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(CEAP)

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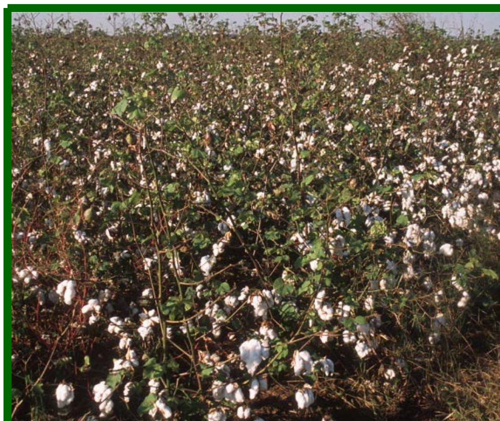
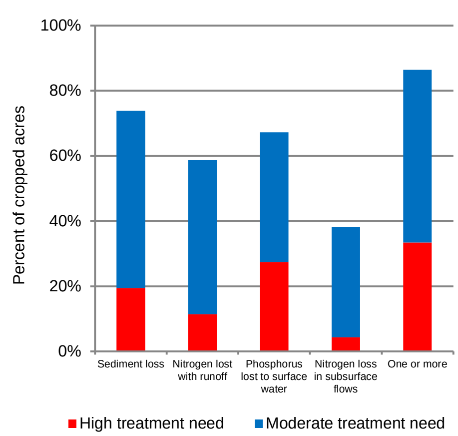
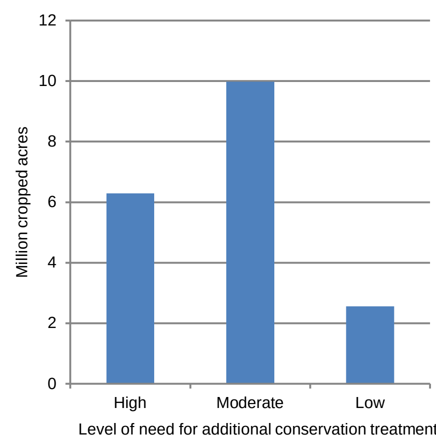
Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Lower Mississippi River Basin







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Cover photos by (clockwise from top left) **Lynn Betts, Bob Nichols, Kirk Patrick, Bob Nichols,** USDA Natural Resources Conservation Service

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 Cooperative State Research, Education, and Extension Service (CSREES—now National Institute of Food and Agriculture [NIFA]) in response to a general call for better accountability of how society would benefit from the 2002 Farm Bill's substantial increase in conservation program funding (Mausbach and Dedrick 2004). 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 provide research and assessment on how to best use conservation practices in managing agricultural landscapes to protect and enhance environmental quality.

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*; *Grazing lands,* including rangeland, pastureland, and grazed forest land; 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.

Research and assessment efforts were designed to estimate the effects and benefits of conservation practices through a mix of research, data collection, model development, and model application. A vision for how CEAP can contribute to better and more effective delivery of conservation programs in the years ahead is addressed in Maresch, Walbridge, and Kugler (2008). 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), Texas AgriLife Research, and the University of Massachusetts.

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Foreword

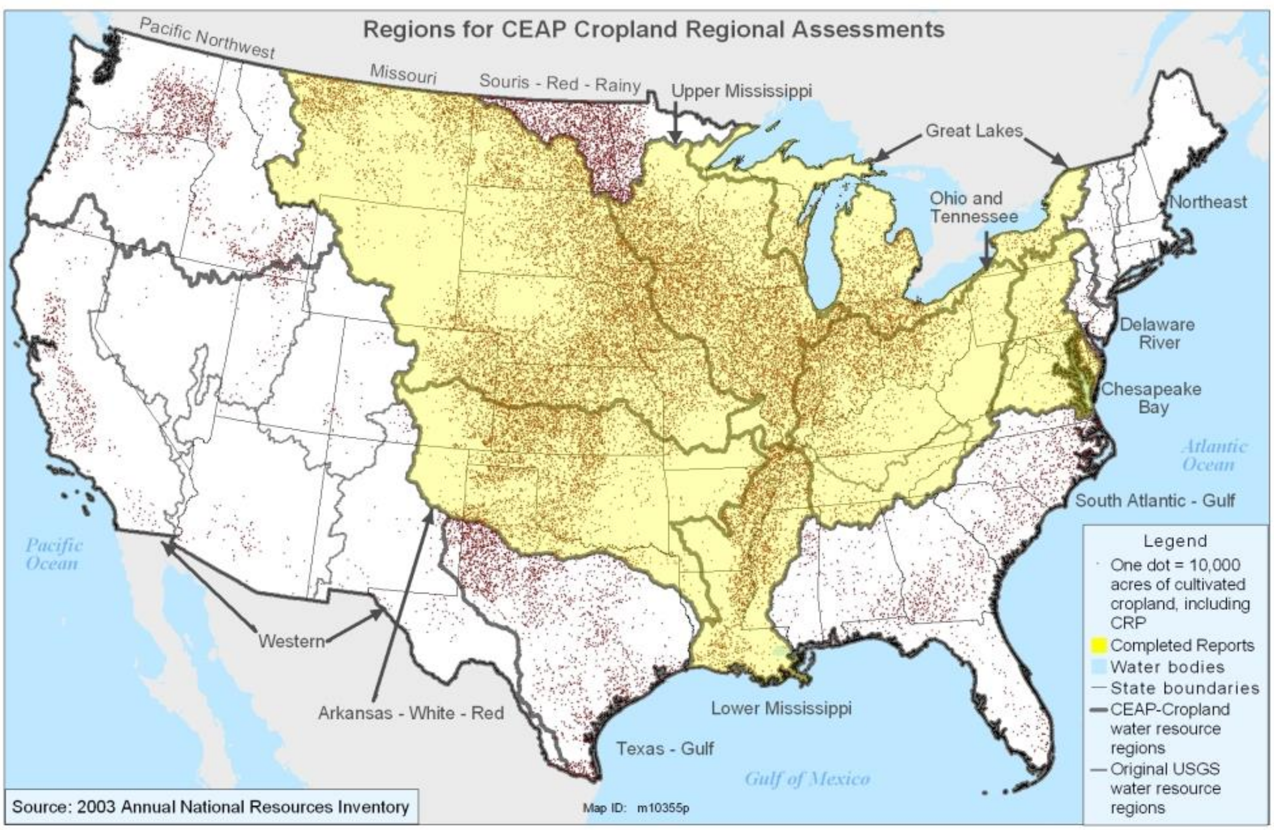
The United States Department of Agriculture has a rich tradition of working with farmers and ranchers to enhance agricultural productivity and environmental protection. Conservation pioneer Hugh Hammond Bennett worked tirelessly to establish a nationwide Soil Conservation Service along with a system of Soil and Water Conservation Districts. The purpose of these entities, now as then, is to work with farmers and ranchers and help them plan, select, and apply conservation practices to enable their operations to produce food, forage, and fiber while conserving the Nation's soil and water resources.

USDA conservation programs are voluntary. Many provide financial assistance to producers to help encourage adoption of conservation practices. Others provide technical assistance to design and install conservation practices consistent with the goals of the operation and the soil, climatic, and hydrologic setting. 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 to 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 to conserve resources and maintain the long-term productivity of crop and pasture land; and
- retire land too fragile for continued agricultural production by planting and maintaining on them grasses, trees, or wetland vegetation.

Once soil conservation became a national priority, assessing the effectiveness of conservation practices also became important. Over the past several decades, the relationship between crop production and the landscape in which it occurs has become better understood in terms of the impact on sustainable agricultural productivity and the impact of agricultural production on other ecosystem services that the landscape has potential to generate. Accordingly, the objectives of USDA conservation policy have expanded along with the development of conservation practices to achieve them.

The Conservation Effects Assessment Project (CEAP) continues the tradition within USDA of assessing the status, condition, and trends of natural resources to determine how to improve conservation programs to best meet the Nation's needs. CEAP reports use a sampling and modeling approach to quantify the environmental benefits that farmers and conservation programs are currently providing to society, and explore prospects for attaining additional benefits with further conservation treatment. CEAP findings are being released in a series of regional reports for the regions shown in the following map.



Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Lower Mississippi River Basin

Contents

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. (Click on "Cropland" and then click on "documentation reports and associated publications.") Included are the following reports that provide details on the modeling and databases used in this study:

- The HUMUS/SWAT National Water Quality Modeling System and Databases
- Calibration and Validation of CEAP-HUMUS
- Delivery Ratios Used in CEAP Cropland Modeling
- APEX Model Validation for CEAP
- Pesticide Risk Indicators Used in CEAP Cropland Modeling
- Integrated Pest Management (IPM) Indicator Used in CEAP Cropland Modeling
- NRI-CEAP Cropland Survey Design and Statistical Documentation
- Transforming Survey Data to APEX Model Input Files
- Modeling Structural Conservation Practices for the Cropland Component of the National Conservation Effects Assessment Project
- APEX Model Upgrades, Data Inputs, and Parameter Settings for Use in CEAP Cropland Modeling
- APEX Calibration and Validation Using Research Plots in Tifton, Georgia
- The Agricultural Policy Environmental EXtender (APEX) Model: An Emerging Tool for Landscape and Watershed Environmental Analyses
- The Soil and Water Assessment Tool: Historical Development, Applications, and Future Research Directions
- Historical Development and Applications of the EPIC and APEX Models
- Assumptions and Procedures for Simulating the Natural Vegetation Background Scenario for the CEAP National Cropland Assessment
- Manure Loadings Used to Simulate Pastureland and Hayland in CEAP HUMUS/SWAT modeling
- Adjustment of CEAP Cropland Survey Nutrient Application Rates for APEX Modeling

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Executive Summary

Agriculture in the Lower Mississippi River Basin

The Lower Mississippi River Basin covers 105,000 square miles (67 million acres) and extends southward from the Mississippi River's confluence with the Ohio River near Thebes, IL, and discharges into the Gulf of Mexico south of New Orleans, LA. The basin includes most of Louisiana and parts of Arkansas, Kentucky, Mississippi, Missouri, and Tennessee. The Lower Mississippi River Basin receives streamflow from four other major river basins that make up the Mississippi River drainage system—the Ohio-Tennessee River Basin, the Upper Mississippi River Basin, the Missouri River Basin, and the Arkansas-White-Red Basin.

The Lower Mississippi River Basin is the smallest of the five major river basins that make up the Mississippi River drainage system. Thirty-three percent of the land base (exclusive of water) in the Lower Mississippi River Basin is cultivated cropland, second only to the Upper Mississippi River Basin, with 53 percent. At 20 million acres of cultivated cropland, the Lower Mississippi River Basin has less cultivated cropland acres than any of the other four major river basins.

The value of agricultural sales in 2007 was about $9.6 billion in the Lower Mississippi River Basin—about 72 percent from crops and 28 percent from livestock. Soybeans, corn, cotton, and rice are the principal crops grown. Farmers in the region produced 65 percent of all rice harvested in the United States in 2007 on 1.8 million acres. They also produced 26 percent of the national cotton crop on 2.6 million acres and 9 percent of the national soybean crop on 5.9 million acres. Livestock operations in the region produced 4 percent of all poultry and egg sales in the United States in 2007, totaling $1.6 billion in value. Cattle sales are also important in the region, totaling $482 million in 2007.

The 2007 Census of Agriculture reported 76,362 farms in the Lower Mississippi River Basin, about 3 percent of the total number of farms in the United States. About 85 percent of farms have less than 500 acres, 11 percent have 500–2,000 acres, and only 4 percent have more than 2,000 acres. Seventy-eight percent had less than $50,000 in total farm sales and 9 percent had $50,000–$250,000 in total farm sales. Farms with total agricultural sales greater than $250,000 accounted for 13 percent of the farms in the region. About 42 percent of the principal farm operators indicated that farming was their principal occupation.

Cropping systems in the Lower Mississippi River Basin differ substantially from those in other basins within the Mississippi River drainage system. Continuous soybeans (22 percent of cropped acres), continuous cotton (19 percent), and rice and soybean rotations (19 percent) are common in the Lower Mississippi River Basin and rare or nonexistent in the other four basins. The Lower Mississippi River Basin also has the highest percentage of irrigated acres (46 percent of cropped acres, half of which are rice acres) and the lowest percentage of acres with manure applied (1 percent of cropped acres).

Focus of CEAP Study Is on Edge-Of-Field Losses from Cultivated Cropland

The primary focus of the CEAP Lower Mississippi River Basin study is on the 20 million acres of cultivated cropland, including land in long-term conserving cover. The study was designed to—

- quantify the effects of conservation practices commonly used on cultivated cropland in the Lower Mississippi River Basin during 2003–06,
- evaluate the need for additional conservation treatment in the region on the basis of edge-of-field losses, and
- estimate the potential gains that could be attained with additional conservation treatment.

The assessment uses a statistical sampling and modeling approach to estimate the effects of conservation practices. The National Resources Inventory, a statistical survey of conditions and trends in soil, water, and related resources on U.S. non-Federal land conducted by USDA's Natural Resources Conservation Service, provides the statistical framework. Physical process simulation models were used to estimate the effects of conservation practices in use during the period 2003–06. Information on farming activities and conservation practices was obtained primarily from a farmer survey conducted as part of the study. The assessment includes not only practices associated with Federal conservation programs but also the conservation efforts of States, independent organizations, and individual landowners and farm operators. The analysis assumes that structural practices (such as buffers, terraces, and grassed waterways) reported in the farmer survey or obtained from other sources were appropriately designed, installed, and maintained.

The assessment was done using a common set of criteria and protocols applied to all regions in the country to provide a systematic, consistent, and comparable assessment at the national level. The sample size of the farmer survey—18,700 sample points nationally with 1,735 sample points in the Lower Mississippi River Basin—is sufficient for reliable and defensible reporting at the subregional scale for all but the two southernmost subregions, each with less than 2 percent of the cultivated cropland in the region**.**

Voluntary, Incentives-Based Conservation Approaches Are Achieving Results

Results from the farmer survey show that farmers in the Lower Mississippi River Basin have made significant progress in reducing sediment, nutrient, and pesticide losses from farm fields through conservation practice adoption, but results also show that much more could be done to protect farm fields from losses in this region.

Conservation Practice Use

The farmer survey found, for the period 2003–06, that producers use either residue and tillage management practices or structural practices, or both, on 90 percent of the acres.

- Structural practices for controlling water erosion are in use on 21 percent of cropped acres. Twelve percent of cropped acres are designated as highly erodible land; structural practices designed to control water erosion are in use on 42 percent of these acres.
- Reduced tillage is common in the region; 82 percent of the cropped acres meet criteria for either no-till (28 percent) or mulch till (53 percent). All but 13 percent of the acres have evidence of some kind of reduced tillage on at least one crop in the rotation.

The farmer survey also found that the majority of acres have evidence of some nitrogen or phosphorus management. For example—

- About 21 percent of cropped acres have no nitrogen applied, nearly all of which are continuous soybeans. An additional 66 percent meet criteria for appropriate timing of nitrogen applications on all crops in the rotation, 50 percent meet criteria for appropriate method of application, and 23 percent meet criteria for appropriate rate of application.
- About 4 percent of cropped acres have no phosphorus applied. An additional 78 percent meet criteria for appropriate timing of phosphorus applications on all crops in the rotation, 64 percent meet criteria for appropriate method of application, and 30 percent meet criteria for appropriate rate of application.

There was less evidence, however, of consistent use of appropriate rates, timing, *and* method of nutrient application on <u>each</u> crop in <u>every</u> year of production.

- Appropriate nitrogen application rates, timing of application, and application method for all crops during every year of production are in use on only about 14 percent of cropped acres.
- Appropriate phosphorus management practices (rate, timing, and method) are in use on 17 percent of the acres on all crops during every year of production.
- Only about 9 percent of cropped acres meet full nutrient management criteria for *both* phosphorus and nitrogen management on all crops during every year of production.

Land in long-term conserving cover, as represented by enrollment in the CRP General Signup, consists of 1.0 million acres in the region, of which 47 percent is highly erodible land.

Conservation Accomplishments at the Field Level

Compared to a model scenario without conservation practices, field-level model simulations on cropped acres showed that conservation practice use during the period 2003–06 has—

- reduced waterborne sediment loss from fields by 27 percent;

- reduced nitrogen lost with surface runoff (attached to sediment and in solution) by 26 percent;
- reduced nitrogen loss in subsurface flows by 5 percent;
- reduced total phosphorus loss (all loss pathways) from fields by 39 percent; and
- reduced pesticide loss from fields to surface water, resulting in a 24-percent reduction in edge-of-field pesticide risk (all pesticides combined) for humans and a 39-percent reduction for aquatic ecosystems.

The use of conservation practices in the Lower Mississippi River Basin lags behind the other regions within the Mississippi River drainage system. The average annual percent reductions in sediment and nitrogen losses due to conservation practice use (2003–06) are also lower for the Lower Mississippi River Basin than the other four basins. Percent reductions for phosphorus loss were lowest for the Ohio-Tennessee River Basin followed by the Lower Mississippi River Basin.

These results also indicate that conservation practices in this region have a low impact on total nitrogen loss. Structural erosion control practices, residue management practices, and reduced tillage slow the flow of surface water runoff and allow more of the water to infiltrate into the soil. This re-routing of surface water to subsurface flow not only redirects the dissolved nitrogen into subsurface flow but also can reduce nitrogen volatilization and extract additional nitrogen from the soil as the water passes through the soil profile, including nitrogen produced by legumes such as soybeans (nitrogen biofixation). On about half of the cropped acres in the Lower Mississippi River Basin, the re-routing of surface water runoff to subsurface flow pathways, in combination with ineffective or incomplete nutrient management practices, results in sufficient amounts of additional nitrogen being leached from the soil to more than offset the reductions in nitrogen that would otherwise have been lost with surface runoff or volatilization and produce a small net increase in total nitrogen loss. Model simulation of additional conservation treatment shows that pairing effective nutrient management practices (consistent use of proper rate, form, timing, *and* method of application) with water erosion control practices could reduce nitrogen loss in subsurface flow to acceptable levels for 85 percent of the cropped acres in this region.

For land in long-term conserving cover (1.0 million acres), soil erosion and sediment loss have been almost completely eliminated. Compared to a cropped condition without conservation practices, total nitrogen loss has been reduced by 92 percent, total phosphorus loss has been reduced by 98 percent, and soil organic carbon has been increased by an average of 716 pounds per acre per year.

Conservation Accomplishments at the Watershed Level

Reductions in field-level losses due to conservation practices, including land in long-term conserving cover, are expected to reduce loads delivered from cultivated cropland to rivers and streams in the region. Edge-of-field losses of sediment, nitrogen, phosphorus, and the pesticide atrazine were incorporated into a national water quality model to estimate the extent to which conservation practices have reduced amounts of these contaminants delivered to rivers and streams throughout the region. Transport of sediment, nutrients, and pesticides 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 loads delivered to rivers and streams.

On a per-acre basis, loads delivered to rivers and streams within the Lower Mississippi River Basin far outpace the per-acre loads from other basins:

- 1.2 tons per acre per year of sediment, compared to 0.6 ton per acre per year or less for other basins,
- 27 pounds per acre per year of nitrogen, compared to 19 pounds per acre per year or less for other basins, and
- 2.6 pounds per acre per year of phosphorus, compared to 2.0 pounds per acre per year or less for other basins.

The model simulations also showed that conservation practices in use during the period 2003–06 have reduced average annual loads delivered to rivers and streams within the basin, compared to a no-practice scenario, by—

- 35 percent for sediment,
- 21 percent for nitrogen,
- 52 percent for phosphorus, and
- 26 percent for atrazine.

Percent reductions in sediment loads delivered from cultivated cropland to rivers and streams due to conservation practice use were much lower in the Lower Mississippi River Basin for sediment and nitrogen than in the other four basins that make up the Mississippi River drainage system, whereas percent reductions for phosphorus loads in the Lower Mississippi River Basin were higher than in the Upper Mississippi River Basin and the Ohio-Tennessee River Basin.

If the 2003–06 level of conservation practice use is not maintained, some of these gains will be lost.

> The evaluation of conservation practices and associated estimates of sediment, nitrogen, and pesticide losses from farm fields are based on practice use derived from a farmer survey conducted during the years 2003–06. Since then, implementation of the 2008 Farm Bill and the Mississippi River Basin Healthy Watersheds Initiative (MRBI) greatly expanded conservation funding in the region. As a result, farmers have increased the use of proper nutrient management, cover crops, integrated pest management, and other practices. Split applications of nitrogen and use of urease inhibitors has been widely adopted in some parts of the region. Farmers are using more cover crops for the purpose reducing nitrogen and fertilizer demands, reducing tillage requirements, pest control, and improving overall crop production. There has been a switch to higher efficiency irrigation systems resulting in reduced amounts of irrigation-induced soil erosion. Corn has since replaced cotton on many acres, and farmers are now rotating corn with other crops as a common practice. Organic farms are increasing.
>
> It is therefore likely that the effects of conservation practice use within this region are greater today than determined during this study.

High Precipitation and Intense Storms Heighten the Conservation Challenge in the Lower Mississippi River Basin

The Lower Mississippi River Basin has the highest annual precipitation within the Mississippi River drainage system. The average annual precipitation for cropland acres in the region is 53 inches per year, compared to 42 inches per year for the Ohio-Tennessee River Basin, 34 inches per year for the Upper Mississippi River Basin, and less than 30 inches per year for the Missouri River Basin and the Arkansas-White-Red Basin. The Lower Mississippi River Basin is also more frequently impacted by intense tropical systems than other basins in the Mississippi River drainage system. Even though the proportion of soils that are designated as highly erodible is generally low in this region compared to other regions, the high rainfall duration and intensity associated with these storms results in very high levels of sediment and nutrient losses from farm fields periodically.

Edge-of-field losses of sediment and nutrients in the Lower Mississippi River Basin are, on average, higher than in any of the other four basins. Because of the higher annual precipitation and the frequency of intense storms, the Lower Mississippi River Basin, requires enhanced soil erosion control practices and high levels of nutrient management even on soils with low or moderate potential for sediment and nutrient losses. Based on the 2003–06 survey, however, conservation practice use in the Lower Mississippi River Basin lags behind conservation practice use in the other four basins. The percentage of cropped acres with a high or moderately high level of structural practice use is lower for the Lower Mississippi River Basin than any of the other four basins. The percentage of cropped acres with slopes greater than 2 percent or that is highly erodible land is also low, but the higher levels of precipitation and frequency of intense storms argue for greater use of structural practices in this region than in other regions. The percentage of cropped acres with a high or moderately high level of phosphorus management is also lowest in the Lower Mississippi River Basin. Nitrogen management in the Lower Mississippi River Basin is on a par with the Upper Mississippi River Basin and the Ohio-Tennessee River Basin, but residue and tillage management is used much less extensively in the Lower Mississippi River Basin than in basins other than the Arkansas-White-Red Basin.

A factor that exacerbates the impact of the higher annual precipitation and frequency of intense storms in this region is the higher frequency of continuous monoculture crop rotations. Conservation crop rotations are used on only about 48 percent of the cropped acres in the Lower Mississippi River Basin compared to 87 to 90 percent of cropped acres for each of the other four basins. Conservation crop rotations that meet NRCS criteria (NRCS practice code 328) consist of growing different crops in a planned rotation to manage nutrient and pesticide inputs, enhance soil quality, or reduce soil erosion. Including a legume, hay, or a close grown crop in the rotation can have a pronounced effect on long-term average field losses of sediment and nutrients, as well as enhancement of soil quality.

Opportunities Exist to Further Reduce Sediment and Nutrient Losses from Cultivated Cropland

The assessment of conservation treatment needs identifies significant opportunities to further reduce contaminant losses from farm fields. The study found that 33 percent of cropped acres (6.29 million acres) have a **high** level of need for additional conservation treatment. Acres with a **high** level of need consist of the most vulnerable acres with the least conservation treatment and the highest losses of sediment or nutrients. An additional 53 percent of cropped acres (9.98 million acres) have a **moderate** need for additional conservation treatment. The remaining 2.56 million cropped acres (14 percent) have a **low** need for additional treatment and are considered to be adequately treated.

The number of acres with a **high** or **moderate** need for additional conservation treatment in the Lower Mississippi River Basin is less than half the number in the Upper Mississippi River Basin, within about 1 million acres of the number in the Missouri and Ohio-Tennessee River Basins, and about 6 million acres more than in the Arkansas-White-Red Basin. On a percentage basis, however, the Lower Mississippi River Basin has the largest concentration of cropped acres with a **high** or **moderate** need for additional treatment—86 percent of cropped acres compared to 70 percent for the Ohio-Tennessee River Basin, 60 percent for the Upper Mississippi River Basin, 34 percent for the Arkansas-White-Red Basin, and 18 percent for the Missouri River Basin.

The most critical conservation concern in the region is the need for control of surface water runoff and complete and consistent use of nutrient management—appropriate rate, form, timing, *and* method of application of nitrogen and phosphorus.

The high level of annual precipitation in this region results in unacceptable field-level losses in spite of low or moderate soil vulnerability, which is generally not a characteristic of conservation treatment needs in other regions within the Mississippi River drainage system. The bulk of undertreated acres in the Lower Mississippi River Basin (80 percent or more) have a low or moderate soil runoff potential. In contrast, no undertreated acres for sediment loss or nitrogen loss in surface runoff in any of the other four basins have a low or moderate soil runoff potential. Of the undertreated acres for phosphorus lost to surface water, about half in the Ohio-Tennessee River Basin have a low or moderate soil runoff potential, about 10 percent have a low or moderate soil runoff potential in the Upper Mississippi River Basin, and none have a low or moderate soil runoff potential in each of the two remaining basins. This underscores the importance of increased use of enhanced soil erosion control practices throughout the Lower Mississippi River Basin.

Model simulations show that adoption of additional erosion control and nutrient management practices on the 16.27 million acres with a **high** or **moderate** treatment need would, compared to the 2003–06 baseline, further reduce edge-of-field sediment loss in the region by 83 percent, losses of nitrogen with surface runoff by 48 percent, losses of nitrogen in subsurface flows by 44 percent, and losses of phosphorus (sediment-attached and soluble) by 62 percent.

These field-level reductions would, in turn, further reduce loads delivered to rivers and streams within the region. Model simulations show that if **all** of the undertreated acres (16.27 million acres) were fully treated with the appropriate soil erosion control and nutrient management practices, loads <u>from cultivated cropland</u> <u>delivered to rivers and streams</u> in the region would be reduced, relative to the baseline conservation condition—

- 80 percent for sediment,
- 43 percent for nitrogen, and
- 57 percent for phosphorus.

Emerging technologies not evaluated in this study promise to provide even greater conservation benefits once their use becomes more widespread. These include—

- innovations in implement design to enhance precise nutrient application and placement, including variable rate technologies and improved manure application equipment;
- enhanced-efficiency nutrient application products such as slow or controlled release fertilizers(for example: polymer coated products, sulfur-coated products, etc.) and nitrogen stabilizers (for example: urease inhibitors, and nitrification inhibitors);;
- constructed wetlands receiving surface water runoff and drainage water from farm fields prior to discharge to streams and rivers; and

- improved crop genetics that increase yields without increasing nutrient inputs.

Potential for Gains Related to Cover Crop Use

Only about 1 percent of cropped acres had cover crops incorporated into the crop rotation during the 2003–06 time period used to evaluate conservation practices in this study, according to farmer responses in the CEAP cropland survey. Conservation and agricultural experts from the region report that cover crop use has significantly increased since the farmer survey was conducted. Cover crops are planted following crop harvest and are then tilled or killed with herbicides (or by some other means) prior to the next crop planting. When used properly, cover crops protect the soil from erosion during the non-growing season, take up nutrients remaining in the soil, and release plant available nutrients slowly over the subsequent cropping period, thereby reducing nutrient leaching and runoff during the non-growing season. In recent years farmers in the Lower Mississippi River Basin have also been planting cover crops to help control herbicide resistant weeds by increasing competition in the field for nutrients, water, and sunlight.

To demonstrate the potential for cover crops to reduce sediment and nutrient loss from fields in this region, a special "what if" scenario was conducted to simulate the use of cover crops on all cropped acres. Results indicate that a hypothetical full adoption of cover crops in this region would, compared to the baseline conservation condition in 2003 to 2006—

- reduce sediment loss by an average of 70 percent, reducing the average annual sediment loss from farm fields to below 1 ton per acre per year.
- reduce total nitrogen loss (all loss pathways combined) by an average of 22 percent,
- reduce nitrogen loss in surface runoff by an average of 43 percent,
- reduce nitrogen loss in subsurface flows by an average of 42 percent,
- reduce total phosphorus loss by an average of 32 percent, and
- increase soil organic carbon by an average of 117 pounds per acre per year on cropped acres.

Comprehensive Conservation Planning and Targeting Enhance Effectiveness and Efficiency of Conservation Program Implementation

A ***comprehensive conservation planning process is required*** to identify the appropriate combination of nutrient management techniques and enhanced soil erosion control practices needed to simultaneously address soil erosion, soluble phosphorus losses, nitrogen and phosphorus losses in surface runoff, *and* loss of nitrogen in subsurface flows for each field. A field with adequate conservation practice use will have a suite of practices that addresses all the specific inherent vulnerability factors that determine the potential for sediment, nutrient, and pesticide losses through the dominant loss pathways.

Not all acres require the same level of conservation treatment. The more vulnerable acres, such as highly erodible land and soils prone to leaching, inherently lose more sediment or nutrients; therefore greater benefit can be attained with additional conservation treatment. 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. Acres that are essentially flat with permeable 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.

Moreover, model simulations show that treatment of erosion alone can sometimes exacerbate the nitrogen leaching problem because reducing surface water runoff increases infiltration and, therefore, movement of soluble nitrogen into subsurface flow pathways. Soil erosion control practices are effective in reducing the loss of nitrogen in surface runoff, but for some acres the re-routing of surface water runoff to subsurface flow along with incomplete nutrient management results in a small net increase in total nitrogen loss from the field.

These model simulations also showed that a *suite of practices* that includes both soil erosion control and complete and consistent use of nutrient management—appropriate rate, form, timing, *and* method of application—is often *required* to reduce both sediment and nutrient losses from farm fields to acceptable levels simultaneously. Treatment with combinations of soil erosion control practices and nutrient management also makes applied nutrients more available for use by crops.

Targeting program funding and technical assistance for accelerated treatment of acres with the most critical need for additional treatment is the most efficient way to reduce agricultural sources of contaminants from farm fields. The least treated acres provide greater benefits from treatment, especially if they are also inherently vulnerable to runoff or leaching. The farmer survey showed that, while most acres benefit from some use of conservation practices, environmentally "risky" management is still used on some acres (such as fall application of commercial fertilizers and manure, surface broadcast applications of commercial fertilizers and manure, and conventional tillage).

Use of additional conservation practices on acres that have a **high** need for additional treatment—acres most prone to runoff or leaching and with low levels of conservation practice use—can reduce per-acre sediment and nutrient losses by roughly twice as much as treatment of acres with a **moderate** conservation treatment need. Even greater efficiencies are realized when acres with a **high** need for additional treatment are compared to per-acre benefits for acres with a **low** need for additional treatment.

For example, model simulations of additional treatment in the Lower Mississippi River Basin demonstrated that sediment loss would be reduced by an average of 4.74 tons per acre per year on the 6.29 million acres with a **high** need for additional treatment, compared to 1.75 tons per acre per year for additional treatment of the 9.98 million acres with a **moderate** need for additional treatment. The reduction in sediment loss would average only 0.83 tons per acre per year for treatment of the 2.56 million acres with a **low** need for additional treatment, on average. Total nitrogen loss (all loss pathways) would be reduced by an average of 36 pounds per acre per year on the 6.29 million acres with a **high** need for additional treatment, compared to a reduction of 23 pounds per acre for the 9.98 million acres with a **moderate** need for additional treatment and only 12 pounds per acre for the remaining 2.56 million acres with a **low** need for additional treatment. Total phosphorus loss (all loss pathways) would be reduced by an average of 6.7 pounds per acre per year on the 6.29 million acres with a **high** need for additional treatment, compared to a reduction of 1.9 pounds per acre for the 9.98 million acres with a **moderate** need for additional treatment and only 0.8 pound per acre for the remaining 2.56 million acres with a **low** need for additional treatment.

Potential for Conservation Treatment to Reduce Instream Loads Delivered to the Gulf of Mexico

Instream loads represent *all sources* of sediment, nutrients, and pesticides. The computer model simulated stream and channel processes simulated include flood routing, instream degradation processes, streambed deposition, streambank erosion, and reservoir dynamics. A portion of the sediment, nutrients, and pesticides delivered to rivers and streams is removed or trapped during these processes. Some of the nitrogen is lost during instream nitrification processes, and a portion of the sediment and sediment-bound nutrients and pesticides is deposited in streambeds and flood plains during transit. Sediment can also be added to instream loads through streambank erosion and streambed scouring.

Instream loads delivered to the Gulf of Mexico from the Mississippi River drainage system include loads originating from—

- the Missouri River,
- the Upper Mississippi River upstream of Thebes, IL,
- the Ohio and Tennessee Rivers,
- the Arkansas-White-Red Basin,
- Mississippi River drainage within the Lower Mississippi River Basin, and
- smaller rivers and streams along the Louisiana coast.

After accounting for instream deposition, reservoir dynamics, streambank erosion, and other transport processes, model simulations indicate that total instream loads from all of these sources (that is, all five major land resource regions that make up the Mississippi River drainage system) deliver to the Gulf of Mexico per year, on average, for the baseline conservation condition—

- 190 million tons of sediment,
- 3.243 billion pounds of nitrogen,
- 326 million pounds of phosphorus, and
- 438,000 pounds of atrazine.

The effects of conservation practices are estimated for instream loads in the same manner as was done for loads delivered to rivers and streams. The percent reductions in total instream loads, however, are usually much smaller than observed for loads delivered from cultivated cropland to rivers and streams because conservation practices affect only the cultivated cropland component of the total instream load. Conservation practices in use on cultivated cropland in 2003–06, including land in long-term conserving cover, have reduced instream loads from all sources delivered from the Lower Mississippi River Basin to the Gulf of Mexico, per year, on average, by—

- 4 percent for sediment,
- 17 percent for nitrogen,
- 22 percent for phosphorus, and
- 21 percent for atrazine.

These percent reductions reflect the use of conservation practices on cultivated cropland ***throughout*** *the entire Mississippi River drainage system.*

Model simulation results further indicate that additional conservation treatment of *all 94.7 million under-treated acres* in the Mississippi River drainage system would be expected to reduce instream loads from all sources delivered to the Gulf of Mexico per year relative to the baseline, on average, by—

- 5 percent for sediment,
- 15 percent for nitrogen,
- 13 percent for phosphorus, and
- 6 percent for atrazine.

Effects of Conservation Practices on Ecological Conditions Are Beyond the Scope of This Study

Ecological outcomes are not addressed in this report, nor were the estimates of conservation treatment needs specifically derived to attain Federal, State, or local water quality goals within the region.

Ecosystem impacts related to water quality are specific to each water body. Water quality goals also depend on the designated uses for each water body. In order to understand the effects of conservation practices on water quality in streams and lakes, it is first necessary to understand what is happening in the receiving waters and then evaluate whether the practices are having the desired effect on the current state of that aquatic ecosystem.

The regional scale and statistical design of this study precludes these kinds of assessments.

The primary focus of this report is on losses of potential pollutants from farm fields and prospects for attaining further loss reductions with additional soil erosion control and nutrient management practices. Conservation treatment needs were estimated to achieve “full treatment” from the field-level perspective, rather than to reduce instream loads to levels adequate for designated water uses. The simulated treatment levels were designed to minimally affect crop yields and maintain regional production capacity for food, feed, fiber, forage, and fuel.

From this perspective, a field with adequate conservation treatment will have combinations of practices that address all the specific inherent vulnerability factors that determine the potential for sediment, nutrient, and pesticide losses. For purposes of this report, “full treatment” consists of a suite of practices that—

- *avoid* or limit the potential for contaminant losses by using nutrient management practices (appropriate rate, timing, *and* method) on *all* crops in the rotation;
- *control* overland flow where needed; and
- *trap* materials leaving the field using appropriate edge-of-field mitigation.

This field-based concept of “full conservation treatment” will likely be sufficient to protect water quality for some environmental settings. For more sensitive environmental settings, however, it may be necessary to adopt even stricter management criteria and techniques such as widespread use of cover crops, drainage water management, conservation rotations, or emerging production and conservation technologies. In some cases, attainment of water quality goals may even require watershed-scale solutions, such as sedimentation basins, wetland construction, streambank restoration, or an increased proportion of acres in long-term conserving cover.

Chapter 1
Land Use and Agriculture in the Lower Mississippi River Basin

Land Use

The Lower Mississippi River Basin consists of the mainstem of the southern portion of the Mississippi River and associated tributaries, excluding the White, Arkansas, and Red River basins above the points of highest backwater effect of the Mississippi River. It covers 105,000 square miles (67 million acres) and extends from below the confluence with the Ohio River near Thebes, IL, in the north and discharges into the Gulf of Mexico south of New Orleans, LA. The basin includes most of Louisiana and parts of Arkansas, Kentucky, Mississippi, Missouri, and Tennessee.

Land cover in the basin is highly variable (table 1, fig. 1). Cultivated cropland accounts for about 30 percent of the area, most of which is located in the northern portion of the basin. (Cultivated cropland includes land in long-term conserving cover, which is represented by acres enrolled in the General Sign-up of the Conservation Reserve Program [CRP].) Wetlands and open water represent about 28 percent of the area, located mostly in the southern portion of the basin. Forestland accounts for 23 percent of the area. Rangeland, pastureland, and hayland represent about 12 percent of the area.

Table 1. Land cover and use in the Lower Mississippi River Basin

Land use	Acres*	Percent of area (including water)	Percent of land base (excluding water)
Cultivated cropland and land enrolled in the CRP General Signup**	20,278,956	30	33
Hayland not in rotation with crops	1,049,394	2	2
Pastureland not in rotation with crops	3,016,726	4	5
Rangeland—grass	509,506	1	1
Rangeland—brush	3,490,683	5	6
Horticulture	42,264	0	0
Forestland			
Deciduous	6,282,067	9	10
Evergreen	7,605,171	11	12
Mixed	2,103,787	3	3
Urban	3,940,345	6	6
Wetlands			
Forested	9,904,517	15	16
Non-Forested	3,181,515	5	5
Barren	158,245	0	0
Subtotal	61,563,176	92	100
Water	5,538,264	8	
Total	67,101,440	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 based on the NRI-CEAP sample because of differences in data sources and estimation procedures. Acres enrolled in the CRP General Signup are used to represent land in long-term conserving cover.
**Includes hayland and pastureland in rotation with crops.

Urban areas make up about 6 percent of the basin. The major metropolitan areas are New Orleans, LA; Memphis, TN; and Baton Rouge, LA.

Agriculture

The 2007 Census of Agriculture reported 76,362 farms in the Lower Mississippi River Basin, about 3 percent of the total number of farms in the United States (table 2). Land on farms was about 27 million acres, representing 40 percent of the area within the region. Farms in the Lower Mississippi River Basin make up about 3 percent of all land on farms in the nation. According to the 2007 Census of Agriculture, the value of Lower Mississippi River Basin agricultural sales in 2007 was about $9.6 billion—about 72 percent from crops and 28 percent from livestock.

About 62 percent of Lower Mississippi River Basin farms primarily raise crops, about 35 percent are primarily livestock operations, and the remaining 3 percent produce a mix of livestock and crops (table 3).

As in other regions of the country, most of the farms are small. About 85 percent of farms have less than 500 acres, 11 percent have 500–2,000 acres, and only 4 percent of the farms have more than 2,000 acres (table 3). In terms of 2007 gross sales, 78 percent had less than $50,000 in total farm sales and 9 percent had $50,000–$250,000 in total farm sales (table 3). Farms with total agricultural sales greater than $250,000 accounted for 13 percent of the farms in the region. About 58 percent of the principal farm operators indicated that farming was not their principal occupation.

Crop production

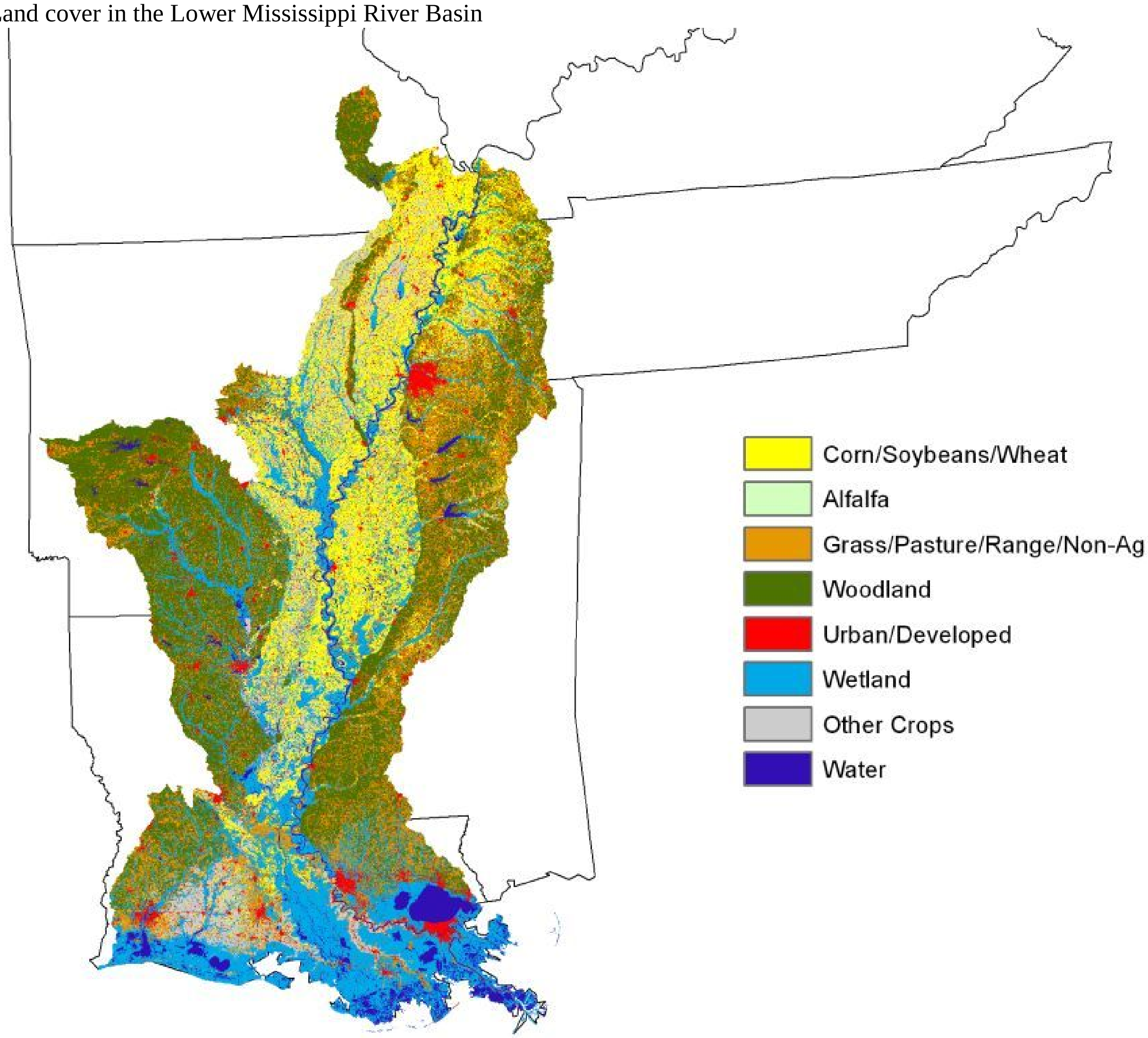
The Lower Mississippi River Basin accounted for about 5 percent of all U.S. crop sales in 2007, totaling $6.8 billion (table 2). Soybeans, corn, cotton, and rice are the principal crops grown. Wheat, hay, and sorghum are important secondary crops.

Farmers in the region produced 65 percent of all rice harvested in the United States in 2007 on 1.8 million acres. They also produced 26 percent of the national cotton crop on 2.6 million acres and 9 percent of the national soybean crop on 5.9 million acres.

Commercial fertilizers and pesticides are widely used throughout the region (table 2). In 2007, 12.8 million acres of cropland were fertilized, 12.4 million acres of cropland and pasture were treated with chemicals for weed control, and 8.3 million acres of cropland were treated for insect control. About 350,000 acres had manure applied in 2007.

Irrigation use is common in the region. About 44 percent of the harvested acres were irrigated in 2007, one-third of which were rice acres.

Figure 1. Land cover in the Lower Mississippi River Basin



Source: National Agricultural Statistics Service (NASS 2007).

Livestock operations

Livestock production in the region is dominated by cattle and poultry. Livestock operations in the region produced 4 percent of all poultry and egg sales in the United States in 2007, totaling $1.6 billion in value (table 2). Cattle sales are also important in the region, totaling $482 million in 2007. Of the 1.8 million livestock animal units in the region, 1.4 million animal units are cattle, horses, sheep, and goats, excluding fattened cattle and dairy cows. (An animal unit is 1,000 pounds of live animal weight, calculated as a yearly average for each farm using information reported in the 2007 Census of Agriculture.) Poultry animal units total about 290,000.

Based on livestock populations on farms as reported in the 2007 agricultural census, only 3,337 of the farms in the region (4 percent) could potentially be defined as animal feeding operations (AFOs) (table 3). AFOs are livestock operations typically with confined poultry, swine, dairy cattle, or beef cattle. An additional 17,300 farms have significant numbers of pastured livestock (23 percent of farms). About 1,000 of the livestock operations (27 percent of the AFOs) are relatively large, with livestock numbers in 2007 above the EPA minimum threshold for a medium concentrated animal feeding operation (CAFO). Of these, about 325 meet livestock population criteria for a large CAFO.

Statistics for the Lower Mississippi River Basin reported in table 2 are for the year 2007 as reported in the Census of Agriculture. For some characteristics, different acre estimates are reported in subsequent sections of this report based on the NRI-CEAP sample. Estimates based on the NRI-CEAP sample are for the time period 2003–2006. See chapter 2 for additional aspects of estimates based on the NRI-CEAP sample.

Table 2. Profile of farms and land in farms in the Lower Mississippi River Basin, 2007

Characteristic	Value	Percent of national total
Number of farms	76,362	3
Acres on farms	27,212,533	3
Average acres per farm	356	
Cropland harvested, acres	16,117,763	5
Cropland used for pasture, acres	1,360,772	4
Cropland on which all crops failed, acres	181,935	2
Cropland in summer fallow, acres	146,407	1
Cropland idle or used for cover crops, acres	1,254,709	3
Woodland pastured, acres	637,973	2
Woodland not pastured, acres	3,320,965	7
Permanent pasture and rangeland, acres	2,757,261	1
Other land on farms, acres	1,434,748	5
Principal crops grown		
Soybeans harvested, acres	5,920,957	9
Field corn for grain harvested, acres	3,010,524	3
Upland cotton harvested, acres	2,605,590	26
Rice harvested, acres	1,803,801	65
Wheat harvested, sum acres	1,542,256	3
Tame and wild hay harvested, acres	1,071,256	3
Sorghum for grain harvested, acres	582,626	9
Irrigated harvested land, acres	7,117,252	14
Irrigated pastureland or rangeland, acres	49,402	1
Cropland fertilized, acres	12,824,337	5
Pastureland fertilized, acres	929,391	4
Land treated for insects on hay or other crops, acres	8,300,361	9
Land treated for nematodes in crops, acres	934,059	12
Land treated for diseases in crops and orchards, acres	2,949,895	13
Land treated for weeds in crops and pasture, acres	12,429,114	5
Crops on which chemicals for defoliation applied, acres	2,922,440	24
Acres on which manure was applied	350,486	2
Total grains and oilseeds sales, million dollars	4,768	6
Total vegetable, melons sales, million dollars	174	1
Total cotton and cottonseed sales, million dollars	1,272	26
Total nursery, greenhouse, and floriculture sales, million dollars	151	1
Total other crops and hay sales, million dollars	494	2
Total crop sales, million dollars	6,860	5
Total dairy sales, million dollars	89	<1
Total hog and pigs sales, million dollars	70	<1
Total poultry and eggs sales, million dollars	1,603	4
Total cattle sales, million dollars	482	1
Total sheep, goats, and their products sales, million dollars	3	<1
Total horses, ponies, and mules sales, million dollars	29	1
Total other livestock sales, million dollars	419	16
Total livestock sales, million dollars	2,696	2
Animal units on farms		
All livestock types	1,818,714	2
Swine	35,598	<1
Dairy cows	45,966	<1
Fattened cattle	4,444	<1
Other cattle, horses, sheep, goats	1,439,184	2
Chickens, turkeys, and ducks	291,518	4
Other livestock	2,005	<1

Source: 2007 Census of Agriculture, National Agricultural Statistics Service, USDA
Note: Information in the Census of Agriculture was used to estimate animal units using methods and assumptions described in USDA/NRCS (2003).

Table 3. Characteristics of farms in the Lower Mississippi River Basin, 2007

	Number of farms	Percent of farms in Lower Mississippi River Basin
Farming primary occupation	32,048	42
Farm size:		
<50 acres	28,135	37
50–500 acres	36,645	48
500–2,000 acres	8,517	11
>2,000 acres	3,065	4
Farm sales:		
<$10,000	46,096	60
$10,000–50,000	13,364	18
$50,000–250,000	7,054	9
$250,000–500,000	3,174	4
>$500,000	6,674	9
Farm type:		
Crop sales make up more than 75 percent of farm sales	47,155	62
Livestock sales make up more than 75 percent of farm sales	26,827	35
Mixed crop and livestock sales	2,380	3
Farms with no livestock sales	36,207	47
Farms with few livestock or specialty livestock types	19,526	26
Farms with pastured livestock and few other livestock types	17,292	23
Farms with animal feeding operations (AFOs)*	3,337	4

Source: 2007 Census of Agriculture, National Agricultural Statistics Service, USDA
* AFOs, as defined here, typically have a total of more than 12 animal units consisting of fattened cattle, dairy cows, hogs and pigs, chickens, ducks, and turkeys.

Watersheds

A hydrologic accounting system consisting of water resource regions, major subregions, and smaller watersheds has been defined by the U.S. Geological Survey (USGS) (1980). Each water resource region is designated with a 2-digit Hydrologic Unit Code (HUC), which is further divided into 4-digit subregions and then into 8-digit cataloging units, or watersheds. The Lower Mississippi River drainage is represented by 9 subregions.

The concentration of cultivated cropland within each subregion is an important indicator of the extent to which sediment and nutrient loads in rivers and streams are influenced by farming operations. The bulk of the cultivated cropland (80 percent) is found in four subregions in the Lower Mississippi River Basin (table 4 and fig. 2), located in the north and central portions of the region—

- the Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802), with 33 percent of the cultivated cropland in the region,
- the Lower Mississippi-Greenville-Yazoo River Basin (code 0803), with 19 percent,
- the Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801), with 15 percent, and
- the Boeuf-Tensas River Basin (code 0805), with 12 percent.

Cultivated cropland is most concentrated in the in the Boeuf-Tensas River Basin (code 0805), where about 73 percent of the land base in the region is cultivated cropland (table 4). In the Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802), about 63 percent of the land base is cultivated cropland.

Cultivated cropland is a minor land use in four subregions, where the percent of cultivated cropland within each subregion is less than 11 percent of the land base (table 4)—

- the Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809),
- the Lower Red and Ouachita River Basin (code 0804),
- the Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807), and
- the Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806).

Cultivated cropland includes land in long-term conserving cover, which represents about 5 percent of the cultivated cropland acres in this region (table 4). Subregions where land in long-term conserving cover is 10 percent or more of cultivated cropland acres are—

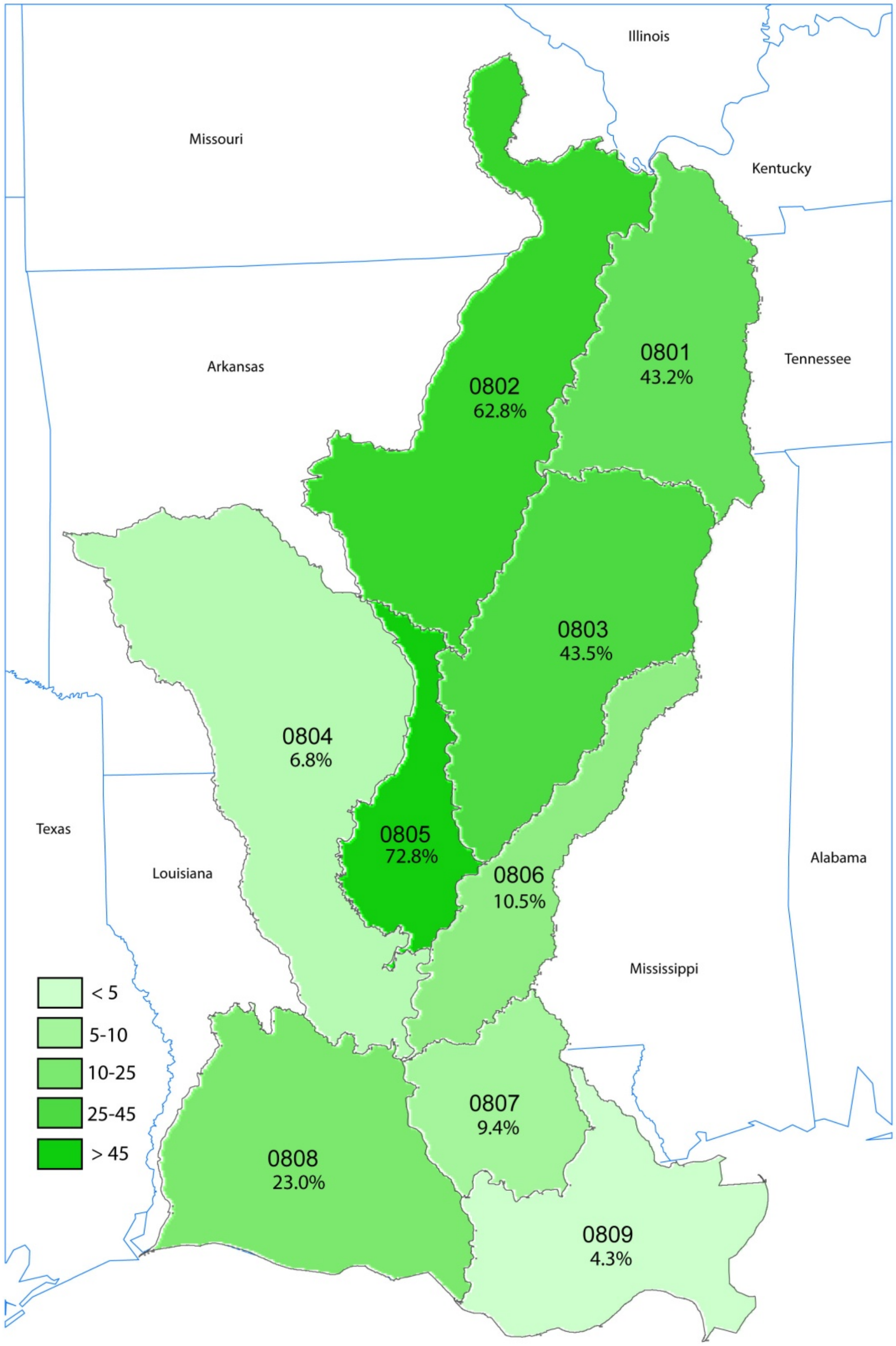
- the Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806), with 35 percent,
- the Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801), with 12 percent, and
- the Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807), with 10 percent.

Table 4. Cultivated cropland use in the 9 subregions in the Lower Mississippi River Basin

Subregion	Total area (acres)	Cultivated cropland (acres)*	Percent cultivated cropland in subregion	Percent of cultivated cropland in Lower Mississippi River Basin	Percent of cultivated cropland acres in long-term conserving cover
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	7,081,544	3,061,626	43.2	15.1	11.6
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	10,788,214	6,772,715	62.8	33.4	1.9
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	9,036,160	3,932,835	43.5	19.4	5.9
Lower Red and Ouachita River Basin (code 0804)	13,108,303	885,859	6.8	4.4	4.0
Boeuf-Tensas River Basin (code 0805)	3,399,005	2,473,560	72.8	12.2	2.9
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	4,540,227	478,111	10.5	2.4	35.1
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807)	3,710,979	349,766	9.4	1.7	10.0
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	8,876,251	2,043,071	23.0	10.1	1.7
Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal Basin (code 0809)	6,560,758	281,413	4.3	1.4	0.0
Total	67,101,440	20,278,956	30.2	100.0	5.2

Source: 2001 National Land Cover Database for the Conterminous United States (Homer et al. 2007) and the 1997 National Resources Inventory (USDA/NRCS 2002).
* Acres of cultivated cropland include land in long-term conserving cover. Estimates of cultivated cropland were obtained from HUMUS databases on land use, differing slightly from acreage estimates obtained with the NRI-CEAP sample.

Figure 2. Percent cultivated cropland, including land in long-term conserving cover, for the 9 subregions in the Lower Mississippi River Basin



Chapter 2
Overview of Sampling and Modeling Approach

Scope of Study

This study was designed to evaluate the effects of conservation practices at the regional scale to provide a better understanding of how conservation practices are benefiting the environment and to determine what challenges remain. The report does the following.

- Evaluates the extent of conservation practice use in the region in 2003–06;
- Estimates the environmental benefits and effects of conservation practices in use;
- Estimates conservation treatment needs for the region; and
- Estimates potential gains that could be attained with additional conservation treatment.

The study was designed to quantify the effects of commonly used conservation practices on cultivated cropland, regardless of how or why the practices came to be in use. This assessment is not an evaluation of Federal conservation programs, because it is not restricted to only those practices associated with Federal conservation programs.

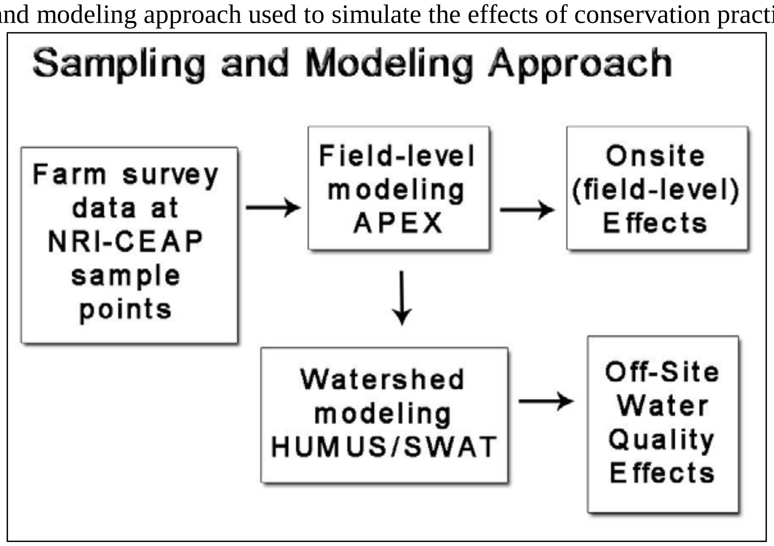
Sampling and Modeling Approach

The assessment uses a statistical sampling and modeling approach to estimate the environmental effects and benefits of conservation practices (fig. 3).

- A subset of 1,735 National Resources Inventory (NRI) sample points provides a statistical sample that represents the diversity of soils and other conditions for cropped acres in the Lower Mississippi River Basin. The sample also includes 564 additional NRI sample points designated as CRP acres to represent 1.0 million acres of land in long-term conserving cover. NRI sample points are linked to NRCS Soil Survey databases and were linked spatially to climate databases for this study.
- A farmer survey—the NRI-CEAP Cropland Survey—was conducted at each of the 1,735 cropped sample points during the period 2003–06 to determine what conservation practices were in use and to collect information on farming practices.
- The field-level effects of the conservation practices were assessed using a field-scale physical process model—the Agricultural Policy Environmental Extender (APEX)—which simulates the day-to-day farming activities, wind and water erosion, loss or gain of soil organic carbon, and edge-of-field losses of soil, nutrients, and pesticides.
- A watershed model and system of databases—the Hydrologic Unit Model for the United States (HUMUS)—was used to simulate how reductions of field losses have reduced instream concentrations and loadings of sediment, nutrients, and pesticides within the Lower Mississippi River Basin. The SWAT model (Soil and Water Assessment Tool) was used to simulate nonpoint source loadings from land uses other than cropland and to route instream loads from one watershed to another.

For purposes of this report, cultivated cropland includes land in row crops or close-grown crops (such as wheat and other small grain crops), hay and pasture in rotation with row crops and close-grown crops, and land in long-term conserving cover. Cultivated cropland does not include agricultural land that has been in hay, pasture, or horticulture for 4 or more consecutive years, corresponding to the cultivated cropland definition used in the NRI. Acres enrolled in the General Signup of the Conservation Reserve Program (CRP) were used to represent cultivated cropland currently in long-term conserving cover.

Figure 3. Statistical sampling and modeling approach used to simulate the effects of conservation practices



The modeling strategy for estimating the effects of conservation practices consists of two model scenarios that are produced for each sample point.

1. A baseline scenario, the "baseline conservation condition" scenario, provides model simulations that account for cropping patterns, farming activities, and conservation practices as reported in the NRI-CEAP Cropland Survey and other sources.
2. An alternative scenario, the "no-practice" scenario, simulates model results as if no conservation practices were in use but holds all other model inputs and parameters the same as in the baseline conservation condition scenario.

The effects of conservation practices are obtained by taking the difference in model results between the two scenarios (fig. 4) [1] For example, to simulate "no practices" for sample points where some type of residue management is used, model simulations were conducted as if continuous conventional tillage had been used. Similarly, for sample points with structural conservation practices (buffers, terraces, grassed waterways, etc.), the no-practice scenario was simulated as if the practices were not present. The no-practice representation for land in long-term conserving cover was derived from model results for cropped acres as simulated in the no-practice scenario, representing how the land would have been managed had crops been grown without the use of conservation practices.

The approach captures the diversity of land use, soils, climate, and topography from the NRI; 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 national and regional levels. Previous studies have used this NRI micro-simulation modeling approach to estimate soil loss, nutrient loss, and change in soil organic carbon (Potter et al. 2006), to estimate pesticide loss from cropland (Kellogg et al. 1992, 1994, 2002; Goss et al. 1998), and to identify priority watersheds for water quality protection from nonpoint sources related to agriculture (Kellogg 2000, Kellogg et al. 1997, Goebel and Kellogg 2002).

The NRI and the CEAP Sample

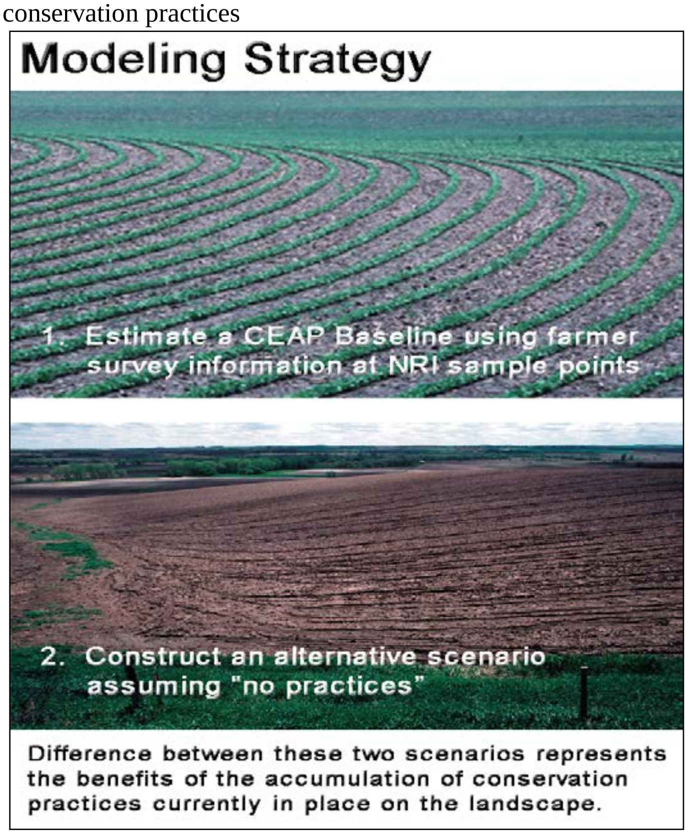
The approach is an extension of the NRI, a longitudinal, scientifically based survey designed to gauge natural resource status, conditions, and trends on the Nation's non-Federal land (Goebel 1998; USDA/NRCS 2002).

[1] This modeling strategy is analogous to how the NRI produces estimates of soil erosion and the intrinsic erosion rate used to identify highly erodible land. The NRI uses the Universal Soil Loss Equation (USLE) to estimate sheet and rill erosion at each sample point on the basis of site-specific factors. Soil loss per unit area is equal to R*K*L*S*C*P. The first four factors—R, K, L, S—represent the conditions of climate, soil, and topography existing at a site. (USDA 1989). The last two factors—C and P—represent the degree to which management influences the erosion rate. The product of the first four factors is sometimes called the intrinsic, or potential, erosion rate. The intrinsic erosion rate divided by T, the soil loss tolerance factor, produces estimates of EI, the erodibility index. The intrinsic erosion rate is thus a representation of a "no-practice" scenario where C=1 represents smooth-tilled continuous fallow and P=1 represents no supporting practices.

The NRI sampling design implemented in 1982 provided a stratified, two-stage, unequal probability area sample of the entire country (Goebel and Baker 1987; Nusser and Goebel 1997). Nominally square areas/segments were selected within geographical strata on a county-by-county basis; specific point locations were selected within each selected segment. The segments ranged in size from 40 to 640 acres but were typically half-mile square areas, and most segments contained three sample points.

At each sample point, information is collected on nearly 200 attributes; some items are also collected for the entire segment. The sampling rates for the segments were variable, typically from 2 to 6 percent in agricultural strata and much lower in remote nonagricultural areas. The 1997 NRI Foundation Sample contained about 300,000 sample segments and about 800,000 sample points.

Figure 4. Modeling strategy used to assess effects of conservation practices



NRCS made several significant changes to the NRI program over the past 10 years, including transitioning from a 5-year periodic survey to an annual survey. The NRI's annual design is a *supplemented panel design.*[2] A *core panel* of 41,000 segments is sampled each year, and *rotation (supplemental) panels* of 31,000 segments each vary by inventory year and allow an inventory to focus on an emerging issue. The core panel and the various supplemental panels are unequal probability subsamples from the 1997 NRI Foundation Sample.

The 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.[3] The sample is statistically representative of cultivated cropland and formerly cultivated land currently in long-term conserving cover.

Nationally, there were over 30,000 samples in the original sample draw. A completed farmer survey was required to include the sample point in the CEAP sample. Some farmers declined to participate in the survey, others could not be located during the time period scheduled for implementing the survey, and other sample points were excluded for administrative reasons such as overlap with other USDA surveys. Some sample points were excluded because the surveys were incomplete or contained inconsistent information, land use found at the sample point had recently changed and was no longer cultivated cropland, or the crops grown were uncommon and model parameters for crop growth were not available. The national NRI-CEAP usable sample consists of about 18,700 NRI points representing cropped acres, and about 13,000 NRI points representing land enrolled in the General Signup of the CRP.

The NRI-CEAP Cropland Survey

A farmer survey—the NRI-CEAP Cropland Survey—was conducted to obtain the additional information needed for modeling the 1,735 sample points with crops.[4] The USDA National Agricultural Statistics Service (NASS) administered the survey. 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.

The survey obtained information on—

- crops grown for the previous 3 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 the previous 3 years;
- application of manure (source and type, consistency, application rate, method, and timing) on the field over the previous 3 years;
- application of pesticides (chemical, rate, timing, and method) for the previous 3 years;
- pest management practices;
- irrigation practices (system type, amount, and frequency);
- timing and equipment used for all field operations (tillage, planting, cultivation, harvesting) over the previous 3 years; and,
- general characteristics of the operator and the operation.

In a separate data collection effort, NRCS field offices provided information on the practices specified in conservation plans for the CEAP sample points.

Because of the large size of the sample, it was necessary to spread the data collection process over a 4-year period, from 2003 through 2006. In each year, surveys were obtained for a separate set of sample points. The final CEAP sample was constructed by pooling the set of usable, completed surveys from all 4 years.

Estimated Acres

Acres reported using the CEAP sample are "estimated" acres because of the uncertainty associated with the statistical sample. For example, the 95-percent confidence interval for the estimate of 18,835,300 cropped acres in the region has a lower bound of 18,145,610 acres and an upper bound of 19,524,990 acres. (The lower bound is the estimate minus the margin of error and the upper bound is the estimate plus the margin of error.)

The CEAP sample was designed to allow reporting of results at the subregion (4-digit HUC) level in most cases. The acreage weights were derived so as to approximate total cropped acres by subregion as estimated by the full 2003 NRI. The sample size is too small, in most cases, for reliable and defensible reporting of results for areas below the subregion level.

In the Lower Mississippi River Basin, sample sizes for two subregions were too small to reliably report cropped acres. Results for the Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809), with 17 sample points, and the Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807), with 15 sample points, were combined for reporting.

NRI-CEAP estimates of cropped acres for the 9 subregions within the Lower Mississippi River Basin are presented in table 5 along with the 95-percent confidence intervals. These estimates of cropped acres differ from cultivated cropland estimates presented in tables 1 and 4 primarily because those tables also include 1.0 million acres of land in long-term conserving cover but also because of differences in data sources and estimation procedures.

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[2] For more information on the NRI sample design, see www.nrcs.usda.gov/technical/NRI/.

[3] 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.

[4] The surveys, the enumerator instructions, and other documentation can be found at www.nrcs.usda.gov/technical/nri/ceap.

Margins of error for a selection of other estimated cropped acres used in this report are presented in appendix A.

Cropping Systems in the Lower Mississippi River Basin

Cropping systems were defined on the basis of the crops grown at CEAP sample points over the 3 years that information was obtained on farming activities at each sample point. Statistical sample weights for each sample point were derived from the NRI crop history at each sample point so as to approximate acres reported in the 2003 NRI for similar cropping systems at the 4-digit HUC level. (Cropping system acres were only one of several factors taken into account in deriving the acreage weights for each sample point.)

Soybean is the most common crop grown in this region. According to the survey, soybean is included in 61 percent of the cropping systems. It is common in this region for soybeans to be grown continuously (22 percent of cropped acres), grown in rotation with corn (12 percent), or grown in rotation with rice (19 percent) (table 6). Cotton is grown continuously on 19 percent of the cropped acres, and rice is grown continuously on 5 percent.

Table 5. Estimated cropped acres based on the NRI-CEAP sample for subregions in the Lower Mississippi River Basin

			95-percent confidence interval	
Subregion	Number of CEAP samples	Estimated acres	Lower bound (acres)	Upper bound (acres)
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	500	2,778,500	2,556,776	3,000,224
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	471	6,895,000	6,479,292	7,310,708
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	343	3,427,100	3,167,097	3,687,103
Lower Red and Ouachita River Basin (code 0804)	42	771,300	575,913	966,687
Boeuf-Tensas River Basin (code 0805)	120	2,234,900	1,910,972	2,558,828
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	22	259,200	168,130	350,270
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	205	1,921,800	1,765,218	2,078,382
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	32	547,500	393,989	701,011
Total	1,735	18,835,300	18,145,610	19,524,990

Note: Estimates are from the NRI-CEAP Cropland Survey.

Table 6. Estimated crop acres for cropping systems in the Lower Mississippi River Basin

				95-percent confidence interval	
Cropping system	Number of CEAP samples	Estimated acres	Percent of total	Lower bound (acres)	Upper bound (acres)
Soybean only	357	4,191,899	22	3,752,979	4,630,819
Corn and soybean only	231	1,591,387	8	1,338,946	1,843,828
Corn and soybean with close grown crops	91	749,945	4	540,253	959,637
Soybean and wheat only	45	507,377	3	333,667	681,087
Soybean and sorghum only	28	363,823	2	196,624	531,022
Cotton only	291	3,529,177	19	3,015,213	4,043,141
Cotton and soybean with or without other crops	86	834,667	4	619,069	1,050,265
Cotton and corn only	68	814,515	4	597,674	1,031,356
Rice only	116	1,028,092	5	825,075	1,231,109
Rice and soybean with or without other crops	283	3,591,479	19	3,128,065	4,054,893
Remaining row crops only	108	1,251,597	7	952,517	1,550,677
Remaining mix of row and close-grown crops	20	235,274	1	103,050	367,498
Hay and crop mix and remaining close grown crops	11	146,070	1	27,235	264,905
Total	1,735	18,835,300	100	18,145,610	19,524,990

Note: Estimates are from the NRI-CEAP Cropland Survey.

Simulating the Effects of Weather

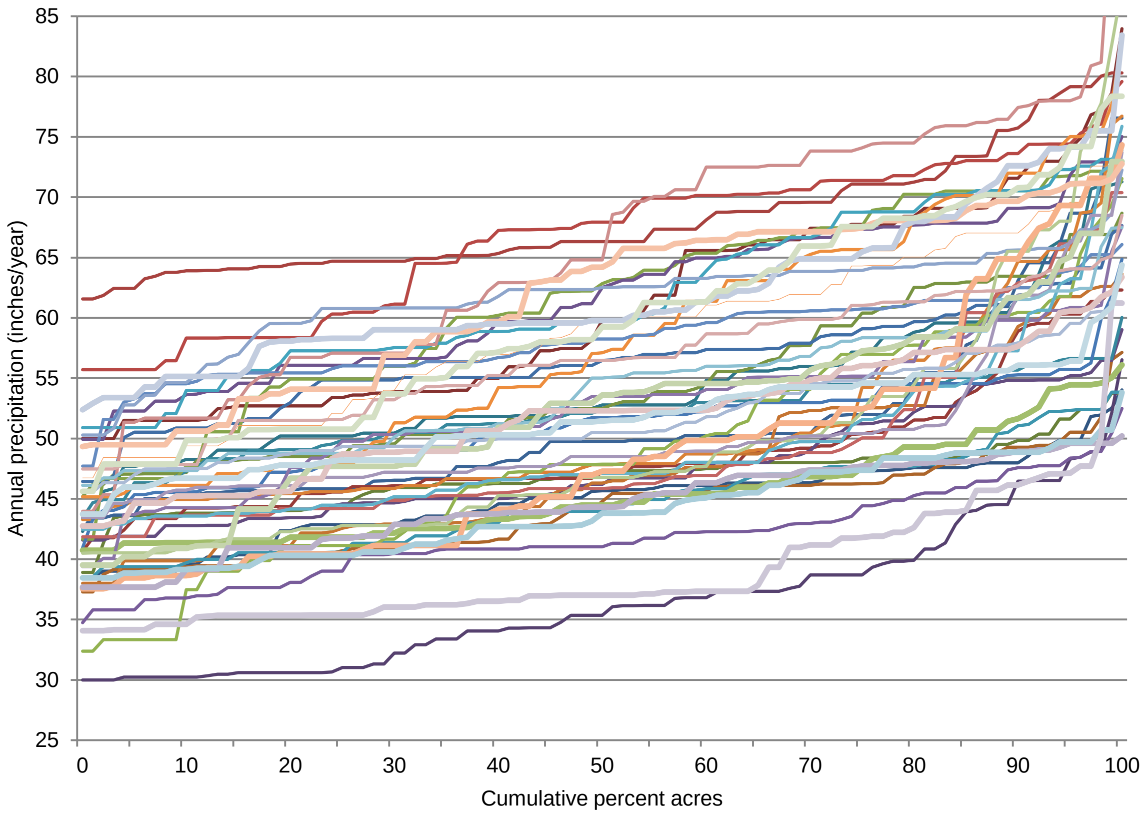
Weather is the predominant factor determining the loss of soil, nitrogen, phosphorus, and pesticides from farm fields, and has a big influence on the effectiveness of conservation practices. To capture the effects of weather, each scenario was simulated using 47 years of actual daily weather data for the time period 1960 through 2006. The 47-year record is a serially complete daily data set of weather station data from weather station records available from the NCDC (National Climatic Data Center) for the period 1960 to 2006, including precipitation, temperature maximum, and temperature minimum (Eischeid et al. 2000). These 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 47-year weather data were used in the HUMUS/SWAT simulations and in the APEX model simulations.

Annual precipitation over the 47-year simulation averaged about 53 inches for cropped acres in this region. However, annual precipitation varied substantially in the model simulations, both within the region and from year to year, as shown in figure 5. Each curve in figure 5 shows how annual precipitation varied over the region in one of the 47 years. The family of curves shows the variability from year to year. In general, annual precipitation ranges from lows of 35–55 inches per year to highs of 50-80 inches per year. The top curves represent very wet years throughout the region, and the bottom curves represent very dry years.

Year-to-year variability is especially pronounced—the average annual precipitation amount (representing all cropped acres) ranged over the 47 years from 36 inches in 1963 to 68 inches in 1973 (fig. 6).

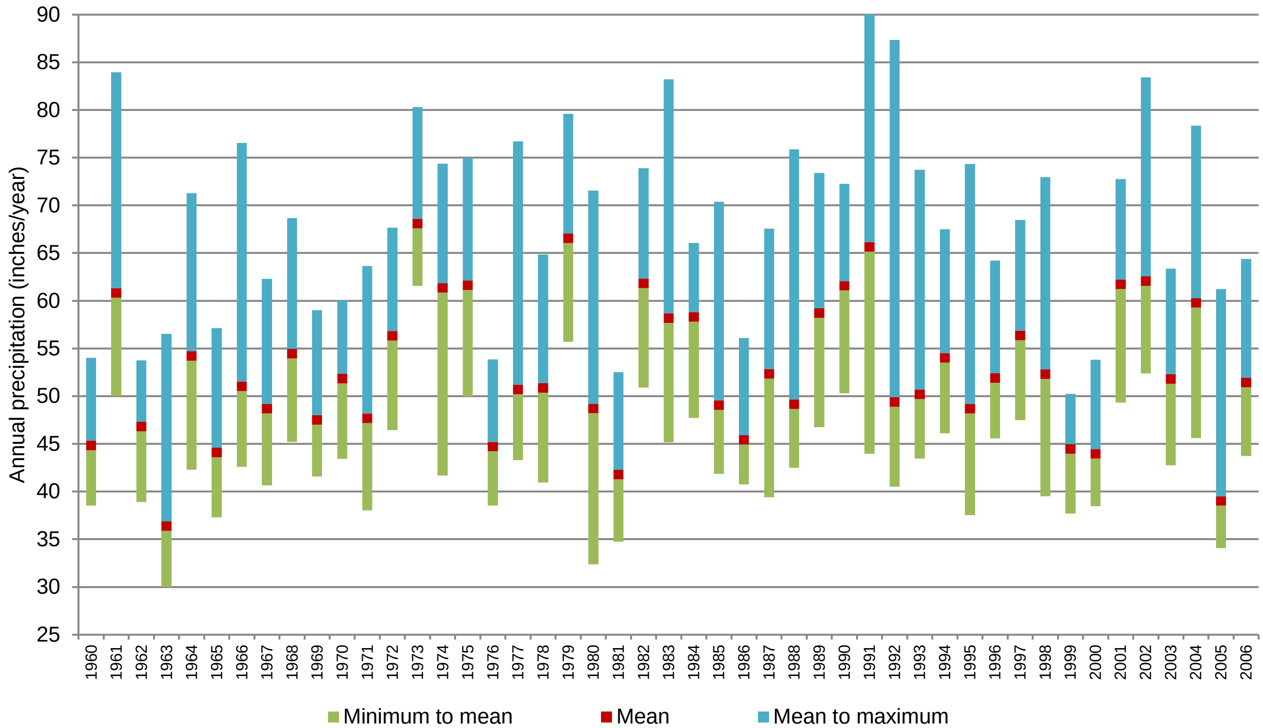
Throughout most of this report model results are presented in terms of the 47-year averages where weather is the only input variable that changes year to year. Since we used the cropping patterns and practices for the 2003–06 period, we did not simulate *actual* loses for each of these years. Rather, we provide estimates of what model outputs would *average* over the long-term if weather varied as it has over the past 47 years. Similarly, estimates of the average effects of conservation practices include effectiveness in extreme weather years, such as floods and prolonged droughts, as represented in the 47-year weather record shown in figures 5 and 6.

Figure 5. Cumulative distributions of annual precipitation used in the model simulations for cropped acres in the Lower Mississippi River Basin



Note:. Each of the 47 curves shown above represents a single year of data and shows how annual precipitation varies over the region in that year, starting with the acres with the lowest precipitation within the region and increasing to the acres with the highest precipitation. The family of curves shows how annual precipitation varies from year to year. Annual precipitation over the 47-year simulation averaged about 53 inches for cropped acres throughout the region.

Figure 6. Mean, minimum, and maximum levels of annual precipitation used in the model simulations for cropped acres in the Lower Mississippi River Basin



Chapter 3
Evaluation of Conservation Practice Use—the Baseline Conservation Condition

This study assesses the use and effectiveness of conservation practices in the Lower Mississippi River Basin for the period 2003 to 2006 to determine the baseline conservation condition for the region. The baseline conservation condition provides a benchmark for estimating the effects of existing conservation practices as well as projecting the likely effects of alternative conservation treatment. Conservation practices that were evaluated include structural practices, annual practices, and long-term conserving cover.

Structural conservation practices, once implemented, are usually kept in place for several years. Designed primarily for erosion control, they also mitigate edge-of-field nutrient and pesticide loss. Structural practices evaluated include—

- in-field practices for water erosion control, divided into two groups:
  - practices that control overland flow (terraces, contour buffer strips, contour farming, stripcropping, 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, field borders); and
- wind erosion control practices (windbreaks/shelterbelts, cross wind trap strips, herbaceous wind barriers, hedgerow planting).

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

- residue and tillage management;
- nutrient management practices;
- pesticide management practices; and
- cover crops.

Long-term conservation cover establishment consists of planting suitable native or domestic grasses, forbs, or trees on environmentally sensitive cultivated cropland.

Historical Context for Conservation Practice Use

The use of conservation practices in the Lower Mississippi River Basin closely reflects the history of Federal conservation programs and technical assistance. In the beginning the focus was almost entirely on reducing soil erosion and preserving the soil's productive capacity. In the 1930s and 1940s, Hugh Hammond Bennett, the founder and first chief of the Soil Conservation Service (now Natural Resources Conservation Service) instilled in the national ethic the need to treat every acre to its potential by controlling soil erosion and water runoff. Land shaping structural practices (such as terraces, contour farming, and stripcropping) and sediment control structures were widely adopted. Conservation tillage emerged in the 1960s and 1970s as a key management practice for enhancing soil quality and further reducing soil erosion. Conservation tillage, along with use of crop rotations and cover crops, was used either alone or in combination with structural practices. The conservation compliance provisions in the 1985 Farm Bill sharpened the focus to treatment of the most erodible acres, tying farm commodity payments to conservation treatment of highly erodible land. The Conservation Reserve Program was established to enroll the most erodible cropland acres in multi-year contracts to plant acres in long-term conserving cover.

During the 1990s, the focus of conservation efforts began to shift from soil conservation and sustainability to reducing pollution impacts associated with agricultural production. Prominent among new concerns were the environmental effects of nutrient export from farm fields. Traditional conservation practices used to control surface water runoff and erosion control were mitigating a significant portion of these nutrient losses. Additional gains were being achieved using nutrient management practices—application of nutrients (appropriate timing, rate, method, and form) to minimize losses to the environment and maximize the availability of nutrients for crop growth.

Summary of Practice Use

The conservation practice information collected during the study was used to assess the extent of conservation practice use in the Lower Mississippi River Basin. Key findings are the following:

- Structural practices for controlling water erosion are in use on only 21 percent of cropped acres. However, all but 8 percent of cropped acres have slopes less than 2 percent, including many acres that may not need to be treated with structural practices. On the 12 percent of the acres designated as highly erodible land, structural practices designed to control water erosion are in use on 42 percent.
- Reduced tillage is common in the region; 82 percent of the cropped acres meet criteria for either no-till (28 percent) or mulch till (53 percent). All but 13 percent of the acres had evidence of some kind of reduced tillage on at least one crop.
- About 35 percent of cropped acres are gaining soil organic carbon.
- Producers use either residue and tillage management practices or structural practices, or both, on 90 percent of cropped acres.
- While most acres have evidence of some nitrogen or phosphorus management, the majority of the acres in the region lack consistent use of appropriate rates, timing, *and* method of application on each crop in every year of production, including most of the acres receiving manure.

- About 21 percent of cropped acres have no nitrogen applied, nearly all of which are continuous soybean acres. An additional 66 percent of cropped acres meet criteria for timing of nitrogen applications on all crops in the rotation, 50 percent meet criteria for method of application, and 23 percent meet criteria for rate of application.
    - About 4 percent of cropped acres have no phosphorus applied. An additional 78 percent of cropped acres meet criteria for timing of phosphorus applications on all crops in the rotation, 64 percent meet criteria for method of application, and 30 percent meet criteria for rate of application.
    - Appropriate nitrogen application rates, timing of application, and application method for all crops during every year of production, however, are in use on only about 14 percent of cropped acres.
    - Good phosphorus management practices (appropriate rate, timing, and method) are in use on 17 percent of the acres on all crops during every year of production.
    - Only about 9 percent of cropped acres meet nutrient management criteria for both nitrogen and phosphorus management.
- During the 2003–06 period of data collection, cover crops were used on less than 1 percent of the acres in the region.
- The Integrated Pest Management (IPM) indicator showed that only about 9.7 percent of the acres were being managed with a relatively high level of IPM.
- Land in long-term conserving cover, as represented by enrollment in the CRP General Signup, consists of 1.0 million acres in the region, of which 47 percent is highly erodible land.

Structural Conservation Practices

Data on structural practices for the farm field associated with each sample point were obtained from four sources:

1. **The NRI-CEAP Cropland Survey** included questions about the presence of 12 types 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, 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 that were enrolled in the Continuous CRP for these structural practices: contour grass strips, filter strips, grassed waterways, riparian buffers (trees), and field windbreaks (Alex Barbarika, USDA/FSA, personal communication).
4. **The 2003 NRI** provided additional information for practices that could be reliably identified from aerial photography as part of the NRI data collection process. These practices include contour buffer strips, contour farming, contour stripcropping, field stripcropping, terraces, cross wind stripcropping, cross wind trap strips, diversions, field borders, filter strips, grassed waterways or outlets, hedgerow planting, herbaceous wind barriers, riparian forest buffers, and windbreak or shelterbelt establishment.

Surface and sub-surface drainage were incorporated into the modeling where farmers reported it was present, but practices such as flashboard risers or slotted inlet pipes used to control the water table depth and other aspects of drainage water management were not simulated. Precision land leveling was also not simulated.

Overland flow control practices are designed to slow the movement of water across the soil surface to reduce 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.[5] These practices are found on about 13 percent of the cropped acres in the region, including 29 percent of the highly erodible land (table 7).

Concentrated flow control practices are designed to prevent the development of gullies along flow paths within the field. NRCS practice standards for concentrated flow control practices include grassed waterways, grade stabilization structures, diversions, and water and sediment control basins. About 10 percent of the cropped acres have one or more of these practices, including 19 percent of the highly erodible land (table 7).

Edge-of-field buffering and filtering practices, consisting of grasses, shrubs, and/or trees, are designed to capture the surface runoff losses that were not avoided or mitigated by the in-field practices. NRCS practice standards for edge-of-field mitigation practices include edge-of-field filter strips, riparian herbaceous buffers, and riparian forest buffers. CRP's buffer practices are included in this category. Edge-of-field buffering and filtering practices are in use on about 3 percent of all cropped acres in the region (table 7).

Overall, about 21 percent of the cropped acres in the Lower Mississippi River Basin are treated with one or more water erosion control structural practices (table 7). The treated percentage for highly erodible land acres is higher—42 percent.

At each sample point, structural conservation practices for water erosion control were classified as either a high, moderately high, moderate, or low level of treatment according to criteria presented in figure 7. Only about 2 percent of cropped acres in the region have a high level of treatment (combination of edge-of-field buffering or filtering and at least one in-field structural practice). About 79 percent of the acres have a low treatment level for structural practices,

[5] Dikes and borders were incorporated into the model simulation for all sample points with rice as ponding of water is required for production. Dikes are typically used for flood protection and were not treated as a field-level conservation practice in this study. The runoff containment benefits of these dikes on rice acres, however, were captured in the modeling for all scenarios.

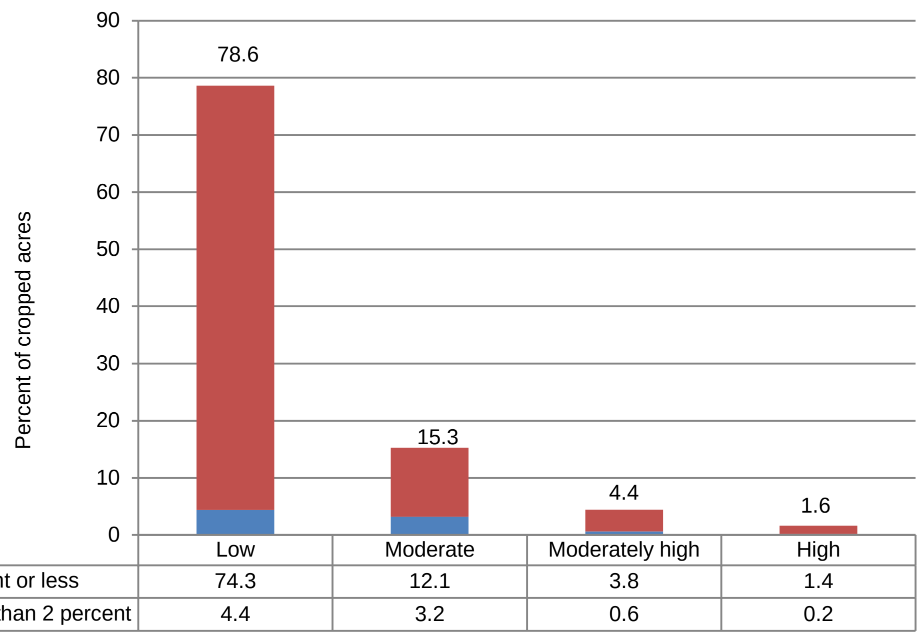
which indicates that these acres do not have any structural practices for water erosion control. However, only 8.4 percent of cropped acres in this region have slopes greater than 2 percent, many of which may not need to be treated with structural practices. (These treatment levels are combined with soil risk classes to estimate acres that appear to be undertreated for water erosion control in chapter 5.)

Table 7. Structural conservation practices in use for the baseline conservation condition, Lower Mississippi River Basin

Structural practice category	Conservation practice in use	Percent of non-HEL	Percent of HEL	Percent of cropped acres
Overland flow control practices	Terraces, contour buffer strips, contour farming, stripcropping, contour stripcropping, field border, in-field vegetative barriers	10	29	13
Concentrated flow control practices	Grassed waterways, grade stabilization structures, diversions, other structures for water control	9	19	10
Edge-of-field buffering and filtering practices	Riparian forest buffers, riparian herbaceous buffers, filter strips	3	3	3
One or more water erosion control practices	Overland flow, concentrated flow, or edge-of-field practice	19	42	21
Wind erosion control practices	Windbreaks/shelterbelts, cross wind trap strips, herbaceous windbreak, hedgerow planting	1	<1	1

Note: About 12 percent of cropped acres in the Lower Mississippi River Basin are highly erodible land (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.

Figure 7. Percent of cropped acres at four conservation treatment levels for structural practices, baseline conservation condition, Lower Mississippi River Basin



Criteria for four levels of treatment with structural conservation practices are:

- **High treatment**: Edge-of-field mitigation *and* at least one in-field structural practice (concentrated flow or overland flow practice) required.
- **Moderately high treatment**: Either edge-of-field mitigation required or both concentrated flow and overland flow practices required.
- **Moderate treatment**: No edge-of-field mitigation, either concentrated flow or overland flow practices required.
- **Low treatment**: No edge-of-field or in-field structural practices.

Note: See appendix B, table B4, for a breakdown of conservation treatment levels by subregion.

Wind erosion control practices are designed to reduce the force of the wind on the field. NRCS practice standards for wind erosion control practices include cross wind ridges, cross wind trap strips, herbaceous wind barriers, and windbreak/shelterbelt establishment. Wind erosion is not a resource concern for most acres in this region. Only about 1 percent of the cropped acres in the region are treated for wind erosion using structural practices (table 7).

Residue and Tillage Management Practices

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 applied. Model outcomes affected by tillage practices, such as erosion and runoff, were determined based on APEX processes of the daily tillage activities as reported in the survey.

To evaluate the level of residue and tillage management, the Soil Tillage Intensity Rating (STIR) (USDA/NRCS 2007) was used for tillage intensity and gains or losses in soil organic carbon (based on model simulation results) were used as an indicator of residue management.

STIR values represent the soil disturbance intensity, which was estimated for each crop at each sample point.[6] The soil disturbance intensity is a function of the kinds of tillage, the frequency of tillage, and the depth of tillage. STIR values were calculated for each crop and for each of the 3 years covered by the NRI-CEAP Cropland Survey (accounting for multiple crops or cover crops). By combining the STIR values for each crop year with model output on the long-term trend in soil organic carbon gain or loss, eight categories of residue and tillage management were identified.[7]

Overall, 82 percent of cropped acres in the Lower Mississippi River Basin meet the tillage intensity rating for either no-till or mulch till (table 8). About 28 percent meet the criteria for no-till, including 54 percent of the HEL. About 53 percent meet the tillage intensity criteria for mulch till. About 7 percent of cropped acres do not meet criteria for mulch till or no-till but have reduced tillage on some crops in the rotation. Only 13 percent of the acres are conventionally tilled for all crops in the rotation.

To evaluate the use of residue and tillage management practices, practice use was classified as high, moderately high, moderate, or low for each sample point according to criteria presented in figure 8. (These residue and tillage management treatment levels were combined with the use of structural practices to estimate conservation treatment levels for water erosion control in chapter 5.) The high and moderately high treatment levels represent the 30.1 percent of cropped acres that meet tillage intensity criteria for either no-till or mulch till and are gaining soil organic carbon.

The high treatment level, representing 26.2 percent of cropped acres, includes only those acres with gains in soil organic carbon and where the tillage intensity criteria are met for *each* crop in the rotation. About 3.9 percent of cropped acres have a moderately high treatment level, where the *average annual* tillage intensity meets criteria for mulch till or no-till and the crop rotation is gaining soil organic carbon.

The bulk of the cropped acres—59.2 percent—have a moderate level of treatment. Most of these acres meet tillage intensity for no-till or mulch till but are losing soil organic carbon. Other acres have reduced tillage but do not meet criteria for no-till or mulch till or they are gaining soil organic carbon but tillage intensity exceeds criteria for mulch till (fig. 8).

About 10.7 percent of the acres have a low treatment level, consisting of continuous conventional tillage for all crops in the rotation and loss of soil organic carbon.

Structural practices and residue and tillage management practices influence losses of sediment, nutrients, and pesticides due to water erosion. Most of the cropped acres (90 percent) in the Lower Mississippi River Basin have one or both of these types of water erosion control practices (table 9). About 17 percent meet tillage intensity for no-till or mulch till *and* have structural practices, including 38 percent of HEL. About 63 percent of cropped acres meet tillage criteria for no-till or mulch till without structural practices in use. Only 3 percent have structural practices without any kind of residue or tillage management (table 9).

Conservation Crop Rotation

In the Lower Mississippi River Basin, crop rotations that meet NRCS criteria (NRCS practice code 328) are used on about 48 percent of the cropped acres. This practice consists of growing different crops in a planned rotation to manage nutrient and pesticide inputs, enhance soil quality, or reduce soil erosion. Including a legume, hay, or a close grown crop in the rotation can have a pronounced effect on long-term average field losses of sediment and nutrients, as well as enhancement of soil quality.

The model outputs reported in chapter 4 reflect the effects of conservation crop rotations, but the benefits of conservation crop rotation practices could not be assessed quantitatively in this study. First, it was not possible to differentiate conservation crop rotations from crop rotations for other purposes, such as the control of pests or in response to changing markets. Second, the "no-practice scenario" would require simulation of mono-cropping systems, which would require arbitrary decisions about which crops to simulate at each sample point to preserve the level of regional production.

[6] Percent residue cover was not used to evaluate no-till or mulch till because this criterion is not included in the current NRCS practice standard for Residue and Tillage Management. Residue is, however, factored into erosion and runoff estimates in APEX.

[7] STIR values in combination with carbon trends are in line with the use of the Soil Conditioning Index (SCI), which approximates the primary criteria for NRCS residue management standards. The NRCS practice standard, as applied at the field, may include other considerations to meet site specific resource concerns that are not considered in this evaluation.

Table 8. Residue and tillage management practices for the baseline conservation condition based on STIR ratings for tillage intensity and model output on carbon gain or loss, Lower Mississippi River Basin

Residue and tillage management practice in use	Percent of non_HEL	Percent of HEL	Percent of all cropped acres
All cropped acres			
Average annual tillage intensity for crop rotation meets criteria for no-till*	24	54	28
Average annual tillage intensity for crop rotation meets criteria for mulch till**	55	32	53
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	7	4	7
Continuous conventional tillage in every year of crop rotation***	13	10	13
Total	100	100	100

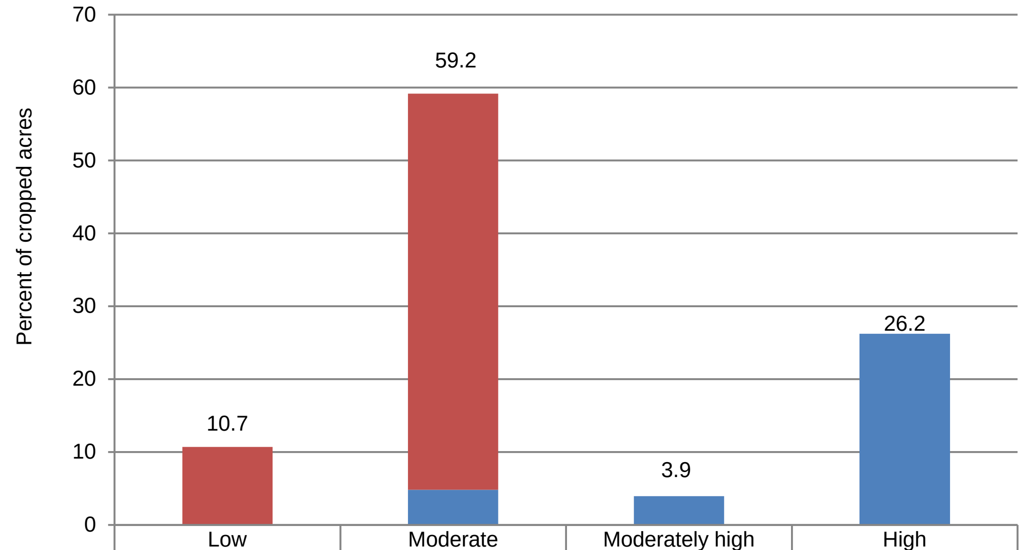
* Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is less than 30.
** Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is between 30 and 100.
*** Soil Tillage Intensity Rating (STIR) for every crop year in the rotation is more than 100.
Note: A description of the Soil Tillage Intensity Rating (STIR) can be found at http://stir.nrcs.usda.gov/.
Note: Percents may not add to totals because of rounding.
Note: Percent residue cover was not used to determine no-till or mulch till.
Note: HEL = highly erodible land. About 12 percent of cropped acres in the Lower Mississippi River Basin are highly erodible land (HEL).

Table 9. Percent of cropped acres with water erosion control practices for the baseline conservation condition, Lower Mississippi River Basin

Conservation treatment	Percent of non-HEL	Percent of HEL	Percent of all cropped acres
No-till or mulch till with carbon gain, no structural practices	25	14	24
No-till or mulch till with carbon loss, no structural practices	40	36	39
Some crops with reduced tillage, no structural practices	6	3	6
Structural practices and no-till or mulch till with carbon gain	6	9	6
Structural practices and no-till or mulch till with carbon loss	9	29	11
Structural practices and some crops with reduced tillage	1	1	1
Structural practices only	3	3	3
No water erosion control treatment	10	6	10
All acres	100	100	100

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

Figure 8. Percent of cropped acres at four conservation treatment levels for residue and tillage management, baseline conservation condition, Lower Mississippi River Basin



	Low	Moderate	Moderately high	High
Losing carbon	10.7	54.4	0.0	0.0
Gaining carbon	0.0	4.8	3.9	26.2

Criteria for four levels of treatment with residue and tillage management are:

- **High treatment**: *All crops* meet tillage intensity criteria for either no-till or mulch till and crop rotation is gaining soil organic carbon.
- **Moderately high treatment**: *Average annual* tillage intensity meets criteria for mulch till or no-till and crop rotation is gaining soil organic carbon; some crops in rotation exceed tillage intensity criteria for mulch till.
- **Moderate treatment**: Most acres in this treatment level meet criteria for no-till or mulch till but are losing soil organic carbon. Some crops have reduced tillage but tillage intensity exceeds criteria for mulch till or crop rotation is gaining soil organic carbon and tillage intensity exceeds criteria for mulch till.
- **Low treatment**: Continuous conventional tillage and crop rotation is losing soil organic carbon.

Note: See appendix B, table B4, for a breakdown of conservation treatment levels by subregion.
Note: Sample points that are gaining or losing soil organic carbon are identified based on APEX model output. In the annual output table, the beginning-of-year and end-of-year soil organic carbon values are recorded. The annual change in soil organic carbon is calculated as the difference between end-of-year and beginning-of-year values, which are then averaged over the 47 years of the model simulation for each sample point.

The evaluation of conservation practices are based on practice use derived from a farmer survey conducted during the years 2003–06. Use of conservation practices can vary year to year depending on economic and environmental factors, including changes in crop rotations in response to market conditions, year-to-year changes in weather-related factors affecting tillage, irrigation, and nutrient management, and conservation program funding levels and program rules.

Since the 2003–06 survey, States in the Lower Mississippi River Basin have continued to work with farmers to enhance conservation practice adoption in an ongoing effort to reduce nonpoint source pollution contributing to water quality concerns. As a result, farmers have increased the use of proper nutrient management, cover crops, integrated pest management, and other practices. Split applications of nitrogen and use of urease inhibitors has been widely adopted in some parts of the region. Farmers are using more cover crops for the purpose reducing nitrogen and fertilizer demands, reducing tillage requirements, pest control, and improving overall crop production. There has been a switch to higher efficiency irrigation systems resulting in reduced amounts of irrigation-induced soil erosion. Corn has replaced cotton on many acres, and farmers are now rotating corn with other crops as a common practice. Organic farms are increasing.

As a result, conservation practices are likely to be in wider use within the watershed than the CEAP survey shows for 2003–06.

Cover Crops

Cover crops are planted when the principal crops are not growing. The two most important functions of cover crops from a water quality perspective are (1) to provide soil surface cover and reduce soil erosion, and (2) to utilize and convert excess nutrients remaining in the soil from the preceding crop into plant biomass, thereby reducing nutrient leaching and minimizing the amount of soluble nutrients in runoff during the non-crop growing season. From a soil quality perspective, cover crops help capture atmospheric carbon in plant tissue, provide habitat for the soil food web, and stabilize or enhance soil aggregate strength.

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

- A cover crop must be a close-grown crop that is not harvested as a principal crop, or if it is harvested, must have been specifically identified in the NRI-CEAP Cropland Survey as a cover crop as an indicator that the harvest was for an acceptable purpose (such as biomass removal or use as mulch or forage material).
- 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, such as protection of small cotton plants
In the Lower Mississippi River Basin, cover crops were not commonly used as a conservation practice during the period covered by the farmer survey (2003–06). Less than 1 percent of the acres (5 sample points) met the above criteria for a cover crop.

Irrigation Management Practices

Irrigation in the United States has its roots in the arid West where precipitation is insufficient to meet the needs of growing crops. In other parts of the United States, rainfall totals are sufficient in most years to produce satisfactory yields. The distribution of the rainfall during the crop growing season, however, is sometimes problematic, especially in years when precipitation is below average. In the Lower Mississippi River Basin, irrigation applications are sometimes used to supplement natural rainfall. This supplemental irrigation water can overcome soil moisture deficiencies during drought stress periods and improve yields.

Irrigation applications are made with either a pressure or a gravity system. Gravity systems, as the name implies, 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 pressure systems, and the water is applied under pressure through pipes and nozzles. There are also variations such as where water is diverted at higher elevations and the pressure head created by gravity is substituted for the energy of a pump.

Proper irrigation involves applying appropriate amounts of water to the soil profile to reduce any plant stress while at the same time minimizing water losses through evaporation, deep percolation, and runoff. Conversion of much of the gravity irrigated area to pressure systems and the advent of pressure systems in rain-fed agricultural areas has reduced the volumes of irrigation water lost to deep percolation and end-of-field runoff, but has greatly increased the volume of water lost to evaporation in the pressurized sprinkling process. Modern sprinklers utilize improved nozzle technology to increase droplet size as well as reduce the travel time from the nozzle to the ground. Irrigation specialists consider the center pivot or linear move sprinkler with low pressure spray and low flow systems such as drip and trickle systems as the current state of the art.

According to the NRI-CEAP cropland survey for 200306, about 46 percent of cropped acres—8.7 million acres—receive irrigation water in the Lower Mississippi River Basin for one or more crops, including 4.6 million acres with rice in the rotation, 2.0 million acres with cotton in the rotation, and 1.9 million acres with soybeans in the rotation.

To evaluate the efficiency of irrigation systems, a single measure of over-all irrigation efficiency was developed—Virtual Irrigation System Efficiency (VISE). VISE consists of three variables with values unique to each of 19 types of irrigation systems. The first of the three variables is an application efficiency, which accounts for some losses from the on-farm conveyance system, the field conveyance mechanism, and as the water is applied to the field. In sprinkler systems this loss could be high due to evaporation. Application efficiency could also be reduced by leaky pipelines or ditches in more porous soils. The second factor is a coefficient that accounts for the loss of water below the root-zone, or deep percolation, during the irrigation process. In gravity systems deep percolation is normally much higher at the upper end of the field and lessens toward the lower end of the field. The deep percolation coefficient ensures that enough water is applied so that the profile is at least filled all across the field, even if that requires excess applications to some parts of the field. The third factor accounts for the percent of water running off the edge of the field. The CEAP surveys reported few fields with runoff, even with gravity systems. While there is likely more runoff than reported, the survey values were used to define the baseline system.

Approximately 18 percent of the irrigation in the Lower Mississippi River Basin is by pressure systems and 82 percent is irrigated with gravity systems. Most common pressure systems are center-pivot or linear-move systems with impact sprinkler heads (10.5 percent of irrigated acres) followed by center-pivot or linear-move systems with low pressure sprays (4.8 percent of irrigated acres). There are also a few center pivots or linear move systems with near ground emitters, side roll or wheel lines, solid set, hand-move sprinkler systems, big gun sprinklers, and a few other pressure systems. Common gravity irrigation systems include open discharges (53 percent of irrigated acres), polypipe (26.4 percent of irrigated acres), and gated pipe (2.4 percent of irrigated acres). In addition there are numerous other gravity systems including siphon tubes and portal systems from unlined ditches and sub-irrigation systems. The open discharge category can include controlled direct discharge from a well, discharge from large irrigation structures, or discharge from alfalfa valves. Approximately 44 percent of the irrigation systems in the Lower Mississippi River Basin are capable of irrigation efficiencies that would be considered appropriate for state-of-the-art irrigation.

Nutrient Management Practices

Nitrogen and phosphorus are essential inputs to profitable crop production. Farmers apply these nutrients to the land as commercial fertilizers and manure to promote plant growth and increase crop yields. Not all of the nutrients applied to the land, however, are taken up by crops; some are lost to the environment, which can contribute to offsite water quality problems.

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.) Such systems are tailored to address the specific cropping system, nutrient sources available, and site characteristics of each field. Nutrient management systems have four basic criteria for application of commercial fertilizers and manure. [8]

1. Apply nutrients at the **appropriate rate** based on soil and plant tissue analyses and realistic yield goals.
2. Apply the **appropriate form** of fertilizer and organic material with compositions and characteristics that resist nutrient losses from the agricultural management zone.
3. Apply at the **appropriate time** to supply nutrients to the crop when the plants have the most active uptake and biomass production, and avoid times when adverse weather conditions can result in large losses of nutrients from the agricultural management zone.
4. Apply using the **appropriate application method** that provides nutrients to the plants for rapid, efficient uptake and reduces the exposure of nutrient material to forces of wind and water.

Depending on the field characteristics, these 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 by careful management and kept within an acceptable level.

The presence or absence of nutrient management practices was based on information on the timing, rate, and method of application for manure and commercial fertilizer as reported by the producer in the NRI-CEAP Cropland Survey. The appropriate form of nutrients applied was not evaluated because the survey was not sufficiently specific about the material formulations that were applied. The following criteria were used to identify the appropriate rate, time, and method of nutrient application for each crop or crop rotation.

- All commercial fertilizer and manure applications are within 3 weeks prior to plant date, at planting, or within 60 days after planting. For fall-planted winter wheat, spring applications also were considered appropriate timing.
- The method of application for commercial fertilizer or manure is some form of incorporation or banding or spot treatment or foliar applied.
- The rate of nitrogen application, including the sum of both commercial 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,[9] 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.
- The rate of phosphorus application summed over all applications and crops in the rotation, including both commercial fertilizer and manure phosphorus, is less than 1.1 times the amount of phosphorus removed in the crop yields at harvest summed over all crops in the rotation.

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. Nitrogen application rate criteria apply to *each* crop in the rotation.

These nutrient management criteria are intended to represent practice recommendations commonly found in comprehensive nutrient management conservation plans and generally are consistent with recommended rates. While consistent with NRCS standards, they do not necessarily represent the best possible set of nutrient management practices. For example, lower application rates are possible when timing and method criteria are also met and when soil erosion and runoff are controlled.

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[8] These criteria are also referred to as "4R nutrient stewardship—right source, right rate, right time, and right place" (Bruulsema et al. 2009).

[9] The 1.4 ratio of application rate to yield represents 70-percent use efficiency for applied nitrogen, which has traditionally been accepted as good nitrogen management practice. The 30 percent "lost" includes plant biomass left in the field, volatilization during and following application, immobilization by soil and soil microbes, and surface runoff and leaching losses. A slightly higher ratio is used for small grain crops to maintain yields at current levels.

As shown in table 10, the majority of acres in the Lower Mississippi River Basin meet one or more of the criteria for nitrogen management. About 21 percent of cropped acres have no nitrogen applied, nearly all of which are continuous soybean acres. An additional 66 percent of cropped acres meet criteria for timing of nitrogen applications on all crops in the rotation, 50 percent meet criteria for method of application, and 23 percent meet criteria for rate of application.

Similar results were found for phosphorus management. About 4 percent of cropped acres have no phosphorus applied. An additional 78 percent of cropped acres meet criteria for timing of phosphorus applications on all crops in the rotation, 64 percent meet criteria for method of application, and 30 percent meet criteria for rate of application.

Only a few acres meet all nutrient management criteria (table 10):

- In addition to the 21 percent of cropped acres without nitrogen applications, 14 percent of the acres meet all criteria for nitrogen applications;
- In addition to the 4 percent of cropped acres without phosphorus applications, 17 percent of the acres meet all criteria for phosphorus applications;
- Only 9 percent of cropped acres meet criteria for *both* phosphorus and nitrogen management, including acres with no nutrient applications.

Lower nitrogen rate criteria are appropriate for acres that meet application timing and method criteria and also are fully treated for soil erosion control because more of the nitrogen applied is retained on the field and is therefore available for crop growth. In the simulation of additional soil erosion control and nutrient management (full treatment) in chapter 6, the rates of nitrogen application, including both commercial fertilizer and manure nitrogen, were proportionately reduced to the following levels—

- 1.2 times the amount of nitrogen removed in the crop yield at harvest for *each* crop, except for cotton and small grain crops;
- 1.5 times the amount of nitrogen removed in the crop yield at harvest for small grain crops; and
- 50 pounds of nitrogen per bale of cotton harvested.

Nine percent of cropped acres in the region meet *all* nutrient management criteria including these lower nitrogen rate criteria and including acres not receiving nutrient applications (table 10).

Only about 1.5 percent of cropped acres in this region had manure applied, according to the CEAP cropland survey for 2003–06.

Four levels of treatment for nitrogen and phosphorus management were derived for use in evaluating the adequacy of nutrient management. (These treatment levels are combined with soil risk classes to estimate acres that appear to be undertreated in chapter 5.) Criteria for the treatment levels are presented in figures 9 and 10. The high treatment level represents consistent use of appropriate rate, timing, and method for all crops, including the lower nitrogen application rate criteria appropriate for full conservation treatment conditions.

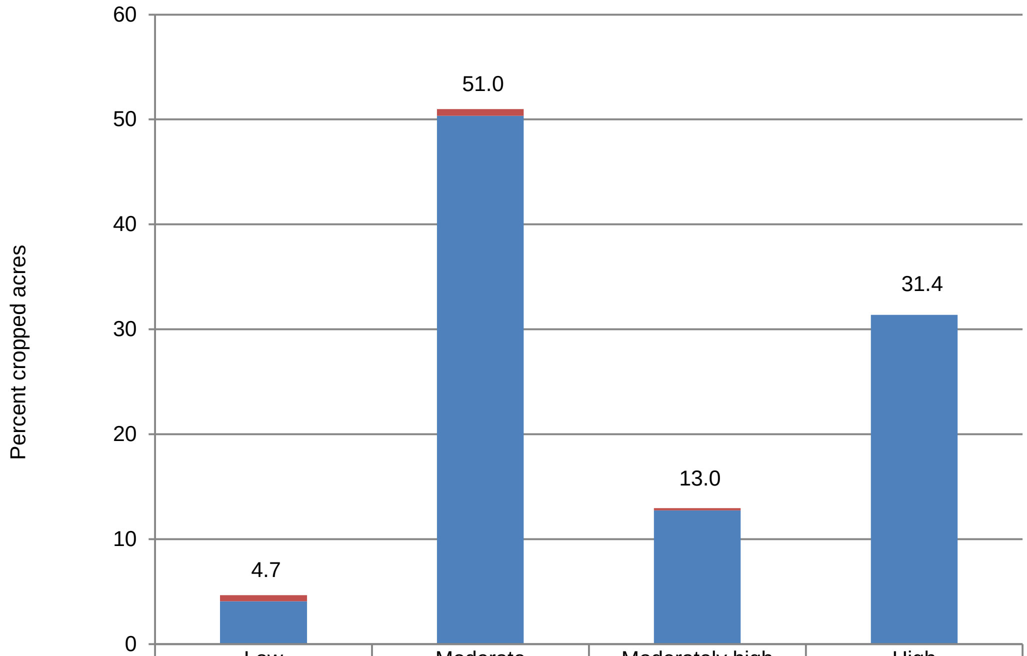
Based on these treatment levels, about 31 percent of the acres in the Lower Mississippi River Basin have a high level of nitrogen management and about 22 percent have a high level of phosphorus management (figs. 9 and 10). About 13 percent of cropped acres have a moderately high treatment level for nitrogen and about 13 percent have a moderately high treatment level for phosphorus. Most acres, however, have either a moderate or low level of treatment—56 percent for nitrogen management and 66 percent for phosphorus management.

Table 10. Nutrient management practices for the baseline conservation condition, Lower Mississippi River Basin

	Percent of all cropped acres
Nitrogen*	
No N applied to any crop in rotation	21
For samples where N is applied:	
Time of application	
All crops have application of N (manure or fertilizer) within 3 weeks before planting or within 60 after planting	66
Some but not all crops have application of N (manure or fertilizer) within 3 weeks before planting or within 60 after planting	4
No crops in rotation have application of N (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	9
Method of application	
All crops in rotation have N applied with incorporation or banding/foliar/spot treatment	50
Some but not all crops in rotation have N applied with incorporation or banding/foliar/spot treatment	16
No crops in rotation have N applied with incorporation or banding/foliar/spot treatment	13
Rate of application	
All crops in rotation meet the nitrogen rate criteria described in text	23
Some but not all crops in rotation meet the nitrogen rate criteria described in text	40
No crops in rotation meet the nitrogen rate criteria described in text	16
Timing and method and rate of application	
All crops meet the nitrogen rate criteria, timing criteria, and method criteria described above	14
Some but not all crops meet the nitrogen rate criteria, timing criteria, and method criteria described above	42
No crops meet the nitrogen rate , timing criteria, and method criteria described above	24
Phosphorus*	
No P applied to any crop in rotation	4
For samples where P is applied:	
Time of application	
All crops in rotation have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	78
Some but not all crops have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	7
No crops in rotation have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	10
Method of application	
All crops in rotation have P applied with incorporation or banding/foliar/spot treatment	64
Some but not all crops in rotation have P applied with incorporation or banding/foliar/spot treatment	17
No crops in rotation have P applied with incorporation or banding/foliar/spot treatment	15
Rate of application	
Crop rotation has P applied at a rate less than 1.1 times the removal of P in the yield at harvest for the crop rotation	30
Crop rotation has P applied at a rate more than 1.1 times the removal of P in the yield at harvest for the crop rotation	66
Timing and method and rate of application	
Crop rotation has P rate less than 1.1 times removal at harvest and meet timing and method criteria described above	17
Crop rotation has P rate less than 1.1 times removal at harvest and some but not all crops meet timing and method criteria described above	9
Crop rotation has P rate more than 1.1 times removal at harvest and may or may not meet timing and method criteria described above	70
Nitrogen and Phosphorus	
Crop rotation P rate less than 1.1 and N rate criteria described in text and all applications within 3 weeks before planting or within 60 days after planting with incorporation or banding/foliar/spot treatment, including acres with no N or P applied	9
Crop rotation P rate less than 1.1 and N rate criteria appropriate for full conservation treatment (see text) and all applications within 3 weeks before planting or within 60 days after planting with incorporation or banding/foliar/spot treatment, including acres with no N or P applied	9
All sample points	100

* 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 and phosphorus when the reported levels were insufficient to support reasonable crop yields throughout the 47 years in the model simulation. The approach taken was to first identify crop samples that have application rates recorded erroneously or were under-reported in the survey. The model was used to identify these samples by running the simulation at optimal levels of nitrogen and phosphorus for crop growth. The set of crop samples identified were treated as if they had missing data. Additional nitrogen or phosphorus was added to these crop samples so that the total nitrogen or phosphorus use was similar to that for the unadjusted set of crop samples. About 12 percent of the acres received a nitrogen adjustment for one or more crops. About 52 percent of the acres received a phosphorus adjustment for one or more crops. Nitrogen and phosphorus were added by increasing the existing applications (thus preserving the reported timing and methods), when present, or were applied at plant. (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

Figure 9. Percent of cropped acres at four conservation treatment levels for nitrogen management, baseline conservation condition, Lower Mississippi River Basin



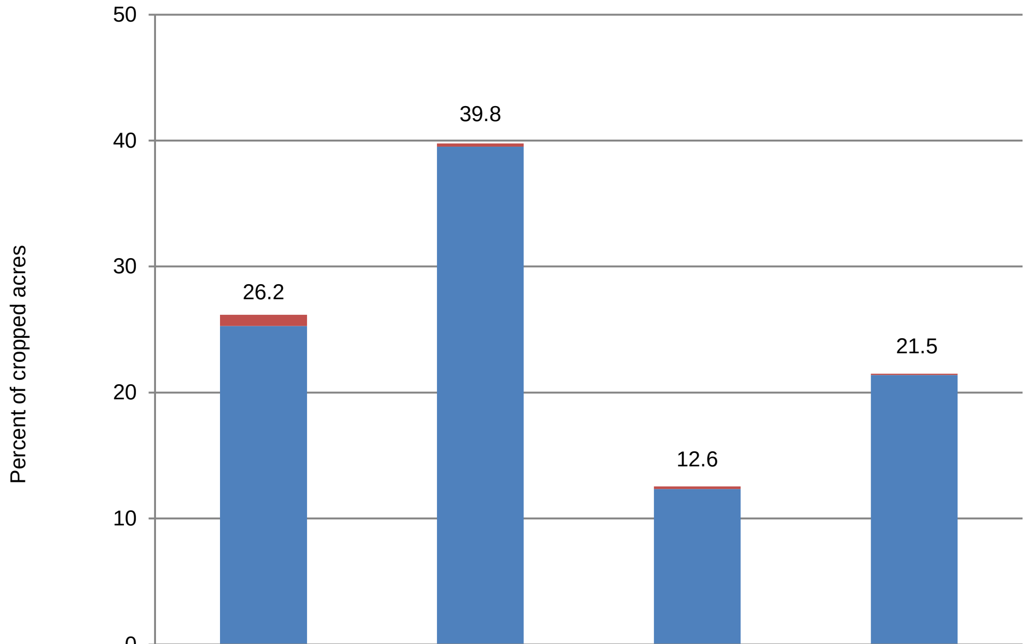
	Low	Moderate	Moderately high	High
Manure applied	0.6	0.6	0.2	0.0
No manure applied	4.1	50.4	12.7	31.4

Criteria for four levels of nitrogen management are:

- **High treatment**: All crops have: (1) total nitrogen application rates (including manure) less than 1.2 times the nitrogen in the crop yield for crops other than cotton and small grains, less than 1.5 times the nitrogen in the crop yield for small grains, and less than 50 pounds of nitrogen applied per cotton bale; (2) all applications occur within 3 weeks before planting or within 60 days after planting; and (3) all applications are incorporated or banding/foliar/spot treatment is used.
- **Moderately high treatment**: All crops have total nitrogen application rates (including manure) less than 1.4 times the nitrogen in the crop yield for crops other than cotton and small grains, less than 1.6 times the nitrogen in the crop yield for small grains, and less than 60 pounds of nitrogen applied per cotton bale for all crops. Timing and method of application criteria may or may not be met.
- **Moderate treatment**: All crops meet either the above criteria for timing *or* method, but do not meet criteria for rate.
- **Low treatment**: Some or all crops in rotation exceed criteria for rate and either timing or method.

Note: See appendix B, table B4, for a breakdown of conservation treatment levels by subregion.

Figure 10. Percent of cropped acres at four conservation treatment levels for phosphorus management, baseline conservation condition, Lower Mississippi River Basin



	Low	Moderate	Moderately high	High
Manure applied	0.9	0.3	0.2	0.1
No manure applied	25.3	39.5	12.3	21.4

Criteria for four levels of phosphorus management are:

- **High treatment**: (1) total phosphorus application rates (including manure) summed over all crops are less than 1.1 times the phosphorus in the crop yields for the crop rotation, (2) all applications occur within 3 weeks before planting or within 60 days after planting, and (3) all applications are incorporated or banding/foliar/spot treatment was used. (Note that phosphorus applications for individual crops could exceed 1.1 times the phosphorus in the crop yield but total applications for the crop rotation could not.)
- **Moderately high treatment**: Total phosphorus application rates (including manure) are less than 1.1 times the phosphorus in the crop yield for the crop rotation. No method or timing of application criteria is applied.
- **Moderate treatment**: Sample points that do not meet the high or moderately high criteria but all phosphorus applications for all crops have appropriate time *and* method of application.
- **Low treatment**: All acres have excessive application rates over the crop rotation and inadequate method or timing of application for at least one crop in the rotation.

Note: See appendix B, table B4, for a breakdown of conservation treatment levels by subregion.

Pesticide Management Practices

The presence or absence of pesticide management practices was based on an Integrated Pest Management (IPM) indicator developed using producer responses to the set of IPM-related questions in the NRI-CEAP Cropland Survey (table 11).[10]

Adoption of IPM systems can be described as occurring along a continuum from largely reliant on prophylactic control measures and pesticides to multiple-strategy, biologically intensive approaches. IPM adoption is not usually an either/or situation. The practice of IPM is site-specific in nature, with individual tactics determined by the particular crop/pest/environment scenario. Where appropriate, each site should have in place a management strategy for **Prevention, Avoidance, Monitoring,** and **Suppression** of pest populations (the **PAMS** approach) (Coble 1998). In order to qualify as IPM practitioners, growers would use tactics in all four PAMS components.

Prevention is the practice of keeping a pest population from infesting a field or site, and should be the first line of defense. It includes such tactics as using pest-free seeds and transplants, preventing weeds from reproducing, irrigation scheduling to avoid situations conducive to disease development, cleaning tillage and harvesting equipment between fields or operations, using field sanitation procedures, and eliminating alternate hosts or sites for insect pests and disease organisms.

Avoidance may be practiced when pest populations exist in a field or site but the impact of the pest on the crop can be avoided through some cultural practice. Examples of avoidance tactics include crop rotation in which the crop of choice is not a host for the pest, choosing cultivars with genetic resistance to pests, using trap crops or pheromone traps, choosing cultivars with maturity dates that may allow harvest before pest populations develop, fertilization programs to promote rapid crop development, and simply not planting certain areas of fields where pest populations are likely to cause crop failure.

Monitoring and proper identification of pests through surveys or scouting programs, including trapping, weather monitoring and soil testing where appropriate, are performed as the basis for suppression activities. Records are kept of pest incidence and distribution for each field or site. Such records form the basis for crop rotation selection, economic thresholds, and suppressive actions.

Suppression of pest populations may be necessary to avoid economic loss if prevention and avoidance tactics are not successful. Suppressive tactics include *cultural* practices such as narrow row spacing or optimized in-row plant populations, alternative tillage approaches such as no-till or strip-till systems, cover crops or mulches, or using crops with allelopathic potential in the rotation. *Physical* suppression tactics include cultivation or mowing for weed control, baited or pheromone traps for certain insects, and temperature management or exclusion devices for insect and disease management. *Biological* controls, including mating disruption for insects, are alternatives to conventional pesticides, especially where long-term control of a troublesome pest species can be attained. Naturally occurring biological controls, where they exist, are important IPM tools. *Chemical pesticides* are applied as a last resort in suppression systems using a sound management approach, including selection of pesticides with low risk to non-target organisms.

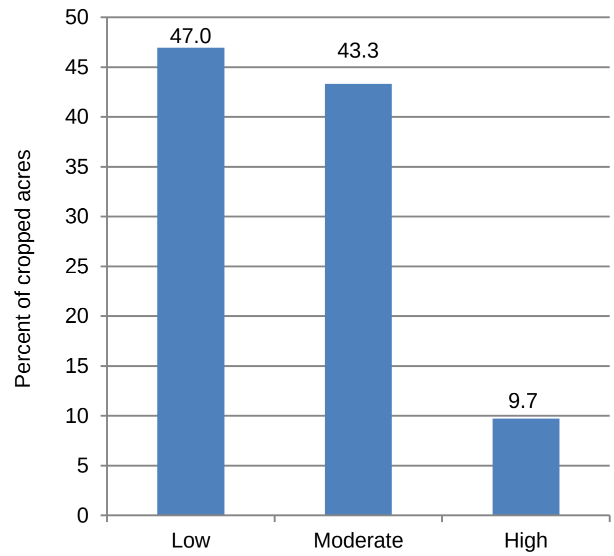
An IPM index was developed to determine the level of IPM activity for each sample point. The index was constructed as follows.

- Scores were assigned to each question by a group of IPM experts.
- Scores for each PAMS category were normalized to have a maximum score of 100.
- The four PAMS categories were also scored in terms of relative importance for an IPM index: prevention = 1/6, avoidance = 1/6, monitoring = 1/3, and suppression = 1/3.
- The IPM indicator was calculated by multiplying the normalized PAMS category by the category weight and summing over the categories.

An IPM indicator score greater than 60 defined sample points with a high level of IPM activity. Sample points with an IPM indicator score of 35 to 60 were classified as moderately high IPM treatment and sample points with an IPM score less than 35 were classified as low IPM treatment.

About 10 percent of the acres in the Lower Mississippi River Basin have a high level of IPM activity (fig. 11). About 43 percent have a moderate level of IPM activity, and 47 percent have a low level of IPM activity.

Figure 11. Integrated Pest Management indicator for the baseline conservation condition, Lower Mississippi River Basin



[10] For a full documentation of the derivation of the IPM indicator, see "Integrated Pest Management (IPM) Indicator Used in the CEAP Cropland Modeling," available at http://www.nrcs.usda.gov/technical/nri/ceap.

Table 11. Summary of survey responses to pest management questions, Lower Mississippi River Basin

Survey question	Number samples with "yes" response	Percent of cropped acres
Prevention		
Pesticides with different action rotated or tank mixed to prevent resistance	442	23%
Plow down crop residues	531	32%
Chop, spray, mow, plow, burn field edges, etc.	918	51%
Clean field implements after use	701	37%
Remove crop residue from field	247	15%
Water management used to manage pests (irrigated samples only)	138	7%
Avoidance		
Rotate crops to manage pests	709	37%
Use minimum till or no-till to manage pests	862	46%
Choose crop variety that is resistant to pests	699	38%
Planting locations selected to avoid pests	107	6%
Plant/harvest dates adjusted to manage pests	131	7%
Monitoring		
Scouting practice: general observations while performing routine tasks	668	36%
Scouting practice: deliberate scouting	862	52%
--Established scouting practice used	491	31%
--Scouting due to pest development model	280	14%
--Scouting due to pest advisory warning	211	11%
Scouting done by: (only highest of the 4 scores is used)		
--Scouting by operator	450	27%
--Scouting by employee	37	2%
--Scouting by chemical dealer	65	3%
--Scouting by crop consultant or commercial scout	419	28%
Scouting records kept to track pests?	555	33%
Scouting data compared to published thresholds?	503	30%
Diagnostic lab identified pest?	93	6%
Weather a factor in timing of pest management practice	653	36%
Suppression		
Pesticides used?	1707	98%
Weather data used to guide pesticide application	1094	61%
Biological pesticides or products applied to manage pests	167	10%
Pesticides with different mode of action rotated or tank mixed to prevent resistance	442	23%
Pesticide application decision factor (one choice only):		
--Routine treatments or preventative scheduling	877	43%
--Comparison of scouting data to published thresholds	144	9%
--Comparison of scouting data to operator's thresholds	174	11%
--Field mapping or GPS	2	0%
--Dealer recommendations	118	8%
--Crop consultant recommendations	239	17%
--University extension recommendations	13	1%
--Neighbor recommendations	0	0%
--"Other"	32	2%
Maintain ground covers, mulch, or other physical barriers	284	15%
Adjust spacing, plant density, or row directions	275	13%
Release beneficial organisms	12	1%
Cultivate for weed control during the growing season	187	13%
Number of respondents	1,735	100

Note: The scores shown in this table were used to develop an IPM indicator as discussed in the text.

Conservation Cover Establishment

Establishing long-term cover of grass, forbs, or trees on a site provides the maximum protection against soil erosion. Conservation cover establishment is often used on cropland with soils that are vulnerable to erosion or leaching. The practice is also effective for sites that are adjacent to waterways, ponds, and lakes. Because these covers do not require annual applications of fertilizer and pesticides, this long-term conserving cover practice greatly reduces the loss of nitrogen and phosphorus from the site, and nearly eliminates pesticide loss. Because conservation covers are not harvested, they generate organic material that decomposes and increases soil organic carbon.

For this study, the effect of a long-term conserving cover practice was estimated using acres enrolled in the General Signup of the CRP. The CRP General Signup is a voluntary program in which producers with eligible land enter into 10- to 15-year contracts to establish long-term cover to reduce soil erosion, improve water quality, and enhance wildlife habitat.

Landowners receive annual rental payments and cost-share assistance for establishing and maintaining permanent vegetative cover. To be eligible for enrollment in the CRP General Signup, the field (or tract) must meet specified crop history criteria.

Other factors governing enrollment in the CRP include natural resource-based eligibility criteria, an Environmental Benefits Index (EBI) used to compare and rank enrollment offers, acreage limits, and upper limits on the proportion of a county's cropland that can be enrolled (USDA Farm Service Agency 2004; Wiebe and Gollehon 2006). Initially, the eligibility criteria included only soil erosion rates and inherent soil erodibility. During the 1990s and to date, the eligibility criteria have continued to evolve, with increasing emphasis placed on issues other than soil erodibility. For contract offer ranking, weight was given to proposals that also benefited wildlife, air and water quality, and other environmental concerns.

As of 2003, about 31.5 million acres were enrolled in the CRP General Signup nationally, including about 1.0 million in the Lower Mississippi River Basin (USDA/NRCS 2007). Approximately 47 percent of the cropland acres enrolled in the CRP in the Lower Mississippi River Basin are classified as highly erodible land. The inclusion of non-highly erodible land is due to both the expansion of enrollment eligibility criteria beyond soil erosion issues and the fact that farmers were allowed to enroll entire fields in the CRP if a specified portion of the field (varied by signup and eligibility criterion) met the criteria.

In the Lower Mississippi River Basin, 65 percent of the CRP land is planted to trees, 31 percent to introduced grasses, 2 percent to native grasses, and 2 percent to wildlife habitat. The plantings designated in the NRI database for each sample point were simulated in the APEX model. However, in all cases the simulated cover was a mix of species and all points included at least one grass and one clover species.

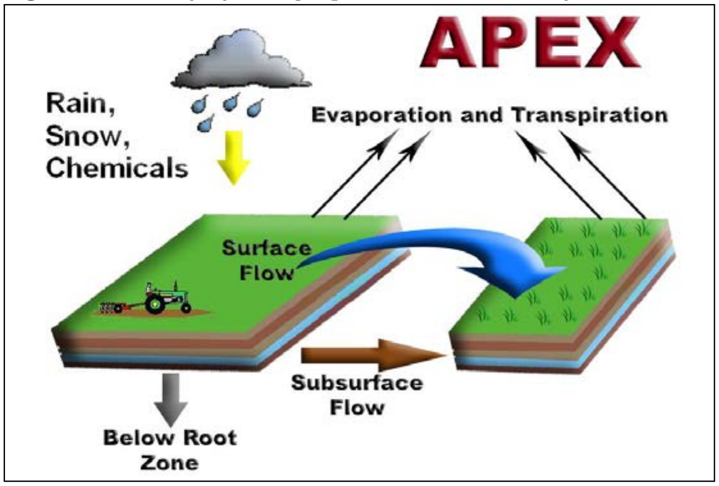
Chapter 4
Onsite (Field-Level) Effects of Conservation Practices

The Field-Level Cropland Model—APEX

A physical process model called APEX was used to simulate the effects of conservation practices at the field level (Williams et al. 2006; Williams et al. 2008; Gassman et al. 2009 and 2010).[11] 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.[12]

The APEX model is a field-scale, daily time-step model that simulates weather, farming operations, crop growth and yield, and the movement of water, soil, carbon, nutrients, sediment, and pesticides (fig. 12). The APEX model and its predecessor, EPIC (Environmental Policy Impact Calculator), have a long history of use in simulation of agricultural and environmental processes and of the effect of agricultural technology and government policy (Izaurralde et al. 2006;Williams 1990; Williams et al. 1984; Gassman et al. 2005).[13]

Figure 12. Daily hydrologic processes simulated by APEX



On a daily basis, APEX simulates the farming operations used to grow crops, such as planting, tillage before and after planting, application of nutrients and pesticides, application of manure, irrigation, and harvest. Weather events and their interaction with crop cover and soil properties are simulated; these events affect crop growth and the fate and transport of water and chemicals through the soil profile and over land to the edge of the field. Over time, the chemical makeup and physical structure of the soil may change, which in turn affect crop yields and environmental outcomes. Crop residue remaining on the field after harvest is transformed into organic matter. Organic matter may build up in the soil over time, or it may degrade, depending on climatic conditions, cropping systems, and management.

APEX simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions. Soil erosion is simulated over time, including 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 their availability for plant growth or for transport from the field. Exchange of gaseous forms between the soil and the atmosphere is simulated, including losses of gaseous nitrogen compounds.

The NRI-CEAP Cropland Survey was the primary source of information on all farming activities simulated using APEX. Crop data were transformed for the model into a crop rotation for each sample point, which was then repeated over the 47-year simulation. The 3 years of data reported in the survey were represented in the model simulation as 1-, 2-, 3-, 4-, or 5-year crop rotations. For example, a 2-year corn-soybean rotation was used if the operator reported that corn was grown in the first year, soybeans in the second year, and corn again in the third year. In this case, only 2 of the reported 3 years of survey data were used. If management differed significantly for the 2 years that corn was grown (manure was applied, for example, or tillage was different), the rotation was expanded to 4 years, retaining the second year of corn and repeating the year of soybeans. In addition, some rotations with alfalfa or grass seed were simulated as 5-year rotations. Specific rules and procedures were established for using survey data to simulate cover crops, double crops, complex systems such as intercropping and nurse crops, perennial hay in rotations, abandoned crops, re-planting, multiple harvests, manure applications, irrigation, and grazing of cropland before and after harvest.[14]

Use of conservation practices in the Lower Mississippi River Basin was obtained from four sources: (1) NRI-CEAP Cropland Survey, (2) NRCS field offices, (3) USDA Farm Service Agency (FSA), and (4) the 2003 NRI. For each sample point, data from these four sources were pooled and duplicate practices discarded.[15]

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

[12] 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.

[13] 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.

[14] For a detailed description of the rules and procedures, see "Transforming Survey Data to APEX Model Input Files," http://www.nrcs.usda.gov/technical/nri/ceap.

[15] For a detailed description of the rules and procedures for simulation of structural conservation practices, see "Modeling Structural Conservation Practices in APEX," http://www.nrcs.usda.gov/technical/nri/ceap.

Simulating the No-Practice Scenario

The purpose of the no-practice scenario is to provide an estimate of sediment, nutrient, and pesticide loss from farm fields under conditions without the use of conservation practices. The benefits of conservation practices in use within the Lower Mississippi River Basin were estimated by contrasting model output from the no-practice scenario to model output from the baseline conservation condition (2003–06). The only difference between the no-practice scenario and the baseline conservation condition is that the conservation practices are removed or their effects are reversed in the no-practice scenario simulations. There were usually several alternatives that could be used to represent "no practices." The no-practice representations derived for use in this study conformed to the following guidelines.

- **Consistency:** It is impossible to determine what an individual farmer would be doing if he or she had not adopted certain practices, so it is important to represent all practices on all sample points in a consistent manner that is 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. Complexity would not only complicate the modeling process but also hamper the interpretation of results.

- **Historical context avoided:** The no-practice scenario is a technological step backward for conservation, not a chronological step back to a prior era when conservation practices were not used. Although the advent of certain conservation technologies can be dated, the adoption of technology is gradual, regionally diverse, and ongoing. It is also important to retain the overall crop mix in the region, as it in part reflects today's market forces. Therefore, moving the clock back to 1950s (or any other time period) agriculture is not the goal of the no-practice scenario. Taking away the conservation ethic is the goal.

- **Moderation:** The no-practice scenario should provide a reasonable level of inadequate conservation so that a reasonable benefit can be determined, where warranted, but not so severe as to generate exaggerated conservation gains by simulating the worst-case condition. Tremendous benefits could be generated if, for example, nutrients were applied at twice the recommended rates with poor timing or application methods in the no-practice simulation. Similarly, large erosion benefits could be calculated if the no-practice representation for tillage was fall plowing with moldboard plows and heavy disking, which was once common but today would generally be considered economically inefficient.

- **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. The same guideline was followed for pest control—the suite of pesticides used was not adjusted in the no-practice scenario because of the likelihood that alternative pesticides would not be as effective and would result in lower yields under actual conditions.

A deliberate effort was made to adhere to these guidelines to the same degree for all conservation practices so that the overall level of representation would be equally moderate for all practices.

Table 12 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 is simply the removal of the structural practices from the modeling process. In addition, the soil condition is changed from "Good" to "Poor" for the determination of the runoff curve number for erosion prediction.

Overland flow. This group includes such practices as terraces and contouring which slow the flow of water across the field. For the practices affecting overland flow of water and therefore the P factor of the USLE-based equations, the P factor was increased to 1. Slope length is also changed for practices such as terraces to reflect the absence of these slope-interrupting practices.

Concentrated flow. This group of practices is designed to address channelized flow and includes grassed waterways and grade stabilization structures. These practices are designed to prevent areas of concentrated flow from developing gullies or to stabilize gullies that have developed. The no-practice protocol for these practices removes the structure or waterway and replaces it with a "ditch" as a separate subarea. This ditch, or channel, represents a gully; however, the only sediment contributions from the gully will come from downcutting. Headcutting and sloughing of the sides are not simulated in APEX.

Edge of field. These practices include buffers, filters, and other practices that occur outside the primary production area and act to mitigate the losses from the field. The no-practice protocol removes these areas and their management. When the practices are removed, the slope length is also restored to the undisturbed length that it would be if the practices were not in place. (When simulating a buffer in APEX, the slope length reported in the NRI is adjusted.)

Wind control. Practices such as windbreaks or shelterbelts, cross wind ridges, stripcropping or trap strips, and hedgerows are examples of practices used for wind control. The unsheltered distance reflects the dimensions of the field as modeled, 400 meters or 1,312 feet. Any practices reducing the unsheltered distance are removed and the unsheltered distance set to 400 meters.

Table 12. Construction of the no-practice scenario for the Lower Mississippi River Basin

Practice adjusted	Criteria used to determine if a practice was in use	Adjustment made to create the no-practice scenario
Structural practices	1. Overland flow practices present	1. USLE P-factor changed to 1 and slope length increased for points with terraces, soil condition changed from good to poor.
	2. Concentrated flow—managed structures or waterways present	2. Structures and waterways replaced with earthen ditch, soil condition changed from good to poor.
	3. Edge-of-field mitigation practices present	3. Removed practice and width added back to field slope length.
	4. Wind erosion control practices present	4. 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
	Gravity systems	Where conveyance is pipeline, change to gated pipe unless existing system is less efficient. Where conveyance is ditch, change to unlined ditch with portals unless existing system is less efficient.
Nitrogen rate	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 1.9 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)
	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 P over all crops in the crop rotation ≤ 1.1 times total harvest P removal over all crops in rotation.	Increase commercial P fertilizer application rates to reach 2.3 times harvest removal for the crop rotation (proportionate increase in all reported applications over the rotation), accounting also for manure P associated with any increase in manure applications to meet nitrogen application criteria for the no practice scenario. Manure applications were not further increased to meet the higher P 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.
Pesticides	1. Practicing high level of IPM	1. All incorporated applications changed to surface application. For each crop, the first application event after planting and 30 days prior to harvest replicated twice, 1 week and 2 weeks later than original.
	2. Practicing moderate level of IPM	2. Same as for high level of IPM, except replication of first application only 1 time, 1 week after original
	3. Spot treatments	3. Application rates for spot treatments were adjusted upward relative to the baseline rate to represent whole-field application (see text)
	4. Partial field treatments	4. Application rates for partial field treatments were adjusted upward relative to the baseline rate to represent whole-field application (see text)

No-practice representation of conservation tillage

The no-practice tillage protocols are designed to remove the benefits of conservation tillage. For all crops grown with some kind of reduced tillage, including cover crops, the no-practice scenario simulates conventional tillage, based on the STIR (Soil Tillage Intensity Rating) value. Conventional tillage for the purpose of estimating conservation benefits is defined as any crop grown with a STIR value above 100. (To put this in context, no-till or direct seed systems have a STIR of less than 30, and that value is part of the technical standard for Residue Management, No-Till/Strip Till/Direct Seed [NRCS Practice Standard 329]). Those crops grown with a STIR value of less than 100 in the baseline conservation condition had tillage operations added in the no-practice scenario.

Simulating conventional tillage for crops with a STIR value of less than 100 requires the introduction of additional tillage operations in the field operations schedule. For the no-practice scenario, two consecutive tandem disk operations were added prior to planting. In addition to adding tillage, the hydrologic condition for assignment of the runoff curve number was changed from good to poor on all points receiving additional tillage. Points that are conventionally tilled for all crops in the baseline condition scenario are also modeled with a "poor" hydrologic condition curve number.

The most common type of tillage operation in the survey was disking, and the most common disk used was a tandem disk for nearly all crops, in all parts of the region, and for both dryland and irrigated agriculture. The tandem disk has a STIR value of 39 for a single use. Two consecutive disking operations will 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. Although a few sample points will have STIR values in the 80s or 90s after adding the two disking operations, the consistency of an across-the-board increase of 78 is simple and provides the effect of a distinctly more intense tillage system.

These additional two tillage operations were inserted in the simulation one week prior to planting, one of the least vulnerable times for tillage operations because it is close to the time when vegetation will begin to provide cover and protection.

No-practice representation of cover crops

The no-practice protocol for this practice removes the planting of the crop and all associated management practices such as tillage and fertilization. In a few cases the cover crops were grazed; when the cover crops were removed, so were the grazing operations.

No-practice representation of irrigation practices

The no-practice irrigation protocols were designed to remove the benefits of better water management and the increased efficiencies of modern irrigation systems. Irrigation efficiencies are represented in APEX by a combination of three coefficients that recognize 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. These coefficients are combined to form an overall system efficiency that varies with soil type and land slope.

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. If the sample was pressure irrigated, the on-farm conveyance was left as reported because pressure systems were often developed along with conveyance technology that was compatible with the landscape. If the system was gravity-fed, conveyance was assumed to be an open ditch in the no-practice scenario. If the no-practice water delivery system was a ditch, gravity systems were simulated with unlined ditches with portals. Where the no-practice conveyance was pipelines, the gravity system reverted back to gated pipe. Pressure systems were replaced with gravity systems for no-practice scenario except on steep slopes and sandy soils where the pressure system was simulated with hand-move sprinklers. In cases where the efficiency of the baseline system was less than the efficiency of the no-practice system, no reduction in irrigation technology was made for the no-practice scenario.

Primary systems in the no-practice scenario are open discharge (52 percent), portal system from unlined ditches (28 percent), and hand-move sprinklers (17 percent).

No-practice representation of nutrient management practices

The no-practice nutrient management protocols are designed to remove the benefits of proper nutrient management techniques.

The NRCS Nutrient Management standard (590) allows a variety of methods to reduce nutrient losses while supplying a sufficient amount of nutrients to meet realistic yield goals. The standard addresses nutrient loss in two primary ways: (1) by altering rates, form, timing, and methods of application, and (2) by installing buffers, filters, or erosion or runoff control practices to reduce mechanisms of loss. The latter method is covered by the structural practices protocols for the no-practice scenario. The goals of the nutrient management no-practice protocols are to alter 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.

Commercial nitrogen fertilizer rate. For the no-practice scenario, the amount of commercial nitrogen fertilizer applied was—

- increased to 1.9 times harvest removal for non-legume crops receiving less than or equal to 1.4 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 1.6 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.

The ratio of 1.9 for the increased nitrogen rate was determined by the average rate-to-yield-removal ratio for crops exceeding the application-removal ratio of 1.4. Where nitrogen was applied in multiple applications, each application was increased proportionately.

The assessment was made on an average annual basis for each crop in the rotation using average annual model output on nitrogen removed with the yield at harvest in the baseline conservation condition scenario.

Commercial phosphorus fertilizer rate. The threshold for identifying proper phosphorus application rates was 1.1 times the amount of phosphorus taken up by all the crops in rotation and removed at harvest. The threshold is lower for phosphorus than for nitrogen because phosphorus is not lost through volatilization to the atmosphere and much less is lost through other pathways owing to strong bonding of phosphorus to soil particles.

For the no-practice scenario, the amount of commercial phosphorus fertilizer applied was increased to 2.3 times the harvest removal rate for the crop rotation. The ratio of 2.3 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 2.3 threshold.

Manure application rate. For sites receiving manure, the appropriate manure application rate in tons per acre was identified on the basis of the total nitrogen application rate, including both manure and commercial nitrogen fertilizer. Thus, if the total for all applications of nitrogen (commercial fertilizer and manure) was less than or equal to 1.4 times removal at harvest for non-legume crops, the no-practice manure application rate was increased such that the combination of commercial fertilizer and manure applications resulted in a total rate of nitrogen application equal to 1.9 times harvest removal. Both commercial nitrogen fertilizer and the amount of manure were increased proportionately to reach the no-practice scenario rate. For small grains and cotton, the same approach was used using the criteria defined above for commercial nitrogen fertilizer. As done with commercial nitrogen fertilizer, the assessment was made separately for each crop in the rotation.

Any increase in phosphorus from manure added to meet the nitrogen criteria for the no-practice scenario was taken into account in setting the no-practice commercial phosphorus fertilizer application rate.

Thus, no adjustment was made to manure applied at rates below the P threshold of 1.1 in the no-practice scenario because the manure application rate was based on the nitrogen level in the manure.

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 for the no-practice scenario.

Timing of manure applications was not adjusted in the no-practice scenario.

Method of application. Nutrient applications, including manure applications, that were incorporated or banded were changed to a surface broadcast application method for the no-practice scenario.

No-practice representation of pesticide management practices

Pesticide management for conservation purposes is a combination of three types of interrelated management activities:

1. A mix of soil erosion control practices that retain pesticide residues within the field boundaries.
2. Pesticide use and application practices that minimize the risk that pesticide residues pose to the surrounding environment.
3. Practice of Integrated Pest Management (IPM), including partial field applications and spot treatment.

The first activity is covered by the no-practice representation of structural practices and residue and tillage management. The second activity, for the most part, cannot be simulated in large-scale regional modeling because of the difficulty in assuring that any changes in the types of pesticides applied or in the method or timing of application would provide sufficient protection against pests to maintain crop yields.[16] Farmers, of course, have such options, and environmentally conscientious farmers make tradeoffs to reduce environmental risk. But without better information on the nature of the pest problem both at the field level and in the surrounding area, modelers have to resort to prescriptive and generalized approaches to simulate alternative pesticides and application

[16] The APEX model can simulate pesticide applications, but it does not currently include a pest population model that would allow simulation of the effectiveness of pest management practices. Thus, the relative effectiveness of pesticide substitution or changes in other pest management practices cannot be evaluated.

techniques, which would inevitably be inappropriate for many, if not most, of the acres simulated.

The no-practice representation for pesticide management is therefore based on the third type of activity—IPM.

One of the choices for methods of pesticide application on the survey was “spot treatment.” Typically, spot treatments apply to a small area within a field and are often treated using a hand-held sprayer. Spot treatment is an IPM practice, as it requires scouting to determine what part of the field to treat and avoids treatment of parts of the field that do not have the pest problem. The reported rate of application for spot treatments was the rate per acre treated. For the baseline simulation, it was assumed that all spot treatments covered 5 percent of the field. Since the APEX model run and associated acreage weight for the sample point represented the whole field, the application rate was adjusted downward to 5 percent of the per-acre rate reported for the baseline scenario. For the no-practice scenario, the pesticide application rate as originally reported was used, simulating treatment of the entire field rather than 5 percent of the field. In the Lower Mississippi River Basin, there were 29 sample points with spot treatments, representing about 2 percent of the cropped acres.

Partial field treatments were simulated in a manner similar to spot treatments. Partial field treatments were determined using information reported in the survey on the percentage of the field that was treated. (Spot treatments, which are also partial field treatments, were treated separately as described above.) For the baseline scenario, application rates were reduced proportionately according to how much of the field was treated. For the no-practice scenario, the rate as reported in the survey was used, simulating treatment of the entire field. However, this adjustment for the no-practice scenario was only done for partial field treatments on less than one-third of the field, as larger partial field treatments could have been for reasons unrelated to IPM. About 1 percent of the cropped acres in the Lower Mississippi River Basin had partial field treatments of pesticides.

The IPM indicator, described in the previous chapter, was used to adjust pesticide application methods and to increase the frequency of applications to represent “no IPM practice.” For samples classified as having either high or moderate IPM use, all soil-incorporated pesticide applications in the baseline condition were changed to surface applications in the no-practice scenario. For high IPM cases, the first application event between planting and 30 days before harvest was replicated twice for each crop, 1 week and 2 weeks after its original application. For moderate IPM cases, the first application event was replicated one time for each crop, 1 week after its original application.

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. For each CRP sample point, a set of cropping simulations was developed to represent the probable mix of management that would be applied to the point if it were cropped. 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.

Potential for Using Model Simulation to Assess Alternative Conservation Policy Options

The models and databases used in this study to assess the effects of conservation practices are uniquely capable of being used to simulate a variety of alternative policy options and answer “what if” questions. The simulation models incorporate a large amount of natural resource and management data and account for the physical processes that determine the fate and transport of soil, nutrients, and pesticides. What is new and innovative about the CEAP-Cropland model simulations is that the farming activities represented at each of the individual sample points are based on actual farming activities that are consistent with the specific natural resource conditions at each sample point—climate, soil properties, and field characteristics—thus accounting for the diversity of farming operation activities and natural conditions that exist in the “real world.” Moreover, the field-level model results are linked to a regional water quality model that provides a direct connection between activities at the farm field level and offsite water quality outcomes.

While many of the results in this report have implications for policy questions, the primary purpose of the study was to assess the effects of conservation practices. Separate model simulations and scenarios that account for the specific goals of policy would need to be constructed to appropriately address other policy-related issues. Examples of conservation policy issues that could be further explored with the CEAP cropland modeling system include—

- simulation of additional conservation treatment required to meet specific water quality goals, including the extent to which conservation treatment can be used to meet nitrogen and phosphorus reduction goals for the region;
- assessment of the impact of climate change on the performance of existing conservation practices and additional conservation treatment required to maintain the level of water quality in future years;
- determination of the number and kind of acres that would provide the most cost-effective approach to meeting regional conservation program goals, given constraints in budget and staff;
- experimentation with alternatives for new conservation initiatives and the environmental benefits that could be attained;
- simulation of proposed rules for carbon or nutrient trading; evaluation of potential future options for Conservation Reserve Program (CRP) enrollments, including identification of the number and kind of acres that would provide the maximum water quality protection; and
- evaluation and assessment of treatment alternatives for specific environmental issues, such as treatment alternatives for tile-drained acres, treatment alternatives for acres receiving manure, or treatment alternatives to reduce soluble nutrient loss.

Effects of Practices on Fate and Transport of Water

Water is a potent force that interacts with or drives almost all environmental processes acting within an agricultural production system. The hydrologic conditions prevalent in the Lower Mississippi River Basin are critical to understanding the estimates of sediment, nutrient, and pesticide loss presented in subsequent sections. The APEX model simulates hydrologic processes at the field scale—precipitation, irrigation, evapotranspiration, surface water runoff, infiltration, and percolation beyond the bottom of the soil profile.

Baseline condition for cropped acres

Precipitation and irrigation are the sources of water for a field. Annual precipitation over the 47-year simulation averaged about 53 inches in this region. (See figs. 5 and 6.) About 46 percent of the cropped acres are irrigated, at an average application of 21 inches per year. About half the irrigated acres are rice-only cropping systems or include rice in the crop rotation.

Most of the water that leaves the field is lost through evaporation and transpiration (evapotranspiration) (fig. 13). Evapotranspiration is the dominant loss pathway for all cropped acres in this region. On average, about 37 inches per year are lost through evapotranspiration, representing about 61 percent of total water loss (table 13). Model results indicate that evapotranspiration losses vary, however, according to soil characteristics and land cover; evapotranspiration ranges from about 50 percent to about 70 percent of the total amount of water that leaves the field on most acres (fig. 14).

The amount of water lost to surface water and to subsurface flows is about the same in this region, averaging 13.4 inches per year for surface water runoff and 10.6 inches per year for subsurface flow pathways (table 13). Subsurface flow pathways include—

1. deep percolation to groundwater, including groundwater return flow to surface water,
2. subsurface flow that is intercepted by tile drains or drainage ditches, when present, and
3. lateral subsurface outflow or quick-return flow that emerges as surface water runoff, such as natural seeps.

For most acres, water lost in surface water runoff exceeds the amount lost to subsurface flow pathways (figure 14). On average, 22 percent of total water loss is due to surface water runoff and 17 percent is lost to subsurface flow pathways. The amounts vary from acre to acre, as shown in figure 14.

Figure 13. Estimates of average annual water lost through three loss pathways for cropped acres in the Lower Mississippi River Basin

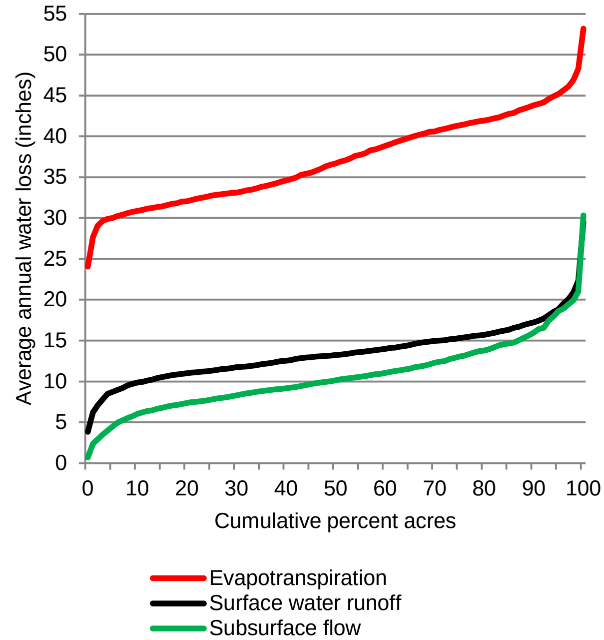
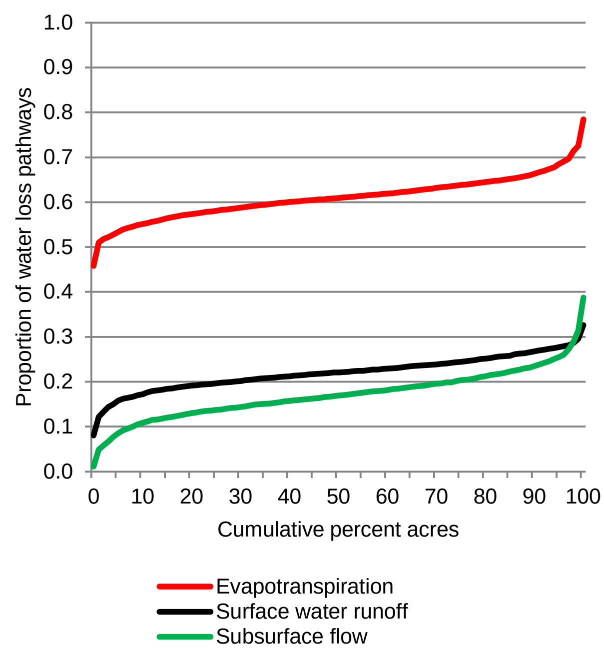


Figure 14. Cumulative distributions of the proportion of water lost through three loss pathways for cropped acres, Lower Mississippi River Basin



Note: The horizontal axis consists of percentiles for each pathway; a given percentile for one curve will not represent the same acres on another curve.

Table 13. Field-level effects of conservation practices on water loss pathways for cultivated cropland in the Lower Mississippi River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (18.8 million acres)				
Water sources				
Non-irrigated acres				
Average annual precipitation (inches)	53.8	53.8	0.0	0
Irrigated acres				
Average annual precipitation (inches)	51.4	51.4	0.0	0
Average annual irrigation water applied (inches)*	20.8	27.6	6.8	25
Water loss pathways				
Average annual evapotranspiration (inches)	37.1	37.0	0.0	0
Average annual surface water runoff (inches)	13.4	15.1	1.7	11
Average annual subsurface water flows (inches)**	10.6	9.4	-1.2***	-13***
Land in long-term conserving cover (1.0 million acres)				
Water sources*				
Average annual precipitation (inches)	54.1	54.1	0.0	0
Average annual irrigation water applied (inches)*	0.0	4.6	4.6	100
Water loss pathways				
Average annual evapotranspiration (inches)	32.3	34.3	2.0	6
Average annual surface water runoff (inches)	8.1	14.2	6.1	43
Average annual subsurface water flow (inches)**	0.2	0.1	-0.05***	-43***

* About 46 percent of the cropped acres in the Lower Mississippi River Basin are irrigated. Land in long-term conserving cover was not irrigated, but some farming practices used to simulate a cropped condition to represent the no-practice scenario included irrigation. Values shown in the table for land in long-term conserving cover are averages over all acres, including non-irrigated acres.
** 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.
*** Represents an average gain in subsurface flows of 1.2 inches per year (13 percent increase) for cropped acres due to the use of conservation practices; represents an average gain of 0.05 inch in subsurface flow for land in long-term conserving cover.
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 B for the 9 subregions.

Tile Drainage

Tile drainage flow is included in the water loss category "subsurface water flows" in this report. (See table 13.) Other components of subsurface water flow include: 1) deep percolation to groundwater, including groundwater return flow to surface water, 2) lateral subsurface flows intercepted by surface drainage ditches, and 3) lateral subsurface outflow or quick-return flow that emerges as surface water runoff, such as natural seeps.

While the farmer survey provided information on whether or not the field with the CEAP sample point had tile drainage, tile drainage flow and loss of soluble nutrients in tile drainage water are not reported separately because other important information on the tile drainage characteristics were not covered in the survey. The missing information includes—

- the depth and spacing of the tile drainage field,
- the extent of the tile drainage network,
- the proportion of the field, or other fields, that benefited from the tile drainage system, and
- the extent to which overland flow and subsurface flow from surrounding areas enters through tile surface inlets.

Without this additional information, it is not possible to accurately separate out the various components of subsurface flow when tile drainage systems are present.

In the Lower Mississippi River basin, only about 5 percent of the cropped acres have some portion of the field that is tile drained, according to the farmer survey (primarily found in subregion 0802).

Effects of conservation practices on cropped acres

Cropped acres. Structural water erosion control practices, residue management practices, and reduced tillage slow the flow of surface water runoff and allow more of the water to infiltrate into the soil.[17] Model simulations indicate that conservation practices have reduced surface water runoff by about 1.7 inches per year averaged over all acres, representing an 11-percent reduction for the region (table 13).

The re-routing of surface water to subsurface flows is shown graphically in figures 15 and 16 for cropped acres. The no-practice scenario curve in figure 15 shows what the distribution of surface water runoff would be if there were no conservation practices in use—more surface water runoff and thus less subsurface flow and less soil moisture available for crop growth.

Reductions in surface water runoff due to conservation practices range from less than zero to above 6 inches per year (fig. 16).[18]The variability in reductions due to practices reflects different levels of conservation treatment as well as differences in precipitation and inherent differences among acres for water to run off.

Use of improved irrigation systems in the Lower Mississippi River Basin increases overall system efficiency from 44 percent in the no-practice scenario to 57 percent in the baseline scenario. This change in efficiency represents an annual decreased need of water diversions of about 6.8 inches per year where irrigation is used (table 13).

Land in long-term conserving cover. Model simulations further show that land in long-term conserving cover (baseline conservation condition) in the region also has, on average, less surface water runoff and more subsurface flow than would occur if the land was cropped (table 13). Evapotranspiration is also slightly lower for land in long-term conservation cover.

Reductions in surface water runoff due to conversion to long-term conserving cover average 6.1 inches per year in this region (table 13), and range from zero to over 10 inches per year for most acres (fig. 17).

Figure 15. Estimates of average annual surface water runoff for cropped acres in the Lower Mississippi River Basin

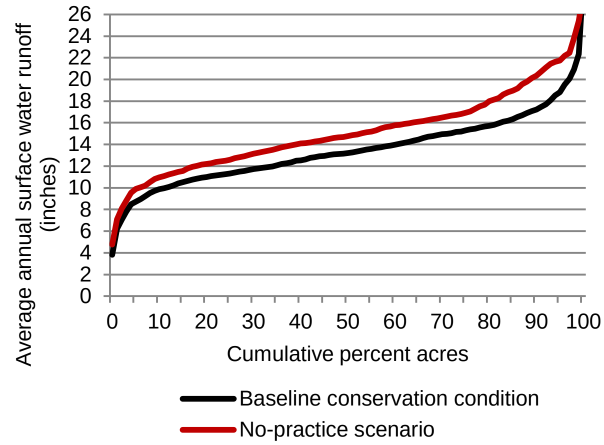


Figure 16. Estimates of average annual reduction in surface water runoff due to the use of conservation practices on cropped acres in the Lower Mississippi River Basin

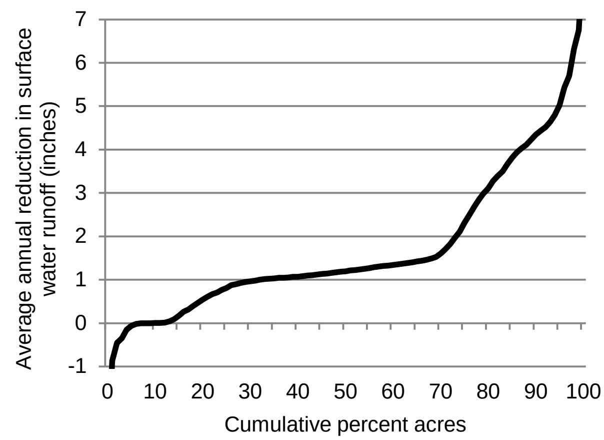
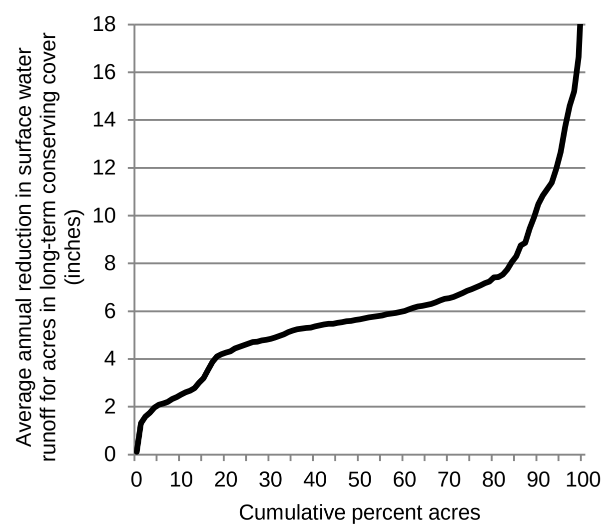


Figure 17. Estimates of average annual reduction in surface water runoff due to conversion to long-term conserving cover in the Lower Mississippi River Basin



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[17] Model simulations did not include increased infiltration for some structural practices—model parameter settings conservatively prevented infiltration of run-on water and its dissolved contaminants in conservation buffers including field borders, filter strips and riparian forest buffers.

[18] About 4 percent of the acres had less surface water runoff in the no-practice scenario than the baseline conservation condition. In general, these gains in surface water runoff due to practices occur on soils with low to moderate potential for surface water runoff together with: (1) higher nutrient application rates in the no-practice scenario that result in more biomass production, which can reduce surface water runoff (typically rotations with hay or continuous corn); or (2) the additional tillage simulated in the no-practice scenario provided increased random roughness of the surface reducing runoff on nearly level landscapes with low crop residue rotations.

Cumulative Distributions Show How Effects of Conservation Practices Vary Throughout the Region

The design of this study provides the opportunity to examine not only the overall mean value for a given outcome, but also the entire distribution of outcomes. This is possible because outcomes are estimated for each of the 1,735 sample points used to represent cropped acres in the Lower Mississippi River Basin and for each of the 564 sample points used to represent land in long-term conserving cover. Cumulative distributions show the full set of estimates and thus demonstrate how conditions and the effects of conservation practices vary throughout the region.

Cumulative distributions shown in this report are plots of the value for each percentile. In figure 15, for example, the curve for average annual surface water runoff for the baseline conservation condition consists of each of the percentiles of the distribution of 1,735 surface water runoff estimates, weighted by the acres associated with each sample point. The 10^{th} percentile for the baseline conservation condition is 9.9 inches per year, indicating that 10 percent of the acres have 9.9 inches or less of surface water runoff, on average. Similarly, the same curve shows that 25 percent of the acres have surface water runoff less than 11.3 inches per year. The 50^{th} percentile—the median—is 13.2 inches per year, which in this case is close to the mean value of 13.4 inches per year. At the high end of the distribution, 90 percent of the acres in this region have surface water runoff less than 17.2 inches per year; and conversely, 10 percent of the acres have surface water runoff greater than 17.2 inches per year.

Thus, the distributions show the full range of outcomes for cultivated cropland acres in the Lower Mississippi River Basin. The full range of outcomes for the baseline condition is compared to that for the no-practice scenario in figure 15 to illustrate the extent to which conservation practices reduce surface water runoff throughout the region.

Figure 16 shows the effects of conservation practices on surface water runoff using the distribution of the *reduction* in surface water runoff, calculated as the outcome for the no-practice scenario minus the outcome for the baseline conservation condition at each of the 1,735 cropped sample points. This distribution shows that, while the mean reduction is 1.7 inches per year, 13 percent of the acres have reductions due to conservation practices greater than 4 inches per year and 4 percent of the acres actually have small increases in surface water runoff (i.e., negative reductions) as a result of conservation practice use.

Effects of Practices on Wind Erosion

Wind velocity, tillage, vegetative cover, and the texture and structure of the soil are primary determinants of wind erosion. Wind erosion removes the most fertile parts of the soil such as the lighter, less dense soil constituents including organic matter, clays, and silts. Wind erosion occurs when the soil is unprotected and wind velocity exceeds about 13 miles per hour near the surface. Wind erosion is estimated in APEX using the Wind Erosion Continuous Simulation (WECS) model. The estimated wind erosion rate is the amount of eroded material leaving the downwind edge of the field.

A concern of crop producers with wind erosion is crop damage to young seedlings exposed to windblown material. Wind erosion rates as low as 0.5 ton per acre have been known to cause physical damage to young seedlings.

Wind erosion can also deposit sediment rich in nutrients into adjacent ditches and surface drainage systems, where it is then transported to water bodies with runoff. Wind erosion rates greater than 2 tons per acre per year can result in significant losses of soil and associated contaminants over time. Wind erosion rates greater than 4 tons per acre can result in excessive soil loss annually and can also have adverse effects on human health.

Baseline condition for cropped acres

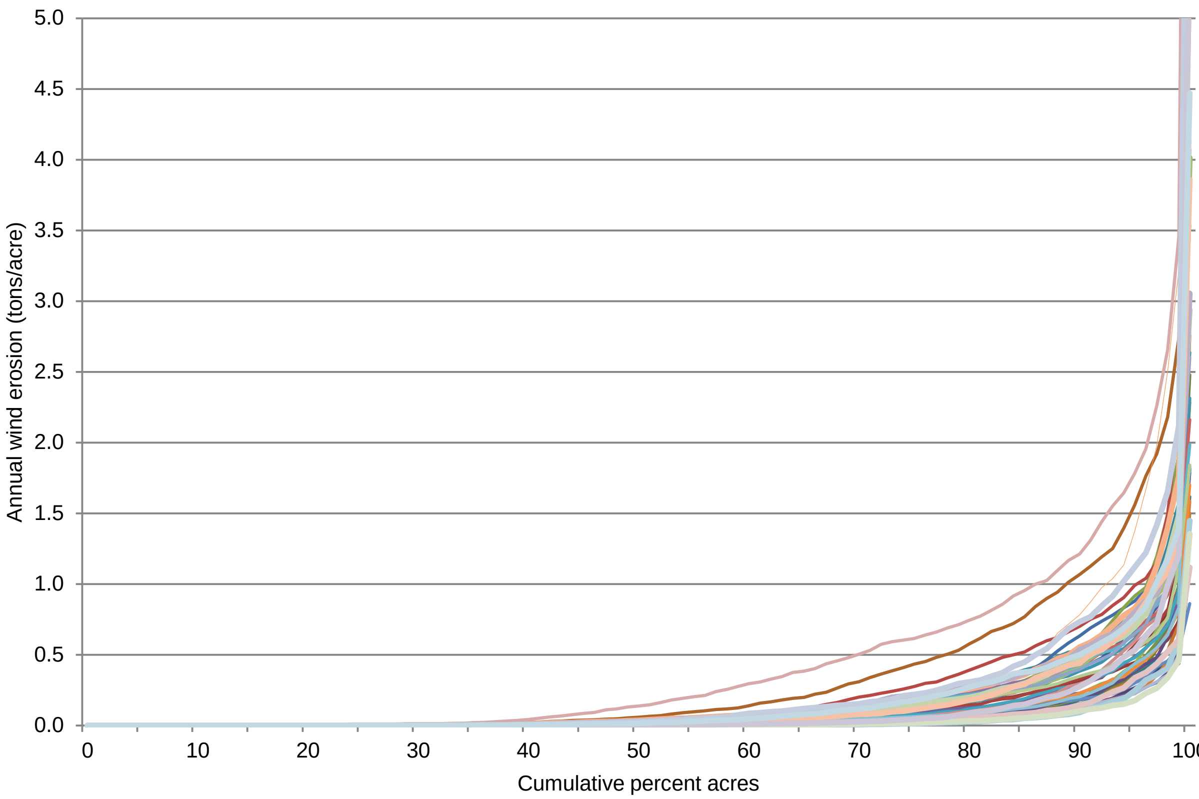
Wind erosion is a relatively minor resource concern in the Lower Mississippi River Basin. For all cropped acres, model simulations show that the average annual rate of wind erosion is 0.12 ton per acre (table 14). However, annual wind erosion can exceed 0.5 ton per acre on some acres in the region in most years and even exceed 2 tons per acre on some acres in some years (fig. 18). In the most extreme year included in the model simulations (representing 1997), wind erosion exceeded 1 ton per acre for 14 percent of the cropped acres and exceeded 2 tons per acre for 3 percent of the acres.

Table 14. Average annual wind erosion (tons/acre) for cultivated cropland in the Lower Mississippi River Basin

	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres	0.12	0.15	0.03	20
Land in long-term conserving cover	<0.01	0.04	0.04	100

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 B for the 9 subregions.

Figure 18. Distribution of annual wind erosion rate for each year of the 47-year model simulation, Lower Mississippi River Basin



Note: This figure shows how annual wind erosion (tons per acre per year) varies within the region and from year to year in the model simulation for cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual wind erosion varies over the region in that year, starting with the acres with the lowest rates and increasing to the acres with the highest rates. The family of curves shows how annual wind erosion rates vary from year to year.

Effects of conservation practices

Farmers address wind erosion using conservation practices designed to enhance the soil's ability to resist and reduce the wind velocity near the soil surface. Properly planned and applied residue management reduces wind erosion by leaving more organic material on the soil surface, which in turn helps preserve soil aggregate stability and promotes further aggregation. Physical barriers such as windbreaks or shelterbelts, herbaceous wind barriers or windbreaks, cross wind trap strips, or ridges constructed perpendicular to the prevailing wind direction also reduce the intensity of wind energy at the surface. Row direction or arrangement, surface roughening, and stripcropping also lessen the wind's energy.

Structural practices for wind erosion control are in use on only 1 percent of the cropped acres in the Lower Mississippi River Basin. However, other practices common in the region, such as residue and tillage management, reduced tillage, and various water erosion control practices, are also effective in reducing wind erosion. Model simulations indicate that conservation practices have reduced the average wind erosion rate by 20 percent in the region (table 14).

Without conservation practices, the average annual wind erosion would have been 0.15 ton per acre per year compared to 0.12 ton per acre average for the baseline conservation condition (table 14). On average, conservation practices have reduced wind erosion by 0.03 ton per acre. Reductions in wind erosion due to conservation practices are higher for some acres than others, reflecting both the level of treatment and the inherent erodibility of the soil (figs. 19 and 20).

Since grass or other cover has been established on land in long-term conserving cover, wind erosion on land in long-term conserving cover is negligible (table 14). If these acres were cropped without any conservation practices, the wind erosion rate on these 1.0 million acres would average about 0.04 ton per acre per year.

Figure 19. Estimates of average annual wind erosion for cropped acres in the Lower Mississippi River Basin

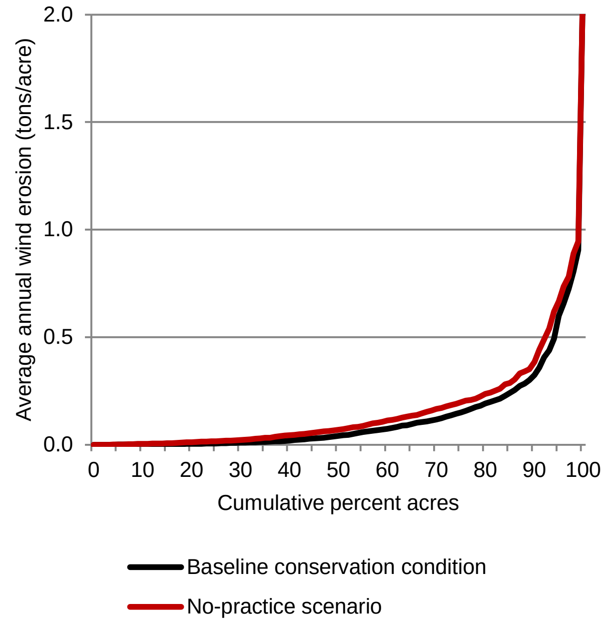
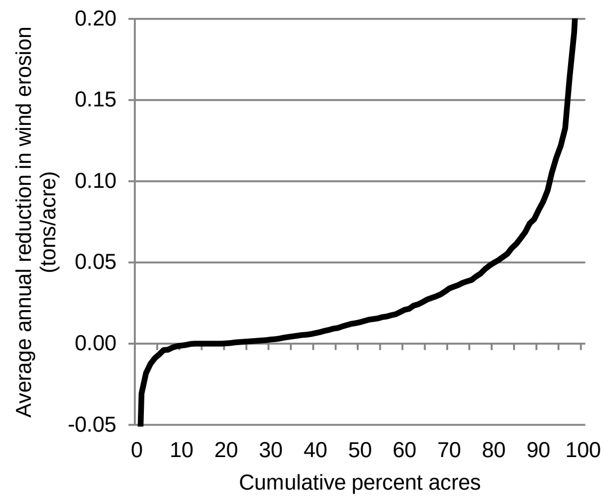


Figure 20. Estimates of average annual reduction in wind erosion due to the use of conservation practices on cropped acres in the Lower Mississippi River Basin



Effects of Practices on Water Erosion and Sediment Loss

Forms of water erosion include sheet and rill, ephemeral gully, classical gully, and streambank. Each type is associated with the progressive concentration of runoff water into channels leading downslope.

Sheet and rill erosion

The first stage of water erosion is sheet and rill erosion, which can be modeled using the Universal Soil Loss Equation (USLE). Sheet and rill erosion is the detachment and movement of soil particles within the field that occurs during rainfall events. Controlling sheet and rill erosion is important for sustaining soil productivity and preventing soil and nutrients from leaving the field.

Model simulations show that sheet and rill erosion on cropped acres in the Lower Mississippi River Basin averages about 1.85 tons per acre per year (table 15). Sheet and rill erosion rates are much higher for highly erodible land, averaging 5.1 tons per acre per year compared to the average annual rate for non-highly erodible land of 1.4 tons per acre.

Model simulation results also show that conservation practices have reduced sheet and rill erosion on cropped acres in the Lower Mississippi River Basin by an average of 0.46 ton per acre per year, representing a 20-percent reduction on average (table 15). The average annual reduction in sheet and rill erosion for highly erodible land is more than 4 times that for non-highly erodible acres (table 15).

For land in long-term conserving cover, sheet and rill erosion has been reduced from 6.9 tons per acre per year if cropped without conservation practices to 0.08 ton per acre (table 15), on average.

Sediment loss from water erosion

Soil erosion and sedimentation are separate but interrelated resource concerns. Sedimentation is that portion of the eroded material that settles out in areas onsite or offsite. Sediment loss, as estimated in this study, includes the portion of the sheet and rill eroded material that is transported beyond the edge of the field and settles offsite as well as some sediment that originates from gully erosion processes. Sediment is composed of detached and transported soil minerals, organic matter, plant and animal residues, and associated chemical and biological compounds. Edge-of-field conservation practices are designed to filter out a portion of the material and reduce sediment loss.

For this study, the APEX model was set up to estimate sediment loss using a modified version of MUSLE, called MUST (not MUSS, as was mistakenly reported in the CEAP reports on the Chesapeake Bay, the Great Lakes, and the Ohio-Tennessee River Basins).[19] The model variant called MUST 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 gully erosion and some ephemeral gully erosion. For this reason, sediment loss rates can exceed sheet and rill erosion rates.

Baseline condition for cropped acres. The average annual sediment loss for cropped acres in the Lower Mississippi River Basin is 3.0 tons per acre per year, according to the model simulation (table 15). As seen for sheet and rill erosion, sediment loss for highly erodible land is much higher than for non-highly erodible land, even though a higher proportion of highly erodible acres have structural water erosion control practices in use.

Sediment loss from farm fields is higher in this region than other regions. Figure 21 shows that, with the conservation practices currently in use in the Lower Mississippi River Basin, annual sediment loss is below 2 tons per acre for only about 30 percent of the acres, including years with high precipitation. In contrast, sediment loss exceeds 4 tons per acre in one or more years on about half of the cropped acres in the region.

The highest losses shown in figure 21 are for acres that have the highest inherent vulnerability to water erosion and have inadequate soil erosion control.

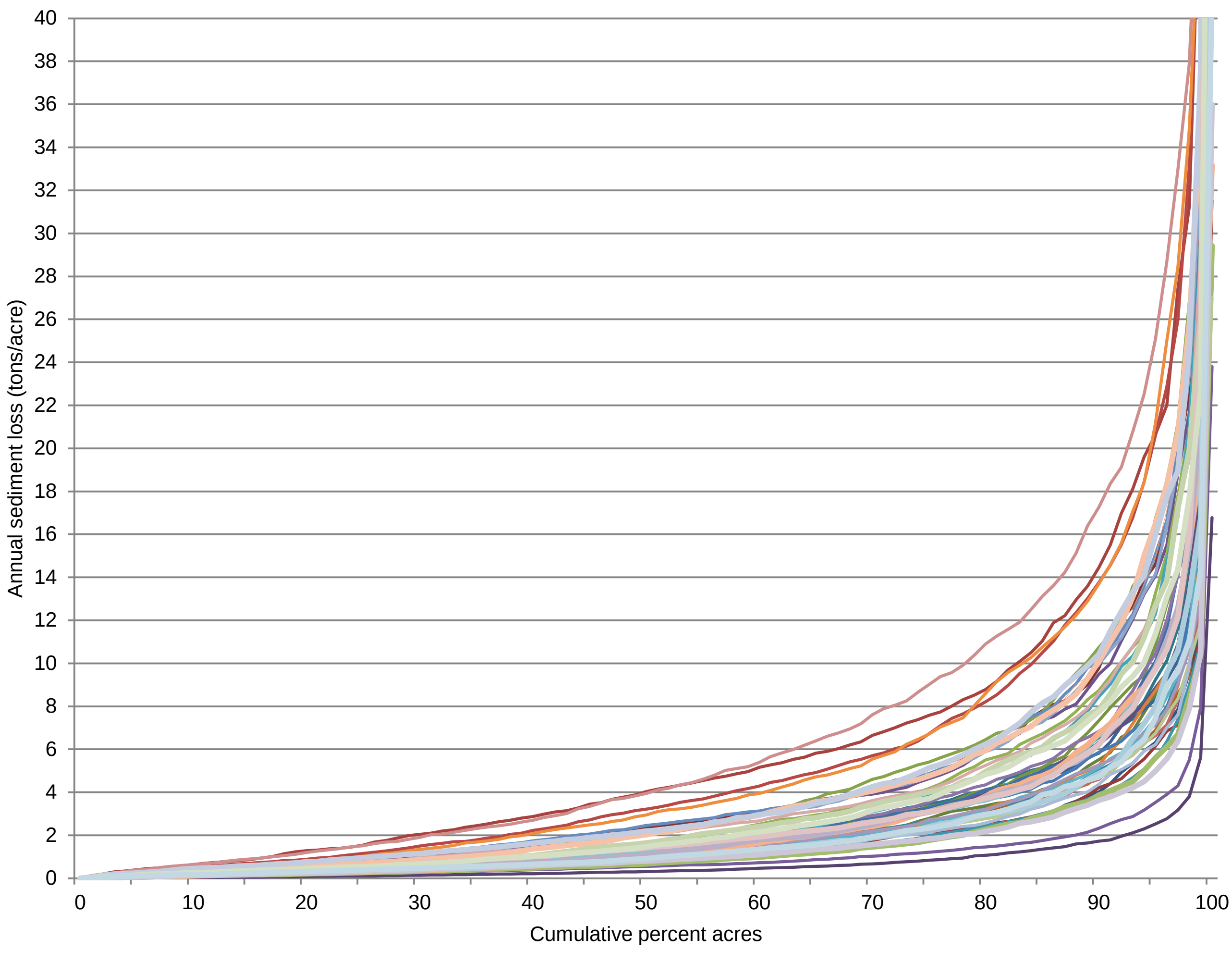
[19] APEX provides a variety of options for modeling erosion and sedimentation, including USLE, RUSLE, MUSS, MUSLE, and MUST. MUST is the most appropriate choice for simulation of sediment loss for small areas (less than 1 hectare, for example).

Table 15. Field-level effects of conservation practices on erosion and sediment loss for cultivated cropland in the Lower Mississippi River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (18.8 million acres)				
Average annual sheet and rill erosion (tons/acre)*	1.85	2.30	0.46	20
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	3.03	4.17	1.14	27
Highly erodible land (12 percent of cropped acres)				
Average annual sheet and rill erosion (tons/acre)*	5.13	7.08	1.95	28
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	7.66	11.91	4.24	36
Non-highly erodible land (88 percent of cropped acres)				
Average annual sheet and rill erosion (tons/acre)*	1.40	1.65	0.25	15
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	2.39	3.11	0.72	23
Land in long-term conserving cover (1.0 million acres)				
Average annual sheet and rill erosion (tons/acre)*	0.08	6.93	6.86	99
Average annual sediment loss at edge of field due to water erosion (tons/acre)	0.08	11.46	11.38	99

* Estimated using the Revised Universal Soil Loss Equation.
**Estimated using MUST, which includes some sediment from gully erosion. See text.
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 B for the 9 subregions.

Figure 21. Distribution of annual sediment loss for each year of the 47-year model simulation, Lower Mississippi River Basin



Note: This figure shows how annual sediment loss (tons per acre per year) varies within the region and from year to year in the model simulation for cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual sediment loss varies over the region in that year, starting with the acres with the lowest sediment loss and increasing to the acres with the highest sediment loss. The family of curves shows how annual sediment loss varies from year to year.

Effects of conservation practices on cropped acres. Model simulations indicate that the use of conservation practices in the Lower Mississippi River Basin has reduced average annual sediment loss from water erosion by 27 percent for cropped acres in the region, including both treated and untreated acres (table 15). Without conservation practices, the average annual sediment loss for these acres would have been 4.17 tons per acre per year compared to 3.03 tons per acre average for the baseline conservation condition.

The effects of conservation practices on reducing sediment loss in this region are small, as shown in figures 22 and 23. Figure 22 shows that about 56 percent of the acres would have more than 2 tons per acre per year sediment loss without practices, on average, compared to 43 percent with conservation practices. Conservation practices have reduced the average annual sediment loss by 1 ton per acre or more on only 27 percent of the cropped acres, as shown in figure 23.

Cropped acres with structural practices had the highest percent reductions, ranging from 40 to 48 percent depending on the extent to which tillage and residue management practices are also present (table 16). Acres with residue management but without any structural practices have much lower reductions, ranging from 19 to 28 percent. Only about 21 percent of cropped acres have structural practices, however, while 69 percent have some form of tillage and residue management.

Figure 22. Estimates of average annual sediment loss for cropped acres in the Lower Mississippi River Basin

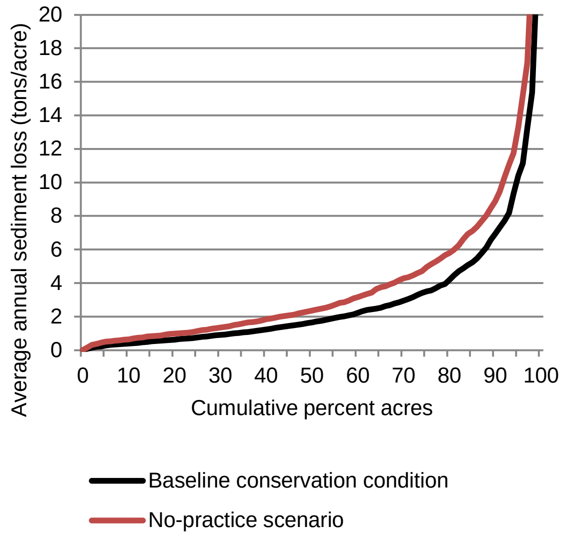


Figure 23. Estimates of average annual reduction in sediment loss due to the use of conservation practices on cropped acres in the Lower Mississippi River Basin

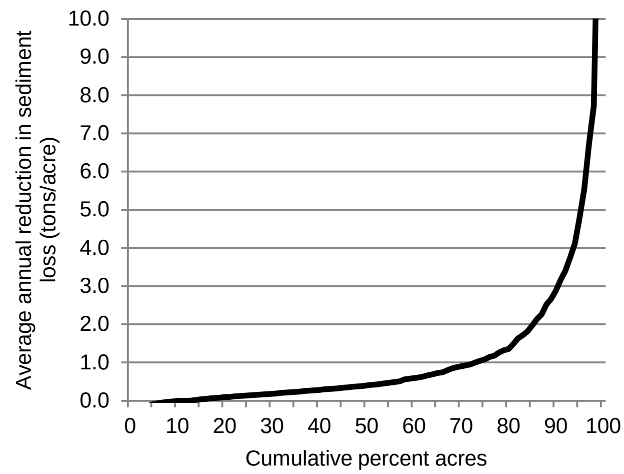


Table 16. Estimates of effects of combinations of structural practices and residue and tillage management on average annual sediment loss for cropped acres in the Lower Mississippi River Basin

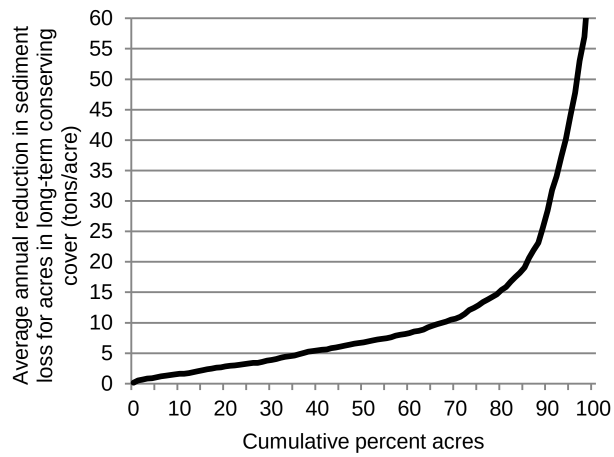
		Average annual sediment loss (tons/acre)			
Conservation treatment	Percent of cropped acres	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
No-till or mulch till with carbon gain, no structural practices	24	1.11	1.55	0.44	28
No-till or mulch till with carbon loss, no structural practices	39	3.32	4.14	0.82	20
Some crops with reduced tillage, no structural practices	6	2.20	2.72	0.51	19
Structural practices and no-till or mulch till with carbon gain	6	1.73	3.30	1.58	48
Structural practices and no-till or mulch till with carbon loss	11	4.59	8.67	4.08	47
Structural practices and some crops with reduced tillage	1	2.40	4.01	1.60	40
Structural practices only	3	3.87	6.83	2.96	43
No water erosion control treatment	10	5.76	5.99	0.23	4
All acres	100	3.03	4.17	1.14	27

Note: Differences in slope, soil texture, hydrologic group, and precipitation for acres in different treatment groups account for some of the differences shown in this table. 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.

Land in long-term conserving cover. Acres in long-term conserving cover have very little erosion or sediment loss, and thus show nearly 100-percent reductions when compared to a cropped condition (table 15). If these 1.0 million acres were still being cropped without any conservation practices, sediment loss would average over 11 tons per acre per year for these acres.

Reductions in sediment loss for land in long-term conserving cover compared to the same acres with crops and no conservation practices vary, as shown in figure 24. About 35 percent of the acres in long-term conserving cover have reductions of less than 5 tons per acre per year. In contrast, reductions greater than 28 tons per acre per year occur on about 10 percent of the acres with long-term conserving cover.

Figure 24. Estimates of average annual reduction in sediment loss due to conversion to long-term conserving cover in the Lower Mississippi River Basin



Effects of Practices on Soil Organic Carbon

The landscape and climate throughout most of the Lower Mississippi River Basin are not conducive to maintaining and enhancing soil organic carbon. The warm, humid climate that exists for most of the year is ideal for degradation of residues as a result of microbial activity. The combination of climate and highly erodible silty soils that dominate some parts of the region is especially detrimental to maintaining soil organic carbon on acres with low-residue crops like cotton and soybeans, or with burning or baling of crop residues as with sugar cane and rice. Even with reduced tillage or no-till systems, carbon maintenance is difficult without the added biomass and soil protection provided by practices such as cover crops. Manure application can help maintain or enhance soil organic carbon, but only about 1.5 percent of cropped acres in this region receive manure, according to the farmer survey.

In this study, estimation of soil organic carbon change is based on beginning soil characteristics that reflect the effects of years of traditional conventional tillage practices and older, lower yielding crop varieties. These effects generally resulted in soils with organic carbon levels at or near their low steady state. Modern high yielding crop varieties with and without the adoption of conservation tillage tend to readily improve the status of carbon in many soils, especially those with beginning stocks far less than the steady state representation of the present management. Beginning the simulations at a lower steady state for carbon allows for a more equitable comparison of conservation practices, particularly conservation tillage. Because of this, however, model estimates of soil organic carbon change may be somewhat larger than shown in other studies. Nevertheless, model estimates obtained in this study fall within the expected range for the continuum of adoption of new crop genetics and tillage practices.

Baseline condition for cropped acres

Model simulation shows that for the baseline conservation condition the average annual soil organic carbon change is a loss of 55 pounds per acre per year, on average (table 17). About 35 percent of cropped acres are gaining soil organic carbon (fig. 25) at an average rate of 75 pounds per acre per year. In contrast, 65 percent of cropped acres are losing soil organic carbon at an average rate of 124 pounds per acre per year.

These estimates account for losses of carbon with sediment removed from the field by wind and water erosion. Loss of soil organic carbon due to wind and water erosion averages about 243 pounds per acre per year for the baseline conservation condition (table 17).

Cropped acres that are gaining soil organic carbon every year provide soil quality benefits that enhance production and reduce the potential for sediment, nutrient, and pesticide losses. Soil organic carbon improves the soil's ability to function with respect to nutrient cycling, improves water holding capacity, and reduces erodibility through enhanced soil aggregate stability.

Cropping systems can be considered to be maintaining soil organic carbon if average annual losses do not exceed 100 pounds per acre per year; this rate of change is typically too small to detect via typical soil sampling over a 20-year period. Applying this criterion, about 35 percent of the acres in the region would be considered to be maintaining—but not enhancing—soil organic carbon (fig. 25). When combined with acres enhancing soil organic carbon, a total of 70 percent of the acres in the region would be either maintaining or enhancing soil organic carbon.

Table 17. Field-level effects of conservation practices on soil organic carbon for cultivated cropland in the Lower Mississippi River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (18.8 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	243	238	-5	-2
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)*	-55	-67	12**	--
Land in long-term conserving cover (1.0 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	136	412	276	67
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	593	-123	716**	--

* Average soil organic carbon values for each sample point were obtained from APEX model output. In the annual output table, the beginning-of-year and end-of-year soil organic carbon values are recorded. The annual change in soil organic carbon is calculated as the difference between end-of-year and beginning-of-year values, which are then averaged over the 47 years of the model simulation for each sample point. Values in the table were obtained by calculating the weighted average over the sample points in the region.

** Gain in soil organic carbon due to conservation practices.

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 B for the 9 subregions.

Effects of conservation practices on cropped acres

In this region, conservation practices have little effect on soil organic carbon levels, as shown in figures 25 and 26. Without conservation practices, the annual change in soil organic carbon would be an average loss of 67 pounds per acre per year, compared to an average loss of 55 pounds per acre for the baseline (table 17). Thus, conservation practice use in the region has resulted in an average annual gain in soil organic carbon of 12 pounds per acre per year on cropped acres.

The average annual gain in soil organic carbon due to practices varies among acres, depending on the extent to which residue and nutrient management is used, as well as the soil's potential to sequester carbon. Very few acres, however, gain more than 100 pounds per acre of soil organic carbon due to conservation practice use (figure 26). Figure 26 also shows that 25 percent of the acres have a higher soil organic carbon increase in the no-practice scenario than in the baseline conservation condition because of the higher fertilization rates, including manure application rates on a few acres, used in the no-practice scenario to simulate the effects of nutrient management practices.

Conservation practice use appears to have little or no effect on the loss of soil organic carbon due to wind and water erosion in this region (table 17). The loss of carbon with wind and water erosion averaged 243 pounds per acre per year for the baseline, and slightly less at 238 pounds per acre for the no-practice scenario. Thus, on average for the region, conservation practice use results in a negligible reduction in the loss of carbon with wind and water erosion—2 percent per year.

For air quality concerns, the analysis centers on the decrease in CO_2 emissions. Soils gaining carbon are obviously diminishing emissions, but so are soils that continue to lose carbon but at a slower rate. For all cropped acres, the gain in soil organic carbon of 12 pounds per acre due to conservation practice use is equivalent to an emission reduction of 0.4 million U.S. ton of carbon dioxide for the Lower Mississippi River Basin.

Figure 25. Estimates of average annual change in soil organic carbon for cropped acres in the Lower Mississippi River Basin

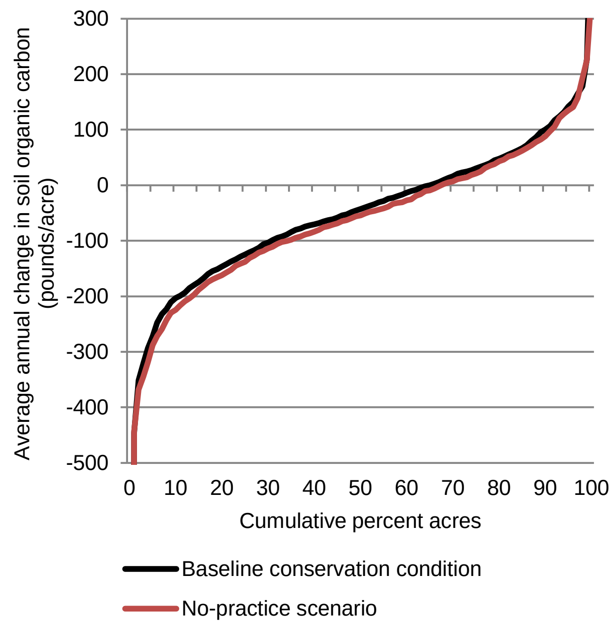
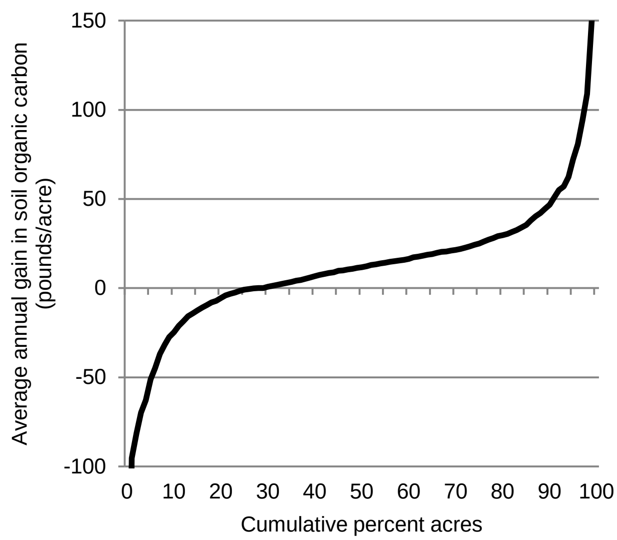


Figure 26. Estimates of average annual gain in soil organic carbon due to the use of conservation practices on cropped acres in the Lower Mississippi River Basin

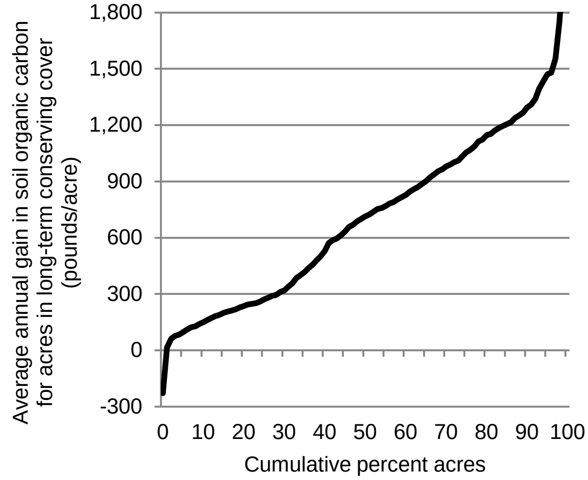


Note: See text for explanation of negative gains due to conservation practice use.

Land in long-term conserving cover

For land in long-term conserving cover, the annual change in soil organic carbon for the baseline conservation condition averages 593 pounds per acre per year (table 17), a rate much higher than for cropped acres. If these acres were still being cropped without any conservation practices, the annual average change in soil organic carbon would be a loss of 123 pounds per acre per year. Thus, the average gain in soil organic carbon due to the long-term conserving cover is 716 pounds per acre per year. This annual gain is much higher on some acres, as shown in figure 27. The gain of 716 pounds per acre is equivalent to an emission reduction of 1.35 million U.S. tons of carbon dioxide for the region.

Figure 27. Estimates of average annual gain in soil organic carbon due to conversion to long-term conserving cover in the Lower Mississippi River Basin



Note: About 1 percent of the acres in long-term conserving cover have decreases in annual carbon gain compared to a cropped condition. Biomass production under long-term conserving cover is typically nitrogen limited. The higher biomass production and resulting crop residue from the fertilization of cropped acres can exceed the carbon benefits of long-term conserving cover under some conditions.

Effects of Practices on Nitrogen Loss

Baseline condition for cropped acres

Plant-available nitrogen sources include application of commercial fertilizer, application of manure, nitrogen produced by legume crops (soybeans, alfalfa, dry beans, and peas), a small amount of manure deposited by grazing livestock, and atmospheric nitrogen deposition. On average, these sources provide about 140 pounds of nitrogen per acre per year for cropped acres in the Lower Mississippi River Basin (table 18).

Model simulations show that about 64 percent of this (89 pounds per acre) is taken up by the crop and removed at harvest in the crop yield, on average, and the remainder is lost from the field through various pathways. [20]

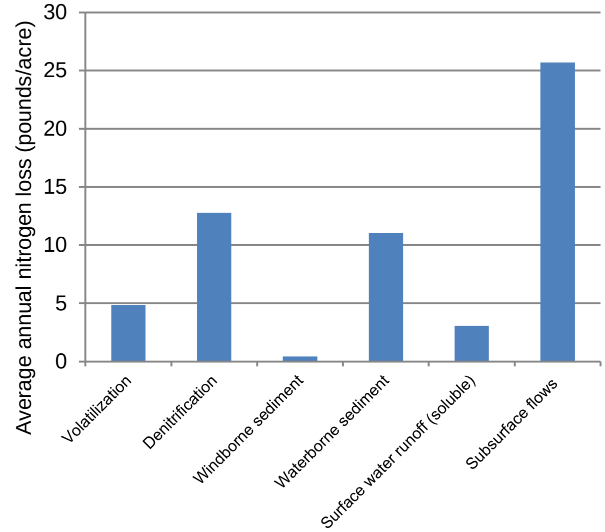
For the baseline conservation condition, the annual average amount of total nitrogen lost from the field, other than the nitrogen removed from the field at harvest, is about 58 pounds per acre. These nitrogen loss pathways are (fig. 28 and table 18)—

- nitrogen lost due to volatilization associated primarily with fertilizer and manure application (average of 4.9 pounds per acre per year);
- nitrogen returned to the atmosphere through denitrification (average of 12.8 pounds per acre per year);
- nitrogen lost with windborne sediment (average of 0.4 pounds per acre per year);
- nitrogen lost with surface runoff (average of 14.1 pounds per acre per year), most of which is nitrogen lost with waterborne sediment; and
- nitrogen loss in subsurface flow pathways (average of 25.7 pounds per acre per year).

The two pathways that impact water quality directly—surface water *and* subsurface flows (average of 39.8 pounds/acre per year) —account for 69 percent of the total nitrogen loss in this region. Most of the nitrogen loss in subsurface flows returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

Total nitrogen losses were higher for highly erodible acres (12 percent of cropped acres) than for non-highly erodible acres. Total nitrogen loss for highly erodible acres averages 63 pounds per acre per year, compared to 57 pounds per acre per year for non-highly erodible acres, even though nitrogen sources were slightly higher for non-highly erodible acres (table 18).

Figure 28. Average annual nitrogen loss by loss pathway, Lower Mississippi River Basin, baseline conservation condition



[20] A small amount may also build up in the soil or be mined from the soil, as shown in table 18 for the variable "change in soil nitrogen."

Model simulation results showed that nitrogen loss to specific pathways varies from acre to acre, as shown in figures 29 and 30. Loss of nitrogen in subsurface flows is the dominant loss pathway for 54 percent of the cropped acres in the region. (The dominant loss pathway was determined for each sample point as the pathway with the highest loss.) Nitrogen loss through denitrification is the dominant loss pathway for 27 percent of the cropped acres, and nitrogen lost with waterborne sediment is the dominant loss pathway for 17 percent of cropped acres. The remaining loss pathways were dominant for only 2 percent of the acres in this region.

Nitrogen loss can be quite high for some acres (fig. 29). Average annual losses of nitrogen in subsurface flows exceed 40 pounds per acre per year for the 19 percent of acres with the highest losses. Average annual losses of nitrogen also exceed 40 pounds per acre through denitrification for 11 percent of cropped acres, and with waterborne sediment for 1 percent of cropped acres.

Figure 29. Cumulative distributions of average annual nitrogen lost through various loss pathways, Lower Mississippi River Basin, baseline conservation condition

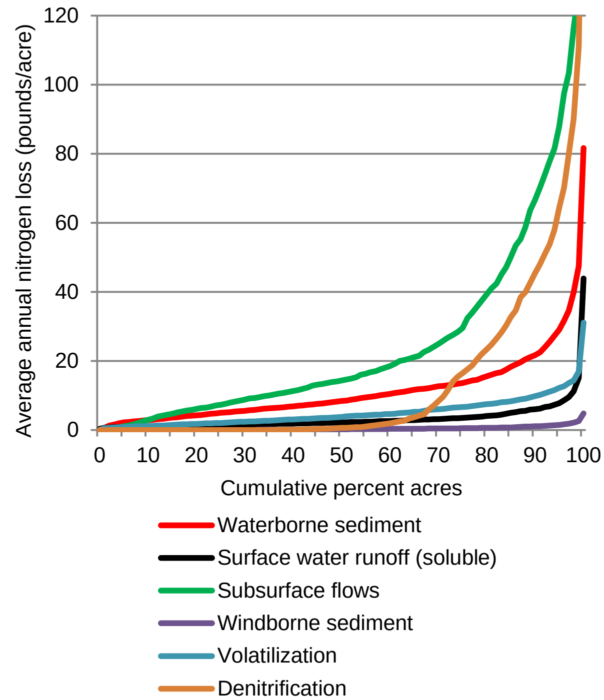
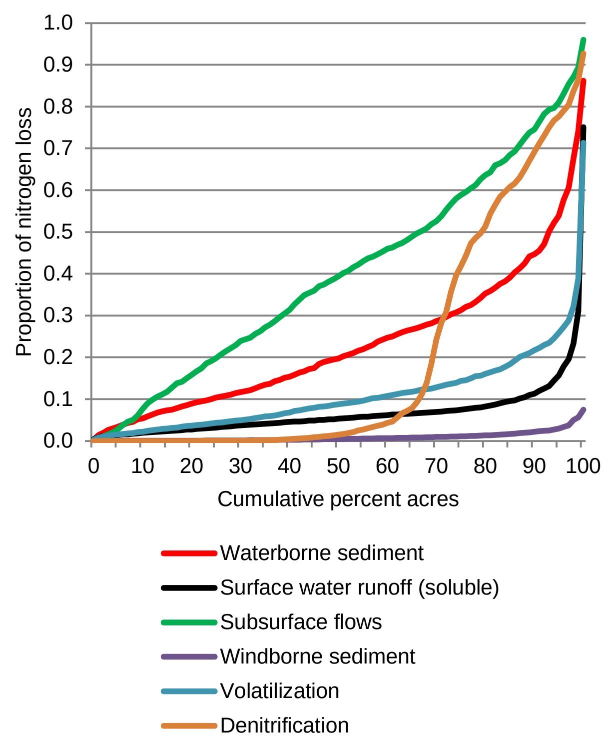


Figure 30. Cumulative distributions of proportions of nitrogen lost through six loss pathways, Lower Mississippi River Basin



Note: The horizontal axis consists of percentiles for each pathway; a given percentile for one curve will not represent the same acres on another curve.

Table 18. Field-level effects of conservation practices on nitrogen sources and nitrogen loss pathways for cropped acres (18.8 million acres) in the Lower Mississippi River Basin

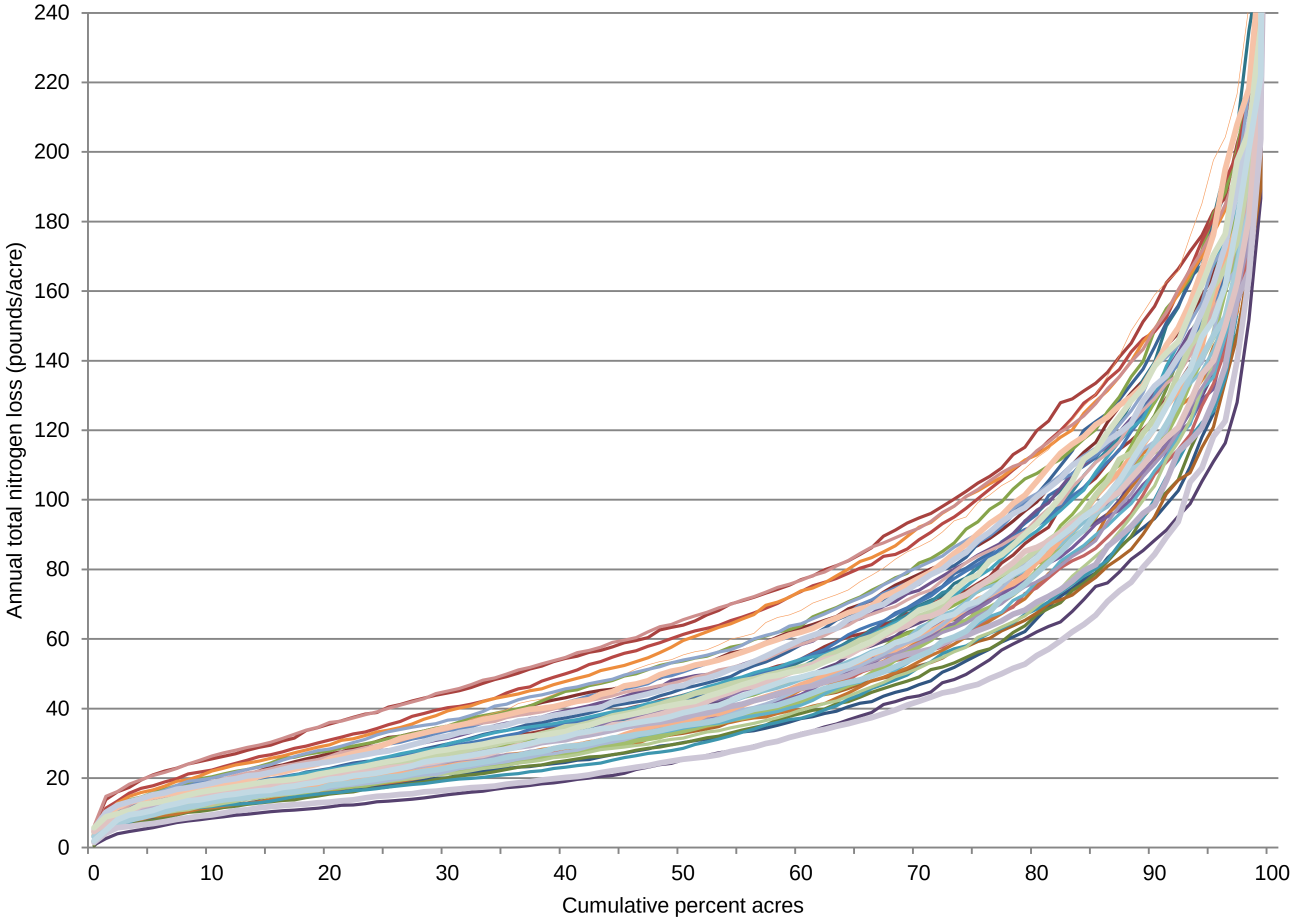
Model simulated outcome	Average annual values in pounds per acre: Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
All cropped acres				
Nitrogen sources				
Atmospheric deposition	6.5	6.5	0.0	0
Bio-fixation by legumes	59.3	57.9	-1.4	-2
Nitrogen applied as commercial fertilizer and manure	74.6	81.8	7.1	9
All nitrogen sources	140.4	146.1	5.7	4
Nitrogen in crop yield removed at harvest	89.2	93.7	4.6*	5
Nitrogen loss pathways				
Nitrogen loss by volatilization	4.9	4.4	-0.4**	-10**
Nitrogen loss through denitrification	12.8	8.8	-4.0**	-45**
Nitrogen lost with windborne sediment	0.4	0.5	0.1	14
Nitrogen loss with surface runoff, including waterborne sediment	14.1	19.1	5.0	26
Nitrogen loss with surface water (soluble)	3.1	6.6	3.5	53
Nitrogen loss with waterborne sediment	11.0	12.5	1.4	11
Nitrogen loss in subsurface flow pathways	25.7	27.1	1.4	5
Total nitrogen loss for all loss pathways	57.9	59.8	2.0	3
Change in soil nitrogen	-7.1	-7.8	-0.7	--
Highly erodible land (12 percent of cropped acres)				
All nitrogen sources	135.4	140.2	4.7	3
Total nitrogen loss for all loss pathways	62.8	69.3	6.5	9
Non-highly erodible land (88 percent of cropped acres)				
All nitrogen sources	141.1	146.9	5.9	4
Total nitrogen loss for all loss pathways	57.2	58.5	1.4	2

* The reduction in yield reflects the increase in nutrients in the representation in the no-practice scenario for nutrient management.
****** On over half of the cropped acres, more nitrogen volatilization occurs with practices than without practices, resulting in only a small change in nitrogen volatilization, on average, for the region due to conservation practices. On nearly three-fourths of cropped acres (73 percent), more nitrogen denitrification occurs with practices than without practices, resulting in a 45-percent increase in nitrogen loss through 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 it is 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 B for the 9 subregions.

Model simulations for the baseline conservation condition indicate that some cropped acres in the Lower Mississippi River Basin are much more susceptible to the effects of weather than other acres and lose much higher amounts of nitrogen (fig. 31). About 25 percent of the acres lose more than 100 pounds per acre in at least some years, and 30 percent lose more than 40 pounds per acre in almost every year. In years with the most extreme weather, up to 8 percent of the acres lose over 160 pounds of nitrogen. Figure 31 also shows that nitrogen loss for the 30 percent of the cropped acres with the highest losses varies significantly from year to year when compared to the 30 percent with the lowest total nitrogen loss.

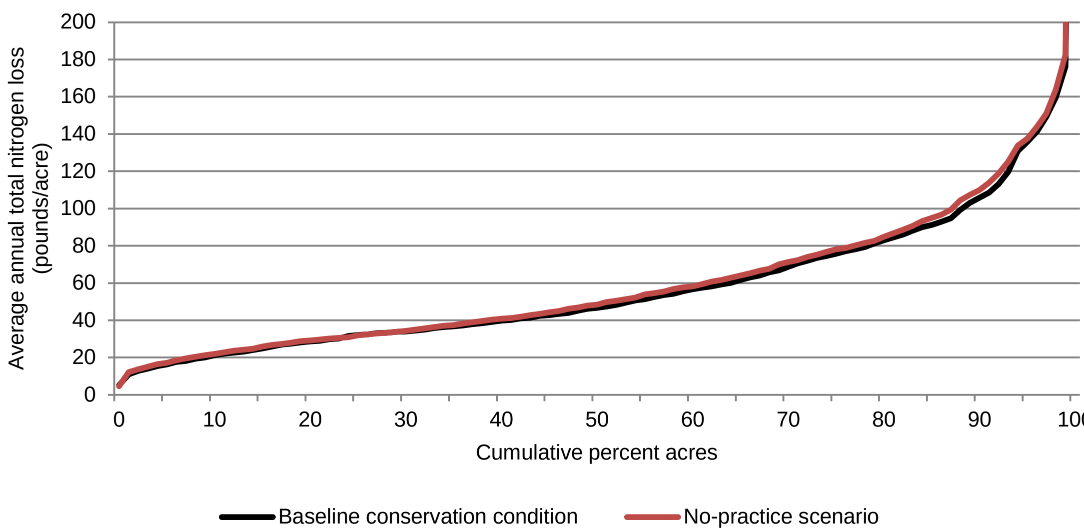
The *average annual* total nitrogen loss for the baseline is shown in figure 32. Acres with the highest nitrogen losses have the highest inherent vulnerability combined with inadequate nutrient management and runoff controls. About 40 percent of cropped acres lose, on average, less than 40 pounds per acre per year, while 11 percent lose 100 pounds or more per acre per year.

Figure 31. Distribution of annual total nitrogen loss for each year of the 47-year model simulation, Lower Mississippi River Basin



Note: This figure shows how annual total nitrogen loss (pounds per acre per year) varied within the region and from year to year in the model simulation for cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual total nitrogen loss varied over the region in that year, starting with the acres with the lowest total nitrogen loss and increasing to the acres with the highest total nitrogen loss. The family of curves shows how annual total nitrogen loss varied from year to year. The average annual curve for the baseline is shown in figure 32 (below).

Figure 32. Estimates of average annual total nitrogen loss for cropped acres in the Lower Mississippi River Basin



Effects of conservation practices on cropped acres

Total nitrogen loss, all pathways. Overall, conservation practices have little effect on nitrogen loss in this region.

Model simulations show that the conservation practices in use in the region have reduced total nitrogen loss from cropped acres by an average of only 2 pounds per acre per year, representing a 3 percent reduction, on average (table 18). Without conservation practices, about 61 percent of the cropped acres would have average annual total nitrogen loss exceeding 40 pounds per acre per year; with conservation practices, 59 percent of acres exceed this level of loss (fig. 32).

The effects of conservation practices vary from acres with increases in nitrogen loss due to practices (negative reductions), to acres with little or no reductions, to acres with significant reductions due to practice use (fig. 33).

About half of the cropped acres have an average annual *increase* in total nitrogen loss due to conservation practice use. Some of these increases are small; 26 percent of the acres have increases of less than 4 pounds per acre. Other acres, however, have increases in nitrogen loss as high as 30-40 pounds per acre per year due to conservation practice use.

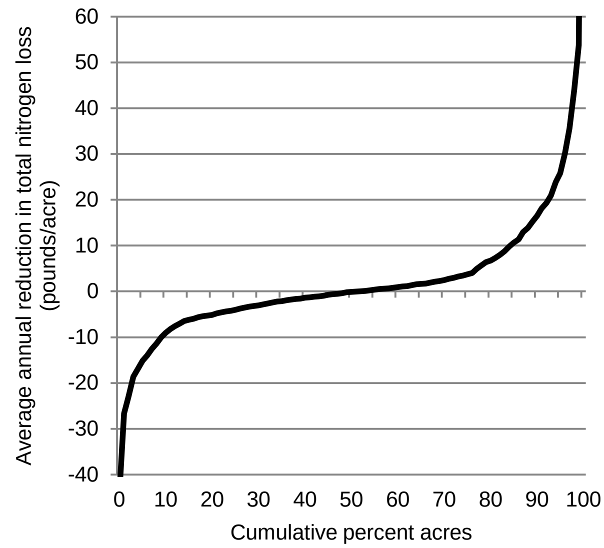
This occurs on soils with relatively high soil nitrogen content and generally low slopes where surface water runoff is redirected to subsurface flow by soil erosion control practices. The higher volume of water moving through the soil profile extracts more nitrogen from the soil than under conditions without conservation practices.

In some cases, the increase in nitrogen loss due to conservation practice use is large enough to offset reductions in other loss pathways. On over half of the cropped acres, more nitrogen volatilization occurs with practices than without practices, resulting in only a small change in nitrogen volatilization, on average, for the region due to conservation practices (table 18). On nearly three-fourths of cropped acres (73 percent), more nitrogen denitrification occurs with practices than without practices, resulting in a 45-percent increase in nitrogen loss through 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.

Cropping systems that include legumes can also result in small overall losses in total nitrogen due to conservation practice use. Cropping systems with legumes have a higher soil nitrogen stock in the baseline conditions because legumes produce proportionately less biofixation of nitrogen under the higher fertilization rates simulated in the no-practice scenario.

About 15 percent of the acres have average annual reductions in total nitrogen loss above 10 pounds per acre per year due to conservation practice use (fig. 33). These are acres with higher levels of treatment and often higher levels of nitrogen use in the no-practice scenario.

Figure 33. Estimates of average annual reduction in total nitrogen loss due to the use of conservation practices on cropped acres in the Lower Mississippi River Basin



Note: See text for discussion of conditions that result in lower total nitrogen loss in the no-practice scenario than in the baseline conservation condition for 51 percent of the acres.

Nitrogen lost with surface runoff. Model simulations show that, on average, nitrogen lost with surface runoff has been reduced 26 percent due to use of conservation practices in the region (table 18). Without conservation practices, about 50 percent of the cropped acres would lose more than 15 pounds per acre per year, on average, compared to 35 percent of the acres in the baseline conservation condition (fig. 34). Figure 35 also shows that about 15 percent of the cropped acres have reductions in nitrogen lost with surface runoff greater than 10 pounds per acre due to conservation practice use. In contrast, however, about 48 percent of the acres have reductions less than 3 pounds per acre due to conservation practices, including 17 percent with small increases in nitrogen lost with surface water due to conservation practice use (less than 3 pounds per acre per year in most cases).

Nitrogen loss in subsurface flows. Conservation practices are effective in reducing nitrogen loss in subsurface flows on some acres in this region, but make little difference on most acres and even result in increases in nitrogen loss in subsurface flows for 50 percent of cropped acres (figs. 35 and 36). (Increases in nitrogen loss in subsurface flows are represented in figure 35 as negative reductions.) On average, conservation practices have reduced nitrogen loss in subsurface flows from 27.1 pounds per acre without practices to 25.7 pounds per acre with practices, representing an average reduction of only 1.4 pounds per acre per year (5-percent reduction) (table 18). Figure 35 shows that reductions in average annual nitrogen loss in subsurface flows exceed 10 pounds per acre for only 9 percent of the cropped acres.

The increases in nitrogen loss in subsurface flows due to conservation practices on 50 percent of the cropped acres (fig. 35) are largely due to relatively weak nutrient management practices on acres with erosion control treatment. A portion of the reduction in nitrogen lost with surface runoff is re-routed to subsurface loss pathways, resulting in gains or only small reductions in nitrogen loss in subsurface flows. This re-routing of surface water runoff to subsurface flow pathways results in additional nitrogen being leached from the soil, diminishing and sometimes offsetting the positive effects of conservation practices on other nitrogen loss pathways.

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 will provide the environmental protection needed.

Figure 34. Estimates of average annual nitrogen lost with surface runoff (including waterborne sediment) for cropped acres in the Lower Mississippi River Basin

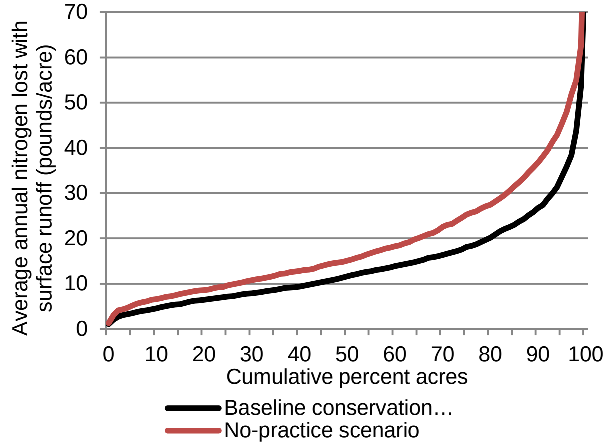
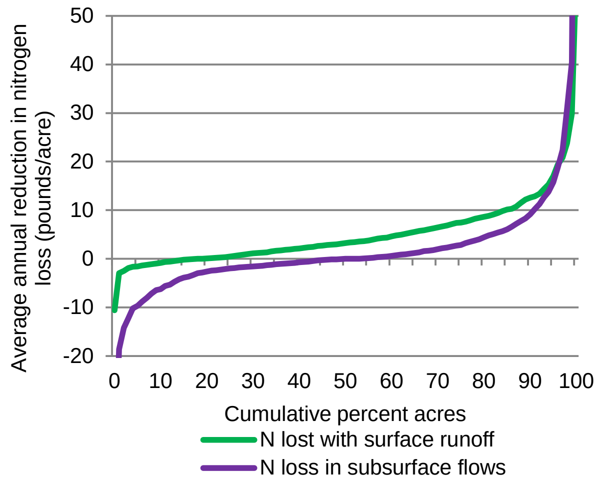
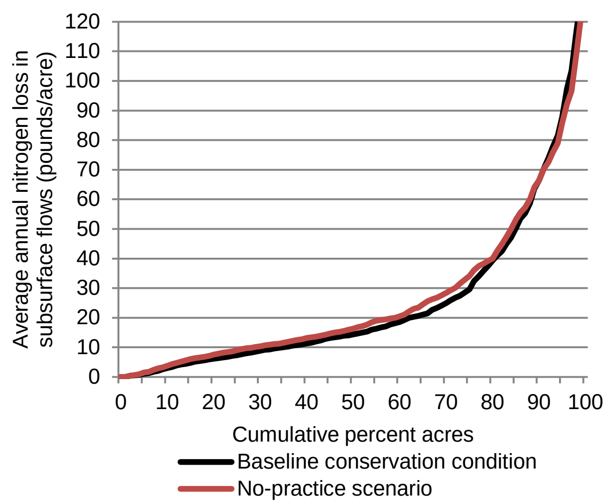


Figure 35. Estimates of average annual reduction in nitrogen lost with surface runoff and reduction in nitrogen loss in subsurface flows due to the use of conservation practices on cropped acres in the Lower Mississippi River Basin



Note: See text for discussion of negative reductions for loss of nitrogen in subsurface flows.

Figure 36. Estimates of average annual nitrogen loss in subsurface flows for cropped acres in the Lower Mississippi River Basin



Tradeoffs in Conservation Treatment

Conservation practices applied on cropland are, for the most part, synergistic. The benefits accumulate as more practices are added to the designed systems. However, when only a single resource concern is addressed (such as soil erosion), antagonism between the practices and other resource concerns may occur. That is why it is essential that all resource concerns be considered during the conservation planning process. Most of the time the tradeoffs are much smaller than the magnitude of the primary resource concerns. Common examples are:

- Terraces and conservation tillage are planned to solve a serious water erosion problem. However, in some areas there may be concern about seeps at the lower part of the field. The planned practices will solve the erosion problem, but could exacerbate the seep problem under some conditions. Ignoring that fact does not make for an adequate conservation plan.
- Conservation tillage is planned for erosion control on a cropland field with a high water table. The reduction in runoff may increase leaching of nitrates into the shallow water table. This potential secondary problem requires additional nutrient management practices to address the concern.
- Implementation of a nutrient management plan may reduce the amount of manure added to a field and thus reduce the loss of nutrients to surface or groundwater. However, this reduction in organic material added to the field may also reduce the soil organic matter or reduce the rate of change in soil organic matter.
- Figure 33 shows that about 51 percent of the acres have an increase in total nitrogen loss due to conservation practice use, although most of these increases are small. This result occurs primarily on soils with relatively high soil nitrogen content and generally low slopes where the surface water runoff is re-directed to subsurface flow by soil erosion control practices. The higher volume of water moving through the soil profile extracts more nitrogen from the soil than under conditions without conservation practices. For these fields, the nutrient management component of a farmer’s conservation plan would need to be enhanced to reduce or eliminate the negative effects of soil erosion control practices on nitrogen loss.

A *comprehensive planning process* is used to identify the appropriate combination of practices needed to address multiple resource concerns by taking into account the specific inherent vulnerabilities associated with each field. To ensure that proper consideration is given to the effects of conservation practices on *all* of the resource concerns, USDA/NRCS developed a comprehensive planning tool referred to as CPPE (Conservation Practice Physical Effects). The CPPE is included in the Field Office Technical Guide. Conservation planners are expected to use CPPE as a reference to ensure that *all* resource concerns are addressed in conservation plans.

Land in long-term conserving cover

Total nitrogen loss has been reduced by about 92 percent on the 1.0 million acres in long-term conserving cover, compared to conditions that would be expected had the acres remained in crops without conservation practices (table 19). Converting cropped acres to long-term conserving cover is very effective in reducing total nitrogen loss, as demonstrated in figure 37 and table 19, although the reductions are much higher for some acres than others. Conversion of cropped acres to long-term conserving cover in the region has reduced total nitrogen loss from these acres from an average loss of 76 pounds per acre per year to about 6 pounds per acre per year, a reduction of 70 pounds per acre per year.

Conversion of cropped acres to long-term conserving cover has also reduced nitrogen lost with surface runoff from these acres from an average loss of 32 pounds per acre per year to about 1 pound per acre per year, a reduction of 31 pounds per acre per year (table 19). Subsurface losses have been reduced from 34 pounds per acre per year to an average of less than 1 pound per acre, a reduction of 33 pounds per acre per year, on average.

Figure 37. Estimates of average annual total nitrogen loss for land in long-term conserving cover in the Lower Mississippi River Basin

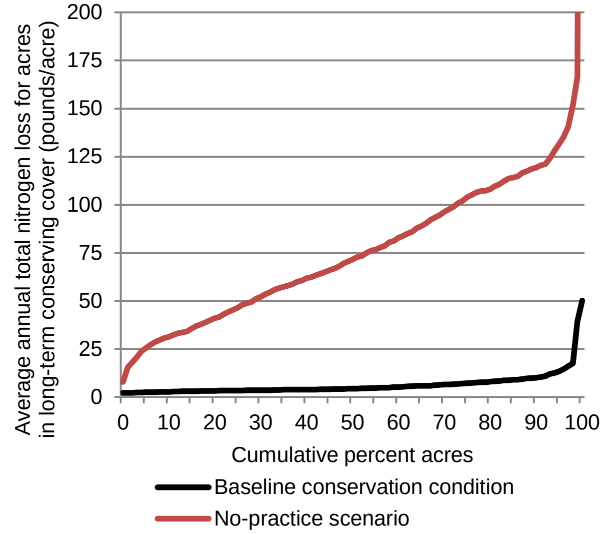


Table 19. Effects of conservation practices on nitrogen sources and nitrogen loss pathways for land in long-term conserving cover (1.0 million acres), Lower Mississippi River Basin

	Average annual values in pounds per acre			
Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Nitrogen sources				
Atmospheric deposition	4.9	4.9	0.0	0
Bio-fixation by legumes	10.3	47.2	36.8	78
Nitrogen applied as commercial fertilizer and manure	0.0	88.3	88.3	100
All nitrogen sources	15.2	140.3	125.1	89
Nitrogen in crop yield removed at harvest	1.7*	77.6	75.8	98
Nitrogen loss pathways				
Nitrogen loss by volatilization	3.8	5.0	1.2	24
Nitrogen loss through denitrification	0.5	4.8	4.3	89
Nitrogen lost with windborne sediment	0.0	0.1	0.1	100
Nitrogen loss with surface runoff, including waterborne sediment	1.2	32.3	31.1	96
Nitrogen loss with surface water (soluble)	0.3	7.1	6.7	95
Nitrogen loss with waterborne sediment	0.9	25.3	24.4	96
Nitrogen loss in subsurface flow pathways	0.6	33.6	33.0	98
Total nitrogen loss for all pathways	6.1	75.8	69.7	92
Change in soil nitrogen	7.9	-13.2	-21.1	--

* Harvest was simulated on acres planted to trees where expected tree age is less than the 47 years included in the model simulation. At tree harvest time, the grass also is removed and replanted.

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

Effects of Practices on Phosphorus Loss

Phosphorus, like nitrogen, is an essential element needed for crop growth. Unlike nitrogen, phosphorus rarely occurs in a gaseous form so the agricultural model has no atmospheric component. Phosphorus compounds that are soluble in water are available for plants to use. Although total phosphorus is plentiful in the soil, only a small fraction is available at any one time for plant uptake. Farmers apply commercial phosphate fertilizers to supplement low quantities of plant-available phosphorus in the soil.

Throughout this report, phosphorus results are reported in terms of elemental phosphorus (i.e., not as the phosphate fertilizer equivalent).

Baseline condition for cropped acres

In the model simulations for the Lower Mississippi River Basin, about 19.5 pounds per acre of phosphorus were applied as commercial fertilizer or in manure to cropped acres, on average, in each year of the model simulation (table 20). About 70 percent of the phosphorus applied is taken up by the crop and removed at harvest—13.7 pounds per acre per year, on average.

Total phosphorus loss for all loss pathways averaged 5.4 pounds per acre per year in the baseline conservation condition (table 20). These phosphorus loss pathways are—

- phosphorus lost with windborne sediment (average of 0.1 pound per acre per year);
- phosphorus lost with waterborne sediment (average of 3.0 pound per acre per year);
- soluble phosphorus lost to surface water, including soluble phosphorus in surface water runoff, and soluble phosphorus that infiltrates into the soil profile but quickly returns to surface water either through quick return lateral flow or intercepted by drainage systems (average of 2.3 pounds per acre per year); and
- soluble phosphorus that percolates through the soil profile into the groundwater (average of less than 0.05 pound per acre per year).

Most phosphorus is lost from farm fields through the two principal loss pathways in the Lower Mississippi River Basin—phosphorus attached to soil particles in waterborne sediment (55 percent of total loss, on average) and soluble phosphorus lost to surface water (42 percent of total loss, on average) (fig. 38, table 20). Phosphorus lost with wind erosion accounts for about 2 percent. A very small amount of soluble phosphorus is lost through percolation into groundwater. The percentage of phosphorus lost in each of the principal loss pathways varies from acre to acre, as shown in figure 39 for cropped acres.

Phosphorus lost with waterborne sediment is the dominant loss pathway for 60 percent of cropped acres. (The dominant loss pathway was determined for each sample point as the pathway with the highest loss.) Soluble phosphorus lost with surface water runoff and lateral flow (including discharge to drainage tiles, ditches, and seeps) was the dominant loss pathway for 40 percent of cropped acres.

Phosphorus losses are also twice as high for highly erodible land as for non-highly erodible land (table 20). Phosphorus losses on the 12 percent of the cropped acres that are highly erodible average about 9.8 pounds per acre per year, compared to 4.8 pounds per acre per year for non-highly erodible acres.

Figure 38. Estimates of average annual phosphorus lost through various loss pathways, Lower Mississippi River Basin, baseline conservation condition

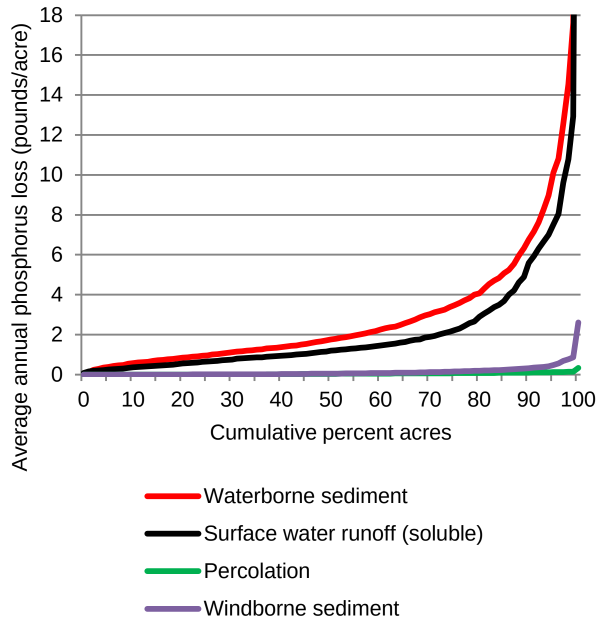


Figure 39. Cumulative distributions of the proportion of phosphorus lost through various loss pathways, Lower Mississippi River Basin, baseline conservation condition

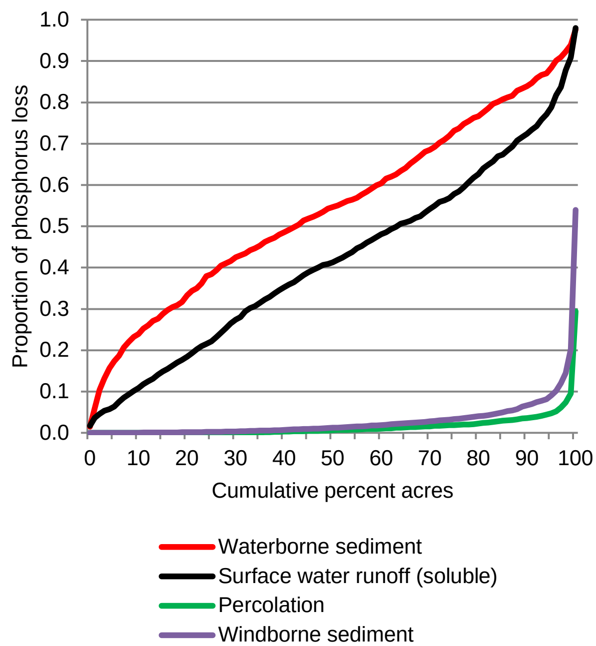


Table 20. Field-level effects of conservation practices on phosphorus sources and phosphorus loss pathways for cultivated cropland in the Lower Mississippi River Basin

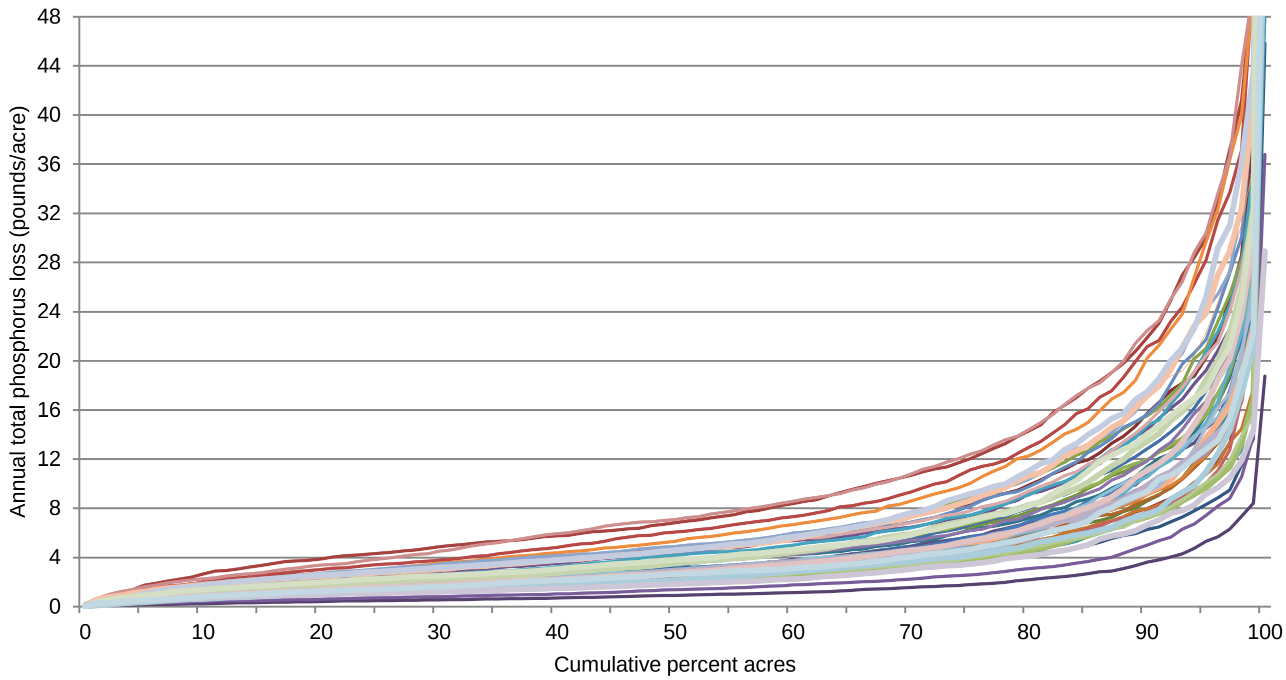
Model simulated outcome	Average annual values in pounds per acre			
	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (18.8 million acres)				
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	19.5	28.0	8.4	30
Phosphorus in crop yield removed at harvest	13.7	14.4	0.8	5
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.1	0.2	0.1	34
Phosphorus lost to surface water (sediment attached and soluble)*	5.2	8.6	3.4	39
Soluble phosphorus lost to surface water*	2.3	4.3	2.0	47
Phosphorus loss with waterborne sediment	3.0	4.3	1.4	31
Soluble phosphorus loss to groundwater	0.0	0.0	0.0	2
Total phosphorus loss for all loss pathways	5.4	8.9	3.5	39
Change in soil phosphorus	0.3	4.6	4.3	--
Highly erodible land (12 percent of cropped acres)				
Phosphorus applied as commercial fertilizer and manure	21.2	24.8	3.6	15
Total phosphorus loss for all loss pathways	9.8	12.5	2.8	22
Non-highly erodible land (88 percent of cropped acres)				
Phosphorus applied as commercial fertilizer and manure	19.3	28.4	9.1	32
Total phosphorus loss for all loss pathways	4.8	8.4	3.6	43
Land in long-term conserving cover (1.0 million acres)				
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	0.0	29.4	29.4	100
Phosphorus in crop yield removed at harvest	0.93**	13.12	12.19	93
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.00	0.03	0.03	100
Phosphorus lost to surface water (sediment attached and soluble)*	0.23	13.50	13.27	98
Soluble phosphorus lost to surface water*	0.16	4.29	4.13	96
Phosphorus loss with waterborne sediment	0.07	9.21	9.14	99
Soluble phosphorus loss to groundwater	0.09	0.04	-0.06	-147
Total phosphorus loss for all loss pathways	0.32	13.57	13.24	98
Change in soil phosphorus	-1.46	2.60	4.07	--

* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.
** Harvest was simulated on acres planted to trees where expected tree age is less than the 47 years included in the model simulation. At tree harvest time, the grass also is removed and replanted.
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 B for the 9 subregions.

Total phosphorus loss varies considerably from year to year and from acre to acre, as shown in figure 40. About 20 percent of the acres lose less than 4 pounds per acre per year through the various loss pathways under *all* weather conditions (fig. 40). In contrast, 42 percent of the acres lose more than 8 pounds per acre in at least some years. Phosphorus losses can exceed 20 pounds per acre in some years for more than 10 percent of cropped acres.

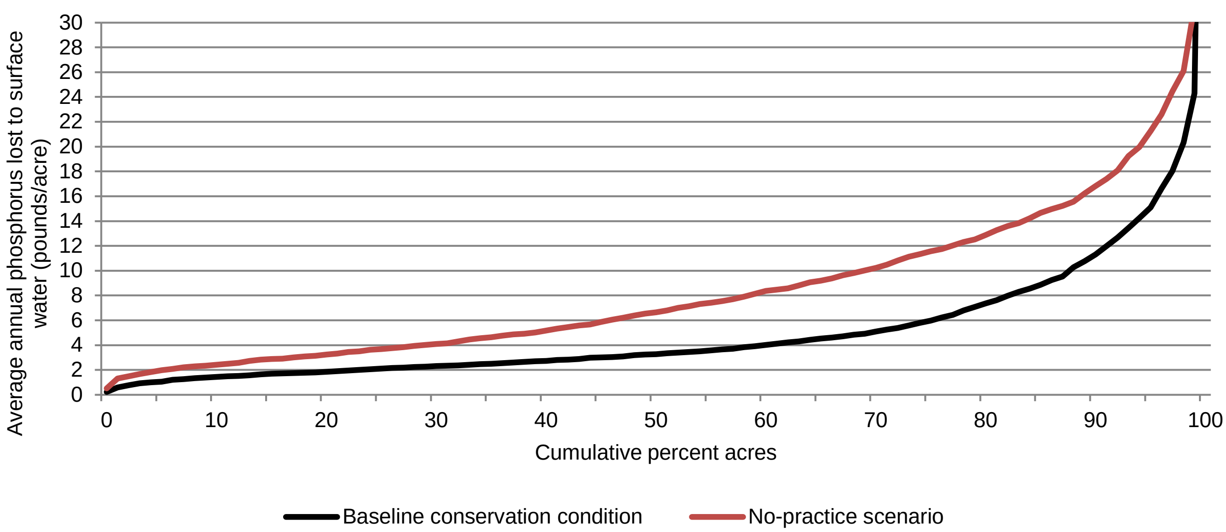
The *average annual* phosphorus lost to surface water for the baseline is shown in figure 41. Acres with the highest phosphorus losses have the highest inherent vulnerability combined with inadequate nutrient management and runoff controls. About 60 percent of cropped acres lose, on average, less than 4 pounds per acre per year, while 12 percent lose 10 pounds or more per acre per year.

Figure 40. Distribution of annual total phosphorus loss for each year of the 47-year model simulation, Lower Mississippi River Basin



Note: This figure shows how annual total phosphorus loss (pounds per acre per year) varied within the region and from year to year in the model simulation on cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual total phosphorus loss varied over the region in that year, starting with the acres with the lowest total phosphorus loss and increasing to the acres with the highest total phosphorus loss. The family of curves shows how annual total phosphorus loss varied from year to year.

Figure 41. Estimates of average annual phosphorus lost to surface water (sediment attached and soluble)* for cropped acres in the Lower Mississippi River Basin



***** Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.

Effects of conservation practices on cropped acres

Conservation practices have reduced total phosphorus lost to surface water for cropped acres by 39 percent, reducing the average loss from 8.6 pounds per acre per year if conservation practices were not in use to 5.2 pounds per acre per year for the baseline conservation condition (table 20). On average, conservation practices have reduced phosphorus loss with waterborne sediment by 31 percent and soluble phosphorus lost to surface water by 47 percent (table 20).

The effects of conservation practices on phosphorus lost to surface water (soluble and sediment attached) are shown in figures 41 and 42 for cropped acres. Without conservation practices in use, 71 percent of cropped acres would exceed 4 pounds per acre per year of phosphorus lost to surface water, on average, compared to 40 percent with conservation practice use as represented in the baseline conservation condition (fig. 41).

The effects of conservation practices on phosphorus lost to surface water vary considerably throughout the Lower Mississippi River Basin, as shown in figure 42. At the high end, reductions exceed 10 pounds per acre for about 10 percent of the acres. These are acres with higher levels of treatment and often higher levels of phosphorus use in the no-practice scenario.

For about 17 percent of the acres, however, conservation practice use results in *increases* in phosphorus lost to surface water, although the increases exceeded 0.5 pound per acre for only 8 percent of the acres. (Increases in phosphorus lost to surface water are represented in figure 42 as negative reductions.) In some cases these increases in phosphorus loss are the result of small increases in surface water runoff due to conservation practice use (see fig. 16 and associated footnote). In other cases, however, increases in phosphorus loss due to conservation practices resulted from a combination of practices and landscape conditions that cause phosphorus levels to concentrate near or on the soil surface, where it is more vulnerable to surface runoff. On these types of landscapes, improved phosphorus management along with light incorporation and maintenance of crop residue on the soil surface may be necessary to reduce soluble phosphorus loss.

Land in long-term conserving cover

For land in long-term conserving cover, total phosphorus loss is 98 percent less than it would have been if crops had been grown and no conservation practices used, reducing total phosphorus loss by 13.6 pounds per acre per year, on average (table 20). Reductions range from less than 5.6 pounds per acre for the 25 percent of acres with the lowest reductions to over 26.6 pounds per acre per year for the 10 percent of acres with the highest reductions (fig. 43).

Figure 42. Estimates of average annual reduction in phosphorus lost to surface water (sediment attached and soluble) due to conservation practices on cropped acres in the Lower Mississippi River Basin

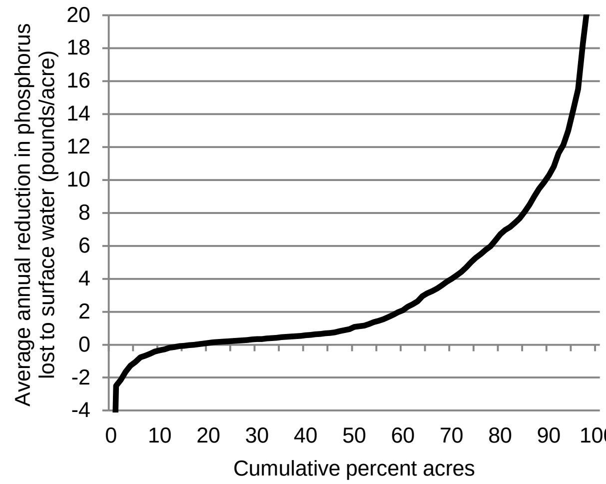
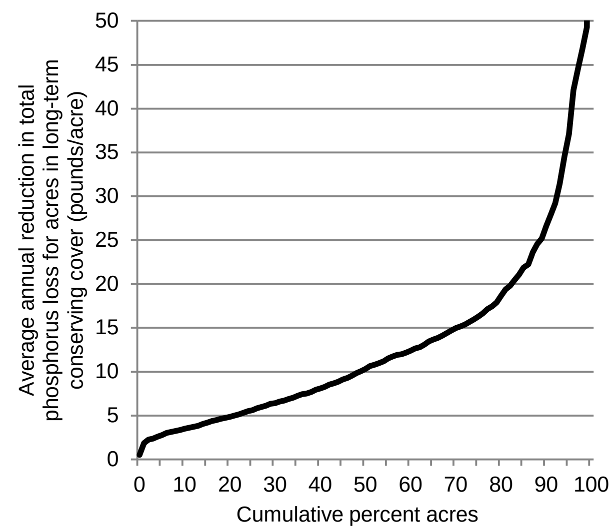


Figure 43. Estimates of average annual reduction in total phosphorus loss due to conversion to long-term conserving cover in the Lower Mississippi River Basin



Effects of Practices on Pesticide Residues and Environmental Risk

Use of pesticides to protect crops from weeds, insects, and diseases is an integral part of crop production. While pesticides are essential for large-scale agriculture, pesticide residues can migrate from the application site and lead to unintentional risk to humans and non-target plants and animals. Most pesticides are applied at much lower rates than nutrients. The fraction of pesticides applied that migrates offsite with water is generally less than 1 to 2 percent. Nevertheless, small amounts of pesticide residue can create water quality concerns depending on the toxicity of the pesticide residues to non-target species and even exceed EPA drinking water standards at times.

Baseline condition for pesticide loss

The APEX model tracks the mass loss of pesticides dissolved in surface water runoff, adsorbed to sediment lost through water erosion, and dissolved in subsurface flow pathways.[21] The distribution of losses through each of these three pathways is contrasted in figure 44. All three pathways are important in the transport of pesticide residues from fields.

The dominant loss pathway for 45 percent of cropped acres was pesticides lost with waterborne sediment. Surface water runoff was the dominant pesticide loss pathway for 33 percent of the acres, and subsurface flows were the dominant pesticide loss pathway for 19 percent of the acres. The remaining 3 percent of the acres had no pesticide loss.

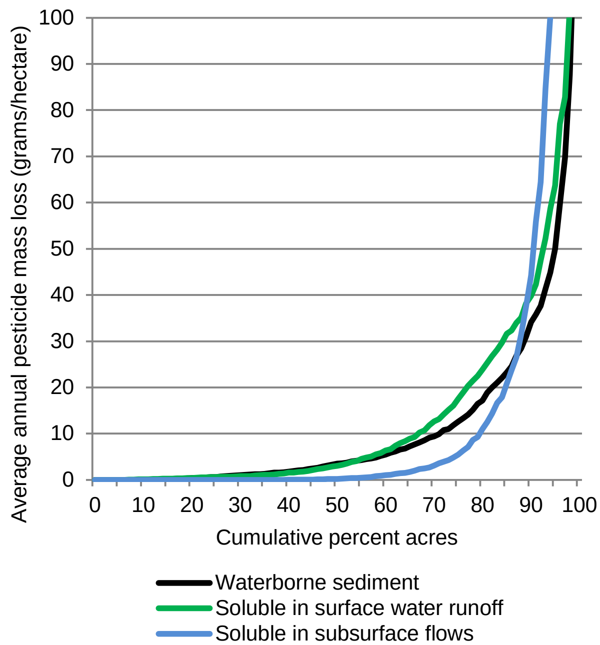
The average annual amount of pesticide lost from farm fields in the Lower Mississippi River Basin is about 70 grams of active ingredient per hectare per year (table 21).[22] As was observed for sediment and nutrient loss, the majority of pesticide loss occurs on a minority of acres within the Lower Mississippi River Basin (fig. 44). The median loss is only 18 grams per hectare.

In the model simulations, the pesticide applied in the largest amount throughout the region was glyphosate at 36 percent of the total weight of pesticides applied (table 22). Ethephon applications represented 8 percent of the total weight of pesticides applied, followed by atrazine with 7 percent and propanil with 6 percent. Other pesticides represented 5 percent or less of the total weight of pesticides applied in the region.

The most common pesticide residues lost from farm fields are sodium chlorate (42 percent of total mass loss), glyphosate (14 percent of total mass loss), quinclorac (11 percent), and atrazine (6 percent) (table 22). These four pesticides account for 73 percent of all pesticide residues lost from fields in the model simulations for the Lower Mississippi River Basin.

Pesticide loss for land in long-term conserving cover was not simulated because the survey did not provide information on pesticide use on land enrolled in CRP General Signups. It was assumed that there were no pesticide residues lost from land in long-term conserving cover.

Figure 44. Estimates of average annual pesticide loss (mass loss of all pesticides combined) for three loss pathways, Lower Mississippi River Basin, baseline conservation condition



[21] The APEX model currently does not estimate pesticides lost in spray drift, volatilization, or with windblown sediment.
[22] Grams per hectare is the standard reporting unit for pesticide active ingredients.

Table 21. Field-level effects of conservation practices on pesticide loss and associated edge-of-field environmental risk for cropped acres in the Lower Mississippi River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Pesticide sources				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	2679	3076	396	13
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	70.5	82.1	11.6	14
Edge-of-field pesticide risk indicator				
Average annual surface water pesticide risk indicator for aquatic ecosystems	3.19	5.24	2.05	39
Average annual surface water pesticide risk indicator for humans	1.14	1.51	0.37	24
Average annual groundwater pesticide risk indicator for humans	0.55	0.56	0.01	2

Note: It was assumed that no pesticides were applied to land in long-term conserving cover and there were no data on residual pesticides in the soil for these acres; thus, the assessment of the effects of this practice on pesticide loss was not done.
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 B for the 9 subregions.

Table 22. Dominant pesticides applied in model simulations and contributing to losses, Lower Mississippi River Basin

Pesticide (active ingredient name)	Pesticide type	Percent of total applied in the region
Pesticide application*		
Glyphosate, isopropylamine salt	Herbicide	36
Ethephon	Herbicide	8
Atrazine	Herbicide	7
Propanil	Herbicide	6
Acephate	Insecticide	5
Diuron	Herbicide	3
Sodium chlorate	Herbicide	3
Malathion	Insecticide	3
Tribuphos	Herbicide	3
Bacillus cereus strain BP01	Bacillus	3
Pendimethalin	Herbicide	3
Glyphosate-trimesium	Herbicide	3
2,4-D, dimethylamine salt	Herbicide	3
S-Metolachlor	Herbicide	1
Dicrotophos	Insecticide	1
Metolachlor	Herbicide	1
Clomazone	Herbicide	1
Total		84
		Percent of total pesticide loss in the region**
Pesticide loss from farm fields*		
Sodium chlorate	Herbicide	42
Glyphosate, isopropylamine salt	Herbicide	14
Quinclorac	Herbicide	11
Atrazine	Herbicide	6
Paraquat dichloride	Herbicide	3
Diuron	Herbicide	2
Triclopyr	Herbicide	2
Acephate	Insecticide	1
Metolachlor	Herbicide	1
MSMA	Herbicide	1
2,4-D, dimethylamine salt	Herbicide	1
Mepiquat chloride	Herbicide	1
Sulfentrazone	Herbicide	1
Total		87

* Pesticides not listed each represented less than 1 percent of the total mass weight applied or lost in the region. Percents may not add to total due to rounding.
** Includes loss of pesticides dissolved in surface water runoff, adsorbed to sediment loss from water erosion, and dissolved in subsurface flow pathways.

Effects of conservation practices on pesticide residues and risk

Management practices that reduce the potential for loss of pesticides from farm fields consist of a combination of Integrated Pest Management (IPM) techniques and water erosion control practices. Water erosion control practices mitigate the loss of pesticides from farm fields by reducing surface water runoff and sediment loss, both of which carry pesticide residues from the farm field to the surrounding environment. IPM is site-specific in nature, with individual tactics determined by the particular crop/pest/environmental condition. IPM consists of a management strategy for prevention, avoidance, monitoring, and suppression of pest populations. When the use of pesticides is necessary to protect crop yields, selection of pesticides that have the least environmental risk is an important aspect of the suppression component of IPM.

Model simulations show that conservation practices—primarily water erosion control practices—are effective in reducing the loss of pesticide residues from farm fields in the Lower Mississippi River Basin. Use of conservation practices has reduced the loss of pesticides (summed over all pesticides) by an average of 11.6 grams of active ingredient per hectare per year, a 14-percent reduction from the 82.1 grams per hectare for the no-practice scenario (table 21).

However, the total quantity of pesticide residues lost from the field is not the most useful outcome measure for assessing the environmental benefits of conservation practices. The environmental impact is specific to the toxicity of each pesticide to non-target species that may be exposed to the pesticide.

Pesticide risk indicators were therefore developed to represent risk at the edge of the field (bottom of soil profile for groundwater). These edge-of-field risk indicators are based on the ratio of average annual pesticide concentrations in water leaving the field to safe concentrations (toxicity thresholds) for each pesticide. As such, these risk indicators do not have units. The pesticide risk indicators were developed so that the relative risk for individual pesticides could be aggregated over the 187 pesticides included in the model for the Lower Mississippi River Basin.[23]

Risk indicator values of less than 1 are considered “safe” because the annual average concentration is below the toxicity threshold for exposure at the edge of the field.[24]

Three edge-of-field risk indicators are used here to assess the effects of conservation practices: (1) surface water pesticide risk indicator for aquatic ecosystems, (2) surface water pesticide risk indicator for humans, and (3) groundwater pesticide risk indicator for humans. The surface water risk indicator includes pesticide residues in solution in surface water runoff and in all subsurface water flow pathways that eventually return to surface water (water flow in a surface or tile drainage system, lateral subsurface water flow, and groundwater return flow). The pesticide risk indicator for aquatic ecosystems was based on chronic toxicities for fish and invertebrates, and acute toxicities for algae and vascular aquatic plants. The pesticide risk indicators for humans were based on drinking water standards or the equivalent for pesticides where standards have not been set.

These indicators provide a consistent measure that is comparable from field to field and that represents the effects of farming activities on risk reduction without being influenced by other landscape factors. In most environmental settings, however, non-target species are exposed to concentrations that have been diluted by water from other sources, even when those environments are located adjacent to a field. Consequently, these edge-of-field risk indicators cannot be used to predict actual environmental impacts.

Atrazine was the dominant pesticide contributing to all three risk indicators (table 23). Based on the model simulations, the edge-of-field risk indicator for atrazine exceeded 1 for 16 percent of the cropped acres for risk to aquatic ecosystems, 9 percent of the cropped acres for surface water risk to humans, and 5 percent of the cropped acres for groundwater risk to humans. Atrazine's dominance in the risk indicators is due to its widespread use, its mobility (solubility = 30 mg/L; Koc = 100 g/ml), its persistence (field half-life = 60 days), its toxicity to aquatic ecosystems (aquatic plant toxicity = 1 ppb), and the human drinking water standard (EPA Maximum Contaminant Level = 3 ppb).

Figure 45 shows that for most years the overall risk for aquatic ecosystems is low, in part because of the conservation practices in use. But the edge-of-field concentrations can be high relative to "safe" thresholds for some acres. The pesticide risk indicator for aquatic ecosystems averaged 3.19 over all years and cropped acres (table 21) for the baseline conservation condition. (The 3.19 value indicates that average annual pesticide concentrations in water leaving cropped fields in the Lower Mississippi River Basin are 3.19 times the “safe” concentration for non-target plant and animal species when exposed to concentrations at the edge of the field.) The median value, however, is only 0.13 (fig. 46).

[23] For a complete documentation of the development of the pesticide risk indicators, see “Pesticide risk indicators used in the CEAP cropland modeling,” found at http://www.nrcs.usda.gov/technical/nri/ceap.

[24] A threshold value of 1 for the pesticide risk indicator applies when assessing the risk for a single pesticide. Since the indicator is summed over all pesticides in this study, a threshold value of 1 would still apply if pesticide toxicities are additive and no synergistic or antagonistic effects are produced when non-target species are exposed to a mix of pesticides.

Pesticide Risk Indicators

Three ***edge-of-field*** pesticide risk indicators were used to assess the effects of conservation practices:

1. surface water pesticide risk indicator for aquatic ecosystems,
2. surface water pesticide risk indicator for humans, and
3. groundwater pesticide risk indicator for humans.

Pesticide risk indicators were calculated for each pesticide as the ratio of the concentration in water leaving the field to the "safe" concentration (toxicity thresholds) for each pesticide, where both are expressed in units of parts per billion. This ratio is called the Aquatic Risk Factor (ARF). ARFs are unit-less numbers that represent the relative toxicity of pesticides in solution. A risk indicator value of less than 1 is considered "safe" because the concentration is below the toxicity threshold for exposure at the edge-of-the field.

$$ARF = \frac{\text{(Annual Concentration)}}{\text{(Toxicity Threshold)}} < 1 \rightarrow \text{Little or no potential adverse impact}$$

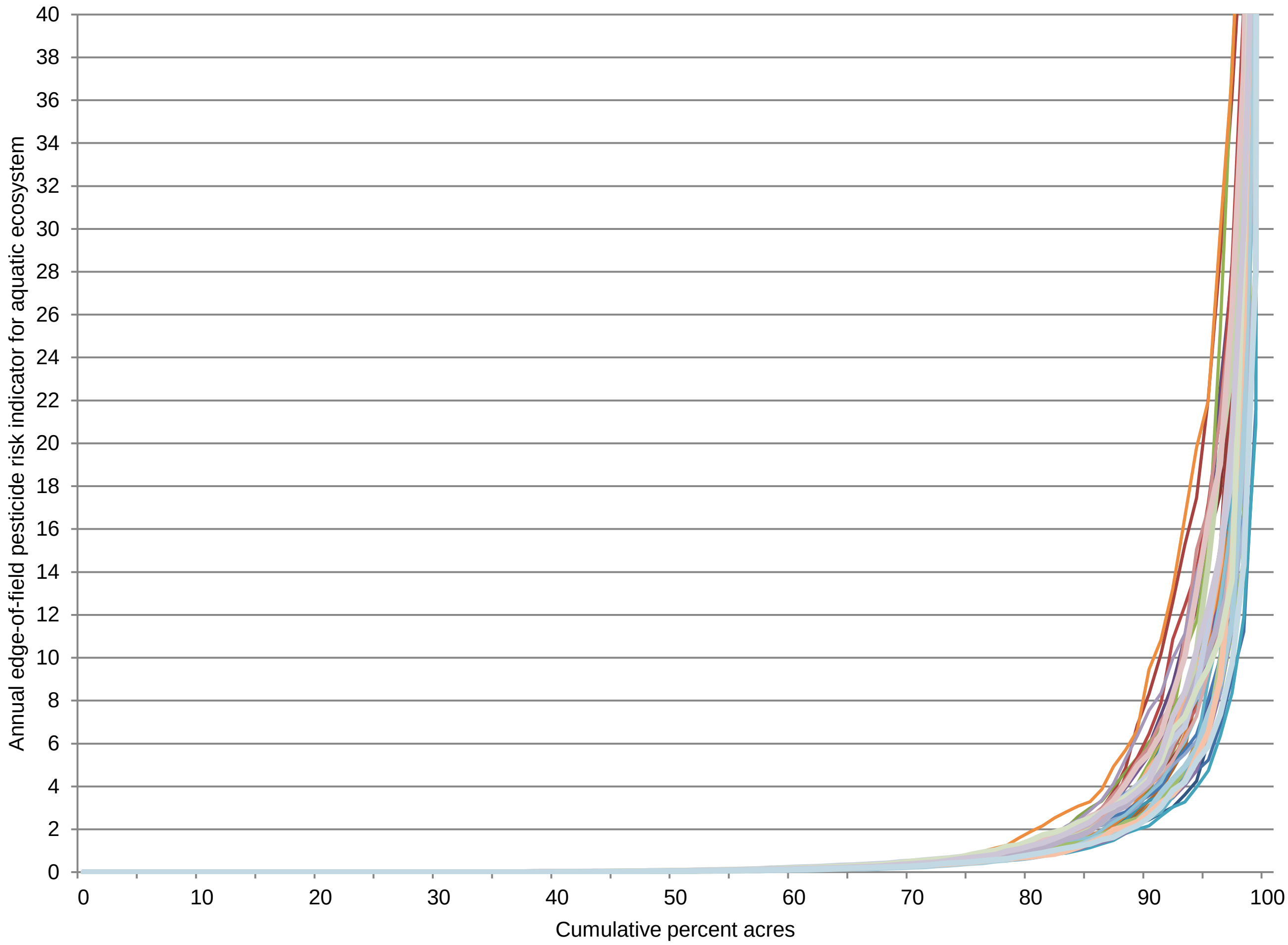
Two aquatic toxicity thresholds were used in estimating potential risk:

- Human drinking water lifetime toxicity thresholds. These thresholds are either taken from the EPA Office of Water Standards, or derived from EPA Reference Doses or Cancer Slopes using the methods employed by the EPA Office of Water.
- Aquatic ecosystem toxicity thresholds. The lowest (most sensitive) toxicity is used from the fish chronic NOEL (No Observable Effect Concentration), invertebrate chronic NOEL, aquatic vascular plant acute EC50 (Effective Concentration that is lethal to 50 percent of the population) and aquatic nonvascular plant acute EC50.

Table 23. Dominant pesticides determining edge-of-field environmental risk, Lower Mississippi River Basin

Pesticide (active ingredient name)	Pesticide type	Percent of cropped acres in the region with average annual edge-of-field risk indicator greater than 1
Risk indicator for aquatic ecosystem		
Atrazine	Herbicide	16
Cyfluthrin	Insecticide	5
lambda-Cyhalothrin	Insecticide	4
Malathion	Insecticide	4
Metolachlor	Herbicide	3
Diuron	Herbicide	3
Dicrotophos	Insecticide	2
Aldicarb	Insecticide	1
Metribuzin	Herbicide	1
All other pesticides combined		6
Risk indicator for humans, surface water		
Atrazine	Herbicide	9
Dicrotophos	Insecticide	8
Acephate	Insecticide	2
Molinate	Herbicide	<1
All other pesticides combined		2
Risk indicator for humans, groundwater		
Atrazine	Herbicide	5
Dicrotophos	Insecticide	5
Fluometuron	Herbicide	<1
All other pesticides combined		<1

Figure 45. Distribution of annual values of the edge-of-field surface water pesticide risk indicator for aquatic ecosystems for each year of the 47-year model simulation, Lower Mississippi River Basin



Note: This figure shows how the annual values of the risk indicator varied within the region and from year to year in the model simulation on cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual values of the risk indicator varied over the region in that year, starting with the acres with the lowest value and increasing to the acres with the highest value. The family of curves shows how annual values vary from year to year.

The pesticide risk indicators for humans were much lower, averaging 1.14 for surface water and 0.55 for groundwater (table 21). The median values are 0.02 for surface water and less than 0.01 for groundwater. About 20 percent of the cropped acres have an average annual edge-of-field surface water pesticide risk indicator for humans greater than 1 for the baseline conservation condition (fig. 47).

The use of conservation practices in the Lower Mississippi River Basin has reduced the pesticide risk indicator for aquatic ecosystems by 39 percent (table 21), averaged over all years, all pesticides, and all cropped acres. The surface water pesticide risk indicator for humans has been decreased by 24 percent and the groundwater pesticide risk indicator for humans has been decreased by 2 percent due to conservation practice use (table 21).

Figure 48 shows the distribution of the reductions due to conservation practices in the two surface water pesticide risk indicators. Significant risk reductions for aquatic ecosystems occur on about 25 percent of the acres, while significant risk reductions for humans occur on only about 15 percent of the acres. The benefits of conservation practices were significant for both aquatic ecosystem risks and human risks on the acres that had those risks, but because aquatic ecosystem risks were more widespread than human risks, conservation practices have greater potential benefit for aquatic ecosystems than for human drinking water.

Figure 46. Estimates of average annual edge-of-field surface water pesticide risk indicator for aquatic ecosystem in the Lower Mississippi River Basin

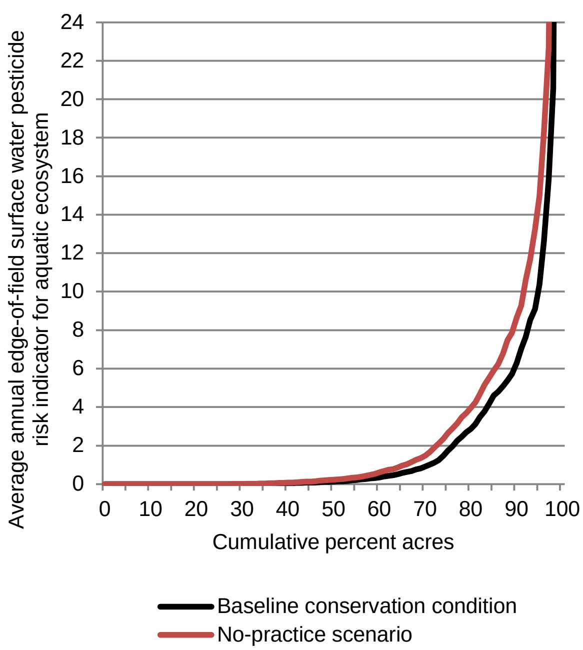


Figure 47. Estimates of average annual edge-of-field surface water pesticide risk indicator for humans in the Lower Mississippi River Basin

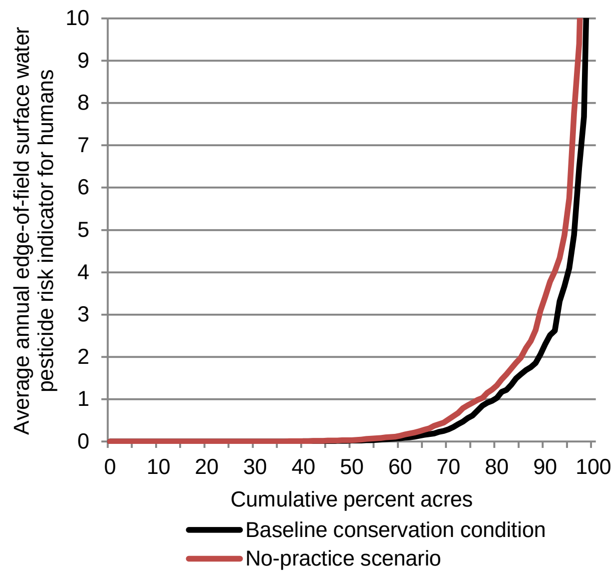
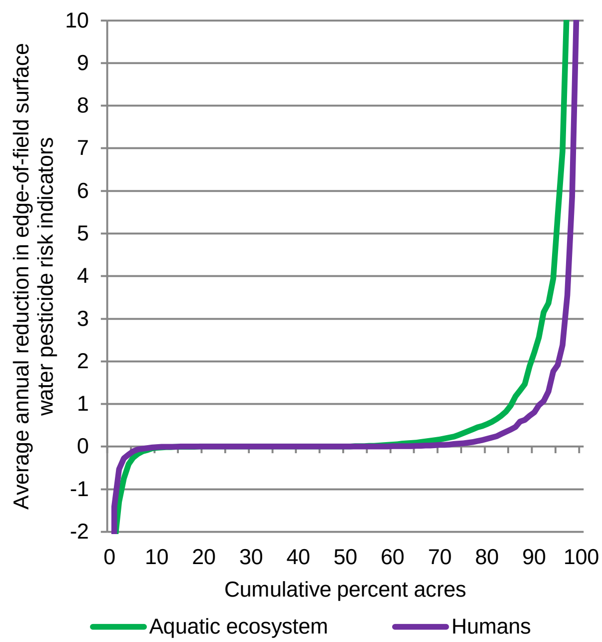


Figure 48. Estimates of average annual reductions in the edge-of-field surface water pesticide risk indicators for aquatic ecosystems in the Lower Mississippi River Basin



Note: Negative reductions in pesticide loss (and therefore risk) similar to negative reductions in soluble phosphorus losses occur on some landscapes as a result of reduced tillage (see discussion related to figure 42 on phosphorus reductions.)

Chapter 5
Assessment of Conservation Treatment Needs

The adequacy of conservation practices in use in the Lower Mississippi River Basin was evaluated to identify remaining conservation treatment needs for controlling water erosion and nutrient loss from fields. The evaluation was based on conservation practice use for the time period 2003 through 2006.

In summary, findings for the Lower Mississippi River Basin indicate that—

- *33 percent of cropped acres (6.29 million acres) have a **high** level of need for additional conservation treatment,*
- *53 percent of cropped acres (9.98 million acres) have a **moderate** level of need for additional conservation treatment, and*
- *14 percent of cropped acres (2.56 million acres) have a **low** level of need for additional treatment and are considered to be adequately treated.*

Field-level model simulation results for the baseline conservation conditions were used to make the assessment. Four resource concerns were evaluated for the Lower Mississippi River Basin:

1. Sediment loss due to water erosion
2. Nitrogen loss with surface runoff (nitrogen attached to sediment and in solution)
3. Nitrogen loss in subsurface flows
4. Phosphorus lost to surface water (phosphorus attached to sediment and in solution, including soluble phosphorus in subsurface lateral flow pathways)

The conservation treatment needs for controlling pesticide loss were not evaluated because the assessment requires information on pest infestations, which was not available for the CEAP sample points. A portion of the pesticide residues are controlled by soil erosion control practices; meeting soil erosion control treatment needs would provide partial protection against loss of pesticide residues from farm fields. Integrated Pest Management (IPM) practices are also effective in reducing the risk associated with pesticide residues leaving the farm field. Determination of adequate IPM, however, is highly dependent on the specific site conditions and the nature and extent of the pest problems.

Adequate conservation treatment consists of combinations of conservation practices that treat the specific inherent vulnerability factors associated with each field. Not all acres require the same level of conservation treatment. Acres with a high level of inherent vulnerability require more treatment than less vulnerable acres to reduce field-level losses to acceptable levels. 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. Acres that are essentially flat with permeable 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.

Undertreated acres were identified by an imbalance between the level of conservation treatment and the level of inherent vulnerability. Derivation of conservation treatment levels and inherent soil vulnerability classes are described in the next two sections, followed by estimates of undertreated acres.

Conservation Treatment Levels

Four levels of conservation treatment (high, moderately high, moderate, and low) were defined. A "high" level of treatment was shown by model simulations (see chapter 6) to reduce sediment and nutrient losses to low levels for nearly all cropped acres in the Lower Mississippi River Basin.

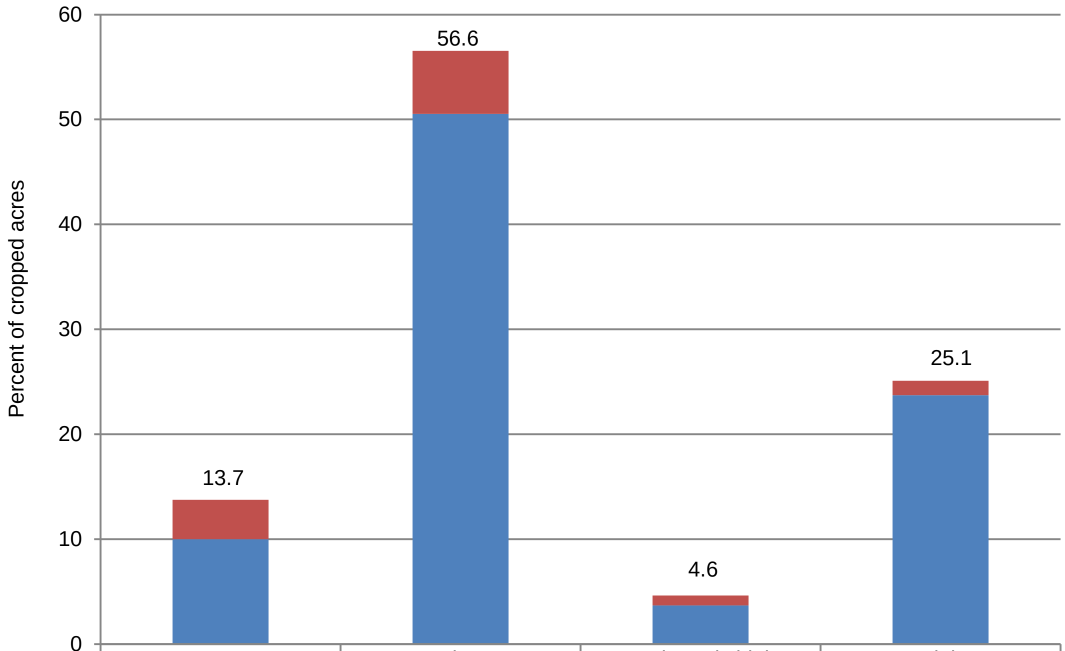
For sediment loss due to water erosion, conservation treatment levels were defined by a combination of structural practices and residue and tillage management practices, as defined in figure 49. A high level of water erosion control treatment is in use on about 25 percent of cropped acres, primarily on non-highly erodible land. About 5 percent have a moderately high level of conservation treatment. About 70 percent of cropped acres have a moderate or low level of conservation treatment for water erosion control, including most of the highly erodible land.

For nitrogen loss with surface runoff, conservation treatment levels were defined by a combination of structural practices, residue and tillage management practices, and nitrogen management practices, as defined in figure 50. A high level of treatment for nitrogen runoff is in use on only 8 percent of cropped acres. The bulk of cropped acres—82 percent—have combinations of practices that indicate a moderately high or moderate level of treatment. About 10 percent of cropped acres have a low level of treatment for nitrogen runoff.

For phosphorus lost to surface water, conservation treatment levels were defined by a combination of structural practices, residue and tillage management practices, and phosphorus management practices, as defined in figure 51. A high level of treatment for phosphorus runoff is in use on only 4 percent of the acres. About 29 percent of cropped acres have combinations of practices that indicate a moderately high level of treatment. About 44 percent of cropped acres have a moderate level of treatment. About 23 percent of cropped acres have a low level of phosphorus management.

The nitrogen management level presented in figure 9 (see chapter 3) was used to evaluate the adequacy of conservation treatment for nitrogen loss in subsurface flows. A high level of treatment for nitrogen loss in subsurface flows is in use on 31 percent of the acres. Only 13 percent of cropped acres have a moderately high level of treatment. About 51 percent of cropped acres have a moderate level and 5 percent have a low level of nitrogen treatment.

Figure 49. Percent of cropped acres at four conservation treatment levels for water erosion control in the baseline conservation condition, Lower Mississippi River Basin



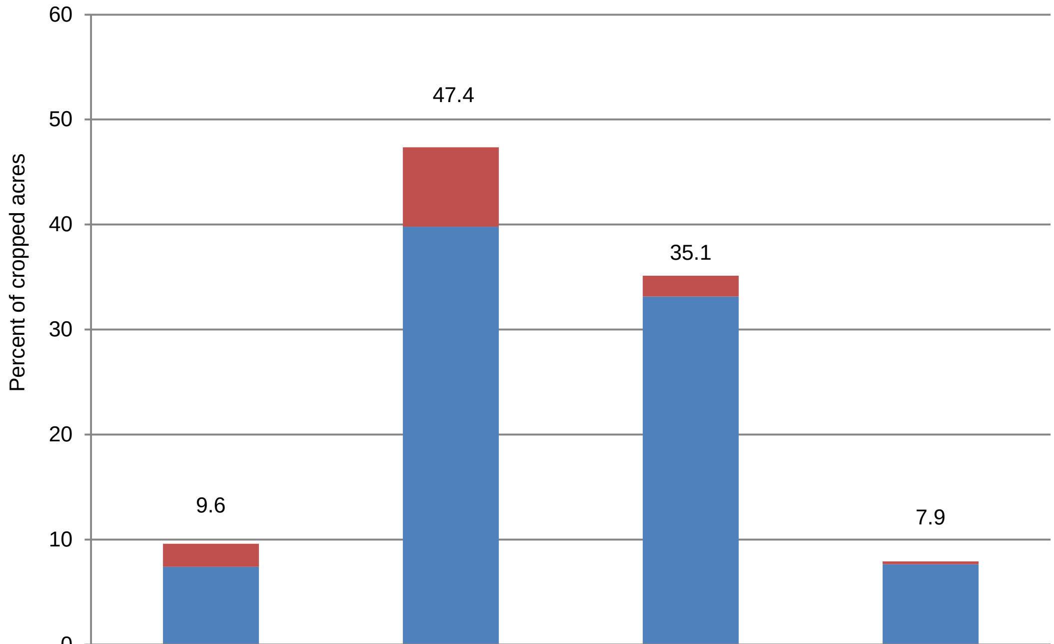
	Low	Moderate	Moderately high	High
HEL	3.7	6.0	0.9	1.4
Non-HEL	10.0	50.5	3.7	23.7

Criteria for water erosion control treatment levels were derived using a combination of structural practice treatment levels and residue and tillage management treatment levels (see figs. 7 and 8). Scores were first assigned to these treatment levels as follows: High=4, Moderately high=3, Moderate=2, and Low=1. If slope was 2 percent or less, the water erosion control treatment level is the same as the residue and tillage management level. If slope was greater than 2 percent, the water erosion control treatment level is determined as follows:

- **High treatment**: Sum of scores is equal to 8. (High treatment level for both structural practices and residue and tillage management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores equal to 4 or 5.
- **Low treatment**: Sum of scores equal to 2 or 3.

Note: About 12 percent of cropped acres in the Lower Mississippi River Basin are highly erodible land.

Figure 50. Percent of cropped acres at four conservation treatment levels for nitrogen runoff control in the baseline conservation condition, Lower Mississippi River Basin



	Low	Moderate	Moderately high	High
HEL	2.2	7.6	2.0	0.3
Non-HEL	7.4	39.8	33.1	7.6

Criteria were derived using a combination of structural practice treatment levels, residue and tillage management treatment levels, and nitrogen management treatment levels (see figs. 7-9). Scores were first assigned to these treatment levels as follows: High=4, Moderately high=3, Moderate=2, and Low=1.

If slope was 2 percent or less, the nitrogen runoff control treatment level is determined as follows:

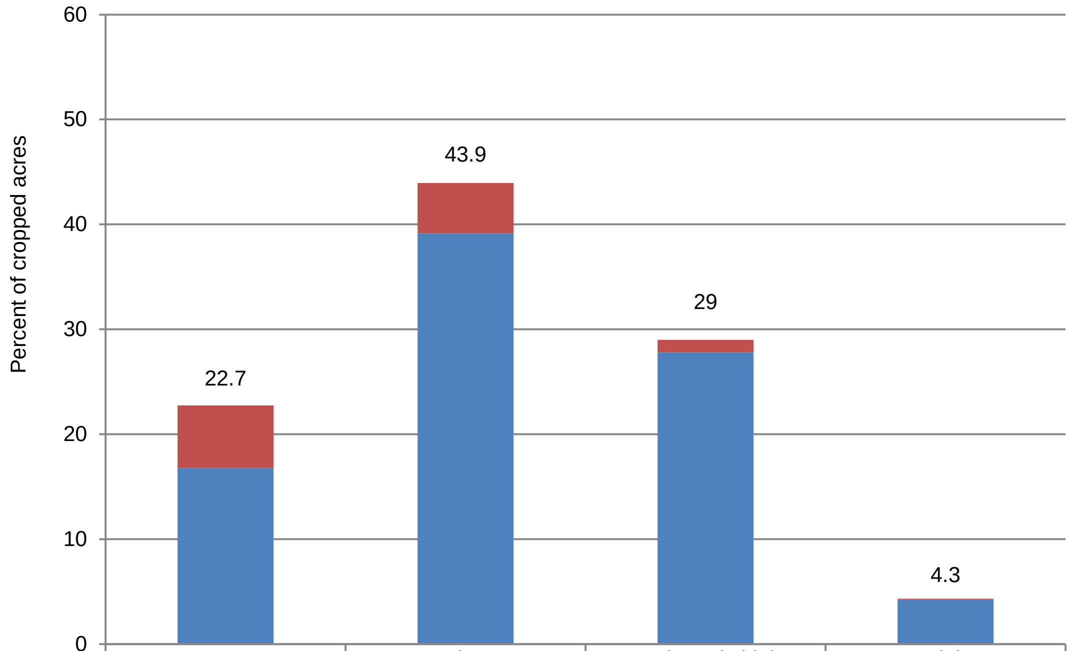
- **High treatment**: Sum of residue and tillage management score and nitrogen management score is equal to 8. (High treatment level for both structural practices and nitrogen management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores equal to 4 or 5.
- **Low treatment**: Sum of scores equal to 2 or 3.

If slope was greater than 2 percent, the nitrogen runoff control treatment level is determined as follows:

- **High treatment**: Sum of structural practice score, residue and tillage management score, and nitrogen management score is equal to 12. (High treatment level for all three treatment types.)
- **Moderately high treatment**: Sum of scores equal to 9, 10, or 11.
- **Moderate treatment**: Sum of scores equal to 6, 7 or 8.
- **Low treatment**: Sum of scores equal to 3, 4, or 5.

Note: About 12 percent of cropped acres in the Lower Mississippi River Basin are highly erodible land.

Figure 51. Percent of cropped acres at four conservation treatment levels for phosphorus runoff control in the baseline conservation condition, Lower Mississippi River Basin



	Low	Moderate	Moderately high	High
HEL	6.0	4.8	1.2	0.1
Non-HEL	16.8	39.1	27.8	4.2

Criteria were derived using a combination of structural practice treatment levels, residue and tillage management treatment levels, and phosphorus management treatment levels (see figs. 7, 8, and 10) in the same manner as the nitrogen runoff control treatment level. Scores were first assigned to these treatment levels as follows: High=4, Moderately high=3, Moderate=2, and Low=1.

If slope was 2 percent or less, the phosphorus runoff control treatment level is determined as follows:

- **High treatment**: Sum of residue and tillage management score and phosphorus management score is equal to 8. (High treatment level for both structural practices and phosphorus management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores equal to 4 or 5.
- **Low treatment**: Sum of scores equal to 2 or 3.

If slope was greater than 2 percent, the phosphorus runoff control treatment level is determined as follows:

- **High treatment**: Sum of structural practice score, residue and tillage management score, and phosphorus management score is equal to 12. (High treatment level for all three treatment types.)
- **Moderately high treatment**: Sum of scores equal to 9, 10, or 11.
- **Moderate treatment**: Sum of scores equal to 6, 7 or 8.
- **Low treatment**: Sum of scores equal to 3, 4, or 5.

Note: About 12 percent of cropped acres in the Lower Mississippi River Basin are highly erodible land.

Inherent Vulnerability Factors

Not all acres require the same level of conservation treatment because of differences in inherent vulnerabilities due to soils and climate. Inherent vulnerability factors for surface runoff include soil properties that promote surface water runoff and erosion—soil hydrologic group, slope, and soil erodibility (the water erosion equation K-factor). Inherent vulnerability factors for loss of nutrients in subsurface flows include soil properties that promote infiltration—soil hydrologic group, slope, water erosion equation K-factor, and coarse fragment content of the soil.

Soil runoff and leaching potentials 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 vulnerability potentials are not well represented in every region.

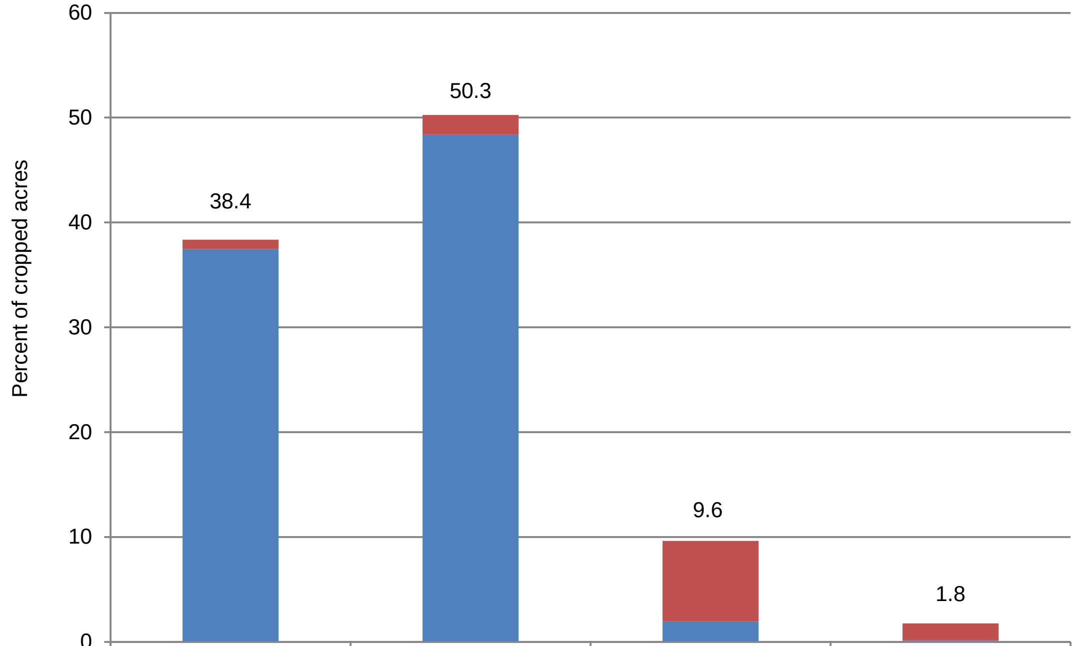
The criteria for the soil runoff potential are presented in figure 52, followed by the spatial distribution of the soil runoff potential within the Lower Mississippi River Basin in figure 53. The criteria and spatial distribution for the soil leaching potential are presented in figures 54 and 55.

The maps show the vulnerability potentials for all soils and land uses in the region. For the assessment of conservation treatment needs, however, only the vulnerability potentials for cropped acres were used.

Most cropped acres in the Lower Mississippi River Basin have a low vulnerability to either leaching or runoff. About 38 percent of cropped acres have a low soil runoff potential and 50 percent have a moderate soil runoff potential (fig. 52). The remaining 12 percent have a high (2 percent) or moderately high (10 percent) soil runoff potential.

Even fewer acres have a high or moderately high potential for leaching (figs. 54 and 55). Only 2.4 percent of cropped acres in this region have a high or moderately high soil leaching potential. The majority of cropped acres—52.5 percent—have a low soil leaching potential. The remaining 45 percent have a moderate soil leaching potential.

Figure 52. Soil runoff potential for cropped acres in the Lower Mississippi River Basin



	Low	Moderate	Moderately high	High
HEL	0.9	1.9	7.7	1.6
Non-HEL	37.5	48.4	2.0	0.2

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

Soil runoff 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	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

Hydrologic soil groups are classified as:

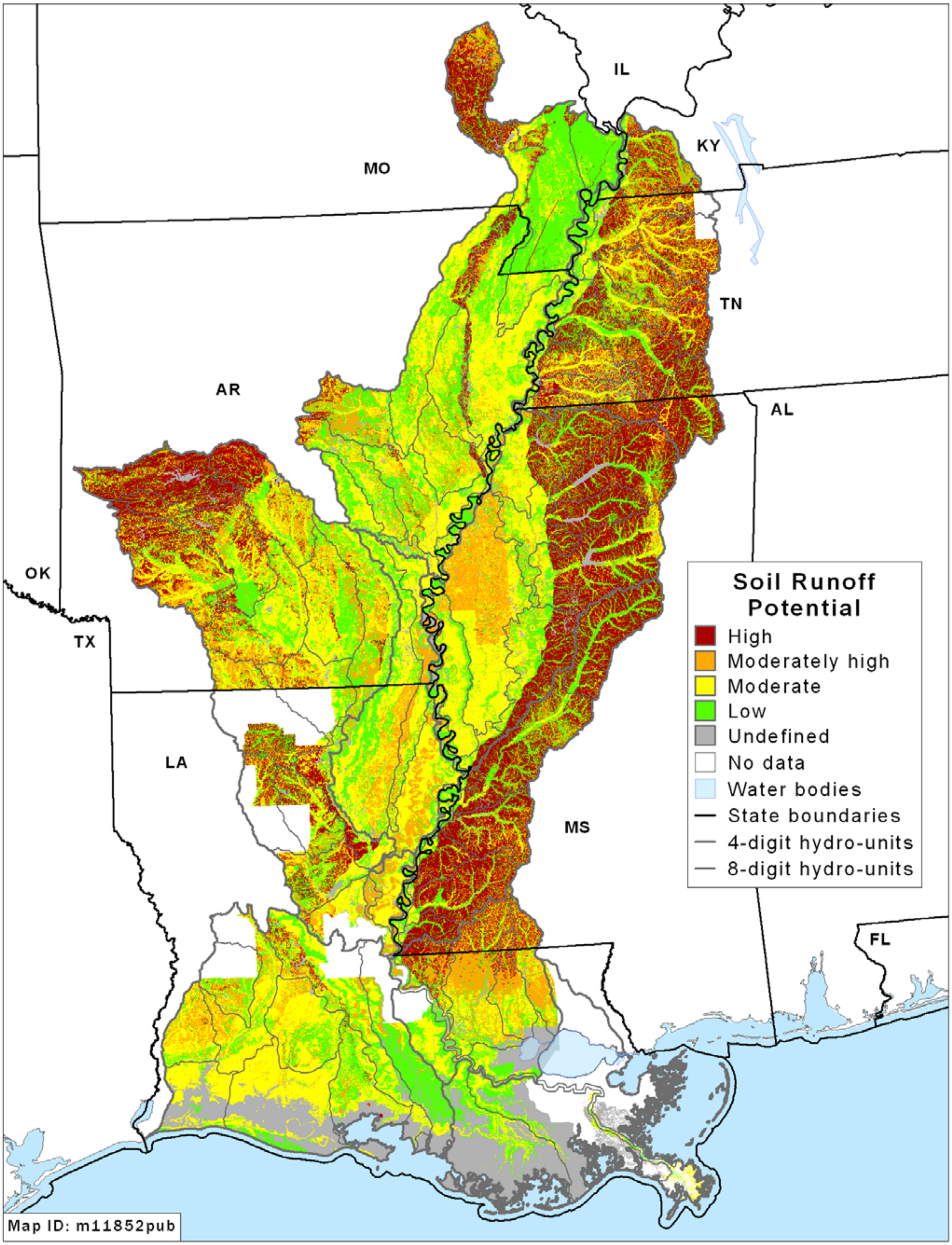
- **Group A—**sand, loamy sand, or sandy loam soils that have low runoff potential and high infiltration rates even when thoroughly wetted.
- **Group B**—silt loam or loam soils that have moderate infiltration rates when thoroughly wetted.
- **Group C**—sandy clay loam soils that have low infiltration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

Note: About 12 percent of cropped acres in the Lower Mississippi River Basin are highly erodible land.

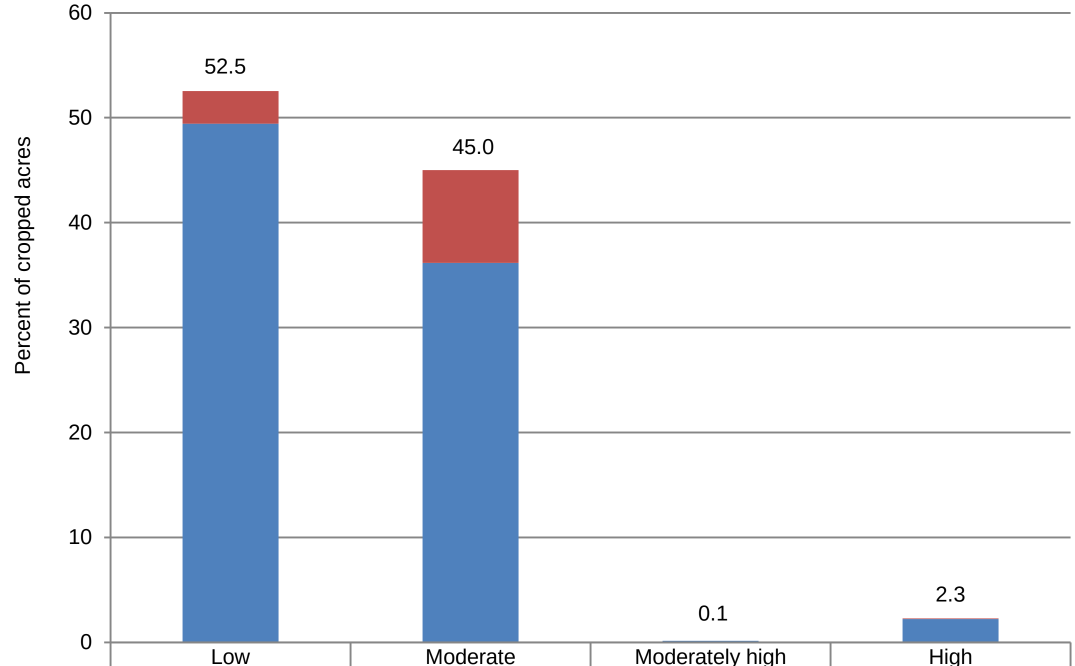
Note: See appendix B, table B4, for a breakdown of soil runoff potential by subregion.

Figure 53. Soil runoff potential for soils in the Lower Mississippi River Basin



Note: The soil runoff potential shown in this map was derived using the criteria presented in figure 52 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

Figure 54. Soil leaching potential for cropped acres in the Lower Mississippi River Basin



	Low	Moderate	Moderately high	High
HEL	3.1	8.9	0.0	0.1
Non-HEL	49.4	36.2	0.1	2.2

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

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

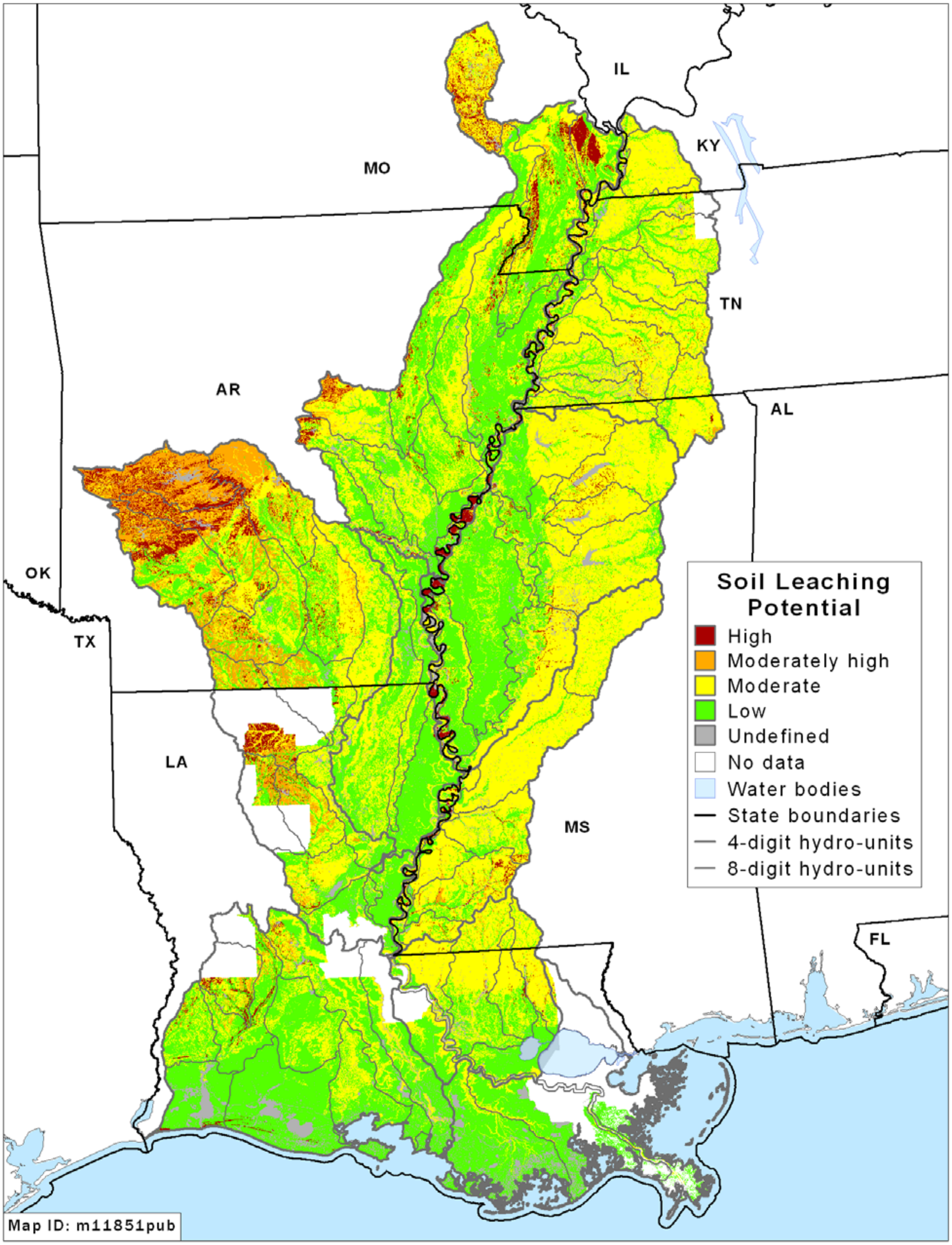
Coarse fragments (stones and rocks) in the soil make it easier for water to infiltrate rather than run off. If the coarse fragment content of the soil was greater than 30 percent, the soil leaching potential was increased two levels (moderate and moderately high to high, and low to moderately high).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

Note: 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.
Note: About 12 percent of cropped acres in the Lower Mississippi River Basin are highly erodible land.
Note: See appendix B, table B4, for a breakdown of soil leaching potential by subregion.

Figure 55. Soil leaching potential for soils in the Lower Mississippi River Basin

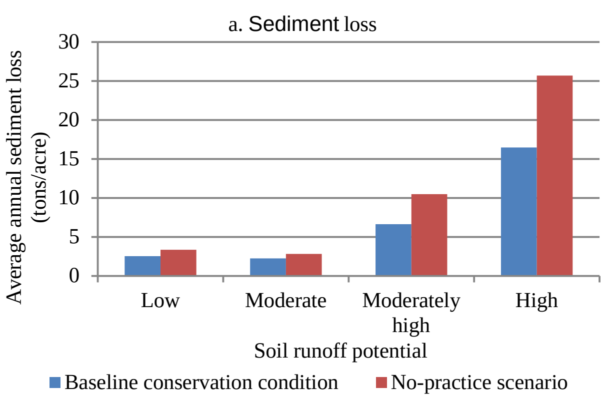


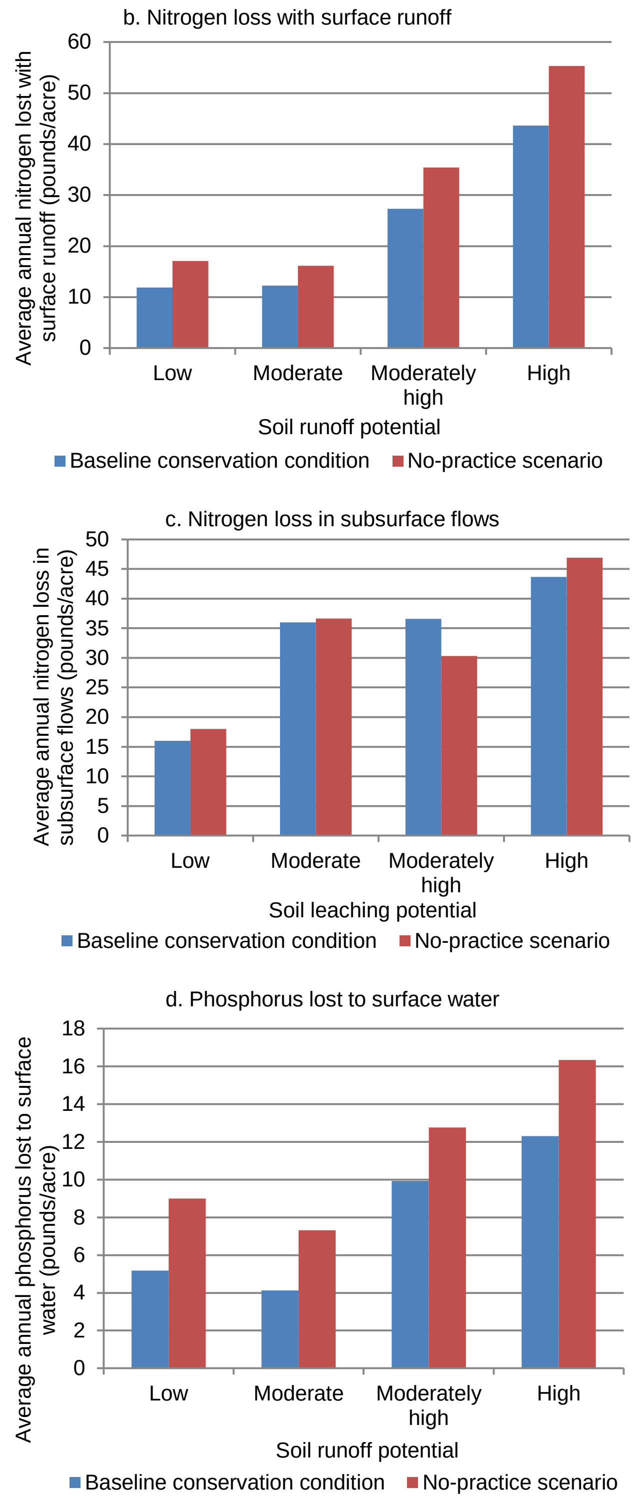
Note: The soil leaching potential shown in this map was derived using the criteria presented in figure 54 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

Estimates of sediment and nutrient losses for the no-practice scenario (without conservation practices), presented in figure 56, demonstrate how vulnerability factors influence losses in the Lower Mississippi River Basin. Estimates for the baseline are also presented in figure 56 to show how current levels of conservation treatment have reduced losses.

- Sediment loss for the high soil runoff potential would have averaged 26 tons per acre per year without conservation practices, compared to 3 tons per acre per year for the low soil runoff potential (fig. 56a). The average annual reduction due to conservation practices is 9.2 tons per acre for soils with a high soil runoff potential, compared to a reduction of only 0.82 ton per acre for soils with a low soil runoff potential.
- Nitrogen loss with surface runoff for the high soil runoff potential would have averaged 55 pounds per acre per year without conservation practices, compared to 17 pounds per acre per year for the low soil runoff potential (fig. 56b). The average annual reduction due to conservation practices is 11.7 pounds per acre for soils with a high soil runoff potential, compared to a reduction of 5.2 pounds per acre for soils with a low soil runoff potential.
- Nitrogen loss in subsurface flows for the high soil leaching potential would have averaged 47 pounds per acre per year without conservation practices, compared to 18 pounds per acre per year for the low soil leaching potential (fig. 56c). The average annual reduction due to conservation practices is 3.2 pounds per acre for soils with a high soil leaching potential, compared to a reduction of 2.0 pounds per acre for soils with a low soil leaching potential.
- Phosphorus lost to surface water for the high soil runoff potential would have averaged 16 pounds per acre per year without conservation practices, compared to 9 pounds per acre per year for the low soil runoff potential (fig. 56d). The average annual reduction due to conservation practices is 4.1 pounds per acre for soils with a high soil runoff potential, compared to a reduction of 3.8 pounds per acre for soils with a low soil runoff potential.

Figure 56. Average annual sediment and nutrient losses for four levels of vulnerability potentials, Lower Mississippi River Basin





Evaluation of Conservation Treatment

The "matrix approach"

A "matrix approach" was used to identify acres where the level of conservation treatment is inadequate relative to the level of inherent vulnerability. These acres are referred to as "under-treated acres." Cropped acres were divided into 16 groups—defined by the four soil vulnerability potentials and four conservation treatment levels. The evaluation of conservation treatment needs was conducted by identifying which of the 16 groups of acres are inadequately treated with respect to the vulnerability potential.

The matrixes are presented for each of the four resource concerns in tables 24 through 27. Each table includes seven sets of matrixes that, taken together, capture the effects of conservation practices in the region and identifies the need for additional conservation treatment.

Acres and model results for each of the 16 groupings are presented in the first five matrixes in each table. The combination of the four soil vulnerability potentials and the four conservation treatment levels separates the acres with high losses from the acres with low losses. There generally is a trend of decreasing losses with increasing conservation treatment levels within each vulnerability potential. The tables also demonstrate that the high and moderately high treatment levels are effective in reducing losses at all vulnerability potentials.

The last two matrixes in each table show how conservation treatment needs were identified. Three levels of conservation treatment need were defined.

- **Acres with a "high" level of need** for conservation treatment consist of the most critical under-treated acres in the region. These are the most vulnerable of the under-treated acres with the least conservation treatment and have the highest erosion and/or loss of nutrients.

- **Acres with a "moderate" level of need** for conservation treatment consist of under-treated acres that generally have lower levels of vulnerability or have more conservation practice use than acres with a high level of need. The treatment level required is not necessarily less, although it can be, but rather the soil and nutrient losses are lower and thus there is less potential on a per-acre basis for reducing agricultural pollutant loadings with additional conservation treatment.

- **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. While gains can be attained by adding conservation practices to some of these acres, additional conservation treatment would reduce field losses by only a small amount.

Specific criteria were used to identify the groups of acres that fall into each of the three levels of conservation treatment need. Criteria were <u>not</u> tailored to a specific region, but were derived for use in all regions of the country to allow for comparisons of under-treated acres across regions using a consistent analytical framework.

The criteria and steps in the process are as follows—

1. The percentage of acres that exceeded a given level of loss was estimated for each cell in the matrix as a guide to determining the extent of excessive losses. These are referred to as "acceptable levels." *Losses above these levels were treated as unacceptable levels of loss.* "Acceptable levels"[25] for field-level losses used in this study are—
   - Average of 2 tons per acre per year for sediment loss,
   - Average of 15 pounds per acre per year for nitrogen loss with surface runoff (soluble and sediment attached),
   - Average of 25 pounds per acre per year for nitrogen loss in subsurface flows, and
   - Average of 4 pounds per acre per year for phosphorus lost to surface water (soluble and sediment attached).
2. 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**.
3. Groups of acres with more than 60 percent of the acres in excess of acceptable levels were designated as having a **high level of conservation treatment need,** indicated by darker shaded cells in the matrixes.
4. The remaining acres were designated as having a **moderate level of conservation treatment need**, indicated by lighter shaded cells in the matrix.

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. In most cases, under-treated acres consist of acres where the conservation treatment level was one step or more below the soil vulnerability potential.

[25] The long-term average loss was used as the criteria because losses vary considerably from year to year, and the evaluation is intended to assess the adequacy of conservation treatment over all years, on average. Average annual losses derived from APEX model output simulated over 47 years of actual weather (1960 through 2006) were compared to the acceptable level criteria for each sample point.

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 be realistically 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 Lower Mississippi River Basin, for example, percentages of acres that can attain these acceptable levels with additional soil erosion control and nutrient management practices on all under-treated acres are (see the next chapter)—

- 97 percent of cropped acres for sediment loss,
- 95 percent of cropped acres for nitrogen loss with surface runoff,
- 85 percent of cropped acres for nitrogen loss in subsurface flows, and
- 95 percent of cropped acres for phosphorus lost to surface water.

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

Why Was a Threshold Approach Not Used?

A threshold approach is where all acres with edge-of-field losses above a specific level are identified as undertreated acres; and thus, all acres below that level of loss are considered adequately treated.

A threshold approach is impractical for use in evaluating the adequacy of conservation practice use at the field level. Determination of the threshold level would need to be based on the environmental goals for a watershed, which would be expected to vary from watershed to watershed. Different thresholds would likely be needed for each field, depending on the cropping system. Moreover, sediment and nutrient losses vary from year to year; a specific set of practices shown to reduce losses below a specific level in some years will fail to do so in other years, even among acres that are fully treated. Inexpensive monitoring technologies do not exist for estimating sediment and nutrient losses on a field-by-field basis to determine what level of treatment is needed to meet an edge-of-field loss threshold, further hampering adaptive management efforts by producers.

The conservation goal is full treatment—not treatment to an arbitrary threshold. Protocols for full treatment—avoid, control, and trap—apply equally to all fields in all settings. The hallmark of the matrix approach is that soil vulnerability levels and the existing conservation treatment levels can be readily determined during the conservation planning process. Acres with treatment needs can be readily identified by farmers and conservation planners and treated as needed.

Table 24. Identification of undertreated acres for sediment loss due to water erosion in the Lower Mississippi River Basin

Soil runoff potential	Conservation treatment levels for water erosion control: Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	1,148,490	4,091,613	386,152	1,597,381	7,223,637
Moderate	666,148	5,484,516	363,341	2,951,471	9,465,476
Moderately high	629,316	926,028	80,757	179,605	1,815,705
High	142,444	149,765	38,273	0	330,482
All	2,586,398	10,651,921	868,523	4,728,458	18,835,300
Percent of cropped acres					
Low	6	22	2	8	38
Moderate	4	29	2	16	50
Moderately high	3	5	<1	1	10
High	1	1	<1	0	2
All	14	57	5	25	100
Sediment loss estimates *without* conservation practices (no-practice scenario, average annual tons/acre)					
Low	5.57	3.53	2.08	1.64	3.36
Moderate	6.73	3.06	1.91	1.61	2.82
Moderately high	12.89	10.45	6.68	3.80	10.47
High	24.76	28.35	18.61	NA	25.67
All	8.71	4.24	3.17	1.70	4.17
Sediment loss estimates for the baseline conservation condition (average annual tons/acre)					
Low	4.98	2.57	1.36	1.01	2.54
Moderate	5.75	2.42	1.65	1.16	2.23
Moderately high	10.13	5.53	2.32	1.98	6.63
High	20.00	16.62	2.61	NA	16.45
All	7.26	2.95	1.62	1.14	3.03
Percent reduction in sediment loss due to conservation practices					
Low	11	27	35	38	24
Moderate	15	21	14	28	21
Moderately high	21	47	65	48	37
High	19	41	86	NA	36
All	17	30	49	33	27
Percent of acres in baseline conservation condition with average annual sediment loss more than 2 tons/acre					
Low	73	44	15	16	41
Moderate	62	45	34	15	36
Moderately high	89	86	45	44	81
High	100	98	29*	NA	91
All	76	49	26	16	43
Estimate of undertreated acres					
Low	1,148,490	4,091,613	0	0	5,240,103
Moderate	666,148	5,484,516	363,341	0	6,514,005
Moderately high	629,316	926,028	80,757	179,605	1,815,705
High	142,444	149,765	38,273	0	330,482
All	2,586,398	10,651,921	482,371	179,605	13,900,295

Note: Yellow and orange shaded cells indicate undertreated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as undertreated acres. Orange-shaded cells indicate critical undertreated acres; critical undertreated acres were defined as groups of acres with more than 60 percent of the acres 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.

Note: NA indicates "not applicable" because there were too few acres in the category to provide representative results.

*This group of acres was classified as under-treated because a lower level of soil vulnerability met the criteria for under-treated acres. Sample size was very small for this cell.

Table 25. Identification of undertreated acres for nitrogen loss with surface runoff (sediment attached and soluble) in the Lower Mississippi River Basin

Soil runoff potential	Conservation treatment levels for nitrogen runoff control: Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	880,004	3,616,935	2,418,212	308,486	7,223,637
Moderate	450,782	3,962,431	3,868,425	1,183,839	9,465,476
Moderately high	422,092	1,094,164	299,449	0	1,815,705
High	53,529	248,879	28,074	0	330,482
All	1,806,407	8,922,409	6,614,160	1,492,324	18,835,300
Percent of cropped acres					
Low	5	19	13	2	38
Moderate	2	21	21	6	50
Moderately high	2	6	2	0	10
High	<1	1	<1	0	2
All	10	47	35	8	100
Estimates of nitrogen loss with surface runoff *without* conservation practices (no-practice scenario, average annual pounds/acre)					
Low	25.0	18.9	12.6	8.8	17.1
Moderate	22.8	18.9	14.7	9.2	16.2
Moderately high	40.2	36.7	24.0	NA	35.4
High	62.6	55.6	39.1	NA	55.3
All	29.1	22.1	14.5	9.1	19.1
Estimates of nitrogen loss with surface runoff for the baseline conservation condition (average annual pounds/acre)					
Low	16.3	12.9	9.2	8.0	11.9
Moderate	17.9	13.1	11.8	8.8	12.2
Moderately high	31.5	28.0	19.0	NA	27.3
High	55.4	43.9	19.1	NA	43.7
All	21.4	15.7	11.2	8.6	14.1
Percent reduction in nitrogen loss with surface runoff due to conservation practices					
Low	35	31	27	9	30
Moderate	22	31	20	5	24
Moderately high	22	24	21	NA	23
High	12	21	51	NA	21
All	27	29	23	6	26
Percent of acres in baseline conservation condition with average annual nitrogen loss with surface runoff more than 15 pounds/acre					
Low	56	37	15	11	31
Moderate	52	32	24	8	27
Moderately high	89	88	80	0	87
High	100	97	50	0	94
All	64	43	23	8	35
Estimate of undertreated acres for nitrogen loss with surface runoff					
Low	880,004	3,616,935	0	0	4,496,939
Moderate	450,782	3,962,431	0	0	4,413,213
Moderately high	422,092	1,094,164	299,449	0	1,815,705
High	53,529	248,879	28,074	0	330,482
All	1,806,407	8,922,409	327,523	0	11,056,339

Note: Yellow and orange-shaded cells indicate undertreated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as undertreated acres. Orange-shaded cells indicate critical undertreated acres; critical undertreated acres were defined as groups of acres with more than 60 percent of the acres 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.

Note: NA indicates "not applicable" because there were too few acres in the category to provide representative results.

Table 26. Identification of undertreated acres for nitrogen loss in subsurface flows in the Lower Mississippi River Basin

Soil leaching potential	Conservation treatment levels for nitrogen management: Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	244,027	4,774,824	1,118,882	3,759,992	9,897,725
Moderate	630,520	4,632,787	1,240,997	1,975,389	8,479,694
Moderately high	0	16,961	0	11,072	28,033
High	4,477	179,189	81,004	165,179	429,849
All	879,024	9,603,761	2,440,883	5,911,632	18,835,300
Percent of cropped acres					
Low	1	25	6	20	53
Moderate	3	25	7	10	45
Moderately high	0	<1	0	<1	<1
High	<1	1	<1	1	2
All	5	51	13	31	100
Estimates of nitrogen loss in subsurface flows *without* conservation practices (no-practice scenario, average annual pounds/acre)					
Low	37.4	22.5	18.4	10.9	18.0
Moderate	57.3	45.6	26.1	15.7	36.7
Moderately high	NA	NA	NA	NA	NA
High	NA	73.7	29.0	27.4	46.9
All	51.6	34.6	22.7	13.0	27.1
Estimates of nitrogen loss in subsurface flows for the baseline conservation condition (average annual pounds/acre)					
Low	33.8	19.5	15.9	10.5	16.0
Moderate	58.3	46.2	20.9	14.5	36.0
Moderately high	NA	NA	NA	NA	NA
High	NA	70.2	24.5	25.2	43.7
All	51.2	33.4	18.7	12.3	25.7
Percent reduction in nitrogen loss in subsurface flows due to conservation practices					
Low	10	13	14	3	11
Moderate	-2	-1	20	8	2
Moderately high	NA	NA	NA	NA	NA
High	NA	5	16	8	7
All	1	4	17	5	5
Percent of acres in baseline conservation condition with average annual nitrogen loss in subsurface flows more than 25 pounds/acre					
Low	49	22	19	3	15
Moderate	84	60	33	8	46
Moderately high	NA	NA	NA	NA	NA
High	NA	74	40	56	60
All	74	41	27	6	30
Estimate of undertreated acres for nitrogen loss in subsurface flows					
Low	244,027	0	0	0	244,027
Moderate	630,520	4,632,787	1,240,997	0	6,504,305
Moderately high	0	16,961	0	0	16,961
High	4,477	179,189	81,004	165,179	429,849
All	879,024	4,828,937	1,322,001	165,179	7,195,141

Note: Yellow and orange-shaded cells indicate undertreated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as undertreated acres. Orange-shaded cells indicate critical undertreated acres; critical undertreated acres were defined as groups of acres with more than 60 percent of the acres 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.

Note: NA indicates "not applicable" because there were too few acres in the category to provide representative results.

Table 27. Identification of undertreated acres for phosphorus lost to surface water (phosphorus attached to sediment and in solution, including soluble phosphorus in subsurface lateral flow pathways) in the Lower Mississippi River Basin

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	1,773,141	3,180,798	1,975,647	294,051	7,223,637
Moderate	1,385,069	4,208,033	3,378,539	493,835	9,465,476
Moderately high	936,426	753,969	101,858	23,452	1,815,705
High	189,368	135,275	5,838	0	330,482
All	4,284,004	8,278,075	5,461,883	811,338	18,835,300
Percent of cropped acres					
Low	9	17	10	2	38
Moderate	7	22	18	3	50
Moderately high	5	4	1	<1	10
High	1	1	<1	0	2
All	23	44	29	4	100
Phosphorus lost to surface water *without* conservation practices (no-practice scenario, average annual pounds/acre)					
Low	8.8	9.3	8.6	9.6	9.0
Moderate	7.9	6.8	7.3	10.4	7.3
Moderately high	14.8	10.5	11.5	NA	12.8
High	18.2	14.3	NA	NA	16.4
All	8.8	9.3	8.6	9.6	9.0
Phosphorus lost to surface water for the baseline conservation condition (average annual pounds/acre)					
Low	8.3	5.4	2.6	1.8	5.2
Moderate	7.4	4.4	2.8	1.9	4.1
Moderately high	13.2	6.9	4.4	NA	9.9
High	15.9	7.8	NA	NA	12.3
All	9.4	5.0	2.8	1.8	5.2
Percent reduction in phosphorus lost to surface water due to conservation practices					
Low	5	42	70	82	42
Moderate	7	36	61	82	44
Moderately high	11	34	62	NA	22
High	13	46	NA	NA	25
All	8	39	65	82	39
Percent of acres in baseline conservation condition with average annual phosphorus lost to surface water more than 4 pounds/acre					
Low	74	38	14	2	39
Moderate	71	39	14	1	33
Moderately high	92	72	41	NA	80
High	100	66	NA	NA	84
All	78	42	14	1	40
Estimate of undertreated acres for phosphorus lost to surface water					
Low	1,773,141	3,180,798	0	0	4,953,938
Moderate	1,385,069	4,208,033	0	0	5,593,102
Moderately high	936,426	753,969	101,858	0	1,792,253
High	189,368	135,275	5,838	0	330,482
All	4,284,004	8,278,075	107,696	0	12,669,775

Note: Yellow and orange-shaded cells indicate undertreated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as undertreated acres. Orange-shaded cells indicate critical undertreated acres; critical undertreated acres were defined as groups of acres with more than 60 percent of the acres 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.

Note: NA indicates "not applicable" because there were too few acres in the category to provide representative results.

Conservation treatment needs by resource concern

Most of the cropped acres in the Lower Mississippi River Basin were determined to be undertreated and in need of additional conservation treatment. The proportion of cropped acres with a high or moderate need for additional conservation treatment was determined to be (fig. 57 and table 28)—

- 74 percent for sediment loss (19 percent with a high need for treatment),
- 59 percent for nitrogen loss with runoff (11 percent with a high need for treatment),
- 67 percent for phosphorus lost to surface water (28 percent with a high need for treatment), and
- 38 percent for nitrogen loss in subsurface flows (4 percent with a high need for treatment), most of which returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

The bulk of undertreated acres in this region have a low or moderate level of soil vulnerability (tables 24-27). Eighty-five percent of acres undertreated for sediment loss have a low or moderate soil runoff potential, 81 percent for acres undertreated for nitrogen loss with surface runoff, and 83 percent for acres undertreated for phosphorus lost to surface water. Ninety-four percent of acres undertreated for nitrogen loss in subsurface flow paths have a low or moderate soil leaching potential.

This is a direct result of the high level of annual precipitation in this region, which results in unacceptable field-level losses in spite of low or moderate soil vulnerability. Because of the higher precipitation and more frequent and intense storms this region needs enhanced soil erosion control practices and high levels of nutrient management even on soils with low or moderate potential for sediment and nutrient losses.

Undertreated acres in the Lower Mississippi River Basin are presented by combinations of resource concerns in table 28. About 28 percent of the undertreated acres are undertreated for all four resource concerns, and another 27 percent are undertreated for all but nitrogen leaching.

The most critical conservation concern in the region is the need for control of surface water runoff and complete and consistent use of nutrient management—appropriate rate, form, timing, *and* method of application of nitrogen and phosphorus (fig. 57 and table 28). All but 14 percent of the cropped acres need additional conservation treatment in this region (fig. 58).

Figure 57. Percent of cropped acres that are undertreated in the Lower Mississippi River Basin, by resource concern

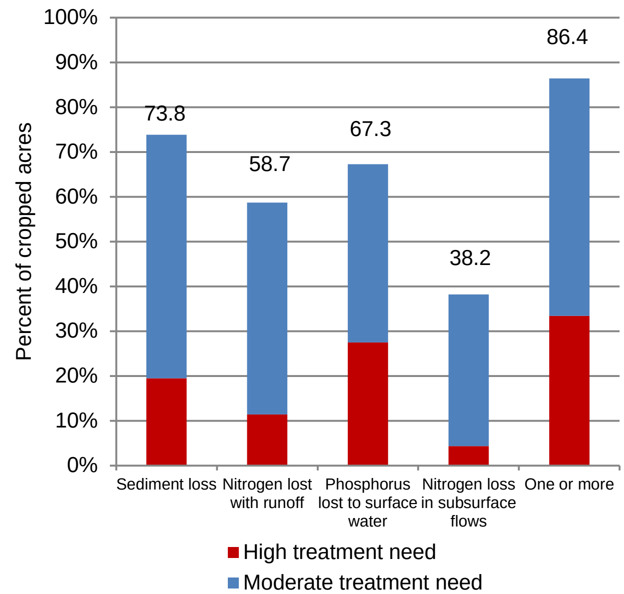


Table 28. Undertreated acres with resource concerns needing treatment in the Lower Mississippi River Basin

Reason for treatment need	Estimated acres needing treatment	Percent of cropped acres	Percent of undertreated acres
Sediment, nitrogen runoff, nitrogen leaching, and phosphorus runoff	4,579,178	24.3	28.1
Sediment, nitrogen runoff, phosphorus runoff	4,453,056	23.6	27.4
Sediment, phosphorus runoff	2,216,255	11.8	13.6
Sediment only	990,989	5.3	6.1
Sediment and nitrogen runoff	806,698	4.3	5.0
Nitrogen leaching only	789,409	4.2	4.9
Sediment, nitrogen runoff, nitrogen leaching	735,814	3.9	4.5
Phosphorus runoff only	611,356	3.2	3.8
Phosphorus runoff and nitrogen leaching	490,843	2.6	3.0
Nitrogen leaching and nitrogen runoff	236,186	1.3	1.5
Nitrogen runoff, nitrogen leaching, and phosphorus runoff	245,407	1.3	1.5
Sediment, phosphorus runoff, nitrogen leaching	73,679	0.4	0.5
Sediment and nitrogen leaching	44,625	0.2	0.3
All undertreated acres	16,273,497	86.4	100

Note: This table summarizes the undertreated acres identified in tables 24-27 and reports the joint set of acres that need treatment according to combinations of resource concerns.
Note: Percents may not add to totals because of rounding.

Conservation treatment needs for one or more resource concern

Some acres require additional treatment for only one of the four resource concerns, while other acres require additional treatment for two or more resource concerns. After accounting for acres that need treatment for multiple resource concerns, the evaluation of conservation treatment needs for the Lower Mississippi River Basin determined the following (fig. 58):

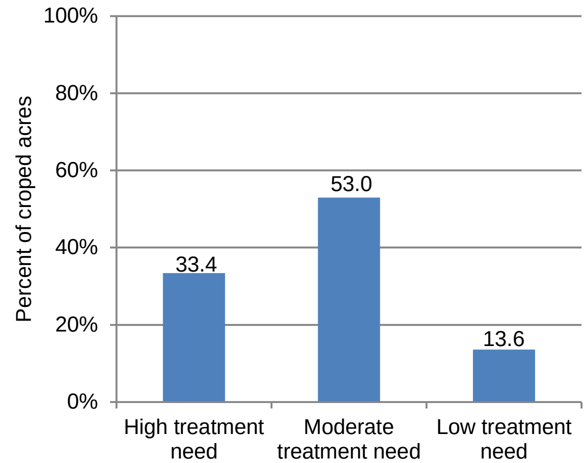
- 33 percent of cropped acres (6.29 million acres) have a **high** level of need for additional conservation treatment,
- 53 percent of cropped acres (9.98 million acres) have a **moderate** level of need for additional conservation treatment, and
- 14 percent of cropped acres (2.56 million acres) have a **low** level of need for additional treatment and are considered to be adequately treated.

High level of need for conservation treatment. These are the most vulnerable of the under-treated acres with the least conservation treatment and have the highest losses of sediment and/or nutrients. In the Lower Mississippi River Basin, these 6.29 million acres lose (per acre per year, on average) 5.2 tons of sediment by water erosion, 8.9 pounds of phosphorus, and 71 pounds of nitrogen (table 29).

Moderate level of need for conservation treatment. 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 practice use than do acres with a high level of need. In the Lower Mississippi River Basin, these 9.98 million acres lose (per acre per year, on average) 2.1 tons of sediment by water erosion, 3.9 pounds of phosphorus, and 55 pounds of nitrogen (table 29).

Low level of need for conservation treatment. 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. In the Lower Mississippi River Basin, these 2.56 million acres lose (per acre per year, on average) 1.1 tons of sediment by water erosion, 2.5 pounds of phosphorus, and 37 pounds of nitrogen (table 29). While gains can be attained by adding conservation practices to some of these acres with a low treatment need, additional conservation treatment would reduce average field losses by only a small amount.

Figure 58. 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 Lower Mississippi River Basin



What is "Adequate Conservation Treatment?"

A field with adequate conservation practice use will have combinations of practices that address all the specific inherent vulnerability factors that determine the potential for sediment, nutrient, and pesticide losses. Full treatment consists of a suite of practices that—

- avoid or limit the potential for contaminant losses by using nutrient management practices (appropriate rate, timing, *and* method) on *all* crops in the rotation;
- control overland flow where needed; and
- trap materials leaving the field using appropriate edge-of-field mitigation.

Not all acres require the same level of conservation treatment. Acres with a high level of inherent vulnerability require more treatment than less vulnerable acres. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable to sediment, nutrient, and pesticide losses beyond the edge of the field. Acres that are essentially flat with permeable soil types are more prone to soluble nutrient and pesticide losses through subsurface flow pathways, most of which return to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

In practice, a *comprehensive planning process* is used to identify the appropriate combination of nutrient management techniques, soil erosion control practices, and other conservation practices needed to address the specific inherent vulnerabilities associated with each field.

In this report, adequate conservation treatment is limited to the use of practices that will not require changes in the cropping systems or changes in regional crop production levels. It may be necessary in some environmental settings to go beyond "adequate conservation treatment" to achieve local environmental goals.

Table 29. Baseline conservation condition model simulation results for subsets of undertreated and adequately treated acres in the Lower Mississippi River Basin

Model simulated outcome, average annual values	Acres with a *low* need for treatment	Acres with a *moderate* need for treatment	Acres with a *high* need for treatment	All acres
Cultivated cropland acres in subset	2,561,803	9,980,439	6,293,058	18,835,300
Percent of acres	13.6%	53.0%	33.4%	100.0%
Water flow				
Surface runoff (inches)	14.3	13.3	13.3	13.4
Subsurface water flow (inches)	9.4	11.0	10.4	10.6
Erosion and sediment loss				
Wind erosion (tons/acre)	0.03	0.11	0.18	0.12
Sheet and rill erosion (tons/acre)	0.46	1.22	3.40	1.85
Sediment loss at edge of field due to water erosion (tons/acre)	1.12	2.11	5.24	3.03
Soil organic carbon				
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	73	-55	-107	-55
Nitrogen				
Nitrogen sources (pounds/acre)				
Atmospheric deposition	6.6	6.5	6.5	6.5
Bio-fixation by legumes	101.2	60.4	40.5	59.3
Nitrogen applied as commercial fertilizer and manure	52.5	71.0	89.4	74.6
All nitrogen sources	160.3	137.8	136.3	140.4
Nitrogen in crop yield removed at harvest (pounds/acre)	119.9	89.4	76.3	89.2
Nitrogen loss				
Loss of nitrogen through volatilization (pounds/acre)	4.9	4.4	5.6	4.9
Nitrogen returned to the atmosphere through denitrification (pounds/acre)	13.7	15.2	8.5	12.8
Loss of nitrogen with windborne sediment (pounds/acre)	0.2	0.4	0.5	0.4
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	9.4	11.5	20.2	14.1
Nitrogen loss in subsurface flows (pounds/acre)	8.5	23.6	36.0	25.7
Total nitrogen loss for all pathways (pounds/acre)	36.8	55.1	70.9	57.9
Phosphorus				
Phosphorus applied (pounds/acre)	19.9	17.8	22.2	19.5
Phosphorus in crop yield removed at harvest (pounds/acre)	16.5	14.3	11.6	13.7
Phosphorus loss				
Loss of phosphorus with windborne sediment (pounds/acre)	0.0	0.1	0.2	0.1
Loss of phosphorus to surface water, including both soluble and sediment attached (pounds/acre)*	2.5	3.8	8.6	5.2
Total phosphorus loss for all pathways (pounds/acre)	2.5	3.9	8.9	5.4
Pesticide loss				
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	45.7	66.5	87.0	70.5
Surface water pesticide risk indicator for aquatic ecosystem	1.4	2.8	4.6	3.2
Surface water pesticide risk indicator for humans	0.3	1.0	1.6	1.1

* Includes phosphorus lost with waterborne sediment and soluble phosphorus in subsurface flows that are intercepted by tile drains and drainage ditches, lateral subsurface outflow (seeps), and groundwater return flow.

Conservation treatment needs by cropping systems

Eight of the 13 cropping systems in this region have a disproportionately high percentage of acres that need additional treatment, shown in table 30, although some are only weakly disproportionate. Under-treated acres are disproportionately high for a given cropping system when the proportion of under-treated acres is greater than the proportion of cropped acres, as shown in table 30. The most striking examples are "cotton only" and "cotton and corn only" cropping systems, which make up 23 percent of the cropped acres in the basin but account for 27 percent of the under-treated acres in the basin. Over 99 percent of the cropped acres in these two cropping systems are under-treated, compared to 86 percent for all cropped acres.

Five of the 13 cropping systems have a disproportionately low percentage of under-treated acres (table 30). The most striking examples are "soybean only" and "soybean and wheat only" cropping systems, which make up 25 percent of the cropped acres in the basin but account for 21 percent of the under-treated acres in the basin. About 75 percent of the cropped acres in these two cropping systems are under-treated, compared to 86 percent for all cropped acres.

This disproportionality is more pronounced for the critical undertreated acres (acres with a high need for additional treatment) (table 31). The "cotton only" cropping system, which represents 19 percent of cropped acres, accounts for 34 percent of the critical under-treated acres in the region. Sixty-one percent of all "cotton only" acres have a high need for additional conservation treatment, compared to 33 percent for all cropped acres.

In contrast, cropping systems with rice only or rice and soybeans or other crops account for only 13.5 percent of the critical undertreated acres but represent 24 percent of all cropped acres. For these two cropping systems, only about 18 percent of the acres have a high need for additional treatment, compared to 33 percent for all cropped acres.

Table 30. Percent of undertreated acres (acres with a *high* or *moderate* level of treatment need) by cropping system, Lower Mississippi River Basin

Cropping system	Percent of cropped acres in Lower Mississippi River Basin	Percent of undertreated acres in Lower Mississippi River Basin	Percent of undertreated acres in cropping system
Disproportionately high percentage of undertreated acres			
Hay and crop mix and remaining close grown crops*	1	1	100.0
Cotton and corn only	4	5	99.6
Cotton only	19	22	99.3
Remaining mix of row and close-grown crops	1	1	96.5
Remaining row crops only	7	7	94.7
Corn and soybean with close grown crops	4	4	91.6
Cotton and soybean with or without other crops	4	5	90.5
Soybean and sorghum only	2	2	86.8
Disproportionately low percentage of undertreated acres			
Soybean only	22	19	74.3
Soybean and wheat only	3	2	76.3
Rice and soybean or other crop	19	18	80.9
Corn and soybean only	8	8	84.8
Rice only	5	5	86.1
Total	100.0	100.0	86.4**

Note: Percents may not add to totals because of rounding.
* Based on only 11 CEAP samples.
** Percent of under-treated acres in the region.

Table 31. Percent of critical undertreated acres (acres with a *high* level of treatment need) by cropping system, Lower Mississippi River Basin

Cropping system	Percent of cropped acres in Lower Mississippi River Basin	Percent of critical undertreated acres in Lower Mississippi River Basin	Percent of critical undertreated acres in cropping system
Disproportionately high percentage of critical undertreated acres			
Cotton only	19	34.0	60.6
Cotton and soybean with or without other crops	4	6.7	50.4
Cotton and corn only	4	6.0	46.2
Corn and soybean only	8	11.3	44.9
Corn and soybean with close grown crops	4	5.3	44.5
Remaining mix of row and close-grown crops	1	1.3	35.4
Disproportionately low percentage of critical undertreated acres			
Soybean and sorghum only	2	0.8	13.2
Rice only	5	2.8	17.0
Rice and soybean or other crop	19	10.7	18.8
Soybean only	22	12.6	18.9
Remaining row crops only	7	5.4	27.2
Hay and crop mix and remaining close grown crops*	1	0.7	28.7
Soybean and wheat only	3	2.5	30.8
Total	100.0	100.0	33.4**

Note: Percents may not add to totals because of rounding.
* Based on only 11 CEAP samples.
** Percent of critical under-treated acres in the region.

Conservation treatment needs by subregions

Undertreated acres in the Lower Mississippi River Basin are distributed throughout all of the subregions, but are most concentrated in two subregions (table 32)—

- the Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806), where 100 percent of cropped acres are under-treated, and
- the Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)), where 99 percent of cropped acres are under-treated.

Two other subregions have less pronounced disproportionately high percentages of under-treated acres. Four subregions have disproportionately low percentages of undertreated acres, although not by much.

Critical undertreated acres, however, are more disproportionately distributed throughout the region (table 33). Two subregions in particular have disproportionately high percentages of critical undertreated acres—

- the Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801), where 67 percent of cropped acres are critical under-treated acres compared to 33 percent for all cropped acres in the region, and
- the Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806), where 54 percent of cropped acres are critical undertreated acres.

See appendix B, table B5, for a subregion breakdown of conservation treatment needs by resource concern.

Table 32. Percent of undertreated acres (acres with a *high* or *moderate* level of treatment need) by subregion, Lower Mississippi River Basin

Subregion	Percent of cropped acres in Lower Mississippi River Basin	Percent of undertreated acres in Lower Mississippi River Basin	Percent of undertreated acres in subregion
Disproportionately high percentage of undertreated acres			
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	1	2	100.0
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	10	12	98.7
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	3	3	96.5
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	15	16	92.9
Disproportionately low percentage of undertreated acres			
Boeuf-Tensas River Basin (code 0805)	12	11	80.3
Lower Red and Ouachita River Basin (code 0804)	4	4	81.6
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	37	35	82.5
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	18	18	84.5
Total	100.0	100.0	86.4*

Note: Percents may not add to totals because of rounding.
* Percent of undertreated acres in the Lower Mississippi River Basin.

Table 33. Percent of critical undertreated acres (acres with a *high* level of treatment need) by subregion, Lower Mississippi River Basin

Subregion	Percent of cropped acres in Lower Mississippi River Basin	Percent of critical undertreated acres in Lower Mississippi River Basin	Percent of critical undertreated acres in subregion
Disproportionately high percentage of critical undertreated acres			
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	15	30	67.2
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	1	2	53.7
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	18	20	36.7
Disproportionately low percentage of critical undertreated acres			
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	3	1	6.4
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	37	26	23.7
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	10	8	26.5
Boeuf-Tensas River Basin (code 0805)	12	10	27.6
Lower Red and Ouachita River Basin (code 0804)	4	4	30.6
Total	100.0	100.0	33.4*

Note: Percents may not add to totals because of rounding.
* Percent of critical undertreated acres in the Lower Mississippi River Basin.

Chapter 6
Assessment of Potential Field-Level Gains from Further Conservation Treatment

Model simulations were used to evaluate the potential gains from further conservation treatment in the Lower Mississippi River Basin. The simulated treatment levels were designed to minimally affect crop yields and maintain regional production capacity for food, fiber, forage, and fuel. The existing practices were augmented with additional practices to—

- avoid or limit the potential for loss by using nutrient management practices (appropriate rate, timing, *and* method) on *all* crops in the rotation;
- control overland flow where needed; and
- trap materials leaving the field using appropriate edge-of-field mitigation where absent.

Three sets of additional conservation practices were simulated:

1. Additional water erosion control practices consisting of three types of structural practices—overland flow practices, concentrated flow practices, and edge-of-field mitigation.
2. Application of nitrogen and phosphorus using appropriate rate, timing, and method.
3. Increases in the efficiency of irrigation water application.

Four conservation treatment scenarios were simulated to evaluate the potential gains from further conservation treatment:

1. Treatment of the 6.29 million critical undertreated acres (acres with a high need for conservation treatment) with water erosion control practices only.
2. Treatment of all 16.27 million undertreated acres (acres with a high or moderate need for conservation treatment) with water erosion control practices only.
3. Treatment of the 6.29 million critical undertreated acres with nutrient management practices in addition to water erosion control practices to address nutrient losses.
4. Treatment of all 16.27 million undertreated acres with nutrient management practices in addition to water erosion control practices to address nutrient losses.

In summary, the potential for achieving additional field-level savings from further conservation treatment is high in this region, especially for additional reductions in nitrogen loss. Conservation practices in use in 2003–06 achieved 30 percent of potential reductions in sediment loss, 7 percent for nitrogen, and 51 percent for phosphorus. By treating all 16.27 million undertreated acres in the region with additional erosion control and nutrient management practices, an additional 67 percent in savings would be attained for sediment, 87 percent for nitrogen, and 48 percent for phosphorus. To achieve 100 percent of potential savings (i.e., an additional 3 percent for sediment,6 percent for nitrogen, and 2 percent for phosphorus), additional conservation treatment for the remaining 2.56 million acres with a low need for additional treatment would be required, which would result in very small conservation gains on a per-acre basis.

The specific conservation practices used in the simulated treatments are not intended to be a prescription for how to construct conservation plans, but rather are a general representation of sets or suites of conservation practices that could be used to address multiple resource concerns. In actual planning situations a variety of alternative practice scenarios would be presented to the producer and selections would be based on the level of treatment need, cost of conservation implementation, impact on production goals, and preferences of the farm operator.

In the derivation of conservation plans, other conservation practices would be considered, such as cover crops, tillage and residue management, conservation crop rotations, drainage water management, and emerging conservation technologies. Only erosion control structural practices and consistent nutrient management techniques were simulated here to serve as a proxy for the more comprehensive suite of practices that is obtained through the conservation planning process. For example, a conservation plan may include tillage and residue management and cover crops instead of some of the structural practices included in the model simulation. Similarly, drainage water management or cover crops might be used as a substitute for—or in addition to—strict adherence to the right rate, timing, and method of nutrient application.

Long-term conserving cover was not included in the treatment scenarios. Long-term conserving cover represents the ultimate conservation treatment for acres that are highly vulnerable to sediment and nutrient loss, but if it was widely used, regional crop production levels could not be maintained. Enrolling more cultivated cropland acres in programs that provide the economic incentives for long-term conserving cover may be necessary in some areas to meet water quality goals for environmental protection.

Pesticide management was also not addressed directly in the treatment scenarios. While erosion control practices influence pesticide transport and loss, significant reductions in pesticide edge-of-field environmental risk within the region will require more intensive Integrated Pest Management (IPM) practices, including pesticide substitutions. Simulation of additional IPM and any associated pesticide substitutions is site specific and requires more information about the sample fields than was available from the farmer survey.

The level of conservation treatment is simulated to show *potential* environmental benefits, but is not designed to achieve specific environmental protection goals.

Nor were treatment scenarios designed to represent actual program or policy options for the Lower Mississippi River Basin. Economic and programmatic aspects—such as producer costs, conservation program costs, and capacity to deliver the required technical assistance—were not considered in the assessment of the potential gains from further conservation treatment.

Simulation of Additional Water Erosion Control Practices

Treatment to control water erosion and surface water runoff consists of structural and vegetative practices that slow runoff water and capture contaminants that it may carry. Simulations of practices were added where needed (summarized in table 34) according to the following rules.

- **In-field mitigation:**
  - Terraces were added to all sample points with slopes greater than 6 percent, and to those with slopes greater than 4 percent *and* a high potential for excessive runoff (hydrologic soil groups C or D). Although terraces may be too expensive or impractical to implement in all cases, they serve here as a surrogate for other practices that control surface water runoff.
  - Contouring or stripcropping (overland flow practices) was added to all other fields with slope greater than 2 percent that did not already have those practices and did not have terraces.
  - Concentrated flow practices were not applied since they occur on unique landscape situations within the field; landscape data other than slope and slope length were not available for CEAP sample points.
- **Edge-of-field mitigation:**
  - Fields adjacent to water received a riparian buffer, if one was not already present.
  - Fields not adjacent to water received a filter strip, if one was not already present.

In addition, the implementation of structural and vegetative practices is simulated by an adjustment in the land condition parameter used to estimate the NRCS Runoff Curve Number (RCN). The RCN is an empirical parameter used in surface hydrology for predicting direct runoff or infiltration. The hydrologic condition (a component in the determination of the RCN) was adjusted from "poor" to "good" for sample points where these additional practices were simulated.

Table 34. Summary of additional structural practices for water erosion control simulated for undertreated acres to assess the potential for gains from additional conservation treatment in the Lower Mississippi River Basin

	Critical undertreated acres (acres with a high level of treatment need)		Non-critical undertreated acres (acres with a moderate level of treatment need)		All undertreated acres	
Additional practice	Treated acres	Percent of total	Treated acres	Percent of total	Treated acres	Percent of total
Overland flow practice only	0	0	0	0	0	0
Terrace only	11,763	<1	0	0	11,763	<1
Terrace plus overland flow practice	0	0	0	0	0	0
Filter only	3,769,246	60	7,105,041	71	10,874,288	67
Filter plus overland flow practice	435,807	7	15,203	0	451,010	3
Filter plus terrace	465,307	7	0	0	465,307	3
Filter plus overland flow practice plus terrace	0	0	0	0	0	0
Buffer only	1,275,954	20	2,660,383	27	3,936,337	24
Buffer plus overland flow practice	52,072	1	0	0	52,072	<1
Buffer plus terrace	101,110	2	0	0	101,110	1
Buffer plus overland flow practice plus terrace	0	0	0	0	0	0
One or more additional practices	6,111,259	97	9,780,627	98	15,891,886	98
No structural practices	181,799	3	199,812	2	381,611	2
Total	6,293,058	100	9,980,439	100	16,273,497	100

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

Simulation of Additional Nutrient Management Practices

The nutrient management treatment scenario consists of additional nutrient management practices where needed *in addition to* the erosion control practices. The nutrient management practices simulated the application of nutrients at an appropriate rate, in an appropriate form, at appropriate times, and using an appropriate method of application to provide sufficient nutrients for crop growth while minimizing losses to the environment. Simulation of nutrient management required changes to nutrient applications for one or more crops on all but 9 percent of the acres (see table 10).

Specific rules for application timing

The goal for appropriate timing is to apply nutrients close to the time when the plant is likely to require them, thereby minimizing the opportunity for loss from the field. Rules for the timing of nutrient applications (both nitrogen and phosphorus) are:

- All commercial fertilizer applications were adjusted to 14 days prior to planting, except for acres susceptible to leaching loss.
- For acres susceptible to leaching loss (hydrologic soil group A, soils with sandy textures, or tile drained fields), nitrogen was applied in split applications, with 25 percent of the total application 14 days before planting and 75 percent 30 days after planting.
- Manure applications during winter months (December, January, February, and March) were moved to 14 days pre-plant or April 1, whichever occurs first.

In the baseline condition, about 8 percent of the cropped acres in the Lower Mississippi River Basin receive fertilizer applications in the fall for at least one spring-planted row crop in the rotation. The only fall application of nutrients simulated in the nutrient management treatment scenario was for fall seeded crops that received a starter fertilizer at planting time.

Specific rules for method of application

If the method of application was other than incorporation then in the simulations fertilizer and manure applications became incorporated or injected. Incorporation reduces the opportunity for nutrients on the soil surface to volatize or be carried away in soluble form or attached to eroding particles. For manure applications on no-till fields, if the manure was in liquid or slurry form and had been sprayed/broadcast applied it was changed to injected or placed under the soil surface. Manure of solid consistency was incorporated by disking without regard to the tillage management type. If the tillage type had been originally no-till, the incorporation of the manure changed the tillage type to mulch tillage.

Specific rules for the form of application

If the tillage type was no-till, commercial fertilizer was changed to a form that could be knifed or injected below the soil surface. The change in form did not change the ammonium or nitrate ratio of the fertilizer.

Specific rules for the rate of nutrient applied

Nitrogen application rates above 1.2 times the crop removal rate were reduced in the simulations to 1.2 times the crop removal rate for all crops except cotton and small grain crops. The 1.2 ratio is in the range of rates recommended by many of the land grant universities. This rate accounts for the savings in nutrients due to improved application timing and implementation of water erosion control practices and also replaces a reduced amount of environmental losses that occur during the cropping season.

For small grain crops (wheat, barley, oats, rice, rye, buckwheat, emmer, spelt, and triticale), nitrogen applications above 1.5 times the crop removal rate were reduced to 1.5 times the crop removal rate. For cotton, nitrogen applications were reduced to 50 pounds per bale for sample points with application rates exceeding 50 pounds per bale.

Phosphorus application rates above 1.1 times the amount of phosphorus removed in the crop at harvest over the crop rotation were adjusted to be equal to 1.1 times the amount of phosphorus removed in the crop at harvest over the crop rotation. Application rates for all phosphorus applications in the rotation were reduced in equal proportions.

Simulation of Irrigation Water Use Efficiency

Increases in the efficiency of irrigation water conveyances and water application were simulated in both the erosion control scenario and the erosion control with nutrient management treatment scenario. The volume of irrigation water used was simulated in the same manner as described for the baseline scenario in chapter 4. (Irrigation water was applied in the APEX model when a yield stress exceeded a specified threshold; the amount of irrigation water applied was determined by the amount of irrigation water required to fill the root-zone after accounting for conveyance losses.)

The treatment scenarios had four components.

1. The on-farm conveyance ditches were upgraded to pipelines.
2. Pressure systems were upgraded to center pivot or linear move sprinkler systems utilizing low-pressure sprinkler heads. Gravity systems were upgraded and gated pipe replaced ditches.
3. Irrigation water management practices were simulated, which consisted of timing and rate of application adjustments designed to attain specified irrigation efficiencies.
4. Edge-of-field irrigation-induced runoff was essentially eliminated on irrigated acres.

Implementation of the treatment scenario on all irrigated acres would result in an additional 3.51 million acres converted to center pivot or linear move sprinkler systems with low pressure heads.

In the Lower Mississippi River Basin, the representation of irrigation management in the treatment scenarios increased the average Virtual Irrigation System Efficiency (VISE) from 57 percent in the baseline conservation condition to 80 percent in the treatment scenarios. (As discussed in chapter 3, irrigation efficiencies were represented in APEX simulations as a combination of three different coefficients [losses at the head of the field, percolation losses, and end-of-field runoff] combined into a single efficiency value, VISE).

If all irrigated acres were treated, VISE would be increased by—

- 1-10 percent on 0.92 million acres (11 percent of irrigated acres),
- 10-20 percent on 2.3 million acres (26 percent),
- 20-30 percent on 4.1 million acres (47 percent), and
- 30-43 percent on 1.4 million acres (16 percent).

Emerging Technologies for Reducing Nutrient Losses from Farm Fields

The nutrient management simulated to assess the potential for further gains from conservation treatment represents traditional nutrient management techniques that have been in use for several years and would be expected to be found in current NRCS conservation plans. There are, however, emerging conservation technologies that have the potential to further reduce nutrient loss from farm fields and provide even greater crop use efficiencies once the technologies become more widespread. These include—

- innovations in implement design to enhance precise nutrient application and placement, including variable rate technologies;
- enhanced-efficiency nutrient application products such as slow or controlled release fertilizers (for example, polymer coated products, sulfur-coated products, etc.) and nitrogen stabilizers (for example, urease inhibitors, and nitrification inhibitors);
- constructed wetlands receiving surface water runoff or drainage water from farm fields prior to discharge to streams and rivers; and
- use of riparian corridors for treating drainage water.

New technologies that have the potential to increase crop yields without increasing nutrient inputs could further improve crop nutrient use efficiency and reduce offsite transport of nutrients relative to the level of crop production.

Potential for Field-Level Gains

Treatment of the 6.29 million critical undertreated acres

Average annual model output is presented in table 35 for the 6.29 million critical undertreated acres (acres with a high level of treatment need). The baseline results for these acres are contrasted to model output for the two treatment simulations in that table. According to the model simulation, treatment of these acres with water erosion control practices would substantially reduce sediment loss from water erosion and nitrogen and phosphorus losses with surface water ruoff. Sediment loss would be reduced to an annual average of about 0.5 ton per acre per year for these acres, a 90-percent reduction. Nitrogen loss with surface runoff would be reduced to 9.2 pounds per acre per year on average (54-percent reduction), and phosphorus lost to surface water would be reduced to 5.2 pounds per acre per year (40-percent reduction). The re-routing of surface water to subsurface flow pathways would decrease nitrogen loss in subsurface flows by only about 2 percent for these acres, on average.

The addition of nutrient management would have little additional effect on sediment loss, but would be effective in reducing nitrogen loss in subsurface flows and further reducing nitrogen and phosphorus lost to surface water (table 35). Nitrogen loss in subsurface flows for these acres would be reduced to an average of 17.5 pounds per acre per year, representing a 51-percent reduction compared to losses simulated for the baseline conservation condition. Nitrogen lost to surface water would be reduced to an average of 7.9 pounds per acre per year for these acres, representing a 61-percent reduction. Phosphorus lost to surface water would be reduced to an average of 2.0 pounds per acre per year for these acres, representing a 77-percent reduction.

These results support the conclusion drawn from the assessment of the effects of conservation practices in chapter 4 that nutrient management practices need to be paired with erosion control practices to attain significant reductions in the loss of soluble nutrients from cropped fields.

Treatment of all 16.27 million undertreated acres

Average annual model output is presented in table 36 for the treatment of <u>all</u> 16.27 million undertreated acres (acres with a high or moderate level of treatment need). The 16.27 million undertreated acres include 9.98 million acres with a moderate need for treatment that are less vulnerable or have more conservation practice use than the critical undertreated acres, and therefore the potential for gains with additional treatment is less for those acres. Thus, table 36 shows that per-acre percent reductions of sediment and nutrient loss due to additional practices would be less, on average, than percent reductions for treatment of the 6.29 million most vulnerable undertreated acres alone.

Nonetheless, the per-acre gains from additional treatment of these acres would be substantial. Treatment with both erosion control and nutrient management would, compared to the baseline results for these 16.7 million acres—

- reduce average annual sediment loss from 3.3 tons per acre for the baseline to 0.4 ton per acre (an 87-percent reduction),
- reduce average annual nitrogen loss with surface runoff (including waterborne sediment) from 14.9 pounds per acre to 7.0 pounds per acre (a 53-percent reduction),
- reduce average annual nitrogen loss in subsurface flows from 28.4 pounds per acre to 15.3 pounds per acre (a 46-percent reduction),
- reduce total nitrogen loss (all loss pathways) from 61.2 pounds per acre per year to 33.0 pounds per acre per year (a 46-percent reduction), and
- reduce average annual phosphorus lost to surface water from 5.7 pounds per acre to 1.9 pounds per acre for these acres (a 66-percent reduction).

Diminishing returns from additional conservation treatment

Per-acre gains from additional conservation treatment are highest for the more vulnerable and less treated acres than for the less vulnerable and more treated acres. These “diminishing returns” to additional treatment indicate that targeting treatment to the acres with the greatest need is an efficient way to reduce agricultural sources of contaminants from farm fields within the basin.

Table 37 contrasts the per-acre model simulation results for additional erosion control and nutrient management on three subsets of acres in the Lower Mississippi River Basin—

1. the 6.29 million undertreated acres with a “high” need for additional treatment,
2. the 9.98 million undertreated acres with a “moderate” need for additional treatment, and
3. the 2.56 million acres with a “low” need for additional treatment.

Diminishing returns from additional conservation treatment is demonstrated by comparing the average annual per-acre reductions in losses among the three groups of acres.

For example, conservation treatment of the 6.29 million critical undertreated acres would reduce sediment loss an average of 4.74 tons per acre per year on those acres. In comparison, additional treatment of the 9.98 million undertreated acres with a moderate need for treatment would reduce sediment loss by about 1.75 tons per acre per year on those acres, and treatment of the remaining 2.56 million acres would reduce sediment loss by only 0.83 ton per acre per year on those acres, on average (table 37).

Table 35. Conservation practice effects for additional treatment of 6.29 million critical undertreated acres (acres with a *high* need for conservation treatment) in the Lower Mississippi River Basin

Model simulated outcome	Baseline conservation condition: Average annual amount	Treatment with erosion control practices: Average annual amount	Treatment with erosion control practices: Percent reduction	Treatment with erosion control and nutrient management practices: Average annual amount	Treatment with erosion control and nutrient management practices: Percent reduction
Water flow					
Surface water runoff (inches)	13.3	11.0	17.3	11.0	17.2
Subsurface water flow (inches)	10.4	11.1	-6.6	11.1	-7.2
Erosion and sediment loss					
Wind erosion (tons/acre)	0.18	0.17	8.8	0.17	9.7
Sheet and rill erosion (tons/acre)	3.40	2.32	31.8	2.26	33.6
Sediment loss at edge of field due to water erosion (tons/acre)	5.24	0.51	90.2	0.51	90.3
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-107	-78	26.4	-80	25.4
Nitrogen					
Nitrogen sources					
Atmospheric deposition	6	6	0.0	6	0.0
Bio-fixation by legumes	40	39	2.7	41	-2.3
Nitrogen applied (pounds/acre)	89	86	3.5	57	36.3
All nitrogen sources	136	132	3.1	105	23.2
Nitrogen in crop yield removed at harvest (pounds/acre)	76	75	2.2	73	4.8
Total nitrogen loss for all loss pathways (pounds/acre)	70.9	59.5	16.0	35.0	50.6
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	20.2	9.2	54.3	7.9	60.8
Nitrogen loss in subsurface flows (pounds/acre)	36.0	35.4	1.7	17.5	51.4
Phosphorus					
Phosphorus applied (pounds/acre)	22.2	21.8	1.8	12.0	45.9
Phosphorus in crop yield removed at harvest (pounds/acre)	11.6	11.3	2.3	11.1	4.5
Total phosphorus loss for all loss pathways (pounds/acre)	8.9	5.4	38.6	2.2	75.7
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	8.6	5.2	39.6	2.0	76.9
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	87.0	66.7	23.3	66.6	23.4
Surface water pesticide risk indicator for aquatic ecosystems	4.61	2.56	44.6	2.59	43.9
Surface water pesticide risk indicator for humans	1.64	1.34	18.2	1.33	18.7

* Total nitrogen and phosphorus applied were less in the treatment scenario than in the baseline because a small fraction of the field was removed from production to simulate use of additional edge-of-field buffer and filtering practices. This also explains the small decrease in nitrogen in the crop yield at harvest.
Note: Values reported in this table are for the 6.29 million critical undertreated acres only. Percent reductions are with respect to the baseline conservation condition.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 36. Conservation practice effects for additional treatment of 16.27 million undertreated acres (acres with a *high* or *moderate* need for conservation treatment) in the Lower Mississippi River Basin

	Baseline conservation condition	Treatment with erosion control practices		Treatment with erosion control and nutrient management practices	
Model simulated outcome	Average annual amount	Average annual amount	Percent reduction	Average annual amount	Percent reduction
Water flow					
Surface water runoff (inches)	13.3	11.0	17.4	11.0	17.4
Subsurface water flow (inches)	10.8	11.2	-4.1	11.2	-4.4
Erosion and sediment loss					
Wind erosion (tons/acre)	0.14	0.13	8.1	0.13	8.6
Sheet and rill erosion (tons/acre)	2.06	1.53	26.0	1.50	27.2
Sediment loss at edge of field due to water erosion (tons/acre)	3.32	0.42	87.3	0.42	87.3
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-75	-58	22.5	-61	18.5
Nitrogen					
Nitrogen sources					
Atmospheric deposition	6	6	0.0	6	0.0
Bio-fixation by legumes	53	51	3.7	52	0.8
Nitrogen applied (pounds/acre)	78	76	3.3	50	36.1
All nitrogen sources	137	133	3.3	109	20.9
Nitrogen in crop yield removed at harvest (pounds/acre)	84	82	3.2	79	6.2
Total nitrogen loss for all loss pathways (pounds/acre)	61.2	53.9	12.0	33.0	46.0
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	14.9	7.9	47.0	7.0	52.9
Nitrogen loss in subsurface flows (pounds/acre)	28.4	28.0	1.3	15.3	46.0
Phosphorus					
Phosphorus applied (pounds/acre)	19.5	19.2	1.4	13.2	32.0
Phosphorus in crop yield removed at harvest (pounds/acre)	13.2	12.8	3.3	12.5	5.7
Total phosphorus loss for all loss pathways (pounds/acre)	5.8	3.9	33.5	2.1	64.4
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	5.7	3.7	34.4	1.9	65.8
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	74.4	61.5	17.4	61.5	17.4
Surface water pesticide risk indicator for aquatic ecosystems	3.48	2.24	35.7	2.25	35.2
Surface water pesticide risk indicator for humans	1.27	0.94	25.7	0.94	25.9

* Total nitrogen and phosphorus applied were less in the treatment scenario than in the baseline because a small fraction of the field was removed from production to simulate use of additional edge-of-field buffer and filtering practices. This also explains the small decrease in nitrogen in the crop yield at harvest.

Note: Values reported in this table are for the 16.27 million undertreated acres only. Percent reductions are with respect to the baseline conservation condition.

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

Table 37. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices for three groups of acres comprising the 18.8 million cropped acres in the Lower Mississippi River Basin

	Additional treatment for 6.29 million critical undertreated acres*			Additional treatment for 9.98 million non-critical undertreated acres*			Additional treatment for remaining 2.56 million acres		
	Baseline	Treatment scenario		Baseline	Treatment scenario		Baseline	Treatment scenario	
	Average annual amount	Average annual amount	Reduction	Average annual amount	Average annual amount	Reduction	Average annual amount	Average annual amount	Reduction
Water flow									
Surface water runoff (inches)	13.3	11.0	2.3	13.3	11.0	2.3	14.3	11.6	2.7
Subsurface water flow (inches)	10.4	11.1	-0.8	11.0	11.3	-0.3	9.4	9.8	-0.4
Erosion and sediment loss									
Wind erosion (tons/acre)	0.18	0.17	0.02	0.11	0.10	0.01	0.03	0.03	0.00
Sheet and rill erosion (tons/acre)	3.40	2.26	1.14	1.22	1.03	0.20	0.46	0.39	0.07
Sediment loss at edge of field due to water erosion (tons/acre)	5.24	0.51	4.74	2.11	0.37	1.75	1.12	0.29	0.83
Soil organic carbon									
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-107	-80	27**	-55	-49	5**	73	69	-3**
Nitrogen									
Nitrogen sources									
Atmospheric deposition	6	6	0	6	6	0	7	7	0
Bio-fixation by legumes	40	41	-1	60	59	1	101	98	3
Nitrogen applied (pounds/acre)	89	57	32	71	46	25	52	36	17
All nitrogen sources	136	105	32	138	111	27	160	140	20
Nitrogen in crop yield removed at harvest (pounds/acre)	76	73	4	89	83	6	120	112	8
Total nitrogen loss for all loss pathways (pounds/acre)	70.9	35.0	35.9	55.1	31.8	23.3	36.8	24.7	12.1
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	20.2	7.9	12.3	11.5	6.4	5.1	9.4	6.2	3.2
Nitrogen loss in subsurface flows (pounds/acre)	36.0	17.5	18.5	23.6	14.0	9.6	8.5	7.3	1.3
Phosphorus									
Phosphorus applied (pounds/acre)	22.2	12.0	10.2	17.8	14.0	3.7	19.9	17.0	3.0
Phosphorus in crop yield removed at harvest (pounds/acre)	11.6	11.1	0.5	14.3	13.4	0.9	16.5	15.3	1.2
Total phosphorus loss for all loss pathways (pounds/acre)	8.9	2.2	6.7	3.9	2.0	1.9	2.5	1.8	0.8
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	8.6	2.0	6.6	3.8	1.9	1.9	2.5	1.7	0.8
Pesticide loss									
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	87.0	66.6	20.4	66.5	58.3	8.3	45.7	43.4	2.3
Surface water pesticide risk indicator for aquatic ecosystem	4.61	2.59	2.02	2.76	2.04	0.72	1.36	1.07	0.29
Surface water pesticide risk indicator for humans	1.64	1.33	0.31	1.04	0.69	0.34	0.35	0.28	0.06

*Critical undertreated acres have a high need for additional treatment. Non-critical undertreated acres have a moderate need for additional treatment.
** Gain in soil organic carbon.

Similarly, diminishing returns were pronounced for nitrogen and phosphorus loss. Total nitrogen loss would be reduced by an average of 36 pounds per acre per year on the 6.29 million critical undertreated acres, compared to a reduction of 23 pounds per acre for the 9.98 million undertreated acres with a moderate need for treatment, and only 12 pounds per acre for the remaining 2.56 million acres.

Nitrogen loss in subsurface flows would be reduced by an average of 18.5 pounds per acre per year on the 6.29 million critical undertreated acres and 9.6 pounds per acre per year on the 9.98 million acres with a moderate need for treatment, compared to a reduction of 1.3 pounds per acre for the remaining 2.56 million acres.

Nitrogen lost with surface water would be reduced by an average of 12.3 pounds per acre per year on the 6.29 million critical undertreated acres and by 5.1 pounds per acre per year on the 9.98 million acres with a moderate need for treatment, compared to a reduction of only 3.2 pounds per acre for the remaining 2.56 million acres.

Total phosphorus loss would be reduced by an average of 6.7 pounds per acre per year on the 6.29 million critical undertreated acres, compared to a reduction of 1.9 pounds per acre for the 9.98 million undertreated acres with a moderate need for treatment and only 0.8 pound per acre for the remaining 2.56 million acres.

Diminishing returns for reduction in environmental risk for pesticides are also evident to some extent because of the additional soil erosion control treatment.

(This rudimentary assessment of diminishing returns ignores the cost of treatment and is focused only on reducing edge-of-field losses. If the cost of treatment for the critical undertreated acres is substantially greater than the non-critical undertreated acres, the optimal strategy would be to treat a mix of critical and non-critical undertreated acres so as to maximize total edge-of-field savings for a given level of expenditure. If the objective of the conservation treatment was specifically to protect water quality, the relative environmental benefits of sediment and nutrient reductions would need to also be considered.)

Estimates of edge-of-field sediment and nutrient savings due to use of conservation practices

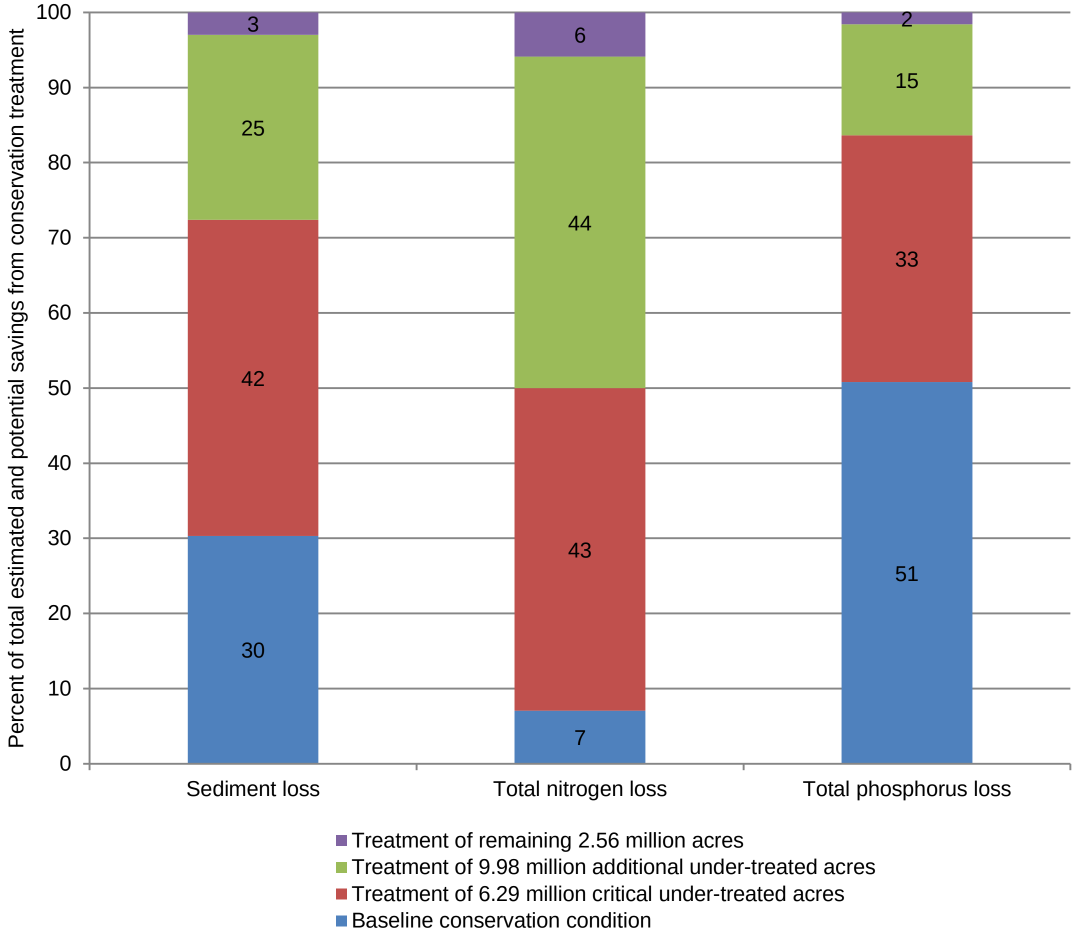
Potential sediment and nutrient savings from additional conservation treatment are contrasted to estimated savings for the conservation practices in use in 2003–06 in figure 59. The no-practice scenario represents the maximum losses that would be expected without any conservation practices in use. Treatment of *all acres* with nutrient management and erosion control practices was used to represent a "full-treatment" condition. The difference in sediment and nutrient loss between these two scenarios represents the maximum savings possible for conservation treatment, which totaled 71 million tons of sediment, 262,976 tons of nitrogen, and 64,325 tons of phosphorus for the Lower Mississippi River Basin (fig. 59).

For sediment loss, about 30 percent of the potential savings are accounted for by the conservation practices already in use, as represented by the baseline conservation condition (fig. 59). Additional treatment of the 6.29 million critical undertreated acres would account for another 42 percent of the potential sediment savings. Treatment of the 9.98 million undertreated acres with a moderate need for treatment would account for about 25 percent of the potential savings. Treatment of the 2.56 million adequately treated acres would account for the last 3 percent of potential sediment savings.

For nitrogen loss, only about 7 percent of the potential savings are accounted for by the conservation practices already in use, as represented by the baseline conservation condition (fig. 59). Additional treatment of the 6.29 million critical undertreated acres would account for another 43 percent of the potential nitrogen savings. Treatment of the 9.98 million undertreated acres with a moderate need for treatment would account for about 44 percent of the potential savings. Treatment of the 2.56 million adequately treated acres would account for the last 6 percent of potential nitrogen savings.

For phosphorus loss, about 51 percent of the potential savings are accounted for by the conservation practices already in use, as represented by the baseline conservation condition (fig. 59). Additional treatment of the 6.29 million critical undertreated acres would account for another 33 percent of the potential phosphorus savings. Treatment of the 9.98 million undertreated acres with a moderate need for treatment would account for about 15 percent of the potential savings. Treatment of the 2.56 million adequately treated acres would account for the last 2 percent of potential phosphorus savings.

Figure 59. Comparison of estimated sediment, nitrogen, and phosphorus savings (field-level) that are due to practices in use in the baseline conservation condition and potential savings with additional water erosion control *and* nutrient management treatment of cropped acres in the Lower Mississippi River Basin



Tons of sediment, nitrogen, and phosphorus saved or potentially saved due to conservation practices

	Estimated savings due to conservation practice use (baseline conservation condition)	Potential savings from treatment of 6.29 million critical undertreated acres*	Potential savings from treatment of 9.98 million additional undertreated acres*	Potential savings from treatment of remaining 2.56 million acres*	Total estimated and potential savings from conservation treatment
Sediment	21,493,729	29,799,883	17,442,614	2,129,968	70,866,194
Nitrogen	18,526	112,906	116,050	15,493	262,976
Phosphorus	32,673	21,133	9,499	1,020	64,325

*Treatment with erosion control practices and nutrient management practices on all acres.

Note: Calculations do not include land in long-term conserving cover.

Note: Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

Expected regional results assuming all undertreated acres were treated

As shown in figure 59, the potential for reducing overall field-level losses with additional conservation practices is high in this region. Table 38 presents estimates of how treatment of only the 6.29 million critical undertreated acres in the region would reduce *overall* edge-of-field losses *for the region as a whole*. These results were obtained by combining treatment scenario model results for the 6.29 million acres with model results from the baseline conservation condition for the remaining acres.

Compared to the baseline conservation condition, treating the 6.29 million critical undertreated acres with soil erosion control practices *and* nutrient management practices would, for the region as a whole (table 38)—

- reduce sediment loss in the region to an average of 1.4 tons per acre per year, a 52 percent reduction from the baseline conservation condition;
- reduce total nitrogen loss by 21 percent, on average:
  - reduce nitrogen loss with surface runoff (sediment adsorbed and soluble) by 29 percent, and
  - reduce nitrogen loss in subsurface flows by 24 percent;
- reduce phosphorus lost to surface water (sediment adsorbed and soluble) by 42 percent; and
- reduce environmental risk from loss of pesticide residues by 9–21 percent.

Compared to the baseline conservation condition, treating all 16.27 million undertreated acres with soil erosion control practices *and* nutrient management practices would, for the region as a whole (table 39)—

- reduce sediment loss in the region by 83 percent on average;
- reduce total nitrogen loss by 42 percent:
  - reduce nitrogen loss with surface runoff (sediment adsorbed and soluble) by 48 percent, and
  - reduce nitrogen loss in subsurface flows by 44 percent;
- reduce phosphorus lost to surface water by 62 percent; and
- reduce environmental risk from loss of pesticide residues by 25 to 33 percent.

Nearly all of these reductions in sediment loss and nitrogen lost with surface water, and environmental risk from loss of pesticide residues are due to the erosion control practices, as shown in table 39. The additional nutrient management practices accounted for a significant portion of the reductions in phosphorus lost to surface water and essentially all of the reduction in nitrogen loss in subsurface flows.

The effects of treating the undertreated acres for the region as a whole are graphically shown in figures 60 through 66. In these figures the model results for the baseline distribution are compared to the distributions for two levels of treatment with soil erosion control and nutrient management practices: 1) treatment of the 6.29 million critical undertreated acres, and 2) treatment of all 16.27 million undertreated acres. For perspective, the distribution of loss estimates if no conservation practices were in use, represented by the no-practice scenario, is also shown.

The distributions show how the number of acres with high losses could be reduced dramatically in the region by treating the undertreated acres. For example, 44 percent of the acres in the Lower Mississippi River Basin exceed an annual average loss of sediment of 2 tons per acre per year in the baseline conservation condition. Model simulations indicate that treating the most critical undertreated acres (6.29 million acres) with water erosion control practices would reduce the acres exceeding sediment loss of 2 tons per acre per year to 23 percent of cropped acres (fig. 60). Expanding the treatment to include all undertreated acres (16.27 million acres) would further reduce the acres exceeding annual sediment loss of 2 tons per acre to 3 percent.

Soil organic carbon would be minimally affected by the additional soil erosion control and nutrient management practices. Increases in soil organic carbon would occur largely because of savings of carbon that would otherwise be lost from the field through wind and water erosion. Figure 61 shows that the percentage of acres building soil organic carbon would increase from 35 percent for the baseline conservation condition to 40 percent with additional conservation treatment of all the undertreated acres.

Treatment of critical undertreated acres with water erosion control *and* nutrient management would reduce the acres exceeding 15 pounds per acre of nitrogen lost with runoff from 36 percent for the baseline to 17 percent (fig. 62). Treatment of all 16.27 million undertreated acres would further reduce the share of cropped acres losing more than 15 pounds per acre to 5 percent within the region.

For nitrogen loss in subsurface flow pathways, treatment of all 16.27 million undertreated acres would be required to reduce the overall regional edge-of-field losses to acceptable levels (fig. 63). About 35 percent of the acres in the region have nitrogen loss in subsurface flows greater than 25 pounds per acre per year for the baseline conservation condition. Treating the 6.29 million critical undertreated acres with nutrient management practices would reduce this percentage to 23 percent of cropped acres. Treatment of all 16.27 million undertreated acres would reduce the percentage to 15 percent.

For total nitrogen loss to all pathways, 60 percent of the acres in the baseline conservation condition exceed losses of 40 pounds per acre per year. Treating the most critical undertreated acres would reduce the acres exceeding this level of loss to 44 percent (fig. 64). Expanding the treatment to include all undertreated acres would further reduce the acres exceeding 40 pounds per acre to 24 percent.

Acres exceeding 4 pounds per acre of phosphorus lost to surface water would be reduced from 41 percent for the baseline to 20 percent by treating the critical acres and to 5 percent by treating all undertreated acres (fig. 65).

One of the objectives in constructing the treatment scenarios was to maintain the level of regional crop production. The removal of nitrogen at harvest serves as a useful proxy for crop yields and allows for aggregation over the mix of crops.

The average annual amount of nitrogen removed at harvest would be reduced about 5 percent for the region as a whole if the 16.27 million undertreated acres were fully treated with additional soil erosion control and nutrient management practices (table 39). Figure 66 shows that the distribution of nitrogen removed at harvest would be slightly lower for the treatment scenario with nutrient management, but otherwise similar to the distribution for the baseline conservation condition.

Table 38. Conservation practice effects for the region as a whole* after additional treatment of 6.29 million critical undertreated acres (acres with a *high* need for conservation treatment) in the Lower Mississippi River Basin

	Baseline conservation condition	Treatment with erosion control practices		Treatment with erosion control and nutrient management practices	
Model simulated outcome	Average annual amount	Average annual amount	Percent reduction	Average annual amount	Percent reduction
Water flow					
Surface water runoff (inches)	13.4	12.7	5.7	12.7	5.7
Subsurface water flow (inches)	10.6	10.8	-2.2	10.8	-2.4
Erosion and sediment loss					
Wind erosion (tons/acre)	0.12	0.12	4.4	0.12	4.9
Sheet and rill erosion (tons/acre)	1.85	1.48	19.6	1.46	20.7
Sediment loss at edge of field due to water erosion (tons/acre)	3.03	1.44	52.2	1.44	52.3
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-55	-45	17.2	-46	16.5
Nitrogen					
Nitrogen sources					
Atmospheric deposition	6	6	0.0	6	0.0
Bio-fixation by legumes	59	59	0.6	60	-0.5
Nitrogen applied (pounds/acre)	75	74	1.4	64	14.5
All nitrogen sources	140	139	1.0	130	7.5
Nitrogen in crop yield removed at harvest (pounds/acre)	89	89	0.6	88	1.4
Total nitrogen loss for all loss pathways (pounds/acre)	57.9	54.1	6.5	45.9	20.7
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	14.1	10.5	25.9	10.0	29.0
Nitrogen loss in subsurface flows (pounds/acre)	25.7	25.5	0.8	19.5	24.1
Phosphorus					
Phosphorus applied (pounds/acre)	19.5	19.4	0.7	16.1	17.4
Phosphorus in crop yield removed at harvest (pounds/acre)	13.7	13.6	0.7	13.5	1.3
Total phosphorus loss for all loss pathways (pounds/acre)	5.4	4.3	21.2	3.2	41.6
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	5.2	4.1	21.8	3.0	42.4
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	70.5	63.8	9.6	63.7	9.6
Surface water pesticide risk indicator for aquatic ecosystems	3.19	2.50	21.5	2.51	21.2
Surface water pesticide risk indicator for humans	1.14	1.04	8.7	1.04	9.0

* Results presented for the region as a whole combine model output for the 6.29 million treated acres with model results from the baseline conservation condition for the remaining acres.
** Total nitrogen and phosphorus applied were less in the treatment scenario than in the baseline because a small fraction of the field was removed from production to simulate use of additional edge-of-field buffer and filtering practices.
Note: Percent reductions are with respect to the baseline conservation condition.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 39. Conservation practice effects for the region as a whole* after additional treatment of 16.27 million undertreated acres (acres with a *high* or *moderate* need for conservation treatment) in the Lower Mississippi River Basin

Model simulated outcome	Baseline conservation condition	Treatment with erosion control practices		Treatment with erosion control and nutrient management practices	
	Average annual amount	Average annual amount	Percent reduction	Average annual amount	Percent reduction
Water flow					
Surface water runoff (inches)	13.4	11.4	14.9	11.4	14.9
Subsurface water flow (inches)	10.6	11.0	-3.6	11.0	-3.8
Erosion and sediment loss					
Wind erosion (tons/acre)	0.12	0.11	7.8	0.11	8.3
Sheet and rill erosion (tons/acre)	1.85	1.38	25.2	1.36	26.3
Sediment loss at edge of field due to water erosion (tons/acre)	3.03	0.52	82.9	0.52	82.9
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-55	-40	26.6	-43	21.8
Nitrogen					
Nitrogen sources					
Atmospheric deposition	6	6	0.0	6	0.0
Bio-fixation by legumes	59	58	2.8	59	0.6
Nitrogen applied (pounds/acre)	75	72	3.0	50	32.7
All nitrogen sources	140	136	2.8	116	17.6
Nitrogen in crop yield removed at harvest (pounds/acre)	89	87	2.6	85	5.0
Total nitrogen loss for all loss pathways (pounds/acre)	57.9	51.5	10.9	33.6	42.0
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	14.1	8.1	42.7	7.3	48.1
Nitrogen loss in subsurface flows (pounds/acre)	25.7	25.4	1.2	14.4	43.9
Phosphorus					
Phosphorus applied (pounds/acre)	19.5	19.3	1.2	14.2	27.5
Phosphorus in crop yield removed at harvest (pounds/acre)	13.7	13.6	0.7	13.5	1.3
Total phosphorus loss for all loss pathways (pounds/acre)	13.7	13.3	2.8	13.0	4.7
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	5.2	3.5	32.2	2.0	61.6
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	70.5	59.3	15.9	59.4	15.8
Surface water pesticide risk indicator for aquatic ecosystems	3.19	2.12	33.7	2.13	33.1
Surface water pesticide risk indicator for humans	1.14	0.86	24.6	0.86	24.9

* Results presented for the region as a whole combine model output for the 16.27 million treated acres with model results from the baseline conservation condition for the remaining acres.
** Total nitrogen and phosphorus applied were less in the treatment scenario than in the baseline because a small fraction of the field was removed from production to simulate use of additional edge-of-field buffer and filtering practices. This also explains the small decrease in nitrogen in the crop yield at harvest.
Note: Percent reductions are with respect to the baseline conservation condition.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Figure 60. Estimates of average annual sediment loss for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Lower Mississippi River Basin

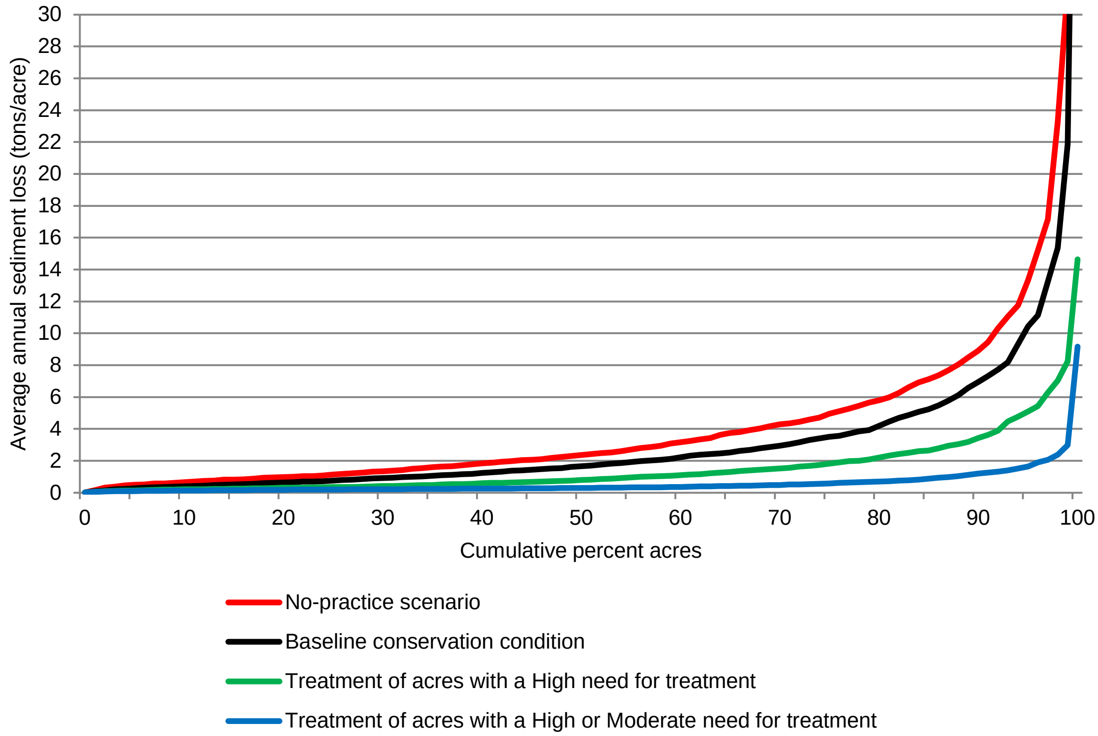


Figure 61. Estimates of average annual change in soil organic carbon for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Lower Mississippi River Basin

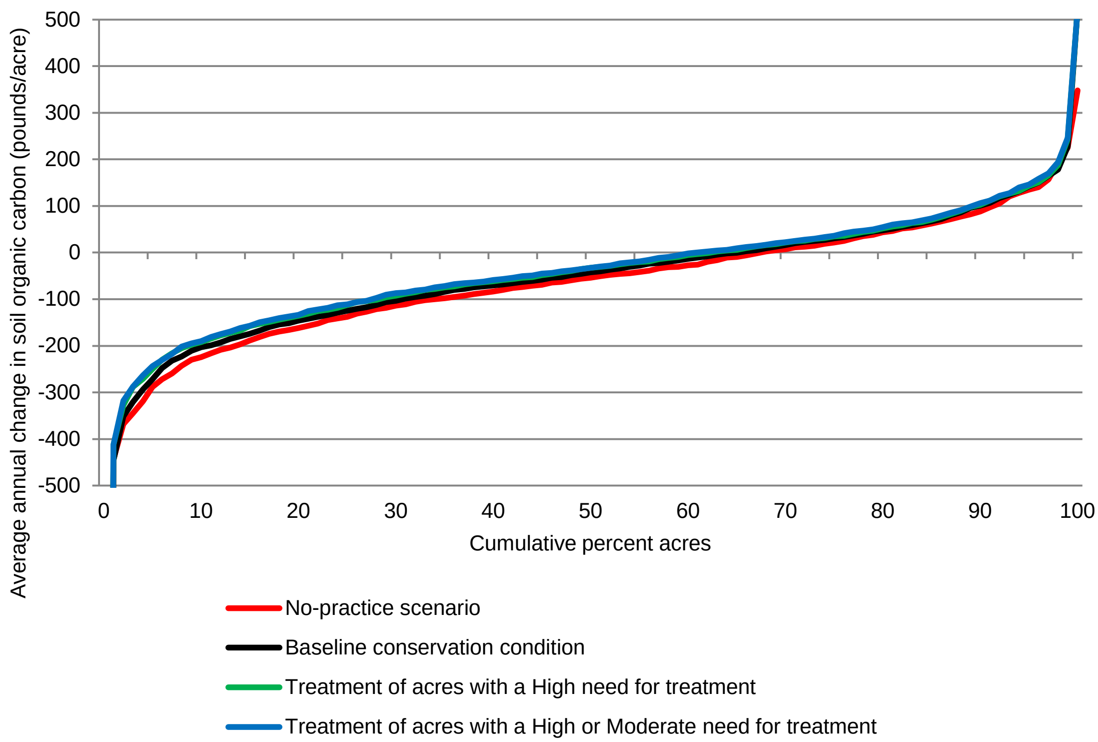


Figure 62. Estimates of average annual loss of nitrogen with surface runoff for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Lower Mississippi River Basin

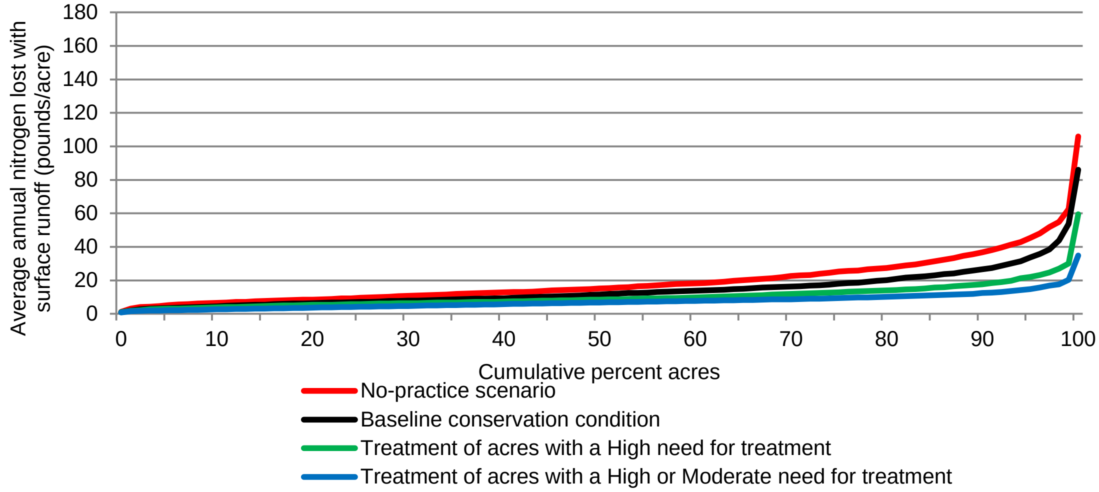


Figure 63. Estimates of average annual loss of nitrogen in subsurface flows for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Lower Mississippi River Basin

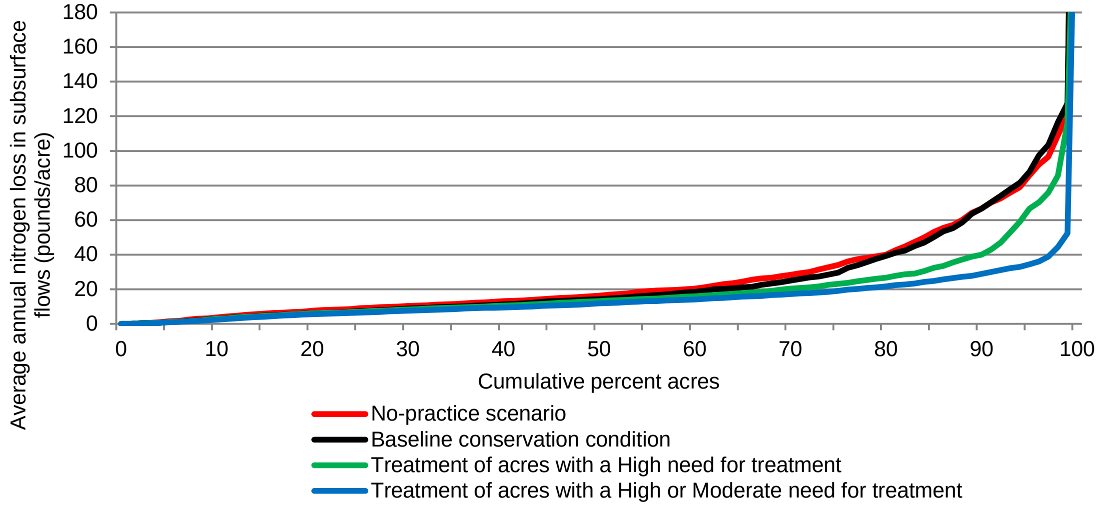


Figure 64. Estimates of average annual total nitrogen loss for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Lower Mississippi River Basin

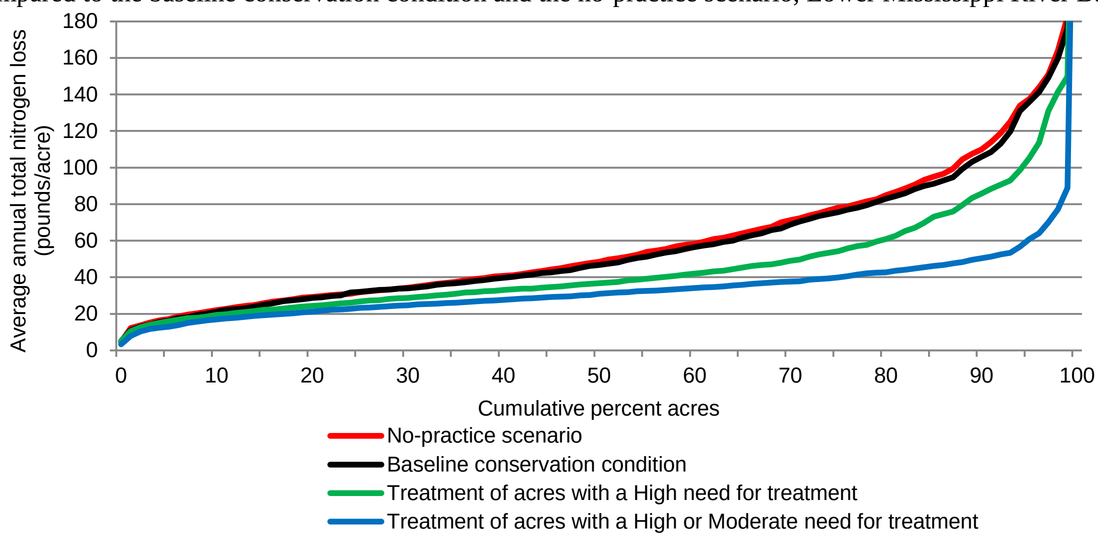
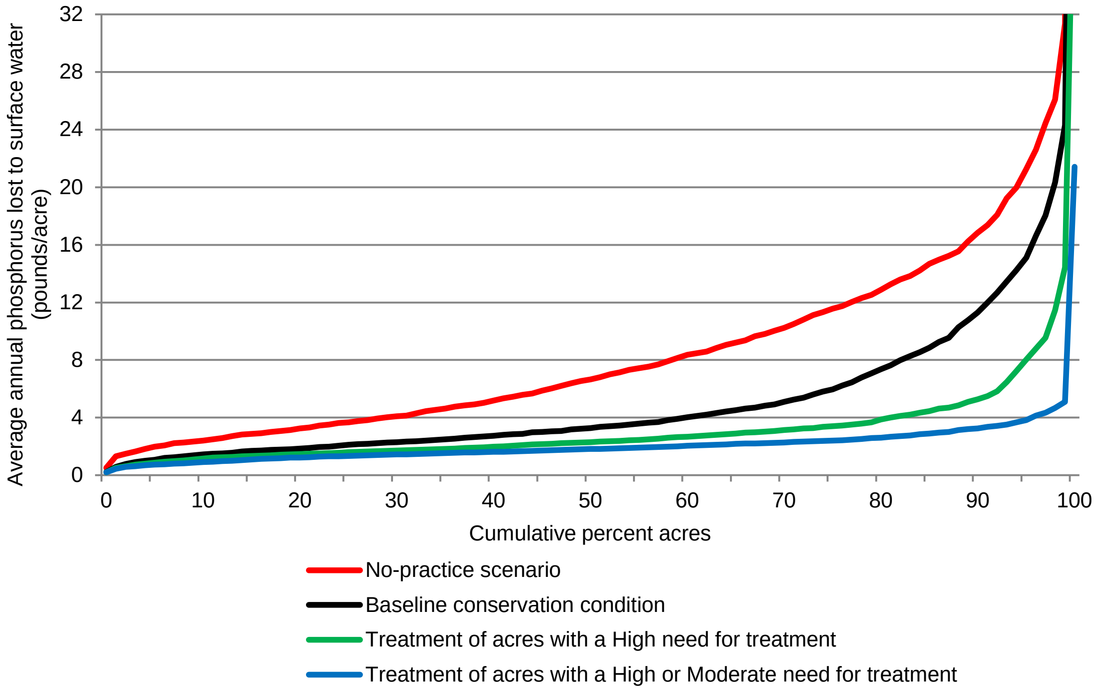
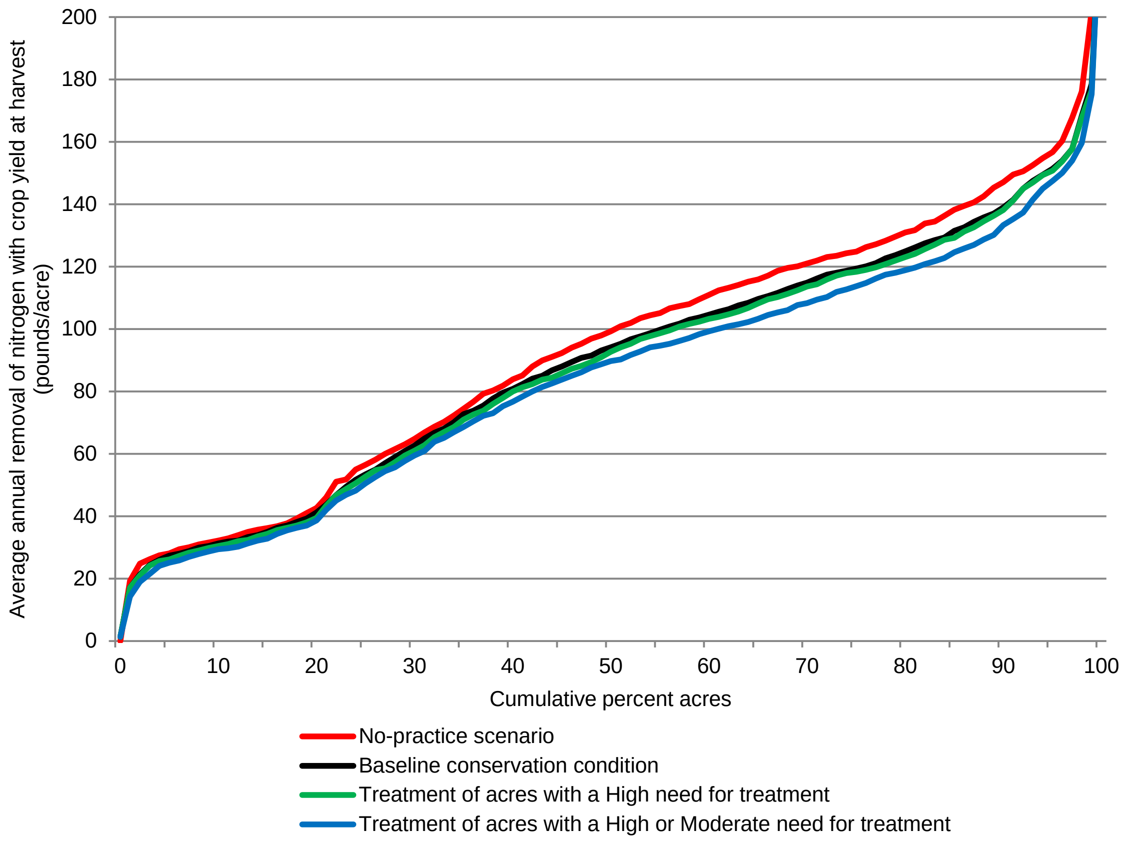


Figure 65. Estimates of average annual phosphorus lost to surface water (sediment attached and soluble)* for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Lower Mississippi River Basin



* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.

Figure 66. Estimates of average annual removal of nitrogen with crop yield at harvest for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Lower Mississippi River Basin



Potential for Gains Related to Cover Crop Use

Only about 1 percent of cropped acres had cover crops incorporated into the crop rotation during the 2003–06 time period used to evaluate conservation practices in this study, according to farmer responses in the CEAP cropland survey. Conservation and agricultural experts from the region report that cover crop use has significantly increased since the farmer survey was conducted. Cover crops are planted following crop harvest and are then tilled or killed with herbicides (or by some other means) prior to the next crop planting. When used properly, cover crops protect the soil from erosion during the non-growing season, take up nutrients remaining in the soil, and release plant available nutrients slowly over the subsequent cropping period, thereby reducing nutrient leaching and runoff during the non-growing season. In recent years farmers in the Lower Mississippi River Basin have also been planting cover crops to help control herbicide resistant weeds by increasing competition in the field for nutrients, water, and sunlight.

To demonstrate the potential for cover crops to reduce sediment and nutrient loss from fields in this region, a special "what if" scenario was conducted to simulate the use of cover crops on all cropped acres. Cover crops were inserted into the crop rotations of the baseline according to the following rules:

1. For every sample, in every crop year, the crop rotation was examined and if no crop was growing during the traditional winter period, a cover crop was "planted" the day after harvest, or the day after the last major fall tillage operation. The crop was allowed to grow until the time of the first spring tillage operation, or 1 week before the planting operation, in the case of a no-till spring planting.
2. Rye was used as the cover crop.
3. There was no other change to the baseline other than the addition of a broadcast seeder to plant the cover crop in the fall.

Results indicate that a hypothetical full adoption of cover crops in this region would, compared to the baseline conservation condition in 2003 to 2006—

- reduce sediment loss by an average of 70 percent, reducing the average annual sediment loss from farm fields to below 1 ton per acre per year.
- reduce total nitrogen loss (all loss pathways combined) by an average of 22 percent,
- reduce nitrogen loss in surface runoff by an average of 43 percent,
- reduce nitrogen loss in subsurface flows by an average of 42 percent,
- reduce total phosphorus loss by an average of 32 percent, and
- increase soil organic carbon by an average of 117 pounds per acre per year on cropped acres.

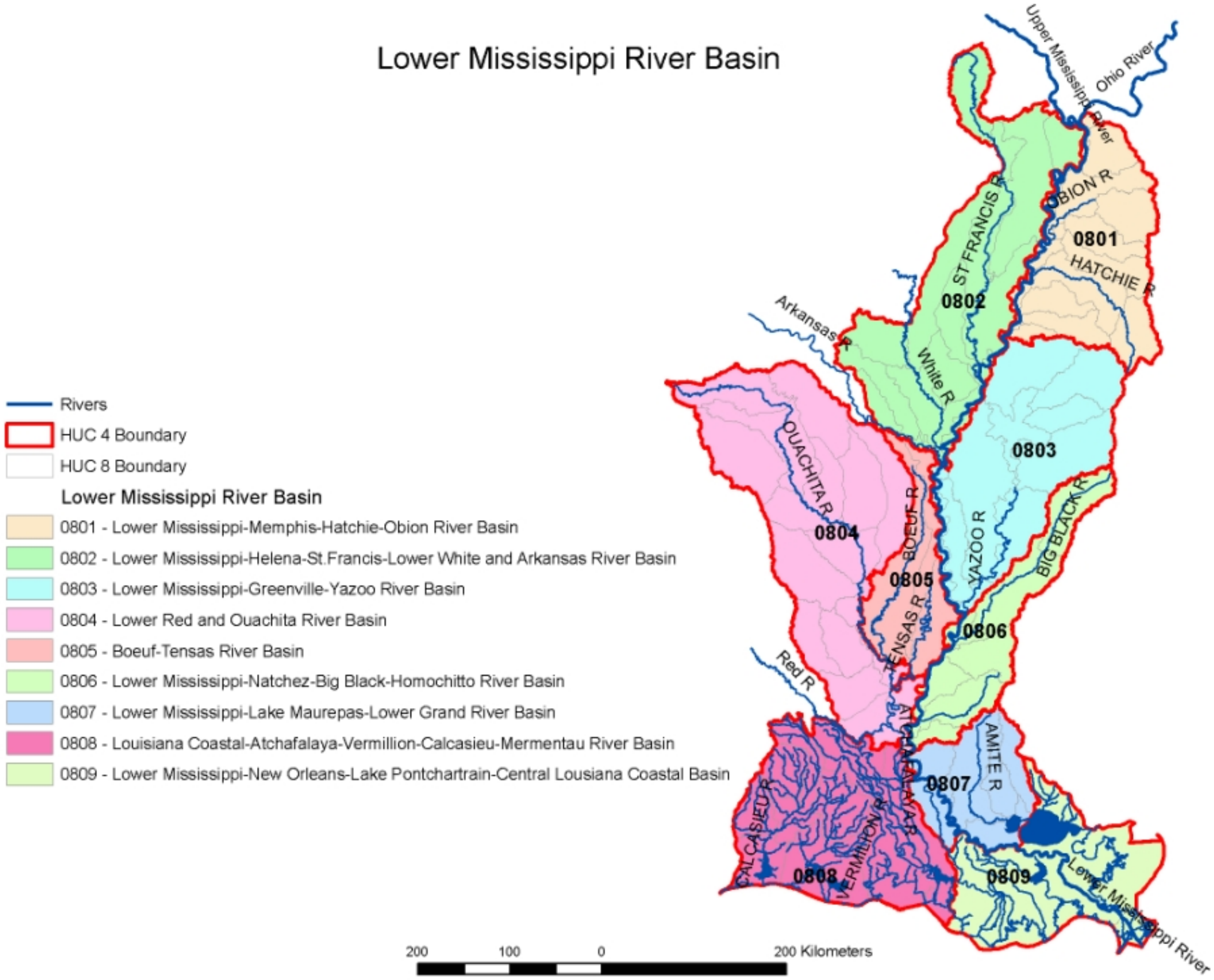
Chapter 7
Offsite Water Quality Effects of Conservation Practices

Field-level losses of sediment, nitrogen, phosphorus, and atrazine estimated using APEX were integrated into a large-scale water quality model to estimate the extent to which conservation practices reduce—

- loads delivered to rivers and streams within the basin, and
- loads exported from the region to the Gulf of Mexico.

Load estimates are reported for each of the 9 subregions (4-digit hydrologic unit code) in the Lower Mississippi River Basin, shown in figure 67, with two exceptions. Two subregions--the Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and the Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809) have too few CEAP sample points to report results for cultivated cropland separately. Results for these two subregions are therefore combined for reporting.

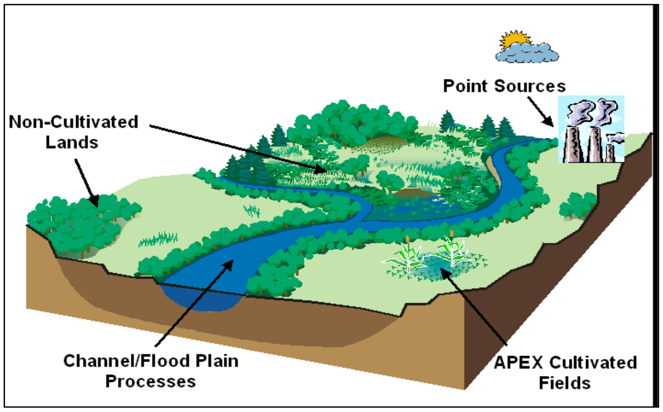
Figure 67. The 9 subregions in the Lower Mississippi River Basin



The National Water Quality Model—HUMUS/SWAT

Offsite estimates of water quality benefits were assessed using HUMUS/SWAT, a combination of the SWAT model (Soil and Water Assessment Tool) and HUMUS (Hydrologic Unit Modeling for the United States) databases required to run SWAT at the watershed scale for all watersheds in the United States (Arnold et al. 1999; Srinivasan et al. 1998). SWAT simulates the transport of water, sediment, pesticides, and nutrients from the land to receiving streams and routes the flow downstream to the next watershed and ultimately to estuaries and oceans (fig. 68).

Figure 68. Sources of water flows, sediment, and agricultural chemicals simulated with HUMUS/SWAT



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).[26] The hydrologic cycle in the model is divided into two parts. The land phase of the hydrologic cycle, or upland processes, simulates the amount of water, sediment, nutrients, and pesticides delivered from the land to the outlet of each watershed. The routing phase of the hydrologic cycle, or channel processes, simulates the movement of water, sediment, nutrients, and pesticides from the outlet of the upstream watershed through the main channel network to the watershed outlet.

Upland processes

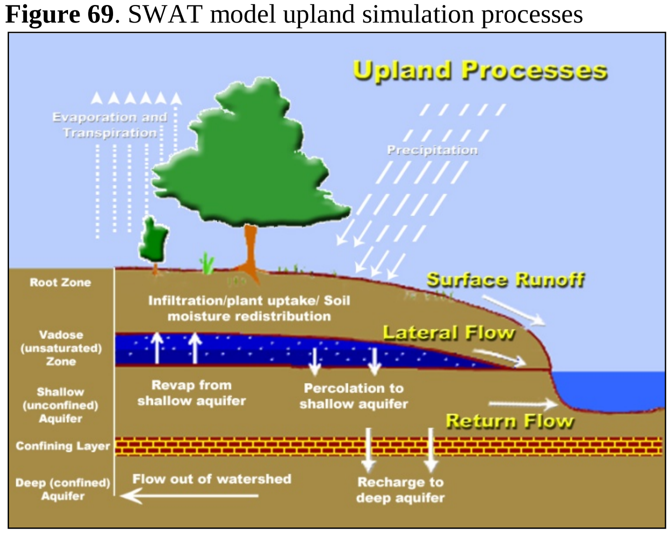
The water balance is the driving force for transport and delivery of sediment, nutrients, and pesticides from fields to streams and rivers. For this study, upland processes for non-cultivated cropland were modeled using SWAT, while source loads for cultivated cropland are estimated by APEX.

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

- Pastureland
- Permanent hayland
- 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 HUC) (fig. 69). The model simulates surface runoff estimated from daily rainfall; 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 69. SWAT model upland simulation processes



Agricultural sources

Upland processes for cultivated cropland (including land in long-term conserving cover) were modeled using APEX as described in previous chapters. The weighted average of per-acre APEX model output for surface water delivery, sediment, nutrients, and pesticides was multiplied by the acres of cultivated cropland in the HUMUS database and used as SWAT model inputs for cultivated cropland for each 8-digit Hydrologic Unit Code (HUC). The acreage weights for the CEAP sample points were used to calculate the per-acre loads. Some of the 8-digit watersheds in this region had too few CEAP sample points to reliably estimate edge-of-field per-acre loads. In these cases, the 6-digit per acre loads were used to represent cultivated cropland.

Various types of agricultural land management activities were modeled in SWAT. For permanent hayland, the following management activities were simulated:

- 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.

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

- Legume hay was grown in a 4-year rotation and 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.
- Recoverable manure from animal feeding operations was applied to 12 percent of the hayland acres at rates estimated from probable land application of manure from animal feeding operations, estimated using the methods described in USDA/NRCS (2003). (These calculations indicated that 12 percent of hayland acres in the Lower Mississippi River Basin could have received manure from animal feeding operations.)
- Three hay cuttings were simulated per crop year for grass hay and four hay cuttings were simulated per year for legume hay.
- For hayland acres that land-use databases indicated were irrigated, water was applied at a frequency and rate defined by an auto-irrigation routine.

For pastureland and rangeland, the following management activities were simulated:

- Continuous grazing was simulated by algorithms that determined the length of the grazing period, amount of biomass removed, and amount of biomass trampled. Grazing occurs whenever the plant biomass is above a specified minimum plant biomass for grazing. The amount of biomass trampled daily is converted to residue.
- Manure nutrients from grazing animals were simulated for pastureland and rangeland 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.
- Recoverable manure from animal feeding operations was applied to about 3 percent of pastureland acres at rates estimated from probable land application of manure obtained from animal feeding operations as estimated in USDA/NRCS (2003). (These calculations indicated that about 3 percent of pastureland acres in the Lower Mississippi River Basin could have received manure from animal feeding operations.)
- Supplemental commercial nitrogen fertilizers were applied to pastureland according to the crop need as determined by an auto-fertilization routine, which was set to grow grass without undue nitrogen stress.

Horticulture land was fertilized with 100 pounds per acre of nitrogen per year and 44 pounds per acre of phosphorus. For the irrigated horticultural acres, water was applied at a frequency and rate defined by an auto-irrigation routine.

Land application of biosolids from wastewater treatment facilities was not simulated. Manure nutrients from wildlife populations are not included in the model simulation.

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 modeling, is presented in table 40.[27]

Urban Sources

Urban sources include (1) loads from point sources discharged from industrial and municipal wastewater treatment plants and (2) loads from urban land runoff.

Discharges from industrial and municipal wastewater treatment plants can be major sources of nutrients and sediment in some watersheds. Point sources of water flow, total suspended sediment, total phosphorus, and Kjeldahl nitrogen were estimated using county-level data on population change to adjust 1980 estimates of point source loadings published by Resources for the Future (Gianessi and Peskin 1984) to the year 2000. The original Resources for the Future assessment covered 32,000 facilities, including industries, municipal wastewater treatment plants, and small sanitary waste facilities for the years 1977 to 1981. A GIS-based procedure was used to convert county data to the 8-digit HUC level. Point source loads are aggregated within each watershed and average annual loads input into SWAT at the watershed outlet.

Urban runoff is estimated separately for three categories of cover within an urban HRU: 1) Pervious surfaces such as lawns, golf courses, and gardens, 2) impervious surfaces hydraulically connected to drainage systems such as paved roads and paved streets draining to storm drains, and 3) impervious surfaces not hydraulically connected to drainage systems such as a house roof draining to a pervious yard that is not directly connected to drains (composite urban surface consisting of impervious roof surface and pervious yard surface).

Pervious surfaces are simulated in the same manner as other grass areas (such as pasture). Surface runoff from pervious surfaces is calculated using the curve number approach. Nitrogen fertilizer (40 pounds per acre per year) is applied on grassed urban area such as lawns and grassed roadsides using an auto-fertilizer routine to grow grass without undue nitrogen stress. The grass is considered irrigated as needed based on plant stress demand using an auto-irrigation routine.

[27] For information on how manure nutrients were calculated for use in HUMUS modeling, see "Manure Loadings Used to Simulate Pastureland and Hayland in CEAP HUMUS/SWAT Modeling," available at: http://www.nrcs.usda.gov/technical/nri/ceap.

Table 40. Summary of commercial fertilizer and manure nutrients applied to agricultural land in HUMUS/SWAT (pastureland, rangeland, hayland, and horticulture) and APEX (cultivated cropland) models, Lower Mississippi River Basin

Subregion	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			
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	100,123	2,694	102,818	31,013	875	31,888
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	252,821	2,047	254,868	66,016	1,063	67,079
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	138,826	0	138,826	28,088	0	28,088
Lower Red and Ouachita River Basin (code 0804)	18,206	240	18,446	6,614	197	6,811
Boeuf-Tensas River Basin (code 0805)	81,996	203	82,199	22,635	65	22,700
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	13,558	3,904	17,463	1,841	1,166	3,007
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	67,812	544	68,357	16,259	226	16,486
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	19,753	0	19,753	7,875	0	7,875
Total	693,096	9,632	702,729	180,341	3,592	183,933
			Hayland			
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	6,724	132	6,856	6	68	74
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	5,783	195	5,978	26	102	128
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	5,290	56	5,346	1	34	34
Lower Red and Ouachita River Basin (code 0804)	5,686	3,486	9,172	7	1,605	1,612
Boeuf-Tensas River Basin (code 0805)	172	3	175	2	2	4
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	2,699	337	3,037	0	162	162
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	3,731	111	3,842	9	58	67
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	3,376	945	4,321	8	422	430
Total	33,461	5,265	38,726	57	2,454	2,511
			Pastureland and rangeland			
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	2,115	8,505	10,620	1,218	4,892	6,110
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	1,193	4,827	6,020	691	2,789	3,480
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	1,470	5,898	7,368	886	3,552	4,438
Lower Red and Ouachita River Basin (code 0804)	2,855	13,555	16,410	1,664	7,643	9,307
Boeuf-Tensas River Basin (code 0805)	33	133	167	21	83	103
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	1,074	4,507	5,581	638	2,648	3,287
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	2,716	10,878	13,594	1,666	6,669	8,334
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	1,849	7,727	9,576	1,031	4,270	5,301
Total	13,304	56,031	69,335	7,816	32,546	40,361

Note: The amounts reported in this table are as elemental nitrogen and elemental phosphorus (not fertilizer equivalents).

Table 40--continued. Summary of commercial fertilizer and manure nutrients applied to agricultural land in HUMUS/SWAT (pastureland, rangeland, hayland, and horticulture) and APEX (cultivated cropland) models, Lower Mississippi River Basin

Subregion	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)
			Horticulture			
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	359	0	359	158	0	158
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	298	0	298	131	0	131
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	346	0	346	152	0	152
Lower Red and Ouachita River Basin (code 0804)	188	0	188	83	0	83
Boeuf-Tensas River Basin (code 0805)	148	0	148	65	0	65
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	142	0	142	62	0	62
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	364	0	364	160	0	160
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	280	0	280	123	0	123
Total	2,125	0	2,125	935	0	935
			Total for all agricultural land			
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	109,322	11,331	120,652	32,394	5,835	38,230
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	260,095	7,068	267,163	66,864	3,954	70,818
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	145,932	5,954	151,886	29,127	3,586	32,713
Lower Red and Ouachita River Basin (code 0804)	26,935	17,281	44,216	8,368	9,445	17,813
Boeuf-Tensas River Basin (code 0805)	82,349	340	82,690	22,723	149	22,872
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	17,473	8,748	26,221	2,541	3,977	6,519
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	74,623	11,533	86,156	18,094	6,953	25,047
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	25,258	8,673	33,931	9,037	4,692	13,729
Total	741,987	70,928	812,915	189,149	38,592	227,741

Note: The amounts reported in this table are as elemental nitrogen and elemental phosphorus (not fertilizer equivalents).

For estimating surface water runoff from impervious urban areas, a runoff curve number of 98 was used for surfaces connected hydraulically to drainage systems. A composite runoff curve number was used for impervious surfaces not hydraulically connected to drainage systems. Sediment and nutrients carried with stormwater runoff to streams and rivers were estimated using the build up-wash off algorithm developed by Huber and Dickinson (1988). The concept behind the build up-wash off algorithm is that over a period of time, dust, dirt and other constituents are built up on street surfaces during dry periods. During a storm event the materials are washed off. The build up-wash off algorithms are developed from an EPA national urban water quality database that relates storm runoff loads to rainfall, drainage area and impervious area.

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

A summary of the total amount of nitrogen and phosphorus applied to nonagricultural land in the model simulation is presented in table 41. Nutrients from septic systems were not included in the model simulations as data on locations of septic systems, populations using the septic systems, and types of septic systems were not available.

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 (NAPD 2004). When a rainfall event occurs in the model simulation, the amount of rainfall is multiplied by the average ammonium and nitrate concentrations calculated for the watershed to account for wet deposition. An additional amount of ammonium and nitrate are added on a daily basis to account for dry deposition. A summary of the total amount of nitrogen deposition included as inputs to the HUMUS/SWAT model simulation is presented in table 41.

Table 41. Summary of nutrients applied to urban land, nutrients originating from point sources, and wet and dry atmospheric deposition of nitrogen used as inputs to the HUMUS/SWAT model, Lower Mississippi River Basin.

	Urban land	Point sources		Wet and dry atmospheric deposition
Subregion	Nitrogen fertilizer (tons/year)	Nitrogen (tons/year)	Phosphorus (tons/year)	Nitrogen (tons/year)
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	5,799	24,900	6,192	13,078
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	5,771	1,976	978	13,086
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	4,666	954	248	14,839
Lower Red and Ouachita River Basin (code 0804)	7,026	4,443	392	42,939
Boeuf-Tensas River Basin (code 0805)	1,588	476	46	2,780
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	1,903	1,104	276	12,624
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	5,389	9,793	1,366	18,977
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	5,509	13,060	4,173	29,465
Total	37,651	56,706	13,673	147,788

Note: The amounts reported in this table are as elemental nitrogen and elemental phosphorus (not fertilizer equivalents).

"Legacy Phosphorus" Not Accounted for in Modeling

"Legacy phosphorus" results from the over-application of phosphorus on farm fields in past years. When excessive amounts of fertilizer or manure are applied to a farm field, soil phosphorus levels increase dramatically. It may take many years or even decades for phosphorus levels to return to background levels once these practices are halted. Use of soil testing to determine the need for phosphorus applications can prevent further over-application, but there remains other phosphorus material locked into the soil profile within the field, along the edge of the field and drainage ways, and in streambeds that cannot be offset by current management activities.

In addition, the transport of sediment—and the phosphorus bound to those particles—from farm fields to rivers and streams can take many years. Eroded soil particles leaving a farm field can be deposited where runoff slows or ponding occurs before reaching a stream or river. Once the sediment has entered streams, some of the soil particles settle out and can remain in the streambed or settle on the floodplain when the water is high and slow moving. These sediments can remain in place for years until a storm creates enough surface water runoff to re-suspend the previously eroded soil, or until streamflow cuts into streambanks made up of deposits of previously eroded soil. Windborne sediment transported into waterways can similarly be a mixture of newly eroded and previously eroded materials.

Consequently, the phosphorus content of eroded soil from farm fields can be high even when excessive amounts of fertilizer or manure are no longer being applied, including eroded soil from land that is not currently farmed. The measured phosphorus levels in rivers and streams include not only phosphorus lost from farm fields as a result of current farming activities but also "legacy phosphorus" adsorbed to soil particles as a result of prior farming activities. Some of this sediment-adsorbed "legacy phosphorus" can be solubilized by chemical reactions within the water body and measured as soluble phosphorus.

The simulation models used in this study do not account for these "legacy phosphorus" levels. There is recognition, however, that "legacy phosphorus" can be an important contributor to current levels of instream phosphorus loads, including soluble phosphorus.

Routing and channel processes

SWAT simulates stream/channel processes including channel flood routing, channel sediment routing, nutrient and pesticide routing, and transformations modified from the QUAL2E model (fig. 70).

- **Flood routing**. As water flows downstream, some may be lost due to evaporation and transmission through the channel bed. Another potential loss is removal of water from the channel for agricultural or human use. Flow may be supplemented by rainfall directly on the channel and/or addition of water from point source discharges.

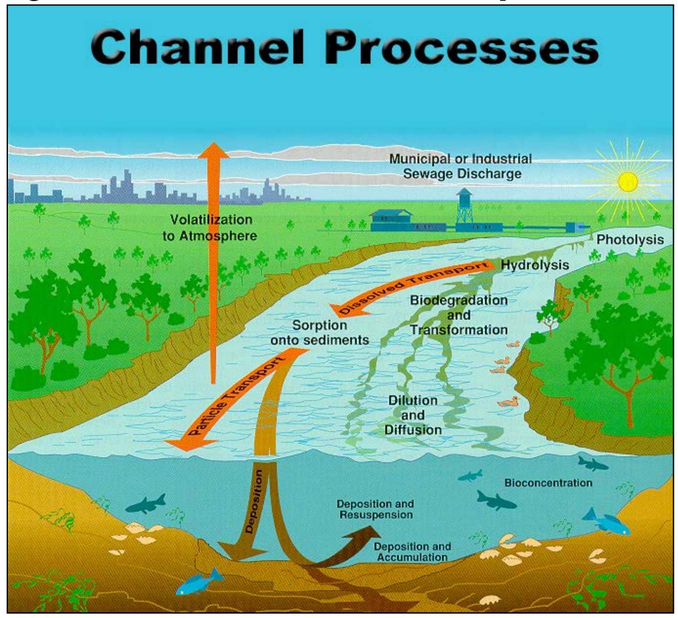
- **Sediment routing—deposition, bed degradation, and streambank erosion**. Sediment transport in the stream network is a function of two processes, deposition and degradation. SWAT computes deposition and degradation simultaneously within the reach. Deposition is based on the fall velocity of the sediment particles and the travel time through each stream. Stream power is used to predict bed and bank degradation; excess stream power results in degradation. Bed degradation and streambank erosion are based on the erodibility and vegetative cover of the bed or bank and the energy available to carry sediment (a function of depth, velocity and slope). The maximum amount of sediment that can be transported from a reach segment is a function of the peak channel velocity. Available stream power is used to re-entrain loose and deposited material until all of the material is removed.[28]

- **Nutrient routing**. Nutrient transformations in the stream are controlled by the instream water quality component of the model. The model tracks nutrients dissolved in the stream and nutrients adsorbed to the sediment. Dissolved nutrients are transported with the water, while those adsorbed to sediments are deposited with the sediment on the bed of the channel.

- **Pesticide routing**. As with nutrients, the total pesticide load in the channel is partitioned into dissolved and sediment-attached components. While the dissolved pesticide is transported with water, the pesticide attached to sediment is affected by sediment transport and deposition processes. Pesticide transformations in the dissolved and adsorbed phases are governed by first-order decay relationships. The major instream processes simulated by the model are settling, burial, resuspension, volatilization, diffusion, and transformation.

[28] There are no national estimates of streambank erosion that can be uniformly used to calibrate this component of the model. Parameters governing instream sediment processes are adjusted in concert with those governing upland sediment yields such that HUMUS predictions at calibration sites mimic measured sediment data. Sediment data collected at a single stream gauging site is a combination of upland and instream sources, which cannot be proportioned by source. Collectively a network of sediment monitoring sites may be used to develop a sediment budget for a watershed which may include a stream bank component. When such studies are available for a HUMUS region they are used as ancillary data during model calibration.

Figure 70. SWAT model channel simulation processes



Reservoirs

Reservoirs alter the dynamics of a free-flowing river, resulting in different rates of sediment deposition and chemical transformations. SWAT includes routines for reservoirs that account for the hydrological aspects of reservoirs. Basic reservoir data such as storage capacity and surface area were obtained from the dams database.

- **Reservoir outflow**. A simple target volume approach was used in this study to simulate reservoir outflow. The algorithm attempts to keep reservoir storage near the principal spillway volume during the flood season but allow water storage to accumulate above the principal storage during the non-flood season.

- **Sediment routing**. The concentration of sediment in the reservoir is estimated using a simple continuity equation based on volume and concentration of inflow, outflow, and water retained in the reservoir. Settling of sediment in the reservoir is governed by an equilibrium sediment concentration and the median sediment particle size. The amount of sediment in the reservoir outflow is the product of the volume of water flowing out of the reservoir and the suspended sediment concentration in the reservoir at the time of release.

- **Reservoir nutrients**. The model assumes that (1) the reservoir is completely mixed, (2) phosphorus is the limiting nutrient, and (3) total phosphorus is a measure of the trophic status. The phosphorus mass balance equation includes the concentration in the reservoir, inflow, outflow, and overall loss rate.

- **Reservoir pesticides**. The model partitions the system into a well-mixed surface water layer underlain by a well-mixed sediment layer for simulating the fate of pesticides. The pesticide is partitioned into dissolved and particulate phases in both the water and sediment layers. The major processes simulated by the model are loading, outflow, transformation, volatilization, settling, diffusion, resuspension, and burial.

Calibration

Existing SWAT/HUMUS models developed within the Mississippi River Basin, including the Upper Mississippi, Missouri, Ohio-Tennessee, and Arkansas-White-Red River Basins, were linked with the Lower Mississippi River Basin model. A diversion was added to the Lower Mississippi River Model below Knoxville, LA to transfer 30% of flow and loads from the Mississippi River to the Atchafalaya River through Old River Outflow Channel (figures 67 and 72). The Lower Mississippi River Basin model was calibrated with gauging stations selected on the main stem of the Mississippi River and its tributaries. Time series calibration of streamflow was conducted at seven gauging stations in the Lower Mississippi River Basin for the period between 1961 and 2006, depending on the length of data available. Predicted annual flows were compared against the gage data for the calibration period. Hydrologic parameters in APEX (used for simulating cultivated cropland) and SWAT (used for simulating non-cultivated land) such as curve number, soil water depletion coefficient, available water holding capacity, soil and plant evaporation compensation factors and ground water related parameters were adjusted to match the flow at the gages.[29] When necessary, channel losses, seepage, and evaporation losses in reservoirs were adjusted to match the predicted flow time series with that of monitored data. Reservoirs were a relatively minor consideration in the Lower Mississippi River Basin due to the lack of structures on the main stem of the Mississippi.

Sediment was calibrated using USGS monitoring data. These observations were grab-sample concentrations of suspended sediment. Annual average sediment loads were estimated using this sediment concentration data combined with daily gage flow using the USGS's Estimator software. Estimated annual sediment loads at seven gauges were used to calibrate the HUMUS/SWAT model. Upland soil erosion and sediment yields were calibrated by adjusting the soil erodibility factor and residue cover. Instream sediment loads were calibrated using parameters controlling stream power and sediment carrying capacity of channels. Delivery ratios from field to 8-digit watershed outlet and 8-digit watershed to river were adjusted to match predicted sediment load with that of observations for each gaging station. Where necessary, parameters affecting settling of sediment in reservoirs were adjusted.

Total nitrogen and total phosphorus loads were calibrated at 8 gauging stations. Nitrate-nitrogen and nitrite-nitrogen (sum), and orthophosphate were calibrated in stations where observed data were available. Much of the data for nutrient calibration were taken from the USGS-NASQAN data monitoring program. Nutrient loads were estimated from grab-sample concentrations using the same procedure outlined for sediment. Upland nutrient loads were calibrated using parameters controlling nutrient uptake by plants, leaching to groundwater, and mineralization. Instream nutrient loads were calibrated using parameters affecting benthic nutrient source rates, mineralization, hydrolysis, and settling of particulate nutrients. Where necessary, parameters affecting settling of nutrients in reservoirs were also adjusted.

Atrazine loads were not calibrated due to a lack of adequate sampling data at the selected calibration gages with which to estimate loads.

The "background" scenario

An additional scenario was conducted to represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by simulating with APEX a grass-and-tree-mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.[30] All SWAT modeling remained the same for this scenario. Thus, "background" loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

Source Loads and Instream Loads

All source loads are introduced into SWAT at the outlet of each watershed (8-digit hydrologic unit code [HUC]). Flows and source loads from upstream watersheds are routed through each downstream watershed, including reservoirs when present.[31]

A sediment delivery ratio was used to account for deposition in ditches, floodplains, and tributary stream channels during transit from the edge of the 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 most distant point in the watershed 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 from the remotest point in the watershed to reach the channel) and the

[29] For a complete documentation of calibration procedures and results for the Arkansas-White-Red River Basin, see "Calibration and Validation of CEAP HUMUS" at http://www.nrcs.usda.gov/technical/nri/ceap.

[30] In a natural ecosystem, the vegetative cover would include a mix of species, which would continually change until a stable ecosystem was established. APEX allows for multiple species and simulates plant competition over time according to plant growth, canopy cover, vegetative form, and relative maturity or growth stage. The initial mix of species at the beginning of the 47-year simulation was similar to the mix of grasses and trees used to establish long-term conserving cover. Mixes included at least one grass and one legume. Over the 47-year simulation, the mix of grasses and trees shifted due to plant competition. The grass species typically dominate in the simulation until shaded out by tree cover. For further details on how the background simulation was conducted, see "Assumptions and Procedures for Simulating the Natural Vegetation Background Scenario for the CEAP National Cropland Assessment" at http://www.nrcs.usda.gov/technical/nri/ceap.

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

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.[32]

In addition to the sediment delivery ratio, an enrichment ratio was used to simulate organic nitrogen, organic phosphorus, and sediment-attached pesticide transport in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The enrichment ratio was defined as the organic nitrogen, organic phosphorus, and sediment attached pesticide concentrations transported with sediment to the watershed outlet divided by their concentrations at the edge of the field. As sediment is transported from the edge of field to the watershed outlet, coarse sediments are deposited first while more of the fine sediment that hold organic particles remain in suspension, thus enriching the organic concentrations delivered to the watershed outlet.

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

There are four points in the modeling process at which source loads or instream loads are assessed, shown in the schematic in figure 71 for sediment.

1. Edge-of-field loads from cultivated cropland—aggregated APEX model output as reported in the previous chapter.

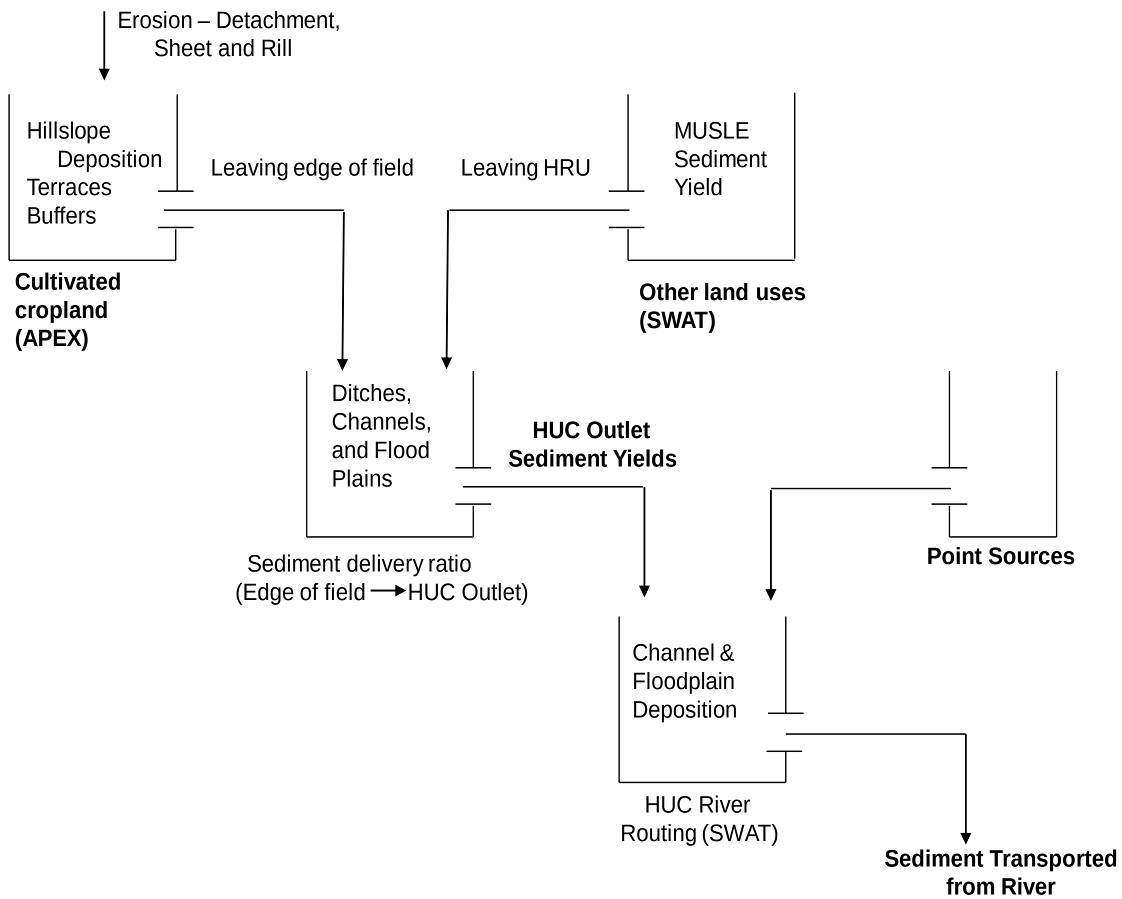
2. Delivery to the watershed outlet from cultivated cropland—aggregated edge-of-field loads after application of delivery ratios. Loadings delivered to streams and rivers differ from the amount leaving the field because of losses during transport from the field to the stream. Delivery ratios are used 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.

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.

[32] For a complete documentation of delivery ratios used for the Lower Mississippi River Basin, see "Delivery Ratios Used in CEAP Cropland Modeling" at http://www.nrcs.usda.gov/technical/nri/ceap.

Figure 71. Schematic of sediment sources and delivery as modeled with HUMUS/SWAT for the Lower Mississippi River Basin



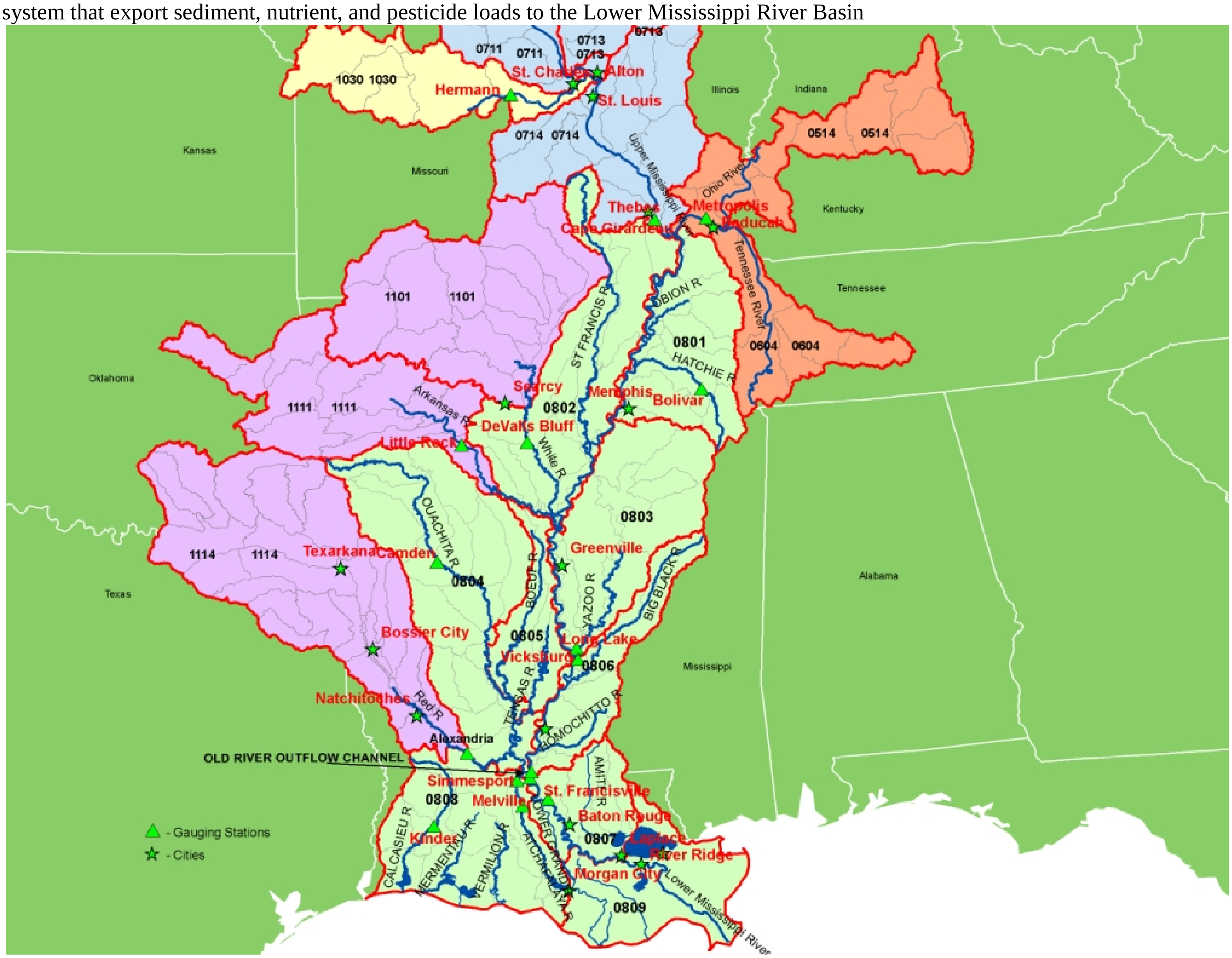
Instream loads in the Lower Mississippi River Basin include sediment, nutrient, and pesticide loads originating from other basins within the Mississippi drainage system as well as loads originating from within the Lower Mississippi River basin. The Missouri River joins the Upper Mississippi River north of St. Louis, MO, at the outlet of subregion 1030, as shown in figure 72. Loads from the Upper Mississippi River Basin along with the loads from the Missouri River Basin are delivered to the Lower Mississippi River basin near Thebes, IL, at the outlet of subregion 0714. (Instream loads delivered from the Upper Mississippi River Basin alone are estimated by subtracting the subregion 1030 loads from the loads delivered at the outlet of 0714.) The Ohio River, including flow from the Tennessee River (outlet of subregion 0604), joins the Mississippi River just south of Thebes, IL, at the outlet of subregion 0514.

Loads from the Upper White River and the Lower Arkansas River originate from the Arkansas-White-Red Basin and combine with loads originating from the Lower Mississippi River Basin subregion 0802. Loads delivered from the Upper White River at the outlet of subregion 1101 and loads delivered from the Lower Arkansas River at the outlet of subregion 1111 are ultimately delivered to the mainstem of the Mississippi River north of Greenville, MS.

Flow from the Red River at the outlet of subregion 1114 (near Alexandria, LA) joins with the Ouachita River in subregion 0804 and combines with flow from subregion 0805 prior to being discharged into the Atchafalaya River near the outlet of subregion 0804 (fig. 72). The Tensas and Boeuf Rivers in subregion 0805 join the Ouachita River in subregion 0804. Thus, subregions 0804, 0805 and parts of subregion 0808 together form part of the Atchafalaya River system, which also discharges into the Gulf of Mexico.

A portion of the instream loads from the mainstem of the Mississippi River are diverted through the Old River Outflow Channel to the Atchafalaya River system near Knox Landing, LA, as shown in figure 72. The amount diverted varies from year to year, but averaged about 30 percent of the flow from the Mississippi River in these model simulations.

Figure 72. Schematic showing the Lower Mississippi River Basin and the location of other basins within the Mississippi drainage system that export sediment, nutrient, and pesticide loads to the Lower Mississippi River Basin



Modeling Land Use in the Lower Mississippi River Basin

The USGS National Land-Cover Database for 2001 (Homer et al. 2007) was the principal source of acreage estimates for HUMUS/SWAT modeling. The 2003 National Resources Inventory (USDA-NRCS 2007) was used to adjust NLCD cropland acreage estimates to include acres in Conservation Reserve Program General Signups, used here to represent cropland in long-term conserving cover. Consequently, cultivated cropland acres used to simulate the water quality effects of conservation practices differ slightly from the cropped acres reported in the previous chapters that were based on the CEAP Cropland sample.

Estimates of the acreage by land use used in the model simulation to estimate the effects of conservation practices in this chapter are presented in figure 73 and table 42. Cultivated cropland is the dominant land use in 4 subregions—subregions 0801, 0802, 0803, and 0805—located in the northern portion of the basin. For the remaining subregions, however, forest land and wetlands together represent more than half of the land base (tables 4 and 42).

Overall for the basin, forestland and wetlands make up 48 percent of the land base and cultivated cropland makes up 33 percent (fig.73). Pasture and grazing land makes up about 11 percent of the land in the basin and hayland makes up about 2 percent. Urban land makes up 6 percent of the land base in the basin.

Cultivated cropland is a minor land use in three subregions, where less than 10 percent of the land base in each subregion is cultivated cropland (tables 4 and 42)—

- The Lower Red and Ouachita River Basin (code 0804),
- Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and
- Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809).

Cultivated cropland includes land in long-term conserving cover, which represents about 5 percent of the cultivated cropland acres in this region (table 4). In the Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806), however, land in long-term conserving cover represents 35 percent of cultivated cropland (table 4). In this subregion the predominance of land in long-term conserving cover is an important determinant of the extent to which sediment and nutrient loads are reduced by conservation practice use.

Figure 73. Percent acres for land use/cover types in the Lower Mississippi River Basin, exclusive of water

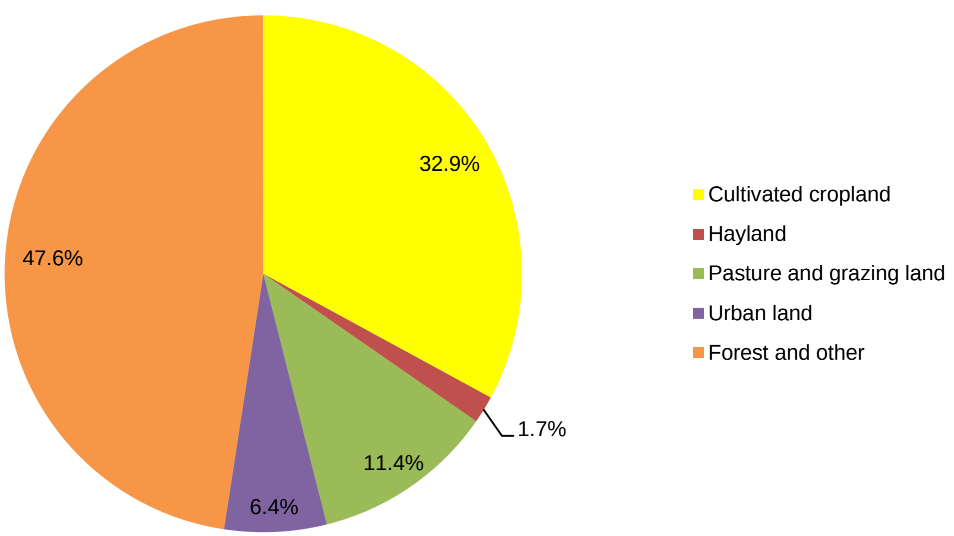


Table 42. Acres by land use, exclusive of water, used in model simulations to estimate instream sediment, nutrient, and atrazine loads for the Lower Mississippi River Basin

Subregions	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 exclusive of water (acres)
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	3,061,626	191,828	740,364	609,540	2,266,179	6,869,537
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	6,772,715	173,334	358,179	606,893	2,580,393	10,491,515
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	3,932,835	151,402	1,024,271	486,217	3,022,158	8,616,883
Lower Red and Ouachita River Basin (code 0804)	885,859	235,088	1,750,460	729,092	9,208,248	12,808,746
Boeuf-Tensas River Basin (code 0805)	2,473,560	6,915	12,614	176,211	643,013	3,312,314
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	478,111	75,886	885,133	211,980	2,781,508	4,432,618
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	2,043,071	99,397	1,312,055	493,821	4,081,068	8,029,411
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	631,179	115,544	933,837	626,592	4,694,999	7,002,151
Regional total	20,278,956	1,049,394	7,016,915	3,940,345	29,277,566	61,563,176

*Acres of cultivated cropland include land in long-term conserving cover as well as hay land and pastureland in rotation with crops.

**Includes grass and brush rangeland categories.

***Includes forests (all types), wetlands, horticulture, and barren land.

Note: Estimates were obtained from HUMUS databases on land use, and thus cultivated cropland estimates do not exactly match the acreage estimates obtained from the NRI-CEAP sample.

Loads Delivered from Cultivated Cropland to Rivers and Streams within the Region

HUMUS/SWAT accounts for the transport of water, sediment, pesticides, 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 sediment, nutrients, and pesticides that leave farm fields are delivered to streams and rivers. Some material is bound up in various parts of the landscape during transport. Loads delivered from cultivated cropland and other sources to rivers and streams within the Lower Mississippi River Basin are presented in this section.

The water quality effects of conservation practices in use during 2003–06 on loads delivered from cultivated cropland to rivers and streams were assessed by comparing HUMUS/SWAT model simulation results for the baseline conservation condition to simulation results for the no-practice scenario. For the no-practice scenario, only the conditions for cultivated cropland were changed, as described previously. All other aspects of the simulations—including sediment and nutrient loads from point sources and land uses other than cultivated cropland—remained the same.

The field-level model results for the treatment scenarios with additional erosion control practices and nutrient management (chapter 6) were used with the HUMUS/SWAT model to determine the *potential for further reductions* in loads delivered from cultivated cropland to rivers and streams throughout the region with additional conservation treatment. Percent reductions relative to the baseline conservation condition were estimated for each of two treatment scenarios—

1. Treatment of the 6.29 million critical under-treated acres, which have a "high" need for additional treatment for one or more resource concerns (33.4 percent of cropped acres in the region), and
2. Treatment of all 16.27 million acres with a "high" or "moderate" need for additional treatment for one or more resource concerns (86.4 percent of cropped acres in the region).

Acres not receiving treatment in the simulation retained baseline values. Thus, the distribution of undertreated acres within the region influences the extent to which individual subregions benefit from additional treatment, since additional treatment was simulated only for the undertreated acres. The distribution of undertreated acres within the Lower Mississippi River Basin is shown in chapter 5, tables 32–33.

In summary, findings for the Lower Mississippi River Basin indicate that for the baseline conservation condition, sediment, nutrient, and atrazine loads ***delivered to rivers and streams from cultivated cropland sources*** *per year, on average, are—*

- *23.4 million tons of sediment (78 percent of loads from all sources);*
- *555 million pounds of nitrogen (53 percent of loads from all sources);*
- *53 million pounds of phosphorus (43 percent of loads from all sources); and*
- *88,000 pounds of atrazine.*

Conservation practices in use on cultivated cropland in 2003-06, including land in long-term conserving cover, have reduced sediment, nutrient, and atrazine loads ***delivered to rivers and streams from cultivated cropland sources*** *per year, on average, by—*

- *35 percent for sediment;*
- *21 percent for nitrogen;*
- *52 percent for phosphorus, and*
- *26 percent for atrazine.*

Model simulations showed that if the 6.29 million ***critical*** *undertreated acres were fully treated with the appropriate soil erosion control and nutrient management practices, loads from cultivated cropland delivered to rivers and streams in the Lower Mississippi River Basin would be reduced by, relative to the baseline conservation condition—*

- *48 percent for sediment,*
- *23 percent for nitrogen,*
- *38 percent for phosphorus, and*
- *5 percent for atrazine.*

Percent reductions were usually highest in subregions with the highest proportion of critical undertreated acres within the subregion.

Model simulations further showed that if ***all*** *of the undertreated acres (an additional 9.98 million acres) were fully treated with the appropriate soil erosion control and nutrient management practices, loads from cultivated cropland delivered to rivers and streams in the watershed would be reduced, relative to the baseline conservation condition—*

- *80 percent for sediment,*
- *43 percent for nitrogen,*
- *57 percent for phosphorus, and*
- *15 percent for atrazine.*

Sediment

Baseline condition. Model simulation results show that of the 58.6 million tons of sediment exported from farm fields in the Lower Mississippi River Basin (table 43), about 23.4 million tons are delivered to rivers and streams each year (table 44), on average, under conditions represented by the baseline conservation condition, which simulates farming activities and conservation practices in use during the period 2003 to 2006. About 1.15 tons of sediment per acre of cultivated cropland are delivered to rivers and streams per year, on average, within the region (table 44).

About half of the sediment delivered to rivers and streams from cultivated cropland in this region originates in two subregions—the Lower Mississippi-Greenville-Yazoo River Basin (code 0803) with 31 percent and the Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801) with 21 percent (table 44).

On a per-acre basis, sediment delivery from cultivated cropland is highest in these same two subregions plus a third. Sediment delivery averages 1.86 tons per acre for the Lower Mississippi-Greenville-Yazoo River Basin (code 0803), 1.59 tons per acre for the Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801), and 1.43 tons per acre for the Lower Red and Ouachita River Basin (code 0804) (table 44). Sediment delivered to rivers and streams ranges from an average of 0.53 ton per acre of cultivated cropland to 1.20 tons per acre of cultivated cropland in the remaining subregions.

Sediment delivered to rivers and streams from cultivated cropland represents about 78 percent of the total sediment load delivered from all sources in the region (table 45, fig. 74). In contrast, cultivated cropland acres make up a much smaller percentage of the land base in the region—33 percent (fig. 73). The percent of the total sediment load originating from cultivated cropland exceeds 90 percent in 2 subregions—

- the Boeuf-Tensas River Basin (code 0805)and
- the Lower Mississippi-Greenville-Yazoo River Basin (code 0803).

Urban point and nonpoint sources account for about 10 percent of the total sediment load delivered to rivers and streams within the Lower Mississippi River Basin, on average (table 45). The remaining 12 percent originates from hayland, pastureland, rangeland, forest land, wetlands, and other minor land use/land cover categories.

Effects of conservation practices. Model simulations indicate that conservation practices have reduced the delivery of sediment from fields to rivers and streams by about 35 percent (table 44), on average, in this region. Reductions due to conservation practices vary throughout the region, ranging from a low of 16 percent for the Lower Red and Ouachita River Basin (code 0804) to a high of 75 percent for the Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806). The higher percent reduction for the Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806) is in part due to the high proportion (35 percent) of cultivated cropland acres in long-term conserving cover.

Potential gains from further conservation treatment. Because of the relatively high levels of water-eroded sediment loss from farm fields throughout most of this region, the potential for additional gains from further conservation treatment is substantial, as shown in figure 59 in the previous chapter. Model simulations show that use of additional erosion control practices on the 6.29 million critical under-treated acres in the region would reduce overall sediment loads delivered to rivers and streams by about 11 million tons per year, representing a reduction from baseline levels of 48 percent (table 46). Use of additional erosion control practices on all 16.27 million under-treated acres in the region would reduce sediment loads delivered to rivers and streams by nearly 19 million tons per year, representing a reduction from baseline levels of 80 percent (table 46, fig. 75).

The largest gain in terms of tons saved would occur in the Lower Mississippi-Greenville-Yazoo River Basin (code 0803), where 5.9 million tons of sediment per year would be saved with additional conservation treatment for all under-treated acres (table 46). The second-largest gain would occur in the Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801), where 4.3 million tons of sediment per year would be saved with additional conservation treatment for all under-treated acres.

In terms of the largest percent reduction, sediment loads delivered to rivers and streams would be reduced 88 percent in the Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801) and 87 percent in the Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806) with additional conservation treatment for all under-treated acres.

Table 43. Average annual sediment loads ***delivered to edge of field*** (APEX model output) from cultivated cropland in the Lower Mississippi River Basin

Subregions	Baseline conservation condition: Amount (1,000 tons)	Baseline conservation condition: Percent of basin total	Baseline conservation condition: Tons delivered per cultivated cropland acre	No-practice Scenario (1,000 tons)	Reductions in loads due to conservation practices: Reduction (1,000 tons)	Reductions in loads due to conservation practices: Percent
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	13,260	23	4.33	27,120	13,860	51
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	9,038	15	1.33	12,810	3,772	29
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	18,240	31	4.64	24,650	6,410	26
Lower Red and Ouachita River Basin (code 0804)	2,654	5	3.00	3,156	502	16
Boeuf-Tensas River Basin (code 0805)	7,366	13	2.98	10,760	3,394	32
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	1,346	2	2.82	5,616	4,270	76
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	5,163	9	2.53	6,449	1,286	20
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	1,524	3	2.42	2,123	599	28
Regional total	58,591	100	2.89	92,684	34,093	37

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.

Table 44. Average annual sediment loads ***delivered to watershed outlets*** (8-digit HUCs) ***from cultivated cropland*** in the Lower Mississippi River Basin

Subregions	Baseline conservation condition: Amount (1,000 tons)	Baseline conservation condition: Percent of basin total	Baseline conservation condition: Tons delivered per cultivated cropland acre	No-practice Scenario (1,000 tons)	Reductions in loads due to conservation practices: Reduction (1,000 tons)	Reductions in loads due to conservation practices: Percent
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	4,854	21	1.59	9,855	5,001	51
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	3,586	15	0.53	5,107	1,521	30
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	7,312	31	1.86	9,736	2,424	25
Lower Red and Ouachita River Basin (code 0804)	1,268	5	1.43	1,503	235	16
Boeuf-Tensas River Basin (code 0805)	2,980	13	1.20	4,370	1,390	32
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	479	2	1.00	1,895	1,416	75
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	2,243	10	1.10	2,798	555	20
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	687	3	1.09	929	243	26
Regional total	23,409	100	1.15	36,193	12,785	35

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 43 are due to the application of delivery ratios, which were used to simulate delivery of sediment from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.

Table 45. Average annual sediment loads ***delivered to watershed outlets*** (8-digit HUCs) in the Lower Mississippi River Basin, baseline conservation condition, by source

Subregions	All sources	Cultivated cropland*	Hayland	Pasture and grazing land	Urban nonpoint sources**	Urban point sources	Forest and other***
				Amount (1,000 tons)			
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	5,795	4,854	30	127	520	112	153
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	4,274	3,586	30	77	425	5	151
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	7,865	7,312	12	96	229	4	212
Lower Red and Ouachita River Basin (code 0804)	2,632	1,268	37	158	655	10	505
Boeuf-Tensas River Basin (code 0805)	3,131	2,980	1	1	122	3	24
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	1,148	479	18	186	174	7	283
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	3,469	2,243	11	157	313	19	726
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	1,687	687	14	101	362	44	480
Regional total	30,002	23,409	151	904	2,800	203	2,536
				Percent of all sources			
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	100	84	1	2	9	2	3
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	100	84	1	2	10	<1	4
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	100	93	<1	1	3	<1	3
Lower Red and Ouachita River Basin (code 0804)	100	48	1	6	25	<1	19
Boeuf-Tensas River Basin (code 0805)	100	95	<1	<1	4	<1	1
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	100	42	2	16	15	1	25
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	100	65	<1	5	9	1	21
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	100	41	1	6	21	3	28
Regional total	100	78	1	3	9	1	8

* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, horticulture, and barren land.

Figure 74. Percentage by source of average annual sediment loads delivered to rivers and streams in the Lower Mississippi River Basin, baseline conservation condition

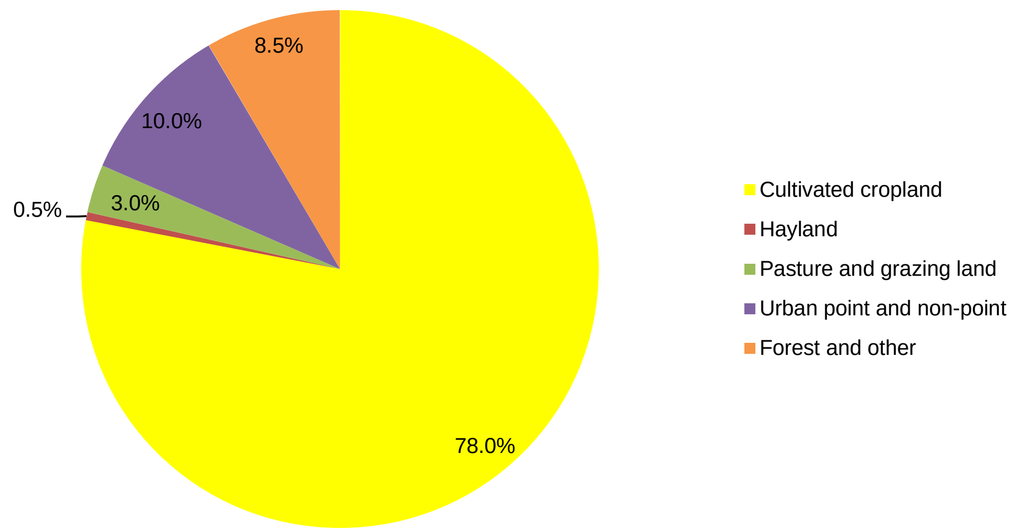
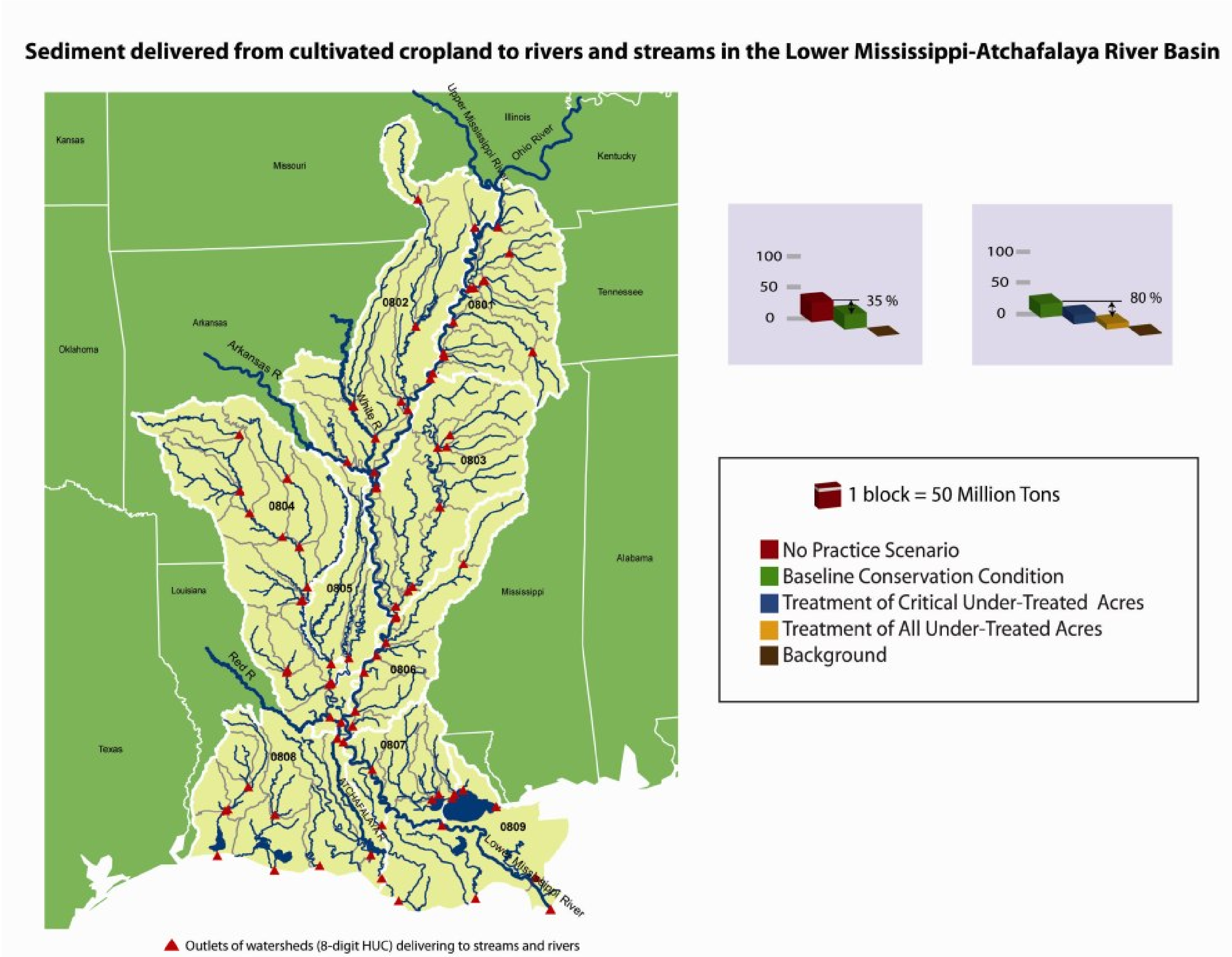


Table 46 Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **sediment source loads *delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the Lower Mississippi River Basin

	Baseline conservation condition	Treatment of 6.29 million critical undertreated acres		Treatment of all 16.27 million undertreated acres	
Subregion	Average annual load (1,000 tons)	Average annual load (1,000 tons)	Percent reduction	Average annual load (1,000 tons)	Percent reduction
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	4,854	881	82	592	88
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	3,586	2,571	28	1,021	72
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	7,312	3,922	46	1,427	80
Lower Red and Ouachita River Basin (code 0804)	1,268	876	31	311	75
Boeuf-Tensas River Basin (code 0805)	2,980	1,714	42	729	76
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	479	202	58	63	87
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	2,243	1,439	36	372	83
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	686.5	668.8	3	115.2	83
Regional total	23,409	12,273	48	4,630	80

Notes: 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. Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

Figure 75. Effects of conservation practices on average annual sediment loads delivered to rivers and streams, Lower Mississippi River Basin



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 or pesticides for all cultivated cropland acres in the watershed. “Background” loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources. In this graphic, however, only the loads delivered from cultivated cropland are shown; consequently, the background load is nearly negligible.

Total Nitrogen

Baseline condition. Model simulation results show that of the 695 million pounds of nitrogen exported from farm fields in the Lower Mississippi River Basin (table 47), about 555 million pounds are delivered to rivers and streams each year (table 48), on average, under conditions represented by the baseline conservation condition, which simulates farming activities and conservation practices in use during the period 2003 to 2006. About 45 percent of the nitrogen delivered to rivers and streams from cultivated cropland in this region originates in two subregions—the Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802) with 24 percent and the Lower Mississippi-Greenville-Yazoo River Basin (code 0803) with 21 percent (table 48).

On a per-acre basis, about 27 pounds of nitrogen per acre of cultivated cropland are delivered to rivers and streams per year, on average, within the region (table 48). Nitrogen delivery from cultivated cropland is highest in the subregions nearest to the Gulf of Mexico (codes 0806, 0807, 0808, and 0809), where nitrogen delivery to rivers and streams ranged from 34 pounds per cultivated cropland acre to 46 pounds per cultivated cropland acre (table 48).

Nitrogen delivered to rivers and streams from cultivated cropland represents about 53 percent of the total nitrogen load delivered from all sources in the region (table 49, fig. 76). This percentage varies among the subregions, however. The three subregions with the highest percent of total nitrogen load originating from cultivated cropland acres are—

- the Boeuf-Tensas River Basin (code 0805)with 90 percent,
- the Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802) with 85 percent, and
- the Lower Mississippi-Greenville-Yazoo River Basin (code 0803) with 75 percent.

Urban point and nonpoint sources account for about 15 percent of the total nitrogen load delivered to rivers and streams within the Lower Mississippi River Basin, on average (table 49). The remaining 32 percent originates from hayland, pastureland, rangeland, forest land, wetlands, and other minor land use/land cover categories.

Effects of conservation practices. Model simulations indicate that conservation practices have reduced the delivery of nitrogen from fields to rivers and streams by about 21 percent (table 48), on average, in this region. Reductions due to conservation practices vary throughout the region, ranging from a low of 12 percent for the Lower Red and Ouachita River Basin (code 0804) to a high of 41 percent for the Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806). The higher percent reduction for the Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806) is in part due to the high proportion (35 percent) of cultivated cropland acres in long-term conserving cover.

Potential gains from further conservation treatment. The potential for additional gains from further conservation treatment is substantial, as shown in figure 59 in the previous chapter. Model simulations show that use of additional erosion control and nutrient management practices on the 6.29 million critical under-treated acres in the region would reduce overall nitrogen loads delivered to rivers and streams by about 125 million pounds per year, representing a reduction from baseline levels of 23 percent (table 50). Use of additional practices on all 16.27 million under-treated acres in the region would reduce nitrogen loads delivered to rivers and streams by nearly 239 million pounds per year, representing a reduction from baseline levels of 43 percent (table 50, fig. 77).

The largest gain in terms of pounds saved would occur in the Lower Mississippi-Greenville-Yazoo River Basin (code 0803), where 55 million pounds of nitrogen per year would be saved with additional conservation treatment for all under-treated acres (table 50). About 45 million pounds of nitrogen per year would be saved in the Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801) and about 43 million pounds would be saved in the Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802).

In terms of the largest percent reduction, nitrogen loads delivered to rivers and streams would be reduced 72 percent in the Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806) with additional conservation treatment for all under-treated acres.

Table 47. Average annual nitrogen loads ***delivered to edge of field*** (APEX model output) from cultivated cropland in the Lower Mississippi River Basin

Subregions	Baseline conservation condition			No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices	
	Amount (1,000 pounds)	Percent of basin total	Pounds delivered per cultivated cropland acre		Reduction (1,000 pounds)	Percent
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	117,700	17	38	152,200	34,500	23
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	157,100	23	23	202,300	45,200	22
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	171,000	25	43	198,500	27,500	14
Lower Red and Ouachita River Basin (code 0804)	30,000	4	34	33,930	3,930	12
Boeuf-Tensas River Basin (code 0805)	86,640	12	35	111,800	25,160	23
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	23,890	3	50	42,550	18,660	44
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	78,110	11	38	96,330	18,220	19
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	30,540	4	48	35,850	5,310	15
Regional total	694,980	100	34	873,460	178,480	20

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.

Table 48. Average annual nitrogen loads ***delivered to watershed outlets*** (8-digit HUCs) ***from cultivated cropland*** in the Lower Mississippi River Basin

Subregions	Baseline conservation condition			No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices	
	Amount (1,000 pounds)	Percent of basin total	Pounds delivered per cultivated cropland acre		Reduction (1,000 pounds)	Percent
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	88,640	16	29	111,400	22,760	20
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	133,600	24	20	174,900	41,300	24
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	115,200	21	30	133,000	17,800	13
Lower Red and Ouachita River Basin (code 0804)	26,360	5	30	30,080	3,720	12
Boeuf-Tensas River Basin (code 0805)	71,950	13	29	93,920	21,970	23
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	21,100	4	44	35,560	14,460	41
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	69,730	13	34	86,870	17,140	20
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	28,790	5	46	33,500	4,710	14
Regional total	555,370	100	27	699,230	143,860	21

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 47 are due to the application of delivery ratios, which were used to simulate delivery of nitrogen from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.

Table 49. Average annual nitrogen loads ***delivered to watershed outlets*** (8-digit HUCs***)*** in the Lower Mississippi River Basin, baseline conservation condition, by source

Subregions	All sources	Cultivated cropland*	Hayland	Pasture and grazing land	Urban nonpoint sources**	Urban point sources	Forest and other***
				Amount (1,000 pounds)			
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	141,759	88,640	647	5,881	13,169	28,008	5,414
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	157,130	133,600	799	2,606	9,542	2,222	8,360
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	153,908	115,200	750	5,922	12,914	1,073	18,049
Lower Red and Ouachita River Basin (code 0804)	176,028	26,360	3,134	22,218	14,909	4,998	104,409
Boeuf-Tensas River Basin (code 0805)	79,834	71,950	60	233	2,441	536	4,614
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	59,191	21,100	981	9,641	2,282	1,242	23,946
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	144,213	69,730	513	8,306	16,638	11,015	38,010
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	141,699	28,790	1,087	8,076	20,393	14,692	68,661
Regional total	1,053,763	555,370	7,971	62,883	92,289	63,786	271,464
				Percent of all sources			
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	100	63	<1	4	9	20	4
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	100	85	1	2	6	1	5
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	100	75	<1	4	8	1	12
Lower Red and Ouachita River Basin (code 0804)	100	15	2	13	8	3	59
Boeuf-Tensas River Basin (code 0805)	100	90	<1	<1	3	1	6
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	100	36	2	16	4	2	40
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	100	48	<1	6	12	8	26
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	100	20	1	6	14	10	48
Regional total	100	53	1	6	9	6	26

* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, horticulture, and barren land.

Figure 76. Percentage by source of average annual nitrogen loads delivered to rivers and streams in the Lower Mississippi River Basin, baseline conservation condition

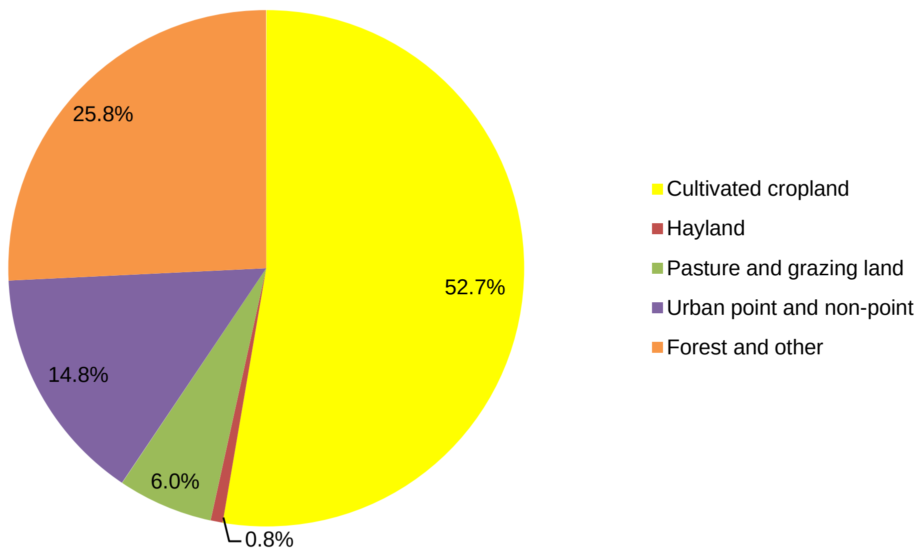
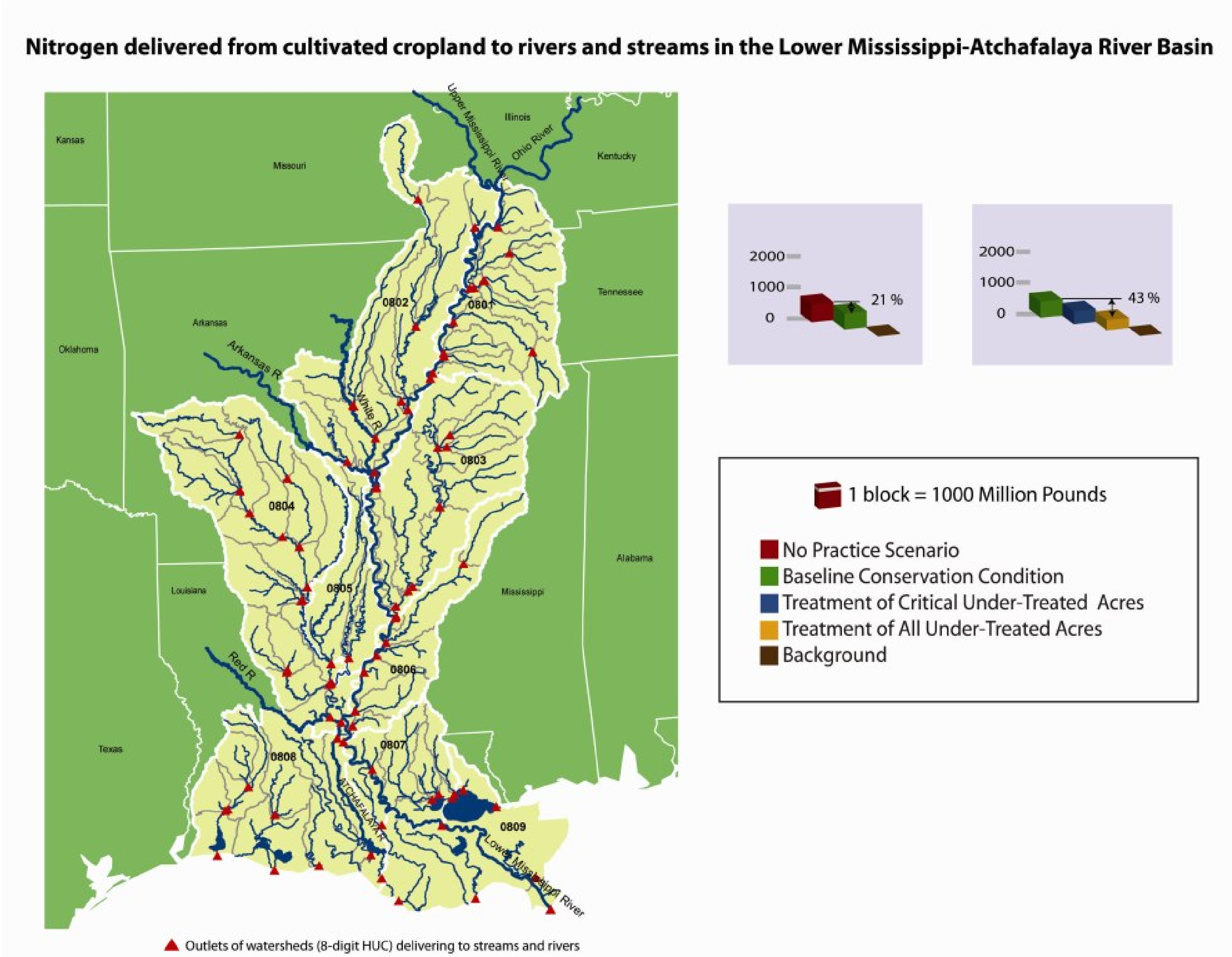


Table 50. Effects of additional conservation treatment with erosion control practices ***and*** nutrient management practices on average annual **nitrogen source loads *delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the Lower Mississippi River Basin

	Baseline conservation condition	Treatment of 6.29 million critical undertreated acres		Treatment of all 16.27 million undertreated acres	
Subregion	Average annual load (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	88,640	49,460	44	43,470	51
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	133,600	115,600	13	90,420	32
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	115,200	84,660	27	60,440	48
Lower Red and Ouachita River Basin (code 0804)	26,360	22,380	15	18,350	30
Boeuf-Tensas River Basin (code 0805)	71,950	62,460	13	49,620	31
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	21,100	10,200	52	5,996	72
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	69,730	61,670	12	39,540	43
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	28,790.0	23,900.0	17	8,745.0	70
Regional total	555,370	430,330	23	316,581	43

Notes: 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. Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

Figure 77. Effects of conservation practices on average annual nitrogen loads delivered to rivers and streams, Lower Mississippi River Basin



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 or pesticides for all cultivated cropland acres in the watershed. “Background” loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources. In this graphic, however, only the loads delivered from cultivated cropland are shown; consequently, the background load is nearly negligible.

Total Phosphorus

Baseline condition. Model simulation results show that of the 98.8 million pounds of phosphorus exported from farm fields in the Lower Mississippi River Basin (table 51), about 53.3 million pounds are delivered to rivers and streams each year (table 52), on average, under conditions represented by the baseline conservation condition, which simulates farming activities and conservation practices in use during the period 2003 to 2006. About 44 percent of the phosphorus delivered to rivers and streams from cultivated cropland in this region originates in two subregions—the Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801) and the Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802), each with 22 percent (table 52).

On a per-acre basis, about 2.63 pounds of phosphorus per acre of cultivated cropland are delivered to rivers and streams per year, on average, within the region (table 52). Phosphorus delivery from cultivated cropland exceeds 3 pounds per cultivated cropland acre in four subregions—

- the Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801) with 3.91 pounds per acre,
- the Boeuf-Tensas River Basin (code 0805)with 3.67 pounds per acre,
- the Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806) with 3.39 pounds per acre, and
- the Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808) with 3.14 pounds per acre.

Phosphorus delivered to rivers and streams from cultivated cropland represents about 43 percent of the total phosphorus load delivered from all sources in the region (table 53, fig. 78). This percentage varies among the subregions, however. The three subregions with the highest percent of total phosphorus load originating from cultivated cropland acres are—

- the Boeuf-Tensas River Basin (code 0805)with 89 percent,
- the Lower Mississippi-Greenville-Yazoo River Basin (code 0803) with 76 percent. and
- the Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802) with 75 percent.

Urban point and nonpoint sources account for about 27 percent of the total phosphorus load delivered to rivers and streams within the Lower Mississippi River Basin, on average (table 53). The remaining 30 percent originates from pastureland, rangeland, forest land, wetlands, and other minor land use/land cover categories.

Effects of conservation practices. Model simulations indicate that conservation practices have reduced the delivery of phosphorus from fields to rivers and streams by about 52 percent (table 52, fig. 79), on average, in this region. Reductions due to conservation practices vary throughout the region, ranging from a low of 15 percent for the Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801) to a high of 94 percent for Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and the Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809) combined.

Potential gains from further conservation treatment. The potential for additional gains from further conservation treatment is substantial, as shown in figure 59 in the previous chapter. Model simulations show that use of additional erosion control practices on the 6.29 million critical under-treated acres in the region would reduce overall phosphorus loads delivered to rivers and streams by about 21 million pounds per year, representing a reduction from baseline levels of 38 percent (table 54). Use of additional erosion control practices on all 16.27 million under-treated acres in the region would reduce phosphorus loads delivered to rivers and streams by more than 30 million pounds per year, representing a reduction from baseline levels of 57 percent (table 54, fig. 79).

The largest reduction would occur in the Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801),where 9.2 million pounds of phosphorus per year would be saved with additional conservation treatment for all under-treated acres (table 54).

In terms of the largest percent reduction, phosphorus loads delivered to rivers and streams would be reduced 77 percent in both the Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801) and the Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806) with additional conservation treatment for all under-treated acres.

Table 51. Average annual phosphorus loads ***delivered to edge of field*** (APEX model output) from cultivated cropland in the Lower Mississippi River Basin

Subregions	Baseline conservation condition: Amount (1,000 pounds)	Baseline conservation condition: Percent of basin total	Baseline conservation condition: Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	23,660	24	7.73	31,430	7,770	25
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	21,440	22	3.17	39,920	18,480	46
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	21,050	21	5.35	32,780	11,730	36
Lower Red and Ouachita River Basin (code 0804)	3,976	4	4.49	6,752	2,776	41
Boeuf-Tensas River Basin (code 0805)	14,350	15	5.80	25,170	10,820	43
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	2,656	3	5.56	8,176	5,520	68
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	10,310	10	5.05	26,000	15,690	60
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	1,311	1	2.08	14,080	12,769	91
Regional total	98,753	100	4.87	184,308	85,555	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.

Table 52. Average annual phosphorus loads ***delivered to watershed outlets*** (8-digit HUCs) ***from cultivated cropland*** in the Lower Mississippi River Basin

Subregions	Baseline conservation condition: Amount (1,000 pounds)	Baseline conservation condition: Percent of basin total	Baseline conservation condition: Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	11,980	22	3.91	14,140	2,160	15
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	11,880	22	1.75	23,800	11,920	50
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	9,164	17	2.33	15,200	6,036	40
Lower Red and Ouachita River Basin (code 0804)	2,426	5	2.74	4,698	2,272	48
Boeuf-Tensas River Basin (code 0805)	9,075	17	3.67	17,010	7,935	47
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	1,620	3	3.39	4,190	2,570	61
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	6,423	12	3.14	19,420	12,997	67
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	733	1	1.16	11,965	11,232	94
Regional total	53,301	100	2.63	110,423	57,122	52

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 51 are due to the application of delivery ratios, which were used to simulate delivery of phosphorus from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.

Table 53. Average annual phosphorus loads ***delivered to watershed outlets*** (8-digit HUCs) in the Lower Mississippi River Basin, baseline conservation condition, by source

Subregions	All sources	Cultivated cropland*	Hayland	Pasture and grazing land	Urban nonpoint sources**	Urban point sources	Forest and other***
				Amount (1,000 pounds)			
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	26,519	11,980	134	1,581	886	11,609	329
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	15,915	11,880	115	918	815	1,834	353
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	12,119	9,164	67	1,312	671	465	440
Lower Red and Ouachita River Basin (code 0804)	16,396	2,426	748	5,480	1,805	735	5,200
Boeuf-Tensas River Basin (code 0805)	10,205	9,075	8	80	424	86	532
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	8,145	1,620	218	3,151	442	518	2,197
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	16,227	6,423	84	3,244	820	2,562	3,094
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	18,531	733	222	2,457	1,031	7,824	6,264
Regional total	124,055	53,301	1,597	18,222	6,895	25,632	18,408
				Percent of all sources			
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	100	45	1	6	3	44	1
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	100	75	1	6	5	12	2
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	100	76	1	11	6	4	4
Lower Red and Ouachita River Basin (code 0804)	100	15	5	33	11	4	32
Boeuf-Tensas River Basin (code 0805)	100	89	<1	1	4	1	5
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	100	20	3	39	5	6	27
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	100	40	1	20	5	16	19
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	100	4	1	13	6	42	34
Regional total	100	43	1	15	6	21	15

* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, horticulture, and barren land.

Figure 78. Percentage by source of average annual phosphorus loads delivered to rivers and streams in the Lower Mississippi River Basin, baseline conservation condition

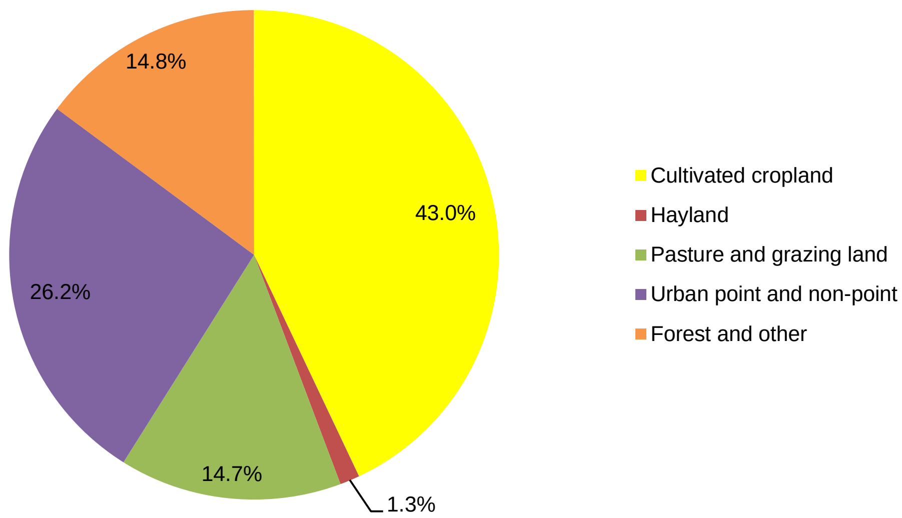
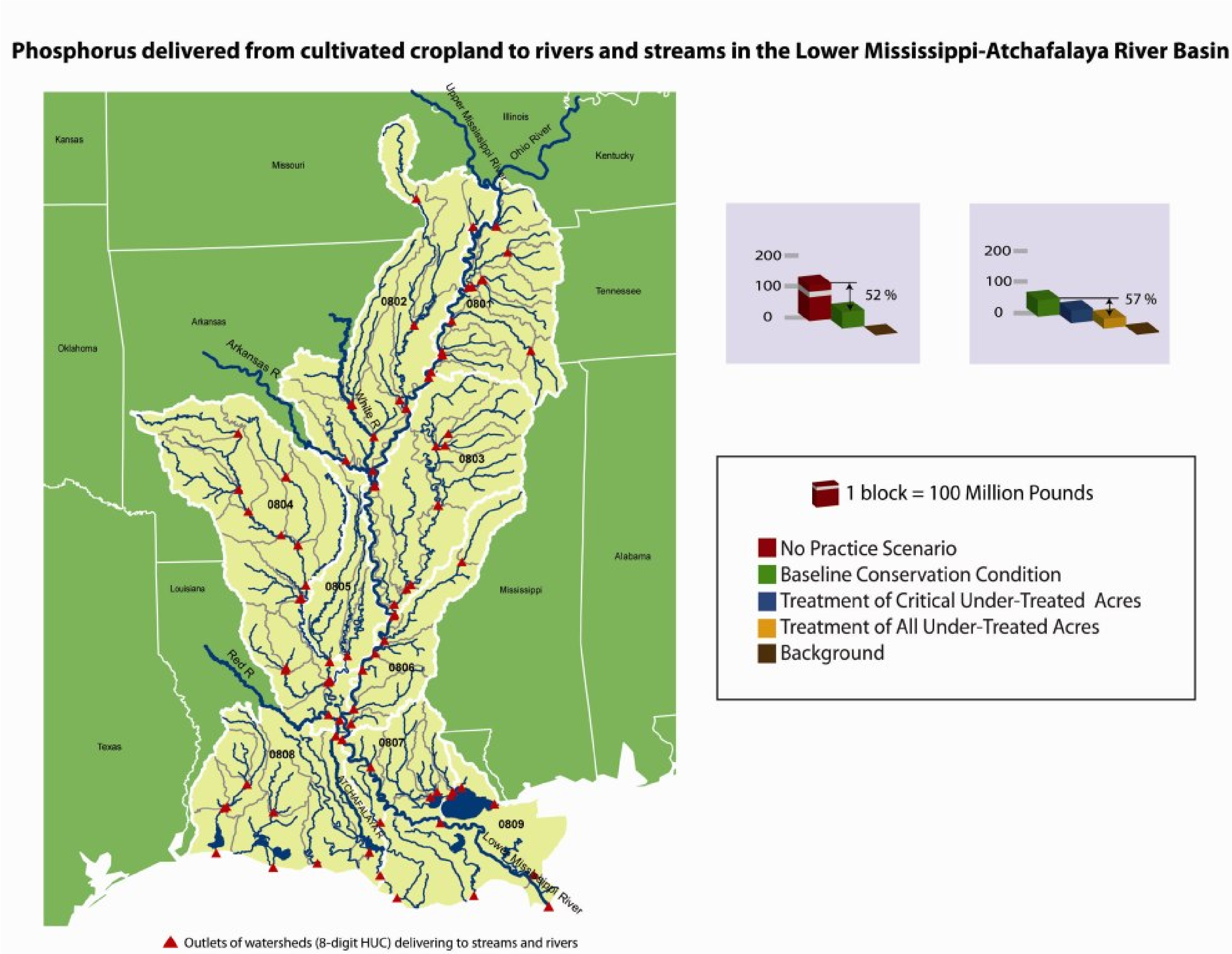


Table 54 Effects of additional conservation treatment with erosion control practices ***and*** nutrient management practices on average annual **phosphorus source loads *delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the Lower Mississippi River Basin

	Baseline conservation condition	Treatment of 6.29 million critical undertreated acres		Treatment of all 16.27 million undertreated acres	
Subregion	Average annual load (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	11,980	4,175	65	2,742	77
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	11,880	9,006	24	5,999	50
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	9,164	6,174	33	4,951	46
Lower Red and Ouachita River Basin (code 0804)	2,426	1,701	30	1,324	45
Boeuf-Tensas River Basin (code 0805)	9,075	5,149	43	3,896	57
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	11,980	4,175	65	2,742	77
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	412	396	4	252	39
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	733.4	717.8	2	565.9	23
Regional total	53,301	32,800	38	22,871	57

Notes: 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. Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

Figure 79. Effects of conservation practices on average annual phosphorus loads delivered to rivers and streams, Lower Mississippi River Basin



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 or pesticides for all cultivated cropland acres in the watershed. "Background" loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources. In this graphic, however, only the loads delivered from cultivated cropland are shown; consequently, the background load is nearly negligible.

Atrazine

Although the full suite of pesticides was modeled for edge-of-field losses, atrazine was the only pesticide for which instream loads were assessed because it was the dominant contributor to mass loss of pesticide residues from farm fields and the primary contributor to environmental risk from pesticide use in the region. First registered in the United States in 1959, atrazine is used to control broadleaf and grassy weeds. Cultivated cropland (primarily corn acres) was the only source for atrazine in the model simulations.

Baseline condition. Model simulation results show that about 96,000 pounds of atrazine are lost from farm fields (edge-of-field) through pathways that result in delivery to streams and rivers within the Lower Mississippi River Basin (table 55). Of this, about 88,000 pounds are delivered into rivers and streams each year, on average, under conditions represented by the baseline conservation condition (table 56).

The amounts of atrazine delivered to rivers and streams are relatively low in this region and sources tend to be evenly distributed throughout the region (table 56).

Effects of conservation practices. Conservation practices—including Integrated Pest Management (IPM) techniques and practices—have reduced the delivery of atrazine from fields to rivers and streams by about 26 percent (table 56, fig. 80), on average. Within the subregions, reductions due to conservation practices range from a low of zero for the Lower Red and Ouachita River Basin (code 0804) to a high of 63 percent for the Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806).

Potential gains from further conservation treatment. Model simulations show that use of additional conservation practices—primarily erosion control practices—on the 16.27 million under-treated acres in the region would reduce overall atrazine loads delivered to rivers and streams by about 13,300 pounds per year, representing a reduction from baseline levels of 15 percent (table 57, fig. 80). The largest gains would occur in the Lower Red and Ouachita River Basin (code 0804).

Table 55. Average annual atrazine source loads ***delivered to edge of field*** (APEX model output) from cultivated cropland for the Lower Mississippi River Basin

Subregions	Baseline conservation condition: Amount (1,000 pounds)	Baseline conservation condition: Percent of basin total	Baseline conservation condition: Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	18	19	0.006	23	5	20
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	17	18	0.003	22	4	20
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	16	17	0.004	22	6	26
Lower Red and Ouachita River Basin (code 0804)	9	10	0.011	9	0	0
Boeuf-Tensas River Basin (code 0805)	12	12	0.005	18	6	34
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	2	2	0.004	5	3	61
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	14	14	0.007	21	7	33
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	6	7	0.010	7	1	11
Regional total	96	100	0.005	126	30	24

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.

Table 56. Average annual atrazine source loads ***delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the Lower Mississippi River Basin

Subregions	Baseline conservation condition: Amount (1,000 pounds)	Baseline conservation condition: Percent of basin total	Baseline conservation condition: Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	18	20	0.006	22	4	20
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	16	19	0.002	21	4	20
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	15	17	0.004	20	6	28
Lower Red and Ouachita River Basin (code 0804)	8	9	0.009	8	0	0
Boeuf-Tensas River Basin (code 0805)	11	13	0.004	17	6	36
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	2	2	0.004	5	3	63
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	13	15	0.006	20	7	35
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	6	7	0.009	7	1	16
Regional total	88	100	0.004	120	31	26

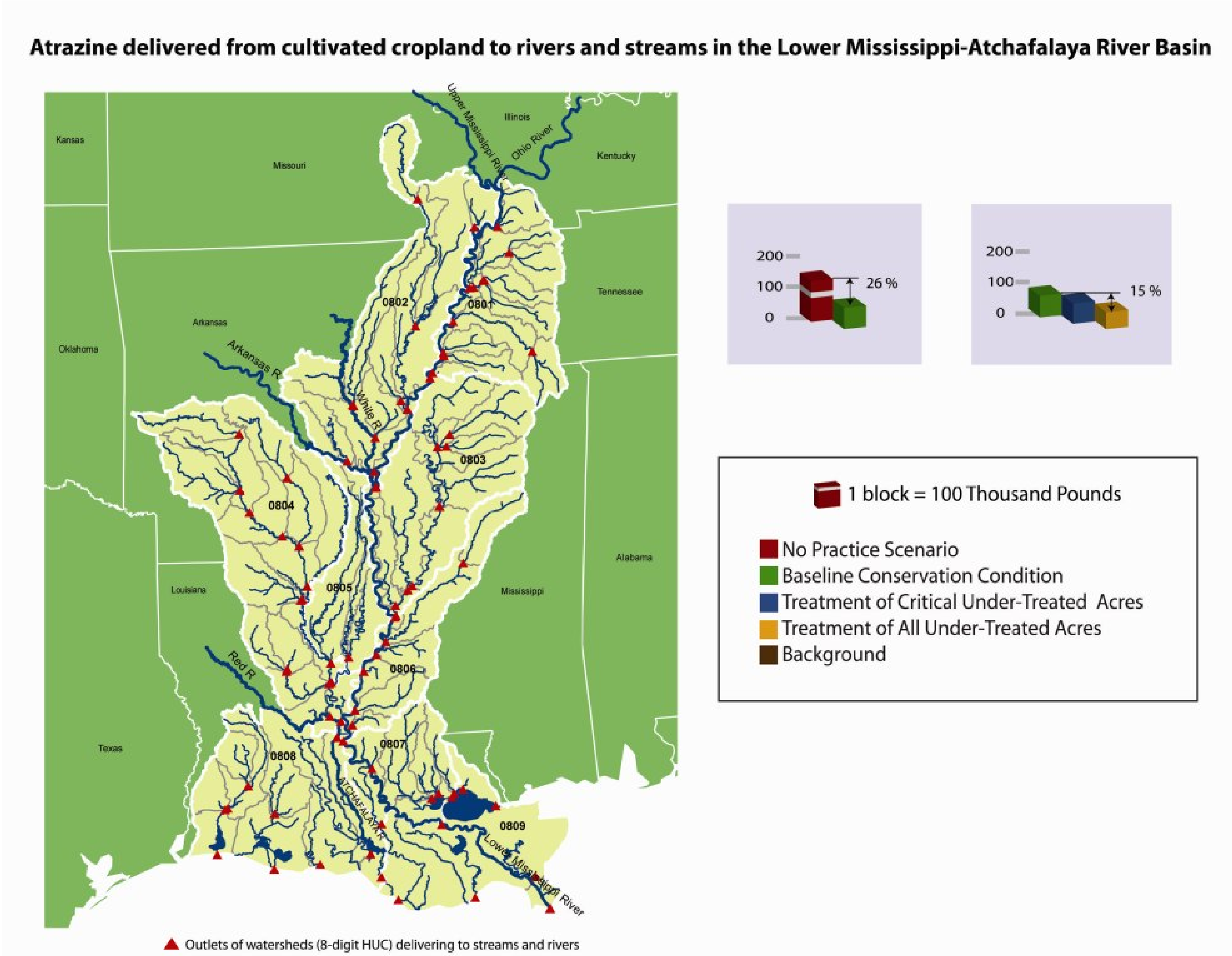
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 55 are due to the application of delivery ratios, which were used to simulate delivery of atrazine from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.

Table 57. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **atrazine source loads *delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the Lower Mississippi River Basin

	Baseline conservation condition	Treatment of 6.29 million critical undertreated acres		Treatment of all 16.27 million undertreated acres	
Subregion	Average annual load (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)	17.5	15.9	9	15	12
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)	16.4	15.5	6	13	18
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)	14.6	13.7	6	12	15
Lower Red and Ouachita River Basin (code 0804)	8.2	7.8	5	5	36
Boeuf-Tensas River Basin (code 0805)	11.1	10.6	4	10	13
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)	1.7	1.7	4	2	6
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)	12.9	13.4	-3	12	8
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)	5.8	5.8	1	5.3	9
Regional total	88	84	5	75	15

Notes: 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. Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

Figure 80. Effects of conservation practices on average annual atrazine loads delivered to rivers and streams, Lower Mississippi River Basin



Note: Cultivated cropland is the only source of atrazine included in the modeling; consequently, “background sources” are zero for atrazine.

Instream Loads from All Sources Delivered to the Gulf of Mexico

Instream loads are estimated by starting with the loads delivered from *all sources* at the outlet of each 8-digit HUC and routing those loads downstream. Stream and channel processes are simulated, including flood routing, instream degradation processes, streambed deposition, streambank erosion, and reservoir dynamics. A portion of the sediment, nutrients, and pesticides delivered to rivers and streams is removed or trapped during these processes. Some of the nitrogen is lost during instream nitrification processes, and a portion of the sediment and sediment-bound nutrients and pesticides is deposited in streambeds and flood plains during transit. Large reservoirs can trap significant amounts of loads delivered to rivers and streams, keeping those loads from being transferred downstream. Sediment can also be added to instream loads through streambank erosion and streambed scouring.

Instream loads represent *all sources* of sediment, nutrients, and pesticides. In some river systems, the predominant source of instream loads originates from urban point sources, while in other river systems the predominant source of instream loads is from cultivated cropland. In river systems like the Lower Mississippi River Basin, however, instream loads are a mix from a variety of sources, including upstream portions of the drainage system.

Baseline conservation condition

Instream loads delivered to the Gulf of Mexico from the Mississippi River drainage system include loads originating from—

- the Missouri River,
- the Upper Mississippi River upstream of Thebes, IL,
- the Ohio and Tennessee Rivers,
- the Arkansas-White-Red Basin,
- Mississippi River drainage within the Lower Mississippi River Basin, and
- Smaller rivers and streams along the Louisiana coast.

After accounting for instream deposition, reservoir dynamics, streambank erosion, and other transport processes, model simulations indicate that total instream loads from all of these sources deliver to the Gulf of Mexico per year, on average, for the baseline conservation condition (tables 58, 60, 62, and 64)—

- 190 million tons of sediment,
- 3,243 million pounds of nitrogen,
- 326 million pounds of phosphorus and
- 438,000 pounds of atrazine.

Instream loads delivered to the Lower Mississippi River Basin from other basins have been estimated in previous CEAP reports. Average baseline loads per year from upstream basins in the Mississippi River drainage system have been estimated to be (tables 58, 60, 62, and 64)—

- 136 million tons of sediment,
- 2,774 million pounds of nitrogen,
- 250 million pounds of phosphorus and
- 386,000 pounds of atrazine.

The best estimate we have of the instream loads originating within the Lower Mississippi River Basin is the difference between the total instream loads delivered to the Gulf and the loads delivered to the Lower Mississippi River Basin from other basins. Annual instream baseline loads originating within the Lower Mississippi River Basin are estimated in this manner to be, on average—

- 54 million tons of sediment,
- 469 million pounds of nitrogen,
- 75 million pounds of phosphorus and
- 52,000 pounds of atrazine.

These estimates of instream sediment and phosphorus loads originating in the Lower Mississippi River Basin exceed sediment loads delivered from each of the other 4 Mississippi River Basins (table 58). Instream nitrogen and atrazine loads originating in the Lower Mississippi River Basin are exceeded by nitrogen and atrazine loads delivered from the Missouri River, the Upper Mississippi River Basin, and the Ohio-Tennessee River Basin (tables 60 and 64). Instream phosphorus loads originating in the Lower Mississippi River Basin are exceeded only by phosphorus loads delivered from the Ohio-Tennessee River Basin (table 62).

The results of the “background scenario,” described previously, were used to estimate the percentage of instream sediment and nutrient loads that would likely be attributable to cultivated cropland sources. The background scenario represents loads that would be expected if no acres in the drainage system were cultivated. The amount attributed to cultivated cropland was determined by subtracting the instream loads in the “background” scenario from the total load from all sources in the baseline conservation scenario. Using this approach, the percentage of instream loads delivered to the Gulf of Mexico that is attributed to cultivated cropland sources, based on the model simulation, is (tables 58, 60, and 62)—

- 14 percent for sediment,
- 43 percent for total nitrogen, and
- 29 percent for total phosphorus.

Effects of conservation practices

The effects of conservation practices are estimated for instream loads in the same manner as was done for loads delivered to rivers and streams. The percent reductions in total instream loads, however, are usually much smaller than observed for loads delivered from cultivated cropland to rivers and streams because conservation practices affect only the cultivated cropland component of the total instream load.

Conservation practices in use on cultivated cropland in 2003-06, including land in long-term conserving cover, have reduced instream loads from all sources delivered from the Lower Mississippi River Basin to the Gulf of Mexico, per year, on average, by (tables 58, 60, 62, and 64 and figures 81, 83, 85, and 87)—

- 4 percent for sediment,
- 17 percent for nitrogen,
- 22 percent for phosphorus, and
- 21 percent for atrazine.

These percent reductions reflect the use of conservation practices on cultivated cropland throughout the entire Mississippi River drainage system.

Potential gains from further conservation treatment

Estimates are also available for how much additional reduction in instream loads from all sources might be possible from further conservation treatment. Two sets of results were obtained. The first is based on simulation of additional conservation treatment, including both soil erosion control and nutrient management, for all acres throughout the Mississippi River drainage system that have a high need for additional treatment (critical undertreated acres). The second is based on the same level of conservation treatment but for all undertreated acres in the drainage system (acres with a high or moderate level of need for additional treatment). The table below summarizes the extent of undertreated acres in the 5 basins that make up the Mississippi River drainage system.

	Million critical undertreated acres (acres with a high need for additional treatment)	Million undertreated acres (acres with a high or moderate need for additional treatment)
Upper Mississippi River Basin	8.98	35.20
Missouri River basin	1.23	15.31
Ohio-Tennessee River Basin	6.01	17.52
Arkansas-White-Red Basin	1.30	10.40
Lower Mississippi River Basin	6.29	16.27
Total	23.81	94.70

Model simulation results indicate that additional conservation treatment of the 23.81 million critical under-treated acres in the Mississippi River drainage system would be expected to further reduce instream loads from all sources delivered to the Gulf of Mexico per year relative to the baseline, on average, by (tables 59, 61, 63, and 65)—

- 2 percent for sediment;
- 5 percent for nitrogen;
- 7 percent for phosphorus, and
- 2 percent for atrazine.

Model simulation results further indicate that additional conservation treatment of *all* 94.7 million under-treated acres in the Mississippi River drainage system would be expected to reduce instream loads from all sources delivered to the Gulf of Mexico per year relative to the baseline, on average, by (tables 59, 61, 63, and 65 and figures 82, 84, 86, and 88)—

- 5 percent for sediment;
- 15 percent for nitrogen;
- 13 percent for phosphorus, and
- 6 percent for atrazine.

Table 58. Average annual ***instream sediment loads*** (all sources) delivered to the Gulf of Mexico from the Lower Mississippi River

Source of average annual instream loads delivered to the Gulf of Mexico	Baseline conservation condition: Load from all sources (1,000 tons)	Baseline conservation condition: Background sources* (1,000 tons)	Baseline conservation condition: Percent of load attributed to cultivated cropland sources	No-practice scenario (1,000 tons)	Reductions in loads due to conservation practices: Reduction (1,000 tons)	Reductions in loads due to conservation practices: Percent
Instream loads from other basins delivered to the Lower Mississippi River Basin (reported in previous CEAP reports)						
Subregion 0714, combination of loads from Missouri River and Upper Mississippi River Basins	84,500	65,700	22%	92,700	8,200	9%
Subregion 1030, loads from Missouri River Basin only	44,010	34,210	22%	45,620	1,610	4%
Estimate of loads from Upper Mississippi River Basin only**	40,490	31,490	22%	47,080	6,590	14%
Subregion 0514, loads from the Ohio and Tennessee River Basins	29,900	24,100	19%	35,100	5,200	15%
Subregion 1101, loads from the Upper White River	1,589	1,430	10%	1,665	76	5%
Subregion 1111, loads from the Lower Arkansas River-Robert Kerr Reservoir	1,173	1,014	14%	1,268	95	7%
Subregion 1114, loads from the Red River Basin upstream of Alexandria, LA	18,580	17,110	8%	19,420	840	4%
Total instream loads from other basins	135,742	109,354	19%	150,153	14,411	10%
Instream Loads for Lower Mississippi River						
Subregion 809, loads from the Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal area, including loads from all basins and subregions upstream of subregion 809***	115,200	99,120	14%	120,300	5,100	4%
Subregion 808, loads from the Atchafalaya-Vermillion-Calcasieu-Mermentau Rivers and Louisiana Coastal drainage area, including loads from the Red River Basin and subregions 804 and 805***	74,800	64,120	14%	78,350	3,550	5%
Total loads delivered to the Gulf of Mexico	190,000	163,240	14%	198,650	8,650	4%

***** “Background sources” represent loadings 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 or pesticides for all cultivated cropland acres in the watershed.

** Instream loads delivered from the Upper Mississippi River Basin alone are estimated by subtracting the loads delivered from the Missouri River Basin. This calculation may not fully isolate the loads from the Upper Mississippi River Basin, however, as it does not account for deposition within subregion 0714 of the load originating from the Missouri River, nor does it account for re-suspension of bed and bank sediment within subregion 0714 as a result of the additional stream flow from the Missouri River.

*** On average about 30 percent of the flow from the mainstem of the Mississippi River is diverted through the Old River Outflow Channel to the Atchafalaya River near Knox Landing, LA (see figure 81 for location). Loads for subregion 0808 include loads associated with this 30 percent of the flow from the mainstem of the Mississippi River. Loads reported for subregion 0809 exclude these loads.

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.

Figure 81. Average annual ***instream sediment loads*** (all sources) delivered to the Gulf of Mexico from the Lower Mississippi River

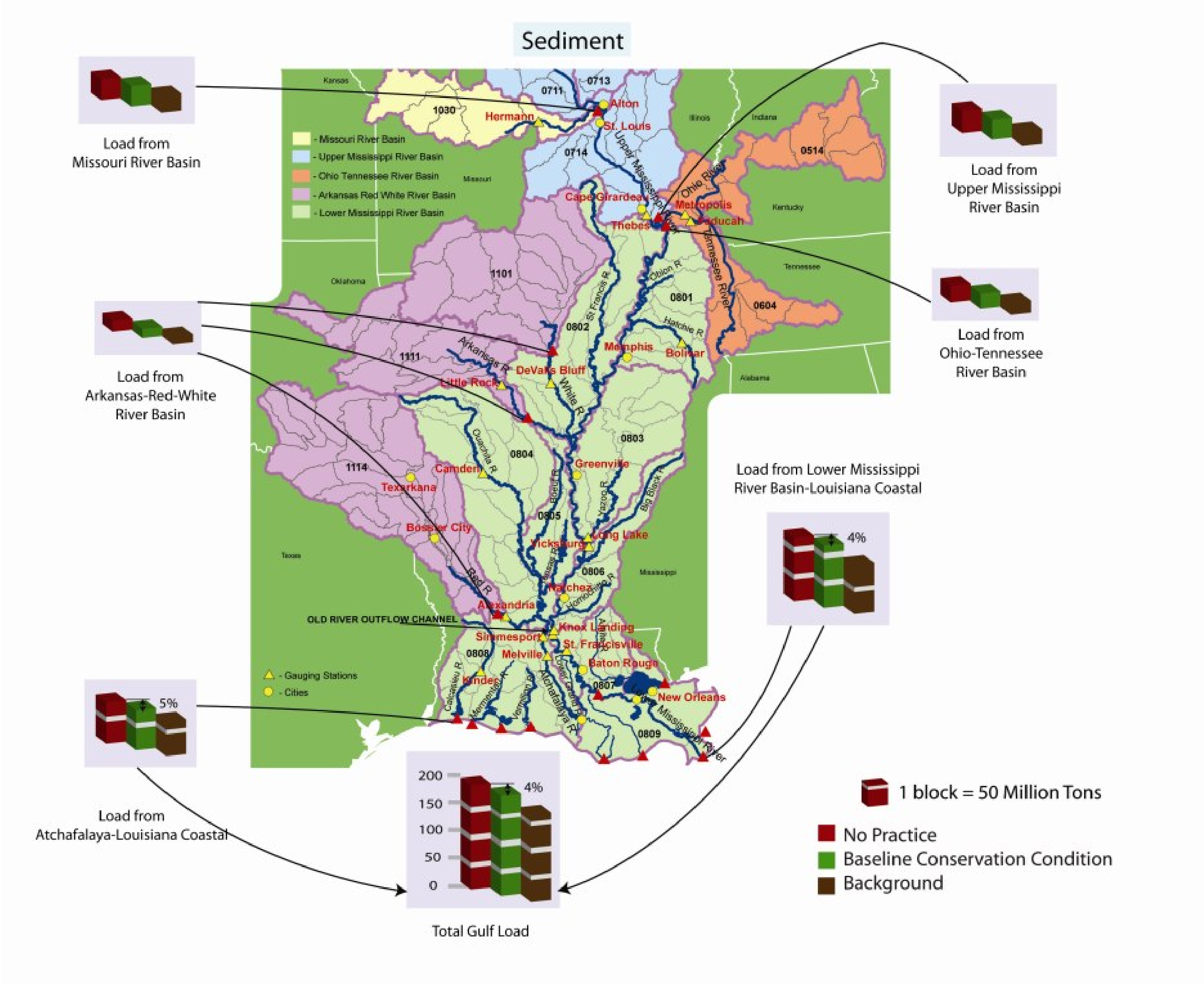


Table 59. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream sediment loads*** from all sources delivered to the Gulf of Mexico from the Lower Mississippi River

	Baseline conservation condition		Treatment of critical undertreated acres		Treatment of all undertreated acres	
Source of average annual instream loads delivered to the Gulf of Mexico	Average annual load from all sources (1,000 tons)	Average annual load from background sources* (1,000 tons)	Average annual load (1,000 tons)	Percent reduction	Average annual load (1,000 tons)	Percent reduction
Instream loads from other basins delivered to the Lower Mississippi River Basin (reported in previous CEAP reports)						
Subregion 0714, combination of loads from Missouri River and Upper Mississippi River Basins	84,500	65,700	82,600	2%	80,800	4%
Subregion 1030, loads from Missouri River Basin only	54,650	34,210	53,950	1%	52,540	4%
Estimate of loads from Upper Mississippi River Basin only**	29,850	31,490	28,650	4%	28,260	5%
Subregion 0514, loads from the Ohio and Tennessee River Basins	29,900	24,100	26,800	10%	25,800	14%
Subregion 1101, loads from the Upper White River	1,589	1,430	1,589	<1%	1,535	3%
Subregion 1111, loads from the Lower Arkansas River-Robert Kerr Reservoir	1,173	1,014	1,171	<1%	1,150	2%
Subregion 1114, loads from the Red River Basin upstream of Alexandria, LA	18,580	17,110	18,580	<1%	18,450	1%
Total instream loads from other basins	135,742	109,354	130,740	4%	127,735	6%
Instream Loads for Lower Mississippi River						
Subregion 809, loads from the Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal area, including loads from all basins and subregions upstream of subregion 809***	115,200	99,120	112,600	2%	110,100	4%
Subregion 808, loads from the Atchafalaya-Vermillion-Calcasieu-Mermentau Rivers and Louisiana Coastal drainage area, including loads from the Red River Basin and subregions 804 and 805***	74,800	64,120	72,840	3%	70,830	5%
Total loads delivered to the Gulf of Mexico	190,000	163,240	185,440	2%	180,930	5%

***** "Background sources" represent loadings 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 or pesticides for all cultivated cropland acres in the watershed.
** Instream loads delivered from the Upper Mississippi River Basin alone are estimated by subtracting the loads delivered from the Missouri River Basin. This calculation may not fully isolate the loads from the Upper Mississippi River Basin, however, as it does not account for deposition within subregion 0714 of the load originating from the Missouri River, nor does it account for re-suspension of bed and bank sediment within subregion 0714 as a result of the additional stream flow from the Missouri River.
*** On average about 30 percent of the flow from the mainstem of the Mississippi River is diverted through the Old River Outflow Channel to the Atchafalaya River near Knox Landing, LA (see figure 81 for location). Loads for subregion 0808 include loads associated with this 30 percent of the flow from the mainstem of the Mississippi River. Loads reported for subregion 0809 exclude these loads.

Note: Critical under-treated acres have a high need for additional conservation treatment. All under-treated acres have a high or moderate need for additional conservation treatment. 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.

Figure 82. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream sediment loads*** from all sources delivered to the Gulf of Mexico from the Lower Mississippi River

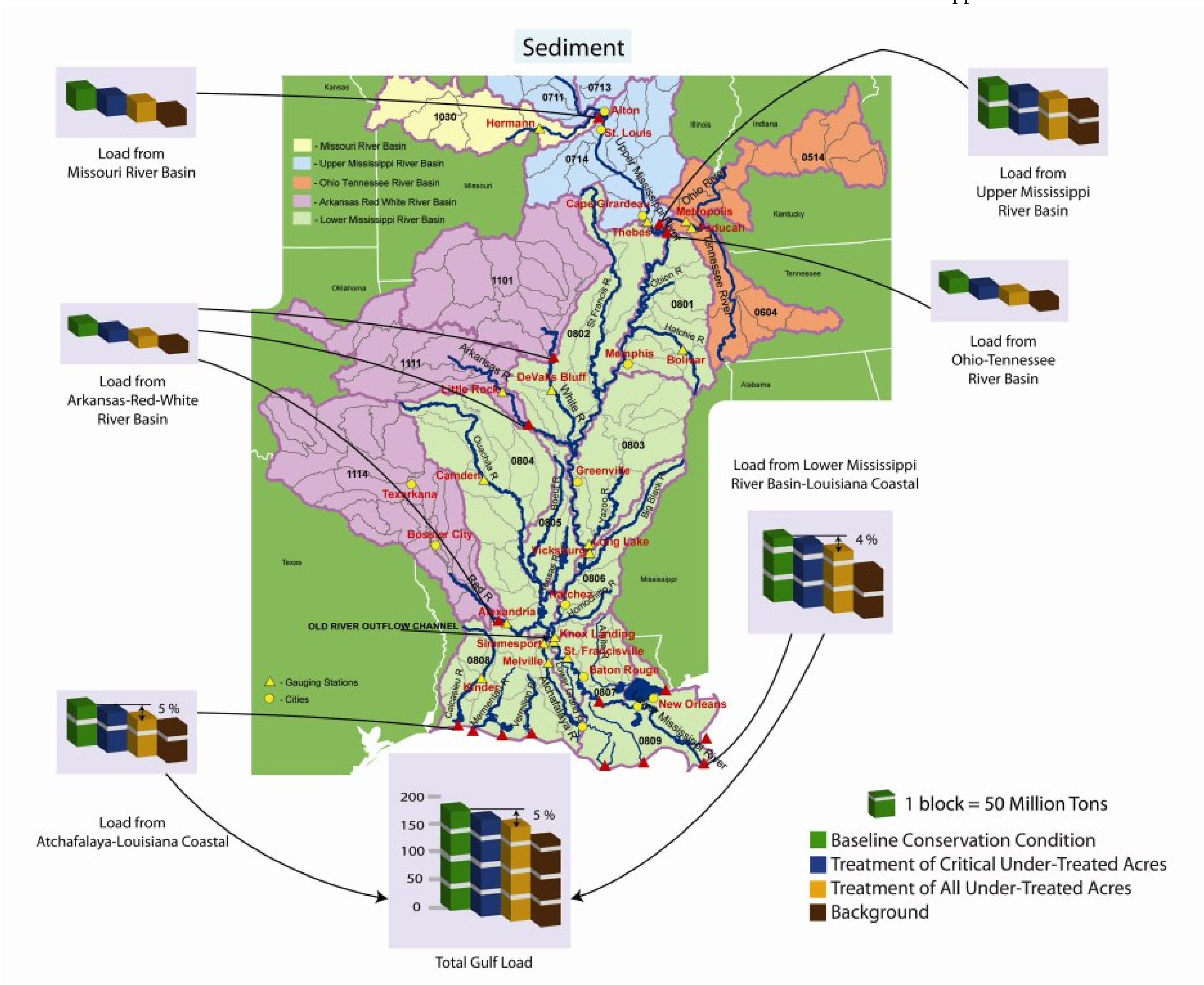


Table 60. Average annual ***instream nitrogen loads*** (all sources) delivered to the Gulf of Mexico from the Lower Mississippi River

Source of average annual instream loads delivered to the Gulf of Mexico	Baseline conservation condition: Load from all sources (1,000 pounds)	Baseline conservation condition: Background sources* (1,000 pounds)	Baseline conservation condition: Percent of load attributed to cultivated cropland sources	No-practice scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
Instream loads from other basins delivered to the Lower Mississippi River Basin (reported in previous CEAP reports)						
Subregion 0714, combination of loads from Missouri River and Upper Mississippi River Basins	1,580,000	474,000	70%	2,110,000	530,000	25%
Subregion 1030, loads from Missouri River Basin only	511,300	167,700	67%	792,800	281,500	36%
Estimate of loads from Upper Mississippi River Basin only**	1,068,700	306,300	71%	1,317,200	248,500	19%
Subregion 0514, loads from the Ohio and Tennessee River Basins	970,000	468,000	52%	1,150,000	180,000	16%
Subregion 1101, loads from the Upper White River	52,900	41,900	21%	58,760	5,860	10%
Subregion 1111, loads from the Lower Arkansas River-Robert Kerr Reservoir	102,600	60,230	41%	167,700	65,100	39%
Subregion 1114, loads from the Red River Basin upstream of Alexandria, LA	68,060	58,690	14%	81,060	13,000	16%
Total instream loads from other basins	2,773,560	1,102,820	60%	3,567,520	793,960	22%
Instream Loads for Lower Mississippi River						
Subregion 809, loads from the Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal area, including loads from all basins and subregions upstream of subregion 809***	2,171,000	1,238,000	43%	2,630,000	459,000	17%
Subregion 808, loads from the Atchafalaya-Vermillion-Calcasieu-Mermentau Rivers and Louisiana Coastal drainage area, including loads from the Red River Basin and subregions 804 and 805***	1,072,000	622,400	42%	1,274,000	202,000	16%
Total loads delivered to the Gulf of Mexico	3,243,000	1,860,400	43%	3,904,000	661,000	17%

***** "Background sources" represent loadings 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 or pesticides for all cultivated cropland acres in the watershed.

** Instream loads delivered from the Upper Mississippi River Basin alone are estimated by subtracting the loads delivered from the Missouri River Basin. This calculation may not fully isolate the loads from the Upper Mississippi River Basin, however, as it does not account for deposition within subregion 0714 of the load originating from the Missouri River, nor does it account for re-suspension of bed and bank sediment within subregion 0714 as a result of the additional stream flow from the Missouri River.

*** On average about 30 percent of the flow from the mainstem of the Mississippi River is diverted through the Old River Outflow Channel to the Atchafalaya River near Knox Landing, LA (see figure 83 for location). Loads for subregion 0808 include loads associated with this 30 percent of the flow from the mainstem of the Mississippi River. Loads reported for subregion 0809 exclude these loads.

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.

Figure 83. Average annual ***instream nitrogen loads*** (all sources) delivered to the Gulf of Mexico from the Lower Mississippi River

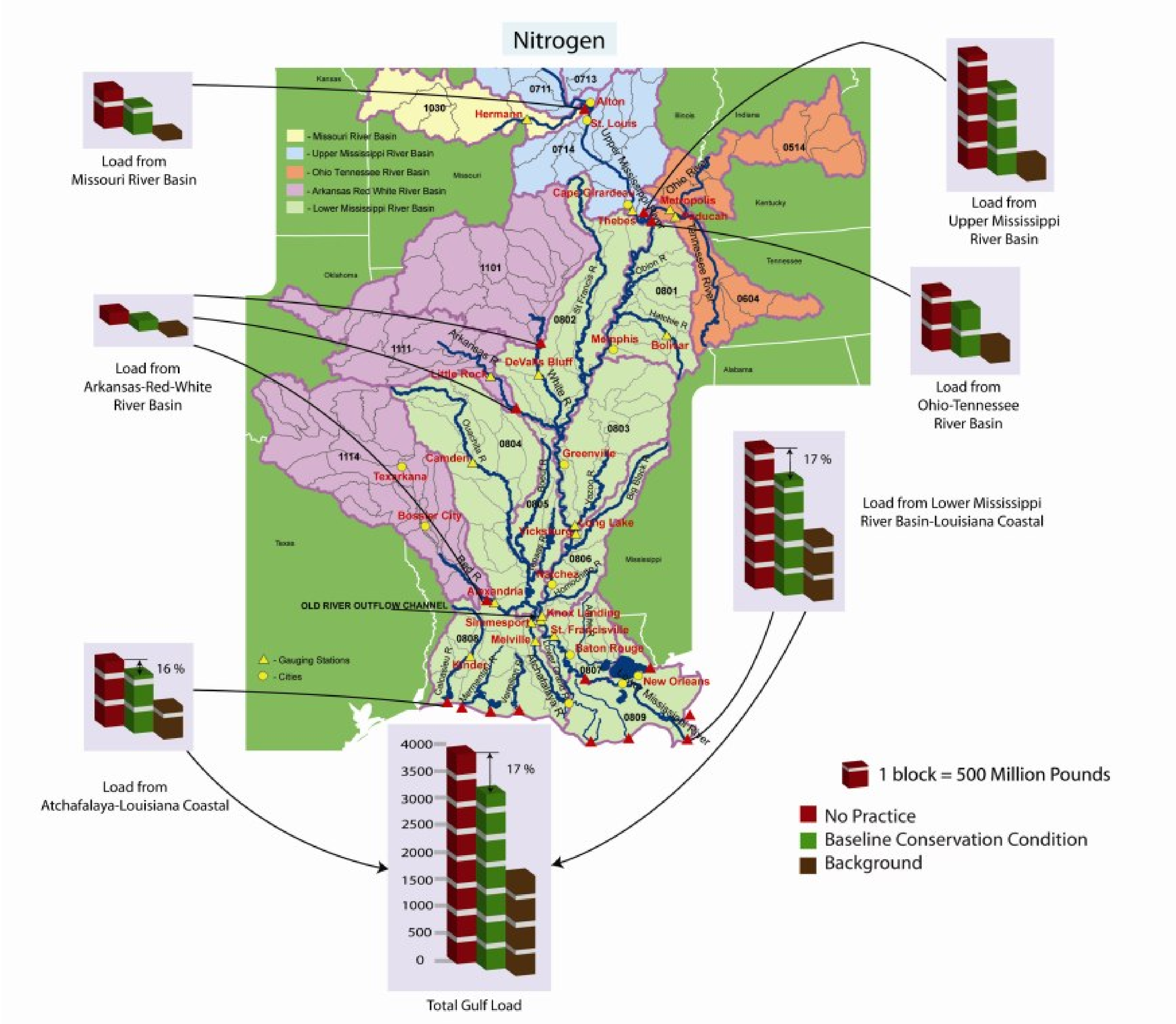


Table 61. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream nitrogen loads*** from all sources delivered to the Gulf of Mexico from the Lower Mississippi River

	Baseline conservation condition		Treatment of critical undertreated acres		Treatment of all undertreated acres	
Source of average annual instream loads delivered to the Gulf of Mexico	Average annual load from all sources (1,000 pounds)	Average annual load from background sources* (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
Instream loads from other basins delivered to the Lower Mississippi River Basin (reported in previous CEAP reports)						
Subregion 0714, combination of loads from Missouri River and Upper Mississippi River Basins	1,580,000	474,000	1,480,000	6%	1,200,000	24%
Subregion 1030, loads from Missouri River Basin only	511,300	167,700	502,000	2%	482,100	6%
Estimate of loads from Upper Mississippi River Basin only**	1,068,700	306,300	978,000	8%	717,900	33%
Subregion 0514, loads from the Ohio and Tennessee River Basins	970,000	468,000	874,000	10%	761,000	22%
Subregion 1101, loads from the Upper White River	52,900	41,900	52,900	<1%	51,740	2%
Subregion 1111, loads from the Lower Arkansas River-Robert Kerr Reservoir	1,173	60,230	1,171	<1%	1,150	2%
Subregion 1114, loads from the Red River Basin upstream of Alexandria, LA	18,580	58,690	18,580	<1%	18,450	1%
Total instream loads from other basins	2,622,653	1,102,820	2,426,651	7%	2,032,340	23%
Instream Loads for Lower Mississippi River						
Subregion 809, loads from the Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal area, including loads from all basins and subregions upstream of subregion 809***	2,171,000	1,238,000	2,062,000	5%	1,835,000	15%
Subregion 808, loads from the Atchafalaya-Vermillion-Calcasieu-Mermentau Rivers and Louisiana Coastal drainage area, including loads from the Red River Basin and subregions 804 and 805***	1,072,000	622,400	1,019,000	5%	916,000	15%
Total loads delivered to the Gulf of Mexico	3,243,000	1,860,400	3,081,000	5%	2,751,000	15%

***** "Background sources" represent loadings 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 or pesticides for all cultivated cropland acres in the watershed.
** Instream loads delivered from the Upper Mississippi River Basin alone are estimated by subtracting the loads delivered from the Missouri River Basin. This calculation may not fully isolate the loads from the Upper Mississippi River Basin, however, as it does not account for deposition within subregion 0714 of the load originating from the Missouri River, nor does it account for re-suspension of bed and bank sediment within subregion 0714 as a result of the additional stream flow from the Missouri River.
*** On average about 30 percent of the flow from the mainstem of the Mississippi River is diverted through the Old River Outflow Channel to the Atchafalaya River near Knox Landing, LA (see figure 83 for location). Loads for subregion 0808 include loads associated with this 30 percent of the flow from the mainstem of the Mississippi River. Loads reported for subregion 0809 exclude these loads.

Note: Critical under-treated acres have a high need for additional conservation treatment. All under-treated acres have a high or moderate need for additional conservation treatment. 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.

Figure 84. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream nitrogen loads*** from all sources delivered to the Gulf of Mexico from the Lower Mississippi River

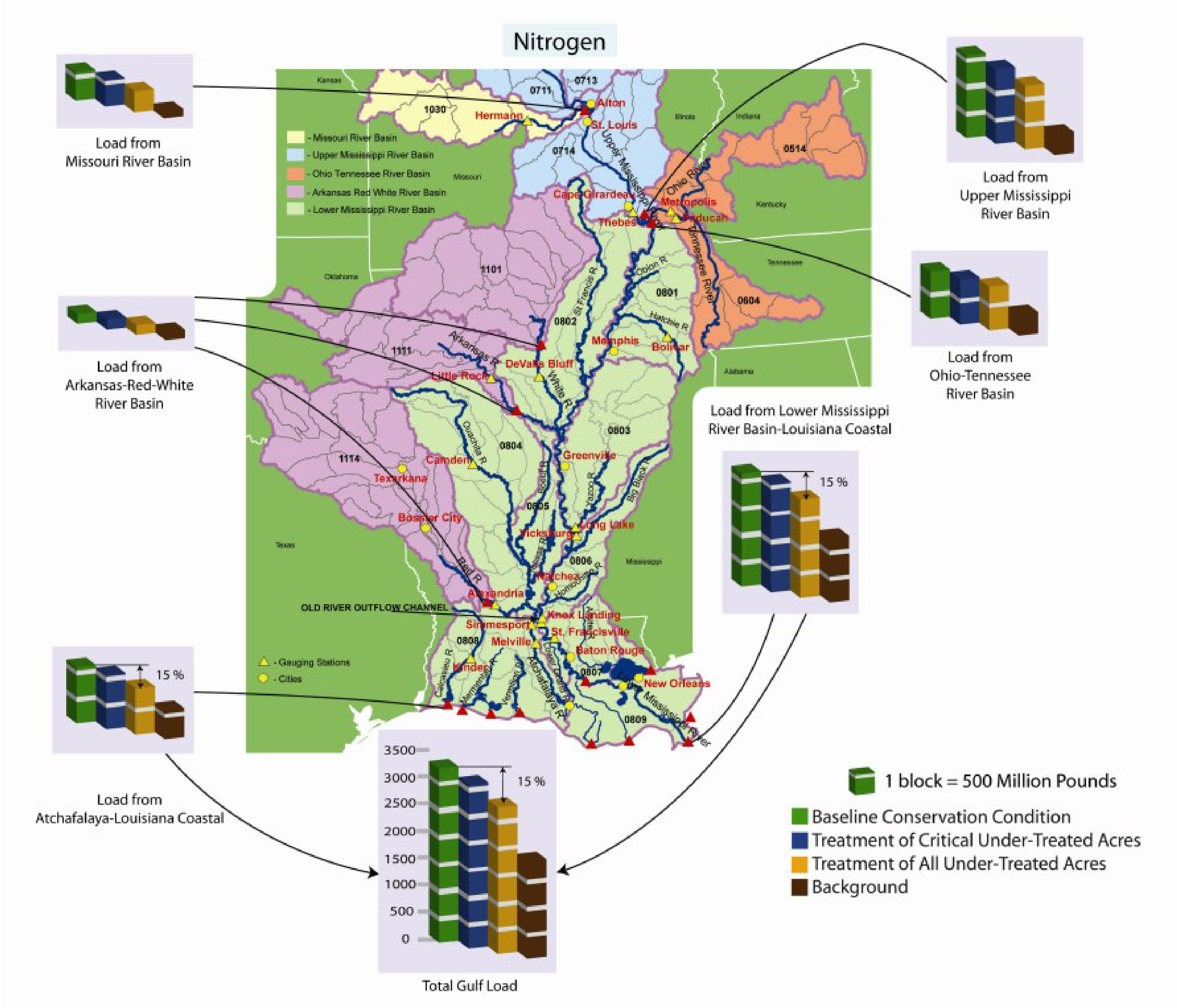


Table 62. Average annual ***instream phosphorus loads*** (all sources) delivered to the Gulf of Mexico from the Lower Mississippi River

Source of average annual instream loads delivered to the Gulf of Mexico	Baseline conservation condition: Load from all sources (1,000 pounds)	Baseline conservation condition: Background sources* (1,000 pounds)	Baseline conservation condition: Percent of load attributed to cultivated cropland sources	No-practice scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
Instream loads from other basins delivered to the Lower Mississippi River Basin (reported in previous CEAP reports)						
Subregion 0714, combination of loads from Missouri River and Upper Mississippi River Basins	124,000	64,200	48%	170,000	46,000	27%
Subregion 1030, loads from Missouri River Basin only	54,650	37,180	32%	76,100	21,450	28%
Estimate of loads from Upper Mississippi River Basin only**	69,350	27,020	61%	93,900	24,550	26%
Subregion 0514, loads from the Ohio and Tennessee River Basins	96,000	46,600	51%	121,000	25,000	21%
Subregion 1101, loads from the Upper White River	3,416	2,532	26%	5,329	1,913	36%
Subregion 1111, loads from the Lower Arkansas River-Robert Kerr Reservoir	11,080	9,199	17%	13,230	2,150	16%
Subregion 1114, loads from the Red River Basin upstream of Alexandria, LA	15,730	14,300	9%	17,770	2,040	11%
Total instream loads from other basins	250,226	136,831	45%	327,329	77,103	24%
Instream Loads for Lower Mississippi River						
Subregion 809, loads from the Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal area, including loads from all basins and subregions upstream of subregion 809***	212,800	152,400	28%	271,200	58,400	22%
Subregion 808, loads from the Atchafalaya-Vermillion-Calcasieu-Mermentau Rivers and Louisiana Coastal drainage area, including loads from the Red River Basin and subregions 804 and 805***	112,900	77,240	32%	148,700	35,800	24%
Total loads delivered to the Gulf of Mexico	325,700	229,640	29%	419,900	94,200	22%

***** "Background sources" represent loadings 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 or pesticides for all cultivated cropland acres in the watershed.

** Instream loads delivered from the Upper Mississippi River Basin alone are estimated by subtracting the loads delivered from the Missouri River Basin. This calculation may not fully isolate the loads from the Upper Mississippi River Basin, however, as it does not account for deposition within subregion 0714 of the load originating from the Missouri River, nor does it account for re-suspension of bed and bank sediment within subregion 0714 as a result of the additional stream flow from the Missouri River.

*** On average about 30 percent of the flow from the mainstem of the Mississippi River is diverted through the Old River Outflow Channel to the Atchafalaya River near Knox Landing, LA (see figure 85 for location). Loads for subregion 0808 include loads associated with this 30 percent of the flow from the mainstem of the Mississippi River. Loads reported for subregion 0809 exclude these loads.

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.

Figure 85. Average annual ***instream phosphorus loads*** (all sources) delivered to the Gulf of Mexico from the Lower Mississippi River

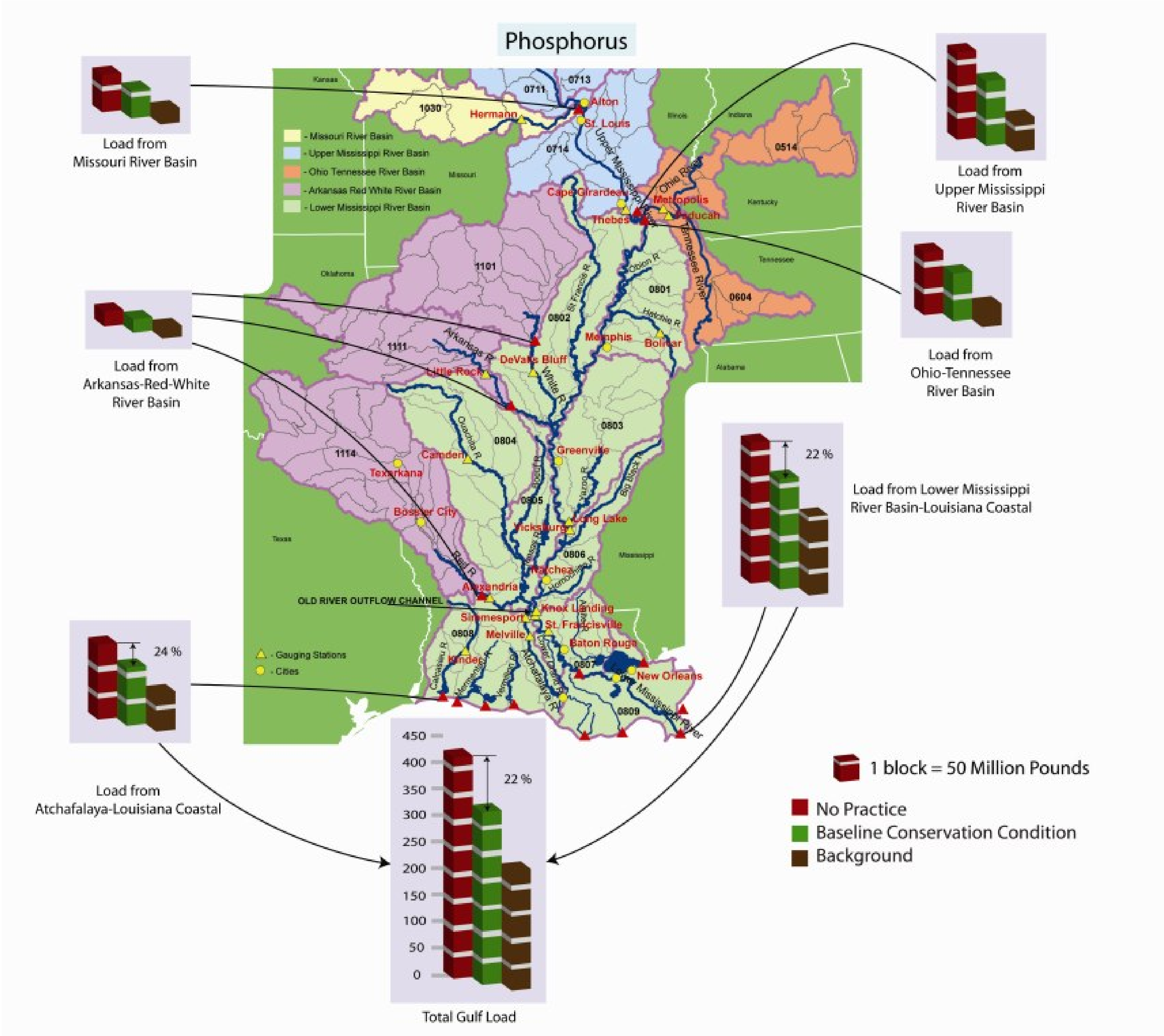


Table 63. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream phosphorus loads*** from all sources delivered to the Gulf of Mexico from the Lower Mississippi River

	Baseline conservation condition		Treatment of critical undertreated acres		Treatment of all undertreated acres	
Source of average annual instream loads delivered to the Gulf of Mexico	Average annual load from all sources (1,000 pounds)	Average annual load from background sources* (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
Instream loads from other basins delivered to the Lower Mississippi River Basin (reported in previous CEAP reports)						
Subregion 0714, combination of loads from Missouri River and Upper Mississippi River Basins	124,000	64,200	117,000	6%	104,000	16%
Subregion 1030, loads from Missouri River Basin only	54,650	37,180	53,950	1%	52,540	4%
Estimate of loads from Upper Mississippi River Basin only**	69,350	27,020	63,050	9%	51,460	26%
Subregion 0514, loads from the Ohio and Tennessee River Basins	96,000	46,600	83,600	13%	66,100	31%
Subregion 1101, loads from the Upper White River	3,416	2,532	3,416	<1%	3,315	3%
Subregion 1111, loads from the Lower Arkansas River-Robert Kerr Reservoir	11,080	9,199	11,080	<1%	10,840	2%
Subregion 1114, loads from the Red River Basin upstream of Alexandria, LA	15,730	14,300	15,720	<1%	15,560	1%
Total instream loads from other basins	250,226	136,831	230,816	8%	199,815	20%
Instream Loads for Lower Mississippi River						
Subregion 809, loads from the Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal area, including loads from all basins and subregions upstream of subregion 809***	212,800	152,400	200,100	6%	187,900	12%
Subregion 808, loads from the Atchafalaya-Vermillion-Calcasieu-Mermentau Rivers and Louisiana Coastal drainage area, including loads from the Red River Basin and subregions 804 and 805***	112,900	77,240	103,800	8%	96,240	15%
Total loads delivered to the Gulf of Mexico	325,700	229,640	303,900	7%	284,140	13%

***** "Background sources" represent loadings 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 or pesticides for all cultivated cropland acres in the watershed.
** Instream loads delivered from the Upper Mississippi River Basin alone are estimated by subtracting the loads delivered from the Missouri River Basin. This calculation may not fully isolate the loads from the Upper Mississippi River Basin, however, as it does not account for deposition within subregion 0714 of the load originating from the Missouri River, nor does it account for re-suspension of bed and bank sediment within subregion 0714 as a result of the additional stream flow from the Missouri River.
*** On average about 30 percent of the flow from the mainstem of the Mississippi River is diverted through the Old River Outflow Channel to the Atchafalaya River near Knox Landing, LA (see figure 85 for location). Loads for subregion 0808 include loads associated with this 30 percent of the flow from the mainstem of the Mississippi River. Loads reported for subregion 0809 exclude these loads.

Note: Critical under-treated acres have a high need for additional conservation treatment. All under-treated acres have a high or moderate need for additional conservation treatment. 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.

Figure 86. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream phosphorus loads*** from all sources delivered to the Gulf of Mexico from the Lower Mississippi River

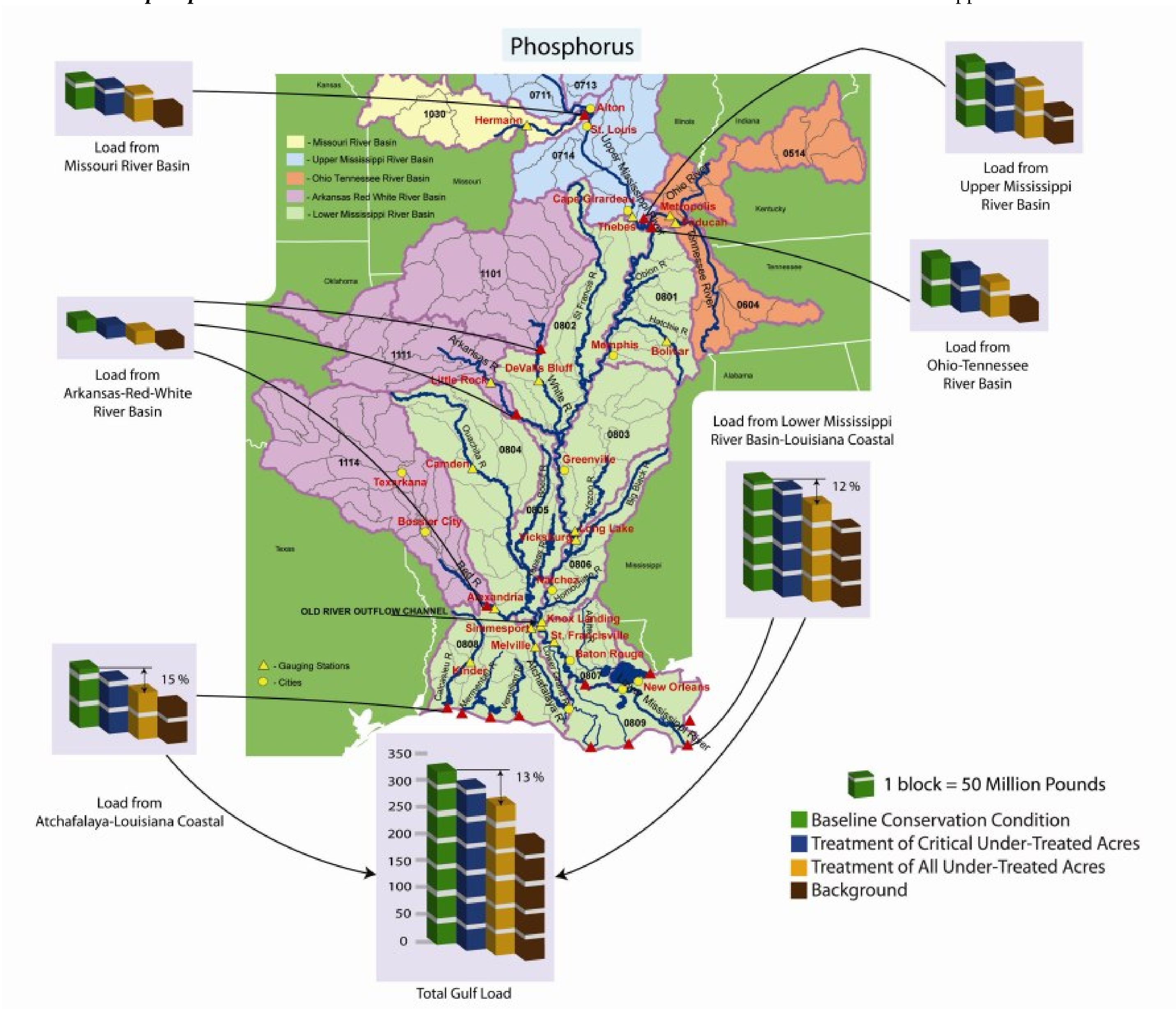


Table 64. Average annual ***instream atrrazine loads*** (all sources) delivered to the Gulf of Mexico from the Lower Mississippi River

Source of average annual instream loads delivered to the Gulf of Mexico	Baseline conservation condition (1,000 pounds)	No-practice scenario (1,000 pounds)	Reductions in loads due to conservation practices (1,000 pounds)	Percent reduction
Instream loads from other basins delivered to the Lower Mississippi River Basin (reported in previous CEAP reports)				
Subregion 0714, combination of loads from Missouri River and Upper Mississippi River Basins	202	290	88	30%
Subregion 1030, loads from Missouri River Basin only	61	90	29	32%
Estimate of loads from Upper Mississippi River Basin only*	141	200	59	30%
Subregion 0514, loads from the Ohio and Tennessee River Basins	177	217	40	18%
Subregion 1101, loads from the Upper White River	1	1	0	24%
Subregion 1111, loads from the Lower Arkansas River-Robert Kerr Reservoir	5	5	0	6%
Subregion 1114, loads from the Red River Basin upstream of Alexandria, LA	1	2	0	31%
Total instream loads from other basins	386	515	129	25%
Instream Loads for Lower Mississippi River				
Subregion 809, loads from the Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal area, including loads from all basins and subregions upstream of subregion 809**	315	394	79	20%
Subregion 808, loads from the Atchafalaya-Vermillion-Calcasieu-Mermentau Rivers and Louisiana Coastal drainage area, including loads from the Red River Basin and subregions 804 and 805**	123	158	35	22%
Total loads delivered to the Gulf of Mexico	438	552	114	21%

* Instream loads delivered from the Upper Mississippi River Basin alone are estimated by subtracting the loads delivered from the Missouri River Basin. This calculation may not fully isolate the loads from the Upper Mississippi River Basin, however, as it does not account for deposition within subregion 0714 of the load originating from the Missouri River, nor does it account for re-suspension of bed and bank sediment within subregion 0714 as a result of the additional stream flow from the Missouri River.

** On average about 30 percent of the flow from the mainstem of the Mississippi River is diverted through the Old River Outflow Channel to the Atchafalaya River near Knox Landing, LA (see figure 87 for location). Loads for subregion 0808 include loads associated with this 30 percent of the flow from the mainstem of the Mississippi River. Loads reported for subregion 0809 exclude these loads.

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.

Figure 87. Average annual ***instream atrazine loads*** (all sources) delivered to the Gulf of Mexico from the Lower Mississippi River

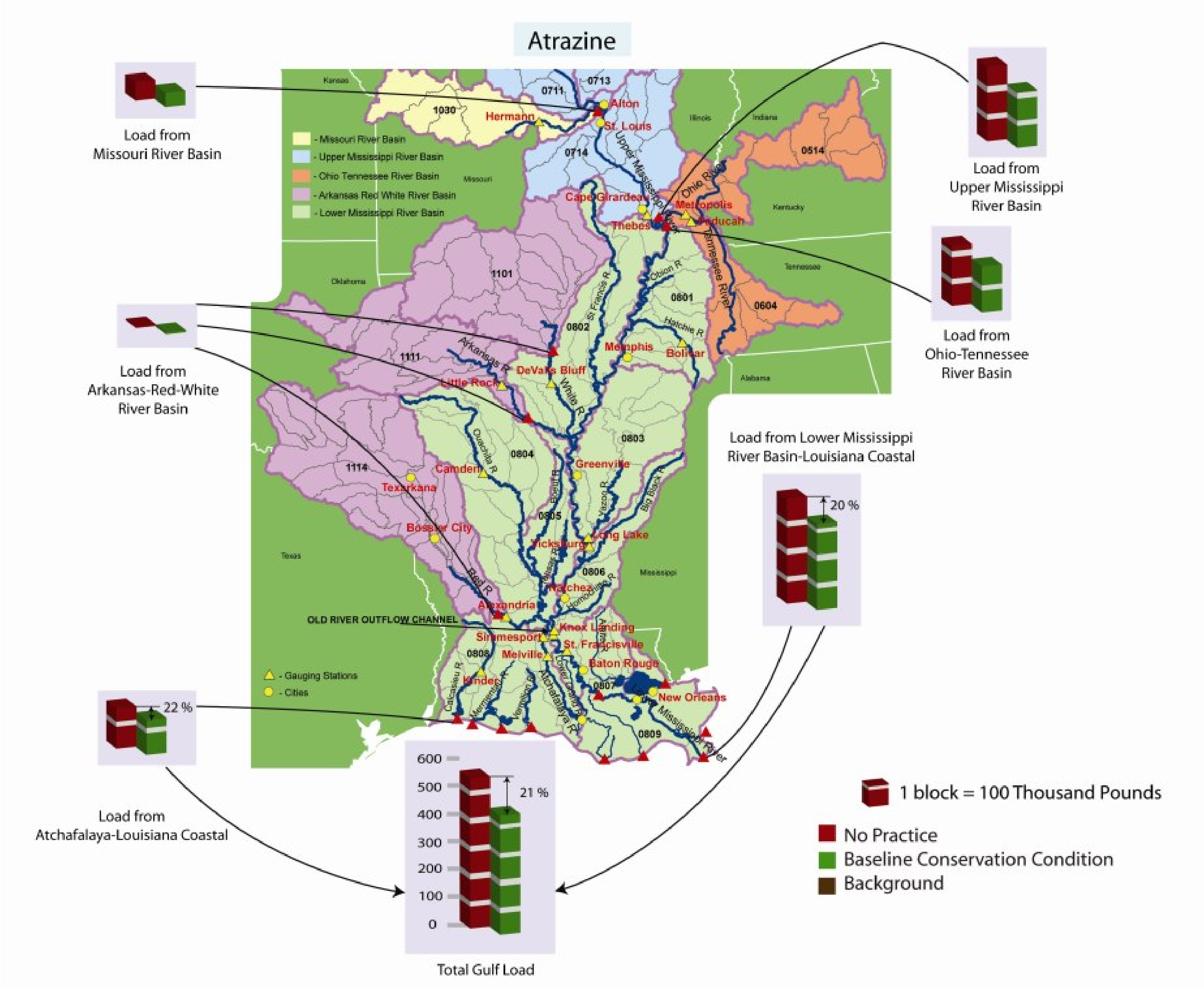


Table 65. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream atrazine loads*** from all sources delivered to the Gulf of Mexico from the Lower Mississippi River

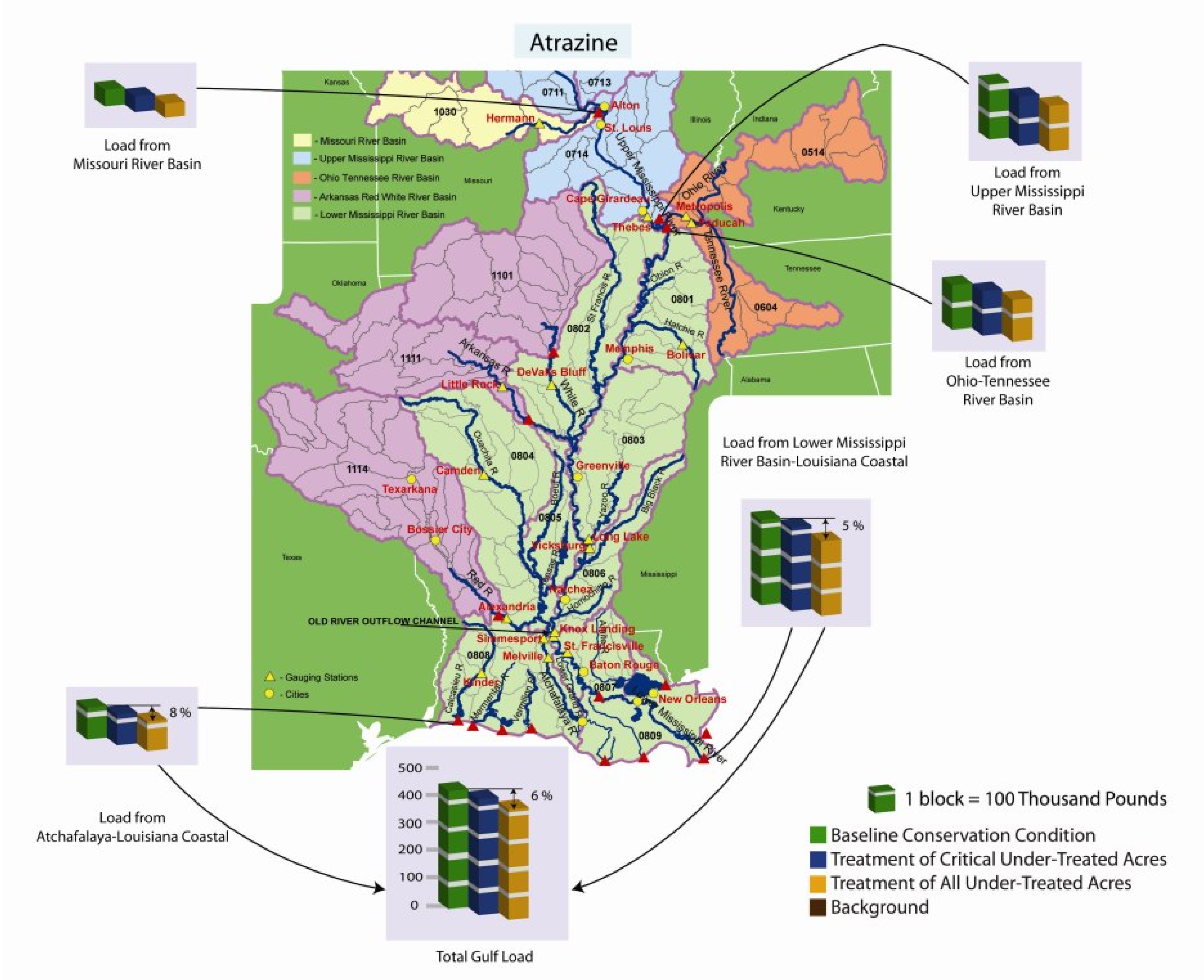
	Baseline conservation condition	Treatment of critical undertreated acres		Treatment of all undertreated acres	
Source of average annual instream loads delivered to the Gulf of Mexico	Average annual load (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
Instream loads from other basins delivered to the Lower Mississippi River Basin (reported in previous CEAP reports)					
Subregion 0714, combination of loads from Missouri River and Upper Mississippi River Basins	202	197	2%	184	9%
Subregion 1030, loads from Missouri River Basin only	61	61	1%	59	4%
Estimate of loads from Upper Mississippi River Basin only*	141	136	3%	125	11%
Subregion 0514, loads from the Ohio and Tennessee River Basins	177	170	4%	157	11%
Subregion 1101, loads from the Upper White River	NA	NA	NA	NA	NA
Subregion 1111, loads from the Lower Arkansas River-Robert Kerr Reservoir	NA	NA	NA	NA	NA
Subregion 1114, loads from the Red River Basin upstream of Alexandria, LA	NA	NA	NA	NA	NA
Total instream loads from other basins	386	374	3%	356	8%
Instream Loads for Lower Mississippi River					
Subregion 809, loads from the Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal area, including loads from all basins and subregions upstream of subregion 809**	315	308	2%	300	5%
Subregion 808, loads from the Atchafalaya-Vermillion-Calcasieu-Mermentau Rivers and Louisiana Coastal drainage area, including loads from the Red River Basin and subregions 804 and 805**	123	120	2%	113	8%
Total loads delivered to the Gulf of Mexico	438	429	2%	413	6%

* Instream loads delivered from the Upper Mississippi River Basin alone are estimated by subtracting the loads delivered from the Missouri River Basin. This calculation may not fully isolate the loads from the Upper Mississippi River Basin, however, as it does not account for deposition within subregion 0714 of the load originating from the Missouri River, nor does it account for re-suspension of bed and bank sediment within subregion 0714 as a result of the additional stream flow from the Missouri River.
** On average about 30 percent of the flow from the mainstem of the Mississippi River is diverted through the Old River Outflow Channel to the Atchafalaya River near Knox Landing, LA (see figure 87 for location). Loads for subregion 808 include loads associated with this 30 percent of the flow from the mainstem of the Mississippi River. Loads reported for subregion 809 exclude these loads.

Note: Critical under-treated acres have a high need for additional conservation treatment. All under-treated acres have a high or moderate need for additional conservation treatment. 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.

Note: NA indicates estimates not available from the previously published CEAP report.

Figure 88. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream atrazine loads*** from all sources delivered to the Gulf of Mexico from the Lower Mississippi River



Chapter 8
Summary of Findings

Field Level Assessment

Evaluation of practices in use

The first Federal conservation efforts on cropland were focused primarily on water management and soil erosion control. Structural practices such as waterways, terraces, and diversions were installed along with supporting practices such as contour farming and stripcropping. Conservation tillage emerged in the 1960s and 1970s as a key management practice for enhancing soil quality and further reducing soil erosion. The conservation compliance provisions in the 1985 Farm Bill sharpened the focus to treatment of the most erodible acres—highly erodible land. This legislation created the Conservation Reserve Program as a mechanism for establishing long-term conserving cover on the most erodible cropland through multi-year contracts with landowners. More recently, the focus has shifted from soil conservation and sustainability to a broader goal of reducing all pollution impacts associated with agricultural production. Prominent among new concerns are the environmental effects of nutrient and pesticide export from farm fields.

The application of conservation practices in the Lower Mississippi River Basin reflects this history of Federal conservation programs and technical assistance. An assessment, based on a farmer survey representing practice use and farming activities for the period 2003–06, found the following:

- Structural practices for controlling water erosion are in use on only 21 percent of cropped acres (table 7). However, 92 percent of cropped acres in this region have slopes less than 2 percent, including many acres that may not need to be treated with structural practices. On the 12 percent of the acres designated as highly erodible land, structural practices designed to control water erosion are in use on 42 percent.
- Reduced tillage is common in the region; 82 percent of the cropped acres meet criteria for either no-till (28 percent) or mulch till (53 percent) (table 8). All but 13 percent of the acres had evidence of some kind of reduced tillage on at least one crop.
- About 35 percent of cropped acres are gaining soil organic carbon (fig. 8).
- Producers use either residue and tillage management practices or structural practices, or both, on 90 percent of cropped acres (table 9).
- While most acres have evidence of some nitrogen or phosphorus management, the majority of the acres in the region lack consistent use of appropriate rates, timing, *and* method of application on each crop in every year of production (table 10).
    - About 21 percent of cropped acres have no nitrogen applied, nearly all of which are continuous soybeans. An additional 66 percent of cropped acres meet criteria for timing of nitrogen applications on all crops in the rotation, 50 percent meet criteria for method of application, and 23 percent meet criteria for rate of application.
    - About 4 percent of cropped acres have no phosphorus applied. An additional 78 percent of cropped acres meet criteria for timing of phosphorus applications on all crops in the rotation, 64 percent meet criteria for method of application, and 30 percent meet criteria for rate of application.
    - Appropriate nitrogen application rates, timing of application, and application method for all crops during every year of production, however, are in use on only about 14 percent of cropped acres.
    - Good phosphorus management practices (appropriate rate, timing, and method) are in use on 17 percent of the acres on all crops during every year of production.
    - Only about 9 percent of cropped acres meet nutrient management criteria for both nitrogen and phosphorus management.
- During the 2003–06 period of data collection, cover crops were used on less than 1 percent of the acres in the region.
- The Integrated Pest Management (IPM) indicator showed that only about 9.7 percent of the acres were being managed with a relatively high level of IPM (fig. 11).
- Land in long-term conserving cover, as represented by enrollment in the CRP General Signup, consists of 1.0 million acres in the region, of which 47 percent is highly erodible land.

Annual precipitation over the 47-year simulation averaged about 53 inches in this region. About 46 percent of the cropped acres are irrigated, at an average application of 21 inches per year. About half the irrigated acres are rice-only cropping systems or include rice in the crop rotation.

Effects of conservation practices

Model simulation results show that, for cropped acres in the region, *on average* conservation practices have—

- reduced surface water flow from fields by 11 percent, re-routing most of the water to subsurface flow pathways (table 13);
- reduced wind erosion by 20 percent, from 0.15 ton per acre without conservation practices to 0.03 ton per acre with conservation practices (table 14);
- reduced sediment loss from fields caused by water erosion by 27 percent, from 4.17 tons per acre without conservation practices to 3.03 tons per acre with conservation practices (table 15);
- reduced total nitrogen loss (volatilization, denitrification, surface runoff, and subsurface flow losses) from fields by 3 percent, from 59.8 pounds per acre without conservation practices to 57.9 pounds per acre with conservation practices (table 18):
    - reduced nitrogen lost with surface runoff (attached to sediment and in solution) by 26 percent, from 19.1 pounds per acre without conservation practices to 14.1 pounds per acre with conservation practices;
    - reduced nitrogen loss in subsurface flows by 5 percent, from 27.1 pounds per acre without

conservation practices to 25.7 pounds per acre with conservation practices;

- reduced total phosphorus loss from fields by 39 percent, from 8.9 pounds per acre without conservation practices to 5.4 pounds per acre with conservation practices (table 20); and
- reduced pesticide loss from fields to surface water, resulting in a 39-percent reduction in edge-of-field pesticide risk (all pesticides combined) for aquatic ecosystems and a 24-percent reduction in edge-of-field surface water pesticide risk for humans (table 21).

These results indicate that conservation practices in this region have a relatively low impact on nitrogen loss. Structural erosion control practices, residue management practices, and reduced tillage slow the flow of surface water runoff and allow more of the water to infiltrate into the soil. This re-routing of surface water to subsurface flow not only redirects the dissolved nitrogen into subsurface flow but also can extract additional nitrogen from the soil as the water passes through the soil profile, including nitrogen produced by legumes such as soybeans (nitrogen biofixation). On about half of the cropped acres in this region, the rerouting of surface water runoff to subsurface flow pathways, in combination with ineffective or incomplete nutrient management practices, results in sufficient amounts of additional nitrogen being leached from the soil to more than offset the reductions in nitrogen lost with surface runoff and produce a small net increase in total nitrogen loss. Model simulation of additional conservation treatment shows that pairing effective nutrient management practices (consistent use of proper rate, form, timing, *and* method of application) with water erosion control practices could reduce nitrogen loss in subsurface flow to acceptable levels for 85 percent of the cropped acres in this region.

For land in long-term conserving cover (1.0 million acres), soil erosion and sediment loss have been almost completely eliminated. Compared to a cropped condition without conservation practices, total nitrogen loss has been reduced by 92 percent, total phosphorus loss has been reduced by 98 percent, and soil organic carbon has been increased by an average of 716 pounds per acre per year.

Conservation treatment needs

The adequacy of conservation practices in use in the Lower Mississippi River Basin for the time period 2003–06 was evaluated to identify conservation treatment needs for four resource concerns (see chapter 5):

- Sediment loss from fields.
- Nitrogen lost with surface runoff (attached to sediment and in solution).
- Nitrogen loss in subsurface flows.
- Phosphorus lost to surface water (includes soluble phosphorus in lateral flow).

Not all acres require the same level of conservation treatment. Acres with a high level of inherent vulnerability require more treatment than less vulnerable acres to reduce field-level losses to acceptable levels. 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. Acres that are essentially flat with permeable 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.

Undertreated acres were identified by an imbalance between the level of conservation treatment and the level of inherent vulnerability. Three levels of treatment need were identified:

- Acres with a "high" level of need for conservation treatment consist of the most critical undertreated acres in the region. These are the most vulnerable of the undertreated acres with the least conservation treatment and have the highest losses of sediment and/or nutrients.
- Acres with a "moderate" level of need for conservation treatment consist of undertreated acres that generally have lower levels of vulnerability and/or have more conservation practice use than acres with a high level of need. The treatment level required is not necessarily less, although it can be, but rather the sediment and nutrient losses are lower and thus there is less potential on a per-acre basis for reducing agricultural pollutant loadings with additional conservation treatment.
- 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. While gains can be obtained by adding conservation practices to some of these acres, additional conservation treatment would reduce field losses by only a small amount.

The most critical conservation concern in the region is the need for control of surface water runoff and complete and consistent use of nutrient management—appropriate rate, form, timing, *and* method of application of nitrogen and phosphorus. All but 14 percent of the cropped acres need additional conservation treatment in this region:

- 33 percent of cropped acres (6.29 million acres) have a **high** level of need for additional conservation treatment.
- 53 percent of cropped acres (9.98 million acres) have a **moderate** level of need for additional conservation treatment.

The proportion of cropped acres with a high or moderate need for additional conservation is (fig. 57)—

- 74 percent for sediment loss (19 percent with a high need for treatment),
- 59 percent for nitrogen loss with runoff (11 percent with a high need for treatment),
- 67 percent for phosphorus lost to surface water (28 percent with a high need for treatment), and
- 38 percent for nitrogen loss in subsurface flows (4 percent with a high need for treatment), most of which returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

The bulk of undertreated acres in this region have a low or moderate level of soil vulnerability (tables 24-27). Eighty-five percent of acres undertreated for sediment loss have a low or moderate soil runoff potential, 81 percent for acres undertreated for nitrogen loss with surface runoff, and 83 percent for acres undertreated for phosphorus lost to surface water. Ninety-four percent of acres undertreated for nitrogen loss in subsurface flow paths have a low or moderate soil leaching potential. Because of the higher precipitation and more frequent and intense storms this region needs enhanced soil erosion control practices and high levels of nutrient management even on soils with low or moderate potential for sediment and nutrient losses.

About 28 percent of these undertreated acres are undertreated for all four resource concerns, and another 27 percent are undertreated for all but nitrogen loss in subsurface flows (table 28).

The 6.29 million acres with a "high" level of need for conservation treatment lose (per acre per year, on average) 5.2 tons of sediment by water erosion, 8.9 pounds of phosphorus, and 71 pounds of nitrogen.

The 9.98 million acres with a "moderate" level of need for conservation treatment lose (per acre per year, on average) 2.1 tons of sediment by water erosion, 3.9 pounds of phosphorus, and 55 pounds of nitrogen.

In contrast, the 2.56 million acres with a "low" level of need for conservation treatment lose (per acre per year, on average) 1.1 tons of sediment by water erosion, 2.5 pounds of phosphorus, and 37 pounds of nitrogen.

The cotton-only cropping system, which represents 19 percent of cropped acres, accounts for 34 percent of the critical under-treated acres in the region (table 31). Sixty-one percent of all "cotton only" acres have a high need for additional conservation treatment, compared to 33 percent for all cropped acres. In contrast, cropping systems with rice only or rice and soybeans or other crops account for only 13.5 percent of the critical undertreated acres but represent 24 percent of all cropped acres. For these two cropping systems, only about 18 percent of the acres have a high need for additional treatment.

Critical undertreated acres (acres with a high need for additional conservation treatment) are also more concentrated in some areas within the region. Two subregions in particular have disproportionately high percentages of critical undertreated acres:

- The Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801), where 67 percent of cropped acres are critical under-treated acres compared to 33 percent for all cropped acres in the region.
- The Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806), where 54 percent of cropped acres are critical under-treated acres.

Simulation of additional conservation treatment

Model simulations were used to evaluate the potential gains from further conservation treatment in the Lower Mississippi River Basin (see chapter 6).

Three sets of additional conservation practices were simulated:

1. Additional wind and water erosion control practices consisting of four types of structural practices—overland flow practices, concentrated flow practices, edge-of-field mitigation—and wind erosion control practices.
2. Application of nitrogen and phosphorus using appropriate rate, timing, and method.
3. Increases in the efficiency of irrigation water application.

Model simulation was used to estimate the gains that could be attained when additional soil erosion control practices, nutrient management practices, and increased irrigation efficiencies are applied in this region:

- Conservation treatment of the 6.29 million acres with a high need for additional treatment would reduce sediment loss an average of 4.74 tons per acre per year on those acres. In comparison, additional treatment of the 9.98 million undertreated acres with a moderate need for additional treatment would reduce sediment loss by about 1.75 tons per acre per year on those acres. Treatment of the remaining 2.56 million acres would reduce sediment loss by only 0.83 ton per acre per year on those acres, on average.
- Total nitrogen loss would be reduced by an average of 36 pounds per acre per year on the 6.29 million acres with a high need for additional treatment, compared to a reduction of 23 pounds per acre for the 9.98 million undertreated acres with a moderate need for additional treatment, and only 12 pounds per acre for the remaining 2.56 million acres.
- Nitrogen loss in subsurface flows would be reduced by an average of 18.5 pounds per acre per year on the 6.29 million acres with a high need for additional treatment and 9.6 pounds per acre per year on the 9.98 million acres with a moderate need for additional treatment, compared to a reduction of 1.3 pounds per acre for the remaining 2.56 million acres.
- Nitrogen lost with surface water would be reduced by an average of 12.3 pounds per acre per year on the 6.29 million acres with a high need for additional treatment and by 5.1 pounds per acre per year on the 9.98 million acres with a moderate need for additional treatment, compared to a reduction of only 3.2 pounds per acre for the remaining 2.56 million acres.
- Total phosphorus loss would be reduced by an average of 6.7 pounds per acre per year on the 6.29 million acres with a high need for additional treatment, compared to a reduction of 1.9 pounds per acre for the 9.98 million undertreated acres with a moderate need for additional treatment and only 0.8 pound per acre for the remaining 2.56 million acres.

Model simulations demonstrated that sediment and nitrogen losses with surface runoff could be effectively controlled in the region with additional erosion control practices. However, model simulations also showed that a suite of practices that includes both soil erosion control and consistent nutrient management is often *required* to adequately address both soil erosion *and* nutrient loss through all loss pathways. Treatment with combinations of soil erosion control practices and nutrient management makes applied nutrients more available for use by crops and thus significantly reduces the rerouting of soluble nitrogen and phosphorus to subsurface loss pathways.

Compared to the baseline conservation condition, treating all 16.27 million undertreated acres with soil erosion control practices *and* nutrient management practices would, for the region as a whole (table 39)—

- reduce sediment loss in the region by 83 percent on average;
- reduce total nitrogen loss by 42 percent:
  - reduce nitrogen loss with surface runoff (sediment adsorbed and soluble) by 48 percent, and
  - reduce nitrogen loss in subsurface flows by 44 percent;
- reduce phosphorus lost to surface water by 62 percent; and
- reduce environmental risk from loss of pesticide residues by 25 to 33 percent.

The potential for achieving additional field-level savings from further conservation treatment is high in this region, especially for additional reductions in nitrogen loss. Conservation practice use in 2003–06 achieved: 30 percent of potential savings for sediment loss, 7 percent for nitrogen, and 51 percent for phosphorus (fig. 59). By treating all 16.27 million undertreated acres in the region with additional erosion control and nutrient management practices, an additional 67 percent in savings would be attained for sediment, 87 percent for nitrogen, and 48 percent for phosphorus. To achieve 100 percent of potential savings (i.e., an additional 3 percent for sediment, 6 percent for nitrogen, and 2 percent for phosphorus), additional conservation treatment for the 2.56 million acres with a low need for additional treatment would be required, which would result in very small conservation gains on a per-acre basis.

Loads Delivered to Rivers and Streams within the Region

Reductions in field-level losses due to conservation practices, including land in long-term conserving cover, translate into improvements in water quality in streams and rivers in the region. Transport of sediment, nutrients, and pesticides 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 instream loads.

Cultivated cropland represents about 33 percent of the land base in the Lower Mississippi River Basin. At the 2003–06 level of conservation practice use, cultivated cropland delivered a disproportionate amount of sediment and nutrients to rivers and streams within the region. Of the total loads delivered to rivers and streams from all sources, cultivated cropland is the source for 78 percent of the sediment, 53 percent of the nitrogen, and 43 percent of the phosphorus.

Model simulation results for the Lower Mississippi River Basin indicate that for the baseline conservation condition, sediment, nutrient, and atrazine loads **delivered to rivers and streams from cultivated cropland sources** per year, on average, are—

- 23.4 million tons of sediment (78 percent of loads from all sources);
- 555 million pounds of nitrogen (53 percent of loads from all sources);
- 53 million pounds of phosphorus (43 percent of loads from all sources); and
- 88,000 pounds of atrazine.

Conservation practices in use on cultivated cropland in 2003-06, including land in long-term conserving cover, have reduced sediment, nutrient, and atrazine loads **delivered to rivers and streams from cultivated cropland sources** per year, on average, by—

- 35 percent for sediment;
- 21 percent for nitrogen;
- 52 percent for phosphorus, and
- 26 percent for atrazine.

Model simulations showed that if the 6.29 million **critical** undertreated acres were fully treated with the appropriate soil erosion control and nutrient management practices, loads from cultivated cropland delivered to rivers and streams in the Lower Mississippi River Basin would, relative to the baseline conservation condition, be reduced by —

- 48 percent for sediment,
- 23 percent for nitrogen,
- 38 percent for phosphorus, and
- 5 percent for atrazine.

Model simulations further showed that if **all** of the undertreated acres (an additional 9.98 million acres) were fully treated with the appropriate soil erosion control and nutrient management practices, loads from cultivated cropland delivered to rivers and streams in the watershed would be reduced, relative to the baseline conservation condition—

- 80 percent for sediment,
- 43 percent for nitrogen,
- 57 percent for phosphorus, and
- 15 percent for atrazine.

Instream Loads from All Sources Delivered to the Gulf of Mexico

Instream loads are estimated by starting with the loads delivered from *all sources* at the outlet of each 8-digit HUC and routing those loads downstream. Stream and channel processes are simulated, including flood routing, instream degradation processes, streambed deposition, streambank erosion, and reservoir dynamics. A portion of the sediment, nutrients, and pesticides delivered to rivers and streams is removed or trapped during these processes. Some of the nitrogen is lost during instream nitrification processes, and a portion of the sediment and sediment-bound nutrients and pesticides is deposited in streambeds and flood plains during transit. Large reservoirs can trap significant amounts of loads delivered to rivers and streams, keeping those loads from being transferred downstream. Sediment can also be added to instream loads through streambank erosion and streambed scouring.

Instream loads represent *all sources* of sediment, nutrients, and pesticides. In some river systems, the predominant source of instream loads originates from urban point sources, while in other river systems the predominant source of instream loads is from cultivated cropland. In river systems like the Lower Mississippi River Basin, however, instream loads are a mix from a variety of sources, including upstream portions of the drainage system. Instream loads delivered to the Gulf of Mexico from the Mississippi River drainage system include loads originating from—

- the Missouri River,
- the Upper Mississippi River upstream of Thebes, IL,
- the Ohio and Tennessee Rivers,
- the Arkansas-White-Red Basin,
- Mississippi River drainage within the Lower Mississippi River Basin, and
- smaller rivers and streams along the Louisiana coast.

After accounting for instream deposition, reservoir dynamics, streambank erosion, and other transport processes, model simulations indicate that total instream loads from all of these sources deliver to the Gulf of Mexico per year, on average, for the baseline conservation condition—

- 190 million tons of sediment,
- 3.243 billion pounds of nitrogen,
- 326 million pounds of phosphorus, and
- 438,000 pounds of atrazine.

Instream loads delivered to the Lower Mississippi River Basin from other basins have been estimated in previous CEAP reports. Average baseline loads per year from upstream basins in the Mississippi River drainage system have been estimated to be—

- 136 million tons of sediment,
- 2.774 billion pounds of nitrogen,
- 250 million pounds of phosphorus, and
- 386,000 pounds of atrazine.

The best estimate we have of the instream loads originating within the Lower Mississippi River Basin is the difference between the total instream loads delivered to the Gulf and the loads delivered to the Lower Mississippi River Basin from other basins. Annual instream baseline loads originating within the Lower Mississippi River Basin are estimated in this manner to be, on average—

- 54 million tons of sediment,
- 469 million pounds of nitrogen,
- 75 million pounds of phosphorus, and
- 52,000 pounds of atrazine.

The effects of conservation practices are estimated for instream loads in the same manner as was done for loads delivered to rivers and streams. The percent reductions in total instream loads, however, are usually much smaller than observed for loads delivered from cultivated cropland to rivers and streams because conservation practices affect only the cultivated cropland component of the total instream load. Conservation practices in use on cultivated cropland in 2003-06, including land in long-term conserving cover, have reduced instream loads from all sources delivered from the Lower Mississippi River Basin to the Gulf of Mexico, per year, on average, by—

- 4 percent for sediment,
- 17 percent for nitrogen,
- 22 percent for phosphorus, and
- 21 percent for atrazine.

These percent reductions reflect the use of conservation practices on cultivated cropland ***throughout*** *the entire Mississippi River drainage system.*

Model simulation results further indicate that additional conservation treatment of *all 94.7 million under-treated acres* in the Mississippi River drainage system would be expected to reduce instream loads from all sources delivered to the Gulf of Mexico per year relative to the baseline, on average, by—

- 5 percent for sediment,
- 15 percent for nitrogen,
- 13 percent for phosphorus, and
- 6 percent for atrazine.

Comparison of Findings to Other Regions

The Lower Mississippi River Basin is the smallest of the five major river basins (water resource regions) that make up the Mississippi River drainage system (table 66). Thirty-three percent of the land base in the Lower Mississippi River Basin is cultivated cropland, second only to the Upper Mississippi River Basin, with 53 percent. At 20 million acres of cultivated cropland, the Lower Mississippi River Basin has less cultivated cropland acres than any of the other four major river basins.

Basin characteristics

The principal cropping systems in the Lower Mississippi River Basin differ substantially from those in other basins (table 66). Continuous soybeans (22 percent of cropped acres), continuous cotton (19 percent), and rice and soybean rotations (19 percent) are common in the Lower Mississippi River Basin and uncommon or do not exist in the other four basins. The Arkansas-White-Red Basin and the western portion of the Missouri River Basin are dominated by wheat and other close-grown crops, whereas corn and soybean rotations are the dominant cropping system throughout the Ohio-Tennessee and Upper Mississippi River Basins and the eastern portion of the Missouri River Basin. The Lower Mississippi River Basin also has the highest percentage of irrigated acres (46 percent of cropped acres, half of which are rice acres) and the lowest percent of acres with manure applied (1 percent of cropped acres).

The Lower Mississippi River Basin has the highest annual precipitation (table 66 and fig. 88), which is an important determinant of how much sediment, nutrients, and pesticides are lost from farm fields. The average annual precipitation for cropland acres in the region is 53 inches per year, compared to 42 inches per year for the Ohio-Tennessee River Basin, 34 inches per year for the Upper Mississippi River Basin, and less than 30 inches per year for the Missouri River Basin and the Arkansas-White-Red Basin. The high amount of annual precipitation increases the potential for field-level losses in the Lower Mississippi River Basin relative to the other four basins.

The Lower Mississippi River Basin also has the smallest proportion of cropland acres that are highly erodible and the smallest proportions of acres with a high or moderately high level of vulnerability to runoff and leaching (table 66 and figs. 89 and 90).

The Missouri River Basin and the Arkansas-White-Red Basin are the only basins within the Mississippi River drainage system with significant vulnerability to wind erosion, primarily because of the low levels of annual precipitation in those two basins.

The Lower Mississippi River Basin is more frequently impacted by intense tropical systems than other basins in the Mississippi River drainage system. Even though the soil erodibility is generally low in this region compared to other regions, the high rainfall duration and intensity associated with these storms results in very high levels of sediment and nutrient losses from farm fields periodically. The Lower Mississippi River Basin, more so than other basins in the Mississippi River drainage system, requires enhanced soil erosion control practices and high levels of nutrient management even on soils with low or moderate inherent potential for sediment and nutrient losses.

Figure 88. Comparison of distributions of average annual precipitation among the five basins (water resource regions) that make up the Mississippi River drainage system

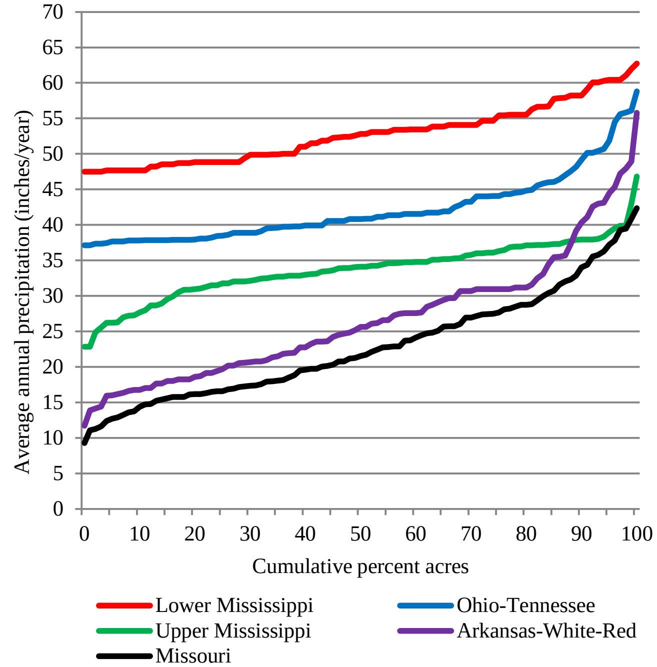


Figure 89. Comparison of the percent of cropped acres that is highly erodible among the five basins (water resource regions) that make up the Mississippi River drainage system

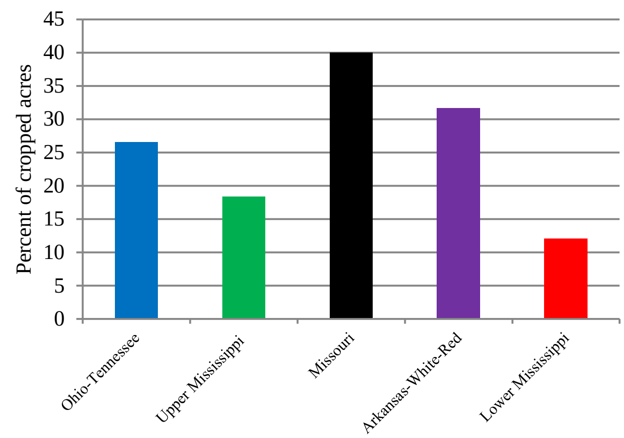
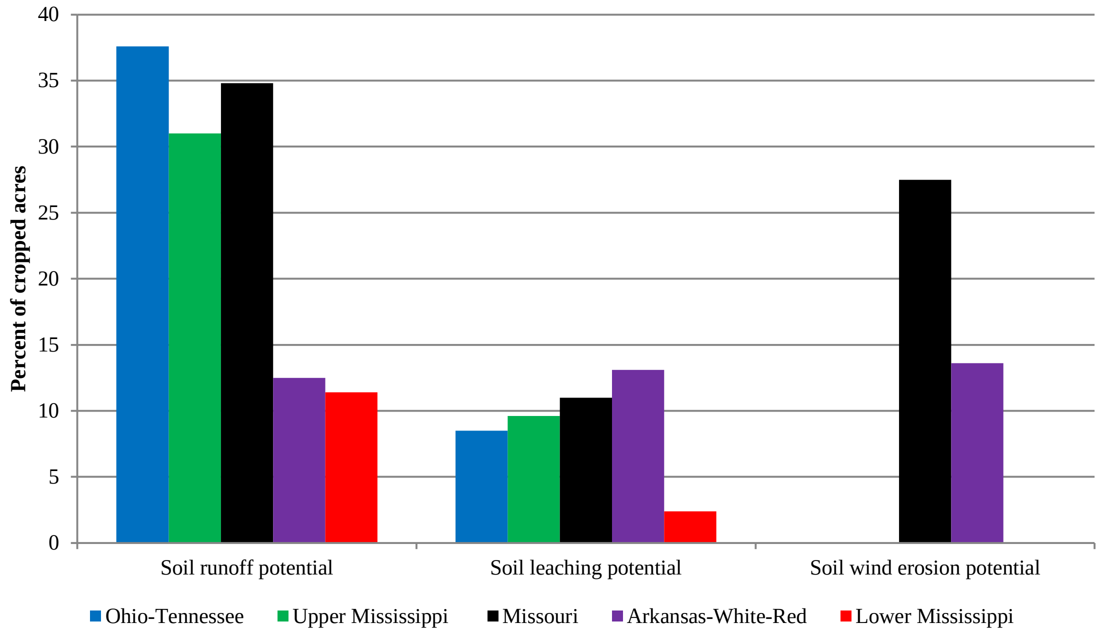


Table 66. Comparison of land use, vulnerability, and conservation practice use among the five basins (water resource regions) that make up the Mississippi River drainage system

	Lower Mississippi River Basin	Arkansas-White-Red Basin	Missouri River Basin	Upper Mississippi River Basin	Ohio-Tennessee River Basin
Total acres in basin (million acres excluding water)	61.6	156.5	322.2	118.2	128.5
Total acres of cultivated cropland (million acres)	20.3	35.3	95.1	62.9	26.8
Land use (percent of total acres excluding water)					
Cultivated cropland	33	23	30	53	21
Hayland	2	3	3	5	6
Pasture and rangeland	11	46	53	7	12
Urban land	6	5	3	8	9
Forest and other	48	23	11	26	52
Cultivated cropland (percent of cropped acres)					
Crop rotations with corn and soybean only	8	2	32	74	69
Crop rotations with wheat or other close-grown crops only, including rice	6	52	30	<1	<1
Soybean only	22	1	2	3	5
Cotton only	19	0	0	0	0
Rice and soybeans	19	2	0	0	0
Irrigated	46	20	14	2	1
Manure applied	1	4	5	16	9
Vulnerability factors					
Average annual precipitation (inches)	53	27	23	34	42
Slopes greater than 2% (percent of cropped acres)	8	15	48	42	33
Highly Erodible Land (percent of cropped acres)	12	32	40	18	27
High soil runoff potential (percent of cropped acres)	2	<1	12	13	9
High or moderately high soil leaching potential (percent of cropped acres)	2	13	11	10	8
High or moderately high soil wind erosion potential (percent of cropped acres)	0	14	28	1	0
Conservation practice use					
No-till (percent of cropped acres)	28	14	46	28	52
Mulch till (percent of cropped acres)	53	44	47	63	41
Structural practices for water erosion control (percent of cropped acres)	21	46	41	45	40
Structural practices for wind erosion control (percent of cropped acres)	1	7	10	3	2
High tillage and residue management level (percent of cropped acres)	26	18	52	63	59
High or moderately high nitrogen management level (percent of cropped acres)	44	63	65	41	42
High or moderately high phosphorus management level (percent of cropped acres)	34	62	63	54	43
Land in long-term conserving cover (acres enrolled in CRP General Sign-Up) as a percent of cultivated cropland acres	5	17	12	5	4

Figure 90. Comparison of the percent of cropped acres with a high or moderately high level of inherent vulnerability among the five basins (water resource regions) that make up the Mississippi River drainage system*



* See chapter 5 for a discussion of soil vulnerability measures and criteria. Moderate and low levels of soil vulnerability were also defined and estimated in chapter 5.

Conservation practice use

Conservation practice use in the Lower Mississippi River Basin generally lags behind conservation practice use in the other four basins (table 66 and fig. 91).

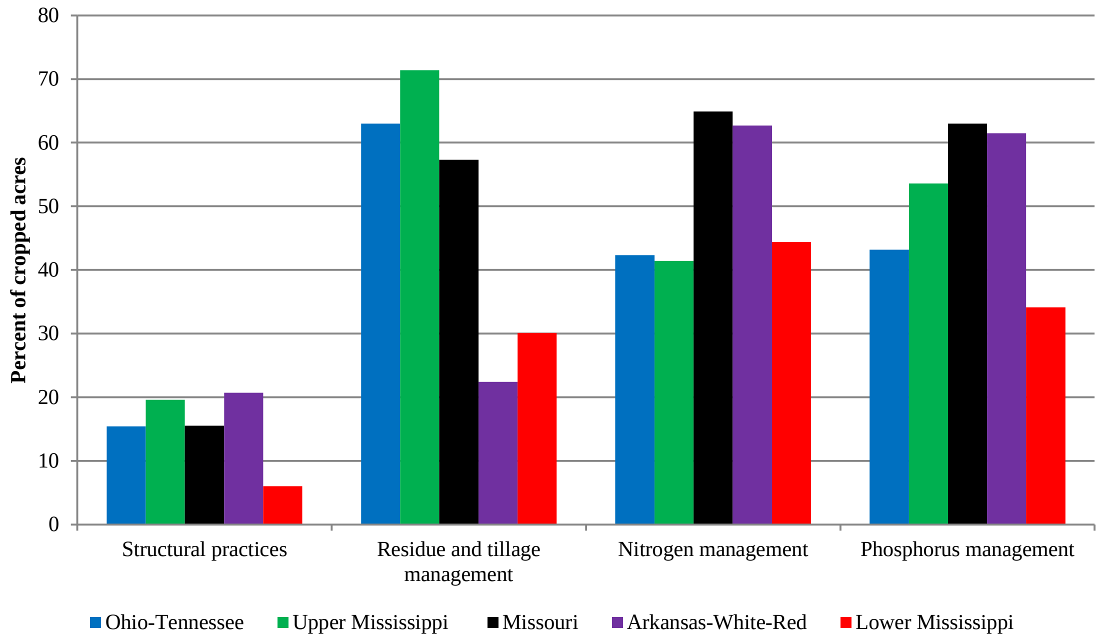
The percentage of cropped acres with a high or moderately high level of structural practice use is lower for the Lower Mississippi River Basin than any of the other four basins (fig. 91). The percentage of cropped acres with slopes greater than 2 percent or that is highly erodible land is also low, but the higher levels of precipitation and frequency of intense storms is cause for greater use of structural practices in this region than in other regions.

Moreover, the percentage of cropped acres with a high or moderately high level of phosphorus management is also lowest in the Lower Mississippi River Basin. Nitrogen management in the Lower Mississippi River Basin is on a par with the Upper Mississippi River Basin and the Ohio-Tennessee River Basin, but residue and tillage management is used much less extensively in the Lower Mississippi River Basin than in basins other than the Arkansas-White-Red Basin (table 66 and fig. 91).

Conservation crop rotations that meet NRCS criteria (NRCS practice code 328) consist of growing different crops in a planned rotation to manage nutrient and pesticide inputs, enhance soil quality, or reduce soil erosion. Including a legume, hay, or a close-grown crop in the rotation can have a pronounced effect on long-term average field losses of sediment and nutrients, as well as enhancement of soil quality.

In the Lower Mississippi River Basin, conservation crop rotations are used on only about 48 percent of the cropped acres, compared to 87 to 90 percent for each of the other four basins. The higher frequency of continuous crop rotations in the Lower Mississippi River Basin also contributes to higher field-level losses relative to the other four basins.

Figure 91. Comparison of the percent of cropped acres with a high or moderately high level of conservation treatment among the five basins (water resource regions) that make up the Mississippi River drainage system*



* See chapter 3 for the criteria for the high and moderately high levels of conservation treatment. Moderate and low levels of conservation treatment were also defined and estimated in chapter 3. These four levels of conservation treatment were used with the four levels of soil vulnerability in chapter 5 to estimate three levels of conservation treatment needs.

Baseline conservation condition

Baseline edge-of-field losses of sediment and nutrients are higher in the Lower Mississippi River Basin, on average, than any of the other four basins (table 67). This is a reflection not only of the higher level of precipitation but also the lower level of conservation practice use and the lower level of effectiveness of conservation practice use in the Lower Mississippi River Basin.

Figures 92 through 95 compare the distributions of sediment and nutrient losses among the regions for the baseline conservation condition, which reflects the effects of conservation practices in use in 2003–06. These figures show that the higher edge-of-field losses found in the Lower Mississippi River Basin are widespread within the region. The most striking example is for total nitrogen loss (all loss pathways), where 37 percent of the cropped acres in the Lower Mississippi River Basin lose more than 60 pounds per acre of nitrogen, compared to 16 percent for the Ohio-Tennessee River Basin, 11 percent for the Upper Mississippi River Basin, and less than 10 percent for the Missouri River and Arkansas-White-Red Basins (fig. 93). These higher nitrogen losses in the Lower Mississippi River Basin are not due to higher sources of nitrogen, as shown in figure 96, but are influenced by the lower amount of nitrogen in crop yields removed at harvest in the Lower Mississippi River Basin, as shown in figure 97.

The average annual change in soil organic carbon is also lower in the Lower Mississippi River Basin than in the other four basins under conditions represented by the baseline conservation condition, with an average loss of 55 pounds per acre per year (table 67). The distribution of annual change in soil organic carbon, shown in figure 98, shows that only about a third of cropped acres in the Lower Mississippi River and Arkansas-White-Red Basins are gaining soil organic carbon compared to about 60 percent in the Missouri River Basin, two-thirds of the acres in the Ohio-Tennessee River Basin, and three-fourths of the acres in the Upper Mississippi River Basin.

Table 67. Comparison of field level losses and the effects of conservation practices among the five basins (water resource regions) that make up the Mississippi River drainage system

	Lower Mississippi River Basin	Arkansas-White-Red Basin	Missouri River Basin	Upper Mississippi River Basin	Ohio-Tennessee River Basin
Average annual change in soil organic carbon, baseline conservation condition	-55	-48	52	71	27
Average annual wind erosion and edge-of-field sediment and nutrient loss, baseline conservation condition					
Wind erosion (tons/acre)	0.12	2.17	1.13	0.23	0.02
Sediment loss (tons/acre)	3.03	0.34	0.26	0.89	1.59
Total nitrogen loss (pounds/acre)	57.9	28.3	23.4	39.0	42.6
Nitrogen lost with windborne sediment (pounds/acre)	0.4	6.5	5.8	2.1	0.2
Nitrogen loss with surface runoff (pounds/acre)	14.1	2.5	2.6	8.8	13.2
Nitrogen loss in subsurface flows (pounds/acre)	25.7	11.3	6.9	18.7	19.2
Total phosphorus loss (pounds/acre)	5.4	2.4	1.7	3.2	4.6
Phosphorus lost with windborne sediment (pounds/acre)	0.1	1.5	1.0	0.4	0.0
Phosphorus lost to surface water, sediment attached and soluble (pounds/acre)	5.2	0.8	0.7	2.7	4.5
Percent reduction in average annual wind erosion and edge-of-field sediment and nutrient loss due to conservation practice use (2003–06)					
Wind erosion	20	31	58	64	60
Sediment loss	27	61	73	61	52
Total nitrogen loss	3	46	39	20	17
Nitrogen lost with windborne sediment	14	27	46	37	47
Nitrogen loss with surface runoff	26	51	58	45	35
Nitrogen loss in subsurface flows	5	57	45	9	11
Total phosphorus loss	39	47	58	44	33
Phosphorus lost with windborne sediment	34	40	58	55	63
Phosphorus lost to surface water, sediment attached and soluble	39	57	59	42	33

Figure 92. Comparison of distributions of average annual sediment loss among the five basins (water resource regions) that make up the Mississippi River drainage system, baseline conservation condition

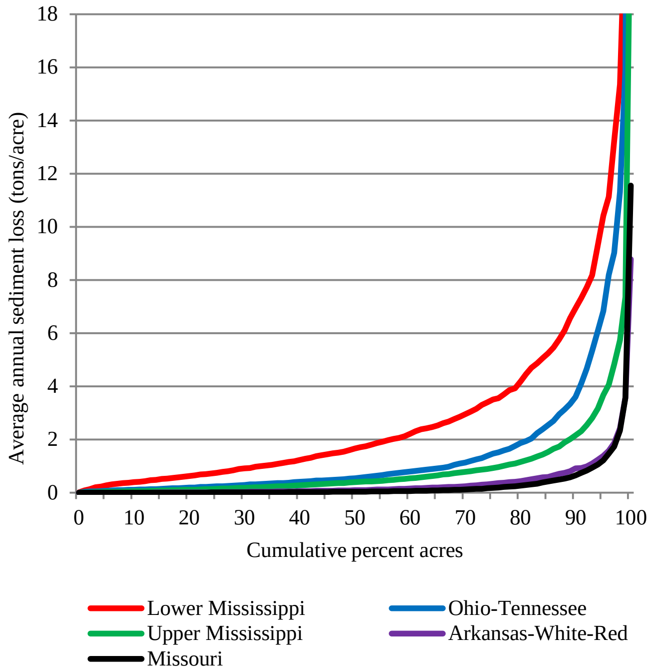


Figure 93. Comparison of distributions of average annual nitrogen loss through all loss pathways among the five basins (water resource regions) that make up the Mississippi River drainage system, baseline conservation condition

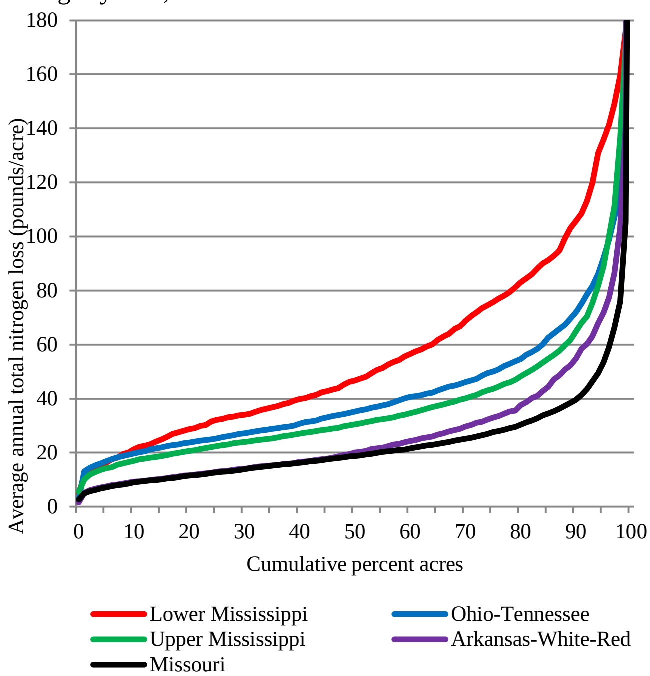


Figure 94. Comparison of distributions of average annual nitrogen loss in subsurface flows among the five basins (water resource regions) that make up the Mississippi River drainage system, baseline conservation condition

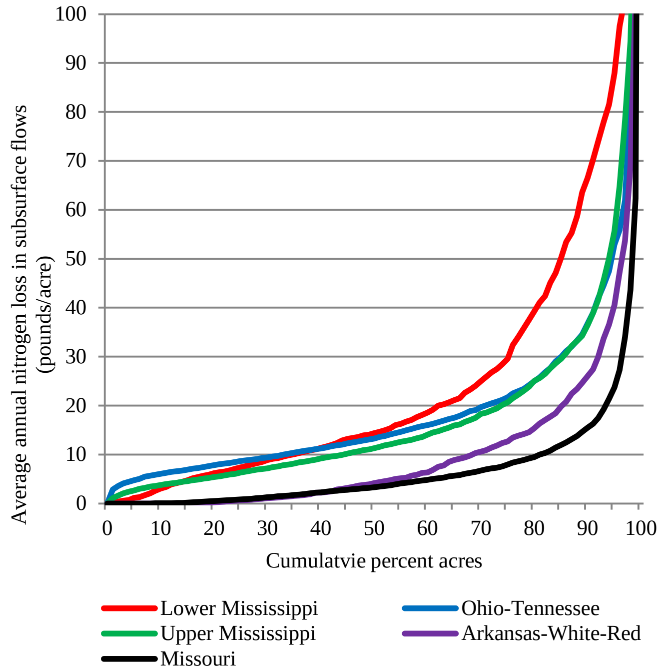


Figure 95. Comparison of distributions of average annual phosphorus loss through all loss pathways among the five basins (water resource regions) that make up the Mississippi River drainage system, baseline conservation condition

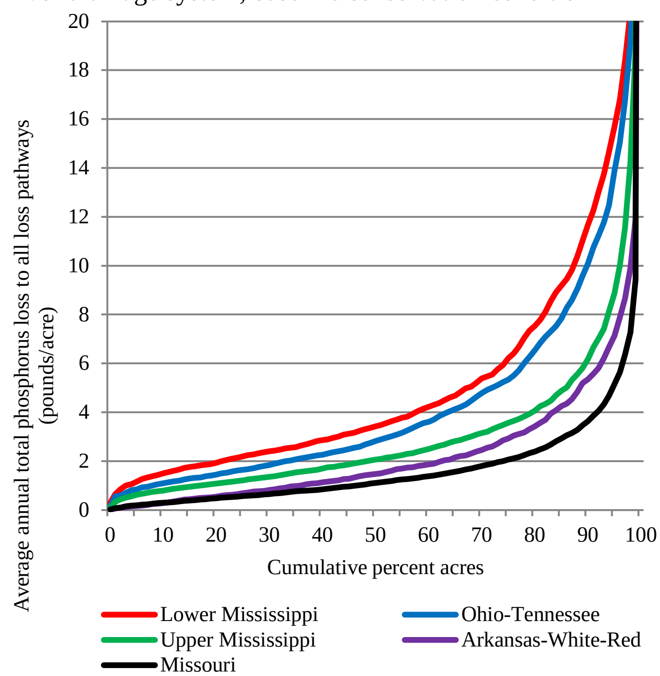


Figure 96. Comparison of distributions of average annual nitrogen sources (atmospheric deposition, bio-fixation by legumes, and nitrogen applied as fertilizer and manure) among the five basins (water resource regions) that make up the Mississippi River drainage system, baseline conservation condition

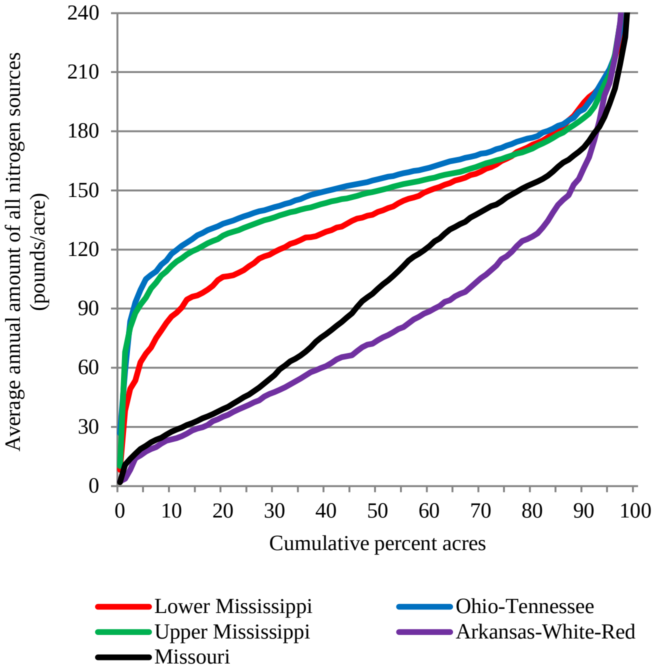


Figure 97. Comparison of distributions of average annual nitrogen in crop yield removed at harvest among the five basins (water resource regions) that make up the Mississippi River drainage system, baseline conservation condition

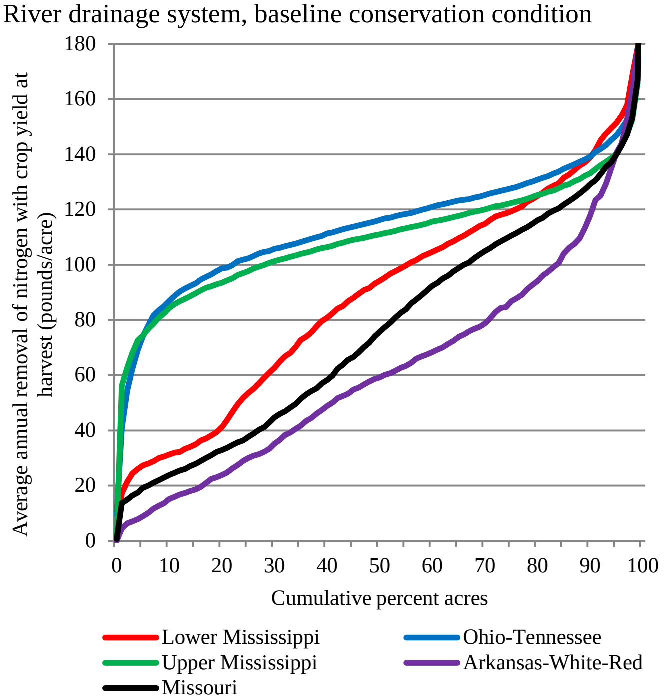
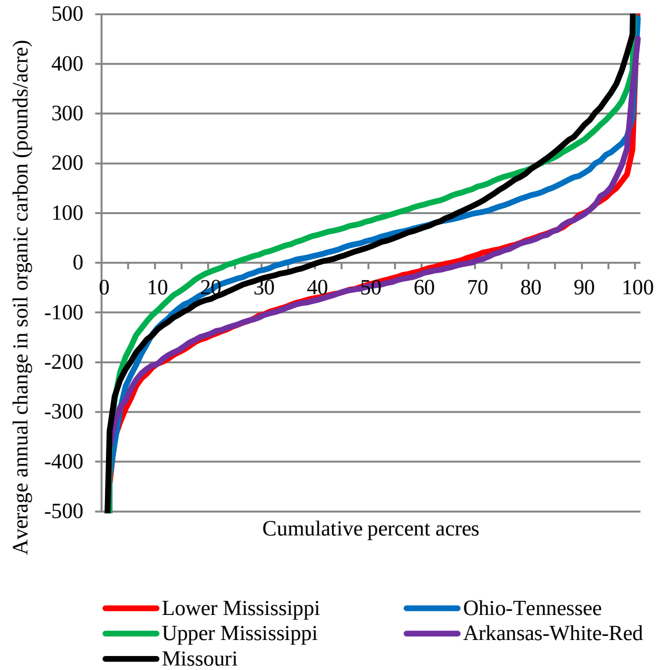


Figure 98. Comparison of distributions of average annual change in soil organic carbon among the five basins (water resource regions) that make up the Mississippi River drainage system, baseline conservation condition



Effects of conservation practices

The lag behind the other regions in conservation practice use in the Lower Mississippi River Basin is reflected in estimates of the effects of conservation practices. The average annual percent reductions in sediment and nutrient losses due to conservation practice use (2003–06) are lower for the Lower Mississippi River Basin than the other four basins except for total phosphorus loss, which is slightly higher for the Lower Mississippi River Basin than in the Ohio-Tennessee River Basin (table 67).

The distributions, however, show that the reductions in sediment loss due to conservation practice use in the Lower Mississippi River Basin are slightly higher than reductions in the Missouri River and Arkansas-White-Red Basins for the majority of acres but lower than reductions in either the Ohio-Tennessee River or Upper Mississippi River Basins for nearly all the acres (fig. 99). For total nitrogen loss, reductions due to conservation practices are much smaller in the Lower Mississippi River Basin than in the other four basins (fig. 100). The distributions for total phosphorus loss show that phosphorus loss reductions were much higher than in other regions on about 30 percent of the cropped acres in the Lower Mississippi River Basin (fig. 101).

The effects of conservation practices on soil organic carbon are small throughout most of the cropped acres in the Lower Mississippi River Basin compared to gains due to conservation practices in other regions within the Mississippi River drainage system (fig. 102).

Figure 99. Comparison of distributions of average annual reduction in sediment loss due to conservation practice use among the five basins (water resource regions) that make up the Mississippi River drainage system

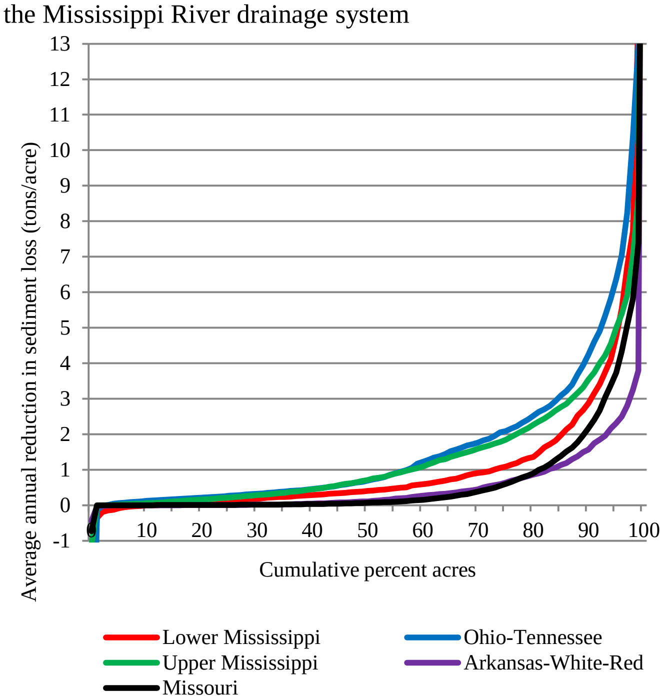


Figure 100. Comparison of distributions of average annual reduction in total nitrogen loss (all loss pathways) due to conservation practice use among the five basins (water resource regions) that make up the Mississippi River drainage system

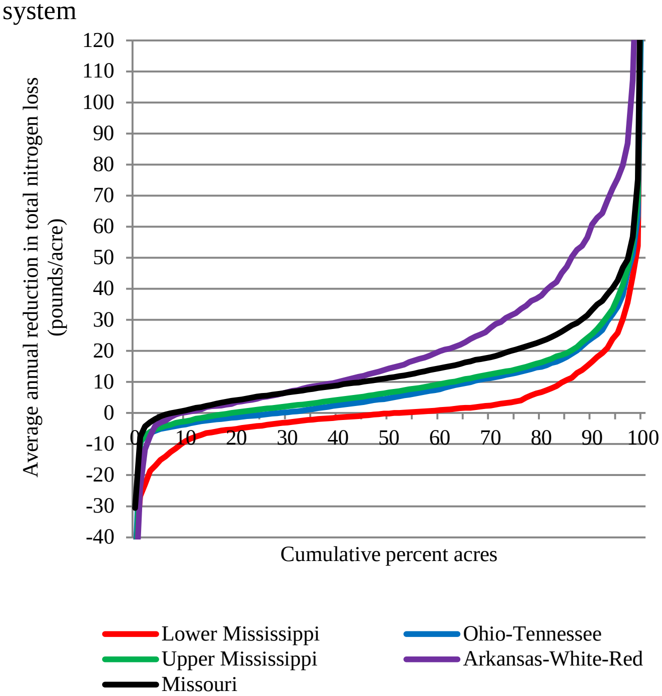


Figure 101. Comparison of distributions of average annual reduction in total phosphorus loss (all loss pathways) due to conservation practice use among the five basins (water resource regions) that make up the Mississippi River drainage system

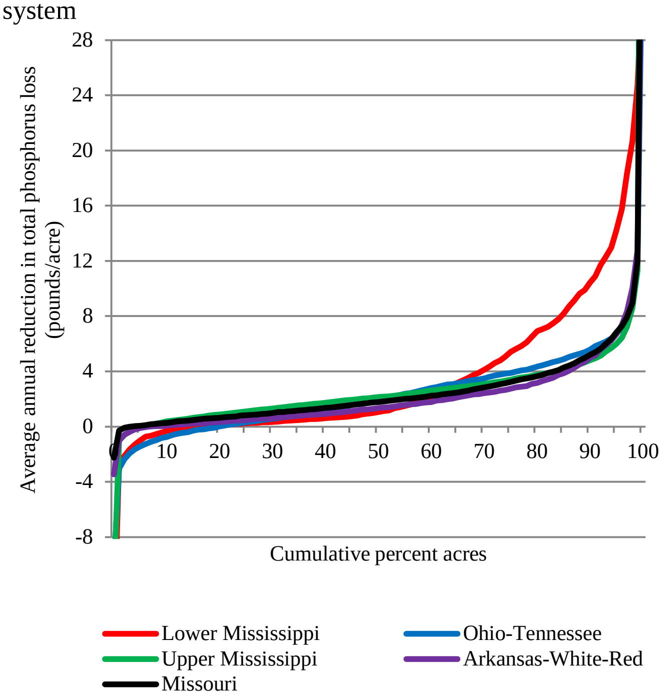
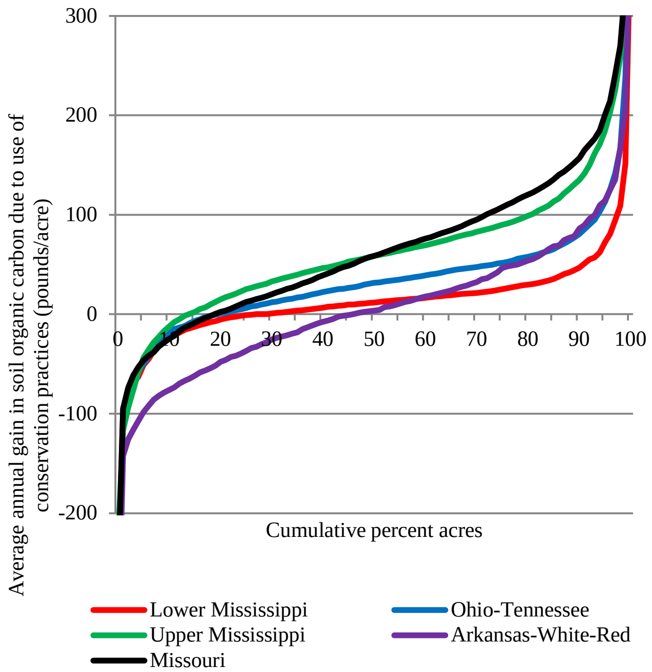


Figure 102. Comparison of distributions of average annual gain in soil organic carbon due to conservation practice use among the five basins (water resource regions) that make up the Mississippi River drainage system



Conservation treatment needs

The number of acres with a high or moderate need for additional conservation treatment in the Lower Mississippi River Basin is less than half the number in the Upper Mississippi River Basin, within about 1 million acres of the number in the Missouri River Basin and the Ohio-Tennessee River Basin, and about 6 million acres more than in the Arkansas-White-Red Basin (table 68, fig. 103). On a percentage basis, however, the Lower Mississippi River Basin has the largest concentration of cropped acres with a high or moderate need for additional treatment—86 percent of cropped acres compared to 70 percent for the Ohio-Tennessee River Basin, 60 percent for the Upper Mississippi River Basin, 34 percent for the Arkansas-White-Red Basin, and 18 percent for the Missouri River Basin (fig. 104).

The most critical conservation concern related to cropland differs among the regions as shown in table 68 and figures 105 through 108:

- Sediment loss is the most serious resource concern in the Lower Mississippi River Basin, where the percentage of cropped acres with a high or moderate need for additional treatment is 74 percent. Sediment loss is also an important resource concern in the Ohio-Tennessee and Upper Mississippi River Basins, where the percentage of undertreated acres is 25 percent and 10 percent of cropped acres, respectively.

Figure 103. Comparison undertreated acres among the five basins (water resource regions) that make up the Mississippi River drainage system

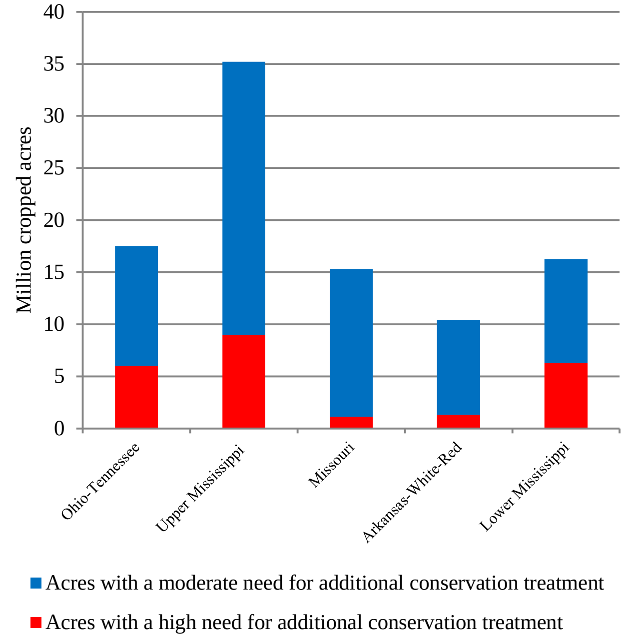


Figure 104. Comparison of the percentage of cropped acres that are undertreated among the five basins (water resource regions) that make up the Mississippi River drainage system

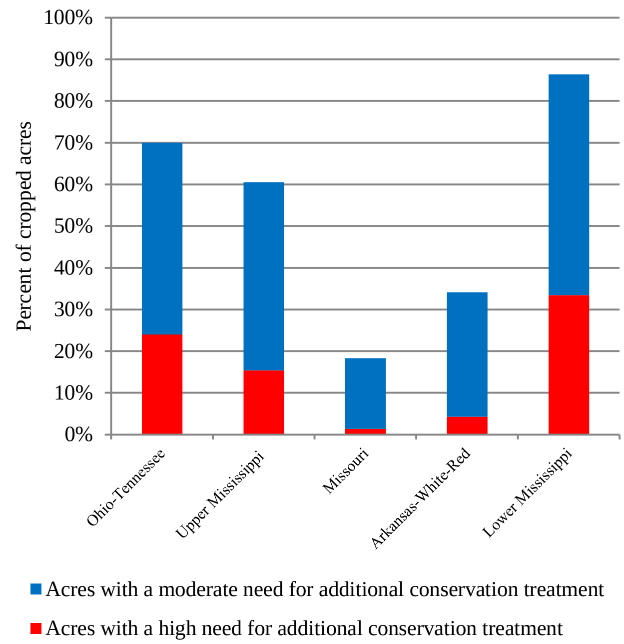


Table 68. Comparison of conservation treatment needs among the five basins (water resource regions) that make up the Mississippi River drainage system

	Lower Mississippi River Basin	Arkansas-White-Red Basin	Missouri River Basin	Upper Mississippi River Basin	Ohio-Tennessee River Basin
Conservation treatment needs (percent of cropped acres)					
Sediment loss					
High level of treatment need	19	0	<1	10	14
Moderate level of treatment need	54	2.5	3	0	12
Undertreated (high or moderate level of treatment need)	74	2.5	3	10	25
Nitrogen lost with runoff					
High level of treatment need	11	0	<1	11	12
Moderate level of treatment need	47	0	3	12	16
Undertreated (high or moderate level of treatment need)	59	0	4	24	29
Nitrogen loss in subsurface flows					
High level of treatment need	4	<1	<1	3	2
Moderate level of treatment need	34	9	2	45	16
Undertreated (high or moderate level of treatment need)	38	9	2	47	17
Phosphorus lost to surface water					
High level of treatment need	27	2	<1	5	20
Moderate level of treatment need	40	0	<1	18	44
Undertreated (high or moderate level of treatment need)	67	2	1	22	63
Wind erosion					
High level of treatment need	0	2	<1	0	0
Moderate level of treatment need	0	20	12	0	0
Undertreated (high or moderate level of treatment need)	0	23	12	0	0
One or more resource concern					
High level of treatment need	33	4	1	15	24
Moderate level of treatment need	53	30	17	45	46
Undertreated (high or moderate level of treatment need)	86	34	18	60	70
Conservation treatment needs for one or more resource concerns (million acres)					
High level of treatment need	6.293	1.304	1.127	8.980	6.012
Moderate level of treatment need	9.980	9.093	14.179	26.218	11.506
Undertreated (high or moderate level of treatment need)	16.273	10.397	15.306	35.198	17.518

- Nitrogen lost with surface runoff is also an important resource concern in these same three basins where the percentage of cropped acres with a high or moderate need for additional treatment is 59 percent in the Lower Mississippi River Basin, 29 percent in the Ohio-Tennessee River Basin, and 24 percent in the Upper Mississippi River Basin.
- Nitrogen loss in subsurface flows is the major need for additional conservation treatment in the Upper Mississippi River Basin, where 47 percent of cropped acres have a high or moderate need for treatment for this concern. The percentage of acres needing additional treatment for this resource concern in the Lower Mississippi River Basin is also high—38 percent—compared to 17 percent of cropped acres in the Ohio-Tennessee River Basin, 9 percent of cropped acres in the Arkansas-White-Red Basin, and 2 percent of cropped acres in the Missouri River Basin.
- Phosphorus lost to surface water is also a critical resource concern in the Lower Mississippi River Basin, where 67 percent of cropped acres are undertreated, and the most critical resource concern in the Ohio-Tennessee River Basin, where 63 percent of cropped acres are undertreated.
- Wind erosion is the dominant need for conservation treatment in both the Arkansas-White-Red Basin and the Missouri River Basin. About 23 percent of cropped acres in the Arkansas-White-Red Basin are undertreated for wind erosion, and 12 percent of cropped acres in the Missouri River Basin are undertreated for wind erosion. Wind erosion is generally not a resource concern in the Upper Mississippi River Basin, the Ohio-Tennessee River Basin, and the Lower Mississippi River Basin (table 68).

The high level of annual precipitation in this region results in unacceptable field-level losses in spite of low or moderate soil vulnerability, which is generally not a characteristic of conservation treatment needs in other regions within the Mississippi River drainage system. The bulk of undertreated acres in the Lower Mississippi River Basin (80 percent or more) have a low or moderate soil runoff potential. In contrast, no undertreated acres in any of the other four basins have a low or moderate soil runoff potential for sediment loss or nitrogen loss in surface runoff. About half or the undertreated acres for phosphorus lost to surface water in the Ohio-Tennessee River Basin have a low or moderate soil runoff potential as well as about 10 percent in the Upper Mississippi River Basin and none in each of the two remaining basins.

Figure 105. Comparison of the percentage of cropped acres that are undertreated for sediment loss among the five basins (water resource regions) that make up the Mississippi River drainage system

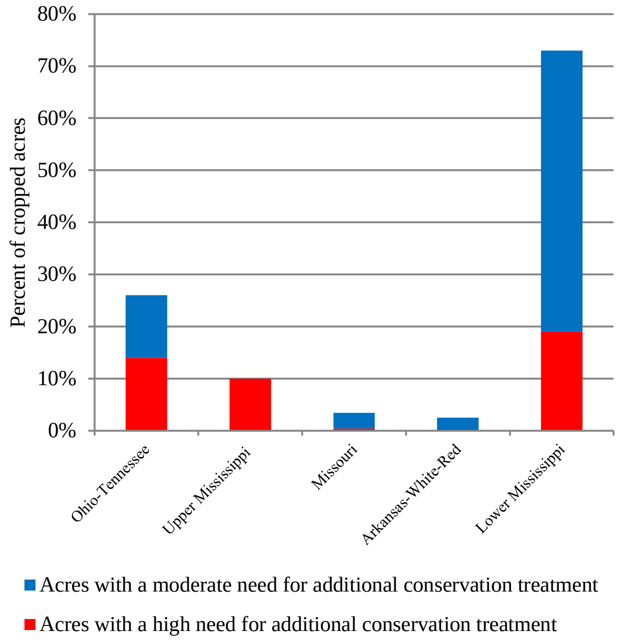


Figure 107. Comparison of the percentage of cropped acres that are undertreated for nitrogen loss in subsurface flows among the five basins (water resource regions) that make up the Mississippi River drainage system

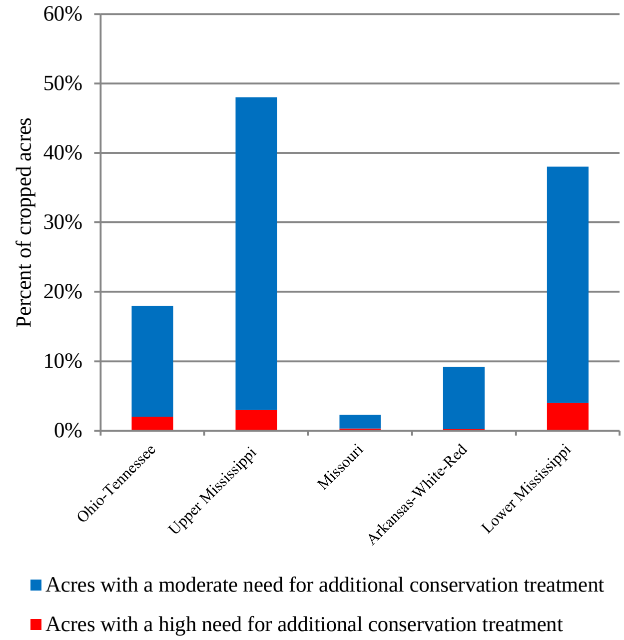


Figure 106. Comparison of the percentage of cropped acres that are undertreated for nitrogen loss with surface runoff among the five basins (water resource regions) that make up the Mississippi River drainage system

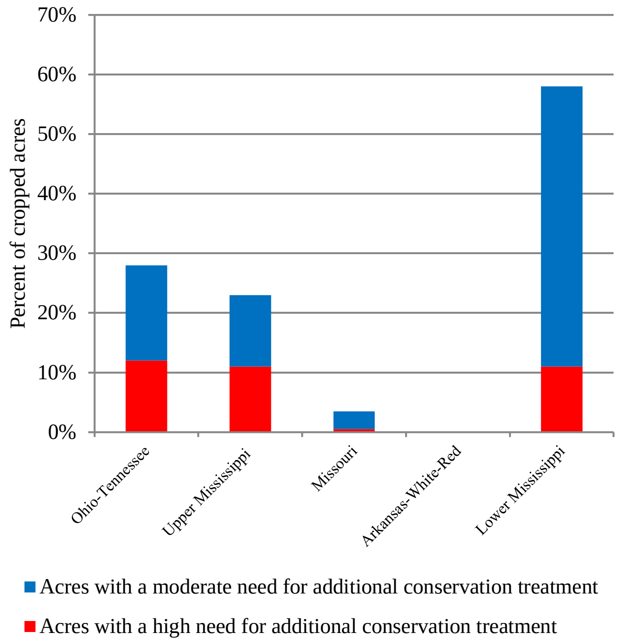
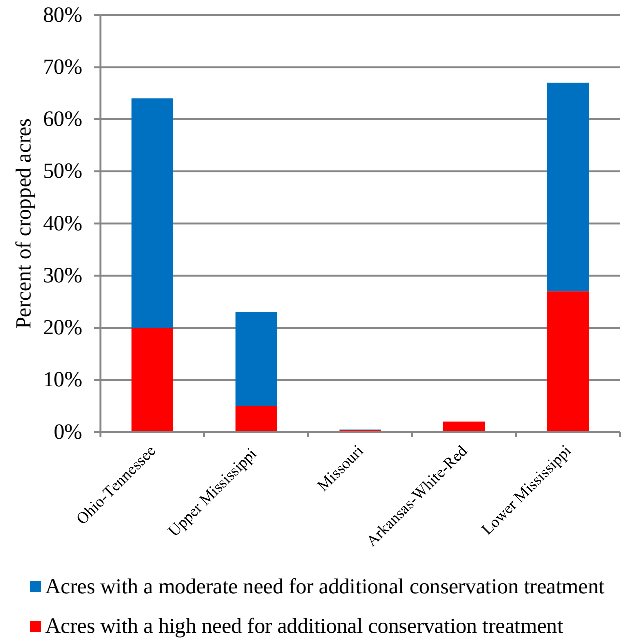


Figure 108. Comparison of the percentage of cropped acres that are undertreated for phosphorus lost to surface water among the five basins (water resource regions) that make up the Mississippi River drainage system



Potential for achieving field-level savings from further conservation treatment

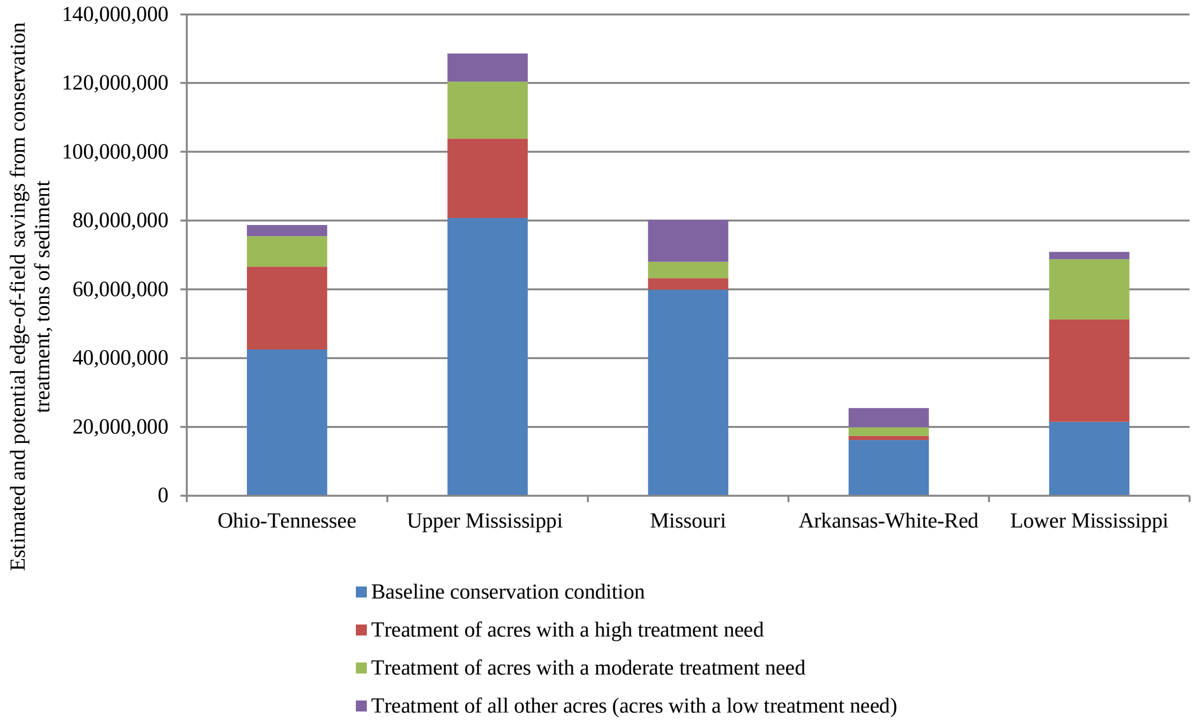
The potential for achieving field-level sediment and nutrient savings from further conservation treatment is higher in the Lower Mississippi River Basin than in any of the other four basins, as shown in figures 109 through 114.

Treatment of acres with a high need for additional treatment would save an additional 29.8 million tons of sediment in the Lower Mississippi River basin, more than could be saved in any of the other basins (fig. 109). This represents 42 percent of the total estimated and potential savings that are possible with additional conservation treatment in the Lower Mississippi River Basin, compared to 31 percent for the Ohio-Tennessee River Basin and less than 20 percent for each of the remaining three basins (fig. 110). Treatment of acres with a moderate need for additional treatment would save another 17.4 million tons of sediment in the Lower Mississippi River Basin (fig. 109), representing 25 percent of the total estimated and potential savings that are possible with additional conservation treatment in the Lower Mississippi River Basin, compared to less than 15 percent for the other basins (fig. 110).

For nitrogen, higher savings in terms of tons saved are possible in the Upper Mississippi River Basin with additional treatment (fig. 111), but the percent of total savings is highest for the Lower Mississippi River Basin. About 43 percent of the total estimated and potential savings can be achieved in the Lower Mississippi River Basin with additional treatment of acres with a high need for additional treatment, compared to 28 percent for the Ohio-Tennessee River Basin and less than 20 percent in each of the remaining three basins (fig. 112). Treatment of acres with a moderate need for additional treatment could save 44 percent of the potential nitrogen savings in the Lower Mississippi River Basin (fig. 112), compared to 37 percent for the Upper Mississippi River Basin, 31 percent for the Ohio-Tennessee River Basin, and less than 12 percent for the remaining two basins (fig. 112).

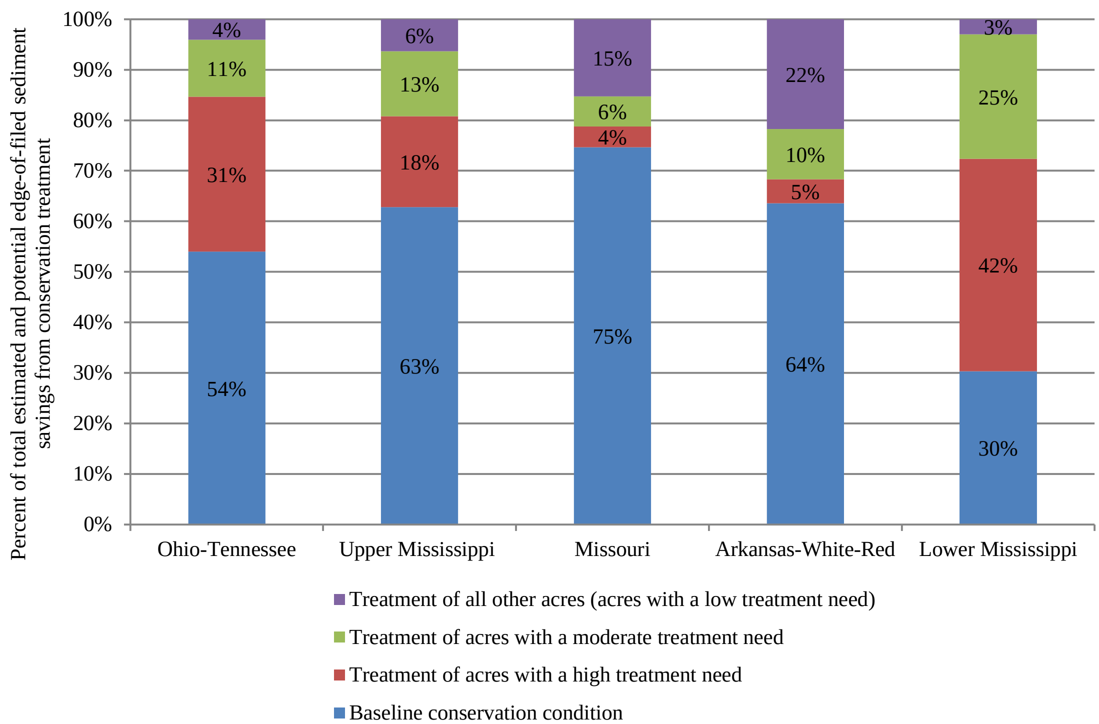
Treatment of acres with a high need for additional treatment would save an additional 21.1 million tons of phosphorus in the Lower Mississippi River basin, more than could be saved in any of the other basins (fig. 113). This represents 33 percent of the total estimated and potential savings that are possible with additional conservation treatment in the Lower Mississippi River Basin, compared to 27 percent for the Ohio-Tennessee River Basin and less than 15 percent for each of the remaining three basins (fig. 114). Treatment of acres with a moderate need for additional treatment would save 26 percent of the potential phosphorus savings in the Ohio-Tennessee River Basin, 19 percent in the Upper Mississippi River Basin, and 15 percent in the Lower Mississippi River Basin (fig. 112).

Figure 109. Estimated tons of sediment savings (field-level) due to practices in use in the baseline conservation condition and potential sediment savings with additional water erosion control and nutrient management treatment of cropped acres for the five basins (water resource regions) that make up the Mississippi River drainage system*



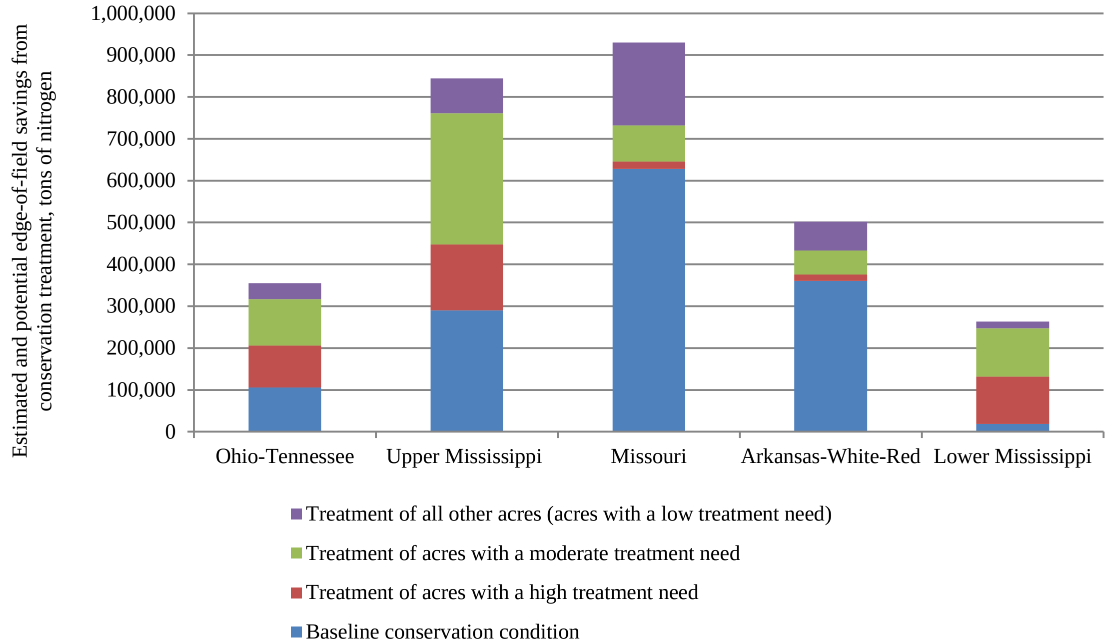
* See figure 59 and associated text for discussion of how savings were estimated.

Figure 110. Percent of total estimated sediment savings (field-level) due to practices in use in the baseline conservation condition and potential sediment savings with additional water erosion control and nutrient management treatment of cropped acres for the five basins (water resource regions) that make up the Mississippi River drainage system*



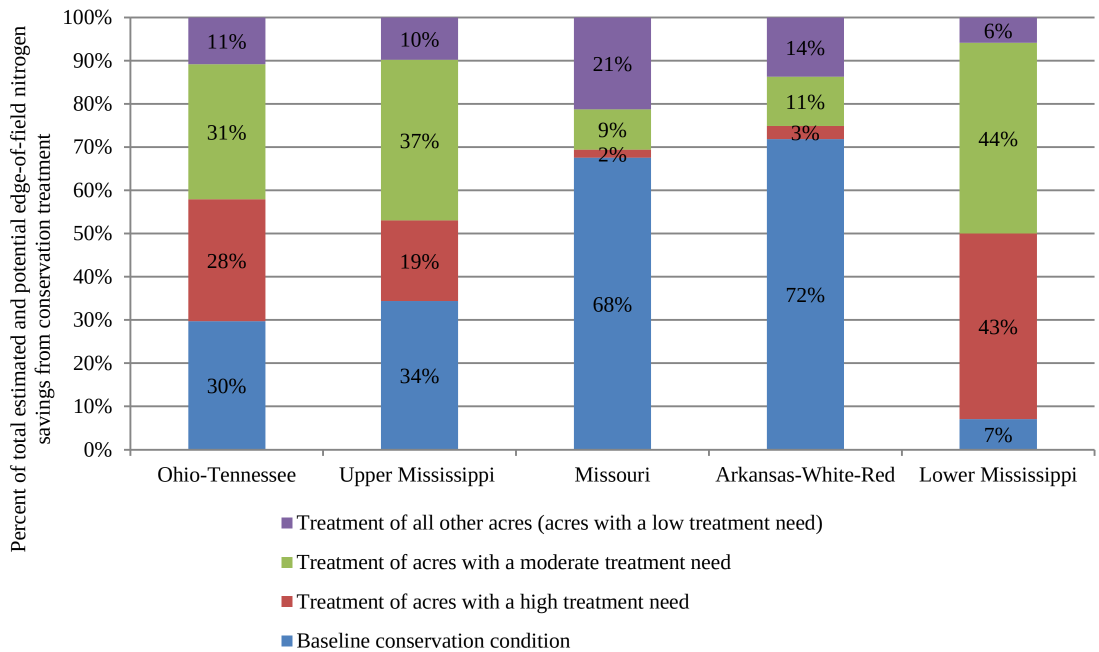
* See figure 59 and associated text for discussion of how savings were estimated.

Figure 111. Estimated tons of nitrogen savings (field-level) due to practices in use in the baseline conservation condition and potential nitrogen savings with additional water erosion control and nutrient management treatment of cropped acres for the five basins (water resource regions) that make up the Mississippi River drainage system*



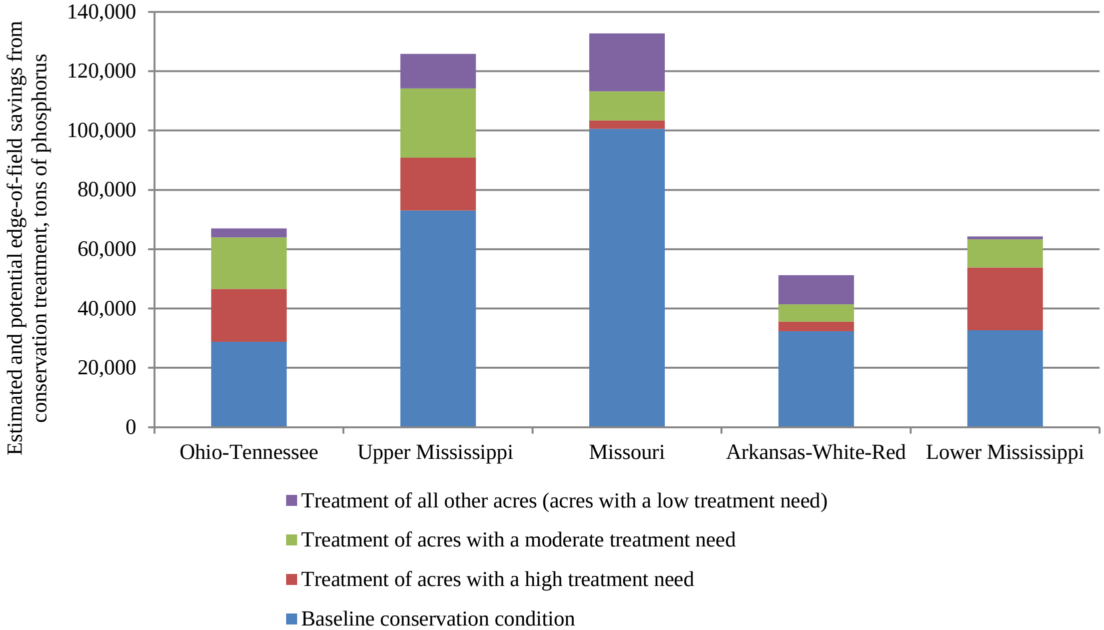
* See figure 59 and associated text for discussion of how savings were estimated.

Figure 112. Percent of total estimated nitrogen savings (field-level) due to practices in use in the baseline conservation condition and potential nitrogen savings with additional water erosion control and nutrient management treatment of cropped acres for the five basins (water resource regions) that make up the Mississippi River drainage system*



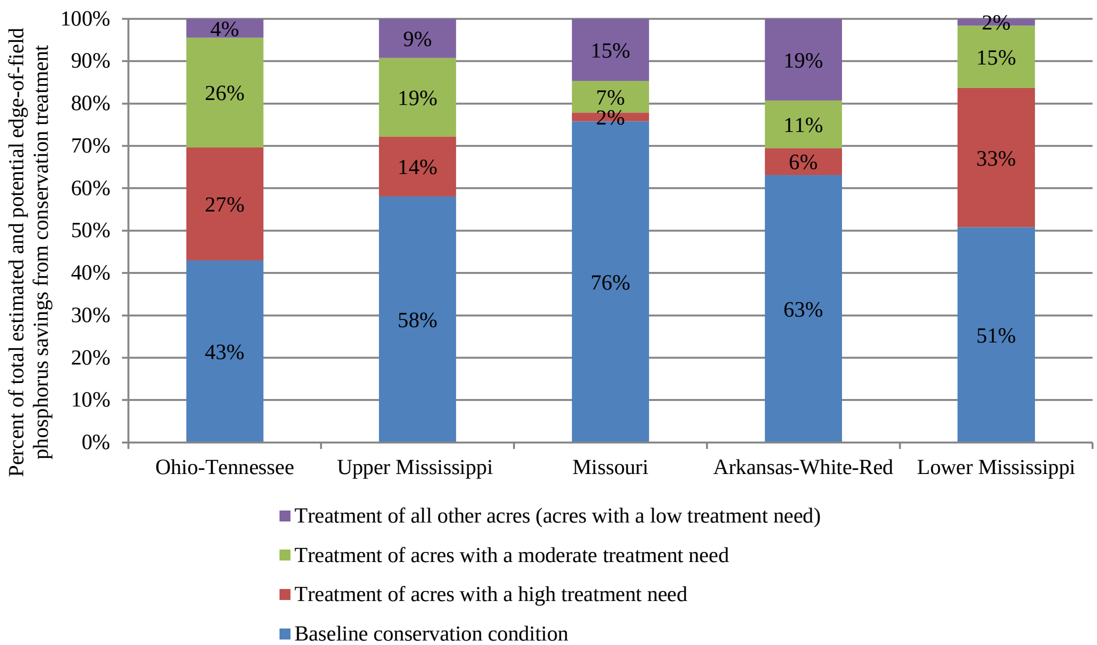
* See figure 59 and associated text for discussion of how savings were estimated.

Figure 113. Estimated tons of phosphorus savings (field-level) due to practices in use in the baseline conservation condition and potential phosphorus savings with additional water erosion control and nutrient management treatment of cropped acres for the five basins (water resource regions) that make up the Mississippi River drainage system*



* See figure 59 and associated text for discussion of how savings were estimated.

Figure 114. Percent of total estimated phosphorus savings (field-level) due to practices in use in the baseline conservation condition and potential phosphorus savings with additional water erosion control and nutrient management treatment of cropped acres for the five basins (water resource regions) that make up the Mississippi River drainage system*



* See figure 59 and associated text for discussion of how savings were estimated.

Loads delivered from cultivated cropland to rivers and streams

Cultivated cropland is the source of a larger proportion of the total sediment delivered to rivers and streams in the Lower Mississippi River Basin than in any of the other four basins—78 percent of all sediment sources (table 69). The Missouri River Basin and the Upper Mississippi River Basin also have high proportions of total sediment delivered from cultivated cropland to rivers and streams—72 percent for the Missouri River Basin and 71 percent for the Upper Mississippi River Basin. Cultivated cropland is the source of a smaller proportion of nitrogen and phosphorus delivered to rivers and streams within the Lower Mississippi River Basin—53 percent of the total nitrogen load and 43 percent of the total phosphorus load. In contrast, the proportion of the total nitrogen load delivered to rivers and streams that originates from cultivated cropland is 71 percent in the Upper Mississippi River Basin and 68 percent in the Missouri River Basin, and the proportion of the total phosphorus load delivered to rivers and streams that originates from cultivated cropland is 62 percent in the Upper Mississippi River Basin.

The Lower Mississippi River Basin delivers the most sediment to rivers and streams from cultivated cropland acres of all the five major basins in the Mississippi River drainage system—23 million tons per year compared to 18 million tons per year for the Upper Mississippi River Basin and 15 million tons per year or less for the other three basins (table 69).

The most nitrogen and phosphorus is delivered to rivers and streams from cultivated cropland acres in the Upper Mississippi River Basin (table 69)—81 million pounds per year of phosphorus and 1.040 billion pounds per year of nitrogen.

On a per-acre basis, however, the loads delivered to rivers and streams within the Lower Mississippi River Basin far outpace the per-acre loads from other basins (table 69):

- 1.15 tons per acre per year of sediment, compared to 0.6 ton per acre per year or less for other basins,
- 27 pounds per acre per year of nitrogen, compared to 19 pounds per acre per year or less for other basins, and
- 2.6 pounds per acre per year of phosphorus, compared to 2.0 pounds per acre per year or less for other basins.

Percent reductions in loads delivered from cultivated cropland to rivers and streams due to conservation practice use were much lower in the Lower Mississippi River Basin for sediment and nitrogen than in the other four basins (table 69), averaging only 35 percent for sediment and 21 percent for nitrogen compared to highs of 76 percent for sediment in the Missouri River Basin and 59 percent for nitrogen in the Arkansas-White-Red Basin. The percent reduction in phosphorus loads for the Lower Mississippi River Basin due to practice use, 52 percent, is less than in the Missouri River Basin and the Arkansas-White-Red Basin (60 percent and 59 percent reductions, respectively) but higher than in the Upper Mississippi River Basin and the Ohio-Tennessee River Basin (41 percent and 32 percent reductions, respectively).

The potential for further reductions in loads delivered to rivers and streams from cultivated cropland due to additional conservation treatment is higher in the Lower Mississippi River Basin than in most of the other basins in the Mississippi River drainage system. Model simulations show that treatment of all undertreated acres (acres with a high or moderate need for conservation treatment) would reduce sediment loads delivered from cultivated cropland to rivers and streams by 80 percent in the Lower Mississippi River, compared to 81 percent for the Ohio-Tennessee River basin, 74 percent for the Upper Mississippi River Basin, and less than 30 percent for each of the remaining two basins.

Treatment of all undertreated acres would reduce nitrogen loads delivered from cultivated cropland to rivers and streams by 43 percent in the Lower Mississippi River, compared to 49 percent for the Upper Mississippi River Basin, 41 percent for the Ohio-Tennessee River Basin, and less than 22 percent for each of the remaining two basins.

Treatment of all undertreated acres would reduce phosphorus loads delivered from cultivated cropland to rivers and streams by 57 percent in the Lower Mississippi River, compared to 58 percent for the Ohio-Tennessee River Basin, 41 percent for the Upper Mississippi River Basin, and less than 15 percent for each of the remaining two basins.

Table 69. Comparison of loads delivered from cultivated cropland to rivers and streams among the five basins (water resource regions) that make up the Mississippi River drainage system

	Lower Mississippi River Basin	Arkansas-White-Red Basin	Missouri River Basin	Upper Mississippi River Basin	Ohio-Tennessee River Basin
Loads originating from cultivated cropland as a percent of total loads delivered from all sources, baseline conservation condition					
Sediment	78	30	72	71	53
Nitrogen	53	43	68	71	49
Phosphorus	43	20	46	62	48
Average annual loads delivered from cultivated cropland to rivers and streams per year, baseline conservation condition					
Sediment (million tons/year)	23	7	14	18	15
Nitrogen (million pounds/year)	555	283	500	1040	500
Phosphorus (million pounds/year)	53	17	33	81	55
Average annual loads per cultivated cropland acre, baseline conservation condition					
Sediment (tons/acre/year)	1.15	0.20	0.15	0.29	0.6
Nitrogen (pounds/acre/year)	27	8	5	16.5	19
Phosphorus (pounds/acre/year)	2.6	0.5	0.3	1.3	2.0
Percent reduction in loads delivered from cultivated cropland to rivers and streams due to 2003–06 conservation practices					
Sediment	35	64	76	65	55
Nitrogen	21	59	54	26	26
Phosphorus	52	59	60	41	32
Percent reduction in loads delivered from cultivated cropland to rivers relative to the baseline due to additional conservation treatment of cropped acres with a high or moderate treatment need					
Sediment	80	25	28	74	81
Nitrogen	43	21	13	49	41
Phosphorus	57	13	12	41	58

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Appendix A: Estimates of Margins of Error for Selected Acre Estimates

The 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 sample for cropped acres consists of 1,735 sample points in the Lower Mississippi River Basin. 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 A1 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 A1. Margins of error for acre estimates based on the CEAP sample, Lower Mississippi River Basin

	Estimated acres	Margin of error
Highly erodible land (HEL)	2,268,350	315,621
Acres receiving manure	277,242	144,897
Use of structural practices (table 7)		
Overland flow control practices	2,363,817	355,975
Concentrated flow control practices	1,936,292	354,319
Edge-of-field buffering and filtering practices	638,890	204,536
One or more water erosion control practices	4,021,580	463,133
Wind erosion control practices	233,128	131,312
Use of cover crops	35,189	35,101
Use of residue and tillage management (table 8)		
Average annual tillage intensity for crop rotation meets criteria for no-till	5,267,327	463,470
Average annual tillage intensity for crop rotation meets criteria for mulch till	9,910,832	661,530
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	1,224,370	291,855
Continuous conventional tillage in every year of crop rotation	2,432,771	382,562
Use of structural practices and/or residue and tillage management (table 9)		
No-till or mulch till with carbon gain, no structural practices	4,504,117	436,630
No-till or mulch till with carbon loss, no structural practices	7,386,443	774,704
Some crops with reduced tillage, no structural practices	1,057,493	268,065
Structural practices and no-till or mulch till with carbon gain	1,149,393	281,045
Structural practices and no-till or mulch till with carbon loss	2,138,206	327,313
Structural practices and some crops with reduced tillage	166,878	118,554
Structural practices only	567,104	256,297
No water erosion control treatment	1,865,667	343,190
Conservation treatment levels for structural practices (fig. 7)		
High level of treatment	307,632	169,179
Moderately high level of treatment	831,617	193,851
Moderate level of treatment	2,882,332	413,491
Low level of treatment	14,813,720	861,243

Table A1—continued.

	Estimated acres	Margin of error
Conservation treatment levels for residue and tillage management (fig. 8)		
High level of treatment	4,934,438	427,821
Moderately high level of treatment	743,414	193,663
Moderate level of treatment	11,145,053	841,604
Low level of treatment	2,012,395	338,302
Conservation treatment levels for nitrogen management (fig. 9)		
High level of treatment	5,911,632	574,269
Moderately high level of treatment	2,440,883	411,981
Moderate level of treatment	9,603,761	665,424
Low level of treatment	879,024	322,374
Conservation treatment levels for phosphorus management (fig. 10)		
High level of treatment	4,046,423	553,697
Moderately high level of treatment	2,364,964	323,135
Moderate level of treatment	7,492,243	613,090
Low level of treatment	4,931,671	548,634
Conservation treatment levels for IPM (fig. 11)		
High level of treatment	1,828,847	386,303
Moderate level of treatment	8,161,112	710,169
Low level of treatment	8,845,341	583,824
Conservation treatment levels for water erosion control practices (fig. 49)		
High level of treatment	4,728,458	426,358
Moderately high level of treatment	868,523	189,364
Moderate level of treatment	10,651,921	830,349
Low level of treatment	2,586,398	383,181
Conservation treatment levels for nitrogen runoff control (fig. 50)		
High level of treatment	1,492,324	300,332
Moderately high level of treatment	6,614,160	547,085
Moderate level of treatment	8,922,409	688,571
Low level of treatment	1,806,407	315,088
Conservation treatment levels for phosphorus runoff control (fig. 51)		
High level of treatment	811,338	269,936
Moderately high level of treatment	5,461,883	501,696
Moderate level of treatment	8,278,075	827,803
Low level of treatment	4,284,004	422,695
Soil runoff potential (fig. 52)		
High	330,482	101,421
Moderately high	1,815,705	286,924
Moderate	9,465,476	613,810
Low	7,223,637	670,418
Soil leaching potential (fig. 54)		
High	429,849	235,537
Moderately high	28,033	38,647
Moderate	8,479,694	692,003
Low	9,897,725	594,067
Level of conservation treatment need by resource concern		
Sediment loss (table 24)		
High (critical undertreated)	3,662,190	387,155
Moderate (non-critical undertreated)	10,238,105	785,583
Low (adequately treated)	4,935,005	413,028

Table A1—continued.

	Estimated acres	Margin of error
Level of conservation treatment need by resource concern--continued		
Nitrogen loss with surface runoff (sediment attached and soluble) (table 25)		
High (critical undertreated)	2,146,187	324,823
Moderate (non-critical undertreated)	8,910,152	705,867
Low (adequately treated)	7,778,961	565,888
Nitrogen loss in subsurface flows (table 26)		
High (critical undertreated)	814,186	296,507
Moderate (non-critical undertreated)	6,380,955	669,757
Low (adequately treated)	11,640,159	564,777
Phosphorus lost to surface water (table 27)		
High (critical undertreated)	5,173,248	466,218
Moderate (non-critical undertreated)	7,496,527	755,895
Low (adequately treated)	6,165,525	517,307
Level of conservation treatment need for one or more resource concerns		
Lower Mississippi River Basin		
High (critical undertreated)	6,293,058	539,070
Moderate (non-critical undertreated)	9,980,439	679,484
Low (adequately treated)	2,561,803	411,805
Lower Mississippi-Memphis-Hatchie-Obion River Basin (code 0801)		
High (critical undertreated)	1,867,079	217,269
Moderate (non-critical undertreated)	713,042	139,197
Low (adequately treated)	198,380	74,137
Lower Mississippi-Helena-St. Francis-Lower White and Arkansas River Basin (code 0802)		
High (critical undertreated)	1,631,463	246,926
Moderate (non-critical undertreated)	4,058,056	559,233
Low (adequately treated)	1,205,481	273,727
Lower Mississippi-Greenville-Yazoo River Basin (code 0803)		
High (critical undertreated)	1,259,256	198,910
Moderate (non-critical undertreated)	1,635,979	251,890
Low (adequately treated)	531,865	145,086
Lower Red and Ouachita River Basin (code 0804)		
High (critical undertreated)	236,363	241,021
Moderate (non-critical undertreated)	392,795	292,348
Low (adequately treated)	142,142	143,418
Boeuf-Tensas River Basin (code 0805)		
High (critical undertreated)	616,000	263,974
Moderate (non-critical undertreated)	1,178,729	310,695
Low (adequately treated)	440,170	205,411
Lower Mississippi-Natchez-Big Black-Homochitto River Basin (code 0806)		
High (critical undertreated)	139,172	73,324
Moderate (non-critical undertreated)	120,028	51,441
Low (adequately treated)	0	NA
Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin (code 0808)		
High (critical undertreated)	508,458	180,552
Moderate (non-critical undertreated)	1,388,738	214,687
Low (adequately treated)	24,604	30,576
Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)		
High (critical undertreated)	35,267	56,440
Moderate (non-critical undertreated)	493,072	170,947
Low (adequately treated)	19,162	28,226

Appendix B: Model Simulation Results for the Baseline Conservation Condition for Subregions in the Lower Mississippi River Basin

Model simulation results presented in Chapter 4 for the baseline conservation condition are presented in tables B1–B5 for the subregions in the Lower Mississippi River Basin. For reporting, results for some subregions were combined because of small sample sizes. The column headings refer to the 4-digit Hydrologic Unit Codes (HUC), as shown below:

Subregion code	Subregion name
801	Lower Mississippi-Memphis-Hatchie-Obion River Basin
802	Lower Mississippi-Helena-St.Francis-Lower White and Arkansas River Basin
803	Lower Mississippi-Greenville-Yazoo River Basin
804	Lower Red and Ouachita River Basin
805	Boeuf-Tensas River Basin
806	Lower Mississippi-Natchez-Big Black-Homochitto River Basin
808	Louisiana Coastal-Atchafalaya-Vermillion-Calcasieu-Mermentau River Basin
807 and 809	Lower Mississippi-Lake Maurepas-Lower Grand River Basin (code 0807) and Lower Mississippi-New Orleans-Lake Pontchartrain-Central Louisiana Coastal (code 0809)

Table B1. Basin characteristics and average annual estimates of water flow, erosion, and soil organic carbon for the baseline conservation condition for cropped acres, by subregion, in the Lower Mississippi River Basin

Model simulated outcome	Lower Mississippi River Basin	0801	0802	0803	0804	0805	0806	0808	0807 and 0809
CEAP sample size for estimating cropped acres	1,735	500	471	343	42	120	22	205	32
Cropped acres (million acres)	18,835,300	2,778,500	6,895,000	3,427,100	771,300	2,234,900	259,200	1,921,800	547,500
Percent of acres in region	100	15	37	18	4	12	1	10	3
Percent of acres highly erodible	12	47	5	11	1	7	18	0	4
Percent of acres irrigated	46	2	74	35	30	51	0	49	0
Water sources (average annual inches)									
Non-irrigated acres									
Precipitation	53.8	51.9	48.49	54.79	56.1	54.28	55.79	60.16	61.11
Irrigated acres									
Precipitation	51.41	51.16	48.66	54.23	54.13	53.78	NA	59.1	NA
Irrigation water applied	20.82	17.98	21.97	22.64	21.24	22.99	NA	9.71	NA
Water loss pathways (average annual inches)									
Evapotranspiration	37.1	31.9	38.4	36.8	36.3	39.1	34.6	38.1	38.4
Surface water runoff	13.4	11.3	12.9	15.1	14.6	14.9	12.3	13.8	12.6
Subsurface water flow	10.6	9.1	11.6	9.6	10.3	10.2	9.1	11.9	10.1
Erosion and sediment loss (average annual tons/acre)									
Wind erosion	0.12	0.05	0.06	0.34	0.17	0.08	0.09	0.11	0.03
Sheet and rill erosion	1.85	3.16	0.55	3.04	2.58	2.22	3.72	1.66	1.27
Sediment loss at edge of field due to water erosion	3.03	4.60	1.30	5.15	3.72	3.52	4.29	2.35	2.21
Soil organic carbon (average annual pounds/acre)									
Loss of soil organic carbon with wind and water erosion	243	354	178	294	246	280	342	191	154
Change in soil organic carbon, including loss of carbon with wind and water erosion	-55	-44	-6	-73	-78	-75	-103	-197	27

Table B2. Average annual estimates of nitrogen loss for the baseline conservation condition for cropped acres, by subregion, in the Lower Mississippi River Basin

Model simulated outcome	Lower Mississippi River Basin	0801	0802	0803	0804	0805	0806	0808	0807 and 0809
Nitrogen (average annual pounds/acre)									
Nitrogen sources									
Atmospheric deposition	6.5	6.7	6.4	6.2	6.9	6.9	6.3	6.4	6.8
Bio-fixation by legumes	59.3	57.2	71.3	58.8	75.1	56.6	16.1	33.7	19.8
Nitrogen applied as commercial fertilizer and manure	74.6	74.0	73.9	81.0	47.8	73.6	134.7	71.1	72.2
All nitrogen sources	140.4	137.9	151.6	146.0	129.8	137.1	157.2	111.2	98.7
Nitrogen in crop yield removed at harvest	89.2	84.2	106.5	82.9	87.9	90.3	55.0	60.9	47.4
Nitrogen loss pathways									
Nitrogen loss by volatilization	4.9	8.3	4.6	4.2	4.1	4.8	8.1	2.7	1.9
Nitrogen loss through denitrification	12.8	2.2	16.5	10.7	3.9	9.8	1.3	30.3	1.8
Nitrogen lost with windborne sediment	0.4	0.2	0.3	1.0	0.5	0.4	0.5	0.4	0.1
Nitrogen loss with surface runoff , including waterborne sediment	14.1	21.2	9.2	17.8	15.0	17.3	22.2	11.3	8.7
Nitrogen loss in subsurface flow pathways	25.7	27.5	16.6	37.3	26.9	23.0	79.1	26.2	40.1
Total nitrogen loss for all loss pathways	57.9	59.4	47.2	71.0	50.5	55.2	111.2	70.9	52.6
Change in soil nitrogen	-7.1	-6.5	-2.5	-8.2	-8.9	-9.0	-10.6	-20.8	-1.4

Table B3. Average annual estimates of phosphorus loss and pesticide loss for the baseline conservation condition for cropped acres, by subregion, in the Lower Mississippi River Basin

Model simulated outcome	Lower Mississippi River Basin	0801	0802	0803	0804	0805	0806	0808	0807 and 0809
Phosphorus (average annual pounds/acre)									
Phosphorus applied as commercial fertilizer and manure	19.5	23.0	19.5	16.4	17.7	20.3	23.2	17.2	28.8
Phosphorus in crop yield removed at harvest	13.7	12.2	14.7	11.8	12.3	12.9	8.9	13.2	29.1
Phosphorus loss pathways									
Phosphorus lost with windborne sediment	0.1	0.1	0.1	0.3	0.2	0.1	0.1	0.1	0.0
Phosphorus lost to surface water, including waterborne sediment and soluble phosphorus in surface water runoff and lateral flow into drainage tiles and ditches and natural seeps	5.2	8.4	3.3	6.0	5.0	6.8	9.8	4.9	1.9
Soluble phosphorus loss to groundwater	0.04	0.05	0.05	0.04	0.04	0.03	0.03	0.02	0.03
Total phosphorus loss for all loss pathways	5.4	8.5	3.4	6.3	5.2	6.9	9.9	5.1	1.9
Change in soil phosphorus	0.4	1.9	1.3	-1.8	0.2	0.3	3.9	-1.2	-2.4
Pesticides									
Average annual amount of pesticides applied (grams of active ingredient/hectare)	2,679	2,415	2,003	4,052	3,402	2,964	4,215	2,072	3,166
Pesticide loss									
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	70.5	40.1	69.1	106.7	46.2	94.6	84.9	41.2	48.5
Edge-of-field pesticide risk indicator									
Average annual surface water pesticide risk indicator for aquatic ecosystem	3.19	1.79	2.99	2.95	5.63	6.41	3.53	1.72	2.74
Average annual surface water pesticide risk indicator for humans	1.14	0.63	0.63	2.42	1.19	0.78	11.75	0.57	0.61
Average annual groundwater pesticide risk indicator for humans	0.55	0.29	0.23	1.56	2.00	0.28	0.24	0.06	0.53

Table B4. Percent of cropped acres for conservation treatment levels and soil vulnerability potentials, by subregion, in the Lower Mississippi River Basin

Model simulated outcome	Lower Mississippi River Basin	0801	0802	0803	0804	0805	0806	0808	0807 and 0809
Percent of cropped acres within subregion at four conservation treatment levels for structural practices (see figure 7)									
High conservation treatment level	2	3	1	1	1	4	2	1	0
Moderately-high conservation treatment level	4	10	4	5	0	3	11	3	0
Moderate conservation treatment level	15	30	8	9	18	16	35	22	37
Low conservation treatment level	79	57	88	85	80	78	52	75	63
Percent of cropped acres within subregion at four conservation treatment levels for residue and tillage management (see figure 8)									
High conservation treatment level	26	33	35	19	25	29	3	1	13
Moderately-high conservation treatment level	4	2	4	4	1	<1	0	5	29
Moderate conservation treatment level	59	59	55	57	56	56	90	81	56
Low conservation treatment level	11	6	6	20	18	15	7	13	2
Percent of cropped acres within subregion at four conservation treatment levels for nitrogen management (see figure 9)									
High conservation treatment level	31	19	31	36	58	47	6	21	20
Moderately-high conservation treatment level	13	15	17	8	10	19	4	3	12
Moderate conservation treatment level	51	57	49	51	24	30	81	76	63
Low conservation treatment level	5	9	4	5	8	4	9	1	5
Percent of cropped acres within subregion at four conservation treatment levels for phosphorus management (see figure 10)									
High conservation treatment level	21	4	24	24	23	30	25	26	6
Moderately-high conservation treatment level	13	9	14	2	2	8	8	22	87
Moderate conservation treatment level	40	23	36	57	59	48	26	41	7
Low conservation treatment level	26	64	26	17	16	15	40	11	0
Percent of cropped acres within subregion at four conservation treatment levels of soil runoff potential (see figure 52)									
High soil vulnerability potential	2	9	1	<1	0	1	0	0	0
Moderately high soil vulnerability potential	10	39	4	8	5	5	25	2	0
Moderate soil vulnerability potential	50	20	53	52	56	65	8	70	32
Low soil vulnerability potential	38	32	42	40	39	30	67	28	68
Percent of cropped acres within subregion at four conservation treatment levels of soil leaching potential (see figure 54)									
High soil vulnerability potential	2	1	5	1	0	0	0	1	0
Moderately high soil vulnerability potential	<1	0	<1	0	1	0	0	0	0
Moderate soil vulnerability potential	45	75	40	44	43	30	89	27	68
Low soil vulnerability potential	53	24	55	55	56	70	11	71	32

Table B5. Percent of cropped acres for conservation treatment needs, by subregion, in the Lower Mississippi River Basin

Model simulated outcome	Lower Mississippi River Basin	0801	0802	0803	0804	0805	0806	0808	0807 and 0809
Percent of cropped acres within subregion with conservation treatment needs for sediment loss									
High level of treatment need	19	42	10	26	22	18	25	14	2
Moderate level of treatment need	54	34	54	54	53	54	72	82	66
Percent of cropped acres within subregion with conservation treatment needs for nitrogen lost with runoff									
High level of treatment need	11	47	4	8	5	6	25	2	0
Moderate level of treatment need	47	26	45	52	42	38	70	83	63
Percent of cropped acres within subregion with conservation treatment needs for phosphorus lost to surface water									
High level of treatment need	27	62	19	31	20	21	54	17	0
Moderate level of treatment need	40	24	42	34	53	40	18	58	51
Percent of cropped acres within subregion with conservation treatment needs for nitrogen loss in subsurface flows									
High level of treatment need	4	8	4	5	7	2	9	1	5
Moderate level of treatment need	34	60	31	33	11	21	74	20	58
Percent of cropped acres within subregion with conservation treatment needs for one or more resource concern									
High level of treatment need	33	67	24	37	31	28	54	26	6
Moderate level of treatment need	53	26	59	48	51	53	46	72	90
Undertreated (high or moderate level of treatment need)	86	93	83	84	82	80	100	99	97