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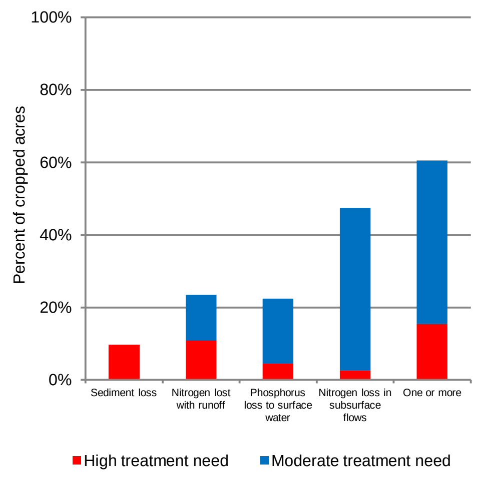
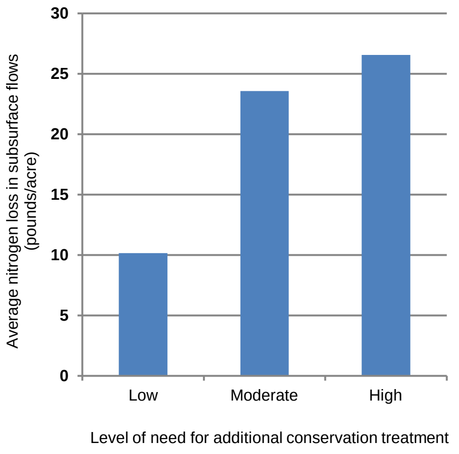
United States Department of Agriculture
Natural Resources Conservation Service

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

Conservation Effects
Assessment Project
(CEAP)

Revised JULY 2012





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CEAP—Strengthening the science base for natural resource conservation

The Conservation Effects Assessment Project (CEAP) was initiated by USDA's Natural Resources Conservation Service (NRCS), Agricultural Research Service (ARS), and 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/.

Revised CEAP Report for the Upper Mississippi River Basin

This final report on the Upper Mississippi River Basin was originally released as a draft report in June 2010. The draft report, which was the first regional CEAP report released, was subsequently revised in March 2012 to maintain consistency with findings reported for other CEAP regions. Modeling routines were revised prior to release of the second CEAP report (Chesapeake Bay Region, released in February 2011) to incorporate improved algorithms for modeling winter plant growth and hydrology.

Some of the results reported in this final report for the Upper Mississippi River Basin differ from those reported in the earlier draft report. While the overall conclusions related to conservation treatment needs were unaffected, the changes in model routines produced slightly different estimates of sediment and nutrient loss from farm fields for all scenarios. This final report also includes additional detail on instream loadings delivered from the basin to the Mississippi River, and provides a comparison of findings to CEAP findings for two other basins in the Mississippi River drainage system—the Upper Mississippi River Basin and the Missouri River Basin.

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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The team also acknowledges the many helpful and constructive suggestions and comments by reviewers who participated in the peer review of earlier versions of the report.

Foreword

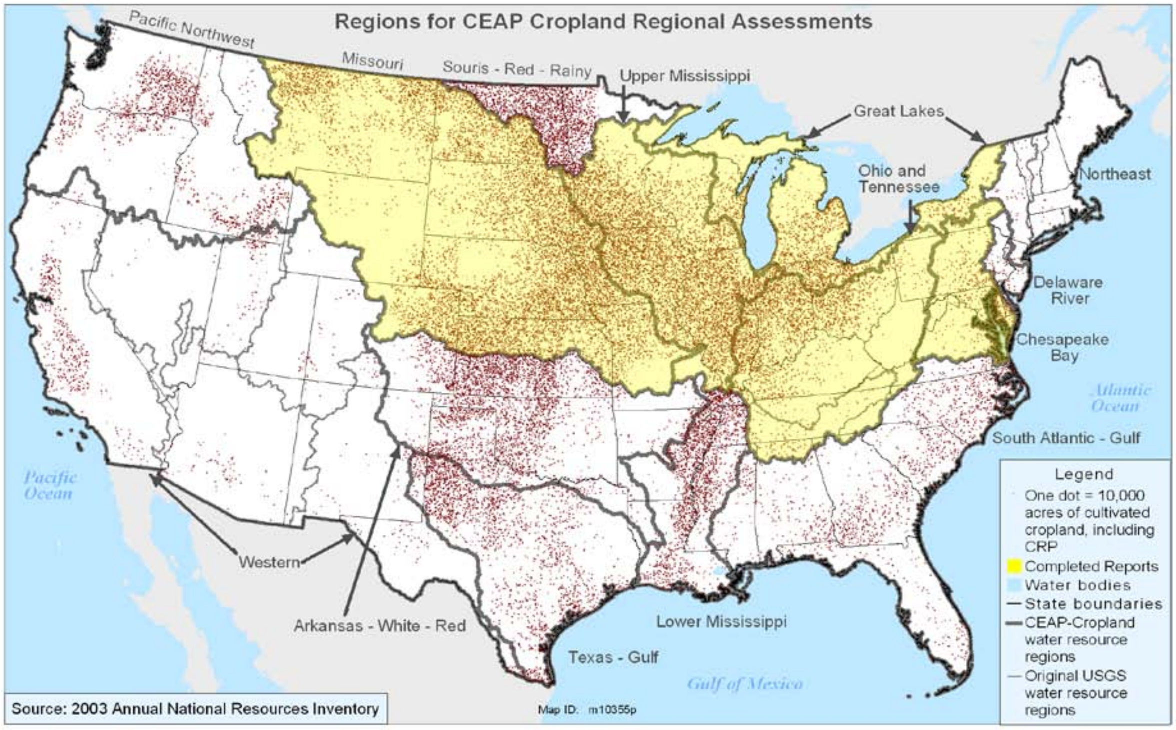
The United States Department of Agriculture has a rich tradition of working with farmers and ranchers to enhance agricultural productivity and environmental protection. Conservation pioneer Hugh Hammond Bennett worked tirelessly to establish a nationwide Soil Conservation Service along with a system 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, feed, forage, fuel, 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.



Source: 2003 Annual National Resources Inventory

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

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Documentation Reports

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

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

Executive Summary

Agriculture in the Upper Mississippi River Basin

The Upper Mississippi River Basin covers 190,000 square miles between Lake Itasca in northern Minnesota and the confluence of the Mississippi and Ohio Rivers at the southern tip of Illinois. The basin includes large parts of Illinois, Iowa, Minnesota, Missouri, and Wisconsin, and small areas in Indiana, Michigan, and South Dakota.

The dominant land cover in the basin is cultivated cropland, which accounts for about 52 percent of the area. The highest concentrations of cropland are in northeastern and central Iowa and southern Minnesota, where cropland makes up more than 80 percent of the land in some counties. (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].)

The value of agricultural sales in 2007 was about $44 billion—about 57 percent from crops and 43 percent from livestock. Corn and soybeans are the principal crops grown. Livestock production in the region is dominated by swine operations, followed by dairy. Livestock operations in the region produced 35 percent of all hog and pig sales in the United States in 2007, exceeding $6.2 billion in value. Sales of dairy products ranked second in the region at $5.3 billion, representing 17 percent of the U.S. total.

The 2007 Census of Agriculture reported that there were about 278,687 farms in the region—13 percent of the farms in the United States. About 84 percent of farms have less than 500 acres, 14 percent have 500–2,000 acres, and only 2 percent of the farms have more than 2,000 acres. In terms of 2007 gross sales, 59 percent had less than $50,000 in total farm sales and 20 percent had $50,000–$250,000 in total farm sales. About 66 percent of the farms primarily raise crops, about 25 percent are primarily livestock operations, and the rest produce a mix of livestock and crops.

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

The primary focus of the CEAP Upper Mississippi River Basin study is on the 63 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 Upper 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 that were 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 3,703 sample points in the Upper Mississippi River Basin—is sufficient for reliable and defensible reporting at the regional scale for the 14 watershed subregions within the basin.

Voluntary, Incentives-Based Conservation Approaches Are Achieving Results

Results from the farmer survey show that farmers in the Upper Mississippi River Basin have made significant progress in reducing sediment, nutrient, and pesticide losses from farm fields through conservation practice adoption.

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 96 percent of the acres.

- Structural practices for controlling water erosion are in use on 45 percent of cropped acres. Eighteen percent of cropped acres are designated as highly erodible land; structural practices designed to control water erosion are in use on 72 percent.
- Reduced tillage is common in the region; 91 percent of the cropped acres meet criteria for either no-till (28 percent) or mulch till (63 percent). All but 5 percent of the acres had 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—

- Appropriate *timing* of nitrogen applications is in use on about 45 percent of the acres for all crops in the rotation, and appropriate *timing* of phosphorus applications is in use on about 50 percent of the acres for all crops in the rotation.
- Appropriate *rates* of nitrogen application are in use on about 39 percent of the acres for all crops in the rotation, and 53 percent meet criteria for phosphorus application rates for the full crop rotation.

There was less evidence, however, of consistent use of appropriate rates, timing, *and* method of nutrient application on each crop in every 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 16 percent of cropped acres.
- Appropriate phosphorus management practices (rate, timing, and method) are in use on 28 percent of the acres on all crops during every year of production.
- Only about 13 percent of cropped acres meet full nutrient management criteria for *both* phosphorus and nitrogen management.

About 76 percent of cropped acres are gaining soil organic carbon. An additional 14 percent of cropped acres are considered to be “maintaining” soil organic carbon (average annual loss less than 100 pounds per acre). Overall, 90 percent of cropped acres are maintaining or enhancing soil organic carbon.

Land in long-term conserving cover, as represented by enrollment in the CRP General Signup, consists of 2.8 million acres in the region, of which 69 percent is highly erodible land.

Conservation Accomplishments

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 wind erosion by 64 percent;
- reduced waterborne sediment loss from fields by 61 percent;
- reduced nitrogen lost with surface runoff (attached to sediment and in solution) by 45 percent;
- reduced nitrogen loss in subsurface flows by 9 percent;
- reduced total phosphorus loss (all loss pathways) from fields by 44 percent;
- reduced pesticide loss from fields to surface water, resulting in a 35-percent reduction in edge-of-field pesticide risk (all pesticides combined) for humans and a 41-percent reduction for aquatic ecosystems; and
- increased the percentage of cropped acres gaining soil organic carbon from 60 to 76.

For land in long-term conserving cover (2.8 million acres), soil erosion and sediment loss have been almost completely eliminated. Compared to a cropped condition without conservation practices, average annual total nitrogen loss has been reduced by 78 percent, average annual total phosphorus loss has been reduced by 93 percent, and soil organic carbon has been increased by an average of 382 pounds per acre per year.

Reductions in field-level losses due to conservation practices, including land in long-term conserving cover, are expected to improve water quality in streams and rivers 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 instream loads.

The model simulations 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 65 percent for sediment, 26 percent for nitrogen, 41 percent for phosphorus, and 31 percent for atrazine. The national water quality model also provided estimates of reductions in ***instream loads*** due to conservation practice use. *When considered along with loads from all other sources*, conservation practices in use on cultivated cropland in 2003–06 have reduced total instream loads delivered from the region to the Mississippi River at Cairo, IL, by—

- 14 percent for sediment,
- 19 percent for nitrogen,
- 26 percent for phosphorus, and
- 30 percent for atrazine.

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

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

The assessment of conservation treatment needs presented in this study identifies significant opportunities to further reduce contaminant losses from farm fields. The study found that 15 percent of cropped acres (9.0 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 45 percent of cropped acres (26.2 million acres) have a **moderate** need for additional conservation treatment. The remaining 23.0 million cropped acres (40 percent) have a **low** need for additional treatment, and are considered to be adequately treated.

Model simulations show that adoption of additional erosion control and nutrient management practices on the 35.2 million acres with a **high** or **moderate** treatment need would, compared to the 2003–06 baseline, further reduce edge-of-field sediment loss by 76 percent, losses of nitrogen with surface runoff by 58 percent, losses of nitrogen in subsurface flows by 48 percent, and losses of phosphorus (sediment-attached and soluble) by 50 percent. These field-level reductions would, in turn, further reduce ***instream loads***. Relative to the 2003–06 baseline, this level of additional conservation treatment would reduce total ***instream loads*** *delivered from the region to the Mississippi River at Cairo, IL, from all sources* by—

- 14 percent for sediment,
- 19 percent for nitrogen,
- 26 percent for phosphorus, and
- 30 percent for atrazine.

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, polymer coated products, nitrogen stabilizers, urease inhibitors, and nitrification inhibitors;
- Drainage water management that controls discharge of drainage water and treats contaminants, thereby reducing the levels of nitrogen and even some soluble phosphorus loss;
- 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.

Comprehensive Conservation Planning and Implementation Are Essential

The most critical conservation concern in the region is loss of nitrogen through leaching. About 47 percent of cropped acres require additional nutrient management to address excessive levels of nitrogen loss in subsurface flow pathways, most of which returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow. Over half of the undertreated acres in the region need treatment *only* for nitrogen loss in subsurface flow. About 3 percent of the acres in the region have a **high** need for additional nutrient management to address this concern, and an additional 44 percent have a **moderate** need.

The proportion of cropped acres with a **high** or **moderate** need for additional conservation treatment for other resource concerns was determined to be—

- 10 percent for sediment loss (all with a **high** need for treatment),
- 24 percent for nitrogen loss with runoff (11 percent with a **high** need for treatment), and
- 22 percent for phosphorus lost to surface water (5 percent with a **high** need for treatment)

Treatment of erosion alone can 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. This re-routing of surface water to subsurface flow not only re-directs the dissolved nitrogen into subsurface flow but also can extract additional nitrogen from the soil as the water passes through the soil profile.

The high loss of nitrogen and sometimes phosphorus from farm fields in the region can be addressed with complete and consistent use of nutrient management—appropriate rate, form, timing, *and* method of application. This is especially important for acres that have or need soil erosion control. 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 reduces total phosphorus loss and nitrogen loss in subsurface flows to acceptable levels for nearly all acres in the region.

A ***comprehensive conservation planning process*** is required to identify the appropriate combination of nutrient management techniques and 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. About 37 percent of undertreated acres in the region are undertreated for multiple resource concerns. 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.

Targeting Enhances Effectiveness and Efficiency

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.

Not all acres provide the same benefit from 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.

The least treated acres also 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 about twice as much as treatment of acres with a **moderate** conservation treatment need. Even greater efficiencies are realized when acres with either a **high** or **moderate** 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 Upper Mississippi River Basin demonstrated that total nitrogen loss would be reduced by an average of 35 pounds per acre per year on the 9.0 million acres with a **high** need for additional treatment, compared to 24 pounds per acre per year for additional treatment of the 26.2 million acres with a **moderate** need for additional treatment. The reduction in total nitrogen loss would average only 7 pound per acre per year for treatment of the 23.0 million acres with a **low** need for additional treatment, on average.

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 of the 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 Upper Mississippi River Basin

Land Use

The Upper Mississippi River Basin covers 190,000 square miles between Lake Itasca in northern Minnesota and the confluence of the Mississippi and Ohio Rivers at the southern tip of Illinois. The basin includes large parts of Illinois, Iowa, Minnesota, Missouri, and Wisconsin, and small areas in Indiana, Michigan, and South Dakota.

The dominant land cover in the basin is cultivated cropland, which accounts for about 52 percent of the area (table 1, fig. 1). The highest concentrations of cropland are in northeastern and central Iowa and southern Minnesota, where cropland makes up more than 80 percent of the land in some counties. (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].)

Forestland accounts for 20 percent of the area, most of which is located in the northern parts of the basin (Minnesota and Wisconsin) or in the southern tip of the basin (Missouri). Permanent pasture and hayland represent 9 percent of the area, and rangeland, water, wetlands, horticulture, and barren land account for about 11 percent of the area.

Table 1. Land cover and use in the Upper 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**	62,904,183	52	53
Hayland not in rotation with crops	4,646,173	4	4
Pastureland not in rotation with crops	6,117,978	5	5
Rangeland—grass	2,954,358	2	3
Rangeland—brush	621,187	1	1
Horticulture	126,678	<1	<1
Forestland			
Deciduous	22,239,130	18	19
Evergreen	1,673,102	1	1
Mixed	971,464	1	1
Urban	9,916,203	8	8
Wetlands			
Forested	3,303,242	3	3
Non-Forested	2,614,229	2	2
Barren	84,843	<1	<1
Subtotal	118,172,768	97	100
Water	3,338,245	3	
Total	121,511,013	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 8 percent of the basin. The major metropolitan areas are Chicago, IL; Minneapolis-St. Paul, MN; St. Louis, MO; Des Moines, IA; and the Quad Cities area of Illinois and Iowa.

Agriculture

The 2007 Census of Agriculture reported 278,687 farms in the Upper Mississippi River Basin, about 13 percent of the total number of farms in the United States (table 2). Land on farms was nearly 81 million acres, representing two-thirds of the land base within the region. Farms in the Upper Mississippi River Basin make up about 9 percent of all land on farms in the nation. According to the 2007 Census of Agriculture, the value of Upper Mississippi River Basin agricultural sales in 2007 was about $44 billion—about 57 percent from crops and 43 percent from livestock.

About 66 percent of Upper Mississippi River Basin farms primarily raise crops, about 25 percent are primarily livestock operations, and the remaining 9 percent produce a mix of livestock and crops (table 3).

As in other regions of the country, most of the farms are small. About 84 percent of farms have less than 500 acres, 14 percent have 500–2,000 acres, and only 2 percent of the farms have more than 2,000 acres (table 3). In terms of 2007 gross sales, 59 percent had less than $50,000 in total farm sales and 20 percent had $50,000–$250,000 in total farm sales (table 3). Farms with total agricultural sales greater than $250,000 accounted for 21 percent of the farms in the region. About 51 percent of the principal farm operators indicated that farming was not their principal occupation.

Crop production

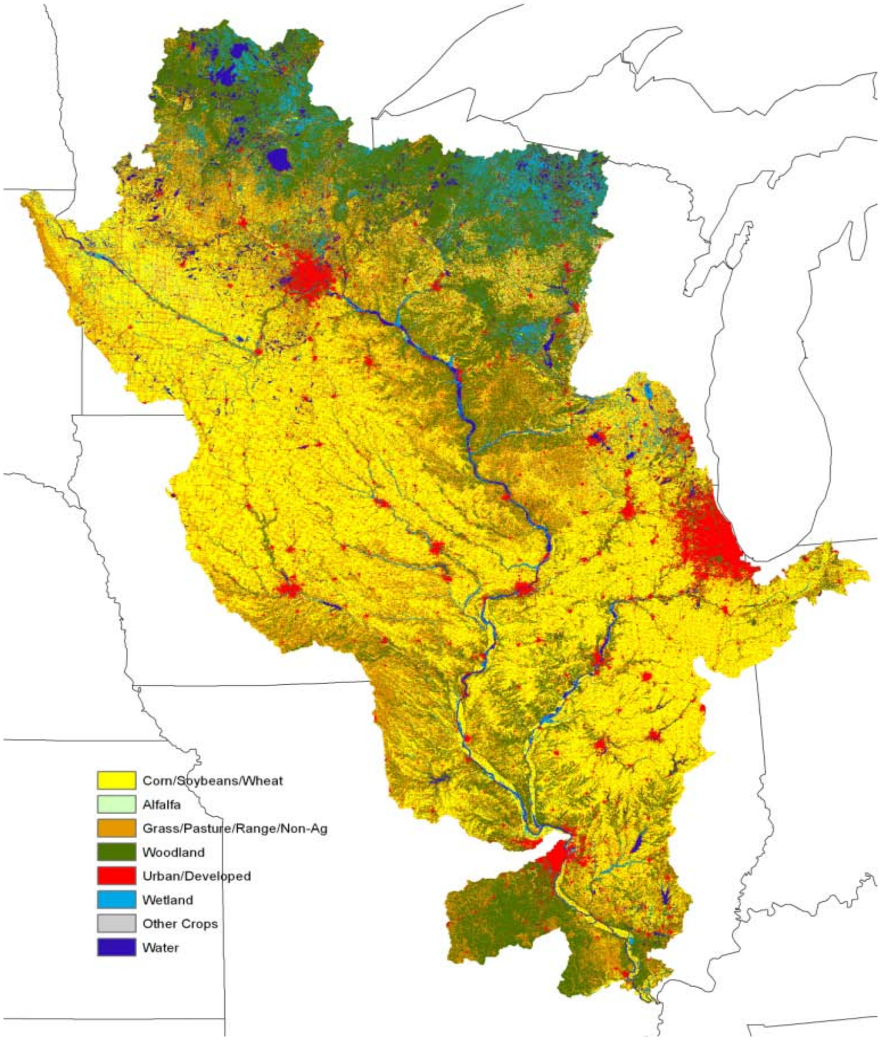
The Upper Mississippi River Basin accounted for about 17 percent of all U.S. crop sales in 2007, totaling $25 billion (table 2). Corn and soybeans are the principal crops grown. Wheat and hay are important secondary crops.

Farmers in the region produced 41 percent of all corn harvested for grain in the United States in 2007—5.2 billion bushels—on about 32 million acres. They also produced 34 percent of the national soybean crop (900 million bushels) on 19 million acres.

Commercial fertilizers and pesticides are widely used throughout the region (table 2). In 2007, 47 million acres of cropland were fertilized, 47 million acres of cropland and pasture were treated with chemicals for weed control, and 20 million acres of cropland were treated for insect control. About 5.3 million acres had manure applied in 2007.

Irrigation use is uncommon in the region. Only about 2 percent of the harvested acres were irrigated in 2007.

Figure 1. Land cover in the Upper Mississippi River Basin



Source: National Agricultural Statistics Service (NASS 2007).

Livestock operations

Livestock production in the region is dominated by swine operations, followed by dairy. Livestock operations in the region produced 35 percent of all hog and pig sales in the United States in 2007, exceeding $6.2 billion in value (table 2). Sales of dairy products ranked second in the region at $5.3 billion, representing 17 percent of the U.S. total. Cattle sales are also important in the region, totaling $4.9 billion in 2007.

In terms of animal units, livestock populations in the region are dominated by two categories: 1) swine and 2) cattle, horses, sheep, and goats (table 2). 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. Of the 11.6 million livestock animal units in the region, 3.7 million animal units are cattle, horses, sheep, and goats, excluding fattened cattle and dairy cows, and 3.6 million animal units are swine. Dairy cow animal units total about 2.1 million and fattened cattle animal units total about 1.4 million.

About 45,000 of the farms in the region (16 percent) could 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 35,000 farms have significant numbers of pastured livestock (13 percent of farms). About 7,900 of the livestock operations (18 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 2,700 meet livestock population criteria for a large CAFO.

Statistics for the Upper 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 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 Upper Mississippi River Basin, 2007

Characteristic	Value	Percent of national total
Number of farms	278,687	13
Acres on farms	80,748,559	9
Average acres per farm	290	
Cropland harvested, acres	59,369,843	19
Cropland used for pasture, acres	1,866,087	5
Cropland on which all crops failed, acres	199,293	3
Cropland in summer fallow, acres	114,569	1
Cropland idle or used for cover crops, acres	3,484,935	9
Woodland pastured, acres	1,716,667	6
Woodland not pastured, acres	5,039,206	11
Permanent pasture and rangeland, acres	5,117,665	1
Other land on farms, acres	3,840,294	12
Principal crops grown		
Field corn for grain harvested, acres	31,852,104	37
Field corn for silage harvested, acres	1,081,711	18
Soybeans harvested, acres	19,283,549	30
Wheat harvested, sum acres	1,354,073	3
Alfalfa hay harvested, acres	2,767,896	14
Tame and wild hay harvested, acres	1,515,047	4
Irrigated harvested land, acres	1,364,944	3
Irrigated pastureland or rangeland, acres	12,650	<1
Cropland fertilized, acres	46,981,154	19
Pastureland fertilized, acres	1,247,434	5
Land treated for insects on hay or other crops, acres	19,616,465	22
Land treated for nematodes in crops, acres	1,643,590	22
Land treated for diseases in crops and orchards, acres	2,581,415	11
Land treated for weeds in crops and pasture, acres	46,529,531	21
Crops on which chemicals for defoliation applied, acres	154,525	1
Acres on which manure was applied	5,297,994	24
Total grains and oilseeds sales, million dollars	22,870	30
Total fruit and berry sales, million dollars	239	1
Total vegetable, melons sales, million dollars	632	4
Total nursery, greenhouse, and floriculture sales, million dollars	890	5
Total crop sales, million dollars	25,097	17
Total dairy sales, million dollars	5,308	17
Total hog and pigs sales, million dollars	6,239	35
Total poultry and eggs sales, million dollars	2,188	6
Total cattle sales, million dollars	4,892	8
Total sheep, goats, and their products sales, million dollars	61	9
Total horses, ponies, and mules sales, million dollars	49	2
Total livestock sales, million dollars	18,962	12
Animal units on farms		
All livestock types	11,597,119	11
Swine	3,604,576	35
Dairy cows	2,136,316	17
Fattened cattle	1,411,518	11
Other cattle, horses, sheep, goats	3,672,881	6
Chickens, turkeys, and ducks	734,365	9
Other livestock	37,464	9

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 Upper Mississippi River Basin, 2007

	Number of farms	Percent of farms in Upper Mississippi River Basin
Farming primary occupation	135,688	49
Farm size:		
<50 acres	88,987	32
50–500 acres	145,408	52
500–2,000 acres	39,814	14
>2,000 acres	4,478	2
Farm sales:		
<$10,000	120,763	43
$10,000–50,000	45,195	16
$50,000–250,000	54,422	20
$250,000–500,000	25,075	9
>$500,000	33,232	12
Farm type:		
Crop sales make up more than 75 percent of farm sales	184,653	66
Livestock sales make up more than 75percent of farm sales	69,224	25
Mixed crop and livestock sales	24,810	9
Farms with no livestock sales	143,046	51
Farms with few livestock or specialty livestock types	55,333	20
Farms with pastured livestock and few other livestock types	35,150	13
Farms with animal feeding operations (AFOs)*	45,158	16

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. For example, in the Upper Mississippi River Basin the 8-digit watershed “07110009” belongs to the “07” 2-digit region and the “0711” 4-digit subregion. The Upper Mississippi River drainage is represented by 14 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. Cultivated cropland is the dominant land use in all but four northern subregions and the southernmost subregion. Over half of the cultivated cropland in the Upper Mississippi River Basin is found in four subregions (table 4):

- Upper Mississippi-Iowa-Skunk-Wapsipinicon (code 0708)
- Minnesota River Basin (code 0702)
- Lower Illinois River Basin (code 0713)
- Des Moines River Basin (code 0710)

In each of these four subregions, more than 70 percent of the landscape is cultivated cropland. This region of concentrated cultivated cropland extends through the central portion of the basin, as shown in figures 1 and 2. Pastureland, hayland, and woodland are more prominent land covers in the northern and southern subregions.

Cultivated cropland is a minor land use in the St. Croix River Basin (code 0703), where only 13 percent of the total area is cultivated cropland (table 4).

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—

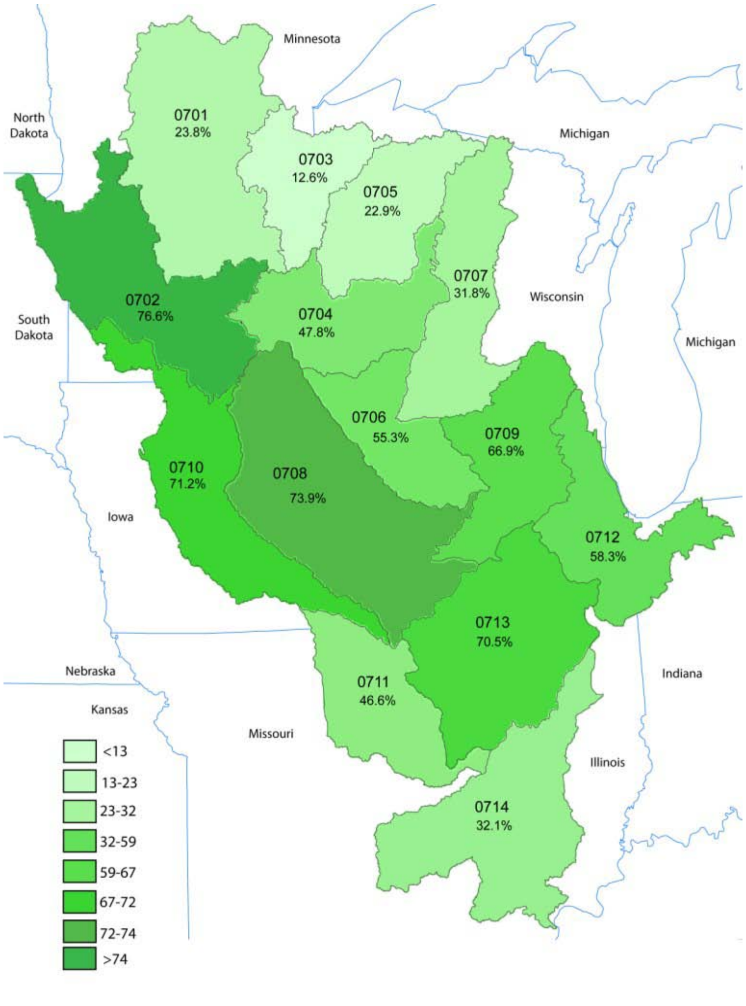
- Upper Mississippi-Salt Rivers (code 0711), with 15 percent, and
- Upper Mississippi-Maquoketa-Plum Rivers (code 0706), with 11 percent.

Table 4. Cultivated cropland use in the 14 subregions in the Upper Mississippi River Basin

Subregion	Total area (acres)	Cultivated cropland (acres)*	Percent cultivated cropland in subregion	Percent of cultivated cropland in Upper Mississippi River Basin	Percent of cultivated cropland acres in long-term conserving cover
Mississippi Headwaters (code 0701)	12,904,262	3,072,114	23.8	4.9	6.0
Minnesota River Basin (code 0702)	10,802,165	8,270,525	76.6	13.1	4.3
St. Croix River Basin (code 0703)	4,949,549	623,496	12.6	1.0	7.3
Upper Mississippi-Black-Root Rivers (code 0704)	6,880,103	3,290,446	47.8	5.2	7.9
Chippewa River Basin (code 0705)	6,108,878	1,398,599	22.9	2.2	3.5
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	5,488,743	3,037,483	55.3	4.8	10.9
Wisconsin River Basin (code 0707)	7,632,776	2,424,034	31.8	3.9	6.1
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	14,673,531	10,849,535	73.9	17.2	5.3
Rock River Basin (code 0709)	7,005,055	4,686,407	66.9	7.5	4.4
Des Moines River Basin (code 0710)	9,265,631	6,599,435	71.2	10.5	5.3
Upper Mississippi-Salt Rivers (code 0711)	6,445,240	3,002,771	46.6	4.8	15.4
Upper Illinois River Basin (code 0712)	6,979,557	4,067,028	58.3	6.5	0.9
Lower Illinois River Basin (code 0713)	11,462,837	8,079,072	70.5	12.8	1.5
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	10,912,687	3,503,238	32.1	5.6	6.6
Total	121,511,013	62,904,183	51.8	100.0	5.3

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 14 subregions in the Upper 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.

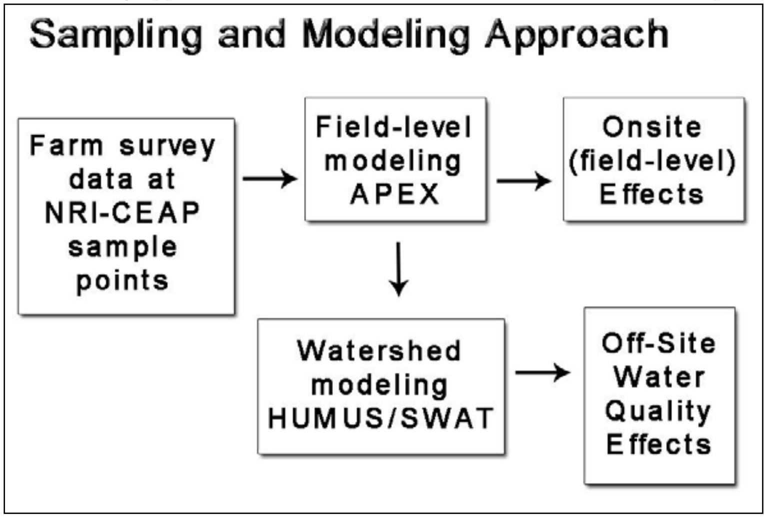
For purposes of this report, cultivated cropland includes land in row crops or close-grown crops (such as wheat and other small grain crops), hay and pasture in rotation with row crops and close-grown crops, and land in long-term conserving cover. Cultivated cropland does not include agricultural land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

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 3,703 National Resources Inventory (NRI) sample points provides a statistical sample that represents the diversity of soils and other conditions for cropped acres in the Upper Mississippi River Basin. The sample also includes 1,815 additional NRI sample points designated as CRP acres to represent 2.8 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 3,703 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 Upper 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.

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).

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

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[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.

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 3,703 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 58,153,500 cropped acres in the region has a lower bound of 57,145,150 acres and an upper bound of 59,161,850 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.

NRI-CEAP estimates of cropped acres for the 14 subregions within the Upper 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 2.8 million acres of land in long-term conserving cover but also because of differences in data sources and estimation procedures.

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

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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.

Cropping Systems in the Upper 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.)

Nearly all crop rotations (97 percent of cropped acres) include either corn or soybeans in this region. The dominant cropping system is corn and soybean rotations without other crops, representing about 74 percent of cropped acres (table 6). Other rotations that include corn represent an additional 18 percent of cropped acres. About 5 percent of cropped acres include soybeans with or without crops other than corn.

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

			95-percent confidence interval	
Subregion	Number of CEAP samples	Estimated acres (1,000 acres)	Lower bound (1,000 acres)	Upper bound (1,000 acres)
Mississippi Headwaters (code 0701)	139	2,672,400	2,262,491	3,082,309
Minnesota River Basin (code 0702)	344	7,343,800	6,573,302	8,114,298
St. Croix River Basin (code 0703)	39	505,800	385,109	626,491
Upper Mississippi-Black-Root Rivers (code 0704)	314	2,704,200	2,407,102	3,001,298
Chippewa River Basin (code 0705)	51	878,900	672,439	1,085,361
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	217	2,602,200	2,295,195	2,909,205
Wisconsin River Basin (code 0707)	81	1,363,100	1,125,146	1,601,054
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	636	10,383,100	9,724,719	11,041,481
Rock River Basin (code 0709)	322	4,206,000	3,852,134	4,559,866
Des Moines River Basin (code 0710)	318	6,309,500	5,784,064	6,834,936
Upper Mississippi-Salt Rivers (code 0711)	235	2,780,300	2,490,191	3,070,409
Upper Illinois River Basin (code 0712)	261	3,989,500	3,574,741	4,404,259
Lower Illinois River Basin (code 0713)	452	8,346,900	7,764,373	8,929,427
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	294	4,067,800	3,662,027	4,473,573
Total	3,703	58,153,500	57,145,150	59,161,850

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

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

				95-percent confidence interval	
Cropping system	Number of CEAP samples	Estimated acres (acres)	Percent of total	Lower bound (acres)	Upper bound (acres)
Corn-soybean only	2,694	42,980,688	74	41,998,547	43,962,829
Corn-soybean with close grown crops	164	2,144,046	4	1,795,289	2,492,803
Corn only	316	5,037,033	9	4,451,143	5,622,923
Corn and close grown crops	41	752,294	1	432,017	1,072,571
Soybean only	105	1,507,404	3	1,163,769	1,851,039
Soybean-wheat only	63	783,464	1	519,038	1,047,890
Hay-crop mix including corn	162	2,460,351	4	1,944,159	2,976,543
Hay-crop mix without corn	75	1,192,680	2	791,409	1,593,951
Remaining mix of crops	83	1,295,541	2	862,989	1,728,093
Total	3,703	58,153,500	100	57,145,150	59,161,850

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

Simulating the Effects of Weather

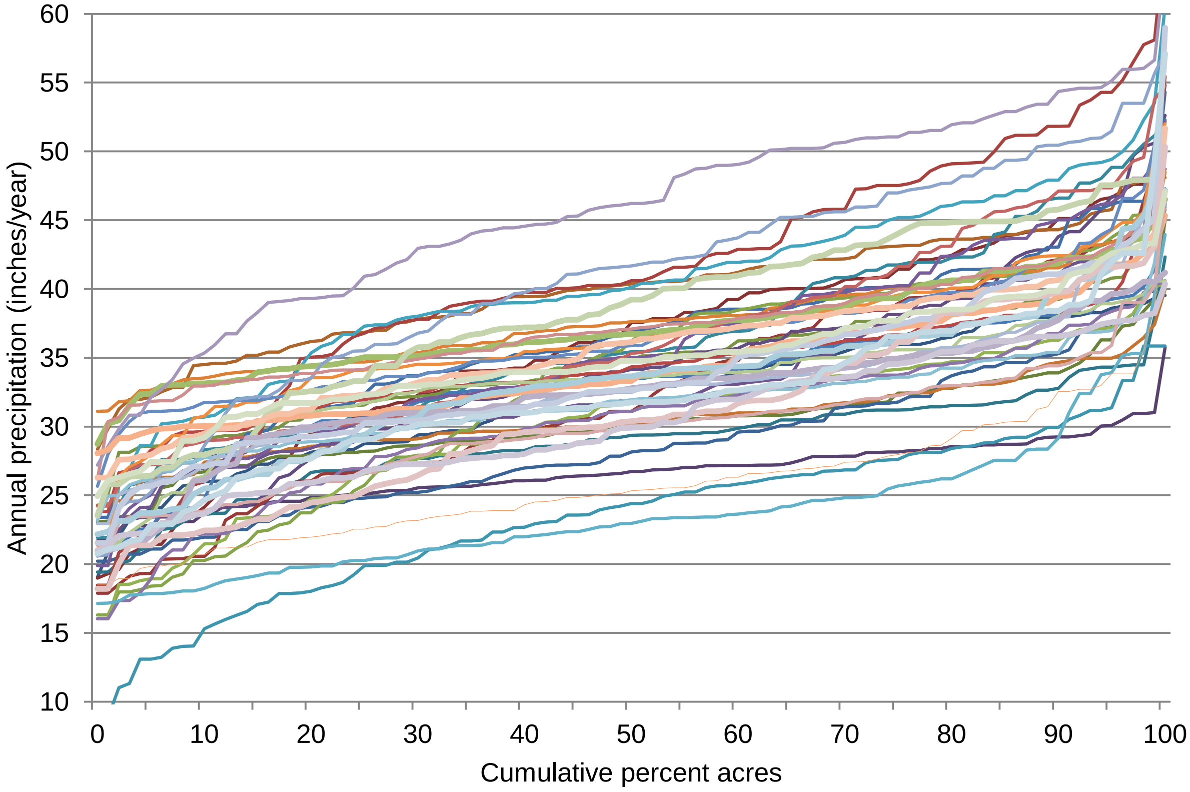
Weather is the predominant factor determining the loss of soil, nitrogen, phosphorus, and pesticides from farm fields, and has a big influence on the effectiveness of conservation practices. To capture the effects of weather, each scenario was simulated using 47 years of actual daily weather data for 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 34 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 15–30 inches per year to highs of 40-60 inches per year. The top curve shown is for the year 1993, the wettest year in this region during the 47 years. The curve for 1993 shows that precipitation exceeded the long-term annual average of 34 inches for 93 percent of the cropped acres in the Upper Mississippi River Basin. The bottom curves are drought years for most of the region—1963, 1966, 1976, 1988, and 1989—most of the cropped acres had less precipitation than the long-term annual average.

Year-to-year variability is especially pronounced—the average annual precipitation amount (representing all cropped acres) ranged from 23 inches in 1976 to 46 inches in 1993 over the 47 years (fig. 6).

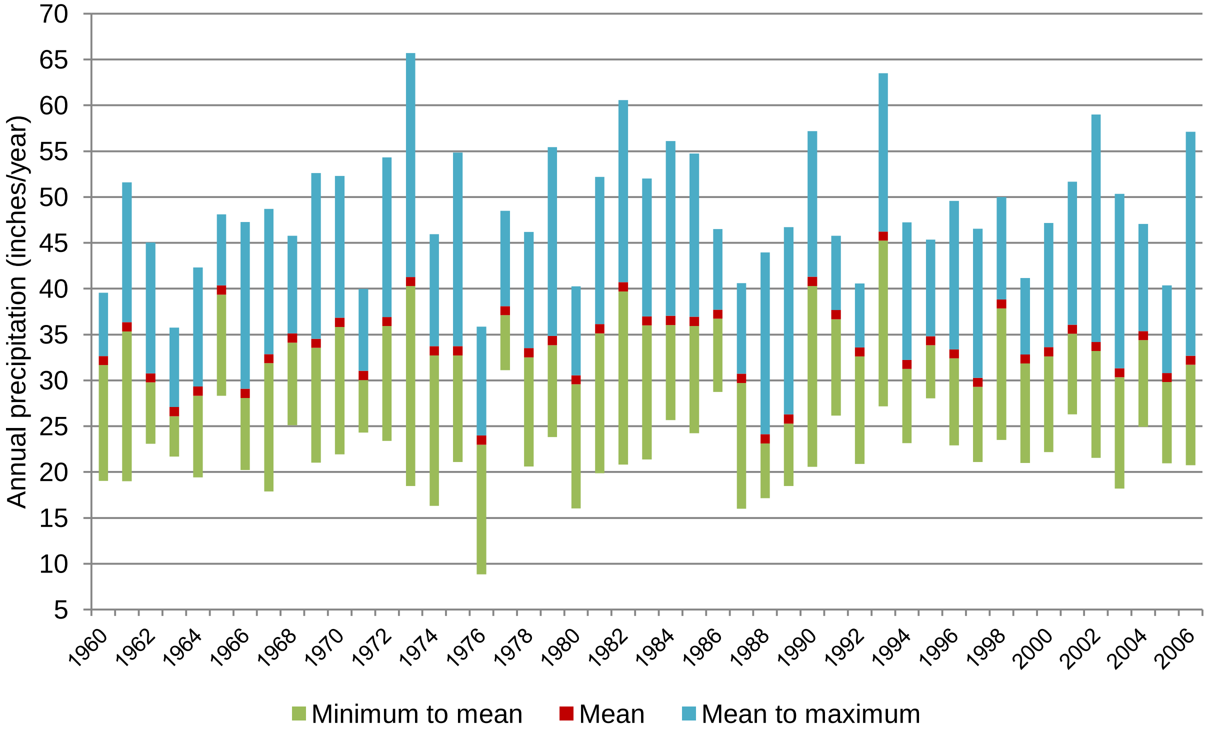
Throughout most of this report model results are presented in terms of the 47-year averages where weather is the only input variable that changes year to year. Since we used the cropping patterns and practices for the 2003–06 period, we did not simulate *actual* loses for each of these years. Rather, 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 Upper 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 34 inches for cropped acres throughout the region. The top curve shown is for the year 1993, the wettest year on record in this region. The curve for 1993 shows that precipitation exceeded 34 inches for 93 percent of cropped acres.

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

Given the long history of conservation in the UMRB, it is not surprising to find that nearly all cropped acres in the region have evidence of some kind of conservation practice, especially erosion control practices. The conservation practice information collected during the study was used to assess the extent of conservation practice use. Key findings are the following:

- Structural practices for controlling water erosion are in use on 45 percent of cropped acres. On the 18 percent of the acres designated as highly erodible land, structural practices designed to control water erosion are in use on 72 percent.
- Reduced tillage is common in the region; 91 percent of the cropped acres meet criteria for either no-till (28 percent) or mulch till (63 percent). All but 5 percent of the acres had evidence of some kind of reduced tillage on at least one crop.
- Three-fourths of cropped acres are gaining soil organic carbon.
- Producers use either residue and tillage management practices or structural practices, or both, on 96 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.

  - Appropriate timing of nitrogen application is in use on about 45 percent of the acres for all crops in the rotation.
  - Appropriate rates of nitrogen application are in use on about 39 percent of the acres for all crops in the rotation.
  - 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 16 percent of cropped acres. Thus, about 84 percent of the acres lack consistent use of appropriate nitrogen application rates, method of application, and time of nitrogen application. including nearly all of the acres receiving manure.
  - Good phosphorus management practices (appropriate rate, timing, and method) are in use on 28 percent of the acres on all crops during every year of production.
  - Only about 13 percent of cropped acres meet nutrient management criteria for both nitrogen and phosphorus management, including acres not receiving nutrient applications.
- 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 10 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 2.8 million acres in the region, of which 69 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.

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. These practices are found on about 21 percent of the cropped acres in the region, including 46 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 32 percent of the cropped acres have one or more of these practices, including 55 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 9 percent of all cropped acres in the region (table 7).

Overall, about 45 percent of the cropped acres in the Upper 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—72 percent.

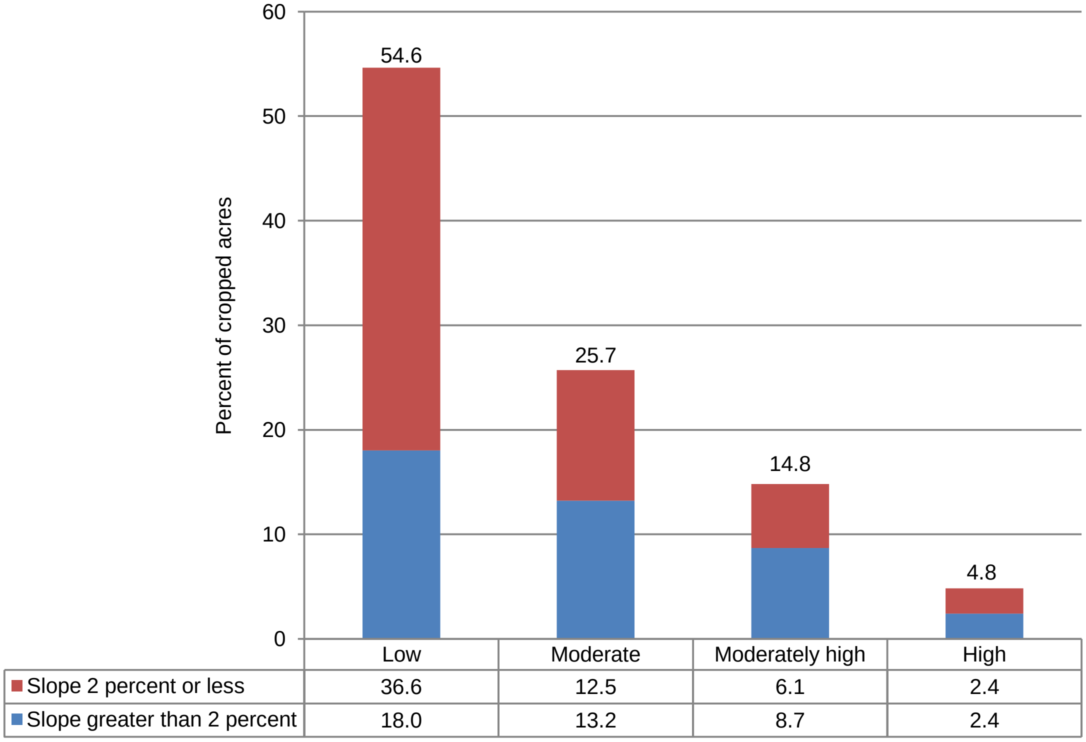
At each sample point, structural conservation practices for water erosion control were classified as either a high, moderately high, moderate, or low level of treatment according to criteria presented in figure 7. About 5 percent of cropped acres in the region have a high level of treatment (combination of edge-of-field buffering or filtering and at least one in-field structural practice). About 55 percent of the acres do not have structural practices for water erosion control; however, two-thirds of these acres have slopes less than 2 percent, some 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, Upper 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	15	46	21
Concentrated flow control practices	Grassed waterways, grade stabilization structures, diversions, other structures for water control	27	55	32
Edge-of-field buffering and filtering practices	Riparian forest buffers, riparian herbaceous buffers, filter strips	10	8	9
One or more water erosion control practices	Overland flow, concentrated flow, or edge-of-field practice	39	72	45
Wind erosion control practices	Windbreaks/shelterbelts, cross wind trap strips, herbaceous windbreak, hedgerow planting	3	3	3

Note: About 18 percent of cropped acres in the Upper 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, Upper Mississippi River Basin



	Low	Moderate	Moderately high	High
🟥 Slope 2 percent or less	36.6	12.5	6.1	2.4
🟦 Slope greater than 2 percent	18.0	13.2	8.7	2.4

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 3 percent of the cropped acres in the region are treated for wind erosion using structural practices.

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.[5] 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, as defined in table 8.[6]

Overall, 91 percent of cropped acres in the Upper 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—23 percent of cropped acres with gains in soil organic carbon and 5 percent with soil organic carbon loss. About 63 percent meet the tillage intensity criteria for mulch till—48 percent of cropped acres with gains in soil organic carbon and 15 percent with soil organic carbon loss. About 4 percent of cropped acres did not meet criteria for mulch till or no-till but had reduced tillage on some crops in the rotation. Only 5 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 71 percent of cropped acres that meet tillage intensity criteria for either no-till or mulch till with gains in soil organic carbon.

The high treatment level, representing 62.8 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 8.6 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 crop rotation is gaining soil organic carbon.

About 25 percent of cropped acres have a moderate level of treatment because some crops 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 3 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 (96 percent) in the Upper Mississippi River Basin have one or both of these types of water erosion control practices (table 9). About 43 percent meet tillage intensity for no-till or mulch till *and* have structural practices, including 70 percent of HEL. About 48 percent of cropped acres meet tillage criteria without structural practices in use. Only 1 percent has structural practices without any kind of residue or tillage management.

Conservation Crop Rotation

In the Upper Mississippi River Basin, crop rotations that meet NRCS criteria (NRCS practice code 328) are used on about 88 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.

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[5] 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.

[6] 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, Upper Mississippi River Basin

Residue and tillage management practice in use	Percent of non_HEL	Percent of HEL	Percent of all cropped acres
All acres			
Average annual tillage intensity for crop rotation meets criteria for no-till*	23	49	28
Average annual tillage intensity for crop rotation meets criteria for mulch till**	67	46	63
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	4	2	4
Continuous conventional tillage in every year of crop rotation***	6	2	5
Total	100	100	100
Acres with carbon gain			
Average annual tillage intensity for crop rotation meets criteria for no-till*	21	34	23
Average annual tillage intensity for crop rotation meets criteria for mulch till**	53	25	48
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	3	1	2
Continuous conventional tillage in every year of crop rotation***	2	1	2
Total	79	60	76
Acres with carbon loss			
Average annual tillage intensity for crop rotation meets criteria for no-till*	2	16	5
Average annual tillage intensity for crop rotation meets criteria for mulch till**	13	21	15
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	2	2	2
Continuous conventional tillage in every year of crop rotation***	4	2	3
Total	21	40	24

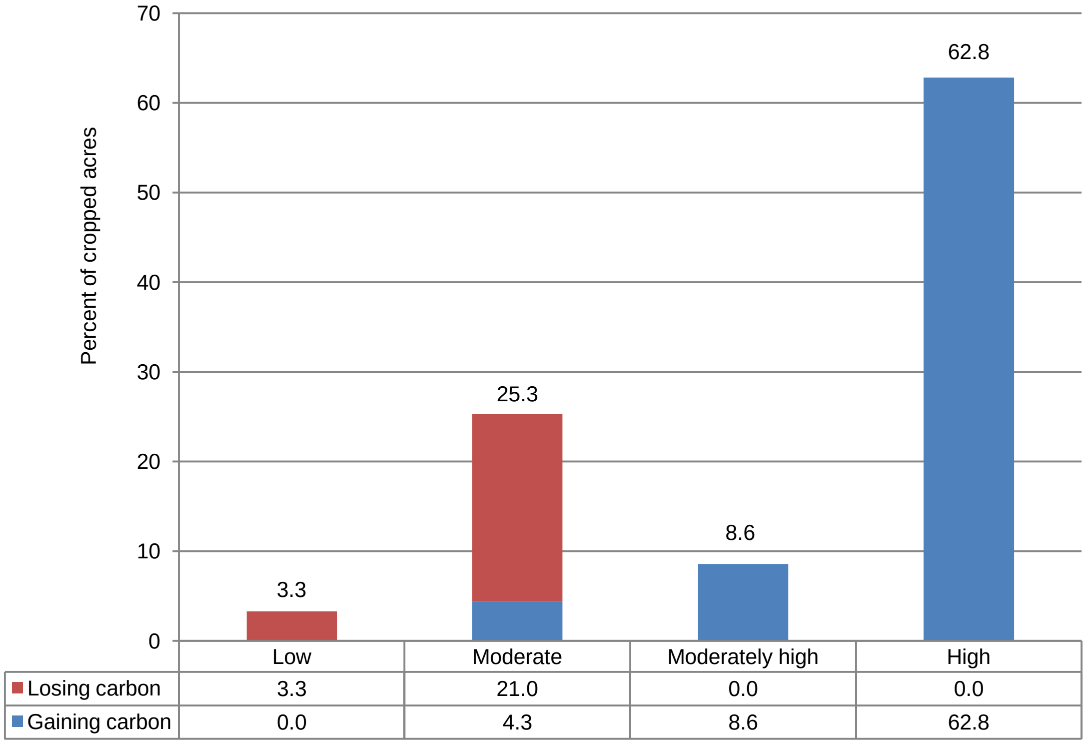
* Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is less than 30.
** Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is between 30 and 100.
*** Soil Tillage Intensity Rating (STIR) for every crop year in the rotation is 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 18 percent of cropped acres in the Upper Mississippi River Basin are highly erodible land (HEL).

Table 9. Percent of cropped acres with water erosion control practices for the baseline conservation condition, Upper 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	42	11	37
No-till or mulch till with carbon loss, no structural practices	10	14	11
Some crops with reduced tillage, no structural practices	3	1	3
Structural practices and no-till or mulch till with carbon gain	32	48	35
Structural practices and no-till or mulch till with carbon loss	5	22	8
Structural practices and some crops with reduced tillage	1	1	1
Structural practices only	1	1	1
No water erosion control treatment	5	2	4
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, Upper Mississippi River Basin



	Low	Moderate	Moderately high	High
🟥 Losing carbon	3.3	21.0	0.0	0.0
🟦 Gaining carbon	0.0	4.3	8.6	62.8

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**: 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; most acres in this treatment level are losing soil organic carbon.
- **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.

The evaluation of conservation practices and associated estimates of conservation treatment needs 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 Upper 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, some practices may be in wider use within the watershed than the CEAP survey shows for 2003–06. Changes in land use and cropping system in response to market conditions could also result in less use of some conservation practices.

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 of spring crops such as sugar beets and potatoes. Early spring vegetation protects young crop seedlings.

In the Upper 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 (14 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 Upper 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.

Only about 2.5 percent of cropped acres—1.46 million acres—receive irrigation water in the Upper Mississippi River Basin. Irrigation in the region is almost exclusively by pressure systems; about 5 percent of irrigated acres use gravity irrigation systems. Most common pressure systems are center-pivot or linear-move systems with impact sprinkler heads (59 percent of irrigated acres) followed by center-pivot or linear-move systems with more efficient low-pressure spray (29 percent of irrigated acres) or near-ground emitters (3 percent of irrigated acres). Traveling big gun sprinklers are used on 2.4 percent of irrigated acres.

In the Upper Mississippi River Basin approximately 469,000 acres (32 percent of irrigated acres) have systems with efficiencies at the current state of the art.

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. [7]

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.
- 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,[8] 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);
  - less than 60 pounds of nitrogen per bale of cotton harvested.[9]
- 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.

As shown in table 10, the majority of acres in the Upper Mississippi River Basin meet one or more of the criteria for nutrient management:

- 90 percent of cropped acres meet criteria for timing of nitrogen applications for one or more crops and 91 percent meet criteria for timing of phosphorus applications for one or more crops;
- 94 percent of cropped acres meet criteria for method of nitrogen application for one or more crops and 95 percent meet criteria for method of phosphorus application for one or more crops;
- 92 percent of cropped acres meet criteria for nitrogen application rate for one or more crops; and
- 2 percent of cropped acres have no nitrogen applied and less than 1 percent has no phosphorus applied.

Fewer acres, however, meet criteria for all crops in the rotation:

- 45 percent of cropped acres meet criteria for timing of nitrogen applications on all crops and 50 percent of cropped acres meet criteria for timing of phosphorus applications on all crops.
- 56 percent of cropped acres meet criteria for method of nitrogen application on all crops and 57 percent meet criteria for method of phosphorus application on all crops.
- 39 percent of cropped acres meet criteria for nitrogen application rate on all crops and 53 percent meet criteria for phosphorus application rates for the full crop rotation.

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

[8] 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.

[9] There was one sample point with cotton in the CEAP sample for this region.

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

	Percent of acres without manure applied	Percent of acres with manure applied	Percent of all cropped acres
Nitrogen*			
No N applied to any crop in rotation	3	0	2
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	51	11	45
Some but not all crops have application of N (manure or fertilizer) within 3 weeks before planting or within 60 after planting	41	64	45
No crops in rotation have application of N (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	5	25	8
Method of application			
All crops in rotation have N applied with incorporation or banding/foliar/spot treatment	59	42	56
Some but not all crops in rotation have N applied with incorporation or banding/foliar/spot treatment	34	57	38
No crops in rotation have N applied with incorporation or banding/foliar/spot treatment	5	1	4
Rate of application			
All crops in rotation meet the nitrogen rate criteria described in text	39	40	39
Some but not all crops in rotation meet the nitrogen rate criteria described in text	54	52	53
No crops in rotation meet the nitrogen rate criteria described in text	5	8	5
Timing and method and rate of application			
All crops meet the nitrogen rate criteria, timing criteria, and method criteria described above	19	2	16
Some but not all crops meet the nitrogen rate criteria, timing criteria, and method criteria described above	68	71	68
No crops meet the nitrogen rate , timing criteria, and method criteria described above	10	27	13
Phosphorus*			
No P applied to any crop in rotation	0.5	0.0	0.4
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	57	13	50
Some but not all crops have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	36	63	41
No crops in rotation have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	6	24	9
Method of application			
All crops in rotation have P applied with incorporation or banding/foliar/spot treatment	59	48	57
Some but not all crops in rotation have P applied with incorporation or banding/foliar/spot treatment	35	51	38
No crops in rotation have P applied with incorporation or banding/foliar/spot treatment	5	1	4
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	58	26	53
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	41	74	46
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	33	2	28
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	24	22	23
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	43	76	48
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	15	1	13
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	10	0	8
All sample points	100	100	100

Note: About 16 percent of cropped acres (9.5 million acres) have manure applied. Percents may not add to 100 because of rounding.

* These estimates include adjustments made to the reported data on nitrogen and phosphorus application rates from the survey because of missing data and data-entry errors. In the case of phosphorus, the 3-year data period for which information was reported was too short to pick up phosphorus applications made at 4- and 5-year intervals between applications, which is a common practice for producers adhering to sound phosphorus management techniques. Since crop growth, and thus canopy development which decreases erosion, is a function of nitrogen and phosphorus, it was necessary to add additional nitrogen 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 20 percent of the acres received a nitrogen adjustment for one or more crops. About 50 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

Nutrients applied in the fall for a spring-planted crop are generally more susceptible to environmental losses than spring applications. Based on the survey, about 45 percent of the cropped acres in the Upper Mississippi River Basin received fall applications of either commercial nitrogen fertilizer or manure on at least one crop in the rotation, excluding cases where a fall crop was planted.. About 41 percent of cropped acres received fall applications of either commercial phosphorus fertilizer or manure on at least one crop in the rotation, excluding cases where a fall crop was planted.

Acres with manure applied—about 16 percent of cropped acres in the region—generally meet the criteria for nutrient application less frequently than for acres receiving only commercial fertilizer (table 10):

- Only 11 percent of cropped acres receiving manure meet criteria for timing of nitrogen on all crops, compared to 51 percent for acres not receiving manure;
- Only 13 percent of cropped acres receiving manure meet criteria for timing of phosphorus applications on all crops, compared to 57 percent for acres not receiving manure;
- 42 percent of cropped acres receiving manure meet criteria for nitrogen application method on all crops, compared to 59 percent for acres not receiving manure;
- 48 percent of cropped acres receiving manure meet criteria for phosphorus application method on all crops, compared to 59 percent for acres not receiving manure;
- 40 percent of cropped acres receiving manure meet criteria for nitrogen application rates, compared to 39 percent for acres not receiving manure; and
- 26 percent of cropped acres receiving manure meet criteria for phosphorus application rates, compared to 58 percent for acres not receiving manure.

The highest percentages of cropped acres with manure applied are in the northeast portion of the region: the Chippewa River subregion (code 0705) with 63 percent, the St. Croix River subregion (code 0703) with 47 percent, and the Wisconsin River subregion (code 0707) with 46 percent (Appendix B, table B1).

Only a few acres meet all nutrient management criteria, including very few of the acres receiving manure (table 10):

- 16 percent of the acres meet all criteria for nitrogen applications, including only 2 percent of the acres receiving manure;
- 28 percent of the acres meet all criteria for phosphorus applications, including only 2 percent of the acres receiving manure;
- Only 13 percent of cropped acres meet criteria for *both* phosphorus and nitrogen management, including acres not receiving 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—

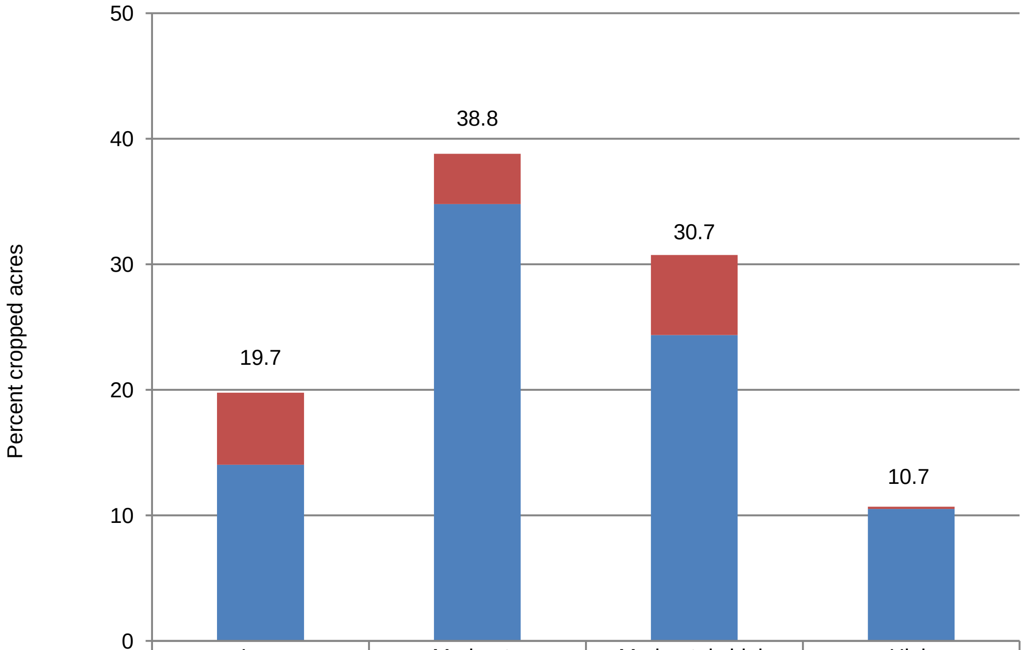
- 1.2 times the amount of nitrogen removed in the crop yield at harvest for *each* crop, except for cotton and small grain crops;
- 1.5 times the amount of nitrogen removed in the crop yield at harvest for small grain crops; and
- 50 pounds of nitrogen per bale of cotton harvested.

Only 8 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).

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 11 percent of the acres in the Upper Mississippi River Basin have a high level of nitrogen management and about 28 percent have a high level of phosphorus management (figs. 9 and 10). Few acres with manure applied meet the criteria for the high treatment levels. About 31 percent of cropped acres have a moderately high treatment level for nitrogen and about 25 percent have a moderately high treatment level for phosphorus. About 20 percent of cropped acres have a low level of nitrogen management and 37 percent of the acres have a low level of phosphorus management.

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



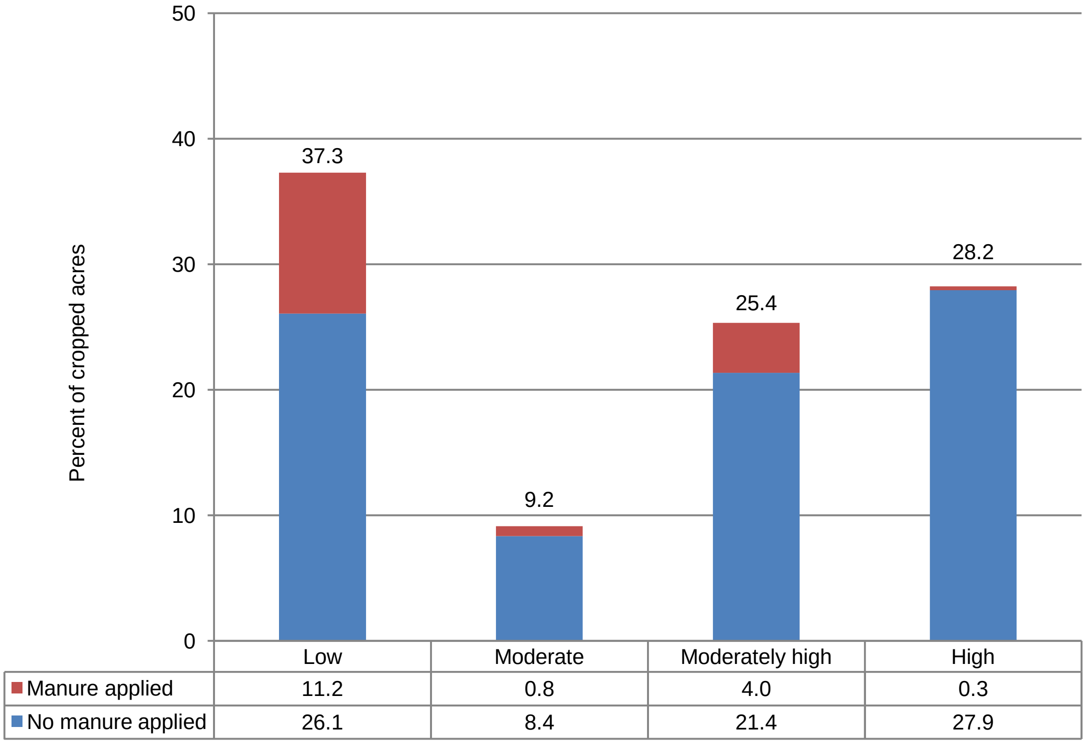
	Low	Moderate	Moderately high	High
🟥 Manure applied	5.7	4.0	6.4	0.2
🟦 No manure applied	14.0	34.8	24.3	10.5

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, Upper Mississippi River Basin



	Low	Moderate	Moderately high	High
🟥 Manure applied	11.2	0.8	4.0	0.3
🟦 No manure applied	26.1	8.4	21.4	27.9

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 exist, 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.

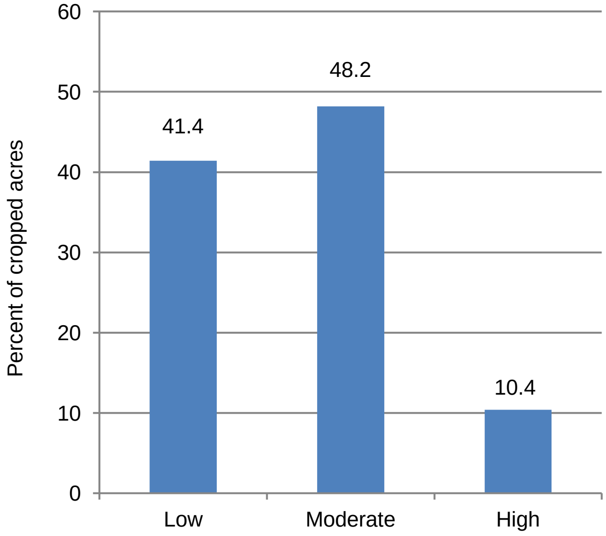
An IPM index was developed to determine the level of IPM activity for each sample point. The index was constructed as follows.

- 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 Upper Mississippi River Basin have a high level of IPM activity (fig. 11). About 48 percent have a moderate level of IPM activity, and 41 percent have a low level of IPM activity.

Figure 11. Integrated Pesticide Management indicator for the baseline conservation condition, Upper Mississippi River Basin



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[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, Upper 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	1,298	37
Plow down crop residues	518	16
Chop, spray, mow, plow, burn field edges, etc.	1,502	42
Clean field implements after use	1,205	32
Remove crop residue from field	240	8
Water management used to manage pests (irrigated samples only)	18	1
Avoidance		
Rotate crops to manage pests	2,877	77
Use minimum till or no-till to manage pests	1,864	50
Choose crop variety that is resistant to pests	1,550	44
Planting locations selected to avoid pests	333	10
Plant/harvest dates adjusted to manage pests	232	7
Monitoring		
Scouting practice: general observations while performing routine tasks	1,506	40
Scouting practice: deliberate scouting	1,830	50
--Established scouting practice used	614	18
--Scouting due to pest development model	345	9
--Scouting due to pest advisory warning	553	16
Scouting done by: (only highest of the 4 scores is used)		
--Scouting by operator	1,306	35
--Scouting by employee	27	1
--Scouting by chemical dealer	356	10
--Scouting by crop consultant or commercial scout	181	5
Scouting records kept to track pests?	683	20
Scouting data compared to published thresholds?	1,103	32
Diagnostic lab identified pest?	157	5
Weather a factor in timing of pest management practice	1,411	37
Suppression		
Pesticides used?	3,622	98
Weather data used to guide pesticide application	2,454	66
Biological pesticides or products applied to manage pests	243	7
Pesticides with different mode of action rotated or tank mixed to prevent resistance	1,298	37
Pesticide application decision factor (one choice only):		
--Routine treatments or preventative scheduling	2,174	58
--Comparison of scouting data to published thresholds	177	5
--Comparison of scouting data to operator's thresholds	286	8
--Field mapping or GPS	6	<1
--Dealer recommendations	660	17
--Crop consultant recommendations	115	3
--University extension recommendations	4	<1
--Neighbor recommendations	1	<1
--"Other"	60	2
Maintain ground covers, mulch, or other physical barriers	1,273	36
Adjust spacing, plant density, or row directions	663	19
Release beneficial organisms	14	<1
Cultivate for weed control during the growing season	499	16
Number of respondents	3,703	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 2.8 million in the Upper Mississippi River Basin (USDA/NRCS 2007). Approximately 69 percent of the cropland acres enrolled in the CRP in the Upper 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 Upper Mississippi River Basin, 69 percent of the CRP land is planted to introduced grasses, 6 percent to trees, 12 percent to native grasses, and 13 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.

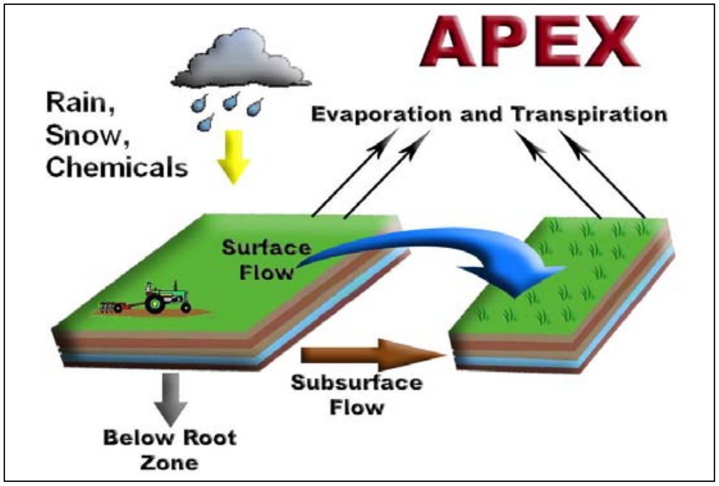
Chapter 4
Onsite (Field-Level) Effects of Conservation Practices

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 Upper 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]

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[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 Upper 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 Upper 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
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 1.64 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 1.6 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 and samples with pressurized systems, such as center pivot, side roll, and low flow (drip), were changed to “hand move sprinklers,” which represents an early form of pressure system. The “Big Gun” systems, which make up 2.4 percent of the irrigated acres, are by and large already less efficient than the “hand move sprinklers,” and these were not converted. The no-practice representation of gravity systems would use a ditch system with portals which is more efficient than the open discharge configuration, so these also were not converted.

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 nutrient 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 1.64 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 1.64 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 1.6 times the harvest removal rate for the crop rotation. The ratio of 1.6 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 1.6 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 1.64 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 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

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[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.

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 Upper Mississippi River Basin, there were 17 sample points with spot treatments, representing less than 1 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 2 percent of the cropped acres in the Upper 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 answers “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 Upper 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 34 inches in this region (table 13). (Also see figs. 5 and 6.) Only about 2.5 percent of cropped acres are irrigated, at an average application of 9 inches per year.

Most of the water that leaves the field is lost through evaporation and transpiration (evapotranspiration) (fig. 13). Evapotranspiration is the dominant loss pathway for 99 percent of cropped acres. On average, about 69 percent of the water loss for cropped acres in this region is through evapotranspiration (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 90 percent of the total amount of water that leaves the field (fig. 14).

Subsurface flow pathways are the second largest source of water loss at an average of about 6 inches per year for cropped acres (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.

The percentage of water loss represented by subsurface flows averages about 18 percent for cropped acres (table 13). However, this percentage ranges from less than 10 percent to over 30 percent for cropped acres in the Upper Mississippi River Basin, as shown in figure 14.

Surface water runoff averages about 13 percent of water loss for cropped acres (table 13), ranging from zero to about 20 percent (fig. 14). Average surface water loss for cropped acres is about 4.4 inches per year (table 13). The amount of surface water runoff varies from acre to acre, ranging from an annual average of about 1 inch per year to about 9 inches per year (fig. 15).

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

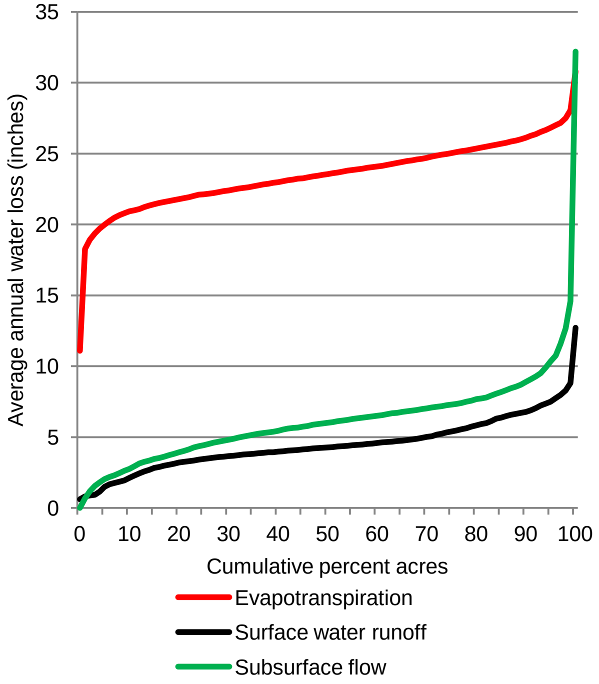
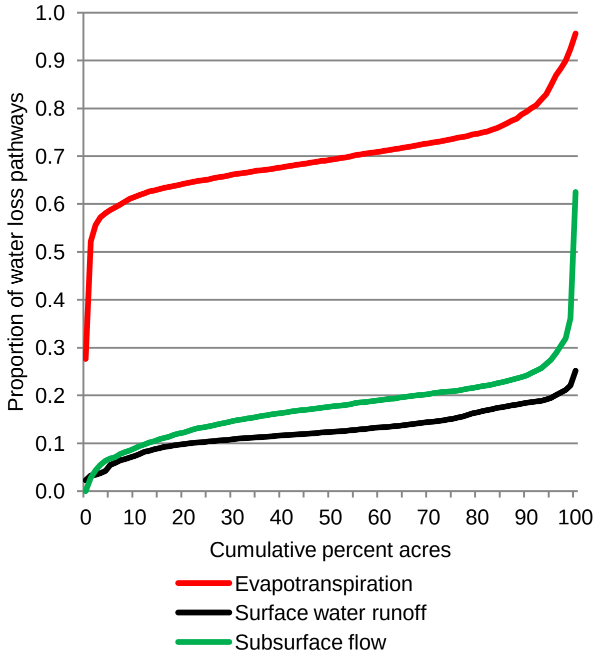


Figure 14. Cumulative distributions of the proportion of water lost through three loss pathways for cropped acres, Upper Mississippi River Basin



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 Upper Mississippi River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (58.2 million acres)				
Water sources				
Non-irrigated acres				
Average annual precipitation (inches)	33.7	33.7	0.0	0
Irrigated acres				
Average annual precipitation (inches)	33.1	33.1	0.0	0
Average annual irrigation water applied (inches)*	9.1	16.8	7.7	46
Water loss pathways				
Average annual evapotranspiration (inches)	23.5	23.8	0.2	1
Average annual surface water runoff (inches)	4.4	4.9	0.4	9
Average annual subsurface water flows (inches)**	6.0	5.4	-0.6***	-12***
Land in long-term conserving cover (2.8 million acres)				
Water sources*				
Average annual precipitation (inches)	34.0	34.0	0	0
Average annual irrigation water applied (inches)*	0.0	0.2	0.2	100
Water loss pathways				
Average annual evapotranspiration (inches)	22.6	23.4	0.8	4
Average annual surface water runoff (inches)	3.0	5.0	2.0	40
Average annual subsurface water flow (inches)**	8.9	5.5	-3.4***	-61***

* About 2.5 percent of the cropped acres in the Upper 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 0.6 inch per year (12 percent increase) for cropped acres due to the use of conservation practices; represents an average gain of 3.4 inches 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 14 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 Upper Mississippi River basin, about 57 percent of the cropped acres have some portion of the field that is tile drained, according to the farmer survey. For these acres, about 82 percent of the subsurface flow in the baseline—as well as the soluble nutrients carried in the subsurface flow—was allocated by the physical process model (APEX) to tile drainage flow in this region.

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 0.4 inch per year averaged over all acres, representing a 9-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 1.5 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 Upper Mississippi River Basin increases overall system efficiency from 43 percent in the no-practice scenario to 65 percent in the baseline scenario. This change in efficiency represents an annual decreased need of water diversions of about 7.7 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 slightly lower for land in long-term conservation cover.

Reductions in surface water runoff due to conversion to long-term conserving cover average 2.0 inches per year in this region (table 13), and range from zero to 5 inches per year for most acres (fig. 17).

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

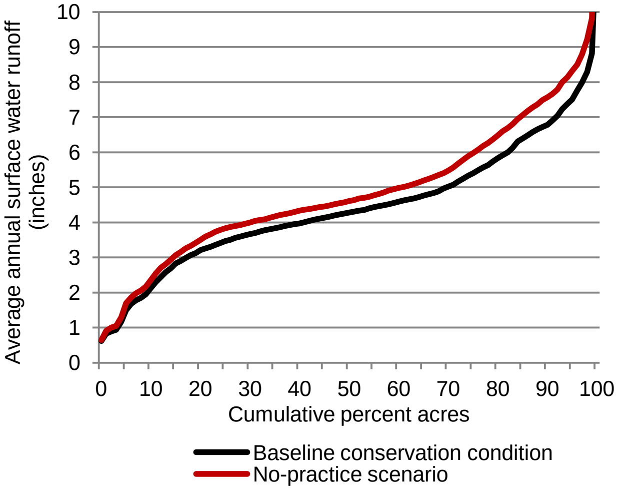


Figure 16. Estimates of average annual reduction in surface water runoff due to the use of conservation practices on cropped acres in the Upper Mississippi River Basin

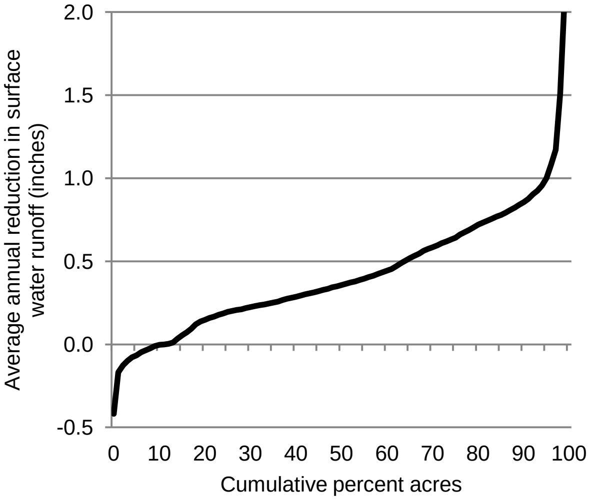
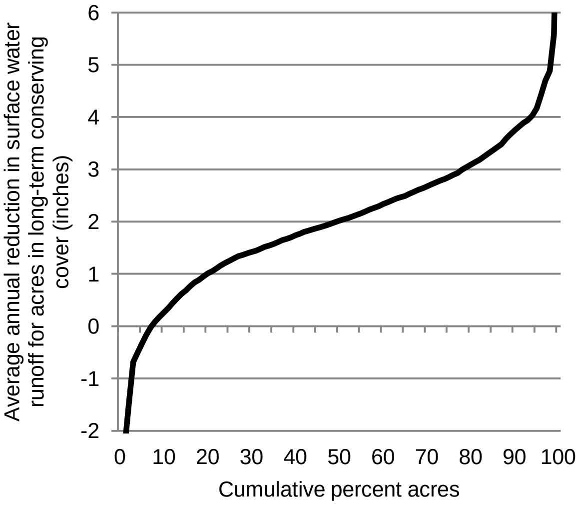


Figure 17. Estimates of average annual reduction in surface water runoff due to conversion to long-term conserving cover in the Upper Mississippi River Basin



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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 8 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 3,703 sample points used to represent cropped acres in the Upper Mississippi River Basin and for each of the 1,815 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 3,703 surface water runoff estimates, weighted by the acres associated with each sample point. The 10th percentile for the baseline conservation condition is 2.1 inches per year, indicating that 10 percent of the acres have 2.1 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 3.5 inches per year. The 50th percentile—the median—is 4.3 inches per year, which in this case is close to the mean value of 4.4 inches per year. At the high end of the distribution, 90 percent of the acres in this region have surface water runoff less than 6.8 inches per year; and conversely, 10 percent of the acres have surface water runoff greater than 6.8 inches per year.

Thus, the distributions show the full range of outcomes for cultivated cropland acres in the Upper 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 3,703 cropped sample points. This distribution shows that, while the mean reduction is 0.4 inch per year, 13 percent of the acres have reductions due to conservation practices greater than 0.8 inch per year and 8 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

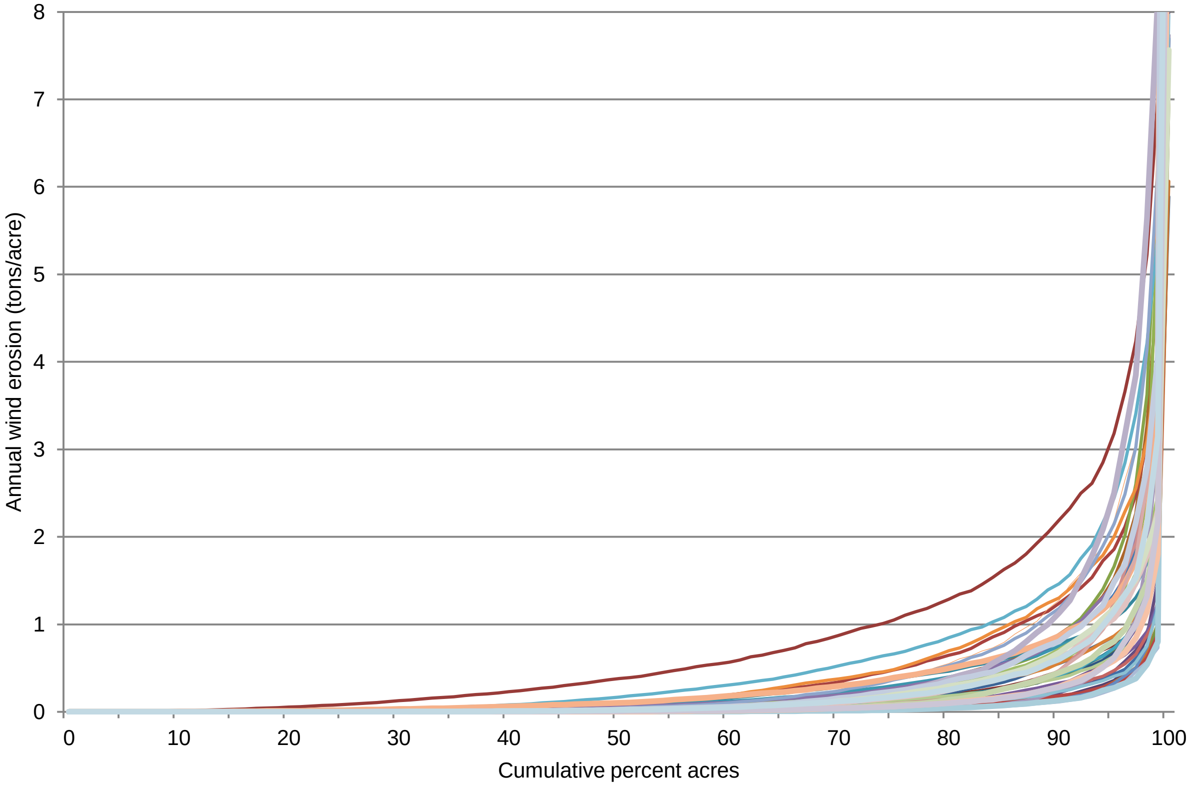
Wind erosion is a relatively minor resource concern in the Upper Mississippi River Basin. For all cropped acres, model simulations show that the average annual rate of wind erosion is 0.11 ton per acre (table 14). However, annual wind erosion can exceed 0.5 ton per acre on some acres in the region in 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 1967), wind erosion exceeded 1 ton per acre for 23 percent of the cropped acres and exceeded 2 tons per acre for 11 percent of the acres.

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

	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres	0.11	0.31	0.20	64
Land in long-term conserving cover	<0.01	0.07	0.07	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 14 subregions.

Figure 18. Distribution of annual wind erosion rate for each year of the 47-year model simulation, Upper 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 3 percent of the cropped acres in the Upper 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 64 percent in the region (table 14).

Without conservation practices, the average annual wind erosion would have been 0.31 ton per acre per year compared to 0.11 ton per acre average for the baseline conservation condition (table 14). On average, conservation practices have reduced wind erosion by 0.20 ton per acre. Reductions in wind erosion due to conservation practices are much higher for some acres than others, reflecting both the level of treatment and the inherent erodibility of the soil (fig. 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 2.8 million acres would average about 0.07 ton per acre per year.

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

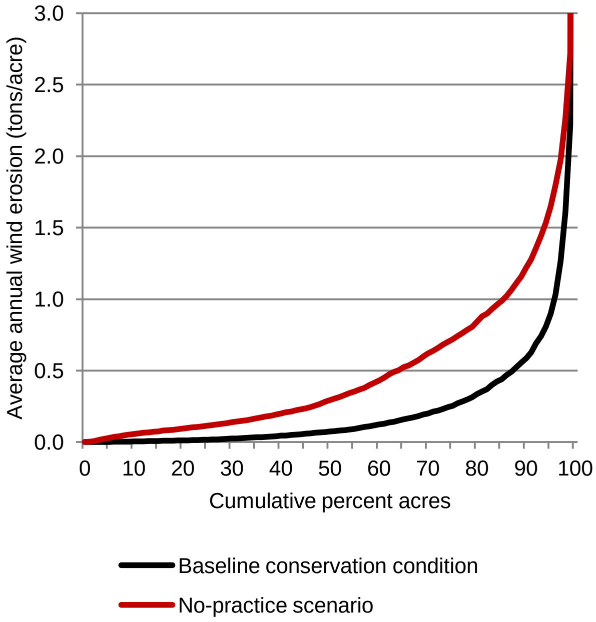
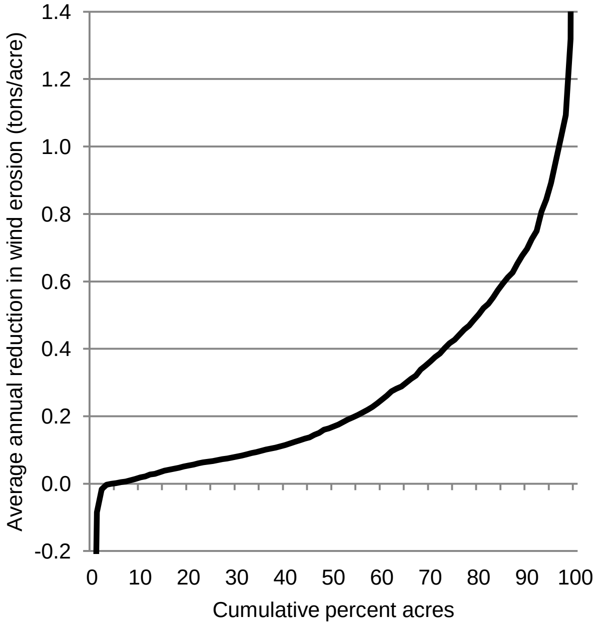


Figure 20 Estimates of average annual reduction in wind erosion due to the use of conservation practices on cropped acres in the Upper Mississippi River Basin



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 from leaving the field.

Model simulations show that sheet and rill erosion on cropped acres in the Upper Mississippi River Basin averages about 0.9 ton per acre per year (table 15). Sheet and rill erosion rates are higher for highly erodible land, averaging 2.15 tons per acre per year compared to the average annual rate for non-highly erodible land of 0.61 ton per acre.

Model simulation results also show that conservation practices have reduced sheet and rill erosion on cropped acres in the Upper Mississippi River Basin by an average of 0.85 ton per acre per year, representing a 49-percent reduction on average (table 15). While the average annual reduction in sheet and rill erosion for highly erodible land is about 4 times that for non-highly erodible acres (table 15), the percent reduction due to conservation practices is about the same.

For land in long-term conserving cover, sheet and rill erosion has been reduced from 3.7 tons per acre per year if cropped without conservation practices to 0.2 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.

Estimates of sediment loss from water erosion do not include wind-eroded material that is subsequently deposited along field borders or in ditches and transported as sediment with rainfall and runoff events. The current state of water erosion modeling does not include sediment displaced from the field by wind. (Wind eroded material incorporated into the soil with tillage or biological activity prior to a runoff event would be included, however.) Wind-eroded material can be an important source of sediment delivered to rivers and streams in some parts of this region.

Baseline condition for cropped acres. The average annual sediment loss for cropped acres in the Upper Mississippi River Basin is 0.9 ton 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.

On an annual basis, sediment loss can vary from year to year, although high losses are restricted to a minority of the acres. Figure 21 shows that, with the conservation practices currently in use in the Upper Mississippi River Basin, annual sediment loss is below 2 tons per acre for about 70 percent of the acres under all conditions, including years with high precipitation. In contrast, sediment loss exceeds 6 tons per acre in one or more years on about 10 percent of the cropped acres.

Figure 21 also illustrates the extent to which high sediment losses are restricted to a minority of acres within the region, even during years with high precipitation. These are the acres that have the highest inherent vulnerability to water erosion and have inadequate soil erosion control.

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[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 Upper Mississippi River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (58.2 million acres)				
Average annual sheet and rill erosion (tons/acre)*	0.89	1.74	0.85	49
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	0.89	2.28	1.39	61
Highly erodible land (18 percent of cropped acres)				
Average annual sheet and rill erosion (tons/acre)*	2.15	4.32	2.17	50
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	2.60	6.49	3.89	60
Non-highly erodible land (82 percent of cropped acres)				
Average annual sheet and rill erosion (tons/acre)*	0.61	1.16	0.55	48
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	0.51	1.33	0.83	62
Land in long-term conserving cover (2.8 million acres)				
Average annual sheet and rill erosion (tons/acre)*	0.20	3.72	3.52	94
Average annual sediment loss at edge of field due to water erosion (tons/acre)	0.21	5.43	5.22	96

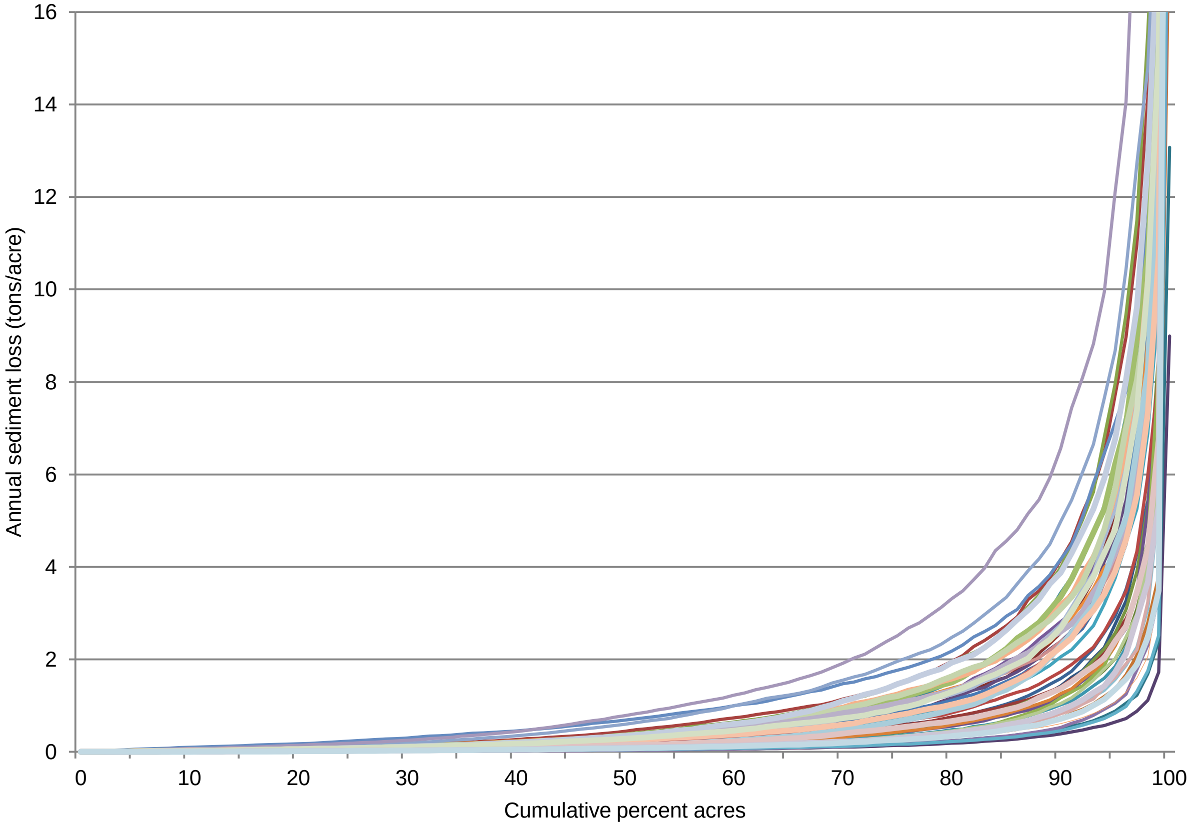
* Estimated using the Revised Universal Soil Loss Equation.

**Estimated using MUSS, 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 14 subregions.

Figure 21. Distribution of annual sediment loss for each year of the 47-year model simulation, Upper 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 Upper Mississippi River Basin has reduced average annual sediment loss from water erosion by 61 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 2.3 tons per acre per year compared to 0.9 ton per acre average for the baseline conservation condition. Figure 22 shows that about 37 percent of the acres would have more than 2 tons per acre per year sediment loss without practices, on average, compared to 11 percent with conservation practices.

Reductions in sediment loss due to conservation practices are much higher for some acres than others, reflecting both the level of treatment and the inherent erodibility of the soil. For about 25 percent of cropped acres, the average annual sediment loss reduction due to practices is less than 0.22 ton per acre (fig. 23). The top 10 percent of the acres had reductions in average annual sediment loss greater than 3.5 tons per acre.

Cropped acres with a combination of structural practices and residue and tillage management have the highest percent reduction in sediment loss (table 16). Acres that are treated with structural practices, meet tillage intensity criteria for no-till or mulch till, and are gaining soil organic carbon (about 35 percent of cropped acres) have reduced sediment loss by 78 percent, on average. For these treated acres, annual sediment loss averages only about 0.65 ton per acre in this region.

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

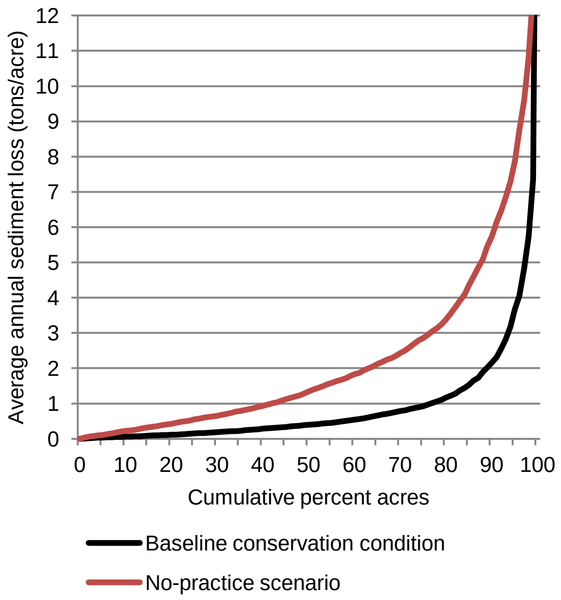


Figure 23. Estimates of average annual reduction in sediment loss due to the use of conservation practices on cropped acres in the Upper Mississippi River Basin

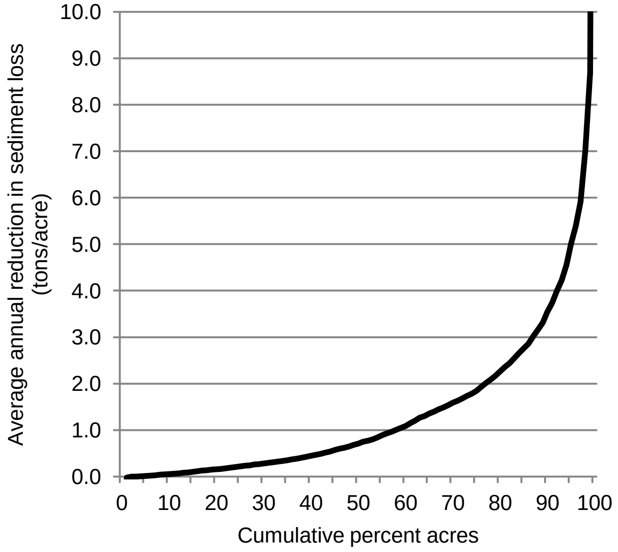


Table 16. Estimates of effects of combinations of structural practices and residue and tillage management on average annual sediment loss for cropped acres in the Upper Mississippi River Basin

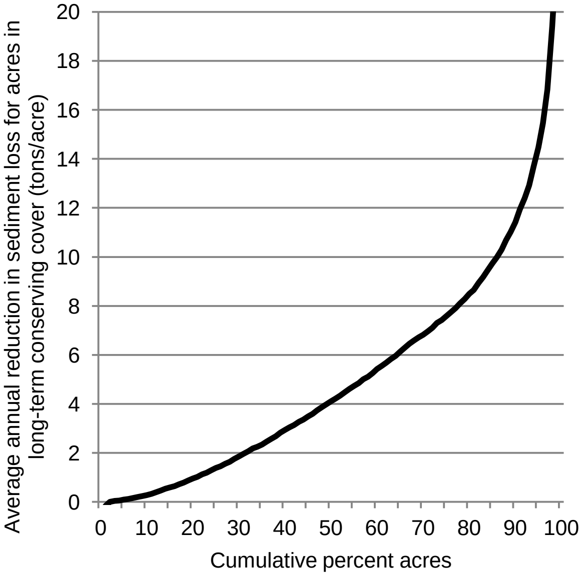
		Average annual sediment loss (tons/acre)			
Conservation treatment	Percent of cropped acres	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
No-till or mulch till with carbon gain, no structural practices	37	0.52	1.08	0.56	52
No-till or mulch till with carbon loss, no structural practices	11	1.60	2.39	0.78	33
Some crops with reduced tillage, no structural practices	3	0.74	0.96	0.22	23
Structural practices and no-till or mulch till with carbon gain	35	0.65	2.90	2.26	78
Structural practices and no-till or mulch till with carbon loss	8	2.13	5.34	3.22	60
Structural practices and some crops with reduced tillage	1	1.01	2.44	1.43	59
Structural practices only	1	1.51	3.31	1.80	54
No water erosion control treatment	4	1.78	1.83	0.05	3
All acres	100	0.89	2.28	1.39	61

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 2.8 million acres were still being cropped without any conservation practices, sediment loss would average about 5.4 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 40 percent of the acres in long-term conserving cover have reductions of less than 3 tons per acre per year. In contrast, reductions greater than 10 tons per acre per year occur on about 14 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 Upper Mississippi River Basin



Effects of Practices on Soil Organic Carbon

The landscape in the UMRB is conducive to maintaining and enhancing soil organic carbon. The combination of gently sloping to level soils that tend to be moderately well drained or have loamy textures inherently allows the soils to withstand more intense tillage and maintain or enhance carbon stores relative to most other regions of the country. This ability is complemented by the high-residue crop rotations commonly used by farmers in the basin; over 94 percent of the acres have corn, small grains, or hay in the rotation.

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 gain of about 71 pounds per acre per year, on average (table 17), with about 76 percent of the acres gaining annually in soil organic carbon and 24 percent of cropped acres losing soil organic carbon, on average. 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 199 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 14 percent of the acres in the region would be considered to be maintaining (but not enhancing) soil organic carbon. When combined with acres enhancing soil organic carbon, a total of 90 percent of the acres in the region would be either maintaining or enhancing soil organic carbon. This achievement is in large part due to the high rate of conservation tillage adoption, particularly no-till and the high residue crop rotations on most of the acres.

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

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (58.2 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	199	225	26	12
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	71	10	62*	--
Land in long-term conserving cover (2.8 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	103	364	261	72
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	317	-64	382*	--

***** 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 14 subregions.

Effects of conservation practices on cropped acres

Without conservation practices, the annual change in soil organic carbon would be an average gain of 10 pounds per acre per year, compared to an average gain of 71 pounds per acre for the baseline (table 17). Thus, conservation practices in the region have resulted in an average annual gain in soil organic carbon of 62 pounds per acre per year on cropped acres.

However, average annual change in soil organic carbon varies considerably among acres in the region, as shown in figure 25. For the baseline conservation condition, the 76 percent of acres gaining soil organic carbon have an average annual gain of 139 pounds per acre per year. If conservation practices were not in use, only 60 percent of the acres would be gaining soil organic carbon and the annual rate of gain would be about 105 pounds per acre per year on those acres.

The average annual gain in soil organic carbon due to practices varies among acres, as shown in figure 26, depending on the extent to which residue and nutrient management is used, as well as the soil's potential to sequester carbon.

Some of the increased gain in soil organic carbon due to conservation practices is the result of soil erosion control—keeping soil organic carbon on the field promotes soil quality. If conservation practices were not in use, loss of soil organic carbon due to wind and water erosion would average 225 pounds per acre per year, compared to 199 pounds per acre with conservation practices (table 17).

For air quality concerns, the analysis centers on the decrease in CO2 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 62 pounds per acre due to conservation practice use is equivalent to a CO2 emission reduction of 6.6 million U.S. tons of carbon dioxide for the Upper Mississippi River Basin.

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

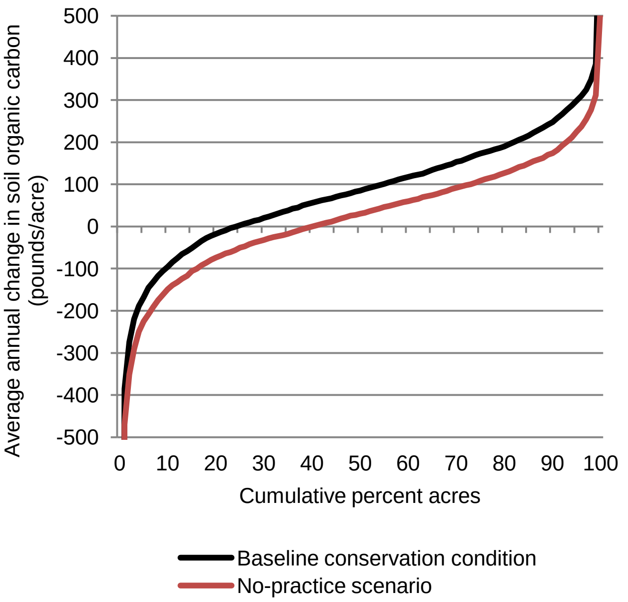
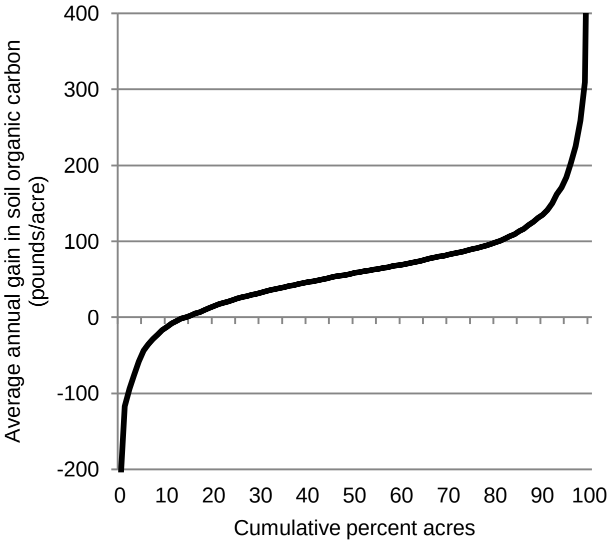


Figure 26. Estimates of average annual gain in soil organic carbon due to the use of conservation practices on cropped acres in the Upper Mississippi River Basin



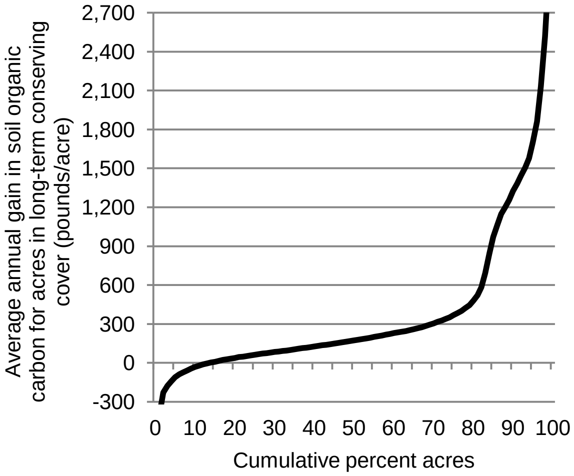
Note: About 13 percent of the acres have a higher soil organic carbon increase in the no-practice scenario than the baseline conservation condition because of the higher fertilization rates, including manure application rates, used in the no-practice scenario to simulate the effects of nutrient management practices.

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 317 pounds per acre per year (table 17). If these acres were still being cropped without any conservation practices, the annual average change in soil organic carbon would be a loss of 64 pounds per acre per year.

For these 2.8 million acres, the gain in soil organic carbon averages 382 pounds per acre compared to a cropped condition without conservation practices. This is equivalent to a CO2 emission reduction of 1.9 million U.S. tons of carbon dioxide for the region. However, the rate of emission reduction due to conservation practices varies considerably among acres in long-term conserving cover, as shown in figure 27.

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



Note: About 13 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 152 pounds of nitrogen per acre per year for cropped acres in the Upper Mississippi River Basin (table 18).

Model simulations show that about 72 percent of this (110 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 39.0 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 6.9 pounds per acre per year);
- nitrogen returned to the atmosphere through denitrification (average of 2.3 pounds per acre per year);
- nitrogen lost with windborne sediment (average of 2.1 pounds per acre per year);
- nitrogen lost with surface runoff (average of 8.8 pounds per acre per year), most of which is nitrogen lost with waterborne sediment; and
- nitrogen loss in subsurface flow pathways (average of 18.7 pounds per acre per year).

The two pathways that impact water quality directly—surface water *and* subsurface flows (average of 27.5 pounds/acre per year) —account for 71 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.

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 63 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 with waterborne sediment is the dominant loss pathway for 19 percent of the cropped acres, and nitrogen lost through volatilization is the dominant loss pathway for 14 percent of cropped acres. The remaining loss pathways were dominant for only 4 percent of the acres in this region.

Loss of nitrogen in subsurface flows can be quite high for some acres (fig. 29). Average annual losses of nitrogen in subsurface flows exceed 50 pounds per acre per year for the 6 percent of acres with the highest losses.

Acres receiving manure (16 percent of cropped acres) have higher nitrogen loss than acres not receiving manure. Total nitrogen loss for acres receiving manure was 60 pounds per acre per year, compared to 35 pounds per acre per year for acres not receiving manure (table 18). Total nitrogen losses were also higher for highly erodible acres (18 percent of cropped acres) compared to non-highly erodible acres. Total nitrogen loss for highly erodible acres is 48 pounds per acre per year, compared to 37 pounds per acre per year for non-highly erodible acres (table 18).

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

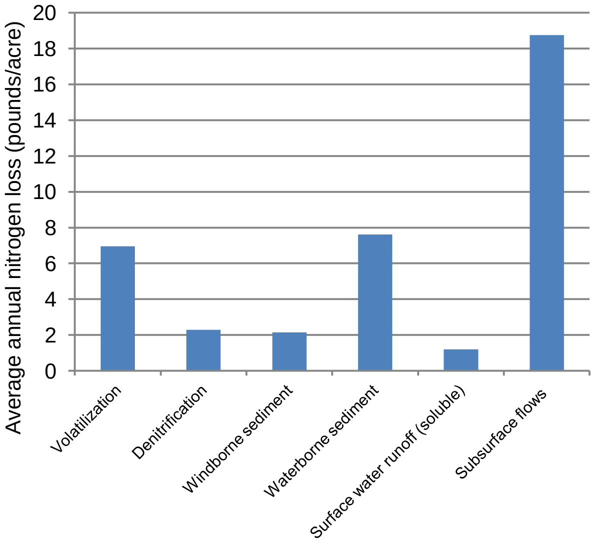
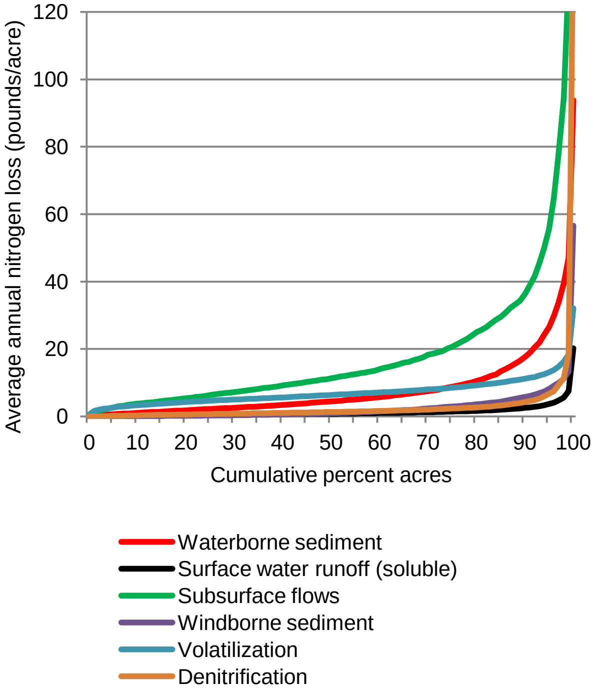


Figure 29. Cumulative distributions of average annual nitrogen lost through various loss pathways, Upper Mississippi River Basin, baseline conservation condition



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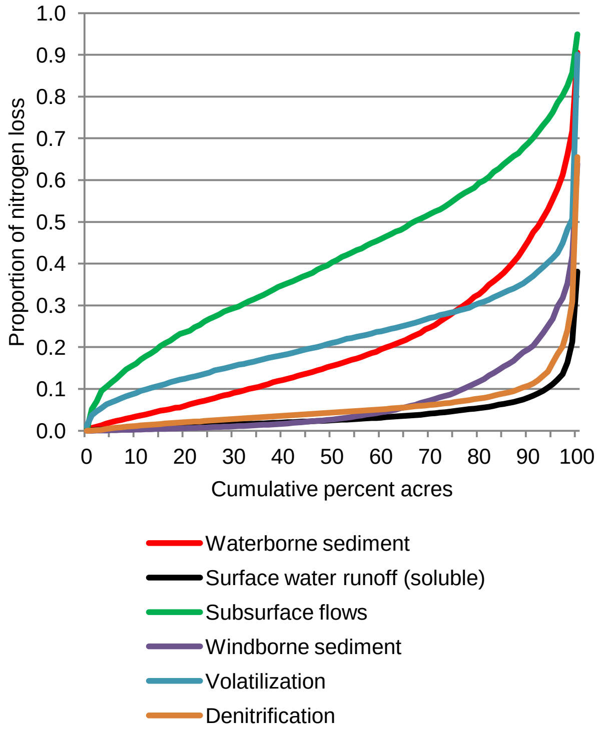
[20] A small amount may also build up in the soil or be mined from the soil, as shown in table 18 for the variable "change in soil nitrogen."

Figure 30. Cumulative distributions of proportions of nitrogen lost through six loss pathways, Upper 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.

Model simulations for the baseline conservation condition indicate that some cropped acres in the Upper 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 41 percent of the acres lose less than 40 pounds per acre per year through the various loss pathways under *all* weather conditions. About 15 percent of the acres, on the other hand, lose more than 100 pounds per acre in at least some years, and lose more than 40 pounds per acre in almost every year. In years with the most extreme weather, up to 5 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 69 percent of cropped acres lose less than 40 pounds per acre per year, while 4 percent lose 100 pounds or more per acre per year.

Table 18. Field-level effects of conservation practices on nitrogen sources and nitrogen loss pathways for cropped acres (58.2 million acres) in the Upper Mississippi River Basin

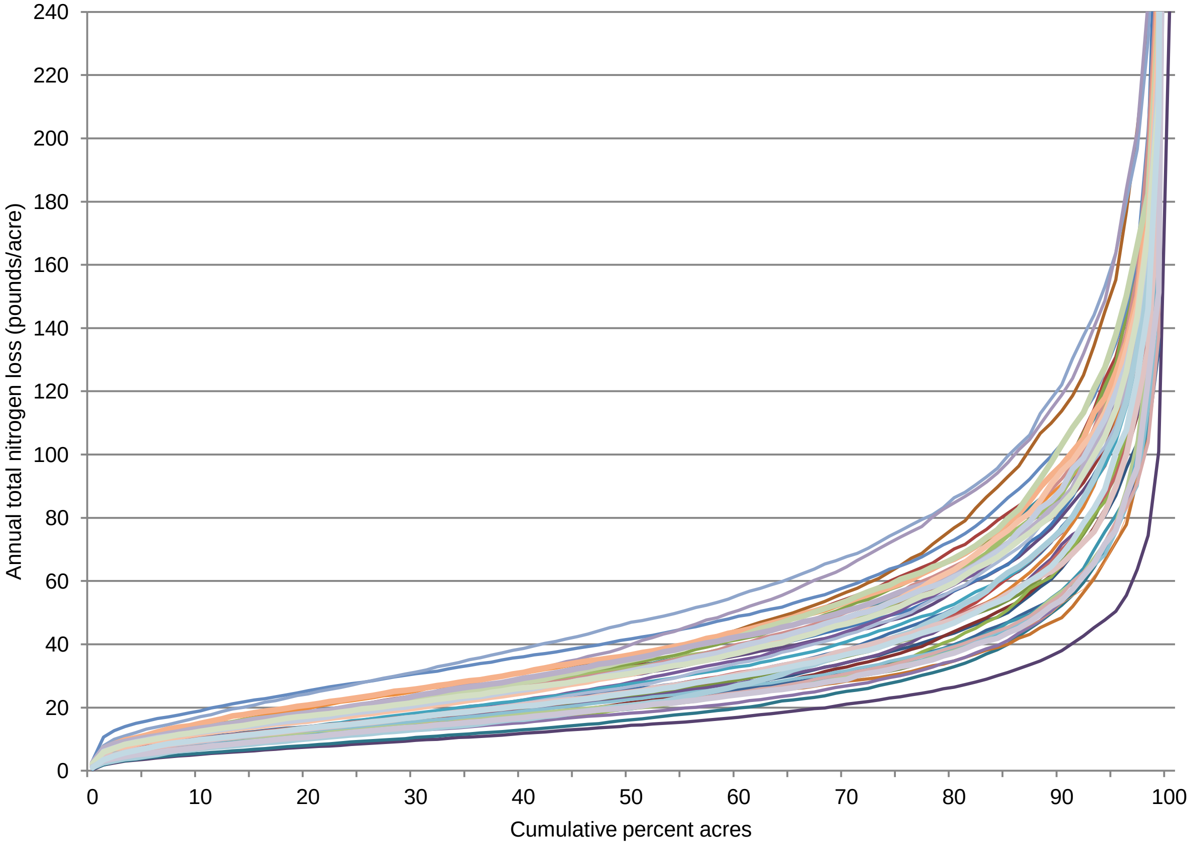
	Average annual values in pounds per acre			
Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
All cropped acres				
Nitrogen sources				
Atmospheric deposition	7.9	7.9	0.0	0
Bio-fixation by legumes	57.1	55.3	-1.8	-3
Nitrogen applied as commercial fertilizer and manure	87.4	101.4	14.0	14
All nitrogen sources	152.4	164.6	12.2	7
Nitrogen in crop yield removed at harvest	110.0	116.5	6.5*	6*
Nitrogen loss pathways				
Nitrogen loss by volatilization	6.9	6.7	-0.2**	-3**
Nitrogen loss through denitrification	2.3	2.2	-0.1**	-5**
Nitrogen lost with windborne sediment	2.1	3.4	1.3	37
Nitrogen loss with surface runoff, including waterborne sediment	8.8	16.0	7.1	45
Nitrogen loss with surface water (soluble)	1.2	4.2	3.0	71
Nitrogen loss with waterborne sediment	7.6	11.8	4.1	35
Nitrogen loss in subsurface flow pathways	18.7	20.6	1.9	9
Total nitrogen loss for all loss pathways	39.0	48.9	10.0	20
Change in soil nitrogen	2.0	-2.0	-3.9	--
Highly erodible land (18 percent of cropped acres)				
All nitrogen sources	157.5	169.1	11.6	7
Total nitrogen loss for all loss pathways	47.8	64.4	16.6	26
Non-highly erodible land (82 percent of cropped acres)				
All nitrogen sources	151.3	163.6	12.4	8
Total nitrogen loss for all loss pathways	37.0	45.4	8.5	19
Acres with manure applied (16 percent of cropped acres)				
All nitrogen sources	179.4	203.4	24.0	12
Total nitrogen loss for all loss pathways	60.2	80.8	20.6	25
Acres without manure applied (84 percent of cropped acres)				
All nitrogen sources	147.1	157.1	9.9	6
Total nitrogen loss for all loss pathways	34.8	42.7	7.9	19

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

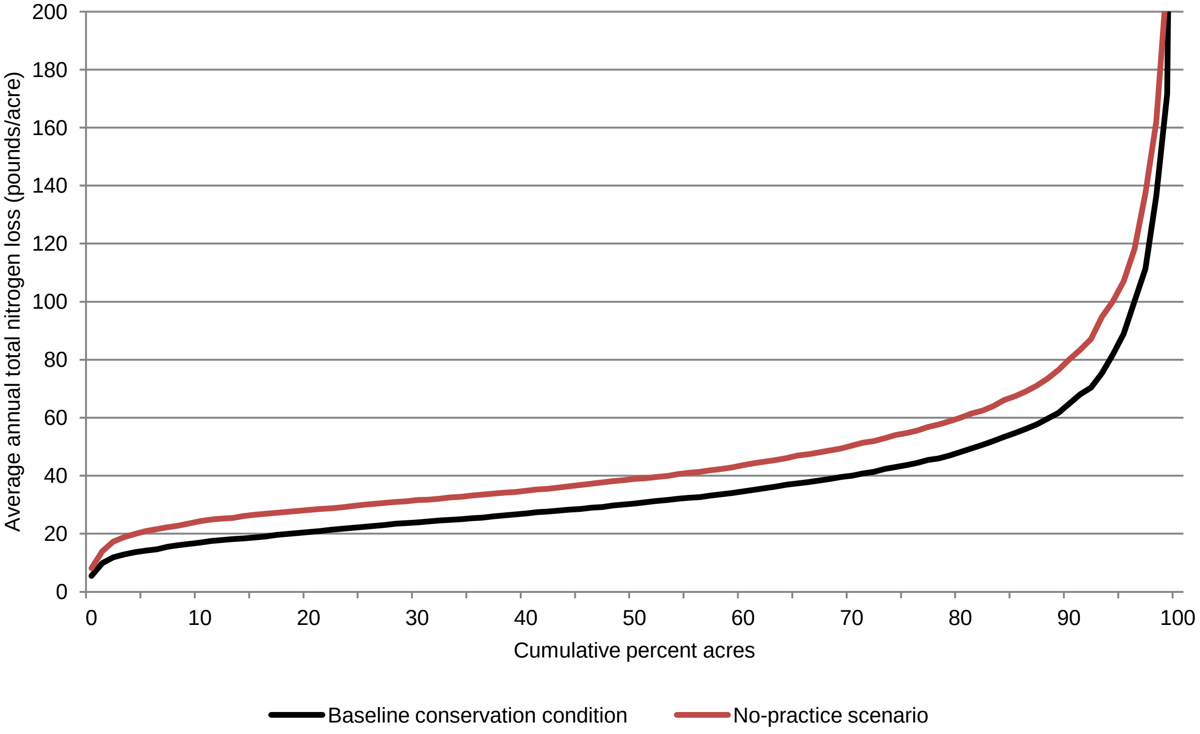
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Model simulation results for the baseline conservation condition are presented in appendix B for the 14 subregions.

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



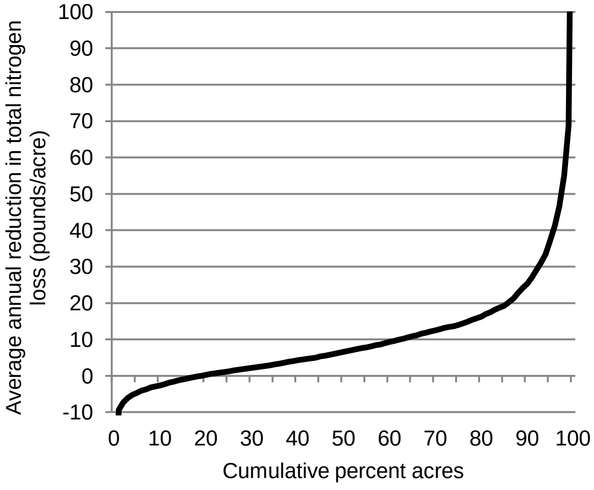
Effects of conservation practices on cropped acres

Total nitrogen loss, all pathways. Model simulations show that the conservation practices in use in the region have reduced total nitrogen loss from cropped acres by an average of 10 pounds per acre per year, representing a 20 percent reduction, on average (table 18). Without conservation practices, about 46 percent of the cropped acres would have average annual total nitrogen loss exceeding 40 pounds per acre per year; with conservation practices, 30 percent of acres exceed this level of loss (fig. 32).

The effects of conservation practices vary from acre to acre (fig. 33). About half of the acres have average annual reductions in total nitrogen loss below 6.5 pounds per acre. In contrast, about 14 percent of the acres have reduced total nitrogen loss by an average of over 20 pounds per acre per year. These are acres with higher levels of treatment and often higher levels of nitrogen use in the no-practice scenario.

Figure 33 also shows that about 18 percent of the acres have an *increase* in total nitrogen loss due to conservation practice use. Most of these increases are small; only 6 percent of the acres have increases of more than 4 pounds per acre. This result occurs primarily on soils with relatively high soil nitrogen content and generally with low slopes where the 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. Cropping systems that include legumes can 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.

Figure 33. Estimates of average annual reduction in total nitrogen loss due to the use of conservation practices on cropped acres in the Upper 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 18 percent of the acres.

Nitrogen lost with surface runoff. Model simulations show that, on average, nitrogen lost with surface runoff has been reduced 45 percent due to use of conservation practices in the region (table 18). Without conservation practices, about 37 percent of the cropped acres would have nitrogen lost with surface runoff in excess of an average of 15 pounds per acre per year, compared to only 15 percent of the acres in the baseline conservation condition (fig. 34). Figure 35 shows that about 21 percent of the cropped acres have reductions in nitrogen lost with surface runoff greater than 10 pounds per acre due to conservation practice use. Figure 35 also shows, however, that about 51 percent of the acres have reductions less than 5 pounds per acre due to conservation practices.

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

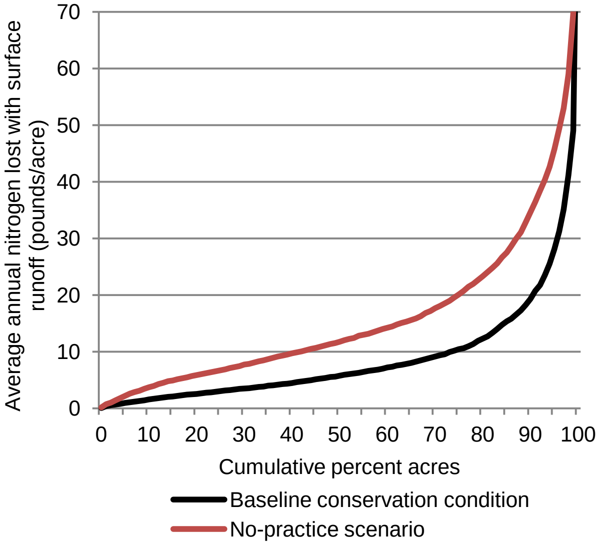
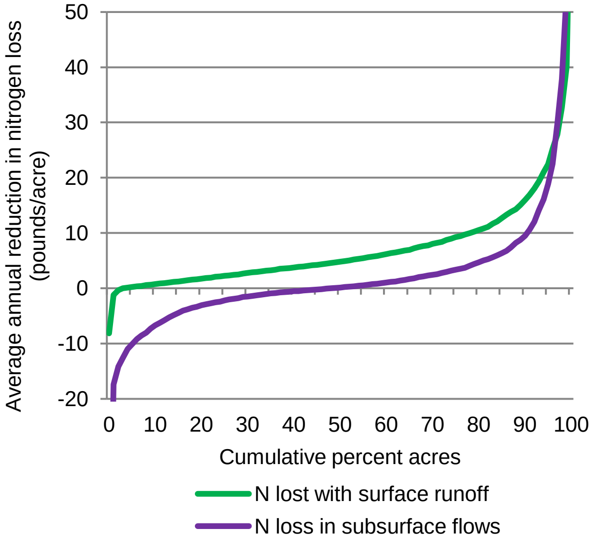


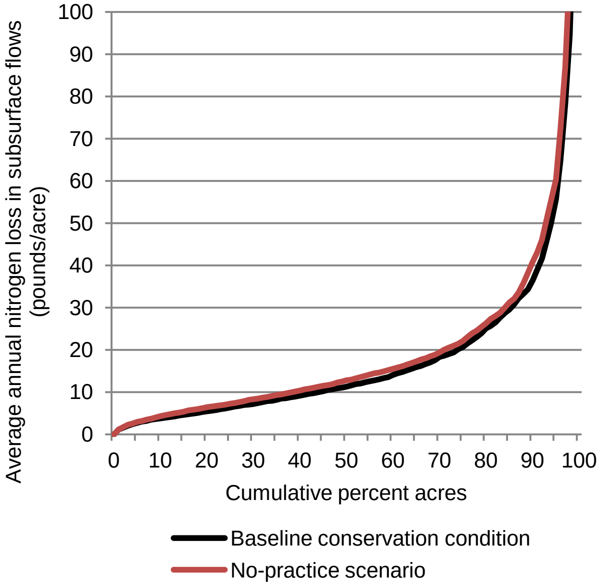
Figure 35. Estimates of average annual reduction in nitrogen lost with surface runoff and reduction in nitrogen loss in subsurface flows due to the use of conservation practices on cropped acres in the Upper Mississippi River Basin



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

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 48 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 20.6 pounds per acre without practices to 18.7 pounds per acre with practices, representing an average reduction of only 1.9 pounds per acre per year (9-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.

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



The increases in nitrogen loss in subsurface flows due to conservation practices on 48 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 overall positive effects of conservation practices on total nitrogen loss.

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.

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.
- A nutrient management plan reduces the amount of manure added to a field to reduce the loss of nutrients to surface or groundwater. However, the reduction in organic material added to the field may reduce the soil organic matter or reduce the rate of change in soil organic matter.
- Figure 33 shows that about 18 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 78 percent on the 2.8 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 59 pounds per acre per year to about 13 pounds per acre per year, a reduction of 46 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 29.9 pounds per acre per year to about 2.7 pounds per acre per year, a reduction of 27 pounds per acre per year. Subsurface losses have been reduced from 19.4 pounds per acre per year to an average of 1.35 pounds per acre, a reduction of 18.05 pounds per acre per year.

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

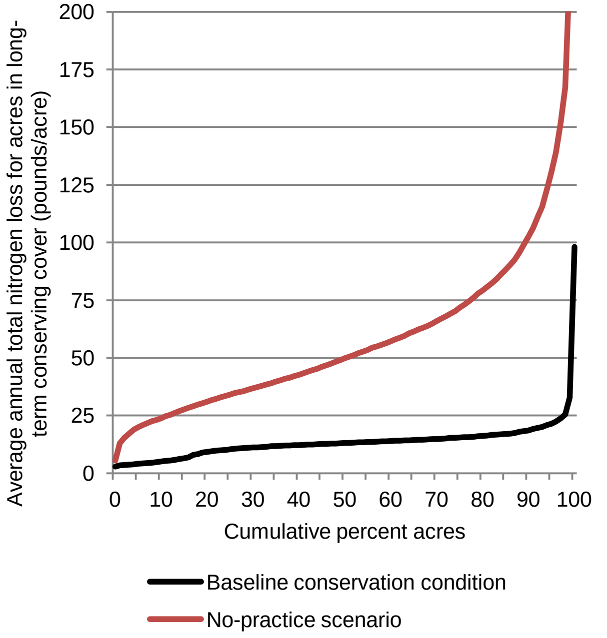


Table 19. Effects of conservation practices on nitrogen sources and nitrogen loss pathways for land in long-term conserving cover (2.8 million acres), Upper Mississippi River Basin

	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	5.9	5.9	0.0	0
Bio-fixation by legumes	11.8	56.2	44.4	79
Nitrogen applied as commercial fertilizer and manure	0.0	99.8	99.8	100
All nitrogen sources	17.7	161.9	144.2	89
Nitrogen in crop yield removed at harvest	1.0*	111.1	110.0	99
Nitrogen loss pathways				
Nitrogen loss by volatilization	7.55	6.82	-0.73	-11
Nitrogen loss through denitrification	1.55	2.83	1.28	45
Nitrogen lost with windborne sediment	0.00	0.42	0.42	100
Nitrogen loss with surface runoff, including waterborne sediment	2.71	29.93	27.22	91
Nitrogen loss with surface water (soluble)	0.19	3.99	3.80	95
Nitrogen loss with waterborne sediment	2.53	25.94	23.41	90
Nitrogen loss in subsurface flow pathways	1.35	19.41	18.05	93
Total nitrogen loss for all pathways	13.17	59.41	46.24	78
Change in soil nitrogen	2.92	-9.34	-12.27	--

* 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 Upper Mississippi River Basin, about 23 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 76 percent of the phosphorus applied is taken up by the crop and removed at harvest—17 pounds per acre per year, on average.

Total phosphorus loss for all loss pathways averaged 3.2 pounds per acre per year in the baseline conservation condition (table 20). These phosphorus loss pathways are—

- phosphorus lost with windborne sediment (average of 0.4 pound per acre per year);
- phosphorus lost with waterborne sediment (average of 1.5 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 1.2 pounds per acre per year); and
- soluble phosphorus that percolates through the soil profile into the groundwater (average of less than 0.02 pound per acre per year).

Most phosphorus is lost from farm fields through the two principal loss pathways in the Upper Mississippi River Basin—phosphorus attached to soil particles in waterborne sediment (48 percent of total loss, on average) and soluble phosphorus lost to surface water (38 percent of total loss, on average) (fig. 38, table 20). Phosphorus lost with wind erosion accounts for about 14 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 47 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 35 percent of cropped acres. Phosphorus lost with wind erosion was the dominant loss pathway on 18 percent of cropped acres.

As shown previously for nitrogen, phosphorus losses are much higher for acres receiving manure (5.9 pounds per acre on average) than for acres that did not receive manure (2.6 pounds per acre on average) (table 20). This difference is directly related to the amount of phosphorus applied, which was much higher for acres receiving manure than for acres not receiving manure. Phosphorus losses are also nearly twice as high for highly erodible land as for non-highly erodible land.

About 50 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, 28 percent of the acres lose more than 8 pounds per acre in at least some years. Phosphorus loses can exceed 16 pounds per acre in some years for more than 10 percent of cropped acres.

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

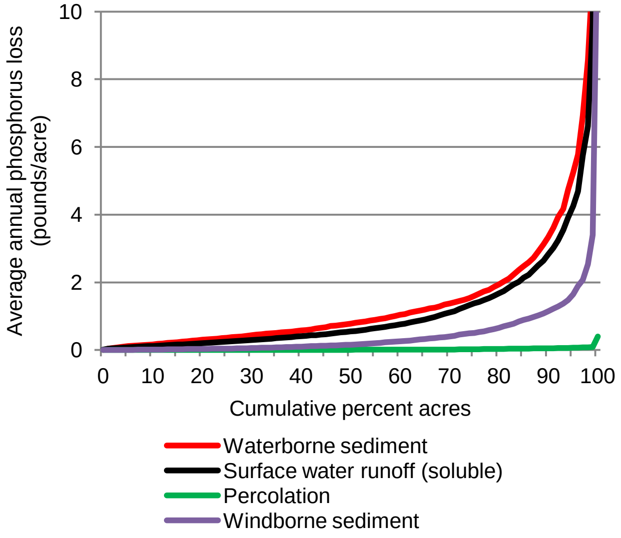


Figure 39. Cumulative distributions of the proportion of phosphorus lost through various loss pathways, Upper Mississippi River Basin, baseline conservation condition

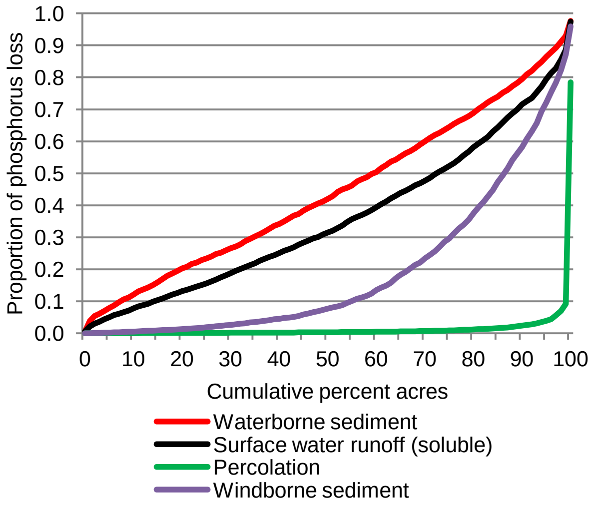


Table 20. Field-level effects of conservation practices on phosphorus sources and phosphorus loss pathways for cultivated cropland in the Upper Mississippi River Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
	Average annual values in pounds per acre			
Cropped acres (58.2 million acres)				
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	22.8	29.7	6.9	23
Phosphorus in crop yield removed at harvest	17.4	18.4	1.0	5
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.4	1.0	0.5	55
Phosphorus lost to surface water (sediment attached and soluble)*	2.7	4.7	2.0	42
Soluble phosphorus lost to surface water*	1.2	1.7	0.5	29
Phosphorus loss with waterborne sediment	1.5	3.0	1.5	50
Soluble phosphorus loss to groundwater	<0.02	0.02	<0.01	15
Total phosphorus loss for all loss pathways	3.2	5.7	2.5	44
Change in soil phosphorus	2.1	5.6	3.4	--
Highly erodible land (18 percent of cropped acres)				
Phosphorus applied as commercial fertilizer and manure	23.6	29.1	5.5	19
Total phosphorus loss for all loss pathways	5.1	9.0	3.9	43
Non-highly erodible land (82 percent of cropped acres)				
Phosphorus applied as commercial fertilizer and manure	22.6	29.9	7.2	24
Total phosphorus loss for all loss pathways	2.7	4.9	2.2	45
Acres with manure applied (16 percent of cropped acres)				
Phosphorus applied as commercial fertilizer and manure	37.3	44.6	7.3	16
Total phosphorus loss for all loss pathways	5.9	9.0	3.2	35
Acres without manure applied (84 percent of cropped acres)				
Phosphorus applied as commercial fertilizer	20.0	26.8	6.8	26
Total phosphorus loss for all loss pathways	2.6	5.0	2.4	48
Land in long-term conserving cover (2.8 million acres)				
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	0.00	29.78	29.78	100
Phosphorus in crop yield removed at harvest	0.45**	16.95	16.49	97
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.00	0.11	0.11	100
Phosphorus lost to surface water (sediment attached and soluble)*	0.43	7.45	7.02	94
Soluble phosphorus lost to surface water*	0.16	1.59	1.43	90
Phosphorus loss with waterborne sediment	0.27	5.86	5.59	95
Soluble phosphorus loss to groundwater	0.07	0.03	-0.04	-155
Total phosphorus loss for all loss pathways	0.50	7.58	7.09	93
Change in soil phosphorus	-1.07	4.81	5.87	--

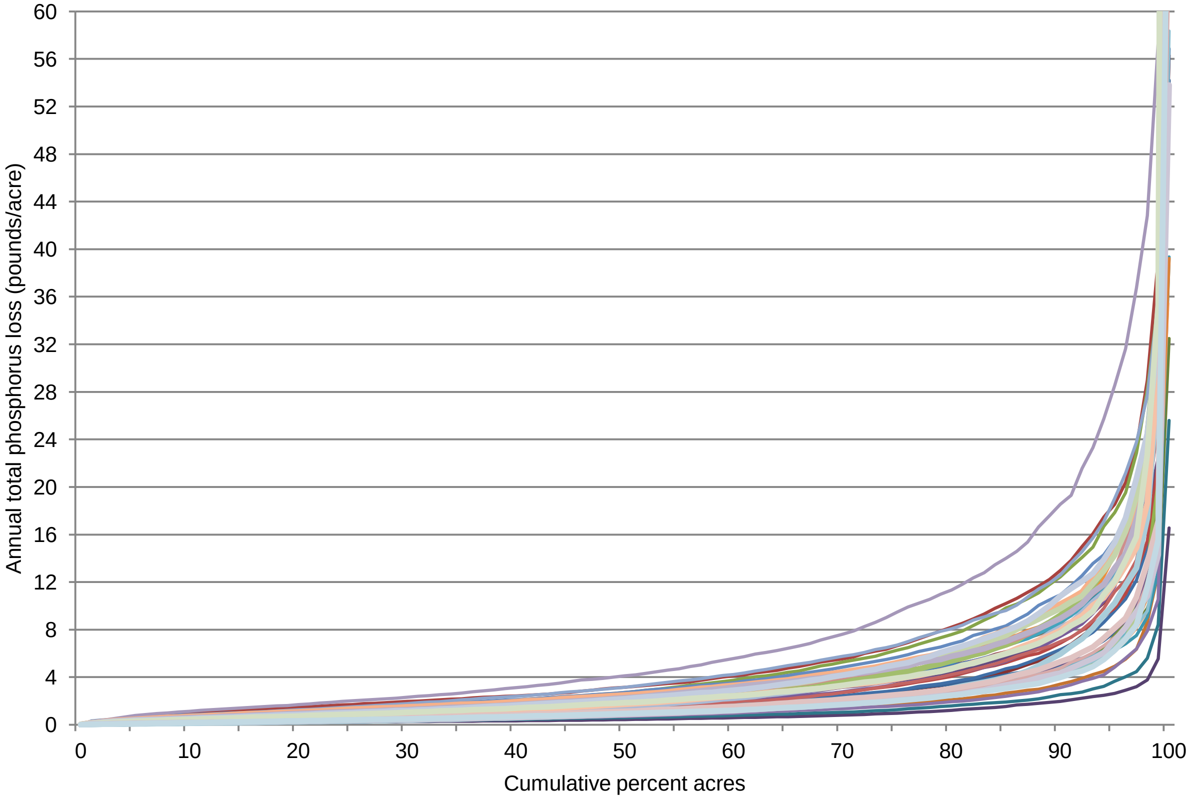
* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.

** 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.

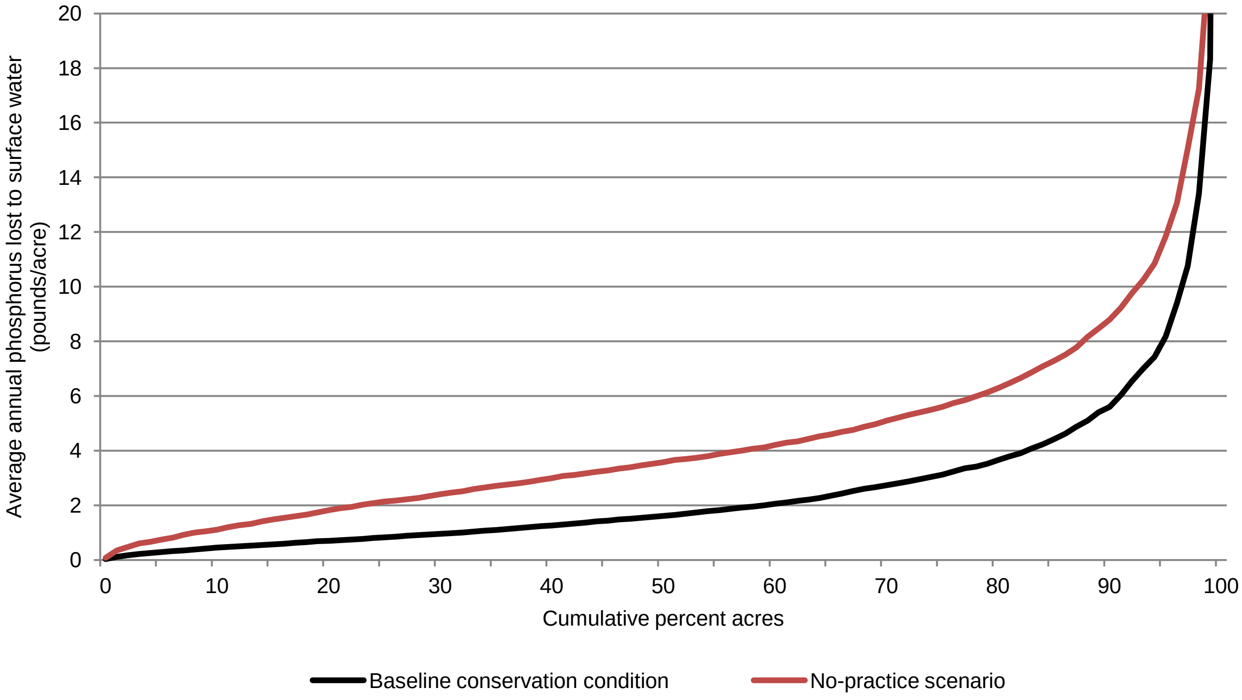
Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 14 subregions.

Figure 40. Distribution of annual total phosphorus loss for each year of the 47-year model simulation, Upper 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 Upper 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

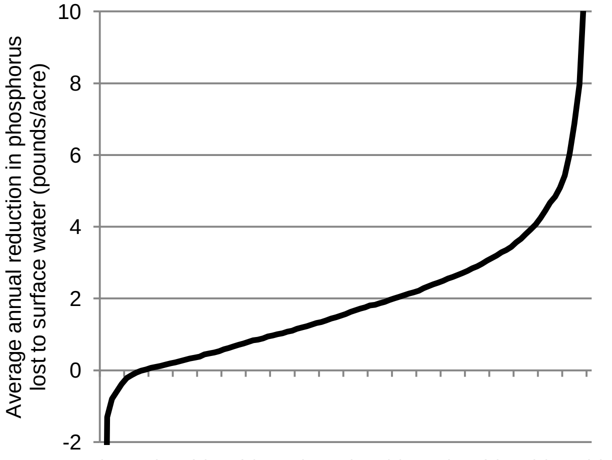
Conservation practices have reduced total phosphorus lost to surface water for cropped acres by 42 percent, reducing the average loss from 4.7 pounds per acre per year if conservation practices were not in use to 2.7 pounds per acre per year for the baseline conservation condition (table 20). On average, conservation practices have reduced phosphorus loss with waterborne sediment by 50 percent, whereas soluble phosphorus lost to surface water has been reduced only 29 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. With the conservation practices in use as represented by the baseline conservation condition, about 17 percent of cropped acres exceed 4 pounds per acre per year of phosphorus lost to surface water, on average. Without those practices in use, phosphorus lost to surface water would exceed 4 pounds per acre for 43 percent of the acres (fig. 41).

The effects of conservation practices on phosphorus lost to surface water vary considerably throughout the Upper Mississippi River Basin, as shown in figure 42. At the high end, reductions exceed 3 pounds per acre for about 21 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 8 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 3 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 practices (see fig. 16 and associated footnote).

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 Upper Mississippi River Basin

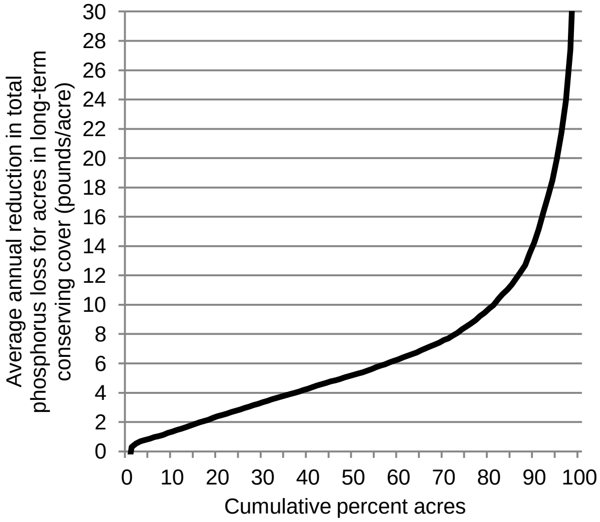


In other cases, however, increases in phosphorus loss due to conservation practices resulted from a combination of practices and landscape conditions that cause phosphorus levels to concentrate near or on the soil surface, where it is more vulnerable to surface runoff. On these types of landscapes, improved 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 93 percent less than it would have been if crops had been grown and no conservation practices used, reducing total phosphorus loss by 7 pounds per acre per year, on average (table 20 and fig. 43). Reductions range from less than 3 pounds per acre for the 25 percent of acres with the lowest reductions to over 18 pounds per acre per year for the 5 percent of acres with the highest reductions.

Figure 43. Estimates of average annual reduction in total phosphorus loss due to conversion to long-term conserving cover in the Upper 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, but the majority of pesticide loss is dissolved in surface water runoff. On average for the region, pesticides dissolved in surface water runoff accounted for 71 percent of the total mass loss, waterborne sediment accounted for 21 percent, and pesticides in subsurface flows accounted for 8 percent.

The dominant loss pathway for 66 percent of cropped acres was pesticides dissolved in surface water runoff. Waterborne sediment was the dominant pesticide loss pathway for 24 percent of the acres, and subsurface flows were the dominant pesticide loss pathway for 7 percent of the acres. The remaining 3 percent of the acres had no pesticide loss.

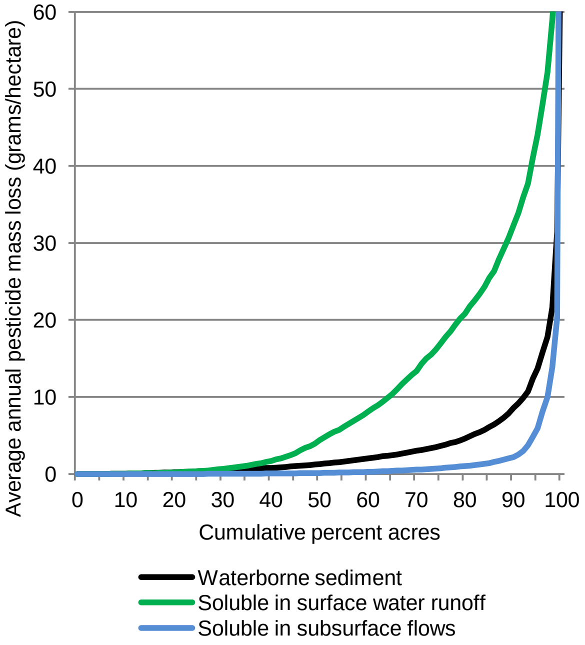
The average annual amount of pesticide lost from farm fields in the Upper Mississippi River Basin is about 16 grams of active ingredient per hectare per year (table 21).[22] As was observed for sediment and nutrient loss, the majority of pesticide loss occurs on a minority of acres within the Upper Mississippi River Basin (fig. 44). The median loss is only 8 grams per hectare.

In the model simulations, the pesticide applied in the largest amount throughout the region was glyphosate at 28 percent of the total weight of pesticides applied, followed closely by atrazine at 23 percent (table 22). The herbicides acetochlor and S-metolachlor represented 18 and 9 percent, respectively, of the total weight of pesticides applied. These four pesticides accounted for 78 percent of the pesticides applied in the region, by weight.

The most common pesticide residues lost from farm fields are atrazine (43 percent of total mass loss), acetochlor (15 percent), S-metolachlor (11 percent), and glyphosate (8 percent) (table 22). Sulfentrazone, metolachlor, and dimethenamide-P each represent 2 to 4 percent of the total mass loss. These seven pesticides account for 86 percent of all pesticide residues lost from fields in the model simulations for the Upper 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, Upper Mississippi River Basin, baseline conservation condition



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[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 Upper 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)	1,634	2,014	380	19
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	15.8	24.5	8.6	35
Edge-of-field pesticide risk indicator				
Average annual surface water pesticide risk indicator for aquatic ecosystems	3.62	6.17	2.55	41
Average annual surface water pesticide risk indicator for humans	0.74	1.14	0.40	35
Average annual groundwater pesticide risk indicator for humans	0.12	0.16	0.05	28

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 14 subregions.

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

Pesticide (active ingredient name)	Pesticide type	Percent of total applied in the region
Pesticide application*		
Glyphosate, isopropylamine salt	Herbicide	28
Atrazine	Herbicide	23
Acetochlor	Herbicide	18
S-Metolachlor	Herbicide	9
Metolachlor	Herbicide	2
Pendimethalin	Herbicide	2
Dimethenamide-P	Herbicide	2
Chlorpyrifos	Insecticide	2
Trifluralin	Herbicide	1
Dimethenamid	Herbicide	1
Glyphosate	Herbicide	<1
Glyphosate-trimesium	Herbicide	<1
Alachlor	Herbicide	<1
2,4-D 2-ethylhexyl ester	Herbicide	<1
Total		90
		Percent of total pesticide loss in the region**
Pesticide loss from farm fields*		
Atrazine	Herbicide	43
Acetochlor	Herbicide	15
S-Metolachlor	Herbicide	11
Glyphosate, isopropylamine salt	Herbicide	8
Sulfentrazone	Herbicide	4
Metolachlor	Herbicide	3
Dimethenamide-P	Herbicide	2
Pendimethalin	Herbicide	1
Simazine	Herbicide	1
Dimethenamid	Herbicide	1
Flufenacet	Herbicide	<1
2,4-D 2-ethylhexyl ester	Herbicide	<1
Dicamba, potassium salt	Herbicide	<1
Alachlor	Herbicide	<1
Mesotrione	Herbicide	<1
Total		93

* 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. Use of conservation practices has reduced the loss of pesticides (summed over all pesticides) by an average of 8.6 grams of active ingredient per hectare per year, a 35-percent reduction from the 24.5 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 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 163 pesticides included in the model for the Upper Mississippi River Basin.[23]

Risk indicator values of less than 1 are considered “safe” because the 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 43 percent of the cropped acres for risk to aquatic ecosystems, 23 percent of the cropped acres for surface water risk to humans, and 1.5 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 in some years the edge-of-field concentrations can be high relative to "safe" thresholds for some acres. The pesticide risk indicator for aquatic ecosystems averaged 3.62 over all years and cropped acres (table 21) for the baseline conservation condition. (The 3.62 value indicates that pesticide concentrations in water leaving cropped fields in the Upper Mississippi River Basin are, on average, 3.62 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 1.38 (fig. 46).

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[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.

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

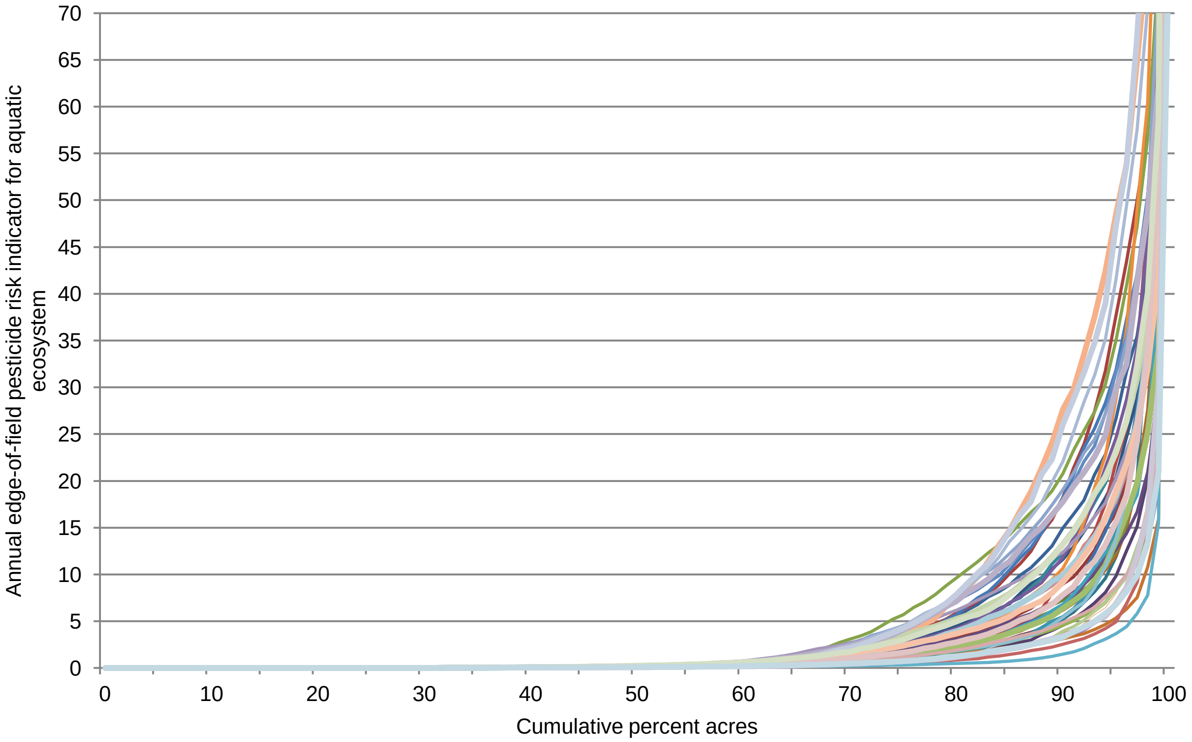
Two aquatic toxicity thresholds were used in estimating potential risk:

- 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, Upper 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	43
Acetochlor	Herbicide	15
Phostebupirim	Insecticide	4
Sulfentrazone	Herbicide	4
2,4-D, 2-ethylhexyl ester	Herbicide	4
Metolachlor	Herbicide	3
Chlorpyrifos	Insecticide	1
Tefluthrin	Insecticide	<1
S-Metolachlor	Herbicide	<1
Alachlor	Herbicide	<1
All other pesticides combined		2
Risk indicator for humans, surface water		
Atrazine	Herbicide	23
Alachlor	Herbicide	<1
Simazine	Herbicide	<1
Acetochlor	Herbicide	<1
All other pesticides combined		<1
Risk indicator for humans, groundwater		
Atrazine	Herbicide	1.5
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, Upper 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 0.74 for surface water and 0.12 for groundwater (table 21). The median values are 0.46 for surface water and 0.01 for groundwater. About 27 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 Upper Mississippi River Basin has reduced the pesticide risk indicators by 28 to 41 percent (table 21), averaged over all years, all pesticides, and all cropped acres.

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 38 percent of the acres, while significant risk reductions for humans occur on only about 11 percent of the acres. The benefits of conservation practices were significant for both aquatic risks and human risks on the acres that had those risks, but because aquatic risks were more widespread than human risks so 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 Upper Mississippi River Basin

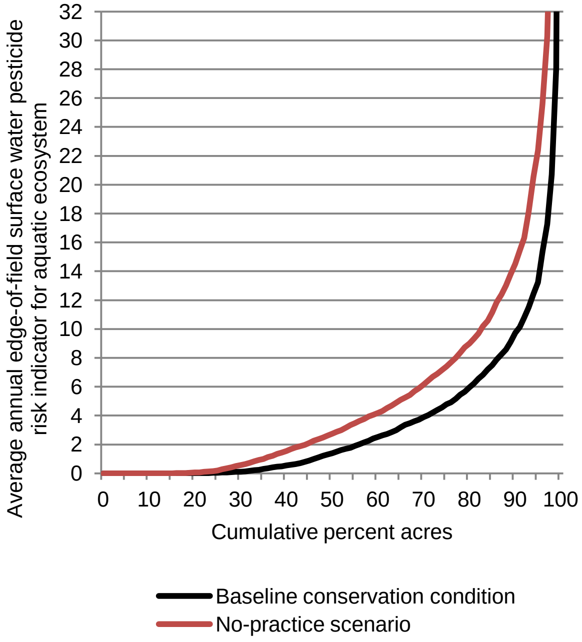


Figure 47. Estimates of average annual edge-of-field surface water pesticide risk indicator for humans in the Upper Mississippi River Basin

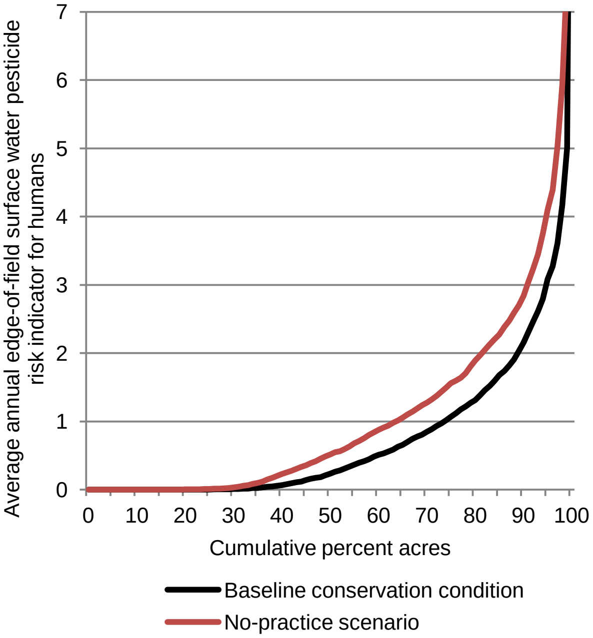
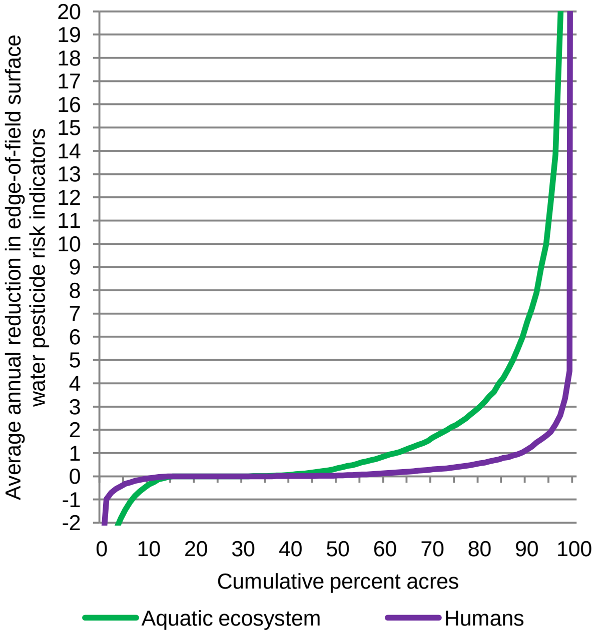


Figure 48. Estimates of average annual reductions in the edge-of-field surface water pesticide risk indicators for aquatic ecosystems in the Upper Mississippi River Basin



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 Upper 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 Upper Mississippi River Basin indicate that—

- *15 percent of cropped acres (9 million acres) have a* ***high*** *level of need for additional conservation treatment,*
- *45 percent of cropped acres (26 million acres) have a* ***moderate*** *level of need for additional conservation treatment, and*
- *40 percent of cropped acres (23 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 Upper 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 Upper Mississippi River Basin.

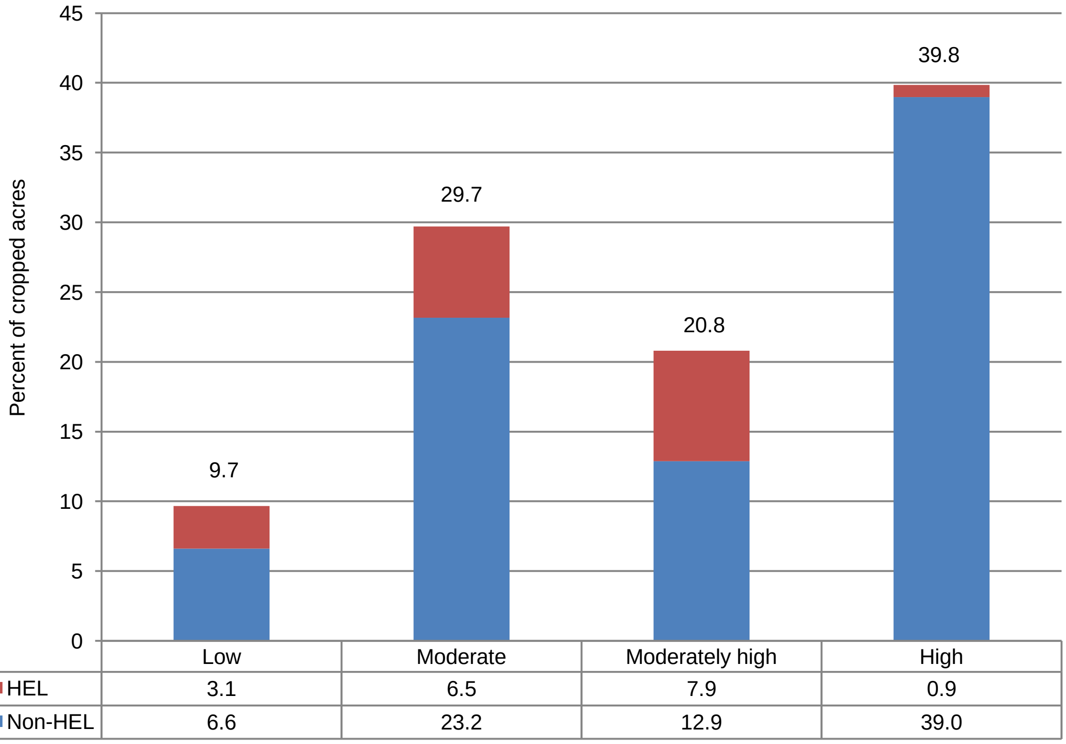
For sediment loss due to water erosion, conservation treatment levels were defined by a combination of structural practices and residue and tillage management practices, as defined in figure 49. A high level of water erosion control treatment is in use on about 40 percent of cropped acres, primarily on non-highly erodible land. About 21 percent have a moderately high level of conservation treatment. About 39 percent of cropped acres have a moderate or low level of conservation treatment for water erosion control, including about half 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 3 percent of cropped acres. The bulk of cropped acres—89 percent—have combinations of practices that indicate a moderately high or moderate level of treatment. About 8 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 11 percent of the acres. About 78 percent of cropped acres have combinations of practices that indicate a moderately high or moderate level of treatment. About 11 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 11 percent of the acres. About 69 percent of cropped acres have combinations of practices that indicate a moderately high or moderate level of treatment. About 20 percent of cropped acres have a low level of nitrogen management.

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



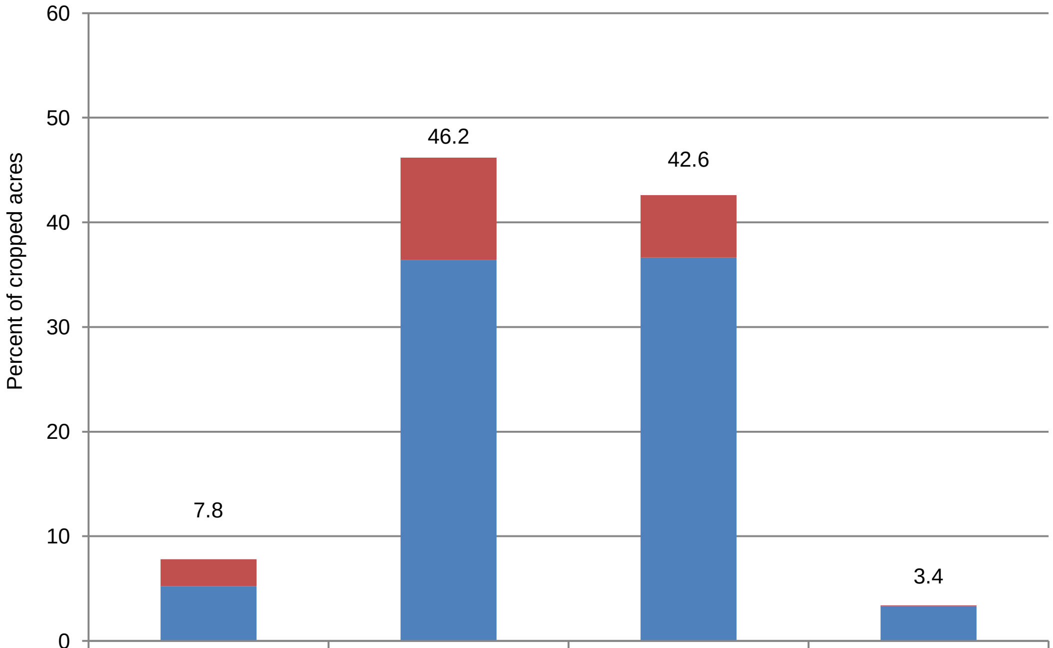
	Low	Moderate	Moderately high	High
🟥 HEL	3.1	6.5	7.9	0.9
🟦 Non-HEL	6.6	23.2	12.9	39.0

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 18 percent of cropped acres in the Upper 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, Upper Mississippi River Basin



	Low	Moderate	Moderately high	High
🟥 HEL	2.6	9.8	6.0	0.1
🟦 Non-HEL	5.2	36.4	36.6	3.3

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:

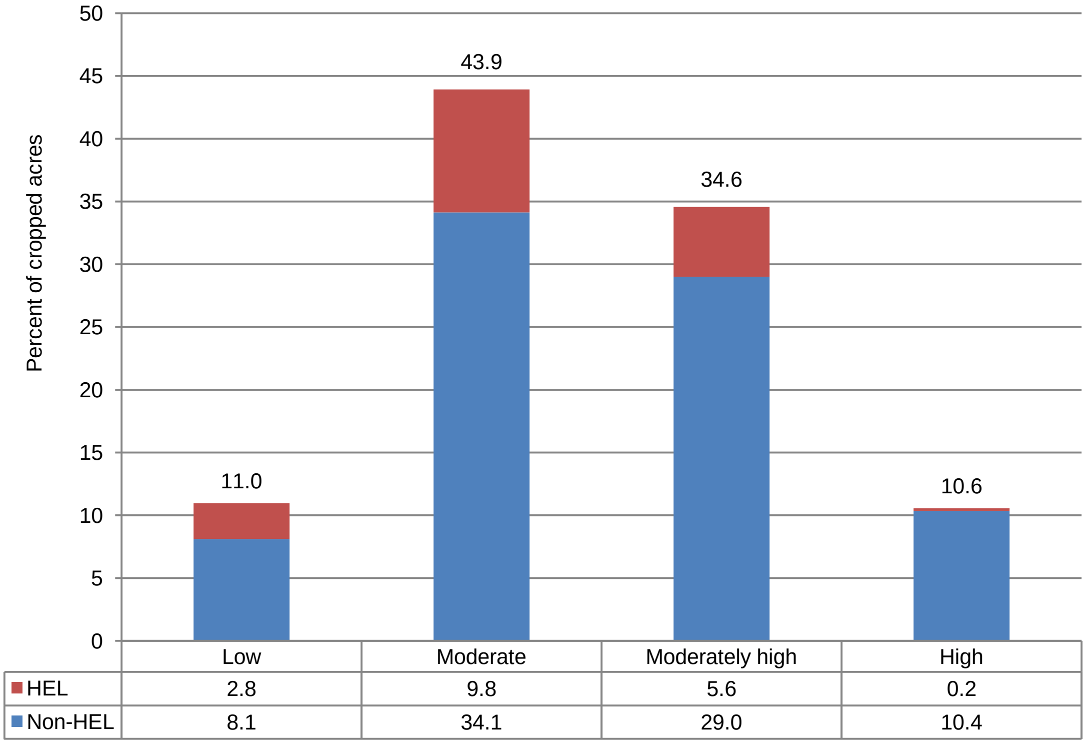
- **High treatment**: Sum of residue and tillage management score and nitrogen management score is equal to 8. (High treatment level for both structural practices and nitrogen management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores 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 18 percent of cropped acres in the Upper 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, Upper Mississippi River Basin



	Low	Moderate	Moderately high	High
🟥 HEL	2.8	9.8	5.6	0.2
🟦 Non-HEL	8.1	34.1	29.0	10.4

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 18 percent of cropped acres in the Upper 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.

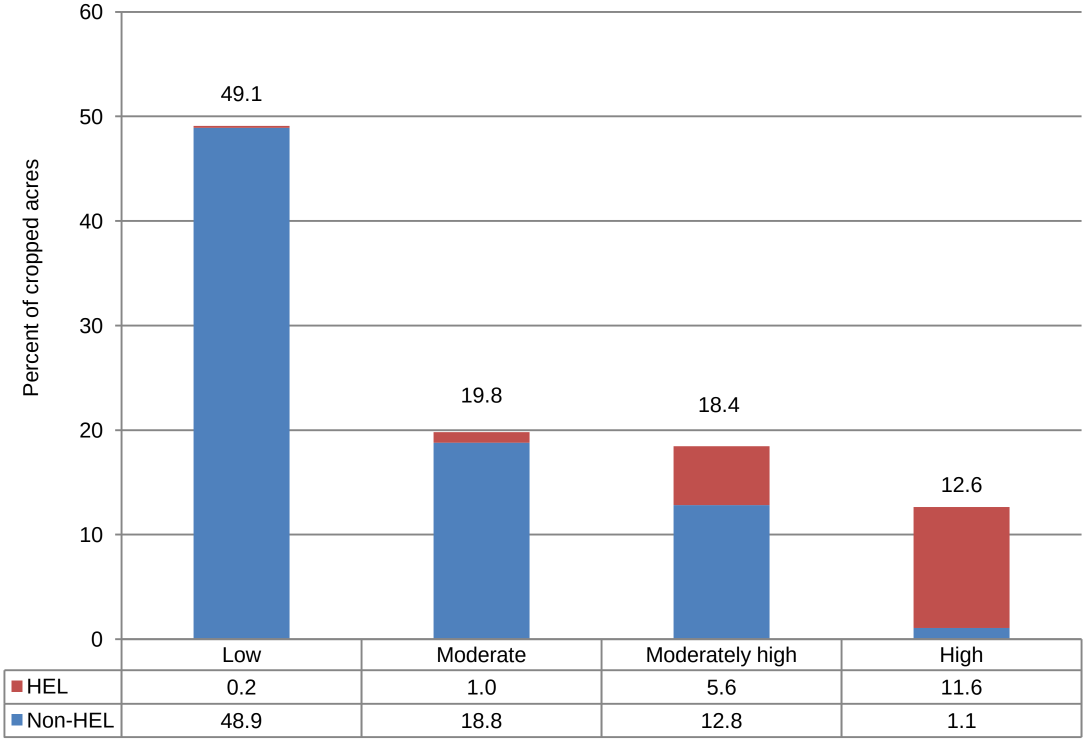
The criteria for the soil runoff potential are presented in figure 52, followed by the spatial distribution of the soil runoff potential within the Upper Mississippi River Basin in figure 53. The criteria and spatial distribution for the soil leaching potential are presented in figures 54 and 55.

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.

Cropped acres in the Upper Mississippi River Basin are a mix of vulnerable and non-vulnerable acres. About 49 percent of cropped acres have a low soil runoff potential (fig. 52). About 13 percent of the acres have a high soil runoff potential, consisting mostly of highly erodible land, and 38 percent have a moderate or moderately high soil runoff potential.

Few cropped acres in this region have a high or moderately high soil leaching potential—9.6 percent (fig. 54). The bulk of cropped acres—69 percent—have a moderate soil leaching potential. The remaining 22 percent have a low soil leaching potential.

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



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:

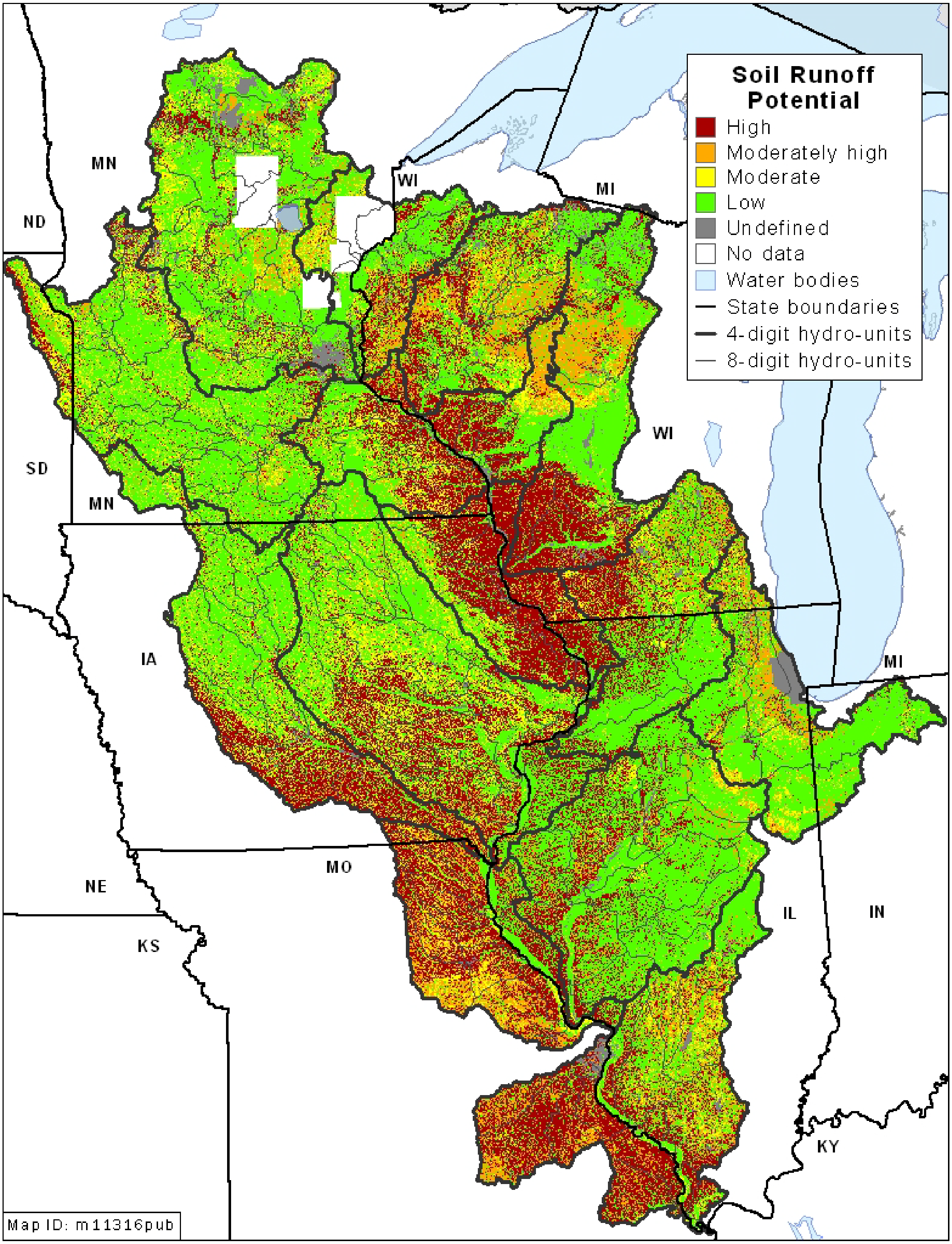
- **Group A—**sand, loamy sand, or sandy loam soils that have low runoff potential and high infiltration rates even when thoroughly wetted.
- **Group B**—silt loam or loam soils that have moderate infiltration rates when thoroughly wetted.
- **Group C**—sandy clay loam soils that have low infiltration 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 18 percent of cropped acres in the Upper Mississippi River Basin are highly erodible land.

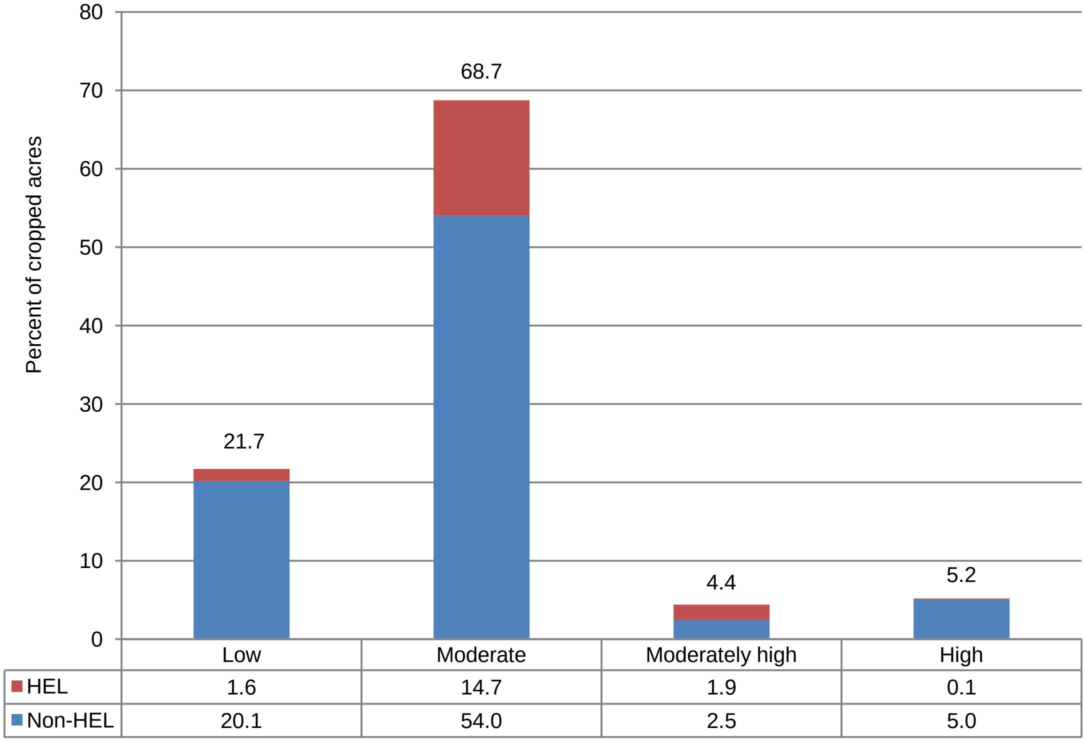
Note: See appendix B, table B4, for a breakdown of soil runoff potential by subregion.

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



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:

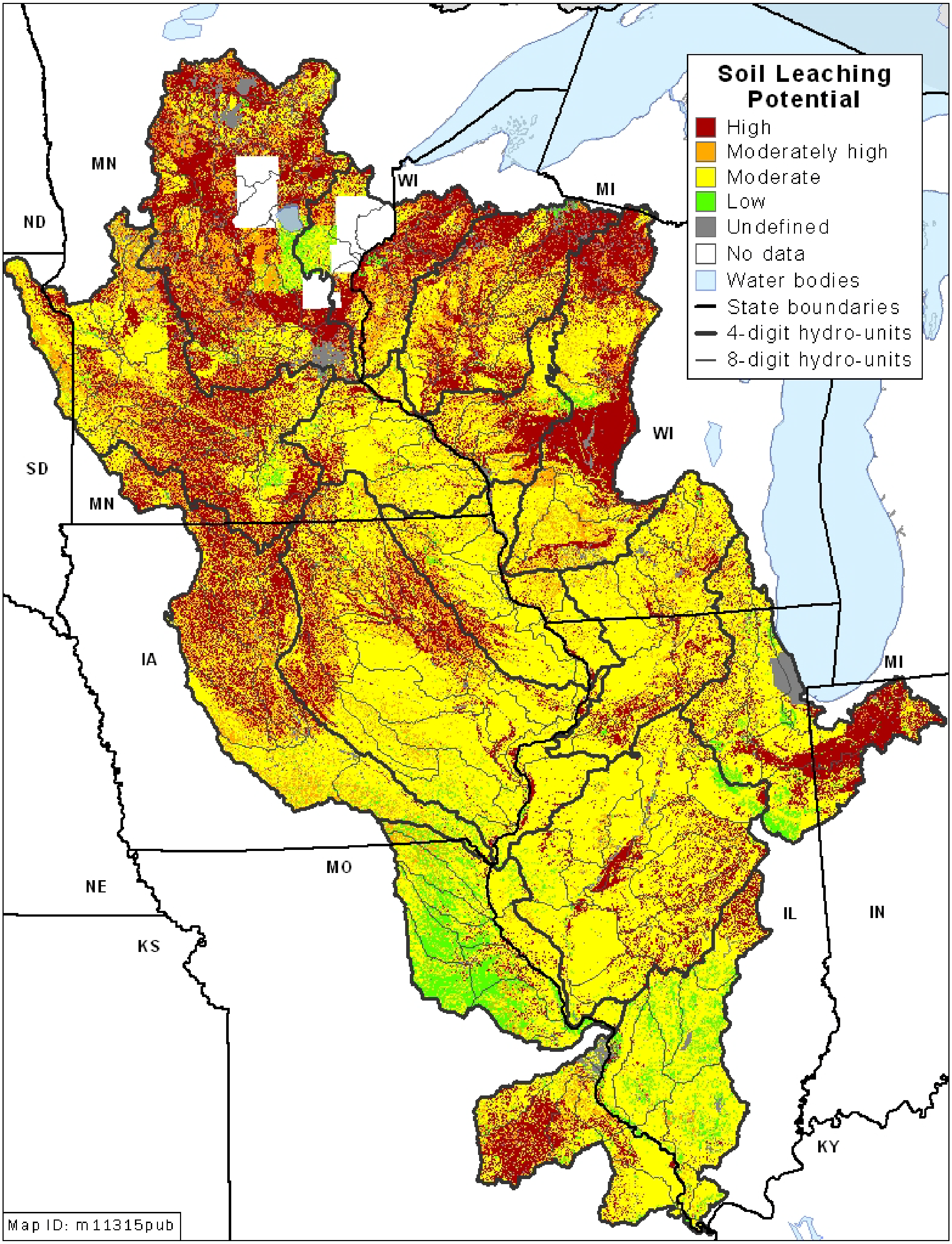
- **Group A**—sand, loamy sand, or sandy loam soils that have low runoff potential and high infiltration rates even when thoroughly wetted.
- **Group B**—silt loam or loam soils that have moderate infiltration rates when thoroughly wetted.
- **Group C**—sandy clay loam soils that have low infiltration 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 18 percent of cropped acres in the Upper 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 Upper Mississippi River Basin

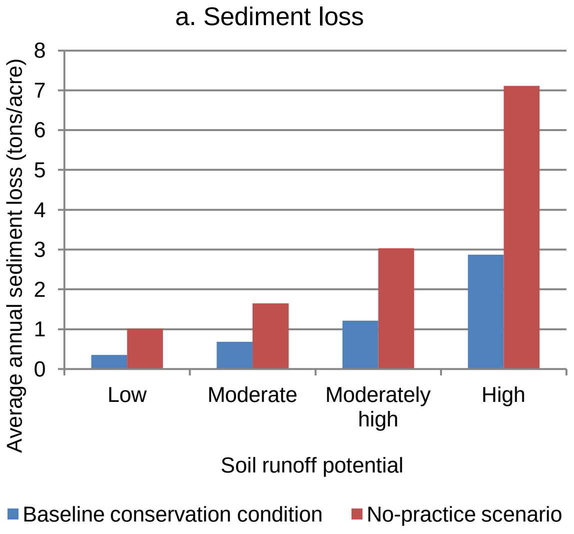


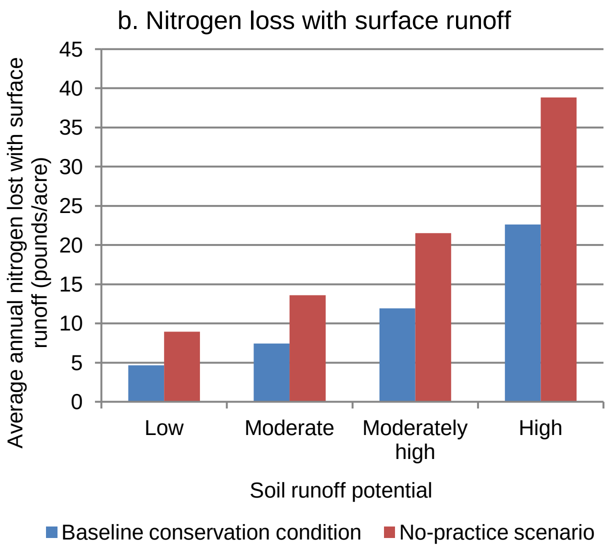
Note: The soil leaching potential shown in this map was derived using the criteria presented in figure 54 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

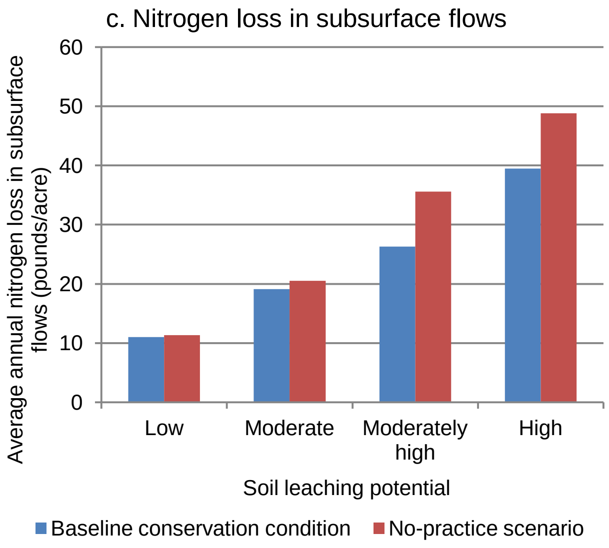
Estimates of sediment and nutrient losses for the no-practice scenario (without conservation practices), presented in figure 56, demonstrate how vulnerability factors influence losses in the Upper Mississippi River Basin. Estimates for the baseline are also presented in figure 56 to show how current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

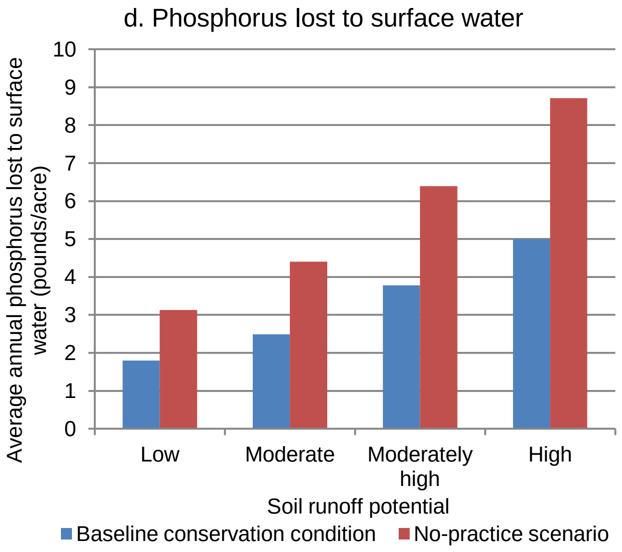
- Sediment loss for the high soil runoff potential would have averaged 7.1 tons per acre per year without conservation practices, compared to 1.0 ton per acre per year for the low soil runoff potential (fig. 56a).
- Nitrogen loss with surface runoff for the high soil runoff potential would have averaged 39 pounds per acre per year, compared to 9 pounds per acre per year for the low soil runoff potential (fig. 56b).
- Nitrogen loss in subsurface flows for the high soil leaching potential would have averaged 49 pounds per acre per year, compared to 11 pounds per acre per year for the low soil leaching potential (fig. 56c).
- Phosphorus lost to surface water for the high soil runoff potential would have averaged 8.7 pounds per acre per year, compared to 3.1 pounds per acre per year for the low soil runoff potential (fig. 56d).

Figure 56. Average annual sediment and nutrient losses for four levels of vulnerability potentials, Upper 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 due to soils and climate. These acres are referred to as “undertreated acres.” Cropped acres were divided into 16 groups defined by 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 soil runoff or soil leaching potential.

The high treatment levels are effective in reducing losses for all soil potentials, compared to the low treatment level, as shown in figures 57 through 60 using the results for the baseline conservation condition.

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. The average results for each of the 16 groups of acres reveal the following trends:

- Estimates of sediment and nutrient loss for the no-practice scenario consistently increased from small losses for the low soil runoff or leaching potential to large losses for the high soil runoff or leaching potential (also shown in fig. 56). As the no-practice scenario represents crop production without conservation practices, there is no consistent relationship in loss estimates among the four conservation treatment levels. The differences in losses among conservation treatment levels reflect the underlying variability, which is also influenced by the number of acres in each group.
- Estimates of sediment and nutrient loss for the baseline conservation condition exhibit a nearly consistent trend of decreasing loss with increasing treatment level within each soil runoff or leaching potential.
- The highest losses in the baseline conservation condition were for groups of acres where the conservation treatment level was one step or more below the soil leaching or runoff potential.

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

Figure 57. Trend in average annual sediment loss for increasing levels of soil runoff potential at two levels of conservation treatment, Upper Mississippi River Basin.

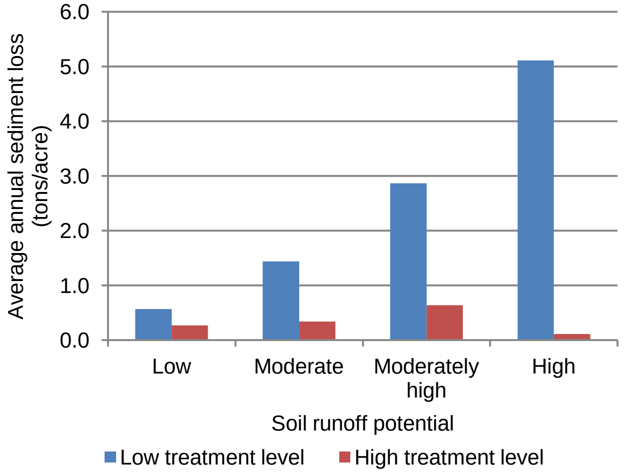


Figure 58. Trend in average annual nitrogen loss with surface runoff for increasing levels of soil runoff potential at two levels of conservation treatment, Upper Mississippi River Basin.

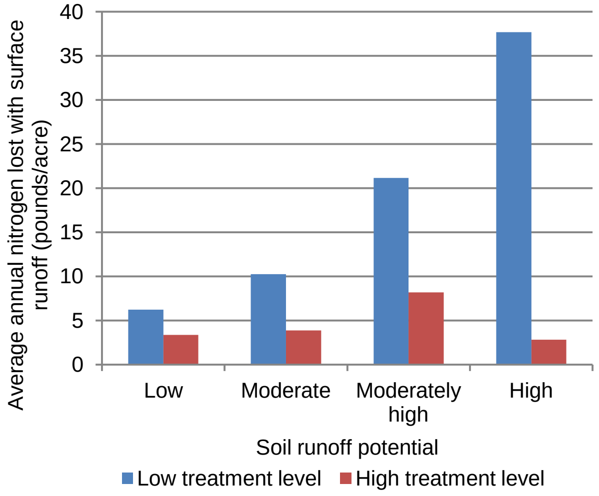
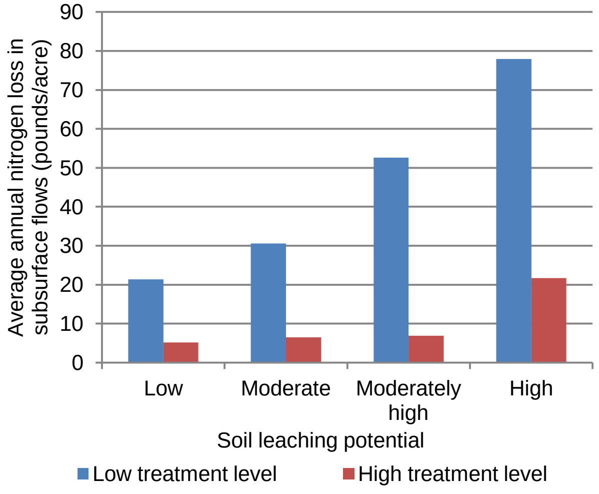


Figure 59. Trend in average annual nitrogen loss in subsurface flows for increasing levels of soil leaching potential at two levels of conservation treatment, Upper Mississippi River Basin



- **Acres with a "moderate" level of need** for conservation treatment consist of undertreated 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 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.

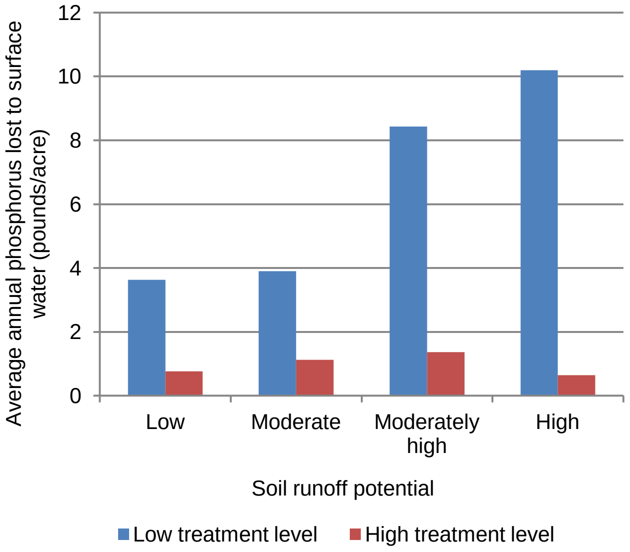
- **Acres with a "low" level of need** for conservation treatment consist of acres that are adequately treated with respect to the level of inherent vulnerability. While gains can be obtained by adding conservation practices to some of these acres, additional conservation treatment would reduce field losses by only a small amount.

Specific criteria were used to identify the groups of acres that fall into each of the three levels of conservation treatment need. Criteria were not tailored to a specific region, but were derived for use in all regions of the country to allow for comparisons of undertreated 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" for field-level losses used in this study are[25]—
   - 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
   - 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 (orange).
4. The remaining acres were designated as having a **moderate level of conservation treatment need**, indicated by lighter shaded cells in the matrix (yellow).

Figure 60. Trend in average annual phosphorus lost to surface water for increasing levels of soil runoff potential at two levels of conservation treatment, Upper Mississippi River Basin.



Undertreated 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, undertreated acres consisted of acres where the conservation treatment level was one step or more below the soil leaching or runoff potential (indicated by the red boundary shown in the baseline conservation condition matrix).

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 Upper 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 undertreated acres are (see the next chapter)—

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

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[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.

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 often used in regulatory schemes to denote compliance versus non-compliance.

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 Upper Mississippi River Basin

	Conservation treatment levels for water erosion control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	1,466,847	7,585,408	3,899,592	15,597,704	28,549,550
Moderate	1,338,413	3,427,681	1,923,803	4,834,143	11,524,041
Moderately high	1,495,790	3,410,211	3,373,100	2,447,773	10,726,875
High	1,318,396	2,845,120	2,896,985	292,534	7,353,035
All	5,619,446	17,268,420	12,093,480	23,172,155	58,153,500
Percent of cropped acres					
Low	3	13	7	27	49
Moderate	2	6	3	8	20
Moderately high	3	6	6	4	18
High	2	5	5	1	13
All	10	30	21	40	100
Sediment loss estimates *without* conservation practices (no-practice scenario, average annual tons/acre)					
Low	0.82	0.87	1.49	0.98	1.01
Moderate	1.88	1.77	2.57	1.14	1.65
Moderately high	3.59	2.81	3.67	2.11	3.03
High	7.14	7.51	6.72	7.03	7.11
All	3.29	2.53	3.52	1.21	2.28
Sediment loss estimates for the baseline conservation condition (average annual tons/acre)					
Low	0.57	0.42	0.43	0.27	0.35
Moderate	1.44	0.88	0.63	0.34	0.68
Moderately high	2.87	1.32	0.8	0.64	1.21
High	5.11	3.46	1.55	0.11	2.87
All	2.45	1.19	0.83	0.32	0.89
Percent reduction in sediment loss due to conservation practices					
Low	30	51	71	72	65
Moderate	23	50	75	70	59
Moderately high	20	53	78	70	60
High	28	54	77	98	60
All	25	53	76	73	61
Percent of acres in baseline conservation condition with average annual sediment loss more than 2 tons/acre					
Low	5	1	1	<1	1
Moderate	20	9	4	0	6
Moderately high	62	21	7	<1	17
High	79	67	25	0	50
All	41	17	9	0	11
Estimate of undertreated acres					
Low	0	0	0	0	0
Moderate	0	0	0	0	0
Moderately high	1,495,790	0	0	0	1,495,790
High	1,318,396	2,845,120	0	0	4,163,516
All	2,814,186	2,845,120	0	0	5,659,307

Note: Cells below the red boundary shown for the baseline conservation condition are the acres where the level of conservation treatment is one step or more below the soil runoff potential. These cells consistently had the highest losses in the model simulations.

Note: Color-shaded cells indicate undertreated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as undertreated acres. Darker color-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.

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

	Conservation treatment levels for nitrogen runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	1,304,417	12,313,068	13,609,280	1,322,786	28,549,550
Moderate	932,807	5,306,843	4,854,402	429,988	11,524,041
Moderately high	1,169,976	5,166,471	4,196,585	193,843	10,726,875
High	1,125,334	4,075,304	2,119,507	32,889	7,353,035
All	4,532,534	26,861,685	24,779,774	1,979,506	58,153,500
Percent of cropped acres					
Low	2	21	23	2	49
Moderate	2	9	8	1	20
Moderately high	2	9	7	<1	18
High	2	7	4	<1	13
All	8	46	43	3	100
Estimates of nitrogen loss with surface runoff *without* conservation practices (no-practice scenario, average annual pounds/acre)					
Low	10	9	9	7	9
Moderate	16	14	13	10	14
Moderately high	26	22	20	17	22
High	45	38	37	33	39
All	24	17	14	9	16
Estimates of nitrogen loss with surface runoff for the baseline conservation condition (average annual pounds/acre)					
Low	6	5	4	3	5
Moderate	10	9	6	4	7
Moderately high	21	13	8	8	12
High	38	23	15	3	23
All	19	10	6	4	9
Percent reduction in nitrogen loss with surface runoff due to conservation practices					
Low	40	42	54	54	48
Moderate	35	38	55	61	45
Moderately high	19	40	60	52	45
High	17	40	61	92	42
All	23	40	57	57	45
Percent of acres in baseline conservation condition with average annual nitrogen loss with surface runoff more than 15 pounds/acre					
Low	11	4	<1	0	3
Moderate	15	11	1	0	7
Moderately high	66	35	9	0	28
High	89	64	43	0	62
All	45	21	6	0	15
Estimate of undertreated acres for nitrogen loss with surface runoff					
Low	0	0	0	0	0
Moderate	0	0	0	0	0
Moderately high	1,169,976	5,166,471	0	0	6,336,446
High	1,125,334	4,075,304	2,119,507	0	7,320,146
All	2,295,310	9,241,775	2,119,507	0	13,656,592

Note: Cells below the red boundary shown for the baseline conservation condition are the acres where the level of conservation treatment is one step or more below the soil runoff potential. These cells consistently had the highest losses in the model simulations.

Note: Color-shaded cells indicate undertreated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as undertreated acres. Darker color-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.

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

	Conservation treatment levels for nitrogen management				
Soil leaching potential	Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	2,180,025	4,287,894	4,660,222	1,495,398	12,623,538
Moderate	8,542,782	16,135,462	11,447,641	3,833,986	39,959,870
Moderately high	529,397	890,546	749,925	384,512	2,554,380
High	250,469	1,241,745	1,021,216	502,282	3,015,713
All	11,502,673	22,555,647	17,879,003	6,216,177	58,153,500
Percent of cropped acres					
Low	4	7	8	3	22
Moderate	15	28	20	7	69
Moderately high	1	2	1	1	4
High	<1	2	2	1	5
All	20	39	31	11	100
Estimates of nitrogen loss in subsurface flows *without* conservation practices (no-practice scenario, average annual pounds/acre)					
Low	19	10	10	8	11
Moderate	31	22	15	11	20
Moderately high	66	36	27	11	36
High	77	51	42	42	49
All	31	22	15	13	21
Estimates of nitrogen loss in subsurface flows for the baseline conservation condition (average annual pounds/acre)					
Low	21	13	6	5	11
Moderate	31	23	9	6	19
Moderately high	53	29	14	7	26
High	78	52	24	22	39
All	31	23	9	7	19
Percent reduction in nitrogen loss in subsurface flows due to conservation practices					
Low	-11	-27	35	35	2
Moderate	0	-7	38	39	7
Moderately high	20	18	48	38	26
High	-1	-1	43	49	19
All	1	-7	39	41	9
Percent of acres in baseline conservation condition with average annual nitrogen loss in subsurface flows more than 25 pounds/acre					
Low	18	10	1	0	7
Moderate	35	32	3	1	21
Moderately high	53	47	13	0	31
High	88	79	22	16	50
All	34	31	4	2	20
Estimate of undertreated acres for nitrogen loss in subsurface flows					
Low	0	0	0	0	0
Moderate	8,542,782	16,135,462	0	0	24,678,244
Moderately high	529,397	890,546	0	0	1,419,943
High	250,469	1,241,745	0	0	1,492,215
All	9,322,648	18,267,753	0	0	27,590,402

Note: Cells below the red boundary shown for the baseline conservation condition are the acres where the level of conservation treatment is one step or more below the soil leaching potential. These cells consistently had the highest losses in the model simulations.

Note: Color-shaded cells indicate undertreated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as undertreated acres. Darker color-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.

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 Upper Mississippi River Basin

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	2,337,873	11,417,013	10,510,662	4,284,003	28,549,550
Moderate	1,332,290	5,142,787	3,930,652	1,118,313	11,524,041
Moderately high	1,494,094	4,962,554	3,593,770	676,456	10,726,875
High	1,209,940	4,019,108	2,064,982	59,004	7,353,035
All	6,374,196	25,541,463	20,100,066	6,137,775	58,153,500
Percent of cropped acres					
Low	4	20	18	7	49
Moderate	2	9	7	2	20
Moderately high	3	9	6	1	18
High	2	7	4	<1	13
All	11	44	35	11	100
Phosphorus lost to surface water *without* conservation practices (no-practice scenario, average annual pounds/acre)					
Low	4.98	3.2	2.88	2.56	3.13
Moderate	5.1	4.3	4.48	3.78	4.4
Moderately high	10.43	6.13	5.43	4.52	6.39
High	12.64	8.38	7.1	6.68	8.71
All	7.74	4.8	4.08	3.04	4.69
Phosphorus lost to surface water for the baseline conservation condition (average annual pounds/acre)					
Low	3.64	2.38	1.18	0.77	1.8
Moderate	3.9	3.06	1.65	1.12	2.49
Moderately high	8.43	3.99	2.02	1.37	3.78
High	10.2	4.85	2.34	0.64	4.99
All	6.06	3.22	1.54	0.9	2.7
Percent reduction in phosphorus lost to surface water due to conservation practices					
Low	27	26	59	70	43
Moderate	24	29	63	70	43
Moderately high	19	35	63	70	41
High	19	42	67	90	43
All	22	33	62	70	42
Percent of acres in baseline conservation condition with average annual phosphorus lost to surface water more than 4 pounds/acre					
Low	29	13	2	<1	8
Moderate	31	24	2	0	15
Moderately high	75	30	8	<1	27
High	88	47	12	0	44
All	51	24	4	0	17
Estimate of undertreated acres for phosphorus lost to surface water					
Low	0	0	0	0	0
Moderate	1,332,290	0	0	0	1,332,290
Moderately high	1,494,094	4,962,554	0	0	6,456,648
High	1,209,940	4,019,108	0	0	5,229,048
All	4,036,323	8,981,663	0	0	13,017,986

Note: Cells below the red boundary shown for the baseline conservation condition are the acres where the level of conservation treatment is one step or more below the soil runoff potential. These cells consistently had the highest losses in the model simulations.

Note: Color-shaded cells indicate undertreated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as undertreated acres. Darker color-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.

Conservation treatment needs by resource concern

The proportion of cropped acres with a high or moderate need for additional conservation treatment was determined to be (fig. 61)—

- 9.7 percent for sediment loss (all with a high need for treatment),
- 23.5 percent for nitrogen loss with runoff (11.0 percent with a high need for treatment),
- 22.4 percent for phosphorus lost to surface water (4.6 percent with a high need for treatment),
- 47.4 percent for nitrogen loss in subsurface flows (2.6 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.

Undertreated acres in the Upper Mississippi River Basin are presented by combinations of resource concerns in table 28. About 63 percent of the undertreated acres are undertreated for only one of the four resource concerns, primarily nitrogen leaching—

- 54.3 percent of undertreated acres are undertreated only for nitrogen leaching,
- 5.1 percent of undertreated acres are undertreated only for phosphorus runoff, and
- 3.4 percent of undertreated acres are undertreated only for nitrogen runoff.

About 8 percent of undertreated acres were determined to be undertreated for all four resource concerns. Nine percent of undertreated acres need additional treatment for nitrogen runoff and leaching and phosphorus runoff.

The most critical conservation concern in the region is the need for complete and consistent use of nutrient management—appropriate rate, form, timing, *and* method of application, especially for nitrogen loss in subsurface flows (fig. 61, table 28). Additional erosion control is also needed for a significant number of acres.

Figure 61. Percent of cropped acres that are undertreated in the Upper Mississippi River Basin, by resource concern

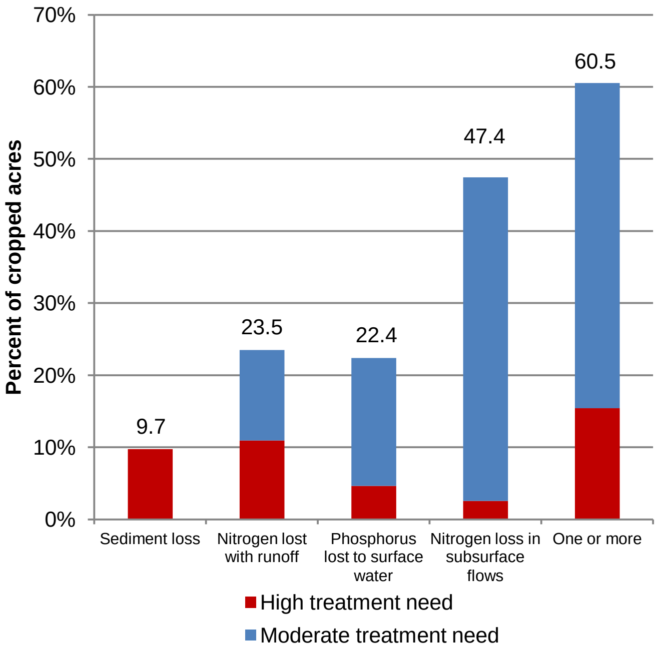


Table 28. Undertreated acres with resource concerns needing treatment in the Upper Mississippi River Basin

Reason for treatment need	Estimated acres needing treatment	Percent of cropped acres	Percent of undertreated acres
Nitrogen leaching only	19,103,106	32.8	54.3
Nitrogen runoff, nitrogen leaching and phosphorus runoff	3,258,370	5.6	9.3
Sediment loss, nitrogen and phosphorus runoff, and nitrogen leaching	2,912,163	5.0	8.3
Sediment loss, nitrogen runoff and phosphorus runoff	2,335,645	4.0	6.6
Phosphorus runoff and nitrogen runoff	2,073,511	3.6	5.9
Phosphorus runoff only	1,786,397	3.1	5.1
Nitrogen leaching and nitrogen runoff	1,452,844	2.5	4.1
Nitrogen runoff only	1,212,560	2.1	3.4
Nitrogen leaching and phosphorus runoff	651,900	1.1	1.9
Sediment loss, nitrogen runoff, and nitrogen leaching	212,020	0.4	0.6
Sediment loss and nitrogen runoff	199,480	0.3	0.6
All undertreated acres	35,197,994	100	100

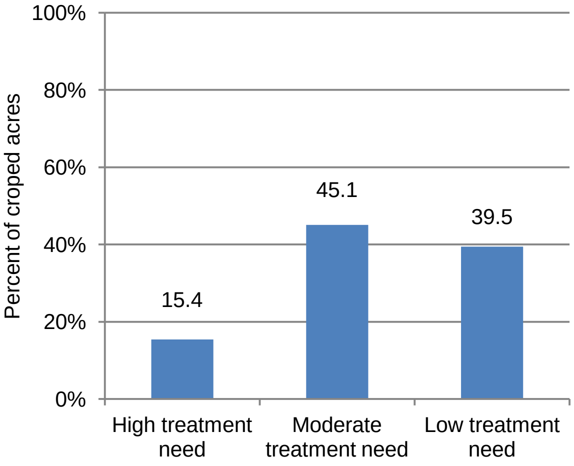
Note: This table summarizes the undertreated acres identified in tables 24-27 and reports the joint set of acres that need treatment according to combinations of resource concerns.
Note: Percents may not add to totals because of rounding.

Conservation treatment needs for one or more resource concern

After accounting for acres that need treatment for multiple resource concerns, the evaluation of treatment needs for the Upper Mississippi River Basin determined the following (fig. 62):

- 15 percent of cropped acres (9.0 million acres) have a **high** level of need for additional conservation treatment,
- 45 percent of cropped acres (26.2 million acres) have a **moderate** level of need for additional conservation treatment, and
- 40 percent of cropped acres (23.0 million acres) have a **low** level of need for additional treatment and are considered to be adequately treated.

Figure 62. 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 Upper Mississippi River Basin



High level of need for conservation treatment. These are the most vulnerable of the undertreated acres with the least conservation treatment and have the highest losses of sediment and/or nutrients. In the Upper Mississippi River Basin, these acres lose (per acre per year, on average) (table 29 and figs. 63 through 66)—

- 2.7 tons of sediment by water erosion,
- 5.3 pounds of phosphorus lost to surface water,
- 20.4 pounds of nitrogen with surface runoff, and
- 26.6 pounds of nitrogen in subsurface flows.

Acres with a high level of treatment need have the greatest potential for reducing agricultural pollutant loadings with additional conservation treatment.

Moderate level of need for conservation treatment. 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 sediment and nutrient losses are lower than those with a high need for additional treatment and thus there is less potential on a per-acre basis for reducing agricultural pollutant loadings with additional conservation treatment. In the Upper Mississippi River Basin, these acres lose (per acre per year, on average) (table 29 and figs. 63 through 66)—

- 0.69 ton of sediment by water erosion,
- 2.6 pounds of phosphorus lost to surface water,
- 7.8 pounds of nitrogen with surface runoff, and
- 23.6 pounds of nitrogen in subsurface flows.

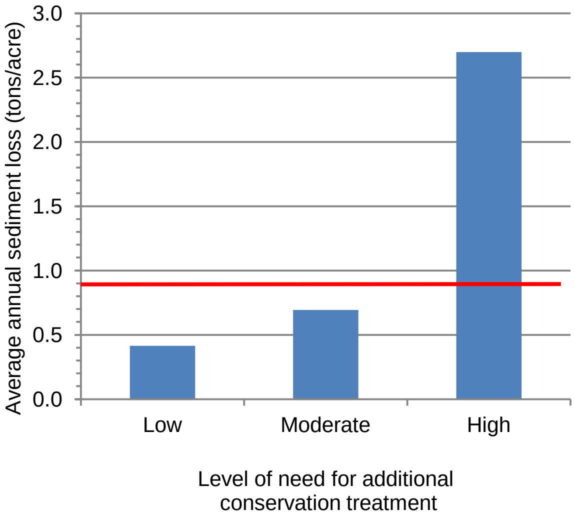
While the benefit of additional treatment of acres with a moderate level of treatment need is less than for acres with a high level of treatment need, a portion of these acres may need to be treated to meet water quality goals in the region.

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 Upper Mississippi River Basin, these acres lose (per acre per year, on average) (table 29 and figs. 63 through 66)—

- 0.41 ton of sediment by water erosion,
- 1.8 pounds of phosphorus lost to surface water,
- 5.4 pounds of nitrogen with surface runoff, and
- 10.2 pounds of nitrogen in subsurface flows.

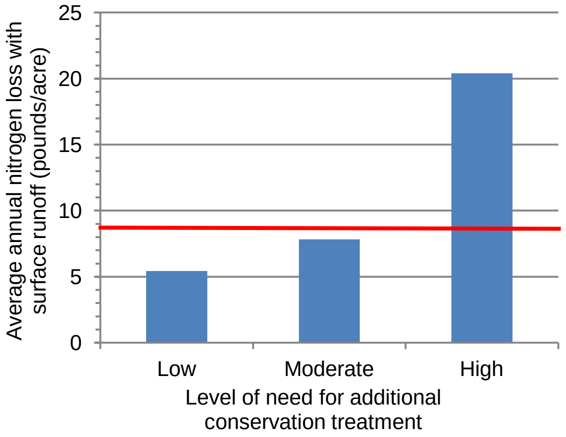
While gains can be obtained by adding conservation practices to some of these acres, additional conservation treatment would reduce field losses by only a small amount.

Figure 63. Average per-acre sediment loss for three levels of conservation treatment need for one or more resource concerns, Upper Mississippi River Basin



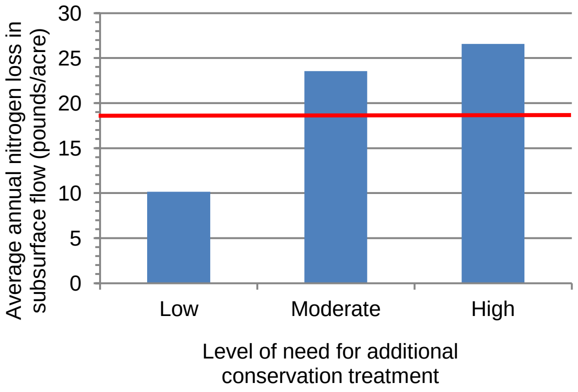
Note: The average sediment loss for all cropped acres is 0.89 tons per acre per year, shown in red.

Figure 64. Average per-acre nitrogen lost with surface runoff for three levels of conservation treatment need for one or more resource concerns, Upper Mississippi River Basin



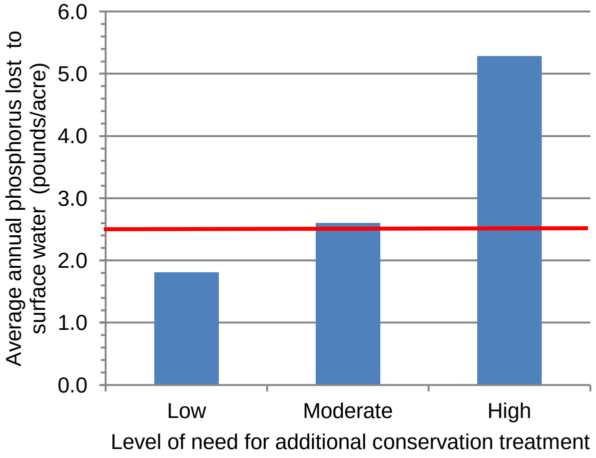
Note: The average nitrogen loss with surface water for all cropped acres is 8.82 pounds per acre per year, shown in red.

Figure 65. Average per-acre nitrogen loss in subsurface flow pathways for three levels of conservation treatment need for one or more resource concerns, Upper Mississippi River Basin



Note: The average nitrogen loss in subsurface flow pathways for all cropped acres is 18.72 pounds per acre per year, shown in red.

Figure 66. Average per-acre phosphorus lost to surface water for three levels of conservation treatment need for one or more resource concerns, Upper Mississippi River Basin



Note: The average phosphorus lost to surface water for all cropped acres is 2.7 pounds per acre per year, shown in red.

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 Upper 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	22,955,506	26,218,461	8,979,533	58,153,500
Percent of acres	39.5%	45.1%	15.4%	100.0%
Water flow				
Surface runoff (inches)	4.7	4.1	4.6	4.4
Subsurface water flow (inches)	5.6	6.2	6.9	6.0
Erosion and sediment loss				
Wind erosion (tons/acre)	0.23	0.22	0.28	0.23
Sheet and rill erosion (tons/acre)	0.49	0.83	2.09	0.89
Sediment loss at edge of field due to water erosion (tons/acre)	0.41	0.69	2.70	0.89
Soil organic carbon				
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	70	113	-48	71
Nitrogen				
Nitrogen sources (pounds/acre)				
Atmospheric deposition	8	8	8	8
Bio-fixation by legumes	63	54	50	57
Nitrogen applied as commercial fertilizer and manure	69	99	101	87
All nitrogen sources	140	161	159	152
Nitrogen in crop yield removed at harvest (pounds/acre)	111	110	107	110
Total nitrogen loss for all pathways (pounds/acre)	26.0	43.4	59.0	39.0
Loss of nitrogen through volatilization (pounds/acre)	6.1	7.6	7.3	6.9
Nitrogen returned to the atmosphere through denitrification (pounds/acre)	2.0	2.4	2.8	2.3
Loss of nitrogen with windborne sediment (pounds/acre)	2.3	2.0	2.0	2.1
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	5.4	7.8	20.4	8.8
Nitrogen loss in subsurface flows (pounds/acre)	10.2	23.6	26.6	18.7
Phosphorus				
Phosphorus applied (pounds/acre)	19.7	24.4	25.9	22.8
Phosphorus in crop yield removed at harvest (pounds/acre)	17.6	17.5	16.4	17.4
Total phosphorus loss for all pathways (pounds/acre)	2.2	3.0	5.8	3.2
Loss of phosphorus to surface water, including both soluble and sediment attached (pounds/acre)*	1.8	2.6	5.3	2.7
Loss of phosphorus with windborne sediment	0.4	0.4	0.5	0.4
Pesticide loss				
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	14.0	15.6	21.5	15.8
Surface water pesticide risk indicator for aquatic ecosystem	3.8	3.4	3.9	3.6
Surface water pesticide risk indicator for humans	0.7	0.7	0.8	0.7

* 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

The breakdown of undertreated acres by cropping system showed a generally proportionate distribution of undertreated acres among cropping systems, shown in table 30, indicating that no cropping system was more likely to be undertreated than other cropping systems. Percentages of undertreated acres are close to the same percentages for cultivated cropland in the region. The only exception was for the "soybean only" cropping system, which had a disproportionately low percentage of undertreated acres but only occurs on 3 percent of the acres in the region.

However, for the critical undertreated acres (acres with a high need for treatment), corn-soybean rotations have a disproportionately lower percentage of acres that need additional treatment (table 31). Corn-soybean rotations make up 74 percent of the cropped acres in the region, but only 54 percent of critical undertreated acres in the region. Overall, only 11 percent of corn-soybean rotations are critically undertreated. The other cropping systems in this region have a disproportionately higher number of acres needing additional conservation treatment. The most striking are corn and close-grown crops, hay-crop mixes, and remaining crop mixes. For these cropping systems, 32 to 41 percent of the acres are critically undertreated (table 31).

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

Cropping system	Percent of cropped acres in Upper Mississippi River Basin	Percent of undertreated acres in Upper Mississippi River Basin	Percent of undertreated acres in cropping system
Disproportionately high percentage of undertreated acres			
Corn and close-grown crops	1	2	81
Hay-crop mix	6	7	68
Corn only	9	10	67
Corn-soybean with close-grown crops	4	4	64
Remaining mix of crops	2	2	64
Disproportionately low percentage of undertreated acres			
Soybeans only	3	1	25
Soybean-wheat only	1	1	52
Corn-soybean only	74	73	60
Total	100.0	100.0	60.5*

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

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

Cropping system	Percent of cropped acres in Upper Mississippi River Basin	Percent of critical undertreated acres in Upper Mississippi River Basin	Percent of critical undertreated acres in cropping system
Disproportionately high percentage of critical undertreated acres			
Corn and close-grown crops	1	3	41
Hay-crop mix	6	15	38
Remaining mix of crops	2	5	32
Soybean-wheat only	1	2	27
Corn only	9	13	23
Corn-soybean with close-grown crops	4	5	19
Soybeans only	3	3	16
Disproportionately low percentage of critical undertreated acres			
Corn-soybean only	74	54	11
Total	100.0	100.0	15.4*

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

Conservation treatment needs by subregions

Undertreated acres in the Upper Mississippi River Basin are presented in table 32 by subregion. Percentages of undertreated acres are fairly close to the percentages of the region's cultivated cropland in most subregions, indicating that undertreated acres are generally spread proportionately throughout the region. The two regions with the largest percentages of undertreated acres are the Upper Mississippi-Maquoketa-Plum River Basin (code 0706) and the Chippewa River Basin (code 0705), where the percentage of undertreated acres in each subregion exceeds 75 percent. The average for the entire region is 60.5 percent. The region with the lowest proportion of undertreated acres is the Des Moines River Basin (code 0710), where the percentage of undertreated acres is about 50 percent.

Critical undertreated acres, however, are more disproportionately distributed throughout the region (table 33). Nine subregions have a disproportionately high percentage of the region's critical undertreated acres. The extent of critical undertreated acres exceeds 30 percent of cropped acres in three of the subregions [the Chippewa River Basin (code 0705), the Wisconsin River Basin (code 0707), and the St. Croix River Basin (code 0703)], compared to the regional average of 15.4 percent.

In contrast, three subregions have fewer than 10 percent of cropped acres that are critically undertreated—the Des Moines River Basin (code 0710), the Lower Illinois River Basin (code 0713), and the Minnesota River Basin (code 0702) (table 33).

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

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

Subregion	Percent of cropped acres in Upper Mississippi River Basin	Percent of undertreated acres in Upper Mississippi River Basin	Percent of undertreated acres in subregion
Disproportionately high percentage of undertreated acres			
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	4.5	5.9	79.3
Chippewa River Basin (code 0705)	1.5	1.9	76.6
Upper Mississippi-Black-Root Rivers (code 0704)	4.7	5.4	70.9
Rock River Basin (code 0709)	7.2	8.2	68.9
Lower Illinois River Basin (code 0713)	14.4	15.2	63.9
Upper Mississippi-Salt Rivers (code 0711)	4.8	4.8	61.0
Disproportionately low percentage of undertreated acres			
Des Moines River Basin (code 0710)	10.8	8.9	49.7
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	7.0	6.4	55.3
Upper Illinois River Basin (code 0712)	6.9	6.4	56.5
St. Croix River Basin (code 0703)	0.9	0.8	56.5
Minnesota River Basin (code 0702)	12.6	11.9	57.0
Wisconsin River Basin (code 0707)	2.3	2.3	58.1
Mississippi Headwaters (code 0701)	4.6	4.4	58.1
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	17.9	17.5	59.3
Total	100.0	100.0	60.5*

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

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

Subregion	Percent of cropped acres in Upper Mississippi River Basin	Percent of critical undertreated acres in Upper Mississippi River Basin	Percent of critical undertreated acres in subregion
Disproportionately high percentage of critical undertreated acres			
Chippewa River Basin (code 0705)	1.5	4.2	43.4
Wisconsin River Basin (code 0707)	2.3	5.4	35.3
St. Croix River Basin (code 0703)	0.9	1.9	33.0
Upper Mississippi-Black-Root Rivers (code 0704)	4.7	8.9	29.4
Mississippi Headwaters (code 0701)	4.6	8.1	27.3
Upper Mississippi-Salt Rivers (code 0711)	4.8	8.2	26.3
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	4.5	6.9	23.9
Rock River Basin (code 0709)	7.2	8.8	18.9
Upper Illinois River Basin (code 0712)	6.9	8.0	17.9
Disproportionately low percentage of critical undertreated acres			
Des Moines River Basin (code 0710)	10.8	4.1	5.9
Lower Illinois River Basin (code 0713)	14.4	7.2	7.8
Minnesota River Basin (code 0702)	12.6	6.8	8.3
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	17.9	14.7	12.7
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	7.0	6.9	15.1
Total	100.0	100.0	15.4*

Note: Percents may not add to totals because of rounding.
* Percent of critical undertreated acres in the Upper 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 Upper 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, 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 9.0 million critical undertreated acres (acres with a high need for conservation treatment) with water erosion control practices only.
2. Treatment of all 35.2 million undertreated acres (acres with a high or moderate need for conservation treatment) with water erosion control practices only.
3. Treatment of the 9.0 million critical undertreated acres with nutrient management practices in addition to water erosion control practices to address nutrient losses.
4. Treatment of all 35.2 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. The percent of potential savings represented by practices in use in 2003–06 are: 63 percent for sediment, 34 percent for nitrogen, and 58 percent for phosphorus. By treating all 35.2 million undertreated acres in the region with additional erosion control and nutrient management practices, an additional 32 percent in savings would be attained for sediment, 56 percent for nitrogen, and 33 percent for phosphorus. To achieve 100 percent of potential savings (i.e., an additional 6 percent for sediment and 9-10 percent for nitrogen and phosphorus), additional conservation treatment for the remaining 23.0 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 Missouri 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 Upper 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	286,884	1	286,884	1
Terrace only	109,197	1	241,374	1	350,571	1
Terrace plus overland flow practice	0	0	0	0	0	0
Filter only	1,482,828	17	11,364,097	43	12,846,925	36
Filter plus overland flow practice	945,898	11	4,381,069	17	5,326,967	15
Filter plus terrace	4,003,117	45	2,135,950	8	6,139,067	17
Filter plus overland flow practice plus terrace	0	0	0	0	0	0
Buffer only	790,924	9	4,350,728	17	5,141,652	15
Buffer plus overland flow practice	220,581	2	1,423,497	5	1,644,078	5
Buffer plus terrace	1,333,802	15	1,006,376	4	2,340,178	7
Buffer plus overland flow practice plus terrace	0	0	0	0	0	0
One or more additional practices	8,886,346	99	25,189,974	96	34,076,321	97
No structural practices	93,186	1	1,028,487	4	1,121,674	3
Total	8,979,533	100	26,218,461	100	35,197,994	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 about 8 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. This rule allows for late March applications of manure in the warmer climates of the Upper Mississippi River Basin. April 1 is near the period when the soils warm and become biologically active. However, this late date could begin to pressure manure storage capacities and it is recognized that this could create storage problems.

In the baseline condition, about 48 percent of the cropped acres in the Upper 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 ammonia 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 and the erosion control with nutrient management treatment scenarios. 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. Gravity systems and pressure systems were upgraded to center pivot or linear move sprinkler systems utilizing low-pressure sprinkler heads.[26]
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.

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[26] An exception is in rice production areas where gravity systems are required to flood the fields. In these areas, gated pipe replaced ditches in the treatment simulations. There were two sample points with rice in this region.

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, polymer coated products, nitrogen stabilizers, urease inhibitors, and nitrification inhibitors;
- drainage water management that controls discharge of drainage water and provides treatment of contaminants, thereby reducing the levels of nitrogen and even some soluble phosphorus loss;
- 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 9.0 million critical undertreated acres

Average annual model output is presented in table 35 for the 9.0 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 and nitrogen and phosphorus lost to surface water. Sediment loss would be reduced to an annual average of about 0.13 ton per acre per year for these acres, a 95-percent reduction. Nitrogen loss with surface runoff would be reduced to 4.3 pounds per acre per year on average (79-percent reduction), and phosphorus lost to surface water would be reduced to 2.06 pounds per acre per year (61-percent reduction).

However, the re-routing of surface water to subsurface flow pathways would *increase* nitrogen loss in subsurface flows by a small amount, representing an increase in loss of about 1 percent for these acres, on average.

The addition of nutrient management would have little additional effect on sediment loss or nitrogen loss with surface runoff, but would be effective in reducing nitrogen loss in subsurface flows and further reducing phosphorus lost to surface water (table 35). Nitrogen loss in subsurface flows for these acres would be reduced to an average of 11.4 pounds per acre per year, representing a 57-percent reduction compared to losses simulated for the baseline conservation condition. Phosphorus lost to surface water would be reduced to an average of 1.43 pound per acre per year for these acres, representing a 73-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 35.2 million undertreated acres

Average annual model output is presented in table 36 for the treatment of <u>all</u> 35.2 million undertreated acres (acres with a high or moderate level of treatment need). The 35.2 million undertreated acres include 26.2 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 9.0 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 35.2 million acres—

- reduce average annual sediment loss from 1.21 ton per acre for the baseline to less than 0.1 ton per acre,
- reduce average annual nitrogen loss with surface runoff (including waterborne sediment) from 11 pounds per acre to 2.6 pounds per acre (a 77-percent reduction),
- reduce average annual nitrogen loss in subsurface flows from 24.6 pounds per acre to 9.4 pounds per acre (a 61-perent reduction),
- reduce total nitrogen loss (all loss pathways) from 47.4 pounds per acre per year to 20.6 pounds per acre per year (a 57-percent reduction), and
- reduce average annual phosphorus lost to surface water from 3.29 pounds per acre to 1.05 pounds per acre for these acres (a 68-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 Upper Mississippi River Basin—

1. the 9.0 million undertreated acres with a “high” need for additional treatment,
2. the 26.2 million undertreated acres with a “moderate” need for additional treatment, and
3. the 23.0 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 9.0 million critical undertreated acres would reduce sediment loss an average of 2.57 tons per acre per year on those acres. In comparison, additional treatment of the 26.2 million undertreated acres with a moderate need for treatment would reduce sediment loss by about 0.63 ton per acre per year on those acres, and treatment of the remaining 23.0 million acres would reduce sediment loss by only 0.36 ton per acre per year on those acres, on average.

Similarly, diminishing returns were pronounced for nitrogen and phosphorus loss. Total nitrogen loss would be reduced by an average of 35 pounds per acre per year on the 9.0 million critical undertreated acres, compared to a reduction of 24 pounds per acre for the 26.2 million undertreated acres with a moderate need for treatment, and only 7 pounds per acre for the remaining 23.0 million acres.

Table 35. Conservation practice effects for additional treatment of 9.0 million critical undertreated acres (acres with a *high* need for conservation treatment) in the Upper 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)	4.6	4.0	14%	4.0	14%
Subsurface water flow (inches)	6.9	7.4	-7%	7.4	-8%
Erosion and sediment loss					
Wind erosion (tons/acre)	0.28	0.23	16%	0.22	19%
Sheet and rill erosion (tons/acre)	2.09	0.66	69%	0.62	70%
Sediment loss at edge of field due to water erosion (tons/acre)	2.70	0.13	95%	0.13	95%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-48	45	--	42	--
Nitrogen					
Nitrogen applied (pounds/acre)	101	97	4%*	69	32%
Nitrogen in crop yield removed at harvest (pounds/acre)	107	104	2%*	101	6%
Total nitrogen loss for all loss pathways (pounds/acre)	59.0	43.1	27%	23.9	60%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	20.4	4.3	79%	3.6	82%
Nitrogen loss in subsurface flows (pounds/acre)	26.6	26.9	-1%	11.4	57%
Phosphorus					
Phosphorus applied (pounds/acre)	25.9	25.4	2%*	22.2	14%
Total phosphorus loss for all loss pathways (pounds/acre)	5.79	2.52	57%	1.83	68%
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	5.29	2.06	61%	1.43	73%
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	21.5	11.9	44%	11.9	44%
Surface water pesticide risk indicator for aquatic ecosystems	3.90	3.09	21%	3.07	21%
Surface water pesticide risk indicator for humans	0.78	0.61	21%	0.61	22%

* 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 9.0 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 35.2 million undertreated acres (acres with a *high* or *moderate* need for conservation treatment) in the Upper 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)	4.3	3.7	13%	3.7	12%
Subsurface water flow (inches)	6.4	6.7	-6%	6.8	-8%
Erosion and sediment loss					
Wind erosion (tons/acre)	0.23	0.21	11%	0.20	15%
Sheet and rill erosion (tons/acre)	1.15	0.40	66%	0.37	68%
Sediment loss at edge of field due to water erosion (tons/acre)	1.21	0.08	93%	0.08	93%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	72	117	--	115	--
Nitrogen					
Nitrogen applied (pounds/acre)	100	96	4%*	67	33%
Nitrogen in crop yield removed at harvest (pounds/acre)	109	106	3%*	103	6%
Total nitrogen loss for all loss pathways (pounds/acre)	47.4	39.6	17%	20.6	57%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	11.0	3.2	71%	2.6	77%
Nitrogen loss in subsurface flows (pounds/acre)	24.3	24.6	-1%	9.4	61%
Phosphorus					
Phosphorus applied (pounds/acre)	24.8	24.3	2%*	20.7	16%
Total phosphorus loss for all loss pathways (pounds/acre)	3.74	2.14	43%	1.41	62%
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	3.29	1.71	48%	1.05	68%
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	17.1	11.4	33%	11.4	33%
Surface water pesticide risk indicator for aquatic ecosystems	3.49	2.82	19%	2.81	20%
Surface water pesticide risk indicator for humans	0.74	0.59	20%	0.59	21%

* 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 35.2 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 58.2 million cropped acres in the Upper Mississippi River Basin

	Additional treatment for 9.0 million critical undertreated acres*			Additional treatment for 26.2 million non-critical undertreated acres*			Additional treatment for remaining 23.0 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)	4.6	4.0	0.6	4.1	3.6	0.5	4.7	4.0	0.7
Subsurface water flow (inches)	6.9	7.4	-0.5	6.2	6.6	-0.5	5.6	6.2	-0.6
Erosion and sediment loss									
Wind erosion (tons/acre)	0.28	0.22	0.053	0.22	0.19	0.028	0.23	0.21	0.025
Sheet and rill erosion (tons/acre)	2.09	0.62	1.47	0.83	0.28	0.55	0.49	0.20	0.29
Sediment loss at edge of field due to water erosion (tons/acre)	2.70	0.13	2.57	0.69	0.06	0.63	0.41	0.06	0.36
Soil organic carbon									
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-48	42	90*	113	140	27*	70	90	19*
Nitrogen									
Nitrogen applied (pounds/acre)	101	69	33	99	67	32	69	59	9
Nitrogen in crop yield removed at harvest (pounds/acre)	107	101	6	110	103	7	111	107	5
Total nitrogen loss for all loss pathways (pounds/acre)	59.0	23.9	35.1	43.4	19.5	23.9	26.0	18.8	7.2
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	20.4	3.6	16.8	7.8	2.2	5.6	5.4	2.2	3.2
Nitrogen loss in subsurface flows (pounds/acre)	26.6	11.4	15.2	23.6	8.7	14.8	10.2	7.8	2.4
Phosphorus									
Phosphorus applied (pounds/acre)	25.9	22.2	3.7	24.4	20.2	4.2	19.7	18.4	1.3
Total phosphorus loss for all loss pathways (pounds/acre)	5.79	1.83	4.0	3.04	1.26	1.8	2.24	1.23	1.0
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	5.29	1.43	3.9	2.60	0.92	1.7	1.81	0.86	0.9
Pesticide loss									
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	21.5	11.9	9.5	15.6	11.2	4.3	14.0	10.6	3.4
Surface water pesticide risk indicator for aquatic ecosystem	3.90	3.07	0.83	3.35	2.72	0.63	3.81	2.94	0.87
Surface water pesticide risk indicator for humans	0.78	0.61	0.17	0.72	0.58	0.14	0.74	0.58	0.16

*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.

Nitrogen loss in subsurface flows would be reduced by an average of 15 pounds per acre per year on the 9.0 million critical undertreated acres as well as the 26.2 million acres with a moderate need for treatment, compared to a reduction of 2.4 pounds per acre for the remaining 23.0 million acres.

Total phosphorus loss would be reduced by an average of 4.0 pounds per acre per year on the 9.0 million critical undertreated acres, compared to a reduction of 1.8 pounds per acre for the 26.2 million undertreated acres with a moderate need for treatment and only 1.0 pound per acre for the remaining 23.0 million acres.

Diminishing returns for reduction in environmental risk for pesticides are generally not evident because pesticide risk was not taken into account in the identification of undertreated acres or the assessment of conservation treatment needs.

(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.)

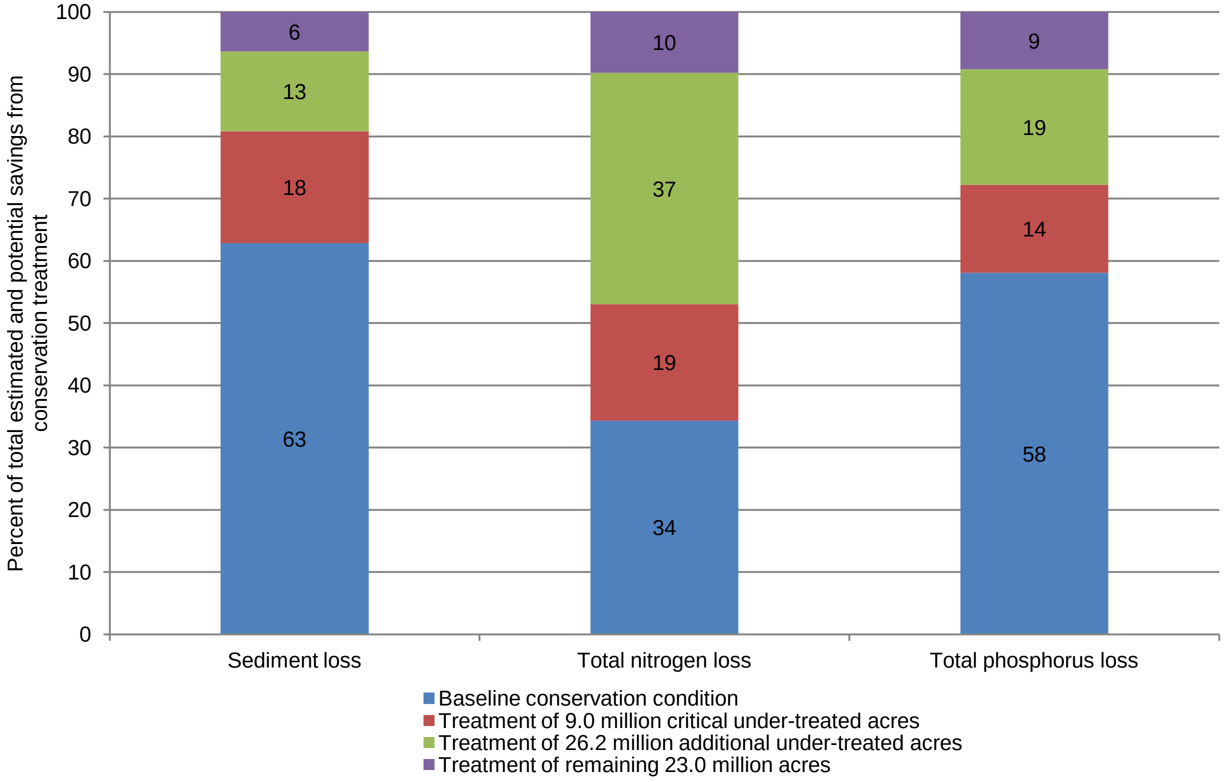
Estimates of edge-of-field sediment and nutrient savings due to use of conservation practices

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 67. 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 129 million tons of sediment, 844,362 tons of nitrogen, and 125,844 tons of phosphorus for the Upper Mississippi River Basin (fig. 67).

For sediment loss, about 63 percent of the potential savings are accounted for by the conservation practices already in use, as represented by the baseline conservation condition (fig. 67). Additional treatment of the 9.0 million critical undertreated acres would account for another 18 percent of the potential sediment savings. Treatment of the 26.2 million undertreated acres with a moderate need for treatment would account for about 13 percent of the potential savings. Treatment of the 23.0 million adequately treated acres would account for the last 6 percent of potential savings.

The proportions of savings from existing practices with additional conservation treatment are somewhat lower for phosphorus (58 percent) and much lower for nitrogen (34 percent) than for sediment loss. Correspondingly, there is more opportunity to reduce nitrogen and phosphorus losses with additional conservation treatment in this region (fig. 67).

Figure 67. 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 Upper 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 9.0 million critical undertreated acres*	Potential savings from treatment of 26.2 million additional undertreated acres*	Potential savings from treatment of remaining 23.0 million acres*	Total estimated and potential savings from conservation treatment
Sediment	80,793,196	23,082,453	16,533,425	8,164,740	128,573,814
Nitrogen	290,051	157,800	313,697	82,813	844,362
Phosphorus	73,078	17,790	23,344	11,632	125,844

*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 67, 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 9.0 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 9.0 million acres with model results from the baseline conservation condition for the remaining acres.

Compared to the baseline conservation condition, treating the 9.0 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 0.5 ton per acre per year, a 44 percent reduction from the baseline conservation condition;
- reduce total nitrogen loss by 14 percent, on average:
  - reduce nitrogen loss with surface runoff (sediment adsorbed and soluble) by 29 percent, and
  - reduce nitrogen loss in subsurface flows by 12 percent;
- reduce phosphorus lost to surface water (sediment adsorbed and soluble) by 22 percent; and
- reduce environmental risk from loss of pesticide residues by 4 percent.

Compared to the baseline conservation condition, treating all 35.2 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 76 percent on average;
- reduce total nitrogen loss by 42 percent:
  - reduce nitrogen loss with surface runoff (sediment adsorbed and soluble) by 58 percent, and
  - reduce nitrogen loss in subsurface flows by 48 percent;
- reduce phosphorus lost to surface water by 50 percent; and
- reduce environmental risk from loss of pesticide residues by 11-12 percent.

Nearly all of these reductions in sediment loss, nitrogen lost with surface water, phosphorus lost to 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 all of the reduction in nitrogen loss in subsurface flows, reducing the annual loss from about 18.7 pounds per acre to 9.7 pounds per acre, an average reduction of 48 percent compared to the baseline for 2003-06. Nutrient management in this region is also important for attaining further reductions in phosphorus loss.

The effects of treating the undertreated acres for the region as a whole are graphically shown in figures 68 through 74. 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 9.0 million critical undertreated acres, and 2) treatment of all 35.2 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, 11 percent of the acres in the Upper 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 (9.0 million acres) with water erosion control practices would reduce the acres exceeding sediment loss of 2 tons per acre per year to 4 percent of cropped acres (fig. 68). Expanding the treatment to include all undertreated acres (35.2 million acres) would further reduce the acres exceeding annual sediment loss of 2 tons per acre to 1 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 69 shows that the percentage of acres building soil organic carbon would increase from 76 percent for the baseline conservation condition to 82 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 16 percent for the baseline to 8 percent (fig. 70). Treatment of all 35.2 million undertreated acres would further reduce the percent losing more than 15 pounds per acre to 2 percent of cropped acres in the region.

For nitrogen loss in subsurface flow pathways, however, treatment of all 35.2 million undertreated acres would be required to reduce the overall regional edge-of-field losses to acceptable levels (fig. 71). About 29 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 9.0 million critical undertreated acres with nutrient management practices would reduce this percentage to 20 percent of cropped acres. Treatment of all 35.2 million undertreated acres would reduce the percentage to 10 percent.

For total nitrogen loss to all pathways, 30 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 22 percent (fig. 72). Expanding the treatment to include all undertreated acres would further reduce the acres exceeding 40 pounds per acre to 5 percent.

Acres exceeding 4 pounds per acre of phosphorus lost to surface water would be reduced from 18 percent for the baseline to 11 percent by treating the critical acres and to 5 percent by treating all undertreated acres (fig. 73).

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 4 percent for the region as a whole if the 35.2 million undertreated acres were fully treated with additional soil erosion control and nutrient management practices (table 39). Figure 74 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 9.0 million critical undertreated acres (acres with a *high* need for conservation treatment) in the Upper 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)	4.4	4.3	2%	4.3	2%
Subsurface water flow (inches)	6.0	6.1	-1%	6.1	-1%
Erosion and sediment loss					
Wind erosion (tons/acre)	0.23	0.23	3%	0.22	4%
Sheet and rill erosion (tons/acre)	0.89	0.67	25%	0.66	25%
Sediment loss at edge of field due to water erosion (tons/acre)	0.89	0.50	44%	0.50	44%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	71	85	--	85	--
Nitrogen					
Nitrogen applied (pounds/acre)	87	87	1%**	82	6%
Nitrogen in crop yield removed at harvest (pounds/acre)	110	110	0%	109	1%
Total nitrogen loss for all loss pathways (pounds/acre)	39.0	36.5	6%	33.5	14%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	8.8	6.3	28%	6.2	29%
Nitrogen loss in subsurface flows (pounds/acre)	18.7	18.8	<1%	16.4	12%
Phosphorus					
Phosphorus applied (pounds/acre)	22.8	22.7	<1%**	22.2	3%
Total phosphorus loss for all loss pathways (pounds/acre)	3.15	2.65	16%	2.54	19%
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	2.70	2.21	18%	2.11	22%
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	15.8	14.4	9%	14.4	9%
Surface water pesticide risk indicator for aquatic ecosystems	3.62	3.49	3%	3.49	4%
Surface water pesticide risk indicator for humans	0.74	0.71	4%	0.71	4%

* Results presented for the region as a whole combine model output for the 9.0 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 35.2 million undertreated acres (acres with a *high* or *moderate* need for conservation treatment) in the Upper 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)	4.4	4.1	7%	4.1	7%
Subsurface water flow (inches)	6.0	6.3	-4%	6.3	-5%
Erosion and sediment loss					
Wind erosion (tons/acre)	0.23	0.22	7%	0.21	9%
Sheet and rill erosion (tons/acre)	0.89	0.43	51%	0.42	53%
Sediment loss at edge of field due to water erosion (tons/acre)	0.89	0.21	76%	0.21	76%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	71	98	--	97	--
Nitrogen					
Nitrogen applied (pounds/acre)	87	85	2%**	68	22%
Nitrogen in crop yield removed at harvest (pounds/acre)	110	108	2%	106	4%
Total nitrogen loss for all loss pathways (pounds/acre)	39.0	34.2	12%	22.7	42%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	8.8	4.1	54%	3.7	58%
Nitrogen loss in subsurface flows (pounds/acre)	18.7	18.9	-1%	9.7	48%
Phosphorus					
Phosphorus applied (pounds/acre)	22.8	22.5	1%**	20.3	11%
Total phosphorus loss for all loss pathways (pounds/acre)	3.15	2.18	31%	1.74	45%
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	2.70	1.75	35%	1.35	50%
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	15.8	12.4	22%	12.4	22%
Surface water pesticide risk indicator for aquatic ecosystems	3.62	3.21	11%	3.20	11%
Surface water pesticide risk indicator for humans	0.74	0.65	12%	0.65	12%

* Results presented for the region as a whole combine model output for the 35.2 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 68. 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, Upper Mississippi River Basin

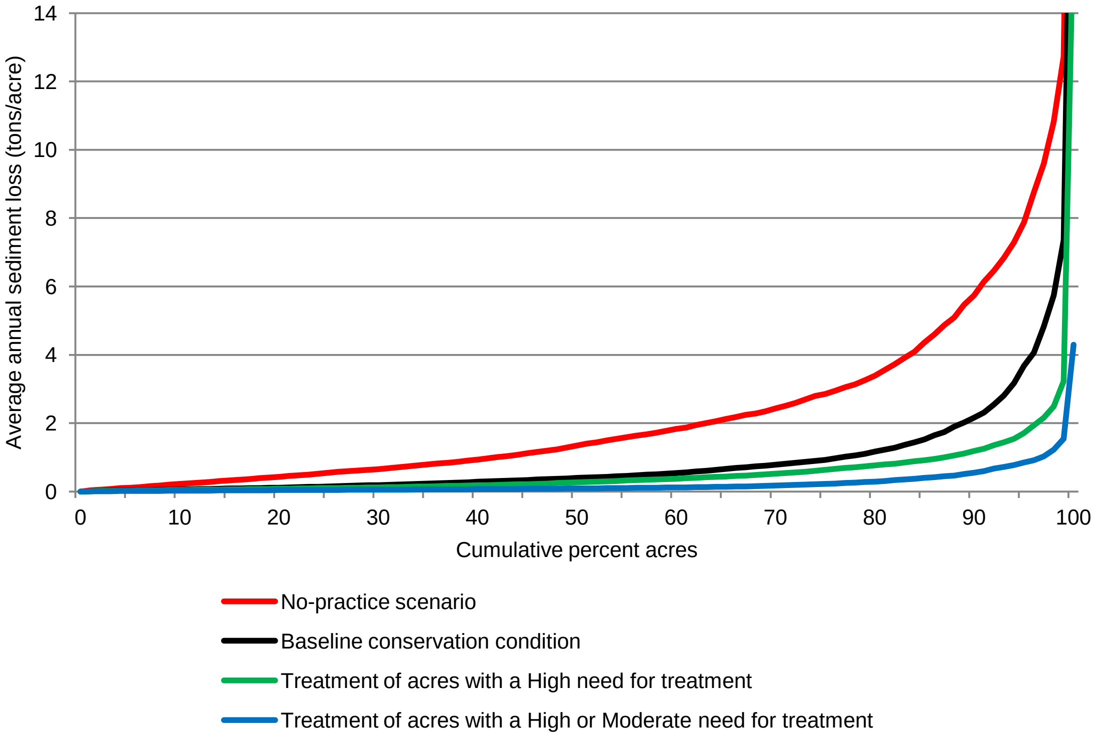


Figure 69. Estimates of average annual change in soil organic carbon for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Upper Mississippi River Basin

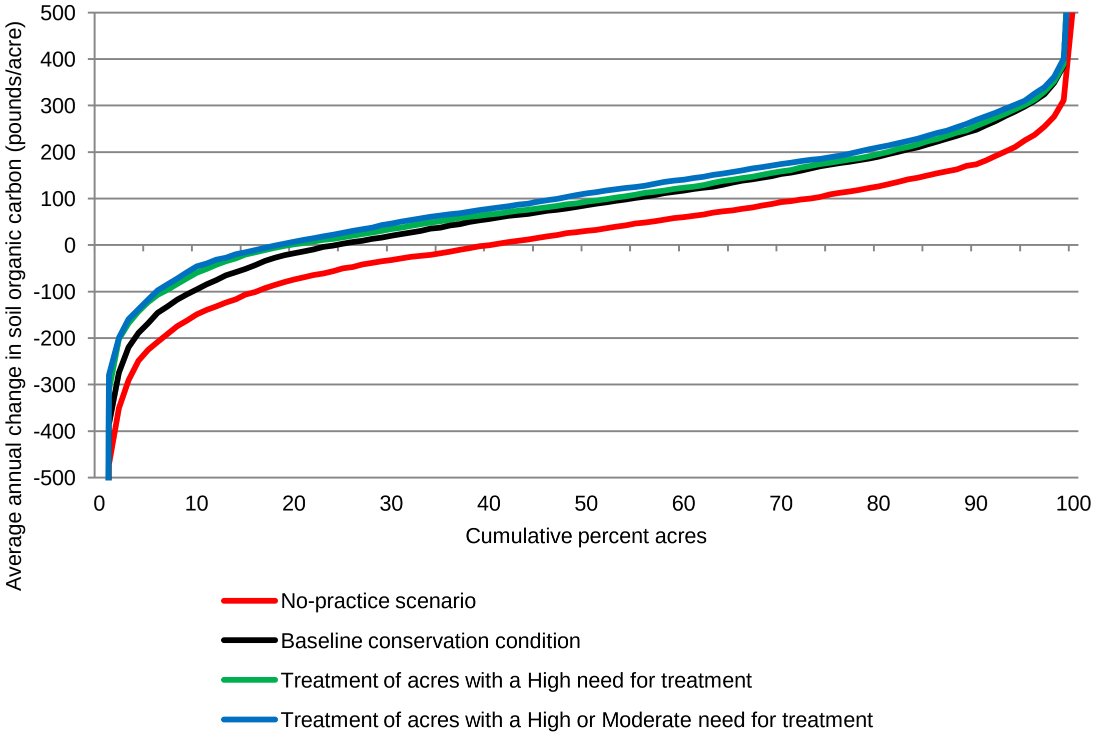


Figure 70. Estimates of average annual loss of nitrogen with surface runoff for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Upper Mississippi River Basin

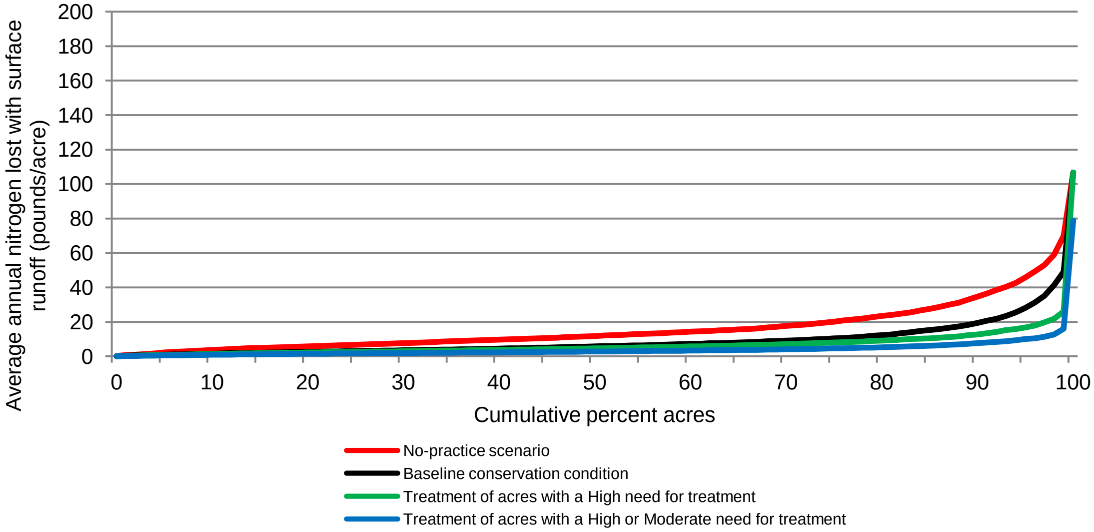


Figure 71. Estimates of average annual loss of nitrogen in subsurface flows for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Upper Mississippi River Basin

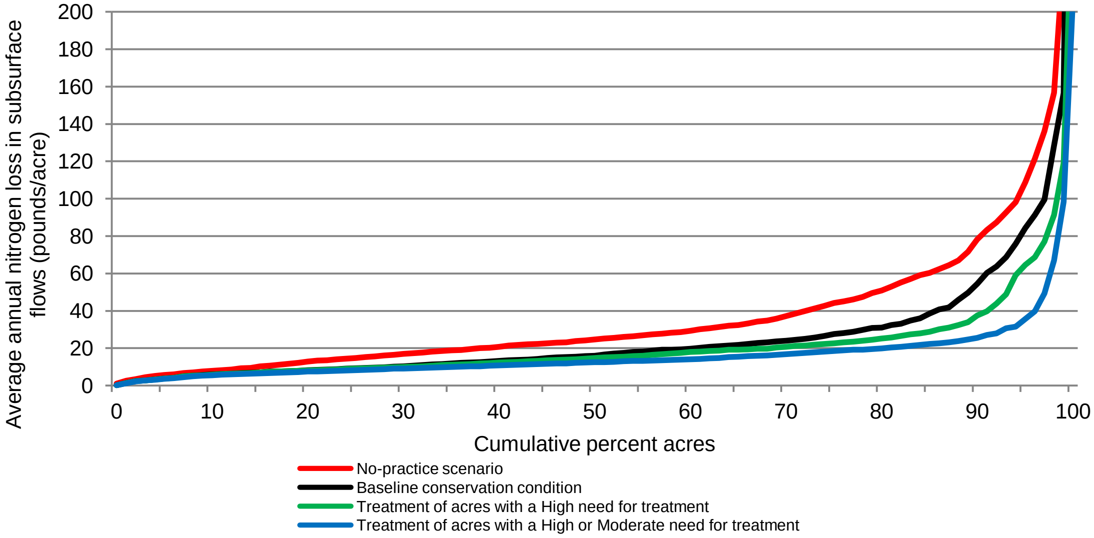


Figure 72. Estimates of average annual total nitrogen loss for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Upper Mississippi River Basin

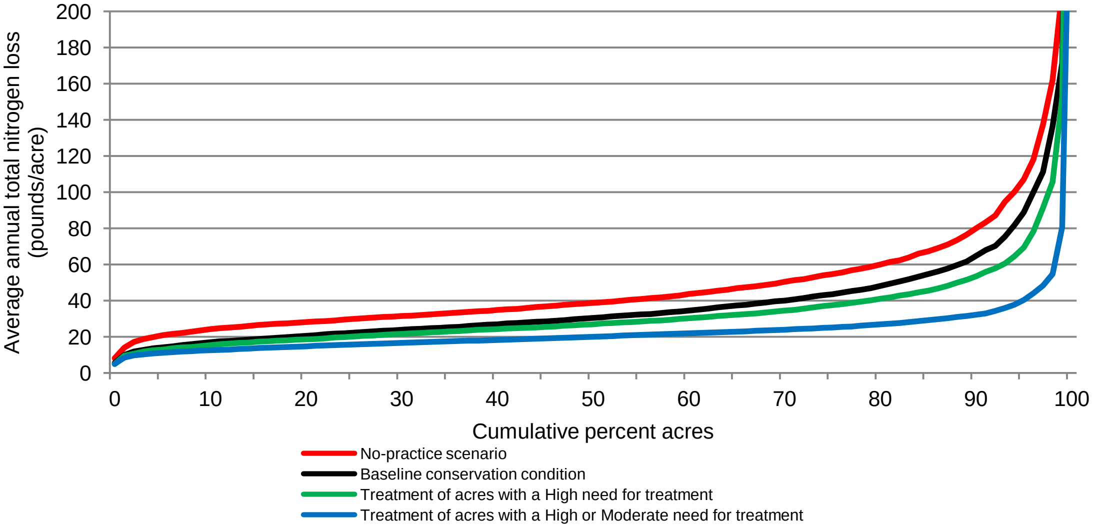
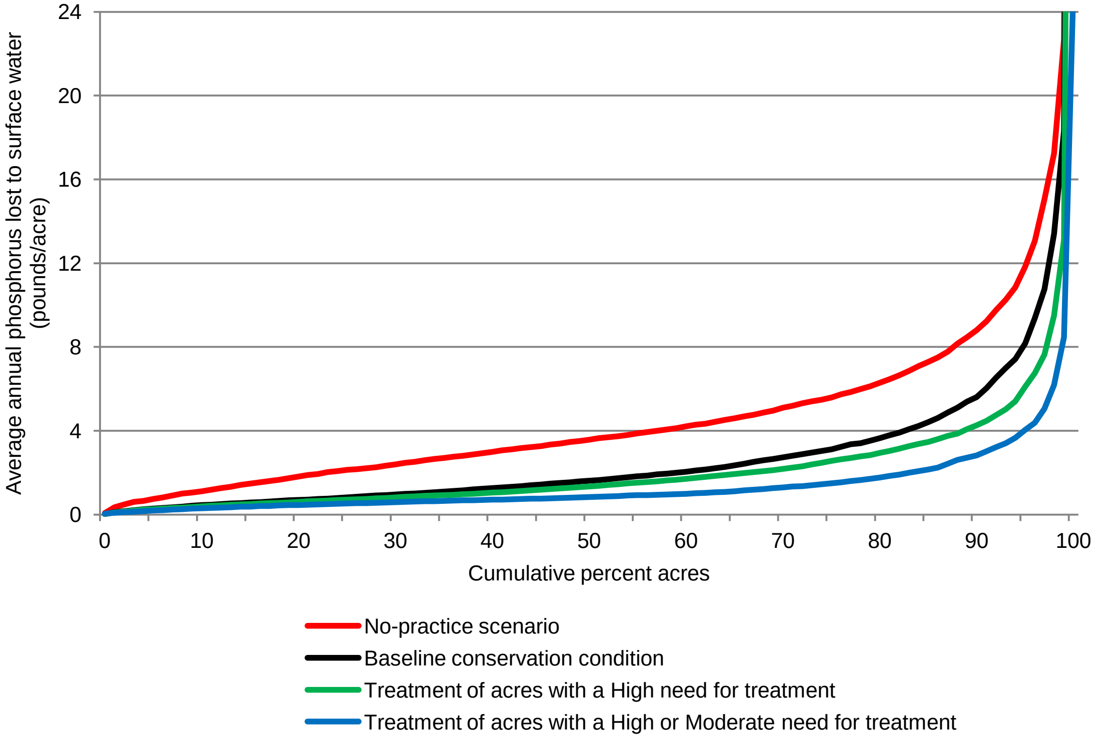
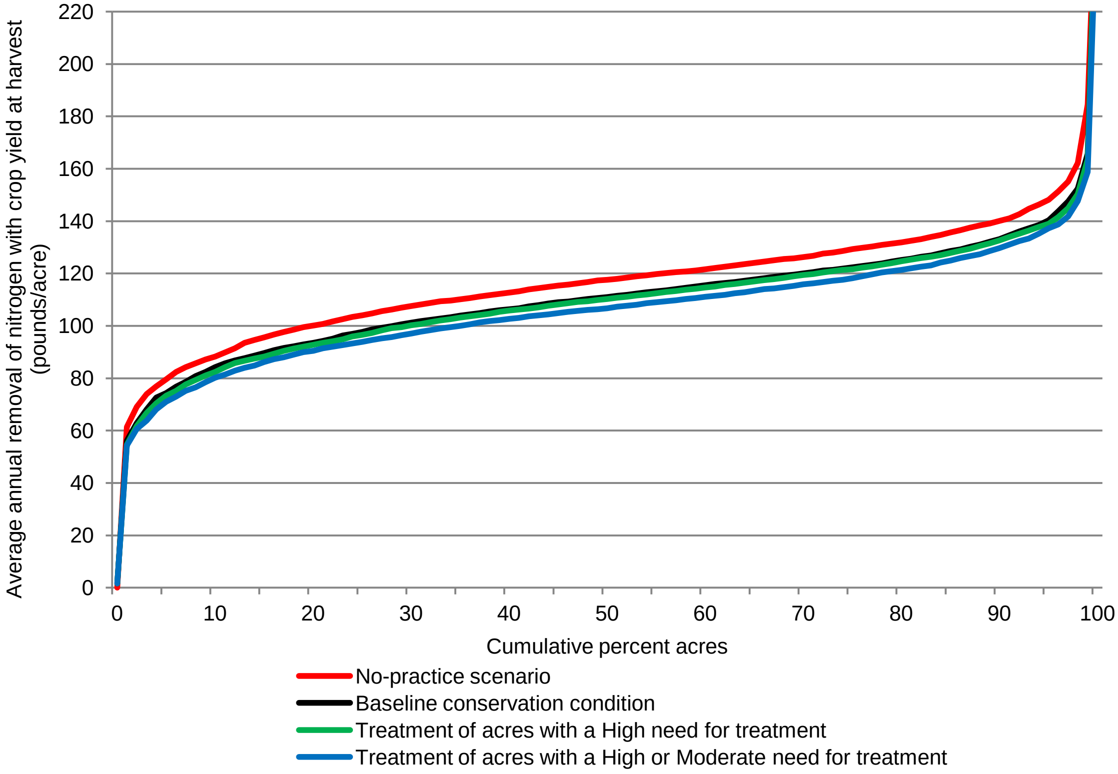


Figure 73. Estimates of average annual phosphorus lost to surface water (sediment attached and soluble)* for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Upper Mississippi River Basin



* 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 74. 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, Upper Mississippi River Basin



Chapter 7
Offsite Water Quality Effects of Conservation Practices

Field-level losses of sediment, nutrients, 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,
- instream loads at various points within the basin, and
- loads exported from the region to the Lower Mississippi River Basin.

Load estimates are reported for each of the 14 subregions (4-digit hydrologic unit code), shown in figure 75.

The Missouri River joins the Mississippi River north of St. Louis, MO, as shown in figure 76. Instream loads delivered to the Lower Mississippi River Basin (estimated at the outlet of subregion 0714 below Thebes, IL) thus include instream loads from the Missouri River Basin as well as the Upper Mississippi River Basin.

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 streamflow from the Missouri River.

Figure 75. Subregions and 8-digit HUC groups used for reporting of source loads and instream loads for the 14 subregions in the Upper Mississippi River Basin

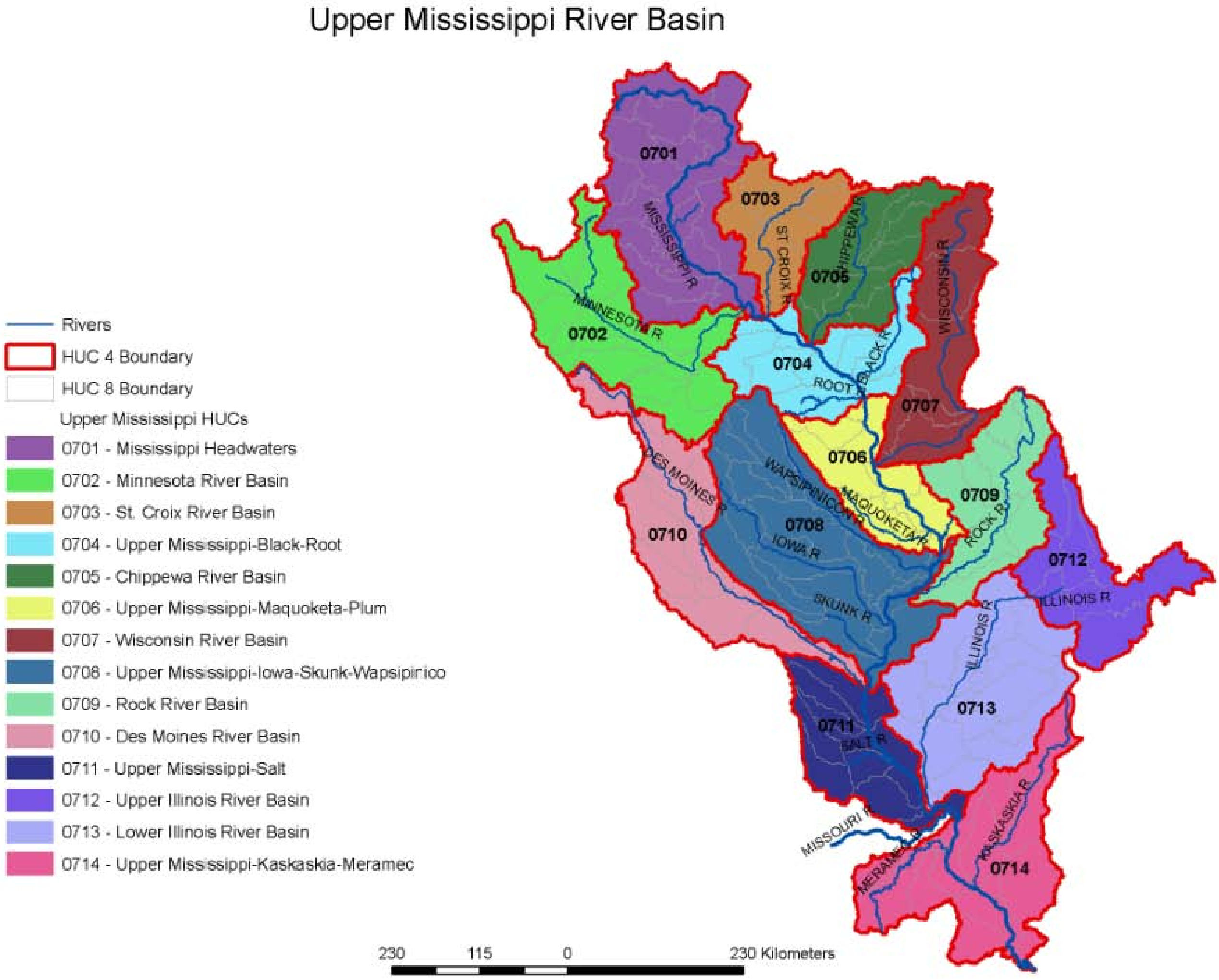
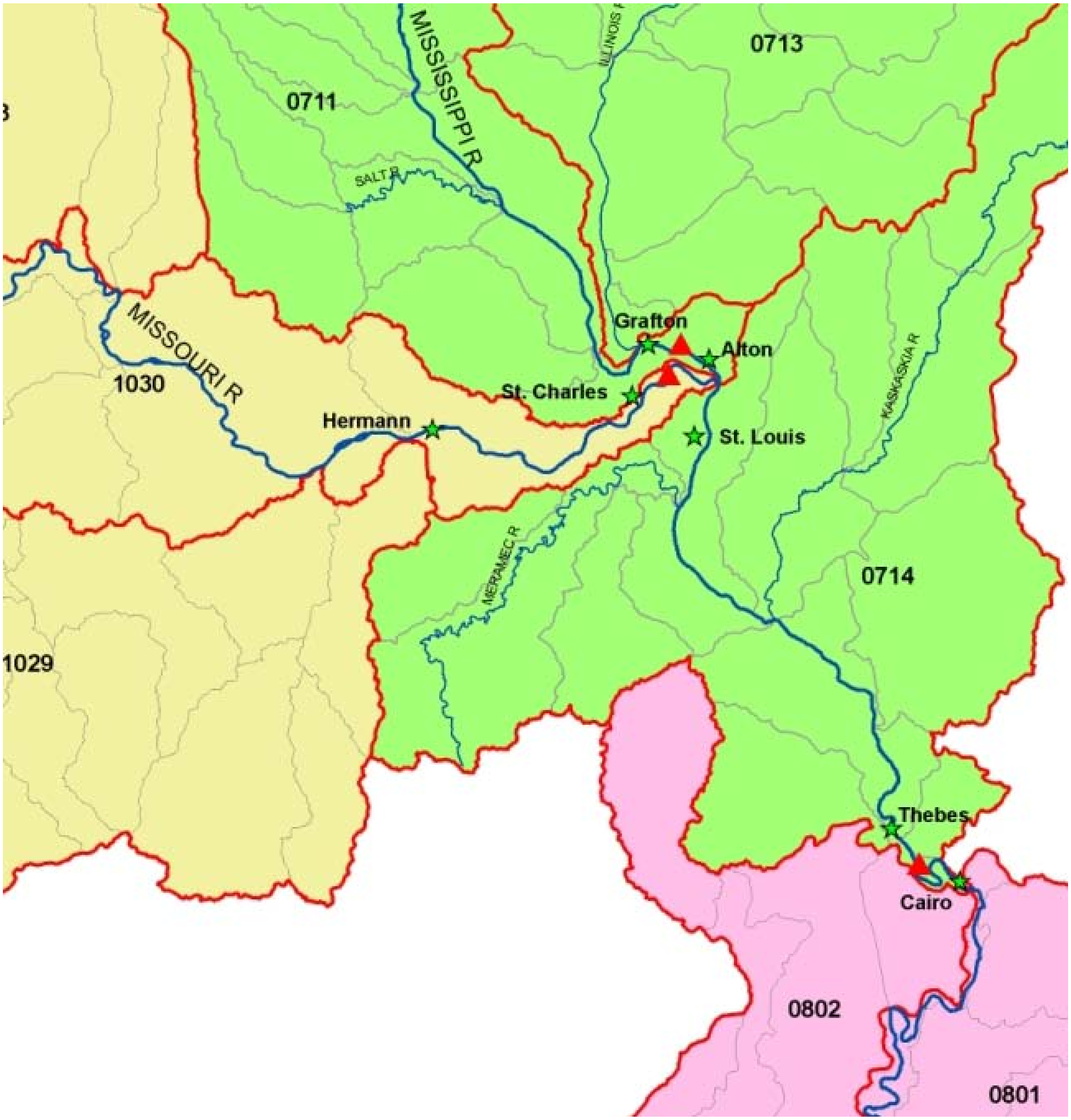


Figure 76. Schematic showing the confluence of the Missouri River and the Mississippi River, located upstream of subregion 0714 within the Upper Mississippi River Basin.

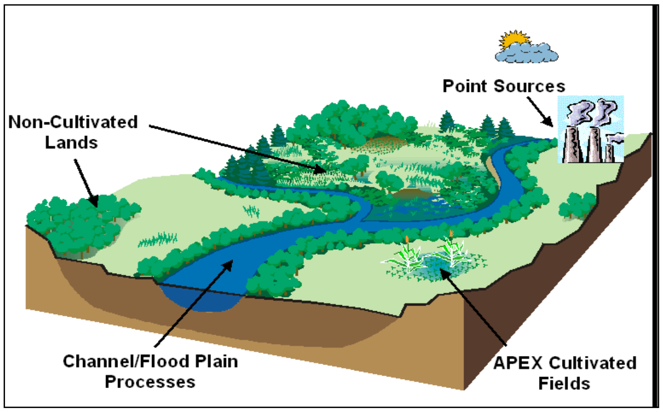


Note: Red triangles indicate the outlets of 4-digit hydrologic units.

The National Water Quality Model—HUMUS/SWAT

Offsite estimates of water quality benefits were assessed using HUMUS/SWAT, a combination of the SWAT model 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. 77).

Figure 77. 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).[27] 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

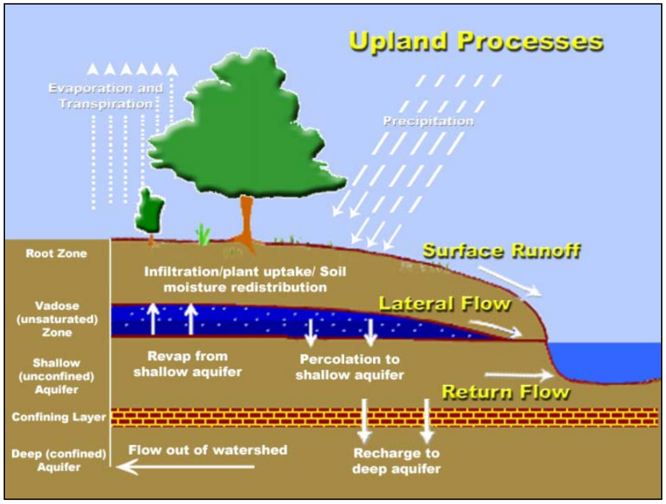
The water balance is the driving force for transport and delivery of sediment, nutrients, and pesticides from fields to streams and rivers. For this study, upland processes for non-cultivated cropland were modeled using SWAT, while source loads for cultivated cropland are estimated by APEX.

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. 78). 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 78. 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.

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[27] 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.
- Manure was applied to less than 1 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 less than 1percent of hayland acres in the Upper 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.
- Manure was applied to about 1 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 1 percent of pastureland acres in the Upper 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.[28]

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. 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.

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[28] 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, Upper 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						
Mississippi Headwaters (code 0701)	84,490	28,967	113,457	16,658	11,944	28,602
Minnesota River Basin (code 0702)	245,569	40,266	285,835	61,411	16,076	77,487
St. Croix River Basin (code 0703)	12,347	10,038	22,385	2,743	3,796	6,539
Upper Mississippi-Black-Root Rivers (code 0704)	92,911	36,290	129,201	18,091	14,617	32,708
Chippewa River Basin (code 0705)	20,945	21,276	42,222	3,649	8,095	11,744
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	94,934	30,579	125,513	19,358	11,846	31,204
Wisconsin River Basin (code 0707)	39,378	39,485	78,863	8,139	17,070	25,208
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	406,754	55,360	462,114	98,025	19,071	117,096
Rock River Basin (code 0709)	167,421	28,005	195,426	37,566	10,884	48,450
Des Moines River Basin (code 0710)	225,148	32,200	257,348	57,572	10,660	68,232
Upper Mississippi-Salt Rivers (code 0711)	99,322	4,572	103,894	27,757	1,764	29,521
Upper Illinois River Basin (code 0712)	164,477	10,373	174,850	37,117	4,849	41,966
Lower Illinois River Basin (code 0713)	384,825	7,192	392,017	93,970	3,466	97,435
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	152,297	4,816	157,113	44,021	2,632	46,653
Total	2,190,818	349,419	2,540,237	526,076	136,769	662,846
Hayland						
Mississippi Headwaters (code 0701)	8,645	360	9,005	1,835	170	2,005
Minnesota River Basin (code 0702)	677	78	754	975	39	1,015
St. Croix River Basin (code 0703)	2,333	62	2,395	726	29	755
Upper Mississippi-Black-Root Rivers (code 0704)	13	224	237	2,155	104	2,259
Chippewa River Basin (code 0705)	922	54	976	917	24	941
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	0	145	145	1,761	62	1,823
Wisconsin River Basin (code 0707)	18	48	67	1,146	22	1,169
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	1,182	170	1,352	1,654	88	1,742
Rock River Basin (code 0709)	457	176	633	1,748	81	1,829
Des Moines River Basin (code 0710)	2,256	89	2,346	946	43	989
Upper Mississippi-Salt Rivers (code 0711)	9,903	139	10,041	367	73	440
Upper Illinois River Basin (code 0712)	0	17	17	429	9	438
Lower Illinois River Basin (code 0713)	1,169	54	1,223	533	28	561
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	12,350	189	12,539	477	94	571
Total	39,925	1,806	41,731	15,669	867	16,537
Pastureland and rangeland						
Mississippi Headwaters (code 0701)	4,370	17,748	22,118	1,826	7,421	9,246
Minnesota River Basin (code 0702)	5,243	21,013	26,256	1,946	7,799	9,745
St. Croix River Basin (code 0703)	1,149	4,670	5,820	506	2,056	2,562
Upper Mississippi-Black-Root Rivers (code 0704)	4,379	17,519	21,898	1,685	6,742	8,427
Chippewa River Basin (code 0705)	1,065	4,260	5,325	403	1,612	2,015
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	4,658	18,754	23,412	1,989	8,005	9,993
Wisconsin River Basin (code 0707)	1,642	6,567	8,209	631	2,523	3,153
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	7,895	31,653	39,548	3,391	13,598	16,989
Rock River Basin (code 0709)	4,565	18,389	22,955	1,646	6,637	8,283
Des Moines River Basin (code 0710)	5,624	22,556	28,180	2,595	10,402	12,997
Upper Mississippi-Salt Rivers (code 0711)	3,644	14,706	18,351	2,037	8,204	10,240
Upper Illinois River Basin (code 0712)	1,314	5,293	6,607	476	1,922	2,398
Lower Illinois River Basin (code 0713)	2,597	10,439	13,036	1,279	5,138	6,417
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	3,876	15,611	19,487	2,074	8,347	10,421
Total	52,022	209,178	261,201	22,484	90,403	112,887

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, Upper 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						
Mississippi Headwaters (code 0701)	942	0	942	415	0	415
Minnesota River Basin (code 0702)	171	0	171	75	0	75
St. Croix River Basin (code 0703)	309	0	309	136	0	136
Upper Mississippi-Black-Root Rivers (code 0704)	595	0	595	262	0	262
Chippewa River Basin (code 0705)	178	0	178	78	0	78
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	62	0	62	27	0	27
Wisconsin River Basin (code 0707)	678	0	678	298	0	298
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	281	0	281	124	0	124
Rock River Basin (code 0709)	746	0	746	328	0	328
Des Moines River Basin (code 0710)	234	0	234	103	0	103
Upper Mississippi-Salt Rivers (code 0711)	213	0	213	94	0	94
Upper Illinois River Basin (code 0712)	1,227	0	1,227	540	0	540
Lower Illinois River Basin (code 0713)	236	0	236	104	0	104
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	427	0	427	188	0	188
Total	6,300	0	6,300	2,773	0	2,773
Total for all agricultural land						
Mississippi Headwaters (code 0701)	98,447	47,075	145,522	20,733	19,535	40,268
Minnesota River Basin (code 0702)	251,660	61,357	313,017	64,407	23,914	88,322
St. Croix River Basin (code 0703)	16,139	14,770	30,909	4,111	5,881	9,992
Upper Mississippi-Black-Root Rivers (code 0704)	97,897	54,033	151,930	22,192	21,463	43,655
Chippewa River Basin (code 0705)	23,110	25,591	48,701	5,048	9,731	14,779
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	99,653	49,478	149,131	23,135	19,912	43,047
Wisconsin River Basin (code 0707)	41,716	46,100	87,816	10,214	19,615	29,829
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	416,113	87,183	503,296	103,194	32,757	135,951
Rock River Basin (code 0709)	173,190	46,570	219,760	41,289	17,602	58,890
Des Moines River Basin (code 0710)	233,262	54,846	288,108	61,216	21,105	82,321
Upper Mississippi-Salt Rivers (code 0711)	113,081	19,417	132,499	30,254	10,041	40,295
Upper Illinois River Basin (code 0712)	167,018	15,683	182,701	38,563	6,779	45,342
Lower Illinois River Basin (code 0713)	388,828	17,685	406,513	95,886	8,632	104,517
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	168,951	20,616	189,567	46,760	11,073	57,833
Total	2,289,066	560,403	2,849,469	567,003	228,040	795,043

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, Upper 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)
Mississippi Headwaters (code 0701)	8,478	3,481	919	26,817
Minnesota River Basin (code 0702)	6,923	1,035	239	7,709
St. Croix River Basin (code 0703)	2,102	254	98	13,521
Upper Mississippi-Black-Root Rivers (code 0704)	4,455	1,559	378	13,590
Chippewa River Basin (code 0705)	2,693	583	152	16,868
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	3,020	866	315	9,504
Wisconsin River Basin (code 0707)	4,306	1,079	220	21,328
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	11,854	4,482	1,494	16,012
Rock River Basin (code 0709)	6,496	2,821	607	8,838
Des Moines River Basin (code 0710)	6,361	1,195	301	10,114
Upper Mississippi-Salt Rivers (code 0711)	4,017	745	170	12,483
Upper Illinois River Basin (code 0712)	15,956	46,967	6,467	11,530
Lower Illinois River Basin (code 0713)	9,164	3,352	669	13,502
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	10,469	3,497	798	29,338
Total	96,294	71,915	12,827	211,154

Note: The amounts reported in this table are as elemental nitrogen and elemental phosphorus (not fertilizer equivalents).

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. 79).

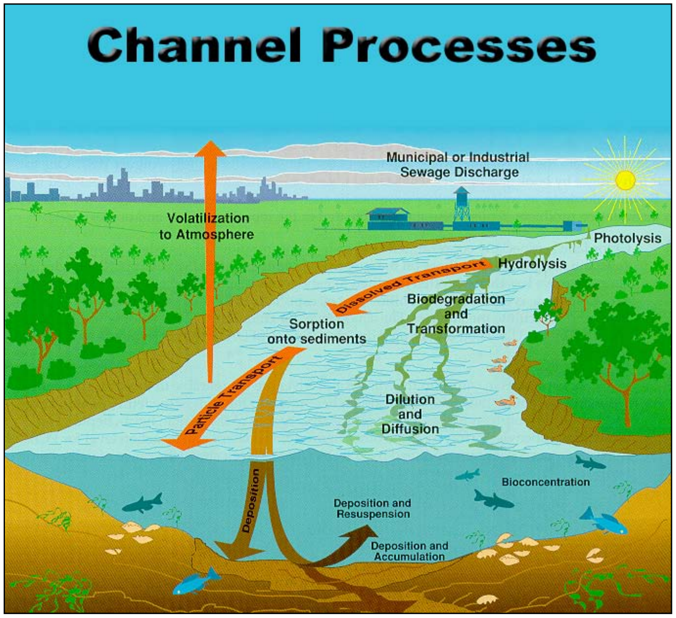
- **Flood routing**. As water flows downstream, some may be lost due to evaporation and transmission through the channel bed. Another potential loss is removal of water from the channel for agricultural or human use. Flow may be supplemented by rainfall directly on the channel and/or addition of water 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.[29]

- **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.

Figure 79. 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

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[29] 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.

processes simulated by the model are loading, outflow, transformation, volatilization, settling, diffusion, resuspension, and burial.

Calibration

Delivery of surface water and subsurface water from upland processes (HRUs and CEAP sample points) was spatially calibrated for each subregion to ensure that streamflow was in agreement with long-term average runoff for the region. Hydrologic parameters in APEX (cultivated cropland) and SWAT (other HRUs) were adjusted separately for each 8-digit watershed until differences in the long-term water yield were minimized. Time series of predicted annual and monthly streamflow were compared against the monitored counterpart. If necessary, the channel losses, seepage, and evaporation losses in reservoirs were adjusted to match the predicted flow time series with that of observed data. The calibration period is from 1961–1990 and the validation period from 1991–2006. Most of the flow calibration was carried out for the upland runoff with minimal or no parameterization for the time series of annual and monthly streamflow. [30]

For sediment calibration, observations were taken from USGS monitoring stations. Most of the sediment observations were grab sample concentrations of suspended sediment. These, along with monitored daily flow data were processed using a load estimator or load runner program to estimate annual average sediment load. The estimated annual average sediment load was used to validate the predicted sediment load from HUMUS. In the Upper Mississippi River Basin, predicted sediment load was calibrated/validated to match the observations collected at six different gauging stations. For calibration of upland soil erosion, soil erodibility factor and residue cover were adjusted.

For adjusting instream sediment load, parameters controlling stream power and sediment carrying capacity of the channel were adjusted. Delivery ratios from field to 8-digit watershed and 8-digit watershed to river were adjusted to match predicted sediment load with that of observations for each validation station. Where necessary, parameters affecting settling of sediment in reservoirs were also adjusted.

Seven gauging stations were selected in the Upper Mississippi River Basin for nutrient calibration. Most of the data for nutrient calibration were taken from the USGS-NASQAN data monitoring program. Available nutrient observations include five stations in Mississippi river and two in its tributaries (Iowa River and Illinois River). Nutrient loads were estimated from grab sample concentrations using the same procedure outlined for sediment.

For calibration of upland nutrient load, parameters controlling nutrient uptake by plants, leaching to groundwater and mineralization were adjusted. For calibration of instream nutrient load, parameters affecting benthic source rate, mineralization, hydrolysis, and settling with sediment were adjusted. Where necessary, parameters affecting settling of nutrients in reservoirs were also adjusted.

Data for atrazine calibration came from USGS monitoring stations. Only the soluble form of atrazine is calibrated because atrazine is most likely to appear in soluble form rather than with sediment. Four gauging stations were selected to calibrate soluble atrazine; two in the Mississippi River and two in tributaries (Iowa River and Illinois River). The delivery ratio and instream parameters controlling decay, settling, burial, and resuspension of atrazine were adjusted to match predicted atrazine load with that of observations.

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.[31] 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.[32]

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[30] For a complete documentation of calibration procedures and results for the Upper Mississippi River Basin, see “Calibration and Validation of CEAP HUMUS” at http://www.nrcs.usda.gov/technical/nri/ceap.

[31] 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.

[32] 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.

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 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.[33]

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 80 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.

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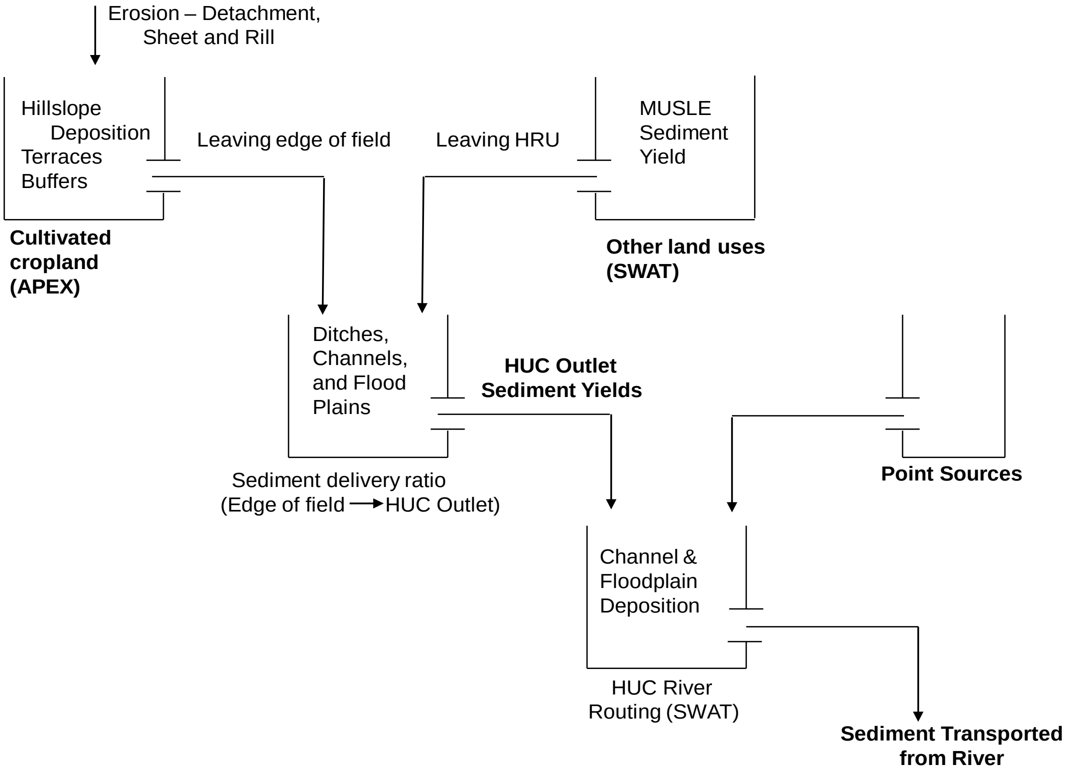
[33] For a complete documentation of delivery ratios used for the Upper Mississippi River Basin, see “Delivery Ratios Used in CEAP Cropland Modeling” at http://www.nrcs.usda.gov/technical/nri/ceap.

Figure 80. Schematic of sediment sources and delivery as modeled with HUMUS/SWAT for the Upper Mississippi River Basin



"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 drainageways, 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 loads.

Modeling Land Use in the Upper 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 81 and table 42. Cultivated cropland is the dominant land use in the region, making up slightly more than half of the land base (tables 4 and 42). Pasture and grazing land makes up about 8 percent of the land in the basin and hayland makes up about 4 percent. Urban land makes up about 8 percent of the acres in the basin, and forest and other land uses make up 26 percent.

Cultivated cropland is the dominant land use in all but the four northern subregions and the southernmost subregion. The area of greatest concentration of cultivated cropland extends through the central portion of the basin, as shown in figures 1 and 2. Cultivated cropland is a minor land use in the St. Croix River Basin (code 0703), where only 13 percent of the subregion is cultivated cropland (tables 4 and 42).

Cultivated cropland includes land in long-term conserving cover, which represents about 5 percent of the cultivated cropland acres in this region (table 4).

Figure 81. Percent acres for land use/cover types in the Upper Mississippi River Basin, exclusive of water

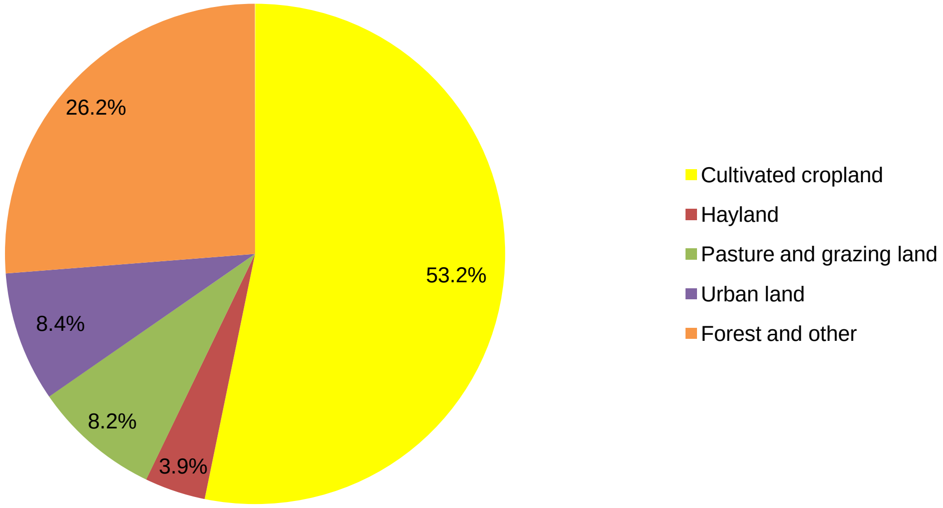


Table 42. Acres by land use, exclusive of water, used in model simulations to estimate instream sediment, nutrient, and atrazine loads for the Upper Mississippi River Basin

Subregions	Cultivated cropland (acres)*	Hay land 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)
Mississippi Headwaters (code 0701)	3,072,114	650,780	1,397,224	863,053	5,870,848	11,854,020
Minnesota River Basin (code 0702)	8,270,525	246,866	588,402	694,678	688,453	10,488,924
St. Croix River Basin (code 0703)	623,496	228,192	624,778	220,484	3,076,850	4,773,799
Upper Mississippi-Black-Root Rivers (code 0704)	3,290,446	478,865	455,094	463,388	2,042,707	6,730,500
Chippewa River Basin (code 0705)	1,398,599	236,140	129,278	280,161	3,822,067	5,866,246
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	3,037,483	387,567	610,464	315,292	998,097	5,348,903
Wisconsin River Basin (code 0707)	2,424,034	262,905	208,108	444,782	4,025,696	7,365,525
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	10,849,535	396,222	1,028,162	1,223,901	1,013,619	14,511,439
Rock River Basin (code 0709)	4,686,407	405,571	362,154	666,766	775,777	6,896,675
Des Moines River Basin (code 0710)	6,599,435	279,050	829,864	656,255	786,166	9,150,769
Upper Mississippi-Salt Rivers (code 0711)	3,002,771	364,557	1,163,052	427,432	1,364,503	6,322,314
Upper Illinois River Basin (code 0712)	4,067,028	99,226	315,349	1,628,296	755,643	6,865,542
Lower Illinois River Basin (code 0713)	8,079,072	150,110	489,568	945,673	1,645,872	11,310,296
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	3,503,238	460,122	1,492,025	1,086,042	4,146,390	10,687,816
Regional total	62,904,183	4,646,173	9,693,523	9,916,203	31,012,687	118,172,768

*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.

Conservation Practice Effects on Water Quality

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. In addition, instream degradation processes and streambed deposition and accumulation remove or trap a portion of the sediment, nutrients, and pesticides after delivery to streams and rivers.

The results from the onsite APEX model simulations for cultivated cropland, including land in long-term conserving cover, were integrated into HUMUS/SWAT to assess the effects of conservation practices on instream loads of sediment, nitrogen, phosphorus, and atrazine. The effects of conservation practices on water quality 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.

In summary, findings for the Upper Mississippi River Basin indicate that for the baseline conservation condition—

- *Amounts of sediment, nutrients, and atrazine loads* ***delivered to rivers and streams from cultivated cropland sources*** *per year, on average, are:*
  - *18.5 million tons of sediment (71 percent of loads from all sources);*
  - *1,040 million pounds of nitrogen (71 percent of loads from all sources);*
  - *81 million pounds of phosphorus (62 percent of loads from all sources); and*
  - *238,400 pounds of atrazine.*

- *The largest amounts of sediment, nutrients, and atrazine originate in three of the 14 subregions— the Upper Mississippi-Iowa-Skunk-Wapsipinicon (code 0708), the Rock River (code 0709), and the Lower Illinois River (code 0713). These three subregions contribute 44 percent of the sediment, 42 percent of the nitrogen, 43 percent of the phosphorus, and 53 percent of the atrazine delivered to rivers and streams from cultivated cropland in the region. In contrast, these three subregions account for only 37.5 percent of the cultivated cropland in the region.*

- *Three subregions contribute among the smallest sediment, nutrient, and atrazine loads from agricultural sources— the St. Croix River (code 0703), the Chippewa River (code 0705), and the Mississippi Headwaters (code 0701). These three subregions also have the lowest percentage of land cover in cultivated cropland (less than 25 percent).*

- *Instream* ***loads from all sources delivered from the region to the Mississippi River*** *per year, on average, are:*
  - *40 million tons of sediment (22 percent attributable to cultivated cropland sources);*
  - *1,069 million pounds of nitrogen (71 percent attributable to cultivated cropland sources);*
  - *69 million pounds of phosphorus (61 percent attributable to cultivated cropland sources); and*
  - *144,600 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:*
  - *65 percent for sediment;*
  - *26 percent for nitrogen;*
  - *41 percent for phosphorus, and*
  - *31 percent for atrazine.*

- *Reduced instream* ***loads from all sources delivered from the region to the Mississippi River*** *per year, on average, by:*
  - *14 percent for sediment;*
  - *19 percent for nitrogen;*
  - *26 percent for phosphorus, and*
  - *30 percent for atrazine.*

The Upper Mississippi-Maquoketa-Plum watershed (code 0706) and the Upper Mississippi-Salt (code 0711) have among the highest percent reductions of sediment and nutrients delivered into streams and rivers due to conservation practices. These two subregions also have the highest proportion of cultivated cropland acres in long-term conserving cover—more than 10 percent of the cultivated cropland in each subregion.

Sediment

Baseline condition. Model simulation results show that of the 53.3 million tons of sediment exported from farm fields in the Upper Mississippi River Basin (table 43), about 18.5 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 0.29 ton per acre of sediment from cultivated cropland is delivered to rivers and streams per year, on average for the region (table 44).

About 44 percent of the sediment delivered to rivers and streams from cultivated cropland originates in three subregions—the Upper Mississippi-Iowa-Skunk-Wapsipinicon (code 0708) with 18 percent of the total load for the region, the Lower Illinois River (code 0713) with 14 percent, and the Rock River (code 0709) with 12 percent.

On a per-acre basis, sediment delivery from cultivated cropland is highest in the St. Croix River Basin (code 0703), the Upper Mississippi-Salt River Basin (code 0711), and the Rock River Basin (code 0709). Sediment delivery averages 0.54 ton per acre for the St. Croix River Basin (code 0703), 0.50 ton per acre for the Upper Mississippi-Salt River Basin (code 0711), and 0.47 ton per acre for the Rock River Basin (code 0709) (table 44).

Sediment delivered to rivers and streams from cultivated cropland represents about 71 percent of the total sediment load delivered from all sources in the region (table 45, fig. 82). This percentage ranges, however, from a low of 44 percent in the Upper Illinois River Basin (code 0712) to a high of 89 percent in the Rock River Basin (code 0709). Cultivated cropland is the dominant source of sediment delivered to rivers and streams in all subregions except the Upper Illinois River (code 0712), where urban nonpoint sources deliver the majority of sediment to rivers and streams (table 45).

Instream sediment loads delivered from all sources in the region to the Mississippi River, after accounting for instream deposition and transport processes, total about 40 million tons per year, averaged over the 47 years of weather as simulated in the model (table 46, fig. 83). Of this, about 22 percent is attributed to cultivated cropland sources in the model simulation. The amount attributed to cultivated cropland was determined by subtracting the instream loads in the "background" scenario (no cultivation) from the total load from all sources in the baseline conservation scenario (table 46).

Among the tributary subregions, the Lower Illinois River (code 0713) and the Chippewa River (code 0705) have the highest percentage of instream sediment loads attributable to cultivated cropland—33 percent.

Six of the 14 subregions have outlets along the main stem of the Upper Mississippi River and receive loads from upstream sources in addition to loads from within the subbasin (table 46). Instream loads for the Lower Illinois River (code 0713) also include loads from the Upper Illinois River (code 0712). Instream loads for these subregions consistently increase from the upstream to the downstream subregions (table 46, fig. 83).

The Missouri River converges with the Upper Mississippi River in subregion 0714 (the Upper Mississippi-Kaskaskia-Meramec Rivers subregion), as shown in figure 76.The instream sediment load reported in table 46 for the outlet of subregion 0714—84.5 million tons—includes 44 million tons delivered to the Upper Mississippi River from the Missouri River. The estimate of the instream sediment load originating only from the Upper Mississippi River Basin—40 million tons (table 46 and fig. 83)—was derived by subtracting the load delivered from the Missouri River Basin from the instream load at the outlet of subregion 0714.

Effects of conservation practices. Sediment loads delivered to streams and rivers would have been much larger if soil erosion control practices were not in use. Model simulations indicate that conservation practices have reduced the delivery of sediment from fields to rivers and streams by about 65 percent (table 44), on average. Reductions due to conservation practices vary throughout the region, ranging from a low of 42 percent for the Mississippi Headwaters subregion (code 0701) to a high of 77 percent for the Des Moines River subregion (code 0710).

Model simulations of instream loads indicate that conservation practices have reduced the delivery of sediment from the Upper Mississippi River Basin to the Lower Mississippi River Basin by about 14 percent overall (table 46, fig. 83). Without conservation practices, the total amount of sediment delivered to the Lower Mississippi River Basin would be larger by 6.6 million tons per year. The largest percent reduction in instream loads among tributary subregions is in the Wisconsin River Basin (code 0707)—32 percent.

Table 43. Average annual sediment loads ***delivered to edge of field*** (APEX model output) from cultivated cropland in the Upper Mississippi River Basin

Subregions	Baseline conservation condition			No-practice Scenario (1,000 tons)	Reductions in loads due to conservation practices	
	Amount (1,000 tons)	Percent of basin total	Tons delivered per cultivated cropland acre		Reduction (1,000 tons)	Percent
Mississippi Headwaters (code 0701)	1,650	3	0.54	2,820	1,170	41
Minnesota River Basin (code 0702)	1,490	3	0.18	3,650	2,160	59
St. Croix River Basin (code 0703)	997	2	1.60	1,950	953	49
Upper Mississippi-Black-Root Rivers (code 0704)	4,160	8	1.26	10,000	5,840	58
Chippewa River Basin (code 0705)	1,840	3	1.32	3,980	2,140	54
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	3,650	7	1.20	13,400	9,750	73
Wisconsin River Basin (code 0707)	2,730	5	1.13	5,930	3,200	54
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	9,750	18	0.90	34,000	24,250	71
Rock River Basin (code 0709)	6,310	12	1.35	14,900	8,590	58
Des Moines River Basin (code 0710)	2,570	5	0.39	11,200	8,630	77
Upper Mississippi-Salt Rivers (code 0711)	4,190	8	1.40	13,400	9,210	69
Upper Illinois River Basin (code 0712)	2,380	4	0.59	5,710	3,330	58
Lower Illinois River Basin (code 0713)	7,200	14	0.89	18,400	11,200	61
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	4,350	8	1.24	9,670	5,320	55
Regional total	53,267	100	0.85	149,010	95,743	64

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 Upper Mississippi River Basin

Subregions	Baseline conservation condition			No-practice Scenario (1,000 tons)	Reductions in loads due to conservation practices	
	Amount (1,000 tons)	Percent of basin total	Tons delivered per cultivated cropland acre		Reduction (1,000 tons)	Percent
Mississippi Headwaters (code 0701)	600	3	0.20	1,040	440	42
Minnesota River Basin (code 0702)	524	3	0.06	1,330	806	61
St. Croix River Basin (code 0703)	335	2	0.54	665	330	50
Upper Mississippi-Black-Root Rivers (code 0704)	1,420	8	0.43	3,480	2,060	59
Chippewa River Basin (code 0705)	621	3	0.44	1,360	739	54
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	1,260	7	0.41	4,730	3,470	73
Wisconsin River Basin (code 0707)	891	5	0.37	1,960	1,069	55
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	3,340	18	0.31	11,800	8,460	72
Rock River Basin (code 0709)	2,180	12	0.47	5,210	3,030	58
Des Moines River Basin (code 0710)	871	5	0.13	3,810	2,939	77
Upper Mississippi-Salt Rivers (code 0711)	1,500	8	0.50	4,810	3,310	69
Upper Illinois River Basin (code 0712)	837	5	0.21	2,070	1,233	60
Lower Illinois River Basin (code 0713)	2,570	14	0.32	6,660	4,090	61
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	1,530	8	0.44	3,450	1,920	56
Regional total	18,479	100	0.29	52,375	33,896	65

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 Upper 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)			
Mississippi Headwaters (code 0701)	935	600	13	20	241	7	55
Minnesota River Basin (code 0702)	861	524	4	4	298	2	28
St. Croix River Basin (code 0703)	453	335	11	12	57	1	37
Upper Mississippi-Black-Root Rivers (code 0704)	1,661	1,420	60	12	119	3	46
Chippewa River Basin (code 0705)	763	621	21	2	75	2	42
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	1,498	1,260	72	21	91	2	52
Wisconsin River Basin (code 0707)	1,156	891	54	3	117	4	86
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	4,238	3,340	136	31	668	8	55
Rock River Basin (code 0709)	2,461	2,180	65	6	191	4	15
Des Moines River Basin (code 0710)	1,463	871	120	32	389	2	49
Upper Mississippi-Salt Rivers (code 0711)	2,405	1,500	63	303	385	2	152
Upper Illinois River Basin (code 0712)	1,906	837	0	2	1,023	32	11
Lower Illinois River Basin (code 0713)	2,997	2,570	4	5	391	4	22
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	3,229	1,530	84	415	880	9	311
Regional total	26,027	18,479	707	868	4,926	84	962
				Percent of all sources			
Mississippi Headwaters (code 0701)	100	64	1	2	26	1	6
Minnesota River Basin (code 0702)	100	61	1	1	35	<1	3
St. Croix River Basin (code 0703)	100	74	2	3	13	<1	8
Upper Mississippi-Black-Root Rivers (code 0704)	100	85	4	1	7	<1	3
Chippewa River Basin (code 0705)	100	81	3	<1	10	<1	5
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	100	84	5	1	6	<1	4
Wisconsin River Basin (code 0707)	100	77	5	<1	10	<1	7
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	100	79	3	1	16	<1	1
Rock River Basin (code 0709)	100	89	3	<1	8	<1	1
Des Moines River Basin (code 0710)	100	60	8	2	27	<1	3
Upper Mississippi-Salt Rivers (code 0711)	100	62	3	13	16	<1	6
Upper Illinois River Basin (code 0712)	100	44	<1	<1	54	2	1
Lower Illinois River Basin (code 0713)	100	86	<1	<1	13	<1	1
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	100	47	3	13	27	<1	10
Regional total	100	71	3	3	19	<1	4

* 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 82. Percentage by source of average annual sediment loads delivered to rivers and streams in the Upper Mississippi River Basin, baseline conservation condition

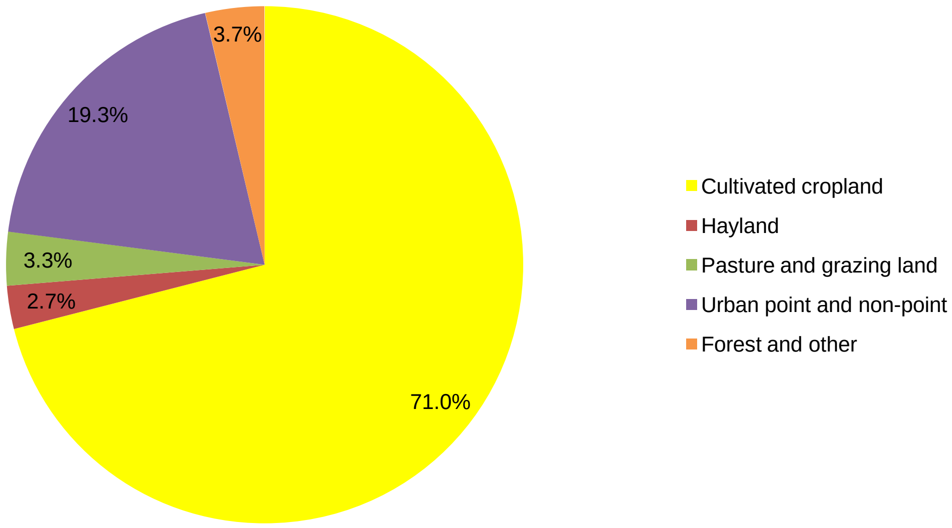


Table 46. Average annual ***instream sediment loads*** (all sources) for the Upper Mississippi River Basin

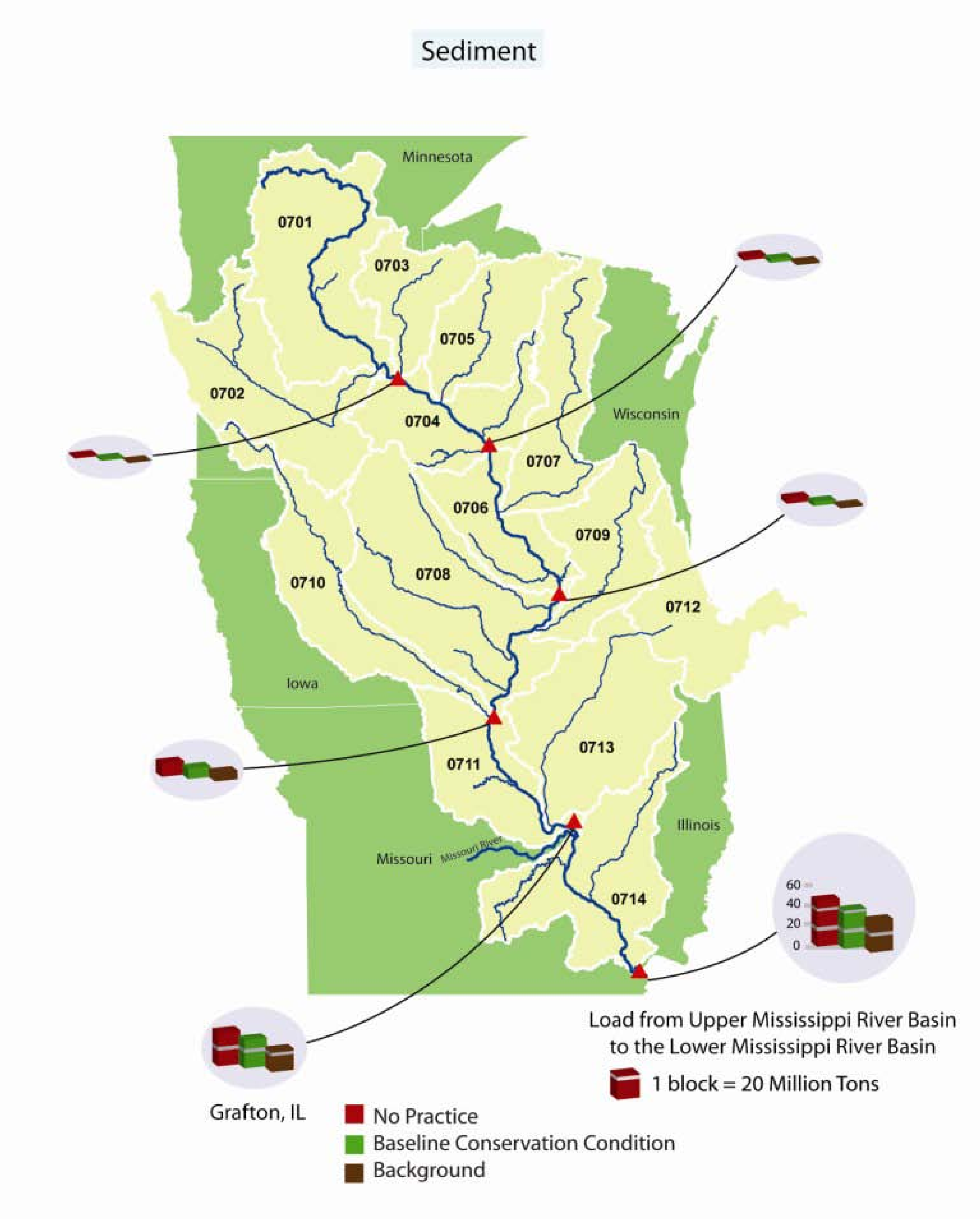
	Baseline conservation condition				Reductions in loads due to conservation practices	
Subregions	Load from all sources (1,000 tons)	Background sources* (1,000 tons)	Percent of load attributed to cultivated cropland sources	No-practice scenario (1,000 tons)	Reduction (1,000 tons)	Percent
Tributary subregions						
Minnesota River Basin (code 0702)	947	702	26	1,060	113	11
St. Croix River Basin (code 0703)	177	149	16	203	26	13
Chippewa River Basin (code 0705)	186	125	33	242	56	23
Wisconsin River Basin (code 0707)	267	199	25	391	124	32
Iowa River within 0708	2,690	1,900	29	3,240	550	17
Rock River Basin (code 0709)	1,310	980	25	1,780	470	26
Des Moines River Basin (code 0710)	458	363	21	468	10	2
Lower Illinois River Basin (code 0713)	7,180	4,840	33	9,080	1,900	21
Upper Illinois River Basin only (code 0712)	3,280	2,860	13	3,570	290	8
Outlets along mainstem						
Mississippi Headwaters (code 0701)	1,710	1,240	27	1,940	230	12
Upper Mississippi-Black-Root Rivers (code 0704)	2,110	1,430	32	2,500	390	16
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	2,880	1,620	44	4,120	1,240	30
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	11,200	8,260	26	15,000	3,800	25
Upper Mississippi-Salt Rivers (code 0711 near Grafton, IL)	29,200	21,900	25	36,500	7,300	20
Load delivered from Missouri River Basin	44,010	34,210	22	45,620	1,610	4
Load delivered to Lower Mississippi River Basin (0714 near Thebes, IL), including load from Missouri River Basin	84,500	65,700	22	92,700	8,200	9
Load delivered from Upper Mississippi River Basin to Lower Mississippi River Basin, exclusive of Missouri River Basin**	40,490	31,490	22	47,080	6,590	14

* "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.

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.

** 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.

Figure 83. Estimates of average annual instream sediment loads for the baseline conservation condition compared to the no-practice scenario for the Upper Mississippi River Basin*



* Instream sediment loads (all sources) are shown for each subregion with an outlet along the main stem of the river, corresponding to estimates presented in table 46.

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.

Total Nitrogen

Baseline condition. Model simulation results show that of the 1,345 million pounds of nitrogen exported from farm fields in the Upper Mississippi River Basin (table 47), about 1,040 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 16.5 pounds per acre of nitrogen from cultivated cropland are delivered to rivers and streams per year, on average for the region (table 48).

Generally, the amount of nitrogen delivered to rivers and streams varies among subregions according to the number of cultivated cropland acres in each subregion. Over half of the nitrogen delivered to rivers and streams from cultivated cropland originates in the four subregions with the most cultivated cropland—

- The Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708), with 18 percent of the total load for the region,
- The Lower Illinois River Basin (code 0713), with 16 percent,
- The Minnesota River Basin (code 0702), with 11 percent, and
- The Des Moines River Basin (code 0710), with 10 percent.

On a per-acre basis, nitrogen delivery from cultivated cropland is highest in two subregions—the Upper Illinois River Basin (code 0712), with 23.3 pounds per acre, and the St. Croix River Basin (code 0703), with 21.7 pounds per acre (table 48). Per acre nitrogen delivery to rivers and streams is lowest in the Mississippi Headwaters subregion (code 0701), with 11.0 pounds per acre, and the Upper Mississippi-Salt Rivers Basin (code 0711), with 11.6 pounds per acre.

Nitrogen delivered to rivers and streams from cultivated cropland represents about 71 percent of the total nitrogen load delivered from all sources in the region (table 49, fig. 84). This percentage ranges, however, from a low of 47 percent in the Upper Illinois River Basin (code 0712) to a high of 92 percent in the Lower Illinois River Basin (code 0713). Cultivated cropland is the dominant source of nitrogen delivered to rivers and streams in all subregions (table 49). In the Upper Illinois River Basin (code 0712), however, the amount of nitrogen delivered from urban point sources is nearly the same as nitrogen delivered from cultivated cropland.

Instream nitrogen loads delivered from all sources in the region to the Mississippi River, after accounting for instream deposition and transport processes, total about 1,069 million pounds per year, averaged over the 47 years of weather as simulated in the model (table 50, fig. 85). Of this, about 71 percent is attributed to cultivated cropland sources in the model simulation. The amount attributed to cultivated cropland was determined by subtracting the instream loads in the "background" scenario (no cultivation) from the total load from all sources in the baseline conservation scenario (table 50).

Among the tributary subregions, the Minnesota River Basin (code 0702) has the highest percentage of instream nitrogen loads attributable to cultivated cropland—85 percent (table 50). The St. Croix River Basin (code 0703) has the lowest—29 percent.

Six of the 14 subregions have outlets along the main stem of the Upper Mississippi River and receive loads from upstream sources in addition to loads from within the subbasin (table 50). Instream loads for the Lower Illinois River (code 0713) also include loads from the Upper Illinois River (code 0712). Instream loads for these subregions consistently increase from the upstream to the downstream subregions (table 50, fig. 85).

The Missouri River converges with the Upper Mississippi River in subregion 0714 (the Upper Mississippi-Kaskaskia-Meramec Rivers subregion), as shown in figure 76.The instream nitrogen load reported in table 50 for the outlet of subregion 0714—1,580 million pounds—includes 511 million pounds delivered to the Upper Mississippi River from the Missouri River. The estimate of the instream nitrogen load originating only from the Upper Mississippi River Basin—1,069 million pounds (table 50 and fig. 85)—was derived by subtracting the load delivered from the Missouri River Basin from the instream load at the outlet of subregion 0714.

Effects of conservation practices. Nitrogen loads delivered to rivers and streams would have been much larger if soil erosion control practices were not in use. Model simulations indicate that conservation practices have reduced the delivery of nitrogen from fields to rivers and streams by about 26 percent (table 48), on average. Reductions due to conservation practices vary throughout the region, ranging from a low of 11 percent for the Lower Illinois River Basin (code 0713) to 40 percent or more for three subregions:

- The Upper Mississippi-Salt Rivers (code 0711),
- The Upper Mississippi-Maquoketa-Plum Rivers (code 0706), and
- The Mississippi Headwaters (code 0701).

Model simulations of instream loads indicate that conservation practices have reduced the delivery of nitrogen from the Upper Mississippi River Basin to the Lower Mississippi River Basin by about 19 percent overall (table 50, fig. 85). Without conservation practices, the total amount of nitrogen delivered to the Lower Mississippi River Basin would be larger by 248 million pounds per year. The largest percent reduction in instream loads among tributary subregions is in the Wisconsin River Basin (code 0707)—29 percent.

Table 47. Average annual nitrogen loads ***delivered to edge of field*** (APEX model output) from cultivated cropland in the Upper Mississippi River Basin

	Baseline conservation condition				Reductions in loads due to conservation practices	
Subregions	Amount (1,000 pounds)	Percent of basin total	Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent
Mississippi Headwaters (code 0701)	48,300	4	16	77,600	29,300	38
Minnesota River Basin (code 0702)	125,000	9	15	169,000	44,000	26
St. Croix River Basin (code 0703)	19,600	1	31	28,000	8,400	30
Upper Mississippi-Black-Root Rivers (code 0704)	81,600	6	25	127,000	45,400	36
Chippewa River Basin (code 0705)	31,100	2	22	48,500	17,400	36
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	67,600	5	22	121,000	53,400	44
Wisconsin River Basin (code 0707)	72,200	5	30	108,000	35,800	33
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	238,000	18	22	354,000	116,000	33
Rock River Basin (code 0709)	123,000	9	26	173,000	50,000	29
Des Moines River Basin (code 0710)	112,000	8	17	160,000	48,000	30
Upper Mississippi-Salt Rivers (code 0711)	53,100	4	18	94,900	41,800	44
Upper Illinois River Basin (code 0712)	105,000	8	26	136,000	31,000	23
Lower Illinois River Basin (code 0713)	199,000	15	25	234,000	35,000	15
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	69,700	5	20	93,500	23,800	25
Regional total	1,345,200	100	21	1,924,500	579,300	30

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 Upper Mississippi River Basin

	Baseline conservation condition				Reductions in loads due to conservation practices	
Subregions	Amount (1,000 pounds)	Percent of basin total	Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent
Mississippi Headwaters (code 0701)	33,800	3	11.0	56,500	22,700	40
Minnesota River Basin (code 0702)	119,000	11	14.4	158,000	39,000	25
St. Croix River Basin (code 0703)	13,500	1	21.7	19,000	5,500	29
Upper Mississippi-Black-Root Rivers (code 0704)	52,700	5	16.0	80,300	27,600	34
Chippewa River Basin (code 0705)	20,300	2	14.5	31,700	11,400	36
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	42,300	4	13.9	70,500	28,200	40
Wisconsin River Basin (code 0707)	49,200	5	20.3	72,100	22,900	32
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	183,000	18	16.9	249,000	66,000	27
Rock River Basin (code 0709)	78,900	8	16.8	108,000	29,100	27
Des Moines River Basin (code 0710)	101,000	10	15.3	130,000	29,000	22
Upper Mississippi-Salt Rivers (code 0711)	34,800	3	11.6	58,800	24,000	41
Upper Illinois River Basin (code 0712)	94,600	9	23.3	122,000	27,400	22
Lower Illinois River Basin (code 0713)	166,000	16	20.5	186,000	20,000	11
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	51,300	5	14.6	68,600	17,300	25
Regional total	1,040,400	100	16.5	1,410,500	370,100	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 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 Upper 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)			
Mississippi Headwaters (code 0701)	54,905	33,800	3,122	4,426	5,347	6,960	1,250
Minnesota River Basin (code 0702)	140,293	119,000	920	10,144	7,637	2,070	523
St. Croix River Basin (code 0703)	21,594	13,500	1,771	1,850	1,828	508	2,136
Upper Mississippi-Black-Root Rivers (code 0704)	70,873	52,700	4,106	4,664	5,110	3,118	1,174
Chippewa River Basin (code 0705)	28,284	20,300	1,229	1,334	2,699	1,166	1,557
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	57,928	42,300	3,975	6,246	3,116	1,731	559
Wisconsin River Basin (code 0707)	62,235	49,200	2,389	2,275	4,793	2,157	1,422
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	251,775	183,000	7,077	26,801	23,012	8,962	2,923
Rock River Basin (code 0709)	103,017	78,900	3,636	7,091	7,305	5,641	444
Des Moines River Basin (code 0710)	142,221	101,000	5,362	18,166	13,343	2,390	1,961
Upper Mississippi-Salt Rivers (code 0711)	69,381	34,800	4,511	13,518	10,966	1,490	4,096
Upper Illinois River Basin (code 0712)	202,855	94,600	16	2,558	11,449	93,917	315
Lower Illinois River Basin (code 0713)	181,200	166,000	48	1,782	5,974	6,702	695
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	86,182	51,300	1,581	7,640	14,026	6,992	4,642
Regional total	1,472,745	1,040,400	39,743	108,495	116,606	143,805	23,697
				Percent of all sources			
Mississippi Headwaters (code 0701)	100	62	6	8	10	13	2
Minnesota River Basin (code 0702)	100	85	1	7	5	1	<1
St. Croix River Basin (code 0703)	100	63	8	9	8	2	10
Upper Mississippi-Black-Root Rivers (code 0704)	100	74	6	7	7	4	2
Chippewa River Basin (code 0705)	100	72	4	5	10	4	6
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	100	73	7	11	5	3	1
Wisconsin River Basin (code 0707)	100	79	4	4	8	3	2
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	100	73	3	11	9	4	1
Rock River Basin (code 0709)	100	77	4	7	7	5	<1
Des Moines River Basin (code 0710)	100	71	4	13	9	2	1
Upper Mississippi-Salt Rivers (code 0711)	100	50	7	19	16	2	6
Upper Illinois River Basin (code 0712)	100	47	<1	1	6	46	<1
Lower Illinois River Basin (code 0713)	100	92	<1	1	3	4	<1
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	100	60	2	9	16	8	5
Regional total	100	71	3	7	8	10	2

* 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 84. Percentage by source of average annual nitrogen loads delivered to rivers and streams in the Upper Mississippi River Basin, baseline conservation condition

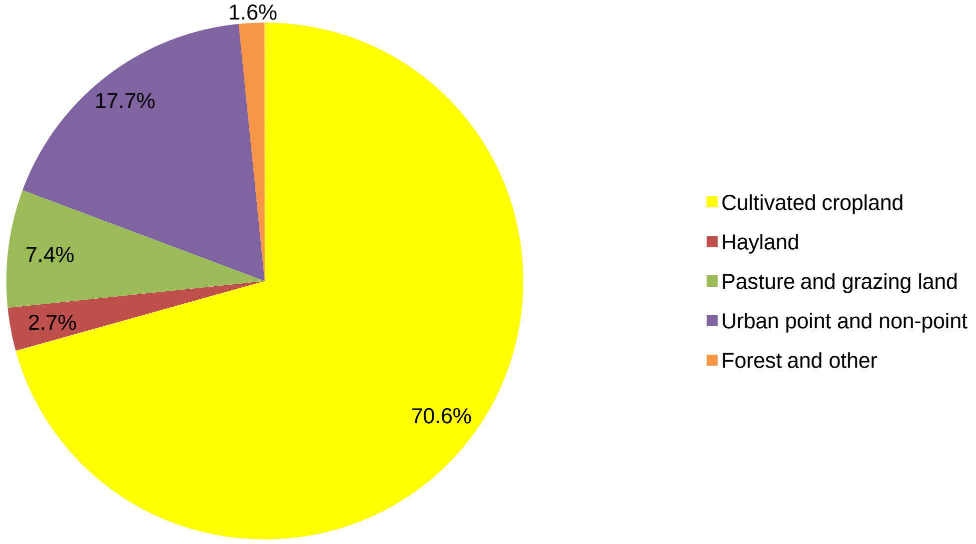


Table 50. Average annual ***instream nitrogen loads*** (all sources) for the Upper Mississippi River Basin

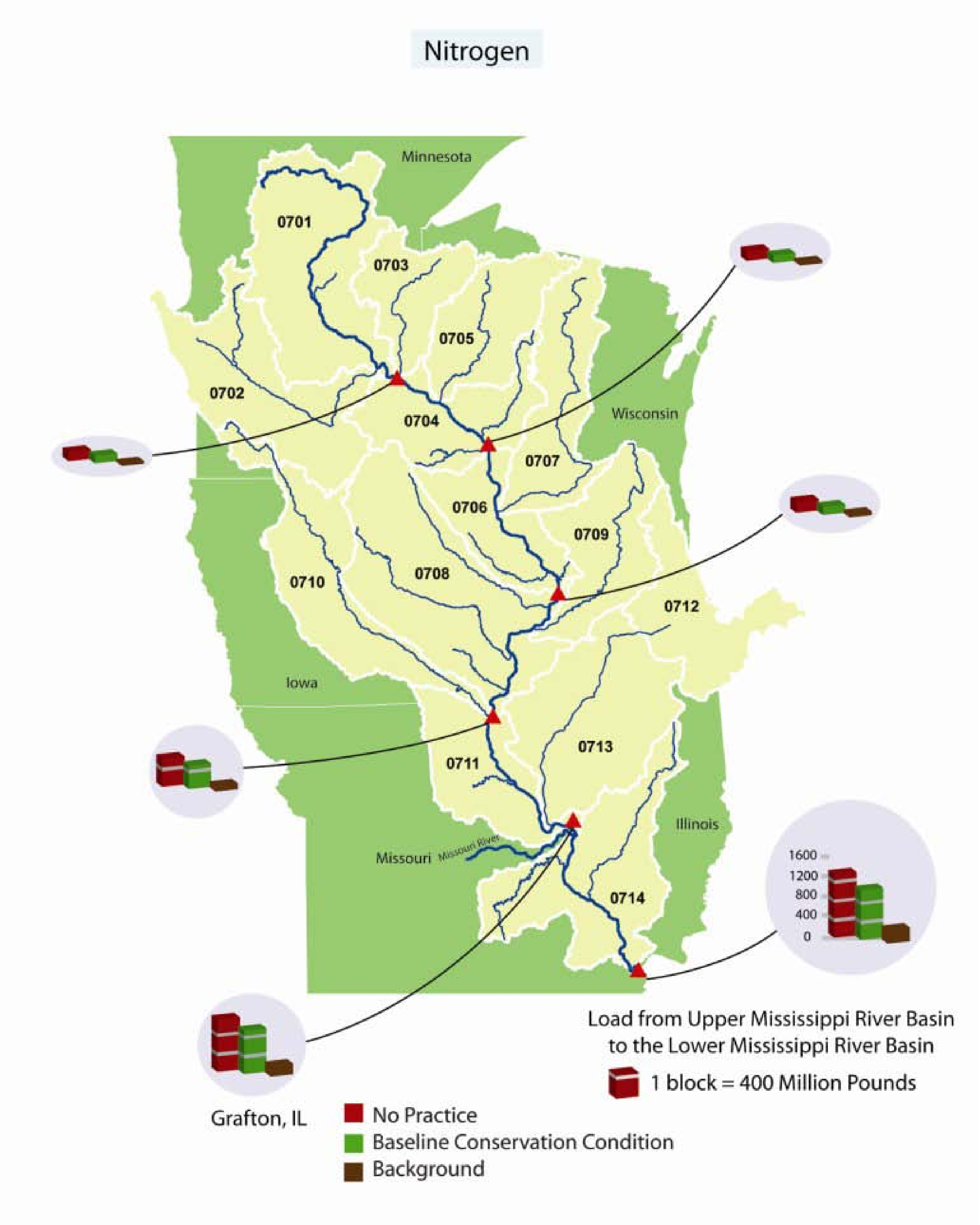
	Baseline conservation condition				Reductions in loads due to conservation practices	
Subregions	Load from all sources (1,000 pounds)	Background sources* (1,000 pounds)	Percent of load attributed to cultivated cropland sources	No-practice scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent
Tributary subregions						
Minnesota River Basin (code 0702)	105,000	15,800	85	133,000	28,000	21
St. Croix River Basin (code 0703)	9,240	6,580	29	10,400	1,160	11
Chippewa River Basin (code 0705)	9,910	3,930	60	13,000	3,090	24
Wisconsin River Basin (code 0707)	14,100	4,830	66	19,900	5,800	29
Iowa River within 0708	108,000	34,100	68	138,000	30,000	22
Rock River Basin (code 0709)	54,900	14,700	73	68,000	13,100	19
Des Moines River Basin (code 0710)	117,000	36,900	68	137,000	20,000	15
Lower Illinois River Basin (code 0713)	257,000	52,300	80	288,000	31,000	11
Upper Illinois River Basin only (code 0712)	153,000	92,800	39	170,000	17,000	10
Outlets along mainstem						
Mississippi Headwaters (code 0701)	157,000	30,400	81	202,000	45,000	22
Upper Mississippi-Black-Root Rivers (code 0704)	168,000	36,100	79	221,000	53,000	24
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	193,000	44,700	77	259,000	66,000	25
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	456,000	121,000	73	589,000	133,000	23
Upper Mississippi-Salt Rivers (code 0711 near Grafton, IL)	947,000	252,000	73	1,160,000	213,000	18
Load delivered from Missouri River Basin	511,300	167,700	67	792,800	281,500	36
Load delivered to Lower Mississippi River Basin (0714 near Thebes, IL), including load from Missouri River Basin	1,580,000	474,000	70	2,110,000	530,000	25
Load delivered from Upper Mississippi River Basin to Lower Mississippi River Basin, exclusive of Missouri River Basin**	1,068,700	306,300	71	1,317,200	248,500	19

***** “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.

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.

** 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.

Figure 85. Estimates of average annual instream nitrogen loads for the baseline conservation condition compared to the no-practice scenario for the Upper Mississippi River Basin*



* Instream nitrogen loads (all sources) are shown for each subregion with an outlet along the main stem of the river, corresponding to estimates presented in table 50.

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.

Total Phosphorus

Baseline condition. Model simulation results show that about 163 million pounds of phosphorus are lost from farm fields (edge-of-field) per year within the Upper Mississippi River Basin (table 51) under conditions represented by the baseline conservation condition, which includes farming activities and conservation practices in use during the period 2003 to 2006. Of this, about 81 million pounds are delivered into rivers and streams per year, on average (table 52). About 1.29 pounds per acre of phosphorus from cultivated cropland are delivered to rivers and streams per year, on average for the region (table 52).

About 43 percent of the phosphorus delivered to rivers and streams from cultivated cropland originates in three subregions—the Upper Mississippi-Iowa-Skunk-Wapsipinicon (code 0708) with 17 percent of the total load for the region, the Lower Illinois River (code 0713) with 16 percent, and the Rock River (code 0709) with 10 percent.

On a per-acre basis, phosphorus delivery to rivers and streams from cultivated cropland is highest in the Wisconsin River Basin (code 0703), averaging 2.76 pounds per acre (table 52). Per acre phosphorus delivery is lowest in the Minnesota River Basin (code 0702), with 0.44 pound per acre, the Mississippi Headwaters subregion (code 0701), with 0.77 pound per acre, and the Des Moines River Basin (code 0710), with 0.79 pound per acre.

Phosphorus delivered to rivers and streams from cultivated cropland represents about 62 percent of the total phosphorus load delivered from all sources in the region (table 53, fig. 86). This percentage ranges, however, from a low of 32 percent in the Upper Illinois River Basin (code 0712) to a high of 89 percent in the Lower Illinois River Basin (code 0713).

Cultivated cropland is the dominant source of phosphorus delivered to rivers and streams in all subregions except the Upper Illinois River (code 0712), where urban point sources deliver the majority of phosphorus to rivers and streams (table 53). Urban point sources are also an important contributor of phosphorus delivery in the Mississippi Headwaters subregion (code 0701). Pasture and grazing land are important sources of phosphorus delivered to rivers and streams in two subregions—the Upper Mississippi-Salt Rivers Basin (code 0711) and the Des Moines River Basin (code 0710). About one-third of the phosphorus delivered to rivers and streams originates from pasture and grazing land in these two subregions (table 53).

Instream phosphorus loads delivered from all sources in the region to the Mississippi River, after accounting for instream deposition and transport processes, total about 69 million pounds per year, averaged over the 47 years of weather as simulated in the model (table 54, fig. 87). Of this, about 61 percent is attributed to cultivated cropland sources in the model simulation. The amount attributed to cultivated cropland was determined by subtracting the instream loads in the “background” scenario (no cultivation) from the total load from all sources in the baseline conservation scenario (table 54).

Among the tributary subregions, the Rock River (code 0709), the Lower Illinois River (code 0713), and the Wisconsin River (code 0707) have the highest percentages of instream phosphorus loads attributable to cultivated cropland—78 to 80 percent.

Six of the 14 subregions have outlets along the main stem of the Upper Mississippi River and receive loads from upstream sources in addition to loads from within the subbasin (table 54). Instream loads for the Lower Illinois River (code 0713) also include loads from the Upper Illinois River (code 0712). Instream loads for these subregions consistently increase from the upstream to the downstream subregions (table 54, fig. 87).

The Missouri River converges with the Upper Mississippi River in subregion 0714 (the Upper Mississippi-Kaskaskia-Meramec Rivers subregion), as shown in figure 76.The instream phosphorus load reported in table 54 for the outlet of subregion 0714—124 million pounds—includes 55 million pounds delivered to the Upper Mississippi River from the Missouri River. The estimate of the instream phosphorus load originating only from the Upper Mississippi River Basin—69 million pounds (table 54 and fig. 87)—was derived by subtracting the load delivered from the Missouri River Basin from the instream load at the outlet of subregion 0714.

Effects of conservation practices. Phosphorus loads delivered to streams and rivers would have been much larger if soil erosion control practices were not in use. Model simulations indicate that conservation practices have reduced the delivery of phosphorus from fields to rivers and streams by about 41 percent (table 52), on average. Reductions due to conservation practices vary throughout the region, ranging from a low of 29 percent for the Wisconsin River Basin (code 0707) to a high of 51 percent for the Mississippi Headwaters subregion (code 0701).

Model simulations of instream loads indicate that conservation practices have reduced the delivery of phosphorus from the Upper Mississippi River Basin to the Lower Mississippi River Basin by about 26 percent overall (table 54, fig. 87). Without conservation practices, the total amount of phosphorus delivered to the Lower Mississippi River Basin would be larger by 24.5 million pounds per year. The largest percent reduction in instream loads among tributary subregions is in the Minnesota River Basin (code 0702)—46 percent.

Table 51. Average annual phosphorus loads ***delivered to edge of field*** (APEX model output) from cultivated cropland in the Upper Mississippi River Basin

	Baseline conservation condition				Reductions in loads due to conservation practices	
Subregions	Amount (1,000 pounds)	Percent of basin total	Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent
Mississippi Headwaters (code 0701)	5,200	3	1.69	9,920	4,720	48
Minnesota River Basin (code 0702)	6,530	4	0.79	13,100	6,570	50
St. Croix River Basin (code 0703)	2,490	2	3.99	4,230	1,740	41
Upper Mississippi-Black-Root Rivers (code 0704)	9,420	6	2.86	18,500	9,080	49
Chippewa River Basin (code 0705)	4,740	3	3.39	7,350	2,610	36
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	8,590	5	2.83	19,500	10,910	56
Wisconsin River Basin (code 0707)	13,400	8	5.53	20,300	6,900	34
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	28,200	17	2.60	56,100	27,900	50
Rock River Basin (code 0709)	17,100	10	3.65	29,500	12,400	42
Des Moines River Basin (code 0710)	9,930	6	1.50	22,200	12,270	55
Upper Mississippi-Salt Rivers (code 0711)	10,100	6	3.36	20,700	10,600	51
Upper Illinois River Basin (code 0712)	9,490	6	2.33	17,000	7,510	44
Lower Illinois River Basin (code 0713)	24,400	15	3.02	40,400	16,000	40
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	13,400	8	3.83	21,800	8,400	39
Regional total	162,990	100	2.59	300,600	137,610	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 Upper Mississippi River Basin

	Baseline conservation condition				Reductions in loads due to conservation practices	
Subregions	Amount (1,000 pounds)	Percent of basin total	Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent
Mississippi Headwaters (code 0701)	2,380	3	0.77	4,810	2,430	51
Minnesota River Basin (code 0702)	3,640	4	0.44	7,110	3,470	49
St. Croix River Basin (code 0703)	1,160	1	1.86	1,840	680	37
Upper Mississippi-Black-Root Rivers (code 0704)	4,300	5	1.31	7,760	3,460	45
Chippewa River Basin (code 0705)	2,240	3	1.60	3,250	1,010	31
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	3,990	5	1.31	7,880	3,890	49
Wisconsin River Basin (code 0707)	6,680	8	2.76	9,440	2,760	29
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	13,800	17	1.27	23,800	10,000	42
Rock River Basin (code 0709)	7,750	10	1.65	12,700	4,950	39
Des Moines River Basin (code 0710)	5,220	6	0.79	9,980	4,760	48
Upper Mississippi-Salt Rivers (code 0711)	4,650	6	1.55	8,400	3,750	45
Upper Illinois River Basin (code 0712)	5,230	6	1.29	9,030	3,800	42
Lower Illinois River Basin (code 0713)	12,900	16	1.60	20,000	7,100	36
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	7,180	9	2.05	11,000	3,820	35
Regional total	81,120	100	1.29	137,000	55,880	41

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 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 Upper 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)			
Mississippi Headwaters (code 0701)	4,603	2,380	51	325	270	1,493	84
Minnesota River Basin (code 0702)	4,650	3,640	16	327	243	388	35
St. Croix River Basin (code 0703)	1,654	1,160	34	159	84	159	57
Upper Mississippi-Black-Root Rivers (code 0704)	5,938	4,300	150	621	175	614	78
Chippewa River Basin (code 0705)	2,910	2,240	69	146	118	246	92
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	5,585	3,990	181	681	159	512	63
Wisconsin River Basin (code 0707)	7,567	6,680	107	143	168	358	111
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	20,349	13,800	461	2,508	1,041	2,427	112
Rock River Basin (code 0709)	9,653	7,750	167	402	302	987	45
Des Moines River Basin (code 0710)	10,509	5,220	474	3,280	925	488	122
Upper Mississippi-Salt Rivers (code 0711)	10,354	4,650	382	3,867	979	276	200
Upper Illinois River Basin (code 0712)	16,474	5,230	1	95	625	10,506	17
Lower Illinois River Basin (code 0713)	14,506	12,900	10	147	332	1,088	29
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	15,562	7,180	377	4,020	2,241	1,296	448
Regional total	130,319	81,120	2,480	16,721	7,661	20,838	1,498
				Percent of all sources			
Mississippi Headwaters (code 0701)	100	52	1	7	6	32	2
Minnesota River Basin (code 0702)	100	78	<1	7	5	8	1
St. Croix River Basin (code 0703)	100	70	2	10	5	10	3
Upper Mississippi-Black-Root Rivers (code 0704)	100	72	3	10	3	10	1
Chippewa River Basin (code 0705)	100	77	2	5	4	8	3
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	100	71	3	12	3	9	1
Wisconsin River Basin (code 0707)	100	88	1	2	2	5	1
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	100	68	2	12	5	12	1
Rock River Basin (code 0709)	100	80	2	4	3	10	<1
Des Moines River Basin (code 0710)	100	50	5	31	9	5	1
Upper Mississippi-Salt Rivers (code 0711)	100	45	4	37	9	3	2
Upper Illinois River Basin (code 0712)	100	32	<1	1	4	64	<1
Lower Illinois River Basin (code 0713)	100	89	<1	1	2	7	<1
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	100	46	2	26	14	8	3
Regional total	100	62	2	13	6	16	1

* 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 86. Percentage by source of average annual phosphorus loads delivered to rivers and streams in the Upper Mississippi River Basin, baseline conservation condition

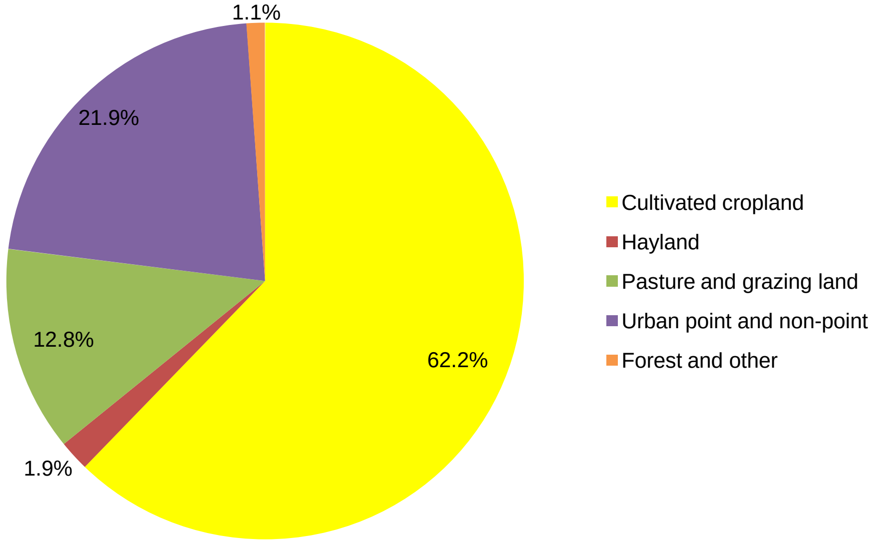


Table 54. Average annual ***instream phosphorus loads*** (all sources) for the Upper Mississippi River Basin

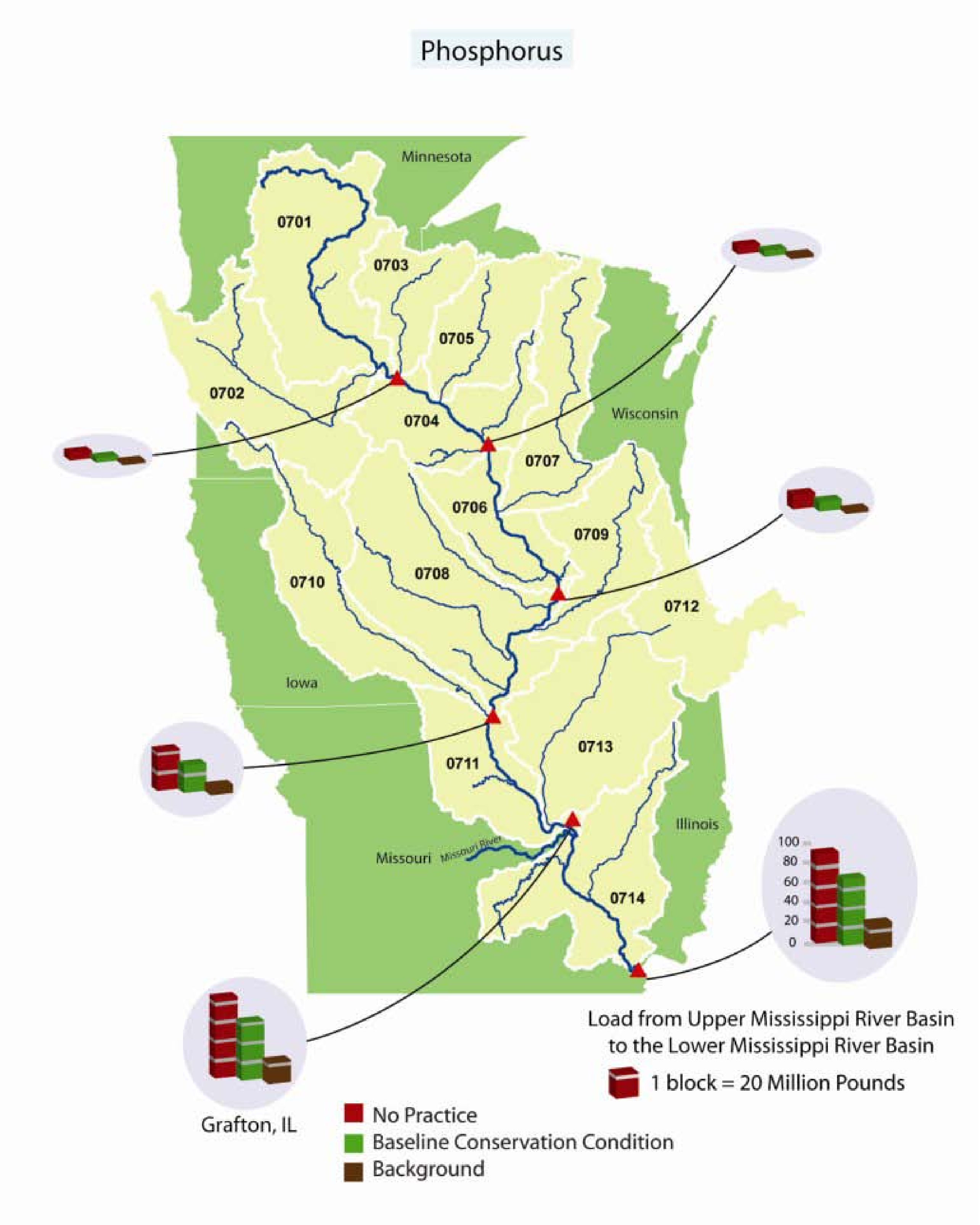
	Baseline conservation condition				Reductions in loads due to conservation practices	
Subregions	Load from all sources (1,000 pounds)	Background sources* (1,000 pounds)	Percent of load attributed to cultivated cropland sources	No-practice scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent
Tributary subregions						
Minnesota River Basin (code 0702)	1,940	504	74	3,580	1,640	46
St. Croix River Basin (code 0703)	521	333	36	639	118	18
Chippewa River Basin (code 0705)	1,040	332	68	1,360	320	24
Wisconsin River Basin (code 0707)	1,700	373	78	2,340	640	27
Iowa River within 0708	5,100	1,210	76	7,290	2,190	30
Rock River Basin (code 0709)	4,610	903	80	6,710	2,100	31
Des Moines River Basin (code 0710)	6,560	3,760	43	8,770	2,210	25
Lower Illinois River Basin (code 0713)	14,100	2,920	79	19,800	5,700	29
Upper Illinois River Basin only (code 0712)	9,970	7,330	26	12,100	2,130	18
Outlets along mainstem						
Mississippi Headwaters (code 0701)	4,780	1,980	59	8,230	3,450	42
Upper Mississippi-Black-Root Rivers (code 0704)	6,610	2,250	66	10,600	3,990	38
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	11,200	2,990	73	17,100	5,900	35
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	29,400	8,990	69	42,800	13,400	31
Upper Mississippi-Salt Rivers (code 0711 near Grafton, IL)	60,400	21,100	65	85,400	25,000	29
Load delivered from Missouri River Basin	54,650	37,180	32	76,100	21,450	28
Load delivered to Lower Mississippi River Basin (0714 near Thebes, IL), including load from Missouri River Basin	124,000	64,200	48	170,000	46,000	27
Load delivered from Upper Mississippi River Basin to Lower Mississippi River Basin, exclusive of Missouri River Basin**	69,350	27,020	61	93,900	24,550	26

***** "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.

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.

** 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..

Figure 87. Estimates of average annual instream phosphorus loads for the baseline conservation condition compared to the no-practice scenario for the Upper Mississippi River Basin*



* Instream phosphorus loads (all sources) are shown for each subregion with an outlet along the main stem of the river, corresponding to estimates presented in table 54.

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.

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 334,000 pounds of atrazine are lost from farm fields (edge-of-field) through pathways that result in delivery to streams and rivers within the Upper Mississippi River Basin (table 55). Of this, about 238,400 pounds are delivered into rivers and streams each year, on average, under conditions represented by the baseline conservation condition (table 56).

About 46 percent of the atrazine delivered to rivers and streams from cultivated cropland in the region comes from two subregions— the Lower Illinois River (code 0713) with 24 percent of the total load for the region and the Upper Mississippi-Iowa-Skunk-Wapsipinicon (code 0708) with 22 percent.

Instream atrazine loads delivered to the Lower Mississippi River Basin, after accounting for instream deposition and transport processes and loads coming from the Missouri River Basin, total about 141,000 pounds per year, averaged over the 47 years of weather as simulated in the model (table 57 and fig. 88). Among the tributary subregions, the atrazine load at the outlet of the subregion is highest for the Lower Illinois River Basin (code 0713)—52,000 pounds, which includes instream loads from the Upper Illinois River Basin.

The Missouri River converges with the Upper Mississippi River in subregion 0714 (the Upper Mississippi-Kaskaskia-Meramec Rivers subregion), as shown in figure 76.The instream atrazine load reported in table 57 for the outlet of subregion 0714—202,000 pounds—includes 61,000 pounds delivered to the Upper Mississippi River from the Missouri River. The estimate of the instream atrazine load originating only from the Upper Mississippi River Basin—141,000 pounds (table 57 and fig. 88)—was derived by subtracting the load delivered from the Missouri River Basin from the instream load at the outlet of subregion 0714.

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 31 percent (table 56), on average. Within the subregions, reductions due to conservation practices range from a low of 17 percent for the Mississippi Headwaters subregion (code 0701) to a high of 54 percent for the Minnesota River subregion (code 0702).

Model simulations of instream loads indicate that conservation practices have reduced the delivery of atrazine from the Upper Mississippi River Basin to the Lower Mississippi River Basin by about 30 percent overall (table 57). Without conservation practices, the total atrazine load delivered to the Mississippi River would be larger by about 59,000 pounds per year (table 57, fig. 88).

Table 55. Average annual atrazine source loads ***delivered to edge of field*** (APEX model output) from cultivated cropland for the Upper Mississippi River Basin

	Baseline conservation condition				Reductions in loads due to conservation practices	
Subregions	Amount (1,000 pounds)	Percent of basin total	Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent
Mississippi Headwaters (code 0701)	3.6	1	0.0012	4.3	0.8	18
Minnesota River Basin (code 0702)	3.8	1	0.0005	8.1	4.3	53
St. Croix River Basin (code 0703)	1.2	<1	0.0019	1.5	0.4	24
Upper Mississippi-Black-Root Rivers (code 0704)	6.1	2	0.0018	9.3	3.2	34
Chippewa River Basin (code 0705)	4.0	1	0.0029	6.7	2.6	39
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	13.7	4	0.0045	19.9	6.2	31
Wisconsin River Basin (code 0707)	4.0	1	0.0017	5.9	1.9	32
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	72.8	22	0.0067	113.0	40.2	36
Rock River Basin (code 0709)	25.4	8	0.0054	39.2	13.8	35
Des Moines River Basin (code 0710)	18.6	6	0.0028	30.7	12.2	40
Upper Mississippi-Salt Rivers (code 0711)	32.8	10	0.0109	42.1	9.3	22
Upper Illinois River Basin (code 0712)	32.2	10	0.0079	44.5	12.3	28
Lower Illinois River Basin (code 0713)	79.1	24	0.0098	117.0	37.9	32
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	36.7	11	0.0105	49.7	13.0	26
Regional total	334.0	100	0.0053	491.9	157.9	32

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 Upper Mississippi River Basin

	Baseline conservation condition				Reductions in loads due to conservation practices	
Subregions	Amount (1,000 pounds)	Percent of basin total	Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent
Mississippi Headwaters (code 0701)	2.5	1	0.0008	3.0	0.5	17
Minnesota River Basin (code 0702)	2.6	1	0.0003	5.7	3.1	54
St. Croix River Basin (code 0703)	0.8	<1	0.0013	1.1	0.3	25
Upper Mississippi-Black-Root Rivers (code 0704)	4.0	2	0.0012	6.0	2.0	33
Chippewa River Basin (code 0705)	2.8	1	0.0020	4.5	1.7	38
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	9.5	4	0.0031	13.4	3.9	29
Wisconsin River Basin (code 0707)	2.9	1	0.0012	4.0	1.1	28
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	51.8	22	0.0048	78.6	26.8	34
Rock River Basin (code 0709)	17.5	7	0.0037	26.9	9.4	35
Des Moines River Basin (code 0710)	13.3	6	0.0020	21.5	8.3	39
Upper Mississippi-Salt Rivers (code 0711)	23.9	10	0.0080	29.7	5.8	19
Upper Illinois River Basin (code 0712)	23.4	10	0.0058	32.6	9.2	28
Lower Illinois River Basin (code 0713)	56.8	24	0.0070	84.2	27.4	33
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	26.6	11	0.0076	36.1	9.5	26
Regional total	238.4	100	0.0038	347.3	108.9	31

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.

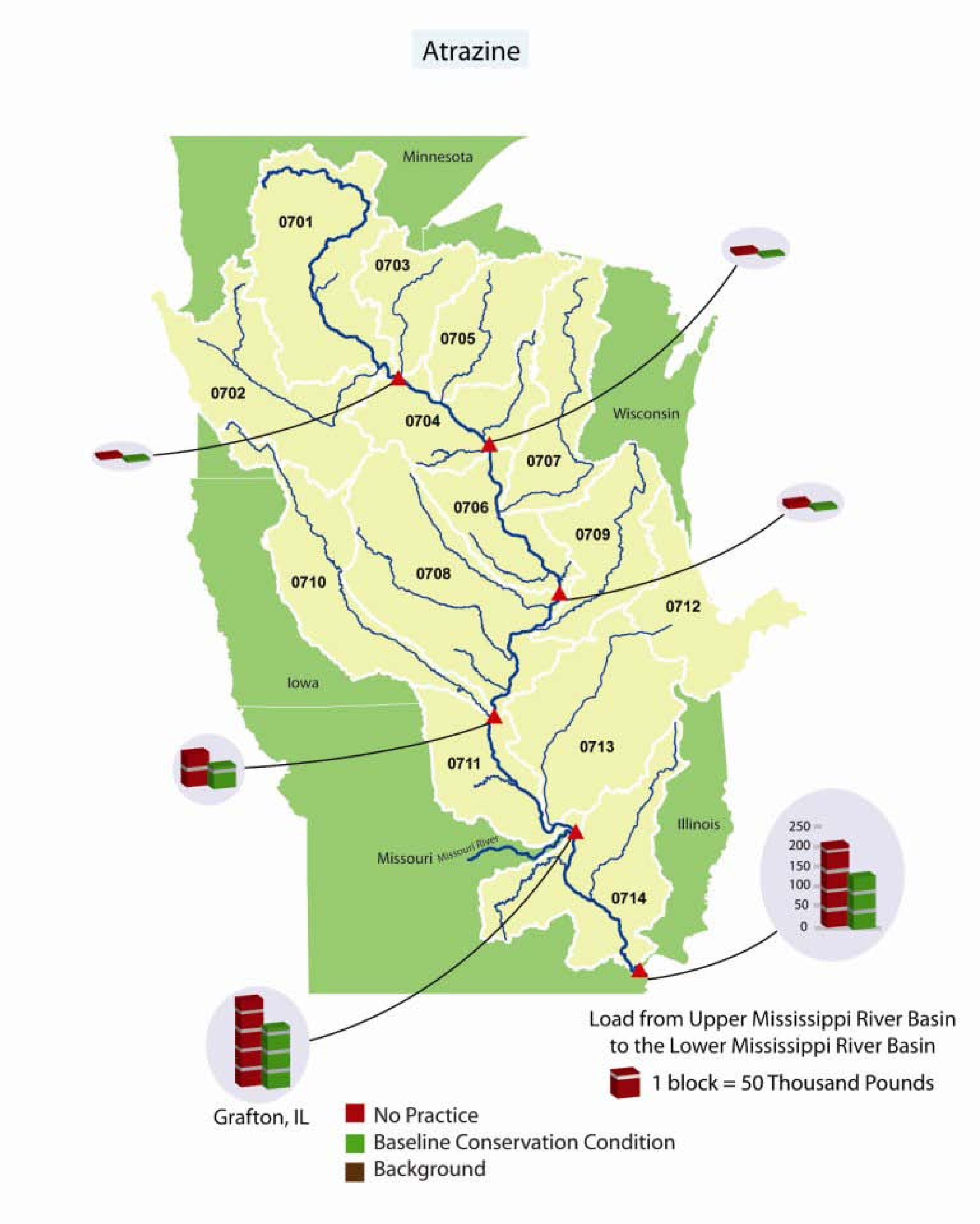
Table 57. Average annual ***instream atrazine loads*** for the Upper Mississippi River Basin

Subregions	Baseline conservation condition (1,000 pounds)	No-practice scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent reduction
Tributary subregions				
Minnesota River Basin (code 0702)	2	4	2	53
St. Croix River Basin (code 0703)	0	0	0	25
Chippewa River Basin (code 0705)	1	1	0	40
Wisconsin River Basin (code 0707)	1	1	0	5
Iowa River within 0708	14	21	7	32
Rock River Basin (code 0709)	7	10	4	35
Des Moines River Basin (code 0710)	5	7	2	34
Lower Illinois River Basin (code 0713)	52	77	25	32
Upper Illinois River Basin only (code 0712)	14	19	4	24
Outlets along mainstem				
Mississippi Headwaters (code 0701)	3	5	2	44
Upper Mississippi-Black-Root Rivers (code 0704)	4	6	2	37
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	9	11	3	24
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	52	76	24	32
Upper Mississippi-Salt Rivers (code 0711 near Grafton, IL)	132	191	59	31
Load delivered from Missouri River Basin	61	90	29	32
Load delivered to Lower Mississippi River Basin (0714 near Thebes, IL), including load from Missouri River Basin	202	290	88	30
Load delivered from Upper Mississippi River Basin to Lower Mississippi River Basin, exclusive of Missouri River Basin*	141	200	59	30

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.

* Instream loads delivered from the Upper Mississippi River Basin alone are estimated by subtracting the loads delivered from the Missouri River Basin. This calculation does 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.

Figure 88. Estimates of average annual instream atrazine loads for the baseline conservation condition compared to the no-practice scenario for the Upper Mississippi River Basin*



* Instream atrazine loads (all sources) are shown for each subregion with an outlet along the main stem of the river, corresponding to estimates presented in table 57.

Assessment of Potential Water Quality Gains from Further Conservation Treatment

The field-level model results for the 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 and instream loads throughout the region with additional conservation treatment.

Percent reductions relative to the baseline conservation condition were estimated for each of two scenarios—

1. Treatment of the 9.0 million critical undertreated acres, which have a high need for additional treatment for one or more resource concern (15 percent of cropped acres in the region), and
2. Treatment of the 35.2 million acres with a high or moderate need for additional treatment for one or more resource concern, including the 9.0 million critical undertreated acres (60 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 Upper Mississippi River Basin is shown in chapter 5, tables 32–33.

Model simulations showed that if the 9.0 million **critical** undertreated acres were fully treated with the appropriate soil erosion control and nutrient management practices, loads <u>from cultivated cropland delivered to rivers and streams</u> in the Upper Mississippi River Basin would be reduced by, relative to the baseline conservation condition (tables 58, 60, 62, and 64)—

- 43 percent for sediment,
- 14 percent for nitrogen,
- 15 percent for phosphorus, and
- 4 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 26.2 million acres) were fully treated with the appropriate soil erosion control and nutrient management practices, loads <u>from cultivated cropland delivered to rivers and streams</u> in the watershed would be reduced, relative to the baseline conservation condition (tables 58, 60, 62, and 64)—

- 74 percent for sediment,
- 49 percent for nitrogen,
- 41 percent for phosphorus, and
- 13 percent for atrazine.

These reductions in loads delivered to rivers and streams from cultivated cropland would reduce the total loads delivered from the region to the Lower Mississippi River Basin. If the critical undertreated acres (9.0 million acres) were fully treated with the appropriate soil erosion control and nutrient management practices, <u>total loads delivered to the Lower Mississippi River Basin from all sources</u> would be reduced, relative to the baseline conservation condition (tables 59, 61, 63, and 65, and figs. 89 through 92)—

- 5 percent for sediment,
- 8 percent for nitrogen,
- 9 percent for phosphorus, and
- 3 percent for atrazine.

If **all** the undertreated acres (35.2 million acres) were fully treated with the appropriate soil erosion control and nutrient management practices, <u>total loads delivered to the Lower Mississippi River Basin from all sources</u> would be reduced, relative to the baseline conservation condition (tables 59, 61, 63, and 65, and figs. 89 through 92)—

- 8 percent for sediment,
- 33 percent for nitrogen,
- 26 percent for phosphorus, and
- 11 percent for atrazine.

As shown in table 59 and figure 89, sediment loads delivered from the region to the Lower Mississippi River Basin would be close to “background” levels after additional conservation treatment of the undertreated acres, indicating that sediment contributions from cultivated cropland would be nearly negligible. The background scenario represents loads that would be expected if no acres in the watershed were cultivated. Background sediment loads delivered to the Lower Mississippi River Basin total 31.5 million tons (table 59) compared to 37.2 million tons delivered from all sources after treating all undertreated cropped acres with appropriate conservation treatment, leaving only about 5.7 million tons originating from cultivated cropland.

Using similar calculations, if all undertreated acres were fully treated throughout the region, instream nutrient loads originating from cultivated cropland delivered to the Lower Mississippi River Basin would be reduced to about 412 million pounds for nitrogen and 24 million pounds for phosphorus (tables 61 and 63). To reduce loads further would require additional conservation treatment of the remaining 23.0 million cropped acres with a low level of conservation treatment need, which would have a low per-acre benefit as shown in table 37.

Table 58. 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 Upper Mississippi River Basin

	Baseline conservation condition	Treatment of 9.0 million critical undertreated acres		Treatment of all 35.2 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
Mississippi Headwaters (code 0701)	600	354	41	195	68
Minnesota River Basin (code 0702)	524	404	23	238	55
St. Croix River Basin (code 0703)	335	91	73	37	89
Upper Mississippi-Black-Root Rivers (code 0704)	1,420	461	68	217	85
Chippewa River Basin (code 0705)	621	186	70	49	92
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	1,260	610	52	198	84
Wisconsin River Basin (code 0707)	891	320	64	208	77
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	3,340	1,990	40	879	74
Rock River Basin (code 0709)	2,180	1,290	41	460	79
Des Moines River Basin (code 0710)	871	713	18	348	60
Upper Mississippi-Salt Rivers (code 0711)	1,500	677	55	356	76
Upper Illinois River Basin (code 0712)	837	612	27	352	58
Lower Illinois River Basin (code 0713)	2,570	2,020	21	822	68
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	1,530	826	46	392	74
Regional total	18,479	10,554	43	4,751	74

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.

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 Mississippi River from the Upper Mississippi River Basin

	Baseline conservation condition		Treatment of 9.0 million critical undertreated acres		Treatment of all 35.2 million undertreated acres	
Subregions	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
Tributary subregions						
Minnesota River Basin (code 0702)	947	702	923	3	898	5
St. Croix River Basin (code 0703)	177	149	158	11	153	14
Chippewa River Basin (code 0705)	186	125	140	25	129	31
Wisconsin River Basin (code 0707)	267	199	224	16	216	19
Iowa River within 0708	2,690	1,900	2,640	2	2,510	7
Rock River Basin (code 0709)	1,310	980	1,160	11	1,000	24
Des Moines River Basin (code 0710)	458	363	457	0	454	1
Lower Illinois River Basin (code 0713)	7,180	4,840	6,890	4	6,340	12
Upper Illinois River Basin only (code 0712)	3,280	2,860	3,250	1	3,170	3
Outlets along mainstem						
Mississippi Headwaters (code 0701)	1,710	1,240	1,650	4	1,560	9
Upper Mississippi-Black-Root Rivers (code 0704)	2,110	1,430	1,870	11	1,760	17
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	2,880	1,620	2,390	17	2,070	28
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	11,200	8,260	10,400	7	9,650	14
Upper Mississippi-Salt Rivers (code 0711 near Grafton, IL)	29,200	21,900	27,600	5	26,200	10
Load delivered from Missouri River Basin	44,010	34,210	43,940	0	43,620	1
Load delivered to Lower Mississippi River Basin (0714 near Thebes, IL), including load from Missouri River Basin	84,500	65,700	82,600	2	80,800	4
Load delivered from Upper Mississippi River Basin to Lower Mississippi River Basin, exclusive of Missouri River Basin**	40,490	31,490	38,660	5	37,180	8

* "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, forestland, and urban land—as well as point sources.

** 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.

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.

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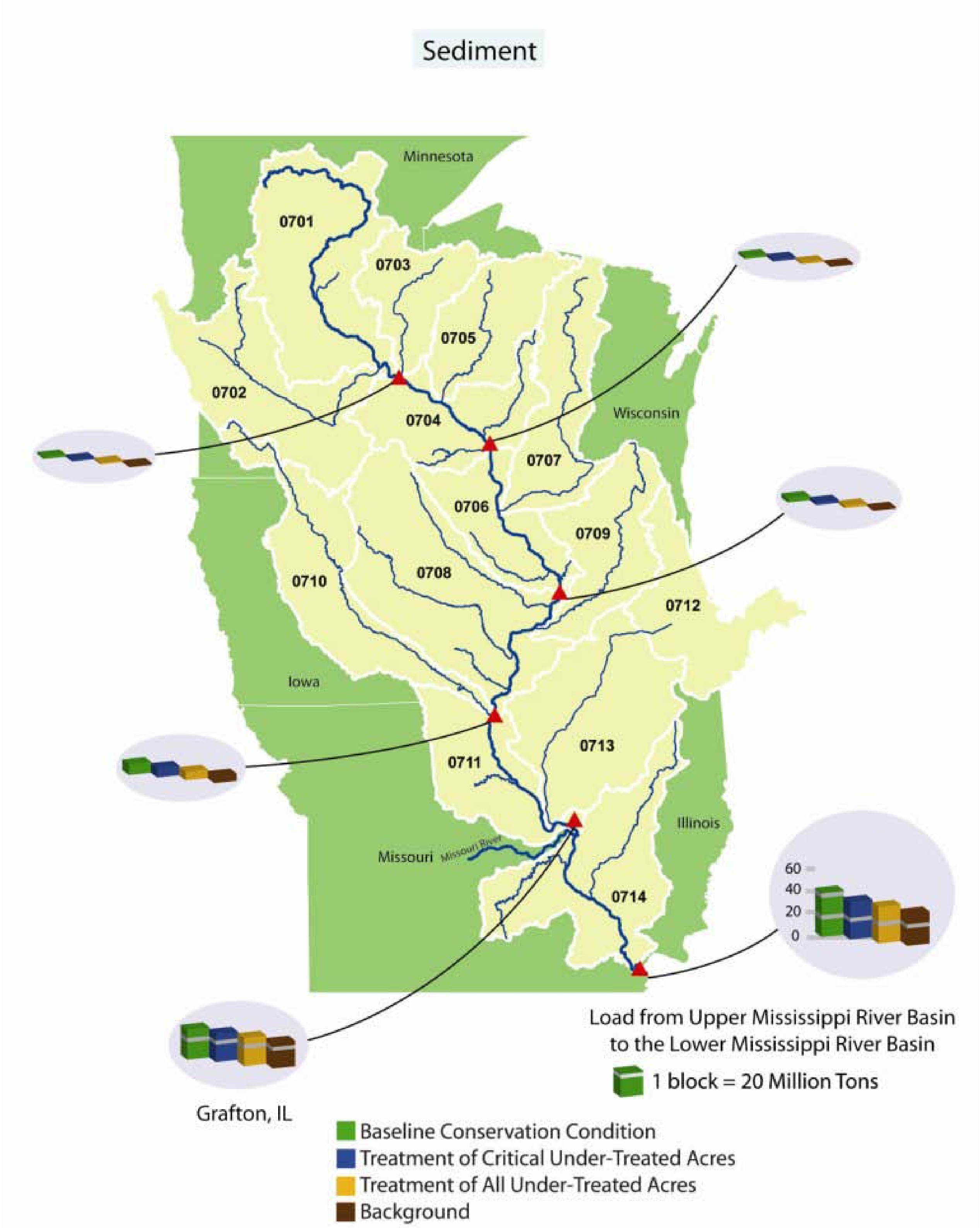
Figure 89. Estimates of average annual instream sediment loads* for the baseline conservation condition compared to two scenarios simulating additional erosion control and nutrient management practices for the Upper Mississippi River Basin



* Instream sediment loads (all sources) are shown for each subregion with an outlet along the main stem of the river, corresponding to estimates presented in table 59.

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.

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

Table 60. 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 Upper Mississippi River Basin

	Baseline conservation condition	Treatment of 9.0 million critical undertreated acres		Treatment of all 35.2 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
Mississippi Headwaters (code 0701)	33,800	27,400	19	20,400	40
Minnesota River Basin (code 0702)	119,000	110,000	8	60,100	49
St. Croix River Basin (code 0703)	13,500	11,000	19	8,250	39
Upper Mississippi-Black-Root Rivers (code 0704)	52,700	37,900	28	23,700	55
Chippewa River Basin (code 0705)	20,300	12,800	37	8,400	59
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	42,300	33,000	22	20,400	52
Wisconsin River Basin (code 0707)	49,200	34,100	31	19,200	61
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	183,000	157,000	14	94,200	49
Rock River Basin (code 0709)	78,900	64,700	18	38,500	51
Des Moines River Basin (code 0710)	101,000	97,800	3	59,400	41
Upper Mississippi-Salt Rivers (code 0711)	34,800	28,500	18	20,100	42
Upper Illinois River Basin (code 0712)	94,600	82,100	13	55,700	41
Lower Illinois River Basin (code 0713)	166,000	154,000	7	74,400	55
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	51,300	46,700	9	32,000	38
Regional total	1,040,400	897,000	14	534,750	49

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.

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 Mississippi River from the Upper Mississippi River Basin

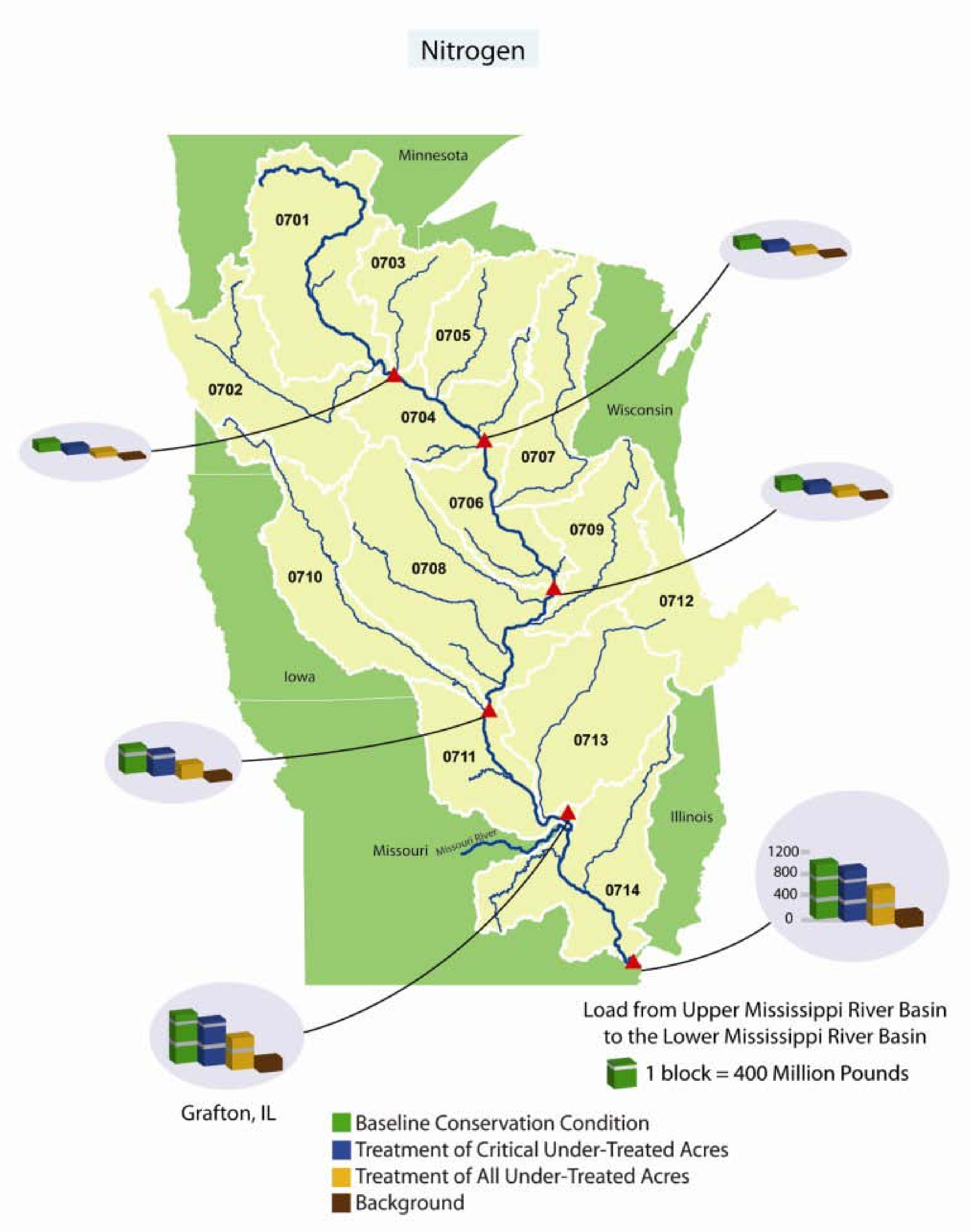
	Baseline conservation condition		Treatment of 9.0 million critical undertreated acres		Treatment of all 35.2 million undertreated acres	
Subregions	Average annual load from all sources (1,000 pounds)	Average annual load from background sources* (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
Tributary subregions						
Minnesota River Basin (code 0702)	105,000	15,800	96,800	8	59,200	44
St. Croix River Basin (code 0703)	9,240	6,580	8,820	5	8,290	10
Chippewa River Basin (code 0705)	9,910	3,930	7,520	24	6,170	38
Wisconsin River Basin (code 0707)	14,100	4,830	11,300	20	8,860	37
Iowa River within 0708	108,000	34,100	102,000	6	77,500	28
Rock River Basin (code 0709)	54,900	14,700	46,400	15	32,500	41
Des Moines River Basin (code 0710)	117,000	36,900	115,000	2	84,000	28
Lower Illinois River Basin (code 0713)	257,000	52,300	240,000	7	160,000	38
Upper Illinois River Basin only (code 0712)	153,000	92,800	142,000	7	129,000	16
Outlets along mainstem						
Mississippi Headwaters (code 0701)	157,000	30,400	145,000	8	96,700	38
Upper Mississippi-Black-Root Rivers (code 0704)	168,000	36,100	150,000	11	104,000	38
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	193,000	44,700	170,000	12	119,000	38
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	456,000	121,000	405,000	11	289,000	37
Upper Mississippi-Salt Rivers (code 0711 near Grafton, IL)	947,000	252,000	867,000	8	613,000	35
Load delivered from Missouri River Basin	511,300	167,700	502,000	2	482,100	6
Load delivered to Lower Mississippi River Basin (0714 near Thebes, IL), including load from Missouri River Basin	1,580,000	474,000	1,480,000	6	1,200,000	24
Load delivered from Upper Mississippi River Basin to Lower Mississippi River Basin, exclusive of Missouri River Basin**	1,068,700	306,300	978,000	8	717,900	33

* “Background sources” represent loads that would be expected if no acres in the watershed were cultivated..

** 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.

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 90. Estimates of average annual instream nitrogen loads* for the baseline conservation condition compared to two scenarios simulating additional erosion control and nutrient management practices for the Upper Mississippi River Basin



* Instream nitrogen loads (all sources) are shown for each subregion with an outlet along the main stem of the river, corresponding to estimates presented in table 61.

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.

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

Table 62. 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 Upper Mississippi River Basin

	Baseline conservation condition	Treatment of 9.0 million critical undertreated acres		Treatment of all 35.2 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
Mississippi Headwaters (code 0701)	2,380	1,920	19	1,560	34
Minnesota River Basin (code 0702)	3,640	3,390	7	2,640	27
St. Croix River Basin (code 0703)	1,160	883	24	643	45
Upper Mississippi-Black-Root Rivers (code 0704)	4,300	3,040	29	2,340	46
Chippewa River Basin (code 0705)	2,240	1,760	21	1,370	39
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	3,990	3,110	22	2,580	35
Wisconsin River Basin (code 0707)	6,680	5,460	18	2,870	57
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	13,800	12,100	12	8,700	37
Rock River Basin (code 0709)	7,750	6,110	21	3,920	49
Des Moines River Basin (code 0710)	5,220	5,000	4	3,460	34
Upper Mississippi-Salt Rivers (code 0711)	4,650	3,610	22	2,630	43
Upper Illinois River Basin (code 0712)	5,230	4,950	5	3,520	33
Lower Illinois River Basin (code 0713)	12,900	11,800	9	7,280	44
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	7,180	5,980	17	4,030	44
Regional total	81,120	69,113	15	47,543	41

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.

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 Mississippi River from the Upper Mississippi River Basin

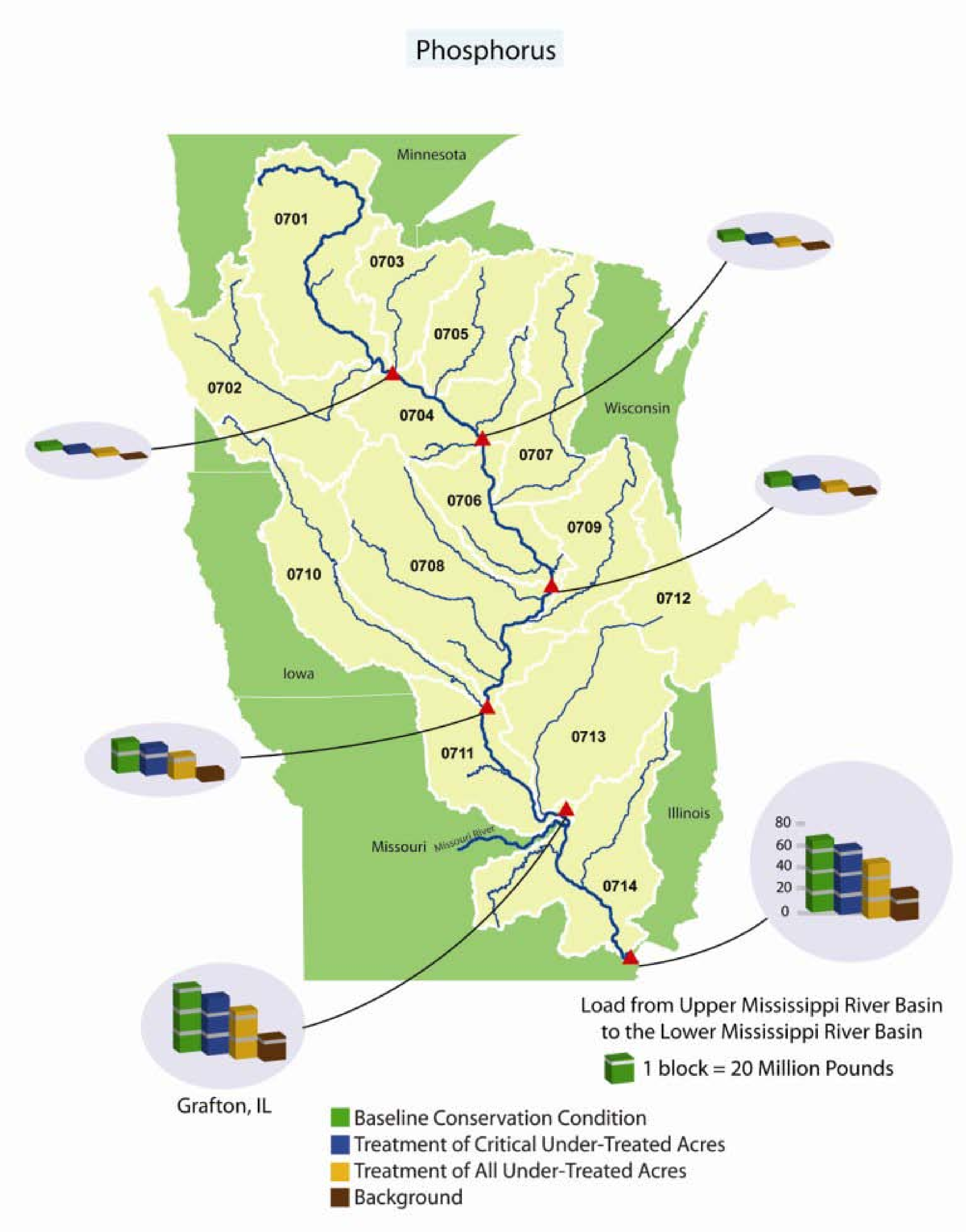
	Baseline conservation condition		Treatment of 9.0 million critical undertreated acres		Treatment of all 35.2 million undertreated acres	
Subregions	Average annual load from all sources (1,000 pounds)	Average annual load from background sources* (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
Tributary subregions						
Minnesota River Basin (code 0702)	1,940	504	1,810	7	1,560	20
St. Croix River Basin (code 0703)	521	333	477	8	440	16
Chippewa River Basin (code 0705)	1,040	332	904	13	793	24
Wisconsin River Basin (code 0707)	1,700	373	1,550	9	1,110	35
Iowa River within 0708	5,100	1,210	4,850	5	3,900	24
Rock River Basin (code 0709)	4,610	903	3,730	19	2,590	44
Des Moines River Basin (code 0710)	6,560	3,760	6,450	2	5,680	13
Lower Illinois River Basin (code 0713)	14,100	2,920	13,400	5	9,730	31
Upper Illinois River Basin only (code 0712)	9,970	7,330	9,830	1	9,160	8
Outlets along mainstem						
Mississippi Headwaters (code 0701)	4,780	1,980	4,500	6	4,040	15
Upper Mississippi-Black-Root Rivers (code 0704)	6,610	2,250	5,870	11	5,190	21
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	11,200	2,990	9,730	13	7,800	30
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	29,400	8,990	26,100	11	20,900	29
Upper Mississippi-Salt Rivers (code 0711 near Grafton, IL)	60,400	21,100	55,400	8	44,400	26
Load delivered from Missouri River Basin	54,650	37,180	53,950	1	52,540	4
Load delivered to Lower Mississippi River Basin (0714 near Thebes, IL), including load from Missouri River Basin	124,000	64,200	117,000	6	104,000	16
Load delivered from Upper Mississippi River Basin to Lower Mississippi River Basin, exclusive of Missouri River Basin**	69,350	27,020	63,050	9	51,460	26

* "Background sources" represent loads that would be expected if no acres in the watershed were cultivated..

** 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.

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 91. Estimates of average annual instream phosphorus loads* for the baseline conservation condition compared to two scenarios simulating additional erosion control and nutrient management practices for the Upper Mississippi River Basin



* Instream phosphorus loads (all sources) are shown for each subregion with an outlet along the main stem of the river, corresponding to estimates presented in table 63.

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.

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

Table 64. 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 Upper Mississippi River Basin

	Baseline conservation condition	Treatment of 9.0 million critical undertreated acres		Treatment of all 35.2 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
Mississippi Headwaters (code 0701)	2.5	2.3	7	2	16
Minnesota River Basin (code 0702)	2.6	2.6	3	2	15
St. Croix River Basin (code 0703)	0.8	0.7	13	1	21
Upper Mississippi-Black-Root Rivers (code 0704)	4.0	3.5	13	3	23
Chippewa River Basin (code 0705)	2.8	2.4	13	2	28
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	9.5	8.8	7	7	22
Wisconsin River Basin (code 0707)	2.9	2.7	5	2	15
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	51.8	49.2	5	44	16
Rock River Basin (code 0709)	17.5	16.8	4	15	15
Des Moines River Basin (code 0710)	13.3	12.9	3	12	12
Upper Mississippi-Salt Rivers (code 0711)	23.9	22.5	6	21	12
Upper Illinois River Basin (code 0712)	23.4	22.9	2	21	9
Lower Illinois River Basin (code 0713)	56.8	55.8	2	50	11
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	26.6	25.4	5	24	11
Regional total	238.4	228.4	4	206	13

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.

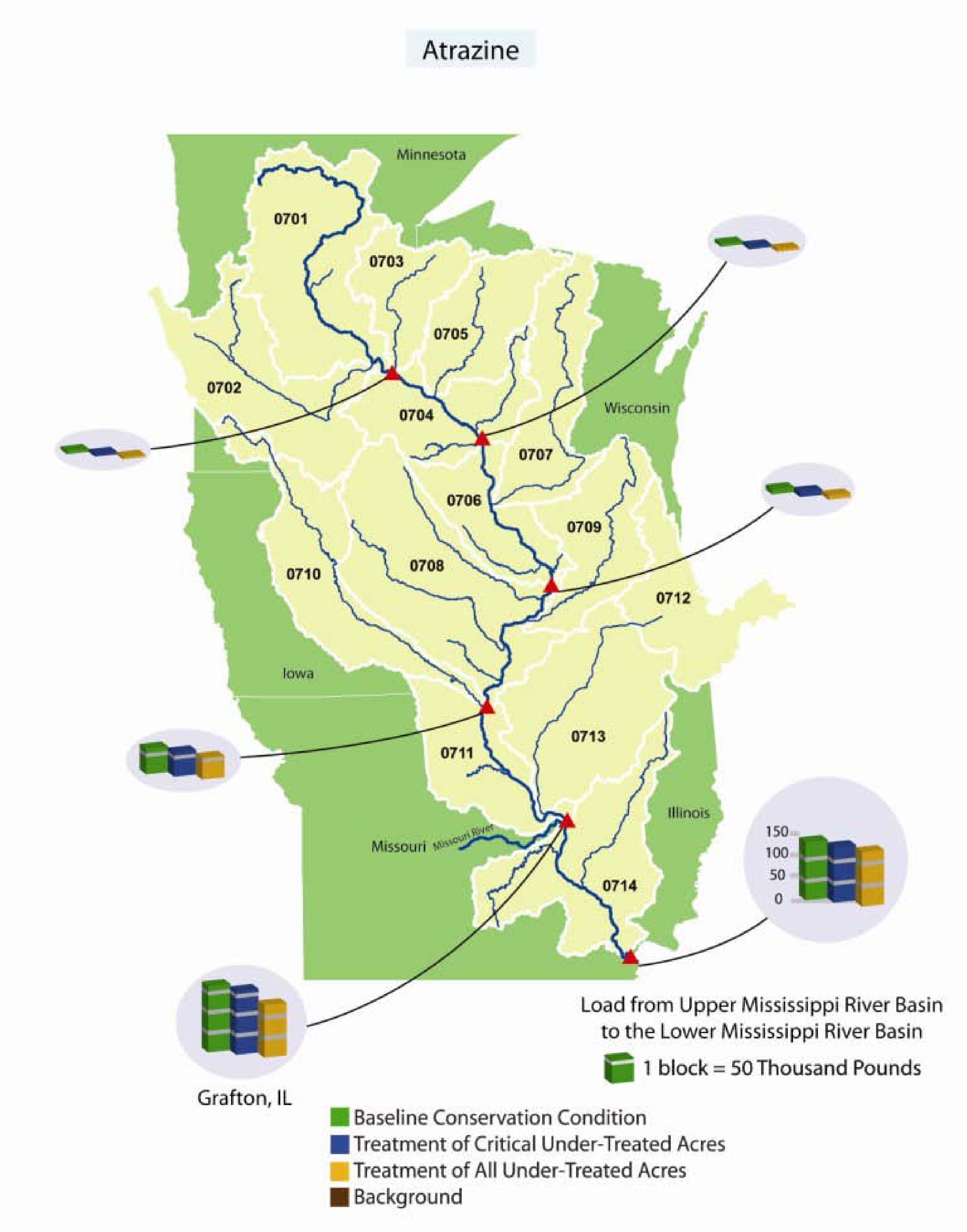
Table 65. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream atrazine loads*** delivered to the Mississippi River from the Upper Mississippi River Basin

	Baseline conservation condition	Treatment of 9.0 million critical undertreated acres		Treatment of all 35.2 million undertreated acres	
Subregions	Average annual load from all sources (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction	Average annual load (1,000 pounds)	Percent reduction
Tributary subregions					
Minnesota River Basin (code 0702)	2	2	2	2	12
St. Croix River Basin (code 0703)	0	0	0	0	0
Chippewa River Basin (code 0705)	1	1	5	1	12
Wisconsin River Basin (code 0707)	1	1	3	1	5
Iowa River within 0708	14	14	3	12	15
Rock River Basin (code 0709)	7	7	0	7	0
Des Moines River Basin (code 0710)	5	5	3	4	13
Lower Illinois River Basin (code 0713)	52	51	2	47	10
Upper Illinois River Basin only (code 0712)	14	14	3	13	8
Outlets along mainstem					
Mississippi Headwaters (code 0701)	3	3	0	3	5
Upper Mississippi-Black-Root Rivers (code 0704)	4	4	3	4	9
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	9	9	0	8	5
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	52	51	2	47	10
Upper Mississippi-Salt Rivers (code 0711 near Grafton, IL)	132	129	2	118	11
Load delivered from Missouri River Basin	61	61	1	59	4
Load delivered to Lower Mississippi River Basin (0714 near Thebes, IL), including load from Missouri River Basin	202	197	2	184	9
Load delivered from Upper Mississippi River Basin to Lower Mississippi River Basin, exclusive of Missouri River Basin*	141	136	3	125	11

* Instream loads delivered from the Upper Mississippi River Basin alone are estimated by subtracting the loads delivered from the Missouri River Basin. This calculation does 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.

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 92. Estimates of average annual instream atrazine loads* for the baseline conservation condition compared to two scenarios simulating additional erosion control and nutrient management practices for the Upper Mississippi River Basin



* Instream atrazine loads (all sources) are shown for each subregion with an outlet along the main stem of the river, corresponding to estimates presented in table 65.

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

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 Upper Mississippi River Basin closely reflects this history of Federal conservation programs and technical assistance. An assessment of the extent of conservation practice use, 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 45 percent of cropped acres. On the 18 percent of the acres designated as highly erodible land, structural practices designed to control water erosion are in use on 72 percent.
- Reduced tillage is common in the region; 91 percent of the cropped acres meet criteria for either no-till (28 percent) or mulch till (63 percent). All but 5 percent of the acres had evidence of some kind of reduced tillage on at least one crop.
- Three-fourths of cropped acres are gaining soil organic carbon.
- Producers use either residue and tillage management practices or structural practices, or both, on 96 percent of the 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.
  - Appropriate timing of nitrogen applications is in use on about 45 percent of the acres for all crops in the rotation.
  - About 39 percent of cropped acres meet criteria for appropriate nitrogen application rates for all crops in the rotation.
  - 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 16 percent of cropped acres.
  - Good phosphorus management practices (appropriate rate, timing, and method) are in use on 28 percent of the acres on all crops during every year of production.
  - Only about 13 percent of cropped acres meet full nutrient management criteria for *both* phosphorus and nitrogen management, including acres not receiving nutrient applications.
- During the 2003–06 period of data collection, cover crops were used on about 2 percent of the acres in the region.
- An Integrated Pest Management (IPM) indicator showed that only about 10 percent of the acres were being managed at a relatively high level of IPM.
- Land in long-term conserving cover, as represented by enrollment in the CRP General Signup, consists of about 2.8 million acres in the region, of which 69 percent is highly erodible land.

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 9 percent, re-routing most of the water to subsurface flow pathways;
- Reduced wind erosion by 64 percent, from 0.31 ton per acre without conservation practices to 0.11 ton per acre with conservation practices;
- Reduced sediment loss from fields caused by water erosion by 61 percent, from 2.3 tons per acre without conservation practices to 0.9 tons per acre with conservation practices;
- Decreased the percentage of acres that are losing soil organic carbon from 40 percent to 24 percent;
- Reduced total nitrogen loss (volatilization, denitrification, surface runoff, and subsurface flow losses) from fields by 20 percent, from 49 pounds per acre without conservation practices to 39 pounds per acre with conservation practices:
  - reduced nitrogen lost with surface runoff (attached to sediment and in solution) by 45 percent, from 16 pounds per acre without conservation practices to 9 pounds per acre with conservation practices;
  - reduced nitrogen loss in subsurface flows by 9 percent, from 20.6 pounds per acre without conservation practices to 18.7 pounds per acre with conservation practices;
- Reduced total phosphorus loss from fields by 44 percent, from 5.7 pounds per acre without conservation practices to 3.2 pounds per acre with conservation practices; and
- Reduced pesticide loss from fields to surface water, resulting in a 41-percent reduction in edge-of-field pesticide risk (all pesticides combined) for aquatic ecosystems and a 35-percent reduction in edge-of-field pesticide risk for humans.

The relatively low reductions in nitrogen loss in subsurface flows result from a combination of incomplete nutrient management and the re-routing of surface water runoff to subsurface flows by water erosion control practices on some acres in the region. On 48 percent of the cropped acres, nitrogen losses in subsurface flows increase as a result of conservation practices, although most of these increases are small. 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.

The increase in nitrogen loss in subsurface flow results from a combination of incomplete nutrient management and the re-routing of surface water runoff to subsurface flow by water erosion control practices. 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 re-directs the dissolved nitrogen into subsurface flow but also can extract additional nitrogen from the soil as the water passes through the soil profile. On about 18 percent of the acres in this region, the re-routing of surface water runoff to subsurface flow pathways 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 reduces nitrogen loss in subsurface flow to acceptable levels for nearly all acres in the region.

For land in long-term conserving cover (2.8 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 78 percent, total phosphorus loss has been reduced by 93 percent, and soil organic carbon has been increased by an average of 382 pounds per acre per year.

Conservation Treatment Needs

The adequacy of conservation practices in use in the Upper Mississippi River Basin for the time period 2003–06 was evaluated to identify conservation treatment needs for four resource concerns:

- sediment loss from fields,
- nitrogen lost with surface runoff (attached to sediment and in solution),
- nitrogen loss in subsurface flows, and
- 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 complete and consistent use of nutrient management—appropriate rate, form, timing, *and* method of application, especially for nitrogen loss in subsurface flows. About 47.4 percent of the acres in the region have a “high” or “moderate” need for additional nutrient management to address this concern (2.6 percent with a “high” need for treatment). The proportion of cropped acres with a “high” or “moderate” need for additional conservation treatment for other resource concerns was determined to be—

- 9.7 percent for sediment loss (all with a “high” need for treatment),
- 23.5 percent for nitrogen loss with runoff (11.0 percent with a “high” need for treatment), and
- 22.4 percent for phosphorus lost to surface water (4.6 percent with a “high” need for treatment).

Thirty-seven percent of cropped acres require additional treatment for two or more resource concerns. After accounting for acres that need treatment for multiple resource concerns, the evaluation of treatment needs for the Upper Mississippi River Basin determined the following:

- 15 percent of cropped acres (9.0 million acres) have a “high” level of need for additional conservation treatment for one or more resource concerns.
- 45 percent of cropped acres (26.2 million acres) have a “moderate” level of need for additional conservation treatment for one or more resource concerns.
- 40 percent of cropped acres (23.0 million acres) have a “low” level of need for additional treatment and are considered to be adequately treated.

The 9.0 million acres with a “high” level of need for conservation treatment lose (per acre per year, on average)—

- 2.7 tons of sediment by water erosion,
- 5.3 pounds of phosphorus,
- 20.4 pounds of nitrogen with surface runoff, and
- 26.6 pounds of nitrogen in subsurface flows.

The 26.2 million acres with a “moderate” level of need for conservation treatment lose (per acre per year, on average)—

- 0.69 ton of sediment by water erosion,
- 2.6 pounds of phosphorus,
- 7.8 pounds of nitrogen with surface runoff, and
- 23.6 pounds of nitrogen in subsurface flows.

Loses for the 23 million acres with a “low” level of need for conservation treatment are small on a per-acre basis. These acres lose (per acre per year, on average)—

- 0.4 ton of sediment by water erosion,
- 1.8 pounds of phosphorus,
- 5.4 pounds of nitrogen with surface runoff, and
- 10.2 pounds of nitrogen in subsurface flows.

About 63 percent of the undertreated acres are undertreated for only one of the four resource concerns, primarily nitrogen leaching—

- 54.3 percent of undertreated acres are undertreated only for nitrogen leaching,
- 5.1 percent of undertreated acres are undertreated only for phosphorus runoff, and
- 3.4 percent of undertreated acres are undertreated only for nitrogen runoff.

About 8 percent of undertreated acres were determined to be undertreated for all four resource concerns. Nine percent of undertreated acres need additional treatment for nitrogen runoff and leaching and phosphorus runoff.

Percentages of undertreated acres are fairly close to the percentages of the region’s cultivated cropland in most subregions, indicating that undertreated acres are generally spread proportionately throughout the region. Critical undertreated acres, however, are more disproportionately distributed throughout the region. Nine subregions have a disproportionately high percentage of the region’s critical undertreated acres. The extent of critical undertreated acres exceeds 30 percent of cropped acres in three of the subregions [the Chippewa River Basin (code 0705), the Wisconsin River Basin (code 0707), and the St. Croix River Basin (code 0703)], compared to the regional average of 15.4 percent. In contrast, three subregions have fewer than 10 percent of cropped acres that are critically undertreated—the Des Moines River Basin (code 0710), the Lower Illinois River Basin (code 0713), and the Minnesota River Basin (code 0702) (table 33).

Simulation of Additional Conservation Treatment

Model simulations were used to evaluate the potential gains from further conservation treatment in the Upper Mississippi River Basin. Additional soil erosion control practices and nutrient management practices are expected to achieve the following:

- Conservation treatment of the 9.0 million acres with a high need for treatment would reduce sediment loss by an average of 2.57 tons per acre per year on those acres. In comparison, additional treatment of the 26.2 million acres with a moderate need for treatment would reduce sediment loss by about 0.63 ton per acre per year on those acres. Treatment of the remaining 23.0 million acres would reduce sediment loss on those acres by less than 0.4 ton per acre, on average.
- Total nitrogen loss would be reduced by an average of 35.1 pounds per acre per year on the 9.0 million acres with a high need for treatment, compared to a reduction of 23.9 pounds per acre for the 26.2 million acres with a moderate need for treatment, and only 7.2 pounds per acre for the remaining 23.0 million acres.
- Nitrogen loss in subsurface flows would be reduced by an average of 15.2 pounds per acre per year on the 9.0 million acres with a high need for treatment, compared to a reduction of 14.8 pounds per acre for the 26.2 million acres with a moderate need for treatment. The reduction for treatment of the remaining 23.0 million acres would average only 2.4 pounds per acre.
- Total phosphorus loss would be reduced by an average of 4.0 pounds per acre per year on the 9.0 million acres with a high need for treatment, compared to a reduction of 1.8 pounds per acre for the 26.2 million acres with a moderate need for treatment and only 1.0 pound per acre for the remaining 23.0 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 re-routing of soluble nitrogen and phosphorus to subsurface loss pathways.

Treatment of the 9.0 million acres with a high need for additional treatment would achieve the following gains ***for the region as a whole*** *when both soil erosion control practices and nutrient management practices were applied where needed*:

- Sediment loss from fields would average 0.5 ton per acre per year, compared to the baseline conservation condition average of 0.89 ton per acre per year (a 44-percent reduction).
- Nitrogen lost from the field with surface runoff (attached to sediment and in solution) would average 6.2 pounds per acre per year, compared to the baseline conservation condition average of 8.8 pounds per acre per year (a 29-percent reduction).
- Nitrogen loss from the field in subsurface flows would average 16.4 pounds per acre per year, compared to the

baseline conservation condition average of 18.7 pounds per acre per year (a 12-percent reduction).
- Total phosphorus loss, mostly to surface water, would average 2.54 pounds per acre per year, compared to 3.15 pounds per acre per year for the baseline conservation condition (a 19-percent reduction).
- Environmental risk from the loss of pesticide residues would be reduced about 4 percent.

Treatment of all 35.2 million undertreated acres would achieve the following gains ***for the region as a whole*** *when both soil erosion control practices and nutrient management practices were applied where needed*:
- Sediment loss from fields would average 0.21 ton per acre per year, compared to the baseline conservation condition average of 0.89 tons per acre per year (a 76-percent reduction).
- Nitrogen lost from the field with surface runoff (attached to sediment and in solution) would average 3.7 pounds per acre per year, compared to the baseline conservation condition average of 8.8 pounds per acre per year (a 58-percent reduction).
- Nitrogen loss from the field in subsurface flows would average 9.7 pounds per acre per year, compared to the baseline conservation condition average of 18.7 pounds per acre per year (a 48-percent reduction).
- Total phosphorus loss, mostly to surface water, would average 1.74 pounds per acre per year, compared to 3.15 pounds per acre per year for the baseline conservation condition (a 45-percent reduction).
- Environmental risk from the loss of pesticide residues would be reduced about 11–12 percent.

Conservation Practice Effects on Water Quality

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 53 percent of the land base in the Upper 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 and ultimately to the Lower Mississippi River. Of the total loads delivered to rivers and streams from all sources, cultivated cropland is the source for 71 percent of the sediment, 71 percent of the nitrogen, and 62 percent of the phosphorus.

Figures 93, 94, and 95 summarize the extent to which conservation practices on cultivated cropland acres have reduced, and can further reduce, sediment, nitrogen, and phosphorus loads in the Upper Mississippi River Basin, on the basis of the model simulations.

In each figure, the top map shows delivery from cultivated cropland to rivers and streams within the basin and the bottom map shows delivery from all sources to the Lower Mississippi River after accounting for losses and gains through instream processes during transport through the Upper Mississippi River system.

The effects of practices in use during 2003–06 are seen by contrasting loads for the baseline conservation condition to loads for the no-practice scenario.

The effects of additional conservation treatment on loads are seen by contrasting the loads for the baseline condition to either—
1. loads for treatment of acres with a “high” level of treatment need (9.0 million acres), or
2. loads for treatment of all undertreated acres (35.2 million acres with either a “high” or “moderate” level of treatment need).

Background levels, representing loads that would be expected if no acres in the watershed were cultivated, are also shown in the bar charts. These estimates simulate a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed. Background loads also include loads from all other land uses—hayland, pastureland, forestland, and urban land—as well as point sources.

Sediment loss

In figure 93, the top map shows that the use of conservation practices has reduced ***sediment loads delivered from cropland to rivers and streams*** within the basin by 65 percent from conditions that would be expected without conservation practices. Application of additional conservation practices on acres with a “high” level of treatment need would reduce baseline sediment loads delivered to rivers and streams by 43 percent. Treating ALL undertreated acres (acres with either a “high” or “moderate” need for treatment) would reduce baseline sediment loads delivered to rivers and streams within the basin by 74 percent.

The bottom map shows that the use of conservation practices on cropland in the Upper Mississippi River basin has reduced ***sediment loads delivered to the Lower Mississippi River from all sources*** by 14 percent from conditions that would be expected without conservation practices. Application of additional conservation practices on acres with a “high” level of treatment need would reduce baseline sediment loads delivered to the Lower Mississippi River by 5 percent. Treating ALL undertreated acres (acres with either a “high” or “moderate” need for treatment) would reduce baseline sediment loads delivered to the Lower Mississippi River by 8 percent.

Total nitrogen loss

In figure 94, the top map shows that the use of conservation practices has reduced ***total nitrogen loads delivered from cropland to rivers and streams*** within the basin by 26 percent from conditions that would be expected without conservation practices. Application of additional conservation practices on acres with a “high” level of treatment need would reduce baseline total nitrogen loads delivered to rivers and streams within the basin by 14 percent. Treating ALL undertreated acres (acres with either a “high” or “moderate” need for treatment) would reduce baseline nitrogen loads delivered to rivers and streams within the basin by 49 percent.

The bottom map shows that the use of conservation practices on cropland in the Upper Mississippi River Basin has reduced ***total nitrogen loads delivered to the Lower Mississippi River from all sources*** by 19 percent from conditions that would be expected without conservation practices. Application of additional conservation practices on acres with a “high” level of treatment need would reduce baseline total nitrogen loads delivered to the Lower Mississippi River by 8 percent. Treating ALL undertreated acres (acres with either a “high” or “moderate” need for treatment) would reduce baseline nitrogen loads delivered to the Lower Mississippi River by 33 percent.

Total phosphorus loss

In figure 95, the top map shows that the use of conservation practices has reduced ***total phosphorus loads delivered from cropland to rivers and streams*** within the basin by 41 percent from conditions that would be expected without conservation practices. Application of additional conservation practices on acres with a “high” level of treatment need would reduce baseline total phosphorus loads delivered to rivers and streams by 15 percent. Treating ALL undertreated acres (acres with either a “high” or “moderate” need for treatment) would reduce baseline phosphorus loads delivered to rivers and streams within the basin by 41 percent.

The bottom map shows that the use of conservation practices on cropland in the Upper Mississippi River Basin has reduced ***total phosphorus loads delivered to the Lower Mississippi River from all sources*** by 26 percent from conditions that would be expected without conservation practices. Application of additional conservation practices on acres with a “high” level of treatment need would reduce baseline total phosphorus loads delivered to the Lower Mississippi River by 9 percent. Treating ALL undertreated acres (acres with either a “high” or “moderate” need for treatment) would reduce baseline phosphorus loads delivered to the Lower Mississippi River by 26 percent.

Atrazine loss

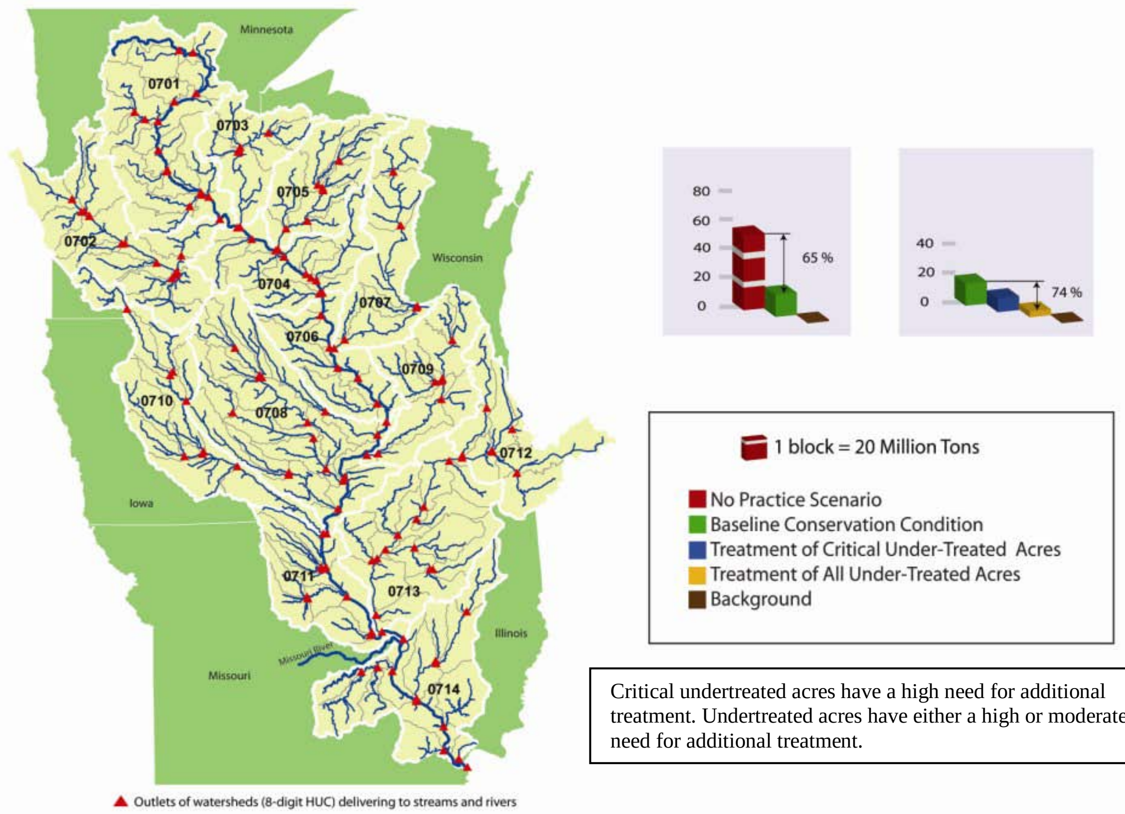
Although the full suite of pesticides was modeled for edge-of-field losses, atrazine was the only pesticide for which instream loads were assessed because it was the dominant contributor to mass loss of pesticide residues from farm fields and the primary contributor to environmental risk from pesticides in the region. Cultivated cropland was the only source for atrazine in the model simulations.

The use of conservation practices has reduced ***atrazine loads delivered from cropland to rivers and streams*** within the basin by 31 percent from conditions that would be expected without conservation practices. The use of conservation practices on cropland has also reduced ***atrazine loads delivered to the Lower Mississippi River*** by 30 percent.

Application of additional erosion control and nutrient management conservation practices on acres with a “high” level of treatment need would reduce baseline atrazine loads delivered to the Lower Mississippi River by 3 percent. Treating ALL undertreated acres (acres with either a “high” or “moderate” need for treatment) would reduce baseline atrazine loads delivered to the Lower Mississippi River by 11 percent.

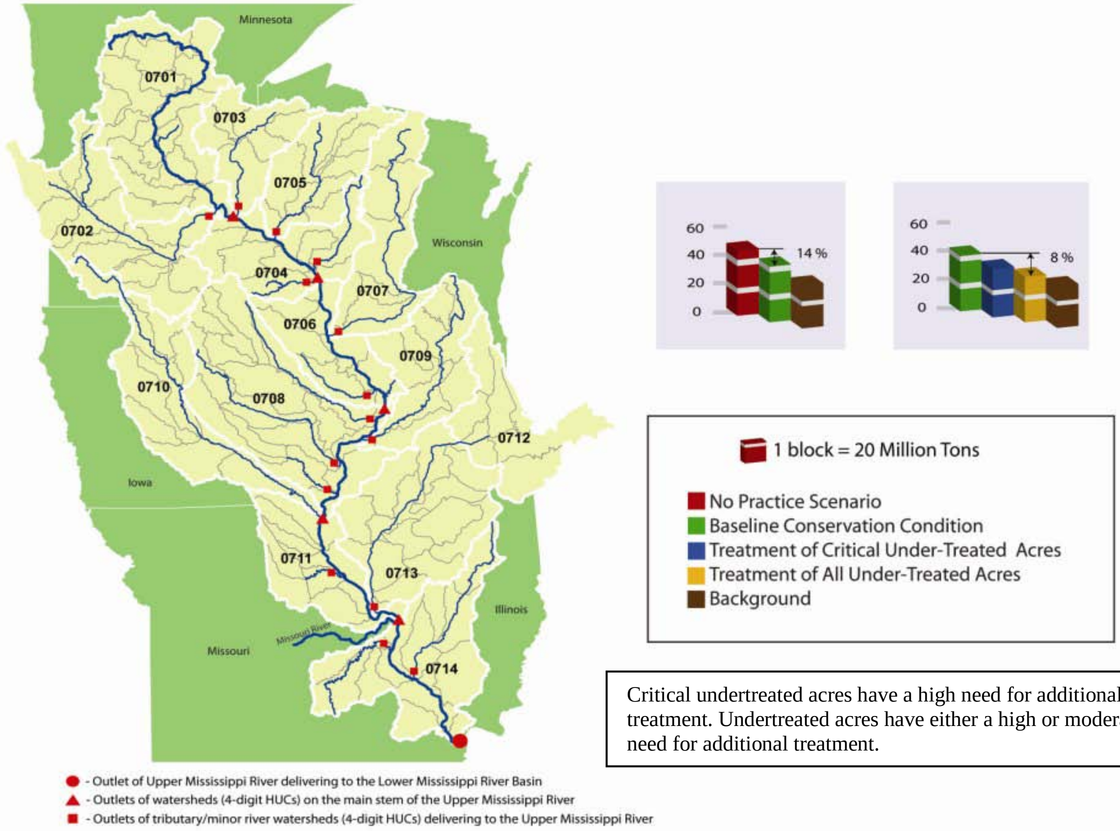
Figure 93. Summary of the effects of conservation practices on sediment loads in the Upper Mississippi River Basin

Sediment delivered from cultivated cropland to rivers and streams in the Upper Mississippi River Basin



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

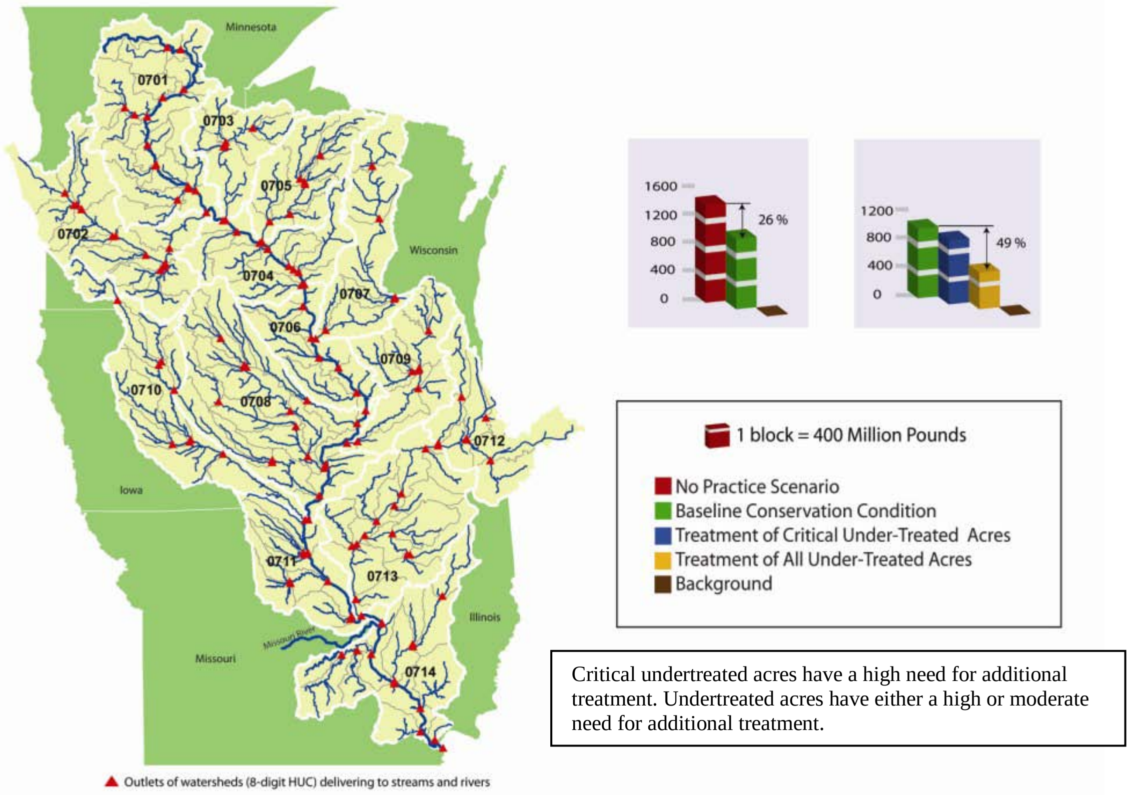
Sediment delivered to the Lower Mississippi River Basin from the Upper Mississippi River Basin (all sources - instream loads)



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

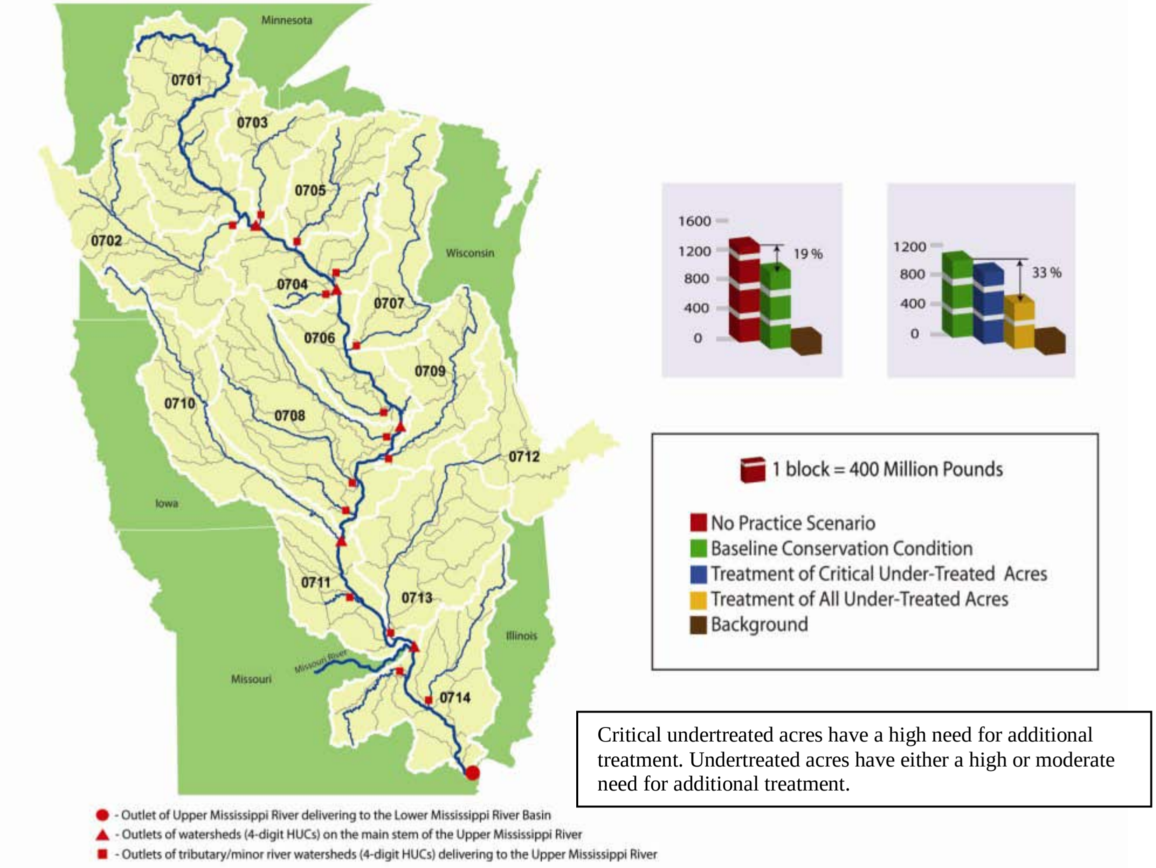
Figure 94. Summary of the effects of conservation practices on total nitrogen loads in the Upper Mississippi River Basin

Nitrogen delivered from cultivated cropland to rivers and streams in the Upper Mississippi River Basin



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

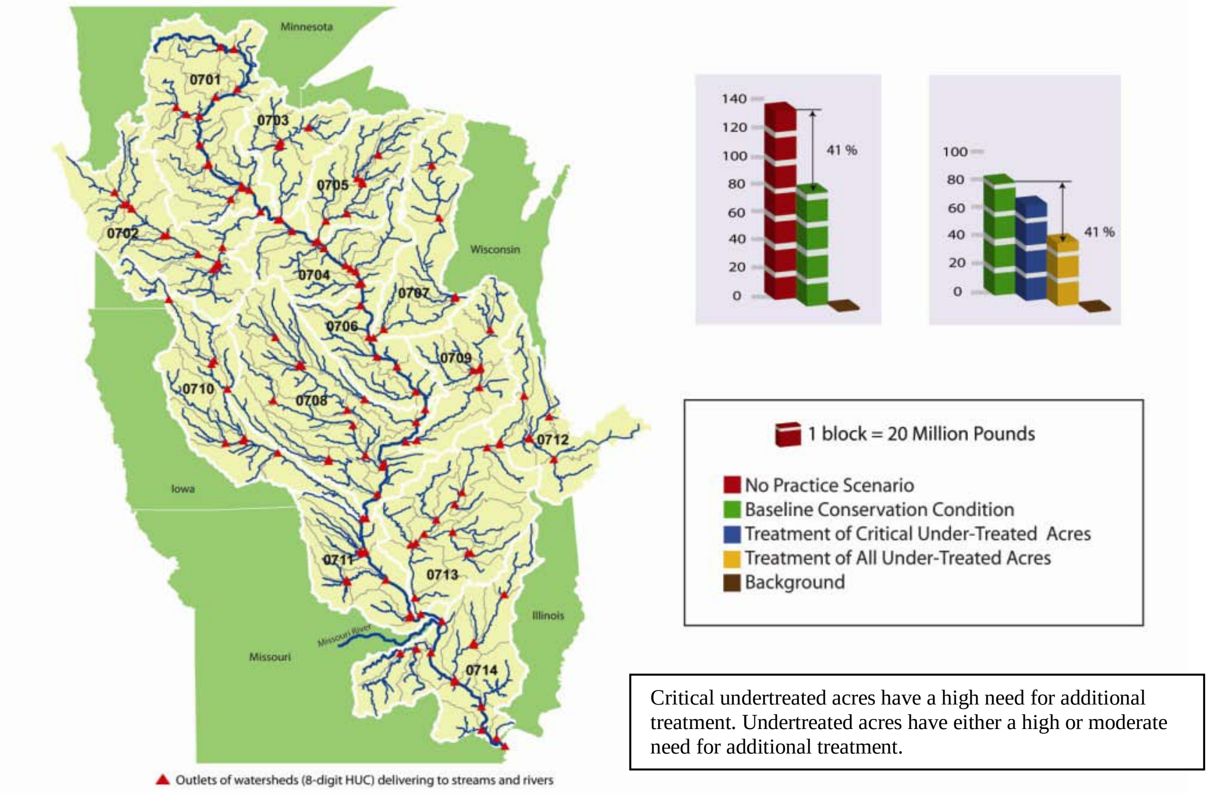
Nitrogen delivered to the Lower Mississippi River Basin from the Upper Mississippi River Basin (all sources - instream loads)



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

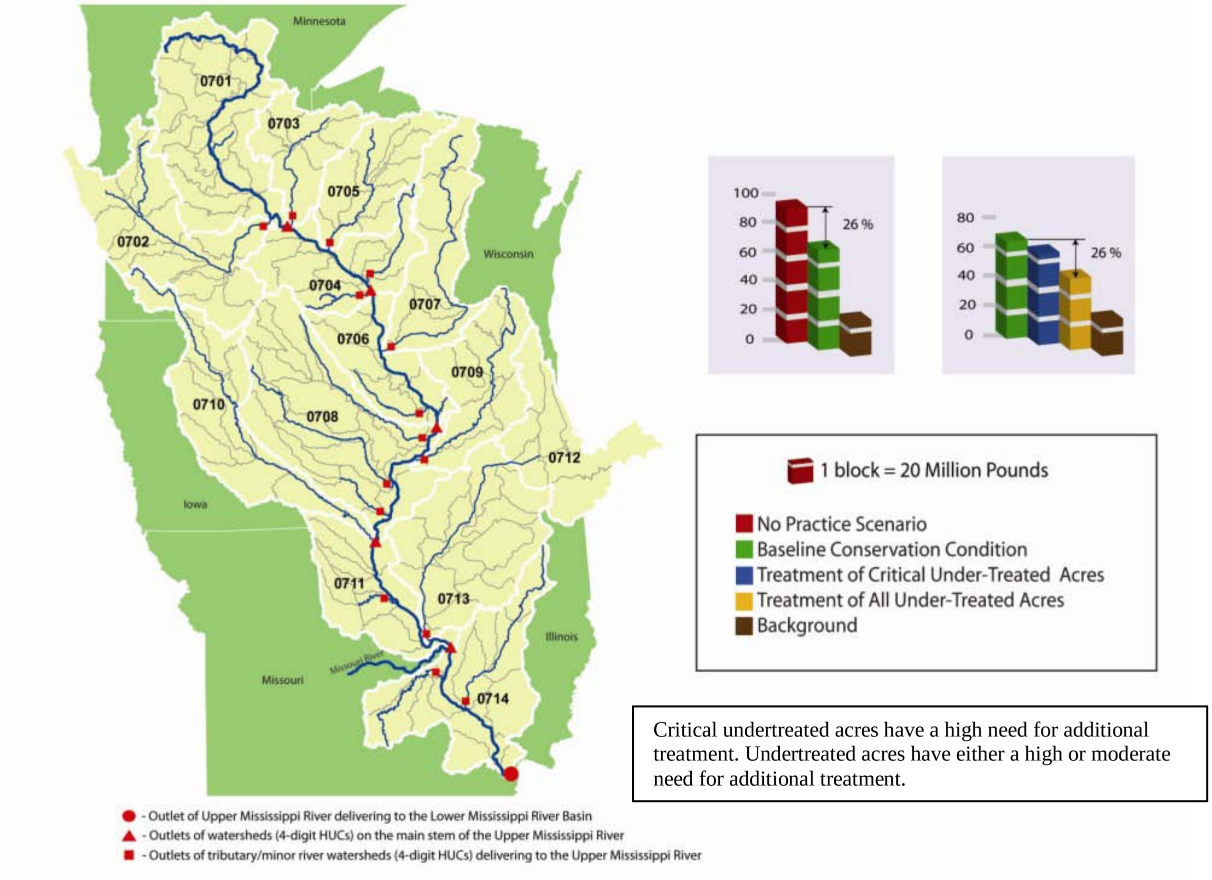
Figure 95. Summary of the effects of conservation practices on total phosphorus loads in the Upper Mississippi River Basin

Phosphorus delivered from cultivated cropland to rivers and streams in the Upper Mississippi River Basin



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

Phosphorus delivered to the Lower Mississippi River Basin from the Upper Mississippi River Basin (all sources - instream loads)



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

Comparison of Findings to Other Regions

The Upper Mississippi, Missouri, and Ohio-Tennessee River Basins make up the northern part of the Mississippi River drainage area. Tables 66 through 69 compare basin characteristics and CEAP findings among these three important water resource regions.

The Missouri River Basin is the largest of the three regions and has more cultivated cropland. However, cultivated cropland is much more concentrated in the Upper Mississippi River Basin. About 53 percent of land within the Upper Mississippi River Basin is in cultivated cropland, compared to 30 percent in the Missouri River Basin and 21 percent in the Ohio-Tennessee River Basin. The crop mix found in the Upper Mississippi River Basin is similar to that in the Ohio-Tennessee River Basin—dominated by corn and soybean rotations—but differs significantly from the higher percentage of wheat and close grown crops in the western portion of the Missouri River Basin. Irrigation is important in parts of the Missouri River Basin, but relatively uncommon in the Upper Mississippi and Ohio-Tennessee River Basins. While livestock production is important in all three regions, confined livestock production and associated land application of manure on cropland are more prevalent in the Upper Mississippi River Basin.

The vulnerability profile of the Upper Mississippi River Basin benefits by having a lower proportion of highly erodible land than the other two regions. With the exception of annual precipitation, other vulnerability factors are generally similar among the three basins. Average annual precipitation in the Upper Mississippi River Basin is 11 inches per year more than in the Missouri River Basin and 8 inches per year less than in the Ohio-Tennessee River Basin. Because of the low precipitation in the Missouri basin, soils there are prone to wind erosion, especially in the western part of the region. Wind erosion is not a serious resource concern in most parts of the Upper Mississippi and Ohio-Tennessee River Basins.

Soil erosion control practices are about equally represented among the three regions, except that a higher proportion of cropped acres in the Missouri River basin have structural practices designed to mitigate wind erosion (table 66). No-till or mulch till are in widespread use (greater than 90 percent of cropped acres) in all three regions, with somewhat more extensive use of mulch till in the Upper Mississippi River basin and less use of no-till than in the other regions.

The extent of appropriate nutrient management practices in the Upper Mississippi River Basin is similar to that in the Ohio-Tennessee River Basin, but less than that in the Missouri River Basin (table 66). The percent of cropped acres in the Upper Mississippi River Basin with a high or moderately high level of nutrient management was 41 percent for nitrogen and 54 percent for phosphorus, compared to 65 percent and 63 percent, respectively, in the Missouri River Basin.

The proportion of cultivated cropland in long-term conserving cover (CRP General Signup) is over twice as high in the Missouri River Basin as it is in the Upper Mississippi and Ohio-Tennessee River Basins (table 66), contributing to lower sediment and nutrient loads per acre delivered to rivers and streams from cultivated cropland in the Missouri River Basin.

Model simulations for cropped acres show that the average per-acre waterborne sediment and nutrient losses from farm fields are much higher in the Upper Mississippi River and Ohio-Tennessee River Basins than in the Missouri River Basin (table 67). In contrast, average windborne sediment and nutrient per-acre losses are very low in the Upper Mississippi and Ohio-Tennessee River Basins but are the major loss pathway for nutrients in the Missouri River Basin. Overall, average annual per-acre sediment and nutrient losses are highest in the Ohio-Tennessee River Basin.

In terms of percent reductions, practices in use in 2003–06 were generally more effective in reducing sediment and nutrient losses in the Missouri River Basin than in the other two regions (table 67). For example, total nitrogen loss (all loss pathways) has been reduced by 39 percent by conservation practices in the Missouri River Basin, compared to only 20 percent in the Upper Mississippi River Basin and 17 percent in the Ohio-Tennessee River Basin. Percent reductions for wind erosion and windborne nitrogen and phosphorus due to conservation practices are about the same in all three regions, but the magnitude of the reduction is much larger in the Missouri River Basin.

The most critical conservation concern related to cropland differs among the regions (table 68)—

- 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 (compared to 17 percent of cropped acres in the Ohio-Tennessee River Basin and 2 percent of cropped acres in the Missouri River Basin);
- Phosphorus lost to surface water is the major need for additional conservation treatment in the Ohio-Tennessee River Basin, where 63 percent of cropped acres have a high or moderate need for treatment for this concern (compared to 22 percent of cropped acres in the Upper Mississippi River Basin and 1 percent of cropped acres in the Missouri River Basin);
- Wind erosion is the dominant need for conservation treatment in the Missouri River Basin, where 12 percent of cropped acres have a high or moderate need for treatment for this concern (compared to zero percent of cropped acres in the Upper Mississippi and Ohio-Tennessee River Basins).

Overall, the Upper Mississippi River Basin has about twice as many undertreated cropped acres (35.2 million undertreated acres, 60 percent of cropped acres) as the Missouri River Basin (15.3 million undertreated acres, 18 percent of cropped acres) or the Ohio-Tennessee River Basin (17.5 million undertreated acres, 70 percent of cropped acres) (table 68).

Table 66. Comparison of land use, vulnerability, and conservation practice use among three of the five water resource regions that make up the Mississippi River drainage system

	Upper Mississippi River Basin	Missouri River Basin	Ohio-Tennessee River Basin
Total acres in basin (million acres excluding water)	118.2	322.2	128.5
Total acres of cultivated cropland (million acres)	62.9	95.1	26.8
Land use (percent of total acres excluding water)			
Cultivated cropland	53	30	21
Hayland	5	3	6
Pasture and rangeland	7	53	12
Urban land	8	3	9
Forest and other	26	11	52
Cultivated cropland (percent of cropped acres)			
Crop rotations with corn and soybean only	74	32	69
Crop rotations with wheat or other close-grown crops only	<1	30	<1
Crop rotations with hay and other crops	6	5	4
Irrigated	2	14	1
Manure applied	16	5	9
Vulnerability factors			
Average annual precipitation (inches)	34	23	42
Slopes greater than 2% (percent of cropped acres)	42	48	33
Highly Erodible Land (percent of cropped acres)	18	40	27
High soil runoff potential (percent of cropped acres)	13	12	9
High or moderately high soil leaching potential (percent of cropped acres)	10	11	8
High or moderately high soil wind erosion potential (percent of cropped acres)	1	28	0
Conservation practice use			
No-till (percent of cropped acres)	28	46	52
Mulch till (percent of cropped acres)	63	47	41
Structural practices for water erosion control (percent of cropped acres)	45	41	40
Structural practices for wind erosion control (percent of cropped acres)	3	10	2
High tillage and residue management level (percent of cropped acres)	63	52	59
High or moderately high nitrogen management level (percent of cropped acres)	41	65	42
High or moderately high phosphorus management level (percent of cropped acres)	54	63	43
Land in long-term conserving cover (acres enrolled in CRP General Sign-Up) as a percent of cultivated cropland acres	5	12	4

Table 67. Comparison of field level losses and the effects of conservation practices among three of the five water resource regions that make up the Mississippi River drainage system

	Upper Mississippi River Basin	Missouri River Basin	Ohio-Tennessee River Basin
Average annual change in soil organic carbon, baseline conservation condition (pounds/acre)	71	52	27
Average annual wind erosion and edge-of-field sediment and nutrient loss, baseline conservation condition			
Wind erosion (tons/acre)	0.23	1.13	0.02
Sediment loss (tons/acre)	0.89	0.26	1.59
Total nitrogen loss (pounds/acre)	39.0	23.4	42.6
Nitrogen lost with windborne sediment (pounds/acre)	2.1	5.8	0.2
Nitrogen loss with surface runoff (pounds/acre)	8.8	2.6	13.2
Nitrogen loss in subsurface flows (pounds/acre)	18.7	6.9	19.2
Total phosphorus loss (pounds/acre)	3.2	1.7	4.6
Phosphorus lost with windborne sediment (pounds/acre)	0.4	1.0	0.0
Phosphorus lost to surface water, sediment attached and soluble (pounds/acre)	2.7	0.7	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	64	58	60
Sediment loss	61	73	52
Total nitrogen loss	20	39	17
Nitrogen lost with windborne sediment	37	46	47
Nitrogen loss with surface runoff	45	58	35
Nitrogen loss in subsurface flows	9	45	11
Total phosphorus loss	44	58	33
Phosphorus lost with windborne sediment	55	58	63
Phosphorus lost to surface water, sediment attached and soluble	42	59	33

Table 68. Comparison of conservation treatment needs among three of the five water resource regions that make up the Mississippi River drainage system

	Upper Mississippi River Basin	Missouri River Basin	Ohio-Tennessee River Basin
Conservation treatment needs (percent of cropped acres)			
Sediment loss			
High level of treatment need	10	<1	14
Moderate level of treatment need	0	3	12
Undertreated (high or moderate level of treatment need)	10	3	25
Nitrogen lost with runoff			
High level of treatment need	11	<1	12
Moderate level of treatment need	12	3	16
Undertreated (high or moderate level of treatment need)	24	4	29
Nitrogen loss in subsurface flows			
High level of treatment need	3	<1	2
Moderate level of treatment need	45	2	16
Undertreated (high or moderate level of treatment need)	47	2	17
Phosphorus lost to surface water			
High level of treatment need	5	<1	20
Moderate level of treatment need	18	<1	44
Undertreated (high or moderate level of treatment need)	22	1	63
Wind erosion			
High level of treatment need	0	<1	0
Moderate level of treatment need	0	12	0
Undertreated (high or moderate level of treatment need)	0	12	0
One or more resource concern			
High level of treatment need	15	1	24
Moderate level of treatment need	45	17	46
Undertreated (high or moderate level of treatment need)	60	18	70
Conservation treatment needs for one or more resource concerns (million acres)			
High level of treatment need	8.980	1.127	6.012
Moderate level of treatment need	26.218	14.179	11.506
Undertreated (high or moderate level of treatment need)	35.198	15.306	17.518

The use of conservation practices is effective in reducing sediment, nutrients, and atrazine delivered from cultivated cropland to rivers and streams in all three basins. Effectiveness, however, appears to have been greatest in the Missouri River Basin and least in the Ohio-Tennessee River Basin. Table 69 shows that average per-acre loads delivered to rivers and streams from cultivated cropland are highest in the Ohio-Tennessee River Basin and lowest in the Missouri River Basin for sediment, nutrients, and atrazine. Similarly, the percent reductions in loads due to 2003–06 conservation practices are consistently highest in the Missouri River Basin and lowest in the Ohio-Tennessee River Basin. Potential percent reductions due to additional conservation treatment of undertreated acres are much lower in the Missouri River Basin than in the other two regions because the proportion of acres needing additional treatment is much smaller in the Missouri River Basin.

Instream loads delivered from each of the three basins to the Lower Mississippi River Basin were estimated using the HUMUS/SWAT model. Instream loads include sediment, nutrients, and atrazine from all sources, including point sources and cultivated cropland. As shown in table 69 for the baseline conservation condition, the largest average annual sediment loads originate from the Missouri River Basin (44 million tons), the largest average annual total nitrogen loads originate from the Upper Mississippi River basin (1.1 billion pounds), and the largest average annual total phosphorus loads (88 million pounds) and atrazine loads (178,000 pounds) originate from the Ohio-Tennessee River Basin.

On a percentage basis, instream sediment and nutrient loads delivered to the Lower Mississippi that are attributable to cultivated cropland sources are highest for the Upper Mississippi River Basin (table 69). Sixty-one percent of the instream phosphorus load delivered from the Upper Mississippi River Basin to the Lower Mississippi River is attributable to cultivated cropland, compared to 32 percent for the Missouri River Basin and 51 percent for the Ohio-Tennessee River Basin. Similarly, 71 percent of the instream nitrogen load delivered from the Upper Mississippi River Basin to the Lower Mississippi River is attributable to cultivated cropland, compared to 67 percent for the Missouri River Basin and 49 percent for the Ohio-Tennessee River Basin. About one-fifth of the sediment load delivered to the Lower Mississippi River is attributable to cultivated cropland in each of the three basins (table 69).

Percent reductions in instream loads (all sources) due to 2003-06 conservation practice use and due to additional conservation treatment are also contrasted among the three regions in table 69. These percentages are heavily influenced by the extent to which cultivated cropland is the source of contaminants in each basin, as well as the extent of conservation treatment within each basin.

Table 69. Comparison of loads delivered from cultivated cropland to rivers and streams and instream loads (all sources) among three of the five water resource regions that make up the Mississippi River drainage system

	Upper Mississippi River Basin	Missouri River Basin	Ohio-Tennessee River Basin
Loads delivered to rivers and streams from cultivated cropland			
Average annual amount per cultivated cropland acre, baseline conservation condition			
Sediment (tons/acre/year)	0.29	0.15	0.6
Nitrogen (pounds/acre/year)	16.5	5	19
Phosphorus (pounds/acre/year)	1.3	0.3	2.0
Atrazine (pounds/acre/year)	0.001	0.001	0.009
Percent of total loads delivered from all sources, baseline conservation condition			
Sediment	71	72	53
Nitrogen	71	68	49
Phosphorus	62	46	48
Atrazine	100	100	100
Percent reduction due to 2003–06 conservation practices			
Sediment	65	76	55
Nitrogen	26	54	26
Phosphorus	41	60	32
Atrazine	31	36	18
Percent reduction due to additional conservation treatment of cropped acres with a high or moderate treatment need			
Sediment	74	28	81
Nitrogen	49	13	41
Phosphorus	41	12	58
Atrazine	13	5	11
Instream loads from all sources at the outlet of the basin			
Baseline conservation condition			
Sediment (average annual 1,000 tons)	40,490	44,010	26,300
Nitrogen (average annual 1,000 pounds)	1,068,700	511,300	897,082
Phosphorus (average annual 1,000 pounds)	69,350	54,650	87,800
Atrazine (average annual 1,000 pounds)	141	61	178
Percent of total loads attributed to cultivated cropland sources, baseline conservation condition			
Sediment	22	22	20
Nitrogen	71	67	49
Phosphorus	61	32	51
Atrazine	100	100	100
Percent reduction in total loads due to 2003–06 conservation practice use on cultivated cropland acres			
Sediment	14	4	16
Nitrogen	19	36	15
Phosphorus	26	28	21
Atrazine	30	32	18
Percent reduction in total loads due to additional conservation treatment of cropped acres with a high or moderate treatment need			
Sediment	8	1	15
Nitrogen	33	6	20
Phosphorus	26	4	31
Atrazine	11	4	11

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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 3,703 sample points in the Upper 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

	Estimated acres	Margin of error
Cropped Acres (table 5)		
Mississippi Headwaters (code 0701)	2,672,400	409,909
Minnesota River Basin (code 0702)	7,343,800	770,498
St. Croix River Basin (code 0703)	505,800	120,691
Upper Mississippi-Black-Root Rivers (code 0704)	2,704,200	297,098
Chippewa River Basin (code 0705)	878,900	206,461
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	2,602,200	307,005
Wisconsin River Basin (code 0707)	1,363,100	237,954
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	10,383,100	658,381
Rock River Basin (code 0709)	4,206,000	353,866
Des Moines River Basin (code 0710)	6,309,500	525,436
Upper Mississippi-Salt Rivers (code 0711)	2,780,300	290,109
Upper Illinois River Basin (code 0712)	3,989,500	414,759
Lower Illinois River Basin (code 0713)	8,346,900	582,527
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	4,067,800	405,773
Total for Upper Mississippi River Basin	58,153,500	1,008,350

Table A1—continued.

	Estimated acres	Margin of error
Highly erodible land (HEL)		
Mississippi Headwaters (code 0701)	83,406	127,567
Minnesota River Basin (code 0702)	241,780	126,142
St. Croix River Basin (code 0703)	144,059	94,116
Upper Mississippi-Black-Root Rivers (code 0704)	807,422	195,954
Chippewa River Basin (code 0705)	210,686	126,275
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	1,333,770	342,309
Wisconsin River Basin (code 0707)	298,691	205,480
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	2,233,213	360,257
Rock River Basin (code 0709)	1,063,027	221,369
Des Moines River Basin (code 0710)	846,436	272,400
Upper Mississippi-Salt Rivers (code 0711)	1,336,300	292,477
Upper Illinois River Basin (code 0712)	229,731	109,115
Lower Illinois River Basin (code 0713)	1,011,811	194,054
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	850,600	210,724
Total for Upper Mississippi River Basin	10,690,931	758,312
Acres receiving manure		
Mississippi Headwaters (code 0701)	893,682	267,513
Minnesota River Basin (code 0702)	1,232,389	354,413
St. Croix River Basin (code 0703)	240,226	137,280
Upper Mississippi-Black-Root Rivers (code 0704)	747,829	178,345
Chippewa River Basin (code 0705)	549,596	181,396
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)	969,129	260,834
Wisconsin River Basin (code 0707)	626,227	186,384
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)	1,562,671	445,433
Rock River Basin (code 0709)	696,618	234,547
Des Moines River Basin (code 0710)	884,887	212,454
Upper Mississippi-Salt Rivers (code 0711)	259,918	206,570
Upper Illinois River Basin (code 0712)	275,674	171,484
Lower Illinois River Basin (code 0713)	366,271	170,311
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)	178,306	119,737
Total for Upper Mississippi River Basin	9,483,423	742,898
Cropping systems (table 6)		
Corn-soybean only	42,980,688	982,141
Corn-soybean with close grown crops	2,144,046	348,757
Corn only	5,037,033	585,890
Corn and close grown crops	752,294	320,277
Soybean only	1,507,404	343,635
Soybean-wheat only	783,464	264,426
Hay-crop mix including corn	2,460,351	516,192
Hay-crop mix without corn	1,192,680	401,271
Remaining mix of crops	1,295,541	432,552

Table A1—continued.

	Estimated acres	Margin of error
Use of structural practices (table 7)		
Overland flow control practices	12,076,294	794,548
Concentrated flow control practices	18,720,178	852,462
Edge-of-field buffering and filtering practices	5,401,666	745,465
One or more water erosion control practices	26,379,512	1,321,336
Wind erosion control practices	1,669,636	368,610
Use of cover crops	156,222	92,429
Use of residue and tillage management (table 8)		
Average annual tillage intensity for crop rotation meets criteria for no-till	16,070,159	874,533
Average annual tillage intensity for crop rotation meets criteria for mulch till	36,628,847	966,028
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	2,359,019	439,966
Continuous conventional tillage in every year of crop rotation	3,095,474	557,989
Use of structural practices and/or residue and tillage management (table 9)		
No-till or mulch till with carbon gain, no structural practices	21,237,203	1,164,723
No-till or mulch till with carbon loss, no structural practices	6,323,088	704,910
Some crops with reduced tillage, no structural practices	1,659,550	303,336
Structural practices and no-till or mulch till with carbon gain	20,274,760	1,065,869
Structural practices and no-till or mulch till with carbon loss	4,863,956	491,908
Structural practices and some crops with reduced tillage	699,470	317,695
Structural practices only	541,327	193,574
No water erosion control treatment	2,554,147	619,726
Conservation treatment levels for structural practices (fig. 7)		
High level of treatment	2,806,781	440,134
Moderately high level of treatment	8,613,655	724,658
Moderate level of treatment	14,959,077	1,141,205
Low level of treatment	31,773,988	1,191,319
Conservation treatment levels for residue and tillage management (fig. 8)		
High level of treatment	36,528,665	1,280,505
Moderately high level of treatment	4,983,298	565,127
Moderate level of treatment	14,726,530	889,480
Low level of treatment	1,915,007	430,879
Conservation treatment levels for nitrogen management (fig. 9)		
High level of treatment	6,216,177	663,372
Moderately high level of treatment	17,879,003	635,165
Moderate level of treatment	22,555,647	1,082,060
Low level of treatment	11,502,673	872,947
Conservation treatment levels for phosphorus management (fig. 10)		
High level of treatment	16,423,988	1,147,937
Moderately high level of treatment	14,727,546	875,838
Moderate level of treatment	5,310,025	603,121
Low level of treatment	21,691,942	887,840
Conservation treatment levels for IPM (fig. 11)		
High level of treatment	6,040,290	817,724
Moderate level of treatment	28,033,273	1,367,635
Low level of treatment	24,079,938	941,435

Table A1—continued.

	Estimated acres	Margin of error
Conservation treatment levels for water erosion control practices (fig. 49)		
High level of treatment	23,172,155	1,023,192
Moderately high level of treatment	12,093,480	967,225
Moderate level of treatment	17,268,420	1,038,693
Low level of treatment	5,619,446	701,110
Conservation treatment levels for nitrogen runoff control (fig. 50)		
High level of treatment	1,979,506	416,717
Moderately high level of treatment	24,779,774	1,385,426
Moderate level of treatment	26,861,685	1,462,303
Low level of treatment	4,532,534	635,846
Conservation treatment levels for phosphorus runoff control (fig. 51)		
High level of treatment	6,137,775	780,415
Moderately high level of treatment	20,100,066	1,192,931
Moderate level of treatment	25,541,463	1,374,566
Low level of treatment	6,374,196	655,319
Soil runoff potential (fig. 52)		
High	7,353,035	648,503
Moderately high	10,726,875	902,214
Moderate	11,524,041	1,096,202
Low	28,549,550	729,458
Soil leaching potential (fig. 54)		
High	3,015,713	626,209
Moderately high	2,554,380	411,963
Moderate	39,959,870	1,539,331
Low	12,623,538	973,985
Level of conservation treatment need by resource concern		
Sediment loss (table 24)		
High (critical undertreated)	5,659,307	575,421
Moderate (non-critical undertreated)	0	0
Low (adequately treated)	52,494,193	967,149
Nitrogen loss with surface runoff (sediment attached and soluble) (table 25)		
High (critical undertreated)	6,370,614	674,638
Moderate (non-critical undertreated)	7,285,978	664,826
Low (adequately treated)	44,496,908	788,575
Nitrogen loss in subsurface flows (table 26)		
High (critical undertreated)	1,492,215	431,440
Moderate (non-critical undertreated)	26,098,187	1,256,245
Low (adequately treated)	30,563,098	1,203,189
Phosphorus lost to surface water (table 27)		
High (critical undertreated)	2,704,034	573,046
Moderate (non-critical undertreated)	10,313,952	918,145
Low (adequately treated)	45,135,514	921,238
Level of conservation treatment need for one or more resource concerns		
Upper Mississippi River Basin		
High (critical undertreated)	8,979,533	794,879
Moderate (non-critical undertreated)	26,218,461	1,414,323
Low (adequately treated)	22,955,506	1,034,947

Table A1—continued.

	Estimated acres	Margin of error
Level of conservation treatment need for one or more resource concerns--continued		
Mississippi Headwaters (code 0701)		
High (critical undertreated)	728,671	303,520
Moderate (non-critical undertreated)	824,746	315,237
Low (adequately treated)	1,118,983	325,211
Minnesota River Basin (code 0702)		
High (critical undertreated)	610,749	212,893
Moderate (non-critical undertreated)	3,574,456	628,365
Low (adequately treated)	3,158,595	681,489
St. Croix River Basin (code 0703)		
High (critical undertreated)	166,776	117,102
Moderate (non-critical undertreated)	118,767	93,681
Low (adequately treated)	220,257	130,627
Upper Mississippi-Black-Root Rivers (code 0704)		
High (critical undertreated)	795,416	135,062
Moderate (non-critical undertreated)	1,122,330	266,580
Low (adequately treated)	786,454	210,973
Chippewa River Basin (code 0705)		
High (critical undertreated)	381,579	160,878
Moderate (non-critical undertreated)	291,587	159,034
Low (adequately treated)	205,733	138,028
Upper Mississippi-Maquoketa-Plum Rivers (code 0706)		
High (critical undertreated)	622,236	212,685
Moderate (non-critical undertreated)	1,440,180	215,114
Low (adequately treated)	539,784	193,700
Wisconsin River Basin (code 0707)		
High (critical undertreated)	480,501	167,992
Moderate (non-critical undertreated)	312,074	149,836
Low (adequately treated)	570,524	223,779
Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers (code 0708)		
High (critical undertreated)	1,316,467	332,548
Moderate (non-critical undertreated)	4,842,170	653,779
Low (adequately treated)	4,224,463	546,521
Rock River Basin (code 0709)		
High (critical undertreated)	793,835	176,937
Moderate (non-critical undertreated)	2,106,124	301,780
Low (adequately treated)	1,306,042	274,986
Des Moines River Basin (code 0710)		
High (critical undertreated)	371,177	167,345
Moderate (non-critical undertreated)	2,763,897	519,225
Low (adequately treated)	3,174,426	569,117
Upper Mississippi-Salt Rivers (code 0711)		
High (critical undertreated)	732,508	280,907
Moderate (non-critical undertreated)	962,728	168,892
Low (adequately treated)	1,085,064	266,763
Upper Illinois River Basin (code 0712)		
High (critical undertreated)	715,792	241,299
Moderate (non-critical undertreated)	1,540,159	298,455
Low (adequately treated)	1,733,549	322,195

Table A1—continued.

	Estimated acres	Margin of error
Level of conservation treatment need for one or more resource concerns--continued		
Lower Illinois River Basin (code 0713)		
High (critical undertreated)	647,699	228,495
Moderate (non-critical undertreated)	4,687,172	488,351
Low (adequately treated)	3,012,029	481,365
Upper Mississippi-Kaskaskia-Meramec Rivers (code 0714)		
High (critical undertreated)	616,126	184,347
Moderate (non-critical undertreated)	1,632,071	240,814
Low (adequately treated)	1,819,602	332,791

Appendix B: Model Simulation Results for the Baseline Conservation Condition for Subregions in the Upper 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 Upper 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
0701	Mississippi Headwaters
0702	Minnesota River Basin
0703	St. Croix River Basin
0704	Upper Mississippi-Black-Root Rivers
0705	Chippewa River Basin
0706	Upper Mississippi-Maquoketa-Plum Rivers
0707	Wisconsin River Basin
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon Rivers
0709	Rock River Basin
0710	Des Moines River Basin
0711	Upper Mississippi-Salt Rivers
0712	Upper Illinois River Basin
0713	Lower Illinois River Basin
0714	Upper Mississippi-Kaskaskia-Meramec Rivers

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 Upper Mississippi River Basin

Model simulated outcome	Upper Mississippi River Basin	0701	0702	0703	0704	0705	0706
CEAP sample size for estimating cropped acres	3,703	139	344	39	314	51	217
Cropped acres (million acres)	58,153	2,672	7,344	506	2,704	879	2,602
Percent of acres in region	100	5	13	1	5	2	4
Percent of acres highly erodible	18	3	3	28	30	24	51
Percent of acres irrigated	3	14	<1	2	1	2	0
Percent of acres receiving manure	16	33	17	47	28	63	37
Water sources (average annual inches)							
Non-irrigated acres							
Precipitation	33.7	28.0	27.4	31.0	32.2	32.1	34.1
Irrigated acres							
Precipitation	33.1	27.1	25.6	31.3	31.1	31.8	NA
Irrigation water applied	9.1	7.2	9.7	8.2	9.3	14.0	NA
Water loss pathways (average annual inches)							
Evapotranspiration	23.5	20.4	22.3	20.6	22.6	21.5	23.0
Surface water runoff	4.4	3.0	2.0	3.9	3.9	4.3	4.5
Subsurface water flow	6.1	5.8	3.1	7.0	5.7	7.4	6.6
Erosion and sediment loss (average annual tons/acre)							
Wind erosion	0.23	0.66	0.58	0.43	0.17	0.18	0.14
Sheet and rill erosion	0.89	0.71	0.37	1.27	0.98	1.21	1.08
Sediment loss at edge of field due to water erosion	0.89	0.60	0.19	1.62	1.27	1.66	1.35
Soil organic carbon (average annual pounds/acre)							
Loss of soil organic carbon with wind and water erosion	199	126	128	226	226	193	236
Change in soil organic carbon, including loss of carbon with wind and water erosion	71	-76	25	-77	39	-43	133

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 Upper Mississippi River Basin**--continued**

Model simulated outcome	0707	0708	0709	0710	0711	0712	0713	0714
CEAP sample size for estimating cropped acres	81	636	322	318	235	261	452	294
Cropped acres (million acres)	1,363	10,383	4,206	6,309	2,780	3,989	8,347	4,068
Percent of acres in region	2	18	7	11	5	7	14	7
Percent of acres highly erodible	22	22	25	13	48	6	12	21
Percent of acres irrigated	7	2	2	1	1	5	4	0
Percent of acres receiving manure	46	15	17	14	9	7	4	4
Water sources (average annual inches)								
Non-irrigated acres								
Precipitation	32.2	34.3	34.1	31.8	37.5	36.2	36.5	40.4
Irrigated acres								
Precipitation	32.1	35.1	34.7	30.1	37.9	37.8	36.7	NA
Irrigation water applied	4.8	9.5	9.1	13.0	13.9	10.0	10.3	NA
Water loss pathways (average annual inches)								
Evapotranspiration	21.7	23.7	23.2	23.3	24.9	23.8	25.2	25.9
Surface water runoff	4.4	4.6	4.7	3.5	6.6	5.5	5.1	7.0
Subsurface water flow	6.4	6.2	6.3	5.0	6.9	8.0	6.7	8.0
Erosion and sediment loss (average annual tons/acre)								
Wind erosion	0.23	0.21	0.09	0.36	0.09	0.10	0.05	0.03
Sheet and rill erosion	0.83	1.02	1.25	0.64	1.56	0.70	0.91	1.06
Sediment loss at edge of field due to water erosion	1.22	0.94	1.43	0.43	1.61	0.63	0.90	1.25
Soil organic carbon (average annual pounds/acre)								
Loss of soil organic carbon with wind and water erosion	193	231	235	172	280	161	200	235
Change in soil organic carbon, including loss of carbon with wind and water erosion	-42	110	48	109	35	69	144	57

Table B2. Average annual estimates of nitrogen loss for the baseline conservation condition for cropped acres, by subregion, in the Upper Mississippi River Basin

Model simulated outcome	Upper Mississippi River Basin	0701	0702	0703	0704	0705	0706
Nitrogen (average annual pounds/acre)							
Nitrogen sources	7.9	6.1	7.0	6.4	7.6	7.7	8.1
Atmospheric deposition	57.1	36.9	47.2	48.4	49.4	44.4	55.2
Bio-fixation by legumes	87.4	84.9	77.8	88.5	95.6	96.1	96.5
Nitrogen applied as commercial fertilizer and manure	152.4	127.9	132.0	143.3	152.5	148.2	159.8
All nitrogen sources	110.0	97.3	98.3	91.1	104.6	103.4	110.7
Nitrogen in crop yield removed at harvest	7.9	6.1	7.0	6.4	7.6	7.7	8.1
Nitrogen loss pathways							
Nitrogen loss by volatilization	7.0	5.2	7.0	7.5	8.0	8.2	7.8
Nitrogen loss through denitrification	2.3	1.1	1.6	1.2	2.4	1.3	3.2
Nitrogen lost with windborne sediment	2.1	3.1	5.4	2.9	1.8	1.3	1.2
Nitrogen loss with surface runoff , including waterborne sediment	8.8	5.8	2.7	12.2	12.0	11.5	12.4
Nitrogen loss in subsurface flow pathways	18.7	24.3	16.7	35.7	23.2	27.7	16.8
Total nitrogen loss for all loss pathways	39.0	39.5	33.3	59.5	47.4	50.0	41.5
Change in soil nitrogen	2.0	-10.0	-0.9	-8.5	-1.1	-7.2	6.1

Table B2. Average annual estimates of nitrogen loss for the baseline conservation condition for cropped acres, by subregion, in the Upper Mississippi River Basin**--continued**

Model simulated outcome	0707	0708	0709	0710	0711	0712	0713	0714
Nitrogen (average annual pounds/acre)								
Nitrogen sources								
Atmospheric deposition	9.1	8.5	7.9	8.0	7.7	8.6	8.4	7.7
Bio-fixation by legumes	43.3	60.8	52.3	63.7	70.2	53.4	63.2	70.8
Nitrogen applied as commercial fertilizer and manure	115.7	89.0	92.9	81.6	74.7	87.7	93.9	77.2
All nitrogen sources	168.1	158.4	153.1	153.3	152.6	149.6	165.6	155.7
Nitrogen in crop yield removed at harvest	108.1	113.8	105.2	112.7	118.1	106.7	117.9	119.7
Nitrogen loss pathways								
Nitrogen loss by volatilization	8.3	7.2	8.0	6.7	6.8	6.7	6.2	6.3
Nitrogen loss through denitrification	2.9	2.8	3.3	1.9	2.3	2.7	2.3	1.8
Nitrogen lost with windborne sediment	1.7	2.2	1.1	3.9	1.0	0.8	0.5	0.3
Nitrogen loss with surface runoff , including waterborne sediment	11.0	9.8	13.2	5.0	14.4	7.5	9.3	11.5
Nitrogen loss in subsurface flow pathways	40.7	16.3	20.6	16.1	10.2	22.9	19.7	13.8
Total nitrogen loss for all loss pathways	64.6	38.3	46.3	33.7	34.7	40.6	37.9	33.6
Change in soil nitrogen	-6.1	4.4	0.0	5.4	-1.1	0.8	8.4	1.0

Table B3. Average annual estimates of phosphorus loss and pesticide loss for the baseline conservation condition for cropped acres, by subregion, in the Upper Mississippi River Basin

Model simulated outcome	Upper Mississippi River Basin	0701	0702	0703	0704	0705	0706
Phosphorus (average annual pounds/acre)							
Phosphorus applied as commercial fertilizer and manure	22.8	21.4	21.1	25.9	24.2	26.7	24.0
Phosphorus in crop yield removed at harvest	17.4	15.7	15.3	12.5	16.0	14.1	17.0
Phosphorus loss pathways							
Phosphorus lost with windborne sediment	0.4	0.9	1.0	0.9	0.4	0.3	0.2
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	2.7	1.9	0.8	4.0	3.1	3.8	3.1
Soluble phosphorus loss to groundwater	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total phosphorus loss for all loss pathways	3.2	2.8	1.8	5.0	3.4	4.2	3.3
Change in soil phosphorus	2.1	3.0	3.9	8.4	4.5	8.3	3.5
Pesticides							
Average annual amount of pesticides applied (grams of active ingredient/hectare)	1,634	1,041	1,271	835	1,272	1,022	1,468
Pesticide loss							
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	15.9	4.9	2.2	8.5	9.6	11.4	16.4
Edge-of-field pesticide risk indicator							
Average annual surface water pesticide risk indicator for aquatic ecosystem	3.62	1.19	0.93	0.97	1.43	1.48	3.68
Average annual surface water pesticide risk indicator for humans	0.74	0.34	0.12	0.31	0.32	0.42	0.67
Average annual groundwater pesticide risk indicator for humans	0.12	0.02	0.02	0.03	0.03	0.14	0.13

Table B3. Average annual estimates of phosphorus loss and pesticide loss for the baseline conservation condition for cropped acres, by subregion, in the Upper Mississippi River Basin**--continued**

Model simulated outcome	0707	0708	0709	0710	0711	0712	0713	0714
Phosphorus (average annual pounds/acre)								
Phosphorus applied as commercial fertilizer and manure	37.0	22.6	23.0	21.6	21.2	21.0	23.4	22.9
Phosphorus in crop yield removed at harvest	14.7	18.5	16.7	18.1	18.0	17.4	19.0	18.3
Phosphorus loss pathways								
Phosphorus lost with windborne sediment	0.5	0.4	0.2	0.7	0.2	0.2	0.1	0.1
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	5.8	2.7	3.9	1.6	3.8	2.4	3.1	3.9
Soluble phosphorus loss to groundwater	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total phosphorus loss for all loss pathways	6.4	3.2	4.1	2.4	4.1	2.6	3.2	4.0
Change in soil phosphorus	16.1	0.6	1.9	1.1	-1.0	1.0	0.9	0.5
Pesticides								
Average annual amount of pesticides applied (grams of active ingredient/hectare)	1,778	1,736	1,734	1,555	1,689	1,979	2,044	1,750
Pesticide loss								
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	11.9	20.0	18.1	8.4	28.6	18.9	22.8	27.3
Edge-of-field pesticide risk indicator								
Average annual surface water pesticide risk indicator for aquatic ecosystem	2.18	4.07	3.75	2.82	5.87	5.46	6.17	4.09
Average annual surface water pesticide risk indicator for humans	0.34	0.91	0.65	0.46	1.57	0.94	1.20	1.07
Average annual groundwater pesticide risk indicator for humans	0.06	0.14	0.10	0.08	0.09	0.28	0.19	0.18

Table B4. Percent of cropped acres for conservation treatment levels and soil vulnerability potentials, by subregion, in the Upper Mississippi River Basin

Category	0701	0702	0703	0704	0705	0706	0707
Percent of cropped acres within subregion at four conservation treatment levels for structural practices (see figure 7)							
High conservation treatment level	0	2	0	5	0	5	1
Moderately-high conservation treatment level	7	7	11	20	16	41	7
Moderate conservation treatment level	12	13	22	31	21	32	24
Low conservation treatment level	81	78	66	44	63	21	68
Percent of cropped acres within subregion at four conservation treatment levels for residue and tillage management (see figure 8)							
High conservation treatment level	24	54	17	48	23	65	26
Moderately-high conservation treatment level	12	5	11	9	17	11	21
Moderate conservation treatment level	37	38	58	40	43	23	41
Low conservation treatment level	27	3	14	4	18	2	11
Percent of cropped acres within subregion at four conservation treatment levels for nitrogen management (see figure 9)							
High conservation treatment level	15	13	13	10	12	12	21
Moderately-high conservation treatment level	36	22	54	32	35	29	32
Moderate conservation treatment level	39	55	22	44	33	37	30
Low conservation treatment level	10	11	11	14	21	21	17
Percent of cropped acres within subregion at four conservation treatment levels for phosphorus management (see figure 10)							
High conservation treatment level	39	32	38	47	19	25	26
Moderately-high conservation treatment level	25	15	12	18	22	23	16
Moderate conservation treatment level	8	11	8	14	18	17	15
Low conservation treatment level	28	42	41	22	42	35	43
Percent of cropped acres within subregion at four conservation treatment levels of soil runoff potential (see figure 52)							
High soil vulnerability potential	6	6	18	26	24	40	16
Moderately high soil vulnerability potential	19	7	28	22	26	30	27
Moderate soil vulnerability potential	24	26	13	9	8	11	18
Low soil vulnerability potential	50	61	41	43	42	19	40
Percent of cropped acres within subregion at four conservation treatment levels of soil leaching potential (see figure 54)							
High soil vulnerability potential	25	3	11	5	9	1	16
Moderately high soil vulnerability potential	11	2	32	11	29	4	28
Moderate soil vulnerability potential	42	68	55	78	59	82	52
Low soil vulnerability potential	21	27	1	6	3	13	4

Note: Percents may not add to 100 within categories due to rounding.

Table B4. Percent of cropped acres for conservation treatment levels and soil vulnerability potentials, by subregion, in the Upper Mississippi River Basin**--continued**

Category	0708	0709	0710	0711	0712	0713	0714
Percent of cropped acres within subregion at four conservation treatment levels for structural practices (see figure 7)							
High conservation treatment level	9	4	7	1	4	5	5
Moderately-high conservation treatment level	18	13	18	23	16	10	7
Moderate conservation treatment level	32	32	23	34	17	31	27
Low conservation treatment level	40	52	52	42	63	54	61
Percent of cropped acres within subregion at four conservation treatment levels for residue and tillage management (see figure 8)							
High conservation treatment level	72	63	72	57	68	82	63
Moderately-high conservation treatment level	10	9	11	4	8	7	7
Moderate conservation treatment level	18	26	17	39	23	11	29
Low conservation treatment level	1	3	1	<1	1	<1	2
Percent of cropped acres within subregion at four conservation treatment levels for nitrogen management (see figure 9)							
High conservation treatment level	9	8	10	17	7	7	15
Moderately-high conservation treatment level	35	28	41	38	28	22	31
Moderate conservation treatment level	35	39	24	29	45	43	39
Low conservation treatment level	20	25	25	15	21	29	16
Percent of cropped acres within subregion at four conservation treatment levels for phosphorus management (see figure 10)							
High conservation treatment level	29	31	22	29	32	18	27
Moderately-high conservation treatment level	24	23	33	24	24	35	32
Moderate conservation treatment level	8	11	6	6	8	5	10
Low conservation treatment level	39	36	39	41	35	41	30
Percent of cropped acres within subregion at four conservation treatment levels of soil runoff potential (see figure 52)							
High soil vulnerability potential	16	15	10	23	2	5	9
Moderately high soil vulnerability potential	13	20	14	38	17	20	26
Moderate soil vulnerability potential	20	18	24	23	17	18	22
Low soil vulnerability potential	50	47	52	17	64	56	43
Percent of cropped acres within subregion at four conservation treatment levels of soil leaching potential (see figure 54)							
High soil vulnerability potential	4	5	1	0	19	2	<1
Moderately high soil vulnerability potential	2	7	1	10	3	<1	0
Moderate soil vulnerability potential	73	77	69	38	58	79	71
Low soil vulnerability potential	21	11	29	52	21	19	29

Note: Percents may not add to 100 within categories due to rounding.

Table B5. Percent of cropped acres for conservation treatment needs, by subregion, in the Upper Mississippi River Basin

Category	0701	0702	0703	0704	0705	0706	0707
Percent of cropped acres within subregion with conservation treatment needs for sediment loss							
High level of treatment need	17	5	30	22	32	15	18
Moderate level of treatment need	0	0	0	0	0	0	0
Percent of cropped acres within subregion with conservation treatment needs for nitrogen lost with runoff							
High level of treatment need	9	6	25	25	32	23	22
Moderate level of treatment need	15	5	14	14	13	32	16
Percent of cropped acres within subregion with conservation treatment needs for phosphorus lost to surface water							
High level of treatment need	11	1	11	8	22	4	17
Moderate level of treatment need	12	15	31	25	26	38	25
Percent of cropped acres within subregion with conservation treatment needs for nitrogen loss in subsurface flows							
High level of treatment need	9	2	3	3	5	0	9
Moderate level of treatment need	32	47	31	50	45	53	36
Percent of cropped acres within subregion with conservation treatment needs for one or more resource concern							
High level of treatment need	27	8	33	29	43	24	35
Moderate level of treatment need	31	49	23	42	33	55	23
Undertreated (high or moderate level of treatment need)	58	57	56	71	77	79	58

Table B5. Percent of cropped acres for conservation treatment needs, by subregion, in the Upper Mississippi River Basin**--continued**

Category	0708	0709	0710	0711	0712	0713	0714
Percent of cropped acres within subregion with conservation treatment needs for sediment loss							
High level of treatment need	7	13	4	19	5	4	13
Moderate level of treatment need	0	0	0	0	0	0	0
Percent of cropped acres within subregion with conservation treatment needs for nitrogen lost with runoff							
High level of treatment need	11	14	6	22	5	5	11
Moderate level of treatment need	11	13	8	22	8	13	17
Percent of cropped acres within subregion with conservation treatment needs for phosphorus lost to surface water							
High level of treatment need	3	7	1	11	2	3	6
Moderate level of treatment need	16	21	14	34	10	12	21
Percent of cropped acres within subregion with conservation treatment needs for nitrogen loss in subsurface flows							
High level of treatment need	1	3	0	0	12	2	0
Moderate level of treatment need	46	53	39	24	39	57	40
Percent of cropped acres within subregion with conservation treatment needs for one or more resource concern							
High level of treatment need	13	19	6	26	18	8	15
Moderate level of treatment need	47	50	44	35	39	56	40
Undertreated (high or moderate level of treatment need)	59	69	50	61	57	64	55