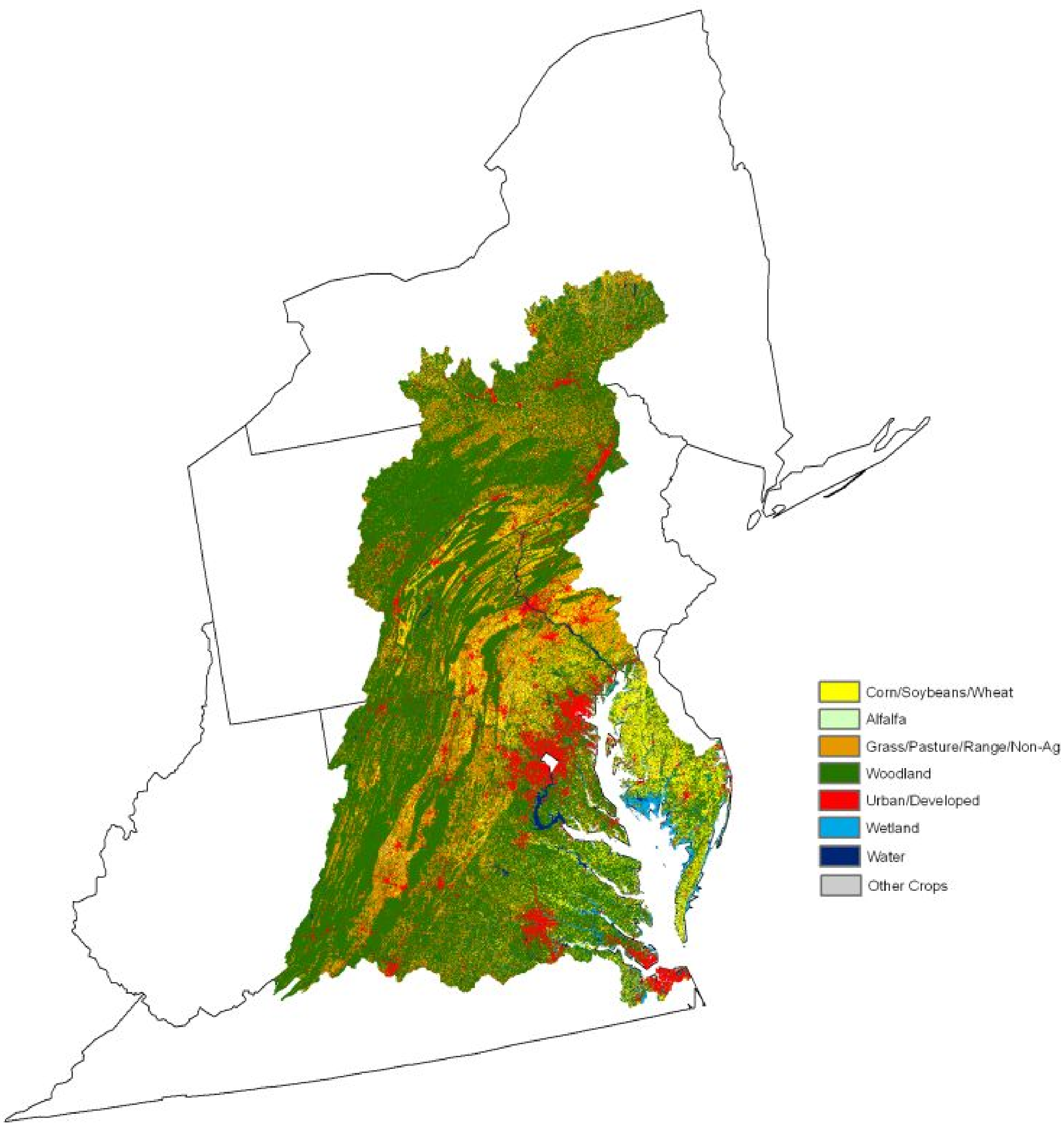
United States Department of Agriculture

Conservation Effects Assessment Project (CEAP)

Conservation Progress Report

NOVEMBER 2013

Impacts of Conservation Adoption on Cultivated Acres of Cropland in the Chesapeake Bay Region, 2003-06 to 2011



Cover Photo: Land cover in the Chesapeake Bay region. Source: National Agricultural Statistics Service (NASS, 2007).

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CEAP—Strengthening the science base for natural resource conservation

The Conservation Effects Assessment Project (CEAP) was initiated by USDA's Natural Resources Conservation Service (NRCS), Agricultural Research Service (ARS), and National Institute of Food and Agriculture (NIFA) [formally known as Cooperative State Research, Education, and Extension Services (CSREES)] in 2002 as a means by which to analyze societal and environmental benefits gained from the 2002 Farm Bill's substantial increase in conservation program funding. The original goals of CEAP were to estimate conservation benefits for reporting at the national and regional levels and to establish the scientific understanding of the effects and benefits of conservation practices at the watershed scale. As CEAP evolved, the scope was expanded to assess the impacts and efficacy of various conservation practices on maintaining and improving soil and water quality at regional, national, and watershed scales.

CEAP activities are organized into three interconnected efforts:

- *Bibliographies, literature reviews, and scientific workshops* to establish what is known about the environmental effects of conservation practices at the field and watershed scale.
- *National and regional assessments* to estimate the environmental effects and benefits of conservation practices on the landscape and to estimate conservation treatment needs. The four components of the national and regional assessment effort are *Cropland*; *Wetlands*; *Grazinglands*, including rangeland, pastureland, and grazed forestland; and *Wildlife*.
- *Watershed studies* to provide in-depth quantification of water quality and soil quality impacts of conservation practices at the local level and to provide insight on what practices are the most effective and where they are needed within a watershed to achieve environmental goals.

CEAP benchmark results, currently published for six watersheds, provide a scientific basis for interpreting conservation practice implementation impacts and identifying remaining conservation practice needs. These reports continue to inform decision makers, policy makers, and the public on the environmental and societal benefits of conservation practice use.

Additional information on the scope of the project can be found at http://www.nrcs.usda.gov/technical/nri/ceap/.

This report was prepared by the Conservation Effects Assessment Project (CEAP) Cropland Modeling Team and published by the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS). The modeling team consists of scientists and analysts from NRCS, the Agricultural Research Service (ARS), the University of Massachusetts, and Texas A&M AgriLife Research.

Natural Resources Conservation Service, USDA
Lee Norfleet, **Project Coordinator,** Temple, TX, Soil Scientist
Jay D. Atwood, Temple, TX, Agricultural Economist
Tim Dybala, Temple, TX, Civil Engineer
Maria Hrebik, Temple, TX, Civil Engineer
Kevin Ingram, Beltsville, MD, Agricultural Economist
Mari-Vaughn V. Johnson, Temple, TX, Agronomist
Chris Lester, Temple, TX, Soil Conservationist
Daryl Lund, Beltsville, MD, Soil Scientist
Loretta J. Metz, Temple, TX, Rangeland Management Specialist
Ann Graham, Temple, TX, Senior Editor

Agricultural Research Service, USDA, Grassland, Soil, and Water Research Laboratory, Temple, TX
Jeff Arnold, Agricultural Engineer
Daren Harmel, Agricultural Engineer
Mike White, Agricultural Engineer

Blackland Research & Extension Center, Texas A&M AgriLife Research, Temple, TX
Tom Gerik, Director
Santhi Chinnasamy, Agricultural Engineer
Mauro Di Luzio, Research Scientist
Arnold King, Resource Conservationist
David C. Moffitt, Environmental Engineer
Theresa Pitts, Programmer
Xiuying (Susan) Wang, Agricultural Engineer
Jimmy Williams, Agricultural Engineer

University of Massachusetts Extension, Amherst, MA
Stephen Plotkin, Water Quality Specialist

The study was conducted under the direction of **Micheal Golden**, Deputy Chief for Soil Science and Resource Assessment, **Michele Laur**, Director for Resource Assessment Division, and **Douglas Lawrence,** former Deputy Chief for Soil Survey and Resource Assessment, NRCS. Executive support was provided by NRCS Chief **Jason Weller**, and former NRCS Chief **Dave White**.

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Last, but certainly not least, our gratitude is owed to the producers, land operators, farmers and ranchers, without whose continued cooperation the CEAP effort, including this report, would not be possible.

Foreword

This report marks the first revisit of a region originally surveyed and assessed by the USDA NRCS through the Conservation Effects Assessment Project (CEAP) (USDA NRCS 2011). The original Chesapeake Bay report was the second report released in the national CEAP series of regional reports, continuing the tradition within USDA of assessing the status, condition, and trend of natural resources to determine how to improve conservation programs to best meet the Nation's needs. The regional CEAP reports use a sampling and modeling approach to quantify the environmental benefits that farmers and conservation programs currently provide to society, and to explore prospects for attaining additional benefits with further or alternative conservation treatment.

The original report, based on a 2003-06 survey and published in 2011, provides quantified reference points against which to compare subsequent studies, including this report. The revisit to the region allows examination of the changes and trends in conservation practice use over time by comparing the baseline 2003-06 survey results with the results from the 2011 survey. The comparison illuminates changes in patterns and impacts of voluntary conservation adoption in the Chesapeake Bay region. This resurvey improves our scientific understanding of the effects and benefits of conservation practices at the watershed scale and increases the scientific knowledge base helping policy makers implement appropriate programs and helping land managers and farmers apply appropriate practices to best meet conservation goals in the region.

This report differs from the 2011 published "Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Chesapeake Bay Region" in several key aspects. The two reports cover the same areal extent, but the survey data for the original report was collected over a multi-year period (2003-06) as part of the original CEAP national survey, while the resurvey activity occurred only in the Chesapeake Bay region and solely in the fall of 2011. During the interim between the publication of the benchmark report in 2011 and this report, there have been numerous improvements and updates performed on the Agricultural Policy/Environmental eXtender (APEX) and Soil Water Assessment Tool (SWAT) models, improvements in soils input data, increased weather data availability, and refinement of analytical techniques for evaluating the model results. As these changes impacted data interpretation, model function, and results, the 2003-06 data was reanalyzed alongside the 2011 data. The more robust approach utilized in this analysis produced results that differ from the results reported in the original USDA NRCS CEAP report for the Chesapeake Bay region (USDA NRCS 2011). Therefore, readers of both reports will notice differences in certain results, procedures, and interpretations.

The United States Department of Agriculture (USDA) has a rich tradition of working with farmers and ranchers to enhance agricultural productivity and environmental conservation through voluntary programs. Many USDA programs provide financial assistance to producers to encourage adoption of conservation practices appropriate to local soil and site conditions. Other USDA programs, in tandem with state and local programs, provide technical assistance to design, install, and implement conservation practices that are consistent with farmer objectives and policy goals. By participating in USDA conservation programs, producers are able to:

- install structural practices such as riparian buffers, grass filter strips, terraces, grassed waterways, and contour farming, all of which reduce erosion, sedimentation, and nutrients leaving the field;
- adopt conservation systems and practices such as conservation tillage, comprehensive nutrient management, integrated pest management, and irrigation water management, which conserve resources and maintain the long-term productivity of crop and pastureland; and
- retire land too fragile for continued agricultural production by planting and maintaining on them grasses, trees, or wetland vegetation.

As soil and water conservation remain a national priority, it is imperative to quantify the effectiveness of current conservation practices and identify the potential for improving conservation gains. Over the past several decades, as the relationship between crop production and the environment in which it occurs has become better understood, goals have shifted from solely preventing erosion to achieving sustainable agricultural productivity by balancing the trade-offs associated with agricultural production and other potential ecosystem services. Expansion of our scientific understanding of agroecological systems has contributed to a broadening of USDA conservation policy objectives and development of more sophisticated conservation planning, practice design, and implementation. These more holistic conservation goals and management approaches enable the Natural Resources Conservation Service (NRCS) to work with farmers and ranchers to plan, select, and apply conservation practices that enable their operations to produce food, forage, and fiber while conserving the Nation's soil and water resources.

Impacts of Conservation Adoption on Cultivated Acres of Cropland in the Chesapeake Bay Region, 2003-06 to 2011

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Documentation Reports

There are a series of documentation reports and associated publications by the modeling team posted on the CEAP website at: http://www.nrcs.usda.gov/technical/nri/ceap.

Impacts of Conservation Adoption on Cultivated Acres of Cropland in the Chesapeake Bay Region, 2003-06 to 2011

Key Findings

The voluntary, incentives-based conservation approach continues to be effective. Historic levels of conservation implementation are achieving unprecedented results in the Chesapeake Bay region. Farmers, ranchers, and forestland owners voluntarily install or adopt conservation practices on their lands as part of a conservation plan, in partnership with USDA's Natural Resources Conservation Service (NRCS), soil and water conservation districts, state agencies, and private organizations. These voluntary and collaborative investments help support agricultural producers and rural economies, protect wildlife habitat, and improve water quality in the Chesapeake Bay region.

The first national Conservation Effects Assessment Project (CEAP) farmer surveys documented the conservation and production practices in place from 2003-06 and informed the original Chesapeake Bay region CEAP report, the "Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Chesapeake Bay Region" (USDA NRCS 2011). This report demonstrated that during the time period 2003-06, most cropland acres in the Chesapeake Bay region were treated with structural or residue management conservation practices, or both, with the goal of controlling erosion, reducing nutrient losses, and improving soil and water quality. In order to provide more up-to-date information and assess the benefits of more recent conservation investments in the Chesapeake Bay region, NRCS performed a second CEAP survey in the region during the fall of 2011 and covered the conservation and production practices in use from 2009 to 2011.

This new report, "Impacts of Conservation Adoption on Cultivated Acres of Cropland in the Chesapeake Bay Region, 2003-06 to 2011," using the data collected in 2003-06 and 2011, demonstrates that during the time between the two surveys, agricultural producers have significantly increased their use of an array of conservation measures to improve and protect water and soil quality in the Chesapeake Bay region. These conservation practices are generating substantial natural resource benefits for producers and the communities of the Chesapeake Bay region.

These additional conservation measures have resulted in reductions in rill erosion rates by 57 percent and edge-of-field sediment losses by 62 percent since 2006. In addition, the average annual rate of soil carbon loss was reduced by 50 percent. The 2011 survey results indicate that edge-of-field nitrogen losses in surface runoff were reduced by 38 percent, nitrogen losses in subsurface flows were reduced by 12 percent, and phosphorus losses were reduced by 45 percent compared to 2003-06 loss rates. The edge-of-field conservation achievements on the Chesapeake Bay watershed's cropped acres ultimately helped the Chesapeake Bay itself by reducing the total cumulative instream delivery from all sources (urban, rural, point, and non-point). In fact, achievements in agricultural conservation adopted between 2003-06 and 2011 reduced the cumulative instream loads delivered to the Chesapeake Bay by 8 percent for sediment, 6 percent for nitrogen, and 5 percent for phosphorus. These percentage reductions equate to annual reductions of 15.1 million tons of sediment and 48.6 million pounds and 7.1 million pounds of nitrogen and phosphorous, respectively.

Structural practices, including buffers or terraces, play important controlling and trapping functions in the "Avoid, Control, Trap" (ACT) conservation system approach for reducing losses of sediment and nutrients from cropland acres. Structural practices were in use on 52 percent of cropped acres in 2003-06. By 2011, structural practices were adopted on 66 percent of cropped acres, or a 27 percent increase between the survey periods.

Annual practices such as cover crops and conservation tillage serve all three important avoiding, controlling, and trapping functions in the ACT conservation system approach. Conservation tillage adoption on one or more crops in rotation increased from occurring on 74 percent of cropped acres in 2003-06 to 90 percent of cropped acres in 2011. As for cover crop use, farmers substantially expanded their use of this core ACT practice. In the 2003-06 survey, only 5 percent of cropped acres in the Chesapeake Bay region used cover crops every year and 88 percent of cropped acres were never planted to cover crops; in the 2011 survey, however, the number of cropped acres that farmers planted to cover crops every year more than tripled (to 18 percent of cropped acres) and more than half of all cultivated acres in the region (52 percent) had cover crops applied at least one out of every four years.

Livestock and poultry producers have improved their manure management practices in recent years, leading to manure being spread on more acres in the region in 2011 than it was in 2003-06. The number of acres receiving manure increased almost 30 percent (growing from 37 percent to 48 percent of cropped acres receiving manure between the 2003-06 and 2011 surveys). Likewise, as an indicator of enhanced nutrient management, there was nearly a 147 percent increase in soil testing on manured acres prior to applying more manure (increasing from 15 percent to 37 percent of cropped acres between the surveys). There are also indications of a growing manure market in the region. Manured acres applied with purchased, rather than manure produced-on-farm, nearly quadrupled, increasing from 57,000 acres in 2003-06 to 203,000 acres in 2011.

Progress has been made toward addressing conservation needs, and opportunities exist to increase conservation on cropped acres in the Chesapeake Bay region. The conservation efforts of the region's farmers on their own and with support from local, state, and Federal programs, especially focused programs like the Chesapeake Bay Watershed Initiative (CBWI), have generated significant progress in addressing conservation concerns on cropland acres with a high potential benefit for protecting and improving water quality. Acres with high potential benefits are those that could respond well to additional conservation treatments and have the greatest potential for losses of sediment and nutrients. Conservation measures adopted between 2003-06 and 2011 reduced the number of cropped acres with high potential benefits by 80 percent, dropping from the 2003-06 level of 813,000 acres (19 percent of all cropped acres) to 157,000 acres (4 percent of all cropped acres) in 2011. As of 2011, more than half the acres in the region were classified as having low needs for additional conservation treatment. Compared to 2003-06 conditions, the additional conservation practices in place in 2011 increased the number of acres with low conservation needs by almost 32 percent (or increasing from 41 percent of cropped acres in 2003-06 to 54 percent in 2011).

Although significant gains were made in the controlling and trapping components of the ACT conservation system approach, opportunities remain for progress in avoiding nutrient losses through improved nutrient application management. Specifically, avoidance could be better achieved through better incorporation of the 4Rs (the *right* rate, the *right* timing, the *right* method, and the *right* form) into nutrient management plans. Improvement in 4R implementation would be particularly beneficial on acres on which manure application occurs because manure requires different application strategies than do commercial fertilizers.

Comprehensive conservation planning that incorporates targeting is essential for effectiveness and efficiency. Prioritizing one or more conservation goals, identifying acres with the highest potential for conservation gains per conservation dollar investment, and identifying the appropriate suites of treatments for each acre significantly improves the effectiveness of conservation practice implementation and increases the value of the conservation dollar. Suites of practices that comprehensively address all three components of the ACT strategy are required to adequately address soil erosion, nutrient losses in runoff, *and* nitrogen losses through leaching. This study shows that the increased use of additional conservation practices on acres with high potential benefits significantly reduced losses due to runoff. The increased use of cover crops and winter annuals decreased leaching losses. Additional gains will depend on continued use of current practices and continuing improvement in the application rate, timing, method, *and* form of nutrients.

Executive Summary

Background on This Report

Historic levels of conservation implementation are achieving unprecedented results in the Chesapeake Bay region. Farmers, ranchers, and forestland owners voluntarily install or adopt conservation practices on their lands as part of comprehensive conservation planning, in partnership with USDA's Natural Resources Conservation Service (NRCS), soil and water conservation districts, state agencies, and private organizations. These voluntary and collaborative investments help support agricultural producers and rural economies, protect wildlife habitat, and improve water quality in the Chesapeake Bay region.

The Conservation Effects Assessment Project (CEAP) is a multi-agency USDA effort to quantify the environmental effects of the conservation practices adopted by producers. CEAP cropland reports integrate farmer surveys (conducted by NASS), natural resource information (land use and soils), and modeling to estimate the impact of conservation practices on nutrient and sediment loadings. The lead CEAP partners are USDA's Natural Resources Conservation Service (NRCS) and Agricultural Research Service (ARS) and Texas A&M AgriLife Extension Services.

NRCS released the first Chesapeake Bay region CEAP cropland assessment in March 2011, which relied on data gathered through farmer surveys conducted from 2003 to 2006. The first report demonstrated that conservation practices and systems were delivering benefits for the Bay watershed. The surveys informing for the first CEAP report were conducted too early to capture the growth in use of cover crops in the Bay watershed, and also did not capture the impact of accelerated conservation implementation made possible through the increased funding provided by State and Local partners, and by the Chesapeake Bay Watershed Initiative (CBWI), authorized in the 2008 Farm Bill.

There was considerable interest among Chesapeake Bay stakeholders in updating the 2011 report with new farmer surveys to evaluate the progress made by Bay farmers since 2006. NRCS conducted a new set of farmer surveys in late 2011, and also updated the CEAP models and improved soils and weather data. This is the first time NRCS has updated a CEAP cropland report for a particular region, allowing for comparison in conservation effects between two points in time. The results indicate that conservation planning and practice implementation being adopted by Chesapeake Bay farmers are producing substantial water quality benefits by reducing sediment and nutrient delivery to the Chesapeake Bay. Because NRCS conservation efforts complement those of private landowners, non-governmental organizations, other Federal, State, and local agencies working toward natural resources conservation and reduction of nutrient and sediment losses into the Chesapeake Bay, this report considers impacts of all conservation practices, regardless of NRCS involvement.

Cultivated Cropland Acres in the Chesapeake Bay Region Receiving Conservation Treatment Under USDA Programs. Data are broken out by program or initiative. Totals are not summed by year because the same acreage may be counted under multiple programs or initiatives and acres treated over multiple years were counted in each year of treatment. Treatment costs vary by acre and treatment applied.

Acres Receiving Federal Assistance	2003-06	2007	2008	2009	2010	2011
Chesapeake Bay Watershed Initiative	-	-	-	4,349	89,321	111,350
Conservation Reserve Program	36,337	20,083	11,481	5,939	5,050	4,057
Financial Assistance Programs	131,122	130,504	125,995	133,748	95,486	66,648
Conservation Technical Assistance	250,760	278,538	302,096	294,370	305,454	292,813

This report demonstrates substantial conservation practice adoption and improvement of conservation benefits between the 2003-06 and 2011 sampling periods. However, this report does not capture the full impact of the conservation partnership's focused conservation efforts in the Chesapeake Bay region since 2008, or the full impacts of the 2008 Farm Bill's financial contributions to the region. Since 2011, when the farmer survey informing this report was conducted, various Federal, State, and local agencies and entities in the District of Columbia and the six states in the Chesapeake Bay region have continued to work with farmers to accelerate conservation practice adoption. State and Federal programs have expanded incentives for cover crop adoption, manure incorporation, use of variable rate applications, side-dressing of nutrients, and other production techniques targeted at reducing losses of sediment and nutrients from farm fields. Based on the analyses in this report, we anticipate that the focused funding efforts will continue to accelerate conservation gains in the region.

Overview of Data Collection and Modeling

In March 2011, the NRCS released the "Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Chesapeake Bay Region", the benchmark USDA NRCS CEAP report on the Chesapeake Bay region (USDA NRCS 2011). This report relied on data collected between 2003-06 and provides an historical point of reference by which to measure progress in conservation adoption and conservation practice efficacy in the region. Due to stakeholder interest and an increased focus on farmer conservation adoption since the last survey was completed in 2006, NRCS prioritized a second assessment of the state of conservation practice adoption and achievements on cropped acres in the Chesapeake Bay region. Farmer surveys for this assessment were conducted in the fall of 2011.

The benchmark survey (2003-06), in combination with the resurvey in 2011, enables this report's statistically based identification and quantification of emergent trends in agricultural conservation impacts in the Chesapeake Bay region between 2003-06 and 2011. This is the first CEAP report in which a watershed is revisited for a second round of analyses. This study reports on changes in conservation adoption, estimates the impact of these changes on reduction of both edge-of-field losses and instream sediment and nutrient loads delivered to the Chesapeake Bay, and evaluates the need for additional conservation treatment on cropland in the region. The analyses reflect the environmental impact of management of the region's cropped acres, which makes up 10 percent of the Chesapeake Bay region (4.35 million acres). Changes in and impacts of agricultural conservation practices were isolated from other land use changes and impacts by holding other land uses (hay, pasture, urban point and non-point, forests, etc.) and their management constant at 2003-06 conservation levels for analyses of both the 2003-06 and 2011 data. Therefore, all changes in nutrient and sediment dynamics observed in the simulations comparing the 2003-06 baseline condition with the 2011 conservation condition are solely attributable to changes in agricultural practices. It is not the intent of this report to estimate progress toward the overall regional goals related to conservation practice changes on land uses other than cultivated cropland.

Simulation models were used to estimate the effects of conservation practices. During the interim between the publication of the original report in 2011 and this report, there have been numerous improvements and updates performed on the Agricultural Policy/Environmental eXtender (APEX) and Soil Water Assessment Tool (SWAT) simulation models, improvements in soils input data, increased weather data availability, and refinement of analytical techniques for evaluating the model results. The 2003-06 data was reanalyzed using the same model version and data interpretation used to analyze the 2011 data in order to allow the 2003-06 data to inform a baseline condition by which to assess changes between the two survey periods. The more robust approach used in this analysis produced results that differ from the results reported in the original USDA NRCS CEAP report for the Chesapeake Bay region (USDA NRCS 2011). Therefore, readers of both reports will notice differences in certain results, procedures, and interpretations.

The National Resources Inventory (NRI), a statistical survey of conditions and trends in soil, water, and related resources on U.S. non-Federal land conducted by USDA NRCS, provides the statistical framework for the analyses. The same framework was used for both sets of data collections, although the data collection informing the 2003-06 conservation practice use assessment was part of a national survey and the data collection informing 2011 practice trends was collected in a regional survey. This statistical framework allows for comparison between the original survey and all resurveys, all of which represent the region and are not subject to bias due to land-use conversion at any sample point (i.e., conversion of cropland to urbanland).

Information on farming activities and conservation practices was obtained primarily from a farmer survey designed for CEAP by the USDA National Agricultural Statistics Service (NASS). Additional practice information was obtained from USDA Farm Services

Agency, the USDA NRCS NRI, and USDA NRCS field office records. This assessment is not directly reflective of Federal conservation program benefits, as it includes impacts of the conservation efforts of local, State, and regional governmental agencies and independent organizations, as well as those of individual landowners and farm operators.

Farmer Survey Summary

A 2011 farmer survey obtained information on the extent of conservation practice used in the Chesapeake Bay region for the period 2009 to 2011. The most extensive change observed since the 2003-06 survey was the increased adoption of structural practices, conservation tillage, and cover crops. Nutrient management changes are best characterized as largely being maintained at 2003-06 conservation levels, with progress in some aspects countered by declines in others. While most acres have evidence of some nitrogen or phosphorus management, there is opportunity to enhance existing nutrient management practices on most acres, especially on those receiving manure. Consistent application of the 4Rs (*right* rate, *right* timing, *right* method, and *right* form) of nutrient application management across all crops in a rotation is still a priority need. Skilled management is required to shift conservation planning to match current production goals with soil types and effective nutrient application strategies. Maintaining production goals while adopting new nutrient management strategies increases management complexity and risk to the farmer. The 2003-06 survey data provides the baseline against which conservation gains could be measured; the following is an overview of key trends:

Changes in adoption of conservation tillage, structural practices, residue management, and cover crops on cultivated cropland in the Chesapeake Bay region, 2003-06 to 2011:

- Structural practices for controlling water erosion: *14 percentage point increase*, from 52 to 66 percent of cropped acres;
- Practices designed to trap sediment and nutrients at the edge-of-field: *17 percentage point increase*, from 14 percent to 31 percent of cropped acres;
- Some form of conservation tillage without any conventional tillage: *23 percentage point increase*, from 56 to 79 percent of cropped acres;
- Continuous No-till on all crops in a rotation: *16 percentage point increase*, from 38 to 54 percent of cropped acres; and
- Cover crops use at some point in rotation: *40 percentage point increase*, from 12 to 52 percent of cropped acres.

Changes in nitrogen management, including commercial fertilizer and manure applications on cultivated cropland in the Chesapeake Bay region, 2003-06 to 2011:

- Annual nitrogen application: 10 *percent increase*, from 95.0 to 104.5 pounds per acre per year, including a *9 percent increase* in commercial fertilizer application (6.7 pound per acre per year increase) and a *13 percent increase* in manure nitrogen application (2.8 pound per acre per year increase).

On cropped acres receiving commercial nitrogen and/or manure based nitrogen in 2003-06 and 2011:

- Appropriate nitrogen application **rate** on **all crops** in rotation, including manure applications: *9 percentage point decline*, from 32 to 23 percent of cropped acres; appropriate nitrogen application **timing** on **all crops** in rotation, including manure applications: *14 percentage point decline*, from 50 to 36 percent of cropped acres; and appropriate nitrogen application **method** on **all crops** in rotation, including manure applications: *7 percentage point decline*, from 34 to 27 percent of cropped acres.

- Appropriate nitrogen application **rate** on **none of the crops** in rotation, including manure applications: *7 percentage point decline*, from 13 to 6 percent of cropped acres; appropriate **timing** on **none of the crops** in rotation, including manure applications: *maintained 2003-06 conservation level*, 11 percent of cropped acres for both 2003-06 and 2011; and appropriate nitrogen application **method** on **none of the crops** in rotation, including manure applications: *maintained 2003-06 conservation level*, 21 and 18 percent of cropped acres in 2003-06 and 2011, respectively.

- Appropriate **rate, timing, *and* method** of nitrogen application, including manure applications:
  - on **some, but not all crops** in rotation: *6 percentage point increase*, from 87 to 93 percent of cropped acres;
  - on **all crops** in the rotation: *6 percentage point decline*, from 13 to 7 percent of cropped acres.

Changes in phosphorus management, including commercial fertilizer and manure applications on cultivated cropland in the Chesapeake Bay region, 2003-06 to 2011:

- Annual phosphorus application: *6 percent increase*, from 23.8 to 25.2 pounds per acre per year, including a *5 percent increase* in commercial fertilizer application (1.0 pound per acre per year increase) and an *11 percent increase* in manure nitrogen application (0.4 pound per acre per year increase).

On cropped acres receiving commercial phosphorus and or manure based nitrogen between 2003-06 and 2011:

- Appropriate phosphorus application **rate** on **all crops** in rotation, including manure applications: *maintained 2003-06 conservation level*, 54 and 57 percent of cropped acres in 2003-06 and 2011, respectively; appropriate phosphorus application **timing** on **all crops** in rotation, including manure applications: *11 percentage point decline,* from 53 to 42 percent of cropped acres; and appropriate phosphorus application **method** on **all crops** in rotation, including manure applications: *maintained 2003-06 conservation level*, 42 and 37 percent of cropped acres in 2003-06 and 2011, respectively;

- Appropriate phosphorus application **timing** on **none of the crops** in rotation, including manure applications: *6 percentage point increase,* from 13 to 19 percent of cropped acres; appropriate phosphorus application **method** on **none of the crops** in rotation, including manure applications: *maintained 2003-06 conservation level,* 30 and 32 percent of cropped acres in 2003-06 and 2011, respectively; and

- Appropriate **rate, timing, *and* method** of phosphorus application, including manure applications:
  - on ***some, but not all*** crops in rotation: *maintained 2003-06 conservation levels*, 78 and 79 percent of cropped acres in 2003-06 and 2011, respectively; and
  - on ***all*** applications in the crop rotation: *maintained 2003-06 conservation levels,* 22 and 21 percent of cropped acres in 2003-06 and 2011, respectively.

Changes in manure management (with or without supplemental commercial nutrient inputs) on cultivated cropland in the Chesapeake Bay region, 2003-06 and 2011:

- Manure application rate: *25 percent increase*, from 12.6 to 16.8 tons per acre per year;
- Manure application at some point in the crop rotation: *10 percentage point increase*, from 38 to 48 percent of cropped acres;
- Manured acres applied with off-farm-sourced manure: *17 percentage point increase*, from 17 to 34 percent of manured cropped acres;
- Manured acres applied with purchased manure: *6 percentage point increase*, from 4 to 10 percent of manured cropped acres; and
- Management of manure as a nitrogen source on manured acres:
  - Appropriate application **rates** for **all crops** in rotation: *8 percentage point decline*, from 17 to 9 percent of manured cropped acres; appropriate application **timing** for **all crops** in rotation: *6 percentage point decline*, from 18 to 12 percent of manured cropped acres; and appropriate application **method** on **all crops**: *6 percentage point decline*, from 22 to 16 percent of manured cropped acres;
  - Appropriate application **rates** for **none of the crops** in rotation: *15 percentage point decline*, from 24 to 9 percent of manured cropped acres; appropriate application **timing** for **none of the crops** in rotation*: 6 percentage point decline*, from 16 to 10 percent of manured cropped acres; and appropriate application **method** for **none of the crops** in rotation: *maintained 2003-06 conservation levels*, 16 and 17 percent of manured cropped acres in 2003-06 and 2011, respectively;
- Management of manure as a phosphorus source on manured acres:
  - Appropriate application **timing** for **none of the crops** in rotation: *12 percentage point increase,* from 16 to 28 percent of manured cropped acres; appropriate application **method** for **none of the crops** in rotation: *14 percentage point increase,* from 30 and 44 percent of manured cropped acres; and
  - Appropriate application **timing** for **all crops** in rotation: *maintained 2003-06 conservation level*, 16 and 13 percent of manured cropped acres in 2003-06 and 2011, respectively; appropriate application **method** on **all crops** in rotation: *7 percentage point decline*, from 28 to 21 percent of manured cropped acres.

Conservation Accomplishments

Compared to edge-of-field conservation accomplishments in the 2003-06 baseline condition, model scenarios suggest that practices adopted in the 2011 conservation condition have further reduced agricultural impacts in the Chesapeake Bay region. Specifically, compared to the 2003-06 baseline condition, the 2011 conservation condition has reduced:

- sediment loss from fields: *63 percent reduction*, from 5.1 to 1.9 tons per acre per year;
- acres with sheet and rill erosion greater than soil loss tolerance (T): *17 percentage point reduction*, from 28 to 11 percent of acres;
- nitrogen loss with surface runoff, including nitrogen attached to sediment and nitrogen in solution: *38 percent reduction*, from 15.7 to 9.7 pounds per acre per year;
- nitrogen loss in subsurface flows by leaching: *12 percent reduction*, from 25.9 to 22.9 pounds per acre per year;
- total phosphorus loss from fields: *44 percent reduction*, from 3.4 to 1.9 pounds per acre per year;
- acres losing soil organic carbon: *20 percentage point reduction*, from 66 to 46 percent of cropped acres; and
- soil carbon loss from fields: *50 percent reduction*, from 189 to 95 pounds per acre per year.

The comprehensive Avoid, Control, Trap (ACT) conservation system approach requires that all three aspects of the system be accommodated with appropriate and complementary conservation practice adoption. Nutrient applications and tillage management are necessary for crop production and even when appropriately applied will have losses of sediment and nutrients. Therefore losses that cannot be avoided with these management approaches should be controlled within the field with practices such as terraces, grassed waterways, or contouring. Some practices may serve the ACT strategy in multiple ways. For example, conservation tillage can both serve to avoid losses and control losses. Practices designed to trap sediment and nutrients at the edge-of-field (e.g., filter strips and buffers) are necessary for a complete approach to reducing the impacts of cultivated cropland on water quality. In the Chesapeake Bay region, achievements in nutrient management have largely come from the control and trap components of the ACT system. Future conservation practice success requires a renewed emphasis on the avoidance aspect of the system. Specifically, significant improvements can be realized with more focus on implementing the 4Rs of nutrient application. Key among these is timing, with a need to shift more nutrient applications to the time after crop has been planted, which matches nutrient application and availability temporally with nutrient demand.

The simulated change in nitrogen dynamics between the 2003-06 baseline condition and the 2011 conservation condition demonstrate the potential pitfalls of focusing on only one or two parts of the ACT strategy. Water erosion control practices were very effective at controlling and trapping sediment and nutrients on farm fields. The widespread adoption of structural erosion control practices, residue management practices, and reduced tillage slowed the flow of surface water runoff, allowing more sediment and nutrients to remain into the field, as well as allowing more water to infiltrate into the soil. This re-routing of surface water to subsurface flows redirects the soluble nitrogen into subsurface flows and may potentially extract additional nitrogen from the soil as the water filters through the soil profile. Although the 2011 conservation condition reduced nitrogen losses via subsurface flow by 12 percent on cropped acres as compared to the 2003-06 baseline condition, high losses of nitrogen in subsurface flows remain a challenge in the region.

Gains Related to Cover Crop and Winter Cover Use

In the context of this report, cover crops are considered a unique subset of winter cover. Cover crops are planted for agroecological purposes, including soil and nutrient conservation and soil health benefits. Cover crops are grown when principal crops are not growing (this typically includes, but is not limited to, winter months). Cover crops are not planted with the intent to harvest and are generally terminated by tillage or herbicide application prior to maturity. Winter cover includes crops (mostly small grains planted for spring harvest) that may be grazed and or harvested for grain, hay, or both.

In 2003-06, only 5 percent of cropped acres in the Chesapeake Bay region had cover crops planted every year and 88 percent of acres never had any cover crops planted. In 2011, 52 percent of acres had cover crops planted at least once every 4 years and 18 percent of acres had cover crops planted every year. It was estimated that relative to the 2003-06 baseline condition, the increased annual use of cover crops in the 2011 conservation condition enhanced reduction in sediment loss by an average of 78 percent, surface loss of nitrogen by 35 percent, subsurface nitrogen loss by 40 percent, and total phosphorus loss by 30 percent. In the 2011 conservation condition, the average annual rate of carbon change due to annual application of cover crops improved by an average 148 percent as compared to carbon dynamics in the 2003-06 baseline condition. State incentive programs have been pivotal in the continued increases in cover crop adoption. For example, in 2011 Maryland farmers, supported through the state's Cover Crop Program, voluntarily planted nearly 430,000 acres to cover crops.

Winter cover adoption, other than cover crops, increased as well. In 2003-06 only 3 percent of cropped acres in the region were planted with winter cover annually, but by 2011 annual winter cover was grown on 17 percent of cropped acres. In 2003-06 winter cover was a part of crop rotations at least 1 out of every 4 years on only 47 percent of acres and by 2011, 65 percent of cropped acres in the region had the soil covered during at least one winter in a 4-year crop rotation. The increased use of winter annuals in the crop rotation may be attributed to market forces and the flexibility in cover crop programs, such as those which allow farmers to opt to manage their intended cover crop for grain harvest in return for a reduced or no cost share on the cover crop.

For 2011, a comparison between acres with no winter cover and those adopting some form of cover during the winter months for at least part of the crop rotation, show that winter cover adoption, solely or along with other conservation activities (table 2.4):

- reduced sediment losses by 37 percent;
- reduced surface losses of nitrogen by 28 percent;
- reduced subsurface losses of nitrogen by 18 percent;
- reduced total phosphorus losses by 29 percent; and
- reduced carbon losses by 46 percent.

Reductions in Conservation Treatment Needs

The conservation practices reported in the 2011 survey of the Chesapeake Bay region were compared to the conservation practice conditions reported in the 2003-06 survey to evaluate remaining conservation treatment needs. ***Acres with high potential benefits to water quality*** ("high conservation needs acres") are the most vulnerable of the acres, have the least conservation treatment, and have the highest losses of sediment and/or nutrients. ***Acres with moderate potential benefits to water quality*** ("moderate conservation needs acres") generally have lower levels of inherent vulnerability or have more existing conservation practices in use than do high conservation needs acres. For the purposes of this report, acres with ***currently low potential benefits to water quality*** ("low conservation needs acres") are considered to be sufficiently treated; combinations of conservation practices on these acres address all the inherent vulnerability factors that determine the potential for sediment and nutrient losses.

Simulations and analyses show conservation treatment needs for the Chesapeake Bay region were reduced between the 2003-06 baseline condition and the 2011 conservation condition, but opportunities for improvement remain on nearly half of the acres in the region:

- Cropped acres with ***high*** needs for additional conservation treatment for one or more resource concern: *15 percentage point decline*, from 19 to 4 percent of cropped acres;
- Cropped acres with ***moderate*** needs for additional conservation treatment for one or more resource concern: *maintained 2003-06 conservation levels*, at 40 and 42 percent of cropped acres in 2003-06 and 2011, respectively; and
- Cropped acres with adequate conservation treatment, or ***low*** needs for additional conservation treatment for one or more resources concern: *13 percentage point increase,* from 41 to 54 percent of acres.[1]

Significant progress was made on adoption of complementary structural and vegetative practices, such as cover crops, edge-of-field filters, and buffers, all of which reduce sediment and nutrient losses associated with runoff. Under the 2011 conservation condition, only 15 percent of cropped acres were in need of additional treatments to prevent sediment loss and only 11 percent of acres required treatment for sheet and rill erosion to prevent exceedance of the soil loss tolerance (T). In the 2003-06 baseline condition, 42 percent of acres had additional need for erosion control treatment and 28 percent were in need of further treatment to prevent exceedance of T. In the 2011 conservation condition, only 3 percent of cropped acres had a high need for additional soil erosion control and 12 percent had a moderate need. Adoption of the complementary structural and vegetation practices also contributed to a shift in carbon trends on cropped acres in the Chesapeake Bay region, which were, on average, losing carbon in the 2003-06 baseline condition, but were, on average, maintaining carbon in the 2011 conservation condition. Conservation gains made largely via adoption of practices such as cover crops, conservation tillage, and high residue crop rotations require careful planning and persistence in order to maintain the levels of erosion reduction, sediment loss reduction, and carbon gain realized in 2011 conservation condition.

The greatest conservation need in the region in 2003-06 remained the greatest opportunity for increased conservation gains in 2011: adoption of consistent nutrient application management adhering to the 4R's: right rate, timing, method, *and* form of application. In some cases, only minor adjustments to an existing nutrient management plan are needed to bring the management up to current standards (590 practice code for Nutrient Management), while other acres require more extensive adjustments.

As of 2011, most cropped acres had some nutrient application management practices in use, but 46 percent of cropped acres in the region would benefit from additional treatment to better prevent sediment, nitrogen, or phosphorus loss from fields. Although all acres with high needs for subsurface flow losses were treated in the 2011 conservation condition, 36 percent of cropped acres still needed conservation treatments to address nitrogen loss in subsurface flow pathways, most of which returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow. Adoption of erosion control prevention practices reduced acreage needing treatment for surface nitrogen losses from 35 to 14 percent of cropped acres between the 2003-06 baseline condition and 2011 conservation condition, respectively.

Effects of Conservation Treatment on Water Quality in the Chesapeake Bay

Reductions in edge-of-field losses translate into potential improvements in water quality in streams and rivers in the region. Transport of sediment and nutrients from farm fields to streams and rivers and ultimately into the Bay involves a variety of processes and time-lags. Nutrient and sediment dynamics at the edge-of-field do not directly or immediately relate to instream loads measured in rivers, streams, and the Bay, all of which may be impacted by storm events, tidal surges, and the legacy of past land use and management.

2011 Agricultural Achievements in Conservation

Relative to conditions simulated in the "no practice scenario", in which no conservation practices were applied to cultivated cropland, the 2011 conservation condition reduced total loads ***delivered from the edge-of-field to rivers and streams*** by:

- 82 percent for sediment;
- 44 percent for nitrogen; and
- 75 percent for phosphorus.

As compared to the 2003-06 baseline condition, the 2011 conservation condition reduced delivery by:

- 60 percent for sediment;
- 20 percent for nitrogen; and
- 41 percent for phosphorus.

Sediment and nutrients being delivered to the Chesapeake Bay come from a variety of sources, including cultivated cropland, hayland, forestland, and urbanlands. This is not an assessment of overall progress in conservation on all acreage in the Chesapeake Bay. Rather, this report holds the sediment and nutrient contributions of all other land uses at their 2003-06 levels for all analyses, enabling an unencumbered comparison of gains made due to changes on cultivated cropland between the 2003-06 and 2011 surveys. Relative to the no practice scenario, the 2011 conservation condition reduced total loads ***delivered to the Bay*** (all sources – instream loads) by:

[1] Rounding causes apparent mathematical discrepancies.

- 22 percent for sediment;
- 17 percent for nitrogen; and
- 21 percent for phosphorus.

As compared to the 2003-06 baseline condition, the 2011 conservation condition reduced delivery by:

- 8 percent for sediment;
- 6 percent for nitrogen; and
- 5 percent for phosphorus.

Targeting. Not all acres suffer the same losses and not all acres provide the same benefit from conservation treatment. Some acres are inherently more vulnerable, such as those that are highly erodible or have leaching-prone soils. These more vulnerable acres tend to lose more sediment and/or nutrients than do less vulnerable acres. Therefore greater per-acre benefits can be attained with focused comprehensive conservation treatment on these most vulnerable acres. One strategy of conservation treatment is to target the soils with the highest inherent erosion and leaching risks for enhanced treatment with a comprehensive conservation treatment plan. In the case of the Chesapeake Bay, the region as a whole has been targeted with an intensification of conservation practices and conservation programming, including the Chesapeake Bay Watershed Initiative. Analyses included in this report demonstrate that this regional targeting approach is working. However, while substantial progress has been achieved, there are still undertreated acres on which improved conservation practice adoption could make significant impacts on sediment and nutrient losses.

Chapter 1
Sampling and Modeling Approach

Scope of Study

This study was designed to provide a regional-scale evaluation of the trends in and effects of conservation practice adoption in the Chesapeake Bay region in 2003-06 as compared to 2011. This report considers conservation practice impacts at two scales: at the edge-of-field and on instream water quality. Simulated sediment, soil carbon, nitrogen, and phosphorus dynamics related to reported changes in conservation practice adoption are analyzed. This report:

- Evaluates the extent of conservation practice adoption in the region as of 2011, with specific comparison to the benchmark condition observed in 2003-06 and a hypothetical "no practice" condition in which no conservation practices are applied;
- Estimates the anticipated long-term environmental benefits and effects of conservation practices in use in 2011, with specific comparison to anticipated long-term effects of practices in place in 2003-06 and a hypothetical "no practice" condition in which no conservation practices are applied, and;
- Estimates conservation treatment needs on cropped acres in the region as of 2011, with specific comparison to conservation treatment needs on cropped acres identified during the benchmark period of 2003-06.

This study quantifies and compares the anticipated long-term impacts of conservation practices in place in 2003-06 and 2011, regardless of how, when, or why the practices came to be in use. It includes practices adopted by farmers on their own, as well as practices that are the result of state or local programs. Because it is not restricted to practices associated with Federal conservation programs, this report should not be considered an evaluation of Federal conservation programs. The model results provide estimates of average benefits achievable through long-term adoption of the conservation practices surveyed to be on the ground in 2003-06 or 2011. These long-term estimates are based on the assumption that weather patterns observed over the last half century continue into the future. The long-term nature of the simulations also produces results that may be expected once conservation practices on the ground in 2003-06 and 2011 actually take effect. This report was designed to provide a long-term view of conservation practice impacts, rather than to simulate water, sediment, and nutrient dynamics actually observed in the years 2003-06 and 2011. Due to the impacts of legacy sediments and legacy nutrients, the benefits of conservation practices are often not measureable for a number of years post-installation. To put this another way, the instream measurements taken in 2003-06 and 2011 reflect the legacy of prior management rather than the benefits of conservation practices on the ground during the two survey periods. Legacy impacts and associated time-lags are further addressed in Chapter 5, which also addresses benefits of agricultural conservation practices on sediment and nutrient loads delivered to the Chesapeake Bay.

It is beyond the scope of this report to estimate gains that could be attained with adoption of additional conservation treatments beyond those in use in 2011. A subsequent publication will explore the potential impacts of enhanced conservation practice adoption and targeting of specific acreage for various natural resource goals. The subsequent publication will also consider more specific economic aspects of natural resource management in the Chesapeake Bay region, including estimation of benefits associated with various investment strategies and increments of investment in conservation on cropped acres in the region.

National Resources Inventory (NRI) data were updated between the two survey periods, enabling the update of cropped acres for the 2011 period. The 2003-06 cropped acre estimates are based on acreage weights derived from the 2003 NRI, while the estimates for cropped acres in 2011 are based on acreage weights from the 2007 NRI. Cropped acreage amounts, management of cropped acres, and conservation treatments applied to the cropped acres were the only changes simulated between the two survey periods. Impacts of all other land uses were held constant across all analyses. Therefore, this report provides a focused analysis on conservation gains due to changes in conservation practices on cropped acres at both the edge-of-field and instream scales.

The 2007 NRI indicates the Chesapeake Bay region has about 4.4 million acres of cultivated cropland. The estimated cropped acreage was 4.28 million acres for the 2003-06 period and 4.35 million acres for the 2011 survey, a difference of less than 2 percent, and within the margins of error for both surveys.

For purposes of this report, cropped acres include land in row crops or close-grown crops, and hay and pasture in rotation with row crops and close-grown crops. Cultivated cropland does not include land that has been in hay, pasture, or horticulture for 4 or more consecutive years. This report does not consider conservation gains made between 2003-06 and 2011 on any other land use other than cultivated cropland.

The timing of this report is not coincident with a release of information on land use by the USGS National Land Cover Dataset (NLCD). Therefore, acreage estimates in this report derived from both the National Census of Agriculture and NLCD are identical to data applied in the original USDA NRCS CEAP report for the Chesapeake Bay region (USDA NRCS 2011; Appendix A).

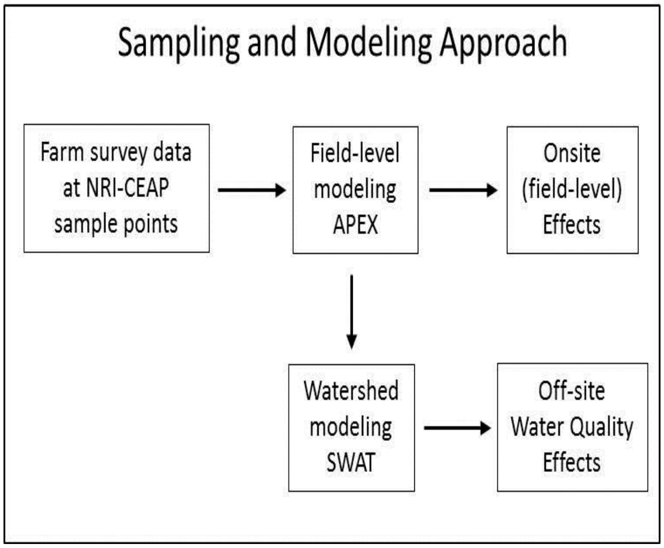
Sampling and Modeling Approach

The assessment uses a statistical sampling and modeling approach to estimate the environmental effects and benefits of conservation practices (fig. 1.1). The following methods were used:

- The 771 points sampled for the 2003-06 baseline are a subset of sample points from the 2003 NRI.[1] The 904

[1] Information about the CEAP sample design is in "NRI-CEAP Cropland Survey Design and Statistical Documentation," available at http://www.nrcs.usda.gov/technical/nri/ceap.

Figure 1.1. Flow diagram of statistical sampling and modeling approach used to simulate the effects of conservation practices.



points sampled for the 2011 dataset are a subset drawn from the 2007 NRI. These collections provide two statistical samples selected from the same population of points representing the diversity of soils and other conditions for cropped acres in the Chesapeake Bay region. All NRI sample points are linked to NRCS Soil Survey databases and are linked spatially to climate databases for these analyses;

- During both sampling periods, a farmer survey—the NRI-CEAP Cropland Survey—was conducted at the NRI sample points to determine what conservation practices were in use and to collect detailed information on farming practices;
- The field-level effects of the crop management and conservation practices were estimated with a field-scale physical process model—the Agricultural Policy/Environmental eXtender (APEX)—which simulates day-to-day farming activities, wind and water erosion, loss or gain of soil organic carbon, and edge-of-field losses of water, soil, and nutrients; and
- The SWAT model (Soil and Water Assessment Tool) was used to simulate non-point source loadings from land uses other than cropland and to route instream loads from one watershed to another.

The modeling strategy for estimating the long-term effects of conservation practices in place during the benchmark survey of 2003-06 as compared to long-term effects of conservation practices in place in 2011 consists of three model scenarios produced for each sample point:

1. The "2011 current conservation condition" scenario provides model simulations that account for cropping patterns, farming activities, and conservation practices as reported in the 2011 NRI-CEAP Cropland Survey and other sources;
2. The "2003-06 baseline conservation condition" scenario provides model simulations that account for cropping patterns, farming activities, and conservation practices as reported in the 2003-06 NRI-CEAP Cropland Survey and other sources; and
3. A "no-practice" scenario simulates the impact of not adopting any conservation practices on croplands, but holds all other model inputs and parameters the same as in the 2003-06 baseline conservation condition scenario. This scenario provides perspective on the benefits of all conservation practices on cultivated cropland and the loads that would impact the Chesapeake Bay if no conservation practices were adopted on cultivated cropland in the watershed (Appendix B).

The approach captures the diversity of land use, soils, climate, and topography from the two NRI sampling periods; accounts for site-specific farming activities; estimates the loss of materials at the field scale where the science is most developed; and provides a statistical basis for aggregating results to the regional and national levels. Both 2003-06 and 2011 scenarios relied heavily on four sources of conservation practice information:

1. NASS CEAP Farmer Surveys;
2. National Resources Inventory (NRI);
3. Conservation Plans on file at NRCS district field offices; and
4. Reports on Conservation Reserve Enhancement Program (CREP) and Continuous Conservation Reserve Program (CCRP) practices from USDA FSA offices.

The CEAP sample was designed to enable reporting of results for the four subregions (4-digit HUCs) within the Chesapeake Bay region. The acreage weights were derived to approximate total cropped acres by 4-digit HUC, as estimated by the full 2003 and 2007 NRI. The sample size restricts reliable and defensible reporting of results to the subregion level. Acres reported using the CEAP sample are estimated acres. Margins of error for estimated acres used in this report are provided in Appendix C.

Sampling: the NRI-CEAP Cropland Survey

Analyses for cropped acres in this report, with the exception of Table AA1.1 and Chapter 5, are based on an NRI-CEAP Cropland Survey administered by the USDA National Agricultural Statistics Service (NASS). Farmer participation was voluntary, and the information gathered is confidential. The survey content was specifically designed to provide information on farming activities for use with a physical process model to estimate field-level effects of conservation practices.

Data from the original 771 sample points collected in 2003-06 provide a 2003-06 baseline condition against which to compare the 2011 conservation condition, which was based on analyses of 904 sample points collected in 2011.[2] Of the 904

[2] The surveys, the enumerator instructions, and other documentation can be found at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?cid=nrcs143_014163

sample points visited in 2011, 364 had been sampled in the 2003-06 survey. The selection of these 364 points was purely coincident in the random sample draw. These re-sampled points were not preferentially selected, as that would violate the principles of the statistical framework designed to represent the Chesapeake Bay region. Selecting specific points for resampling would not only violate the rigorous statistical approach derived for NRI sampling, but would also shift the focus of the report away from a regional analysis to consideration of changes at those specific points. Intentional point resampling might also lead to bias due to changing land use, ownership, or tenure, and landowner/operator refusal to participate in future surveys.

Relevant to this report, the survey obtained information on:

- crops grown in the survey year and the 2 previous years, including double crops and cover crops;
- field characteristics, such as proximity to a water body or wetland and presence of tile or surface drainage systems;
- conservation practices associated with the field;
- crop rotation plan;
- application of commercial fertilizers (rate, timing, method, and form) for crops grown in the survey year and the 2 previous years;
- application of manure (source and type, nutrient content, consistency, application rate, method, and timing) on the field in the survey year and the 2 previous years;
- irrigation practices (system type, amount, and frequency);
- timing and equipment used for all field operations (tillage, planting, cultivation, and harvesting) in the survey year and the 2 previous years; and
- general characteristics of the operator and the operation.

In a separate survey, NRCS field offices provided information on the practices specified in conservation plans for the selected points in the region.

The 771 sample points from 2003-06 were a subset of a national survey; data collection was necessarily a multi-year effort due to the large number of sample points surveyed nationally. In the fall of 2011 the Chesapeake Bay region was the only area of the country where points were resampled, enabling all points to be sampled in a single year. In each sampling period, surveys were obtained for a statistically appropriate, representative set of sample points. The final CEAP sample was constructed by pooling the set of usable, completed surveys from each survey period.

Modeling Changes, Issues, and Assumptions

APEX Model Version Changes

In this report, the 2003-06 and 2011 datasets were each analyzed with the newest version of the APEX model, APEXv1307. The APEX model is dynamic and APEX developers continuously upgrade, amend, or add to its modeling routines as new technologies emerge, as the science of modeling natural processes improves, and as the needs of new users introduce the model to new applications. The APEX simulation results reported in the original USDA NRCS CEAP report for the Chesapeake Bay region were analyzed with an older version of APEX, APEXv2110 (USDA NRCS 2011). Changes in the model versions contribute to the differences between simulated results reported here for 2003-06 and those reported in the original report for the same survey period (USDA NRCS 2011).

The APEX model version 1307 used in this report incorporates significant improvements in the routing of surface and subsurface losses of nutrients and sediments from one subarea to the next. The upgrades also enable APEXv1307 to more accurately simulate the mitigating effects of buffers, filters, and drainage water management on edge-of-field losses. The new model version also better addresses changing conservation practice needs and impacts due to climate change predictions.

Erosion Equation Changes

The APEX component for water-induced erosion simulates erosion caused by rainfall, runoff, and irrigation. APEX contains eight equations capable of simulating rainfall and runoff erosion: the Universal Soil Loss Equation (USLE); Onstad-Foster modification of the USLE; the Revised Universal Soil Loss Equation (RUSLE); RUSLE2; the Modified Universal Soil Loss Equation (MUSLE); two variations of MUSLE; and a MUSLE structure that accepts input coefficients. In any given simulation, the model user specifies only one of the equations to interact with other APEX components.

This report uses the soil loss equation MUSLE, rather than MUST (modified universal soil loss equation-theoretical), which was used in the original Chesapeake Bay region CEAP report (USDA NRCS 2011). This change contributes to differences in model outputs used for analyses in each of the two reports. This improvement is one reason that the simulation results reported here for 2003-06 data differ from those in the original report (USDA NRCS 2011).

In the original report, MUST, a theoretical version of the modified universal soil loss equation (MUSLE), was the erosion driver in APEX (USDA NRCS 2011). Compared to MUSLE, the MUST equation tends to be more sensitive to lower, less intense rainfall and runoff events, and generates higher sediment yields for these events. MUST also tends to deliver slightly more sediment for areas smaller than 40 acres.

This report, and future CEAP modeling efforts, will use the MUSLE equation as the specified driver in APEX. MUSLE enables better simulation of variable field dimensions and sizes and provides better sediment yield estimates for more significant events. MUSLE sensitivity also facilitates a better determination of conservation treatment needs in relation to the potential for increasing frequency and intensity of storm events associated with climate change. However, the adoption of MUSLE over MUST will tend to increase model estimates of nutrient loss via surface runoff pathways and decrease estimates of nutrients lost by subsurface pathways for all climate scenarios.

Soil Data Changes

Each NRI CEAP point is linked to a soil map unit and the interpretive soils information contained in the National Soil Information System (NASIS). This database was designed to support NRCS conservation planning needs and provide inputs for the agency's empirical erosion and engineering models. NASIS data was not designed to meet the needs of many of the process-based equations in the APEX model. The NASIS data for soil properties is organized in layers which may be composed of one or more soil horizons. The surface layers have the properties of the first horizon throughout the layer. Subsequent layers usually have the properties associated with the most limiting horizon within the layer. Although useful in empirical models, this approach creates unnatural boundaries between soil layers, which, when input into process-based models, unrealistically impact water flow, root growth, soil organic carbon, pH, and bulk density. NASIS also tends to overestimate soil carbon stores since the surface carbon content is assumed to extend throughout the entire first soil layer. Further, construction of the NASIS database is land-use independent; therefore, some map unit values may not be reflective of the land uses being modeled.

In the modeling process used in the original Chesapeake Bay region CEAP report (USDA NRCS 2011), NASIS challenges were addressed by adjusting the affected model parameters and/or soil data inputs. The adjustments for the soil layer data were obtained from the national soil characterization database, which is derived from point data and organized by horizons. It is the core data upon which the interpretive data in NASIS is based. Adjustments applied to overcome the idiosyncrasies of the NASIS data, such as the aforementioned issue with artificial boundaries between soil layers, often disallowed appropriate simulation of the effects of a limiting horizon within a layer. To eliminate this problem, this and future CEAP reports will use horizon-based data from the soil characterization database or a close taxonomic representative for each map unit. This improvement is one reason that the simulation results in this report are slightly different for 2003-06 data than they were in the original report (USDA NRCS 2011).

All other interpretive data elements from NASIS for key model inputs were used without modification. These properties are for interpretations such as water table depth, flood frequency, ponding, soil albedo, and other properties used by some of the more empirical model relationships and equations. These properties are also used for categorization and data analysis.

Simulating the Effects of Weather

Weather is the predominant factor determining the loss of soil and nutrients from farm fields; weather also plays a large role in determining the effects of conservation practices. To capture the effects of weather, each scenario was simulated using 52 years of actual daily weather data. Thus, in this report, the weather period provides data on 5 more years of weather than were available during the analyses conducted for the original Chesapeake Bay region CEAP report (USDA NRCS 2011). This improvement in weather input data contributes to slight differences in model outputs used for analyses in each of the two reports.

The 52-year serially complete daily weather dataset for the Chesapeake Bay region used in this report is the extent of the data available from the National Climatic Data Center (NCDC). Weather was recorded for the period 1960 to 2011, including precipitation, temperature maximum, and temperature minimum (Eischeid et al. 2000). These weather station data were combined with the respective PRISM (Parameter–Elevation Regressions on Independent Slopes Model) (Daly et al. 1994) monthly map estimates to construct daily estimates of precipitation and temperature (Di Luzio et al. 2008). The same 52 years of weather data were applied to both the 2003-06 and the 2011 datasets used in the APEX and SWAT model simulations.

Annual precipitation over the 52 years ranged from 31 to 59 inches, and averaged about 42 inches for cropped acres in this region. Annual precipitation varied spatially within the region and between years. Reported estimates of the average effects of conservation practices include consideration of effectiveness in extreme weather years, such as during floods and prolonged droughts, as captured in the natural variability inherent in the 52-year weather record.

Throughout most of this report, model results are presented in terms of the 52-year model runs, where weather is the only input variable that changes from year to year. We did not simulate *actual* losses expected to be observed during 2003-06 and 2011. Rather, model outputs predict *average* long-term impacts of cropping patterns and conservation practices reported to be in use during 2003-06 or 2011, assuming weather patterns observed from 1960 to 2011 continue.

Watersheds

According to the U.S. Geological Survey's hydrologic accounting system, the Chesapeake Bay region includes four subregions within the Mid-Atlantic Water Resource Region. Each water resource region is designated with a 2-digit code, and may be divided into 4-digit subregions, which may be further subdivided into 8-digit watersheds, or Hydrologic Unit Codes (HUCs) (USGS 1980).

Agricultural land use within each of the four subregions in the Chesapeake Bay region is summarized in Table 1.1. The Upper Chesapeake Bay subregion is the smallest subregion and has the highest concentration of cropped acres (18 percent). About 11 percent of the largest subregion, the Susquehanna River subregion, is maintained in cropped acres. About three-fourths of the cropped acres in the region are in the Susquehanna River and Upper Chesapeake Bay subregions. The remaining two subregions, the Potomac River Basin and the Lower Chesapeake Bay, have 8 and 5 percent of their land base in cropped acres, respectively.

Estimates presented in this report for field-level effects of conservation practices (chapters 2-4) are for the Chesapeake Bay region, whereas estimates of instream water quality effects (Chapter 5) are for the Chesapeake Bay watershed. The Chesapeake Bay watershed *excludes* two 8-digit watersheds in the Upper Chesapeake Bay subregion that drain to the Atlantic Ocean (8-digit HUCs 02060010 and 02080110). The area that *includes* these two watersheds is referred to as the Chesapeake Bay region.

Table 1.1. Agricultural land use in the four subregions of the Chesapeake Bay region, 2011.

Subregion code	Subregion name	Total Acres (thousands)*	Cropped acres (thousands)**	Percent of subregion in cropped acres	Percent of cropped acres in Chesapeake Bay region
0205	Susquehanna River	17,596	1,996	11	46
0206	Upper Chesapeake Bay	5,773	1,021	18	23
0207	Potomac River Basin	9,404	733	8	17
0208	Lower Chesapeake Bay	11,080	603	5	14
	Total	**43,853**	**4,353**	**10**	**100**

* Source: 2001 National Land Cover Database for the Conterminous United States (Homer et al. 2007)

** Source: 2007 National Resources Inventory (USDA NRCS 2007). Does not include acres in long-term conserving cover (i.e., CRP general signups).

Chapter 2
Evaluation of Changes in Conservation Practice Use—2003-06 to 2011

This study assesses the long-term effects of conservation practices in use in the Chesapeake Bay region in 2011. It further provides a 2011 conservation condition for the region, against which changes in conservation gains and needs since the 2003-06 benchmark survey may be gauged.

The original Chesapeake Bay region CEAP report applied APEX to 2003-06 survey data to construct a baseline conservation condition (USDA NRCS 2011). However, model improvements and changes in soils and weather data made it imperative that the 2003-06 data be reanalyzed for this report. The 2003-06 and 2011 data have both been analyzed with the most current version of the APEX model in order to provide a revised baseline and to enable comparisons between the two survey periods. Conservation practices evaluated include structural, vegetative, and annual practices. Methods for counting practices and thresholds were revised and improved during the time between the two reports, which also contributes to slightly different classifications between the two reports.

The USDA NRCS promotes a comprehensive conservation plan to address all resource concerns, recognizing there are no single practice solutions to address all resource concerns and that some positive actions for one resource concern may require additional efforts to offset any negative impacts on another resource. It is not the intent of this report to parse or isolate the individual effects of each conservation practice adopted. This report was designed to assess the impacts of the conservation systems in place at the time of the two surveys. Simulation modeling was applied to predict the anticipated long term impacts of these practices if they are maintained into the future.

Historical Context for Conservation Practice Use

Conservation practices have long been used in the Chesapeake Bay region. The first numeric goals for nutrient pollution reduction were set in the 1987 Chesapeake Bay Agreement. In the early 1990s the Chesapeake Bay region states prioritized addressing the issue of nutrient management. Similarly, during the 1990s, NRCS conservation efforts began to broaden from prevention of soil erosion and enhancement of production sustainability to encompass goals of reducing other environmental impacts associated with agricultural production, including reducing nutrient export from farm fields. Although traditional conservation practices used to control surface water runoff and erosion mitigate a significant portion of potential nutrient losses, additional gains can be achieved with adoption of appropriate practices designed for nutrient management. For example, management strategies that adopt the 4R's (right rate, right timing, right method, and right form of nutrient application) help achieve the avoidance component of an Avoid, Control, Trap (ACT) conservation system approach by minimizing nutrient losses to the environment while maximizing availability of nutrients for crop growth.

The Avoid, Control, Trap approach operates on the concept that land managers adopt conservation systems that include practices that *Avoid* excess tillage and nutrient application in order to avoid sediment and nutrient losses. Some losses cannot be avoided. In these instances practices such as terraces or contouring help *Control* losses from the crop field. Complementing the *Avoid* and *Control* components of the system a third layer of conservation protection practices are designed to *Trap* runoff or leaching losses from the production area. The *Trap* practices includes filter strips, buffers, or in the case of subsurface losses, drainage water management. Under certain circumstances, wetlands may be constructed or restored to trap both surface and subsurface losses.

Given the long history of conservation in the Chesapeake Bay region, it is not surprising that nearly all cropped acres in the region have evidence of some kind of conservation practice, especially erosion control practices. Conservation practices continue to make headway in important, measurable ways. The most striking changes in conservation practice adoption noted between the two survey periods include significant increases in adoption of structural practices, conservation tillage, and cover crops.

Structural and vegetative conservation practices (referred to as "structural practices" herein), once implemented, are usually kept in place for several years. Designed primarily for erosion control, structural practices also mitigate edge-of-field nutrient losses, providing both the controlling and trapping benefits in a comprehensive Avoid, Control, Trap (ACT) conservation plan. Structural practices include:

- in-field practices for water erosion control, divided into two groups:
  - practices that control overland flow (terraces, contour buffer strips, contour farming, stripcropping, and contour stripcropping); and

- practices that control concentrated flow (grassed waterways, grade stabilization structures, diversions, and other structures for water control);
- edge-of-field practices for buffering and filtering surface runoff before it leaves the field (riparian forest buffers, riparian herbaceous cover, filter strips, and field borders);
- irrigation practices (irrigation method and irrigation water management); and
- wind erosion control practices (windbreaks, shelterbelts, crosswind trap strips, herbaceous wind barriers, and hedgerow planting).

*Annual conservation practic*es are management practices that are an active part of the crop production system each year. These practices are designed to promote soil quality, reduce in-field erosion, and reduce the availability of sediment and nutrients for transport by wind or water. They include:

- residue and tillage management;
- conservation crop rotations;
- nutrient management; and
- cover crops.

Structural Conservation Practices

Structural practices and conservation tillage have been adopted on nearly all cropped acres in the region and typically provide the control and trap components of the ACT system approach. These practices were the primary drivers behind reductions in sediment and nutrient losses from farm fields between 2003-06 and 2011. Cover crop adoption was also a significant driver of improved conservation management. Cover crops, especially when used in combination with conservation tillage or structural practices, had significant impacts on reducing edge-of-field losses.

Data on structural practices associated with each sample point were obtained from four sources:

1. The 2003-06 and 2011 **NRI-CEAP Cropland Surveys,** which included questions about the presence of structural practices: terraces, grassed waterways, vegetative buffers (in-field), hedgerow plantings, riparian forest buffers, riparian herbaceous buffers, windbreaks or herbaceous wind barriers, contour buffers (in-field), field borders, filter strips, critical area planting, grassed waterways, and grade stabilization structures;

2. For fields with conservation plans, **NRCS field offices** provided data on all structural practices included in the plans;

3. The **USDA Farm Service Agency** (FSA) provided practice information for fields enrolled in the Continuous Conservation Reserve Program (CCRP) and Conservation Reserve Enhancement Program (CREP) for the following structural practices: contour grass strips, filter strips, grassed waterways, riparian buffers (trees), and field windbreaks (Rich Iovanna, USDA FSA, personal communication, 2013); and

4. The **2003** and **2007 National Resources Inventory (NRI)** provided additional information for practices that could be reliably identified from overhead photography as part of the NRI data collection process. These practices include contour buffer strips, contour farming, contour stripcropping, field stripcropping, terraces, crosswind stripcropping, crosswind trap strips, diversions, field borders, filter strips, grassed waterways or outlets, hedgerow planting, herbaceous wind barriers, riparian forest buffers, and windbreak or shelterbelt establishment.

The methods for identifying and developing modeling techniques for the practices reported in these four sources were improved in the interim between this and the original Chesapeake Bay region CEAP report (USDA NRCS 2011). These improvements, which altered practice counts in the 2003-06 data as compared to the original report, also required that the 2003-06 and 2011 data both be analyzed under the same constraints to enable comparison in this report.

Overall, adoption of structural practices for water erosion control increased in the Chesapeake Bay region during the interim between the two reports (table 2.1). In the Chesapeake Bay region, between 2003-06 and 2011, the following changes were noted on all cropped acres:

- Adoption of one or more structural practice for water erosion control: *14 percentage point improvement*, increasing from occurring on 52 to 66 percent of cropped acres;
- Cropped highly erodible land (HEL) acres treated with one or more structural practice for water erosion control: *maintained 2003-06 conservation levels*, at 70 percent;
- Cropped acres with adoption of two or more structural practices for water erosion control: *16 percentage point improvement*, increasing from occurring on 17 to 33 percent of cropped acres; and
- Cropped HEL acres treated with two or more structural practice for water erosion control: *6 percentage point improvement*, increasing from 23 to 29 percent of cropped HEL acres.

Additionally, the surveys suggest a positive trend in adoption of all three erosion control practices (overland flow, concentrated flow, and edge-of-field mitigation) on all cropped acres and cropped HEL acres. However, throughout this report changes of 5 percent or less are considered to be maintaining 2003-06 conservation levels.

Overland flow control practices are designed to slow the movement of water across the soil surface, thereby reducing both surface water runoff and sheet and rill erosion. NRCS practice standards for overland flow control include terraces, contour farming, stripcropping, in-field vegetative barriers, and field borders. Overland flow control practices are the most commonly implemented structural practice in the Chesapeake Bay region. Between 2003-06 and 2011, the following changes in overland flow control practice adoption were noted (table 2.1):

- Overland flow control practice adoption on all cropped acres: *7 percentage point improvement*, increasing from occurring on 38 to 45 percent of cropped acres;

- Overland flow control practice adoption on non-highly erodible lands (NHEL): *13 percentage point improvement*, increasing from occurring on 29 to 42 percent of cropped NHEL acres; and
- Overland flow control practice adoption on highly erodible lands (HEL): *6 percentage point decline*, decreasing from occurring on 55 to 49 percent of cropped HEL acres.

For the purposes of this report tillage management, residue management, and cover crop adoption are not analyzed as solely overland flow control practices. However, these practices are often used in conjunction with overland control practices or in lieu of overland control practices, especially when slopes are gentler or fields have complex contours, which make the more engineered overland flow control practices difficult to implement and maintain.

Concentrated flow control practices are designed to prevent the development of gullies along flow paths within a field. NRCS concentrated flow control practice standards include grassed waterways, grade stabilization structures, diversions, and water and sediment control basins. These practices are typically installed to control both ephemeral and classic gullies. Concentrated flow control practices used in conjunction with overland flow control practices can have a significant impact on sediment loss from cultivated cropland.

Between 2003-06 and 2011, the following changes in concentrated flow control practice adoption were noted (table 2.1):

- Concentrated flow control practice adoption on all cropped acres: *11 percentage point improvement*, increasing from occurring on 20 to 31 percent of cropped acres;
- Concentrated flow control practice adoption on non-highly erodible lands (NHEL): *10 percentage point improvement*, increasing from occurring on 13 to 23 percent of cropped NHEL acres; and
- Concentrated flow control practice adoption on highly erodible lands (HEL): *8 percentage point improvement*, increasing from occurring on 35 to 43 percent of cropped HEL acres.

Edge-of-field buffering and filtering practices are designed to capture the surface runoff losses that are not mitigated by the in-field conservation practices. NRCS practice standards for edge-of-field mitigation include edge-of-field filter strips, riparian herbaceous buffers, and riparian forest buffers. CCREP and CREP buffer practices are included in this category. Between 2003-06 and 2011, the following changes in edge-of-field mitigation practice adoption were noted (table 2.1):

Table 2.1. Structural conservation practices in use in the Chesapeake Bay region, 2003-06 and 2011.

Structural practice category	Conservation practice	2003-06 Percent of NHEL	2011 Percent of NHEL	2003-06 Percent of HEL	2011 Percent of HEL	2003-06 Percent of all cropped acres	2011 Percent of all cropped acres
Overland flow control practices	Terraces, contour buffer strips, contour farming, stripcropping, contour stripcropping, field border, in-field vegetative barriers	29	42	55	49	38	45
Concentrated flow control practices	Grassed waterways, grade stabilization structures, diversions, other structures for water control	13	23	35	43	20	31
Edge-of-field buffering and filtering practices	Riparian forest buffers, riparian herbaceous buffers, filter strips	15	36	11	24	14	31
One or more water erosion control practice	Either overland flow, concentrated flow, or edge-of-field practice	43	64	70	70	52	66
Two or more water erosion control practices	Two practices, to include overland flow, concentrated flow, or edge-of-field practice	11	24	23	29	17	33
All three water erosion control practices	Overland flow, concentrated flow, and edge-of-field practice	2	6	4	9	2	7

Note: In the 2003-06 survey there were an estimated 1.87 million HEL acres (44 percent). The subset of NRI points for the 2011 survey had 1.75 million HEL acres (40 percent); a difference within the margins of error. The full set of 2007 NRI points for cropped acres in this region indicate 40 percent of the acres are HEL. Soils are classified as HEL if they have an erodibility index (EI) score of 8 or higher. A numerical expression of the potential of a soil to erode, EI considers the physical and chemical properties of the soil and climatic conditions where it is located. The higher the index, the greater the investment needed to maintain the sustainability of the soil resource base if intensively cropped.

- Edge-of-field mitigation practice adoption on all cropped acres: *17 percentage point improvement*, increasing from occurring on 14 to 31 percent of cropped acres;
- Edge-of-field mitigation practice adoption on non-highly erodible lands (NHEL): *21 percentage point improvement*, increasing from occurring on 15 to 36 percent of cropped NHEL acres; and
- Edge-of-field mitigation practice adoption on highly erodible lands (HEL): *13 percentage point improvement*, increasing from occurring on 11 to 24 percent of cropped HEL acres.

Wind erosion is not a significant problem for most cropland acres in this region. Wind erosion control practices are generally found on acres on which crops such as vegetables and melons are produced. Soils prone to wind erosion are commonly found in the coastal plain region and tend to be sandy or organic. Simulations shown in 2003-06 and 2011, 93 and 96 percent of cropped acres had average annual wind erosion rates below 0.1 ton, respectively. The simulated maximum average annual amount of soil lost per acre to wind erosion under the 2003-06 baseline condition or 2011 conservation condition was 3.3 tons, but some acres in some years can lose as much as 25 tons of soil to wind erosion. The few acres in the region vulnerable to wind erosion due to their combinations of cropping systems and soil types show significant improvement with conservation practices. There are so few of these acres in this regional context that analysis of the benefits of wind erosion control practices are impractical in the scope of this report. It should be noted, however, that many of the practices intended to reduce sediment loss to water erosion also have beneficial impacts on reducing wind erosion losses.

Residue and Tillage Management Practices

Tillage type impacts conservation goals for several reasons:

- Tillage may provide better aeration and weed control, but there are also potential negative effects, including increased respiration rates, which contribute to soil organic carbon loss, a decline in agroecological diversity, and a decline in density of soil organisms;
- Tillage breaks up and buries plant residues, reducing the soil surface protection against erosion;
- Tillage may compact the soil, decreasing soil health and possibly stressing crop roots;
- Tillage operations require time and energy inputs, which increase operational costs and increase carbon dioxide emissions; and
- Periodic use of more intense tillage alternated with conservation tillage can significantly reduce or eliminate the positive effects of conservation tillage.

Simulations of the use of residue and tillage management practices were based on the field operations and machinery types reported in the NRI-CEAP Cropland Survey for each sample point. The survey obtained information on the timing, type, and frequency of each tillage implement used during the previous 3 years, including the crop to which the tillage operation was applied.

The Soil Tillage Intensity Rating (STIR) (USDA NRCS 2007) was used to determine the soil disturbance intensity for each crop at each sample point for each year included in the NRI CEAP Cropland Surveys (2003-06 and 2011). STIR values are a function of the kinds of tillage, the frequency of tillage, and the depths of tillage. Analyzing the STIR values for each crop year in conjunction with model output on long-term soil organic carbon (SOC) trends elucidated the connections between tillage intensity and carbon dynamics, including carbon gain, maintenance, or loss.

Tillage management and conservation tillage adoption was assessed on a crop by crop basis for each cropping system. Each crop was classified according to its average annual Soil Tillage Intensity Rating (STIR). For the purpose of these analyses, crops produced with a STIR rating exceeding 80 were considered conventionally tilled, crops produced with a STIR value between 20 and 80 were considered mulch-till, and crops with a STIR value less than 20 were considered no-till. These classifications used in the 2003-06 assessment were changed from the classifications to reflect improvements in the NRCS residue and tillage management practice standards. Previously, crops produced with a STIR value of 30 or less were considered no-till and conventional tillage was determined by STIR values greater than 100.

The benefits of adopting less intense tillage are realized only with consistent use of reduced tillage for all crops in a rotation. Many farmers will employ “rotational tillage”, in which they apply one type of tillage on one crop and use a different intensity of tillage on the succeeding crop. Use of conventional tillage on one crop in a rotation can diminish or negate many of the positive aspects associated with adoption of conservation tillage, especially no-till. However, no-till is not the tillage solution for all crops on all acres. In particular, appropriate manure management requires a means of incorporation in the application method. This can generally be accomplished with some form of mulch-tillage or specially developed low impact methods of manure incorporation.

To assess the conservation tillage adoption trends between the two survey periods the following classifications were developed for cultivated cropland in the Chesapeake Bay region:

- Continuous Conventional Tillage: all crops conventionally tilled (STIR >80);
- Seasonal Conventional Tillage: at least one crop in rotation conventionally tilled and at least one crop conservation tilled;
- Continuous Mulch-tillage: all crops in rotation mulch-tilled, with STIR values for each crop between 20 and 80;
- Seasonal No-till: at least one crop produced with no-till (STIR <20) and no crop in rotation conventionally tilled; and
- Continuous No-till: all crops in rotation are no-till and produced with STIR values <20.

Adoption of conservation tillage, especially no-till, made rapid gains in the Chesapeake Bay region between 2003-06 and 2011 (fig. 2.1). Findings related to tillage practice changes on cultivated cropland between 2003-06 and 2011 include:

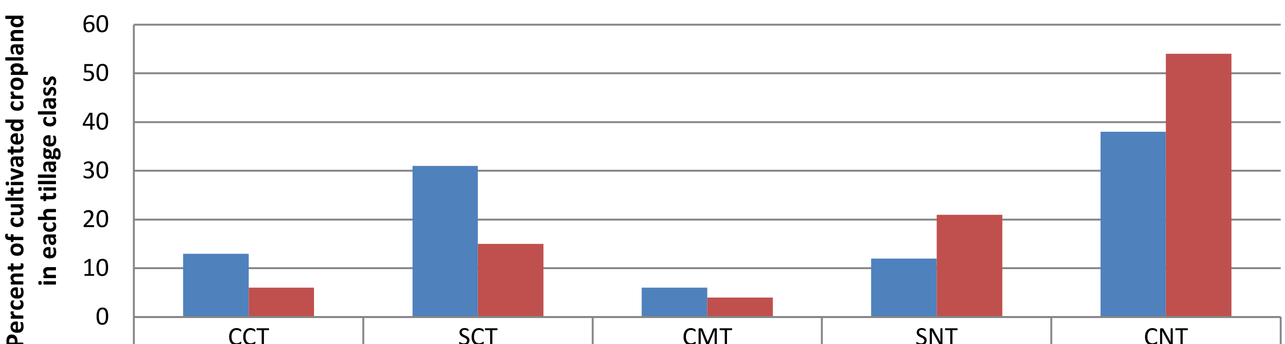
- Management using either continuous or seasonal conventional tillage decreased by half, dropping from being practiced on 44 to 21 percent of acres;
- Acres on which continuous conventional tillage was applied decreased by half, dropping from 13 to 6 percent of acres;
- Seasonal use of conventional tillage declined by half, dropping from being practiced on 31 to 15 percent of acres;
- Use of some form of conservation tillage without any conventional tillage increased from being in use on 56 to 79 percent of acres;
- Management using either continuous or seasonal no-till, without the use of conventional tillage on any crop increased from occurring on 50 to 75 percent of acres;
- Acres on which seasonal no-till was applied nearly doubled, increasing from 12 to 21 percent of acres; and
- Use of continuous no-till increased from 38 to 54 percent of acres.

The decreased use of conventional tillage at any point in the rotation enables the retention of more residue, which protects the soil and associated nutrients from being lost to wind and water erosion. The increased residue associated with adopting conservation tillage over conventional tillage not only protects the soil surface from erosion, but also improves infiltration, increases water availability for the crops, and builds soil health.

The effectiveness of conservation tillage and structural erosion control practices are both improved by inclusion of the other in a comprehensive conservation plan. The use of conservation tillage without structural practices ***and*** the use of structural practices without conservation tillage both declined between 2003-06 and 2011 (table 2.2). Adoption of suites of conservation practices that combine conservation tillage and structural practices now occurs on a majority of the cropped acres in the region. Between 2003-06 and 2011, the following changes were noted on cropped acres in the Chesapeake Bay region (table 2.3):

- Adoption of some kind of water erosion control practice, either reduced tillage, structural practice(s), or both: *10 percentage point improvement*, increasing from occurring on 87 to 97 percent of cropped acres; and
- Adoption of some kind of water erosion control practice ***and*** conservation tillage: *24 percentage point improvement*, increasing from occurring on 39 to 63 percent of cropped acres.

Figure 2.1. Changes in tillage management, as calculated from average annual STIR values for each crop in the rotation in the Chesapeake Bay region, 2003-06 and 2011.[1]



	CCT	SCT	CMT	SNT	CNT
2003-06	13	31	6	12	38
2011	6	15	4	21	54

* CCT = continuous conventional tillage; SCT = seasonal conventional tillage; CMT = continuous mulch-tillage; SNT = seasonal no-till; CNT = continuous no-till.

[1] Average Soil Tillage Intensity Rating (STIR) over all crop years in the rotation less than or equal to 20 is considered no-till; STIR less than or equal to 80 is considered mulch-till; and STIR values greater than 80 are considered conventional tillage.

Table 2.2. Conservation tillage, including no-till and mulch-till, applied singularly or in conjunction with structural practices in the Chesapeake Bay region, 2003-06 and 2011.

	2003-06		2011	
Combination of conservation practice	**Acres (thousands)**	**Acres (percent)**	**Acres (thousands)**	**Acres (percent)**
Conservation tillage only*	1,477.1	35	1,164.3	27
Conservation tillage with structural practices*	1,660.3	39	2,755.6	63
Structural practices only	602.6	14	296.6	7
No water erosion control treatment	539.9	13	136.9	3
Total	**4,279.9**	**100**	**4,353.4**	**100**

Note: Percents may not add to totals because of rounding.
* NRCS practice standards for residue and tillage management have been revised since the publication of the original report (USDA NRCS 2011). Average Soil Tillage Intensity Rating (STIR) over all crop years in the rotation must be less than or equal to 20 for no-till; average STIR less than or equal to 80 is considered mulch-till; and STIR values greater than 80 are considered conventional tillage. These STIR criteria are different from those applied in the original report, under which a value of 30 or less was classified and no-till and 100 or greater was classified as conventional tillage.

Table 2.3. Cropped acres in the Chesapeake Bay region, 2003-06 and 2011.

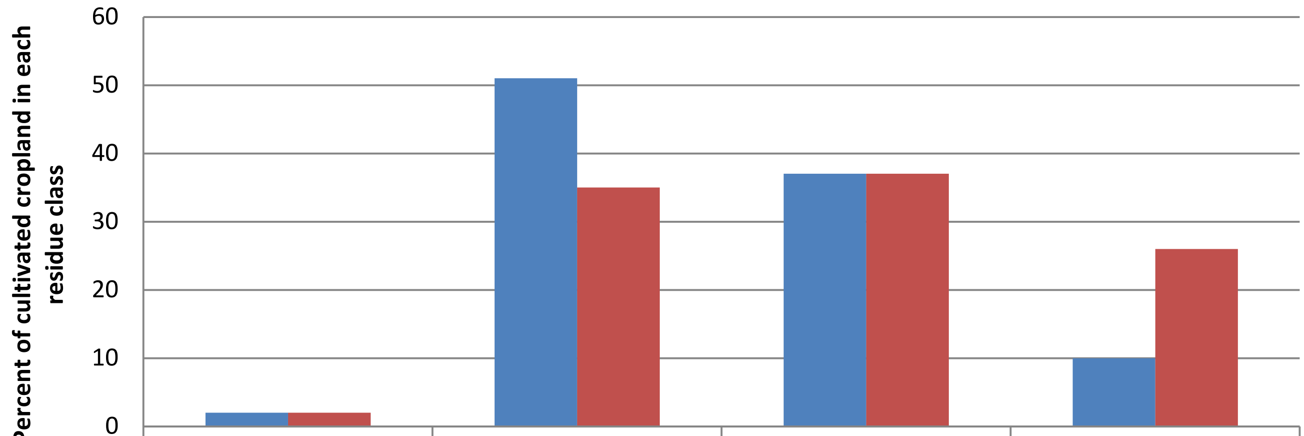
	2003-06		2011	
Cropping System	Acres (thousands)	Acreage (percent)	Acres (thousands)	Acreage (percent)
Corn only	690	16.1	364	8.4
Soybean only	161	3.8	128	2.9
Corn-Soybean	1,175	27.4	880	20.2
Corn with wheat or close-grown crop	272	6.4	336	7.7
Soybean-Wheat	125	2.9	120	2.8
Soybean with close-grown crop	7	0.2	45	1.0
Corn-Soybean with wheat or close-grown crop	798	18.6	1,252	28.7
Vegetables or Tobacco, excluding hay	143	3.3	209	4.8
Hay and any other	627	14.7	701	16.1
Remaining mix of crops	282	6.6	318	7.3
Totals	**4,280**		**4,353**	

Note: The difference between 2003-06 and 2011 cropping systems represent land-use changes in the 4-year time period between the two surveys. The 2003-06 estimates are based on acreage weights derived from the 2003 NRI, while the 2011 estimates are based on acreage weights derived from the 2007 NRI. Estimates for 2011 cropped acres do not account for cover crops applied to the rotations, while the 2003-06 estimates do account for cover crops applied to the rotations.

Conservation Crop Rotation

Conservation crop rotation (NRCS practice code 328) involves growing various crops on the same piece of land in a planned sequence to deliver conservation benefits. For example, this sequence may contribute to development of soil organic carbon pools by growing high residue-producing crops such as corn or wheat in rotation to offset the effects of growing low residue-producing crops, such as vegetables or soybeans. The rotation may also involve growing forage crops or cover crops in rotation with various field crops, which may increase the multi-functionality of the land and diversify the farmer's economic base while also conserving soil. Increasing adoption of high residue crop rotations in the Chesapeake Bay region between 2003-06 and 2011 reflects the increasing diversification of cropping systems, concurrent with a reduction in low residue monocultures and simple corn-soybean rotations (table 2.3). This positive trend in conservation crop rotation adoption has markedly improved annual residue scores in the region (fig. 2.2). Cover crop adoption has become an important complementary practice to conservation crop rotation. However, it should be noted that cover crop adoption is only one part of an effective conservation management plan. To produce consistent and beneficial results, conservation management plans must be reevaluated and applied appropriately and consistently.

Figure 2.2. Average annual residue scores in the Chesapeake Bay region, 2003-06 and 2011.



	Score <1	Score 1 to 2	Score 2 to 3	Score 3 to 4
2003-06	2	51	37	10
2011	2	35	37	26

To allow numerical comparison of the residue level of various crop rotations, a simple scoring system was developed using relative values to represent a crop's residue production value. Hay crops scored the highest possible score of 4, as they are typically established for two or more years and hay crop residue confers excellent erosion protection. High residue annual crops like corn and wheat have a score of 2 and low residue crops, such as silage, soybeans, or cotton, score only 1.

Vegetable crop management tends to provide low residue and include heavy tillage following removal of the entire plant. Such cropping systems score 0.25, as the residue contribution of four such crops in a year would be required to provide the conservation value derived from one low residue crop.

On a given acre, total points for all the crops in rotation, including cover crops, are summed and divided by the length of the rotation. For example, the 1.5 corn-soybean rotation score can be increased to 2.5 via the addition of a cover crop between the corn and soy. Use of a cover crop after each commodity crop would raise the rotation score to 3.5.

Changing crop rotations and adoption of conservation practices that increase residue scores occurred between 2003-06 and 2011 (fig. 2.2). Between 2003-06 and 2011 the acreage maintained as monocultures of corn or soybeans or a simple corn-soybean rotation declined from 47 to 32 percent of cropland acres (table 2.2). Crop rotations increased in complexity, primarily due to the addition of wheat or other close-grown winter annuals, including cover crops. Crop diversification has improved residue scores. Acreage with scores between 1 and 2, typical of a corn-soybean rotation, declined from 51 percent to 35 percent of acres. This 16 percentage point decline in acreage scoring 1 to 2 was accompanied by a 16 percentage point increase in acres scoring 3 to 4. The increase is in large part due to the increase in cover crop adoption and inclusion of winter annual small grains.

Cover Crops and Winter Cover

Cover cropping consists of planting grass, small grains, or legumes between primary crop intervals, enabling farmers to better manage nutrient inputs, enhance soil quality, and/or reduce soil erosion. In the context of this report cover crops are considered a unique subset of winter cover. Cover crops are planted when principal crops are not growing, which may include, but is not limited to, winter months. Cover crops are not planted with the intent to harvest and are generally terminated by tillage or herbicide application prior to maturity. Winter cover includes crops that may be grazed and/or harvested for grain, hay, or both. Cover crops and conservation crop rotations that include winter annuals are critical to protecting soil and water quality in the Chesapeake Bay region. Local emphasis on these practices has helped make significant improvements towards reducing the impacts of cropped acres on the Chesapeake Bay. The benefits of including cover crops in crop rotations most notably include reduction in runoff losses and erosion (table 2.4). Simulations suggest that increased adoption of winter cover observed in 2011 reduced 2003-06 loss rates by 37 percent for sediment, 28 percent for nitrogen via surface water, 18 percent for nitrogen via subsurface flow, 29 percent for phosphorus, and 46 percent for carbon (table 2.4).

Conservation crop rotation has contributed to more acres being protected by vegetation during the late fall and winter months. Some rotations also promote soil health and water quality by reducing nutrient input requirements for crop production or by utilizing "leftover" nutrients from previous crops, making them less available to losses via erosion. Cover crops and winter cover also contribute to soil quality by converting atmospheric carbon into plant tissue, which eventually becomes soil organic matter and contributes to soil carbon pools. Additionally, depending on management, cover crops may provide pollinator or wildlife benefits, including habitat and food production.

Table 2.4. Reduction in specified losses due to adoption of winter cover in at least part of the crop rotation, between 2003-06 and 2011 conditions.

Loss Category	Reduction (percent)
Sediment	37
Nitrogen via Surface Water	28
Nitrogen via Subsurface Water	18
Total Phosphorus	29
Carbon	46

Benefits of cover cropping specific to individual conservation crop rotation practices could not be assessed as cover crops were often adopted as part of a suite of conservation practices in a comprehensive conservation plan. Benefits of cover crops, conservation crop rotations, conservation tillage, structural practices, and nutrient management strategies are often intertwined.

The major distinction between cover crops and other types of winter cover is the approach to nutrient management. Winter annuals grown for grain are generally "top dressed" with nitrogen in early spring to ensure availability of nutrients necessary for grain production. When appropriately applied to an actively growing crop, the majority of these nutrients tend to be taken up quickly by the plants, so that the fertilizer application usually has very little impact on offsite water quality.

The presence or absence of cover crops and winter cover was determined from farmer responses in the NRI-CEAP Cropland Survey. The following criteria were used to identify use of a cover crop and to differentiate winter cover from cover crops:

- Winter cover is limited to close-grown crops grown over the winter months and subsequently harvested for hay or grain or both. These crops may be grazed.
- A cover crop is not harvested as a principal crop. If it is harvested, it must have been specifically identified in the NRI-CEAP Cropland Survey as a cover crop harvestable for an acceptable purpose (such as biomass removal or use as mulch or forage material).[2]
- Spring-planted cover crops are inter-seeded into a growing crop or are followed by the seeding of a summer or late fall crop that may be harvested during that same year or early the next year.
- Late-summer-planted cover crops are followed by the harvest of another crop in the same crop year or the next spring.
- Fall-planted cover crops are followed by the spring planting of a crop for harvest the next year.

Some cover crops are planted for soil protection during establishment of spring crops such as melons, spinach, and potatoes. Early-spring cover crop vegetation protects both soil and young crop seedlings.

In recent years both state and Federal programs have contributed to significant increases in voluntary adoption of cover crops and winter cover in the Chesapeake Bay region. Cover crop adoption rose dramatically in the subregions encompassing Maryland (Upper Chesapeake Bay–subregion 0206 and the Potomac River Basin–subregion 0207). Between 2003-06 and 2011 cropped acreage receiving cover crops at some point in the rotation in the Upper Chesapeake Bay subregion more than tripled, increasing from 14 to 65 percent of cropped acres. During the same interim, acreage receiving cover crops at some point in the rotation in the Potomac River Basin subregion nearly tripled as well, increasing from 17 to 62 percent of cropped acres (table 2.5).

Between 2003-06 and 2011, the following trends related to cover crops and winter cover were noted in the Chesapeake Bay region's cultivated cropland (tables 2.5 and 2.6):

- Annual use of cover crops: *13 percentage point improvement*, increased from occurring on 5 to 18 percent of cropped acres;
- Annual use of winter cover, which protects the soil over the winter months: *14 percentage point improvement*, increased from occurring on 3 to 17 percent of cropped acres;
- Cover crops used at some point in the crop rotation: *40 percentage point improvement*, increased from occurring on 12 to 52 percent of cropped acres; and
- Cropped acres including winter cover as part of the crop rotation, which protects the soil over the winter months: *18 percentage point improvement*, increased from occurring on 47 to 65 percent of cropped acres.

The increased use of winter annuals in the crop rotation may be attributed to market forces (e.g., higher wheat prices) and the flexibilities of some of the region's cover crop programs, which allow farmers to opt to manage their cover crop for grain harvest in return for a reduced cost share on the cover crop. State programs also continue to contribute to winter cover and cover crop adoption. For example, the Maryland Department of Agriculture cover crop program reported 414,000 acres were planted to cover crops in 2012.

[2] Except for the 2003 survey, the questionnaire allowed the respondent to list the purpose for which a crop was grown, including cover crop. This information was not a reliable indicator of a cover crop for conservation purposes for all sample points, based on other information in the survey on crops planted and field operations.

Table 2.5. Percent of cropped acres that apply cover crops as a conservation practice in the Chesapeake Bay region by subregion, 2003-06 and 2011.

Subregion Name:	Susquehanna River Basin (0205)		Upper Chesapeake Bay (0206)		Potomac River Basin (0207)		Lower Chesapeake Bay (0208)		2003-06 Chesapeake Bay Region	2011 Chesapeake Bay Region
Cover crop strategy	2003-06 percent	2011 percent	2003-06 percent	2011 percent	2003-06 percent	2011 percent	2003-06 percent	2011 percent		
Every year	5	13	4	26	10	26.	3	13	5	18
2 of every 3 years	2	5	2	20	<1	16	2	23	2	13
Every other year	0	0	1	0	0	0	<1	0	<1	0
Less than every other year	3	17	7	20	7	20	1	33	4	20
None	91	65	86	35	83	38	93	30	88	48

Table 2.6. Percent of cropped acres that utilize winter cover as part of their crop rotation in the Chesapeake Bay region by subregion, 2003-06 and 2011.

Subregion Name:	Susquehanna River Basin (0205)		Upper Chesapeake Bay (0206)		Potomac River Basin (0207)		Lower Chesapeake Bay (0208)		2003-06 Chesapeake Bay Region	2011 Chesapeake Bay Region
Winter cover strategy	2003-06 percent	2011 percent	2003-06 percent	2011 percent	2003-06 percent	2011 percent	2003-06 percent	2011 percent		
Every year	5	14	2	20	4	24	2	10	3	17
2 of every 3 years	15	18	5	16	12	17	10	8	11	16
Every other year	6	9	16	16	9	11	15	28	11	14
Less than every other year	24	16	23	21	19	22	16	21	22	19
None	49	42	55	27	56	25	57	33	53	35

Irrigation Management Practices

In the Chesapeake Bay region, irrigation applications are sometimes used to supplement natural rainfall. Irrigation is performed with either a gravity system or a pressure system. Gravity systems utilize gravitational energy to move water from higher elevations to lower elevations, such as moving water from a ditch at the head of a field, across the field to the lower end. Pumps are most often used to create the pressure in pressurized systems, and the water is delivered through nozzles or emitters.

Proper irrigation involves efficient use of water such that plant water stress is alleviated and minimal water is lost. The widespread trend of converting gravity irrigation systems to pressure systems and the advent of pressure systems in rain-fed agricultural areas has reduced the volume of irrigation water lost to deep percolation and end-of-field runoff, but has increased the volume of water lost to evaporation due to the sprinkling process associated with most pressure systems.

Between 2003-06 and 2011, irrigated acreage in the Chesapeake Bay region increased from 209,000 acres to 261,000 acres. Pressure systems were used on 97 percent of irrigated acres in the region during both survey periods. The most common and efficient pressure systems, center-pivot or linear move systems with low pressure spray, were in use on 34 percent of irrigated acres in 2003-06 and 46 percent of irrigated acres in 2011. Center-pivot or linear move systems, with less efficient impact sprinklers, declined from being in use on 44 to 28 percent of irrigated acres between 2003-06 and 2011.

As of 2011, low flow irrigation systems such as drip, trickle, or micro emitters were used on 13 percent of the irrigated acres in the region. Irrigated acreage on which highly efficient, state of the art systems (e.g., center pivot or linear move systems with low pressure, near-ground emitters, or low flow systems such as drip and trickle) were applied increased from 39 to 60 percent of cropped acres between 2003-06 and 2011.

Nutrient Management Criteria

Nitrogen and phosphorus are essential inputs for profitable and sustainable crop production. Farmers supply these nutrients to the land with commercial fertilizers and/or manure. A large portion of the nutrients applied to the land are taken up by the crops and removed from the fields at harvest. However, crops do not use all of the applied nutrients; some are lost to the environment through various pathways, including leaching, erosion, and in the case of nitrogen, volatilization. When edge-of-field losses are combined with naturally occurring nutrients, nutrients from past losses, or nutrients from other sources, they can contribute to offsite water quality problems.

Nutrient management is an active management practice and plays an important role in the Avoid, Control, Trap (ACT) conservation system approach. Nutrient management planning should be used in conjunction with conservation practices designed to control and trap nutrients and sediment. Appropriate nutrient application management must be utilized each year and on each crop in the rotation in order for the conservation benefits of the 4R's (the *right* rate, the *right* timing, the *right* method, and the *right* form) to persist in the region.

Sound nutrient management systems can minimize nutrient losses from the agricultural management zone while providing adequate soil fertility and nutrient availability to ensure realistic yields. The agricultural management zone is defined as the zone surrounding a field that is bounded by the bottom of the root zone, edge of the field, and top of the crop canopy. Nutrient management systems are tailored to address the specific cropping system, nutrient sources, and site characteristics of each field. However, the 4R's provide basic criteria for appropriate application of commercial fertilizers and manure:

1. Apply nutrients at the **right rate** based on soil and plant tissue analyses and realistic yield goals.
2. Apply nutrients at the **right time** to supply the crop with nutrients when the plants have the most active uptake and biomass production; avoid applying nutrients when adverse weather conditions can result in large losses of nutrients from the agricultural management zone.
3. Apply nutrients using the **right method** of application for the nutrient source being applied in order to enable rapid, efficient plant uptake and reduce the exposure of nutrient material to forces of wind and water.
4. Apply the **right form** of commercial fertilizer and/or manure, with compositions and characteristics that resist nutrient losses from the agricultural management zone.

Depending on the field characteristics, nutrient management techniques can be coupled with other conservation practices such as conservation crop rotations, cover crops, residue management practices, and structural practices to minimize the potential for nutrient losses from the agricultural management zone. Even though nutrient transport and losses from agricultural fields cannot be completely eliminated, they can be minimized, with careful ACT conservation planning and implementation of complementary conservation practices.

Determination of appropriate nutrient management practices was based on information on the rate, timing, and method of application for manure and commercial fertilizer, as reported by the producer in the NRI-CEAP Cropland Survey. The appropriateness of nutrient form was not evaluated due to insufficient survey data. Although it is not discussed in this report, the appropriateness of nutrient form should be considered in conjunction with rate, timing, and method of nutrient application in the development of sound nutrient management plans.

The following criteria enable comparison of changes in conservation benefits due to changing nutrient management plans between 2003-06 and 2011. Criteria used here to classify nutrient management practices, while consistent with NRCS standards, do not necessarily represent the best possible set of nutrient management practices for these acres. These nutrient management criteria are intended to represent practice recommendations commonly found in comprehensive nutrient management conservation plans. The following criteria were used to identify appropriate rate, timing, and method of nutrient applications for each crop or crop rotation.

Appropriate Rate Criteria

- Nitrogen application rate criteria apply to ***each crop*** in the rotation.
- The rate of nitrogen application, including the sum of commercial nitrogen fertilizer and manure nitrogen available for crops in the year of application, is—
  - less than 1.4 times the amount of nitrogen removed in the crop yield at harvest for ***each crop***, except for cotton and small grain crops;
  - less than 1.6 times the amount of nitrogen removed in the crop yield at harvest for small grain crops (wheat, barley, oats, rice, rye, buckwheat, emmer, spelt, and triticale); and
  - less than 60 pounds of nitrogen per bale of cotton harvested.
- Phosphorus application rate criteria apply to the ***full crop rotation*** to account for infrequent applications intended to provide phosphorus for multiple crops or crop years, which is often the case with manure applications.[3]
- The rate of phosphorus application, including both manure and commercial fertilizer, summed over all applications and crops in the rotation is less than 1.2 times the amount of phosphorus removed in the crop yields at harvest summed over all crops in the rotation.

It should be noted that in the analysis of the 2003-06 survey in the original Chesapeake Bay region CEAP report, the phosphorus application rate threshold criterion was 1.1 times the phosphorus removed at harvest and for the 2011 analysis this value has been increased to 1.2 (USDA NRCS 2011). This change was necessary due to improvements in the phosphorus adsorption/desorption routine in APEXv1307. The 1.1 criterion produced extensive phosphorus stress and significantly reduced yields in the simulation. The incremental increases to 1.2 reduced phosphorus stress and maintained expected yields.

Appropriate Timing Criteria

Timing application close to planting supplies nutrients closer to the time when the crop needs them, thereby reducing the risk of loss. The analyses in the original report required proper timing of all commercial fertilizer and manure applications to be within 21 days before or after planting. In the analysis for this report the criteria was changed to only evaluate the length

[3] For this reason the appropriateness of rate of application for phosphorus cannot be analyzed in the same manner used for nitrogen, resulting in slightly different information being presented in tables 2.7 and 2.8.

of time between the application dates *prior to planting*. The change was made to eliminate the erroneous classification of acres where spring applications of nutrients were appropriately applied to winter annuals outside of the 42-day window.

Appropriate Method Criteria

To meet nutrient application method criteria, application of commercial fertilizer or manure must include some form of incorporation, banding, spot treatment, or foliar application.

Survey Results – Nutrient Management Practices

Survey results suggest that although some conservation gains achieved between 2003-06 and 2011 could be attributed to improved nutrient management practices, there is still ample opportunity to improve nutrient management planning in the region. Differences between values reported here as compared to those in the 2011 report are in large part attributable to improvements in the APEX model related to nutrient cycles for both nitrogen and phosphorus. Interpretation of application timing values also differ between the two reports due to a change in evaluation criteria.

Nitrogen – Appropriate Rate

Between 2003-06 and 2011, the following trends related to nitrogen application rates were noted in the Chesapeake Bay region's cultivated cropland (table 2.7):

- Nitrogen receiving acres on which nitrogen application rate criteria were met for ***all*** crops in rotation: *9 percentage point decline*, decreased from 32 to 23 percent of cropped acres;
- Nitrogen receiving acres on which nitrogen application rate criteria were met for ***some but not all*** crops in rotation: *17 percentage point improvement*, increased from 54 to 71 percent of cropped acres;
- Nitrogen receiving acres on which nitrogen application rate criteria were ***not*** met on ***any*** crop in the rotation: *7 percentage point improvement*, decreased from 13 to 6 percent of cropped acres; and
- Cropped acres with no nitrogen application: *maintained 2003-06 conservation levels* (5 and 2 percent of cropped acres in 2003-06 and 2011, respectively).

When rate criteria were applied by crop rather than by management over the entire rotation, adherence to appropriate nitrogen application rates maintained conservation levels achieved in 2003-06 (52 and 55 percent of crops in 2003-06 and 2011, respectively).

Commercial fertilizer was the only source of nitrogen for 2.5 and 2.2 million cropped acres in 2003-06 and 2011, respectively. Between 2003-06 and 2011, the following trends related to nitrogen application rates were noted in the Chesapeake Bay region's cultivated cropland acres receiving commercial fertilizer as their sole nitrogen source, with no manure inputs (table 2.7):

- Commercial nitrogen receiving acres (no manure inputs) on which nitrogen application rate criteria were met on ***all*** crops in rotation: *7 percentage point decline*, decreased from 42 to 35 percent;
- Commercial nitrogen receiving acres (no manure inputs) on which nitrogen application rate criteria were met on ***some but not all*** crops in rotation: *10 percentage point improvement*, increased from 52 to 62 percent; and
- Commercial nitrogen receiving acres (no manure inputs) on which nitrogen application rate criteria were ***not*** met on ***any*** crop in the rotation: *maintained 2003-06 conservation levels* (6 and 3 percent of cropped acres in 2003-06 and 2011, respectively).

The most significant changes to nitrogen application rates occurred on acreage on which manure is applied to one or more of the crops in rotation, either as a sole nutrient source or in conjunction with commercial fertilizers. Between 2003-06 and 2011, the practice of applying manures as a nitrogen source increased from occurring on 38 percent (1.6 million acres) to 48 percent (2.1 million acres) of cropped acres in the region. Between 2003-06 and 2011, the following trends related to nitrogen application rates were noted in the Chesapeake Bay region's cultivated cropland acres receiving manure inputs as a nitrogen source, with or without additional commercial fertilizer inputs (table 2.7):

- Manured acres on which nitrogen application rate criteria were met on ***all*** crops in rotation: *8 percentage point decline*, decreased from 17 to 9 percent;
- Manured acres on which nitrogen application rate criteria were met on ***some but not all*** crops in rotation: *23 percentage point improvement*, increased from 59 to 82 percent; and
- Manured acres on which nitrogen application rate criteria were ***not*** met on ***any*** crop in the rotation: *15 percentage point improvement*, decreased from 24 to 9 percent.

Nitrogen – Appropriate Timing

Between 2003-06 and 2011, the following trends related to nitrogen application timing were noted in the Chesapeake Bay region's cultivated cropland (table 2.7):

- Nitrogen receiving acres on which nitrogen application timing criteria were met for ***all*** crops in rotation: *14 percentage point decline*, decreased from 50 to 36 percent of cropped acres;
- Nitrogen receiving acres on which nitrogen application timing criteria were met for ***some but not all*** crops in rotation;
- *16 percentage point improvement*, increased from 34 to 50 percent of cropped acres; and
- Nitrogen receiving acres on which nitrogen application timing criteria were ***not*** met on ***any*** crop in the rotation: *maintained 2003-06 conservation levels* (11 percent in both surveys).

Table 2.7. Nitrogen management practices and percent of cropped acres within each category for the Chesapeake Bay region, 2003-06 and 2011.

Nitrogen*	**2003-06 acres**	**2011 acres**	**2003-06 percent**	**2011 percent**
No N applied to any crop in rotation	214,000	87,000	5	2
For acres where N is applied:			95	98
Commercial Fertilizer Only	2,457,000	2,177,000	60	51
Manure with or without Commercial Fertilizer	1,608,000	2,089,000	40	49
Rate of application:				
Acres receiving commercial fertilizer and/or manure applications:				
All crops in rotation meet the nitrogen rate criteria described in text			32	23
Some but not all crops in rotation meet the nitrogen rate criteria described in text			54	71
No crops in rotation meet the nitrogen rate criteria described in text			13	6
Acres receiving commercial fertilizer applications only:				
All crops in rotation meet the nitrogen rate criteria described in text			42	35
Some but not all crops in rotation meet the nitrogen rate criteria described in text			52	62
No crops in rotation meet the nitrogen rate criteria described in text			6	3
Acres receiving manure with or without commercial fertilizer applications:				
All crops in rotation meet the nitrogen rate criteria described in text			17	9
Some but not all crops in rotation meet the nitrogen rate criteria described in text			59	82
No crops in rotation meet the nitrogen rate criteria described in text			24	9
Time of application:				
Acres receiving commercial fertilizer and/or manure applications:				
All crops in rotation have application of nitrogen fertilizer less than 21 days before planting			50	36
Some but not all crops have application of nitrogen fertilizer within 21 days before planting			34	50
No crops in rotation have application of nitrogen fertilizer within 21 days before planting			11	11
Acres receiving commercial fertilizer applications only:				
All crops in rotation have application of nitrogen fertilizer less than 21 days before planting			69	59
Some but not all crops have application of nitrogen fertilizer within 21 days before planting			15	25
No crops in rotation have application of nitrogen fertilizer within 21 days before planting			9	13
Acres receiving manure with or without commercial fertilizer applications:				
All crops in rotation have application of manure less than 21 days before planting			18	12
Some but not all crops have application of manure within 21 days before planting			66	78
No crops in rotation have application of manure within 21 days before planting			16	10
Method of application:				
Acres receiving commercial fertilizer and/or manure applications:				
All crops in rotation have N applied with incorporation or banding/foliar/spot treatment			34	27
Some but not all crops in rotation have N applied with incorporation or banding/foliar/spot treatment			45	55
No crops in rotation have N applied with incorporation or banding/foliar/spot treatment			21	18
Acres receiving commercial fertilizer applications only:				
All crops in rotation have N applied with incorporation or banding/foliar/spot treatment			41	37
Some but not all crops in rotation have N applied with incorporation or banding/foliar/spot treatment			34	44
No crops in rotation have N applied with incorporation or banding/foliar/spot treatment			25	19
Acres receiving manure with or without commercial fertilizer applications:				
All crops in rotation have manure applied with incorporation or banding/foliar/spot treatment			22	16
Some but not all crops in rotation have manure applied with incorporation or banding/foliar/spot treatment			63	67
No crops in rotation have manure applied with incorporation or banding/foliar/spot treatment			16	17
Rate *and* timing *and* method of application (excludes acres not receiving nitrogen)				
All crops meet the nitrogen rate criteria described in text and application within 3 weeks before planting with incorporation or banding/foliar/spot treatment			13	7
Some but not all crops meet the nitrogen rate criteria described in text or application within 3 weeks before planting with incorporation or banding/foliar/spot treatment			87	93
Nitrogen *and* Phosphorus				
Crop rotation P rate and N rate criteria described in text and all applications within 3 weeks before planting with incorporation or banding/foliar/spot treatment, including acres with no N or P applied			8	5

Note: Percents may not add to 100 because of rounding.

* These estimates include adjustments made to the reported data on nitrogen and phosphorus application rates from the survey because of missing data and data entry errors. In the case of phosphorus, the 3-year data period for which information was reported was too short to pick up phosphorus applications made at 4- and 5-year intervals between applications, which is a common practice for producers adhering to sound phosphorus management techniques. Since crop growth, and thus canopy development which decreases erosion, is a function of nitrogen and phosphorus, it was necessary to add additional nitrogen when the reported levels were insufficient to support reasonable crop yields throughout the 52 years in the model simulation. For additional information on adjustment of nutrient application rates, see "Adjustment of CEAP Cropland Survey Nutrient Application Rates for APEX Modeling," available at http://www.nrcs.usda.gov/technical/nri/ceap).

Between 2003-06 and 2011, the following trends related to nitrogen application timing were noted in the Chesapeake Bay region's cultivated cropland acres receiving commercial fertilizer as their sole nitrogen source, with no manure inputs (table 2.7):

- Commercial nitrogen receiving acres (no manure inputs) on which nitrogen application timing criteria were met on ***all*** crops in rotation: *10 percentage point decline*, decreased from 69 to 59 percent;
- Commercial nitrogen receiving acres (no manure inputs) on which nitrogen application timing criteria were met on ***some but not all*** crops in rotation: *10 percentage point improvement*, increased from 15 to 25 percent; and
- Commercial nitrogen receiving acres (no manure inputs) on which nitrogen application timing criteria were ***not*** met on ***any*** crop in the rotation: *maintained 2003-06 conservation levels* (9 and 13 percent of cropped acres in 2003-06 and 2011, respectively).

Between 2003-06 and 2011, the following trends related to nitrogen application timing were noted in the Chesapeake Bay region's cultivated cropland acres receiving manure inputs as a nitrogen source, with or without additional commercial fertilizer inputs (table 2.7):

- Manured acres on which nitrogen application timing criteria were met on ***all*** crops in rotation: *6 percentage point decline,* decreased from 18 to 12 percent;
- Manured acres on which nitrogen application timing criteria were met on ***some but not all*** crops in rotation: *12 percentage point improvement*, increased from 66 to 78 percent; and
- Manured acres on which nitrogen application timing criteria were ***not*** met on ***any*** crop in the rotation: *6 percentage point improvement,* declined from 16 to 10 percent.

Between 2003-06 and 2011, manure application expanded from occurring on 38 to 48 percent of cropped acres (fig. 2.3). Manure was applied to these acres as part of their nutrient management plan, either as the sole nutrient source, or in conjunction with commercial fertilizers. The decline in use of the more optimal 21 days out manure application timing for ***all*** crops in rotation may be the result of traditional manure users applying manure to more acres and requiring more management time to get it spread. Additionally, it is possible new manure users are adjusting to managing a new nutrient source. The finding that more acres are receiving appropriately timed manure applications on ***some*** crops in rotation is a positive sign.

Nitrogen – Appropriate Method

Between 2003-06 and 2011, the following trends related to nitrogen application method were noted in the Chesapeake Bay region's cultivated cropland (table 2.7):

- Nitrogen receiving acres on which nitrogen application method criteria were met for ***all*** crops in rotation: *7 percentage point decline*, decreased from 34 to 27 percent of cropped acres;
- Nitrogen receiving acres on which nitrogen application method criteria were met for ***some but not all*** crops in rotation: *10 percentage point improvement,* increased from 45 to 55 percent of cropped acres; and
- Nitrogen receiving acres on which nitrogen application method criteria were ***not*** met on ***any*** crop in the rotation: *maintained 2003-06 conservation levels* (21 and 18 percent of cropped acres in 2003-06 and 2011, respectively).

Between 2003-06 and 2011, the following trends related to nitrogen application method were noted in the Chesapeake Bay region's cultivated cropland acres receiving commercial fertilizer as their sole nitrogen source, with no manure inputs (table 2.7):

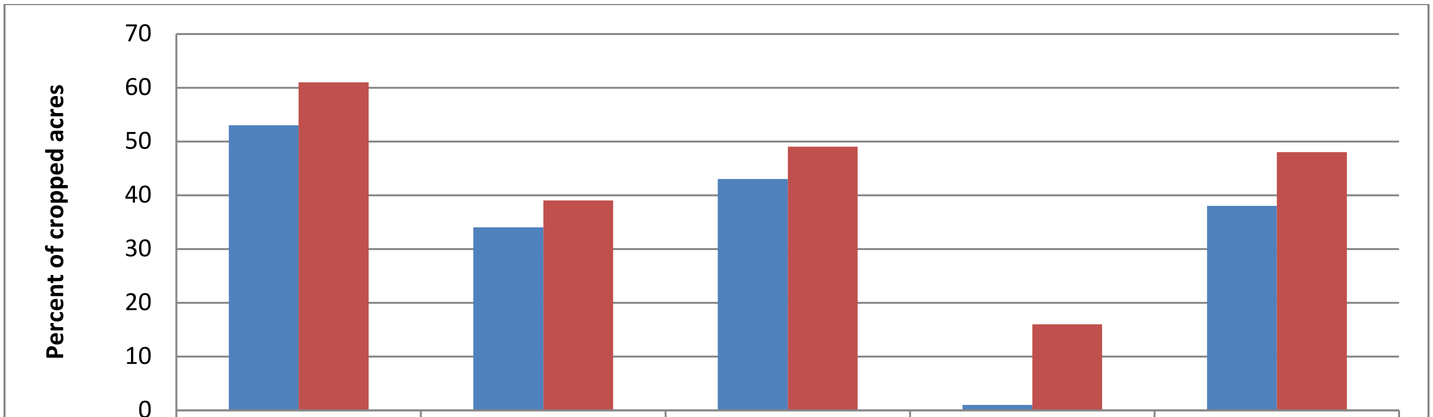
- Commercial nitrogen receiving acres (no manure inputs) on which nitrogen application method criteria were met on ***all*** crops in rotation: *maintained 2003-06 conservation levels* (41 to 37 percent of cropped acres in 2003-06 and 2011, respectively);
- Commercial nitrogen receiving acres (no manure inputs) on which nitrogen application method criteria were met on ***some but not all*** crops in rotation: *10 percentage point improvement* (increased from 34 to 44 percent); and
- Commercial nitrogen receiving acres (no manure inputs) on which nitrogen application method criteria were ***not*** met on ***any*** crop in the rotation: *6 percentage point improvement*, (increased from 25 to 19 percent of cropped acres in 2003-06 and 2011, respectively).

Between 2003-06 and 2011, the following trends related to nitrogen application method were noted in the Chesapeake Bay region's cultivated cropland acres receiving manure inputs as a nitrogen source, with or without additional commercial fertilizer inputs (table 2.7):

- Manured acres on which nitrogen application method criteria were met on ***all*** crops in rotation: *6 percentage point decline* (decreased from 22 to 16 percent);
- Manured acres on which nitrogen application method criteria were met on ***some but not all*** crops in rotation: *maintained 2003-06 conservation levels* (63 and 67 percent of cropped acres in 2003-06 and 2011, respectively); and
- Manured acres on which nitrogen application timing criteria were ***not*** met on ***any*** crop in the rotation: *maintained 2003-06 conservation levels* (16 and 17 percent of cropped acres in 2003-06 and 2011, respectively).

Management of nitrogen application method on acres receiving manure was very similar in both survey periods, with approximately 84 percent of manured acres managed with incorporation at some point in the rotation. The increase in manured acres and the presumed concurrent increase in

Figure 2.3. Average annual percent of cropped acres in each of the subareas receiving manure in the Chesapeake Bay region, 2003-06 and 2011.



	0205	0206	0207	0208	Chesapeake Bay region
2003-06	53	34	43	1	38
2011	61	39	49	16	48

*0205=Susquehanna River Basin; 0206=Upper Chesapeake Bay; 0207=Potomac River Basin; 0208=Lower Chesapeake Bay.

manure users may partially explain the decline in acres utilizing proper manure application techniques on ***all*** crops in rotation. The increase in acres under no-till could also explain this decline in use of appropriate application method. Appropriate manure application includes incorporation into the soil, which is not easily accommodated by no-till systems. Application techniques of knifing or injecting manures could be employed to maintain a low disturbance tillage system, but the manure form would need to be amenable to these technologies. In management systems with manure applications, a mulch-till system may be more appropriate than a no-till system, as mulch-till systems allow light disking of the manure at application.

Phosphorus – Appropriate Rate

Phosphorus is often applied infrequently, with the intent of an application providing phosphorus availability for multiple crops or years. Therefore, although nitrogen rate criteria can be applied to each crop in the rotation, phosphorus application rate criteria apply only to the full crop rotation. The appropriate rate is determined by the sum of all applications over the entire rotation divided by the sum of all crop removal at harvest and should equal 1.2 or less (see discussion at the end of the “Appropriate Rate Criteria” section on page 15). Between 2003-06 and 2011, the following trends related to phosphorus application rates were noted in the Chesapeake Bay region’s cultivated cropland (table 2.8):

- Phosphorus receiving acres on which phosphorus application rate criteria were met: *maintained 2003-06 conservation levels* (54 and 57 percent of cropped acres in 2003-06 and 2011, respectively);
- Phosphorus receiving acres on which phosphorus application rate criteria were ***not*** met: *maintained 2003-06 conservation levels* (46 and 43 percent of cropped acres in 2003-06 and 2011, respectively); and
- Cropped acres with no phosphorus application: *maintained 2003-06 conservation levels* (1 and <1 percent of cropped acres in 2003-06 and 2011, respectively).

Commercial fertilizer was the only source of phosphorus for 2.4 and 2.3 million cropped acres in 2003-06 and 2011, respectively. Between 2003-06 and 2011, the following trends related to phosphorus application rates were noted in the Chesapeake Bay region’s cultivated cropland acres receiving commercial fertilizer as their sole phosphorus source, with no manure inputs (table 2.8):

- Commercial phosphorus receiving acres (no manure inputs) on which phosphorus application rate criteria were met: *8 percentage point improvement*, increased from 68 to 76 percent; and
- Commercial phosphorus receiving acres (no manure inputs) on which phosphorus application rate criteria were ***not*** met: *8 percentage point improvement*, decreased from 32 to 24 percent.

Even though acreage receiving manure inputs as a phosphorus fertilizer source increased from 1.6 to 2.1 million acres, the trends previously noted related to nitrogen application rates and manure adoption were not apparent in the relationship between phosphorus application rates and manure adoption. Between 2003-06 and 2011, the practice of applying manures as a phosphorus source increased from occurring on 40 to 48 percent of phosphorus receiving cropped acres in the region, but there were neither improvements nor declines in phosphorus rate application adherence associated with the adoption of manure as a phosphorus source. Between 2003-06 and 2011, the following trends related to phosphorus application rates were noted in the Chesapeake Bay region’s cultivated cropland acres receiving manure inputs as a phosphorus source, with or without additional commercial fertilizer inputs (table 2.8):

- Manured acres on which phosphorus application rate criteria were met: *maintained 2003-06 conservation levels* (32 and 35 percent of cropped acres in 2003-06 and 2011, respectively); and
- Manured acres on which phosphorus application rate criteria were ***not*** met: *maintained 2003-06 conservation levels* (68 and 65 percent of cropped acres in 2003-06 and 2011, respectively).

In 2003-06 and 2011, 20 and 25 percent of manured cropped acres had nutrient application rates at or below crop removal rates. The continued adherence to this management may indicate an improvement in manure management and adherence to soil test results and/or manure test results for the possibility of reducing soil phosphorus stores.

Phosphorus – Appropriate Timing

Between 2003-06 and 2011, the following trends related to phosphorus application timing were noted in the Chesapeake Bay region's cultivated cropland (table 2.8):

- Cropped acres on which phosphorus application timing criteria were met for ***all*** crops in rotation: *11 percentage point decline*, decreased from 53 to 42 percent;
- Cropped acres on which phosphorus application timing criteria were met for ***some but not all*** crops in rotation: *maintained 2003-06 conservation levels* (34 and 38 percent of cropped acres in 2003-06 and 2011, respectively); and
- Cropped acres on which phosphorus application timing criteria were ***not*** met on ***any*** crop in the rotation: *6 percentage point decline*, decreased from13 and 19 percent.

Between 2003-06 and 2011, the following trends related to phosphorus application timing were noted in the Chesapeake Bay region's cultivated cropland acres receiving commercial fertilizer as their sole phosphorus source, with no manure inputs (table 2.8):

- Commercial phosphorus receiving acres (no manure inputs) on which phosphorus application timing criteria were met on ***all*** crops in rotation: *6 percentage point decline*, decreased from 75 to 69 percent;
- Commercial phosphorus receiving acres (no manure inputs) on which phosphorus application timing criteria were met on ***some but not all*** crops in rotation: *maintained 2003-06 conservation levels* (13 and 18 percent of cropped acres in 2003-06 and 2011, respectively); and
- Commercial phosphorus receiving acres (no manure inputs) on which phosphorus application timing criteria were ***not*** met on ***any*** crop in the rotation: *maintained 2003-06 conservation levels* (12 and 11 percent of cropped acres in 2003-06 and 2011, respectively).

Between 2003-06 and 2011, the following trends related to phosphorus application timing were noted in the Chesapeake Bay region's cultivated cropland acres receiving manure inputs as a phosphorus source, with or without additional commercial fertilizer inputs (table 2.8):

- Manured acres on which phosphorus application timing criteria were met on ***all*** crops in rotation: *maintained 2003-06 conservation levels* (16 and 13 percent of cropped acres in 2003-06 and 2011, respectively);
- Manured acres on which phosphorus application timing criteria were met on ***some but not all*** crops in rotation: *8 percentage point decline*, decreased from 67 to 59 percent; and
- Manured acres on which nitrogen application timing criteria were ***not*** met on ***any*** crop in the rotation: *12 percentage point decline*, increased from 16 to 28 percent.

These results suggest that there is significant opportunity to improve the timing of manure applications, particularly when the manures are being used as a phosphorus source.

Phosphorus – Appropriate Method

Overall, the surveys revealed that there was no significant change in adoption of more or less responsible phosphorus application methods. Between 2003-06 and 2011, the following trends related to phosphorus application methods were noted in the Chesapeake Bay region's cultivated cropland (table 2.8):

- Phosphorus receiving acres on which phosphorus application method criteria were met for ***all*** crops in rotation: *maintained 2003-06 conservation levels* (42 and 37 percent of cropped acres in 2003-06 and 2011, respectively);
- Phosphorus receiving acres on which phosphorus application method criteria were met for ***some but not all*** crops in rotation: *maintained 2003-06 conservation levels* (28 and 30 percent of cropped acres in 2003-06 and 2011, respectively); and
- Phosphorus receiving acres on which nitrogen application method criteria were ***not*** met on ***any*** crop in the rotation: maintained 2003-06 conservation levels (30 and 32 percent of cropped acres in 2003-06 and 2011, respectively).

Phosphorus application method management in systems with only commercial phosphorus sources and no inclusion of manures improved slightly between 2003-06 and 2011. Between 2003-06 and 2011, the following trends related to phosphorus application method were noted in the Chesapeake Bay region's cultivated cropland acres receiving commercial fertilizer as their sole phosphorus source, with no manure inputs (table 2.8):

Table 2.8. Phosphorus management practices and percent cropped acres within each category for the Chesapeake Bay region, 2003-06 and 2011.

Phosphorus*	**2003-06 acres**	**2011 acres**	**2003-06 percent**	**2011 percent**
No P applied to any crop in rotation	43,000	0	1	0
For acres where P is applied:			99	100
Commercial Fertilizer Only	2,414,000	2,264,000		
Manure with or without Commercial Fertilizer	1,608,000	2,089,000		
Rate of application:				
Acres receiving commercial fertilizer and/or manure applications:				
Rotation meets the phosphorus rate criteria described in text			54	57
Rotation does not meet the phosphorus rate criteria described in text			46	43
Acres receiving commercial fertilizer applications only:				
Rotation meets the phosphorus rate criteria described in text			68	76
Rotation does not meet the phosphorus rate criteria described in text			32	24
Acres receiving manure with or without commercial fertilizer applications:				
All crops in rotation meet the phosphorus rate criteria described in text			32	35
Some but not all crops in rotation meet the phosphorus rate criteria described in text			68	65
Time of application:				
Acres receiving commercial fertilizer and/or manure applications:				
All applications of phosphorus fertilizer less than 21 days before planting			53	42
Some but not all applications of phosphorus fertilizer within 21 days before planting			34	38
No applications of phosphorus fertilizer within 21 days before planting			13	19
Acres receiving commercial fertilizer applications only:				
All applications of phosphorus fertilizer less than 21 days before planting			75	69
Some but not all applications of phosphorus fertilizer within 21 days before planting			13	18
No applications of phosphorus fertilizer within 21 days before planting			12	11
Acres receiving manure with or without commercial fertilizer applications:				
All applications of phosphorus fertilizer less than 21 days before planting			16	13
Some but not all applications of phosphorus fertilizer within 21 days before planting			67	59
No applications of phosphorus fertilizer within 21 days before planting			16	28
Method of application:				
Acres receiving commercial fertilizer and/or manure applications:				
All applications of phosphorus include incorporation or banding/foliar/spot treatment			42	37
Some but not all applications of phosphorus include incorporation or banding/foliar/spot treatment			28	30
No applications of phosphorus include incorporation or banding/foliar/spot treatment			30	32
Acres receiving commercial fertilizer applications only:				
All applications of phosphorus include incorporation or banding/foliar/spot treatment			51	53
Some but not all applications of phosphorus include incorporation or banding/foliar/spot treatment			19	26
No applications of phosphorus include incorporation or banding/foliar/spot treatment			31	22
Acres receiving manure with or without commercial fertilizer applications:				
All applications of phosphorus include incorporation or banding/foliar/spot treatment			28	21
Some but not all applications of phosphorus include incorporation or banding/foliar/spot treatment			42	35
No applications of phosphorus include incorporation or banding/foliar/spot treatment			30	44
Timing and method and rate of application (excludes acres not receiving phosphorus):				
All applications meet the phosphorus rate criteria described in text and application within 3 weeks before planting with incorporation or banding/foliar/spot treatment			22	21
Some but not all applications meet the phosphorus rate criteria described in text or application within 3 weeks before planting with incorporation or banding/foliar/spot treatment			78	79
Nitrogen *and* Phosphorus				
Crop rotation P rate and N rate criteria described in text and all applications within 3 weeks before planting with incorporation or banding/foliar/spot treatment, including acres with no N or P applied			8	5

Note: Percents may not add to 100 because of rounding.

* These estimates include adjustments made to the reported data on nitrogen and phosphorus application rates from the survey because of missing data and data entry errors. In the case of phosphorus, the 3-year data period for which information was reported was too short to pick up phosphorus applications made at 4- and 5-year intervals between applications, which is a common practice for producers adhering to sound phosphorus management techniques. Since crop growth, and thus canopy development which decreases erosion, is a function of nitrogen and phosphorus, it was necessary to add additional phosphorus when the reported levels were insufficient to support reasonable crop yields throughout the 52 years in the model simulation. (For additional information on adjustment of nutrient application rates, see "Adjustment of CEAP Cropland Survey Nutrient Application Rates for APEX Modeling," available at http://www.nrcs.usda.gov/technical/nri/ceap).

- Commercial phosphorus receiving acres (no manure inputs) on which phosphorus application method criteria were met on ***all*** crops in rotation: *maintained 2003-06 conservation levels* (51 and 53 percent of cropped acres in 2003-06 and 2011, respectively);
- Commercial phosphorus receiving acres (no manure inputs) on which phosphorus application method criteria were met on ***some but not all*** crops in rotation: *7 percentage point improvement*, increased from 19 to 26 percent; and
- Commercial phosphorus receiving acres (no manure inputs) on which phosphorus application method criteria were ***not*** met on ***any*** crop in the rotation: *9 percentage point improvement*, declined from 31 to 22 percent.

Phosphorus application method management in manured systems did not improve between 2003-06 and 2011. Between 2003-06 and 2011, the following trends related to phosphorus application methods were noted in the Chesapeake Bay region's cultivated cropland acres receiving manure inputs as a phosphorus source, with or without additional commercial fertilizer inputs (table 2.8):

- Manured acres on which phosphorus application method criteria were met on ***all*** crops in rotation: *7 percentage point decline,* decreased from 28 to 21 percent;
- Manured acres on which phosphorus application method criteria were met on ***some but not all*** crops in rotation: *7 percentage point decline,* decreased from 42 to 35 percent; and
- Manured acres on which nitrogen application timing criteria were ***not*** met on ***any*** crop in the rotation: *14 percentage point decline,* increased from 30 to 44 percent.

These results indicate a significant need for improving manure application methods.

Nitrogen and Phosphorus Management – Rate, Timing, and Method

The avoidance component of the ACT strategy is partially achieved through appropriate nutrient application management, including the 4R's (right *rate*, right *timing*, right *method,* and right *form* of application). Nutrient application management planning and actuation did not see the significant gains accomplished in the adoption of Control and Trap practices. However, there was a generally positive trend in the observed decline of acreage on which ***no*** crops in rotation had appropriate rate, timing, or method of nutrient application. There was also a trend towards a slight decline in acres on which ***all*** crops in rotation received appropriate rate, timing, or method of nutrient application. While most acres have evidence of some nitrogen or phosphorus management, the majority of the acres in the region lack consistent use of the 4R's on each crop in every year of production. This is especially true for manured acres, on which the 4R's are not being met through comprehensive nutrient management plans. Between 2003-06 and 2011, the following trends related to achieving right rate, right timing, and right method of nutrient application were noted in the Chesapeake Bay region's cultivated cropland acres (tables 2.7 and 2.8):

- Nitrogen receiving acres on which ***all*** crops were managed with the right nitrogen rate, timing, and method: *6 percentage point decline,* decreased from 13 to 7 percent;
- Nitrogen receiving acres on which ***some but not all*** of the 4R's were met: *6 percentage point improvement*, increased from 87 to 93 percent;
- Phosphorus receiving acres on which ***all*** crops were managed with the right phosphorus rate, timing, and method: *maintained 2003-06 conservation levels* (22 and 21 percent of cropped acres in 2003-06 and 2011, respectively);
- Phosphorus receiving acres on which ***some but not all*** of the 4R's were met: *maintained 2003-06 conservation levels* (78 and 79 percent of cropped acres in 2003-06 and 2011, respectively); and
- Nutrient receiving acres on which ***all*** crops were managed with the right rate, timing, and method for ***both nitrogen and phosphorus***: *maintained 2003-06 conservation levels* (8 and 5 percent of cropped acres in 2003-06 and 2011, respectively).

A number of factors may contribute to current challenges in nutrient application management. First, cropped acres receiving manure increased from 38 to 48 percent between 2003-06 and 2011 (fig. 2.3). The negative trends in timing and method of manure application may be the result of traditional manure users applying manure to more acres. The greater time requirement associated with spreading manure on more acres may inhibit their ability to meet application timing criteria. Also, new manure users may be adjusting to managing this new nutrient source. Further complicating the issue of responsible manure management is the widespread adoption of conservation tillage systems. No-till systems in particular require changes in form and/or method of manure application in order to maintain a no-till system while also meeting responsible manure application criteria. A number of technologies and methodologies have been developed to reduce soil disturbance associated with manure incorporation. For example, a no-till system is compatible with injected liquid manures. Alternatively, light disking associated with mulch-till systems would allow the farmer to maintain a conservation tillage system while also meeting the incorporation needs of manures. This approach would keep soil disturbance at a minimum while still incorporating manure, thus reducing the risk of nutrient loss. A final factor potentially complicating nutrient management in the region is the widespread adoption of new cropping systems (table 2.3, 2.5, and 2.6).

Nutrient Application Management Treatment Levels

Four treatment levels indicating management intensity for nitrogen and phosphorus were derived to enable evaluation of nutrient management levels in the Chesapeake Bay region during both survey periods. Management treatment levels combined with soil risk classes were used to construct conservation treatment levels, which estimate under-treated acres and treatment needs in chapter 4. Criteria for the scoring system for determining treatment levels are presented in Appendix D.

The same scoring classification was used in classifying the level of nutrient application management in place during each survey period. This scoring and evaluation system differs from the previous report's evaluation process and therefore the classification of acres will not be directly comparable between this and the original Chesapeake Bay region CEAP report (USDA NRCS 2011). This new classification system applies a score for rate, timing, and method. The classification method accommodates manure and commercial fertilizer management and allows for split applications. Although it is not discussed in this report, the appropriateness of the form of nutrient being delivered should be considered in conjunction with rate, method, and timing of nutrient application in the development of sound nutrient management plans. The choice of form is often dictated by the farm operation and economics. The maximum score is 60 points, with 20 potential points in each category (rate, timing, and method) (Appendix D). Treatment level scores are as follows:

- **High**: 45 or more points; represents acres with nutrient management meeting or exceeding management criteria in each of the three scoring categories;
- **Moderately High**: Less than 45 points but more than or equal to 30 points; requires that management in at least 1 category meets or exceeds acceptable criteria;
- **Moderate**: Less than 30 points but more than or equal to 20 points; generally requires rate, timing, or method management score to be at or near appropriate levels; and
- **Low**: Less than 20 points; management in no category meets the criteria to qualify as appropriate application management.

In reference to nitrogen fertilizer applications, the percent of cropped acres with ***high*** (5 and 6 percent of cropped acres in 2003-06 and 2011, respectively) and ***low*** (21 and 20 percent of cropped acres during 2003-06 and 2011, respectively) levels of conservation practices for nitrogen application management were maintained at 2003-06 levels during both survey periods (fig. 2.4). Acreage receiving ***moderately high*** nitrogen application management declined by 11 percent, decreasing from 39 to 28 percent of cropped acres between 2003-06 and 2011. Concurrently, acreage receiving ***moderate*** levels of treatment increased from 34 to 47 percent of cropped acres between 2003-06 and 2011 (fig. 2.4).

As noted in table 2.7, relative to 2003-06, nitrogen application management in 2011 was less consistent in application of appropriate rates, timing, and method for ***all*** crops in rotation on a given acre. The increase in acres with manure application providing nitrogen inputs between 2003-06 and 2011 appears to be a driver of this decline. Non-manured acres with ***moderately high*** treatment levels declined from 33 to 22 percent of acres between 2003-06 and 2011. This 11 percentage point decline occurred at the same time manured acres with ***moderate*** treatment levels of nitrogen application management experienced an 11 percentage point increase (fig. 2.4)

Between 2003-06 and 2011, acres receiving ***low*** levels of nitrogen application management remained constant, whether manured (16 and 15 percent of cropped acres in 2003-06 and 2011, respectively) or non-manured (5 percent in both survey periods). Similarly, acres receiving ***high*** levels of nitrogen application management remained constant, whether manured (<1 and 1 percent of cropped acres in 2003-06 and 2011, respectively) or non-manured (5 percent in both survey periods).

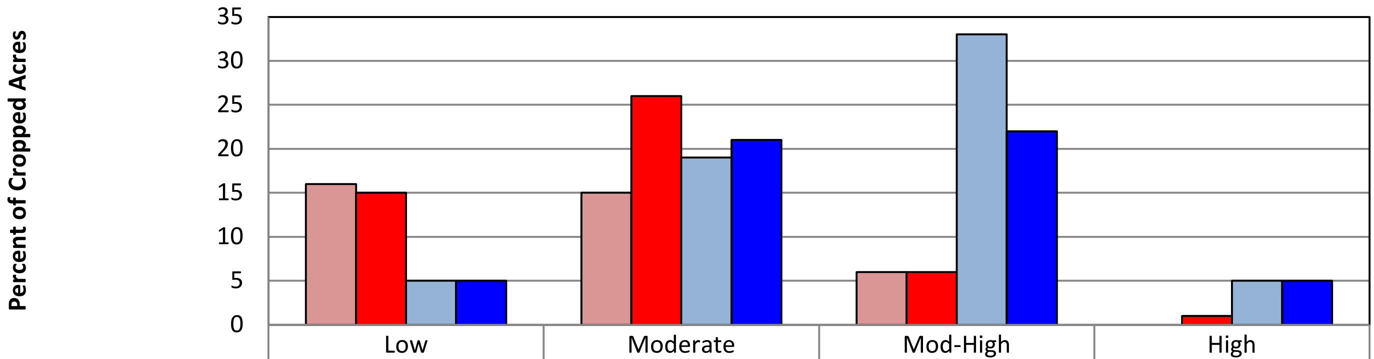
Phosphorus application management did not change appreciably between the two survey periods (fig. 2.5). Overall, the percent of cropped acres were ***high*** (24 and 27 percent of cropped acres in 2003-06 and 2011, respectively), ***moderate*** (19 and 18 percent of cropped acres in 2003-06 and 2011, respectively), and ***low*** (19 and 22 percent of cropped acres in 2003-06 and 2011, respectively). Levels of conservation practices for phosphorus application management were maintained at 2003-06 levels during both survey periods (fig. 2.3). Acreage receiving ***moderately high*** phosphorus application management declined by 6 percent, decreasing from 38 to 32 percent of cropped acres between 2003-06 and 2011. The only change noted in non-manured acreage phosphorus application management occurred in the ***moderately high*** treatment category, where acreage declined 7 percentage points, from 28 to 21 percent of all cropped acres. Phosphorus application management of manured acres did not change between the two survey periods (fig. 2.5). The ability to maintain 2003-06 conservation levels could be considered a positive outcome, considering the 10 percent increase in manured acres that occurred between the two survey periods (fig. 2.3).

Manure Management

The 2011 data in the Chesapeake Bay CEAP analysis indicate both increased manure application in the Chesapeake Bay region and a complementary increased awareness of nutrient management concerns associated with manure application. However, as noted in the previous sections on nutrient management trends, opportunity remains to improve adoption of consistent and proper nutrient application management plans.

In 2011, the percent of acres on which manure was used as a nutrient source increased or were maintained at 2003-06 levels in each of the four subregions of the Chesapeake Bay region (fig. 2.3). The basin with the highest percentage of acres receiving manure applications is the Susquehanna River Basin (subregion 0205), in which manure use increased from occurring on 53 to 61 percent of cropped acres between 2003-06 and 2011 (fig. 2.3). The largest change in manure adoption was seen in the Lower Chesapeake Bay subregion (0208), where manured acreage increased from 1 to 16 percent of cropped acres between 2003-06 and 2011. Still, the Lower Chesapeake Bay subregion remains the subregion with the fewest manured acres and the lowest percent of cropped acres receiving manure.

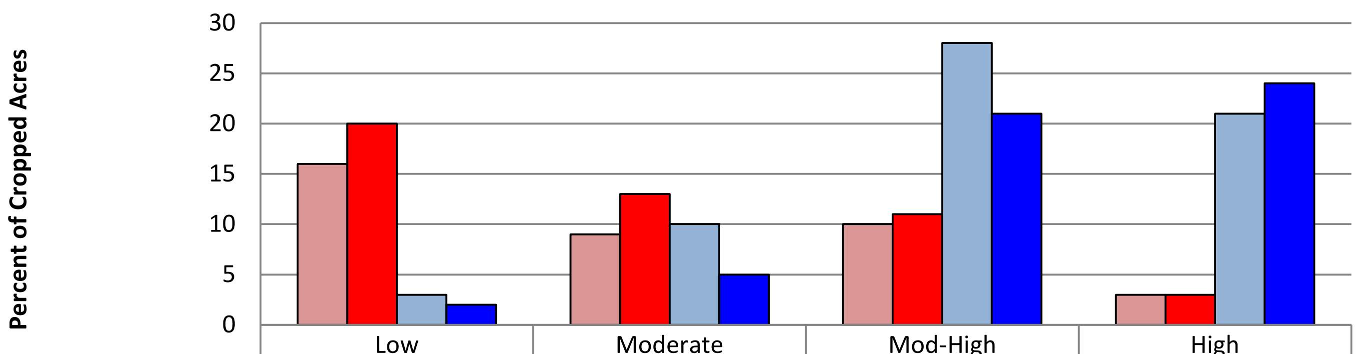
Figure 2.4. Conservation treatment levels for nitrogen application management level in the Chesapeake Bay region, 2003-06 and 2011.



	Low	Moderate	Mod-High	High
2003-06 Manured	16	15	6	0
2011 Manured	15	26	6	1
2003-06 No Manure	5	19	33	5
2011 No Manure	5	21	22	5

*See Appendix D for explanation of criteria delineating the four levels of nitrogen management intensity, Low, Moderate, Moderately High (Mod-High), and High.

Figure 2.5. Conservation treatment levels for phosphorus application management level in the Chesapeake Bay region, 2003-06 and 2011.



	Low	Moderate	Mod-High	High
2003-06 Manured	16	9	10	3
2011 Manured	20	13	11	3
2003-06 No Manure	3	10	28	21
2011 No Manure	2	5	21	24

*See Appendix D for explanation of criteria delineating the four levels of phosphorus management intensity, Low, Moderate, Moderately High (Mod-High), and High.

In 2003-06, 13.4 million tons of manure was applied in one or more years of the crop rotation to 38 percent of the cropped acres in the Chesapeake Bay region (1.6 million acres) (fig. 2.3). By 2011, the amount of manure applied had increased to 22.1 million tons and the acreage receiving manure had increased to 48 percent of the cropped acres in the Chesapeake Bay region (2.1 million acres). This change is calculated on a weight basis rather than on the basis of the nutrient content of the applied manure.

The 65 percent increase in total tons of manure applied between 2003-06 and 2011 occurred with a trend toward fluid manure applications. Manure in liquid form accounted for 26 percent of total manure applied in 2003-06 and 42 percent of the total in 2011.

Manure application rates also increased between 2003-06 and 2011, rising from an average application rate of 12.6 to 16.8 tons per acre per year, respectively. The average per acre amount of nitrogen applied as manure increased by 13 percent, rising from 22.0 to 24.8 pounds per acre between 2003-06 and 2011. The average per acre application of phosphorus applied as manure increased by 10 percent, rising from 3.7 to 4.1 pounds per acre between 2003-06 and 2011.

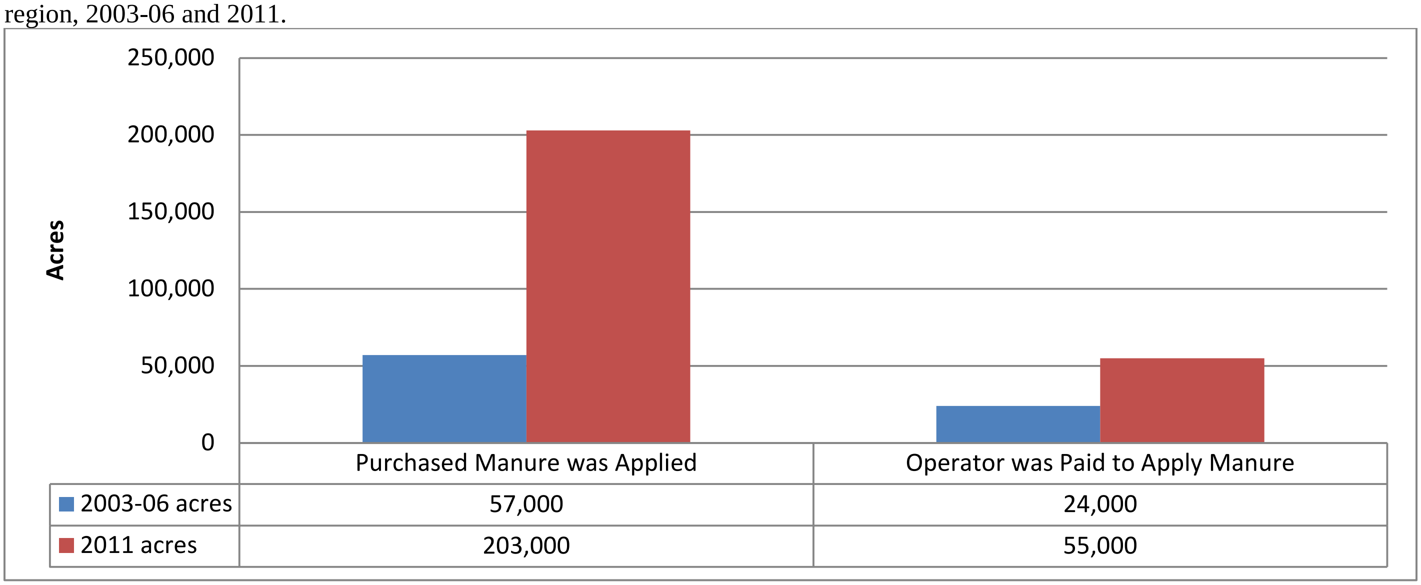
Manure from livestock producers is being spread on more acres and in particular, on off-farm acres. In this context, off-farm acres are those cropped acres on farms where manure is not produced. While acreage receiving manure increased by half a million acres, acreage receiving manure produced on-farm actually decreased slightly, falling from 883,000 acres in 2003-06 to 865,000 acres in 2011. The cropped acres receiving manure from on-farm sources represented 83 percent of the total manured acres in 2003-06, but only 66 percent in 2011. The number of manured acres on which the operator purchased manure nearly quadrupled between 2003-06 and 2011, rising from 57,000 acres to 203,000 acres (fig. 2.6).

Additionally, the region saw a doubling of manured acres on which the operator was paid to apply manure; these rose from 24,000 to 55,000 acres between 2003-06 and 2011 (fig. 2.6). The proportion of manured acres where tested manures were applied increased from 15 percent (154,000 acres) in 2003-06 to 37 percent (488,000 acres) in 2011. There have been a vigorous education campaigns in the past decade in the Chesapeake Bay region to encourage operators to do better phosphorus management, which would at least in part account for lower phosphorus application rates per acre in 2011 with tested manure.

In the Chesapeake Bay region, the percent of acres being applied with manure according to a requirement or standard increased from 14 to 42 percent between 2003-06 and 2011. Of the 14 percent of manured acres receiving manure according to a requirement or standard in 2003-06, 36 percent had manure applied at a nitrogen standard and 14 percent had manure applied at a phosphorus standard. In 2011, only 16 percent of manured acres had manure applied at a nitrogen standard, but 24 percent applied manure at a phosphorus standard. Both the increase in acres receiving manure according to a requirement or standard in 2011, and the increase of acres applying manure according to a phosphorus analysis during the same period signal a concerted effort to address nutrient management concerns in the Chesapeake Bay (fig. 2.5).

In the 2011 survey, operators were asked for the soil test phosphorus level in the field if the manure was applied according to a requirement or standard. Responses indicate that 25 percent of acres receiving manure in 2011 according to a requirement or standard had a soil test to determine the phosphorus level before manure was applied. However, this question was not included in the 2003-06 survey, so no trend could be noted.

Figure 2.6. Cropland acres where manure was purchased or where the operator was paid to apply manure in the Chesapeake Bay region, 2003-06 and 2011.



Chapter 3
Onsite (Field-Level) Effects of Conservation Practices

Relative to the original Chesapeake Bay region CEAP report (USDA NRCS 2011), this report applies an updated version of the APEX model, revised soils data, a different soil erosion equation, new weather data, and improved methods of accounting for conservation practices. To enable comparisons between the 2003-06 baseline conditions and the 2011 conservation conditions, the 2003-06 data and the 2011 data were each analyzed with the same constraints under the improved modeling system. Because of these changes, the data analyses for 2003-06 data produced different values than those reported in the original Chesapeake Bay region CEAP report (USDA NRCS 2011).

The use of cover crops was the most significant change in conservation practice adoption in the region, increasing from use on only 12 to 52 percent of cultivated cropland acres in 2003-06 and 2011, respectively. Cover crops are a unique conservation practice in that they impact both surface and subsurface loss pathways by reducing runoff and scavenging excess nutrients from previous crops. However, cover crops, like any singular conservation practice, are not a panacea. The efficacy of cover crops for reducing subsurface losses is highly dependent upon their frequency of use, other conservation and management practices applied, and the hydrologic properties of the soil in which they are grown. Unless they are paired with a responsible nutrient application plan, cover crops are less effective in the near term on soils with an inherently high leaching potential because these soils quickly lose applied nutrients to the environment when they are not utilized by the primary crop or are lost before the cover is planted. Coarse textured soils with high leaching potentials are especially benefited by consistent cover crop use and reduced tillage, two complementary management techniques that improve the soils' ability to retain water and nutrients.

Because of the importance of cover crop use in this region a model scenario was developed to assess the effects of cover crop application frequency on the overall benefits of the practice. Specifically the scenario considered the added benefit cover crops provide related to reduction of sediment and nutrient losses, as well as the improvements in soil organic carbon. The simulated losses under the 2011 conservation condition were compared to a scenario in which all 2011 conservation practices were maintained with the exception of cover crop application. This assumes that farmers surveyed in 2011 did not alter any other crop field operations or plant dates in the absence of cover crops. The estimated increased benefit is an average across a variety of soil types and suites of conservation systems employed with the cover crops. The improvement attributable to cover crops regarding the reduction of sediment, nitrogen, and phosphorus losses, as well as the changes in soil carbon dynamics are discussed in each loss pathway's section.

The Field-Level Cropland Model—APEX

A physical process-based model, the Agricultural Policy Environmental eXtender (APEX), was used to simulate long-term effects of conservation practice adoption at the field scale (Williams et al. 2006; Williams et al. 2008; Gassman et al. 2009 and 2010).[1] The I_APEX model run management software, developed at the Center for Agricultural and Rural Development (Iowa State University), was used to perform the simulations in batch mode.[2]

The APEX model is a field-scale, daily time-step model able to simulate interactions between weather, farming operations, crop growth and yield, and the movement of water, soil, carbon, nutrients, sediment, and pesticides (fig. 3.1). APEX and its predecessor, EPIC (Environmental Policy Impact Calculator), have a long history of use in simulation of agricultural and environmental processes and the effect of agricultural technology and government policy on natural resources (Izaurralde et al. 2006; Williams 1990; Williams et al. 1984; Gassman et al. 2009).[3]

APEX simulates the effects of farming operations such as planting; tillage; application of commercial fertilizers, manures, and pesticides; irrigation; and harvest operations. Daily weather events and their interaction with crop cover and soil properties are simulated on a daily basis to realistically affect simulated crop growth and the fate and transport of water and chemicals through the soil profile and over land to the edge of the field. The model transforms crop residue remaining on the field after harvest into organic matter, which the model may degrade quickly or allow to build up in the soil over time, depending on the residue quality, tillage system, and site-specific conditions.

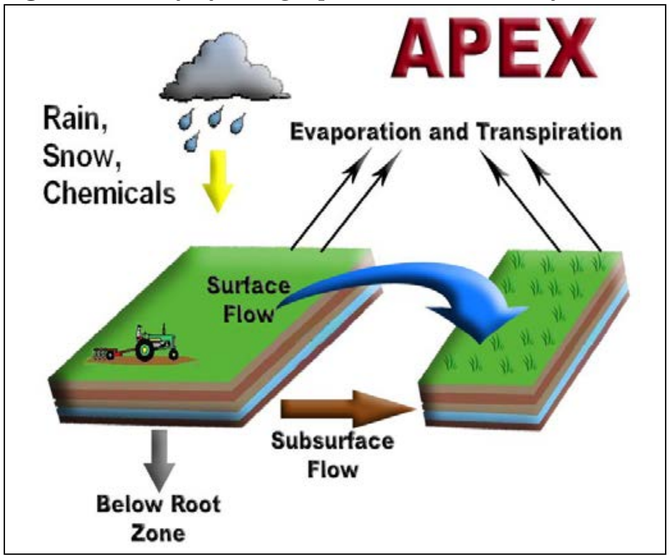
APEX also simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions on a daily time-step. Simulated soil erosion includes wind erosion, sheet and rill erosion, and the loss of sediment beyond the edge of the field. The nitrogen, phosphorus, and carbon cycles are simulated, including chemical transformations in the soil that affect nutrient availability for plant growth or for transport from the field. Gaseous exchange between the soil and the atmosphere is simulated, including losses of gaseous nitrogen.

[1] The full theoretical and technical documentation of APEX can be found at http://epicapex.brc.tamus.edu/downloads/user-manuals.aspx.

[2] The I_APEX software steps through the simulations one at a time, extracting the needed data from the Access input tables, executes APEX, and then stores the model output in Access output files. The Web site for that software is http://www.card.iastate.edu/environment/interactive_programs.aspx.

[3] Summaries of APEX model validation studies on how well APEX simulates measured data are presented in Gassman et al. (2009) and in "APEX Model Validation for CEAP" found at http://www.nrcs.usda.gov/technical/nri/ceap.

Figure 3.1. Daily hydrologic processes simulated by APEX.



Effects of Practices on Fate and Transport of Water

The hydrologic conditions of cropped acres in the Chesapeake Bay region interact with or drive the estimates of sediment and nutrient losses from these agroecological systems. The APEX model simulates hydrologic processes at the field scale, accounting for precipitation, irrigation, evapotranspiration, surface water runoff, infiltration, and percolation beyond the bottom of the soil profile.

Precipitation, sometimes supplemented by irrigation, supplies water to cropped acres. Annual precipitation used in the 52-year simulation averaged about 42 inches across the Chesapeake Bay region (table 3.1). Annual precipitation ranged from 34 to 46 inches per year, with some points experiencing up to 68 inches in wet years and other points experiencing as little as 26 inches during dry years. Approximately 5 and 6 percent of cropped acres were irrigated in 2003-06 and 2011, respectively. Between 2003-06 and 2011, the estimated per acre irrigation rate decreased by 7 percent, dropping from an average of 7.5 to 7.0 inches of irrigation water applied per acre per year (table 3.1).

Evapotranspiration, a combination of evaporation and transpiration by which water is lost to the atmosphere, remains the dominant water loss pathway for cropped acres in the Chesapeake Bay region (table 3.1). Evapotranspiration accounted for 57 and 58 percent of water losses from cropped acres in 2003-06 and 2011, respectively. On average, transpiration losses totaled 24.2 and 24.9 inches of water per acre per year in 2003-06 and 2011, respectively. Variability in soil characteristics, irrigation method, precipitation, and land cover characteristics all contribute to variability in evapotranspiration-driven per acre losses.

Structural water erosion control practices, residue management practices, and conservation tillage slow the flow of surface water, reducing runoff losses and allowing water to infiltrate into the soil. This water is available to plants as it passes through the root zone. However, the re-routed water, previously vulnerable to loss via surface flow, becomes vulnerable to loss via subsurface flow pathways. Subsurface flow pathways include: (1) deep percolation to groundwater, including groundwater return flow to surface water; (2) subsurface flow into a tile or ditch drainage system; (3) lateral subsurface outflow; and (4) quick-return subsurface flow.

Conservation practices did not appreciably reduce overall water losses, although the simulations suggest that dominant water loss pathways have shifted due to conservation adoption. Without any conservation practices in place, model simulations suggest surface water runoff from cropped acres in the region would average 10.1 inches per acre per year (24 percent of all water losses) and subsurface losses would average 8.4 inches per acre per year (20 percent of all water losses). Under conservation conditions of 2003-06 and 2011, surface water runoff accounted for roughly 21 percent (8.8 inches per acre per year) and 20 percent (8.5 inches per acre per year) of water losses from cropped acres, respectively (table 3.1). Relative to the no-practice scenario, the surface-runoff reducing practices in place in 2003-06 and 2011 decreased surface losses by 13 percent (1.3 inches per acre per year) and 16 percent (1.6 inches per acre per year), respectively. Subsurface flow losses accounted for 23 percent (9.6 inches per acre per year) and 22 percent (9.3 inches per acre per year) of all water losses from cropped acres in 2003-06 and 2011, respectively (table 3.1).

The reductions in surface losses were accomplished at the cost of simultaneously increasing subsurface losses by 14 percent (1.2 inches per acre per year) and 11 percent (0.9 inches per acre per year), in 2003-06 and 2011, respectively.

The distribution of water losses via surface runoff (fig. 3.2) and subsurface flow (fig.3.3) show the variability of these two flow paths across the region's variable soil types, cropping systems, and conservation efforts.

Effects of Practices on Water Erosion and Sediment Loss

Soil erosion and sedimentation are separate but interrelated resource concerns. Soil erosion is the detachment and transport of soil particles in the field, while sedimentation describes the portion of the eroded material that settles in areas onsite or offsite. Sediment loss describes the sediment transported beyond the edge of the field by water. For the purposes of this report, the "field" includes the cropped portion of the field and any edge-of-field filtering and buffering conservation practices. Controlling sheet and rill erosion helps prevent sediment loss and sustain soil productivity.

Table 3.1. Field-level effects of conservation practices on water loss pathways on cropped acres in the Chesapeake Bay region: the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.

Model simulated outcome on cropped acres	No-practice Scenario	2003-06 Baseline	2011 Condition	Reduction: No-practice to 2003-06	Reduction: 2003-06 to 2011
Water sources					
Non-irrigated acres					
Average annual precipitation (inches)	42.3	42.3	42.3		
Irrigated acres					
Average annual precipitation (inches)	42.7	42.7	43.1		
Average annual irrigation water applied(inches)*	7.5	7.5	7.0		
Water loss pathways					
Average annual evapotranspiration (inches)	24.3	24.2	24.9	0.03	-0.7***
Average annual surface water runoff (inches)	10.1	8.8	8.5	1.3	0.3
Average annual subsurface water flows (inches) **	8.4	9.6	9.3	-1.2	0.3

* Irrigation practices remained fairly constant between the two surveys. Irrigation was practiced on 5 and 6 percent of the cropped acres in the Chesapeake Bay region in 2003-06 and 2011, respectively.

** Subsurface flow pathways include: (1) deep percolation to groundwater, including groundwater return flow; (2) subsurface flow into a drainage system; (3) lateral subsurface outflow; and (4) quick-return subsurface flow.

*** Negative values connote an increase in losses rather than a reduction in losses. For example, this suggests an average increase in evapotranspiration losses of 0.7 inch per year (3 percent increase) for cropped acres due to the changes in conservation practices between 2003-06 and 2011.

Figure 3.2. Estimates of long-term average annual surface runoff losses of water on cropped acres in the Chesapeake Bay region: the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.

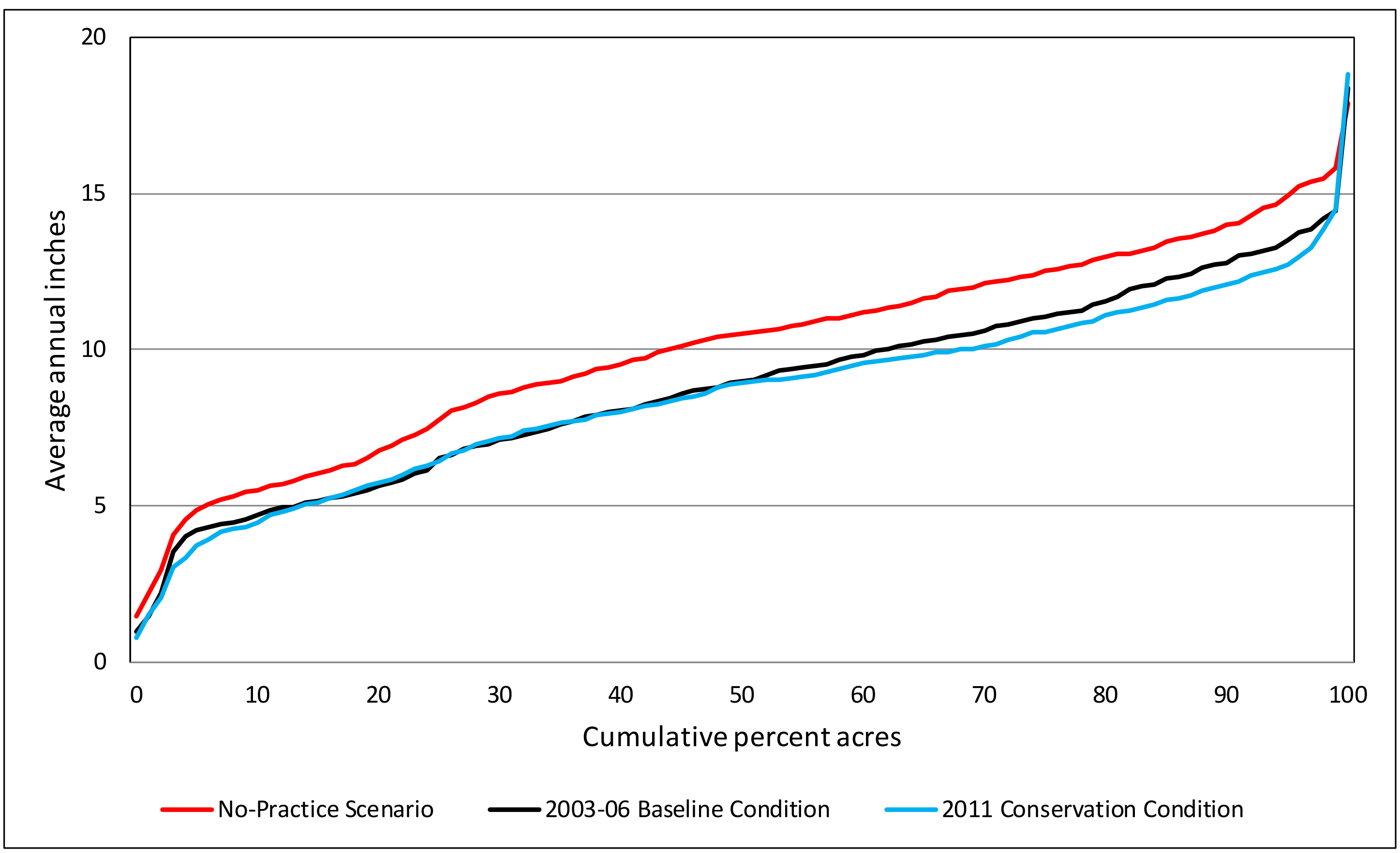
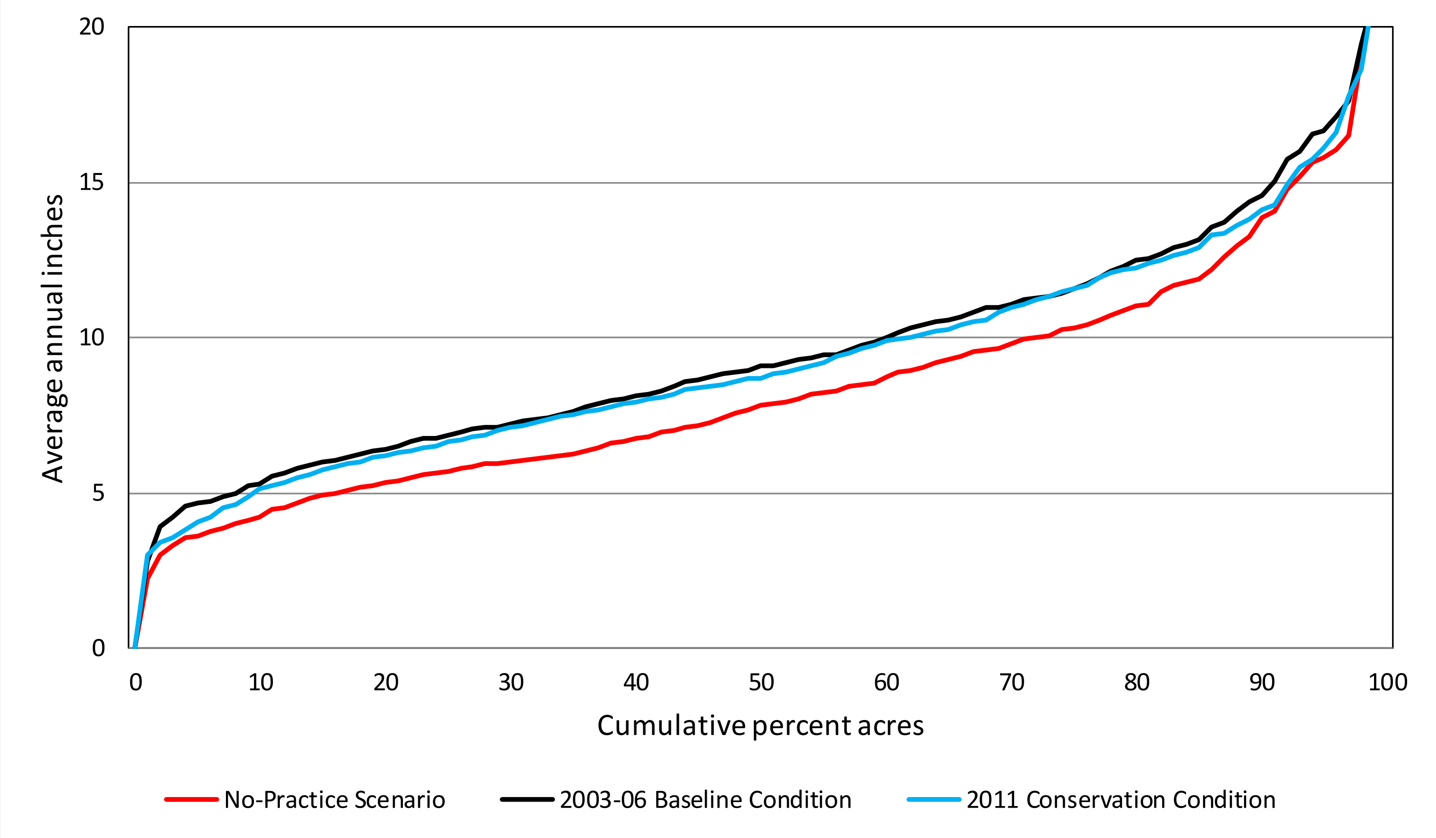


Figure 3.3. Estimates of long-term average annual subsurface flow losses of water on cropped acres in the Chesapeake Bay region: the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.



Sediment loss, as estimated in this study, includes the portion of the sheet and rill eroded material that settles offsite, as well as sediment that originates from ephemeral gully erosion processes.[4] Sediment is composed of detached and transported soil particles, organic matter, plant and animal residues, and associated chemical and biological compounds, including nutrients.

The full set of 2007 NRI points for cropped acres in this region and the sample set from 2011 indicate slightly more than 40 percent of the acres (1.75 million) are classified as highly erodible land (HEL). The 2003-06 survey documented 44 percent HEL acres, which is within the margin of error. Most of the HEL acres are located in the Appalachian Highlands physiographic region (including the Piedmont province, Appalachian Plateaus province, and Allegheny Mountain section), where relatively shallow cropped soils tend to occur on moderately sloping to steep landscapes. In these more vulnerable landscapes, annual sediment losses can vary considerably due to variability in storm intensity and length of weather events.

[4] For this study, the APEX model was set up to estimate sediment loss using a modified version of USLE, called MUSLE, which uses an internal sediment delivery ratio to estimate the amount of eroded soil that actually leaves the boundaries of the field. A large percentage of the eroded material is redistributed and deposited within the field or trapped by buffers and other conservation practices and does not leave the boundary of the field, which is taken into account in the sediment delivery calculation. The estimate also includes some ephemeral gully erosion. For this reason, sediment loss rates can exceed sheet and rill erosion rates.

Sheet and rill erosion

Traditional conservation planning efforts to control sheet and rill erosion focus on achieving a calculated soil loss tolerance (T). The T value represents the maximum annual soil loss rate at which current production levels are sustainable. Simulations show that between 2003-06 and 2011, conservation efforts made gains in reducing the incidences of field erosion losses greater than T. Cropland on which losses greater than T occurred were reduced from 28 to 11 percent of cropped acres between 2003-06 and 2011 (table 3.2 and fig. 3.4). These conservation gains were driven largely by the significant reduction of HEL acres on which sheet and rill erosion exceeded T, which dropped from 57 to 19 percent of HEL acres between 2003-06 and 2011(table 3.2 and fig. 3.4).

Relative to a no-practice scenario, model simulations suggest that conservation practices adopted in 2003-06 reduced sheet and rill erosion by 51 percent, an average reduction of 3.9 tons per acre per year. Relative to 2003-06 losses, conservation practices adopted in 2011reduced sheet and rill erosion by an additional 59 percent, an average reduction of 2.2 tons per acre per year (table 3.3). In 2003-06, the 10 percent of cropped acres most affected by sheet and rill erosion were losing more than 10 tons of soil per acre per year. By 2011, only 3 percent of acres were losing more than 10 tons of soil per year to sheet and rill erosion.

Table 3.2. Assessment of sheet and rill erosion based on T.

		2003-06 Acres (1,000's)	2011 Acres (1,000's)	2003-06 Percent of Acres	2011 Percent of Acres
NHEL	≤T	2,468.1	2,467.2	86	95
NHEL	>T	394.6	141.7	14	5
NHEL	all	2,862.7	2,608.9		
HEL	≤T	611.1	1,412.1	43	81
HEL	>T	806.1	332.4	57	19
HEL	all	1,417.2	1,744.5		
All	≤T	3,079.2	3,879.3	72	89
All	>T	1,200.7	474.1	28	11
All	All	4,279.9	4,353.4		

Note: Erosion estimates were made with RUSLE2, within APEX. HEL are highly erodible acres; NHEL are non-highly erodible acres. The full set of NRI points for cropped acres in this region indicates slightly more than 40 percent of the acres are classified as HEL.

Simulations show that relative to a no-practice scenario, 2003-06 conservation practices reduced sheet and rill erosion losses on highly erodible land (HEL) by 53 percent (8.7 tons per acre per year) and on non-highly erodible land (NHEL) by 50 percent (1.6 tons per acre per year) (table 3.3). Relative to the 2003-06 conservation condition, the additional practices adopted in 2011 reduced sheet and rill erosion losses on HEL by 66 percent (5.0 tons per acre per year) and on NHEL by 50 percent (0.8 ton per acre per year).

Sediment loss due to water erosion

Reductions in sediment loss due to conservation practices are much higher for some acres than others, reflecting both the variability in the level of treatment applied and differences in the inherent erodibility of the soil. Relative to a no-practice scenario, model simulations suggest that conservation practices adopted in 2003-06 reduced sediment losses by 54 percent, an average reduction of 6.0 tons per acre per year. Relative to 2003-06 losses, conservation practices adopted in 2011 reduced edge-of-field sediment losses by an additional 63 percent, an average reduction of 3.2 tons per acre per year (table 3.3). Model simulations show that under 2003-06 baseline conditions, 59 percent of cropped acres lost less than 2 tons of sediment per acre per year and the 10 percent of cropped acres with the worst sediment loss problems lost more than 15.7 tons of sediment per acre per year. Under the 2011 conservation condition, 83 percent of cropped acres lost less than 2 tons of sediment per acre per year and only 3 percent of cropped acres lost more than 15.7 tons of sediment per acre per year.

Simulations show that relative to a no-practice scenario, 2003-06 conservation practices reduced sediment losses on highly erodible land (HEL) by 56 percent (14.0 tons per acre per year) and on non-highly erodible land (NHEL) by 53 percent (2.3 tons per acre per year) (table 3.3). Relative to the 2003-06 conservation condition, the additional practices adopted in 2011 reduced sediment losses on HEL by 68 percent (7.5 tons per acre per year) and on NHEL by 60 percent (1.2 tons per acre per year).

The model scenario in which cover crops were removed from the 2011 conservation systems indicates that on average cover crop use improved reduction of sediment losses by nearly 58 percent. Frequency of use made a substantial difference. Annual adoption of cover crops improved sediment reduction by 78 percent, while use at a frequency of one out of every three years or more, but not annually, improved the sediment reduction by 56 percent. Less frequent cover crop use still provided sediment loss reduction improvements of 38 percent. The annual use of cover crops and their effect on sediment loss reduction illustrates the valuable conservation service they provide in keeping the soil covered and protected from fall and winter storm events.

The APEX simulations suggest that conservation practices adopted between 2003-06 and 2011 had similar impacts on surface water runoff (table 3.1). As noted above, relative to a no-practice scenario, conservation practices adopted in 2003-06 and 2011 reduced surface water losses by 13 and 16 percent, respectively. However, simulations suggest that during the same time periods, conservation practices reduced sediment losses by 63 and 83 percent, relative to a no-practice scenario (table 3.3, fig. 3.5). The lack of synchrony in conservation gains for surface water and sediment loss indicates that the concentration of sediment in surface water decreased between 2003-06 and 2011. In other words, although water losses were reduced by 13 and 16 percent, the water that was lost was not laden with sediment. Sediment concentrations in surface water may have been diminished by conservation practices that reduced rain drop impacts, such as cover crop adoption and reduced tillage practices. Conservation practices such as reduced tillage, cover crops, and buffers also slow water runoff, allowing sediment to fall out of suspension and be retained on the field.

Ironically, this cleaner surface water is less viscous and would have higher erosive energy than would a similar volume of sediment laden runoff. This phenomena is often observed within in no till fields, where the residues intercepting the raindrop impact produce cleaner runoff, which, when concentrated, can produce ephemeral gully erosion. The cleaner, faster flowing water would also have a greater capacity for picking up previously deposited sediments. This potentially negative impact that cleaner water has on gully formation is due to positive conservation outcomes of sediment loss reduction practices. This flow dynamic caused by the adoption of upland erosion control practices will take time to stabilize before the full benefit of the additional conservation practices are realized. These complicated interactions demonstrate the importance of comprehensive conservation planning.

In addition to reducing overall average annual sediment losses, conservation practices put in place between 2003-06 and 2011 decreased the annual number and severity of significant single storm events causing large losses. Instead of examining the losses of a significant weather event such as a 25-year storm, this analysis looks at the predicted sediment loss from strong storms of any magnitude. Acreage with a sound conservation management plan may have losses from a rare storm event well below losses typical of acreage with a low level of conservation and less intense storm. Sediments lost from these significant events cause excessive damage to the environment and tend to persist in the ecosystem, only to be re-suspended months or years later with subsequent exceptional storms.

Figure 3.4. Estimates of long-term average annual sheet and rill erosion on cropped acres in the Chesapeake Bay region: the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.

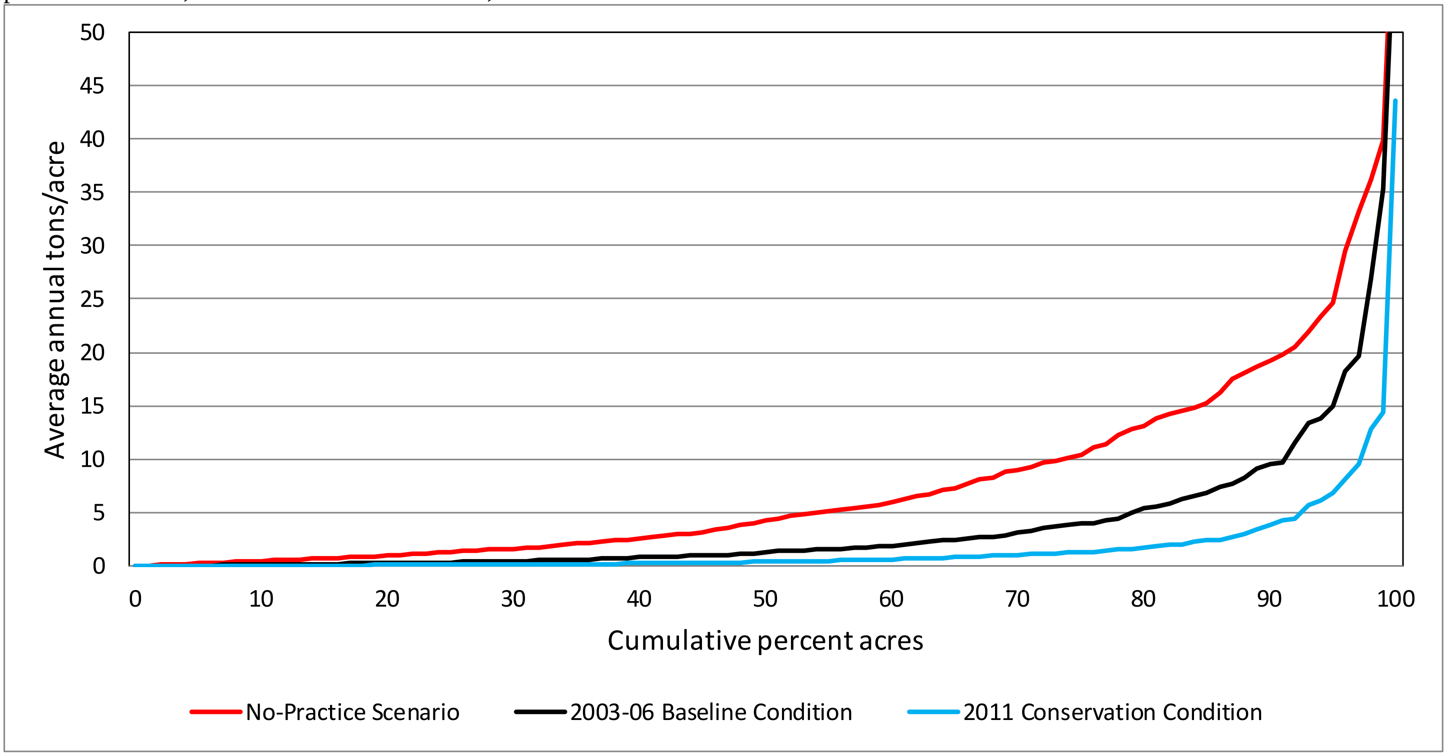


Table 3.3. Changes in average field-level effects of conservation practices on erosion and sediment loss on cropped acres in the Chesapeake Bay region between 2003-06 and 2011.

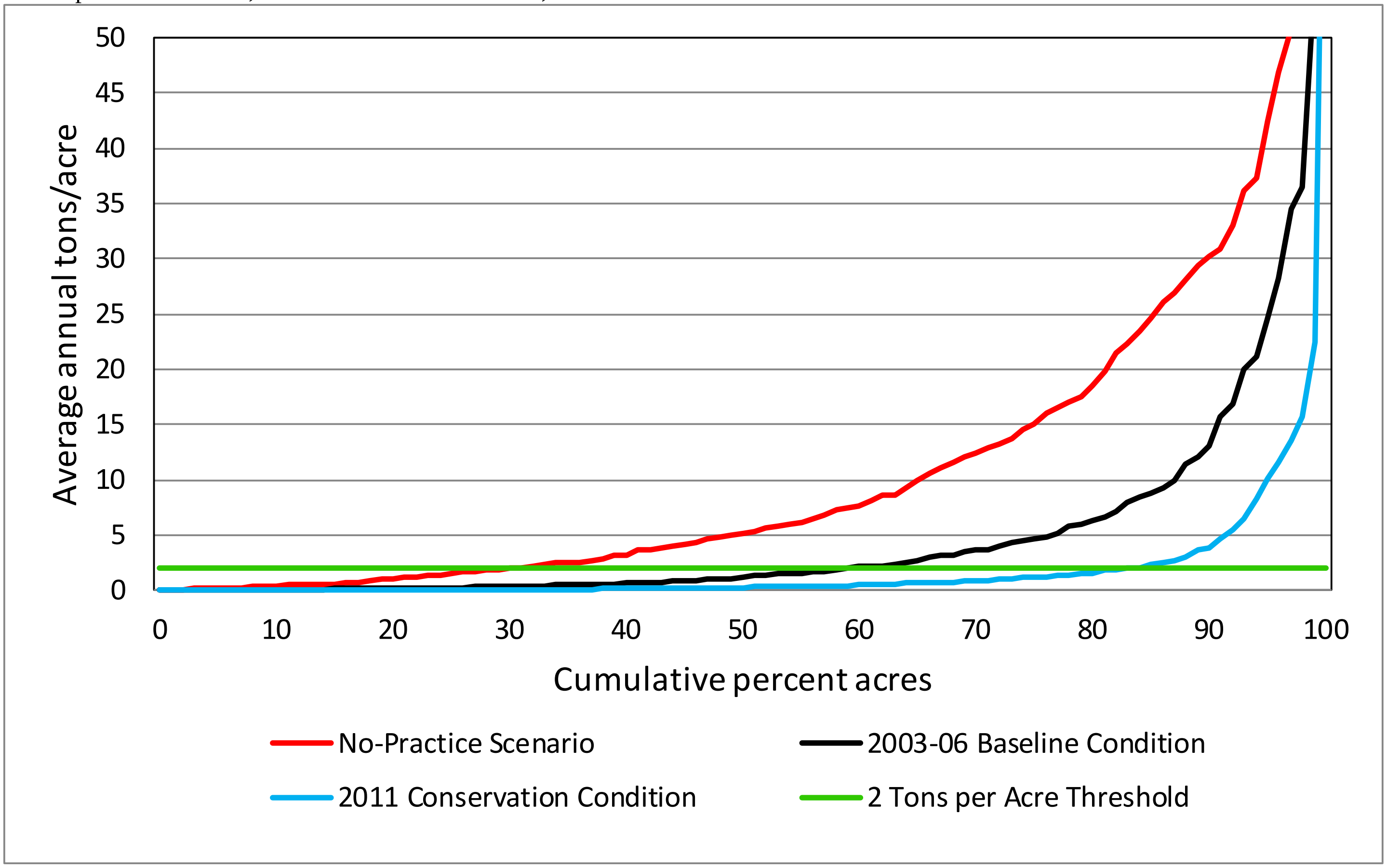
Model simulated outcome	No-practice (tons/acre	2003-06 (tons/acre)	2011 (tons/acre)	Reduction: No-practice to 2003-06 (tons/acre)	Reduction: 2003-06 to 2011 (tons/acre)
Cropped acres					
Average annual sheet and rill erosion*	7.6	3.7	1.5	3.9	2.2
Average annual sediment loss at edge-of-field due to water erosion	11.1	5.1	1.9	6.0	3.2
Highly erodible land (HEL)					
Average annual sheet and rill erosion*	16.3	7.6	2.6	8.7	5.0
Average annual sediment loss at edge-of-field due to water erosion	25.0	11.0	3.5	14.0	7.5
Non-highly erodible land (NHEL)					
Average annual sheet and rill erosion*	3.2	1.6	0.8	1.6	0.8
Average annual sediment loss at edge-of-field due to water erosion	4.3	2.0	0.8	2.3	1.2

* Estimated using the Revised Universal Soil Loss Equation.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Note: In the 2003-06 survey there were an estimated 1.87 million HEL acres (44 percent). The subset of NRI points for the 2011 survey had 1.75 million HEL acres (40 percent); a difference of 4 percent and also within the margins of error. The full set of NRI points for cropped acres in this region indicates slightly more than 40 percent of the acres are HEL.

Figure 3.5. Estimates of long-term average annual sediment losses to water erosion on cropped acres in the Chesapeake Bay region: the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.



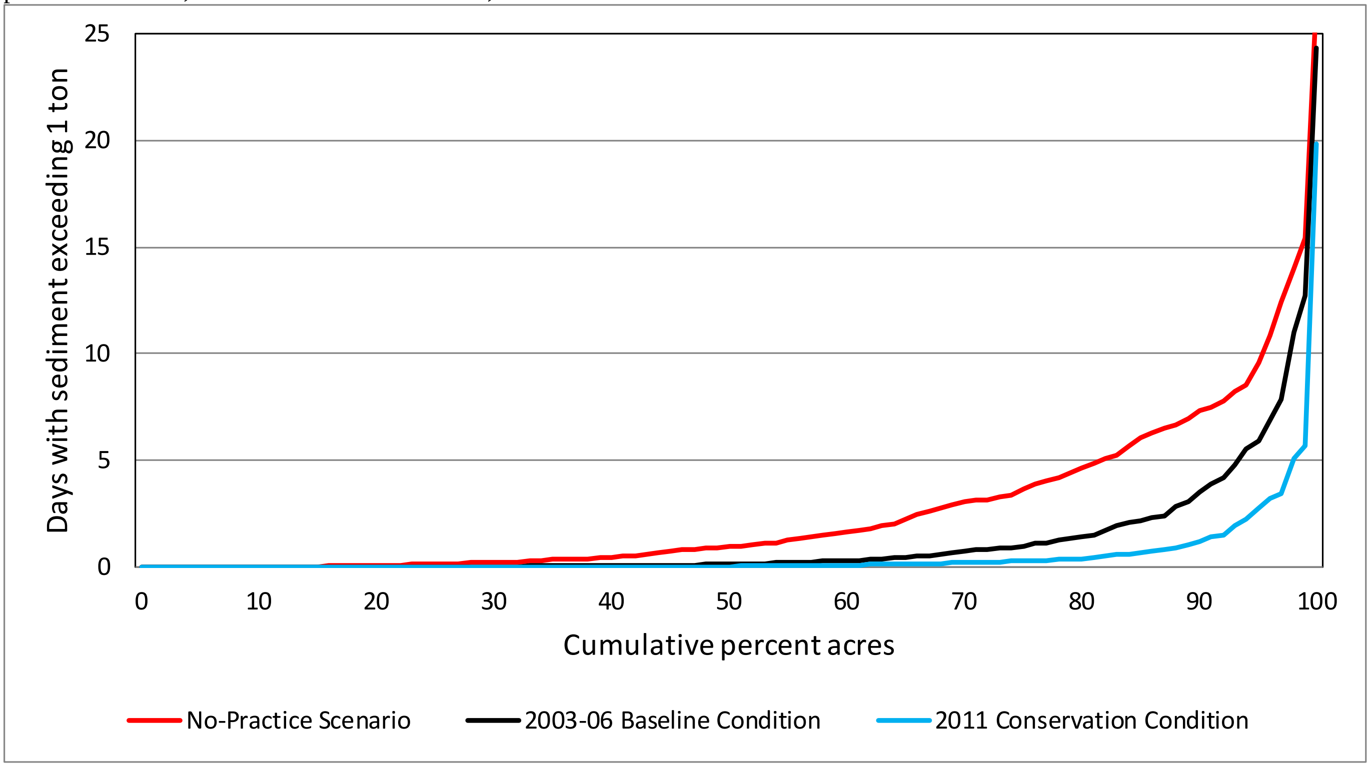
In this study, a system is considered adequately treated for sediment if, over the 52 years of weather conditions, it loses on average less than 2 tons of sediment per acre per year. Figure 3.6 shows the average number of days each year in which a storm event is predicted to produce more than 1 ton of sediment loss. Acres on which sediment losses of this level were predicted to occur on more than 2 days within one year are considered lacking in adequate sediment conservation treatment. In the no-practice scenario over 50 percent of the acres have more than 2 tons of sediment loss from just two storm events each year. Under 2003-06 conservation conditions, simulations show 17 percent of cropped acres would exceed the 2-ton loss threshold due to only two storm events, each of which would cause a loss of 1 or more tons of sediment. Relative to 2003-06, conservation practices adopted in 2011 would decrease the acres experiencing annual losses in excess of 2 tons due to two storm events to only 7 percent of cropped acres. If adoption of suites of soil conservation practices continue, these large single loss events are likely to become less frequent (fig. 3.6).

Effects of Practices on Soil Organic Carbon

Soil organic carbon (SOC) reduces erodibility and improves the soil's structure, nutrient cycling capacity, water holding capacity, and biotic integrity. The most practical way to improve soil health is to manage for soil organic matter (SOM). SOM enhances soil's ability to perform all of its vital functions, including maintaining crop production with concurrent reduction in the potential for sediment, nutrient, and pesticide losses. Because carbon is SOM's primary constituent, increasing SOM also sequesters carbon and reduces atmospheric carbon dioxide, lessening agriculture's contribution to climate change.

In this study, estimation of soil organic carbon (SOC) change assumes a starting point for the simulation based on soil characterization data from soils impacted by years of cultivation practices. To more appropriately approximate soil carbon stores for the surveyed point's soil map unit we used, measured soil characterization data that included SOC from pedons with evidence of tillage. The carbon data for these soil characterization pedons was also compared to data collected from the USDA NRCS Soil Science Division's Rapid Carbon Assessment (RaCa) project. To date over 35,000 sites across multiple land uses have been sampled and analyzed for SOC. The SOC for the soils used in this study were compared to the middle 80 percent of the range of results for similar soils in the RaCa database. Data falling outside the range were adjusted to the median values found in the RaCa soils. These more realistic starting carbon levels attempt to not impart erroneous stores of organic nitrogen since SOM generally maintains a carbon to nitrogen ratio of 10:1.

Figure 3.6. Estimates of average number of days each year in which a storm event produced more than 1 ton of sediment loss: the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.



Simulation modeling shows carbon management improved or was maintained on all cropped acres in 2011, as compared to 2003-06. As noted previously, the widespread adoption of high residue crop rotations, cover crops, structural practices, and conservation tillage between 2003-06 and 2011 played a significant role in the widespread positive changes in soil carbon trends (table 3.4). It should be noted that annual SOC dynamics and the impact of conservation practices on those dynamics vary considerably among acres in the region.

The combination of high rainfall on sloping soils and mild winters that allow rapid degradation of organic materials make carbon accumulation challenging in the Chesapeake Bay region. Further, the highly weathered, less reactive nature of the soils in this region makes them vulnerable to carbon loss under even moderately intense tillage. Therefore, the ***maintenance*** of SOC requires a comprehensive conservation plan on most acres. Maintaining adequate carbon levels is a valuable conservation achievement. For the purposes of this report, cropping systems are considered to be maintaining SOC if average annual gains or losses do not exceed 100 pounds per acre per year. This rate of change is difficult to detect in a short time period. It may take more than 20 years for a 0.1 percent change in SOC to occur.

Model simulations show that in 2003-06 cultivated cropland acres in the Chesapeake Bay region were on average losing SOC at a rate of 189 pounds per acre per year (table 3.4). The increased adoption of cover crops, conservation tillage, and structural practices in 2011 reduced average SOC losses to 95 pounds per acre per year. Thus, adoption of the conservation practices in place in 2011 changed the overall trend in the Chesapeake Bay region. Conditions on cultivated cropland in the region were improved such that on average, acres went from losing SOC to maintaining SOC.

The data in Table 3.4 is divided into categories denoting the three potential soil organic carbon (SOC) trends: gaining, maintaining, or losing. These categories are further stratified by average tillage type for the crop rotation. Acreage gaining more than 100 pounds of SOC per year increased by 9 percentage points, from only 3 percent of acres in 2003-06 to 12 percent in 2011. Not only were more acres gaining SOC in 2011 than in 2003-06, but acres gaining SOC were gaining an average of 30 more pounds of SOC in 2011 than in 2003-06. Acres maintaining SOC also increased, from 31 to 42 percent of acres in 2003-06 and 2011, respectively. In both survey periods, the average rate of SOC change on acres maintaining SOC decreased from an average annual loss rate of 29 pounds per acre per year in 2003-06 to 10 pounds per acre per year in 2011. The most significant change between the survey periods was the 20 percentage point decline in acres losing SOC. In 2003-06, 66 percent of cultivated acres in the Chesapeake Bay region were losing SOC at an average rate of 289 pounds per acre per year. Under 2011 conservation conditions, 46 percent of acres were losing an average of 245 pounds of SOC per acre per year.

The model scenario removing cover crops only from 2011 conservation systems indicate that on average cover crop use improved enhancement of soil organic carbon levels by 63 percent. Most conservation practices adopted to build SOC act

Table 3.4. Residue and tillage management practices in the Chesapeake Bay region, 2003-06 and 2011.

Residue and tillage management practice in use	Average Annual STIR value*	2003-06 Acres (1,000's)	2003-06 Acres in Chesapeake Bay region (percent)	2003-06 Average Soil Carbon change (lbs/acre/yr)	2011 Acres (1,000's)	2011 Acres in Chesapeake Bay region (percent)	2011 Average Soil Carbon change (lbs/acre/yr)
Acres with carbon gain (gaining >100 lbs/acre/year)		119.8	3	159	513.3	12	189
Average annual tillage intensity for crop rotation meets criteria for no-till	<20	89.5	2	168	405.8	9	195
Average annual tillage intensity for crop rotation meets criteria for mulch till	20-80	15.4	<1	135	80.8	2	161
Continuous conventional tillage in every year of crop rotation	>80	14.9	<1	127	26.7	1	184
Acres maintaining carbon (gaining or losing <100 lbs/acre/year)		1,346.8	31	-29	1,838.9	42	-10
Average annual tillage intensity for crop rotation meets criteria for no-till	<20	695.2	16	-25	1,272.9	29	-11
Average annual tillage intensity for crop rotation meets criteria for mulch till	20-80	416.2	10	-33	425.6	10	-5
Continuous conventional tillage in every year of crop rotation	>80	235.4	6	-32	140.4	3	-17
Acres losing carbon (losing >100 lbs/acre/year)		2,813.3	66	-289	2,001.2	46	-245
Average annual tillage intensity for crop rotation meets criteria for no-till	<20	963.2	23	-235	1,126.4	26	-216
Average annual tillage intensity for crop rotation meets criteria for mulch till	20-80	957.8	22	-280	608.4	14	-249
Continuous conventional tillage in every year of crop rotation	>80	892.2	21	-329	266.4	6	-355
Total or Average		4,279.9		-189	4,353.4		-95

* Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation.
Note: A description of the Soil Tillage Intensity Rating (STIR) can be found at http://stir.nrcs.usda.gov/.
Note: In the 2003-06 survey there were an estimated 1.87 million HEL acres (44 percent). The subset of NRI points for the 2011 survey had 1.75 million HEL acres (40 percent); a difference of 6 percent and also within the margins of error. The full set of NRI points for cropped acres in this region indicates slightly more than 40 percent of the acres are HEL. Soils are classified as HEL if they have an Erodibility Index (EI) score of 8 or higher. A numerical expression of the potential of a soil to erode, EI considers the physical and chemical properties of the soil and climatic conditions where it is located. The higher the index, the greater the investment needed to maintain the sustainability of the soil resource base if intensively cropped.
Note: Percents may not add to totals because of rounding.

to preserve residues and prevent runoff losses. Cover crops provide those benefits and add to the residue available for conversion to soil organic matter (SOM). Relative to no use of cover crops, annual adoption improved the average annual change in soil carbon by 148 percent. Use at a frequency of one out of every three years or more, but not annually, improved the systems' carbon enhancement by 53 percent, while less frequent use still provided a 21 percent benefit to carbon dynamics.

The average annual impact of conservation practices on SOC dynamics varies among acres, as shown in table 3.4, depending on the extent to which residue and nutrient management is used, the local climate, and the soil's inherent potential to sequester carbon. Carbon loss is mitigated by improved tillage and erosion control practices, both of which reduce the physical factors that contribute to carbon loss. However, SOM maintenance also depends on the function of soil microbes. A diverse and well-functioning community of soil microbes requires nutrient inputs, primarily nitrogen, to enable the soil to maintain and gain SOC. Comprehensive nutrient management plans need to consider not only the inputs necessary to feed the crop, but also inputs required to feed the soil microbes essential for soil health. Insufficient nutrient availability can cause SOM to decline. This will in turn release carbon and change the soil structure and function. Soil physical properties will begin to breakdown, increasing soil erosion and runoff losses.

The APEX model also estimates carbon lost from the soil surface due to water and wind erosion (table 3.5). Changes in conservation practices between 2003-06 and 2011 contributed to a 109 pound per acre (27 percent) reduction in carbon lost from the soil surface of cropped acres in the Chesapeake Bay region. This carbon at the surface is a very important part of the agroecological system: it helps protect the soil surface from erosive forces, serves as an important part of the food supply for soil organisms which maintain soil health, and provides the material that eventually becomes part of the SOC pool. Because of the relationship between carbon and nitrogen use in the soil microbe communities, the observed annual on-field increase of 109 pounds of carbon (table 3.6) may confer to the soil biota the ability to take up an additional 3 to 10 pounds of nitrogen, depending on the carbon to nitrogen ratios of the residues and their stage of decomposition into the organic fraction. The enhanced use of the nitrogen by the soil communities prevents the nitrogen from being lost from the system. Therefore, maintaining surface carbon enhances healthy microbial communities in the soil, which in turn provide an additional benefit to water quality while simultaneously improving soil health. Compared to 2003-06 baseline conditions, nitrogen additions in the Chesapeake Bay region increased by more than 14 pounds per acre on average in 2011, but nitrogen and carbon losses both declined between the two survey periods. This may be indicative of improved SOM and associated soil health on cropped acres in the region.

Four runoff classes were devised for all cropped acres in the Chesapeake Bay region based on inherent vulnerability to soil erosion and associated nutrient losses through runoff (table 3.5). Relative to the no-practice scenario, 2003-06 conservation practices reduced carbon losses and/or contributed to enhanced carbon gains in each of the four runoff classes (table 3.5).This trend continued with the enhanced conservation practice adoption in 2011 (fig. 3.7). The gains noted in 2011 demonstrate the benefits of using residue and tillage management in conjunction with structural practices and cover crops. Not only did every runoff class experience a 16 to 27 percentage point reduction in acres losing SOC (table 3.5), but also the amount of carbon lost per acre by runoff class decreased by between 75 and 107 pounds per acre, with the greatest reductions in the ***moderately-high runoff*** and the ***high runoff*** classes. Soils with ***low runoff*** potentials realized the largest pound per acre gains in SOC.

Table 3.5. Field-level effects of conservation practices on carbon for cropped acres in the Chesapeake Bay region, 2003-06 and 2011.

Model simulated outcome	2003-06 (pounds/acre)	2011 (pounds/acre)	Reduction: 2003-06 to 2011 (pounds/acre)	Reduction: 2003-06 to 2011 (percent)
Cropped acres				
Average annual carbon lost from the edge of the agricultural management zone, *including* impacts of edge-of-field conservation practices	407	298	109	27

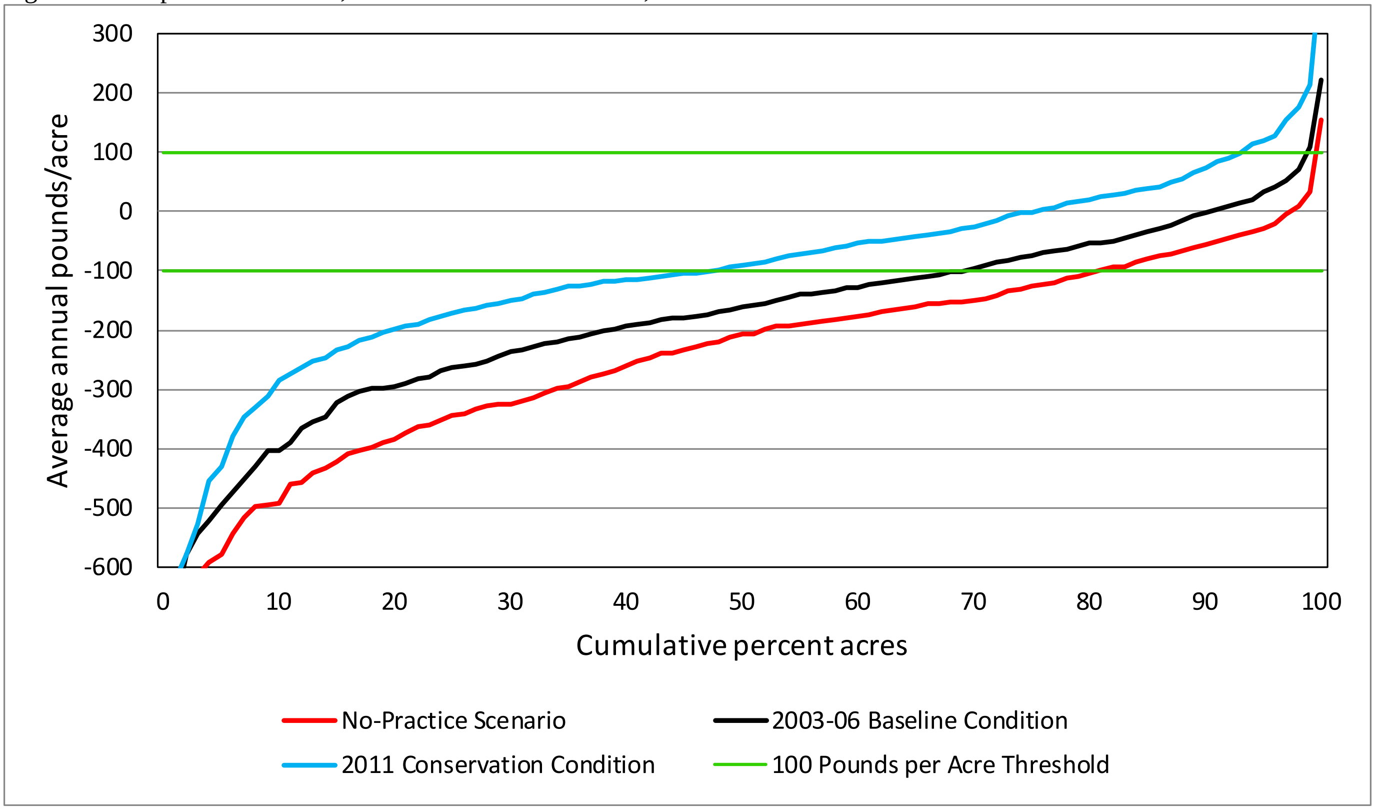
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in Appendix E for the 4 subregions.

Table 3.6. Soil organic carbon dynamics by runoff class in the Chesapeake Bay region, 2003-06 and 2011.

	Runoff Classes									
	Low		Moderate		Moderately High		High		All	
	2003-06	2011	2003-06	2011	2003-06	2011	2003-06	2011	2003-06	2011
Percent of acres Losing Carbon	54	35	79	52	66	50	83	64	66	46
Percent of acres Maintaining Carbon	43	49	21	41	30	39	13	30	31	42
Percent of acres Gaining Carbon	3	17	0	6	4	11	3	5	3	12

Note: Percents may not total to 100 because of rounding.

Figure 3.7. Estimates of long-term average annual change in soil organic carbon (SOC) on cropped acres in the Chesapeake Bay region: the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.



Effects of Practices on Nitrogen Loss

Plant-available nitrogen sources include applied commercial fertilizer, applied manure, nitrogen produced by legume crops (e.g., soybeans, alfalfa, beans, and peas), manure deposited by grazing livestock, and atmospheric nitrogen deposition. Simulation results suggest that relative to the no-practice scenario the conservation practices on the ground in 2003-06 reduced annual nitrogen inputs by 15 percent, from 160.1 to 135.6 pounds per acre per year. Conservation practices adopted in 2011 actually increased average annual nitrogen inputs by 11 percent, from 135.6 to 149.9 pounds per cropped acre per year (table 3.7). Although nitrogen inputs increased between 2003-06 and 2011, roughly 66 percent of the nitrogen inputs were taken up by the crop and removed at harvest in the crop yield in both conditions. Crop use efficiency remained relatively constant between the three scenarios, at 62 percent for the no-practice scenario and 66 percent under both the 2003-06 and 2011 scenarios.

Acres with the highest nitrogen losses typically have the highest inherent vulnerability combined with inadequate nutrient management and runoff controls. Between 2003-06 and 2011, although annual nitrogen inputs increased by 11 percent (14.3 pounds per acre per year), the average amount of total nitrogen lost from the field annually via all pathways, other than the nitrogen removed from the field at harvest, decreased by about 7 percent, dropping from 58.8 to 54.9 pounds per acre (table 3.7, fig. 3.8). These improvements in nitrogen loss rates between 2003-06 and 2011 can be attributed to the adoption of new conservation practices and their impacts on various nitrogen loss pathways.

As expected, model simulation results showed that quantity of nitrogen lost to specific pathways varies from acre to acre (fig. 3.8). Of all the nitrogen loss pathways, surface and subsurface flows have the greatest potential to directly impact water quality. Most nitrogen lost to subsurface flows returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow. Relative to a no-practice scenario, the conservation practices adopted in 2003-06 reduced the cumulative total nitrogen lost via surface water and subsurface flows by 29 percent, decreasing loss rates from 58.3 to 41.6 pounds per acre per year. Conservation conditions adopted in 2011 reduced 2003-06 losses by 22 percent, decreasing the average nitrogen loss rate to surface and subsurface flows from 41.6 to 32.6 pounds per acre per year.

On average, the impact of the surface loss pathway for nitrogen loss decreased with conservation practice adoption. The surface loss pathway accounted for 36, 27, and 18 percent of all nitrogen losses in the no-practice, 2003-06, and 2011 scenarios, respectively (table 3.7). While the role of the surface loss pathway declined, the role of the subsurface loss pathway remained fairly constant, accounting from 29, 44, and 42 percent of nitrogen losses in the no-practice, 2003-06, and 2011 scenarios, respectively. The decline in surface flow losses in conjunction with the stability in subsurface losses is a positive sign, considering that the achievements reducing

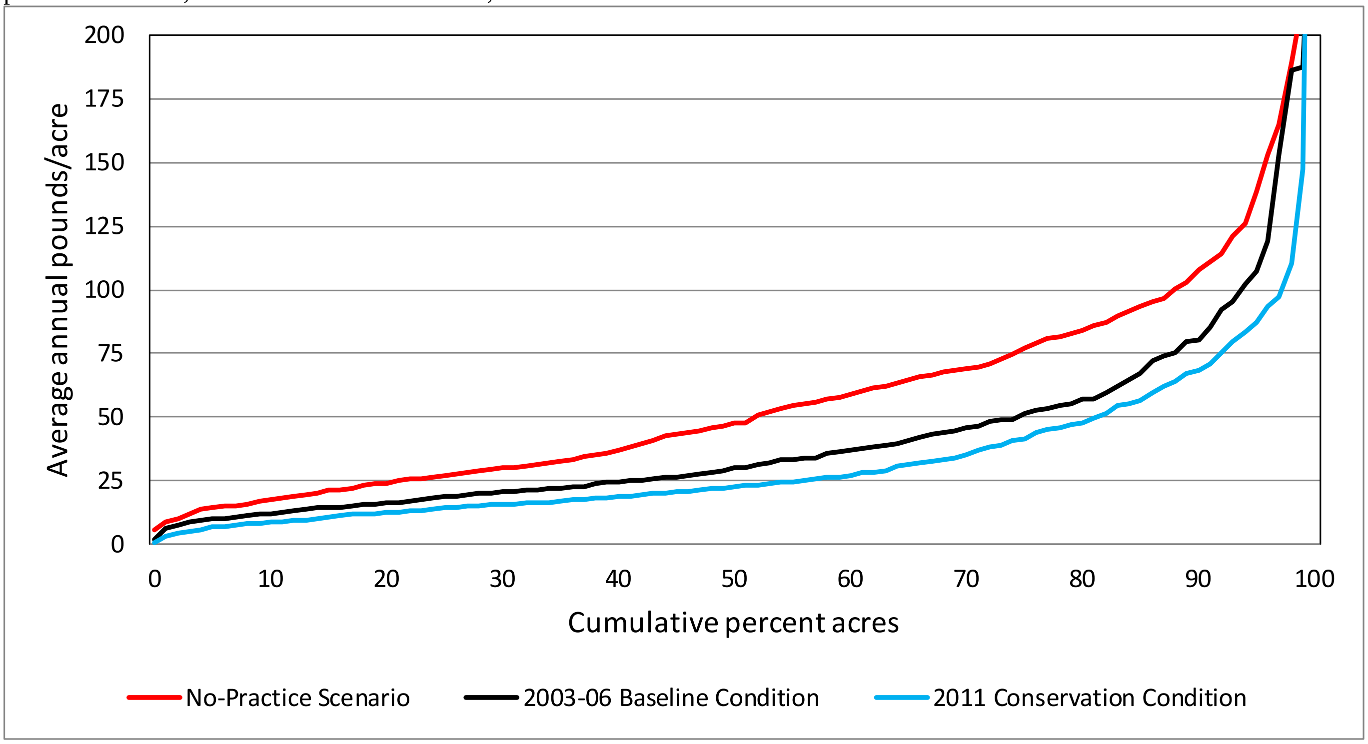
Table 3.7. Estimates of long-term average annual field-level effects of conservation practices on nitrogen sources and loss pathways on cropped acres in the Chesapeake Bay region: the no practice scenario, 2003-06 baseline condition, and 2011 conservation condition.

		Average annual values in pounds per acre			
Model simulated outcome	**No-practice Scenario**	**2003-06**	**2011**	**Change: No-practice to 2003-06**	**Change: 2003-06 to 2011**
All cropped acres					
Nitrogen sources					
Atmospheric deposition	8.8	8.8	8.9	0	0.1
Bio-fixation by legumes	31.9	31.8	36.4	-0.1	4.6
Commercial fertilizer	94.9	73.0	79.7	-21.9	6.7
Manure	24.6	22.0	24.8	-2.6	2.8
All nitrogen sources	160.1	135.6	149.9	-24.5	14.3
Nitrogen in crop yield removed at harvest	99.7	89.0	98.4	-10.7	9.4
Nitrogen loss pathways					
Volatilization	18.4	14.2	17.4	-4.2	3.2
Denitrification processes	1.8	3.0	4.9	1.2	1.9
Windborne sediment	0.11	0.09	0.05	-0.02	-0.04
Surface runoff, including waterborne sediment	27.9	15.7	9.7	-12.2	-6.0
Surface water (soluble)	4.9	2.4	2.1	-2.5	-0.3
Waterborne sediment	23.0	13.3	7.6	-9.7	-5.7
Subsurface flow pathways	30.4	25.9	22.9	-4.5	-3.0
Total nitrogen loss for all loss pathways	78.4	58.8	54.9	-19.6	-3.9
Change in soil nitrogen	-23.3	-17.2	-10.8	6.1	6.4
Highly erodible land (HEL)					
Nitrogen applied as commercial fertilizer and manure	128.8	105.2	103.7	-23.6	-1.5
Total nitrogen loss for surface and subsurface loss pathways	80.5	54.3	36.1	-26.2	-18.2
Non-highly erodible land (NHEL)					
Nitrogen applied as commercial fertilizer and manure	114.9	89.9	105.1	-25.0	15.2
Total nitrogen loss for surface and subsurface loss pathways	47.3	35.5	30.3	-11.8	-5.2
Acres with manure applied					
Nitrogen applied as commercial fertilizer and manure	161.7	133.3	130.8	-28.4	-2.5
Total nitrogen loss for surface and subsurface loss pathways	78.8	58.9	40.5	-19.9	-18.4
Acres without manure applied					
Nitrogen applied as commercial fertilizer	95.0	72.8	80.8	-22.2	8.0
Total nitrogen loss for surface and subsurface loss pathways	46.4	31.7	25.5	-14.7	-6.2

****** On about half of the cropped acres, more nitrogen volatilization and denitrification occurs with practices than without practices, resulting in only a small change in nitrogen volatilization and denitrification on average for the region due to conservation practices. In preventing nitrogen loss to other loss pathways, conservation practices keep more of the nitrogen compounds on the field longer, where they are exposed to wind and weather conditions that promote volatilization and denitrification.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Model simulation results for the baseline conservation condition are presented in Appendix E for the 4 subregions.

Figure 3.8. Estimates of long-term average annual total nitrogen losses on cropped acres in the Chesapeake Bay region: the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.



surface flow reduction caused more nitrogen to be retained on farm fields, making it more vulnerable to loss via subsurface flow.

Acres classified as Highly Erodible Lands (HEL) received a similar amount of total nitrogen inputs in both survey periods, with 105.2 and 103.7 pounds per acre per year applied as commercial fertilizer and/or manures in 2003-06 and 2011, respectively. However, conservation practices reduced nitrogen losses on HEL acres by 50 percent, or 18.2 pounds per acre per year, between 2003-06 and 2011. On cropped non-highly erodible land (NHEL), nitrogen application from commercial fertilizer and manures increased by 14 percent, or 15.2 pounds per acre per year, but losses simultaneously declined by 14 percent, or 5.2 pounds per acre per year. It is important to note that not all the nitrogen available for loss comes from intentionally applied fertilizers and manures; bio-fixed nitrogen and atmospheric nitrogen also contribute to the pool of inputs upon which agricultural conservation practices are acting.

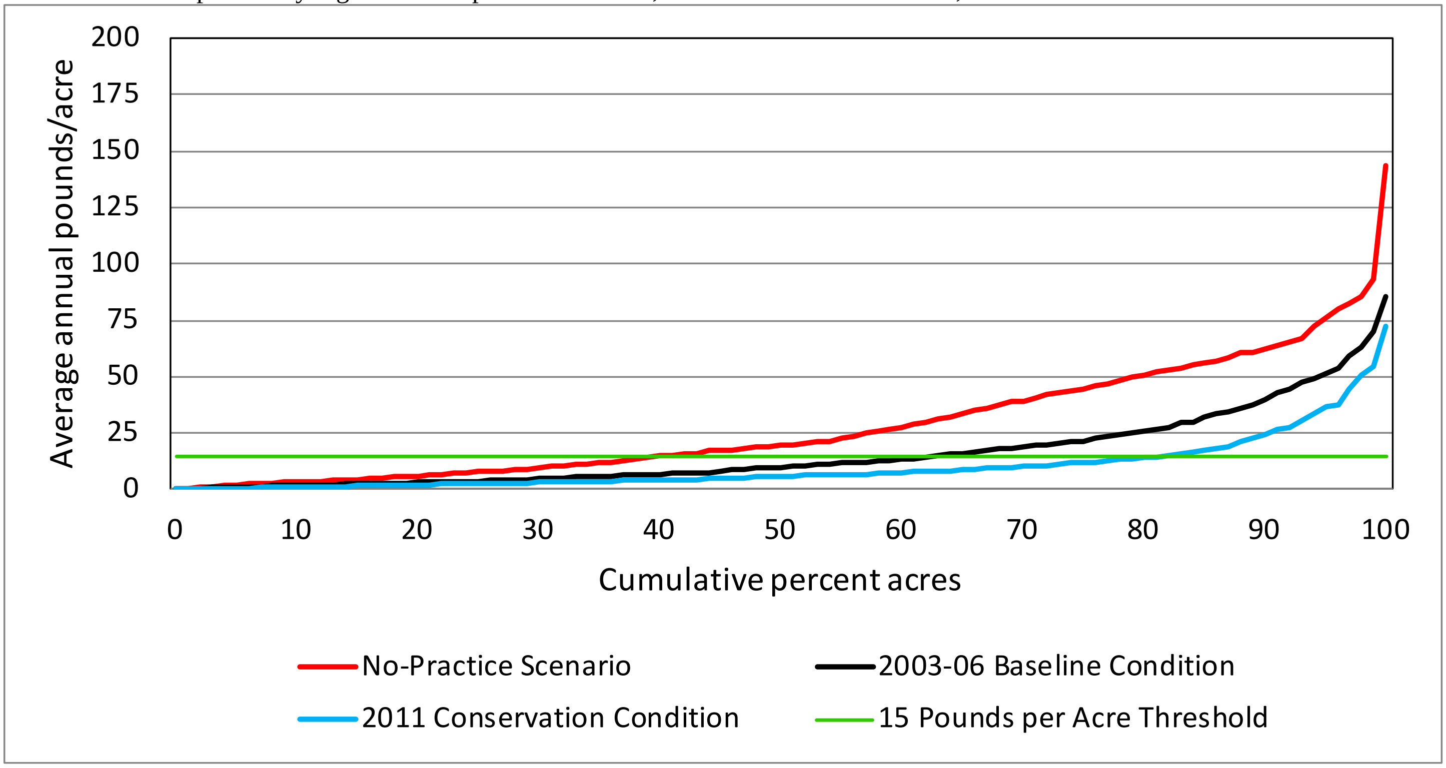
Progress toward effective management of nutrient losses associated with manured systems is demonstrated by the fact that although the amount of nitrogen applied to acres receiving manure remained unchanged between 2003-06 and 2011 (a 2.5-pound increase is within the margins of error), nitrogen losses from manured fields declined by 18.4 pounds, or 45 percent over the same period (table 3.7). Between 2003-06 and 2011, the commercial-fertilizer-only acres saw an increase of 10 percent, or 8.0 pounds, in average annual nitrogen inputs and yet achieved a 24 percent, or 6.2 pound, reduction in the amount of nitrogen lost. However, in absolute terms the manured acres lost 40.5 pounds of nitrogen per acre per year in 2011, while the non-manured acres lost 25.5 pounds per acre. The disparity in pound per acre nitrogen loss rates between manured and non-manured acres signifies the need for a higher level of management when manure is part of the cropping system.

Acres not receiving manure as part of their nutrient inputs had nitrogen application rates 66.7, 60.5, and 50.0 pounds lower than the average nitrogen application rate for manured fields in the no-practice, 2003-06, and 2011 scenarios, respectively (table 3.7). Similarly, non-manured acres had nitrogen loss rates 32.4, 27.2, and 15.0 pounds lower than the average nitrogen loss rate for manured fields in the no-practice, 2003-06, and 2011 scenarios.

Nitrogen lost via surface runoff

Conservation practices adopted in 2003-06 and 2011 were effective at reducing nitrogen losses associated with runoff, including nitrogen lost with waterborne sediment. Relative to the no-practice scenario, conservation practices in place in 2003-06 reduced nitrogen losses in surface runoff by 44 percentage points, decreasing losses from 27.9 to 15.7 pounds per acre per year. The conservation practices adopted in 2011 reduced nitrogen losses in surface runoff from 15.7 to 9.7 pounds per acre per year, a 38 percentage point reduction from 2003-06 loss rates (table 3.7; fig. 3.9). Conservation practice adoption between the no-practice scenario and 2003-06 baseline

Figure 3.9 Estimates of long-term average annual nitrogen losses with surface runoff (including waterborne sediment) on cropped acres in the Chesapeake Bay region: the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.



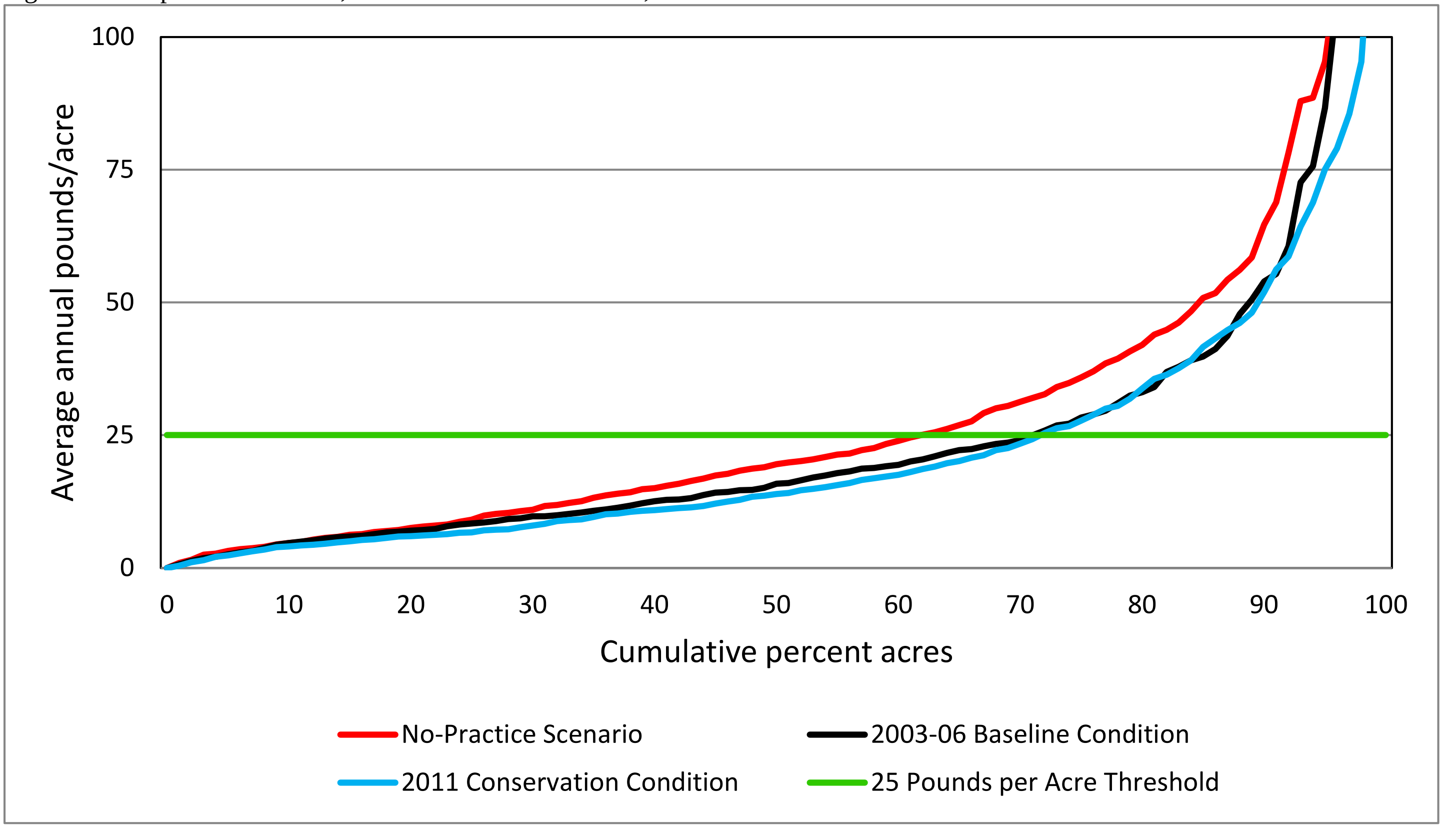
condition reduced the percentage of acres on which surface runoff losses exceeded 15 pounds of nitrogen annually from 60 to 37 percent of cropped acres. In the 2011 conservation condition, only 18 percent of cropped acres experienced runoff losses exceeding 15 pounds of nitrogen annually. The significant increase in adoption of structural practices, cover crops, and conservation tillage, contributed to the control and trap aspects of the Avoid, Control, Trap (ACT) conservation system strategy. These practices are largely responsible for the reduction in nitrogen losses. There is still opportunity to improve the avoidance aspect of ACT through better nutrient application management, which, as discussed in Chapter 2, was largely maintained at 2003-06 conservation levels. This indicates that there is potential for more nutrient loss reduction with improved nutrient application management. It is critical to note that practices such as cover crops and conservation tillage need to be maintained as active parts of the cropping systems and management strategies if these gains are to be continually realized in the future.

The model scenario removing cover crops only from the 2011 conservation systems indicates on average their use improved reduction of nitrogen losses with surface flow by over 26 percent. Frequency of use made a substantial difference. Annual use of cover crops improved nitrogen runoff reductions by 40 percent and cover crop application at a frequency of one out of every three years or more, but not annually, reduced nitrogen loss to surface flow by 23 percent. Less frequent use of cover crops still provided for up to 19 percent reductions in nitrogen loss to surface flows. The annual use of cover crops reduces nitrogen runoff losses by scavenging carryover nutrients so that they cannot be lost with runoff and by providing protective soil cover over the fall and winter. The efficacy of cover crop adoption, even at non-annual adoption rates, demonstrates the critical value provided by this practice in reducing impacts of nitrogen runoff on water quality, particularly in fall and winter storm events.

Nitrogen lost via subsurface flow

Simulation modeling shows the subsurface flow pathway was the dominant nitrogen loss pathway under all three simulated scenarios. Roughly 39, 44, and 42 percent of total nitrogen lost was lost via subsurface flow in the no-practice, 2003-06, and 2011 scenarios, respectively. The continued dominant role of this loss pathway is a consequence of conservation practice success in preventing edge-of-field nitrogen losses. However, there have been conservation gains in decreasing nitrogen losses to subsurface flows. Between the no-practice scenario and the 2003-06 baseline condition, nitrogen losses to subsurface flow pathways decreased by 15 percentage points, from an average loss rate of 30.4 to 25.9 pounds per acre per year. The 2011 conservation condition decreased the loss rate by 13 percentage points, from 25.9 to 22.9 pounds per acre per year (table 3.7, fig. 3.10). These reductions are not as large as those observed for the surface flow loss pathway. This is not unexpected given that nitrogen application management was maintained at 2003-06 levels in 2011 (Chapter 2). The subsurface losses are also being impacted by improved runoff control measures, which redirect water and nutrients into the soil, making them vulnerable to leaching losses. In the no-practice scenario 52 percent of nitrogen losses associated with

Figure 3.10. Estimates of long-term average annual nitrogen losses in subsurface flow on cropped acres in the Chesapeake Bay region: the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.



water movement were by subsurface pathways. The conservation in place 2003-06 decreased surface losses, but increased subsurface losses to account for 62 percent of water related nitrogen losses and the improved runoff control in 2011 increased the proportion to 69 percent. Improving nutrient management plans and better adherence to the 4R's as part of a more robust ACT conservation strategy will provide opportunity for significant conservation gains.

These model simulation results underscore the importance of pairing water erosion control practices with effective nutrient management practices so that the full suite of conservation practices work in concert to provide the environmental protection needed. Although overall conservation practice adoption reduced nitrogen losses to surface and subsurface flows, management opportunities remain. For a small percent of cropped acres, adoption of effective structural conservation practices to treat surface flow losses may result in small increases in nitrogen loss via subsurface flow. While our results indicate that even with this re-routing of nutrients, the reduction in surface losses of nitrogen typically far exceed the increased subsurface nitrogen losses, these acres present important nutrient management opportunities A commonly effective way of addressing excess losses from leaching is to better manage the rate, time, method, and form of application of nutrients and irrigation water.

Practices that control runoff tend to redirect flow and increase subsurface losses of nitrogen. This improves the opportunity for crops to utilize the nitrogen by moving the nutrient through its root zone, but may also impact water quality. A recent USGS study determined that more than a quarter of the nitrogen currently in the groundwater in the Delmarva Peninsula in the Chesapeake Bay watershed may continue to contribute nitrogen to the Chesapeake Bay for more than 50 years (Sanford and Pope 2013, accepted). A comprehensive conservation plan should include cover crops as a means of reducing subsurface losses by scavenging carryover nitrogen in the soil and preventing its loss during the fall and winter months. Model results from the scenario removing cover crops demonstrate that on average, annual use of cover crops reduced subsurface nitrogen losses by 35 percent. When utilized less frequently than annually but at least one out of every three years, cover crop application reduced the average percentage of nitrogen lost in subsurface flows by 20 percent compared to losses without cover crop management. Cover crops provided benefits even when applied less frequently than one out of three years, but at least once every five years; in this scenario average cover crop adoption reduced annual subsurface nitrogen losses by 9 percent. It should be noted these are average reductions across all cropping systems and nutrient management strategies. Reduction amounts varied greatly due to geography and other management and conservation practices.

Other nitrogen loss pathways

Nitrogen loss via volatilization and denitrification can be undesirable, but does not directly impact water quality. Most of the gaseous losses are in the N_2 form, but there is risk of some increased NO_x greenhouse gas emissions. The role of volatilization remained constant between the no-practice and 2003-06 scenarios, accounting for 23 and 24 percent of all nitrogen losses (table 3.7). However, under conservation practices in place in 2011, the role of volatilization increased by 8 percentage points and accounted for 32 percent of all nitrogen losses from cultivated cropland in the Chesapeake Bay region. This increase is likely due in large part to the increased use of manure in the region. Increased infiltration rates resulting from successful control of surface runoff will increase the frequency in which subsurface horizons reach saturation, which will tend to promote denitrification. The role of the denitrification pathway remained small, but increased slightly across all scenarios, accounting for 2, 5, and 9 percent of nitrogen losses in the no-practice, 2003-06, and 2011 scenarios, respectively.

Effects of Practices on Phosphorus Loss

Phosphorus, like nitrogen, is an essential element needed for crop growth. Unlike nitrogen, however, phosphorus rarely occurs in a gaseous form, so the APEX model does not include an atmospheric component for simulation of phosphorus dynamics. Although total phosphorus is plentiful in the soil, only the small water-soluble fraction is available at any one time for plant uptake. Farmers apply commercial phosphate fertilizers and manures to supplement low quantities of plant-available phosphorus in the soil.

Simulation results suggest that relative to the no-practice scenario the conservation practices on the ground in 2003-06 reduced annual phosphorus inputs by 31 percent, from 34.6 to 23.8 pounds per acre per year. Conservation practices adopted in 2011 actually increased average annual phosphorus inputs by 6 percent, from 23.8 to 25.2 pounds per cropped acre per year (table 3.8). Although phosphorus inputs increased between 2003-06 and 2011, 62 and 63 percent of the phosphorus inputs were taken up by the crop and removed at harvest in the crop yield in 2003-06 and 2011, respectively. Conservation practice adoption clearly improved crop use efficiency, which increased from 48 percent under the no-practice scenario to 62 and 63 percent under both the 2003-06 and 2011 scenarios, respectively.

Acres with the highest phosphorus losses typically have the highest inherent vulnerability combined with inadequate nutrient management and runoff controls. Between 2003-06 and 2011, although annual phosphorus inputs increased by 6 percent (1.4 pounds per acre per year), the average amount of total phosphorus lost from the field annually via all pathways, other than the phosphorus removed from the field at harvest, decreased by about 44 percent, dropping from 3.4 to 1.9 pounds per acre (table 3.8, fig. 3.11). These improvements in phosphorus loss rates between 2003-06 and 2011 can be attributed to the adoption of new conservation practices and their impacts on various phosphorus loss pathways.

As expected, model simulation results showed that the quantity of phosphorus lost to specific pathways varies from acre to acre (fig. 3.11). Unlike nitrogen, phosphorus has no gaseous loss pathways. Therefore, nearly all phosphorus losses, whether they are via surface flow or subsurface flow, have a high potential to impact water quality. Most phosphorus lost to subsurface flows returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow. Relative to a no-practice scenario, the conservation practices adopted in 2003-06 reduced the cumulative total phosphorus lost via surface water and subsurface flows by 57 percent, decreasing cumulative loss rates from 8.0 to 3.4 pounds per acre per year. Conservation conditions adopted in 2011 reduced 2003-06 losses by 44 percent, decreasing the average phosphorus loss rate to surface and subsurface flows from 3.4 to 1.9 pounds per acre per year. These practices also contributed to the increased rate of accumulation of soil phosphorus, which rose from 0.5 to 2.6 pounds per acre between 2003-06 and 2011 (table 3.8).

These changes in soil phosphorus reflect the impacts of conservation management reported in the 2003-06 and 2011 survey periods. These results are not derived from actual soil test results for the farm fields. The appropriateness of a phosphorus management plan can only be determined with the trend compared to the soil test recommendation. For example, a negative trend coupled with a high soil test phosphorus level would indicate a sound nutrient management plan for reducing the risk of water quality impairment. However, the same negative trend with low soil test phosphorus could lead to unsustainably mining the soil and would be detrimental to both soil health and crop productivity. The significant change in the soil phosphorus levels from 2003-06 to 2011, while a good sign of retaining more phosphorus on the land, indicates that producers need to be more aware of their soil phosphorus and align their annual phosphorus management plans with their soil test phosphorus results to reduce the risk of impacting water quality.

While there is no significant change in the role of the surface loss pathway in phosphorus losses, the emerging trend suggests conservation practices on the ground are reducing the role of this pathway. Under the 2003-06 baseline condition, the surface loss pathway accounted for 97 percent of phosphorus losses, which was no different from the no-practice scenario, in which the surface loss pathway accounted for 99 percent of phosphorus losses. Under the conservation practices adopted in 2011, the role of the surface loss pathway accounted for 94 percent of phosphorus losses (table 3.8).

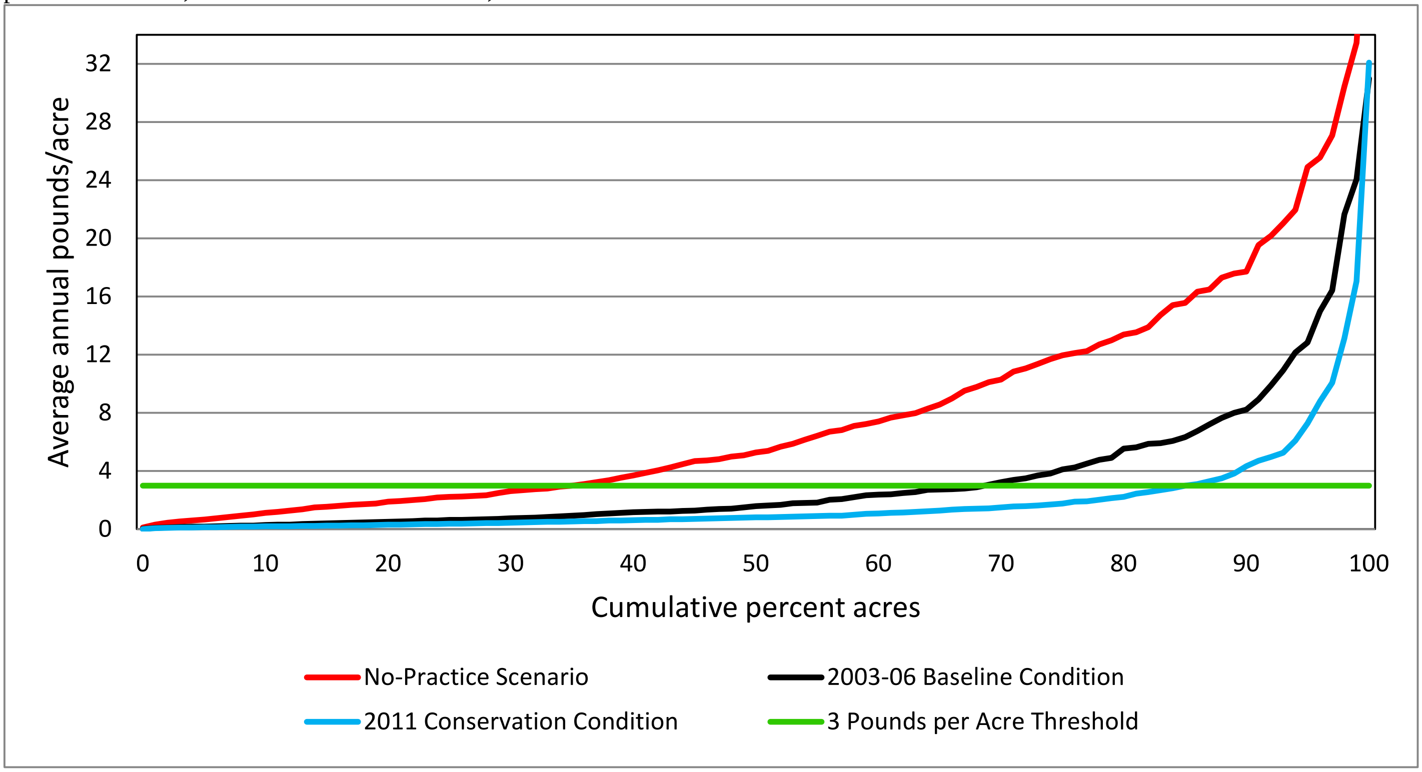
Acres classified as Highly Erodible Lands (HEL) received the same amount of total phosphorus inputs, 26.2 pounds per acre, in both survey periods. However, conservation practices reduced phosphorus losses on HEL acres by 57 percent, or 3.8 pounds per acre per year, between 2003-06 and 2011. On the cropped non-Highly Erodible Lands (NHEL), phosphorus application from fertilizer and manures increased by 8 percent, or 1.8 pounds per acre per year , but losses simultaneously declined by 33 percent, or 0.6 pounds per acre per year.

Table 3.8. Estimates of long-term average annual field-level effects of conservation practices on phosphorus sources and loss pathways on cropped acres in the Chesapeake Bay region: the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.

	Average annual values in pounds per acre				
Model simulated outcome	**No-practice Scenario**	**2003-06**	**2011**	**Change: No-practice to 2003-06**	**Change: 2003-06 to 2011**
Cropped acres					
Phosphorus sources					
Commercial fertilizer	30.4	20.1	21.1	-10.3	1.0
Manure	4.2	3.7	4.1	-0.5	0.4
Total Phosphorus inputs	34.6	23.8	25.2	-10.8	1.4
Phosphorus in crop yield removed at harvest	16.7	14.8	15.8	-1.9	1.0
Phosphorus loss pathways					
Windborne sediment	0.02	0.01	0.01	-0.01	<0.01
Surface water (sediment attached and soluble)*	7.9	3.3	1.8	-4.6	-1.5
Surface water (soluble)	1.1	0.5	0.5	-0.6	<0.01
Waterborne sediment	6.8	2.8	1.3	-4.0	-1.5
Subsurface flow pathways	0.1	0.1	0.1	<0.01	<0.01
Total phosphorus loss for all loss pathways	8.0	3.4	1.9	-4.6	-1.5
Change in soil phosphorus	4.3	0.5	2.6	-3.8	2.1
Highly erodible land (HEL)					
Phosphorus applied as commercial fertilizer and manure	34.4	26.2	26.2	-8.2	<0.01
Total phosphorus loss for surface and subsurface loss pathways	15.2	6.7	2.9	-8.5	-3.8
Non-highly erodible land (NHEL)					
Phosphorus applied as commercial fertilizer and manure	34.7	22.7	24.5	-12	1.8
Total phosphorus loss for surface and subsurface loss pathways	4.4	1.8	1.2	-2.6	-0.6
Acres with manure applied					
Phosphorus applied as commercial fertilizer and manure	46.8	39.0	35.6	-7.8	-3.4
Total phosphorus loss for surface and subsurface loss pathways	8.9	4.2	2.2	-4.7	-2.0
Acres without manure applied					
Phosphorus applied as commercial fertilizer	27.6	15.1	15.7	-12.5	0.6
Total phosphorus loss for surface and subsurface loss pathways	7.5	2.9	1.6	-4.6	-1.3

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Figure 3.11. Estimates of long-term average annual total phosphorus losses on cropped acres in the Chesapeake Bay region: the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.



As with nitrogen, total phosphorus application rates are much higher for cropped acres on which manure is part of the nutrient management plan than on acres relying solely on commercial phosphorus inputs (table 3.8). Progress toward effective management of nutrient losses associated with manured systems is demonstrated by the fact that the amount of phosphorus applied to acres receiving manure fell by 9 percent, or 3.4 pounds per acre between 2003-06 and 2011. Phosphorus losses from manured fields also declined by 2.0 pounds, or 48 percent over the same period (table 3.8). Between 2003-06 and 2011, the commercial-fertilizer-only acres had no appreciable change in annual phosphorus inputs and achieved a 45 percent, or 1.3 pound, reduction in the amount of phosphorus lost. However, in absolute terms the manured acres lost 2.2 pounds of phosphorus per acre per year in 2011, while the non-manured acres lost only 1.6 pounds per acre per year. The disparity in pound per acre phosphorus loss rates between manured and non-manured acres is not as great as the nitrogen disparity in manured and non-manured acre losses. However, it still signifies the need for a higher level of management when manure is part of the cropping system. Acres not receiving manure as part of their nutrient inputs had phosphorus application rates 19.2, 23.9, and 19.9 pounds lower than the average nitrogen application rate for manured fields in the no-practice, 2003-06, and 2011 scenarios, respectively (table 3.8). Similarly, non-manured acres had phosphorus loss rates 1.4, 1.3, and 0.6 pounds lower than the average phosphorus loss rates for manured fields in the no-practice, 2003-06, and 2011 scenarios, respectively. It is noteworthy that in all cases, the manured acres lost a lower percentage of the phosphorus applied than did the non-manured acres. The manured acres lost 19, 11, and 6 percent of phosphorus applied in the no-practice, 2003-06, and 2011 scenarios, respectively. The non-manured acres lost 27, 19, and 10 percent of applied phosphorus in the no-practice, 2003-06, and 2011 scenarios, respectively.

Phosphorus lost via surface runoff

Surface runoff was the dominant loss pathway for phosphorus, accounting for 99, 97, and 94 percent of all phosphorus losses in the no-practice, 2003-06, and 2011 scenarios, respectively. Data suggest the role of the loss pathway is diminishing, but in 2011 it was still responsible for 94 percent of all phosphorus losses. However, conservation practices adopted in 2003-06 and 2011 were effective at reducing pounds per acre phosphorus losses associated with runoff, including both soluble and sediment-bound phosphorus. Relative to the no-practice scenario, conservation practices in place in 2003-06 reduced phosphorus losses in surface runoff by 58 percentage points, decreasing losses from 7.9 to 3.3 pounds per acre per year. The conservation practices adopted in 2011 reduced phosphorus losses in surface runoff from 3.3 to 1.8 pounds per acre per year, a 46 percentage point reduction from 2003-06 loss rates (table 3.8).

Within the surface loss fraction, phosphorus bound to sediment accounts for the majority of the phosphorus lost. Of all lost phosphorus, the sediment bound phosphorus lost in surface flow accounted for 85, 82, and 68 percent of phosphorus losses in the no-practice, 2003-06, and 2011 scenarios, respectively. Since phosphorus tends to move with sediment, these reductions in phosphorus losses may be interpreted as a direct result of the controlling and trapping practices adopted between 2003-06 and 2011, such as increased adoption of cover crops, structural practices (such as filters and buffers), and reduced tillage. Opportunities remain to augment these improvements in the controlling and trapping aspects of the Avoid, Control, Trap (ACT) conservation strategy with practices that avoid nutrient losses. Changes in phosphorus application management likely played little role in achieving the observed loss reductions, but improved phosphorus application management could provide future conservation gains.

There is still opportunity to improve the avoidance aspect of ACT through better nutrient application management, which, as discussed in Chapter 2, was largely maintained at 2003-06 conservation levels. Although conservation practices adopted between 2003-06 and 2011 made demonstrable gains on reducing sediment associated phosphorus losses in surface runoff, the soluble fraction of phosphorus lost in surface runoff remained constant, maintaining an average loss rate of 0.5 pounds per acre. Because of the 44 percent reduction in total phosphorus losses, the role of the surface loss pathway in relation to soluble phosphorus loss increased in relevance, accounting for 15 percent of losses in 2003-06, but 26 percent of losses in 2011 (table 3.8). This indicates that there is potential for more nutrient loss reduction with improved nutrient application management. It is critical to note that practices such as cover crops and conservation tillage need to be maintained as active parts of the cropping systems and management strategies if these gains are to be continually realized in the future.

Conservation practice adoption between the no-practice scenario and 2003-06 scenario reduced the percentage of acres on which surface runoff losses exceeded 3 pounds of phosphorus annually from 66 to 31 percent of cropped acres. In the 2011 conservation condition, only 15 percent of cropped acres experienced runoff losses exceeding 3 pounds of phosphorus annually. While these trends are promising, the number of acres exceeding the 3-pound threshold demonstrates opportunity for continued conservation gains in phosphorus loss reduction.

The model scenario removing cover crops only from the 2011 conservation systems indicates on average their use improved reduction of phosphorus losses by 36 percent. Frequency of use did not substantially impact efficacy of cover crop adoption in improving phosphorus loss reduction. Annual use of cover crops improved phosphorus reduction by 30 percent, while application of cover crops at a frequency of one out of every 3 years or more, but not annually, provided phosphorus loss reductions of 28 percent. Relative to no cover crop adoption, less frequent cover crop use reduced phosphorus losses by up to 19 percent. The cause for the lesser impact of cover crop adoption on phosphorus losses relative to sediment and nitrogen losses is unclear, but may be related to application timing with respect to crop needs and runoff events. There is a significantly lower risk of phosphorus loss to subsurface flows due to its much lower mobility relative to nitrogen.

Phosphorus lost via subsurface flow

The subsurface flow pathway accounts for very little phosphorus loss under all three simulated scenarios. Roughly 1, 3, and 5 percent of phosphorus lost was lost via subsurface flows in the no-practice, 2003-06, and 2011 scenarios, respectively. The trend towards increasing importance of this pathway is due to conservation successes that have reduced overall phosphorus losses. In fact, this loss pathway accounted for an average of 0.1 pound of phosphorus loss per acre per year under all three scenarios.

These model simulation results underscore the importance of pairing water erosion control practices with effective nutrient management practices so that the full suite of conservation practices work in concert to provide the environmental protection needed.

Chapter 4
Assessment of Conservation Treatment Needs

The conservation practices in use in the Chesapeake Bay region during 2003-06 and 2011 were evaluated to identify the long-term impact of the practices on sediment and nutrient losses and to estimate conservation ***treatment needs*** for controlling sediment and nutrient losses from fields.

Four resource concerns were evaluated for the Chesapeake Bay region:

- Sediment loss due to water erosion;
- Nitrogen loss with surface runoff (nitrogen attached to sediment and in solution);
- Nitrogen loss via subsurface flow pathways; and
- Phosphorus loss (phosphorus attached to sediment and in solution in surface water and soluble phosphorus in subsurface flow pathways).

Adequate treatment for each resource concern is site-specific and is achieved by adopting conservation practices that treat the specific inherent vulnerability factors associated with each field. Not all acres require the same level of conservation treatment and a singular practice, or even a given suite of practices, will not provide the same amount of conservation benefit for all acres. Acres with high inherent vulnerability require more treatment than do less vulnerable acres. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable to sediment and nutrient losses beyond the edge of the field via overland flow losses. Acres that are essentially flat and have porous soil types are more prone to nutrient losses through subsurface flow pathways, most of which return to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

Model results suggest that adoption of structural practices intended to reduce sediment losses coupled with adoption of practices intended to reduce nutrient losses had significant impacts in the Chesapeake Bay region between 2003-06 and 2011. Acres requiring additional treatment for one or more resource concerns declined from 59 to 46 percent of acres. Although gains have been made, roughly half of the acres in the region still require additional treatment for one or more resource concerns. Further, acres that are adequately treated require continued conservation planning and management to maintain current conservation gains. In summary, APEX simulations for the Chesapeake Bay region indicate the following changes due to conservation practice adoption between 2003-06 and 2011:

- Acres requiring additional treatment to control sediment runoff losses: *were reduced by 28 percentage points,* dropping from 43 to 15 percent of acres;
- Acres requiring additional treatment to control nitrogen runoff: *were reduced by 21 percentage points,* dropping from 35 to 14 percent of acres;
- Acres requiring additional treatment to control subsurface nitrogen losses: *increased by 11 percentage* points, from 25 to 36 percent of acres; and
- Acres requiring additional treatment to control phosphorus losses: *were reduced by 18 percentage* points, from 30 to 12 percent of acres.

Conservation Treatment Levels

In this study, ***treatment needs*** for cropped acres in the Chesapeake Bay region were estimated by cross-referencing ***conservation treatment levels*** (defined by the type and combinations of conservation practices documented in the 2003-06 and 2011 surveys) with ***inherent vulnerability potentials*** (which reflect inherent risks to soils and nutrients due to soil properties and landscape characteristics).

Conservation treatment criteria have been refined since the previous report (USDA NRCS 2011). The assessment of conservation treatment needs for the 2003-06 period was re-analyzed according to the improved criteria. Therefore, the findings reported here for that survey period differ from those previously reported.

Four levels of conservation treatment (***high, moderately high, moderate,*** and ***low***) were defined for each resource concern:

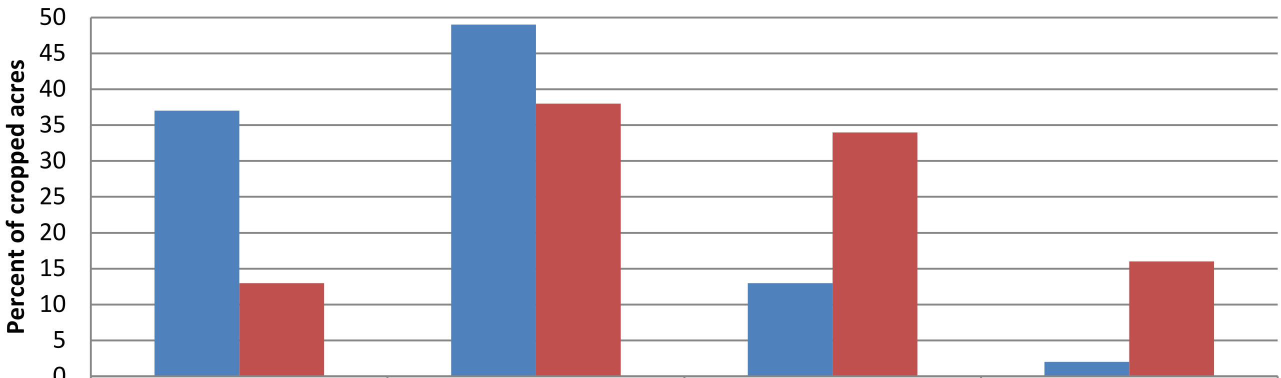
- Sediment loss due to water erosion: conservation treatment levels were defined by a combination of structural practices, cover crops, and residue and tillage management practices (fig. 4.1);
- Nitrogen loss with surface water runoff: conservation treatment levels were defined by a combination of structural practices, cover crops, residue and tillage management practices, ***and*** nitrogen application management practices (fig. 4.2);
- Nitrogen loss via subsurface flow: conservation treatment levels were defined by a combination of the level of residue produced by the full crop rotation ***and*** nitrogen application management practices (figs. 2.3 and 4.3); and
- Phosphorus loss with surface water runoff: conservation treatment levels were defined by a combination of structural practices, cover crops, residue and tillage management practices, ***and*** phosphorus application management practices (figs. 2.6 and 4.4).

When not exposed to excessive tillage, high residue crop rotations, especially those with cover crops, tend to retain more nutrients in the organic fractions of the soil, thereby reducing the amount of nutrients lost to ground and surface waters. Cropped acres managed with a ***high treatment level*** typically maintained significantly reduced sediment and nutrient losses as compared to acres with lower levels of treatment (tables 4.1 through 4.4).

Sediment Losses

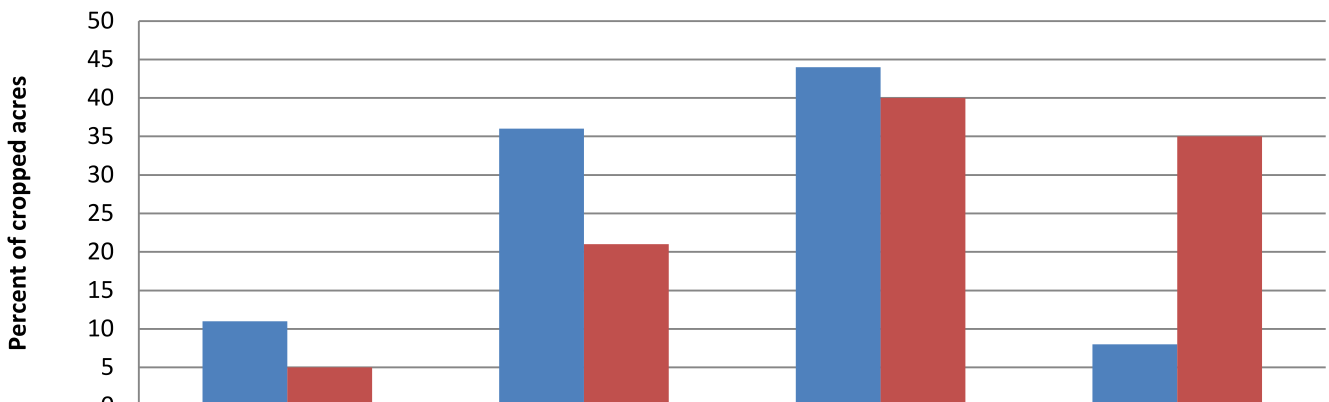
Marked increases in levels of treatment and associated sediment-related conservation gains were largely driven by significant increases in adoption of structural practices, cover crops, and conservation tillage (Chapter 3).

Figure 4.1. Percent of cropped acres in each conservation treatment level for water erosion control in the Chesapeake Bay region, 2003-06 and 2011.



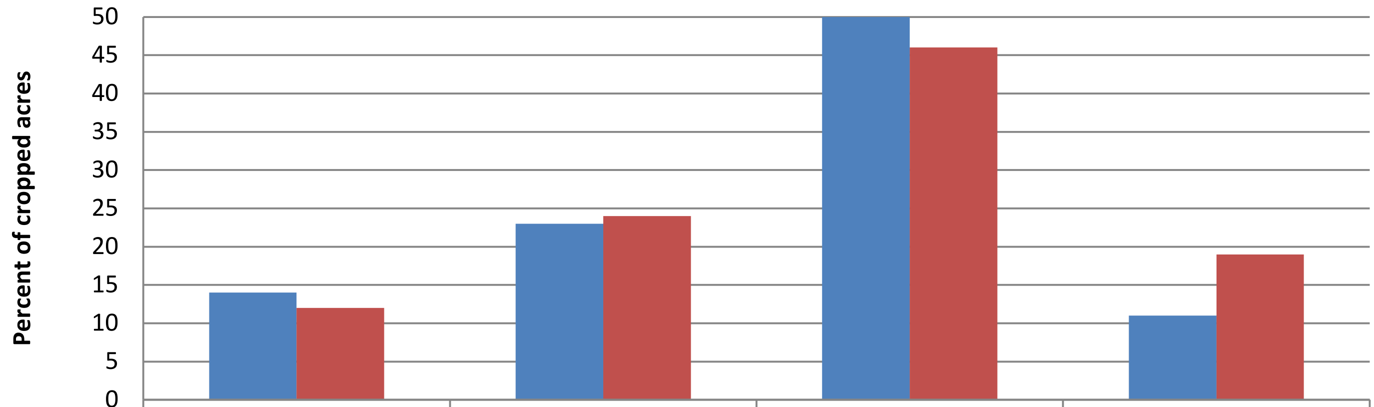
	Low	Moderate	Moderately High	High
2003-06	37	49	13	2
2011	13	38	34	16

Figure 4.2. Percent of cropped acres in each conservation treatment level for nitrogen runoff control in the Chesapeake Bay region, 2003-06 and 2011.



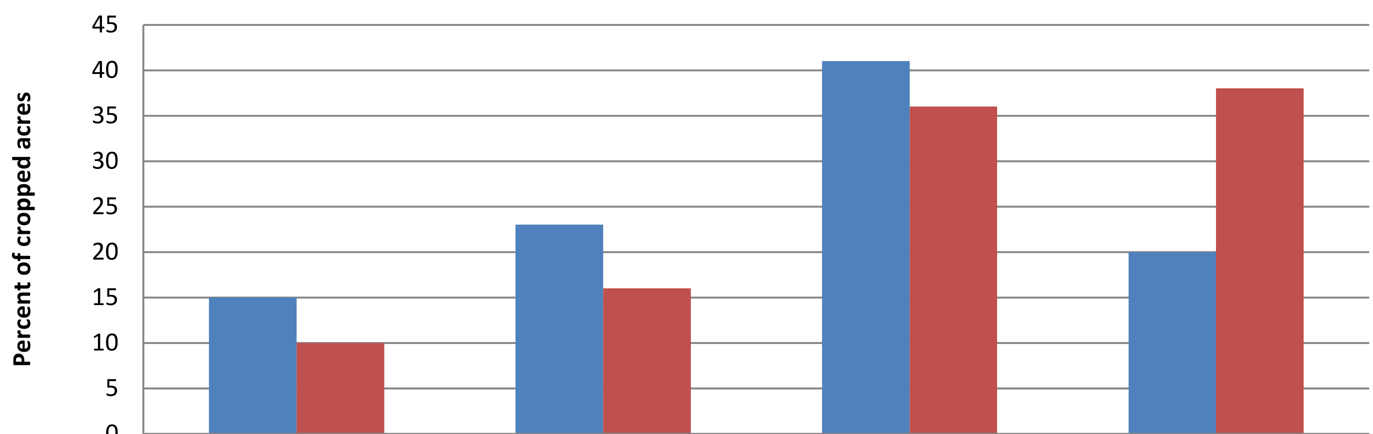
	Low	Moderate	Moderately High	High
2003-06	11	36	44	8
2011	5	21	40	35

Figure 4.3. Percent of cropped acres in each conservation treatment level for nitrogen leaching control in the Chesapeake Bay region, 2003-06 and 2011.



	Low	Moderate	Moderately High	High
2003-06	14	23	50	11
2011	12	24	46	19

Figure 4.4. Percent of cropped acres in each conservation treatment level for phosphorus runoff control in the Chesapeake Bay region, 2003-06 and 2011.



	Low	Moderate	Moderately High	High
2003-06	15	23	41	20
2011	10	16	36	38

Table 4.1. Estimated average annual sediment loss for levels of soil runoff potential by levels of conservation treatment, Chesapeake Bay region (2011 conservation condition).

	Sediment Treatment Level (tons/acre)			
Runoff Potential	Low	Moderate	Mod. High	High
Low	3.1	0.8	0.5	0.2
Moderate	7.8	1.3	1.0	0.3
Mod. High	9.3	1.8	0.8	0.2
High	19.8	6.6	2.3	4.4

Table 4.2. Estimated average annual nitrogen loss with surface runoff for levels of soil runoff potential by levels of conservation treatment, Chesapeake Bay region (2011 conservation condition).

	Nitrogen Runoff Treatment Level (pounds/acre)			
Runoff Potential	Low	Moderate	Mod. High	High
Low	14.0	8.2	6.7	3.9
Moderate	13.5	18.5	10.8	6.8
Mod. High	31.5	17.9	11.2	8.0
High	38.4	28.3	21.3	12.6

Table 4.3. Estimated average annual nitrogen loss in subsurface flows for levels of soil leaching potential by levels of conservation treatment, Chesapeake Bay region (2011 conservation condition).

	Nitrogen Leaching Treatment Level (pounds/acre)			
Leaching Potential	Low	Moderate	Mod. High	High
Low	26.4	29.7	13.6	10.7
Moderate	47.5	27.1	17.1	16.6
Mod. High	36.1	29.9	16.0	10.6
High	71.1	34.0	29.9	10.9

Table 4.4. Estimated average annual phosphorus loss to surface water for levels of soil runoff potential by levels of conservation treatment, Chesapeake Bay region (2011 conservation condition).

	Phosphorus Runoff Treatment Level (pounds/acre)			
Runoff Potential	Low	Moderate	Mod. High	High
Low	4.0	1.8	1.0	0.6
Moderate	3.7	3.0	2.3	1.1
Mod. High	6.8	3.8	2.1	1.0
High	8.6	7.4	4.8	1.9

Model simulations demonstrated the following changes in conservation treatment levels for sediment losses due to water erosion on cropped acres in the Chesapeake Bay region in the 2003-06 baseline condition and 2011 conservation condition (fig. 4.1 and table 4.5):

- Acres receiving a ***high treatment level*** of water erosion control: *14 percentage point increase,* from 2 to 16 percent of cropped acres;
- Acres receiving a ***moderately high treatment level*** of water erosion control: *21 percentage point increase,* from 13 to 34 percent of cropped acres;
- Acres receiving a ***moderate treatment level*** of water erosion control: *11 percentage point decrease,* from 49 to 38 percent of cropped acres; and
- Acres receiving a ***low treatment level*** of water erosion control: *24 percentage point decrease,* from 37 to 13 percent of cropped acres.

Declines in the number of acres in the ***low*** and ***moderate treatment level*** categories are a positive trend. These declines demonstrate that more acres are receiving higher levels of treatment to prevent sediment losses.

Nitrogen Losses

Model simulations demonstrated the following changes in conservation treatment levels for nitrogen losses via surface water pathways on cropped acres in the Chesapeake Bay region in the 2003-06 baseline condition and 2011 conservation condition (fig. 4.2 and table 4.6):

- Acres receiving a ***high treatment level*** of surface nitrogen loss controls: *27 percentage point increase,* from 8 to 35 percent of cropped acres;
- Acres receiving a ***moderately high treatment level*** of surface nitrogen loss controls: *maintained 2003-06 conservation treatment levels,* at 44 and 40 percent of cropped acres;
- Acres receiving a ***moderate treatment level*** of surface nitrogen loss controls: *15 percentage point decrease,* from 36 to 21 percent of cropped acres; and
- Acres receiving a ***low treatment level*** of surface nitrogen loss controls: *6 percentage point decrease,* from 11 to 5 percent of cropped acres.

Declines in the number of acres in the ***low*** and ***moderate treatment level*** categories are a positive trend. These declines demonstrate that more acres are receiving higher levels of treatment to prevent nitrogen losses in surface runoff.

Model simulations demonstrated the following changes in conservation treatment levels for nitrogen losses via subsurface flow pathways on cropped acres in the Chesapeake Bay region in the 2003-06 baseline condition and 2011 conservation condition. (fig. 4.3 and table 4.7):

- Acres receiving a ***high treatment level*** of subsurface nitrogen loss controls: *8 percentage point increase,* from 11 to 19 percent of cropped acres;

Table 4.5. Estimation of under-treated acres for sediment loss due to water erosion in the Chesapeake Bay region, 2003-06 baseline condition and 2011 conservation condition.

	Conservation treatment levels for water erosion control				
Soil runoff potential	Low	Moderate	Mod-High	High	All
I. 2003-06 Estimated cropped acres					
Low	799,009	954,338	221,865	17,201	1,992,414
Moderate	204,474	223,051	59,635	8,861	496,021
Moderately high	268,264	403,203	127,054	13,618	812,140
High	319,046	495,226	130,583	34,470	979,325
All	1,590,793	2,075,818	539,138	74,151	4,279,900
Percent of Total	37%	49%	13%	2%	100%
II. 2003-06 Percent of acres in baseline conservation condition with annual average sediment loss less than 2 tons/acre					
Low	62	88	78	100	77
Moderate	37	84	62	100	62
Moderately High	32	59	69	100	52
High	6	37	38	63	28
All	43	69	65	83	59
III. 2003-06 Estimate of under-treated acres					
Low	0	0	0	0	0
Moderate	204,474	0	0	0	204,474
Moderately High	268,264	403,203	0	0	671,467
High	319,046	495,226	130,583	0	944,855
All	791,784	898,429	130,583	0	1,820,796
IV. 2011 Estimated cropped acres					
Low	267,400	713,400	524,100	309,800	1,814,700
Moderate	82,100	291,400	241,300	75,200	690,000
Moderately high	91,000	288,500	332,800	92,000	804,300
High	121,800	354,100	349,400	219,100	1,044,400
All	562,300	1,647,400	1,447,600	696,100	4,353,400
Percent of Total	13%	38%	34%	16%	100%
V. 2011 Percent of acres in current conservation condition with annual average sediment loss less than 2 tons/acre					
Low	77	93	98	96	93
Moderate	34	83	91	100	82
Moderately high	44	82	93	100	85
High	11	57	81	87	66
All	51	82	92	94	83
VI. 2011 Estimate of under-treated acres					
Low	0	0	0	0	0
Moderate	82,100	0	0	0	82,100
Moderately high	91,000	0	0	0	91,000
High	121,800	354,100	0	0	475,900
All	294,900	354,100	0	0	649,000

Note: Color-shaded cells indicate under-treated acres. Bright yellow-shaded cells indicate groups of acres in which more than 30 percent of the acres have losses exceeding acceptable levels and were defined as moderate needs acres. Darker yellow-shaded cells indicate high needs under-treated acres, which were defined as groups of acres in which more than 60 percent of the acres have losses in excess of acceptable levels.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.

Table 4.6. Estimation of under-treated acres for nitrogen loss due to surface runoff in the Chesapeake Bay region, 2003-06 baseline condition and 2011 conservation condition.

	Conservation treatment levels for nitrogen runoff control				
Soil runoff potential	Low	Moderate	Mod-High	High	All
I. 2003-06 Estimated cropped acres					
Low	208,143	741,688	904,986	137,597	1,992,414
Moderate	51,509	187,142	201,473	55,897	496,021
Moderately high	99,010	265,455	386,254	61,421	812,140
High	109,317	354,150	413,920	101,939	979,325
All	467,979	1,548,435	1,906,632	356,854	4,279,900
Percent of Total	11%	36%	44%	8%	100%
II. 2003-06 Percent of acres in baseline conservation condition with annual average nitrogen loss less than 15 lbs/acre					
Low	68	79	90	99	84
Moderate	73	38	81	93	65
Moderately High	18	43	69	65	56
High	5	24	32	46	28
All	43	55	72	77	63
III. 2003-06 Estimate of under-treated acres					
Low	0	0	0	0	0
Moderate	0	187,142	0	0	187,142
Moderately High	99,010	265,455	0	0	364,465
High	109,317	354,150	413,920	101,939	979,325
All	208,327	806,747	413,920	101,939	1,530,932
IV. 2011 Estimated cropped acres					
Low	93,500	389,500	664,900	666,800	1,814,700
Moderate	16,900	131,800	315,400	225,900	690,000
Moderately high	26,100	164,800	328,800	284,600	804,300
High	67,200	226,300	414,300	336,600	1,044,400
All	203,700	912,400	1,723,400	1,513,900	4,353,400
Percent of Total	5%	21%	40%	35%	100%
V. 2011 Percent of acres in current conservation condition with annual average nitrogen loss less than 15 lbs/acre					
Low	59	97	94	97	94
Moderate	*	63	80	88	79
Moderately high	7	52	97	91	83
High	13	52	64	79	63
All	40	73	85	90	82
VI. 2011 Estimate of under-treated acres					
Low	93,500	0	0	0	93,500
Moderate	*	0	0	0	0
Moderately high	26,100	164,800	0	0	190,900
High	67,200	226,300	0	0	293,500
All	186,800	391,100	0	0	577,900

Note: Color-shaded cells indicate under-treated acres. Bright yellow-shaded cells indicate groups of acres in which more than 30 percent of the acres have losses exceeding acceptable levels and were defined as moderate needs acres. Darker yellow-shaded cells indicate high needs under-treated acres, which were defined as groups of acres in which more than 60 percent of the acres have losses in excess of acceptable levels.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.

Table 4.7. Estimation of under-treated acres for nitrogen loss due to subsurface flow and leaching in the Chesapeake Bay region, 2003-06 baseline condition and 2011 conservation condition.

	Conservation treatment levels for subsurface nitrogen loss control				
Soil leaching potential	Low	Moderate	Mod-High	High	All
I. 2003-06 Estimated cropped acres					
Low	64,940	82,214	114,084	13,801	275,040
Moderate	311,527	480,004	1,018,873	227,855	2,038,260
Moderately high	203,854	220,431	695,473	129,409	1,249,166
High	50,358	218,012	333,166	115,899	717,434
All	630,678	1,000,661	2,161,597	486,964	4,279,900
Percent of Total	15%	23%	50%	11%	100%
II. 2003-06 Percent of acres in baseline conservation condition with annual average nitrogen loss less than 25 lbs/acre					
Low	59	71	92	100	78
Moderate	34	69	81	86	72
Moderately High	21	58	83	100	71
High	53	51	69	100	67
All	34	63	81	93	71
III. 2003-06 Estimate of under-treated acres					
Low	64,940	0	0	0	64,940
Moderate	311,527	0	0	0	311,527
Moderately High	203,854	220,431	0	0	424,285
High	50,358	218,012	0	0	268,369
All	630,678	438,442	0	0	1,069,121
IV. 2011 Estimated cropped acres					
Low	4,800	85,500	103,600	75,900	269,800
Moderate	295,600	676,400	1,270,900	484,000	2,726,900
Moderately high	87,300	113,400	420,900	130,400	752,000
High	115,100	174,300	186,400	128,900	604,700
All	502,800	1,049,600	1,981,800	819,200	4,353,400
Percent of Total	12%	25%	46%	19%	100%
V. 2011 Percent of acres in current conservation condition with annual average nitrogen loss less than 25 lbs/acre					
Low	*	48	92	80	74
Moderate	56	59	78	76	71
Moderately high	40	51	87	87	76
High	50	54	71	92	66
All	52	57	80	81	71
VI. 2011 Estimate of under-treated acres					
Low	*	85,500	0	0	85,500
Moderate	295,600	676,400	0	0	972,000
Moderately high	87,300	113,400	0	0	200,700
High	115,100	174,300	0	0	289,400
All	498,000	1,049,600	0	0	1,547,600

Note: Color-shaded cells indicate under-treated acres. Bright yellow-shaded cells indicate groups of acres in which more than 30 percent of the acres have losses exceeding acceptable levels and were defined as moderate needs acres. Darker yellow-shaded cells indicate high needs under-treated acres, which were defined as groups of acres in which more than 60 percent of the acres have losses in excess of acceptable levels.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.

- Acres receiving a ***moderately high treatment level*** of subsurface nitrogen loss controls: *maintained 2003-06 conservation treatment levels,* at 50 and 46 percent of cropped acres;
- Acres receiving a ***moderate treatment level*** of subsurface nitrogen loss controls: *maintained 2003-06 conservation treatment levels,* at 23 and 24 percent of cropped acres; and
- Acres receiving a ***low treatment level*** of subsurface nitrogen loss controls: *maintained 2003-06 conservation treatment levels,* at 14 and 12 percent of cropped acres.

These results suggest that less progress was made in terms of advancing treatment for preventing nitrogen losses in subsurface flows. Accomplishing a reduction in surface losses necessarily increases the potential for subsurface losses because water and nutrients are kept on the farm field, where they may be lost to subsurface flow pathways. Opportunities for conservation gains related to subsurface nitrogen losses remain, particularly in light of the numerous conservation practices adopted to reduce surface losses.

Phosphorus Losses

Model simulations demonstrated the following changes in conservation treatment levels for phosphorus losses via surface runoff pathways on cropped acres in the Chesapeake Bay region in the 2003-06 baseline condition and 2011 conservation condition (fig. 4.4 and table 4.8):

- Acres receiving a ***high treatment level*** of phosphorus loss controls: *18 percentage point increase,* from 20 to 38 percent of cropped acres;
- Acres receiving a ***moderately high treatment level*** of phosphorus loss controls: *maintained 2003-06 conservation treatment levels,* at 41 and 36 percent of cropped acres;
- Acres receiving a ***moderate treatment level*** of phosphorus loss controls: *7 percentage point decline,* decreased from 23 to 16 percent of cropped acres; and
- Acres receiving a ***low treatment level*** of phosphorus loss controls: *maintained 2003-06 conservation treatment levels,* at 15 and 10 percent of cropped acres.

Criteria for water erosion control treatment levels were derived using the sediment scoring system (Appendix F), where the relative ability of each practice to avoid, control, and trap sediment losses is rated for each of the preceding mitigation categories. Each practice has a maximum of 20 points for each mitigation category, for a total of 60 points. Each practice occurring at a survey point is scored and summed for the total points for that conservation system. The categorization of treatment levels for erosion control is as follows:

- ***High treatment***: Sum of scores is equal to or greater than 100;
- ***Moderately high treatment***: Sum of scores is equal to or greater than 70;
- ***Moderate treatment***: Sum of scores is equal to or greater than 40; and
- ***Low treatment***: Sum of scores is less than 40.

Criteria for nitrogen runoff treatment levels were derived from an equal combination of the scores for sediment control (Appendix F) and the nitrogen application scores (fig. 2.3) to produce a nitrogen runoff management score. The sediment control scores are normalized to match the scale of the potential points for nitrogen applications. Crop residue classification for the rotation is also used to define the treatment level for nitrogen runoff. The categorization of treatment levels for nitrogen runoff control is as follows:

- ***High treatment***: Acres with a nitrogen runoff management score greater than 65 or a score greater than 50 with a moderate residue rotation score (>1);
- ***Moderately high treatment***: Acres with a nitrogen runoff management score greater than or equal to 50 or a score greater than or equal to 40 with a moderate residue rotation score (>1);
- ***Moderate treatment***: Acres with a nitrogen runoff management score greater than or equal to 30; and
- ***Low treatment***: Acres with a nitrogen runoff management score less than 30.

Criteria for nitrogen treatment levels for leaching are based on the nitrogen application scores (fig. 2.3) and the rotation's crop residue classification (fig. 2.2). The categorization of treatment levels for nitrogen subsurface loss control is as follows:

- ***High treatment***: Acres with a nitrogen application score greater than 45 or a score greater than 30 with a high residue rotation score (>3);
- ***Moderately high treatment***: Acres with a nitrogen application score greater than 30 and at least a moderate residue rotation or a score greater than 20 and a high residue rotation score (>3);
- ***Moderate treatment***: Acres with a nitrogen application score greater than 20 and at least a moderate residue rotation score (>1); and
- ***Low treatment***: Acres with a nitrogen application score less than or equal to 20 and all other cases not accounted for in the above criteria. These are typically low residue rotations with nitrogen application scores less than or equal to 30.

Criteria for phosphorus runoff treatment levels were derived from an equal combination of the scores for sediment control (Appendix F) and the phosphorus application scores (fig. 2.5) to produce a phosphorus runoff management score. The sediment control scores are normalized to the match the scale of the potential points for phosphorus applications. Crop residue classification for the rotation is also used to define the treatment level for phosphorus runoff. The categorization of treatment levels for phosphorus runoff control is as follows:

- ***High treatment***: Acres with a phosphorus runoff management score greater than 65 or a score greater than 50 with a moderate residue rotation score (>1);
- ***Moderately high treatment***: Acres with a phosphorus runoff management score greater than or equal to 50 or a score greater than or equal to 40 with a moderate residue rotation score (>1);

Table 4.8. Estimation of under-treated acres for phosphorus loss due to surface runoff in the Chesapeake Bay region, 2003-06 baseline condition and 2011 conservation condition.

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Mod-High	High	All
I. 2003-06 Estimated cropped acres					
Low	222,493	667,221	613,357	489,343	1,992,414
Moderate	99,683	156,847	153,334	86,157	496,021
Moderately high	135,212	290,999	264,243	121,686	812,140
High	212,395	295,932	316,374	154,623	979,325
All	669,783	1,410,999	1,347,308	851,810	4,279,900
Percent of Total	15%	33%	31%	20%	100%
II. 2003-06 Percent of acres in baseline conservation condition with annual average phosphorus loss less than 3 lbs/acre					
Low	66	79	94	100	87
Moderate	71	45	76	89	68
Moderately High	35	48	71	99	61
High	14	25	53	60	37
All	44	57	78	91	69
III. 2003-06 Estimate of under-treated acres					
Low	0	0	0	0	0
Moderate		156,847	0	0	156,847
Moderately High	135,212	290,999	0	0	426,211
High	212,395	295,932	316,374	0	824,702
All	347,607	743,778	316,374	0	1,407,760
IV. 2011 Estimated cropped acres					
Low	177,100	262,600	634,000	741,000	1,814,700
Moderate	62,800	111,500	251,500	264,200	690,000
Moderately high	67,900	139,200	310,700	286,500	804,300
High	148,000	159,000	363,300	374,100	1,044,400
All	455,800	672,300	1,559,500	1,665,800	4,353,400
Percent of Total	10%	15%	36%	38%	100%
V. 2011 Percent of acres in current conservation condition with annual average phosphorus loss less than 3 lbs/acre					
Low	71	97	95	99	94
Moderate	72	74	84	92	85
Moderately high	54	59	89	91	82
High	35	59	70	89	70
All	57	76	86	94	85
VI. 2011 Estimate of under-treated acres					
Low	0	0	0	0	0
Moderate	0	0	0	0	0
Moderately high	67,900	139,200	0	0	207,100
High	148,000	159,000	0	0	307,000
All	215,900	298,200	0	0	514,100

Note: Color-shaded cells indicate under-treated acres. Bright yellow-shaded cells indicate groups of acres in which more than 30 percent of the acres have losses exceeding acceptable levels and were defined as moderate needs acres. Darker yellow-shaded cells indicate high needs under-treated acres, which were defined as groups of acres in which more than 60 percent of the acres have losses in excess of acceptable levels.

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.

- ***Moderate treatment***: Acres with a phosphorus runoff management score greater than or equal to 30; and
- ***Low treatment***: Acres with a phosphorus runoff management score less than 30.

Inherent Vulnerability Factors

The same level of conservation treatment will not yield identical conservation benefits on all acres due to site differences, including variability of inherent vulnerabilities due to soils and climate. Inherent vulnerability factors are immutable, but conservation practices can prevent or mitigate the impacts of these vulnerabilities on natural resource sustainability and water quality. Inherent vulnerability factors affecting surface runoff potential include soil properties that promote surface water runoff and erosion—soil hydrologic group, slope, and K-factor. Inherent factors affecting leaching potential for loss of nutrients via subsurface flow include soil properties that promote permeability and/or infiltration—soil hydrologic group, slope, K-factor, wetness periods, and coarse fragment content of the soil.

Soil runoff potential and leaching potential were estimated for each sample point on the basis of vulnerability criteria. A single set of criteria was developed for all regions and soils in the United States to allow for regional comparisons. Thus, some soil runoff and leaching potentials are not well represented in every region. The criteria were not designed to enable comparisons at the within-region scale.

Relative to USDA NRCS's previous CEAP report on the region, this report uses improved soils data (USDA NRCS 2011). Criteria for soil runoff and soil leaching potentials are presented in Appendix G and H. Figures 4.5 and 4.6 show the spatial distribution of ***inherent vulnerability potentials*** to runoff and leaching for all soils and land uses in the region. The inherent runoff and leaching potentials for cropped acres were used to assess conservation treatment needs.

Cropped acres in the Chesapeake Bay region have a mix of vulnerability levels relative to potential soil and nutrient losses via surface runoff loss pathways. Highly erodible lands (HEL) tend to be more vulnerable to runoff losses than do non-highly erodible lands (NHEL). Under 2011 conservation conditions:

- 23 percent of cropped acres have a ***high soil runoff potential***;
- 19 percent of cropped acres have a ***moderately high soil runoff potential***;
- 12 percent of cropped acres have a ***moderate soil runoff potential***; and
- 47 percent, of cropped acres have a ***low soil runoff potential***.

Compared to variability in runoff vulnerability, cropped acres in the region have a relatively consistent need for conservation treatments to address nitrogen leaching. Though nearly half of the acres have low vulnerability to soil runoff, only 6 percent have low vulnerability to leaching. Nitrogen leaching vulnerability is not correlated with erodibility. Approximately 7 percent of cropped acres in the region have the unique combination of high vulnerability to leaching and HEL classification. These soils are generally found on sloping soils in the Susquehanna Valley and tend to be shallow with more than 10 percent rock fragments in the surface. Under 2011 conservation conditions:

- 17 percent of cropped acres have a ***high soil leaching potential***;
- 29 percent of cropped acres have a ***moderately high soil leaching potential***;
- 48 percent of cropped acres have a ***moderate soil leaching potential***; and
- 6 percent of cropped acres have a ***low soil leaching potential***.

Estimation of Remaining Conservation Treatment Needs

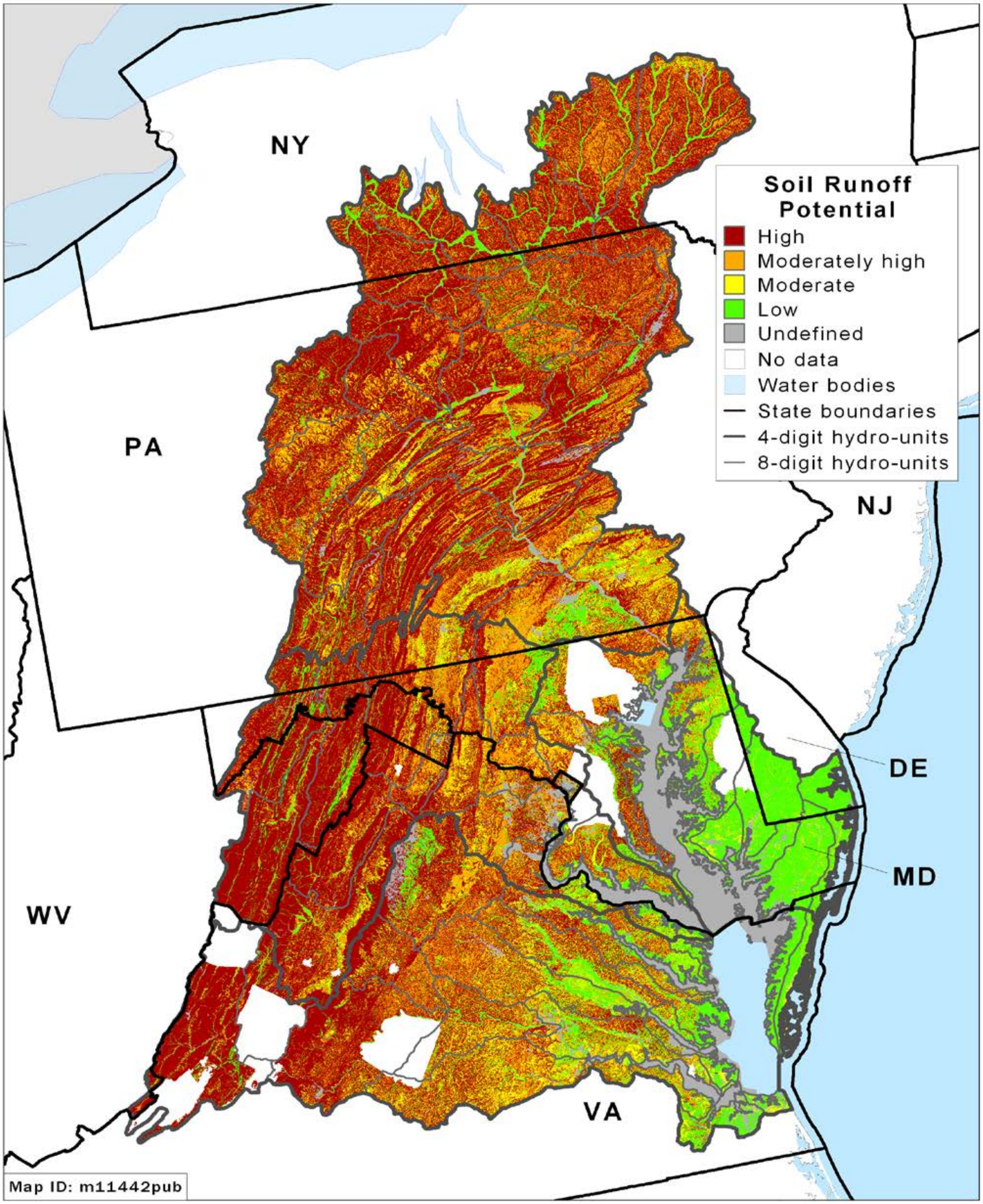
Treatment needs were evaluated by using a "matrix approach" to contrast the ***conservation treatment level*** of each acre with its own ***inherent vulnerability potential*** for runoff and/or leaching. Application of the matrix approach classified cropped acres into 16 groups—4 classes of soil ***inherent vulnerability potentials*** by 4 ***conservation treatment levels.*** In this way, the matrix approach identified acres on which the level of conservation treatment was inadequate relative to the inherent conservation need. This matrix approach may be used to inform a targeted approach to natural resources management, as it enables identification of the most probable combinations of ***inherent vulnerability potentials*** and ***conservation treatment levels*** in need of further treatment and also indicates how critical that need may be. Thus, the matrix approach is a useful tool for field offices and programs to better focus resources toward acres with low conservation treatment levels and high inherent vulnerability potentials to better address conservation needs.

Relative to lower conservation treatment levels, ***high*** or ***moderately high treatment levels*** tend to be far more effective at reducing losses for all classes of ***inherent vulnerability potential***, as shown in tables 4.1 through 4.4. Inadequately treated acres are referred to as "under-treated acres." By segregating acres with high loss potential from acres with low loss potential, the matrix approach provides an estimate of the acres with the greatest ***conservation treatment needs***. Using this approach, each category is within 4 percent of the estimated acres needing treatment for the NRCS-identified threshold for that resource concern (tables 4.5 through 4.8).

As expected, simulated estimates of sediment and nutrient loss exhibited a trend of decreasing loss with increasing conservation treatment level within a given inherent vulnerability potential class. The highest losses were predicted for groups of acres where the conservation treatment level was one step or more below the soil leaching or runoff potential class.

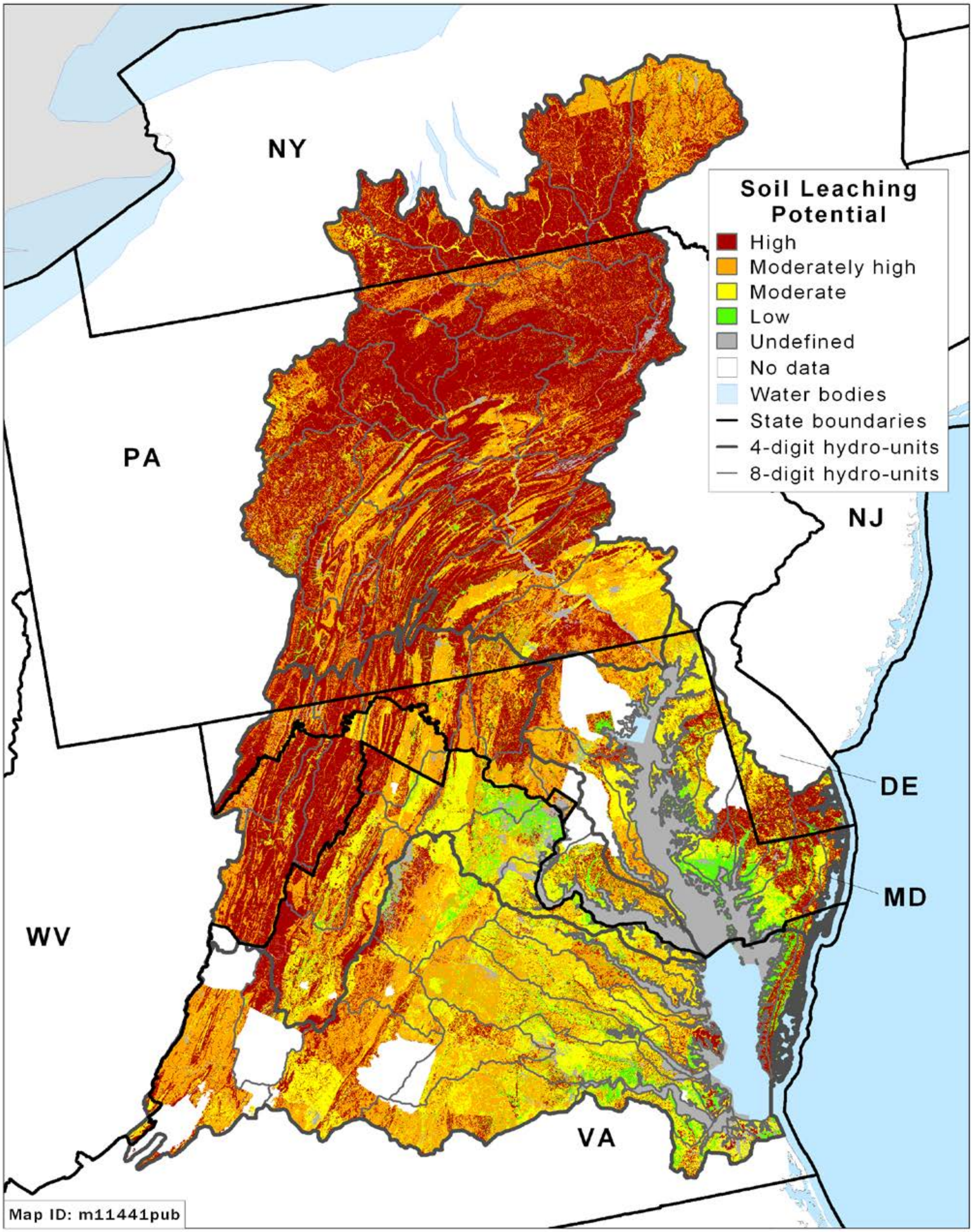
The evaluation of conservation treatment needs was conducted by identifying which of the 16 groups of acres were inadequately treated with respect to inherent soil runoff or soil leaching potential. Three levels of conservation treatment need were identified and applied to the matrices (tables 4.5 through 4.8):

Figure 4.5. Soil runoff potential vulnerability classes for soils in the Chesapeake Bay region.



Note: The soil runoff vulnerability potential shown in this map was derived using the criteria presented in Appendix G applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

Figure 4.6. Soil leaching potential vulnerability classes for soils in the Chesapeake Bay region.



Note: The soil leaching potential classes shown in this map were derived using the criteria presented in Appendix H applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

- ***High needs acres:*** the most vulnerable of the under-treated acres, with the least conservation treatment and the highest losses of sediment and/or nutrients. Groups of acres in which more than 60 percent of the acres have losses in excess of acceptable levels were designated as having a high level of conservation treatment need, indicated by the darkest shading in the cells in the matrices.
- ***Moderate needs acres:*** under-treated acres that generally have lower levels of vulnerability and/or have more conservation practices in place than do high needs acres. The treatment level required to adequately treat these acres is not necessarily less than what is required on high needs acres, although it can be. The sediment and/or nutrient losses are lower on these acres than on high needs acres and thus there is less potential on a per-acre basis for reducing sediment and nutrient loadings with additional conservation treatment. Acres with a moderate level of conservation treatment needs are indicated by the lighter shading in the cells in the matrices; and
- ***Low needs acres:*** acres that are adequately treated with respect to their level of inherent vulnerability. While gains can be obtained by adding conservation practices to some of these acres, current losses are small and additional conservation treatment would reduce field losses by only a small amount. Groups of acres with less than 30 percent of the acres exceeding acceptable levels were defined as adequately treated acres and designated as having a low level of conservation treatment need. These cells are not shaded in the matrices.

The matrices III and VI in each of the tables 4.5 through 4.8 identify ***conservation treatment needs***. Specific criteria were used to identify the groups of acres that fall into each of the three levels of conservation treatment need. Criteria were not tailored to a specific region, but were derived for use in all regions of the country to allow for comparisons of adequacy of treatment and identification of under-treated acres across regions using a consistent analytical framework. The criteria and steps in the process are as follows.

The percent of acres that exceeded a given level of nutrient or sediment loss was estimated for each cell in the matrix as a guide to determine the extent of losses (tables 4.5 through 4.8). These thresholds are referred to as "acceptable levels." *Losses above these levels were considered unacceptable levels of loss. Acres with losses above these thresholds were considered to be in need of further treatment*. "Acceptable levels" for field-level losses used in this study are an annual average of —

- 2 tons per acre for sediment loss;
- 15 pounds per acre for nitrogen loss with surface runoff (soluble and sediment attached);
- 25 pounds per acre for nitrogen loss in subsurface flow; and
- 3 pounds per acre for phosphorus loss to surface water (soluble and sediment-attached).

The threshold for acceptable per acre phosphorus loss was lowered from 4 to 3 pounds for this report. A 4-pound threshold was used in the original USDA NRCS CEAP report for the Chesapeake Bay region (USDA NRCS 2011). The increase in manure usage and the persistence of phosphorus in previously eroded sediments necessitates this lower phosphorus loss threshold to further reduce loads to the Bay.

Under-treated acres—those groups of acres with either a high or moderate level of conservation treatment need—are shown in the last matrix in each table (tables 4.5 through 4.8). In most cases, under-treated acres consisted of acres where the conservation treatment level was one step or more below the soil leaching or runoff potential class.

Acceptable levels were initially derived through a series of forums held at professional meetings of researchers working on fate and transport of sediment and nutrients in agriculture. Those meetings produced a range of estimates for edge-of-field sediment loss, nitrogen loss, and phosphorus loss, representing what could realistically be achieved with today's production and conservation technologies. The range was narrowed by further examination of APEX model output, which also showed that the levels selected were agronomically feasible in all agricultural regions of the country. In the Chesapeake Bay region, for example, cropped acres that, with adequate levels of conservation treatment (including structural practices and nutrient management), could attain these acceptable levels are:

- 99 percent of cropped acres for sediment loss;
- 99 percent of cropped acres for nitrogen loss with surface runoff;
- 88 percent of cropped acres for nitrogen loss in subsurface flow pathways; and
- 91 percent of cropped acres for phosphorus loss to surface water.

The criteria used to identify acres that need additional treatment, including those with currently acceptable levels, are not intended to provide adequate protection for water quality, although in some environmental settings they may be suitable for that purpose. Evaluation of how much additional conservation treatment is needed to meet Federal, State, and/or local water quality goals in the region is beyond the scope of this study.

Changes in Conservation Treatments and Treatment Needs, by Resource Concern

The decline in the number of acres with high treatment needs between 2003-06 and 2011 was largely due to widespread adoption of structural practices, reduced tillage, and cover crops, all designed with a primary goal of reducing runoff. Improvements due to nutrient application management generally benefitted acreage managed at low conservation treatment levels.

Under-treated acres in the Chesapeake Bay region are presented by combinations of resource concerns in table 4.9.

APEX simulations revealed the following trends in treatment needs per each resource concern in the Chesapeake Bay region in the 2003-06 baseline condition and 2011 conservation condition (table 4.9):

Sediment loss:

- High conservation treatment needs acres: *maintained 2003-06 conservation levels,* at 7 and 3 percent of acres;
- Moderate conservation treatment needs acres: *decreased by 23 percentage points,* from 35 to 12 percent of acres; and
- Low conservation treatment needs acres: *increased by 28 percentage points*, from 57 to 85 percent of acres.

Nitrogen loss in surface flow:

- High conservation treatment needs acres: *decreased by 11 percentage points,* from 13 to 2 percent of acres;
- Moderate conservation treatment needs acres: *decreased by 10 percentage points,* from 22 to 12 percent of acres; and
- Low conservation treatment needs acres: *increased by 21 percentage points,* from 65 to 86 percent of acres.

Nitrogen loss in subsurface flow:

- High conservation treatment needs acres: *maintained 2003-06 conservation levels,* at 5 and <1 percent of acres;
- Moderate conservation needs acres: *increased by 16 percentage points,* from 20 to 36 percent of acres; and
- Low conservation treatment needs acres: *decreased by 11 percentage points*, from 75 to 64 percent of acres.

Phosphorus loss in surface flow:

- High conservation treatment needs acres: *maintained 2003-06 conservation levels,* at 5 and <1 percent of acres;
- Moderate conservation treatment needs acres: *decreased by 13 percentage points,* from 25 to 12 percent of acres; and
- Low conservation treatment needs acres: *decreased by 18 percentage points*, from 70 to 88 percent of acres.

Overall, acreage with ***high conservation treatment needs*** for one or more resource concern was improved by 15 percentage points, such that cropped acres with a high need for one or more resource concern declined from 19 to 4 percent of cropped acres between 2003-06 and 2011. About 46 percent of cropped acres are under-treated for only one of the four resource concerns, most commonly nitrogen leaching for which roughly 28 percent of cropped acres are under-treated. Eight percent of cropped acres are under-treated only for phosphorus runoff. On acres requiring treatment to address *more than one* resource concern, nitrogen runoff and phosphorus runoff were the most frequently occurring combination of resource concerns, representing 15 percent of cropped acres in the region. About 12 percent of cropped acres were determined to be under-treated for all four resource concerns.

Table 4.9. Percent of acres with ***high, moderate,*** and ***low treatment needs.***

	Low	Moderate	High
Sediment Loss Treatment Needs:			
2003-06	57%	35%	7%
2011	85%	12%	3%
Change	28%	-23%	-4%
Nitrogen Surface Runoff Treatment Needs:			
2003-06	65%	22%	13%
2011	86%	12%	2%
Change	21%	-10%	-11%
Nitrogen in Subsurface Flow Pathways:			
2003-06	75%	20%	5%
2011	64%	36%	<1%
Change	-11%	16%	-5%
Phosphorus in Surface Runoff:			
2003-06	70%	25%	5%
2011	88%	12%	<1%
Change	18%	-13%	-5%
Treatment Needs for One or More Resource Concern:			
2003-06	41%	40%	19%
2011	54%	42%	4%
Change	13%	2%	-15%

Note: may not total to 100 percent due to rounding.

The most critical conservation need in the region is the need for complete and consistently applied nutrient application management following the 4R's: appropriate rate, timing, method, *and* form of nitrogen and phosphorus application. Cropped acres with a ***high need*** to control nitrogen and/or phosphorus losses in surface runoff were largely addressed, such that they were reduced from 18 to 2 percent of cropped acres in the region. However, many of these gains were made via structural practice, tillage management, and cover crop adoption, all of which support the control and trap aspects of an ACT conservation approach. There is still opportunity to address the avoid component of ACT through better nutrient application management adhering to the 4R's. About 40 percent of cropped acres in the region have a ***high*** or ***moderate need*** for additional nutrient management for nitrogen and/or phosphorus (table 4.9).

Conservation treatment needs for one or more resource concern

As just discussed, approximately 2 million cultivated cropland acres (46 percent) require additional conservation treatment for only one of the four resource concerns, while other acres require additional treatment for two or more resource concerns. Simulations accounting for acres with treatment needs for multiple resource concerns determined that conservation practices adopted in the 2003-06 baseline condition and 2011 conservation condition achieved the following on acres needing treatment for more than one resource concern (fig. 4.7 and tables 4.9 and 4.10):

- ***High treatment needs*** acres: *decreased by 15 percentage points*, from 19 percent (813,000 acres) to 4 percent (157,000 acres) of the region's cultivated cropland;
- ***Moderate treatment needs*** acres: *maintained 2003-06 conservation levels at* 40 and 43 percent of acres in 2003-06 and 2011; and
- ***Low conservation needs*** acres: *increased by 13 percentage points,* from 41 percent (1,754,390 acres) to 54 percent (2,334,400 acres) of the region's cultivated cropland.

High Conservation Treatment Needs Acres: Acres with a high level of need for conservation treatment are typically the most vulnerable of the under-treated acres, have the least conservation treatment in place, and suffer the highest losses of sediment and/or nutrients. Ninety-three percent of these acres have losses higher than the acceptable level criteria used in the matrix approach for either sediment or nutrients (tables 4.5 to 4.8). Under the 2011 conservation condition these acres lost (per acre per year, on average):

- 12.7 tons of sediment;
- 31 pounds of nitrogen with surface runoff;
- 41 pounds of nitrogen in subsurface flow; and
- 7.9 pounds of phosphorus.

Because losses are high on these acres, acres with a high level of treatment need have the greatest potential for reducing agriculturally derived sediment and nutrient loadings with additional conservation treatment.

***Moderate Conservation Treatment Needs Acres*:** Acres with a moderate level of need for conservation treatment consist of under-treated acres that generally have lower levels of vulnerability and/or have more conservation practices in place than do acres with a high level of need. The sediment and/or nutrient losses tend to be lower than they are on acres with high conservation treatment needs and thus in terms of pounds and tons, there is less potential on a per-acre basis for reducing nutrient and sediment losses with additional conservation treatments. Seventy percent of these acres have losses higher than the acceptable level criteria used in the matrix approach for either sediment or nutrients (tables 4.5 to 4.8). In 2011 these acres lost (per acre per year, on average):

- 3.6 tons of sediment;
- 14 pounds of nitrogen with surface runoff;
- 29 pounds of nitrogen in subsurface flows; and
- 2.9 pounds of phosphorus.

While the potential benefits of additional treatment on ***moderate conservation treatment needs*** acres are less than they are for ***high conservation treatment needs*** acres, a portion of these acres may need to be treated to meet water quality goals in the region. Evaluation of conservation treatment needed to meet water quality goals in the region is beyond the scope of this study.

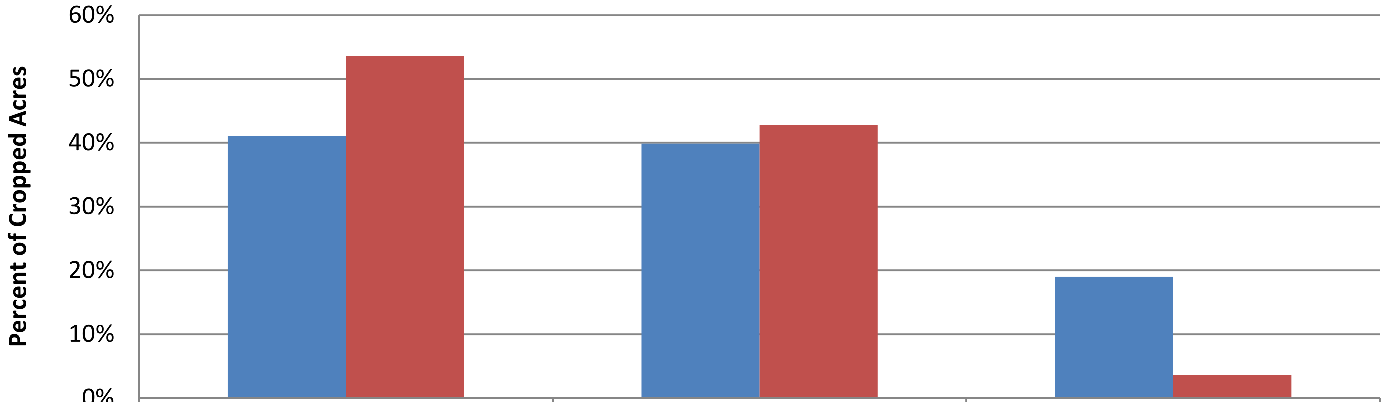
Low Conservation Treatment Needs Acres: Acres with a low level of need for conservation treatment consist of acres that are adequately treated with respect to the level of inherent vulnerability. Only 16 percent of these acres have losses higher than the acceptable level criteria used in the matrix approach, almost all of which are for a single resource concern (tables 4.5 to 4.8). In 2011 these acres lost (per acre per year, on average):

- 1.1 tons of sediment;
- 7 pounds of nitrogen with surface runoff;
- 17 pounds of nitrogen in subsurface flows; and
- 1.2 pounds of phosphorus.

While gains can be obtained by adopting additional conservation practices on some of these acres, because losses are small, additional conservation treatment would reduce field losses by only a small amount.

It should also be noted that continued conservation planning and management is necessary to keep acreage adequately treated and in this ***low conservation treatment needs*** category. Most, if not all, conservation practices require annual or semi-annual maintenance or annual application. In particular, the full benefits of sound nutrient management are only accrued if the management is consistently applied to every crop grown on a given acre. Acreage currently in this low needs category is receiving adequate treatments to meet conservation needs. Were these treatments removed, these acres would likely be re-categorized as ***moderate*** or ***high conservation treatment needs*** acres due to the increased nutrient and sediment losses that would accompany conservation practice abandonment.

Figure 4.7. Percent of cropped acres with a high, moderate, or low level of need for additional conservation treatment for one or more resource concern in the Chesapeake Bay region, 2003-06 baseline condition and 2011 conservation condition.



	Low Treament Needs	Moderate Treatment Needs	High Treatment Needs
2003-06	41%	40%	19%
2011	54%	43%	4%

Table 4.10. Under-treated acres for the four sub-regions in the Chesapeake Bay region, 2003-06 baseline condition and 2011 conservation condition.

				High Treatment Need acres			All Under-Treated acres		
Sub-region code	**Sub-region name**	**Data Year**	**Percent of cropped acres in Chesapeake Bay region**	**Acres**	**Percent of acres in Chesapeake Bay region**	**Percent of acres in subregion**	**Acres**	**Percent of acres in Chesapeake Bay region**	**Percent of acres in subregion**
0205	Susquehanna River	2003-06	41	585,833	14	34	1,297,467	30	75
		2011	46	150,800	4	8	1,047,500	24	52
0206	Upper Chesapeake Bay	2003-06	28	45,621	1	4	504,579	12	42
		2011	23	0	0	0	399,200	9	39
0207	Potomac River	2003-06	16	140,251	3	21	476,953	11	70
		2011	17	4,200	<1	1	355,900	8	49
0208	Lower Chesapeake Bay	2003-06	16	41,117	1	6	237,716	6	35
		2011	14	1,700	<1	<1	216,400	5	36
	Total.	2003-06	100	812,823	19	100	2,516,715	59	100
		2011	100	156,700	4	100	2,019,000	46	100

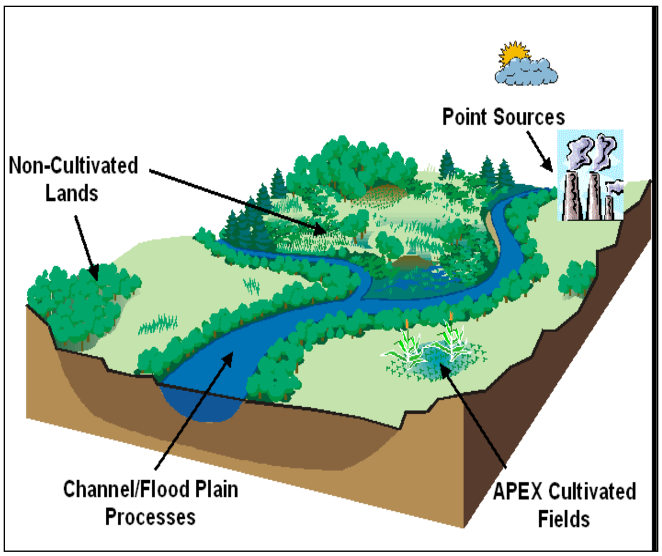
Note: Percents may not add to totals because of rounding.

Chapter 5
Offsite Water Quality Effects of Conservation Practices

The Soil and Water Assessment Tool—SWAT

Offsite estimates of water quality benefits were assessed using the Soil and Water Assessment Tool (SWAT) and inputs from a number of databases required to run SWAT at the watershed scale (Arnold et al. 1999; Srinivasan et al. 1998). SWAT is capable of simulating the transport of water, sediment, pesticides, and nutrients from the land to receiving streams, routing the flow downstream to the next watershed, and ultimately simulating delivery to estuaries, bays, and oceans (fig. 5.1).

Figure 5.1. Sources of water flows, sediment, and agricultural chemicals simulated with SWAT.



The analyses conducted for this report were intended to provide long-term estimates of benefits associated with adoption of conservation practices on cultivated cropland. For that reason, the only land use changed between the two sampling periods is land use associated with cultivated cropland. In order to compare the impacts of conservation practices on cultivated croplands in 2003-06 with the impacts of new and improved conservation practices in 2011, all other land use loads were held at the same rate for analyses of both sampling periods. Therefore, this chapter does not account for any conservation practice changes made in other land use sectors, including land in long term conserving cover like CRP.

Like APEX, SWAT is a physical process model with a daily time step (Arnold and Fohrer 2005; Arnold et al. 1998; Gassman et al. 2007).[1] The hydrologic cycle in the model is divided into two phases. The land phase (upland processes) simulates the amount of water, sediment, and nutrients delivered from the land to the outlet of each watershed. The routing phase (channel processes) simulates the movement of water, sediment, and nutrients from the outlet of the upstream watershed through the main channel network to the watershed outlet.

Upland Processes

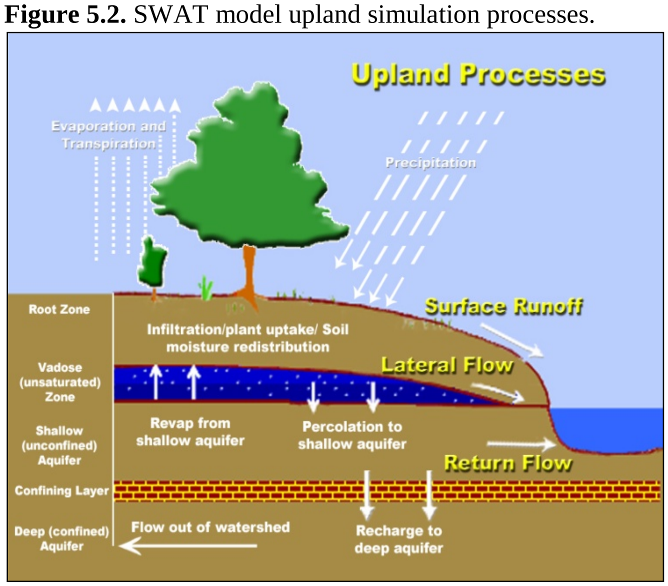
The water balance is the driving force for transport and delivery of sediment and nutrients from fields to streams and rivers. For this study, upland processes for non-cultivated cropland were modeled using SWAT, while source loads for cultivated cropland were estimated with APEX.

In SWAT, each watershed is divided into multiple Hydrologic Response Units (HRUs) that are simulated as having homogeneous land use, management, and soil characteristics. An HRU is not a contiguous land area, but rather represents the percentage of the watershed that has the characteristics represented by that HRU. In this study, SWAT was used to simulate the fate and transport of water, sediment, and nutrients for the following land use categories, referred to as HRUs:

- Pastureland
- Range shrub
- Range grass
- Urban
- Mixed forest
- Deciduous forest
- Evergreen forest
- Horticultural lands
- Forested wetlands
- Non-forested wetlands

Upland processes were modeled for each of these HRUs in each watershed (8-digit hydrologic unit code [HUC]) (fig. 5.2). The model simulates surface runoff from daily rainfall and irrigation; percolation modeled with a layered storage routing technique combined with a subsurface flow model; lateral subsurface flow; groundwater flow to streams from shallow aquifers; potential evapotranspiration; snowmelt; transmission losses from streams; and water storage and losses from ponds.

Figure 5.2. SWAT model upland simulation processes.



[1] A complete description of the SWAT model can be found at http://www.brc.tamus.edu/swat/index.html.

Upland processes for cultivated cropland were modeled using APEXv1307, as described in previous chapters. The cultivated cropland in long-term conserving cover was held constant at 2003-06 conservation levels and was considered to have the same impact on instream water quality in both 2003-06 and 2011. The weighted averages of per acre APEX model output for surface water delivery, sediment, and nutrients was multiplied by the acres of cultivated cropland and used as SWAT model inputs to simulate each 8-digit HUC. The acreage weights for the CEAP sample points were used to calculate the per-acre loads. Several of the 8-digit HUC watersheds in each region had too few CEAP sample points to reliably estimate edge-of-field per-acre loads. In these cases, the 6-digit HUC per-acre loads and sometimes the 4-digit HUC per-acre loads were used to represent cultivated cropland.

Land management activities for permanent hayland, pasture-land, and long-term conserving cover were modeled in SWAT. No management was simulated for rangeland, forestland, urban land, or horticulture. For permanent hayland, the following management activities were simulated:

- Three hay cuttings per crop year;
- Hay was fertilized with nitrogen according to the crop need, as determined by an auto-fertilization routine, which was set to grow the crop without undue nitrogen stress;
- For legume hay, phosphorus was applied at the time of planting every fourth year at a rate of 50 pounds per acre, followed by applications of 13 pounds per acre every other year;
- Manure was applied to hayland at rates estimated from probable land application of manure, using the methods described in USDA NRCS (2003); and
- For hayland acres which land-use databases indicated were irrigated, water was applied at a frequency and rate defined by an auto-irrigation routine in SWAT.

For pastureland, the following management activities were simulated:

- Grazing, via simulation of four grass cuttings per year;
- Pastureland was fertilized with nitrogen, as determined by an auto-fertilization routine, which was set to grow grass without undue nitrogen stress;
- Manure was applied to pastureland at rates estimated from probable land application of manure, using the methods described in USDA NRCS (2003); and
- Manure nutrients from grazing animals were simulated for pastureland according to the density of pastured livestock as reported in the 2002 Census of Agriculture. Non-recoverable manure was estimated by subtracting recoverable manure available for land application from the total manure nutrients representing all livestock populations. Non-recoverable manure nutrients include the non-recoverable portion from animal feeding operations. Estimates of manure nutrients were derived from data on livestock populations as reported in the 2002 Census of Agriculture, which were available for each 6-digit HUC and distributed among the 8-digit HUCs on a per-acre basis.

Cropped acres could also be converted to long-term conserving cover, establishment of which consists of planting suitable native or domestic grasses, forbs, or trees, typically on environmentally sensitive cultivated cropland. The national database documenting acreage in long-term conserving cover was not updated between the publication dates of the previous and current report (USDA NRCS 2011). Therefore, simulations reported herein use the same acreage amounts (100,000 acres) for land in long-term conserving cover for both 2003-06 and 2011 and there is no change in benefits from this management practice. It should be noted that conversion to long-term conserving cover virtually eliminates soil erosion and sediment losses.

A summary of the total amount of nitrogen and phosphorus applied to agricultural land in the model simulation, including nitrogen and phosphorus applied to cultivated cropland in the APEX model, is presented in table 5.1. Manure nutrients from wildlife are not included.

Urban Sources

Discharges from industrial and municipal wastewater treatment plants can be major sources of sediment and nutrients in some watersheds. For this study, the point source database developed by the Environmental Protection Agency (EPA) for use in the Chesapeake Bay model was used for the period from 1985 through 2011. For the years before 1985, the annual point source loads of 1985 were used. Point source loads are aggregated within each watershed and average annual loads are input into SWAT at the watershed outlet.

Urban runoff is estimated separately for three categories of cover: 1) impervious surfaces, such as buildings, parking lots, paved streets, etc.; 2) impervious surfaces hydraulically connected to drainage systems, such as storm drains; and 3) impervious surfaces not hydraulically connected to drainage systems. For estimating surface water runoff, a runoff curve number of 98 was used for impervious surfaces connected hydraulically to drainage systems and a composite runoff curve number was used for impervious surfaces not hydraulically connected to drainage systems. Sediment and nutrients carried with storm water runoff to streams and rivers were estimated using regression equations developed by Driver and Tasker (1988).

Construction areas were assumed to represent 3 percent of urban areas. Parameters in the SWAT soil input file were modified to produce surface runoff and sediment yield that mimicked the average sediment load from published studies on construction sites.

Not included in the point source data are: 1) pseudo-point sources, such as confined animal feeding operations and fertilizer handling and distribution centers; 2) urban applications of nutrients and chemicals (lawns, golf-courses, etc.); or 3) small communities and homes not connected to sewer systems.

Table 5.1. Summary of commercial fertilizer and manure nutrients applied to agricultural land in SWAT (pastureland and hayland) and APEX (cultivated cropland) model simulations, Chesapeake Bay watershed, 2003-06 baseline condition and 2011 conservation condition.

Sub-region code	Subregion name	Commercial nitrogen fertilizer (tons/year)	Nitrogen from manure (tons/year)	Total nitrogen (tons/year)	Commercial phosphorus fertilizer (tons/year)	Phosphorus from manure (tons/year)	Total phosphorus (tons/year)
			Cultivated Cropland (2003-06)				
0205	Susquehanna River	51,207	38,243	89,450	10,530	14,356	24,887
0206	Upper Chesapeake Bay	37,207	14,803	52,009	6,034	4,557	10,592
0207	Potomac River	23,683	12,494	36,177	4,650	5,633	10,282
0208	Lower Chesapeake Bay	25,670	184	25,854	5,234	94	5,328
	Total	137,767	65,724	203,491	26,449	24,640	51,089
			Cultivated Cropland (2011)				
0205	Susquehanna River	59,827	47,074	106,901	12,734	16,568	29,303
0206	Upper Chesapeake Bay	41,173	12,702	53,875	5,698	4,651	10,348
0207	Potomac River	25,490	14,401	39,891	4,034	5,642	9,676
0208	Lower Chesapeake Bay	24,141	3,060	27,202	4,509	987	5,495
	Total	150,632	77,236	227,868	26,975	27,848	54,822
			Hayland (2003-06 and 2011)				
0205	Susquehanna River	22,681	3,196	25,876	2,774	1,446	4,220
0206	Upper Chesapeake Bay	787	309	1,096	110	142	252
0207	Potomac River	14,913	5,136	20,049	632	2,448	3,080
0208	Lower Chesapeake Bay	13,479	1,065	14,544	181	514	695
	Total	51,860	9,706	61,566	3,698	4,549	8,247
			Pastureland and Rangeland (2003-06 and 2011)				
0205	Susquehanna River	8,532	36,160	44,693	3,150	13,496	16,646
0206	Upper Chesapeake Bay	1,880	9,091	10,971	822	4,000	4,821
0207	Potomac River	6,928	33,652	40,580	3,386	16,362	19,748
0208	Lower Chesapeake Bay	3,394	14,382	17,777	1,927	8,080	10,008
	Total	20,734	93,285	114,020	9,285	41,939	51,224

Note: Nitrogen and phosphorus applications for Hayland, Pastureland, and Rangeland were held to 2003-06 estimates for analyses of both sampling periods.

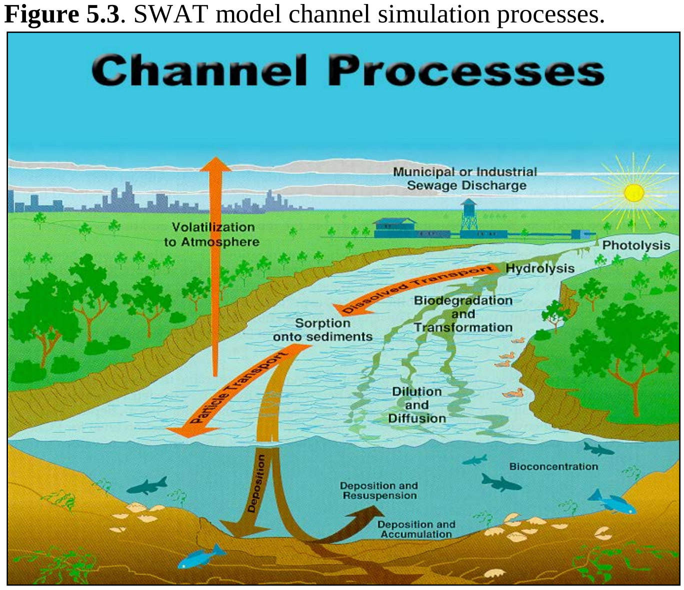
Atmospheric Nitrogen Deposition

Atmospheric deposition of nitrogen can be a significant component of the nitrogen balance. Nitrogen deposition data (loads and concentrations) were developed from the National Atmospheric Deposition Program/National Trends Network database (NADP/NTN 2004). To account for impacts of wet deposition, when a rainfall event occurred in the model simulation, the amount of rainfall was multiplied by the average ammonium and nitrate concentrations calculated for the watershed. The simulation also added an additional amount of ammonium and nitrate on a daily basis to account for dry deposition. Changes in atmospheric nitrogen as a result of changes in conservation or production practices are not considered in this report, as these effects are prospective and not yet available in deposition data.

Routing and Channel Processes

SWAT simulates stream and channel processes, including channel flood routing, channel sediment routing, nutrient routing, and transformations modified from the QUAL2E model (Fig. 5.3). As water flows downstream, some may be lost to evaporation and transmission through the channel bed. Another potential loss pathway is removal of water from the channel for agricultural, rural, or urban use. Flow may be supplemented by rainfall directly on the channel and/or addition of water from point source discharges.

Figure 5.3. SWAT model channel simulation processes.



Source Loads and Instream Loads

All source loads are introduced into SWAT at the outlet of each watershed (8-digit HUC). Flows and source loads from upstream watersheds are routed through each downstream watershed, including reservoirs when present. [2]

A sediment delivery ratio was used to account for deposition in ditches, floodplains, and tributary stream channels during transit from the edge-of-field to the outlet. The sediment delivery ratio used in this study is a function of the ratio of the time of concentration for the HRU (land uses other than cultivated cropland) or field (cultivated cropland) to the time of concentration for the watershed (8-digit HUC). The time of concentration for the watershed is the time from when a surface water runoff event occurs at the watershed's point most distant from the outlet to the time the surface water runoff reaches the outlet of the watershed. It is calculated by summing the overland flow time (the time it takes for flow to move from the remotest point in the watershed to the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). The time of concentration for the field is derived from APEX. The time of concentration for the HRU is derived from characteristics of the watershed, the HRU, and the proportion of total acres represented by the HRU. Consequently, each cultivated cropland sample point has a unique delivery ratio within each watershed, as does each HRU.[3] The sediment delivery ratio and an enrichment ratio were used to simulate organic nitrogen and organic phosphorus in ditches, floodplains, and tributary stream channels during transit from the edge-of-field to the outlet. The enrichment ratio was defined as the organic nitrogen and organic phosphorus concentrations from the edge-of-field divided by their concentrations at the watershed outlet. As sediment is transported from the edge-of-field to the watershed outlet, coarse sediments are deposited first while the fine sediment that holds organic particles remains in suspension, enriching the organic concentrations delivered to the watershed outlet.

A separate delivery ratio is used to simulate the transport of nitrate nitrogen and soluble phosphorus. In general, the proportion of soluble nutrients delivered to rivers and streams is higher than the proportion attached to sediments because they are not subject to sediment deposition.

For reporting purposes, edge-of-field loads and source loads were aggregated over the 8-digit HUCs to the four subregions in the region (4-digit HUCs). Figure 5.4 shows the location of each subregion and the 8-digit HUCs included in each. For the Susquehanna River and the Potomac River (8-digit HUC groups I and III), instream loads represent the loads at the outlet of the subregion. For the Upper Chesapeake (8-digit HUC group II), the instream loads represent the sum of the loads at the outlets of 8-digit HUCs draining to into Chesapeake Bay in subregion 0206. For the Lower Chesapeake (8-digit HUC groups IV), instream loads represent the sum of the loads at the outlets of the Rappahannock, York, and James Rivers in subregion 0208. For the Lower Chesapeake (8-digit HUC group V), instream loads represent the load at the outlet of the Lower Eastern 8-digit HUC (0208).

There are four points in the modeling process at which source loads or instream loads are assessed for sediment, shown in the schematic in figure 5.5.

1. Edge-of-field loads from cultivated cropland—aggregated APEX model output as reported in the previous chapter. Edge-of-field loads for the Chesapeake Bay watershed differ slightly from those reported in the previous chapter because in the discussion on the Chesapeake Bay *region,* two 8-digit HUCS that drain to the Atlantic and loads from land in long-term conserving cover were included;
2. Delivery to the watershed outlet from cultivated cropland—aggregated edge-of-field loads after application of delivery ratios. Loadings delivered to streams and rivers differ from the amount leaving the field because of losses during transport from the field to the stream. Delivery ratios are used to make this adjustment;
3. Delivery to the watershed outlet from land uses other than cultivated cropland as simulated by SWAT, after application of delivery ratios. Point sources are included; and
4. Loadings in the stream or river at a given point. Instream loads include loadings delivered to the watershed outlet from all sources as well as loads delivered from upstream watersheds, after accounting for channel and reservoir processes.

Terminology Used in this Report:
Chesapeake Bay Watershed
Versus
Chesapeake Bay Region

Estimates presented in this chapter exclude two 8-digit watersheds in the Upper Chesapeake Bay subregion that drain to the Atlantic Ocean (8-digit HUCs 02060010 and 02080110). The area excluding these two subregions is referred to as the Chesapeake Bay watershed. However, tables and figures elsewhere in the report include the cropped acres in these two 8-digit HUCs; the area that includes these two watersheds is referred to as the Chesapeake Bay region.

[2] For a complete documentation of HUMUS/SWAT as it was used in this study, see "The HUMUS/SWAT National Water Quality Modeling System" at http://www.nrcs.usda.gov/technical/nri/ceap.

[3] For a complete documentation of delivery ratios used for the Chesapeake Bay region, see "Delivery Ratios Used in CEAP Cropland Modeling" at http://www.nrcs.usda.gov/technical/nri/ceap.

Figure 5.4. Subregions and 8-digit HUC groups used for reporting of source loads and instream loads for the Chesapeake Bay watershed.

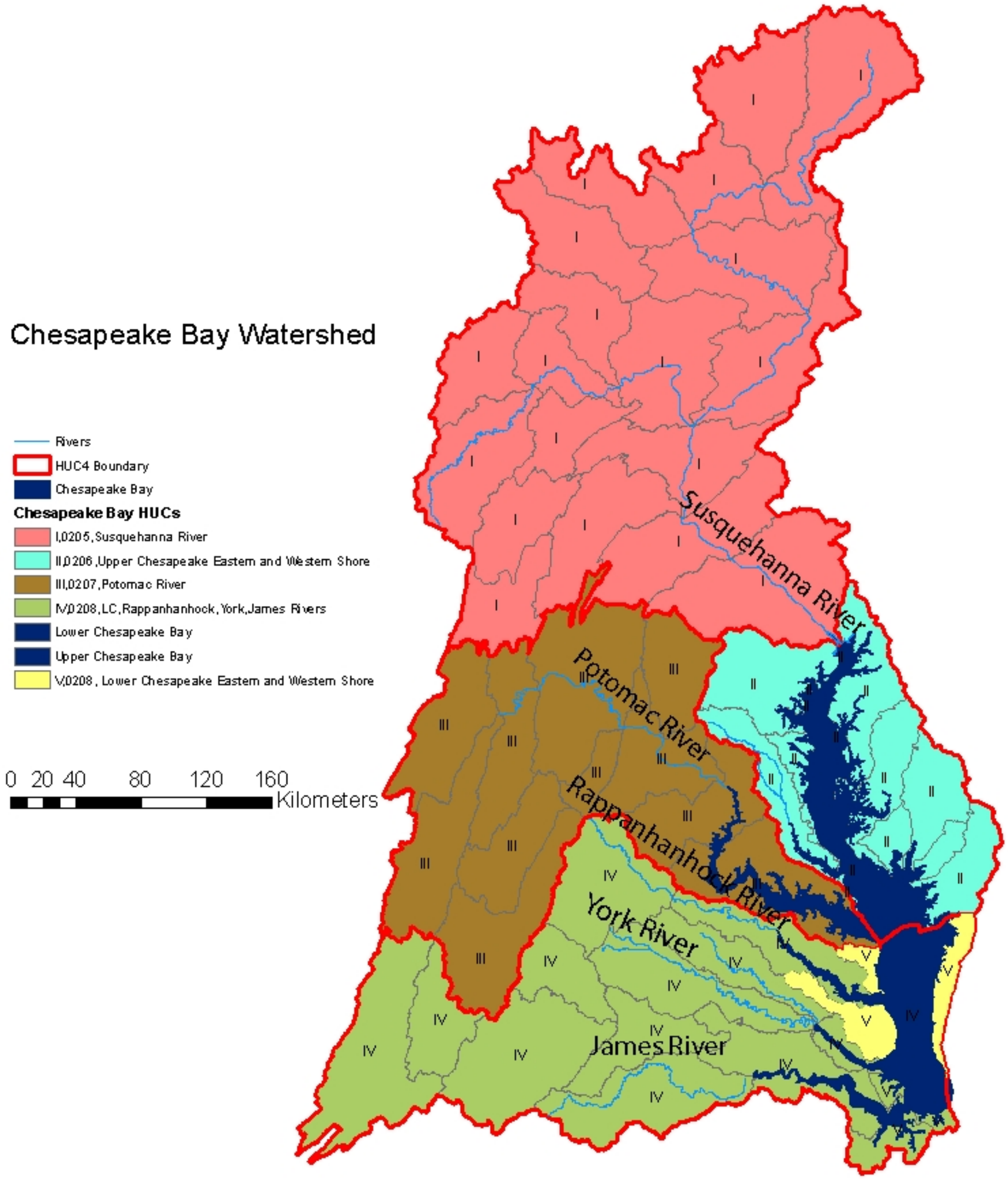
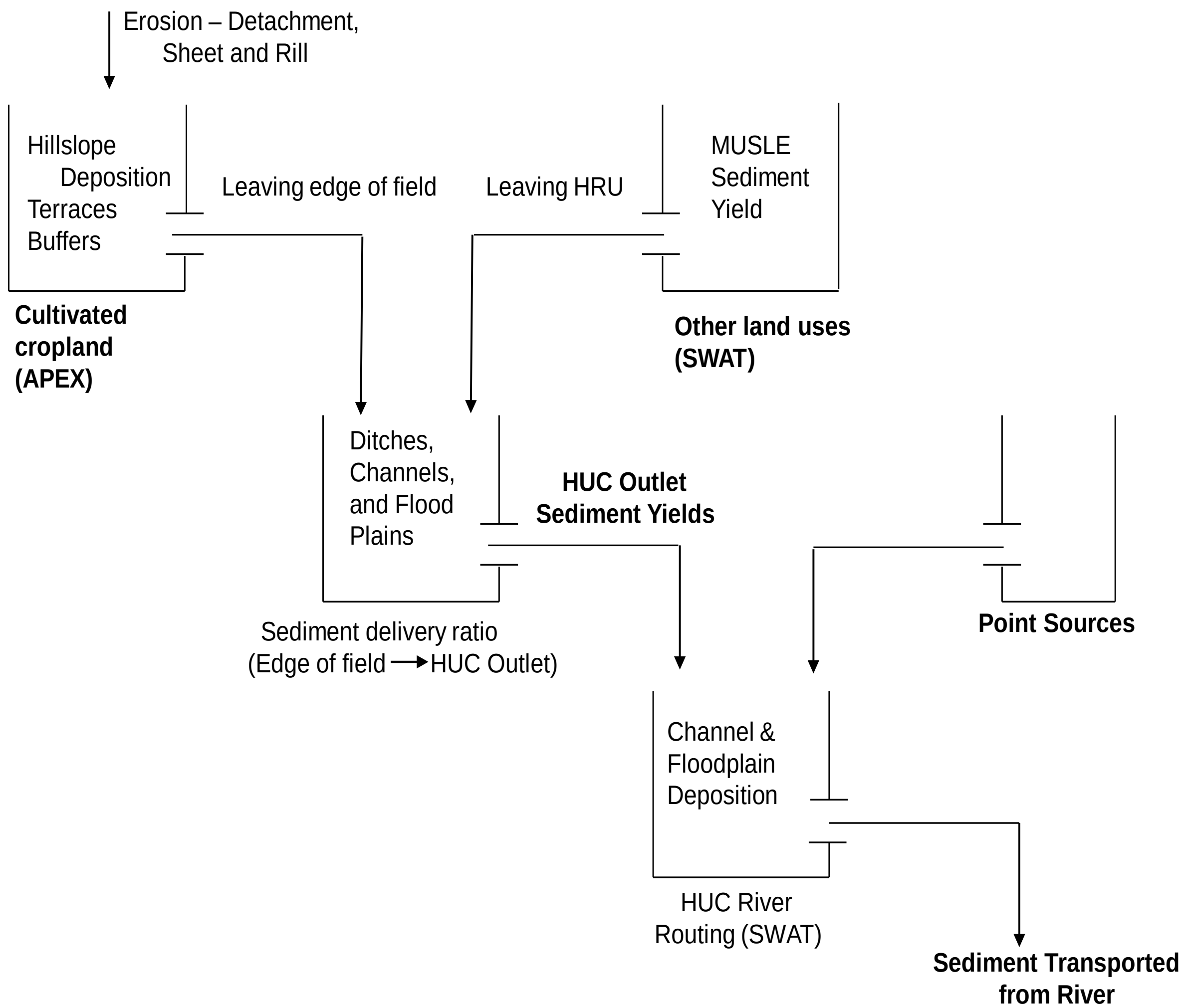


Figure 5.5. Schematic of sediment sources and delivery as modeled with SWAT for the Chesapeake Bay watershed.



Conservation Practice Effects on Water Quality

The results from the onsite APEX model simulations for cropped acres, excluding acres of cultivated cropland classified as land in long-term conserving cover, were integrated into SWAT to assess the effects of conservation practices on instream loads of sediment, nitrogen, and phosphorus. The simulated results for land in long-term conserving cover were kept constant for the re-analysis of the 2003-06 and the 2011 survey results. The effects of conservation practices on water quality were assessed by comparing SWAT model simulation results for the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition. For each scenario, only the management of cropped acres was changed. All other aspects of the simulations, including sediment and nutrient loads from point sources and land uses other than cultivated cropland, remained the same.

When the original USDA NRCS Chesapeake Bay region report was written (USDA NRCS 2011), the 2001 National Land Cover Database (NLCD) (Homer et al. 2007) provided the most timely and robust estimates of non-cultivated cropland, such as pastureland and permanent hayland, and non-agricultural land uses, such as forests and urban areas. The 2001 NLCD, therefore, informed the SWAT modeling of instream effects estimates in the original report. The modeling efforts in this report rely on the most recent (2007) NRI estimates for cultivated acres of cropland values and keep all other land use estimates consistent with the original Chesapeake Bay region CEAP report (USDA NRCS 2011), including land in long-term conserving cover. By holding these inputs constant, the focus of this report is on the effect of changing conservation practices on the cropped acres in the 2003-06 baseline condition as compared to the 2011 conservation condition. By holding all other inputs constant, these differences can be isolated, without confounding effects from the changes in loads from the other land uses.

SWAT accounts for the transport of water, sediment, and nutrients from the land to receiving streams and routes the flow downstream to the next watershed and ultimately to estuaries and oceans. Not all of the water, sediment, and nutrients that leave farm fields are delivered to streams and rivers. Water may be lost to deep water storage or evaporation. Some material is bound up permanently in various parts of the landscape during transport. In addition, instream degradation processes may release previously deposited sediment and nutrients into the instream flow and streambed deposition and accumulation may remove or trap a portion of the sediment and/or nutrients after delivery to streams and rivers.

Agricultural conservation practices have been adopted in the Chesapeake Bay region, with the goal of lowering nitrogen, phosphorus, and sediment contributions to the Chesapeake Bay, thus contributing to an improvement of the ecological health of the Bay. At the field scale, conservation practices have been linked to measureable effects and tangible benefits. However, demonstrating conservation practice effects at larger spatial scales has proven far more challenging. The apparent dissociation between edge-of-field assessments and watershed or sub-watershed scale assessments has been attributed to a number of causes, including legacy sediment and nutrients and the associated lag-time commonly observed between conservation adoption and quantifiable large scale results.

Streams, tributaries, and rivers have received sediment and nutrient inputs throughout their histories. Once introduced into a waterway, sediment and nutrients may be carried downstream, or may accumulate at any point along the pathway from edge-of-field to the Bay. Once sediment and nutrients have settled out of the flowing water, they become a part of “legacy” sediment and nutrients. Resuspension and redistribution may occur days, years, or decades in the future (McDowell et al. 2002). Delivery of legacy sediment and nutrients to the estuaries or Bay often masks the impacts of current and recently applied conservation practices. Legacy sediment and nutrients are one of the primary reasons that evaluation of conservation practice success and identification of remaining challenges in watershed management cannot be regarded as solely reflective of today’s management (Sharpley et al. 2013).

There are numerous causes that contribute to reintroduction of legacy sediment and nutrients into the water. Storms and flooding may dislodge sediment and nutrients, not only in the rivers and streams, but also in the Bay itself. Estuaries, of which Chesapeake Bay is North America’s largest, naturally accumulate sediments and nutrients. In fact, it is estimated that the estuaries along the East Coast of the United States have trapped roughly 90 percent of the sediment their tributaries have delivered (Meade 1982). This function makes estuaries vulnerable to large storms, which are often associated with large discharges of sediment and associated nutrients. For example, Tropical Storm Agnes (1972) caused the resuspension and discharge of about 31 million tons of sediment and associated nutrients into the Chesapeake Bay, drastically disrupting biological communities in the Bay, some of which were still not recovered by 2005 (Schubel 1977; Lynch 2005). In 2011, flooding associated with Tropical Storm Lee resuspended and flushed 6.7 million tons of sediments from the Susquehanna River into the Bay, creating a dense sediment plume across half of Chesapeake Bay (Cheng et al. 2013). Though less dramatic, the effects of Tropical Storm Lee may still be impacting sediment and nutrient quantification in the Bay. As the Chesapeake Bay region is anticipated to suffer more tropical storm activity in the future, it will become more important that these weather events, currently viewed as anomalies, are accounted for when quantifying nutrient and sediment loads in efforts to analyze conservation effects.

Additionally, even in the absence of storms and associated flooding, conservation practices may, themselves contribute to increased sediment and nutrient dislodging caused by scouring and channel cutting of streams and rivers. This is because when practices are successful at removing sediment and nutrients prior to the water leaving the field (or other source), and practices are not put in place to attenuate the hydrologic discharge, the cleaner water has a higher potential to detach sediment. Flume studies have shown sediment detachment to decrease by as much as 42 percent with increasing sediment concentrations in the water; as water saturates with higher sediment loads, deposition eventually exceeds detachment (Merten et al. 2001). The erosion of stream and river banks and beds may release legacy sediment and nutrients deposited there due to losses from past land uses. The cleaner water may also cause nutrients bound to the sediment to unbind from the soil particles and dissolve into the water. These instream processes may delay quantifiable effects of upland conservation practices on sediment and nutrient loads delivered to the Bay.

Legacy nutrients and sediments contribute to lag-times, the length of which are dictated by the interaction of multiple factors, including: the time required for the conservation practice to produce an effect at the field scale; the time it takes for that effect to be delivered to the watershed or sub-watershed; the time it takes for that field-scale benefit to translate to a watershed or sub-watershed benefit; and the amount of time it takes for sampling protocol to quantify the benefit (Meals et al. 2010). Lag-times between conservation practice adoption and observable impact are well documented (Sharpley et al. 2013). The University of Maryland Eastern Shore’s research farm is located on the site of a former poultry operation, with 30 years of poultry litter application. Experiments to decrease the phosphorus loads from the soils did not show a benefit, even at the field-scale, for nearly a decade (Kleinman et al. 2011). In 2005 Maryland’s governor declared the Corsica River as the State’s targeted restoration watershed. A massive effort of private, local, State, and Federal collaboration led to the adoption of numerous conservation practices in the river’s watershed, including installation of buffers, stormwater and sewage treatment upgrades, wetland restoration, and shoreline enhancement. However, Maryland’s Department of Natural Resources reports that from 2006 to 2011, the majority of sites in the watershed showed no change in their biological condition. Further, observable nutrient reduction occurred in only two of the Corsica’s non-tidal tributaries (DNR 2012). An independent study found that the most pronounced trends occurred after 2010, suggesting that it took 5 years for the conservation measures to manifest in decreased sediment deposition in the river (Palinkas 2013). It will likely take longer for the benefits to be quantifiable in the Bay. A recent USGS study suggests under current conservation conditions, total daily nitrogen loads will continue to rise until the year 2050 due to lag-times associated with legacy nitrogen in groundwater, which may take more than 50 years to flush through the groundwater system on the Delmarva Peninsula in the Chesapeake Bay. (Sanford and Pope 2013, accepted).

Similarly, all measured instream nutrient and sediment fluxes collected during each survey period informing this report do not reflect impacts of conservation practices installed during the same survey period. If the 5-year lag-time observed in the Corsica River study were applicable across the region, it is reasonable to consider the instream, outlet, and Bay nutrient and sediment loading quantified in 2011 are reflective of conservation practices in place during the first sampling period (2003-06). However, Phillips and Lindsey (2003) suggest that it may take decades for benefits of conservation practices to have demonstrable impact in the Chesapeake Bay. Even if the shorter observed lag-times hold true, the benefits of the widespread conservation practices put in place as a result of the 2009 Chesapeake Bay Protection and Restoration Executive Order will likely not be evident in the instream, outlet, and Bay data collected in the 2011 sampling period and may not be observable until 2014 or sometime thereafter.

Land Use in the Chesapeake Bay Watershed

The 2001 National Land Cover Database (NLCD) (Homer et al. 2007) was the principle source of acreage for SWAT modeling (table 5.2). The 2003 National Resources Inventory (NRI) was used to adjust NLCD cropland acreage estimates to include acres enrolled in the Conservation Reserve Program General Signups, used here to represent cropland currently maintained in long-term conserving cover. Consequently, cultivated cropland acres used to simulate the effects of conservation practices on water quality differ slightly from the cultivated cropland acres reported in the previous chapters, which were estimated on the basis of the CEAP Cropland sample. In addition, estimates presented in this chapter on off-site water quality in the Chesapeake Bay watershed *exclude* two 8-digit HUC watersheds in the Upper Chesapeake Bay subregion that drain to the Atlantic Ocean (8-digit HUCs 02060010 and 02080110). These watersheds were included in analyses of the Chesapeake Bay region, discussed in previous chapters.

Table 5.2. Land use in the Chesapeake Bay watershed.

Sub-region code	Subregion name	Cultivated cropland (acres)*	Hayland not in rotation with crops (acres)	Pasture and grazing land not in rotation with crops (acres)	Urban land (acres)	Forest and other (acres)**	Total land (acres)***
0205	Susquehanna River	2,007,380	1,314,114	1,519,448	1,314,783	11,230,468	17,386,193
0206	Upper Chesapeake Bay	1,218,106	49,817	812,045	526,715	2,310,880	4,917,564
0207	Potomac River	611,355	670,212	1,565,170	1,021,360	5,385,808	9,253,905
0208	Lower Chesapeake Bay	553,641	451,427	1,381,713	734,820	7,307,893	10,429,494
	Total	4,390,482	2,485,571	5,278,375	3,597,679	26,235,048	41,987,155

Note: Estimates in this table differ from estimates for the Chesapeake Bay region by excluding the two 8-digit HUCs draining into the Atlantic Ocean.
* Acres of cultivated cropland include land in long-term conserving cover as well as hayland and pastureland in rotation with crops from 2003-06 survey.
** Includes forests (all types), wetlands, range brush, horticulture, and barren land.
*** Exclusive of water.

Sediment

Simulation results suggest the continued adoption of new and improved conservation practices aimed at sediment load reduction on cultivated croplands is working. Model simulation results show that conservation practices reduced the amount of sediment lost at the edge-of-field from 54.1 million tons (no-practice scenario) to 24.9 million tons of sediment (2003-06 baseline condition) to 9.9 million tons of sediment (2011 conservation condition) (table 5.3; fig. 5.6). Relative to 2003-06 baseline condition, conservation practices in place in 2011 reduced edge-of-field sediment losses by 60 percent. Similar reductions were achieved on sediment loads delivered to rivers and streams each year. Sediment losses to rivers and streams of roughly 21.1 million tons under the no-practice scenario were reduced 9.6 and 3.9 million tons of sediment under 2003-06 baseline condition and 2011 conservation condition, respectively (table 5.4). The 2011 conservation condition reduced the delivery of sediment to the Bay by about 22 and 8 percent relative to the no-practice scenario and the 2003-06 baseline condition, respectively (table 5.5).

Although relative to the no-practice scenario, edge-of-field sediment losses were reduced by 82 percent due to conservation practices in place in 2011 (table 5.3), opportunities to reduce sediment losses remain. For example, the sediment loss reduction gains in the Susquehanna River subregion are not as high a percentage as the conservation gains in other subregions in the Chesapeake Bay. In the Susquehanna River subregion, the 2011 conservation condition reduced annual edge-of-field sediment losses by 78 percent (29.6 million tons) relative to the no-practice scenario and by 59 percent (11.9 million tons) relative to the 2003-06 baseline condition. The 11.9 million ton reduction in edge-of-field sediment loss accounted for nearly 79 percent of all the 15.1 million tons of sediment loss reduction in the 2011 conservation condition as compared to the 2003-06 baseline condition. Model simulations show that without any conservation in place, the Susquehanna River subregion would account for 70 percent of the region's edge-of-field sediment losses. However, the Susquehanna River subregion, which contains 46 percent of the Chesapeake Bay region's cropland accounted for 81 and 83 percent of edge-of-field sediment losses under the 2003-06 baseline condition and the 2011 conservation condition, respectively. This subregion has a higher proportion of cropland acres with greater vulnerability to runoff, which likely require a greater level of conservation practices to control and trap sediment (table 5.3).

With 2011 conservation practices in place, cultivated cropland is the source of 46 percent of sediment loads delivered to rivers and streams in the Chesapeake Bay watershed (table 5.6, fig. 5.6). As just noted, 83 percent of these losses occur in one subwatershed, the Susquehanna River. Under 2011 conditions, runoff from forests, wetlands, range brush, horticulture, and barren land contributed 25 percent of sediment delivered to watershed outlets, while urban nonpoint sources represented about 21 percent of the total sediment load delivered to streams and rivers. Under 2011 conditions hayland, pasture and grazingland, and point sources each contributed 5 percent or less of the total sediment delivered to watershed outlets (table 5.6).

Under the 2011 conservation condition, instream loads—the amount of sediment delivered from all sources to the Chesapeake Bay after accounting for instream deposition and transport processes—averaged about 7.0 million tons, down from 7.6 million and 9.0 million tons of sediment delivered to the Bay under the 2003-06 baseline condition and the no-practice scenario, respectively (table 5.5, fig. 5.6).

Under the 2011 conservation condition, the Upper Chesapeake Bay contributed 64 percent of the instream sediment loads, while the Lower Chesapeake Bay contributed 36 percent (table 5.5). Instream loads were greatest from the Rappahannock, York, and James Rivers subregion of the Lower Chesapeake Bay and the Potomac River subregion of the Upper Chesapeake Bay (table 5.5), which accounted for 35 and 34 percent of sediment delivered to the Chesapeake Bay, respectively. The large contributions of these subregions are due in part to their proximity to the Bay, which reduces opportunities for sediment deposition during transport.

Transport processes are an important consideration in sediment conservation. Under the 2011 conservation condition, the Susquehanna River subregion delivered more sediment to rivers and streams (53 percent of sediment from all sources) than did the Potomac River (17 percent of sediment from all sources; table 5.6). However, the Susquehanna River's instream load contribution to the Chesapeake Bay only accounts for 18 percent of the total instream sediment load from all sources, while the Potomac River instream contribution accounts for 34 percent of the total instream load from all sources (table 5.5). The Conowingo Reservoir, located just above the outlet of the Susquehanna River, traps a significant portion of the sediment from the Susquehanna River, preventing its transport to the Bay.

The Upper Chesapeake subregion had the highest percent reduction in instream loads delivered to the Bay due to conservation practice adoption. Relative to the no-practice scenario, instream loads were reduced by 35 percent in the 2003-06 baseline condition and 50 percent in the 2011 conservation condition, (table 5.5). Of all the subregions, the Upper Chesapeake subregion also had the greatest percentage decrease in sediment delivered to the Chesapeake Bay, which dropped by 26 percent between the 2003-06 baseline condition and the 2011 conservation condition.

Table 5.3. Average annual sediment loads delivered to *edge-of-field* (APEX model output) from cultivated cropland for the four subregions in the Chesapeake Bay watershed: the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.

			Conservation Practice Impacts (1,000 tons)			Load reductions due to conservation practices (percent change)		
8-digit HUC group*	Sub-region code	Subregion name	2011 Conservation condition	2003-06 Baseline condition	No-practice scenario	2003-06 Vs. No-practice	2011 Vs. No-practice	2011 vs. 2003-06
I	0205	Susquehanna River	8,198	20,141	37,827	47	78	59
II	0206	Upper Chesapeake**	338	1,461	4,496	67	92	77
III	0207	Potomac River	924	1,905	7,272	74	87	51
IV + V	0208	Lower Chesapeake**	399	1,415	4,508	69	91	72
		Total	9,859	24,922	54,100	54	82	60

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Some columns do not add to totals because of rounding.
* See Figure 5.4.
** Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

Table 5.4. Average annual sediment loads delivered to *watershed outlets* (8-digit HUCs) from cultivated cropland for the four subregions in the Chesapeake Bay watershed: no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.

			Conservation Practice Impacts (1,000 tons)			Load reductions due to conservation practices (percent change)		
8-digit HUC group*	Sub-region code	Subregion name	2011 Conservation condition	2003-06 Baseline condition	No-practice scenario	2003-06 vs. No-practice	2011 vs. No-practice	2011 vs. 2003-06
I	0205	Susquehanna River	3,161	7,662	14,495	47	78	59
II	0206	Upper Chesapeake**	152	577	1,768	67	91	74
III	0207	Potomac River	369	753	2,922	74	87	51
IV + V	0208	Lower Chesapeake**	173	616	1,919	68	91	72
		Total	3,854	9,608	21,104	54	82	60

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 5.3 are due to the application of delivery ratios, which were used to simulate delivery of sediment from the edge-of-field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.
* See Figure 5.4.
** Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

Table 5.5. Average annual *instream* sediment loads (all sources) delivered to the Chesapeake Bay, 2011 conservation condition.

8-digit HUC group*	Sub-region code	Subregion name		Conservation Practice Impacts (1,000 tons): 2011 Conservation condition	2003-06 Baseline condition	No-practice scenario	Load reductions due to conservation practices (percent change): 2003-06 vs. No-practice	2011 vs. No-practice	2011 vs. 2003-06
		Upper Chesapeake Bay							
I	0205	Susquehanna River		1,270	1,279	1,284	<1	1	1
II	0206	Upper Chesapeake		809	1,053	1,609	35	50	23
III	0207	Potomac River		2,381	2,518	3,018	17	21	5
			Sub-total	4,460	4,849	5,911	18	25	8
		Lower Chesapeake Bay							
IV	0208	Rappahannock, York, and James Rivers		2,458	2,634	2,989	12	18	7
V	0208	Eastern and Western Shores		74	83	108	23	31	11
			Sub-total	2,532	2,717	3,097	12	18	7
			Total	6,992	7,566	9,008	16	22	8

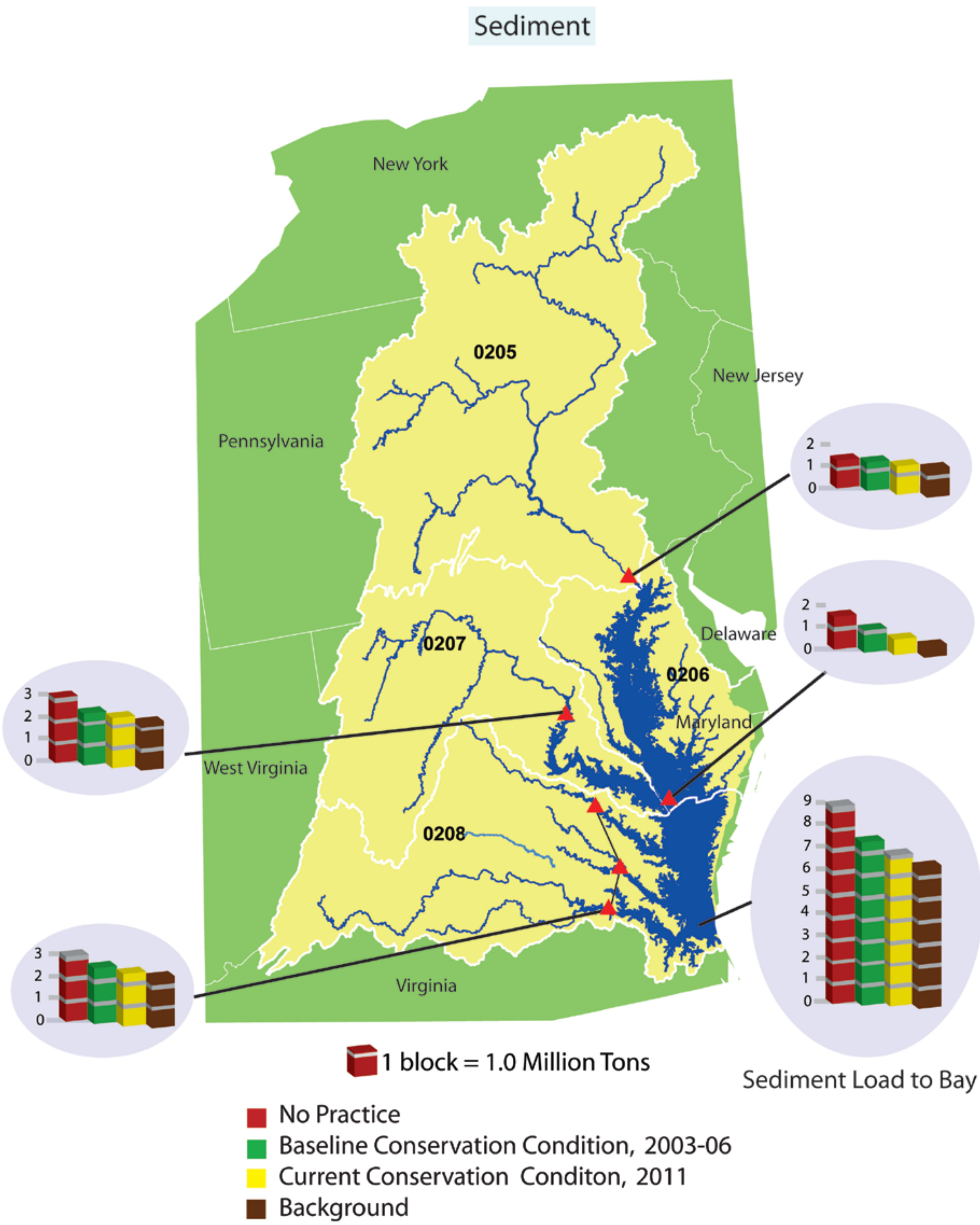
* See Figure 5.4.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Table 5.6. Average annual sediment loads delivered to *watershed outlets* (8-digit HUCs) from all sources for the four subregions in the Chesapeake Bay watershed, 2011 conservation condition.

8-digit HUC group	Sub-region code	Subregion name	All sources	Cultivated cropland*	Hayland	Pasture and grazing land	Urban: Non-point sources**	Urban: Point sources	Forest and other***
		Amount (1,000 tons)							
I	0205	Susquehanna River	4,393	3,161	259	78	482	3	393
II	0206	Upper Chesapeake****	1,058	152	5	52	322	<1	585
III	0207	Potomac River	1,389	369	65	70	497	1	361
IV + V	0208	Lower Chesapeake****	1,514	173	60	144	432	3	727
		Total	8,354	3,854	389	344	1,734	7	2,065
		Percent of all sources							
I	0205	Susquehanna River	52	38	3	1	6	<1	5
II	0206	Upper Chesapeake****	13	2	<1	1	4	<1	7
III	0207	Potomac River	17	4	1	1	6	<1	4
IV + V	0208	Lower Chesapeake****	18	2	1	2	5	<1	9
		Total	100	46	5	4	21	<1	25

* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, range brush, horticulture, and barren land.
**** Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

Figure 5.6. Estimates of average annual instream sediment loads for the 2003-06 baseline condition and 2011 conservation condition with comparison to the no-practice and background scenarios for subregions in the Chesapeake Bay watershed.*



* Instream sediment loads delivered to the Chesapeake Bay (all sources) are shown for each of the four subregions, corresponding to estimates presented in table 5.5. The total sediment load delivered to the Chesapeake Bay from all areas is shown in the bar chart in the lower right hand corner, labeled "Sediment Load to Bay."

Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, forestland, and urban land—as well as point sources.

Total Nitrogen

The model simulations suggest that continued adoption of new and improved conservation practices aimed at nitrogen load reduction are working. Model simulation results show that conservation practices reduced the amount of nitrogen lost at the edge-of-field from 275.9 million pounds (no-practice scenario) to 186.6 million pounds of nitrogen (2003-06 baseline condition) to 138.0 million pounds of nitrogen (2011 conservation condition) (table 5.7). Relative to the 2003-06 baseline condition, conservation practices in place in 2011 reduced edge-of-field nitrogen losses by 26 percent. The edge-of-field losses delivered to rivers and streams impact surface water quality and do not include percolation losses to deep aquifers. The nitrogen lost to deep percolation may become trapped or may take many years to reach surface waters.

Similar reductions were achieved on nitrogen loads delivered to rivers and streams each year: roughly 130.9 million pounds of nitrogen were lost to rivers and streams each year in the 2003-06 baseline condition, a 30 percent reduction from the no-practice scenario losses of 186.7 million pounds. Conservation practices in use in 2011 reduced these losses to 104.2 million pounds, a 20 percent reduction from loss rates in the 2003-06 baseline condition (table 5.8).

The 2011 conservation practices reduced the delivery of nitrogen to the Bay by about 17 and 6 percent relative to the no-practice scenario and the 2003-06 baseline condition, respectively (table 5.9).

With 2011 conservation practices in place, cultivated cropland is the source of 29 percent of nitrogen loads delivered to rivers and streams in the Chesapeake Bay watershed (table 5.10, fig. 5.7). Roughly 41 percent of these losses occur in one subwatershed, the Susquehanna River. Urban point sources were the source of 27 percent of nitrogen loads delivered to watershed outlets and urban non-point sources account for another 10 percent; pasture and grazing land contributed 14 percent of the nitrogen load delivered to watershed outlets; hayland contributed 8 percent of the total nitrogen delivered to watershed outlets; and runoff from forests, wetlands, range brush, horticulture, and barren land contributed 12 percent of nitrogen delivered to watershed outlets (table 5.10).

Under 2011 conservation conditions, instream loads—the amount of nitrogen delivered from all sources to the Chesapeake Bay after accounting for instream deposition and transport processes—averaged about 290.3 million pounds, down from 309.8 million and 351.5 million pounds of nitrogen delivered to the Bay under the 2003-06 baseline condition and the no-practice scenario, respectively (table 5.9, Figure 5.7).

Transport processes are an important consideration in nitrogen conservation. Nitrogen dynamics differ markedly from sediment dynamics. For example, under the 2011 conservation condition, the Susquehanna River subregion delivered 45 percent of nitrogen from all sources to rivers and streams, while the Potomac River delivered 17 percent of nitrogen from all sources; table 5.10). However, the Susquehanna River's instream load contribution to the Chesapeake Bay accounts for 41 percent of the total instream nitrogen load from all sources, while the Potomac River instream contribution accounts for 21 percent of the total instream load from all sources (table 5.9). Because of the solubility of nitrogen, the Conowingo Reservoir, located just above the outlet of the Susquehanna River, does not have the same impact on nitrogen dynamics as it did on sediment dynamics. Nitrogen bound to sediment can become soluble and move past the dam and into the Chesapeake Bay.

Table 5.7. Average annual nitrogen source loads delivered to *edge-of-field* (APEX model output) from cultivated cropland for the four subregions in the Chesapeake Bay watershed: the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.

				Conservation Practice Impacts (1,000 pounds)			Load reductions due to conservation practices (percent change)		
8-digit HUC group*	Sub-region code	Subregion name		2011 Conservation condition	2003-06 Baseline condition	No-practice scenario	2003-06 vs. No-practice	2011 vs. No-practice	2011 vs. 2003-06
I	0205	Susquehanna River		81,074	110,080	163,970	33	51	26
II	0206	Upper Chesapeake**		29,009	39,224	51,538	20	44	26
III	0207	Potomac River		17,374	21,808	37,575	12	54	20
IV + V	0208	Lower Chesapeake**		10,540	15,455	22,765	22	54	32
			Total	137,997	186,567	275,850	27	50	26

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Some columns do not add to totals because of rounding.
* See Figure 5.4.
** Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

Table 5.8. Average annual nitrogen source loads delivered to *watershed outlets* (8-digit HUCs) from cultivated cropland for the four subregions in the Chesapeake Bay watershed: the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.

				Conservation Practice Impacts (1,000 pounds)			Load reductions due to conservation practices (percent change)		
8-digit HUC group*	Sub-region code	Subregion name		2011 Conservation condition	2003-06 Baseline condition	No-practice scenario	2003-06 vs. No-practice	2011 vs. No-practice	2011 vs. 2003-06
I	0205	Susquehanna River		62,179	78,330	112,440	30	45	21
II	0206	Upper Chesapeake**		21,783	26,681	34,181	22	36	18
III	0207	Potomac River		12,833	15,411	25,042	38	49	17
IV + V	0208	Lower Chesapeake**		7,401	10,424	15,021	31	51	29
			Total	104,200	130,850	186,680	30	44	20

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 5.7 are due to the application of delivery ratios, which were used to simulate delivery of nitrogen from the edge-of-field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.
* See Figure 5.4.
** Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

Table 5.9. Average annual *instream* total nitrogen loads (all sources) delivered to the Chesapeake Bay, 2011 conservation condition.

				Conservation Practice Impacts (1,000 tons)			Load reductions due to conservation practices (percent change)		
8-digit HUC group*	Sub-region code	Subregion name		2011 Conservation condition	2003-06 Baseline condition	No-practice scenario	2003-06 vs. No-practice	2011 vs. No-practice	2011 vs. 2003-06
		Upper Chesapeake Bay							
I	0205	Susquehanna River		120,330	130,440	154,410	16	22	8
II	0206	Upper Chesapeake		52,226	56,894	64,076	11	18	8
III	0207	Potomac River		59,604	61,421	67,834	9	12	8
			Sub-total	232,160	248,750	286,320	13	19	7
		Lower Chesapeake Bay							
IV	0208	Rappahannock, York, and James Rivers		54,221	57,300	61,052	6	11	5
V	0208	Eastern and Western Shores		3,893	3,693	4,168	11	7	-5
			Sub-total	58,114	60,994	65,220	6	11	5
			Total	290,270	309,750	351,540	12	17	6

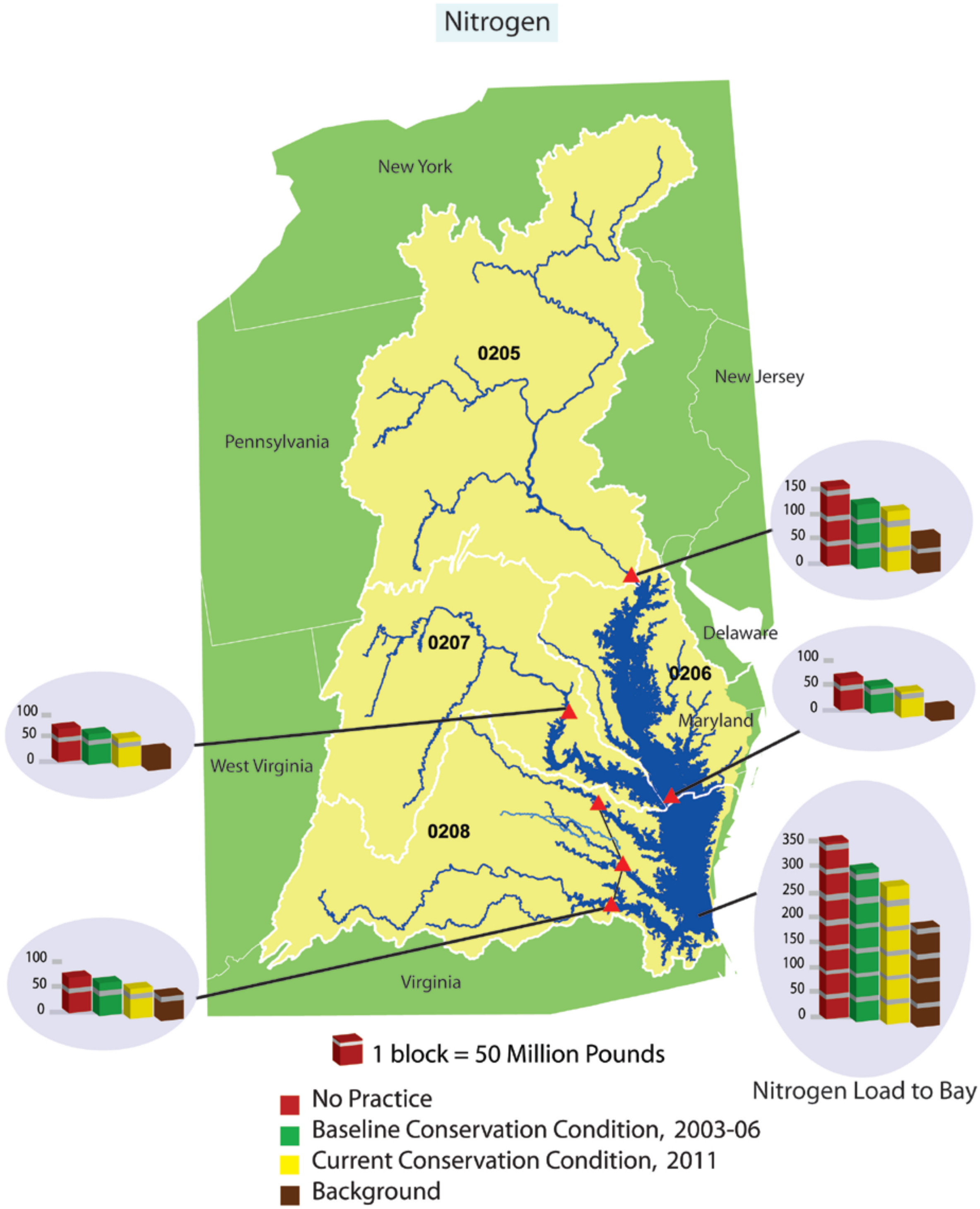
*See Figure 5.7.
Note: Percent reductions were calculated prior to rounding reported values. Some columns do not add to totals because of rounding. The negative reduction simulated in the 2003-06 baseline condition and the 2011 conservation condition on the Eastern and Western Shores in HUC 0208 is due to higher nitrate loadings in 2011 relative to 2003-06.

Table 5.10. Average annual nitrogen loads delivered to *watershed outlets* (8-digit HUCs) from all sources for the four subregions in the Chesapeake Bay watershed, 2011 conservation condition.

							Urban		
8-digit HUC group	Sub-region code	Subregion name	All sources	Cultivated cropland*	Hayland	Pasture and grazingland	Non-point sources**	Point sources	Forest and other***
					Amount (1,000 tons)				
I	0205	Susquehanna River	158,960	62,179	19,276	27,639	8,305	23,728	16,880
II	0206	Upper Chesapeake****	58,849	21,783	591	4,380	4,639	19,662	7,796
III	0207	Potomac River	73,372	12,833	5,455	11,241	10,867	26,889	6,092
IV + V	0208	Lower Chesapeake****	64,747	7,401	2,892	7,615	10,408	25,018	11,411
		Total	355,930	104,200	28,214	50,876	34,219	95,297	42,179
					Percent of all sources				
I	0205	Susquehanna River	45	17	5	8	2	7	5
II	0206	Upper Chesapeake****	17	6	<1	1	1	6	2
III	0207	Potomac River	21	4	2	3	3	8	2
IV + V	0208	Lower Chesapeake****	18	2	1	2	3	7	3
		Total	100	29	8	14	10	27	12

* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, range brush, horticulture, and barren land.
**** Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

Figure 5.7. Estimates of average annual instream nitrogen loads for the 2003-06 baseline condition and 2011 conservation condition with comparison to the no-practice and background scenarios for subregions in the Chesapeake Bay watershed.*



* Instream nitrogen loads delivered to the Chesapeake Bay (all sources) are shown for each of the four subregions, corresponding to estimates presented in table 5.9. The total sediment load delivered to the Chesapeake Bay from all areas is shown in the bar chart in the lower right hand corner, labeled "Nitrogen Load to Bay."

Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, forestland, and urban land—as well as point sources.

Total Phosphorus

Model simulations suggest the continued adoption of new and improved conservation practices aimed at phosphorus load reduction are working. Model simulation results show that conservation practices reduced the amount of phosphorus lost at the edge-of-field from 37.3 million pounds (no-practice scenario) to 15.6 million pounds of phosphorus (2003-06 baseline condition) to 8.5 million pounds of phosphorus (2011 conservation condition) (table 5.11; fig. 5.8). Relative to the 2003-06 baseline condition conservation practices in place in 2011 reduced edge-of-field phosphorus losses by 46 percent. Similar reductions were achieved on phosphorus loads delivered to rivers and streams each year: roughly 5.7 million pounds of phosphorus were lost to rivers and streams each year under the 2003-06 baseline condition, a 59 percent reduction from losses in the no-practice scenario (13.7 million pounds). Conservation practices in use in 2011 reduced these losses to 3.4 million tons, a 41 percent reduction from 2003-06 loss rates (table 5.12). The 2011 conservation condition reduced the delivery of phosphorus to the Chesapeake Bay by about 21 and 5 percent relative to the no- practice scenario and the 2003-06 baseline condition, respectively (table 5.13).

Although relative to the no-practice scenario, edge-of-field phosphorus losses were reduced by 77 percent due to conservation practices in place in 2011 (table 5.11), opportunities to reduce phosphorus losses remain. Phosphorus conservation trends are similar to trends in sediment loss reduction, although they are not identical due to the behavior of the soluble form of phosphorus. For example, the Susquehanna River subregion accounted for a greater percentage of total edge-of-field sediment losses over all three scenarios, highlighting the greater proportion of cropland and greater inherent runoff as compared to the other subregions. Similarly, phosphorus losses in the Susquehanna River subregion, accounted for 62, 72, and 75 percent of edge-of-field phosphorus losses under the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition, respectively (table 5.11). Conservation practice adoption impact on phosphorus reduction in the Susquehanna was significant. Annual phosphorus losses were reduced by 73 percent (16.8 million pounds) under 2011 conservation condition, relative to the no-practice scenario, and by 43 percent (4.9 million pounds) relative to the 2003-06 baseline condition (table 5.11).

With 2011 conservation practices in place, cultivated cropland is the source of 11 percent of phosphorus loads delivered to rivers and streams in the Chesapeake Bay watershed (table 5.14, Figure 5.8). Approximately 72 percent of these losses occur in one subwatershed, the Susquehanna River. Under the 2011 conditions, point sources were the source of 37 percent of phosphorus loads delivered to watershed outlets. Pasture and grazingland contributed 28 percent of the phosphorus load delivered to watershed outlets. Runoff from point sources contributed 10 percent of phosphorus loads delivered to watershed outlets. Runoff from forests, wetlands, range brush, horticulture, and barren land contributed 8 percent of phosphorus delivered to watershed outlets. Hayland contributed 5 percent of total phosphorus delivered to watershed outlets (table 5.14).

Under the 2011 conservation condition, instream loads—the amount of phosphorus delivered from all sources to the Chesapeake Bay after accounting for instream deposition and transport processes—averaged about 14.3 million pounds, down from 15.1 million and 18.1 million pounds of phosphorus delivered to the Bay under the 2003-06 baseline condition and the no-practice scenario, respectively (table 5.13, fig. 5.8).

Under the 2011 conservation condition, the Upper Chesapeake Bay contributed 65 percent of the instream phosphorus loads, while the Lower Chesapeake Bay contributed 35 percent (table 5.13). Instream loads were greatest from the Rappahannock, York and James Rivers subregion of the Lower Chesapeake Bay and the Susquehanna River subregion of the Upper Chesapeake Bay (table 5.13), which accounted for 33 and 25 percent of phosphorus delivered to the Chesapeake Bay, respectively. The large contributions of these subregions are due in part to their proximity to the Bay, which reduces opportunities for sediment-bound phosphorus deposition during transport.

Transport processes are an important consideration in phosphorus conservation. Under 2011 conservation conditions, the Susquehanna River subregion delivered more phosphorus to rivers and streams (41 percent of phosphorus from all sources) than did the Potomac River (19 percent of phosphorus from all sources) (table 5.14). The Susquehanna River's instream load contribution to the Chesapeake Bay only accounts for 25 percent of the total instream phosphorus load from all sources, while the Potomac River instream contribution accounts for 20 percent of the total instream load from all sources (table 5.13). The Conowingo Reservoir, located just above the outlet of the Susquehanna River, traps a significant portion of sediment-bound phosphorus from the Susquehanna River, preventing its transport to the Bay. However, note that the reduction was not as significant as was reported for the dam's impact on sediment retention. This is because phosphorus has both a insoluble form, typically associated with sediment, and a soluble form, which is dissolved in water and may bypass the dam.

Table 5.11. Average annual phosphorus source loads delivered to *edge-of-field* (APEX model output) from cultivated cropland for the four subregions in the Chesapeake Bay watershed: the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.

			Conservation Practice Impacts (1,000 pounds)			Load reductions due to conservation practices (percent change)		
8-digit HUC group*	Sub-region code	Subregion name	2011 Conservation condition	2003-06 Baseline condition	No-practice scenario	2003-06 vs. No-practice	2011 vs. No-practice	2011 vs. 2003-06
I	0205	Susquehanna River	6,383	11,294	23,218	51	73	43
II	0206	Upper Chesapeake**	562	1,404	4,766	71	88	60
III	0207	Potomac River	1,004	1,765	5,793	70	83	43
IV + V	0208	Lower Chesapeake**	519	1,130	3,477	68	85	54
		Total	8,468	15,594	37,254	58	77	46

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Some columns do not add to totals because of rounding.
* See Figure 5.4.
** Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

Table 5.12. Average annual phosphorus source loads delivered to *watershed outlets* (8-digit HUCs) from cultivated cropland for the four subregions in the Chesapeake Bay watershed: the no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.

			Conservation Practice Impacts (1,000 pounds)			Load reductions due to conservation practices (percent change)		
8-digit HUC group*	Sub-region code	Subregion name	2011 Conservation condition	2003-06 Baseline condition	No-practice scenario	2003-06 vs. No-practice	2011 vs. No-practice	2011 vs. 2003-06
I	0205	Susquehanna River	2,406	3,909	8,084	52	70	38
II	0206	Upper Chesapeake**	282	557	1,983	72	86	49
III	0207	Potomac River	434	727	2,206	67	80	40
IV + V	0208	Lower Chesapeake**	241	462	1,421	67	83	48
		Total	3,363	5,654	13,694	59	75	41

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 5.11 are due to the application of delivery ratios, which were used to simulate delivery of phosphorus from the edge-of-field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.
* See Figure 5.4.
** Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

Table 5.13. Average annual *instream* total phosphorus loads (all sources) delivered to the Chesapeake Bay, 2011 conservation condition.

8-digit HUC group*	Sub-region code	Subregion name		Conservation Practice Impacts (1,000 tons): 2011 Conservation condition	2003-06 Baseline condition	No-practice scenario	Load reductions due to conservation practices (percent change): 2003-06 vs. No-practice	2011 vs. No-practice	2011 vs. 2003-06
		Upper Chesapeake Bay							
I	0205	Susquehanna River		3,657	3,988	4,858	18	25	8
II	0206	Upper Chesapeake		2,833	3,018	4,054	26	30	6
III	0207	Potomac River		2,904	3,030	3,558	15	18	4
			Sub-total	9,394	10,036	12,471	20	25	6
		Lower Chesapeake Bay							
IV	0208	Rappahannock, York, and James Rivers		4,792	4,889	5,327	8	10	2
V	0208	Eastern and Western Shores		159	170	257	34	38	6
			Sub-total	4,952	5,059	5,584	9	11	2
			Total	14,346	15,094	18,055	16	21	5

*See Figure 5.4.

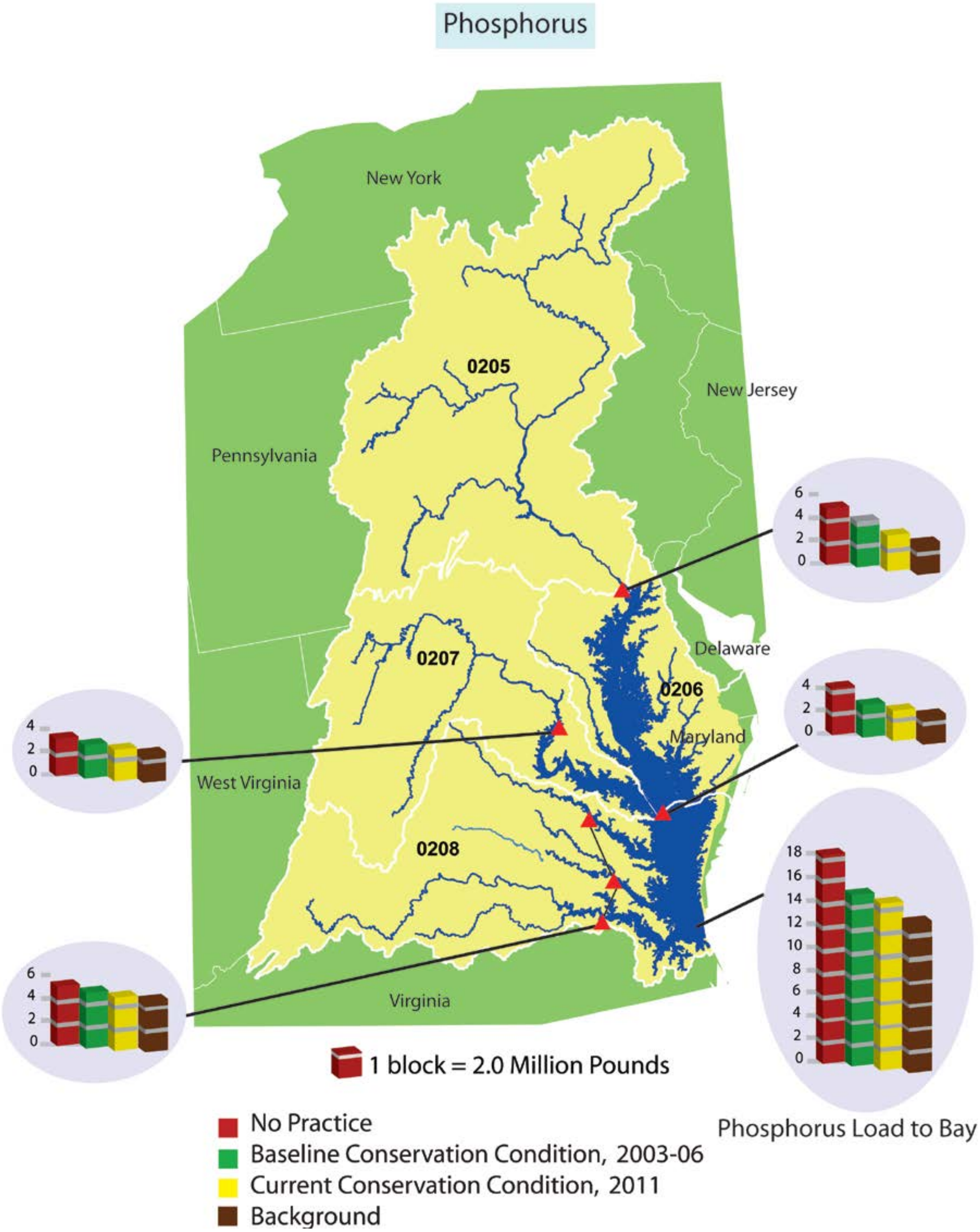
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Table 5.14. Average annual phosphorus loads delivered to *watershed outlets* (8-digit HUCs) from all sources for the four subregions in the Chesapeake Bay watershed, 2011 conservation condition.

8-digit HUC group	Sub-region code	Subregion name	All sources	Cultivated cropland*	Hayland	Pasture and grazing land	Urban: Non-point sources**	Urban: Point sources	Forest and other***
						Amount (1,000 tons)			
I	0205	Susquehanna River	12,473	2,406	1,060	3,055	829	4,299	790
II	0206	Upper Chesapeake****	3,874	282	39	1,037	565	1,459	493
III	0207	Potomac River	5,758	434	256	1,919	739	1,971	440
IV + V	0208	Lower Chesapeake****	8,238	241	269	2,414	940	3,545	827
		Total	30,343	3,363	1,625	8,424	3,073	11,273	2,550
						Percent of all sources			
I	0205	Susquehanna River	41	8	3	10	3	14	3
II	0206	Upper Chesapeake****	13	1	<1	3	2	5	2
III	0207	Potomac River	19	1	1	6	2	6	1
IV + V	0208	Lower Chesapeake****	27	1	1	8	3	12	3
		Total	100	11	5	28	10	37	8

* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, range brush, horticulture, and barren land.
**** Excludes watersheds that drain into the Atlantic Ocean (8-digit HUCs 02060010 and 02080110).

Figure 5.8. Estimates of average annual instream phosphorus loads for the 2003-06 baseline condition and 2011 conservation condition with comparison to the no-practice and background scenarios for subregions in the Chesapeake Bay watershed.*



* Instream phosphorus loads delivered to the Chesapeake Bay (all sources) are shown for each of the four subregions, corresponding to estimates presented in table 5.13. The total sediment load delivered to the Chesapeake Bay from all areas is shown in the bar chart in the lower right hand corner, labeled "Phosphorus Load to Bay."

Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, forestland, and urban land—as well as point sources.

Summary of Conservation Practice Effects on Water Quality in the Chesapeake Bay Watershed

Reductions in field-level losses due to conservation practices, including maintaining land in long-term conserving cover, translate into improvements in water quality in streams and rivers. Transport of sediment and nutrients from farm fields to streams and rivers involves a variety of processes and time-lags, and not all of the potential pollutants leaving fields contribute to current instream loads.

Cultivated cropland represents only about 10 percent of the land base in the Chesapeake Bay watershed. At the 2003-06 baseline condition, relative to loads from all sources, cultivated cropland delivered a disproportionate amount of sediment and significant nutrients to rivers and streams and ultimately to the Chesapeake Bay. Model simulations suggest the long-term contributions of the conservation practices put in place in the 2003-06 baseline condition and the 2011 conservation condition provide significant improvements towards lessening agricultural losses of sediment and nutrients. Of the total loads delivered to rivers and streams at the 8-digit HUC watershed outlets from all sources, cultivated cropland is the source for 46 percent of the sediment, 29 percent of the nitrogen, and 11 percent of the phosphorus.

Figures 5.9, 5.10, and 5.11 summarize the extent to which the 2003-06 baseline condition and the 2011 conservation condition have reduced sediment, nitrogen, and phosphorus loads in the Chesapeake Bay watershed, on the basis of model simulations. In each figure, the top map shows delivery from cultivated cropland to rivers and streams and the bottom map shows delivery from all sources to the Chesapeake Bay. The effects of the 2011 conservation condition are contrasted with the effects of the 2003-06 baseline condition and the no-practice scenario.

Background levels, representing loads that would be expected if no acres in the watershed were cultivated or treated with conservation practices, are also shown in the bar charts. These estimates simulate a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. Background loads also include 2003-06 baseline condition loads from all other land uses—hayland, pastureland, forestland, and urban land—as well as point sources. In the 2003-06 report alternative scenarios were developed to project the potential reductions that could realized by targeting acres with different treatment needs; that analysis was not repeated in this report.

Sediment Loss

In Figure 5.9, the top map shows that the 2003-06 baseline condition reduced sediment loads delivered from cropland to rivers and streams in the watershed by 54 percent relative to the no-practice scenario. The 2011 conservation condition reduced sediment losses by 60 percent relative to the 2003-06 baseline condition.

The bottom map shows that when sediment loads from all sources are considered, the use of conservation practices on cropland reduced sediment loads delivered to the Chesapeake Bay by 16 percent under the 2003-06 baseline condition as compared to the no-practice scenario. The 2011 conservation condition reduced total sediment loads delivered to the Chesapeake Bay by 8 percent relative to the 2003-06 baseline condition.

Total Nitrogen Loss

In Figure 5.10, the top map shows that 2003-06 baseline condition reduced total nitrogen loads delivered from cropland to rivers and streams in the watershed by 30 percent relative to the no-practice scenario. The 2011 conservation condition reduced nitrogen losses by 20 percent relative to the 2003-06 baseline condition.

The bottom map shows that the use of conservation practices on cropland reduced total nitrogen loads delivered to the Chesapeake Bay by 12 percent under the 2003-06 baseline condition as compared to the no-practice scenario. The 2011 conservation condition reduced nitrogen loads delivered to the Chesapeake Bay by 6 percent relative to the 2003-06 baseline condition.

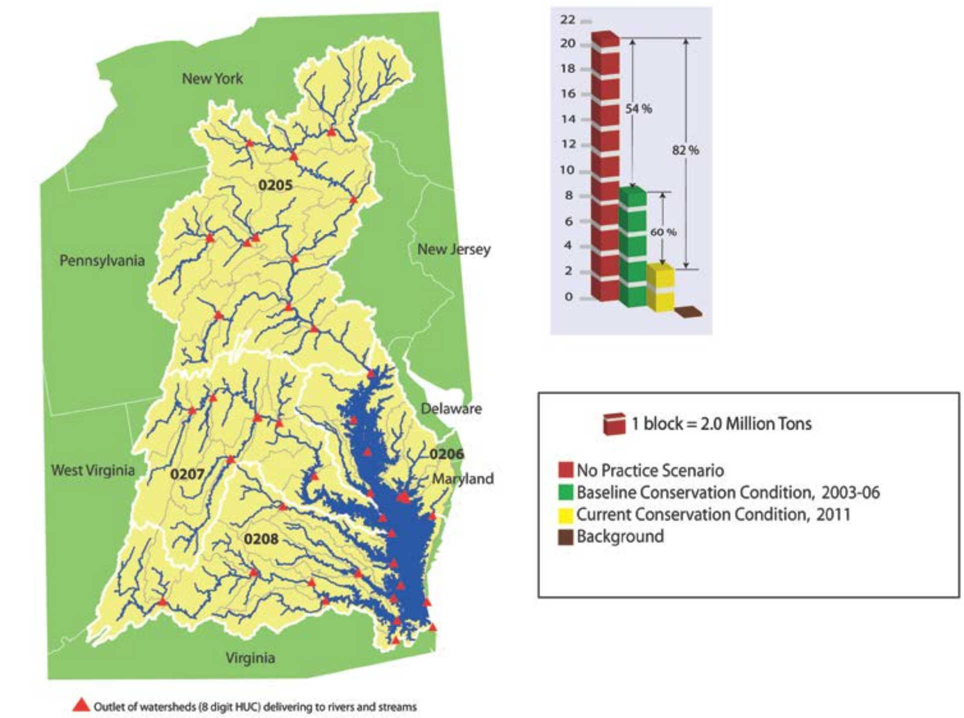
Total Phosphorus Loss

In Figure 5.11, the top map shows that the 2003-06 baseline condition reduced total phosphorus loads delivered from cropland to rivers and streams in the watershed by 59 percent relative to the no-practice scenario. The 2011conservation condition reduced phosphorus losses by 41 percent relative to the 2003-06 baseline condition.

The bottom map shows that the use of conservation practices on cropland reduced total phosphorus loads delivered to the Chesapeake Bay by 16 percent under the 2003-06 baseline condition as compared to the no-practice scenario. The 2011 conservation condition reduced phosphorus loads delivered to the Chesapeake Bay by 5 percent as compared to the 2003-06 baseline condition.

Figure 5.9. Summary of the effects of conservation practices on sediment loads in the Chesapeake Bay watershed: no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.

Sediment delivered from cultivated cropland to rivers and streams in the Chesapeake Bay watershed



Sediment delivered to the Chesapeake Bay (all sources-instream loads)

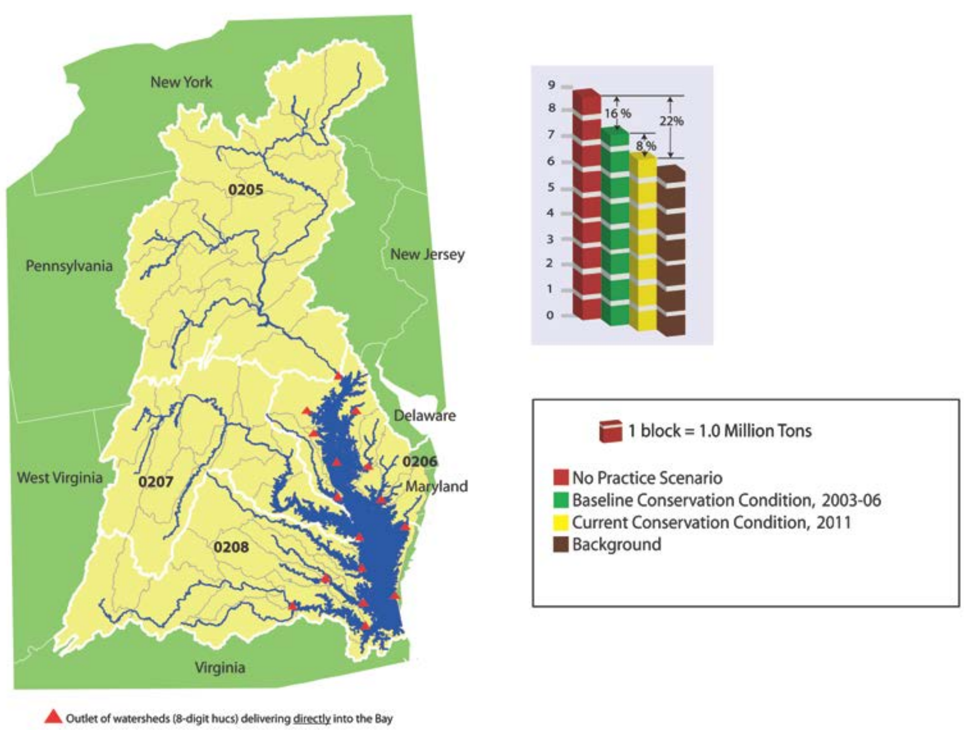
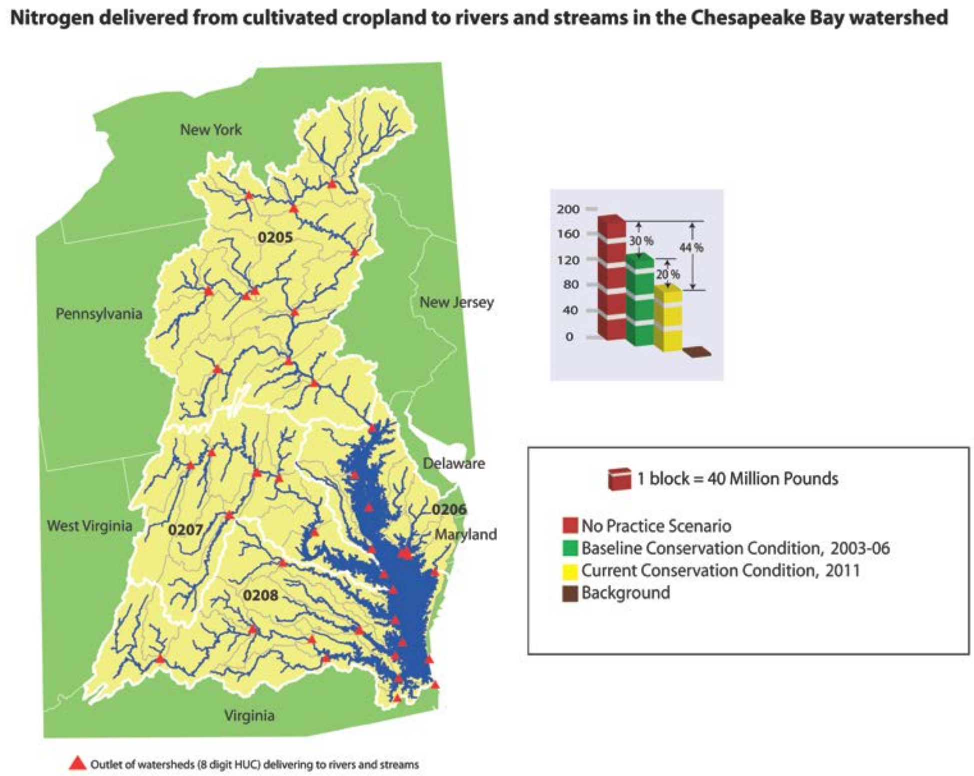


Figure 5.10. Summary of the effects of conservation practices on total nitrogen loads in the Chesapeake Bay watershed: no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.



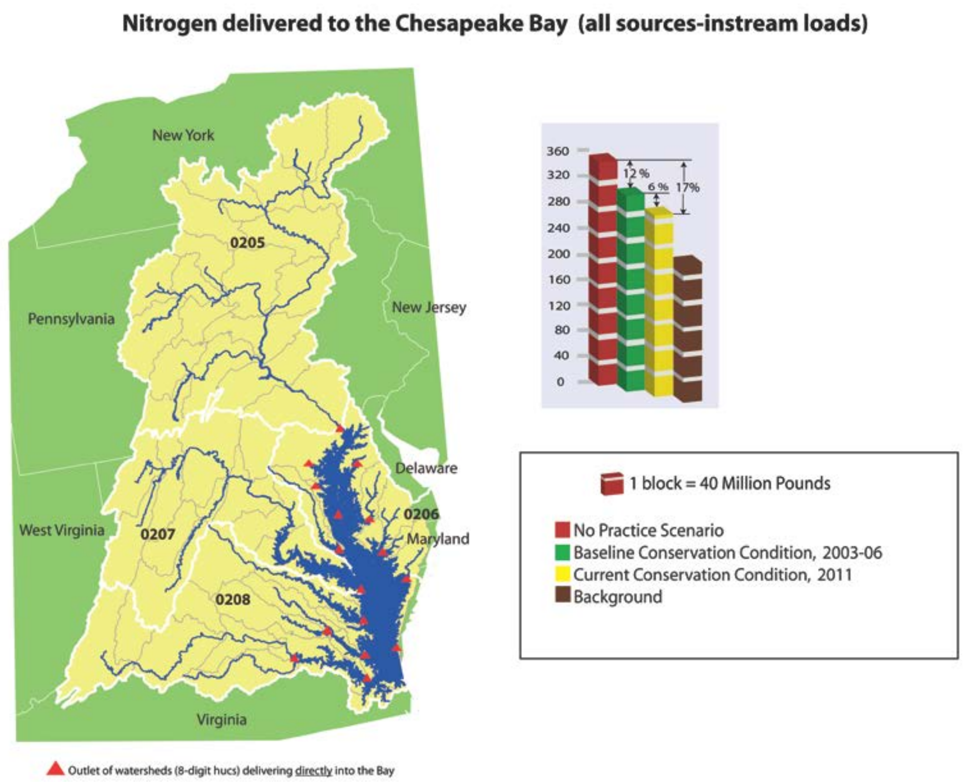
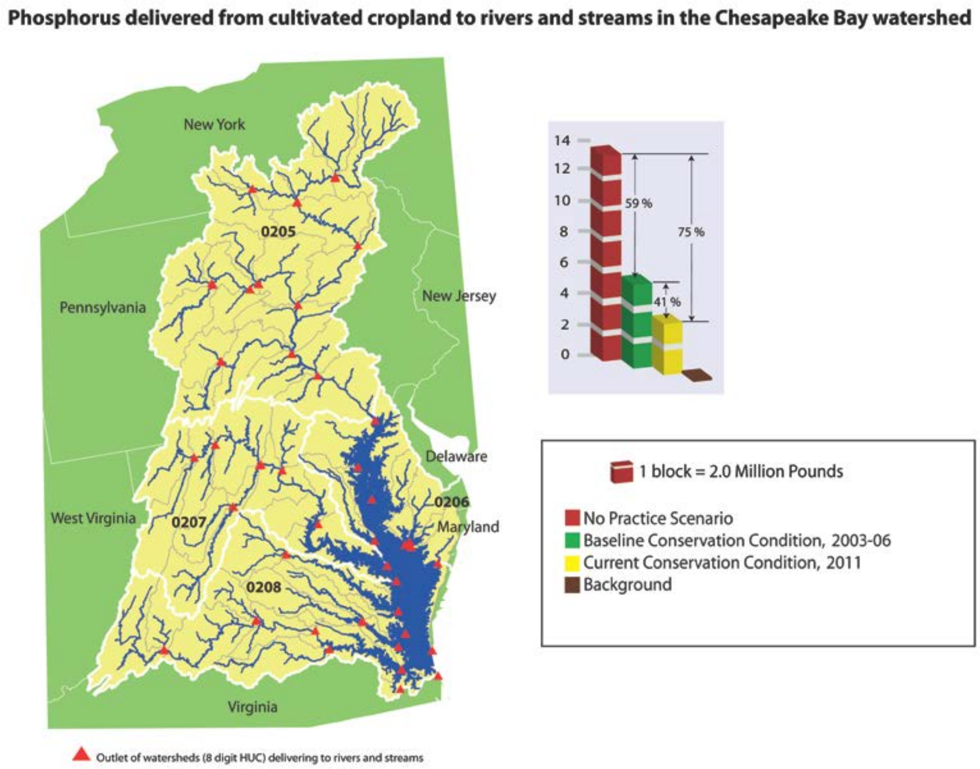
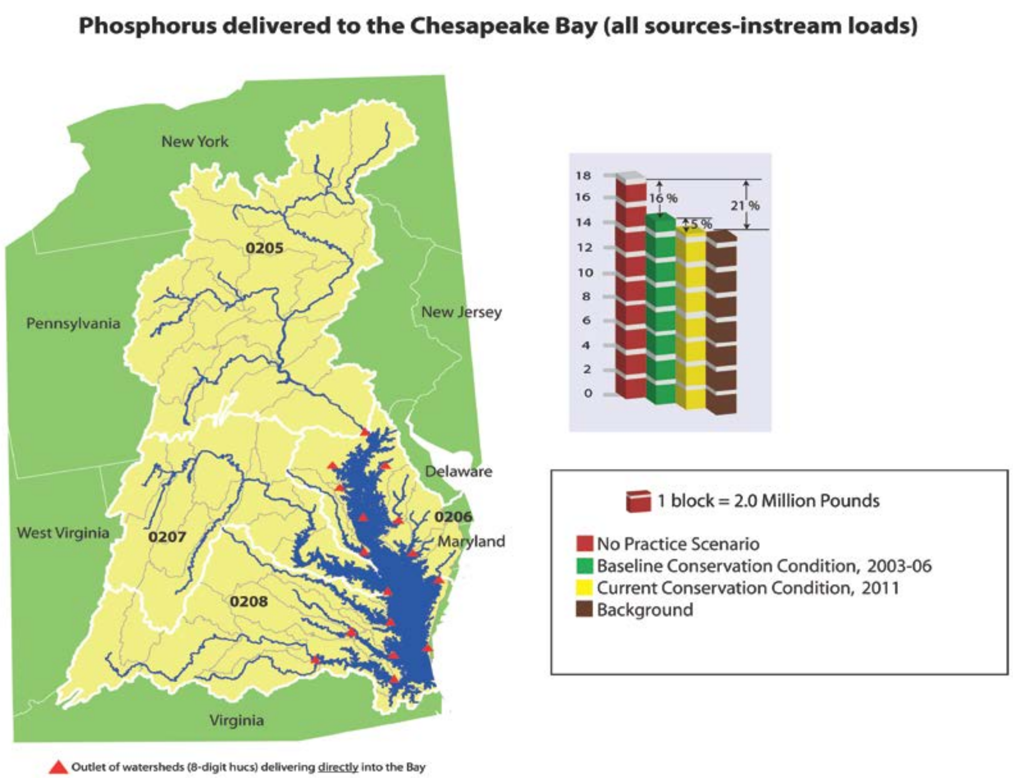


Figure 5.11. Summary of the effects of conservation practices on total phosphorus loads in the Chesapeake Bay watershed: no-practice scenario, 2003-06 baseline condition, and 2011 conservation condition.





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Appendix A
Land Use Data Used in this Report

The Chesapeake Bay region covers about 68,500 square miles and includes parts of New York, Pennsylvania, Maryland, Delaware, Virginia, and West Virginia, as well as the entire District of Columbia. Fifty-nine percent of the land cover in the Chesapeake Bay region is forest; it is primarily deciduous forest, with some areas dominated by conifers and mixed stands. Pastureland and hayland make up about 18 percent of the land cover in the region, while 10 percent is used for crop production. About 6 percent of the area is water and wetlands. Urban areas make up about 8 percent of the Chesapeake Bay region by area (table A1). The major metropolitan areas are Washington, DC; Baltimore, MD; Richmond, VA; Norfolk VA, and; Harrisburg, PA.

The 2007 Census of Agriculture reported that the 83,775 farms in the Chesapeake Bay region account for about 4 percent of the total number of farms in the United States and occupy about 1 percent of all farmland in the nation. According to the 2007 Census of Agriculture, in 2007 agriculture in the Chesapeake Bay region generated about $9.5 billion—24 percent from crops and 76 percent from livestock.

The Chesapeake Bay, the largest estuary in the United States, is about 200 miles long and 30 miles wide at its widest point. The Chesapeake Bay and its tributaries cover about 4,500 square miles of open water with over 11,600 miles of shoreline, while the entire watershed covers about 68,500 square miles shared across six states (Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia) and the District of Columbia. Per the most recent Census of Agriculture, completed in 2007, agricultural land makes up roughly 30 percent of the area and agriculture generates roughly $9.5 billion annually. Cultivated cropland, including land in continuous cover, makes up 10 percent of the region's acreage, while 20 percent is pasture, grassy or brushy range, and hayland. Forest land covers about 58 percent and urban land makes up 8 percent of the region. The remaining 4 percent of the area is in non-forested wetlands or is open water.

A number of factors specific to cultivated cropland in the Chesapeake Bay region contribute to a relatively high vulnerability to soil and nutrient losses. These factors include the region's relatively high annual precipitation, cultivation on highly erodible land, and cultivation of soils with high vulnerability to surface water runoff and/or leaching.

Table A1. Distribution of land cover in the Chesapeake Bay region (USDA/NRCS 2011).

Land use	Acres*	Percent
Cultivated cropland and land enrolled in the CRP general signup	4,588,332	10
Forest deciduous	19,106,747	44
Hay/Pasture not in rotation with crops	7,738,805	18
Urban	3,651,000	8
Water	1,152,262	3
Wetland forested	793,516	2
Rangeland – grasses	142,690	<1
Wetland non-forested	517,632	1
Forest evergreen	2,999,538	7
Forest mixed	2,421,677	6
Rangeland – brush	266,807	1
Horticulture and barren	473,994	1
Totals	**43,853,000**	**100**

Source: 2001 National Land Cover Database for the Conterminous United States (Homer et al. 2007).
*Acreage estimates for cultivated cropland differ slightly from those provided elsewhere in this report because of differences in sources and methods.

Appendix B
Simulating the No-practice Scenario

The no-practice scenario provides an estimate of sediment and nutrient loss from farm fields that would occur in the absence of conservation practices. The benefits of conservation practices in use within the Chesapeake Bay region were estimated by contrasting model output from the no-practice scenario to model output from the baseline conservation conditions for 2003-06 and 2011. The no-practice representations derived for use in this study conformed to the following guidelines:

- Consistency: representation of all practices on all sample points in a consistent manner, based on the intended purpose of each practice;
- Simplicity: Complex rules for assigning "no-practice" activities lead to complex explanations that are difficult to substantiate and sometimes difficult to explain and accept;
- Historical context avoided: The no-practice scenario is a technological, not a chronological, step backward for conservation It is also important to retain the overall crop mix in the region, as it in part reflects market forces. Taking away the conservation ethic is the goal;
- Moderation: The no-practice scenario should provide a reasonable reduction in conservation practices so that believable benefits of additional conservation practices can be determined through comparison with baseline conservation simulations; and
- Maintenance of crop yield or efficacy. It is impossible to avoid small changes in crop yields, but care was taken to avoid no-practice representations that would significantly change crop yields and regional production capabilities.

Table B1 summarizes the adjustments to conservation practices used in simulation of the no-practice scenario.

No-practice representation of structural practices
The no-practice field condition for structural practices simulates the absence of structural practices and uses a runoff curve number for erosion prediction determined from a "poor" soil condition.

- Overland flow. When practices affecting overland flow of water and therefore the P factor of the USLE-based equations were removed, the P factor was increased to 1. Slope length was also changed for practices such as terraces, to reflect the absence of these slope-interrupting practices in the no-practice scenario;
- Concentrated flow. The no-practice protocol removes the structure or waterway that previously channelized the flow and replaces it with a "ditch" as a separate subarea. Although the ditch represents a gully, the only sediment contributions from the gully come from downcutting. Headcutting and sloughing of the sides are not simulated in APEX;
- Edge-of-field. The no-practice protocol removes edge-of-field practices, restoring the slope length to what it would be in the absence of the practices; and
- Wind control. Any practices reducing the unsheltered distance are removed and the unsheltered distance set to 400 meters.

No-practice representation of conservation tillage
The no-practice simulations remove conservation tillage and cover crops benefits. Crops grown with a Soil Tillage Intensity Rating (STIR value) below 100 are considered to be no- or low-till systems and had tillage operations added to them in the no-practice scenario. Specifically, because the most common type of tillage operation reported was disking and the most commonly reported disk implement was a tandem disk, in the no practice scenario two consecutive tandem disk operations prior to planting were added. Two consecutive disking operations add 78 to the existing tillage intensity, which allows for more than 90 percent of the crops to exceed a STIR of 100 and yet maintain the unique suite and timing of operations for each crop in the rotation.

The hydrologic condition for assignment of the runoff curve number on these acres was changed from "good" to "poor" on all points receiving additional tillage. Points conventionally tilled for all crops in the baseline condition scenario are modeled with a "poor" hydrologic condition curve number.

No-practice representation of cover crops
The no-practice protocol for this practice removes the planting of the crop and all associated cultural practices such as tillage, fertilization, and also includes consideration of grazing operations.

No-practice representation of irrigation practices
The no-practice irrigation protocols remove the benefits of increased efficiencies of modern irrigation systems by increasing water losses from the water source to the field, evaporation losses with sprinkler systems, percolation losses below the root-zone during irrigation, and runoff at the lower end of the field.

The quantity of water applied for all scenarios was simulated in APEX using an "auto-irrigation" procedure that applied irrigation water when the degree of plant stress exceeded a threshold. "Auto-irrigation" amounts were determined within pre-set single event minimums and maximums, and an annual maximum irrigation amount. APEX also used a pre-determined minimum number of days before another irrigation event regardless of plant stress. In the no-practice representation, all conservation practices, such as Irrigation Water Management and Irrigation Land Leveling, were removed.

No-practice representation of nutrient management practices
The no-practice nutrient management protocols remove the benefits of proper nutrient management techniques by altering three of the four basic aspects of nutrient application—rate, timing, and method. The form of application was not addressed because of the inability to determine if proper form was being applied.

Table B1. Construction of the no-practice scenario for the Chesapeake Bay region.

Practice adjusted	Criteria used to determine if a practice was in use	Adjustment made to create the no-practice scenario
	Overland flow practices present	USLE P-factor changed to 1 and slope length increased for points with terraces, soil condition changed from good to poor.
	Concentrated flow—managed structures or waterways present	Structures and waterways replaced with earthen ditch, soil condition changed from good to poor.
	Edge-of-field mitigation practices present	Removed practice and width added back to field slope length.
Structural practices	Wind erosion control practices present	Unsheltered distance increased to 400 meters.
Residue and tillage management	STIR ≤100 for any crop within a crop year	Add two tandem diskings 1 week prior to planting.
Cover crop	Cover crop planted for off-season protection	Remove cover crop simulation (field operations, fertilizer, grazing, etc.).
Irrigation	Pressure systems	Change to hand-move sprinkler system except where the existing system is less efficient.
	Total of all applications of nitrogen (commercial fertilizer and manure applications) ≤1.4 times harvest removal for non-legume crops, except for cotton and small grain crops	Increase rate to 1.98 times harvest removal (proportionate increase in all reported applications, including manure).
	Total of all applications of nitrogen (commercial fertilizer and manure applications) ≤1.6 times harvest removal for small grain crops	Increase rate to 2.0 times harvest removal (proportionate increase in all reported applications, including manure).
Nitrogen rate	Total of all applications of nitrogen (commercial fertilizer and manure applications) for cotton ≤60 pounds per bale	Increase rate to 90 pounds per bale (proportionate increase in all reported applications, including manure).
Phosphorus rate	Applied total of fertilizer and manure phosphorus over all crops in the crop rotation ≤ 1.1 times total harvest—phosphorus removal over all crops in rotation.	Increase commercial phosphorus fertilizer application rates to reach 2.2 times harvest removal for the crop rotation (proportionate increase in all reported applications over the rotation), accounting also for manure phosphorus associated with increase to meet nitrogen applications for no-practice scenario. Manure applications were NOT increased to meet the higher phosphorus rate for the no-practice scenario.
Commercial fertilizer application method	Incorporated or banded	Change to surface broadcast.
Manure application method	Incorporated, banded, or injected	Change to surface broadcast.
Commercial fertilizer application timing	Within 3 weeks prior to planting, at planting, or within 60 days after planting.	Moved to 3 weeks prior to planting. Manure applications were not adjusted for timing in the no-practice scenario.

<u>Nitrogen rate</u>. For the no-practice scenario, the amount of commercial nitrogen fertilizer applied was—

- increased to 1.98 times harvest removal for non-legume crops receiving less than or equal to 1.40 times the amount of nitrogen removed at harvest in the baseline scenario, except for cotton and small grain crops;
- increased to 2.0 times harvest removal for small grain crops receiving less than or equal to 1.60 times the amount of nitrogen removed at harvest in the baseline scenario; and
- increased to 90 pounds per bale for cotton crops receiving less than 60 pounds of nitrogen per bale in the baseline scenario.

Where nitrogen was applied in multiple applications, each application was increased proportionately. For sites receiving manure, the threshold for identifying good management was the total nitrogen application rate from both manure and fertilizer, and both fertilizer and manure were increased proportionately to reach the no-practice scenario rate.

Phosphorus rate. For the no-practice scenario, the amount of commercial phosphorus fertilizer applied was increased to 2.2 times the harvest removal rate. For crops receiving manure, any increase in phosphorus from manure added to meet the nitrogen criteria for no-practice was taken into account in setting the no-practice application rate. However, no adjustment was made to manure applied at rates below the P threshold because the appropriate manure rate was based on the nitrogen level in the manure. The ratio of 2.2 for the increased phosphorus rate was determined by the average rate-to-yield-removal ratio for crops with phosphorus applications exceeding 1.1 times the amount of phosphorus taken up by all the crops in rotation and removed at harvest. Multiple commercial phosphorus fertilizer applications were increased proportionately to meet the 2.2 threshold.

Timing of application. Nutrients applied closest to the time when a plant needs them are the most efficiently utilized and least likely to be lost to the surrounding environment. All commercial fertilizer applications occurring within 3 weeks prior to planting, at planting, or within 60 days after planting were moved back to 3 weeks prior to planting for the no-practice scenario. For example, split applications that occur within 60 days after planting are moved to a single application 3 weeks before planting. Timing of manure applications was not adjusted in the no-practice scenario.

Method of application. Nutrient applications, including banded or incorporated manure applications, were changed to a surface broadcast application method.

No-practice representation of land in long-term conserving cover

The no-practice representation of land in long-term conserving cover is cultivated cropping with no conservation practices in use. Cropped sample points were matched to each CRP sample point on the basis of slope, soil texture, soil hydrologic group, and geographic proximity. The cropped sample points that matched most closely were used to represent the cropped condition that would be expected at each CRP sample point if the field had not been enrolled in CRP. In most cases, seven "donor" points were used to represent the crops that were grown and the various management activities to represent crops and management for the CRP sample point "as if" the acres had not been enrolled in CRP. The crops and management activities of each donor crop sample were combined with the site and soil characteristics of the CRP point for the no-practice representation of land in long-term conserving cover.

Appendix C
Estimates of Margins of Error for Selected Acre Estimates

The 2003-06 CEAP cultivated cropland sample is a subset of NRI sample points from the 2003 NRI (USDA NRCS 2007). The 2001, 2002, and 2003 Annual NRI surveys were used to draw the sample. (Information about the CEAP sample design is in "NRI-CEAP Cropland Survey Design and Statistical Documentation," available at http://www.nrcs.usda.gov/technical/nri/ceap.) The 2011 CEAP cultivated cropland sample is a subset of the 2007 NRI. The 2003-06 sample for cropped acres consists of 771 sample points in the Chesapeake Bay region, while the 2011 sample consists of 904 sample points. Acres reported using the CEAP sample are "estimated" acres because of the uncertainty associated with statistical sampling.

Statistics derived from the CEAP database are based upon data collected at sample sites located across all parts of the region. This means that estimates of acreage are statistical estimates and contain some amount of statistical uncertainty. Since the NRI employs recognized statistical methodology, it is possible to quantify this statistical uncertainty.

Margins of error are provided in table C1 for selected acres estimates found elsewhere in the report. The margin of error is a commonly used measure of statistical uncertainty and can be used to construct a 95-percent confidence interval for an estimate. The lower bound of the confidence interval is obtained by subtracting the margin of error from the estimate; adding the margin of error to the estimate forms the upper bound. Measures of uncertainty (e.g., margins of error, standard errors, confidence intervals, coefficients of variation) should be taken into consideration when using CEAP acreage estimates. The margin of error is calculated by multiplying the standard error by the factor 1.96; a coefficient of variation is the relative standard for an estimate, usually in terms of percentages, and is calculated by taking 100 times the standard error and then dividing by the estimate.

The precision of CEAP acres estimates depends upon the number of samples within the region of interest, the distribution of the resource characteristics across the region, the sampling procedure, and the estimation procedure. Characteristics that are common and spread fairly uniformly over an area can be estimated more precisely than characteristics that are rare or unevenly distributed.

Table C1. Margins of error for acre estimates based on the CEAP sample.

	2003-06 Estimated acres	2003-06 Margin of error	2011 Estimated acres	2011 Margin of error	Significant Difference
Cropped Acres					
Susquehanna River (subregion 0205)	1,734.8	186.4	1,996.3	254.6	
Upper Chesapeake Bay (subregion 0206)	1,187.9	100.0	1,021.3	126.4	
Potomac River (subregion 0207)	684.0	102.8	733.3	92.0	
Lower Chesapeake Bay (subregion 0208)	673.2	96.9	602.5	98.7	
Chesapeake Bay region	4,279.9	285.3	4,353.4	302.3	
Highly erodible land (HEL)					
Susquehanna River (subregion 0205)	847.1	146.8	1,170.7	185.7	
Upper Chesapeake Bay (subregion 0206)	133.3	49.4	131.3	47.5	
Potomac River (subregion 0207)	334.5	72.9	356.5	88.1	
Lower Chesapeake Bay (subregion 0208)	102.4	67.2	86.0	35.6	
Chesapeake Bay region	1,417.2	184.1	1,744.5	182.3	
Irrigated acres					
Susquehanna River (subregion 0205)	19.7	29.3	24.0	29.2	
Upper Chesapeake Bay (subregion 0206)	144.3	52.3	226.1	67.3	
Potomac River (subregion 0207)	4.8	10.0	23.5	24.5	
Lower Chesapeake Bay (subregion 0208)	40.2	35.8	33.9	34.6	
Chesapeake Bay region	209.0	67.2	307.5	90.5	
Acres receiving manure					
Susquehanna River (subregion 0205)	913.6	247.9	1,216.4	207.2	
Upper Chesapeake Bay (subregion 0206)	401.8	85.1	400.3	82.9	
Potomac River (subregion 0207)	294.0	96.8	358.3	83.6	
Lower Chesapeake Bay (subregion 0208)	7.8	8.8	93.6	48.7	
Chesapeake Bay region	1,617.2	307.8	2,068.6	283.2	
Cropping Systems (table 2.3)					
Corn-soybean only	1,174.7	175.2	880.4	153.9	
Corn-soybean with close grown crops	797.6	139.5	1,251.6	157.9	*
Corn only	690.4	140.3	364.3	95.3	*
Soybean only	161.1	76.2	128.0	51.2	
Soybean-wheat only	124.7	73.6	119.9	44.0	
Soybean and close grown crops	6.8	8.9	45.3	32.7	
Corn and close grown crops	272.4	91.0	335.9	93.7	
Vegetable or tobacco with or without other crops	142.9	87.5	208.8	102.1	
Hay-crop mix	627.0	141.9	701.4	168.0	
Remaining mix of crops	282.3	87.4	317.8	79.0	
Use of structural practices (table 2.1)					
Overland flow control practices	1,607.0	248.5	1,966.5	189.5	
Concentrated flow control practices	871.9	169.7	1,334.4	174.4	*
Edge-of-field buffering and filtering practices	582.1	138.0	1,339.0	159.0	*
One or more water erosion control practices	2,215.1	311.2	2,884.7	261.4	*
Wind erosion control practices	378.1	114.7	1,024.1	175.7	*
Use of cover crops	497.0	121.6	2,225.2	168.4	*
Conservation treatment levels for nitrogen application management (4R's) (fig. 2.4)					
High level of treatment	209.5	106.4	236.8	93.1	
Moderately high level of treatment	2,335.1	228.4	2,141.0	263.9	
Moderate level of treatment	1,170.1	209.7	1,561.4	181.6	
Low level of treatment	565.3	158.7	414.2	89.4	

Table C1. Margins of error for acre estimates based on the CEAP sample (Cont'd).

	2003-06 Estimated acres	2003-06 Margin of error	2011 Estimated acres	2011 Margin of error	Significant Difference
Conservation treatment levels for phosphorus application management (4R's) (fig. 2.5)					
High level of treatment	1,003.8	188.4	1,180.5	155.6	
Moderately high level of treatment	1,621.6	224.8	1,405.7	144.7	
Moderate level of treatment	829.2	225.3	779.3	195.3	
Low level of treatment	825.3	211.4	987.9	151.1	
Conservation treatment levels for water erosion control practices (fig. 4.1)					
High level of treatment	74.2	44.0	696.1	116.5	*
Moderately high level of treatment	539.1	117.9	1,447.6	197.9	*
Moderate level of treatment	2,075.8	248.2	1,647.4	212.5	
Low level of treatment	1,590.8	191.3	562.3	140.4	*
Conservation treatment levels for nitrogen runoff control (fig. 4.2)					
High level of treatment	356.9	121.9	1,513.9	159.8	*
Moderately high level of treatment	1,922.6	205.0	1,723.4	199.6	
Moderate level of treatment	1,532.5	226.6	912.4	192.7	*
Low level of treatment	468.0	153.6	203.7	57.6	*
Conservation treatment levels for nitrogen leaching control practices (fig. 4.3)					
High level of treatment	487.0	130.4	819.2	150.8	*
Moderately high level of treatment	2,161.6	258.0	1,981.8	229.9	
Moderate level of treatment	1,000.7	198.2	1,049.6	135.0	
Low level of treatment	630.7	178.3	502.8	123.7	
Conservation treatment levels for phosphorus runoff control (fig. 4.4)					
High level of treatment	851.8	173.3	1,665.8	162.0	*
Moderately high level of treatment	1,774.3	239.3	1,559.5	217.1	
Moderate level of treatment	984.0	190.5	701.1	147.8	
Low level of treatment	669.8	188.6	427.0	104.4	

Appendix D
Nutrient Management, Nitrogen and Phosphorus Scoring Method

Table D1 shows the scoring system for nitrogen and phosphorus application management treatment levels. Scores for nitrogen are for each crop and crop year and averaged over the rotation length. For phosphorus, the scores are based on the entire rotation. Scoring for phosphorus timing and method are based on the lowest score for all applications. Maximum score for both nutrients is 60. Rate and timing have a maximum of 20 each and proper method plus split application of nutrients can add an additional 20 points, 10 points each.

Table D1. Scoring System for Nitrogen and Phosphorus application management treatment levels.

Application Category	Application Criteria	Score*
	Nitrogen Rate	
All crops except small grains	Total N Applied / N removed by Harvest	
	< 1.2	20
	< 1.4	15
	< 1.6	10
	< 1.8	5
	> 1.8	0
	No N Applied	15
Small grains	Total N Applied / N removed by Harvest	
	< 1.4	20
	< 1.6	15
	< 1.8	10
	< 2.0	5
	< 2.0	0
	No N Applied	15
	Phosphorus Rate	
Rotation	Total P Applied / P removed by Harvest	
	< 1.0	20
	< 1.2	15
	< 1.4	10
	< 1.6	5
	> 1.6	0
	Timing and Method Scores are the same for both Nitrogen and Phosphorus	
Timing	Application relative to Planting (Days)	
	> 45	0
	> 21 but < 25	5
	> 7 but < 21	10
	+ or – 7	15
	> 7 past planting	20
	Split Applications	
	First application >21 days	0
	First application >7 but <21 days	5
	First application w/in 7 days of plant	10
Method	Type	
	Surface broadcast and no incorporation	0
	Injection, knifed, banded or incorporation	10

*Scores for Nitrogen are for each crop and crop year and averaged over the rotation length. For phosphorus, the scores are based on the entire rotation. Scoring for phosphorus timing and method are based on the lowest score for all applications. Maximum score for both nutrients is 60.

Appendix E
Model Simulation Results for the Baseline Conservation Condition for the Four Subregions in the Chesapeake Bay Region

Model simulation results presented in Chapter 4 for the baseline conservation condition are presented in tables E1 and E2 for the four subregions in the Chesapeake Bay region. The column headings refer to the subregion code. The names of the subregions are shown below:

Subregion code	Subregion name
0205	Susquehanna River
0206	Upper Chesapeake
0207	Potomac River
0208	Lower Chesapeake

Table E1. Average annual estimates of water flow, erosion, and soil organic carbon for the baseline conservation condition for cropped acres, by subregion, in the Chesapeake Bay region.

Model simulated outcome	2003-06 Chesapeake Bay Region	0205	0206	0207	0208	2011 Chesapeake Bay Region	0205	0206	0207	0208
Cropped acres (million acres)	4,279.9	1,734.8	1,187.9	684.0	673.2	4,353.4	1,996.3	1,021.3	733.3	602.5
Percent of acres in region	100.0	40.5	27.8	16.0	15.7	100.0	46.6	23.9	17.1	14.1
Highly erodible acres	1,417.2	847.1	133.3	334.5	102.4	1,744.5	1,170.7	131.3	356.5	86.0
Percent of acres highly erodible	33.1	48.8	11.2	48.9	15.2	40.1	58.6	12.9	48.6	14.3
Irrigated acres	209.0	19.7	144.2	4.8	40.2	300.9	24.0	219.5	23.5	33.9
Percent of acres irrigated	4.9	1.1	12.1	0.7	6.0	6.9	1.2	21.5	3.2	5.6
Manured acres	1,569.8	876.3	396.3	289.5	7.8	2,068.6	1,216.4	400.3	358.3	93.6
Percent of acres receiving manure	36.7	50.5	33.4	42.3	1.2	47.5	60.9	39.2	48.9	15.5
Water sources										
Non-irrigated acres	4,070.9	1,715.1	1,043.7	679.2	633.0	4,052.5	1,972.3	801.8	709.8	568.6
Precipitation (average annual inches)	42.4	41.7	43.8	40.6	43.5	42.3	41.7	43.8	40.8	43.5
Irrigated acres										
Precipitation (average annual inches)	42.7	38.6	43.8	39.4	41.0	40.9	39.3	43.8	39.4	43.2
Irrigation applied (average annual inches)	7.6	7.1	7.8	5.5	7.4	8.1	8.2	6.4	11.1	7.2
Water loss pathways (average annual inches)										
Evapotranspiration	24.2	23.5	24.4	24.8	25.1	24.9	23.9	25.8	25.6	25.9
Surface water runoff	8.8	9.0	8.3	8.0	9.9	8.5	9.0	7.4	7.8	9.9
Subsurface water flow	9.6	9.1	11.8	7.8	8.7	9.3	8.8	12.1	7.9	8.1
Erosion and sediment loss (average annual tons/acre)										
Wind erosion	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Sheet and rill erosion	3.7	6.6	1.1	2.8	1.5	1.5	2.5	0.4	1.1	0.5
Sediment loss at edge-of-field due to water erosion	5.1	9.4	1.1	3.6	2.3	1.9	3.2	0.3	1.4	0.6
Soil organic carbon (average annual pounds/acre)										
Loss of soil organic carbon with wind and water erosion	57.2	45.1	62.8	59.9	75.5	73.0	67.1	69.9	71.4	100.0
Change in soil organic carbon, including loss of carbon with wind and water erosion	-182.2	-256.1	-128.0	-137.5	-132.7	-102.7	-151.2	-55.2	-75.6	-55.4

Table E2. Average annual estimates of nitrogen loss and phosphorus loss for the baseline conservation condition for cropped acres, by subregion, in the Chesapeake Bay region.

Model simulated outcome	2003-06 Chesapeake Bay Region	0205	0206	0207	0208	2011 Chesapeake Bay Region	0205	0206	0207	0208
Nitrogen (average annual pounds/acre)	4,279.9	1,734.8	1,187.9	684.0	673.2	4,353.4	1,996.3	1,021.3	733.3	602.5
Nitrogen sources										
Atmospheric deposition	8.8	9.8	7.5	8.5	8.6	8.9	9.9	7.4	8.5	8.8
Bio-fixation by legumes	31.8	23.8	40.3	29.6	40.0	36.4	33.6	36.8	38.1	42.7
Nitrogen applied as commercial fertilizer and manure	95.0	103.0	87.5	105.7	76.7	104.6	107.0	105.4	108.7	90.2
All nitrogen sources	135.6	136.6	135.3	143.7	125.3	149.9	150.5	149.6	155.3	141.7
Nitrogen in crop yield removed at harvest	88.9	78.0	97.8	93.9	96.9	98.5	90.2	105.5	103.7	107.4
Nitrogen loss pathways										
Nitrogen loss by volatilization	14.2	15.7	13.0	14.7	12.0	17.4	18.9	17.2	17.0	13.4
Nitrogen loss through denitrification	3.0	3.6	2.1	4.3	1.7	4.9	5.7	3.4	6.0	3.6
Nitrogen lost with windborne sediment	0.1	0.0	0.1	0.0	0.2	0.1	0.1	0.1	0.0	0.1
Nitrogen loss with surface runoff , including waterborne sediment	15.7	23.7	6.6	15.6	11.7	9.8	13.7	3.5	9.9	7.0
Nitrogen loss in subsurface flow pathways	25.9	31.5	25.4	23.8	14.6	22.9	26.7	22.6	20.7	13.1
Total nitrogen loss for all loss pathways	58.9	74.5	47.2	58.3	40.1	55.0	65.1	46.8	53.5	37.2
Change in soil nitrogen	-17.3	-24.1	-12.0	-13.8	-12.3	-10.8	-15.2	-6.3	-9.0	-5.9
Phosphorus (average annual pounds/acre)										
Phosphorus applied as commercial fertilizer and manure	23.9	28.7	17.8	30.0	15.8	25.2	29.3	20.2	26.4	18.2
Phosphorus in crop yield removed at harvest	14.8	13.5	15.6	16.1	15.4	15.8	14.7	16.9	16.6	16.9
Phosphorus loss pathways										
Phosphorus lost with windborne sediment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phosphorus lost to surface runoff, including waterborne sediment and soluble phosphorus in surface water runoff and lateral flow into drainage ditches	3.3	5.5	1.1	3.2	1.8	1.8	2.8	0.5	1.6	0.8
Soluble phosphorus loss to groundwater	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total phosphorus loss for all pathways	3.4	5.6	1.1	3.3	1.8	1.9	2.9	0.6	1.7	0.9
Change in soil phosphorus	0.5	1.2	-0.9	3.1	-1.6	2.6	4.6	0.8	2.4	-0.6

Appendix F
Criteria for Water Erosion Control Treatment Levels

The sediment scoring shown in table F1 assigns mitigation points for sediment conserving conservation practices for each method of mitigating sediment loss, avoid, control, and trap (ACT). These points provide a means to evaluate the differences between treatment levels. They are combined with nutrient application scoring in loss matrices for surface loss of nitrogen and phosphorus. Each mitigation technique (Avoid, Control, Trap) addressed by a conservation practice is scored on a scale of 20 points for a maximum score for any individual practice of 60 points. The point assignment is based on professional opinions of NRCS conservationists and based on a practices' relative ability to control sediment loss for that mitigation technique. Two practices may receive the same score and one be generally recognized as more efficient in certain situations, but both are highly effective in their mitigation of losses. For example, no-till and terraces both score 20 points for controlling sediment runoff losses. Terraces are physical barriers that slow runoff and help control concentrate flow. However, terraces do not reduce rainfall impact; soil may be dislodged and may move between terraces, especially if crop residue is not present on the soil surface. The residue cover from no-till provides a physical barrier to raindrop impact and reduces dislodging of soil particles and subsequent erosion. When applied correctly, terraces and no till practices complement each other to reduce erosion to acceptable levels on most land suitable for crop production.

For each point, the sum from all practices applied is calculated for each mitigation technique and as an overall score. For incorporation with the nutrient application scores for determining treatment levels for nitrogen and phosphorus runoff, each mitigation pathway is adjusted to a maximum of 20 points so its scoring scale is equivalent to that for the maximum scores for rate, timing, and method plus split application scores from nutrient application management. For example, the maximum score for avoiding sediment when all practices are summed is 40, so all avoid scores are halved. The maximum for control mitigation is 100 and that for trapping is 80.

Table F1. Criteria for Water Erosion Control Treatment Levels

Sediment Loss (Runoff) Only	Avoid	Control	Trap
Conservation Cover (327)	20	0	0
Conservation Crop Rotation (328)	5	0	0
Contour Buffer Strips (332)	0	20	10
Contour Farming (330)	0	5	0
Cover Crop (340)	0	20	10
Cross Wind Ridges (588)	0	5	0
Cross Wind Trap Strips (589C)	0	10	5
Dike (356)	0	5	5
Diversion (362)	0	10	0
Field Border (386)	0	0	5
Filter Strip (393)	2	0	20
Grade Stabilization Structure (410)	0	10	0
Grassed Waterway (412)	0	10	5
Hedgerow Planting (442)	0	0	5
Herbaceous Wind Barriers (603)	0	10	5
Residue and Tillage Management, No-till/Strip-Till/Direct Seed (329)	20	20	0
Residue and Tillage Management, Mulch-Till (345)	14	14	0
Residue and Tillage Management, Ridge Till (346)	10	14	0
Riparian Forest Buffer (391)	4	0	20
Riparian Herbaceous Buffer (390)	4	0	20
Stripcropping (585)	0	10	0
Terrace (600)	0	20	2
Vegetative Barriers (601)	0	5	5
Vegetative Treatment Area (635)	0	0	10
Windbreak/Shelterbelt Establishment (380)	0	5	5

Appendix G
Criteria for Four Classes of Soil Runoff Potential

Criteria for four classes of soil runoff potential were derived using a combination of soil hydrologic group, slope, and K-factor, as shown in table G1.

Table G1. Criteria for Four Classes of Soil Runoff Potential.

Soil runoff potential	Acres with hydrologic soil Group A*	Acres with hydrologic soil Group B*	Acres with hydrologic soil Group C*	Acres with hydrologic soil Group D*
Low	All acres	Slope<4	Slope<2	Slope<2 and K-factor<0.28**
Moderate	None	Slope >=4 and <=6 and K-factor<0.32**	Slope >=2 and <=6 and K-factor<0.28**	Slope<2 and K-factor>=0.28**
Moderately high	None	Slope >=4 and <=6 and K-factor>=0.32**	Slope >=2 and <=6 and K-factor>=0.28**	Slope >=2 and <=4
High	None	Slope>6	Slope>6	Slope>4

Note: About 40 percent of cropped acres in the Chesapeake Bay region are highly erodible land (HEL).

* Hydrologic soil groups are classified as:

- Group A—sand, loamy sand, or sandy loam soils that have low runoff potential and high infiltration rates even when thoroughly wetted.
- Group B—silt loam or loam soils that have moderate infiltration rates when thoroughly wetted.
- Group C—sandy clay loam soils that have low infiltration rates when thoroughly wetted.
- Group D—clay loam, silty clay loam, sandy clay, silty clay, or clay soils that have very low infiltration rates when thoroughly wetted.

** K-factor is a relative index of susceptibility of bare, cultivated soil to particle detachment and transport by rainfall. It is determined by the composition of the soil, saturated hydraulic conductivity, and soil structure.

Appendix H
Criteria for Four Classes of Soil Leaching Potential

Criteria for four classes of soil leaching potential were derived using a combination of soil hydrologic group, slope, and K-factor, as shown in table H1.

Table H1. Criteria for Four Classes of Soil Leaching Potential.

Soil leaching potential*	Acres with soil hydrologic Group A**	Acres with soil hydrologic Group B**	Acres with soil hydrologic Group C**	Acres with soil hydrologic Group D**
Low	None	None	None	All acres except organic soils
Moderate	None	Slope <=12 and K-factor>=0.24*** or slope>12	All acres except organic soils	None
Moderately high	Slope>12	Slope >=3 and <=12 and K-factor<0.24***	None	None
High	Slope<=12 or acres classified as organic soils	Slope<3 and K-factor <0.24*** or acres classified as organic soils	Acres classified as organic soils	Acres classified as organic soils

Note: About 40 percent of cropped acres in the Chesapeake Bay region are highly erodible land.

*Coarse fragments (stones and rocks) in the soil make it easier for water to infiltrate rather than run off. If the coarse fragment content of the soil was greater than 30 percent by weight, the soil leaching potential was increased two levels (moderate and moderately high to high, and low to moderately high). If the coarse fragment content was greater than 10 percent but less than 30 percent, the soil leaching potential was increased one level.

**Hydrologic soil groups are classified as:

- Group A—sand, loamy sand, or sandy loam soils that have low runoff potential and high infiltration rates even when thoroughly wetted.
- Group B—silt loam or loam soils that have moderate infiltration rates when thoroughly wetted.
- Group C—sandy clay loam soils that have low infiltration rates when thoroughly wetted.
- Group D—clay loam, silty clay loam, sandy clay, silty clay, or clay soils that have very low infiltration rates when thoroughly wetted.

***K-factor is a relative index of susceptibility of bare, cultivated soil to particle detachment and transport by rainfall. It is determined by the composition of the soil, saturated hydraulic conductivity, and soil structure.