplying the percent improvement by 1.5 pushed the resulting health index to that limit.)

For the Business as Usual scenario, the range is tighter, from \$99.1 to \$104 billion, compared to our estimate of \$101.5 billion. The reason for the difference in the span of estimates between the BAU and Blueprint scenarios is that in the BAU scenario, about half of the river segments are projected to experience an increase in health anyway (due to BMPs already in place to reduce pollutant loading), and these gains tend to counteract the decreases projected for other segments. In the Blueprint scenario, by contrast, nearly all river segments would see a reduction in pollutant loads (and an increase in health), and very few of the gains in one segment are offset by losses in another.

For both the Blueprint and BAU scenarios, this sensitivity analysis suggests that the assumption of a linear, one-to-one relationship between percent changes in pollutant loading and changes in ecosystem service productivity is fairly robust. Changes to the assumption do not change the absolute estimates by much and the changes certainly do not alter the result that the Blueprint would produce large annual increases in ecosystem service value relative to the Baseline and even larger increases relative to Business as Usual.

Combined with other assumptions designed to make our estimates conservative (e.g., selecting minimum per-acre values and adjusting for land health in the first place), this result gives great confidence that the estimates are both reasonable and useful as low-end estimates for consideration of the overall, net benefit of the Blueprint.

## CONCLUSION

Natural capital, as the basis for ecosystem service flows, is an important contributor to the Chesapeake Bay region’s economy and quality of life. As these study results suggest, implementing the Chesapeake Clean Water Blueprint could result in important economic benefits relative to today’s conditions and relative to conditions that would be expected to prevail if no further action is taken to reduce pollution of the Chesapeake Bay. These benefits accrue both due to changes in the pattern of land conversion in the region and due to adoption of best management practices that result in reductions of pollutant loads. Both types of change would improve ecosystem service productivity and, assuming stable values for those services, increases in the economic output of the region’s natural capital.

These benefits would naturally be distributed among diverse industries, individuals, and communities throughout and beyond the region. This look at aggregate value of implementing and achieving the Blueprint provides an important perspective on the overall economic contribution of the program. It also gives us a benchmark against which to consider other economic aspects of achieving water quality improvement in the Chesapeake Bay, including the cost of implementing pollution-control measures.

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## APPENDIX A: PER-ACRE ECOSYSTEM SERVICE VALUE

<b>Candidate per-acre values for Land-Use and Ecosystem Service Combinations <sup>A</sup></b> <b>(All values are in 2013 \$)</b>						
<b>Land Use</b>	<b>Ecosystem Service</b>	<b>Min \$/Acre</b>	<b>Midpoint \$/Acre</b>	<b>Maximum \$/Acre</b>	<b>Note</b>	<b>Source<sup>D</sup></b>
Agriculture	Aesthetic Information	\$34.45	\$61.13	\$87.81	B	(Bergstrom, Dillman, & Stoll, 1985)
Agriculture	Aesthetic Information	\$1,833.47	\$1,833.47	\$1,833.47	B	(R. J. Johnston, Opaluch, Grigalunas, & Mazzotta, 2001)
Agriculture	Food	\$2,381.76	\$2,381.76	\$2,381.76		(Kauffmann, Gerald et al., 2011)
Agriculture	Recreation	\$2.13	\$3.53	\$4.94	B	(Knoche & Lupi, 2007)
Forest	Aesthetic Information	\$1,831.47	\$2,639.46	\$3,447.46	B	(Mazzotta, 1996)
Forest	Aesthetic Information	\$4,561.17	\$4,561.17	\$4,561.17	B	(Opaluch, Grigalunas, Diamantedes, Mazzotta, & Johnston, 1999)
Forest	Climate Stability	\$318.60	\$318.60	\$318.60	B	(Flores, Harrison-Cox, Wilson, & Batker, 2013)
Forest	Air Pollution Treatment	\$214.68	\$214.68	\$214.68		(Weber, 2007)
Forest	Recreation	\$2.74	\$249.33	\$495.92	B	(Shafer, Carline, Guldin, & Cordell, 1993)
Forest	Recreation	\$36.54	\$40.66	\$44.78	B	(Prince, n.d.)
Forest	Waste Treatment	\$261.54	\$262.09	\$262.63	B	(Liu, 2006)
Forest	Waste Treatment	\$6,174.59	\$6,174.59	\$6,174.59	B	(Liu, 2006)
Forest	Water Regulation	\$763.20	\$763.20	\$763.20		(Weber, 2007)
Forest	Water Supply	\$1,236.40	\$1,236.40	\$1,236.40		(Weber, 2007)
Open water	Aesthetic Information	\$3,848.73	\$7,707.34	\$11,565.96	B	(Opaluch et al., 1999)

<b>Candidate per-acre values for Land-Use and Ecosystem Service Combinations <sup>A</sup></b> <b>(All values are in 2013 \$)</b>						
<b>Land Use</b>	<b>Ecosystem Service</b>	<b>Min \$/Acre</b>	<b>Midpoint \$/Acre</b>	<b>Maximum \$/Acre</b>	<b>Note</b>	<b>Source<sup>D</sup></b>
Open water	Food	\$25.35	\$82.37	\$139.40	B	(Armstrong, Rooper, & Gunderson, 2003).
Open water	Food	\$67.22	\$67.22	\$67.22	B	(Judith T Kildow, Colgan, Kite-Powell, Shivendu, & Tindall, 2004)
Open water	Food	\$750.20	\$750.20	\$750.20	B	(Kahn & Buerger, 1994)
Open water	Food	\$3,447.46	\$5,548.26	\$7,649.06	B	(Mazzotta, 1996)
Open water	Food	\$29,174.11	\$29,174.11	\$29,174.11	B	(Douglas Lipton, 2009)
Open water	Recreation	\$10.00	\$51.73	\$93.46	B	(Whitehead, Hoban, & Clifford, 1997)
Open water	Recreation	\$108.33	\$208.30	\$308.27	B	(Opaluch et al., 1999)
Open water	Recreation	\$152.88	\$526.19	\$899.51	B	(Cordell & Bergstrom, 1993)
Open water	Recreation	\$185.17	\$301.05	\$416.93	B	(Opaluch et al., 1999)
Open water	Recreation	\$204.04	\$328.99	\$453.94	B	(Judith T Kildow et al., 2004)
Open water	Recreation	\$299.32	\$364.77	\$430.21	B	(Mullen & Menz, 1985)
Open water	Recreation	\$437.31	\$437.31	\$437.31	B	(Hicks, Haab, & Lipton, 2004)
Open water	Recreation	\$652.38	\$699.76	\$747.14	B	(Ribauda & Epp, 1984)
Open water	Recreation	\$1,230.03	\$1,790.48	\$2,350.93	B	(Hayes, Tyrrell, & Anderson, 1992)
Open water	Recreation	\$2,669.01	\$2,763.21	\$2,857.41	B	(Burt & Brewer, 1971)
Open water	Recreation	\$4,087.27	\$9,849.15	\$15,611.04	B	(Shafer et al., 1993)
Open water	Recreation	\$13,614.87	\$13,614.87	\$13,614.87	B	(Mathews, Homans, & Easter, 2002)
Open water	Waste Treatment	\$3,609.10	\$3,609.10	\$3,609.10	B	(Douglas Lipton, 2004)
Open water	Water Supply	\$81.35	\$112.86	\$144.37	B	(Kenneth Mcconnell, n.d.)

<b>Candidate per-acre values for Land-Use and Ecosystem Service Combinations <sup>A</sup></b> <b>(All values are in 2013 \$)</b>						
<b>Land Use</b>	<b>Ecosystem Service</b>	<b>Min \$/Acre</b>	<b>Midpoint \$/Acre</b>	<b>Maximum \$/Acre</b>	<b>Note</b>	<b>Source<sup>D</sup></b>
Open water	Water Supply	\$90.80	\$90.80	\$90.80	B	(Nunes & Bergh, 2004)
Open water	Water Supply	\$639.10	\$639.10	\$639.10	B	(Croke, Fabian, & Brenniman, 1986)
Other	Aesthetic Information	\$246.49	\$448.71	\$650.93	B	(Pompe & Rinehart, 1995)
Other	Recreation	\$6,417.20	\$7,204.21	\$7,991.22	B	(Kline & Swallow, 1998)
Urban Open	Aesthetic Information	\$447.46	\$447.46	\$447.46	B	(R. J. Johnston et al., 2001)
Urban Open	Aesthetic Information	\$990.00	\$1,145.60	\$1,301.20	B	(Qiu, Prato, & Boehrn, 2006)
Urban Open	Aesthetic Information	\$1,699.71	\$2,319.27	\$2,938.82	B	(Opaluch et al., 1999)
Urban Open	Climate Stability	\$414.15	\$414.15	\$414.15	C	(Brenner Guillermo, 2007)
Urban Open	Climate Stability	\$1,116.28	\$1,116.28	\$1,116.28	B	(Mcpherson, 1992)
Urban Open	Air Pollution Treatment	\$31.94	\$31.94	\$31.94	B	(McPherson, Scott, & Simpson, 1998)
Urban Open	Air Pollution Treatment	\$189.28	\$189.28	\$189.28	B	(Mcpherson, 1992)
Urban Open	Recreation	\$2,627.61	\$2,627.61	\$2,627.61	C	(Brenner Guillermo, 2007)
Urban Open	Water Regulation	\$8.19	\$8.19	\$8.19	B	(Mcpherson, 1992)
Urban Open	Water Regulation	\$136.02	\$160.30	\$184.58	B	(The Trust for Public Land, 2010)
Urban Other	Water Regulation	\$7.48	\$7.48	\$7.48	C	(Brenner Guillermo, 2007)
Wetland	Aesthetic Information	\$454.35	\$954.13	\$1,453.92	B	(Thibodeau & Ostro, 1981)
Wetland	Aesthetic Information	\$943.62	\$1,227.72	\$1,511.82	B	(R. J. Johnston et al., 2001)

<b>Candidate per-acre values for Land-Use and Ecosystem Service Combinations <sup>A</sup></b> <b>(All values are in 2013 \$)</b>						
<b>Land Use</b>	<b>Ecosystem Service</b>	<b>Min \$/Acre</b>	<b>Midpoint \$/Acre</b>	<b>Maximum \$/Acre</b>	<b>Note</b>	<b>Source<sup>D</sup></b>
Wetland	Climate Stability	\$61.68	\$2,423.38	\$4,785.07	B	(Flores et al., 2013)
Wetland	Climate Stability	\$211.85	\$211.85	\$211.85	B	(Hughes, 2006)
Wetland	Food	\$5.65	\$356.71	\$707.76	B	(Sandra S. Batie, 1978)
Wetland	Food	\$58.93	\$98.31	\$137.69	B	(Bell, 1989)
Wetland	Food	\$802.40	\$802.40	\$802.40	B	(Hughes, 2006)
Wetland	Food	\$1,000.44	\$1,000.44	\$1,000.44	B	(R. J. Johnston et al., 2001)
Wetland	Air Pollution Treatment	\$74.29	\$85.37	\$96.45	B	(Jenkins, Murray, Kramer, & Faulkner, 2010)
Wetland	Recreation	\$79.42	\$79.42	\$79.42	B	(Bergstrom, Stoll, Titre, & Wright, 1990)
Wetland	Recreation	\$107.55	\$265.33	\$423.11	B	(Robert Costanza, Farber, & Maxwell, 1989)
Wetland	Recreation	\$120.74	\$120.74	\$120.74	B	(Whitehead, Groothuis, Southwick, & Foster-Turley, 2009)
Wetland	Recreation	\$152.75	\$662.39	\$1,172.02	B	(Bell, 1989)
Wetland	Recreation	\$204.69	\$204.69	\$204.69	B	(Kreutzwiser, 1981)
Wetland	Recreation	\$215.29	\$932.29	\$1,649.28	B	(Raphael & Jaworski, 1979)
Wetland	Recreation	\$417.32	\$417.32	\$417.32	B	(G. D. Anderson & Edwards, 1986)
Wetland	Recreation	\$568.66	\$5,382.12	\$10,195.58	B	(Thibodeau & Ostro, 1981)
Wetland	Recreation	\$638.21	\$2,387.46	\$4,136.71	B	(Whitehead, 1990)
Wetland	Recreation	\$1,024.42	\$1,024.42	\$1,024.42	B	(Creel & Loomis, 1992)
Wetland	Waste Treatment	\$65.95	\$3,138.39	\$6,210.84	B	(Breux, Farber, & Day, 1995)
Wetland	Waste Treatment	\$542.22	\$542.22	\$542.22	B	(Jenkins et al., 2010)

<b>Candidate per-acre values for Land-Use and Ecosystem Service Combinations <sup>A</sup></b> <b>(All values are in 2013 \$)</b>						
<b>Land Use</b>	<b>Ecosystem Service</b>	<b>Min \$/Acre</b>	<b>Midpoint \$/Acre</b>	<b>Maximum \$/Acre</b>	<b>Note</b>	<b>Source<sup>D</sup></b>
Wetland	Waste Treatment	\$4,484.94	\$4,484.94	\$4,484.94	B	(Thibodeau & Ostro, 1981)
Wetland	Water Regulation	\$1,271.60	\$1,271.60	\$1,271.60		(Weber, 2007)
Wetland	Water Supply	\$612.83	\$612.83	\$612.83	B	(Creel & Loomis, 1992)
Wetland	Water Supply	\$18,307.22	\$18,307.22	\$18,307.22	B	(Thibodeau & Ostro, 1981)

## Notes:

- A. From this list of candidate values, two options for valuation were created: the minimum of the minimum value for all studies for which an estimate is available for a give land use-ecosystem service pair; and the average of the midpoints of estimates from those studies. Ultimately, and for the sake of providing conservative estimates, the minimum of the minimum values was used for this study. Details are provide in this table to provide a sense of the range of values available in the literature.
- B. These values were obtained via contract for a custom data pull from Earth Economics Ecosystem Valuation Toolkit in March 2014. Earth Economics selected options from thousands of studies based on applicability to the Chesapeake Bay Watershed. <http://esvaluation.org/>.
- C. Values selected from the TEEB (The Economics of Ecosystems and Biodiversity) Valuation Database (Van der Ploeg et al., 2010).
- D. Full references are included under “Works Cited,” above.

APPENDIX B: BENEFIT VALUES FOR CHESAPEAKE BAY JURISDICTIONS BY ECOSYSTEM SERVICE AND LAND TYPE <sup>8</sup>

<b>Baseline Scenario (2013 \$ in millions)</b>							
<b>Ecosystem Service</b>	<b>DC</b>	<b>DE</b>	<b>MD</b>	<b>NY</b>	<b>PA</b>	<b>VA</b>	<b>WV</b>
<b>Aesthetic Information</b>	8,250	179,692	6,170,885	3,535,903	11,037,658	15,314,725	2,198,665
<b>Climate Stability</b>	1,670	35,267	483,557	628,258	1,966,361	1,997,954	385,460
<b>Food</b>	0.03	235,911	1,741,515	1,265,001	4,130,274	4,036,635	719,582
<b>Air Pollution Treatment</b>	0.36	19,690	289,646	400,634	1,242,712	1,266,390	251,829
<b>Recreation</b>	8,040	55,476	605,087	255,730	964,192	1,082,933	99,523
<b>Waste Treatment</b>	4,756	28,250	3,772,701	563,327	1,797,949	5,651,129	337,322
<b>Water Regulation</b>	1,091	70,108	1,097,459	1,419,439	4,394,382	4,511,545	892,300
<b>Water Supply</b>	1,615	110,768	1,731,435	2,292,901	7,103,755	7,333,201	1,445,164
<b>Total</b>	<b>25,422</b>	<b>735,162</b>	<b>15,892,285</b>	<b>10,361,193</b>	<b>32,637,283</b>	<b>41,194,512</b>	<b>6,329,845</b>

<b>Blueprint Scenario (2013 \$ in millions)</b>							
<b>Ecosystem Services</b>	<b>DC</b>	<b>DE</b>	<b>MD</b>	<b>NY</b>	<b>PA</b>	<b>VA</b>	<b>WV</b>
<b>Aesthetic Information</b>	10,110	247,430	8,272,339	4,268,957	13,057,363	18,932,293	2,618,193
<b>Climate Stability</b>	1,940	50,753	566,830	759,832	2,338,966	2,325,674	464,454
<b>Food</b>	0.03	238,828	1,824,795	1,285,065	5,003,963	4,014,719	945,160
<b>Air Pollution Treatment</b>	0.54	27,348	332,845	484,297	1,468,013	1,448,296	299,206
<b>Recreation</b>	7,312	89,211	760,207	311,660	1,258,110	1,504,861	167,488
<b>Waste Treatment</b>	5,245	37,470	5,438,331	679,075	2,130,704	7,778,194	401,397
<b>Water Regulation</b>	1,813	96,929	1,246,646	1,715,802	5,187,391	5,141,342	1,058,259
<b>Water Supply</b>	2,764	152,937	2,007,026	2,771,498	8,383,866	8,394,762	1,713,818
<b>Total</b>	<b>29,185</b>	<b>940,906</b>	<b>20,449,019</b>	<b>12,276,186</b>	<b>38,828,376</b>	<b>49,540,141</b>	<b>7,667,975</b>

<sup>8</sup> Grand totals for the three scenarios may differ slightly from Tables 5-7 due to rounding.

<b>Business As Usual Scenario (2013 \$)</b>							
<b>Ecosystem Service</b>	<b>DC</b>	<b>DE</b>	<b>MD</b>	<b>NY</b>	<b>PA</b>	<b>VA</b>	<b>WV</b>
<b>Aesthetic Information</b>	8,544	168,666	6,001,985	3,606,664	10,357,382	14,294,147	2,215,626
<b>Climate Stability</b>	1,801	34,765	466,061	641,729	1,853,061	1,848,862	390,796
<b>Food</b>	0.03	178,259	1,479,856	1,077,530	4,001,666	3,316,441	785,606
<b>Air Pollution Treatment</b>	0.38	18,459	272,460	409,080	1,165,294	1,152,368	253,301
<b>Recreation</b>	8,725	63,921	622,630	262,713	971,219	1,174,948	122,884
<b>Waste Treatment</b>	4,791	26,337	3,728,580	574,454	1,686,015	5,466,249	340,577
<b>Water Regulation</b>	1,099	65,316	1,013,417	1,449,440	4,118,623	4,089,290	896,657
<b>Water Supply</b>	1,684	103,003	1,624,506	2,341,133	6,656,691	6,663,602	1,452,093
<b>Total</b>	<b>26,644</b>	<b>658,726</b>	<b>15,209,494</b>	<b>10,362,741</b>	<b>30,809,951</b>	<b>38,005,907</b>	<b>6,457,540</b>

<b>Baseline Scenario (2013 \$ in millions)</b>							
<b>Land Use</b>	<b>DC</b>	<b>DE</b>	<b>MD</b>	<b>NY</b>	<b>PA</b>	<b>VA</b>	<b>WV</b>
<b>Agriculture</b>	0	239,508	1,743,352	1,284,039	4,191,535	4,069,002	730,606
<b>Forest</b>	5,703	410,101	6,006,969	8,567,205	26,549,705	27,013,186	5,407,538
<b>Open Water</b>	9,149	10,407	7,194,310	165,747	623,720	8,651,151	66,681
<b>Other</b>	0.04	11,325	177,651	6,187	67,890	192,316	11,947
<b>Urban Open</b>	10,570	59,043	554,715	326,438	1,179,201	1,159,900	113,072
<b>Urban Other</b>	0.08	0.04	2,808	0.50	3,398	3,864	0.36
<b>Wetland</b>	0.008	4,778	212,480	11,576	21,834	105,093	0.17
<b>Total</b>	<b>25,422</b>	<b>735,162</b>	<b>15,892,285</b>	<b>10,361,193</b>	<b>32,637,283</b>	<b>41,194,512</b>	<b>6,329,845</b>

<b>Blueprint Scenario (2013 \$ in millions)</b>							
<b>Land Use</b>	<b>DC</b>	<b>DE</b>	<b>MD</b>	<b>NY</b>	<b>PA</b>	<b>VA</b>	<b>WV</b>
<b>Agriculture</b>	0	242,473	1,816,394	1,304,101	5,078,183	4,033,125	959,596
<b>Forest</b>	9,768	566,183	6,902,187	10,355,417	31,331,768	30,828,530	6,412,810
<b>Open Water</b>	9,778	11,141	10,583,840	196,673	754,680	12,662,977	81,957
<b>Other</b>	0.18	15,255	190,840	7,491	83,639	193,377	17,031
<b>Urban Open</b>	9,639	99,060	739,189	398,298	1,548,301	1,715,263	196,580
<b>Urban Other</b>	0.08	0.06	3,836	0.58	4,318	4,683	0.42
<b>Wetland</b>	0.02	6,794	212,733	14,205	27,487	102,186	0.11
<b>Total</b>	<b>29,185</b>	<b>940,906</b>	<b>20,449,019</b>	<b>12,276,186</b>	<b>38,828,376</b>	<b>49,540,141</b>	<b>7,667,975</b>

<b>Business as Usual Scenario (2013 \$)</b>							
<b>Land Use</b>	<b>DC</b>	<b>DE</b>	<b>MD</b>	<b>NY</b>	<b>PA</b>	<b>VA</b>	<b>WV</b>
<b>Agriculture</b>	0	180,973	1,477,960	1,093,631	4,061,077	3,338,129	797,478
<b>Forest</b>	5,978	381,142	5,657,415	8,747,204	24,877,652	24,536,470	5,433,512
<b>Open Water</b>	9,191	9,830	7,146,112	167,680	587,098	8,558,438	70,550
<b>Other</b>	0.04	10,334	146,250	6,417	64,571	145,578	12,656
<b>Urban Open</b>	11,475	71,768	621,842	335,563	1,194,488	1,348,171	143,343
<b>Urban Other</b>	0.10	0.04	3,302	0.49	3,366	4,120	0.43
<b>Wetland</b>	0	4,679	156,613	12,246	21,699	75,001	0.070
<b>Total</b>	<b>26,644</b>	<b>658,726</b>	<b>15,209,494</b>	<b>10,362,741</b>	<b>30,809,951</b>	<b>38,005,907</b>	<b>6,457,540</b>







The report, commissioned by the Chesapeake Bay Foundation, was developed by Spencer Phillips, Ph.D., with scientific assistance from Beth McGee, Ph.D., and peer reviewed by Dr. Gerald Kaufman of University of Delaware, Dr. Valerie Esposito of Champlain College, Dr. Tania Briceno of Earth Economics, and Mr. Dan Nees of the University of Maryland.

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**October 2014**

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